COLA Center for Ocean-Land-Atmosphere Studies
http://www.iges.org/
dirmeyer@cola.iges.org
IGES Institute of Global Environment and Society
GEORGE MASON UNIVERSITY

10/2011

Predictability in a changing climate

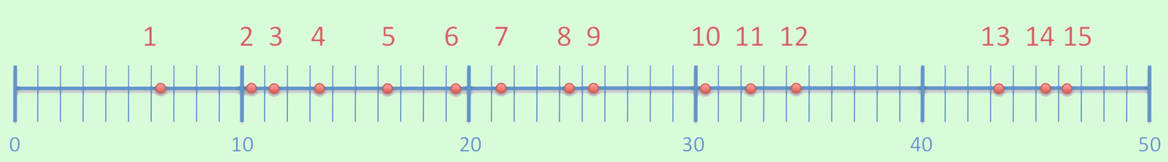
Comparison of intraseasonal to seasonal forecasts in a pre-industrial versus modern background climate

Paul A. Dirmeyer[1], Sanjiv Kumar[1], David Straus[2,1], James L. Kinter III[1,2], Michael Fennessy[1], Benjamin A. Cash[1], Timothy DelSole[2,1], Eric L. Altshuler[1], Daniel A. Paolino[1], Zhichang Guo[1], Bohua Huang[2,1], and J. Shukla[2,1]
[1] Center for Ocean-Land-Atmosphere Studies, Calverton, Maryland, USA
[2] George Mason University, Fairfax, Virginia, USA

The Predictability Experiment

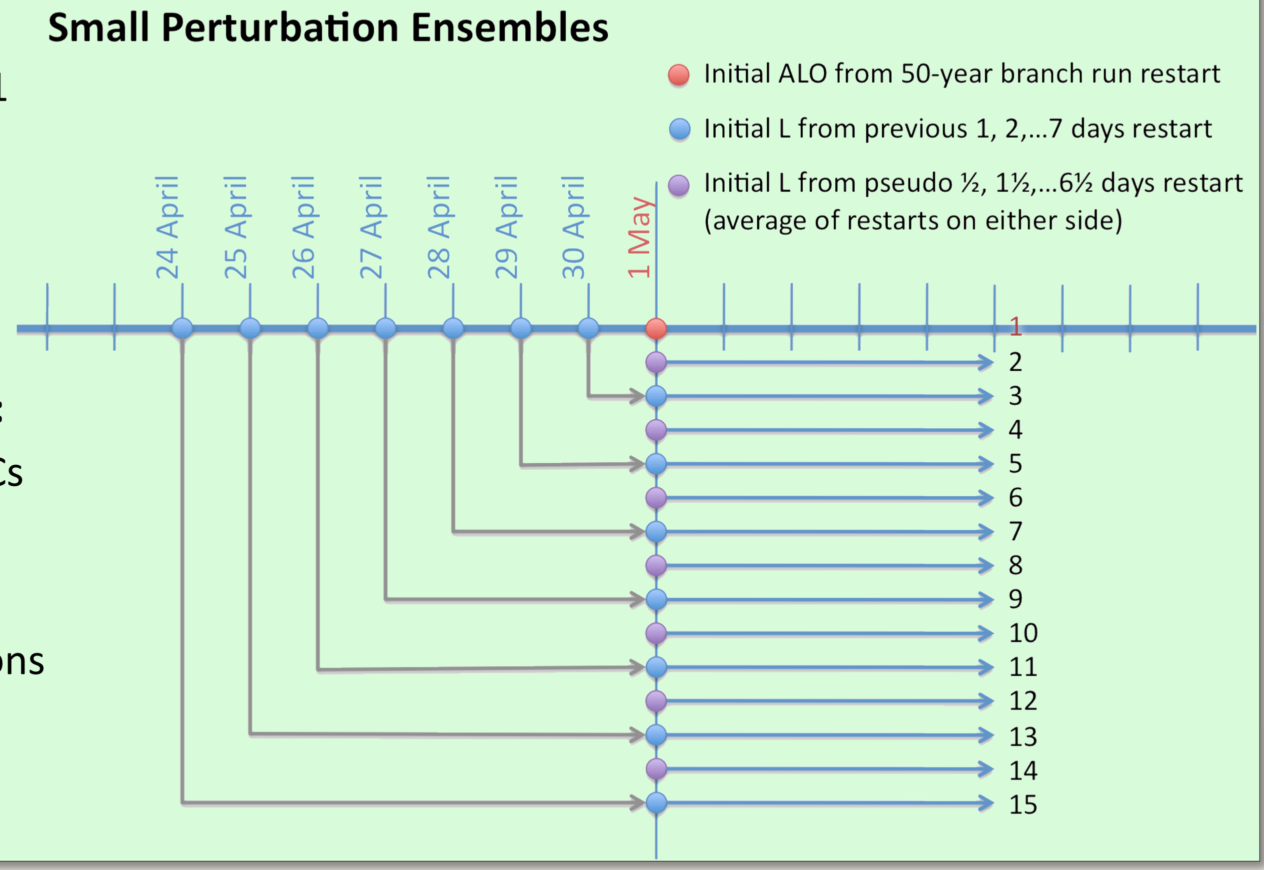
Two sets of "perfect model" ensemble forecasts are generated off 50-year branch runs of the Community Climate System Model (CCSM, Version 4) initialized off long fixed pre-industrial (1850) and transient current (2000) simulations. 90-day forecasts are initialized for Northern Hemisphere cold (1 December) and warm (1 May, 1 June, 1 July) seasons.

Cases and Large Perturbation Ensembles



- Cases chosen to sample 5 El Niño, 5 La Niña and 5 Neutral seasons from 50-year branch run.
- Each case (numbered) spawns 14 perturbed runs (ensemble of 15)
- Each ensemble member has identical initial atmosphere and ocean from branch run.
- For the *Large Perturbation* ensembles, initial land states chosen from each of the other 14 cases.

Small Perturbation Ensembles



Predictability Investigations:

- Realistic vs. Random Land ICs
- Past vs. Current Climate
- Start Date (M, J, J, D)
- Growth of Small Perturbations
- Dependence on Lead Time
- Coupled Ocean Response

Measures of Predictability

Total variance can be decomposed into signal and noise:

$$V_T = V_S + V_N$$

For N forecasts of ensemble size E, the sample climatological variance (total) is given by:

$$V_T = \frac{1}{NE}\sum_{n=1}^{N}\sum_{e=1}^{E}(y_{en} - \bar{y}_{\bullet\bullet})^2$$

(Grand mean)

the sample variance of ensemble means (signal) is:

$$V_S = \frac{1}{N}\sum_{n=1}^{N}(\bar{y}_{\bullet n} - y_{\bullet\bullet})^2$$

(Ensemble mean)

and the variance about ensemble means (noise) is:

$$V_N = \frac{1}{NE}\sum_{n=1}^{N}\sum_{e=1}^{E}(y_{en} - y_{\bullet n})^2$$

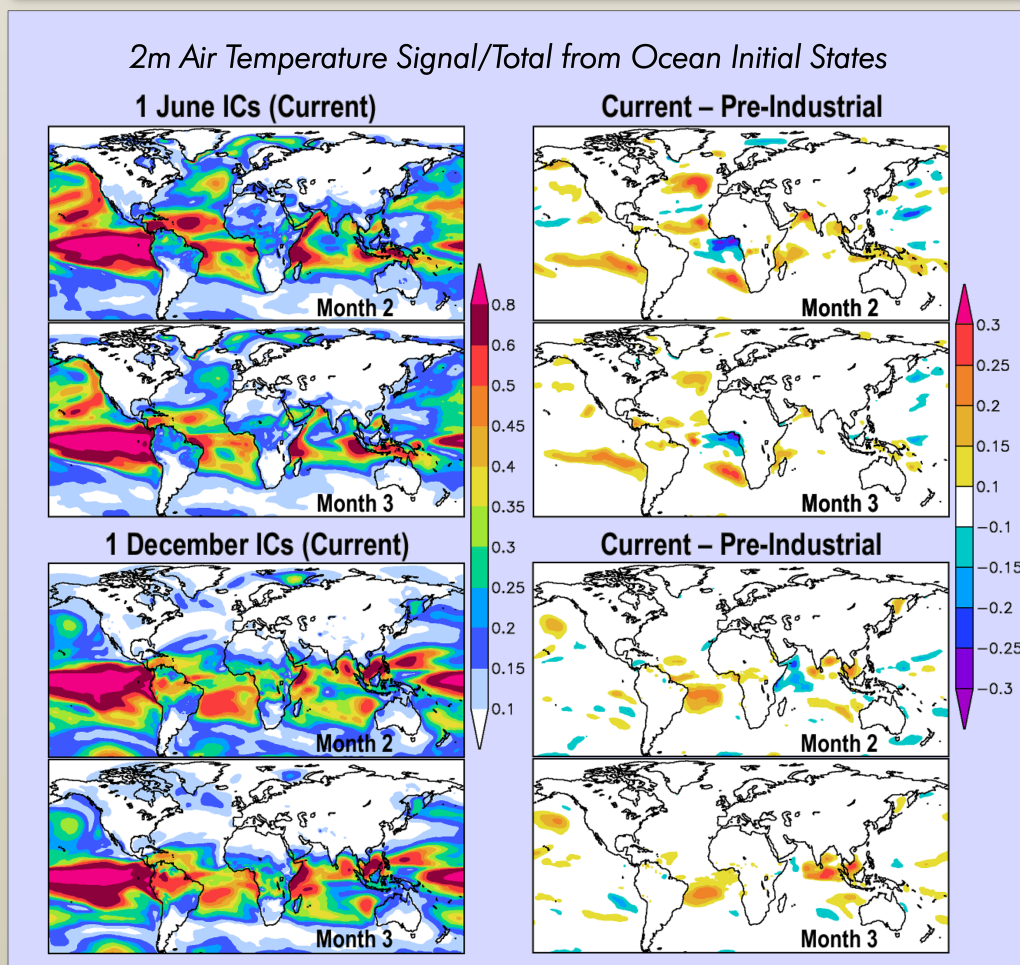
Predictability here is measured by Signal/Total ratio.

The ensembles defined above have these signal characteristics:

- Large Perturbation: Predictability from ocean and atmosphere initial states (AO).
- Small Perturbation: Predictability from land, ocean and atmosphere (LAO).

We can rearrange ensembles from the Large Perturbation case by grouping runs with identical initial land states. Then predictability is only from land (L).

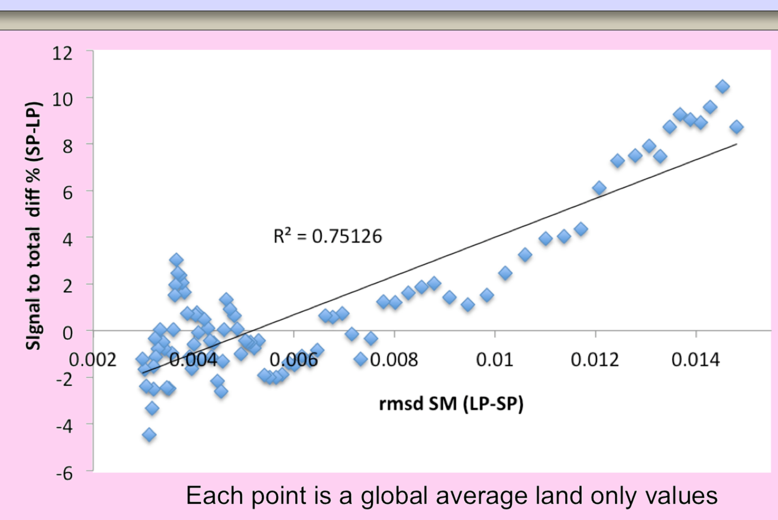
Predictability from the Ocean



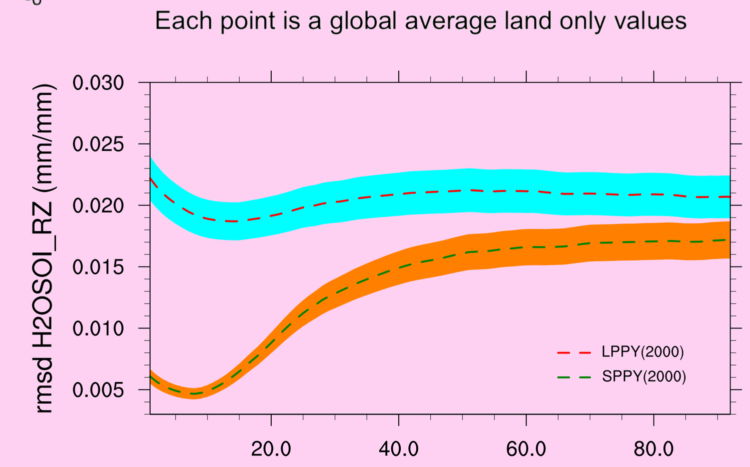
- Land impacts in tropics (South America, Africa, Indonesia), India in July, Australia in February.
- ENSO signal is strong, but Pacific predictability changes little between centuries.
- Changes elsewhere are sparse, but generally positive (predictability increasing with time.
- Major exception is over the Gulf of Guinea in boreal summer.

Global Effects

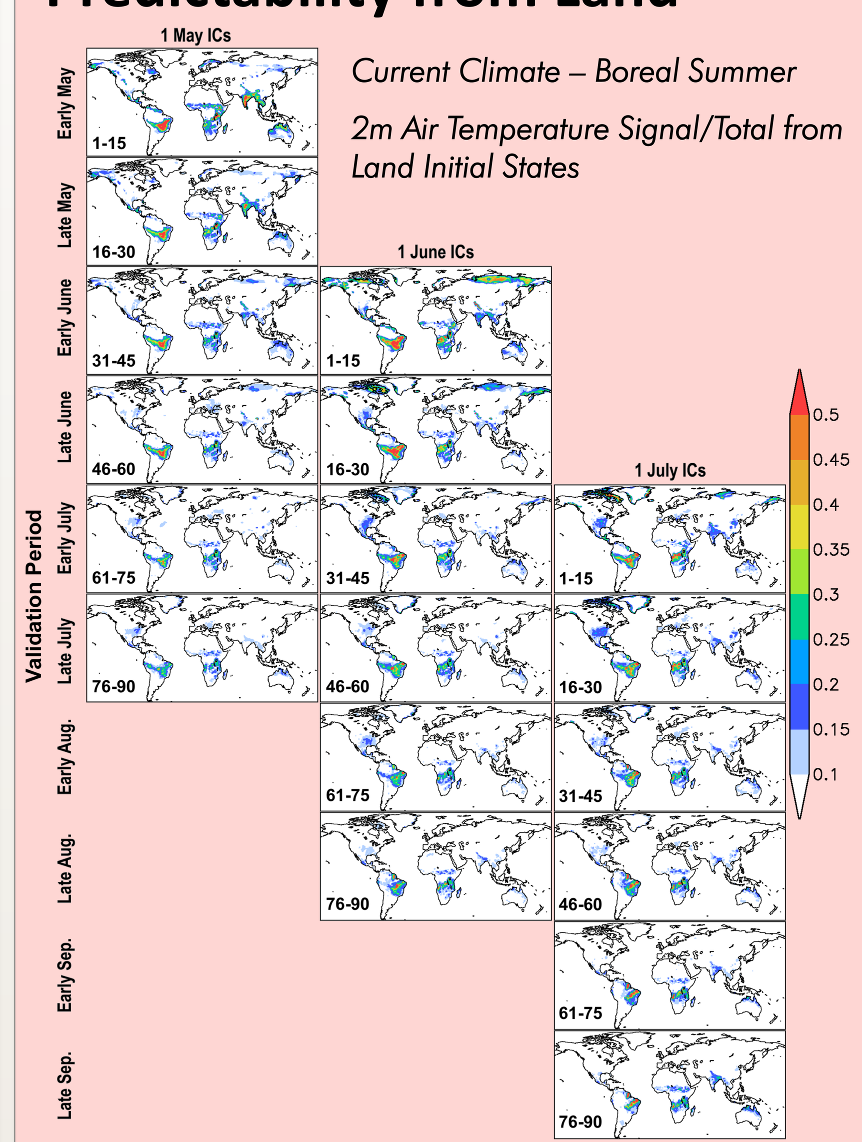
- Larger global root-mean-squared differences of initial soil moisture result in larger responses in global 2m air temperature (top), particularly for the largest differences.
- There is an interesting "spin up" effect in soil moisture, which is initially perturbed among ensembles members (maximally for the large perturbation LPPY run, small for SPPY) while the initial atmosphere is identical (bottom). The soil moisture spread reduces during the first 7-10 days, converging under nearly identical atmospheres. After 10 days, atmospheric chaos begins to dominate.



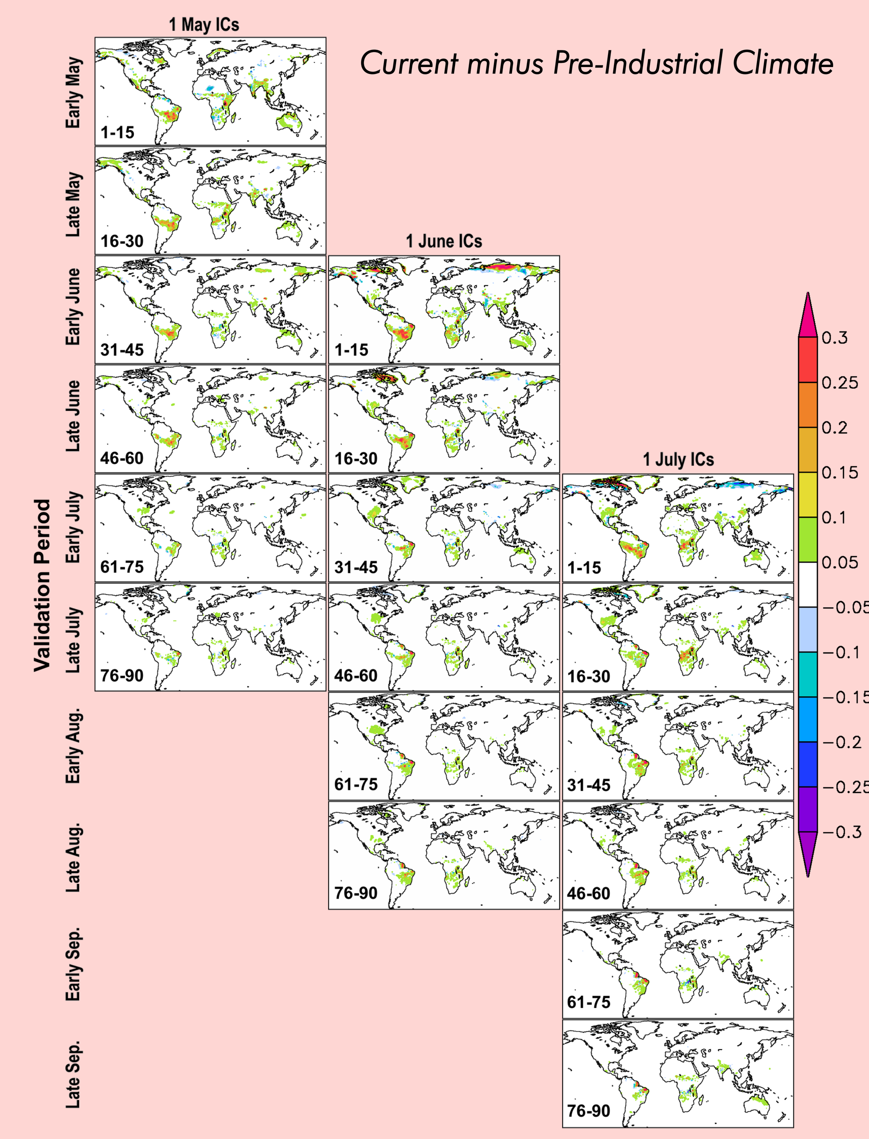
Each point is a global average land only values



Predictability from Land



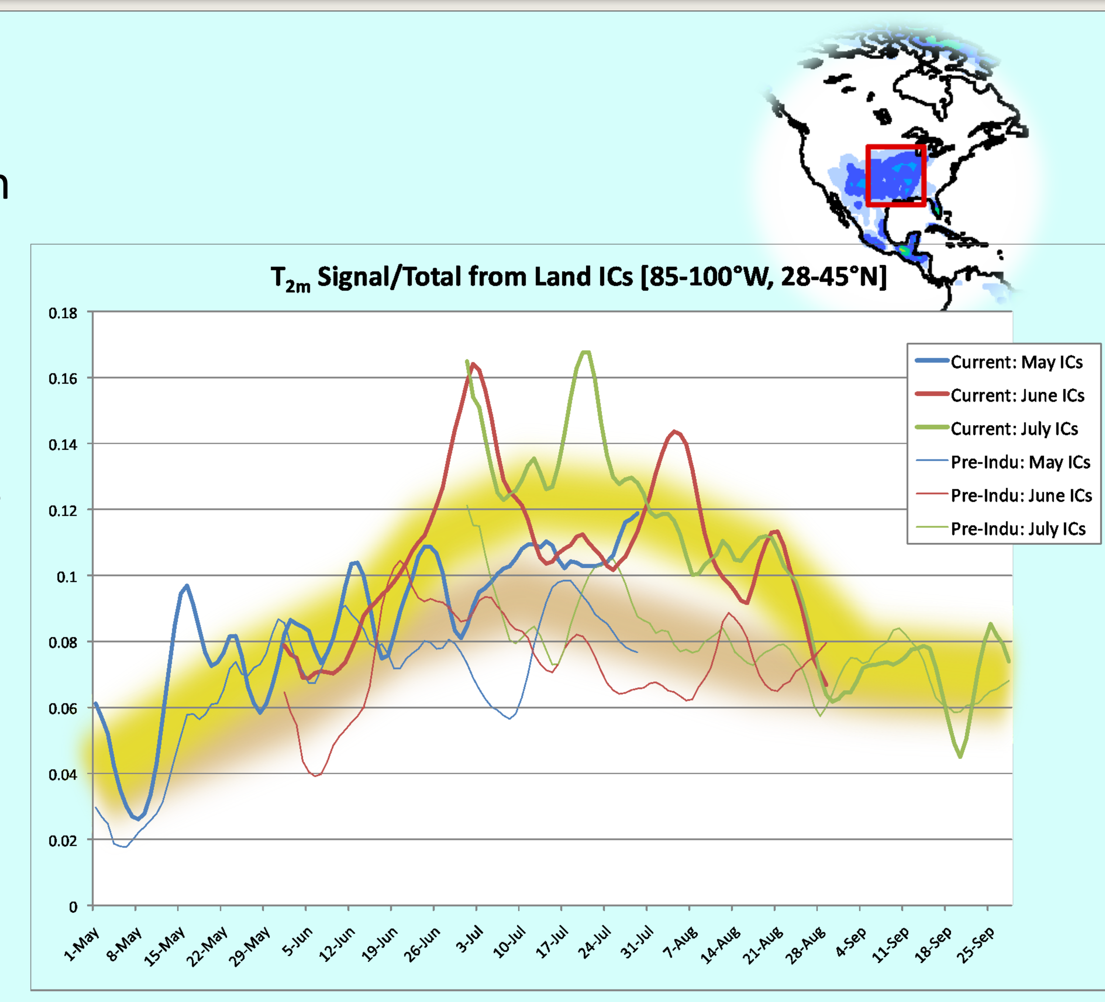
Most impacts are over pre- and post-monsoon areas, central US.

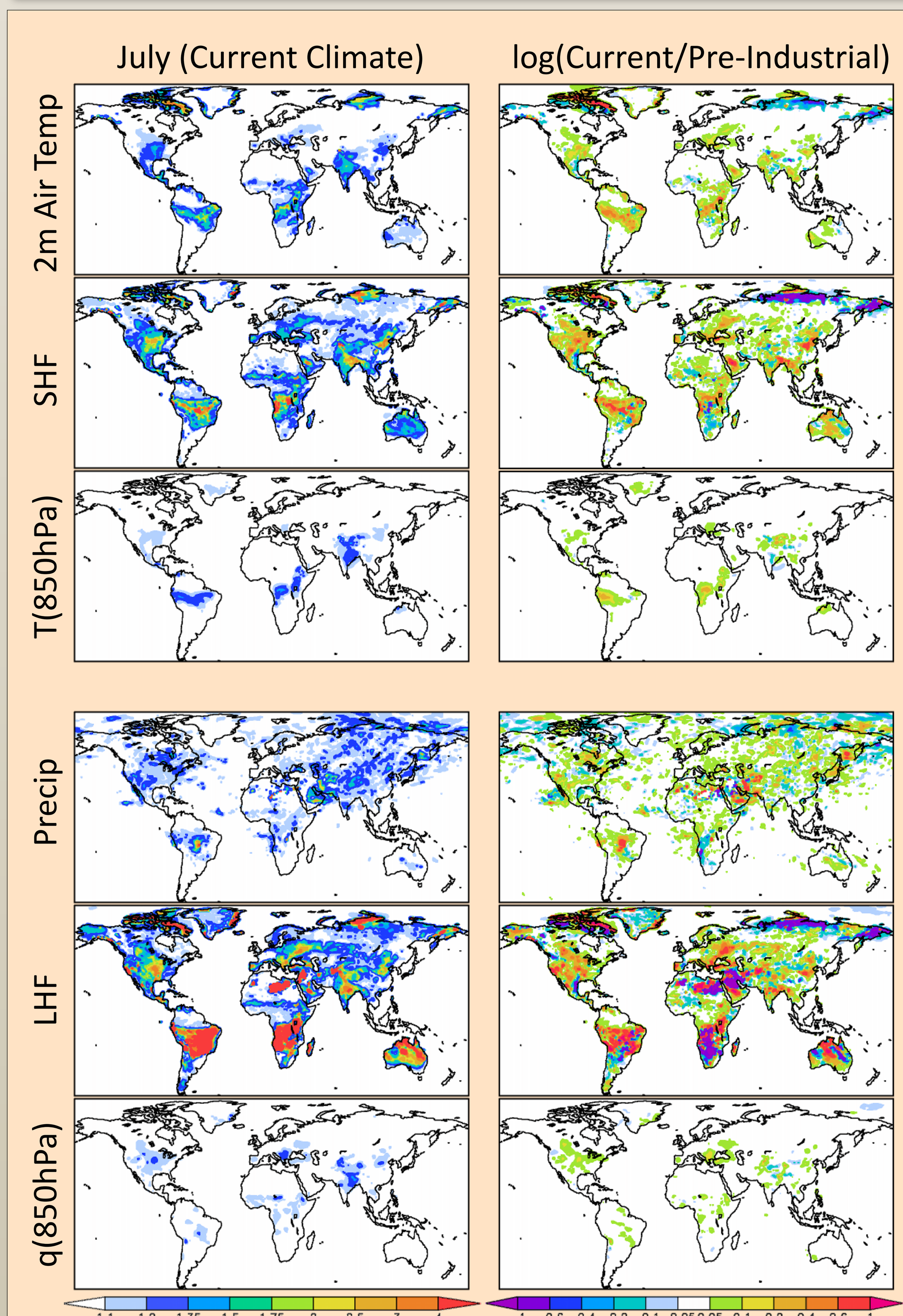


Largely, changes are positive – land impacts on climate are increasing. Why?

Predictability Rebound

As seen in GLACE-2, there is an increase in predictability over the central US during summer. This "rebound" is caused by the annual cycle of land-atmosphere coupling, which is weak during spring but becomes strong in summer. This allows the atmosphere to tap the information in persistent soil moisture anomalies, increasing predictability.





Short-Term Predictability

Ratio of predictabilities (S/T) from small versus large initial land perturbations, averaged over the first week of the simulations.

- The immediate impact of the land states is evident in energy and water cycle terms.
- Surface fluxes strongly reflect regions where soil moisture is a controlling factor.
- Effects propagate vertically into the atmosphere most strongly in the "hot spot" regions.
- Precipitation reflects these impacts over continents.
- Changes from 1800s to today are largely positive – predictability from land increases at weather and time scales.

Early Results

- CCSM4 shows characteristic land "hot spots" of predictability from soil moisture.
- Predictability from land appears to have increased since 1850 at weather and seasonal time scales – this not a statistical artifact of global warming, but shows up with trend effects removed.
- Some indication of increased predictability from ocean, but less clear.
- TBD: Future climate scenarios; Prediction cases; Other models (CFSv2)….