The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1945-5

Conference on African Drought: Observations, Modeling, Predictability, Impacts

2 - 6 June 2008

Oceanic forcing of Sahel rainfall

Alessandra Giannini

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Conference on African Drought at the Abdus Salam ICTP
Trieste, Italy, 2 June 2008

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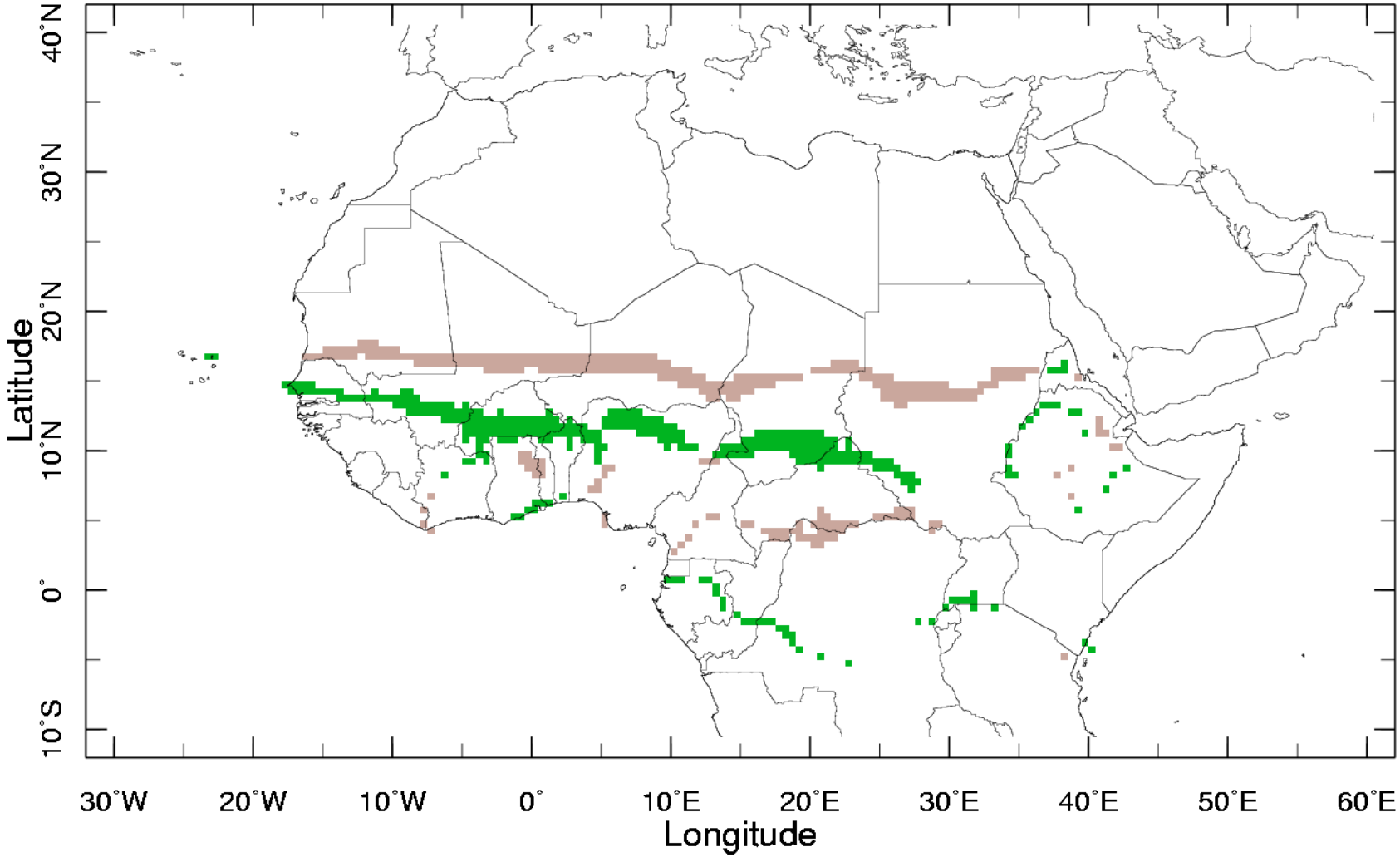
Framework for oceans forcing drought (as opposed to land)

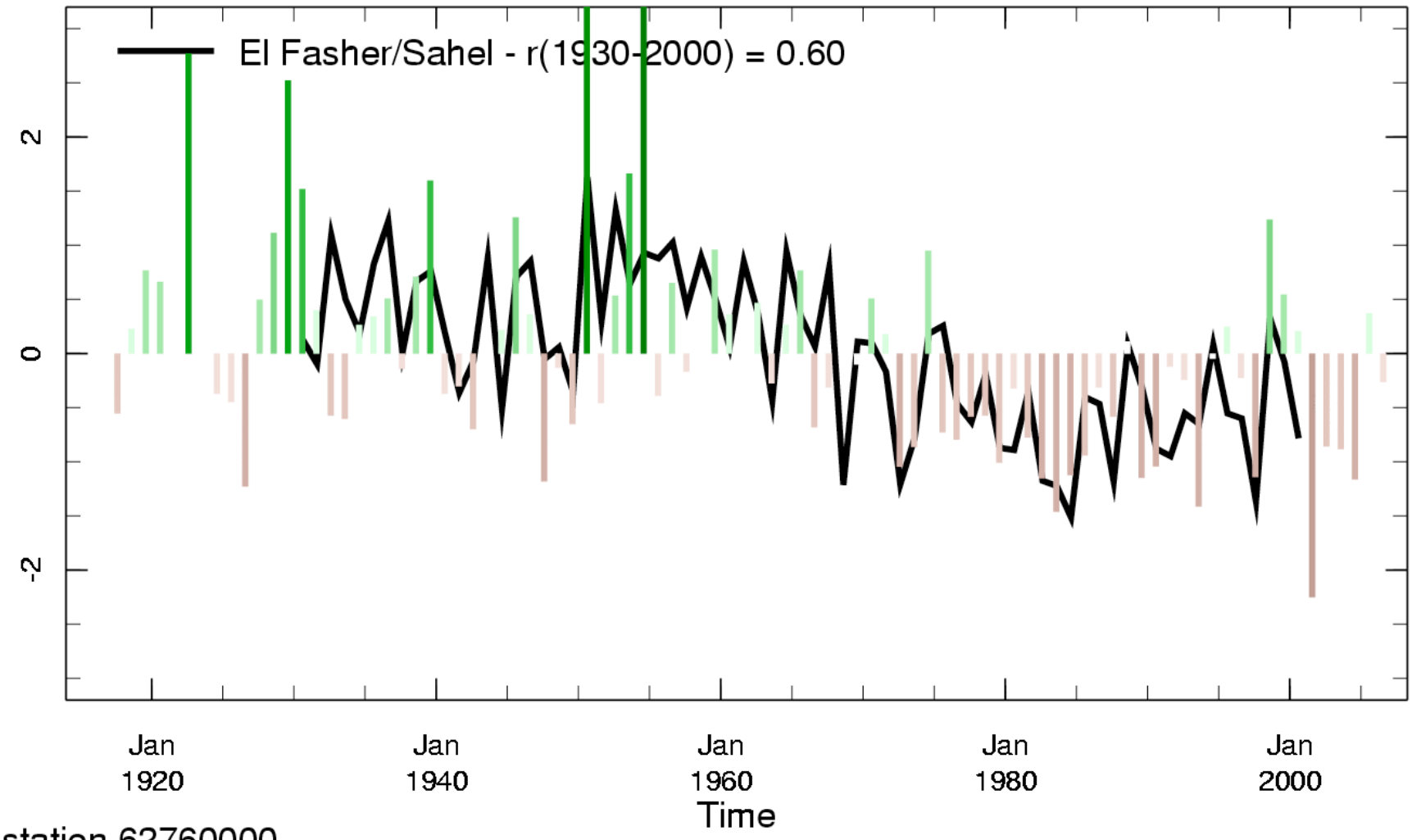
Oceans trigger drought
Land surface reacts in a positive feedback:

- naturally reinforcing the drought
- what anthropogenic contribution from desertification?

… a modeling perspective



1980s v. 1950s: 200-600 mm (July-September totals)
(New et al. precipitation data, UEA/CRU)



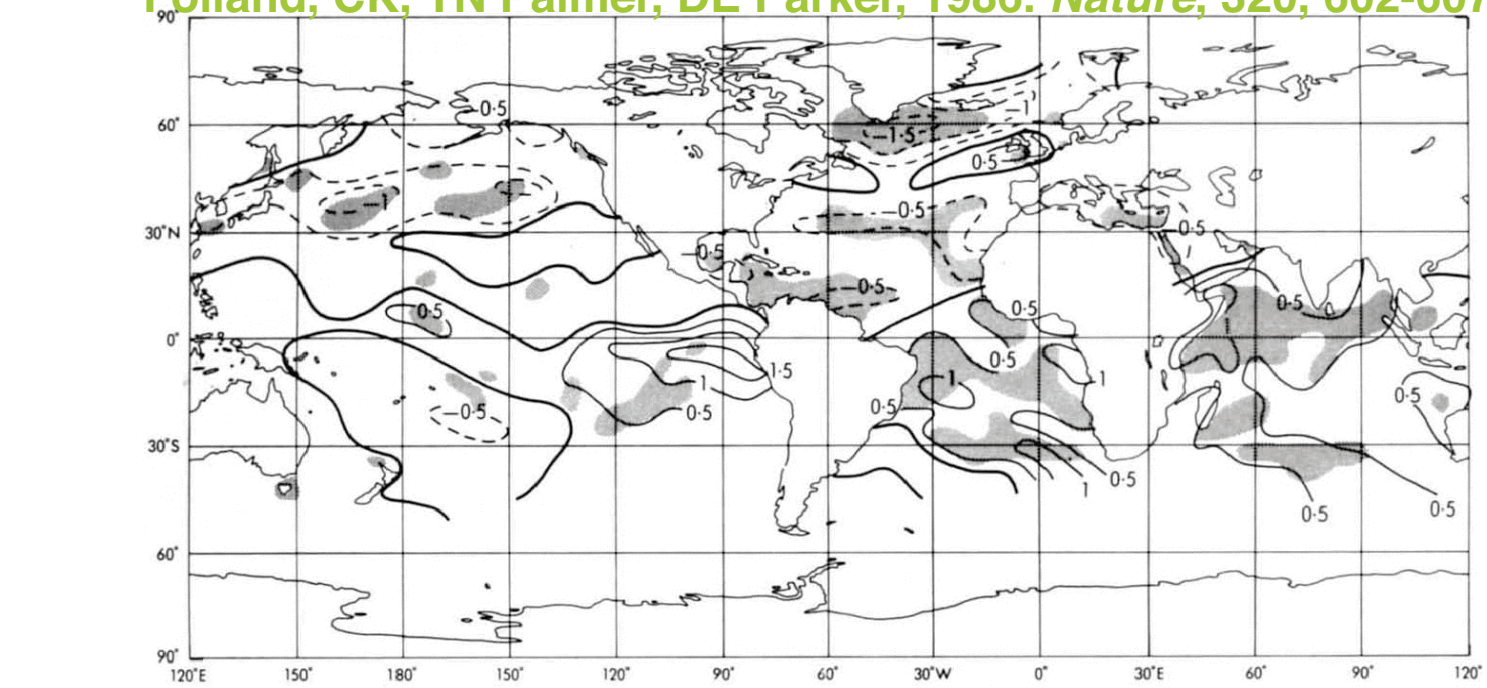
ev 1. station 62760000

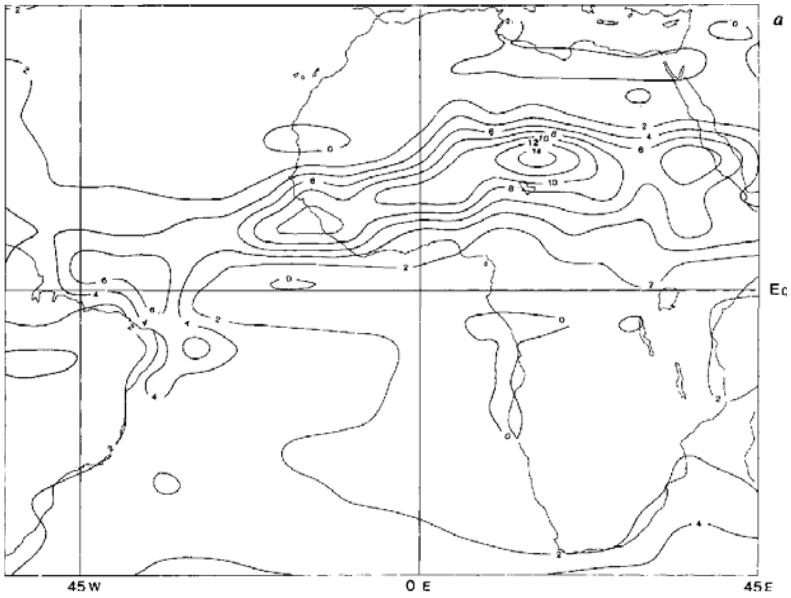
El Fasher long-term mean = 255 mm/year
El Fasher standard deviation = 35 mm/month
Sahel standard deviation = 22 mm/month

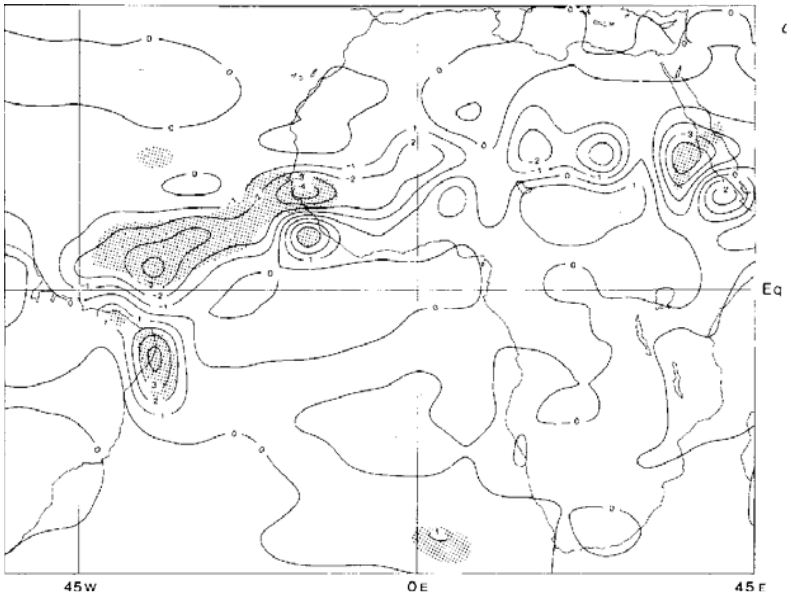
Oceanic forcing of Sahel drought:

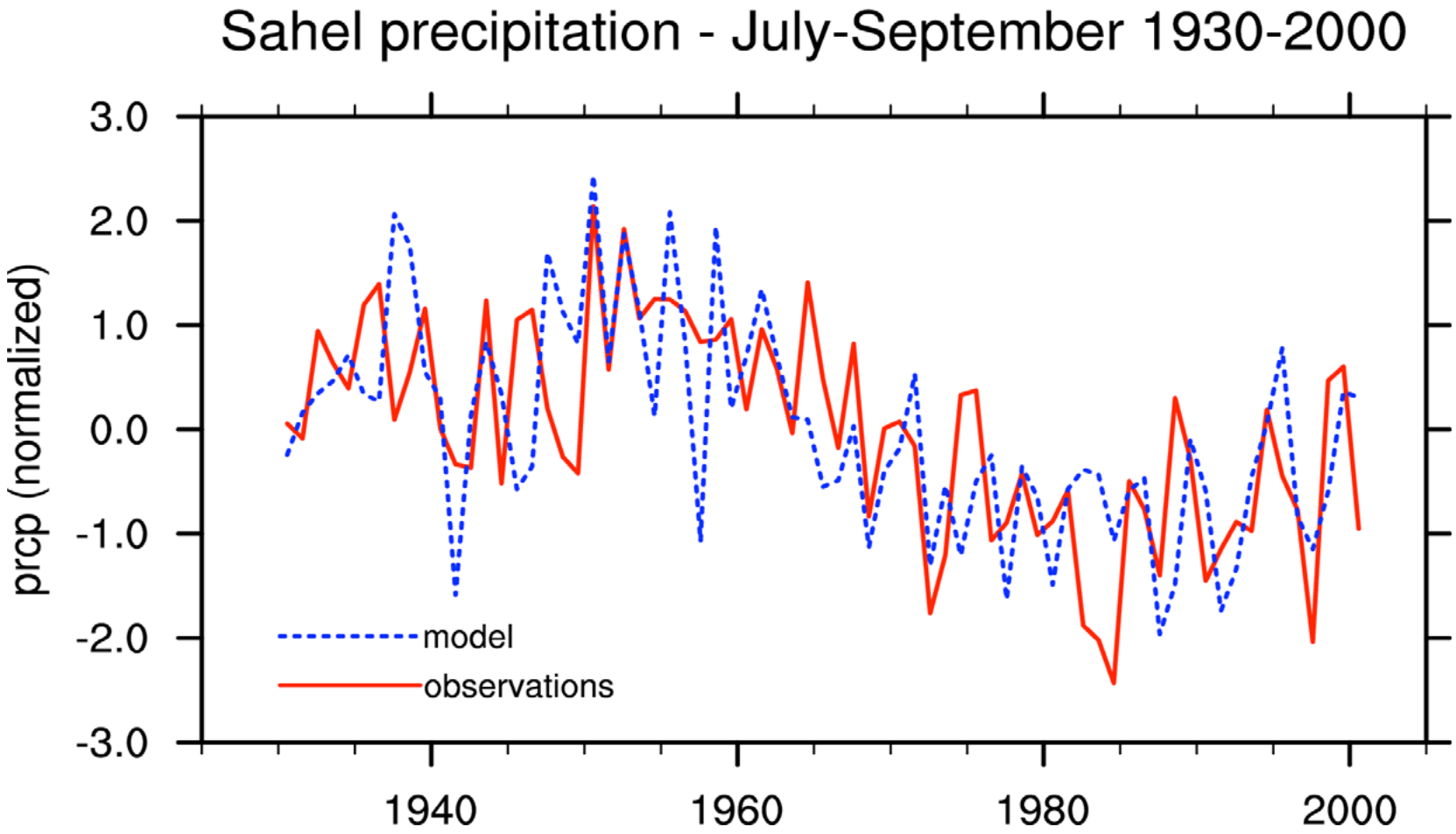
Folland, CK, TN Palmer, DE Parker, 1986. Sahel rainfall and worldwide sea temperatures, 1901-85. *Nature*, **320**, 602-607.
Giannini, A, R Saravanan, P Chang, 2003. Oceanic forcing of Sahel rainfall on interannual to interdecadal time scales. *Science*, **302**, 1027-1030.
Bader, J, M Latif, 2003. The impact of decadal-scale Indian Ocean sea surface temperature anomalies on Sahelian rainfall and the North Atlantic Oscillation. *Geophys. Res. Lett.*, **30**, doi:10.1029/2003GL018426.
Lu, J, TL Delworth, 2005. Oceanic forcing of the late 20th century Sahel drought. *Geophys. Res. Lett.*, **32**, doi:10.1029/2005GL023316.

Folland, CK, TN Palmer, DE Parker, 1986. *Nature*, 320, 602-607









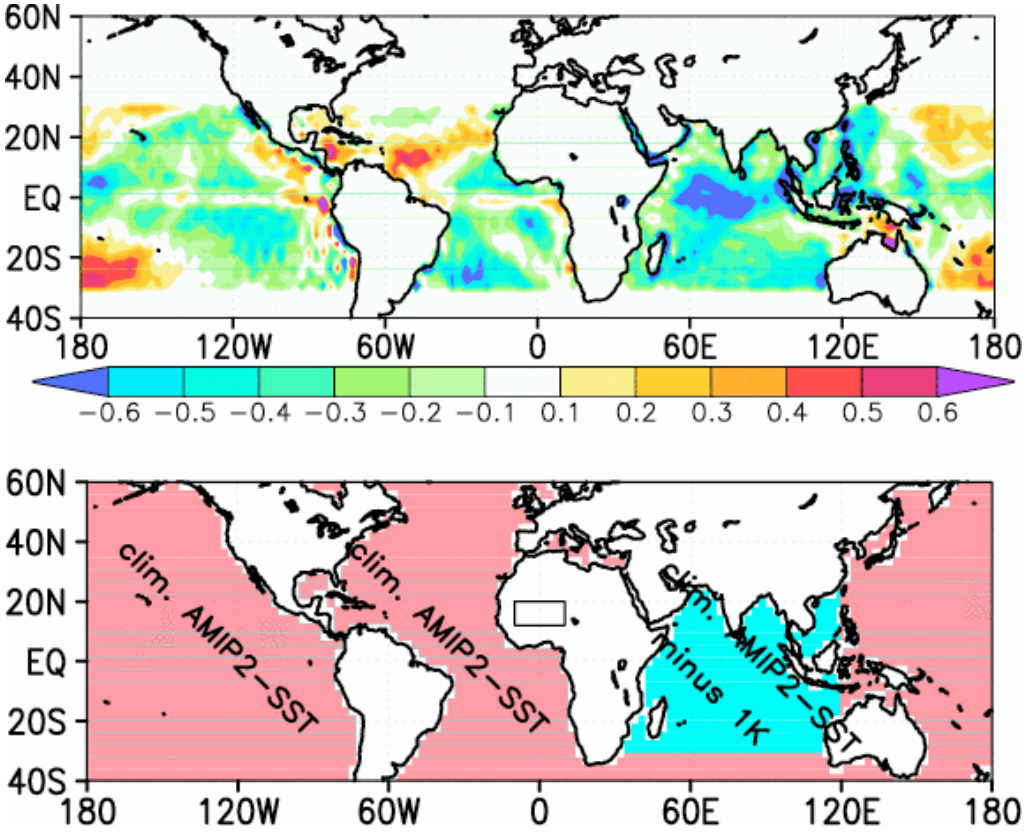
$r = 0.60$

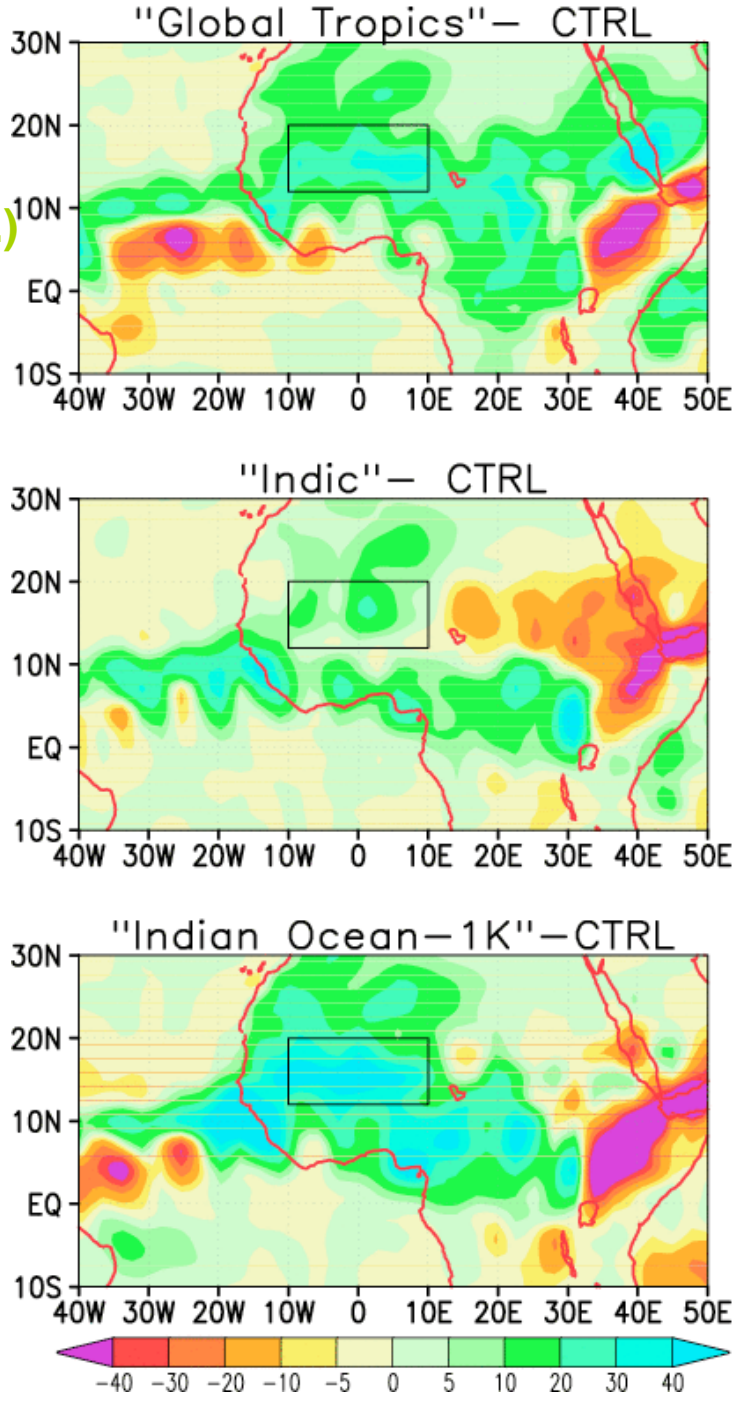
Giannini, A, R Saravanan, P Chang, 2003. *Science*, 320, 1027-1030

The role of Indian Ocean SSTs

20 years of cold SST minus climatology

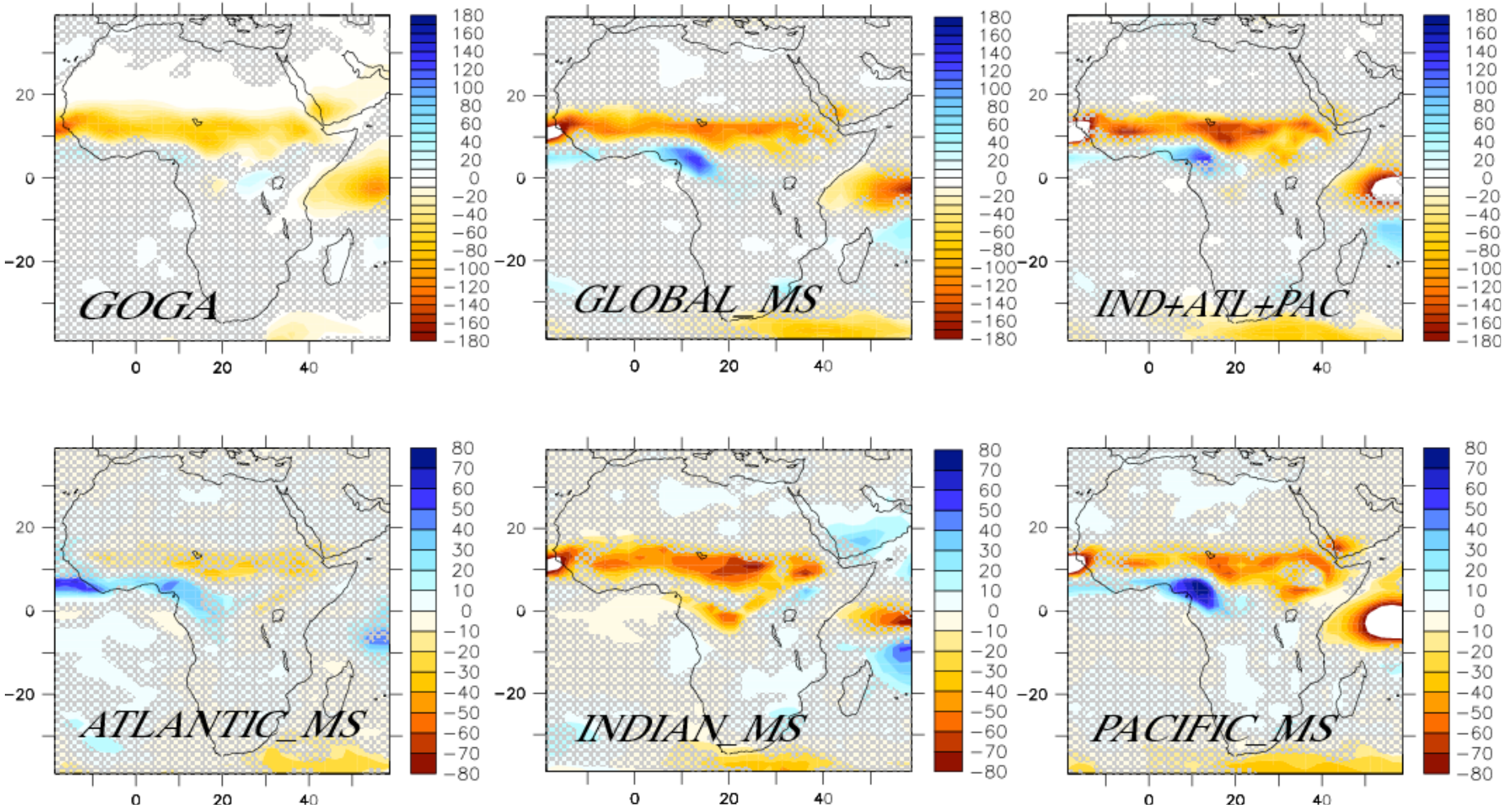
Bader, J and M Latif, 2003 (Geophys. Res. Lett.)





The relative roles of the Atlantic, Indian and Pacific Oceans

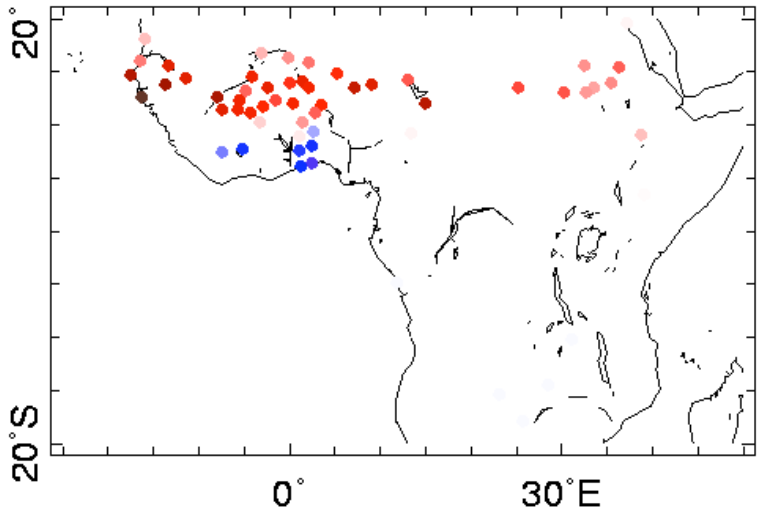
Lu, J and TL Delworth, 2005 (Geophys. Res. Lett.)

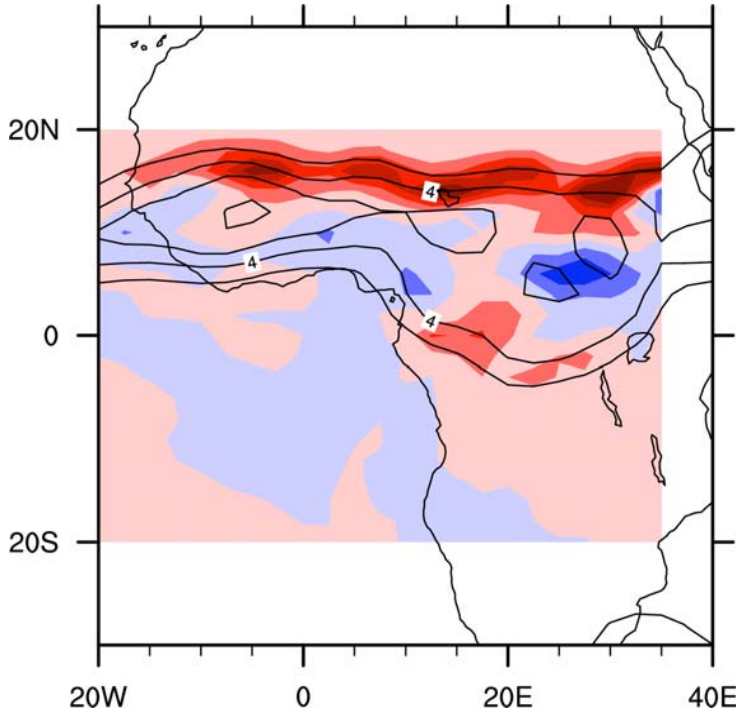


Spatio-temporal patterns and dynamics

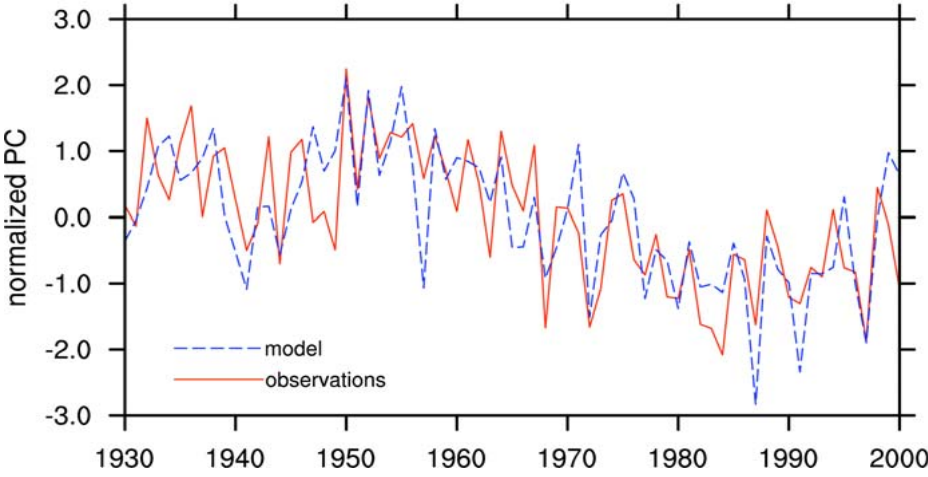
Variability in Sahel rainfall

(25% in obs, 21% in ens-mean)

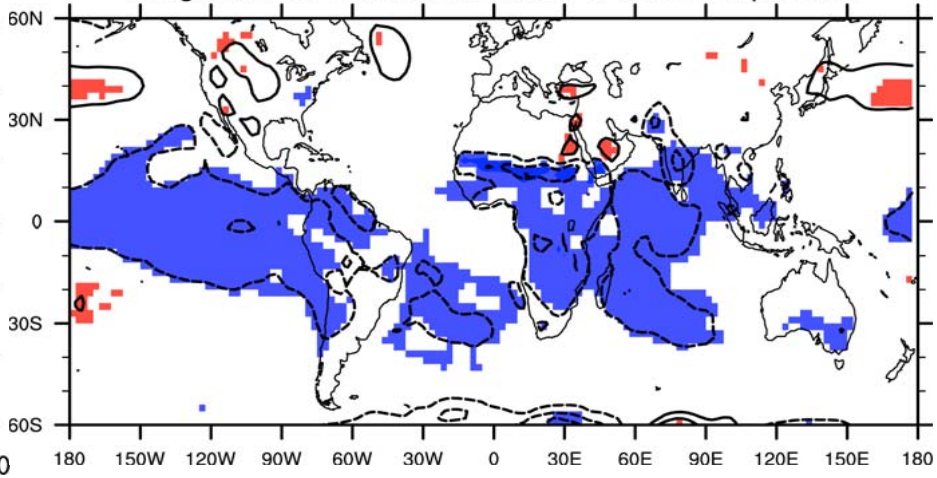




e. Sahel PC of 1930-2000 precipitation

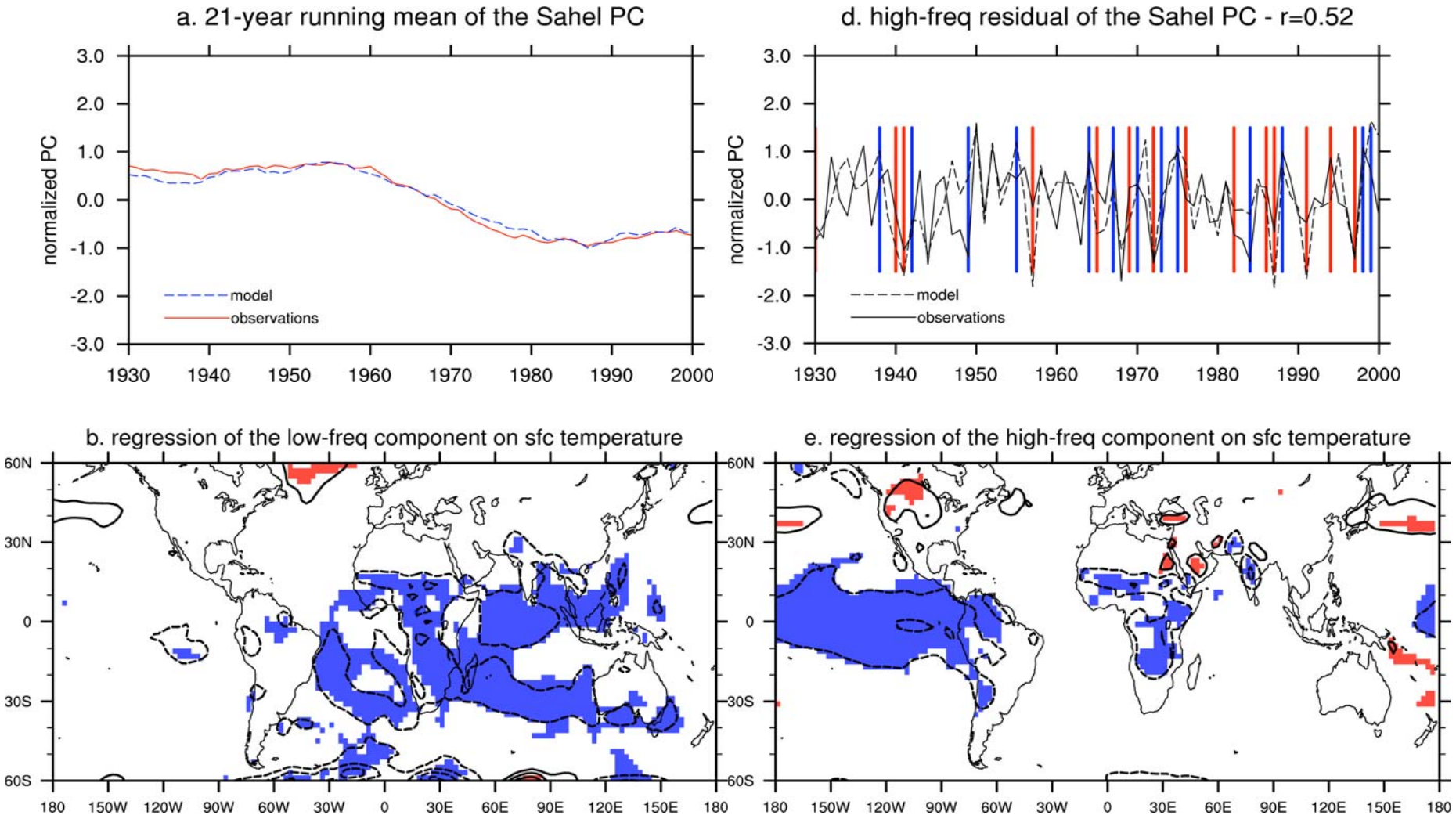


f. regression of the model's Sahel PC on sfc temperature

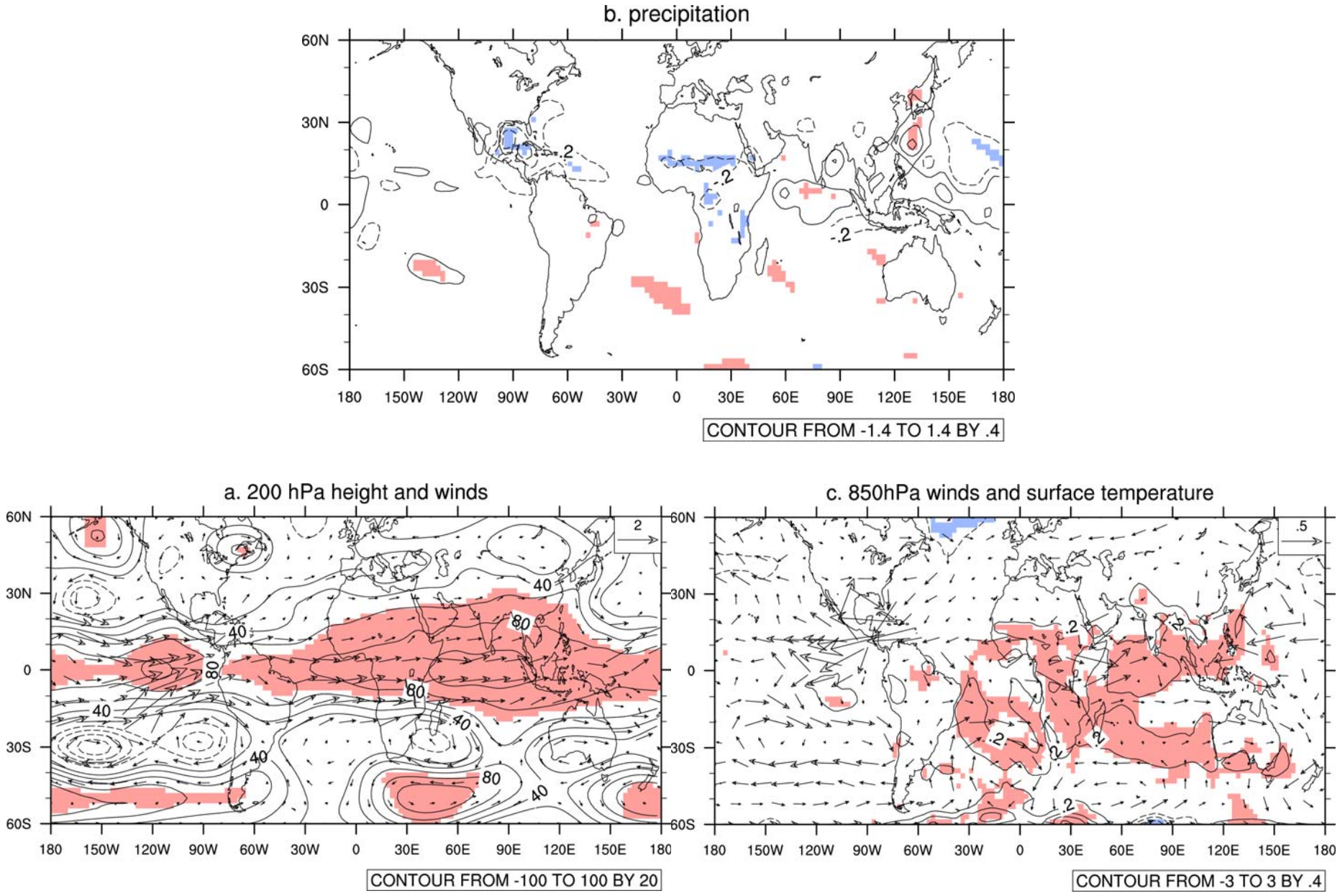


Giannini, A, R Saravanan, P Chang, 2005 (Clim. Dyn.)

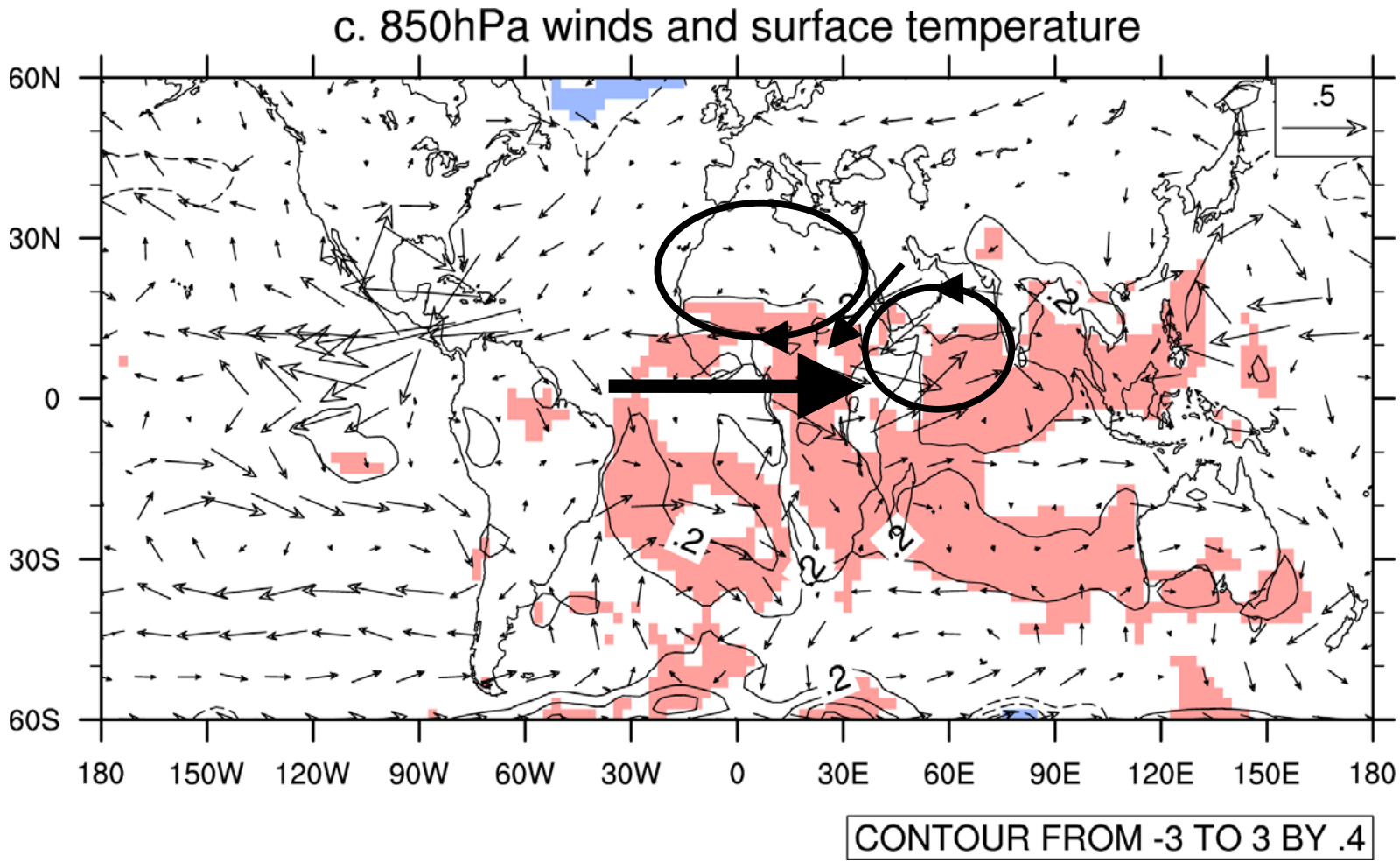
Variability in Sahel rainfall: interdecadal and interannual time scales



Giannini, A, R Saravanan, P Chang, 2003 (*Science*)


b. precipitation
60N
30N
0
30S
60S
180 150W 120W 90W 60W 30W 0 30E 60E 90E 120E 150E 180
CONTOUR FROM -1.4 TO 1.4 BY .4
a. 200 hPa height and winds
2
CONTOUR FROM -100 TO 100 BY 20
c. 850hPa winds and surface temperature
.5
CONTOUR FROM -3 TO 3 BY .4

Response to diabatic heating in the equatorial Indian Ocean



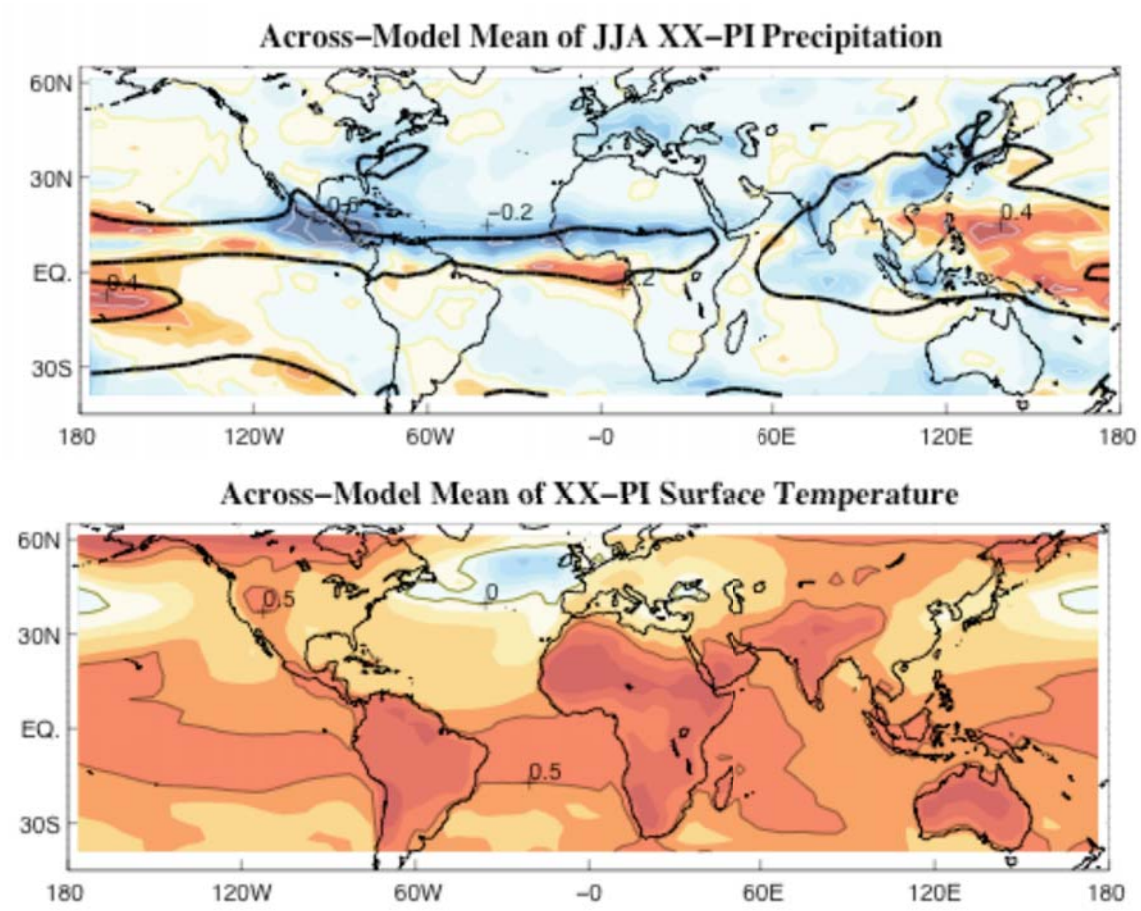
Also see e.g. Hagos and Cook, 2008 (J. Climate)

IPCC 4AR simulations – late 20th century climate change

Biasutti, M and A Giannini, 2006 (Geophys. Res. Lett.)

XX-PI change

19 coupled models



Oceans trigger drought
What role for anthropogenic land use change?

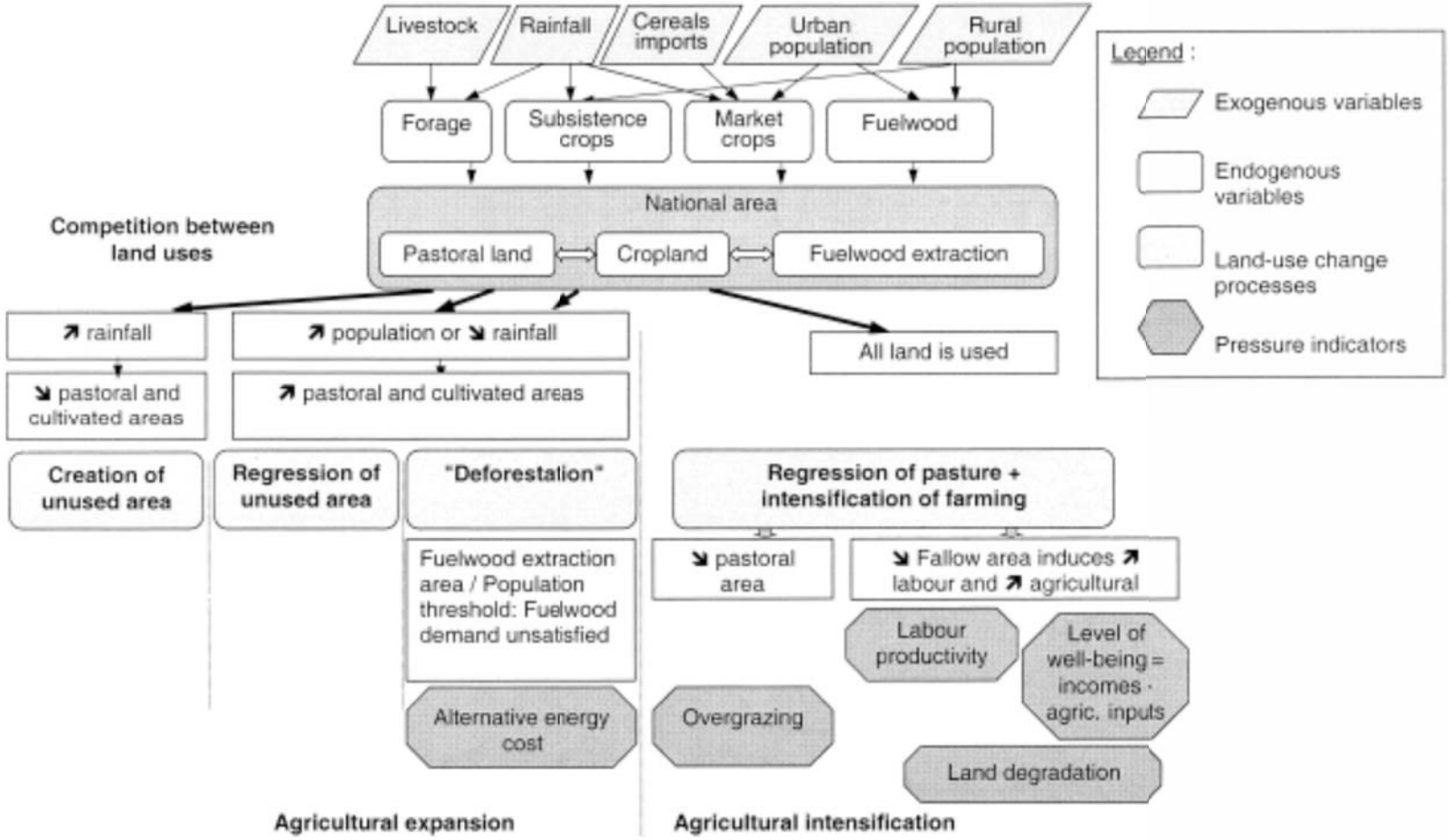
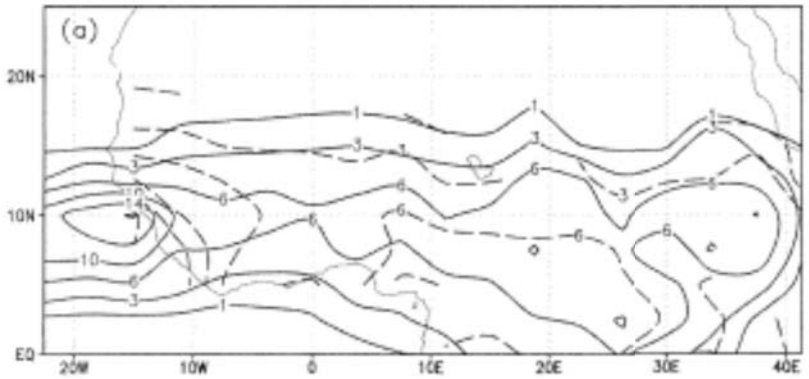


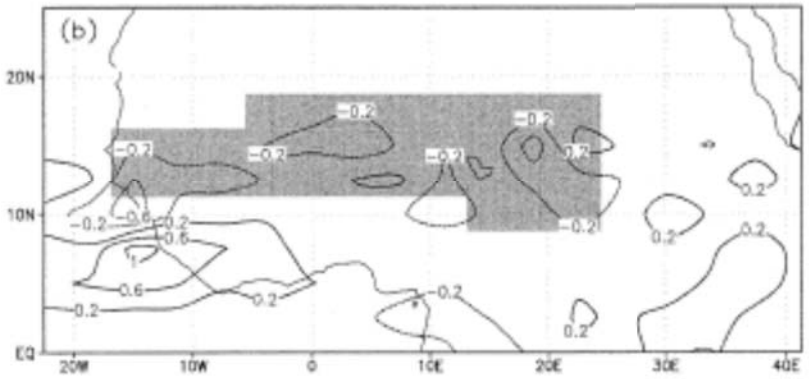
FIG. 2. Overall structure of the SALU model.

Taylor et al, 2002 (J. Climate)

rainfall climatology

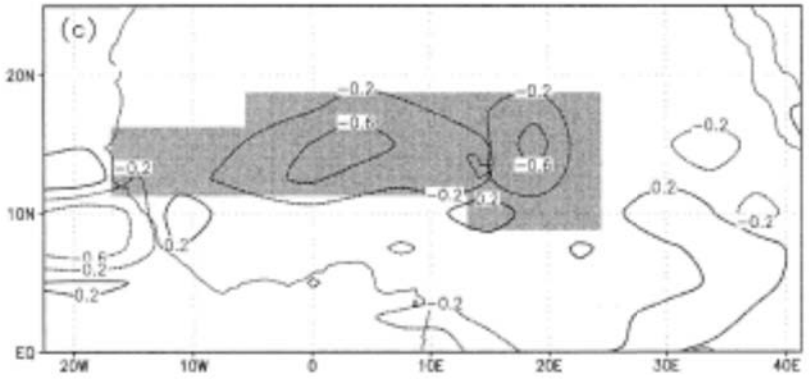


change: 1996-1961 (mm/day)



-4.6%

change: 2015-1961



-8.7%

Taylor et al, 2002 (J. Climate)

Framework for oceans forcing drought (as opposed to land)

Oceans trigger drought
Land surface reacts in a positive feedback:

- naturally reinforcing the drought
- what anthropogenic contribution from desertification?

Independent evidence:

- Fairhead and Leach - “Reframing deforestation”
- A role for local knowledge/experience
  (e.g. as told by Reij et al, Mortimer et al)

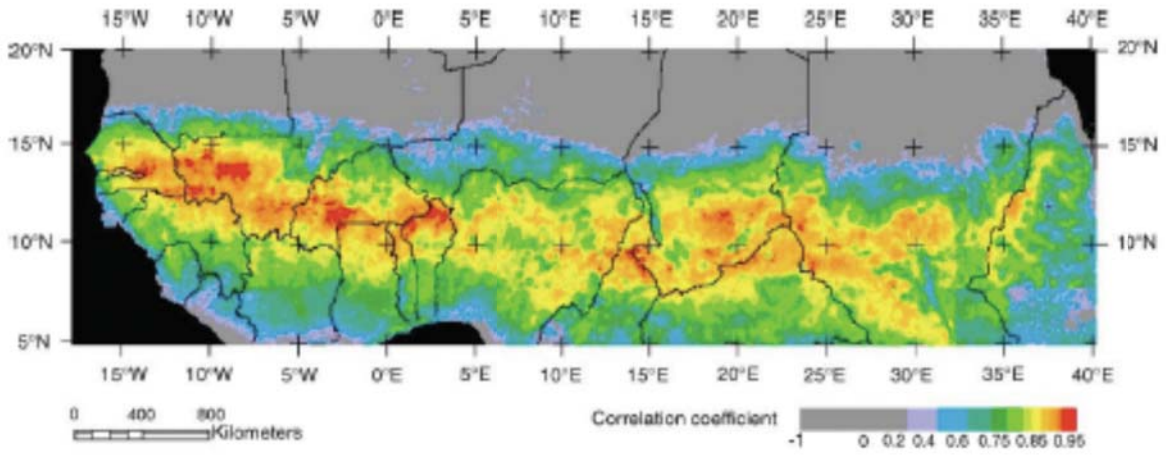


Fig. 3. Linear correlations of monthly NDVI with 3-monthly cumulative rainfall based on GPCP estimates for the period 1982–2003. Note that both variables are highly correlated in the Sahel region.

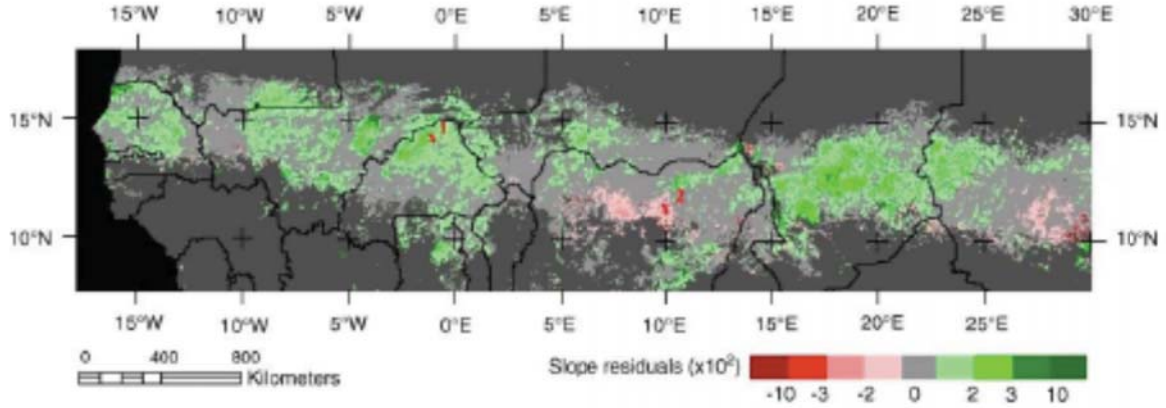


Fig. 4. Overall trends in the residual NDVI throughout the period 1982–2003 based on regression of vegetation greenness (AVHRR NDVI) on 3-monthly cumulative rainfall (GPCP estimate). Slopes of residual NDVI trendlines between 1982 and 2003 are expressed in units of NDVI $\times 10^4$. Locations of sites 1 and 2 are indicated, for which temporal profiles (Figs. 6 and 7) were extracted.

Herrmann et al (2005) Global Env Change

If oceans forced drought
(with oceanic warming leading to drought) then:

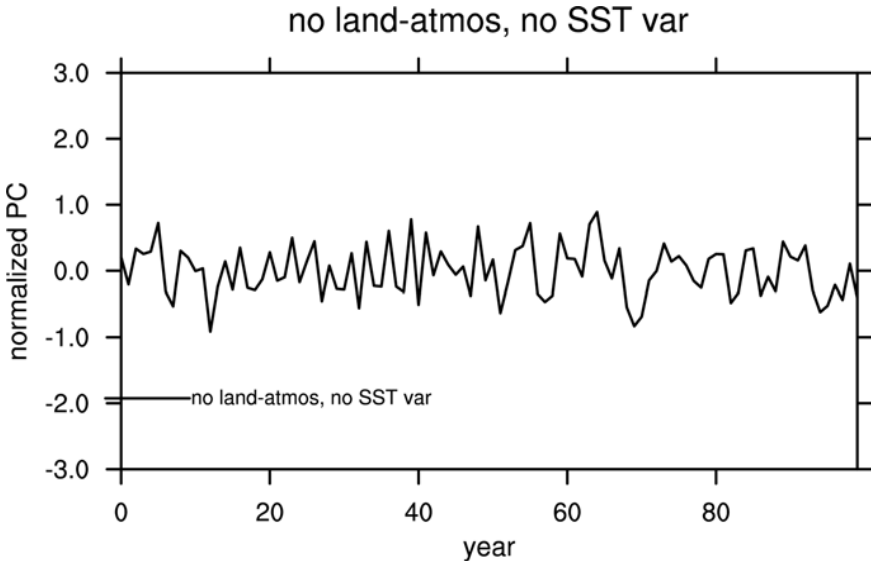
1) To what extent is the persistence of drought
   during the late 20th century anthropogenic
   (i.e. due to emissions of greenhouse gases and aerosols
   from industrialization)?

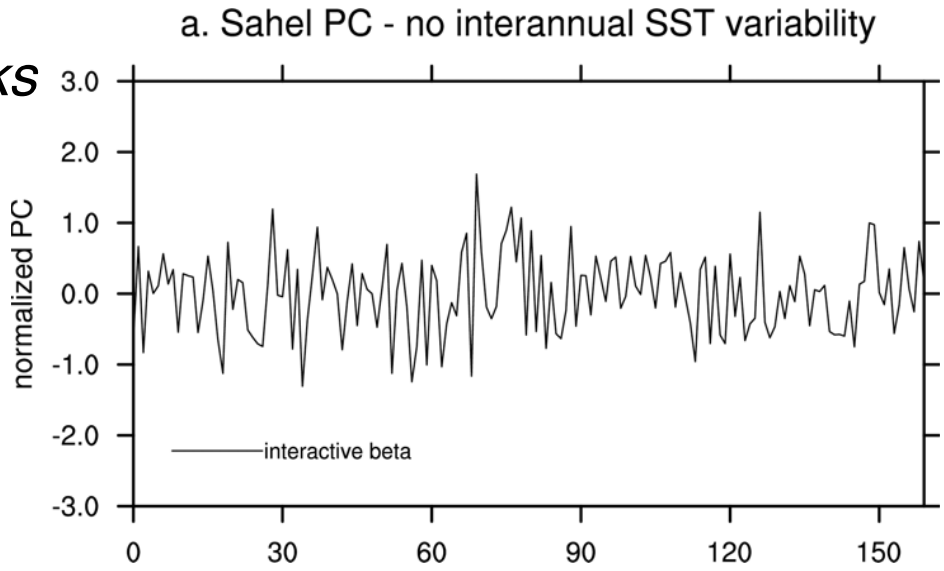
2) What has been happening in recent decades – can the
   “greening” be attributed to a recovery in rain?

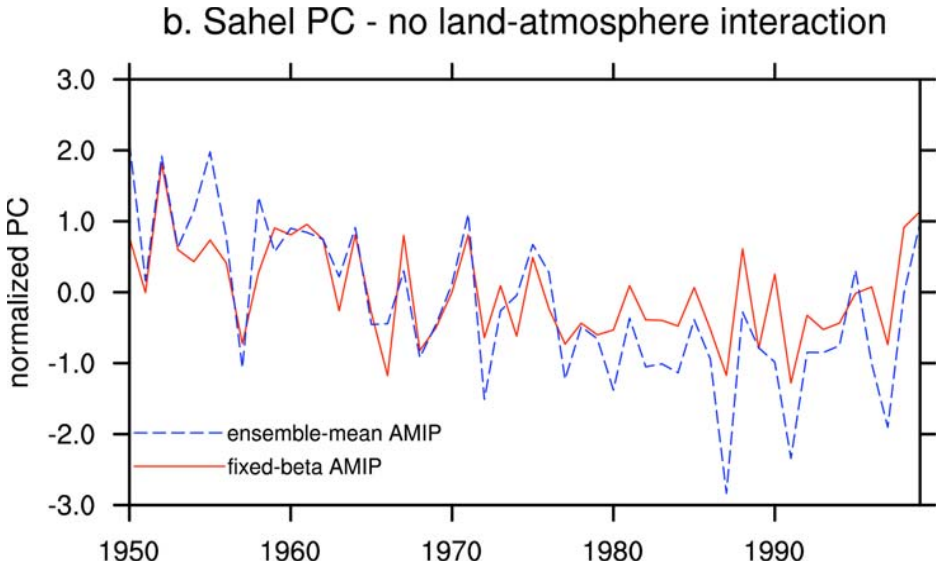
3) What does the future hold?

The role of land surface-atmosphere feedbacks

Giannini et al., 2003 (Science)

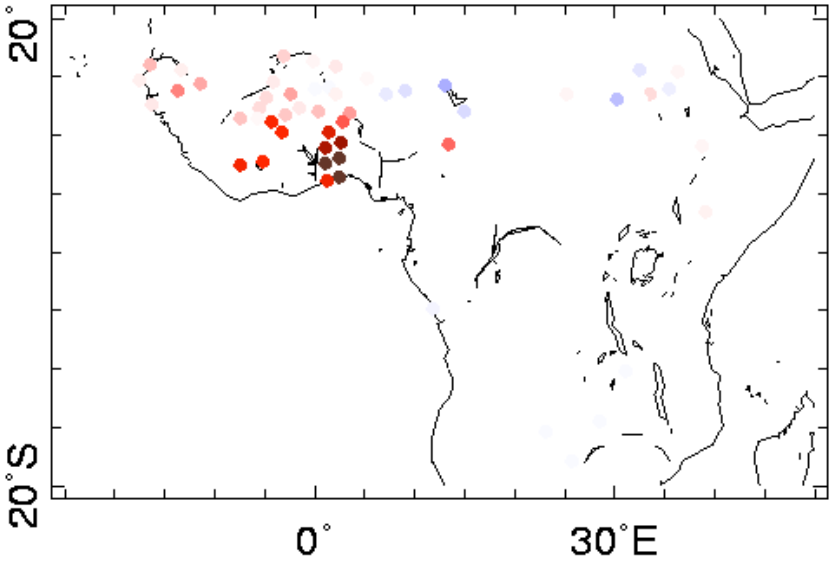


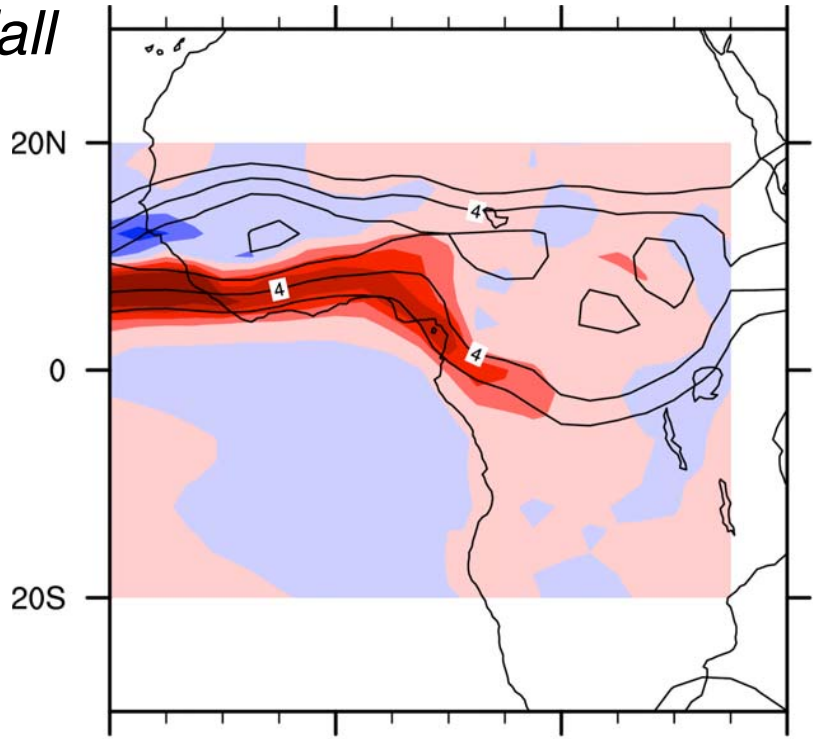




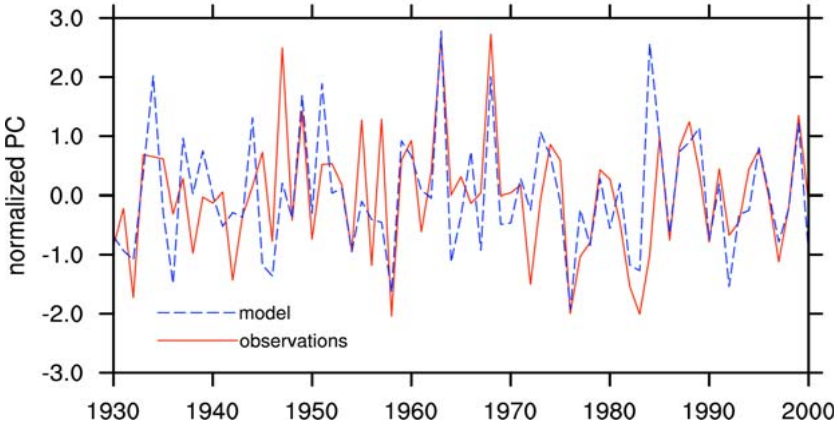
Variability in Gulf of Guinea rainfall

(15% in obs, 32% in ens-mean)

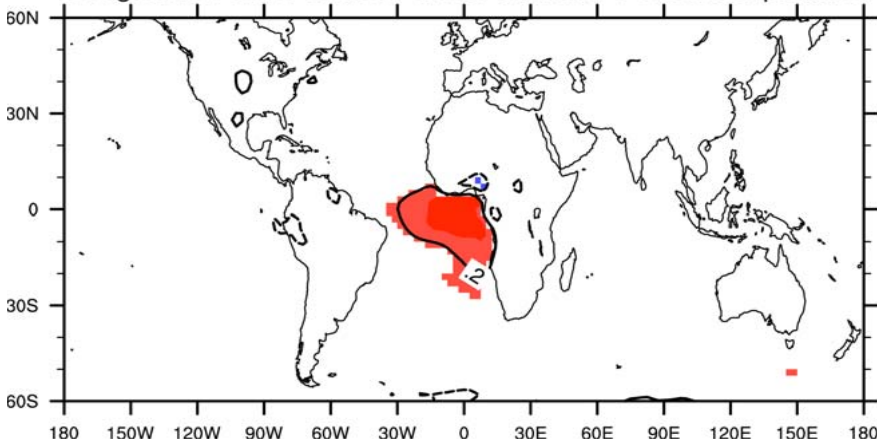




b. Gulf of Guinea PC of 1930-2000 precipitation



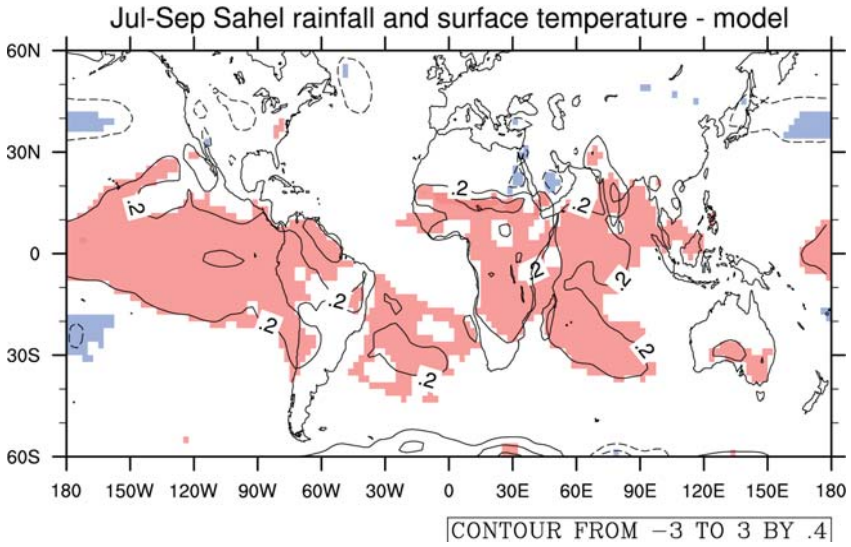
c. regression of the model's Gulf of Guinea PC on sfc temperature



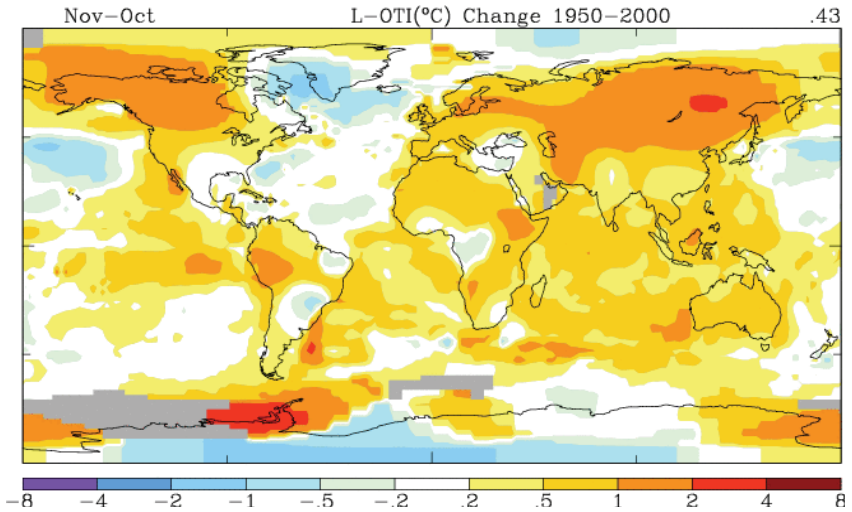
Giannini et al., 2005 (Clim. Dyn.)

Late 20th century surface temperature changes

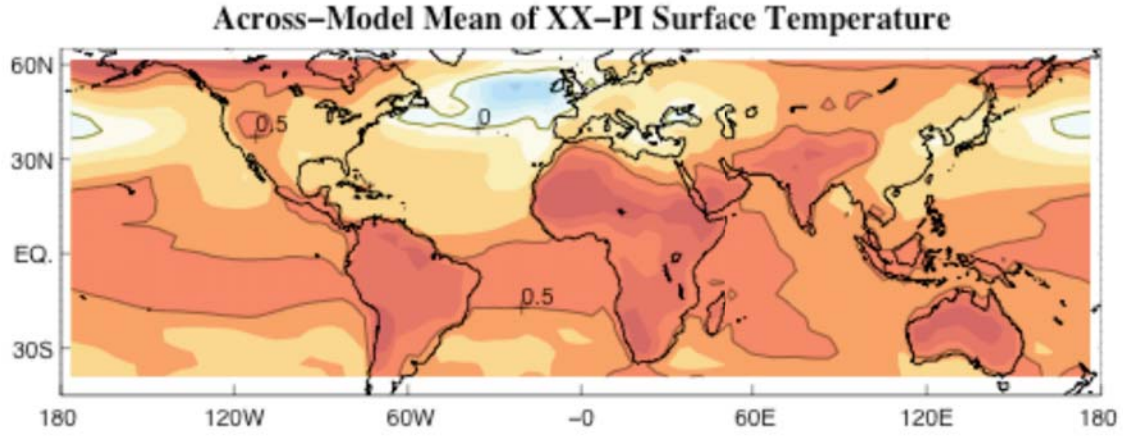
regression of NASA/NSIPP1 Sahel PC and sfc temp
Giannini et al. 2003, 2005



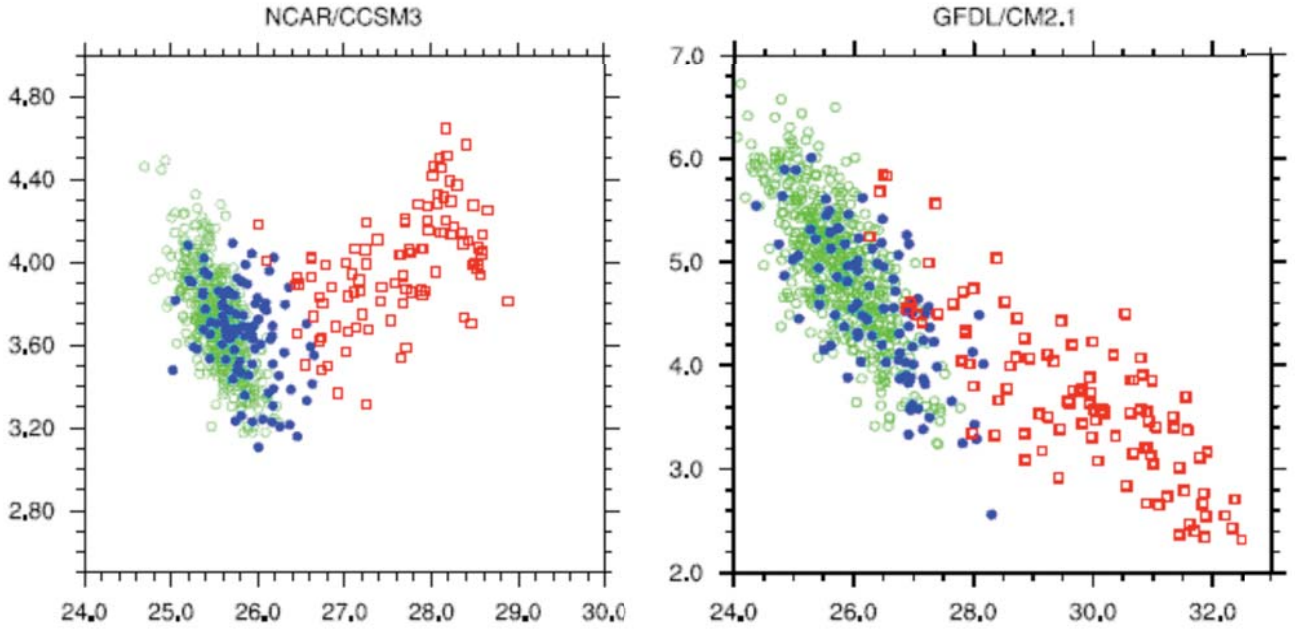
NASA/GISS analysis of surface temp – linear trend 1950-2000
Hansen et al. 1999 (J. Geophys. Res.)



IPCC 4AR: end 20th century – PreIndustrial sfc temp difference
Biasutti and Giannini 2006 (GRL)



The uncertainty in scenarios of Sahel climate change in the temperature-precipitation relationship



green circles: pre-industrial control
blue dots: 20th century simulation
red squares: A1B scenario of 21st century

Data from WCRP/CMIP3/PCMDI archive (IPCC AR4)

The role of (sulfate) aerosols

Rotstayn and Lohmann, *2002 (J Climate)*

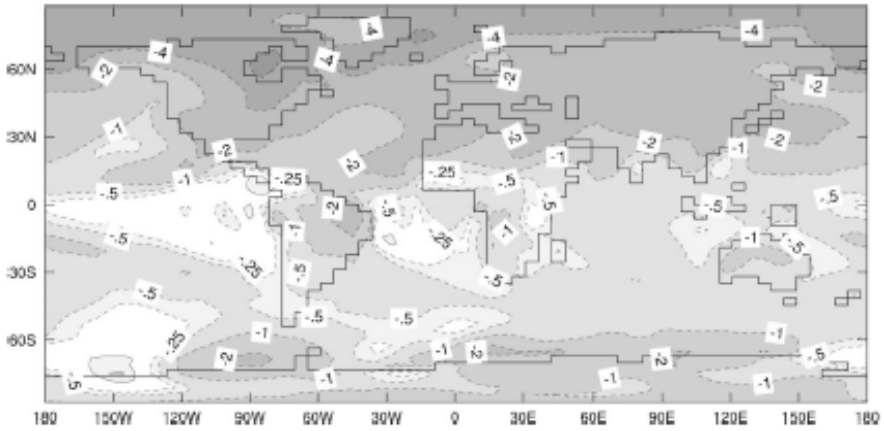


FIG. 2. Difference in annual-mean, near-surface air temperature between the PD and PI runs. Contours are −8, −4, −2, −1, −0.5, −0.25, and 0.25 K.

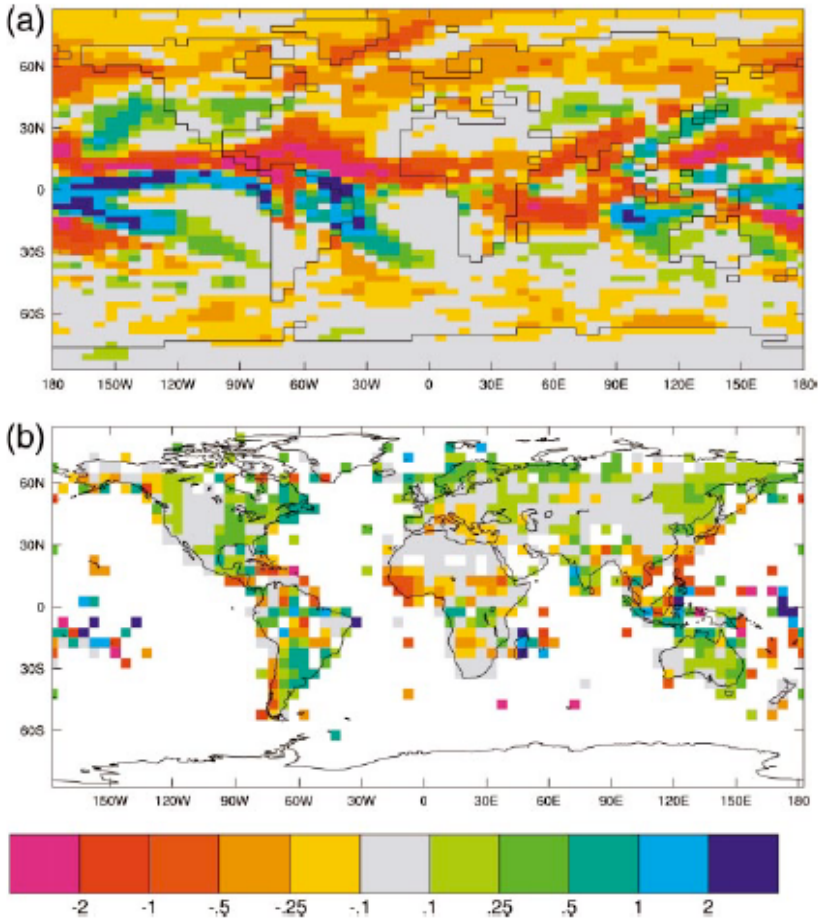


FIG. 4. (a) Difference in annual-mean precipitation between the PD and PI runs in mm day^{-1}. (b) Trend in observed annual-mean precipitation over the period 1901–98 in mm day^{-1} century^{-1}.

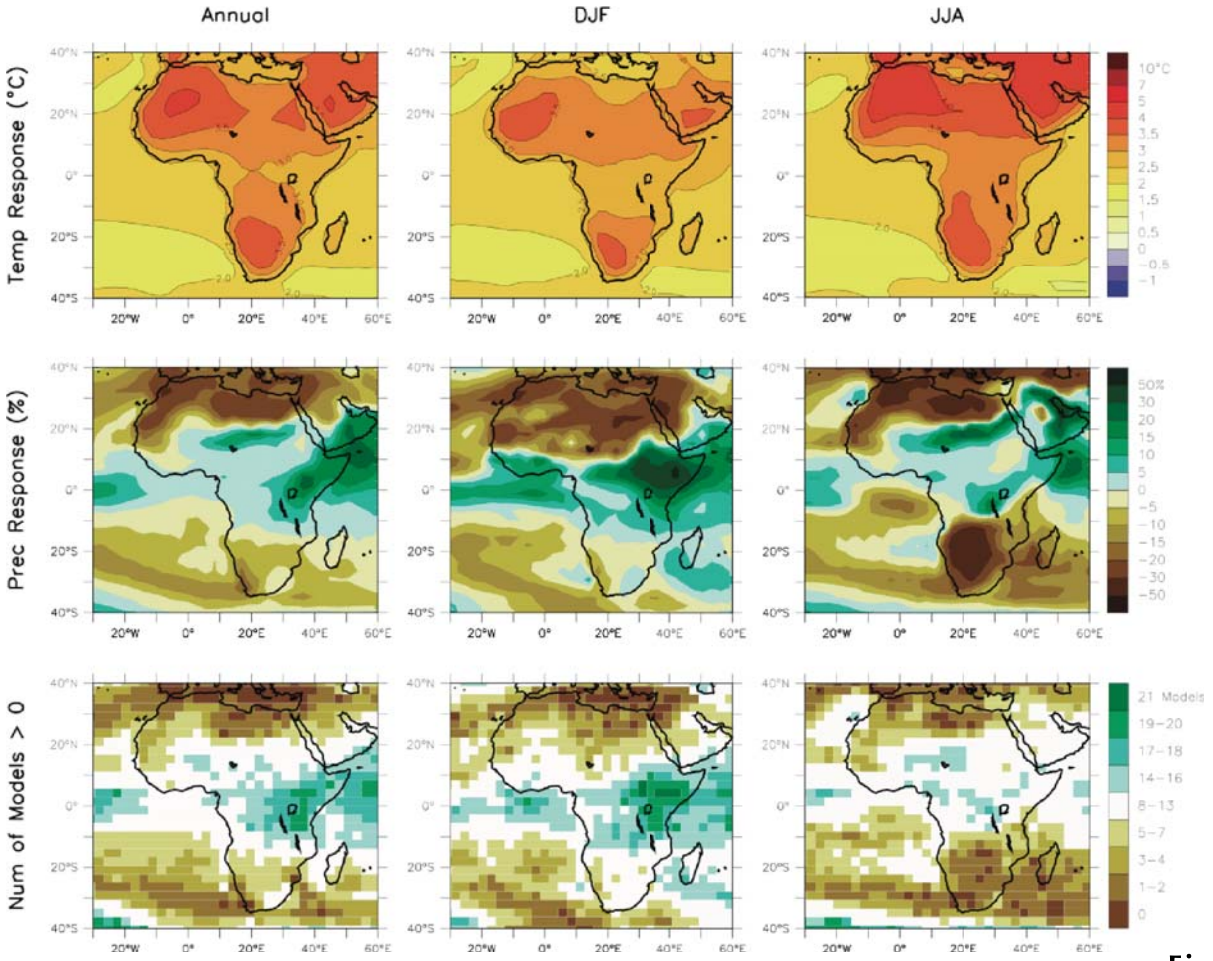


Figure 11.2

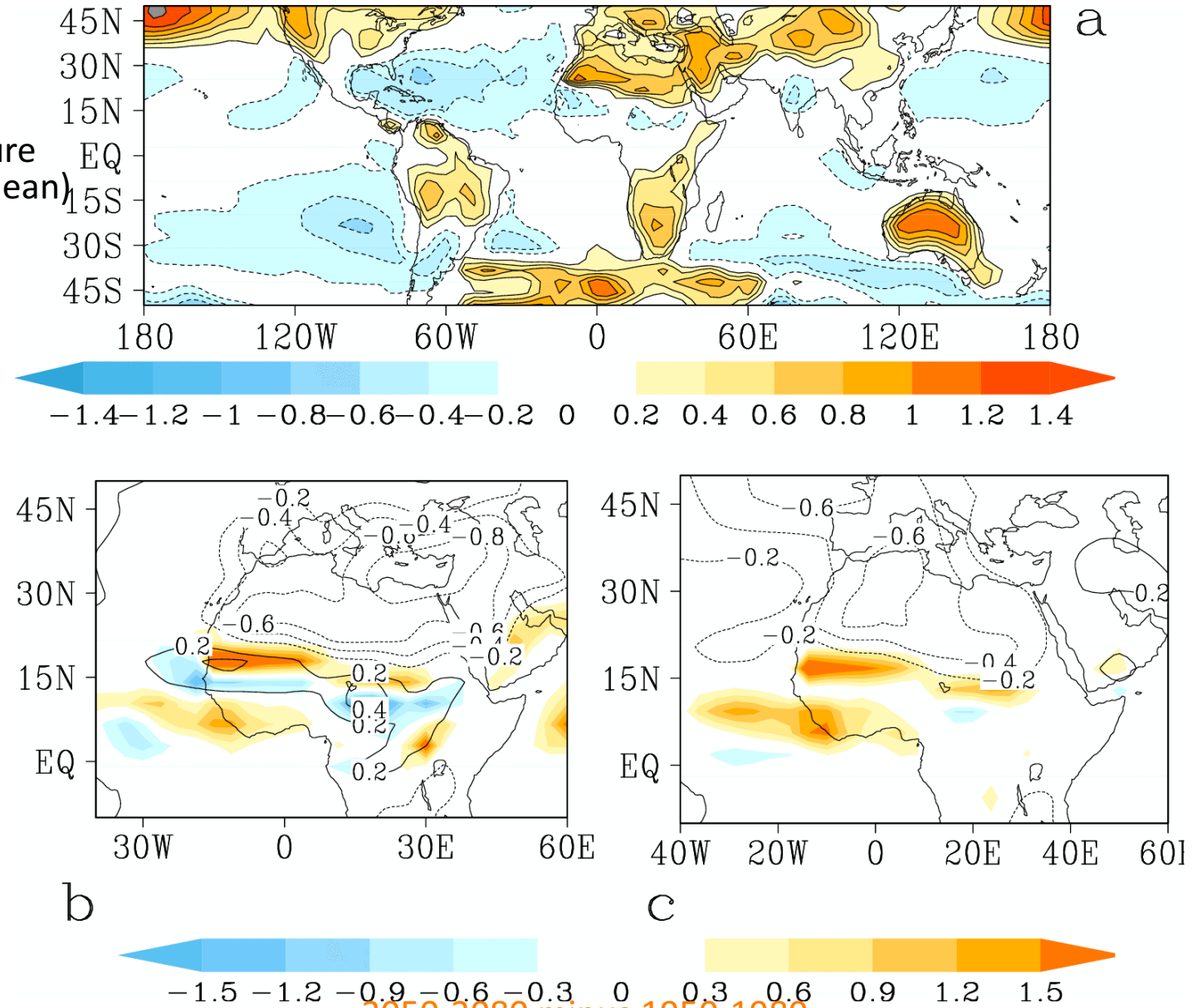
Christensen et al, 2006 (Ch.11 - IPCC AR4/WG I)

Will the African monsoon strengthen?

Haarsma et al, 2005 (Geophys. Res. Lett.)

surface
air temperature
(minus global mean)

precipitation



2050-2080 minus 1950-1980

Or will warmer oceans dry out continents?

Held et al, PNAS 2005

GFDL CM2.0 GMAO(NSIPP1) NCAR CAM3

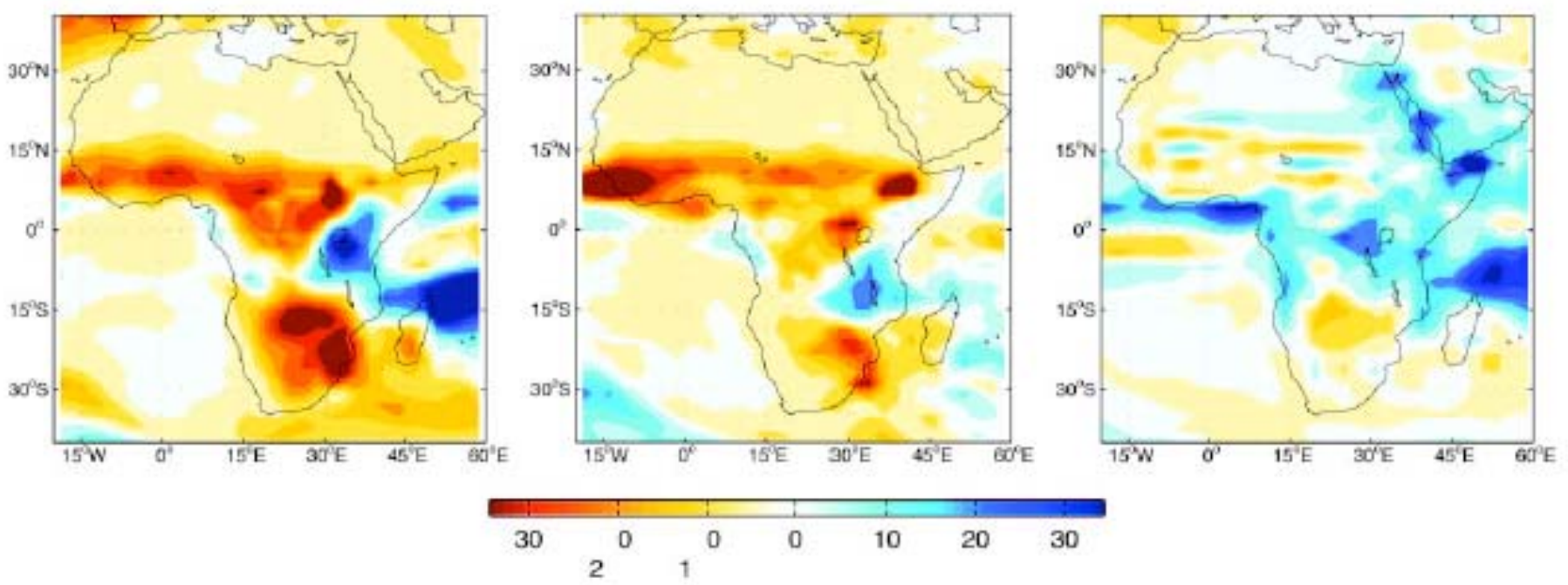
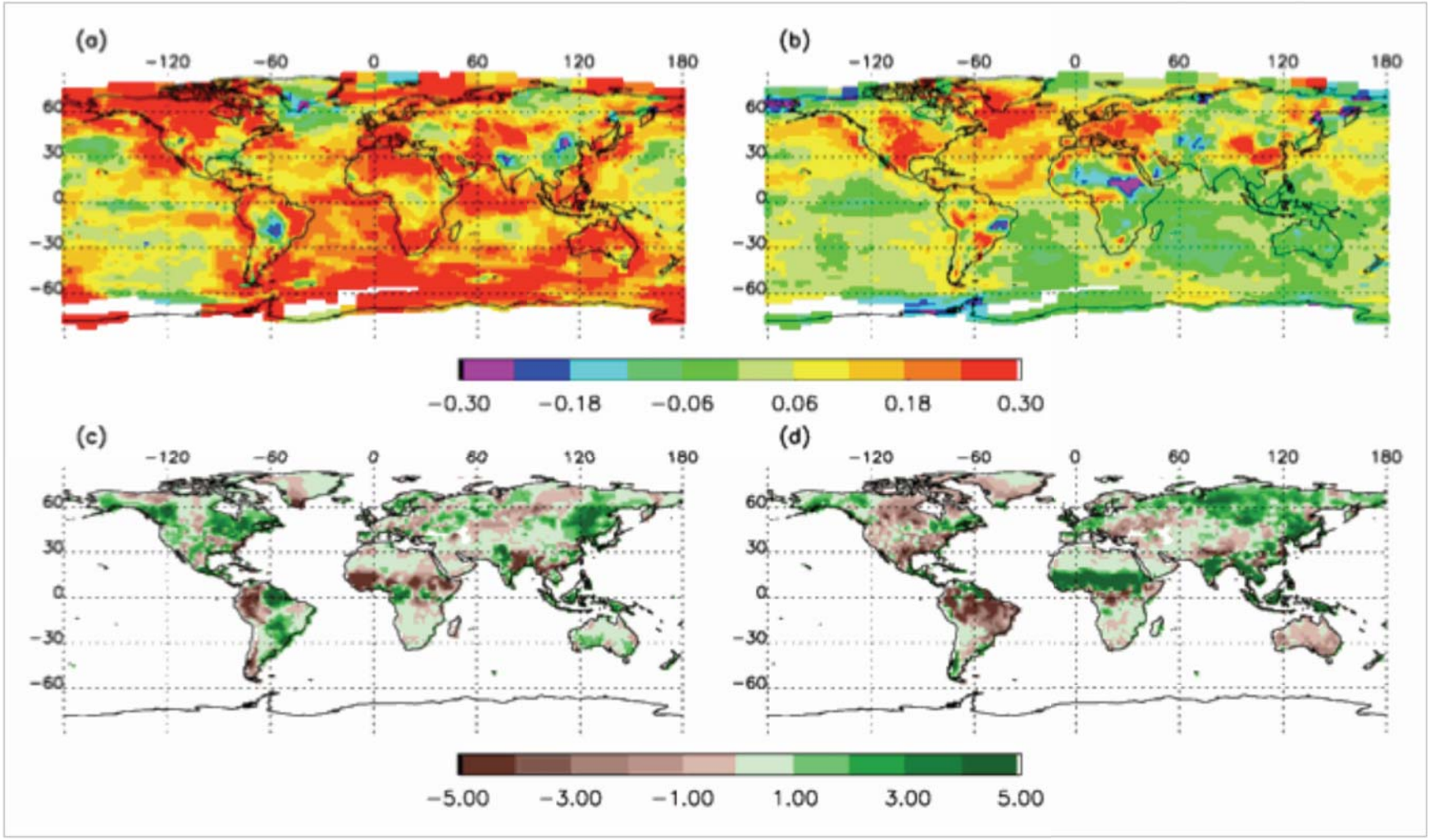


Fig. 5. The annual mean precipitation response of three atmospheric models to a uniform warming of ocean temperatures. (*Left*) The atmospheric component of CM2.0. (*Center*) A model developed at National Aeronautics and Space Administration's Global Modeling and Assimilation Office (J. Bacmeister, personal communication). (*Right*) The CAM3 model developed at the National Center for Atmospheric Research (J. Kiehl, personal communication).

The relative roles of external forcing and internal variability

Mingfang Ting (LDEO), personal communication



Also see e.g. Hoerling et al., 2006 (J. Climate)