GLACE-2

The 2nd phase of the Global Land-Atmosphere Coupling Experiment

Randal Koster (NASA/GSFC/GMAO), with help from Sarith Mahanama, Tomohito Yamada, and the *entire GLACE-2 team* (see later slide)

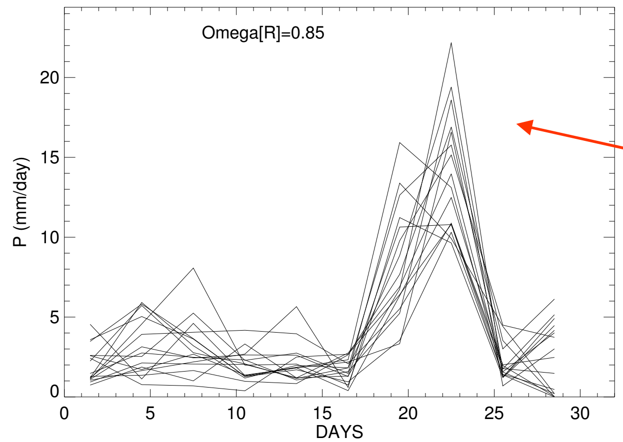
For soil moisture initialization to add to subseasonal or seasonal forecast skill, two criteria must be satisfied:

1. An initialized anomaly must be "remembered" into the forecast period, and

2. The atmosphere must be able to respond to the remembered anomaly.

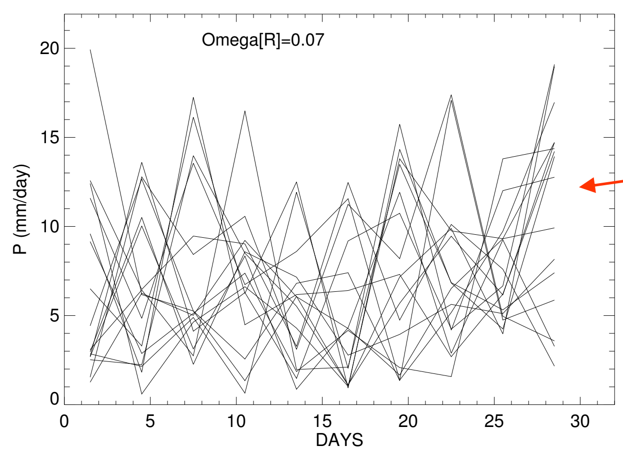
Addressed by GLACE-1

GLACE-1: Ensembles of AGCM simulations are performed, each with the same imposed soil moisture boundary condition.



All simulations in ensemble respond to the imposed land surface boundary condition in the same way

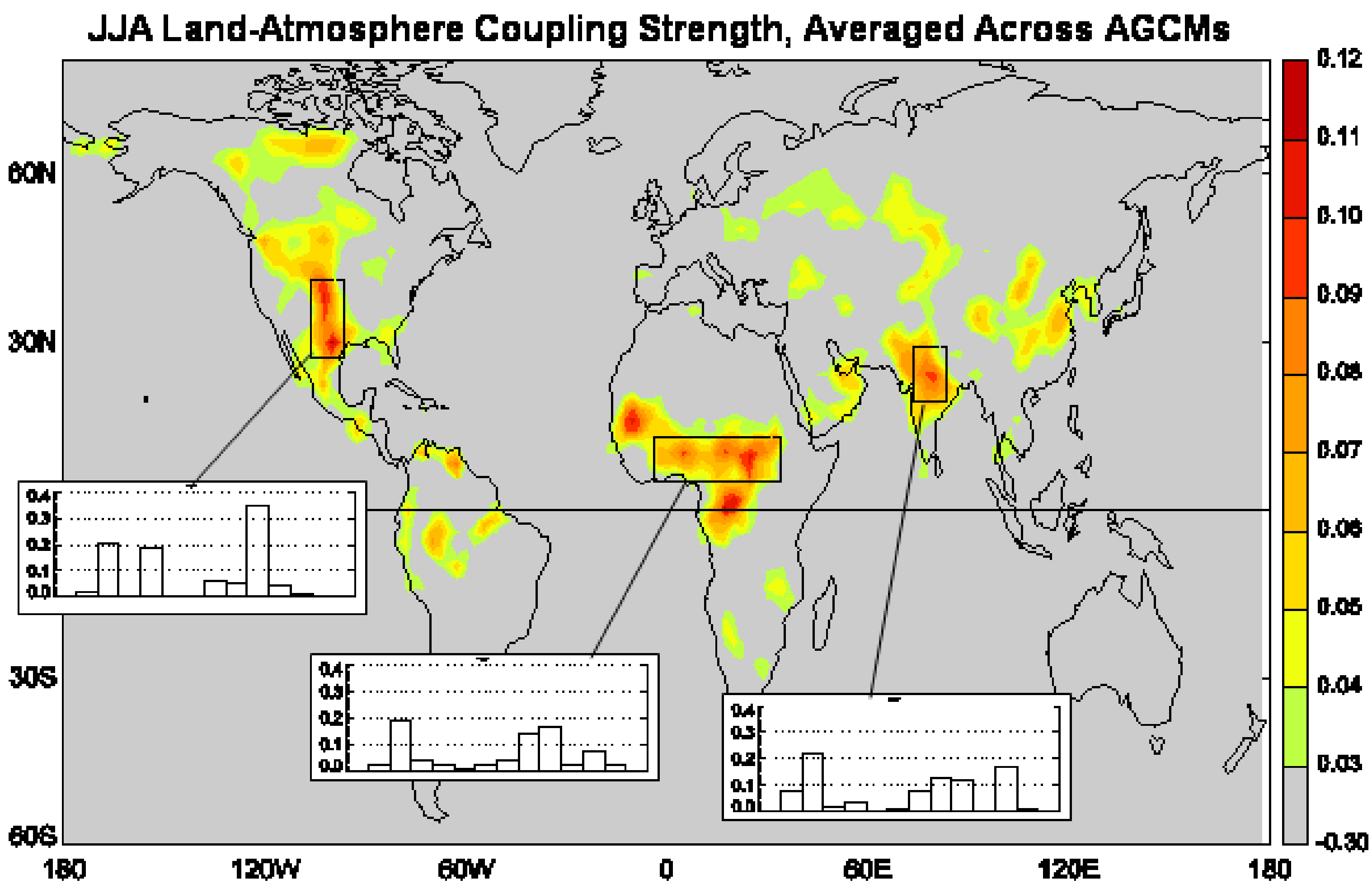
→ Ω is high



Simulations in ensemble have no coherent response to the imposed land surface boundary condition

→ Ω is low

GLACE-1 multi-model coupling strength for precipitation:



For soil moisture initialization to add to subseasonal or seasonal forecast skill, two criteria must be satisfied:

1. An initialized anomaly must be "remembered" into the forecast period, and

2. The atmosphere must be able to respond to the remembered anomaly.

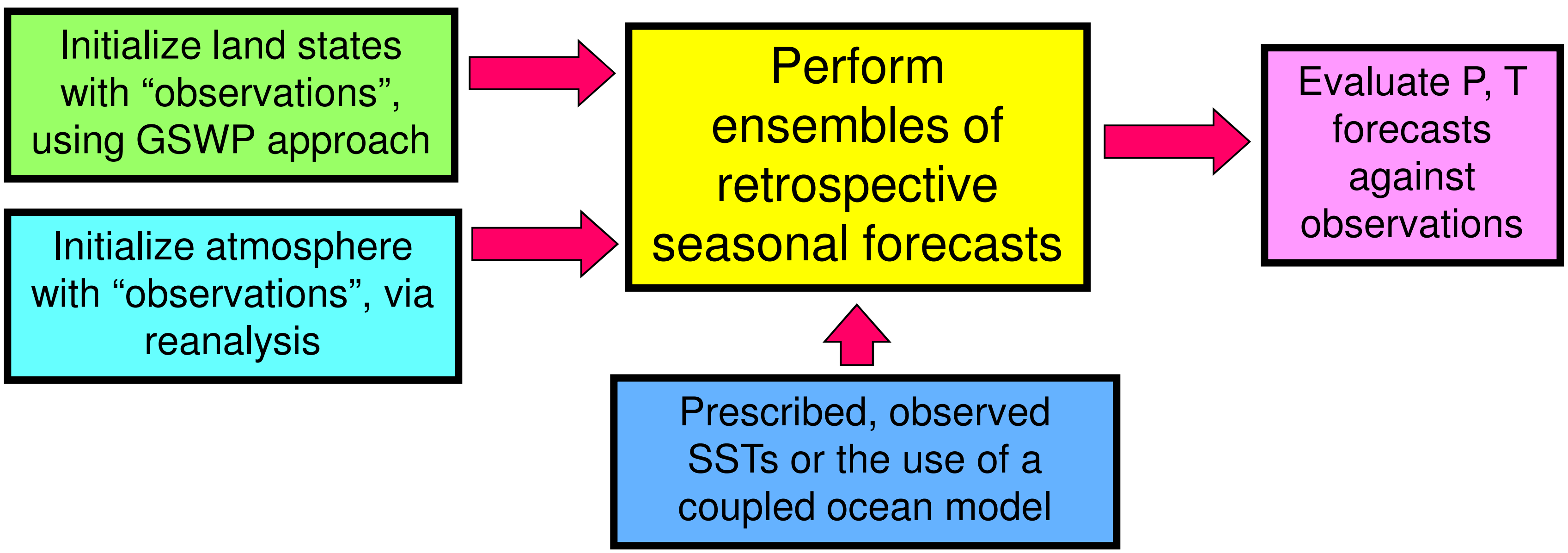
Addressed by GLACE-1

Addressed by GLACE-2, *along with true forecast skill evaluations*

Overall goal of GLACE-2: Determine the degree to which realistic land surface (soil moisture) initialization contributes to forecast skill (rainfall, temperature) at 1-2 month leads, using a wide array of state-of-the-art forecast systems.

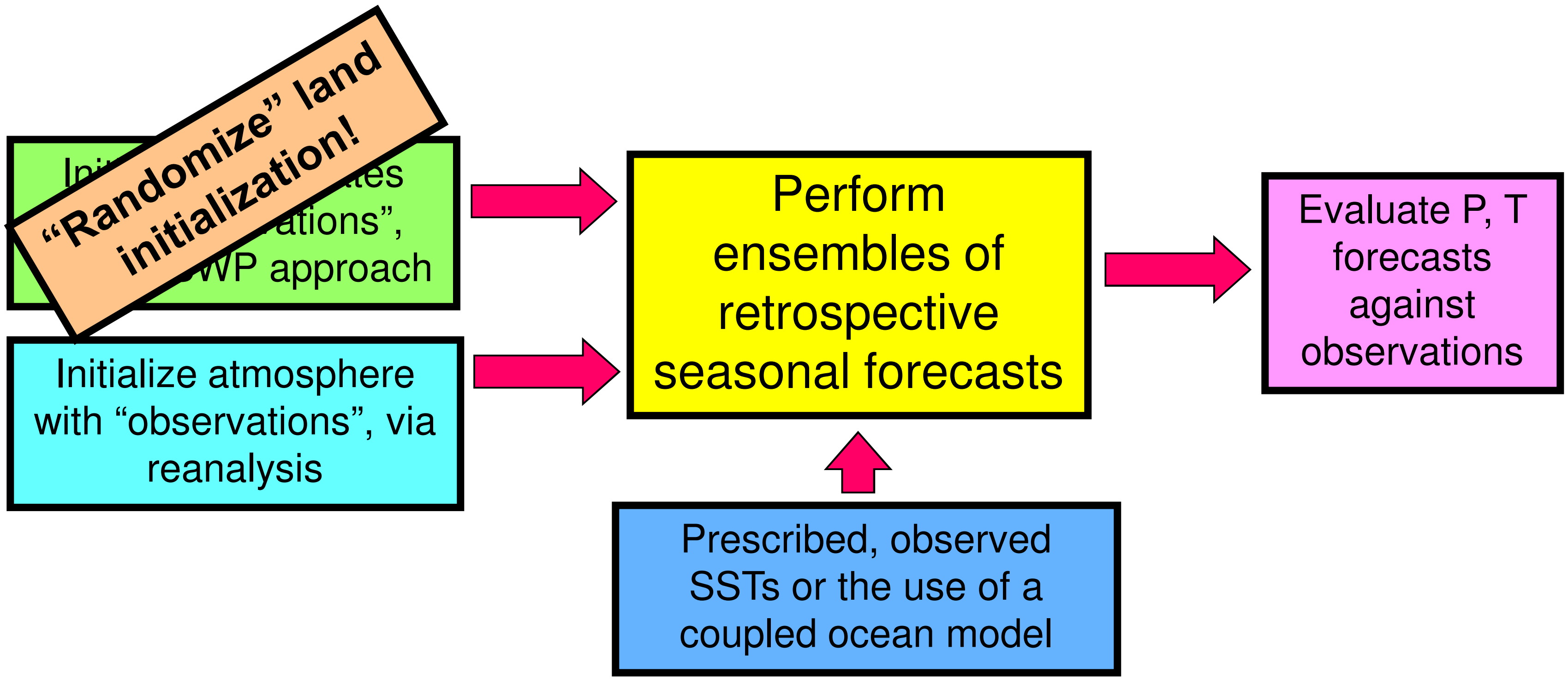
GLACE-2:
Experiment Overview

<u>Series 1:</u>



GLACE-2:
Experiment Overview

Series 2:

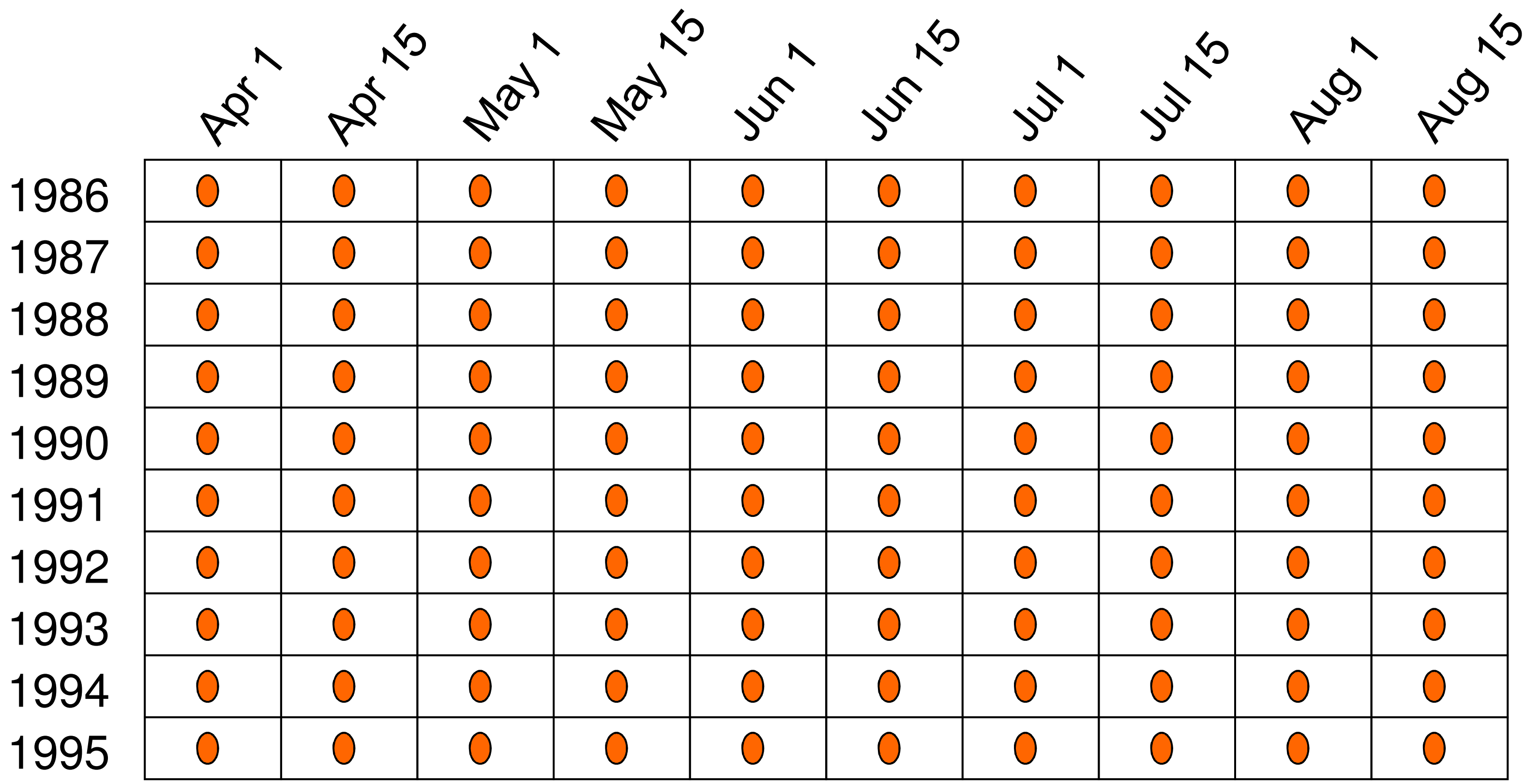


GLACE-2:
Experiment Overview

<u>Step 3:</u> Compare skill in two sets of forecasts; isolate contribution of realistic land initialization.

Forecast skill, Series 1 − Forecast skill, Series 2 = Forecast skill due to land initialization

Baseline: 100 Forecast Start Dates



Each ensemble consists of 10 simulations, each running for 2 months.

➡ 1000 2-month simulations.

Progress to date…

Participant List

Group/Model	# models	Points of Contact
1. NASA/GSFC (USA): GMAO seasonal forecast system (old and new)	2	R. Koster, S. Mahanama
2. COLA (USA): COLA GCM, NCAR/CAM GCM	2	P. Dirmeyer, Z. Guo
3. Princeton (USA): NCEP GCM	1	E. Wood, L. Luo
4. IACS (Switzerland): ECHAM GCM	1	S. Seneviratne, E. Davin
5. KNMI (Netherlands): ECMWF	1	B. van den Hurk
6. ECMWF	1	G. Balsamo, F. Doblas-Reyes
7. GFDL (USA): GFDL system	1	T. Gordon
8. U. Gothenburg (Sweden): NCAR	1	J.-H. Jeong
9. CCSR/NIES/FRCGC (Japan): CCSR GCM	1	T. Yamada
10. FSU/COAPS	1	M. Boisserie
11. CCCma (?)	1	B. Merryfield
	13 models	

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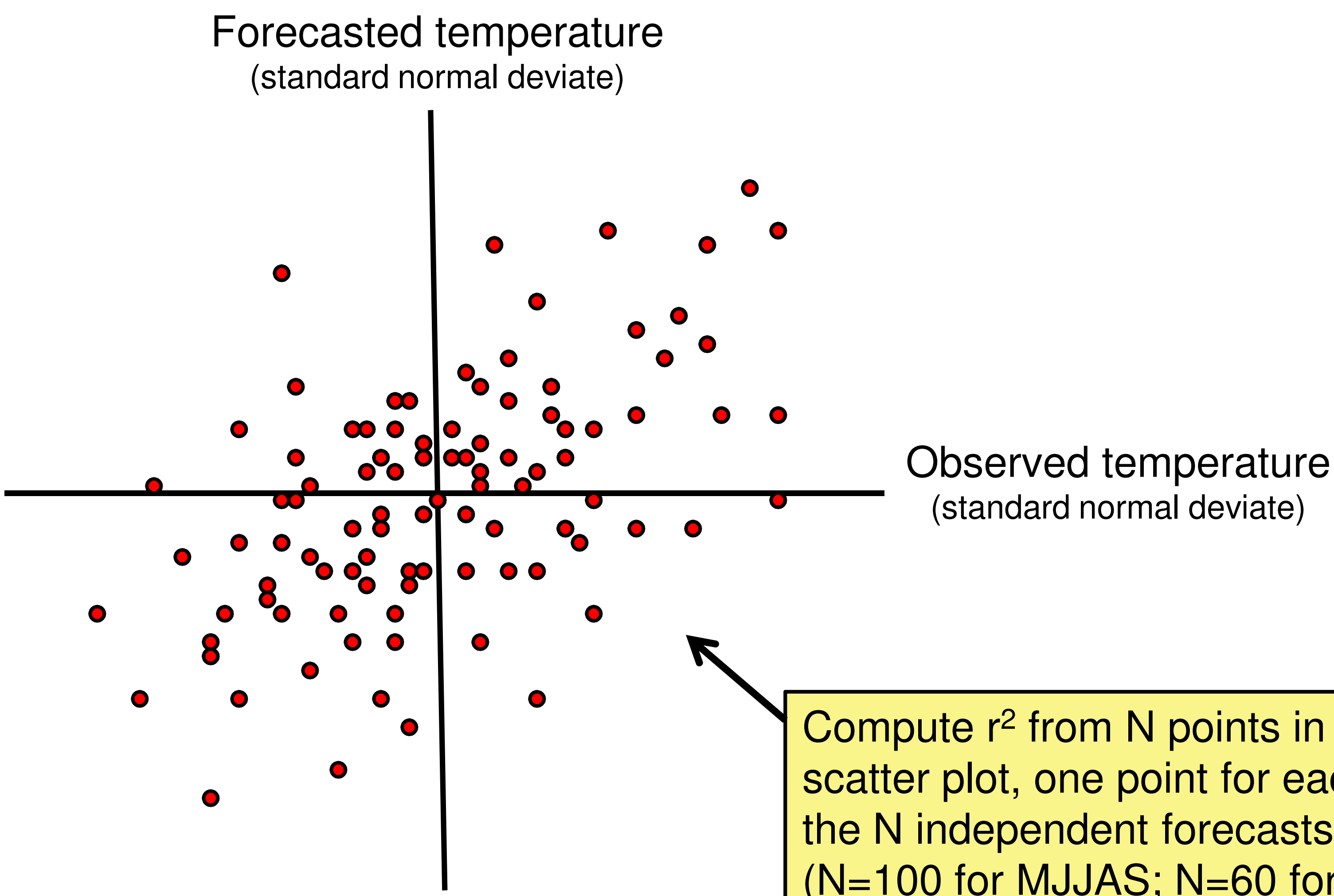
Green: Finished baseline forecasts

Orange: Finished half of baseline forecasts

Skill measure: r^2 when regressed against observations



Compute r^2 from N points in scatter plot, one point for each of the N independent forecasts. (N=100 for MJJAS; N=60 for JJA)

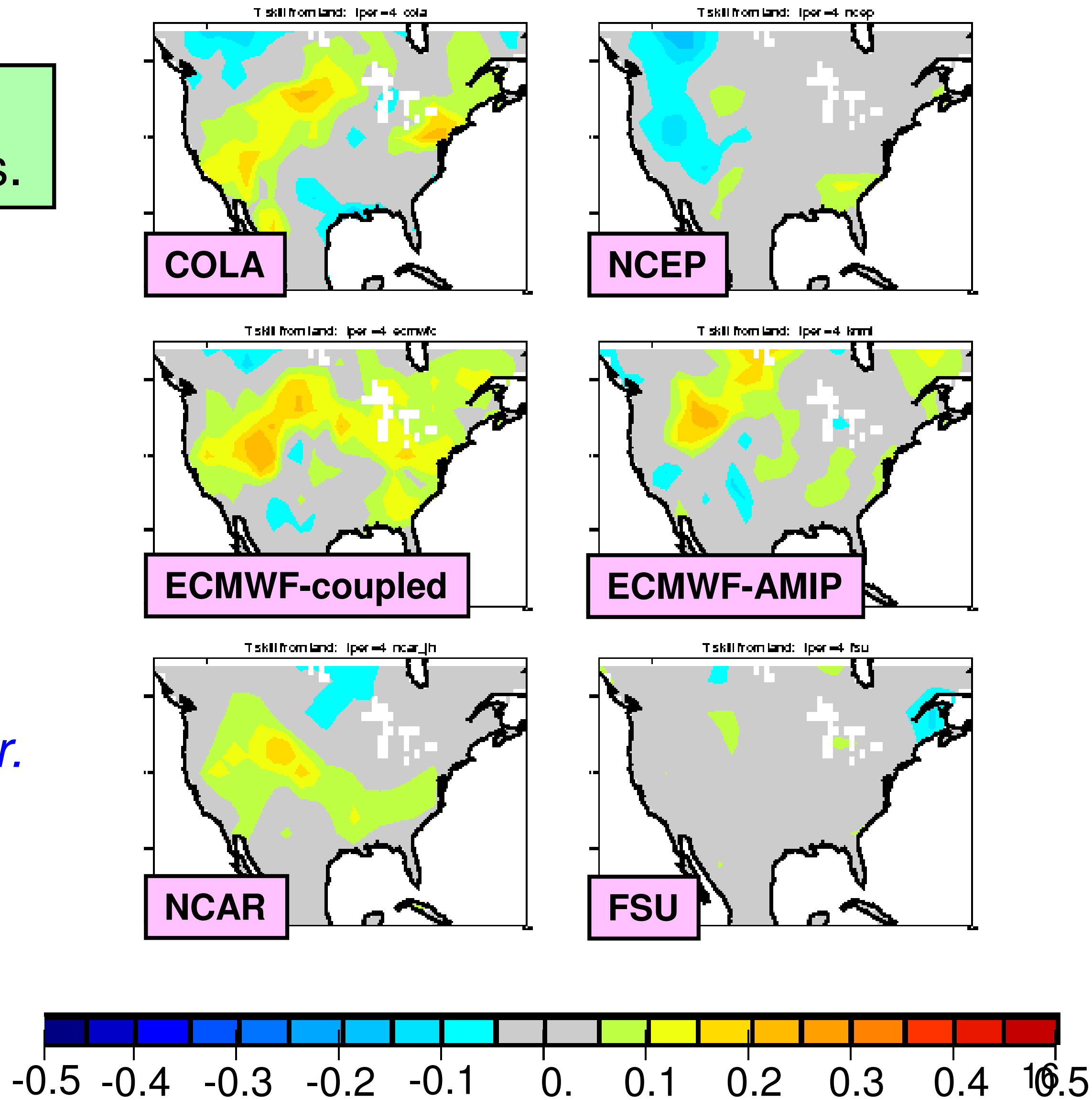
- Results shown on next slides are preliminary, though (at this point) robust. They will be expanded/modified as the final GLACE-2 submissions come in.
- We focus here on JJA, the period when N.H. evaporation is strongest.
- We focus here on the U.S., for which:
  -- models show strong inherent predictability associated with land initialization (GLACE-1!)
  -- observations are reliable over the forecast period

Sample results: Impact of land initialization on r^2 skill score for different models   (r^2 from Series 1 minus r^2 from Series 2).

Predicted variable: Air temperature at 16-30 days.

Models appear to differ in their ability to extract skill from land initialization.

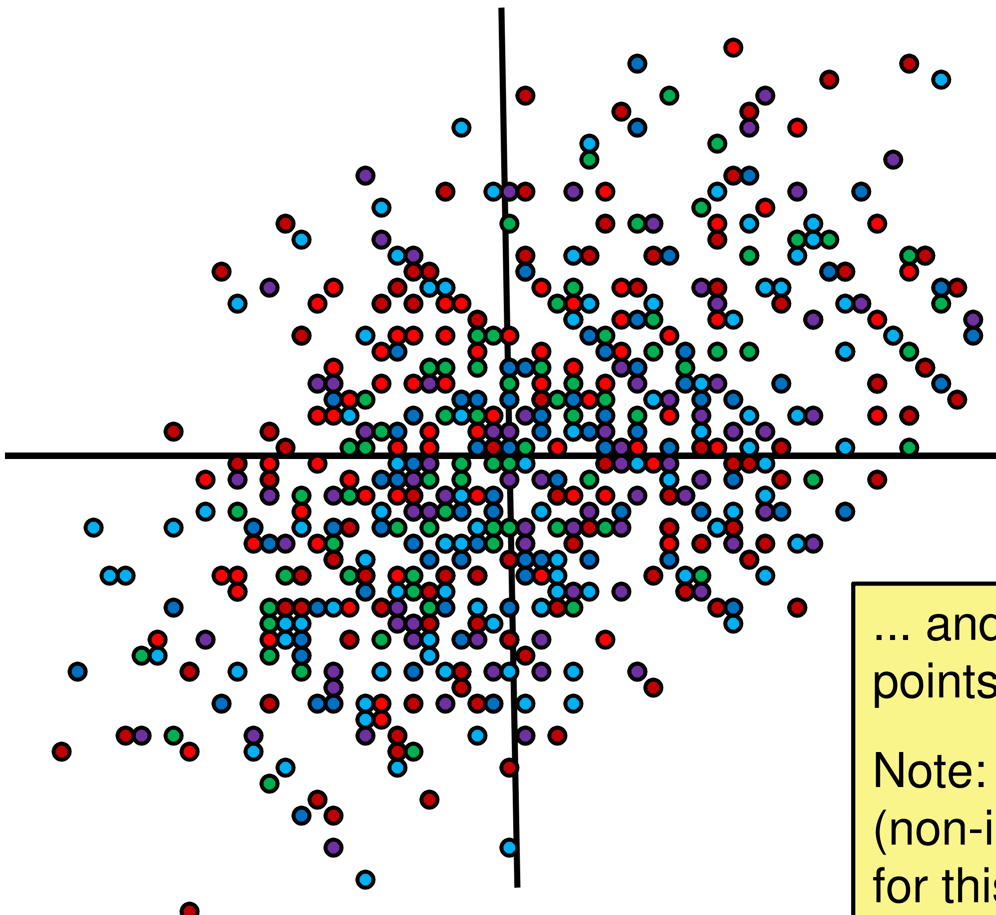
Results for precipitation forecasts are much weaker.



Multi-model “consensus” measure of skill: a prerequisite to a conditional skill analysis

Forecasted temperature
(standard normal deviate)

Plot results for all M models on the same scatterplot...



Observed temperature
(standard normal deviate)

... and then compute r^2 from 6MN points, N from each model.

Note: models may behave similarly (non-independently); must account for this in significance testing.

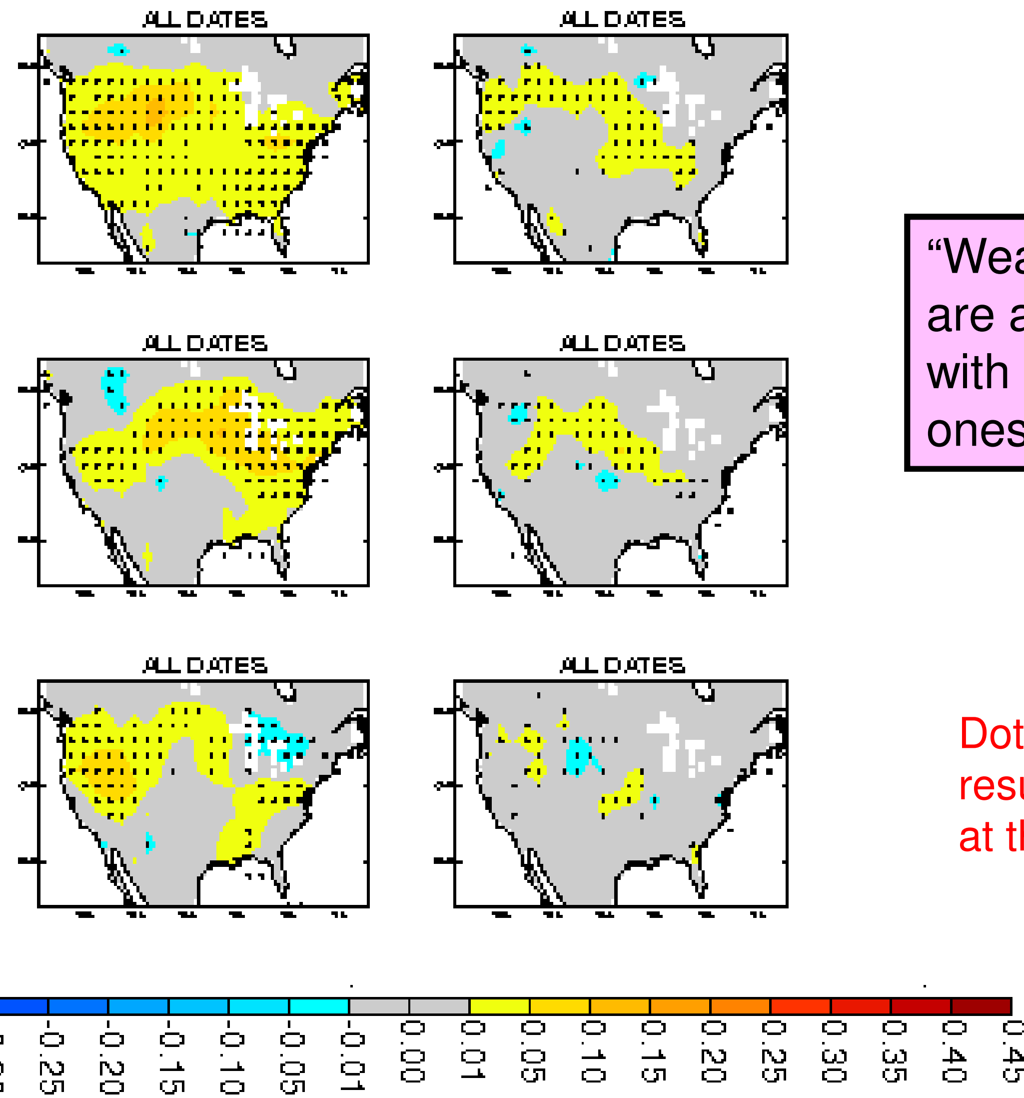
Forecasts: "Consensus" skill due to land initialization (JJA)

temperature precipitation

16-30 days

31-45 days

46-60 days

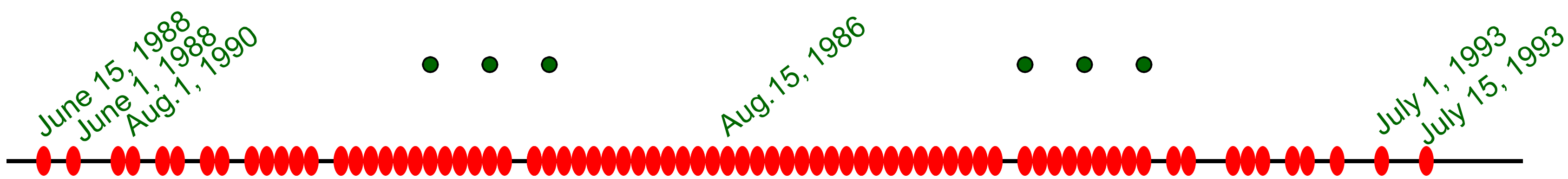


"Weaker" models are averaged in with "stronger" ones.

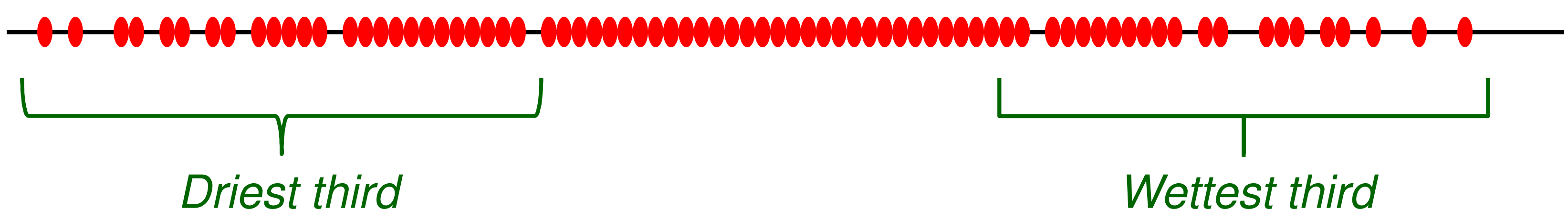
Dots show results significant at the 95% level

<u>Conditional skill:</u> Suppose we know at the start of a forecast that the initial soil moisture anomaly, W_i, is relatively large...

Step 1: At each grid cell, rank the forecast periods from lowest initial soil moisture to highest initial soil moisture:

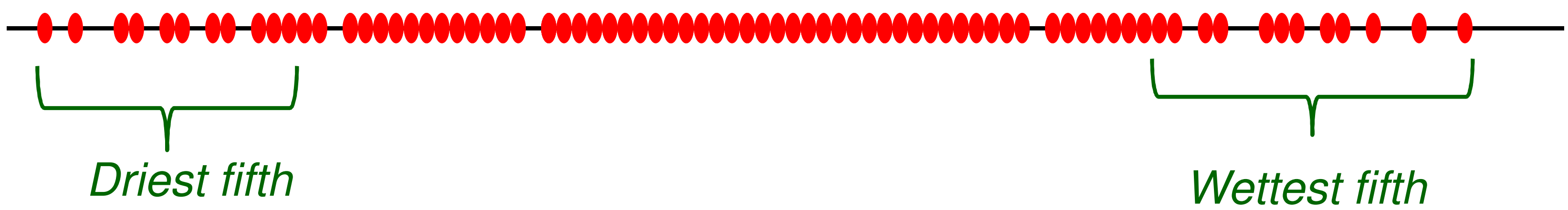


Step 2: Separate into terciles:

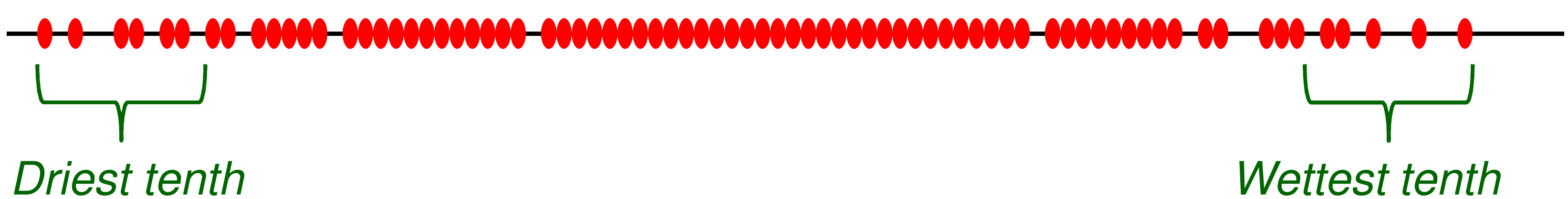


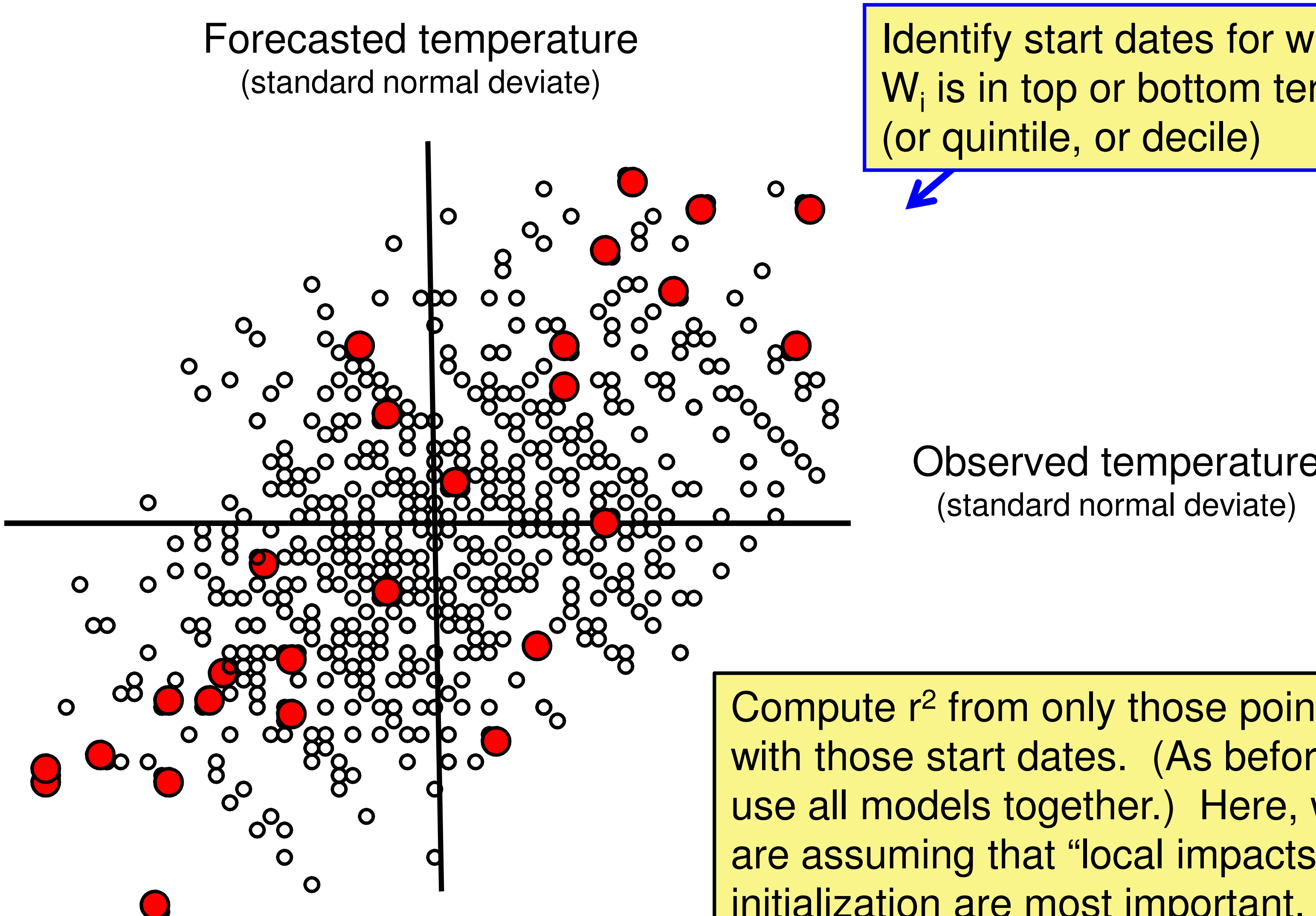
<u>Conditional skill:</u> Suppose we know at the start of a forecast that the initial soil moisture anomaly, W_i, is relatively large...

Step 2: Separate into quintiles:



Step 3: Separate into deciles:

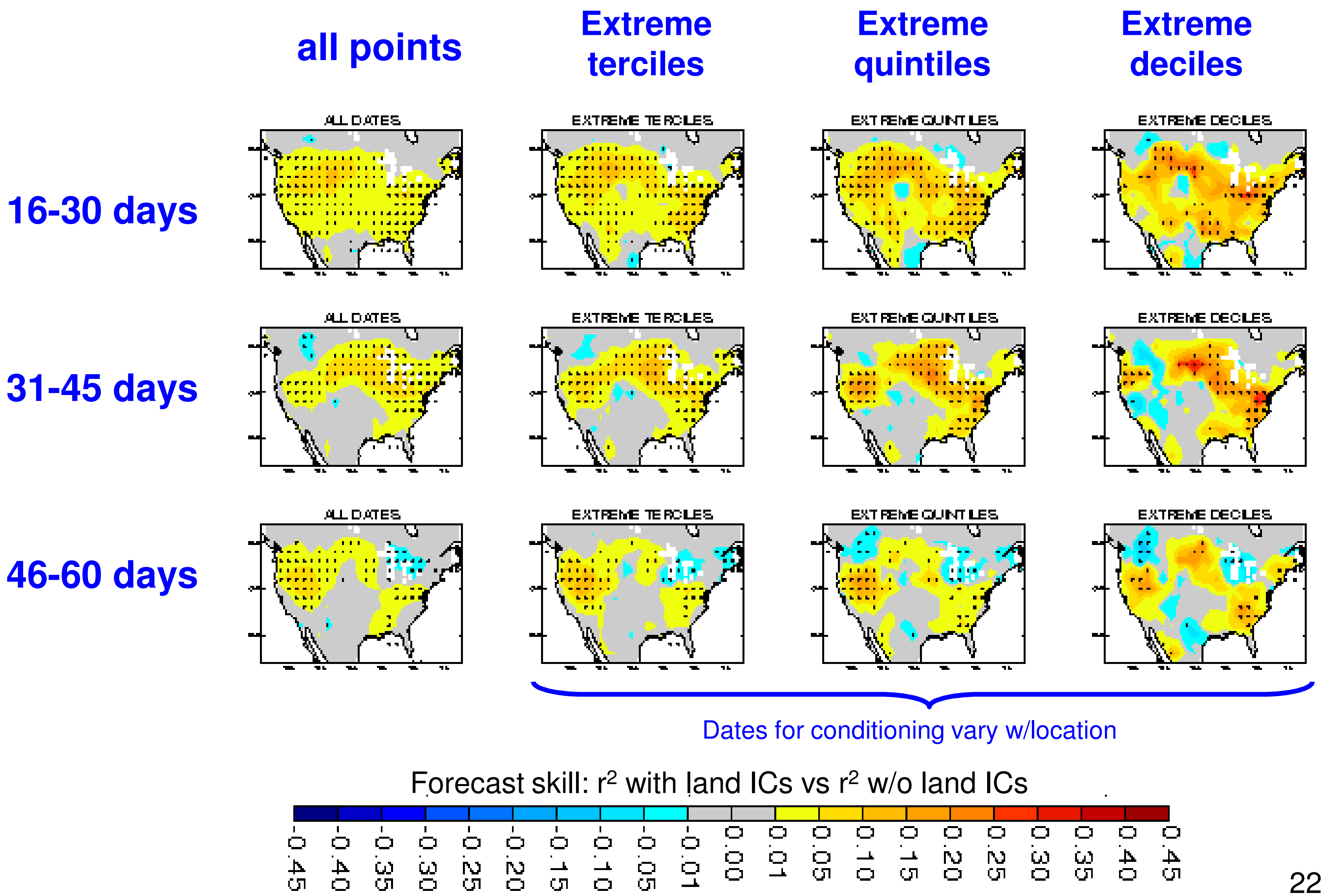




Identify start dates for which W_i is in top or bottom tercile (or quintile, or decile)

Compute r^2 from only those points with those start dates. (As before, use all models together.) Here, we are assuming that “local impacts” of initialization are most important.

Temperature forecasts: Increase in skill due to land initialization (JJA)
(conditioned on strength of local initial soil moisture anomaly)



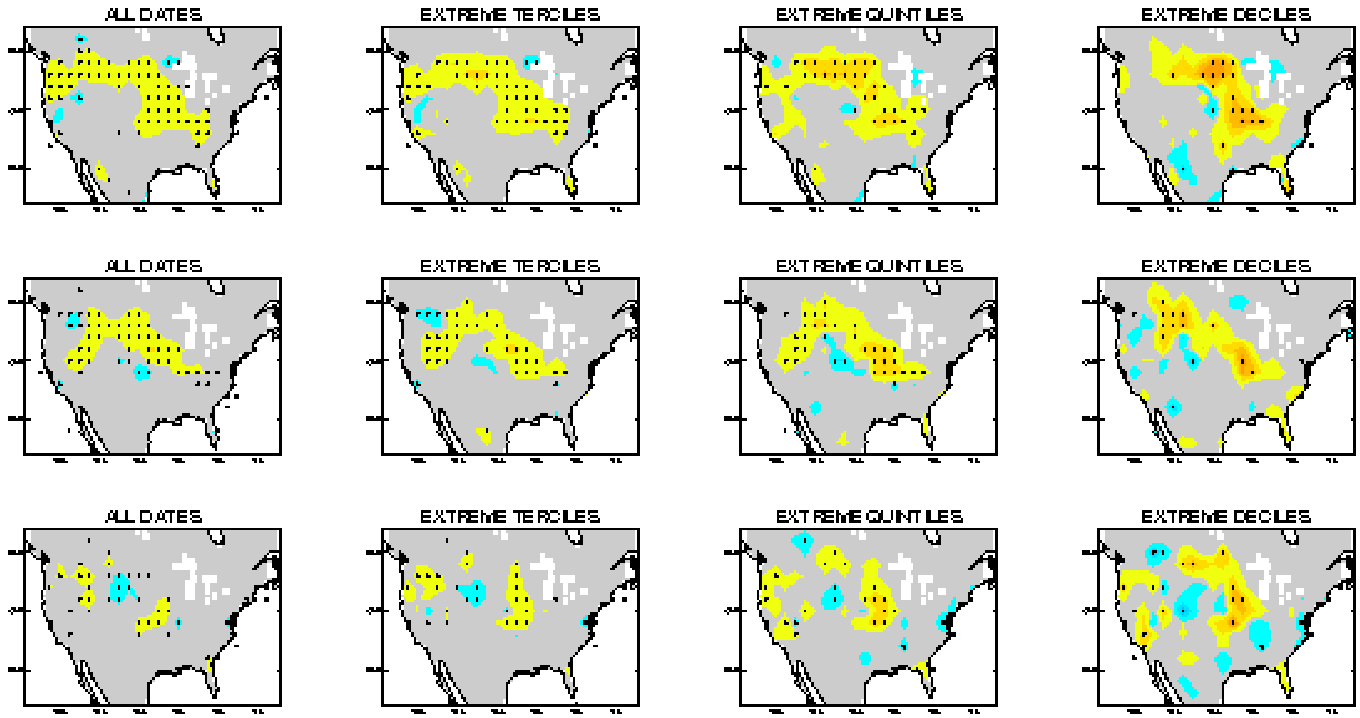
Precipitation forecasts: Increase in skill due to land initialization (JJA)
(conditioned on strength of local initial soil moisture anomaly)

all points | Extreme terciles | Extreme quintiles | Extreme deciles

16-30 days

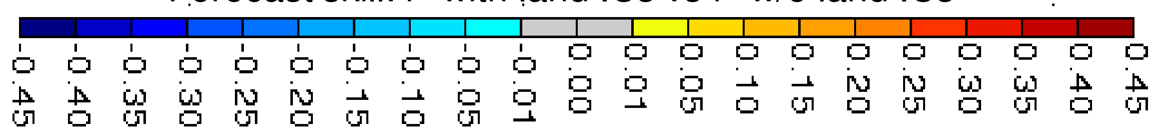
31-45 days

46-60 days



Dates for conditioning vary w/location

Forecast skill: r^2 with land ICs vs r^2 w/o land ICs

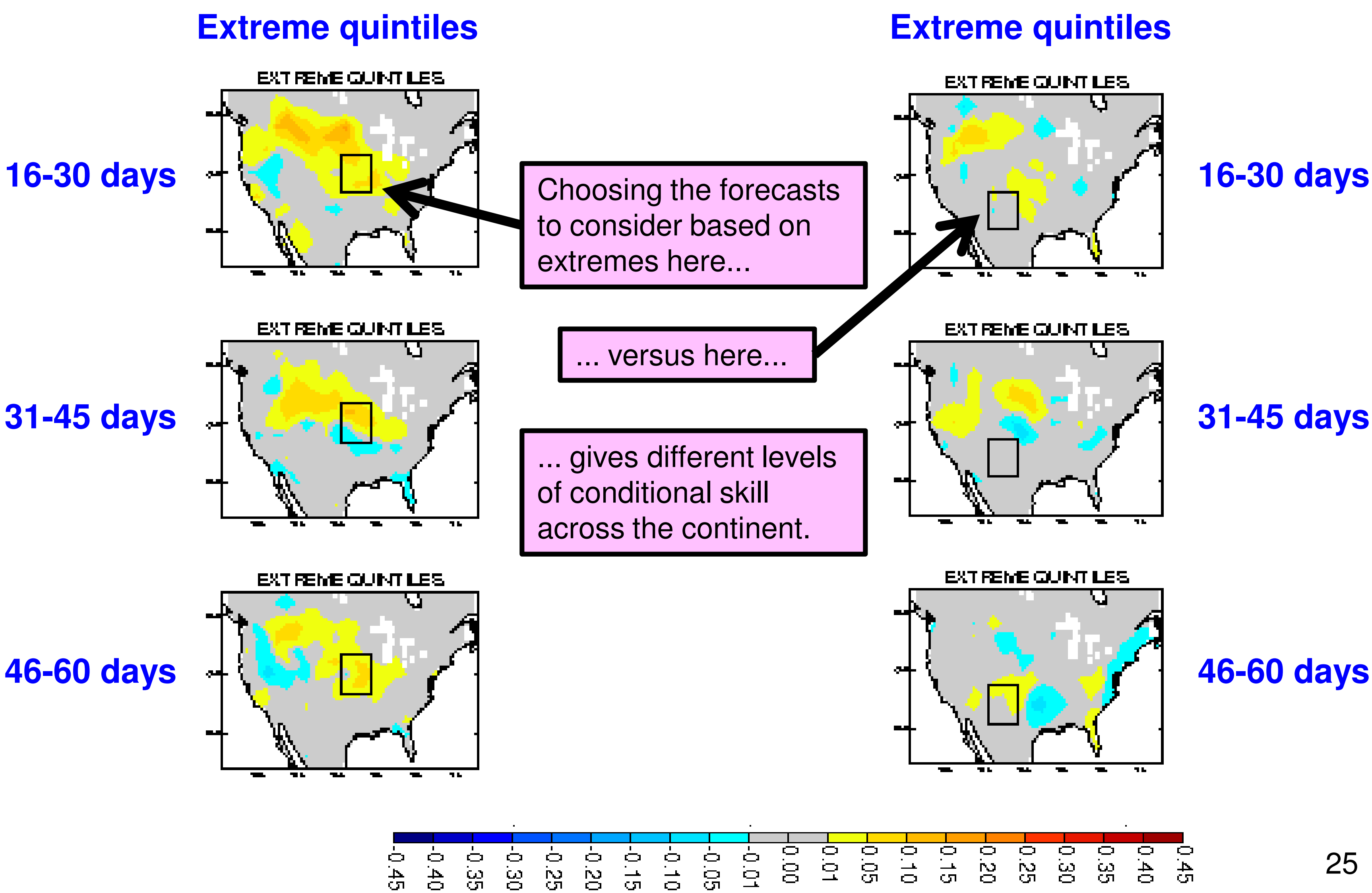


What happens if we relax the “local assumption”?

What if we *instead* condition the forecasts across the U.S. on the initial conditions in a specific region?

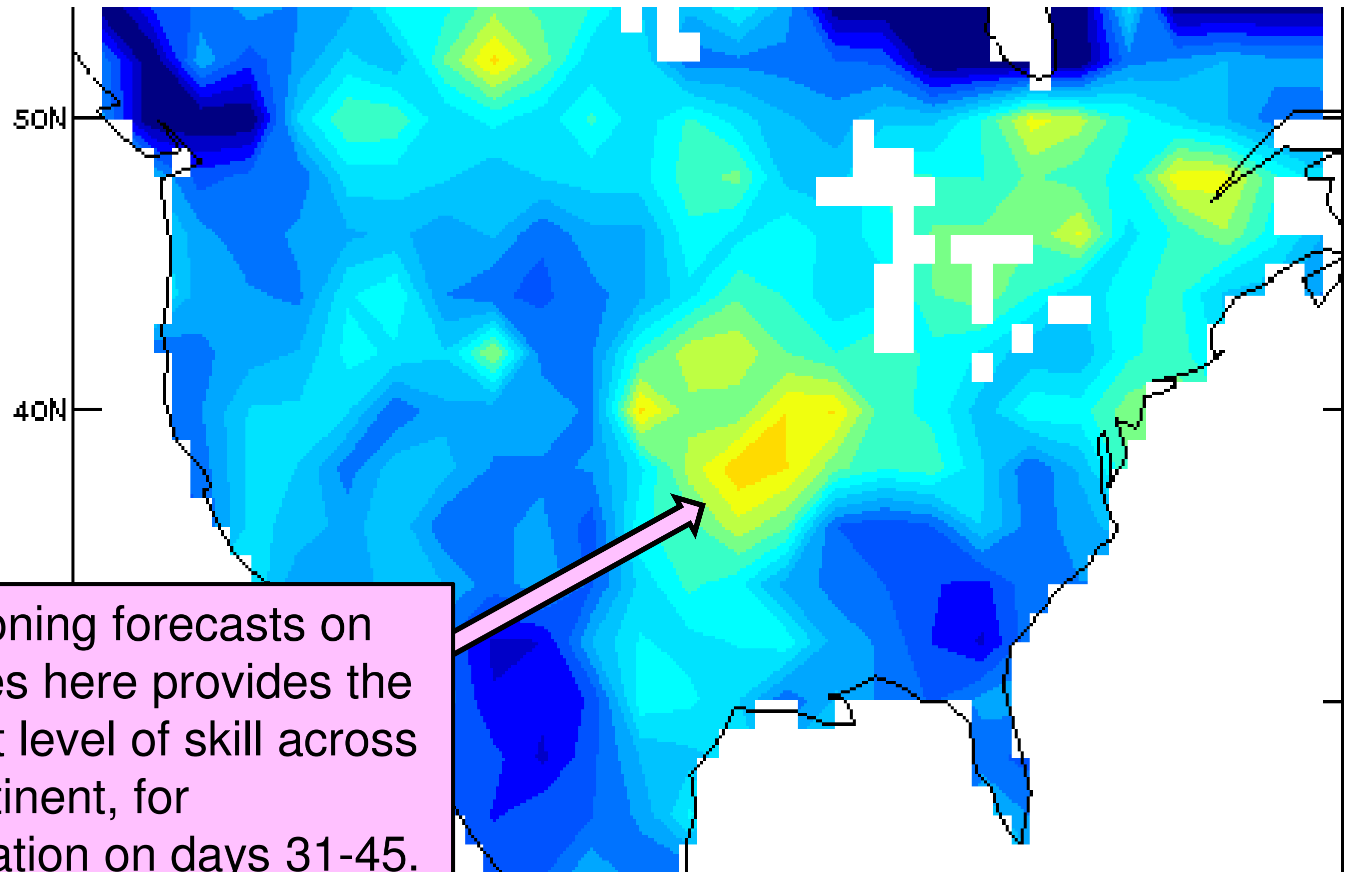
Precipitation forecasts: Increase in skill due to land initialization (JJA)

(conditioned on strength of initial soil moisture anomaly in indicated region)



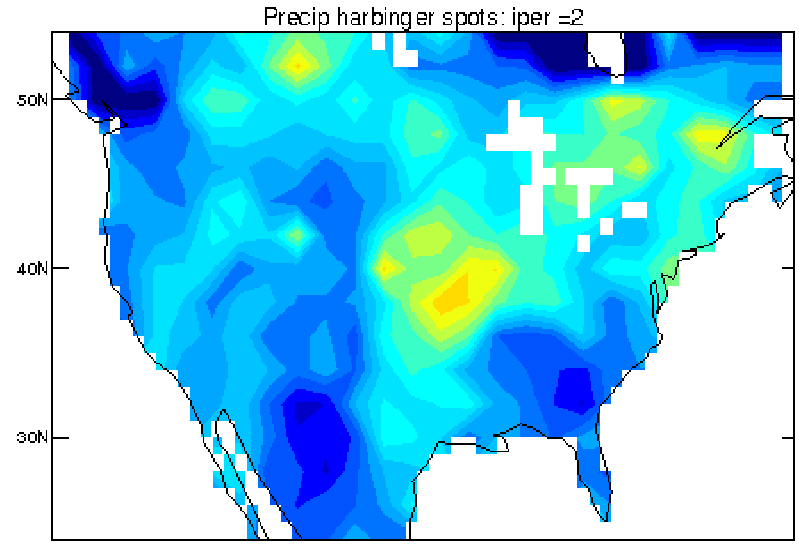
For each grid cell in the U.S., we determine the driest and wettest initial condition quintiles and then use those forecast start dates to compute skill across the U.S. A given grid cell is then associated with a continental-scale integrated skill value. We plot these integrated values here.

➔ *Diagnostically-determined indication of where the conditioning has the largest local + remote impact.*

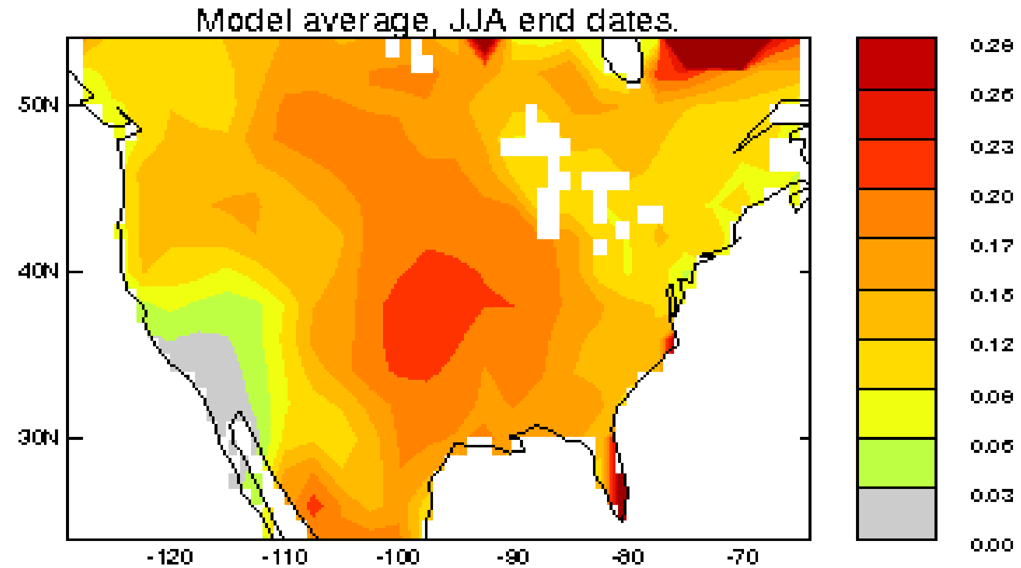


Conditioning forecasts on extremes here provides the greatest level of skill across the continent, for precipitation on days 31-45.

Same map: diagnostically-determined index of the impact of extreme ICs at each location on continental-scale skill.



Standard deviation of JJA evaporative fraction (E/R_{net}), from participating models.



Other ongoing/planned GLACE-2 analyses:

- Global scale focus, including ROC scores over Europe
- Extended time frame for forecasts:
  - -- Decadal variability of skill
  - -- European heat wave
- Analysis of potential asymmetry: are dry cases easier to predict?
- Local versus remote impacts
- Inherent model *predictability* associated with land ICs
- Impacts of water holding capacity on predictability & skill
- Decay of predictability and skill with lead time
- Importance of scaling the land ICs to account for climate biases
- Impacts of offline versus coupled land-atmosphere assimilation

Conclusions of First GLACE-2 Analysis

1. 9 out of 13 of the expected GLACE-2 submissions are in.

2. So far, the individual models vary in their ability to extract forecast skill from land initialization.

   In general:

   -- Low skill for precipitation

   -- Moderate skill (in places) for temperature, even out to two months.

3. Land initialization impacts on skill increase dramatically when conditioned on the size of the initial local soil moisture anomaly.

⇒ If you know the local soil moisture anomaly at time 0 is large, you can expect (in places) that initializing the land correctly will improve your temperature forecast significantly, and your precipitation forecast slightly, even out to 2 months.