High resolution climate simulations with CESM: What does the high resolution buy us?

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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?

Analysis focuses on precipitation and tropical cyclones
United States Topography

- **Observation**
- **CAM at 1 degree** (standard resolution)
- **CAM at T31** (This tutorial)
- **CAM at 0.25 degree** (high resolution)
Precipitation, JJA

Increased precipitation over Africa and South America

Dry bias over Micronesia

Exacerbated double ITCZ

Increased wet bias in northern ITCZ

Observations: TRMM

CAM5: 1 degree

CAM5: 0.25 degree
Asian Monsoon, JJA

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

Wind divergence

Convergence

Air rises more rain

Subsidence less rain

Divergence
Seasonal pattern ↔ High frequency data (daily)

- Seasonal pattern of precipitation
  - Precipitation frequency
  - Precipitation intensity

- How often does it rain?

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

- How hard does it rain?

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

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
Tropical Cyclone Tracks

Observations: IBTrACS

- Tropical cyclone tracks identified by GFDL tracking algorithm

CAM5: 1 degree

CAM5 at 0.25 degree has some skills to simulate tropical cyclones

CAM5: 0.25 degree

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

Global
- Obs
- CAM5

Observations: IBTrACS

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]
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
Thanks !
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

Precipitation intensity

Precipitation 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

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.

Future work:

- Prediction depends on the SSTs.

- Impact of the SST bias and bias correction in the RCP runs.