Remote Teleconnection Influences on Atmospheric Blocking in the Community Earth System Model (CESM)

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Atmospheric Blocking
What, why, when

- Surface high pressure systems in all seasons, generally infrequent
- Can persist for many days (blocks other systems).
- Has poorly understood initiation/maintenance/decay mechanisms (contrast with baroclinic theory)
- Significant impacts on extreme events (heat/cold snaps, atypical weather)
- In climate models it may be a proxy for extreme events when resolution is insufficient
Atmospheric Blocking in CESM

1. WHAT ARE THE DIFFERENCES IN BLOCKING IN RECENT CESM VERSIONS?

2. IS THERE AN OBSERVED TROPICAL INFLUENCE ON BLOCKING?

3. DOES CESM CAPTURE THESE RELATIONSHIPS?
ANALYSIS

NCAR-DOE Community Earth System Model (CESM) fully coupled simulations
Daily means of many quantities (Z500, T2m, precip, (u,v)200mb)

Reanlyses (1979-2010)

MERRA (NASA)
ERA-interim (ECMWF)

Model simulations (1 degree/fully coupled 20th century simulations)

CCSM3 (AR4,5EM) – Poor blocking activity

CCSM4 (AR5,1EM) – Tropical convection changes (better)

CESM1 (AR5,6EM) – Cloud, shallow convection, microphysics and radiation changes (best)
Reanalyses

Daily data 500-mb geopotential height

D’Andrea (1998)

\[
GHGS = \frac{Z(\phi_0) - Z(\phi_S)}{\phi_0 - \phi_S}
\]

\[
GHGS = \frac{Z(\phi_n) - Z(\phi_0)}{\phi_n - \phi_0}
\]

where

\[
\phi_n = 78.75^\circ N + \Delta
\]

\[
\phi_0 = 60^\circ N + \Delta
\]

\[
\phi_S = 41.25^\circ N + \Delta
\]

with

\[
\Delta = -3.75^\circ, 0^\circ, 3.75^\circ.
\]
Model (CESM) Blocking Statistics
Ensemble spread show well separated characteristics

Systematic improvement in blocking Activity from CCSM3->CCSM4->CESM1

Particularly in main error region (Eastern Atlantic)

Significantly different atmospheres CAM3->CAM4->CAM5

Seasonal dependence?
A Tale of 3 Seasons

- DJF has largest seasonal bias in Atlantic region: No model improvements
- MAM smaller Atlantic biases: Significant model improvements through CESM1
- JJA has largest Pacific biases: Significant improvements though CCSM4/CESM1

Is there a remote tropical influence?
Composite Patterns
Blocked (top 20%)
Surface air temperature (K) - High Z500 composite - DJF

- ERAI
- MERRA
- CESM1
- CCSM4
- CCSM3
Surface air temperature (K) - High Z500 composite - JJA
Total precipitation (mm/day) - High Z500 composite - DJF
Total precipitation (mm/day) - High Z500 composite - DJF
Tropical Connections
Moving central analysis longitude to region of blocking model spread

- Coherent non-local signal as large as local signal in reanalysis
- Little tropical signal in models
Total precipitation (mm/day) - High Z500 composite - MAM

- Less coherent signal in reanalyses
- Signal shifts to South America in models CCSM/CESM1
• Less coherent signal in reanalyses
• Signal shifts to South America in models CCSM/CESM1
Total precipitation (mm/day) - High Z500 composite - JJA
Resolution and Future Climate
Resolution Impacts

MAM Blocking frequency (1980-1999)

DJF Blocking frequency (1980-1999)
Climate Change Signal?

MAM Blocking frequency

JJA Blocking frequency

AMWG February 2014
Summary

Systematic improvements with model version (CCSM3->CCSM4->CESM1)

DJF no systematic improvements

MAM/JJA improvements in Atlantic/Pacific

Local composite response in good agreement with reanalyses

Indications of tropical co-variability; weakest agreement in Atlantic (DJF)

Small resolution dependence; small blocking decrease in future

Next Steps
Can we attribute atmosphere model changes to blocking improvements?
   TMS, micro, shCU, DeepCU, dy-core, radiation