MAPP
Modeling, Analysis, Predictions, and Projections

Prediction skill of the 2012 U.S. Great Plains flash drought in Subseasonal Experiment (SubX) models

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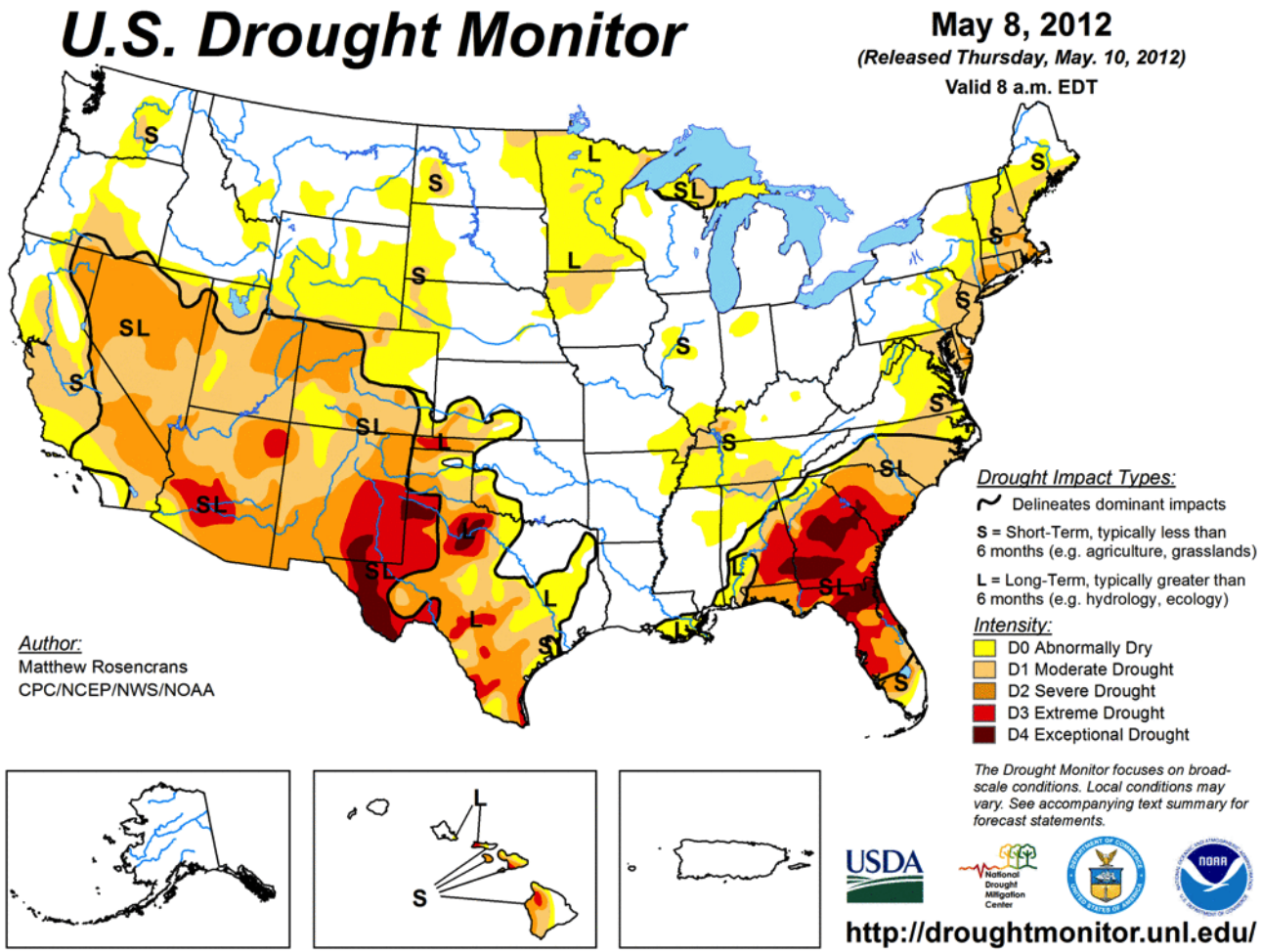
The 2012 U.S. Great Plains Flash Drought



Extreme drought (D3) rapidly developed over the central U.S. between June and August

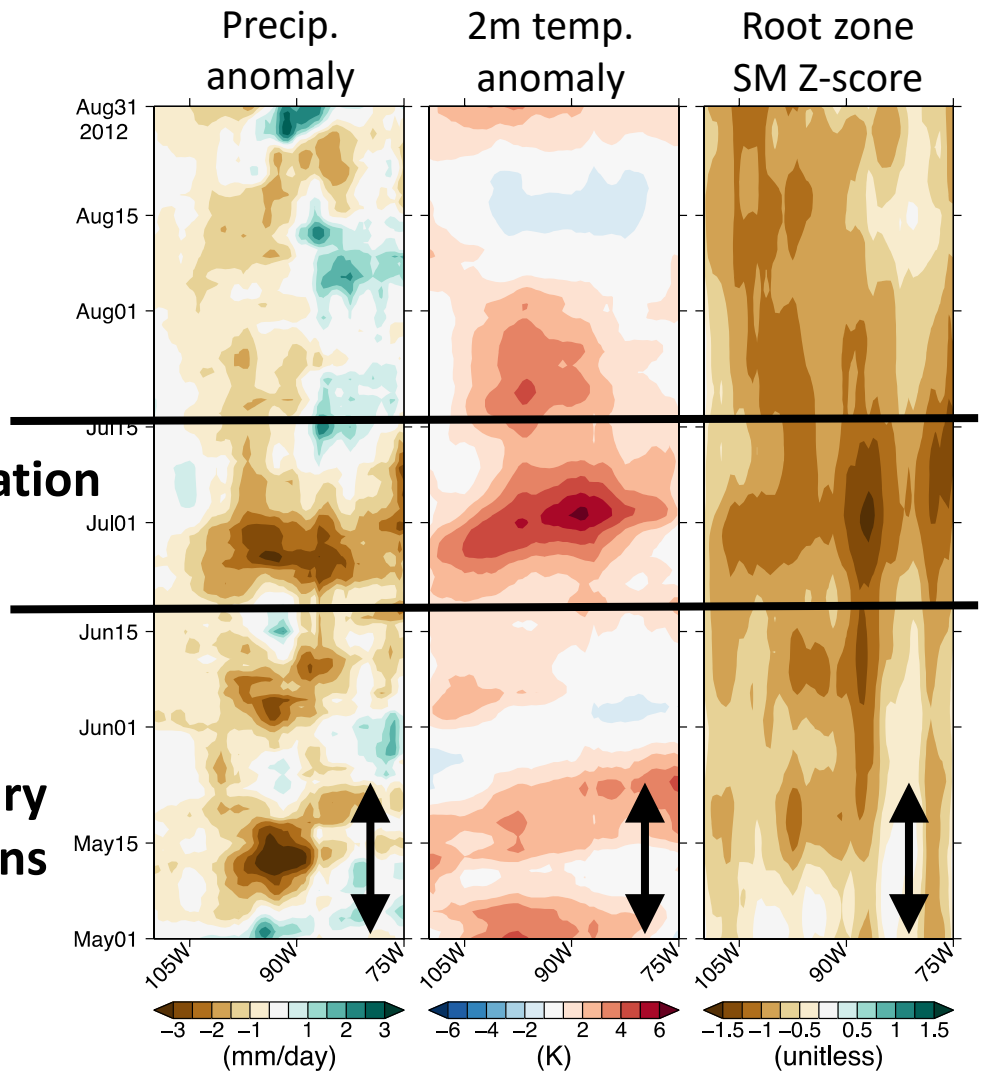
Economic losses > $30 billion (NCDC 2019)

Drivers of the 2012 flash drought:

Temporal evolution of event (averaged over 33-50N)

rapid intensification of drought

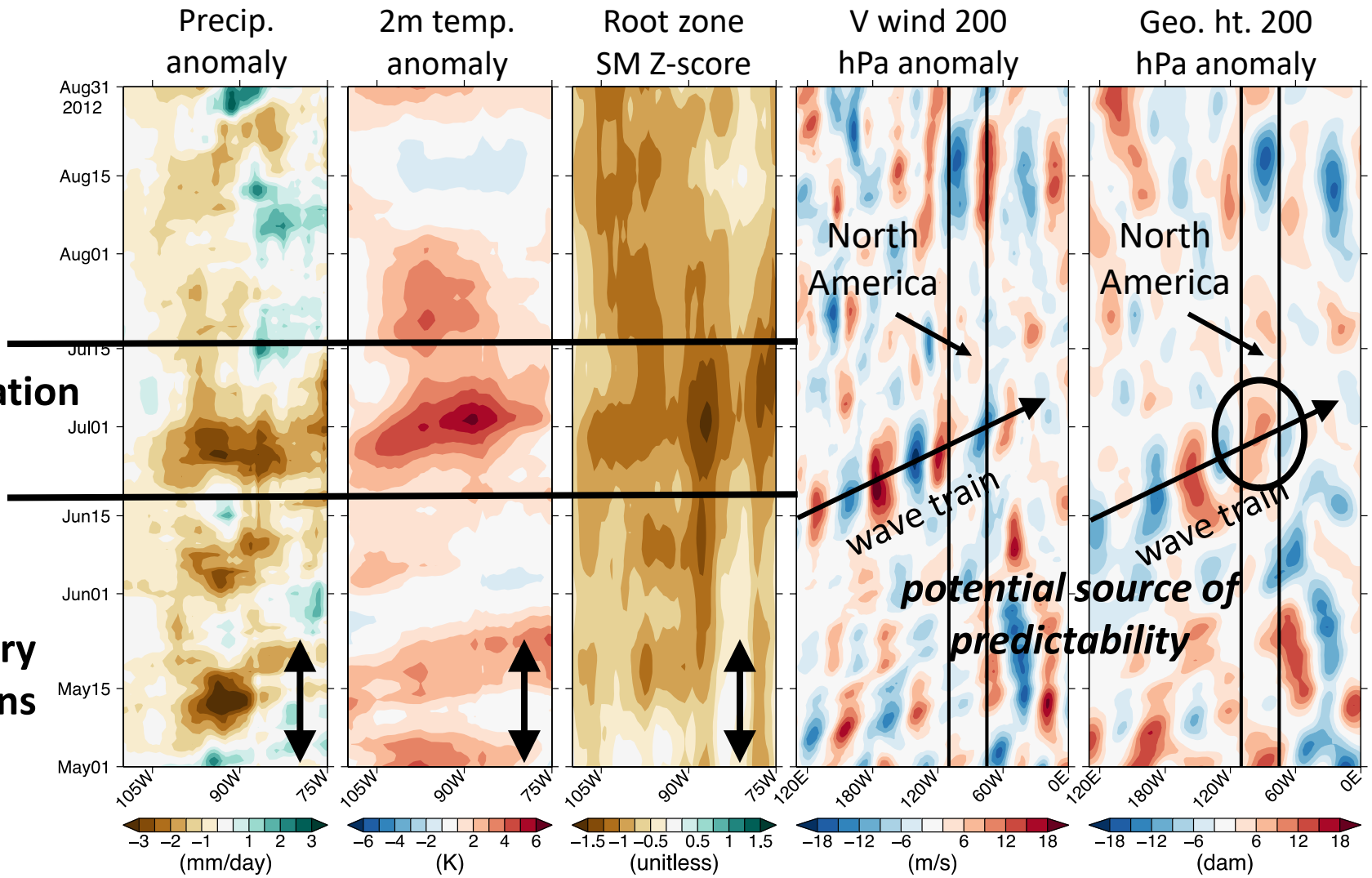
moderately dry land conditions develop



(from MERRA2, anomaly relative to 1999-2015)

Drivers of the 2012 flash drought:

Temporal evolution of event (averaged over 33-50N)



rapid intensification of drought

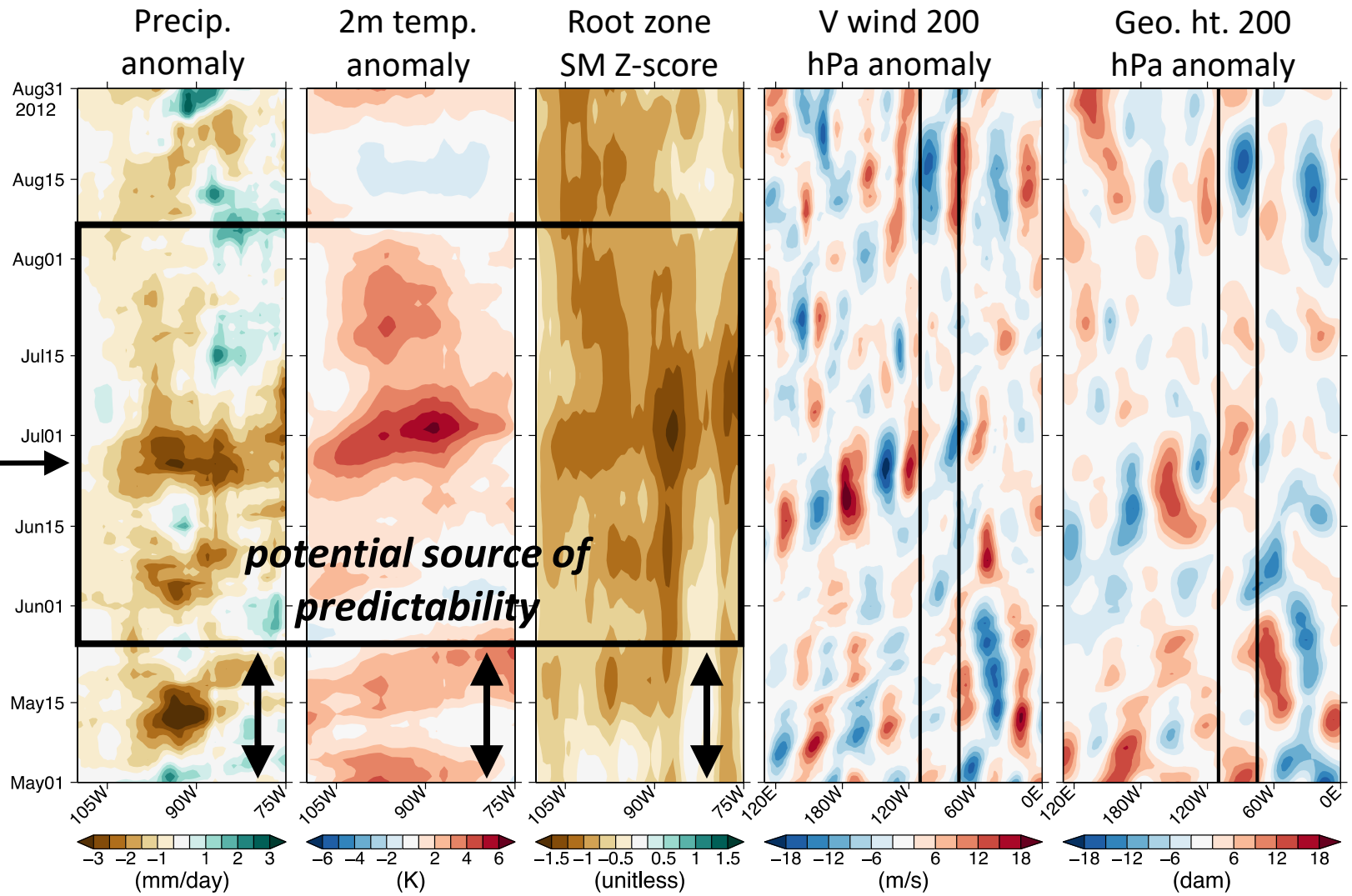
moderately dry land conditions develop

atmospheric ridge

(from MERRA2, anomaly relative to 1999-2015)

Drivers of the 2012 flash drought:

Temporal evolution of event (averaged over 33-50N)

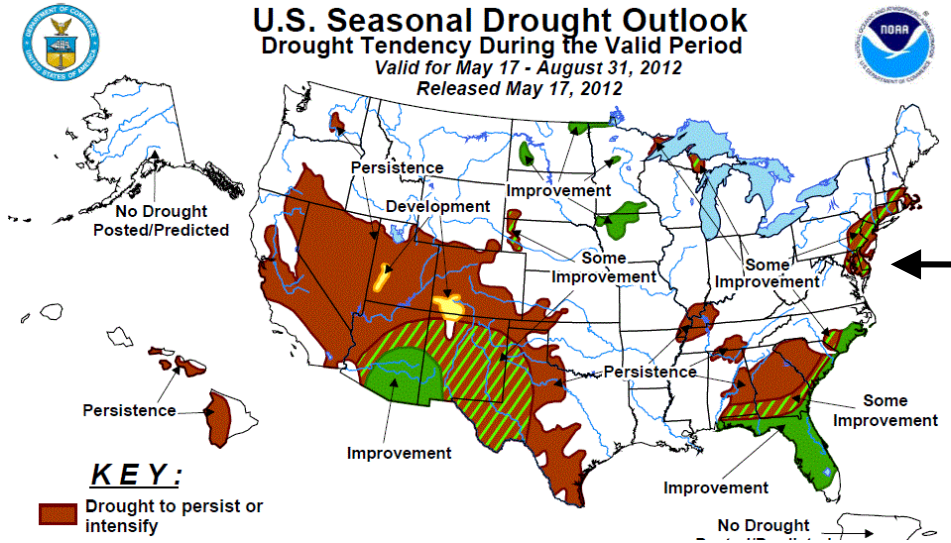


land-atmosphere feedbacks →

moderately dry land conditions develop

(from MERRA2, anomaly relative to 1999-2015)

Prediction of the 2012 flash drought



Operational seasonal forecasts did not predict the drought

CPC drought outlook for the summer of 2012

based, in part, on dynamical models initialized once per month

Could the drought have been predicted with subseasonal-to-seasonal (S2S) forecast models initialized on a weekly basis?

Potential sources of S2S prediction skill for flash drought:

1. **Land (soil moisture)** – accurate initialization and physics
2. **Rossby wave trains** – potential week 2-3 prediction of drought

SubX ***Subseasonal EXperiment Project*** - collection of global forecast systems for S2S prediction

8 Global models

NCAR, NOAA, NASA, NRL, ECCC

17 Years of *retrospective* forecasts (1999-2015)

Initialized every **7** DAYS *at least*

4 to 28 Ensemble members per week

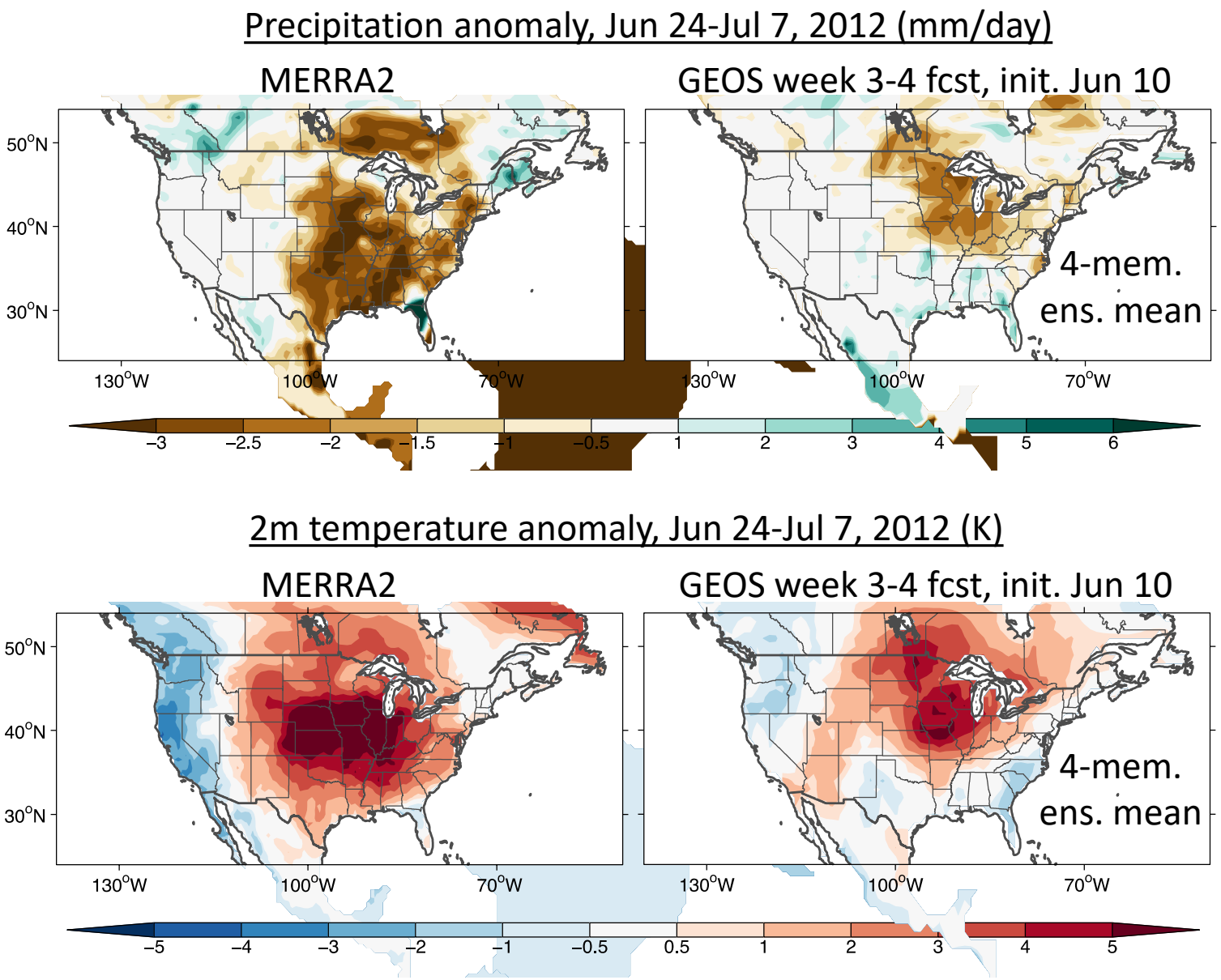
Forecast length of **32-45** days

GOAL: To assess the S2S prediction skill of the 2012 drought in SubX

S2S prediction – ~3-4 weeks in the future, 1-2 week averages

Evaluate forecasts against MERRA-2 reanalysis, focusing on P and T2m*

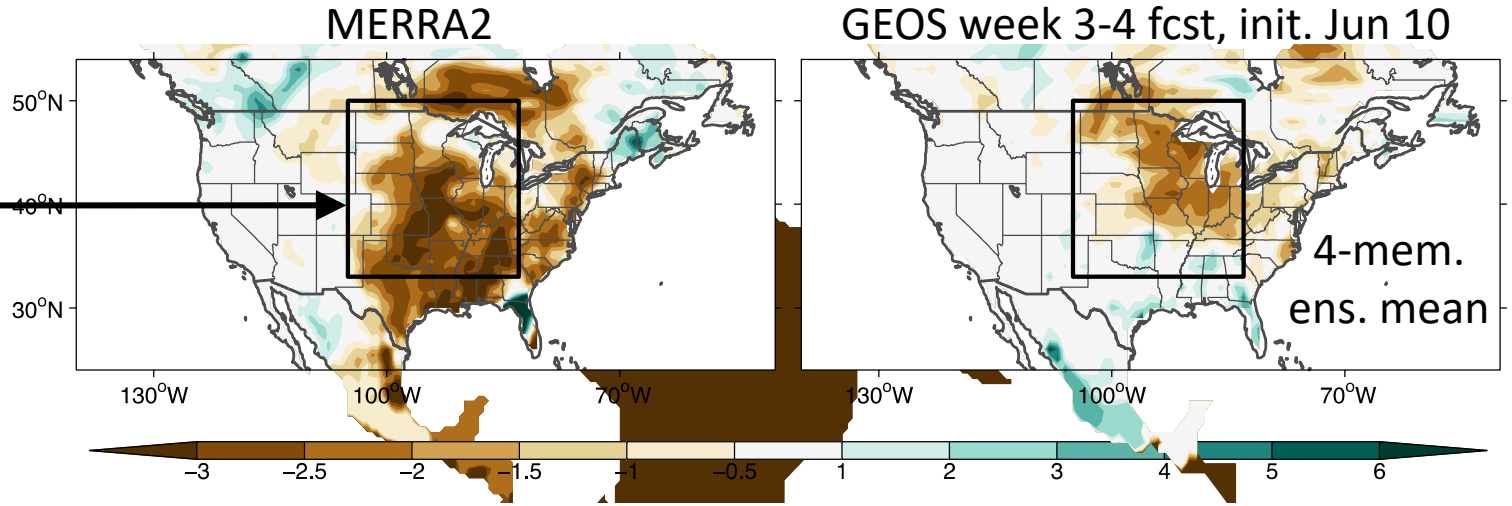
Prediction skill for rapid drought intensification, example model/initialization:



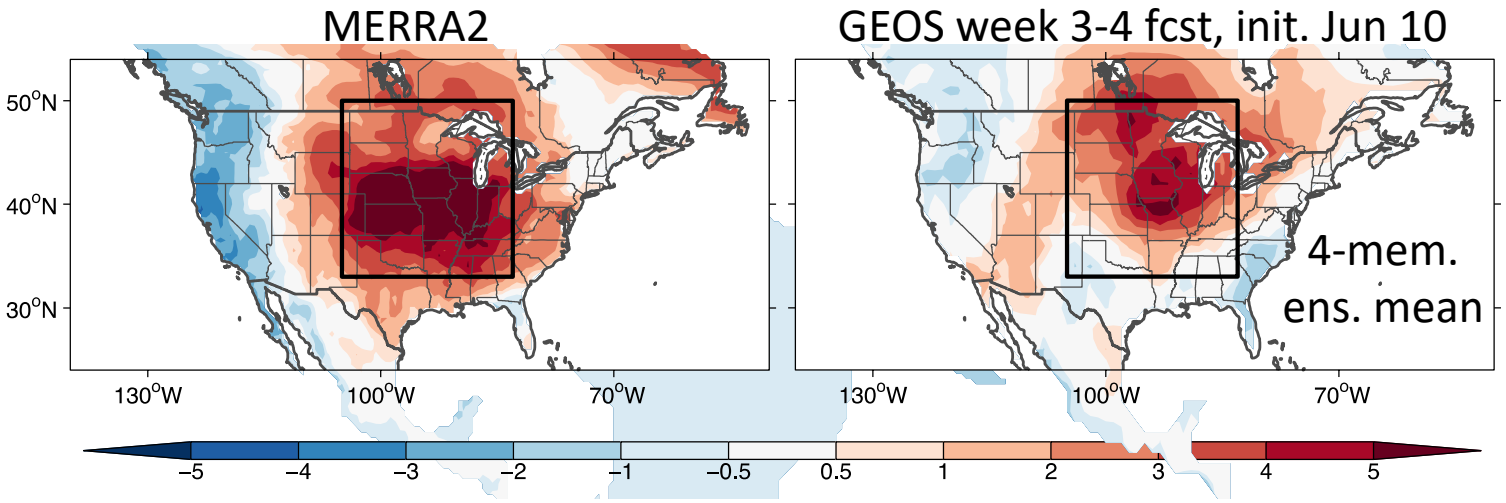
Prediction skill for rapid drought intensification, example model/initialization:

Average anomalies over this region and evaluate the temporal evolution of the event

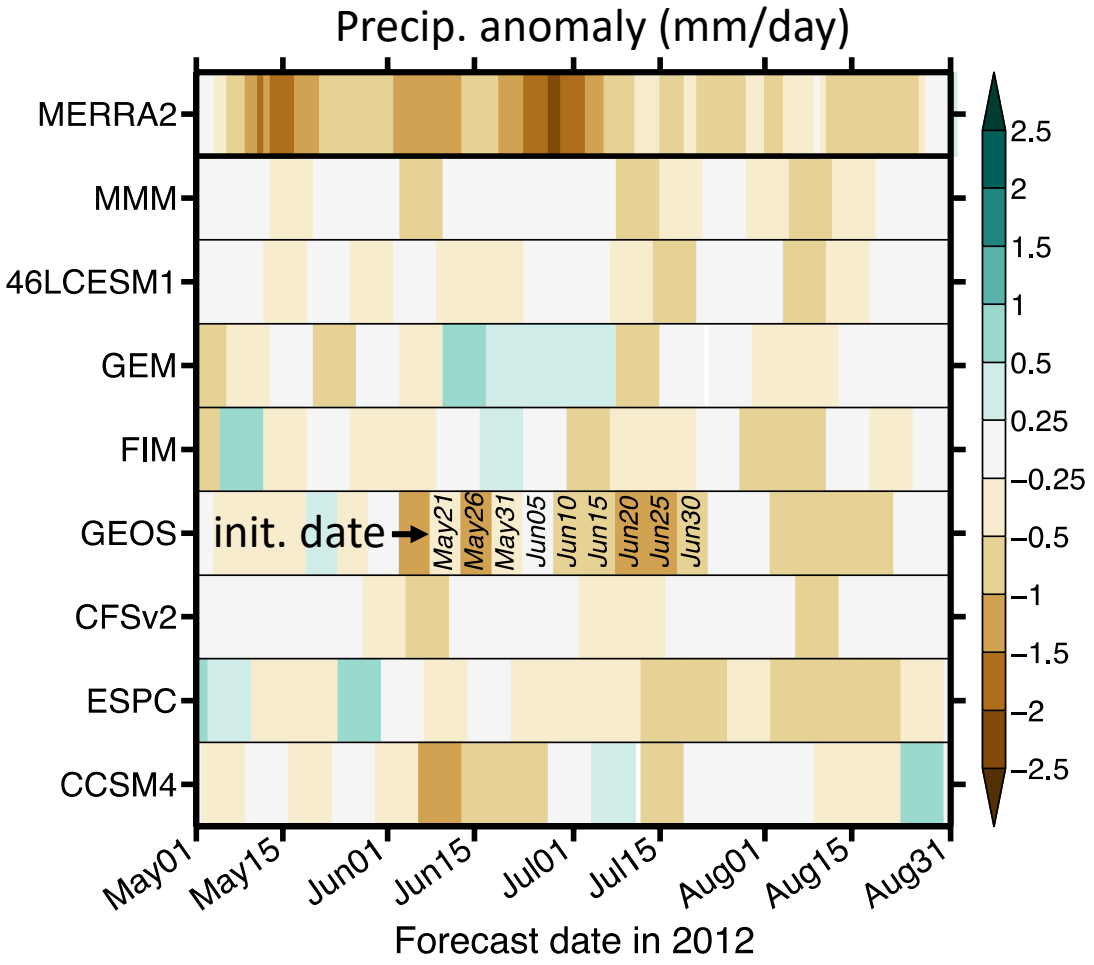
Precipitation anomaly, Jun 24-Jul 7, 2012 (mm/day)

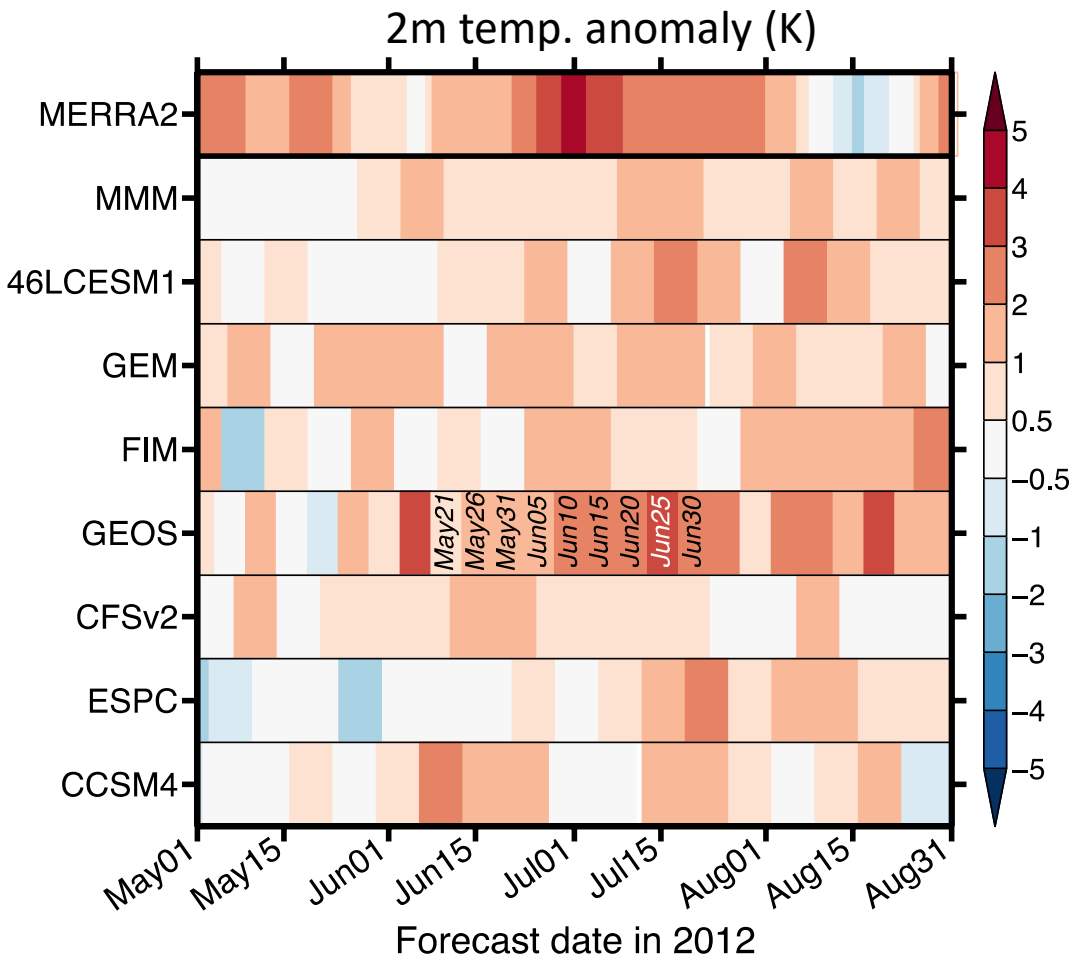


2m temperature anomaly, Jun 24-Jul 7, 2012 (K)



Week 3-4 forecast regional-mean anomalies during summer 2012:





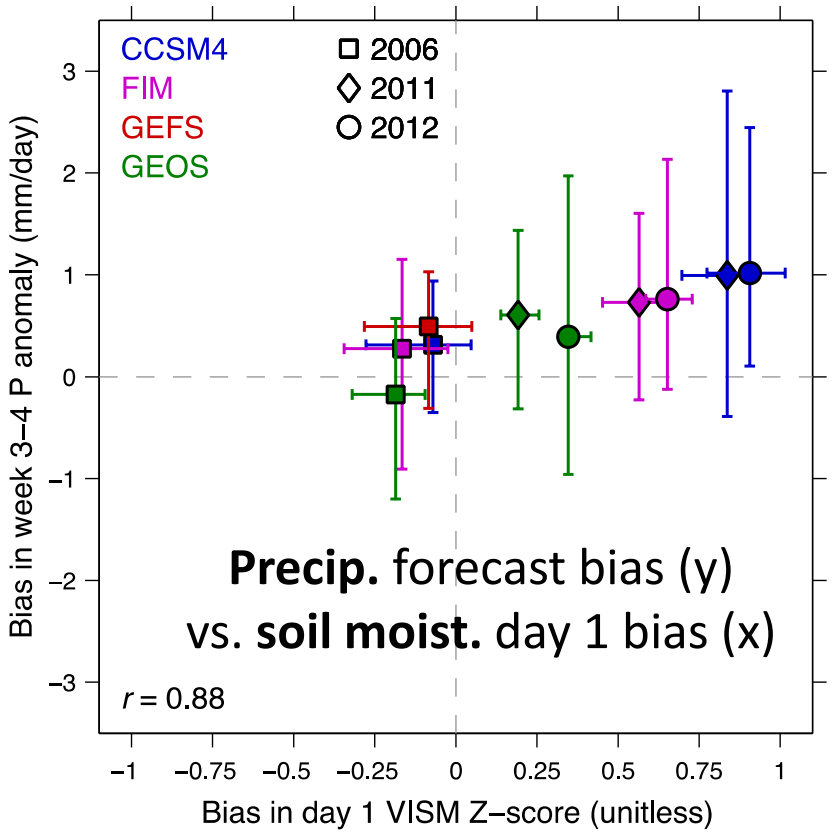
Skill is overall not great but some models/initializations are more skillful.

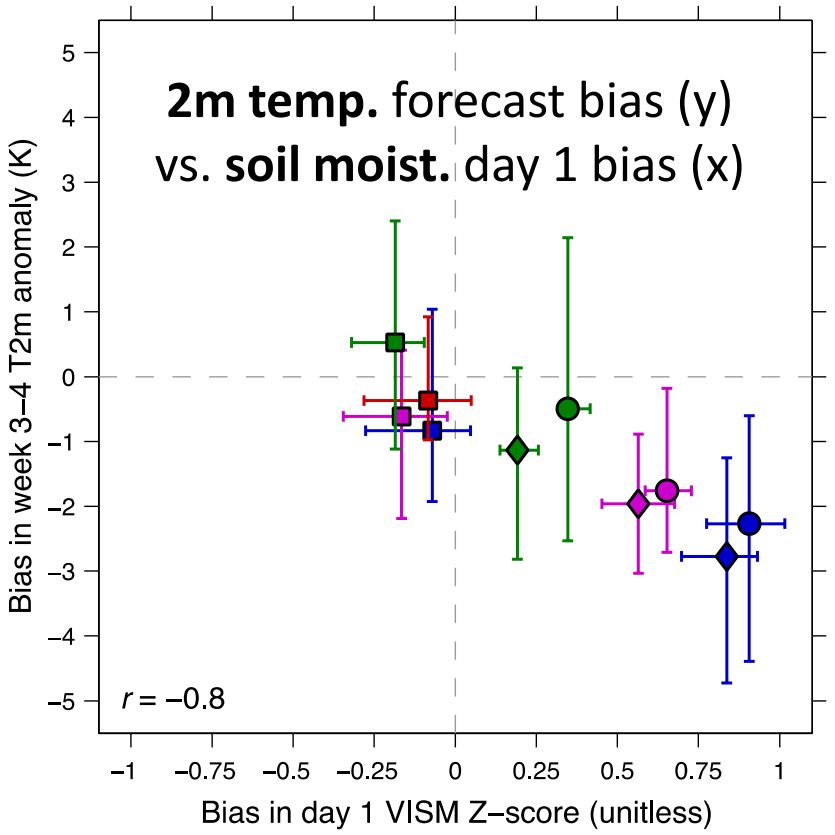
What factors contribute to the more skillful predictions?

Does the accuracy of soil moisture initialization influence the prediction skill?

*Compare **bias in soil moisture anomaly at the start of a forecast** with **corresponding bias in week 3-4 forecast***

4 models, June-July initializations, 3 central U.S. flash droughts (regional means)





Implications:

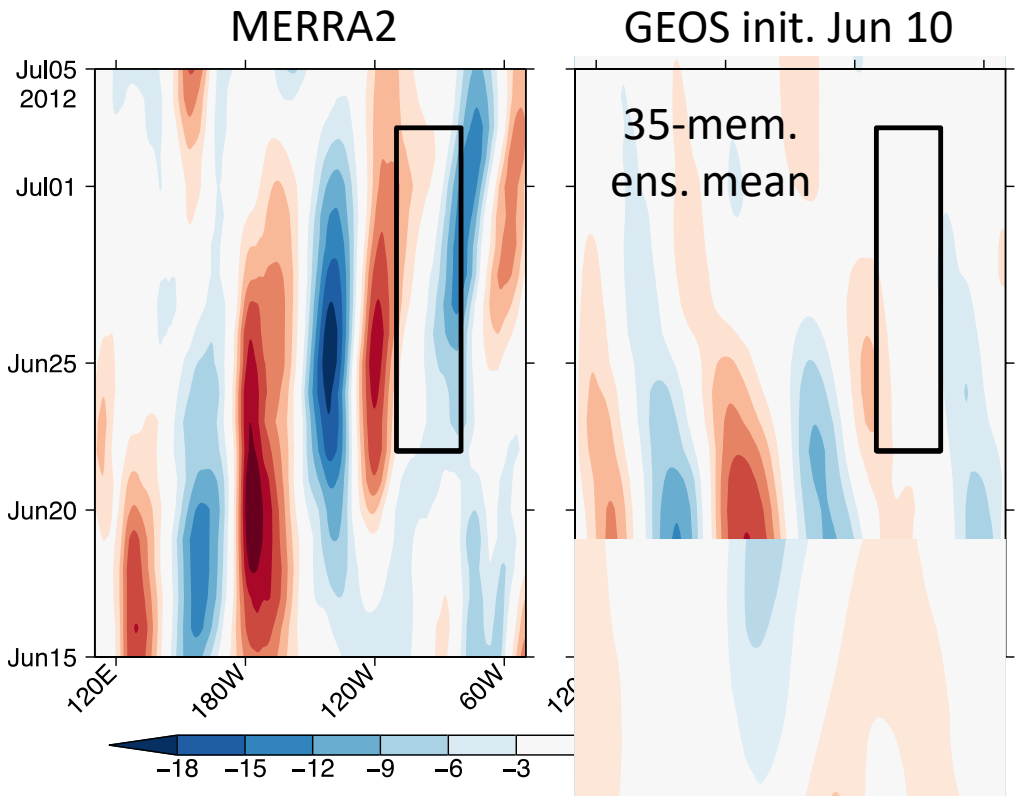
1) Importance of accurate SM initialization
2) Importance of land-atmosphere feedbacks
3) Large spread in SM initialization accuracy

1) and 2) supported with larger-ensemble controlled NASA GEOS simulations

Larger bias in initial SM → larger bias in week 3-4 forecast

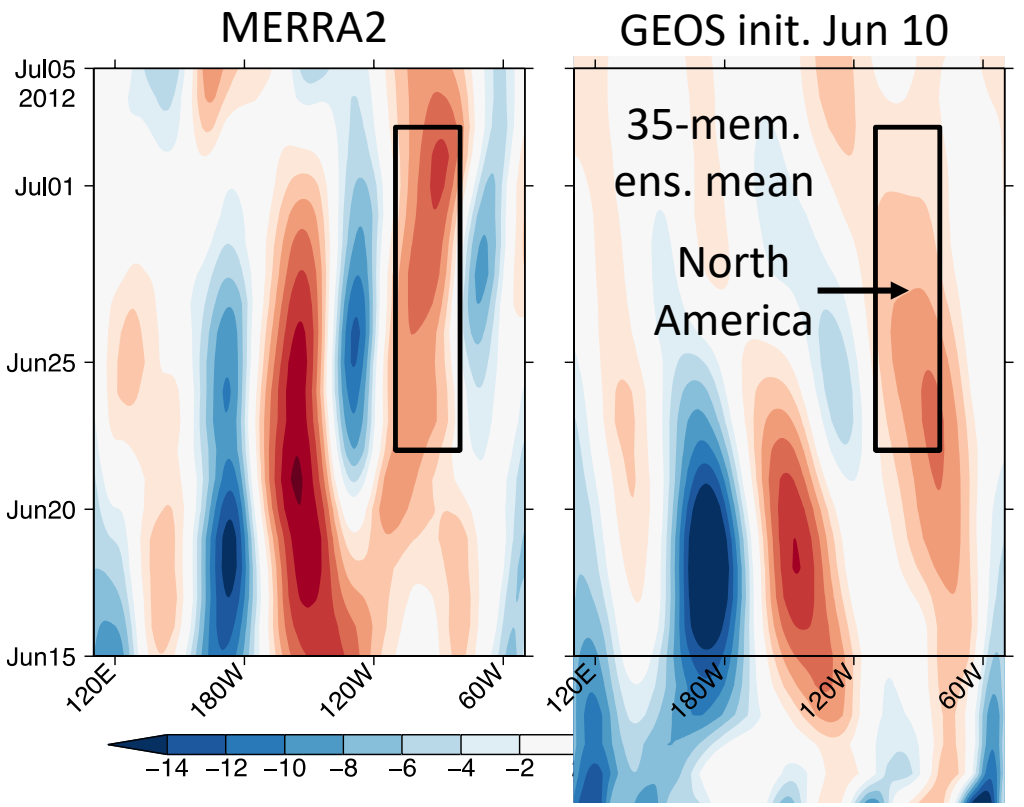
Rossby wave train is sufficiently predicted in some models/initializations

V wind at 200 hPa anomaly (m/s)



Wave train development well predicted

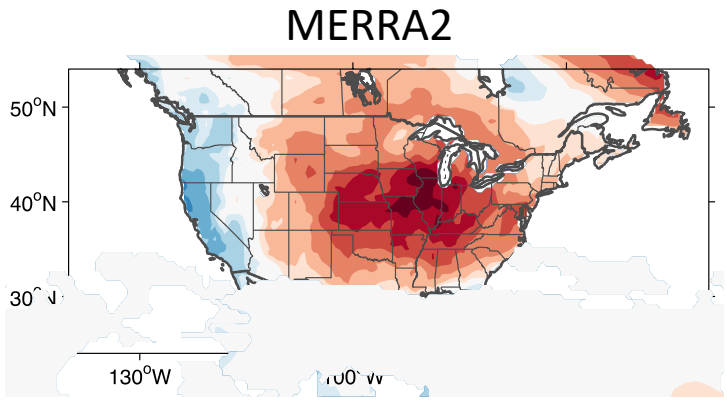
Geo. ht. at 200 hPa anomaly (dam)



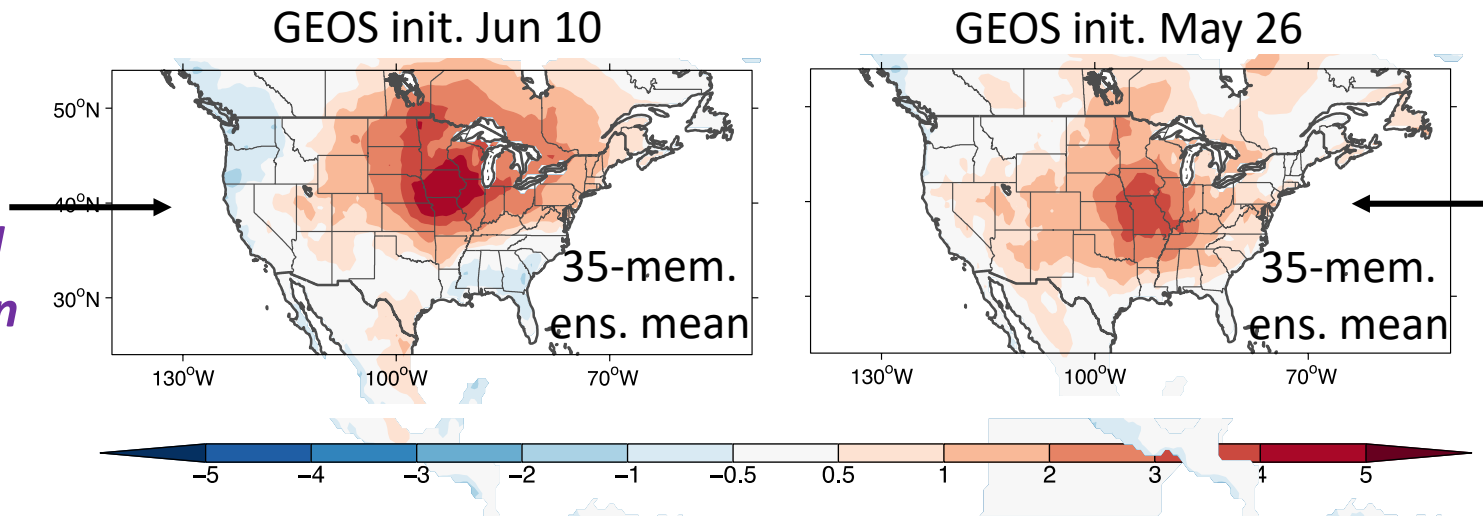
Wave train propagation and ridge over North America reasonably predicted

Recap: Sources of prediction skill for the 2012 extreme heatwave
1. Land initialization, 2. Rossby wave train

2m temp. anomaly for Jun 20 – Jul 9, 2012 (K)



prediction skill from land initialization and Rossby wave train



prediction skill from land initialization only

Conclusions

- Two key factors contribute to skillful predictions of the 2012 Great Plains flash drought in SubX models:
  1. Accurate soil moisture initialization
  2. Quasi-stationary Rossby wave train prediction
- Findings can be generalized to summer flash droughts in the central U.S.
- Results offer hope for the S2S prediction of extreme temperature anomalies associated with flash drought*, but the prediction skill of precipitation is low and needs further study.*
- Important implications:
  - Land initialization approach matters and needs revision in some SubX models.
  - Rossby wave trains can be predicted in some S2S forecast systems, but we do not fully understand why. *More research needed on their sources and predictability.*

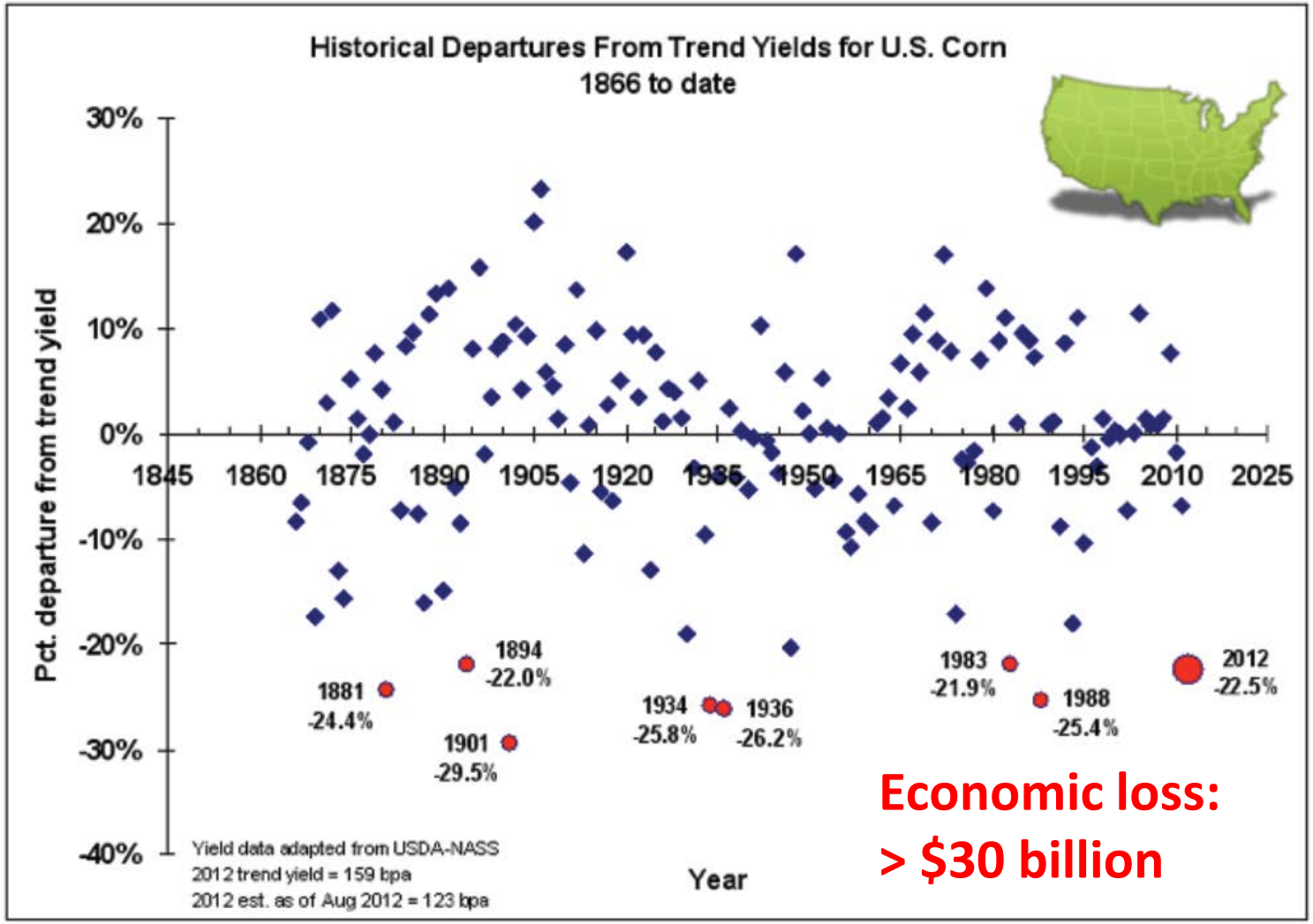

Thank You
Questions?

Extra Slides

What is a *flash drought*?

- **Drought that develops over a short period of time (weeks to a few months)**
- Drivers:
  - Substantial precipitation deficits (*Koster et al. 2019*)
  - High evaporative demand: warm temperatures, low humidity, sunny skies, strong winds (*Otkin et al. 2018*)
- Consequence: Rapid decline in soil moisture

The 2012 Central U.S. Flash Drought Impacts



(source: Hoerling et al. 2013, Assessment Report)

SubX models

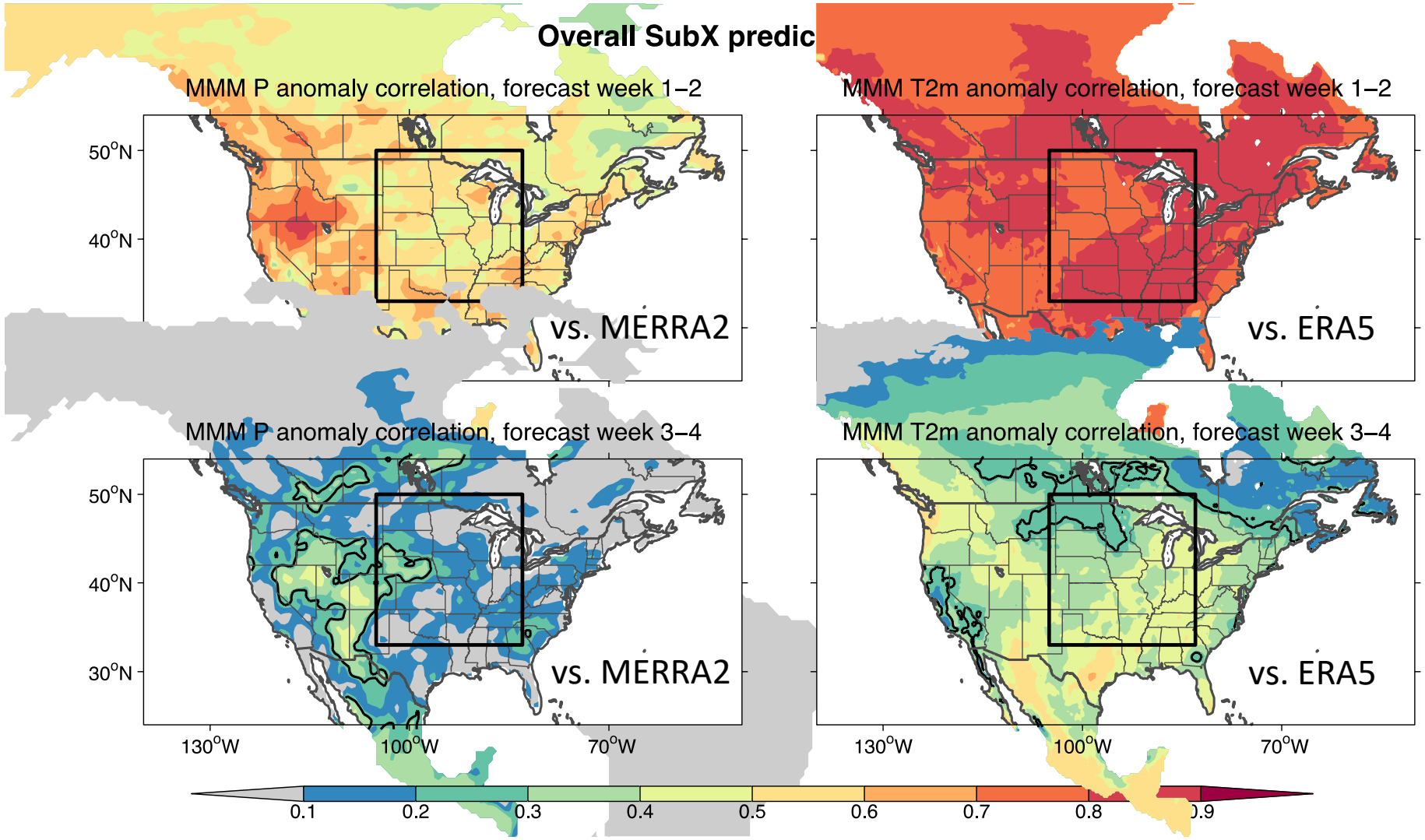
Model	Institution(s)	# Members	Forecast Length	Hindcast Initializations
CESM-46LCESM1	NCAR, NOAA/ESRL	10	45 days	Every Wednesday 1999-2015
ECCC-GEM*+	ECCC, Canada	4	32 days	Every 7 days 1995-2014
EMC-GEFS*+	NCEP/EMC	11	35 days	Every Wednesday 1999-2016
ESRL-FIM	NOAA/ESRL	4	32 days	Every Wednesday 1999-2017
GMAO-GEOS	NASA/GMAO	4	45 days	Every 5 days 1999-2016
NCEP-CFSv2*	NCEP	1	44 days	Every 6 hours 1999-2017
NAVY-ESPC	Naval Research Lab	1	45 days	4 days/week 1999-2016
RSMAS-CCSM4	NCAR, U. Miami	3	45 days	Every 7 days 1999-2016

* Operational models

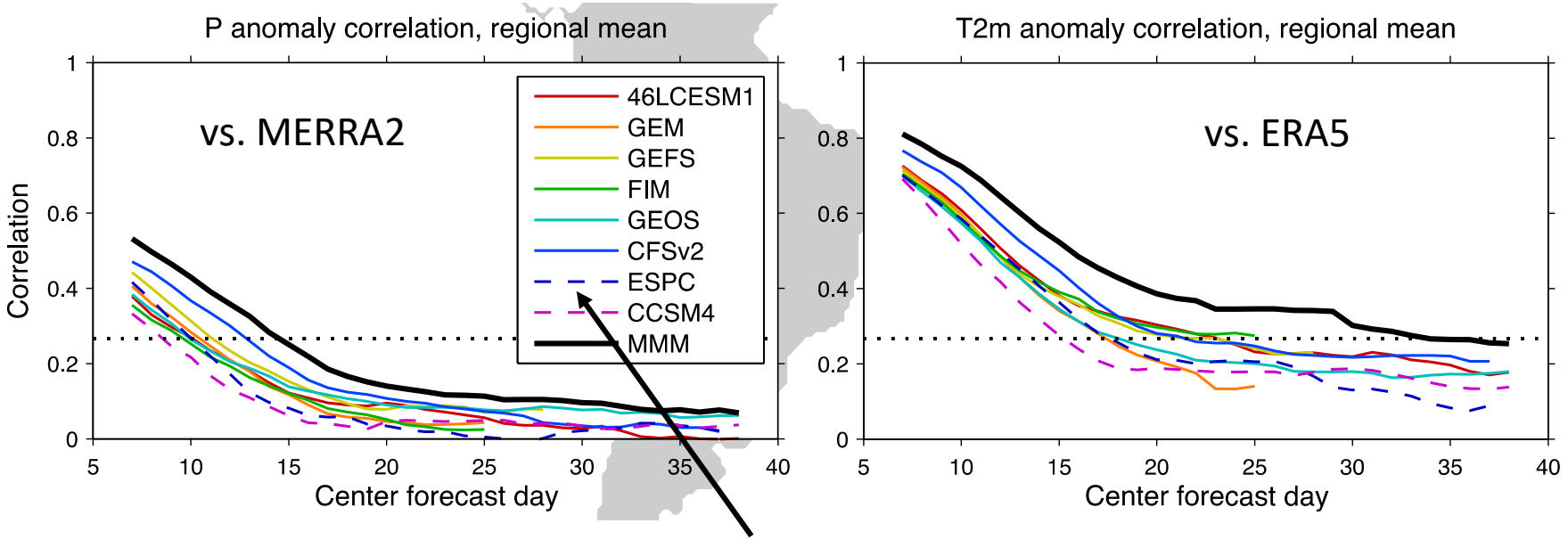
+ Uncoupled models

GEOS model details

- AGCM: Post-MERRA2 generation, 0.5 degree, 72 hybrid sigma/pressure levels
- Catchment land model
- OGCM: MOM5, 0.5 degree, 40 levels
- Sea Ice: CICE-4.0
- Initialization of hindcasts:
  - Atmosphere and land: MERRA2 at 21Z previous day
  - Ocean: Ocean Data Assimilation System (ODAS) output

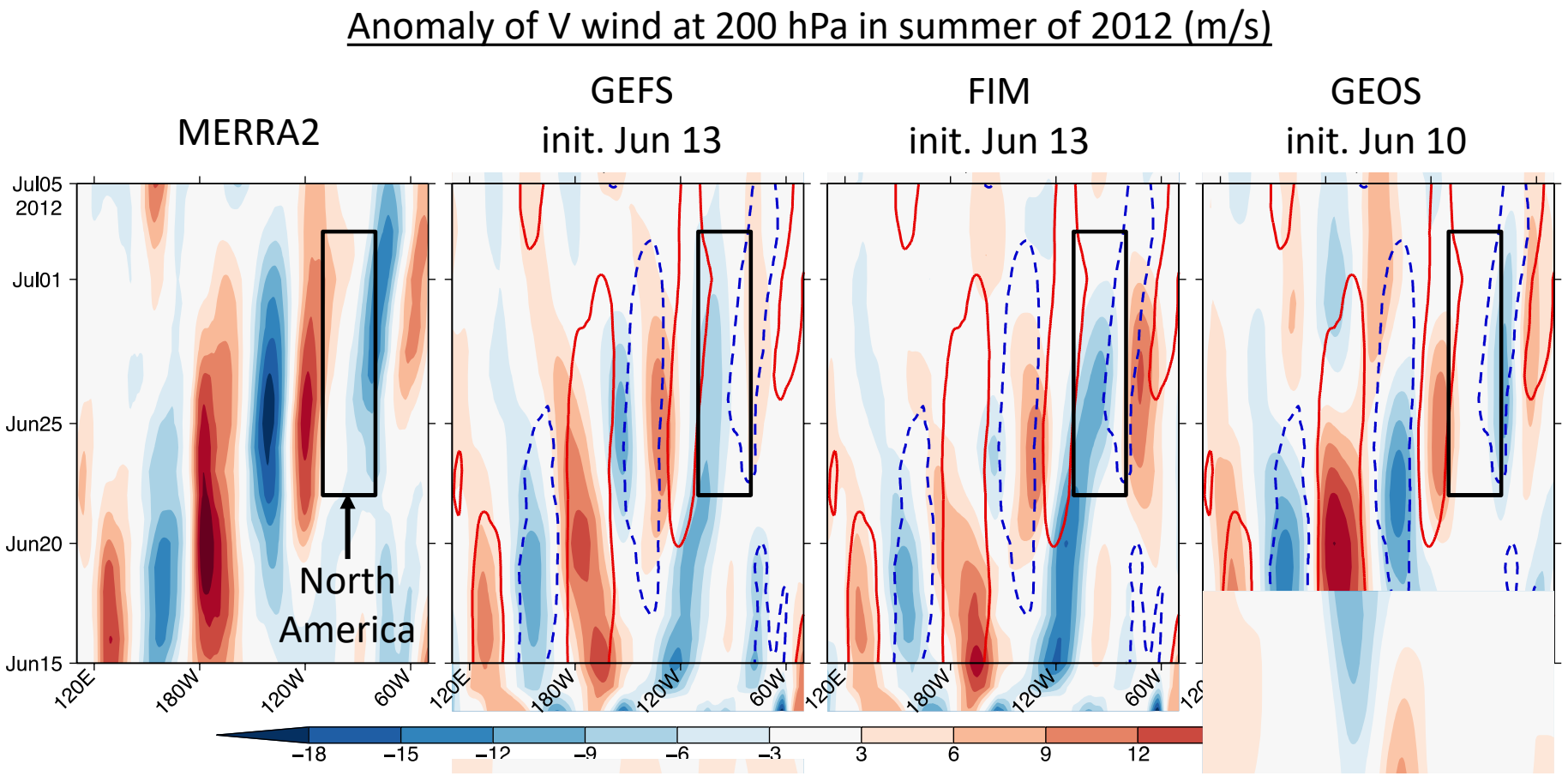


(temporal anomaly correlations for 1999-2015)



Models that use different land models to obtain initialization soil moisture and to produce forecasts

Prediction of quasi-stationary Rossby wave in SubX



Initial development well simulated, but propagation to NA too slow in some models

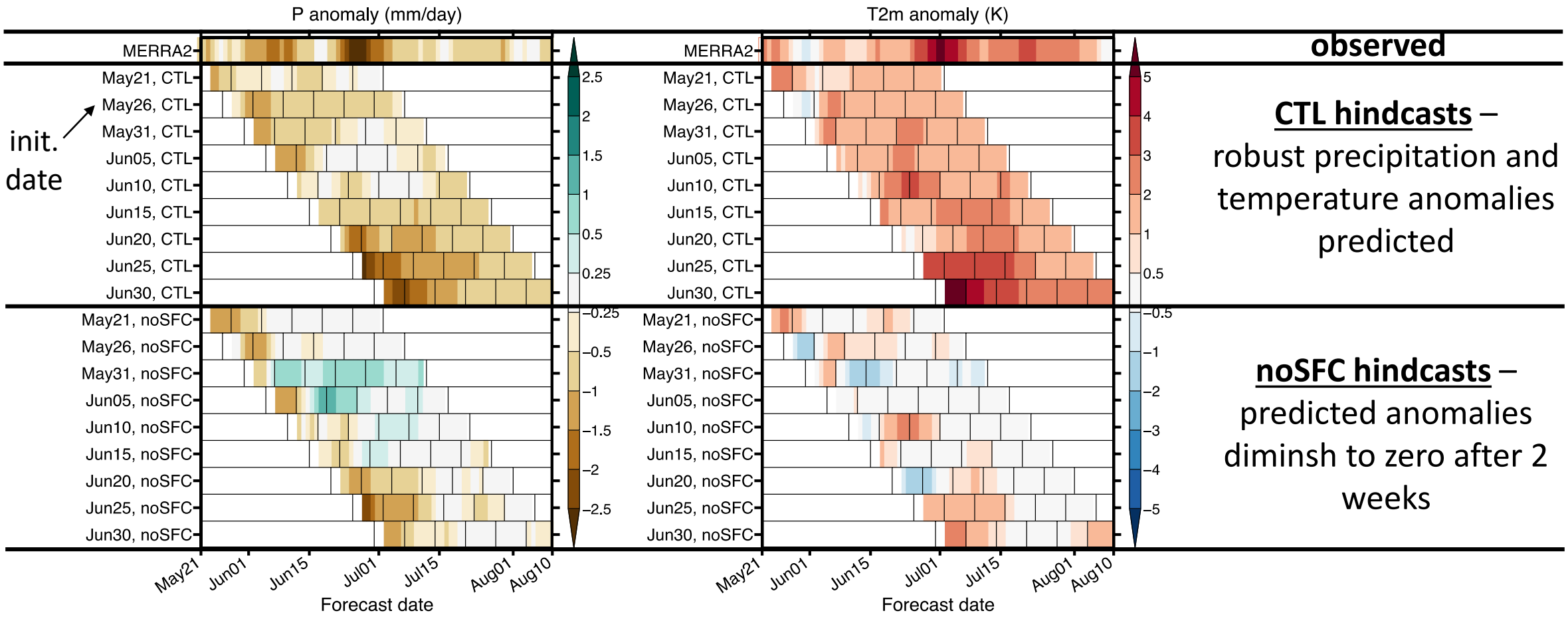
Additional support from GEOS

- We perform **additional hindcasts with the NASA GEOS model** for the summer of 2012 to supplement the analysis.
- **Two experiments**:
  - **CTL** – 35 members with full land-atmosphere-ocean initialization (i.e., SubX+31 members)
  - **noSFC** – 35 runs where the land is initialized from a different year in each run
- **Important results:**
  1. Confirm that land initialization is important for skillful prediction of the 2012 drought. **In the noSFC runs, forecasted anomalies are near-zero.**
  2. Rossby wave train development *(and propagation)* is reasonably predicted in both experiments when GEOS is initialized after June 8, 2012.

Q: How important is land initialization for forecast skill?

A: Very important. GEOS runs support results from SubX ensemble.

Central U.S. regional mean, 7-day running mean

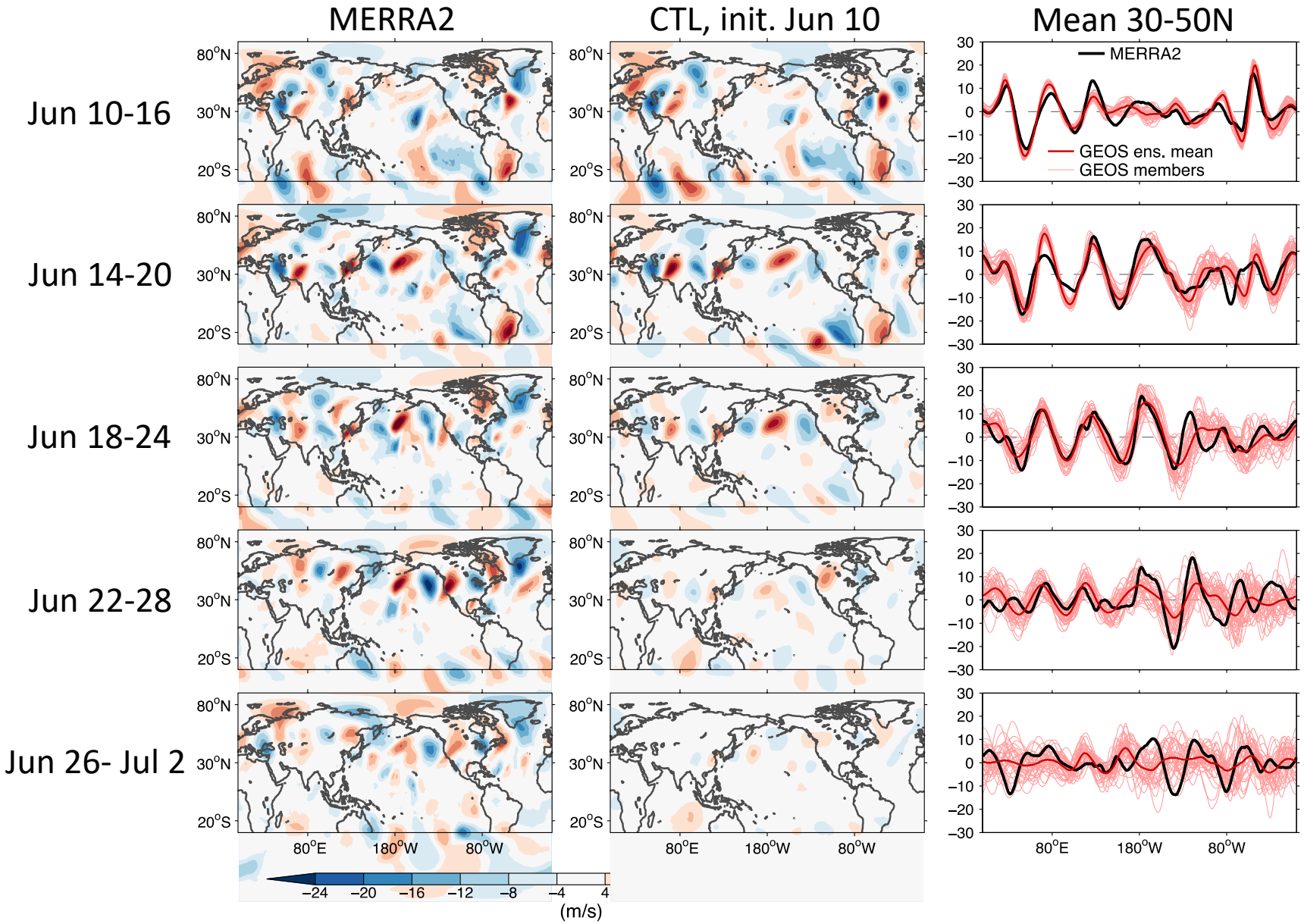


observed

<u>CTL hindcasts</u> – robust precipitation and temperature anomalies predicted

<u>noSFC hindcasts</u> – predicted anomalies diminsh to zero after 2 weeks

Temporal evolution of V wind at 200 hPa



35-member
GEOS ensemble