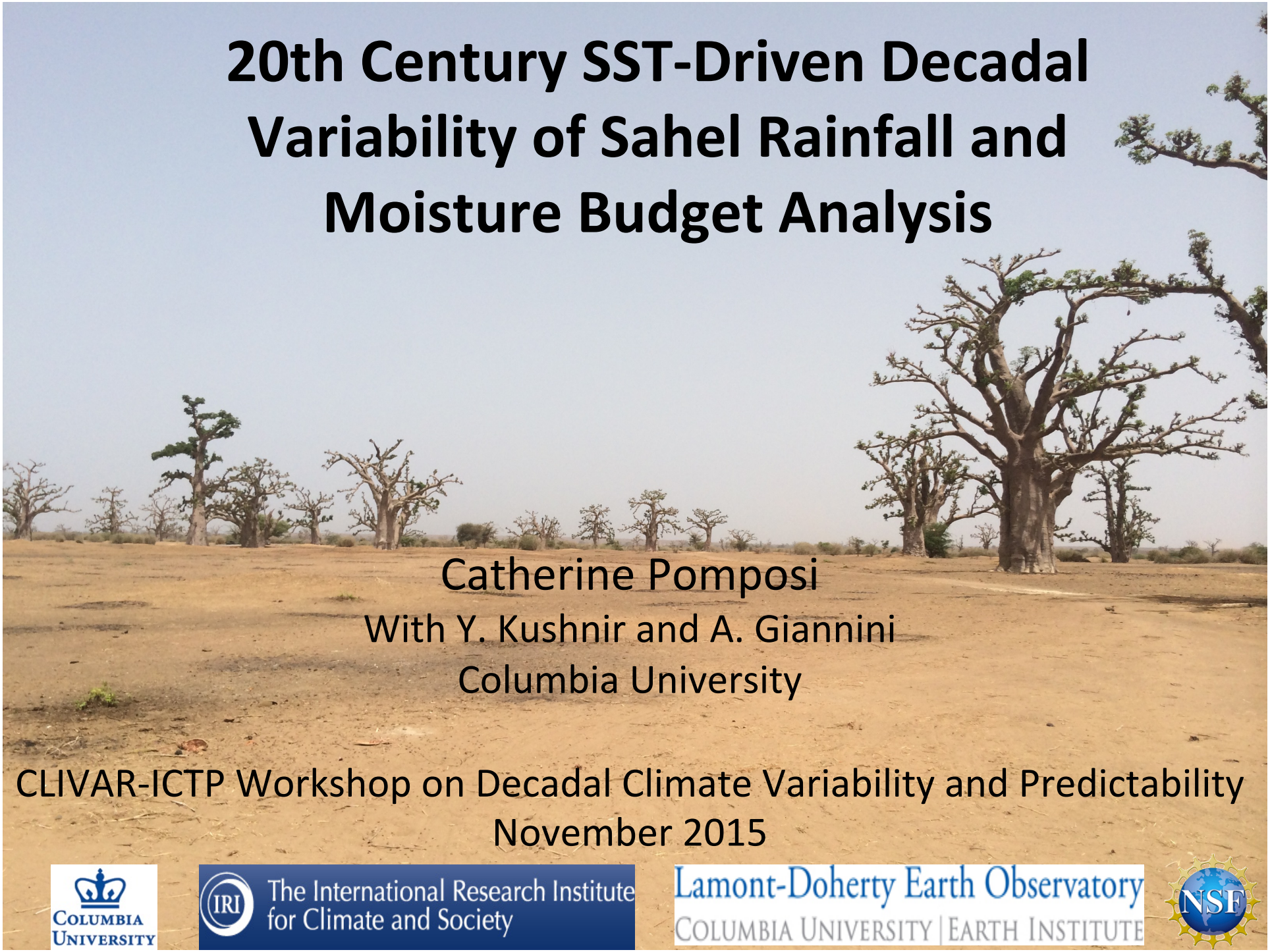
20th Century SST-Driven Decadal Variability of Sahel Rainfall and Moisture Budget Analysis



Catherine Pomposi

With Y. Kushnir and A. Giannini

Columbia University

CLIVAR-ICTP Workshop on Decadal Climate Variability and Predictability

November 2015

Columbia University

The International Research Institute for Climate and Society

Lamont-Doherty Earth Observatory

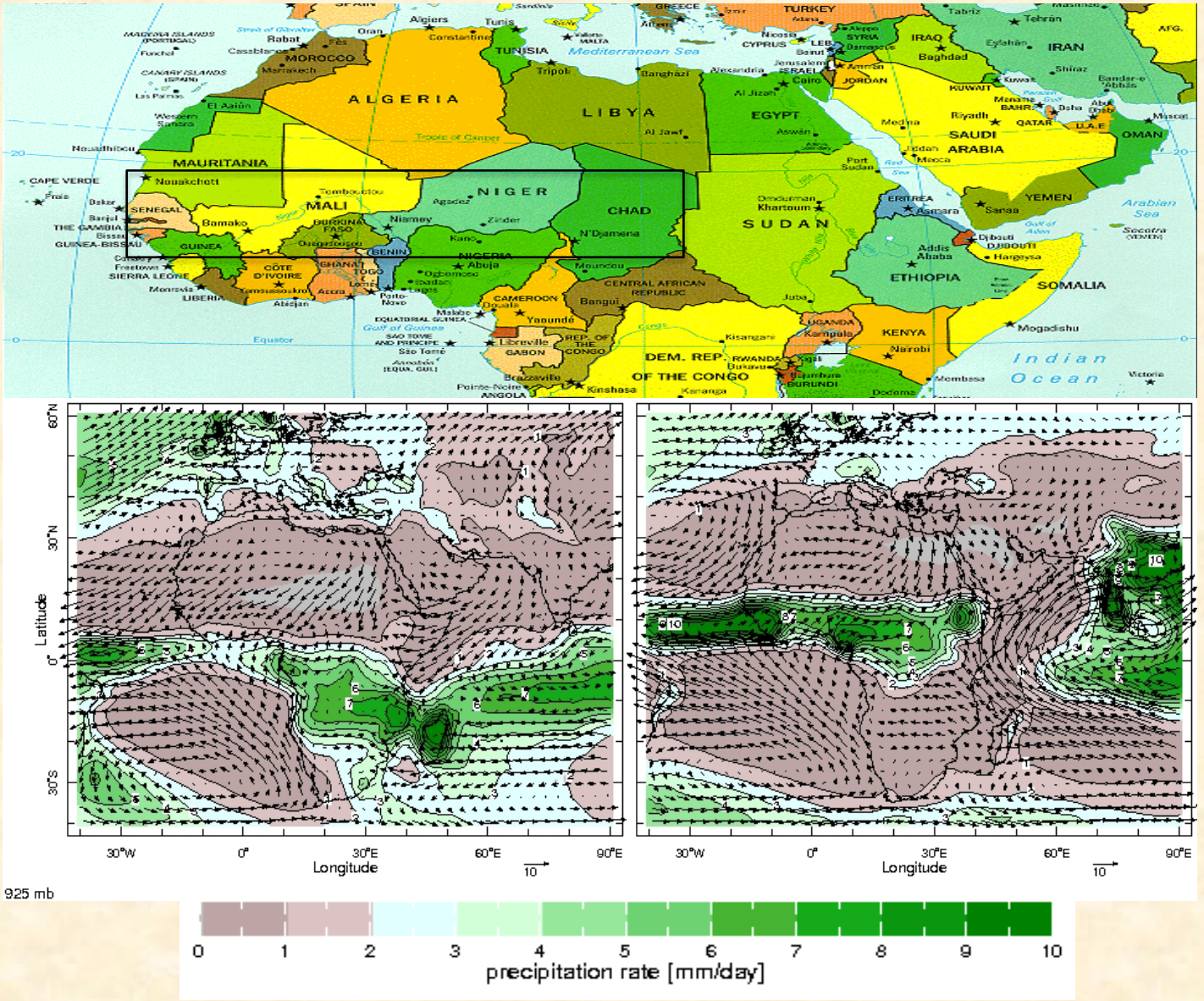
Columbia University | Earth Institute

NSF

Sahel Rainfall Climatology

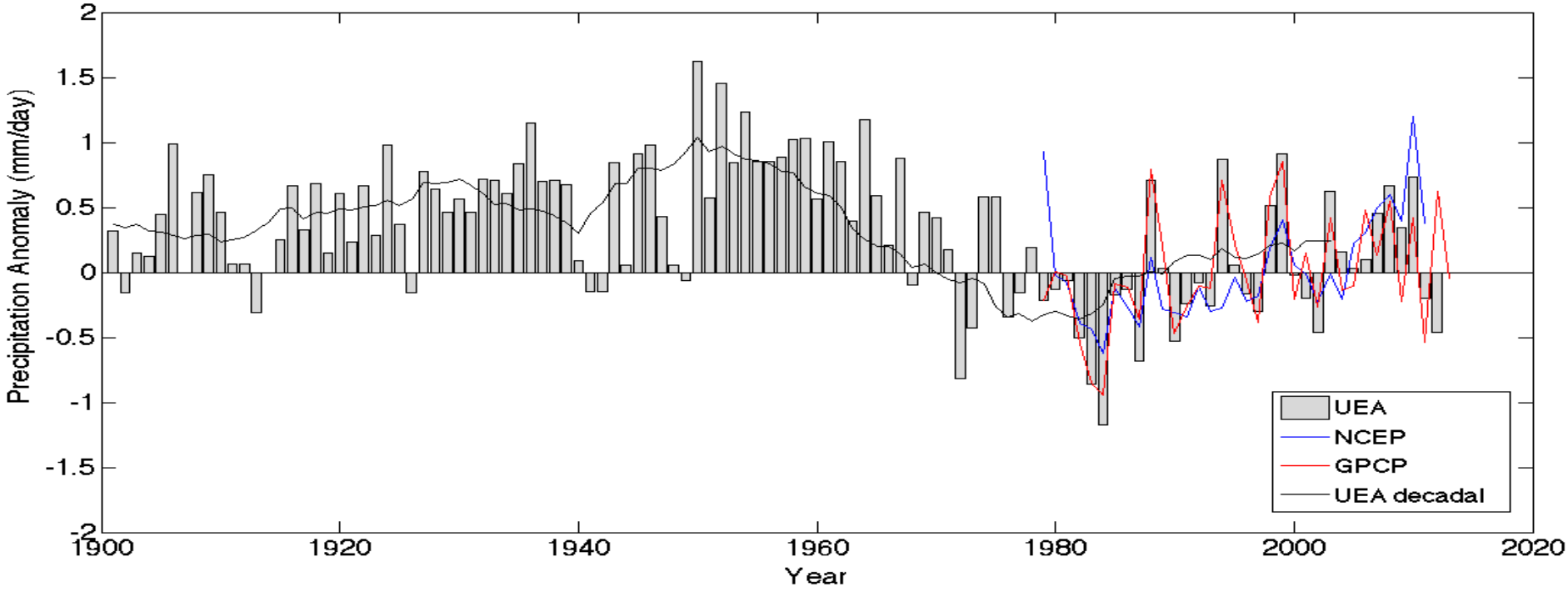
Sahel:
10°-20°N &
15°W-30°E

Yearly rainfall:
ranges from
300-800 mm
during 20th C.
(Nicholson &
Webster
2007)



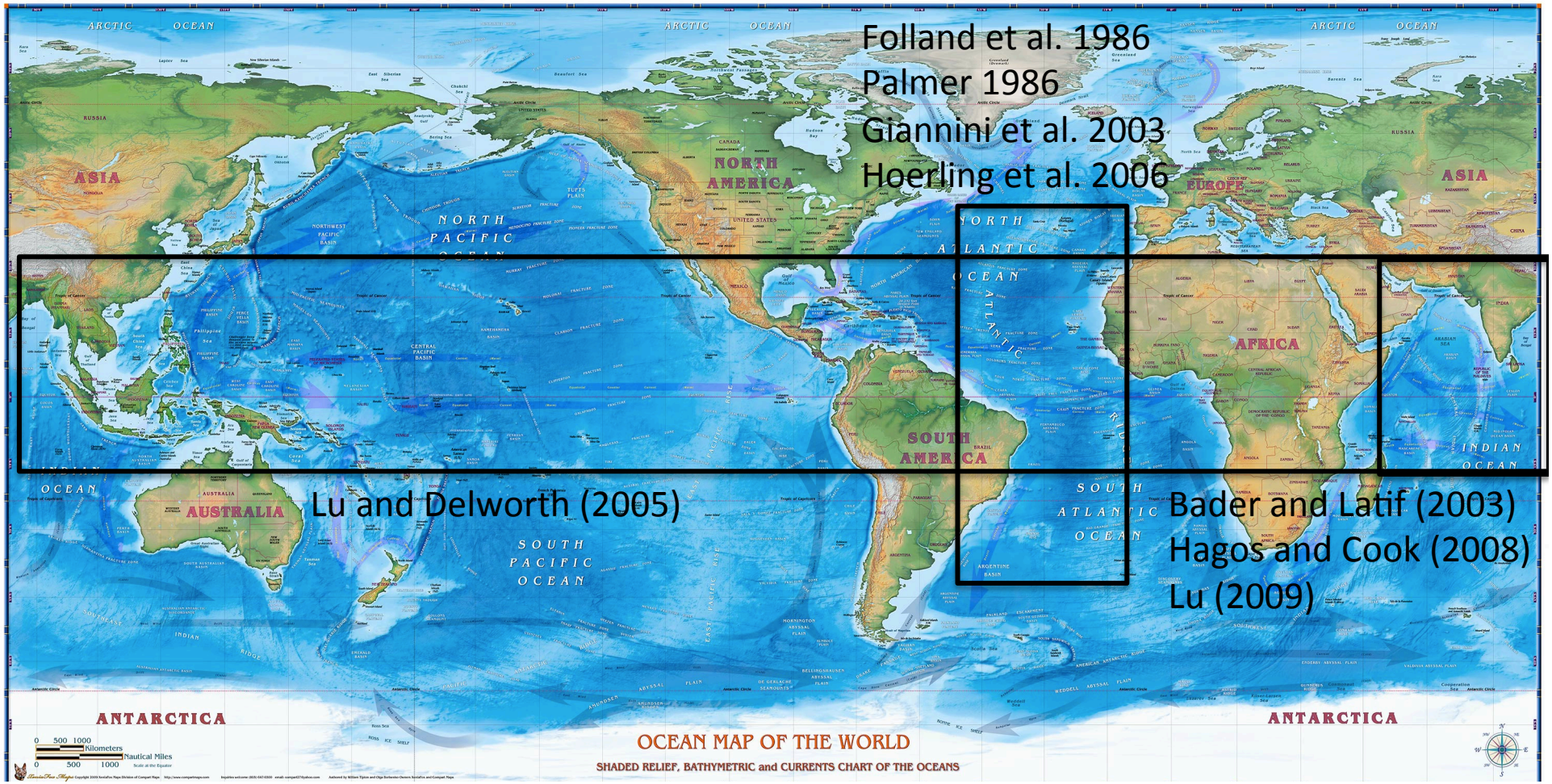
20th C. Sahel Decadal Variability Summary

- Dominant mode of the variability in the region (Nicholson & Palao 1993), driven by SSTs
  - Includes 40% reduction in annual rainfall
    - Unseen in any other region in magnitude or spatial extent (Held et al. 2005)



Sahel Decadal Variability: Driver

- Robust: SSTs are major driver amplified by other forcings
  - **40-50% of long-term variability** (Giannini et al. 2003)



What are the mechanisms of precipitation variability driven by SSTs?

Atmospheric Moisture Budget: allows for understanding of the nature of precipitation in the region (Seager and Henderson 2013)

-MB changes are tied to global oceans in our framework

-CAM4 driven by historic SSTs 1901-2008, N=16 ens. members, 21 vert. levels

$$\rho_w g(\overline{\overline{P}} - \overline{\overline{E}}) = -\left[\sum_{k=1}^{K} \overline{\overline{(\overline{q_k}\nabla\cdot\overline{\mathbf{V}_k} + \overline{\mathbf{V}_k}\cdot\nabla\overline{q_k})}\,\overline{dp_k}} + \nabla\cdot\sum_{k=1}^{K}(\overline{\overline{q_k'\mathbf{V}_k'}}\,\overline{dp_k})\right] - \overline{\overline{q_s\mathbf{V}_s\nabla p_s}}$$

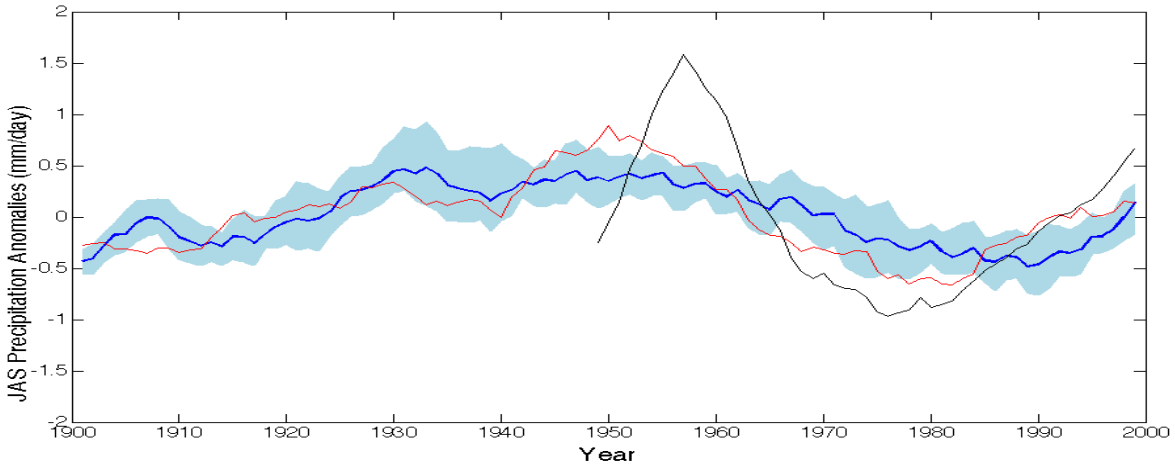
Mass Convergence

Specific Humidity Advection

Moisture Convergence by Mean Flow

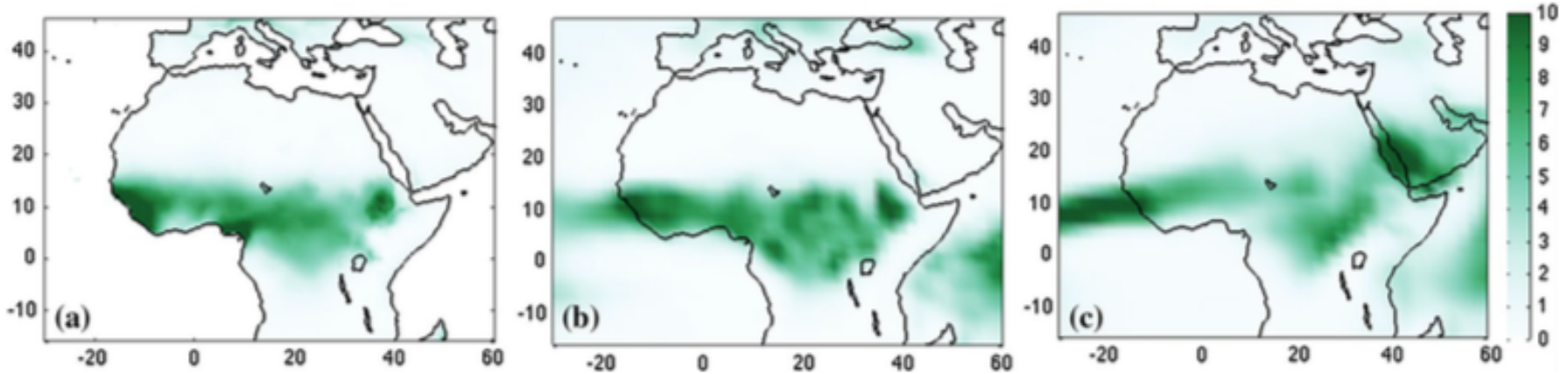
Moisture Convergence by Transients

Model Validation: CAM4

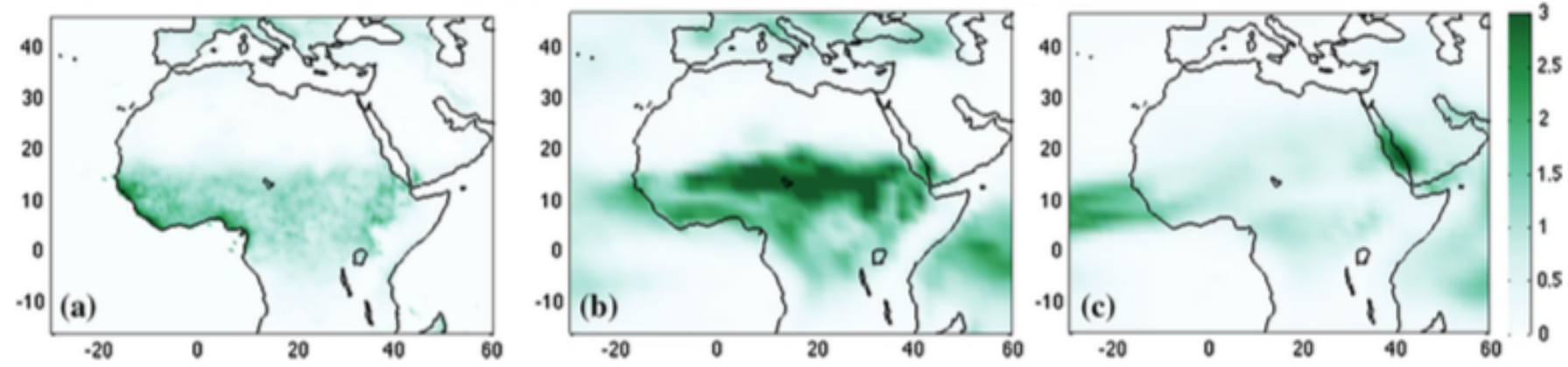


Obs (UEA) NCEP/NCAR CAM4

JAS pre clim (mm/day)

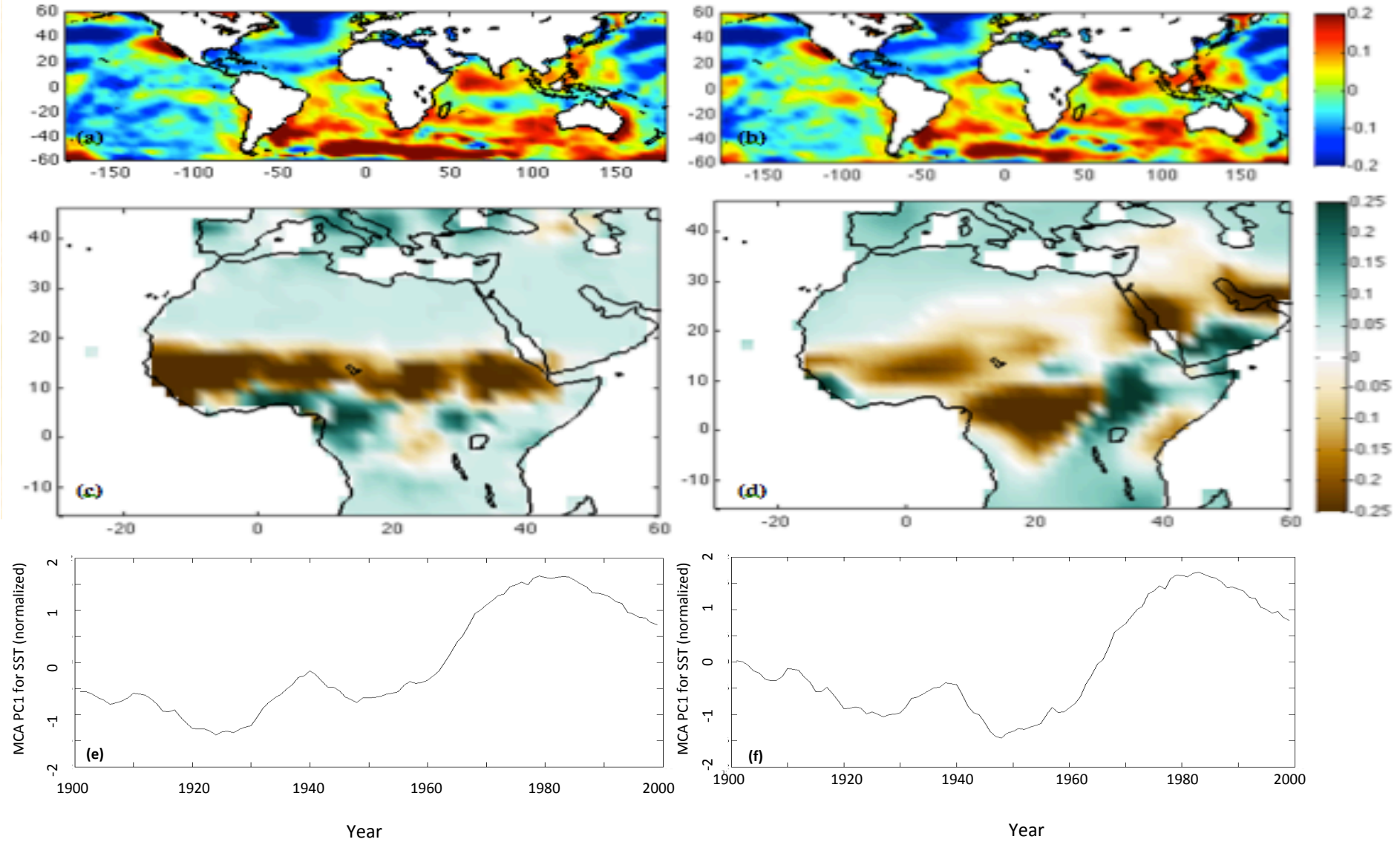


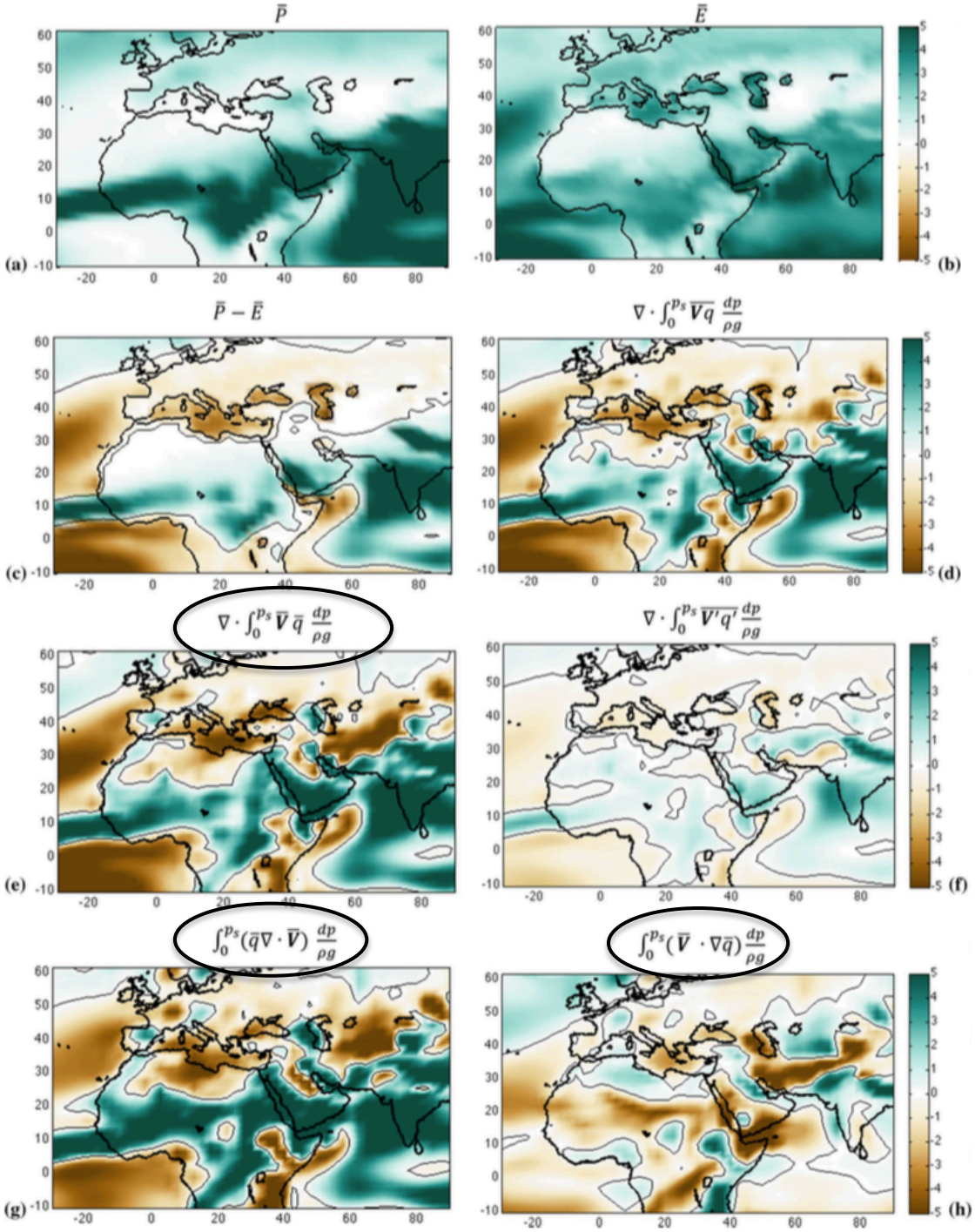
JAS pre RMSA (mm/day)



Covariability between SSTs and Sahel precipitation

Observations CAM4

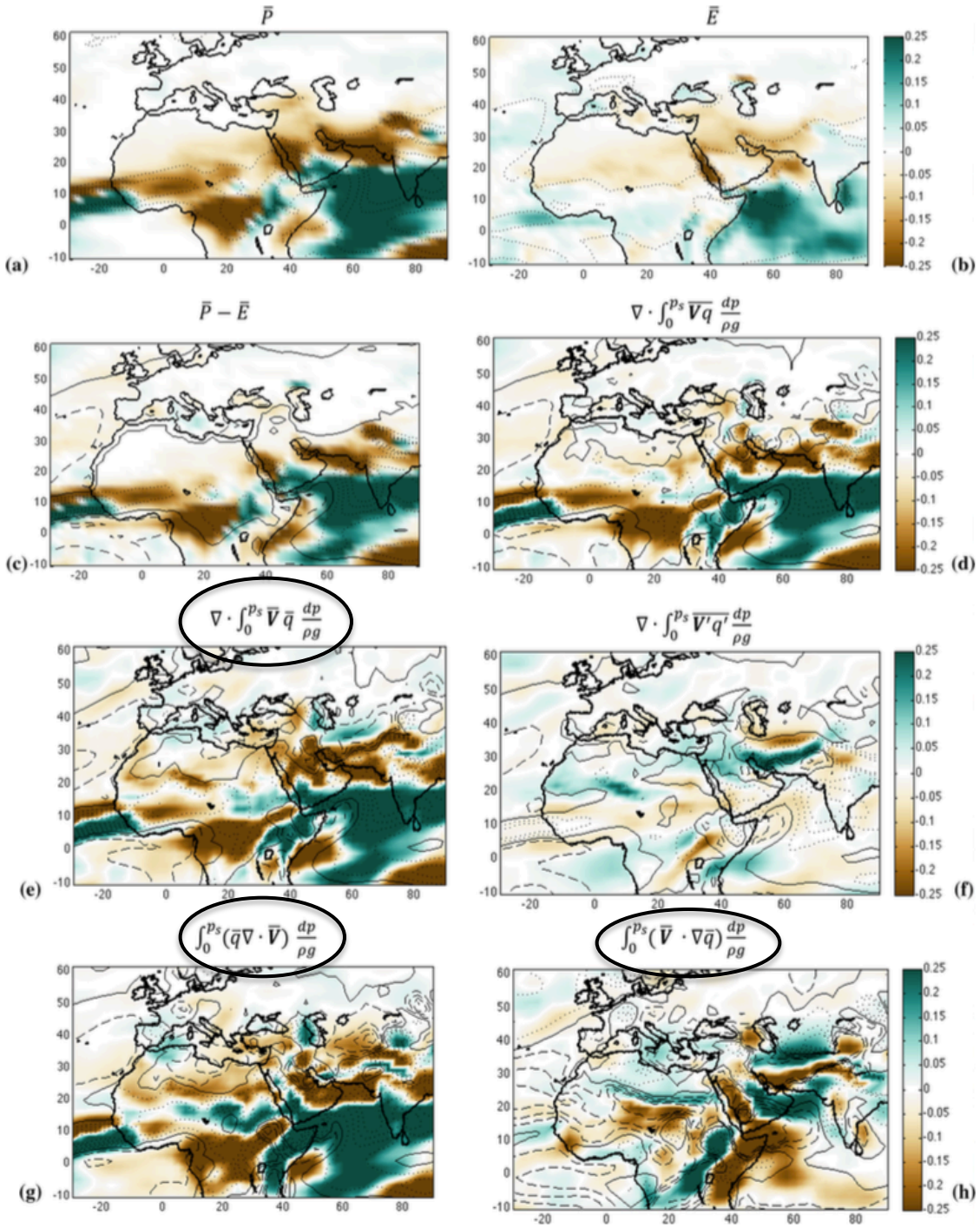




CAM4 Moisture Budget Climatology

Convergence=green
Divergence=brown
All terms in mm/day

Solid Black Line: Zero Contour

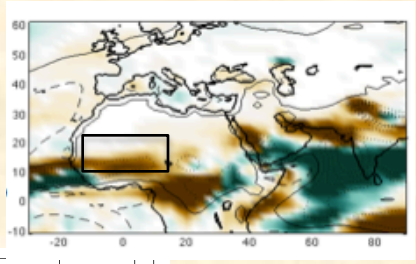


CAM4 Moisture Budget Anomalies Regressed on Decadal Index

Convergence=green
Divergence=brown
All terms in mm/day

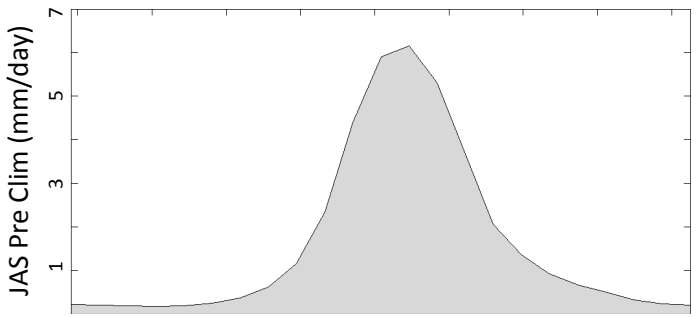
Climatologic Contours
Dotted: Positive
Solid Line: Zero
Dashed: Negative

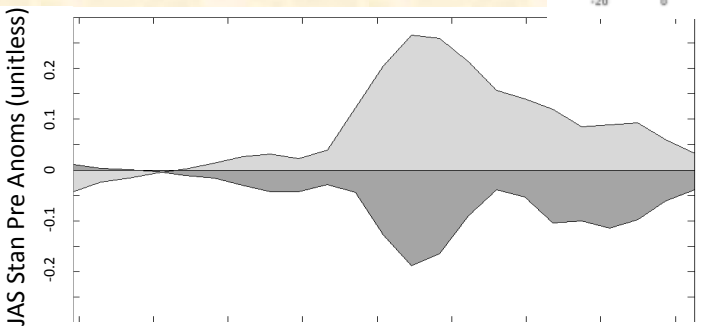
Moisture Budget and Dynamics in Dry and Wet Periods

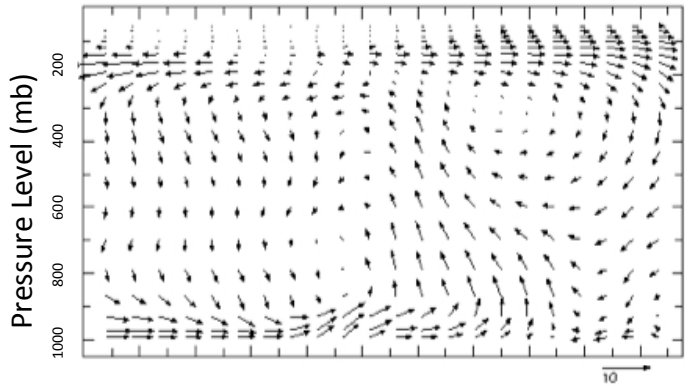


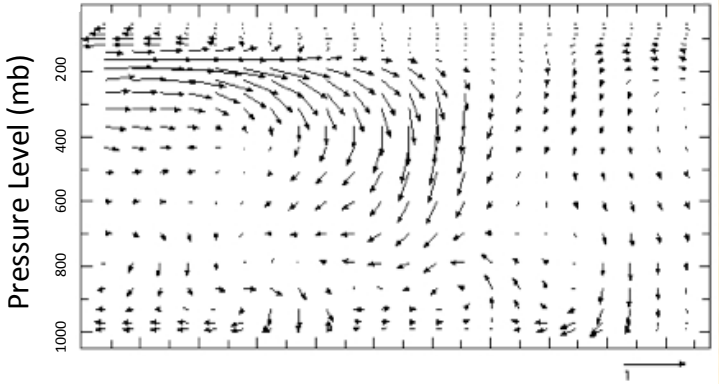
Climatology

Dry-Wet Years

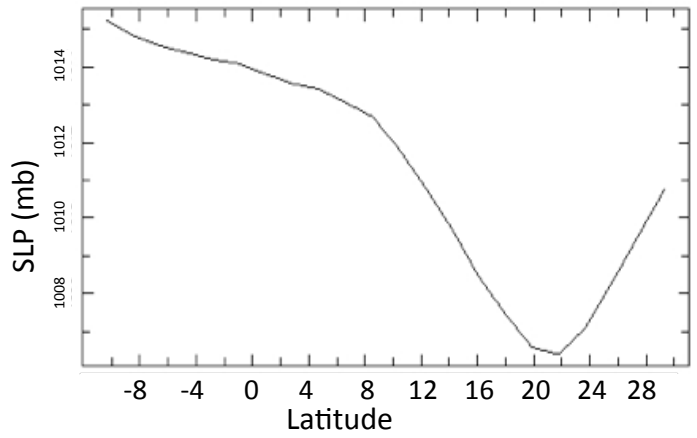


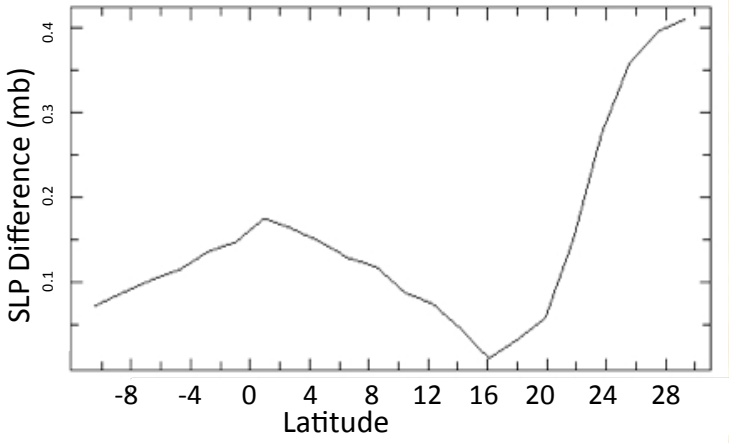




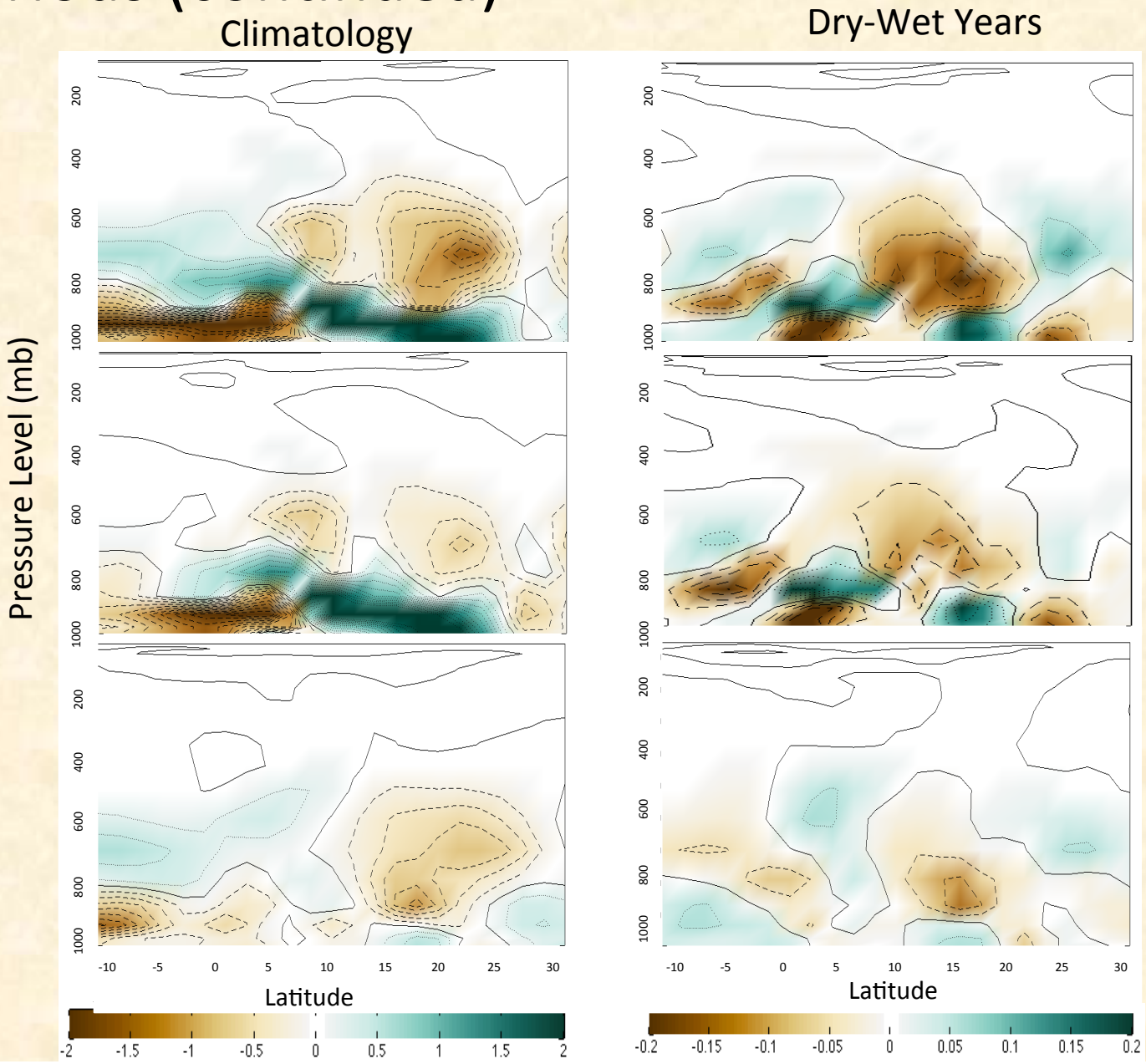


*note ω has been scaled by 10





Moisture Budget and Dynamics in Dry and Wet Periods (continued)



Total Moisture Flux Convergence

Mass Convergence

Specific Humidity Advection

Discussion and Take Away Points

- **Decadal**-scale **variability realistically depicted** by SST-forced CAM4
  - **Confirms** role of **warm Indian** and **meridional temperature gradient** across **Atlantic** in **historic drought**
- **Increased moisture divergence** by the mean flow accounts for most of the drought
  - Some **drying by transients**
- Net **mass convergence** is the dominant term in the **rainbelt**
  - **Advection of specific humidity** sets the **northern margin** of monsoon rains

Questions?

Thanks for your attention!

cpomposi@ldeo.columbia.edu

Pomposi, C., Y. Kushnir, and A. Giannini, 2014. Moisture budget analysis of SST-driven decadal Sahel precipitation variability in the twentieth century. *Climate Dynamics*, **44**, 3303- 3321, doi:10.1007/s00382-014-2382-3