Implied Ocean Heat Transports in the MMF

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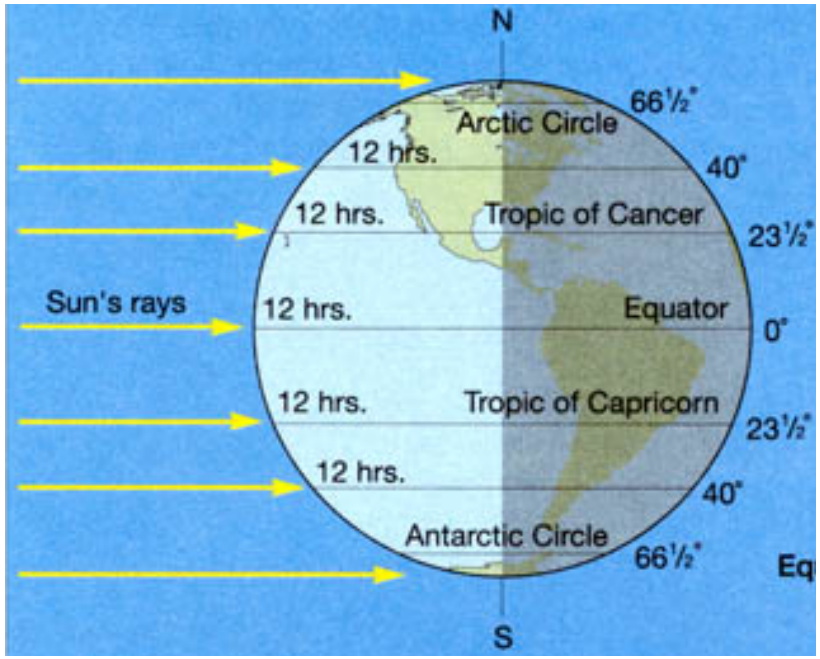
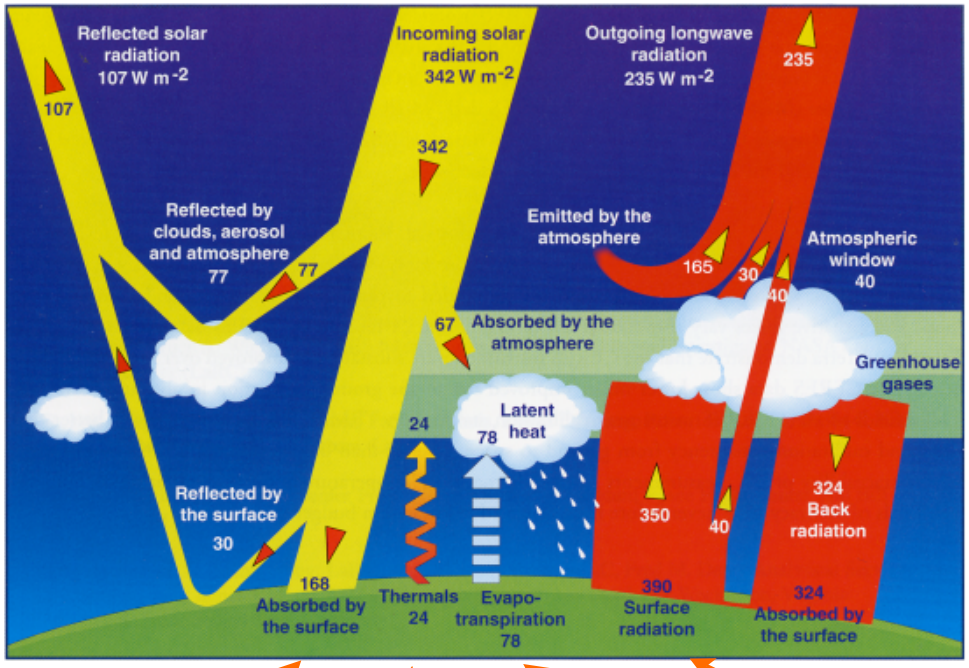
Outline

- A primer on implied ocean heat transports (T_o)
- T_o in CAM3 and the MMF
- Sources of error in MMF T_o
  - Surface shortwave radiation
    - tropical convective anvils
    - marine stratocumulus clouds
  - Latent heat fluxes
- Implications for coupled atmosphere-ocean runs

Calculating Ocean Transports

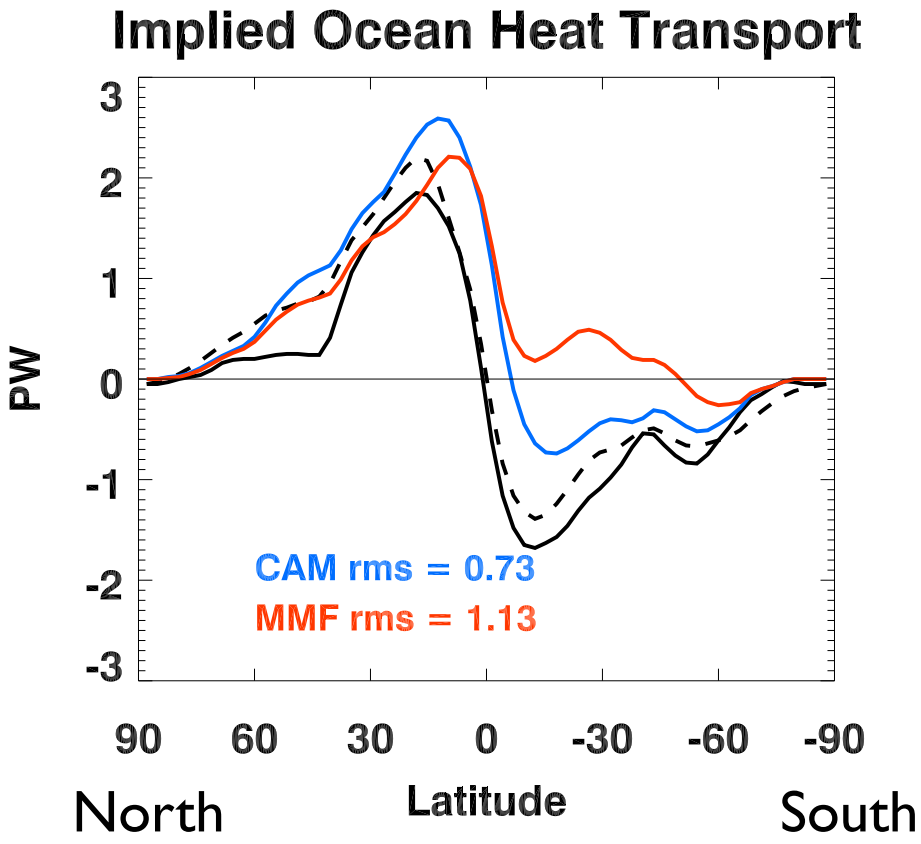




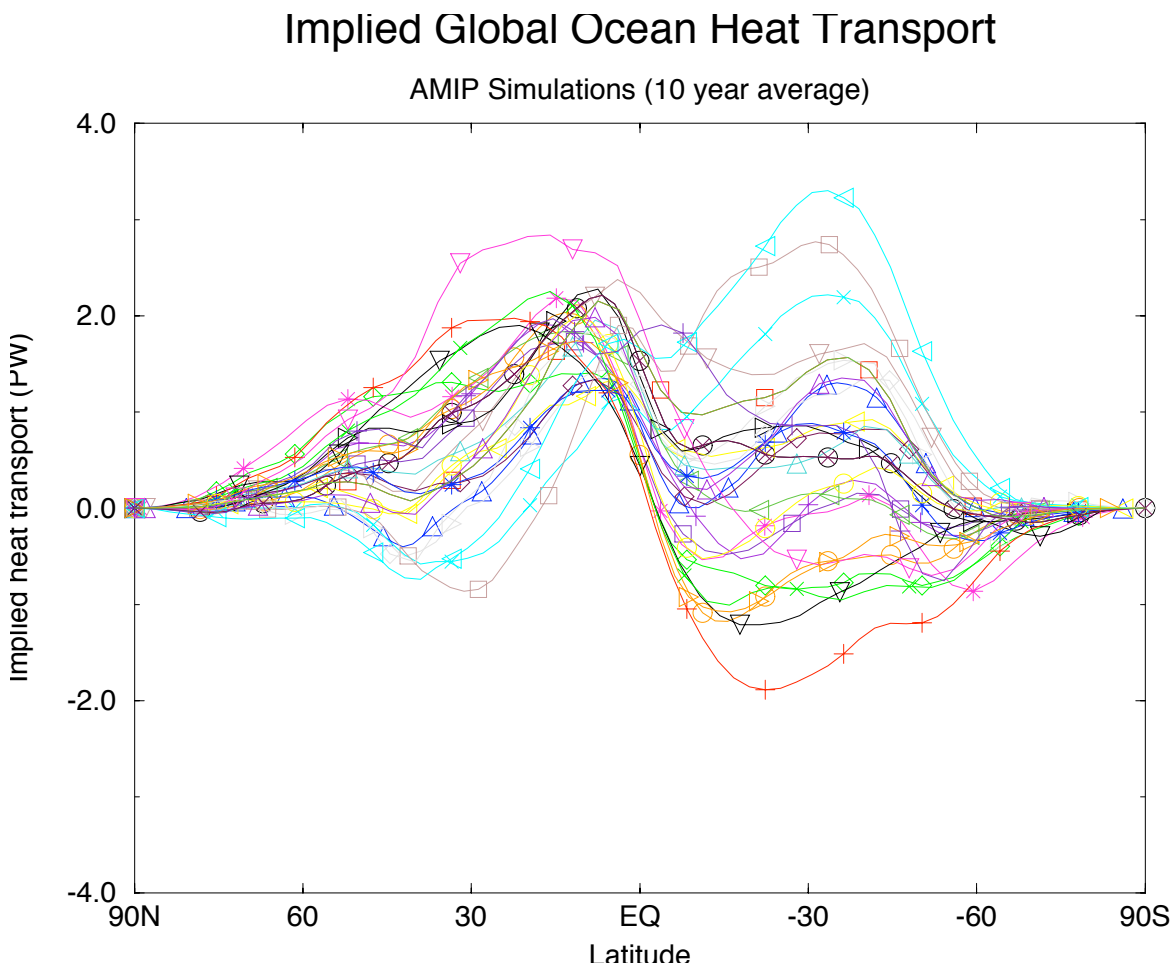
net surface energy = SW + SH + LH + LW

- net surface energy is computed over ocean surface
- for each latitude band, ocean transport is required to offset energy surplus or deficit

T_o in CAM and MMF



T_o in other models

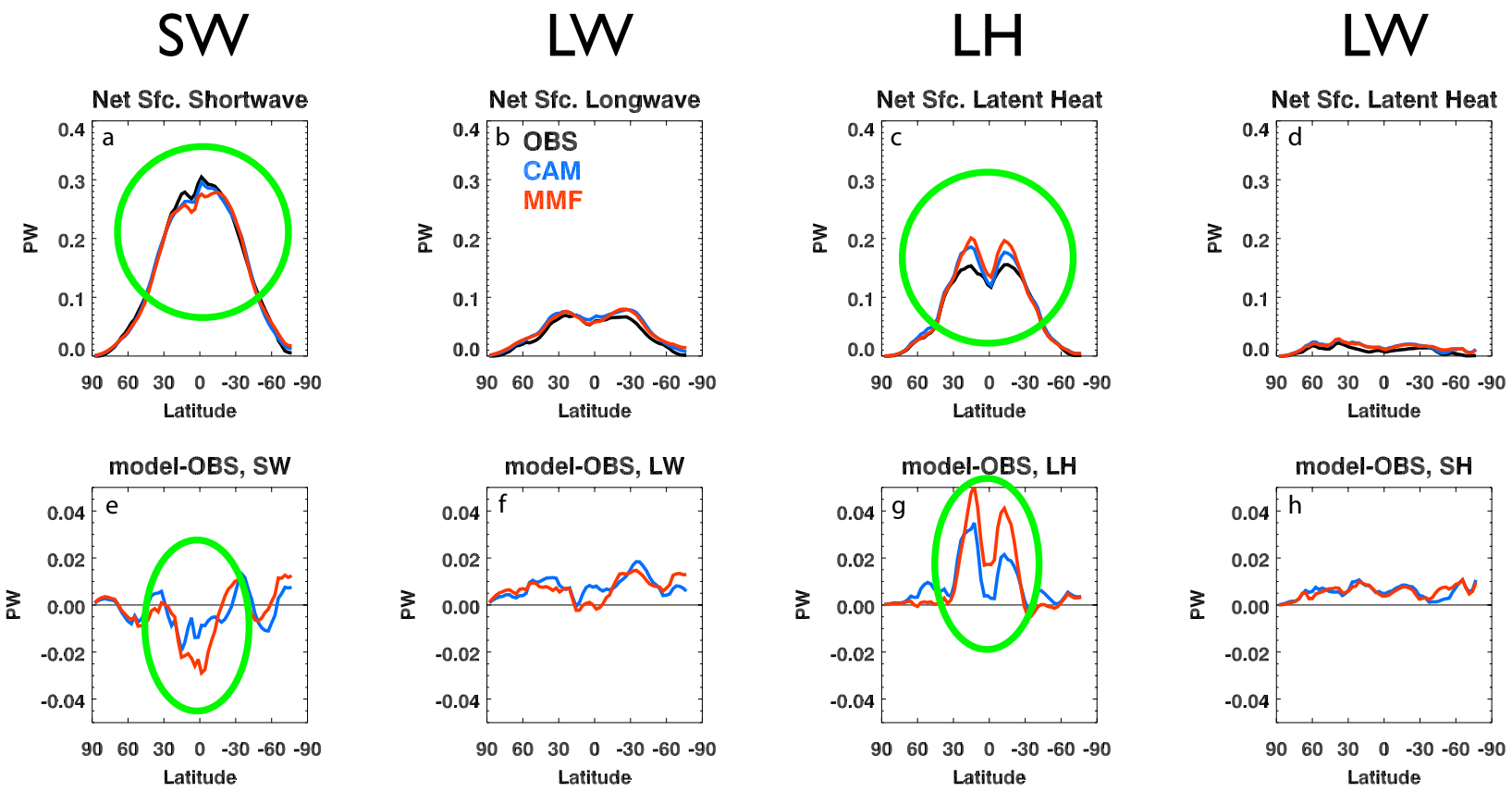


data from Gleckler et al., 1995

Why Ocean Transports?

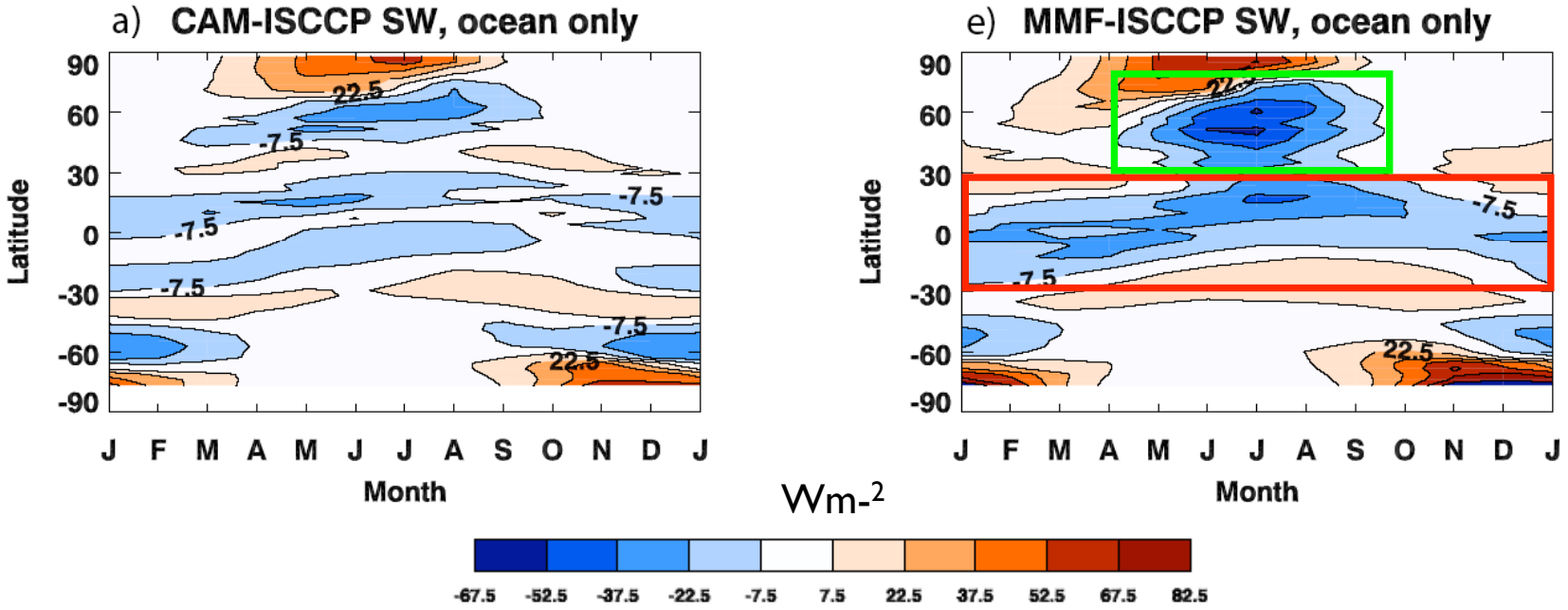
- A simple way to examine the net effect of atmospheric model errors on the simulated climate.
- Each term (SW, LW, SH, and LH) can be evaluated for its contribution to T_o error.
- Errors in each term may be traced to specific regions or processes.
- Reducing the largest errors is the most direct route to an improved simulation.

Surface Energy Errors in CAM, MMF



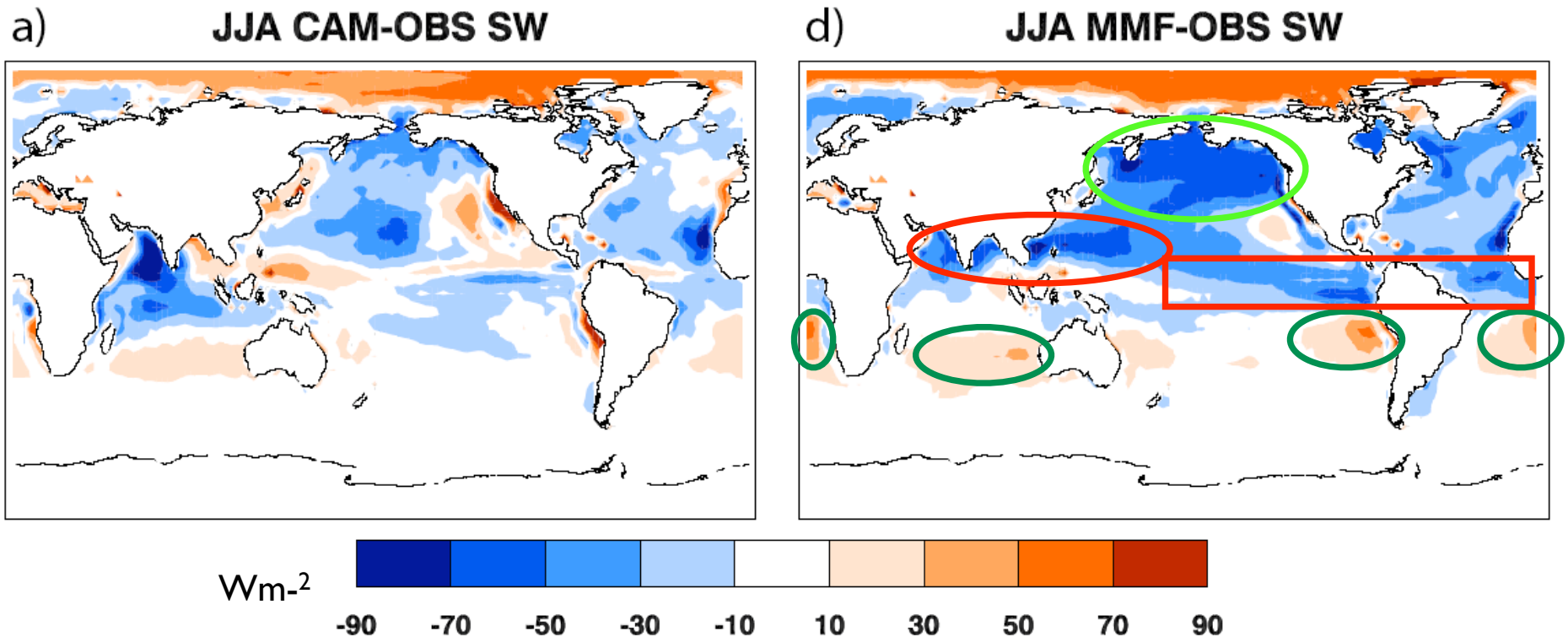
- SW and LH are largest components of surface energy budget
- SW and LH are also largest error sources

Surface SW Errors in CAM, MMF



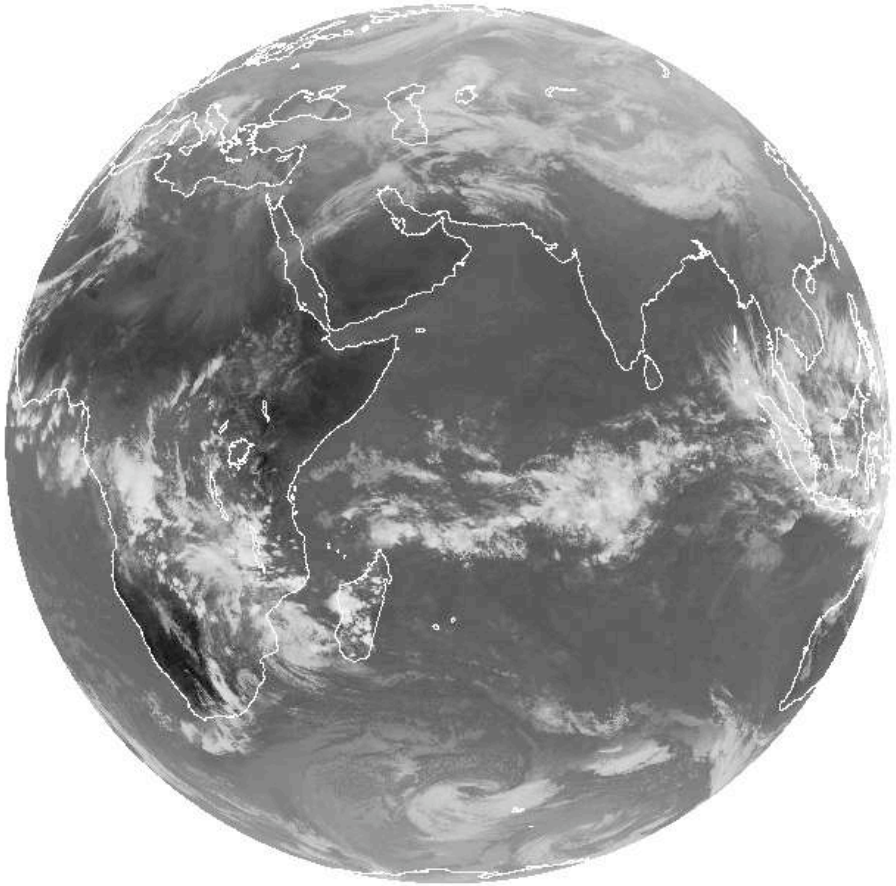
- Largest MMF SW errors associated with ITCZ
- Summertime negative bias in Northern Hemisphere

Surface SW Errors in CAM, MMF



- Deep tropical convection (Asian monsoon, ITCZ)
- SH marine stratocumulus clouds
- North Pacific

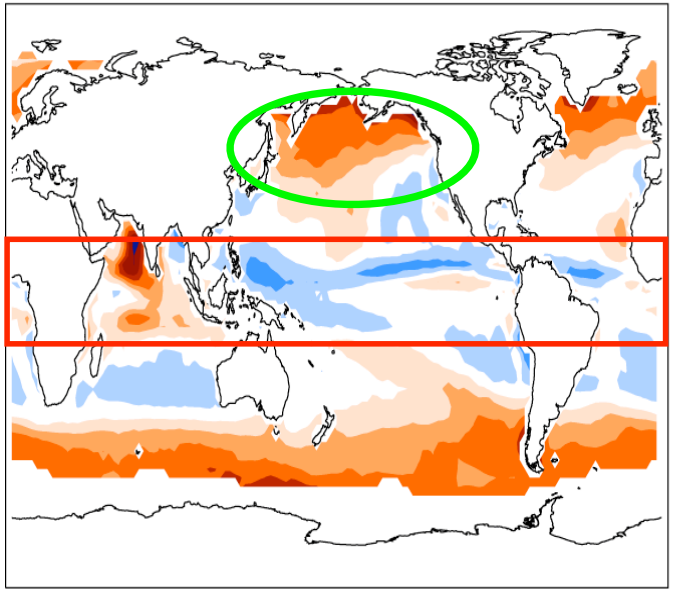
Tropical Convection



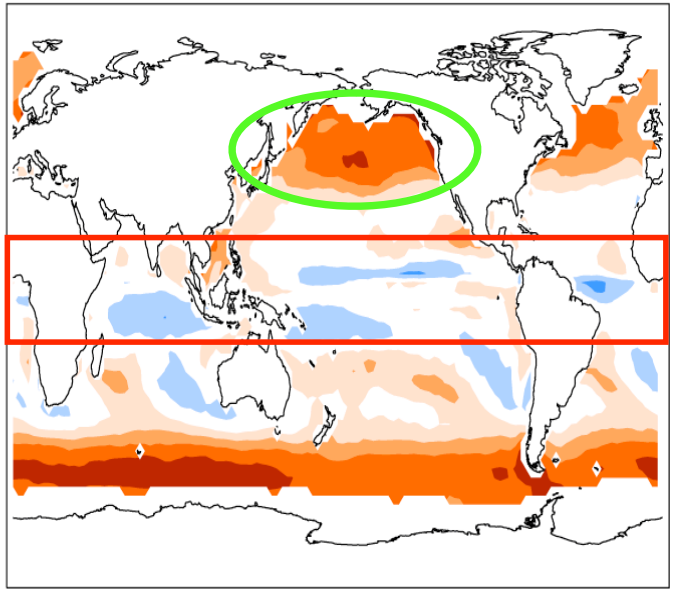
Meteosat IR, 1-1-2009

Liquid Water Path in CAM, MMF

CAM-ISCCP (JJA)



MMF-ISCCP (JJA)



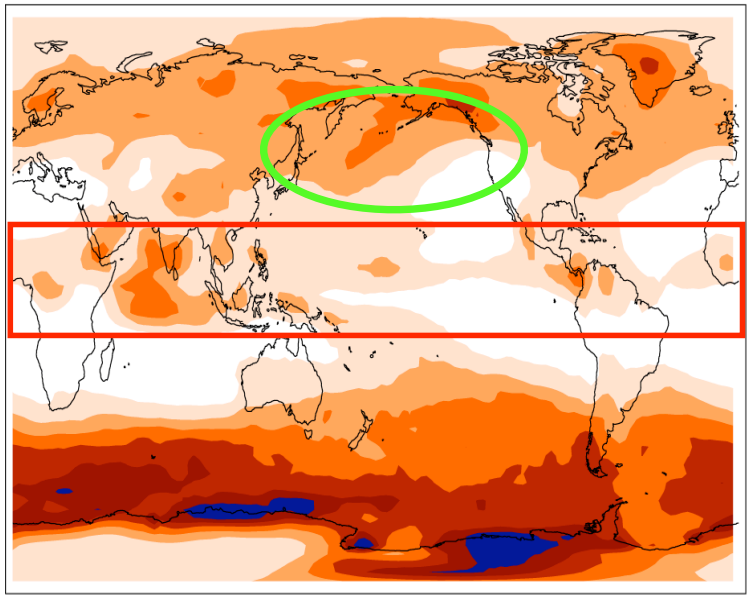
kg m^{-2}

-225 -175 -125 -75 -25 25 75 125 175 225 275

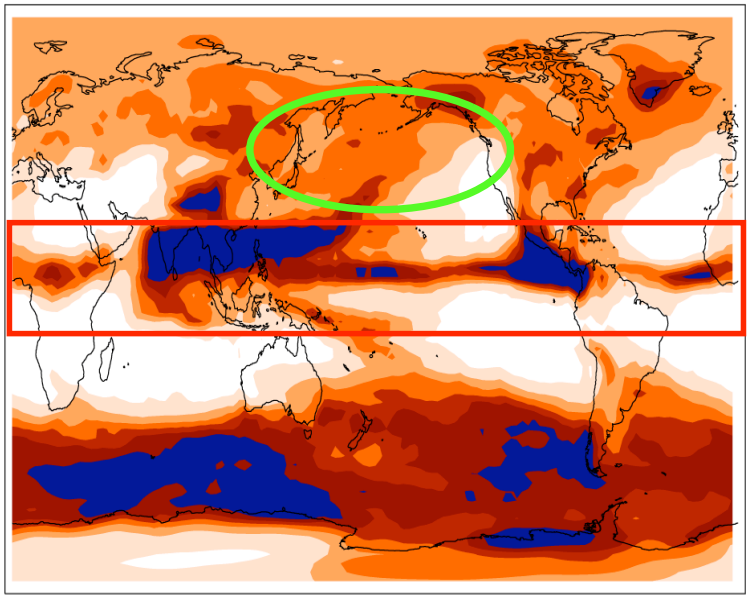
- Tropical LWP improved over CAM
- North Pacific LWP greater than in CAM

Ice Water Path in CAM, MMF

CAM (JJA)



MMF (JJA)

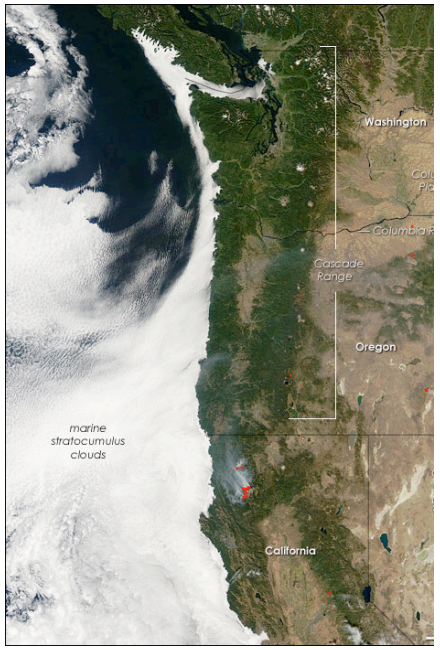


- Excessive ice water in tropics
- North Pacific IWP greater than in CAM

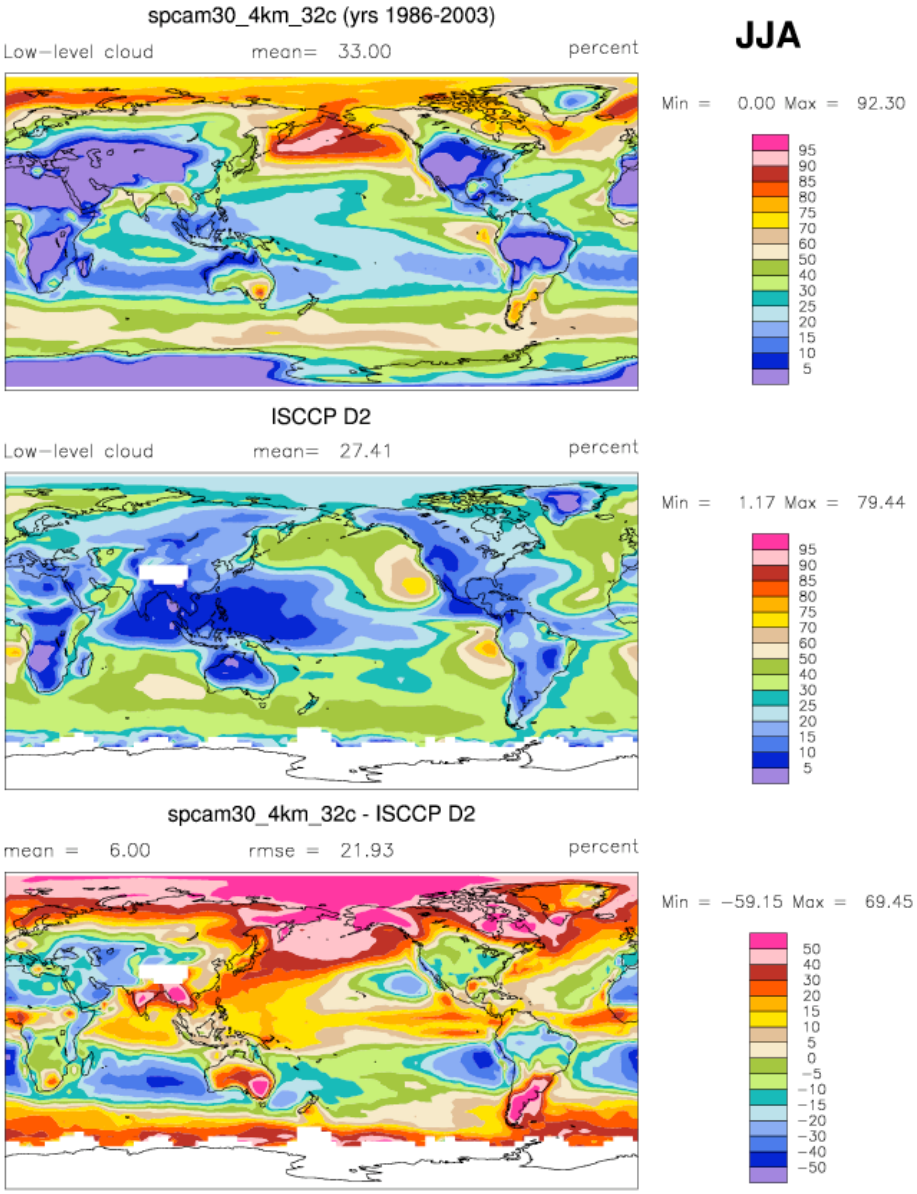
MMF Convective Ice Bias

- Possible causes
  - insufficient settling or precipitation of ice
  - overly vigorous convection
- Potential remedies
  - improvement of ice microphysics
  - 3D embedded cloud resolving model?

Marine Stratocumulus Clouds

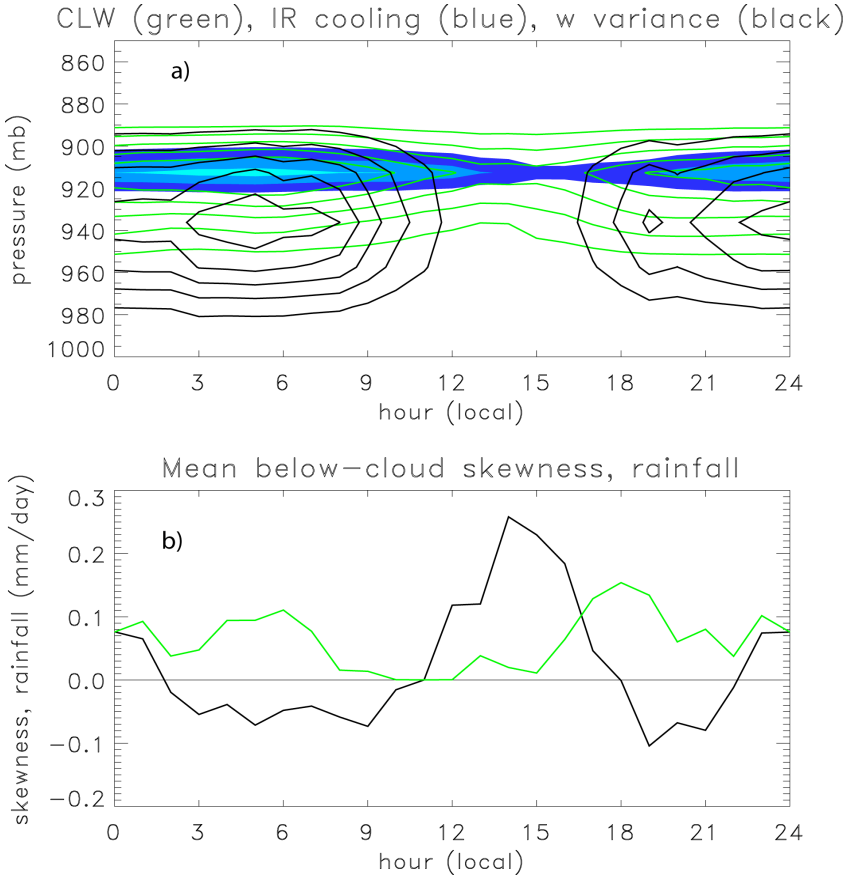


Marine Sc clouds: seasonal mean



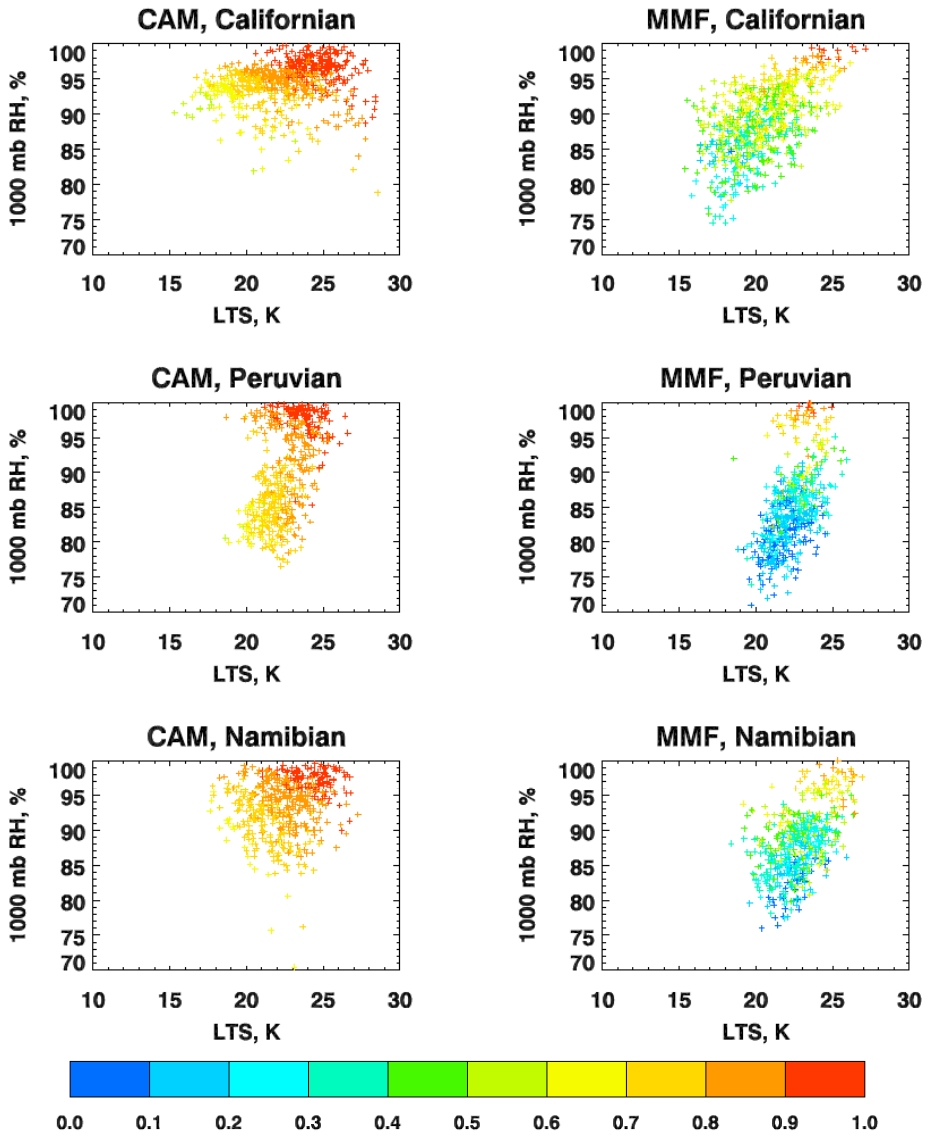
- MMF under-predicts marine Sc clouds

Marine Sc clouds: diurnal cycle



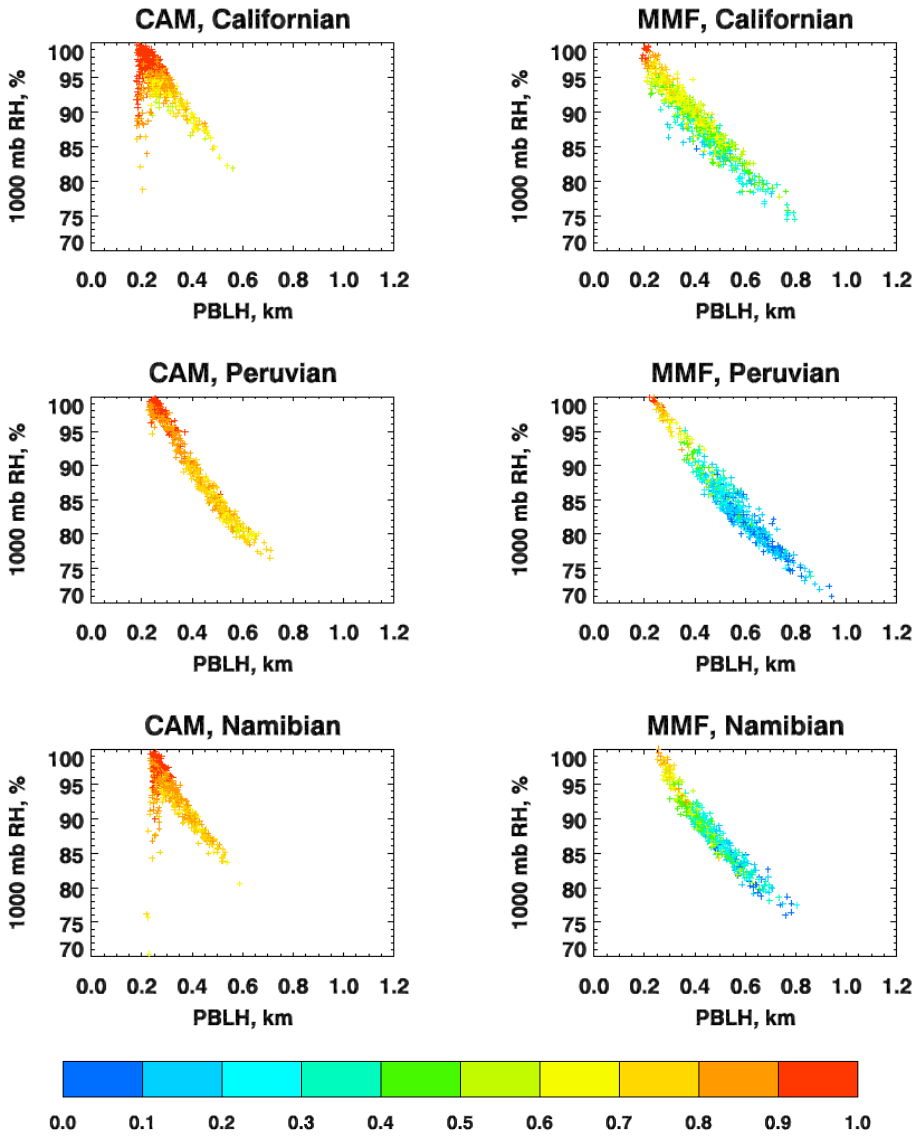
- When present, MMF marine Sc clouds are realistic
- MMF produces marine Sc too infrequently

LTS, surface RH, Cloud Fraction



- CAM, MMF produce similar range of lower tropospheric stability (LTS)
- MMF boundary layer is drier than CAM boundary layer
- MMF low cloud more sensitive to RH than LTS

PBL *h*, surface RH, Cloud Fraction

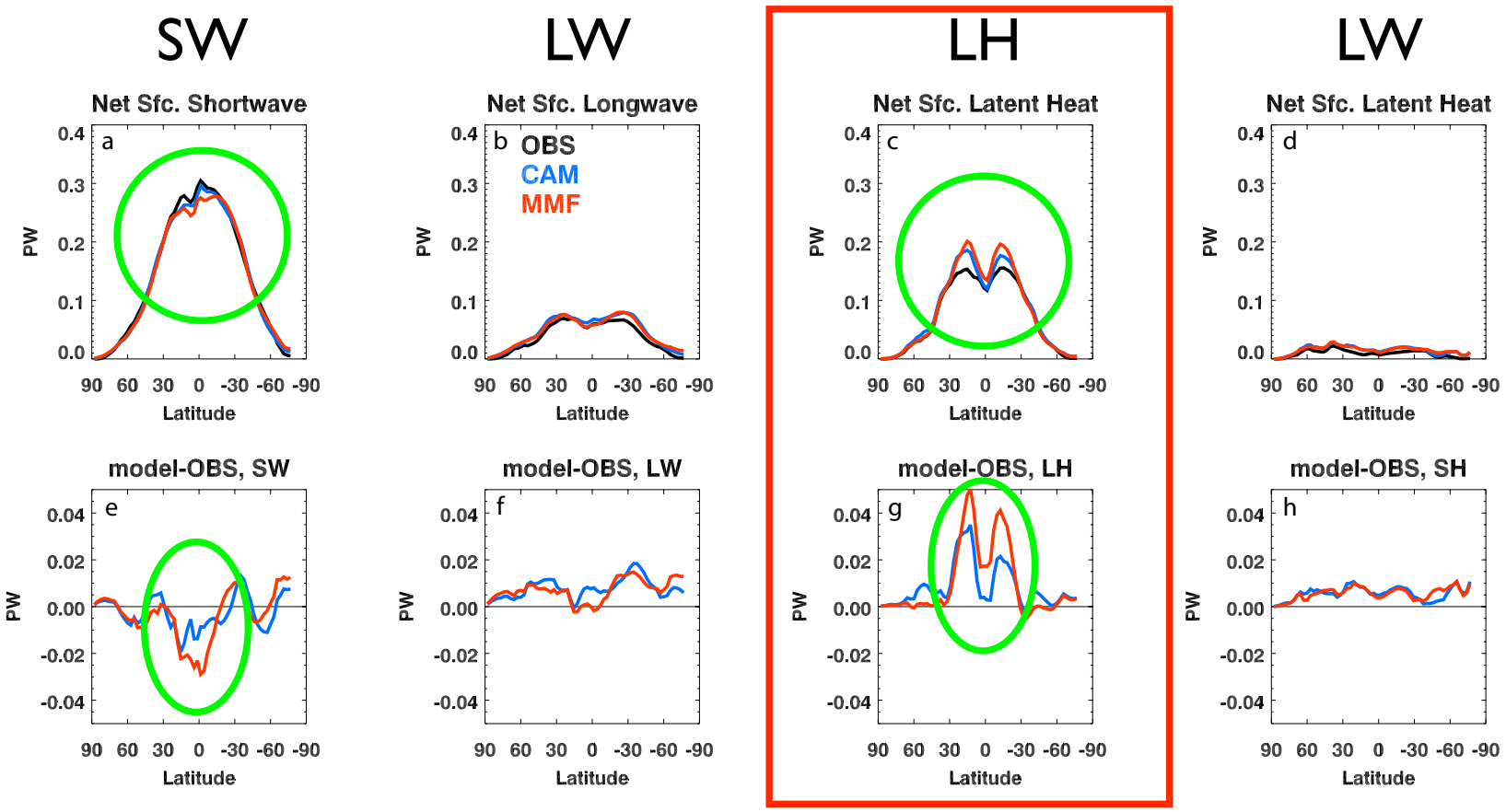


- For marine Sc regions, simulated surface RH is controlled by PBL *h*
- MMF low clouds require high sfc RH
- Suggests that cloud-top entrainment often overcomes sfc fluxes in MMF.

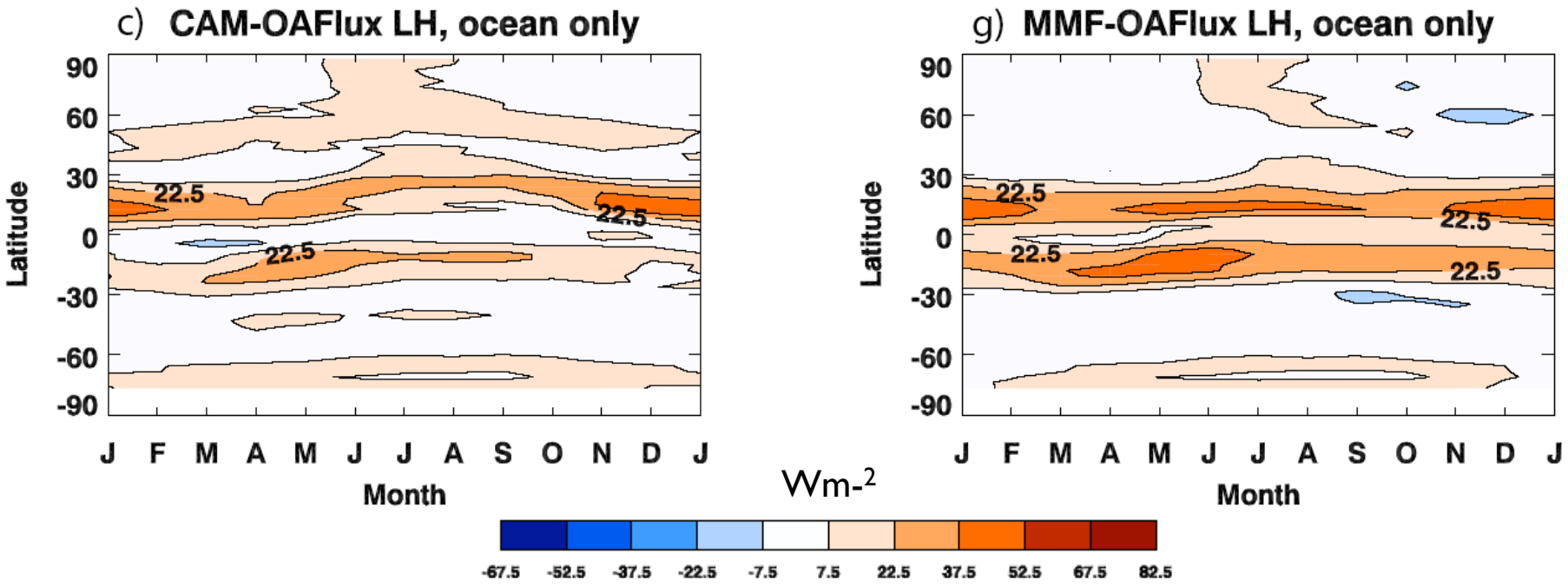
MMF Marine Sc Cloud Bias

- Possible causes
  - insufficient lower tropospheric stability
  - imbalance between surface fluxes and cloud-top entrainment
- Potential remedies
  - finer vertical and/or horizonal resolution of embedded CRM?

On to latent heat flux biases...

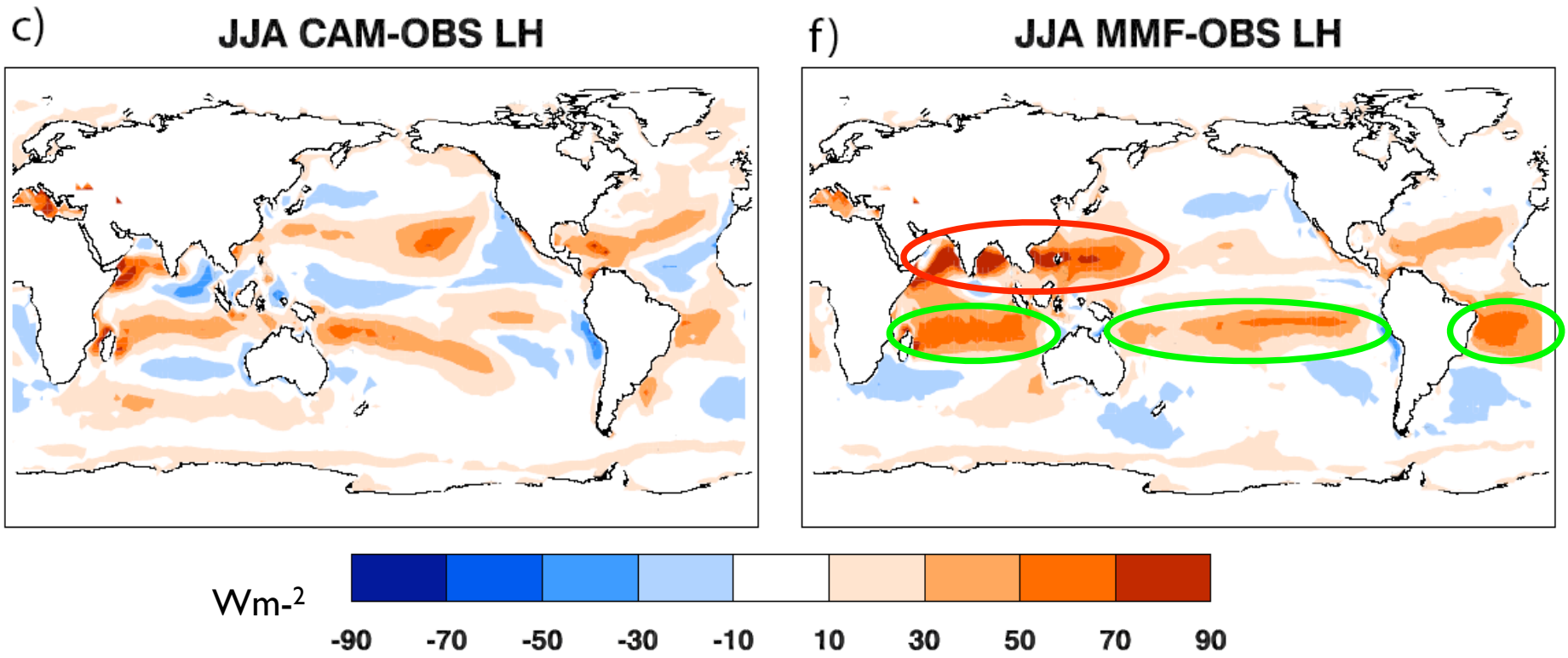


Surface LH Errors in CAM, MMF



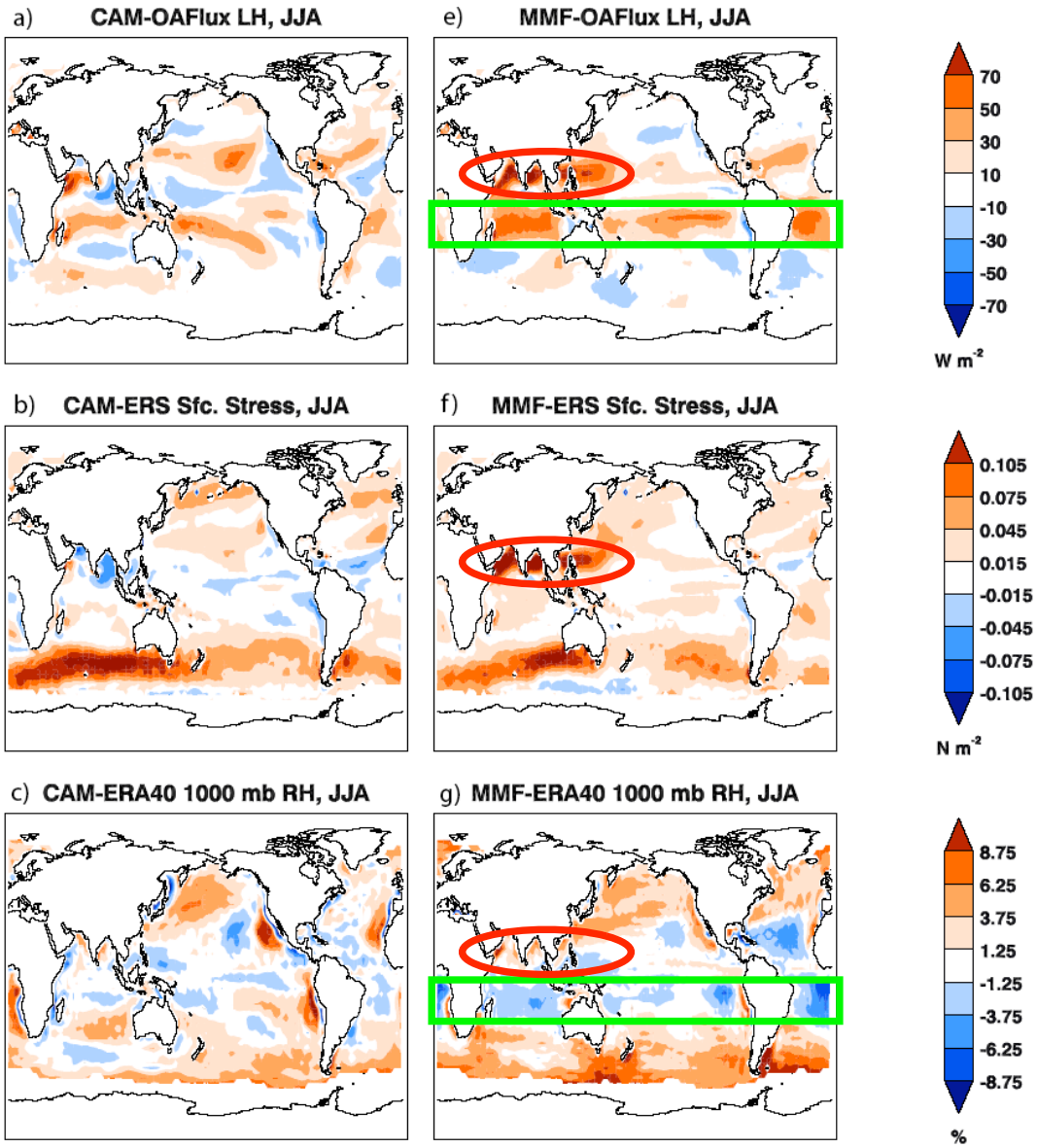
- CAM, MMF biases largest in trade winds
- CAM LH biases migrate with ITCZ; MMF biases appear to be "land-locked"

LH Errors in CAM, MMF



- Asian monsoon region dominates NH bias
- SH biases in trade winds

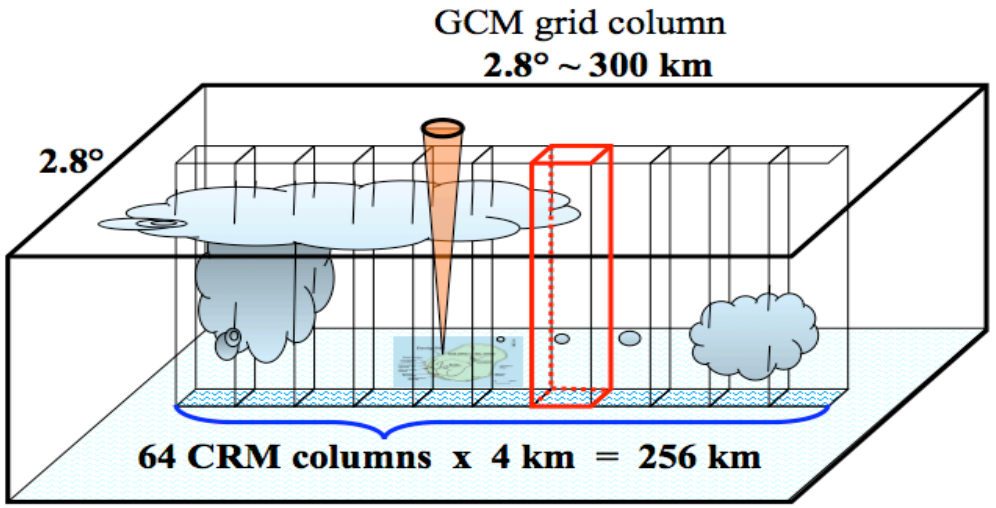
LH Biases: winds or RH?



- Asian monsoon LH biases due to excessive surface winds
- SH trade wind bias due to low RH

MMF Latent Heating Biases

- Possible causes
  - cyclic boundary condition on CRM
- Potential remedies
  - 3D embedded cloud resolving model?



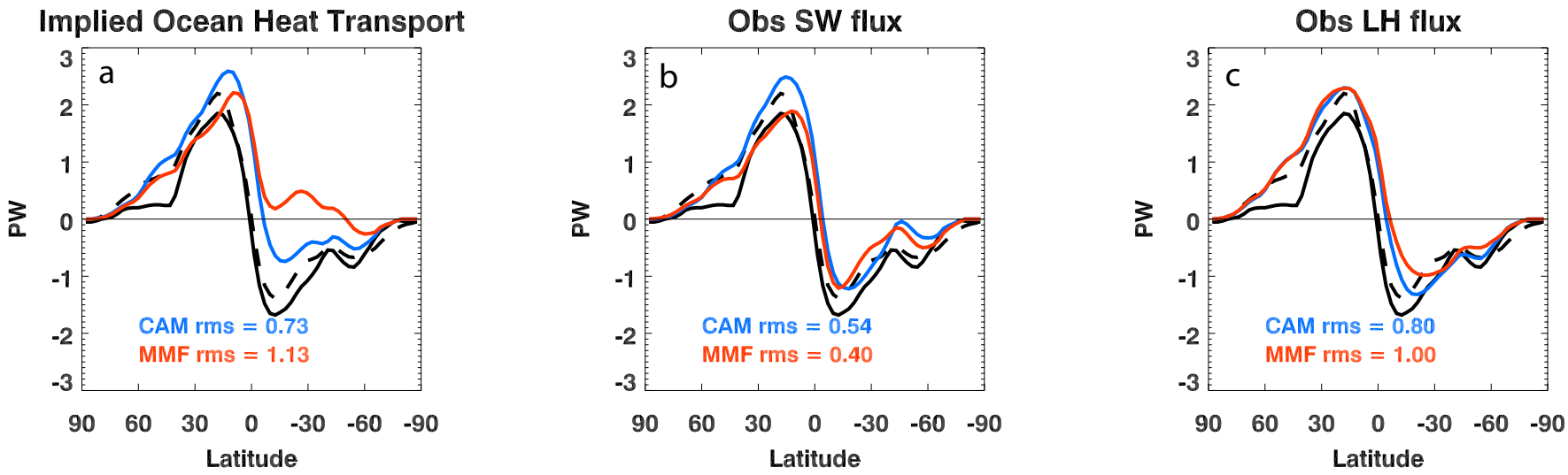
Summary of Issues

- MMF transports implies too much northward transport by oceans
- Surface energy budget errors dominated by
  - shortwave heating
    - excessive ice in tropical convection, esp. Asian Monsoon
    - insufficient marine stratocumulus clouds
  - latent heating
    - concentrated in Asian Monsoon region, trade winds

List of Potential "Fixes"

- Tropical ice water content
  - improve ice microphysics parameterization
  - confidence: high
- Marine stratocumulus clouds
  - increased resolution of CRM, 3D vs 2D
  - confidence: uncertain; further study needed
- Latent heat fluxes
  - 3D CRM or global CRM
  - confidence: moderate, but high computational demands

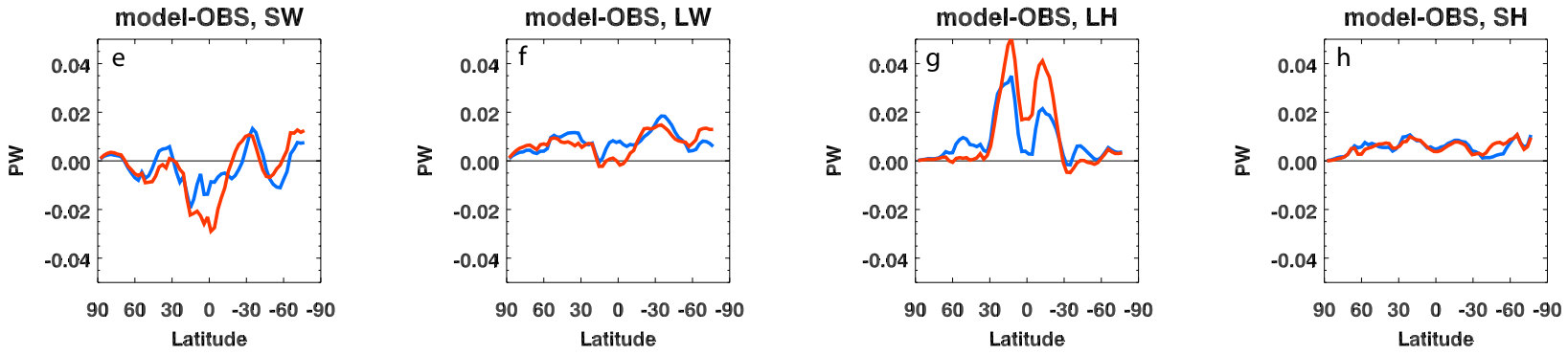
Impact of potential fixes on T_o



- Greatest improvement seen with observed SW
- LH improvements also improve T_o

Implications for coupled runs?

SW LW LH LW



- Initial cooling of tropical SSTs, esp. in Asian Monsoon region
- cooler SSTs may feed back to convective behavior
- impact on *actual* oceanic heat transport requires a (currently) prohibitively expensive run
  - short coupled runs may be useful for studying atmospheric and convective response to different base states