QUANTIFICATION OF SYSTEMATIC BIASES OF CLOUD-RADIATION AND THEIR IMPACTS ON GLOBAL CLIMATE MODELS USING SATELLITE OBSERVATIONS

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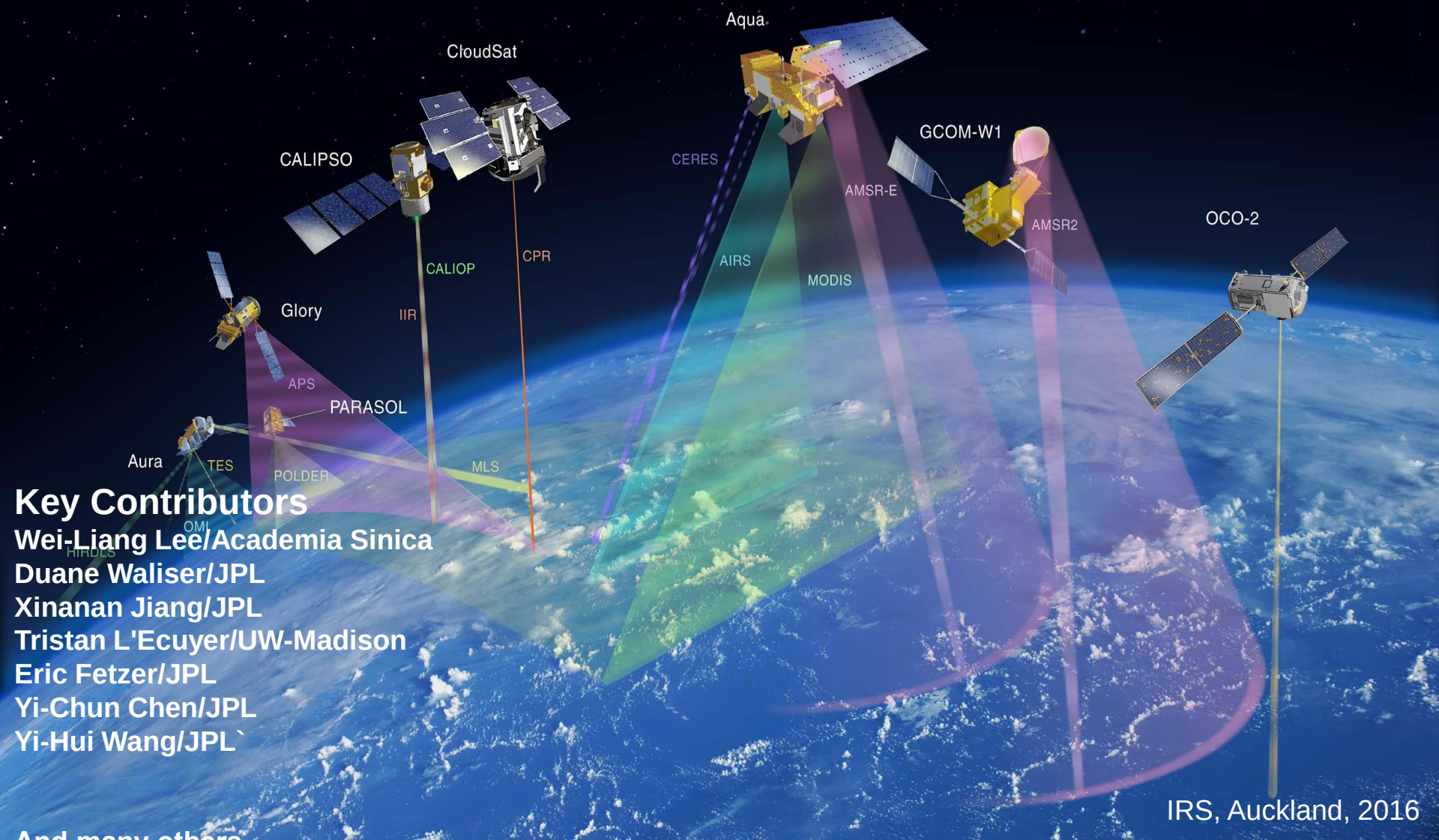

Key Contributors

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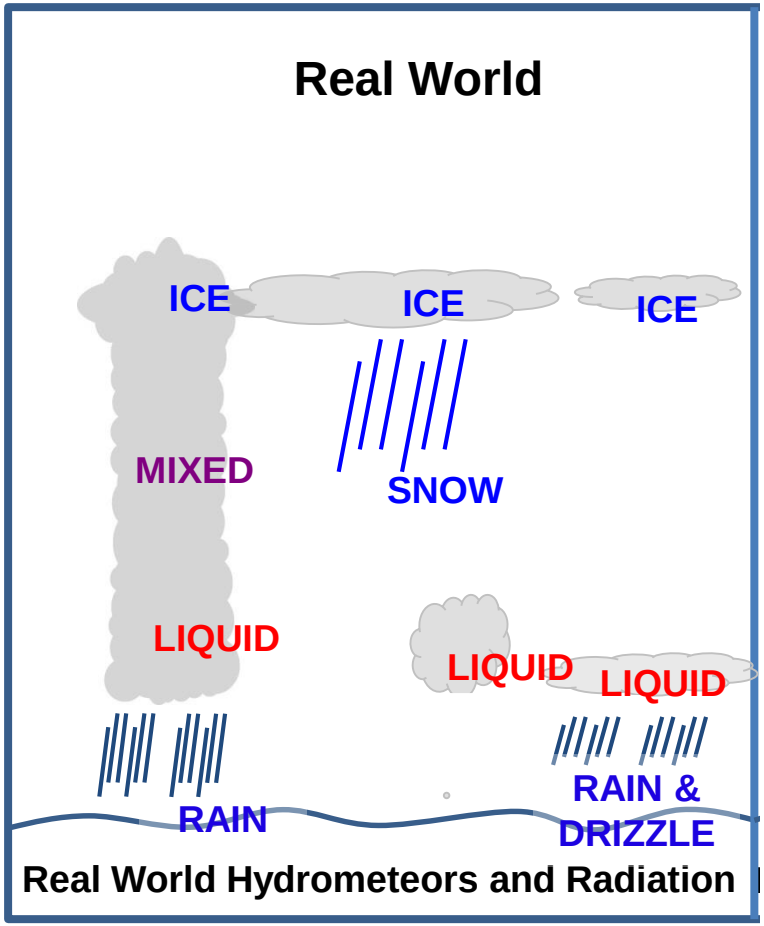
And many others

IRS, Auckland, 2016

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

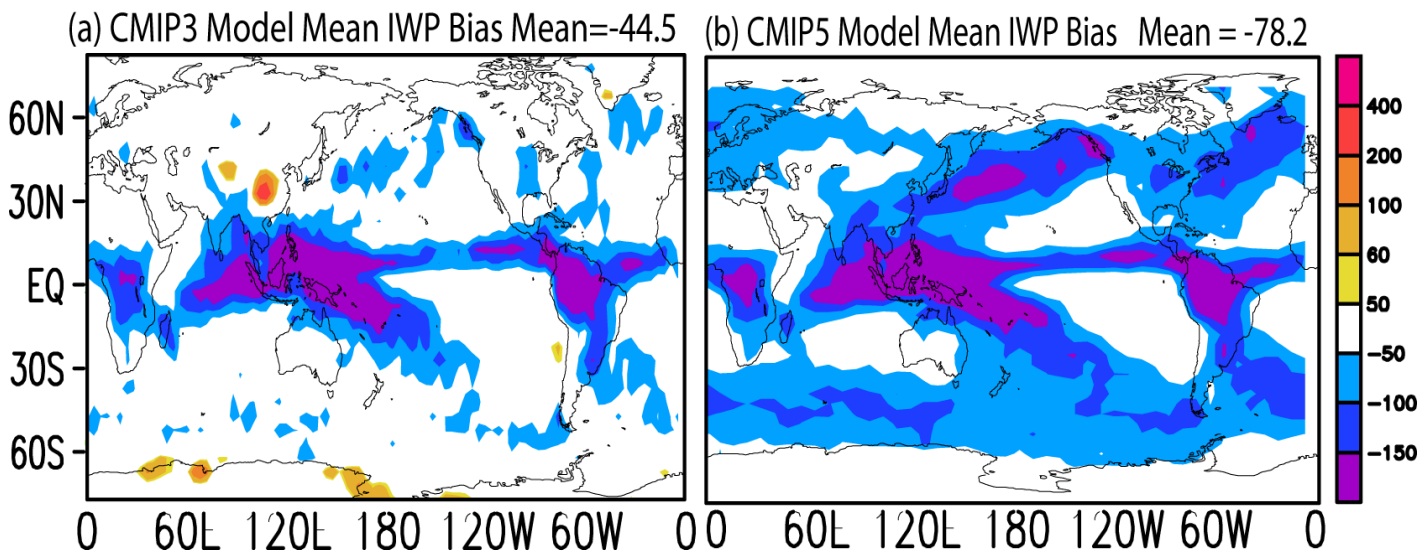


- **Few GCMs such as NASA-GISS model, NCAR-CAM5, GFDL-AM3 and CSIRO etc include *diagnostic* falling snow and/or convective ice (or snow) in their models**

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

CMIP3 **CMIP5**

Total IWP

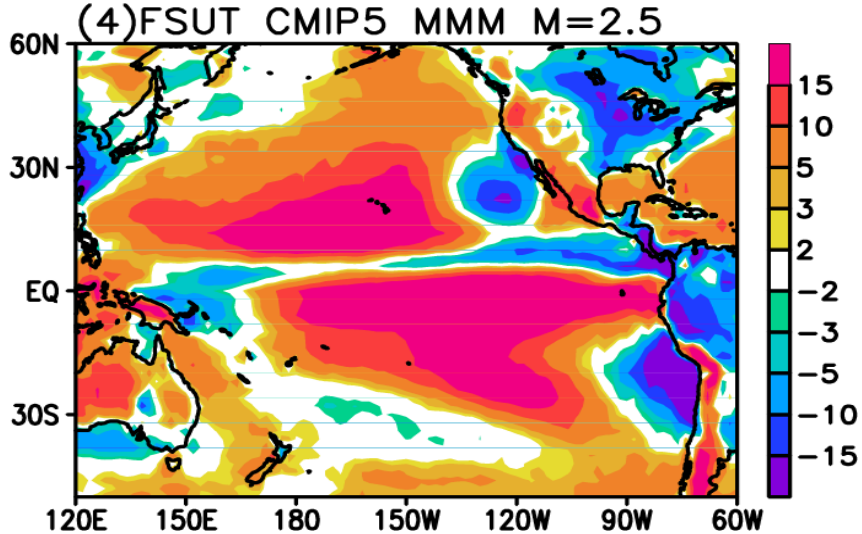


Same as YOTC-GASS IWP (Not Shown)

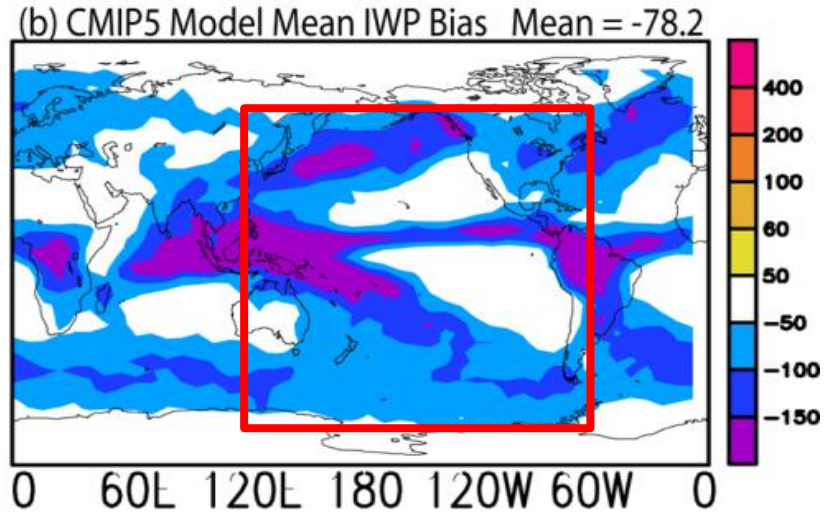
Li, J.-L. F., D. E. Waliser, W.-T. Chen, B. Guan, T. Kubar, G. Stephens, H-Y Ma, D. Ming, L. Donner, C. Seman, and L. Horowitz, (2012), An observationally based evaluation of cloud ice water in CMIP3 and CMIP5 GCMs and contemporary reanalyses using contemporary satellite data, J. Geophys. Res., doi:10.1029/2012JD017640.

Bias of CMIP5 Ensemble Mean Radiation

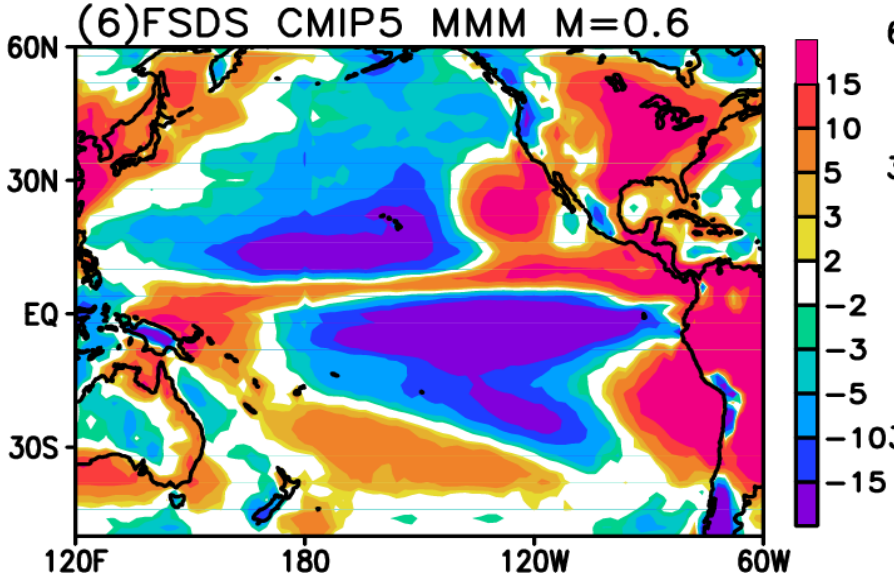
Reflected Shortwave at TOA



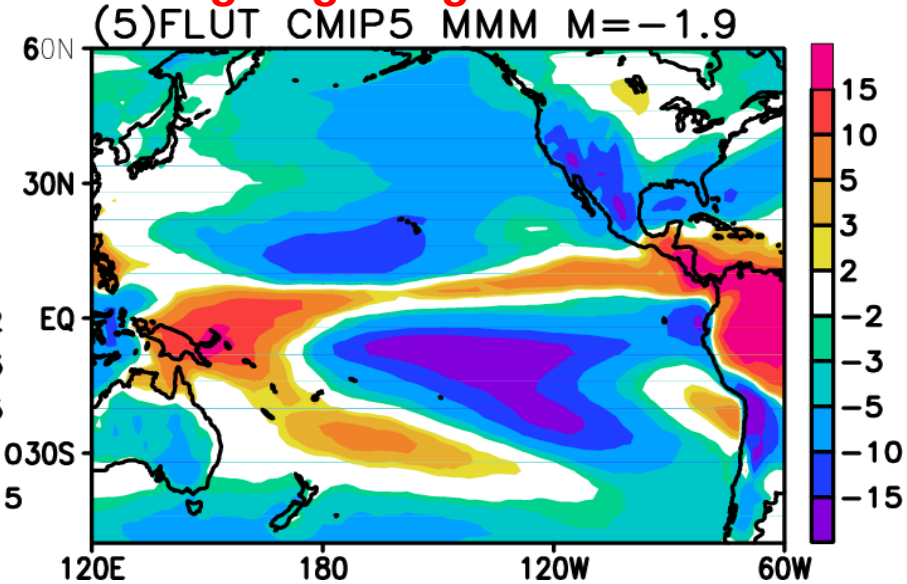
CMIP5



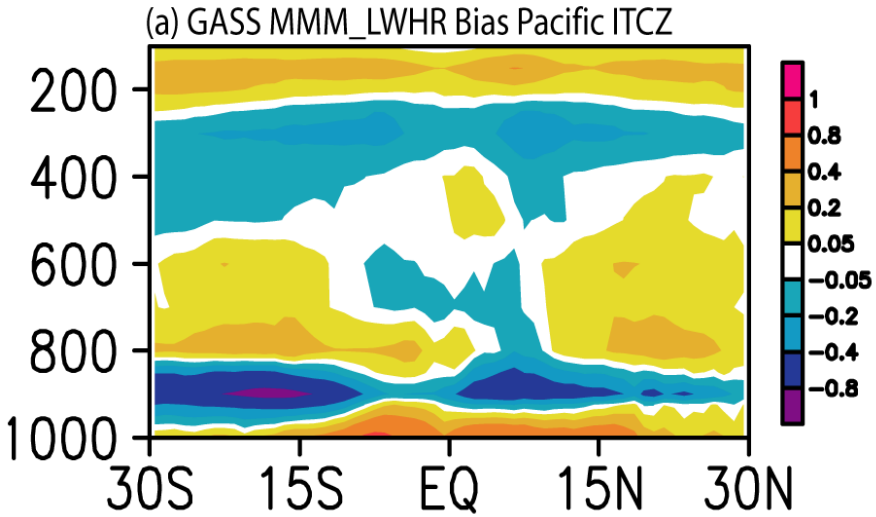
Downward Shortwave at SFC



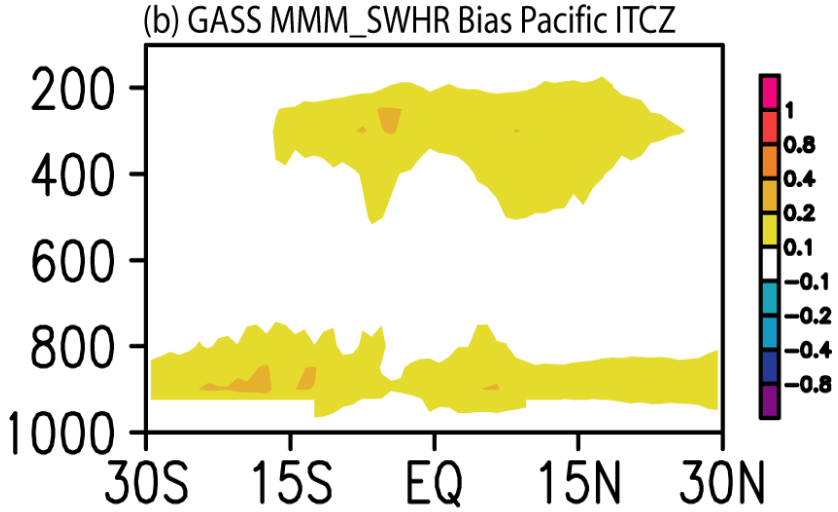
Outgoing Longwave at TOA



Radiative Heating Profile Bias over Pacific Basin

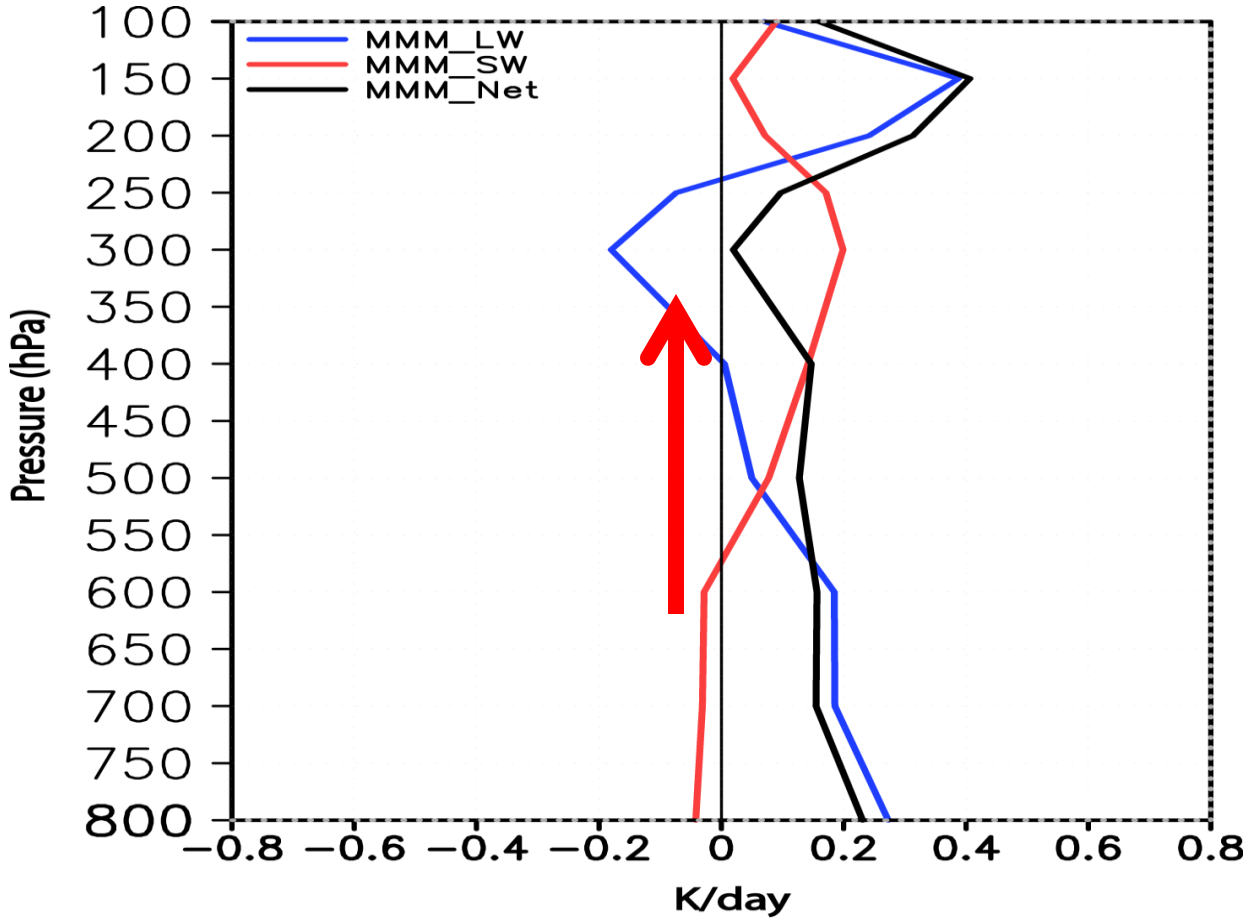


GASS – Total Obs. LWHR



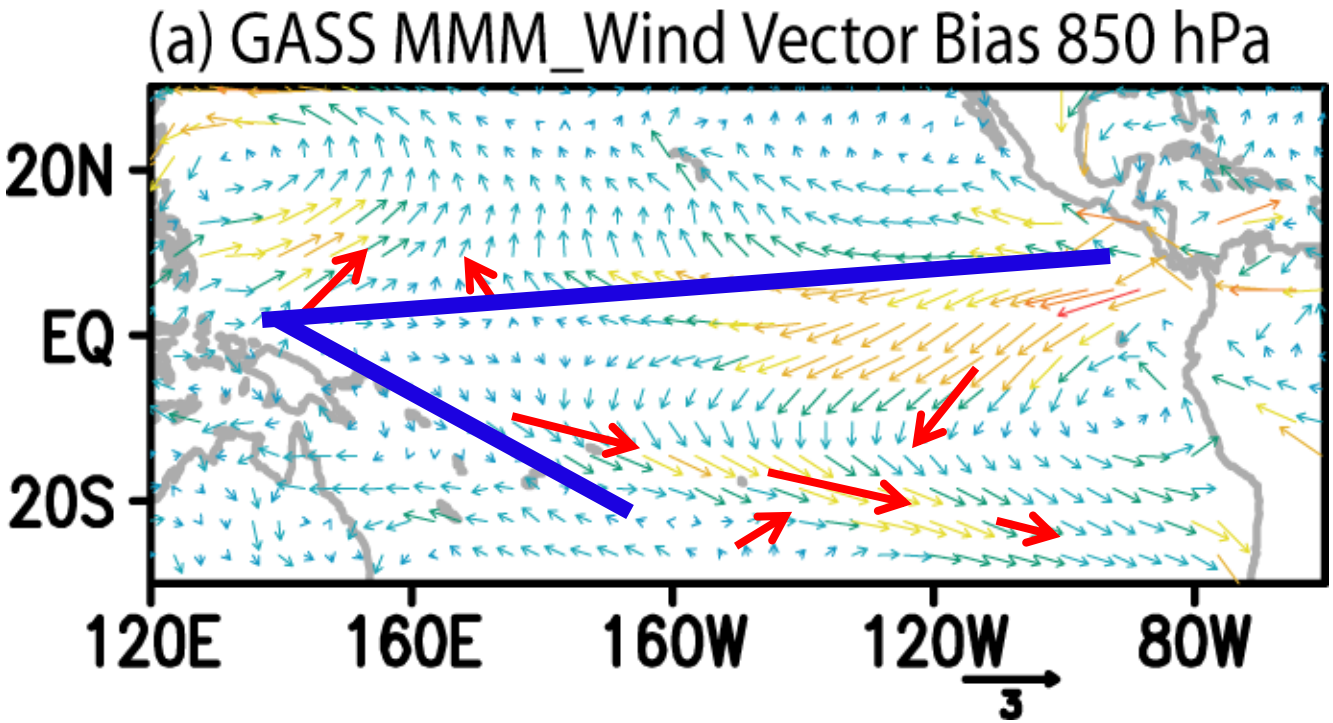
GASS – Total Obs. SWHR

YOTC-GASS Multi-Model Mean Radiative Heating Profiles Bias vs Total Obs. @ ITCZ



This bias of vertically destabilizing radiative heating triggers compensating deep convective activity with stronger condensational heating (Li et al.,2014)

Wind Vectors Bias at 850 hPa

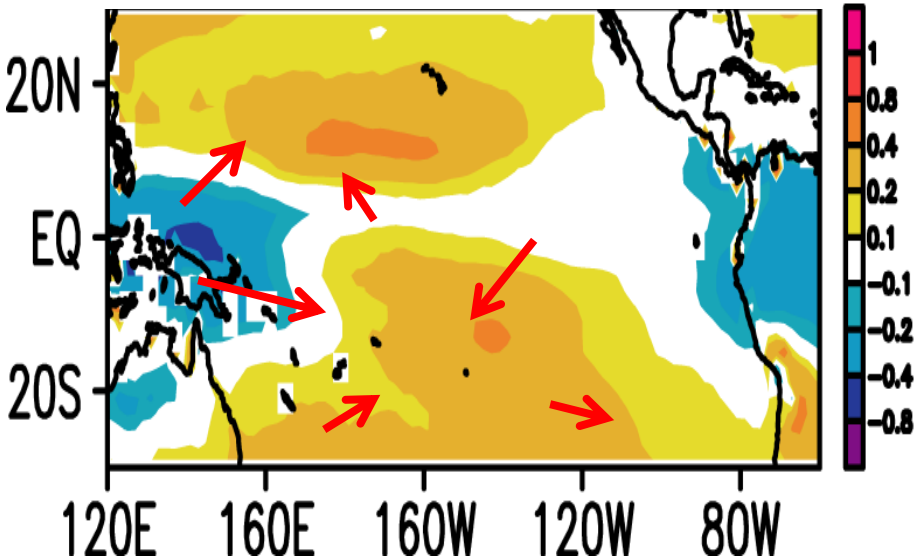


Similar to the low-level wind vectors bias found in CMIP3/CMIP5 (Li et al, 2014)

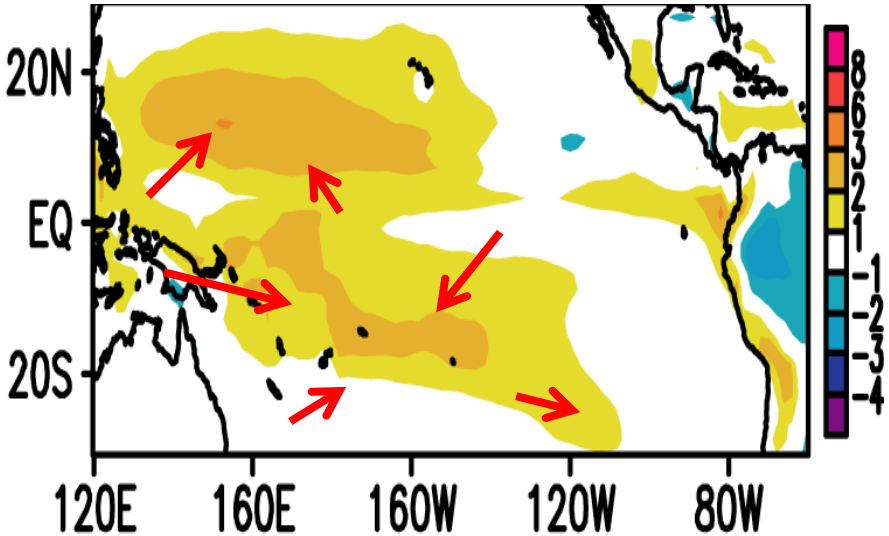
Why there is a low-level outflow pattern from the ITCZ and SPCZ?

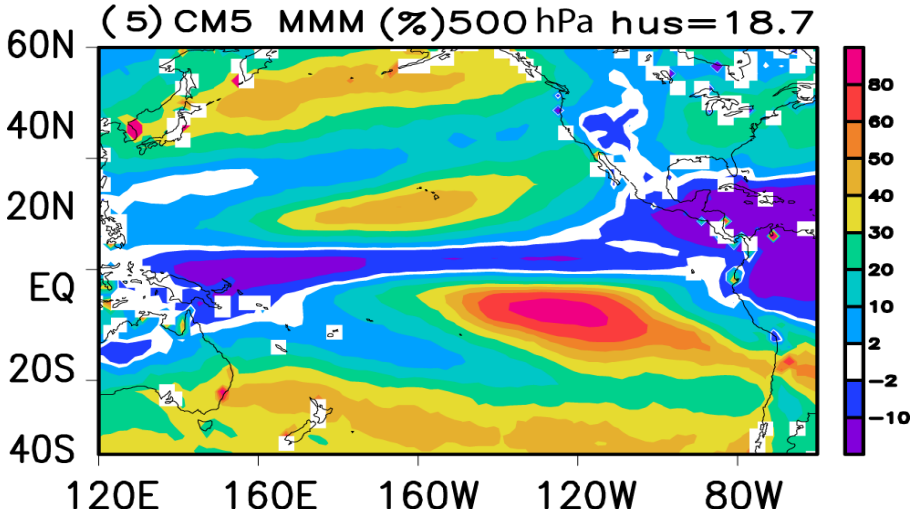
YOITC-GASS Moistures and Precipitation Bias

YOTC-GASS 500 hPa Q vs AIRS



YOTC-GASS Precipitation Bias





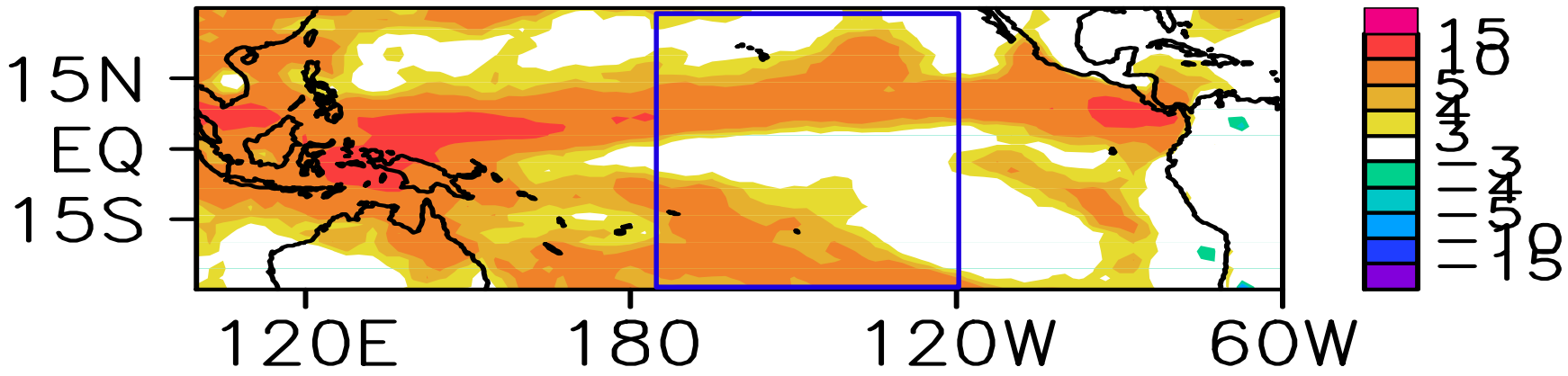
To explore the impacts of cloud snow radiation bias on

- **SW/LW vertical radiative heating structure**
- **the associated cloud condensational heating,**
- **vertical motion, horizontal wind fields,**
- **precipitation and water vapor**

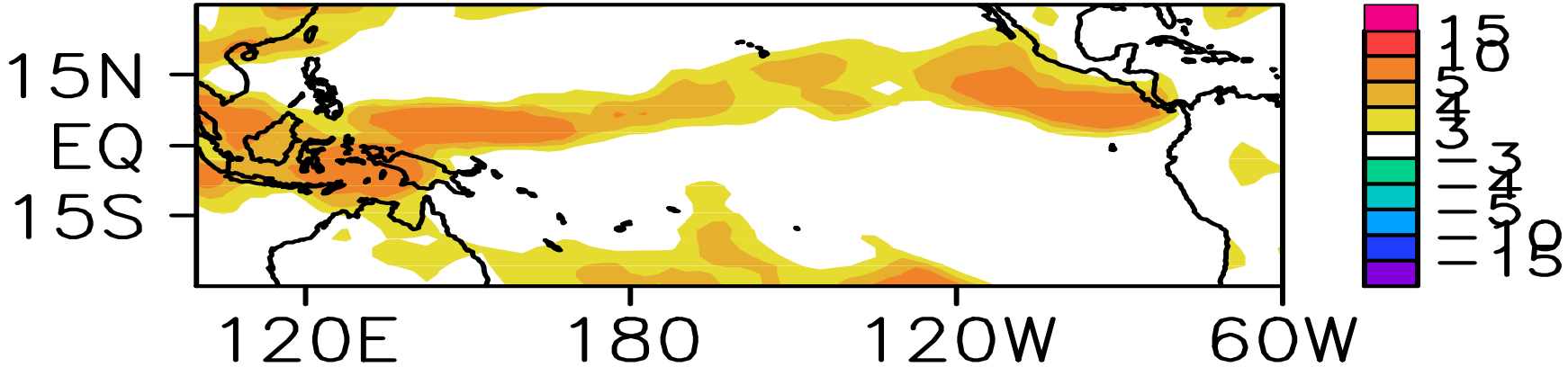
in Tropical Pacific using NCAR uncoupled AGCM with prescribed SSTs.

No Snow-radiative minus Snow-Radiative

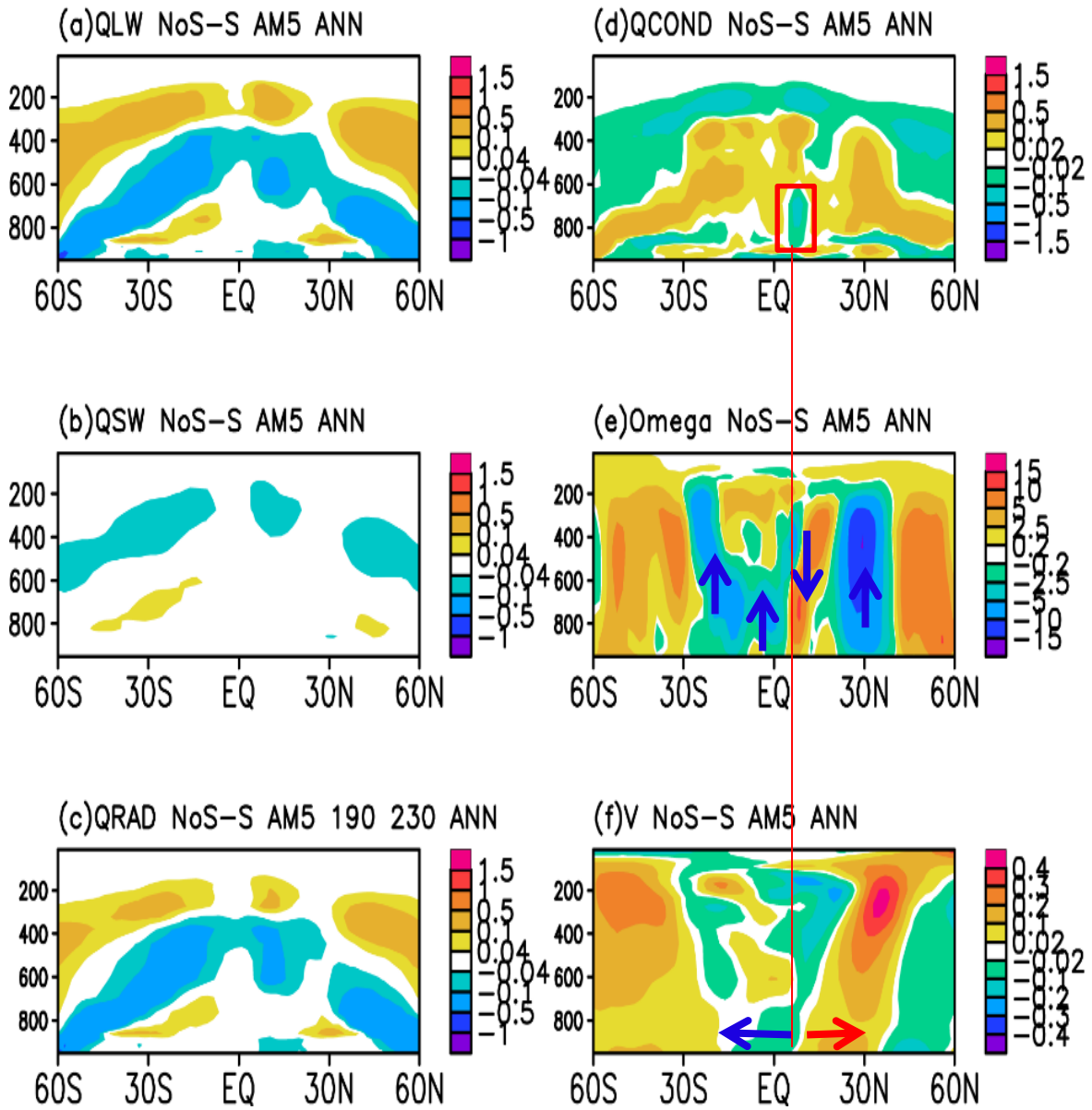
Downward Shortwave Radiation at the Surface



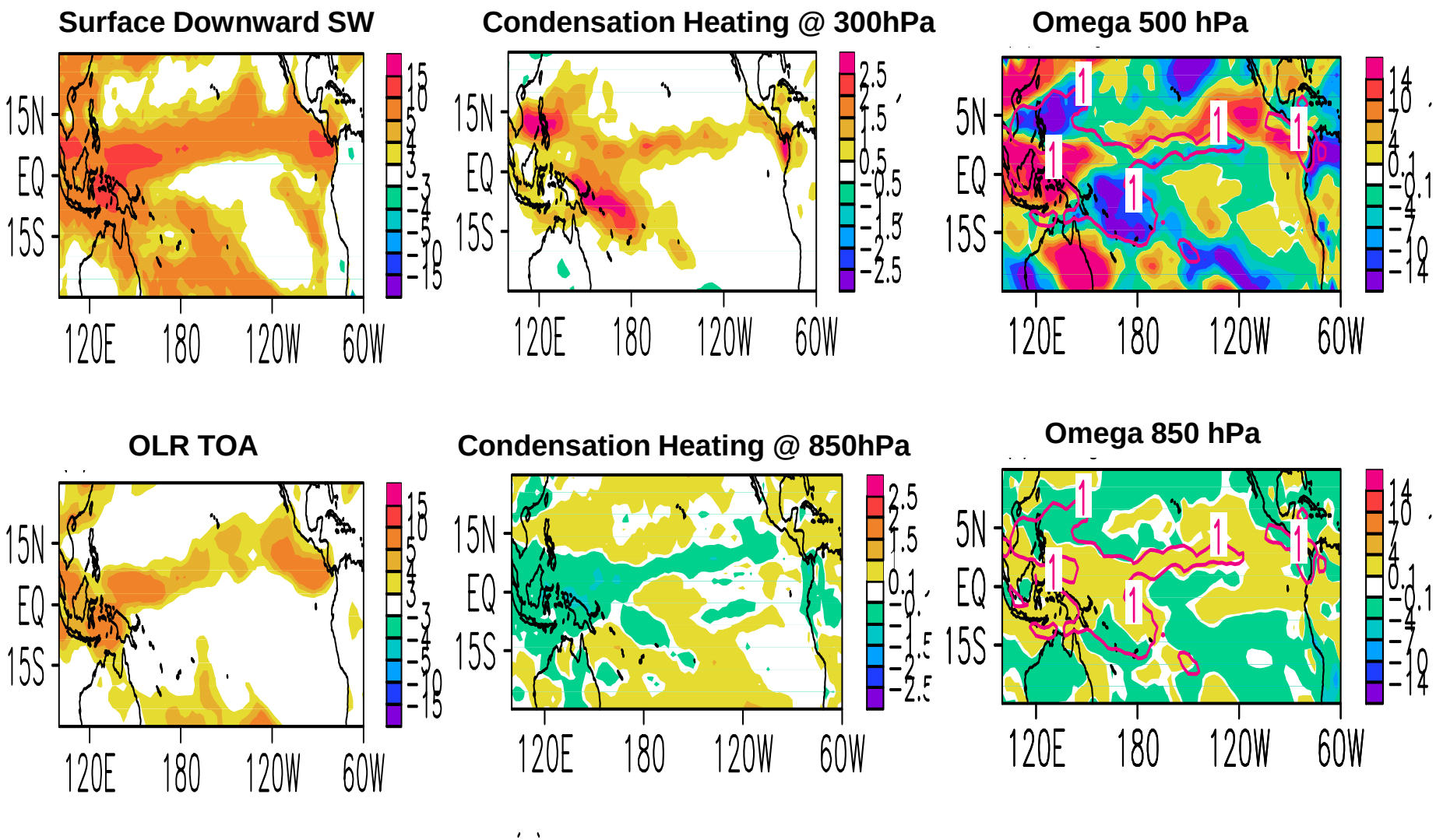
Outgoing Longwave at TOA



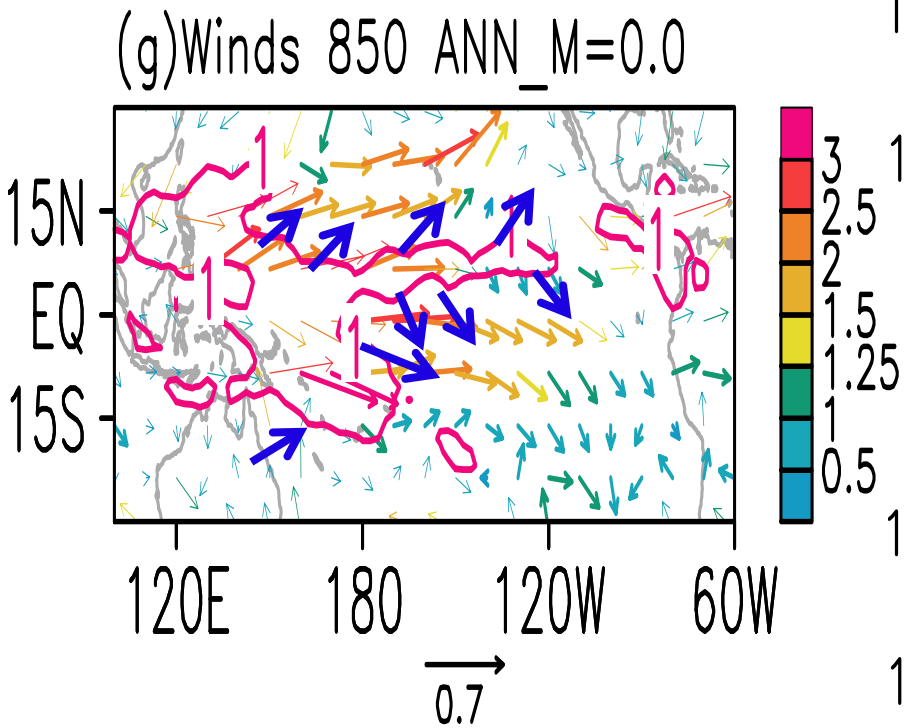
No Snow-radiative minus Snow-Radiative

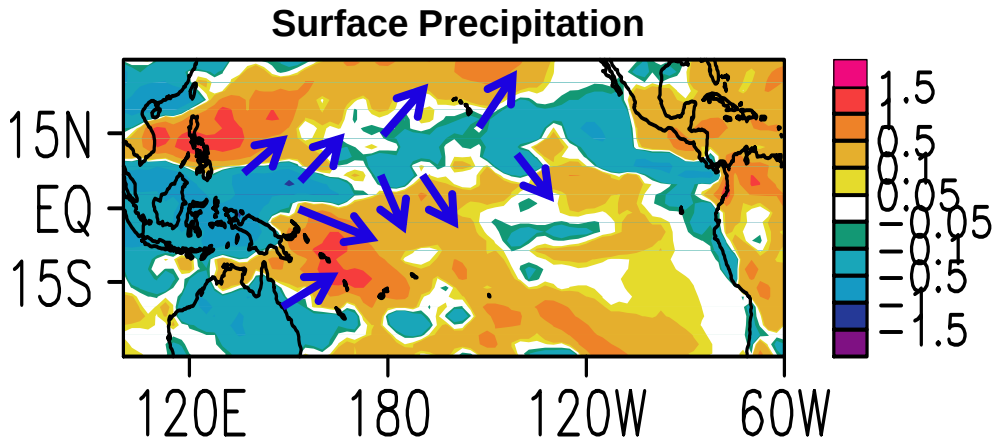


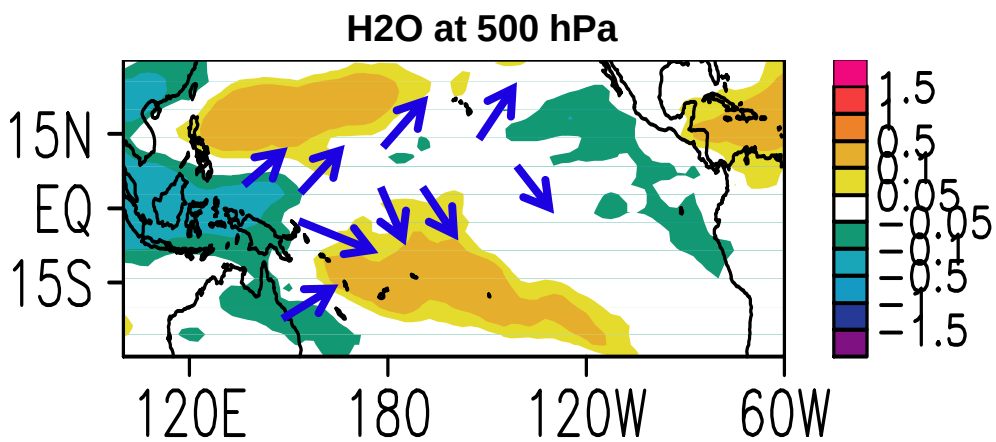
No Snow-radiative minus Snow-Radiative



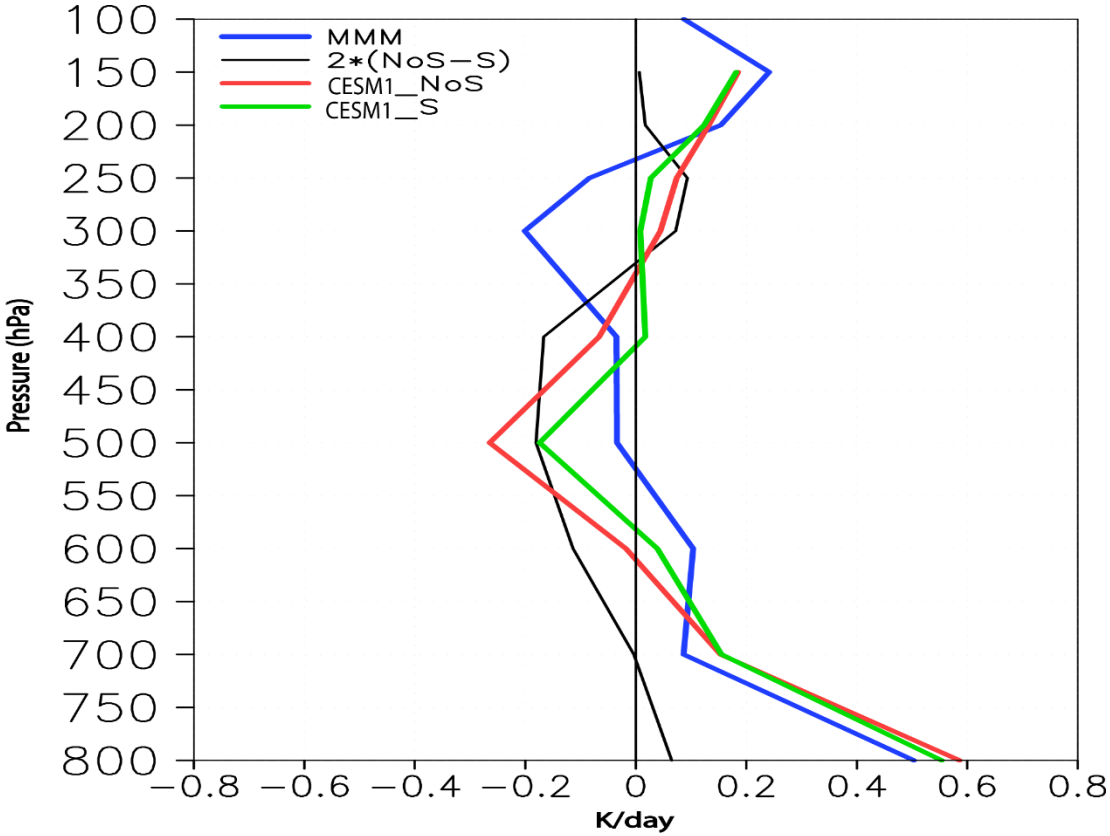
No Snow-radiative minus Snow-Radiative





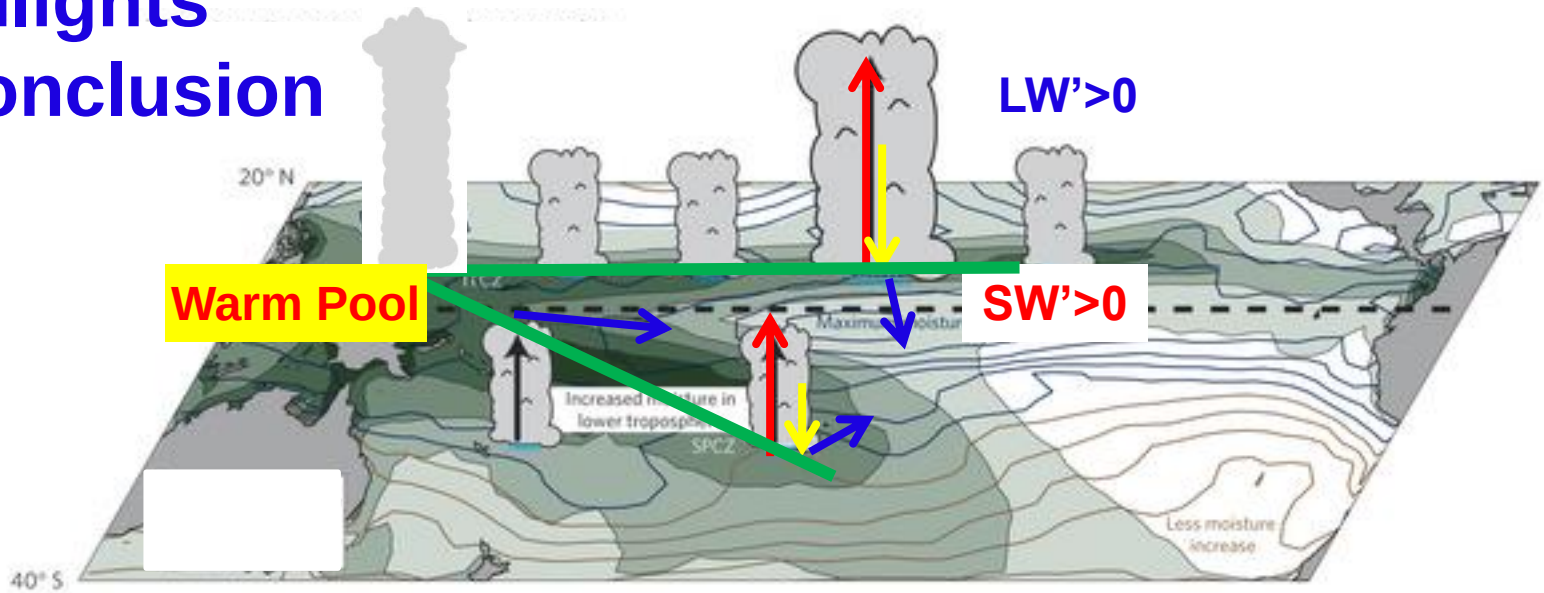


YOTC-GASS Multi-Model Mean Radiative and CAM5 Exp. Heating Profiles Bias vs Obs. In South Pacific (Eq-30S)



This vertically destabilizing radiative heating triggers compensating deep convective activity with stronger condensational heating is associated with
enhanced local descending and low-level wind outflow (Li et al.,2015)

Highlights & Conclusion



The vertically destabilizing radiative cooling profiles associated with the bias of OLR and downward SW are identified over ITCZ/SPCZ and are in conjunctions with

compensating deep convective activity with stronger condensational heating

enhanced mid and upper level local descending and low level descending

low-level wind outflow

Increase column of moistures over trade-wind regions

This mechanism can have a substantial impact on precipitation bias

Using Advances NASA Observations & Modeling to Explore Climate System

Clouds (Ice Water Content) (2012)

Li, J.-L. F., D. E. Waliser, W.-T. Chen, B. Guan, T. Kubar, G. Stephens, H-Y Ma, D. Ming, L. Donner, C. Seman, and L. Horowitz, (2012), An observationally based evaluation of cloud ice water in CMIP3 and CMIP5 GCMs and contemporary reanalyses using contemporary satellite data, J. Geophys. Res., doi:10.1029/2012JD017640.

Cloud and Radiation (2013):

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.

Cloud and Radiation in ECMWF IFS: (2014)

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

Clouds-Cloud snow-Radiation –Dynamics (2014b)

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

Cloud fraction, H2O and Radiation (2014c)

Li, J.-L. F., W.-L. Lee, D. E. Waliser, Justin P. Stachnik, Eric Fetzer, Sun Won, Qing Yue, (2014c), 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.

Sea Surface Temperatures:(2014d)

Li, J-L F., W.-L. Lee, T. Lee, Jia-Yuh Yu, Boening, (2014d), The Impacts of Cloud-Radiation Effects on Pacific Oceans Surface Heat Fluxes, Surface Wind Stress, and Ocean Temperatures in Coupled GCM Simulations, JGR, Under Revision.

Radiative Heating Profiles: (2014 or 2015)

Li, J.-L. F., Wei-Liang Lee, Eric Fetzer,…..(2014f); Quantifying the Systematic Errors in the Vertical Structure of Radiative Heating, Cloud Water and Water Vapor in Contemporary GCMs using A-Train observations, revision

THANKS