Global precipitation changes shaped by natural and anthropogenic forcing

Jian Liu[1], Bin Wang[2], Mark Cane[3], So-Young Yim[2], and collaborators

1. State Key Laboratory of Lake Science and Environment, Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, Nanjing 210008, China
2. International Pacific Research Center and Department of Meteorology, University of Hawaii at Manoa, Honolulu, HI 96825, USA
3. Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964, USA

Mesa Verde

In response to warming:

How much will it rain?

Theory and Models vs. Observations (at least, Wentz et al)

Where will it rain?

Which is related in part to the SST pattern in the tropical Pacific.

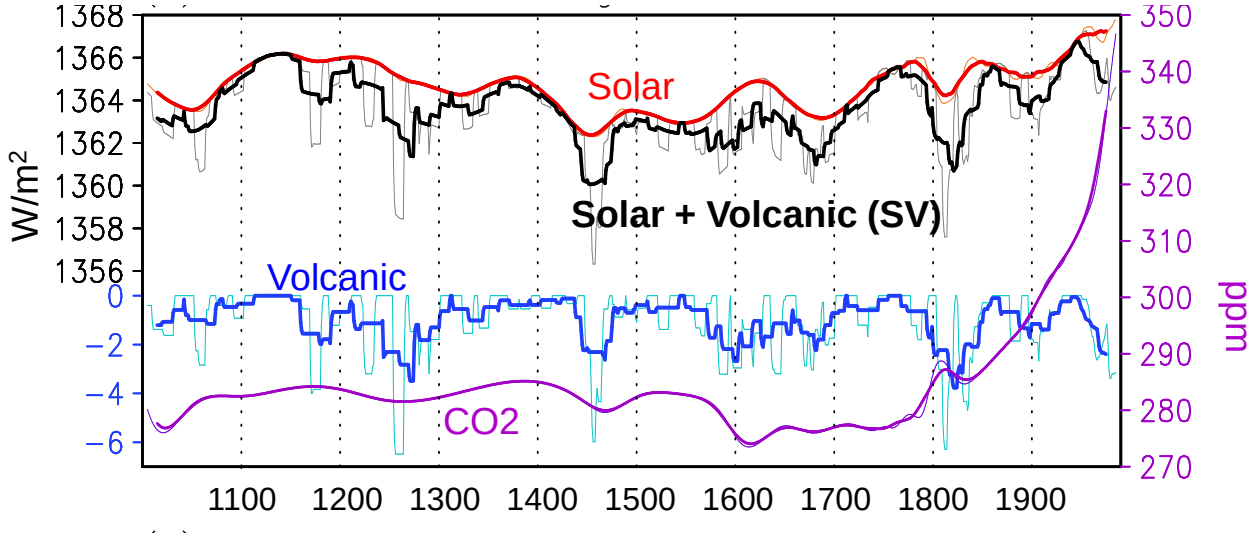
"El Niño like" vs. "La Niña like"

"Weaker Walker" vs. "Ocean Thermostat"

Some lessons from the last millennium
-- primarily from a model simulation of the last millennium

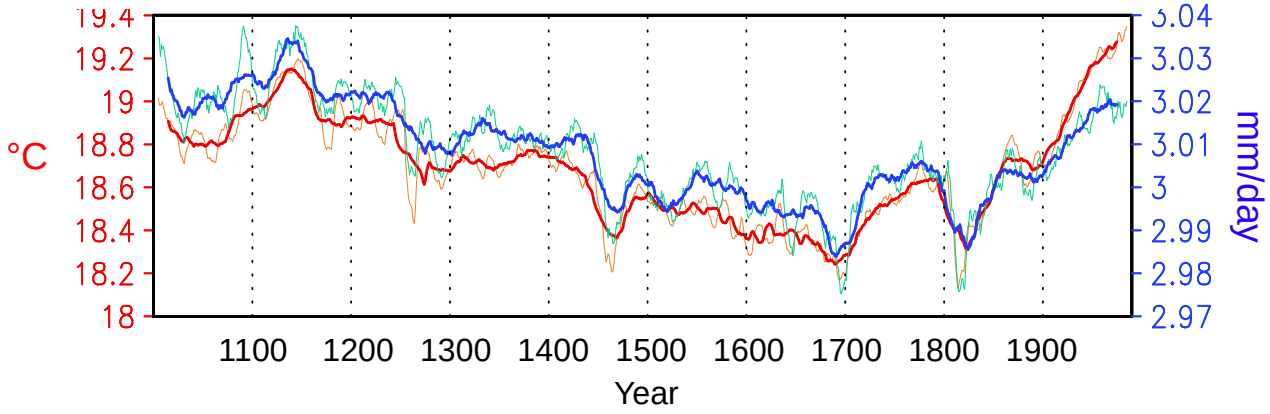
Greenhouse gases vs. Solar-Volcanic

Solar-volcanic (SV) forcing & CO2 concentration (GHG)



FORCING

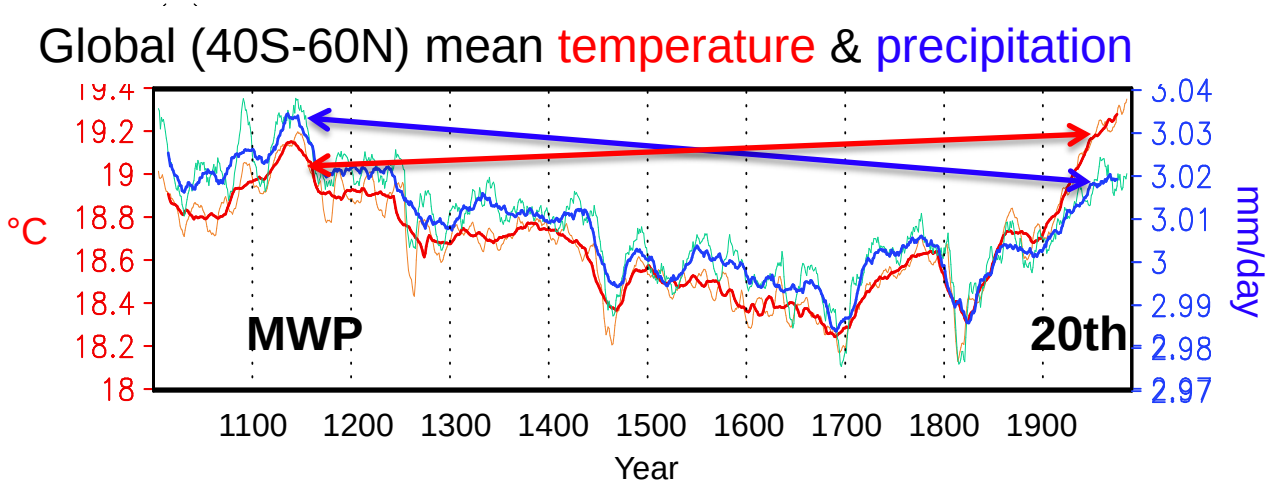
Global (40S-60N) mean temperature & precipitation



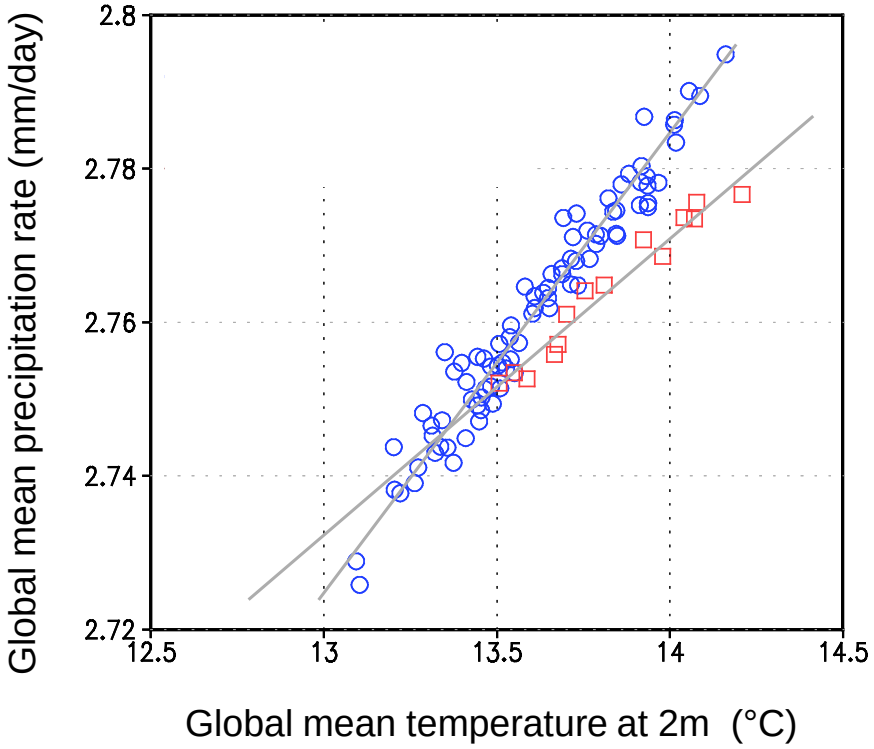
MODEL RESPONSE

From “ERIK”, an ECHO-G simulation of the last millennium
11-year running means

Global mean Temperature in the 20th Century is warmer than in the Medieval Warm Period (MWP) but the Precipitation rate is lower



Global mean precipitation rate versus global mean temperature



- **Solar-Volcanic**

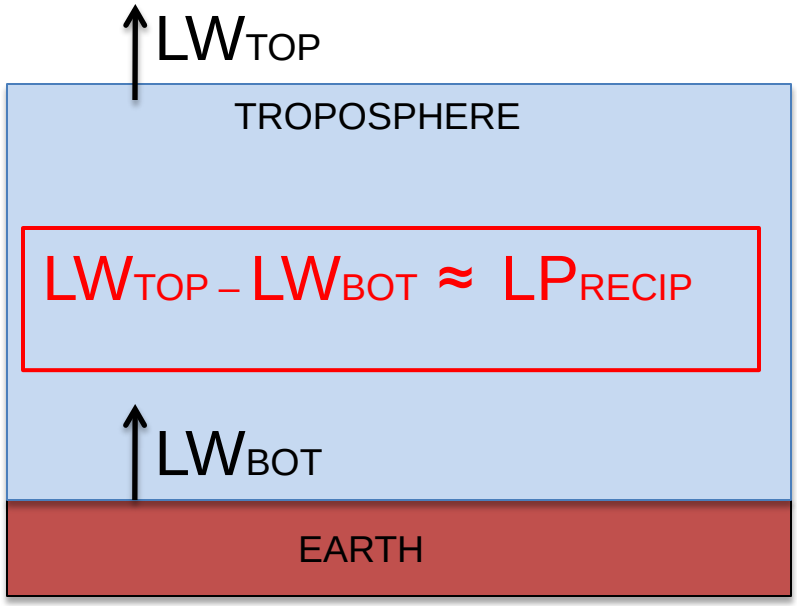
Pre-industrial era (1000-1850):
0.058 mm/day per °C = **2.1% /°C**

□ **GHG** + SV

Industrial era (1850-1990):
0.039 mm/day per °C = **1.4% /°C**

Data are decadal mean values from the ERIK forced millennial simulation.

The global tropospheric balance is **Longwave Flux Divergence ≈ Latent Heating**



Since Δ LW is less for GHG warming than for Solar-volcanic warming, precipitation is less.

See Allan and Ingram 2002, *Nature*

In response to warming:

Where will it rain?

We look at the part related to the SST pattern in the tropical Pacific.

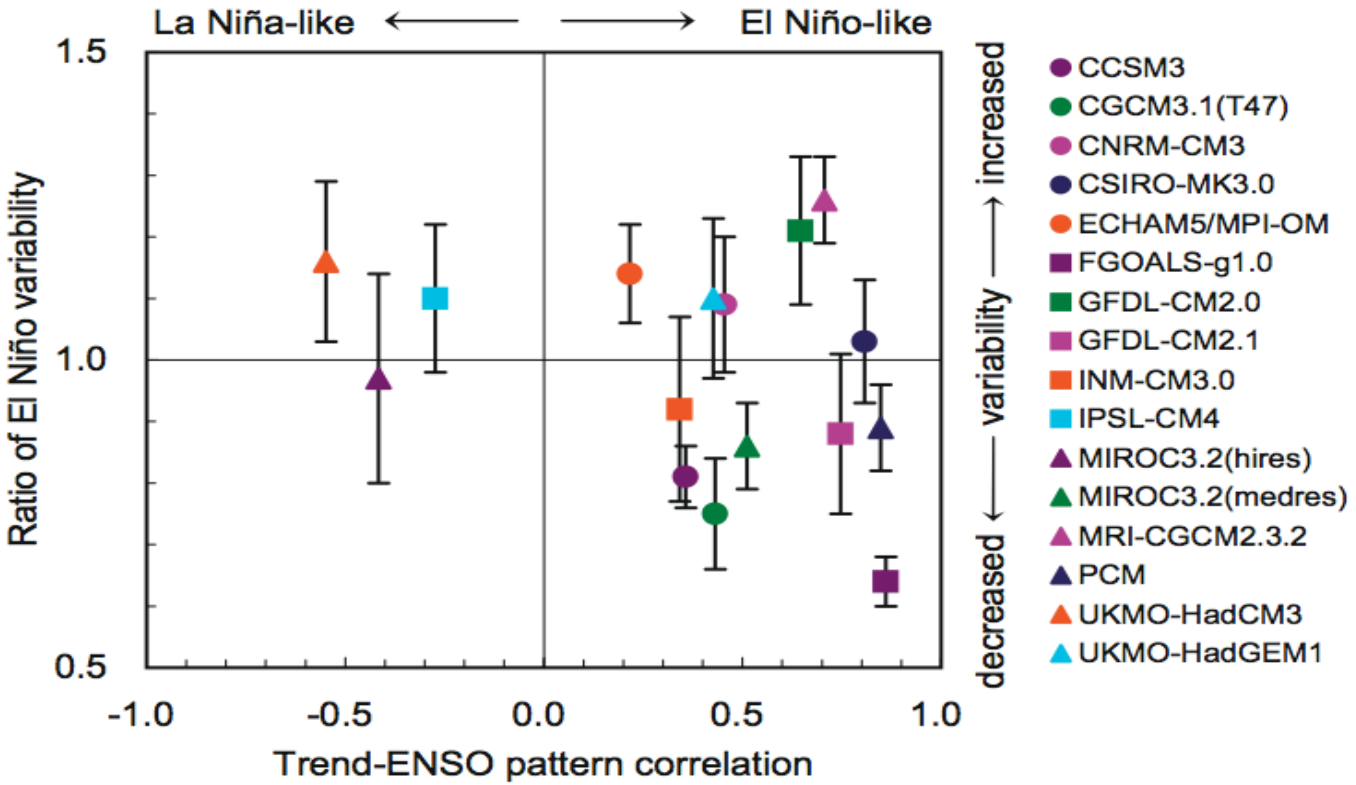
"El Niño like" vs. "La Niña like"

"Weaker Walker" vs. "Ocean Thermostat"

Which theory is right?
Both are sound physics.
Which is applicable?

The tropical Pacific in AR4

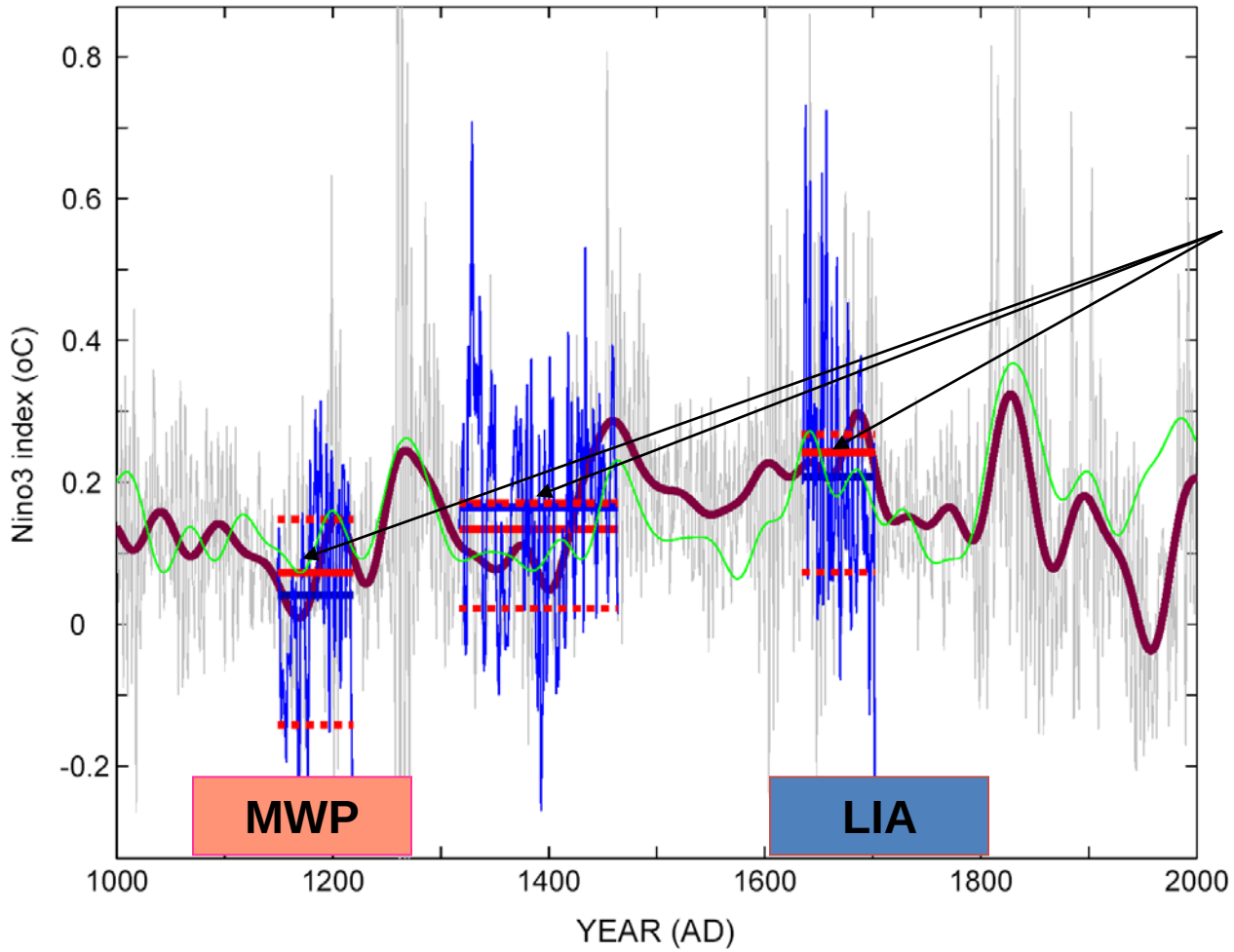
Weaker Walker ☐ El Niño-like



Yamaguchi, K., and A. Noda, 2006: Global warming patterns over the North Pacific: ENSO versus AO. *J. Meteorol. Soc. Japan*, **84**, 221–241.

Zebiak-Cane Model Comparison with Fossil Corals from the Central Pacific

Ocean Thermostat ☐ La Niña-like

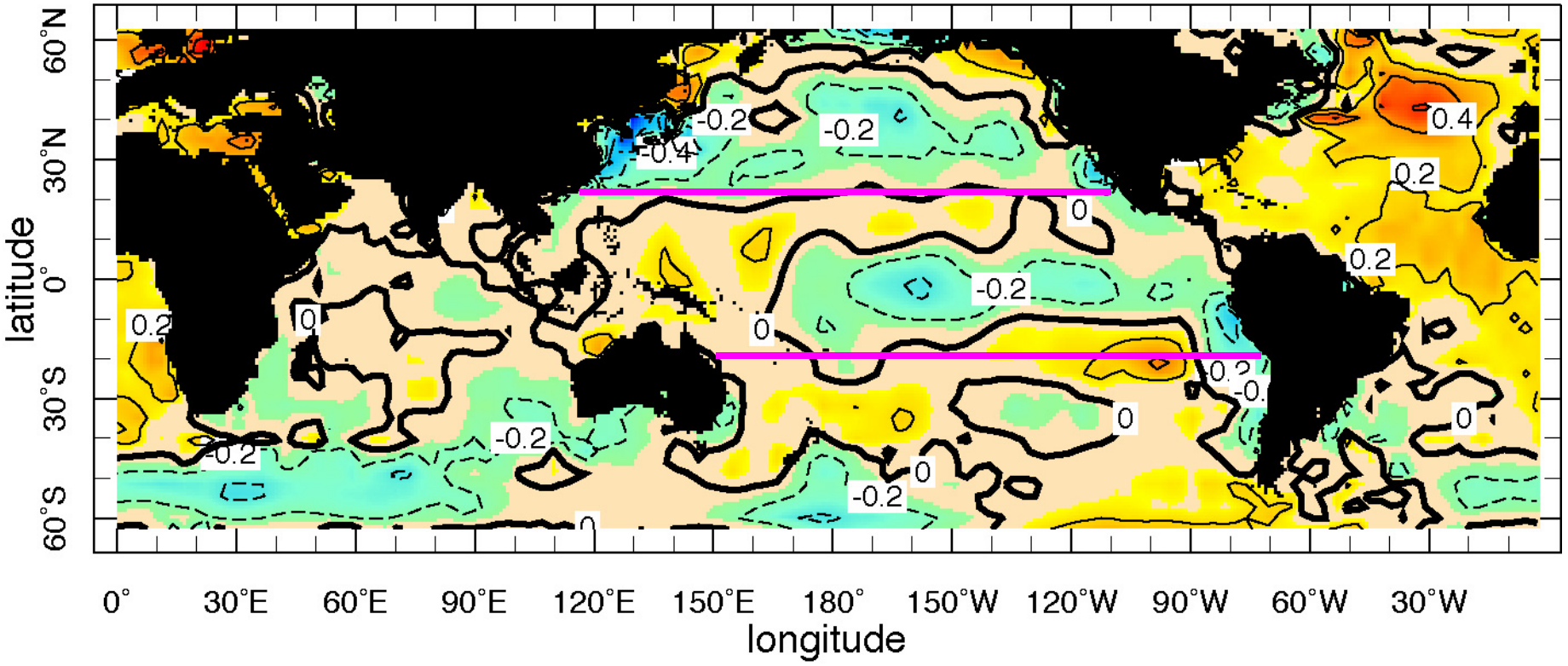


Mean dO^{18} from Palmyra corals (Cobb et al. 2003)

Mann et al. 2004

Sea Surface Temperature Anomaly 1932-1939

OBSERVED

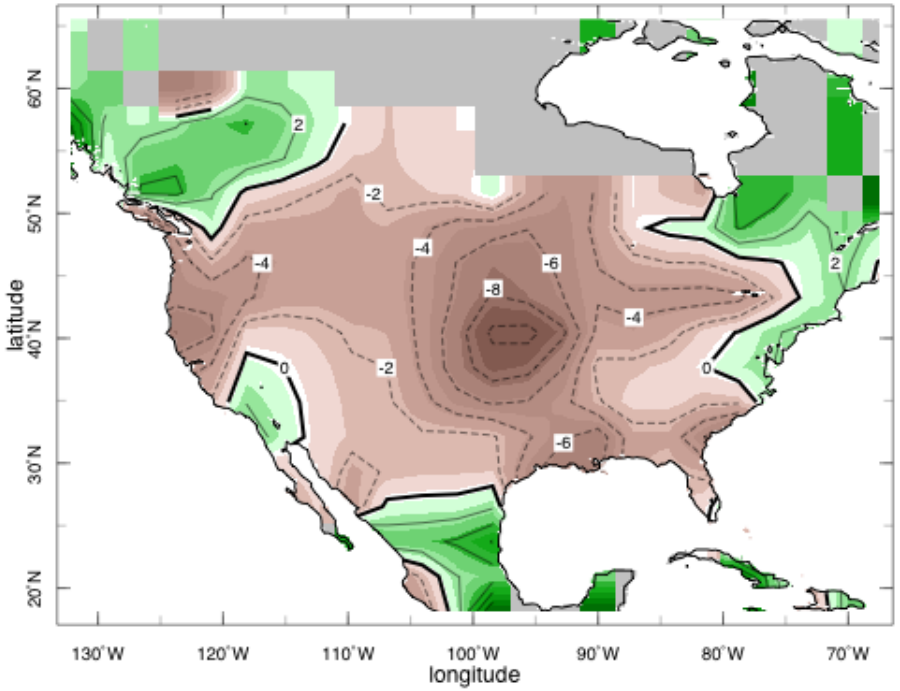


Contour interval = 0.2°C

Courtesy of Richard Seager

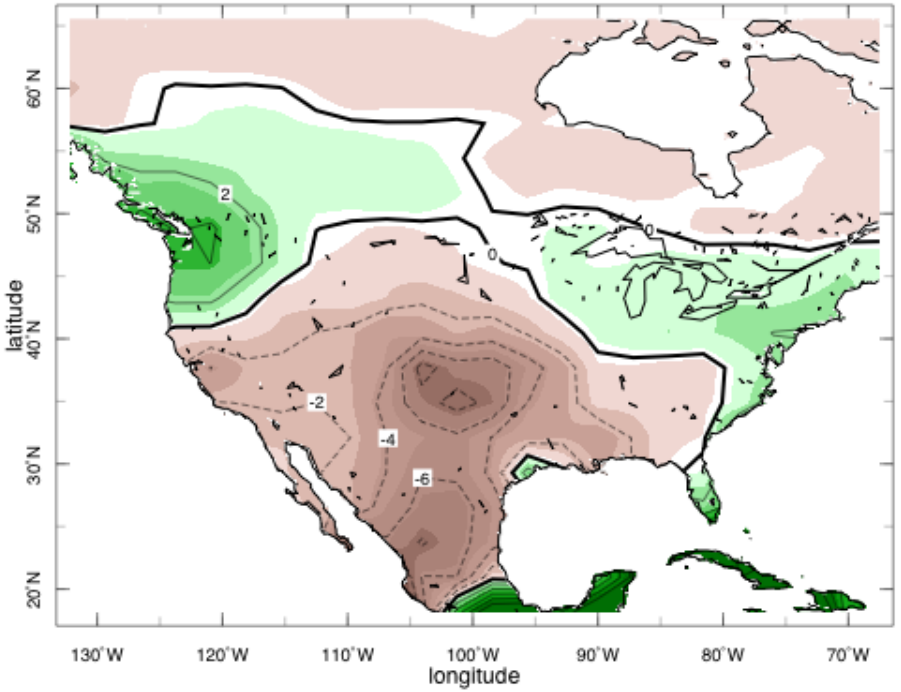
Precipitation Anomaly 1932-1939

OBSERVED



Contour interval = 2 mm/month

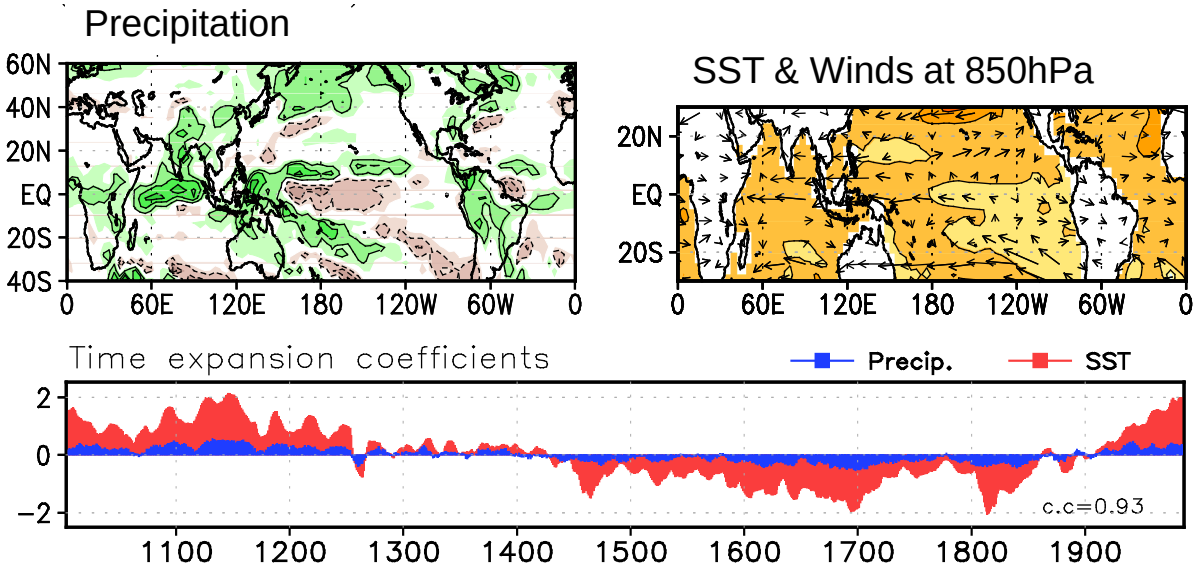
GOGA MODEL



GOGA MODEL = AGCM with Global Sea Surface Temperature Specified

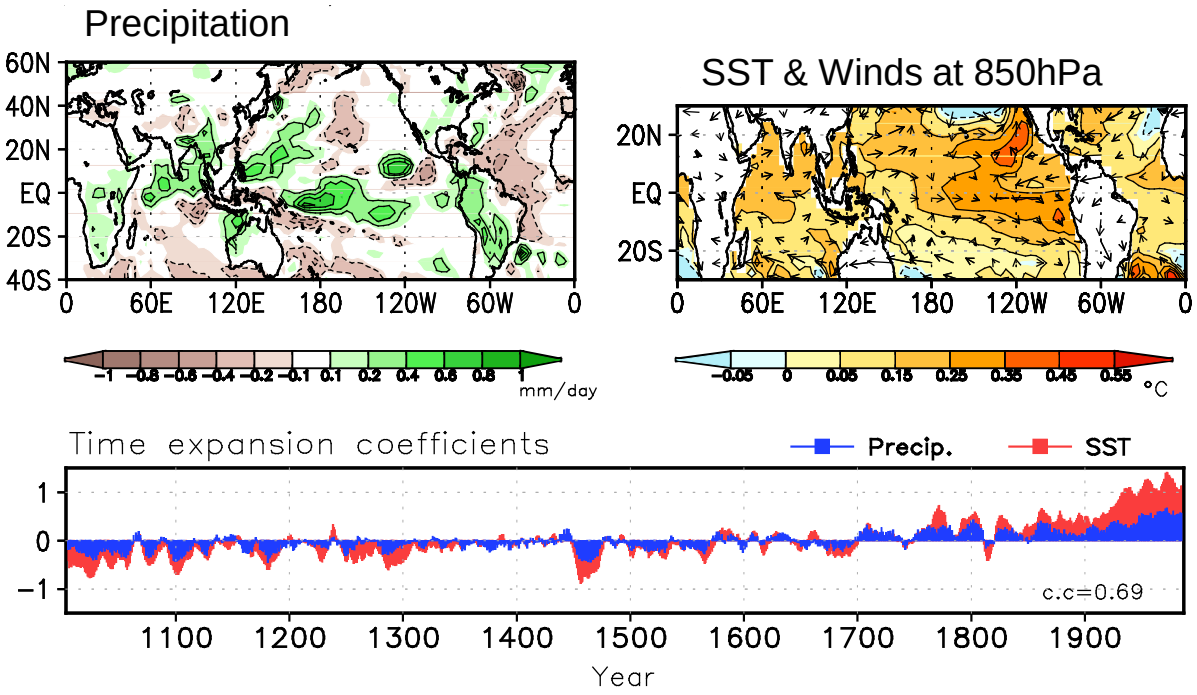
Courtesy of Richard Seager

SVD1 (81%)– THE SV MODE



(top) The leading SVD mode of the precipitation and SST for the period 1000-1990. Also shown are the 850hPa wind anomalies regressed onto the time expansion coefficient of SST.
(bot) As above but for the second SVD mode.

SVD2 (10%)– THE GHG MODE

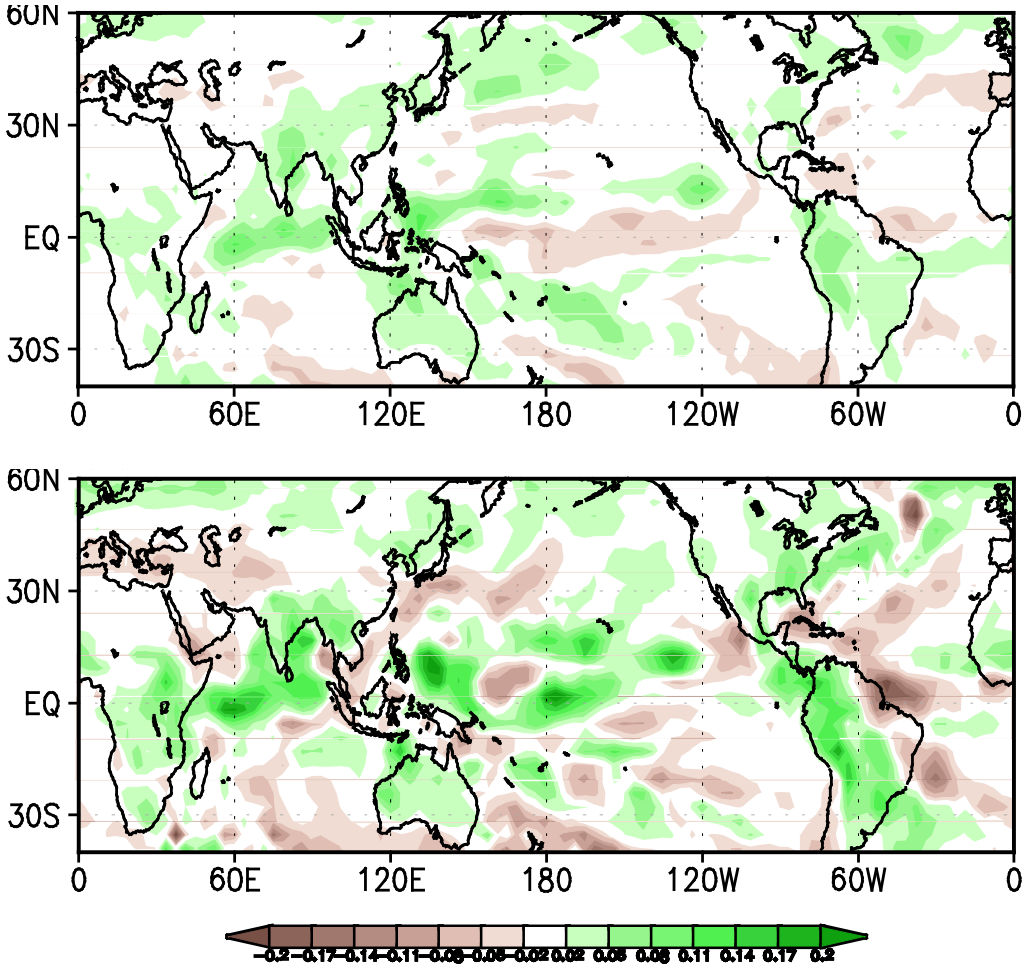


Wind vectors shown are significant above 95% confidence level. The data used are the 11-year running mean after removal of the leading internal mode (EOF1).

Precipitation regressed onto

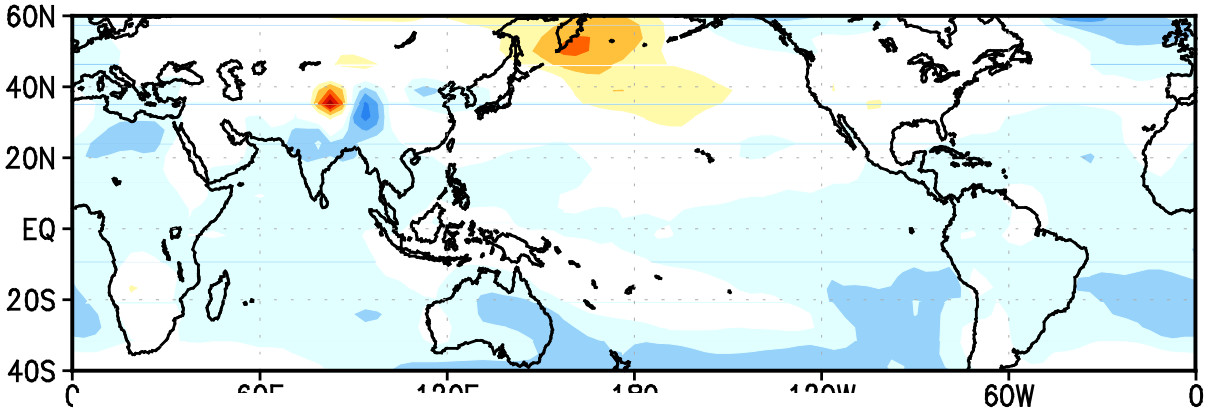
Solar-volcanic (SV) forcing

Greenhouse Gas(GHG) forcing

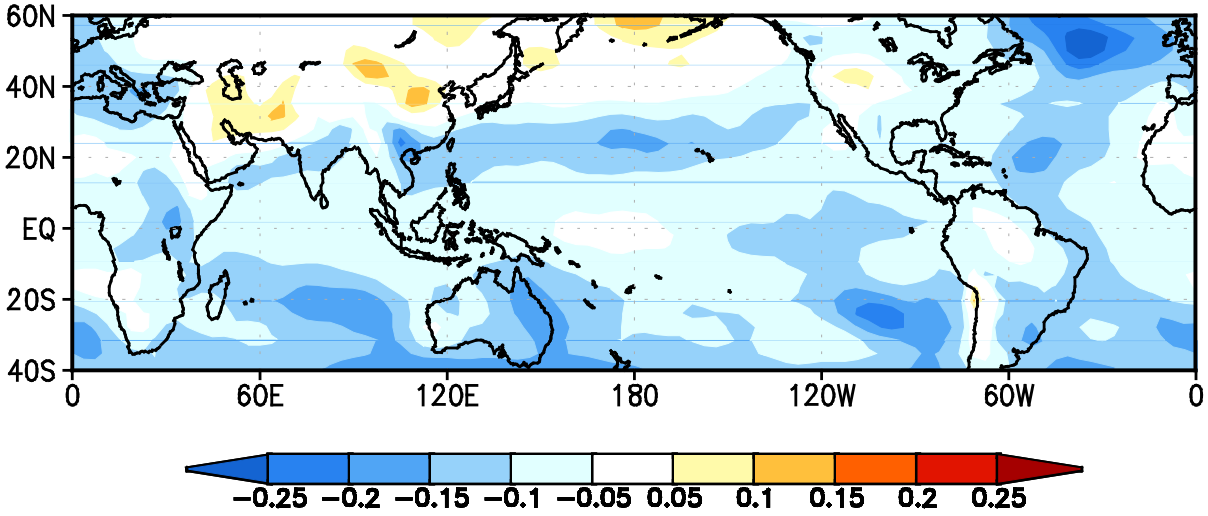


Stability (T850- T500) regressed onto

Solar-Volcanic (SV) mode



Greenhouse gas (GHG) mode



GHG response is more stable, favoring Weaker Walker mechanism

Summary

In many theories for the response to warming, warming is warming, but

the type of forcing does matter.

Greenhouse gases vs. Solar-Volcanic

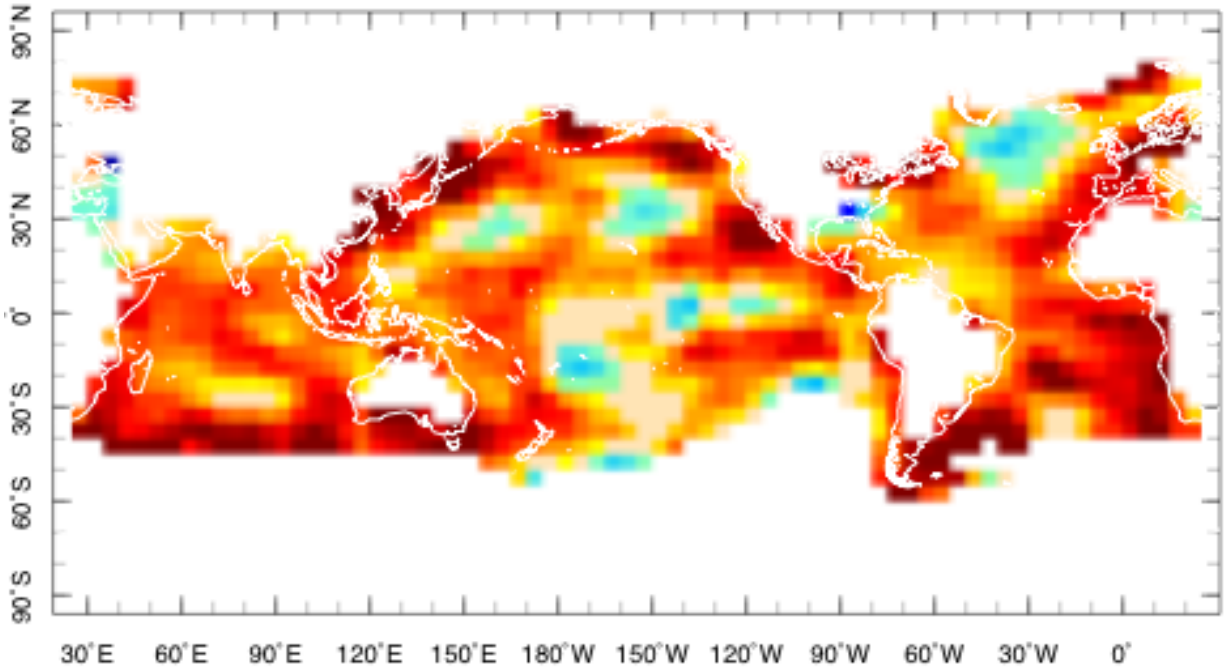
More precip than normal vs. Even more precip
A consequence of global tropospheric energy budget

"El Niño like" vs. "La Niña like"
"Weaker Walker" vs. "Ocean Thermostat"

Favored by static stability differences,
Also see Meehl et al (2003,…) on differences in spatial heating,
DiNezio et al on changes in the thermocline


Thank you
Mesa Verde

20th Century Temperature Trends

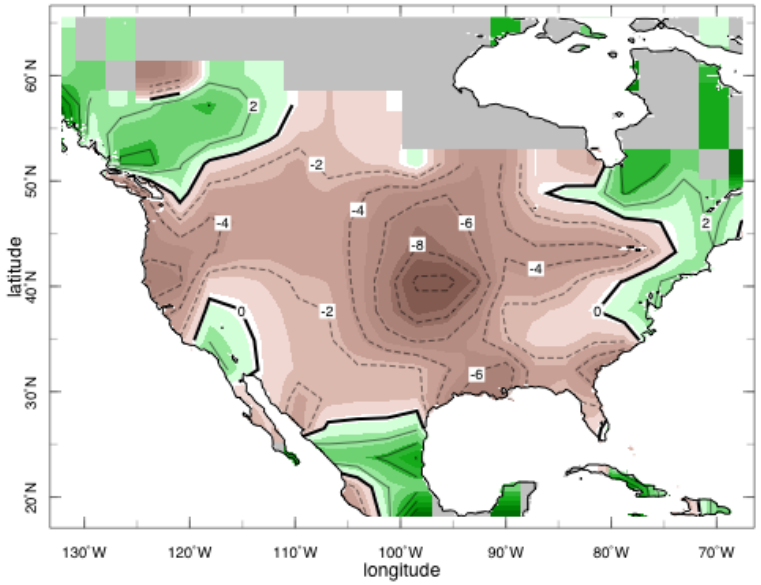


-1.0 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1.0 (°C / 100 years)

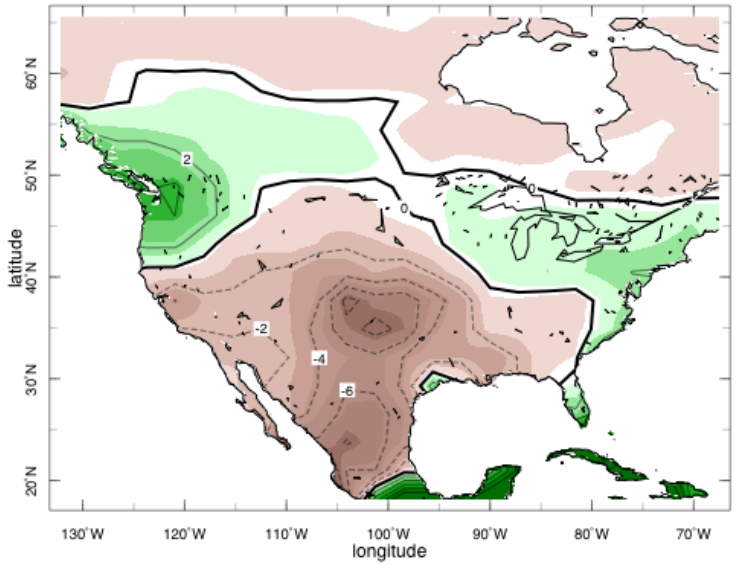
Updated from
Cane et al *Science* 1997

Precipitation Anomaly 1932-1939

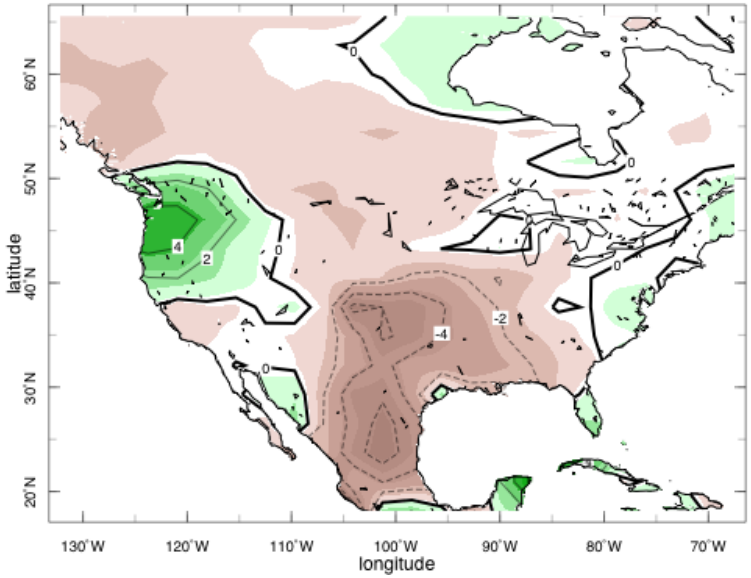
OBSERVED



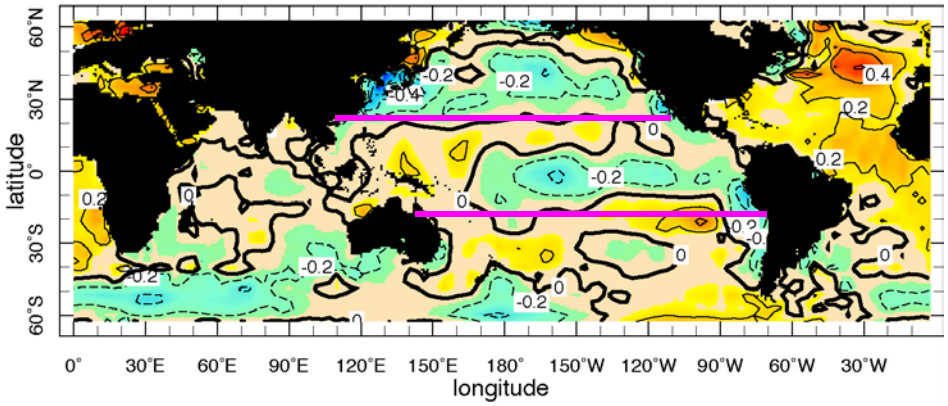
GOGA MODEL



POGA-ML MODEL



OBSERVED SEA SURFACE TEMPERATURE



Courtesy of Richard Seager

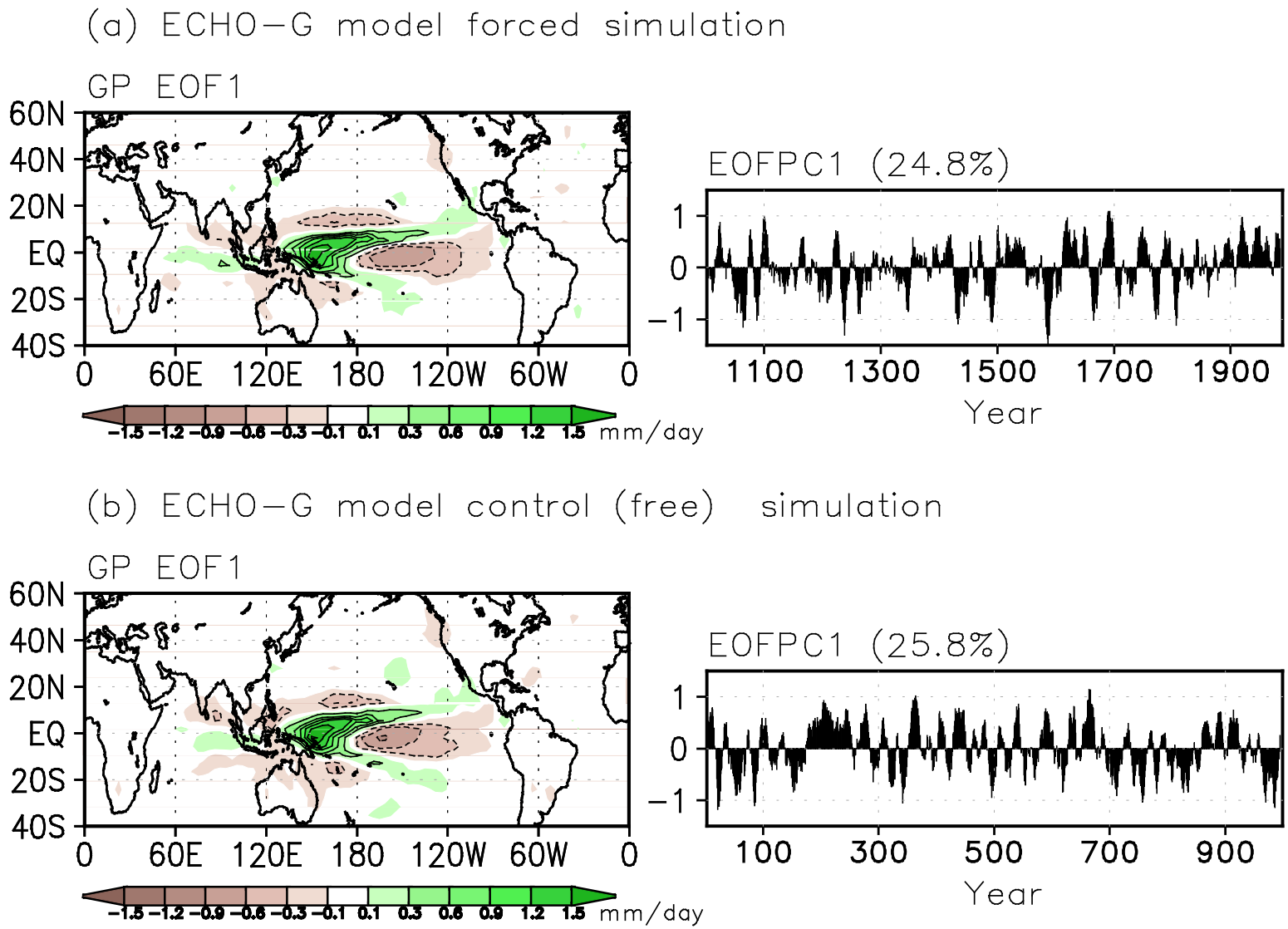
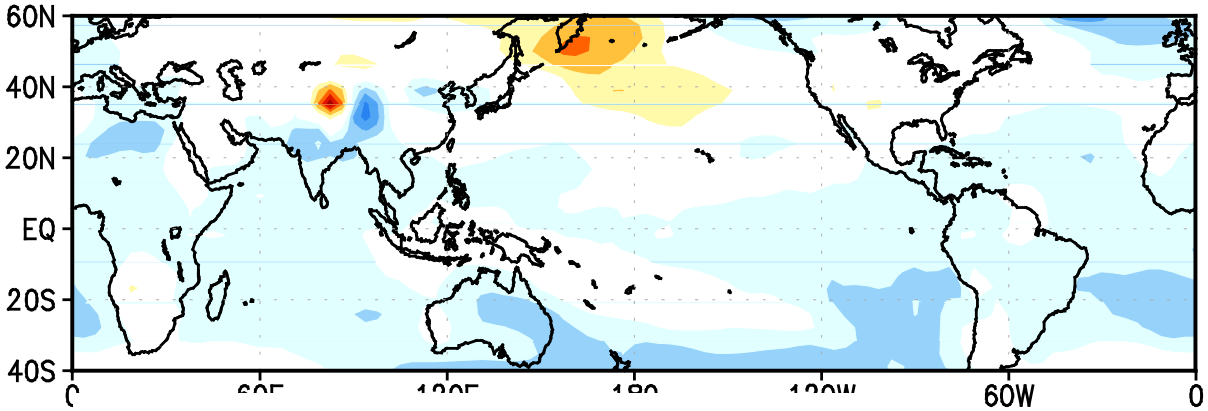


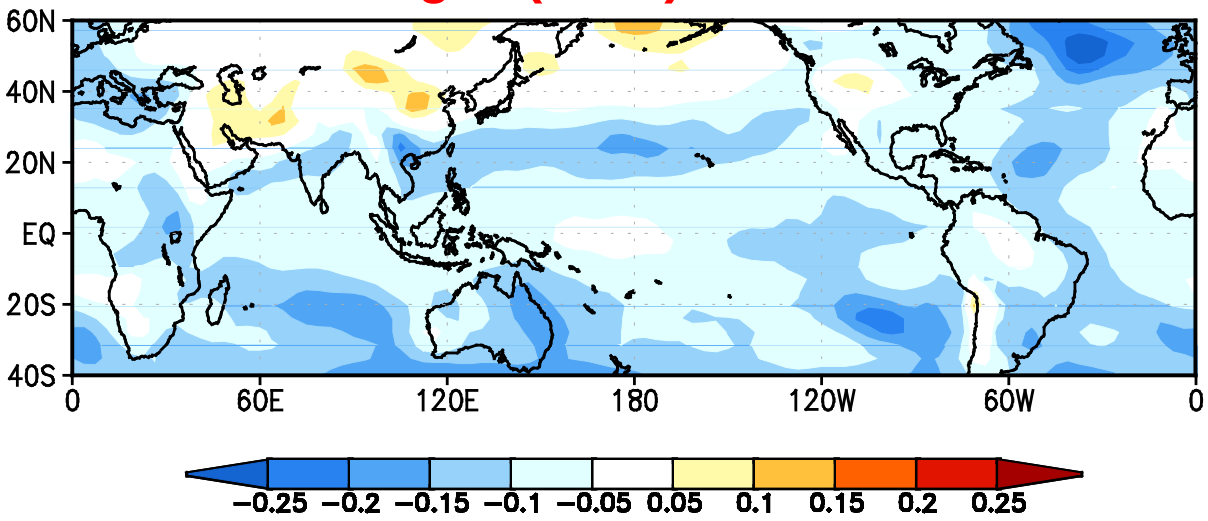
Fig. 2 The internal feedback mode. (a) The spatial structure (left) and principal component (right) of the leading EOF mode of global precipitation obtained from the ECHO-G model forced simulation. (b) The same as in (a) except from the ECHO-G model control (free) simulation. The data used are 11-year running mean time series.

Stability (T850- T500) regressed onto

Solar-Volcanic (SV) mode



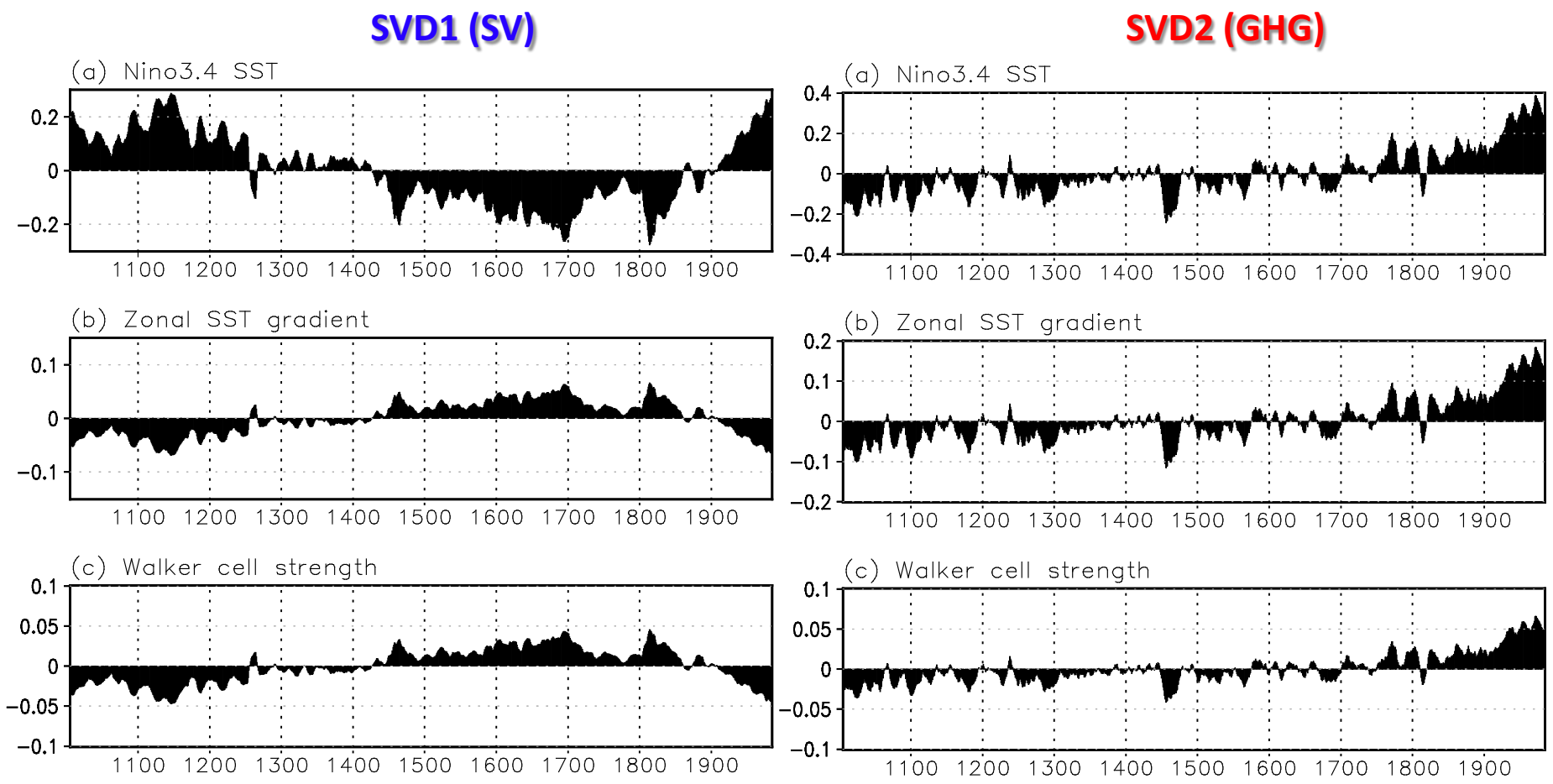
Greenhouse gas (GHG) mode



Static s
forced r
Negativ
stabiliz

V

GHG response is more stable, favoring Weaker Walker mechanism



Characteristics of the SV forced mode (left) and the GHG forced mode (right) for the period 1000-1990: (a) The Nino 3.4 SST, (b) the zonal SST gradient, i.e., the SST in the eastern Pacific (10S-10N, 160W-90W) minus the SST in the western Pacific (10S-10N, 120E-160E), and (c) the low-level Walker cell (the zonal wind at 850 hPa averaged between 10S and 10N and 120E-120W).