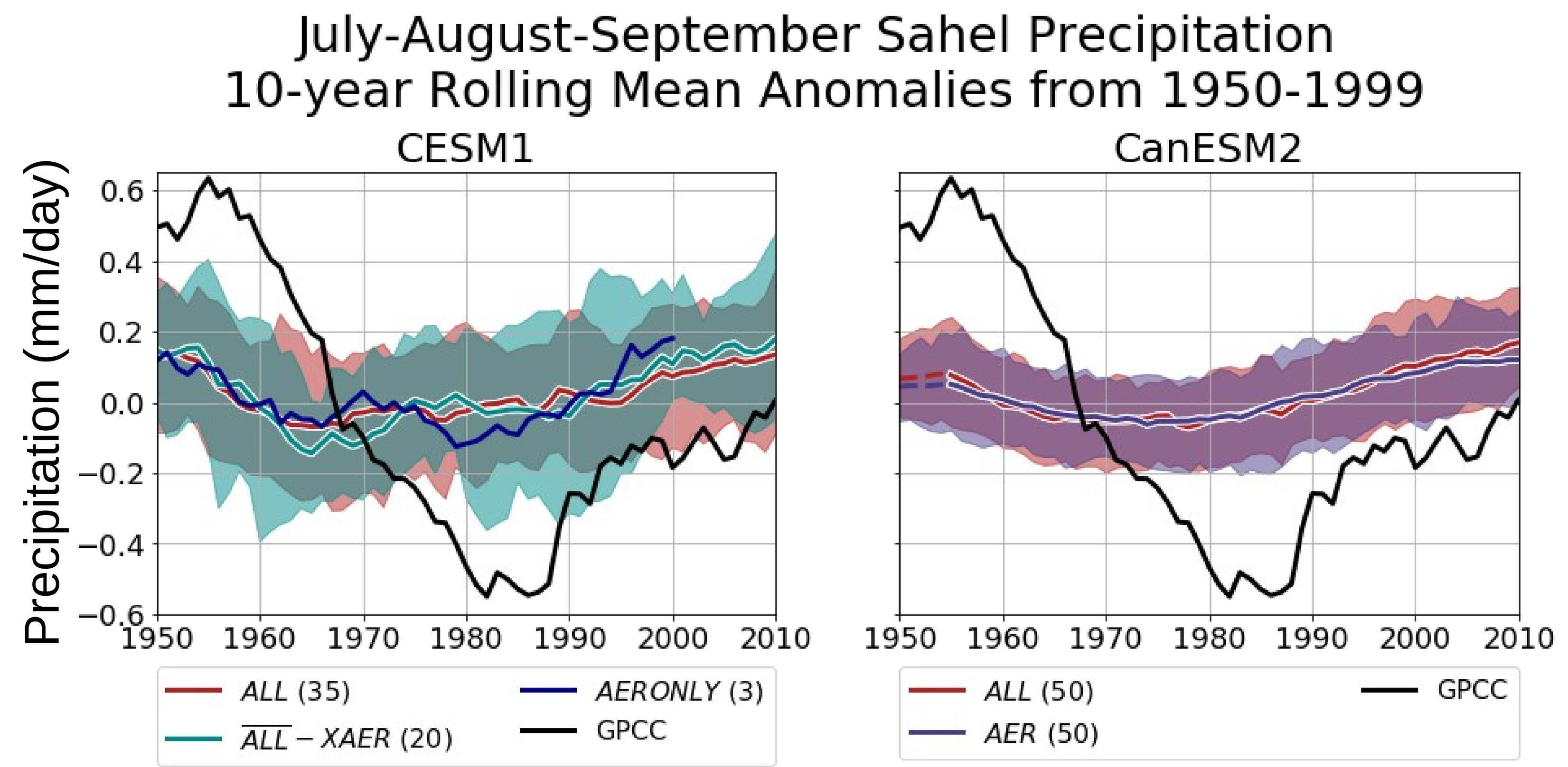
Role of Atmospheric Forcing and Oceanic Feedback in Aerosol Forced 20th century Sahel Precipitation Variability

Haruki Hirasawa[1], Paul Kushner[1], Michael Sigmond[2], John Fyfe[2], Clara Deser[3], Thomas Oudar[4]

[1] University of Toronto, Toronto, ON, Canada [2] Canadian Centre for Climate Modeling and Analysis, Victoria, BC, Canada
[3] National Center for Atmospheric Research, Boulder, CO, USA [4] CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France

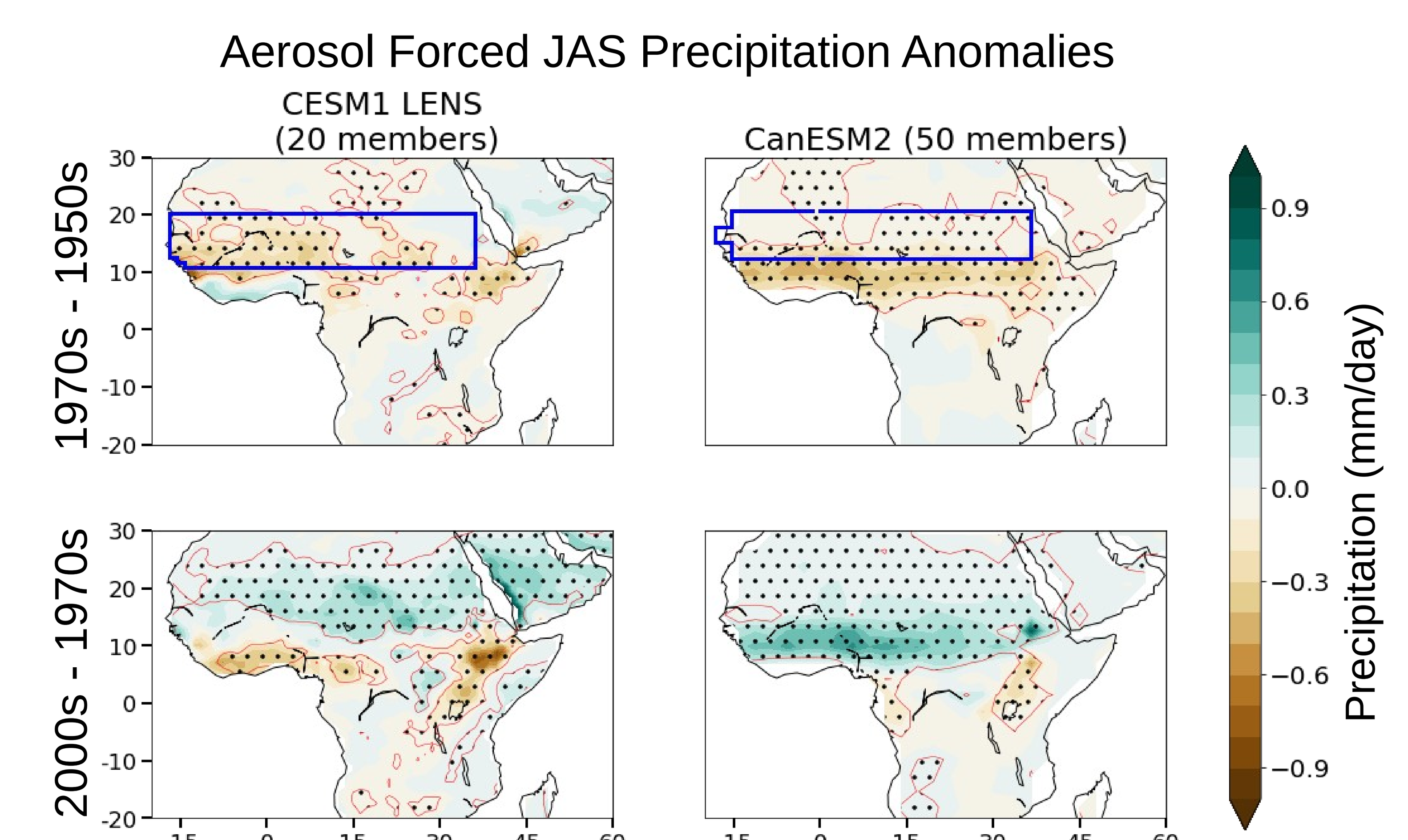
Large Ensemble Analysis



Shading : 5-95 interval among LENS ensemble members
Averaging box : Land grid points within 10N-20N, 20W-35E

- **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]

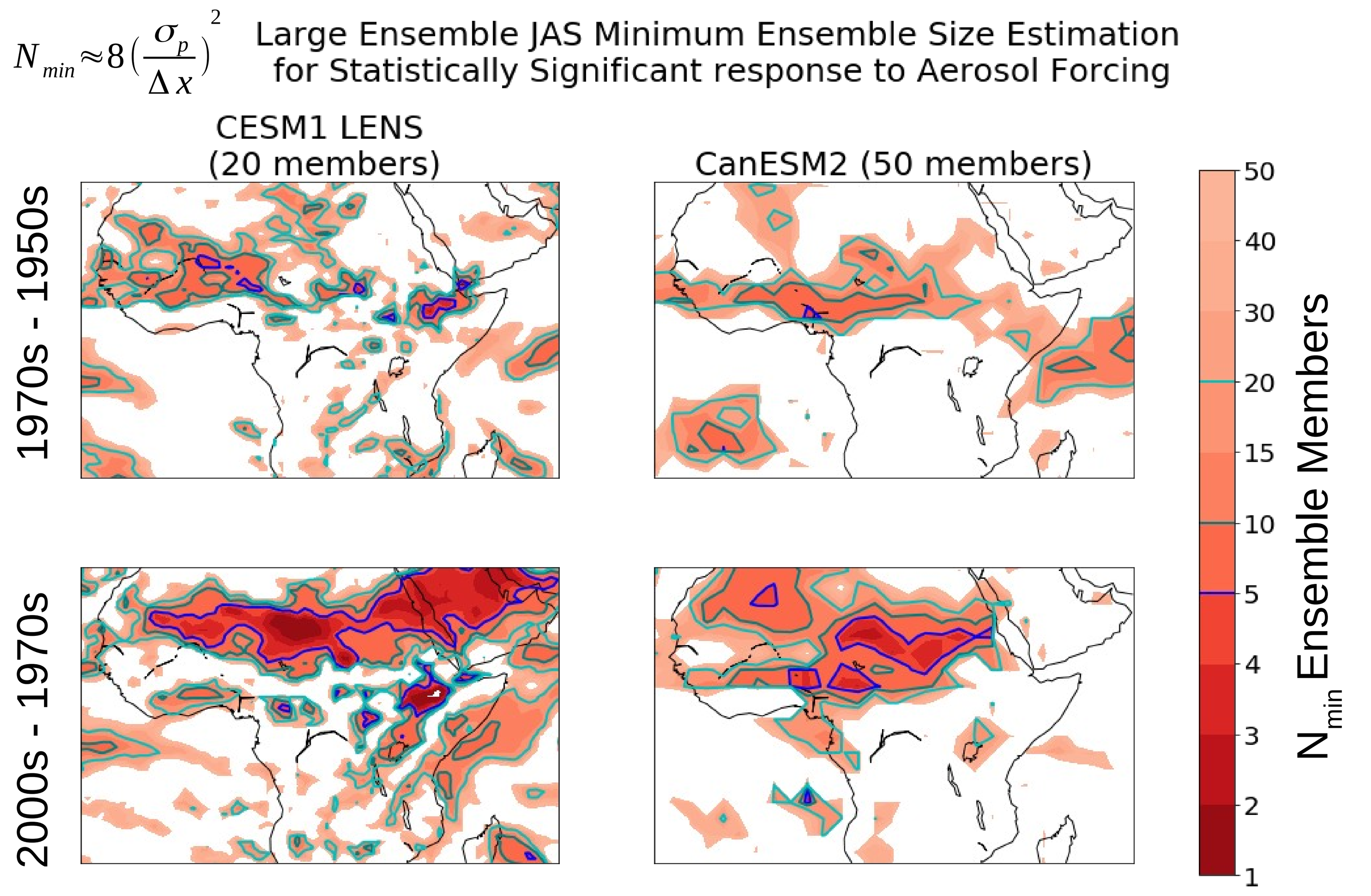
Undorf, S., Polson, D., Bollasina, M. A., Ming, Y., Schurer, A., & Hegerl, G. C. (2018). Detectable Impact of Local and Remote Anthropogenic Aerosols on the 20th Century Changes of West African and South Asian Monsoon Precipitation. Journal of Geophysical Research: Atmospheres, 123(10), 4871–4889.



Stippling: significant at 95% by t-test
Blue Box : Averaging box for Sahel regional averages

- 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.

$$N_{min} \approx 8\left(\frac{\sigma_p}{\Delta x}\right)^2$$

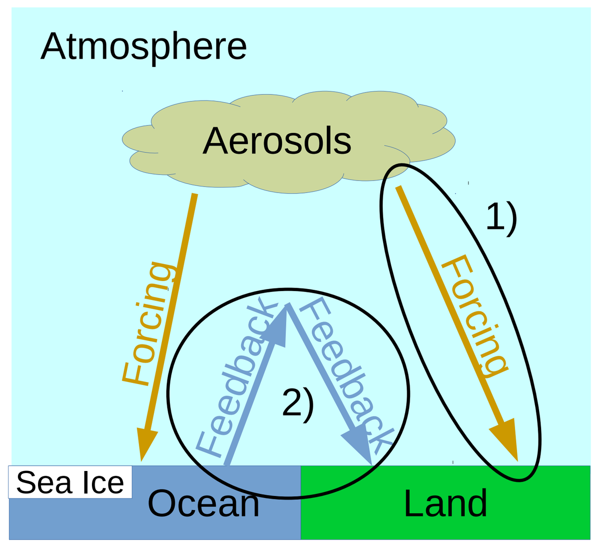


- Much of the aerosol forced change requires **>5 ensemble members** to detect a **significant signal** at the 95% level with a t-test. Particularly for the 1970s-1950s.

Atmospheric vs. Oceanic Decomposition

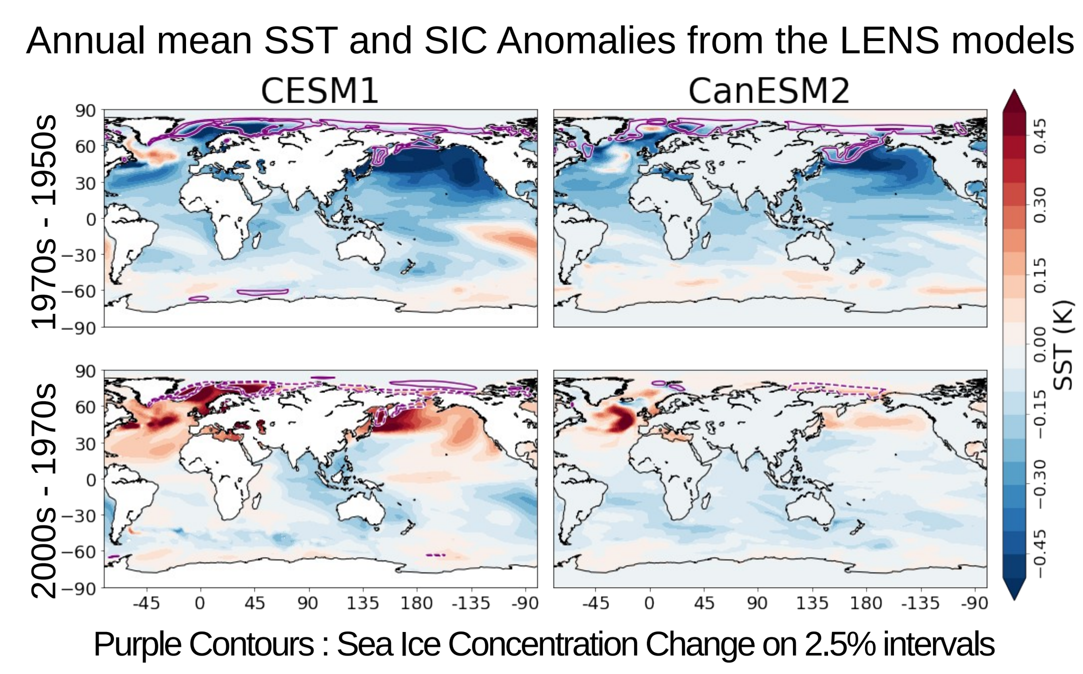
1) Atmospheric Forcing Response (a.k.a the fast response) : Rapid atmospheric response to changing **aerosol and precursor emissions**.

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

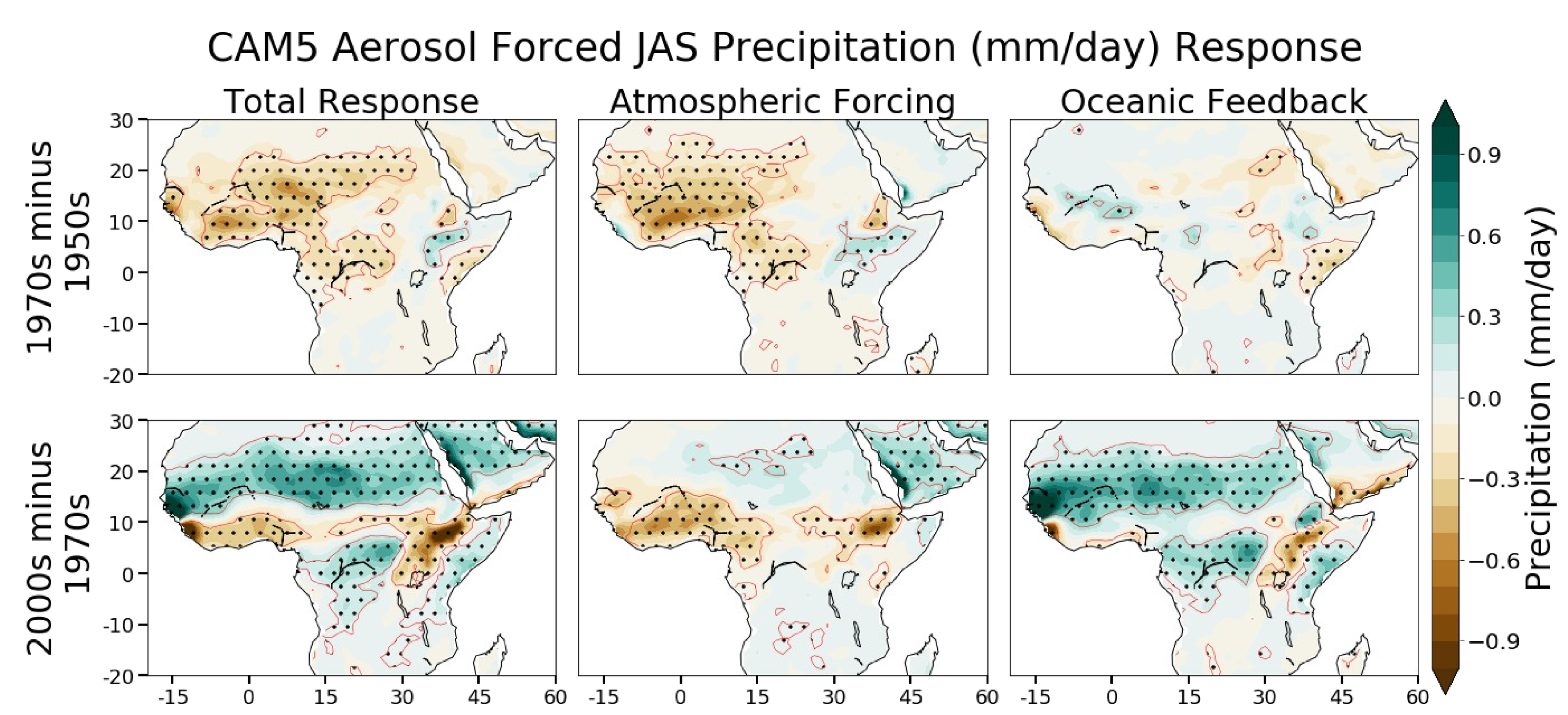


- We run a set of **100-year time slice AGCM** simulations in **CAM5** and **CanAM4**, using the SST/SIC anomalies from their respective coupled **LENS simulations.**

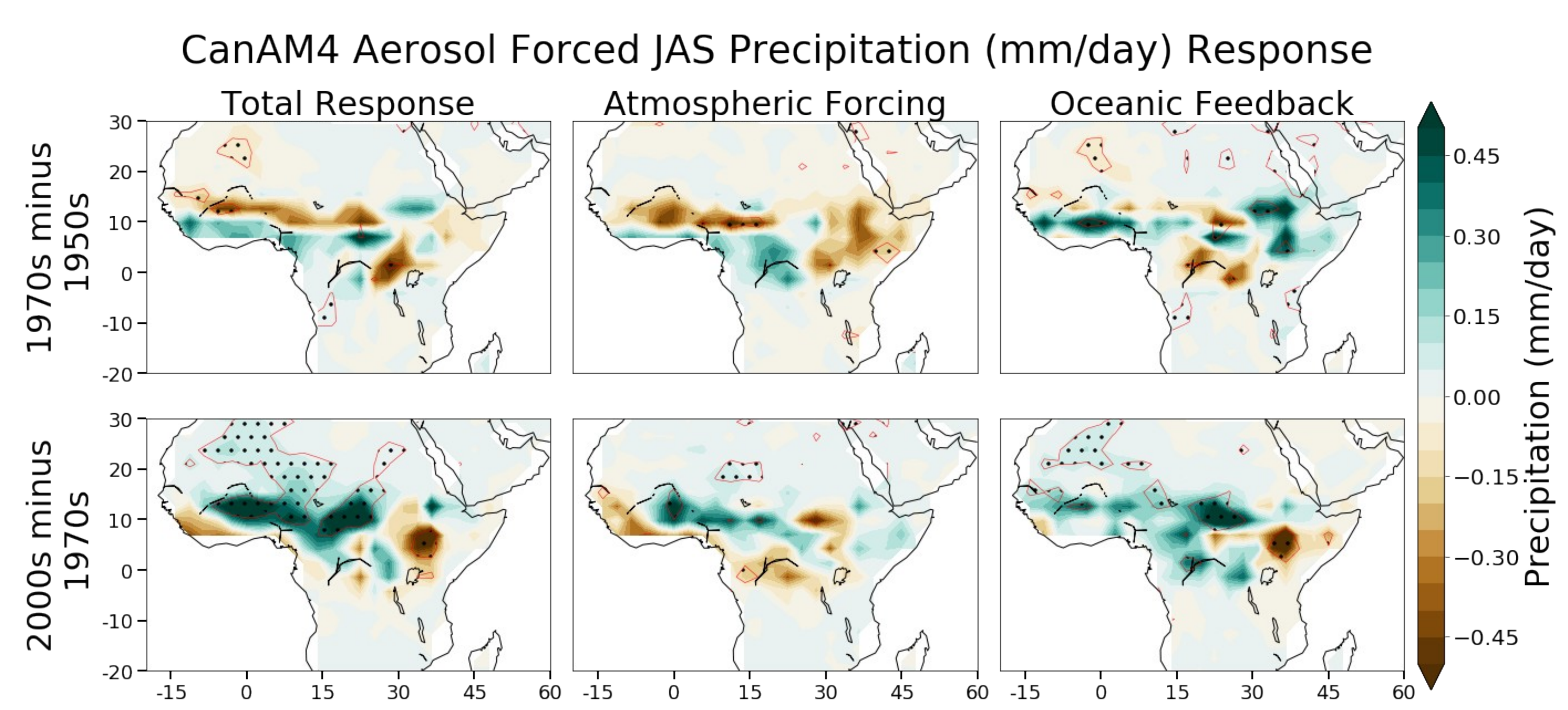
- By using LENS anomalies, we can thoroughly filter internal variability from the SST/SIC perturbations we apply to the AGCM simulations.



Purple Contours : Sea Ice Concentration Change on 2.5% intervals



- **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.