A hybrid dynamic-statistical approach to link predictive understanding to improve seasonal prediction of rainfall anomalies at the regional scale

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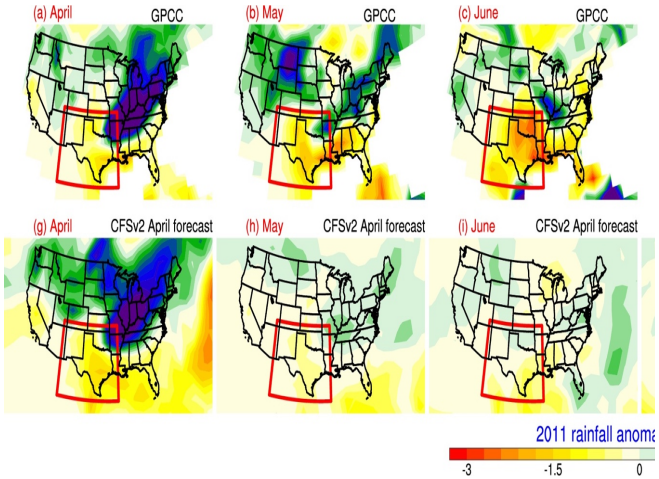
Challenges for seasonal rainfall prediction

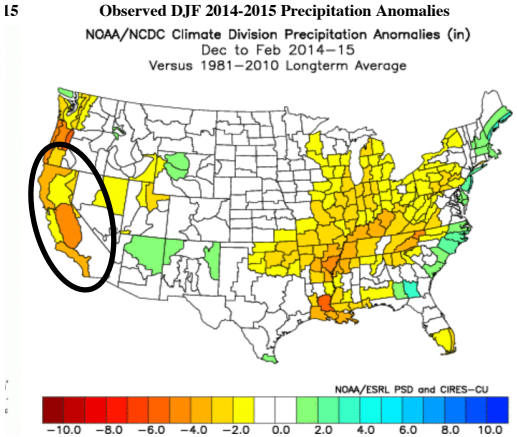
2011 Texas Drought rainfall anomalies

GPCC

CFSv2



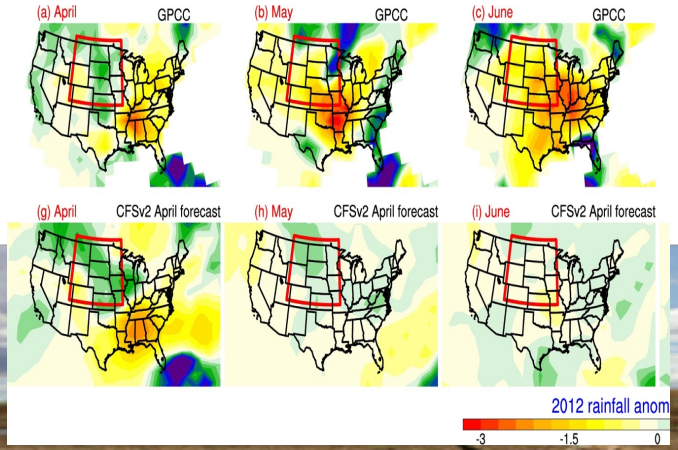
California drought, Dec 2014-Feb. 2015 rainfall anomalies

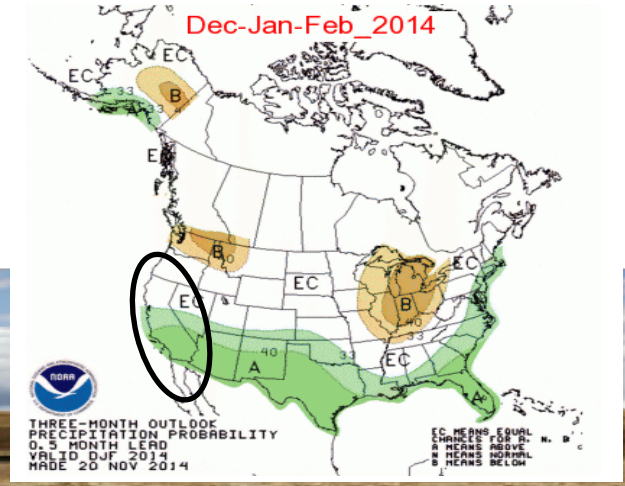


2012 Great Plains' Drought rainfall anomalies

GPCC

CFSv2





Observations: Drought persistence suggests potentially drought predictability for seasonal forecast

Namias 1982; 1991:

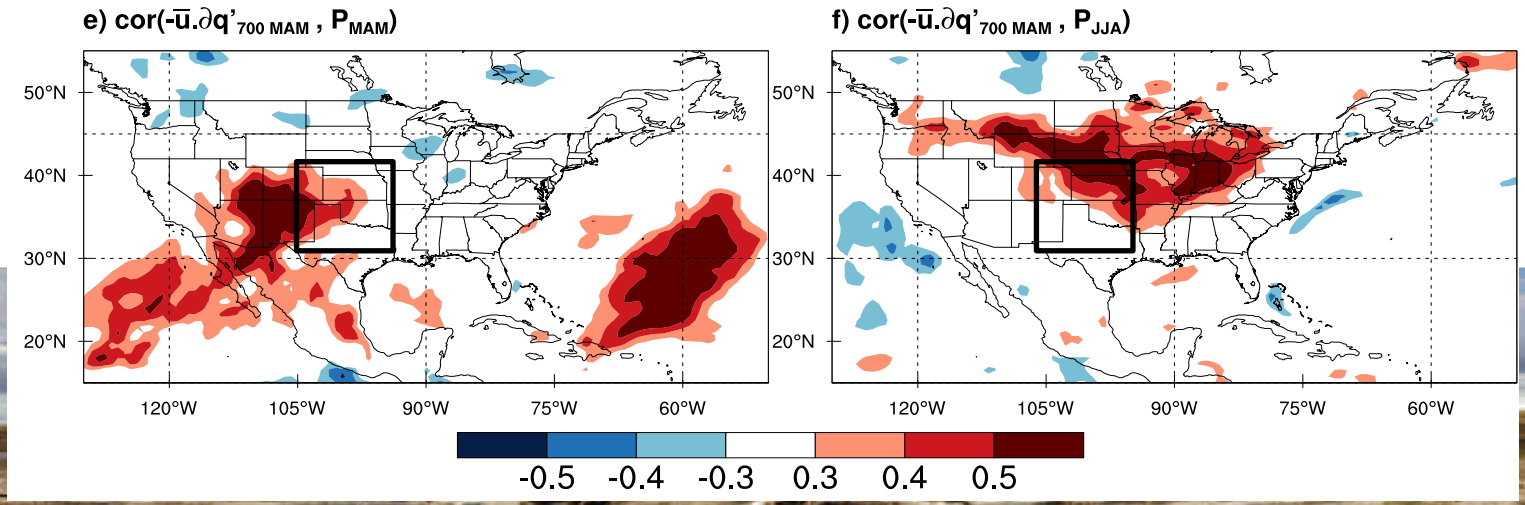
- ***Persistence of the drought circulation anomalies from March to June provides reasonable good predictability for 1980 and 1988 summer droughts.***

Fernando et al. 2016 (Clim Dyn):

- ***13 out of 18 severe-to-extreme summer droughts over the SC US since 1895 are linked to dry spring, only 3 summer droughts occurred after wet springs.***

Erfanian and Fu 2018 (to be submitted, See Poster #29):

- ***Summer rainfall deficits over the US Great Plains are significantly correlated with the spring rainfall deficits over the US SW and reduced zonal moisture transport.***

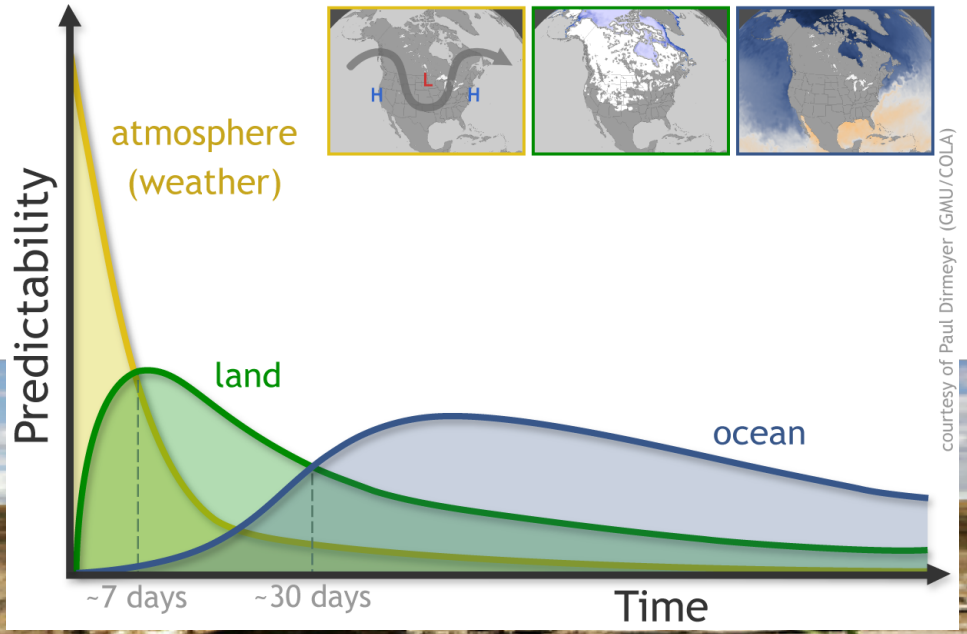


What processes could be responsible for the observed drought persistence at seasonal scale?

- ***Land surface feedbacks: Carson and Sangster 1981; Oglesby and Erickson 1989; Dirmeyer 1994; Myoung and Nielsen-Gammon 2010***
- ***Internal atmospheric variability:***
  - ***"a sequence of unfortunate events" Hoerling et al. 2014***
  - ***Stationary Rossby waves e.g., Wang et al. 2014***
- ***Soil moisture anomalies can influence large-scale circulation remotely: Van den Dool et al. 2003; Koster et al. 2014***

- **Is there real source of predictability?**
- **How can these processes provide predictability at seasonal scale?**

Dirmeyer diagram



Evolution of the summer droughts over the US Great Plains

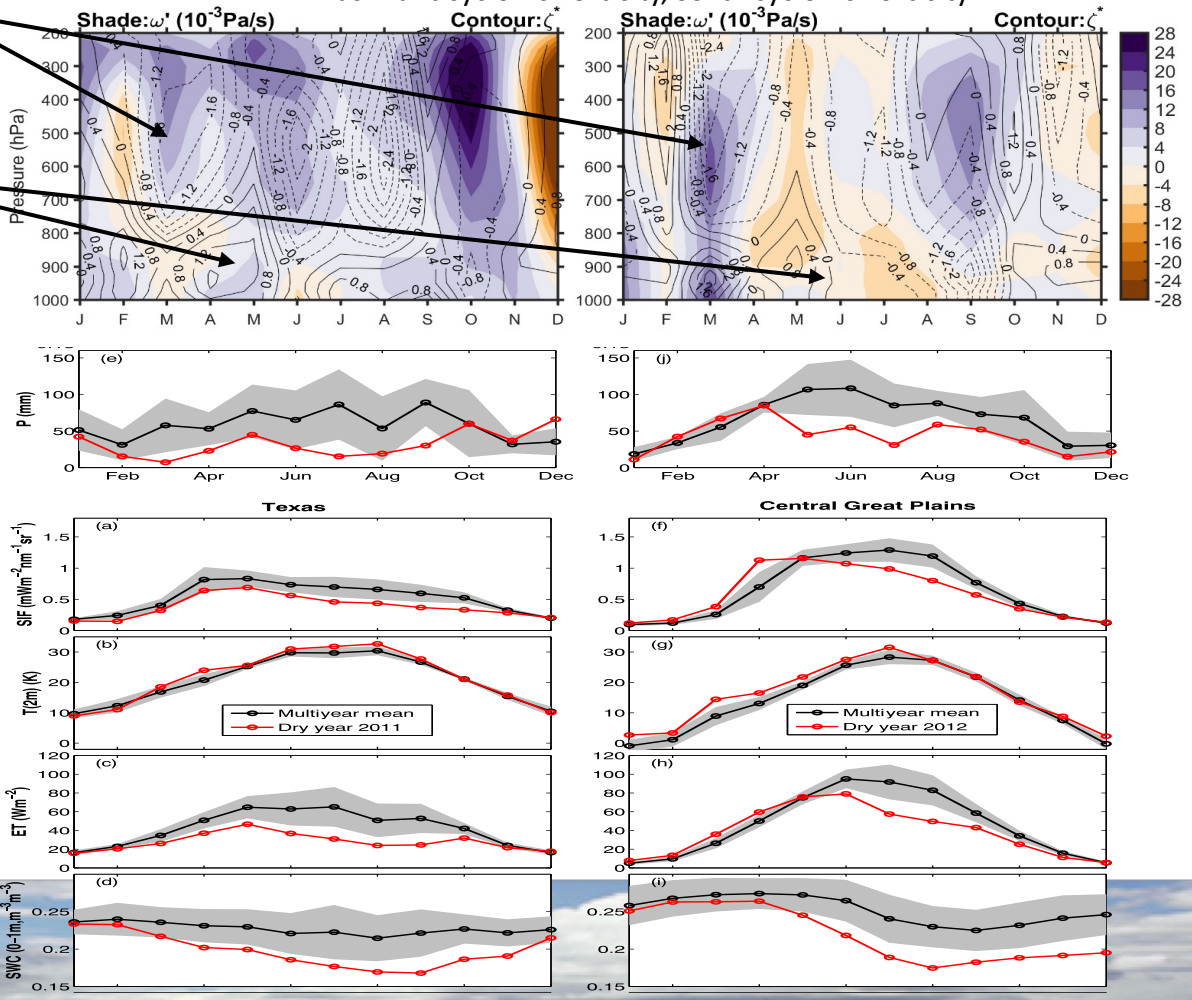
- ***Summer droughts start from rainfall deficits caused by anomalous sub-seasonal large-scale anticyclonic circulation in spring or winter.***
- ***Sub-seasonal variability variability shown in the middle and upper troposphere, but lower-level subsidence persists, leading to persist rainfall deficit and land surface dryness from spring to summer.***

SGP, 2011

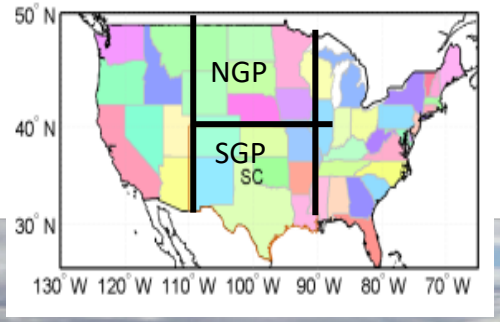
Blue: subsidence, orange: ascending

Dash: anticyclonic vorticity, solid: cyclonic vorticity

NGP, 2012



SGP: 92W-110W, 25N-40N

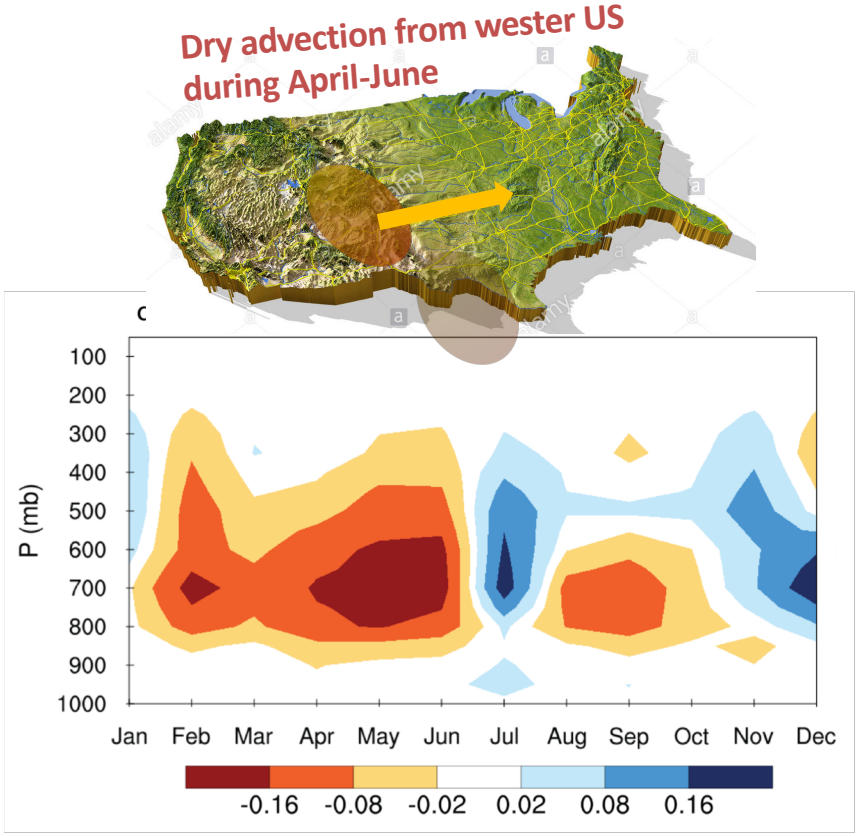


Sun et al. 2015, JGR-bio

What are the underlying processes for the persist rainfall deficits from spring to summer?

- ***Strong decrease of zonal moisture advection in the lower troposphere above the boundary layer from February to June.***
- ***The decrease of zonal moisture transport is mainly due to the spring-time dry conditions over the upwind regions (the Rockies and western United States).***

See Poster #29



Erfanian and Fu 2018, to be submitted

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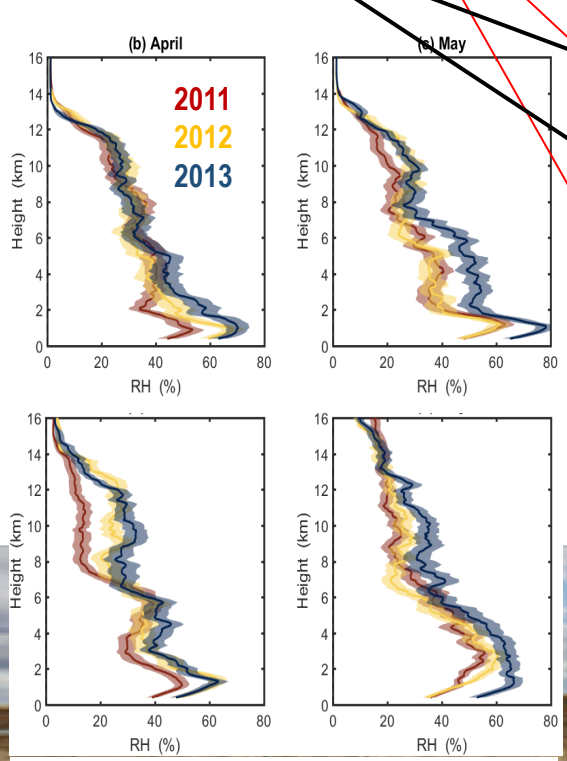
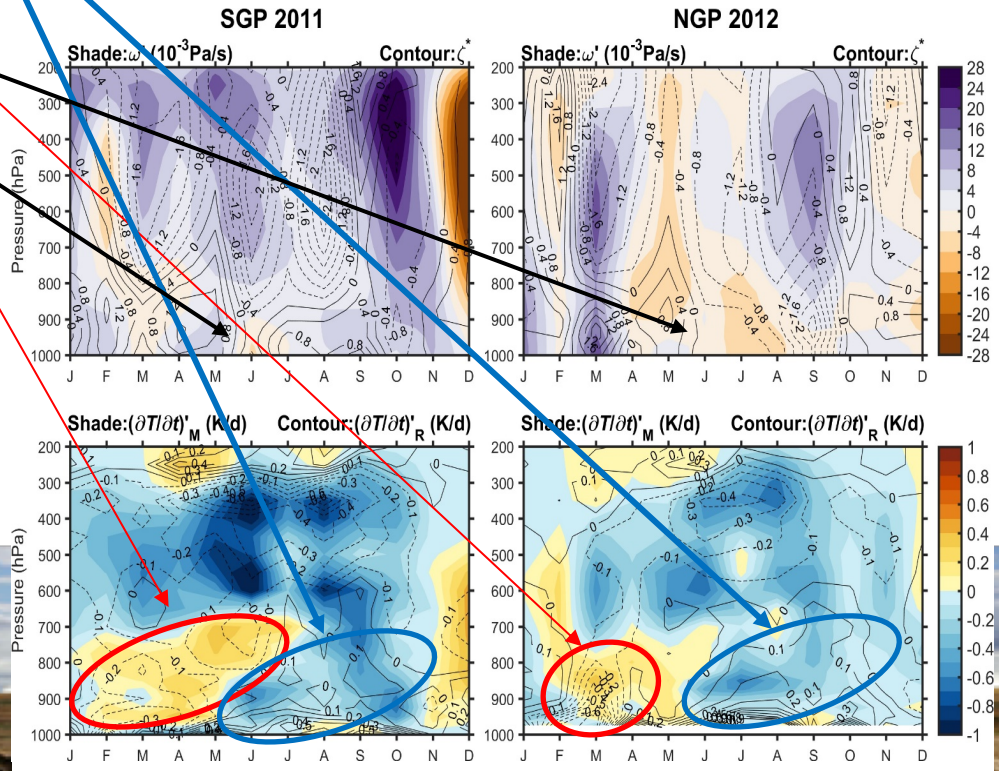
Regional land-atmospheric feedbacks re-enforce the subsidence from spring to summer

- *Reduce moisture in the ABL and lower troposphere in spring*
- *Suppress development of shallow convection, convective congestus and deep convection in late spring and summer*
- *Reduce radiative and latent heating in the atmosphere*
- *Enhance subsidence and re-enforce drought*



ARM SGP soundings

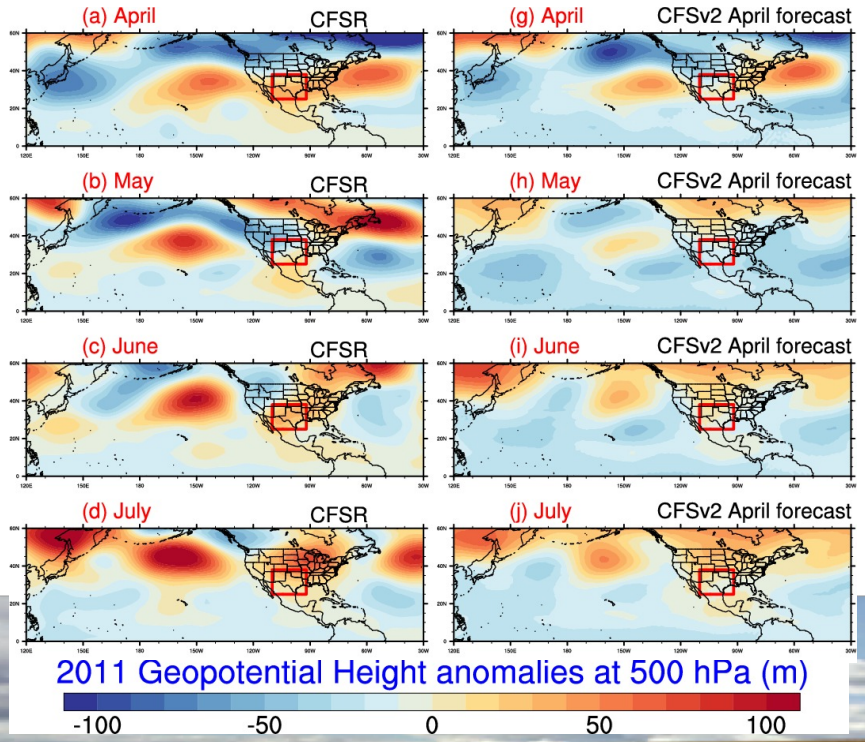


NCEP and MERRA reanalysis products

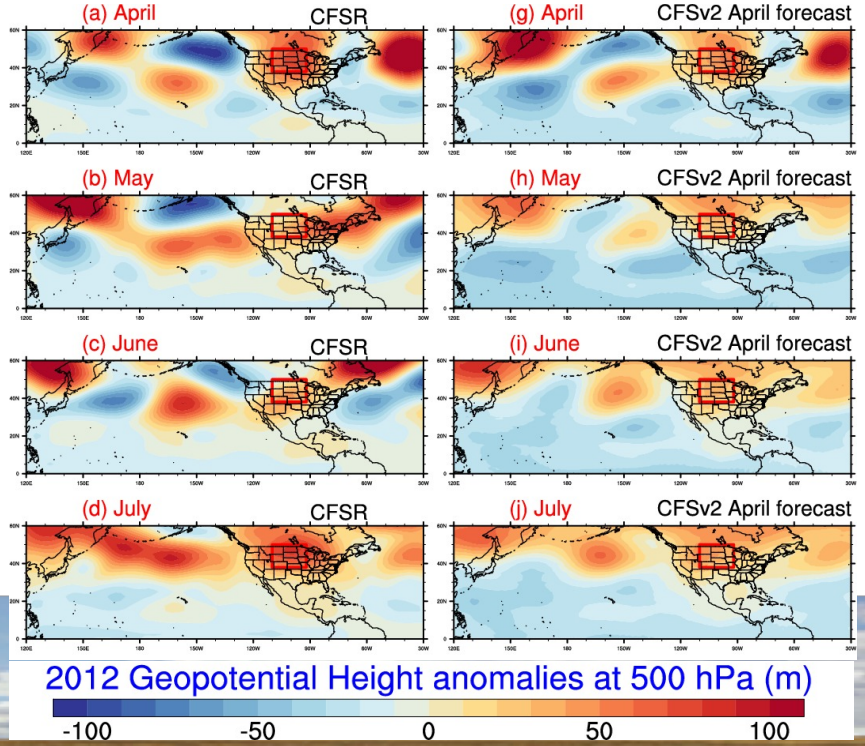
Why do climate models fail to capture persistent drought memory?

- ***The 500 hPa geopotential high anomalies over the US Great Plains is too weak in spring***
- ***The anomalous high decays faster than that observed.***

2011 Texas drought



2012 Great Plains drought



What cause loss of drought memory over US Great Plains?

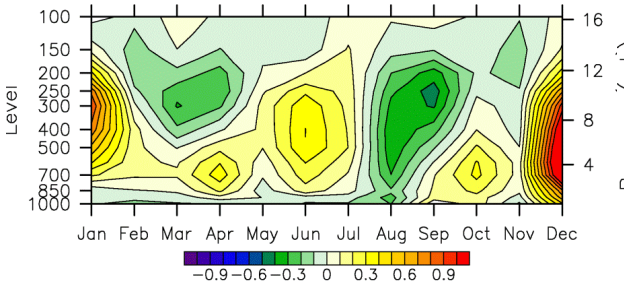
Modeled summer drought

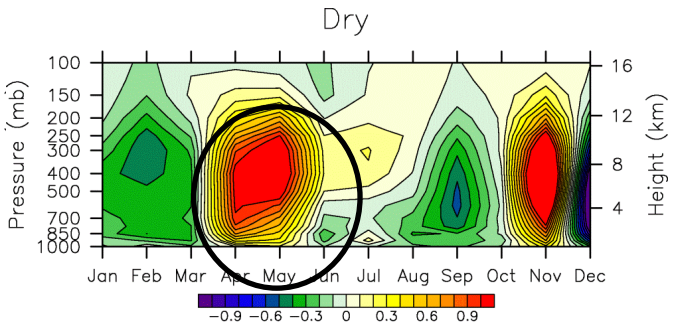
- ***Starts from a top-down, instead of bottom-up, induced subsidence in spring.***
- ***Opposite sign of shallow clouds response compared to that observed in spring.***
- ***Weaker and less persistent negative latent heating (rainfall) anomalies or dry memory.***

SGP: Observation

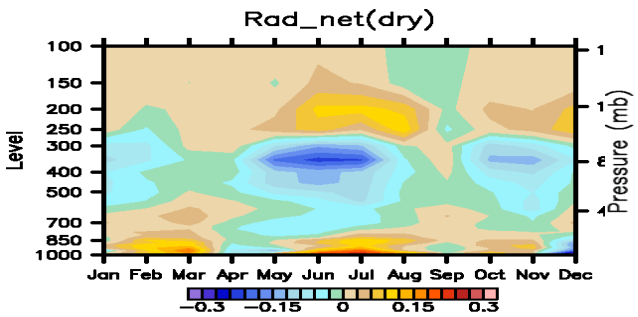
GFDL CM3, AMIP

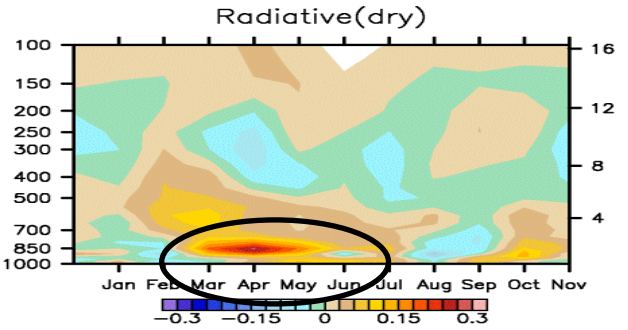
Vertical velocity (Pa/s) from NCEP



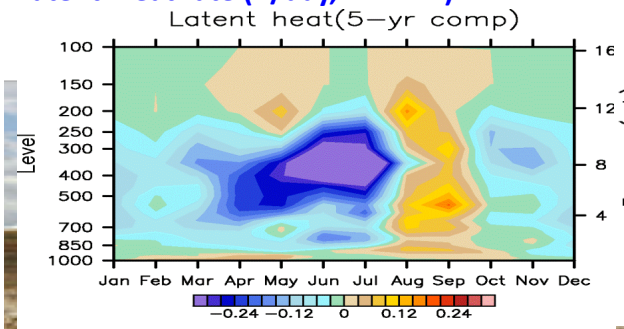


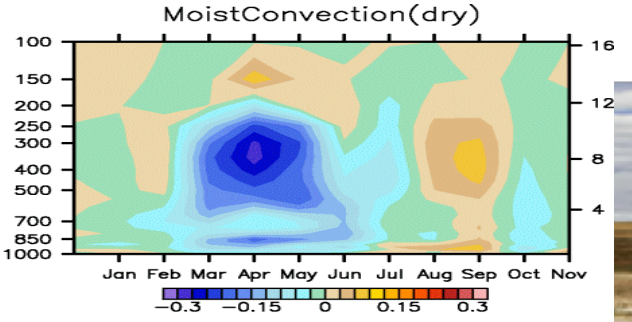
Radiative heat rate (K/day, MERRA)





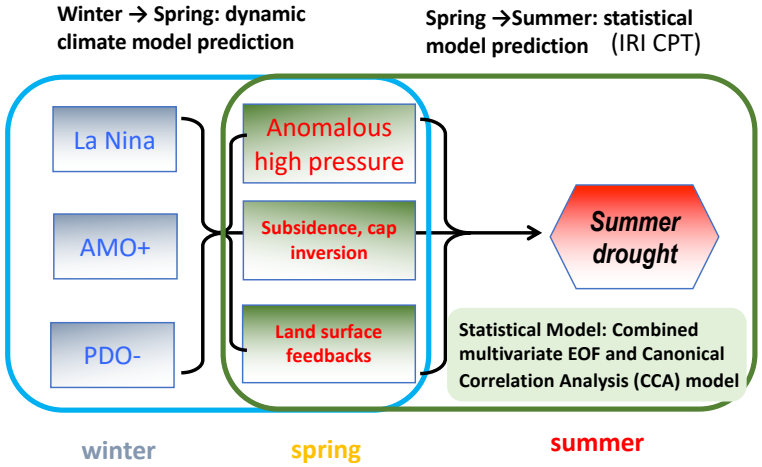
Latent heat rate (K/day, MERRA)





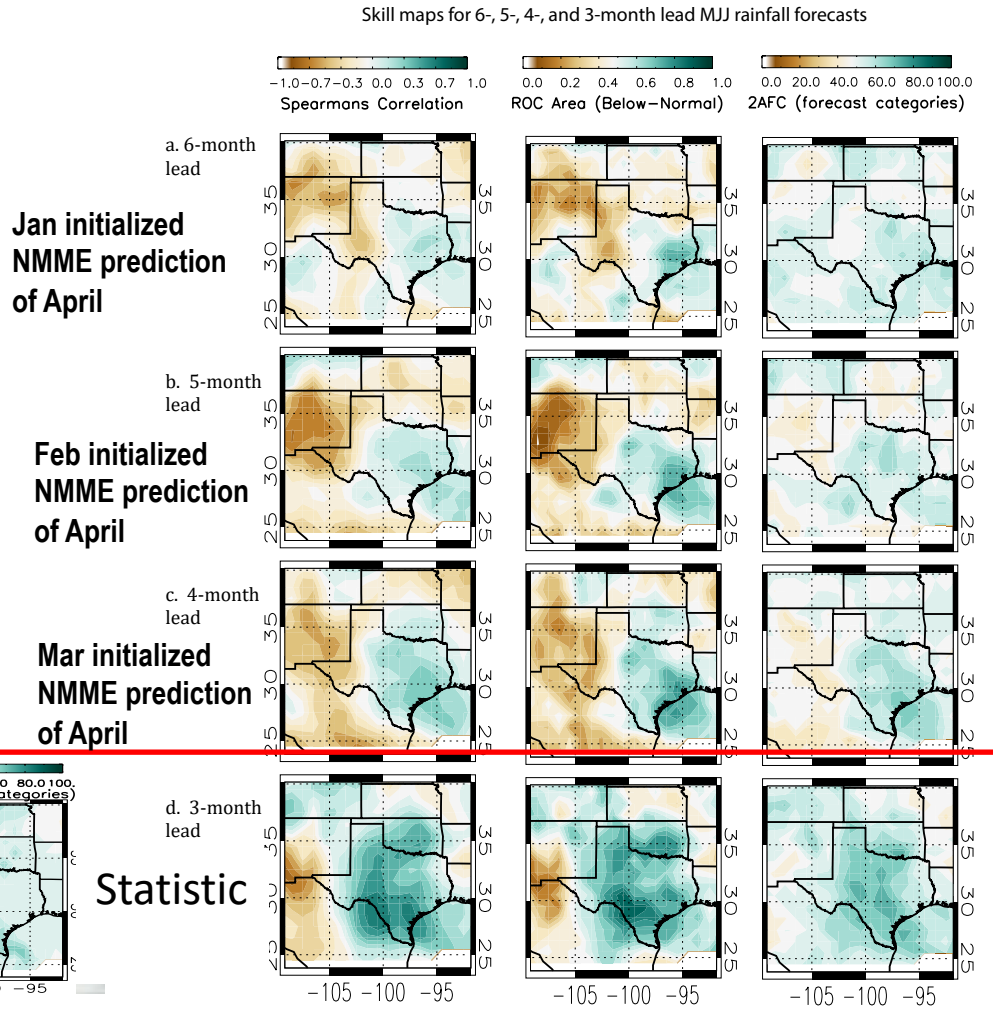
Can these processes improve summer rainfall predictability?

A hybrid physical-empirical model approach:

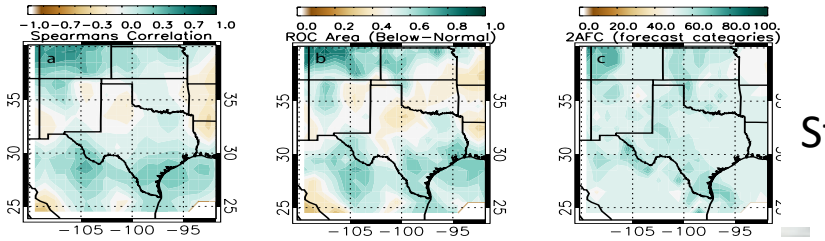


[Prediction provided to Texas stakeholders since 2015 at http://waterdatafortexas.org/drought/drought-forecast).](http://waterdatafortexas.org/drought/drought-forecast)

Hybrid NMME-statistical prediction skills



NMME Skill for MJJ rainfall anomalies



Prediction of MJJ rainfall anomalies initialized by CFSv2 real time forecast in April

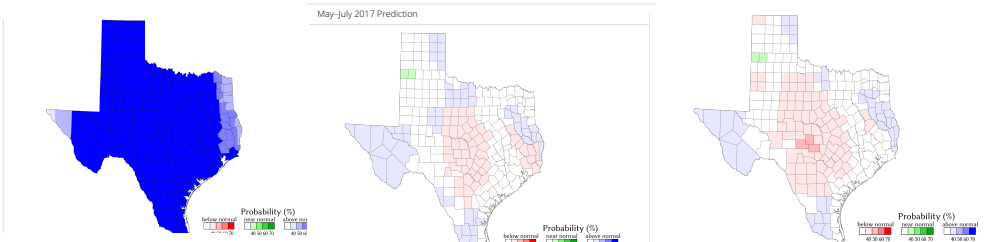
Figure 5. Skill comparison maps for MJJ rainfall anomalies using (a) January-April (6 months lead), (b), February-April (5 months lead), (c) March and April (4 months lead), and (d) April (4 months lead) initial conditions.

Fernando et al 2018, in review

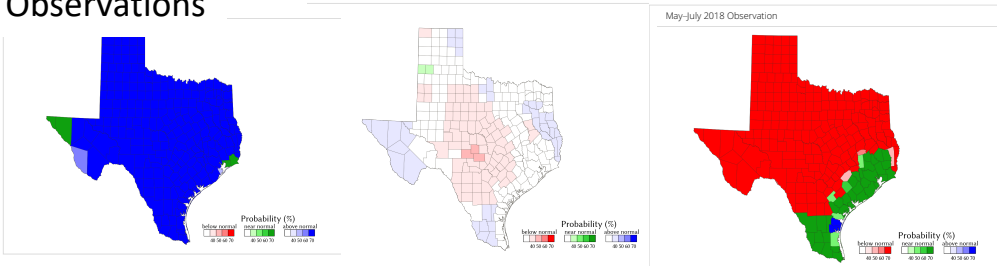
Forecasts initialized in April and observations:

May-July 2015 **May-July 2017** **May-July 2018**

Forecasts



Observations



Made available at https://waterdatafortexas.org/drought/past-rainfall-forecasts

Hindcasts, May-July rainfall anomalies (training period 1982-2005)

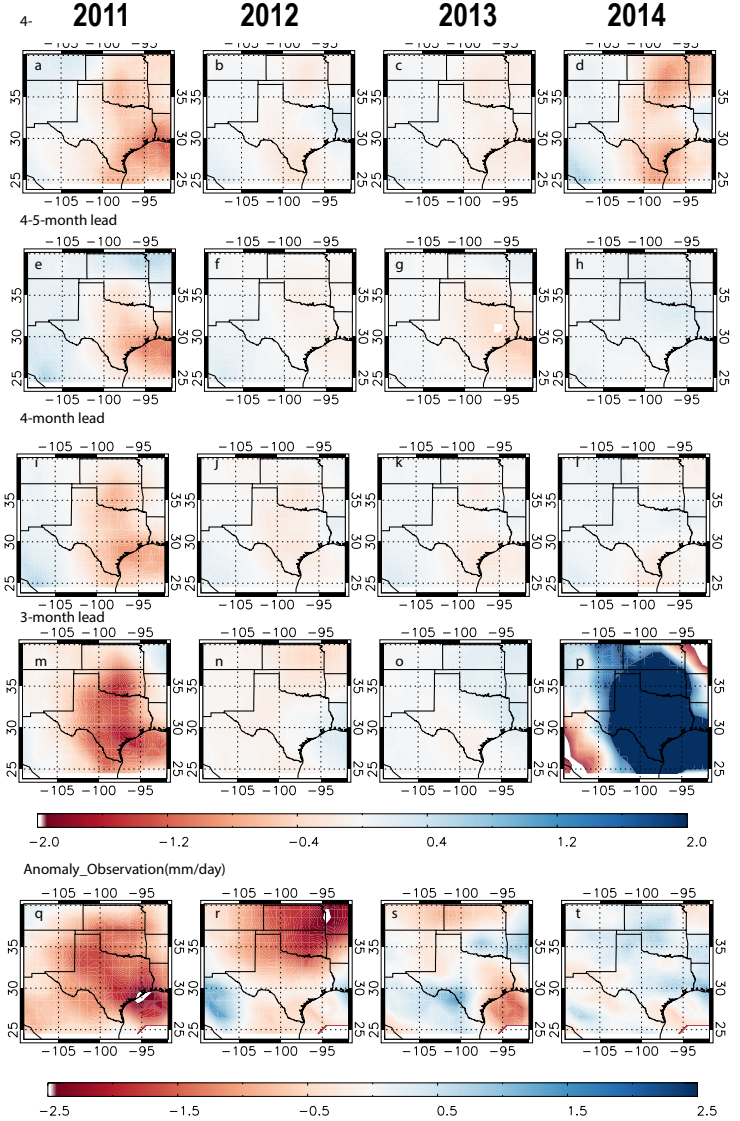


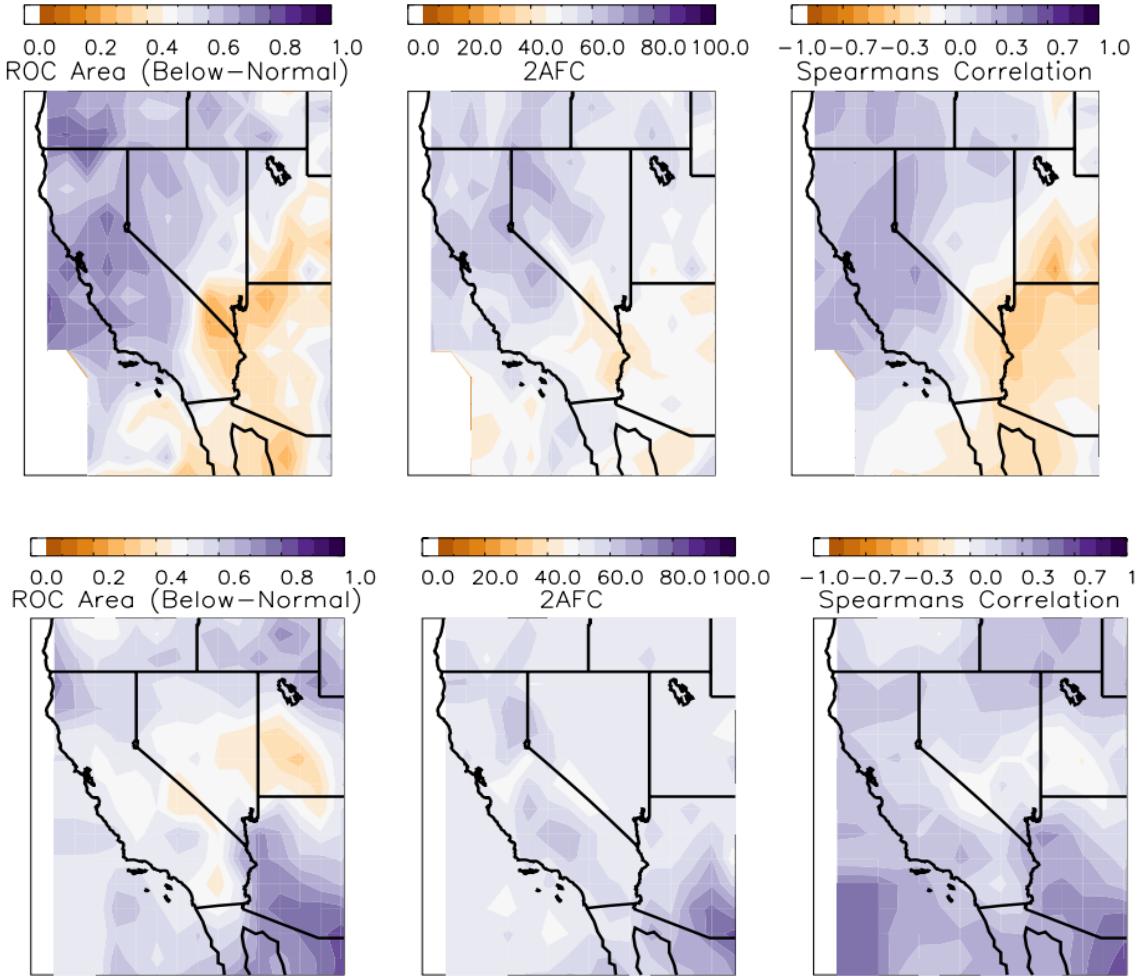
Figure 7. CPT based predicted deterministic forecast maps of of rainfall using (a-d) January-April (4-6 months lead), (e-h), February-April (4-5 months lead), (i-l) March and April (4 months lead), and (m-p) April (4 months lead) initial conditions for 2011- 2014. (q-t) observed precipitation anomaly during 2011-2014 using CPC data sets. All anomalies are estimated based on 1982-2010 mean of hindcasts and observation.

Prototype statistical prediction of winter rainfall anomalies for California/Nevada

- ***Statistical seasonal prediction of winter rainfall anomalies (December-February) show high skills than the seasonal prediction of dynamic climate models over CA/NV.***

Statistical seasonal prediction initialized in October

NMME seasonal prediction initialized in October

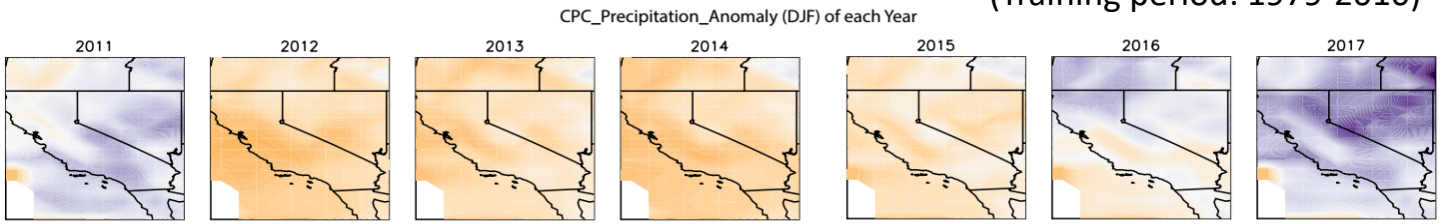


Hindcasts for winter rainfall anomalies during the 2012-2016 drought over California/Nevada

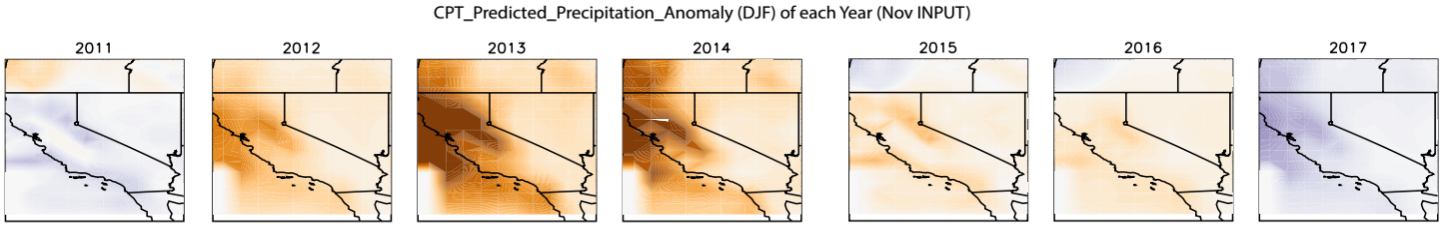
Hindcasts of Dec-Feb standardized rainfall anomalies using October inputs

(Training period: 1979-2010)

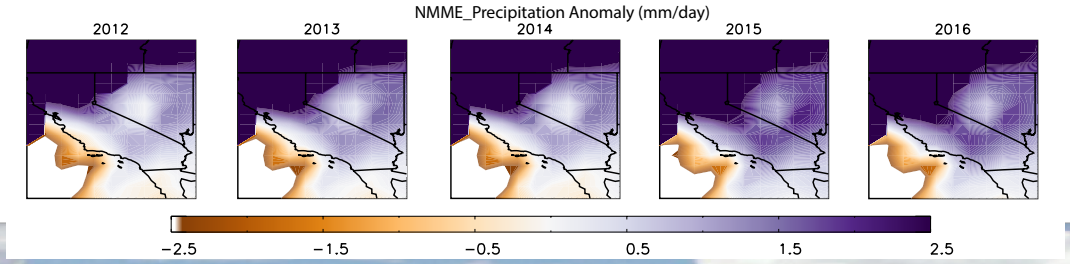
Observation (CPC)

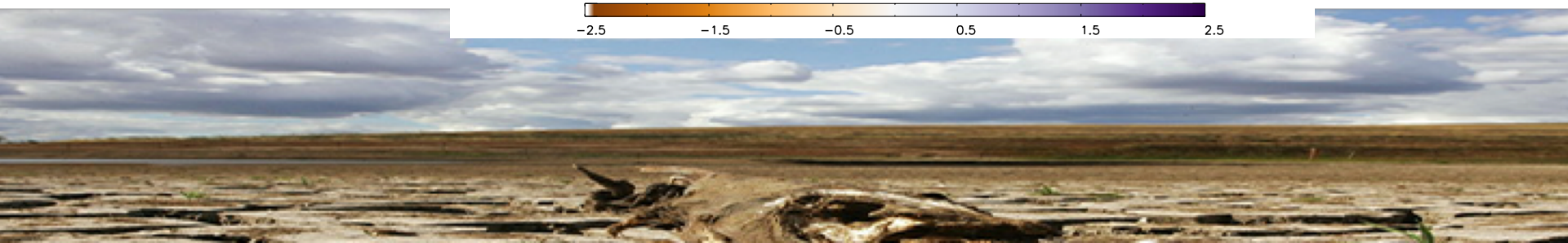


Statistical prediction



NMME prediction





Conclusion

What processes could be responsible for the spring to summer drought persistence over the US Great Plains?

- ***Reduced westerly moisture transport in the lower troposphere, due to dryness over US west, and the positive feedbacks between surface dryness, shallow clouds, deep convection, and large-scale subsidence reinforce the large-scale anomalous drought circulation***

Could dry memory provide improved rainfall predictability on seasonal scale?

- ***Appear to be over the US Great Plains, and possibly over the California/Nevada, as suggested by a hybrid dynamic-statistical seasonal prediction.***

- ***A hybrid dynamic-statistical seasonal prediction could provide a value added product to support NOAA's mission of improving seasonal prediction of regional rainfall over the US to support societal drought preparedness.***

Thank You!