

Using Data to Evaluate CRMs and Super Parameterizations

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Outline of the Presentation

Step 1A: Against data from field experiments for deep convective situations

Step 1B: Against LES results for boundary-layer clouds

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Step 2: Against the monthly means of gridded satellite data

Step 3: Against satellite “cloud object” data

Summary and outlook

Step 1A: Against field experiment data (ARM, GATE, TOGA COARE)

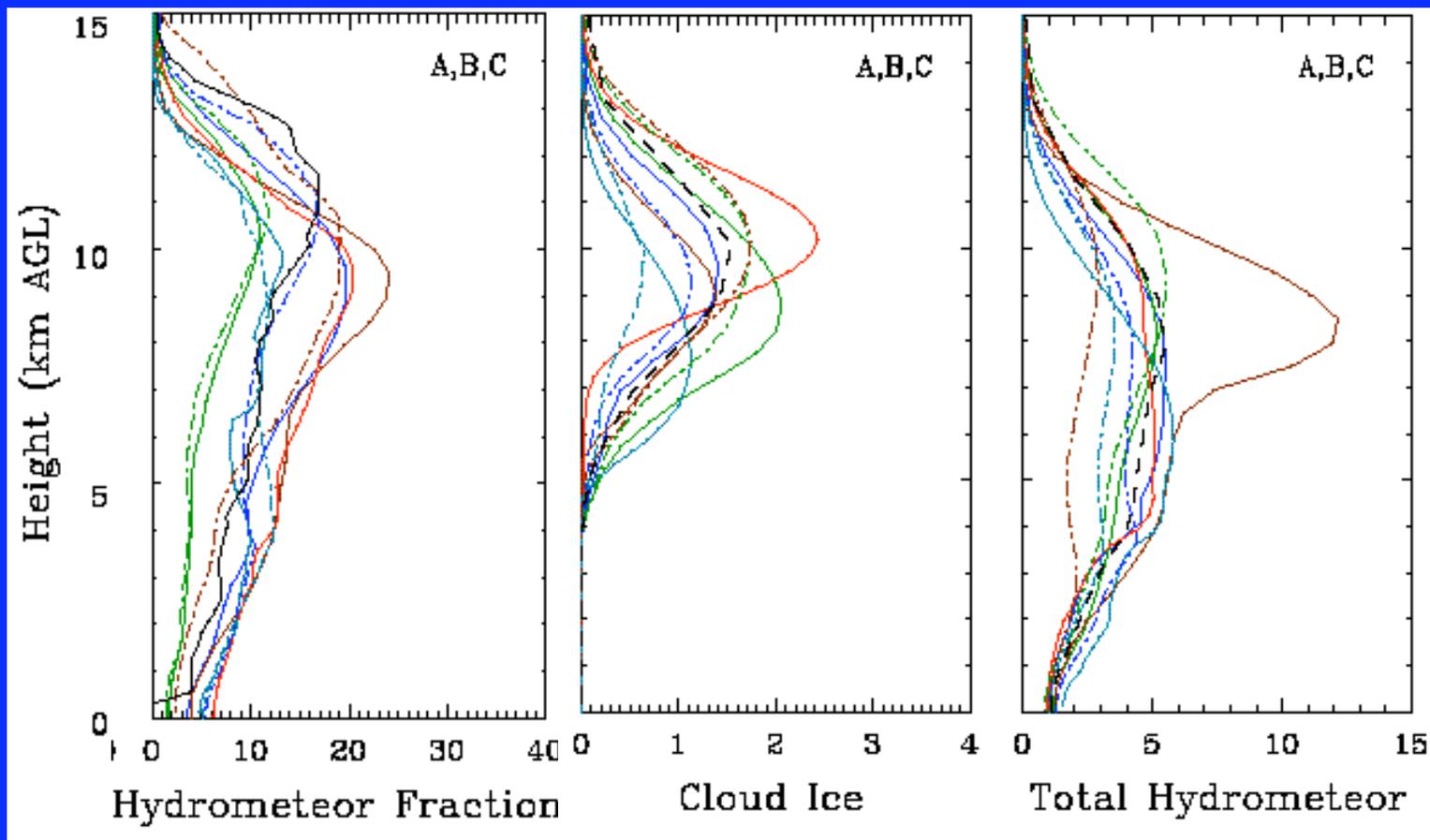
- Simulations of CRM driven by observed forcings, with *comparable* horizontal and vertical resolution used in the Super Parameterization ----- “Offline Testing”
- Metrics that CRM must meet
 - Surface precipitation rate within 10% of the observation for the period mean and a temporal correction over 0.85
 - Column-mean root-mean-square (r.m.s.) errors for temperature less than 1.5 K; less than 10% for relative humidity
 - Hydrometeor fraction within 20% of the observation (MMCR)
 - Within 30% of the consensus of CRM intercomparison cases for *unobserved* variables such as cloud water, cloud ice mixing ratio profiles

Step 1A: Metrics Examples (ARM Case 3)

Models	Mean precipitation rate (mm/h)	Precipitation Correlation	RMS T error (K)	RMS RH error (%)
SP-1: 2D	6.19 (+14%)	0.81	1.59	14.5%
SP-1: 3D	4.52 (-17%)	0.56	1.69	14.9%
SP-2: 2D	5.37 (-1%)	0.79	2.20	18.0%
SP-3: 2D	4.95 (-9%)	0.70	1.73	14.3%
Observation	5.44			
Metrics	< 10%	> 0.85	< 1.5	< 10%

Step 1A: More Examples (ARM Case 3)

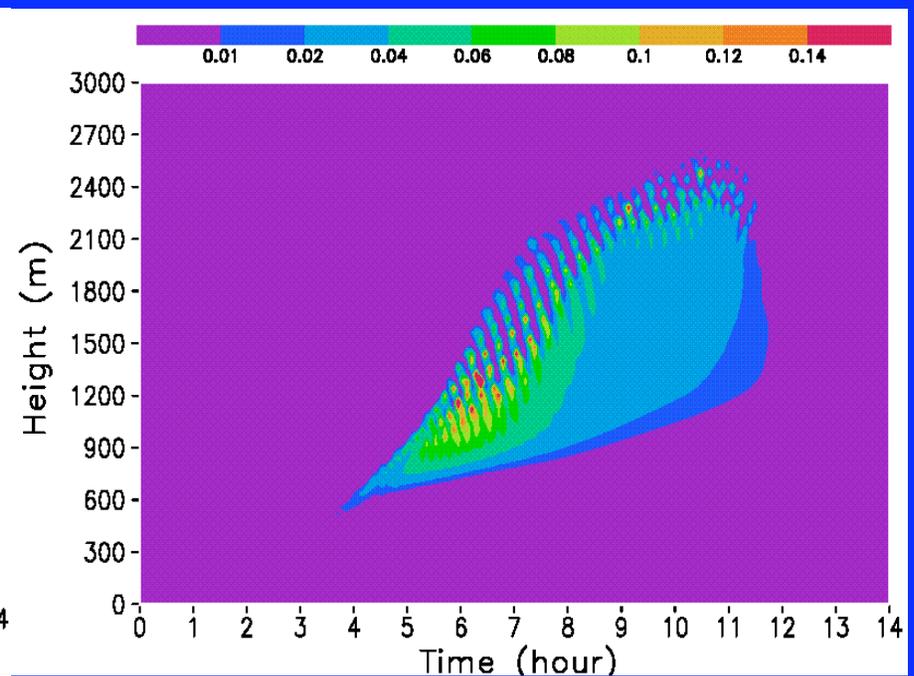
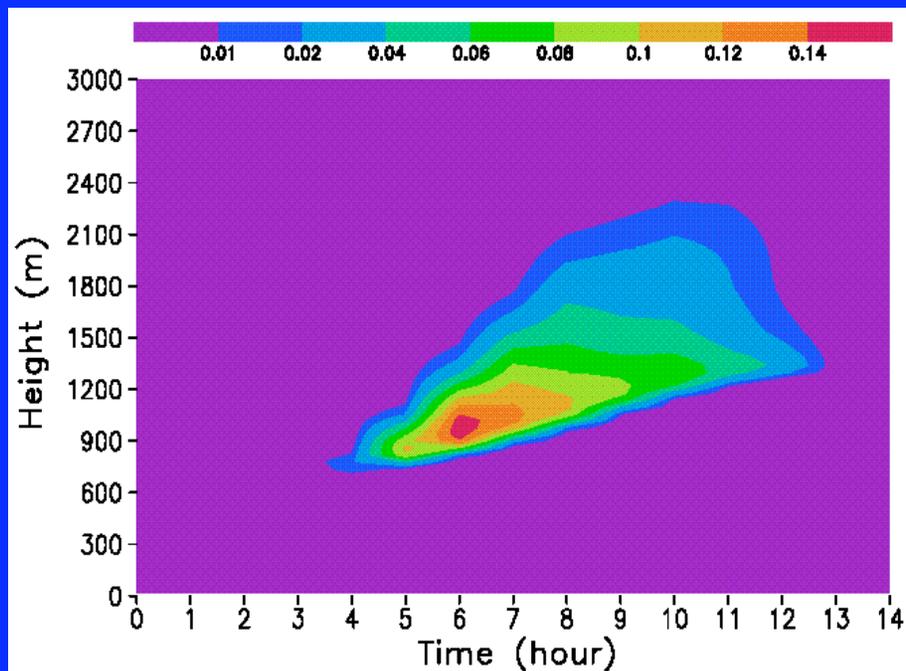
SP1 (Greens); SP2 (Solid brown); SP3 (Solid blue)



Step 1B: Against Large-Eddy Simulation (LES) Results

ARM (KNMI LES)

CRM w/ third-order closure



Improvement of CRM for Boundary-layer Cumulus Simulations

LaRC-a 1D model is used

Formerly UCLA/CSU CRM (Krueger 1988; Xu and Randall 1995)

- o **Fully prognostic**, third moment turbulence closures (35 prognostic equations and one diagnostic equation)
- o Sommeria-Deardorff (1977) turbulence-scale condensation scheme (Chen 1991), with Gaussian probability density function (PDF)

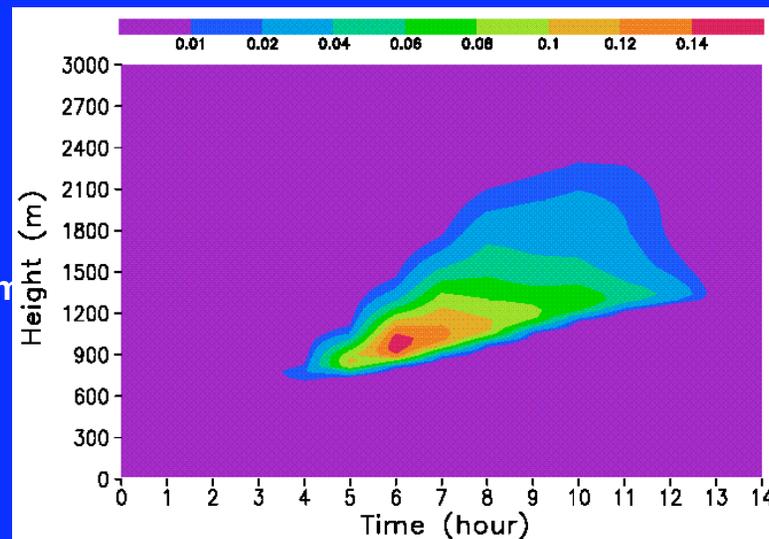
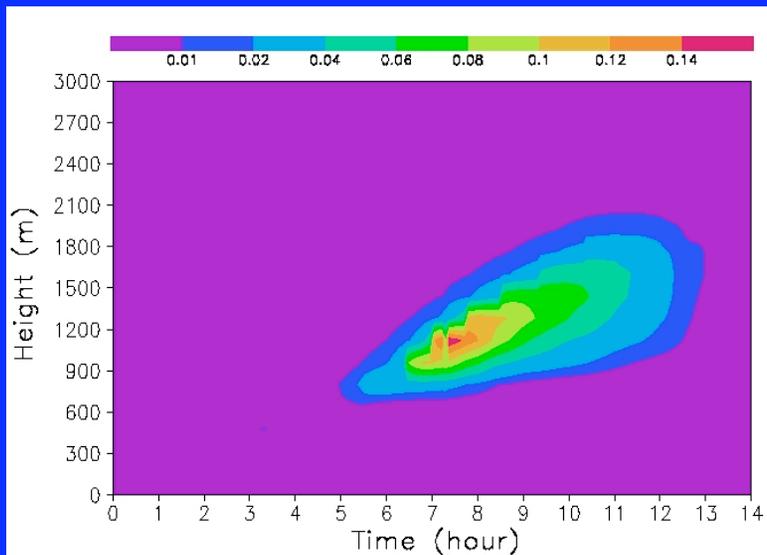
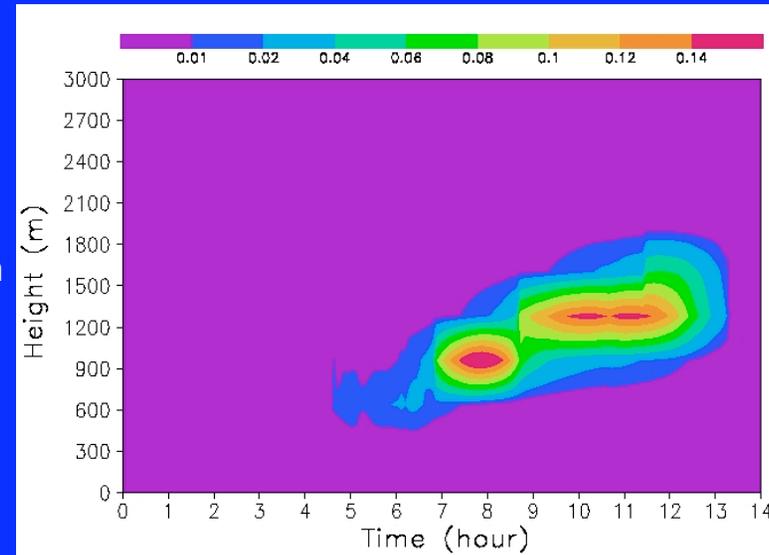
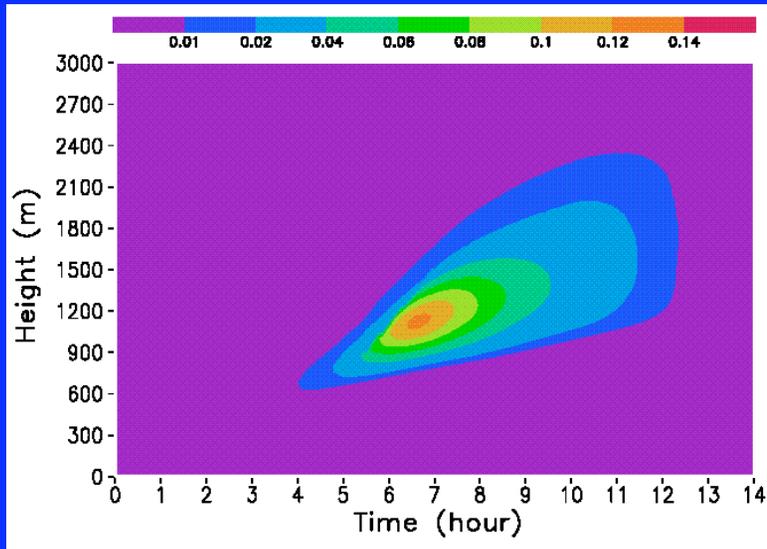
Changes:

- o **Minimally prognostic** turbulence closure model (w'^3 is predicted only) is tested
- o Double-Gaussian PDF is used for turbulence-scale condensation

Ongoing:

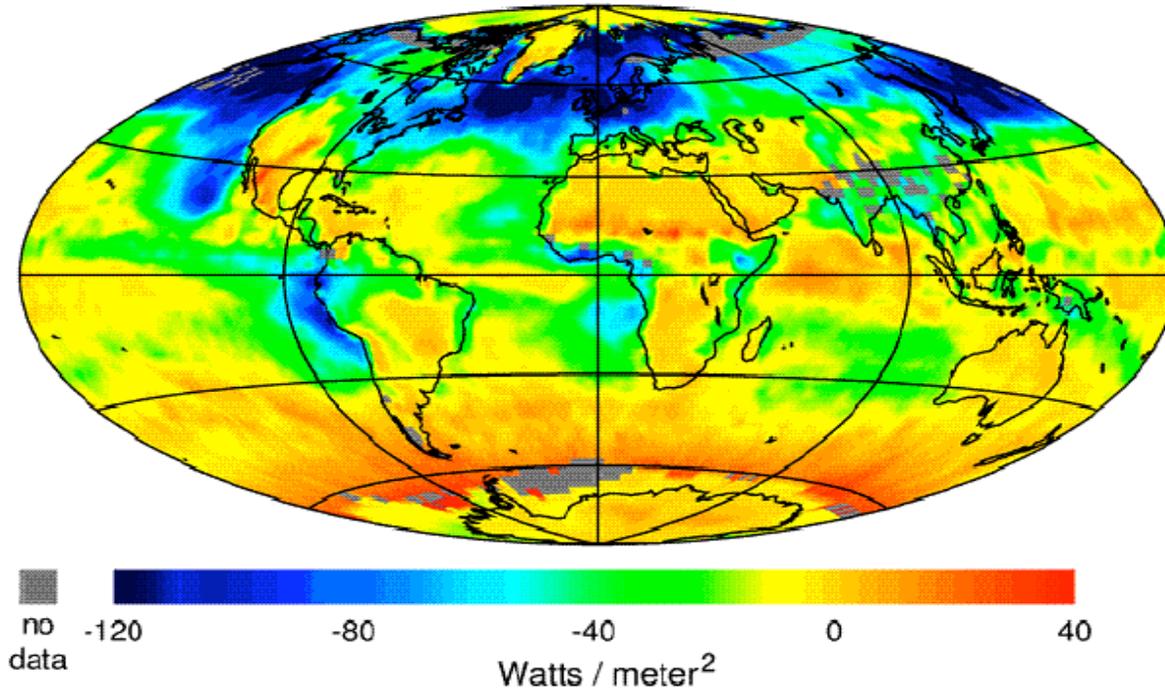
- o **Partially prognostic** turbulence closure model that predicts $q_l'^3$, $q_w'^3$, $q_l'^2 q_w'$, $q_l' q_w'^2$, in addition to w'^3 ; none of these third-moment equations includes the liquid-water buoyancy terms

Step 1B: Against LES Results (dz):



Step 2: Against the New Gridded Monthly-Mean Satellite Data

Net Cloud Forcing from CERES/Terra
July 2000

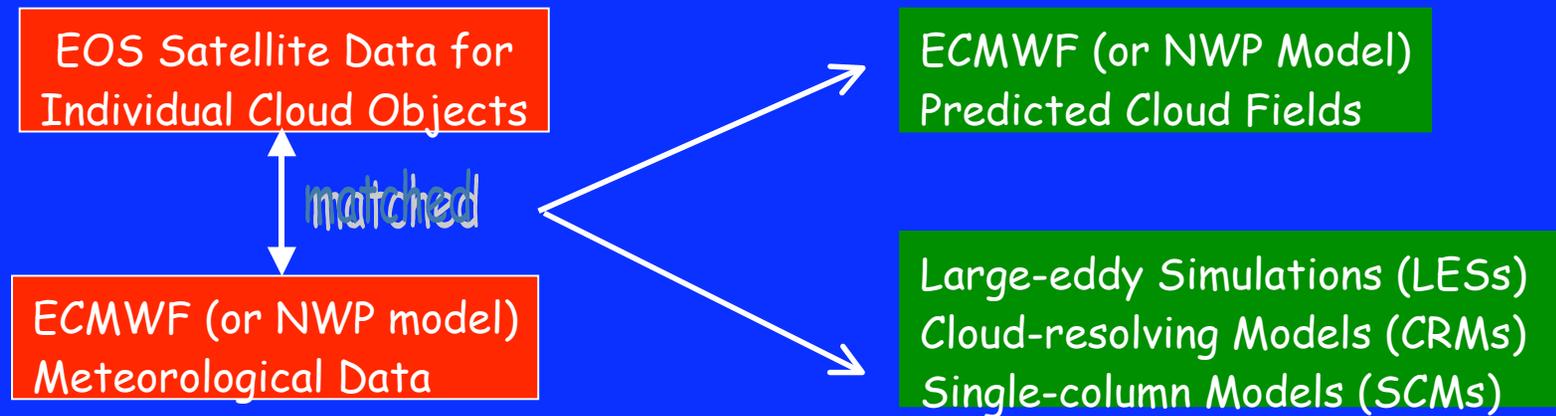


What is Available from CERES?

1. ERBE-Like
2. SFC (TOA/Sfc Fluxes and Clouds): monthly means of hourly data
3. SRBAVG (TOA/Surface Averages): monthly means of interpolated hourly data; monthly-mean hourly data
4. SSF (Single Scanner Footprint): instantaneous data

New Earth Radiation Budget Data Set from TRMM, Terra and Aqua Satellites;
CERES (Clouds and the Earth's Radiant Energy System) Data Products

Step 3: Against Satellite Cloud Object Data



- Analyze the statistics of subgrid characteristics (PDFs) of satellite-observed cloud objects, *not* GCM gridbox means
- Match the CERES SSF (Single Scanner Footprint) cloud and radiative data with ECMWF meteorological data (T, q, u, v and advective tendencies)
- Perform cloud model simulations driven by ECMWF advective tendencies; an iterative process of improvement and evaluation of cloud models
- Also evaluate the ECMWF parameterization using its predicted cloud fields

Step 3: (continued)

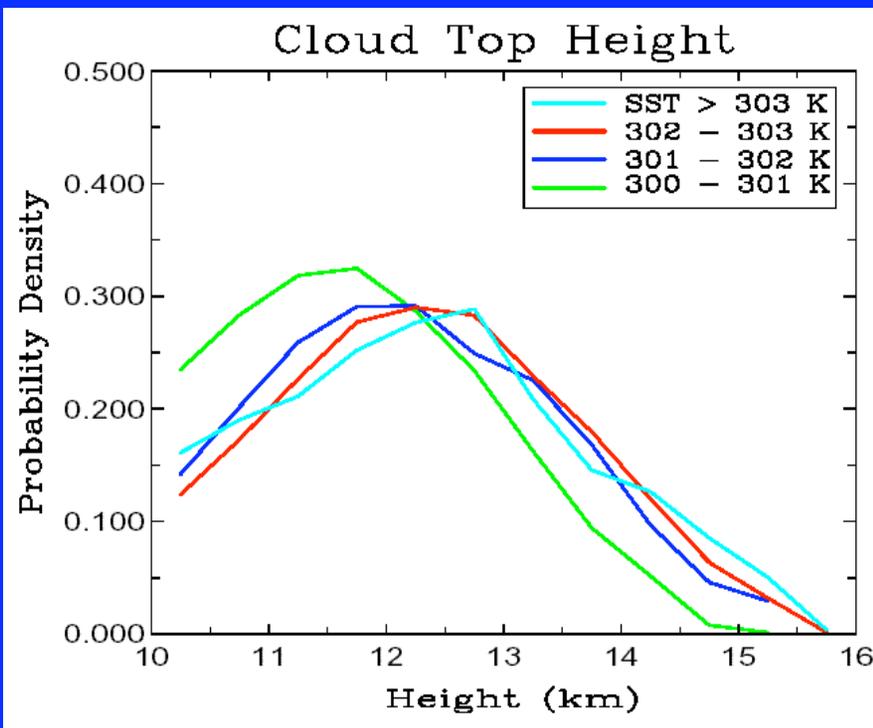
Cloud Object Selection Criteria

- Tropical deep convection
 - (1) $Z_{\text{top}} > 10$ km, (2) $\tau > 10$, (3) $25^\circ \text{S} \sim 25^\circ \text{N}$, (4) **overcast** pixels
- Shallow cumulus
 - (1) $Z_{\text{top}} < 3$ km, (2) cloud cover: **0.1 - 0.4**, (3) $40^\circ \text{S} \sim 40^\circ \text{N}$
- Transition stratocumulus
 - (1) $Z_{\text{top}} < 3$ km, (2) cloud cover: **0.4 - 0.99**, (3) $40^\circ \text{S} \sim 40^\circ \text{N}$
- Solid stratus
 - (1) $Z_{\text{top}} < 3$ km, (2) cloud cover: **0.99 - 1.0**, (3) $40^\circ \text{S} \sim 40^\circ \text{N}$

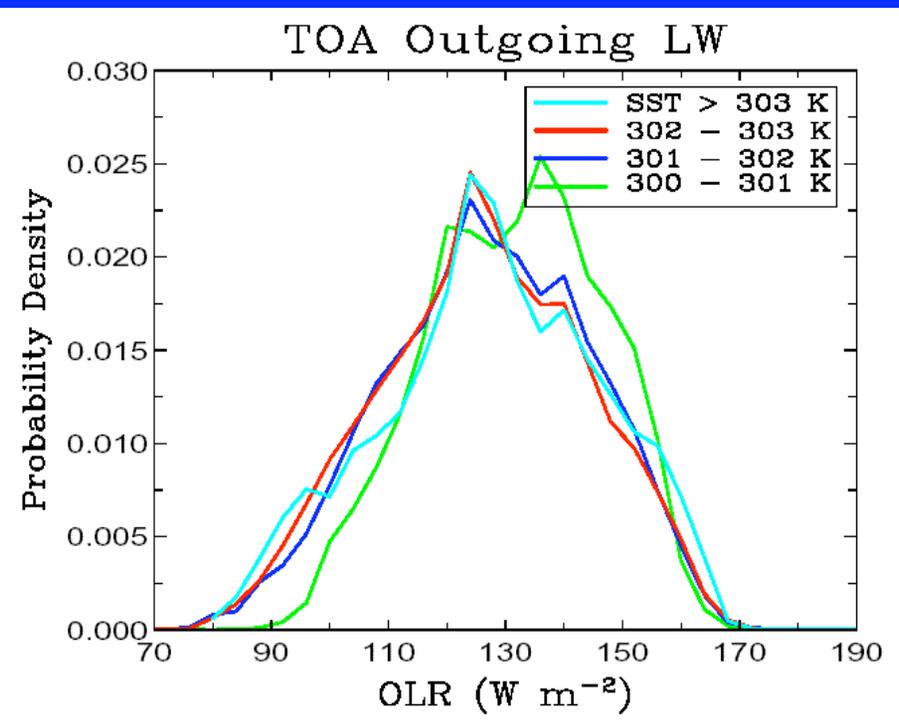
The average pixel size is $23.5 \times 4.6 \text{ km}^2$ for CERES Data

Step 3: Tropical Deep Convective Systems: Sensitivity to SST for March 2000

Cloud Top Height



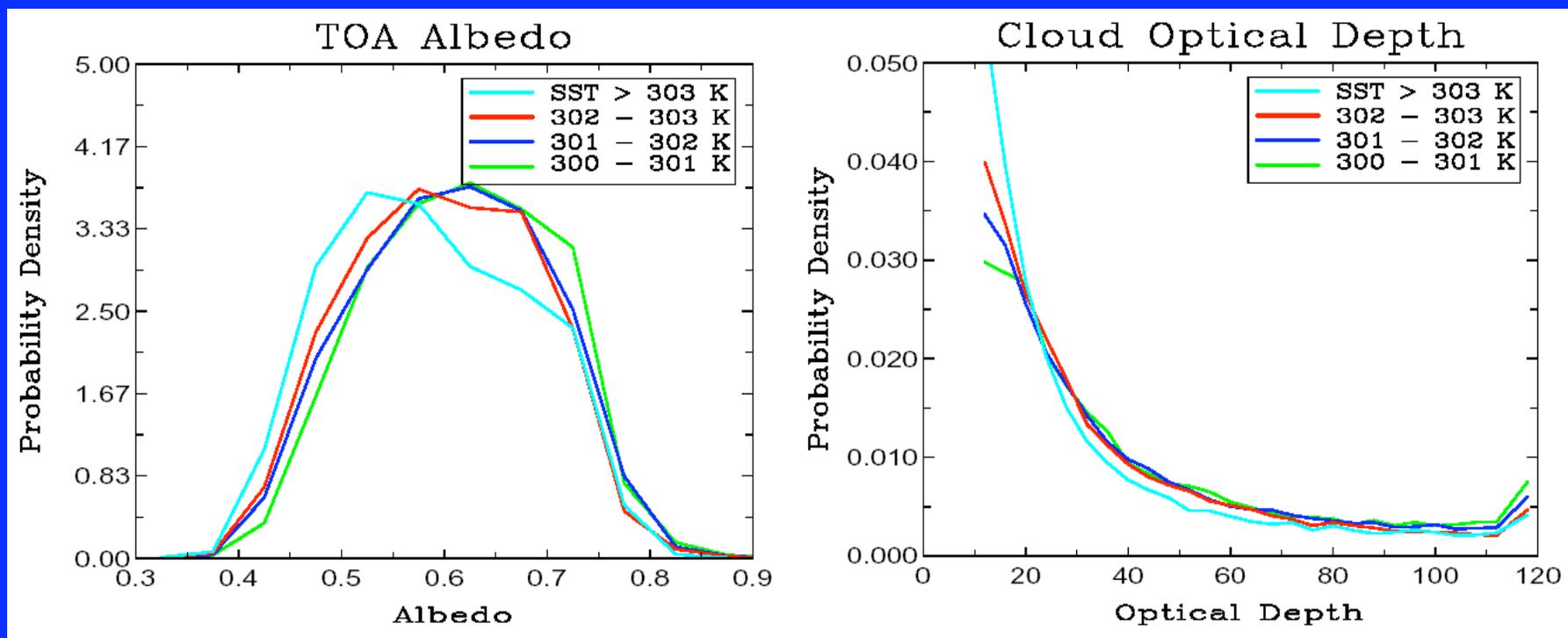
Outgoing LW Radiation



Step 3: Tropical Deep Convective Systems: Sensitivity to SST for March 2000 (cont.)

Top-of-the-Atmosphere Albedo

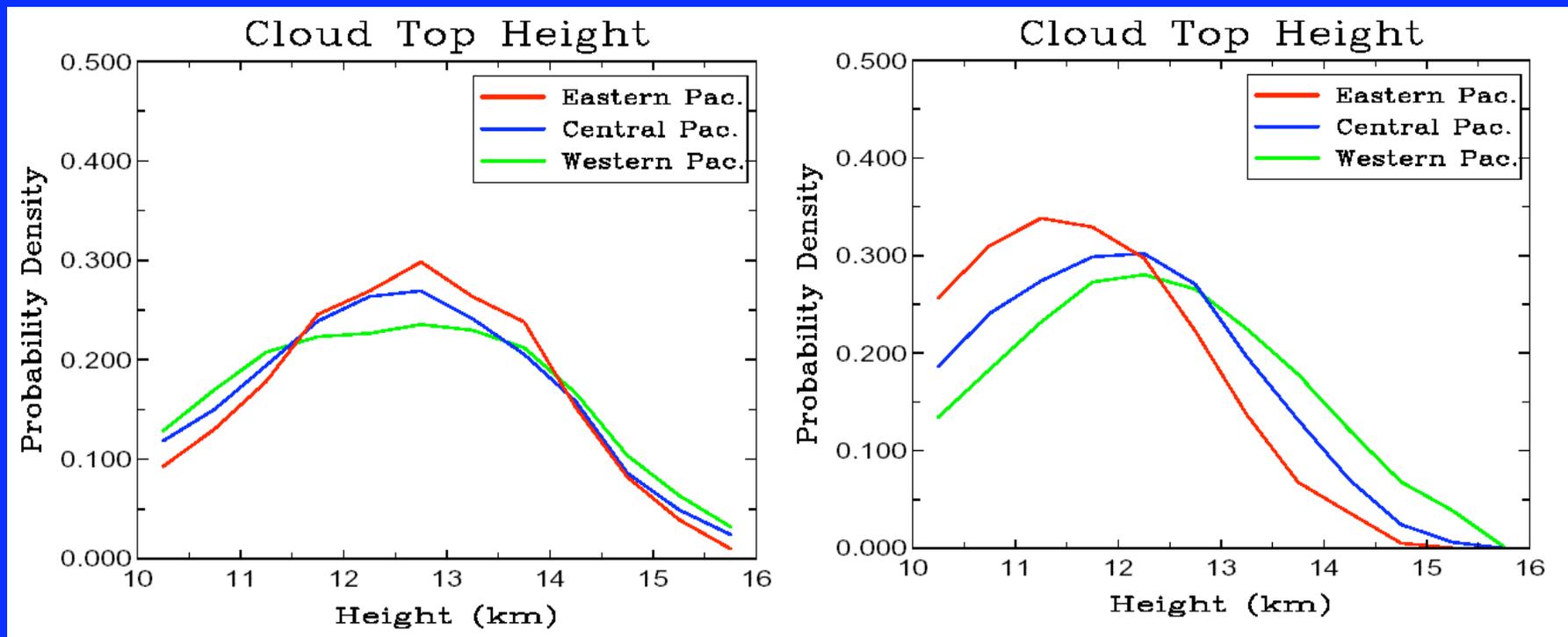
Cloud Optical Depth



Step 3: Tropical Deep Convective Systems: Regional & Interannual Differences

March 1998

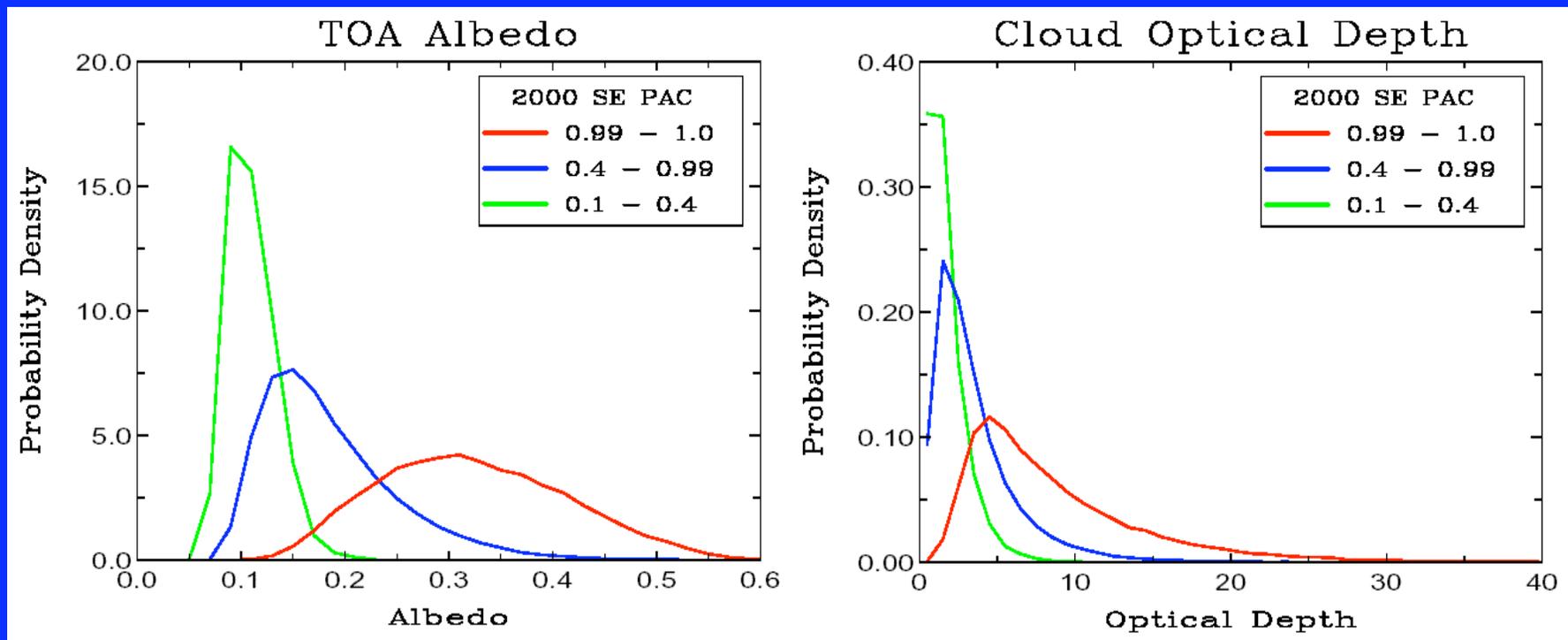
March 2000



Step 3: Subtropical Boundary-layer Cloud Systems: The SE Pacific for March 2000

Top-of-the-atmosphere Albedo

Cloud Optical Depth

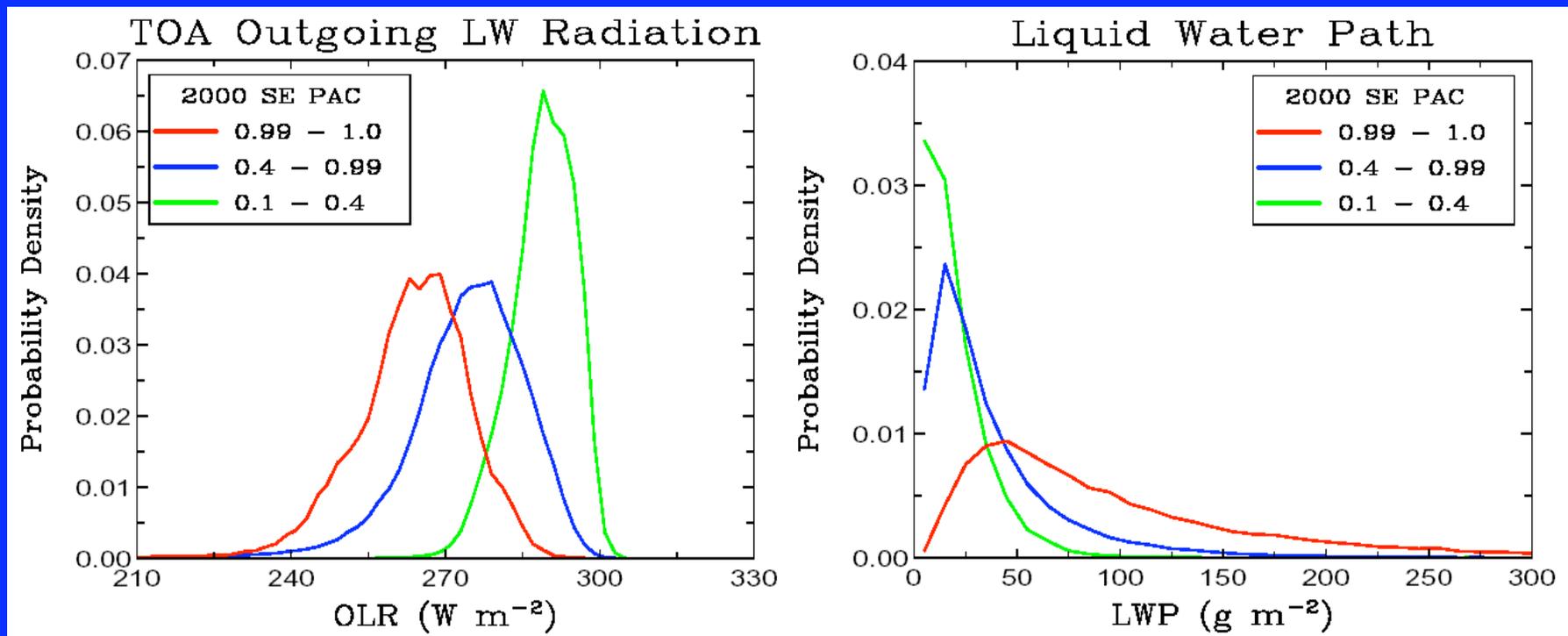


Solid stratus (red), transition stratocumulus (blue), and cumulus (green)

Step 3: Subtropical Boundary-layer Cloud Systems: The SE Pacific for March 2000 (cont.)

OLR

Liquid Water Path



Solid stratus (red), transition stratocumulus (blue), and cumulus (green)

Summary and Outlook

- Strict evaluations of CRMs should be performed before they are embedded in a GCM, using data sets from field experiments and large-eddy simulations, etc.
- A vigorous evaluation of super parameterization should be performed against the cloud object data set, in addition to, traditionally, against monthly mean gridded satellite data set
- Future success of the super parameterization approach depends upon validation data that modelers are *not* afraid to use