CLIVAR Drought Modeling Experiments with CAM3.5: Interim Report

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US CLIVAR DROUGHT WORKING GROUP

Objective: The primary objective of this working group is to facilitate progress on the understanding and prediction of long-term (multi-year) drought over North America and other drought-prone regions of the world, including an assessment of the impact of global change on drought processes.

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.

Modeling Groups

CENTER	MODEL	CONTACT
-NASA/GSFC,………..	NSIPP1….	Siegfried Schubert
-Columbia U/LDEO..	CCM3……	Richard Seager
-NOAA/GFDL………	GFDL2.1..	Tom Delworth
-NCEP……………….	GFS…….	Jae Schemm
-NCAR………………..	CAM3.5…	Adam Phillips / Alfredo Ruiz-Barradas

NCAR Participation

- Was motivated by the improved simulation of North American hydroclimate in the CAM3 development simulations (January 2007).
- Case for NCAR's participation in CLIVAR drought modeling activity was made in last year's CVWG meeting (June 2007)
- CAM3.5's hydroclimate was evaluated in October 2007.
- CAM3.5 AMIP simulation (1870-2005) was initiated in November 2007, and its drought simulation potential evaluated in February 2008.
- Drought integrations commenced in March 2008 and 9 key ones have been completed, thanks to Adam Phillips' untiring efforts and Clara Deser's support.
- We started out being very behind other centers, but are now caught up w.r.t. the core integrations.

How good is CAM3.5?

CAM3.5’s suitability for investigating droughts was assessed by comparing its Vanilla-AMIP simulation against:

- – Station precipitation (US-MEX & CRUTS2.1)
- – Simulations generated by
  - Model’s previous version (CAM3.0; *1st AMIP ensemble member*)
  - Other CLIVAR Drought Working Group models
    - CCM3 (run at LDEO; *CCM3 goga_new runs atm, 1st ensemble member*)
    - NSIPP (NASA/GSFC; *5th AMIP ensemble member*)
    - NOAA GFS & GFDL (Comparisons pending data access)

Summer Precipitation

(JJA, 1950-2000)

CI: 1.0 mm/day (CLIM)

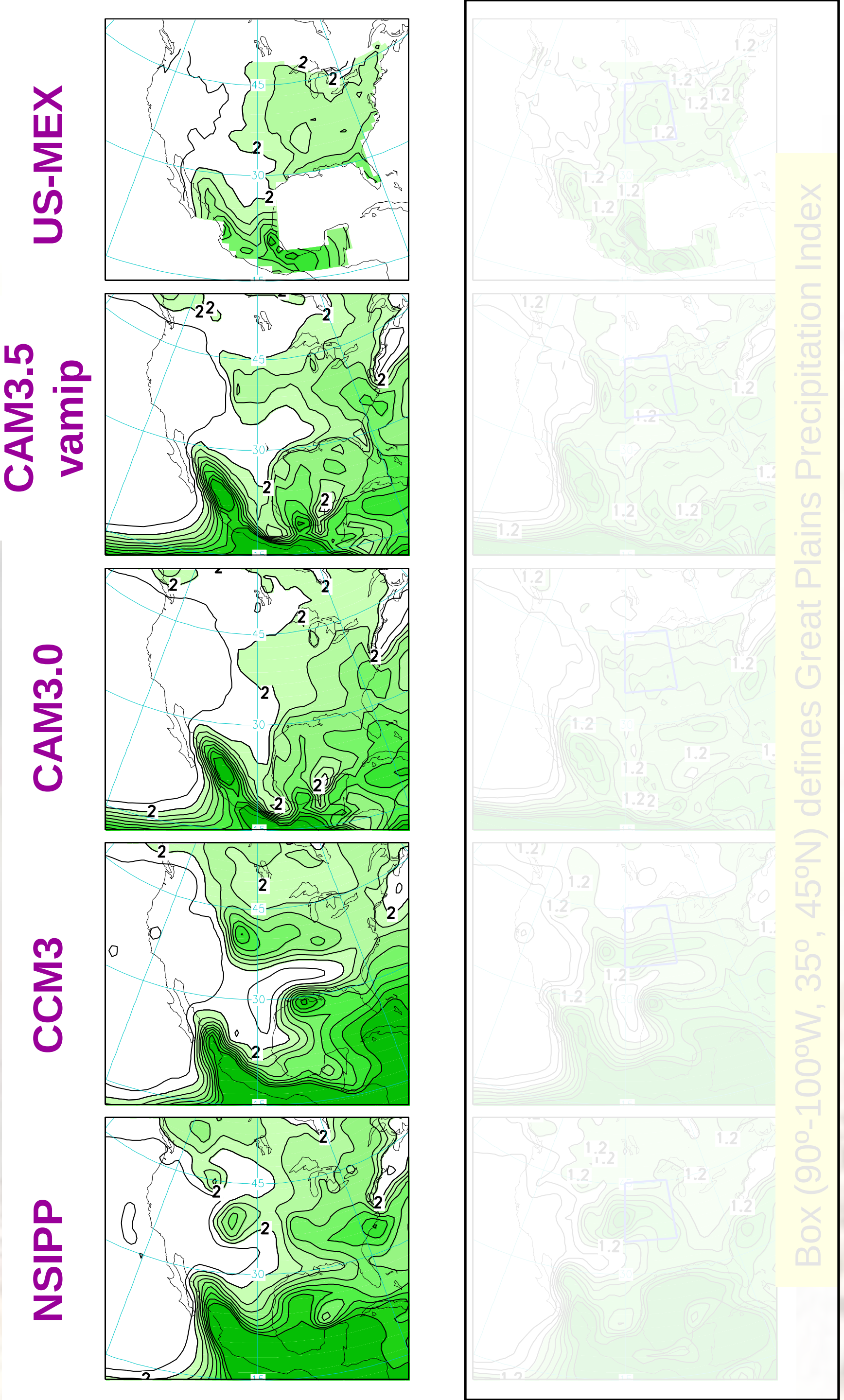
CI: 0.3 mm/day (STD)

Climatology

- CAM3.5 is better than CAM3.0 over central United States, but, perhaps, not elsewhere
- CAM3.5 is however more realistic than CCM3 and NSIPP

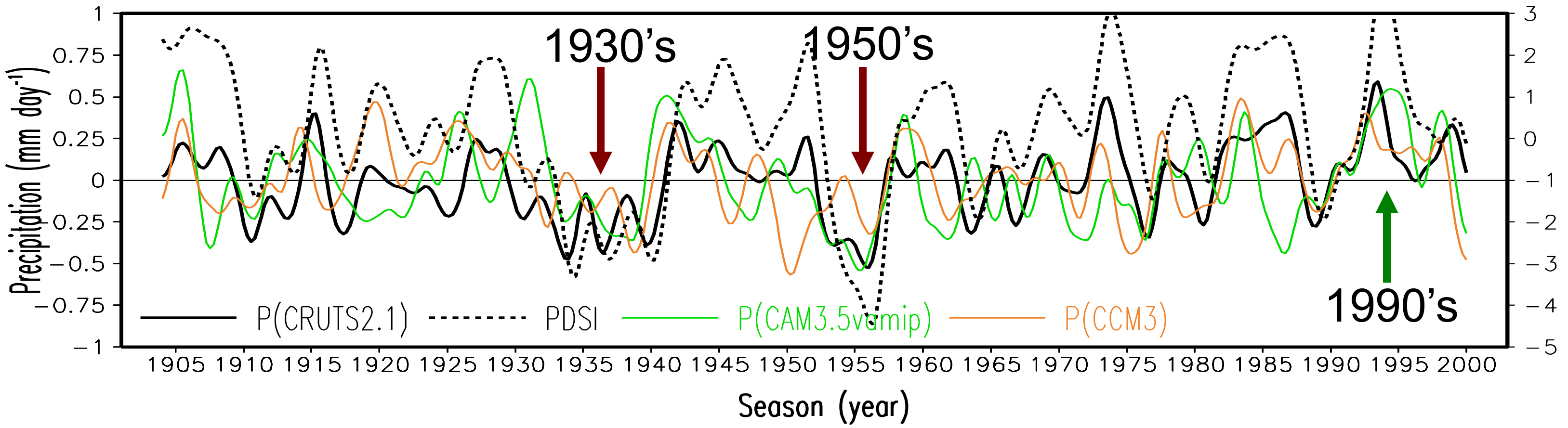
Standard Deviation

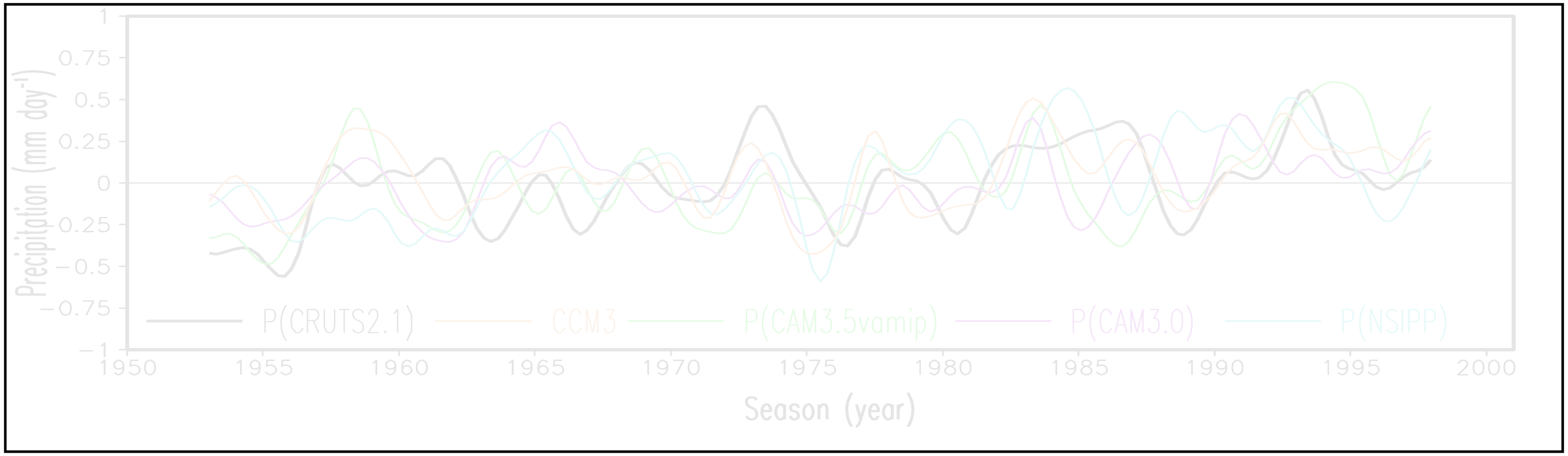
- CAM3.5 has a reasonable STD, but not decidedly superior than others



Great Plains Precipitation Anomaly

Seasonal anomalies smoothed by 12 x (1-2-1 binomial filter)



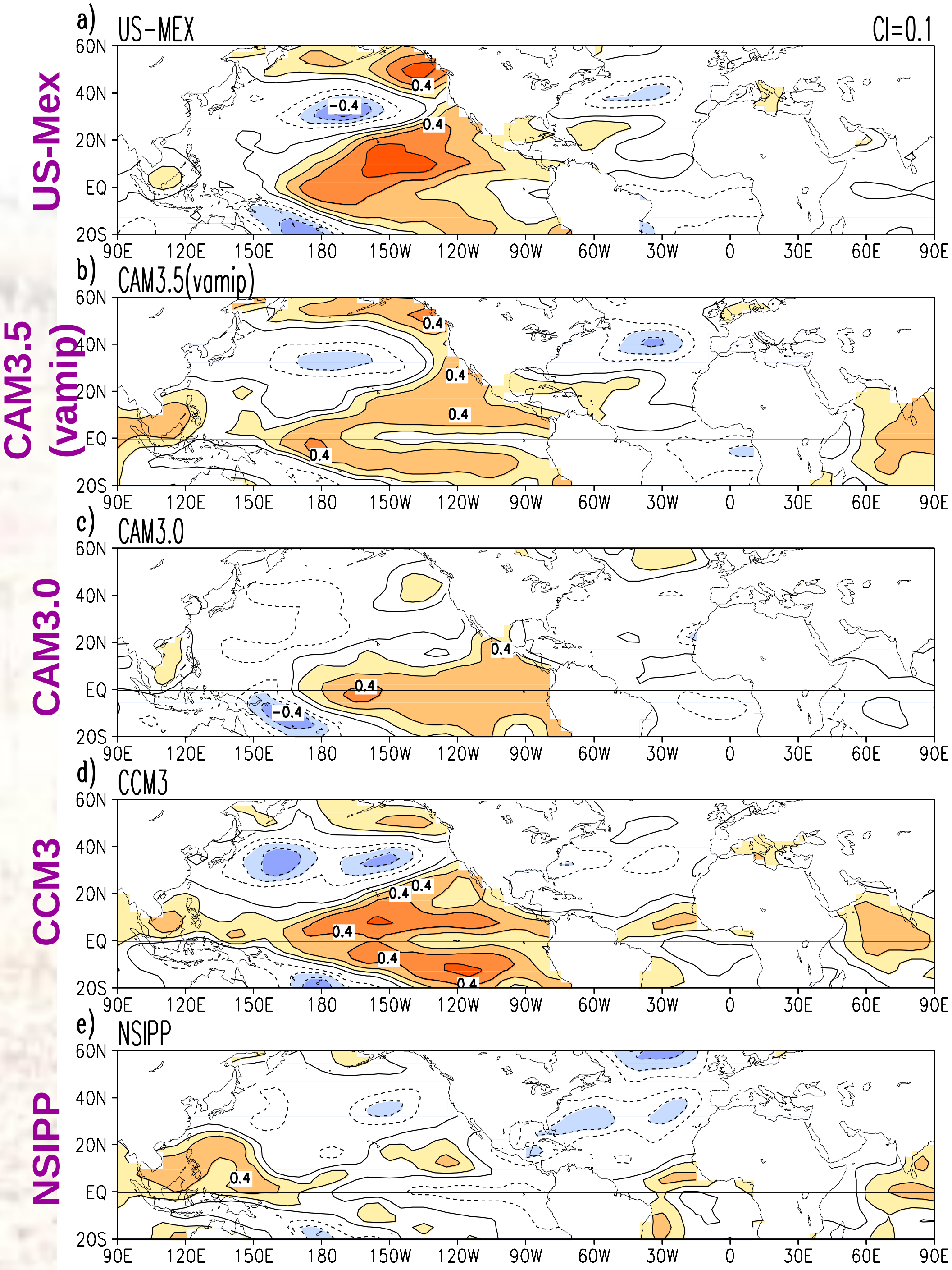


<u>Full Century (1901-2002) Correlations</u>

[CRU_P, CCM3_P] =0.36 (0.37 detrend)
[CRU_P, CAM3.5_P]=0.32 (0.33 detrend)
[CRU_P, PDSI] =0.82 (0.84 detrend)

<u>Half Century (1950-2000) Correlations</u>

[CRU_P, CCM3_P] =0.58 (0.50 detrend)
[CRU_P, CAM3.5_P]=0.38 (0.19 detrend)
[CRU_P, CAM3.0_P]=0.27 (0.10 detrend)
[CRU_P, NSIPP_P] =0.27 (0.04 detrend)



SST Correlations of the Great Plains **Smoothed Summer** Precipitation Indices

(1-2-1 filter applied once over the summer mean indices)

- CAM3.5 correlations are fairly realistic over both the Pacific and Atlantic basins; a definite improvement over CAM3.0
- CCM3 correlations are stronger and somewhat more realistic than CAM3.5's over the Pacific; but not over the Atlantic
- NSIPP correlations are less realistic over both basins

Conclusions on the assessment of CAM3.5

- This first look suggests that CAM3.5 is a competitive model for investigating drought genesis and maintenance.
- CAM3.5 is a better model than CAM3.0 (but not CCM3!), in context of Great Plains hydroclimate variability.
- CAM3.5’s contribution to CLIVAR’s Drought Modeling activities should be insightful.

The go ahead with the Drought Integrations is given


Can we talk about the drought experiments now?

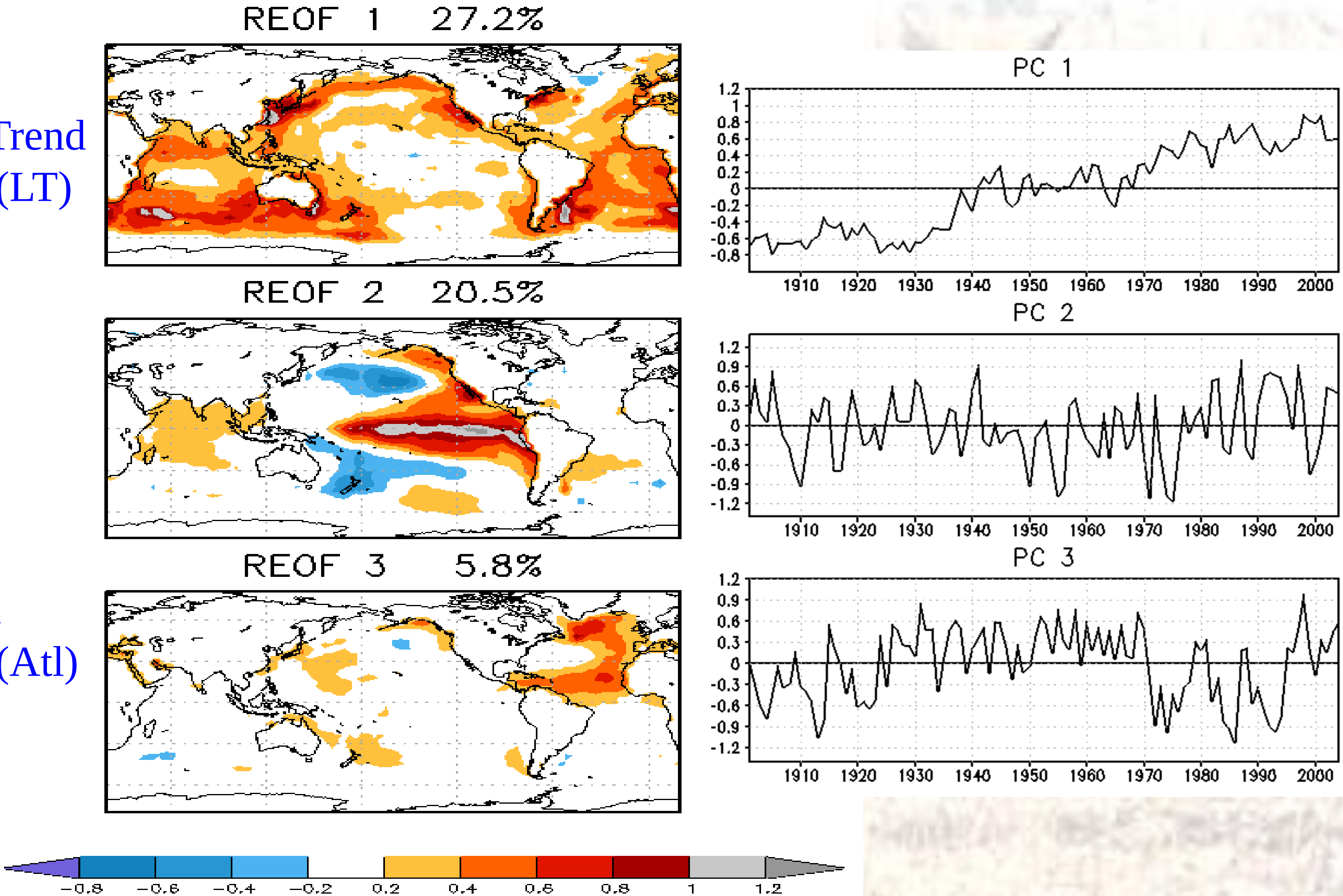
SST forcing patterns for the Drought Integrations

Patterns were obtained from REOF analysis of annual-mean 1901-2004 SST anomalies (Schubert et al.)

Linear Trend Pattern (LT)

Pacific Pattern (Pac)

Atlantic Pattern (Atl)



Experiment Design

Control integration

– A 51-year CAM3.5 integration with monthly SST climatology

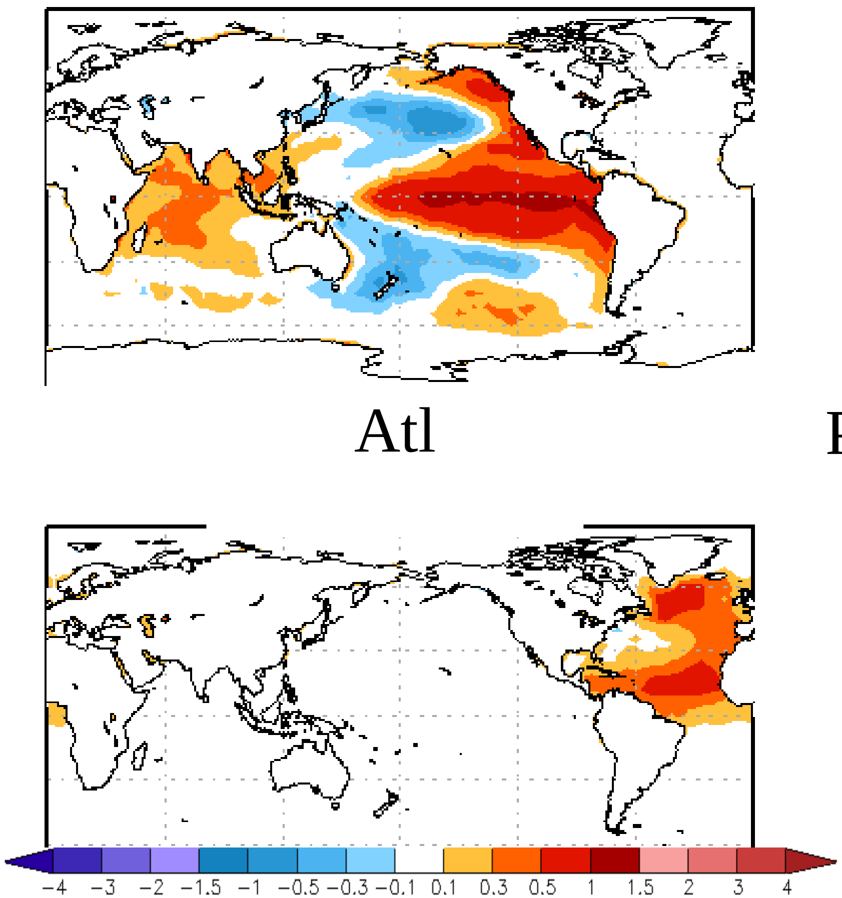
Drought integrations

– Superpose each SST anomaly pattern on the monthly SST climatology
– The SST anomaly pattern itself is seasonally invariant
– Each integration is 51 years long (1 year for spin up)
– 9 integrations have been completed so far
– Drought Working Group recommends many more integrations

The 9 CAM3.5 Drought Experiments

Focus on North American Droughts

Pac



SST forcing patterns
(shown in warm phase)

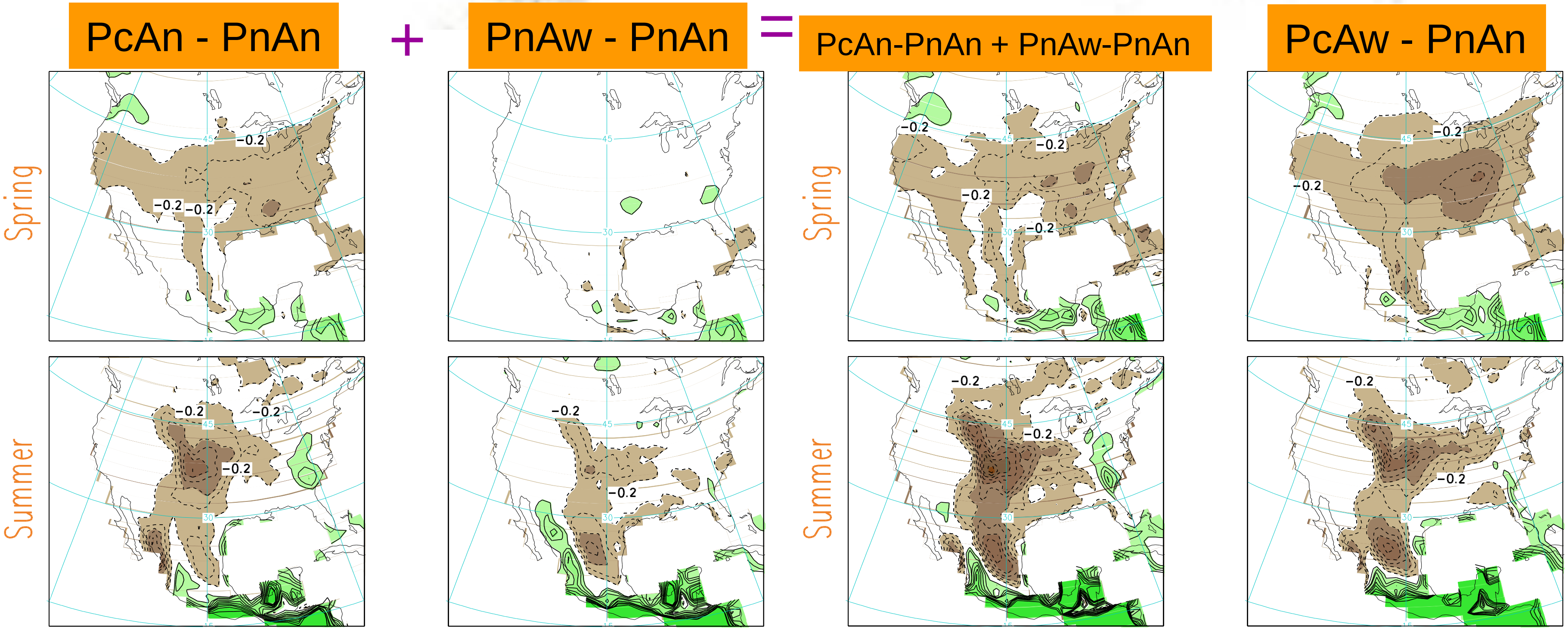
Atl

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

wLT

cTrPac

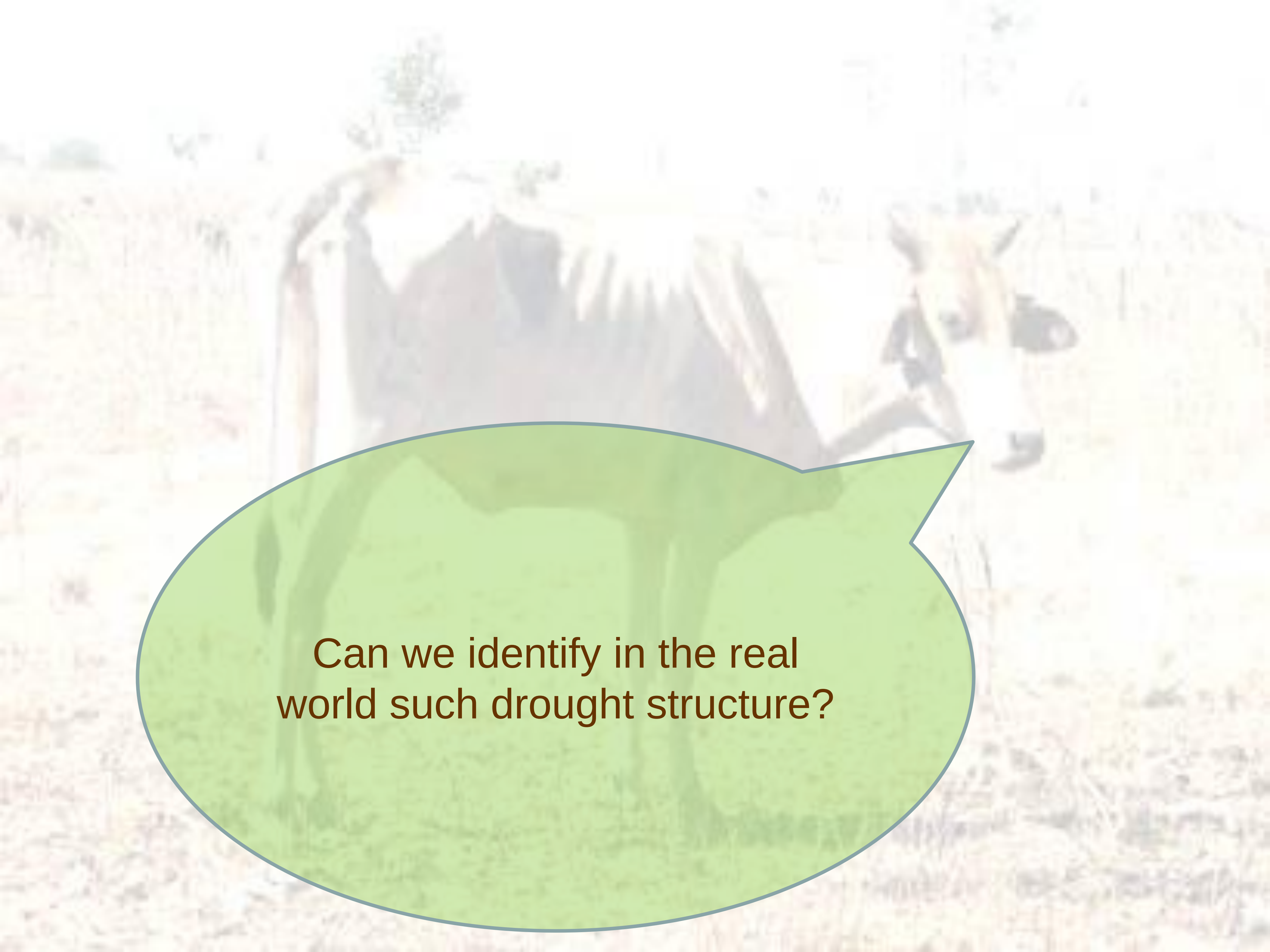
wTrAtl



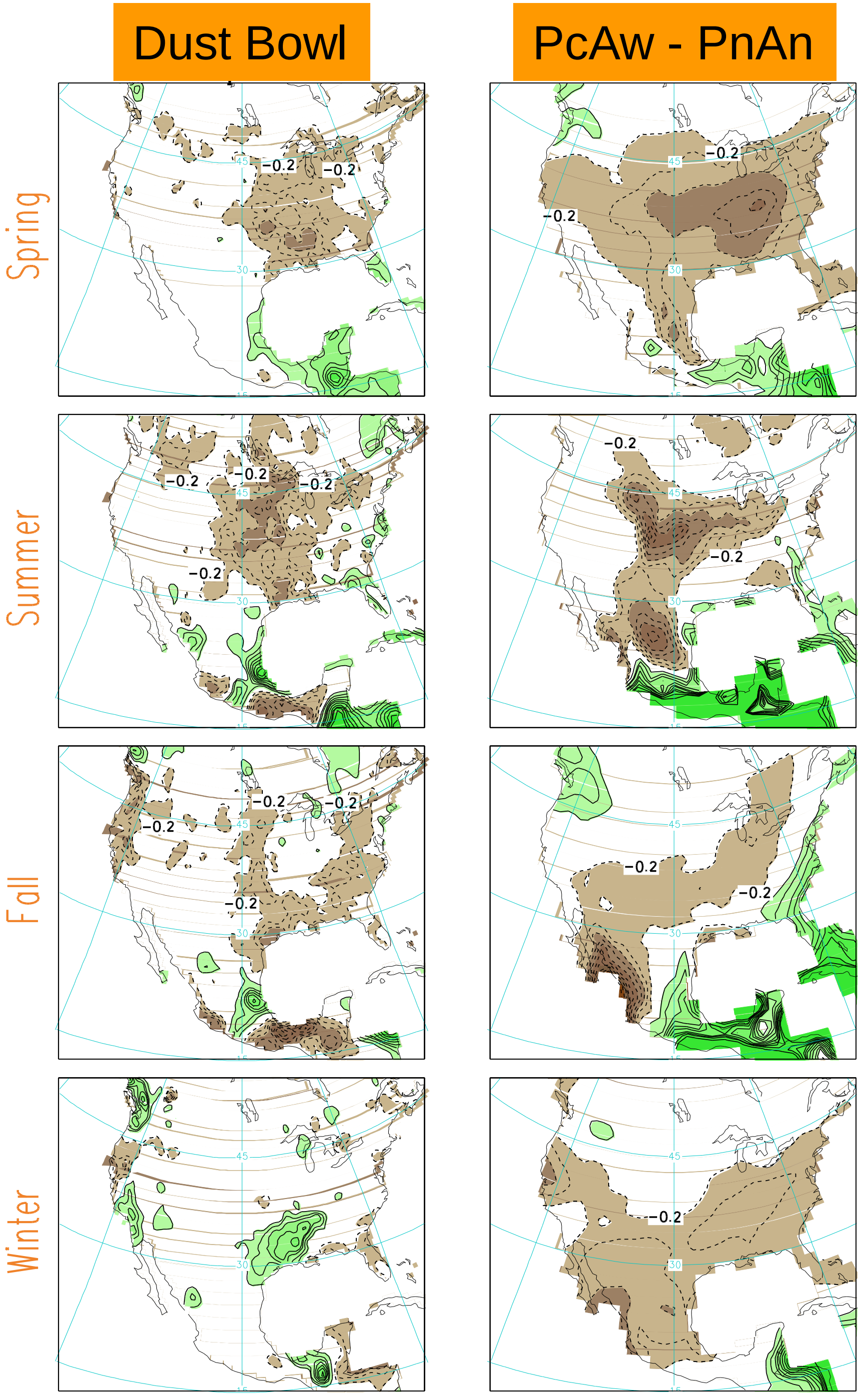
Both, a cold Pacific and a warm Atlantic induce drought conditions over central US with distinct structure and seasonality.

Nonlinearities accentuate the drought in Spring and weaken it in the other seasons, but in any case, the combined response to both basins is quasi-linear.

c.i.=0.2mm/day


Can we identify in the real world such drought structure?

Dust Bowl Mean Seasonal Precipitation Anomalies for the 1930-39 period.



Observed precipitation anomalies:

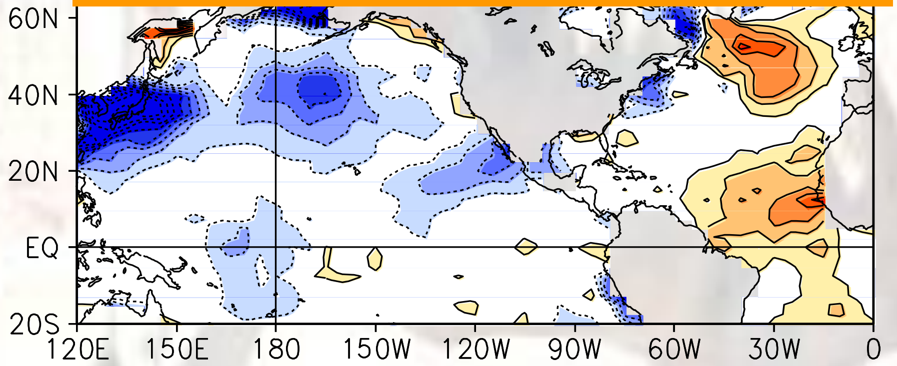
- Appear over southeastern US in Spring.
- Propagate toward central US in Summer.
- Weaken in Fall.
- Climatological conditions are reached over central US in winter.

Evolution and structure of the simulated drought are quasi-realistic.

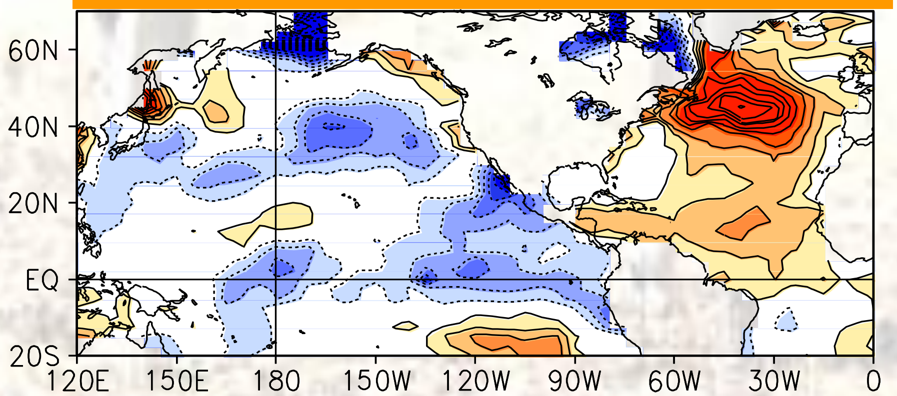
c.i.=0.2mm/day

SST seasonal anomalies during the Dust Bowl period (Guan et al. 2008)

Spring 1931-39

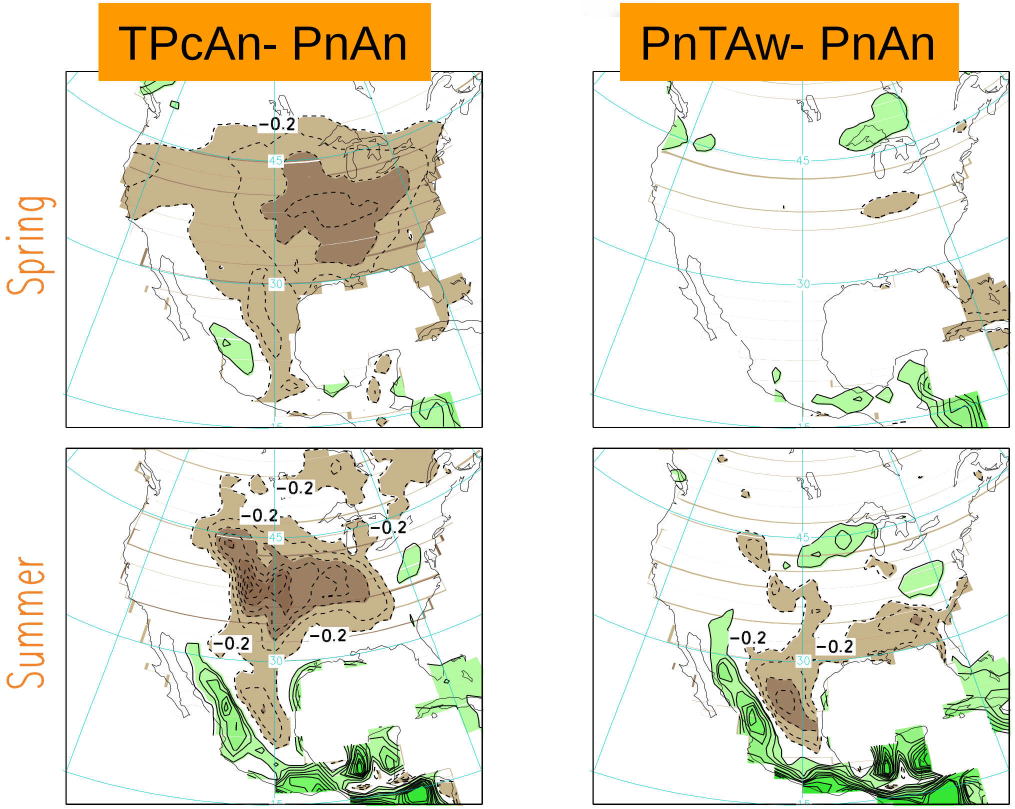


Summer 1931-39



Features to note:

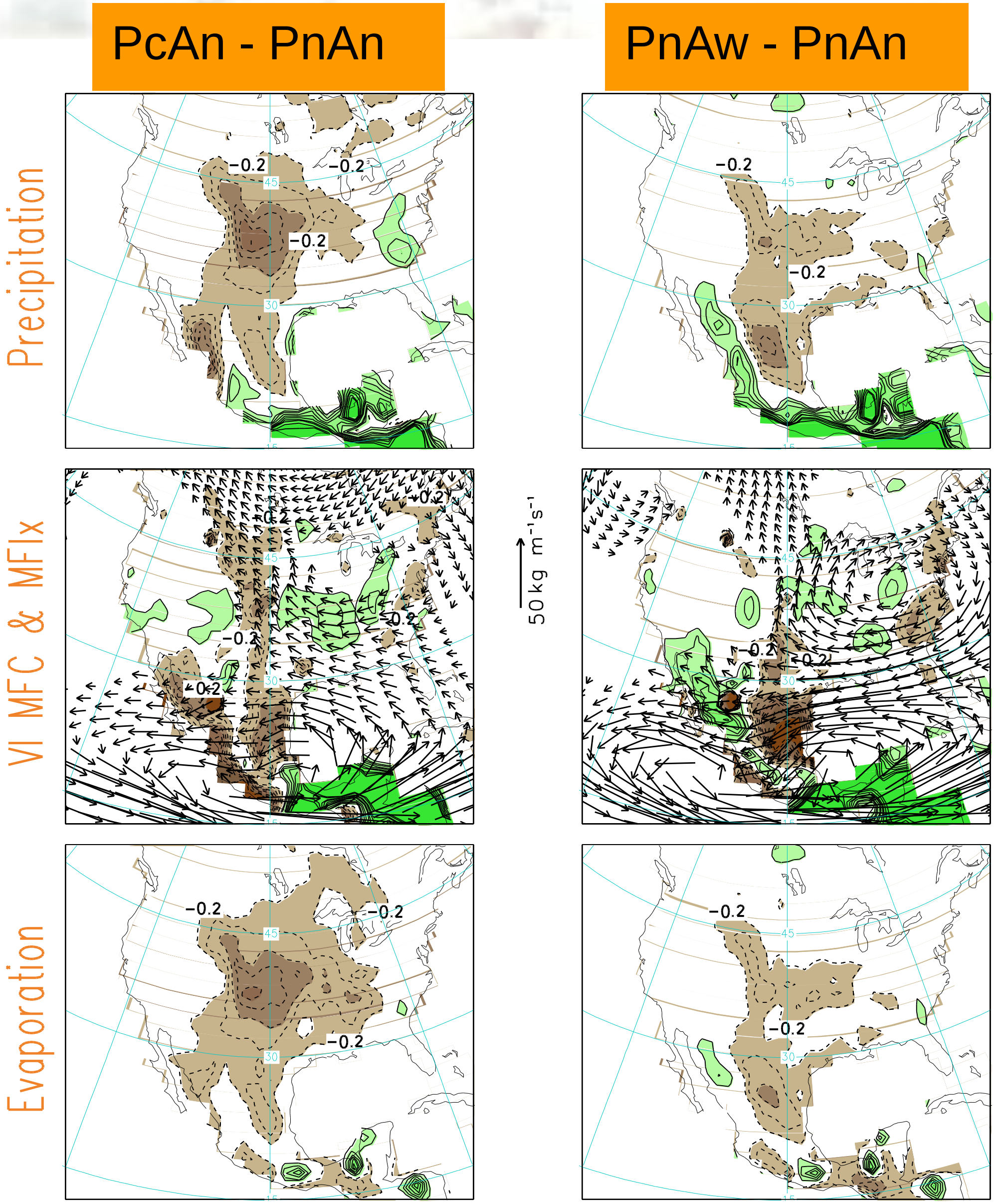
- seasonality of the SST anomalies in both basins, and
- the tropical structure in both basins during summer.



The tropical component of the Pacific and Atlantic SST anomalies induces much of the drought conditions simulated with the whole domain in all seasons.

c.i.=0.2mm/day

Water Balance Components in Summer



- Precipitation deficit, is largely in balance with evaporation in both Integrations. .
- Deficit in precipitation westward of the Rockies is intensified by the reduced vertically integrated moisture flux convergence, particularly in the case of the cold Pacific.

c.i.=0.2mm/day

What about Interannual variability?

How do other models seem to be doing over the Great Plains?

Interannual Variability in Drought Integrations

The Great Plains Precipitation Index

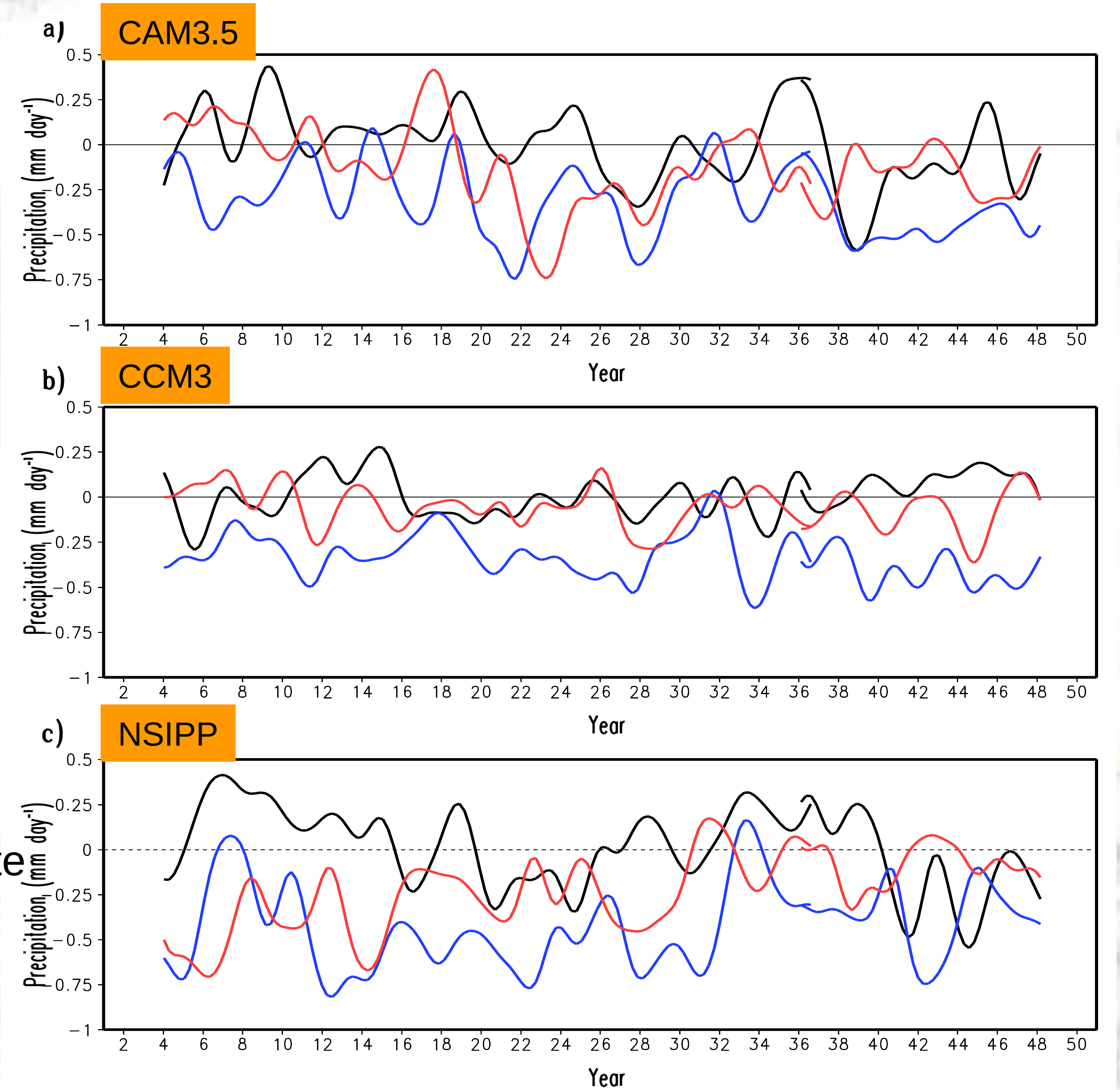
Seasonal anomalies w.r.t. the model's own control climatology are plotted after 12 X (1-2-1) smoothing

Control: **PnAn**

Cold Pacific: **PcAn**

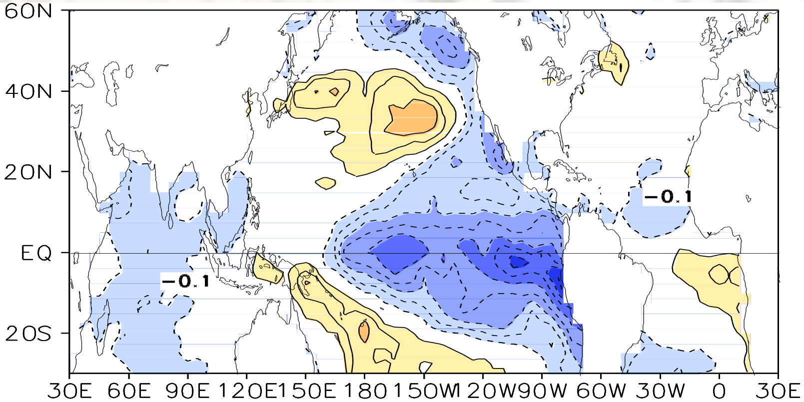
Warm Atlantic: **PnAw**

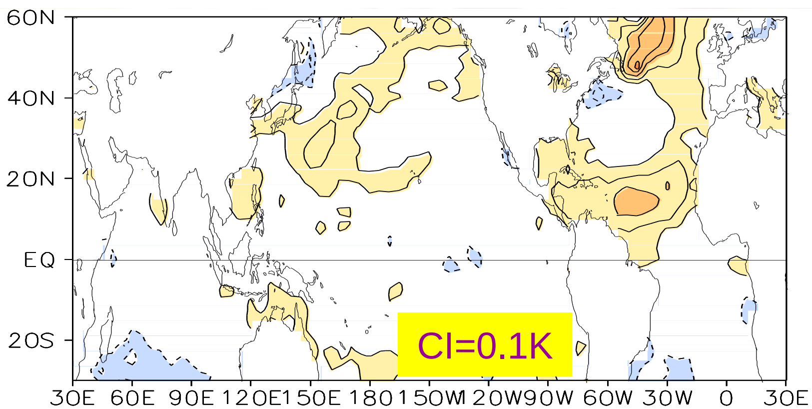
- CAM3.5 & NSIPP produce multi-year drought even in control simulations (**PnAn**)
- Interannual variability in CCM3 is relatively muted
- Cold Pacific (**PcAn**) and Warm Atlantic (**PnAw**) can generate normal hydroclimate conditions
- Cold Pacific is more influential in all 3 models

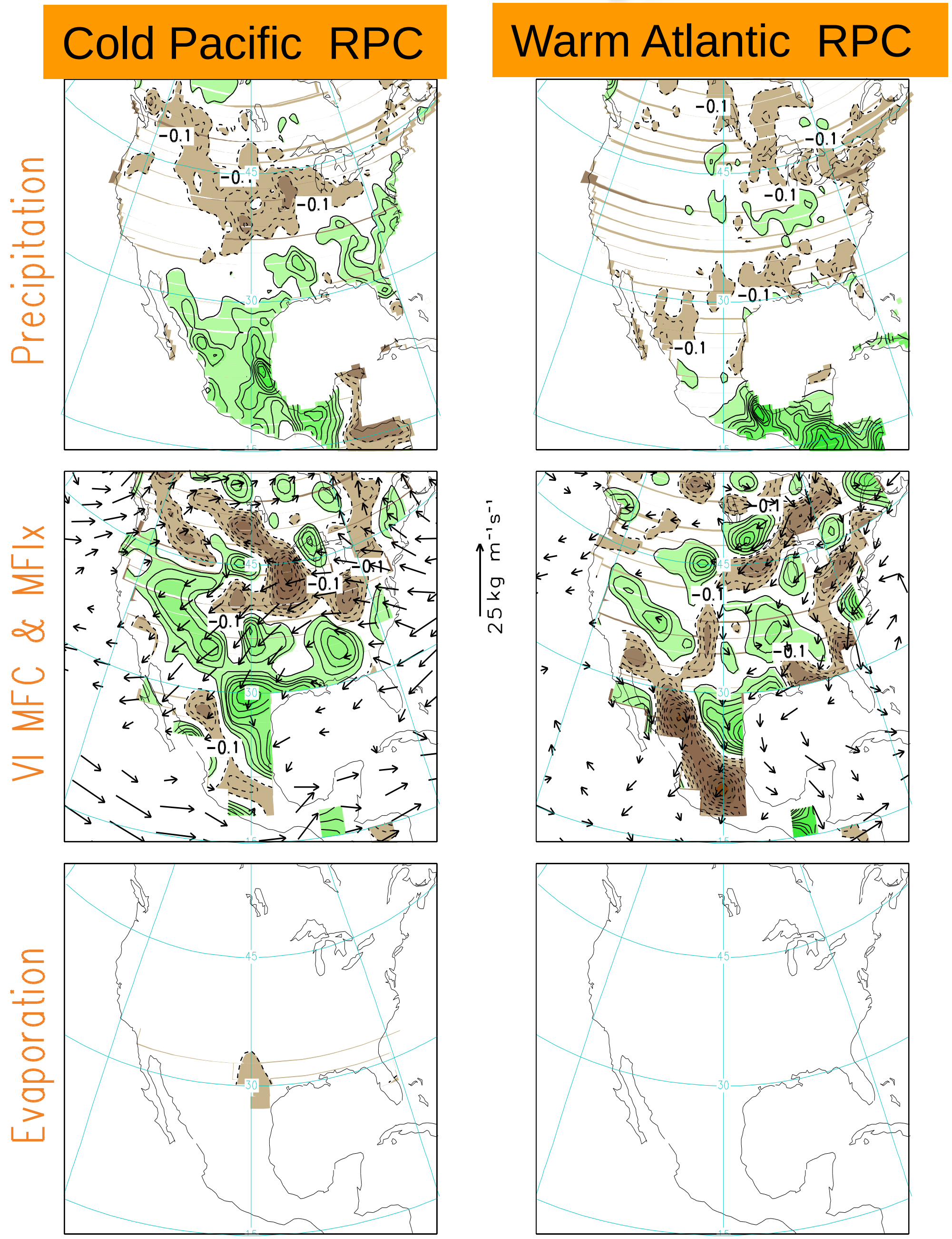



Do we have an observational target for those idealized simulations?

Summer Regressions of the Pacific and Atlantic RPCs (1958-2001)







CI=0.2mm/day

Precipitation deficit, is largely in balance with a reduction in moisture flux convergence over the (northern) Great Plains in both integrations.

Concluding Remarks

- NCAR is an active participant in the CLIVAR sponsored drought modeling activity, well positioned to provide insights
- The Cold Pacific and Warm Atlantic experiments indicate a significant role of SSTs in generating droughts over the central US, with tropical Pacific SSTs being quite influential.
- Basin influences are generally additive, except in Spring.
- Droughts resulting from a cold Pacific and warm Atlantic resemble Dust Bowl conditions, especially in summer.
- Atmospheric water-balance analysis indicates a large role for the land surface (i.e., evaporation), likely due to the forcing of drought runs by perpetual SST anomalies.
- Interannual variability in model simulations is large, leading to both multi-year droughts in control simulations and normal periods in drought simulations.

Thanks

Data availability:

At NCAR MSS:

/ASPHILLI/csm/cam3_3_17_t85_dwg*

At U. of Maryland:

http://dsrs.atmos.umd.edu/DATA/CAM3.5_DWG

Highest Priority: impact of the leading three patterns (Pac, Atl, LT)

Vanilla-style AMIP experiments

-prescribe each pattern on top of seasonally varying SST climatology

- each run should be at least 51 years (first year is spin-up)

-need a 50+ year control with climatological SST

1) Pac and Atl patterns

a) All combinations of patterns

(8 X 50 years =400 years of simulation)

2) Runs involving the LT pattern

a) +/- LT pattern

b) +/- LT added to (Pac- and Atl+)

c) +/- LT added to (Pac+ and Atl-)

(6 X 50 years = 300 years of simulation)

3) Tropical part of Pac and Atl pattern

a) Tropical only +/-Pac and +/- Atl pattern

(4X50 years =200 years of simulation)

4) Uniform SST warming pattern that has the same global mean SST as + LT(0.16° added to climatology)

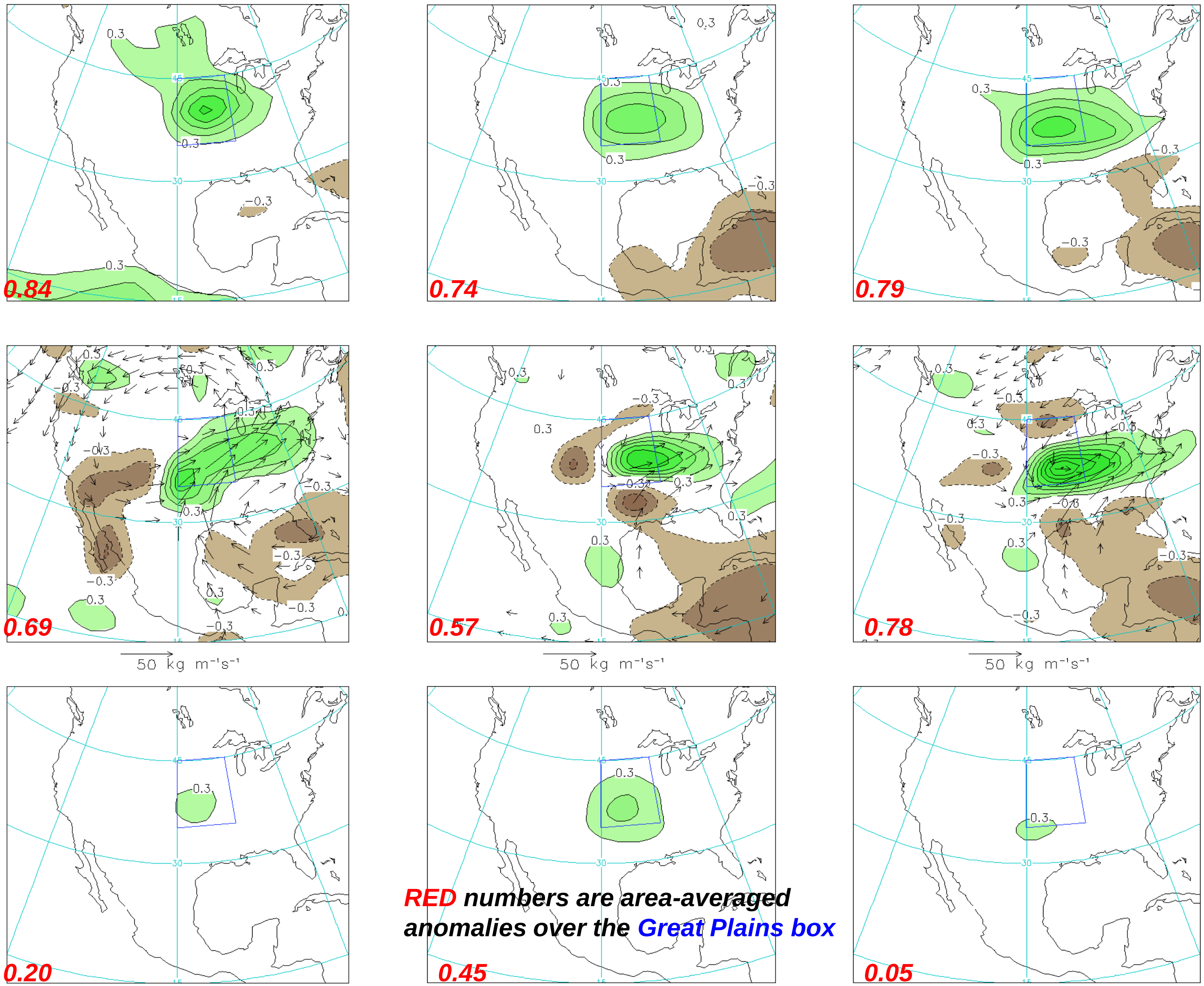
(1X50 years =50 years of simulation)

20 runs=1000 years of simulations
plus
soil moisture –related simulations

Warm-season Regressions of the Great Plains Precipitation Index 1979-2000

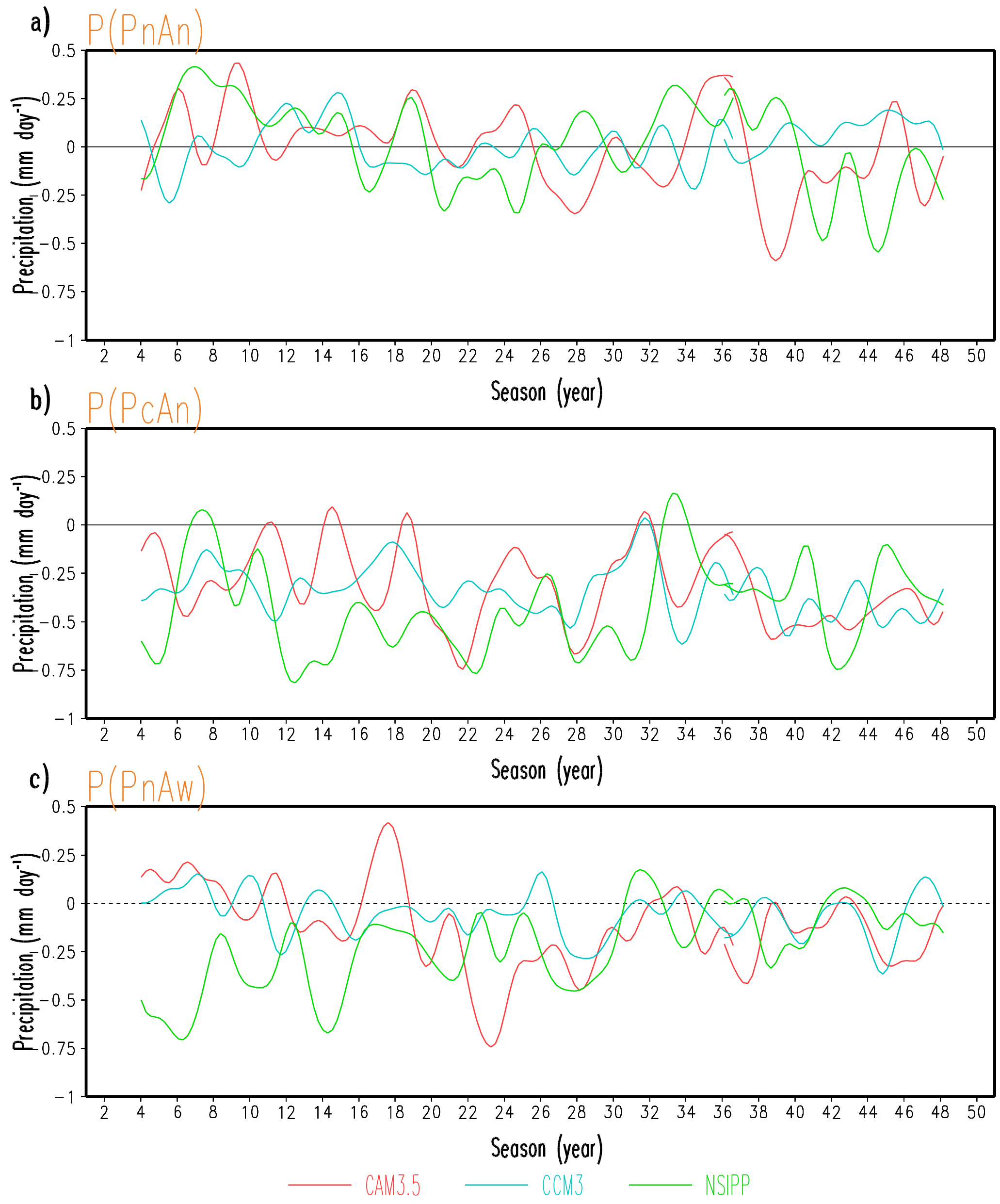
Evaporation Moisture Flux Precipitation

NARR	CAM3 3_fv_cmt2_dilute	CAM3 CAM3.5 ens01



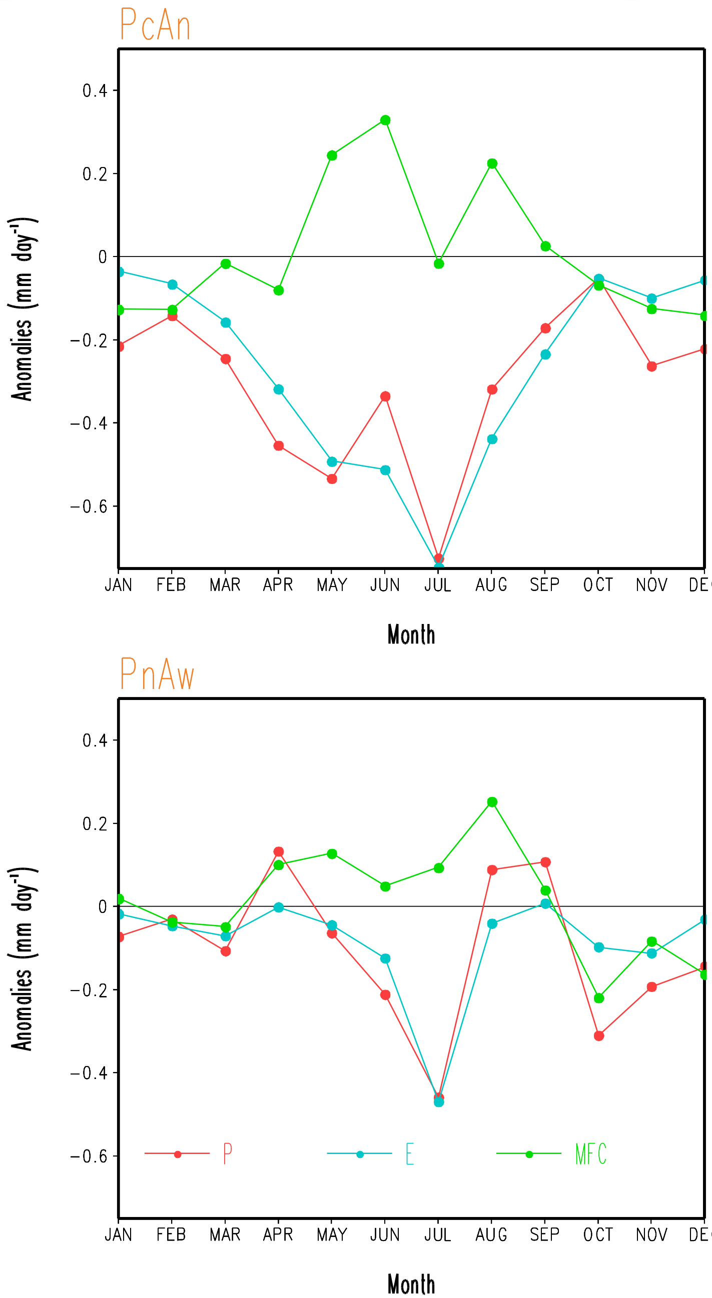
RED numbers are area-averaged anomalies over the Great Plains box

GPP Indices



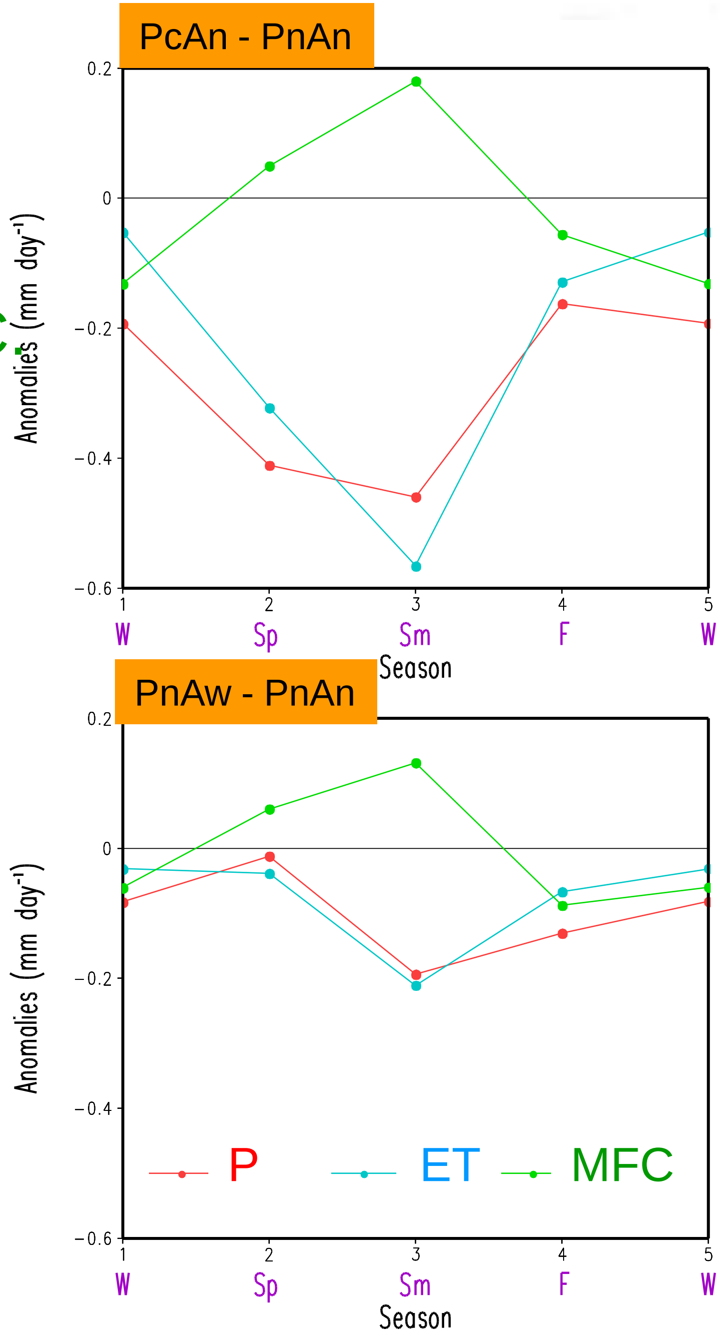
a)
P(PnAn)
Precipitation (mm day⁻¹)
Season (year)
b)
P(PcAn)
Precipitation (mm day⁻¹)
Season (year)
c)
P(PnAw)
Precipitation (mm day⁻¹)
Season (year)
CAM3.5
CCM3
NSIPP

Mean monthly anomalies of smoothed seasonal Great Plains Indices.



Evaporation anomalies are Comparable to precipitation anomalies

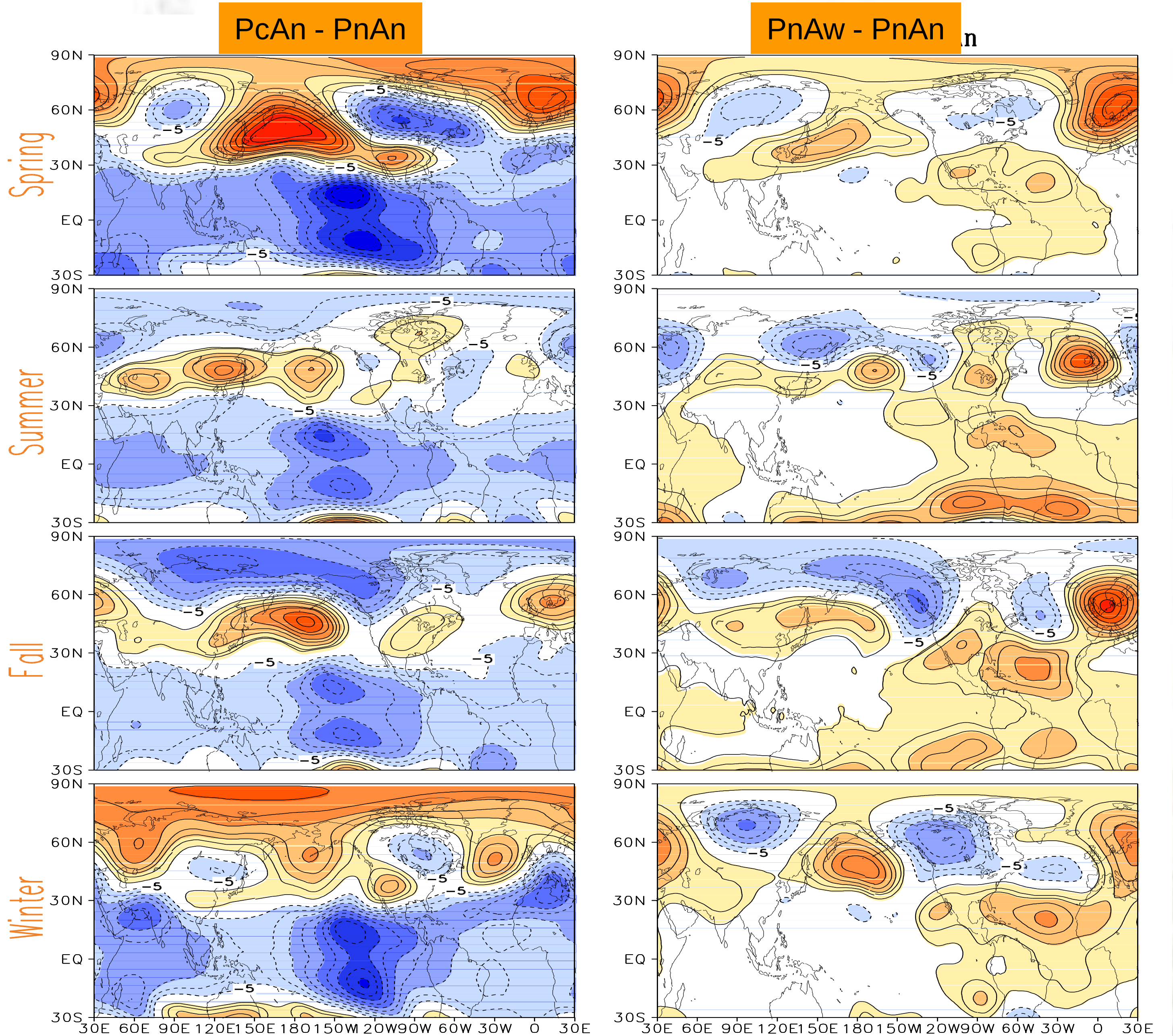
Mean seasonal anomalies of area-averaged Great Plain Indices of P, E, and MFC.



Evaporation anomalies are comparable to precipitation Anomalies.

In Summer:
MFC > P - ET

Geopotential Height at 200 mb



c.i.=5 m