Plans and Progress on a Coordinated Research Effort on Long-Term Drought: The US CLIVAR Working Group on Drought

USCLIVAR Annual Summit

Annapolis, MD
23-25 July 2007

Siegfried Schubert (NASA/GMAO) and Dave Gutzler (Univ New Mexico)
Cochairs

The US CLIVAR Drought Working Group

U.S. Membership

- Tom Delworth NOAA GFDL
- Rong Fu Georgia Institute of Technology
- **Dave Gutzler (co-chair)** University of New Mexico
- Wayne Higgins NOAA/CPC
- Marty Hoerling NOAA/CDC
- Randy Koster NASA/GSFC
- Arun Kumar NOAA/CPC
- Dennis Lettenmaier University of Washington
- Kingtse Mo NOAA CPC
- Sumant Nigam University of Maryland
- Roger Pulwarty NOAA- NIDIS Director
- David Rind NASA - GISS
- **Siegfried Schubert (co-chair)** NASA GSFC
- Richard Seager Columbia University/LDEO
- Mingfang Ting Columbia University/LDEO
- Ning Zeng University of Maryland

International Membership: Ex Officio

- Bradfield Lyon International Research Institute for Climate
- Victor O. Magana Mexico
- Tim Palmer ECMWF
- Ronald Stewart Canada
- Jozef Syktus Australia

The US CLIVAR Drought Working Group

Other interested participants

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Terms of Reference

- propose a working definition of drought and related model predictands of drought
- coordinate evaluations of existing relevant model simulations
- suggest new model experiments designed to address some of the outstanding uncertainties concerning the roles of the ocean and land in long term drought
- coordinate and encourage the analysis of observational data sets to reveal antecedent linkages of multi-year drought
- organize a community workshop in 2008 to present and discuss results

Drought Working Group WebPage

- http://www.usclivar.org/Organization/drought-wg.html
- Information on:
  - Drought WG prospectus
  - Relevant meetings
  - Summary of teleconferences (approximately monthly)
  - List of relevant model simulations
  - List of relevant observational data sets

- maintained by U.S. CLIVAR Project Office (Cathy Stephens)

Current/Planned Activities

- Publications
  - Article in U.S. CLIVAR VARIATIONS (describing Drought WG)
  - BAMS article (“Predicting Drought on Seasonal to Decadal Time Scales” - summary of 2005 Drought Workshop) To appear in BAMS - October 2007.
  - Refereed publication - progress, challenges (BAMS?)
- Drought definition/index subgroup (Dave G.)
- Model simulations subgroup (Siegfried S.)
- Observations subgroup (Sumant N.)
- Drought Workshop in 2008 (with DRICOMP)

Some Results from Drought Index Subgroup

- We hope to develop a working definition of drought (onset and demise) that is useful to both the prediction/research and applications communities. The goal is to define drought in a way that is quantifiable and verifiable for the purpose of model prediction experiments.

The “robustness” of the model-based soil moisture drought index – a study using GSWP-2 data.

(Questions? Contact Randy Koster at 301-614-5781 or randal.d.koster@nasa.gov)

Let $w(j,n)$ = model's total soil moisture for day j of year n.

Define:

$$\boxed{WI(j,n) = \frac{w(j,n) - \mu_w(j)}{\sigma_w(j)}}$$

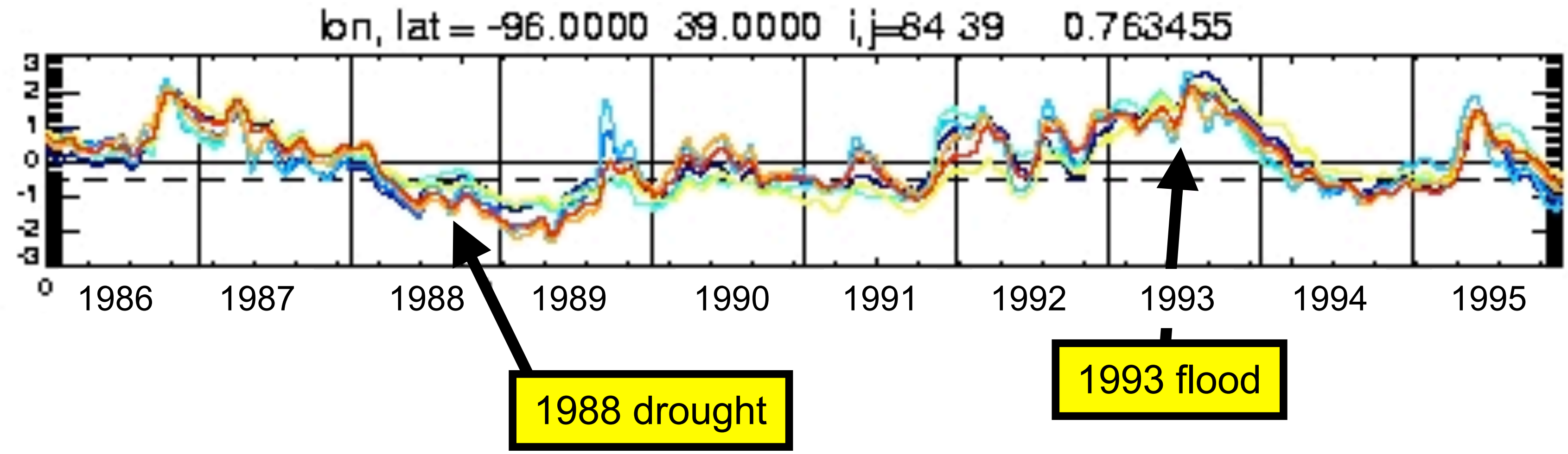
where

$\mu_w(j)$ = Mean (over many years) of w on day j.
$\sigma_w(j)$ = Standard deviation of w on day j.

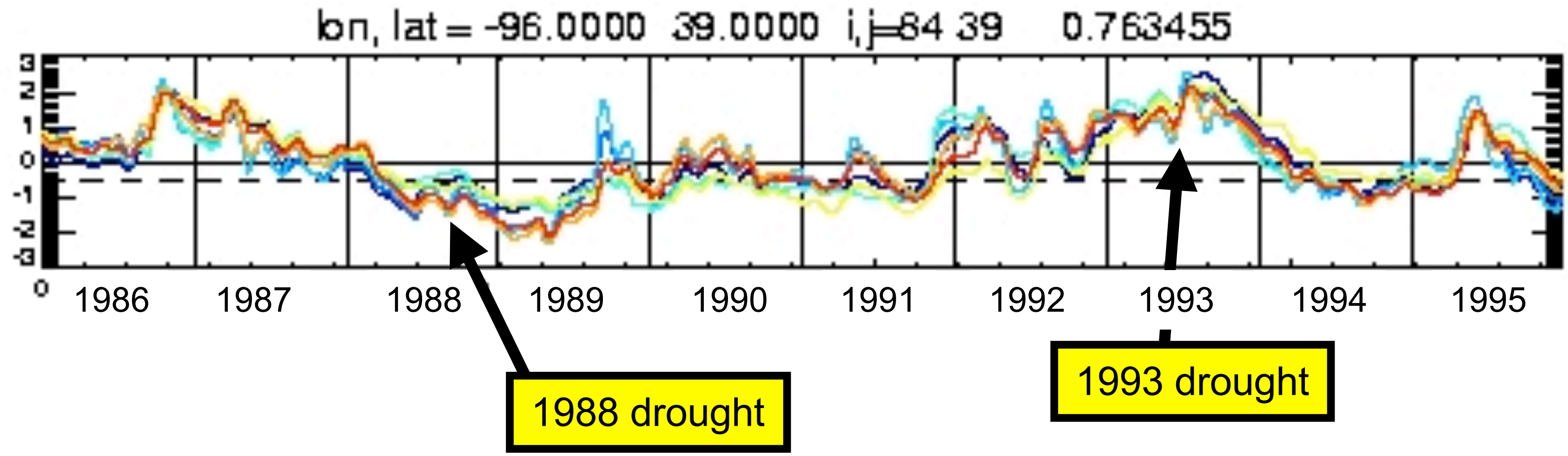
Note: $\mu_w(j)$ and $\sigma_w(j)$ are specific to the model considered. (Their values may differ greatly between models, and not just because of differing profile thicknesses or soil types.)

In GSWP-2, a number of land surface models were driven for 10 years with the same observations-based meteorological forcing. What we will try to demonstrate here is that the models produce a similar WI product – i.e., that WI is largely a model-independent quantity.

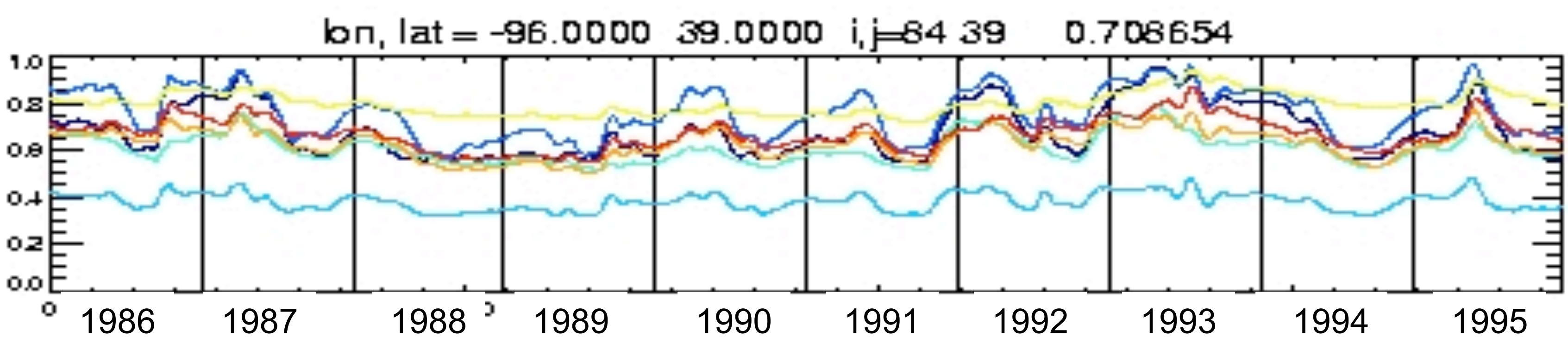
WI values for 7 different GSWP-2 models over a point in the U.S. Great Plains



WI values for 7 different GSWP-2 models over a point in the U.S. Great Plains.

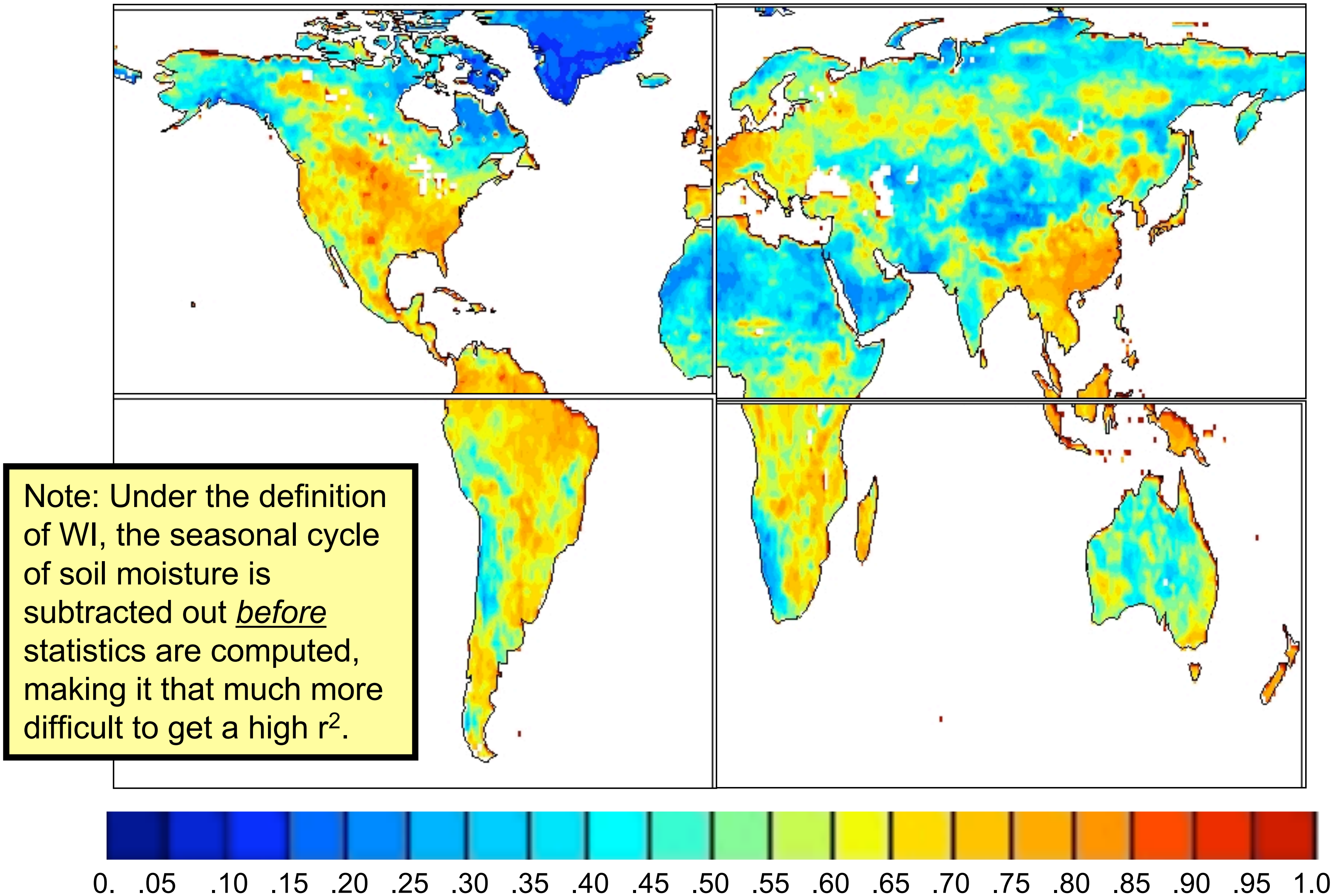


The unprocessed soil water diagnostics (shown here as degree of saturation) are not nearly as model-independent.



Average r^2 between models

31-day smoother, detrended



Some Results from Model Simulation Subgroup

- Existing runs: Website has list of existing relevant model simulations

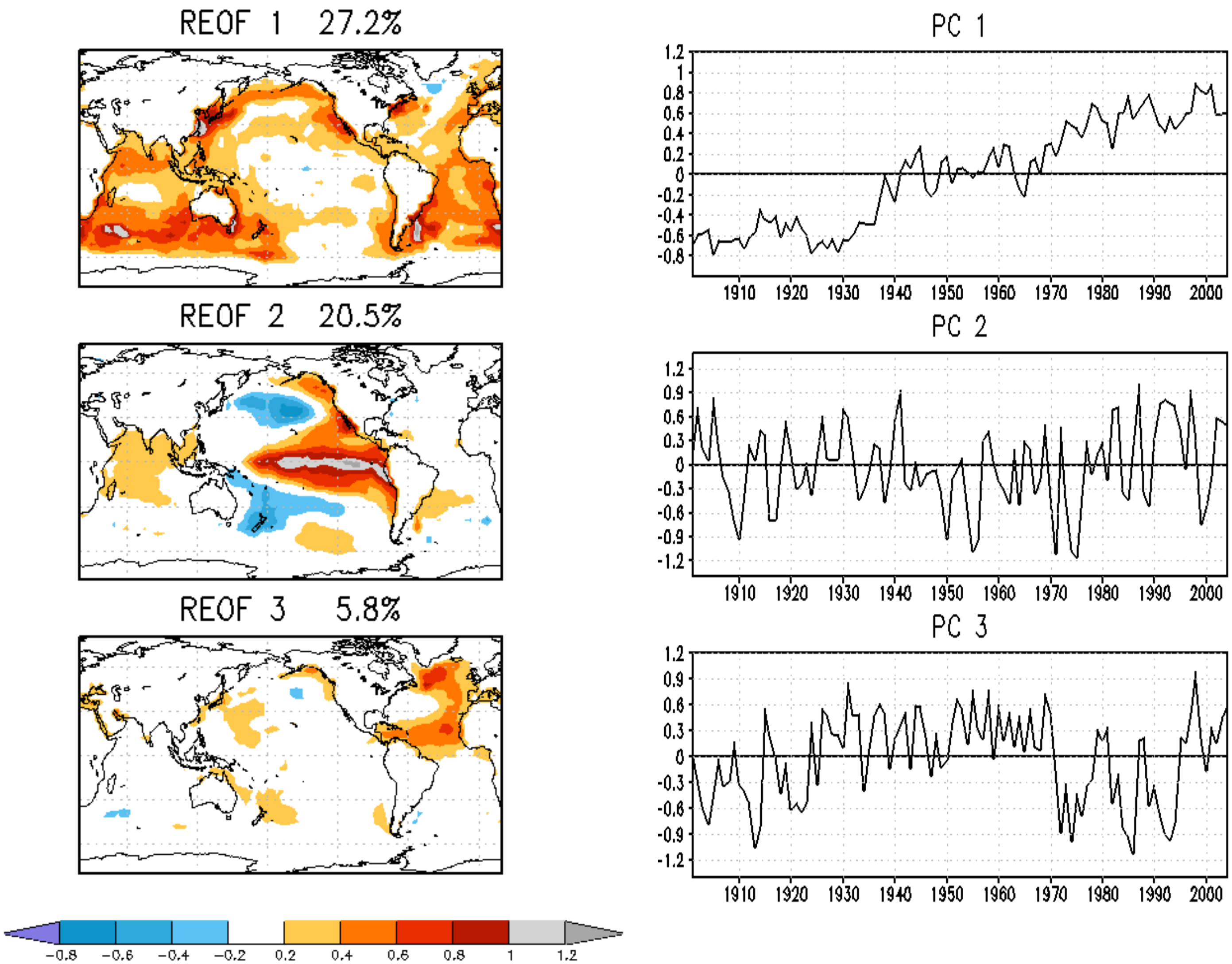
- New runs: The idea is for several modeling groups to do identical (somewhat idealized) experiments to address issues of model dependence on the response to SSTs (and the role of soil moisture), and to look in more detail at the physical mechanisms linking the SST changes to drought

Leading EOFs and Time series (annual mean SST - 1901-2004)

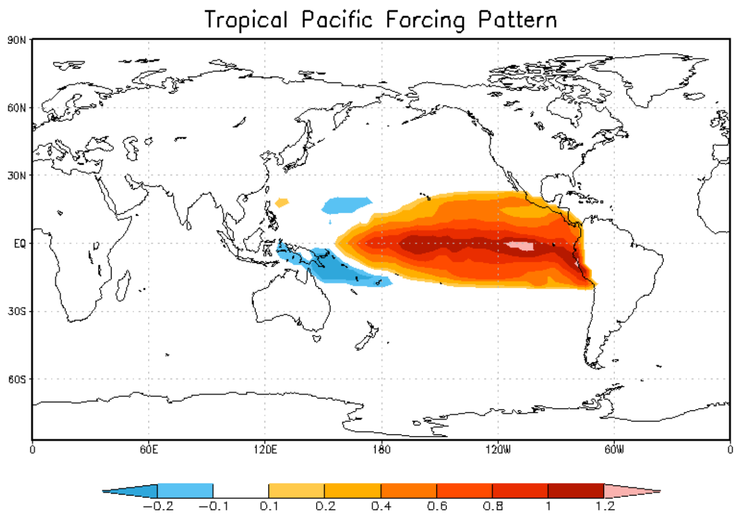
Linear Trend Pattern (LT)

Pacific Pattern (Pac)

Atlantic Pattern (Atl)

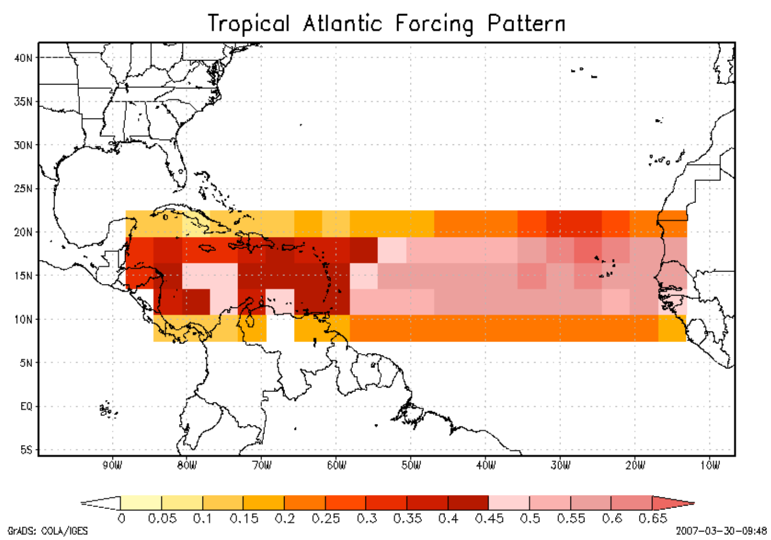


Tropical Only (Pac and Atl)



Tropical Pac

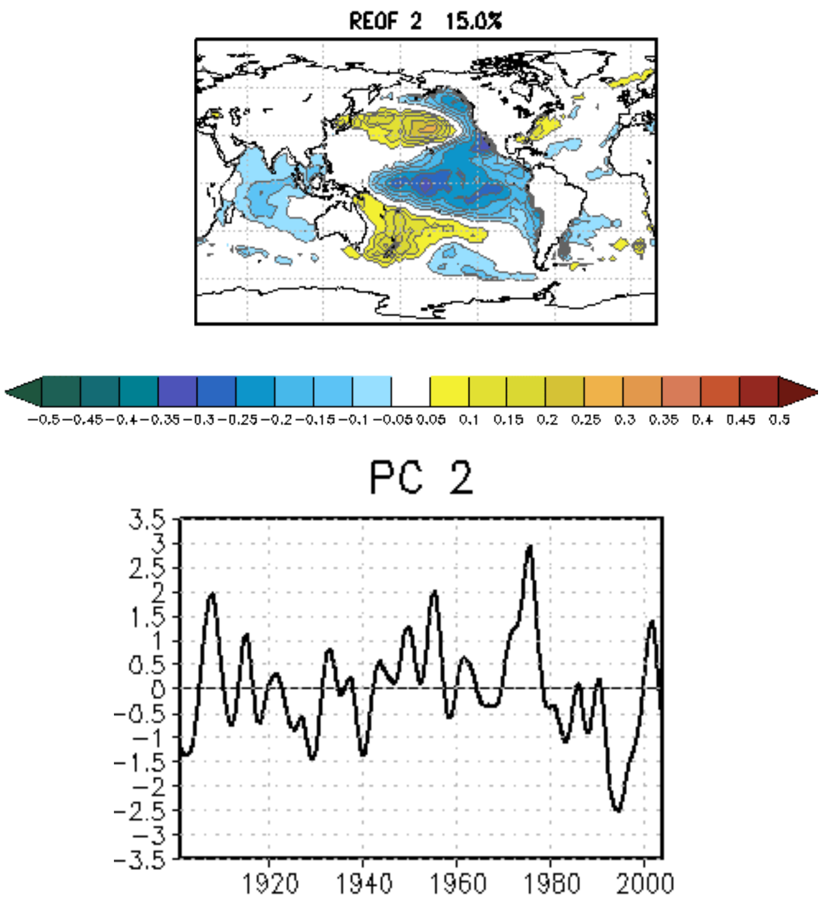
The tropical Pacific region is -21S to 21N, with a taper between 21 and 15. The anomaly is 0 at 21-degrees, 1/2 of the full anomaly at 18-degrees, and the full anomaly equator-ward of 15-degrees.



Tropical Atl

The edges of the box with the full anomalies were chosen as 88W to 13W, and 12 N to 18N. The anomalies were tapered linearly north and south, with latitudes 9N and 21N getting 1/2 the anomaly, and with the anomaly going to 0 at latitudes 6N and 24N.

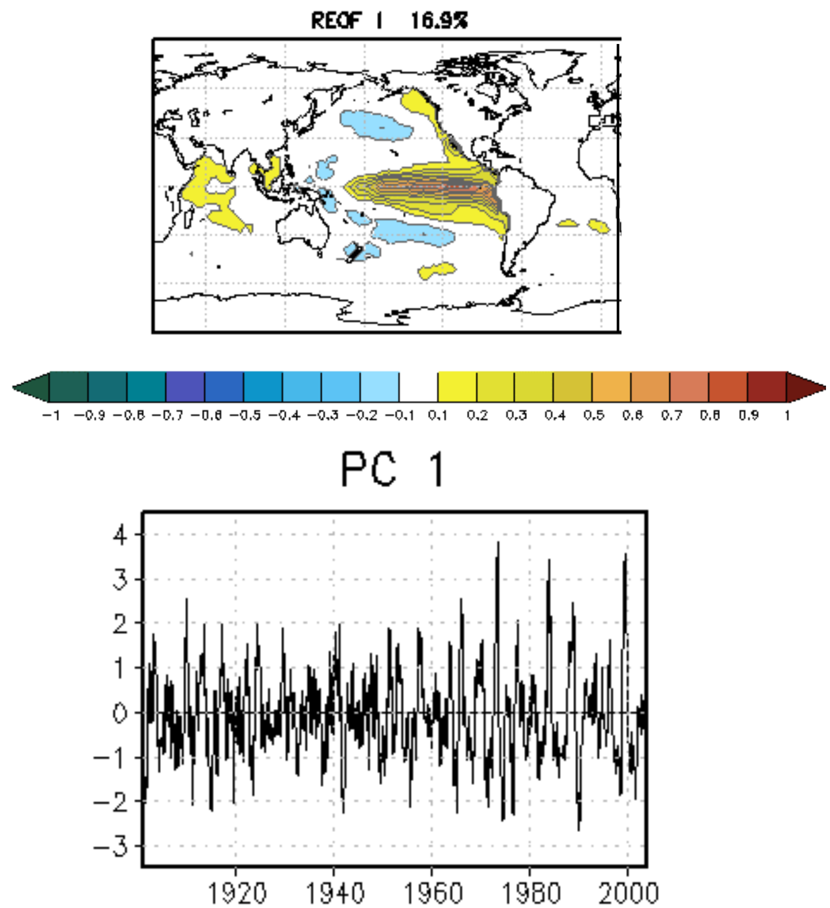
Low Frequency



Time Scales > 6 years

(REOF 2)

ENSO



Time Scales < 6 years

(REOF 1)

Participating models

NASA (NSIPP1 and GEOS-5) - Contact: S. Schubert
GFDL - Contact: Tom Delworth
NCEP - Kingtse Mo and Jae Schemm
CCM3 - Contact: Richard Seager
CAM3.5 - Contact: Aiguo Dai and ?

- Some results with the NASA NSIPP-1 AGCM

AGCM: NSIPP-1 (NASA S-I Prediction Project)

Climatology and Skill (Bacmeister et al. 2000, Pegion et al. 2000, Schubert et al. 2002)

Great Plains drought (Schubert et al. 2003; 2004)

Global grid point dynamical core, 4rth Order (Suarez and Takacs 1995)

Relaxed Arakawa-Schubert Convection (Moorthi and Suarez 1992)

Shortwave/Longwave Radiation (Chou et al. 1994, 1999)

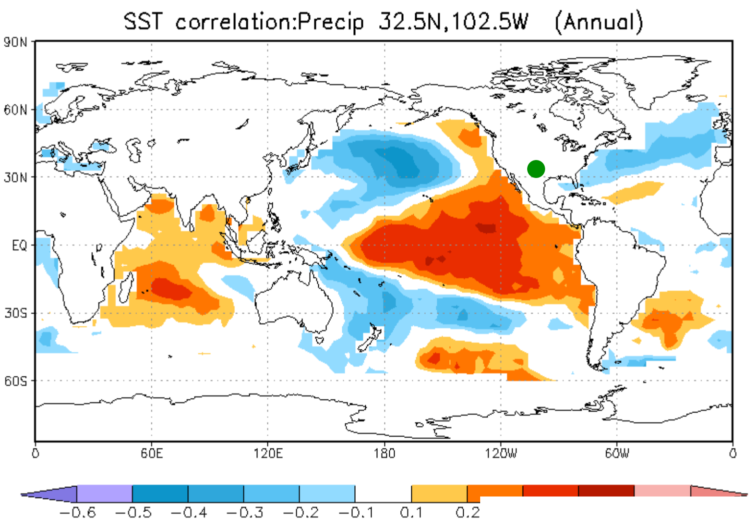
Mosaic interactive land model (Koster and Suarez 1992, 1996)

1st Order PBL Turbulence Closure (Louis et al. 1982)

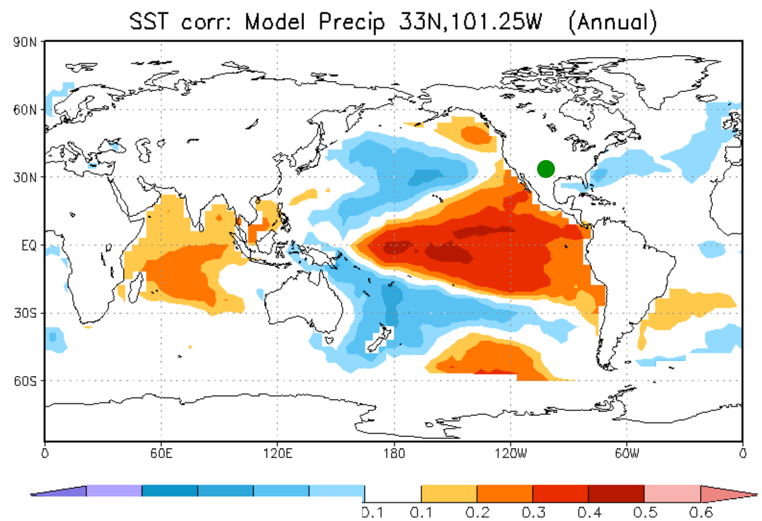
Model resolution: 3 degree latitude by 3.75 degree longitude (34 levels)

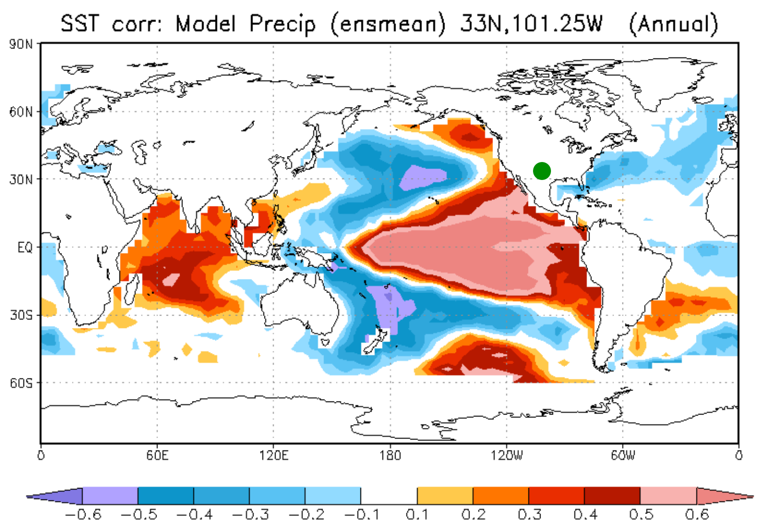
Annual Mean Great Plains Precipitation Correlated with SST (1901-2004)

Observations



Model - individual ens. members

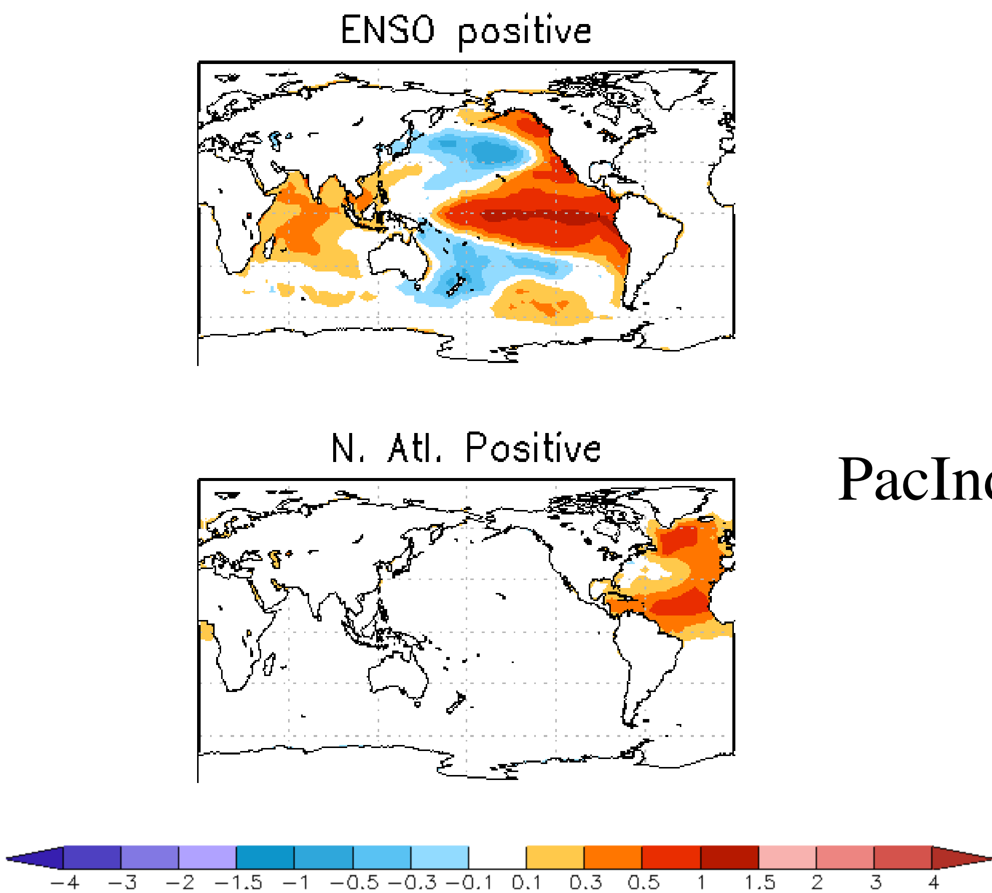




Model - correlation with ensemble Mean

Impacts of Pacific and Atlantic Patterns

Idealized Experiments



SST Forcing patterns
(warm phase)

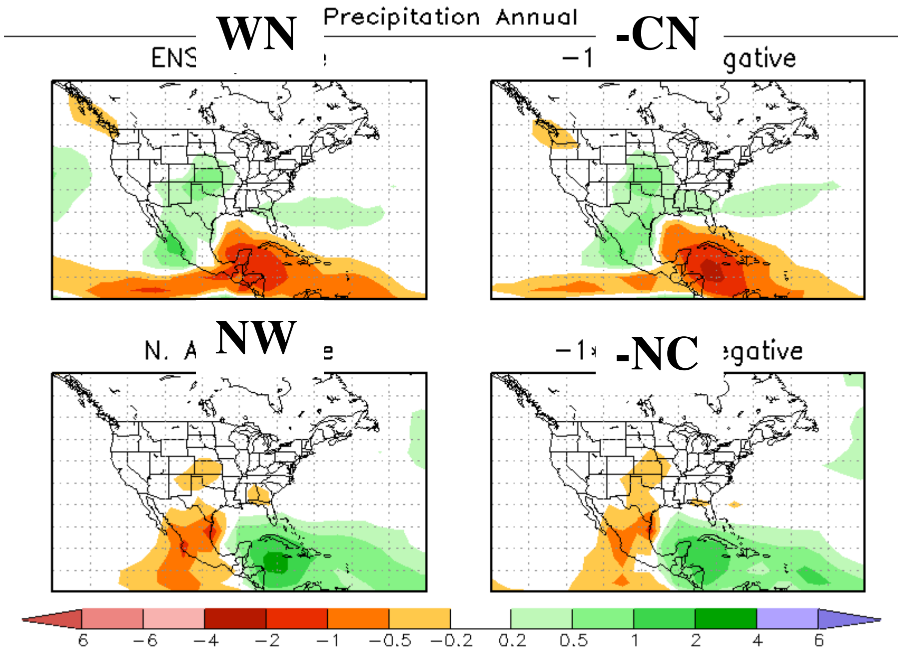
NATL

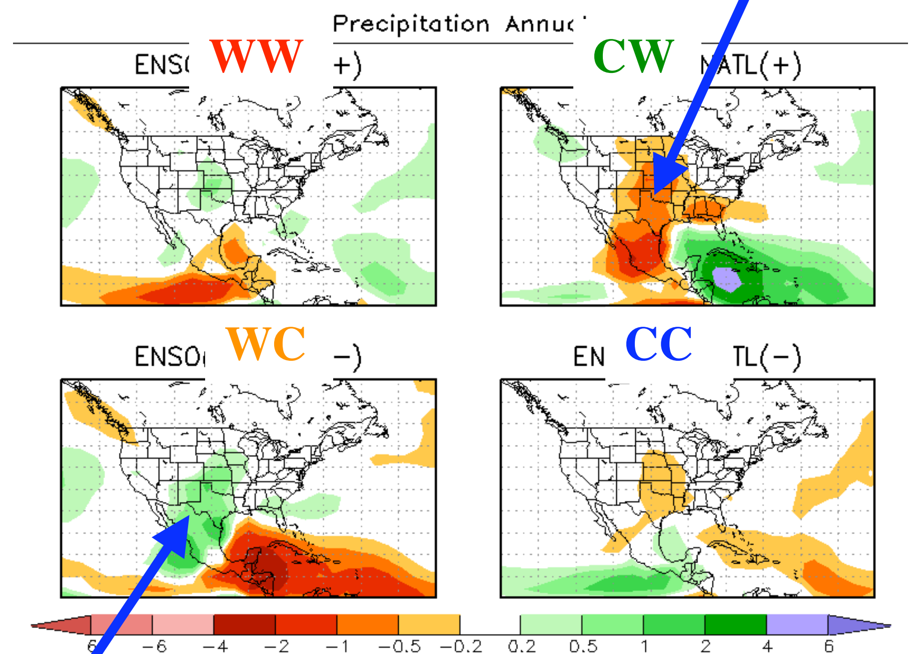
PacInd

	warm	neutral	cold
warm	ww	wn	cw
neutral	nw		nc
cold	wc	cn	cc

Annual Mean Precipitation Responses

Major drought conditions





Responses to individual EOFs

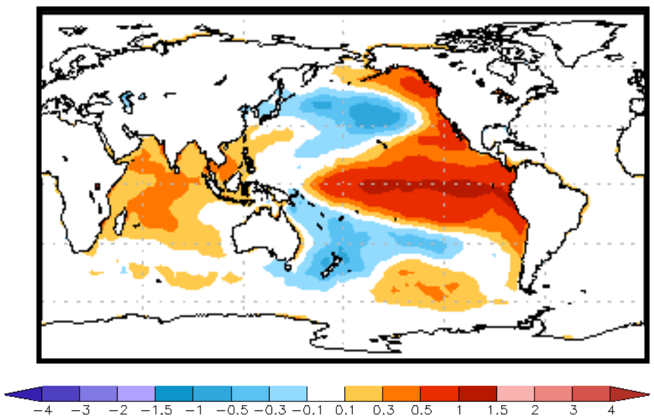
Pluvial conditions

Responses to combined EOFs

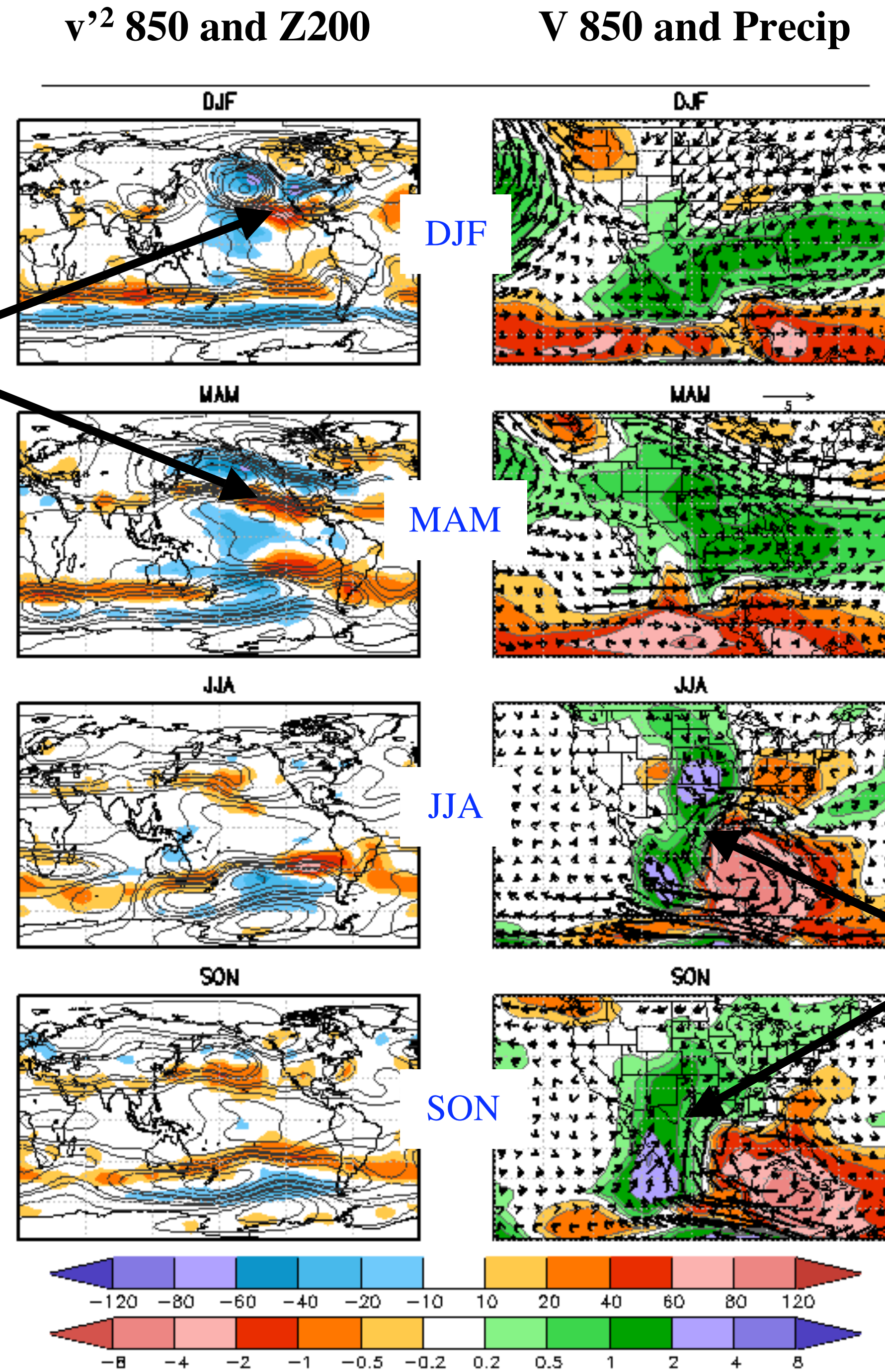
Annual cycle of Response to Pacific and Atlantic Patterns

Seasonality in the Response to Pacific SST

Shift in storm tracks



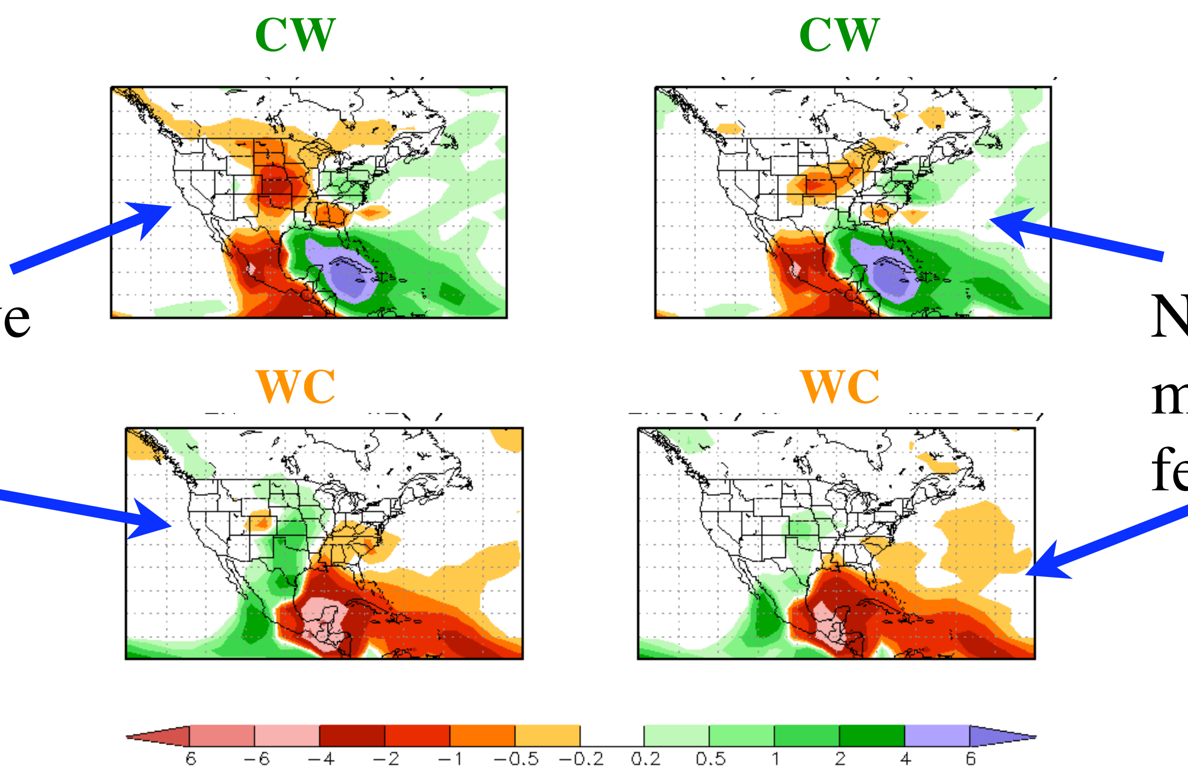
SST forcing



Change in LLJ

Impact of Soil Moisture Feedbacks on JJA Precipitation

Interactive soil moisture



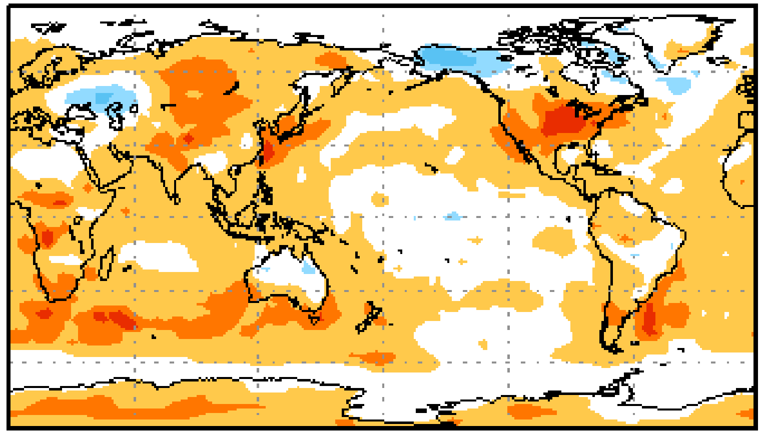
No soil moisture feedbacks

Response to Linear Trend Pattern

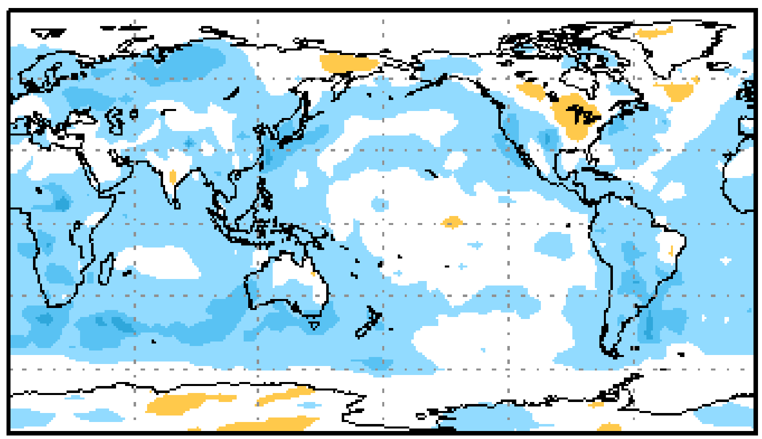
Impact of Linear Trend Pattern

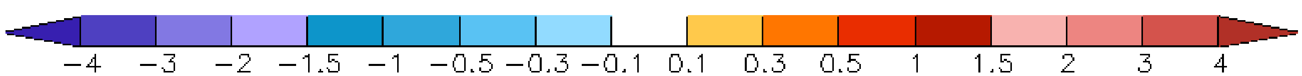
Annual Mean
Surface Temperature

Positive Phase



Negative Phase

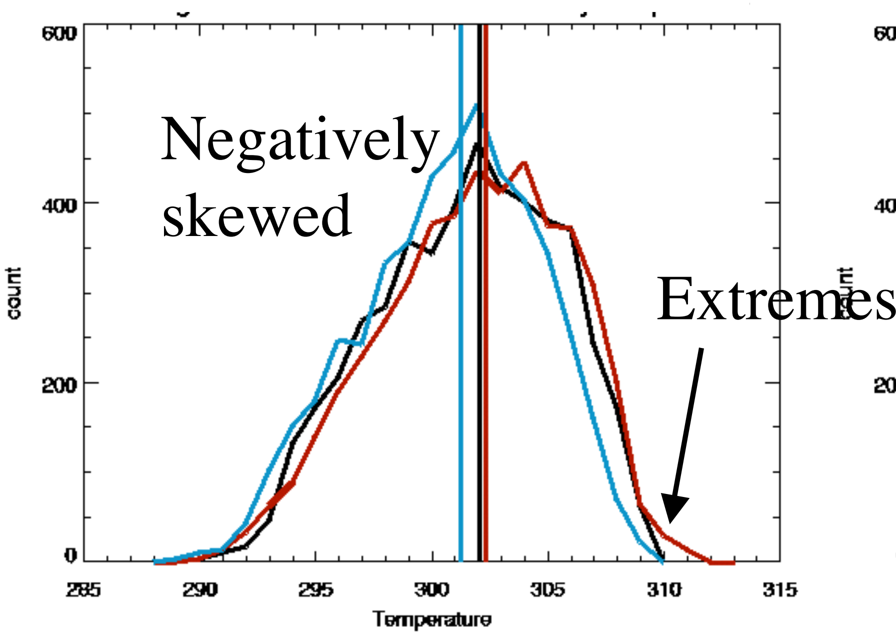




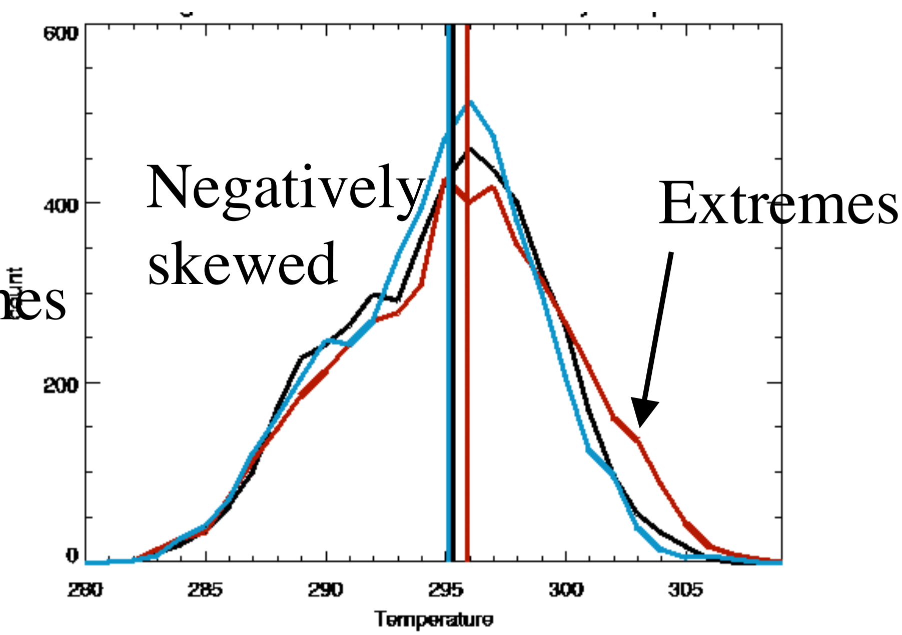
°C

Histograms of Daily Surface Temperature
(Increase in Heat Waves?)

Southern Great Plains



Northern Great Plains



Red: +GW SST, Blue: -GW SST, Black: climatological SST

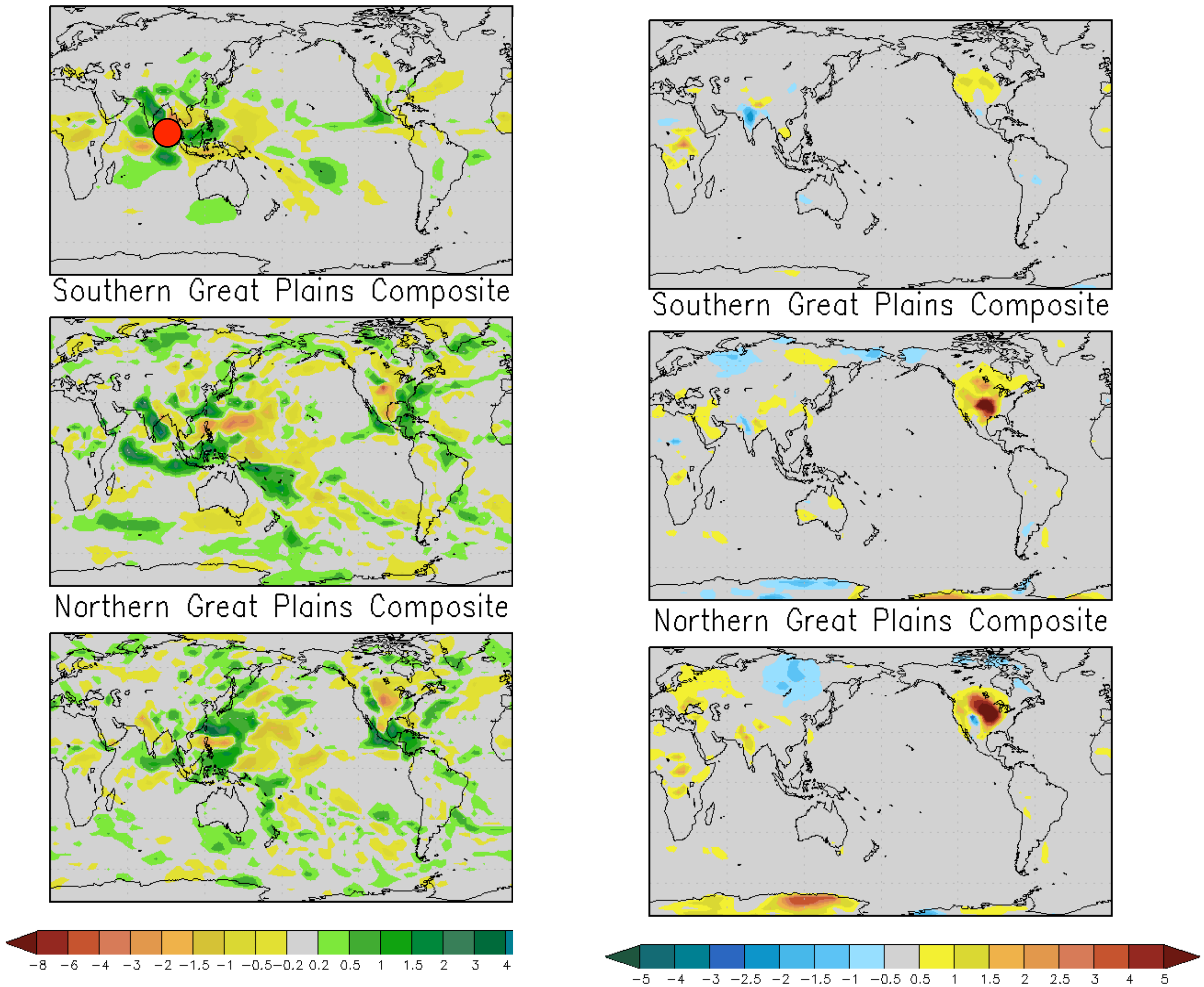
U.S. Heat Waves - A Response to Remote Forcing?

Precipitation | Surface Temperature

Response to idealized heat source in Indian Ocean (90°E)

Composite for >2σ in Tsfc in S. Great Plains

Composite for >2σ in Tsfc in N. Great Plains



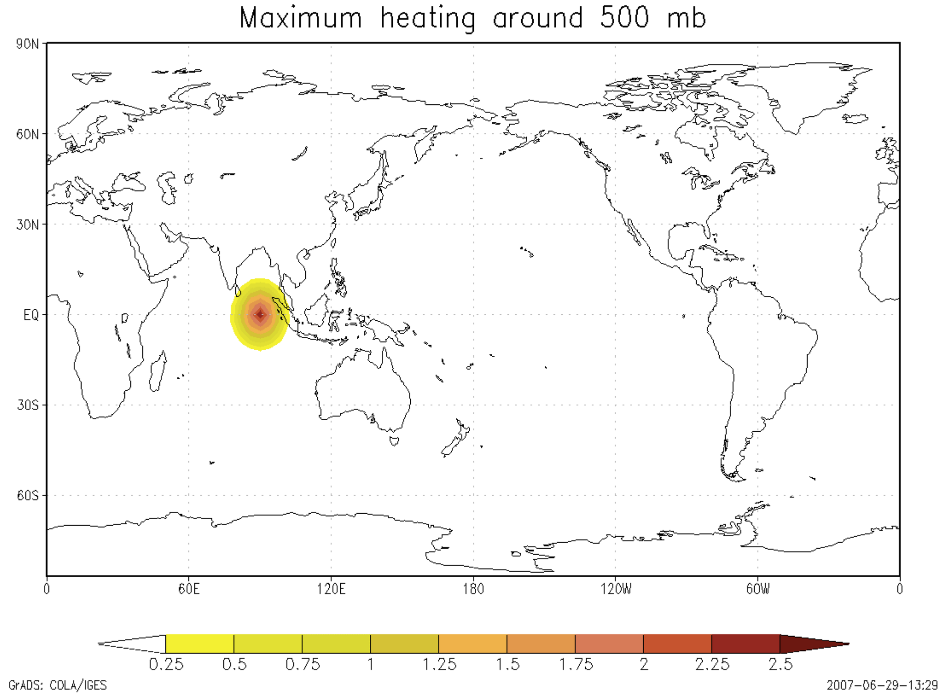
Summary Remarks

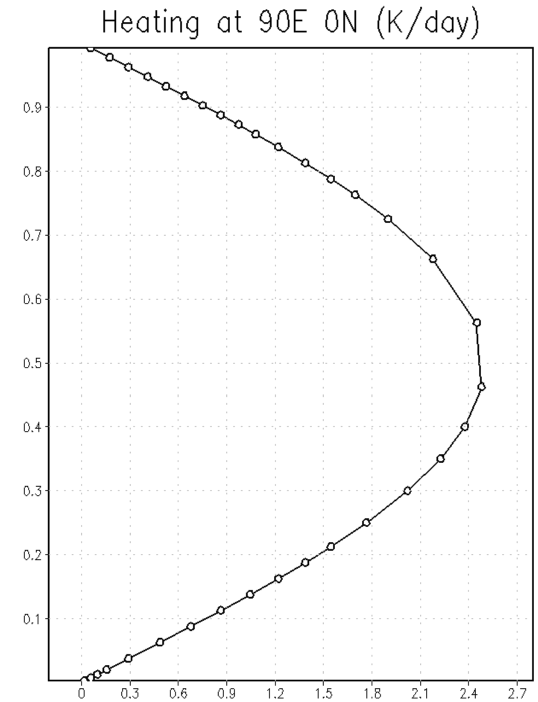
- US CLIVAR Drought Working Group is making progress on achieving its goals
  - propose a working definition of drought and related model predictands of drought
  - coordinate evaluations of existing relevant model simulations
  - suggest new model experiments designed to address some of the outstanding uncertainties concerning the roles of the ocean and land in long term drought
  - coordinate and encourage the analysis of observational data sets to reveal antecedent linkages of multi-year drought
  - organize a community workshop in 2008 to present and discuss results

- We look forward to more community participation
  - We will be making model datasets available (TBD)
  - Please visit our website http://www.usclivar.org/Organization/drought-wg.html
  - Please take a look at latest issue of "U.S. CLIVAR VARIATIONS" for more information
  - Workshop in late 2008 (with DRICOMP)

Extra Slides

Idealized Heating

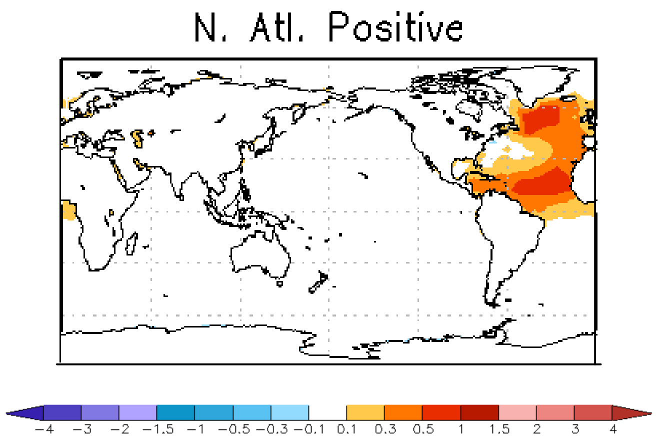




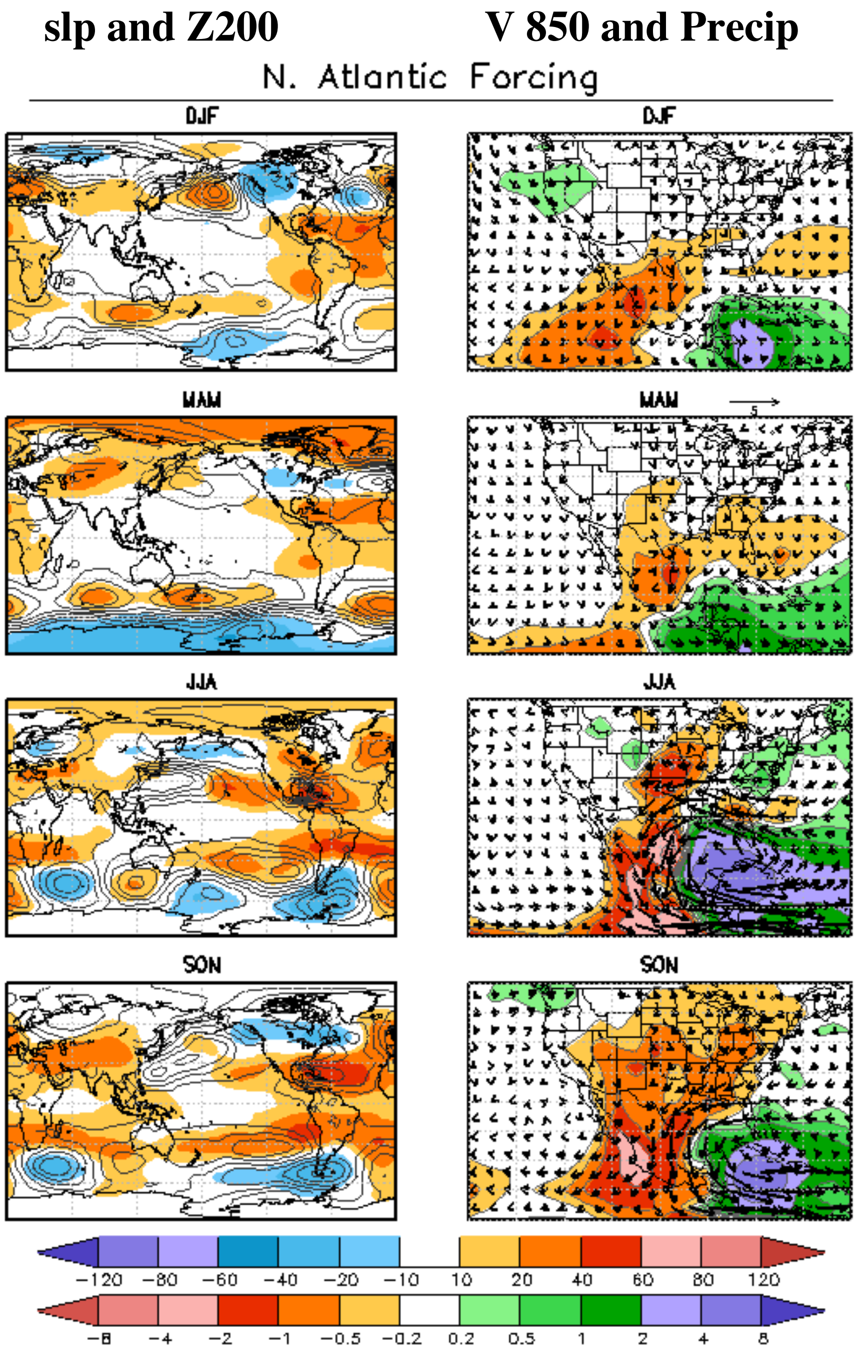
Conclusions

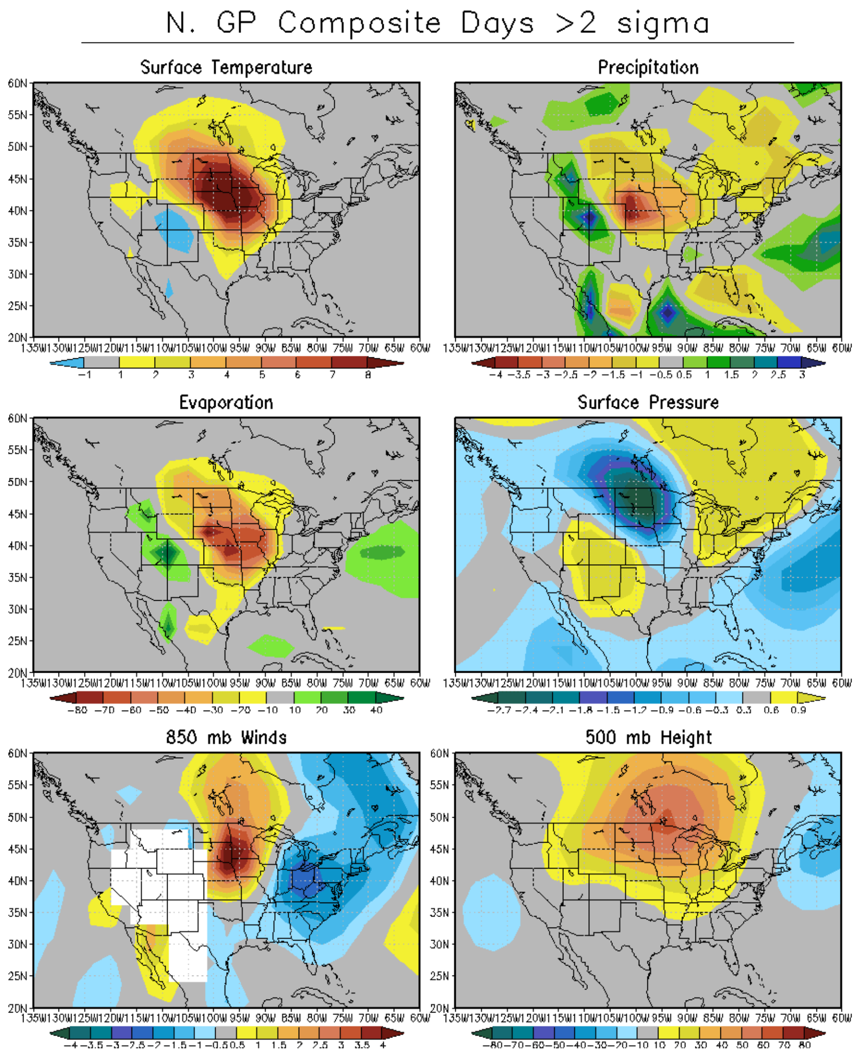
- Both the **Pacific and Atlantic Patterns** impact precip in the Great Plains
  - Cold (warm) Pacific leads to drought (pluvial conditions)
  - Warm (cold) Atlantic leads to drought (pluvial conditions)
  - Largest impacts occur when Pacific and Atlantic have opposite signed SST anomalies
- The influence of **the Atlantic pattern** is largest during the summer and fall
  - impact is on the flow of moisture entering from the Gulf of Mexico
- The **Pacific pattern** impacts Great Plains precipitation during all seasons
  - during winter and spring the influence appears to be primarily through changes in the planetary waves and associated changes in storm tracks
  - during summer and fall the impact appears to be also through an impact on the low level moisture entering the US from the Gulf
- The **Global Warming pattern** shows some regional impact over land
  - In particular, substantial warming over North American Great Plains
  - Idealized heating runs suggest possible link to Indian Ocean/Pacific warm pool

Seasonality in the Response to Atlantic SST

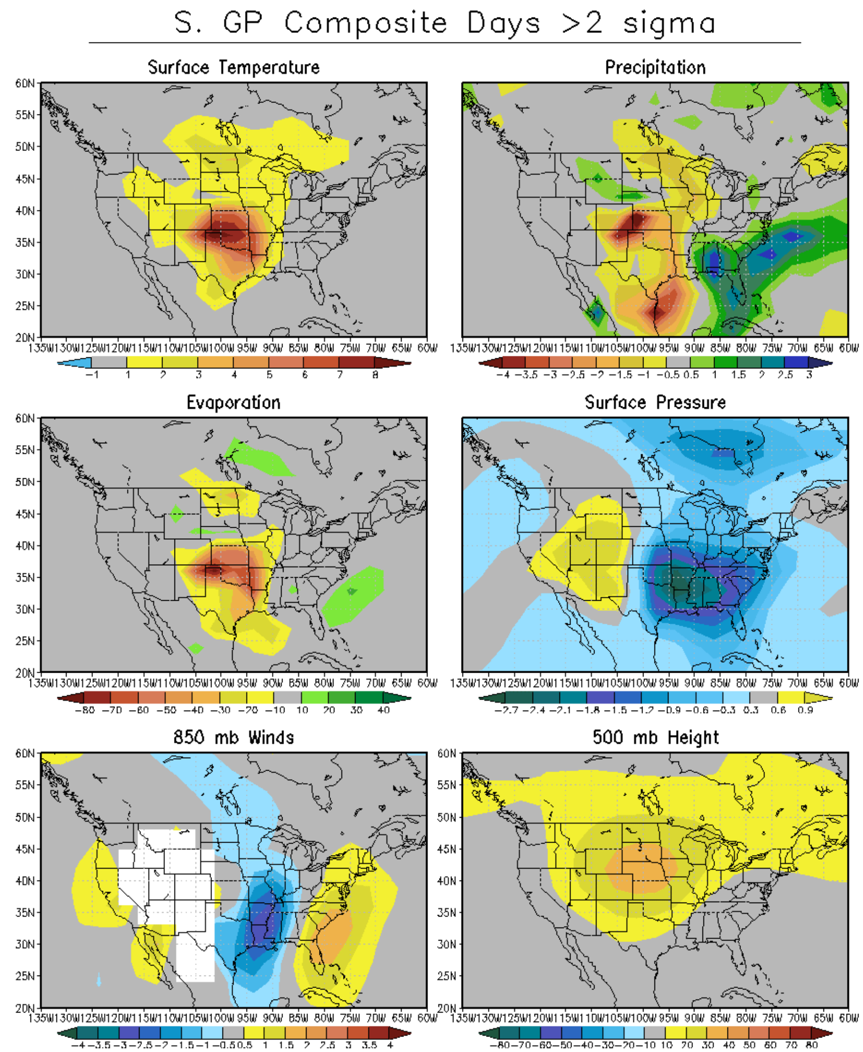


SST forcing





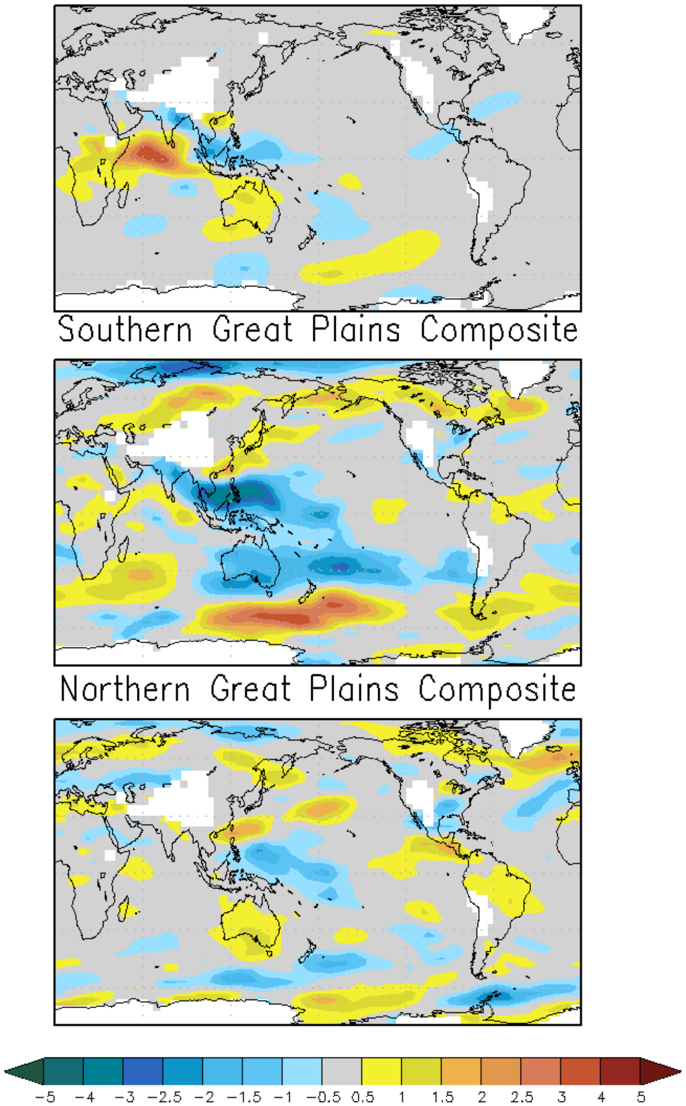
Composite for >2σ in Tsfc in Northern Great Plains



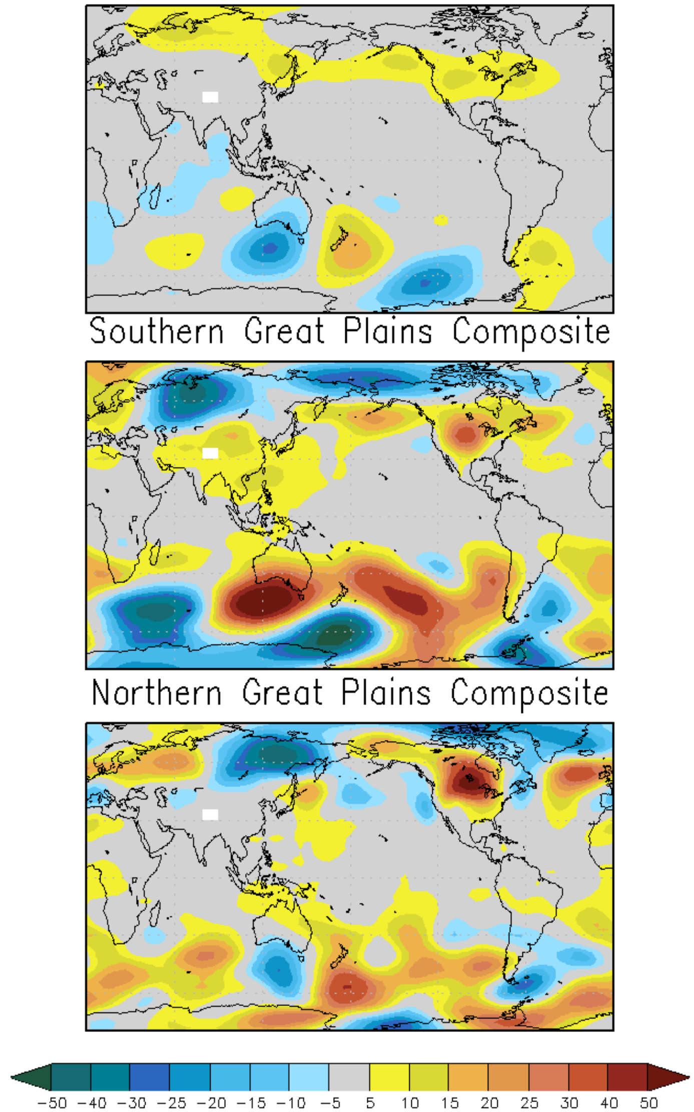
Composite for >2σ in Tsfc in Southern Great Plains

JJA Response to Idealized Heating in the Indian Ocean (90°E)

850mb zonal wind



500mb Height



Seven land surface models were considered → there are 21 different pairings of models.

For each pairing, and at each grid point, compute the r^2 between the two WI time series → 21 values of r^2 at each grid point.

Average the 21 r^2 values → a measure of the "agreement" amongst the model-generated drought indices.