Timeslice Experiments at High Resolution.
What does the resolution buy us?

Cécile Hannay, Rich Neale, Julio Bacmeister
National Center for Atmospheric Research, Boulder

Thanks to DOE for providing allocation on jaguar

AMWG Meeting, Boulder, 1 - 3 February
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 (CAM4)
CAM standalone with prescribed SSTs
Horizontal resolutions: 2°, 1°, 0.25°

Time-slice experiments
present-day conditions (1981-2000)
future conditions (2081-2000)

Analysis focuses on precipitation (Model ⇔ TRMM)

Impact of horizontal resolution on:
Mean climate: seasonal means, daily means, diurnal cycle
Precipitation, JJA
Precipitation, JJA

Improves: Asian monsoon and Saudi Arabia wet bias
Remains the same: double ITCZ
Gets worse: extension of Asian monsoon
Asian Monsoon, JJA

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

TRMM

CAM4 (2°)

CAM4 (0.25°)
Precipitation over the US, DJF

- Dry bias over Southeast (reduced due to better resolved orography)
- Wet bias over Northwest (remains)
Precipitation over the US, JJA

Wet bias over Colorado (“Red Spot”)
- remains with new physics (CAM5) and at higher vertical resolution
- recent research: “Red Spot” disappears with rougher orography
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)
TRMM: Precipitation intensity and frequency (ANN)

In observations, precipitation amount is mainly determined by the precipitation frequency.
Intensity and frequency: CAM (2°) vs obs

TRMM: Precip frequency (%)

CAM (2°) => rains too often

TRMM: Precip intensity (mm/day)

CAM (2°) and 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°) => improved intensity

Problem persists at higher resolution (despite some improvements)!
Diurnal cycle of rainfall: TRMM (3-hourly data)

Land: afternoon/evening max
Ocean: early morning max

Courtesy Rich Neale
Diurnal cycle of rainfall (JJA)

- 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

Courtesy Rich Neale
Diurnal cycle of rainfall (JJA)

TRMM (0.25°)

Courtesy Rich Neale
What is the impact of resolution for future projections?

- Present-day time-slice: Observed SSTs

- Future time-slice: SSTs from RCP8.5
  + use correction for CESM SST bias
  + use correction for sea-ice cover (Hurrell et al, 2008)

Asian monsoon, JJA

Precipitation change by the end of the 21\textsuperscript{th} century

CAM4 (1°)  
CAM4 (0.25°)

\[ \Rightarrow \text{Precipitation extremes are reduced at 0.25°} \]
Change in precipitation over the US

CAM4 (1°)

Summer drought

Changes are less dramatic in winter

mm/day

-2 -1.5 -1 -0.75 -0.5 -0.25 0.25 0.5 0.75 1 1.5 2
Change in precipitation over the US

CAM4 (1°)  CAM4 (0.25°)

J J A

D J F

mm/day

-2  -1.5  -1  -0.75  -0.5  -0.25  0.25  0.5  0.75  1  1.5  2
Change in precip intensity/frequency

Precipitation intensity

CAM4 (1°)  CAM4 (0.25°)

Precipitation frequency

CAM4 (1°)  CAM4 (0.25°)

In warmer climate: it rains harder but less frequently

(Trenberth et al. 2003)
Conclusions

Mean climate:

- **Improvements at higher resolution** due to more accurate representation of the topography and a better simulation of the large-scale circulation (Asian monsoon, Saudi Arabia wet bias, Southwest US dry bias)

- But … some biases **remain** (double ITCZ, Colorado “Red Spot”) or even get **worse** (extension of the Asia Monsoon into the Philippine Sea)

Daily data:

- In observations: distribution of precipitation amount is mainly determined by the **precipitation frequency**

- In CAM4: **rains too often but not hard enough.** Despite some **improvements**, the problem **persists** at higher resolution.
Conclusions

Diurnal cycle

**Observed** diurnal cycle:
- Land: afternoon/evening maximum
- Ocean: early morning maximum

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

Change in precipitation by the end of the 21th
- Resolution has an impact on the climate change signal:
  - JJA drought over US is reduced at 0.25°
- In warmer climate: it *rains harder but less frequently*
Thanks!