

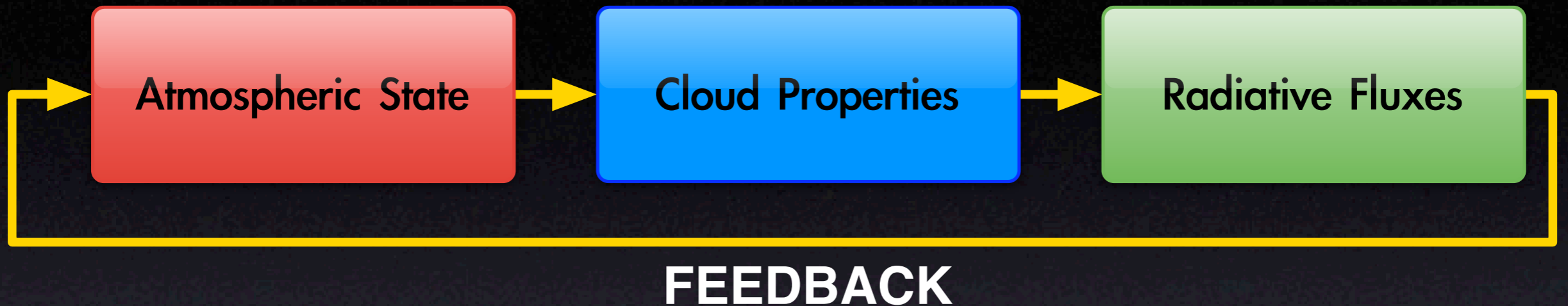
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Cloud Systems: Models vs. CERES Cloud/Flux Data

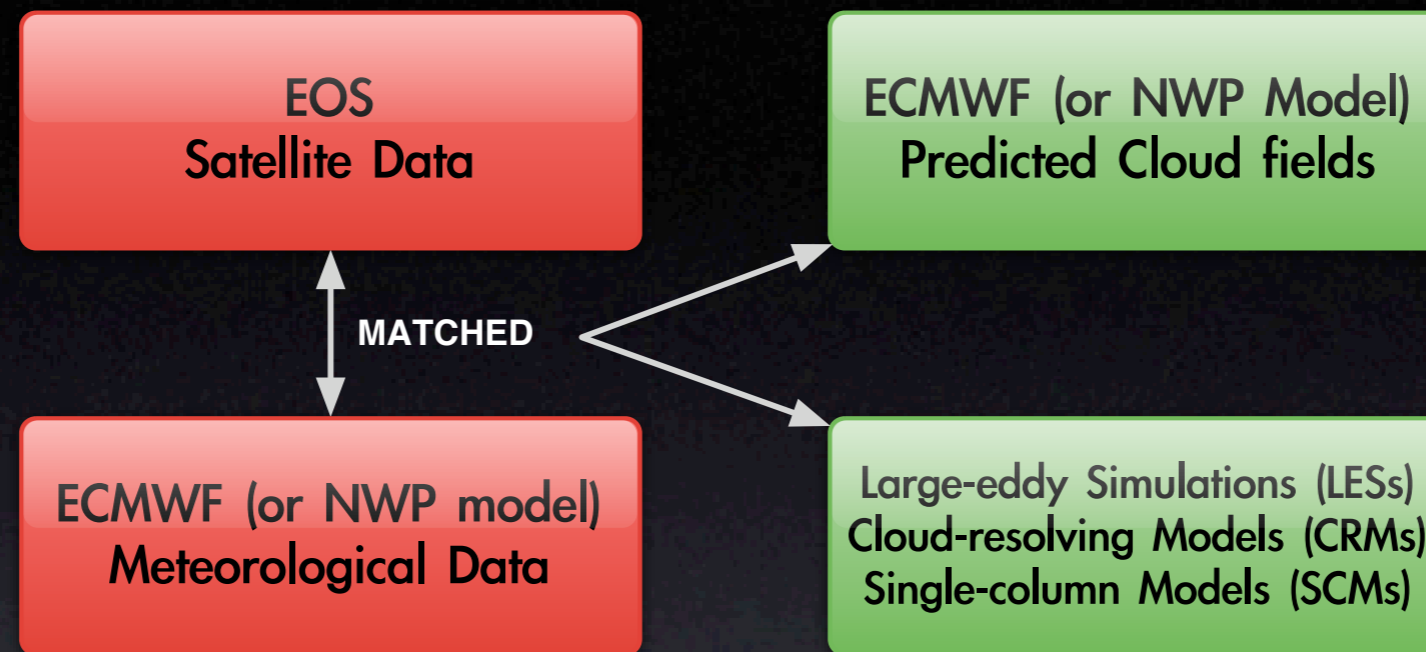
Takmeng Wong, Kuan-Man Xu, Bruce Wielicki,
Zachary A. Eitzen, Anning Cheng and Lindsay Parker

Motivation



- Importance of radiative feedback of clouds in the climate system
- Uncertainties in modeling cloud-radiation interactions in global climate models (GCMs)
- Nonlinearity of cloud processes requiring observations on all relevant modeling scales (in space and in time)
- Inadequate methods of cloud model evaluation

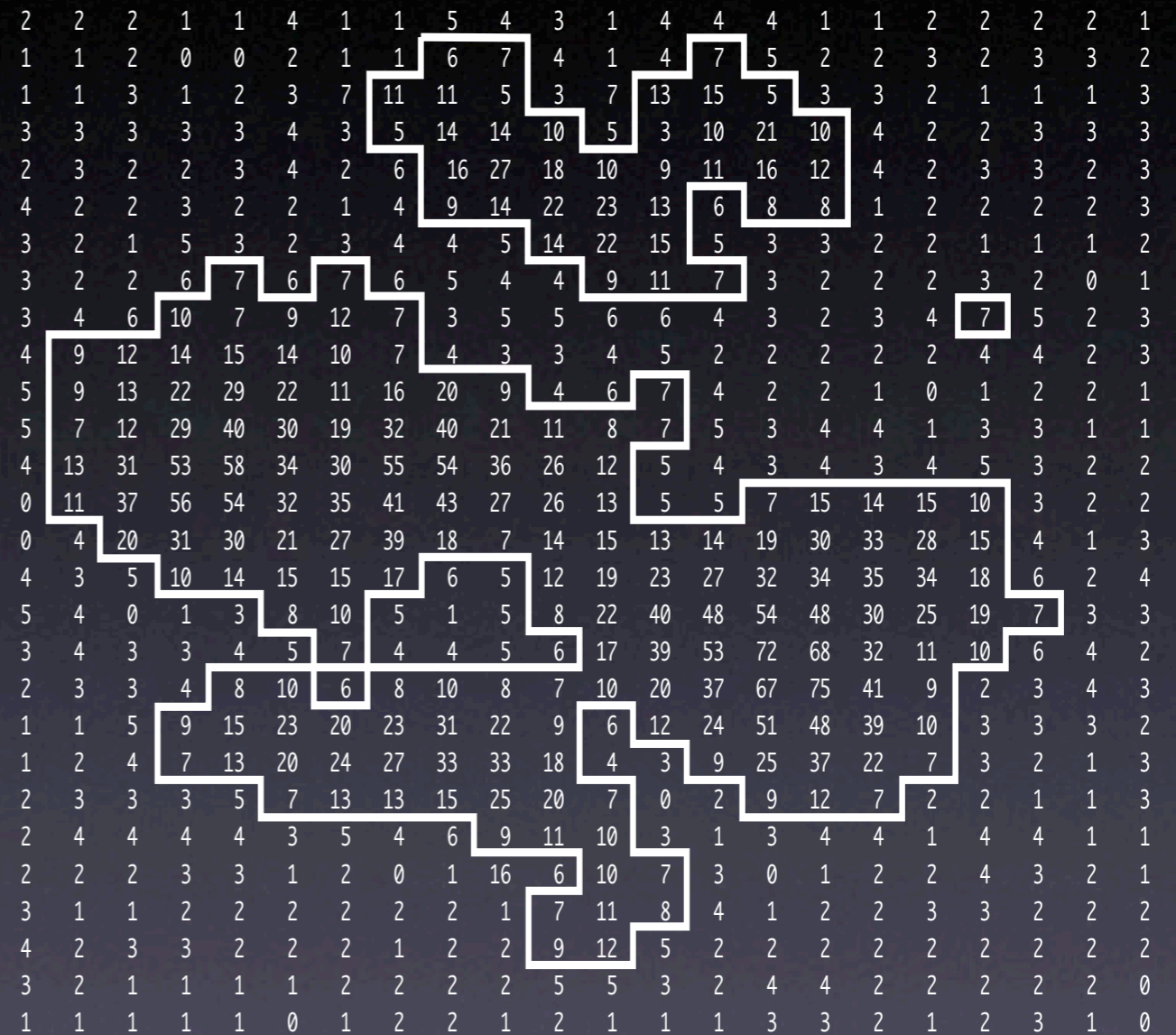
Approach



- 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 the European Centre for Medium-Range Weather Forecast (ECMWF) meteorological data (T, q, u, v and advective tendencies)
- Perform cloud model simulations driven by the 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, $\tau > 10$, 25° S \sim 25° N, overcast pixels

- Trade/shallow cumulus

$Z < 3$ km, cloud cover: 0.1 – 0.4, 40° S \sim 40° N

- Transition stratocumulus

$Z < 3$ km, cloud cover: 0.4 – 0.99, 40° S \sim 40° N

- Solid Stratocumulus

$Z < 3$ km, cloud cover: 0.99 – 1.0, 40° S \sim 40° N

Satellite data analyzed

- March 1998 and March 2000 CERES/TRMM data (>190 GB per month)
- Parameters analyzed from CERES SSF data product: top-of-atmosphere shortwave radiation, top-of-atmosphere albedo, outgoing longwave radiation, emissivity, cloud optical depth, liquid water path, ice particle diameter, top-of-atmosphere longwave, water droplet radius, cloud amount, cloud top pressure, cloud top temperature, and cloud top height
- Probability Density Function (PDF), Mean, Sigma, Skewness, Medium, Maximum, Minimum, and Sample Number

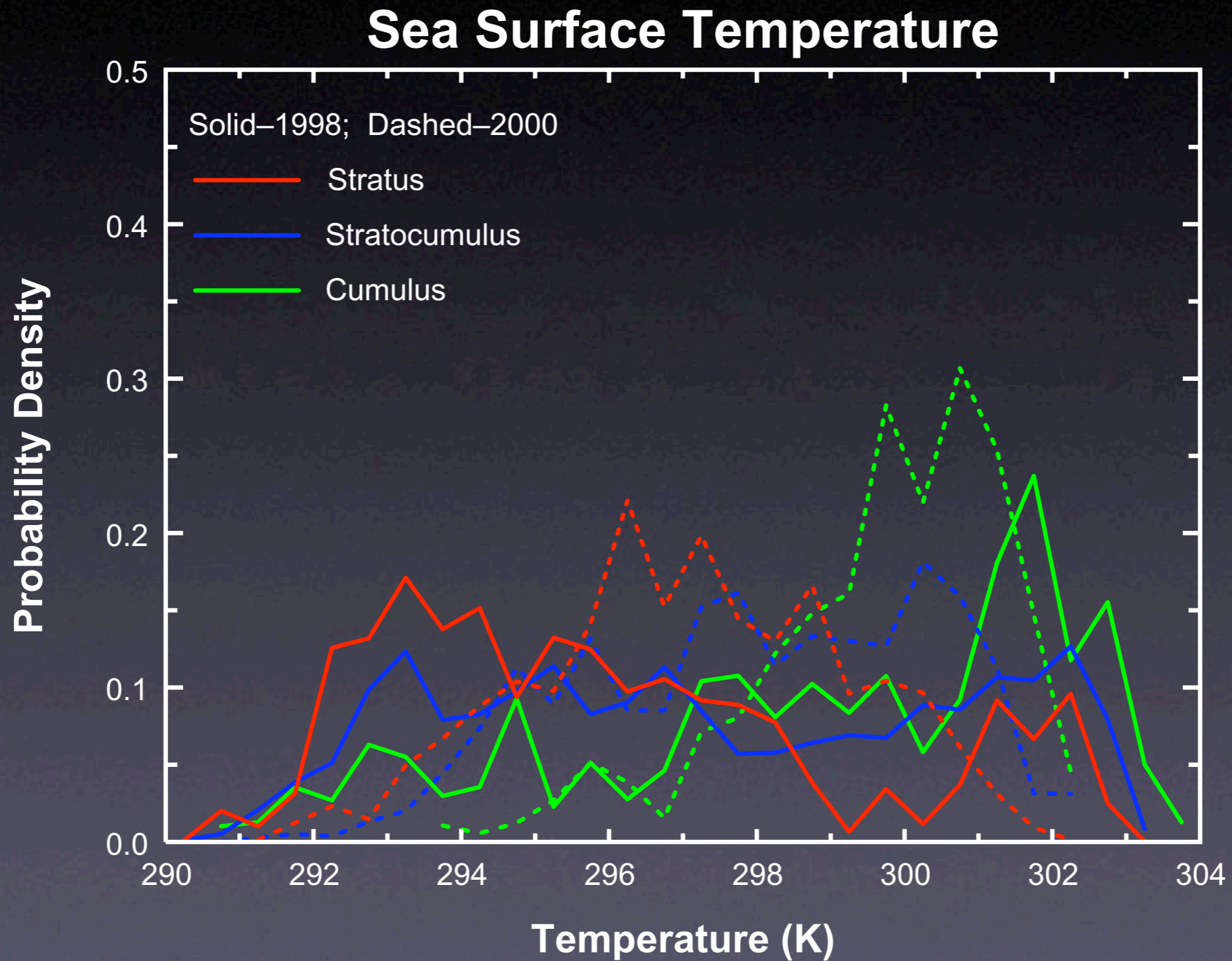
Boundary layer cumulus (BLC)

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

Boundary Layer Cumulus Type	March 1998 (Strong El Niño)	March 2000 (Weak La Niña)
Shallow cumulus	363	686
Transition stratocumulus	1499	1553
Solid stratocumulus	822	761
Total	2684	3000

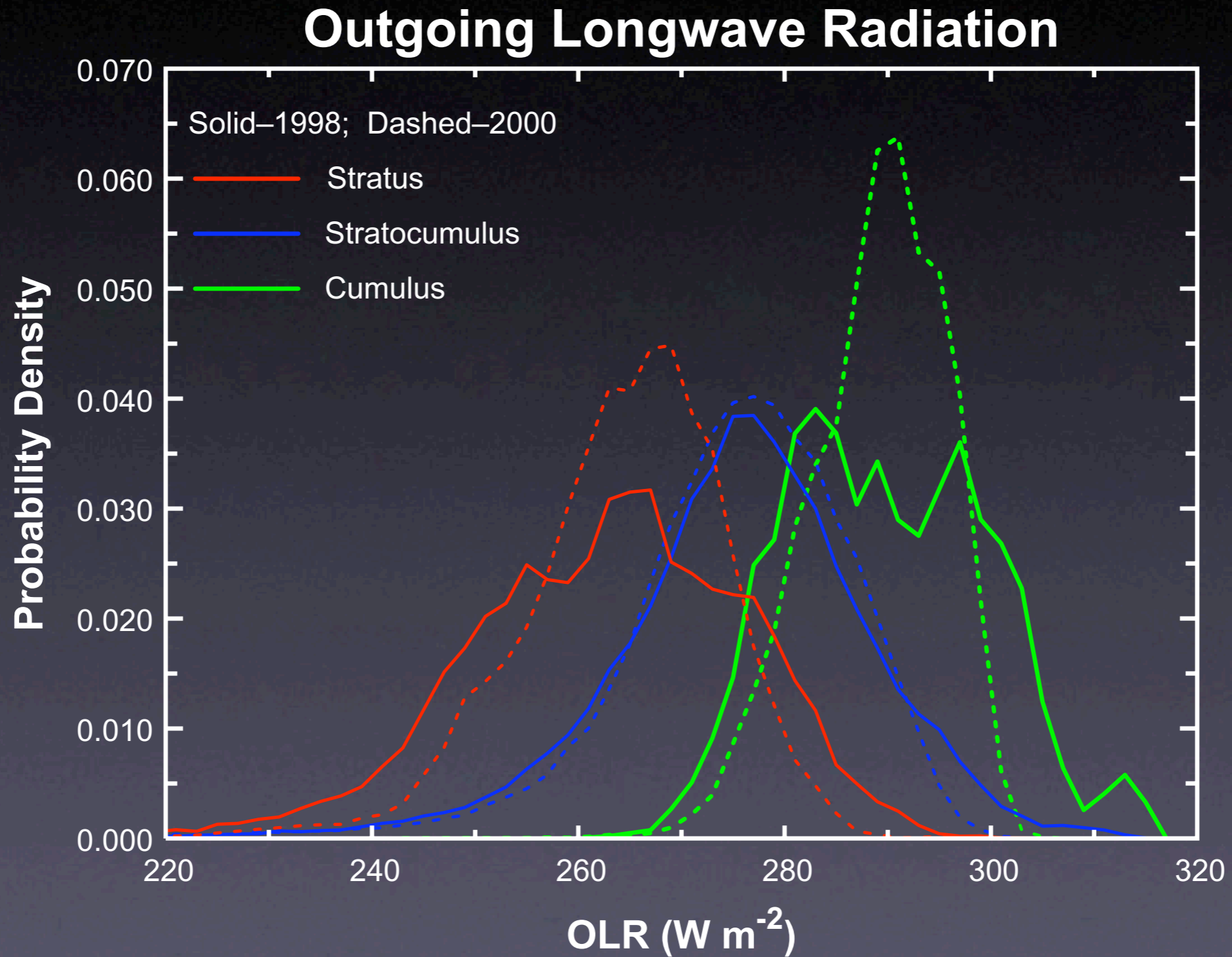
Subgrid characteristics of BLC

PDF of Sea Surface Temperature (SST)



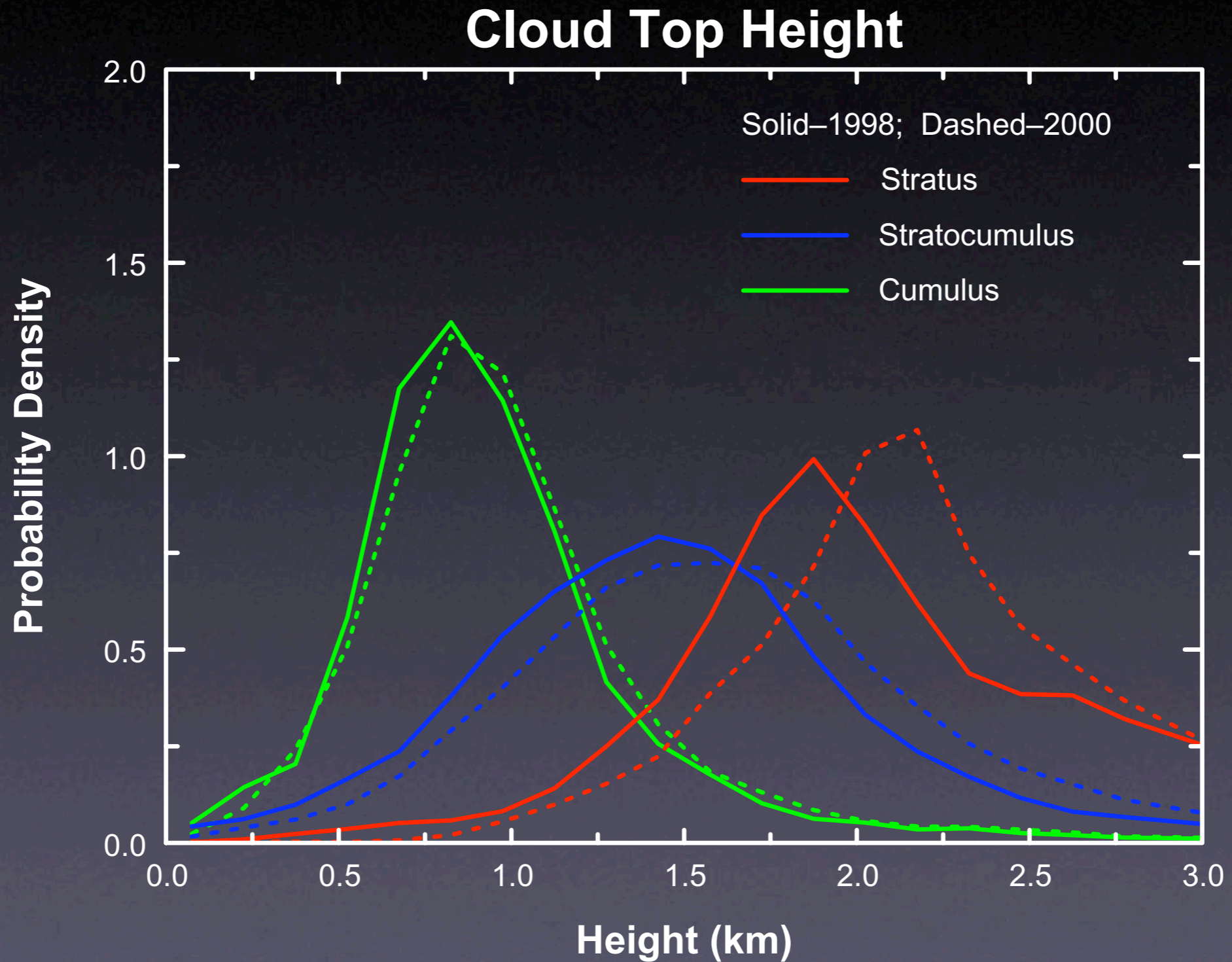
Subgrid characteristics of BLC

PDF of Outgoing Longwave Radiation (OLR)



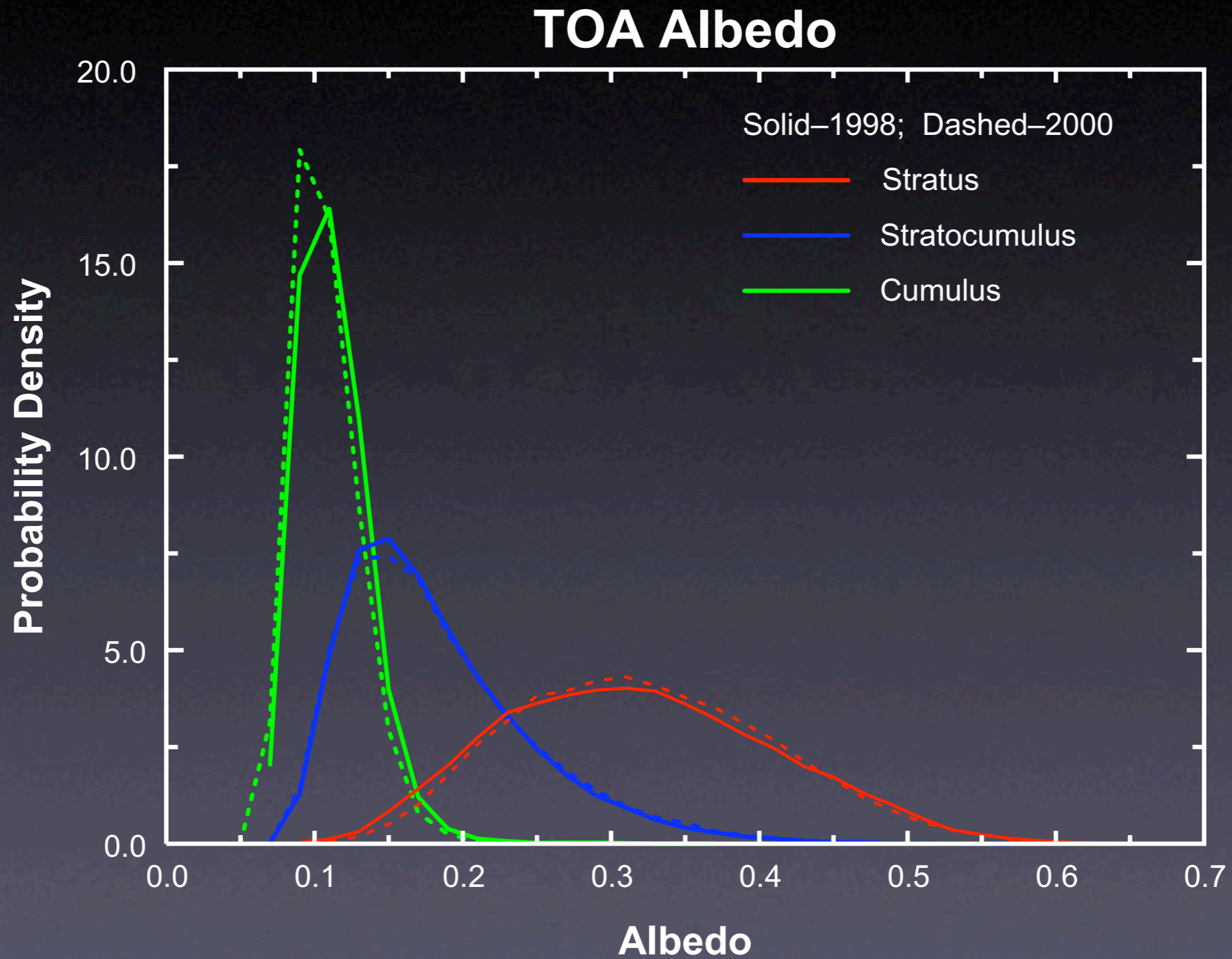
Subgrid characteristics of BLC

PDF of Cloud Top Height



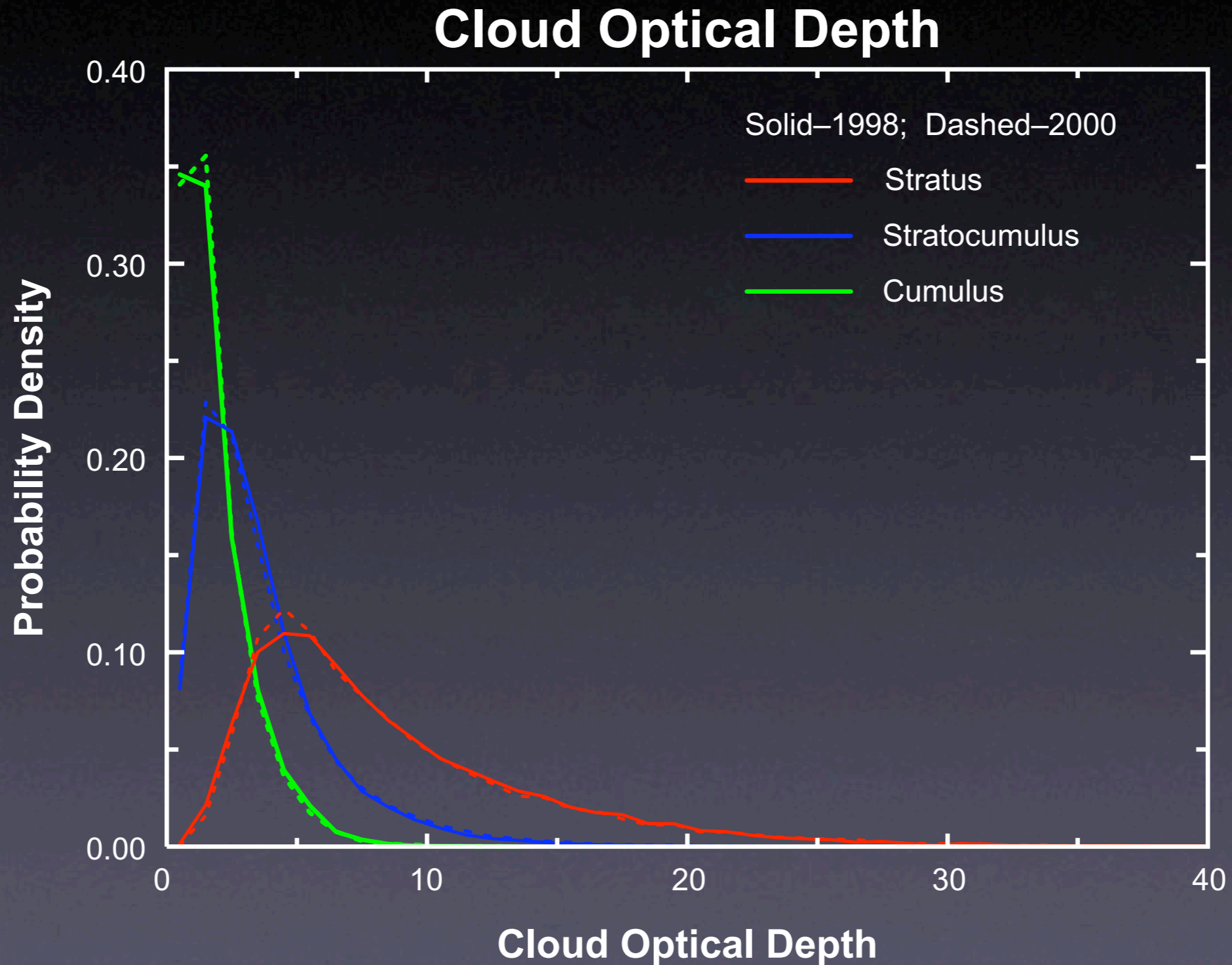
Subgrid characteristics of BLC

PDF of Top-of-atmosphere Albedo



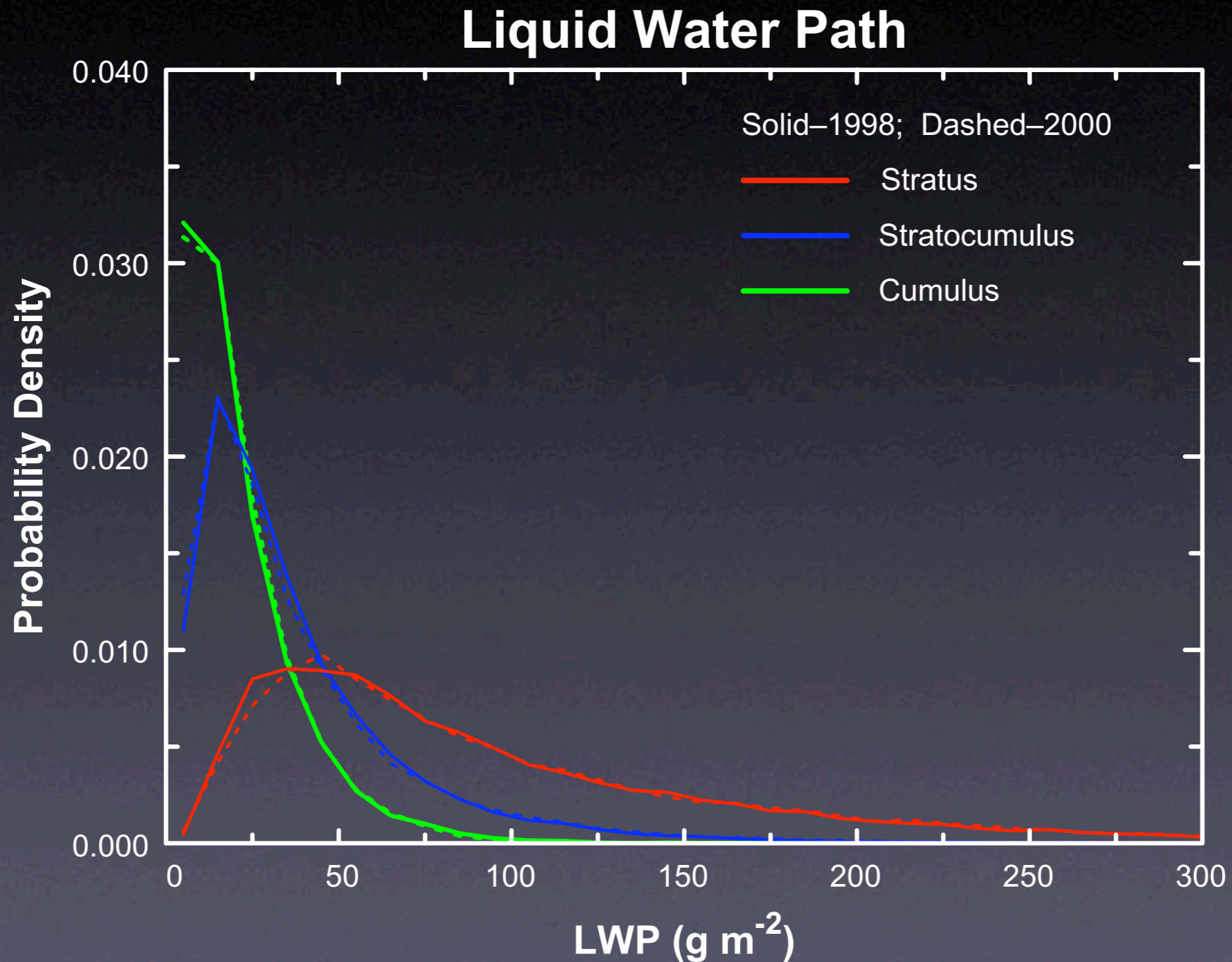
Subgrid characteristics of BLC

PDF of Cloud Optical Depth



Subgrid characteristics of BLC

PDF of Cloud Liquid Water Path



Tropical deep convections (TDC)

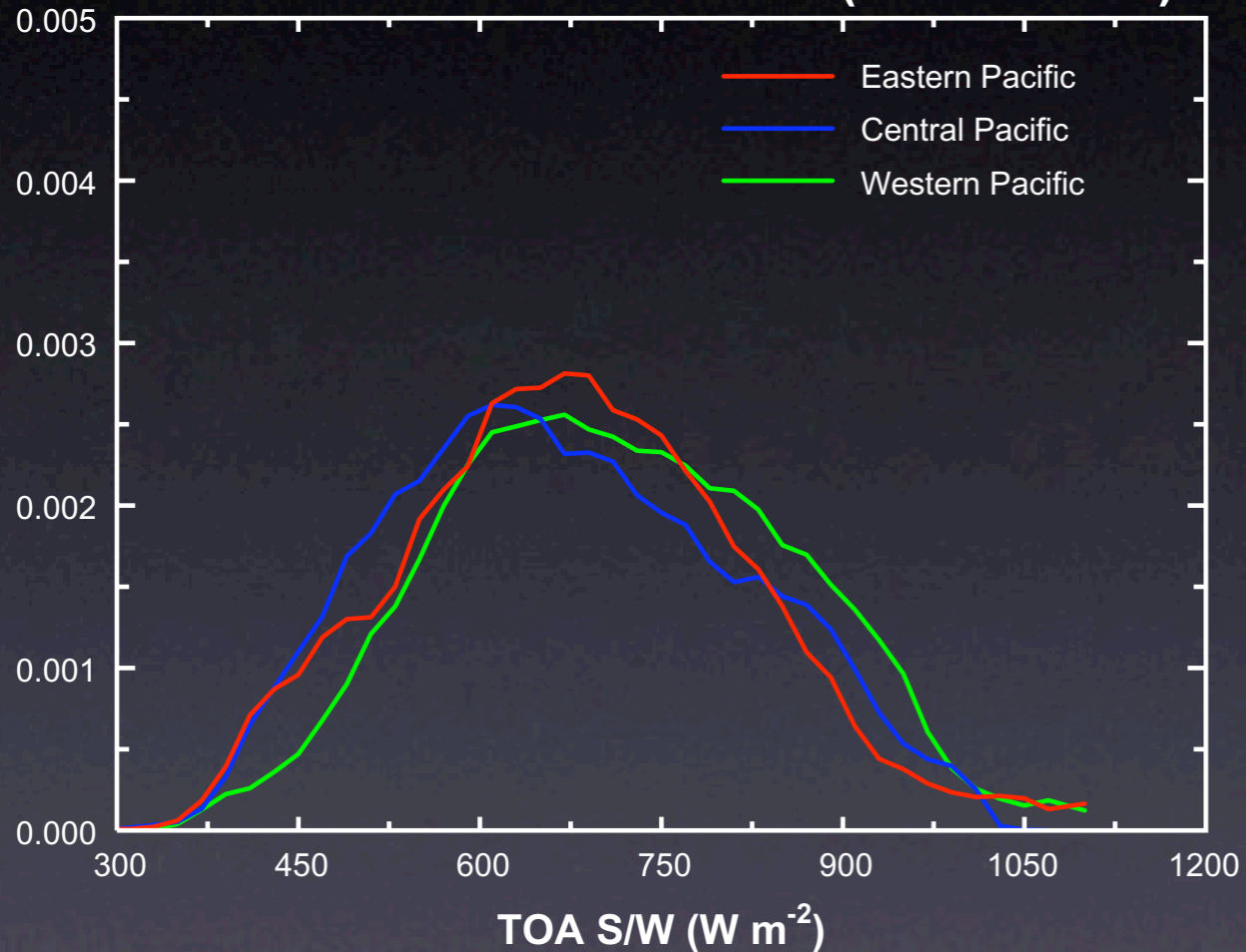
- Number of tropical deep convections over the Pacific Ocean identified from satellite data:

Regions	March 1998 (Extreme El Niño)	March 2000 (Weak La Niña)
Eastern Pacific	78	68
Central Pacific	123	98
Western Pacific	129	174
Total	330	340

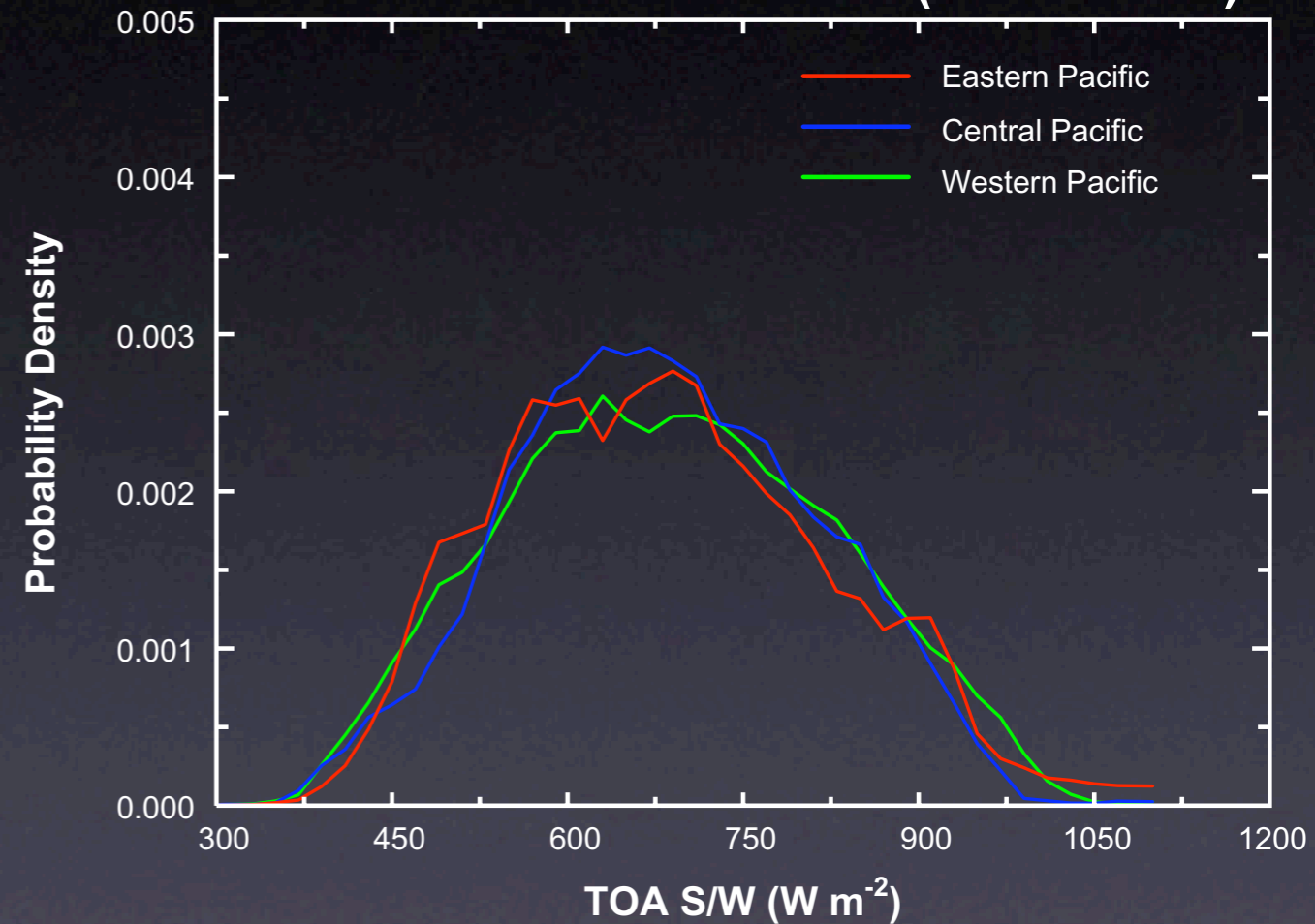
Subgrid characteristics of TDC

PDF of Top-of-atmosphere Reflected Shortwave

TOA Shortwave Reflected (March 1998)



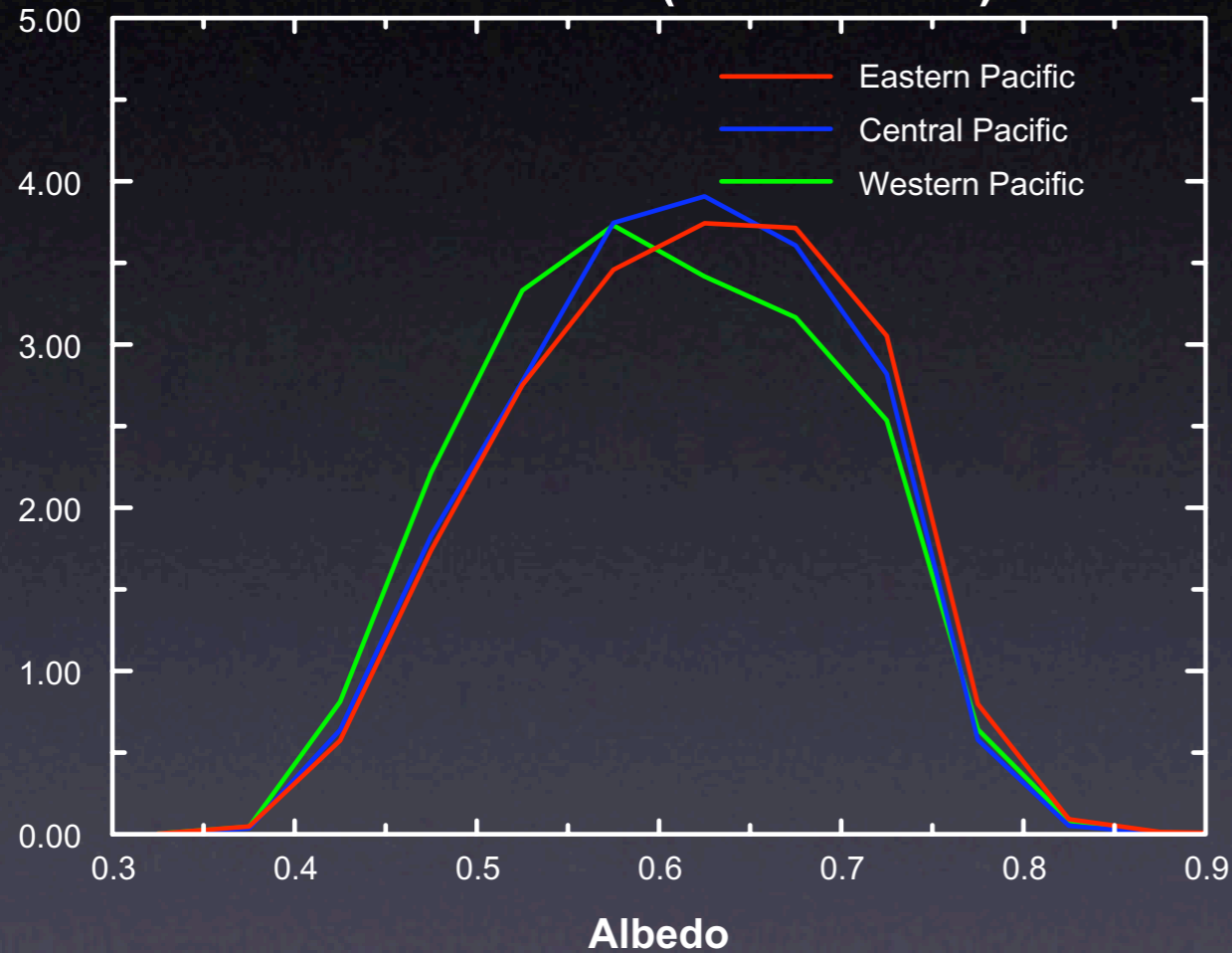
TOA Shortwave Reflected (March 2000)



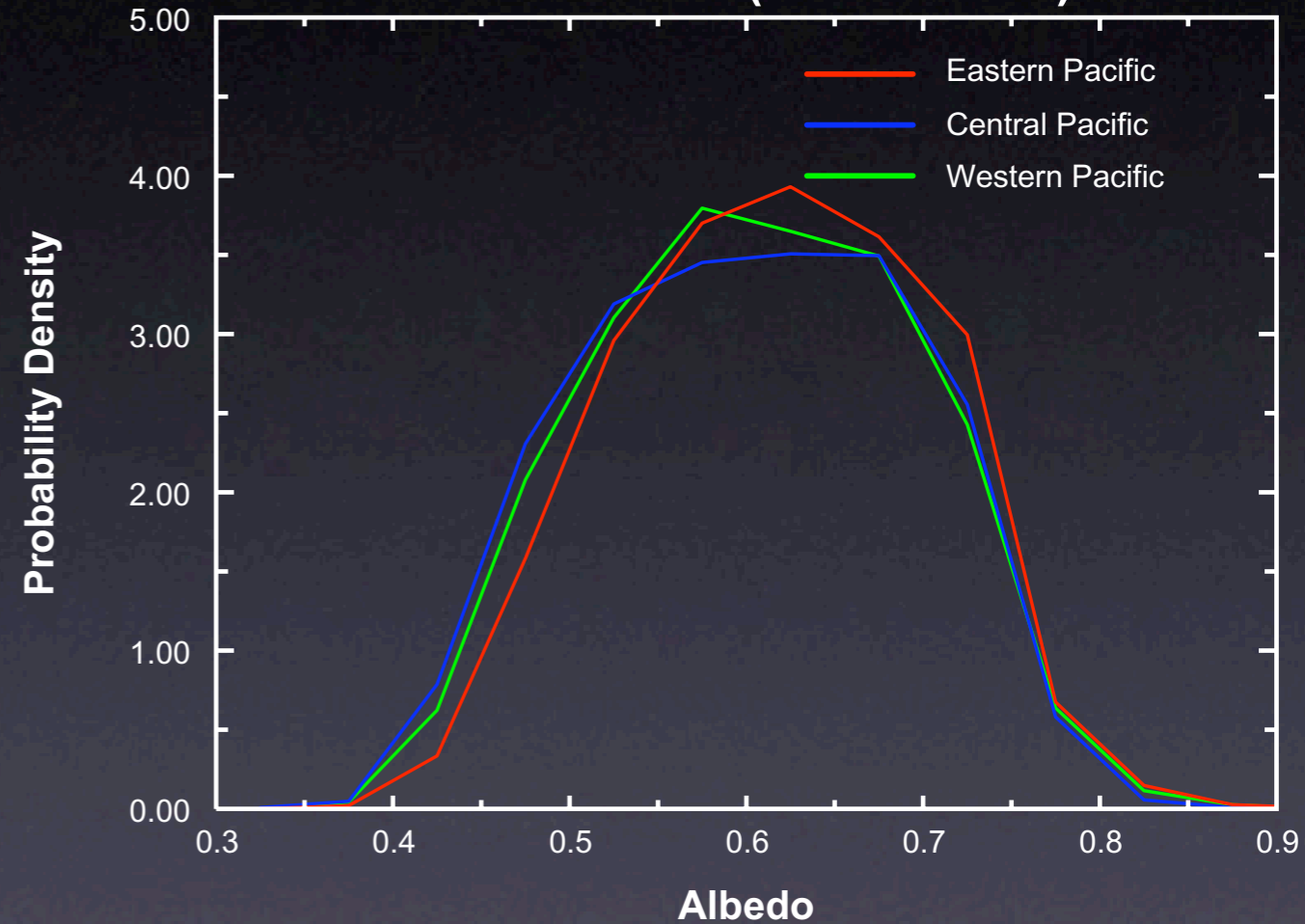
Subgrid characteristics of TDC

PDF of Top-of-atmosphere Albedo

TOA Albedo (March 1998)



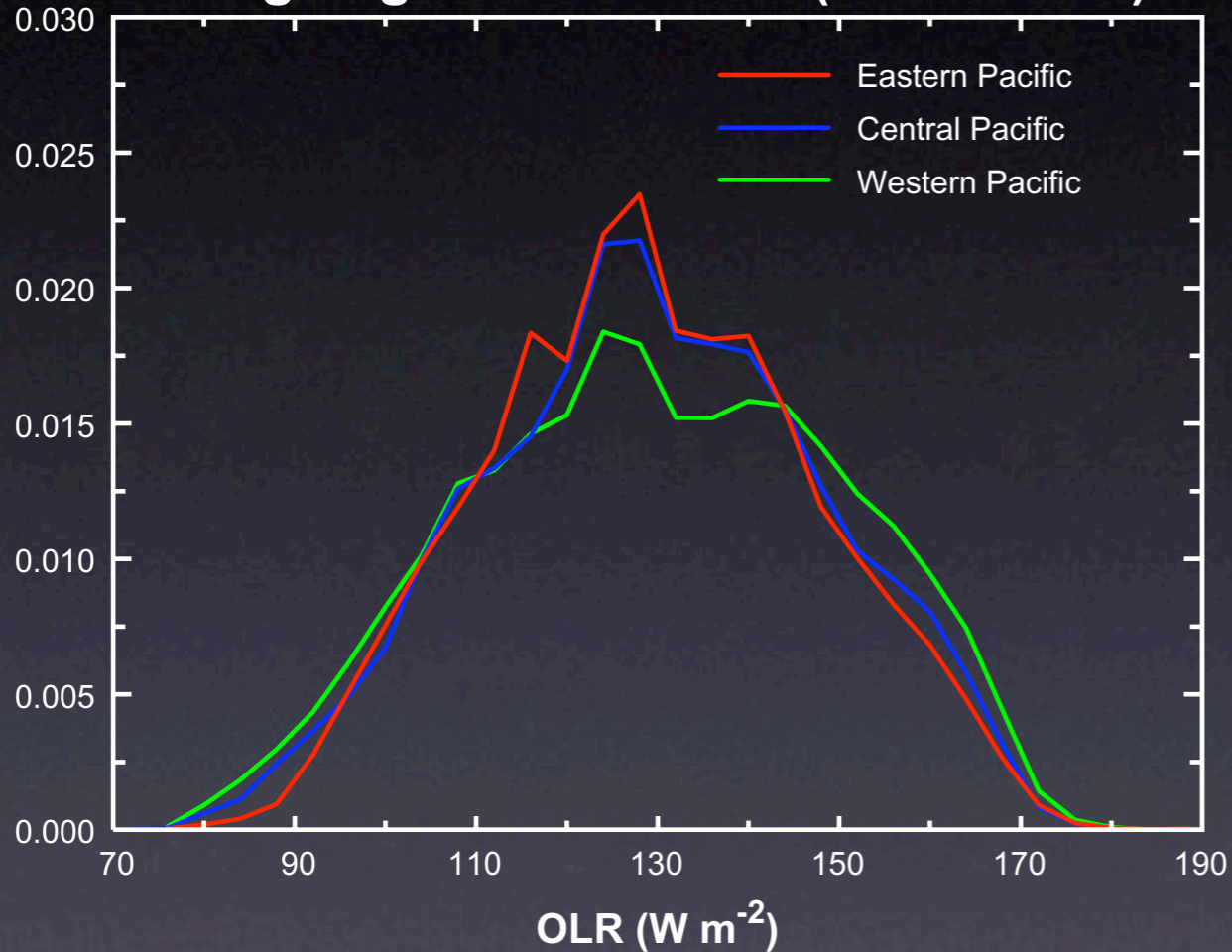
TOA Albedo (March 2000)



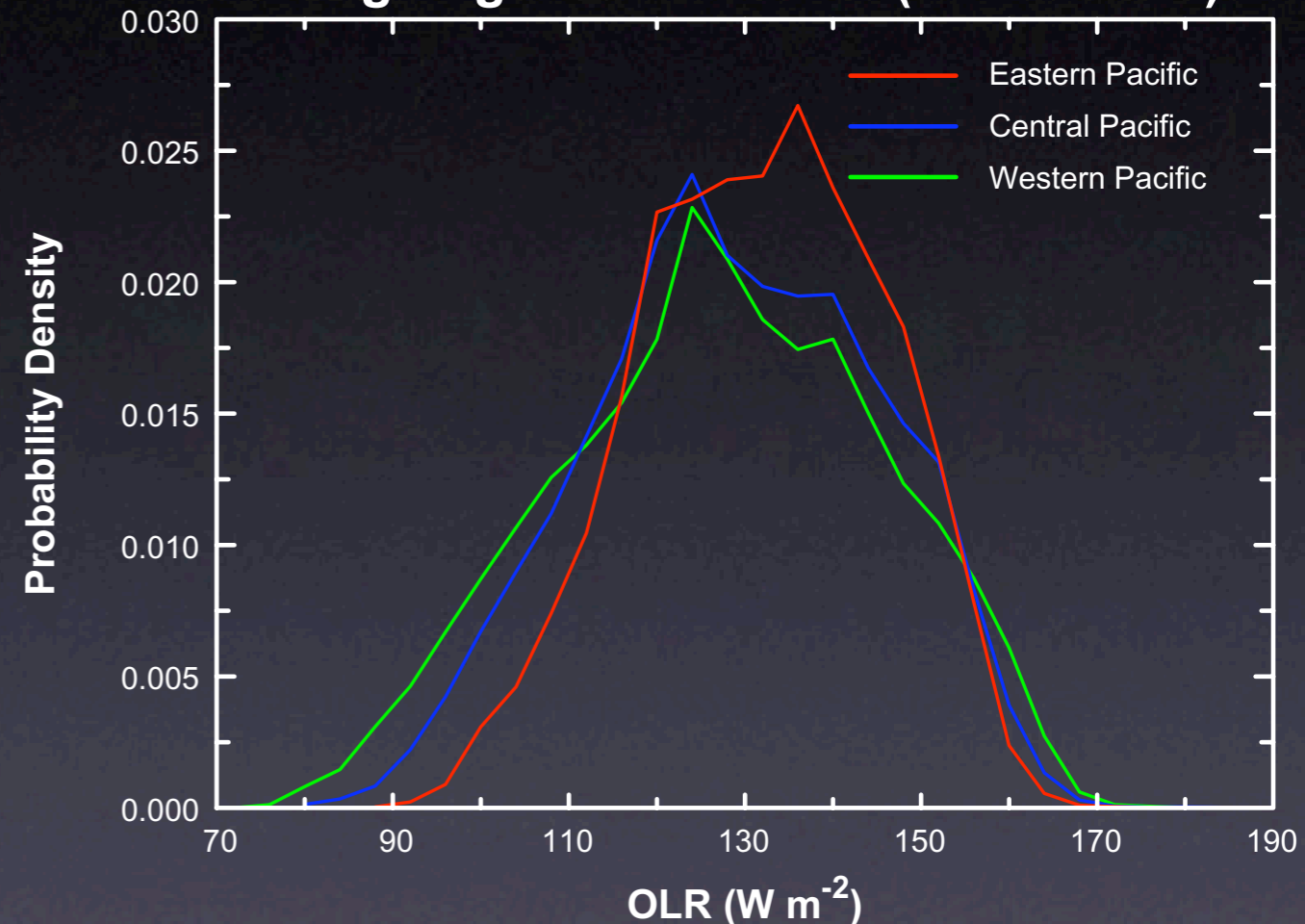
Subgrid characteristics of TDC

PDF of Outgoing Longwave Radiation

Outgoing L/W Radiation (March 1998)



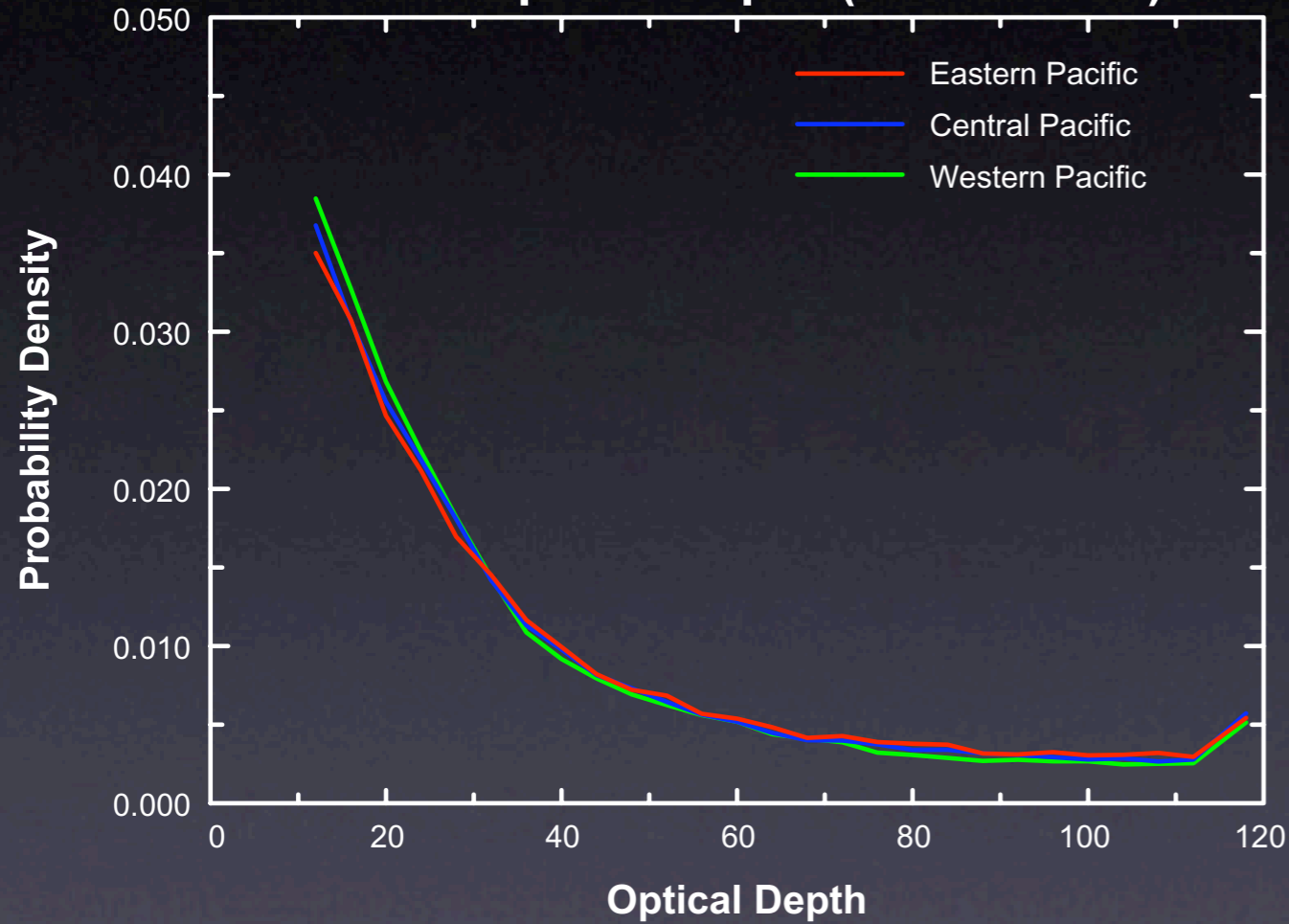
Outgoing L/W Radiation (March 2000)



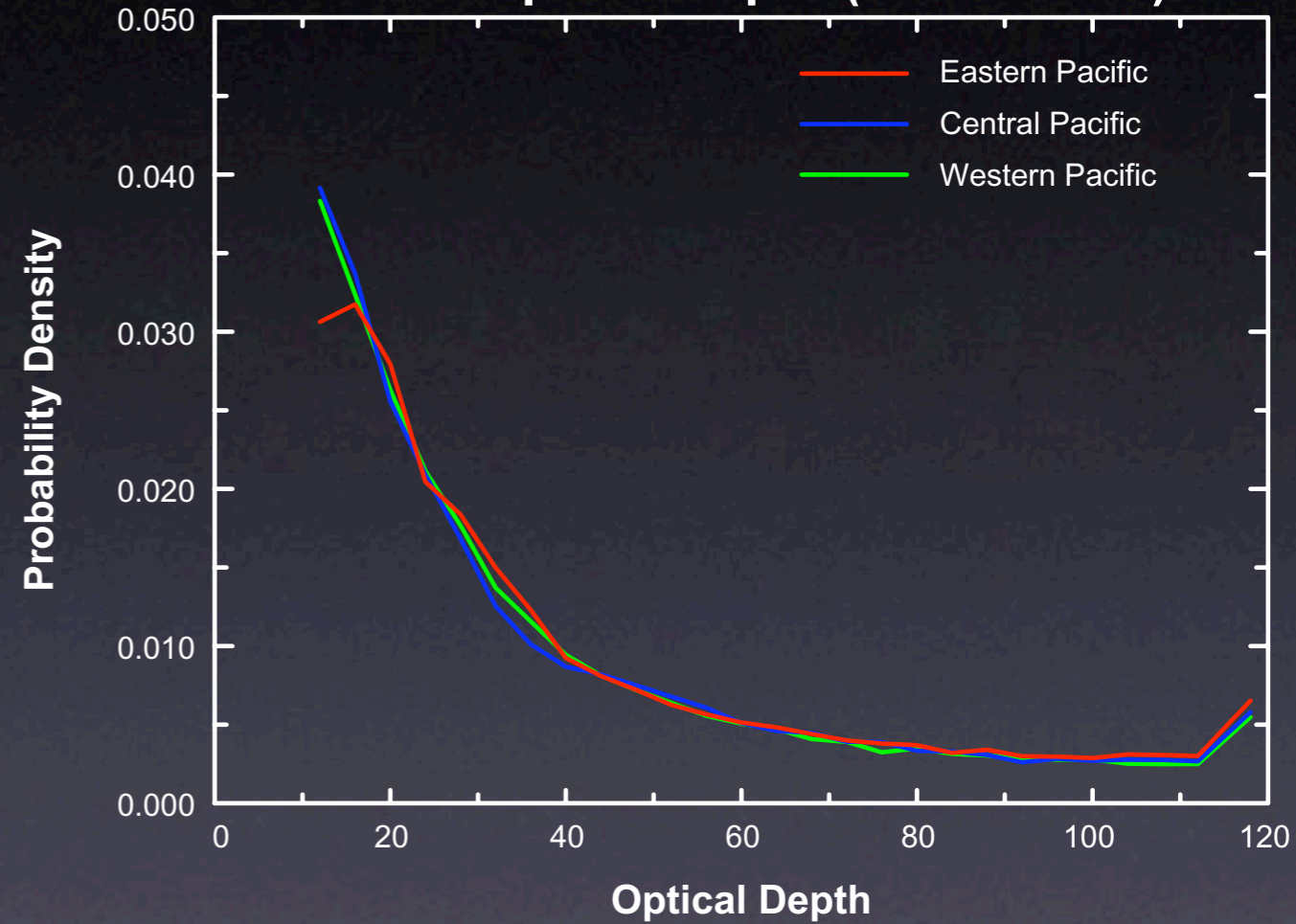
Subgrid characteristics of TDC

PDF of Cloud Optical Depth

Cloud Optical Depth (March 1998)



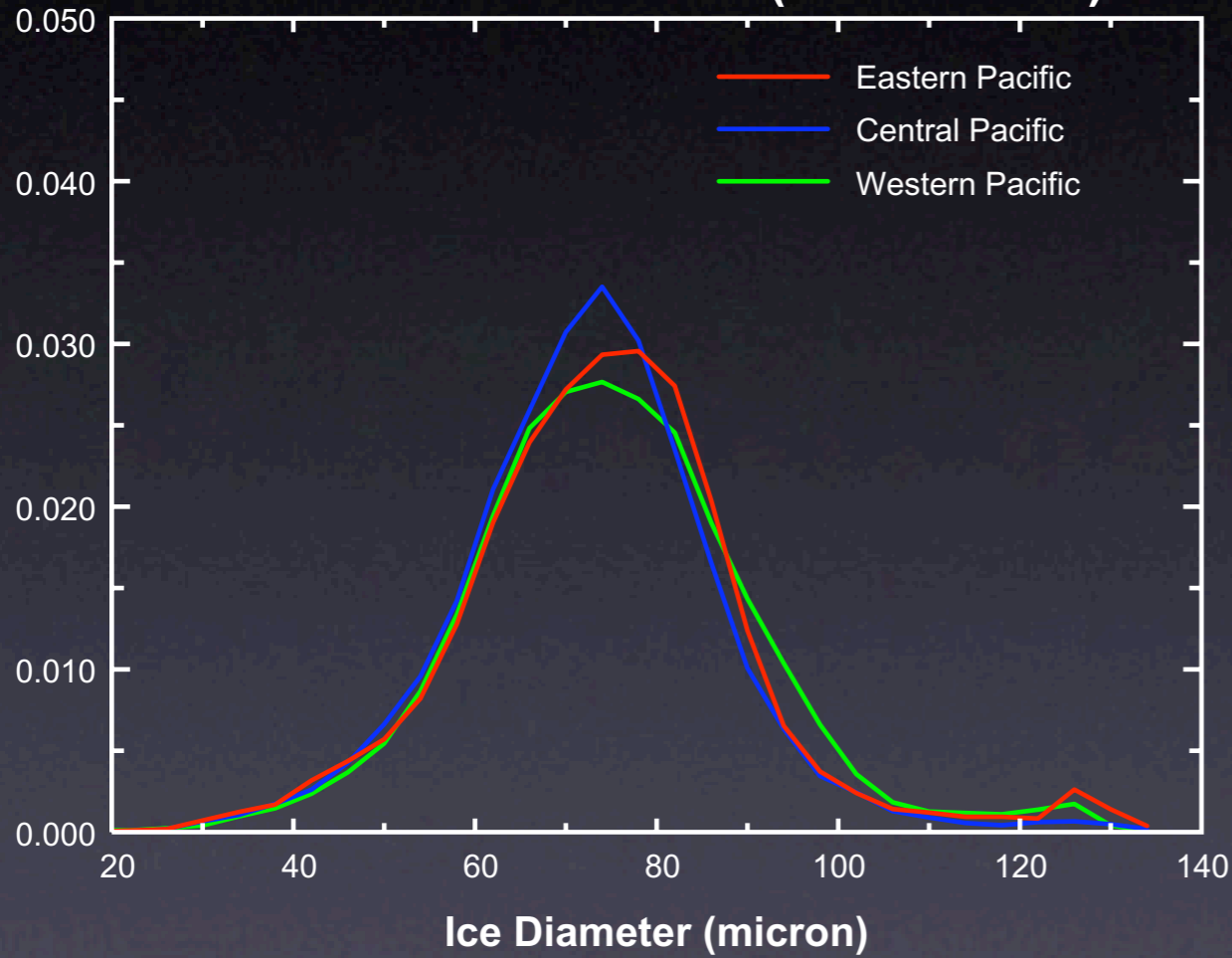
Cloud Optical Depth (March 2000)



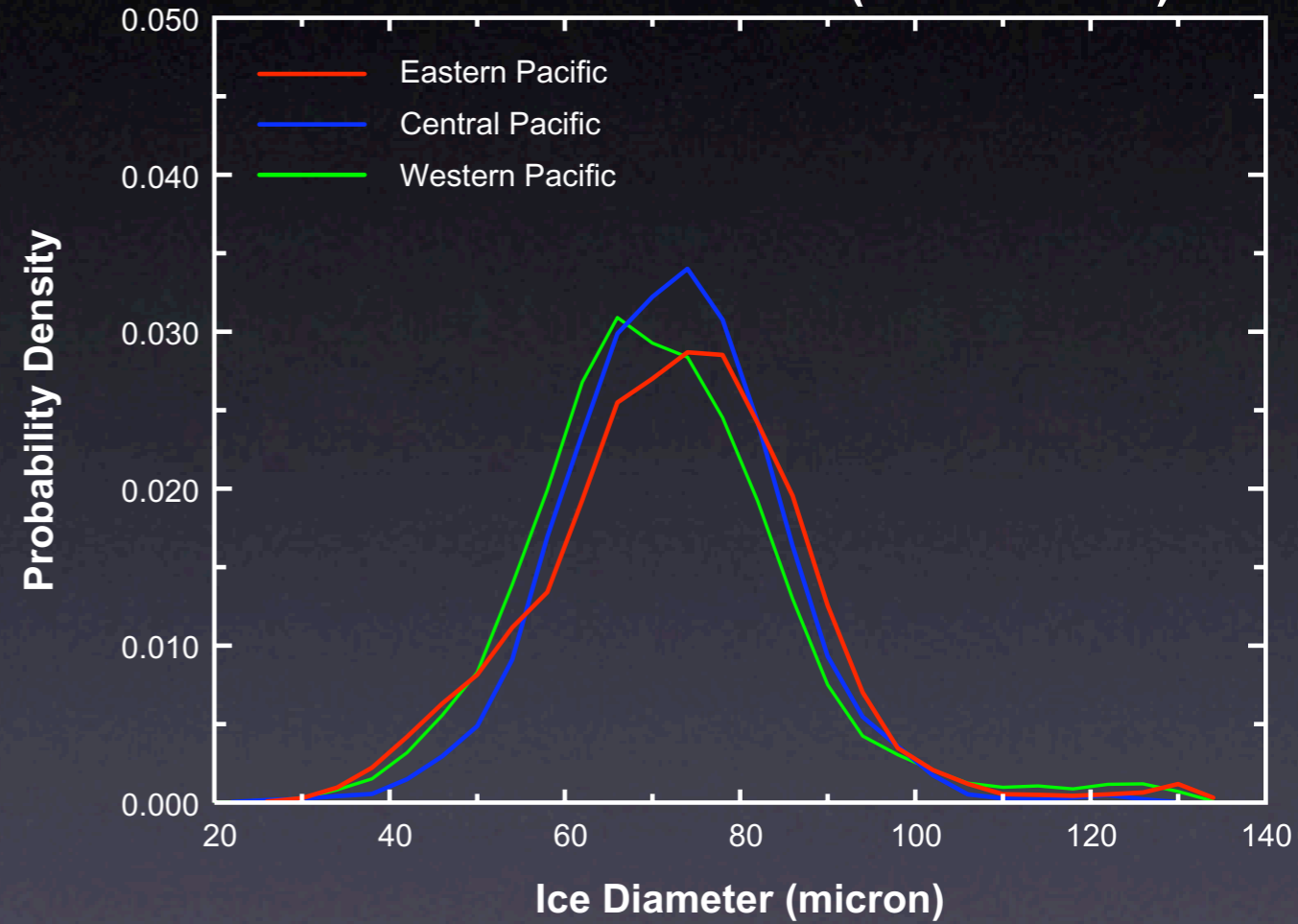
Subgrid characteristics of TDC

PDF of Ice Particle Diameter

Ice Particle Diameter (March 1998)



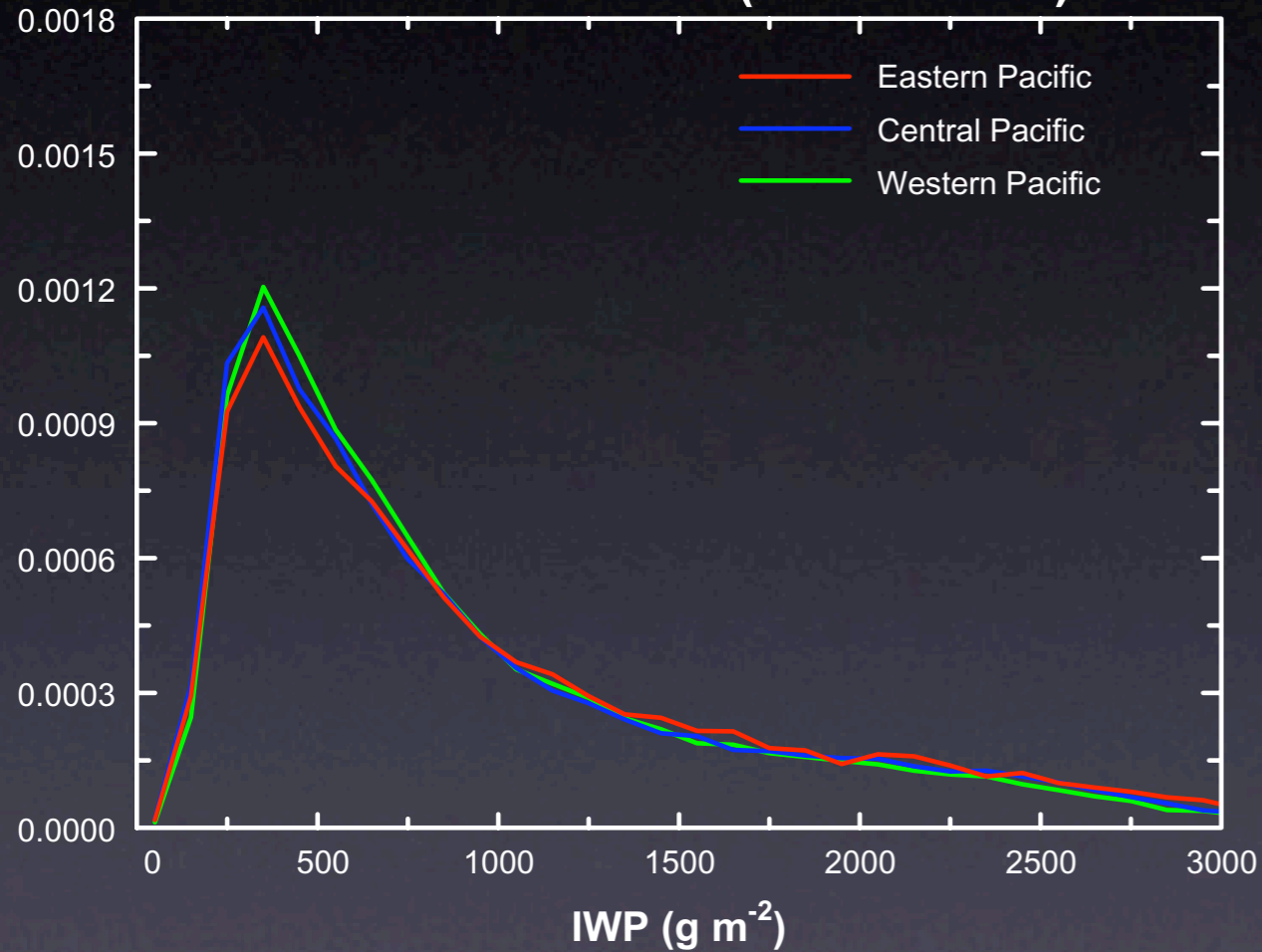
Ice Particle Diameter (March 2000)



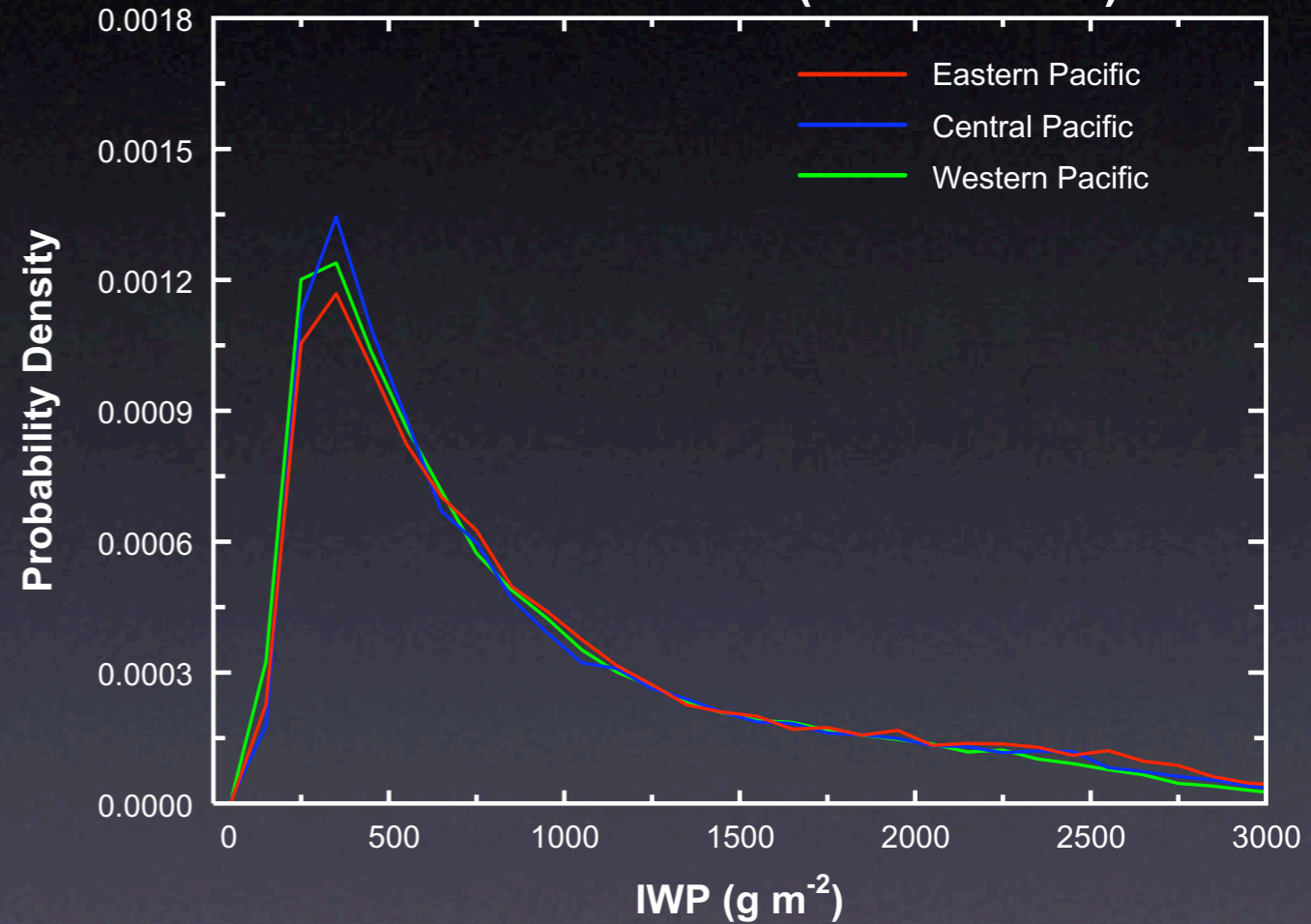
Subgrid characteristics of TDC

PDF of Total Water Path

Total Water Path (March 1998)



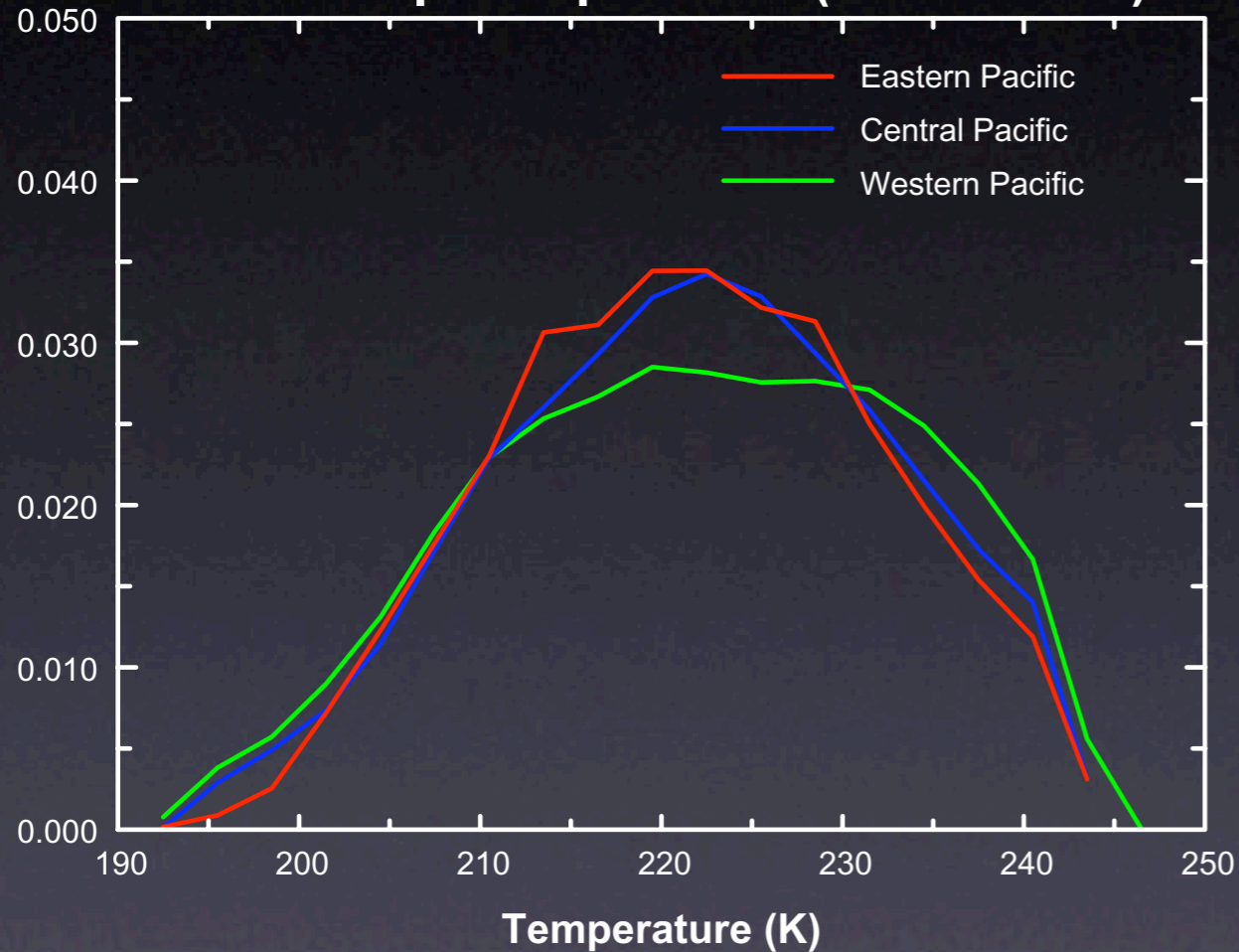
Total Water Path (March 2000)



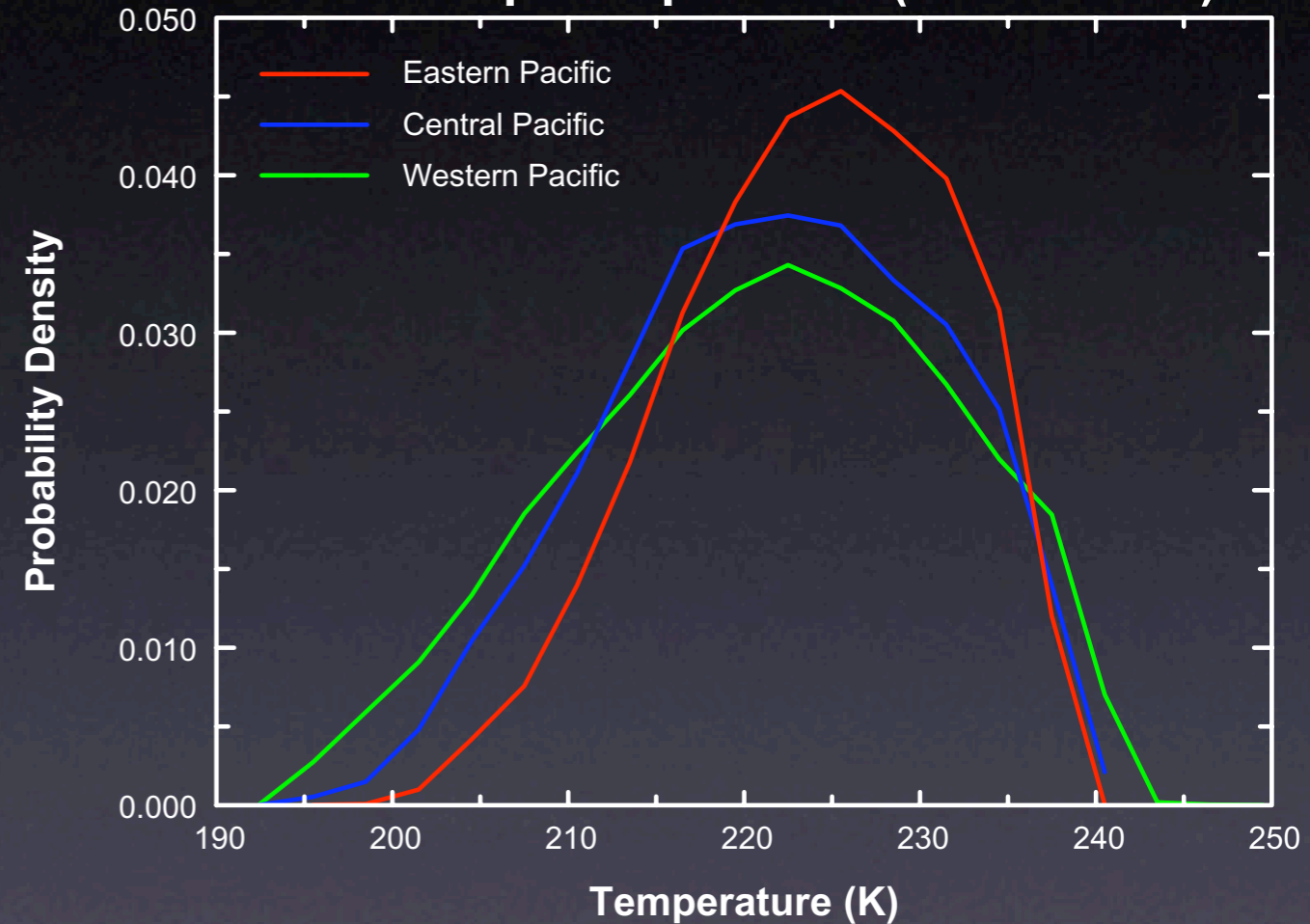
Subgrid characteristics of TDC

PDF of Cloud Top Temperature

Cloud Top Temperature (March 1998)



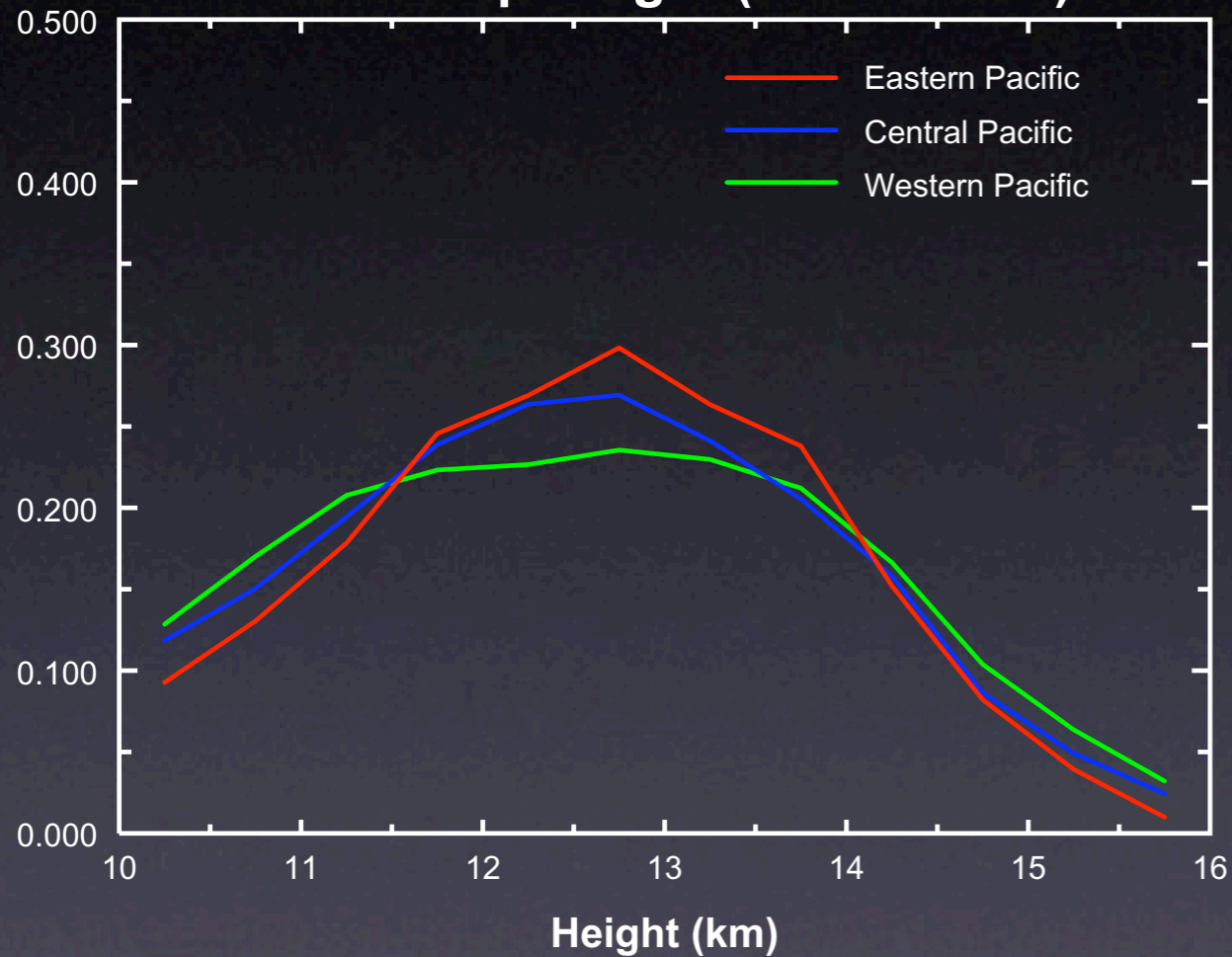
Cloud Top Temperature (March 2000)



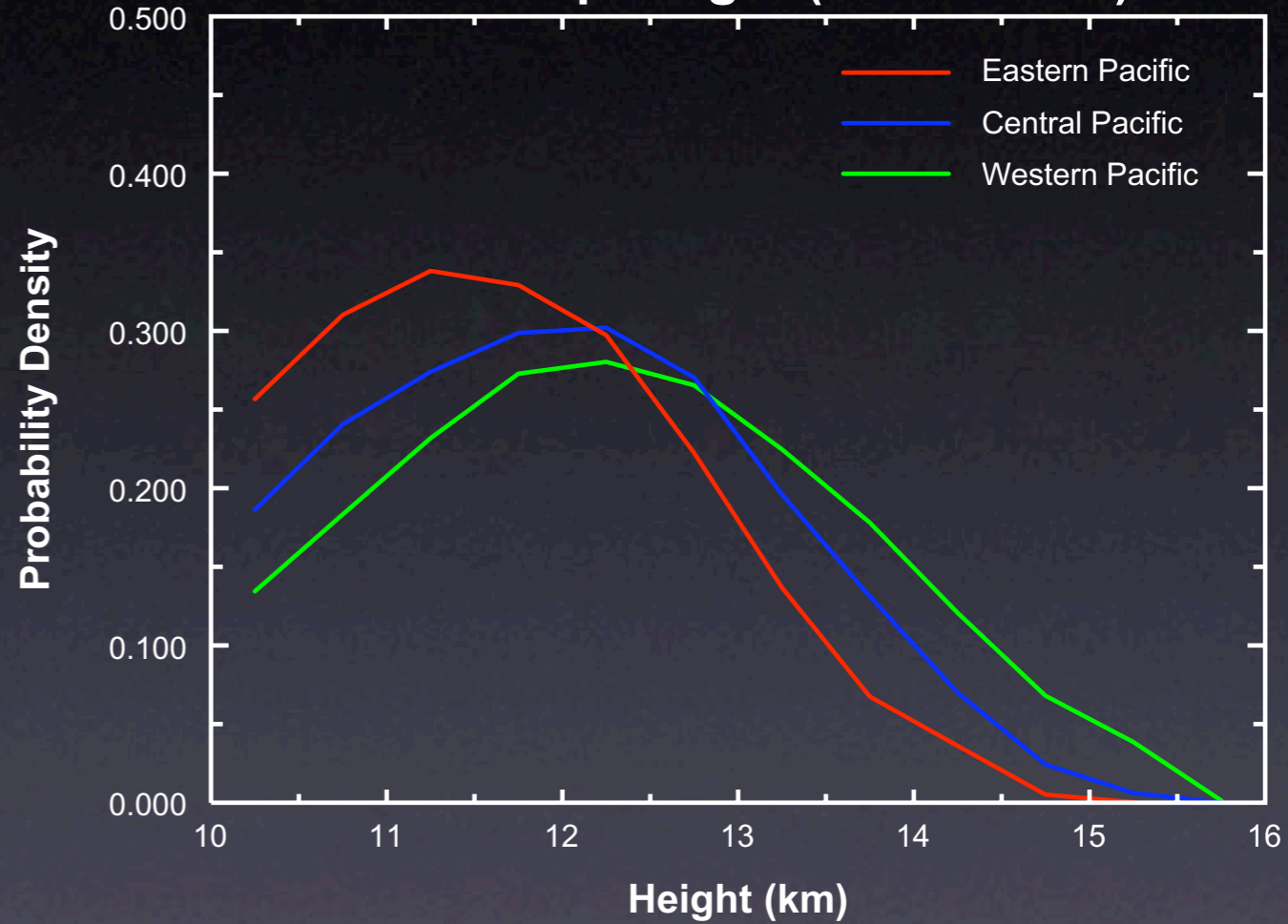
Subgrid characteristics of TDC

PDF of Cloud Top Height

Cloud Top Height (March 1998)



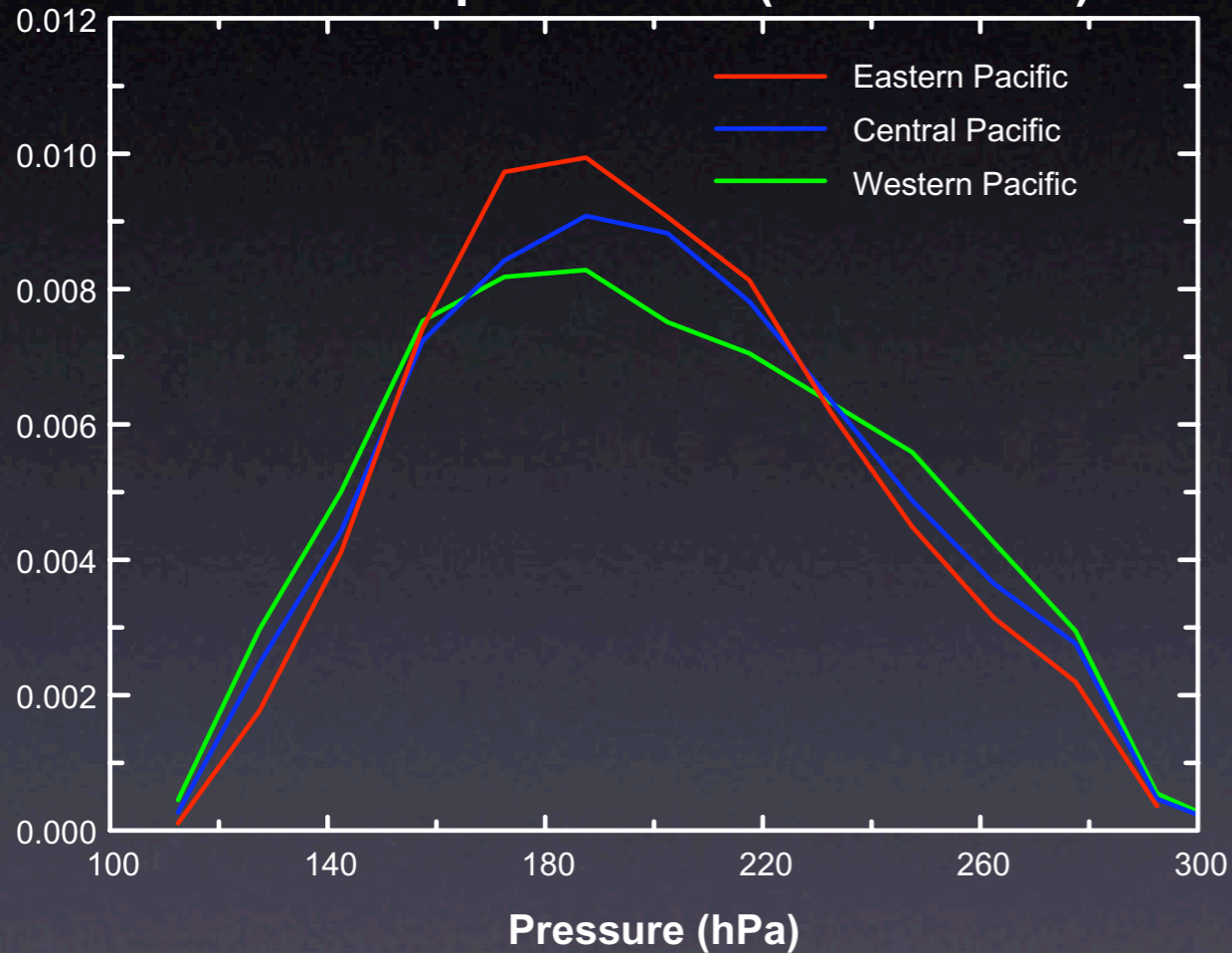
Cloud Top Height (March 2000)



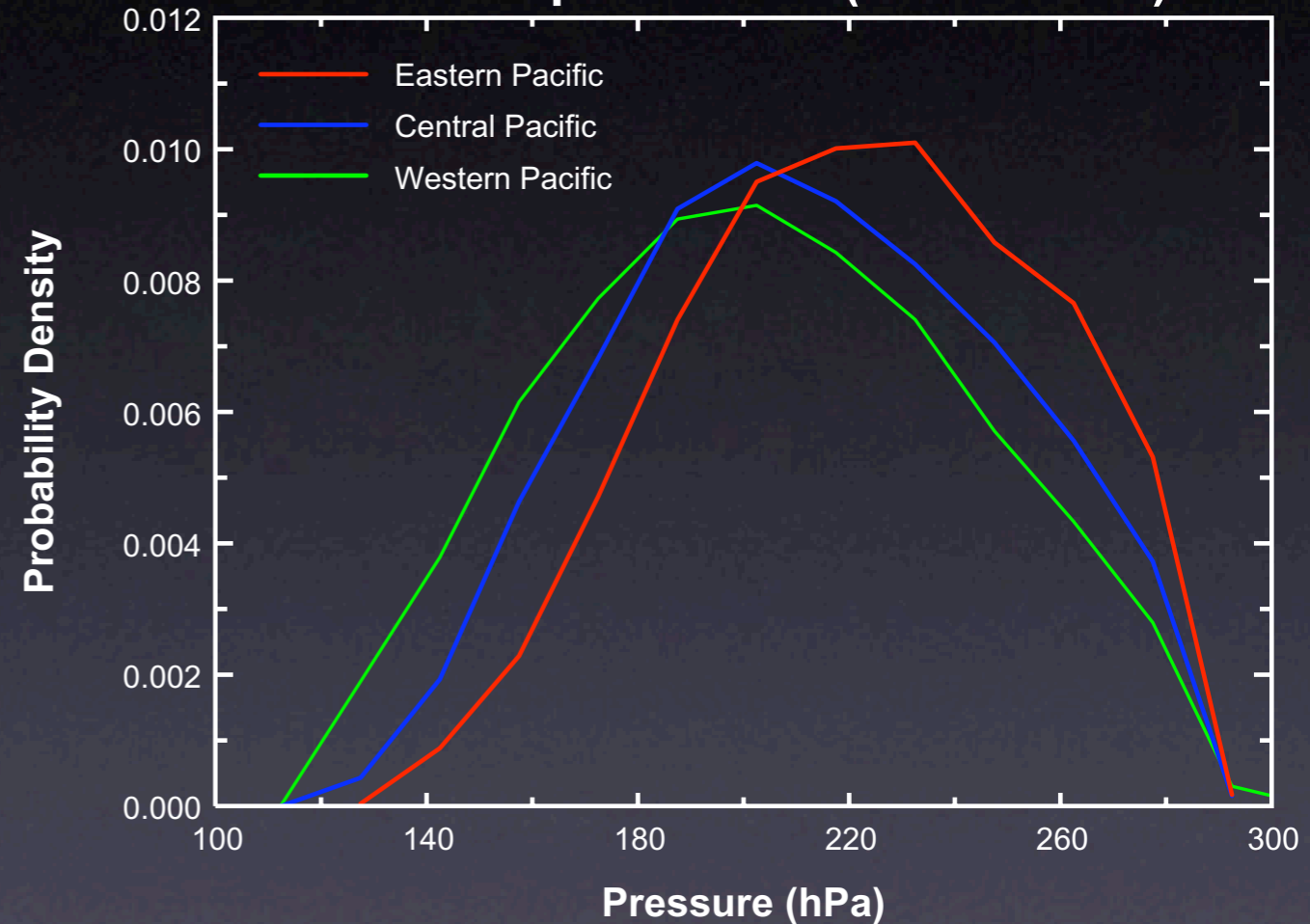
Subgrid characteristics of TDC

PDF of Cloud Top Pressure

Cloud Top Pressure (March 1998)

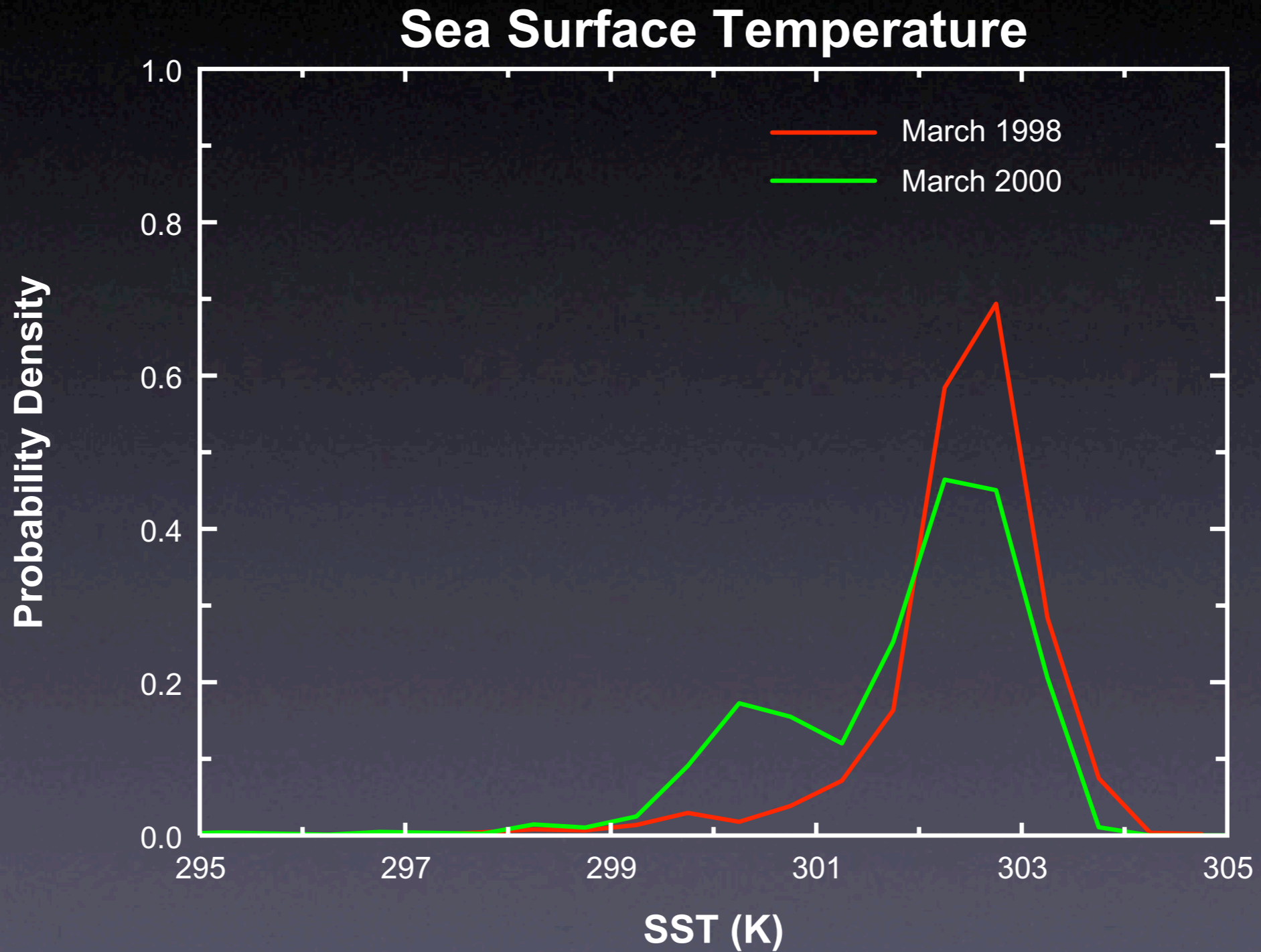


Cloud Top Pressure (March 2000)



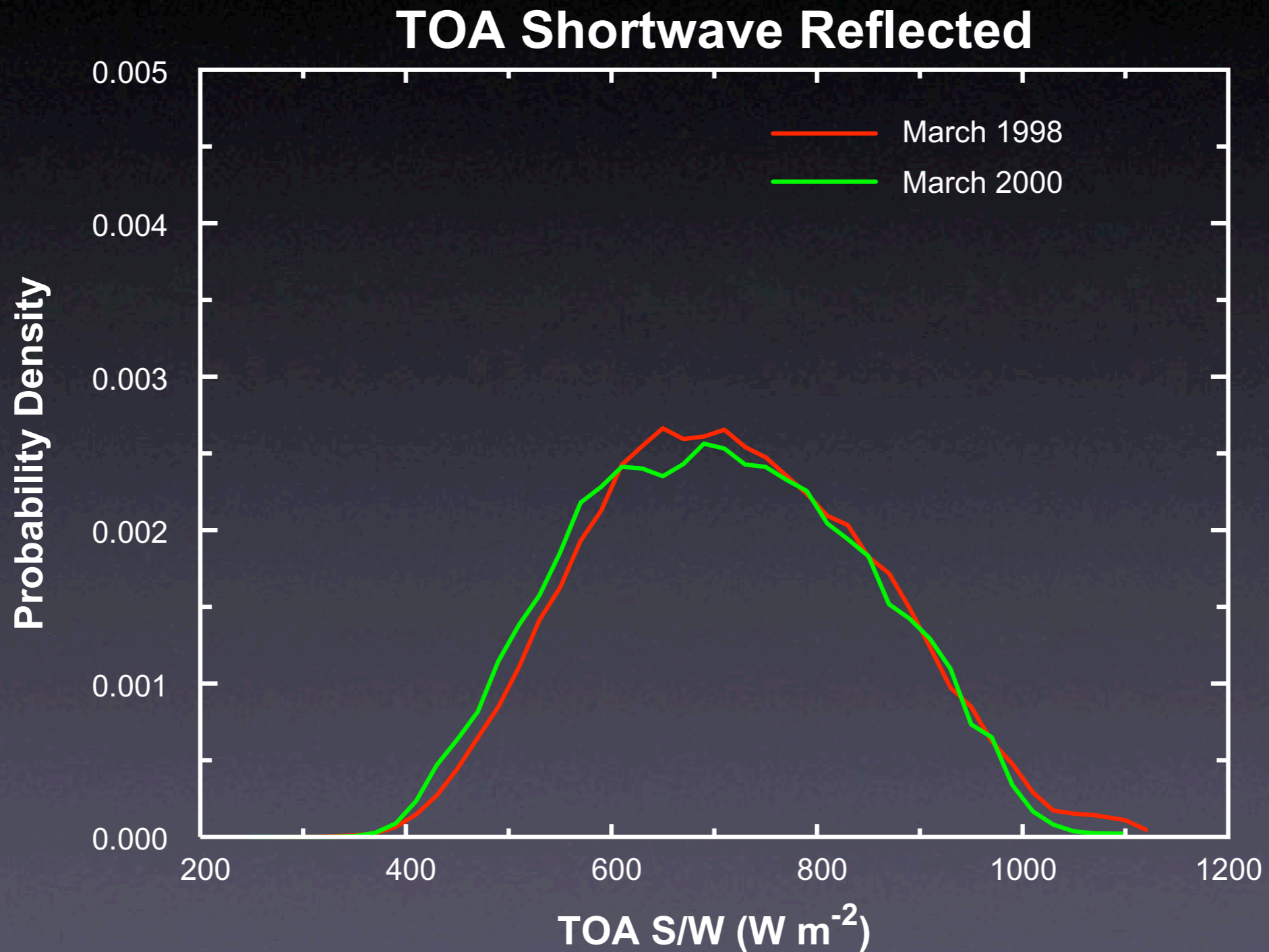
Subgrid characteristics of TDC

PDF of Sea Surface Temperature (SST)



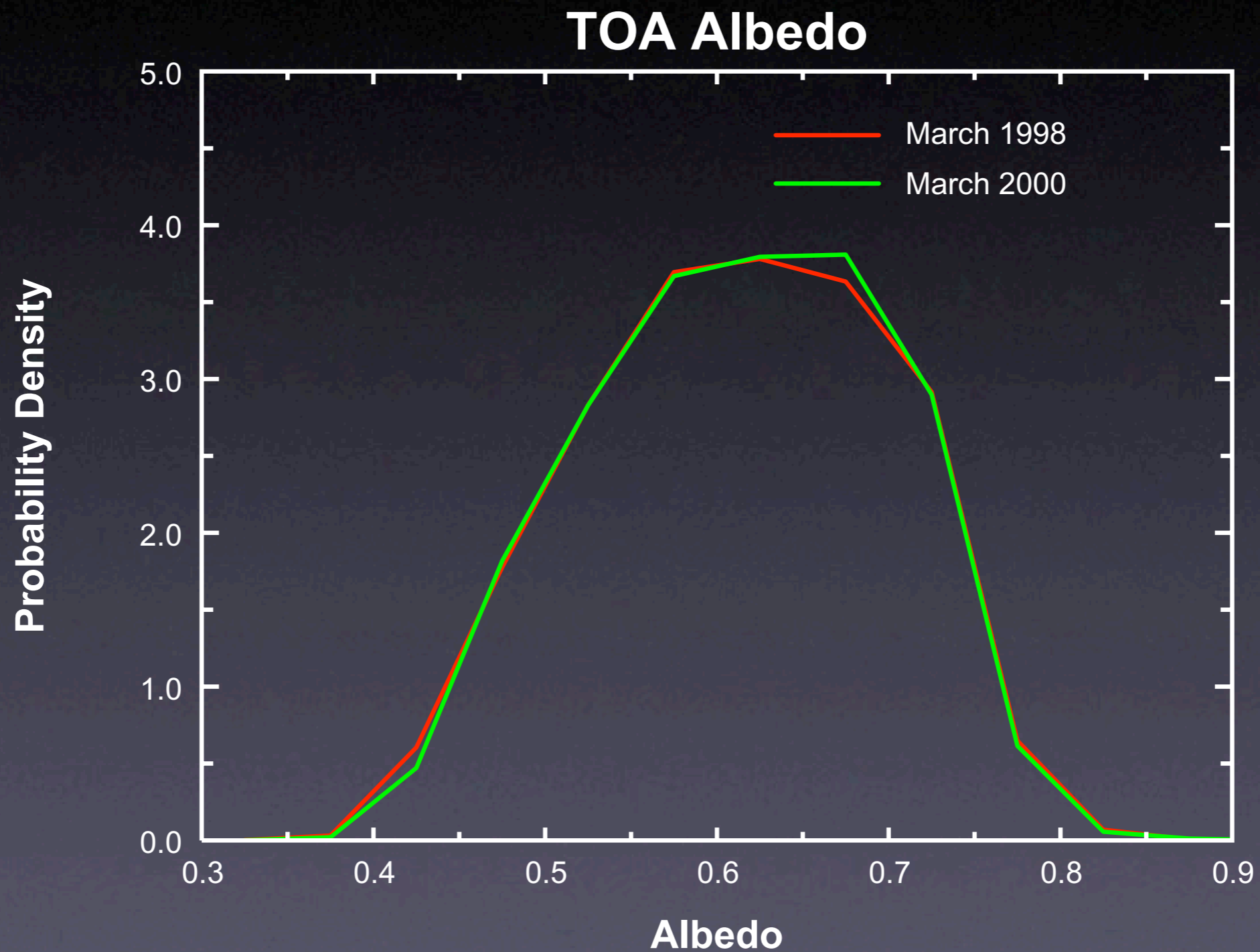
Subgrid characteristics of TDC

PDF of TOA Reflected Shortwave (size > 300km)



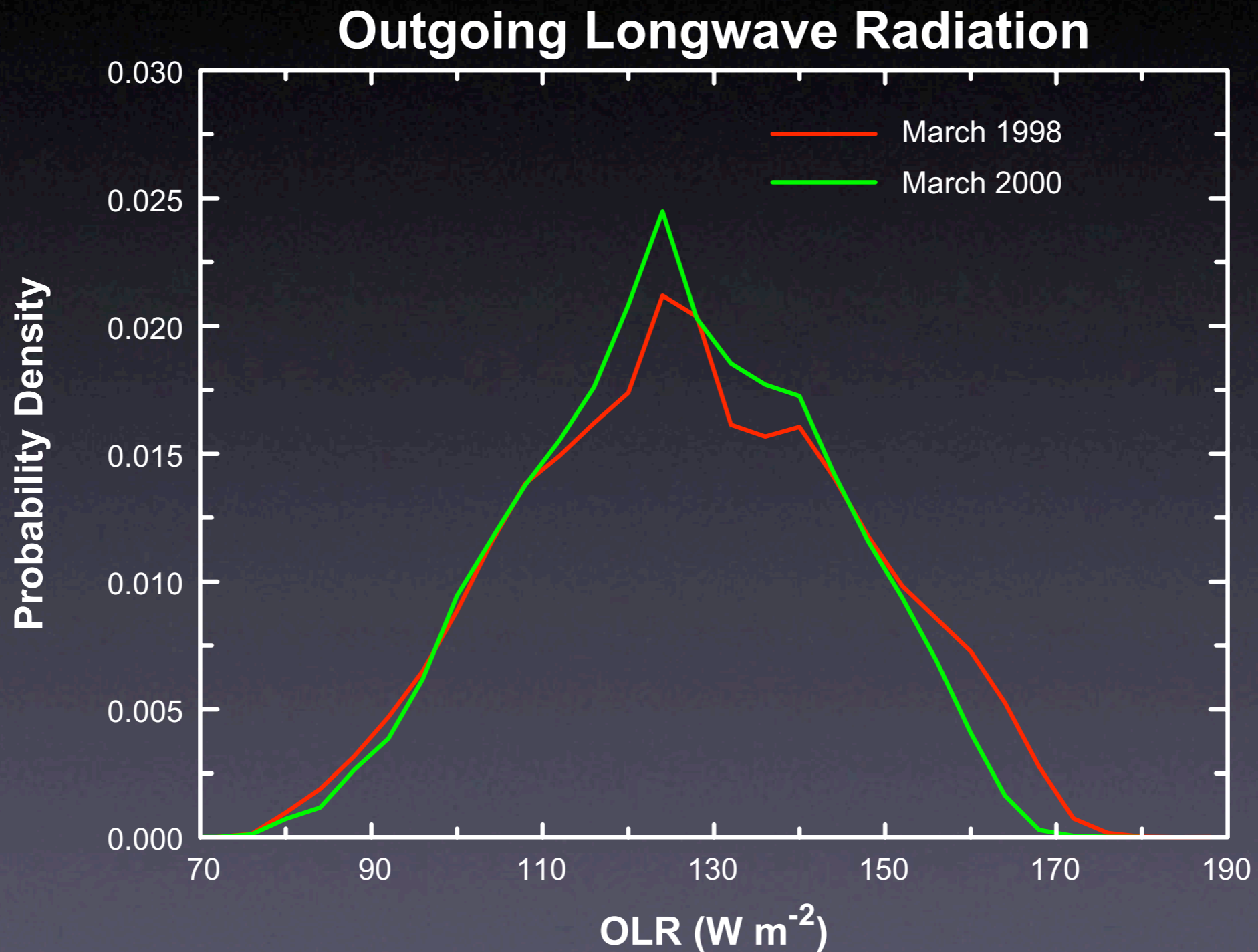
Subgrid characteristics of TDC

PDF of Top-of-atmosphere Albedo (size > 300km)



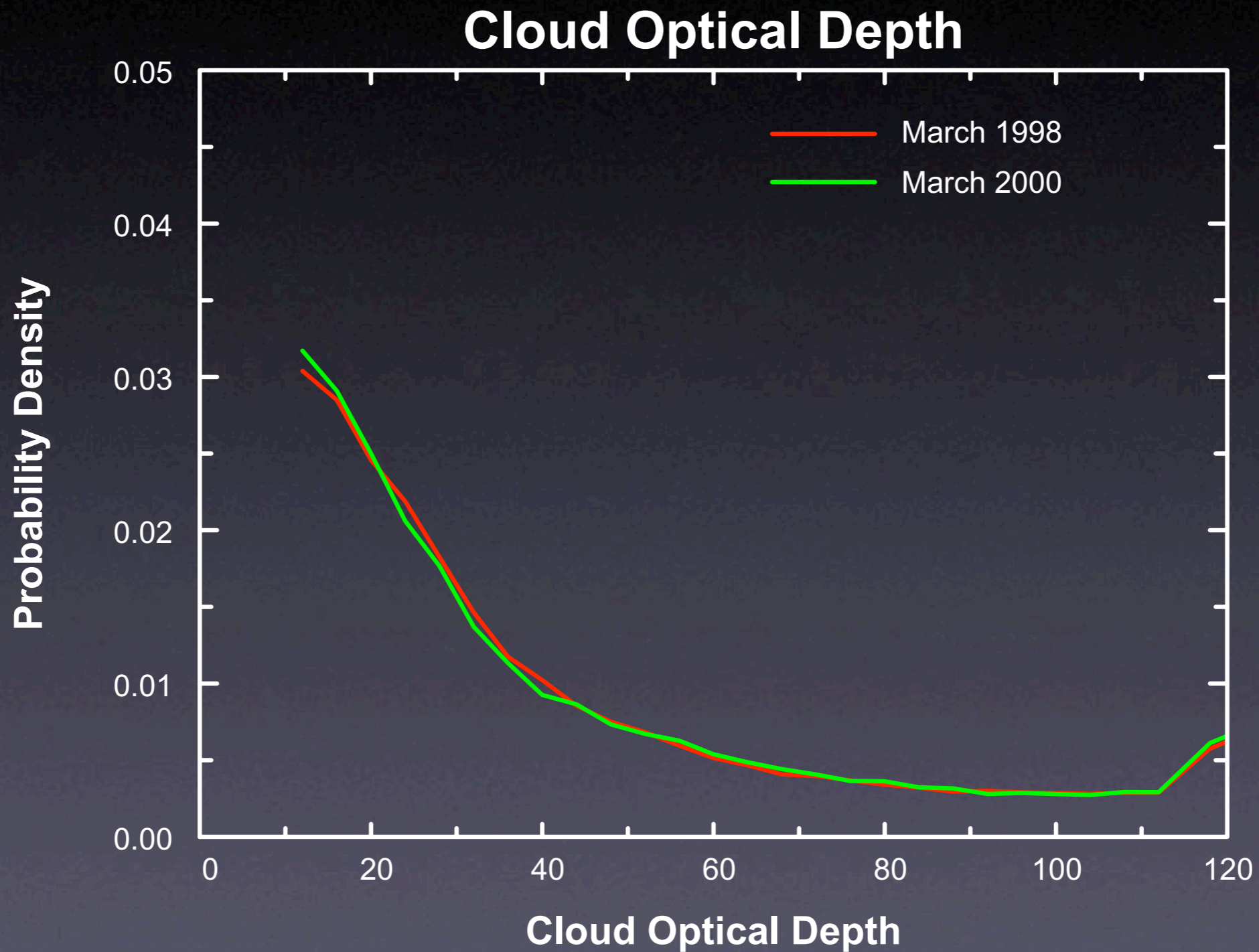
Subgrid characteristics of TDC

PDF of Outgoing Longwave Radiation (size > 300km)



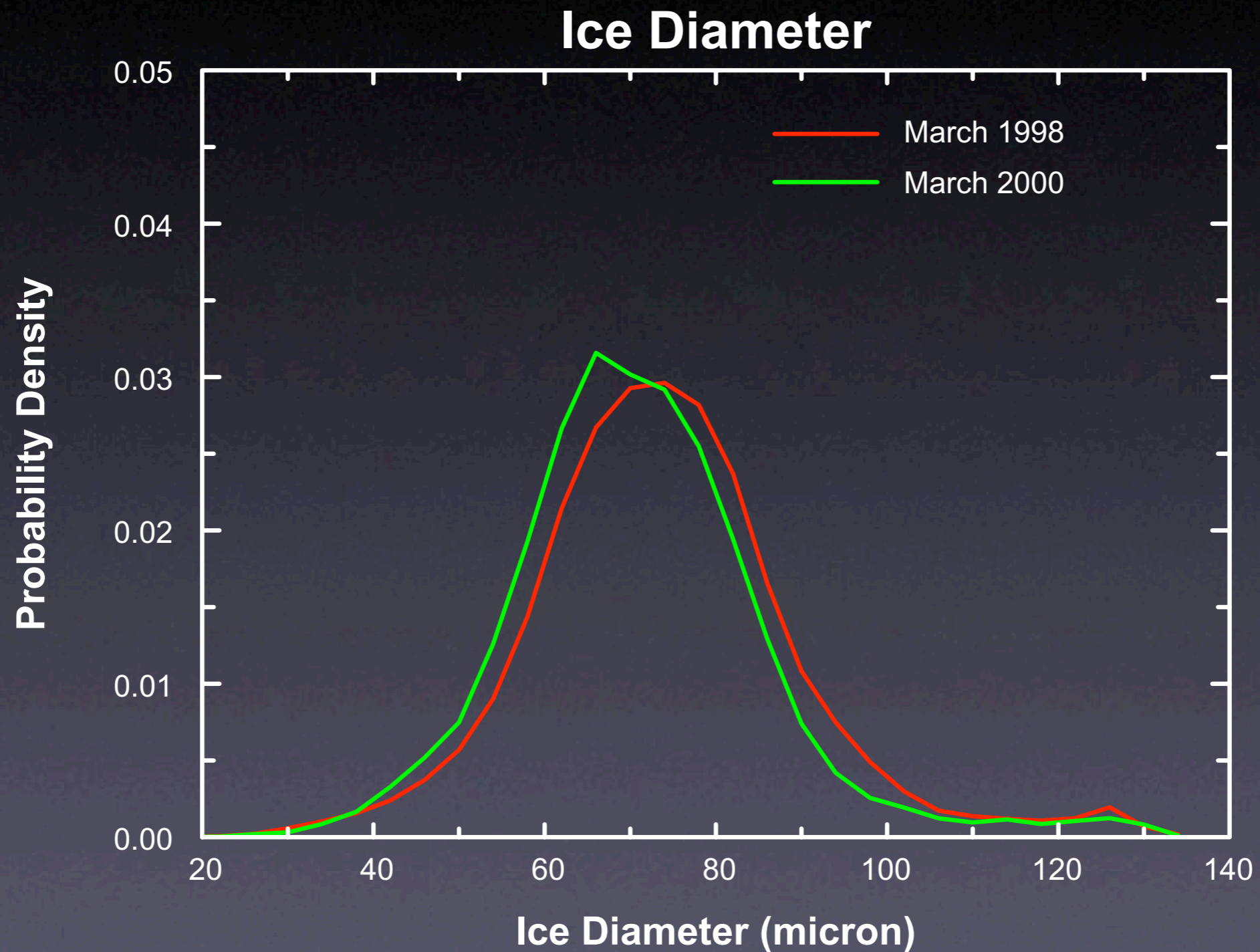
Subgrid characteristics of TDC

PDF of Cloud Optical Depth (size > 300km)



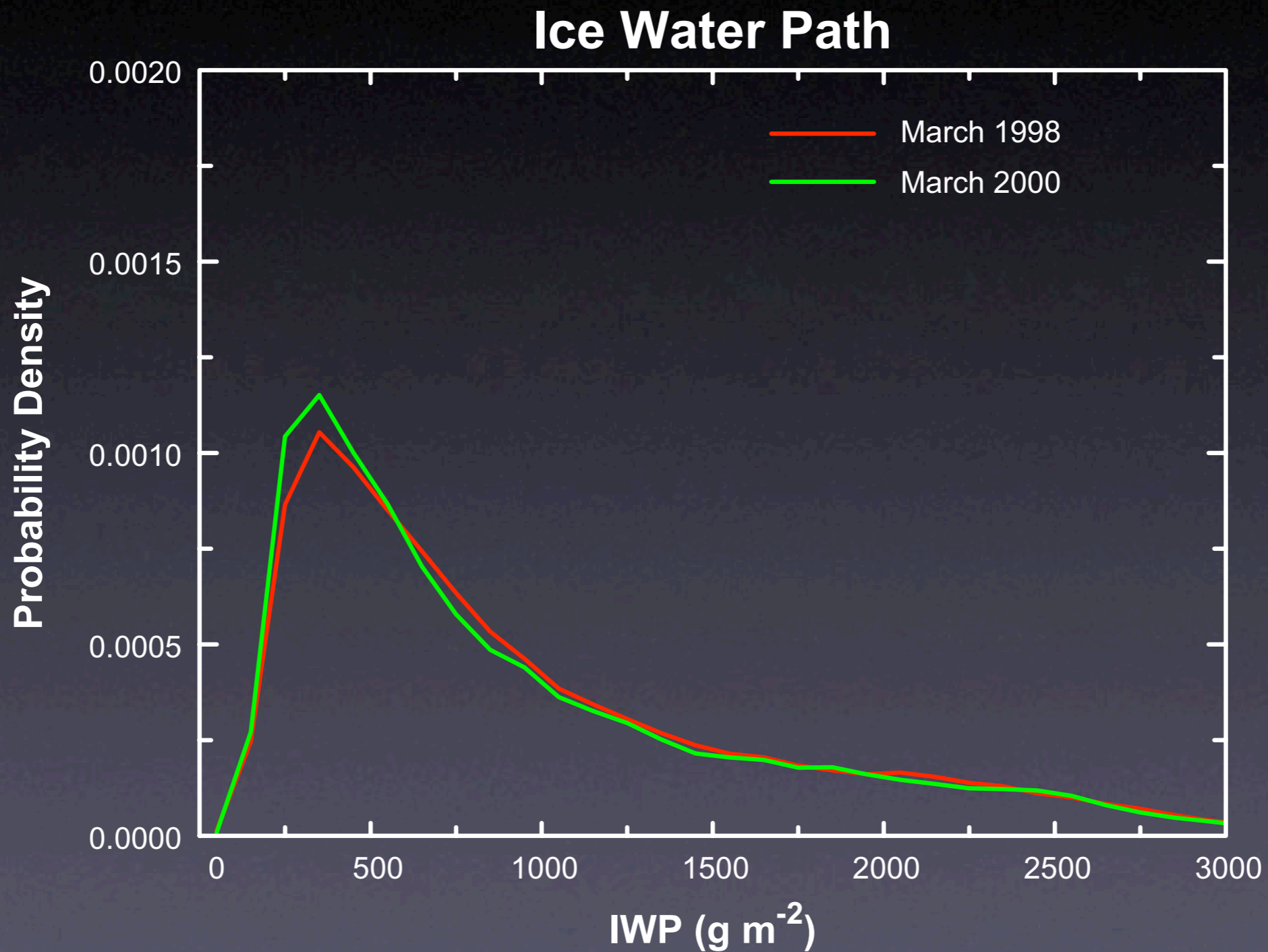
Subgrid characteristics of TDC

PDF of Ice Particle Diameter (size > 300km)



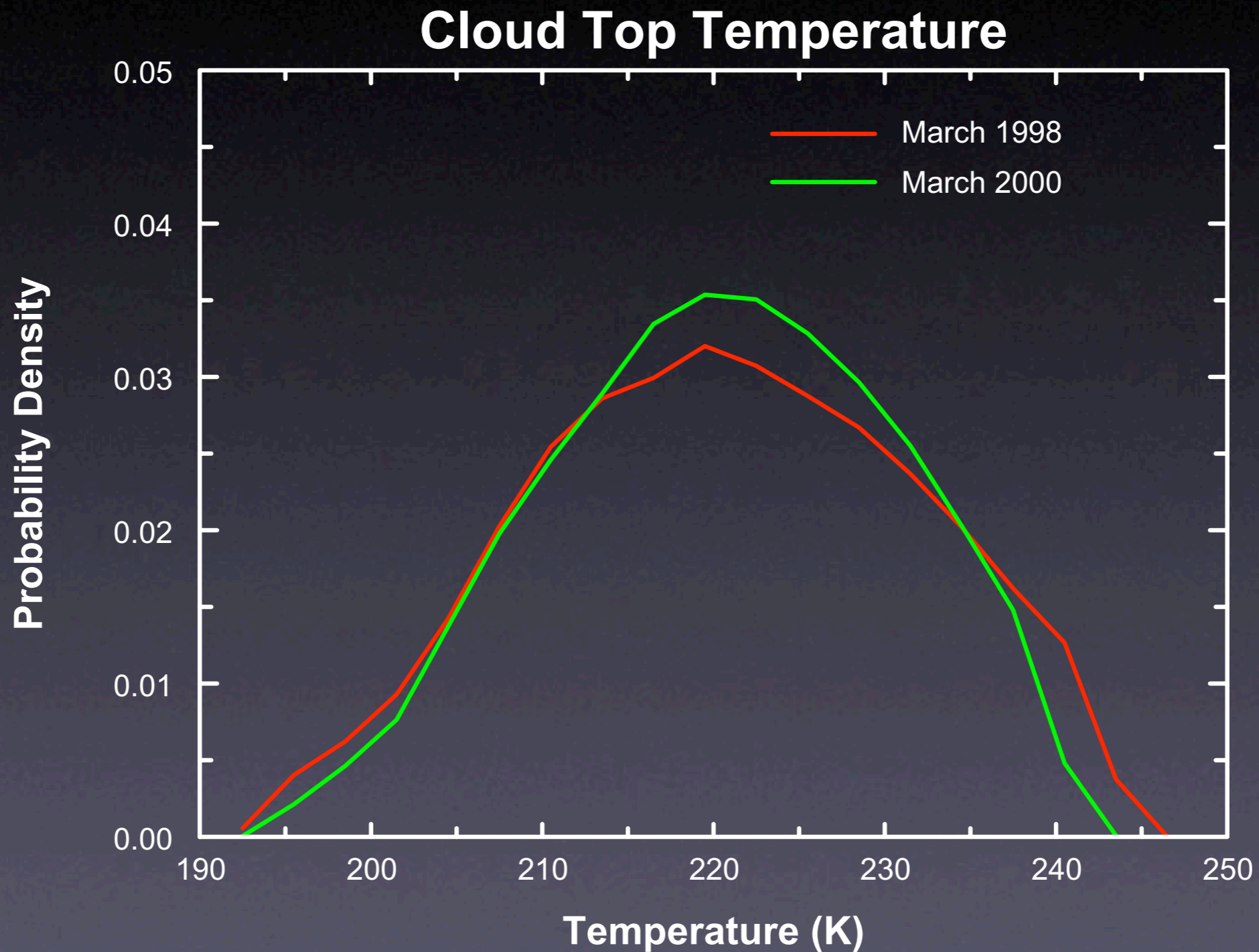
Subgrid characteristics of TDC

PDF of Ice Water Path (size > 300km)



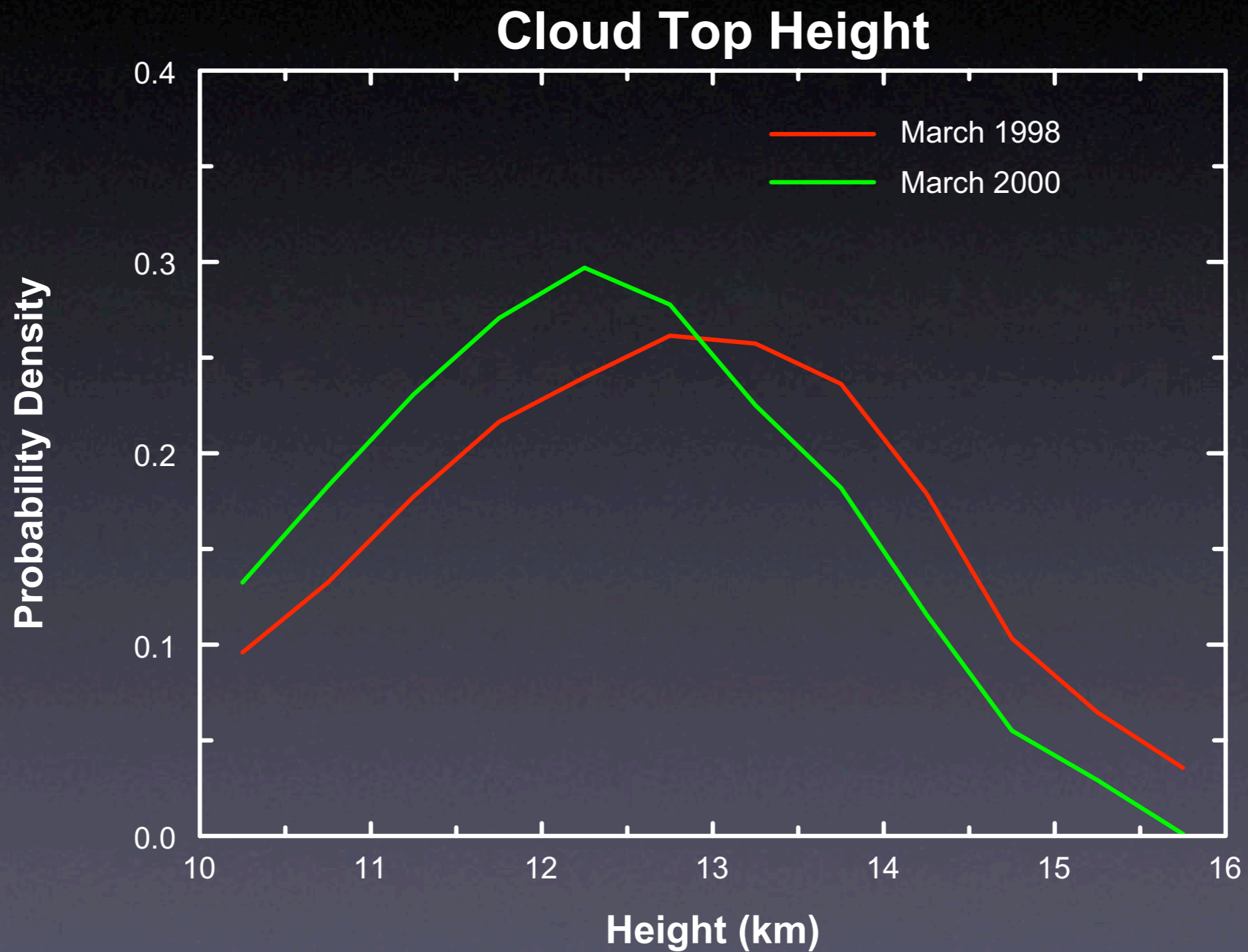
Subgrid characteristics of TDC

PDF of Cloud Top Temperature (size > 300km)



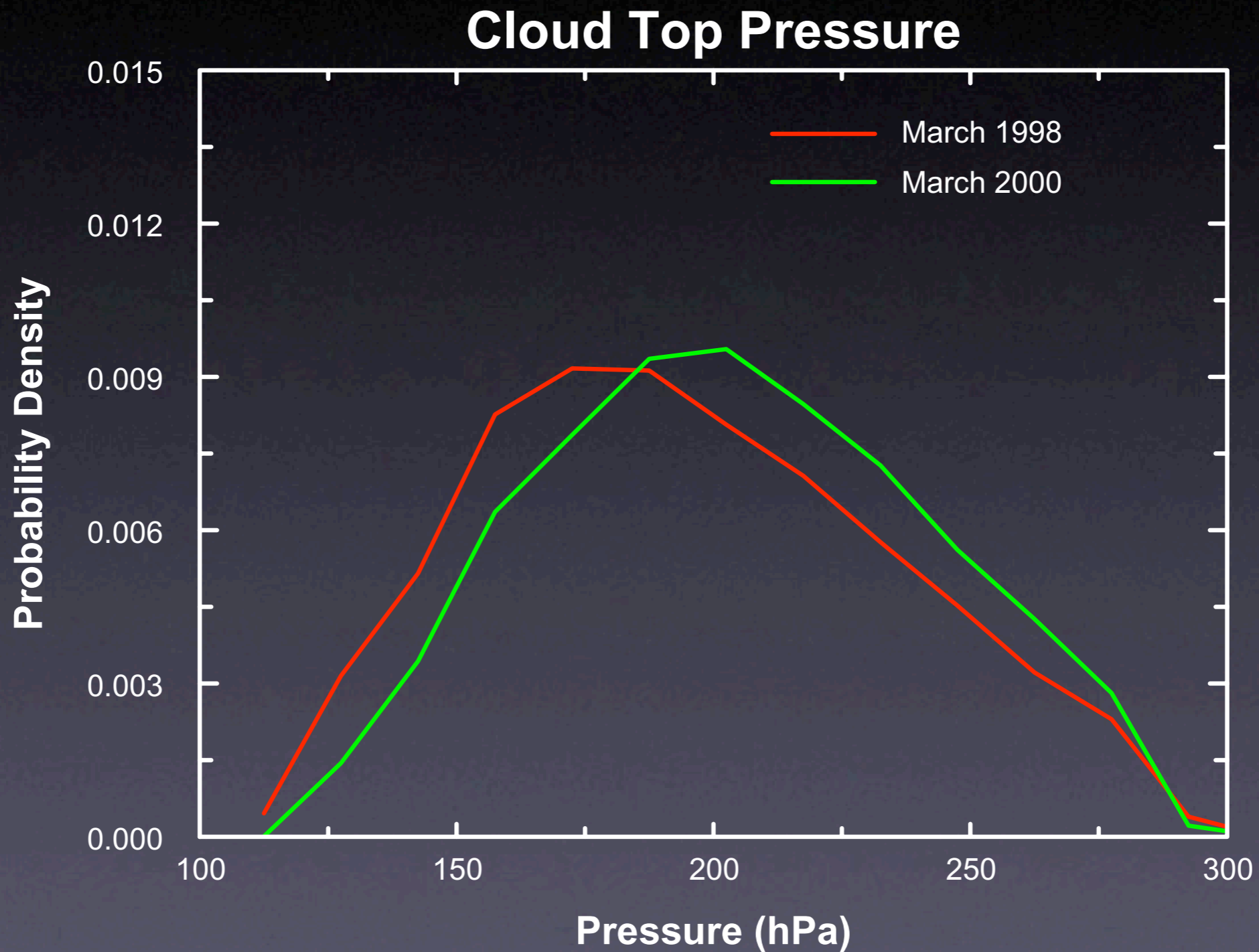
Subgrid characteristics of TDC

PDF of Cloud Top Height (size > 300km)



Subgrid characteristics of TDC

PDF of Cloud Top Pressure (size > 300km)



Sensitivity of TDC to SST

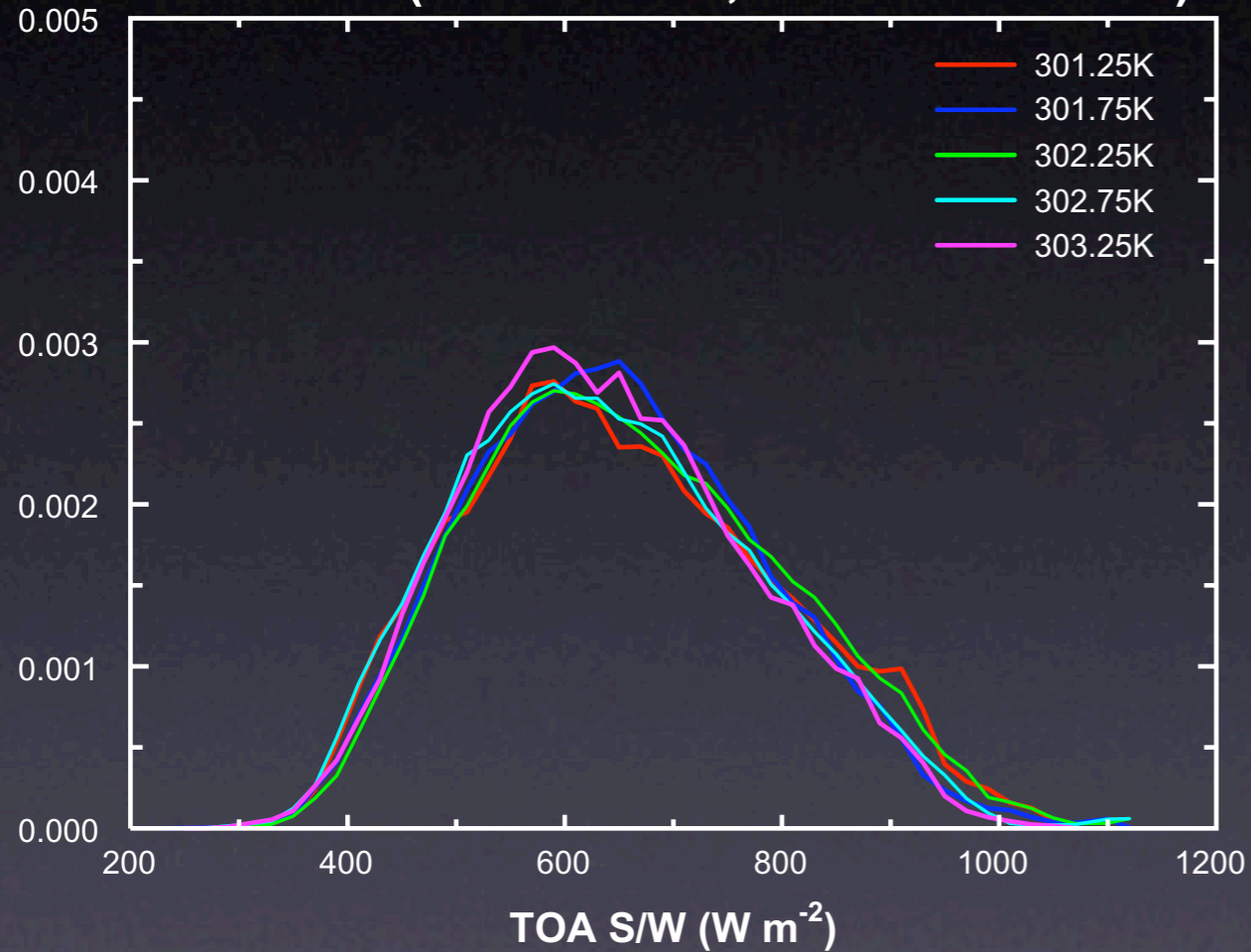
- Number of tropical deep convections as a function of sea surface temperature over the Pacific Ocean between January and August 1998:

SST (K)	100 - 300 km size class	> 300 km size class
301.25	139	30
301.75	277	77
302.25	382	108
303.25	158	55

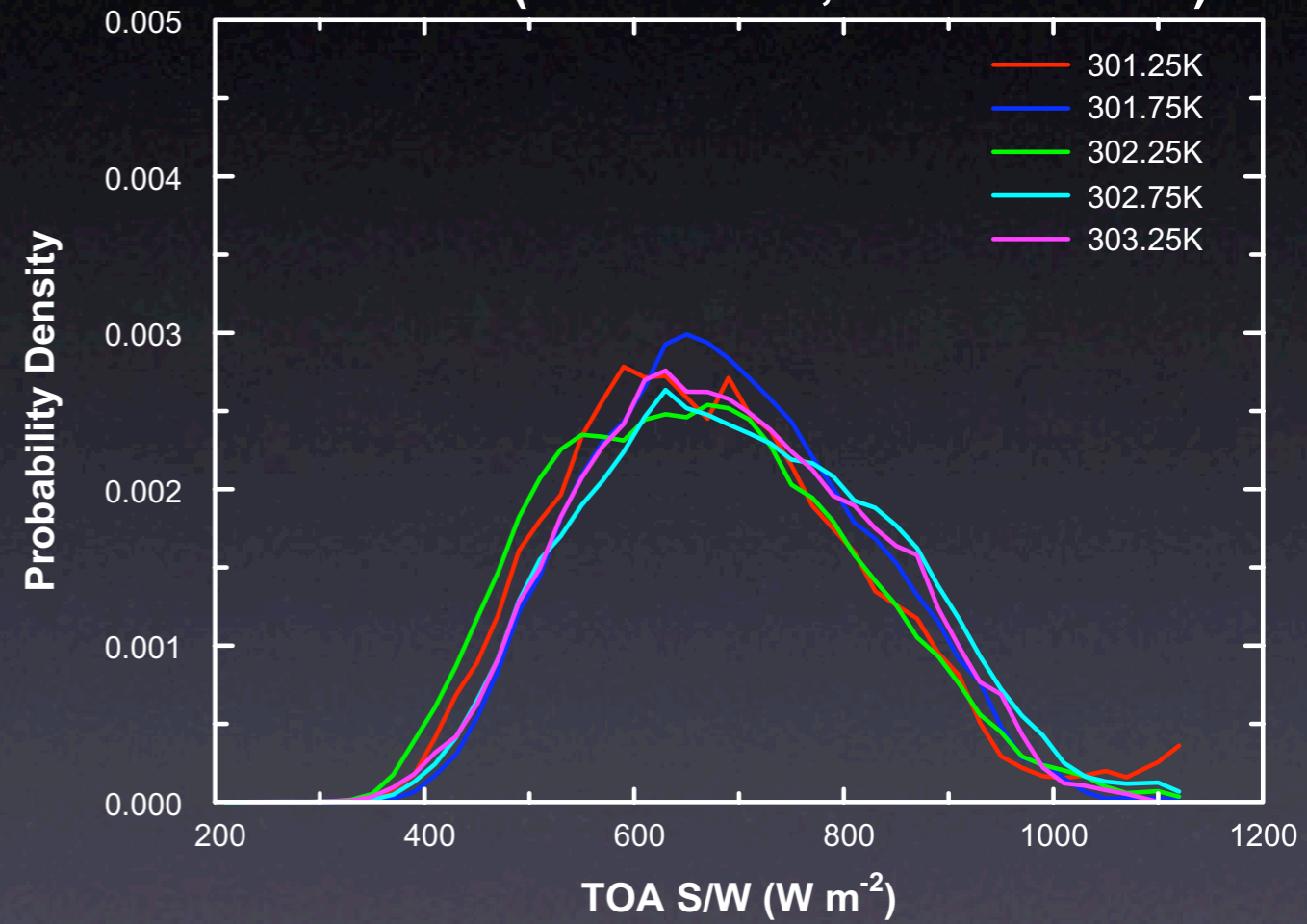
Sensitivity of TDC to SST

PDF of TOA Reflected Shortwave

TOA S/W (March 1998; size 100-300 km)



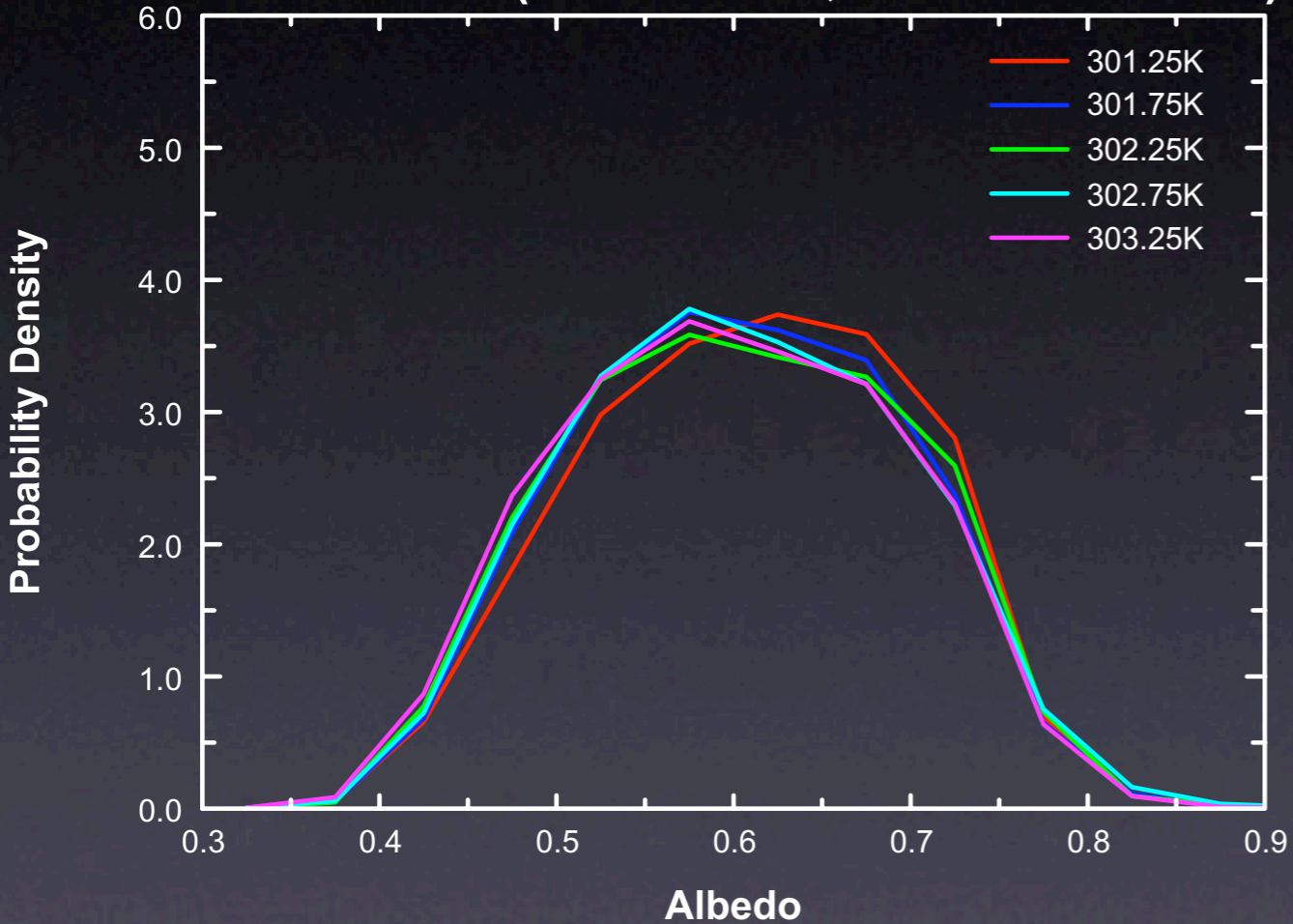
TOA S/W (March 1998; size > 300 km)



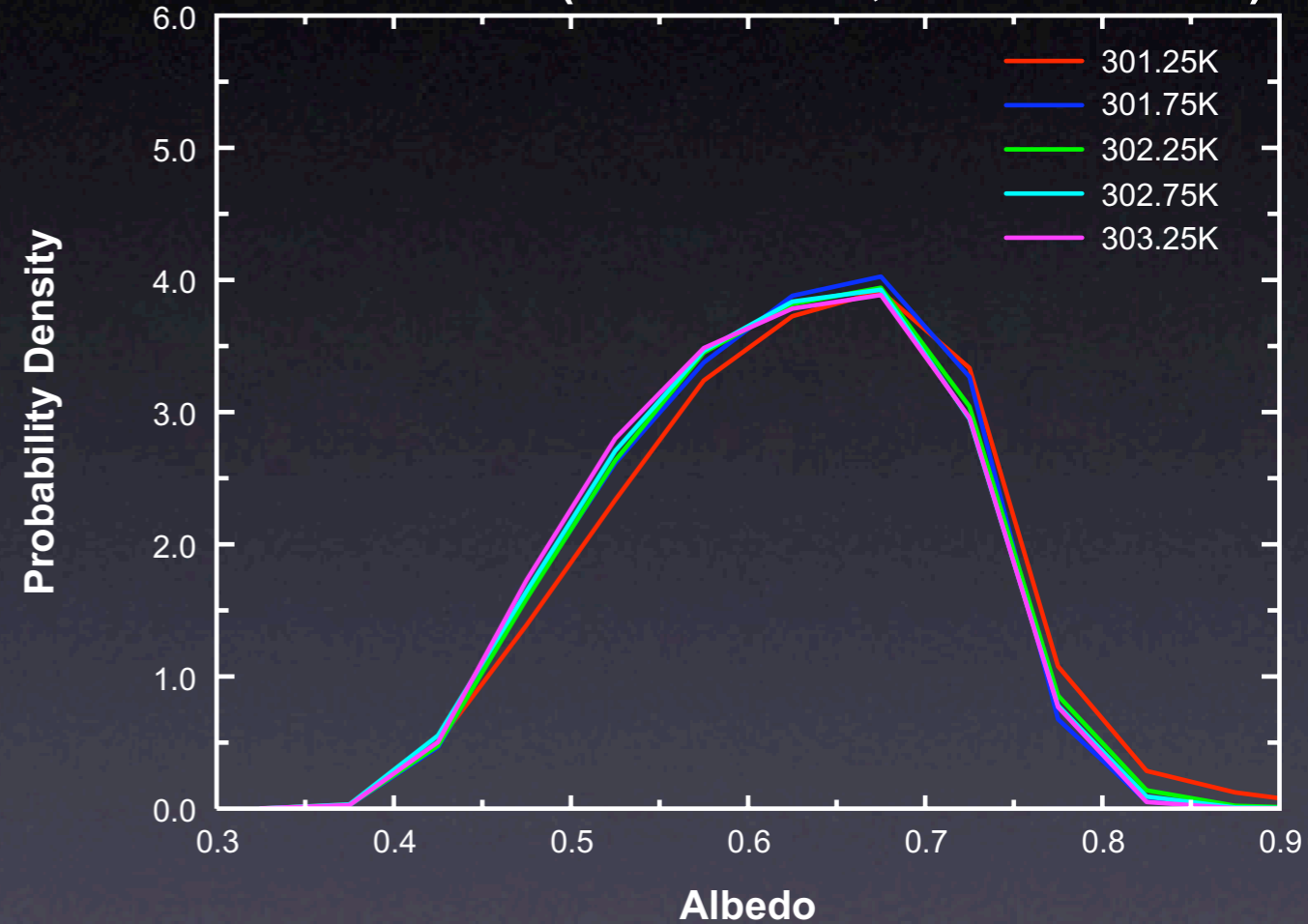
Sensitivity of TDC to SST

PDF of TOA Albedo

TOA Albedo (March 1998; size 100-300 km)



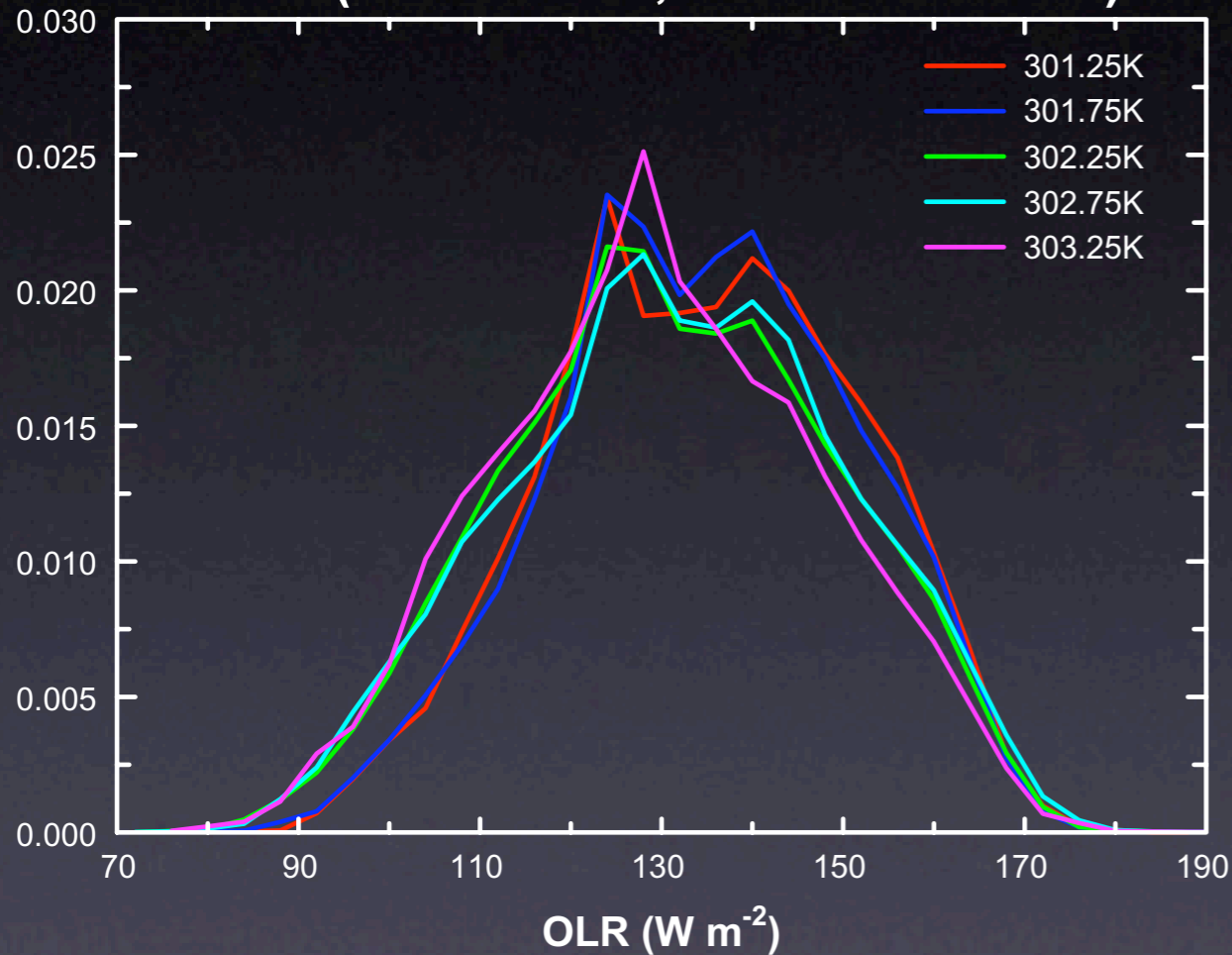
TOA Albedo (March 1998; size > 300 km)



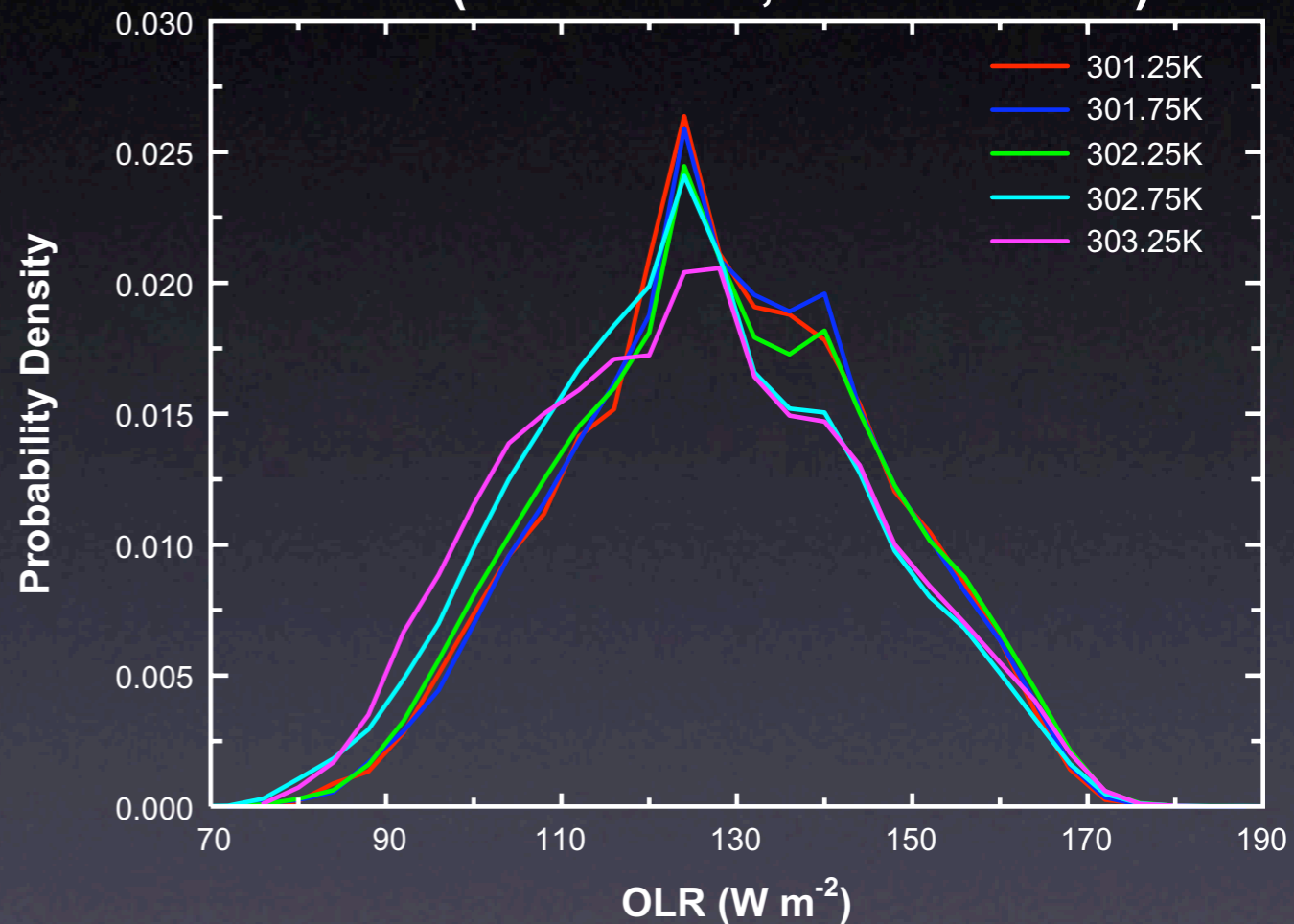
Sensitivity of TDC to SST

PDF of Outgoing Longwave Radiation

OLR (March 1998; size 100-300 km)



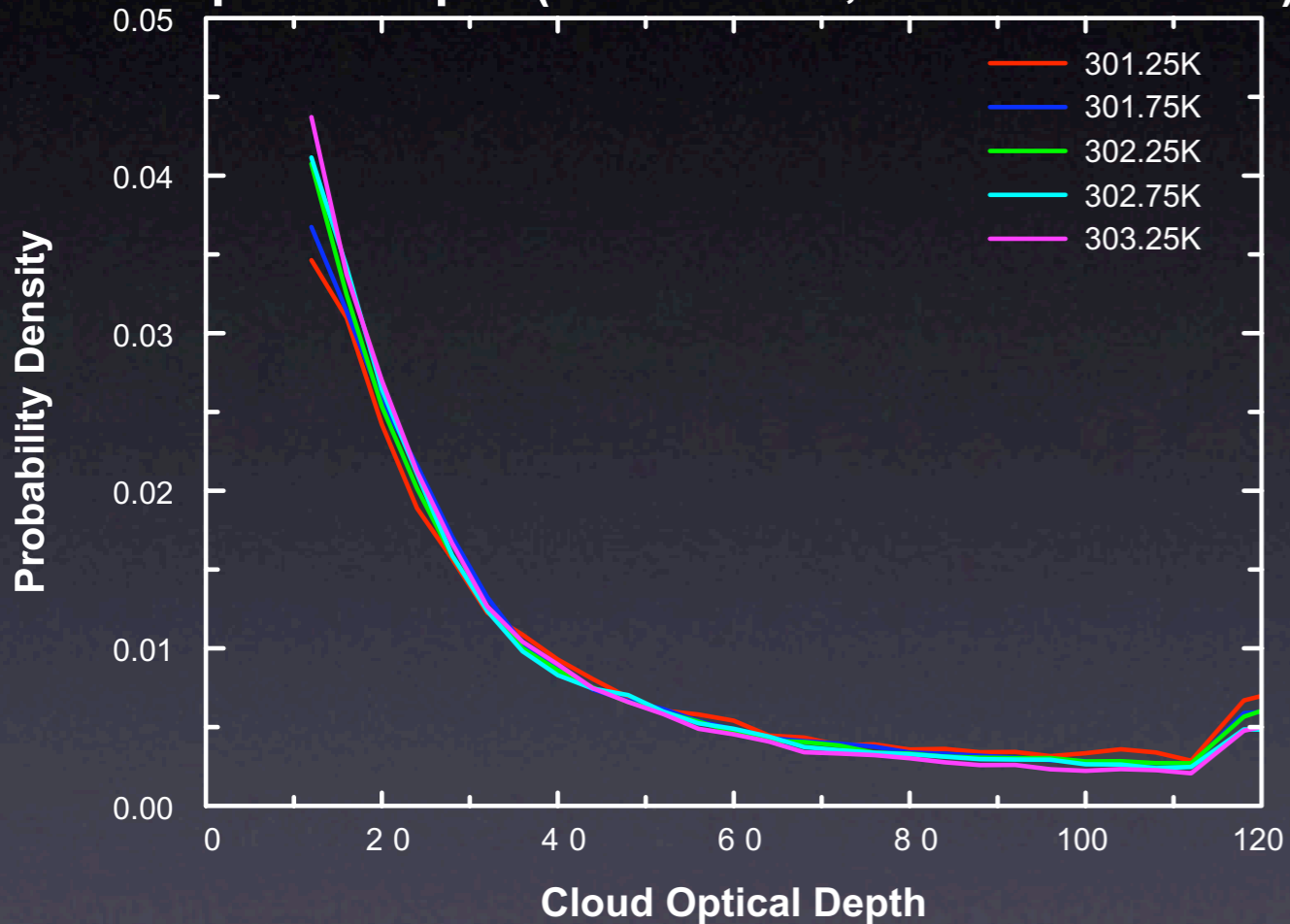
OLR (March 1998; size > 300 km)



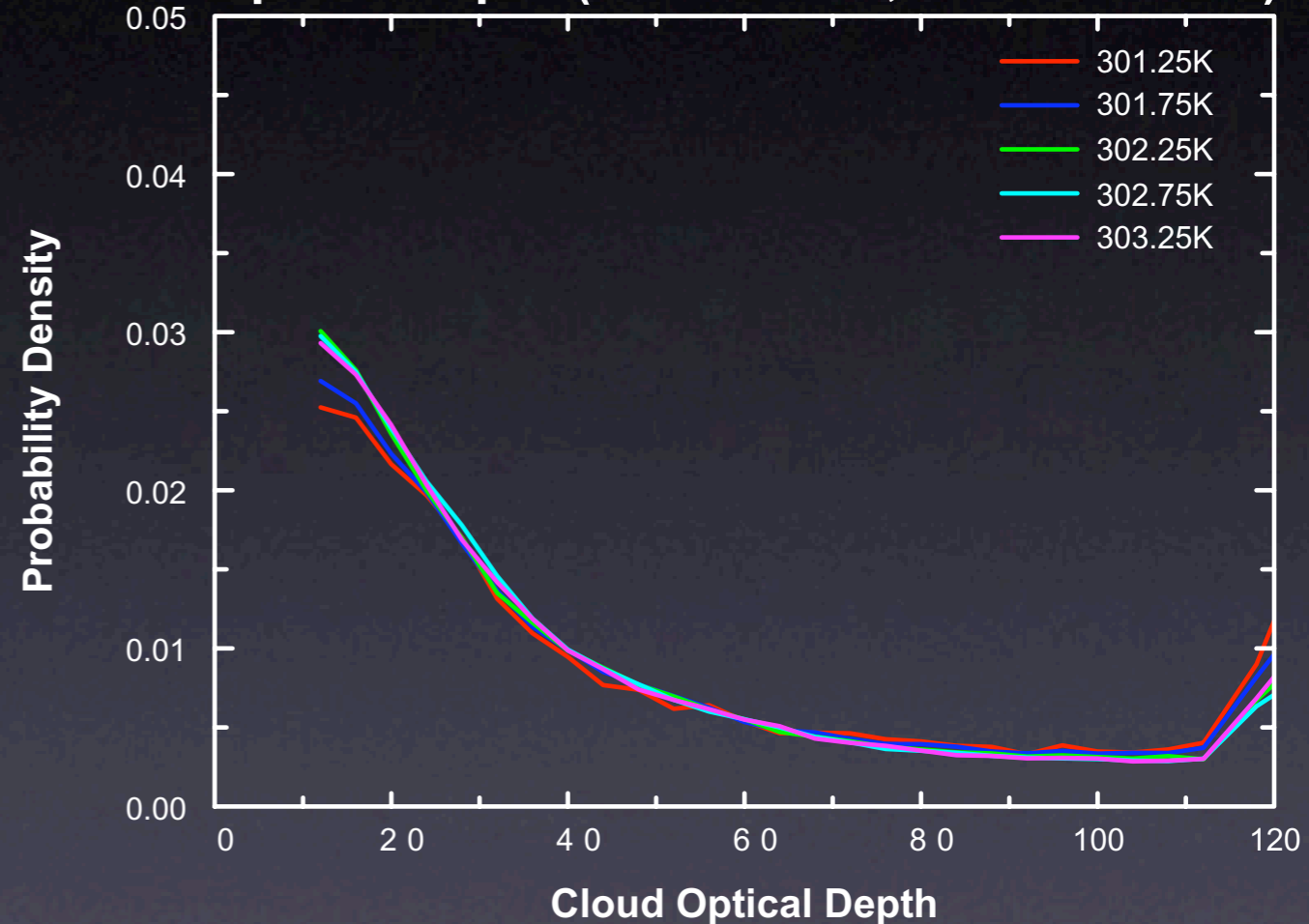
Sensitivity of TDC to SST

PDF of Cloud Optical Depth

Optical Depth (March 1998; size 100-300 km)



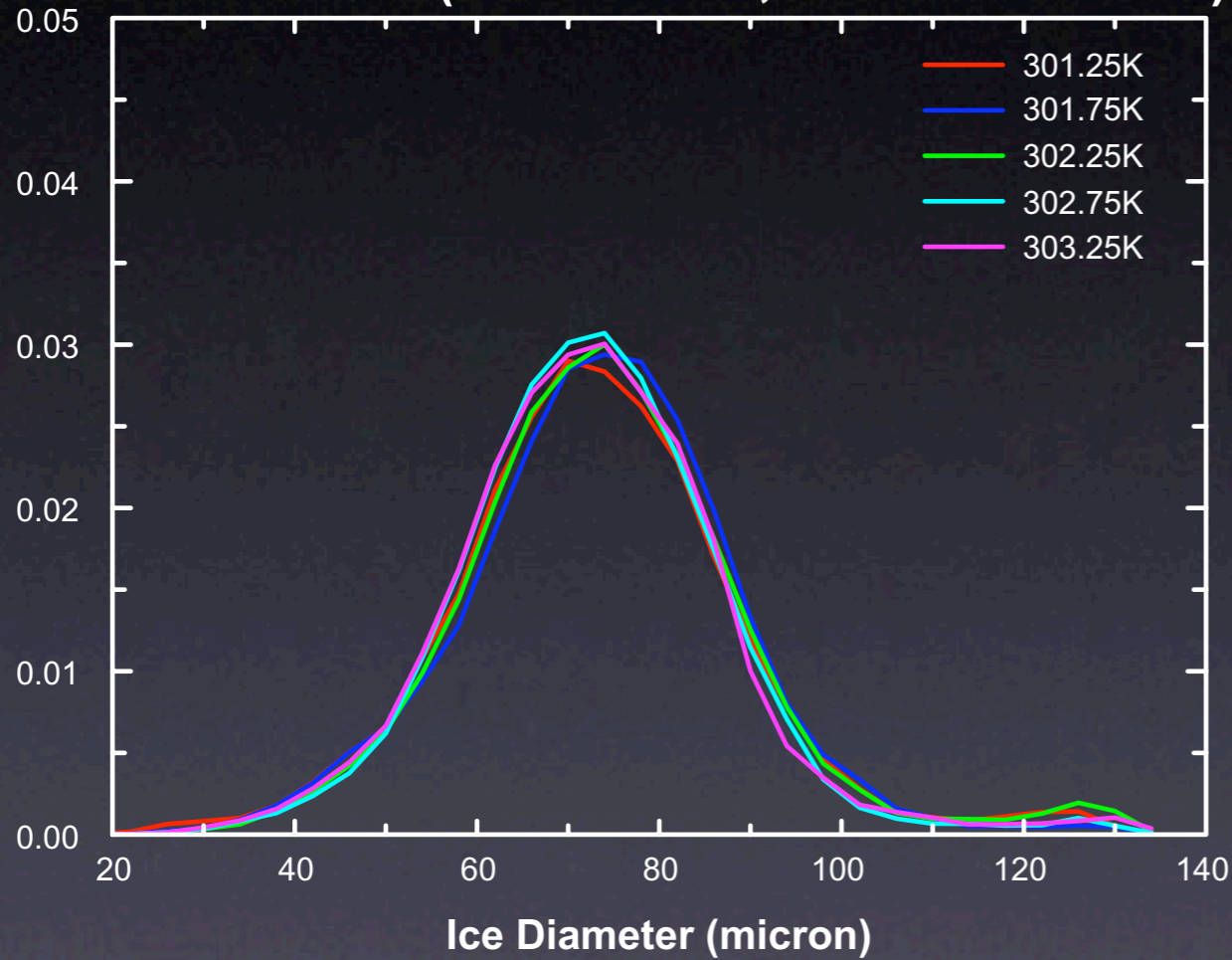
Optical Depth (March 1998; size > 300 km)



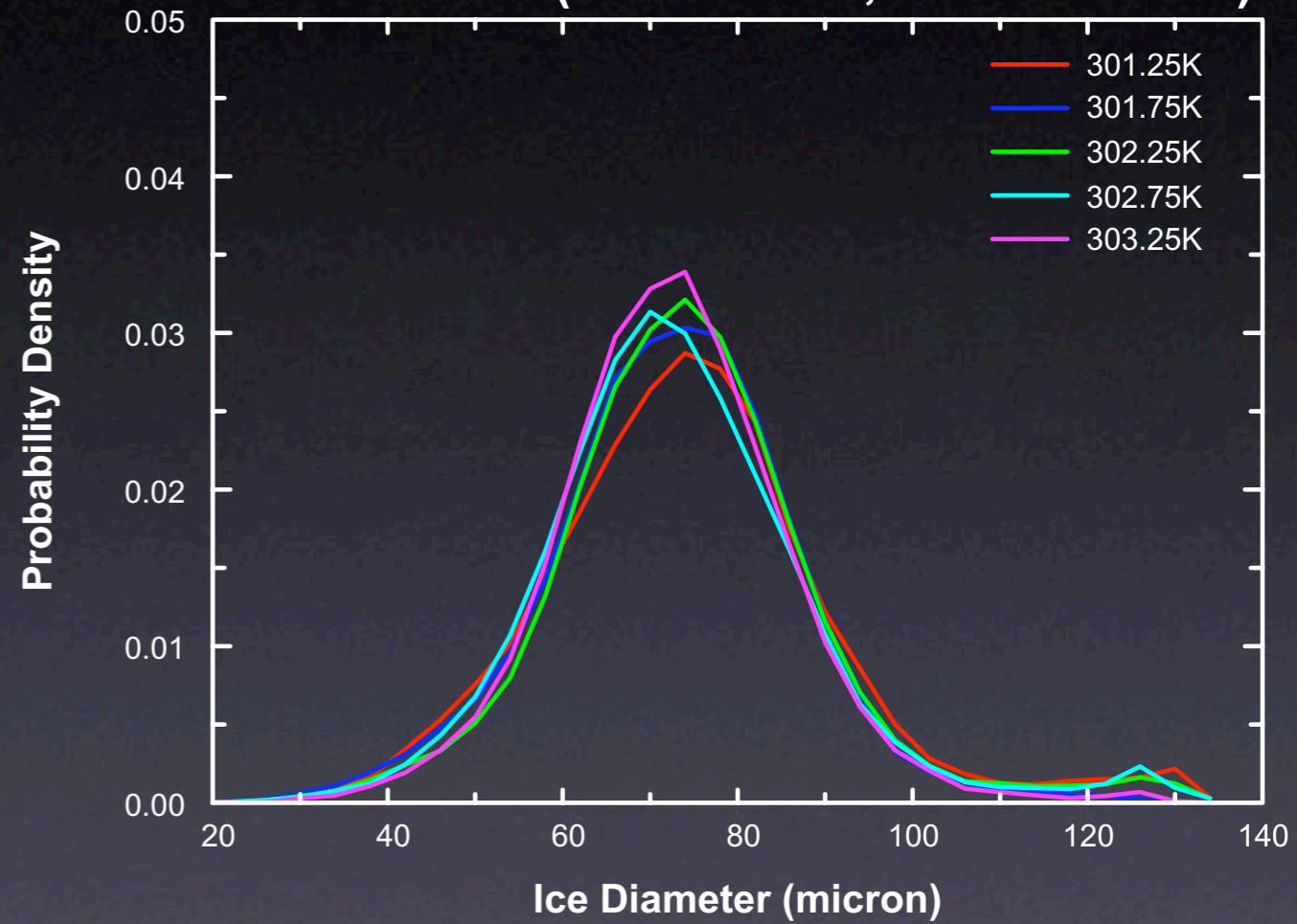
Sensitivity of TDC to SST

PDF of Ice Particle Diameter

Ice Diameter (March 1998; size 100-300 km)



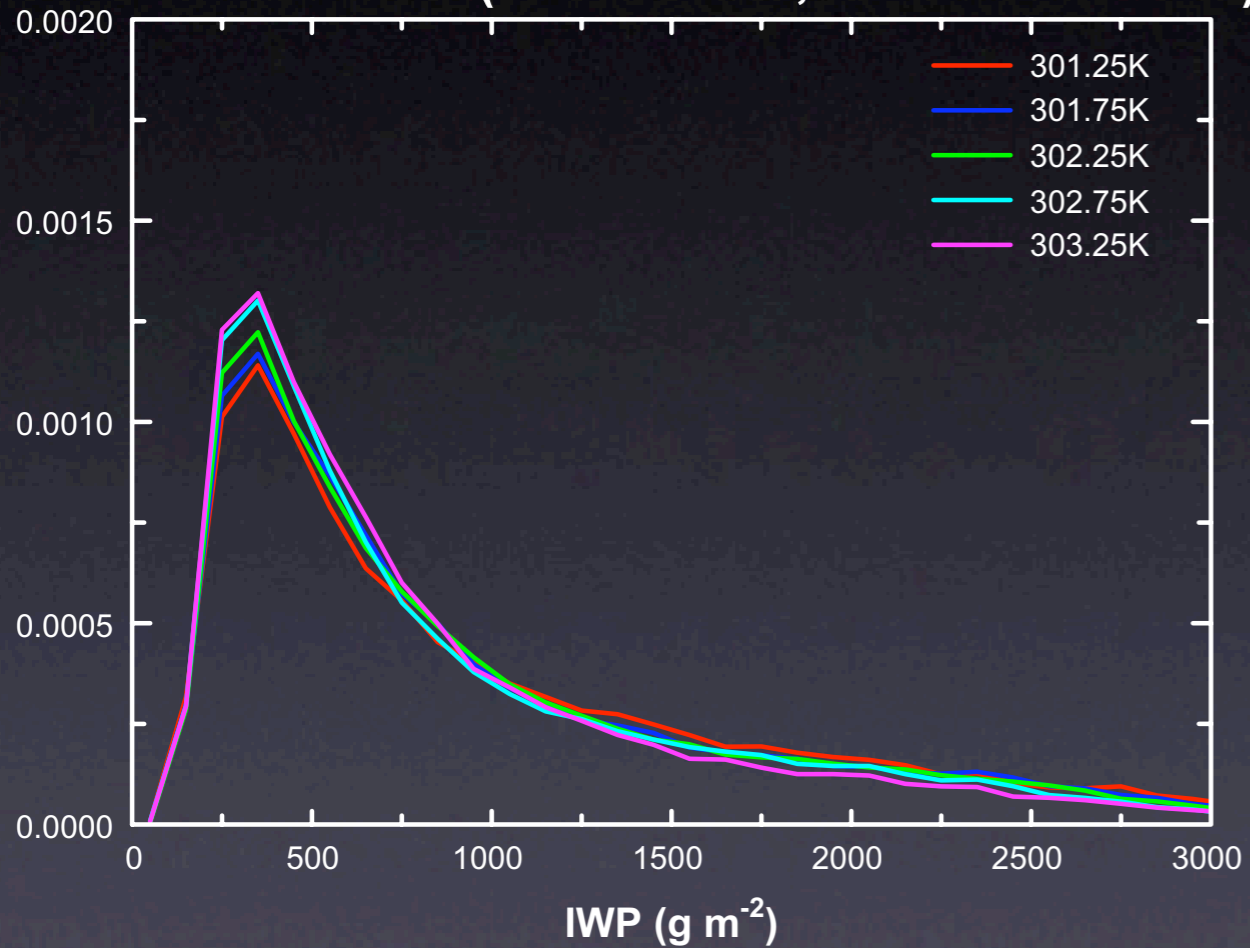
Ice Diameter (March 1998; size > 300 km)



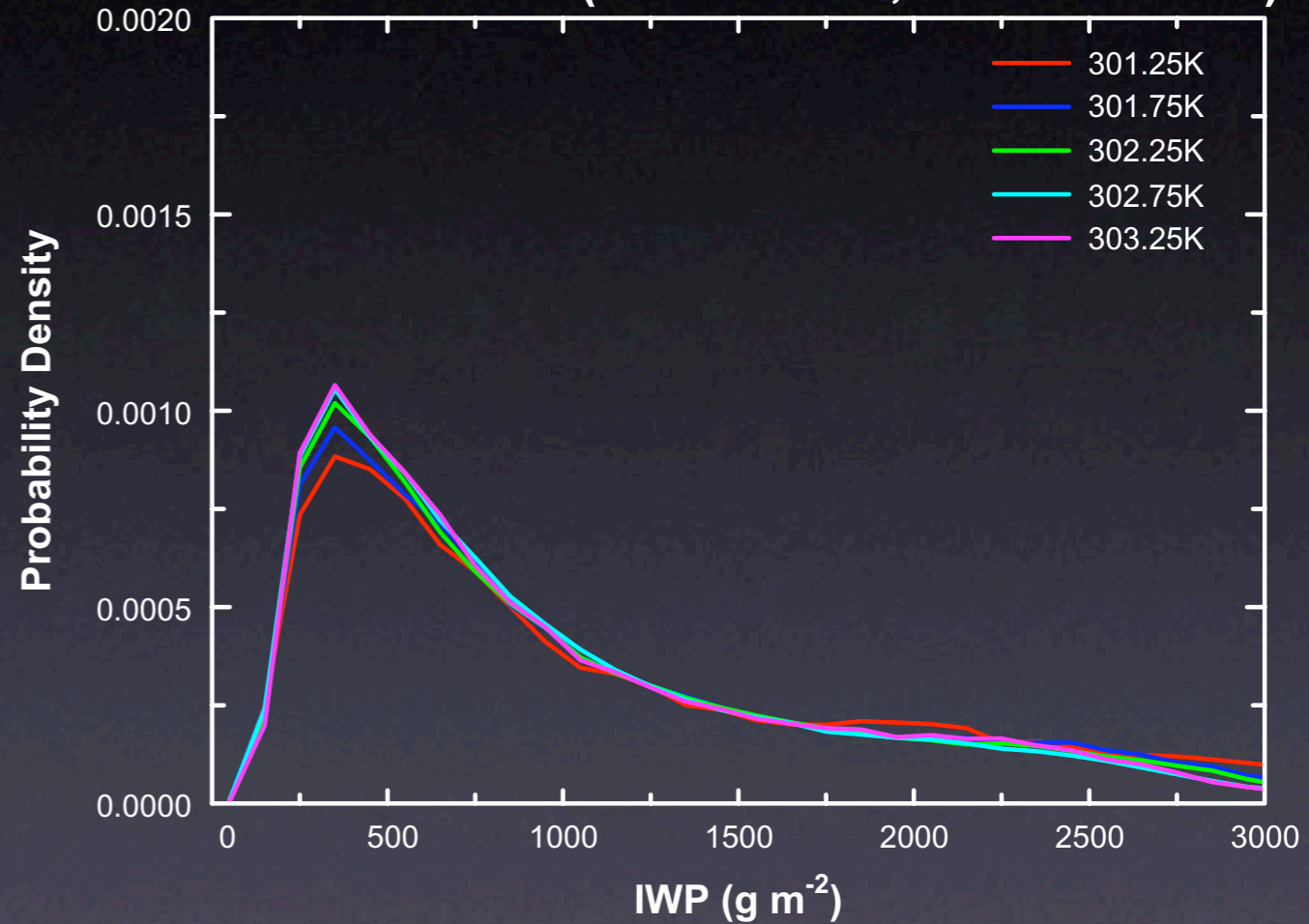
Sensitivity of TDC to SST

PDF of Ice Water Path

Ice Water Path (March 1998; size 100-300 km)



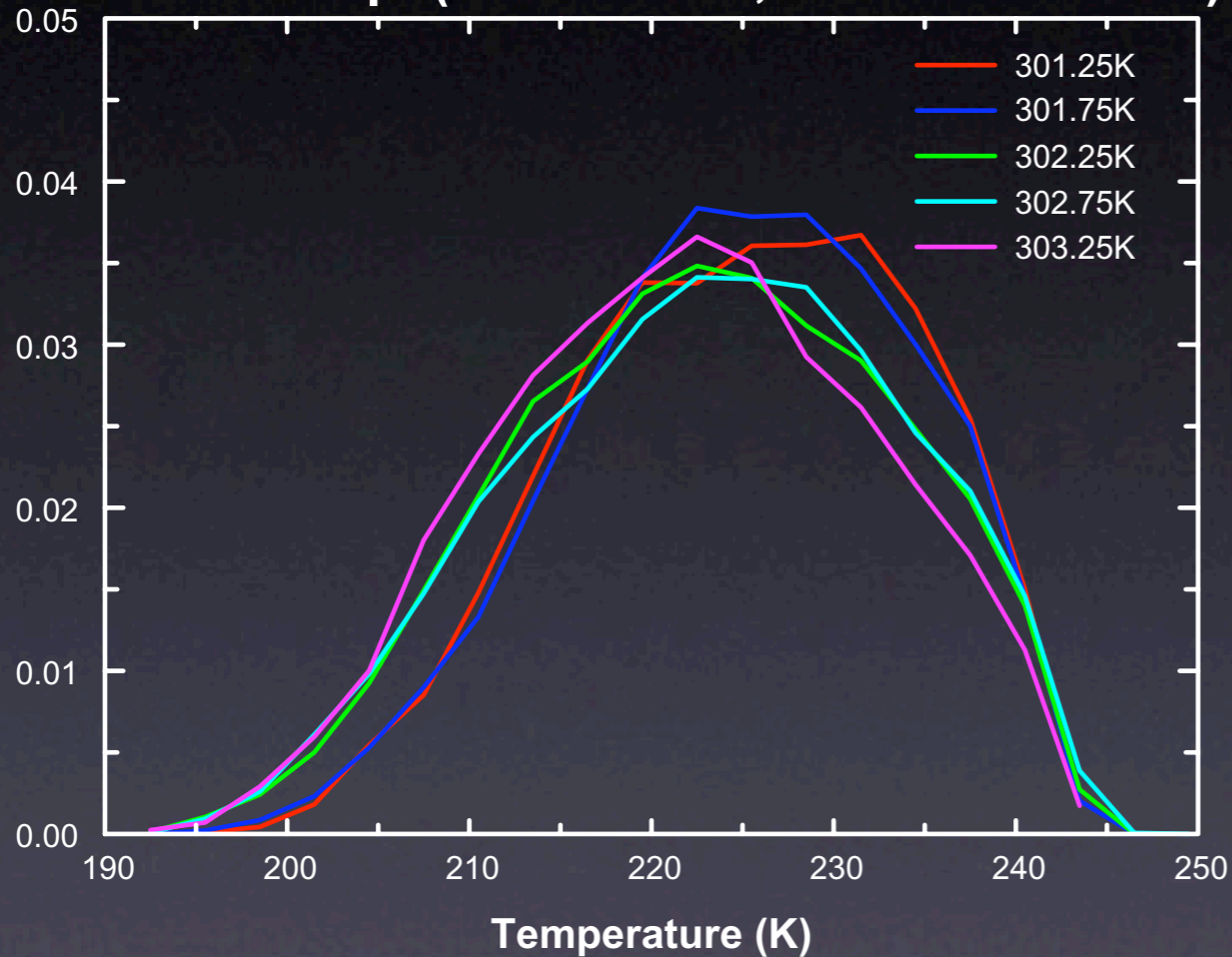
Ice Water Path (March 1998; size > 300 km)



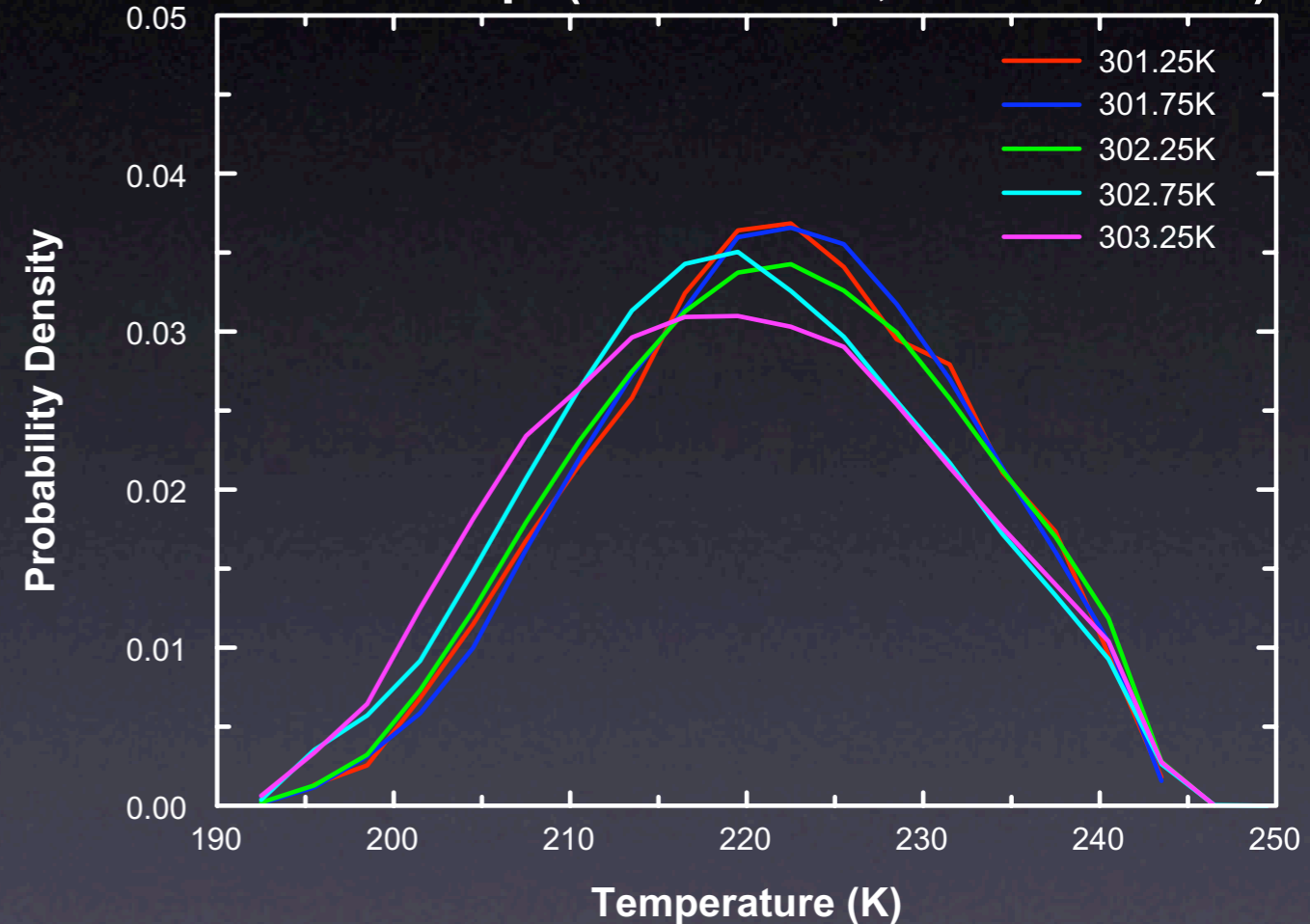
Sensitivity of TDC to SST

PDF of Cloud Top Temperature

Cloud Temp. (March 1998; size 100-300 km)



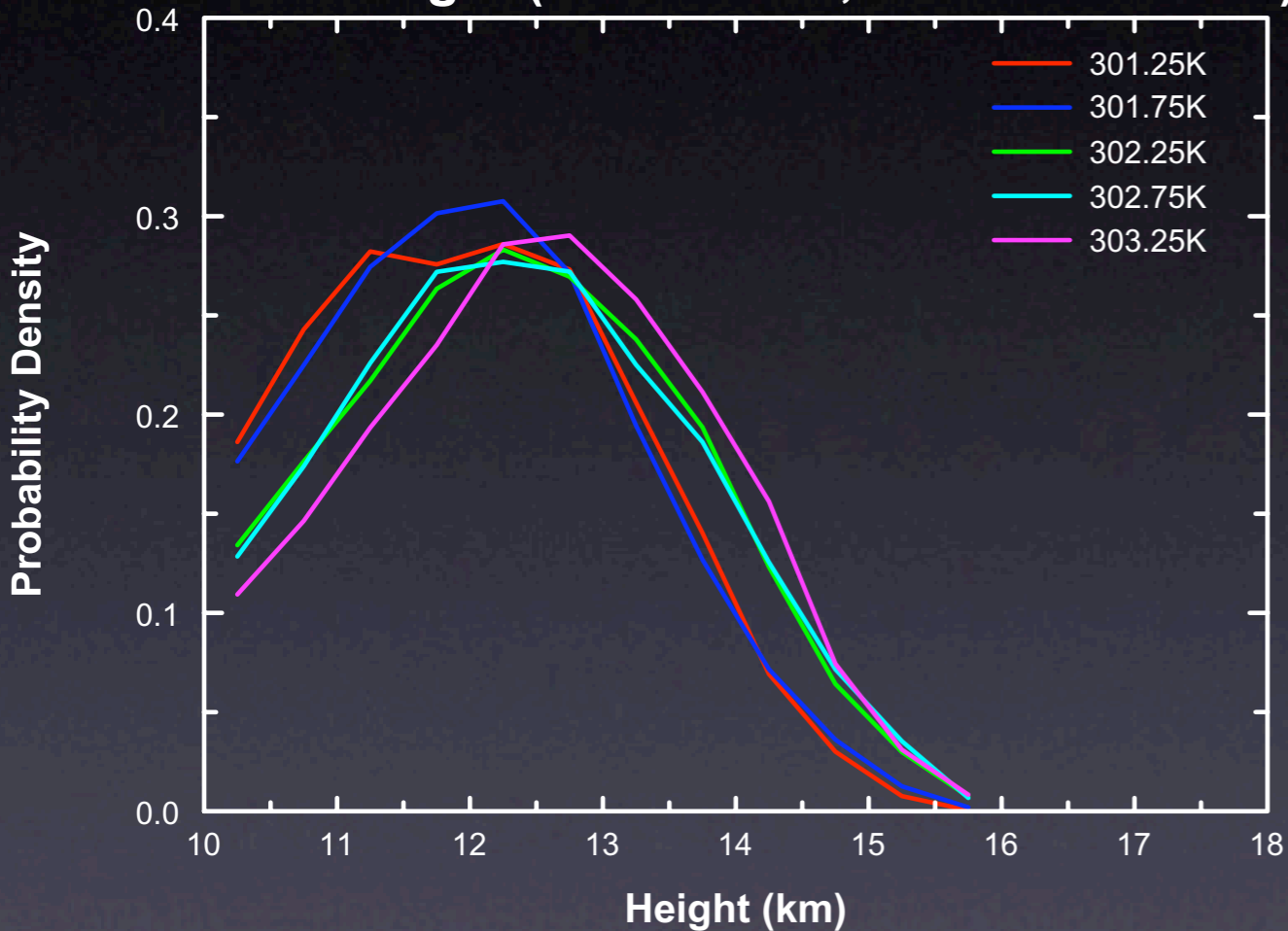
Cloud Temp. (March 1998; size > 300 km)



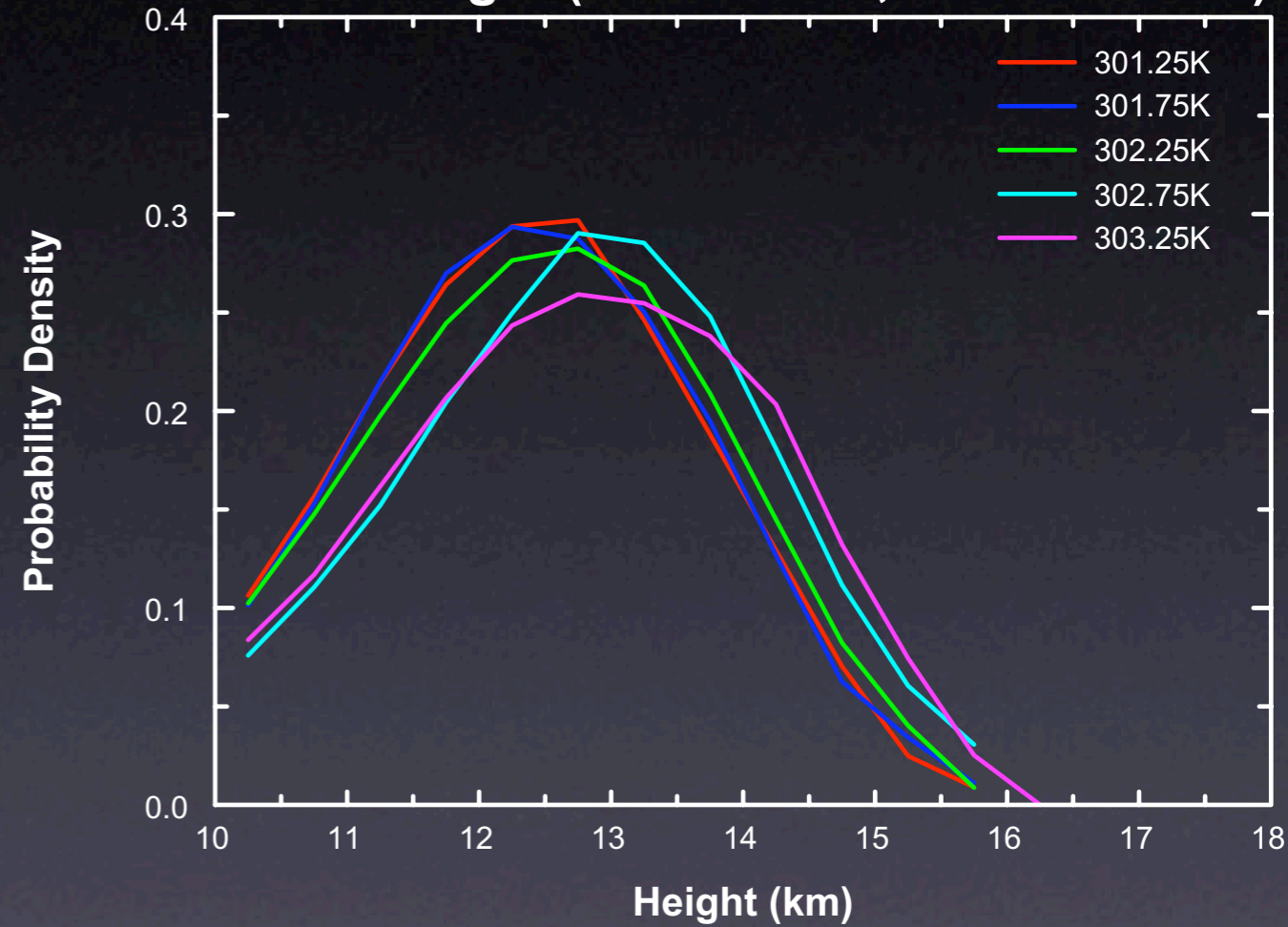
Sensitivity of TDC to SST

PDF of Cloud Top Height

Cloud Height (March 1998; size 100-300 km)



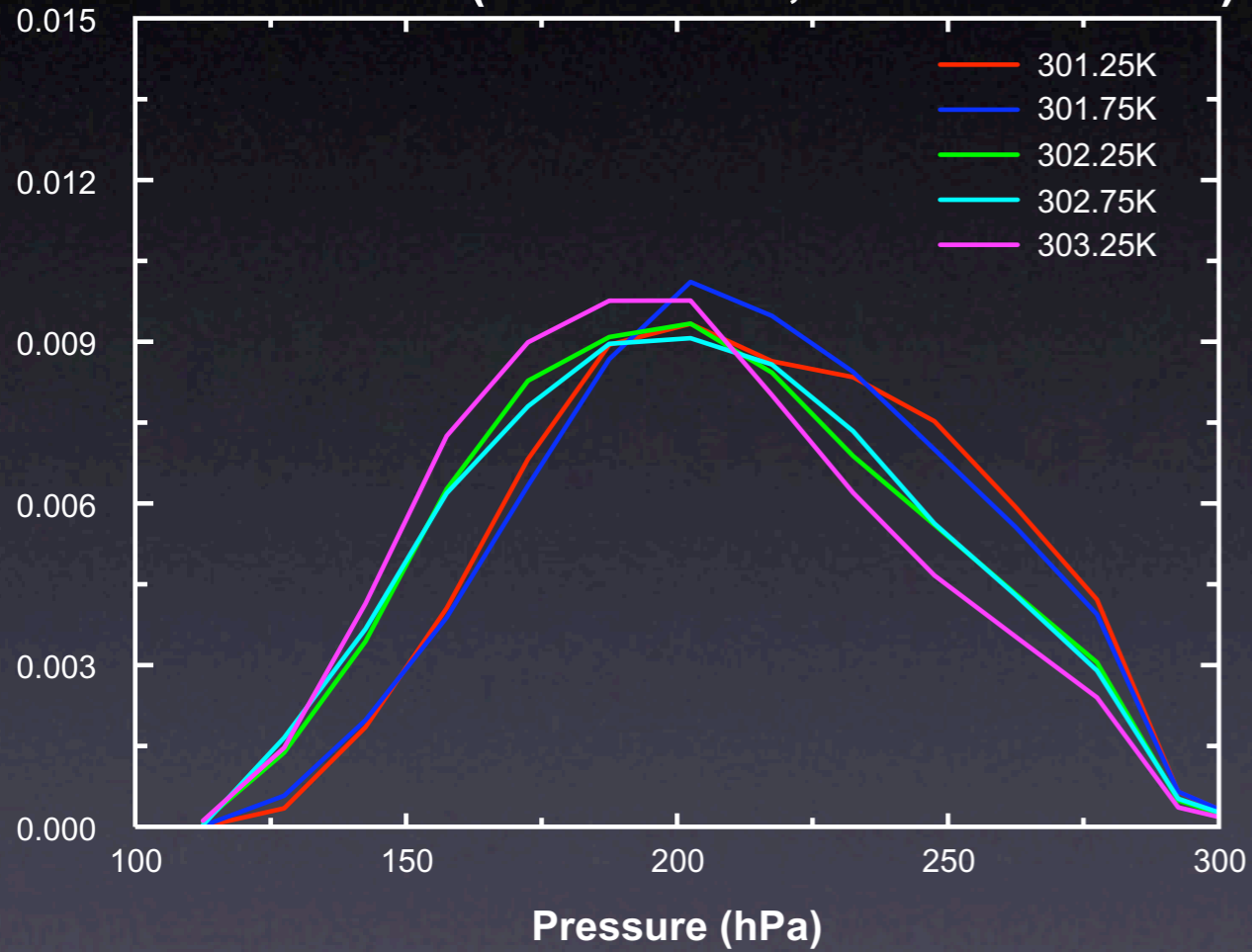
Cloud Height (March 1998; size > 300 km)



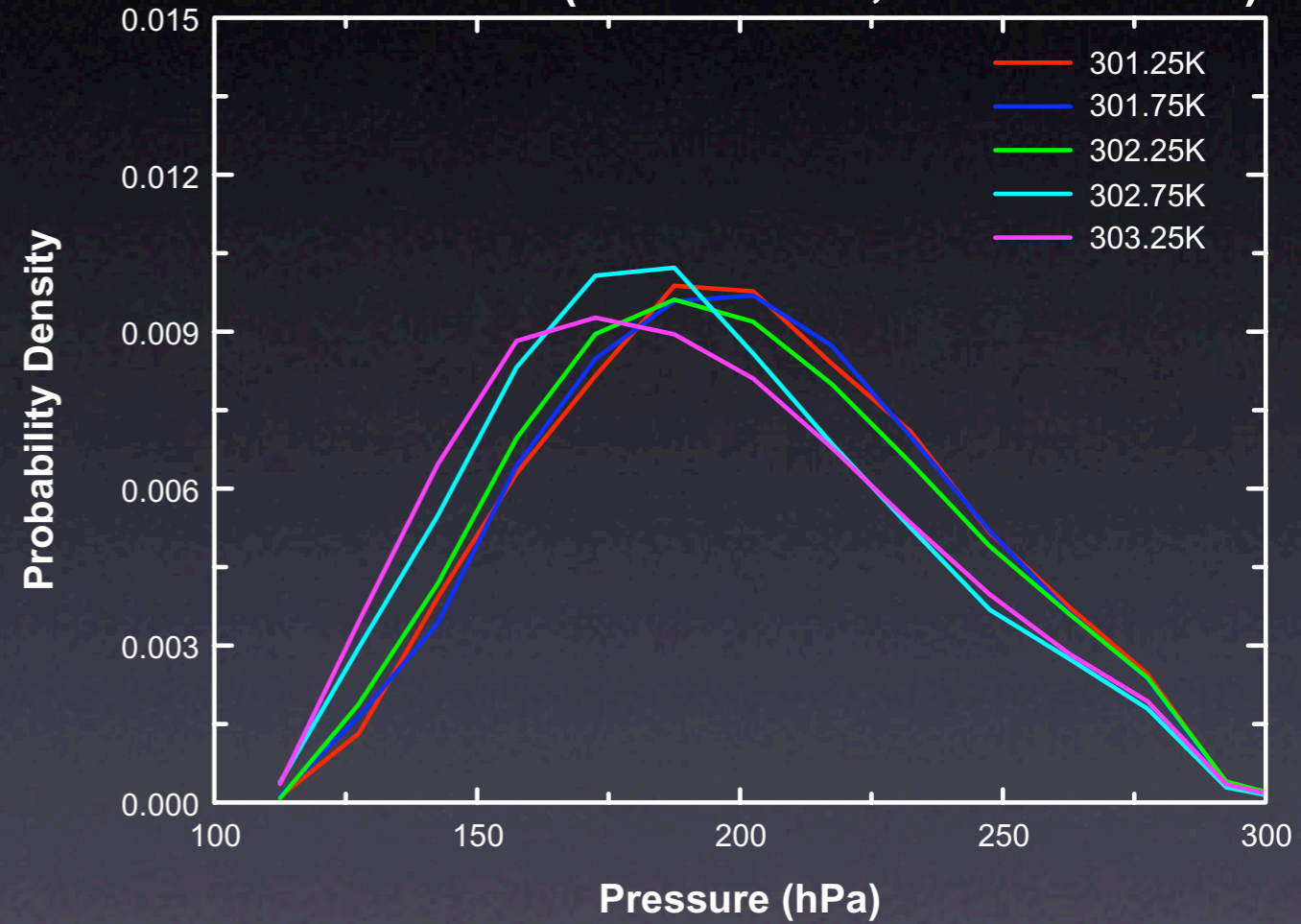
Sensitivity of TDC to SST

PDF of Cloud Top Pressure

Cloud Press. (March 1998; size 100-300km)



Cloud Press. (March 1998; size > 300 km)



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 global climate models.
- **Boundary layer cumulus:** Significant differences in probability density function are found between three types of boundary layer cumulus
- **Tropical deep convection:** Differences in cloud height distribution led to changes in distribution of outgoing longwave radiation between the El Niño-Southern Oscillation year and the La Niña year
- **Climate sensitivity:** With respect to outgoing longwave radiation and cloud top height, the distribution of tropical deep convection are not sensitive to sea surface temperature change above 30K

Future Plans

- 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