Reassessing the Role of Ice Clouds In Earth’s Radiation Budget

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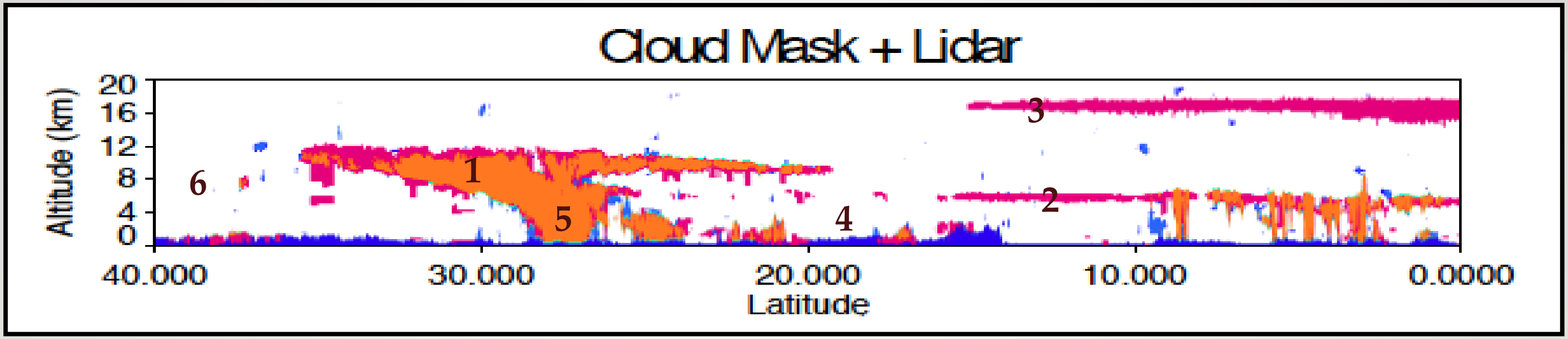
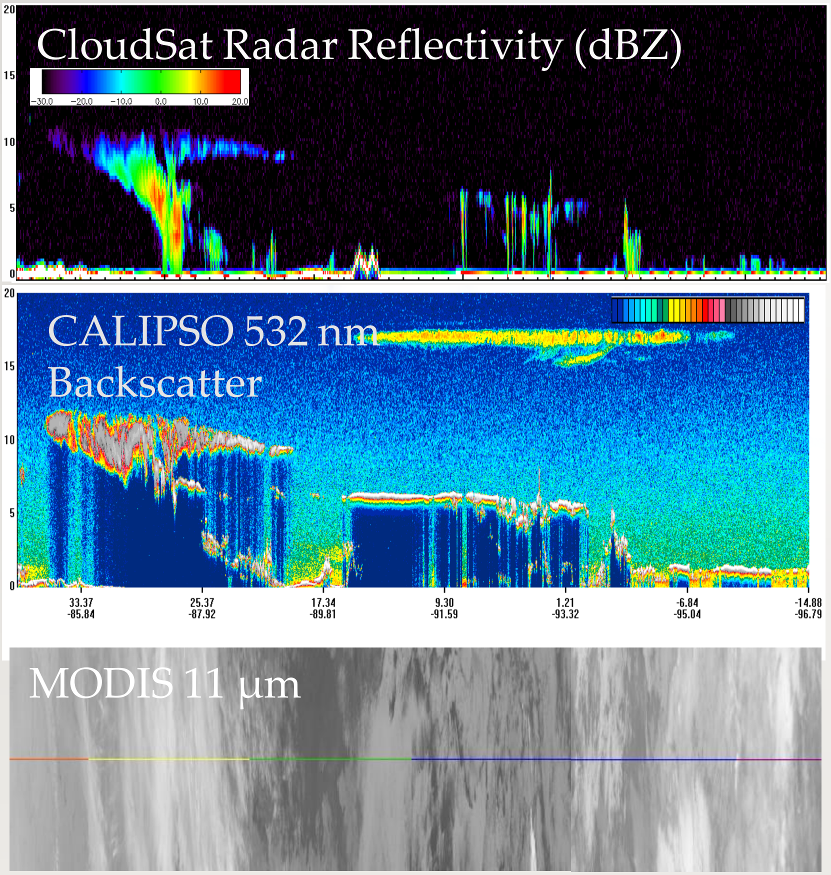
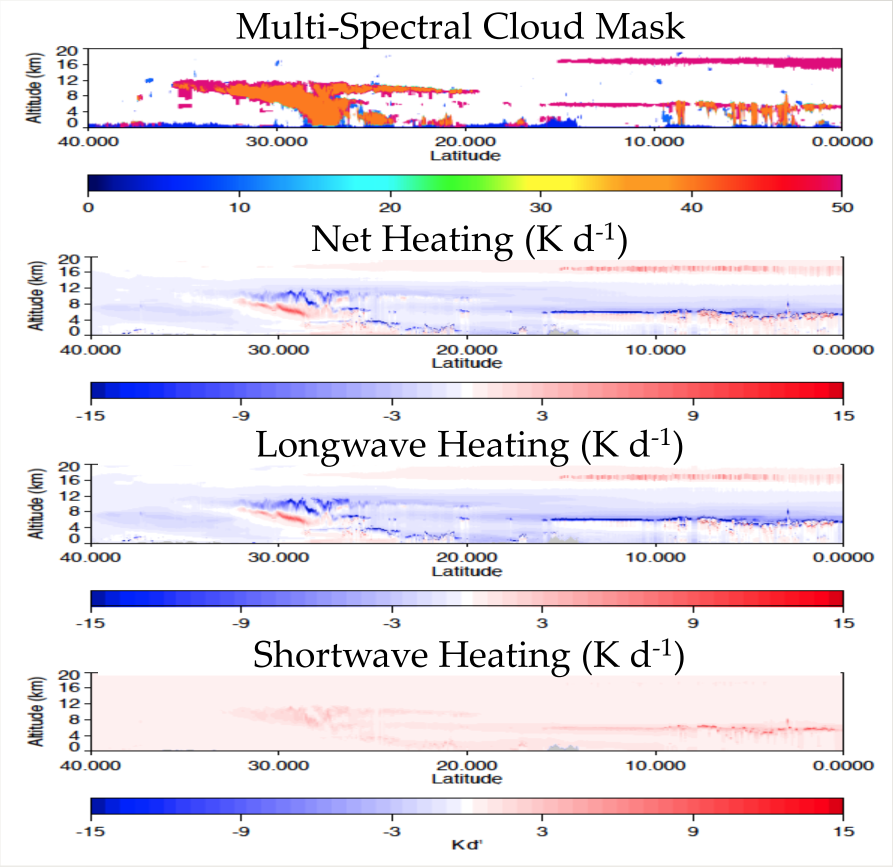
2B-FLXHR-lidar Algorithm



1. Clouds – CloudSat CPR + MODIS optical depth
2. Sub-visual Cirrus – CALIPSO (5 km Cloud Layer Product)
3. Stratus/mixed-phase – CALIPSO (identification) + MODIS (microphysical properties)
4. Aerosol – CALIPSO (5 km Aerosol Layer Product)
5. Precipitation – explicit rain DSD and CloudSat 2C-PRECIP-COLUMN (identification/LWP)
6. Temperature & Humidity – ECMWF/AIRS (in progress)

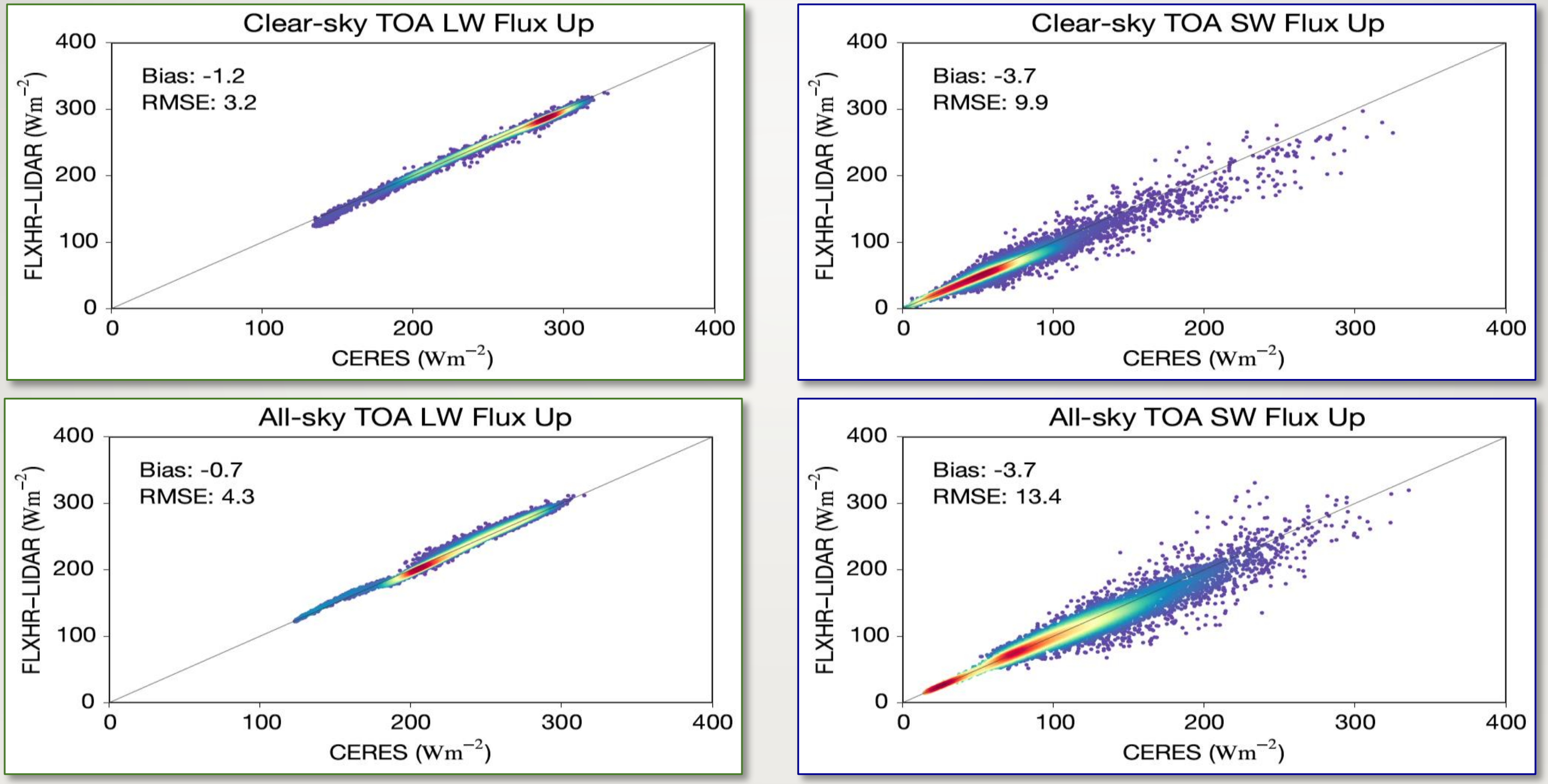
Heating Rate Profiles





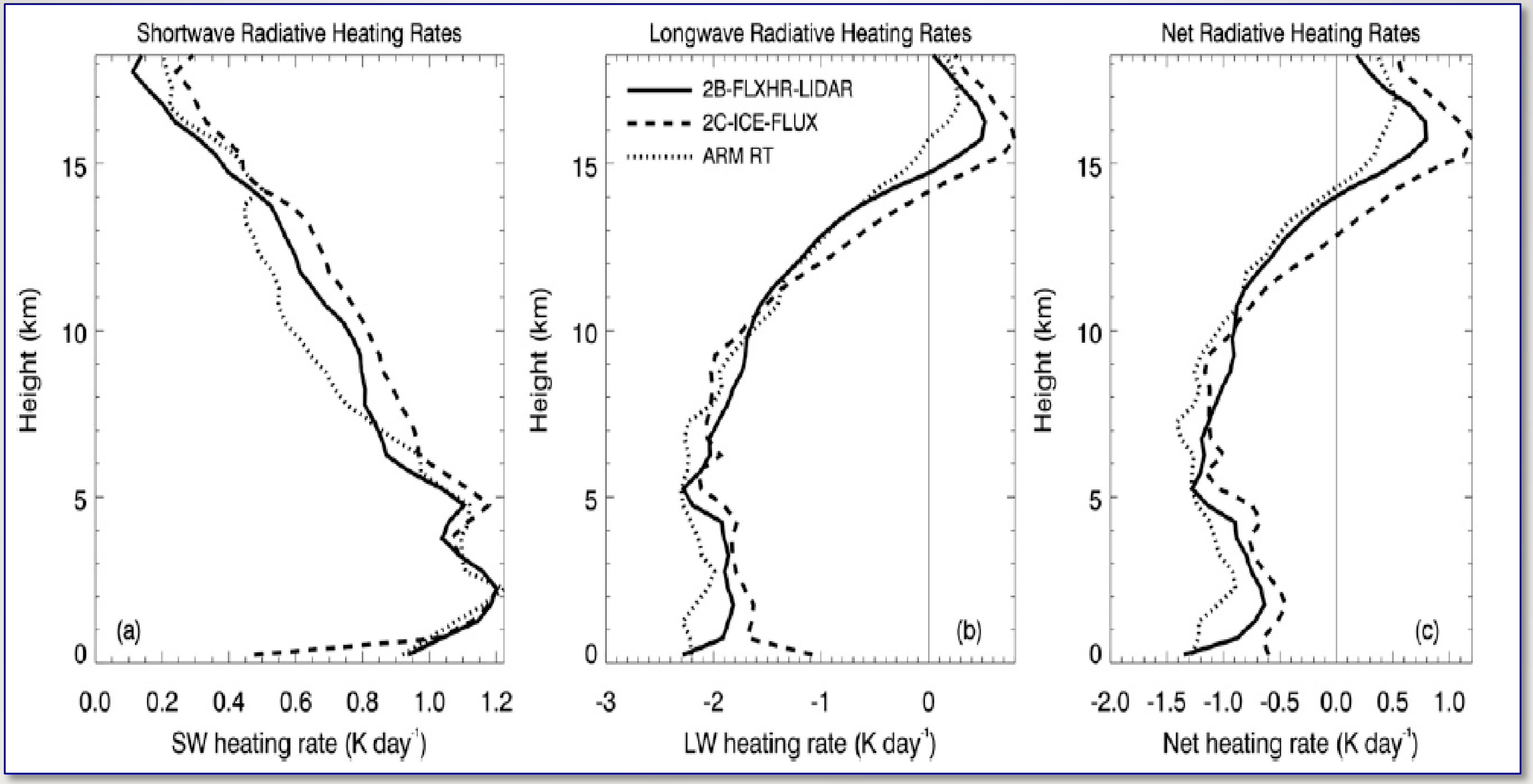
L'Ecuyer et al, JGR (2009)

Comparison with CERES



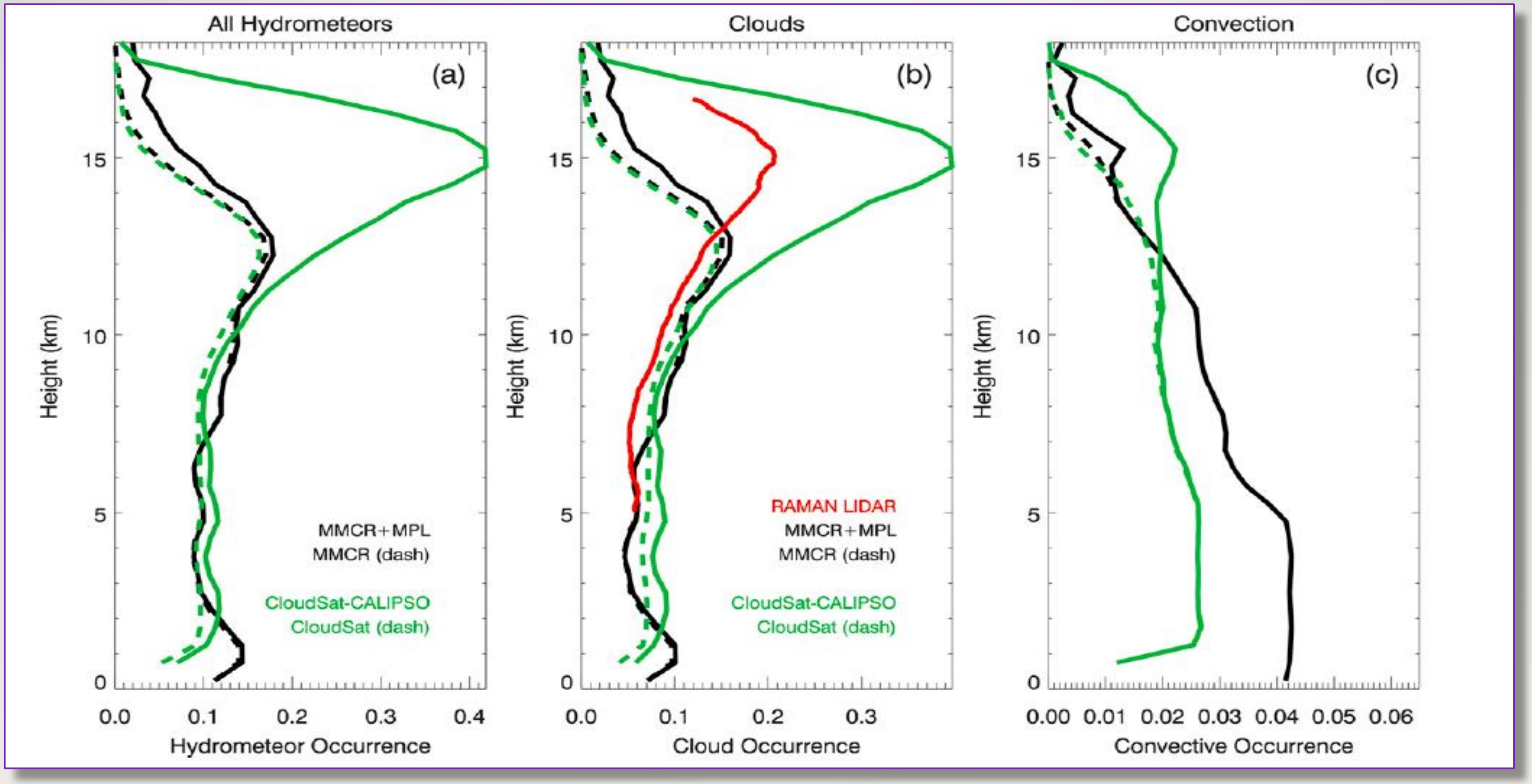
Matus et al, JGR (2017)

Evaluating Vertical Structures



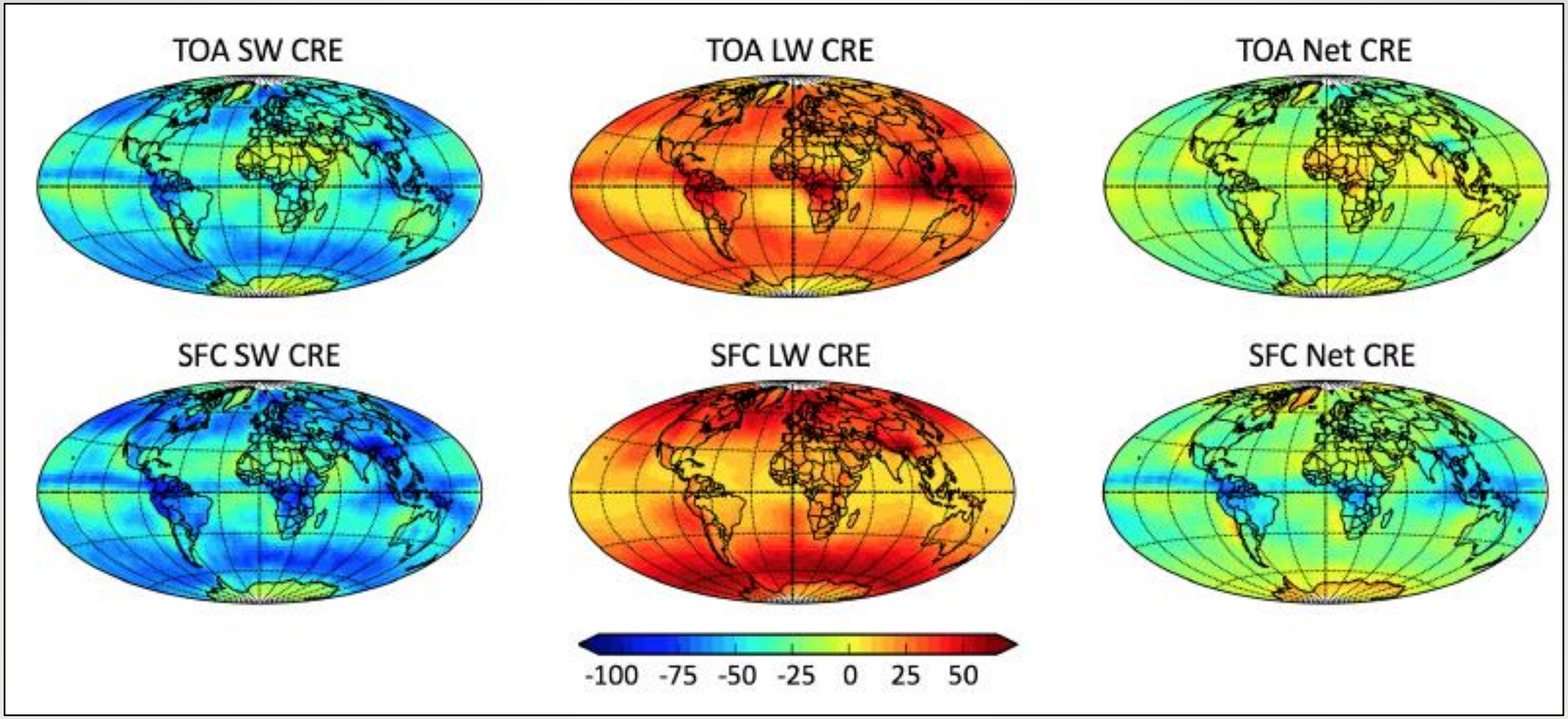
Protat et al, JGR (2014)

Cloud Detection Differences



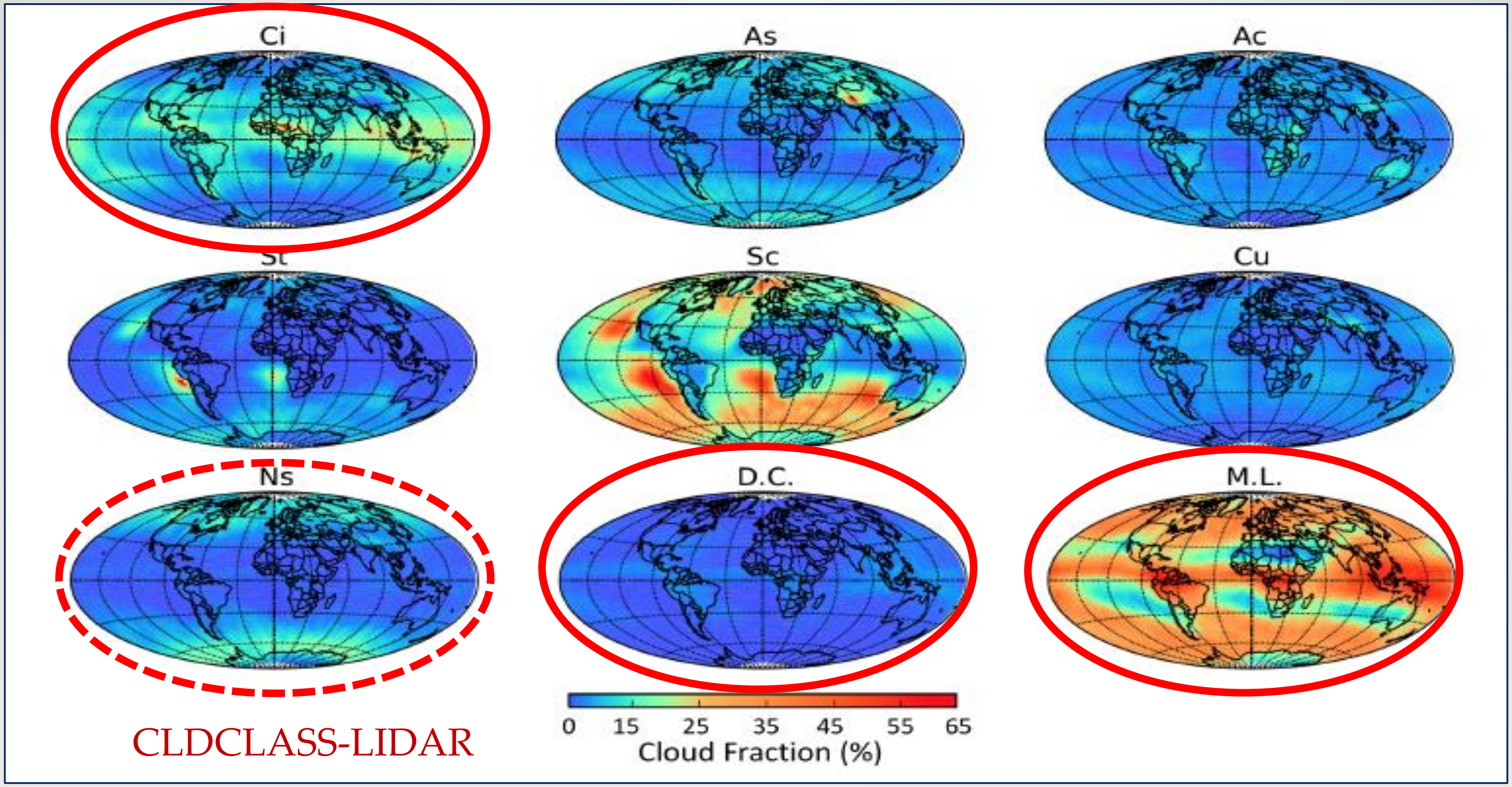
Protat et al, JGR (2014)

Reassessing the Influence of Clouds on Earth's Radiation Budget



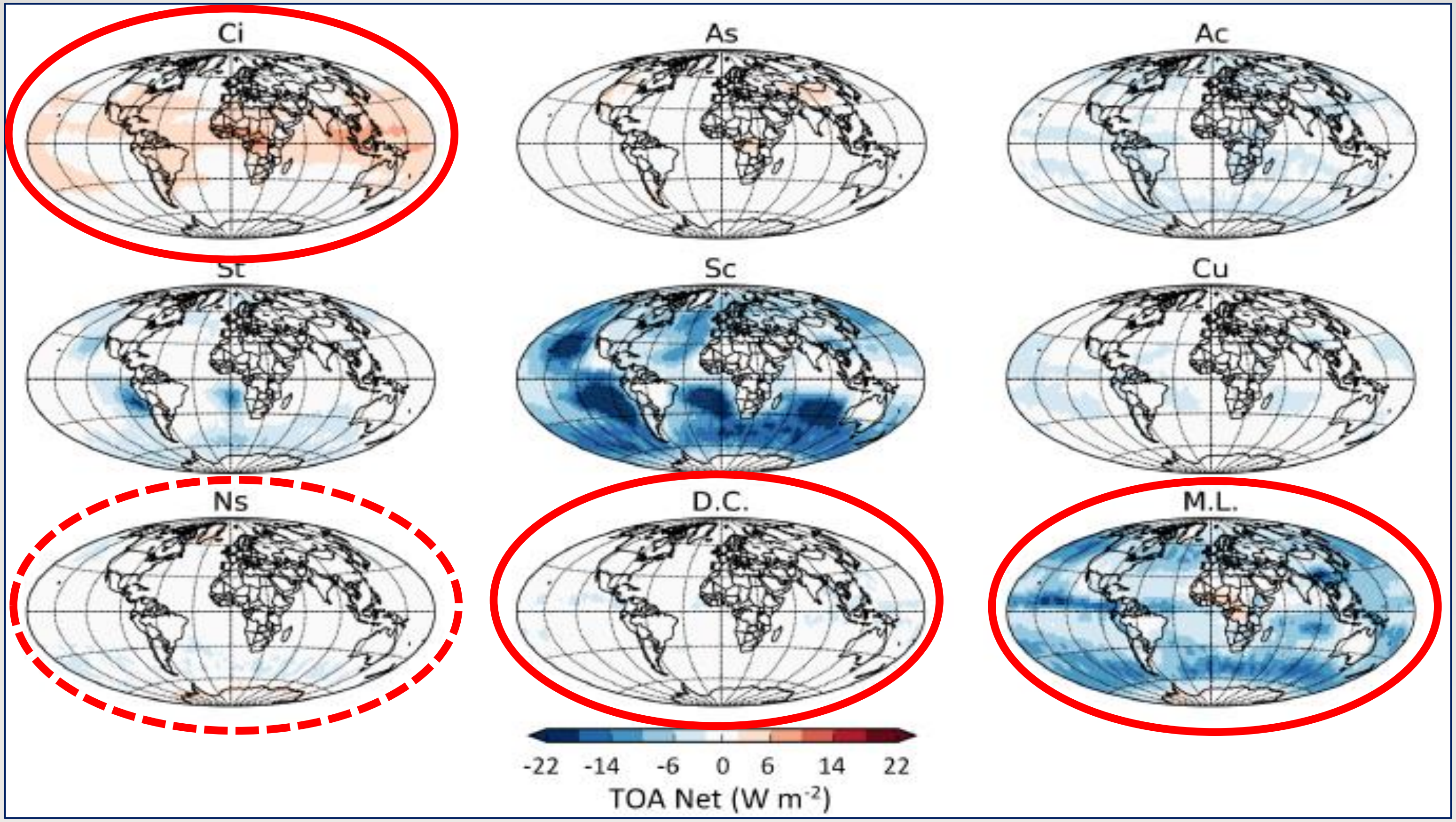
Hang et al, in preparation, 2017

Distinguishing Ice Cloud Regimes



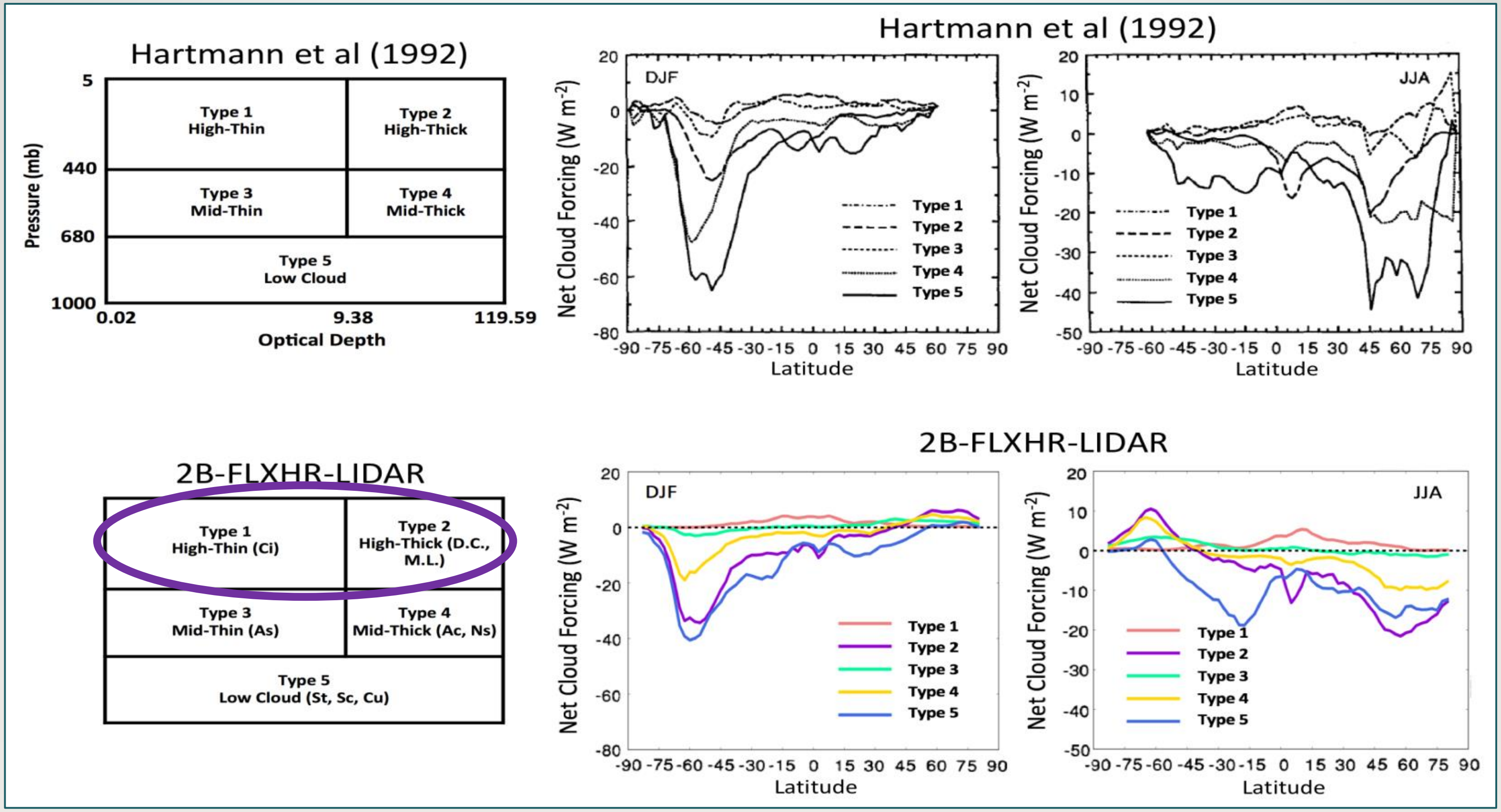
Hang et al, in preparation, 2017

Radiative Impacts (TOA)



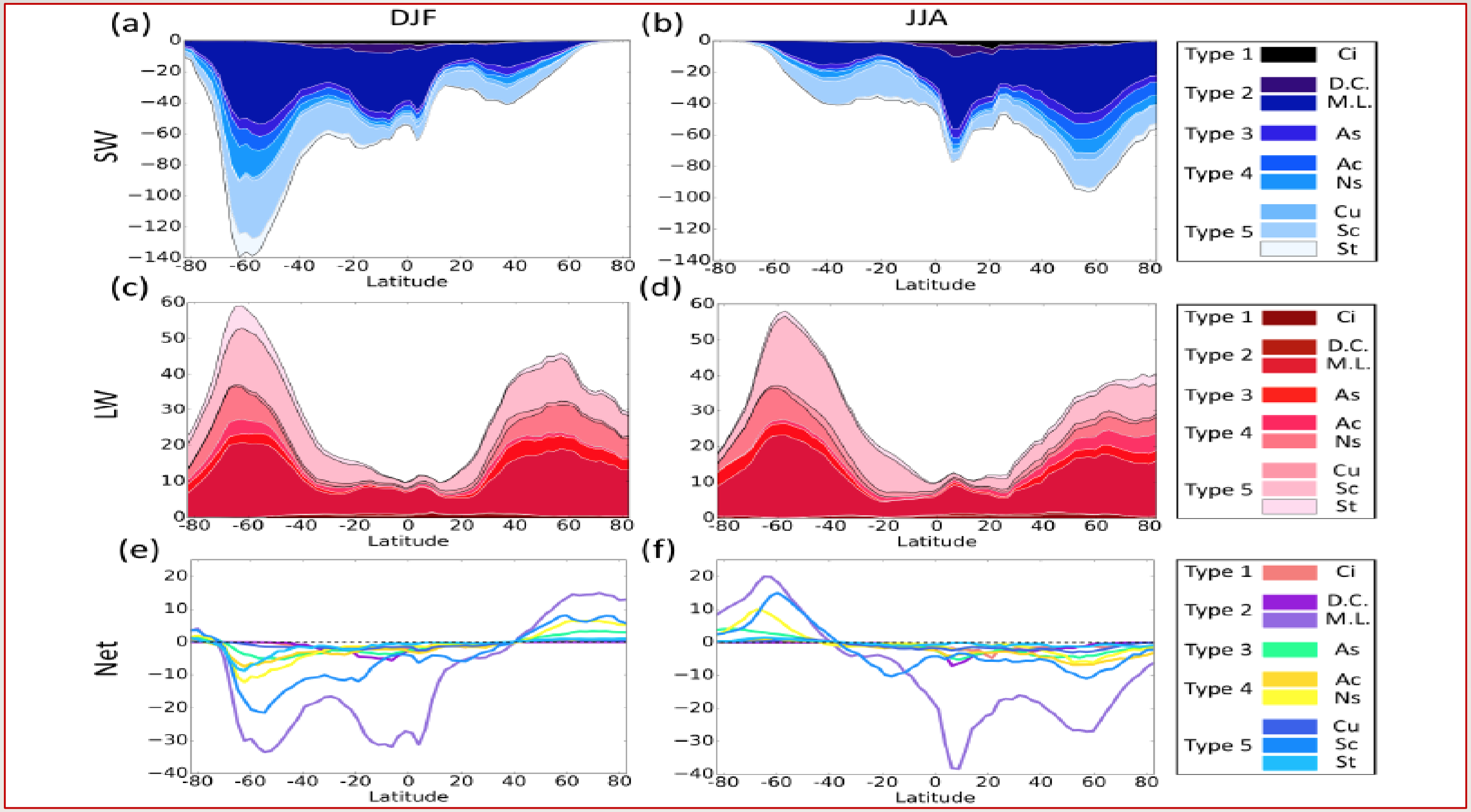
Hang et al, in preparation, 2017

Revisiting the Classical Picture



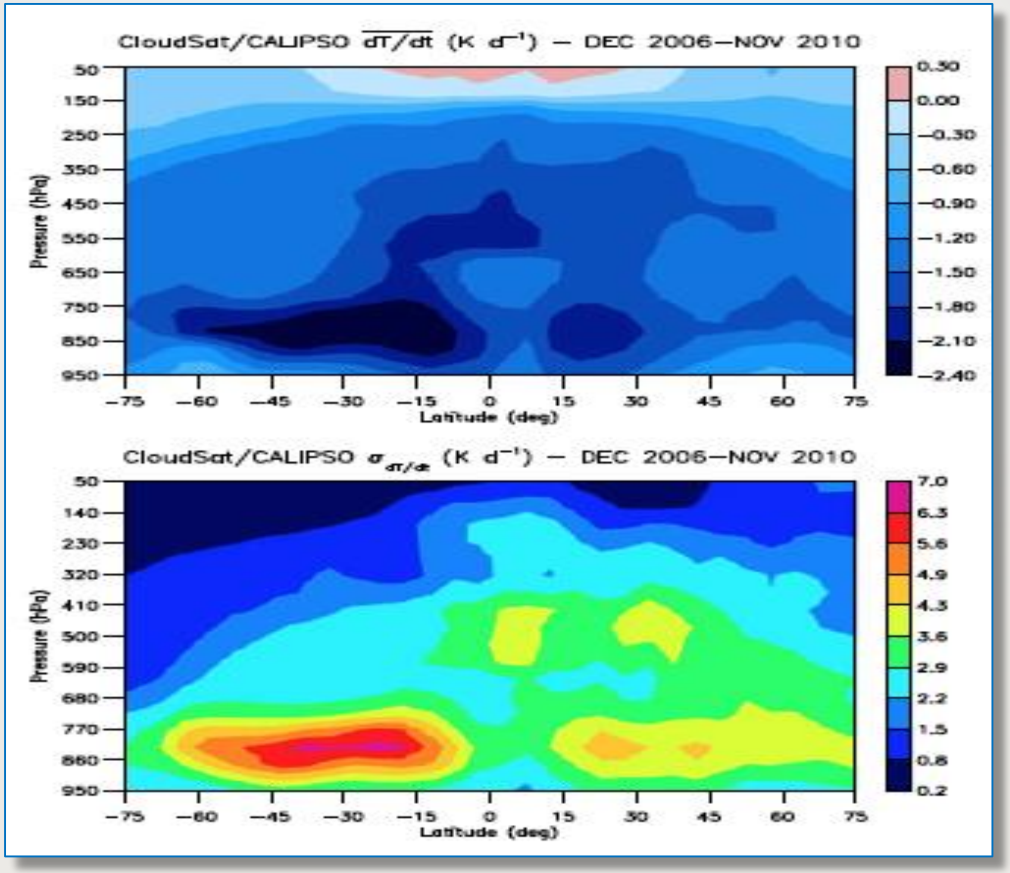
Stephens et al, BAMS, 2017

Quantifying Impacts on *Surface* Radiation Balance



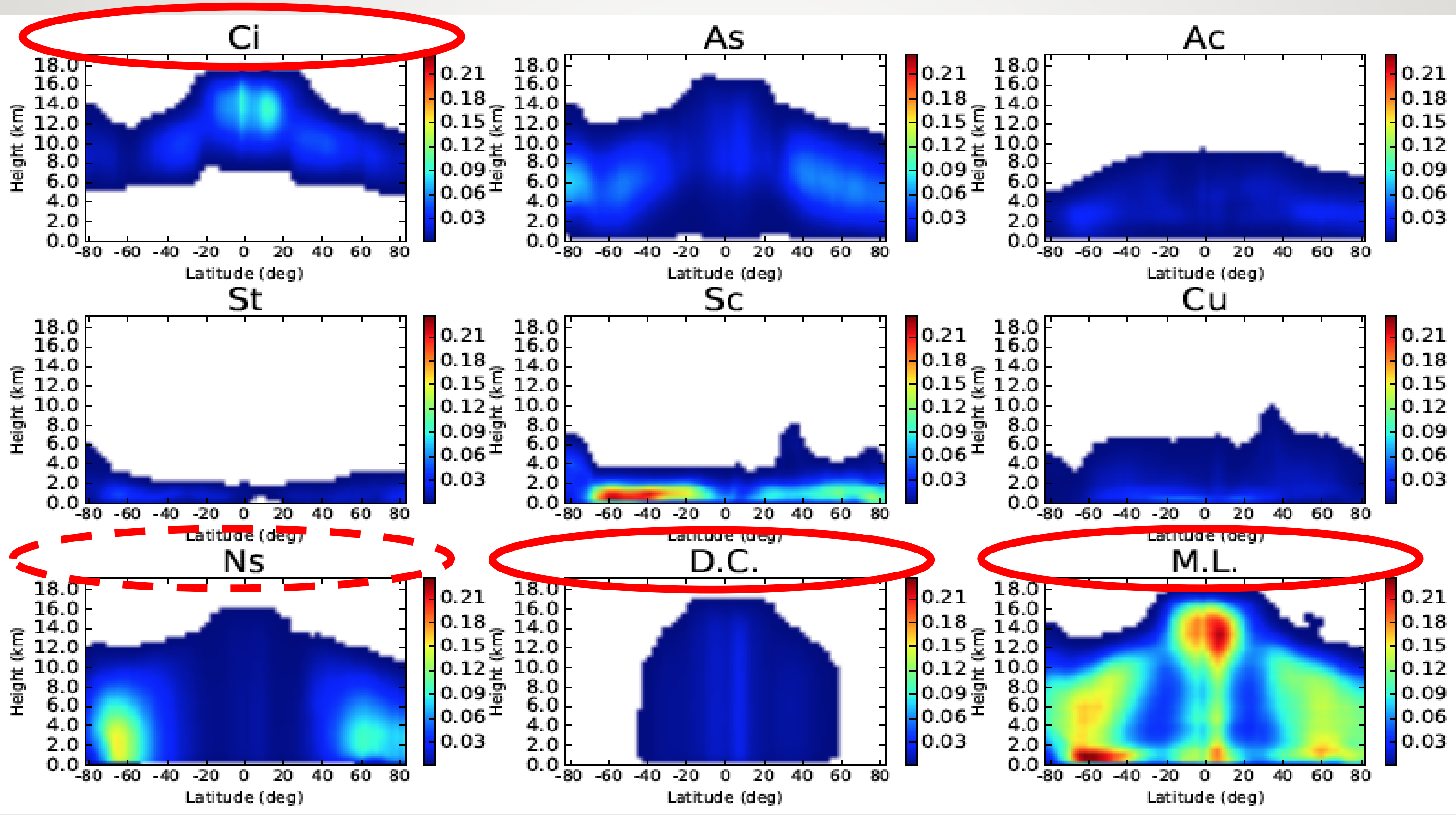
Hang et al, in preparation, 2017

Vertical Structure of Radiative Heating



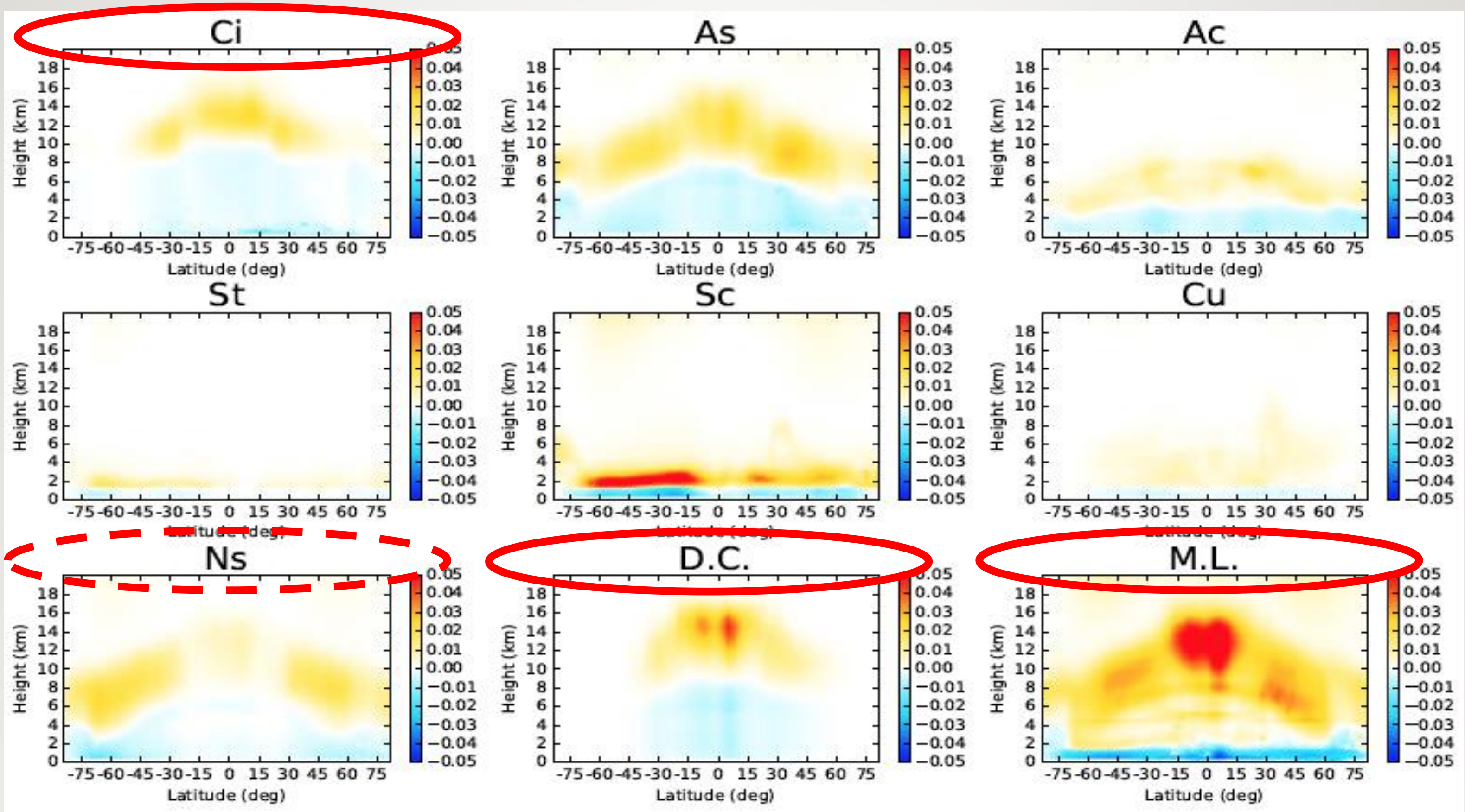
Haynes et al, GRL, 2013

Influence of Ice Cloud Regimes



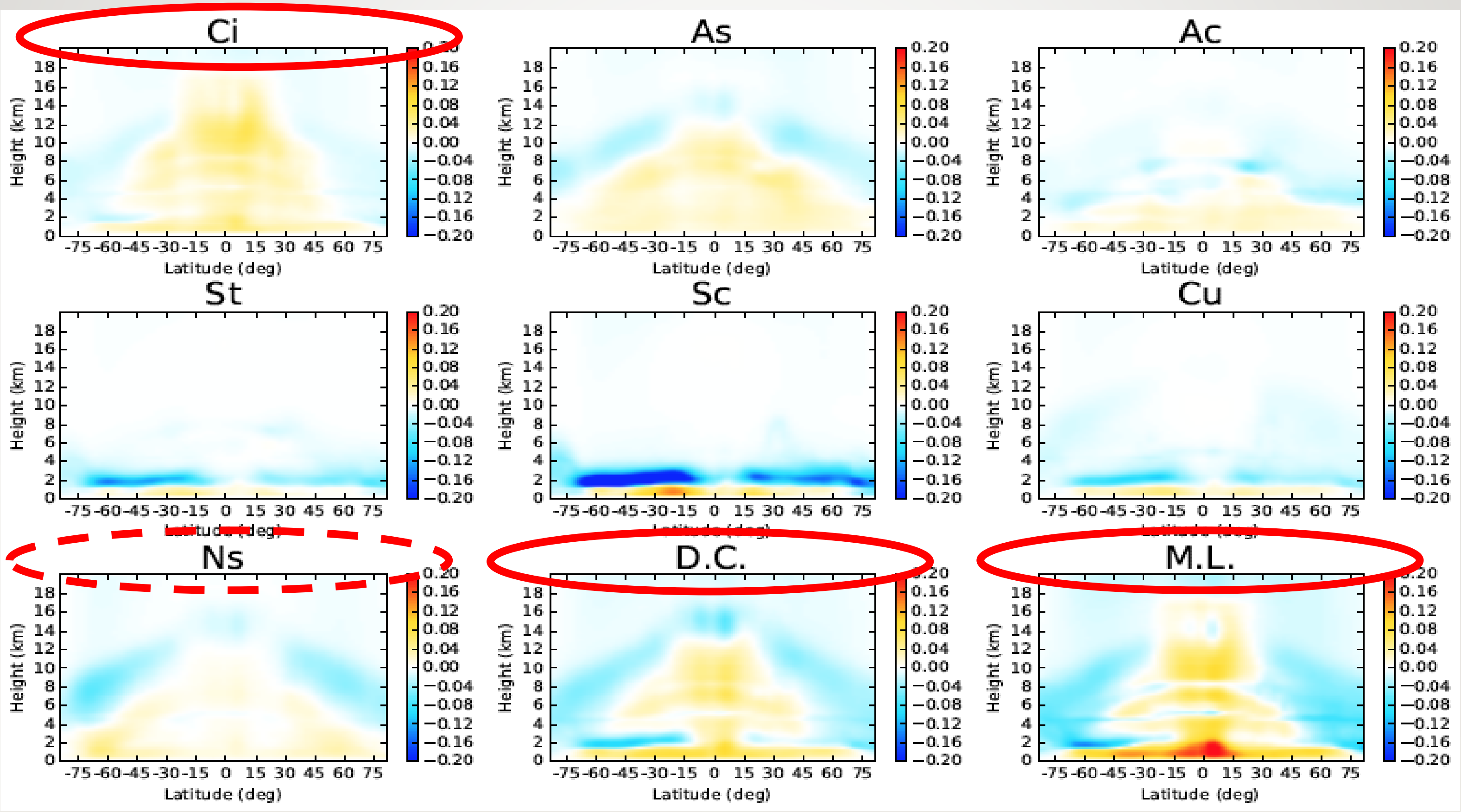
L'Ecuyer and Hang 2017, *in preparation*

Influence on SW Heating



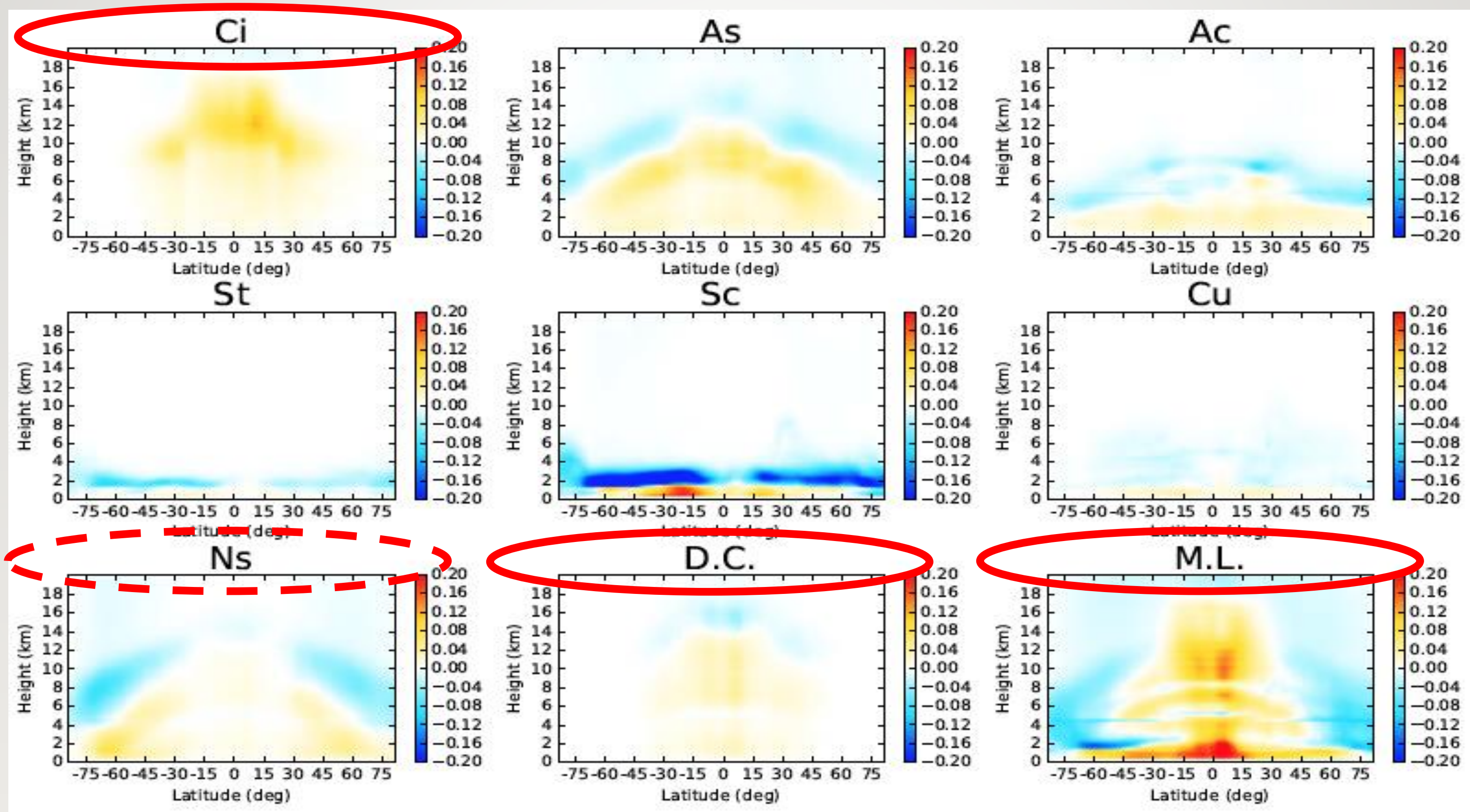
L'Ecuyer and Hang 2017, *in preparation*

Influence on LW Cooling



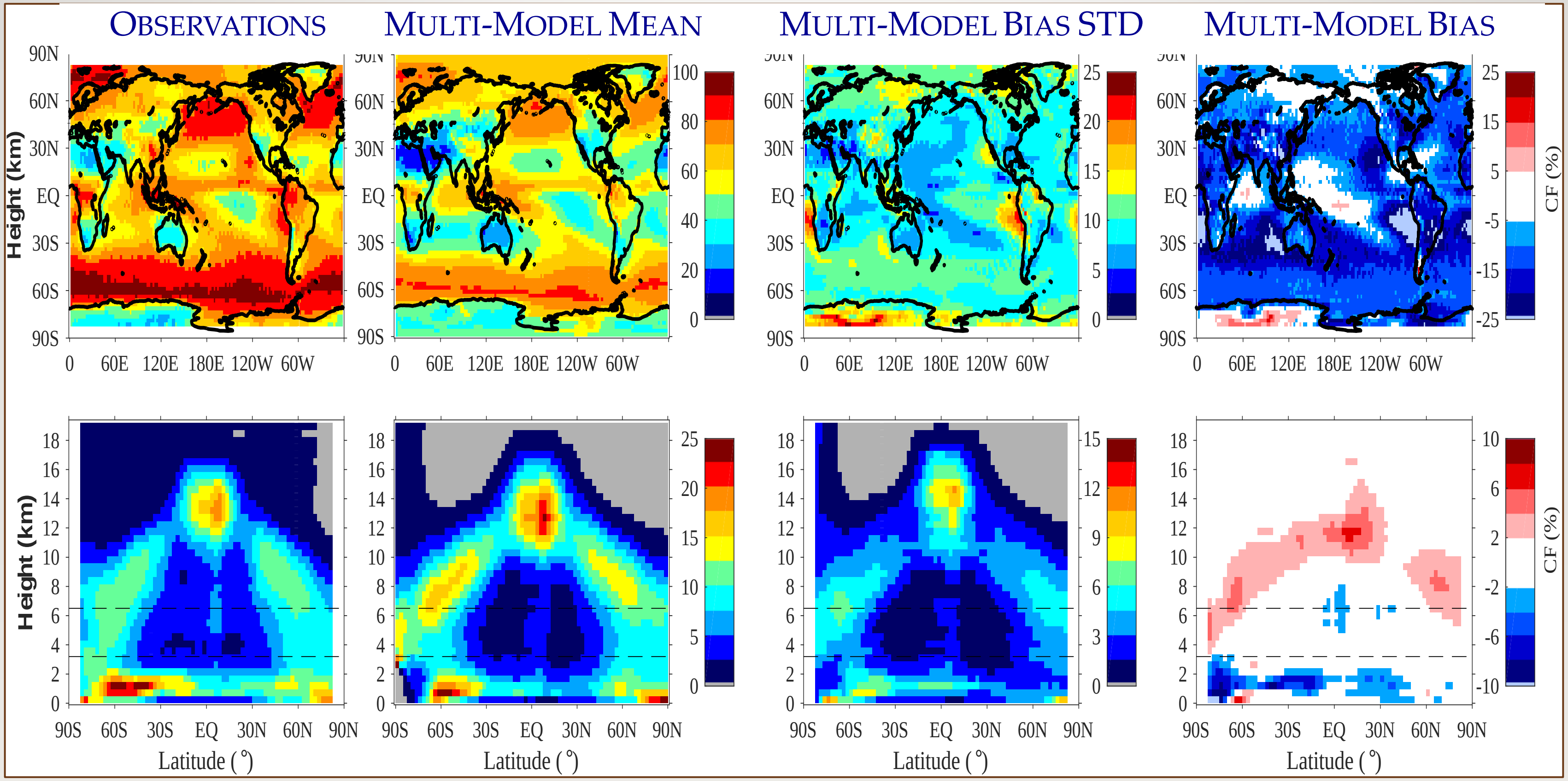
L'Ecuyer and Hang 2017, *in preparation*

Influence on Net $Q_R(z)$



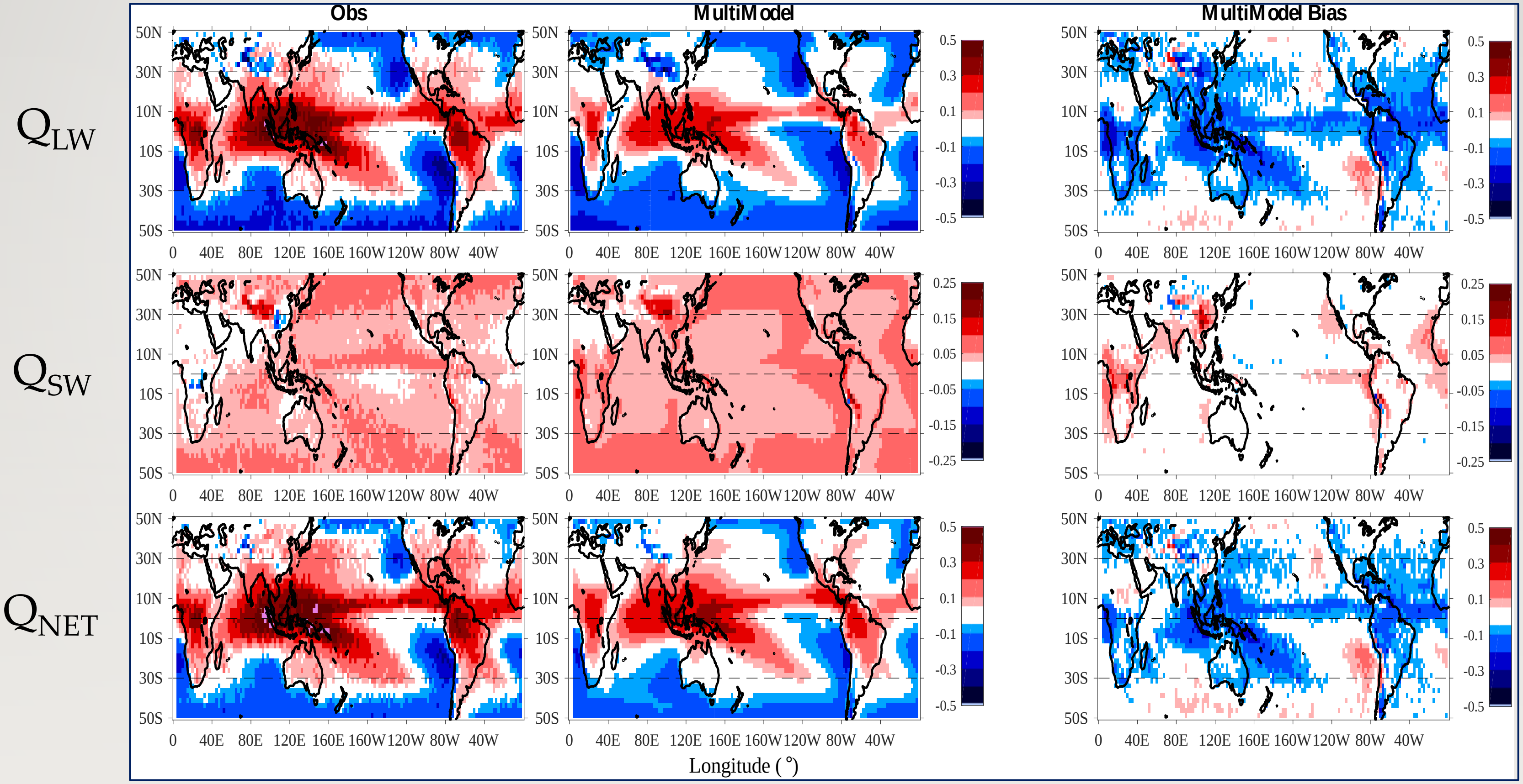
L'Ecuyer and Hang 2017, *in preparation*

Evidence of Model Cloud Biases



Cesana et al, submitted to *J. Climate*, 2017

Implications for Column Heating



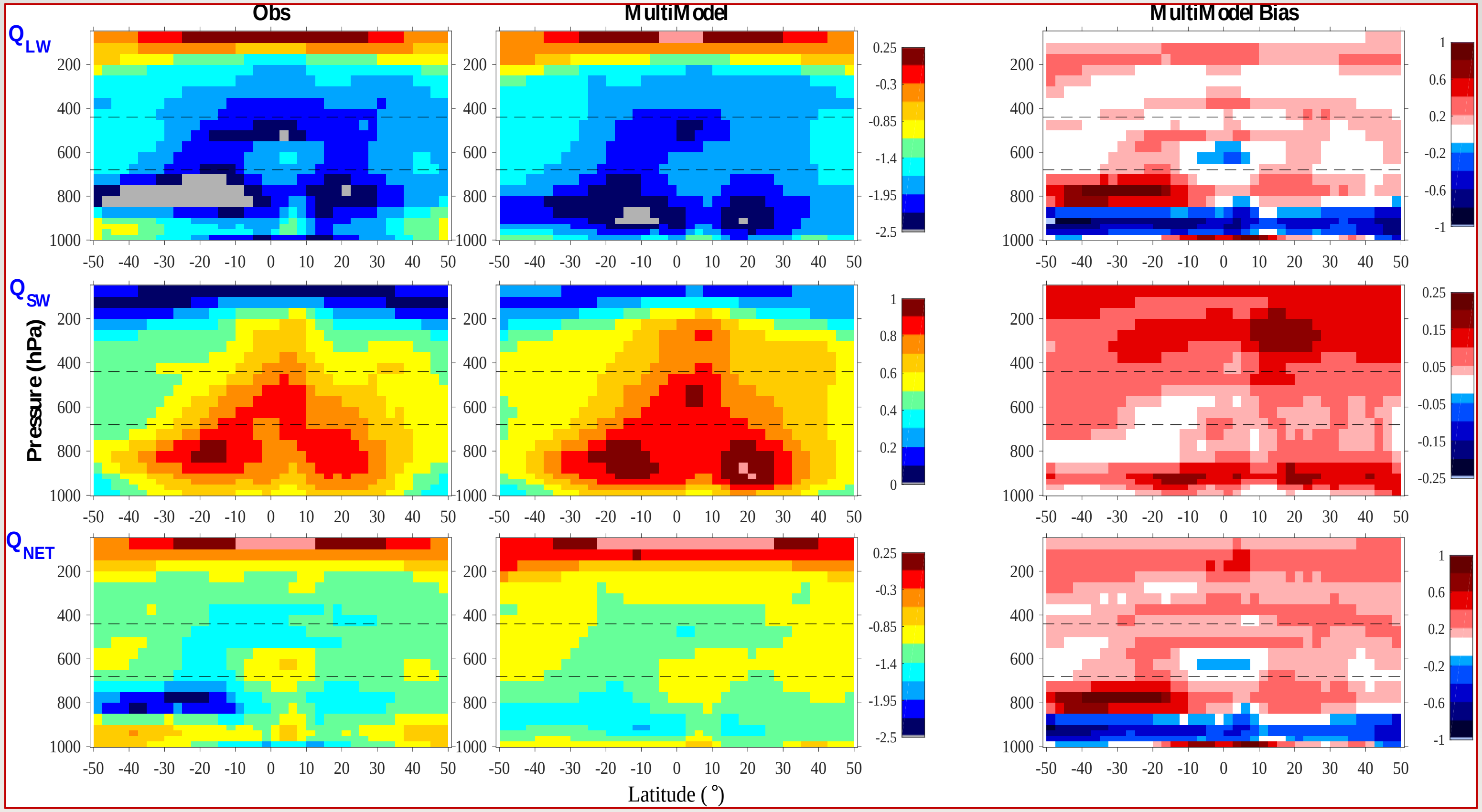
Cesana et al, submitted to *J. Climate*, 2017

Biases in Heating Profiles

Q_{LW}

Q_{SW}

Q_{NET}

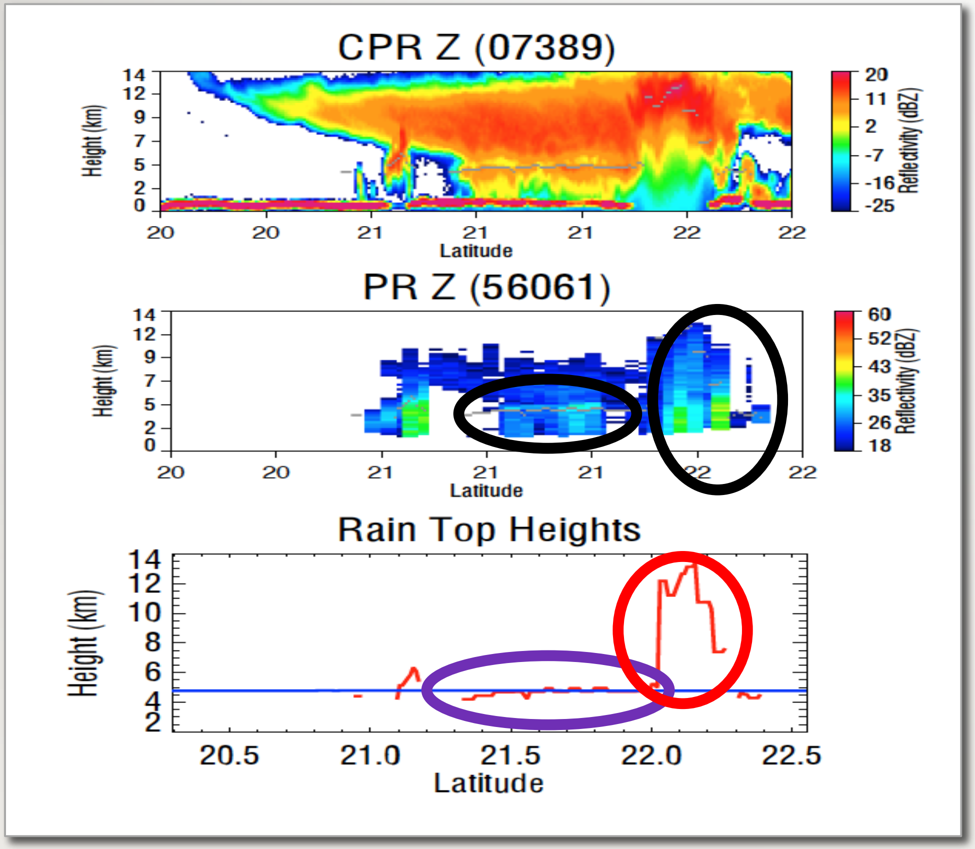


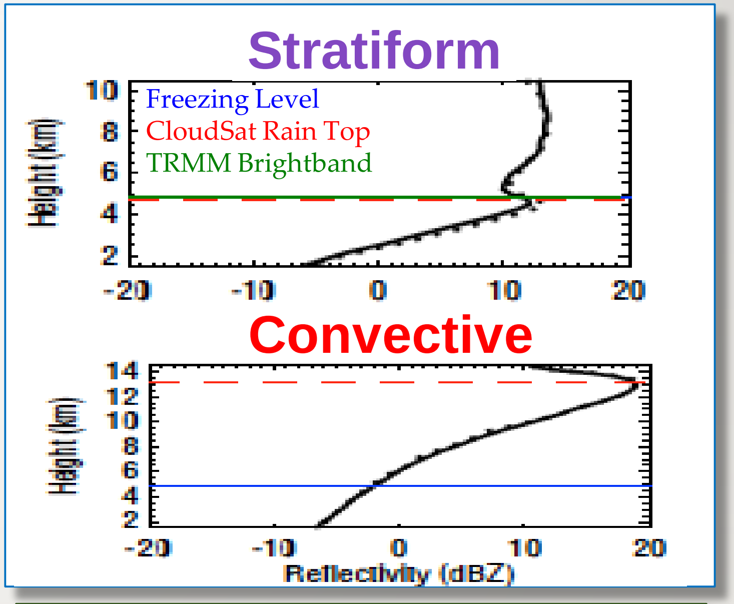
Cesana et al, submitted to *J. Climate*, 2017

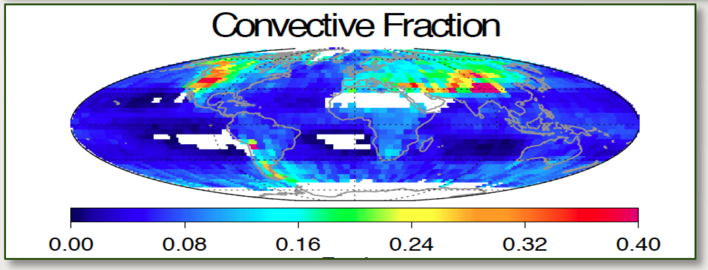
Summary

- 2B-FLXHR-LIDAR dataset yields high resolution radiative flux and heating rate profiles consistent with CloudSat, CALIPSO, MODIS, and AMSR-E observations.
- These data add a new vertical dimension for assessing the impacts of convection and upper tropospheric ice clouds.
- The dataset has been used to document the global radiative impacts of convection and cirrus, quantify the impacts of these cloud regimes on atmospheric radiative heating rates, and evaluate the representation in models.

Identifying Convective Cores

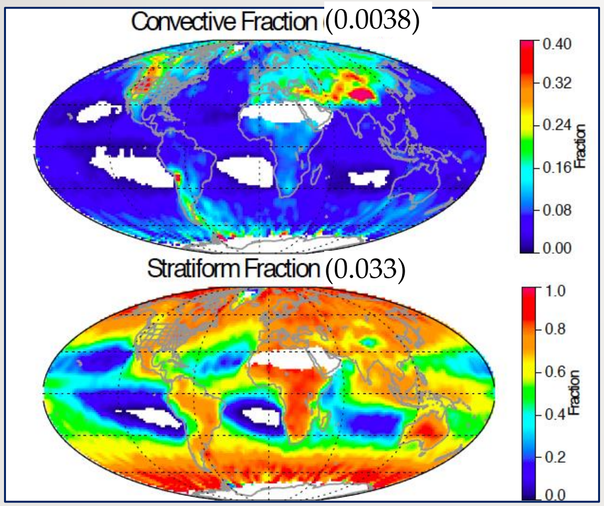


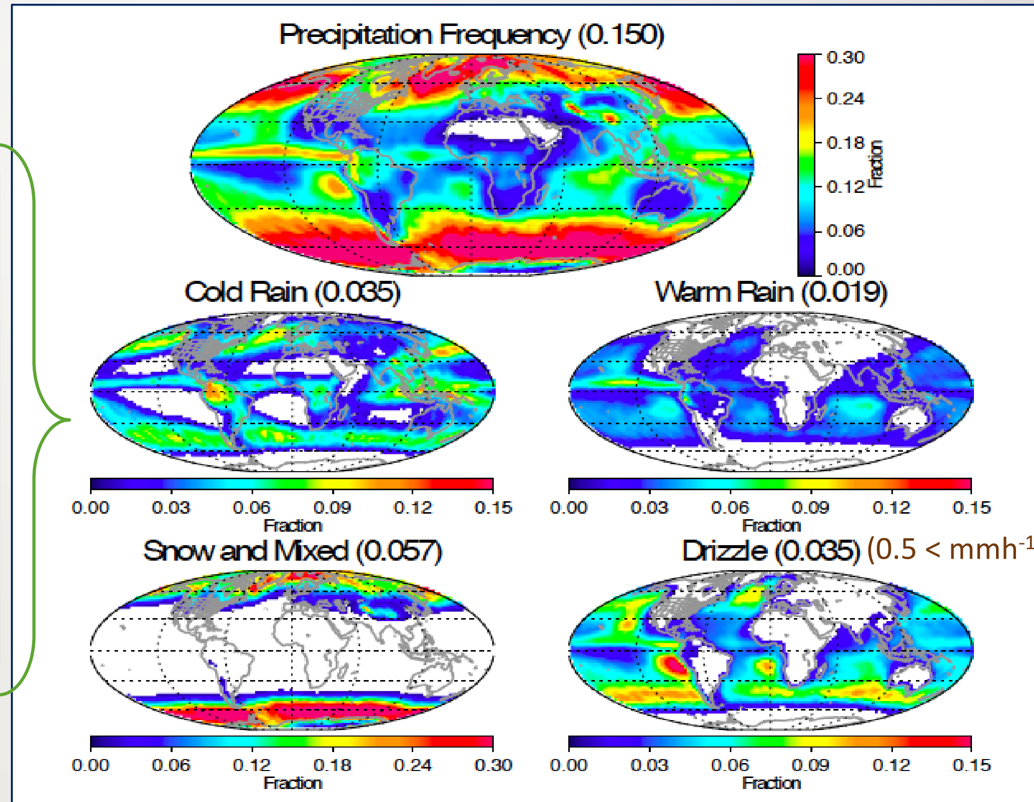




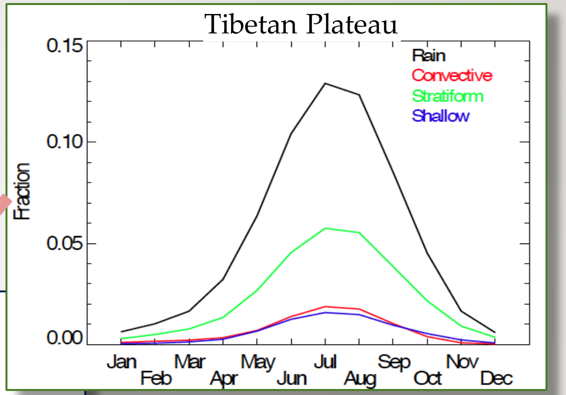
Global Precipitation Regimes

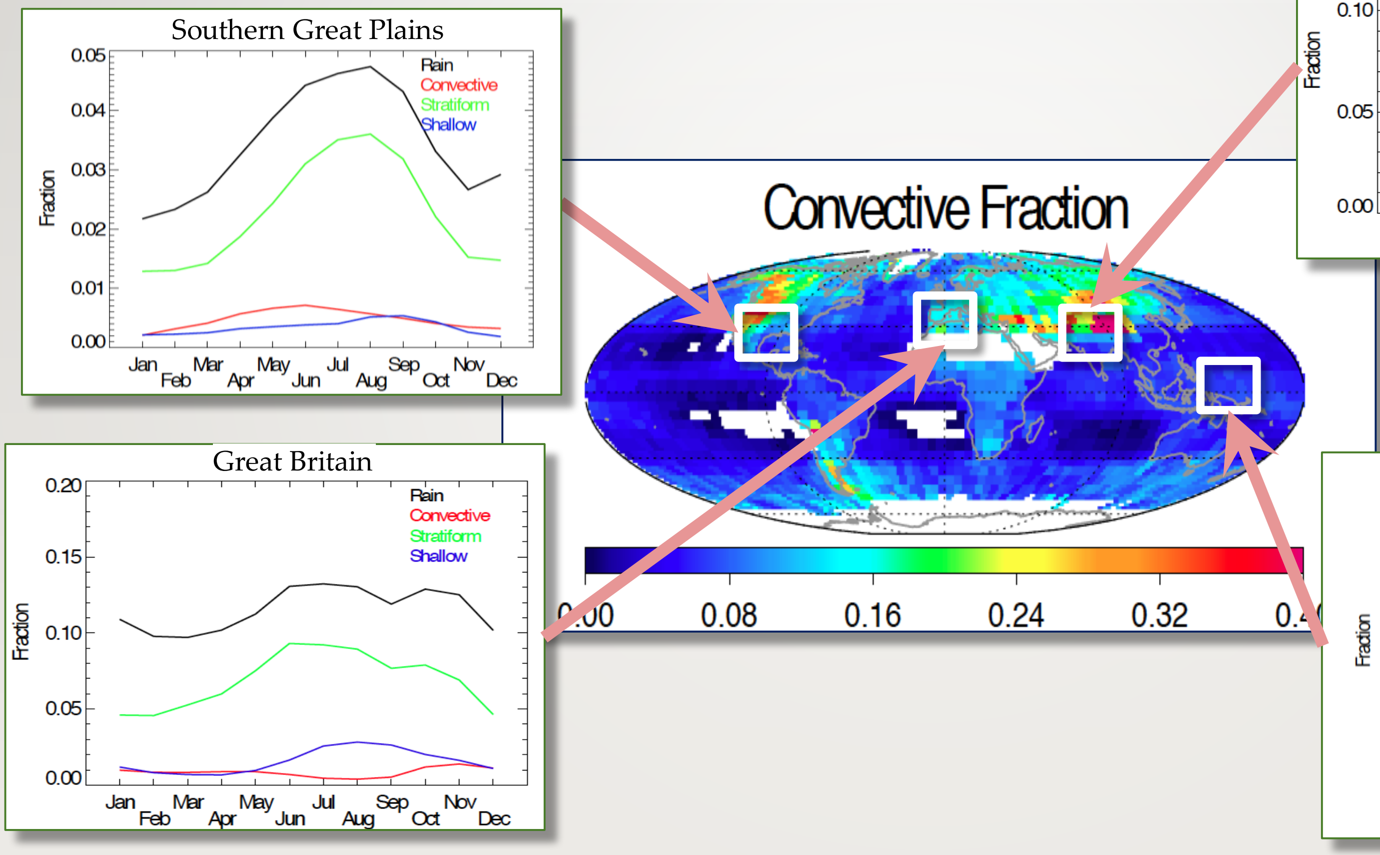
2007-10 mean from 2C-PRECIP-COLUMN

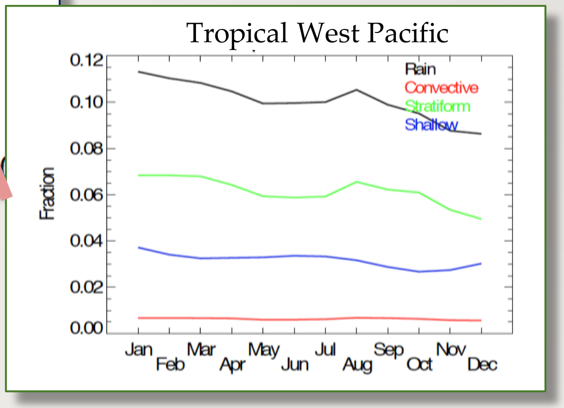




Regional Characteristics



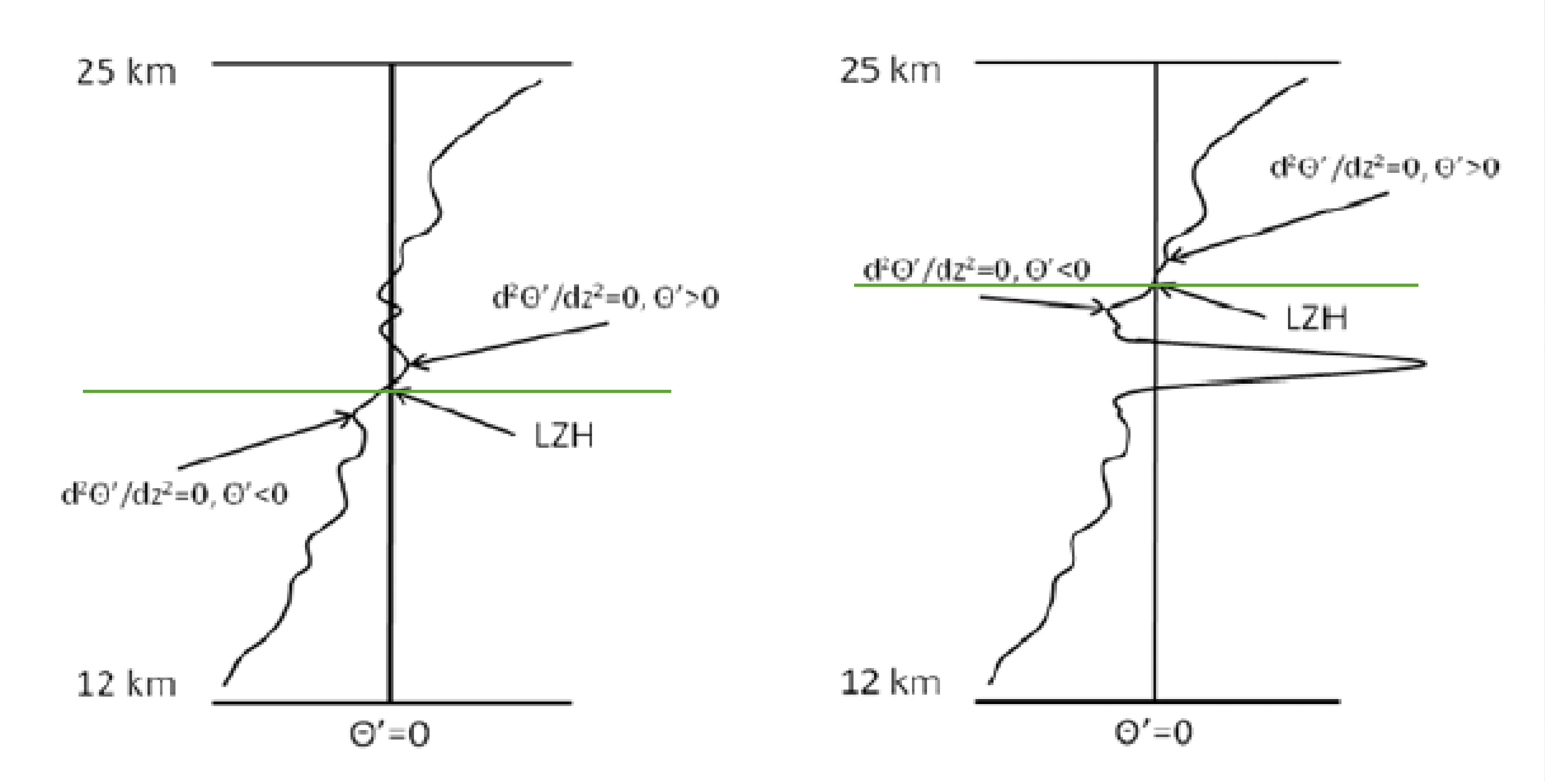




Other Applications

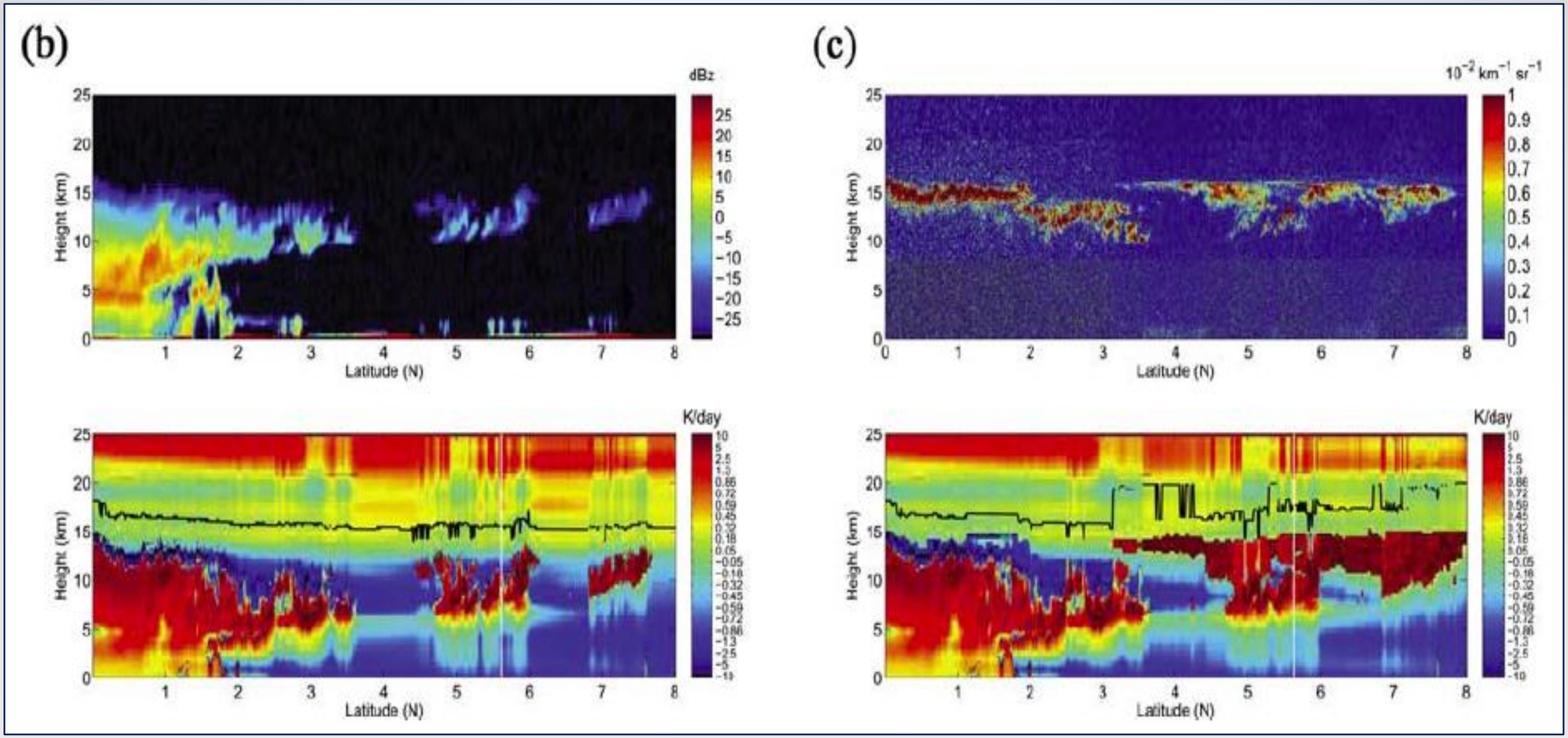
Impacts of Cirrus on the TTL

CLEAR SKY | CIRRUS



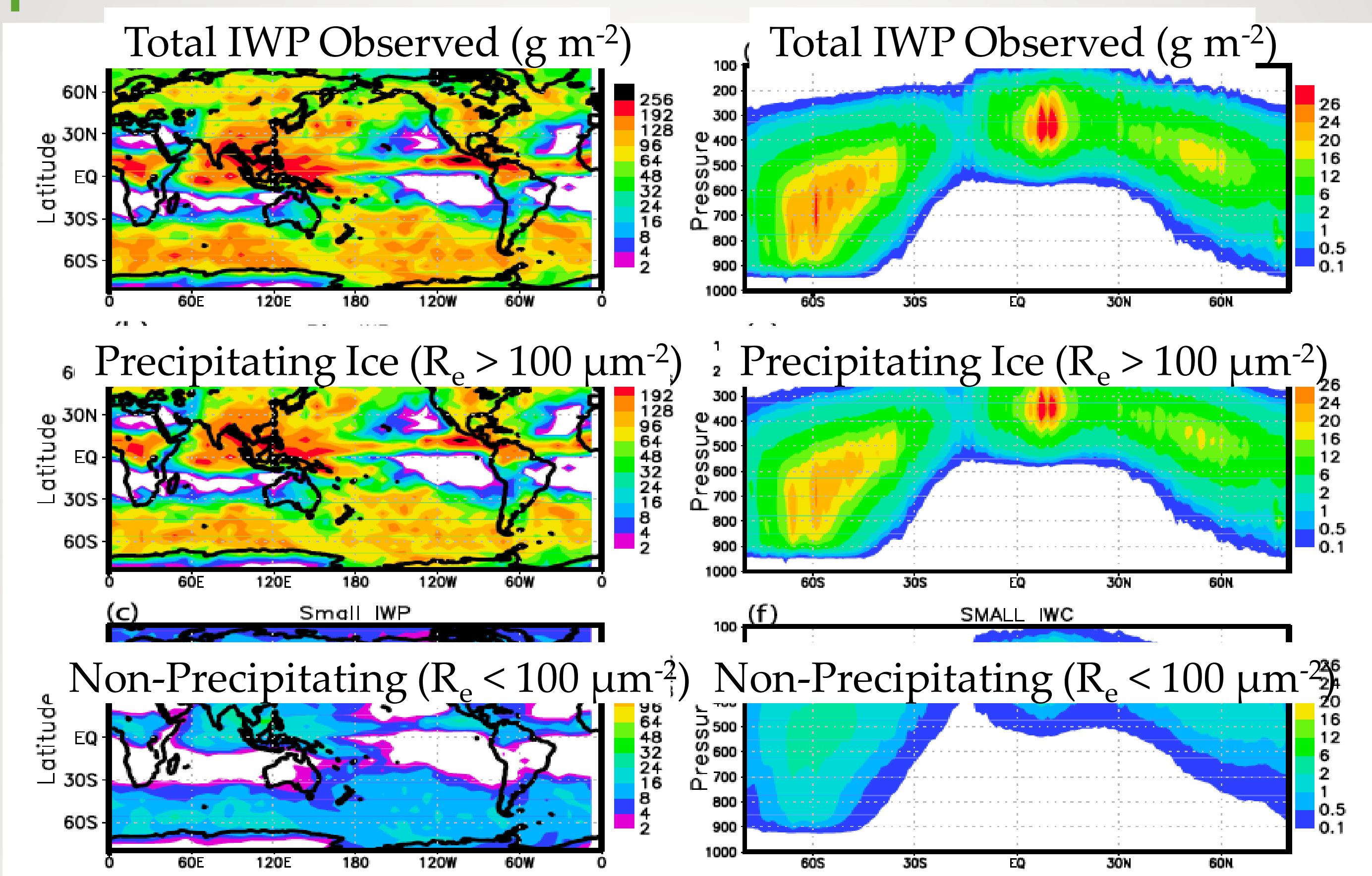
Feldman et al, JGR (2008)

Impacts of Cirrus on the TTL



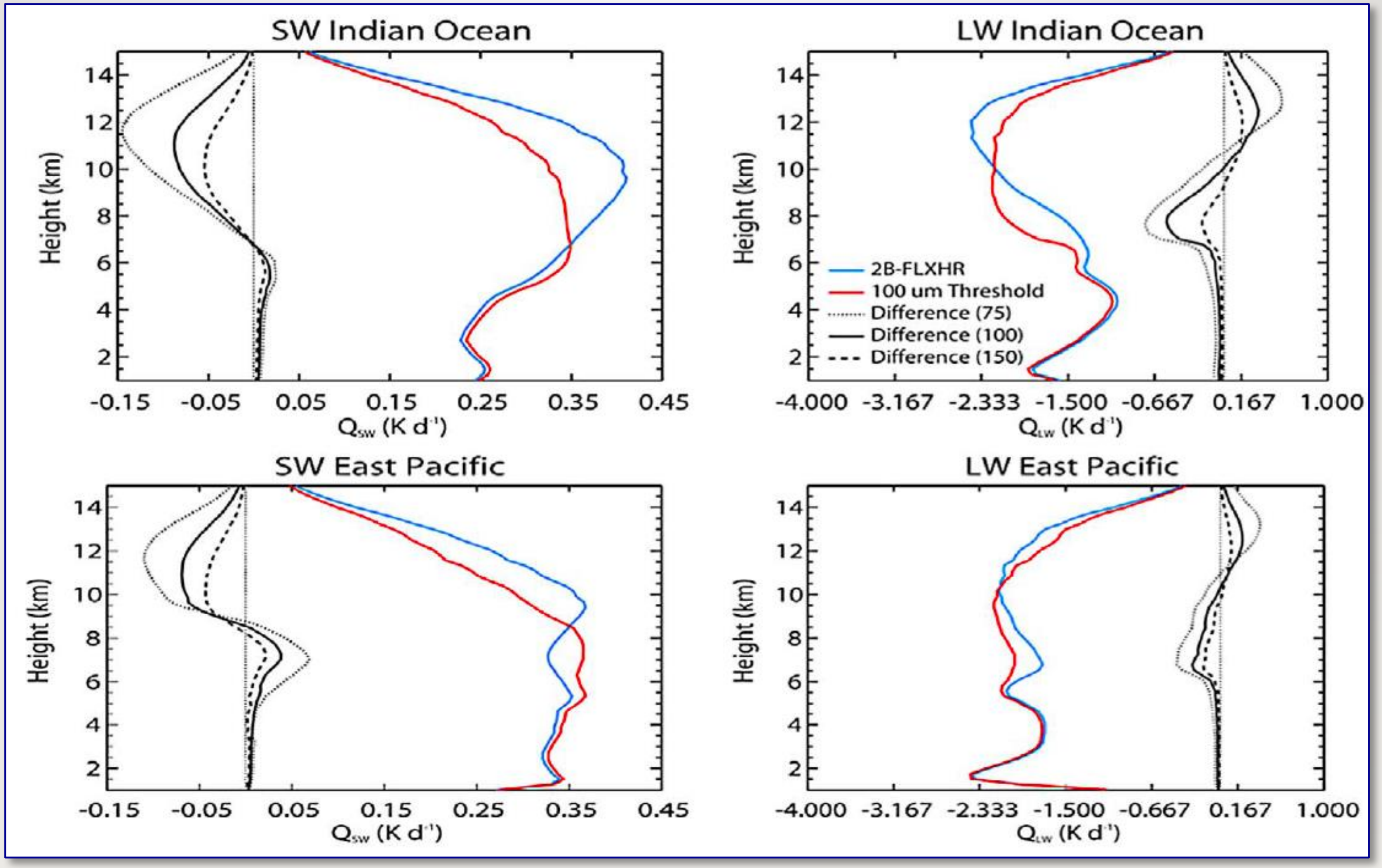
Feldman et al, JGR (2008)

Radiative Impacts of Precipitating Ice



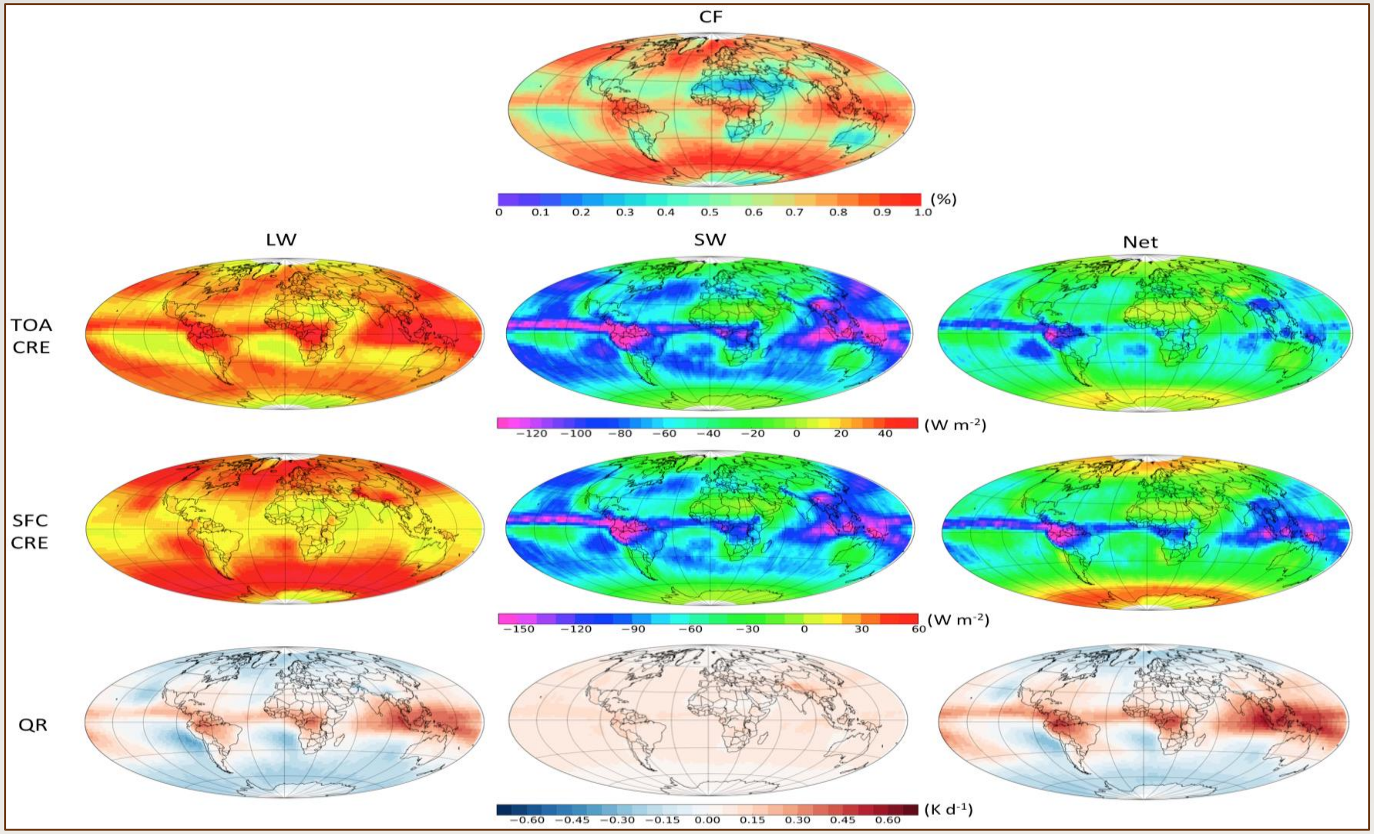
Waliser et al, GRL (2011)

Radiative Impacts of Precipitating Ice



Waliser et al, GRL (2011)

Impact on Atmospheric Heating

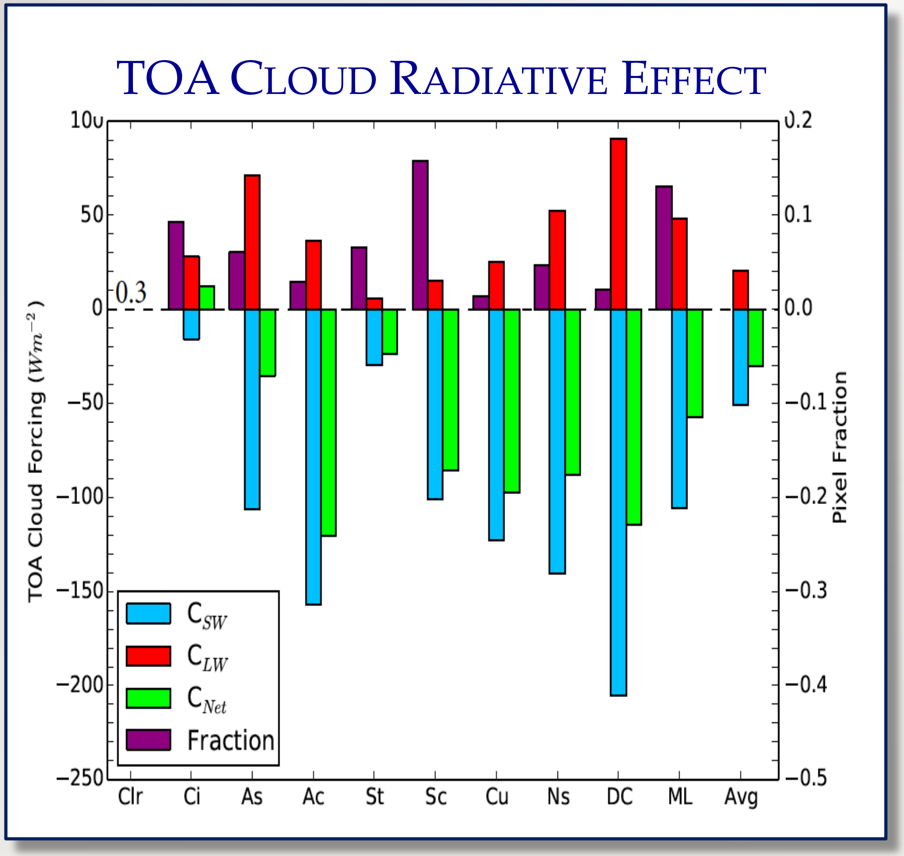


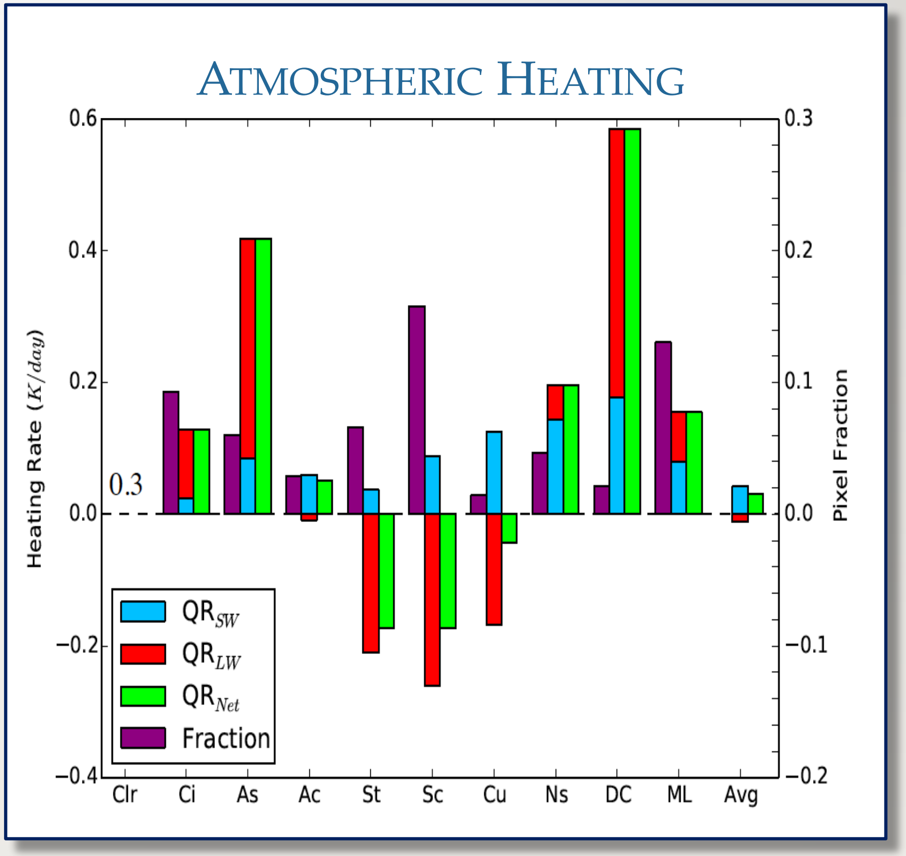
L'Ecuyer and Hang, in preparation, 2017

$$Q = \frac{dT}{dt} = -\frac{g}{c_p}\frac{\Delta F_{NET}}{\Delta p}$$

Cloud Impact = $Q_{all\text{-}sky}$ - $Q_{clr\text{-}sky}$ = CF_{TOA} - CF_{SFC}

Ice Cloud Regimes





L'Ecuyer and Hang, in preparation, 2017