Sources of skill in Sahel precipitation hindcasts in the CESM Decadal Prediction Large Ensemble

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Community Earth System Model (CESM)
Decadal Prediction Large Ensemble (DPLE)

40 members started each year from 1954-2015

10-year-long hindcasts

Ocean and sea ice full fields initialized from an adjusted CORE forced ocean-sea ice hindcast

Same model configuration and forcing as the CESM Large Ensemble (LE) – Kay et al. (2015)

See Yeager et al. 2018 for more details
Improved skill in Sahel precipitation in the CESM DPLE from previous CCSM4 hindcasts. Why?

- Sahel Rainfall Anomaly Correlation Coefficient
- CESM-DPLE
- CCSM4-DP
- CESM-LE

Adapted from Yeager et al. 2018

verified against CRU-TS4.0 precipitation (Harris et al. 2014)
Improved skill in Sahel precipitation in the CESM DPLE from previous CCSM4 hindcasts. Why?

- Sahel Rainfall Anomaly Correlation Coefficient

- CESM and CCSM4 decadal prediction hindcasts differ:
  - CAM5 (CESM) versus CAM4 (CCSM4) atmosphere
  - Ocean Biogeochemistry in CESM
  - Number of ensemble members (40 in CESM vs 10 in CCSM4)
  - Initialization start date (Nov 1 in CESM versus Jan 1 in CCSM4)
  - Hindcast simulations used for full field ocean initial conditions

verified against CRU-TS4.0 precipitation (Harris et al. 2014)
Correlation of summer Sahel precipitation with SST

ERSSTv5 SST
CRU-TS4.0 precipitation (Harris et al., 2014)
Relative SST Index (RSI – Martin and Thorncroft 2014) captures both North Atlantic and tropical SST variability

ERSSTv5 SST
CRU-TS4.0 precipitation (Harris et al., 2014)
Skillful hindcasts of RSI in CESM-DPLE and later forecast years of CCSM4-DP.

Adapted from Yeager et al. 2018
CESM-DPLE and CCSM4-DP both have predictive skill for North Atlantic SST variability: Need to look at tropics

Adapted from Yeager et al. 2018
Two possibilities for improved Sahel prediction in CESM:

1. Improved model
   
   More realistic SST relationship with Sahel precipitation in CESM than in CCSM4

2. Improved initialization
   
   Less initialization shock in CESM-DPLE than in CCSM4-DP
Correlation of CESM Relative SST Index and summer Sahel precipitation

Bootstrapped distribution: 1000 randomly drawn 62-year time series of RSI and associated summer Sahel precipitation from a long CESM preindustrial control simulation.
Summer Sahel precipitation is better correlated with Relative SST Index in CESM than CCSM4

Martin and Thorncroft: more skillful decadal predictions in models with higher RSI/Sahel correlation
Generating bootstrapped hindcasts from the CESM-DPLE and CCSM4-DP

Construct a 62-year long time series of “year N” hindcasts by randomly selecting one of the 40 members for each start time.

- Each hindcast member only 10 years in length.
- 40 (or 10) members initialized each year.
Generating bootstrapped hindcasts from the CESM-DPLE and CCSM4-DP

Construct a 62-year long time series of “year N” hindcasts by randomly selecting one of the 40 members for each start time.

Repeat the random selection many, many times.
Same Sahel-SST relationship in CESM across hindcast lead times

**CESM-DPLE**

Correlation coefficient
JAS Sahel precipitation w/RSI

**CESM PIControl**

Correlation coefficient
JAS Sahel precipitation w/RSI
Sahel-SST relationship in CCSM4-DP weakens with hindcast lead time.

**CESM-DPLE**

**CESM PIControl**

**CCSM4-DP**

**CCSM4 PIControl**

Correlation coefficient
JAS Sahel precipitation w/RSI

Correlation coefficient
JAS Sahel precipitation w/RSI
CESM-DPLE: Sahel rain related to DPLE SST EOF2

% time series with sig. correlation of SST PC2 with Sahel rain

% correlations

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CESM-DPLE: Sahel rain related to DPLE SST EOF2

ERSSTv5 EOF1

CESM-DPLE SST EOF2

% time series with sig. correlation of SST PC2 with Sahel rain

ERSSTv5 PC1

CESM-DPLE SST PC2

% correlations

EOF number
CCSM4-DP: Evolution of ensemble mean SST is wrong

Initialization shock in tropical Pacific: see Yeager et al. (2018), Teng et al. (2016)
500 hPa evolution matches SST evolution

CESM-DPLE 500 hPa EOF2

CCSM4-DP 500 hPa EOF2

CESM-DPLE 500 hPa PC2

CCSM4-DP 500 hPa PC2
Conclusions

• Improved skill in CESM-DPLE Sahel precipitation hindcasts is due to:
  
  (1) improved model representation of Sahel-SST connections in CESM from CCSM4 and,
  
  (2) improved Pacific initialization in the CESM-DPLE from the CCSM4-DP

• Both CESM-DPLE and CCSM4-DP are capturing the global patterns of variability that are correlated with Sahel precipitation, but in CCSM4-DP, the evolution is mistimed because of initialization shock
Extra slides
500 hPa EOF2 related to Sahel rain in both ensembles

% correlations

CESM-DPLE

CCSM4-DP

% correlations
West African (20°W-10°E) climatological summer $u$ (contours), $v$, $w$ (arrows) using JRA-55, CITATION
West African (20°W-10°E) climatological summer $u$ (contours, negative dashed), $v$, $w$ (arrows)
ITCZ subsidence, advection from Sahara, and southward shifted jets associated with low Sahel rain

**Joint summer** $u$ (shading), $v$, $w$ (arrows) **EOF 1**

**Climatological** $u$ (contours)

$R_{u,v,w \text{ JPC1,Sahel}} = -0.75$

using JRA-55, CITATION
Low Sahel rainfall also associated with global contraction of tropics

500 hPa heights EOF2
Low Sahel rainfall also associated with global contraction of tropics

500 hPa heights EOF2

Observed Correlations

\[ R_{Z500 \text{ PC2}, \text{ Sahel}} = 0.46 \]
\[ R_{u,v,w \text{ JPC1}, \text{ Sahel}} = -0.75 \]
\[ R_{Z500 \text{ PC2, uvw JPC1}} = -0.74 \]
Relative SST Index (RSI – Martin and Thornicroft 2014) captures both North Atlantic and tropical SST variability.