(Horizontal) Resolution Dependencies of CAM Simulations

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CAM Horizontal Resolution Dependencies

What model errors are due to under-resolution instead of parameterization errors?

- Resolutions from 2° to 0.25° lat-lon; CAM physics parameters and time step forced to be constant across resolutions
- Weather-forecast integrations initialized from ECMWF 1° operational analyses for January – February 2006
- Examining day 2 simulations from forecasts initiated every day in the two-month period
- Using CAM3.5 + MG microphysics
  - PBL is Holtslag – Boville
  - Shallow convection is Hack

Scientific Focus

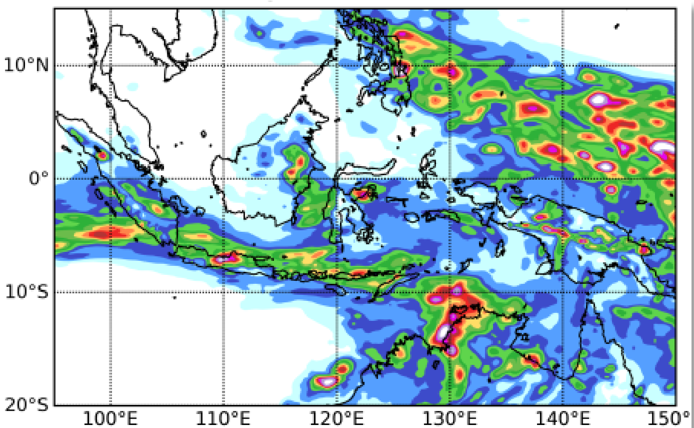
- We focus on tropical moist processes:
  - Precipitation intensity statistics
  - Diurnal cycle of precipitation in the Maritime Continent
  - Amount of stratiform precipitation
  - Relationship of precipitation to column-integrated relative humidity
  - Diabatic heating profiles (not shown)

- This period was selected because of the ARM Tropical Warm Pool – International Cloud Experiment (TWP-ICE) in Darwin, Australia which had intensive in-situ observations *(May et al. 2008, Xie et al. 2010)*

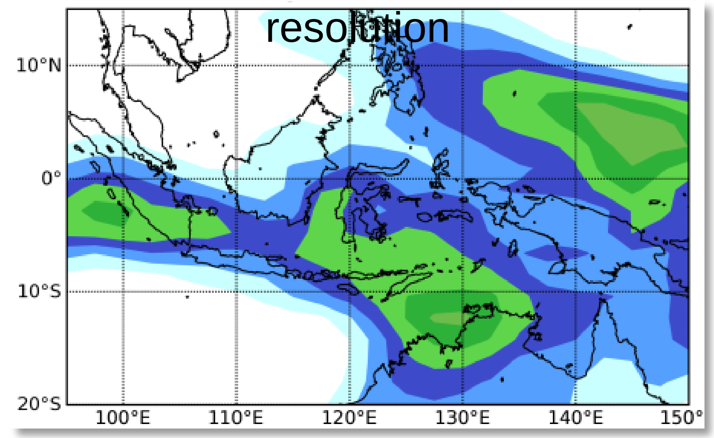
Precipitation Intensity

- 6-day (January 20–25, 2006) mean precipitation

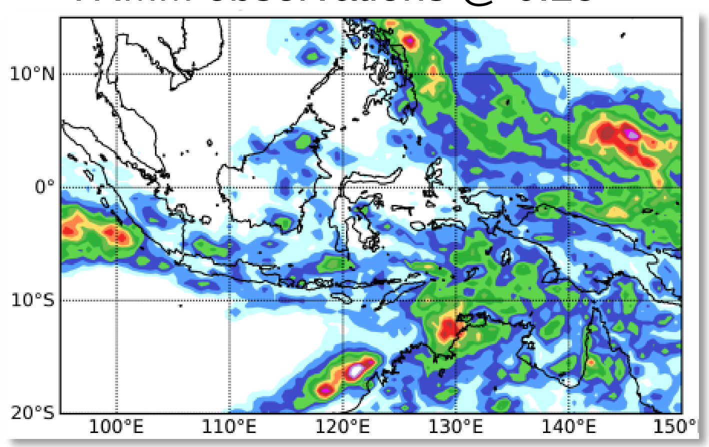
CAM @ 0.23° × 0.31° resolution



CAM @ 1.9° × 2.5° resolution



TRMM observations @ 0.25°

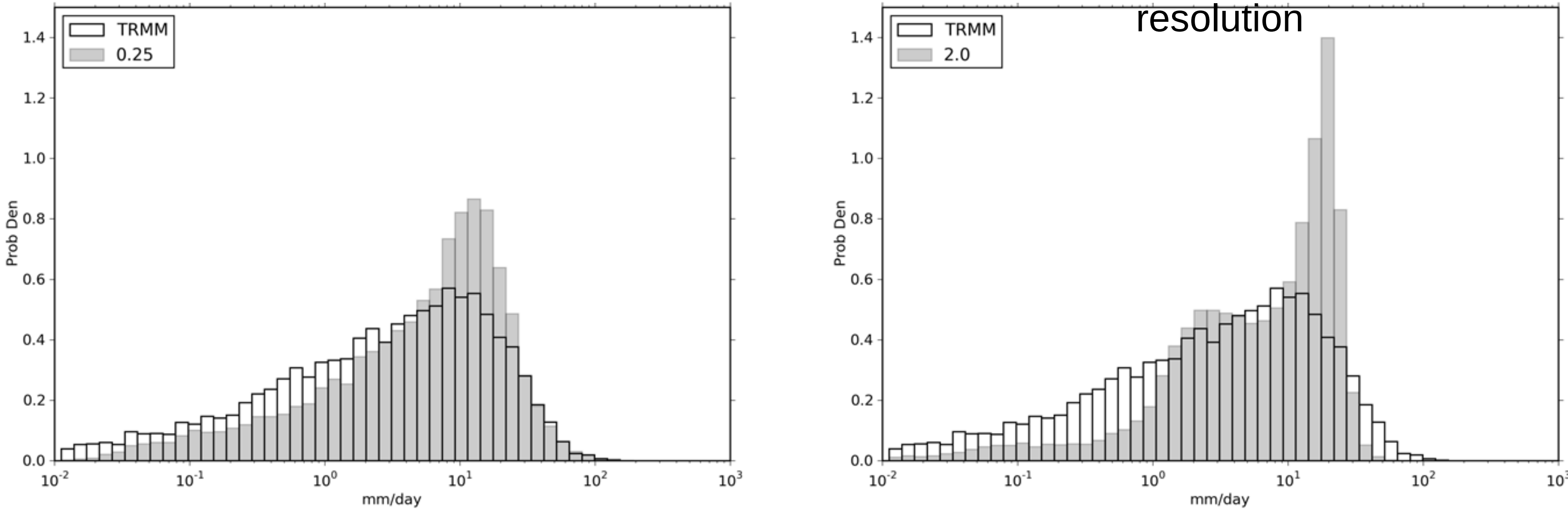


Precipitation Intensity

- Daily mean precipitation @ 2.0° resolution in the Maritime Continent region compared to TRMM precipitation

CAM @ 0.23° × 0.31° resolution

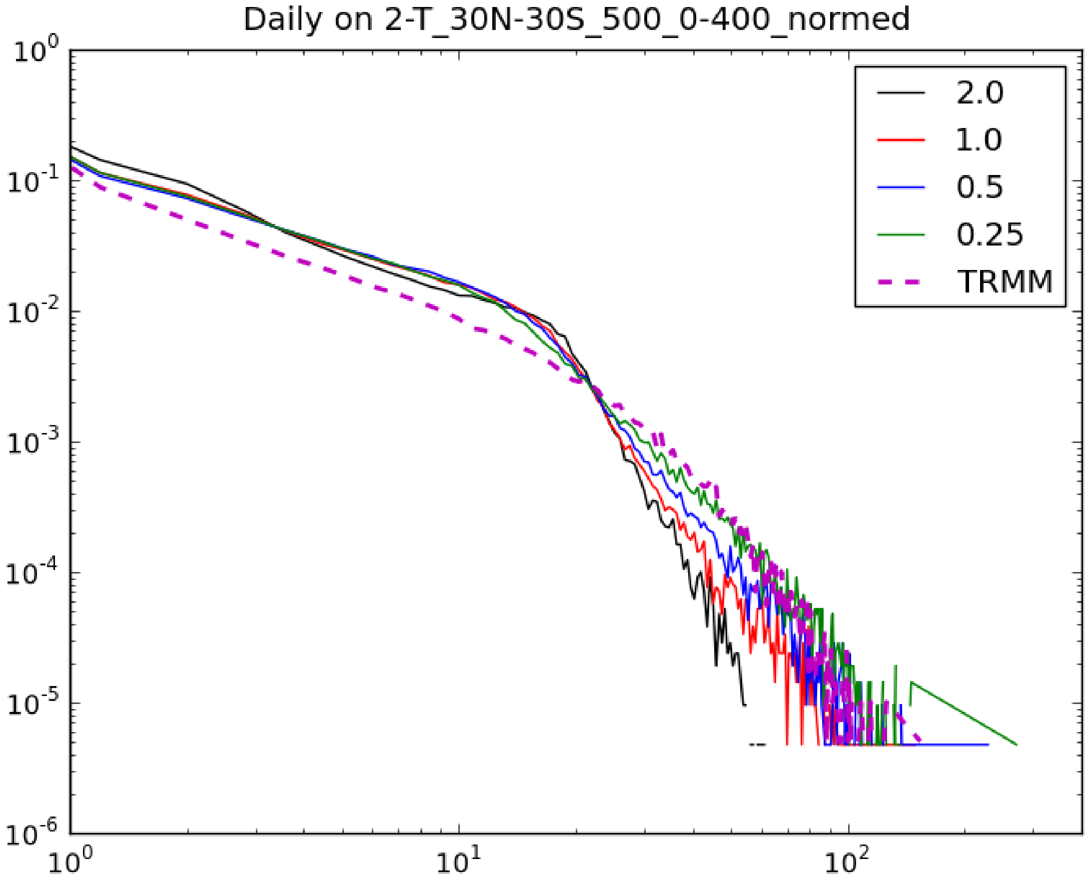
CAM @ 1.9° × 2.5° resolution



Higher resolution not only increases the frequency of intense precipitation it also increases the frequency of little to no precipitation – both are improvements

Precipitation Intensity

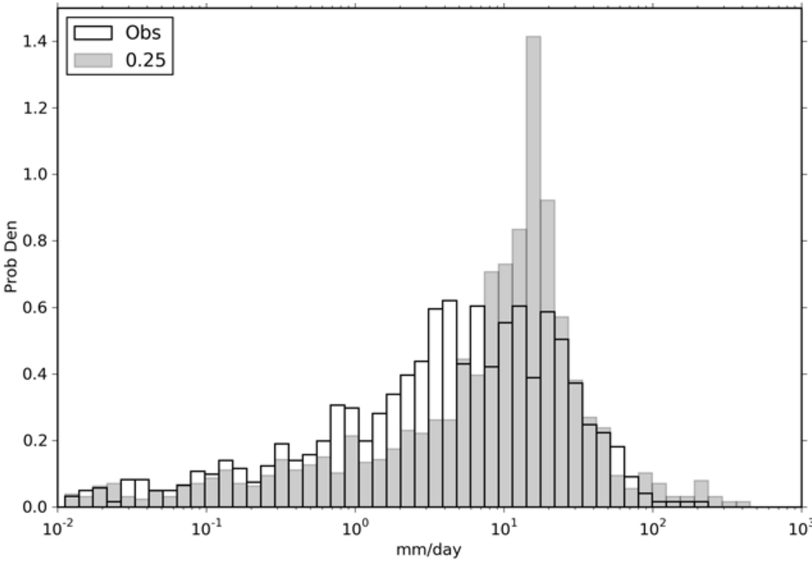
- To look at the high tail of the distribution, here is the absolute frequency on a logarithmic scale



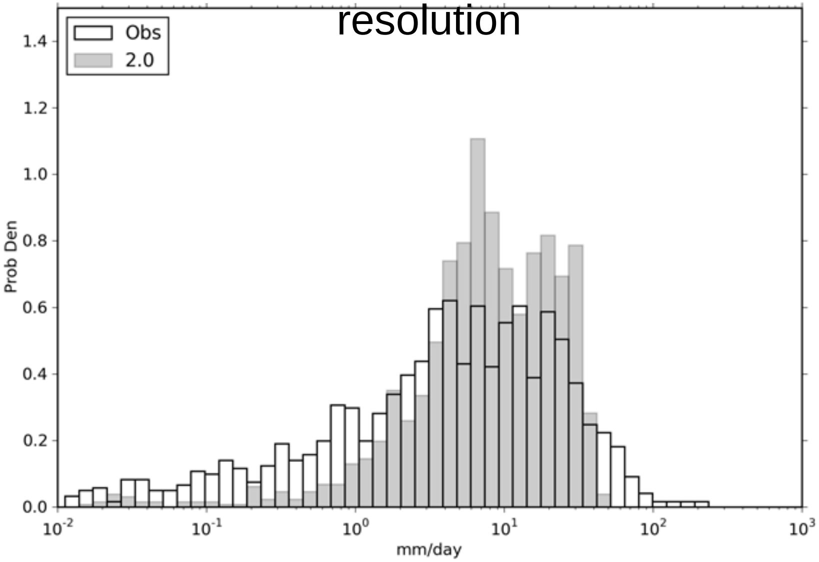
Precipitation Intensity

- Hourly mean precipitation for TWP-ICE region (~1.5° area surrounding Darwin) compared to ground-based precipitation radar (which probably is more accurate than TRMM at seeing shallow and mid-level topped precipitation)

CAM @ 0.23° × 0.31° resolution



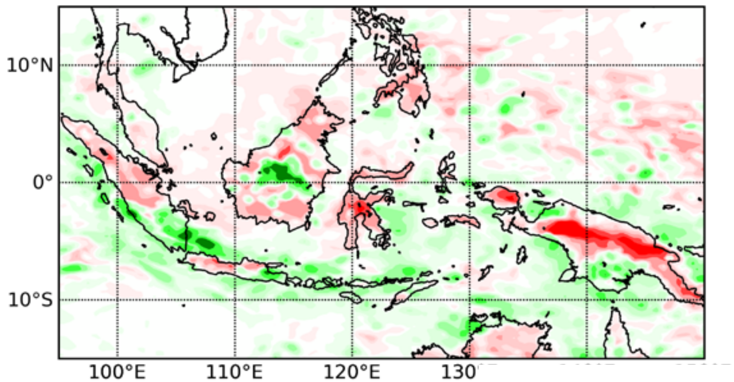
CAM @ 1.9° × 2.5° resolution



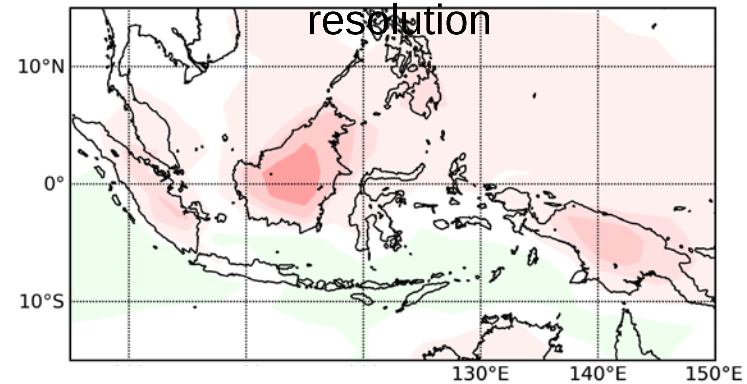
Maritime Continent Diurnal Cycle

- 00 GMT (8 AM Local Time) precipitation anomaly for January – February 2006

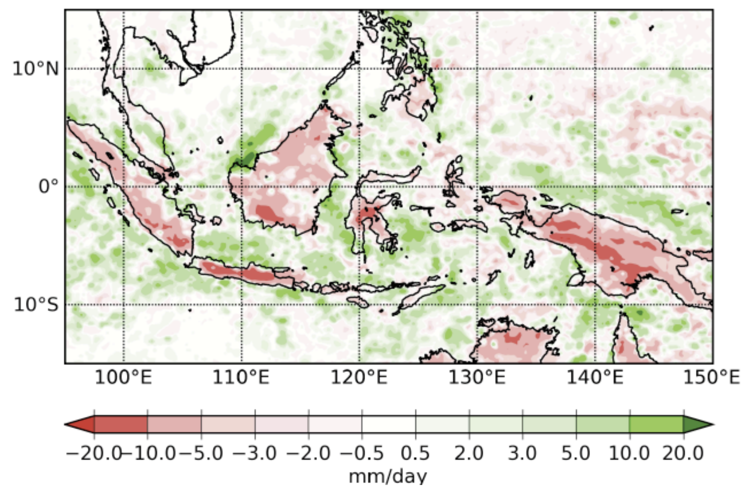
CAM @ 0.23° × 0.31° resolution



CAM @ 1.9° × 2.5° resolution



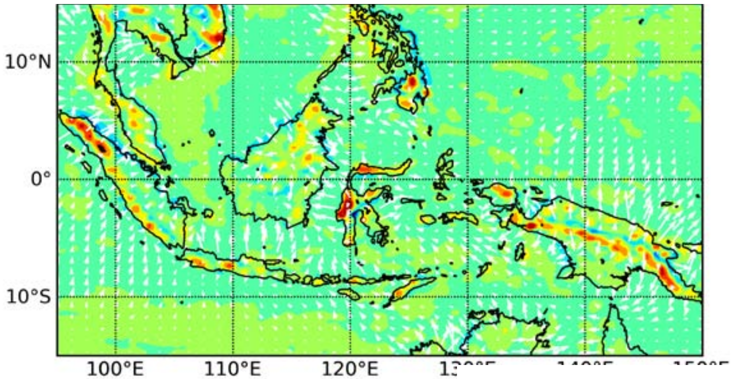
TRMM observations @ 0.25°



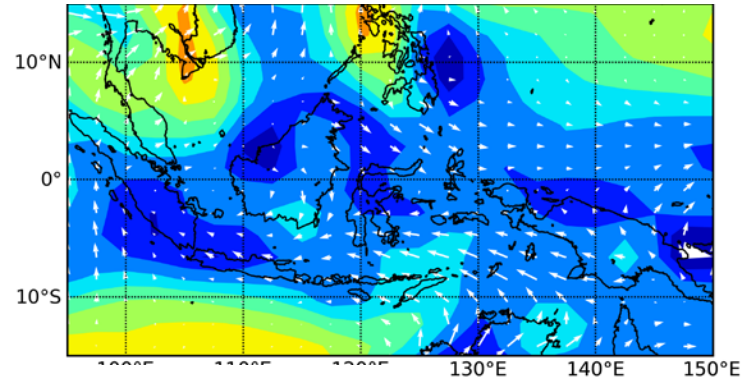
Maritime Continent Diurnal Cycle

- 00 GMT (8 AM Local Time) surface wind and surface divergence anomaly for January – February 2006

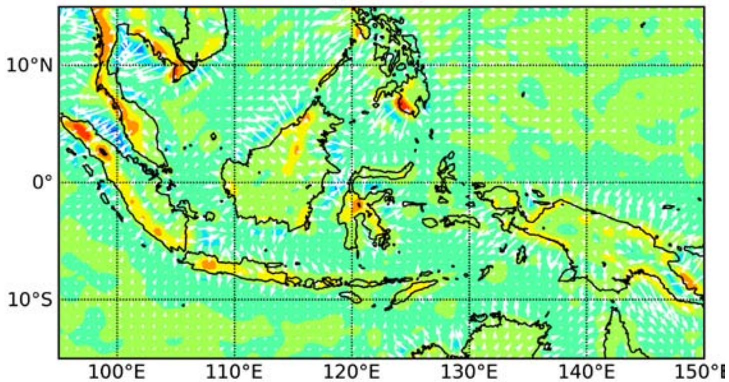
CAM @ 0.23° × 0.31° resolution



CAM @ 1.9° × 2.5° resolution

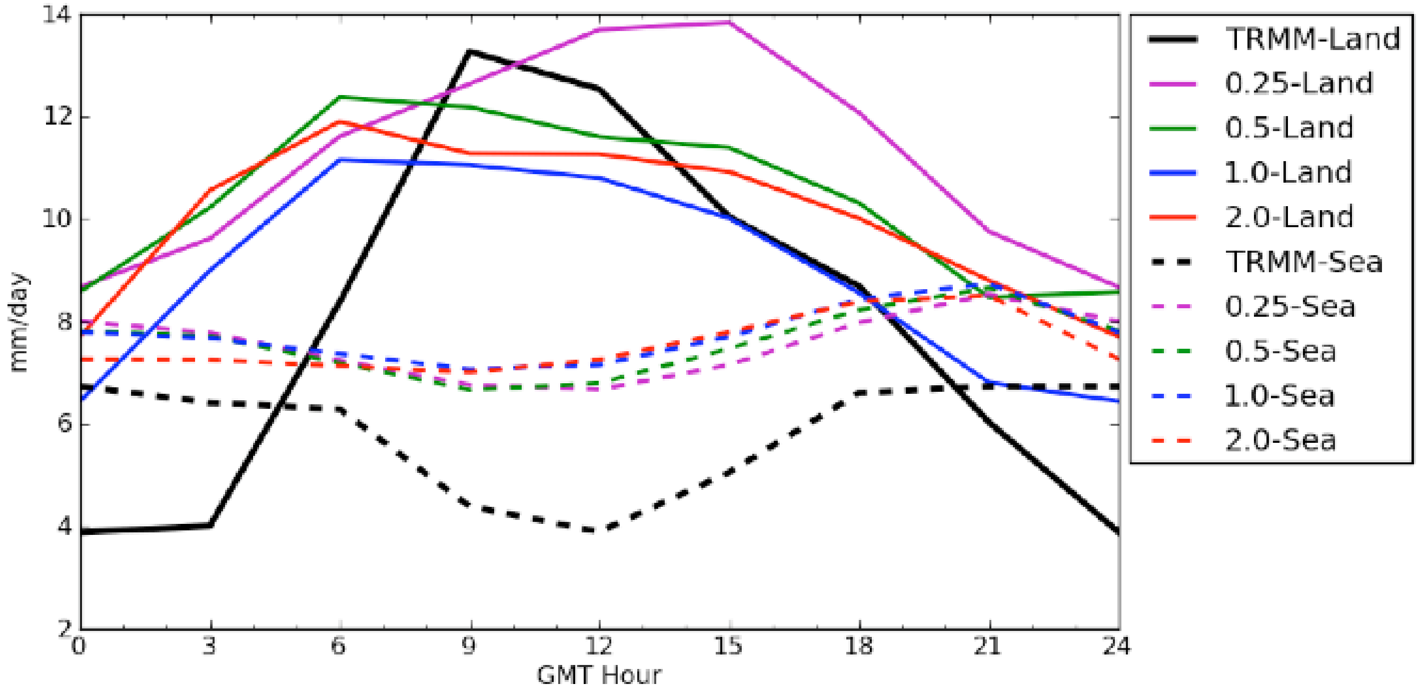


GDAS Analysis



Maritime Continent Diurnal Cycle

- Diurnal cycle of precipitation over land and ocean



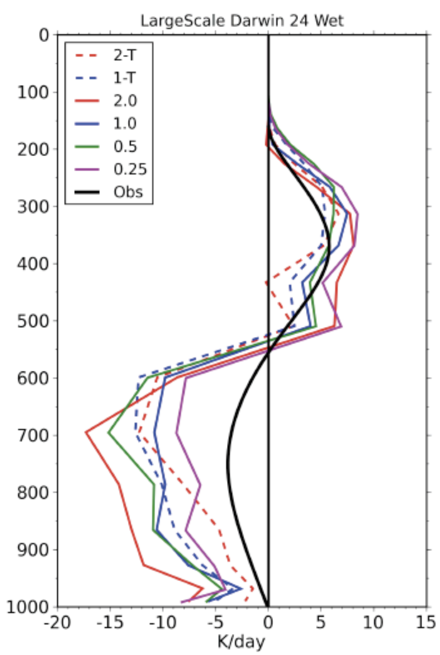
Higher resolution does not increase the amplitude of the diurnal cycle over land or ocean and only the 0.25° model indicates an improvement in the hour of peak precipitation over land

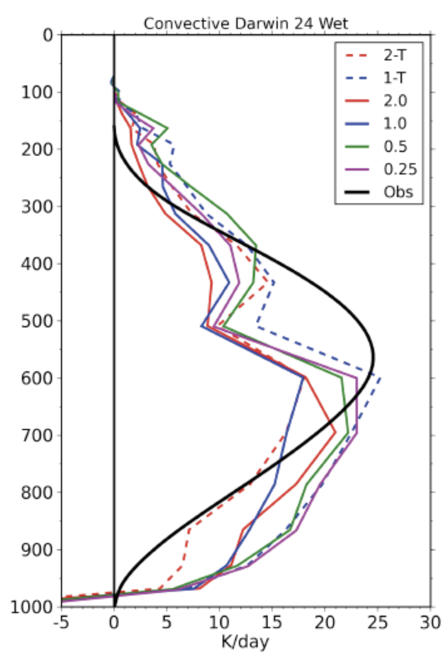
Stratiform Precipitation

- Stratiform precipitation fraction (= large-scale / (large-scale + convective)) increases from 6% @ 2.0° to 39% @ 0.25° resolution during the wet period for the TWP-ICE region; Observational estimate is 27% from Courtney Schumacher's ground-based precipitation radar analysis
- For 20° N to 20° S over the whole 2 months, the stratiform precipitation fraction increases from 10% @ 2.0° to 28% @ 0.25° resolution; Observational estimate from TRMM Precipitation radar is ~40% *(Schumacher and Houze 2003)*

Stratiform Precipitation

- Large-scale diabatic heating for TWP-ICE region during the wet period
- Increased surface stratiform precipitation results from less evaporation of precipitation in the lower troposphere, not more condensation in the upper troposphere





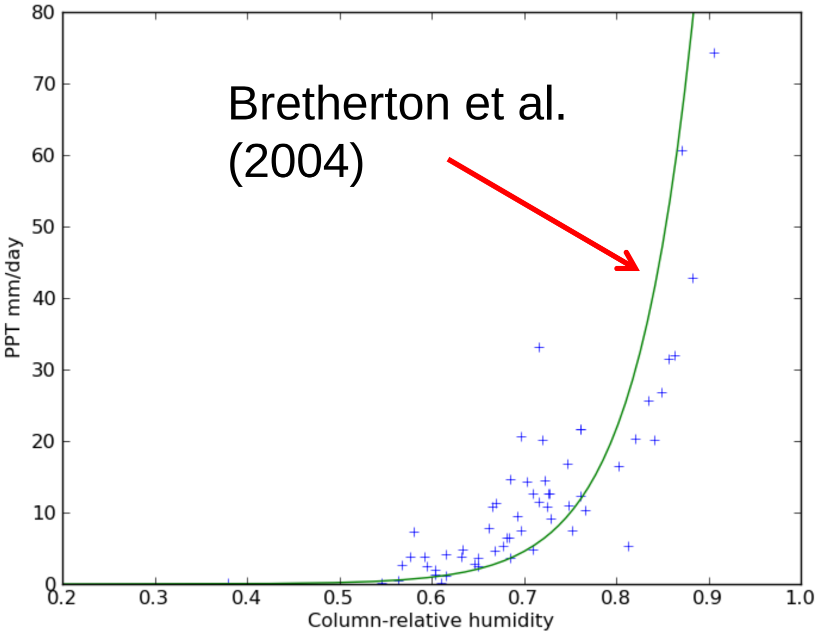
Why?

Maybe surface stratiform precipitation is localized in smaller grid-boxes for which are easier to saturate permitting subsequent precipitation to reach the surface

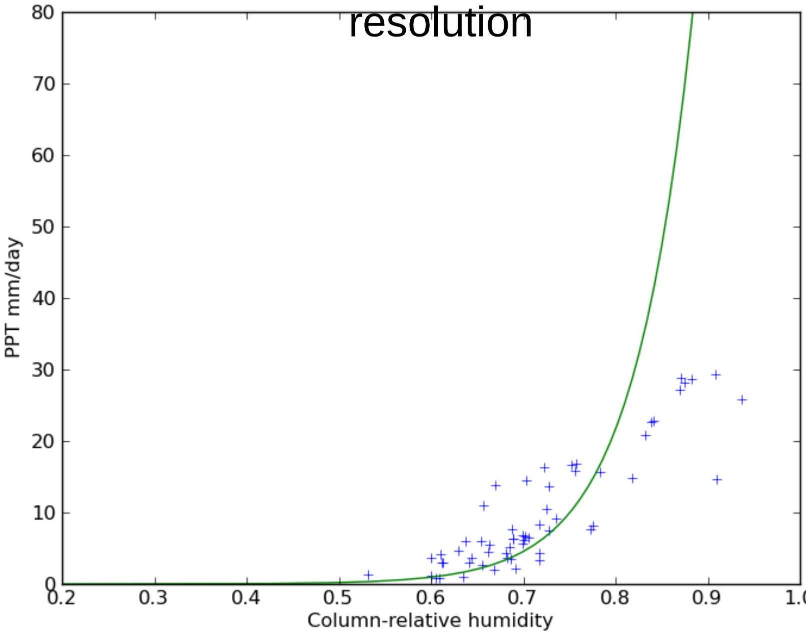
Precipitation – Humidity Relationship

- There is a hint in data from the Darwin region that increased resolution improves the relationship between column-integrated relative humidity and precipitation

CAM @ 0.23° × 0.31° resolution



CAM @ 1.9° × 2.5° resolution



Summary

Increasing CAM horizontal resolution from 2° to 0.25° produces

- Better simulation of precipitation intensity statistics
- Increased (surface) stratiform precipitation
- More localized land-sea breezes
- Hints of improved precipitation – humidity relationships
- No degradation in the good response of the diabatic heating profiles to the imposed large–scale forcing (selection of convection mode between deep, congestus, and land-see breeze) (not shown)
- No improvement in the diurnal cycle of precipitation over land
- No changes in mean precipitation error patterns

Summary

This suggests

- only moderate parameterization efforts will be necessary to yield improved intensity statistics and stratiform precipitation
- parameterization efforts are still needed for the diurnal cycle of precipitation over land

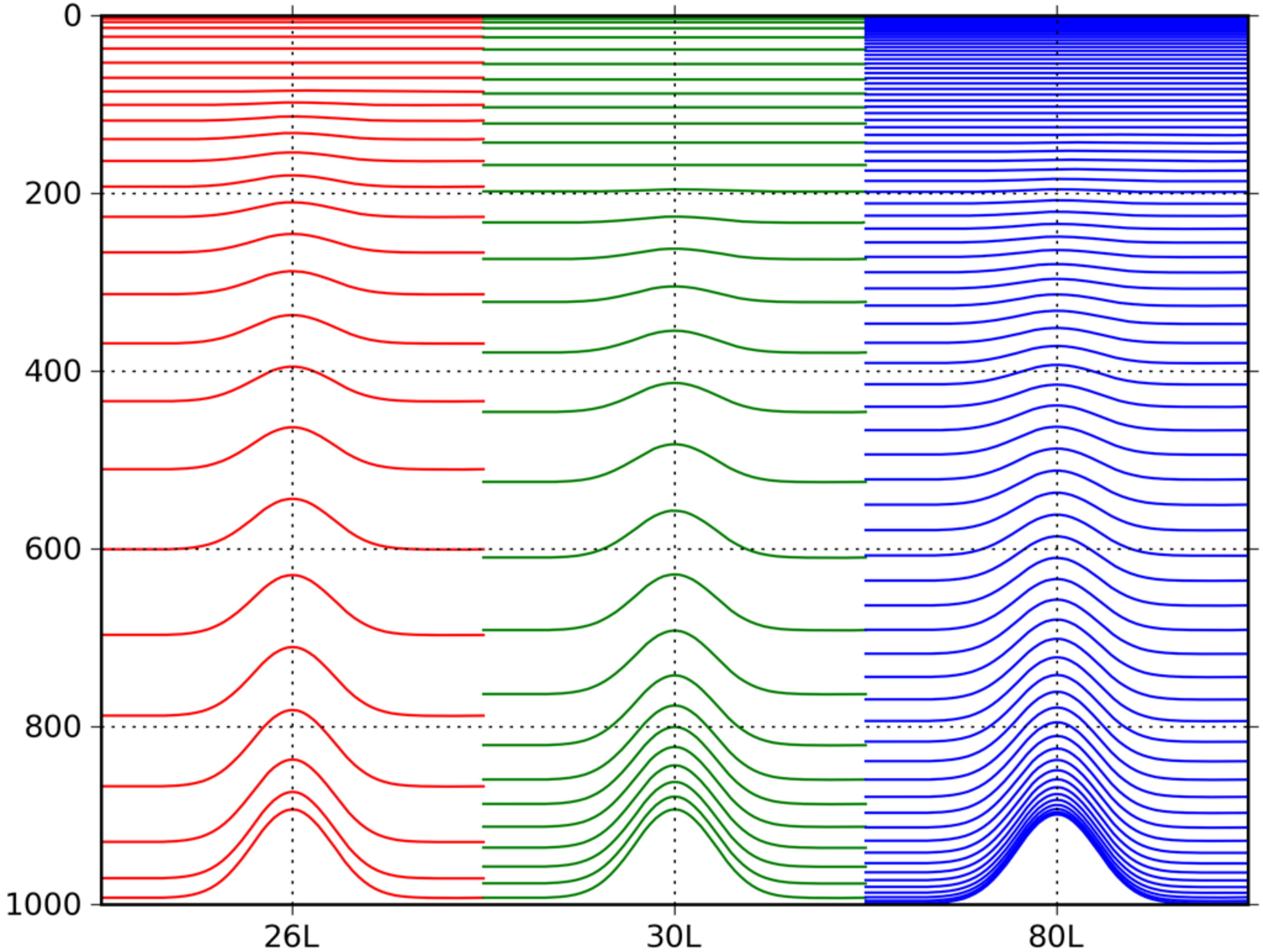
However, we will need to repeat these calculations with the Track 5 model to examine the sensitivity of our conclusions to model physics

EXTRA SLIDES

Vertical Resolution Study

- CAM Track V model (camdev21_cam3_6_26) at @ 2.0° resolution is integrated with observed SSTs (AMIP mode) for 3 years at two resolutions, L30 and L80
- 80 Levels match those of the current operational 91L ECMWF model up to the L30 CAM top at ~3 mb
- This roughly doubles to triples tropospheric vertical resolution
  - 14 levels in L80 vs. 7 in L30 beneath 850 hPa
  - 27 levels in L80 vs. 8 in L30 above 100 hPa

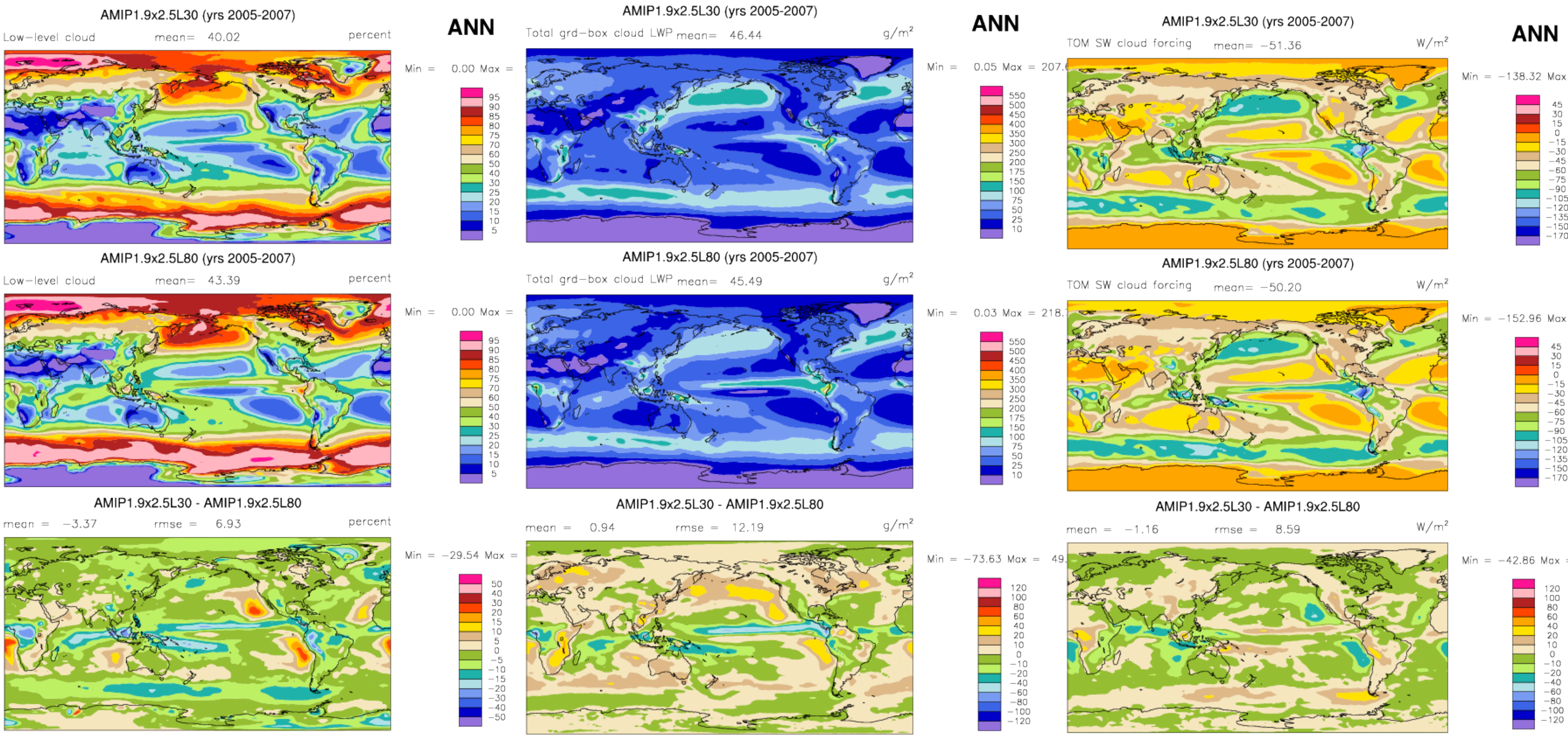
Vertical Resolution Study



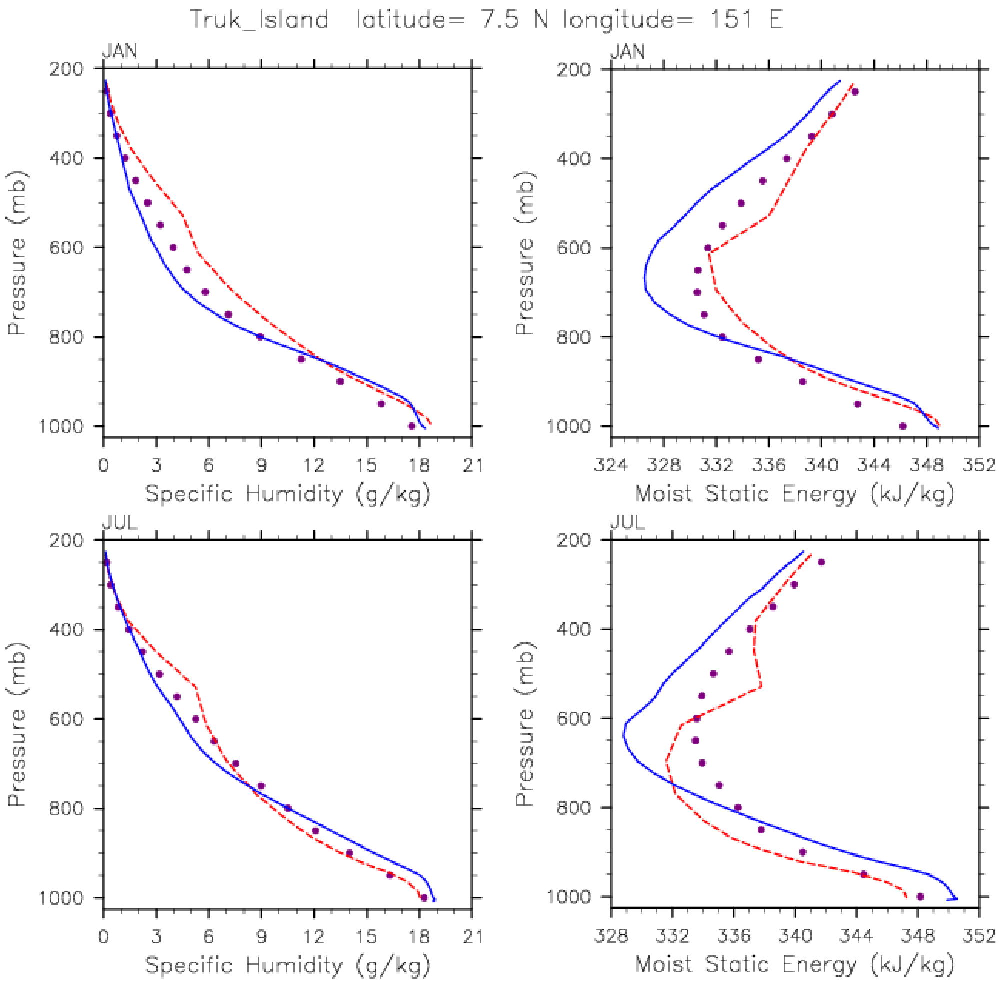
Vertical Resolution Study

- Good news is most things hold together quite well without major changes
  - No catastrophic increase in low cloudiness as Dave Williamson found in CAM3.1
- Increased vertical resolution produces
  - Reduced marine stratocumulus clouds (bad)
  - Smooth vertical and drier tropical moisture profiles (good)
  - Much colder surface temperatures over Greenland and Antarctica in winter (bad?)

Reduced Marine Stratocumulus

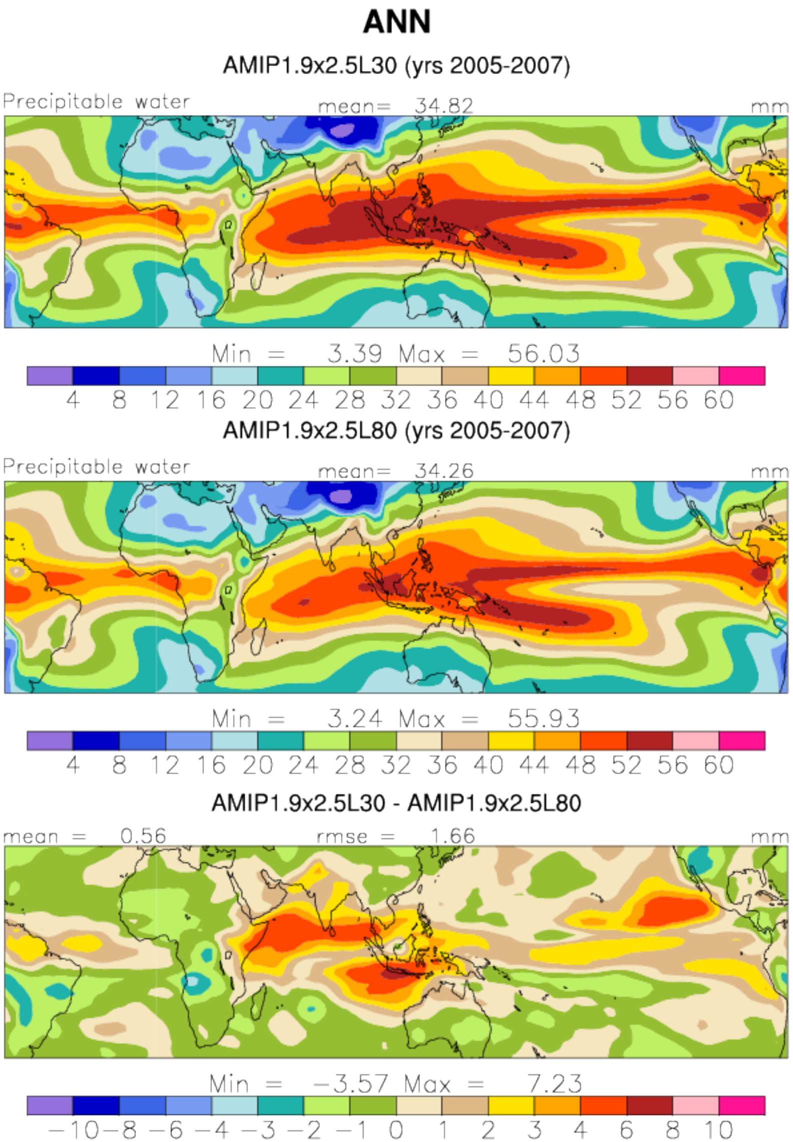


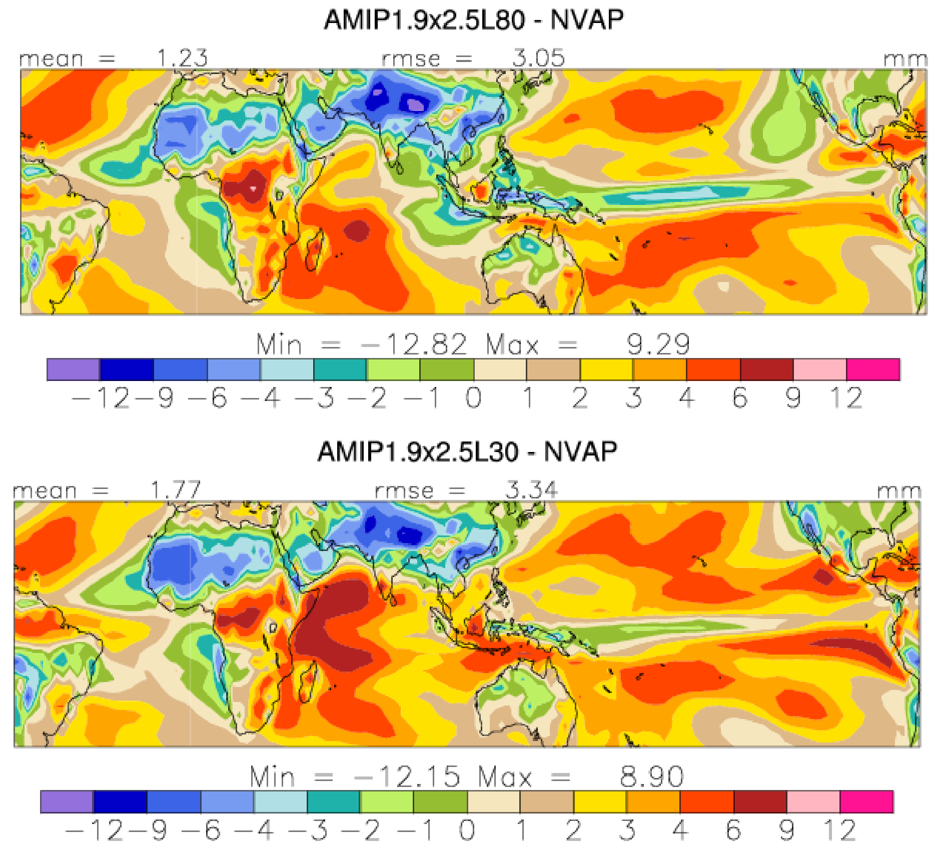
Improved Tropical Humidity



Excess moisture near the melting layer is due to the Zhang-McFarlane deep convection detraining too much

Improved Tropical Humidity



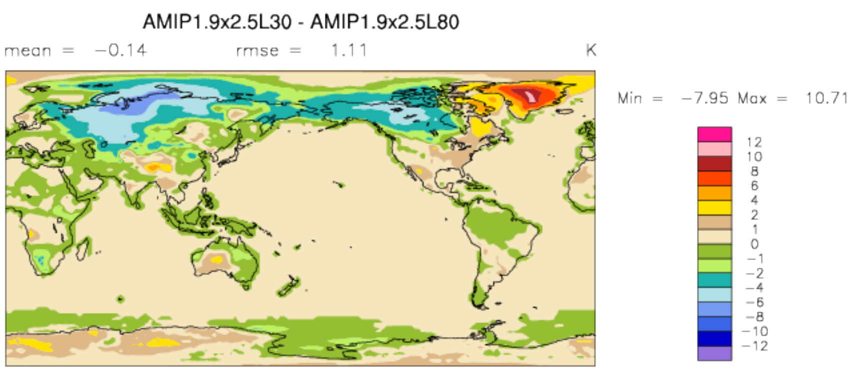


Reduced tropical moisture improves agreement with observations

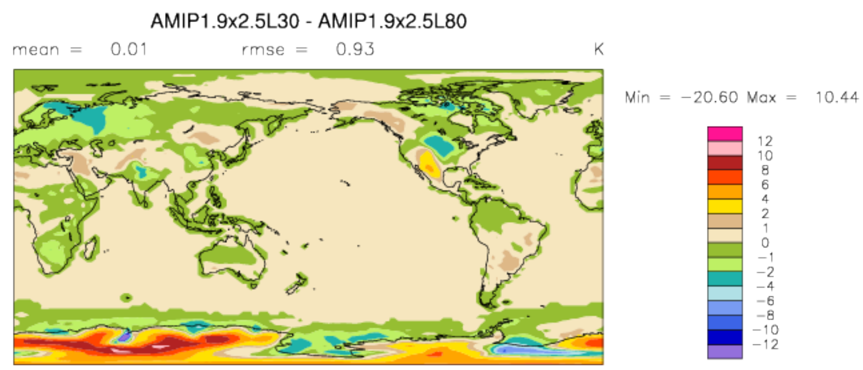
Ice Sheet Surface Temperatures

- In winter, there is a large (~10K) decrease in surface temperatures over Greenland and Antarctica

DJF

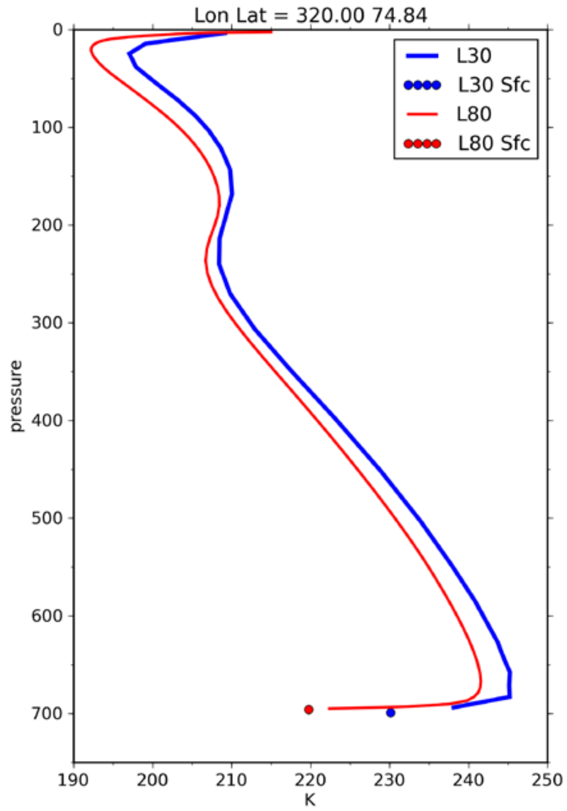


JJA

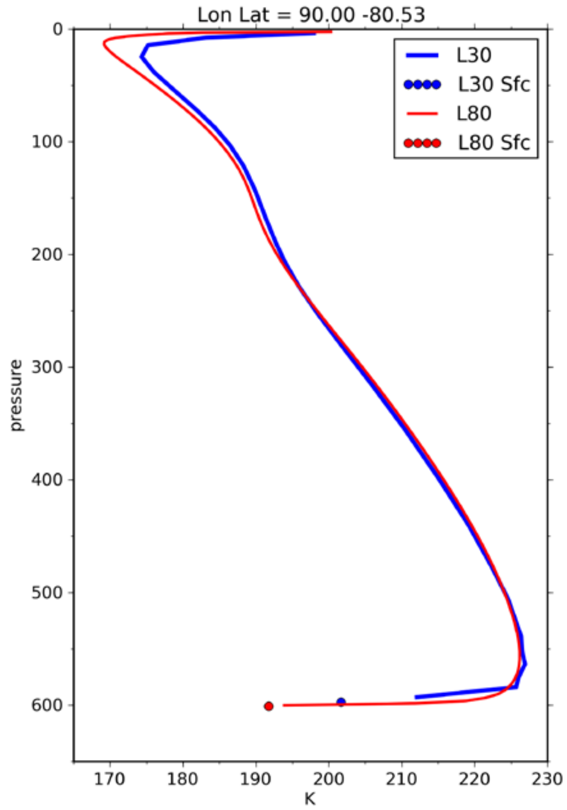


Ice Sheet Surface Temperatures

Greenland in DJF



Antarctica in JJA



- There may be issues in how the stable boundary layer mixing responds to increased vertical resolution

Clear-sky Longwave is improved