Can high resolution climate simulations with the Community Atmospheric Model (CAM) offer a new perspective on 21st century scenarios?

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Motivation

Common wisdom
“The expectation is that increasing spatial resolution will generally cause the simulation to improve because of a more accurate topography, and a better large-scale circulation”

What does the high resolution buy us?
What is the impact for future projections?
At a glance

Model
Community Atmospheric Model (CAM5)
CAM standalone with prescribed SSTs
Horizontal resolutions: 1° and 0.25°

Time-slice experiments

- Present-day conditions
  *Observed SSTs: Merged Hadley-OI*

- Future conditions
  *CESM SSTs: RCP4.5 & RCP8.5*

Analysis focuses on precipitation and tropical cyclones
Precipitation, JJA

- Increased precipitation over Africa and South America
- Dry bias over Micronesia
- Exacerbated double ITCZ
- Increased wet bias in northern ITCZ
Asian Monsoon, JJA

Precipitation (color). Topography (contour line = 500m level)

TRMM

CAM5 (1°)

CAM5 (0.25°)
Asian Monsoon, JJA

Red vector: Winds at 850 mb; Contour: Wind divergence

**ERA-Interim**

**CAM5 (1°)**

**CAM5 (0.25°)**

Wind
10 m/s

Subsidence
less rain

Divergence

Convergence
Air rises
more rain

Air rises more rain

Contour: Wind divergence

Wind
10 m/s

Subsidence
less rain

Divergence

Convergence
Air rises
more rain

Air rises more rain
Seasonal pattern ↔ High frequency data (daily)

- Seasonal pattern of precipitation
  - Precipitation frequency
  - Precipitation intensity

- How often does it rain?

\[
\text{Precipitation frequency (\%)} = \frac{\text{Number of rainy days (}> 1 \text{ mm/day})}{\text{Total number of days}}
\]

- How hard does it rain?

\[
\text{Precipitation intensity (mm/day)} = \frac{\text{Total amount of precipitation}}{\text{Number of rainy days (}> 1 \text{ mm/day})}
\]

*Dai et al. (2007)*
In observations, precipitation amount is mainly determined by the precipitation frequency.
Intensity and frequency: CAM (1°) versus obs

TRMM: Precip frequency (%)
CAM (1°) => rains too often

TRMM: Precip intensity (mm/day)
CAM (1°) but not hard enough
Intensity and frequency: CAM (025°) vs obs

TRMM: Precip frequency (%)  
CAM (0.25°) => improved frequency

TRMM: Precip intensity (mm/day)  
CAM (0.25°) => mixed result

Problem persists at higher resolution (despite some improvements)!
Extreme precipitation

PDFs of precipitation (August 2005)

CAM5 at 0.25 degree has some skills to simulate extreme precipitation

Courtesy Julio Bacmeister
Diurnal cycle of rainfall (JJA)

In observations:
- Land: evening max
- Ocean: early morning max

At coarse resolution,
- Rains too early especially over land
- Diurnal cycle amplitude too weak

Diurnal cycle improves at higher resolution

Courtesy Rich Neale
Diurnal cycle of rainfall (JJA)

TRMM 0.25°
(2001-2010)

CAM5 1°
(2001-2010)

CAM5: 0.25°
(1996-2005)

Courtesy Rich Neale
Tropical Cyclone Tracks

**Observations: IBTrACS**

- Tropical cyclone tracks identified by GFDL tracking algorithm

- CAM5 at 0.25 degree has some skills to simulate tropical cyclones

**CAM5: 1 degree**

**CAM5: 0.25 degree**

*Courtesy: Kevin Reed  [See also: Wehner et al. 2014, JAMES]*
Storm Count: Tropical Storm, Hurricane, Major Hurricane.

Observations: IBTrACS

Global
- Obs
- CAM5

North Atlantic
- Obs
- CAM5

West Pacific
- Obs
- CAM5

CAM5: 0.25 degree

East Pacific
- Obs
- CAM5

Courtesy: Kevin Reed  [See also: Wehner et al. 2014, JAMES]
What is the impact of resolution for future projections?

Time-slice experiments

• Present-day conditions
  *Observed SSTs: Merged Hadley-OI*

• Future conditions
  *CESM SSTs: RCP4.5 & RCP8.5*

+ bias correction

We use the present-day SSTs bias as a correction for RCP SSTs (Use 12-month cycle correction).
Changes in precipitation intensity/frequency

In warmer climate: it rains harder but less frequently

(Consistent with Trenberth et al. 2003)
Extreme precipitation in warmer climate

PDFs of precipitation at 0.25 degree
(August)

Extreme precipitation are more intense in a warmer climate

Courtesy Julio Bacmeister
Tropical Cyclone count and intensity in warmer climate

In warmer climate:
number of tropical cyclones decreases
But the most intense storms become more intense.

Courtesy: Kevin Reed
Conclusions

Mean climate:
- Mean precipitation bias is not much improved at higher resolution.
- Some biases even get worse (dry Micronesia bias, double ITCZ…)

Daily data:
- In CAM5: rains too often but not hard enough. Despite some improvements, the problem persists at higher resolution.

Diurnal cycle
At coarse resolution, CAM fails to reproduce observed diurnal cycle
- Rains too early especially over land
  Diurnal cycle amplitude too weak
- Diurnal cycle improves at higher resolution but some bias remains

Extreme events
CAM at 0.25 degree has some skills to reproduce extreme precipitation and tropical cyclones
Conclusions

In a warmer climate:

- It rains **harder** but **less frequently**

- **Extreme** precipitation are **more intense**

- The **number** of tropical cyclones **decreases**
  but the **most intense storms** become **more intense**.
Thanks!