CLM Performance and Behavior Coupled in Three GCMs

Paul Dirmeyer

Jiangfeng Wei, Zhichang Guo

Center for Ocean-Land-Atmosphere Studies, Calverton, MD

Li Zhang

National Centers for Environmental Prediction, Camp Springs, MD

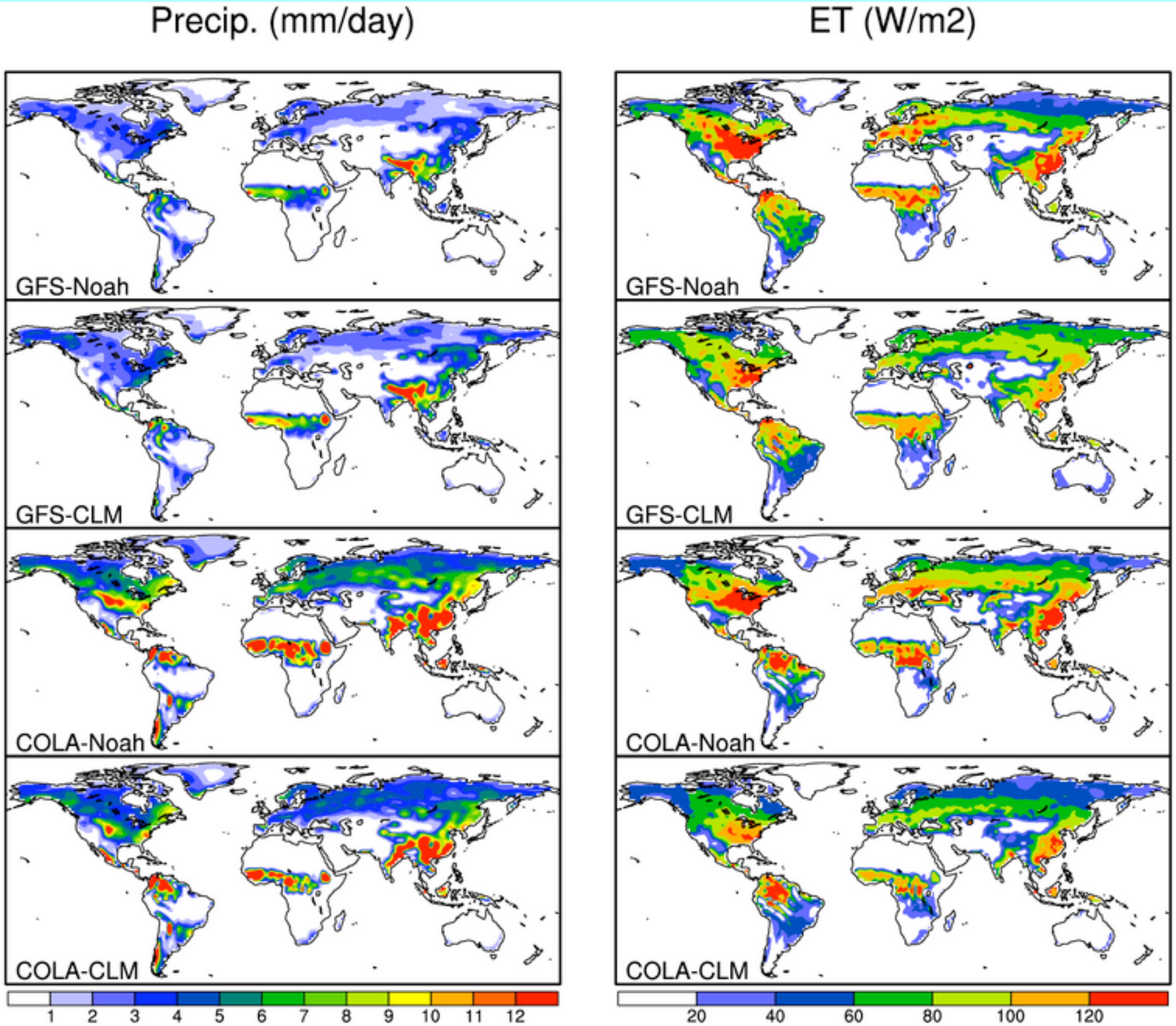
Li Xu

George Mason University, Fairfax, VA

Multi-LSM Coupling

- COLA AGCM v3.2
  - SSiB[2008], CLM[3.5] and Noah[2.7]
- GFS (Global Forecast System)
  - Noah[2.7], CLM[3.5]
- GLACE-1 simulations
  - JJA 1994, 16 ensemble members, one member of control (“W”) ensemble used to specify sub-surface soil moisture in all members of “S” ensemble.
  - Compare effects of different LSSs in same GCM.
  - Compare effects of different GCMs on same LSS.

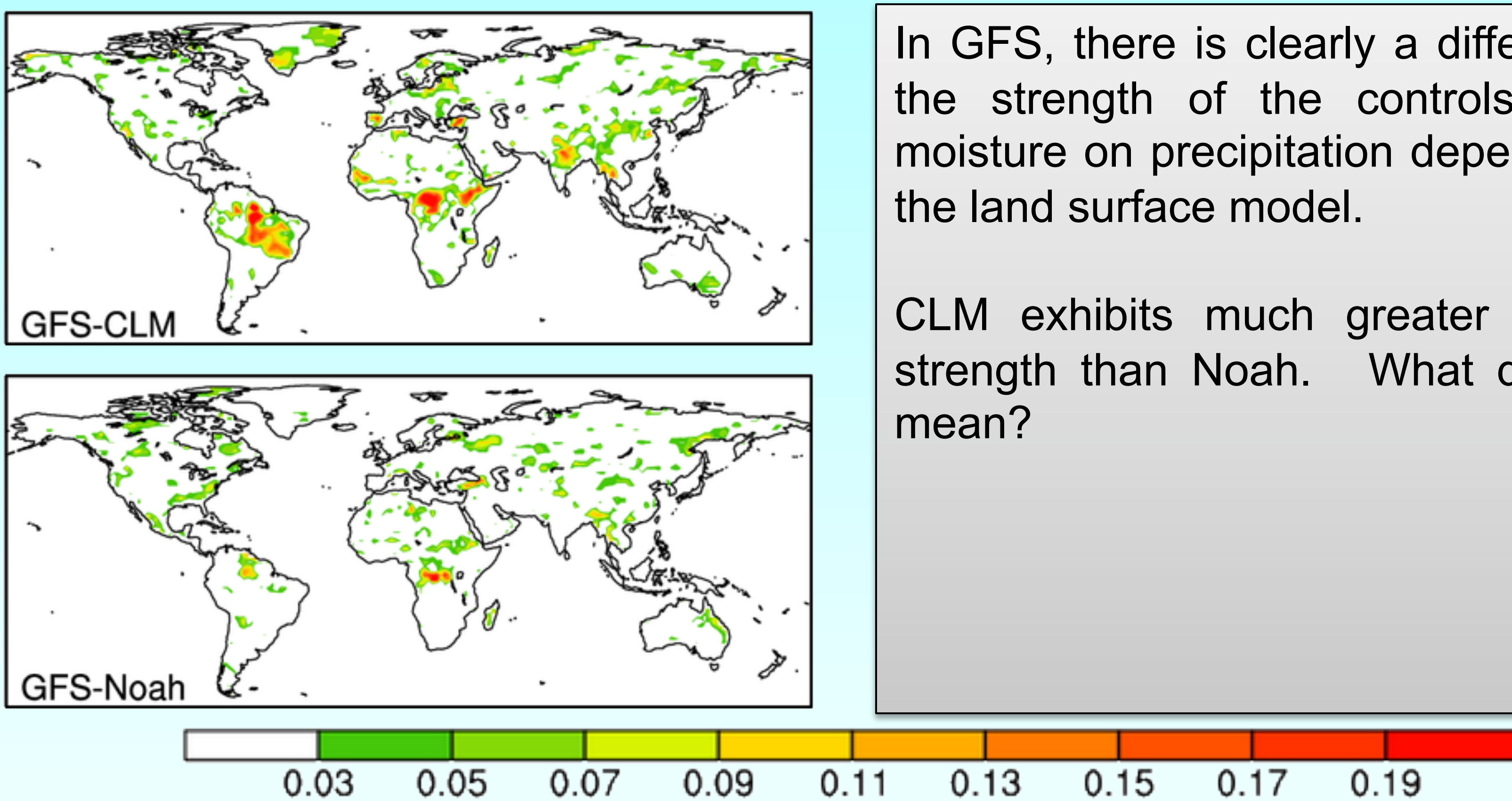
GCM Climatologies (JJA 1994 – GLACE1)



- Precip. pattern and amplitude are largely determined by the AGCM and its associated large-scale forcing.
- The impact of different land models on ET is evident.
- Land models can keep their signatures in ET, even when coupled to different AGCMs.

Coupling strength – subsurface SM to Precip

$\Omega_P(S)-\Omega_P(W)$



In GFS, there is clearly a difference in the strength of the controls of soil moisture on precipitation depending on the land surface model.

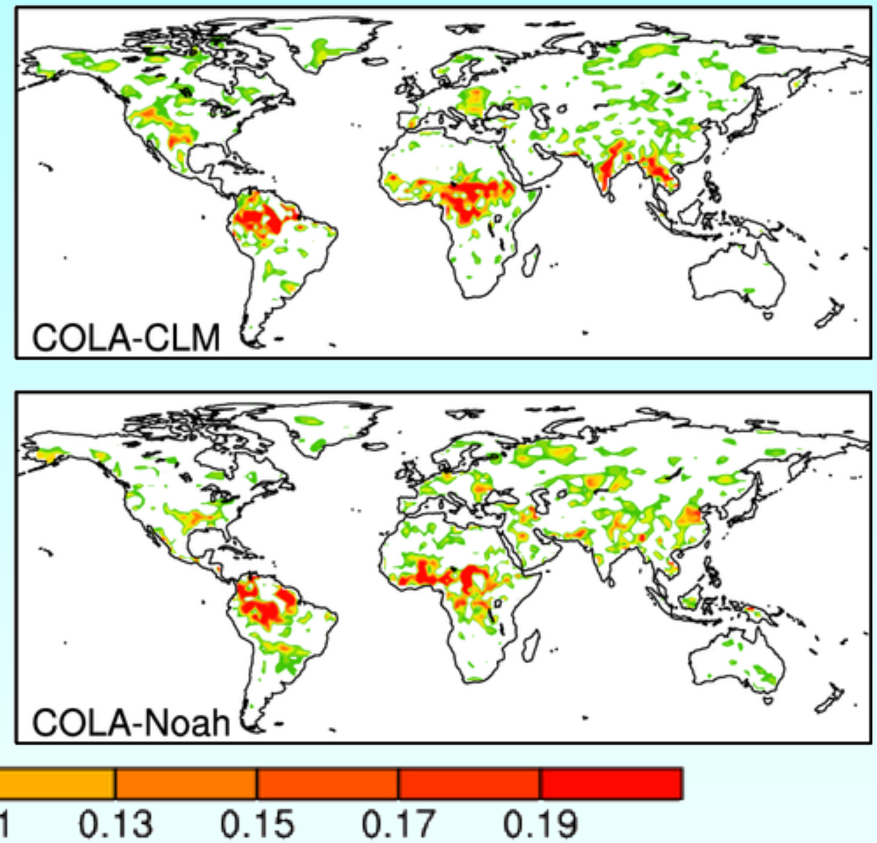
CLM exhibits much greater coupling strength than Noah. What does this mean?

Coupling strength – subsurface SM to Precip

$\Omega_P(S)-\Omega_P(W)$

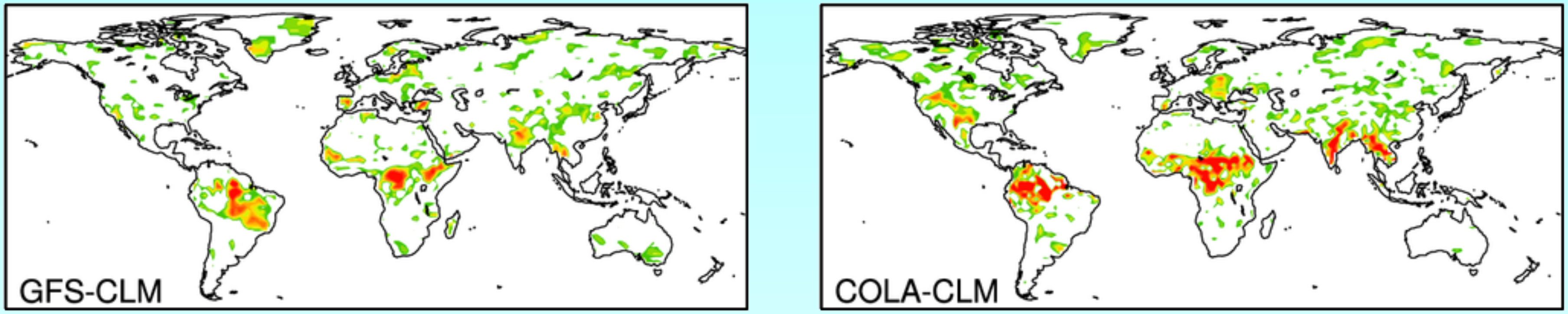
We saw something similar when each land model is coupled to the COLA AGCM. However, the contrast is not quite as stark.

When coupled to the COLA model, Noah shows much stronger coupling strength than when coupled in its “native” GCM.

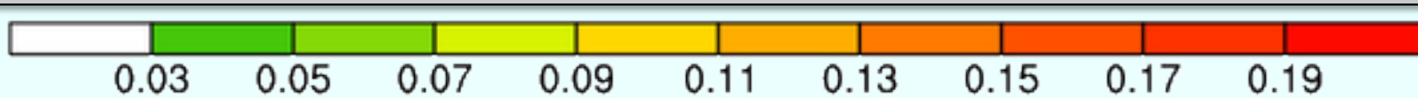


Coupling strength – subsurface SM to Precip

$$\Omega_P(S)-\Omega_P(W)$$



CLM shows a stronger coupling in the COLA AGCM, and a somewhat different pattern.
The different pattern is very much a function of the different rainfall climatologies in the two AGCMs.

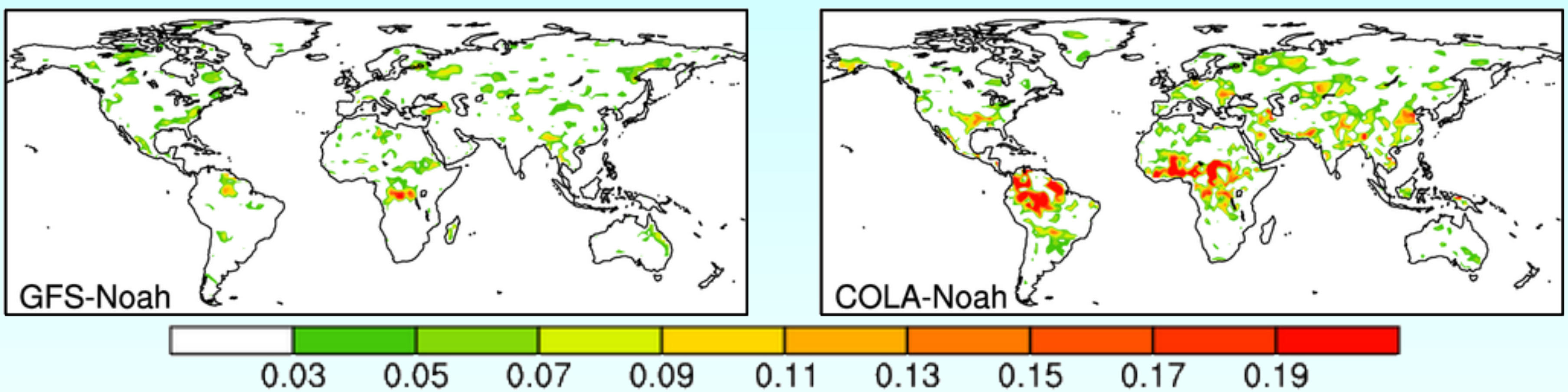


Coupling strength – subsurface SM to Precip

$$\Omega_P(S)-\Omega_P(W)$$

There is an interesting story to the behavior of Noah, however…

…looking at the coupling strength in evaporation, instead of precipitation…

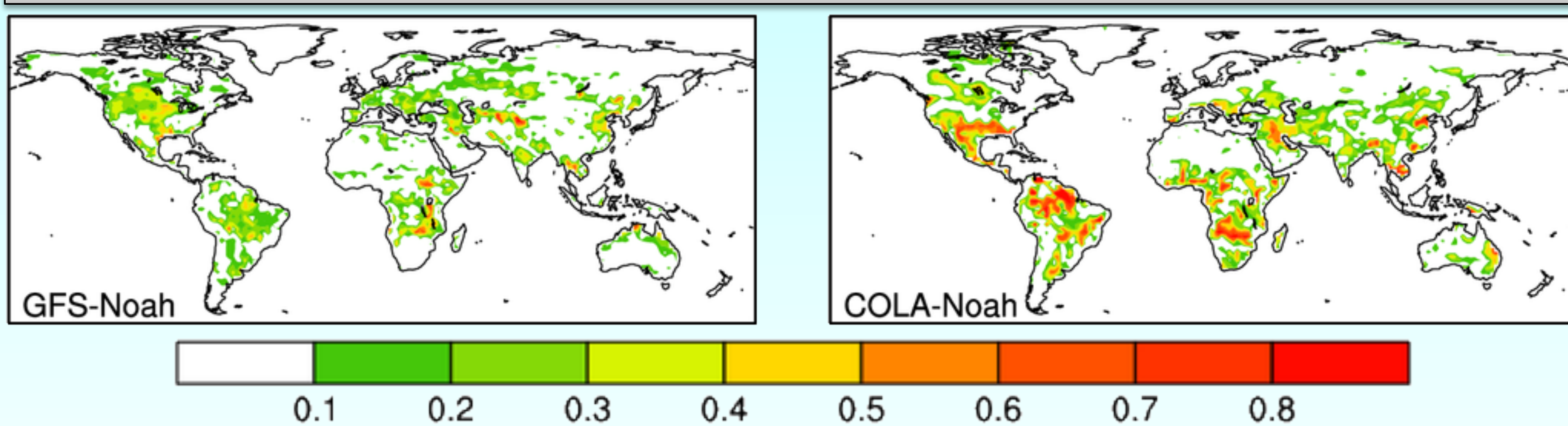


Coupling strength – subsurface SM to ET

$$\Omega_E(S)-\Omega_E(W)$$

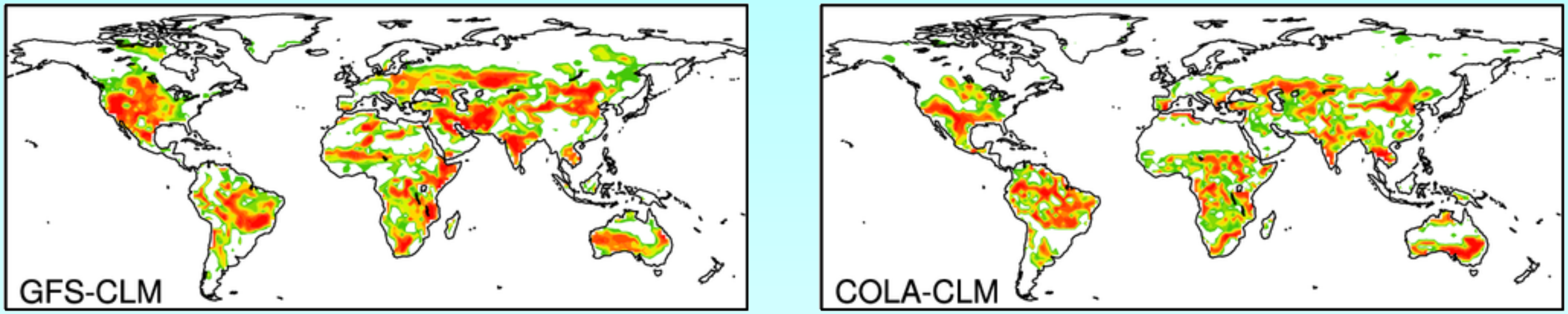
The connection from soil wetness to ET should be very strong. But for Noah it is not. Here's why:

- The top Noah soil layer is very thick (10cm)
- There are roots in this layer
- For grass, crops, and other treeless vegetation types, roots only extend to 40cm.
- Too much ET activity is in the top layer of Noah. The (S) case does not constrain this layer.



Coupling strength – subsurface SM to ET

$\Omega_E(S)-\Omega_E(W)$



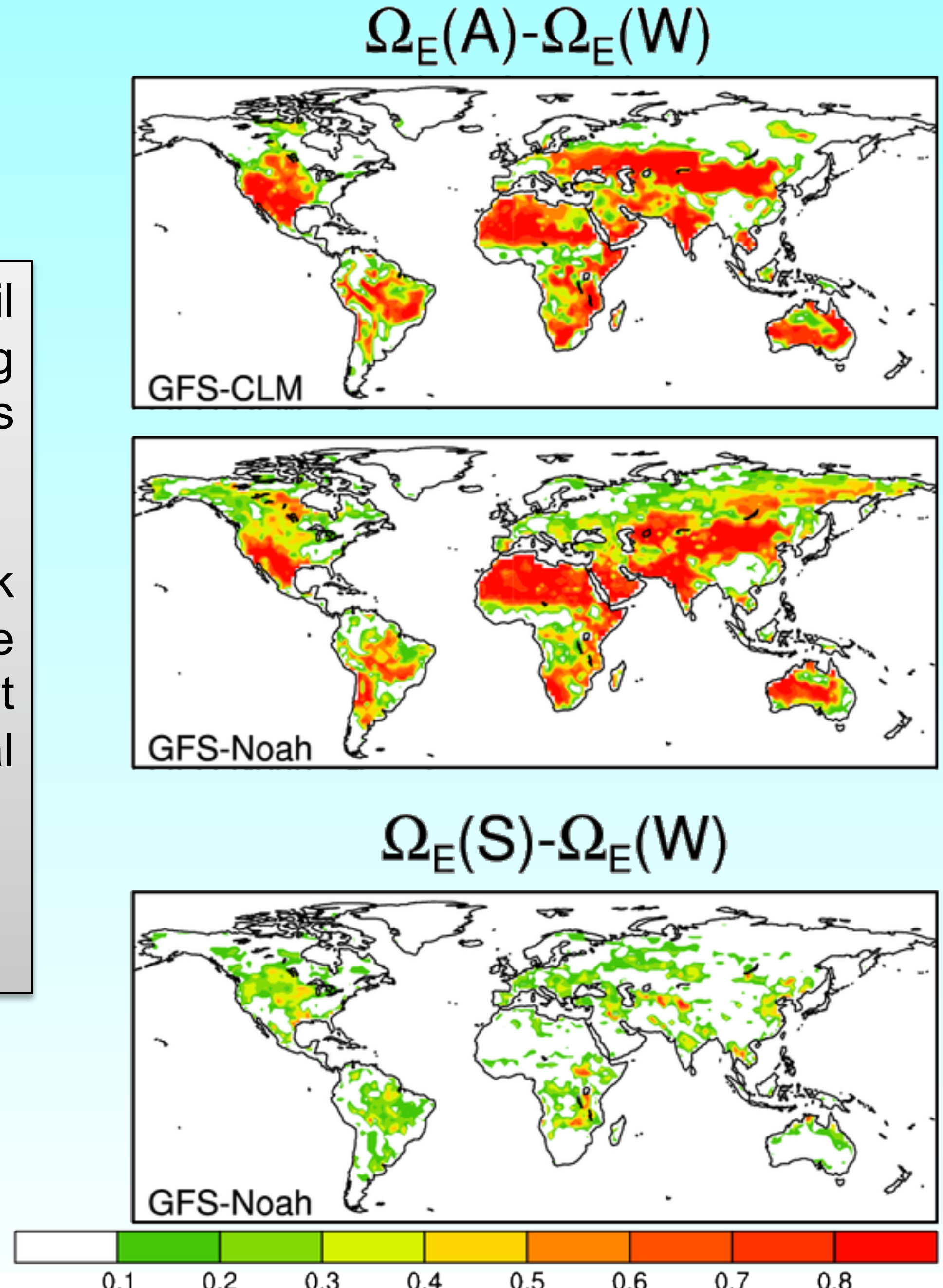
CLM shows much stronger coupling of sub-surface (layers 3-10) soil moisture to total evapotranspiration, over a much larger area, as expected.

Include impact of surface soil moisture

When we include the impact of soil moisture at all layers on coupling strength to ET, Noah appears comparable to CLM.

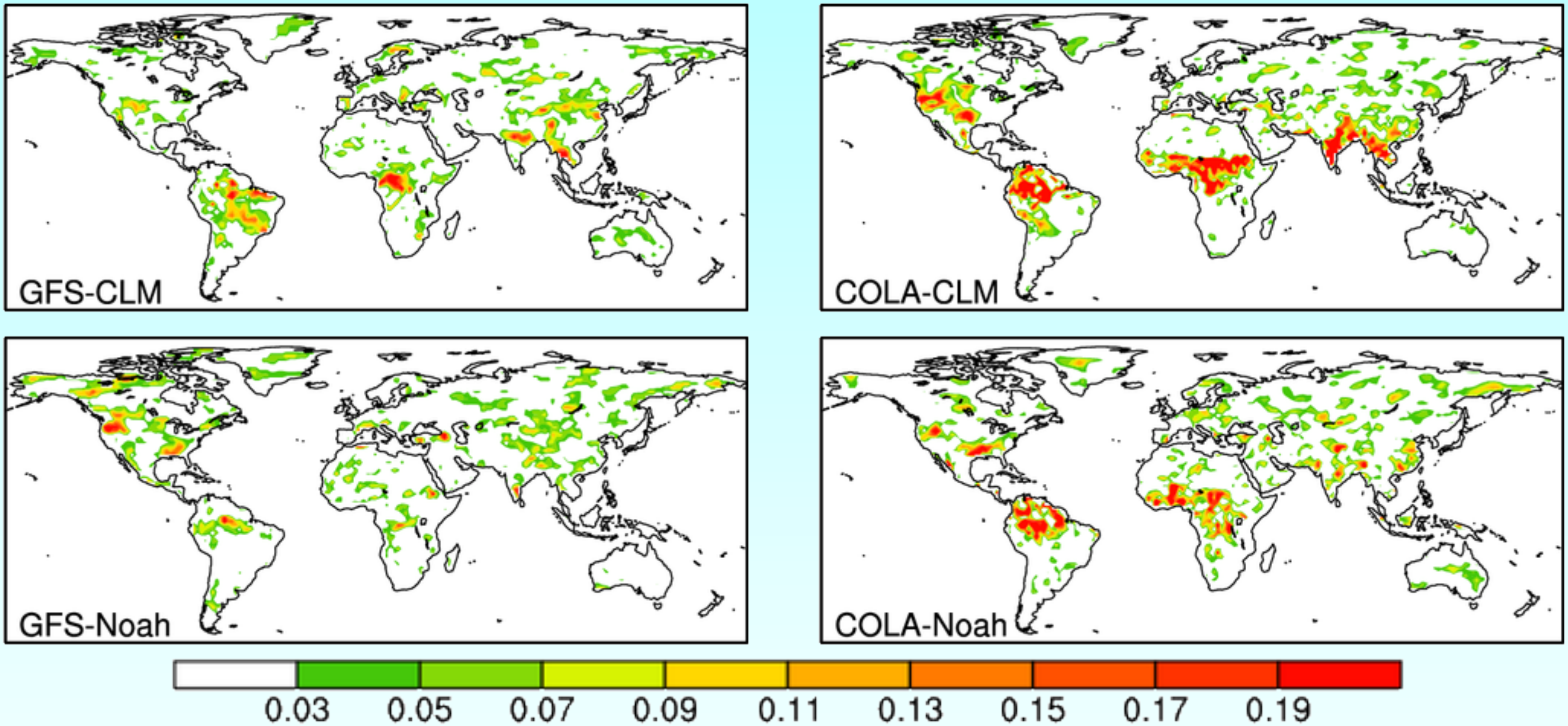
It seem that Noah may not be so weak after all – it is the formulation of the GLACE (S) experiment which is not compatible with the unusual vertical structure of the Noah model.

So then, what about the AGCM?



GFS versus COLA – a fair fight

$\Omega_P(A)-\Omega_P(W)$



Clearly, the GFS AGCM does not translate even strong ET signals into precipitation. NOAA's operational global forecast model is unresponsive to the choice of LSM or the strength of SM ➔ ET coupling.

GLACE-2 and CAM/CLM

Model version: CAM V3.4.10 + CLM 3.5

Resolution: T85

Atmosphere initialization:

ERA-40 reanalysis. Initialization at 00Z from 10 days around the start dates.

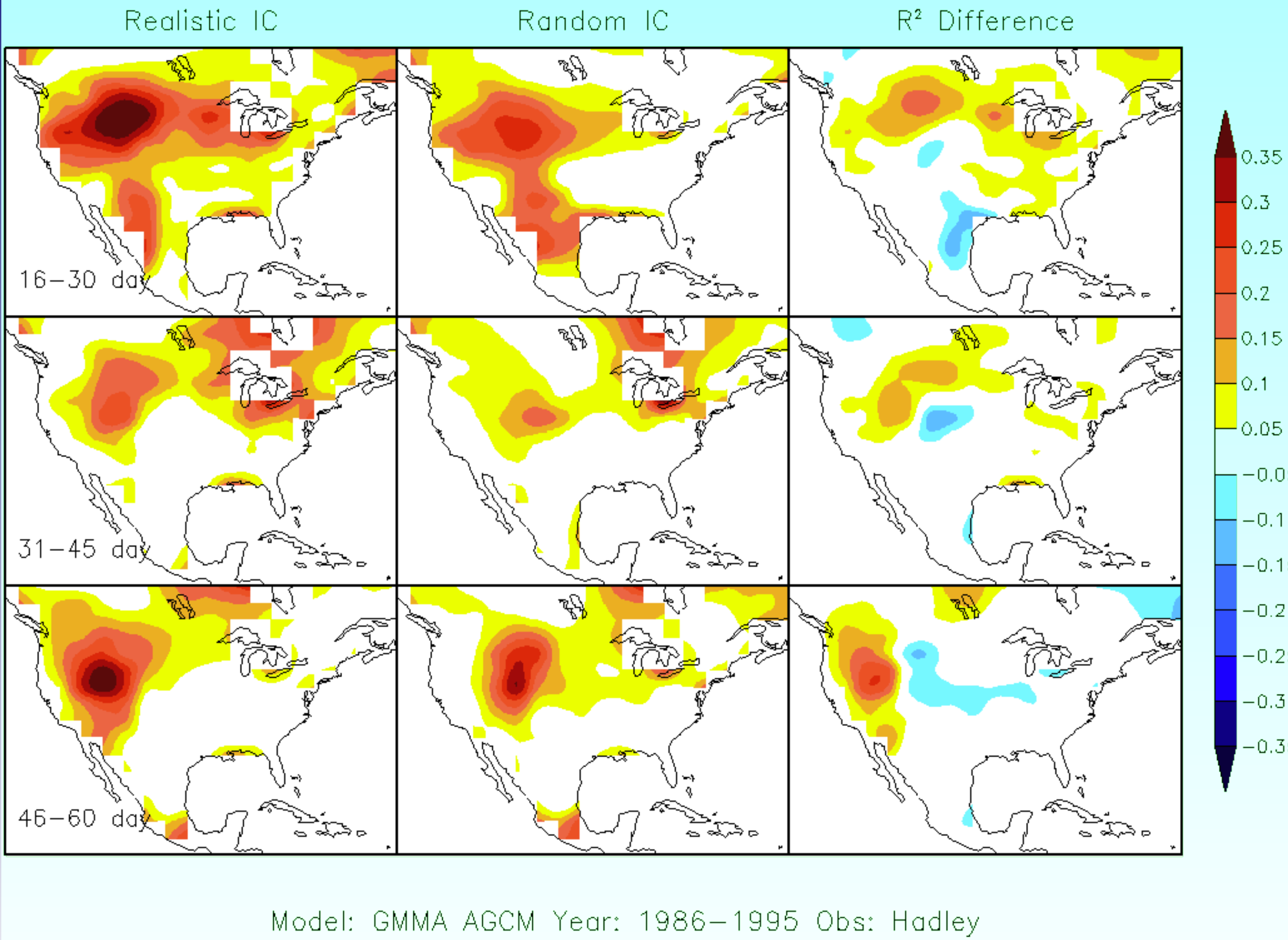
Land surface initialization:

GSWP-type offline simulations with CLM3.5 driven by Princeton meteorological forcing data (1948-2006). *Soil moisture has been scaled to the CAM/CLM climatology*.

Series 1 (“realistic”), same initial field for 10 ensemble members at each starting date (MAMJJ 1st and 15th, 1986-1995).

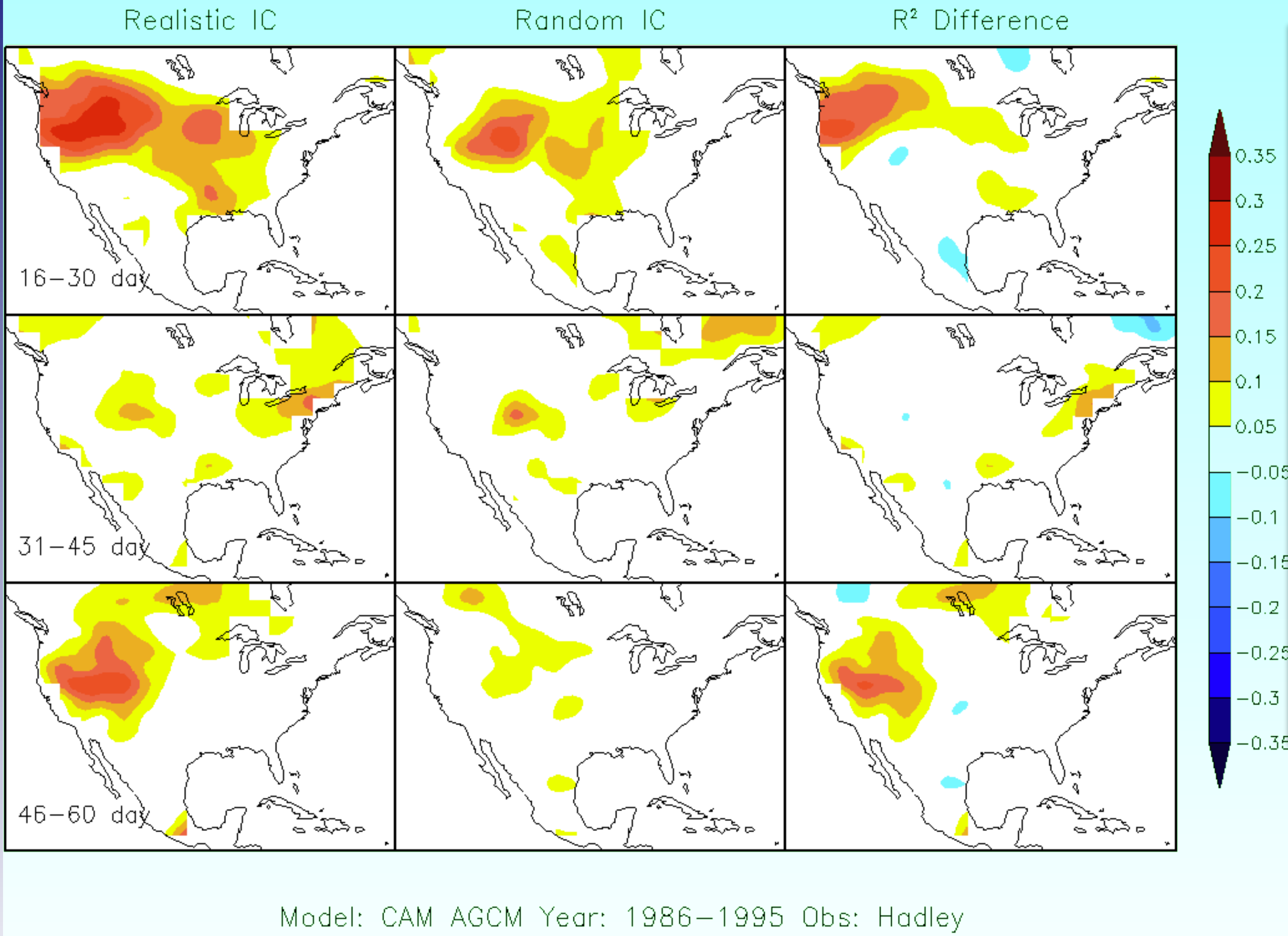
Series 2 (“unrealistic”), initial fields from 10 different years (1986-1995) at each starting date are used for 10 ensemble members at that starting date.

GLACE-2 10-GCM Combined Skill (T)



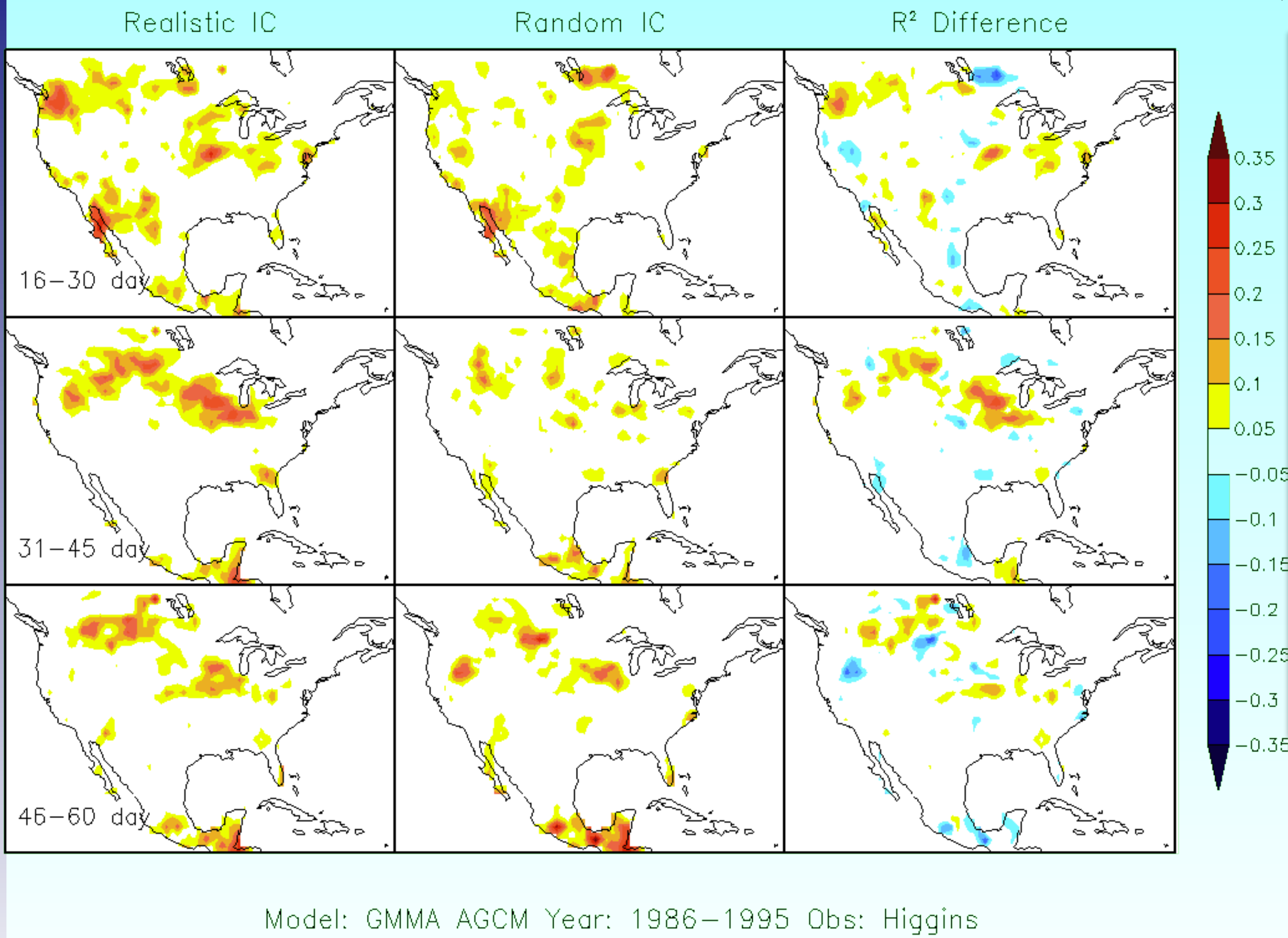
- Skill of multi-model mean is pretty good without realistic land initialization (center column) at all lead times.
- Realistic initialization adds skill (r^2) at all lead times in the West, more widespread at ½-1 month lead.
- This includes CAM3.5/CLM3.5 runs.

CAM3.4.10/CLM3.5 GLACE-2



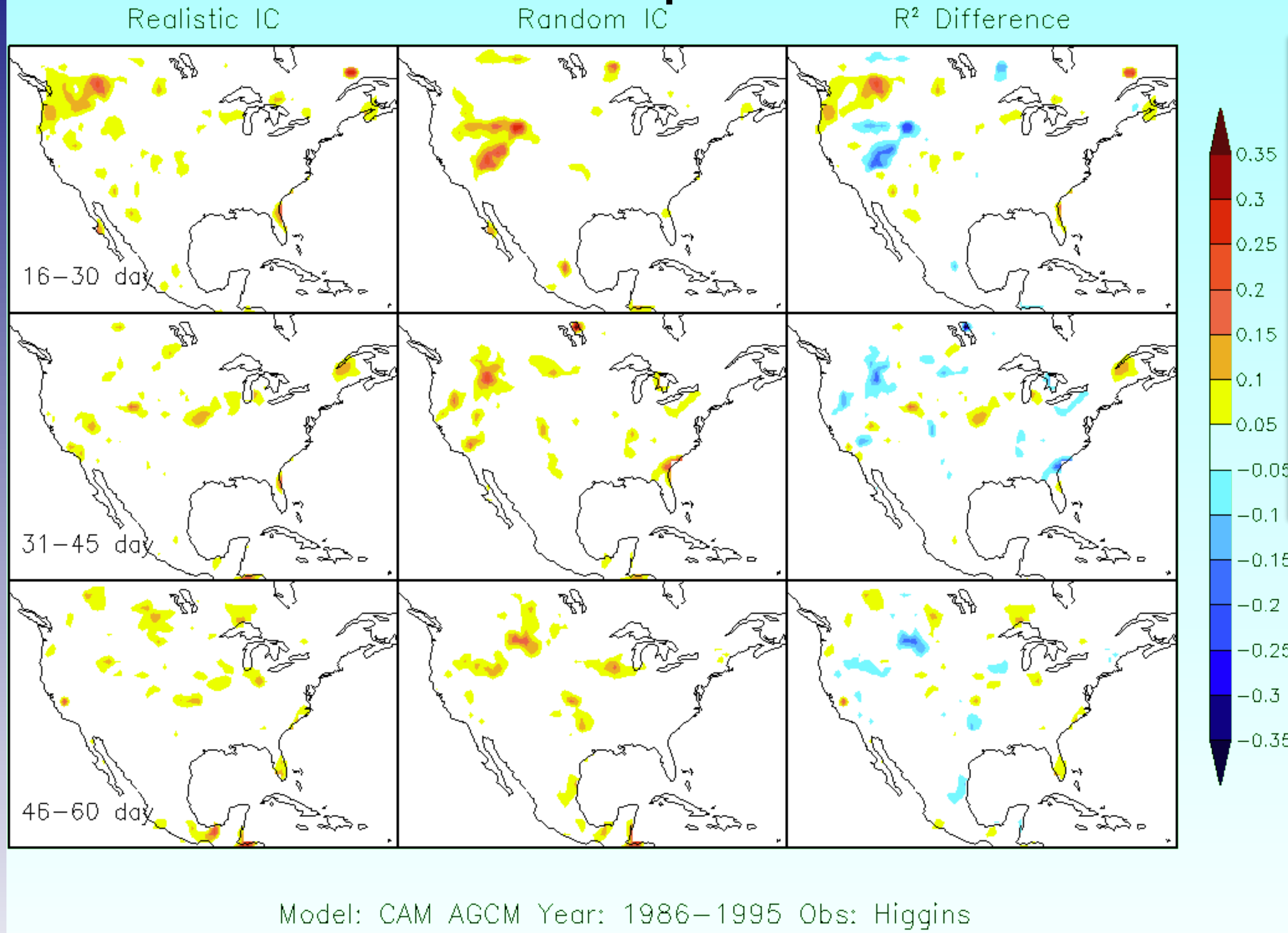
- •Like the multi-model average, most of the positive impact from soil moisture initialization is in the West.
- •Curious recovery of skill in the second half of month 2 - also seen in other GCMs.

GLACE-2 10-GCM Combined Skill (P)



- Skill for precipitation is much weaker than for temperature.
- Improvements from land initialization seem to peak at the start of month 2.
- Spatial scale of signal is much smaller.

CAM/CLM Precip.

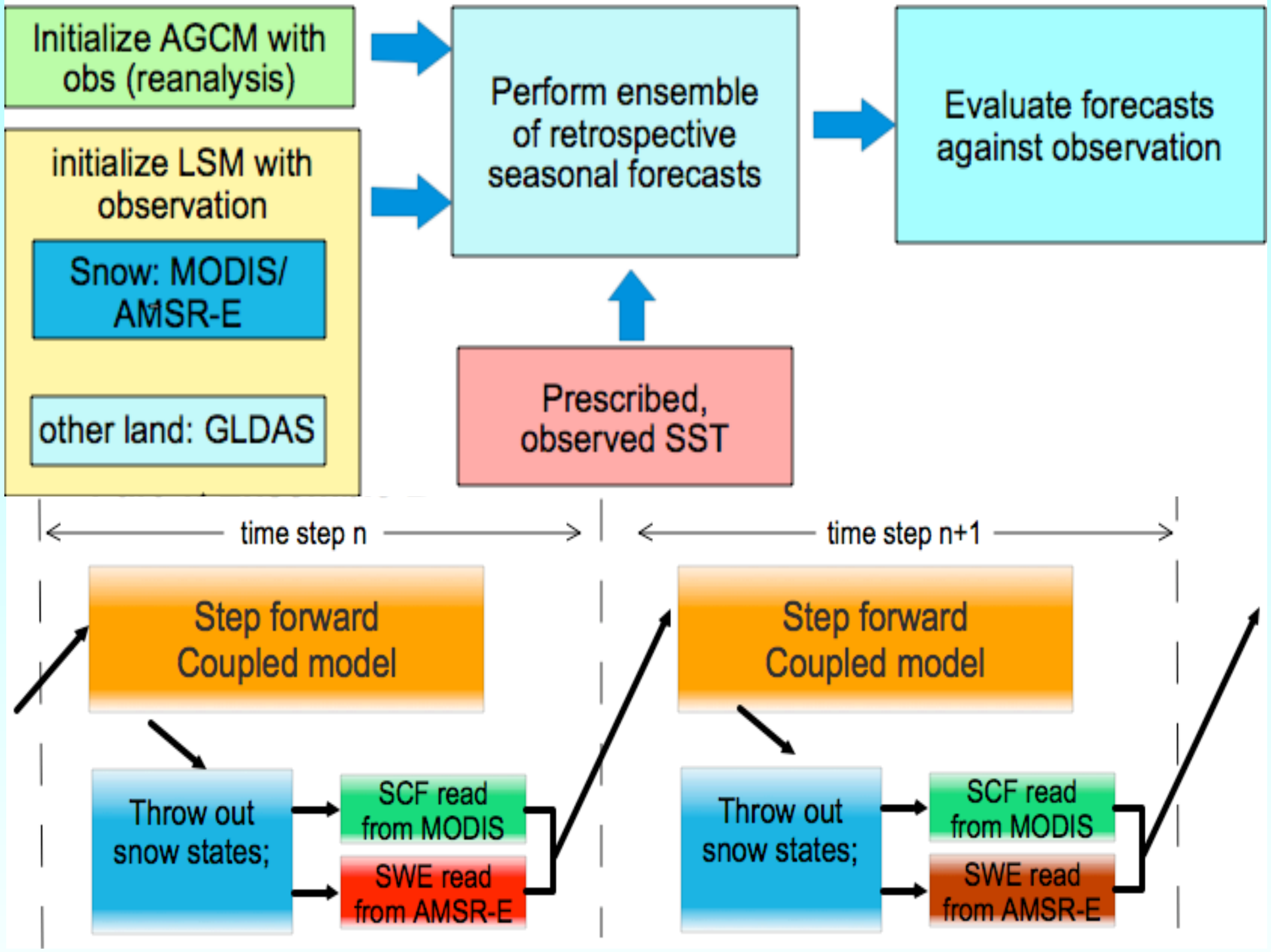


- Baseline skill of CAM/CLM is much lower than multi-model average.
- Realistic initialization has little positive impact.

GLACE for Snow Li Xu dissertation – George Mason U.

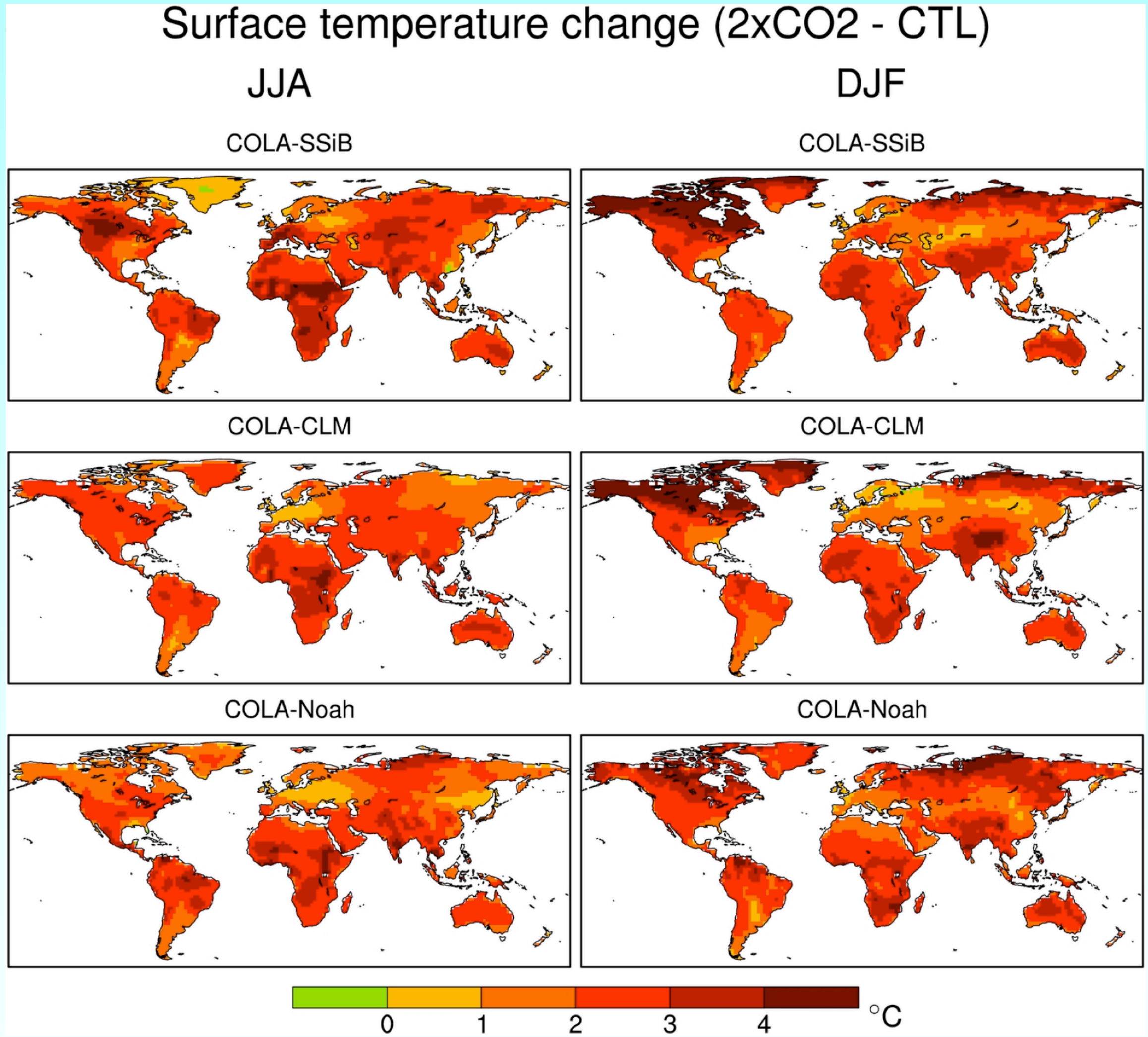
- MAMJJA simulations
- In addition to "perfect model" results, also use MODIS snow cover fraction and/or AMSR-E snow water equivalent data to specify snow boundary conditions.
- Boreal spring (months 1-3) – examine impact of snow anomalies (albedo) on energy balance and climate.
- Boreal summer (months 4-6) – delayed effects on climate via induced soil moisture anomalies.

CAM + CLM, multiple years, GLACE design



Land Impact on Climate Change Projections

- We examined how $2xCO_2$ simulations with the same AGCM are affected by the use of different land models.
- A shortcut – we do not use coupled GCMs, but used observed SST/Sea Ice and specified average of 3 top CMIP3 projections.
- 23-year simulations in each case.
- There is marked difference between the degree and pattern of warming between different models in surface temperature. But annual global mean changes agree within 0.2ºK.
- A cleaner result than Crossley, et al. 2000.



Wei, J., and P. A. Dirmeyer, 2010: Land caused uncertainties in climate change simulations: A study with the COLA AGCM. *Quart. J. Roy. Meteor. Soc.* (submitted).