Radiative effects of upper tropospheric clouds observed by Aura MLS and CloudSat and their impacts on tracer distributions in the UT/LS

Hui Su[1], Jonathan Jiang[1], William Read[1], Yu Gu[2], Nathaniel Livesey[1]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

[2]Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles

Aura Science Team Meeting, Leiden, the Netherlands, September 14-17, 2009

Motivation

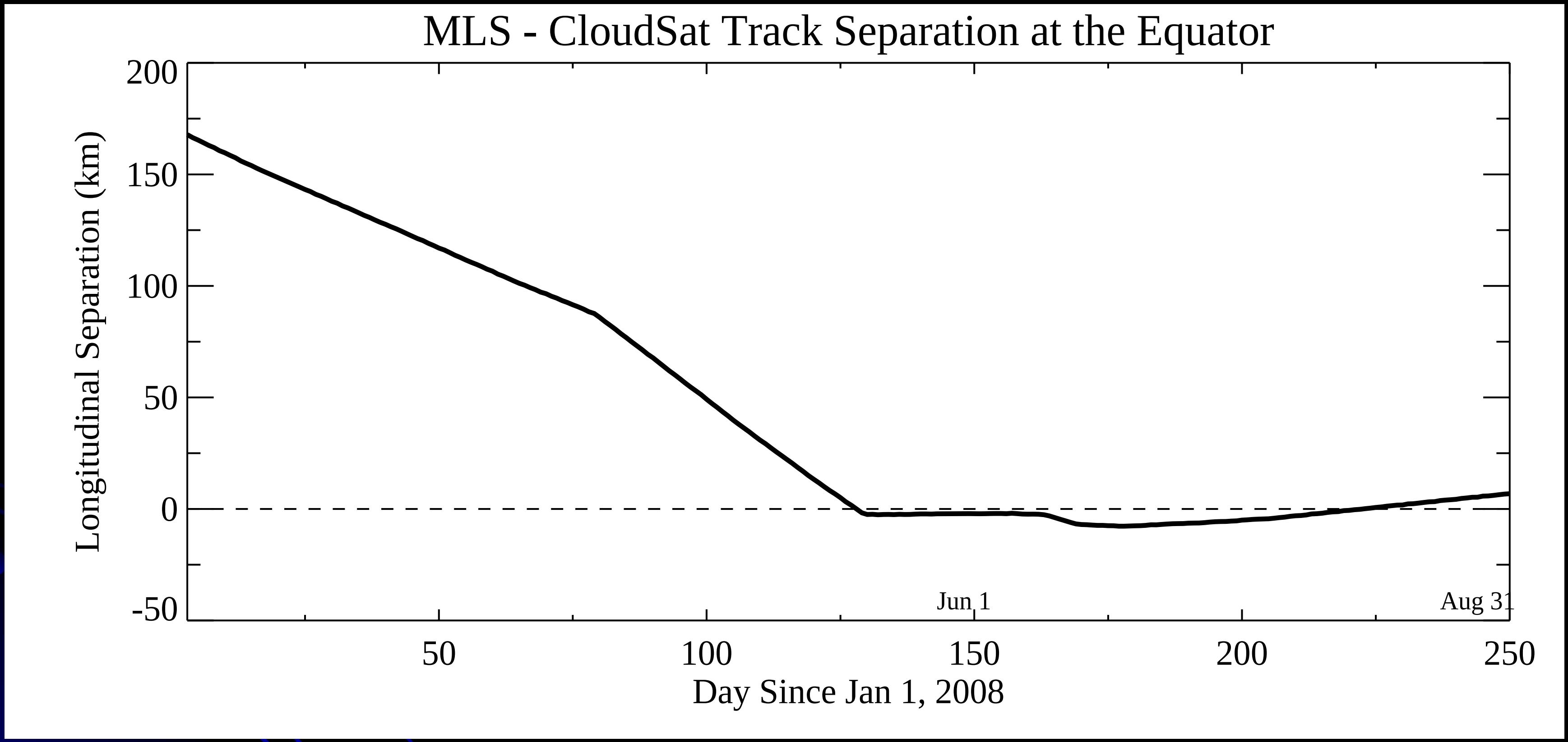
- Clouds remain the largest uncertainty in climate change predictions.

- Cirrus climate feedback has been a subject of intense debate: whether they increase or decrease with surface warming; whether they produce a net warming or cooling?

- Cirrus radiative heating in the tropical tropopause layer (TTL) is important for tracer transport from the troposphere to the stratosphere.

- Different satellite measurements of cirrus clouds have different sensitivity. It is important to compare and contrast different measurements for an accurate quantification of cirrus radiative effects.

CloudSat and Aura Ground Track Separation



Cloud Data

Aura MLS

MLS ice water content (IWC, v2.2) has a horizontal resolution of ~200 km along-track and ~7 km cross-track, and a vertical resolution of ~3 km.

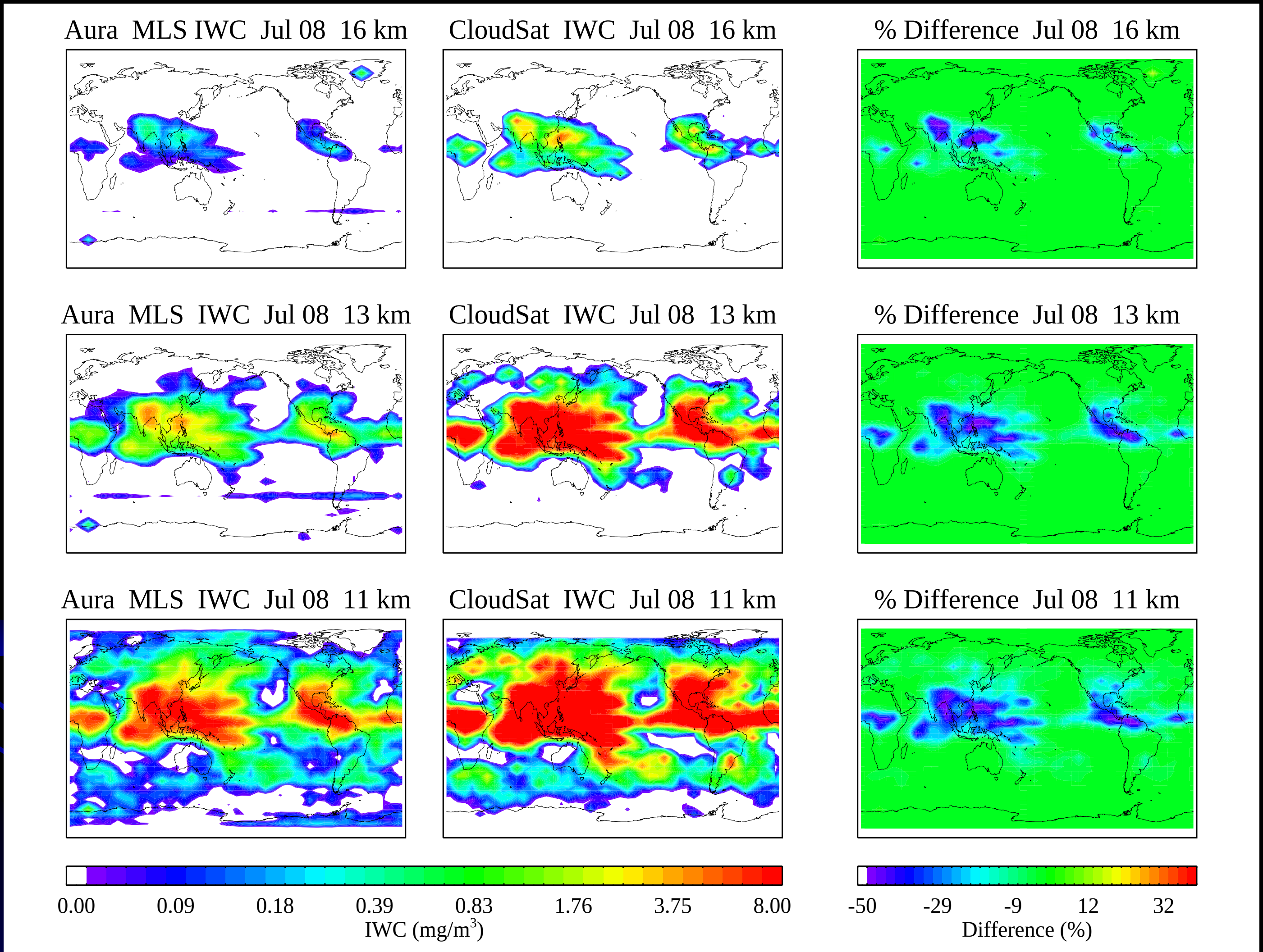
CloudSat

The CloudSat liquid and ice water content (L/IWC) from the Level 2B R04 has a horizontal resolution of 1.7 km along-track and 1.3 km cross-track, and a vertical resolution is ~500 m.

When comparing the mean cirrus distributions, we average both CloudSat and MLS data onto the same 8° (longitude) × 4° (latitude) × 3 km (height) grids centered on the MLS standard retrieval levels at 215 hPa (~11 km), 147 hPa (~13 km) and 100 hPa (~16 km).

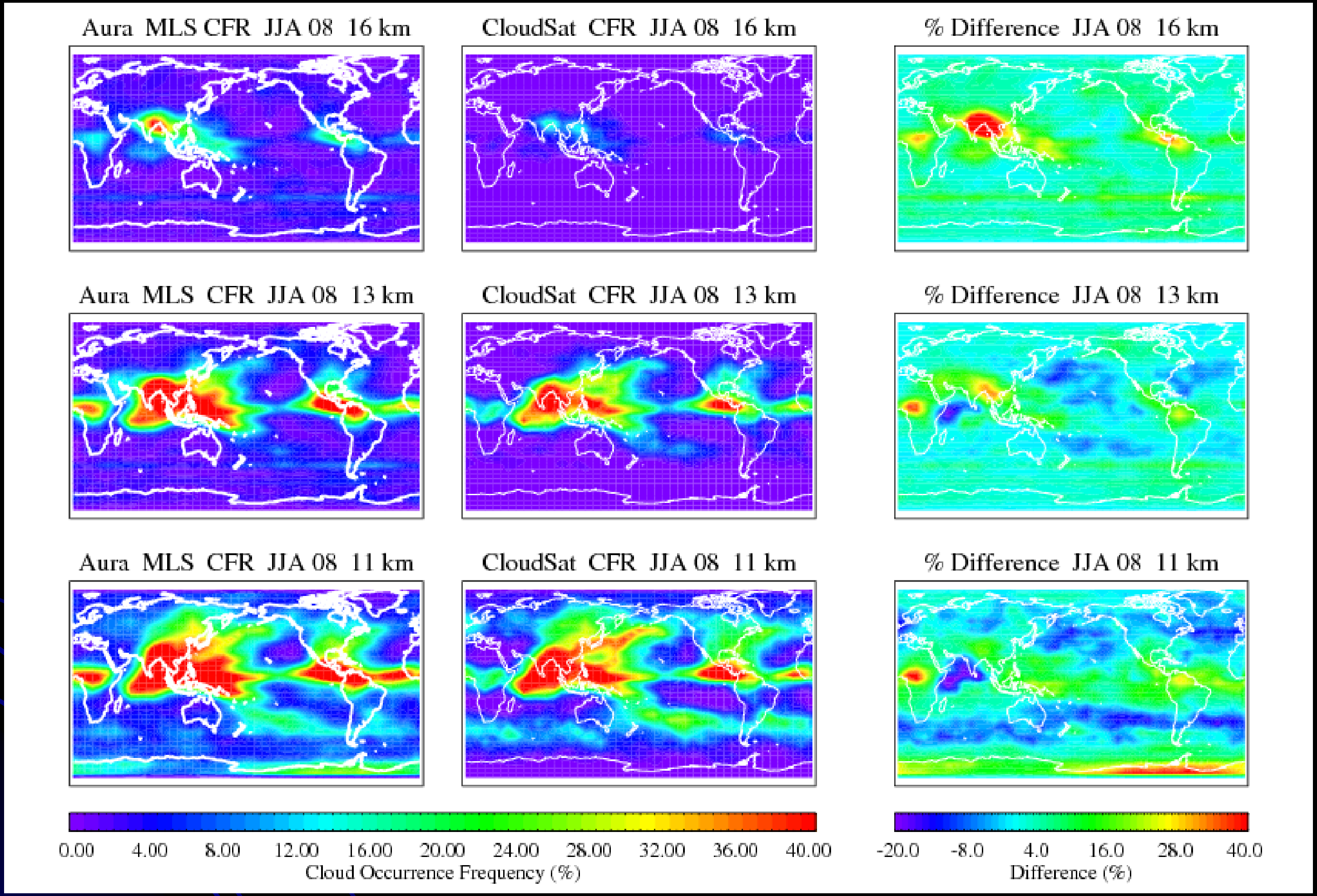
For radiation calculations, we average the CloudSat IWC onto 2° x 0.2° areas centered on the MLS measurement locations and run the radiative transfer model along the MLS tracks. Then radiative fluxes and heating rates are gridded onto 8° x 4° boxes for horizontal maps.

UT Cloud Ice Water Content



Aura MLS IWC retrievals are lower than CloudSat at all levels.

UT Cloud Occurrence Frequency



Aura MLS and CloudSat have different sensitivity to the UT clouds. MLS captures more thin cirrus than CloudSat, especially near the tropopause.

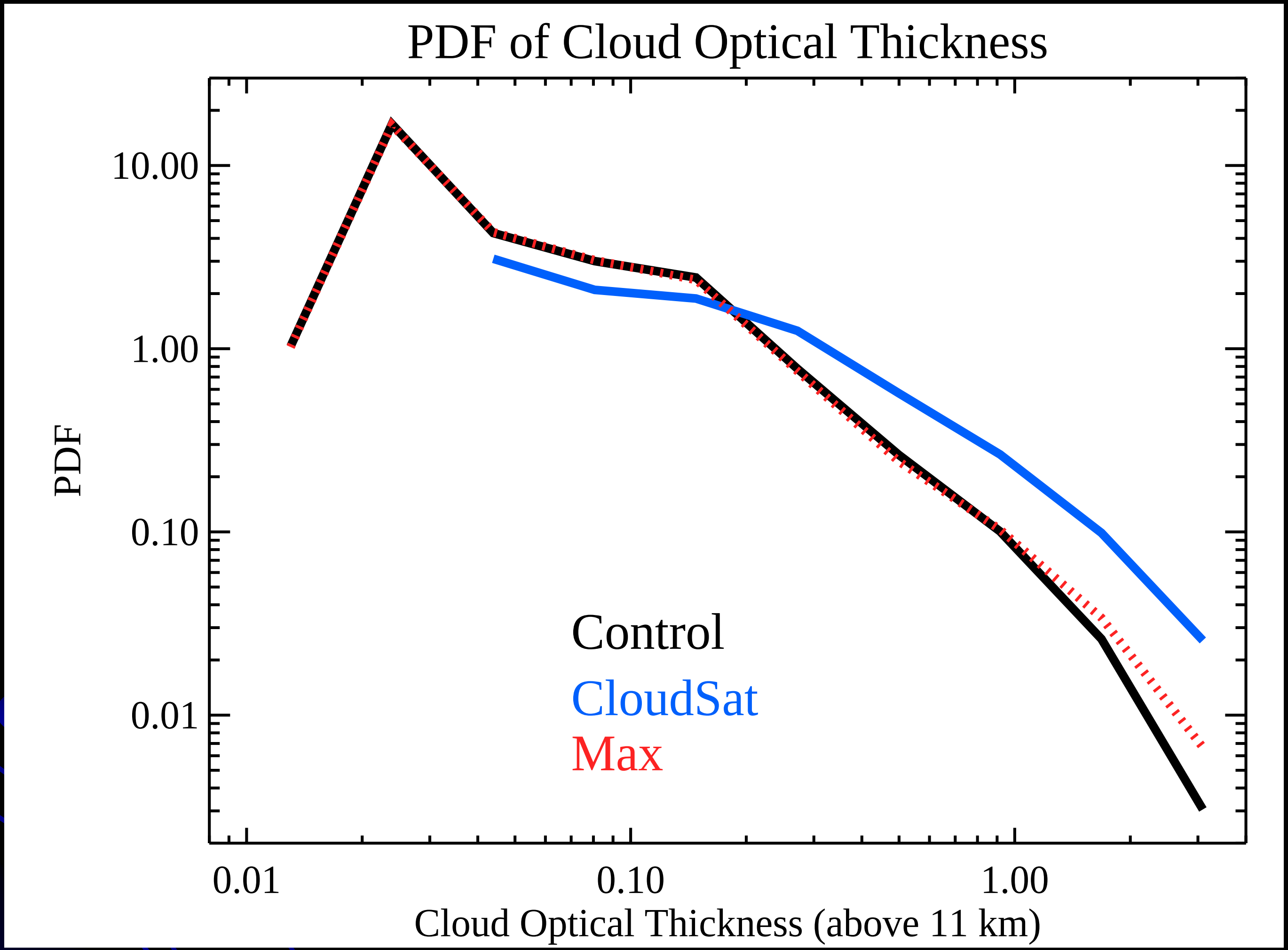
Experimental Model and Design

Fu-Liou Radiative Transfer Model

It uses the delta-four-stream approximation for solar flux calculations (6 bands) and delta-two stream approximation for infrared flux calculations (12 bands). The ice cloud particle size follows *McFarquhar and Heymsfield* [1997], the same as used in the MLS IWC forward model.

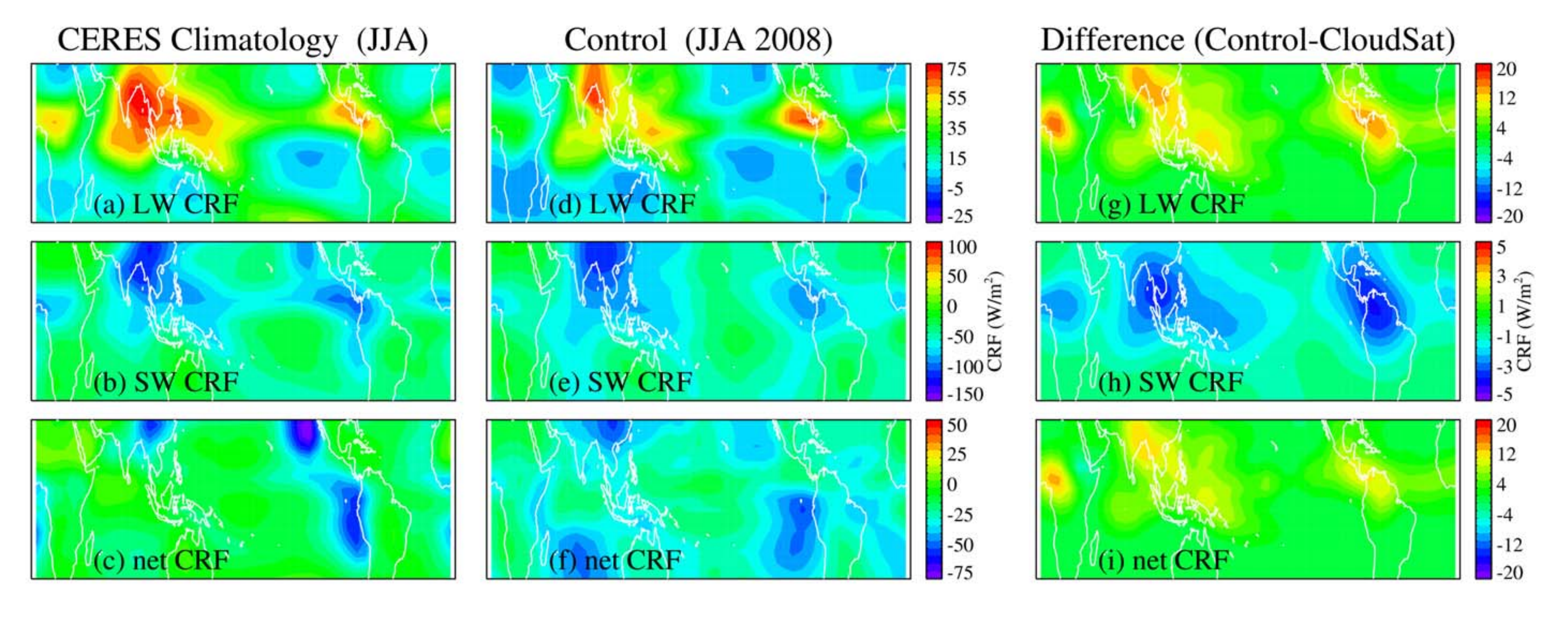
- Control run
  MLS IWC at 215 hPa and above with CloudSat L/IWC below is used.
- CloudSat run
  CloudSat L/IWC throughout the atmospheric column is used.
- Max run
  The larger value of CloudSat and MLS IWC at the same height is used.

Cloud Optical Depth Comparison



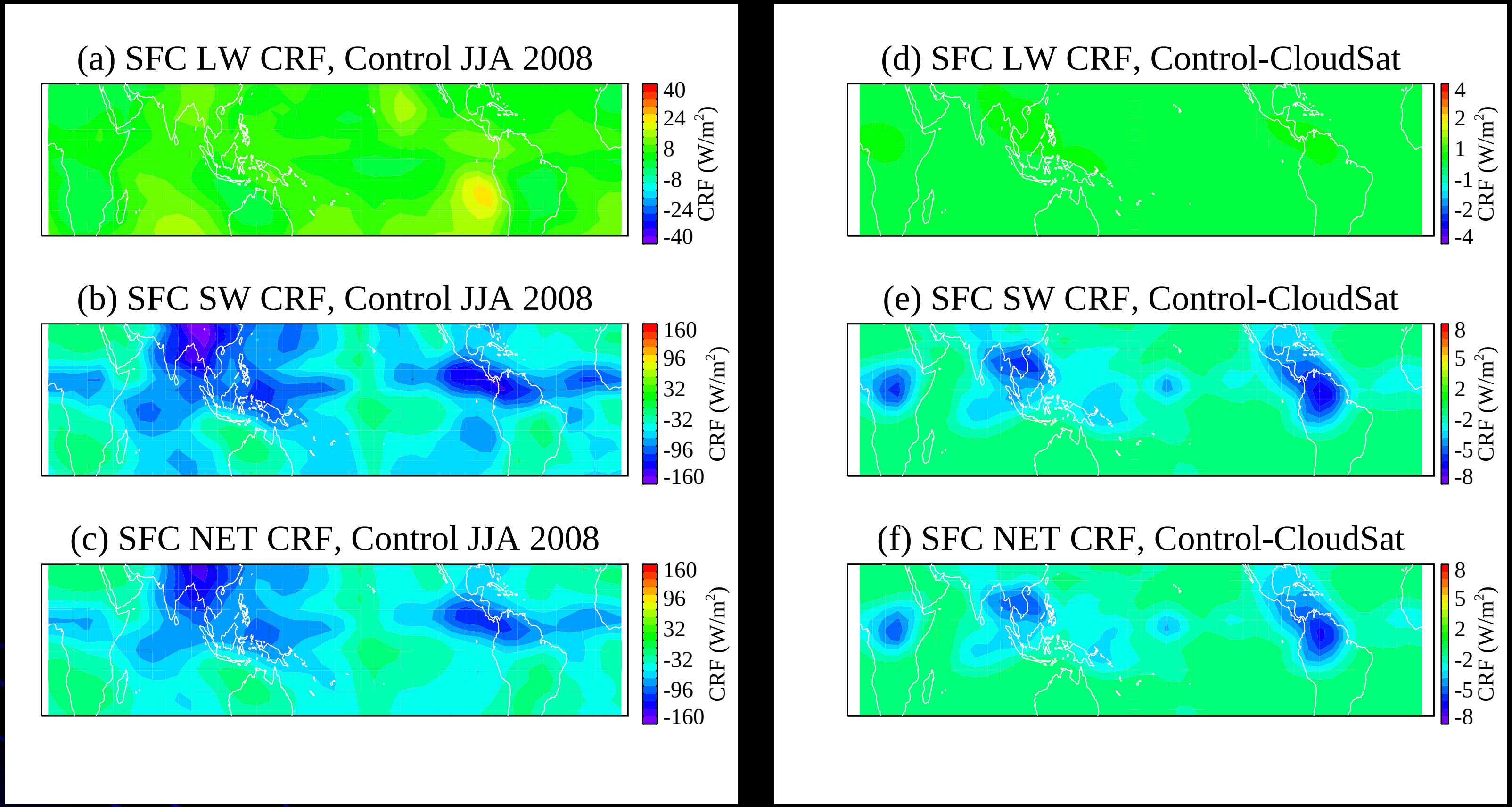
The peak pdf is 0.02 for "Control" and 0.04 for "CloudSat". The percentage of clouds with $\tau < 0.2$ is 0.71 for "Control", 0.34 for "CloudSat" and 0.70 for "Max". For $\tau > 0.2$, CloudSat pdf is higher than MLS.

Observed and Modeled TOA Cloud Forcing



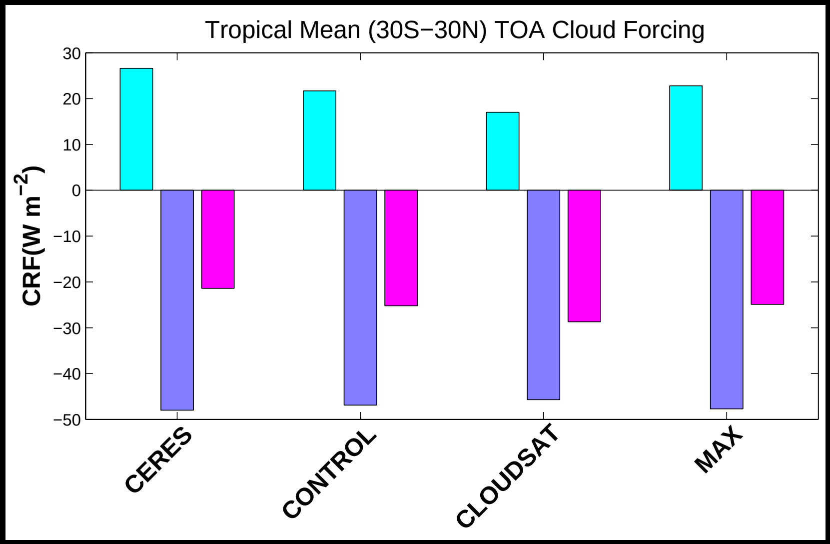
- Model simulated TOA CRF patterns approximately resemble the observed.
- Over the tropics, large LW and SW CRFs are associated with three convective systems – western Pacific, central America and central Africa.
- Strong SW CRF (net cooling) is also seen to the west coast of America.
- The thin cirrus observed by MLS but missed by CloudSat produces net TOA warming.

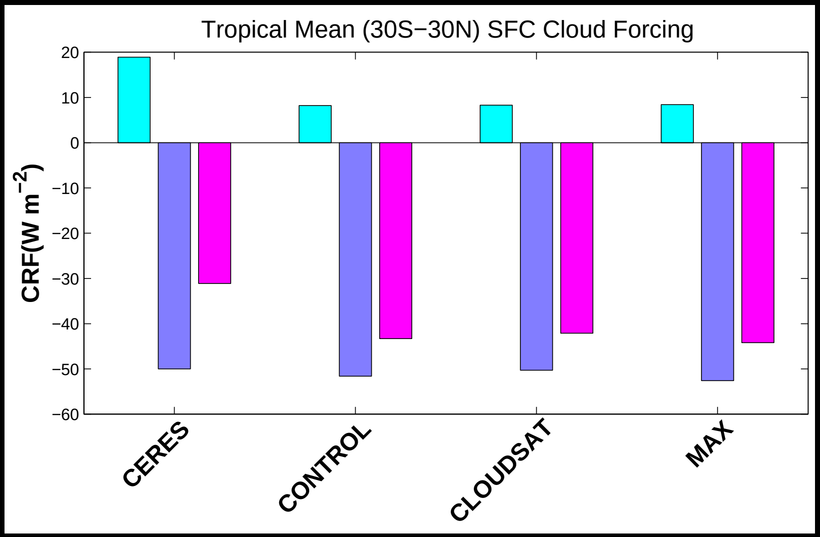
Cloud Forcing at the Surface



- Deep clouds produce a strong SW cooling and relatively weak LW warming at the surface.
- The thin cirrus observed by MLS but missed by CloudSat produces a net cooling at the surface.

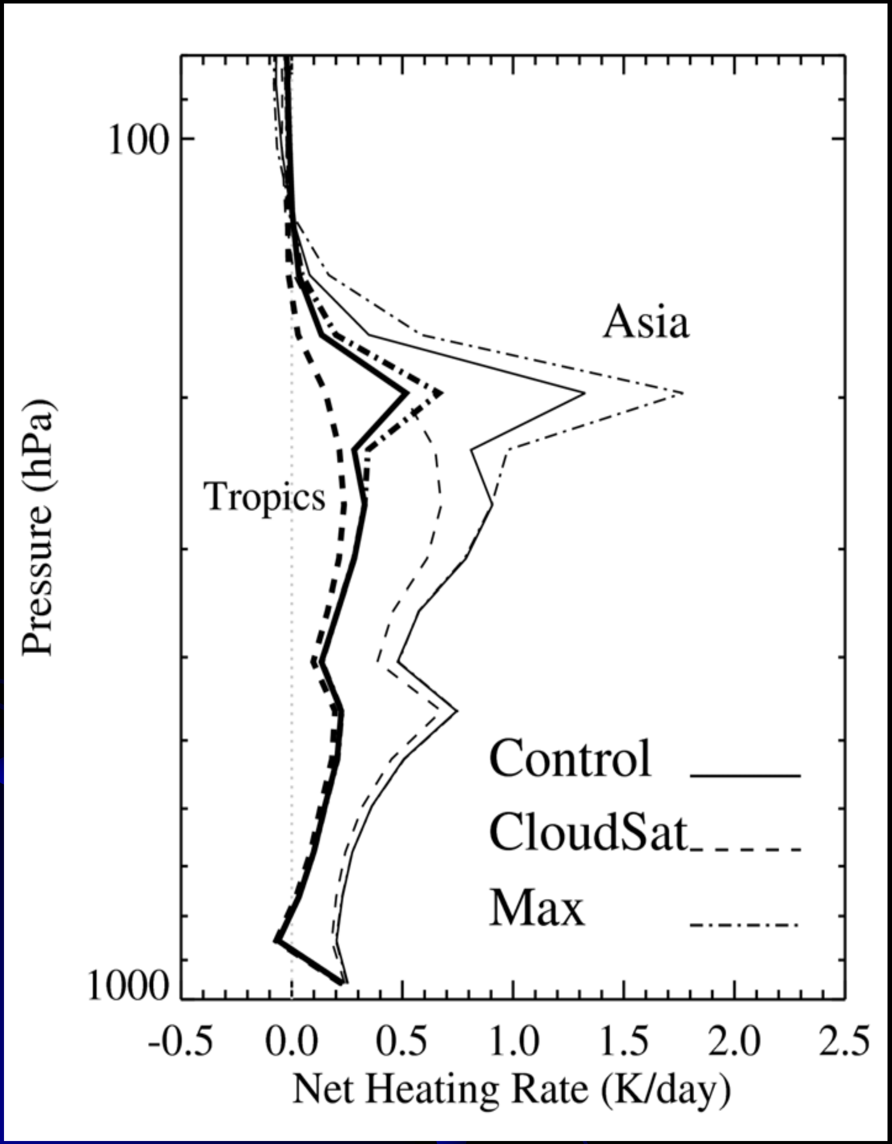
Tropical-mean Cloud Forcings





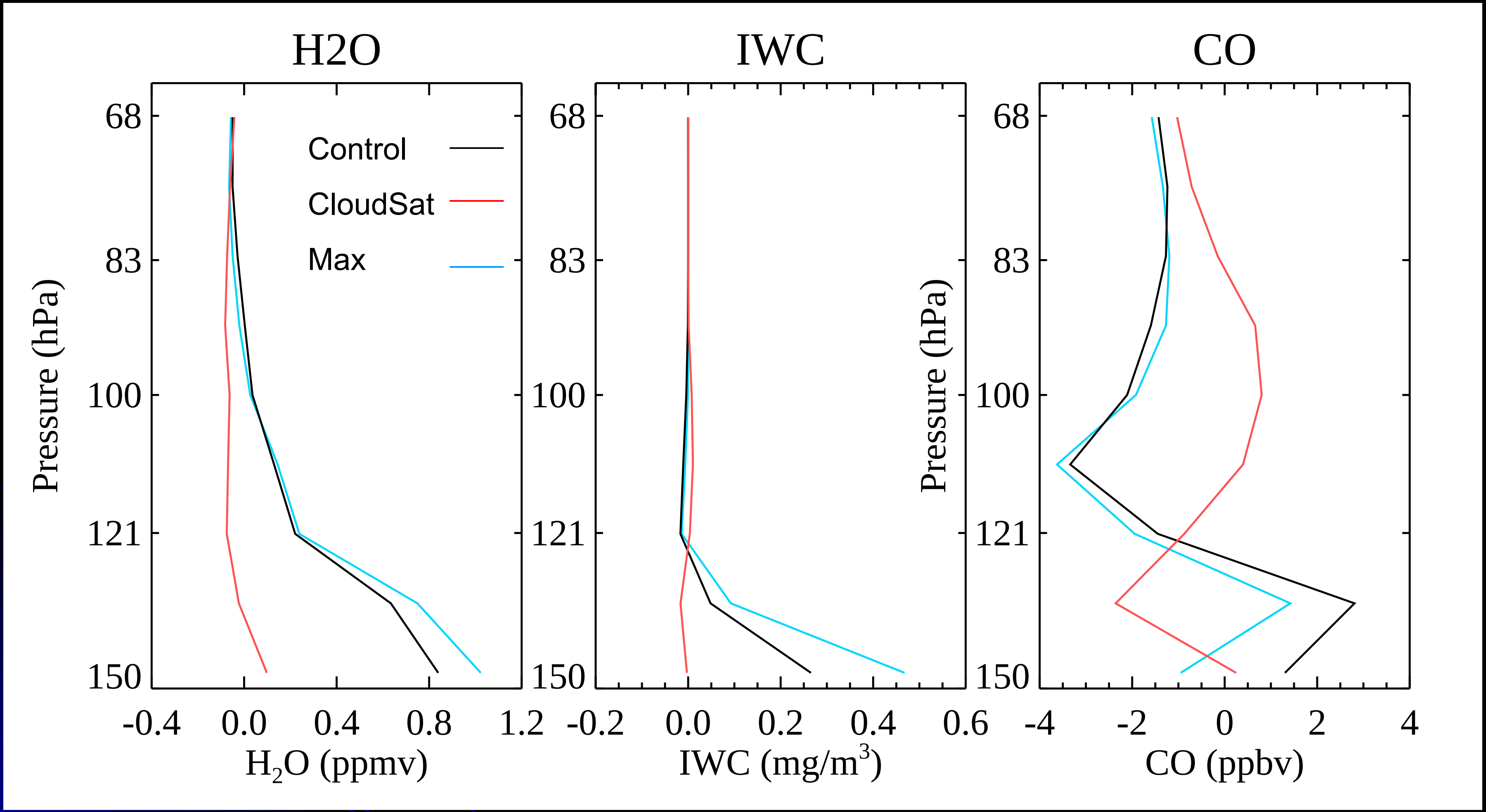
	Observations (ISCCP)	Control Run (MLS+CloudSat)	CloudSat Only	Max of MLS/CloudSat
TOA-LW	26.6±5.0	21.7	17.0	22.8
TOA-SW	-48.0±5.0	-46.9	-45.7	-47.7
TOA-net	-21.4±10.0	-25.2	-28.7	-24.9
SFC-LW	18.9±10.0	8.3	8.2	8.4
SFC-SW	-50.0±10.0	-51.6	-50.3	-52.6
SFC-net	-31.1±20.0	-43.3	-42.1	-44.2

Cloud Radiative Heating Rates



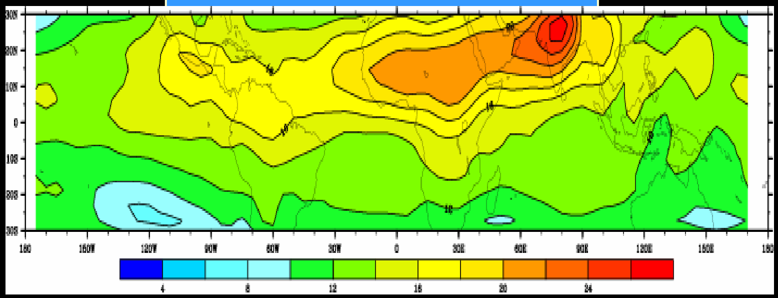
The clouds observed by MLS but missed CloudSat induce a net radiative heating in the UT. Their heating rate at 200 hPa is ~0.35 K/day in the tropical-mean and ~0.8 K/day over South Asia, which is about 3-4 times the clear-sky radiative heating rate.

Impact on UT/LS Tracer Distributions in the 2-D TTL model

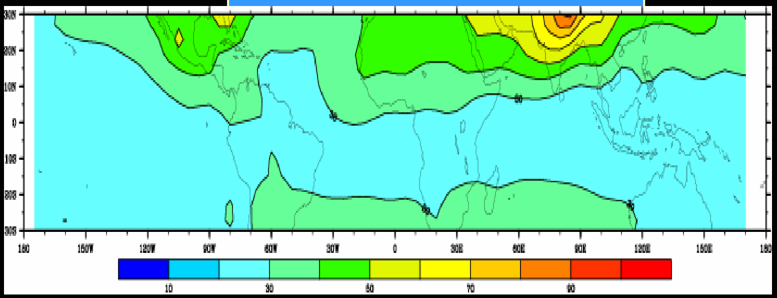


Test Cloud Radiative Effect in the UCLA GCM

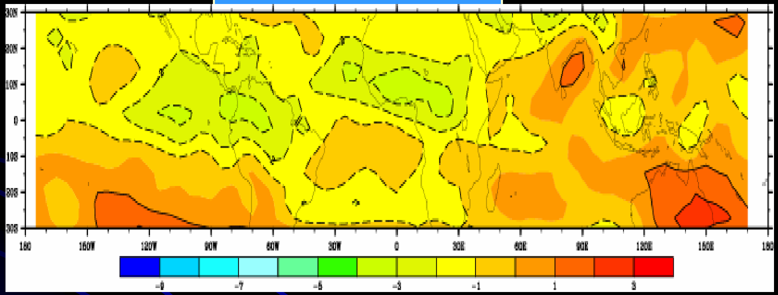
Clear-Sky 100mb H_2O



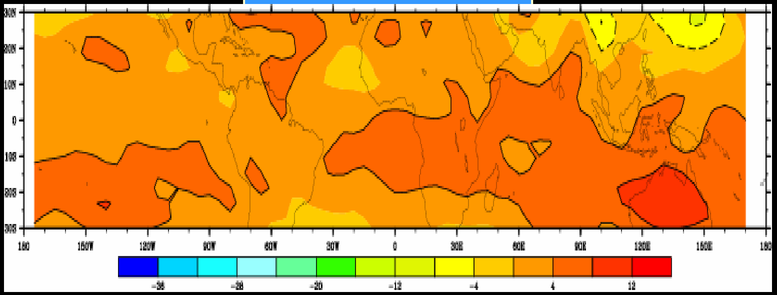
Clear-Sky 150mb H_2O



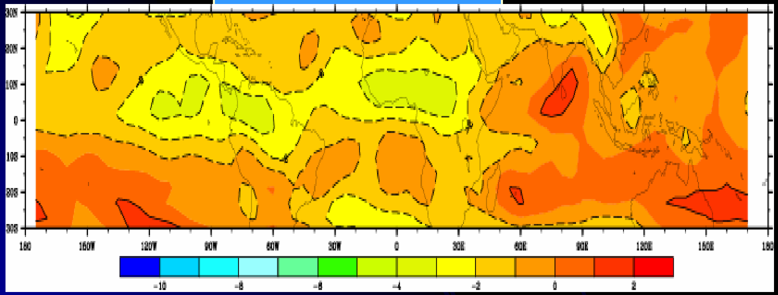
Cloudy - Clear



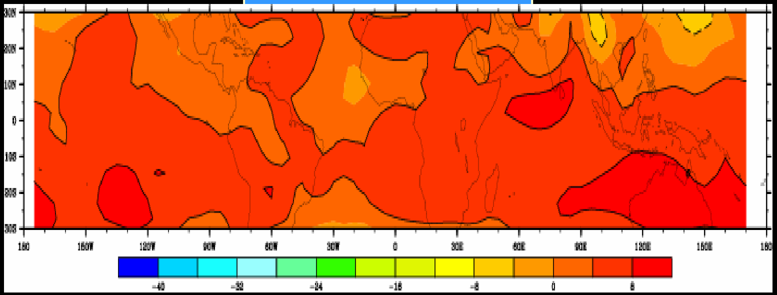
Cloudy - Clear



10per - Clear



10per - Clear



Conclusions

- Aura MLS observes about 10% more thin cirrus ($\tau < 0.2$) than CloudSat near the tropical tropopause. These thin clouds contribute to about 4.5 W m^{-2} LW CRF and 1 W m^{-2} SW CRF at TOA in the tropical average. Their effects at the surface are less than 1 W m^{-2}.

- They induce a net radiative heating in the UT. Their heating rate at 200 hPa is 0.35 K/day in the tropical-mean and ~0.8 K/day over South Asia, which is about 3–4 times the clear-sky radiative heating rate.

- The cloud radiative heating in the TTL produces increased H_2O and IWC in the TTL.

Acknowledgements: we thank the funding supported by ACMAP AST program and MLS project.