Book of Abstracts

Eighteenth Conference on Electromagnetic & Light Scattering

Zhejiang University, Hangzhou city, Zhejiang province, China
10–14 June 2019
OBJECTIVE

The 18th Electromagnetic and Light Scattering Conference (ELS-XVIII) was held at the Zhejiang University, Hangzhou city, Zhejiang province, China during the week of 10–14 June 2019. This conference followed the previous highly successful meetings held in Amsterdam (1995), Helsinki (1997), New York (1998), Vigo (1999), Halifax (2000), Gainesville (2002), Bremen (2003), Salobreña (2005), St.Petersburg (2006), Bodrum (2007), Hatfield (2008), Helsinki (2010), Taormina (2011), Lille (2013), Leipzig (2015), College Park (2017), and College Station (2018), as well as three closely related workshops held in Bremen (1996, 1998) and Moscow (1997). As with the other conferences, the main objective of the ELS-XVIII was to bring together scientists, engineers, postdocs, and PhD students studying diverse aspects of light scattering by particles and particle groups and thereby provide a stimulating atmosphere for thorough and comprehensive discussions of scattering theory, measurements, and practical applications.

SCOPE

The specific topics covered by ELS-XVIII included (but were not limited to) the following:

- new theoretical developments, numerical simulations, and laboratory measurements of light scattering by nonspherical and morphologically complex particles and particle groups
- detection and characterization of atmospheric particulates using laboratory, in situ, and remote sensing techniques
- scattering of light by terrestrial aerosols and clouds
- scattering of light by oceanic particulates
- scattering of light by solar system objects, exoplanets, and exoplanetary environments
- scattering of light by various astrophysical objects
- applications of light scattering methods in biology and biomedicine
- light scattering in densely packed particulate media
- near-field and coherent effects in light scattering, optical trapping, and manipulation
- light scattering methods to control material properties and technological applications

INVITED PRESENTATIONS

- Xiquan Dong, Baike Xi, Patrick Minnis, William Smith Jr, Norman Loeb, and Ping Yang, *Can active and passive instruments remotely sense the same clouds?*
- Oleg Dubovik, Pavel Litvinov, Tatyana Lapyonok, Fabrice Ducos, Xin Huang, David Fuertes, Anton Lopatin, Yevgeny Derimian, Cheng Chen, Lei Li, Benjamin Torres, Yana Karol, Milagros Herrera, Jacques Descloitres, Stefan Amberger, Andreas Hangler, Michael Aspetsberger, and Christian Federspiel, *Retrieval of aerosol properties from multi-angular POLDER polarimetric observations*
• Gérard Gouesbet, *Generalized Lorenz-Mie theories and mechanical effects of laser light: a celebration of Arthur Ashkin’s pioneering work in optical levitation and manipulation*
• Hiroshi Ishimoto, Satoru Adachi, and Kazuhiro Masuda, *X-ray micro-CT imagery of deposited snow in optical modeling of atmospheric ice particles*
• Michael Kahnert and Franz Kanngießer, *Electromagnetic scattering by soot aerosols*
• Seiji Kato, Norman G. Loeb, Fred G. Rose, and David A. Rutan, *Radiative transfer computations in estimating surface and in-atmosphere radiation budget of Earth at a global scale*
• Zhengqiang Li and Weizhen Hou, *Directional Polarimetric Camera (DPC): Monitoring aerosol spectral optical properties over land from satellite observation*
• Olga Muñoz, Jesús Escobar-Cerezo, Juan Carlos Gómez Martín, Daniel Guirado, and Fernando Moreno, *Light Scattering Experiments at visible wavelengths*
• Timo A. Nieminen, Anatolii V. Kashchuk, Isaac C. D. Lenton, Halina Rubinsztein-Dunlop, and Alexander B. Stilgoe, *Direct optical measurement of force and torque in optical tweezers*
• Fuzhong Weng, Yihong Duan, Jun Yang, Peng Zhang, Shouguo Ding, Chuanwen Wei, and Lei Bi, *Advanced radiative transfer modeling system (ARMS) – a new generation of fast and accurate RT models in China*
• Vladislav V. Yakovlev, *Per aspera ad astra: getting light through highly scattering medium*
• Peng-Wang Zhai, Meng Gao, Bryan Franz, Jeremy Werdell, Yongxiang Hu, Kirk D. Knobelspiesse, Brian Cairns, and Amir Ibrahim, *Radiative transfer modeling of the hyperspectral and polarized reflectances for aerosol and ocean color remote sensing*

**CONVENERS**
Lei Bi, *Zhejiang University, Hangzhou, China*
Michael Mishchenko, *NASA GISS, New York, USA*
Jun Wang, *University of Iowa, Iowa City, IA, USA*
Ping Yang, *Texas A&M University, College Station, TX, USA*

**PROGRAM COMMITTEE**
Gérard Gouesbet, *National Institute of Applied Sciences, Rouen, France*
Joop Hovenier, *University of Amsterdam, Amsterdam, The Netherlands*
Nikolai Khlebtsov, *Russian Academy of Sciences, Saratov, Russia*
Gerhard Kristensson, *Lund University, Sweden*
James Lock, *Cleveland State University, OH, USA*
Hal Maring, *NASA HQ, Washington, DC, USA*
M. Pinar Mengüç, *Ozyegin University, Istanbul, Turkey*
Karri Muinonen, *University of Helsinki & National Land Survey, Finland*
Christopher Sorensen, *Kansas State University, Manhattan, KS, USA*
Gorden Videen, *Army Research Laboratory, Adelphi, MD, USA*
Thomas Wriedt, *University of Bremen, Germany*
Maxim Yurkin, *Novosibirsk State University, Russia*

**LOCAL ORGANIZING COMMITTEE**
Qunke Xia, *Zhejiang University, Hangzhou, China*
Long Cao, *Zhejiang University, Hangzhou, China*
Invited Presentations

Ordered alphabetically according to the first author’s last name
Can active and passive instruments remotely sense the same clouds?

Xiquan Dong\textsuperscript{a}, Baike Xi\textsuperscript{a}, Patrick Minnis\textsuperscript{b}, William Smith Jr\textsuperscript{b}, Norman Loeb\textsuperscript{b}, and Ping Yang\textsuperscript{c}

\textsuperscript{a}University of Arizona, 2880 Broadway, 1133 E. James E. Rogers Way, Tucson, AZ 85721, USA
\textsuperscript{b}NASA Langley Research Center, Mail Stop 420, 21 Langley Boulevard Hampton, VA. 23681, USA
\textsuperscript{c}Texas A&M University, College Station, TX 77843, USA

*Presenting author (xdong@email.arizona.edu)

It is a great challenge to derive true cloud fractions (CFs) from both active and passive remote sensing observations, and it is even more difficult to infer their vertical distributions globally and regionally. With the NASA Clouds and the Earth’s Radiant Energy System (CERES) Edition 4 cloud property products in conjunction with the availability of long-term DOE ARM ground-based and NASA CloudSat–CALIPSO spaceborne radar–lidar observations, we will tentatively answer the following two scientific questions:

1) Can space- and ground-based radar–lidar combinations observe the same types and amounts of clouds over different climatic regions, such as those represented by the ARM SGP, NSA, ENA, and TWP sites?

2) Are clouds detected and analyzed using passive satellite remote sensing, such as in the CERES MODIS and GEO products, comparable to these actively sensed clouds over these four regions?

Our preliminary results show that the passively sensed CFs from CERES MODIS and GOES are approximately 10% lower than the CloudSat–CALIPSO radar–lidar detected counterparts. This 10% difference is primarily due to the optically thin clouds detected by CALIPSO but not by passive remote sensors (MODIS and GOES). Comparing to ARM CFs, CERES-retrieved clouds have the same seasonal variations but CERES CFs are 5% and 7% lower than the ARM observations at the ARM NSA and SGP sites, respectively. The CFs detected by the CloudSat–CALIPSO active sensors are 6.3% lower than ARM NSA observations because they missed some low-level clouds (below 1 km) over the Arctic. However, they are 2.3% higher than ARM SGP observations because CALIPSO can detect more optically thin high-level clouds. Therefore, knowing the limitation of platforms and retrieval methods, we have been endeavoring to uncover the physical mechanisms underlying each measurement and retrieval method with the aid of multiple instruments on various platforms. In-depth analyses for ARM ENA and TWP sites are currently ongoing and will be presented at the ELX-XVIII.

Mode of presentation: Invited
Retrieval of aerosol properties from multi-angular POLDER polarimetric observations

Oleg Dubovika,*, Pavel Litvinovb, Tatiana Lapyonoka, Fabrice Duchosa, Xin Huangab, David Fuertesb, Anton Lopatinb, Yevgeny Derimianc, Cheng Chena, Lei Li, Benjamin Torres, Yana Karolb, Milagros Herreraa, Jacques Descloîtresc, Stefan Ambergerd, Andreas Hanglerd, Michael Aspetsbergerd, and Christian Federspield

aLaboratoire d’Optique Atmosphérique, UMR8518, CNRS – Université Lille, Villeneuve d’Ascq, France
bGRASP-SAS, LOA, Université Lille 1, Villeneuve d’Ascq, France
cICARE, CNRS, University of Lille, Villeneuve d’Ascq, France
dCatalysts GmbH, High Performance Computing, Huemerstrasse 23, 4020 Linz, Austria

*Presenting author (oleg.dubovik@univ-lille.fr)

Multi-angular polarimetric imagers are widely considered as the instruments that can provide most of the requisite information about global and regional properties of aerosol. Indeed, combined simultaneous spectral, angular, and polarimetric measurements of atmospheric radiation should maximize the sensitivity of observations to detailed aerosol properties. Numerous theoretical studies concluded that multi-angular polarimetry can provide accurate characterization of aerosol with accuracy sufficient for many important applications. Nevertheless, the overall volume of polarimetric observations of the atmosphere remains small compared to that of photometric observations. Furthermore, the currently available polarimetric observations are mostly considered as useful datasets for understanding the potential of polarimetry and for designing future missions rather than as aerosol information for specific climatological and environmental applications. This situation is undoubtedly the result of the general complexity of polarimetric observations and the retrieval theory. Polarimetry is highly sensitive to a large number of atmospheric parameters, and accounting adequately for all these sensitivities in the retrieval algorithm is very demanding, especially in satellite applications wherein large volumes of data have to be processed. Therefore, the need to develop more robust algorithms for deriving aerosol properties from polarimetry has been clearly identified by the satellite community. As a result, several highly optimized algorithms have recently been developed and demonstrated to provide enhanced aerosol retrievals from satellite polarimetry [1].

The main objective of this presentation is to discuss the achievements and challenges in providing the accurate and complete aerosol retrievals from polarimetric observations. Specifically, 18 months of POLDER-1 and -2 and nine years of POLDER-3 observations have recently been processed with the GRASP algorithm [2,3] and provided to the community. In-depth analysis, validation, and comparison with other data will be provided.

References


Mode of presentation: Invited
Generalized Lorenz–Mie theories and mechanical effects of laser light: a celebration of Arthur Ashkin’s pioneering work in optical levitation and manipulation

Gérard Gouesbet

CORIA-UMR 6614-Normandie Université, CNRS-Université et INSA de Rouen, Campus Universitaire du Madrilliet, 76 800 Saint-Etienne du Rouvray, France (gouesbet@coria.fr)

The generalized Lorenz–Mie theory (GLMT, more generally GLMTs) [1] had initially been developed to address issues in optical particle characterization, more particularly in optical particle sizing, in order to simultaneously measure velocities and sizes of individual particles embedded in flows, with applications to spray combustion or plasma spraying, among others. This line of research, however, has had two opportunities to meet with another line of research, namely the one by Arthur Ashkin dealing with optical levitation, trapping, and manipulation of macroscopic particles. The first opportunity has been that the GLMT (more generally the GLMTs) is able to deal with mechanical effects of light and indeed bridges the gap between the Rayleigh and ray-optics regimes to which the theoretical part of Ashkin’s work was limited. The second opportunity has been that optical levitation experiments promoted by Ashkin have been used to experimentally test the validity of the GLMT.

In this talk, as a celebration of Arthur Ashkin’s pioneering work concerning the mechanical effects of laser light, I shall offer a review and overview of the research devoted to the GLMTs and mechanical effects of laser light, both in Rouen where the GLMT had been developed, and all over the world.

Reference


Mode of presentation: Invited
X-ray micro-CT imagery of deposited snow in optical modeling of atmospheric ice particles

Hiroshi Ishimotoa,*, Satoru Adachib, and Kazuhiko Masudaa

aMeteorological Research Institute, Nagamine 1-1, Tsukuba 305-52, Japan
bNational Research Institute for Earth Science and Disaster Prevention, Snow and Ice Research Center, Nagaoka 940-0821, Japan

*Presenting author (hiroishi@mri-jma.go.jp)

Cryogenic X-ray computed microtomography (micro-CT) is a powerful tool that can be used to analyze the detailed three-dimensional structure of deposited snow. To investigate the optical properties of real snow particles, we developed a technique to extract individual shapes of snow particles from X-ray micro-CT data, and we calculated their single-scattering properties using the conventional Geometrical Optics Method (CGOM) [1]. If we assume that the original shapes of falling ice particles remain in a structure of new deposited snow, realistic models of some large ice particles in the atmosphere, such as snowflakes and graupels, are obtained from the micro-CT data. Moreover, the extracted shape data can be used for the modeling of inhomogeneous particles of an ice/water mixture by adopting numerical simulations of ice melting.

Microwave scattering properties for the modeled particles are calculated by applying the DDA or the FDTD method. On the other hand, the CGOM and the improved geometrical optics method (GOM2/GOIE) are basically applicable to the particles of large size parameters at visible and infrared wavelengths, though some improvements for the numerical codes are necessary because of the two components for the particle material and of the complex shapes defined by a large number of facets. The approach of our particle modeling by using micro-CT data for the calculations of light scattering properties is discussed.

Reference


Mode of presentation: Invited
Electromagnetic scattering by soot aerosols

Michael Kahnert\textsuperscript{a,b,*} and Franz Kanngießer\textsuperscript{b}

\textsuperscript{a}Research Department, Swedish Meteorological and Hydrological Institute, Folkborgsvägen 17, 601 76 Norrköping, Sweden
\textsuperscript{b}Department of Space, Earth and Environment, Chalmers University of Technology, Maskingränd 2, 412 96 Gothenburg, Sweden

*Presenting author (michael.kahnert@smhi.se)

Soot aerosols in the atmosphere are among the most important anthropogenic short-lived climate forcers that contribute to global warming. They can also cause respiratory health problems and degrade atmospheric visibility. The optical properties of these particles are of high interest in both climate modelling, remote sensing, and air-quality forecasting. However, modelling electromagnetic scattering by soot particles poses a formidable challenge on account of the particles’ morphological complexity and variability. Newly formed soot particles typically form relatively lacy fractal aggregates composed of small, (nearly) spherical monomers of amorphous carbonaceous material. After atmospheric aging, the aggregates become more compact and hydrophilic. This can lead to condensation of liquid-phase material, resulting in soot aggregates encapsulated in a shell of sulfate, organic material, water, salt, or mixtures thereof.

Modelling studies on the optical properties of soot often focus on (i) assessments of the impact of specific morphological features on the optical properties (e.g., [1]); (ii) attempts to achieve closure of optical models and laboratory observations (e.g., [2]); and (iii) efforts to devise simple, yet accurate models that can be employed in environmental modelling and remote sensing (e.g., [3]). In this overview talk, the focus will be on the latter type, which, to a large extent, integrates results obtained from the former two types. The kinds of simplifications we can afford in a soot-optics model strongly depend on its intended use. Typically, we can introduce much more drastic simplifications in applications to climate modelling than in applications to remote sensing and chemical data assimilation. This will be illustrated in the talk by providing examples from each of these problems.

References


Mode of presentation: Invited
Radiative transfer computations in estimating surface and in-atmosphere radiation budget of Earth at a global scale

Seiji Kato\textsuperscript{a,}\textsuperscript{*}, Norman G. Loeb\textsuperscript{b}, Fred G. Rose\textsuperscript{b}, and David A. Rutan\textsuperscript{b}

\textsuperscript{a}NASA Langley Research Center, Hampton, VA 23681-2199, USA
\textsuperscript{b}Science Systems and Applications, Inc., Hampton, VA, USA

\textsuperscript{*}Presenting author (seiji.kato@nasa.gov)

The NASA’s Clouds and the Earth’s Radiant Energy System (CERES) project provides earth radiation budget data products. Top-of-atmosphere irradiances are derived from broadband radiance observations [1]. Surface and in-atmosphere irradiances are derived using a radiative model [2]. In order to understand radiation budget at a global scale, surface and in-atmosphere irradiances need to be estimated with a radiative transfer model.

Shortwave (solar) and longwave (emitted by the earth) irradiances are computed separately. The atmosphere is divided into ~50 vertical layers. Spectral region is separated into smaller spectral regions and absorptions by water vapor, ozone, carbon dioxide, and other trace gases are treated with the correlated-\(k\) approximation. Scattering by air molecules, aerosols and clouds are treated by two- and four-stream approximations applied to the integro-differential equation of radiative transfer. It is assumed that aerosol and cloud particles scatter radiation incoherently. Polarization state is ignored. Most inputs to the radiative transfer model come from observations, including temperature, humidity profiles, cloud and aerosol properties. Specifically, cloud and aerosol properties used in the computations are derived from satellite observations of radiances measured at discrete wavelengths.

Despite many approximations and assumptions made in the algorithm, computed surface irradiances agree to within the uncertainty of surface irradiance observations taken at 36 land sites and 46 ocean buoys distributed globally when top-of-atmosphere irradiances are constrained by irradiances derived from broadband radiance measurements by CERES instruments.

In this talk we summarize the method to compute surface and in-atmosphere irradiances, and how these irradiance estimates contribute to the understanding of the energy budget of the Earth and energy transport and hydrological cycle within the system.

References


Mode of presentation: Invited
The Directional Polarimetric Camera (DPC) is the first Chinese multi-angle polarized earth observation satellite sensor, which will be launched onboard the GaoFen-5 Satellite in Chinese High-resolution Earth Observation Program [1]. GaoFen-5 runs in a sun-synchronous orbit with an inclination angle of 98°, a 13:30 PM local overpass time, a 2-day revisiting period. The DPC employed a charge coupled device detection unit with $512 \times 512$ effective pixels from the $544 \times 512$ useful pixels, realizing a spatial resolution of 3.3 km with a swath width of 1850 km. Furthermore, the DPC has three polarized channels (at 490, 670, and 865 nm) together with five non-polarized bands (at 443, 565, 763, 765, and 910 nm), and can obtain at least nine viewing angles by continuously capturing series images over the same target on orbit [2].

Based on the optimal estimation theory and improved bidirectional reflectance distribution function model, an inversion framework for the simultaneous retrieval of aerosol and surface parameters is presented by taking full advantage of available radiometric and polarimetric measurements. The retrieved wavelength-independent fine-mode and coarse-mode aerosol volumes are used to assess the DPC performance on the inversion capability of spectral aerosol optical depth, from which the Ångström exponent and fine-mode fraction could be further obtained. In addition, based on the synthetic DPC data for various observation geometries, aerosol and surface types, the aerosol inversion capabilities are systematically evaluated, and the information content analysis results show that the aerosol spectral optical properties can be well retrieved over various land surfaces [2,3].

References


Light Scattering Experiments at visible wavelengths

Olga Muñoza,*, Jesús Escobar-Cerezoa,b, Juan Carlos Gómez Martína, Daniel Guiradoa, and Fernando Morenoa

aInstituto de Astrofísica de Andalucía (IAA), CSIC. Glorieta de la Astronomía sn, Granada 18008, Spain
bDepartment of Physics, University of Helsinki, P.O. Box 64, FI00014, Finland

*Presenting author (olga@iaa.es)

Small solid particles are present in the atmospheres of planets, satellites, and comets in the form of aerosols, or cover their surfaces as regoliths. Dust particles absorb and scatter solar radiation and that coming from the surface affecting the atmospheric thermal structure. The strong dependence of the light scattered by those particles on their shape/structure, size and composition makes the measurements of the scattering pattern a powerful tool for particle characterization in remote sensing observations.

Over the last 10 years, the COsmic DUst LABoratory (CODULAB) [1] at the IAA-CSIC has produced an important number of high quality scattering matrices for clouds of randomly orient-ed cosmic dust analogues. The CODULAB measurements are performed at three different wave-lengths (448, 520, and 647 nm) covering the scattering angle range from 3° to 177°. The data are available in digital form in the Amsterdam–Granada light scattering database www.iaa.es/scattering [2]. In the database we combine the measurements from CODULAB and those previously obtained with the Amsterdam Light Scattering setup [3]. The samples presented in the database comprise a wide range of sizes (sub-micron up to mm-sized grains), shapes, and compositions. In this talk we will discuss our current efforts to disentangle the influence of size, shape, and composition on the scattering pattern measured in the lab to link remotely observed photo-polarimetric quantities at various wavelengths with dust properties. We will also present a set of test measurements intended for evaluating the performance of the experimental apparatus at the three wavelengths studied.

References


Mode of presentation: Invited
Direct optical measurement of force and torque in optical tweezers

Timo A. Nieminen*, Anatolii V. Kashchuk, Isaac C. D. Lenton, Halina Rubinsztein-Dunlop, and Alexander B. Stilgoe

*Presenting author (timo@physics.uq.edu.au)

The University of Queensland, Brisbane QLD 4072, Australia

A key contribution of optical tweezers to biology and biophysics, recognized by the award of the 2018 Nobel Prize in Physics to Arthur Ashkin, who invented optical tweezers in 1986 [1], has been the measurement of forces on the order of piconewtons in biological systems. There are two main routes to the measurement of forces. First, since the force depends on the position of the trapped particle, the force can be inferred from the position if this dependence is known. Especially in the case of small displacements such that the trap can be treated as a linear spring characterized by a spring constant, this dependence can be found. However, this requires a calibration for each type and size of particle, and needs to be repeated if the properties of the trap change.

The optical force results from the change in momentum of the trapping beam as it is scattered by the trapped particle. Therefore, measurement of the angular distribution of the scattered light allows the direct optical measurement of the force [2]. Most implementations of this make use of a per-particle calibration, but it is possible to calibrate a suitable detector once, and measure the force acting on arbitrary particles, even if the properties of the trap are changed.

In this talk we review the direct optical measurement of forces, including recent developments in calibrate-once methods. Noting that it is generally not possible to capture all of the scattered light, we discuss why, and to what extent, the forces can be accurately measured. We also consider the direct optical measurement of torque, which is straightforward in some cases [3], and a challenge that has yet to be overcome in other cases.

References


Mode of presentation: Invited
Advanced radiative transfer modeling system (ARMS) – a new generation of fast and accurate RT models in China

Fuzhong Weng*a,†, Yihong Duan*a, Jun Yangb, Peng Zhangb, Shouguo Dina, Chuanwen Wei*a, and Lei Bic

*aState Key Laboratory of Severe Weather, No 46 Zhongguancun S. Ave., 100081, Beijing, China
bNational Satellite Meteorological Center, No 46 Zhongguancun S. Ave., 100081, Beijing, China
cZhejiang University, Zhejiang, China

*Presenting author (fweng58@gmail.com)

Many satellite instruments measure the radiation emitted by or reflected from the Earth at different spectral wavelengths. These observations – generally referred to as radiances – contain information about the Earth’s surface and atmosphere. Satellite radiances are not components of the atmospheric state vectors predicted by NWP models. In order for these radiances to be assimilated by the NWP models, a relationship between the model state vectors and the observed radiances is required. This relationship is derived from the forward radiative transfer model simulations (simply forward models) with the state vectors as input. In addition, the Jacobian vectors (or the derivative of radiance relative to the state vectors) are also needed in satellite data assimilation systems. For each satellite mission, a fast and accurate radiative transfer model is deemed necessary for the overall mission success. In the past two decades, the United States, Europe, and many other countries have already invested in the development of fast radiative transfer models through their space programs. These models have resulted in huge successes in uses of satellite data in operations.

In this presentation we review the current capabilities of fast radiative transfer models developed in the numerical weather prediction community, summarize the full requirements on fast radiative transfer models for current and future satellite data assimilation, and propose new techniques for superfast computations of atmospheric and surface radiative transfer processes.

Mode of presentation: Invited
**Per aspera ad astra**: getting light through highly scattering medium

Vladislav V. Yakovlev\textsuperscript{a,b,*}

\textsuperscript{a} Texas A&M University, College Station, Texas 77843, USA  
\textsuperscript{b} Zhejiang University, Hangzhou, Zhejiang, 310027, China  

*Presenting author (yakovlev@tamu.edu)

Strong light scattering can make an optically non-absorbing object opaque. Many far-reaching applications, such as deep brain imaging, could greatly benefit from a better coupling of light into scattering medium and increased penetration depth resulting into greater transmission through a highly scattering medium. In this talk we discuss a simple, but efficient way of increasing light coupling through optical interface engineering \cite{1–3}. Capitalizing on our prior work \cite{4–9}, we provide a theoretical foundation for our experimental findings and discuss potential applications for imaging and sensing \cite{2,4,6–7}.

This work was supported in part by the NSF (DBI-1532188 and ECCS-1509268) and DOD (FA9550-15-1-0517 and N00014-16-1-2578).

References

\begin{itemize}
\end{itemize}

Mode of presentation: Invited
Radiative transfer modeling of the hyperspectral and polarized reflectances for aerosol and ocean color remote sensing

Peng-Wang Zhai\textsuperscript{a,}\textsuperscript{*}, Meng Gao\textsuperscript{b}, Bryan Franz\textsuperscript{c}, Jeremy Werdell\textsuperscript{c}, Yongxiang Hu\textsuperscript{d}, Kirk D. Knobelspiesse\textsuperscript{e}, Brian Cairns\textsuperscript{e}, and Amir Ibrahim\textsuperscript{b}

\textsuperscript{a}JCET/Physics Department, University of Maryland Baltimore County, Baltimore, MD 21250, USA
\textsuperscript{b}SSAI, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, USA
\textsuperscript{c}NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, USA
\textsuperscript{d}NASA Langley Research Center, Hampton, VA 23668
\textsuperscript{e}NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA

\*Presenting author (pwzhai@umbc.edu)

Traditionally ocean color remote sensing relies on spaceborne spectrometers that view an image pixel with discrete spectral bands in only one viewing direction. A list of current ocean color sensors of this type include the Moderate Resolution Imaging Spectroradiometer (MODIS), Visible Infrared Imaging Radiometer Suite (VIIRS), Second Generation Global Imager (SGLI), and Geostationary Ocean Color Imager (GOCI), to name just a few. In order to further enrich the information content and characterize ocean biology and physiology better, the new generation of ocean sensors has evolved to include hyperspectral radiometers. In addition, co-located polarimeters have been proposed to better characterize aerosols and help atmospheric correction of ocean color sensors. One great example is the Ocean Color Instrument (OCI) that is planned to fly onboard NASA’s Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission. The OCI is an advanced spectrometer that makes radiometric measurements with continuous spectral coverage from the ultraviolet (350 nm) to the near-infrared (890 nm), plus a set of discrete shortwave infrared bands (940, 1038, 1250, 1378, 1615, 2130, and 2260 nm). In addition, the PACE mission plans to include two multi-angle polarimeters: the UMBC Hyper Angular Rainbow Polarimeter (HARP-2) and the SRON Spectro-polarimeter for Planetary Exploration (SPEXone).

Radiative transfer modeling is an important tool for interpreting the advanced hyperspectral images and polarization measurements. In this talk we will present a vector radiative transfer package for coupled atmosphere and ocean systems that can be used for the aerosol and ocean color retrieval using co-located spectroradiometer and polarimeter data. The package is flexible in both atmospheric and ocean compositions, includes both elastic and inelastic scattering, and incorporates atmospheric gas absorptions. The radiative transfer code has been used to study the sensitivity of the hyperspectral measurements in response to different atmospheric and ocean configurations. It is particularly interesting to study the different contributions of hyperspectral water leaving signals to the top-of-atmosphere measurements for different ocean water types, phytoplankton fluorescence strength, and most interestingly, non-photochemical quenching effects. Moreover, we will also present our current effort of retrieving aerosol and ocean color information simultaneously using polarimeter data, and use that information in assisting the atmospheric correction of hyperspectral ocean color observations. We will present the properties of aerosols and water leaving radiances retrieved from the airborne Research Scanning Polarimeter data and share the lessons that we have learned from this retrieval activity.
Regular Presentations

Ordered alphabetically according to the first author’s last name
Light scattering studies of composite interstellar dust analogues using computer simulation and laboratory setup

Gazi A. Ahmeda,*, Manash J. Boruaha, and Ankur Gogoi b

a Department of Physics, Tezpur University, Tezpur 784028, Assam, India
b Department of Physics, Jagannath Barooah College, Jorhat 785001, Assam, India

*Presenting author (gazi@tezu.ernet.in)

Dust particles found in the interstellar medium have been reported to be composed of amorphous silicate, graphite, amorphous carbon, carbonates, metal oxide grains, amorphous ice particles and even nanodiamonds. Study of the light scattering properties of such dust particles by using both computer simulations and laboratory experiments (with analogue samples) provide significant information for interpreting scattered light signals from unknown interstellar dust particles.

Here we report the study done on light scattering by interstellar dust analogue mixtures of graphite and fayalite at three incident wavelengths, that is, 543.5, 594.5, and 632.8 nm, using two computational models for particle sizes ranging from 0.3 μm to 5.0 μm. The scattering and extinction efficiencies, single scattering albedo, asymmetry parameter, phase function and degree of linear polarization are calculated using the Discrete Dipole Approximation. A comparative analysis of the theoretical and experimental results of phase function and polarization shows that the percentage composition of a mixture model is very important while simulating interstellar dust particles. The developed computational models are successful in representing a two species mixture of interstellar dust analogues dispersed in both shapes and sizes. This technique can be applied to interpret observed astrophysical data, to study atmospheric aerosols and in remote sensing.

References


Preferred mode of presentation: Oral
Optimization of the discrete dipole approximation applied to particles on a plane substrate

Anna E. Akhmetyanova\textsuperscript{a,b,*} and Maxim A. Yurkina,b

\textsuperscript{a}Voevodsky Institute of Chemical Kinetics and Combustion, SB RAS, 3 Institutskaya Str., 630090 Novosibirsk, Russia
\textsuperscript{b}Novosibirsk State University, 1 Pirogova Str., 630090, Novosibirsk, Russia

\textsuperscript{*}Presenting author (a.akhmetianova@g.nsu.ru)

Investigating optical properties of particles on a substrate is relevant to different scientific and technical applications. On one hand, the synthesis and use of various nanoparticles commonly occur on a substrate. On the other hand, the substrate and/or interface itself enables one to develop new optical methods, for example, total internal reflection microscopy. The discrete dipole approximation (DDA) is an efficient method for simulating the interaction of the electromagnetic field with particles of arbitrary shape and internal structure. This method, derived from the frequency-domain volume-integral Maxwell equation, is numerically exact, i.e., achieves any required accuracy with sufficient computational resources.

The computational problem of the DDA consists in solving a large system of linear equations. High efficiency is achieved by applying a conjugate-gradient iterative solver with the matrix-vector product computed using the fast Fourier transform (FFT). The presence of the substrate requires one to replace the dipole–dipole interaction term with a more complicated expression including the so-called Sommerfeld integrals. The latter lacks a translational symmetry along the surface normal, seemingly breaking the FFT acceleration. Fortunately, this acceleration can be retained by cleverly rearranging the interaction terms [1]. This new formulation has been implemented in the open-source code ADDA [2], reaching the same computational complexity as in the free space (almost linear in the number of dipoles). Still, the calculation of four Sommerfeld integrals for every possible distance between two dipoles takes significant time, in some cases longer than the rest of the simulation.

The goal of this work is to optimize these calculations by using series expansions and asymptotic approximations of the integrals for small and large distances, respectively, and an interpolation over two cylindrical variables in the intermediate region. This approach significantly reduces the number of runs of the integration routines and, consequently, the simulation time, while keeping the same accuracy. We will present specific timing results and simulation examples at the conference.

References


Preferred mode of presentation: Oral
Remote sensing of droplet size profiles in cumulus clouds using the Research Scanning Polarimeter: tests on simulated data

Mikhail D. Alexandrov\textsuperscript{a,b,*}, Daniel J. Miller\textsuperscript{c}, Chamara Rajapakse\textsuperscript{d}, Ann Fridlind\textsuperscript{b}, Bastiaan van Diedenhoven\textsuperscript{a,b}, and Brian Cairns\textsuperscript{b}

\textsuperscript{a}Columbia University, 2880 Broadway, New York, NY 10025, USA
\textsuperscript{b}NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA
\textsuperscript{c}NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
\textsuperscript{d}University of Maryland, Baltimore County, 1000 Hilltop Cir, Baltimore, MD 21250, USA

\textsuperscript{*}Presenting author (mda14@columbia.edu)

The Research Scanning Polarimeter (RSP) is an airborne along-track scanner measuring the polarized and total reflectance in nine spectral channels. Its uniquely high angular resolution allows for the characterization of liquid water cloud droplet sizes using the rainbow structure observed in the polarized reflectance over the scattering angle range from 135° to 165°. We use two separate retrieval techniques. The first one is a parametric fit assuming that cloud droplet size distribution (DSD) has gamma-distribution shape and yielding its effective radius and variance. The second one, the non-parametric Rainbow Fourier Transform (RFT), is able to provide the entire DSD shape with no pre-assumptions. The RSP’s high angular resolution and frequency of measurements also allows for the estimation of cumulus cloud shape and position from the collection of view-lines tangent to the cloud surface.

In this study we introduce retrievals of vertical profiles of droplet size made along the illuminated side of the cumulus cloud. First, we use the RSP’s tangent view-lines to determine the position of the cloud surface. Then for each point on the bright side of this surface we aggregate view-lines passing through it, thereby constructing the polarized reflectance corresponding to that point (as a function of scattering angle). The rainbow part of this reflectance is analyzed yielding the shape and parameters of the cloud DSD. Finally, the retrievals made for all available points on the cloud surface are combined into vertical profiles.

This profiling algorithm was tested by simulating RSP measurements over LES-generated clouds using the MSCART 3D RT code. Towering cumulus clouds were selected for this numerical experiment in preparation for analyses of real RSP measurements during the upcoming Cloud, Aerosol and Monsoon Processes Philippines Experiment. The results of the comparison between the virtual RSP retrievals and the actual microphysical parameters in the LES model show agreement in the effective radius and variance within 1 μm and 0.02, respectively. Also, the non-parametric RFT algorithm was able to detect and characterize two different populations of cloud droplets: one convectively rising from cloud bottom to top, while growing in size; and the other being activated at cloud top due to condensation and consisting of small 5-μm particles. This opens the way to process-oriented remote sensing based on the RSP data.

Preferred mode of presentation: Oral
The application of realistic dust grain shapes to debris disk photometry

Jessica A. Arnolda,*, Alycia J. Weinbergera,*, Gorden Videenb, and E. Zubkc

aCarnegie Institution for Science, Department of Terrestrial Magnetism, 5421 Broad Branch Rd, Washington, DC 20015, USA
bSpace Science Institute, 4750 Walnut St, Suite 205, Boulder, CO 80301, USA
cFar Eastern Federal University, 8 Sukhanova Street, Vladivostok 690950, Russia

*Presenting author (jarnold@carnegiescience.edu)

Debris disks are dusty circumstellar disks analogous to our solar system’s Kuiper belt, asteroid belt, and zodiacal cloud [1]. The dust in these disks is produced by the destruction of comets, asteroids, and protoplanets. Understanding the composition of the material within these extrasolar systems may provide insight into the planet formation process. At visible and near-infrared (VNIR) wavelengths, dust within debris disks is detected via light from the host star scattered by these dust grains. As debris disks are typically too cold to produce key identifying silicate spectral features in thermal emission near 10 μm [2], scattered light in the VNIR wavelength range is important for making compositional determinations. To interpret scattered light observations of debris disks we need to model the light scattering properties of the constituent dust, which depend on grain composition, size, and structure. Often these models assume compact, spherical particles (e.g., [3]), although other grain shapes such as ellipsoids and distributed hollow spheres have been considered (e.g., [4]). We use the discrete dipole approximation method [5,6] to calculate scattering efficiencies for realistic grain shapes [6] and use these to model the optically thin disk AU Microscopii.

References


Preferred mode of presentation: Oral
Study of stochastic processes with time-dependent transition probabilities


Instituto Nacional de Astrofísica, Optica y Electronica INAOE, Dpto. de Optica, Postal 51 y 216, Puebla, Mexico

*Presenting author (jc_atengo@inaoep.mx)

In this work we show applications in the evolution of probabilistic trajectories when the transition probabilities acquire a stationary character which is interpreted as “probabilistic geodesics”.

The evolution of the stochastic process type Markov chain is described when transitions of probability are functions of time. The structure of the process is modeled with a stochastic matrix whose convergence generates stationary trajectories. The model is implemented to the synthesis of optical modes allowing to describe the processes of entanglement and revival of the fields themselves. The fields evolution is describing by the entropy calculus. Computational simulations are shown as results.

Considering families of trajectories, morphological variability of optical fields is described, generating coherence and partial polarization processes.

Reference


Preferred mode of presentation: Poster
Electromagnetic interactions of anisotropic dye molecules surrounding a nanosphere

Baptiste Auguié* and Eric C. Le Ru

School of Chemical and Physical Sciences, Victoria University of Wellington, PO Box 600 Wellington, New Zealand

*Presenting author (baptiste.auguie@vuw.ac.nz)

Nanostructures such as metal colloids can substantially affect the absorption and emission of light by vicinal molecules, raising considerable interest for such diverse applications as light-harvesting in solar cells, or surface-enhanced spectroscopies. The topic is also of great relevance to more fundamental pursuits such as strong coupling between light and molecules. Recent experimental results have revealed that molecular absorption can undergo considerable spectral changes when a molecule is adsorbed on a metal surface [1]. Such changes may be attributed to a variety of causes, some of a more chemical nature – a modification of the molecule interacting with the metal surface – and some that fall in the realm of classical electromagnetic scattering.

This contribution will present an original and rigorous computational model to describe the electromagnetic interactions between collections of anisotropic dye molecules and a core nanosphere in experimentally-relevant configurations. Our model extends the coupled-dipole approximation, which predicts important effects of orientation-dependent dye-dye interactions in a homogeneous medium [2], with a rigorous multipolar description of dye-nanosphere interactions based on a generalised multipolar Mie theory [4]. The predictions of this model reveal a rich interplay between the relative orientation of the dye molecules, their concentration, and their interaction with the metallic core that strongly modifies the local electric field, in amplitude and polarisation. The model qualitatively confirms the results of a simpler core-shell approximation where the dyes are described as a homogeneous effective-medium shell [1,3], but provides a much finer microscopic description of dye-dye interactions for different relative dye orientations and distances, and better insights into the subtle effects of dye-nanoparticle electromagnetic interactions.

References


Preferred mode of presentation: Oral
Plasmonic responses of metallic/dielectric core–shell nanoparticles on a dielectric substrate

Dilan Avşara, Hakan Ertürka, and M. Pinar Mengücb,*

aBoğaziçi University, Department of Mechanical Engineering, Bebek, 34342 Istanbul, Turkey
bCenter for Energy, Environment and Economy (CEE), Özyeğin University, 34794 Istanbul, Turkey

*Presenting author (pinar.menguc@ozyegin.edu.tr)

Core–shell nanoparticles can be classified as dielectric–metal, metal–dielectric, and metal–metal according to their material compositions for the core and shell, respectively. These nanostructures have various advantages: the plasmonic response of the nanoparticles can be tuned and/or hybridized by changing the material composition, core/shell size ratio, and the surrounding medium. Such nanoparticles can offer unprecedented ways to exploit their optical properties with optimum field enhancement and tunable LSPR responses [1]. Their hybrid structures are promising for localized heating applications that necessitate a detailed study of absorption mechanisms with material and size combination.

Although there are numerous numerical studies based on NPs and their LSPR responses, most of them based on geometries involving free space without surface interactions or in an aggregate form. A recent numerical study of silica core-gold shell NP being placed on a BK7 substrate showed that enhanced absorption efficiency and a redshift of the plasmon response can be achieved for selective heating and nano-manufacturing purposes [2]. There are, however, limited number of studies on material comparisons that will guide the experimentalists to the optimum configurations for the enhanced effects. The objective of the present paper is to focus on the spectral absorption profiles of core–shell nanoparticles with various core–shell material and size configurations accompanied with surface interactions. Current study is the follow-up investigation of [2] with single core–shell nanoparticle placed on a semi-infinite BK7 glass substrate being illuminated by an EM light from bottom with total internal reflection. The spectral absorption behavior of core–shell nanoparticle is numerically studied with selected metal–dielectric, and dielectric–metal pairs for core and shell materials, respectively.

In this paper, the effects of material selection on the plasmonic response and local absorption are evaluated for core-shell nanoparticles placed over a BK7 glass substrate. Eight different core-shell pairs are studied using the vectorized version of discrete dipole approximation with surface interactions. Two classes of dielectric core–metallic shell and metallic core–dielectric shell particles are considered. It is shown that core–shell structures with dielectric materials can have absorption enhancement compared to the bare metallic nanoparticles. Moreover, it is observed that core–shell pairs yield multipeak localized surface plasmon resonance (LSPR) response due to their hybrid structure. Absorption enhancement and LSPR tuning ranges are shown with different dielectric materials that can be used in localized heating of designated core–shell NPs placed over a surface for nanomanufacturing purposes. In order to determine the optimum size configurations, a number of core-shell pairs are explored with specified volumetric filling ratio of core materials.

References


Preferred mode of presentation: Oral
Reversal of optical binding force between uniaxial anisotropic heterodimer based on the forced breaking of symmetry

J. Bai, Z. S. Wu*, and C. X. Ge

School of Physics and Optoelectronic Engineering, Xidian University, Xi’an, Shaanxi, 710071, China
Collaborative Innovation Center of Information Sensing and Understanding at Xidian University, Xi’an, Shaanxi, 710071, China

*Corresponding author (wuzhs@mail.xidian.edu.cn)

This study theoretically investigates the optical binding force exerted on uniaxial anisotropic heterodimer induced by an arbitrarily polarized high-order Bessel beam (HOBB). Such non-diffracting light suppressed the influence of the axial intensity profile of the illuminating beams on the self-organization process which then depended critically upon the inter-particles interactions. Using the generalized multi-particle Mie equation (GMM) [1,2], we analyzed the lateral binding force in terms of Maxwell’s stress tensor for various inter-particle distance at some specific wavelengths. The stimulating connection between the reversal of near-field binding force of uniaxial anisotropic heterodimer and the role of symmetry-breaking has not been investigated comprehensively in the literature. In this work, the symmetry of spherical uniaxial anisotropic heterodimer-setup is broken forcefully by shining the light from a specific side of the set-up instead of impinging it from the top. We demonstrate that for the forced symmetry-broken spherical heterodimer-configurations: reversal of lateral and longitudinal near-field binding force follow completely distinct mechanisms. Interestingly, the reversal of lateral binding force can be easily controlled changing the direction of light propagation or by varying their relative orientation. Besides, the polarizations of incident HOBB considerably influence the optical binding force of uniaxial anisotropic nanoparticles. In binding uniaxial anisotropic nanoparticles, the polarization of incident beams should be chosen in accordance with the anisotropic permittivity tensor elements. This simple process of controlling binding force may open a novel generic way of optical manipulation even with the anisotropic heterodimers of other shapes. Though it is commonly believed that the reversal of near-field binding force should naturally occur for the presence of bonding and anti-bonding modes, our study based on Lorentz-force dynamics suggests notably opposite proposals for the aforementioned cases. Observations in this article can be very useful for improved sensors, particle clustering and aggregation.

References


Preferred mode of presentation: Poster
Temperature dependence of ice particle refractive index and implications in sub-millimeter ice cloud retrievals

Adam Bell\textsuperscript{a,*}, Ping Yang\textsuperscript{a}, and D. L. Wu\textsuperscript{b}

\textsuperscript{a}Texas A\&M University, College Station, TX 77843, USA  
\textsuperscript{b}Climate and Radiation Lab, NASA Goddard Space Flight Center, Greenbelt, MD, USA  
\textsuperscript{*Presenting author (bellad1@tamu.edu)}

Ice clouds play a substantial role in the Earth’s climate system, particularly through their influence on the global energy budget. These influences, coupled with the spatiotemporal variability of ice clouds, impose difficulties in understanding their radiative effects and subsequently our current climate and potential future changes [1]. Fundamental ice cloud parameters for quantifying cloud radiative properties are the ice water path (IWP) and ice particle effective diameter. Current general circulation models vary in their estimation of the cloud IWP by as much as an order of magnitude. Imposing constraints from observations is challenging since ice mass retrievals are generally ill conditioned (i.e., less information content in observations than in the requisite solution). Sub-millimeter (sub-mm) wave radiometry is an emerging technique for characterizing cloud properties due to high sensitivity to ice cloud parameters, in particular the IWP.

Even with this increased sensitivity, it is necessary to make assumptions in ice cloud retrievals, such as ice particle shape (habit) which effects particle single scattering properties. Previous studies have also shown sensitivity of ice particle sub-mm single scattering properties to ice refractive index at certain temperatures [2,3].

In this work we present an information content based approach to understand temperature effects on ice refractive index, and subsequent contributions to ice cloud property retrieval uncertainties over a wide range of sub-mm wavelengths.

References


Preferred mode of presentation: Poster
Advances in digital holography of aerosol particles

Matthew J. Berg\textsuperscript{a,}\textsuperscript{*}, Ramesh Giri\textsuperscript{a}, Yuli Heinson\textsuperscript{b}, Osku Kemppinen\textsuperscript{a}, Ryan Mersmann\textsuperscript{a}, Jesse Laning\textsuperscript{a}, Steve Holler\textsuperscript{c}, and Gorden Videen\textsuperscript{d}\textsuperscript{e},\textsuperscript{f}

\textsuperscript{a}Kansas State University, Department of Physics, 1228 N. 17\textsuperscript{th} St., Manhattan, KS 66506-2601, USA
\textsuperscript{b}Department of Energy, Environment & Chemical Engineering, Washington University in Saint Louis, One Brookings Dr., Box 1180, Saint Louis, MO 63130, USA
\textsuperscript{c}Department of Physics and Engineering Physics, Fordham University, Bronx, NY 10458-5198, USA
\textsuperscript{d}Space Science Institute, 4750 Walnut Street Suite 205, Boulder, CO 80301, USA
\textsuperscript{e}Department of Astronomy and Space Science, Kyung Hee University, 1732, Deogyeong-daero, Giheung-gu, Yongin-si, Gyeonggi-do 17104, South Korea
\textsuperscript{f}U.S. Army Research Laboratory, 2800 Powder Mill Road, Adelphi, MD 20783, USA

\textsuperscript{*}Presenting author (matt.berg@phys.ksu.edu)

Digital holography has proven a powerful method to study aerosol particles. In the method, a particle is illuminated by an expanded laser beam and the interference pattern produced by unscattered and forward-scattered light from the particle is recorded on a sensor such as a CCD. This interference pattern is the hologram, and from it, an image of the particle can be unambiguously rendered. However, we have recently shown that other useful information may be obtained from a particle’s hologram [1,2]. For example, we will explain here how the two-dimensional angular scattering pattern in the far-field can be generated from the hologram via Huygens’ principle [2]. We will also discuss our ongoing laboratory and instrument-development work applying digital holography to atmospheric aerosols [3].

References


Preferred mode of presentation: Oral
The invariant imbedding approach to the Debye series for light scattering by nonspherical particles

Lei Bi*, Feng Xu†, and Gérard Gouesbet‡

*Department of Atmospheric Sciences, Zhejiang University, Zhejiang, China
†Jet Propulsion Laboratory, California Institute of Technology, USA
‡CORIA-UMR 6614-Normandie Université, CNRS-Université et INSA de Rouen, Campus Universitaire du Madrillet, 76 800 Saint-Etienne du Rouvray, France

*Presenting author (bilei@zju.edu.cn)

The Debye series was first proposed for light scattering by an infinite circular cylinder [1]. It has been demonstrated to be valuable for optical interpretation of light scattering by spheres, coated spheres, and spheroids (e.g., [2–4]). By applying the extended boundary condition method (EBCM) [5,6] and expanding the Green’s dyadic into the third and fourth vector spherical wave functions, Xu et al. [7,8] derived the Debye series for a homogeneous and coated nonspherical particle. However, like the EBCM-based T-matrix method for computing light scattering by nonspherical particles, the EBCM-based Debye series approach has similar numerical convergence issues in calculating light scattering when the particle size and/or aspect ratio (e.g., for spheroid) gets large. In this talk, we report the progress in using an invariant imbedding approach (IIA, [9]) to compute the Debye series for a large nonspherical particle. The IIA has been successfully applied to compute the T-matrix for large nonspherical particles [10] and found to be also applicable in the framework of the Debye series. First, we show that the T-matrix can be explicitly expanded in terms of an infinite series. To compute the IIA-based Debye series, we derive four matrices associated with the reflection and transmission of wave interaction upon the boundary from the medium to the particle and from the particle to the medium. Second, we demonstrate that the four matrices satisfy the Riccati differential equations which can be solved by the Runge–Kutta method. The results are analytically validated for a sphere and numerically validated for nearly spherical particles (against the results computed by the EBCM-based Debye approach). Finally, the new insights into light scattering by nonspherical particles gained from the Debye series approach are illustrated with representative examples, such as the optical interpretation of light backscattering by nonspherical particles.

References


Preferred mode of presentation: Oral
Measurement of the aspect ratio distribution of rigid arbitrary shaped nanoparticles using the Translational–Rotational Image-based Dynamic Light Scattering

Paul Briarda*, Chen Yuan Li, and Xiao Shu Cai

*Xidian University, 2 South Tai Bai Road, 710071 Xi’an, P. R. China
*University of Shanghai for Science and Technology, 516 Jun Gong Road, 130012 Shanghai, P. R. China

The Dynamic Light Scattering method (DLS) is a method which permits to measure the Stokes radius distribution of a sample of polydisperse arbitrary shaped nanoparticles in Brownian motion, where the Stokes radius of a particle is the radius of the spherical particle which have the same translational Brownian motion [1]. In a conventional DLS experiment, the sample is illuminated by an incident focused laser beam and scatters the light toward a photomultiplier tube. The analysis of the light fluctuations recorded by the photomultiplier tube permits to obtain the distribution of their translational diffusion coefficients. Then, the Stokes radius distribution is measured.

The DLS has been improved in the Ultrafast Image-based Dynamic Light Scattering method (UIDLS) where the fluctuation of the light scattered by the sample is recorded by an image sensor instead of a photomultiplier tube [2,3]. Although the Stokes radius is related with the size, the conventional DLS or by the UIDLS don’t permit to obtain information about the shape of the nanoparticles. This is the reason why we have developed an improvement of the UIDLS, named Translational–Rotational Image-based Dynamic Light Scattering where the light scattered by the sample is recorded by two cameras for two polarization geometries. From the light fluctuations recorded by the cameras, the translational diffusion coefficient distribution and the rotational diffusion coefficient distribution are measured. They are related with the translational and rotational Brownian motion of the nanoparticles and they permit to obtain the aspect ratio distribution of the arbitrary shaped nanoparticle complimentarily with the Stokes radius distribution which is also measured. This talk will be focused on the experimental measurement of the aspect ratio distribution of a sample of 2D nanoparticles, where the aspect ratio a 2D nanoparticle is defined as the aspect ratio of the disk-like particle which have the same translational and rotational Brownian motion.

References


Preferred mode of presentation: Oral
Lidar depolarization ratio for soot fractal aggregates: application to tropospheric and stratospheric smoke

Romain Ceolato\textsuperscript{a},\textsuperscript{*}, Lucas Paulien\textsuperscript{a}, Matthew J. Berg\textsuperscript{b}, William R. Heinson\textsuperscript{c}, Anna Gialitaki\textsuperscript{d}, Alexandra Tsekeri\textsuperscript{d}, Vassilis Amiridis\textsuperscript{d}, and Chris Sorensen\textsuperscript{b}

\textsuperscript{a}ONERA, The French Aerospace Lab, Toulouse FR 31055, France
\textsuperscript{b}Kansas State University, Department of Physics, 1228 N. 17 St., Manhattan, KS 66506-2601, USA
\textsuperscript{c}Washington University in St. Louis, 1 Brookings Drive, St. Louis, MO 63130-4899, USA
\textsuperscript{d}IAASARS, National Observatory of Athens, Athens, Greece

\textsuperscript{*}Presenting author (romain.ceolato@onera.fr)

Lidars are valuable instruments for vertical profiling of aerosols with the capability to remotely probe their radiative properties. Polarization-sensitive lidar systems, or polarimetric lidars, resolve the linear depolarization ratio (LDR) of light backscattered from an illuminated volume of atmospheric constituents. The LDR is a reliable and quantitative parameter that yields information about the aerosol-particle morphology. For example, the LDR can be used to discriminate spherical and non-spherical particle shapes. Generally, the LDR values are small (<5%) for anthropogenic aerosols such as smoke but are greater (20%) for dust, ice in clouds, or volcanic ash. The LDR values for carbonaceous soot particles, however, are less well known. These particles are created during incomplete combustion of biomass and fossil fuel (e.g., diesel and kerosene) and consist of complex aggregates of ultrafine spherical particles. Several studies have been undertaken to compute the LDR of soot aggregates to aid the interpretation of polarimetric lidar measurements. A major challenge with soot aggregates is that their morphology is complex and evolves with time from freshly emitted to aged smoke. Moreover, recent measurements report unexpectedly high LDR values for stratospheric smoke from a biomass-burning event. Such considerations motivate further modeling of how light scatters from soot, and in particular, the broadband backscattering behavior. Here, we model the broadband LDR for soot fractal aggregates from the ultraviolet to infrared wavelengths. Simulation results are presented based on the DDA and MSTM methods for two different fractal aggregates: chain-like aggregates and super-aggregates.

References


Preferred mode of presentation: Oral
Characterization of aerosol optical characteristics, vertical distribution and radiative forcing of ambient aerosols over the Yangtze River Delta during 2013–2015

Huizheng Chea,*, Tianze Suna,f, Bing Qi, Yaqiang Wanga, Yunsheng Dongc, Xiangao Xia, Hong Wanga, Ke Guia, Yu Zhengf, Hujia Zhaoa, Qianli Ma, Rongguang Du, and Xiaoye Zhang

a State Key Laboratory of Severe Weather and Institute of Atmospheric Composition, Chinese Academy of Meteorological Sciences, CMA, Beijing 100081, China
b Hangzhou Meteorological Bureau, Hangzhou 310051, China
c Key Laboratory of Environment Optics and Technology, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Science, Hefei 230031, China
d Laboratory for Middle Atmosphere and Global Environment Observation, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, 100029, China
e School of Geoscience University of Chinese Academy of Science, Beijing, 100049, China
f Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disasters, Nanjing University of Information Science & Technology, Nanjing 210044, China
g Lin’an Regional Air Background Station, Lin’an 311307, China

*Presenting author (chehz@cma.gov.cn)

As the central part of eastern China, the Yangtze River Delta (YRD) region, with its rapid economic growth and industrial expansion, has experienced severe air quality issues. In this study, the monthly variation and interaction between aerosol optical properties, aerosol direct radiative forcing (ADRF) and aerosol vertical structure during 2013–2015 over the YRD were investigated using ground-based observations from a Micro Pulse Lidar and a CE-318 sun-photometer. Combining satellite products from MODIS and CALIPSO, and reanalysis wind fields, enhanced haze pollution events affected by different types of aerosol over the YRD region were analyzed through vertical structures, spatial distributions, backward trajectories, and the potential source contribution function (PSCF) model. The results reveal that a shallower PBL coincides with higher scattering extinction at low altitude, resulting in less heating to the atmosphere and radiative forcing to the surface, which in turn further depresses the PBL. Like in June and September, the hygroscopic growth facilitated by high relative humidity leads to high scattering extinction coefficient and relatively low PBL. In months with a deeper PBL, the extinction coefficient decreases rapidly with altitude, showing stronger atmospheric heating effects and ADRF to the surface by absorptive particles, facilitating the turbulence and vertical diffusion of aerosol particles, which further reduces the extinction and raises the PBL, like July and August with high single scatter albedo (SSA). The PBL height is greater (ranging from 1.23 to 1.84 km) and more variable in the warmer months of March to August, due to the stronger diurnal cycle and exchange of heat. Not only polluted by the local emissions, northern fine-mode pollutants are brought to the YRD at a height of 1.5 km. The SSA increases, creating a feedback to the cooling effect. Originated from the deserts in Xinjiang and Inner Mongolia, long-range transported dust masses are seen at heights of about 2 km over the YRD region with an SSA440 nm below 0.84, which heat air and raise the PBL, accelerating the diffusion of dust particles. Regional transport from biomass-burning spots to the south of the
YRD region bring absorptive particles at a height below 1.5 km, resulting in an SSA$_{440 \text{ nm}}$ below 0.89. During the winter, the accumulation of the local emission layer is facilitated by stable weather conditions, staying within the PBL even below 0.5 km [1,2].

References


Preferred mode of presentation: Oral
Impact of aerosol non-sphericity on the satellite remote sensing of CO₂

Xi Chen, Jun Wang, Dongxu Yang, Xiaoguang Xu, Ping Yang, Oleg Dubovik, Yi Liu, Michael Mishchenko, and Robert Spurr

Department of Chemical and Biochemical Engineering, 4133 Seamans Center, Iowa City, IA 52242-1503, USA
Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
Joint Center for Earth Systems Technology, University of Maryland – Baltimore County, 1000 Hilltop Circle, Baltimore, MD 21250, USA
Department of Atmospheric Sciences, MS 3150, College Station, Texas 77843, USA
Laboratoire d’Optique Atmosphérique, CNRS–Université de Lille, Lille, France
Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA
RT Solutions, Inc. Cambridge, MA 02138, USA

*Presenting author (jun-wang-1@uiowa.edu)

Existing algorithms for satellite remote sensing of CO₂ assume that all atmospheric aerosol particles are spherical. This assumption, however, is only valid for the atmosphere in the absence of dust particles that are non-spherical by their nature. Here, a theoretical analysis is conducted for the dusty atmosphere to analyze the impact of aerosol non-sphericity on the accuracy of CO₂ retrievals from space. The analysis begins by adding new capabilities to the UNL-VRTM, a UNified and Linearized Vector Radiative Transfer Model [1] (http://unl-vrtm.org) which can calculate both the four Stokes parameters and their respective sensitivities to aerosol properties. The new capability builds upon the existing non-spherical scattering property database [2,3] and develops an analytical method to calculate the Jacobians of these scattering properties to aerosol size distribution parameters, index of refraction, and particle shape factors. With this new capability, the UNL-VRTM is upgraded to compute radiative transfer for the spectrum of Tan-Sat [4], and the subsequent retrieval of CO₂ [5] is conducted by using the UNL-VRTM synthetic data. In the presentation, we will describe the development and validation of UNL-VRTM’s new capabilities and provide an analysis of CO₂ retrieval errors due to the lack of consideration of aerosol non-spherical shape in dusty conditions.

References


Preferred mode of presentation: Oral
Retrieval of fine-mode and coarse-mode aerosol optical properties from sun and sky radiance measurements based on aerosol type classification method

Qi-Xiang Chen\textsuperscript{a}, Yuan Yuan\textsuperscript{a,*}, and He-Ping Tan\textsuperscript{b}

\textsuperscript{a}School of energy science and engineering, Harbin Institute of Technology, Harbin, 150001, PR China
\textsuperscript{b}Key Laboratory of Aerospace Thermophysics, Ministry of Industry and Information Technology, Harbin Institute of Technology, Harbin, 150001, PR China

\*Presenting author (yuanyuan83@hit.edu.cn)

Aerosols are an important part of the atmosphere for it changes the radiance balance of the Earth–Ocean–Atmosphere system by absorption and scattering shortwave solar radiation and longwave earth radiation. Detailed knowledge of aerosol optical properties is needed not only to assess the aerosol climate effect but also to improve the accuracy of remote sensing. The widespread ground-based Aerosol Robotic Network (AERONET), as well as the sky radiometer network mainly located in eastern Asia (SKYNET), provides related parameters including the aerosol optical depth, complex refractive index ($m$), and volume size distribution (VSD) \cite{1–3}. However, both the AERONET and SKYNET algorithms use the internal mixing hypothesis that assumes that fine- and coarse-mode aerosol particles have the same $m$ values. This is not correct as the different particle modes have different compositions, and thus different $m$ values \cite{4,5}.

In this study, we propose a new algorithm to retrieve the fine- and coarse-mode $m$ values and VSD simultaneously by using ground-based measurements of direct sun and diffuse sky radiance. Seeing the ill-posed nature of retrieving $m$ and VSD from scattered radiances, using a priori constraints is critical for successfully solving such problems with many parameters. So on the basis of the previous constraints we introduce an aerosol type classification method into the retrieval process to apply specific constraints of modal $m$ values to specific aerosol types. Numerical tests show good performance when the specific a priori constraint for different aerosol types is introduced compared to that a unified a priori constraint is used. Our results also suggests distinct seasonal variations of modal $m$ values in typical AERONET sites.

References


Preferred mode of presentation: Poster
An inverse scattering problem for 2-D dielectrics via Eikonal approximation

Charles E. Chika

The University of Texas at Dallas, 800 W Campbell Rd., Richardson, TX 75080, USA
(cec140330@utdallas.edu)

A non-iterative method for constructing a class of 2-dimensional (2-D) refractive index of a medium from forward scattering amplitude data of electromagnetic plane waves incident at different angles and frequencies was developed. The 2-D Eikonal approximation of the scattering amplitude was derived by considering the integral representation of the solution of the Helmhohlz equation, and then it is used to develop an inverse method to construct the 2-D refractive index. Also, numerical comparisons were carried out for the refractive index constructed from the Eikonal amplitude using the inverse method developed with the one constructed from the exact amplitude as well as the exact refractive index for some known examples. This inverse method will be effective in applications because it is easy to implement and gives good recovery (or construction) of refractive index [1].

In this presentation, we summarize our result, its limitations, advantages and future works.

References


Preferred mode of presentation: Oral
Measurements of light extinction by single aerosol particle elevated by linear electrodynamic quadrupole

Fenghong Chua*, Allen Haddrellb, Antonio Valenzuelab, Jim S. Walkerb, Andrew J. Orr-Ewingb, and Jonathan Reidb

a Shanghai University of Electric Power, 2103 Pingliang Road, Shanghai, 200090, China
b School of Chemistry, University of Bristol, BS8 1TS, UK

*Presenting author (chufenghong@siom.ac.cn)

A new experiment is presented for the measurement of single aerosol particle optical cross section combining laser-based cavity ring-down spectroscopy (CRDS) with a linear electrodynamic quadrupole (LEQ) ion trap in tandem with phase function measurements. The LEQ utilizes the quadrupole field created by four parallel rods spaced in a square pattern with an AC voltage applied to pairs of diametrically opposing rods. The time-varying field constrains charged particles to a point in the two-dimensional plane perpendicular to the rod axes, producing a line of stability along the geometric center [1]. This approach allows direct measurements of the changing optical cross sections of individual aerosol particles over indefinite time-frames facilitating some of the most comprehensive measurements of the optical properties of aerosol particles so far made.

The variation in ringdown time with the position of 1,2,6-hexanetriol particle within the CRD beam is measured. The particle can not only be translated vertically along the z axis by varying DC voltage at the bottom and air flow rate from the top of quadrupole but also along the x-y axis by translating the position of the quadrupole. The measurements illustrate the sensitivity in the ringdown time to the position of the particle within the Gaussian waist of the CRD beam, with the largest reduction observed only when the particle is carefully aligned to the center of the TEM00 mode profile. The radius of 1,2,6-hexanetriol particle at 532 nm is determined from PFs and optical cross section at 405nm is measured over a continuous radius range.

This facility can be also used to measure the optical properties of absorbing aerosols, including brown carbon particulates. These tiny particles affect both the optical properties and the temperature of the Earth’s atmosphere. For example, brown carbon absorbs sunlight, can affect the warming of the atmosphere by solar radiation, and can reduce visibility in polluted environments [2–4].

References


Preferred mode of presentation: Poster
Using Pattern Equation Method for solving the problem of EM scattering by thin dielectric cylinder

Dmitri B. Demina, Andrey I. Kleev, and Alexander G. Kyurkchan*  

*aMoscow Technical University of Communications and Informatics, 8а Aviamotornaya str., Moscow111024, Russian Federation  
bP. L. Kapitza Institute for Physical Problems, Russian Academy of Sciences, 2 Kosygina str., Moscow 119334, Russian Federation  
cKotel’nikov Institute of Radio Engineering and Electronics, Fryazino Branch, Russian Academy of Sciences, pl. Vvedenskogo 1, Fryazino, Moscow oblast, 141190, Russian Federation  
dCentral Research Institute of Communication, 8 1st Perova Polyva Drive, Moscow 111141, Russian Federation  

*Presenting author (agkmtuci@yandex.ru)

At present, the Rayleigh approximation [1] is almost the only mathematical model used in solving the problem of scattering on small bodies. In the well-known monographs [1–3], this approach is described in sufficient detail especially for the cases when the solution of an auxiliary electrostatic problem can be obtained in an explicit form. In this paper, an alternative method is developed based on the Pattern Equation Method (PEM) [4–6]. When constructing a new approach to the analysis of scattering on small bodies, we used the high convergence of the PEM established in the above papers. Indeed, as shown by the calculations, to solve the problem of scattering on bodies whose characteristic size is comparable to the wavelength of the scattering field, it is sufficient to take into account, depending on the polarization of the incident field, from one to three terms in the expansion of the scattering pattern. This circumstance made it possible to obtain explicit formulas for the integral scattering characteristics applicable to scatterers of a complex shape.

References


Preferred mode of presentation: Poster
Analysis of a scattering by a cylinder of a large cross section using the Hybrid Pattern Equations Method

Dmitri B. Demina\textsuperscript{a}, Andrey I. Kleev\textsuperscript{b}, and Alexander G. Kyurkchan\textsuperscript{a,c,d,*}

\textsuperscript{a}Moscow Technical University of Communications and Informatics, 8а Aviamotornaya str., Moscow111024, Russian Federation
\textsuperscript{b}P. L. Kapitsa Institute for Physical Problems, Russian Academy of Sciences, 2 Kosygina str., Moscow 119334, Russian Federation
\textsuperscript{c}Kotel’nikov Institute of Radio Engineering and Electronics, Fryazino Branch, Russian Academy of Sciences, pl. Vvedenskogo 1, Fryazino, Moscow oblast, 141190, Russian Federation
\textsuperscript{d}Central Research Institute of Communication, 8 1st Perova Polya Drive, Moscow 111141, Russian Federation

*Presenting author (agkmtuci@yandex.ru)

Scattering of waves by obstacles whose dimensions substantially exceed the wavelength of the incident radiation is one of the key problems in the theory of diffraction. In the present paper we propose a new methodology based on the Pattern Equations Method (PEM) \cite{1,2}. The high rate of convergence of the PEM established in the above studies can be used to construct various asymptotic approaches. In particular, using PEM, the authors succeeded in obtaining approximate formulas for the integral cross section for scattering by Rayleigh objects \cite{3}. In this paper, we develop a Hybrid Pattern Equations Method (HPEM), based on the use of a combination of PEM and the Physical Optics approximation (PO). The integral–differential equation for the “correction” to the PO solution for the scattering pattern is obtained. It is shown that this approach has a high efficiency and, at the same time, does not require significant computational costs in solving diffraction problems for cylinders, even in cases where the characteristic cross-sectional dimension is large compared to the wavelength of the incident radiation. The rate of convergence, as well as the accuracy of the results obtained, depend weakly on the geometric dimensions of the cross section of the cylinder, which makes this approach a promising method for calculating the scattering characteristics in those cases when the transverse dimension of the scatterer substantially exceeds the wavelength of the incident field.

References


Preferred mode of presentation: Poster
Bio-inspired structures for radiative cooling applications

Azadeh Didari\textsuperscript{a} and M. Pinar Mengüç\textsuperscript{b,*}

\textsuperscript{a}Department of Electrical and Electronics Engineering, Istanbul Şehir University, 34865 Istanbul, Turkey
\textsuperscript{b}Center for Energy, Environment and Economy (CEEE), Ozyegin University, Istanbul 34794, Turkey

*Presenting author (pinar.menguc@ozyegin.edu.tr)

Blue Peruvian \textit{Morpho didius} butterfly is a special butterfly species that shows a magnificent iridescent blue color in its wings. This iridescent structural color which plays a dominant role in the overall glossy blue color of the wings has been evolved for survival and recognizability purposes over the years. Earlier investigations of the wing structures had shown that these butterflies have pheromone-producing organs which act as a thermal regulator system within their wings [1]. Inspired by the micro and nanostructures of their wings, in this work, we present a biomimetic model based on the \textit{Morpho didius} butterfly wings which shows potential to be utilized in radiative cooling applications. This biomimicry design involves SiC palm tree-like structures placed in nano-scale separation of a thin film in a vacuum environment. The near-field energy exchange is enhanced significantly by decreasing the dimensions of the tree and rotating the free-standing tree structure by 90 degrees clockwise and also by decreasing the separation distance with the second thin film. This exchange is calculated by using near-field radiative transfer finite difference time domain algorithm [2]. Several orders of enhancement of near-field heat flux within the infrared atmospheric window (8–13 μm bandwidth) are achieved [3]. This spectrally selective enhancement is due to the geometric variations, the spatial location of the source of excitation and the optical properties of the materials, and can be tuned to tailor strong radiative cooling mechanisms.

References


Preferred mode of presentation: Oral
Multiple scattering of polarized light by particles in an absorbing host medium

Janna M. Dlugach* and Michael I. Mishchenko

*aMain Astronomical Observatory of the National Academy of Sciences of Ukraine, 27 Zabolotny Str., 03680, Kyiv, Ukraine
bNASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA

*Presenting author (dl@mao.kiev.ua)

We use recently developed first-principles tools [1–3] to solve the vector radiative transfer equation for a particulate layer imbedded in an absorbing host medium. The results of extensive computations for typical geophysical scenarios are analyzed, and conclusions are formulated as to the practical importance of the effects of absorption in the host medium.

References


Preferred mode of presentation: Oral
On the order of atmospheric scattering, its polarization and computation efficiency

Minzheng Duan

LAGEO, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, 100029, China
(dmz@mail.iap.ac.cn)

Polarization becomes more and more important in current and future remote sensing of earth’s atmosphere and astronomical observations, as it could provide more information than that of intensity-only measurements. While forward simulation of polarization of light during its transfer in the earth-atmosphere system is still a burden especially for the full polarized radiative transfer with heavy aerosol loading. Based on previously established model-SOSVRT, a full polarized radiative transfer model with successive order of scattering method, the polarization of atmospheric scattering under different aerosol loadings are simulated, the lights for each scattering order, its polarization and the errors introduced by ignoring the polarization are analyzed. We are trying to answer how many orders are necessary in polarization simulations. Finally, a new method to speed up the modelling of polarized radiative transfer is proposed.

Preferred mode of presentation: Poster
Extension of vectorial complex ray model to 3D light scattering by large non-spherical particles

Qingwei Duan\textsuperscript{a,b}, Xiang’e Han\textsuperscript{a}, and Kuan Fang Ren\textsuperscript{b}*

\textsuperscript{a}School of Physics and Optoelectronic Engineering, Xidian University, Xi’an 710071, China
\textsuperscript{b}CORIA-UMR 6614-Normandie Université, CNRS-Université et INSA de Rouen, Campus Universitaire du Madrillet, 76 800 Saint-Etienne du Rouvray, France

*Presenting author (fang@coria.fr)

The calculation for the 3D light scattering of large particle with irregular shape is still a challenging problem because of its complexity. The available numerical methods such as $T$ matrix, discrete multipole approximation, etc., are severely limited by the size parameter of the scatter \cite{1}. The geometric optics approximation method, be flexible as claimed, has made little headway for 3D light scattering due to its inherent drawbacks. And the variable separation methods such as Lorenz-Mie theory and Debye series expansion are limited to objects with regular shapes such as spheres, ellipsoids and cylinders. Ren et al. in \cite{2} proposed the vectorial complex ray model (VCRM), aiming to solve the light scattering by large non-spherical particles. However, the current numerical implementation of the VCRM only addresses rays propagating within a 2D plane \cite{3}.

In this paper, we firstly propose the extension of VCRM to the 3D light scattering by large particles of irregular shapes. The proposed method is very flexible and can be applied, theoretically, to solving the 3D light scattering by any large particle, as long as the particle has a smooth surface. Another significant advantage is its efficiency. For a non-spherical particle with size parameter over 5000, the time needed to calculate the 3D scattering field only takes about 20 minutes on a laptop, without parallel computation. An application of the method to the 3D light scattering by a circular liquid jet \cite{4–6} with irregular geometry is given to show its capability, and the simulation result agrees well with that by experiment.

3D Light scattering by a circular liquid jet with size parameter being about 5000 and surface being complex. Left: propagation directions of scattering rays for different times of interaction. Right: comparison of the scattering field near the 2\textsuperscript{nd} rainbow by simulation (in red) with that by experiment (in hot map).
References


Preferred mode of presentation: Oral
Retrievals of aerosol properties using an AERONET tuned implementation of the Dark Target and GRASP inversion frameworks

W. Reed Espinosa\textsuperscript{a,}\textsuperscript{*,} Robert C. Levy\textsuperscript{a}, Oleg Dubovik\textsuperscript{b}, Yingxi R. Shi\textsuperscript{a,c}, Lorraine A. Remer\textsuperscript{d}, Tatyana Lapyonok\textsuperscript{b}, and David Fuertes\textsuperscript{e}

\textsuperscript{a}Goddard Space Flight Center, Greenbelt, MD, USA
\textsuperscript{b}Laboratoire d’Optique Atmosphérique, UMR8518, CNRS – Université de Lille 1, Villeneuve d’Ascq, France
\textsuperscript{c}GESTAR, Universities Space Research Association, Columbia, MD, USA
\textsuperscript{d}Joint Center for Earth Systems Technology, Baltimore, MD, USA
\textsuperscript{e}GRASP-SAS, Remote sensing developments, Université des Sciences et Technologies de Lille, Villeneuve d’Ascq, France

\textsuperscript{*}Presenting author (reed.espinosa@nasa.gov)

In this work we combine novel and well-established retrieval techniques to obtain improved estimates of aerosol optical depth (AOD) over land and ocean from observations made by the Moderate Resolution Imaging Spectroradiometer (MODIS). The radiances used as retrieval inputs are obtained using the gas absorption corrections as well as the pixel screening and aggregation techniques of the well-established Dark Target algorithm. The long heritage of these techniques provides confidence that the resulting radiances are predominantly free from artifacts that can negatively influence retrievals, including cloud contamination, suspended sediment and sun glint. These preprocessed radiances are then fed into the advanced and highly flexible Generalized Retrieval of Aerosol and Surface Properties (GRASP) algorithm. The versatility of the GRASP inversion framework allows for a set of customized assumptions regarding the surface and intensive aerosol properties. In order to derive a set of assumptions that ultimately best utilizes the limited information content of the MODIS measurement, we make use of the flexibility of the GRASP code and first perform a synergistic joint retrieval on both the MODIS radiances and collocated AOD measurements made by AERONET sun photometers. The resulting retrievals of surface properties as well as aerosol concentration, size, refractive index and shape are then used to constrain a retrieval exclusively utilizing MODIS observations in a manner that is consistent with both the MODIS measurement and the highly accurate AERONET AOD. The tuned MODIS retrieval was then applied to all pixels collocated with 120 globally representative AERONET sites over a 15-year period. Over ocean, the results indicate that at 550 nm the new retrieval was highly correlated with the AERONET AOD’s ($R = 0.900$). Furthermore, the net AOD biases of the new method were consistently below 0.01 across all six retrieved wavelengths, significantly less than the corresponding Dart Target biases of 0.02–0.05. Furthermore, the RMS errors were reduced relative to the standard Dark Target algorithm, with 7% more retrievals falling within the World Meteorological Organization’s target AOD accuracy range of $\Delta \tau = \pm 0.03 \pm 0.1 \tau$.

Preferred mode of presentation: Oral
Internal and near-surface fields of a charged sphere illuminated by a vector Bessel beam

Yinan Feng\textsuperscript{a,†}, Yiming Yang\textsuperscript{a}, and Renxian Li\textsuperscript{a, b,*}

\textsuperscript{a}School of Physics and Optoelectronic Engineering, Xidian University, Xi’an 710071, China
\textsuperscript{b}Collaborative Innovation Center of Information Sensing and Understanding, Xidian University, Xi’an 710071, China

†Presenting author (18292390916@sina.cn)
*Corresponding author (rxli@mail.xidian.edu.cn)

Vector vortex beams (VVBs) \[1\] have recently attracted increasing interest for various applications including super-resolution imaging, on-chip switching, optical tweezers \[2\], and so on. It is worth mentioning that a VVB may carry both phase singularity and polarization singularity. Many researchers have studied the singularities (optical vortices) carried by VVBs, and a new branch of physics name singular optics \[3,4\] is formed. Most the applications involve the interaction of VVBs with particles, which can be rigorously solved using generalized Lorenz–Mie theory \[5\]. However, it gives few clues to the various physical processes that are responsible for the scattering. To isolate the contribution of various scattering process and to further investigate the physical origins of many effects that occur in scattering, the internal and scattering coefficients can be rewritten in terms of Debye series expansion (DSE) \[6–9\].

The aim of this paper is to discuss the internal and near-surface fields of a charged sphere illuminated by a vector Bessel beam using DSE. The internal and scattered coefficients for a charged sphere are first expanded using DSE, and the beam shape coefficients (BSCs) of a VVB are derived using the angular spectrum decomposition and the multipole expansion of spherical harmonic functions. The internal and near-surface fields of a charged sphere illuminated by a VVB are numerically computed. The effects of the carried charges, the order, polarization, and half-cone angle of the beams are discussed. The internal fields for various scattering processes (namely Debye mode \(p\)) are analyzed. Potential applications of these results include particle sizing, optical trapping and manipulation, etc.

References


Preferred mode of presentation: Oral
Monte Carlo code and modelling of polarized radiative transfer in the envelopes of post-AGB objects

Juris Freimanis* and Romāns Peženkovs

Engineering Research Institute “Ventspils International Radio Astronomy Centre” of Ventspils University College, 101 Inženieru iela, Ventspils, LV-3600, Latvia

*Presenting author (jurisf@venta.lv)

It is widely believed that post-asymptotic giant branch (post-AGB) objects are undergoing a transition phase from a “normal” star burning its nuclear fuel to a planetary nebula [1]. Their progenitors are stars with the main sequence mass in the range from (very approximately) 2 to 8 solar masses. They have extended gas–dust envelopes of various (often very peculiar, and often bipolar) shapes created by an intense mass loss. This is an important stage in star’s life; the mass outflow substantially enriches the interstellar medium with heavy elements, driving the chemical evolution of the host galaxy. The asymmetric shape of an outflow from an initially almost spherically symmetric star is not fully explained, but extensive research of this topic is being done worldwide. The binary nature of a star has been proposed as the cause of bipolar outflows, and moreover it has been supposed that some post-AGBs never become planetary nebulae [2].

In recent years, new powerful astronomical instruments have started to provide spatially resolved polarized images of these objects [3,4] as well as high-resolution interferometric data [5]. In order to make conclusions about the morphology and spatial distribution of matter in optically thick circumstellar envelopes as well as about the chemical composition, size, shape and orientation of dust grains, polarized radiative transfer modelling must be performed.

We have created a Monte Carlo computer code for the modelling of polarized continuum radiative transfer in an arbitrarily shaped circumstellar dust cloud. The scattering medium is discretized into rectangular parallelepipeds; the properties of individual dust grains are assumed to be constant inside each parallelepiped, but the concentration of the grains may vary smoothly. The first version of our code assumes a macroscopically isotropic and mirror-symmetric scattering medium [6], but we are working to relax this assumption. The program has been written in the C++ language, and the calculations are done on our computing cluster using one of its nodes with 16 cores.

Our first attempts to interpret really observed post-AGB objects are in progress. Our code can be used for the interpretation of other astronomical objects as well provided that (i) general relativistic effects are not essential, (ii) birefringence is negligible, and (iii) refraction can be neglected, i.e., radiation propagates along straight lines between the successive acts of scattering.

References


Preferred mode of presentation: Oral
Joint retrieval of aerosol properties and water leaving radiance using multi-angular polarimetric measurements over open and coastal ocean waters


aSSAI, NASA Goddard Space Flight Center, Code 616, Greenbelt, Maryland 20771, USA
bJCET/Physics Department, University of Maryland, Baltimore County, Maryland, 21250, USA
cNASA Goddard Space Flight Center, Code 616, Greenbelt, Maryland 20771, USA
dNASA Langley Research Center, Hampton, VA 23668
eNASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA
fSchool of Marine Sciences, University of Maine, Orono, ME 04469, USA

*Presenting author (meng.gao@nasa.gov)

Ocean color remote sensing is a challenging task over coastal waters due to the complex optical properties of aerosols and hydrosols. In order to accurately estimate water leaving signals, we implemented a joint retrieval algorithm to obtain aerosol properties and water leaving signal simultaneously based on polarimetric measurements. The algorithm can be applied to both open and coastal waters. The open water optical properties in the algorithm are modeled by the chlorophyll-a concentration, while the coastal water optical properties are modeled by seven parameters which explicitly account for the absorption and scattering by phytoplankton, colored dissolved organic matter and non-algal particles. The aerosol and ocean optical properties are retrieved by the Levenberg–Marquardt optimization algorithm based on a coupled atmosphere and ocean radiative transfer model. The algorithm has been validated with synthetic data generated by a vector radiative transfer model [1]. We will discuss the retrieval procedure and accuracy using the airborne Research Scanning Polarimeter measurements from two field campaigns [2]. The goal is to assist the future development of the atmospheric correction algorithm using polarimetric measurements for the NASA’s Plankton, Aerosol, Cloud, and ocean Ecosystem mission, which includes a hyperspectral Ocean Color Instrument and two multi-angle polarimeters onboard: the UMBC Hyper Angular Rainbow Polarimeter and the SRON Spectro-polarimeter for Planetary EXploration.

References


Preferred mode of presentation: Oral
A numerical study about optical trapping properties of nanoparticle on composite metallic film

Cheng-Xian Ge, Zhen-Sen Wu, Jing Bai, and Lei Gong

*School of Physics and Optoelectronic Engineering, Xidian University, Xi’an, Shaanxi, 710071, China
bSchool of Photoelectric Engineering, Xi’an Technological University, Xi’an, Shaanxi, 710021, China

*Presenting author (wuzhs@mail.xidian.edu.cn, cxge@stu.xidian.edu.cn)

In recent years, optical trapping and manipulation of particles have been widely used in different areas of science, particularly in researching the optical trapping properties of surface plasmon polaritons due to the advantages of being high precision and sensitivity [1], since the pioneering work of Ashkin et al. on trapping a dielectric microsphere using a single focused laser beam. Nowadays it has been applied to manipulate nanoparticle near the composite metallic film with periodic structure.

Based on the three-dimensional dispersive finite difference time domain method and Maxwell stress tensor equation, the optical trapping properties of nanoparticle placed on the composite metallic film are investigated numerically. Surface plasmon polaritons are excited on the metal-dielectric interface with particular emphasis on the crucial role in tailoring the optical force acting on a nearby nanoparticle. In order to obtain the detailed trapping properties of nanoparticle, selected calculations on the effects of beam waist radius, sizes of nanoparticle and circular holes, distance between incident Gaussian beam and composite metallic film, material of nanoparticle and polarization angles of incident wave are analyzed in detail to demonstrate that the optical trapping force can be interpreted as a virtual spring which has a restoring force to perform positive and negative forces as nanoparticle moving closer to or away from the centers of periodic structure. The results could provide guidelines for further research on the optical system design and manipulation of arbitrary composite nanoparticles.

![Figure 1. Schematic of the target placed on the composite metallic film with periodic structure.](image)

In this paper, the effects of various parameters on the composite model are investigated in detail to obtain the analytical results. Figure 1 shows the main schematic of the research. The meaning of the parameters will be discussed in our future work.
Reference

Light scattering by dust particles in the innermost coma of comet 67P/Churyumov–Gerasimenko: synthetic images from numerical simulations in comparison with Rosetta OSIRIS data

Selina-Barbara Geriga*, Raphael Marschallb, Olga J. Pinzón Rodrígueza, Nicolas Thomasa, and the OSIRIS team

aPhysikalisches Institut, Sidlerstrasse 5, University of Bern, CH-3012 Bern, Switzerland
bInternational Space Science Institute (ISSI), Hallerstrasse 6, CH-3012 Bern, Switzerland

*Presenting author (selina-barbara.gerig@space.unibe.ch)

During two years, from August 2014 – September 2016, ESA’s Rosetta spacecraft followed comet 67P/Churyumov–Gerasimenko (hereafter 67P) along its orbit and collected a vast amount of data about both the nucleus and the innermost coma with a large set of scientific instruments.

Dust in the innermost coma of 67P is visible through sunlight scattered by dust particles, which was caught on the images of Rosetta’s scientific Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) cameras [1]. The dust in the innermost coma is dragged away from the surface by outgassing from sublimating ices on the nucleus and the motion of the dust is coupled, although in a complex way, to the motion of the gas. The OSIRIS image data set offers therefore the unique opportunity to study global gas and dust dynamics and dust grain properties in the innermost coma of comet 67P through sunlight scattered in the coma itself. However, the inverse problem of determining the properties of scattering particles just by the field of scattered light is extremely challenging and complicated to solve unambiguously. Our approach is to numerically model the gas and dust dynamics in the coma around the comet in full 3D and then apply a Mie scattering model to produce synthetic images that can be directly compared to the original data from OSIRIS observations [2]. In our computer model we simulate the dynamic behaviour of 40 discrete dust size bins and weight our results according to a power law function of the type \( n(r_d) \sim r_d^{-b} \), with \( n \) being the number density, \( r_d \) the radius of the dust particles and \( b \) the power law exponent determining the steepness of the particle size distribution. Our simulated dust sizes range between \( r_d = 8 \text{ nm} – 0.3 \text{ mm} \) corresponding to size parameters of \( 0.08 < x < 3265 \) (\( x = 2\pi r_d/\lambda \), with \( \lambda \) being the wavelength of the incident light). This method allows us to test different combinations of input parameters, governing for example the particle size distribution, to determine the most probable set of parameters that best describe the observations.

To study the dynamical behaviour of gas and dust in the innermost coma of 67P we analyse azimuthally averaged pixel column brightnesses with increasing distance from the nucleus, the so-called “azimuthal average profiles” [3]. The column brightness from scattered light by dust particles in the coma is proportional to the integrated number density along the camera line-of-sight for an optically thin coma. Deviations of real data results from simplified model predictions of dust number densities are therefore a direct sign for additional physical processes engaged in the dynamical behaviour of gas and dust not accounted for in the model and hence an interesting field of research.

In our recent studies we have focused on the possibility to explain deviations from simulation results to OSIRIS data especially prominent on the night side of the coma with the presence of...
large particles. Large particles can be captured in gravitationally bound orbits or on long ballistic trajectories around the nucleus and have been observed in the vicinity of 67P (e.g., [4]). Here we explore how to incorporate large particle scattering in our model and study its effects on the azimuthal average profile in combination with the simulated main bulk of the dust coma that is scattering sunlight in the Mie regime.

In this talk we will portray how we use numerical simulation of gas and dust dynamics combined with a Mie particle scattering model to calculate synthetic images in spectral radiance which can be compared directly to OSIRIS images. We will also shortly discuss our latest results regarding the deviations between simulated data and observations and explain our findings and the implications thereof.

The team from the University of Bern is supported through the Swiss National Science Foundation and through the NCCR PlanetS.

OSIRIS was built by a consortium of the Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany; CISAS–University of Padova, Italy, the Laboratoire d’Astrophysique de Marseille, France; the Instituto de Astrofísica de Andalucía, CSIC, Granada, Spain; the Research and Scientific Support Department of the European Space Agency, Noordwijk, The Netherlands; the Instituto Nacional de Tecnica Aeroespacial, Madrid, Spain; the Universidad Politecnica de Madrid, Spain; the Department of Physics and Astronomy of Uppsala University, Sweden; and the Institut fuer Datentechnik und Kommunikationsnetze der Technischen Universitaet Braunschweig, Germany. The support of the national funding agencies of Germany (DLR), France (CNES), Italy (ASI), Spain (MEC), Sweden (SNSB), and the ESA Technical Directorate is gratefully acknowledged.

References


Preferred mode of presentation: Oral
Scattering of Bessel beams in the framework of the discrete dipole approximation

Stefania A. Gluhova\textsuperscript{a,b,*} and Maxim A. Yurkin\textsuperscript{a,b}

\textsuperscript{a}Voevodsky Institute of Chemical Kinetics and Combustion, SB RAS, Institutskaya Str. 3, 630090 Novosibirsk, Russia
\textsuperscript{b}Novosibirsk State University, Pirogova 2, 630090 Novosibirsk, Russia

*Presenting author (stefgluhova@gmail.com)

In recent years Bessel beams have been gaining special popularity [1]. They belong to the class of non-diffraction beams which do not spread out during propagation (like an unbounded plane wave). Despite the fact that the ideal Bessel beam cannot be obtained in the experiment due to finite energy, it is often sufficient to have an approximate Bessel beam in a finite domain. While the scattering of these beams by particles of simple shapes, such as spheres, has been discussed in the literature, it is rarely considered for complex particles.

The discrete dipole approximation (DDA) is a popular method to simulate scattering and absorption of electromagnetic waves by particles of arbitrary shape and internal structure. In this method the volume of the scatterer is divided into small cubical subvolumes (“dipoles”) whose interactions are approximated based on the volume integral equation for the electric field [2]. In principle, the DDA and the corresponding computer codes are applicable to arbitrary incident fields. However, practical simulations for any beam types are much more accessible to the practitioners if they are built into the code. Thus, the main goal of this work is the implementation of Bessel beams in the open-source ADDA code [2].

On one hand, the simplest description is available for linearly polarized beams associated with linearly polarized Hertz potentials of electric (\textit{e}−) or magnetic (\textit{m}−) type [1]. The last two types are linearly independent, even if we consider both \textit{x}- and \textit{y}-polarization for each type. On the other hand, there exist axisymmetric beams which are a superposition of linearly polarized beams of \textit{e}− and \textit{m}− types. They are interesting because they correspond to quasi-Bessel beams obtained by using a conical lens. Therefore, we decided to implement all these types of Bessel beam in the ADDA code. Each of them is described by the corresponding command line option: “\textsc{--beam besselCS}” and “\textsc{--beam besselLP}”, with five parameters: order, convergence angle (tilt angle of a conical lens), and three coordinates of the beam center (relative to the center of the scatterer).

We plan to finish and test the implementation by the time of the conference. As a result, it will be straightforward for anyone to simulate the scattering of Bessel beams by arbitrary inhomogeneous particles.

References


Preferred mode of presentation: Oral/Poster
Aerosol plays a vital role in the Earth’s radiation budget by scattering and absorbing the incoming solar radiation. In general, the aerosol particles are considered as chemically homogeneous spheres in the retrieval techniques of ground and space borne observations [1,2]. Here it is noteworthy to mention that the atmospheric particles (especially dust particles) are highly nonspherical in nature [3,4] and the aforesaid assumption may lead to erroneous observations in retrievals. For better simulation of optical and radiative properties of aerosols, a good knowledge of aerosol’s morphology, chemical composition and internal structure is essential [5,6].

In present work, we characterize the PM$_{10}$ (particulate matter with aerodynamic diameter less than 10 µm) particles collected form typical arid (the Thar Desert, Rajasthan, India) and typical urban (New Delhi, India) environments. The particles were milled several times to investigate their internal structure. The EDS (Energy Dispersive X-ray Spectroscopy) spectra were recorded after each milling to check the variation in the chemical composition. In arid environment, Fe, Ca, C, Al, and Mg rich shell was observed over a Si rich particle. In urban environment, shell of Hg, Ag, C, and N was observed over a Cu rich particle. Based on the aforesaid observations, different model shapes [single species homogenous sphere (S1) and spheroid (SPH1); multiple species mixture homogeneous sphere (S2) and spheroid (SPH2); and core shell (CS)] have been considered for simulating their respective optical properties.

Spectral variation of SSA for the considered model shapes (S1, SPH1, S2, SPH2 and CS).
In case of Si rich particle having shell of Fe, Ca C, Al and Mg, SSA (Single Scattering Albedo) was calculated for the aforementioned model shapes using core-shell optical models (fig. 1). SSA for CS has been observed to be in between the S1, SHP1 and S2, SPH2. This is attributed to the chemical composition of the respective model shapes. For S1 and SPH1 (only quartz), the SSA tends to 1 while the same found to be reduced (b/w 0.5 to 0.6) for S2 and SPH2 (homogeneous mixture of BC, Fe$_2$O$_3$, CaCO$_3$, Al$_2$O$_3$ and MgO). The optics of the other analyzed particles will be discussed in detail during presentation.

References


Preferred mode of presentation: Oral
Laser light scattering particle sizing: inherent limitations and effects of optical model selection, unknown refractive index, and irregular particle shape

Juan Carlos Gómez Martín a, Daniel Guirado a *, Jesús Escobar-Cerezo a, b, Olga Muñoz a, Fernando Moreno a, and Evgenij Zubko c

a Instituto de Astrofísica de Andalucía – CSIC, 18008, Granada, Spain
b Department of Physics, University of Helsinki, Finland
c Far Eastern Federal University, 8 Sukhanova Street, Vladivostok 690950, Russia

* Presenting author (dani@iaa.es)

Measuring the size distribution of dust particle clouds is of interest in many scientific and technological fields. Inversion of the phase function measured by laser light scattering (LLS) [2] is one of the most widely used sizing methods, owing to its speed, bulk-representative sampling, suitability for a wide range of sizes and materials and ease of use [2]. In this presentation, we briefly review different aspects of LLS, including instrumental features, inversion techniques and scattering models. We show that the LLS method using the Mie optical model retrieves robustly size distributions of spherical particles for particle radii \( r \geq 0.2 \mu m \), while the upper limit is determined by how close to zero scattering angle (\( \theta \)) the measurements are performed. The retrieval of size distributions is very sensitive to overestimating the absorption coefficient and underestimating the real part of the refractive index in the small particle range for \( r < 10 \mu m \). The Fraunhofer model can be used in a restricted scattering angle range (\( \theta < 6^\circ \)) and is valid for very absorbing particles for sizes below 1 \( \mu m \), while for non-absorbing particles the retrieved size distributions are reliable for \( r > 3 \mu m \).

Because real world particles are in general irregular, we focus on the application of LLS to the sizing of irregularly-shaped particles (agglomerate debris model [3]) in a critical range where particle size and analysis wavelength are of the same order (0.1 \( \mu m \) – 3 \( \mu m \)). The phase functions modelled with the DDA method in this size range show heavy entanglement of size, refractive index and irregularity effects. It is shown that in this size range reasonable retrievals are obtained for distributions dominated by particles closer to the upper limit of the range (e.g., power-laws with exponent \( p > -2.5 \)), where size remains the dominant effect. In general, irregularity results in narrower forward scattering peaks and lower scattered intensity at side angles compared to spherical analogs. Diffuse scattering inside irregular particles manifest itself in the phase function as an apparent absorption. As a consequence, LLS retrieves distributions with larger effective radius and higher effective absorption coefficient and/or a lower real refractive index. It can be inferred that the use of the scattering pattern of model particles (spherical or irregularly-shaped) with an internal structure different to that of the real samples under study in order to determine the real and imaginary parts of their refractive index may result in wrong estimates, e.g. a higher absorption coefficient if the model particles are more compact. Accounting for this requires a characterization of the additional absorption and extended size range as a function of the internal structure (packing density) of the particles under study.
References


Preferred mode of presentation: Oral
Estimating the effective phase function of cloud particles from the 3MI sensor

Souichiro Hioki\textsuperscript{a,*}, Jérôme Riedi\textsuperscript{a}, Laurent Labonnote\textsuperscript{a}, Mohamed Djellali\textsuperscript{a}, and Huazhe Shang\textsuperscript{a,b}

\textsuperscript{a}Univ. Lille, UMR 8518 – LOA – Laboratoire d’Optique Atmosphérique, F-59000 Lille, France
\textsuperscript{b}Institute of Remote Sensing and Digital Earth, Chinese Academy of Science, Beijing, China

\textsuperscript{*}Presenting author (souichiro.hioki@univ-lille.fr)

The phase function of a collection of cloud particles depends on the thermodynamic phase, size distribution, geometric shape, and surface texture of the particles. \textit{In situ} measurements and remote sensing of the phase function are promising means to study the development and microphysical variation of clouds. For example, multi-viewing satellite instruments, including the Multi-angle Imaging Spectroradiometer (MISR) sensor and the Polarization and Directionality of the Earth’s Reflectance (POLDER) sensors, are sensitive to the phase function at backward scattering directions and provide unique datasets that are used in the validation of the phase functions for satellite data processing.

An effective approach to investigate the phase function of cloud particles from reflectivity measurements is the Spherical Albedo Difference (SAD) method. In this method, the variation of the retrieved cloud spherical albedo is considered an indication of the difference between the true phase function and the phase function used in the spherical albedo retrieval. We further extend the SAD method to retrieve an effective phase function. The extended algorithm is applied to the synthetic data of the Multi-viewing, Multi-channel, Multi-polarisation Imager (3MI) to evaluate the applicability to the new satellite sensor.

The 3MI sensor is a spaceborne imaging spectropolarimeter planned to fly aboard the MetOp Second Generation A satellite platform. The design of the instrument leverages heavily on the POLDER sensors to use most of the expertise we gained through the years of operation of the POLDER sensors. The nominal resolution is 4 km at nadir, and the sensor acquires total and polarimetric reflectivity at nine wavelengths. In this presentation, we summarize the planned Level-2 cloud products from the 3MI sensor and specifically report on the preliminary results from the application of the effective phase function estimation.

Preferred mode of presentation: Oral/Poster
A parallelized Pseudo Spectral Time Domain Model for the light scattering simulation for aerosol particles with irregular shapes and inhomogeneous compositions

Shuai Hu*, Taichang Gao, Lei Liu, and Ming Chen

National Key Laboratory on Electromagnetic Environment and Electro-optical Engineering, National University of Defense Technology, No. 60 Shuanglong Street, Nanjing 211101, China

*Presenting author (hushuai2012@hotmail.com)

To improve the precision of climate modeling and atmospheric remote sensing, radiative transfer models (RTM) that can accurately calculate the radiation transferred through the atmosphere with aerosols and cloud are required [1–3]. As the fundamental input parameters for the radiative transfer simulation, the light scattering properties of aerosols (especially these in solar spectrum) should be accurately modeled [4–7]. However, due to the irregular shapes and inhomogeneous compositions of aerosol particles (like mineral dust, soot, etc.), their light scattering processes have not been adequately understood, and substantial uncertainties still remain in their optical properties [8,9]. To simplify the scattering process of aerosol particles, in the RTMs widely used now, nonspherical aerosol particles are usually taken as the spherical ones with equivalent volume or surface area, which will definitely decrease the computational accuracy of radiative transfer [6,10–12]. Many researchers have also found that the nonspherical shapes of aerosol particles exert a significant influence on the polarized components of radiation [6,9,13].

To improve the modeling accuracy of radiative transfer, the scattering properties of aerosol particles with irregular shapes and inhomogeneous compositions should be accurately simulated. To this end, a light scattering model for nonspherical particles is established based on the Pseudo Spectral Time Domain Model (PSTD) technique. This model is comprised of three modules, i.e., the preprocessing module, electromagnetic field computational module and scattering parameter calculation module. In this model, the Perfectly Matched Layer with Auxiliary Differential Equation (ADE–PML), an excellent absorption boundary condition (ABC) in FDTD, is generalized for PSTD scheme, and the weighted Total Field/Scattered Field (TF/SF) technique is employed to introduce the incident light into 3D computational domain. To improve the computational efficiency, the model is further parallelized by the OpenMP technique. The modeling accuracy of PSTD is validated against Lorenz–Mie, Aden–Kerker and T-matrix theory for spheres, inhomogeneous particles and nonspherical particles, and the influence of the spatial resolution and the thickness of ADE–PML on the modeling accuracy is discussed as well. At last, the parallel computational efficiency of the model is also analyzed. The results show that an excellent agreement is achieved between the results of PSTD and those well-tested scattering models, where the simulation errors of extinction efficiencies are generally smaller than 1%, indicating the high accuracy of our model. Though with a low spatial resolution, reliable modeling precision still can be achieved by PSTD model, especially for large particles. To suppress the electromagnetic wave reflected by the absorption layers, a 6-layer ADE–PML should be set in the computational domain at least.
References


Preferred mode of presentation: Oral
An effective method of degrading electromagnetic field in resonant inductive power transfer of automotive vehicle for public safety

A. U. Ibrahim*, H. A. Umar, and S. Muhammad

Jigawa State Polytechnic, Dutse, Sani Abacha Way, PMB 7040 Dutse, Nigeria

*Presenting author (habuuba@gmail.com, abubakar.uba@jigpoly.edu.ng)

Public exposure to high frequency time varying electromagnetic field is a serious threat to human health, and there has been continued resistance to the rapid development of wireless charging in automotive vehicles. Resonant inductive power transfer (RIPT), especially at high power, becomes a source for such electromagnetic stray field. Consequently, compliance to safety standard guidelines of international and regional regulators could guarantee public safety [1,2].

This work proposes a suitable alternative for degrading such magnetic fields, without adding much complexity to the system. A distinctive mechanism of flux interaction in multichannel RIPT [3,4] has properly been harnessed to degrade the intensity of the potential electromagnetic field reaching general public within a close range. RIPT system of 50 kw/85 Hz has been designed using both single-channel and three-channel topology to compare their extended magnetic stray field at 0.8 m away from the center of the charging zone. Simulation outcomes revealed a significant reduction of these stray fields by the proposed three-channel system to the tune of 68% when compared against the conventional one-channel system. This may expose new possibilities, and could eventually encourage the competitiveness of commercialization of automotive vehicles with wireless charging facility. This is promising especially for public bus transport where a charging system may be needed at high power.

References


Preferred mode of presentation: Oral
A global inverse problem: determining the Bond albedo of the Earth

Olli Ihalainen\textsuperscript{a,*}, Olli Wilkman\textsuperscript{b}, Antti Penttilä\textsuperscript{a}, Guanglang Xu\textsuperscript{a}, Jyri Näränen\textsuperscript{b}, Jouni Peltoniemi\textsuperscript{b}, Sonja Lahtinen\textsuperscript{b}, Niko Kareinen\textsuperscript{b}, Maria Gritsevich\textsuperscript{a}, Markku Poutanen\textsuperscript{b}, Hannu Koivula\textsuperscript{b}, and Karri Muinonen\textsuperscript{a,b}

\textsuperscript{a}University of Helsinki, Department of Physics, P.O. Box 64, 00014 Helsinki, Finland
\textsuperscript{b}Finnish Geospatial Research Institute FGI, P.O. Box 84, 00521 Helsinki, Finland

\textsuperscript{*}Presenting author (olli.ihalainen@helsinki.fi)

Accurate knowledge of the Earth’s radiative energy budget is vital for precise climate modeling. This energy budget is determined by the total outgoing emitted radiation and the Earth’s spherical albedo, which determines the ratio between the incident total radiation and the outgoing scattered radiation from the top of the atmosphere (ToA). The current monitoring of the Earth’s emitted total radiation and spherical albedo is mainly based on radiometric satellite measurements that require interpolation.

We propose a method for determining the time evolution of the Earth’s spherical albedo and the emitted total radiation with an unprecedented level of accuracy, using the effects of the Earth’s radiation pressure on the satellite orbits along with the imaging data gathered by instruments such as the Earth Polychromatic Imaging Camera on the Deep Space Climate Observatory satellite. In the forward problem, we use a discretized model of the ToA for modeling the imaging data and the acceleration caused by Earth’s radiation pressure on the satellites. The discretization is done using a Hierarchical Equal Area isoLatitude Pixelization scheme for the ToA where we classify segments of the pixelization grid based on the underlying scene type.

This first study uses a simplified model with a small number of unknowns for the ToA, a single wavelength for the emitted radiation as well as the scattered radiation, and a box-wing model for the satellites to solve this global statistical inverse problem. Markov chain Monte Carlo sampling is used to estimate the ToA radiation and its effects on the satellites’ orbits, and to find the best fit to both the acceleration data and the imaging data. Then, numerical integration over the entire globe is used to derive the Earth’s spherical albedo and the emitted radiation along with the uncertainties.

We show that the inversion of the spherical albedo and the outgoing emitted total radiation with reasonable accuracy is feasible from the current satellite imaging and space-geodetic measurements. Our next aim is to expand our forward model to include a wide wavelength range for the scattered and emitted radiation, a more detailed satellite model, and a more descriptive ToA model.

Preferred mode of presentation: Oral
The angular light scattering function of atmospheric ice crystal ensembles

Emma P. Järvinen*a,† and Franz M. Schnaiterb

a National Center for Atmospheric Research, PO Box 3000, Boulder, CO 80307, USA
b Karlsruhe Institute of Technology, Kaiserstraße 12, 76131, Karlsruhe, Germany

*Presenting author (jarvinen@ucar.edu)

Ice crystal sub-micrometer structures have a large effect on their optical properties. Theoretical calculations have shown, that compared to pristine crystals, complex ice crystals produce a flat and featureless scattering phase function with a significantly higher fraction of backscattering (e.g., [1–3]). Changing the radiative properties of ice crystals in general circulation models to those of roughened ice crystals could significantly affect the cloud radiative effect. Satellite measurements have indicated that natural ice crystals have a high degree of surface roughness and the latest MODIS collection 6 (C6) product has incorporated complex and roughened ice crystals [4]. However, the use of roughened ice crystals in general circulation models and in satellite retrievals is not well justified as long as observational evidence of the applicability of these models to represent the optical properties of atmospheric ice crystals is given.

In this contribution, we present in situ measurements of the ice crystal angular light scattering function from four airborne field campaigns. The in situ observations show that a uniform angular light scattering function with a relatively low asymmetry parameter is observed globally, which is the result of a high degree of ice particle complexity observed in these clouds. The measured cloud angular light scattering function was compared to a selection of optical particle models, and it was found that the C6 model best represented the measurements. Lastly, we investigate using the in situ dataset how many ice crystals are needed to reproduce the globally observed uniform angular light scattering function.

References
[3] Yang, P., L. Bi, B. A. Baum, K.-N. Liou, et al., 2013: Spectrally consistent scattering, absorption, and polarization properties of atmospheric ice crystals at wavelengths from 0.2 to 100 µm. J. Atmos. Sci. 70, 330–347.

Preferred mode of presentation: Oral
A new *in situ* hyper-angular cloud polarimeter for airborne platforms

Emma P. Järvinen\textsuperscript{a,*} and Franz M. Schnaiter\textsuperscript{b}

\textsuperscript{a}National Center for Atmospheric Research, PO Box 3000, Boulder, CO 80307, USA  
\textsuperscript{b}Karlsruhe Institute of Technology, Kaiserstraße 12, 76131, Karlsruhe, Germany  

*Presenting author (jarvinen@ucar.edu)

Polarimetric satellite observations provide important information on the cloud phase and particle properties. After the end of the PARASOL mission that carried the POLDER polarimeter in 2013, a future satellite mission PACE will carry a hyper-angular polarimeter (HARP-2) instrument that will be used to retrieve, among others parameters, the cloud droplet size distribution, ice particle shape, and roughness.

For validation of polarimetric satellite observations, it is important to establish a direct link between the cloud optical and microphysical properties. An *in situ* hyper-angular polarimeter is capable of measuring the cloud properties within meters from the fuselage. The instrument will be designed to measure the rear partial scattering phase function including the rainbow feature with a high angular resolution of less than a tenth of a degree. This information can be used to accurately derive the droplet size distribution in real time. Additionally, the scattered light intensity is split with respect to its polarization components that define the depolarization and polarization ratios of the cloud particles. These measurements can be used to derive information on the cloud phase, ice crystal shape, and surface roughness and will support space-borne observations by CALIOP and HARP-2.

In this contribution, we present the concept of an *in situ* hyper-angular cloud polarimeter that is currently being developed as a collaboration between National Center for Atmospheric Research and Karlsruhe Institute of Technology. We also present the first measurements performed with a laboratory prototype.

Preferred mode of presentation: Poster
Coating material-dependent differences in modelled lidar-measurable quantities for heavily coated soot particles

Franz Kanngießer\textsuperscript{a,}\textsuperscript{*} and Michael Kahnert\textsuperscript{a,b}

\textsuperscript{a}Department of Space, Earth and Environment, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden
\textsuperscript{b}Research Department, Swedish Meteorological and Hydrological Institute, Folkborgvägen 12, SE-601 76 Norrköping, Sweden

\textsuperscript{*}Presenting author (franz.kanngiesser@chalmers.se)

Atmospheric soot aerosol particles have a strong impact on the Earth’s climate and a negative impact on air quality and human health [1]. With the help of remote sensing techniques, the sources, transport pathways and sinks can be monitored. The interpretation of remote sensing data requires a thorough understanding of the particles’ optical properties. For individual heavily coated soot particles differences in the refractive index of the coating, i.e., different chemical compositions, are among the main sources of uncertainty regarding the linear backscattering depolarisation ratio [2].

The possibility to distinguish between different coating materials based on the depolarisation ratio and the extinction-to-backscatter ratio for a set of heavily coated soot particles following a particle size distribution was investigated. As coating material sulphate and a toluene-based organic material were assumed, whereas the particle size distribution was assumed to follow a log-normal distribution based on \textit{in situ} field measurements [3]. The depolarisation ratio and the extinction-to-backscatter ratio were calculated using the discrete dipole approximation code ADDA (version 1.2) [4] in conjunction with the morphologically complex particle model described in [2]. The calculations were performed for wavelengths of $\lambda = 355, 532, \text{ and } 1064 \text{ nm}$, and the results were compared to existing lidar field measurements.

Although there are clear differences in the depolarisation ratio for the different coating materials, the differences in the extinction-to-backscatter ratio are larger; thus the extinction-to-backscatter ratio may provide a more reliable method for distinguishing coating materials than the depolarisation ratio.

References


Preferred mode of presentation: Oral
An impedance based formulation for passive radiative cooling system design

Muhammed Ali Kecebasa,a*, M. Pinar Mengüçb,c, Ali Kosara,d,e, and Kursat Sendurad,e

Faculty of Engineering and Natural Sciences, Sabanci University, Orhanli-Tuzla, 34956, Istanbul, Turkey
Department of Mechanical Engineering, Ozyegin University, Cekmekoy, 34794, Istanbul, Turkey
Center for Energy, Environment and Economy, Ozyegin University, Cekmekoy, 34794, Istanbul, Turkey
Center of Excellence for Functional Surfaces and Interfaces, Sabanci University, Orhanli-Tuzla, 34956, Istanbul, Turkey
Sabanci University Nanotechnology and Application Center (SUNUM), Orhanli, Tuzla, 34956, Istanbul, Turkey

Presenting author (malikecebas@sabanciuniv.edu)

In recent years, passive radiative cooling has become a widely studied field as a solution to the problem of undesired heat generation problem in open environments. Several forms of daytime radiative cooling devices have been proposed in the literature depending on the applications, e.g., thin-films, metamaterials and those composed of nanoparticles [1–4]. Although various design approaches are reported for radiative coolers, they do not benefit from the existing design approaches that are heavily utilized in microwave and RF applications. Adapting the well-established design techniques from these fields to the problem of passive radiative cooling can have certain advantages over the existing design approaches in terms of performance and efficiency.

To demonstrate the possibility of such an adaptation, we developed a semi-analytical design method with thin-films of preselected materials based on impedance matching. Although impedance matching with transmission lines is heavily utilized in microwave and RF applications, it has not been adapted to problem of designing optical filters [5,6]. We demonstrate that the proposed method is applicable for designing additional layers that enhance the cooling power of existing thin-film structures. It can be easily applied to any thin-film system to design additional layers for various purposes, e.g. protection or cooling power enhancement, without degrading the optical performance of the existing system. In light of this study, several other impedance matching approaches can be adapted to design various optical structures.

This material is based upon work supported by the Air Force Office of Scientific Research (Aerospace Materials for Extreme Environments Program, PM: Dr. Ali Sayir) under award number FA9550-17-1-0092.

References


Preferred mode of presentation: Oral
Atmospheric particle in-situ imaging and classifying with digital holography

Osku Kemppinen*, Ryan Mersmann, Jesse Laning, and Matthew J. Berg

Department of Physics, Kansas State University, 1228 N. 17th St., Manhattan, KS 66506, USA

*Presenting author (okemppin@phys.ksu.edu)

Digital holography is a contact-free imaging method that can work with a naturally flowing air stream. We have built a prototype model for a lightweight, low-cost digital holography instrument, titled HAPI, that can image coarse-mode aerosol particles, with sizes ranging from tens of micrometers up to millimeters, in the atmosphere. We have also developed the necessary algorithms to automatically reconstruct the particles’ two-dimensional silhouettes and classify them into particle species. The instrument is flown on a drone for easy deployment and three-dimensional sampling.

The instrument concept will allow imaging large atmospheric particles almost anywhere in the lower boundary layer with minimal set-up required, and with very low operational costs. We expect the instrument will greatly add to the knowledge of coarse-mode aerosol particle morphology, and we hope to create an aerosol shape database that can be used to improve various atmospheric simulations and retrievals. In this presentation we show the first results of our measurements.

Preferred mode of presentation: Oral/Poster
Application of multiple scattering theory to Doppler velocimetry of ejecta from shock-loaded samples

A. N. Kondrat’ev*, A. V. Andriyasha, S. E. Kuratova, and D. B. Rogozkin

*Presenting author (an.kondratev@physics.msu.ru)

The presentation addresses the actual problem of recovering the physical parameters of ejecta from data of heterodyne Doppler velocimetry (see, e.g., [1–3]). The spectral profile $f(\omega)$ of heterodyne beats underlies our analysis of experimental data. Under the assumption that ejected fragments are randomly spaced and their number within the probed volume is great, the noise-free component of $|f(\omega)|^2$ is shown to be expressed in terms of a solution to the transport equation for the field correlation function which accounts for multiple scattering and absorption of the probing beam in the cloud of moving particles. This provides a means of theoretical modeling of experimental Doppler data.

The ejecta cloud is considered a plane layer of particles moving in the air away from the free-surface. The spatial profile of the extinction coefficient and the cloud thickness are related directly to the distribution of ejected particles over velocities and coordinates. The slowing-down of ejected particles in the air leads to an ambiguous relation between the particle position and its velocity at different moments of time, resulting in essential complication of this distribution. We calculate the particle distribution over velocities and coordinates using a multi-group representation.

In the report we give a generalization of the results in [3] with allowance for the multi-group representation of the ejecta cloud. In this case the transport equation is reduced to a system of linked Milne-like equations. Furthermore, a finite radius of the probing beam is considered. We solve the system numerically with a discrete ordinate program. The spectrum of the backscattering signal is calculated with the discrete Fourier transform. Varying the values of the cloud optical thickness and the parameters of the particle distribution over velocities and sizes, we fit the calculated spectrum to the time-resolved data of heterodyne Doppler measurements. This approach enables us to recover the primary ejecta characteristics (the density–velocity profile, the total ejected mass, and the size distribution of ejected particles) directly from optoheterodyne experiments.

An application of the proposed method to the velocimetry data on ejecta from metal samples is presented.

References


Preferred mode of presentation: Oral
Physical optics method for solving light scattering problem for large particles over all scattering directions

Alexander A. Konoshonkin*, Anatoli G. Borovoi, Natalia V. Kustova, Victor A. Shishko, and Dmitriy N. Timofeev

V. E. Zuev Institute of Atmospheric Optics SB RAS, Akad. Zuev sq. 1, 634055 Tomsk, Russia

*Presenting author (sasha_tvo@iao.ru)

The physical optics method [1] developed at the V. E. Zuev Institute of Atmospheric Optics has been successfully used to solve the light scattering problem for atmospheric ice crystals in the backward scattering direction for lidar applications [2]. The solution of the light scattering problem for ice crystals ranging in size from 10 to 1000 micrometers (size parameters from 60 up to 6000) has been obtained with this method. For small particles, the physical optics approximation is in good agreement with exact numerical methods [3] (such as the DDA and FDTD), while for large particles the solution converges to the solution obtained within the framework of the geometrical optics approximation.

The talk presents a modification of the physical optics method that allows one to obtain a solution to the light scattering problem over all scattering angles (the entire sphere of scattering directions). It shows that starting from a size parameter of 50 the solution agrees well with the solution obtained by the ADDA. Since the computational complexity of the method does not increase with increasing particle size, while the accuracy of the method, on the contrary, becomes better, the physical optics method is a promising technique for solving the light scattering problem for particles much larger then the wavelength of the incident light. In the report, the capabilities of the method are exemplified by solving the light scattering problem for a large fraction of dust aerosol particles.

References


Preferred mode of presentation: Oral
Extinction matrix for cirrus clouds in the visible and infrared regions

Alexander A. Konoshonkin*, Anatoli G. Borovoi, Natalia V. Kustova, Victor A. Shishko, and Dmitriy N. Timofeev

V. E. Zuev Institute of Atmospheric Optics SB RAS, Akad. Zuev sq. 1, 634055 Tomsk, Russia

*Presenting author (sasha_tvo@iao.ru)

The state of polarization of the transmitted radiation varies along the propagation path in scattering media if the media contains a lot of independent nonspherical particles with preferential orientations. This phenomenon is caused by the interference of the incident field with the fields scattered in the forward direction by each particle. One of the examples of such scattering media are cirrus clouds consisting of ice crystals, since the crystals are often oriented quasi-horizontally. The abovementioned interference effects are completely described by the extinction matrix. For ice crystals of cirrus clouds, the matrix was considered by several authors. In particular, the extinction matrix was numerically calculated in [1] with the DDA for small particles. The PO calculations of the extinction matrix for large particle were recently reported in [2,3]. However, [2,3] are based on the assumption of a narrow particle size distribution; as a result, quickly oscillating functions appear. In nature, crystal size distributions are wide, which largely suppresses the oscillating interference effects.

The talk presents the extinction matrix for cirrus clouds calculated for the visible and infrared regions using the physical optics approximation for natural crystal size distributions. The cirrus clouds are modeled as a statistical ensemble of hexagonal ice plates distributed over size and orientations according to the gamma and Gaussian laws, respectively. Then, the extinction matrices as functions of the incident wavelength, incident direction, crystal size, and crystal orientation are numerically calculated for the first time. It is shown that the off-diagonal elements of the matrix are negligible. Therefore, the extinction in cirrus clouds is described with good accuracy by the scalar exponential law.

References


Preferred mode of presentation: Poster
In 2015, our Fortran 90/95 radiative transfer (RT) code IPOL for simulation of multiple scattering of Intensity and POLarization of the monochromatic solar radiation in a plane-parallel atmosphere confirmed high accuracy in a comprehensive polarized (vector) RT codes intercomparison [1]. Since then, we have used IPOL to account for the effect of polarization of light in the Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm [2]. However, IPOL requires further development: speed-up due to neglect of tiny circular polarization in Earth atmosphere, and translation into C/C++ for natural integration with MAIAC.

Similar to RT code Pstar [3], IPOL combines the discrete ordinates and matrix-operator methods. Evaluation of the matrix exponential using eigendecomposition is a key and, arguably, the most time consuming part. The eigendecomposition represents a matrix using its eigenvalues and eigenvectors. In the new C/C++ version of IPOL, we use only left eigenvectors to evaluate the matrix exponential. This is contrary to a common practice of using the right eigenvectors to evaluate the matrix exponential and the left eigenvectors to avoid the inversion of the matrix of the right ones [3,4].

Recently, we published our approach with independently reproducible test cases in JQSRT [5]. In this talk, besides theoretical background and numerical examples, we will discuss the use of object-oriented programming with GNU Scientific Library (GSL) [6] in computationally intensive software, which the RT code is.

References

Preferred mode of presentation: Oral
Application of the method of continuity boundary conditions to the problem of wave diffraction on fractal-like bodies of revolution

Alexander A. Kyurkchan*, Sergey A. Manenkov, and Nadezda I. Smirnova

Moscow Technical University of Communications and Informatics, Aviamotornaya str. 8a, 111024, Moscow, Russia

*Presenting author (agkmtuci@yandex.ru)

The three-dimensional vector problem of diffraction of a plane wave on an ideal conducting body of revolution is solved. The technique proposed in the present work makes it possible to model the scattering characteristics, including the orientations averaged over the angles, for bodies of revolution of practically any geometry. The stated problem was solved using the method of continued boundary conditions [1]. The integral equation of the second kind with respect to some unknown function distributed on the surface of the scatterer is obtained. For the numerical solution of the integral equation, we used the expansion of the Green function and the right side into a Fourier series. To solve one-dimensional integral equations for the Fourier harmonics of the unknown function the Krylov–Bogolyubov method is used [2]. Formulas that make it possible to calculate the scattering pattern averaged over the angles of incidence of the plane wave are obtained.

A number of examples of solving problems of diffraction on different particles in particular fractal-like bodies of revolution [3] are given. The correctness of the method is confirmed by verifying the accuracy of the fulfilment of the optical theorem for various bodies and by comparison with the results of calculations obtained by the modified auxiliary current method [1,2].

References


Preferred mode of presentation: Poster
A fast algorithm for multi-particle scattering in a layered medium

Jun Lai

School of Mathematical Sciences, Zhejiang University, 38 Zheda Rd., Hangzhou, Zhejiang, 310013, China (laijun6@zju.edu.cn)

In this talk, we consider acoustic or electromagnetic scattering in two or three dimensions from an infinite three-layer medium with thousands of wavelength-size dielectric particles embedded in the middle layer. Such geometries are typical of microstructured composite materials, and the evaluation of the scattered field requires a suitable fast solver for either a single configuration or for a sequence of configurations as part of a design or optimization process. We have developed an algorithm for problems of this type by combining the Sommerfeld integral representation, high order integral equation discretization, the fast multipole method and classical multiple scattering theory. The efficiency of the solver is illustrated with several numerical experiments. Extension to periodic layered medium (grating structure) and applications on inverse scattering problems will be also presented.

References


Preferred mode of presentation: Oral
Meta-trapping: optical forces on meta-materials

Isaac C. D. Lenton*, Timo A. Nieminen, Alex B. Stilgoe, and Halina Rubinsztein-Dunlop

School of Mathematics and Physics, The University of Queensland, St. Lucia, Brisbane QLD 4072, Australia

*Presenting author (isaac@isuniversal.com)

In recent years there has been a lot of interest in the field of meta-materials. Progress in this field has been aided by advances in fabrication technologies that led to the realization of both microwave and optical meta-materials [1]. These materials offer the ability to create perfect lenses, invisibility cloaks and control the directionality of scattering [2]. They also allow the creation of new types of optically trapped particles which could be useful for microscopic force probes or use in fundamental science. The possibility to engineer how these particles scatter light could be useful for improving optical trap depth or improving the measurement sensitivity by maximizing light scattered in a particular direction. Full understanding of how these particles scatter light is necessary for intelligently engineering particles or the light fields that manipulate these particles for particular applications.

For spherical particles, the solutions for the scattered field are exact. We can simulate the scattering of these particles by calculating the Mie coefficients with arbitrary values for the permittivity and permeability [3]. The forces acting on the particle can be found by calculating the change in momentum of the scattered light. In order to understand the optical forces on these exotic particles, we consider a vector spherical mode expansion of the scattering in order to look at the different contributions to the force from different modes.

In this presentation we will provide a visual guide for the types of particles which can be optically trapped. We will consider absorbing and emitting materials, particles with non-unity relative permeability and special cases such as zero back scattering particles and trapping of refractive-index matched particles. Beginning with particles which only scatter into the dipole mode, we will then extend the work to the quadrupole mode and higher order modes. We will discuss how these modes can be engineered to enhance optical trapping, either by engineering the beam or the particle. And finally, we will discuss what the results mean for optical trapping of spherical particles in a simple focused Gaussian beam.

References

Preferred mode of presentation: Oral
Estimation of surface solar radiation by Voronoi ice scattering model from Himawari-8 satellite measurements

Husi Letu\textsuperscript{a,b}, Takashi Y. Nakajima\textsuperscript{b}, Hiroshi Ishimoto\textsuperscript{c}, Run Ma\textsuperscript{a}, and Huazhe Shang\textsuperscript{a}

\textsuperscript{a}Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences (CAS), DaTun Road No. 20 (North), Beijing 100101, China
\textsuperscript{b}Research and Information Center (TRIC), Tokai University, 4-1-1 Kitakaname Hiratsuka, Kanagawa 259-1292, Japan
\textsuperscript{c}Meteorological Research Institute, Japan Meteorological Agency (JMA), Nagamine 1-1, Tsukuba 305-0052, Japan

\textsuperscript{*Presenting author (husiletu@radi.ac.cn)}

Himawari-8 is a new-generation geostationary meteorological satellite which is successfully launched by the Japan Meteorological Agency on 7 October 2014. The Himawari-8 carries the multi-spectral Advanced Himawari Imager (AHI). In this study, cloud optical and microphysical properties are retrieved from Himawari-8 satellite measurements. Fractal ice partial scattering model called “Voronoi” \cite{1,2} is applied in the Comprehensive Program for Cloud Optical Measurement algorithm to retrieve ice cloud properties from AHI measurements \cite{3,4}. Retrieval results from AHI are used to estimate the surface solar radiation (SSR) using the Rstar radiative transfer model. Furthermore, AHI cloud property retrievals are compared to the MODIS C6 cloud property product. Finally, SSR data derived from AHI cloud properties is validated using ground-based observation data.

References


Preferred mode of presentation: Oral
Diurnal variability of aerosol type and vertical distribution
and its implication for satellite aerosol remote sensing

Jing Li* and Chong Li

Department of Atmospheric and Oceanic Sciences, School of Physics, Peking University, Beijing 100871, China

*Presenting author (jing-li@pku.edu.cn)

Aerosols vary on different time scales. Compared to seasonal or interannual variability, the diurnal variability of aerosol properties is less studied, mainly because continuous monitoring of aerosol properties over the course of a day is only available at scattered ground sites. However, with the increasing attention being paid to satellite retrievals using geostationary platforms, accurate evaluation of diurnal changes of aerosol properties becomes essential. In this study, we investigate the changes of aerosol optical parameters and vertical distribution using aethalometer, nephelometer, sunphotometer, and lidar measurements in Beijing. A distinct diurnal cycle is found in all these parameters, which are mainly related to the development of the planetary boundary layer but also to other meteorological factors such as winds and humidity. We further use AERONET data to classify aerosols into four major types: dust, fine absorbing, fine scattering, and mixed. We find that in addition to Beijing, significant diurnal changes of aerosol type are noticed at many worldwide locations, in particular, Western US, Southwestern Europe, and South Africa. We further use the 6s radiative transfer model to evaluate the impact of these diurnal changes on aerosol retrievals from geostationary platforms. Specifically, we compare the difference between the retrieved aerosol optical thickness using the mean aerosol model and vertical distribution and that using diurnally resolved values. Large discrepancies, up to 50%, are found between these two values. Our results indicate that diurnal changes of aerosol type and vertical distribution represent a common phenomenon and must not be neglected in aerosol retrievals using geostationary satellites.

Preferred mode of presentation: Oral
Aspect ratio distributions of atmospheric aerosol particles and their effects on skylight polarization

Li Li*, Zhengqiang Li, Xu Zheng, Oleg Dubovik, Zhanhua Li, and Manfred Wendisch

*State Environmental Protection Key Laboratory of Satellite Remote Sensing, Aerospace Information Research Institute, Chinese Academy of Sciences, Beijing 100101, China

Institute of Mechanics, Chinese Academy of Sciences, 100190, Beijing, China

Laboratoire d’Optique Atmosphérique, Université de Lille 1/CNRS, 59655, Lille, France

Leipzig Institute for Meteorology, Leipzig University, 04103, Leipzig, Germany

*Presenting author (lili3@radi.ac.cn)

Atmospheric aerosol particles modify the radiative energy budget of the earth–atmosphere system by scattering and absorbing solar radiation. Considering that particle morphology is of vital importance to how electromagnetic radiation is scattered by a single particle and that light scattering is affected by the shape distribution of volume particles, quantitative knowledge about various non-spherical aerosol shapes gets more and more attention in modelling aerosol volumetric optical properties [1,2]. The shape distribution, expressed as aspect ratio distribution, is derived as the normalized number of the occurrence of aspect ratios of a large sample of individual particles. An a priori fixed shape distribution of dust particles has widely been applied in the inversion of aerosol particle properties based on measurements collected with sun-sky radiometers. This dust particle shape distribution derived from laboratory measurements shows obvious different features compared to the results obtained by direct microscopic observations of aerosol particle samples captured in the natural atmosphere [2].

In this talk, we employ the model of polydisperse randomly oriented spheroids and use a fluorescence microscope to measure the aspect ratio distribution of atmospheric aerosol particles. The effects of different directly microscope-measured and indirectly inversion-based aerosol shape distributions on the radiance and polarization distributions of the skylight in the celestial hemisphere are discussed based on numerical simulations. The results suggest that using representative particle shape distributions obtained by direct microscopic observations of aerosol samples captured in natural atmosphere could improve the retrieval of aerosol shape parameter [3].

References


Preferred mode of presentation: Poster
Measurement of drops with inclusions using rainbow refractometry and time-shift technique

Can Li\textsuperscript{a,b,}*\textsuperscript{, Lingxi Li\textsuperscript{a}, Cameron Tropea\textsuperscript{a}, Xuecheng Wu\textsuperscript{b}, and Yingchun Wu\textsuperscript{b}}

\textsuperscript{a}Institute of Fluid Mechanics and Aerodynamics, Technische Universität Darmstadt, 64287, Darmstadt, Germany
\textsuperscript{b}State Key Lab of Clean Energy Utilization, Zhejiang University, Hangzhou 310027, China

*Presenting author (lican88@zju.edu.cn)

Characterization of drops with inclusions is of great practical interest and has wide industrial applications, for instance spray drying or paint spraying [1]. Reported here is an investigation to simultaneously measure the key parameters (i.e., droplet size, liquid refractive index, drop velocity and inclusion concentration) of a drop with inclusions using rainbow refractometry [2] and the time-shift technique [3].

In this work, a piezoelectric monodisperse droplet generator generates a stream of water drops with a size of 70–200 μm. Polystyrene particles with a diameter of 300 ± 30 nm are dispersed in the distilled water with different concentrations by controlled dilution [4]. With rainbow refractometry the concentration of inclusions can be estimated from the intensity extinction of the rainbow peak and with the time-shift technique an intensity ratio of reflected light to refracted light is employed. Experimental results will be compared with simulated results obtained using a Monte Carlo ray tracing approach [3,5].

References


Preferred mode of presentation: Oral
A study for the measurement of the drop concentration by using the time-shift technique

Lingxi Li\textsuperscript{a,}, Simon Rosenkranz\textsuperscript{b}, Walter Schäfer\textsuperscript{b}, and Cameron Tropea\textsuperscript{a}

\textsuperscript{a}Institute of Fluid Mechanics and Aerodynamics, Technische Universität Darmstadt, 64287, Darmstadt, Germany
\textsuperscript{b}AOM-Systems GmbH, 64646 Heppenheim, Germany

*Presenting author (li@sla.tu-darmstadt.de)

Colloidal drops are encountered frequently in numerous process industries, such as in pharmaceutical products or spray drying to produce powders. However, current optical measurement techniques are not capable of measuring the solid particle concentration in such drops [1]. The present study is devoted to the measurement of drop size and particle concentration of colloidal drops using the time-shift technique [2]. This work builds on first results reported in [3], in which a Monte Carlo ray tracing method was used to predict the time-shift signal received from two-dimensional drops. In the current work, the ray tracing code has been expanded to consider a three-dimensional drop using algorithms described in [4,5]. This approach, building on geometric optics, is more feasible in terms of computational effort than alternative methods (e.g., the discrete dipole approximation, or DDA), especially for larger drops and when the entire passage of the drop through the focused beam of the time-shift device must be captured. However, the DDA can be used to compute the signal amplitude for certain positions of the drop in the illuminating beam, and these results can be compared with the results from the Monte Carlo ray tracing method. The outcome of this investigation is a recommendation of signal processing steps necessary to estimate solid particle concentrations in drops from time-shift signals.

References


Preferred mode of presentation: Oral
Impact of H$_2$O broadening effect on high-accuracy atmospheric trace gases detection

Jingsong Li$^{a,*}$, Hao Deng$^a$, Ningwu Liu$^a$, Zhou Shen$^a$, and Horst Fischer$^b$

$^a$Laser Spectroscopy and Sensing Laboratory, Anhui University, 23061 Hefei, China
$^b$Max Planck Institute for Chemistry, Hahn-Meitner-Weg 1, 55128 Mainz, Germany

$^*$Presenting author (ljs0625@126.com)

Unlike other atmospheric gases, the distribution of water vapor (H$_2$O) in the atmosphere varies with high dynamic range, which is strongly dependent on time, location, and altitude. Therefore, the broadening contribution due to water vapor mixing ratio variation would need to be known with a minimal uncertainty for high-accuracy data retrievals, especially in a humid atmosphere. In this study, a tunable quantum cascade laser spectrometer (QCLS) was developed to study H$_2$O broadening coefficients for CO and N$_2$O transitions at the 4.57 $\mu$m region which contains well-characterized and relatively isolated transitions of appropriate line strengths for sensitive gas detection [1]. The influence of H$_2$O broadening effect on CO R(11) and N$_2$O P(38e) transitions at 2186.639 cm$^{-1}$ and 2187.099 cm$^{-1}$, respectively, was investigated in detail [2]. Our measurements indicate that H$_2$O broadening coefficients are 1.8 and 1.9 times higher than the corresponding air-broadening parameters, respectively. Based on the experimental data, our simulation confirmed that the WMS-2f shapes of CO and N$_2$O lines will be significantly affected by variations of the water vapor mixing ratio, while no significant dependence on target concentration, and prove that the difference between air- and H$_2$O-broadenings thus cannot be neglected if one wants to measure gas concentrations in a high humid environment with a sub-percent precision.

References


Preferred mode of presentation: Poster
An update on the extended advanced IEM for scattering from randomly rough surfaces

Yongxing Li\textsuperscript{a}, Jingsong Yang\textsuperscript{b}, J. C. Shi\textsuperscript{c}, and Yang Du\textsuperscript{a,}\textsuperscript{*}

\textsuperscript{a}Zhejiang University, Hangzhou, Zhejiang, 310027 China
\textsuperscript{b}Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, 310012, China
\textsuperscript{c}Institute of Digital Earth and Remote Sensing Applications, Chinese Academy of Sciences, Beijing, 100101, China

\textsuperscript{*}Presenting author (zjuydu03@zju.edu.cn)

In this study we update the extended advanced integral equation model (EAIEM) for electromagnetic backscattering and bistatic scattering from rough surfaces with small to moderate heights. We extend the first order approximation of the error function as introduced in the EAIEM model to the second order, in the hope to be more suitable for large roughness and high frequency. In addition, a new transition model for the reflection coefficient is proposed to make the dependencies explicit on the average surface curvature, incident frequency, and dielectric constant, whereas making no use of the complementary term, so the effect of inadequate evaluation of this term is mitigated. Comparison with POLARSCAT data for backscattering and with EMSL measurements for bistatic scattering demonstrates the validity of the updated model.

Preferred mode of presentation: Oral
Flame spray pyrolysis (FSP) is a versatile and promising technique for fast and scalable synthesizing nanoparticles [1,2]. Because of high phase purity, well crystallinity and well-control of size, the FSP-synthesized nanoparticles have been used for wide functional applications including sensors, catalysis, phosphors, electroceramics, batteries, and biomaterials. During FSP process, mass transfer of the precursor from liquid droplet to gas phase decides the product quality. Single droplet combustion has been a very valuable tool for providing fundamental knowledge of the FSP process.

Hereby we will present our preliminary results on single isolated burning droplet using digital in-line holography (DIH). DIH is a three-dimensional (3D) laser-based measurement technique, which can detect spatial- and time-resolved information of particle shape, velocity and position [3,4]. DIH has been employed to measure coal particles in flames [5], aluminum droplet combustion [6], and aerodynamic fragmentation of droplets [7]. Thus, we expect to use DIH to detect droplet 3D motion, droplet explosion, as well as the composition and temperature profiles from droplet surface to flame surface during the single droplet combustion of precursor-solvent solutions.

References


Preferred mode of presentation: Oral
Assessing superspheroidal dust models in particle scattering and polarized radiative transfer simulations

Wushao Lin*, Xiaoyun Tang, and Lei Bi

Department of Atmospheric Sciences, Zhejiang University, 38 Zheda Road, Hangzhou, 310027, China

*Presenting author (linwushao@zju.edu.cn)

As one of the major atmospheric aerosols, dust has important effect on the Earth’s radiative energy budget and profoundly affects regional and global climate. Although tremendous efforts have been devoted to parameterizing dust optical properties, there has not been a standard and consistent approach to remote sensing and radiative transfer studies. In this presentation, we report on our recent progress made to improve dust optical modeling in a superspheroidal shape space. Superspheroids have one more freedom than spheroids. However, the additional freedom can be constrained by comparing theoretical simulations with laboratory measurements. In this study, the scattering matrices of 25 dust aerosol samples from the Amsterdam–Granada Light Scattering Database [1] were used. We found that 1) extreme aspect ratios for spheroids in reproducing the measurements were unnecessary if superspheroids were employed [2]; 2) even with equi-probable aspect ratio distribution, concave superspheroids with large roundness parameters (e.g., from 2.4 to 3.0) could concurrently match six nonzero scattering matrix elements from the laboratory measurements [2]; 3) superspheroidal models with constrained roundness parameter also exhibit better performances than spheroids in reproducing backscattering ratios that are critical in active Lidar remote sensing [3]. Additionally, to understand the impact of models in atmospheric radiative transfer, we carried out sensitivity studies on how the shape parameters (i.e., aspect ratio and roundness parameter) affect the TOA radiance and polarization simulations. By analyzing modeling results, the implications of applying superspheroidal dust models in polarized remote sensing will be discussed.

References


Preferred mode of presentation: Poster
A unified-principal-component radiative transfer model

Chao Liu\textsuperscript{a,}, Bin Yao\textsuperscript{a}, Vijay Natraj\textsuperscript{b}, and Yuk L. Yung\textsuperscript{c}

\begin{itemize}
  \item \textsuperscript{a}School of Atmospheric Physics, Nanjing University of Information Science and Technology, Nanjing 210044, China
  \item \textsuperscript{b}Jet Propulsion Laboratory, California Institute of Technology, Pasadena 91125, USA
  \item \textsuperscript{c}Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena 91125, USA
\end{itemize}

*Presenting author (chao_liu@nuist.edu.cn)

This study presents a fast radiative transfer (RT) model, referred to as the UPCRTM (Unified Principal Component RT model), to calculate the high-spectral resolution radiation. The principal component analysis is used twice independently to reduce the number of accurate RT simulations and subsequently minimize the number of channels for which RT calculations are performed. Thus, by performing many fewer accurate radiative transfer simulations (a few tens), we can get high-spectral resolution results (a few tens of thousands) efficiently without significant loss of accuracy. Gas absorption, aerosol scattering, and Rayleigh scattering can be fully considered in the model, and a comprehensive database by considering a large amount of atmospheric and aerosol profiles over the entire solar spectrum is developed for the PCA-based data training and validation. The UPCRTM is found to be three orders of magnitudes faster than the corresponding accurate models, and shows relatively small errors, generally within 0.5%. The efficiency and accuracy of the UPCRTM not only enables its application for high-spectral resolution instruments, but also provides a possible method for accurate RT simulations in mesoscale numerical weather models and general circulation models.

Preferred mode of presentation: Oral
Time-harmonic acoustic scattering from a non-locally perturbed trapezoidal surface

Wangtao Lu\textsuperscript{a,*} and Guanghui Hu\textsuperscript{b}

\textsuperscript{a}Zhejiang University, Hangzhou, 310027, China
\textsuperscript{b}Beijing Computational Science Research Center, Beijing, 100193, China

\textsuperscript{*}Presenting author (wangtaolu@zju.edu.cn)

This paper is concerned with acoustic scattering from a sound-soft trapezoidal surface in two dimensions. The trapezoidal surface is supposed to consist of two horizontal half-lines pointing oppositely, and a single finite vertical line segment connecting their endpoints, which can be regarded as a non-local perturbation of a straight line. For incident plane waves, we enforce that the scattered wave, post-subtracting reflected plane waves by the two half lines of the scattering surface in certain two regions respectively, satisfies an integral form of Sommerfeld radiation condition at infinity. With this new radiation condition, we prove uniqueness and existence of weak solutions by a coupling scheme between finite element and integral equation methods. This consequently indicates that our new radiation condition is sharper than the Angular Spectrum Representation, and has generalized the radiation condition for scattering problems in a locally perturbed half-plane. Furthermore, we develop a numerical mode matching method based on this new radiation condition. A perfectly matched layer is setup to absorb outgoing waves at infinity. Since the medium composes of two horizontally uniform regions, we expand, in either uniform region, the scattered wave in terms of eigenmodes and match the mode expansions on the common interface between the two uniform regions, which in turn gives rise to numerical solutions to our problem. Numerical experiments are carried out to validate the new radiation condition and to show the performance of our numerical method.

Preferred mode of presentation: Oral
Static-limit $T$-matrix for a dielectric torus

Matt R. A. Majic

The MacDiarmid Institute for Advanced Materials and Nanotechnology, School of Chemical and Physical Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand
(mattmajic@gmail.com)

Semi-analytic expressions for the static limit of the $T$-matrix for electromagnetic scattering are derived for a circular torus, expressed in either a basis of toroidal harmonics or spherical harmonics. The scattering problem for an arbitrary static excitation is solved using toroidal harmonics, and these are then compared to the extended boundary condition method to obtain analytic expressions for auxiliary $Q$- and $P$-matrices, from which $T = PQ^{-1}$, where these matrices are expressed in a basis of toroidal harmonics. The electrostatic solution for a dielectric torus has been known since 1972 [1] as a combination of a continued fraction and a recurrence relation, rather than a matrix inverse. The method applied here leads to independent calculations of the plasmon resonances, including a set of resonances unobtainable via the continued fraction approach. Also, by applying the basis transformations between toroidal and spherical harmonics, the quasi-static limit of the electric-electric multipole coupling block $T^{22}$ of [2] is obtained. This allows computations of static limits of the optical cross-sections, and also to obtain analytic expressions for the limit of a thin ring. We discuss the existence of the $T$-matrix for an object of such a complex shape in the Rayleigh limit.

References


Preferred mode of presentation: Oral
Approximate $T$-matrix and optical properties of spheroidal particles to third order in size parameter


The MacDiarmid Institute for Advanced Materials and Nanotechnology, School of Chemical and Physical Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand

*Presenting author (mattmajic@gmail.com)

Nanoparticles are widely used for example in chemistry, medicine, cancer treatment, surface enhanced spectroscopy, partly due to their strong electric field enhancements. Shapes such as nano-rods, disks and deformed spheres are commonly approximated in theory by spheroids to obtain analytic results. The most significant property of small illuminated particles is the induced dipole moment, for which there is a simple expression for spheroids in the electrostatic limit – this involves the “static depolarization factors”. There have been attempts to extend this using “dynamic depolarization factors” [1,2], but these extensions are not consistent with the second order series expansion in size-parameter.

In electromagnetic scattering, the so-called $T$-matrix encompasses the optical response of a scatterer for any incident excitation and is most commonly defined using the basis of multipolar fields [3], generalizing the concept of polarizability of a scatterer. Following our recent paper [4], we calculate the series expansion of the $T$-matrix for a spheroidal particle in the small-size/long-wavelength limit, up to third lowest order with respect to $X$. $T$ is calculated from the extended boundary condition method with a linear system involving two infinite matrices $P$ and $Q$, whose matrix elements are integrals on the particle surface. The limiting form of the $P$- and $Q$-matrices for spheroids [5,6], ensures that this Taylor expansion can be obtained by considering only multipoles of order 3 or less (i.e., dipoles, quadrupoles and octupoles). The lowest order is $O(X^3)$ and equivalent to the quasi-static or Rayleigh approximation. Expressions to order $O(X^5)$ are obtained by Taylor expansion of the integrals in $P$ and $Q$ followed by matrix inversion. We then apply a radiative correction, which makes the resulting expressions valid up to order $O(X^6)$. Orientation-averaged extinction, scattering, and absorption cross-sections are then derived.

These results provide a simple alternative to the exact $T$-matrix method for spheroidal particles smaller than the wavelength, in a size range much larger than for the Rayleigh approximation. The approach also provides details of quadrupole and octopole interactions and their spectral peaks are identified.

References


Preferred mode of presentation: Poster
The Multi-Viewing-Channel-Polarisation Imager (3MI) is planned to fly on the Metop-SGA satellites as part of the EUMETSAT Polar System – Second Generation (EPS-SG) programme in the timeframe beyond 2020. It is a radiometer dedicated to aerosol and cloud characterisation for climate monitoring, atmospheric composition, air quality, and numerical weather prediction. This polarimetric mission is a heritage of the POLDER mission, with improved capabilities. The spectral range (12 channels) was extended from the visible–near-infrared (VIS-NIR) 410 to 910 nm to the shortwave-infrared (SWIR) domain (up to 2200 nm). The spatial resolution (4 km at nadir) and the swath (2200×2200 km²) were also improved compared to previous POLDER instruments. As POLDER, 3MI will provide multi-polarisation (−60°, 0°, and +60°) and multi-angular (10 to 14 views) images of the Earth top of atmosphere outgoing radiance [1].

The POLDER heritage allows adapting techniques developed for PARASOL, e.g., for the vicarious calibration methods. However, the monitoring of the SWIR channels will be a new challenge for the 3MI calibration. The access to a moon observation during commissioning would be very beneficial, in addition to the characterization of many other radiometric aspects. The 3MI will also strongly benefit from cross-calibration (radiometric, spectral, and geometric) with other Metop-SGA instruments like the VIS-IR Imager (METimage) and the ultraviolet–VIS-NIR-SWIR Sounder (Sentinel-5).

The level 1 products available to the users will be geolocated Stokes vectors on the native geometry (Level 1B) and geoprojected multi-directional and spectral Stokes vectors (Level 1C) [2]. Level-2 products will provide geophysical and microphysical parameters for aerosol and clouds. The presentation will overview the mission characteristics and the calibration strategy as well as the products available to the users.

References


Preferred mode of presentation: Oral
Numerical solution for scattering, absorption, and emission by large cometary dust particles

Johannes Markkanen* and Jessica Agarwal

Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg, 37077 Göttingen, Germany

*Presenting author (markkanen@mps.mpg.de)

Remote light-scattering and thermal infrared observations of comet’s comae provide us with hints of physical properties of cometary dust particles such as size, shape, porosity, and composition. Interpretation of such observations requires accurate and efficient numerical methods and models. Unfortunately, the available numerical techniques are either too computer-intensive or introduce insufficient approximations. We present a self-consistent numerical solution for scattering and thermal emission problems by extending the recently introduced dense medium radiative transfer solution [1–4] to treat thermally excited radiation. Further, we combine the radiative heat transfer part to the conductive heat transfer equation by employing the finite-element method. The developed method will be applied to interpret the visible and superheating phase functions of the coma of the comet 67P/Churyumov–Gerasimenko measured by the Rosetta Optical, Spectroscopic, and Infrared Remote Imaging System and the Rosetta Visible and Infrared Thermal Imaging Spectrometer, respectively.

This research was funded by the ERC Starting Grant No 757390.

References


Preferred mode of presentation: Oral
Surface composition of (4) Vesta by modelling light scattering

Julia Martikainen\textsuperscript{a,}, Timo Väisänen\textsuperscript{a}, Antti Penttilä\textsuperscript{a}, and Karri Muinonen\textsuperscript{a,b}

\textsuperscript{a}Department of Physics, University of Helsinki, Finland
\textsuperscript{b}Geospatial Research Institute FGI, National Land Survey, Kirkkonummi, Finland

*Presenting author (julia.martikainen@helsinki.fi)

Understanding light scattering on planetary surfaces is an open problem. Spectroscopic, photometric, and polarimetric features depend strongly on a number of surface properties that can also be affected by space weathering. The surface composition of asteroids has been studied in numerous laboratory experiments and by using empirical models, such as the Hapke model \cite{Hapke93}, but never before using numerical simulations based on the first principles in light scattering.

We have recently developed a new simulation framework to model the spectroscopy, photometry, and polarimetry of planetary surfaces. This approach is used to study asteroid (4) Vesta. We combine approximate multiple scattering codes SIRIS4 \cite{Lindqvist18, Martikainen18} and RT-CB \cite{Muinonen12}, and an exact multiple scattering code JVIE \cite{Markkanen13} that utilizes the volume-integral equation method to account for both the wavelength-scale particles and particles that are larger than the wavelength. With our model, we derive the complex refractive indices and particle size distribution of Vesta’s regolith, and thus explain the observed negative linear polarization, opposition effect, and spectral features in the UV-vis-NIR wavelength region.

References

\begin{enumerate}
\end{enumerate}

Preferred mode of presentation: Oral
The HARP polarimeter family and application to aerosol
and cloud characterizations

J. Vanderlei Martins\textsuperscript{a,b}, Xiaoguang Xu\textsuperscript{a,*}, Brent McBride\textsuperscript{a,b}, Henrique M. J. Barbosa\textsuperscript{c},
Anin Puthukkudy\textsuperscript{a,b}, Noah Sienkiewicz\textsuperscript{b}, and Lorraine Remer \textsuperscript{a}

\textsuperscript{a}Joint Center for Earth Systems Technology, University of Maryland Baltimore County, Baltimore, MD, USA
\textsuperscript{b}Department of Physics, University of Maryland Baltimore County, Baltimore, MD, USA
\textsuperscript{c}Instituto de Física, Universidade de São Paulo, São Paulo, Brazil

\textsuperscript{*}Presenting author (xxu@umbc.edu)

The Hyper-Angular Rainbow Polarimeter (HARP) instruments are designed at the University of Maryland Baltimore County to make multi-angular multispectral polarimetric measurements needed to characterize microphysical properties for aerosols and clouds (https://laco.umbc.edu) [1]. Currently, there are three polarimeters based on the HARP concept: AirHARP, HARP CubeSat, and HARP-2. AirHARP is an airborne prototype instrument, which has been deployed in the NASA Lake Michigan Ozone Study (LMOS) and Aerosol Characterization from Polarimeter and Lidar (ACEPOL) campaigns during 2017. HARP CubeSat is a NASA funded 3U-size satellite to be launched in 2019 and is planned for a one-year mission lifetime. HARP-2 is an improved copy of the HARP CubeSat polarimeter payload and will be equipped on the NASA Plankton, Aerosol, Cloud, Ocean Ecosystems (PACE) mission satellite [2]. Specifically, the HARP polarimeter family measures radiance and polarization at 60 scan angles in the 670-nm wavelength and at 20 (10 for HARP-2) scan angles in each of other three spectral bands (440, 550, and 870 nm). These instruments also feature a 94° cross-track field of view, allowing a wide spatial coverage. In this presentation, we will demonstrate the HARP observation concept with the AirHARP observations collected during the LMOS and ACEPOL campaigns. We will also present preliminary applications of the AirHARP Level-1 products for characterizing cloud droplet size and aerosol microphysical properties.

References


Preferred mode of presentation: Oral
Light scattering studies at the El Paso del Norte Region in Texas

Richard Medina

Lewis Clark State College, 500 8th Ave, Lewiston, ID 83501, USA (rmedinacalderon@lcsc.edu)

The light-scattering properties of mineral dust and soot particles in the El Paso-Juarez Airshed were analyzed using data from an acoustic extinctionometer and a laser particle counter in conjunction with a non-spherical scattering model for polydisperse and randomly oriented particles, the $T$-matrix model. The data selected correspond to days exhibiting a mean relative humidity less than 20% to avoid effects of possible aerosol hygroscopic growth. The inter-comparison for the selected days of the extinction and scattering coefficients results obtained using the $T$-matrix and the laser particle counter, with those obtained from an acoustic extinctionometer at a wavelength of 0.87 μm shows good agreement. In addition, the single-scattering albedo for this region is analyzed for the selected days. The methodology developed in this work can be used as a diagnostic tool to characterize mineral dust and soot particles, and the results of this study will provide a better understanding of the aerosol optical properties for the El Paso-Juarez Airshed.

Preferred mode of presentation: Oral
Propagation of electromagnetic radiation in a slab waveguide with topological insulator walls


aIFRJ-Instituto Federal de Educação, Ciência e Tecnologia do Rio de Janeiro, Av. Prefeito Botafogo, Rio de Janeiro, RJ 27541030, Brazil
bFaculdade de Viçosa, St. Gomes Barbosa 870, Minas Gerais, MG 36570101, Brazil
cUFV-Universidade Federal de Viçosa, Departamento de Física, Viçosa, Minas Gerais, MG 36570000, Brazil

*Presenting author (thiago.melo@ifrj.edu.br)

The topological magnetoelectric effect emerges whenever time reverse symmetry is broken at the surface of three-dimensional topological insulators (3D TIs, like $Bi_2Se_3$, $Bi_2Te_3$, and $Sb_2Te_3$ compounds) in the long-wavelength regime of electromagnetic (EM) radiation [1]. As consequence, the EM response of 3D TIs is given in terms of fine structure constant due to the quantized Hall current excited on the 3D TI surface by a parallel electric field [2,3]. Among other consequences, when light is sent to a TI border, its behavior is deeply modified: for instance, light plane polarization is rotated by a universal angle leading to unusual Kerr/Faraday and EM scattering effects [4].

Here, we shall show that whenever light propagation is guided by 3D-TI walls, it experiences a cutoff frequency coming from topological grounds, $\omega_\theta$, which is related to the penetration length of metallic surface states into the TI-bulk, $l$. The scenario is such that lower frequencies, $\omega_\theta < \omega$, are reflected by the walls, while for $\omega_\theta > \omega$ considerable part of the incident light penetrates into the TI-bulk making wave propagation throughout the waveguide deeply jeopardized. Our findings suggest that TI-made waveguides enable an estimate of the microscopic quantity, $\omega_\theta$ [5]. Furthermore, such topological stability can be useful in waveguides to propagate EM radiation in scattering light experiments and applications [6].

References


Preferred mode of presentation: Oral
A comprehensive analysis of aerosol property retrieval from the MicroNeph–GRASP system

Alireza Moallemia,*, Robin L. Modinia, Tatsiana Lapyonokb, David Fuertesb,c, Anton Lopatinc, Gergely Dolgosd, Yevgeny Derimianb, Benjamin Torressb,c, Oleg Dubovikb,c, and Martin Gysel-Beerab

aLaboratory of Atmospheric Chemistry, Paul Scherrer Institute, Forschungsstrasse 11, 5232 Villigen PSI, Switzerland
bLaboratoire d’Optique Amosphérique, Université de Lille, 59655 Villeneuve d’Ascq Cedex, France
cGRASP-SAS, Remote sensing developments, Université de Lille, 59655 Villeneuve d’Ascq Cedex, France
dMicos Engineering GmbH, Überland Str. 129, 8600 Dübendorf, Switzerland

*Presenting author (alireza.moallemi@psi.ch)

The phase function \((F_{11})\) and polarized phase function \((F_{12})\) are important elements of the scattering matrix that contain implicit information regarding aerosol microphysical properties such as the size distribution, refractive index, and shape. The \(F_{11}\) and \(F_{12}\) can be measured \textit{in situ} with polar imaging nephelometry [1]. The microphysical properties of the aerosol being measured can be inferred from these data by employing aerosol retrieval algorithms such as the Generalized Retrieval Algorithm of Surface and Aerosol Properties (GRASP) [2,3]. Recently, the development began on a miniature version of a polar imaging nephelometer called MicroNeph. The goal of this study is to test the GRASP algorithm on the MicroNeph data.

A thorough numerical analysis is conducted to investigate the retrieval of particle size distribution, refractive index and shape distribution) from the combined MicroNeph–GRASP system. For a number of aerosol models encompassing a variety of microphysical properties, MicroNeph measurements \((F_{11} \text{ and } F_{12} \text{ at three visible wavelength})\) are simulated with the GRASP forward model. The simulated results are subjected to synthetic error and instrument-related parameters such as measured wavelength and angular resolution are manipulated. These data are then introduced to the GRASP inverse model, and the quality of the retrieval is investigated. The role of \textit{a priori} assumptions in the GRASP inverse model on the retrieval quality is also assessed for various parameters such as the spectral refractive index. Finally, it is planned to test the GRASP algorithm on real MicroNeph data using either well-defined aerosol samples or independent measurements of aerosol microphysical properties.

References


Preferred mode of presentation: Oral
Particles with stimulus-responsive fluorescence are in demand for imaging and diagnostic applications [1,2]. Different strategies have been employed to obtain such particles (micellae or liposomes). We report a novel approach based on fatty acids conjugated with a photolabile group, which self-organize into micellae in water. Under near-UV illumination the photolabile group dissociates and becomes fluorescent, accumulating inside the drops.

Our experiments showed the formation of micellae with sizes ranging from one to several tens of micrometers. Initially, particles were not visible under a microscope with a 450–490 nm excitation and >520 nm emission filters. Illumination with a 365 nm LED during 100 ms turned on the orange-colored emission of micellae. The signal was stable for at least an hour. Further UV illumination increased the fluorescence intensity and made even the smallest observed particles very bright. This effect may potentially be used in life sciences (e.g., to track movements of particles from the specific origin) because fatty acids represent a bio-friendly material.

The study was supported by Russian Science Foundation (Grant No. 18-15-00049).

References


Preferred mode of presentation: Oral/Poster
Scattering of light in planetary regoliths: theory, experiments, and applications

Karri Muinonen\textsuperscript{a,b,*}, Timo Väisänen\textsuperscript{a}, Julia Martikainen\textsuperscript{a}, Johannes Markkanen\textsuperscript{c,a}, Antti Penttilä\textsuperscript{a}, Maria Gritsevich\textsuperscript{d}, Jouni Peltoniemi\textsuperscript{b,a}, Jürgen Blume\textsuperscript{e}, Joonas Herranen\textsuperscript{a}, Gorden Videen\textsuperscript{f,g}, Göran Maconi\textsuperscript{f}, Petteri Helander\textsuperscript{a}, Ari Salmi\textsuperscript{a}, Ivan Kassamakov\textsuperscript{a}, and Edward Haeggström\textsuperscript{a}

\textsuperscript{a}Department of Physics, University of Helsinki, Finland
\textsuperscript{b}Finnish Geospatial Research Institute FGI, National Land Survey, Masala, Finland
\textsuperscript{c}Max Planck Institute for Solar System Research, Göttingen, Germany
\textsuperscript{d}Institute of Physics and Technology, Ural Federal University, Ekaterinburg, Russia
\textsuperscript{e}Institut für Geophysik und Extraterrestrische Physik, Technische Universität Braunschweig, Braunschweig, Germany
\textsuperscript{f}Space Science Institute, Boulder, Colorado, USA
\textsuperscript{g}Army Research Laboratory, Adelphi, Maryland, USA

\textsuperscript{*}Presenting author (karri.muinonen@helsinki.fi)

Theoretical, numerical, and experimental methods are presented for scattering of light in macroscopic discrete random media of densely-packed microscopic particles. The theoretical and numerical methods constitute a framework of Radiative Transfer with Reciprocal Transactions (R\textsuperscript{2}T\textsuperscript{2}). The R\textsuperscript{2}T\textsuperscript{2} framework entails Monte Carlo order-of-scattering tracing of interactions in the frequency space, assuming that the fundamental scatterers and absorbers are wavelength-scale volume elements composed of large numbers of randomly distributed particles. The discrete random media are fully packed with the volume elements. For spherical and nonspherical particles, the interactions within the volume elements are computed exactly using the Superposition T-Matrix Method (STMM) and the Volume Integral Equation Method, respectively. For both particle types, the interactions between different volume elements are computed exactly using the STMM. As the tracing takes place within the discrete random media, incoherent electromagnetic fields are utilized, that is, the coherent field of the volume elements is removed from the interactions. The experimental methods are based on acoustic levitation of the samples for non-contact, non-destructive scattering measurements. The levitation entails full ultrasonic control of the sample position and orientation, that is, six degrees of freedom. The light source is a laser-driven white-light source with a monochromator and polarizer. The detector is a mini-photomultiplier tube on a rotating wheel, equipped with polarizers. The R\textsuperscript{2}T\textsuperscript{2} is validated using measurements for a mm-scale spherical sample of densely-packed spherical silica particles. After validation, the methods are applied to interpret astronomical observations for asteroid (4) Vesta and comet 67P/Churyumov–Gerasimenko visited by the NASA Dawn mission and the ESA Rosetta mission, respectively.

Preferred mode of presentation: Oral/Poster
Absorptance of densely packed particulate samples

Andrei E. Mukhanova,* and Dmitrii B. Rogozkina,

*Presenting author (mukhanov@vniia.ru)

This presentation addresses the problem of light transport in a weakly absorbing powder medium. The individual particles of the medium are assumed to be large compared to the wavelength. Different values of the particle refractive index, in the range from 1.3 to 4.0, are used in the calculations. The results of ray tracing Monte Carlo simulations are presented for three models of absorption in the medium. We consider bulk absorption of radiation in the powder particles themselves, absorption in the spaces between the particles, and continuous absorption. The total absorptance and the depth dependence of the absorbed energy are calculated for all these cases. At rather great depths, the obtained results can be fitted by the diffusion law with appropriate values of the absorption and transport mean free path. The value of the transport mean free path is retrieved by fitting the diffusion flux attenuation curve to the data of Monte Carlo simulations for the model of continuous absorption. The dependence of the ratio of the transport mean free path to the particle size on the filling factor of the powder medium and on the particle refractive index is studied. We find that, for given absorption and transport mean free path, the value of the energy absorbed in the sample depends on the model of absorption and differs from the corresponding prediction of the radiative transfer theory. The difference between the obtained results diminishes as the filling factor of the powder medium decreases. We propose a qualitative explanation of the observed effects, based on an analysis of the path distribution of photons in the medium and a comparison of the average photon paths inside and outside the particles.

The presented results can be useful for the management of absorption in various applications such as solar cells and other photovoltaic devices, absorption spectroscopy, and random lasers. See, e.g., [1–3].

References


Preferred mode of presentation: Oral
Constraining aerosol vertical profile in the boundary layer using hyperspectral measurements of oxygen absorption

Vijay Natraj\textsuperscript{a,\*}, Zhao-Cheng Zeng\textsuperscript{b}, Feng Xu\textsuperscript{a}, Thomas J. Pongetti\textsuperscript{a}, Run-Lie Shia\textsuperscript{b}, Eric A. Kort\textsuperscript{c}, Geoffrey C. Toon\textsuperscript{a}, Stanley P. Sander\textsuperscript{a}, and Yuk L. Yung\textsuperscript{b}

\textsuperscript{a}Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, USA
\textsuperscript{b}Division of Geological and Planetary Sciences, California Institute of Technology, 1200 East California Blvd., Pasadena, CA 91125, USA
\textsuperscript{c}Department of Climate and Space Sciences and Engineering, University of Michigan, 500 South State St., Ann Arbor, MI 48109, USA

\textsuperscript{\*}Presenting author (vijay.natraj@jpl.nasa.gov)

Atmospheric aerosols have a major impact on climate, air quality and human health, and also influence greenhouse gas retrievals from space by modifying the path of atmospheric radiation. However, uncertainties about the origin and composition of aerosol particles, their size distribution, concentration, spatial and temporal variability make it challenging to characterize aerosols.

There are four ways to obtain aerosol information from passive remote sensing measurements: multi-angle, multi-wavelength, hyper-spectral and polarization measurements. Multi-angle measurements provide information on the aerosol single scattering albedo and phase function, while observations at multiple wavelengths provide extinction as a function of wavelength, and hence the loading and Ångström exponent. Together, they provide information on the aerosol loading and composition. Polarization measurements provide aerosol particle size, optical depth, and some information on speciation. They can also distinguish between spherical and non-spherical particles. Further, they provide constraints to discriminate from the underlying surface. However, these measurements lack sensitivity to the vertical distribution of aerosols. On the other hand, hyperspectral measurements in gaseous absorption bands (e.g., O\textsubscript{2} A-, B- and γ-bands and H\textsubscript{2}O bands) can be used to characterize the vertical distribution of aerosol loading. This is because the large dynamic range of absorption in these bands allows different regions of the atmosphere to be probed at different absorption line strengths. Measurements in different bands also provide information on the wavelength dependence of aerosol extinction. Further, usage of O\textsubscript{2} absorption has the advantage that O\textsubscript{2} is well mixed with known concentration. H\textsubscript{2}O, on the other hand, is variable, but has absorption features all across the electromagnetic spectrum.

We infer aerosol vertical structure in the urban boundary layer using passive hyperspectral measurements. Our algorithm, which uses hyperspectral measurements in the 1.27 µm oxygen absorption band to retrieve the total aerosol optical depth (AOD) and effective aerosol layer height, is applied to data from the California Laboratory for Atmospheric Remote Sensing instrument, located on a mountaintop overlooking the Los Angeles Basin. The effectiveness and accuracy of the retrievals are assessed by comparisons with AOD measurements from AERONET and aerosol backscatter profile measurements from a Mini MicroPulse Lidar lidar measurements. The proposed method can potentially be applied to existing and future satellite missions with hyperspectral oxygen measurements to constrain aerosol vertical distribution on a global scale.

Preferred mode of presentation: Oral
Multi-mode characterization of total columnar aerosols over China based on SONET ground-based remote sensing measurements since 2010

Yang Ou, Zhengqiang Li*, and Ying Zhang

State Environment Protection Key Laboratory of Satellite Remote Sensing, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing 100101, China

*Presenting author (lizq@radi.ac.cn)

Aerosol is an important component of the terrestrial atmosphere and plays a key role in the determination of global climate change, visibility, and human health. With the rapid development of the economy and human expansion, fine particulate matter is the most important air pollutant in many developing countries. However, the observation sites of Aerosol Robotic Network and Sky Radiometer Network are still very rare and are distributed unevenly over China. Sun-Sky Radiometer Observation Network (SONET, www.sonet.ac.cn) is a ground-based radiometer network with the extension of multiwavelength polarization measurement capability to provide long-term columnar atmospheric aerosol properties over China [1], which is a necessary remedy to an important lack of total columnar atmospheric aerosols over China. There are 16 sites located in typical regions of China, including urban, rural, desert, coastal, basin, mountain, and plateau areas, and the data have been obtained since 2010. The absolute aerosol optical thickness uncertainty can be less than about 0.01–0.02. In this study, we employ a new remote sensing method [2,3] to separate the characteristic peaks of atmospheric columnar aerosol volume particle size distribution (VPSD) and retrieve the complex refractive index (CRI) from the SONET observation over China from 2010–2016. It has been found that the aerosol VPSD can be decomposed into four characteristic peaks, including the fine, sub-fine (SF), sub-coarse (SC), and coarse modes, while CRIs can be separated into fine and coarse modes with CRI errors less than about 0.046 (real part) and 0.003 (imaginary part). The results show the mean central radii of the peaks in the fine, SF, SC, and coarse modes are around 0.15, 0.33, 1.86, and 3.30 μm, respectively. In general, the aerosols are complex and highly varying both in time and geographically. The SF mode is the major one in the eastern region in China. The absorption by aerosol in the eastern region is stronger than in the western region with the larger imaginary part of the CRI, while the scattering is weaker.

References


Preferred mode of presentation: Poster
Demonstration of an overlap range of size parameters for reliable exact and approximate methods of computing single-particle scattering optical properties

R. Lee Panetta\textsuperscript{a,b,*}, Ping Yang\textsuperscript{a}, Jiachen Ding\textsuperscript{a}, Michael Mishchenko\textsuperscript{c}, and Siyao Zhai\textsuperscript{a}

\textsuperscript{a}Department of Atmospheric Sciences, Texas A&M University, College Station, Texas, USA
\textsuperscript{b}Department of Mathematics, Texas A&M University, College Station, Texas, USA
\textsuperscript{c}NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA

\textsuperscript{*}Presenting author (panetta@tamu.edu)

Using any of several numerical methods based directly on Maxwell’s equations to calculate single particle scattering becomes increasingly demanding of computational resources as the size parameter of the particle increases, and as the particle’s index of refraction departs significantly from unity. With these so-called “exact” methods, at any given time there is an upper bound on the size parameter that is feasible for general and practical use, i.e., for “random orientation” calculations of particles that have arbitrary shapes and have indices of refraction that are not close to 1. The bound depends essentially on the state of hardware and software development at that time: beyond the size parameter bound exact methods may be used only under specializing assumptions like symmetry, or single-orientation, or index of refraction differing only slightly from unity. On the other hand, for large enough size parameters, numerical methods that are based on variously improved versions of geometrical and physical optics methods are adequate for computing single scattering properties of practical interest. These methods are not based directly on Maxwell’s equations but on physical approximations to the scattering process, and there is an effective lower bound on the size parameter for reliable calculations set by the physical approximations made.

Until recently there has been a gap in sizes between the upper bound of what can be feasibly handled handled by an exact method and the lower bound on what an approximate method can reliably treat. In this talk we describe success in closing the gap that has recently been achieved by using the exact Invariant Imbedding T-Matrix (II-TM) method in conjunction with an approximate Physical Geometric Optics Method (PGOM). The gap is closed in the sense that there is an overlap range of size parameters, roughly 100–300 in which the two methods agree well in their calculation of single-scattering optical properties. The II-TM method requires no special assumptions on particle symmetry, but it is possible to accelerate the computation of properties when some symmetries are present by improvements in the II-TM algorithm.

Preferred mode of presentation: Oral
Photon Density Wave (PDW) spectroscopy [1,2] is a measurement technique for the determination of the absorption coefficient $\mu_a$ and the reduced scattering coefficient $\mu'_s$ of highly turbid samples [3]. It employs intensity modulated laser light in the MHz to GHz range, coupled into the sample via an optical fiber. The radiation forms a PDW which experiences a phase delay and a dampening in the turbid medium due to scattering and absorption. A receiving fiber feeds a detector attached to a network analyzer which measures the changes in amplitude and phase of the PDW depending on modulation frequency and fiber distance. $\mu_a$ and $\mu'_s$ can be accurately determined via a non-linear fit, even for highly turbid samples ($0.1\text{ mm}^{-1} < \mu'_s < 100\text{ mm}^{-1}$). This makes the PDW ideally suited for inline process analytics of large-scale industrial processes, e.g., paint, cosmetics or polymer production, without a need for sample dilution [4].

Theoretical considerations of the PDW necessarily make approximations in order to solve the related radiative transfer equations, such as the P1 approximation. Our group is exploring the limits of the PDW with respect to extremely high optical densities ($\mu'_s > 100\text{mm}^{-1}$), both through advancements in theory and through experiments.

In this talk we present the development of a specialized Monte Carlo radiative transfer code for the simulation of PDW measurements. High optical depths ($\tau \gg 1000$) require careful treatment and efficient speed-up procedures. We describe some of the techniques we employ, their adaptations to our specific system, and how they impact the simulations. Our code includes photon splitting, path length biasing, a modified random walk approach, parallelization and the peel-off mechanism.

References

New desktop goniopolarimeter at FGI and joint measurement efforts

Jouni I. Peltoniemi*a, Nataliya Zubkoa, Juha Suomalainenb, Teemu Hakalaa, Maria Gritsevichb,c, Lei Yand, Siyuan Liud, Zhongqiu Sun, and Jiao Zitif

a Finnish Geospatial Research Institute (FGI), Masala, Finland
b Department of Physics, University of Helsinki (UH), Finland
c Institute of Physics and Technology, Ural Federal University, Ekaterinburg, Russia
d Peking University, Beijing (PKU), China
e Northeast Normal University (NENU), Changchun, Jilin, China
f Beijing Normal University (BNU), China

*Presenting author (jouni.peltoniemi@nls.fi)

After hundreds of reflectance measurements with Finnish Geodetic Institute’s Field Goniospectrometer (FIGIFIGO) [1], we are complementing our facility with a more precise desktop goniopolarimeter. Field use requires many compromises that can be relaxed in laboratory, and some things are done in different way just to experiment and validate.

The new system is build around a central axis, where the spectrometer shelf, zenith arm, and sample tray on top are connected. It further differs from the old one by the main sensor ASD Field Spec 4 SR, 350–2500 nm (vs. Field Spec Pro FR), broad band wire grid polariser (vs. Glan-Thomas calcite prism), smaller field of view of 5 cm in diameter (vs. 20 cm), shorter arm length of 50–100 cm (vs. 150–250 cm), fully automatic movement (vs. manual azimuth). We further use a smaller 250 W QTH light source from Oriel (vs. 1000 W), with a beam width of 20 cm (vs. 60 cm), polarised using another wire grid (vs. unpolarised), three-lens setup (vs. two mirrors).

First measurements agree within 5% with the FIGIFIGO and confirm there are no fundamental flaws in either design. The new system has better polarisation accuracy, but the reflectance accuracy maybe even less, because of smaller signal after all the optics.

We are working together between FGI, UH, PKU, NENU, and BNU to cross-validate the polarisation accuracy and to design measurement and illumination mechanics and optics further. We will present new results of sand, snow, dirt, and dirty snow. We compare the measurements against models developed in Finland, China, and elsewhere.

Reference


Preferred mode of presentation: Oral/Poster
Space-weathering spectra explained with light scattering simulations


*Department of Physics, University of Helsinki, Finland
bMax Planck Institute for Solar System Research, Göttingen, Germany
cDepartment of Geosciences and Geography, University of Helsinki, Finland
dSpace Science Institute, Boulder, Colorado, USA
eGeospatial Research Institute FGI, National Land Survey, Kirkkonummi, Finland

*Presenting author (antti.i.penttila@helsinki.fi)

Space weathering (SW) of regolith particles on the surfaces of atmosphereless Solar System bodies is a mechanism that has been actively studied since the Apollo lunar samples (see, e.g., [1] and references therein). The mechanism has been verified in laboratory experiments and recently by studying samples from asteroid (25143) Itokawa by the Hayabusa mission [2]. It has been identified that the spectral features associated with SW, namely the darkening and reddening of the spectra, are caused by nano- and microphase Fe inclusions in the thin rim of the regolith particles (see, e.g., [3]).

Until now, the physical first-principles model of the SW effects on spectra by Fe inclusions has been lacking. Extensive work has been done in this field using the Hapke model(s) (e.g., [4–6]), but the model only approximates radiative transfer treatment. One deficiency in the model is the lack of a proper treatment of the size effects of the Fe inclusions. Lucey and Riner [7] assessed this by including Mie scattering for the inclusions. However, current state-of-the-art modeling is missing a proper treatment of (i) surface reflections and volume scattering, and (ii) multiple scattering and incoherent fields associated with the inclusions.

We have recently completed a project aimed at improving the theory and computational tools for radiative transfer–type solutions in dense particulate media [8–10]. These are combined with our existing tools for light-scattering simulations with surface and volume scattering [11,12]. Using these light-scattering simulation tools, we develop a detailed view on how the Fe inclusions affect the spectra of non-weathered silicate minerals.

References

Preferred mode of presentation: Oral
Convolutional neural networks for aerosol scattering: the analogy to image recognition problems

Patricio Piedra*, Aimable Kalume, Yong-Le Pan, and Gorden Videen

*Presenting author (patricio.g.piedracartagena.ctr@mail.mil)

Remote sensing of aerosol properties by inversion commonly requires directionally averaged aerosol light-scattering shape models such as spheres or spheroids. However, using shape-averaged models often yields discrepancies in retrievals at different wavelengths, leading to inaccurate or at-best ambiguous aerosol classification. Furthermore, shape-averaging does not allow discrimination of trace, non-averaged, scattering patterns. In our work, we have applied machine-learning algorithms to the calculated light-scattering patterns from particles of seven different, common, and naturally occurring shapes to test whether their shapes can be classified. Our dataset consists of either the scattering intensity distribution or the degree of linear polarization. Furthermore, our dataset was either one-dimensional, depending on the polar angle, or two-dimensional, depending on both the polar and azimuthal angles. The implementation of a one- or two-dimensional scattering dataset input can be analogous to an image recognition problem, requiring either a fully connected or a convolutional neural network. Prediction capabilities were much greater when the two-dimensional scattering data was used than when only one-dimensional data were considered. When the two-dimensional intensity patterns are considered, the prediction capabilities were approximately 70% for the regularly shaped particles and above 90% for the highly irregularly shaped particles. These capabilities increased slightly when linear polarization was used as input. These results suggest that trace-aerosol shape classification can be achieved using two-dimensional light-scattering patterns and convolutional neural networks.

This work has been funded by the U.S. National Academy of Sciences under National Research Council Postdoctoral Fellowship and by sponsorship from the U.S. Army Research Laboratory.

Preferred mode of presentation: Oral
Electromagnetic scattering by heterogeneous anisotropic structure of high-order Bessel vortex beam

Tan Qua*, Zhensen Wub,c, Qingchao Shangb, Jiaji Wua, and Zhengjun Lib

aSchool of Electronic Engineering, Xidian University, Xi’an 710071, China
bSchool of Physics and Optoelectronic Engineering, Xidian University, Xi’an 710071, China
cCollaborative Innovation Center of Information Sensing and Understanding, Xidian University, Xi’an 710071, China

*Presenting author (tqu@xidian.edu.cn)

Due to their wide applications in microwave technology, integrated optics, and sheath, anisotropic media have been researched extensively over the recent years. With the development of material and processing technology, various anisotropic materials with more complex structures and compositions emerge. The scattering model of a homogeneous anisotropic sphere is not suitable for the description of the problem anymore. In this paper, an analytical solution to the scattering by the heterogeneous anisotropic structure illuminated by a high-order Bessel vortex beam is investigated. By means of the Fourier transform and additional theorem, the internal fields of the heterogeneous anisotropic-sphere periodic structure are expanded in terms of vector spherical wave functions. Combining this with the continuity boundary conditions for the tangential components of electromagnetic fields, the scattering coefficients of the heterogeneous anisotropic structure are solved. Compared with the results of the homogeneous anisotropic sphere, the correctness of the theory and the code are verified. The scattering by heterogeneous anisotropic structures with different compositions, structures, and numbers of particles are numerically analyzed. The orbital angular momentum spectrum of the scattered wave is presented to show the influence of the composition on the phase distortion. The research will provide significant foundation for anisotropic materials and their optical properties.

Preferred mode of presentation: Oral
A practical way to detect and quantify the 3D radiative effects in passive cloud property retrievals: theoretical basis and feasibility study

Chamara Rajapakshe* and Zhibo Zhang

Physics Department, UMBC, Baltimore, Maryland, USA

*Presenting author (cpn here@umbc.edu)

Most operational remote sensing algorithms are based on the computationally efficient 1D radiative transfer (RT) theory, while in reality, the RT process is intrinsically 3D. The 1D RT is based on two fundamental assumptions: the “plane parallel approximation” and “independent pixel approximation”. When actual cloud fields deviate from these assumptions, the cloud radiative properties derived from the 1D RT simulations will be different from the observed values, which is known as the “3D effects” in radiative transfer and cloud remote sensing. As a result, the retrieved cloud properties will be biased depending on the magnitude of the 3D effects and also on the retrieval technique. Take, for example, the bi-spectral cloud optical thickness (COT) and cloud-droplet effective radius (CER) retrieval. The so-called “illuminating effect” can lead to an overestimation of the COT and underestimation of the CER, while the opposite shadowing effect leads to an underestimation of the COT and overestimation of the CER. Despite substantial efforts made in the past, there is still a lack of practical ways to detect and quantify the 3D effects at the pixel level.

Recently, we have developed a theoretical framework that uses a combination of polarimetric and radiometric measurements to detect the pixels of a radiometric image of clouds that are affected by the 3D radiative transfer effects. Moreover, with the aid of synthetic cloud fields from the large-eddy simulation model [1,2] and 3D radiative transfer simulations [3], we have successfully demonstrated how the corrected radiances can significantly improve the statistics of cloud property retrievals.

References


Preferred mode of presentation: Oral/Poster
Decreasing trend of aerosol optical thickness associated with crop residue burning in Shangdong province observed from synthetic satellite data products

Kalluri Raja Obul Reddy, Xiaoyu Zhang*, and Lei Bi

School of Earth Sciences, Zhejiang University, Hangzhou 310027, China.

*Presenting author (zhang_xiaoyu@zju.edu.cn)

Agriculture crop residue burning is an important source of aerosol pollutants. This presentation reports our study to obtain the aerosol change trend associated with crop residue burning from synthetic satellite products. We focus on Shangdong province which is one of largest agricultural provinces in China. Specifically, we use Moderate Resolution Imaging Spectroradiometer AOT products, carbon monoxide (CO) product from the Measurements Of Pollution In The Troposphere, and fire pixel counts (derived from the active fire product) to evaluate the spatial and temporal variation of atmospheric aerosols during 2006 to 2017. First, a clear distinction of the AOTs was found in the two periods (2006–2011, and 2012–2017), with higher AOT in the first period, and weaker AOT in the second half period. Lower AOT in the second half period could be associated with tightening emission control policies. As an evidence, there has been a decrease in atmospheric loading for some anthropogenic aerosols over Shandong and neighboring provinces [1,2]. In addition to the AOT change, the spatial CO concentrations showed higher concentration (>200 ppbv) during 2006–2011 in the near surface level while lower concentrations (<200 ppbv) was observed during 2011–2017. This observation gives us confidence that the AOT change trend [3] was closely related to crop residue burning. Toward a better understanding of the various aerosol sources, we also report the isentropic back trajectory cluster analysis for the entire study period (2006–2017) by using the HYSPLIT model.

References


Preferred mode of presentation: Poster
Assessing particle non-sphericity from the Fourier spectrum of its light-scattering pattern

Andrey V. Romanova,b,*, Valeri P. Maltseva,b,c, and Maxim A. Yurkina,b.

Voevodsky Institute of Chemical Kinetics and Combustion SB RAS, Institutskaya Str. 3, 630090, Novosibirsk, Russia
Novosibirsk State University, Pirogova Str. 2, 630090, Novosibirsk, Russia
Novosibirsk State Medical University, Krasny Prospect 52, 630091, Novosibirsk, Russia

*Presenting author (a.v.romanov94@gmail.com)

Measuring angle-resolved light-scattering patterns (LSPs) of single particles is a powerful approach for their non-invasive characterization. Because of the lack of a universal approach for solving the inverse light-scattering problem, each developed method adjusts to specific tasks and has its own advantages and disadvantages. Due to the wave nature of the studied physical phenomenon, spectral methods for solving inverse problems occupy a special niche, because they allow obtaining reliable results with minimal computational costs, are more resistant to various signal distortions, and afford an easy control of the solution process [1]. A separate issue for all methods is the potential deviation from the used shape model, incurring error in the retrieved particle characteristics. For example, it is difficult to reliably quantitatively describe deviation even from the simplest model of a homogeneous sphere. A brute-force fit of an experimental LSP with the simulated ones can provide an estimation of non-sphericity only if an alternative shape model (e.g., a spheroid) is considered.

In this work, we enhanced the existing spectral method for solving the inverse light scattering problem for a sphere [1] to estimate the non-sphericity of a particle. As before we used the Fourier transformation of the LSP, but the amplitude spectrum only showed resistance to small deviations from sphericity, which is good for characterization, but bad for non-sphericity detection. Therefore, we used the full complex spectrum for a detailed assessment of non-sphericity. The method is based on quantitative comparison of the complex spectrum around the main peak with that corresponding to the effective sphere. The parameters of the latter are determined by the standard (amplitude) spectral method. Moreover, any other characterization method for spheres can be used, for example, non-linear regression applicable to any size and refractive index, but it might significantly increase the computation time.

We also introduced a quantitative definition of non-sphericity for a particle of arbitrary shape. Extensive simulations of LSPs were carried out for spheroids and red blood cells (RBCs). For the former we chose the non-sphericity parameter based on the analysis in the framework of Rayleigh-Gans-Debye approximation as the effective size times squared eccentricity. For the RBCs we applied geometrical fitting of the real shape by a sphere and defined general non-sphericity parameter as absolute volume discrepancy (residual) multiplied by the effective size.

The developed method was validated experimentally on the LSPs of milk fat globules and the red blood cells during spherization process, measured with the scanning flow cytometer. In particular, the RBCs do not seem to reach the ideal spherical shapes, which is either due to the hydrodynamic tensions in the flow or an artefact of the experimental distortions combined with high sensitivity of the method.
Reference


Preferred mode of presentation: Oral
Optical properties of oriented ice crystals and applications in lidar remote sensing and optical phenomenon simulations

Masanori Saito and Ping Yang*

Department of Atmospheric Sciences, Texas A&M University, 3150 TAMU, College Station, TX 77843, USA

*Presenting author (pyang@tamu.edu)

Ice clouds are ubiquitous over the globe, and these clouds consist of various nonspherical ice crystals. Among these ice crystals, horizontally oriented hexagonal plates (HOPs) and columns (HOCs) have unique single-scattering properties such as extremely strong backscattering and angular scattering anisotropy about the scattering azimuth angle. These scattering properties sometimes cause specific optical phenomena in the sky. However, these horizontally oriented ice crystals have significant impacts on lidar measurements [1] and even non-negligible impacts on passive-satellite measurements under particular sun–view geometries [2]. Therefore, better quantitative understanding of the single-scattering properties of horizontally oriented ice crystals is essential to take account of oriented ice crystals in the remote sensing of ice clouds. A recently developed physical-geometric optics method (PGOM) efficiently computes the single-scattering properties of ice crystals [3], which is fairly consistent with the counterparts computed with a rigorous computational technique, the invariant-imbedding T-matrix method (II-TM) [4].

This study develops a single-scattering property database of HOPs and HOCs in various sizes and incident angles at three wavelengths: 355, 532, and 1064 nm using PGOM. In the talk, we will demonstrate the single-scattering properties of a HOP and HOC, and their applications to the simulations of lidar signals and optical phenomena.

References


Preferred mode of presentation: Oral
Far-infrared measurements benefit nighttime ice cloud property retrievals

Masanori Saito* and Ping Yang

Department of Atmospheric Sciences, Texas A&M University, 3150 TAMU, College Station, TX 77843, USA

*Presenting author (masa.saito@tamu.edu)

Ice clouds are ubiquitous and play a pivotal role in the earth–atmosphere system. Satellite measurements have provided the global distribution of ice cloud properties based on passive remote sensing techniques. In particular, the bispectral method based on a pair of visible and near-infrared channels [1] and the split-window method based on the brightness temperature differences between a pair of thermal infrared (TIR) channels (so-called window channels) [2] are the two major retrieval techniques. However, the former approach is not applicable during nighttime, and the latter approach is only sensitive to optically thin clouds with small ice crystals. Therefore, the current understanding of ice cloud properties is quite limited. Recently, a couple of projects focusing on spaceborne far-infrared (FIR) measurements are planned to understand outgoing FIR radiation from Earth. Although these projects do not mainly focus on ice clouds, previous studies demonstrate large sensitivities of FIR measurements to ice cloud properties [3]. This may overcome the shortcomings of the passive cloud remote sensing over nighttime. Therefore, there is a pressing need for quantitative evaluations of the feasibility and capability of the FIR measurements to ice cloud retrievals.

In this presentation, we quantitatively illustrate how much the FIR measurements, in addition to TIR, improve the ice cloud retrievals. Potential inherent error sources of ice cloud retrievals such as temperature-dependent indices of ice refraction and subpixel cloud coverage will be discussed.

References


Preferred mode of presentation: Oral
Analysis of self-regulated processes in optical fields

E. Saldivia-Gomez*, A. Garcia-Guzman, and G. Martinez-Niconoff

Optics Department, Instituto Nacional de Astrofísica Óptica y Electrónica Luis Enrique Erro 1, Tonanzintla, Puebla, 72840, México

*Presenting author (esaldivia@inaoep.mx)

In this work we analyze the evolution of a wave process and describe the synthesis of non-linear effects, by the study of the topological properties and the wave-diffusion transitions effects [1] of the optical field, which induce self-regulated effects; this kind of effects are present near of regions of maxim energy.

In this context the optical field is described as a complex system that presents an asymptotic behavior near the maxim irradiance region which generates entropy effects.

The study is made by the phase function [2] and irradiance driven by a logistic model in the refractive index, which allows us to identify physical properties in regions where singularities of the field exist and the traditional optical models cannot be applied.

With this model we want to explain how the focal regions interact, which explains the generation of optical networks as the pool effect [2], and the generation of a beam rope in the vacuum through zone plates, which can be used to generate new ways of transmitting information.

References


Preferred mode of presentation: Poster
Light scattering by collections of metallic spheroids

Dmitri Schebarchov, Walter R. C. Somerville*, Baptiste Auguié, and Eric C. Le Ru

The MacDiarmid Institute for Advanced Materials and Nanotechnology, School of Chemical and Physical Sciences, Victoria University of Wellington, PO Box 600 Wellington, New Zealand

*Presenting author (walter.somerville@vuw.ac.nz)

Light scattering by nonspherical metallic nanoparticles supporting plasmon resonances is a cornerstone of surface-enhanced spectroscopies, but remains a challenging system to model theoretically. Over the last several years we have extended the Extended Boundary-Condition Method for the specific case of spheroidal particles, as for this particular shape the $T$-matrix elements have unique numerical properties [1,2]. These investigations have resulted in an efficient and accurate numerical implementation for single spheroids [3], which enables benchmark calculations of far-field and near-field properties for a wide range of parameters. In particular, we used this method to demonstrate numerically the limits of the Rayleigh hypothesis, where the multipolar series expansion of the scattered field may fail to converge in the vicinity of the particle [4].

Where light interacts with a collection of particles in relative proximity, multiple scattering effects can substantially affect the optical response. With the individual $T$-matrix of each scatterer already available, the superposition $T$-matrix framework is an appealing approach to describe the collective response of a cluster of such particles [5,6]. We have implemented several algorithms from the literature and compared their performance in the challenging case of light scattering by metallic spheroids. This contribution will present our results for different geometries of particle clusters, and notably discuss the convergence properties of far-field cross-sections and near fields when metallic spheroidal particles are placed such that their smallest circumscribing spheres intersect.

References


Preferred mode of presentation: Oral
Bridging the knowledge gap between light scattering and microphysics on single atmospheric ice crystals

Franz M. Schnaitera,b,* and Emma P. Järvinenc

aKarlsruhe Institute of Technology, Kaiserstraße 12, 76131 Karlsruhe, Germany
bSchnaitEC GmbH, Oberes Buchenfeld 18, 77736 Zell a. H., Germany
cNational Center for Atmospheric Research, 3090 Center Green Dr., Boulder, CO 80301, USA

*Presenting author (martin.schnaiter@kit.edu)

The interaction of shortwave solar radiation with ice particles is an important process in the atmosphere which redistributes solar light on its way to the ground. Therefore, the knowledge of the angular light scattering behavior of atmospheric ice particles is crucial for a reliable calculation of the shortwave radiative transfer in climate models and for retrieving cloud bulk properties from satellites. Much of the current knowledge of the light scattering behavior of atmospheric ice particles is gained from modelling studies, which apply optical models on simplified ice particle morphologies. Although these models have been significantly improved over the last decade, their results are still questionable especially when it comes to the effects of ice crystal complexity like hollowness and surface roughness. This is mainly because there are no in-situ measurements available on single atmospheric ice particles that would allow for a validation from the perspective of fundamental single particle light scattering.

This lack of measurement data was the motivation to develop the Particle Habit Imaging and Polar Scattering (PHIPS) probe [1,2]. The PHIPS takes stereo microscopic bright field images of single atmospheric cloud particles and simultaneously acquires the correlated angular light scattering function. After the demonstration of its full functionality in 2017, the instrument participated in two campaigns targeting mixed-phase and pure ice clouds in high latitudes in 2017 and 2018. A unique and comprehensive data set of the microphysical properties and the correlated light scattering functions of real atmospheric ice particles is now available, and a catalog of individual ice crystals is currently being compiled that will be of high value for modelers developing and applying single particle light scattering models.

In this presentation the PHIPS technology is introduced in detail, followed by an overview of the available single particle data set. First attempts of discussing some of the measured single crystal light scattering functions from a fundamental light scattering perspective are presented. The presentation concludes with an outlook for future instrument upgrades.

References


Preferred mode of presentation: Oral
Scattering matrix of semi-infinite scattering media

Alexey A. Shcherbakov

ITMO University, 49 Kronverksky, 197101 Saint-Petersburg, Russia
(alexey.shcherbakov@metalab.ifmo.ru)

Simulations of light scattering from strongly scattering media are important for many applications ranging from mineralogy to planetary science. When the refractive index contrast is sufficiently large, and the scale of inhomogeneities is comparable to the wavelength of the incident radiation, an accurate prediction of spectral angle-resolved reflection requires a rigorous numerical solution of Maxwell’s equations. A number of approaches dealing with this problem have been investigated, many of them analyzing bounded partitions of scattering media. Thus, often the transition from a single-scattering part to a semi-infinite bulk inhomogeneous material represents a considerable problem.

To cope with the problem we consider two approaches based on the Fourier space S-matrix methods for planar diffractive structures. A thick layer bounded by two planes is represented as an infinite crossed grating. When periods of such grating are taken to be sufficiently large in comparison with both the wavelength and the inhomogeneity scale, and the material and geometric composition of each period corresponds to those of real media, an impact of the periodicity on the reflection characteristics can be made negligible. Simultaneously, this artificial periodicity allows us to apply analytically known S-matrix components of thin grating slices [1] and rigorously calculate the whole layer S-matrix.

As a first approach, the S-matrix composition algorithm can be used to repeatedly double S-matrix (and double the layer thickness respectively) until convergence of reflection parameters to a given accuracy. As a second approach, the Ambartsumian’s invariance principle developed within the radiative transfer theory [2,3] can be applied on the basis of ab initio S-matrix calculations. The principle consisting in the invariance of reflective properties of a semi-infinite medium upon addition of a finite thickness layer yields a matrix Riccati equation. In this contribution, both theoretical formulations of the methods and analyses of their numerical behavior and bottlenecks will be discussed.

References


Preferred mode of presentation: Oral
Features of spectral dependence of single-scattering characteristics for crystalline clouds

Olga V. Shefer

National Research Tomsk Polytechnic University, School of Computer Science & Robotics, 30, Lenin ave., 634050, Tomsk, Russia

Presenting author (shefer-ol@mail.ru)

This work considers the extinction, scattering, and absorption coefficients and quantum survival probability as basic characteristics of single scattering. The physical optics method and the Mie theory are used to calculate these characteristics for individual particles of an ice cloud and for ensembles of crystals with various values of the particle aspect ratio and different parameters of the particle size distribution. The features of extinction, scattering, absorption, and single-scattering albedo are illustrated for various microphysical parameters of the crystal system at visible and infrared wavelengths. Particular attention is paid to the Christiansen spectral regions. According to the results of our numerical study, the most pronounced spectral dependences of the single-scattering characteristics are observed for a system of large predominantly oriented plates and wavelength-sized particles. The difference in their behavior is due to variations in the physicochemical properties of the particles even for identically shaped crystals. With the same concentration of the selected particles, the spectral dependence of the optical characteristics (e.g., extinction coefficient) for the large plates is more pronounced (by orders of magnitude) than for the small particles.

For a system of large translucent horizontally oriented plates, analytical expressions are presented to calculate the absorption and extinction coefficients. These expressions allow us to quantify the influence of microphysical parameters of the particles and their refractive index on the spectral dependence of the optical characteristics for a polydisperse medium containing large horizontally oriented plates with a minimal expenditure of computer resources.

Preferred mode of presentation: Poster
Two dimensional shape retrieval from interferometric out-of-focus images of non-spherical particles

Huanhuan Shen\textsuperscript{a,}*, Lingyuan Wu\textsuperscript{a}, Yanglong Li\textsuperscript{b}, and Weiping Wang\textsuperscript{a}

\textsuperscript{a}Institute of Fluid Physics, CAEP, 64 Mianshan road, Mianyang, 621999, China
\textsuperscript{b}Key Laboratory of Science and Technology on High Energy Laser, CAEP, Mianyang, 621999, China

*Presenting author (huanhuan.shen@caep.cn)

Interferometric out-of-focus images of non-spherical particles are commonly speckle-like patterns. We will present a treatment that is able to retrieve the two dimensional shape of the particle from its simulated interferometric out-of-focus image [1]. Firstly, the information retrieval issue from the interferometric out-of-focus image will be demonstrated identical to the phase retrieval under certain condition. Then the hybrid–input–output algorithm will be employed to conduct the reconstruction [2]. For a successful reconstruction, a tighter support is required. Thus, the method to get a tighter support will be explained. The reconstructed object has the same global two-dimensional shape of the real particle, though an ambiguity of the shape orientation exists. The size of the reconstructed image is scaled by the parameters for the reconstruction. After that, the superposed interferometric out-of-focus image of two single particles which are close enough to each other will be treated. We will show that the proposed treatment is capable to reconstruct the two particles at the same time. Finally, we will analysis the noise in the out-of-focus pattern that would hobble the reconstruction and thus advises will be given for optical system design. Moreover, preliminary experimental results will be presented.

References


Preferred mode of presentation: Oral
Phase critical angle refractometry for nanoscale bubble growth measurement

Lin Shi⁷, Yingchun Wu⁷, Xuecheng Wu⁷, and Jianqi Shen⁸

⁷State Key Laboratory of Clean Energy Utilization, Zhejiang University, 38 Zheda Rd., 310007
Hangzhou, China
⁸University of Shanghai for Science and Technology, 516 Jungong Rd., 200093 Shanghai, China

*Presenting author (shil@zju.edu.cn)

Bubbles exist in a wide range of natural systems and industrial processes [1]. Accurate measurements of bubble size and its transient growth are of great importance, which is able to characterize the interaction between bubbles and surroundings. Nanoscale growth of a micron-sized bubble is difficult to measure since it is beyond the resolution of current bubble sizing techniques [2–4]. In this talk we will present a newly developed phase critical angle refractometry (PCAR) technique for simultaneous size and growth measurement. First, the principle of PCAR was theoretically derived, which reveals that the phase shift of time resolved fine structure of bubble light scattering linearly correlated with bubble growth. Then we verified PCAR through the simulation of bubbles with tiny size change, and the accuracy was analyzed. At last, experiments on a single bubble with tiny bubble growth show the feasibility of PCAR technique. PCAR is a promising tool for bubble study and can be extended to industrially-relevant applications.

References


Preferred mode of presentation: Oral/Poster
Extinction efficiency calculation of an infinite multilayered cylinder using transmission coefficients

Nir Shiloah\textsuperscript{a,*}, Moshe Kleiman\textsuperscript{a}, and Joseph Gurwich\textsuperscript{b}

\textsuperscript{a}Department of Applied Mathematics, Israel Institute for Biological Research, P.O.B. 19, Ness-Ziona, 7410001, Israel
\textsuperscript{b}Department of Electro-Optics, Ben-Gurion University, Beer-Sheva 8434231, Israel

\textsuperscript{*}Presenting author (nirs@iibr.gov.il)

The purpose of this work is to develop a formalism for calculation of extinction efficiency, for infinite multilayer cylinder \cite{1,2}, based on the transmission coefficient.

We investigate particles with a large size parameter (the ratio between the particle size and wavelength) \cite{3}, and with high refractive index (optically non-soft particles, like metal-coated fibers).

The relationships are obtained by comparing the results of Mie calculations of the electromagnetic nearfield \cite{4}, with the classical theory of the electromagnetic field \cite{5}, and by using the fiber impedance parameter.

The mathematical expression obtained for the calculated transmission coefficient (and thus for the extinction efficiency) is quite complex, but it allows extraction of the extinction efficiency, which depends on the fiber parameters and its dielectric properties ($\varepsilon$ and $\mu$).

References


Preferred mode of presentation: Poster
Simulations of scattering by extremely oblate particles with the discrete dipole approximation

D. A. Smuneva,* and M. A. Yurkinb,c

aBelarusian State University, Nezavisimosti Av. 4, 220030 Minsk, Belarus
bVoevodsky Institute of Chemical Kinetics and Combustion SB RAS, Institutskaya Str. 3, 630090, Novosibirsk, Russia
cNovosibirsk State University, Pirogova Str. 2, 630090, Novosibirsk, Russia

*Presenting author (dsmunev@gmail.com)

The discrete dipole approximation (DDA) is a widely used method to simulate scattering and absorption of electromagnetic waves by particles of arbitrary shape and internal structure [1]. In most cases the DDA is used with a cubic lattice of dipoles, although theoretically dipoles (voxels) of any shape can be used, for example cubic (rectangular parallelepiped). Still, the issues associated with the latter has been resolved only in 2015 [2]. Those “rectangular dipoles” allow significant reduction of computational time for some cases. Consider, for example, a graphene nanoplate with sizes 9 μm × 9 μm × 20 nm [2]. Dipole size has to be small to fit into the nanoplate thickness, which implies redundantly large number of dipoles to cover the width. By contrast, rectangular dipoles can be optimized for particular aspect ratios of the scatterer.

In this work we take the next step, by analyzing the rectangular-dipole formulation of the DDA in the limit of very small thicknesses of both dipole and scatterer. Taking the limit of zero thickness greatly simplifies the theoretical formulation, resulting in effectively 2D representation, where all optical quantities scale with various powers of particle thickness. It is equivalent to the Rayleigh–Debye–Gans approximation combined with the boundary conditions at the plane interface. We also proved that the scattering quantities computed with the standard (3D) code are independent of number of dipoles along the particle thickness, when the latter is sufficiently small.

Although the simulations based on the 2D theory are much faster than the standard DDA even for multi-layered structures (no linear system need to be solved), it can still be conveniently done within the framework of the DDA. Thus, we have implemented this capability as the development branch of ADDA: https://github.com/adda-team/adda/tree/2d_dda, as a natural extension of the existing command line options. After the simulation, ADDA generates standard output files, values in which are scaled to the corresponding powers of thickness. This can be used for various applications, including simulations of finite-width metasurfaces.

References


Preferred mode of presentation: Oral
Optical force on a Mie particle by an Airy light-sheet using generalized Lorenz–Mie theory

Ningning Song*a, Renxian Liab,⁎, Jiaming Zhanga, Shu Zhanga, Han Suna, and Bojian Weia

*aSchool of Physics and Optoelectronic Engineering, Xidian University, Xi’an 710071, China
bCollaborative Innovation Center of Information Sensing and Understanding, Xidian University, Xi’an 710071, China

⁎Presenting author (nnsong@stu.xidian.edu.cn)
**Corresponding author (rxli@xidian.edu.cn, rxli@mail.xidian.edu.cn)

Since Ashkin invented optical tweezers in 1986 [1], more and more scientists have been devoted to optical manipulation. The study of optical manipulation of micro- and nano-particles depends on specific light field. Traditional optical tweezers used Gaussian beam as trapping beam. In recent years, some new optical manipulation techniques based on novel laser beams have been developed. Airy light-sheet is a new type of optical field, and its amplitude distribution obeys the airy function. Airy light-sheet have self-healing [2], non-diffraction, self-acceleration [3], self-bending transmission [4] and other excellent characteristics, and provides a possibility for the special and complex manipulation of light on particles. Exact prediction of optical force by laser beam is of practical significance for the development of novel optical tweezer systems.

Generalized Lorenz–Mie theory (GLMT) is an exact solution of the Maxwell equations, and can rigorously predict the optical force on a homogeneous spherical particle induced by laser beams [5]. In this paper, the GLMT is employed to rigorously calculate optical force exerted on a sphere in the Mie regime induced by an Airy light-sheet. The results are of great significance for the development of Airy sheet based optical manipulation technology, and have potential applications in the fields including single-molecule research, living cell research, high-precision measurement, etc. [6].

References

Preferred mode of presentation: Oral
Sensitivity of aerosol refractive index to particle composition and component index uncertainties

Patrick G. Stegmann\textsuperscript{a,b,*}, Benjamin T. Johnson\textsuperscript{a,b}, and Ping Yang\textsuperscript{c}

\textsuperscript{a}NOAA Center for Weather and Climate Prediction, 5830 University Research Ct., College Park, MD 20740, USA
\textsuperscript{b}Joint Center for Satellite Data Assimilation
\textsuperscript{c}Department of Atmospheric Science, Texas A&M University, College Station, TX 77840, USA

*Presenting author (patrick.stegmann@noaa.gov)

Stegmann and Yang\cite{StegmannYang2017} developed a novel, comprehensive refractive index database for dust aerosol species. This database accounts for various dust compositions, including silicates, quartz, carbonates, sulfates, soot (black carbon), and iron oxides. The database was compiled from multiple sources to cover a spectral range from 0.1 to 150 μm and beyond for specific individual species. Furthermore, the database also provides a software tool to compute the Bruggeman effective medium refractive index\cite{Bruggeman1935} of an arbitrary mixture of the components for real-world remote sensing applications. This is achieved through an invariant-imbedding-like approach that not only furnishes a unique solution for the effective index, but also allows to study the sensitivity of the Bruggeman effective medium to its input parameters in a rigorous manner. Similarly, Jacobian and adjoint equations for data assimilation applications can be formulated analytically. While slightly more involved than the traditional weighted summation approach, the proposed method thus offers distinct advantages. In addition to the database itself, the provided code is also available as an open source under the GPL v3.0 and can be cloned from its online repository\cite{Stegmann2017}.

In this talk we summarize the development and extent of the aerosol refractive index database, discuss the approach towards finding a unique solution for a Bruggeman effective medium, and provide sample results to illustrate the sensitivity of the effective refractive index to uncertainties in its composition and input component refractive indices.

References

[3] https://github.com/PStegmann/Bruggeman_Effective_Medium

Preferred mode of presentation: Oral
Fast vector radiative transfer solution using improved small-angle approximation

Bingqiang Sun

Department of Atmospheric and Oceanic Sciences/Institute of Atmospheric Sciences, Fudan University, Shanghai, 200438, China (bingqsun@fudan.edu.cn)

If the scattering phase matrix has a forward diffraction peak, an accurate solution of the corresponding vector radiative transfer equation is time-consuming. By decomposing the scattering phase matrix at certain scattering angles into the forward component and the remaining component, the original vector radiative transfer equation is decomposed into three equations: the forward equation, the regular equation, and the error equation. The forward equation is approximately solved using the small-angle approximation [1]. The regular equation is solved using the adding-doubling method. The error equation is described using the single-scattering approximation. The summation of the solutions from the three equations generates the final solution of the original radiative transfer equation. Using this decomposition, the vector radiative transfer equations with respect to an arbitrary scattering phase matrix can be rapidly but accurately solved. The computational time is significantly reduced because the most time-consuming forward equation is solved by an analytic formula after using the small-angle approximation. The solution is verified against benchmarks and several applications are also shown in this presentation.

Reference


Preferred mode of presentation: Poster
Resonance scattering by a dielectric sphere of a vector Airy beam

Han Sun*, Renxian Li*a,b,**, Jiaming Zhanga, Ningning Songa, Shu Zhanga, and Bojian Weia

aSchool of Physics and Optoelectronic Engineering, Xidian University, Xi’an 710071, China
bCollaborative Innovation Center of Information Sensing and Understanding, Xidian University, Xi’an 710071, China

*Presenting author (hsun_6@stu.xidian.edu.cn)
**Corresponding author (rxli@mail.xidian.edu.cn)

Diffraction is one of the most important factors limiting the accuracy of instruments in optical systems. Since the concept of non-diffraction beams is put forward by Durnin [1], it has rapidly become a hot topic. An Airy beam, a novel non-diffraction beam, has some special characteristics such as self-recovery and self-bending. Resonance scattering analyses of Airy beams have some potential applications in optical manipulation, optical tweezers, imaging systems, and other fields.

In this paper, resonance scattering by a dielectric sphere illuminated by a vector Airy beam is investigated using the generalized Lorenz–Mie theory. A part of the non-resonant background is subtracted from the standard Mie scattering coefficients. Firstly, the electric fields of the vector Airy field is expressed using the angular spectrum decomposition [2]. The beam-shape coefficient is derived using multipole expansion of spherical harmonic functions. To further investigate the physical explanation of some special phenomena, the scattering coefficient of the dielectric sphere is expanded using Debye series [3]. The effects of parameters including the polarization, modulation parameter and transverse scale of Airy Beams are considered [4]. The advantage of the resonance method is that we can quantitatively describe the scattering using Debye series by separate diffraction effects from the external and internal reflections from the sphere.

References


Preferred mode of presentation: Oral
In situ measurement of vertical distribution of CO\textsubscript{2} and CH\textsubscript{4} in the troposphere by aircraft and tethered balloon

Xiaoyu Sun\textsuperscript{a}, Minzheng Duan\textsuperscript{a,*}, Xiangao Xia\textsuperscript{a}, Disong Fu\textsuperscript{a}, and Zhongdong Yang\textsuperscript{b}

\textsuperscript{a}Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
\textsuperscript{b}National Satellite Meteorological Center, CMA, Beijing, China

\textsuperscript{*}Presenting author (dmz@mail.iap.ac.cn)

Several satellites have been launched into space to monitor the greenhouse gases concentration, by observing the backscattered hyper-spectral radiance in the SWIR, in the atmosphere therefore the vertical profile of greenhouse gases, especially carbon dioxide, and aerosol could greatly modulate the retrievals. To investigate how the interplay process of the CO\textsubscript{2} and aerosol scattering in the atmosphere, which is blamed for the uncertainty of the retrieval results of satellite measurements. Therefore, knowledge of CO\textsubscript{2} vertical distribution is crucial for the development of satellite-borne retrieval methods and algorithm. Aircraft in situ measurements of carbon dioxide mixing ratio and methane over Jianshanjiang (46.77°N, 131.99°E) (August 2018) were conducted, and compared to the retrieval results of Orbiting Carbon Observatory 2 (OCO-2) and Chinese Carbon Dioxide Observation Satellite (TanSat). The aircraft measurements were carried out between altitudes of 0.6 to 7 km, and obtained vertical profile of CO\textsubscript{2} and CH\textsubscript{4} by an Ultra-Portable Greenhouse Gas Analyzer (Los Gatos Research, LGR). A constant increase of an averaged 15.26 ppm in CO\textsubscript{2} mixing ratio were observed between altitude 2 to 7 km during the flight period. The methane measurements shows an averaged 0.5 ppm in CH\textsubscript{4} mixing ratio increased below 2.0 to 0.6 km caused by the large emission from wide range paddy field below, and the mixing ratio above 2 km varies between 1.951 to 1.976 ppm without large mutation.

Another vertical profile measurements of CO\textsubscript{2} and CH\textsubscript{4} on tether-balloon platform was conducted on Changshou (107.00°E, 29.84°N) (January 2019). In this study, vertical profiles of CO\textsubscript{2} mixing ratio measurements was made at low troposphere within altitude 0 to 1000 km. A strong vertical mixture of CO\textsubscript{2} was observed between 0 to 700 km, and most profiles presents declining trends of CO\textsubscript{2} and CH\textsubscript{4} mixing ratio with the increase of altitude, since the experiment site located in an industrial park with a large greenhouse gases emission source. The results would enhance the understanding of the spatial variation of CO\textsubscript{2} and CH\textsubscript{4}.

Preferred mode of presentation: Poster
Improving the radiative transfer approximation in the geometric optics regime

Timo Väisänen*, Julia Martikainen, Antti Penttilä, and Karri Muinonen

Department of Physics, University of Helsinki, Finland
Finnish Geospatial Research Institute FGI, National Land Survey, Kirkkonummi, Finland

Presenting author (timo.h.vaisanen@helsinki.fi)

We have developed a set of light-scattering tools which can be used to model the spectroscopy, photometry, and polarimetry of planetary surfaces by linking the tools as a pipeline [1,2]. In these pipelines, scattering by densely packed media in the geometric optics regime is approximated by utilizing radiative transfer. A single diffuse scatterer is created by mixing light-scattering characteristics of individual particles statistically, which is then used as input in the SIRIS4 [2–4]. The problem is that the current approach neglects the so-called shadowing effect.

In order to study the effects of particles shadowing each other, we have developed a new version of the SIRIS which is capable of handling arbitrary geometries. Still, computing multiple scattering from millions of particles with multiple facets in the geometric optics regime is too computer-intensive, and hence we need to utilize our existing radiative transfer approach with possible corrections. We study approaches which might be used to improve the existing pipeline, such as using volume elements to replace the statistically diffuse scatterer or adding particles on top of the geometry containing diffuse scatterers.

References


Preferred mode of presentation: Oral
Location effects induced in moiré patterns with noise

M. Vargas Moralesa,*, G. Martinez Niconoffa, M. A. Torres Rodrigueza, and P. Martinez Vara,b,

a INAOE Instituto Nacional de Astrofísica Óptica y Electrónica, optics department, Luis Enrique Erro 1, Tonantzintla, Puebla, México Zip code 72840
b BUAP Benemérita Universidad Autónoma de Puebla, BUAP, Engineering faculty, Av. San Claudio, Puebla, México

*Presenting author (mvargas@inaoep.mx)

Strictly, all the physical systems present a certain degree of randomness characterized by the presence of noise. When a physical system is in competition with noise, the evolution of the system may induce/generate novel physical properties, an example of this behavior being the generation of localization effects. Mechanism competition is suitably characterized by analyzing the correlation function, it means that the presence of noise generates directionality in the evolution of the physical processes. In this context we describe the evolution of periodical structures when they are perturbed with multiplicative noise. We show that increasing the random character, the structures generate localization when the correlation function takes the form of a decreasing exponential from the physical point of view. As a prototype, we use moiré structures and this analysis is transferred to a plasmonic field propagating trough surface metal thin films. The propagation of plasmonic modes is generated by the coupling of the evanescent behavior.

References


Preferred mode of presentation: Oral/Poster
Doppler velocity comparison of cloud radar and Microrain radar

Xia Wana, Baike Xib,*, Guirong Xua, Chunguang Cui, Linli Zhoua, and Zhikang Fua

aInstitute of Heavy Rain, China Meteorological Administration, Hubei Key Laboratory for Heavy Rain Monitoring and Warning Research, Wuhan 430074, China
bDepartment of Hydrology and Atmospheric Sciences, University of Arizona, Tucson, AZ, USA

*Presenting author (baikex@email.arizona.edu)

This study is trying to address that the uncertainty may be caused by the cloud radar Doppler velocity aliasing issue with the aid of Microrain radar and disdrometer measurements. The Mesoscale Heavy Rain Observing System located at Xianning, Hubei province of China, provides a comprehensive measurement during Integrative Monsoon Frontal Rainfall Experiment (IMFRE) in the summer of 2018. Seven precipitation events during the IMFRE are selected under either convective or stratiform clouds except one event that includes both convective and stratiform rain periods. The data collected during this field champion allow us to investigate (1) the effectively of the existing dealiasing algorithm for cloud radar Doppler velocity; (2) the relationship between the Doppler velocities measured by cloud radar and the precipitation rate measured by the disdrometer. The algorithm is simplified and then applied to seven events of convective clouds and/or stratiform clouds in the campaign. MRR measured velocities are used as a criterion to validate the dealiasing velocities of cloud radar measured Doppler velocities under four different rain rate ranges. The multi-instrument measurements provide a verification for the dealiasing processing. Comparisons reveal cloud radar velocities agree well with MRR velocities under rain rate between 0 and 1 mm/h with correlation coefficient of 0.98 and bias less than –0.3 m/s. For other three rain rate ranges, the agreements are also acceptable, therefore four linear fitting relationships between the dealiasing Doppler velocities and the rain rate are proposed, respectively. Velocity vertical profiles of convective and stratiform clouds are also analyzed, and melting band is consistent with zero degree isotherm for stratiform clouds. At convective regions, the Doppler velocities are positively correlated with the precipitation rate, and the values increases while approaching the ground. At stratiform regions, very strong variation of Doppler velocities within the melting band, and the values are slightly deceasing with height except when the precipitation rate is greater than 10 mm/h.

References

Preferred mode of presentation: Poster
Optical properties of soot particles influenced by mixing structure

Yuanyuan Wang and Weijun Li*

Department of Atmospheric Sciences, School of Earth Sciences, Zhejiang University, Hangzhou, 310027, China

*Presenting author (liweijun@zju.edu.cn)

Soot particles are ubiquitous in the atmosphere and have a strong absorption ability. Soot particles tend to mix with other aerosol particles during ageing in the atmosphere. The aerosol particles of different shapes and size mix with soot particles on various positions, which compromise different mixing structures. Many studies modeled and observed the optical properties of internally mixed soot particles. Some numerical optical models such as the Rayleigh–Debye–Gans approximation, T-matrix, and Discrete Dipole Approximation have been used to simulate the optical properties of soot particles. Besides, some experimental methods such as a combination of the single-particle soot photometer and the three-wavelength photoacoustic soot spectrometer have been applied to characterize physicochemical properties of soot and measured their optical properties [1,2]. However, the calculated optical properties of soot particles are still rather inconsistent with observed ones because of their complex shapes and mixing structures.

In this talk, we compare optical properties of soot particles with different mixing structures. We establish an improved internally mixed soot particles model with coatings of different shapes, numbers, and relative positions to soot particles according to their factual morphologies in the atmosphere. The improved atmospheric soot particle models show different optical properties with those in former works, which provide essential improvement to simulate optical properties of atmospheric internally mixed soot particles.

References


Preferred mode of presentation: Oral
Photonic jets generated by a spherical particle excited by a shaped beam

Jiajie Wang*, Le Zhu, and Yiping Han

School of Physics and Optoelectronic Engineering, Xidian University, 710071, China

*Presenting author (wangjiajie@xidian.edu.cn)

Photonic jets (PJs) are narrow and elongated spots which have a subwavelength beam waist and propagate with little divergence for several wavelengths. The feasibility of using a photonic jet to design super-resolution optical microscopy [1], tools for precision cell surgery and tumor detection [2], applications in optical tweezers [3] as well as to develop optical data storage devices with ultrahigh density of information recording and technologies of direct write nano-patterning [4] makes the photonic jet a hot research spot in recent years.

The key parameters of PJs (transverse dimension, length, peak and intensity) formed in the vicinity of homogeneous dielectric microspheres and microcylinders under exposure of plane wave radiation has been thoroughly studied. These studies have shown that both the PJs shape and intensity depend significantly on the size and optical properties of a generating particle. However, there is limited studies on the investigation of the properties of a PJ excited by a shaped beam. As we realized that by the use of sharply focused laser beams or structured beams, where additional localization of a photonic stream and its effective volume reduction can be achieved, the properties of a PJ would be changed and some features will be enhanced.

In this talk we will report our recent work on the investigation of PJ generated by spherical particles excited by shaped beams. The tunable of PJs parameters brought by structured beams, including Bessel beam, Gaussian beam, and by properties of particles are discussed. Numerical results concerning the position of maximal intensity, longitudinal and transversal dimensions of the PJs, and its peak intensity will be presented.

References


Preferred mode of presentation: Oral
Properties of aerosols and clouds from lidar and radar soundings: experiment and theory

Zhenzhu Wang\textsuperscript{a,}\textsuperscript{*}, Dong Liu\textsuperscript{a}, Anatoli Borovoi\textsuperscript{b}, Chenbo Xie\textsuperscript{a}, and Yingjian Wang\textsuperscript{a}

\textsuperscript{a}Key Laboratory of Atmospheric Optics, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei 230031, China

\textsuperscript{b}V. E. Zuev Institute of Atmospheric Optics, Siberian Branch, Russian Academy of Sciences, Tomsk, 634055, Russia

*Presenting author (zzwang@aiofm.ac.cn)

Aerosols play important roles in environmental quality and sometimes cause serious problems such as endangering human health and reducing visibility. Furthermore, aerosols directly affect the earth’s radiation balance through scattering and absorbing solar radiation, and they indirectly influence the properties and lifetimes of clouds by acting as a condensation nucleus or an ice nucleus in cloud formation, eventually influencing the global climate change. At the meanwhile, Clouds strongly regulate radiative transfer and the hydrological cycle, which are important parts of Earth's weather and climate. The optical characteristics of aerosol and cloud are poorly studied yet because of the strong spatial and temporal variability of them. A lidar and a radar are two common useful tools for aerosol and cloud, which can provide the possibility to retrieve the vertical profiles of both the number density of particles and their microphysical characteristics, in comparison with the passive remote sensing methods. In this study, a multi-wavelength Raman–Mie lidar, a CCD lidar, and a 35-Ghz radar are employed to measure the properties of aerosols and clouds. The extinction at 0.355 and 0.532 μm and backscattering at 0.355, 0.532, and 1.064 μm coefficients and the phase function at 0.532 μm from lidar, and the effective reflectivity factor from radar are inversed for use. Furthermore, the quantities responsible for microphysics can be extracted and explained as the dimensionless values, such as the linear depolarization ratio, the color ratio, the lidar ratio and the other ratios. Then these microphysical properties for aerosol and cloud during campaigns are analyzed in detail.

Preferred mode of presentation: Oral
In a humid environment, wet sea salt aerosols are always considered to be spherical in most climate models. However, sea salt aerosols are inhomogeneous during hygroscopic processes (deliquescence and crystallization). As relative humidity (RH) increases or decreases, sea salt particles are coated by water or crystallized in droplets. In this study, we used a two-layer sphere model to simulate optical properties of wet sea salt in specified ranges of RH. We have found that the asymmetry factor of coated sea salt is much lower than that of the volume equivalent homogeneous spherical sea salt, indicating stronger backscattering of coated sea salt. To assess the impact of the aforementioned inhomogeneity on direct radiative forcing of sea salt aerosols, we used the Community Earth System Model. Results show that on global scale the inhomogeneity of wet sea salt has limited effect on direct radiative forcing; however, over the coastal regions bias of direct radiative forcing between inhomogeneous and homogeneous sea salt aerosols could be up to 10% [1]. From a remote sensing perspective, in coastal regions, both the nonsphericity and inhomogeneity should be considered to compute the optical properties of sea salt aerosols due to a large range of RH [2].

References


Preferred mode of presentation: Poster
Theoretical extension of universal forward and backward Monte Carlo radiative transfer modeling for passive and active polarization observation simulations

Zhen Wang\textsuperscript{a,*}, Shengcheng Cui\textsuperscript{b}, Zhibo Zhang\textsuperscript{c}, Jun Yang\textsuperscript{a}, Haiyang Gao\textsuperscript{a}, and Feng Zhang\textsuperscript{d}

\textsuperscript{a}Key Laboratory for Aerosol–Cloud Precipitation of China Meteorological Administration, School of Atmospheric Physics, Nanjing University of Information Science and Technology, Nanjing 210044, China
\textsuperscript{b}Key Laboratory of Atmospheric Optics, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei 230031, China
\textsuperscript{c}Physics Department, University of Maryland, Baltimore County, Baltimore, MD 21250, USA
\textsuperscript{d}School of Atmospheric Sciences, Nanjing University of Information Science and Technology, Nanjing 210044, China

*Presenting author (intersharp@126.com)

The theoretical framework of universal forward and backward Monte Carlo radiative transfer modeling in [1] is extended for passive and active polarization observation simulations [2]. It is built upon newly derived forward and backward vector scattering order-dependent integral radiative transfer equations (IRTEs). The unified mathematical formalism not only establishes the design of object-oriented software architecture, but also speeds up software development via the reuse of developed scalar code. The polarization simulations are implemented with the addition of the Stokes vector and the Mueller matrix weight tracing schemes. To improve numerical performance order by order, the extension implementation of hybrid scattering order-dependent variance reduction techniques are given detailedly, with a focus on the formulation of scattering phase matrix truncation on the basis of remodeling vector IRTEs. To enrich polarization simulation features, not only scattering operators but also source vector function and detector response matrix function are formulated in unified mathematical forms for the hierarchies organization of various atmosphere, surface, source and detector classes. The framework was fully implemented in MSCART model. For passive simulation, it not only can handle all 1D and 3D test cases in Phases A and B of the IPRT intercomparison project using forward and backward algorithm, but also simulate polarized radiance in a specified direction at a specified position using backward algorithm. For active simulation, lidar backscatter range-resolved signals can be simulated using forward algorithm. The source package is freely available for research purpose from the corresponding author, with online documentation from \url{https://intersharp.gitlab.io/mscart-docs}.

References


Preferred mode of presentation: Oral
Measuring formation of a vapor bubble around a heated nanoparticle and size of nanoparticles by holography

Linglong Wang*, Yingchun Wu, and Xuecheng Wu

State Key Laboratory of Clean Energy Utilization, Zhejiang University, 38 Zheda Rd., 310007 Hangzhou, China

*Presenting author (wanglinglong@zju.edu.cn)

Nanoscale particles and micron-sized bubbles are widely found in many industrial processes. The properties exhibited by nanomaterials in the fields of chemical, medical, material and environment sciences are closely related to particle size [1]. When the laser is focused on liquids dispersed with nanoparticles, the formation of laser-induced bubbles are related to the size of particle [2–5]. In this talk we will present the recovery of the size of nanoparticle by measuring the growth process of the laser-induced bubble when the nanoparticles are dispersed in liquids and irradiated by a strong pulsed laser. First, vapor bubbles are formed due to photothermal conversion between laser pulses and liquids containing absorptive nanoparticles, and the growth process of induced bubbles (including expansion and contraction) is recorded by high-speed holography. Then a bubble growth model is established based on heat transfer and bubble dynamics for predicting the size change of bubble generated by the laser irradiation of the nanoparticle. Finally, the size of nanoparticle is deduced and obtained from the experimentally measured bubble size and the numerical simulation results. The research result provides a method for measuring the size of nanoparticles and vapor bubble variation during liquid flow.

References


Preferred mode of presentation: Oral
Vector radiative transfer properties of inhomogeneous ice clouds in spherical atmosphere

Mingjun Wang*, Jihua Yu, Xizheng Ke, and Leili Guo

School of Automation and Information Engineering, Xi’an University of Technology, 710048 Xi’an, China

*Presenting author (wmjxd@aliyun.com)

Clouds composed of ice crystals are an important part of the atmosphere [1–3]. Research on atmospheric radiative transfer properties under an ice cloud condition is helpful to understand the role of ice clouds on remote sensing, atmospheric detection, and many other fields in atmospheric physics. However, the study of radiative transfer properties involving ice clouds have often been based on the assumption that the atmosphere is plane parallel [4–5]. Because of the influence of a spherical atmosphere, this assumption is no longer valid when the solar zenith angle is greater than 70° [6].

Our presentation will compare the vector radiative transfer properties of inhomogeneous ice clouds in plane parallel and spherical atmospheres at 1.55μm. Changes in the ice cloud transmittance and reflectance with effective radius, ice water content, relative azimuth angle, cloud bottom height, and so on will be computed numerically and analyzed in the case of a spherical atmosphere. The effect of ice particle shapes and degrees of roughness on radiative transfer properties will be also analyzed and compared. This research will provide theoretical support for satellite-to-ground laser communication, satellite remote sensing, and other engineering applications.

This work is partly supported by the National Natural Science Foundation of China (Grant No. 61771385) and the Key industry innovation chain of Shaanxi Province (Grant No. 2017ZDCXL-GY-06-01).

References


Preferred mode of presentation: Poster/Oral
The turbulence influence on average intensity of Gaussian beams

Wang WanJun\textsuperscript{a} and Wu ZHenSen\textsuperscript{a,b,*}

\textsuperscript{a}School of Physics and Optoelectronic Engineering, Xidian University, Xi’an, Shaanxi 710071, China
\textsuperscript{b}Collaborative Innovation Center of Information Sensing and Understanding at Xidian University, Xi’an, Shaanxi 710071, China

\textsuperscript{*}Presenting author (wuzhs@mail.xidian.edu.cn)

As a basic beam, the Gaussian beam is widely studied for its simple form and applied in many areas, such as optical communications, laser radar, image analysis, and so on. It could also be used for comparison with other complex beams. In this paper, the average intensity of Gaussian beams is studied based on the Rytov theory, and the statistical moment of the turbulence phase perturbation is derived. Much work has been done by Andrews \textit{et al.} [1,2], but some derivation process is not explained in detail [3]. In this paper, the work on the statistical moment of the turbulence is summarized and sorted out, the statistical moment of the turbulence is derived using Mathematica, and the final expression references that in [4]. An approximation that may cause a large bias is also pointed out. The final simple form of the polynomials is obtained by the hypergeometric function approximation with the curve fit in Matlab. The expression of the statistical moment of the turbulence is divergent at a large beam radius caused by the approximation of the Rytov theory; a window function is proposed to limit the divergence at the beam edge. This work provides theoretical basis for the application of the Gaussian beams.

References


Preferred mode of presentation: Oral/Poster
Generation of Airy beam using optical antenna

Bojian Wei\textsuperscript{a,*}, Renxian Li\textsuperscript{a,b,**}, Jiaming Zhang\textsuperscript{a}, Shu Zhang\textsuperscript{a}, Ningning Song\textsuperscript{a}, and Han Sun\textsuperscript{a}

\textsuperscript{a}School of Physics and Optoelectronic Engineering, Xidian University, Xi’an 710071, China
\textsuperscript{b}Collaborative Innovation Center of Information Sensing and Understanding, Xidian University, Xi’an 710071, China

\textsuperscript{*}Presenting author (bjwei@stu.xidian.edu.cn)
\textsuperscript{**}Corresponding author (rxli@xidian.edu.cn, rxli@mail.xidian.edu.cn)

In recent years, nanoantennas have had broad applications, such as super-resolution near-field microscopy imaging, high-efficiency solar cells, and nanolithography. Nanoantennas can efficiently collect light energy and confine it to a subwavelength volume, and their basic principle is surface plasmon polarization resonances [1]. Nanoantennas generally consist of complex two-dimensional or three-dimensional nanostructures. It is relatively expensive and difficult to describe the interaction between it and electromagnetic wave with a simple analytical formula. Therefore, we need to numerically simulate the interaction between nanostructures and electromagnetic waves. The results provide clear guidelines for the fabrication of efficient antenna [2]. Non-diffracting beams, do not spread as they propagate. An Airy beam is a non-diffracting beam, and has the property of self-acceleration [3]. This property is particularly useful in many applications.

In this paper, we will develop an optical antenna to generate an Airy beam. The characteristics of the resulting Airy beam are analyzed, and the effects of vary parameters of the optical antenna on the Airy beam are discussed. And by adjusting the parameters, the optical antenna has potential application for generating other novel non-diffracting beams.

References


Preferred mode of presentation: Poster
Infrared limb detection of large HNO₃-containing PSC particles in the Arctic winter stratosphere

Wolfgang Woiwodeᵃ,*, Michael Höpfnerᵃ, Lei Biᵇ, Farahnaz Khosrawiᵃ, and Michelle Santeeᶜ

ᵃInstitute of Meteorology and Climate Research - Atmospheric Trace Gases and Remote Sensing (IMK-ASF), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
ᵇSchool of Earth Sciences, Zhejiang University, Hangzhou, China, 310027
ᶜJet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA

*Presenting author (wolfgang.woiwode@kit.edu)

Growth, sedimentation and sublimation of nitric acid trihydrate (NAT) particles larger than 10 µm in polar stratospheric clouds (PSCs) are known to affect polar stratospheric ozone loss [1]. Parameterizations of large NAT particles in atmospheric models are uncertain, since the particles are difficult to access and only few field observations are available. Satellite-borne MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) infrared limb observations were shown to be sensitive to PSC composition and, specifically, to spherical β-NAT particles with diameters below 6 µm in high volume densities [2]. Based on radiative transfer simulations involving the Mie model it was shown that the ν₂ mode of NO₃⁻ at 820 cm⁻¹ allows a specific detection. However, larger spherical NAT particles with sizes critical for irreversible denitrification are not accessible, since the characteristic signature flattens out. The combination of Arctic airborne MIPAS and in situ field observations in December 2011 suggests that large NAT particles are highly aspherical. Using IIM+SOV (invariant embedding T-matrix method and separation of variables method) calculations [3], a characteristic red-shifted spectral signature below 820 cm⁻¹ in the MIPAS spectra was attributed to highly aspherical β-NAT particles [4].

In the presented study, we analyze capabilities of infrared limb observations of detecting large NAT particles. Our detection algorithm is based on radiative transfer simulations involving IIM+SOV calculations of highly aspherical β-NAT particles. Using MIPAS observations, large NAT particle populations during the Arctic winter 2011/12 are identified vortex-wide. The results are compared with gas phase HNO₃ modulations observed by MLS (Microwave Limb Sounder).

References


Preferred mode of presentation: Oral
Light absorption enhancement of black carbon aerosols due to complex particle morphology

Yu Wu\textsuperscript{a,*}, Tianhai Cheng\textsuperscript{a}, Dantong Liu\textsuperscript{b}, Shuaiyi Shi\textsuperscript{a}, Xin Zuo\textsuperscript{a}, Wannan Wang\textsuperscript{a}, Xiaochuan Zhang\textsuperscript{a}, Can Meng\textsuperscript{a}, and Qi Ruo\textsuperscript{a}

\textsuperscript{a}State Key Laboratory of Remote Sensing Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences. No.20 Datun Road, Chaoyang, Beijing, 100101, China
\textsuperscript{b}Department of Atmospheric Sciences, School of Earth Sciences, Zhejiang University, Hangzhou, Zhejiang, China

\textsuperscript{*}Presenting author (wuyu@radi.ac.cn)

Black carbon (BC) is formed by incomplete combustion of fossil fuels, biofuels, and biomass, and is the second most important anthropogenic contributor to global warming after CO\textsubscript{2}. Climate impact of BC aerosols is poorly qualified due to the systematic discrepancy between model and observation estimates of BC light absorption enhancements ($E_{\text{abs}}$) after aging which transfer directly into large uncertainties in model estimates of BC radiative forcing. Until now, a proper description of $E_{\text{abs}}$ varying with BC aging has not been validated, leading to a crucial question of BC climate impact. In this study, BC absorption enhancements are qualified using a theoretical model considering their realistic particle morphologies and mixing states dependent on aging scales. The fractal aggregated morphologies with bare, partly coated, partially encapsulated, and heavily coated states of BC-containing particles are simulated dependent on the mass ratio of non-BC and BC components in the individual BC-containing particles, and their optical properties are validated by the comprehensive laboratory and field ambient data. Our results indicate that previous conflicting results of $E_{\text{abs}}$ were possibly observed in different BC aging states, which lie in the range of modelling descriptions. The observed $E_{\text{abs}}$ can be simulated by the model considering particle morphology if BC aging states are exactly obtained. The small observed values of $E_{\text{abs}}$ correspond to a partly aging stage with the BC particles that have inclusions and are thinly coated. The large results of $E_{\text{abs}}$ are mainly produced by heavily coated BC particles in their fully aged stage. It is suggested that the predictions of $E_{\text{abs}}$ varying with BC aging can be largely improved by considering their realistic particle morphologies and mixing states dependent on aging scales.

Preferred mode of presentation: Poster
Multiple scattering from liquid cloud measured by using a polarization lidar with two fields of view

Decheng Wu,*, Xianming Sun, Dong Liu, Zhiqing Zhong, Bangxin Wang, and Yingjian Wang

aKey Laboratory of Atmospheric optics, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei, Anhui 230031, China
bSchool of electrical and electronic engineering, Shandong University of Technology, ZiBo, Shandong 255049, China
cUniversity of Science and Technology of China, Hefei, Anhui 230031, China

*Presenting author (dchwu@aiofm.ac.cn)

Liquid clouds play a key role in the earth radiation budget, the liquid droplet size and concentration are two important parameters in the research of liquid cloud radiation character. A linearly polarized laser pulse from lidar penetrates into liquid cloud, multiple scattering will occur in the cloud, and the lidar received multiple scattering signal will be depolarized [1]. The received multiple scattering signal will enhance the received signal intensity and depolarization ratio. The proportion of the multiple scattering signal in the received signal was mainly determined by the receiver’s field of view (FOV), liquid droplet size and concentration. The multiple scattering signal could be obtained from lidar received signals with different FOVs, and the liquid droplet size and concentration could be retrieved from the multiple scattering signal [2].

A polarization lidar with two FOVs was developed to retrieve liquid droplet effective size and concentration from the multiple scattering in the liquid cloud. The lidar system was introduced, and the depolarization ratio was calibrated by rotating a half-wave plate in the laser transmitter. The lidar measurements of multiple scattering from liquid cloud are shown and discussed. The results indicated that the polarization lidar with two FOVs could be employed to measure the droplet effective size and concentration in the liquid cloud.

References


Preferred mode of presentation: Oral/Poster
Simulation of FY-3D observations of Hurricane Maria

Hejun Xie\textsuperscript{a,}\textsuperscript{*}, Lei Bi\textsuperscript{a}, and Wei Han\textsuperscript{b}

\textsuperscript{a}Department of Atmospheric Sciences, School of Earth Sciences, Zhejiang University, Hangzhou, China
\textsuperscript{b}Numerical Weather Prediction Center of China, National Meteorology Center of China, Beijing, China

\textsuperscript{*}Presenting author (3160101409@zju.edu.cn)

In this presentation, we report on our efforts devoted to simulating FY-3D observations of Hurricane with a focus on understanding the impacts of hydrometeor models on the radiative transfer. The FY-3D houses three functioning instruments in the microwave regime, namely MWRI, MWHS, MWTS, whose channels are located at atmospheric windows, absorption lines of vapor and oxygen, respectively. Cases of simulation have been conducted and we found that applying the aspherical shapes mitigates the over-scattering in mid-frequencies (e.g., 30–50 GHz) slightly by reducing the extinction of Mie shape, and enhances the scattering in high-frequencies (e.g., 89–187 GHz) prominently by reducing the asymmetry factor and single scattering albedo (SSA) of Mie shape. These findings are similar to those reported in [1], except that the simulation results of Mie shape in mid-frequencies show no “black hole” as reported in [1]. We also report our efforts on studying the impacts of vertical inhomogeneity of particle shapes. Specifically, we apply the optical database of 10 ice crystal habit [2], with temperature dependence of ice refractive index as its feature, to the observational operator RTTOV (Radiative Transfer for TOVS) [3]. Hydrometeor profiles of GRAPES model have been used for simulation. Hurricane Maria and several other storms in West Pacific Ocean, at various stages of development, are chosen as cases. The vertical distribution of hydrometeors of storms in [4] is used for a reference.

References


Preferred mode of presentation: Poster
Retrieving aerosol height over land via the O$_2$ A&B bands

Xiaoguang Xu$^a$*$^a$ and Jun Wang$^b$

$^a$Joint Center for Earth Systems Technology, University of Maryland – Baltimore County, Baltimore, MD 21228, USA
$^b$Department of Chemical and Biochemical Engineering, The University of Iowa, Iowa City, 52242, IA, USA

*Presenting author (xxu@umbc.edu)

Aerosol vertical distribution is one of the most important but poorly observed variables that govern the aerosol’s radiative impacts on climate and weather. Recently, the determination of aerosol height using passive satellite measurements in the oxygen (O$_2$) A band around 755–775 nm has been increasingly appreciated [1]. Its physical principle relies on the fact that the scattering of aerosol particles reduces the path length and the probability of light being absorbed by the under-neath O$_2$, thus increasing the radiance in O$_2$ A band as observed by a satellite; this brightening is strongly sensitive to the altitude of the aerosol layer. However, such a retrieval over land is challenged by the high surface reflectance in the O$_2$ A band. Measurements in the O$_2$ B band at 685–695 nm, though engaging a relative weaker O$_2$ absorption signal, can complement aerosol height retrieval by taking advantage of the low reflectance of a vegetation surface [2,3].

In this study, we combined radiances in both the O$_2$ A and B bands measured by the Earth Polychromatic Imaging Camera (EPIC) to determine optical depth and layer height of biomass-burning aerosols over vegetated land surfaces. Carried by the Deep Space Climate Observatory satellite that orbits around the Earth–Sun Lagarange-1 point, EPIC observes the entire sun-lit Earth disk every 1 to 2 hours, providing Earth-reflected radiances in 10 narrow bands. In particular, our algorithm first determines the aerosol optical depth using EPIC’s atmospheric window bands (443, 551, 680, and 780 nm), then uses its O$_2$ bands (688 and 763 nm) to derive the effective aerosol optical centroid altitude. The algorithm was applied to EPIC observations of several biomass burning activities over Canada and the United States in August 2017. Validations were performed against aerosol extinction profile scanned by the space-borne lidar, CALIOP, showing an average error of less than 0.6 km in the retrieved aerosol height.

References

Preferred mode of presentation: Oral
Progress on inversion algorithm development for multi-angle polarimetric aerosol retrievals using AirMSPI

Feng Xua,*, Gerard van Hartena, David. J. Dinera, Oleg Dubovikb, and Yoav Schechnerc

aJet Propulsion Laboratory, California Institute of Technology, Pasadena, CA91109, USA
bLaboratoire d’Optique Atmosphérique, CNRS/Université Lille-1, Villeneuve d’Ascq, France
cViterbi Faculty of Electrical Engineering, Technion – Israel Institute of Technology, Haifa, Israel

*Presenting author (fengxu@jpl.nasa.gov)

The Airborne Multiangle SpectroPolarimetric Imager (AirMSPI) was developed for NASA by the Jet Propulsion Laboratory to advance our understanding of the climate and air quality impacts of aerosols, clouds, and the interactions between aerosols and clouds. It performs multi-angle observations of a target area between ±67° off nadir. Imaging is made in eight spectral channels in the UV–NIR (355–935 nm), three of which (centered at 470, 660, and 865 nm) are polarimetric.

For a coupled retrieval of aerosol properties and surface reflectance, an efficient and flexible algorithm has been developed to fully capture the information content of polarimetric observations. Spatial correlation in aerosol properties is utilized to reduce the retrieval parameter space and mitigate the ill-posedness of inversion, as well as to develop a PC based fast radiative transfer model to capture variations of radiation field across an image [1]. Our retrieval imposes constraints on spatial variations of aerosol microphysical properties, spectral variations of the Bidirectional Polarization Distribution Function and angular shape of the Bidirectional Reflectance Distribution Function [2]. Retrievals were tested using remote sensing data AirMSPI acquired in recent field campaigns including the Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys, the Imaging Polarimetric Assessment and Characterization of Tropospheric Particulate Matter, and the Aerosol Characterization from Polarimeter and Lidar campaigns. Validation of retrieved aerosol properties (e.g., aerosol optical depth, single scattering albedo and size distribution) were performed using coincident ground-based measurements by AERONET (NASA/GSFC) in the presence of various types of aerosols (e.g., smoke aerosols, non-spherical dust aerosols, and non-absorbing aerosols) with low to moderately high loadings.

References


Preferred mode of presentation: Oral
Radiative transfer in plane-parallel media using spherical wavelets

Guanglang Xu\textsuperscript{a,\ast}, Antti Penttilä\textsuperscript{a}, Maria Gritsevich\textsuperscript{a,b,c}, Jouni Peltoniemi\textsuperscript{b}, and Karri Muinonen\textsuperscript{a,b}

\textsuperscript{a}Department of Physics, University of Helsinki, Helsinki, Finland
\textsuperscript{b}Finnish Geospatial Research Institute FGI, National Land Survey of Finland, Finland
\textsuperscript{c}Institute of Physics and Technology, Ural Federal University, Ekaterinburg, Russia

\textsuperscript{\ast}Presenting author (guanglang.xu@helsinki.fi)

Wavelets are among the most powerful tools in signal processing owing to their multi-resolution analysis capacity and local support in both frequency and space domain [1]. In recent years, there have been a growing interest in applying wavelet-based methods to solve partial differential equations [2]. The advantages of these methods in solving partial differential equations, in particular the radiative transfer equation, include their adaptivity, sparsity [3], and, more importantly, the feasibility of obtaining data-driven solutions [4]. In this work, we will present a spherical-wavelet-based method for solving the scalar radiative transfer equation in plane-parallel media. In contrast to the conventional methods, such as the discrete-ordinates and adding/doubling methods [5], the monochromatic scalar radiance and single-scattering phase functions will be represented using spherical wavelets in a sparse and adaptive way [6]. The solution to the equation will then be obtained by combining a finite-difference solver. Owing to the capability of data processing using wavelets, this method could open more of the opportunities for cooperation between experiments and numerical simulations.

References


Preferred mode of presentation: Oral
Debye series analysis of plane wave scattering by a charged sphere

Yiming Yang\textsuperscript{a,†}, Yinan Feng\textsuperscript{a}, and Renxian Li\textsuperscript{a,b,*}

\textsuperscript{a}School of Physics and Optoelectronic Engineering, Xidian University, Xi’an 710071, China
\textsuperscript{b}Collaborative Innovation Center of Information Sensing and Understanding, Xidian University, Xi’an 710071, China

\textsuperscript{†}Presenting author (Yimingyang@stu.xidian.edu.cn)
\textsuperscript{*}Corresponding author (rxli@mail.xidian.edu.cn)

Electromagnetic scattering has applications in optical tweezers \cite{1}, optical communications \cite{2}, etc. Most of these applications involve the interaction of a plane wave with a particle. Most studies about the interaction of waves with particles are based on the assumption that the particles are not charged. However, most encountered particles are charged owing to many reasons, for instance, frequent collisions between particles or contacts with reactor walls. Many researches have been devoted to the scattering of a plane wave by a charged sphere \cite{3–5} based on the Lorenz–Mie theory (LMT), which is a rigorous solution of the Maxwell equations and contains all the effects that contribute to scattering. However, the LMT gives few clues to the scattering processes. By writing each term of the Mie series as another infinite series, the Debye series can give a physical interpretation of various scattering processes \cite{6–9}.

In this paper, the Debye series is employed to solve the plane wave scattering by a charged sphere, and various scattering phenomena, such as rainbows, are analyzed. The far-field scattered intensity of a charged sphere illuminated by a plane wave is studied, and the effects of various parameters (including the charge, scattering process (namely Debye mode \(p\)), etc.) on the far-field scattered intensities are mainly discussed. Such results have important applications in various fields, including particle sizing, optical tweezers, etc.

References


\cite{2} Anguita, J. A., J. Herreros, and J. E. Cisternas, 2012: Generation and detection of multiple coaxial vortex beams for free-space optical communications. In 2012 CLEO.


Preferred mode of presentation: Oral/Poster
Computing one-way edge modes in gyromagnetic photonic crystals by Dirichlet-to-Neumann maps

Huajiao Yang and Zhen Hu*

Department of Mathematics, Hohai University, Nanjing, 210098, China

*Presenting author (huzhen@hhu.edu.cn)

Anisotropic photonic crystals (PhCs) give rise to devices with tunable physical properties and lead to interesting phenomena, such as one-way edge modes in gyromagnetic PhCs. These modes are confined at the edge of certain two-dimensional magneto-optical (MO) PhCs and possess group velocities pointing in only one direction, determined by the direction of an applied dc magnetic field. Recently, one-way edge modes have been found at the edge between an MO square lattice PhC and a regular PhC [1], at the zigzag edge of a MO honeycomb lattice PhC [2], in an yttrium-iron-garnet (YIG) PhC slab with triangular lattice [3], and at the edge between MO honeycomb lattice PhCs within different topological phases [4]. To analyze one-way edge modes, efficient numerical methods are essential.

In this talk we present an efficient numerical method to compute one-way edge modes in gyromagnetic PhCs. Our method is based on the Dirichlet-to-Neumann (DtN) maps. By using the DtN map of a supercell, a linear eigenvalue problem with relatively small matrices is formulated on two boundaries of the supercell to solve the edge modes with high accuracy. The eigenvalue is related to the wavenumber of edge modes and the angular frequency is a given parameter.

References


Preferred mode of presentation: Oral
Preliminary exploration of radiative properties of mixed-phase clouds

Bingqi Yi* and Qing Luo

School of Atmospheric Sciences and Guangdong Province Key Laboratory for Climate Change and Natural Disaster Studies, Sun Yat-sen University, Zhuhai, China
Southern Laboratory of Ocean Science and Engineering (Guangdong, Zhuhai), Zhuhai, China

*Presenting author (yibq@mail.sysu.edu.cn)

Mixed-phase clouds are ubiquitous in the troposphere. They play important roles in various processes related to radiative energy balance of the Earth system. However, due to their complex nature, mixed-phase cloud optical properties are difficult to calculate and the corresponding cloud radiative effects remain highly uncertain [1].

In this study, we present preliminary results of mixed-phase cloud optical properties calculated based on different internal and external mixing assumptions of ice and liquid water droplets with various sizes and mixing ratios. A comprehensive ice scattering property database [2] is used, and the Lorenz–Mie theory is applied to liquid water cloud droplets. Similar to Yang et al. [3], our results show that the mixing process is critical in modulating the optical properties of mixed-phase clouds compared with homogeneous ice or liquid water clouds.

References


Preferred mode of presentation: Oral
Unidirectional reflectionless property of periodic structures with $PT$-symmetry

Lijun Yuan

College of Mathematics and Statistics, Chongqing Technology and Business University, 400067 Chongqing, China (ljyuan@ctbu.edu.cn)

Unidirectional reflectionless property is the phenomenon wherein the reflection is zero for an incident wave coming from one side and nonzero for an incident wave coming from the other side [1]. It has been found for many structures such as $PT$-symmetric optical fibers, waveguides, coupled resonator systems, etc. In this talk, I will study the unidirectional reflectionless property of 2D structures with 1D periodicity and $PT$-symmetry (i.e., with balanced gain and loss). The existence of the unidirectional reflectionless property is proved theoretically by using the $S$-matrix and the symmetry. Numerical examples will be presented to show that invisibility can happen by tuning structure parameters such that the phase of the transmitted wave is zero.

Reference


Preferred mode of presentation: Oral
Analysis of energy budget for scattering of fields induced by nearby sources

Maxim A. Yurkin\textsuperscript{a,b,*} and Alexander E. Moskalenskya\textsuperscript{a,b}

\textsuperscript{a}Voevodsky Institute of Chemical Kinetics and Combustion, SB RAS, Institutskaya str. 3, 630090, Novosibirsk, Russia
\textsuperscript{b}Novosibirsk State University, Pirogova 2, 630090 Novosibirsk, Russia

*Presenting author (yurkin@gmail.com)

The frequency-domain volume integral equation (VIE) is a general framework for theoretical analyses and numerical simulations of scattering by particles of arbitrary shape and internal structure. The VIE has been known for more than 60 years, but a number of issues remained, which recently revived the interest in this subject. This led to a rigorous derivation of the VIE for a set of multilayered particles with sharp edges and corners [1], further extended to general incident fields, including those caused by sources located near the scatterer [2]. The only missing element is the energy budget for such general scattering problem. Optical cross sections (extinction, absorption, and scattering) are defined through the power rates (integrals of the Poynting vectors over the closed surfaces) in many textbooks on light-scattering theory. However, those definitions are incomplete and/or ambiguous in the case of source-induced fields.

We provide rigorous definitions of various components of the energy budget for scattering of source-induced electromagnetic fields by a finite non-magnetic object. We use the VIE framework and define power rates in terms of integrals of the Poynting vector over various surfaces, enclosing some or all of the impressed sources, the scatterer, and the environment (such as a planar multilayered substrate). Thus, we generalize the conventional cross sections and obtain new interrelations analogous to the well-known optical theorem. We rigorously treat the strong singularity of the VIE kernel, but keep derivations accessible to a wide audience. The defined power rates are further related to the decay-rate enhancement and apparent quantum yield of an arbitrary emitter, which are the core concepts in nanophotonics, surface-enhanced Raman scattering, and electron-energy-loss spectroscopy. We also discuss the practical calculation of the power rates and decay-rate enhancements in the framework of the discrete dipole approximation (DDA). In particular, we derive the volume-integral expression for the scattered power and use it to prove the automatic satisfaction of the optical theorem irrespective of the discretization level. Thus, the optical theorem cannot be used as an internal measure of the DDA accuracy. The details are given in Ref. [3].

References


Preferred mode of presentation: Oral
Determination of thermal accommodation coefficient and primary particle size of soot through light scattering method

Junyou Zhang, Hong Qi*, and Liming Ruan

Harbin Institute of Technology, Harbin, 150001, China

*Presenting author (qihong@hit.edu.cn)

Soot particles are considered to be the second most important factor in the anthropogenic radiative forcing underlying climate change and can influence cloud formation [1]. Airborne soot also has negative impacts on human health, both directly and as a carrier of other toxic materials [2]. Light scattering-based methods, such as elastic light scattering (ELS) and laser-induced incandescence (LII), provide non-invasive diagnostic techniques for characterizing the morphological properties of these particles. Unfortunately, the morphology measurement involves solving an inverse problem, so an uncertainty of some key LII model parameters like the thermal accommodation coefficient ($\alpha_T$) will lead to obviously inaccurate results. Considering the debate on the actual value of $\alpha_T$ employed in the LII model [3], it is worth simultaneously retrieving $\alpha_T$ and target morphology parameters from the temporal LII signal. In this work, the fractal dimension and aggregate size distribution of polydisperse soot particles are retrieved from the relative intensity of angular ELS, which is based on our previous work [4]. These parameters determined by ELS are then used as input parameters of the temporal LII model to simultaneously retrieve the thermal accommodation coefficient and primary particle size.

References


Preferred mode of presentation: Poster
Optical force on irregular and inhomogeneous particles by an Airy light-sheet using discrete dipole approximation

Jiaming Zhang\textsuperscript{a,}\textsuperscript{*}, Renxian Li\textsuperscript{a,}\textsuperscript{b,}\textsuperscript{**}, Han Sun\textsuperscript{a}, Ningning Song\textsuperscript{a}, Shu Zhang\textsuperscript{a}, and Bojian Wei\textsuperscript{a}

\textsuperscript{a}School of Physics and Optoelectronic Engineering, Xidian University, Xi’an 710071, China
\textsuperscript{b}Collaborative Innovation Center of Information Sensing and Understanding, Xidian University, Xi’an 710071, China

\textsuperscript{*}Presenting author (jmzhang_1@stu.xidian.edu.cn)
\textsuperscript{**}Corresponding author (rxli@mail.xidian.edu.cn)

Optical tweezers [1] have been become a powerful tool for non-contact manipulation of microscopic objects and have found a huge range of applications in various fields [2]. The discrete dipole approximation (DDA) is an efficient tool to calculate optical forces on particles with various shapes illuminated by any beam [3]. Airy light-sheet is a two-dimensional Airy beam and has been widely utilized in optical particle clearing, particle transport, micromanipulation because of their advantages of non-diffraction, self-acceleration, and self-healing [4].

In this research, the angular spectrum decomposition method is used to derive the electromagnetic field components of an Airy light-sheet. Numerical computations for axial and transverse radiation force are computed for $x$-polarized Airy light-sheet with different transverse scale $\omega_0$, modulation parameter $a$, and beam center. $\omega_0$ involves the size of lobes and the number of side lobes. With the increasing of $\omega_0$, all the lobes will expand and the number of side lobes will reduce. $a$ involves the intensity of lobes, and the amplitudes of each lobe will decrease with being greater, while the contrast between the main and side lobes is even more obvious. As the particles shift off the axis in the plane perpendicular to the propagating direction, both stable and unstable equilibrium points are obtained, depending on the size parameters, transverse scale, and modulation parameter.

References


Preferred mode of presentation: Poster
Sensitivity analysis of polarimetric remote sensing of atmospherically-processed brown carbon aerosol

Chenchong Zhang\textsuperscript{a,}\textsuperscript{*}, William R. Heinson\textsuperscript{a}, Benjamin Sumlin\textsuperscript{a}, Michael J. Garay\textsuperscript{b}, Olga Kalashnikovab, and Rajan K. Chakrabarty\textsuperscript{a}

\textsuperscript{a}Washington University in St. Louis, St. Louis, MO 63130, USA
\textsuperscript{b}Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

\textsuperscript{*}Presenting author (chenchongzhang@wustl.edu)

Biomass burning is an important emission source for brown carbon (BrC) aerosol, which has been shown to significantly modulate regional atmospheric radiative forcing by strongly absorbing in the near-UV solar spectra. These particles could also affect cloud microphysical characteristics due to their solubility in a liquid medium. Multiangle spectropolarimetric remote sensing techniques have been found great use in improving the characterization of columnar properties of the atmospheric BrC including its composition and particle vertical distribution [1].

Freshly emitted BrC aerosol has been shown to quickly undergo atmospheric processing resulting in changes of its optical and physicochemical properties on time-scales ranging between minutes to hours [2]. Current remote sensing retrieval algorithms fail to take into consideration parameterizations of BrC aerosol microphysical properties during atmospheric processing. In this study, we propose forward modeling to quantitatively analyze the sensitivity of remote sensing parameters to changing BrC aerosol properties as a function of atmospheric processing. We track the evolution of BrC aerosol after emission by configuring the atmospheric layers in numerical model with aerosols of different aging stages. By doing this, the spectropolarimetric pattern of BrC aerosol will be tracked over a long time-scale. The validation of our forward modeling results will be made with observational data collected by the Jet Propulsion Laboratory’s Airborne Multiangle SpectroPolarimetric Imager (AirMSPI).

References


Preferred mode of presentation: Poster
3-D tomographic morphology of soot aggregates from coal combustion and associated optical properties

Chenchong Zhang\textsuperscript{a,*}, William R. Heinson\textsuperscript{a}, Jingkun Jiang\textsuperscript{b}, and Rajan K. Chakrabarty\textsuperscript{a}

\textsuperscript{a}Washington University in St. Louis, St. Louis, MO 63130, USA
\textsuperscript{b}Tsinghua University, Beijing, 100084, China

\textsuperscript{*}Presenting author (chenchongzhang@wustl.edu)

Soot aggregates constitute the major fraction of particulate matter emitted from anthropogenic sources. Freshly emitted soot particles have complex fractal-like structures. These complex morphologies can significantly influence particle microphysical and optical properties, thereby impacting the earth’s radiative forcing. Accurate parameterization of aggregate morphology is a prerequisite for quantitatively evaluating soot spectral radiative properties.

Electron tomography is a powerful technique which can detect the detailed three-dimensional (3-D) structure of aggregates. However, a defect, namely the missing wedge, inherent to limited-angle projection images limits the accuracy of the final 3-D reconstruction. Here, we demonstrate a novel tomography technique for 3-D reconstruction of soot aggregates sampled from a coal-fired reactor in China. Compared to traditional weighted back projection and iterative reconstruction techniques, we incorporate total variation minimization to compensate for the missing wedge artefacts [1]. The reconstructed soot particle models precisely capture the detailed morphological information of the aggregates, for example, the exact shapes of primary particles and the necking between monomers. Next, we calculate the Fourier Transform of the density auto-correlation function of the voxels (also known as the particle structure factor) to accurately characterize the fractal morphology of the reconstructed particles. Our goal here is to validate the conventional viewpoint regarding combustion-generated fractal aggregates, formed via diffusion limited cluster-cluster aggregation, yielding a universal mass fractal dimension of 1.8 [2]. Finally, we conclude this work by applying the discrete-dipole approximation on reconstructed aggregate models to derive spectral optical properties including scattering and absorption cross-sections, and asymmetry and Stokes parameters.

References


Preferred mode of presentation: Oral
Metasurface based generation of an Airy beam

Shu Zhang\textsuperscript{a,*}, Renxian Li\textsuperscript{a,b,**}, Jiaming Zhang\textsuperscript{a}, Bojian Wei\textsuperscript{a}, Ningning Song\textsuperscript{a}, and Han Sun\textsuperscript{a}

\textsuperscript{a} School of Physics and Optoelectronic Engineering, Xidian University, Xi’an 710071, China.
\textsuperscript{b} Collaborative Innovation Center of Information Sensing and Understanding, Xidian University, Xi’an 710071, China.

*Presenting author (zhangs@stu.xidian.edu.cn)
**Corresponding author (rxli@xidian.edu.cn, rxli@mail.xidian.edu.cn)

Airy beams have many characteristics such as self-bending [1], no diffracting [2], and lateral acceleration [3], and put a great impact on the applications of the trapping in the optical potential, converging transmitted energy during the bending process, and long-distance transmission. Therefore, there are many optical devices to generate Airy beam. To overcome the defect of low loss and heavy attenuation in conventional optical devices, novel devices based on a metasurface are developed [4,5], and they reduce the system complexity and improve system reliability. The metasurface is a material with a thickness less than the wavelength of the incident beam. It has characteristics of flattening and low loss.

In this paper, we design a metasurface to generate an Airy beam with low loss and high efficiency using commercial software COMSOL. The characteristics of the resulting Airy beam are tested and verified. The metasurface can be modified to generate arbitrary beams.

References


Preferred mode of presentation: Oral
Aerosol optical properties and their impacts on cloud remote sensing

Chuanfeng Zhao* and Xin Yang

College of Global Change and Earth System Science, Beijing Normal University, Beijing, 100875, China

*Presenting author (czhao@bnu.edu.cn)

Aerosols, by scattering and absorbing solar radiation, reduce the energy reaching the ground surface. The absorptive properties of aerosols could result in different impacts on the surface radiation. In general, for the same amount of aerosols, the larger the absorption of aerosols, the more the reduction of solar radiation at the surface. Based on the slope ratio of surface radiation to the atmospheric visibility, we first determine the relative strength of aerosol absorption in different regions in China. It is found that the aerosols in Central China have strong absorption [1].

The strong absorption of aerosols in China could further impact the cloud remote sensing based on spectral radiation in visible wavelengths. In principle, it could make the cloud optical depth underestimated and cloud droplet effective radius overestimated for ground-based retrievals since the aerosols reduce the downwelling solar radiation reaching the surface. In contrast, the aerosols could make the cloud optical depth overestimated and cloud droplet effective radius underestimated for satellite-based retrievals since they reduce the cloud albedo by absorbing the solar radiation. These two different effects of aerosols on ground- and satellite-based cloud remote sensing could make the retrievals from these two different methods different from each other [2].

References


Preferred mode of presentation: Oral
Contribution of weak localization to lidar returns from atmospheric particles

Chen Zhou

Nanjing University, Nanjing, China (czhou.atmo@gmail.com)

Lidars have been widely used to detect clouds and aerosols in the atmosphere, and the particle properties can be retrieved from their lidar backscattering signals upon a series of assumptions and approximations. The lidar returns from atmospheric particles might be enhanced by weak localization in both single scattering and multiple scattering processes, depending on particle properties and the off-backscatter observation angle of lidar.

The lidar returns from large aerosol particles and cloud particles may be enhanced by weak localization in single scattering. Solution of Maxwell’s equations to the problem of single scattering can be expanded into iterative series in an order-of-scattering form, where the interference between conjugate terms representing reversible sequences of elementary scatterers is constructive at the backscattering direction, resulting in a coherent backscatter enhancement (CBE) [1]. The backscattering phase function of randomly oriented particles is amplified by CBE with an amplification factor between 1 and 2 depending on particle habit and refractive index. The angular width of the CBE-induced backscattering peak line for a specific particle habit is inversely proportional to the particle size parameter, and CBE peak of cloud and weakly absorbing aerosol particles is wide enough to enhance the returns of most actual lidars.

Lidar backscatter might also be enhanced by interference between conjugate reversible wave paths in multiple scattering (coherent backscattering [2]). However, the angular width of the coherent backscattering peak line in multiple scattering is narrow due to the relatively large distances between neighboring cloud and aerosol particles, so the spaceborne lidar returns would not be enhanced by coherent backscattering due to relatively large off-backscattering observation angle.

References


Preferred mode of presentation: Oral
Model development for nighttime light radiative transfer and application to VIIRS Day Night Band remote sensing of aerosols

Meng Zhou\textsuperscript{a,*}, Xiaoguang Xu\textsuperscript{b}, Jun Wang\textsuperscript{a}, Sepehr Roudini\textsuperscript{a}, Thomas Pongetti\textsuperscript{c}, and Stanley Sander\textsuperscript{a}

\textsuperscript{a}University of Iowa, Iowa Advanced Technology Laboratories, Iowa City, IA 52242-1503, USA
\textsuperscript{b}University of Maryland – Baltimore County, 1000 Hilltop Cir., Baltimore, MD 21250, USA
\textsuperscript{c}NASA Jet Propulsion Laboratory (JPL), 4800 Oak Grove Dr., Pasadena, CA 91109, USA

*Presenting author (meng-zhou-1@uiowa.edu)

The observation of nighttime aerosol condition is important because of aerosol effects on visibility, air quality, and public health. By measuring visible light at night from space, the Visible Infrared Imaging Radiometer Suite Day/Night Band (VIIRS DNB) \cite{1} sensor onboard the NPP and JPSS-1 satellites provides the research and operational communities the capability to explore nighttime atmospheric optical and aerosol properties. To quantitatively use the DNB data for nighttime remote sensing, we developed a nighttime radiative transfer model based on the Unified Linearized Vector Radiative Transfer Model (UNL-VRTM) \cite{2}. With the new development, the UNL-VRTM can simulate light transfer at night with careful consideration of surface light spectra from various types of artificial light sources, gas flares, and wildfires, as well as moonlight and DNB relative sensor response function (RSR).

We used this model to investigate questions key to the remote sensing of aerosol using VIIRS DNB observations: (1) How significantly can the VIIRS RSR impact the AOD retrieval? (2) How much AOD retrieval bias is there for different surface light spectra when a wavelength independent spectrum (or continuum) is used? (3) For cost efficiency, if only one channel is used to retrieve the AOD, what is the equivalent wavelength of our daily life lamps? Our results show the following. First, without considering the DNB RSR, there can be greater than a 100% bias when the AOD is relatively low (less than 0.5). This retrieval bias decreases as the AOD increases. Second, the AOD retrieval bias is spectrum dependent. When a wavelength independent spectrum is used to retrieve the AOD, the bias is around –10% for light-emitting diodes and fluorescent lamps. While for high pressure sodium lamp, this bias is around –30%. This retrieval bias also decreases with increasing AOD. Third, the equivalent wavelength with respect to the AOD retrieval for the chosen three lamp spectra is around 585 nm.

References


Preferred mode of presentation: Oral/Poster
How can the discrete dipole approximation reproduce morphology-dependent resonances of spheres?

Yingying Zhu\textsuperscript{a}, Chao Liu\textsuperscript{a,*}, and Maxim A. Yurkin\textsuperscript{b,c}

\textsuperscript{a}School of Atmospheric Physics, Nanjing University of Information Science and Technology, Nanjing 210044, Jiangsu Province, China

\textsuperscript{b}Voevodsky Institute of Chemical Kinetics and Combustion SB RAS, Institutskaya Str. 3, 630090 Novosibirsk, Russia

\textsuperscript{c}Novosibirsk State University, Pirogova 2, 630090 Novosibirsk, Russia

*Presenting author (chao_liu@nuist.edu.cn)

During the development and application of a scattering algorithm, its accuracy is normally validated by comparing with the results for spherical particles given by the exact Lorenz–Mie theory. The morphology-dependent resonances (MDRs) show significant influences on the scattering properties of particles within sufficiently narrow size ranges \cite{1–3}, and may affect the validation of the numerical models. It is unclear whether numerical models that solve Maxwell’s equations by discretizing the space could reproduce the MDRs of spheres. This presentation investigates the performance of the Discrete Dipole Approximation (DDA) on modeling the scattering properties with the MDRs. Our results indicate that the DDA can capture both the peak position and peak value in the extinction efficiency over the size parameter caused by an MDR only if an extremely fine discretization is used. To be more specific, the dipole size has to have size similar to the width of the MDRs to produce the accurate MDR results. However, the extinction curves simulated by the DDA (even at relatively coarse discretization) can be fitted with a Lorentzian as well as Lorenz–Mie results \cite{4}. Moreover, the convergence of the corresponding peak parameters with refining discretization is relatively smooth, which allows using Richardson extrapolation (to zero dipole size) to accurately restore the reference Mie values.

References


Preferred mode of presentation: Oral
Near-backscattering optical properties of aerosols

Ruirui Zong*, Wushao Lin, and Lei Bi

Department of Atmospheric Sciences, Zhejiang University, 38 Zheda Road, Hangzhou, 310027, China

*Presenting author (21838049@zju.edu.cn)

Knowledge of backscattering optical properties of aerosol particles plays an important role in active lidar remote sensing and particle characterization studies. However, it is challenging to accurately measure the backscattering optical properties of aerosols in a laboratory environment. On the other hand, accurate computation of backscattering optical properties of large-sized model particles has also been a challenging research subject. Therefore, a combination of near-backscattering measurements and modeling analysis [1] would be valuable to obtain a better knowledge of backscattering optical properties at 180°. In this study, we employed an invariant imbedding T-matrix method (IITM) [2,3] to compute the single scattering properties of randomly oriented particles with different size parameters, shape parameters (i.e., aspect ratio and roundness parameter), and refractive indices. For case studies, we applied the IITM to randomly oriented super-spheroids with a size parameter up to 150. The differences of lidar ratios and depolarization ratios at near-backscattering angles (173°, 175°, 178°) and exact-backscattering angle (180°) are quantified with respect to the size parameter and aerosol refractive indices. The findings in this study will be helpful to understand how backscattering ratios change at near backscattering angles, and the uncertainties if optical properties are measured at near-backscattering directions instead of 180°.

References


Preferred mode of presentation: Poster