Assessing hydro-climate impact of a large-scale perennial biofuel crops expansion over the conterminous U.S.

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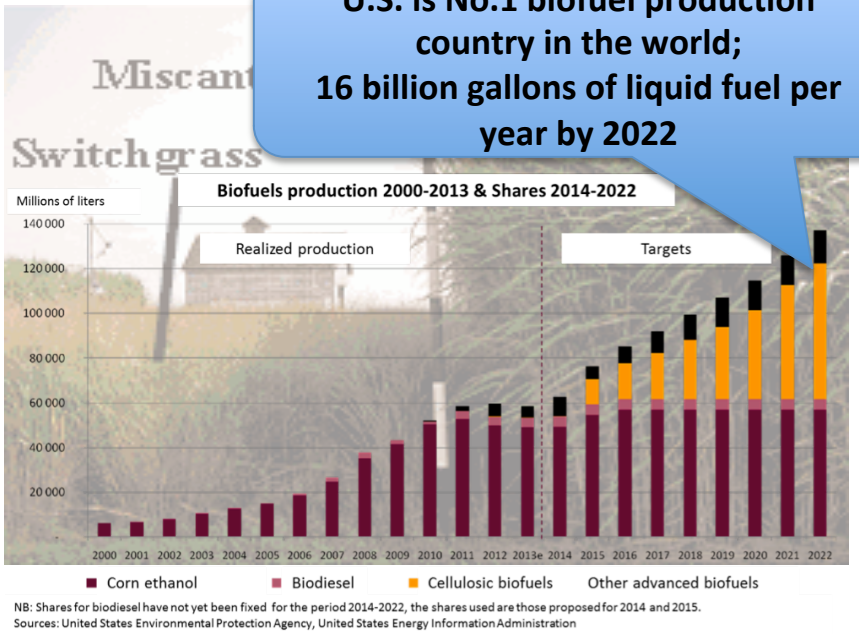
1. Introduction

Importance & Duel feedback impact of Perennial biofuel crops expansion

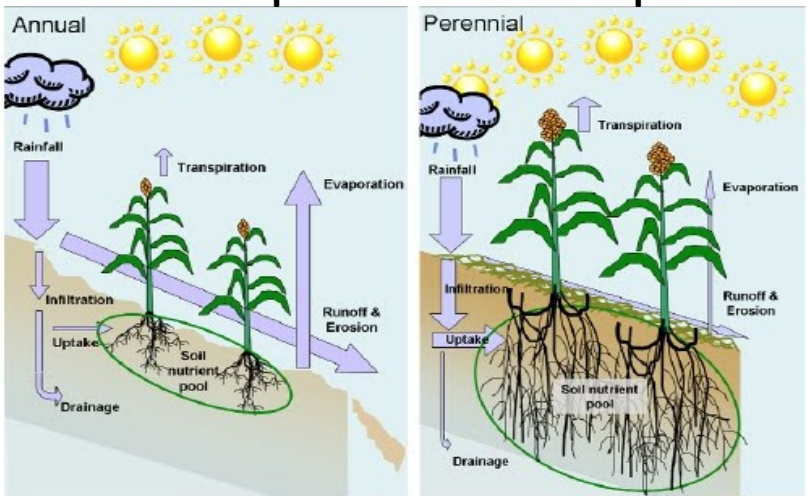
Benefits of this second-generation renewable bioenergy source:

1) high bioenergy productivity
2) low nutrient inputs requirement
3) Biogeochemistry effect:
   e.g. absorbing GHGs as it grows

U.S. is No.1 biofuel production country in the world;
16 billion gallons of liquid fuel per year by 2022

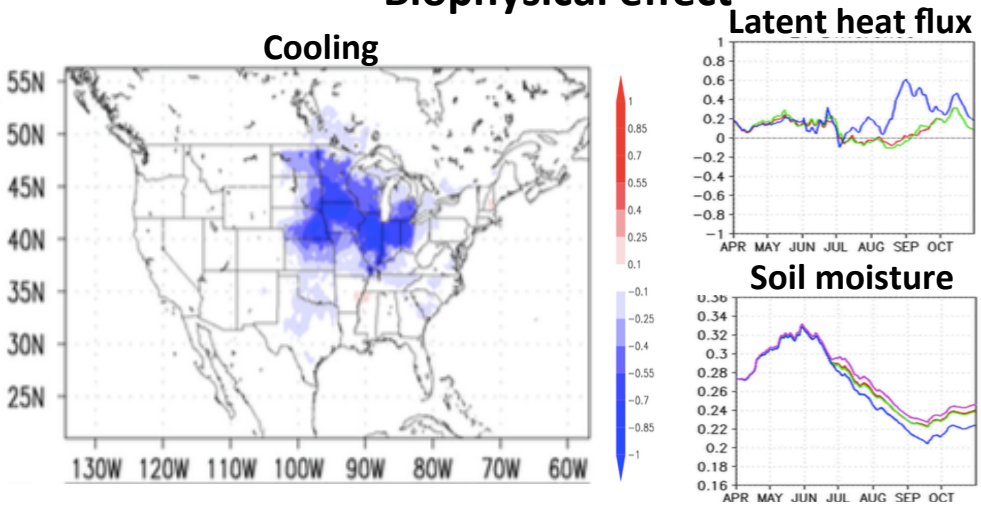


Annual crops V.S. Perennial crops



J. D. Glover, C. M. Cox, J. P. Reganold, *Sci. Am.* **297**(August), 82 (2007).

Biophysical effect



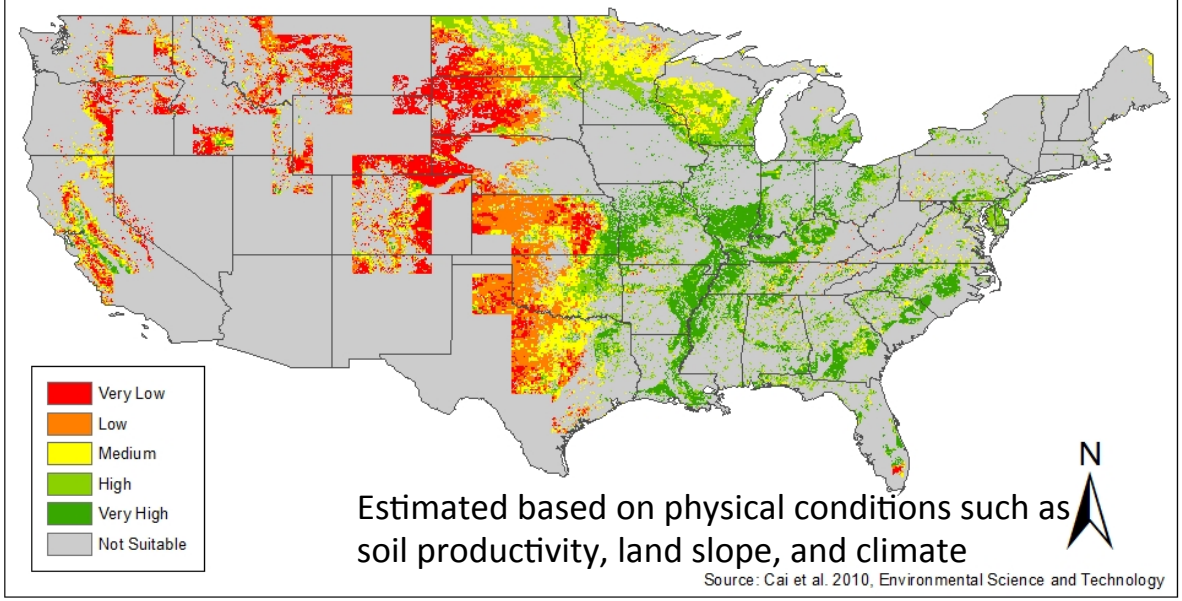
Source: Georgescu et al. 2011, *PNAS*

1. Introduction
Land suitability and expansion scenario for perennial biofuel crops

- Corn to perennial biofuel: competition between food and fuel
- Planting in abandoned and degraded land area can eliminate it.

(Abandoned and degraded land expansion scenario)

Potential Biofuel Crop Suitability

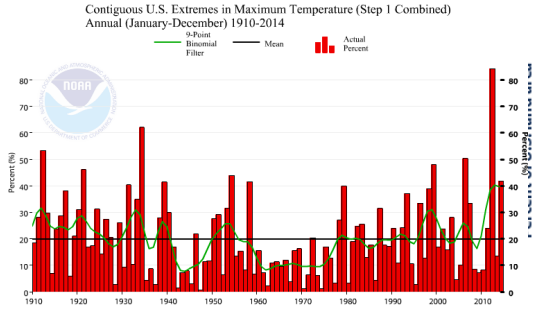


Estimated based on physical conditions such as soil productivity, land slope, and climate

Source: Cai et al. 2010, Environmental Science and Technology

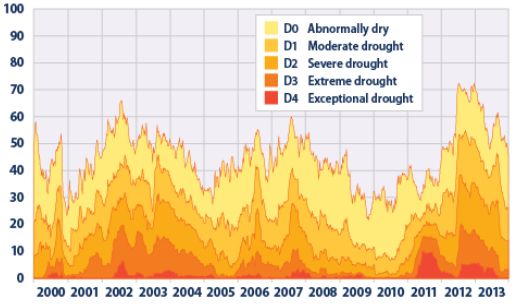
- Studies on long-term, continental scale and undergoing climate extreme conditions remains limit but is necessary

CONUS Extremes in Max Temperature



Source: http://www.ncdc.noaa.gov/extremes/cei/graph

CONUS Drought index



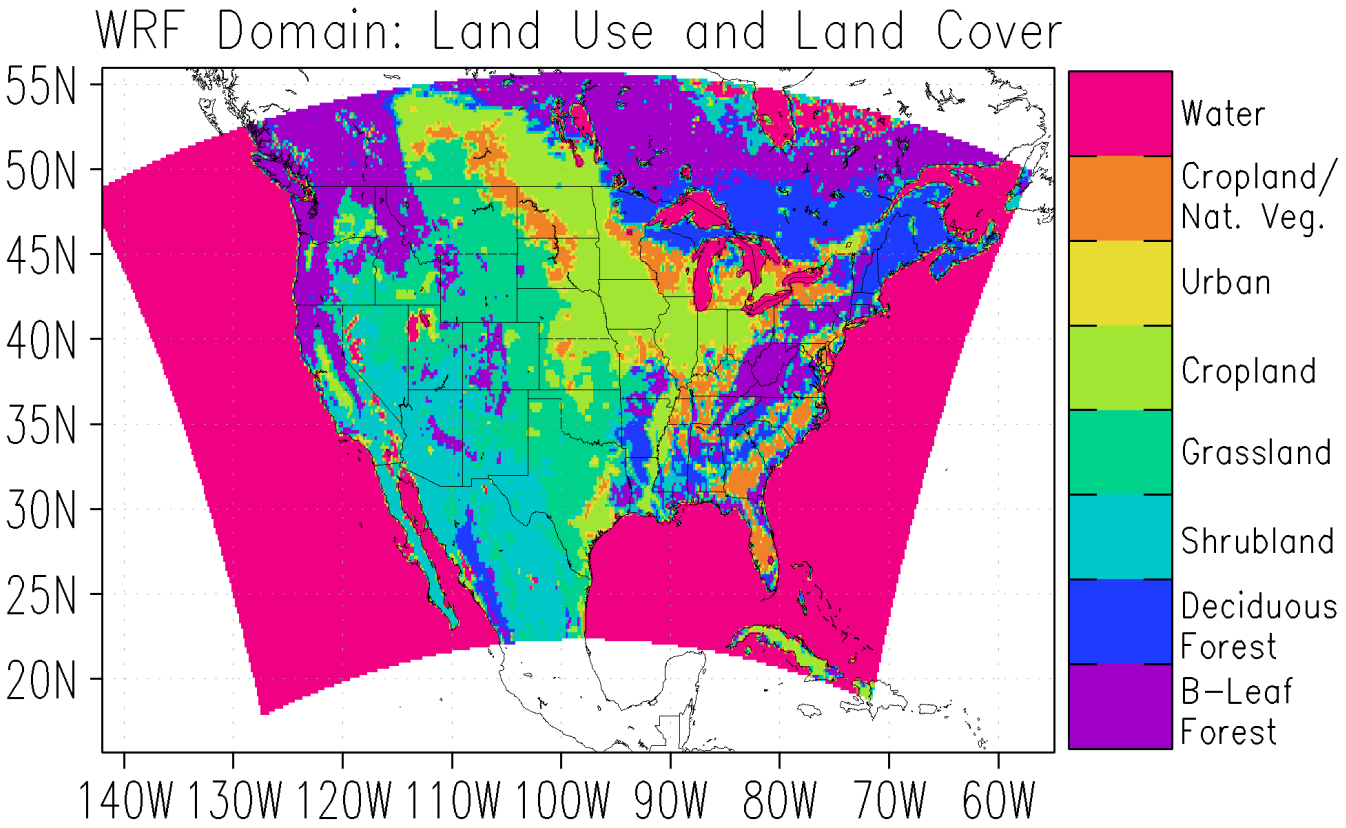
Source: http://www.epa.gov/climatechange/science/indicators/weather-climate/drought.html

Research questions:

(1)	What is the large-scale spatial distribution of hydro-climate impact due to the perennial biofuel crops expansion?
(2)	Where are the ‘hot spots’ for further study?
(3)	What are the association among those feedbacks?

2. Methodologies

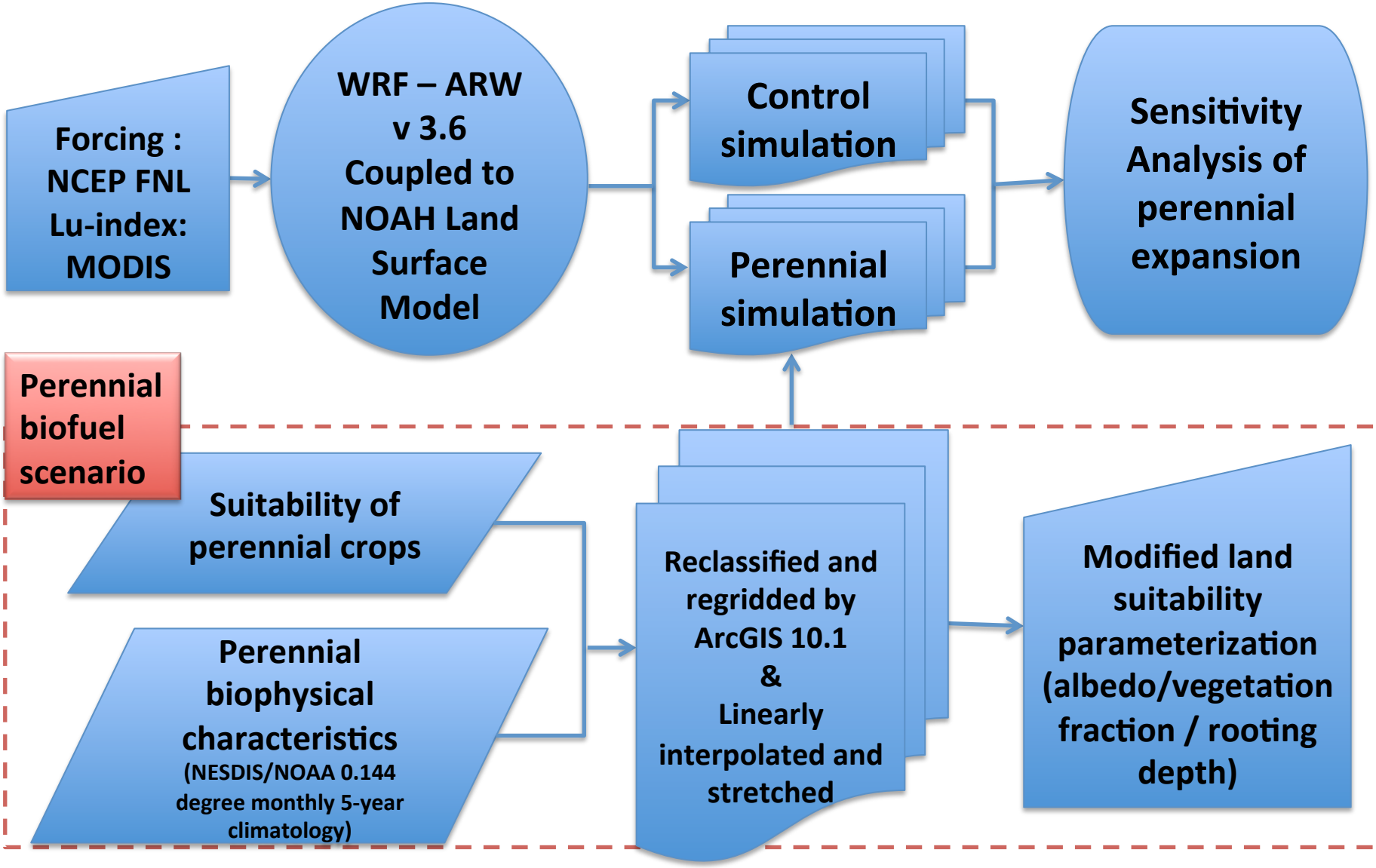
2.1. Simulation domain



Model Version:	WRF V3.6 coupled to Noah LSM
Horizontal (innermost) Grid:	ΔX, ΔY, 20-km
Number of Points:	309 (X-dir.); 189 (Y-dir.)
Vertical Levels:	30 levels
Initialization Time:	Dec 1,1999, 00Z
Terminal Time:	Dec 31, 2009, 21Z
Analysis Time:	Jan 1, 00Z, 2000 to Nov 30, 21Z, 2009

2. Methodologies

2.2. Flow-chart of Process



2. Methodologies
2.3. Simulations

Sensitivity of physics (Ensemble of 14 simulations)

Physics options	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*	*E8*	*E9*	*E10*	*E11*	*E12*	*E13*	*E14*	*explanation*
Microphysics (mp_physics)	3	3	3	3	3	3	3	16	16	16	3	3	3	3	3) WSM 3-class; 16) WDM 6-class
Shortwave Radiation (ra_sw_physics)	1	4	4	4	4	4	4	4	4	4	1	1	4	4	1)Dudhia; 4) RRTMG
Surface Layer (sf_sfclay_physics)	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1) MM5 Similarity Scheme; 2) Eta Similarity Scheme
Planetary Boundary layer (bl_pbl_physics)	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1) YSU scheme; 2) Mellor-Yamada-Janjic (Eta) TKE scheme
Cumulus Parameterization (cu_physics)	1	1	1	1	1	1	1	1	1	1	1	5	1	5	1)Kain-Fritsch scheme ; 5)Grell 3D
spectral nudging	no	no	yes	yes	no	yes	yes	no	yes	yes	yes	yes	yes	yes	
spectral nudging wavelength			3*2	4*3		3*2	4*3		3*2	4*3	4*3	4*3	4*3	4*3	
Initial condtions (1month)	no	no	no	no	no	no	no	no	no	no	yes	yes	yes	yes	

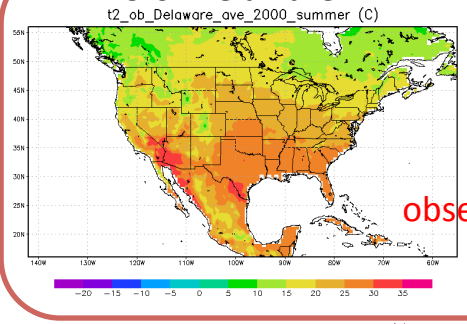
Sensitivity of expansion:

Simulation	Perennial biofuel parameter
Baseline	default
Perennial (piecewise approach)	rooting depth only
	albedo only
	vegetaton fraction only
	All

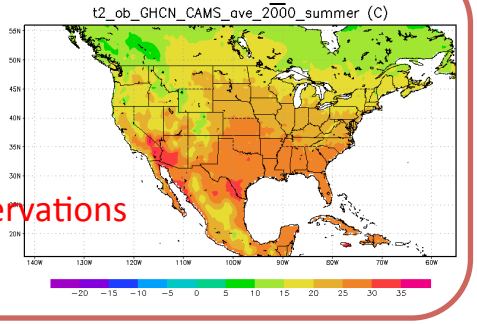
3. Results

3.1 Model evaluation

U of Delaware

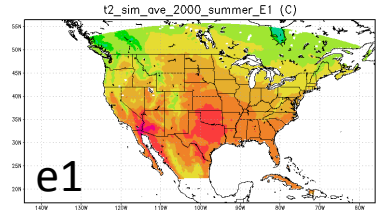


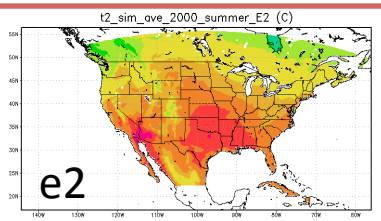
NOAA GHCN_CAMS

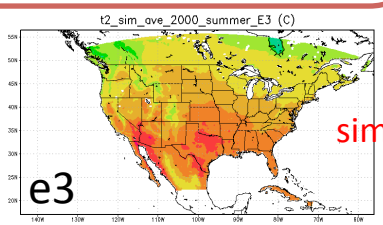


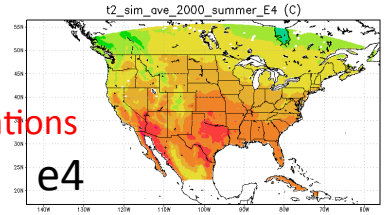
observations

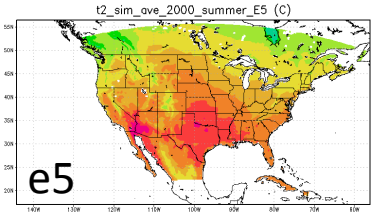
simulations

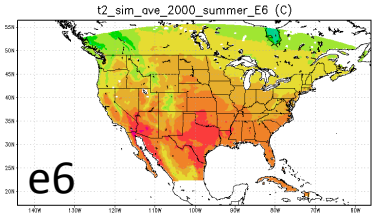


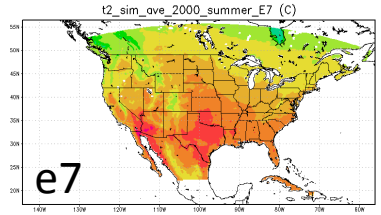


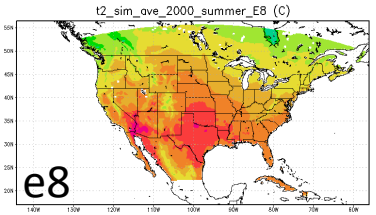


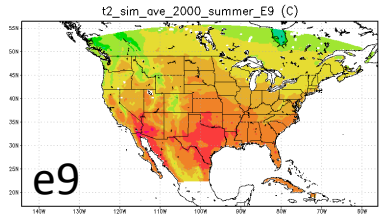


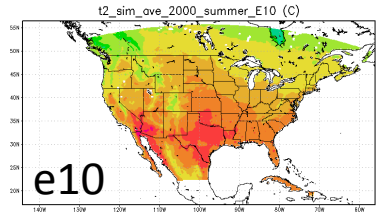


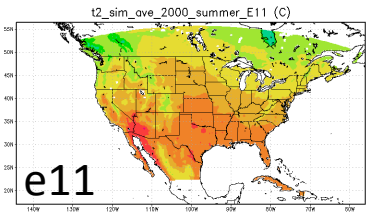


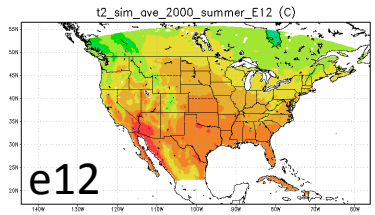


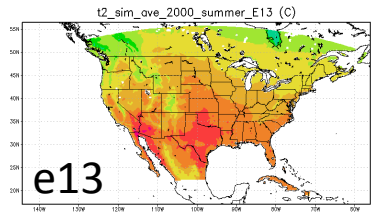


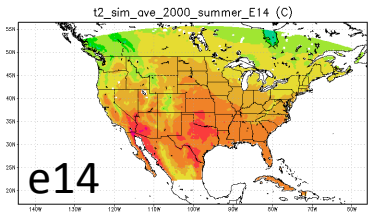




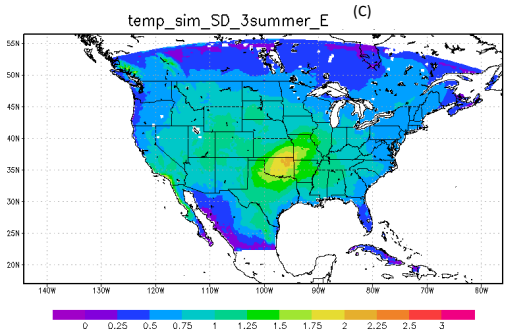








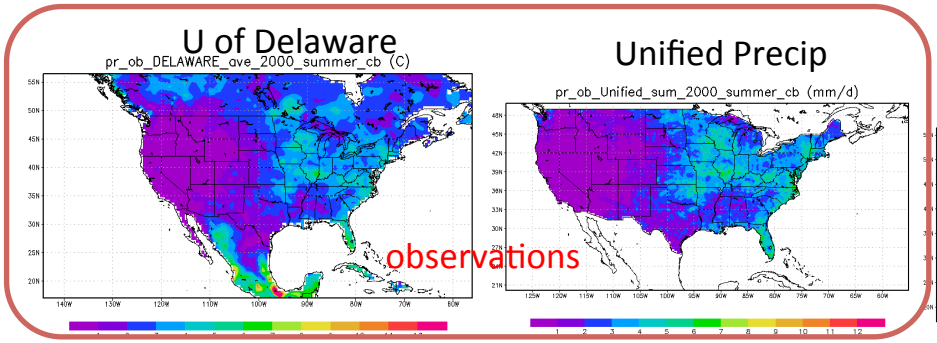
Spatial comparison of seasonal average 2m temperature in Summer

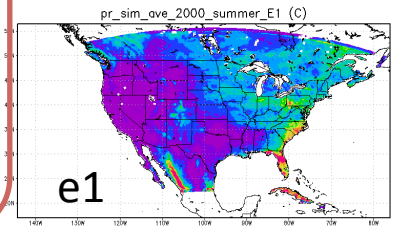


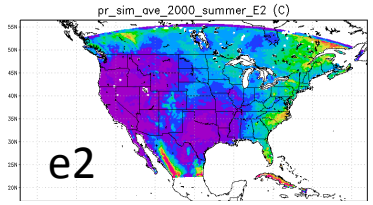
Model variability

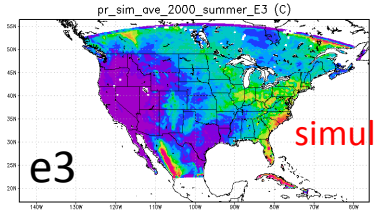
3. Results

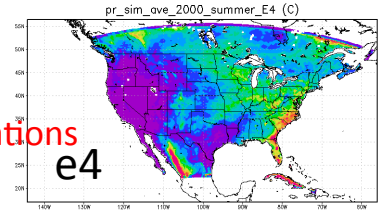
3.1 Model evaluation



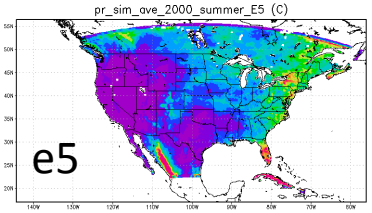


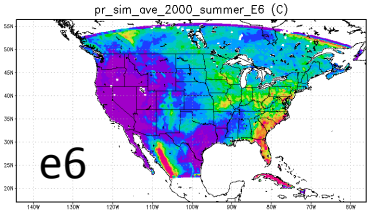


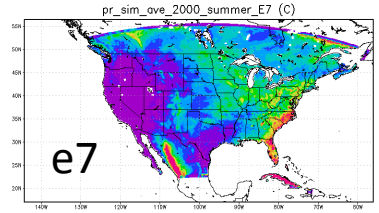


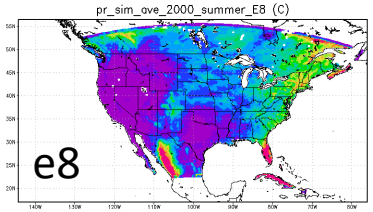


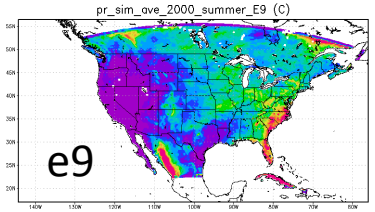
simulations

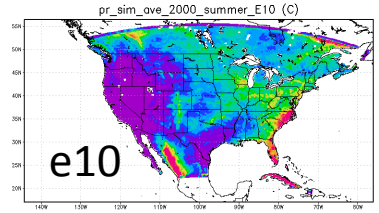


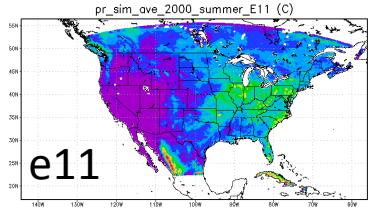


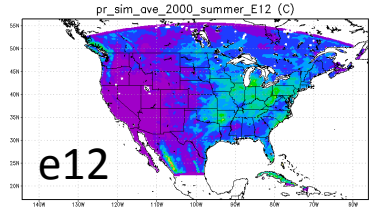


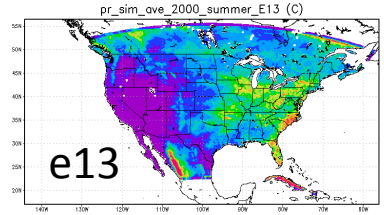


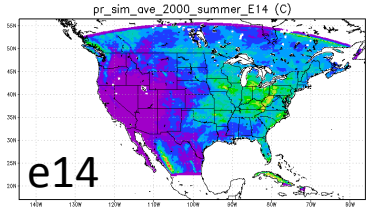




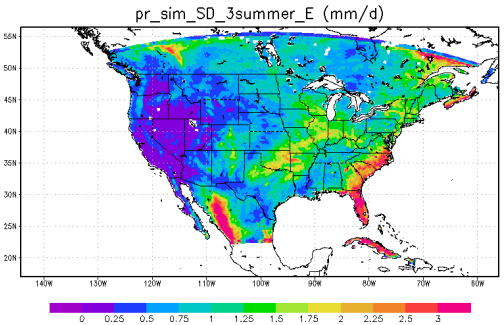








Spatial comparison of seasonal average Precipitation in Summer



Model variability

3. Results

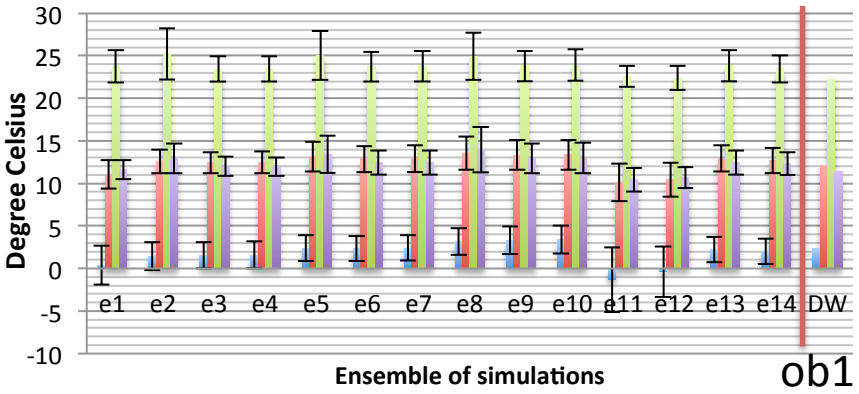
3.1 Model evaluation

Comparison of areal and seasonal average bias and spatial variability

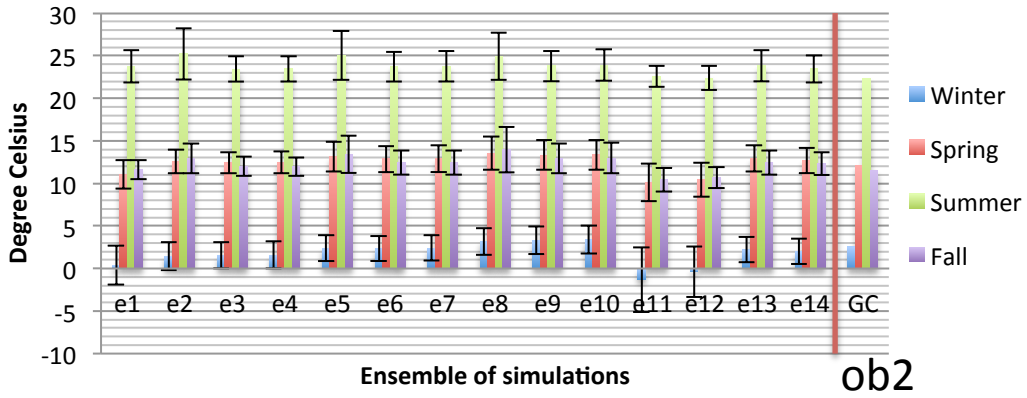
Note: Regrid into 0.5/0.25 degree and maskout regions outside U.S.

Areal and seasonal average in bar +/- spatial variability in error bar(one standard deviation of bias over entire field).

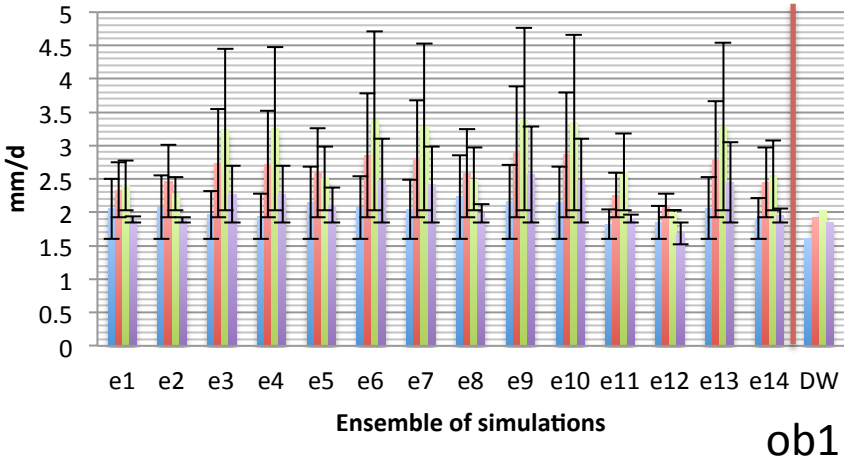
T2 based on Ob1



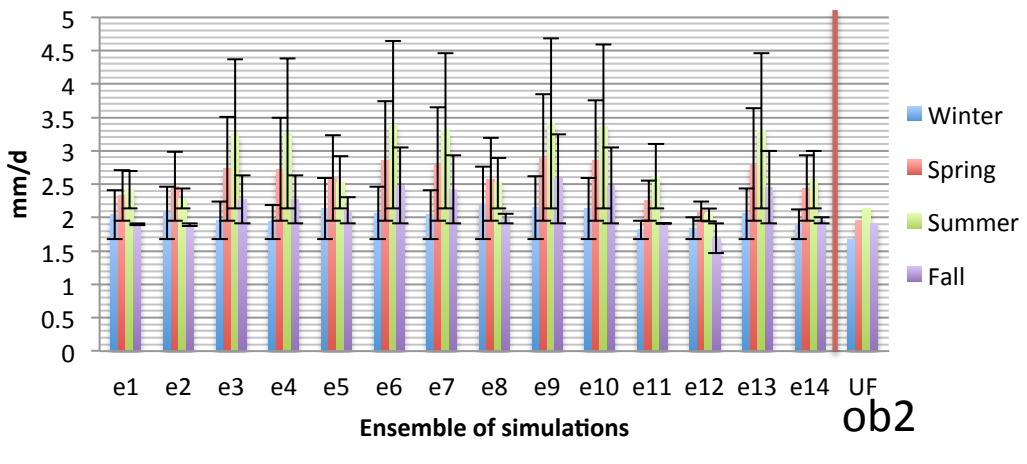
T2 based on Ob2



Precip based on Ob1



Precip based on Ob2

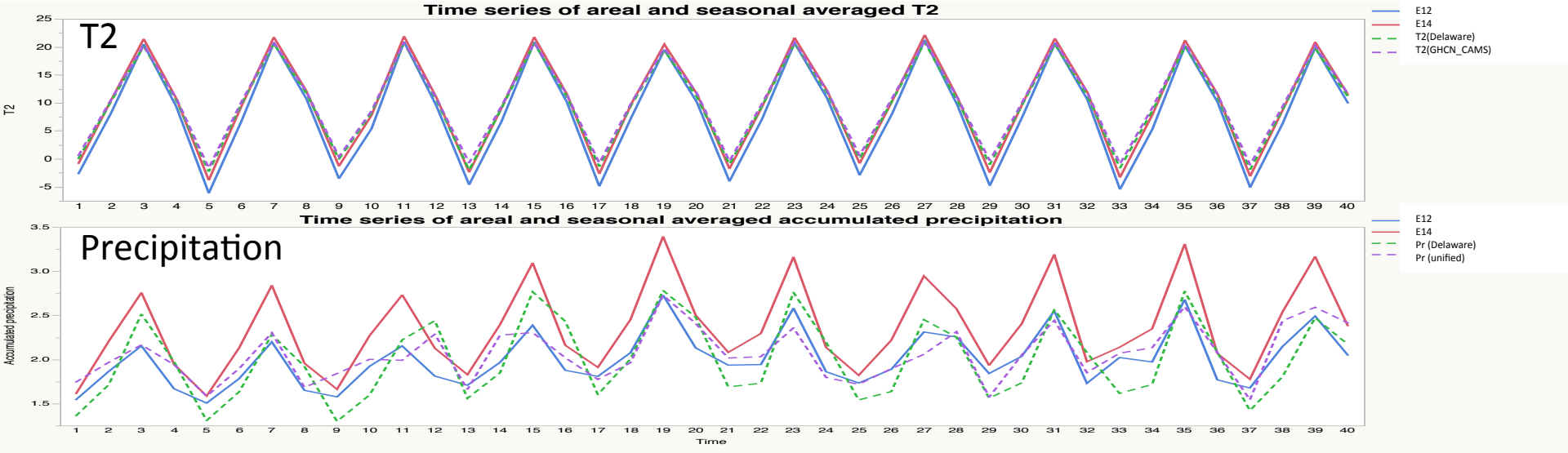


Trade-off between spatial variability of T2 and that of precipitation; Ensemble member 12/14 performs relatively better considering the mean and spatial variability.

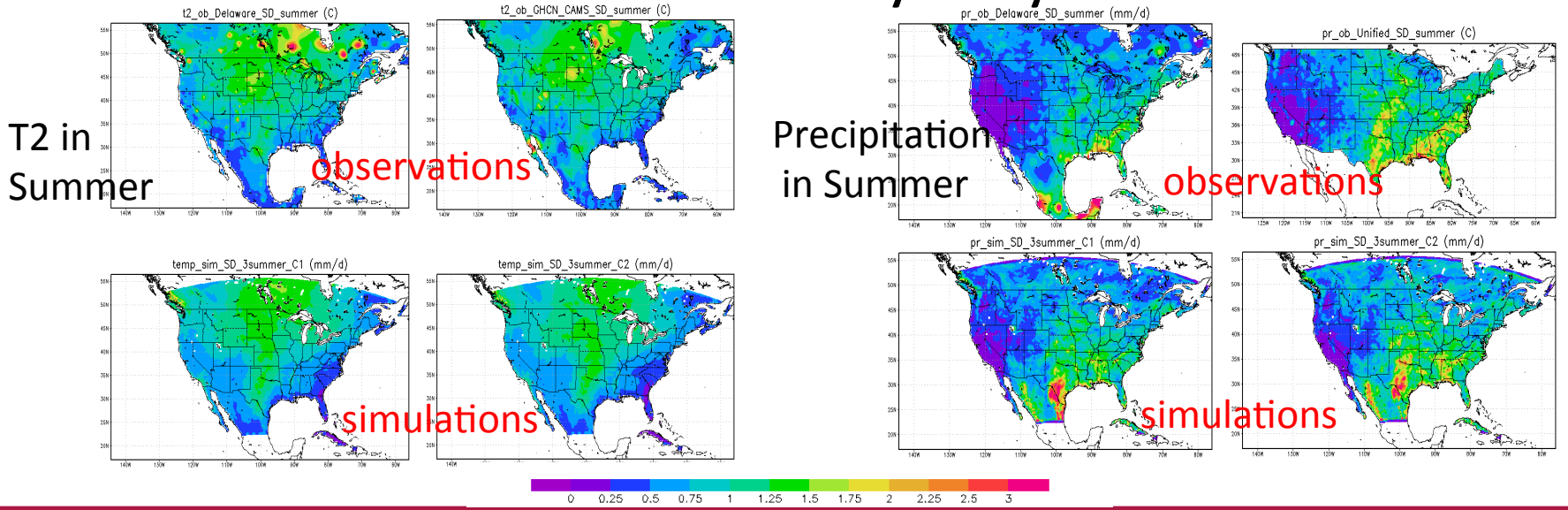
3. Results

3.1 Model evaluation

Time series of areal and seasonal average in 10 years (climate variability)



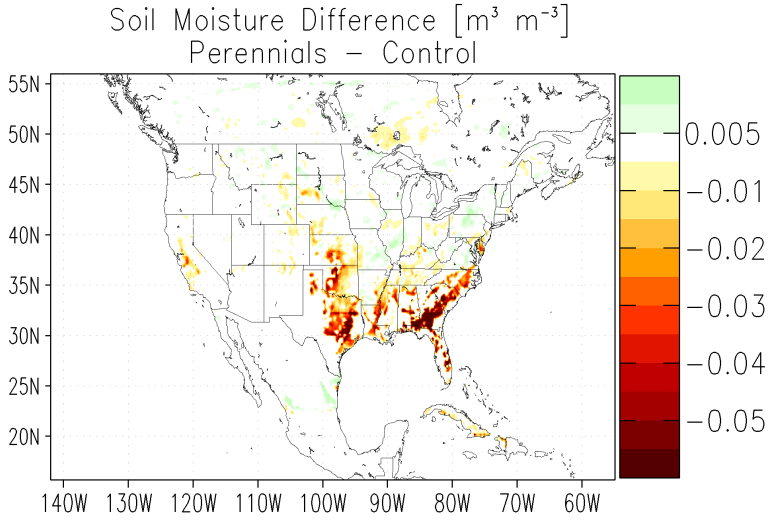
Interannual variability in 10 years

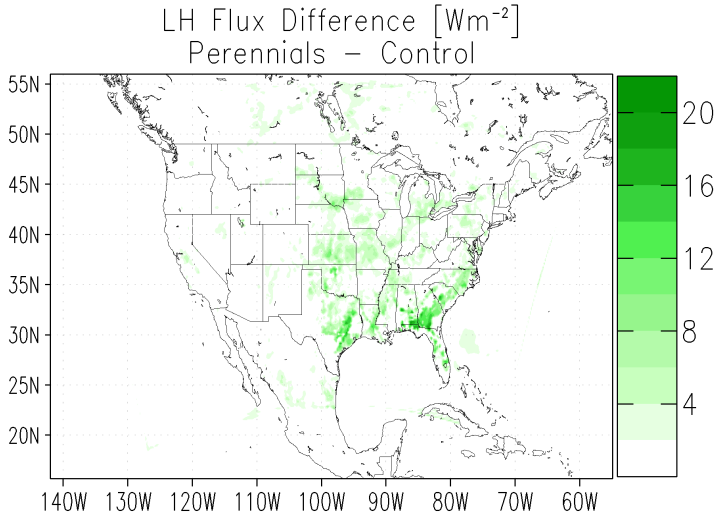


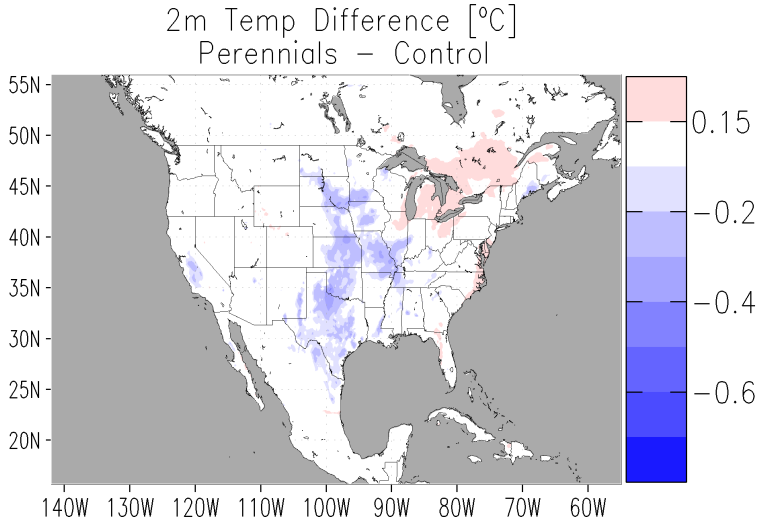
3. Results

3.2 Sensitivity of perennial expansion

One year experiment:
perennial expansion scenario simulation - control simulation
Averaged difference in summer







Physical mechanism:
More water is extracted from soil into atmosphere through ET, latent heat flux is enlarged, which consequently causes a decrease in sensible heat flux and surface temperature.

4. Conclusion and Future Work

- Due to perennial expansion, the maximum cooling effect is about 0.5℃; unintended effect of soil moisture depletion is greater than of 0.05 $m^3 m^{-3}$, and latent heat flux is increased generally between 10-20 W m^{-2}.
- More water is extracted from soil into atmosphere through ET, latent heat flux is enlarged, which consequently causes a decrease in sensible heat flux and surface temperature.
- There exists indirect spatial correspondence between soil moisture reduction and thermal effects.

- Conduct decadal time scale, ensemble-based simulations, using piecewise approach in assessment of biofuel expansion by incorporating biophysical characteristics (e.g. LAI, albedo, vegetation fraction).
- Repeat experiments using NOAH-MP and LEAF-2 to examine impacts on above and groundwater resources.

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Thank you!