

CAM4/HOMME AMIP Results: Hydrological Cycle

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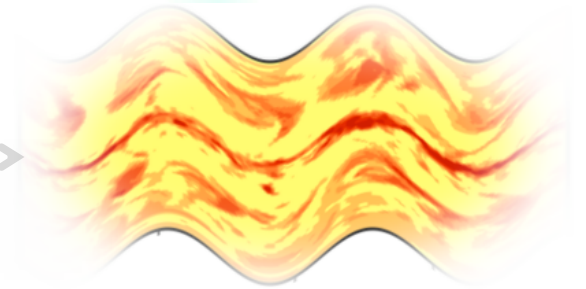
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Background

- HOMME has shown a great scalability (as of now, scalable up to 170, 000 processors)
- Fully integrated into CCSM4 & CESM1 and initial set of simulations are completed
- HOMME has already passed the basic test cases and successful in simpler modeling frameworks i.e. dry test cases & aqua-planet configuration

More details available in:

Mishra et al. JOC, in press 2011

Mishra et al. Ann. Geophys. 29, 221-227, 2011

Taylor et al., JCP, 229, 5879-5895, 2010

Lauritzen et al., JAMES, 2, 1-34, 2010

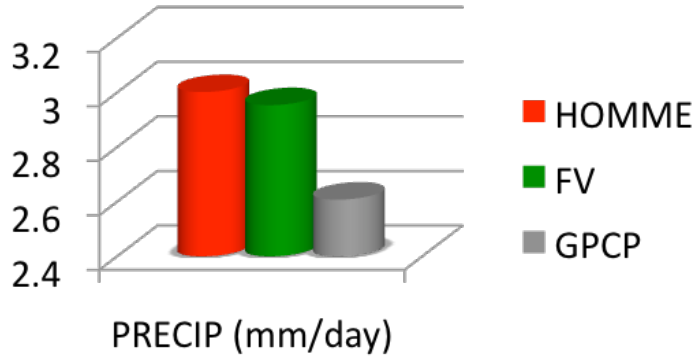
Current Effort (going to present in this talk)

- Verification and validation of the performance of HOMME in AMIP framework using observations, re-analysis, and results from the default dycore of CAM (i.e. FV, our benchmark model; f40.1979_amip.track1.1deg.001).

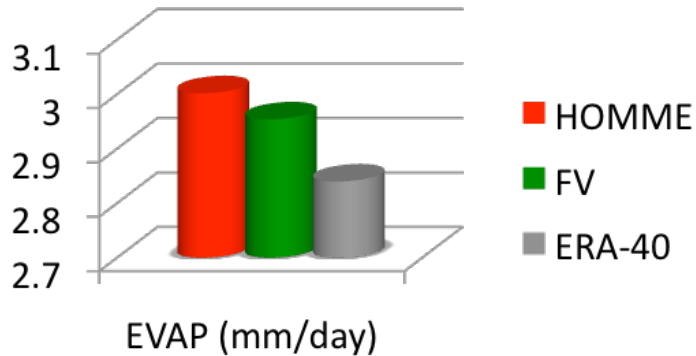
Simulation Overview

- **Framework:** AMIP
- **Simulation Period:** 1979 to 2005
- **Spatial Resolution:** $\sim 1^0$ equivalent (ne30np4 for HOMME and 0.9x1.25 for FV)
- **Physics Time Step Size:** 30 min
- **Tunable Physics Parameters:** Tuned for HOMME-ne30np4 (at ORNL)

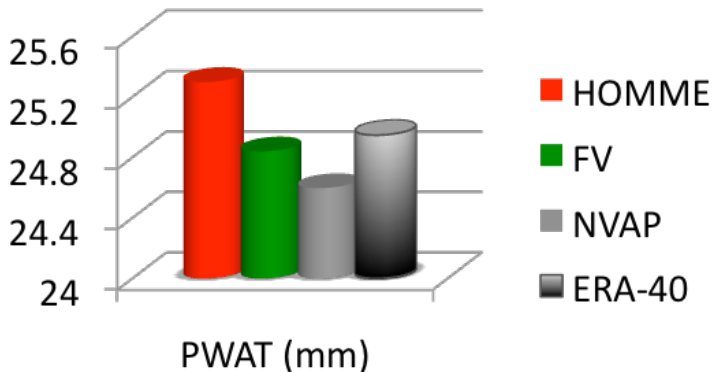
Global Water Budget (annual average)



- ✓ Both the dycores are in close agreement with each other
- ✓ Both of them overestimate the PRECIP by 13% – 15%



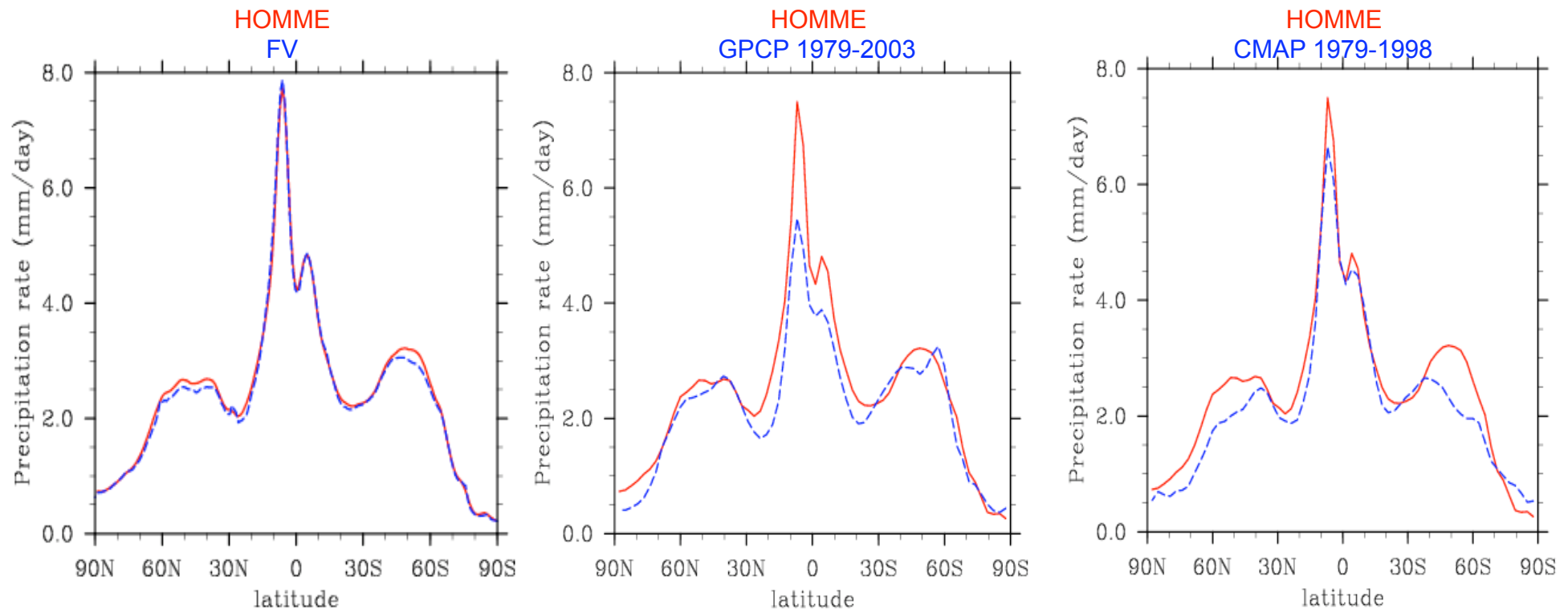
- ✓ Similar biases with EVP
- ✓ Overestimation by 4% – 6%



- ✓ Difference between observations is of similar magnitude to the differences with HOMME & FV, hence PWAT is reasonable in HOMME.

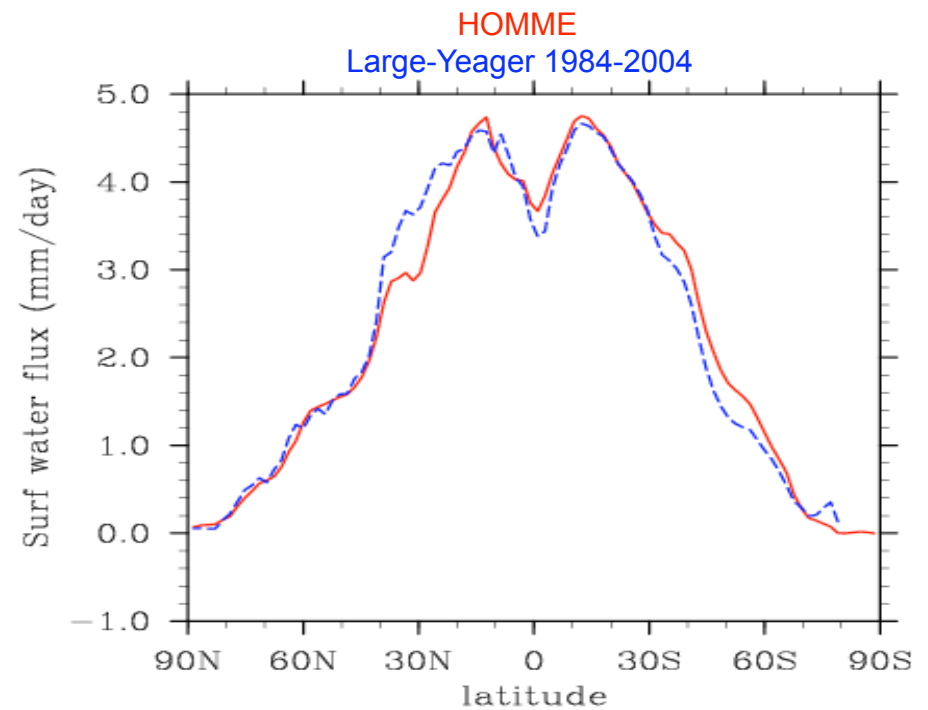
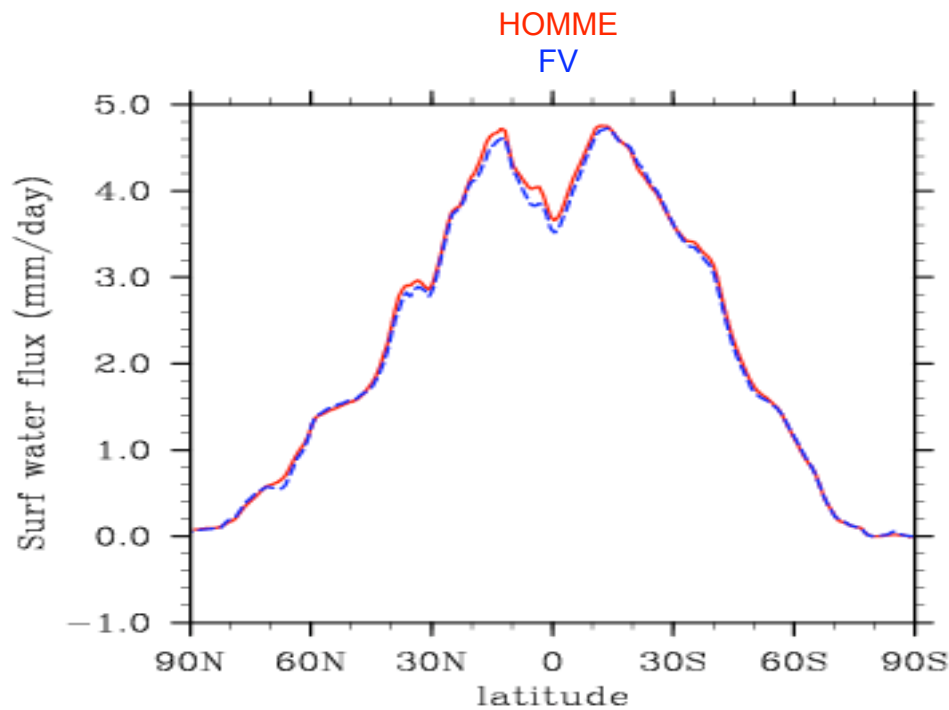
- Global hydrological cycle is marginally stronger in HOMME (but this is a problem with FV too; so may be it is something to do with CAM4-Physics)

Zonal Mean PRECIP (annual average)



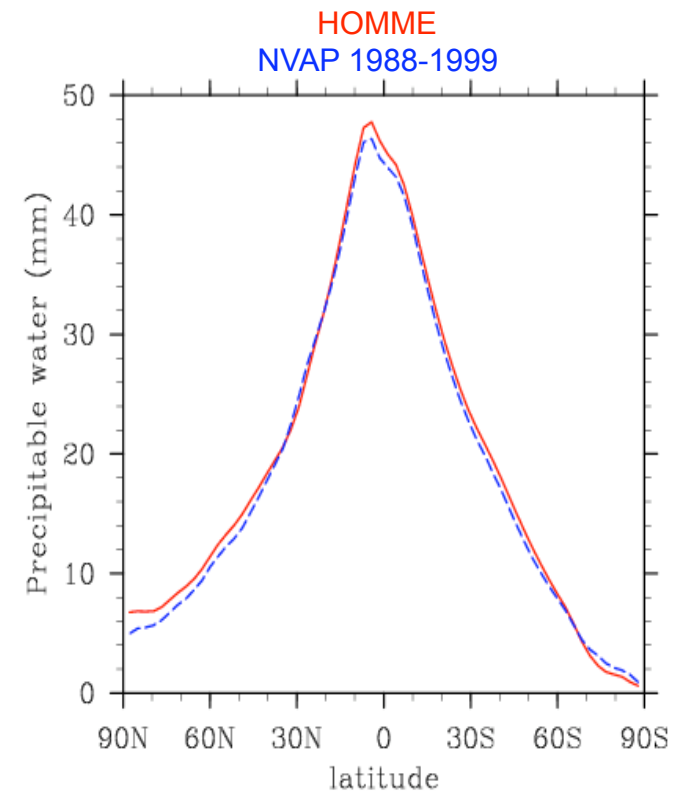
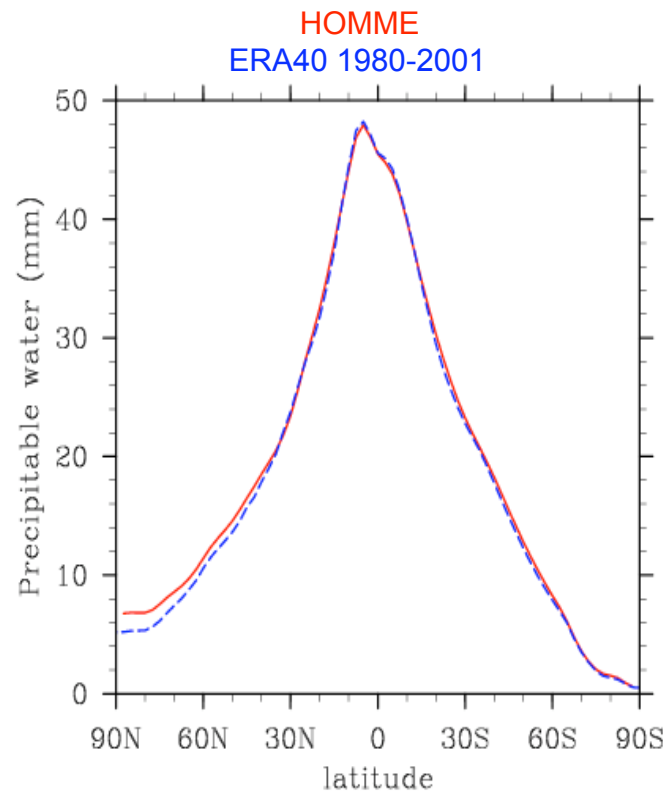
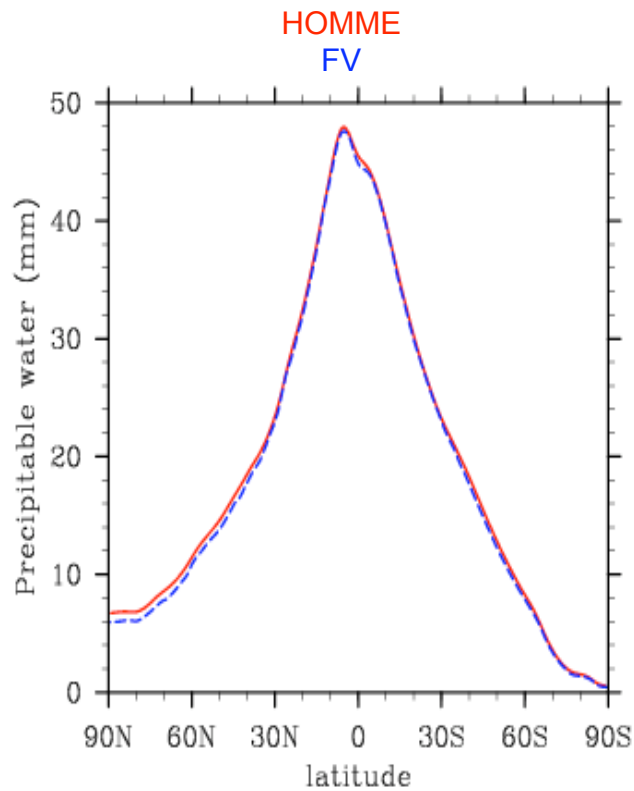
- ✓ HOMME and FV exhibit similar structure and magnitude.
 - Except over the extratropical storm tracks, where PRECIP is marginally stronger in HOMME.
- ✓ In contrast to observational estimates both the dycores overestimate the PRECIP.
 - ❖ With respect to GPCP, it is overestimated over the tropics
 - ❖ With respect to CMAP, extratropics receive too much of PRECIP
 - ❖ However, the biases are of similar magnitude to the differences between the observational estimates
- By and large the zonal average features are well captured, although there are some biases.

Zonal Mean EVAP (annual average)



- ✓ HOMME agrees quite well to the benchmark model and captures the broad features
 - ✧ Vigorous EVAP in the sub-tropics with maximum near 15 S/N
 - ✧ Hemispherical asymmetry i.e. more evaporation in the Southern Hemisphere oceans
 - ✧ Suppressed evaporation over the equatorial belt
- ✓ Models agree satisfactorily with the observational estimates except that there is an overestimation of EVAP over the Southern Hemisphere oceans and an underestimation over the northern sub-tropics.
- ✓ Although the models are successful in capturing the principal features, both of them suffer from similar biases. (seems that: this deficiency is not associated with dycores and may be attributable to the physics package as two very different dycores agree quite well to each other and possess similar biases)

Zonal Mean PWAT (annual average)

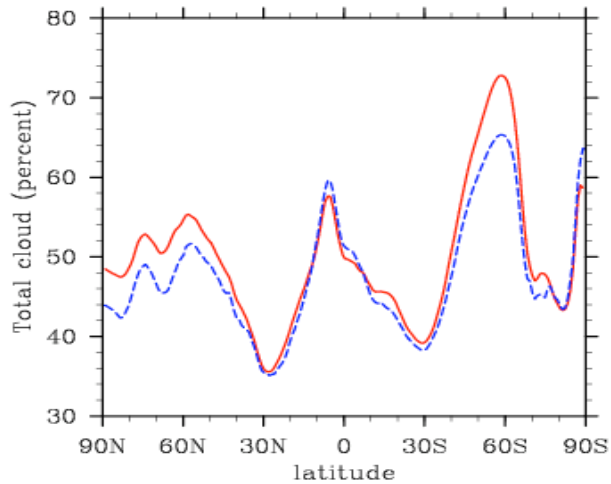


- ✓ HOMME exhibits similar distribution and magnitude as that in FV
 - ❖ Exception: northern hemisphere extratropics is moister in HOMME
- ✓ In comparison to observational estimates, HOMME marginally overestimates PWAT in the extratropics (mainly in the northern hemisphere);
 - ❖ However over the tropics there are differences between the two observational estimates which are of the same order of magnitude as the HOMME - OBS diffs.

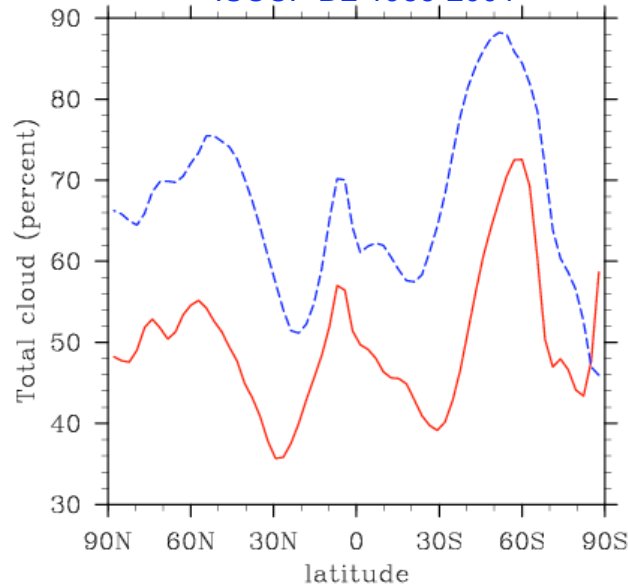
Zonal Mean Total Clouds (annual average)

As clouds modulate the hydrological cycle through radiative heating...

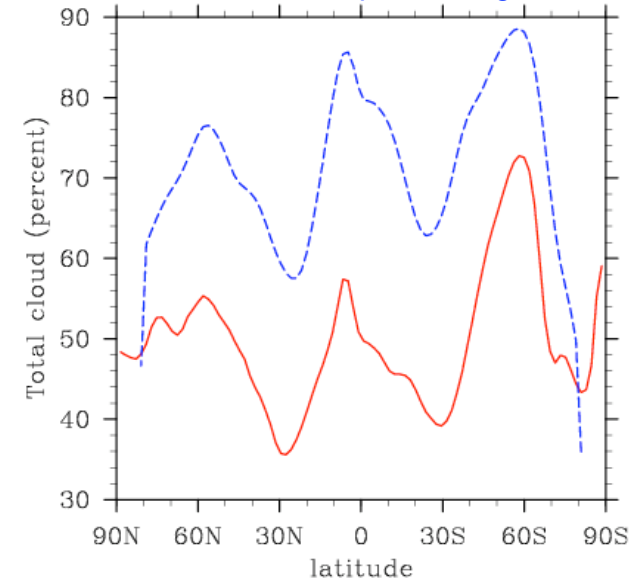
HOMME
FV



HOMME
ISCCP D2 1983-2001



HOMME
CLOUDSAT Sep2006-Aug2007

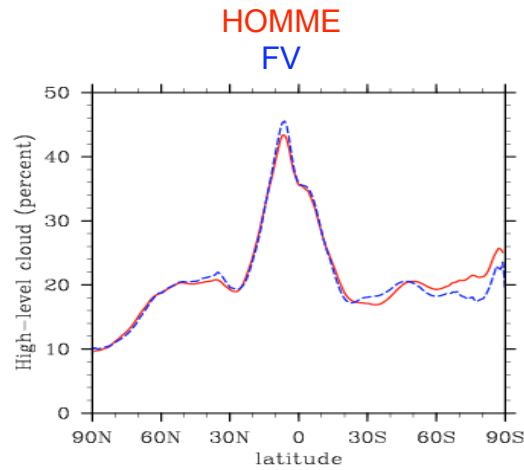
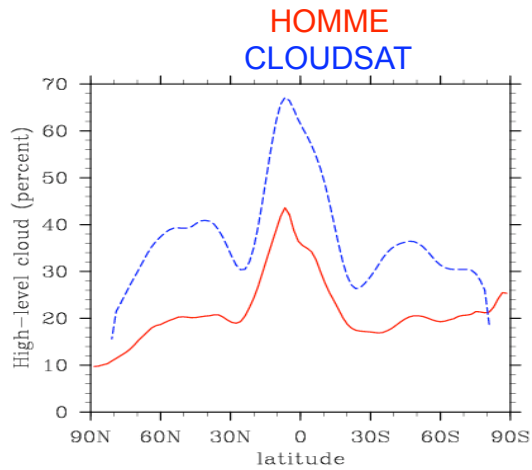


- ✓ The models capture the latitudinal variation of the clouds
 - ❖ maxima over the ITCZs & extratropical storm tracks
 - ❖ minima over the subtropics
- ✓ Both the models underestimate the magnitude of the total clouds
- ✓ Comparatively HOMME does marginally better than FV

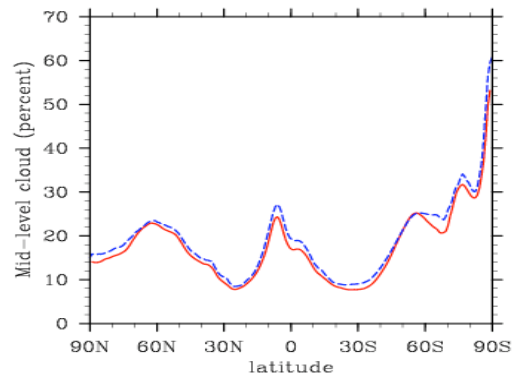
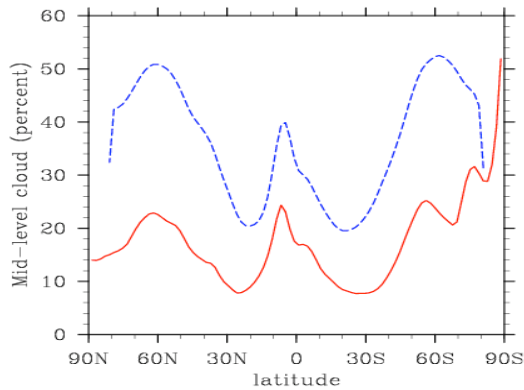
- ✧ **Notable:** RESTOM is 0.843 in HOMME & 1.025 in FV

Let us find out which clouds (high/mid/low) are underestimated...

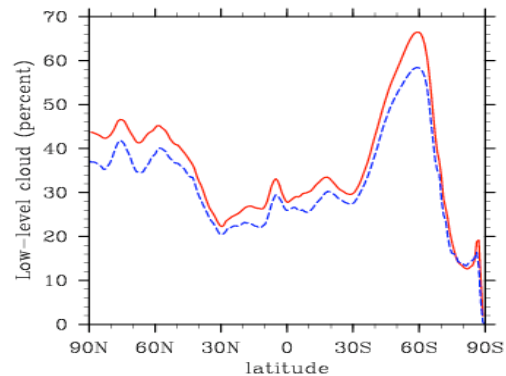
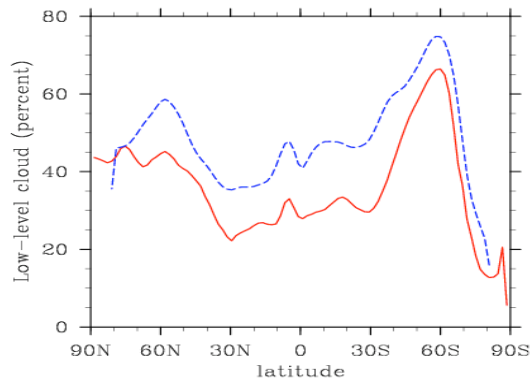
Zonal Mean high/mid/low Clouds (annual average)



- ✓ High clouds are underestimated
- ✓ Both the models agree to each other over most of the latitudes
- ✓ The bias over southern hemisphere extratropics is less in HOMME



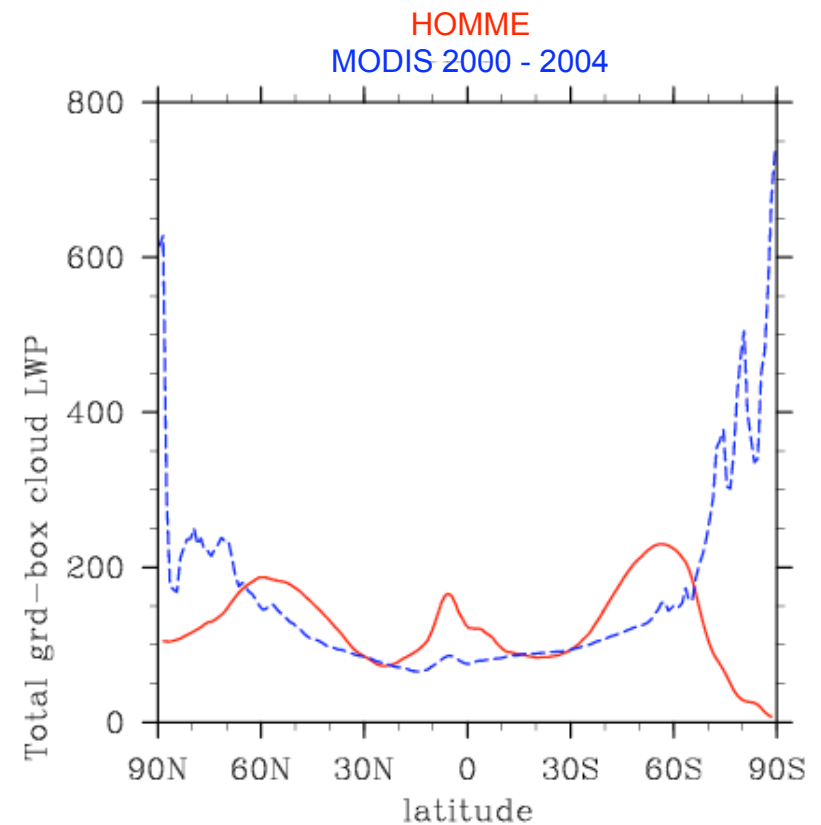
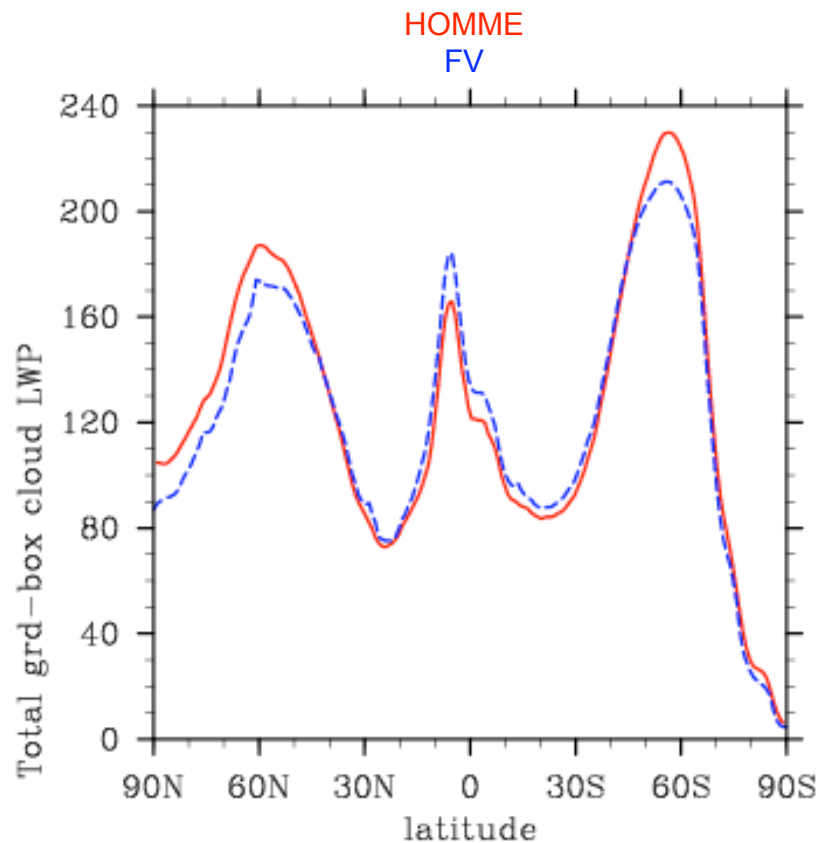
- ✓ Mid-level clouds are also underestimated
- ✓ Both the models agree to each other over most of the globe



- ✓ Low level clouds is underestimated too
- ✓ Biases in HOMME is less severe

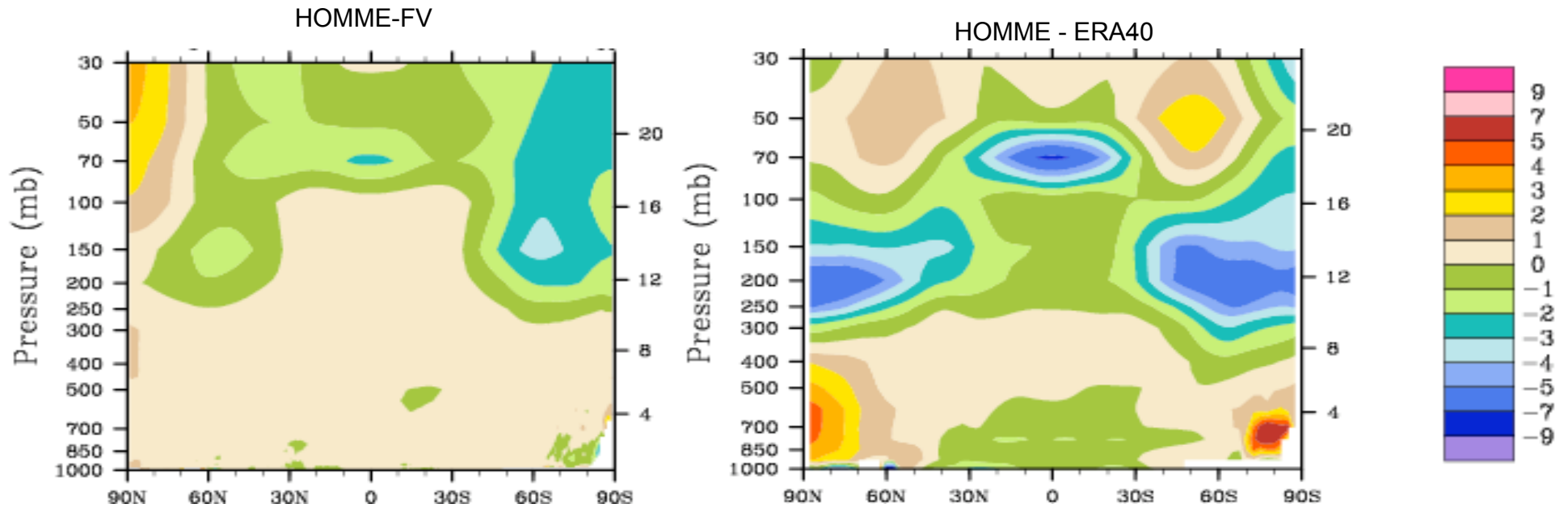
Let us find out why is it so; is it due to less cloud liquid water in models...

Zonal Mean Cloud Liquid Water (annual average; unit is g/m^2)



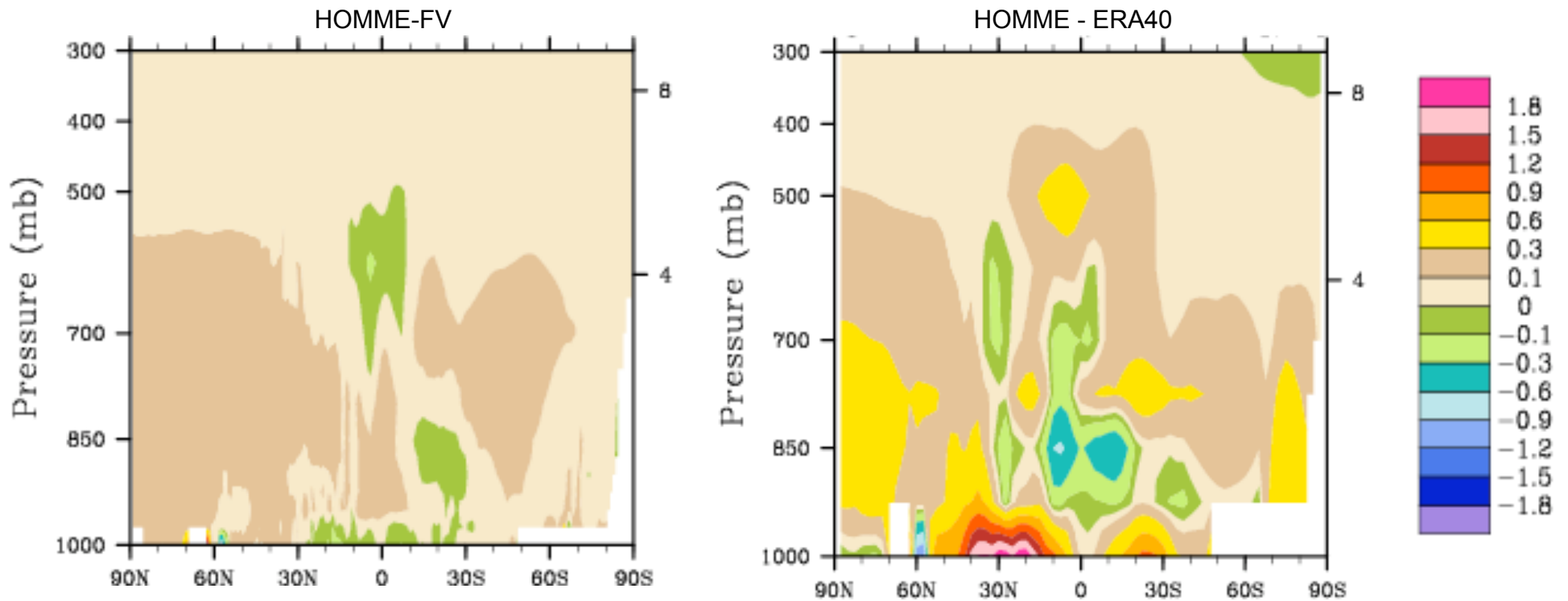
- ✓ Both the dycores show similar distributions, however HOMME has more cloud water in the extratropics, on the contrary FV has more in the tropics (actual reason is not known so far; FV has fine resolution over high latitudes which may be having some drying effects)
- ✓ Model underestimate the cloud water in the polar region (beyond 60 N/S); Bias is less in HOMME
- ✓ Over the tropics and sub-tropics the cloud liquid water is not awful (so what might be the reason behind the underestimation of clouds over the region? may be convective cloud base mass flux is not as strong...or may be the cloud parameters need further tuning...so far not understood...)

Zonal Mean Temperature (annual average)



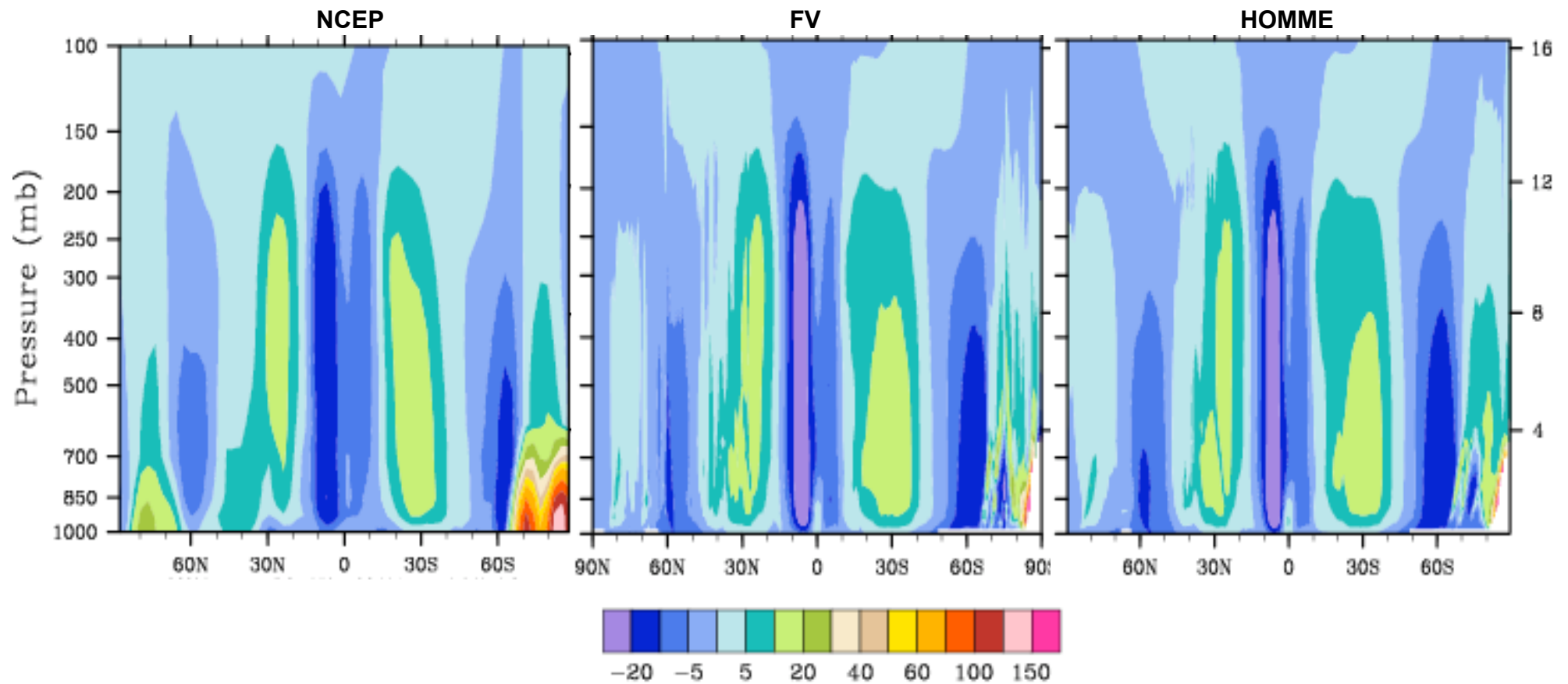
- ✓ Temperature difference between the two models are $< 1^{\circ}$ K for most of the domain
 - ✧ Tropical tropopause is colder by 1° - 2° K in HOMME
 - ✧ Southern hemisphere tropopause is colder by 2° - 3° K in HOMME
 - ✧ Northern hemisphere polar tropopause is warmer 3° - 4° K in HOMME
- ✓ Errors (w.r.t ERA 40) in the simulation:
 - ✧ polar troposphere are warmer up to 4° - 5° K in mid-troposphere
 - ✧ Polar tropopause is colder up to 7° - 9° K (a long standing problem, Boer et al. 1992; Hack et al. 2006)
 - ✧ Tropical tropopause is colder up to 7° - 9° K
- Importantly tropical troposphere is simulated reasonably well within 0° - 1° K of error

Zonal Mean Specific Humidity (annual average)



- ✓ The difference between HOMME and FV is negligible ($|\text{diffs}| < 0.1 \text{ g/kg}$)
- ✓ Relative to reanalysis products the models have a wetter boundary layer and drier lower troposphere in the tropics
- ✓ In the polar region, the low- and mid- troposphere are marginally wetter

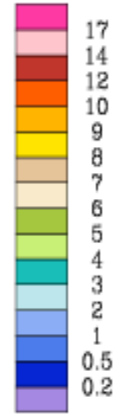
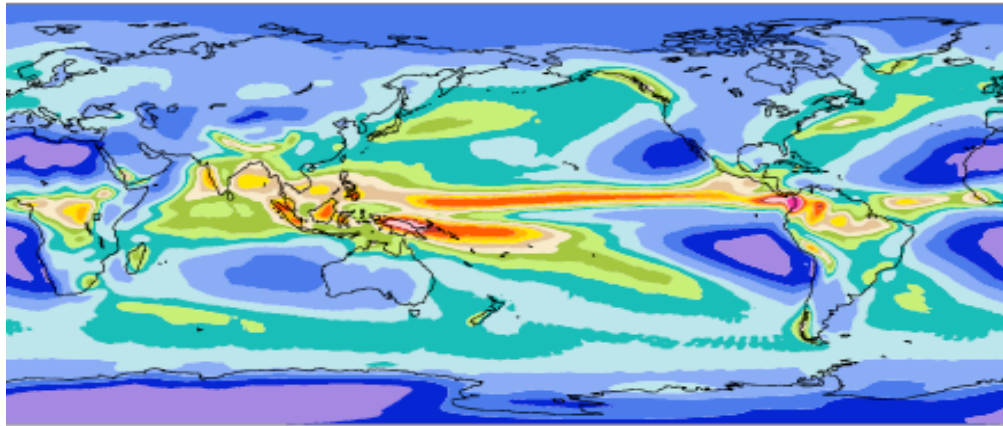
Zonal Mean Vertical Velocity (annual average; unit is in mb/day)



- The undesirable noise in FV is notable
- In HOMME, there is no such noticeable noise!

Horizontal Distribution of Precipitation Rate (annual average; unit is in mm/day)

HOMME



HOMME captures the broad features

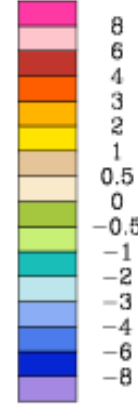
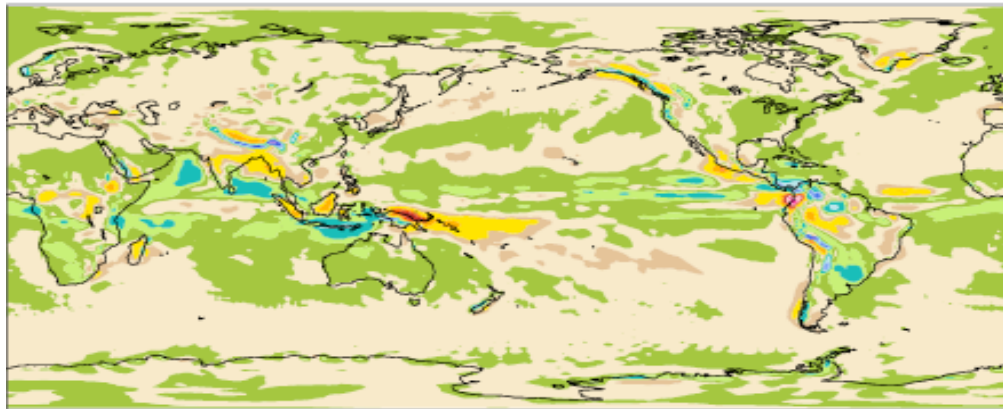
Heavy Precipitation:

ITCZ, SPCZ, , west coast of Oceans
South Asian Monsoon Region
Amazon Basin

Dry zones:

east coast of oceans
North Africa
North Asia

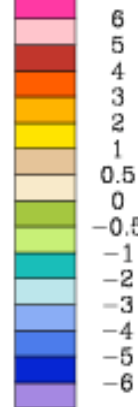
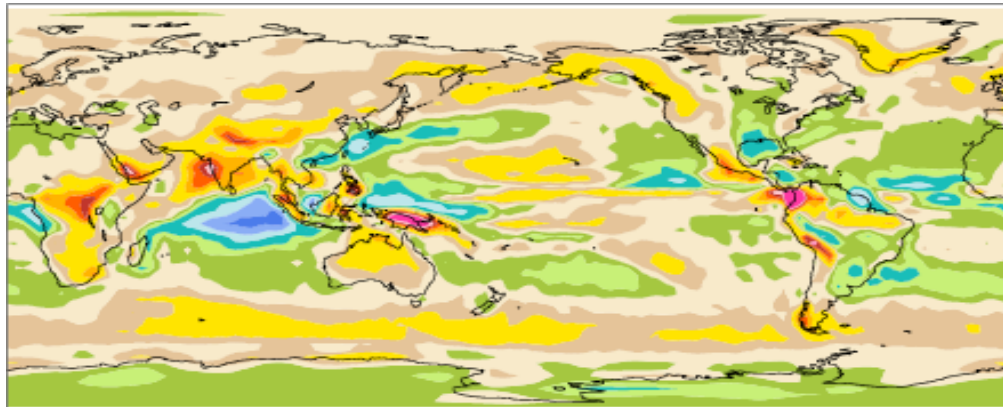
HOMME - FV



Difference with FV is not considerable

RMSE is 0.55

HOMME - CMAP



Errors (w.r.t CMAP):

Excessive PRECIP over land surface &...

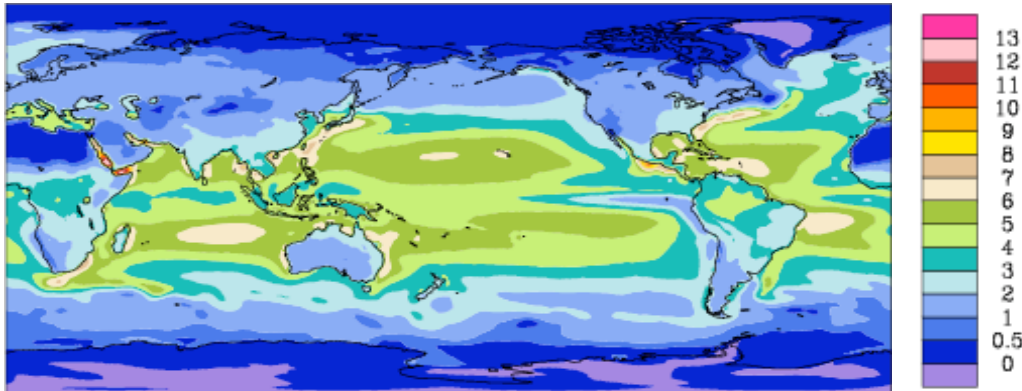
Arabian Sea, SPCZ, central Pacific
Himalaya, Amazon Basin
equatorial Africa, Arabian Peninsula
extratropical storm-tracks

Deficiency over oceans &...

Eastern Indian Ocean
Western subtropical Pacific
Equatorial Atlantic

Horizontal Distribution of Evaporation Rate (annual average; unit is in mm/day)

HOMME



Overall pattern is realistic:

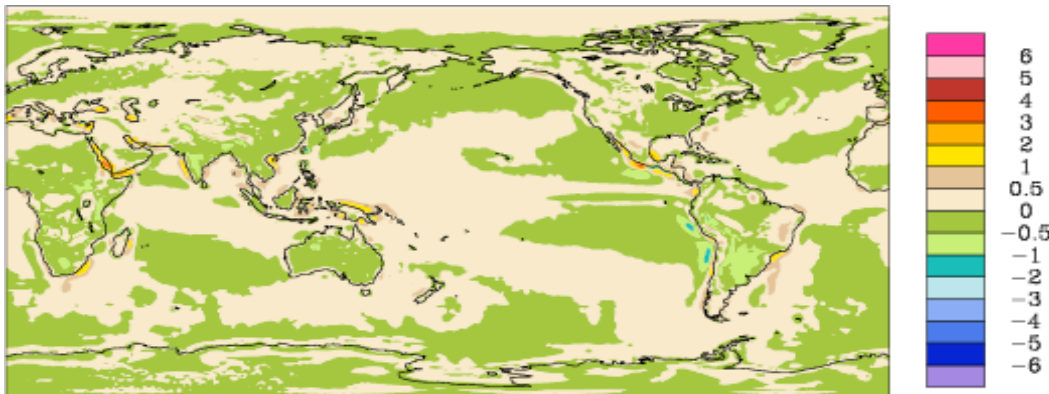
Maxima:

- along the western boundary currents
- Red Sea, BOB, western subtropical Pacific
- western equatorial Atlantic
- southern Indian Ocean

Minimum:

in the ITCZs

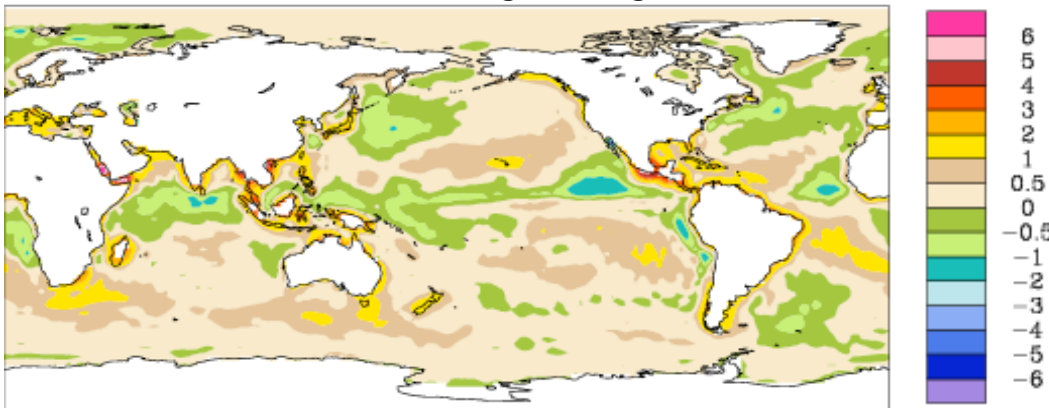
HOMME - FV



✓ There is not much difference with FV

✓ However, it is marginally greater in HOMME

HOMME - Large & Yeager



Biases

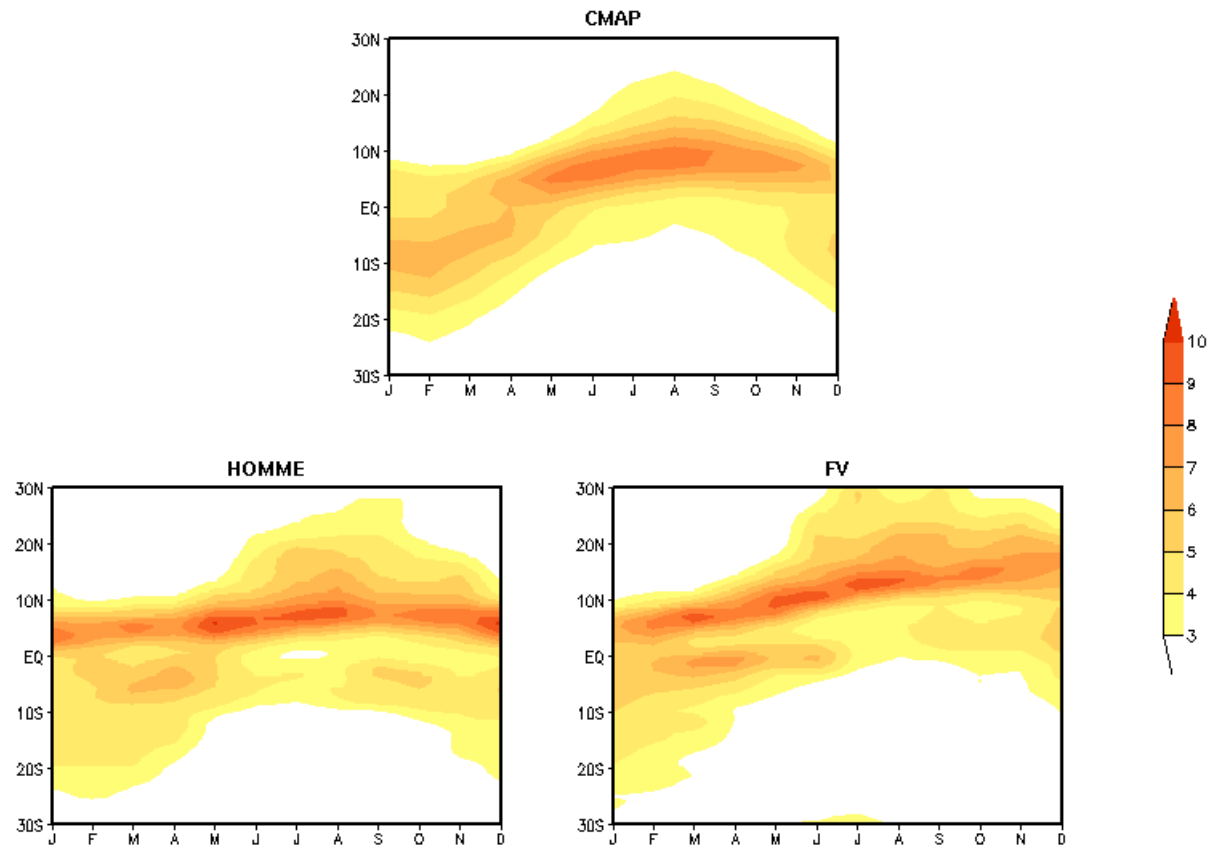
underestimate over :

- western boundary currents
- equatorial IO
- equatorial eastern Pacific

overestimate:

southern oceans

Annual Cycle of PRECIP (zonal average – 0 to 360; unit is in mm/day)



- ✓ **OBS:** The ITCZ starts from $\sim 10^{\circ}$ S in Jan and goes up to 10° N in July, and again comes back to 5° N in Dec
- ✓ **FV:** Unsatisfactory! (monotonically moves towards north till Dec; no retreat is observed)
- ✓ **HOMME:** The broad features of the cycle is captured, though the primary maxima remain in the northern hemisphere throughout the year

Conclusions

- HOMME captures most of the principal features of the hydrological cycle satisfactorily
- The simulation capability of HOMME is found to be as good as FV dycore
- There exist some biases, which are common in both the dycores, and hence seems to be associated with the physics package

Ongoing & Future Work

- Transient features in AMIP simulations (analysis is going on)
- Performance (physical) of HOMME at high resolution (simulations are in progress)
- Performance of HOMME in CAM5 (will be done soon)
- Performance of HOMME at low resolution (for paleoclimate study) (will be done soon)

More Results

For more diagnostics see: <http://users.nccs.gov/~taylorm> & <http://users.nccs.gov/~4ue/homme.html>

Q & Suggestions ...