Role of Atmospheric Forcing and Oceanic Feedback in Aerosol Forced 20th century Sahel Precipitation Variability

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July-August-September Sahel Precipitation 10-year Rolling Mean Anomalies from 1950-1999

CESM1

CanESM2

Atmospheric vs. Oceanic Decomposition

1) Atmospheric Forcing Response
(a.k.a the fast response) : Rapid atmospheric response to changing aerosol and precursor emissions.

2) Oceanic Feedback Response
(a.k.a. the slow response): Effect of aerosol-forced SST/SIC changes feeding back onto the atmosphere

- We run a set of 100-year time slice AGCM simulations in CAM5 and CanAM4, using the SST/SIC anomalies from their respective coupled LENS simulations.

- By using LENS anomalies, we can thoroughly filter internal variability from the SST/SIC perturbations we apply to the AGCM simulations.

Aerosol Forced JAS Precipitation Anomalies

CFSM1 LENS (20 members)

CanESM2 (55 members)

Drying from the 1950s to 1970s is largely due to the response to the Atmospheric Forcing.

Recovery from the 1970s to 2000s is largely due to the response to the Oceanic Feedback.

CanAM4 response is weaker and statistically less robust.

Some qualitative similarities, such as early period Atmospheric drying and later period Oceanic wetting.

Key Points

- In LE simulations, aerosols dominate the forced 20th century Sahel precipitation variability.

- In CAM5 simulations, the early drying is due to atmospheric forcing while the later recovery is due to oceanic feedbacks from changing SST/SIC.

- CanAM4 simulations have weaker/noisier responses, but have qualitative similarities that suggest this breakdown is somewhat robust between the AGCMs.

Large Ensemble Analysis

- Anthropogenic Aerosol Forcing accounts for much of the forced precipitation variability in the Sahel in the NCAR-DOE CESM1 and CCCma CanESM2 Large Ensembles.

- Both models underestimate the magnitude of multi-decadal variability.

- Observed variability is partially attributable to aerosol forcing [Undorf et al., 2016]

- In the Sahel Aerosol Forcing drives drying from the 1950s to 1970s and recovery from the 1970s to 2000s.

- The two Large Ensembles show similar spatial patterns in the response to aerosol forcing.

- Much of the aerosol forced change requires >5 ensemble members to detect a significant signal at the 95% level with a t-test. Particularly for the 1970s-1950s.

Shading: 5-95 interval among LENS ensemble members

Averaging box: Land grid points within 10N-20N, 20W-35E

Precipitation (mm/day)


Aerosol Forcing Response (a.k.a the fast response): Rapid atmospheric response to changing aerosol and precursor emissions.

Oceanic Feedback Response (a.k.a. the slow response): Effect of aerosol-forced SST/SIC changes feeding back onto the atmosphere.

1970s - 1950s

2000s - 1970s

Purple Contours: Sea Ice Concentration Change on 2.5% intervals

Stippling: significant at 95% by t-test

Blue Box: Averaging box for Sahel regional averages

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N_{0} = 8 \left( \frac{\sigma_{\Delta X}}{\Delta X} \right)^{2} \quad \text{Large Ensemble JAS Minimum Ensemble Size Estimation for Statistically Significant Response to Aerosol Forcing}

CFSM1 LENS (20 members)

CanESM2 (55 members)

1970s - 1950s

2000s - 1970s

N_{0} Ensemble Members

5 4

4 3

3 2

2 1

1