Cloud-resolving models: How good are they and what can they do for you?

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What can they do for you?

- predict the weather?
- predict cloud-climate interactions?
- serve as tools for studying and improving weather and climate forecasts?
- predict cloud effects on aerosols?
- predict aerosol effects on clouds?
- predict cloud effects on tracer transport?
Cloud-resolving models

How good are they?

- clouds remain poorly resolved
- many processes are poorly parameterized, not understood, or missing
- results generally unconstrained with even basic field data
- nonetheless often used to replace real data
Dynamics framework

- large-eddy simulation [Stevens and Bretherton, 1997]
- dynamic Smagorinsky subgrid model [Kirkpatrick et al., 2006]
- doubly periodic, 250-m sponge layer at top
- $64 \times 64 \times 96$ mesh, $50$ m $\times$ $20$ m uniform grid
- specified SST, similarity sensible and latent heat fluxes
- specified advective flux and subsidence profiles
- 2-stream radiative transfer, 44 wavelength bands [Toon et al., 1989]
Size-resolved microphysics

- aerosols: 20 bins, 10 nm–1 µm diameter
- liquid: 20 bins, 2 µm–2 mm
- ice: 20 bins, 2 µm–5 mm
- ice nuclei: 10 bins, most to least easily nucleated
- = 90 variables
Microphysical processes

- drop activation, condensation/evaporation
- gravitational collection [Hall, 1980; Beard and Ochs, 1984]
- particle sedimentation
- homogeneous ice formation
- heterogeneous ice formation (deposition/condensation, immersion, contact modes)
- phoretic scavenging [Young, 1974], 0.5 \( \mu \text{m} \) diameter ice nuclei [Rogers et al., 2001]
- deposition/sublimation
- multiplication
Long-lived stratocumulus deck

Image source: AVHRR, Pennsylvania State University M-PACE website
**DHARMA results**

**Liquid Supersaturation (%)**

**Liquid Water Mixing Ratio (g/kg)**

**Ice Supersaturation (%)**

**Ice Water Mixing Ratio (g/kg)**

**Droplet Distribution**

**Ice Crystal Distribution**

### Dharmar Model

**Mixed-Phase Arctic Cloud Experiment (M-PACE)**
In Situ Aircraft Measurements

Source: Fridlind, Ackerman, et al. [JGR, 2007]
MMCR Doppler Velocity

Acknowledgments: DOE ARM data archive, QuickBeam radar simulator [Haynes et al., BAMS, 2007]
Joint ARM/GCSS/SPARC Monsoon Case Study

Acknowledgments: DOE ARM data archive, Shaocheng Xie (LLNL)
Tropical Warm Pool—International Cloud Experiment (TWP-ICE)

**S-Band Reflectivity + Doppler Velocity**

Acknowledgments: DOE ARM data archive, Christopher Williams (NOAA)
S-Band Reflectivity + Doppler Velocity

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25-m/s updraft penetration
25-m/s updraft penetration

A. All aerosols included
B. No aerosols above 8 km
C. No aerosols above 6 km
D. No aerosols above 2 km
E. Clean boundary layer
F. Polluted boundary layer
Funded Projects FY08–FY10

- **Understanding tropical cumulonimbus clouds: Aerosols, updrafts, precipitation, ice crystal size, and climate** (NASA ACRM), Fridlind/Ackerman/Del Genio

- **Arctic stratus and tropical deep convection: Integrating measurements and simulations** (DOE ARM), Fridlind/Ackerman/Koch with collaborators Del Genio/Menon/Comstock/Wiliams/Eloranta/DeBoer

- Need for full-time post-doc on GCM side