African Climate Change

Photo: Pascal Maitre, National Geographic

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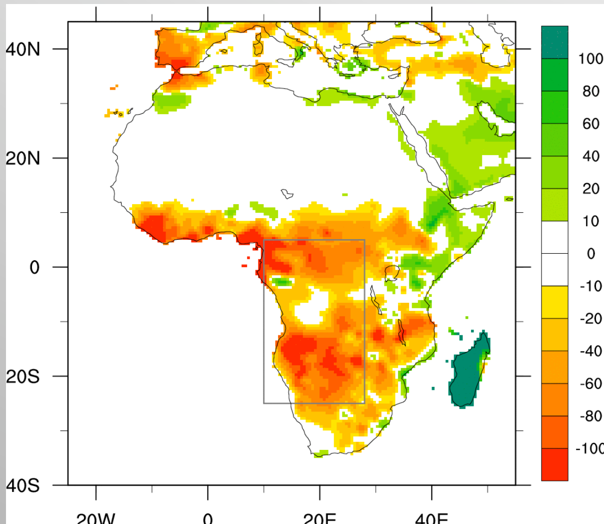
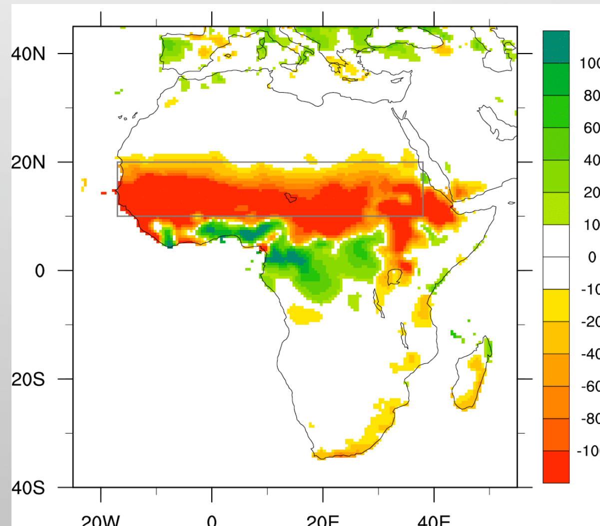
with
Adam Sobel, Alessandra Giannini, and Isaac Held

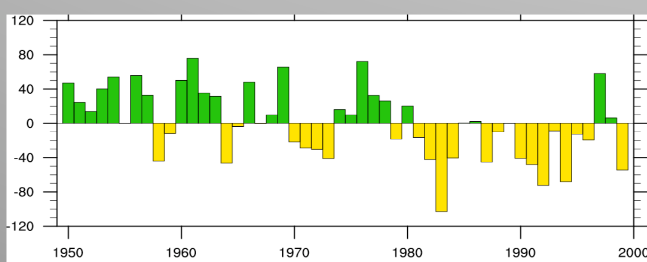
FMA trend ‘50-’99

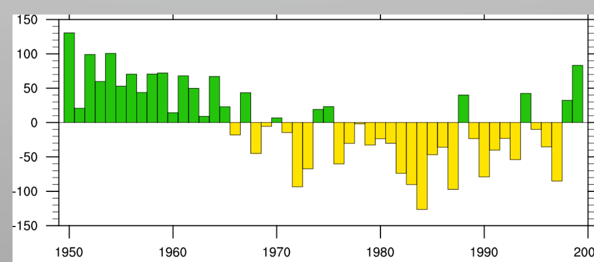


JAS trend ‘50-’99



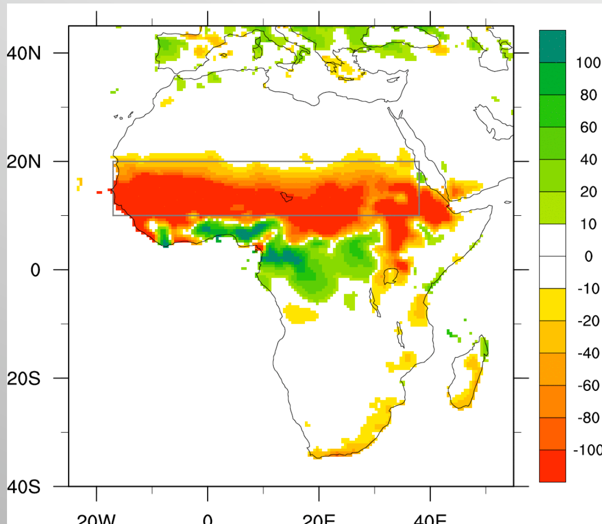
Africa has experienced multi-decadal rainfall trends during the 20th century.

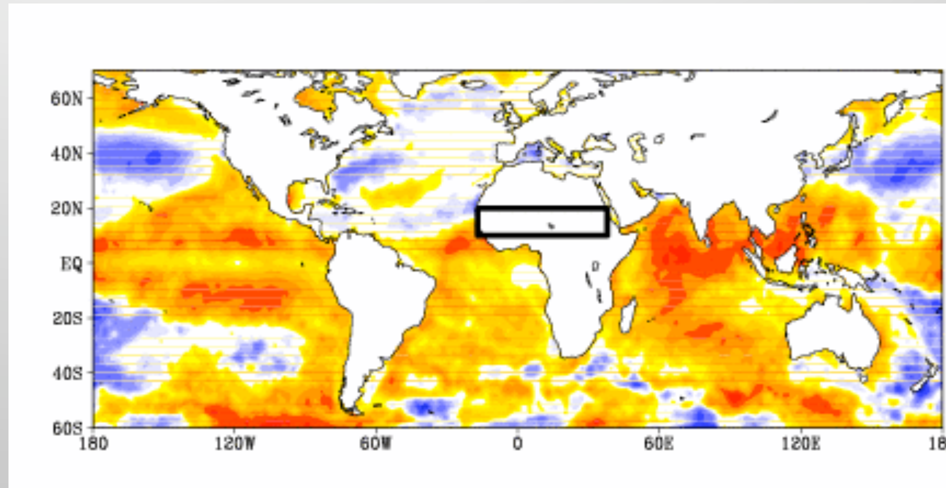


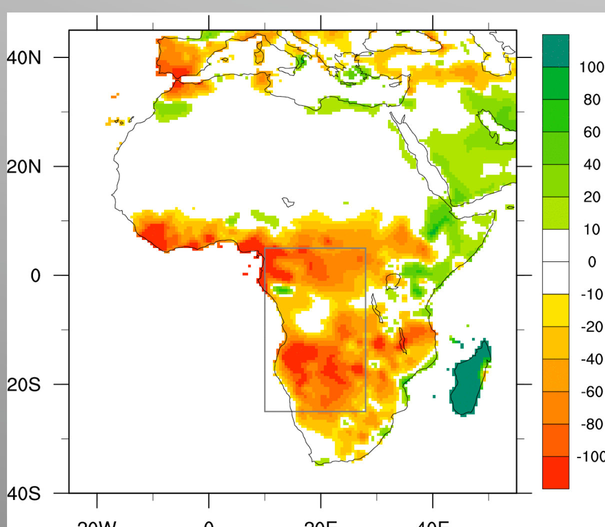


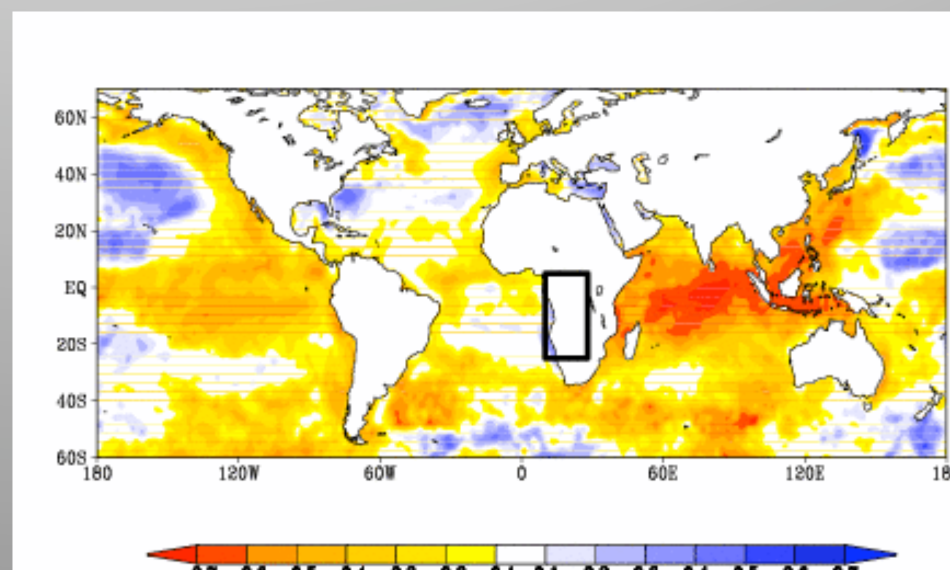
M. Hoerling, J. Hurrell, J. Eischeid, and A. Phillips. Detection and attribution of 20th century northern and southern African rainfall change. J. Climate, 19(16):3989–4008, 2006.

Global SST trends drove the observed 20th Century African rainfall trends (inference from OBS & AGCMs).









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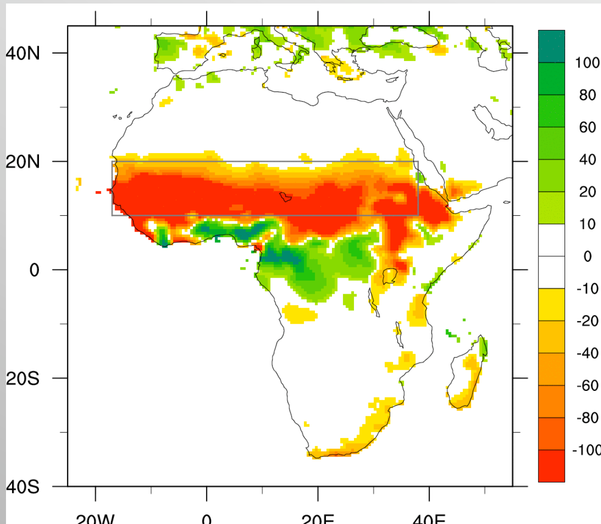
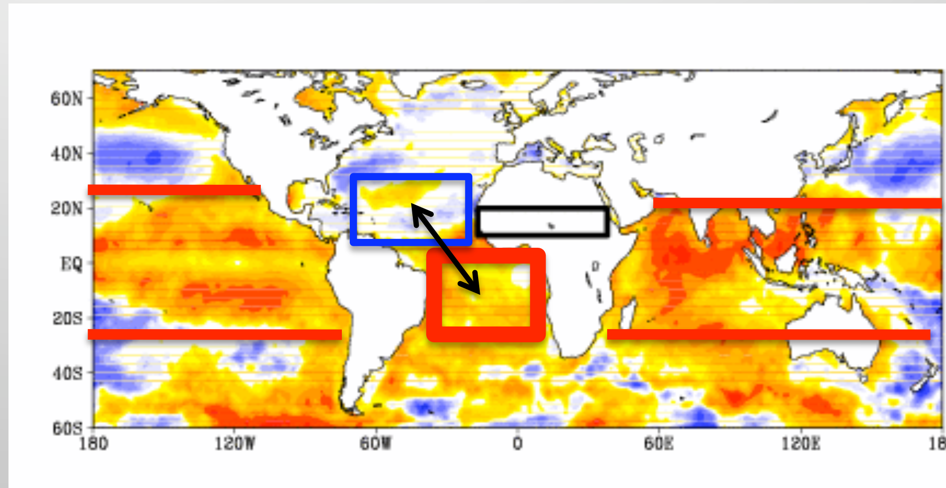
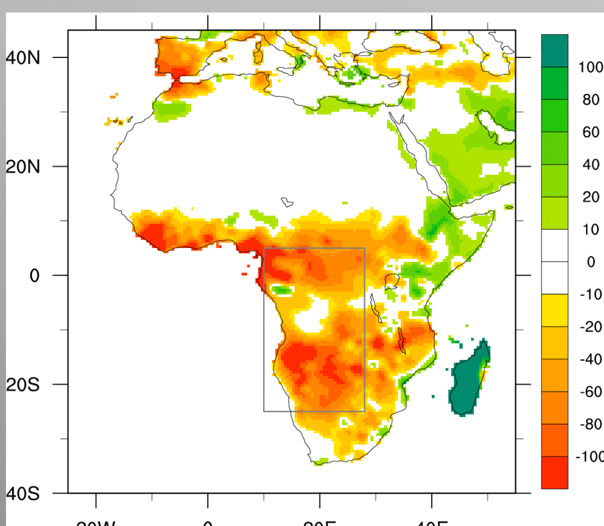
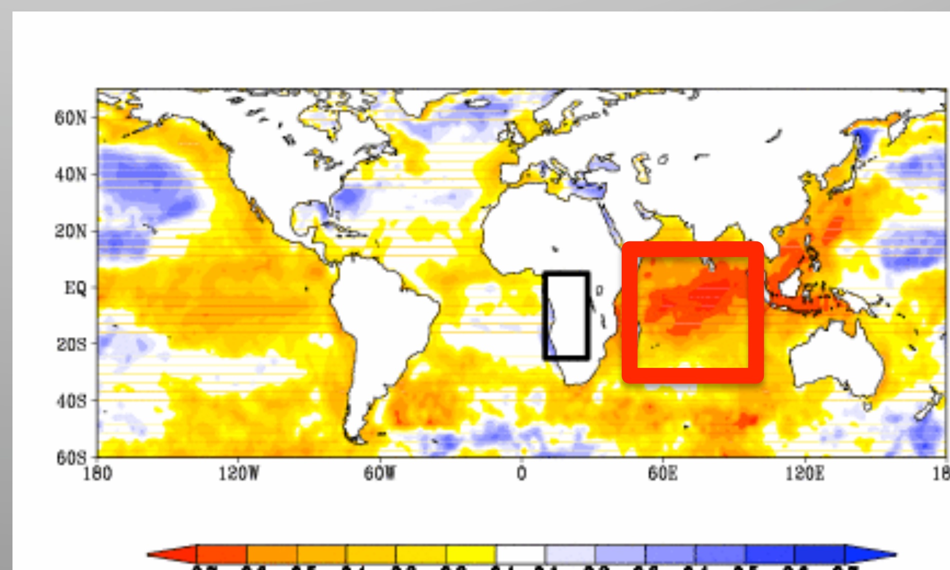
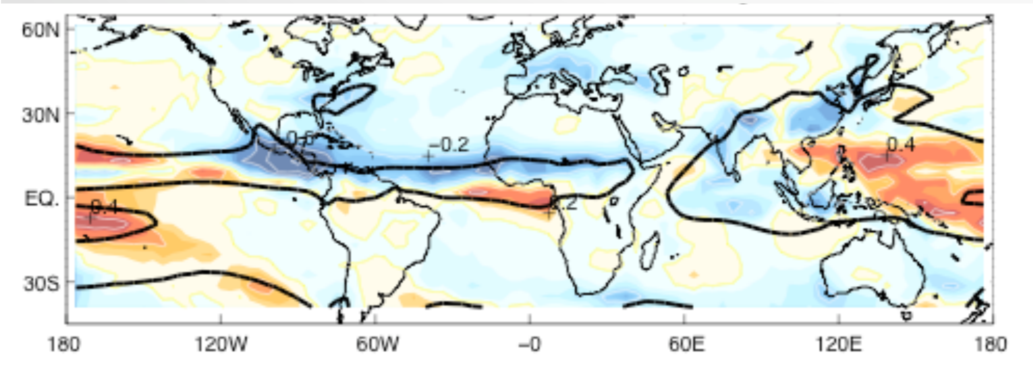


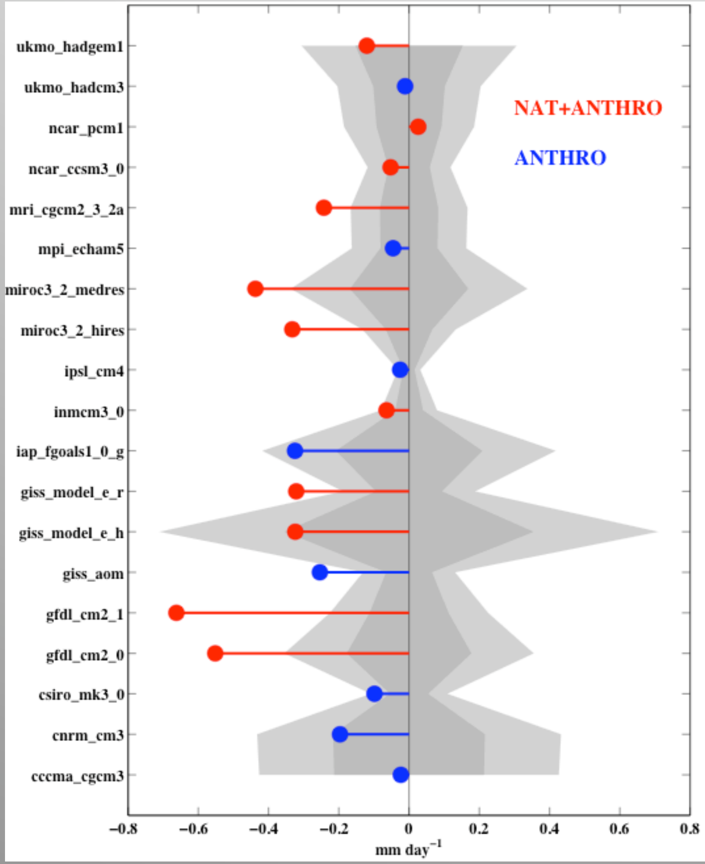






CMIP3: 20C – Pre-Industrial Precipitation



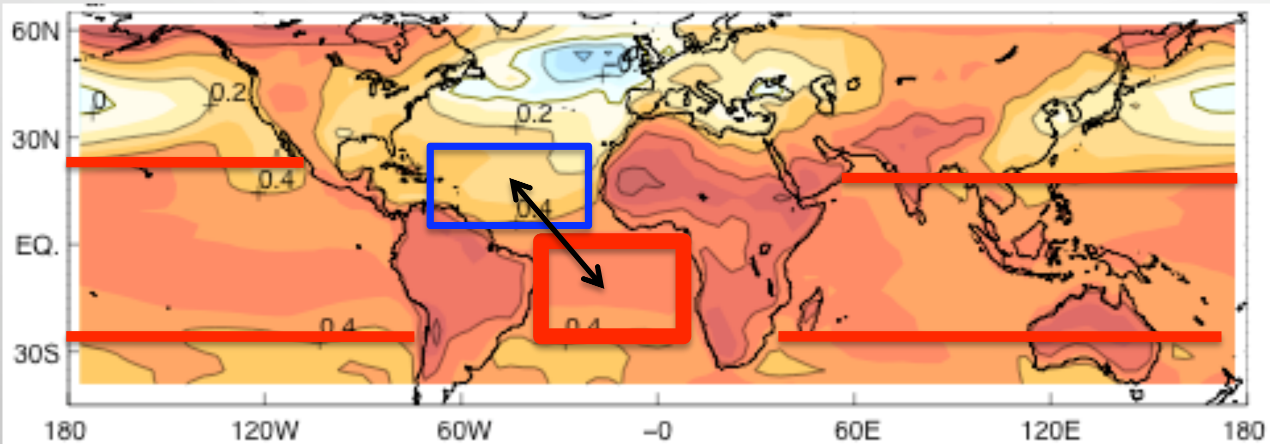


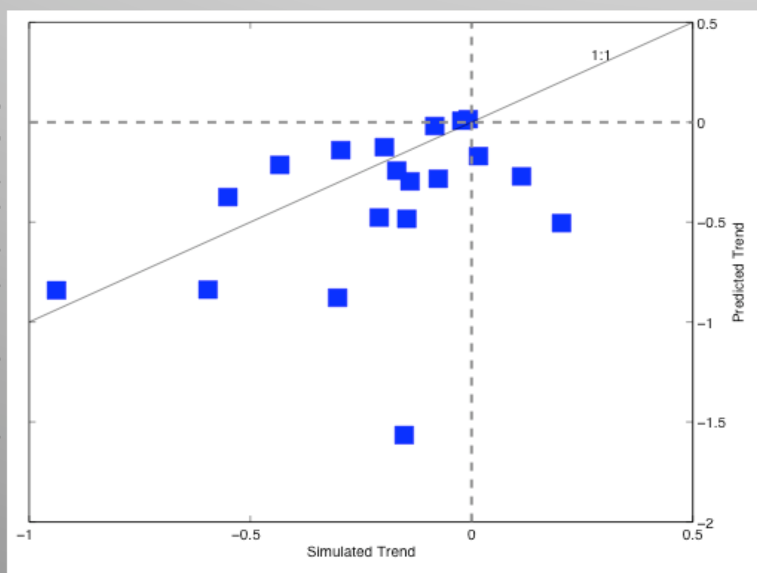
Coupled models (CMIP3) forced by 20th Century forcing reproduce a drought in the Sahel, albeit weaker than observed (~30%).

20th century summer rainfall minus pre-industrial in each CMIP3 model

M. Biasutti and A. Giannini. Robust Sahel drying in response to late 20th century forcings. Geophys. Res. Lett., 2006.

CMIP3: 20C – Pre-Industrial Surface Temperature



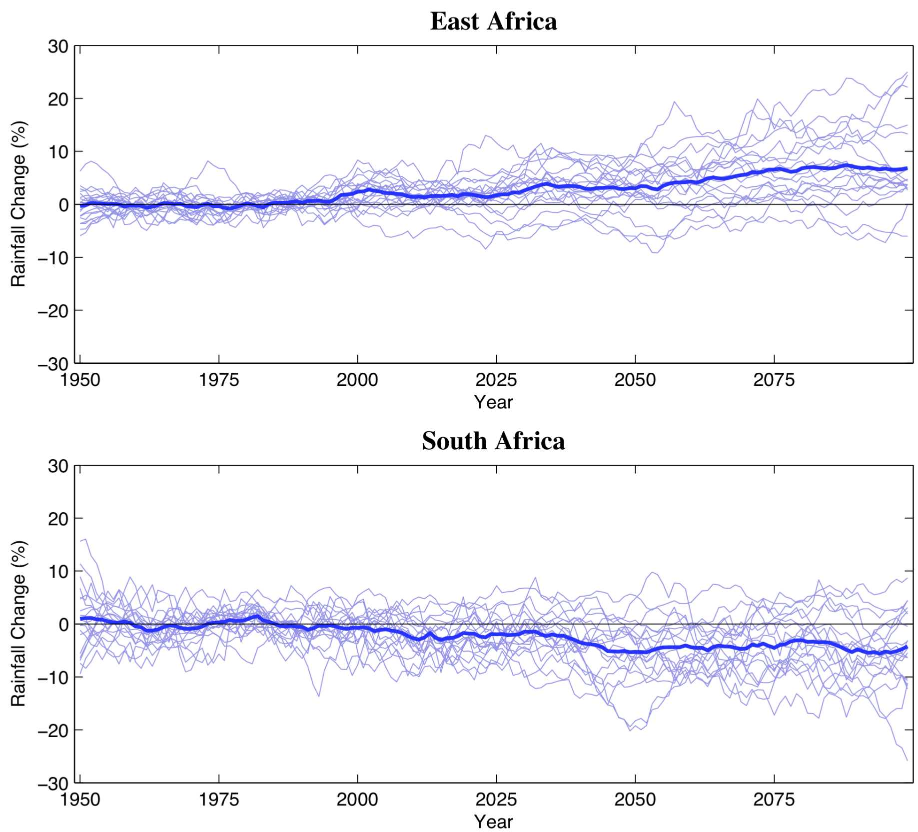


Linearly predicted from simulated SST

Simulated by CGCMs

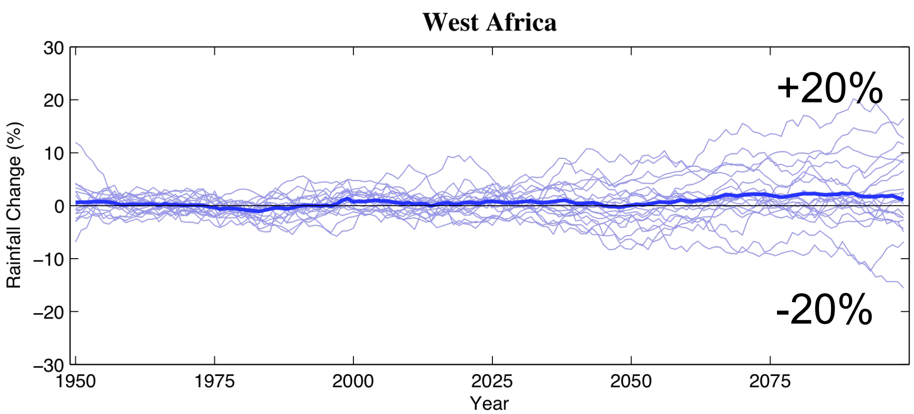
The simulated 20th Century Sahel drought can be reproduced by a linear combination of the trends in Indo-Pacific SST and in Tropical Atlantic SST gradient.

The rainfall/SST regression is obtained from interannual variability in each model.



The CMIP3 coupled models extend to the 21st Century the 20th Century trends in East Africa and in South Africa (consistent with the role of Indian Ocean warming).

A. Giannini, M. Biasutti, A. H. Sobel, and I. M. Held. A global perspective on African climate. Climatic Change, 90:359–383, 2008.



In West Africa and the Sahel, the 20th Century trend does not continue into the 21st Century.

Projections are uncertain and de-coupled from SST projections.

A. Giannini, M. Biasutti, A. H. Sobel, and I. M. Held. A global perspective on African climate. Climatic Change, 90:359–383, 2008.

The lack of robustness in projections of seasonal total Sahel rainfall is a major weakness in the projections.

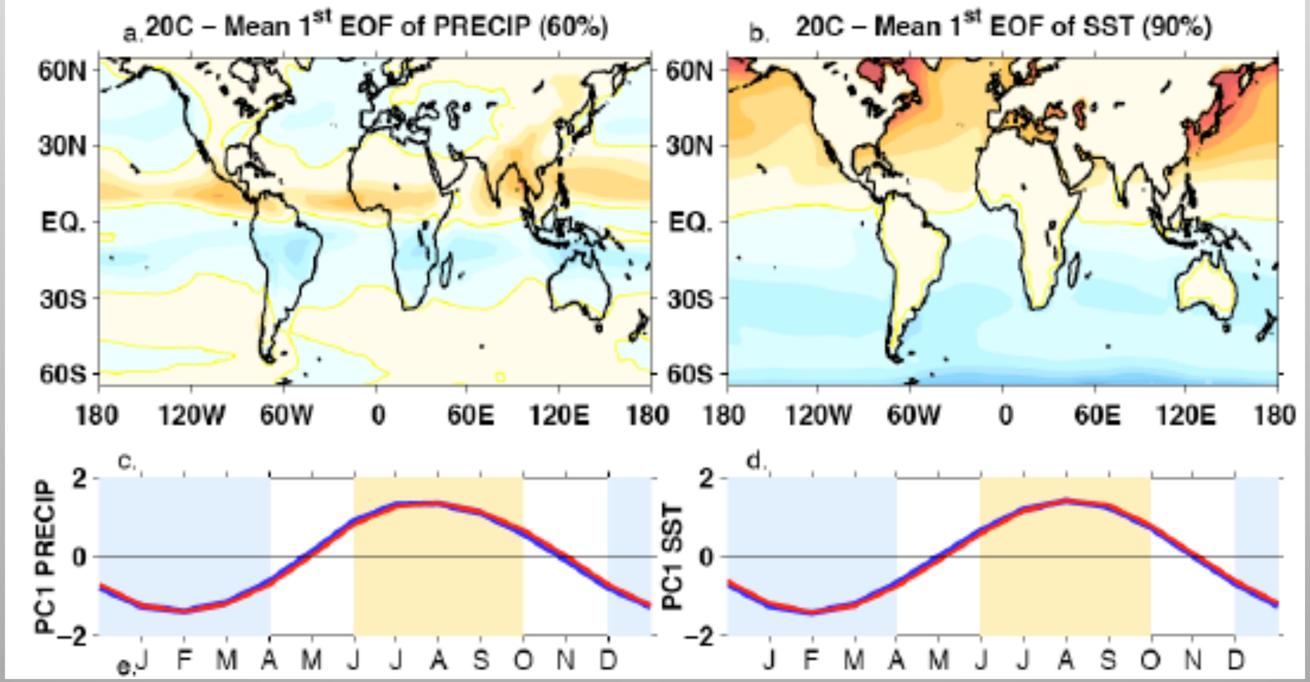
It turns out that there is a robust signal in Sahel rainfall projections, but it is in the timing and length of the rainy season, rather than the total rainfall for a fixed season.

This change in seasonality is not just a regional phenomenon over the Sahel, but is global.

The first EOF/PC pairs of the climatological rainfall and SST capture the seasonal cycle.

20th Century CMIP3 ensemble mean

precip



SST

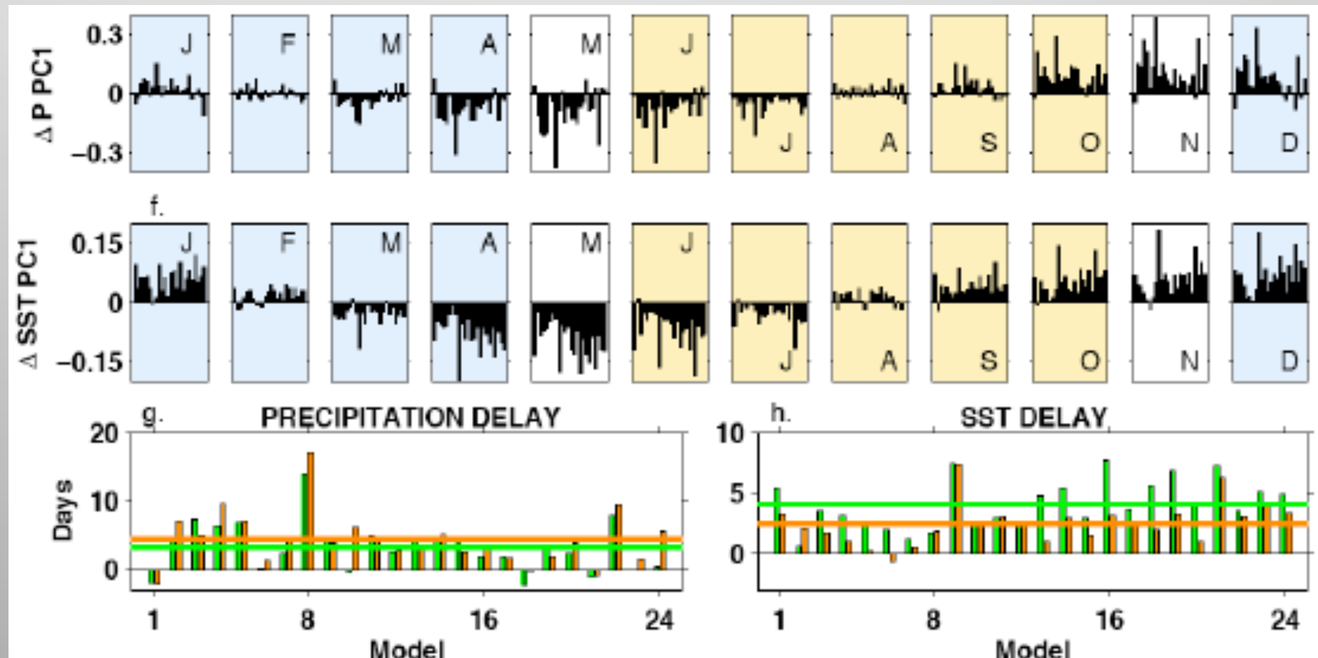
The seasonal cycle, as captured by the first EOF, shifts later as the climate warms

21C-20C change in first EOF of precipitation and SST for each month and each model, A1B

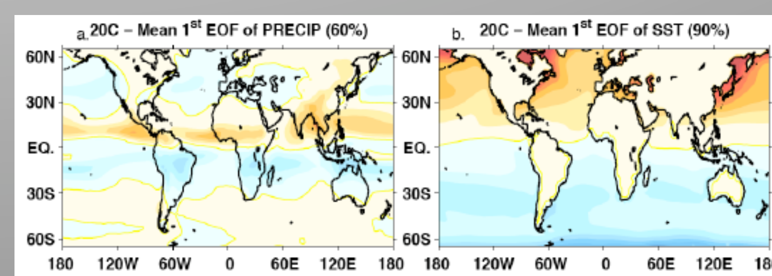
precip

SST

Delay in timing of zero crossing



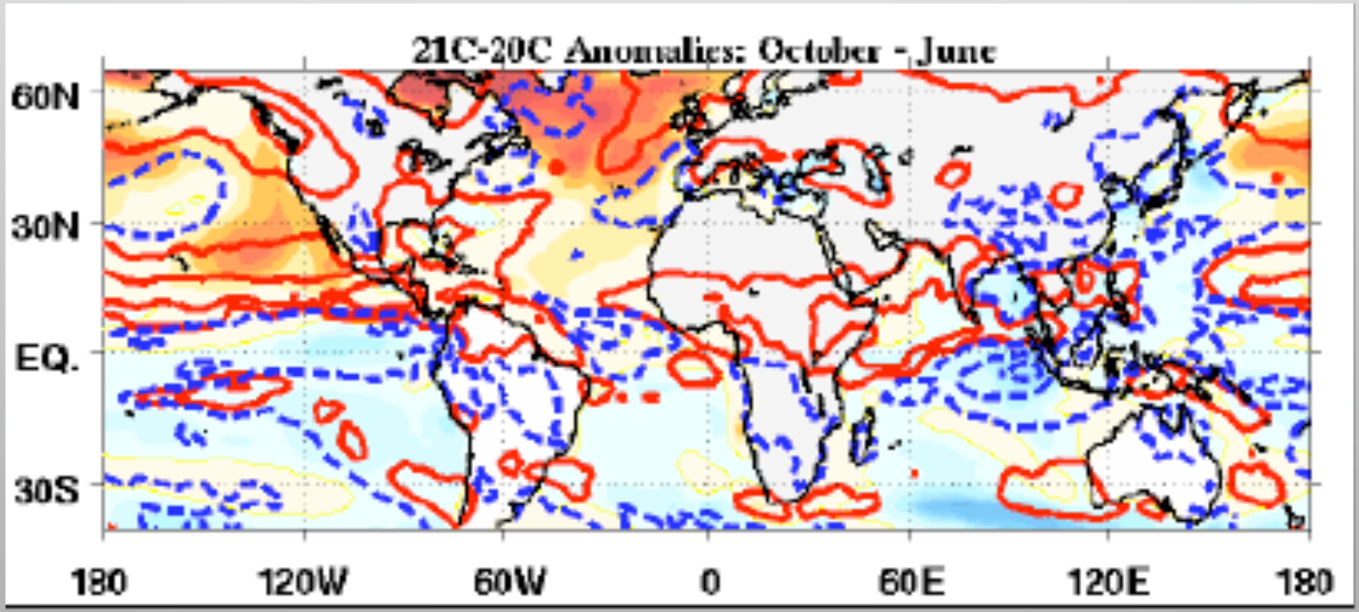
Reminder of EOF structure



Precipitation

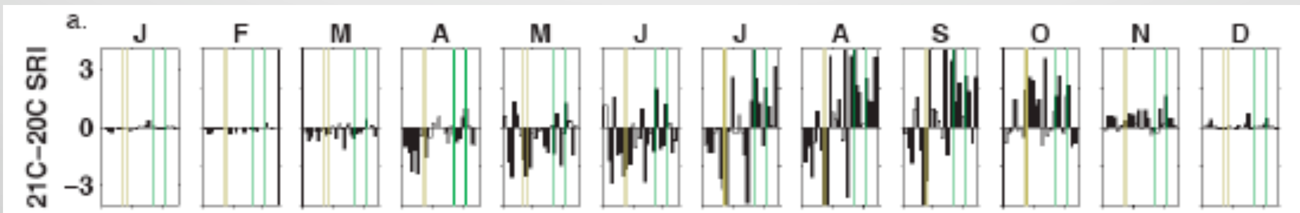
SST

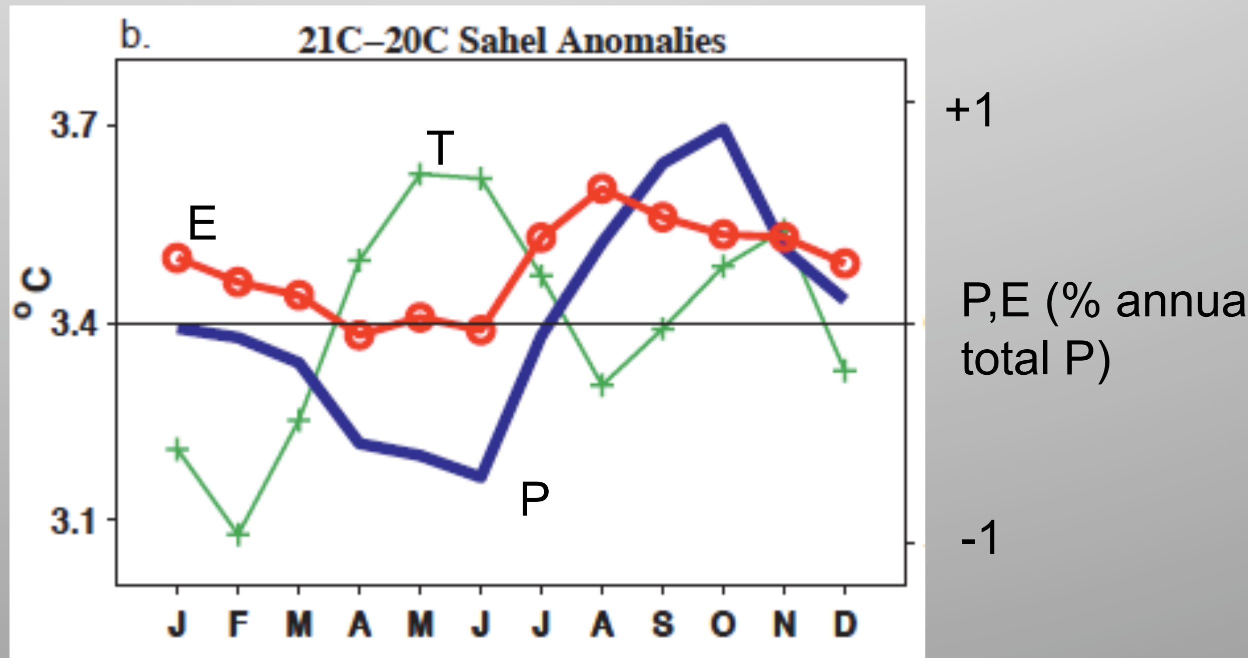
Global structure of delay: strong in E. Pacific & Caribbean, Africa & Indian Ocean; not clear (or opposite sign) in East and Southeast Asia



October-June 21C-20C anomalies in SST (colors) and precipitation (contours); CMIP3 ensemble mean

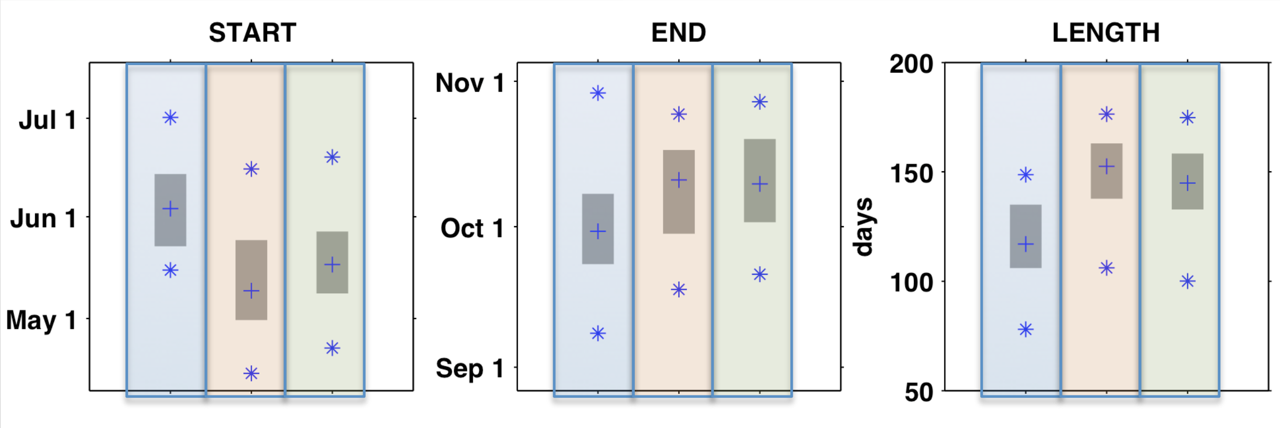
The early rainy season gets dryer (and hotter) and the late rainy season gets wetter





Ensemble mean in precipitation, evaporation, surface T

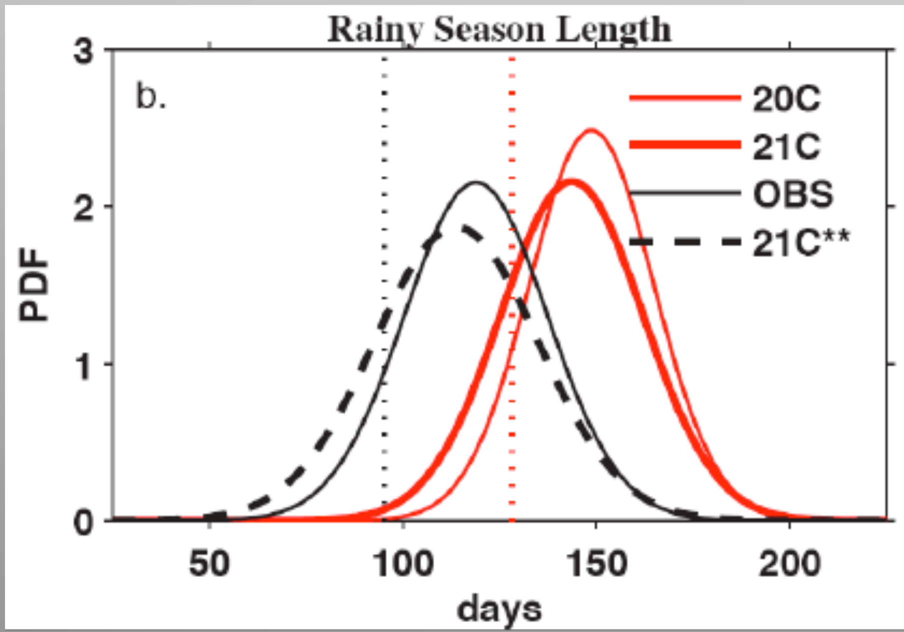
The end of the rainy season shifts less than the beginning: the rainy season gets shorter (by ~5days).



OBS

20C

21C

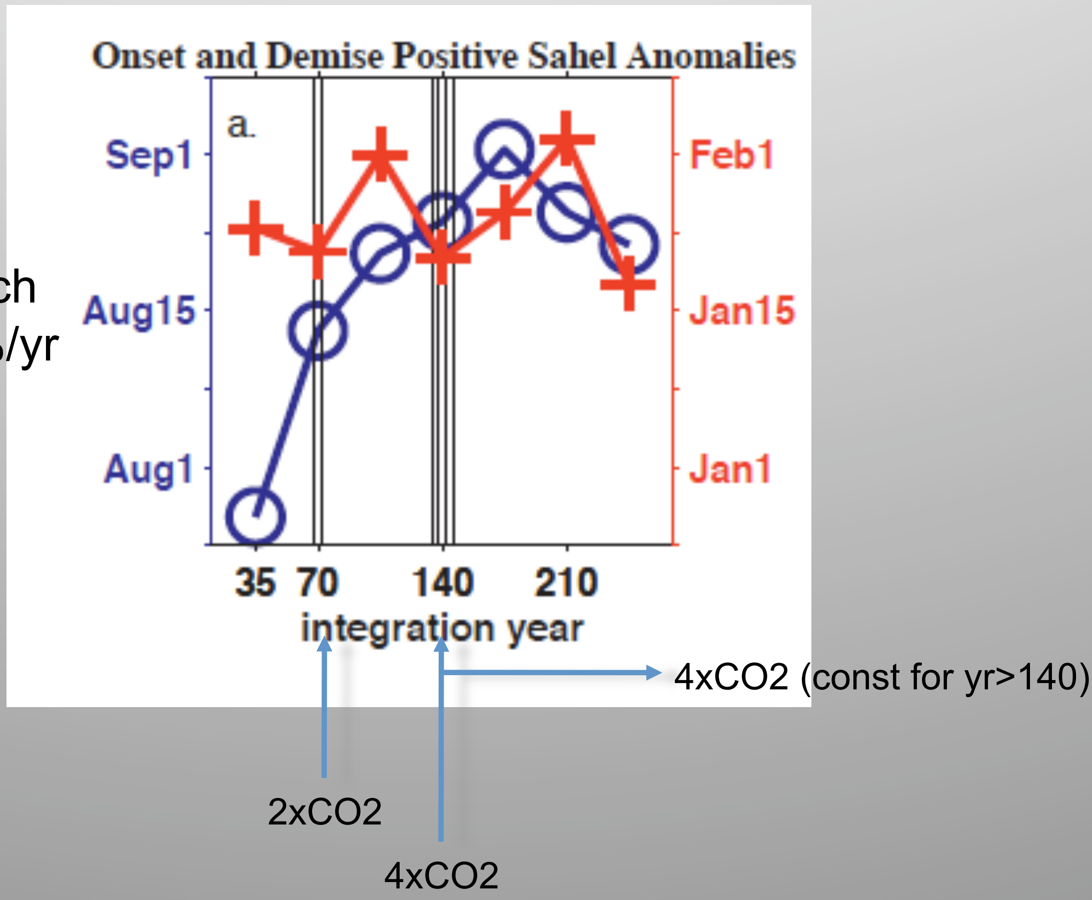


A "1 in 10 years event" becomes twice as frequent.

21C** is computed by applying simulated changes in mean & stdev to observed PDF (bias correction)

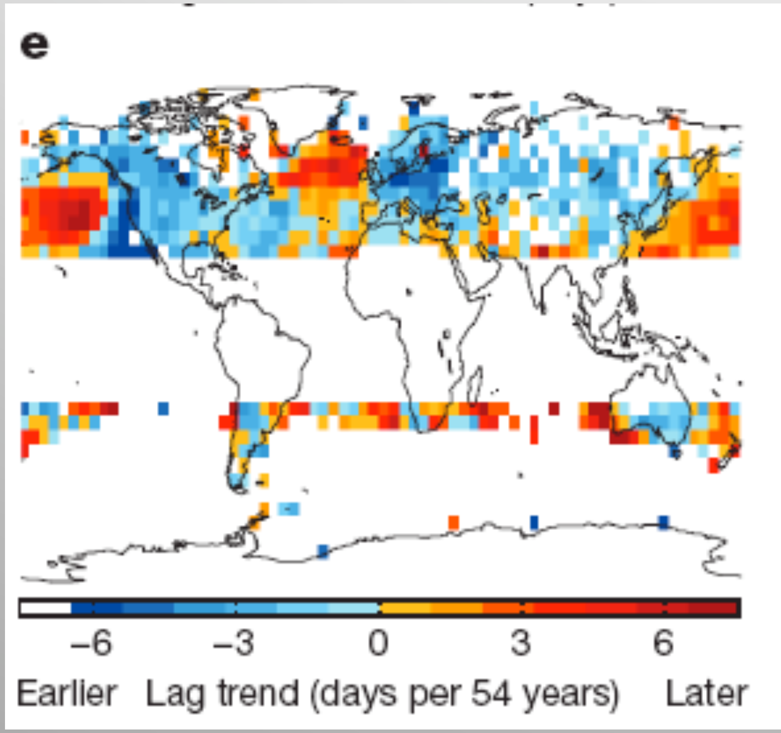
The length of the rainy season is a function of CO_2: onset of positive P anomalies gets later and later as CO_2 concentrations grow (the demise date does not change).

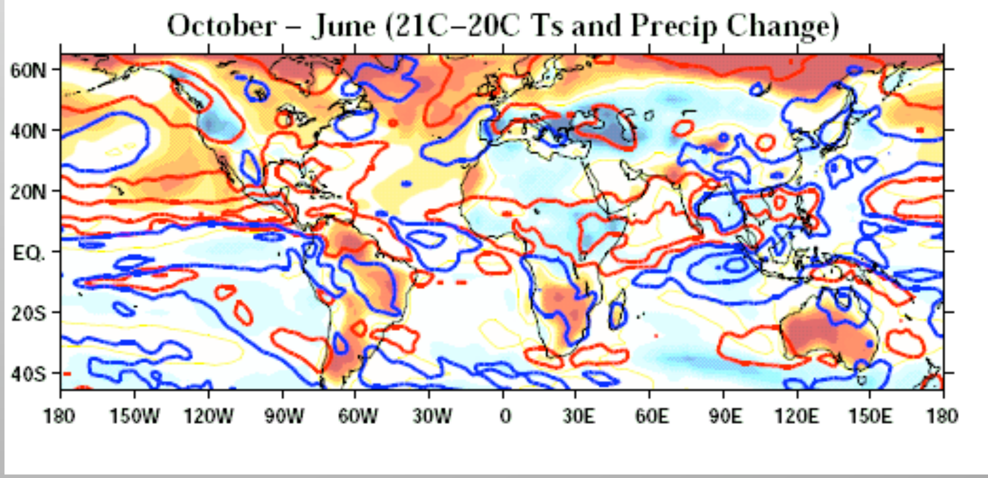
IPCC scenario in which CO2 increases by 1%/yr until 4x present



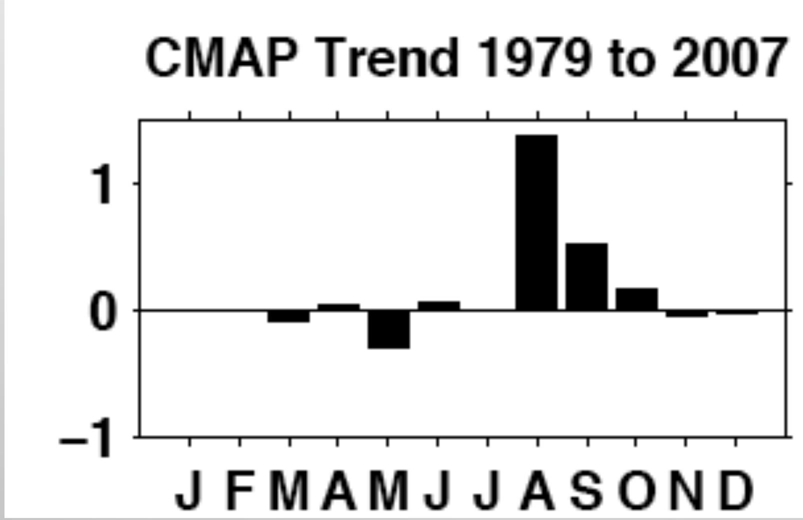
The comparison with 20C temperature observations is inconclusive:

Stine et al. (2009) find shift toward *earlier* seasons in observations

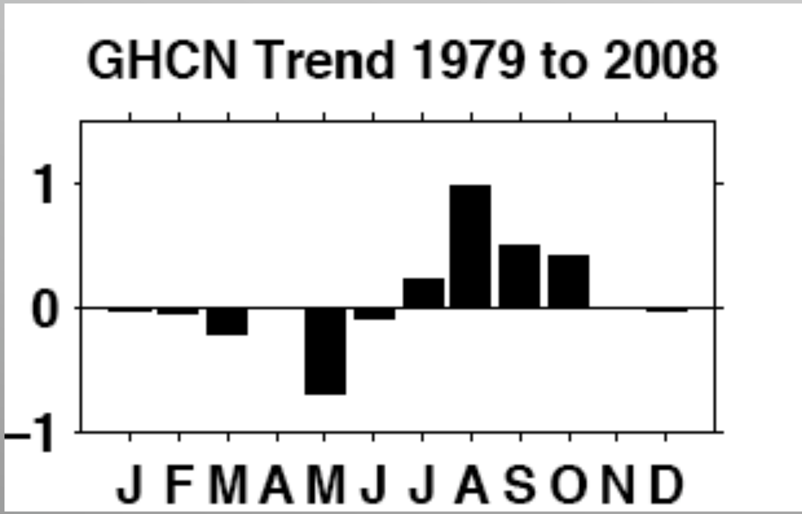




But: the shift we find towards *later* is largest over ocean; Stine et al.'s advance is over land; and there are significant areas of agreement (e.g. N. Atlantic)



The 21st Century shift in the timing of the Sahel rainy season might be emerging in the most recent decades.

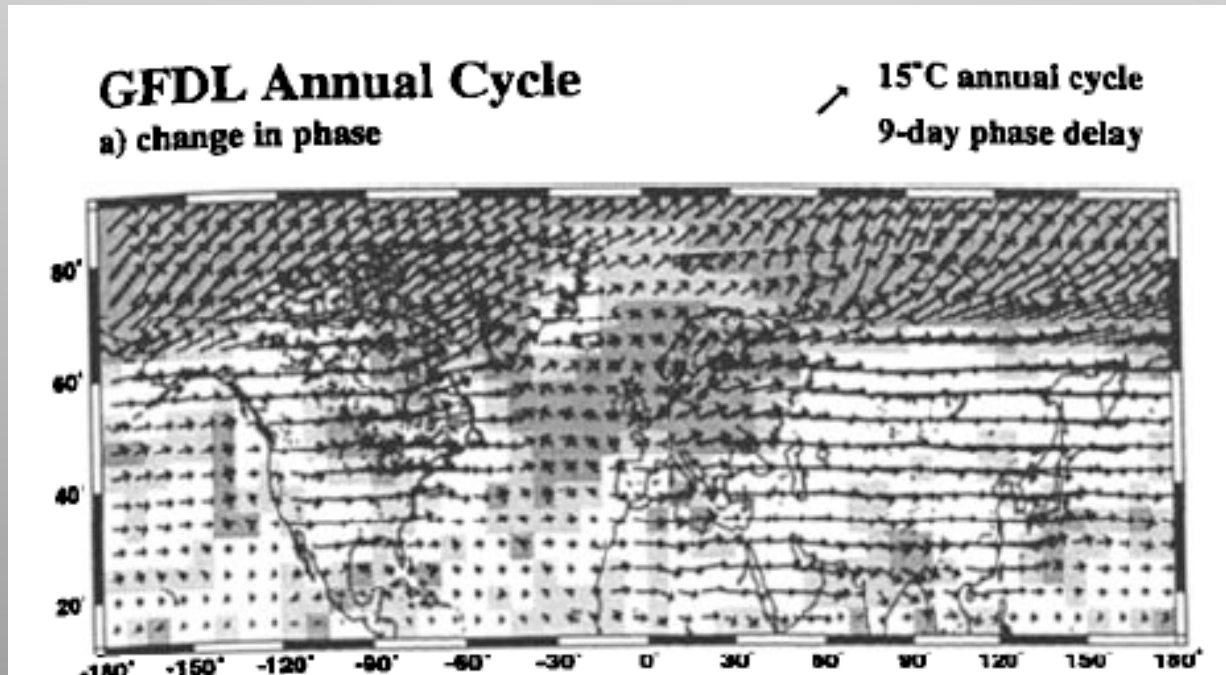


The mechanism of the delay is not known. Mann and Park (1996) found the same behaviour in earlier models and attributed it to loss of sea ice (which leads to larger effective high-latitude surface heat capacity)

Greenhouse warming and changes in the seasonal cycle of temperature: Model versus observations

Michael E. Mann and Jeffrey Park

Department of Geology and Geophysics, Yale University, New Haven, Connecticut



Delay in mid-latitude surface temperature under CO_2 doubling

Conclusions

- 20th Century Sahel drought is partly reproduced by models forced with anthropogenic GHGs and sulphate aerosols.
- The response to 21st Century forcing is a delay and shortening of the rainy season. Summertime anomalies remain uncertain.

- IPCC AR4 projections show an increasing delay in the global seasonal cycle of SST and precipitation as the climate warms in response to GHGs.
- The delay is robust across models and affects the rainy season of several tropical regions (e.g. Sahel, Caribbean, South America).
- The mechanism is unknown, though we have some ideas (sea ice).