BioEarth

Biosphere-relevant earth system model

BOSTON UNIVERSITY

Responses of terrestrial water cycles to changes in climate and phenology over Conterminous U.S. during 1983-2019

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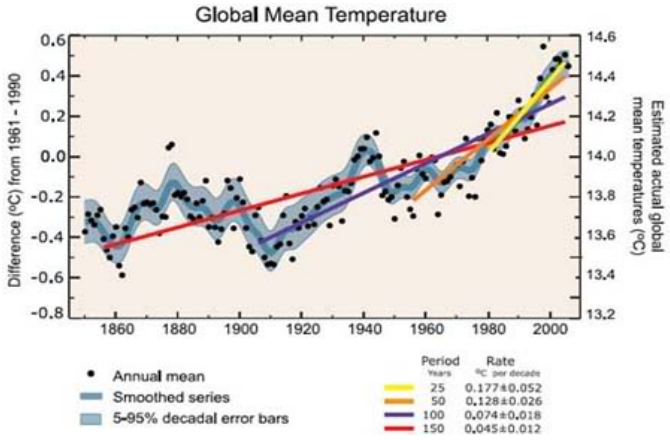
USDA

Introduction

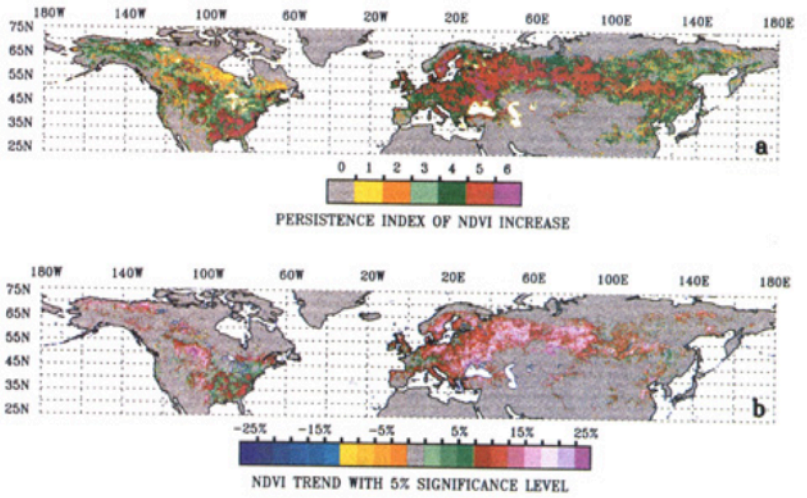
- Climate change (Temperature, Precipitation)
  - Long-term trend
  - Seasonal and diurnal pattern
  - Intensity & frequency of extreme events
- Longer growth season or early greenness in northern hemisphere



IPCC, 2008

Increased plant growth in the northern high latitudes from 1981 to 1991

R. B. Myneni*, C. D. Keeling†, C. J. Tucker‡, G. Asrar§ & R. R. Nemani‖



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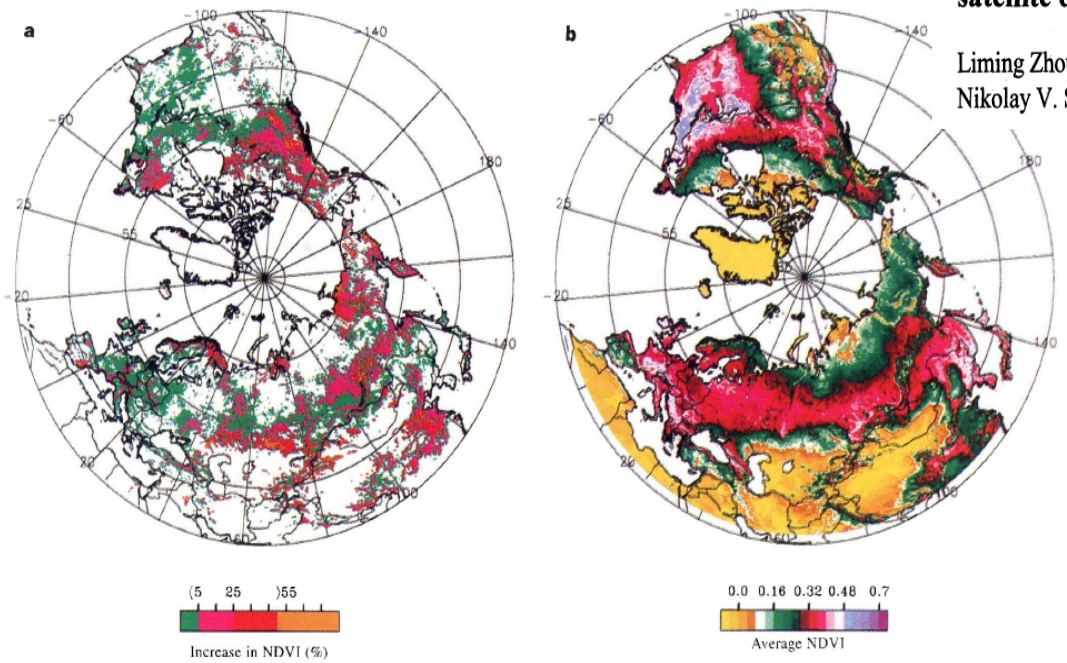
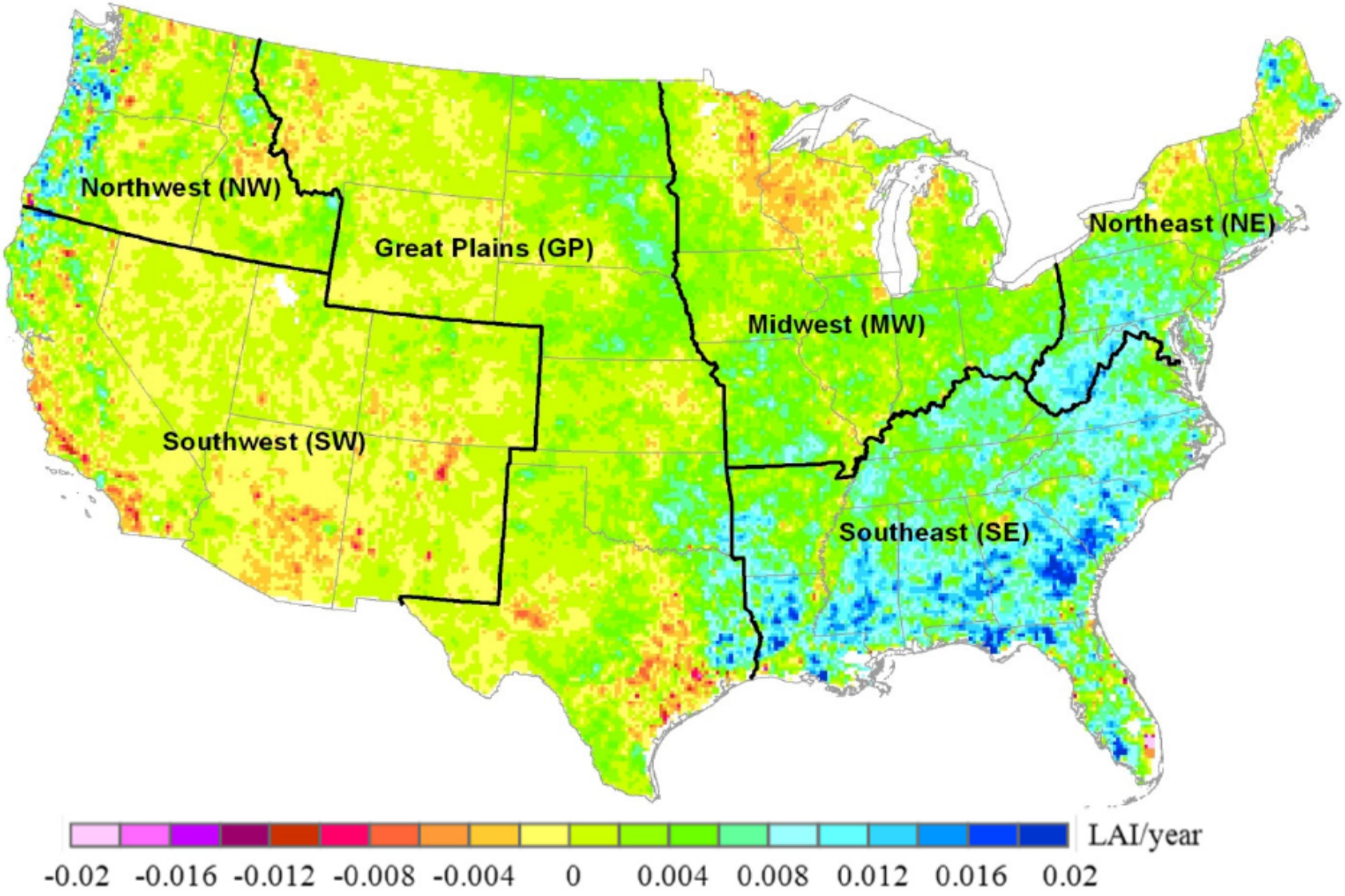
NATURE | VOL 386 | 17 APRIL 1997



Variations in northern vegetation activity inferred from satellite data of vegetation index during 1981 to 1999

Liming Zhou,[1] Compton J. Tucker,[2] Robert K. Kaufmann,[1] Daniel Slayback,[3] Nikolay V. Shabanov,[1] and Ranga B. Myneni[1]


Northwest (NW)
Great Plains (GP)
Northeast (NE)
Midwest (MW)
Southwest (SW)
Southeast (SE)
LAI/year
-0.02 -0.016 -0.012 -0.008 -0.004 0 0.004 0.008 0.012 0.016 0.02

Question:

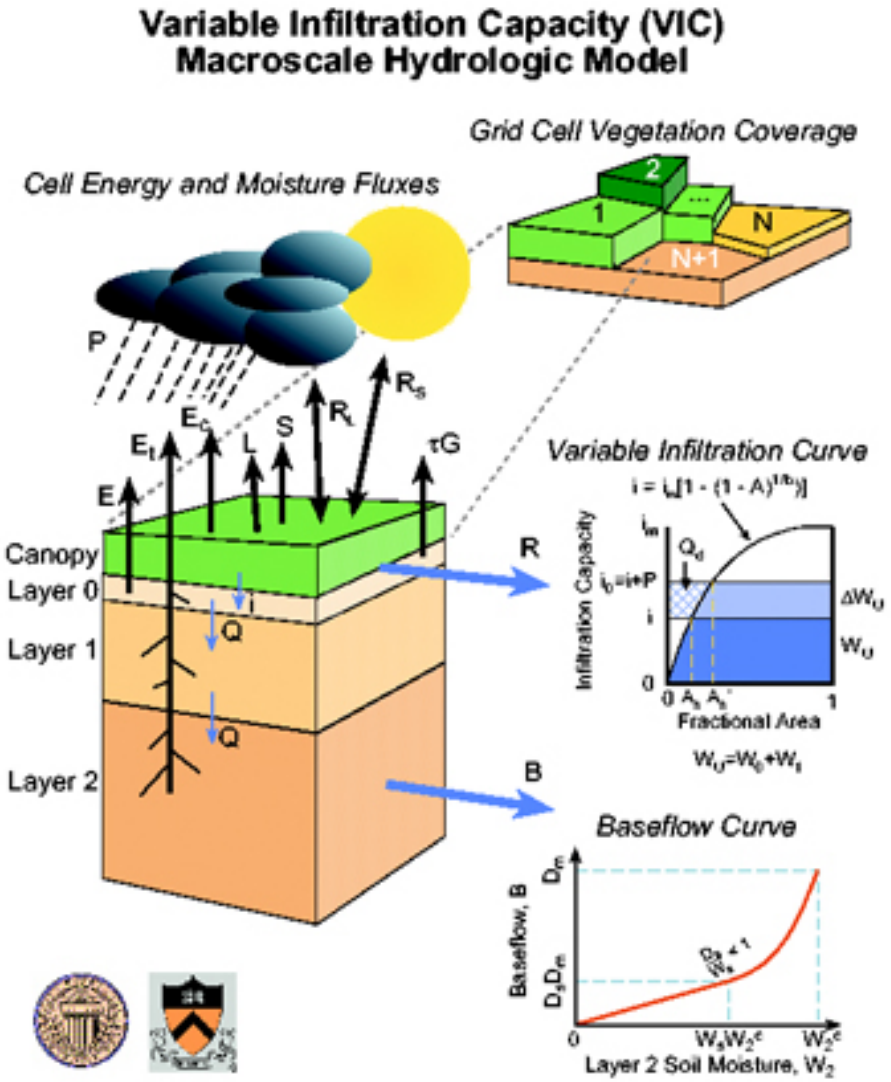
1. How did the changing climate and phenology affect terrestrial water cycles?

2. What's the relative contributions of temperature, precipitation, and phenology to long-term trends and inter-annual variabilities of water cycles and which region and season are most sensitive to the climate change and phenology change over the last several decades?

VIC model

Variable Infiltration Capacity (VIC) is a process-based macro-scale hydrological and land surface model that simulate energy and water fluxes over landscapes and dynamics of water storage such as snowpack, ground water, and soil moisture (Liang et al., 1994; Andreadis et al., 2009, etc.).

Parameters: 1/8th degree data (Maurer et al., 2002)

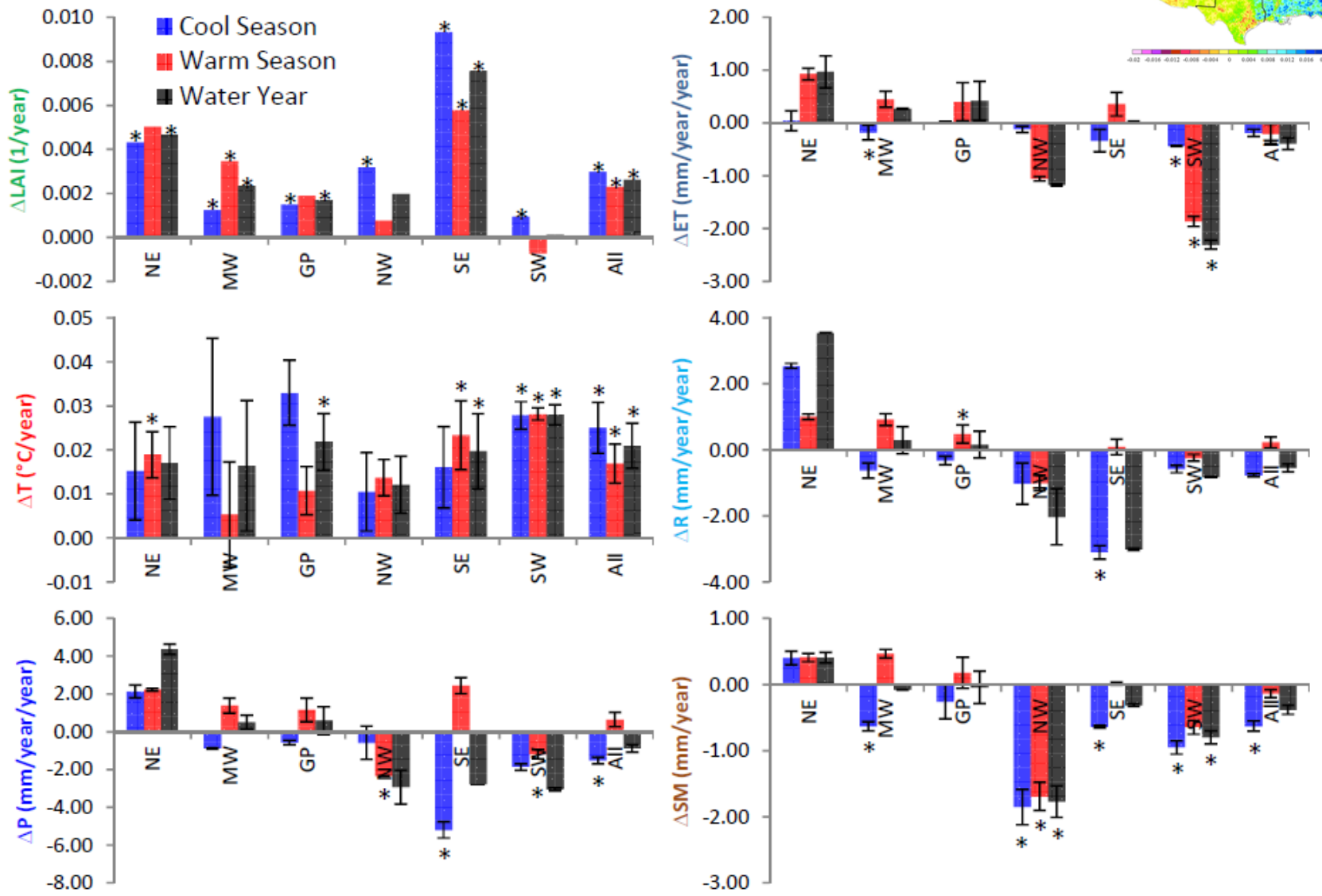


Simulation Experiments

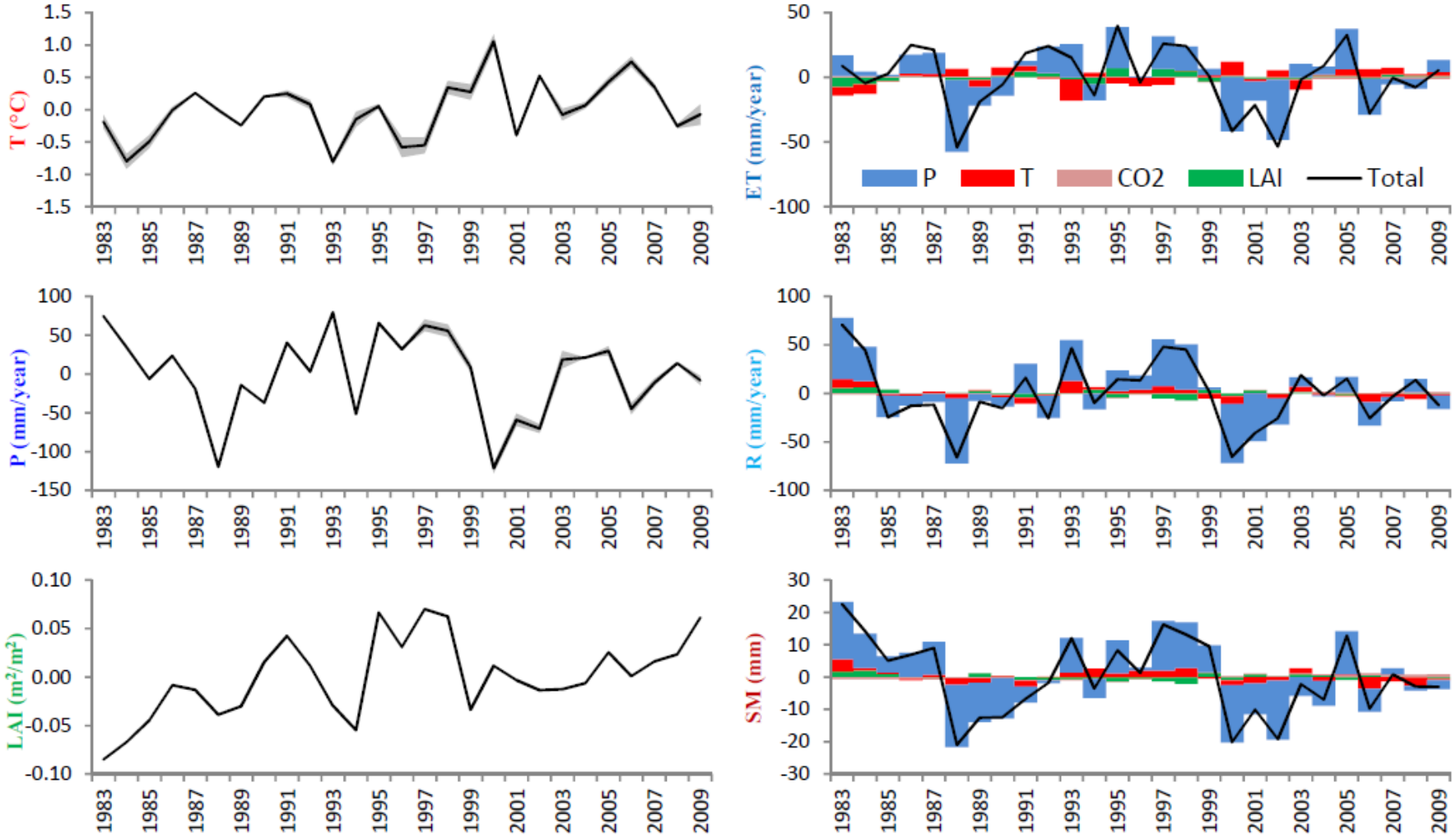
Experiments	T	P	LAI	CO_2
Base	Tr	Tr	Tr	Tr
FixT	-	Tr	Tr	Tr
FixP	Tr	-	Tr	Tr
FixCO2	Tr	Tr	Tr	-
FixLAI	Tr	Tr	-	Tr
FClimate	Tr	Tr	-	-

T: Temperature
P: Precipitation
LAI: Leaf area index
Tr: Transient
- : Mean climate or constant atmosphere CO_2 concentration

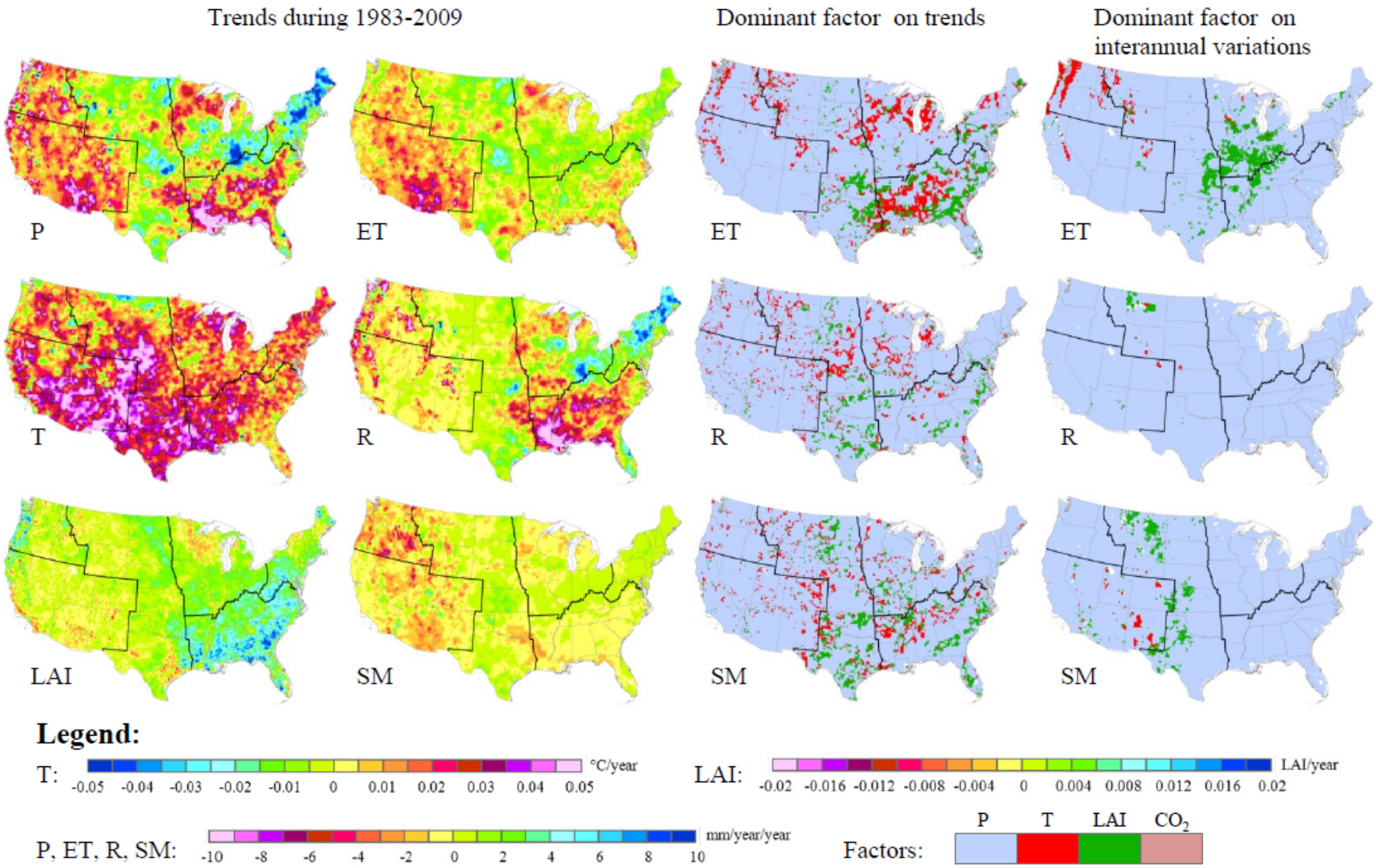
Results



The trends in annual mean temperature, annual precipitation, leaf area index, and simulated ET, runoff, and soil moisture during 1983-2009

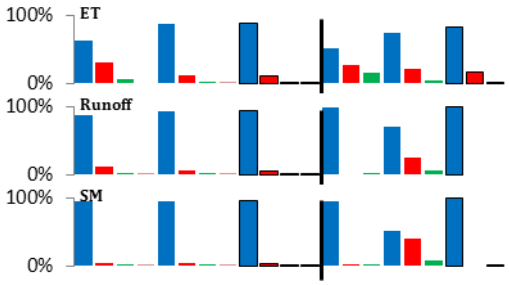


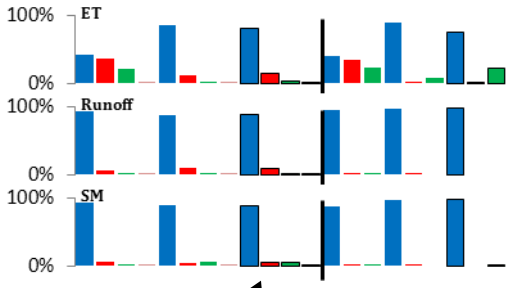
The inter-annual variations in climate and simulated water fluxes and the relative contributions from climate factors and LAI on these hydrological fluxes.

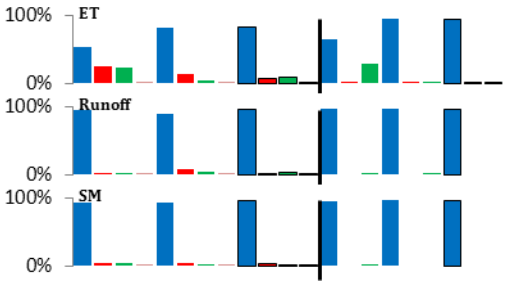


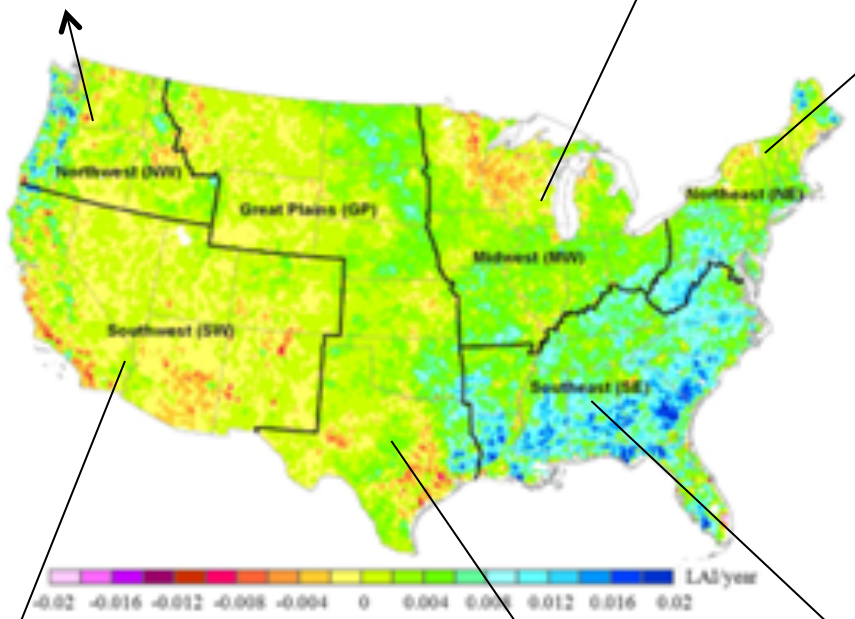
The spatial patterns of trends and the dominate factors on the long-term trends and inter-annual variations.

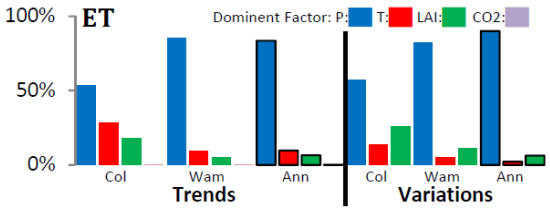
The seasonal dominant contributing factors in long-term trends and inter-annual variations.

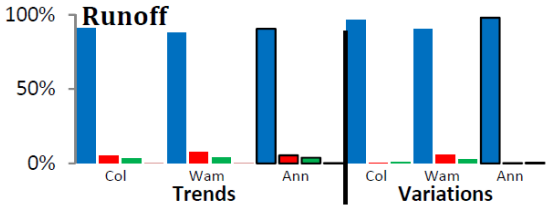


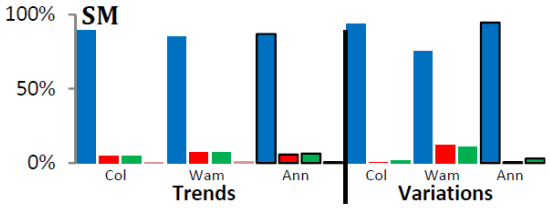


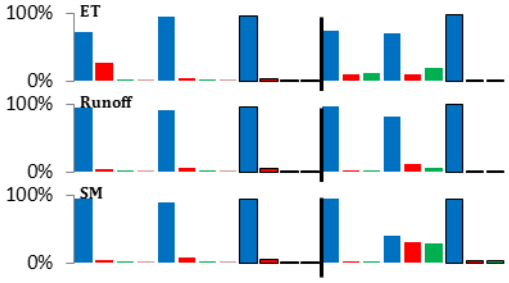


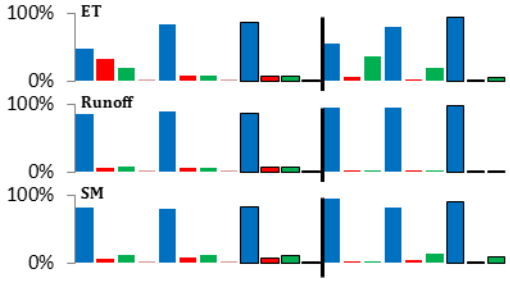


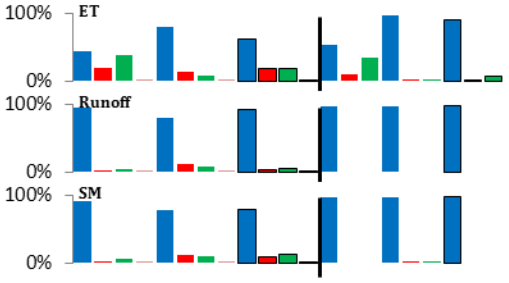


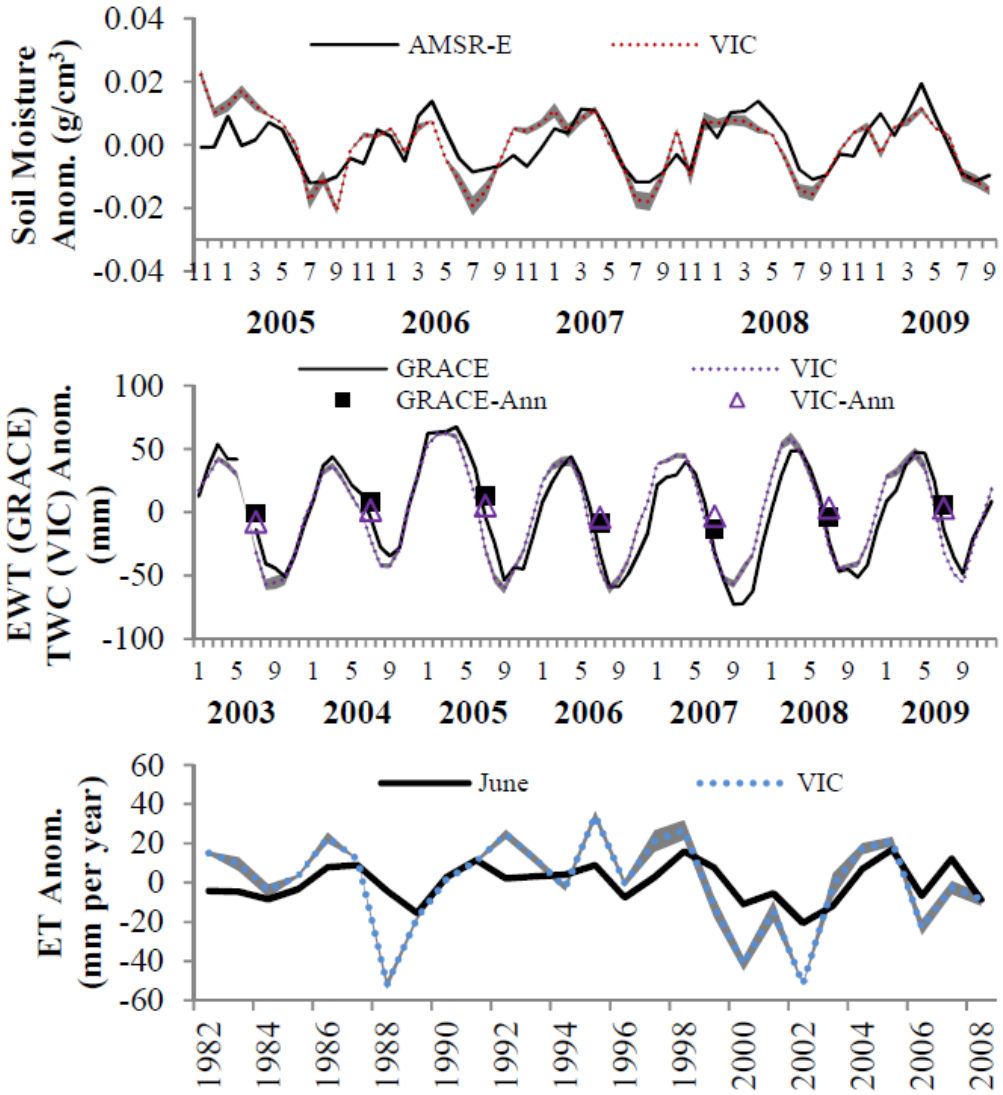






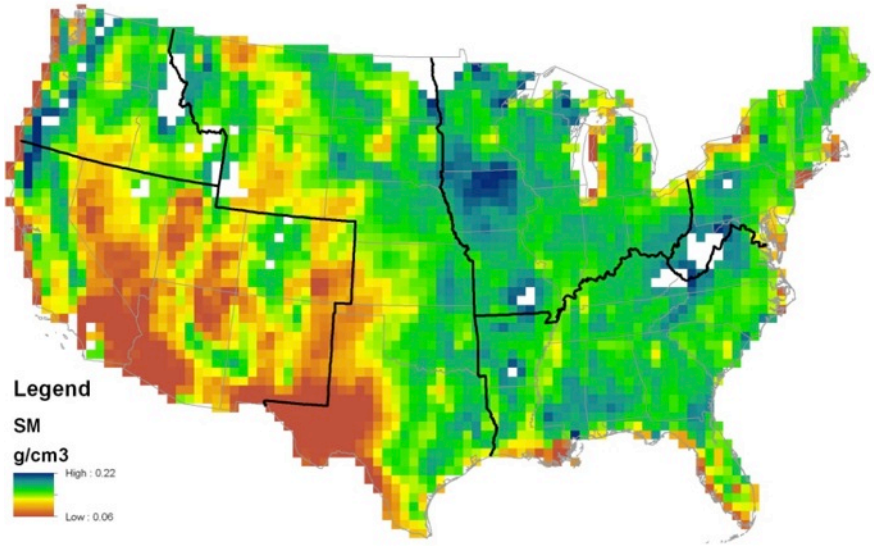




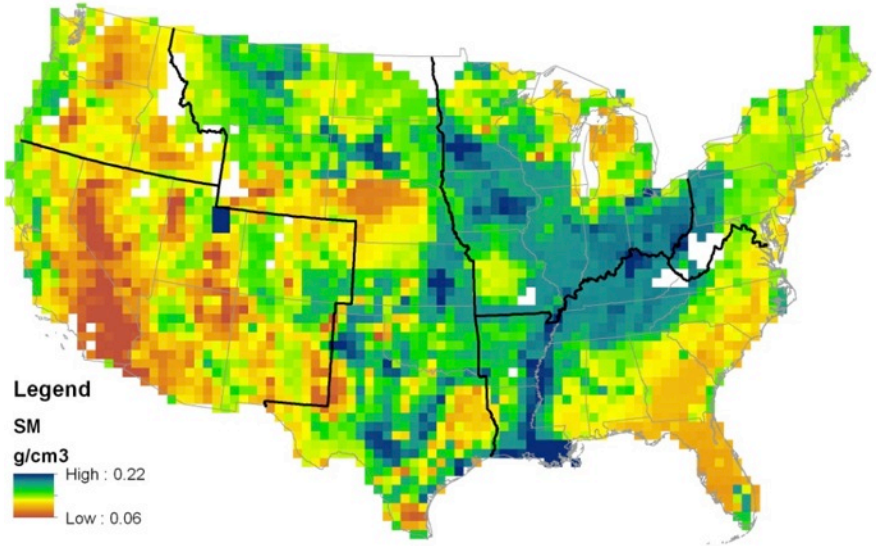


Validations of VIC simulated soil moisture and ET against remote sensing data

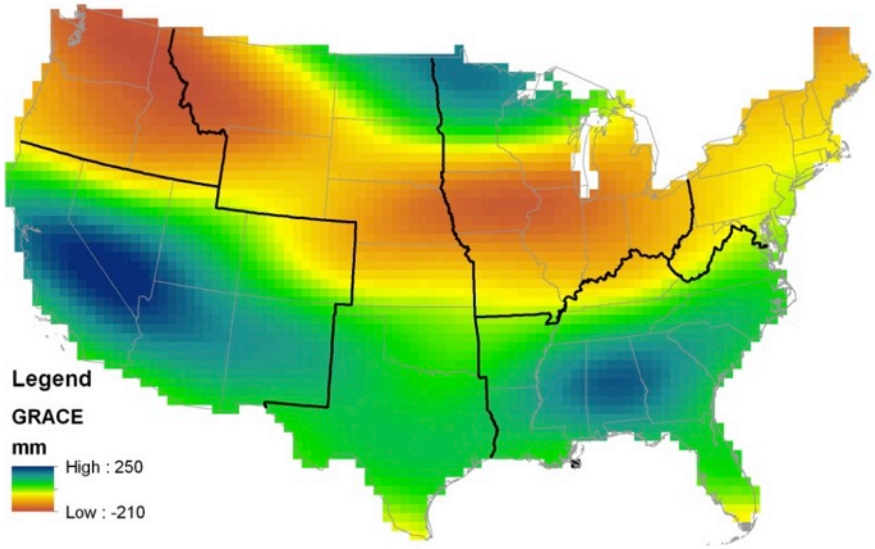
AMSR-E: The Advanced Microwave Scanning Radiometer
GRACE: Gravity Recovery and Climate Experiment
EWT: Equivalent Water Depth
TWC: Total Water Content in the soil profile plus snowpack water equivalence


Legend
SM
g/cm3
High : 0.22
Low : 0.06

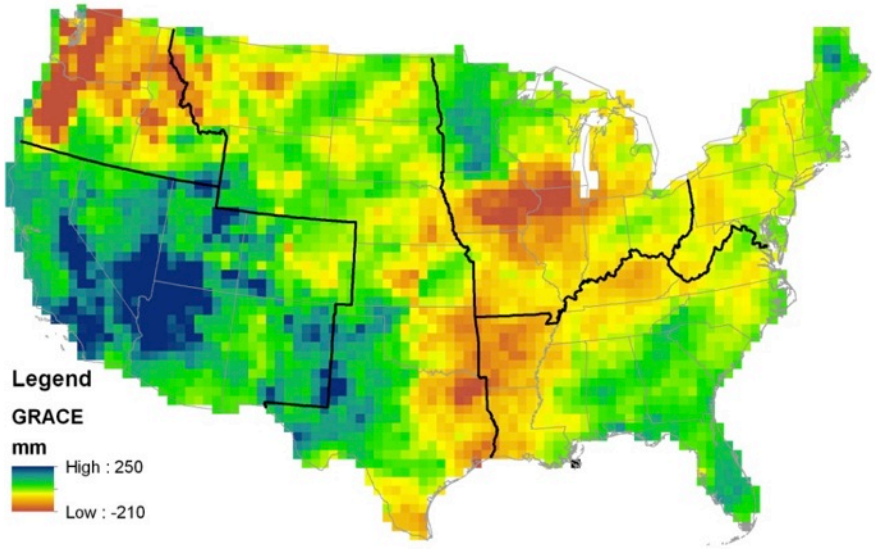
AMSR-E


Legend
SM
g/cm3
High : 0.22
Low : 0.06

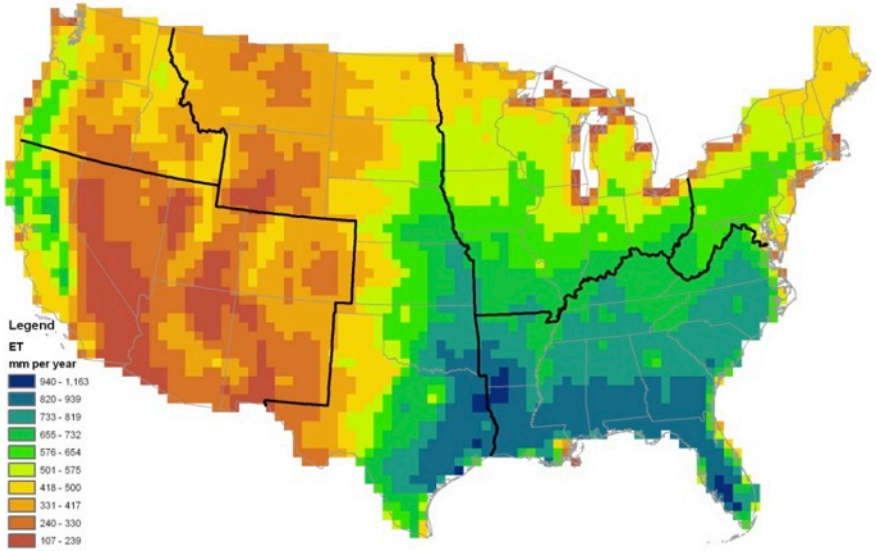
VIC



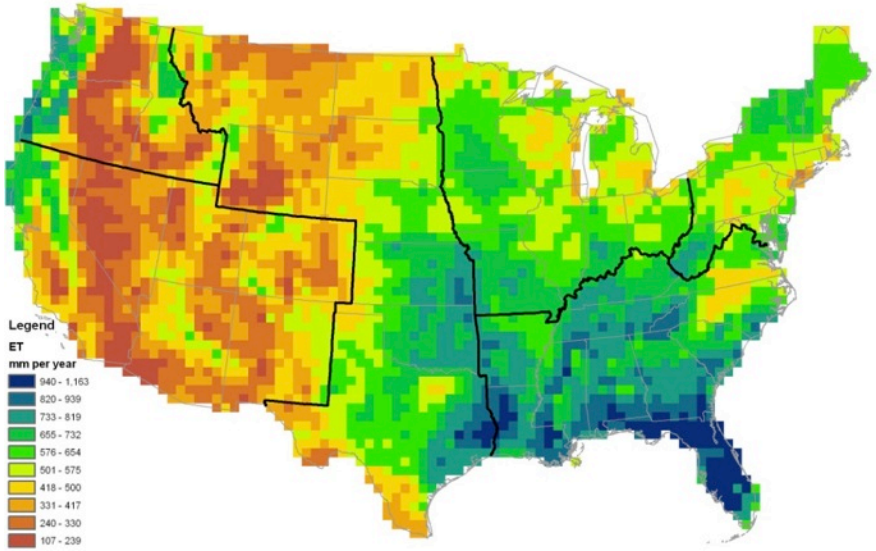
GRACE



VIC-TWC



Jung et al., 2009

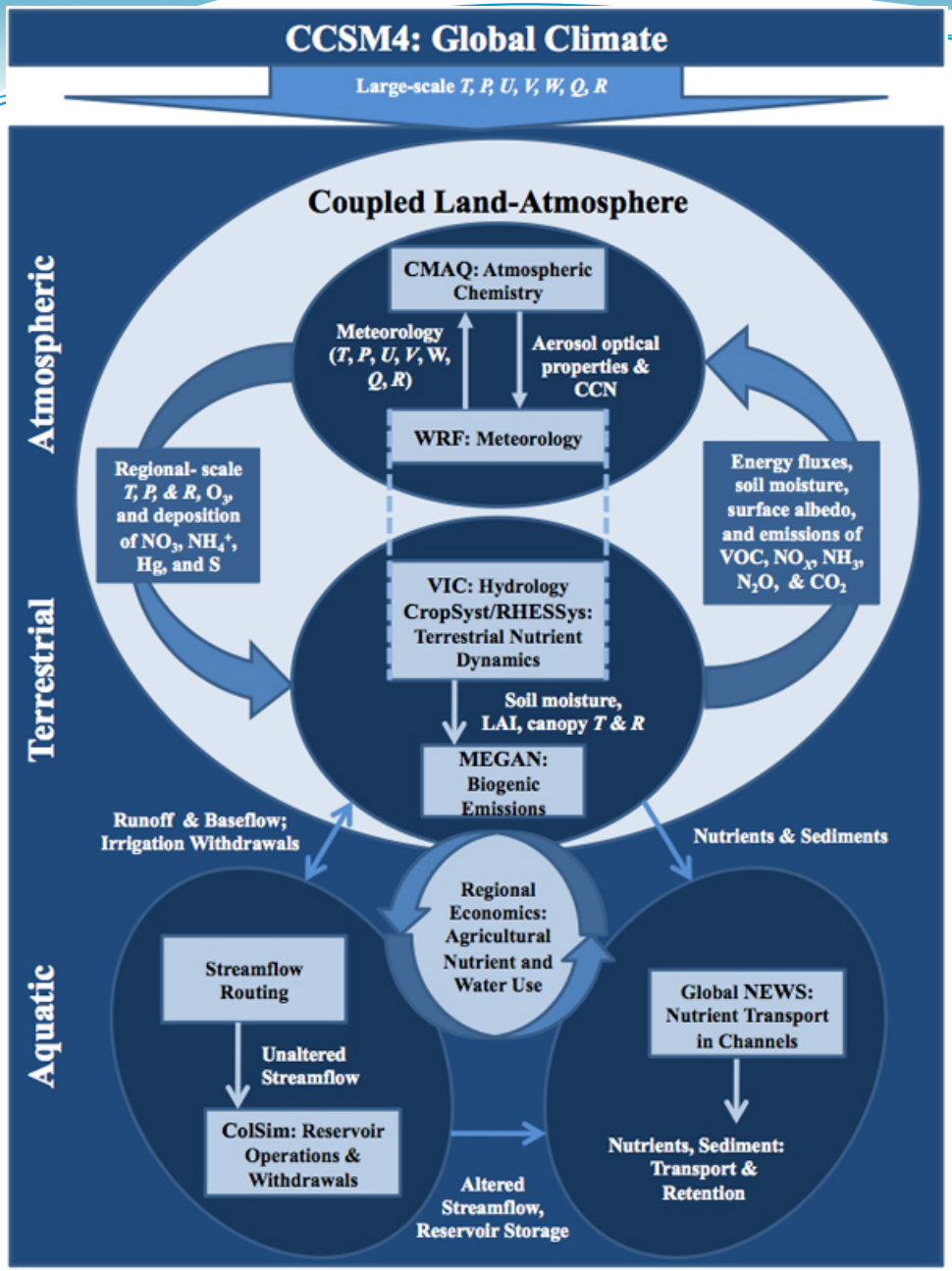


VIC-ET

Limitations and directions for future study:

No vegetation dynamics, i.e. changes in biome or plant functional types in this study. Biogeochemical processes and vegetation dynamics need to be combined into hydrological model;

Need more sensitive analysis and parameter calibrations on response of stomata conductance to extreme drought conditions among different plant functional types;



USDA/NSF/DOE EaSM (Earth System Modeling)

PI: Jennifer C. Adam (WSU)
CoPIs: 18

WSU, OSU, PNNL, UCSB, NCAR, Clark U.

Project Goal:
Improve understanding of the interactions among carbon, nitrogen, and water at the regional scale, in the context of global change, to inform decision makers' strategies regarding natural and agricultural resource management.

http://www.cereo.wsu.edu/bioearth/index.html

Implications & Conclusion

- Increasing leaf area index, which normally means increased growth season and terrestrial ecosystem primary productivity, accelerated land evapotranspiration and decreased runoff in the Continental US during the last 27 years. It has almost the same magnitude of long-term effects on ET and evapotranspirations as the increasing temperature during the last decades.
- Hydrological models should consider the effects of biogeochemical processes on vegetation dynamics which causes LAI variations and hence force long-term trends and season patterns of hydrological cycle.
- Making decisions on ecosystem management including fertilization, tree plantations, fertilizer usage, and cultivations need seriously put regional water cycle consequences into considerations.

Acknowledgment:

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THANK YOU!