Role of land surface in sub-seasonal to seasonal climate predictability

Sanjiv Kumar
Post-doctoral Research Scientist
Center for Ocean-Land-Atmosphere Studies
George Mason University
Fairfax, VA

Visiting Scientist
National Center for Atmospheric Research
Boulder, CO

References/Acknowledgement

1. Straus et al. (2013). The COLA Intraseasonal-to-Interannual Predictability Project Scientific Motivation and Technical Approach, *COLA Technical Report*, 325, 31pp.

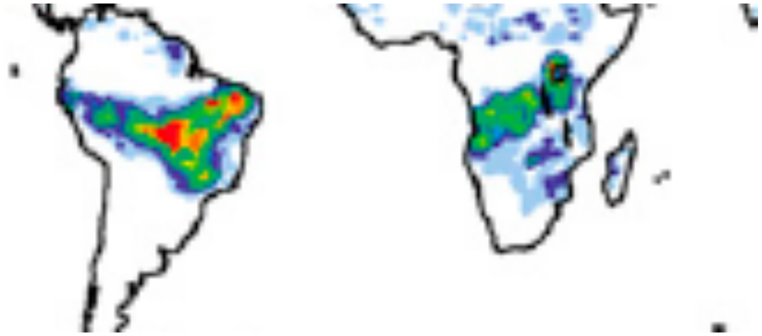
2. Dirmeyer et al. (2013). Model Estimates of Land-Driven Predictability in a Changing Climate, *Journal of Climate*, 26, 8495-8512

3. DelSole et al. (2014). Changes in seasonal Predictability due to global warming, *Journal of Climate*, 27, 300-311.

- ❑ **Thanks to Dave Lawrence and Paul A. Dirmeyer for their valuable inputs**

What's New

1) Only for North America, avoids spurious predictability regions in sub-tropical C4 grass regions

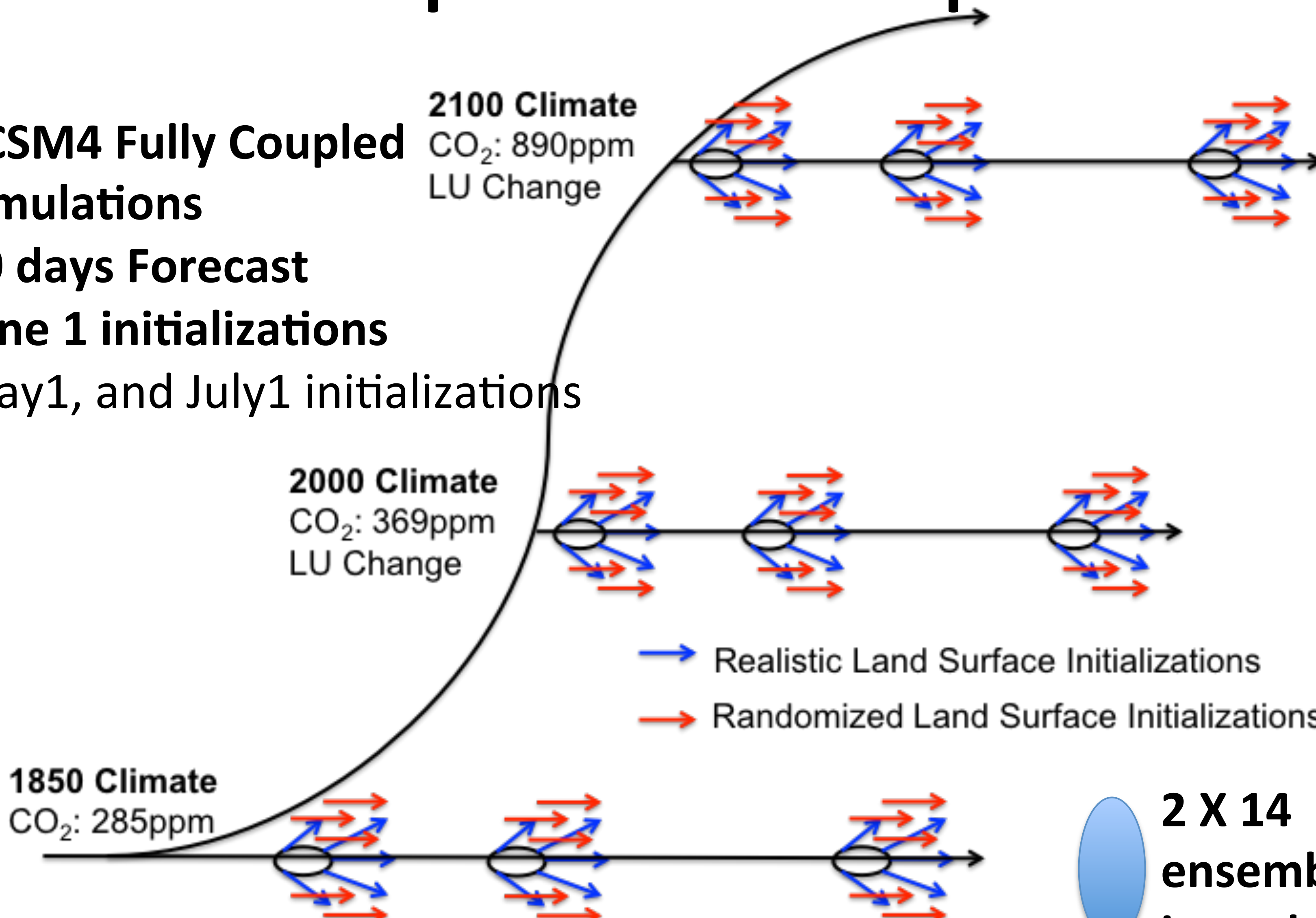


Dirmeyer et al. (2013)

2) Linking climate research to policy/management decisions

Experimental Setup

- **CCSM4 Fully Coupled Simulations**
- **90 days Forecast**
- **June 1 initializations**
- May1, and July1 initializations



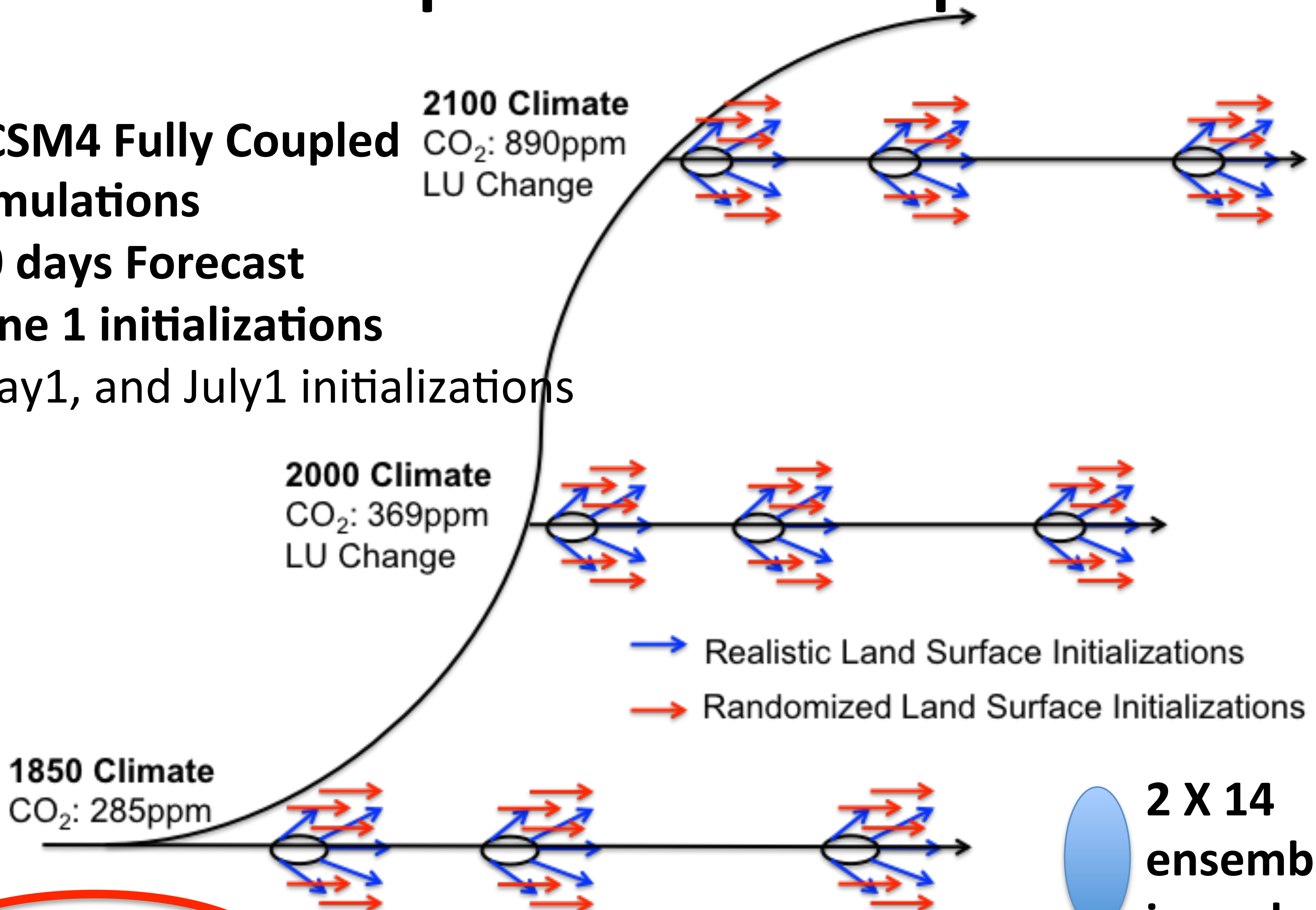
2 X 14 ensembles in each case

Kumar et al., in prep.

15 Cases/years in each climate

Experimental Setup

- CCSM4 Fully Coupled Simulations
- 90 days Forecast
- June 1 initializations
- May1, and July1 initializations

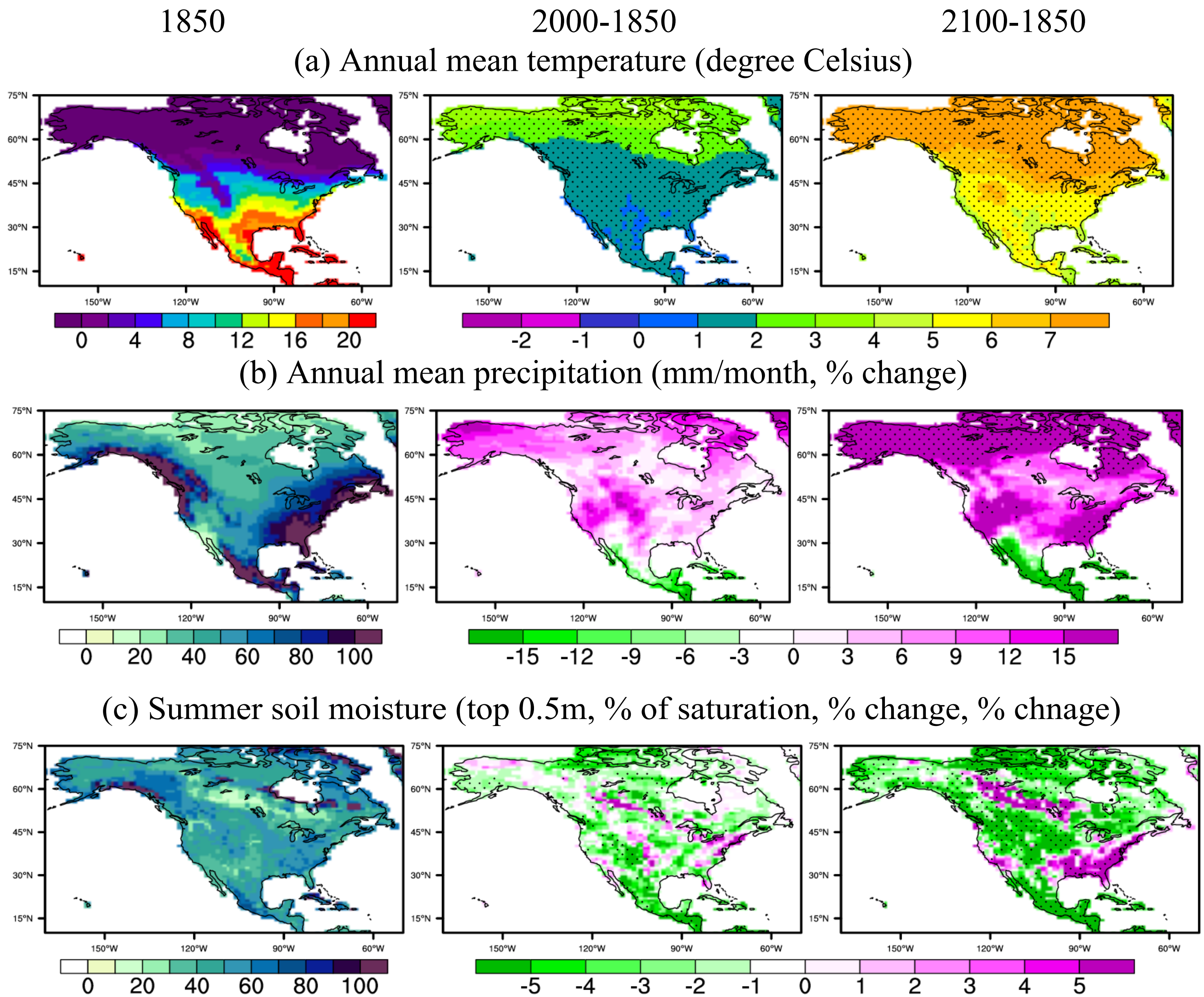


2 X 14 ensembles in each case

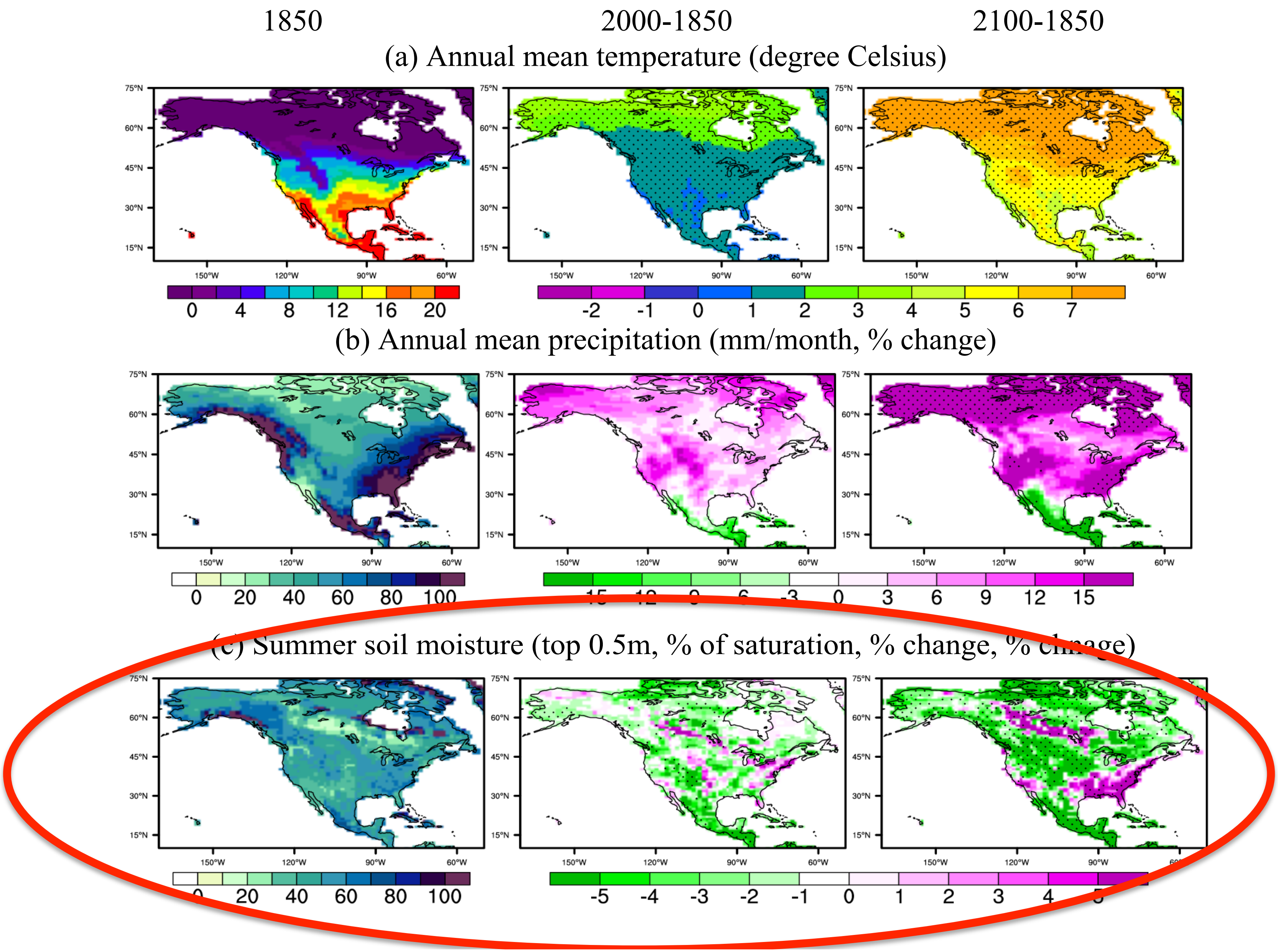
15 Cases/years in each climate

Kumar et al., in prep.

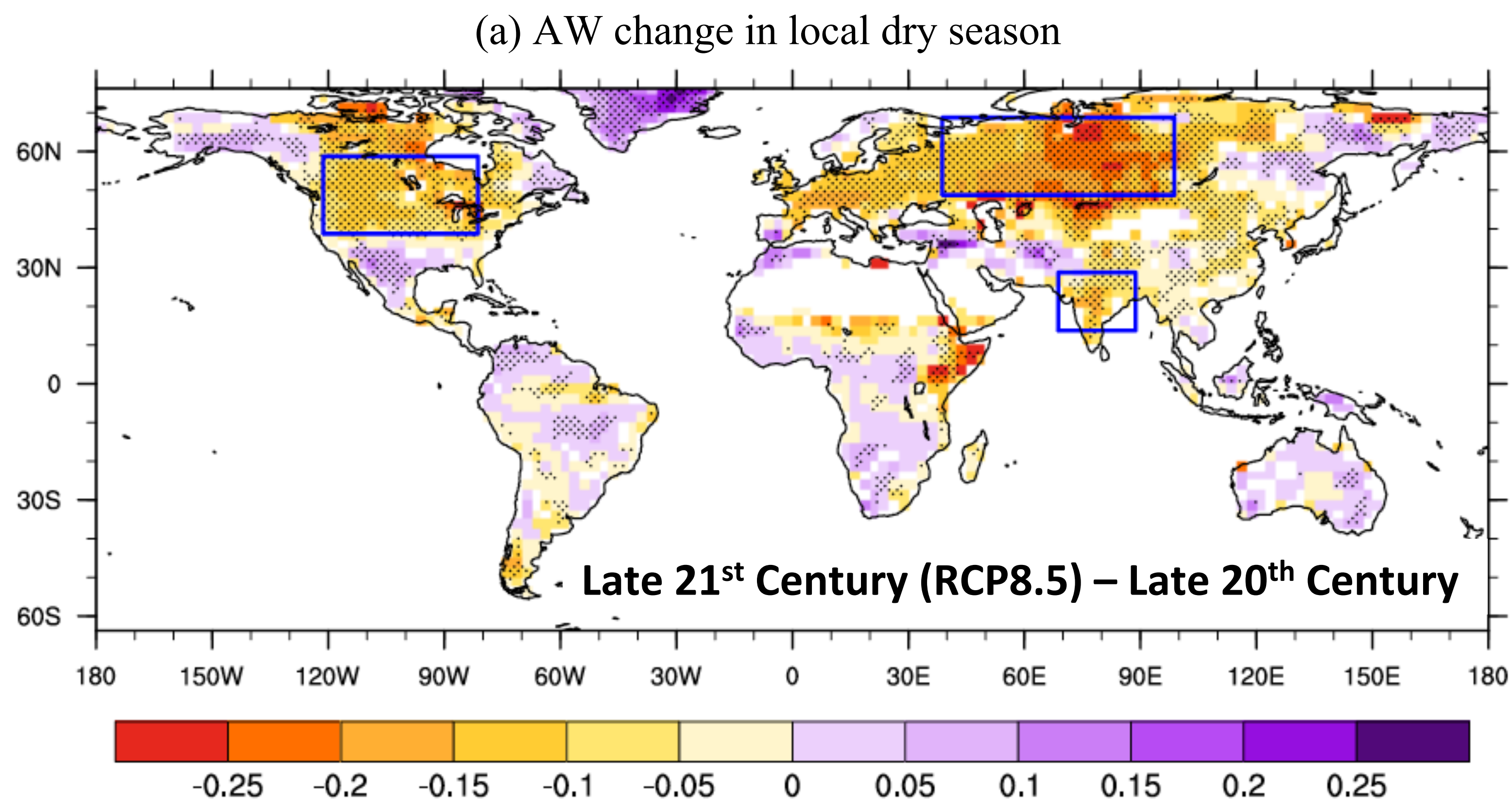
Climate Change in CCSM4



Climate Change in CCSM4



Summer Drying in CMIP5

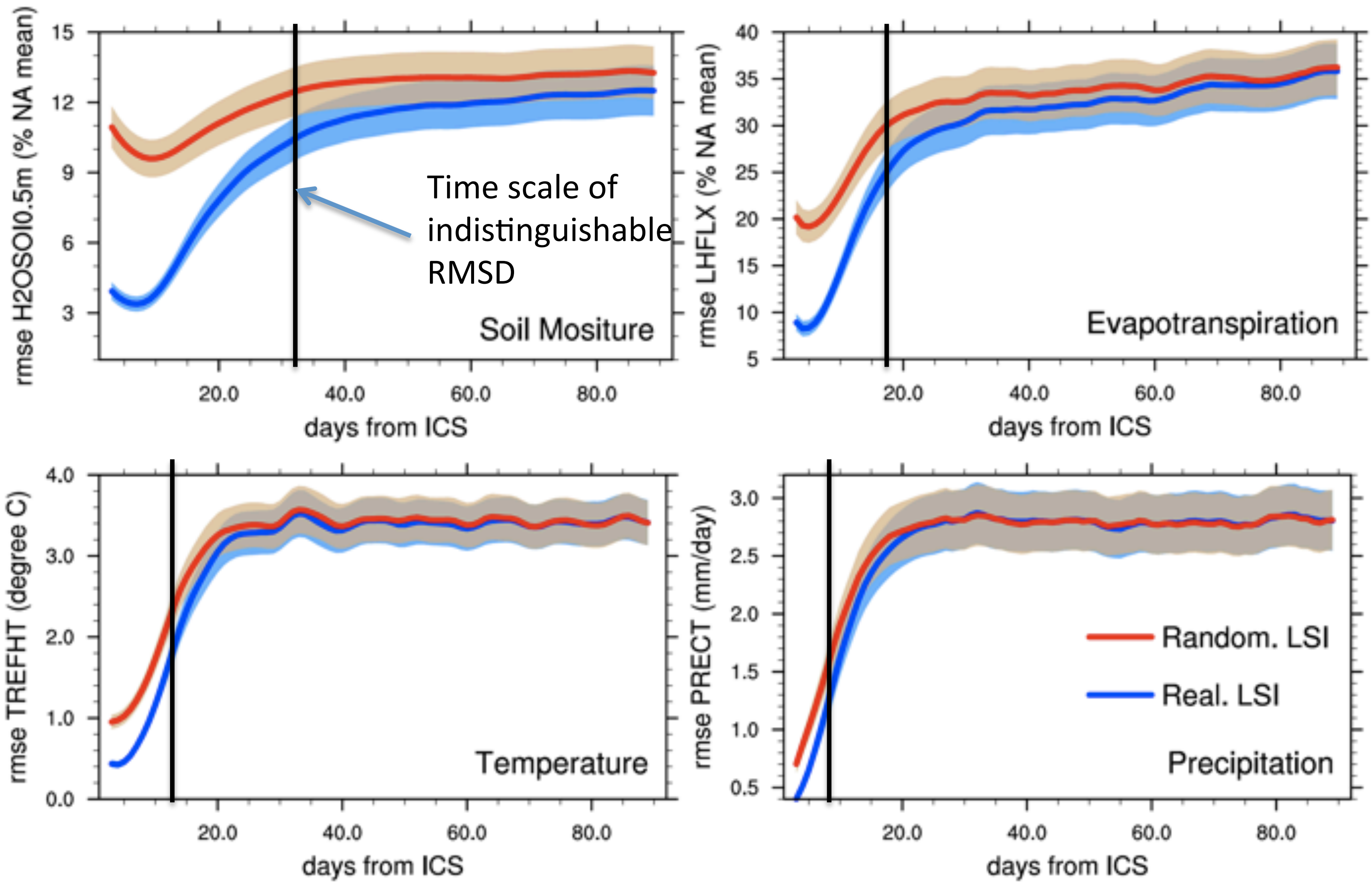


- ❑ Available Water (AW) = $(P_{month}-ET_{month})/P_{climo}$
- ❑ Twenty CMIP5 climate models including CCSM4, and CESM1-CAM5

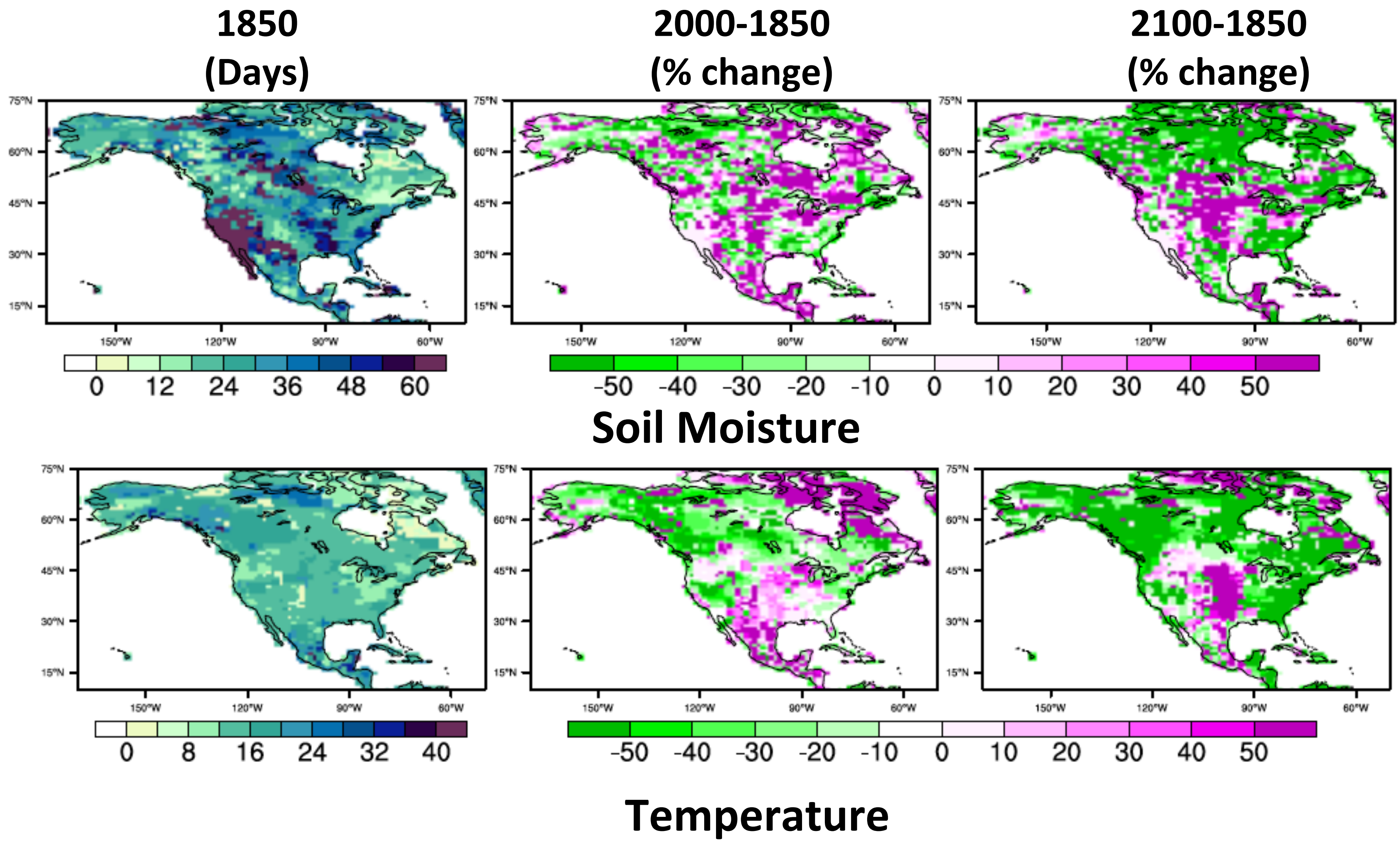
Kumar et al. (2014), Earth's Future, in press

Root Mean Square Difference in 90 days Forecast

(2000 climate)



Time Scale of indistinguishable RMSD (initial condition predictability)

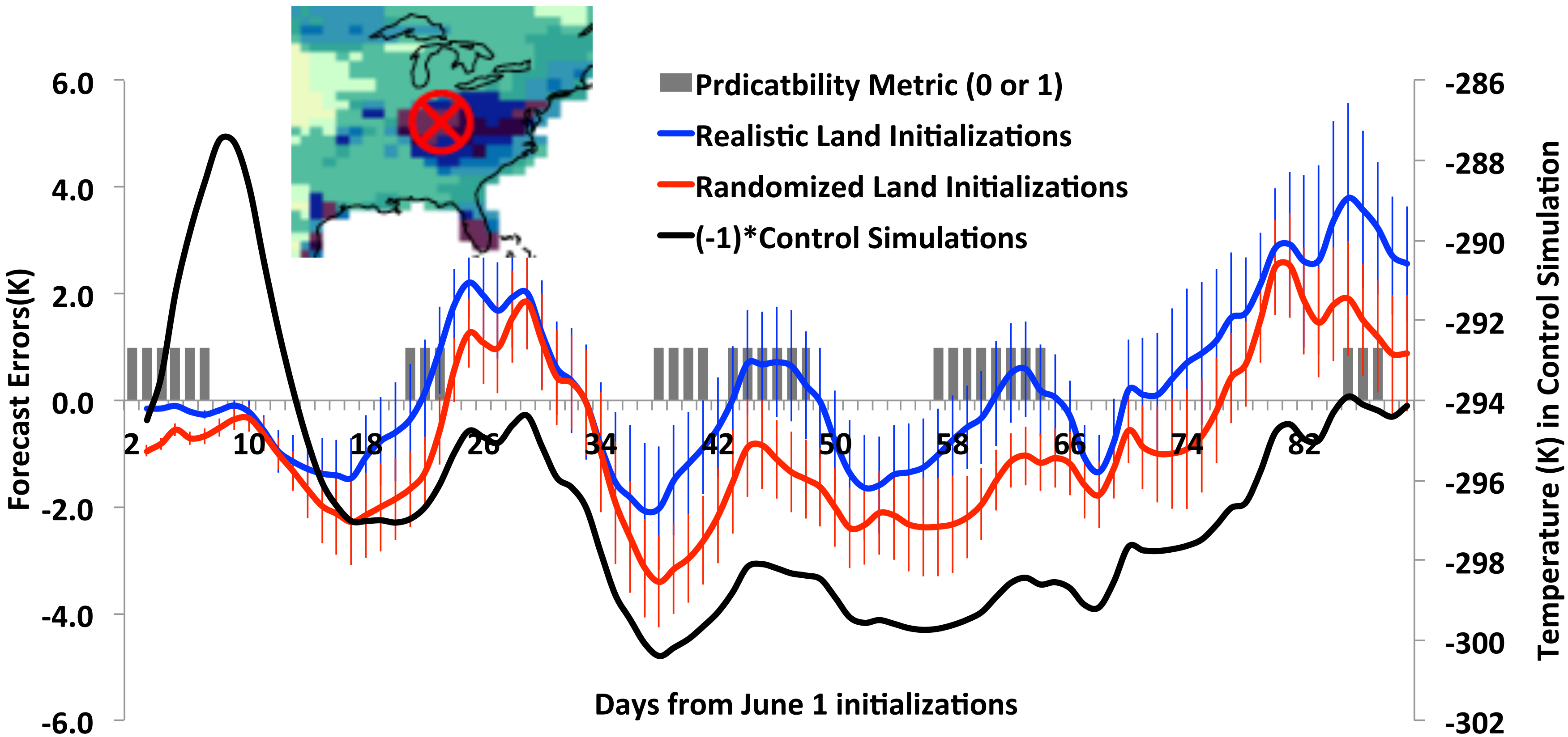


Time Scale of indistinguishable RMSD (initial condition predictability)

Climate	Soil Moisture	Temperature
1850	**34.4 days**	**14.5 days**
2000	37.3 days ↑	13.9 days ↓
2100	30.8 days ↓	9.8 days ↓

Predictability Metric

Predictability beyond two weeks: predictability due to memory



- ❑ Temperature Predictability

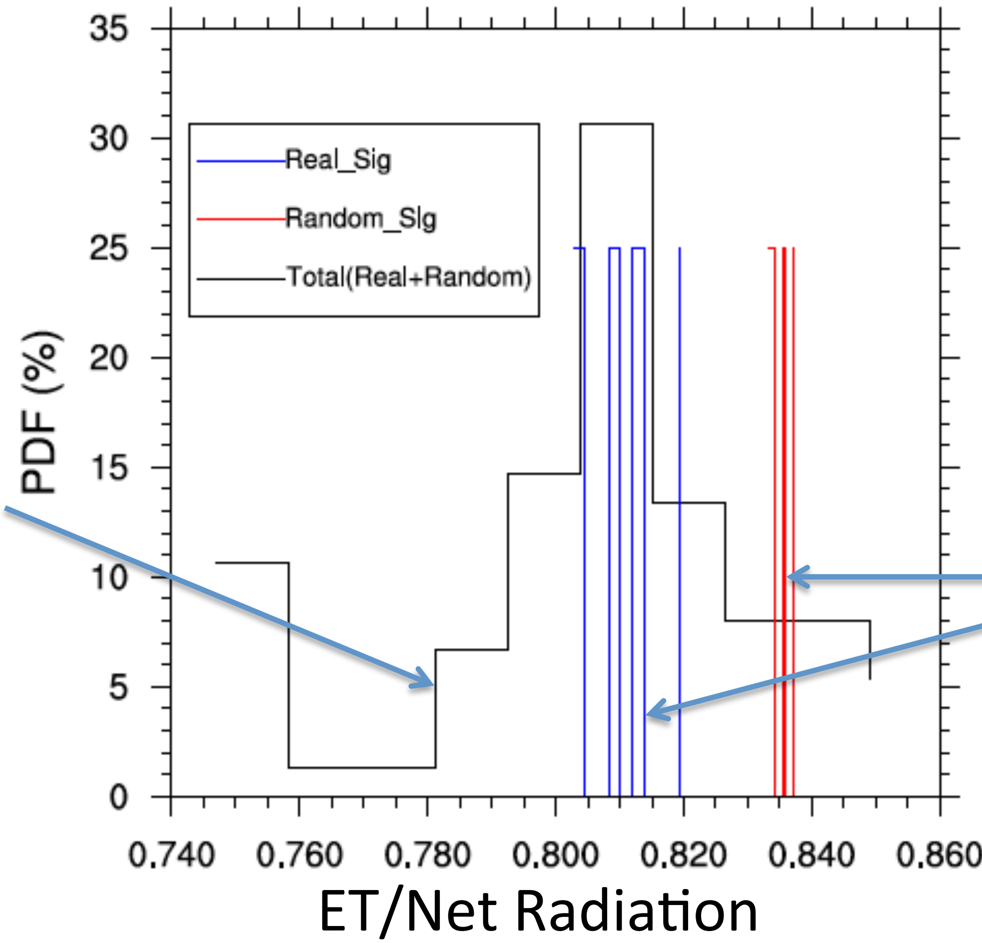
Alignment mismatch - an excel problem

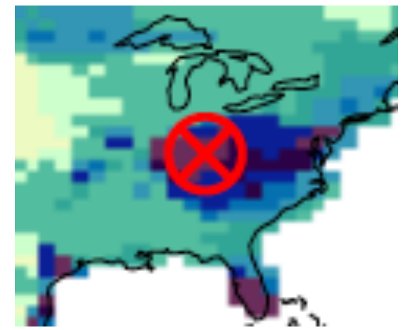
- ❑ A point in the Eastern USA, a single case in 1850 climate
- ❑ A form of Student's t-test

Kumar et al., in prep.

Are random noise … or something related to land?

2 X 15 X 75
data points



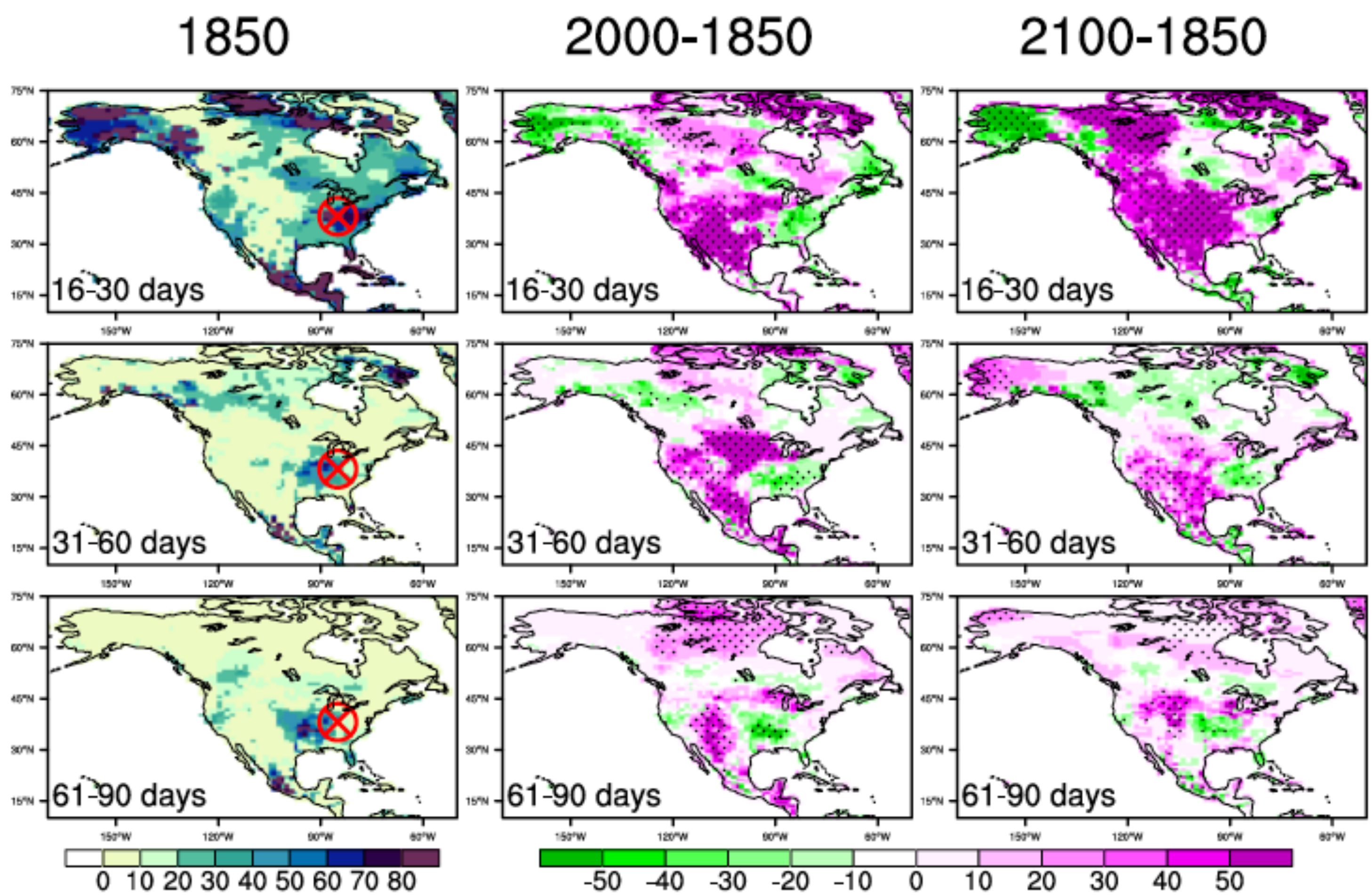


60 data
points

- ❑ A point in the Eastern USA, all 15 cases in 1850 climate
- ❑ Sixteen to 90 days forecasts

Predictability beyond two weeks

% number of days when realistic land surface initializations give significantly different forecast errors than randomized land surface initializations



Temperature Predictability using June 1 Initializations

Predictability beyond two weeks

predictability due to memory

Temperature Predictability using May 1 (May IC), June 1 (June IC), and July 1 (July IC) initializations

	16 to 30 days			31 to 60 days			61 to 90 days			Row Avg.
	May IC	June IC	July IC	May IC	June IC	July IC	May IC	June IC	July IC	
Pre-industrial (1850) climate	53 (36-59)	35 (27-45)	48 (36-58)	15 (13-24)	12 (12-20)	16 (14-26)	09 (07-18)	09 (10-18)	09 (08-25)	23
Present (2000) climate	***33***	***49***	*53*	15	***23***	***12***	***18***	14	***05***	25
Future (2100) climate	54	***56***	35	14	16	22	08	12	08	25
Average for three climates	46			16			10			

- ❑ A generally increased (~ 9%) temperature predictability in the present and future climate compared to pre-industrial climate

Kumar et al., in prep.

Predictability beyond two weeks

predictability due to memory

Temperature Predictability using May 1 (May IC), June 1 (June IC), and July 1 (July IC) initializations

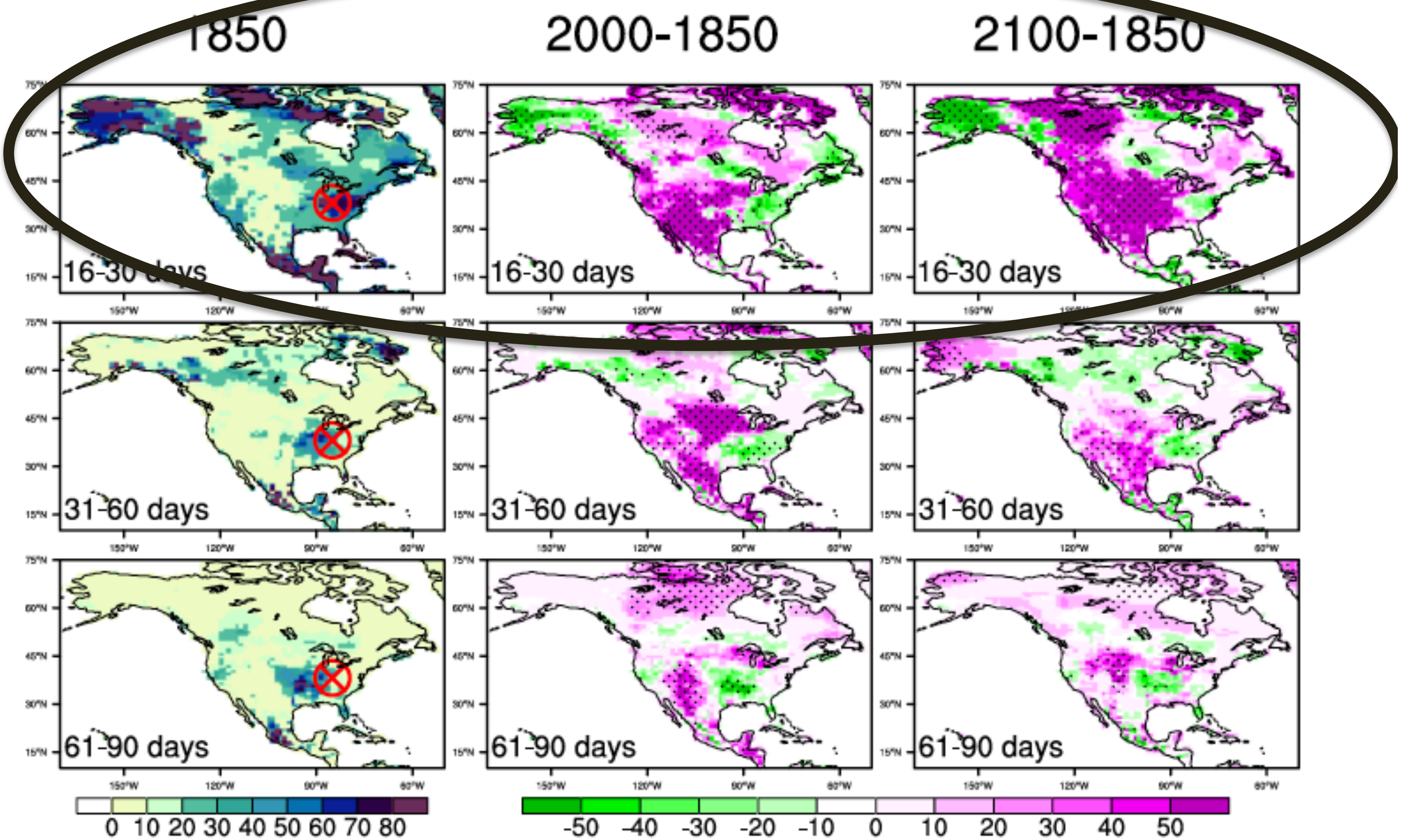
	16 to 30 days			31 to 60 days			61 to 90 days			Row Avg.
	May IC	June IC	July IC	May IC	June IC	July IC	May IC	June IC	July IC	
Pre-industrial (1850) climate	53 (36-59)	35 (27-45)	48 (36-58)	15 (13-24)	12 (12-20)	16 (14-26)	09 (07-18)	09 (10-18)	09 (08-25)	23
Present (2000) climate	***33***	***49***	***53***	15	***23***	***12***	***18***	14	***05***	25
Future (2100) climate	54	***56***	35	14	16	22	08	12	08	25
Average for three climates	46			16			10			

- A generally increased (~ 9%) temperature predictability in the present and future climate compared to pre-industrial climate

Kumar et al., in prep.

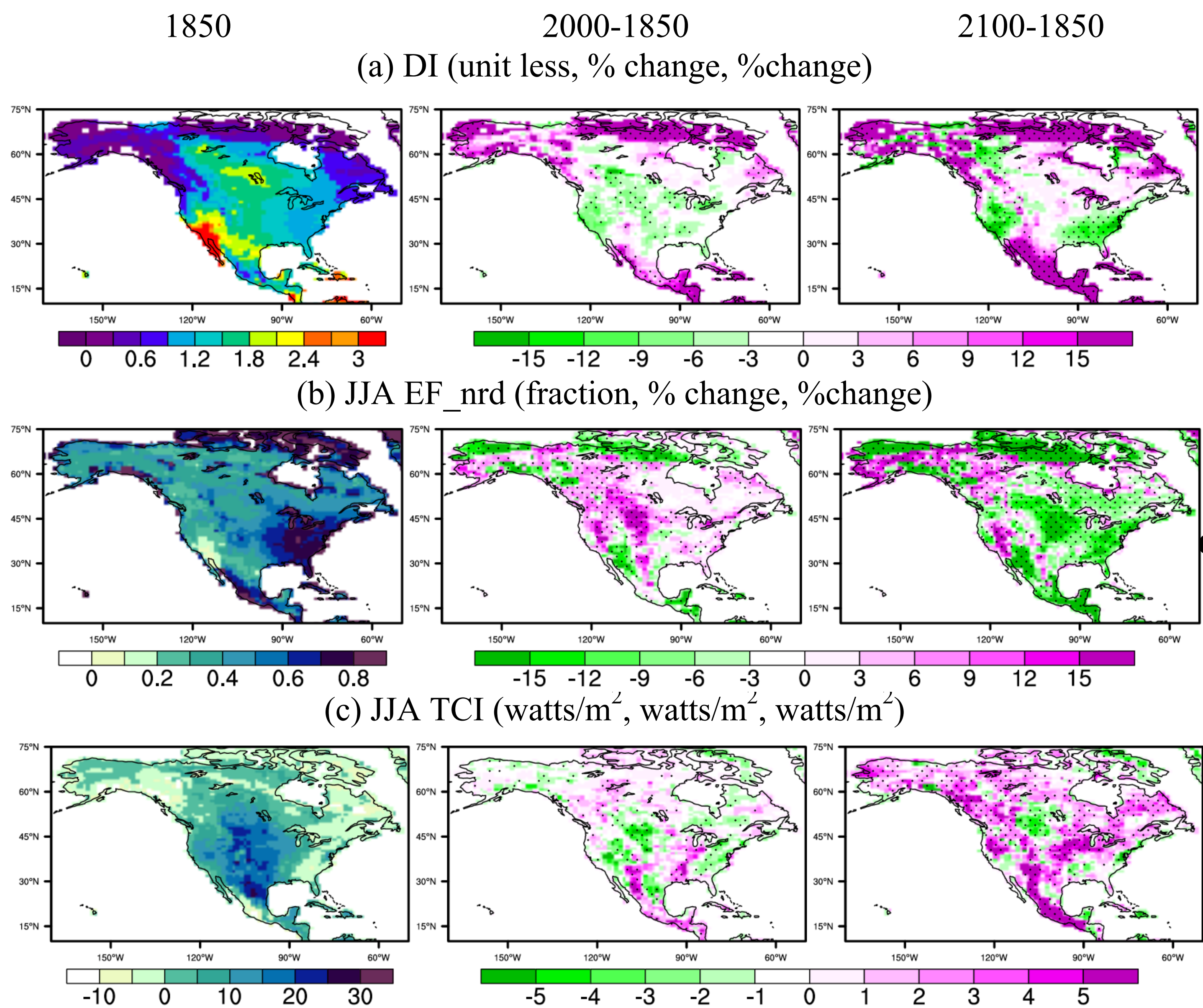
Predictability beyond two weeks

predictability due to memory



Temperature Predictability using June 1 Initializations

Correlations with land related climate change



Dryness Index

Non rainy days evaporative fraction

Terrestrial coupling Index

(Dirmeyer, 2011)

Correlation Results

16 to 30 days, Temperature Predictability Change

2000 predictability change/2100 predictability change

Predictability change	Changes in land related climate variables			
	SM	DI*	EF_nrd	TCI
JJA months				
T Mean	--/--	-0.31/-0.38	0.19/0.30	--/-0.11
T Max	--/--	-0.54/-0.52	0.35/0.37	--/-0.11
T Min	-0.21/--	--/-0.23	--/--	--/--
June month				
T Mean	--/--		0.37/0.43	--/-0.10
T Max	--/0.23		0.54/0.51	0.17/--
T Min	--/0.22		0.29/0.31	--/-0.10

- *For annual mean
- Only statistically significant correlations are shown (~1000 data point)
- Spatial correlations is take care by using equivalent sample size method
- **Correlations results for 30 to 60 days temperature predictability change are similar**

Correlation Results

16 to 30 days, Temperature Predictability Change

Predictability change	Changes in land related climate variables			
	SM	DI*	EF_nrd	TCI
JJA months				
T Mean	--/--	-0.31/-0.38	0.19/0.30	--/-0.11
T Max	--/--	-0.54/-0.52	0.35/0.37	--/-0.11
T Min	-0.21/--	--/-0.23	--/--	--/--
June month				
T Mean	--/--		0.37/0.43	--/-0.10
T Max	--/0.23		0.54/0.51	0.17/--
T Min	--/0.22		0.29/0.31	--/-0.10

− +

- *For annual mean
- Only statistically significant correlations are shown (~1000 data point)
- Spatial correlations is take care by using equivalent sample size method
- **Correlations results for 30 to 60 days temperature predictability change are similar**

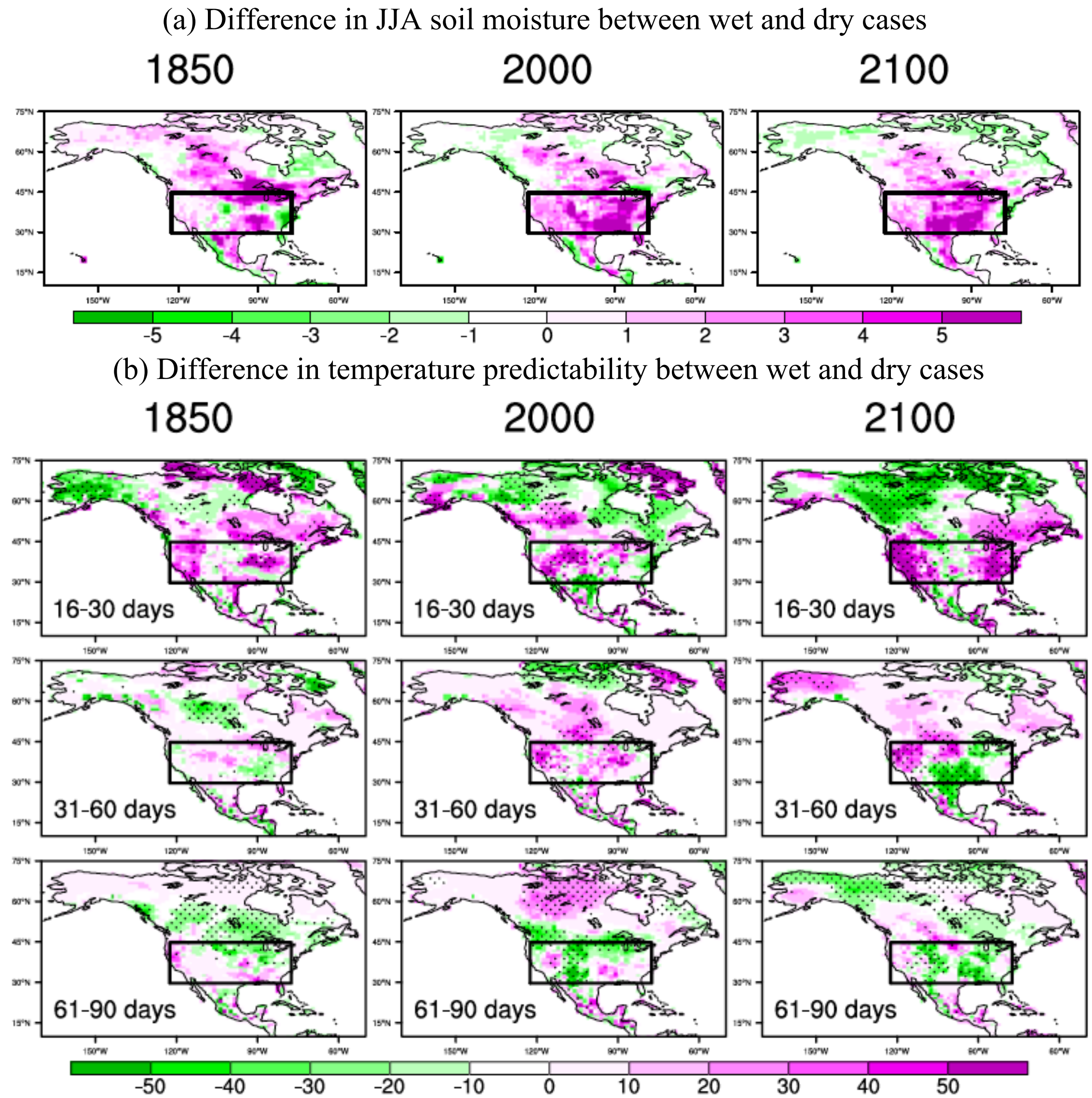
A Hypothesis

- In general, correlations (without additional evidence) does not imply causation.
- **A Hypothesis: A wetter land conditions favor increased land surface contributions to climate predictability compared to dryer land surface conditions**

- Can depend upon season, location, etc.

The Hypothesis Testing Results

- ❑ The ISI experimental setup allows us to test the hypothesis by re-arranging the ensembles
- ❑ Mean temperature predictability change between 8 wet years (in control simulation) and 7 dry years in each climate



The Hypothesis Testing Results

Forecast period	1850	2000	2100	Row Average
	JJA Soil Moisture Difference (% of saturation), USA			
	1.5	3.2	3.0	2.6
	Temperature Predictability Difference (June initialization), USA			
16-30 days	13.6	7.6	23.5	14.9
31-60 days	-0.2	8.3	-5.5	0.9
61-90 days	-4.0	-13.8	-13.5	-10.4

- Average for United States (mid-latitude regions)

Kumar et al., in prep.

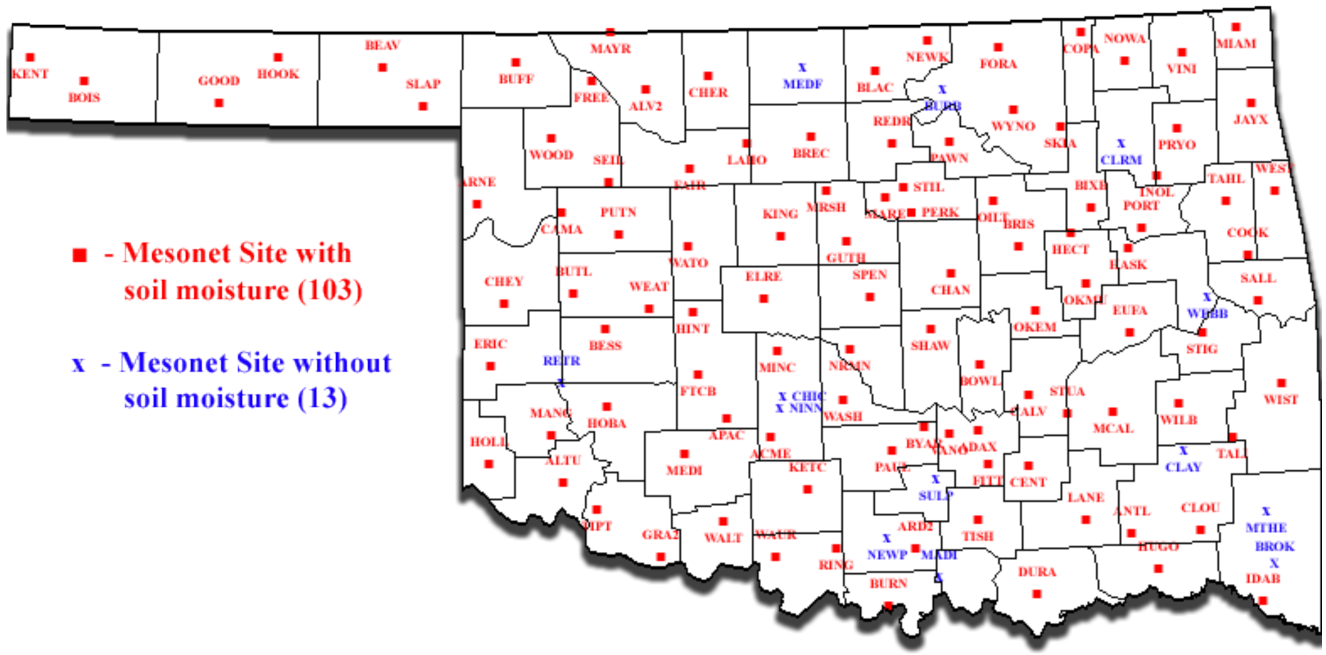
A Related Study

When vegetation feedback is ignored, wetter mean soil moisture in EXP (relative to BASE) leads to higher sensitivity of precipitation to dry anomalies than to wet anomalies, which is the opposite of the comparison in BASE. However, in both BASE and EXP, the impact of dry soil moisture anomalies on subsequent precipitation tends to persist longer than the impact of wet soil moisture anomalies. With

Kim and Wang (2012), Journal of Geophysical Research (Atmosphere).

- ❑ Soil moisture perturbation in ISI experiments (our study) is typically $1/10^{th}$ of soil moisture perturbations in Kim and Wang (2012)

Policy Relevance



- ❑ Funding for soil moisture measurement network (inter-annual variability)
- ❑ Based on forecast if a particular year is going to be wet or dry


Thank You
01/26/2014