Seasonal Climate "Forecasts" in Past, Present and Future Climate Role of the Land Surface

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Predictability in a changing climate

- Can we quantify past-present-future changes?
- Total variance of a climate variable can be decomposed into signal and noise:

$$V_T = V_S + V_N$$

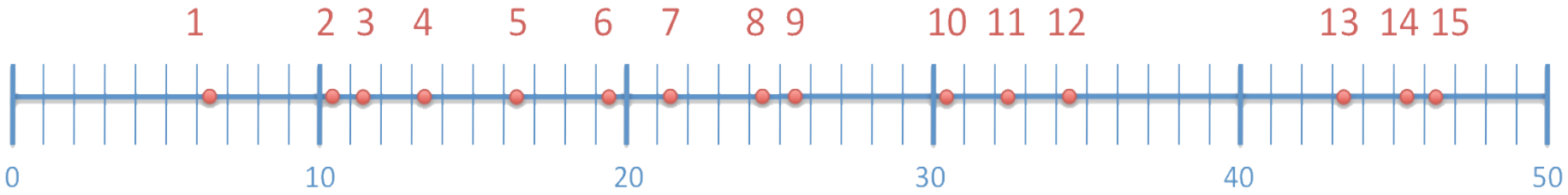
  - Predictability here is measured by Signal/Total ratio.

Predictability in CCSM4

- Three 50-year CCSM4 simulations branching off:
  - Pre-Industrial [40.1850.track1.1deg.006] at year 1201 (of 1300 year run).
  - Historical [b40.20th.track1.1deg.005] at year 2000.
  - RCP 8.5 (b40.rcp8_5.1deg.001) at year 2095.
- 15 years chosen from each run
  - 5 strongest El Niños & La Niñas (NINO3.4)
  - 5 most neutral
  - Seasonal predictions from 1 May, 1 June, 1 July and 1 Dec.

ICs: Land vs Atm+Ocn

Cases and Large Perturbation Ensembles

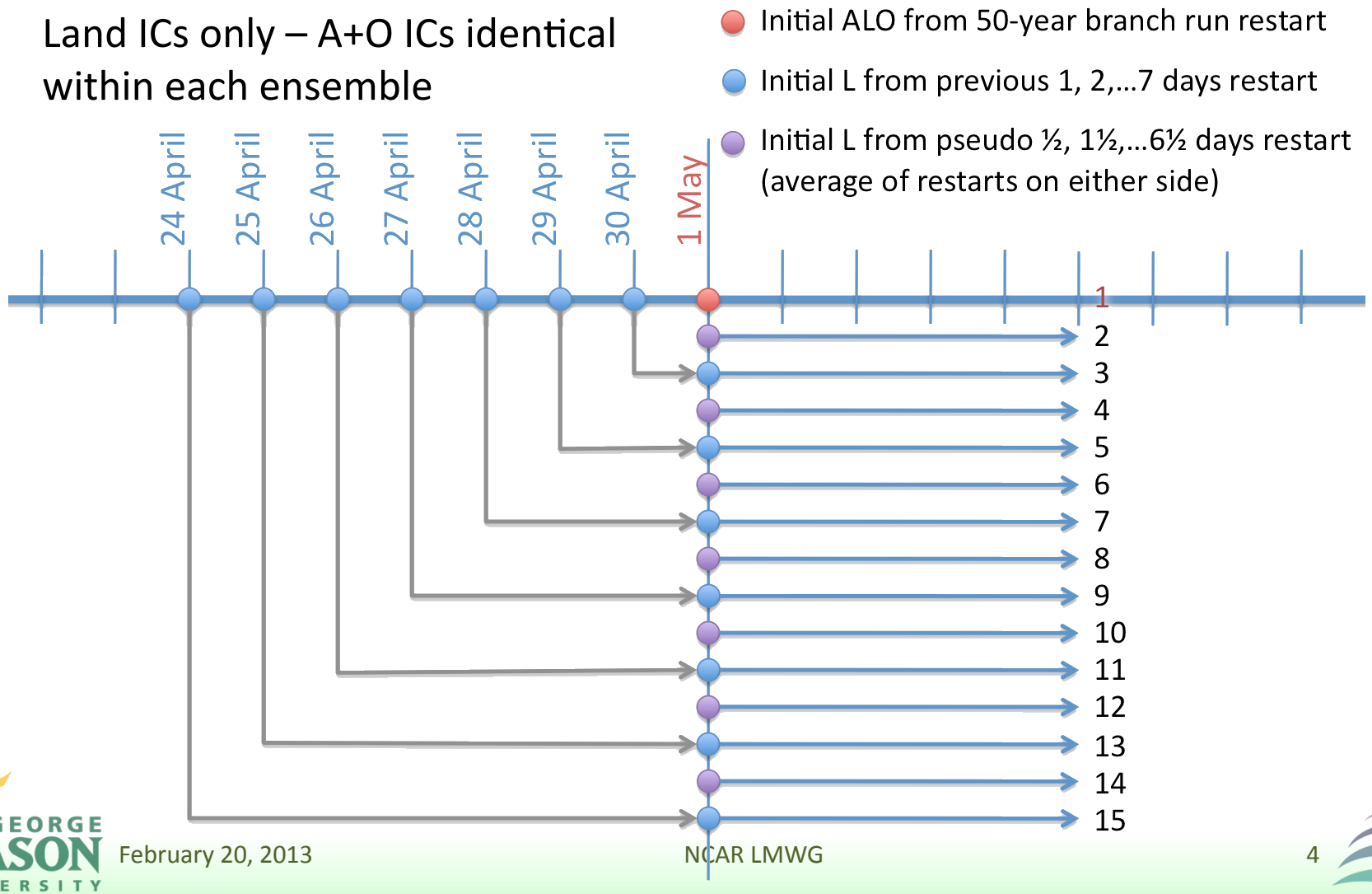


- Cases chosen to sample 5 El Niño, 5 La Niña and 5 Neutral seasons from 50-year branch run.
- Each case (numbered) spawns 14 perturbed runs (ensemble of 15)
- Each ensemble member has identical initial atmosphere and ocean from branch run.
- For the *Large Perturbation* ensembles, initial land states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

Can rearrange to have 15 ensembles with same land IC, shuffled A+O

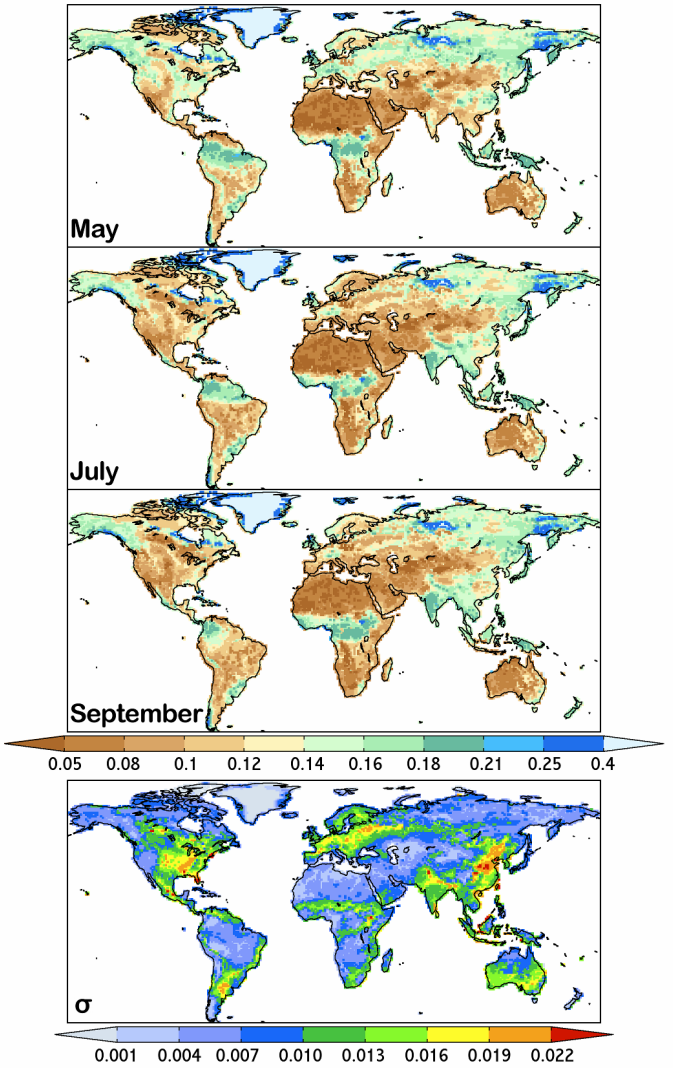
Small Perturbation Ensembles

Land ICs only – A+O ICs identical within each ensemble



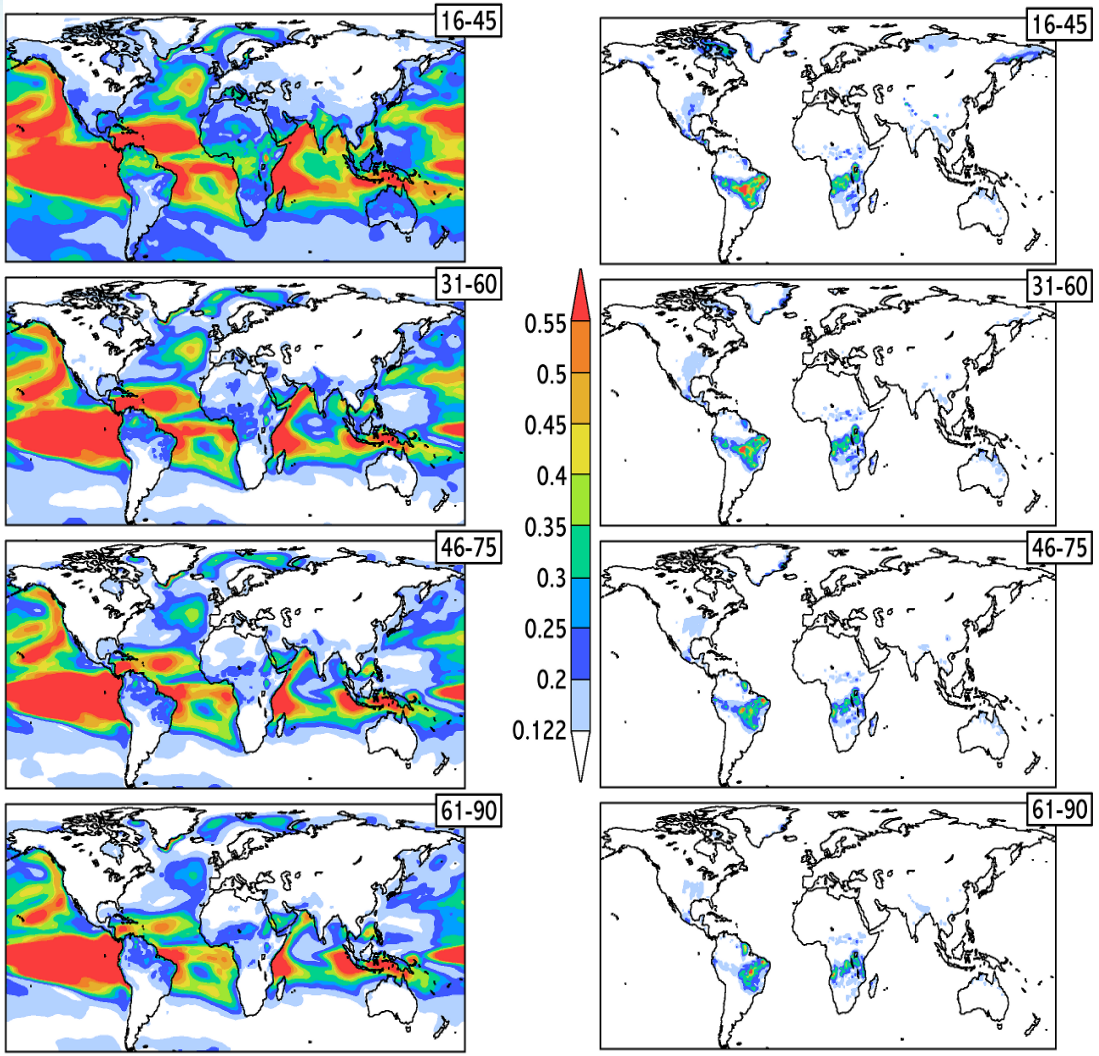
Soil Wetness in CCSM4

- Monthly means across NH spring and summer …
- Interannual standard deviation (bottom)
  - Variability highest in the agricultural zones, monsoon areas.
  - If soil moisture lends predictability to climate, we might expect it there…



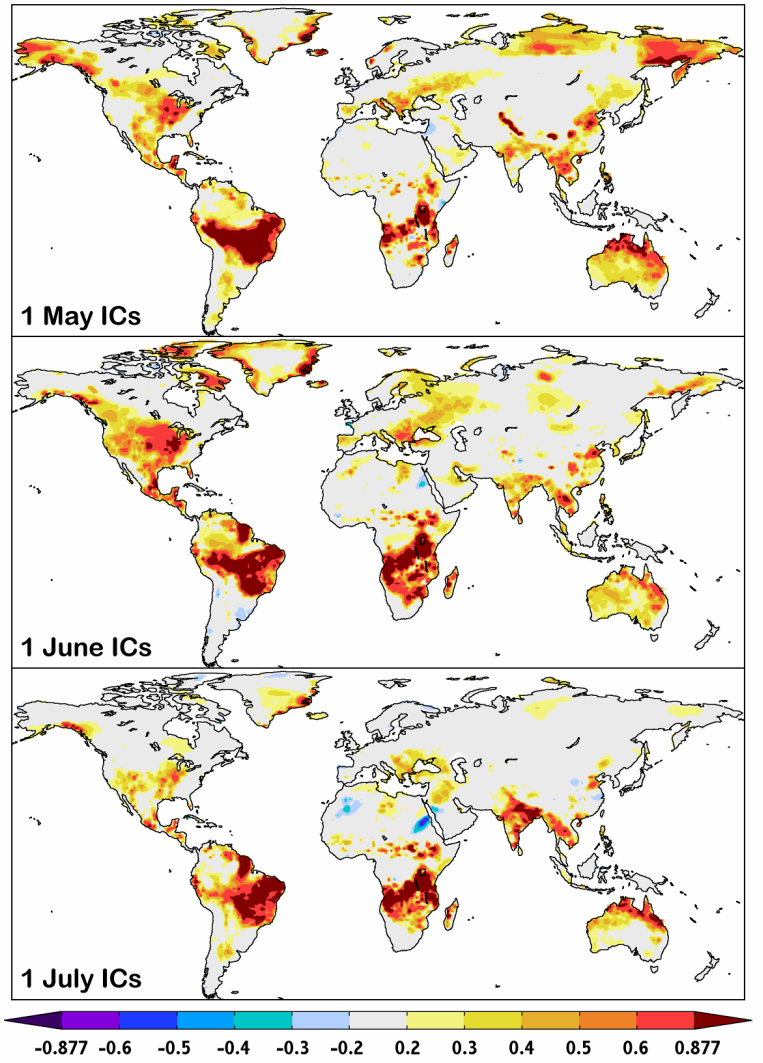
Predictability

- Signal/Total ratio of 30-day mean T_{2m} at various leads from ocean & atmosphere ICs (left) and land ICs (right).
- Land seems very weak because atmosphere randomized within ensembles - *unfair*



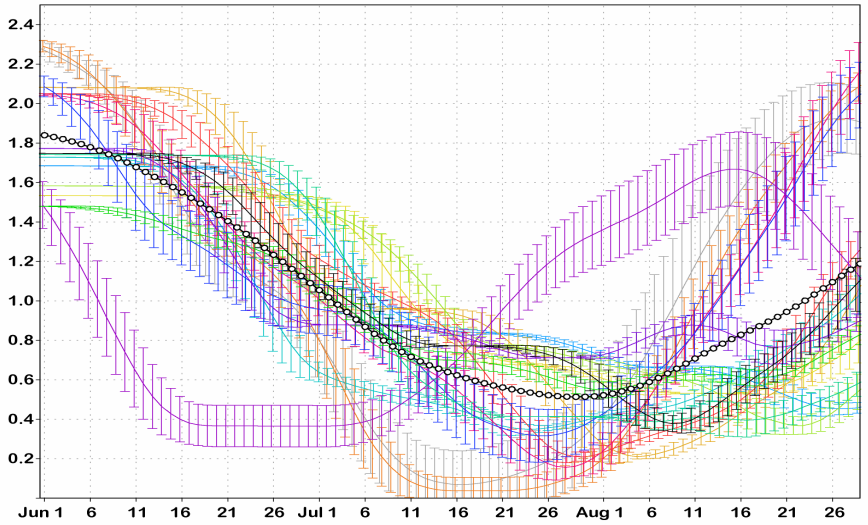
A Fairer Metric

- Change in 31-90 day predictability from realistic (small perturbation) land ICs (relative to randomized land ICs)
- Many of those ag and monsoon areas are lighting up!
- But what's happening over Brazil and southern Africa?



C4 Screwiness

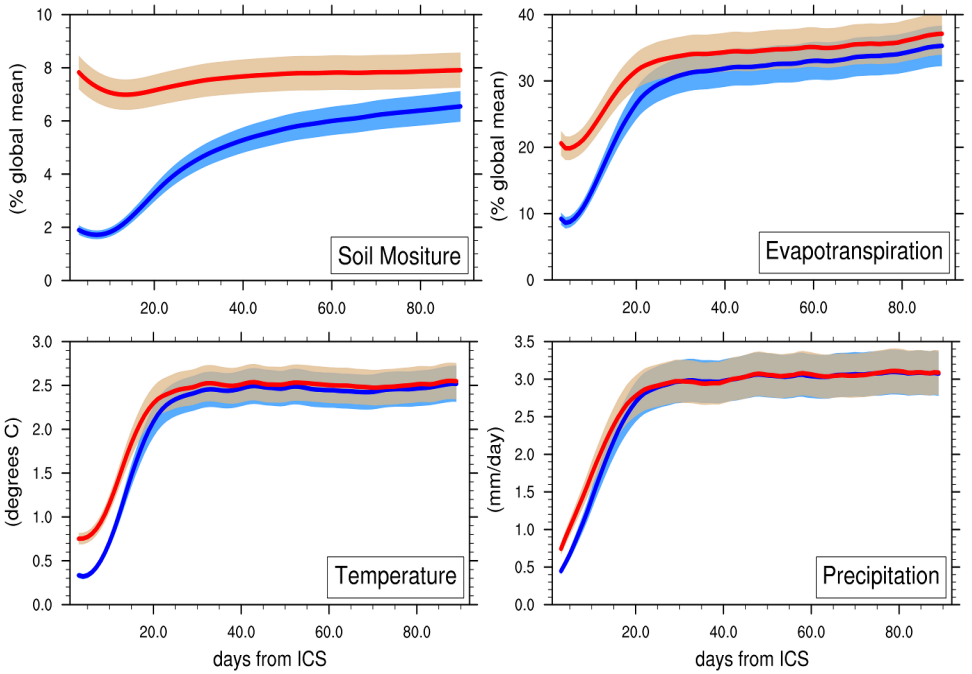
- Daily LAI averaged over Mato Grosso region where the C4 grass PFT ≥ 2/3 of grid box.
- Each line = ensemble mean and ±1σ from the ca. 2000 forecasts.
- Black line = grand mean.



- Strong periodicity – if the LAI starts high, it goes low after ≈1 month, then back high after another month (and vice versa).
- Not realistic – artificial predictability from periodicity.

Global impacts of SM ICs

- Global (land) RMS across ensemble members
  - May, June & July ICs combined
  - 5-day centered running mean
  - Shading: 95% envelope
- SM remains distinct: 90 days
- ET about 3 weeks
- T_{2m}: 16 days
- Precip: 12 days

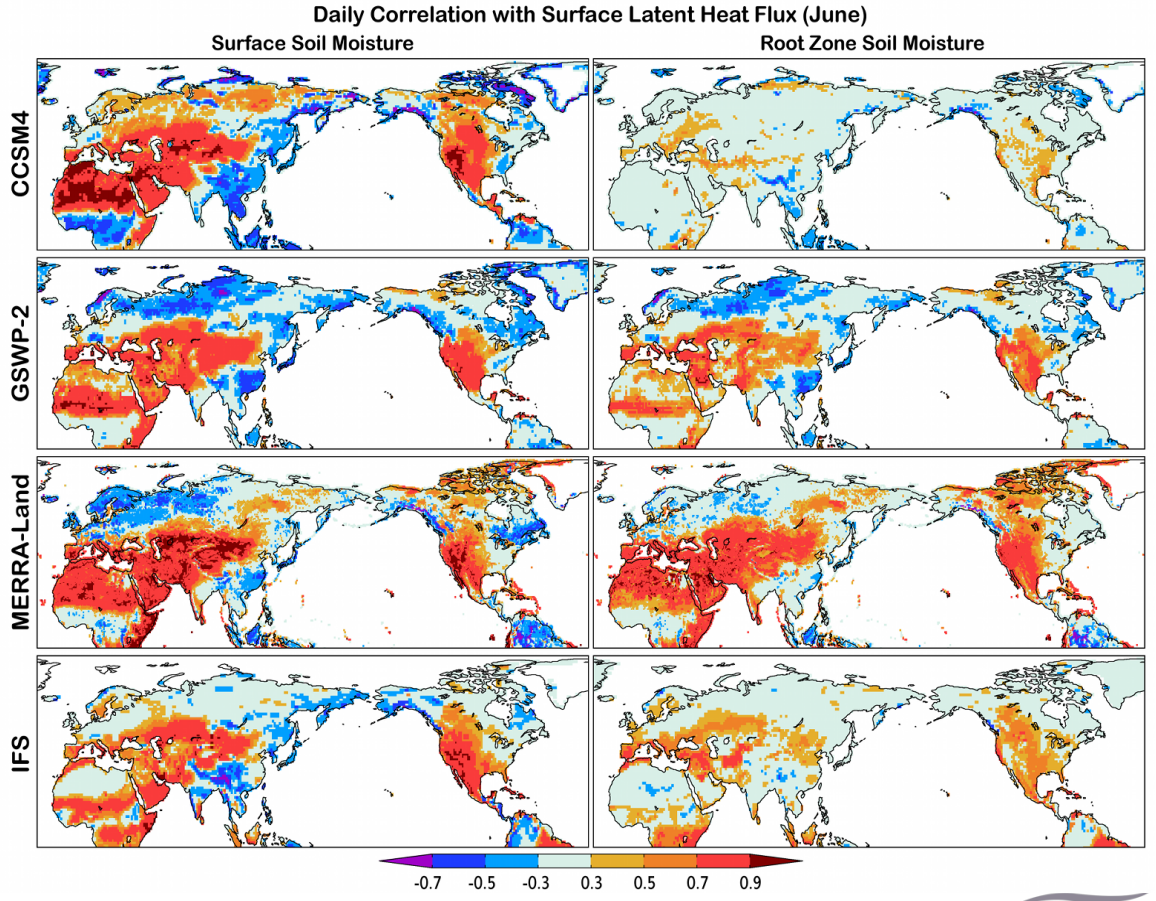


Random Land ICs, same Atm and Ocean ICs

Realistic Land ICs, same Atm and Ocean ICs

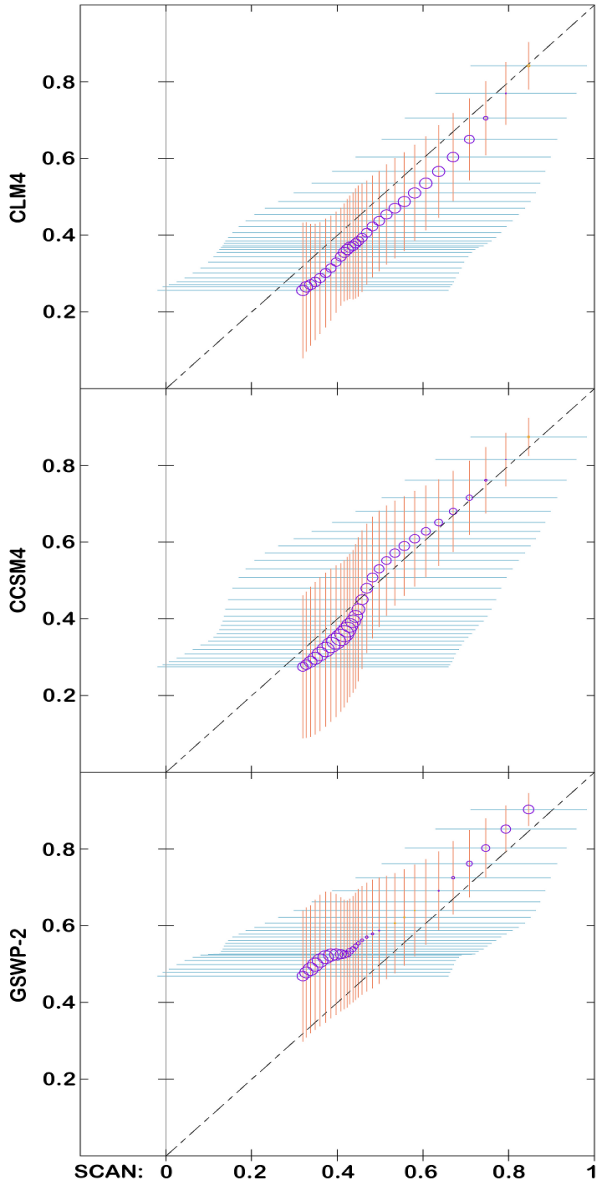
Coupling - Model Dependencies

- Compared to other coupled and offline LSMs, CCSM4 has a weak connection between subsurface (~0.5-1m, for CLM layer 7) soil moisture and LHF.



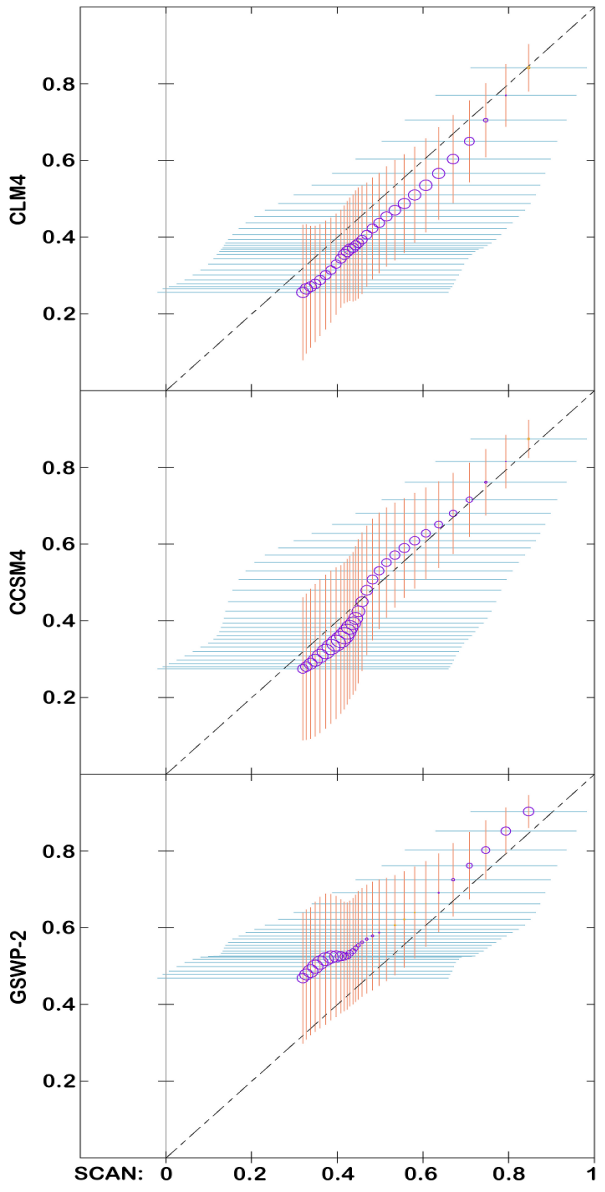
Soil Moisture Memory

- USDA SCAN point soil moisture measurements compared to CLM4 offline, CCSM4 and GSWP-2 (~1°).
  - Lagged autocorrelation of running 7-day means with early June anomalies.
  - Horizontal & vertical lines show range of values across US stations / grid boxes.



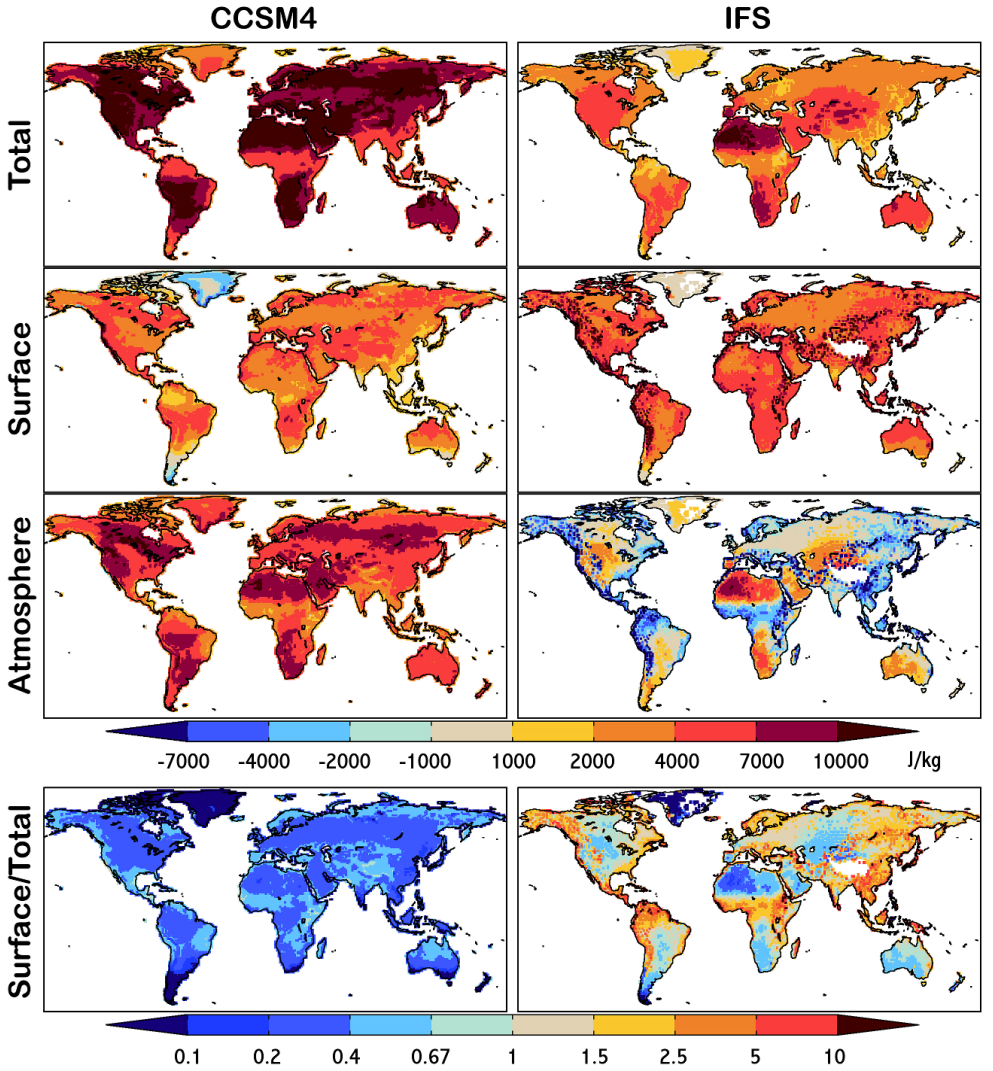
Soil Moisture Memory

- Because of scale differences, we expect gridded models to have more memory than point obs (all else being equal).
- CCSM4 is near or even a little shorter than obs (longer lags)
- Offline CLM4 has even shorter memory (used Sheffield et al. forcing, not Qian)
- All models show too little spatial variability (scale issue again).



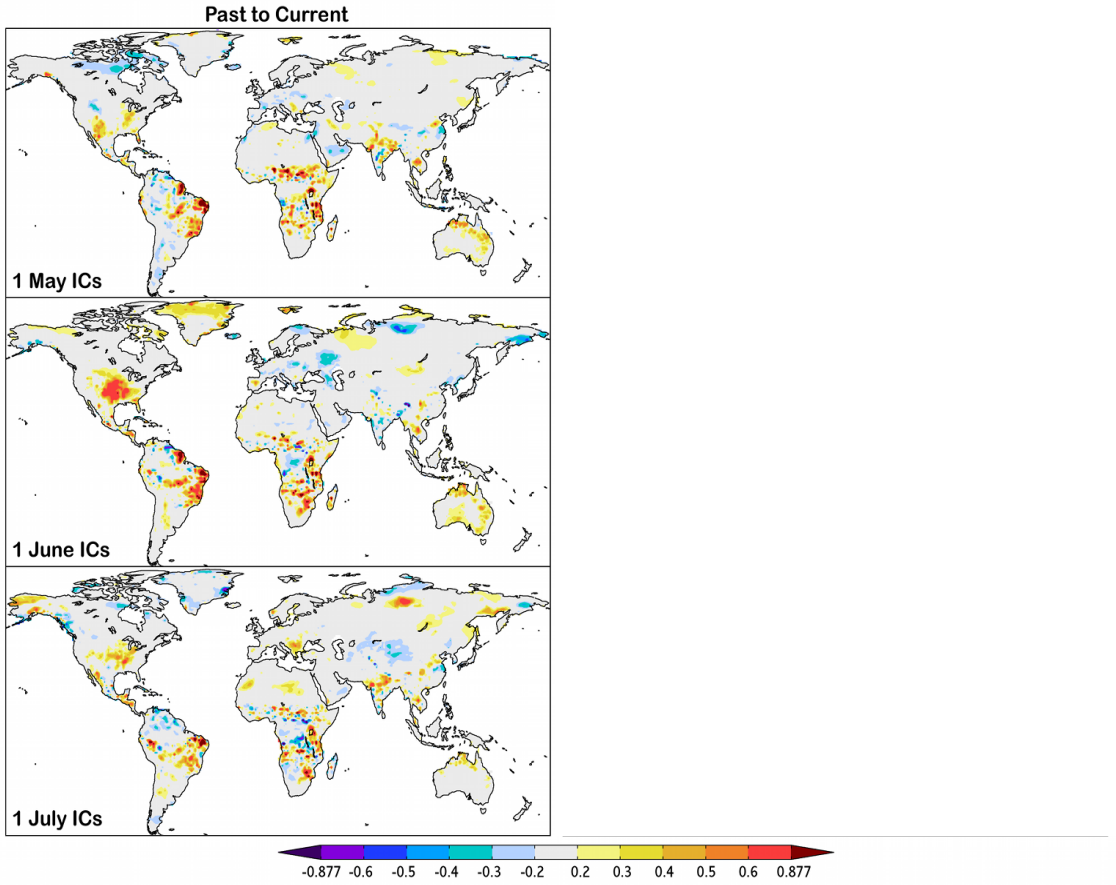
PBL Linkages

- Santanello et al. (2009, 2011) metrics for:
  - Total daytime PBL thermal heating
  - Heating by SHF (Surface)
  - Entrainment + advection (Atmosphere)
- Appears to be too vigorous entrainment from free troposphere (vs. ECMWF), swamps land surface forcing.



Predictability in a Changing Climate

- Predictability from land surface ICs increased from pre-industrial to current.
  - Mostly associated with land use change



Predictability in a Changing Climate

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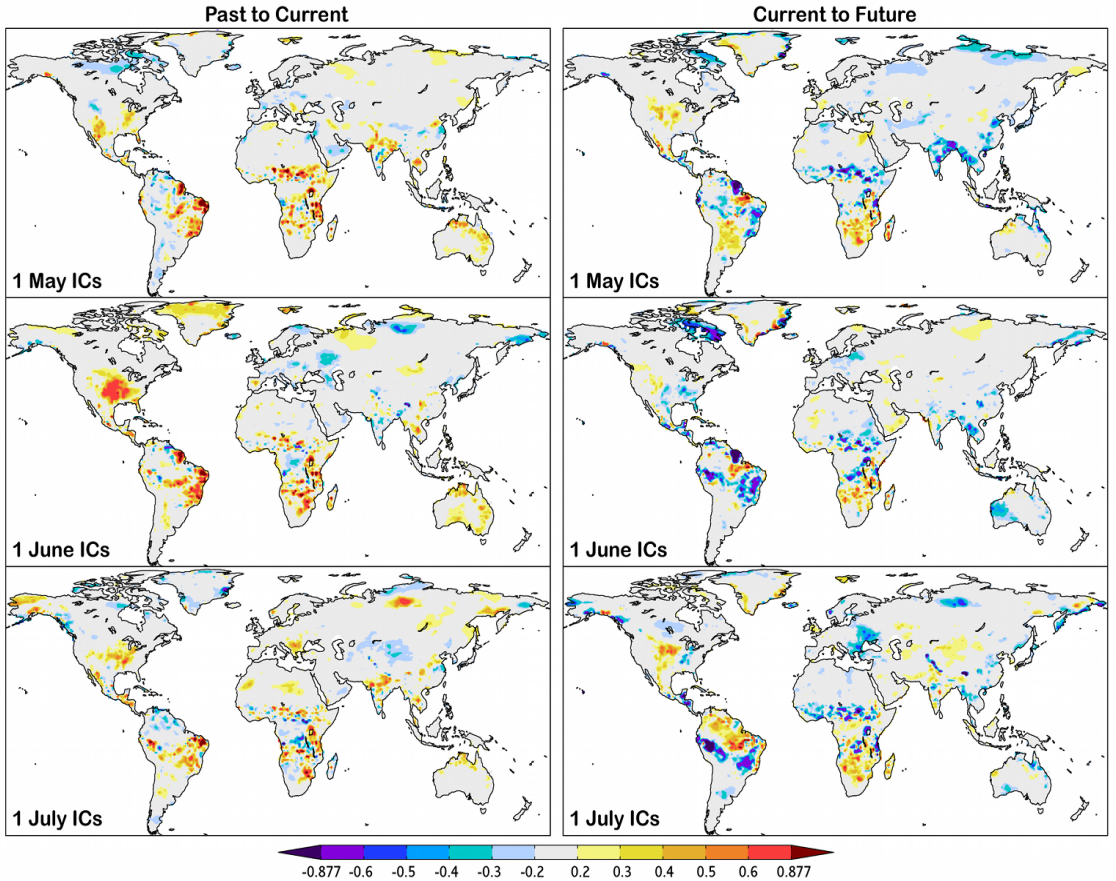
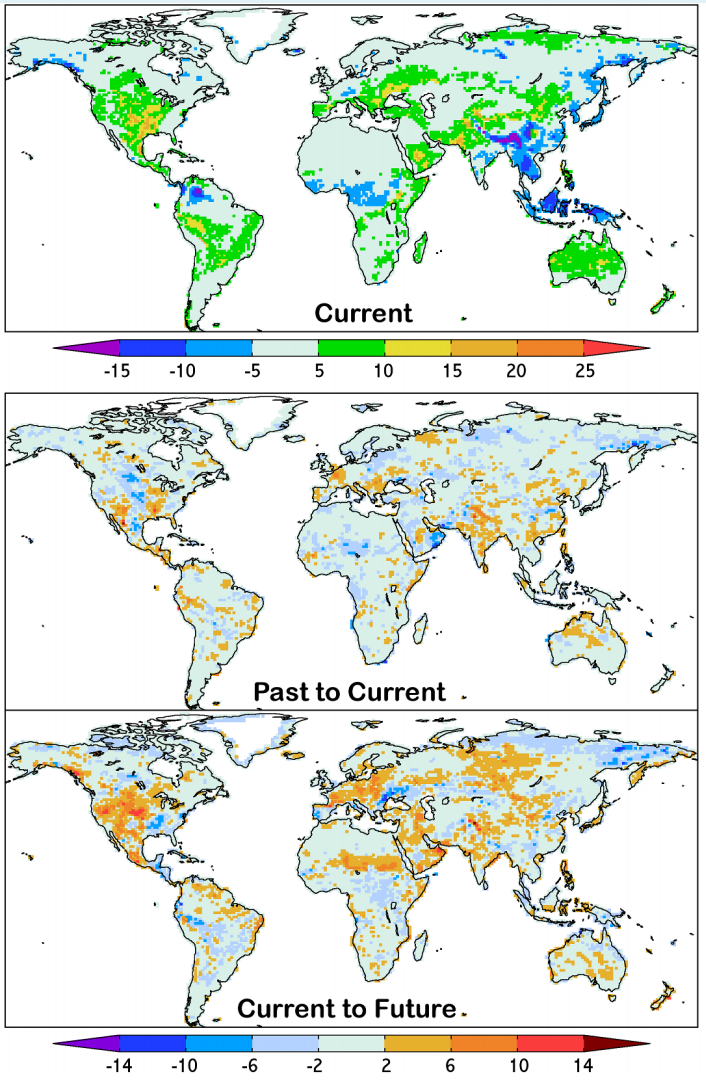
  - Mostly associated with land use change
- Future land use changes mostly in tropics and STs
  - There the effects are mainly negative



Coupling Index

- Product of $r_{LHF,SM}$ and σ_{LHF}.
- Changes past-to-present noisy, weakly positive.
- Future – expansion of range of strong summer land-atmosphere coupling.
- Agrees with CMIP5 model consensus.



Conclusions

- Some significant expansion in areas of strong land-atmosphere coupling for future climate.
- Predictability increased with ag expansion in North America, may decrease where ag expands at low-latitudes.
- We see some issues with vegetation phenology, land-atmosphere coupling strength and soil moisture memory that may weaken overall results.
- We expected land-driven predictability to arise from land-atmosphere coupling, but we do not see this connection for future climate in CCSM – problem with model (PBL? Convective parameterization? Phenology?) or theory?


Thank You