2010 Spring CERES Science Team Meeting

Intrinsic Uncertainty Associated with Different Ways of Deriving Cloud Radiative Forcing: A Perspective from High-Resolution GCM Simulations

Xianglei Huang[1] and Ming Zhao[2]

1. University of Michigan
2. NOAA GFDL

Acknowledge: Dr. V. Ramaswamy

Outline

- Motivations
  - Different ways of estimating CRF
  - High-resolution GCM simulations
- Methodology
- Results
- Conclusions and Discussions

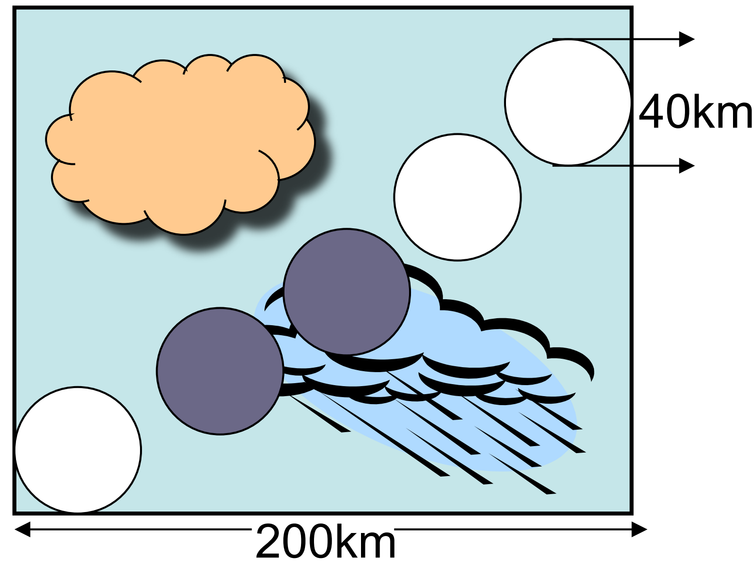
Motivations (I)

- Cloud Radiative Forcing (CRF)
  - Defined as: $Flux_{clear\text{-}sky} - Flux_{all\text{-}sky}$
    - Clear-sky vs. all-sky: everything is identical except clouds
  - Straightforward to get $Flux_{clear\text{-}sky}$ in the models
  - Not easy to get in observations
    - Cloud-cleared radiances: cloud fractions, built-in assumptions, retrieval quality
    - Flux of clear-sky pixel

$$Flux_{true\ clear\text{-}sky} - Flux_{clear\text{-}sky\ pixel} = ?$$

$\text{Flux}_{\text{true clear-sky}} - \text{Flux}_{\text{clear-sky pixel}} = ?$

- Deep convective region
  - Drier clear-sky pixels vs. humid cloudy pixels
  - $\text{OLR}_{\text{true clr-sky}} < \text{OLR}_{\text{clr-sky pixel}}$
- Alway a cold bias? How much?
- Observation-based bias estimation



Dry Bias in Satellite-Derived Clear-Sky Water Vapor and Its Contribution to Longwave Cloud Radiative Forcing

BYUNG-JU SOHN

School of Earth and Environmental Sciences, Seoul National University, Seoul, South Korea

JOHANNES SCHMETZ AND ROLF STUHLMANN

European Organization for the Exploitation of Meteorological Satellites, Darmstadt, Germany

JOO-YOUNG LEE

School of Earth and Environmental Sciences, Seoul National University, Seoul, South Korea

(Manuscript received 19 July 2005, in final form 13 February 2006)

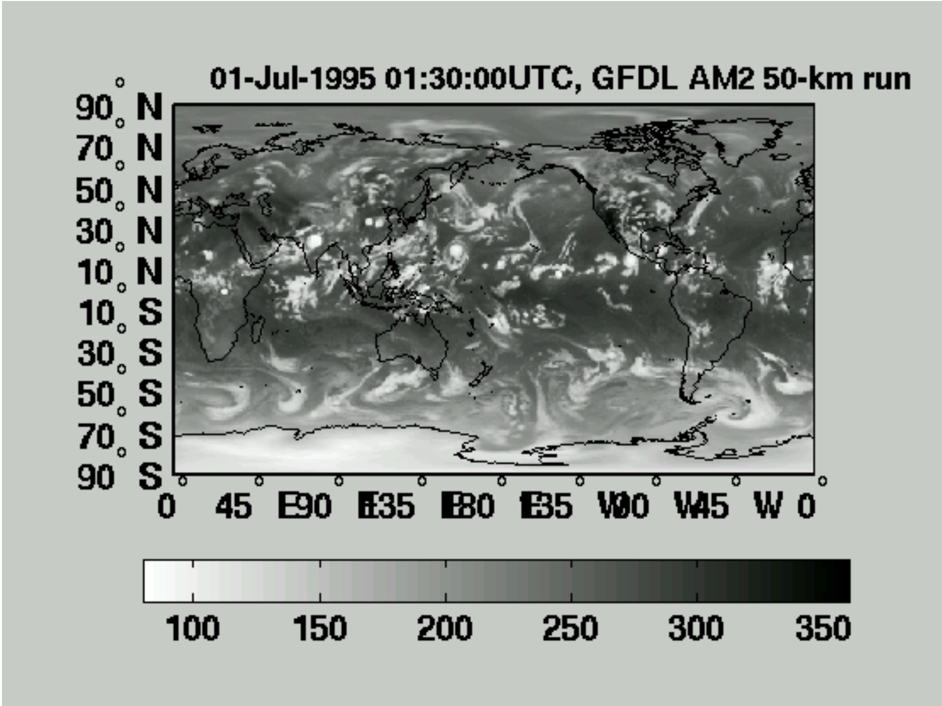
ABSTRACT

In this paper, the amount of satellite-derived longwave cloud radiative forcing (CRF) that is due to an increase in upper-tropospheric water vapor associated with the evolution from clear-sky to the observed all-sky conditions is assessed. This is important because the satellite-derived clear-sky outgoing radiative fluxes needed for the CRF determination are from cloud-free areas away from the cloudy regions in order to avoid cloud contamination of the clear-sky fluxes. However, avoidance of cloud contamination implies a sampling problem as the clear-sky fluxes represent an area drier than the hypothetical clear-sky humidity in cloudy regions. While this issue has been recognized in earlier works this study makes an attempt to quantitatively estimate the bias in the clear-sky longwave CRF. Water vapor amounts in the 200–500-mb layer corresponding to all-sky condition are derived from microwave measurements with the Special Sensor Microwave Temperature-2 Profiler and are used in combination with cloud data for determining the clear-sky water vapor distribution of that layer. The obtained water vapor information is then used to constrain the humidity profiles for calculating clear-sky longwave fluxes at the top of the atmosphere. It is shown that the clear-sky moisture bias in the upper troposphere can be up to 40%–50% drier over convectively active regions. Results indicate that up to 12 W m^{-2} corresponding to about 15% of the satellite-derived longwave CRF in tropical regions can be attributed to the water vapor changes associated with cloud development.

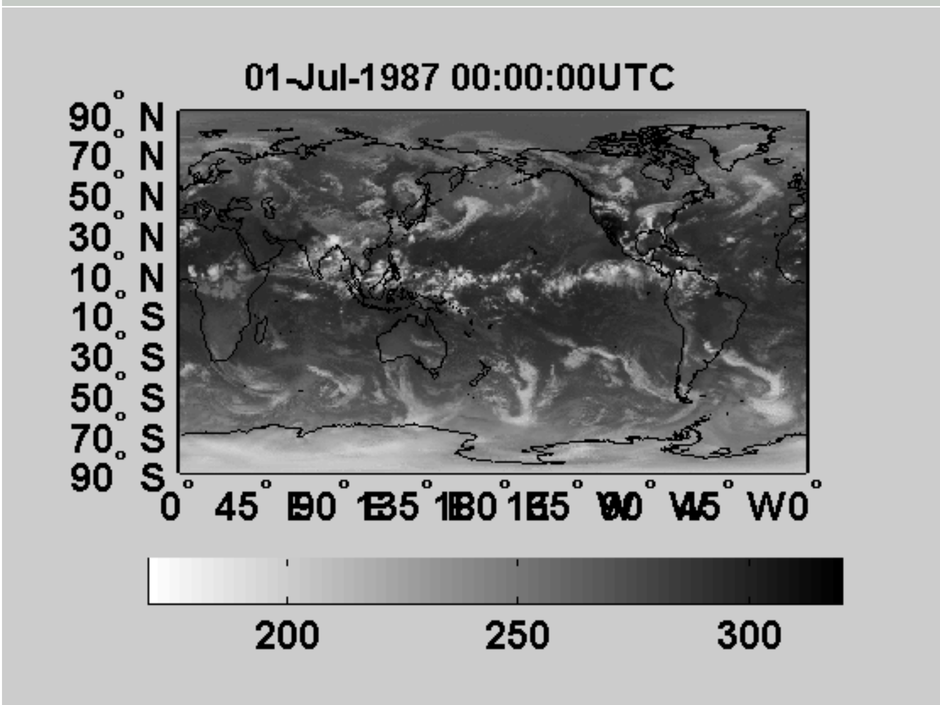
Journal of Climate (2006)

Motivations (II): high-resolution GCM runs

- High-resolution: 25-50km
  - Comparable to satellite footprint
  - AMIP type runs are now affordable
- GFDL HiRam model
  - Cubic-sphere dynamic core
  - AM2 physics, but unified convection schemes (one for both shallow and deep convections) and diagnostic cloud fraction for stratiform clouds
  - Forced with observed SST
  - Improved simulation on cloud and UTH climatology
  - Hurricane climatology and interannual variability
- Archive 3-hourly output from the HiRam run (July 1995-June 1996)
    - Sample it in the satellite way
    - $X_{satellite\_sample}-X_{truth}$

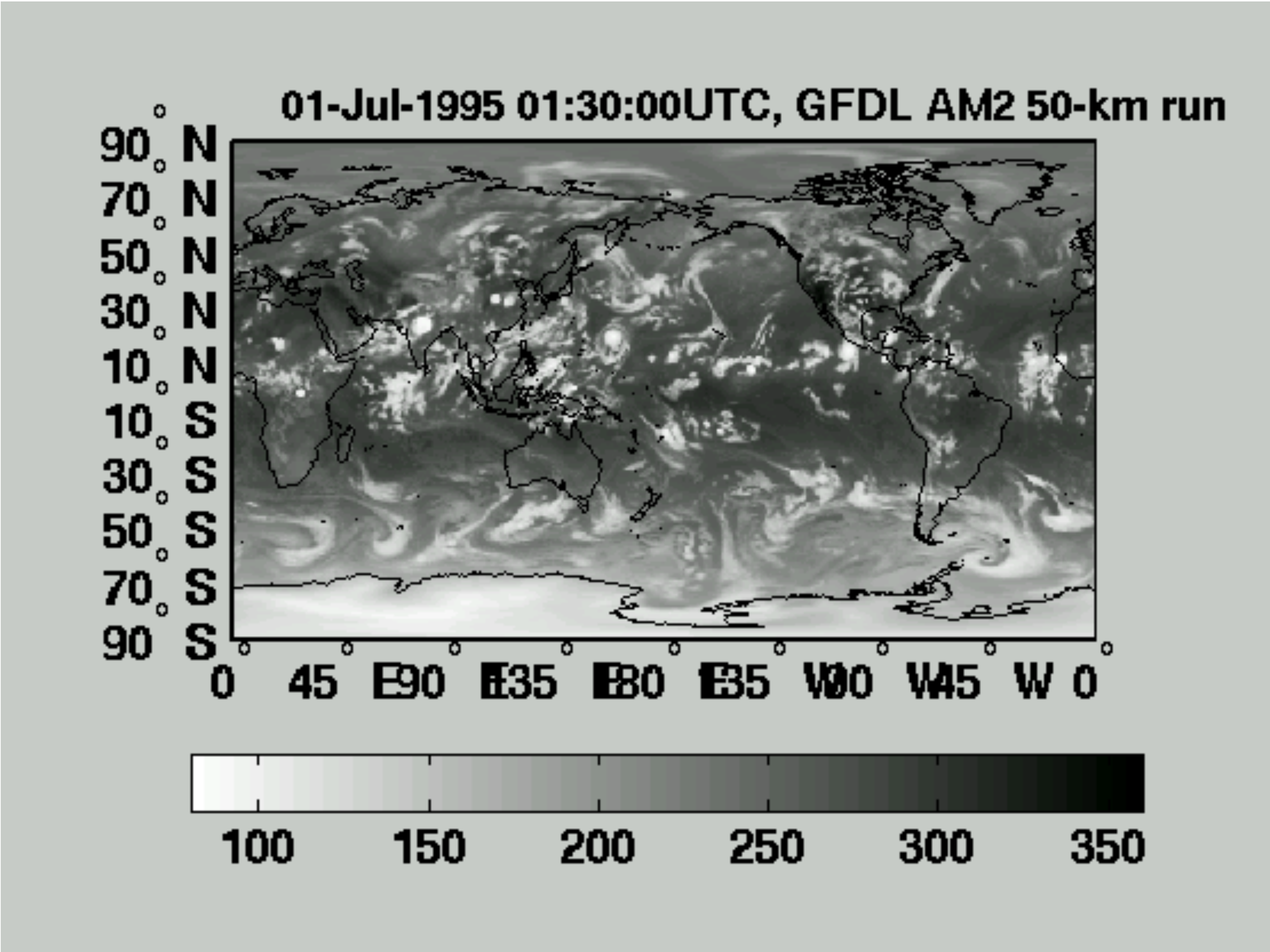


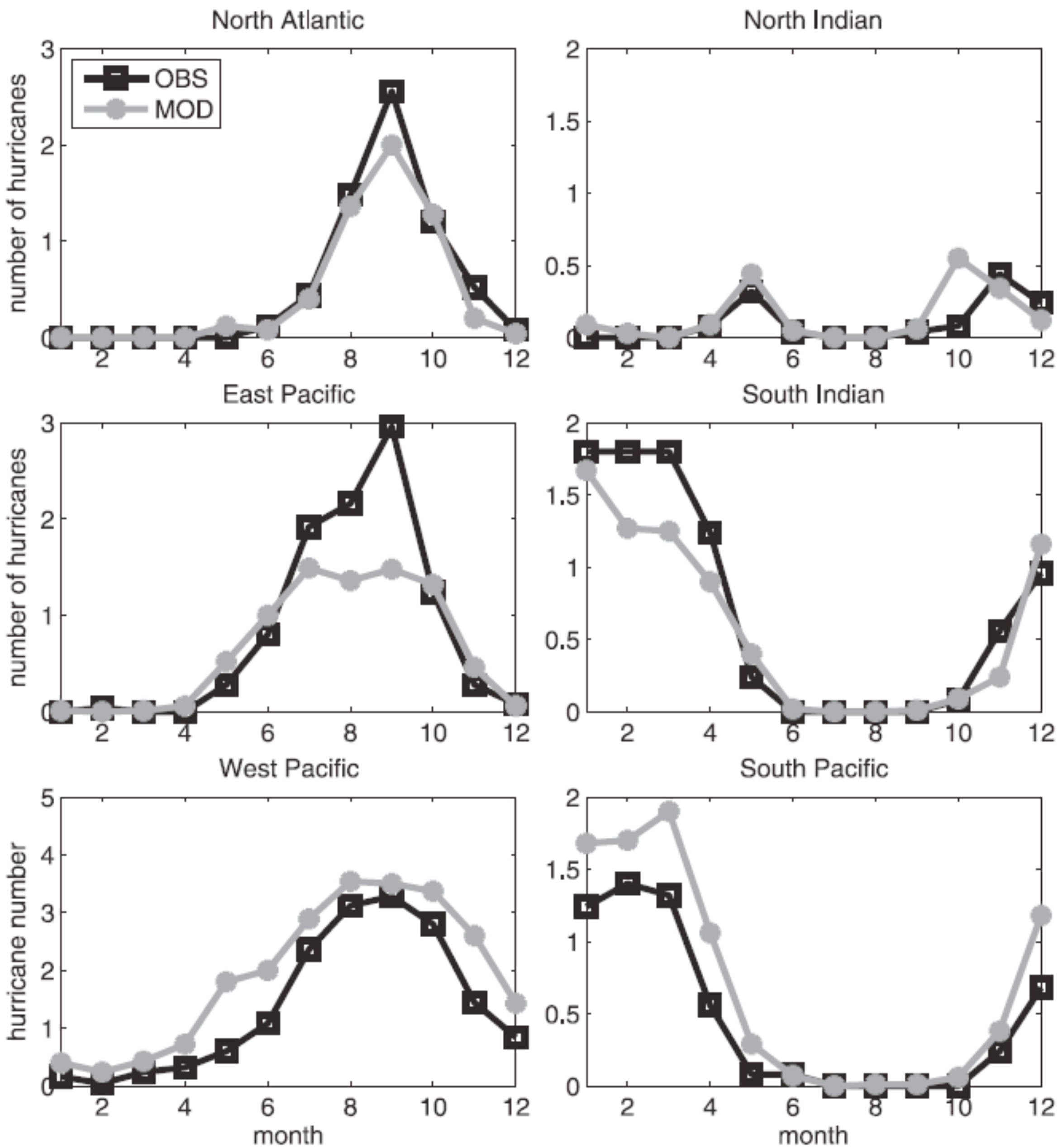
OLR (Wm^{-2})



Geostationary
Satellite
BT of 11μm

GFDL HiRAM OLR (Wm^{-2})





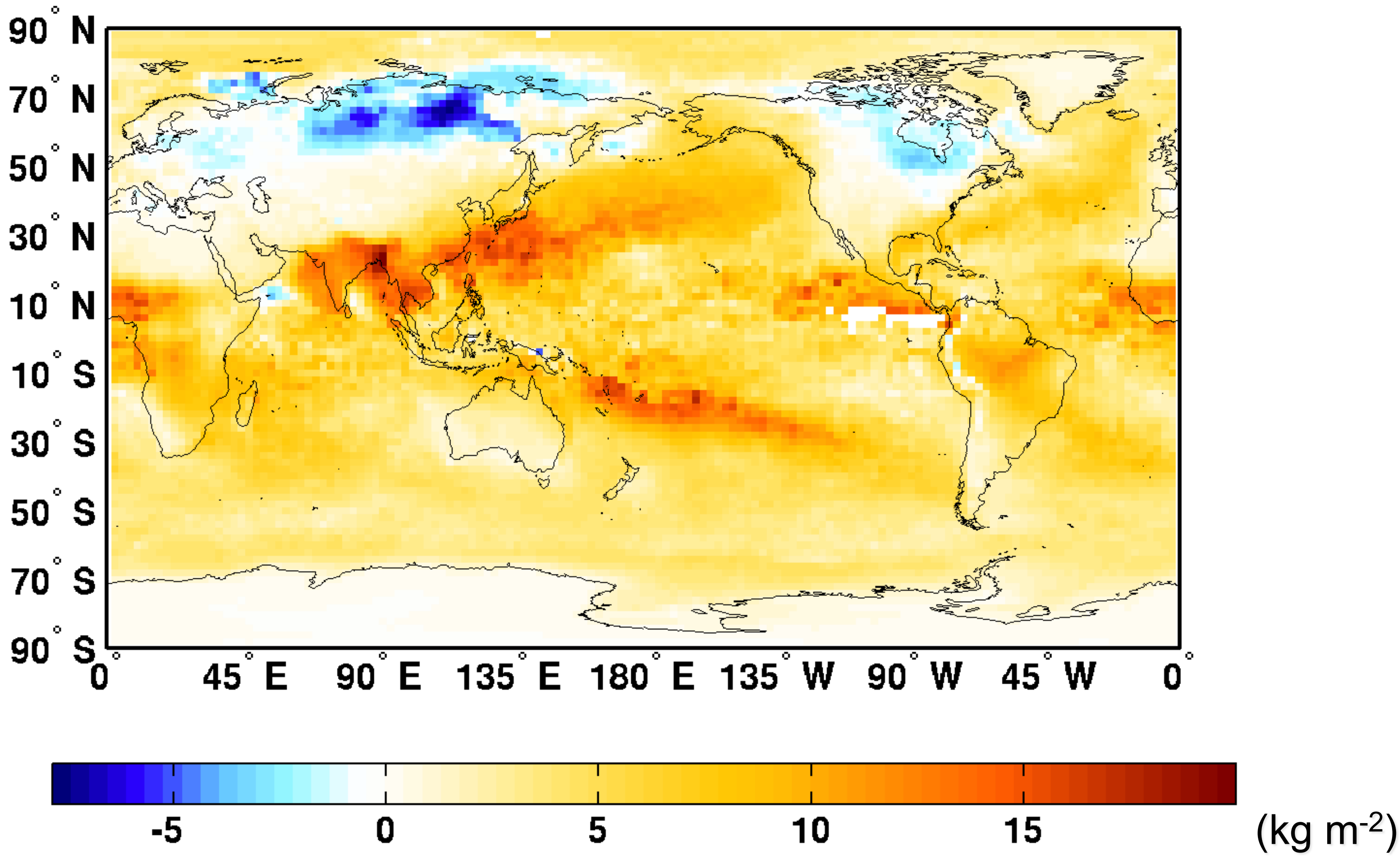
(Zhao et al., 2009, J. Climate)

FIG. 5. Observed and model simulated seasonal cycle (number of hurricanes per month) for each ocean basin from the four-member ensemble mean (1 = January, 12 = December).

Methodology

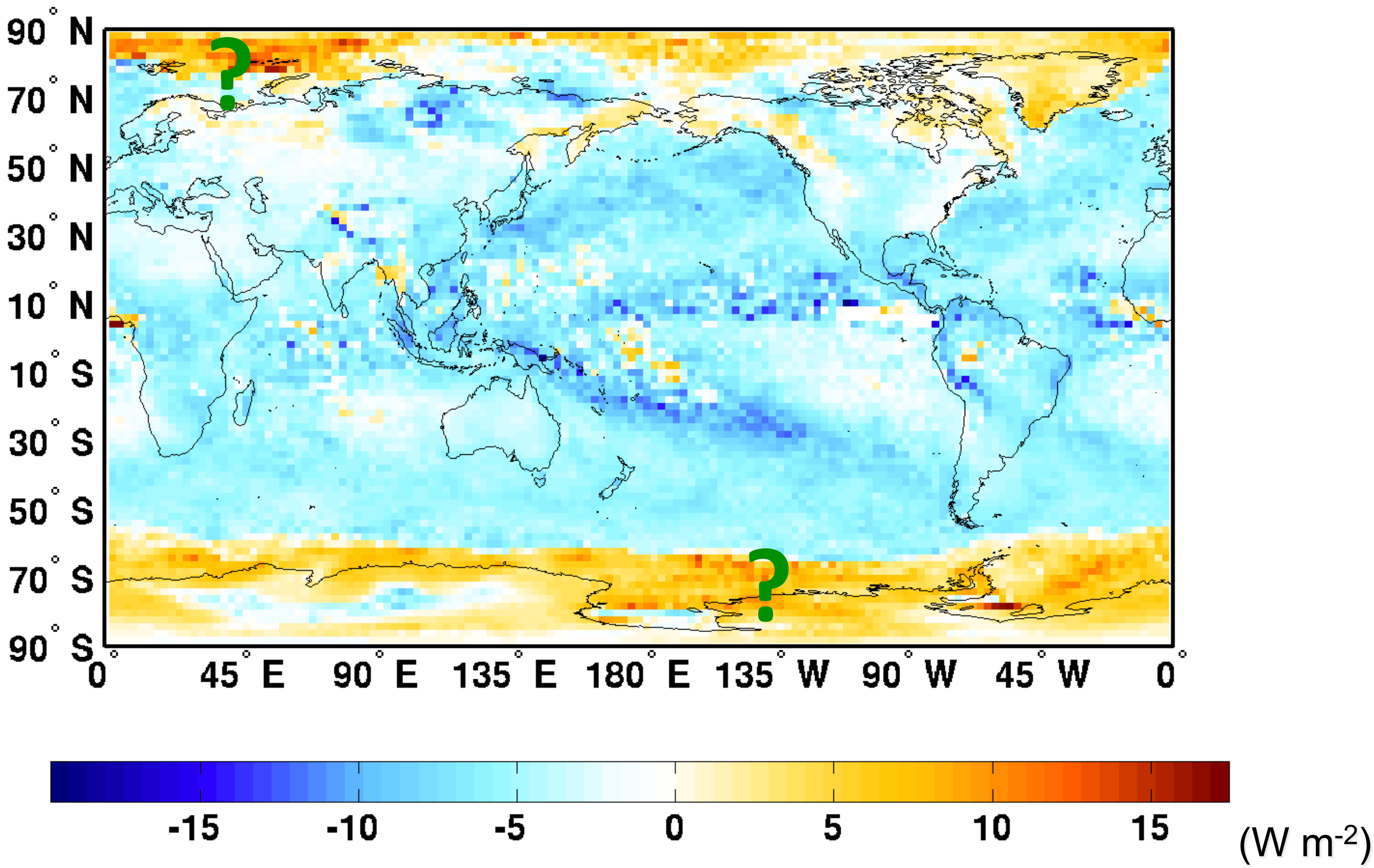
- Grid A: 2.5°(lon)×2 °(lat) (16 native grid cells)
- $Flux_{clr\text{-}sky\text{-}pixel}$=Flux(cells:cld_frac < 1%)
- $Flux_{true\_clr\text{-}sky}$ as computed from the model
- Estimation of monthly-mean clear-sky flux and CRF
  - ensure equal weighting of phases of diurnal cycle
    - First compute monthly mean of each 3-hourly snapshot
    - Average 8 month-mean snapshots equally to obtain the monthly mean
  - Hereafter, "$_{est}$" denotes quantities obtained from this approach
    - $OLRC_{est}$ CRF_{est} $SWFlx_{est}$ WVP_{est}

Difference in Total Precipitable Water ($WVP_{true} – WVP_{est}$, Jul95-Jun96)



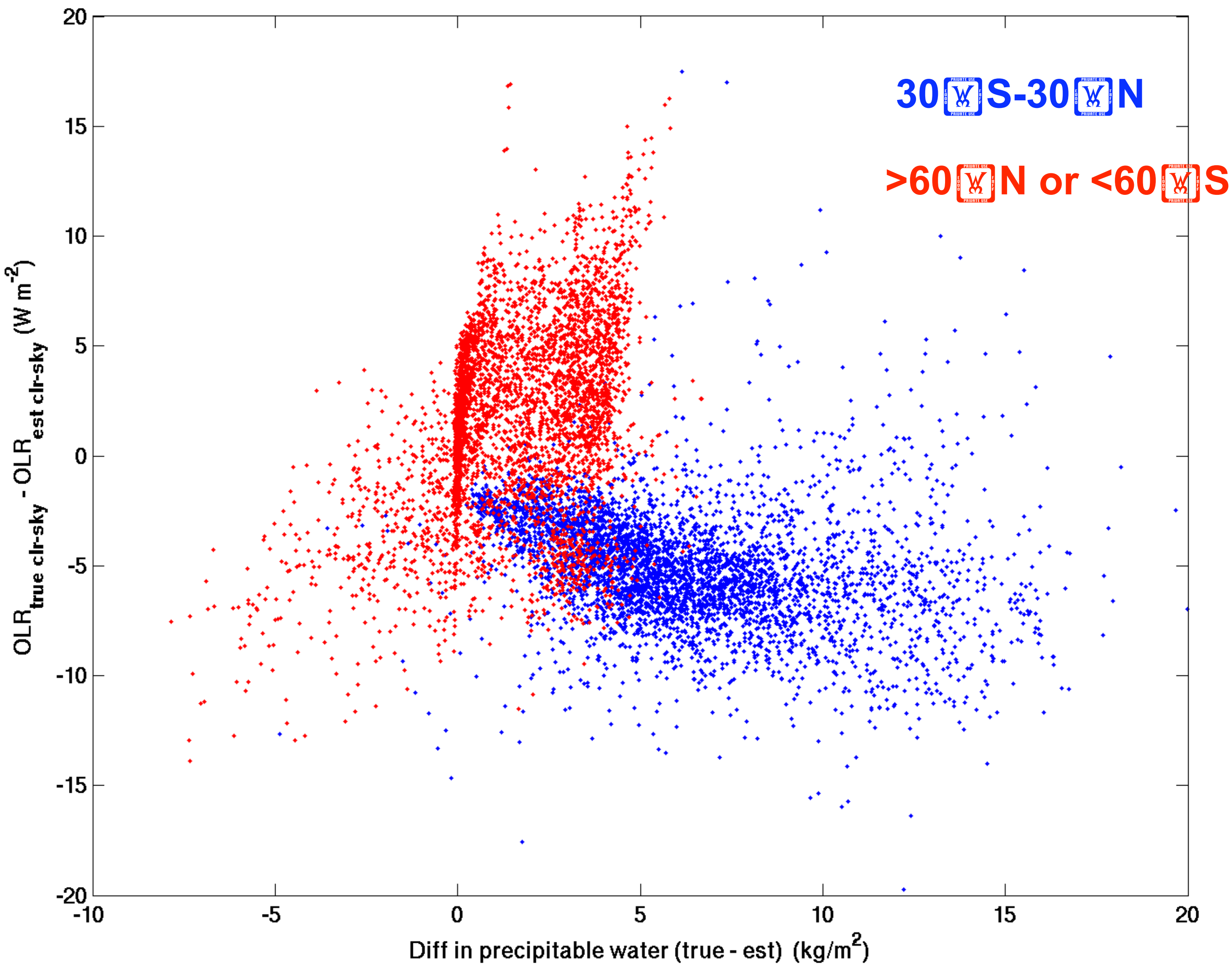
As expected, clear-sky portion is drier than cloudy portion (except two snow region)

Difference in LW CRF
(LW CRF$_{true}$ – LW CRF$_{est}$, Jul95-Jun96)

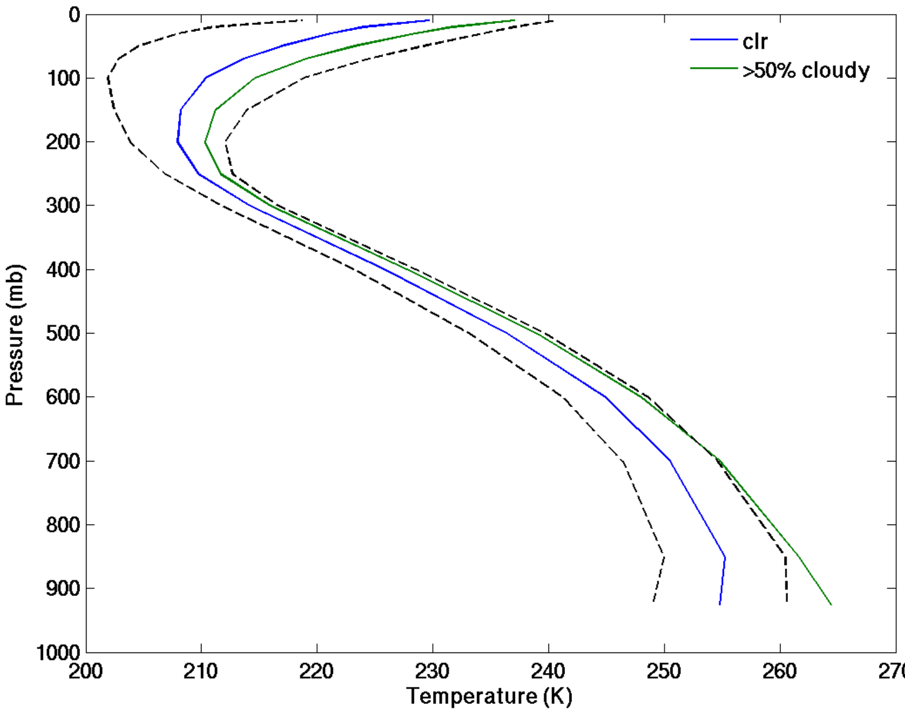


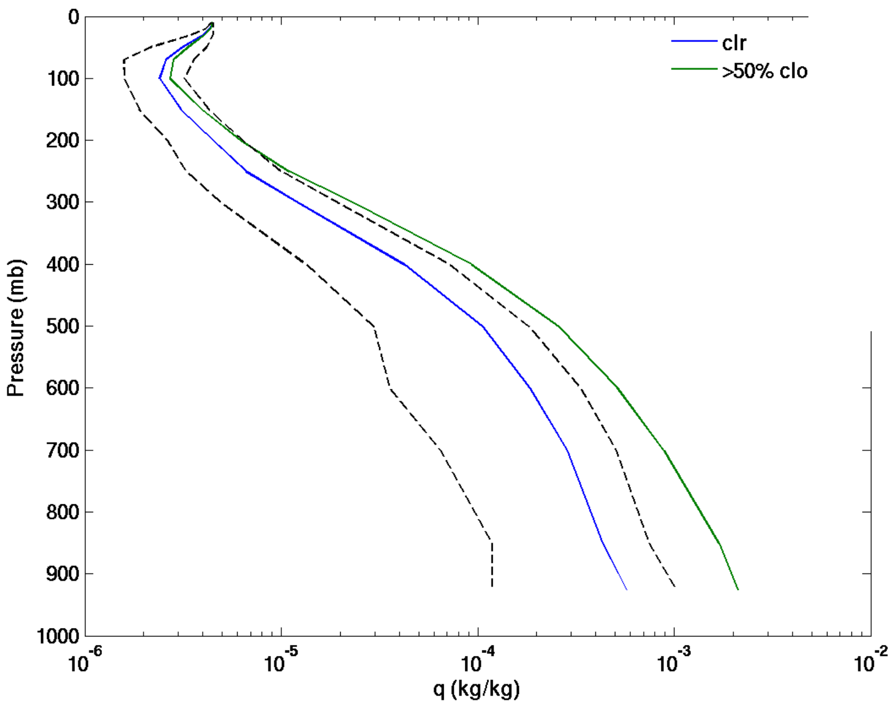
Global annual mean: -4.12 W m^{-2} (True – Estimation)
Small month-to-month variation < 10%

Scatter plot of ΔWVP vs. $\Delta OLR_{clr\text{-}sky}$



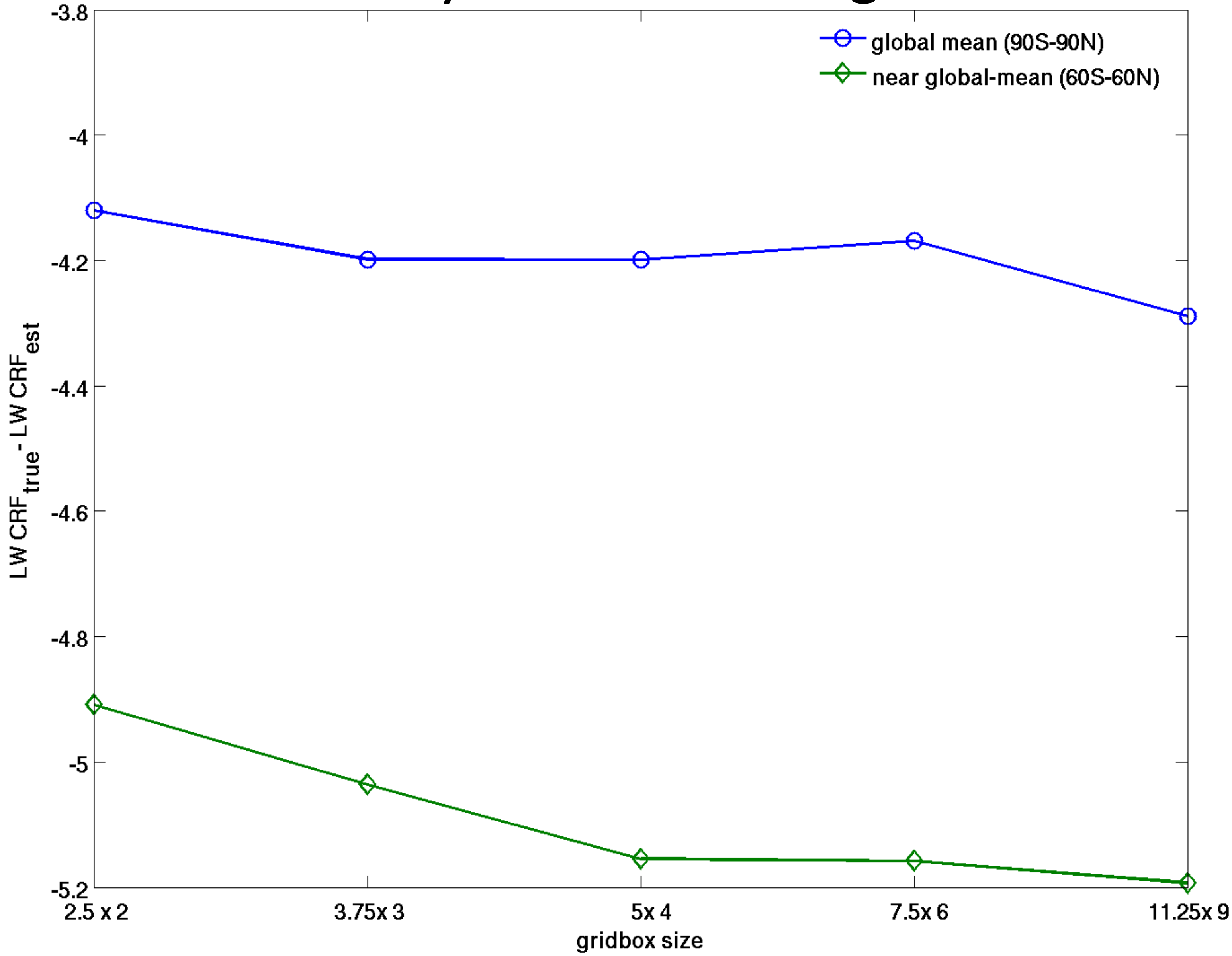
Composite Analysis (Sub Antarctic region)





- Clear-sky pixels: Less humid but also colder
- Run through MODTRAN
  - OLR 189 Wm^{-2}
  - OLR 205 Wm^{-2}

Sensitivity to the size of grid box



Conclusions

- High-resolution GCM runs provide another way to assess the intrinsic bias due to sampling disparity between model and observations
- While clear-sky grid cells are drier than cloudy ones, the temperature difference also needs to be factored in
- In tropics and most parts of mid-latitude, ΔT is small, so dry bias dominant
  - LW CRF (OLRc) +5-10Wm^{-2} bias
- In sub-polar region, drier and colder in the clear-sky grid cells
  - LW CRF (OLRc) –(5-10) Wm^{-2} bias
- Global mean, estimation would have a ~4Wm^{-2} bias