Cloud detection and characterization based on spectro-polarimetry – operational implementation for EPS-SG/3MI

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The 3MI instrument is one of the sensors of the EUMETSAT Polar System Second Generation (EPS-SG) program to be launched in 2022. This polarimetric instrument has a direct heritage from the POLDER instrument, with improved capabilities and is implemented within a fully operational long-term framework. The spectral range was extended from the visible-near-infrared (410–910 nm) to the shortwave-infrared domain (up to 2200 nm). The spatial resolution (4 km at nadir) and the instantaneous swath (2200 × 2200 km²) were also improved compared to previous POLDER instruments. The spectro-polarimetric capabilities of 3MI allows very specific observations of the atmosphere and the particles scattering the solar light. Consequently, 3MI provides new information content, in addition to the usual spectral information, which is beneficial for aerosol and cloud characterization, and also requires more specific retrieval approaches. The cloud detection and characterization is based on a combination of various tests using the polarized, directional, as well as spectral information.

For cloud detection, the following parameters are compared to threshold values or expected range using the most favourable viewing directions for each test (14 different views are available). A target can be identified as cloudy if it is observed a deficit of apparent pressure deducted from oxygen absorption band, a deficit of polarization at 865 nm out of the backscattering, an excess of polarization at 865 nm in the cloud-bow geometry, a deficit of Rayleigh pressure deducted from polarization in the blue, an excess of reflectance at 443 nm over land and 865 nm over ocean, an excess of reflectance in the cirrus band at 1370 nm. At the opposite, a target can be identified as cloud-free if the following parameters are close to the expected values for clear sky : the reflectance at 865 and 1650 nm, the apparent pressure deducted from oxygen absorption band, or several ratios of reflectance (over ocean: 865 to 443 nm and 2130 to 865 nm; over land: 670 to 865 nm and 2130 to 670 nm). A combination of the different results is elaborated, allowing an evaluation of the associated confidence.

The cloud phase is estimated based on the angular polarization signature, completed by the additional information from SWIR. For the specific geometry of the cloud-bow around 140° scattering angle, a low polarization signal is characteristic of non-spherical ice particles, while a significant polarized peak unambiguously identifies liquid spherical particles. In backscattering geometries, the dispersion of the polarization reflectance due to supernumerary bows indicates liquid particles. For all other geometries, the slope of the polarized reflectance with scattering angle will suggest ice particle when negative, and liquid particle when positive. Some undetermined situations can be reclassified based on apparent and Rayleigh pressures. Finally, the ratio of reflectance at 2130 to 670 nm over land and 865 nm over ocean is added to the evaluation. At the end, a score, the associated particle type, as well as the level of uncertainty, can be attributed to the observed target.

Once the surface type as well as particle type are identified, the radiative properties of the cloud are derived as follows. For every view, selection of the pair cloud spherical albedo and effective radius that minimizes the difference between observed reflectances at 2130 nm and 670/865 nm (for land/ocean resp.) and look-up-tables. An averaged value is then derived through a weighted angular mean. Knowing surface and particle types, albedo and particle size are used to derive the spectral cloud albedo and the associated cloud optical thickness.

The vertical structure of the cloud can mostly be assessed through the oxygen pressure derived from bands 763 and 765 nm, and its dispersion among the different views; it is then possible to derive the cloud top pressure, and the cloud middle pressure. Based on these pressures, an estimation of the geometrical extend of the cloud can be estimated. By a combination of the available information from oxygen, Rayleigh pressures, and their respective differences, it is also possible to derive a multi-layer index informing about the vertical structure of the cloud.

An evaluation of the error associated to every parameter will be provided. This information will be completed by the sub-pixel cloud fraction within a 3MI pixel based on the Metimage cloud mask. The proposed cloud algorithm is being implemented on the ground segment and will be available as Day-1 products after the commissioning. A second generation of added-value products, using synergistic opportunity with Metimage on-board the same platform, are under consideration for Day-2 products.

References

[1] Parol, F., *et al*., 1999: First results of the POLDER “Earth Radiation Budget and Clouds” operational algorithm. *IEEE Trans. Geosci. Remote Sens*. **37**, 1597–1612.

[2] Nakajima, T., and M. D. King, 1990: Determination of the optical thickness and effective particle radius of clouds from reflected solar radiation measurements. Part I: Theory. *J. Atmos. Sci*. **47**, 1878–1893.

[3] Desmons, M., *et al*., 2017: A global multilayer cloud identification with POLDER/PARASOL. *J. Appl. Meteor. Climatol*. **56**, 1121–1138.

[4] Zeng, S., *et al*., 2012: A better understanding of cloud optical thickness derived from the passive sensors MODIS/AQUA and POLDER/PARASOL in the A-Train constellation. *Atmos. Chem. Phys*. **12**, 11245–11259.

[5] Ferlay, N., *et al*., 2010: Toward new inferences about cloud structures from multidirectional measurements in the Oxygen A band: middle-of-cloud pressure and cloud geometrical thickness from POLDER-3/PARASOL. *J. Appl. Meteor. Climatol*. **49**, 2492–2507.

[6] J. Riédi *et al*., 2010: Cloud thermodynamic phase inferred from merged POLDER and MODIS data. *Atmos. Chem. Phys*. **10**, 11851–11865.

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