Cloud Systems: Models Vs CERES Cloud/Flux Data

Takmeng Wong[1], Kuan-Man Xu[1], Bruce Wielicki[1],
Zachary A. Eitzen[1,2], Anning Cheng[1,3] and Lindsay Parker[1,4]

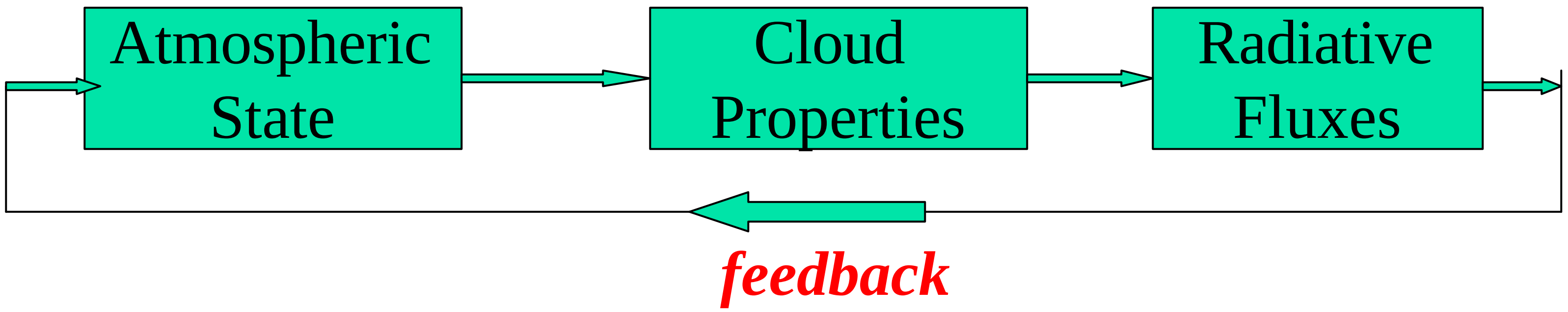
[1]Radiation and Aerosols Branch, Langley Research Center
[2]Colorado State University
[3]Hampton University
[4]SAIC

28th CERES Science Team Meeting
6-8 May, 2003, Norfolk, Virginia

Part 1. Subgrid Characteristics of Cloud Systems from CERES Data
Part 2. Simulation of Cloud Systems Driven by ECMWF Data

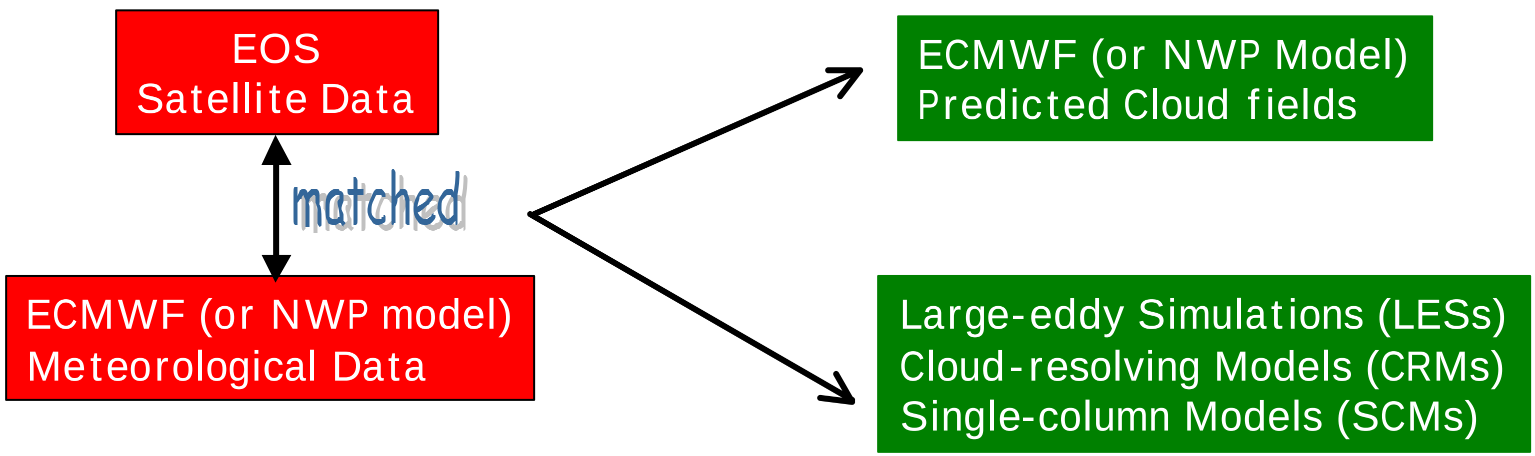
Motivation

1. Importance of radiative feedback of clouds in the climate system
2. Uncertainties in modeling cloud-radiation interactions in global climate models (GCMs)



3. Nonlinearity of cloud processes requiring observations on all relevant modeling scales (in space and in time)
4. Inadequate methods of cloud model evaluation

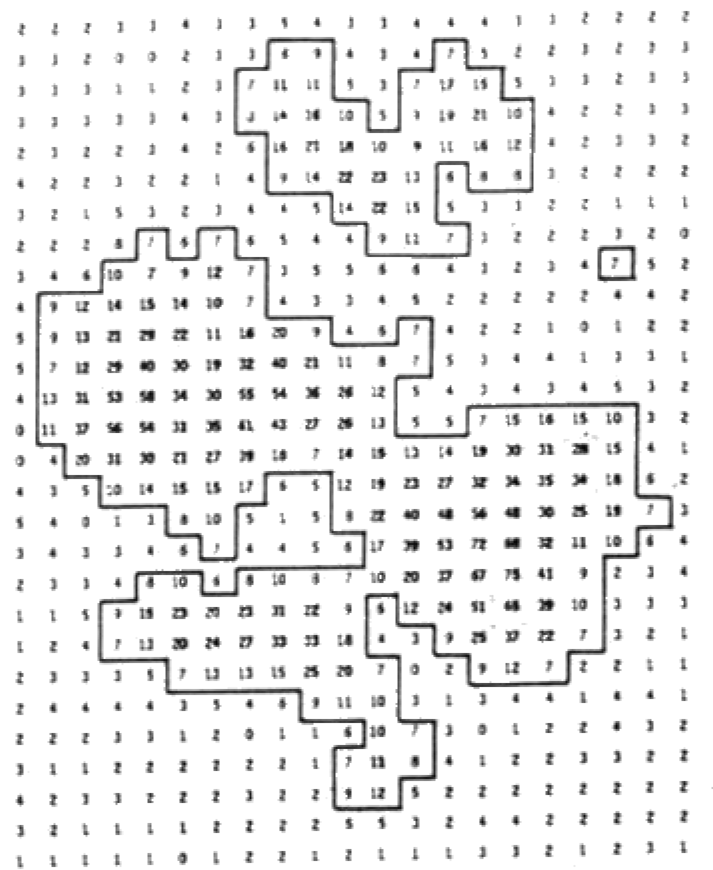
Approach



- Analyze the statistics of subgrid characteristics of cloud systems, *not* just the mean
- 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 soundings and advective tendencies
- Also evaluate the ECMWF parameterizations using their predicted cloud fields

Satellite data analysis method

- Define a cloud system as a contiguous region of the Earth with a **single dominant** cloud type (e.g. stratocumulus, stratus, and deep convection)
- Determine the shapes and sizes of the cloud systems by the satellite data and by the cloud property selection criteria (Wielicki and Welch 1986)



Cloud system selection criteria

- Tropical deep convection
  - Z > 10 km, τ > 10, 25° S ~ 25° N, overcast pixels
- Trade/shallow cumulus
  - Z < 3 km, cloud cover: 0.1 – 0.4, 40° S ~ 40° N
- Transition stratocumulus
  - Z < 3 km, cloud cover: 0.4 – 0.99, 40° S ~ 40° N
- Solid Stratocumulus
  - Z < 3 km, cloud cover: 0.99 – 1.0, 40° S ~ 40° N

Satellite data analyzed

- March 1998 and March 2000 CERES/TRMM data (> 190 GB per month)
- Parameters analyzed from CERES SSF data product: TOA SW, TOA albedo, OLR, emissivity, cloud optical depth, IWP, ice particle diameter, LWP, water droplet radius, cloud amount, cloud top pressure, cloud top temperature, and cloud top height
- Probability Density Function (PDF), Mean, Sigma, Skewness, Medium, Max, Min, and Sample Number.

Boundary layer cumulus (BLC)

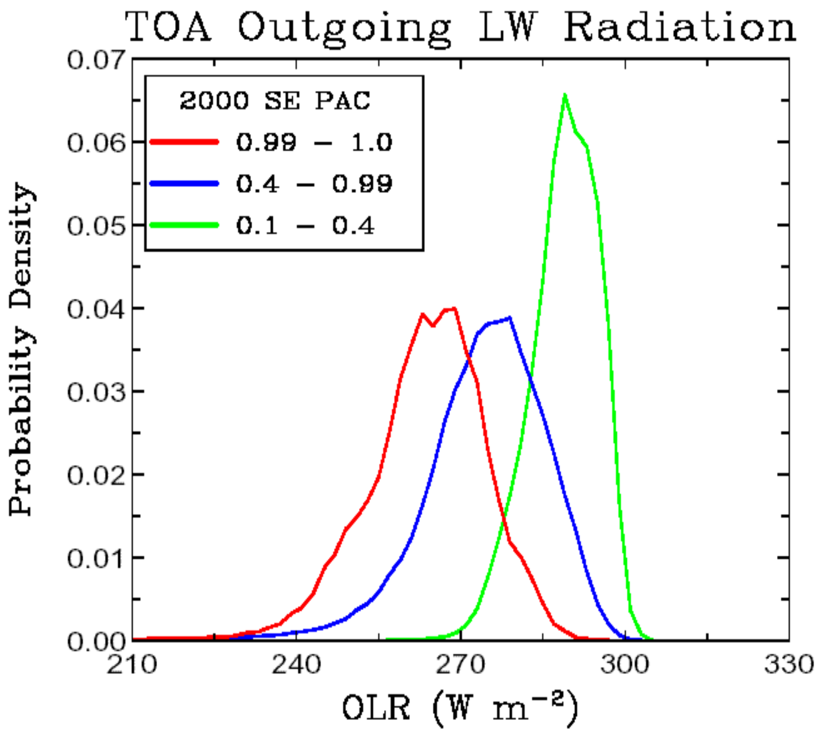
- Number of boundary layer cumulus identified from satellite data over the SE Pacific Region:

Boundary Layer Cumulus Type	March 1998 (Strong El Nino)	March 2000 (Weak La Nina)
Shallow Cumulus	262	509
Transition StratoCumulus	1,902	1,932
Solid StratoCumulus	989	892
Total	3,153	3,333

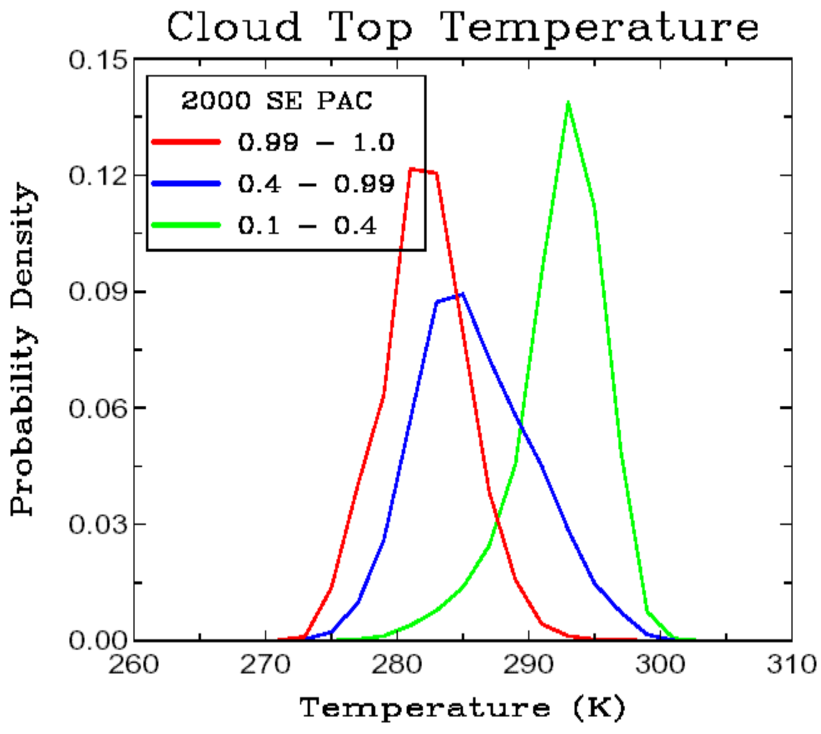
Subgrid characteristics of BLC

PDF of OLR and Cloud Top Temperature

March 2000



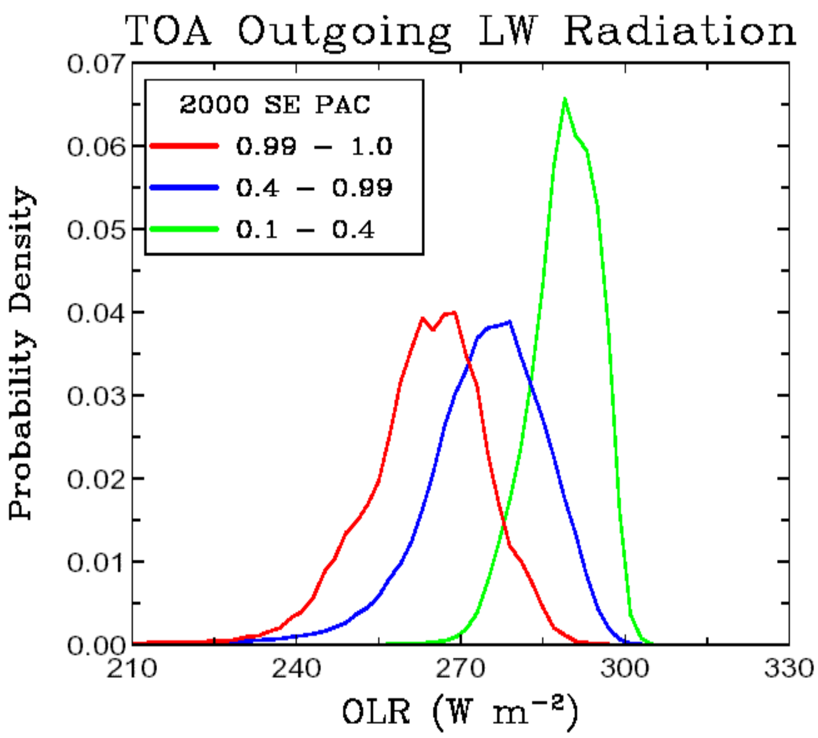
March 2000



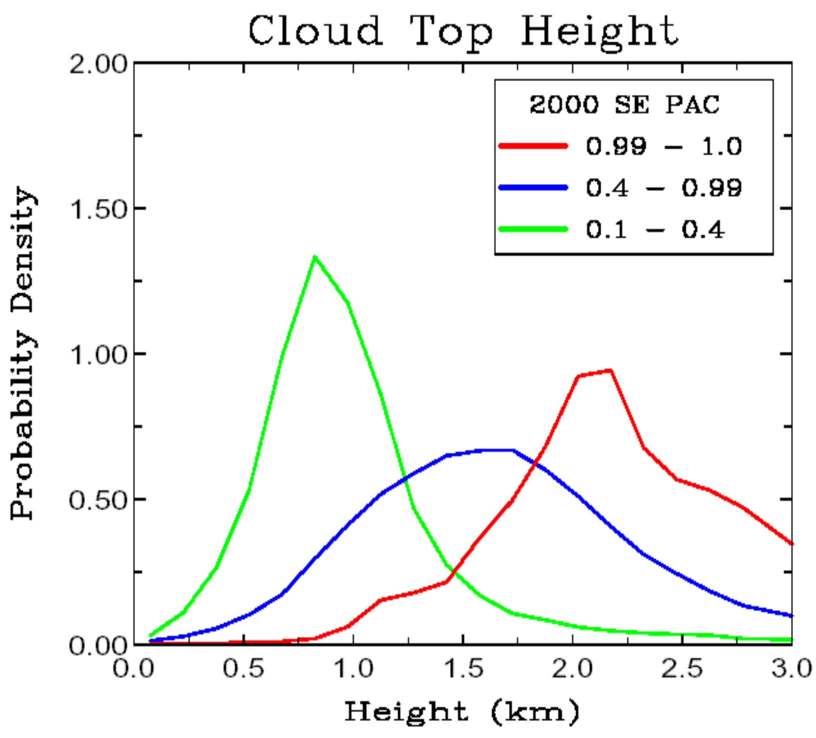
Subgrid characteristics of BLC

PDF of OLR and Cloud Top Height

March 2000



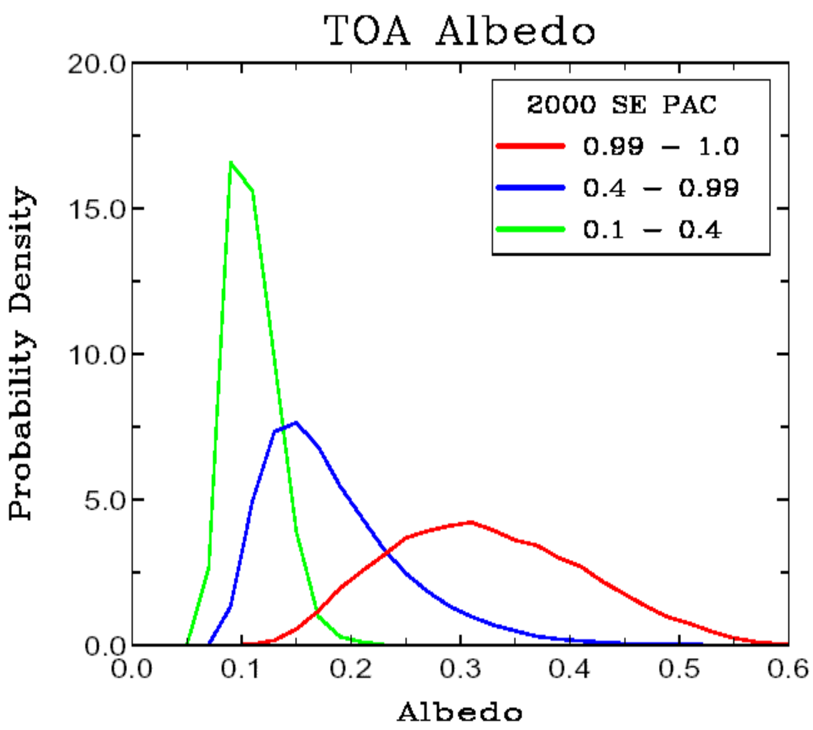
March 2000



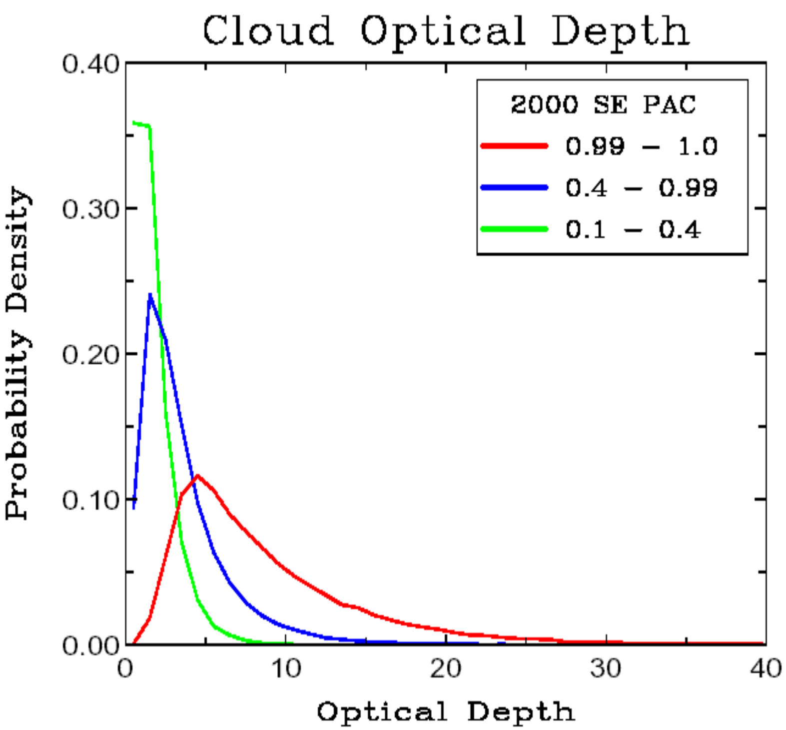
Subgrid characteristics of BLC

PDF of albedo and cloud optical depth

March 2000

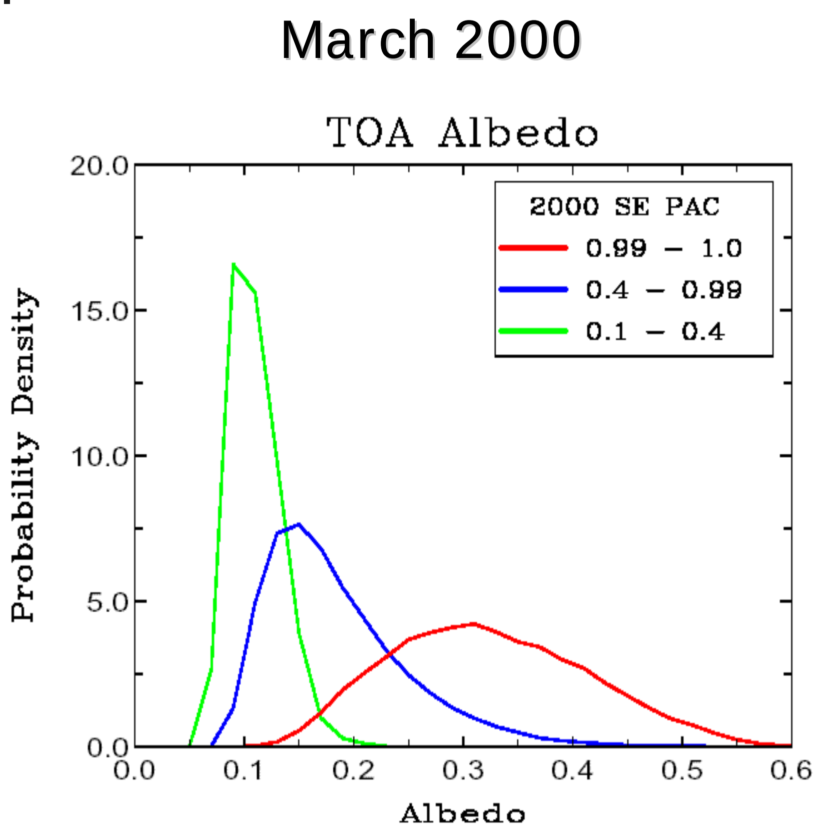


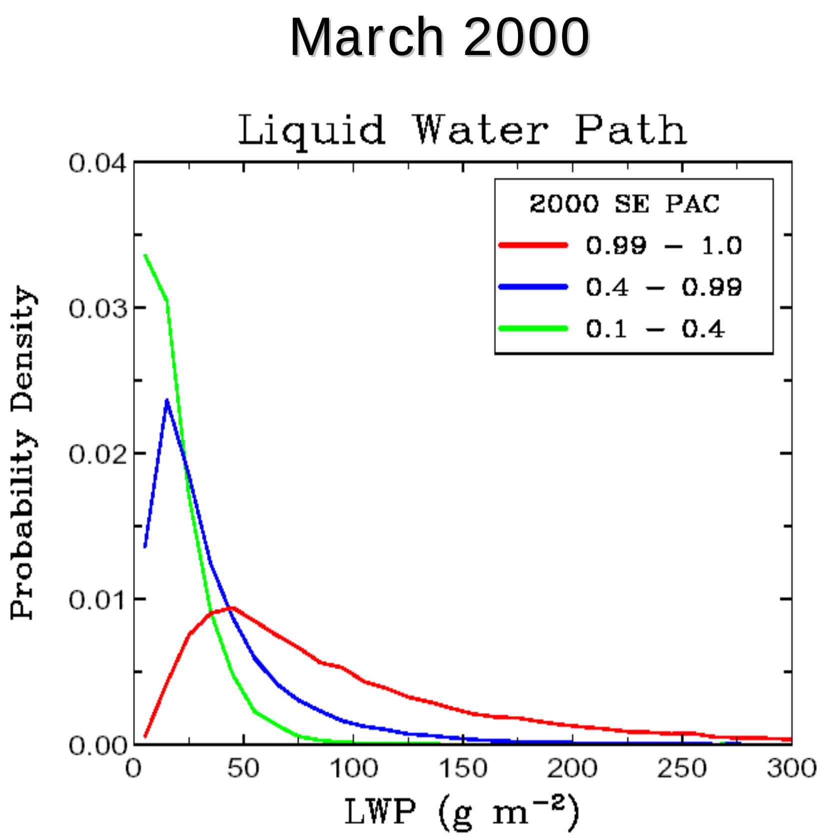
March 2000



Subgrid characteristics of BLC

PDF of albedo and cloud liquid water path





Tropical deep convections (TDC)

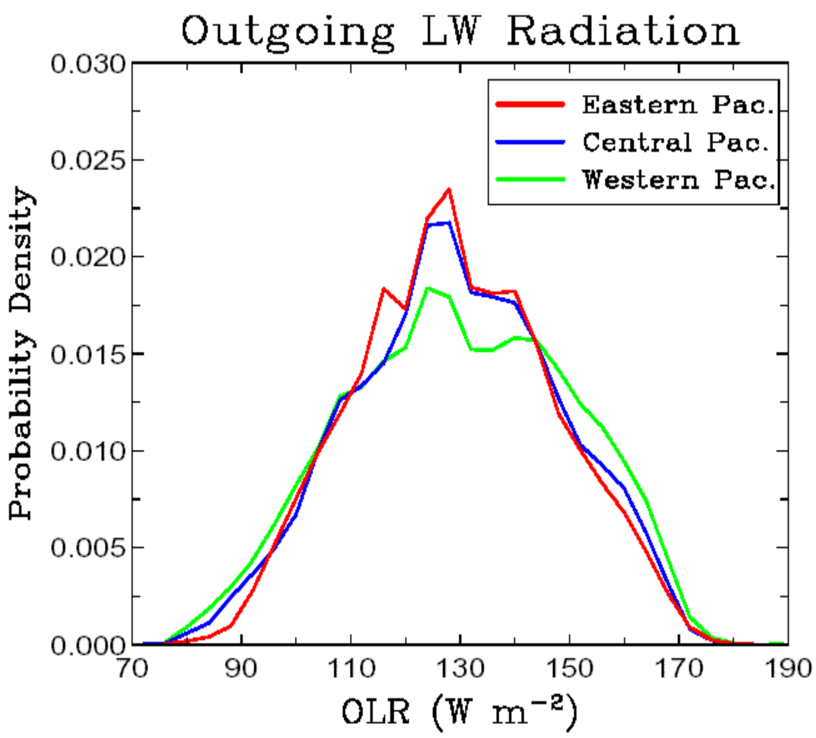
- Number of tropical deep convections over the Pacific Ocean identified from satellite data:

Regions	March 1998 (Extreme El Nino)	March 2000 (Weak La Nina)
Eastern Pacific	88	70
Central Pacific	129	110
Western Pacific	135	195
Total	352	375

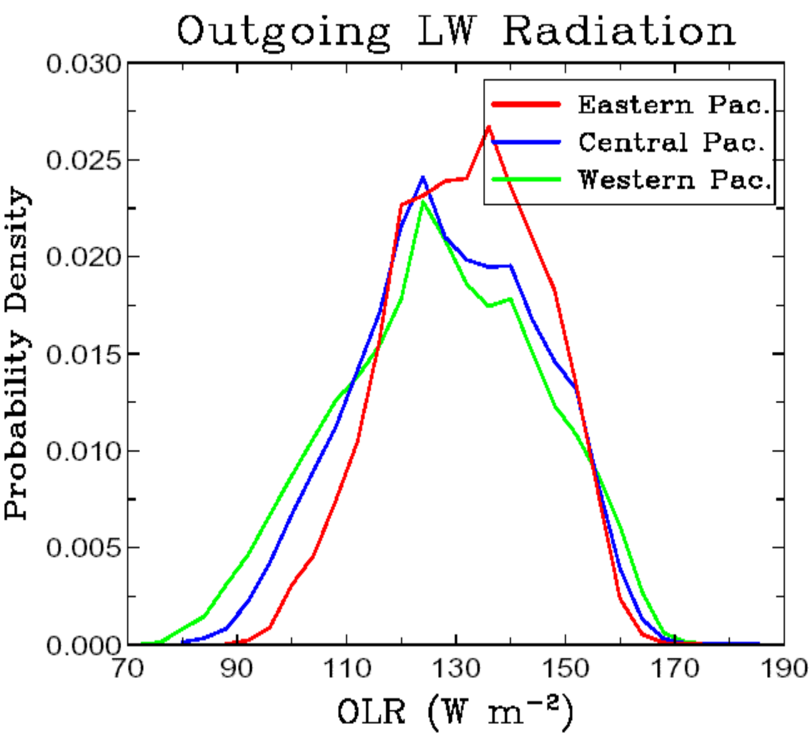
Subgrid characteristics of TDC

PDF of outgoing longwave radiation

March 1998



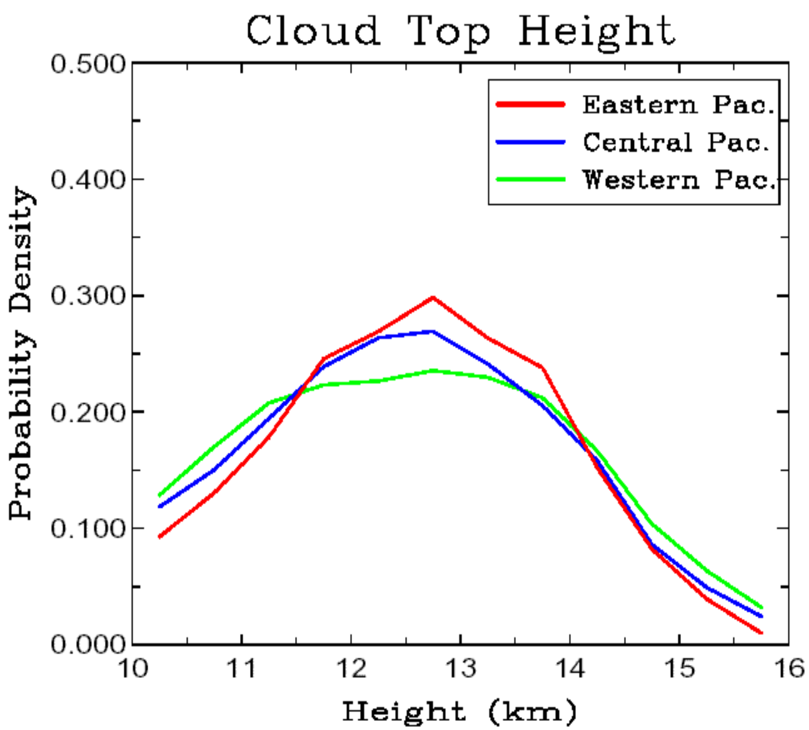
March 2000



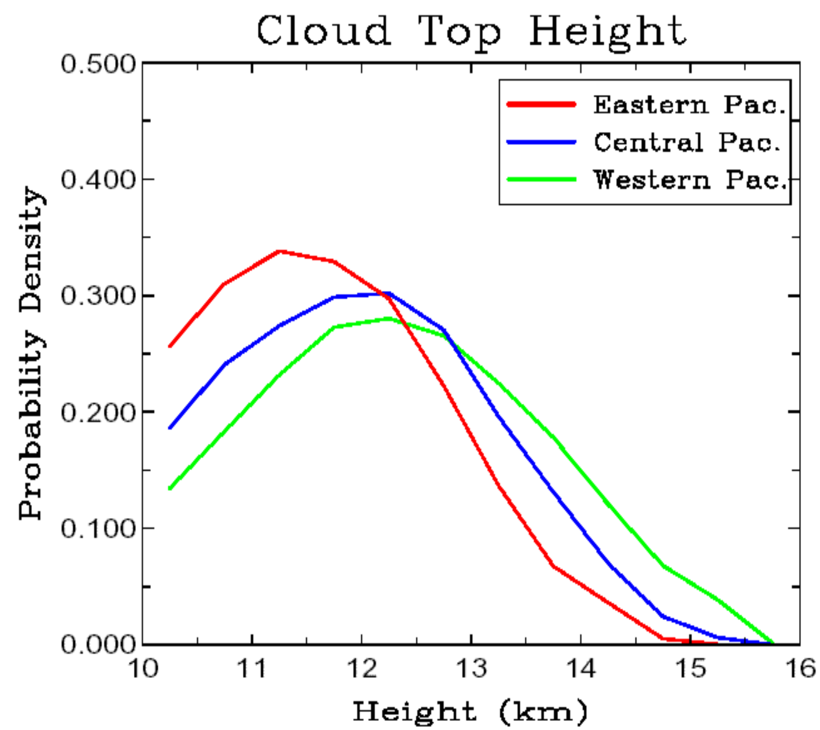
Subgrid characteristics of TDC

PDF of cloud top height

March 1998



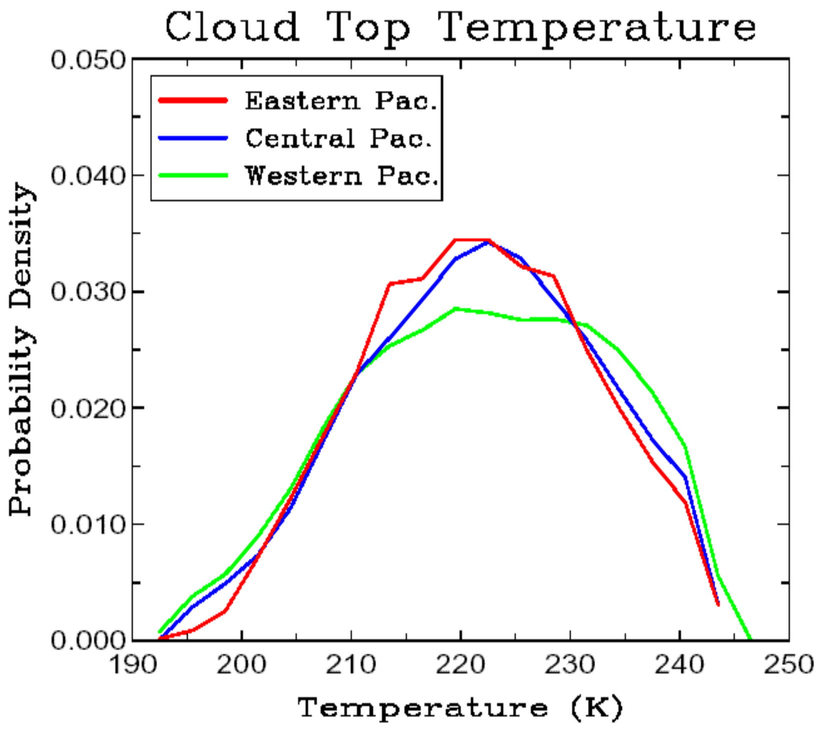
March 2000



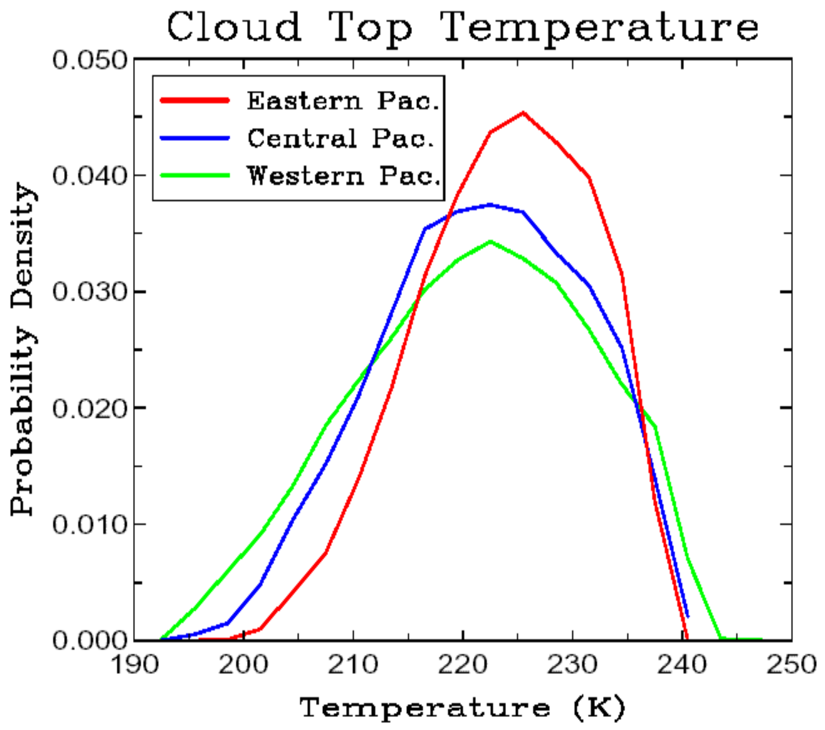
Subgrid characteristics of TDC

PDF of cloud top temperature

March 1998

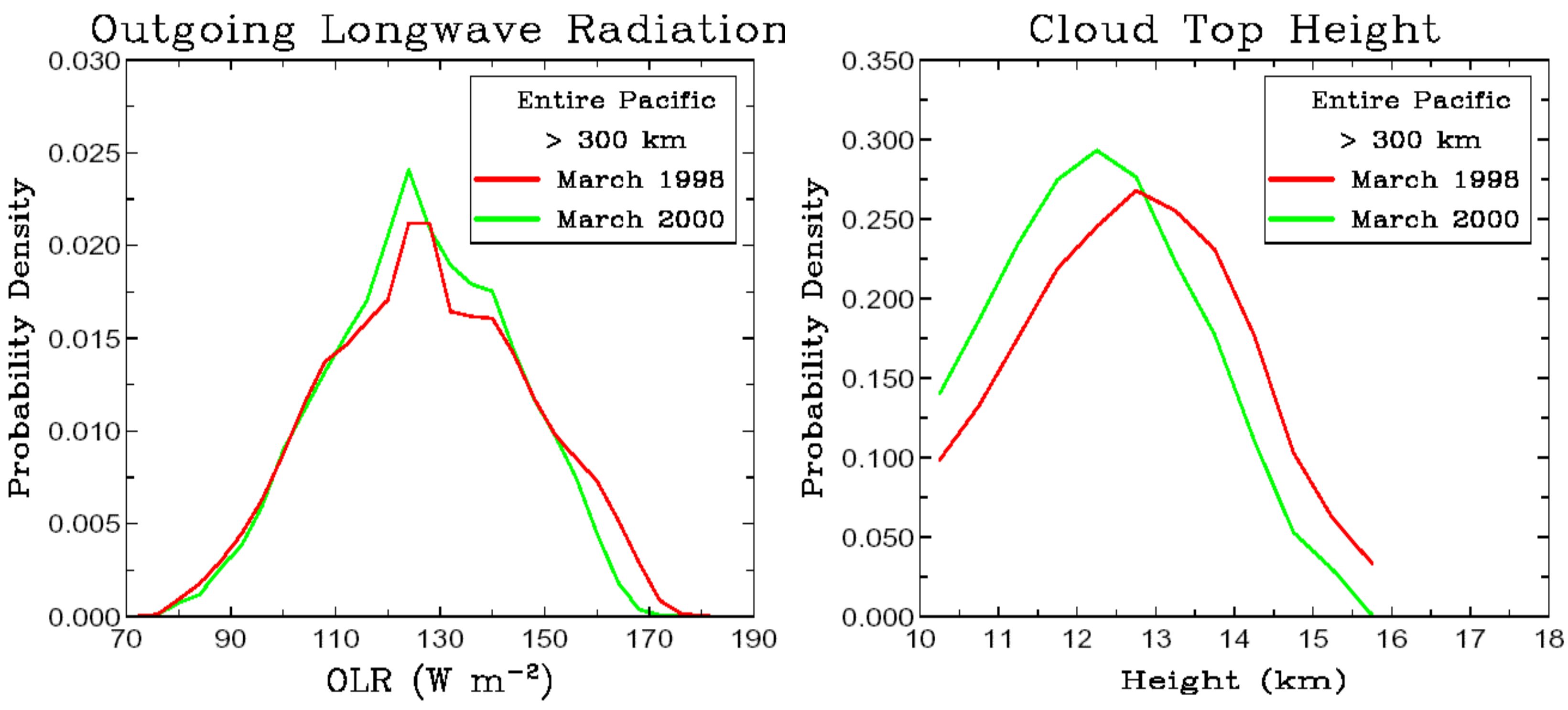


March 2000



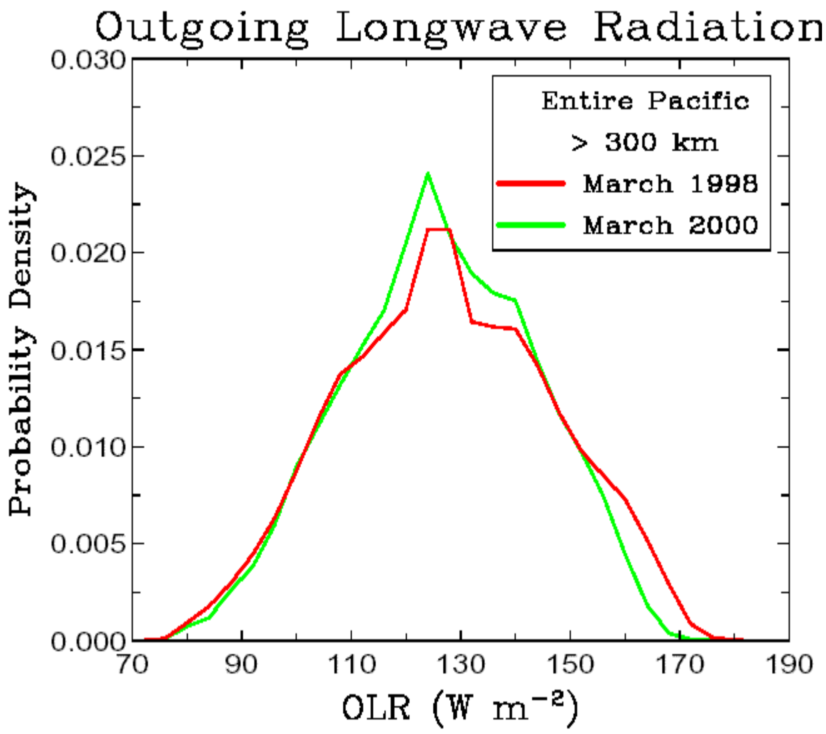
Subgrid characteristics of TDC

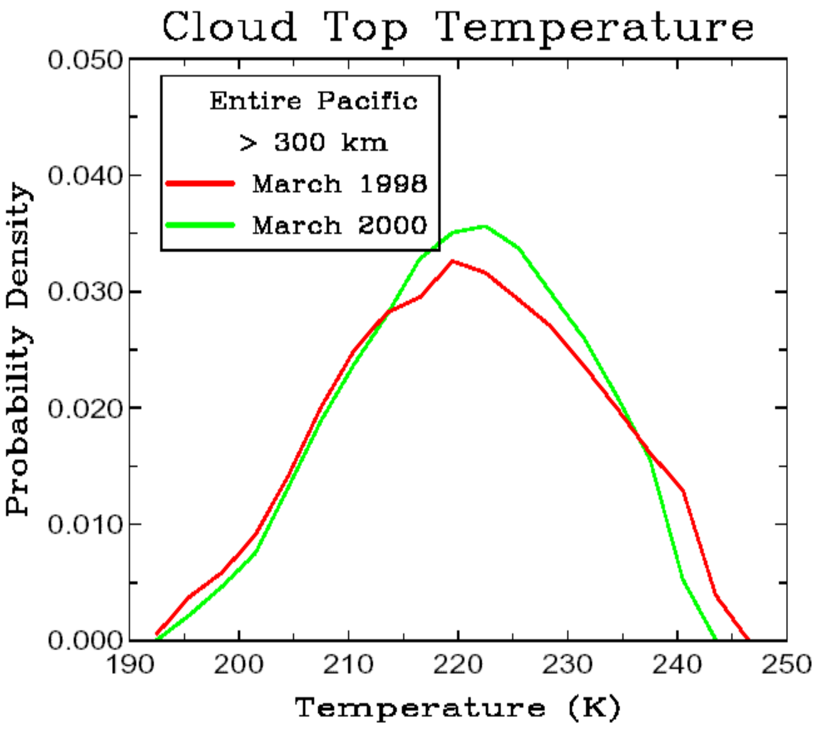
PDF of OLR and cloud top height (Size > 300km)



Subgrid characteristics of TDC

PDF of OLR and cloud top temperature (Size>300km)

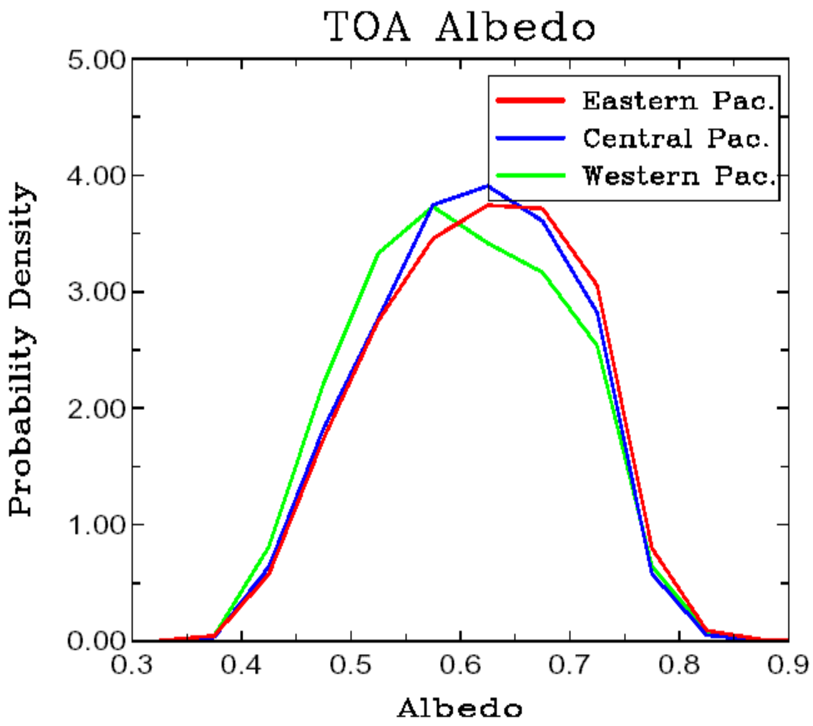




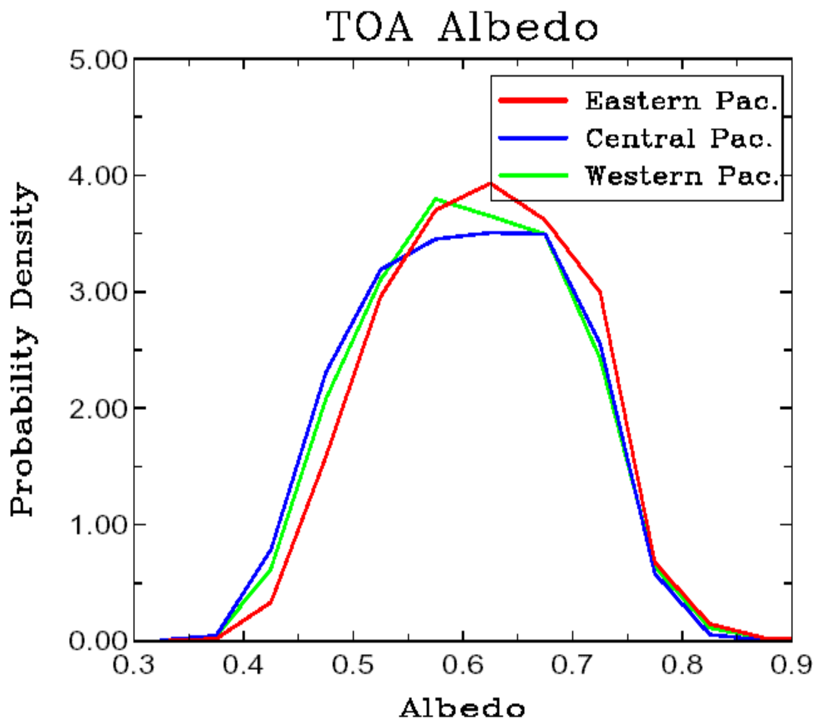
Subgrid characteristics of TDC

PDF of albedo

March 1998

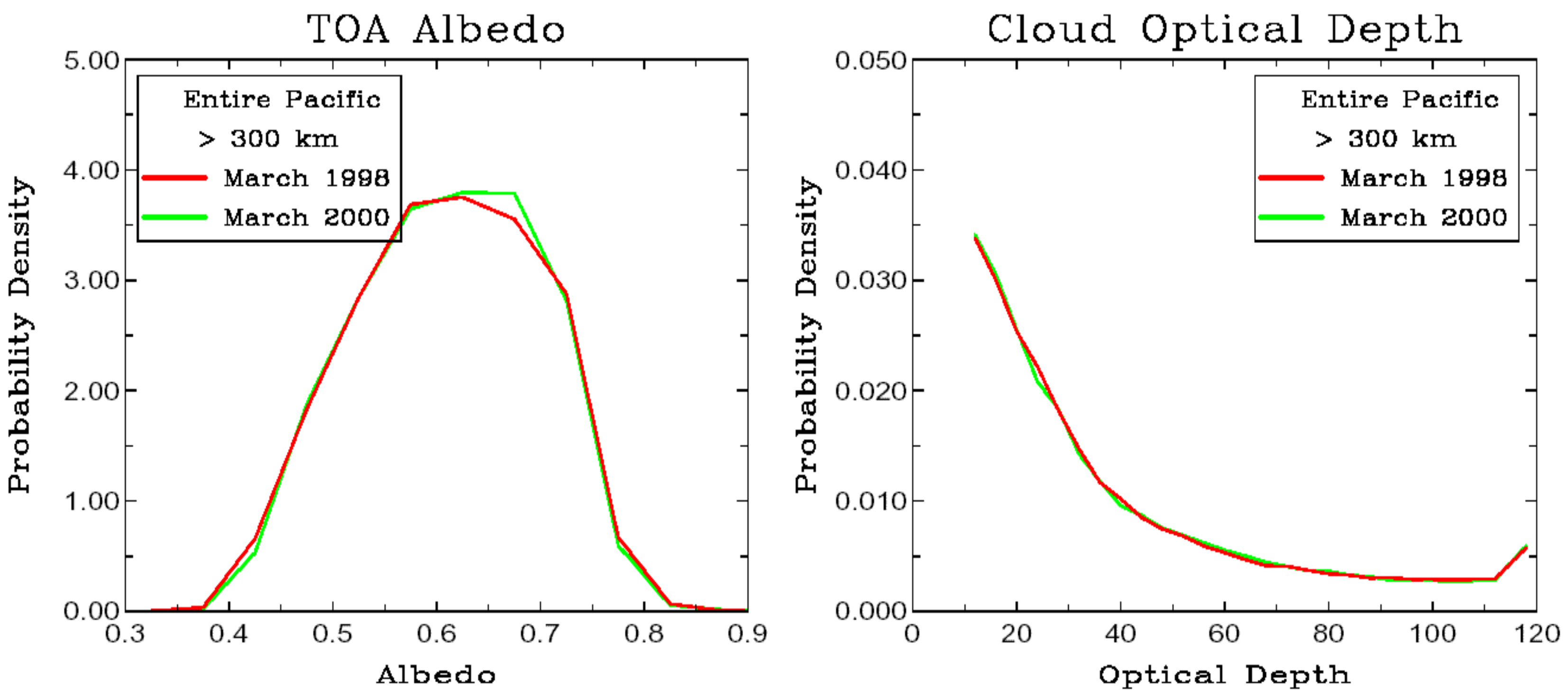


March 2000



Subgrid characteristics of TDC

PDF of albedo and cloud optical depth (Size>300km)



Sensitivity of TDC to SST

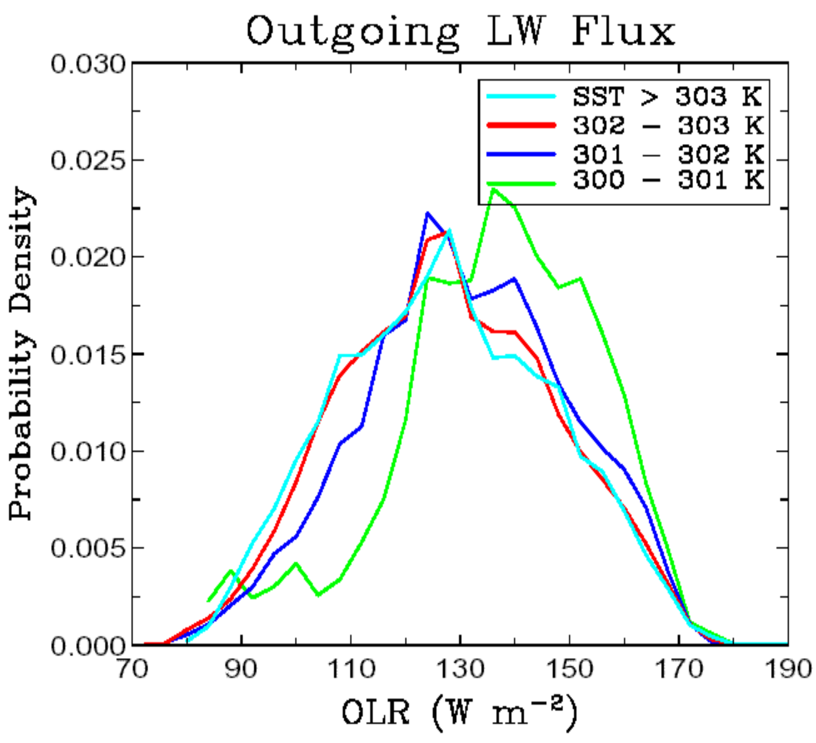
- Number of tropical deep convections as a function of sea surface temperature over the Pacific Ocean:

SST (K)	March 1998 (Extreme El Nino)	March 2000 (Weak La Nina)
300-301	16	46
301-302	66	88
302-303	196	163
> 303	47	26

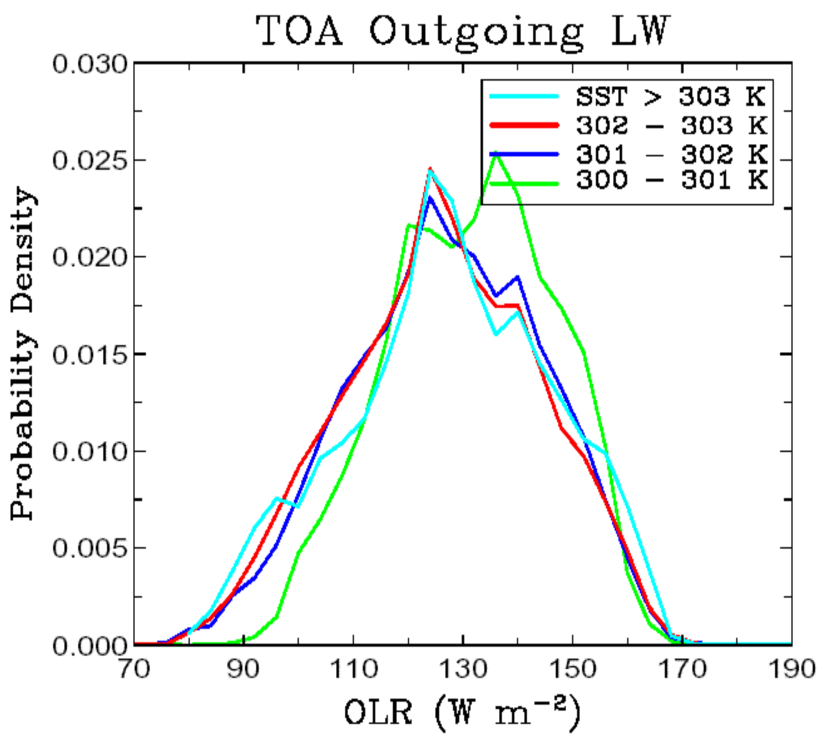
Sensitivity of TDC to SST

PDF of outgoing longwave radiation

March 1998



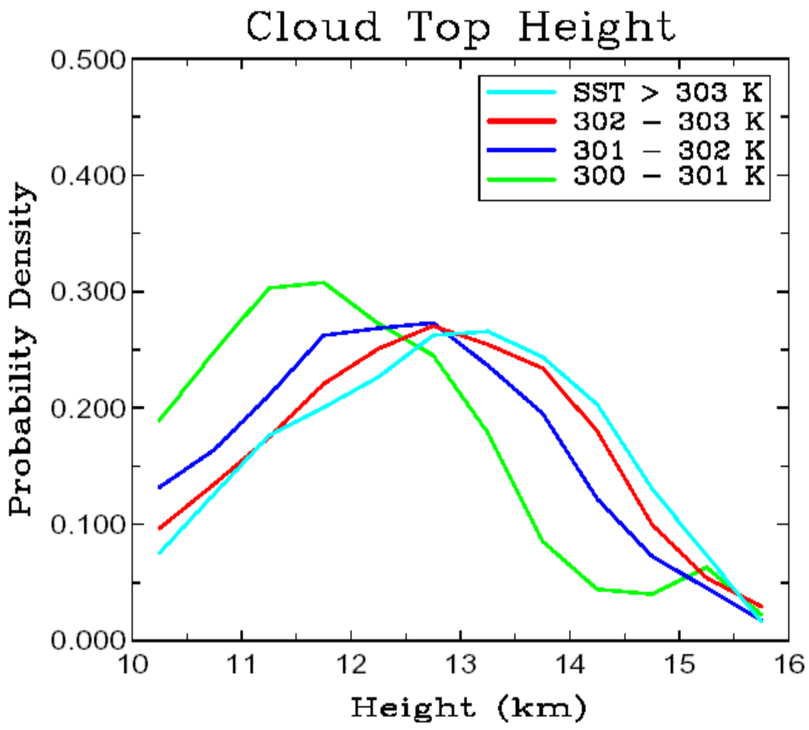
March 2000



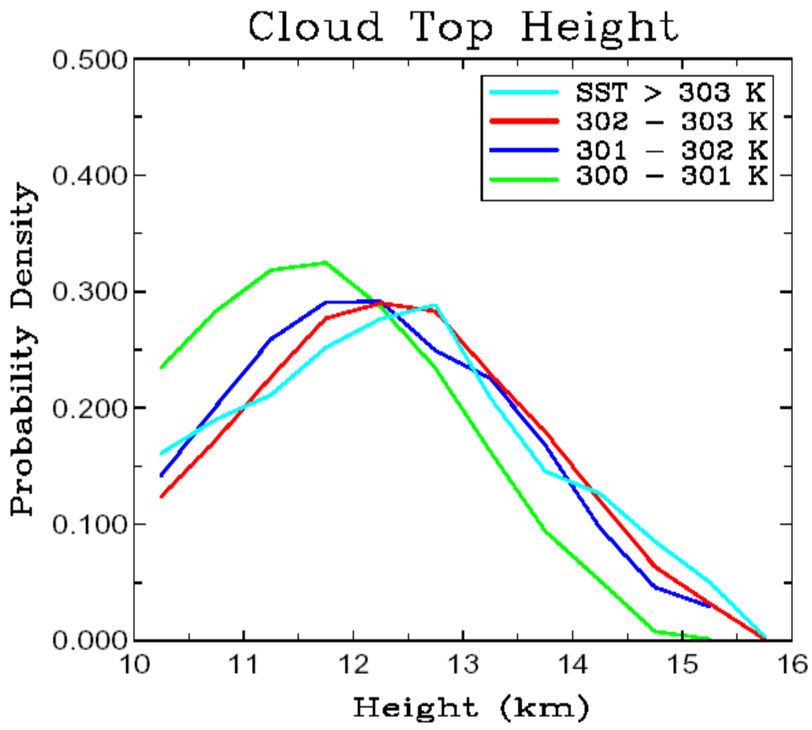
Sensitivity of TDC to SST

PDF of cloud top height

March 1998



March 2000



Summary
Observed Cloud Systems from CERES data

- Cloud system/object analysis based on large ensemble of EOS observed cloud systems provides a new and robust way for examining climate and climate feedback processes and improving cloud parameterizations in GCMs.
- BLC: Significant differences in PDF are found between three types of boundary layer cumulus
- TDC: Differences in cloud height distribution leaded to changes in distribution of OLR between the ENSO year and the La Nina year
- Climate Sensitivity: OLR and Cloud top height Distribution of TDC are not sensitive to SST change above 301K

Future plan

- Extending the analysis of satellite data and matched ECMWF meteorological fields over much longer periods
- Analyzing the observed cloud systems and relating them to climate feedback measures; i.e., as a function of sea surface temperature, atmospheric stability, and convective instability, for all major cloud types
- Providing a comprehensive data set, combining CERES and TRMM, as well as CRM results for shallow and deep cloud systems, for validating simulations of GCMs with both conventional and super parameterizations