Characterizing Tropical Pacific Water Vapor and Radiative Biases in CMIP3 and CMIP5 GCMs: Observation-Based Analyses and a Snow Radiation Interaction Sensitivity Tests

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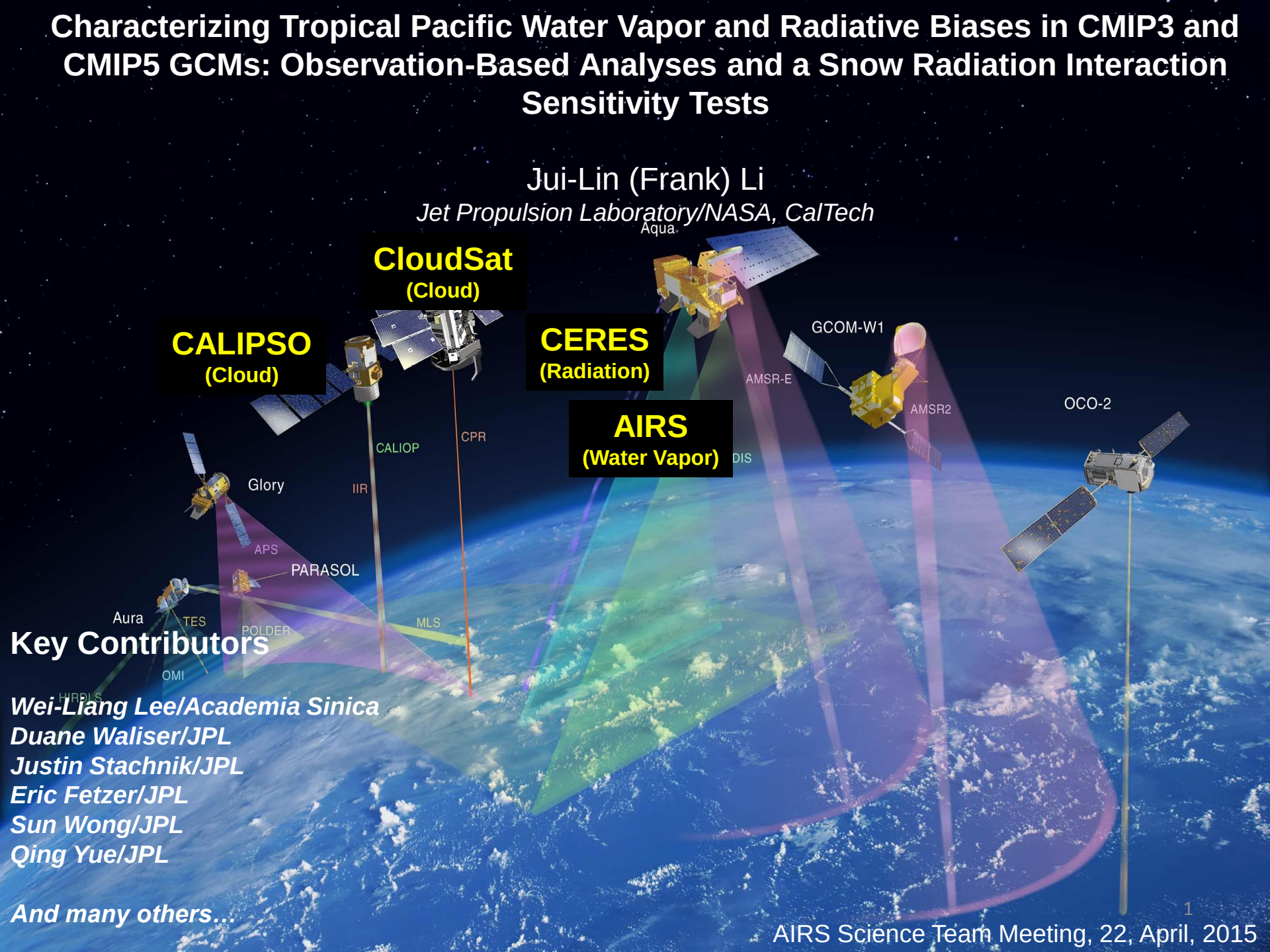

Key Contributors

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Eric Fetzer/JPL
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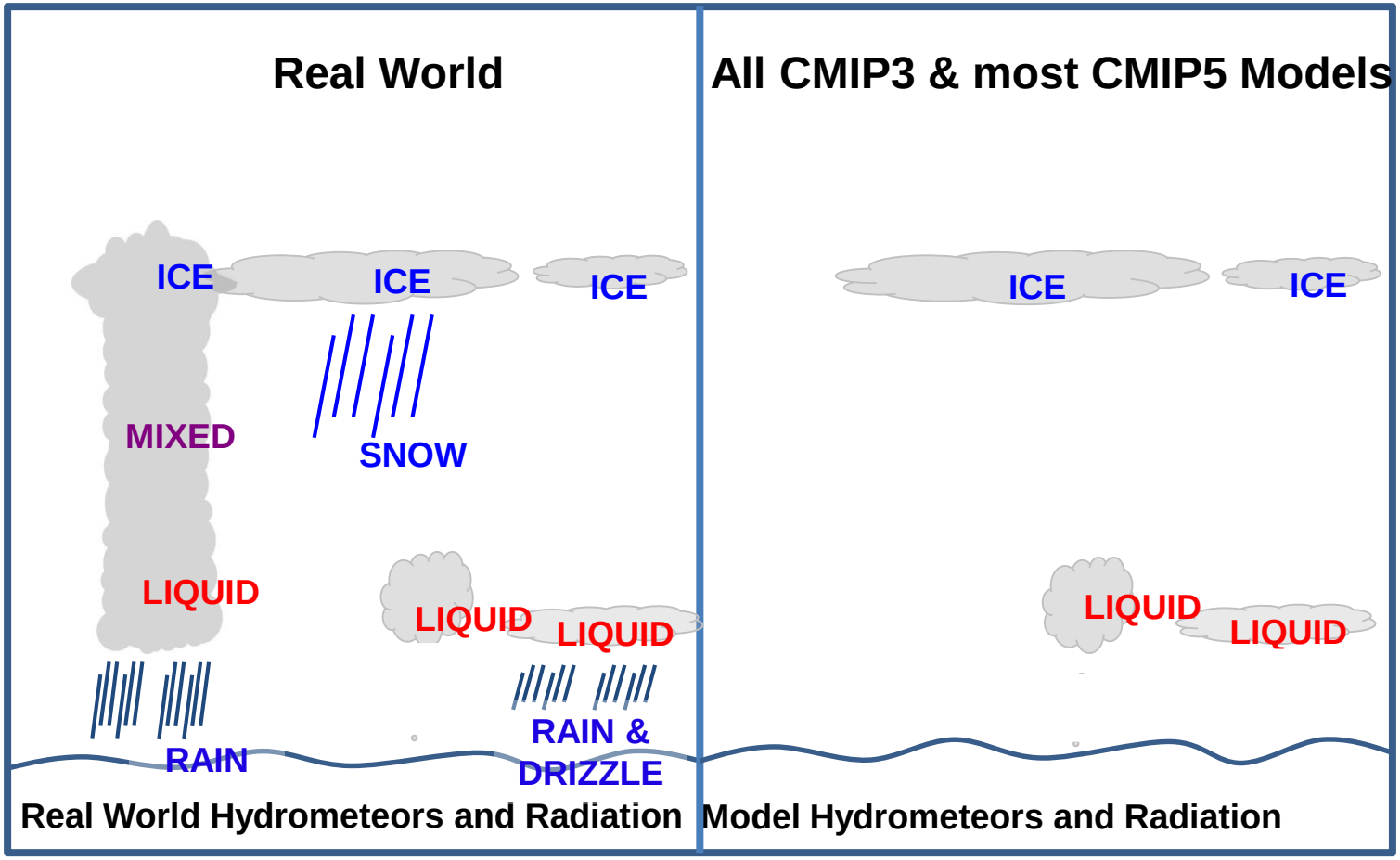
And many others…

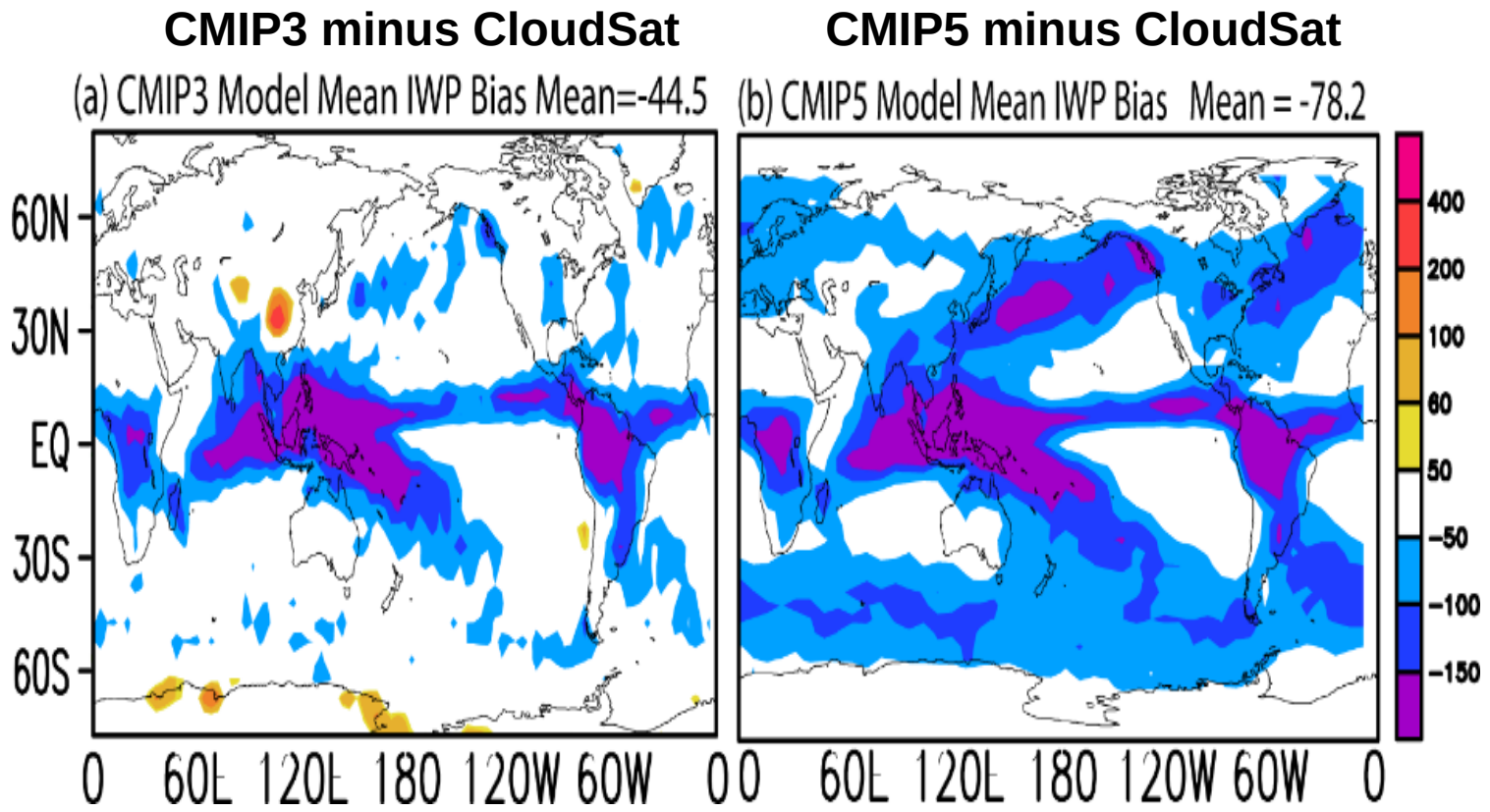
Representation of Cloud Water Content (CWC) for Radiation Calculation in GCMs

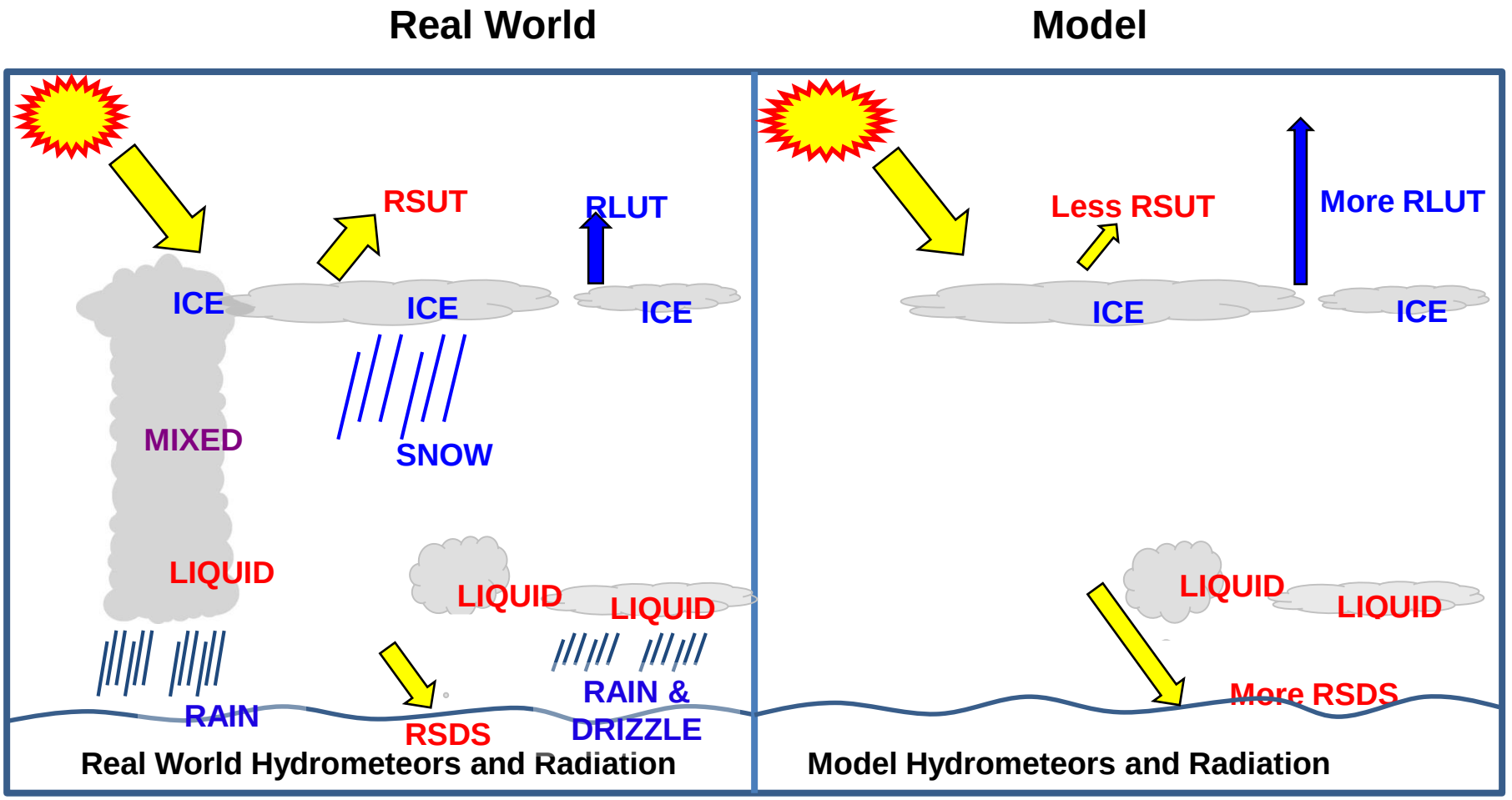


- Few GCMs such as NASA-GISS model, NCAR-CAM5, GFDL-AM3 and CSIRO etc include ***diagnostic*** falling snow and/or convective ice (or snow) in their models

Bias of CMIP Ensemble Mean CIWP vs Obs. *Total CloudSat* IWP

Total IWP

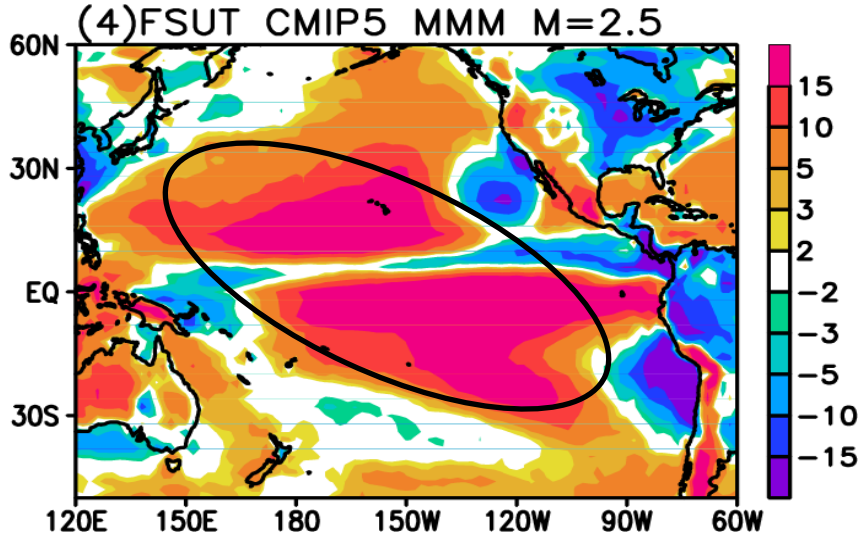




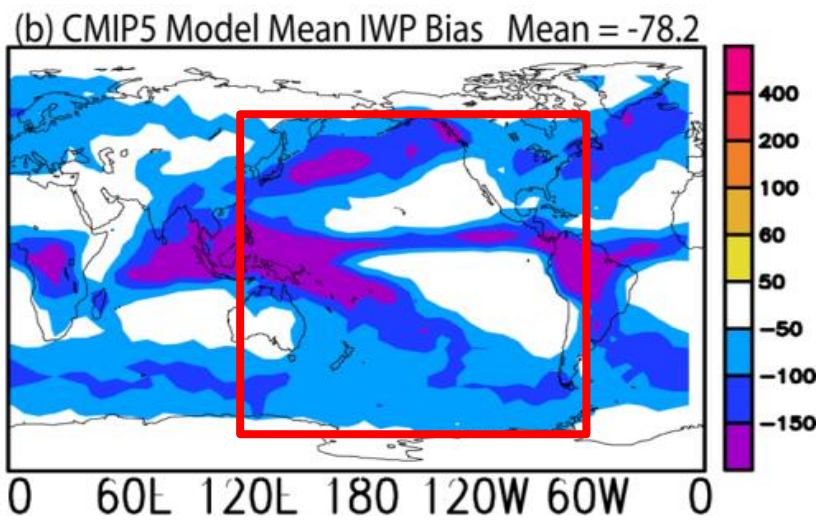
- **Expected to have underestimated RSUT, overestimated RSDS and RLUT in heavy rainfall & convective active regions over ITCZ/SPCZ, Warm Pool, Indian Monsoon as well as South America, Central Africa. (Li et al., 2012;2013a; Waliser et al., 2011)**

Bias of CMIP5 Ensemble Mean Radiation

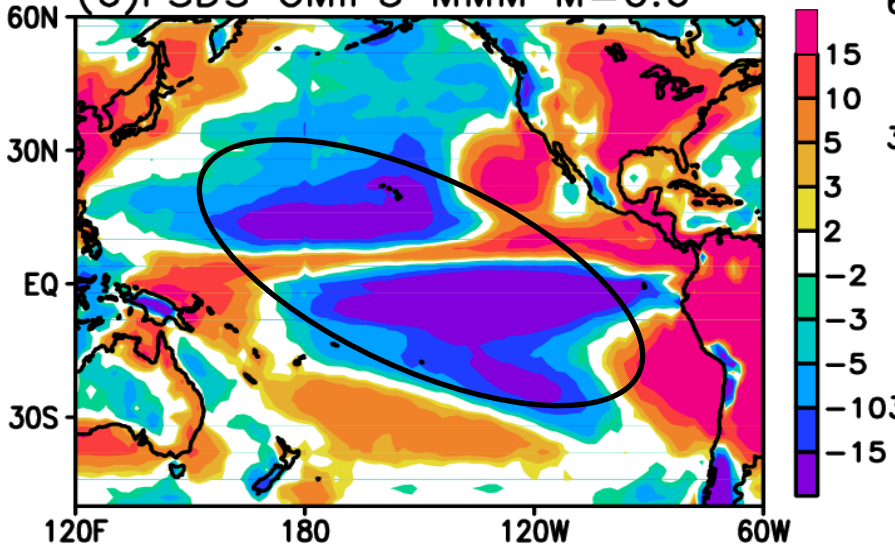
Reflected Shortwave at TOA



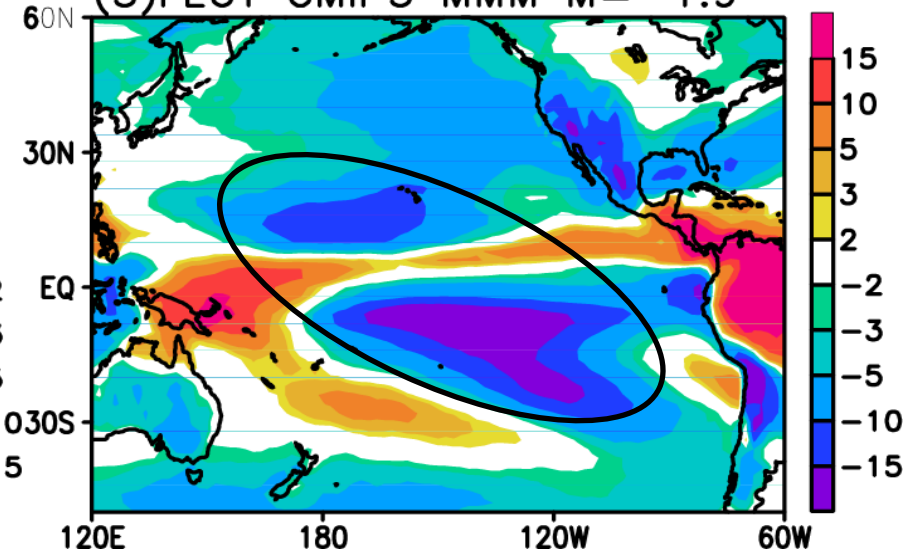
CMIP5



Downward Shortwave at SFC



Outgoing Longwave at TOA



- **NCAR CESM1-CAM5: Exclusion of radiative diagnostic snow**

  - CESM1-CAM5-POP2: CMIP5 Historical Configuration (140 Years)

  NoS = snow-radiation interaction OFF

  S = snow-radiation ON

Moisture bias Impacts on Radiation fields

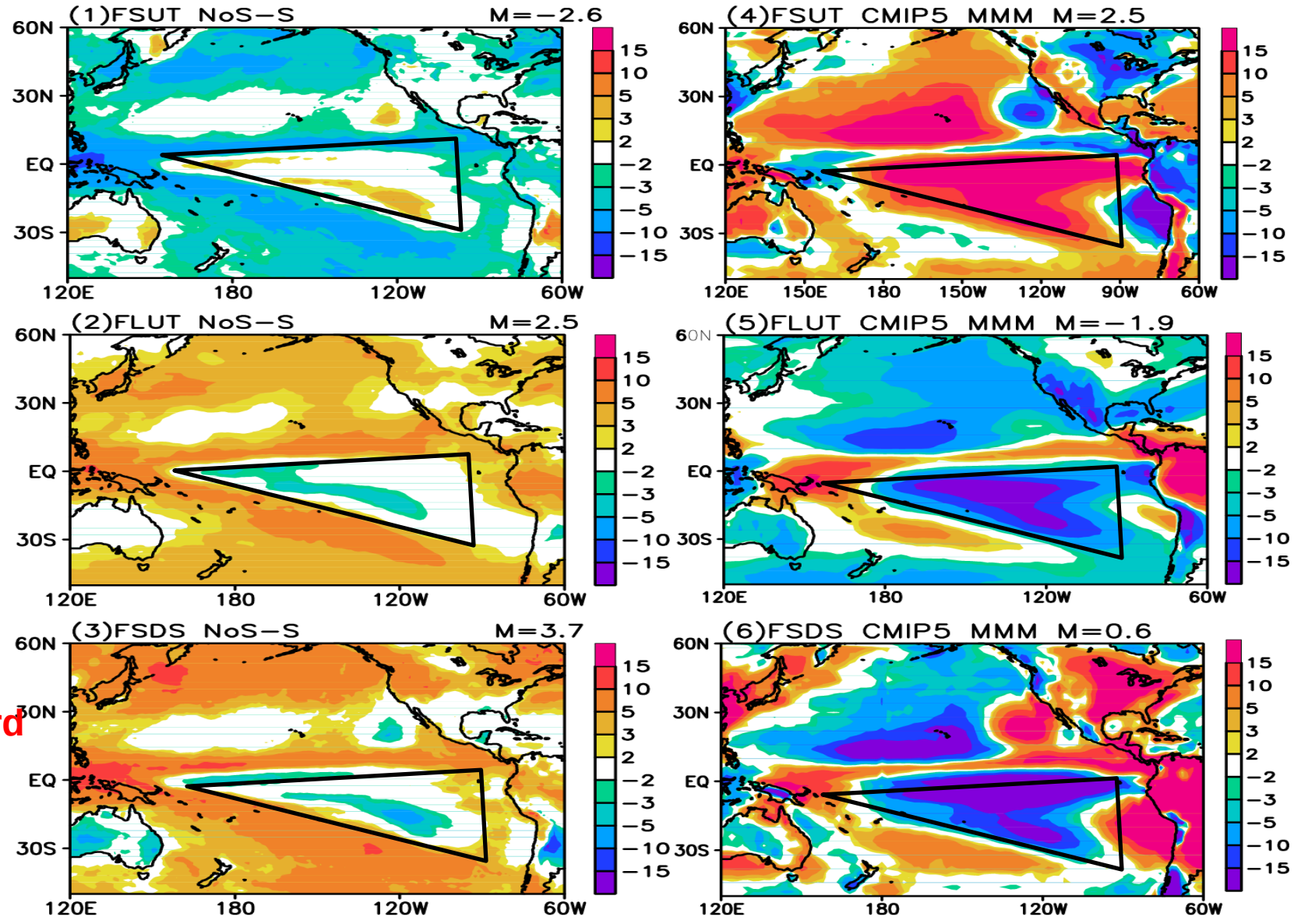
NCAR NoS- S

CMIP5 MMM Bias

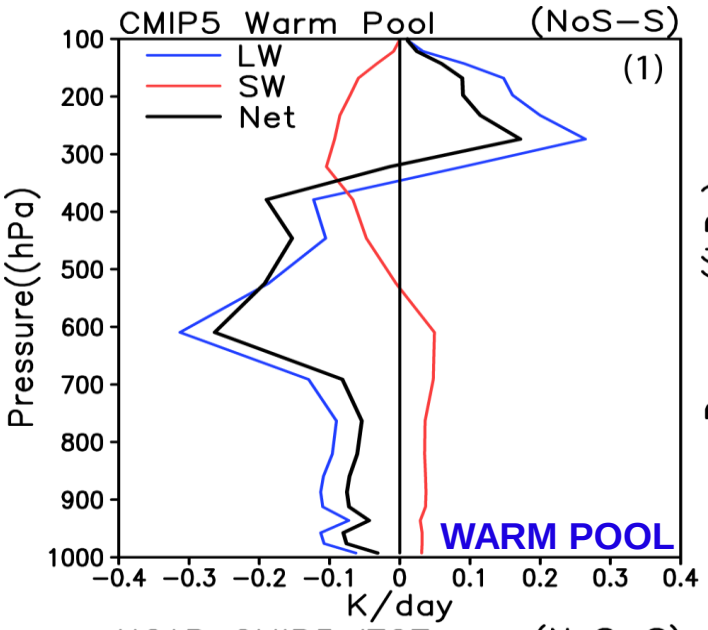
SW TOA

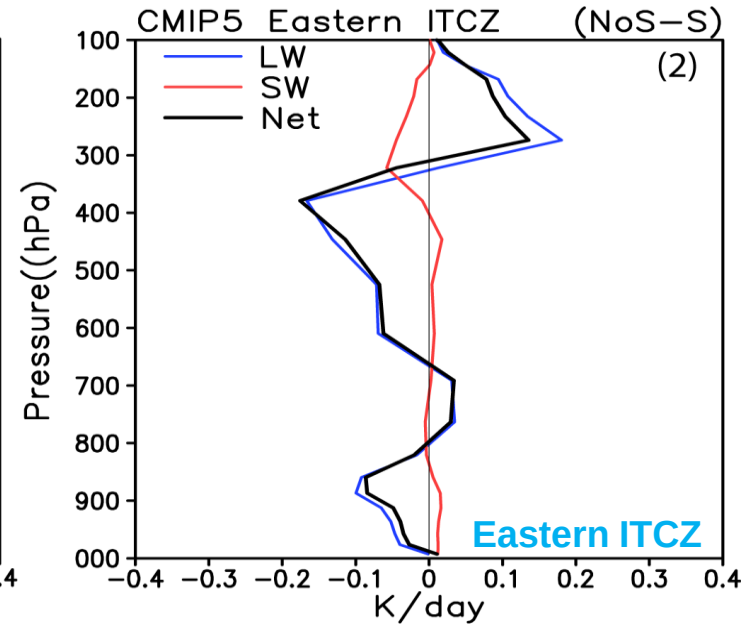
OLR TOA

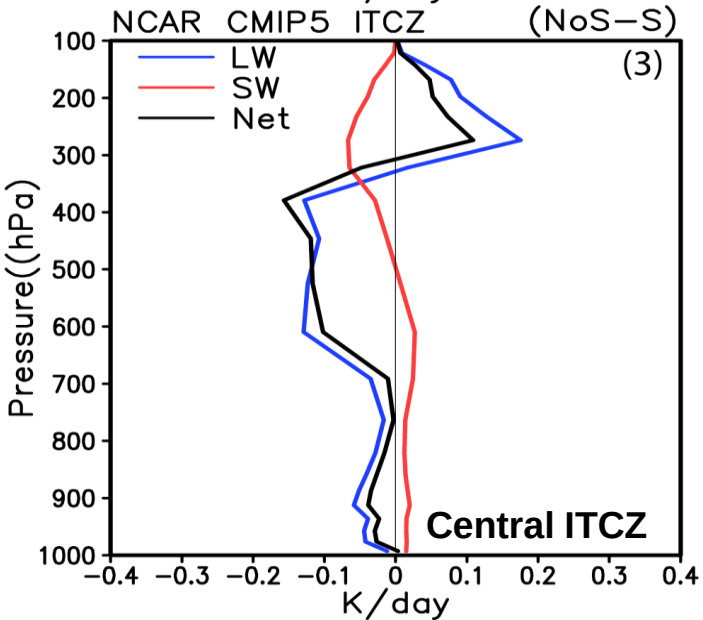
Downward SW Surface

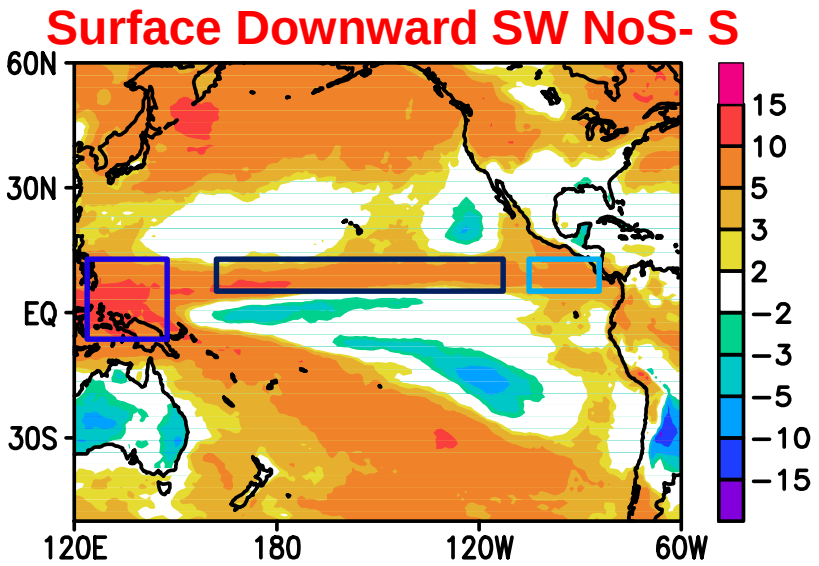


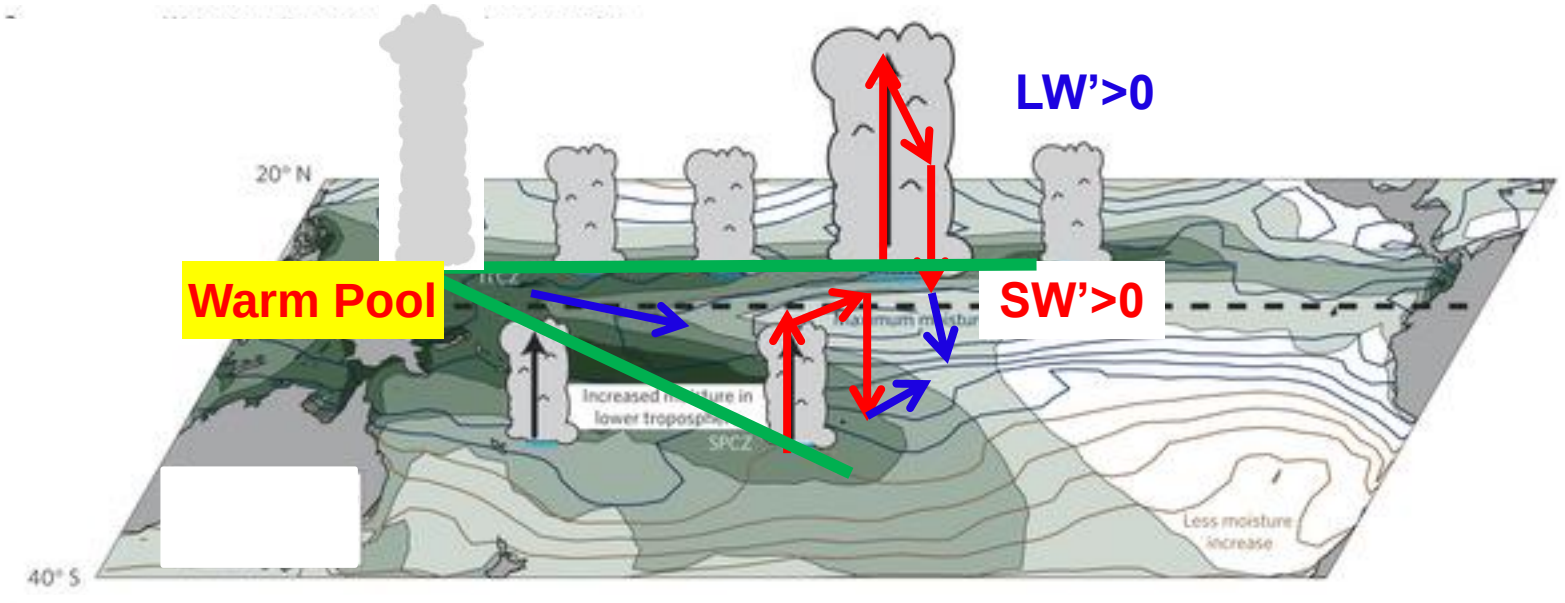
Regional Radiative Heating Profiles
NoS minus S









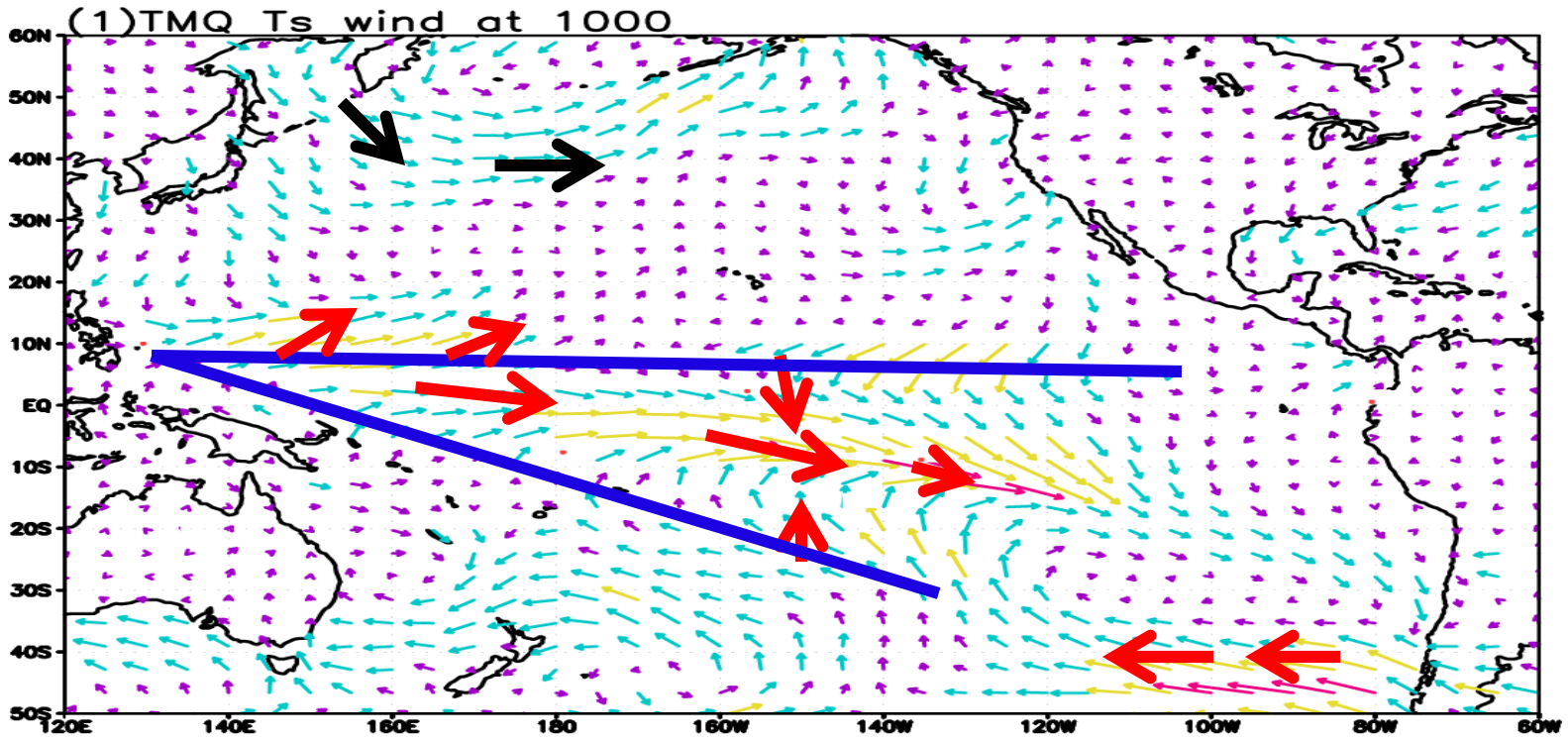


NCAR coupled CMIP historical runs
(140 YEARS):
(Snow-Radiation off) Minus
(Snow-Radiation On)

(Li et al., 2012; 2013; 2014a,b; 2015)

Snow-Radiation off Minus Snow-Radiation On

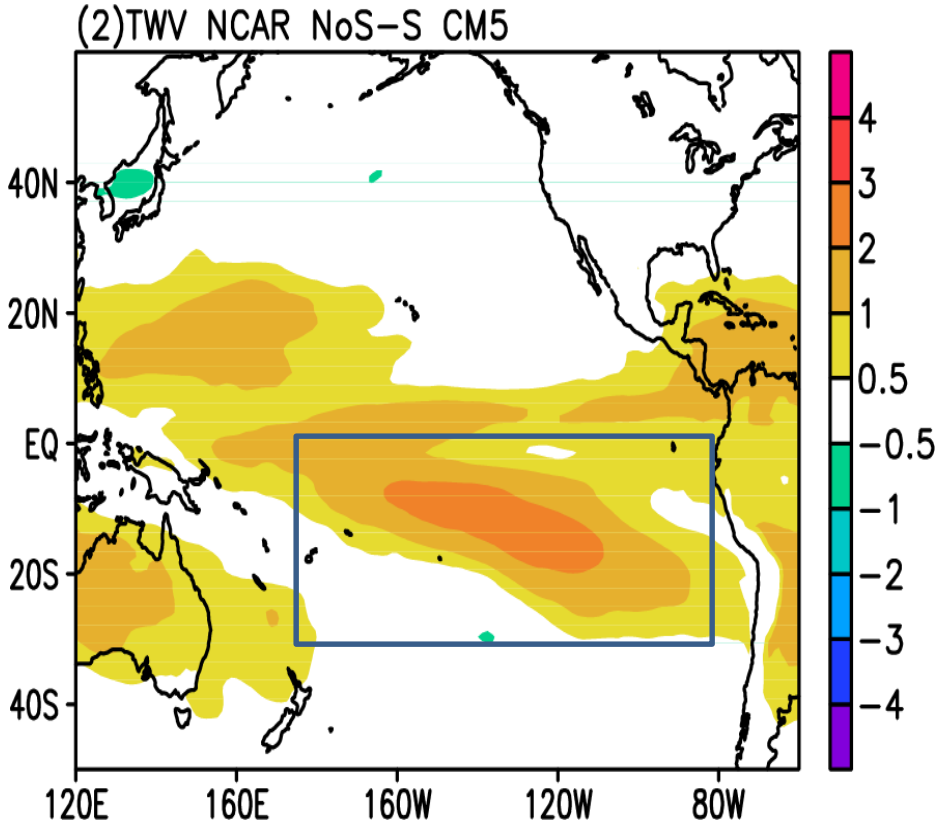
Changes of Ocean Surface Wind Vectors



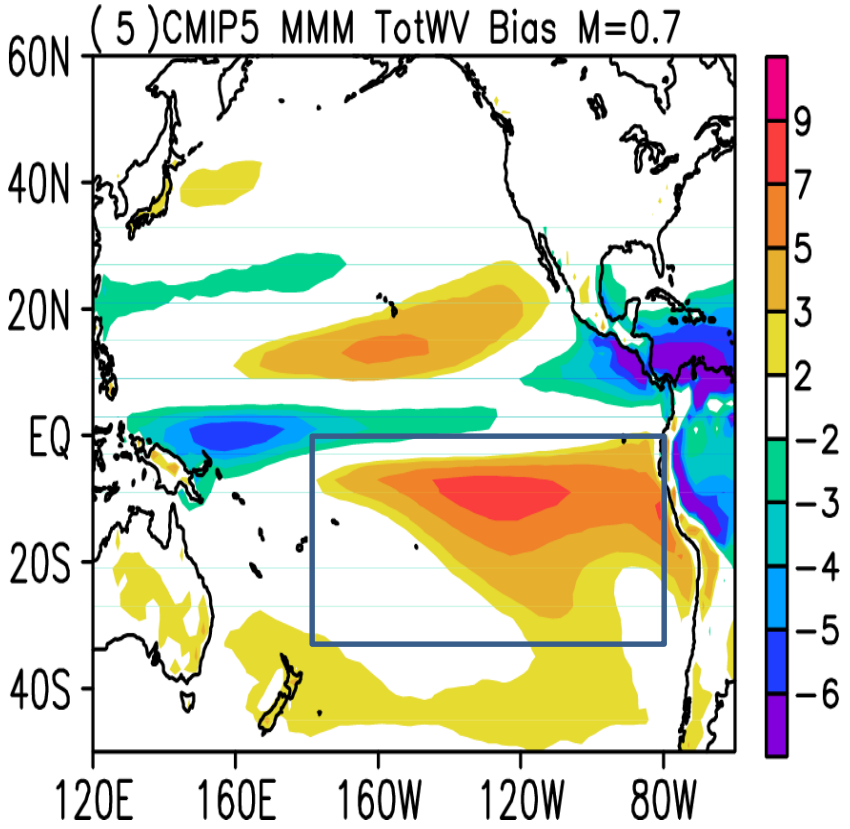
Changes of Surface Wind Stress and their Impacts on Sea Surface Temperatures

Snow-Radiation off Minus Snow-Radiation On
Impacts on Moistures – Total Water Vapor (TMV)

NCAR NoS- S

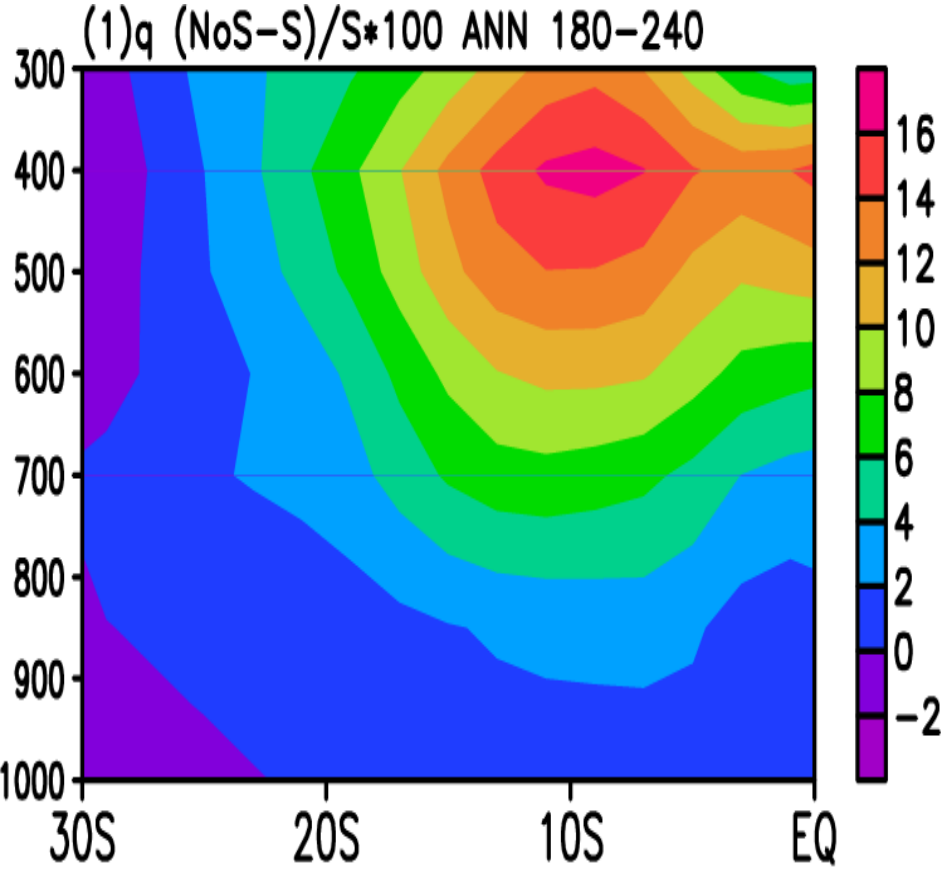


CMIP5 MMM TWV Bias vs AIRS

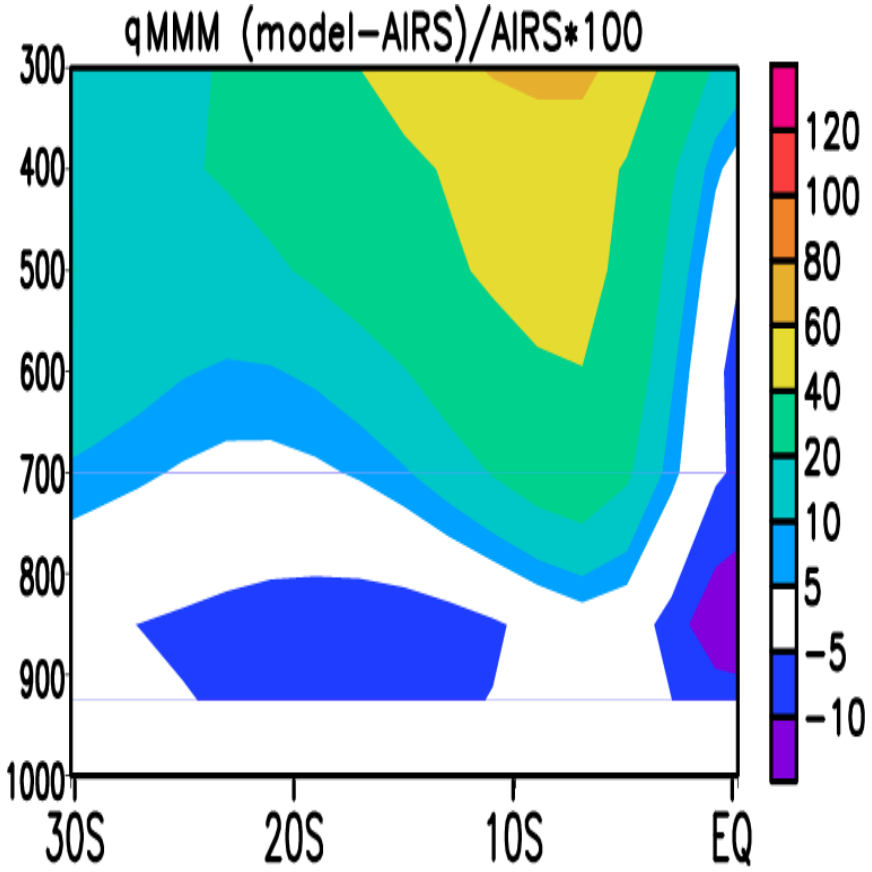


Snow-Radiation off Minus Snow-Radiation On
Impacts on Specific Humidity

NCAR NoS- S



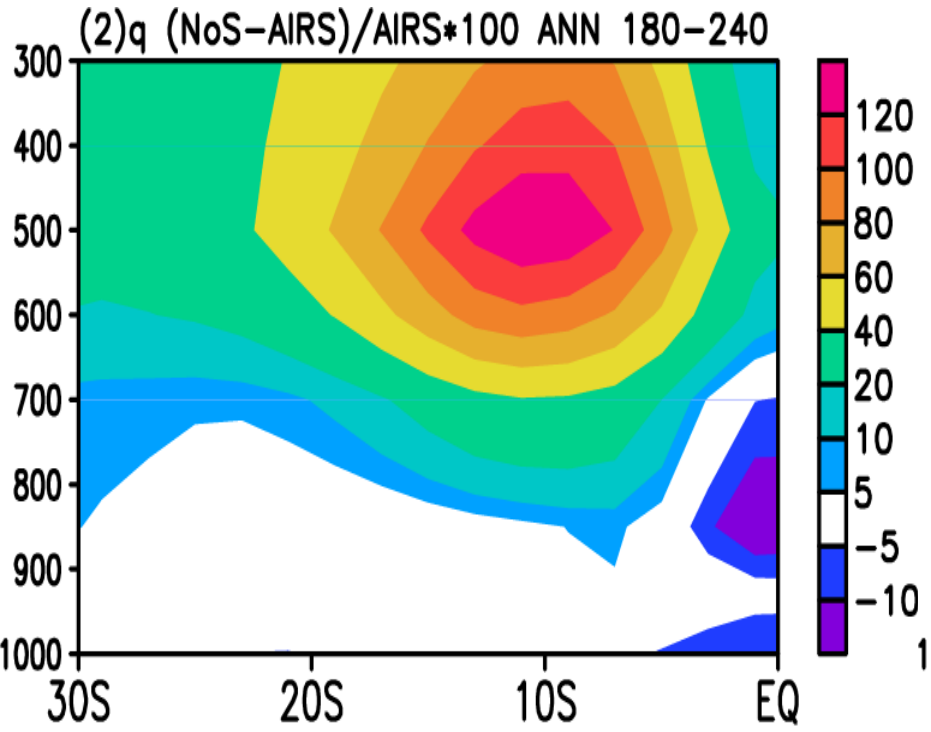
CMIP5 MMM Water Vapor Bias



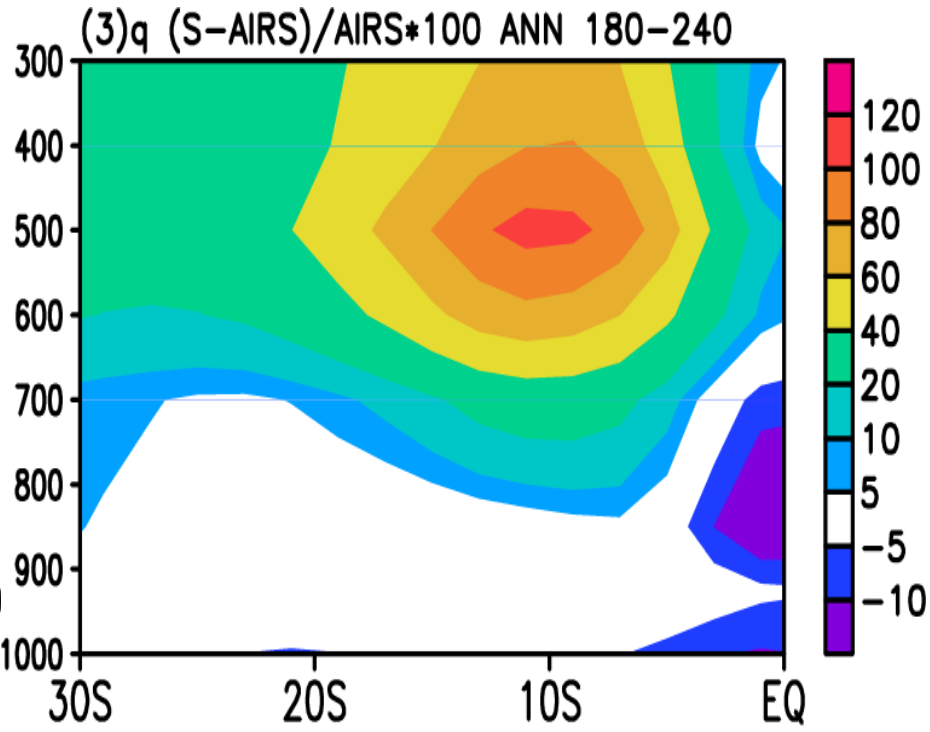
Note: the scales are different!!! Up to 50% and more of humidity bias in CMIP5!!

Snow-Radiation off Minus Snow-Radiation On
Impacts on Specific Humidity

NCAR NoS Bias VS AIRS



NCAR S Bias VS AIRS

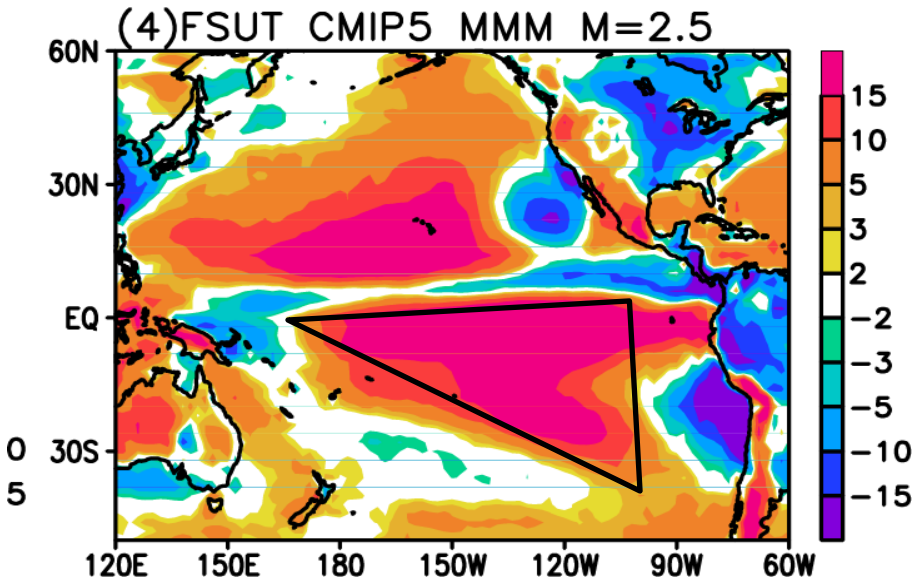


With inclusion of the snow-radiation effect in NCAR-CGCM, the humidity bias reduced from 120% to 60~80%

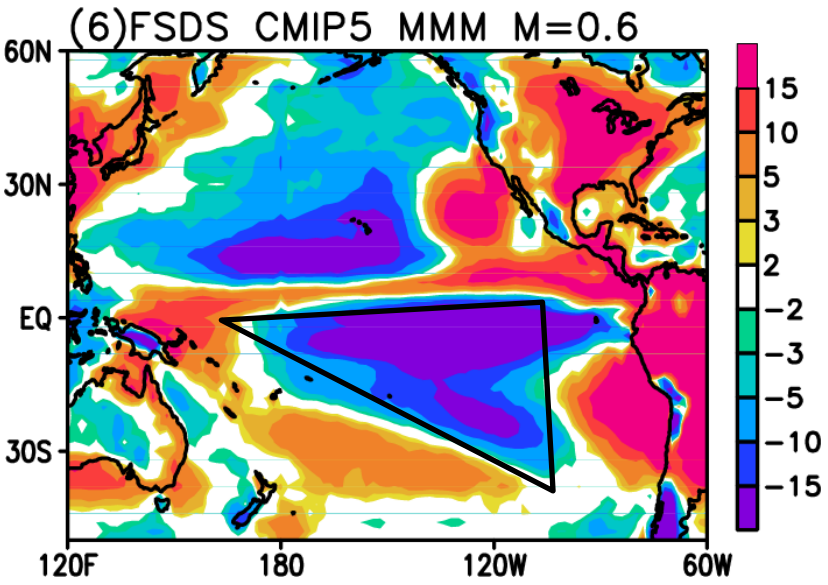
(Li et al., 2014)

Bias of CMIP5 Ensemble Mean Radiation vs. Water Vapor - Total PW

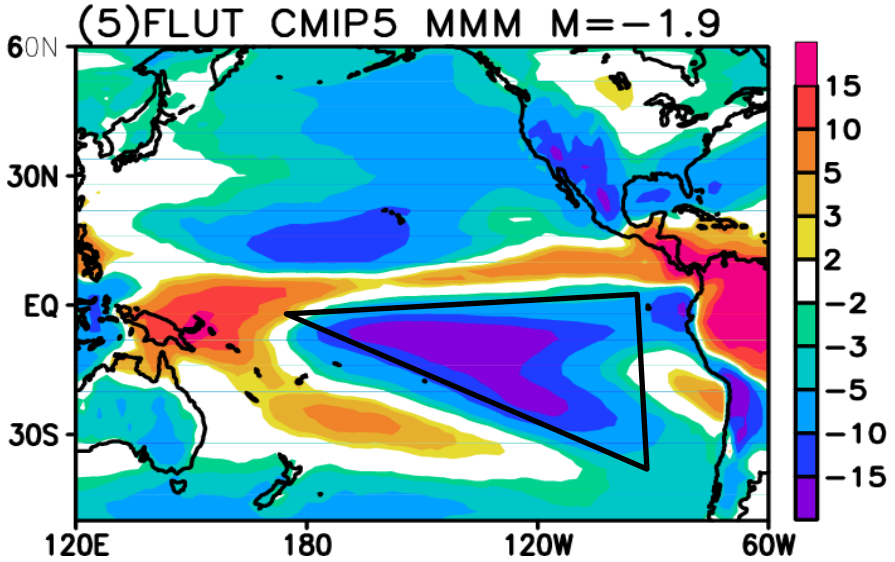
Reflected Shortwave at TOA



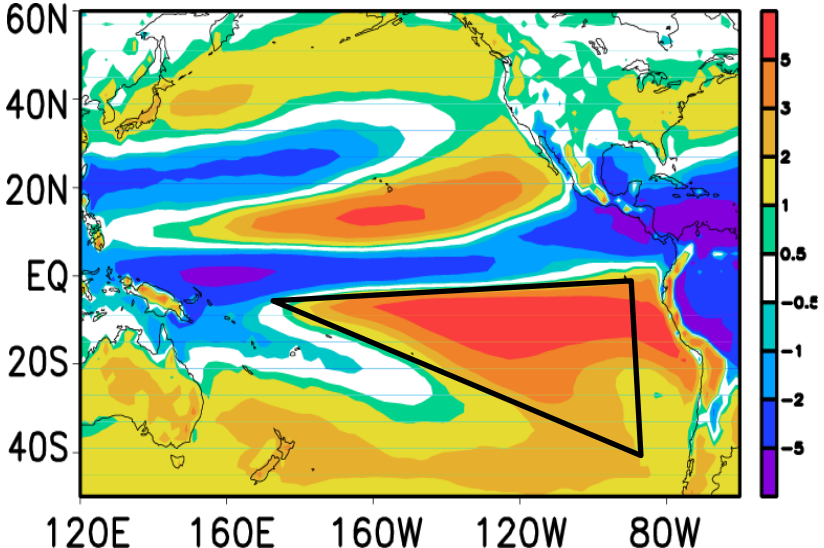
Downward Shortwave at SFC



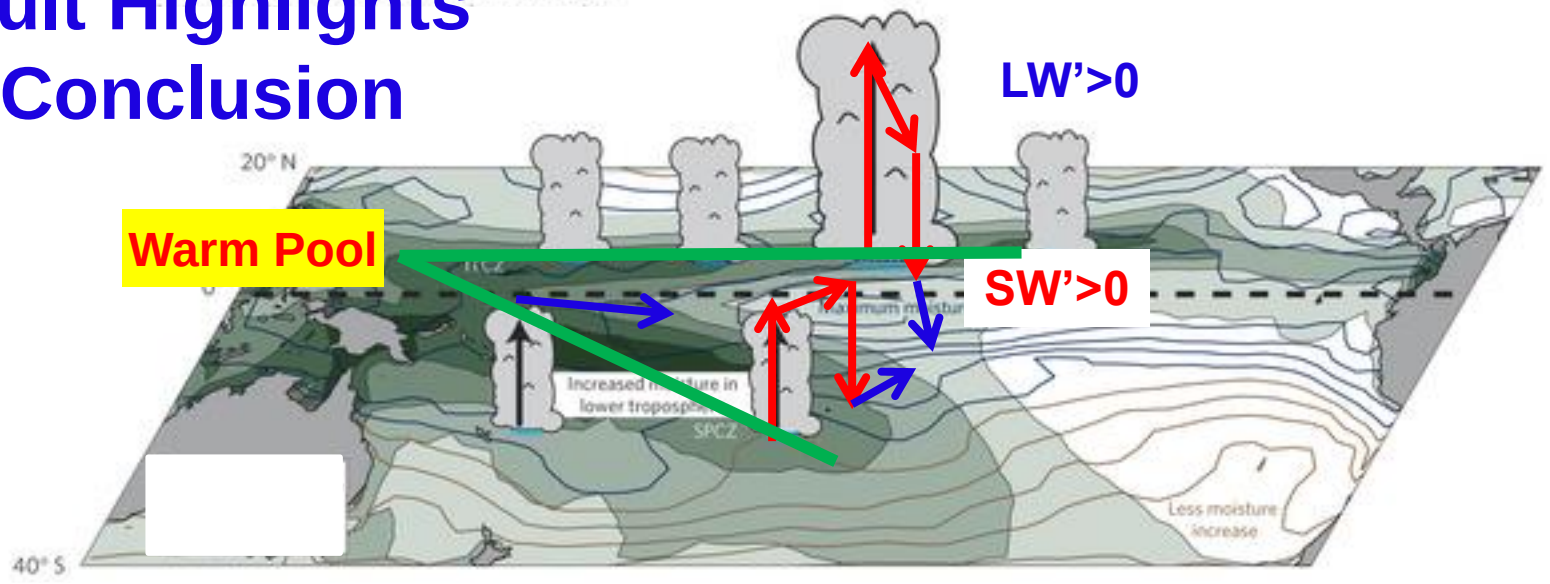
Outgoing Longwave at TOA



CMIP5 Total Precipitable Water (mm)



Result Highlights & Conclusion



Exclusion of snow-radiation effects

Introduce vertically destabilizing radiative heating, triggers compensating deep convective activity and upward motion

enhancing local subsidence and low-level wind convergence

reduces dry air advection by the southeasterly trades (i.e. anomalous southeastward advection of moist, warm air)

increased moisture/cloud and precipitation increases and biases in radiation (clear sky and all sky) within ITCZ and the north and eastward edge of the SPCZ

Related References

Li, J.-L. F., W.-L. Lee, D. E. Waliser, Justin P. Stachnik, Eric Fetzer, Sun Won, Qing Yue, (2014), Characterizing Tropical Pacific Water Vapor and Radiative Biases in CMIP5 GCMs: Observationally-Based Analyses and A Snow and Radiation Interaction Sensitivity Experiment, J. Geophys. Res. Atmos., DOI: 10.1002/2014JD021924.

Li, J.-L. F., R. M. Forbes, D. E. Waliser, G. Stephens, S. W. Lee, (2014), Characterizing impacts of precipitating snow hydrometeors in the radiation using the ECMWF IFS global model, J. Geophys. Res. Atmos., 119, doi:10.1002/2014JD021450.

Li, J.-L. F., W.-L. Lee, D. E. Waliser, J. David Neelin, Justin P. Stachnik, Tong Lee, 2014, Cloud-Precipitation- Radiation-Dynamics Interaction in Global Climate Models: A Snow and Radiation Interaction Sensitivity Experiment, J. Geophys. Res. Atmos., DOI: 10.1002/2013JD021038.

Li, J.-L. F., D. E. Waliser, G. Stephens, S. Lee, T. L'Ecuyer, S. Kato, N. Loeb, and H.-Y. Ma (2013), Characterizing and understanding radiation budget biases in CMIP3/CMIP5 GCMs, contemporary GCM, and reanalysis, J. Geophys. Res. Atmos., 118, doi:10.1002/jgrd.50378.

Thanks