Drought Research Priorities in the United States

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Global Modeling and Assimilation Office
NASA/GSFC

Third Drought Research Initiative Workshop

Calgary AB
17-19 January 2008

Overview

- Research community priorities
  - 2005 Drought workshop

- Progress in addressing priorities
  - USCLIVAR working group

Results and Recommendations of a Workshop on

Observational and Modeling Requirements for Predicting Drought on Seasonal to Decadal Time Scales

17-19 May 2005

University of Maryland Inn and Conference Center

- **Organizers:** *S. Schubert, R. Koster, M. Hoerling, R. Seager, D. Lettenmaier, A. Kumar, and D. Gutzler*

- **Sponsors/support:** NASA programs on Modeling, Analysis and Prediction, and Terrestrial Hydrology, and NOAA's Climate Prediction Program for the Americas
  - *Don Anderson and Jared Entin (NASA)*
  - *Mike Patterson and Jin Huang (NOAA)*

- **The more than 100 participants** included experts in both drought research and applications, and spanned the drought communities of the United States, Canada, Mexico, Central and South America and Australia.

Workshop report is available at

http://gmao.gsfc.nasa.gov/pubs/conf/archive/conf_2005.php

Summary is published in Oct 2007 BAMS

Short-term drought problem

- Develop coordinated effort in drought monitoring, prediction and early warning, in support of NIDIS:
  - Creation of a "National Drought Attribution and Prediction Consortium" that uses multiple models and analysis techniques to address drought problems in coordination with stakeholders
- Establish long (multi-decade) climate records adequate for retrospective studies, and as required for initialization, calibration and validation:
  - global and regional atmosphere/land reanalyses, with a focus on the improved representation of the hydrological cycle
- Improve (real-time) observation/assimilation of key surface variables needed for monitoring, model initialization and/or validation (with uncertainty estimates):
  - soil moisture profiles (monitoring system focused on "sensitive" regions, such as a pilot effort focused on the Great Plains)
  - forcing data (precipitation, radiation, etc.) for land data assimilation
  - vegetation properties (e.g., from NDVI, EDVI MODIS data)
  - Snowpack, surface temperature, streamflow
- Improve coupled (atmosphere-ocean-land) model prediction system. Development should focus on:
  - teleconnections between SST variations and continental precipitation
  - weather statistics (particularly extreme events)
  - land/atmosphere interaction
  - surface/subsurface water reservoirs (including estimates of recovery time)
- Improve understanding of roles of local and remote processes on drought variability and predictability, as a function of timescale:
  - role/predictability of drought-related SST variations (including ENSO)
  - role/predictability of subsurface land water
  - role/predictability of short-term atmospheric variability (e.g., weather, MJO)

Long-term drought problem

- Foster research into the mechanisms that control the land surface branch of the hydrological cycle at multi-year (decadal) timescales:
  - decadal ocean variability in the context of regional drought
  - connection of ENSO and other shorter-term SST variability to the initiation and demise of long-term drought
  - deep soil moisture variability (drought unforced by SSTs)
  - aerosol feedbacks (i.e., the Dust Bowl)
  - decadal vegetation feedback
  - global change
  - drought migration

- A research effort focusing on the causes of historical droughts (attribution studies):
  - multiyear-to-decadal hindcasts of past droughts
  - characterization of drought duration, seasonality and spatial extent
  - development and improved use of paleodata for estimating decadal and longer term drought variations, including mega-droughts

- Improve simulations of hydrological variability on decadal time scales. Development should focus on:
  - realistic decadal SST variability and teleconnections to regional drought
  - realistic simulation of subsurface water on decadal time scales

- Foster research focusing on the predictability of multiyear-to-decadal drought:
  - assess the predictability of SST variability related to long term droughts
  - assess the predictability of the onset and demise of long term drought
  - experimental forecasting of droughts on the multiyear timescale

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

- http://www.usclivar.org/Organization/drought-wg.html

Activities

- Evaluating model-based drought indices
- Coordinating AGCM experiments to assess the roles of the ocean and land in long term drought
- Organizing a community workshop in 2008 to present and discuss results

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

Contact: Randy Koster randal.d.koster@nasa.gov)

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.

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

Define:

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

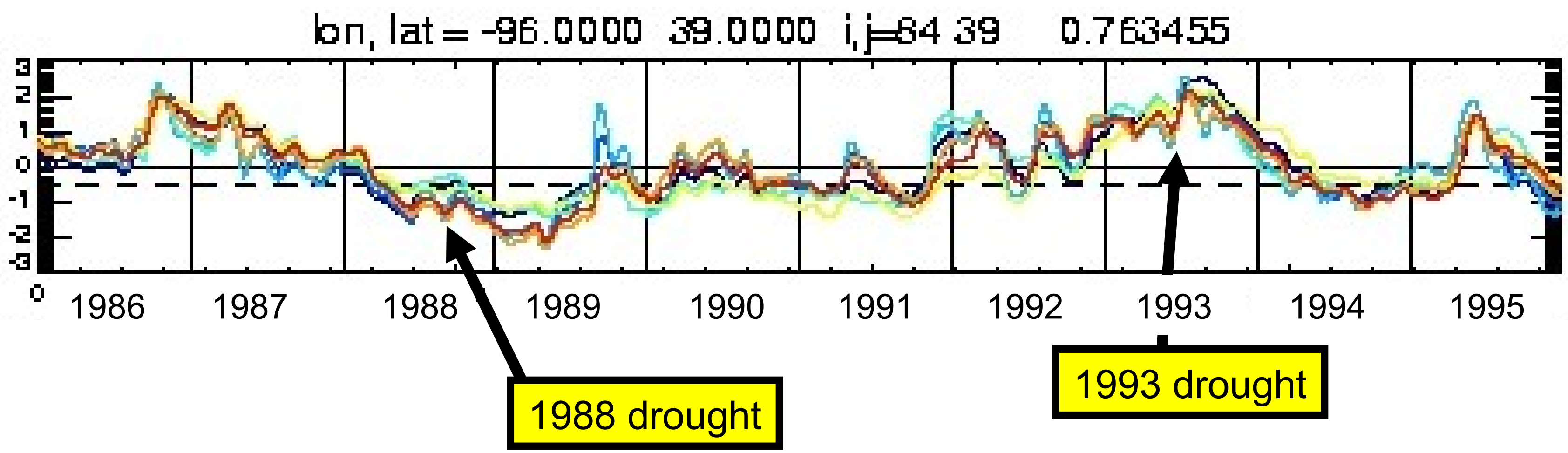
where

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

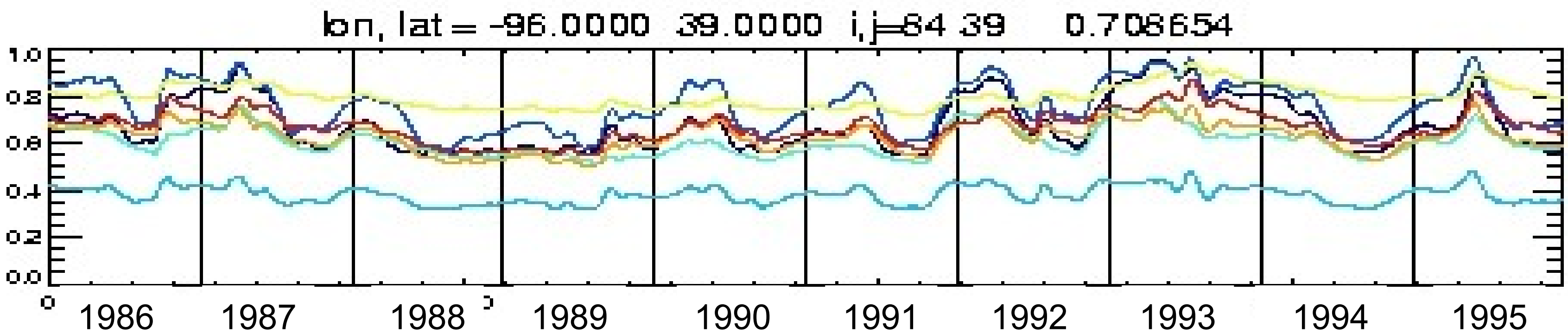
$\sigma_w(j)$ = Standard deviation of w on day j.

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.)

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

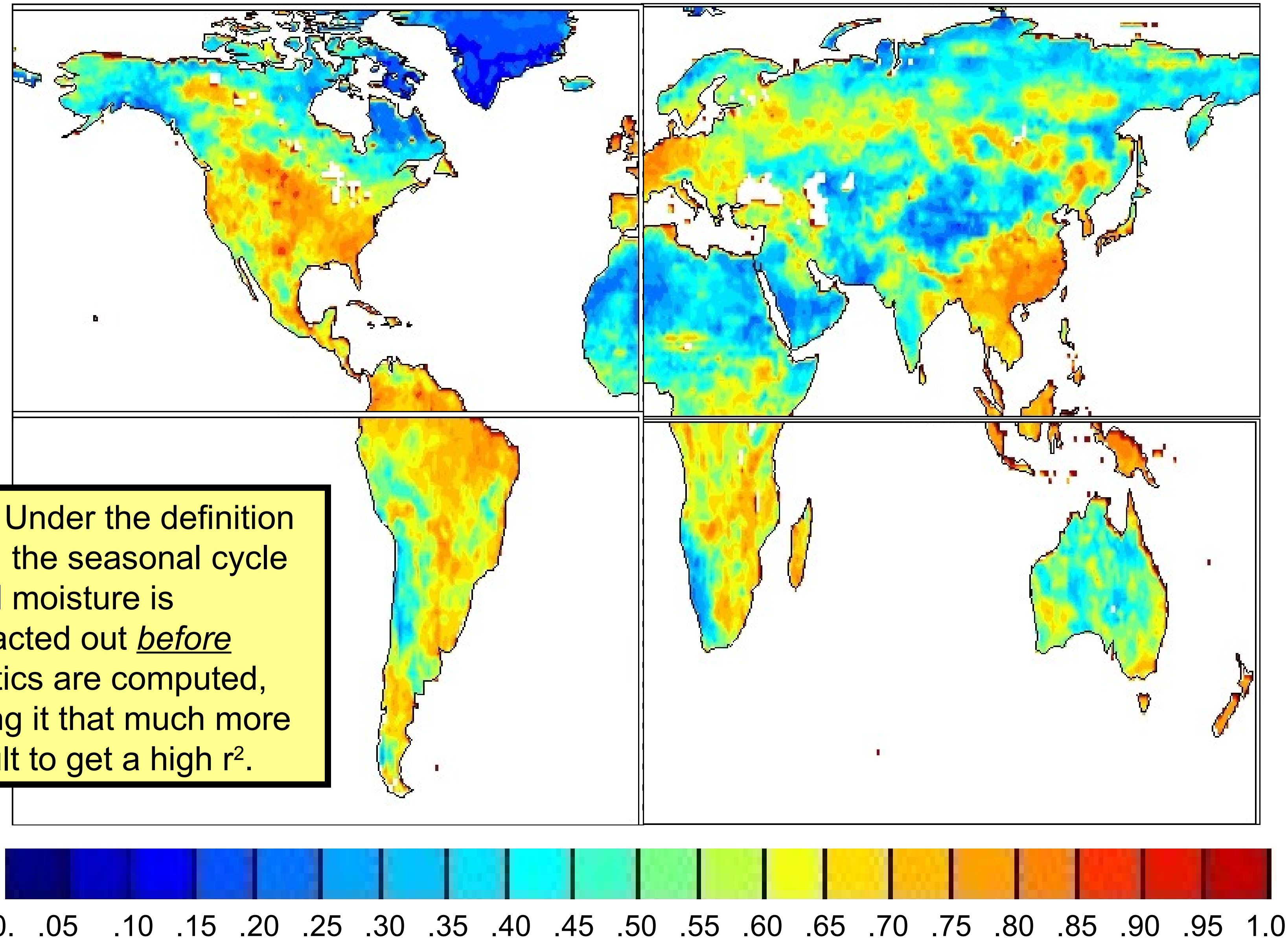


The unprocessed soil water diagnostics (shown here as degree of saturation) are not nearly as model-independent.



Average r^2 between models

31-day smoother, detrended



Note: Under the definition of WI, the seasonal cycle of soil moisture is subtracted out *before* statistics are computed, making it that much more difficult to get a high r^2.

Idealized Model Simulations

- The idea is for several modelling 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

- Currently have results from NSIPP1 (NASA), NCAR's CCM3 (Lamont), and GFS (NCEP). Expect to get results from CAM3 (NCAR), the GFDL model, and NCEP/CFS coupled model (Ben Kirtman, Univ of Miami).

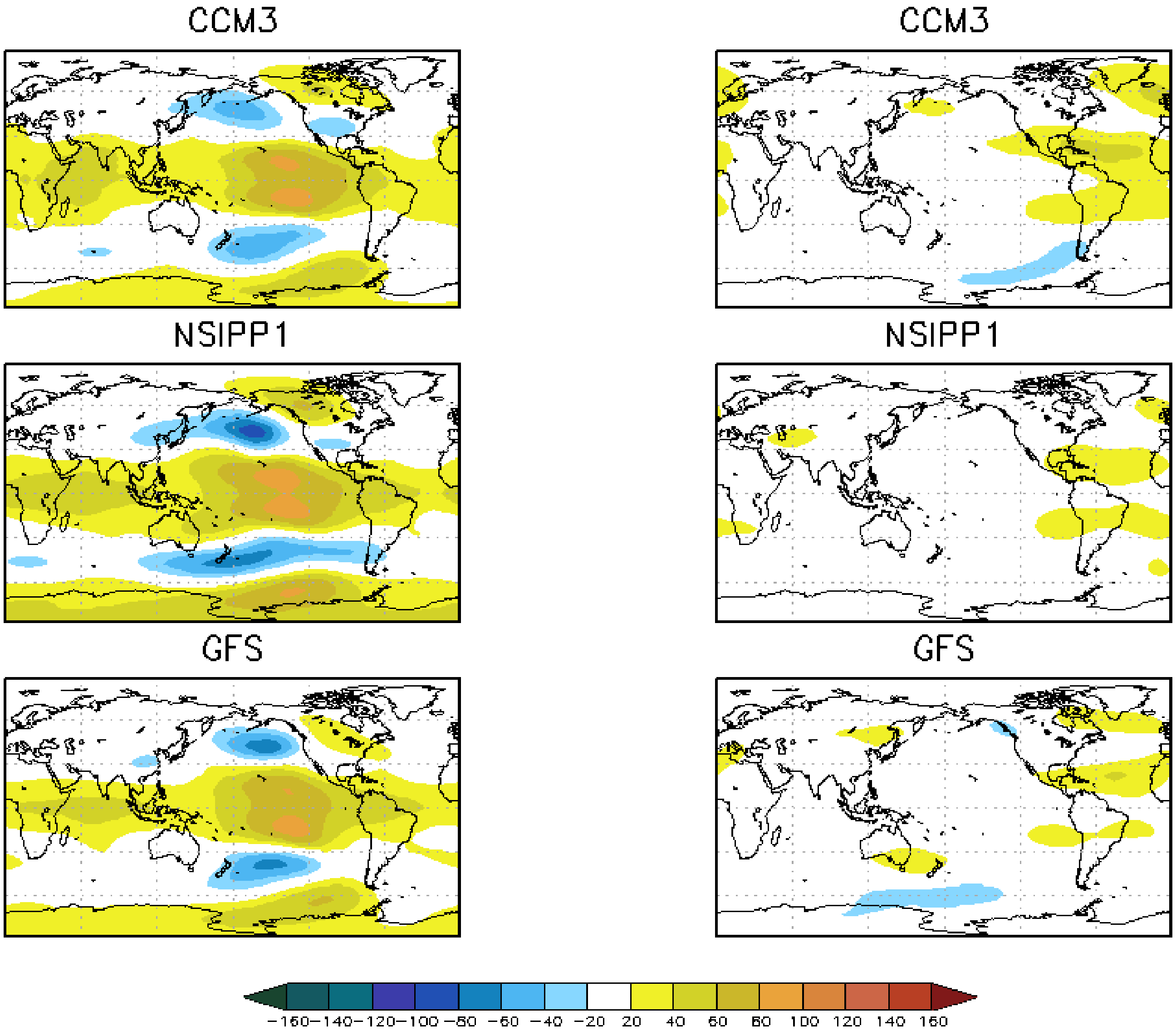
Idealized Forcing Patterns

Second and Third Leading Rotated EOFs of Annual SST (warm phase)

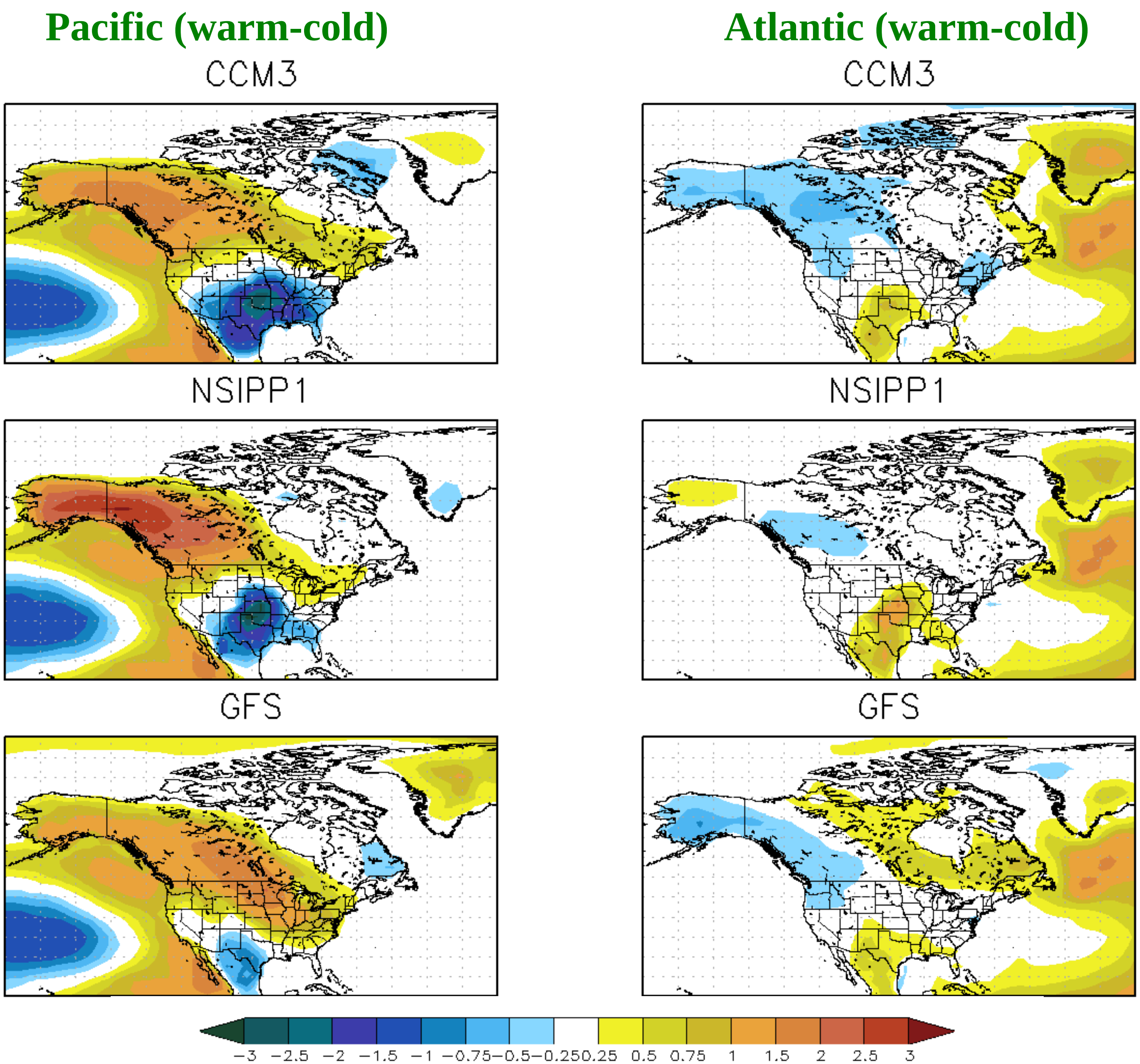
Annual 200mb Height Anomalies (m)

Pacific (warm-cold)

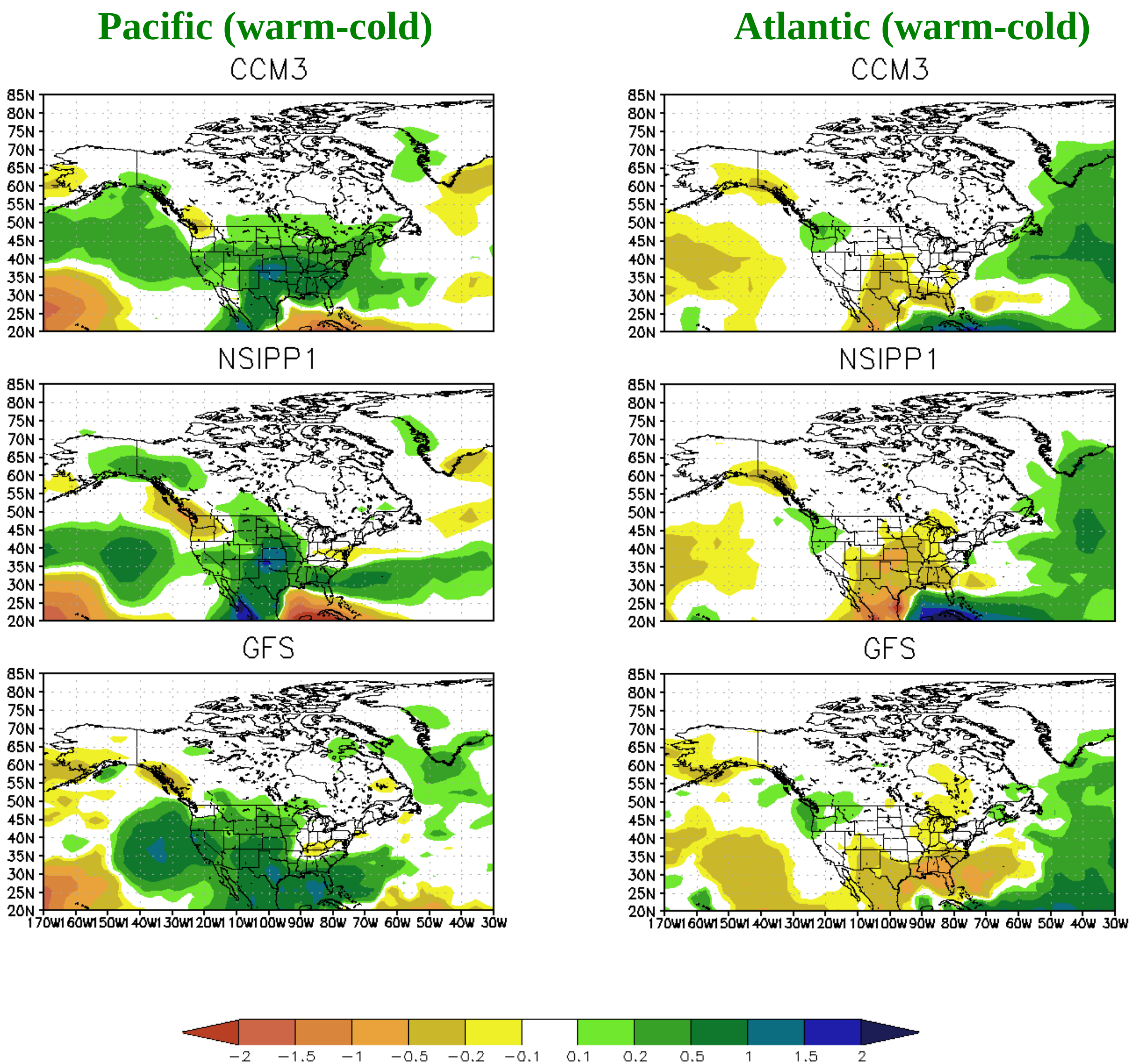
Atlantic (warm-cold)



Annual Mean T_{skin} (°C)

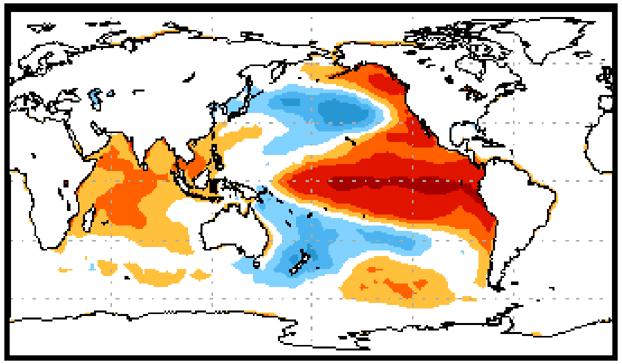


Annual Precipitation (mm/day)



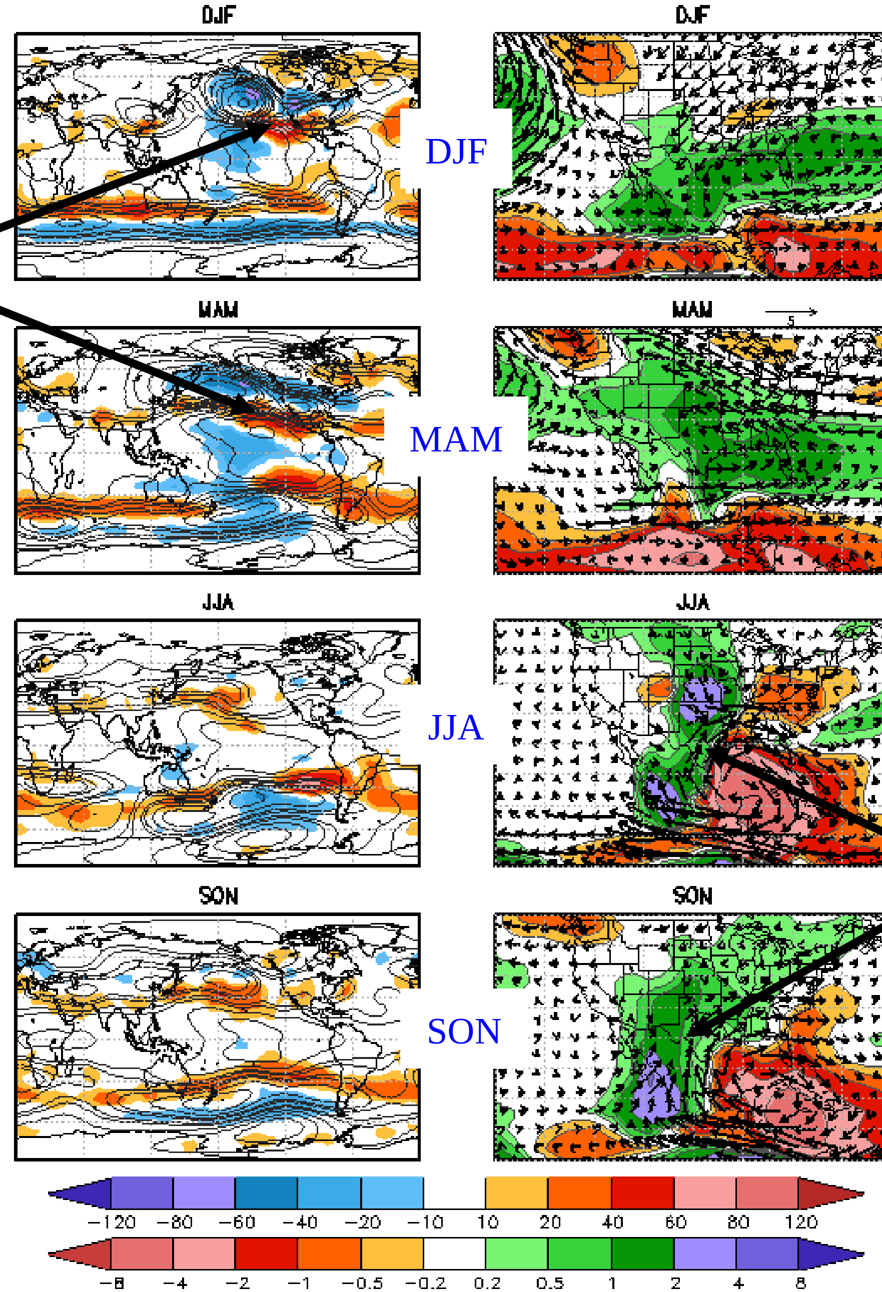
Seasonality in the Response to Pacific SST

Shift in storm tracks



SST forcing

v'^{2} 850 and Z200 | V 850 and Precip



Change in LLJ

Summary Remarks

- US CLIVAR Drought Working Group is making progress on achieving its research goals
  - New model-based definitions of drought for monitoring and validation
  - coordinate evaluations of existing relevant model simulations
  - developed new model experiments designed to address some of the outstanding uncertainties concerning the roles of the ocean and land in long term drought

- We look forward to more community participation
  - We will be making model datasets available (TBD)
  - Joint CDP and USCLIVAR Workshop in Oct 2008 in Nebraska
  - Link to Canadian DRI and follow-on

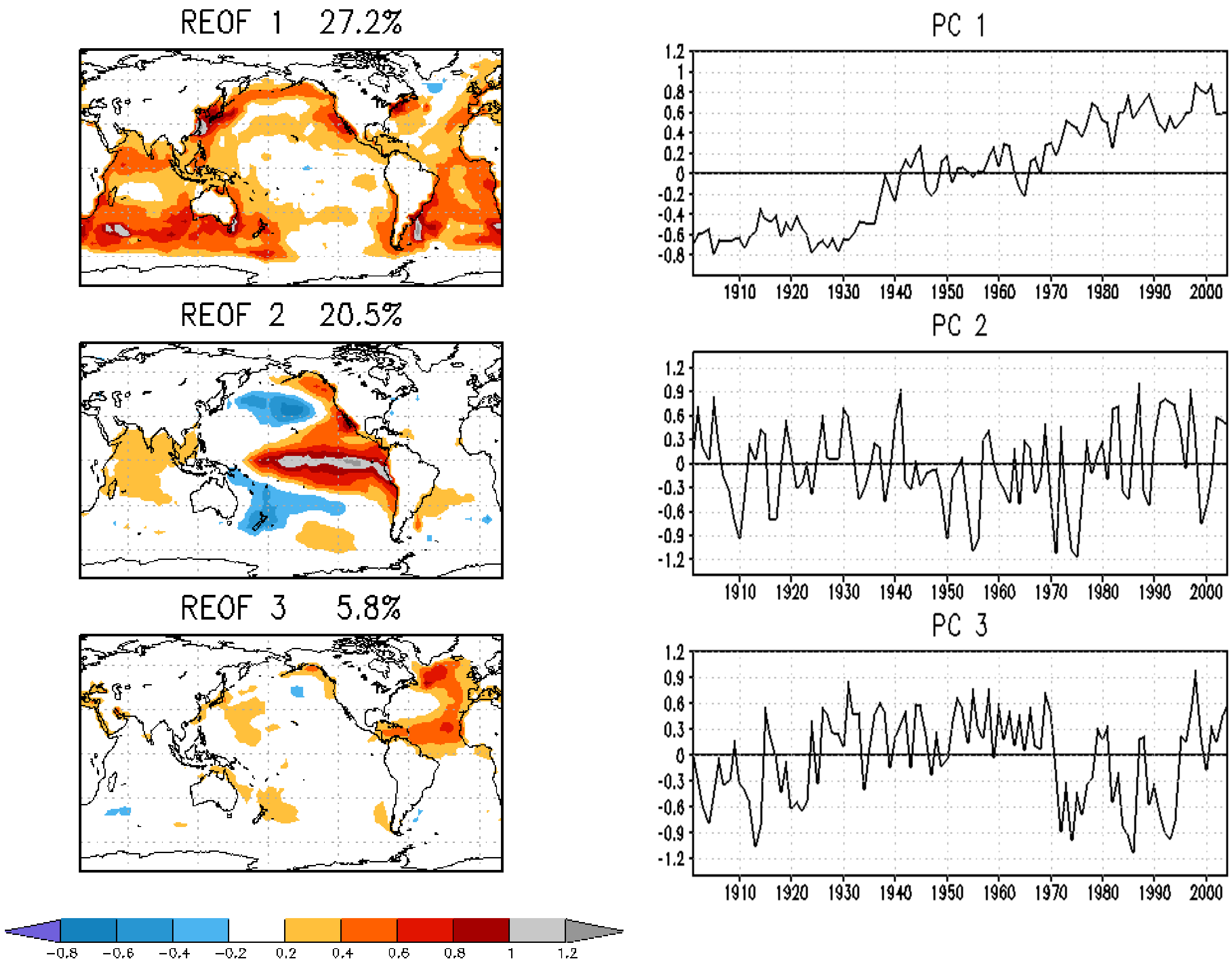
Extra Slides

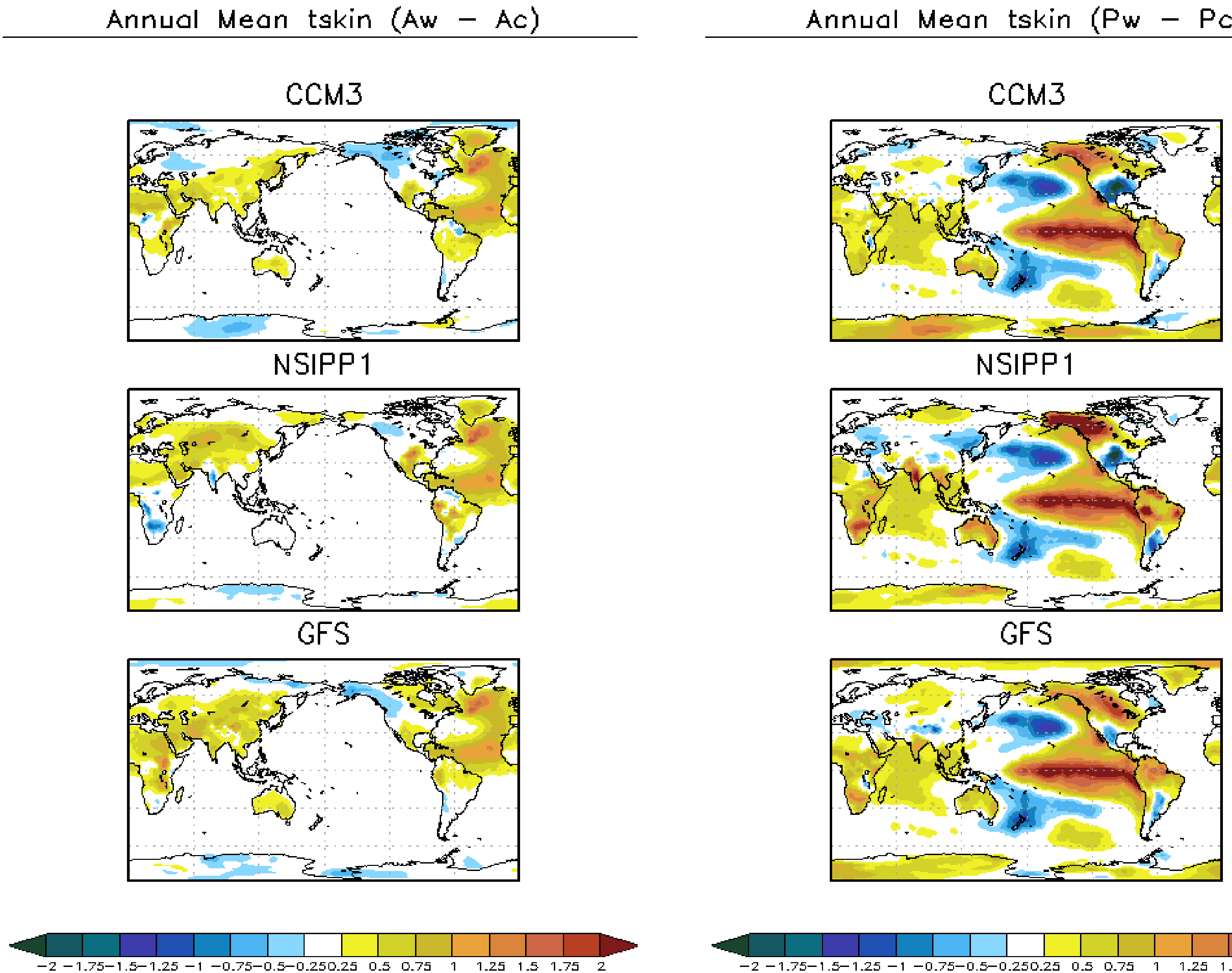
Leading EOFs and Time series (annual mean SST - 1901-2004)

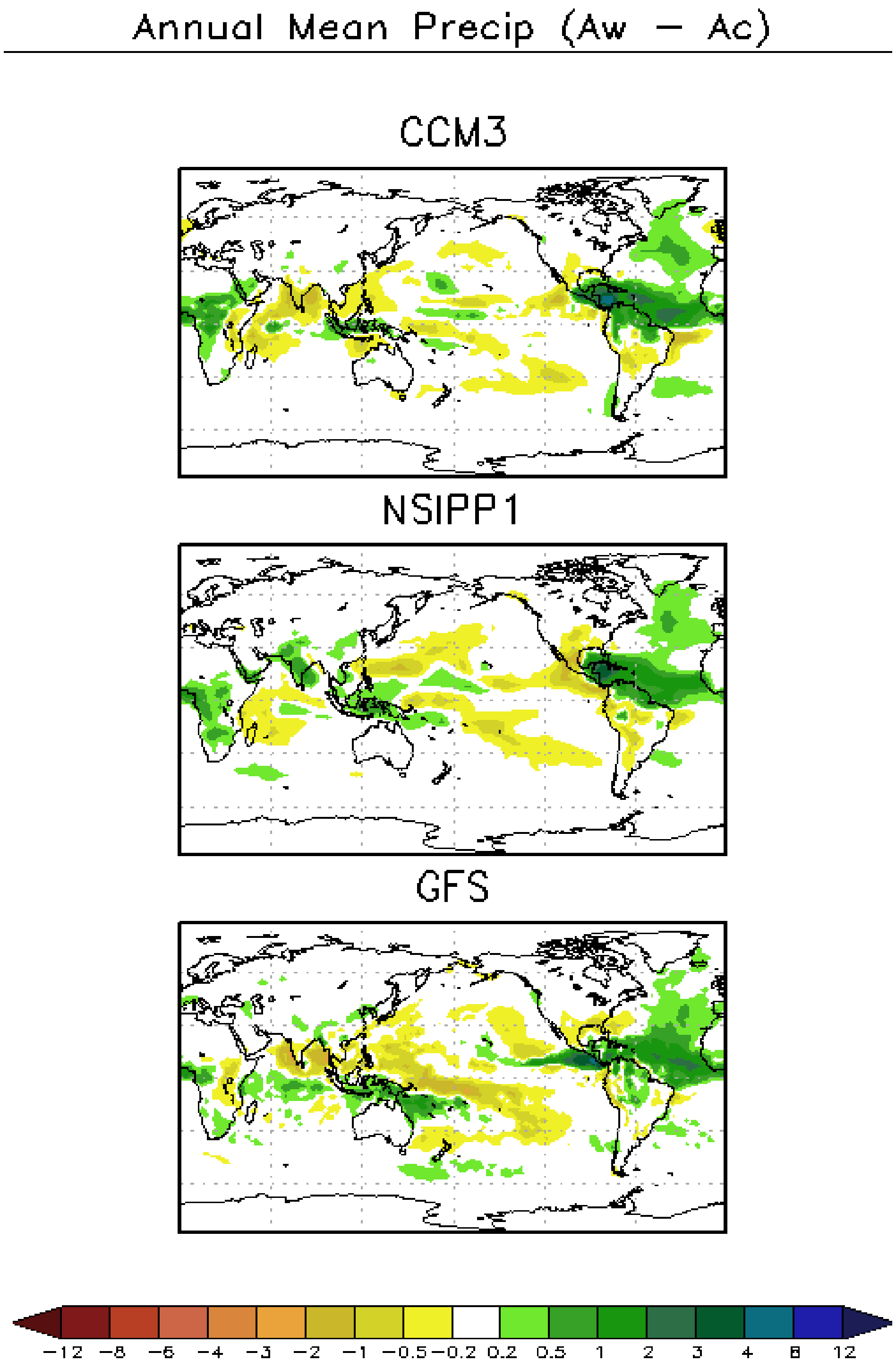
Linear Trend Pattern (LT)

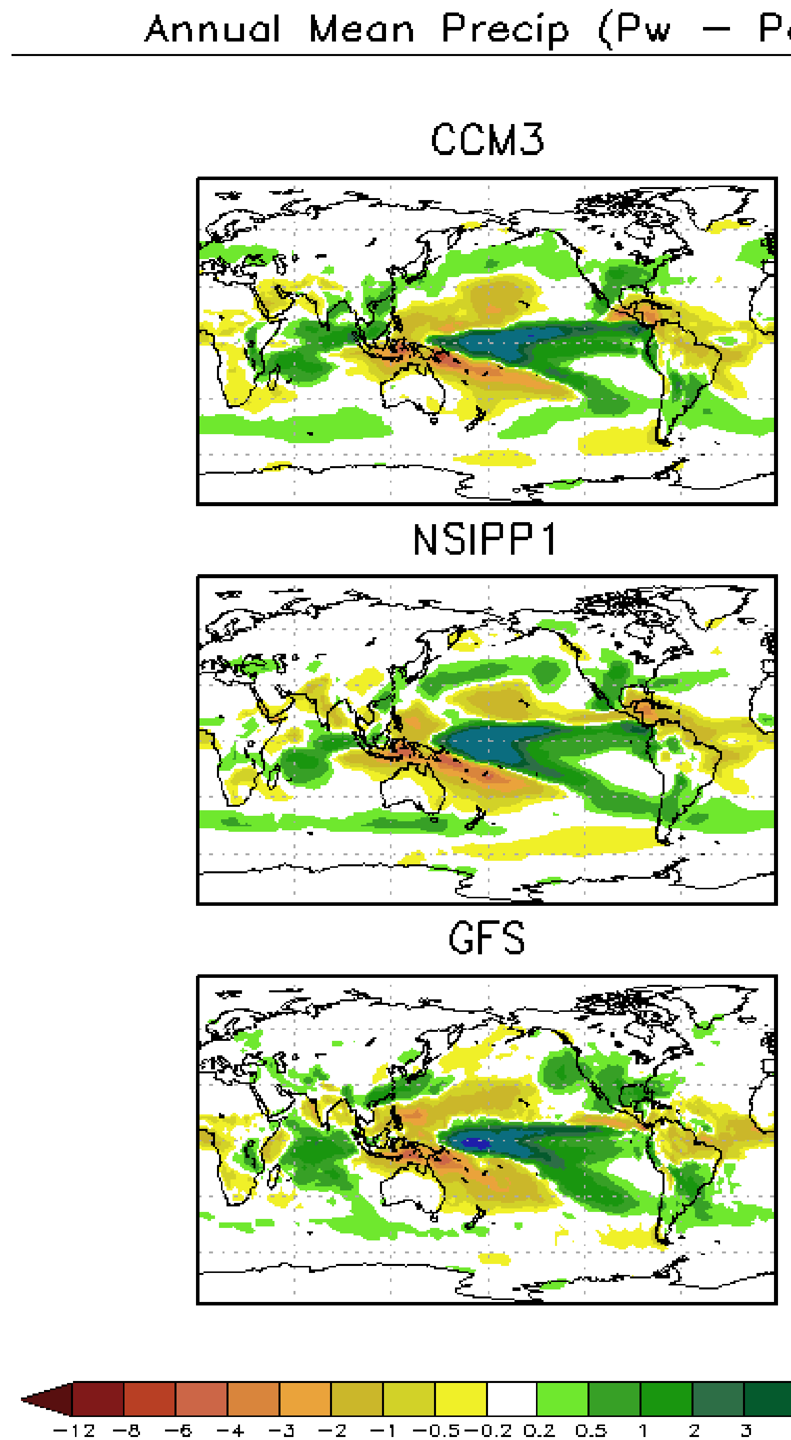
Pacific Pattern (Pac)

Atlantic Pattern (Atl)




Annual Mean tskin (Aw − Ac)
CCM3
NSIPP1
GFS
−2 −1.75 −1.5 −1.25 −1 −0.75 −0.5 −0.25 0.25 0.5 0.75 1 1.25 1.5 1.75 2
Annual Mean tskin (Pw − Pc
CCM3
NSIPP1
GFS


Annual Mean Precip (Aw − Ac)
CCM3
NSIPP1
GFS
−12 −8 −6 −4 −3 −2 −1 −0.5 −0.2 0.2 0.5 1 2 3 4 8 12


Annual Mean Precip (Pw −
CCM3
NSIPP1
GFS
−12 −8 −6 −4 −3 −2 −1 −0.5 −0.2 0.2 0.5 1 2 3

Idealized Experiments

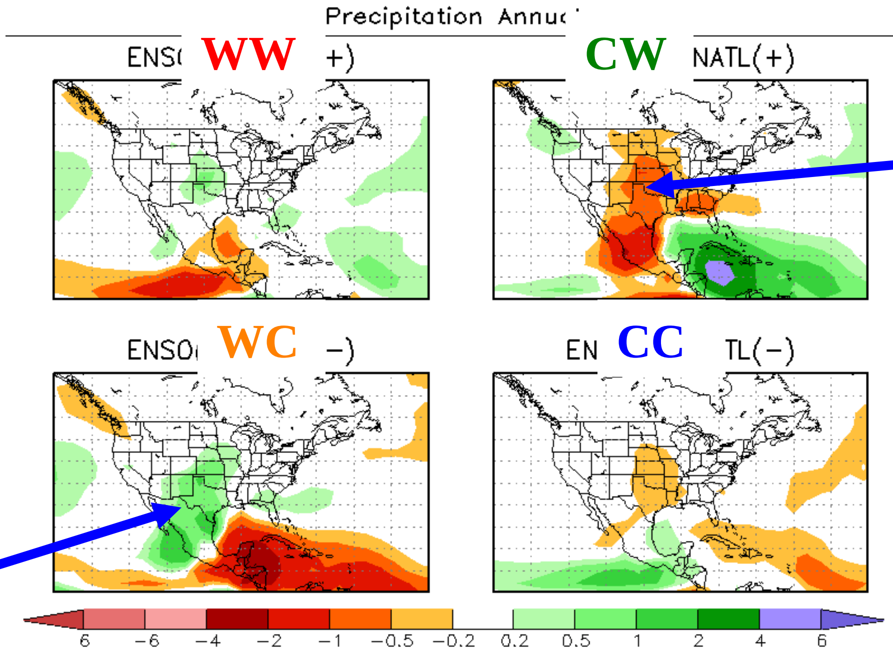
NATL

PacInd

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

SST Forcing patterns
(warm phase)

Annual Mean Precipitation Responses

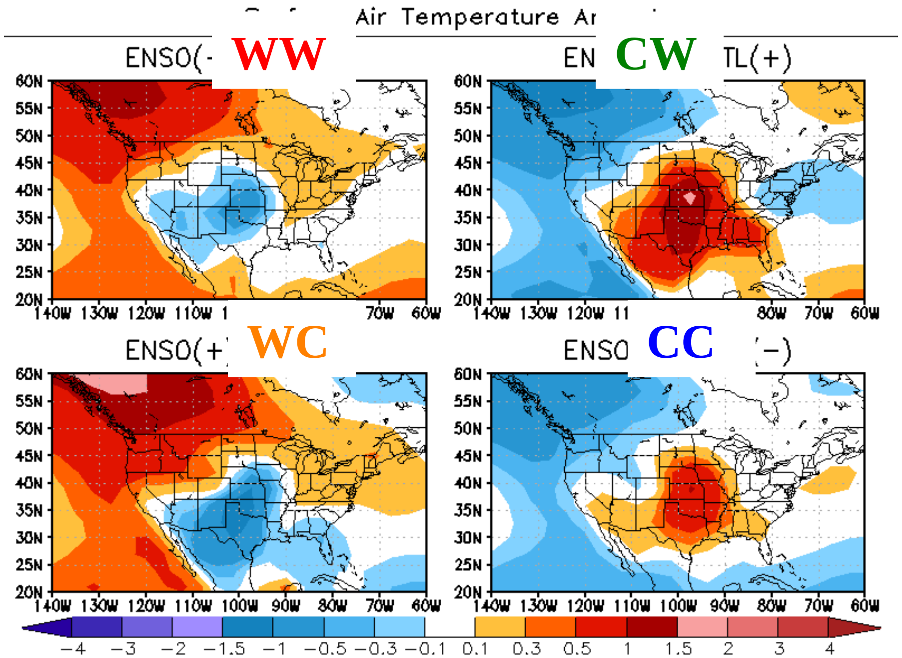


Major drought conditions

Pluvial conditions

Responses to combined EOFs

Annual Mean Temperature Responses



Responses to combined EOFs

Impact of Soil Moisture Feedbacks on JJA Precipitation