CAM4/HOMME AMIP Results: Hydrological Cycle

Saroj K. Mishra (NCAR & CU)
Mark Taylor (SNL)
Ram Nair (NCAR)
Henry Tufo (NCAR & CU)
Joe Tribbia (NCAR)
Kate Evans (ORNL)
Jim Edwards (NCAR & IBM)
Peter Lauritzen (NCAR)
Jose Garcia (NCAR)

CESM AMWG Meeting, Boulder, Colorado
February 2011
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
  - 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:** $\sim 1^\circ$ 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)
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)
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)
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…*

- 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 hgh/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…
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° 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
The difference between HOMME and FV is negligible (|diffs| < 0.1 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 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

Difference with FV is not considerable
RMSE is 0.55

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)

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

There is not much difference with FV
- However, it is marginally greater in HOMME

Biases
- Underestimate over:
  - western boundary currents
  - equatorial IO
  - equatorial eastern Pacific
- Overestimate:
  - southern oceans
OBS: The ITCZ starts from ~10° 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 futures 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 seem 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/~taylorm) & [http://users.nccs.gov/~4ue/homme.html](http://users.nccs.gov/~4ue/homme.html)

Q &Suggestions ...