Climate Downscaling for the National Climate Assessment: Practices and Challenges

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National Centers for Environmental Information (NCEI)

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Outline

- National Climate Assessment (NCA)
- Climate Downscaling for NCA
- Challenges and Paths Forward

National Climate Assessment (NCA)

The NCA is an important resource for understanding and communicating climate change science and impacts in the United States. It informs the nation about already observed changes, the current status of the climate, and anticipated trends for the future. The NCA report process integrates scientific information from multiple sources and sectors to highlight key findings and significant gaps in our knowledge.

http://www.globalchange.gov/

http://scenarios.globalchange.gov/scenarios/climate

http://nca2014.globalchange.gov/report

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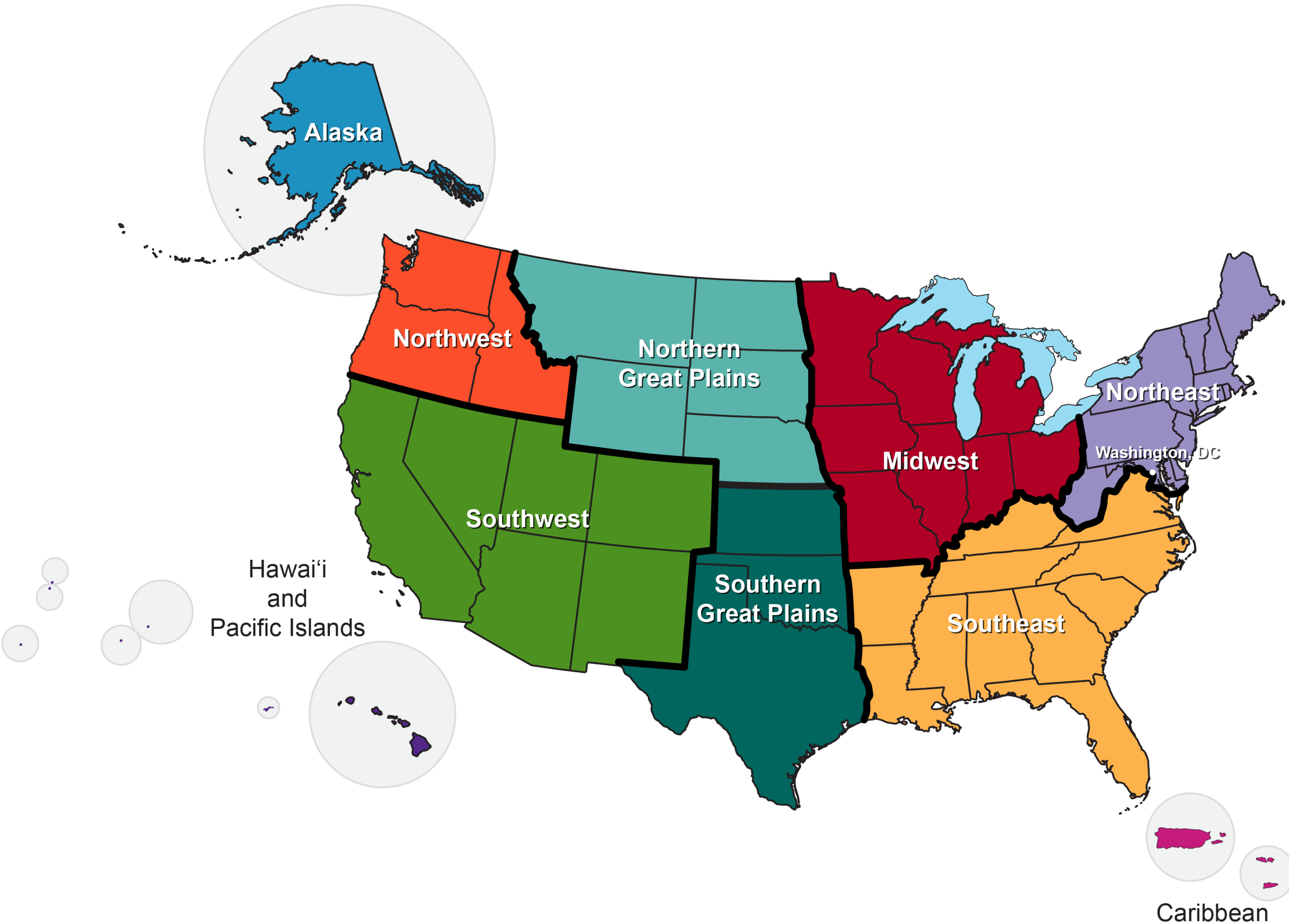
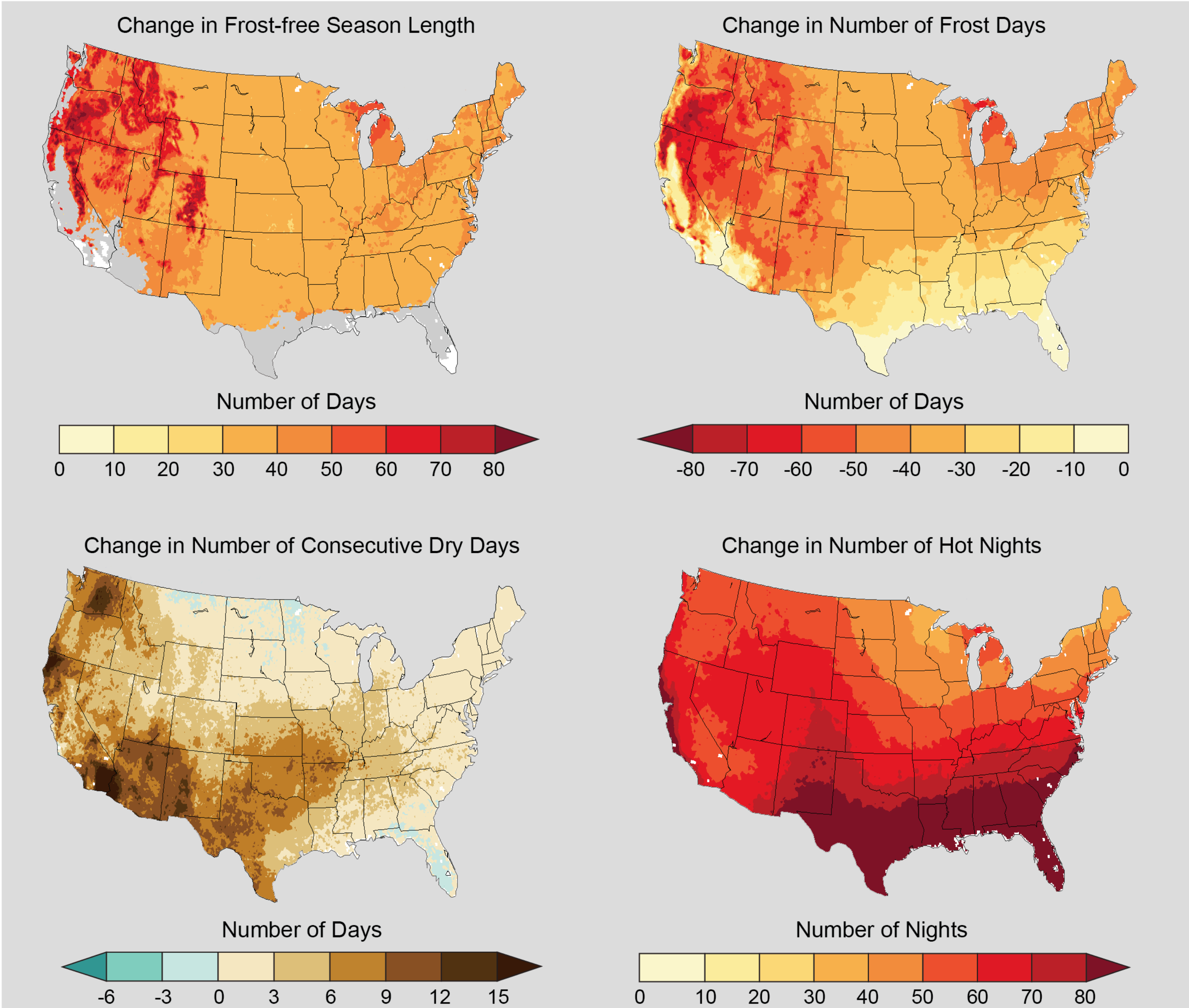
NCA Regions



Alaska
Northwest
Northern Great Plains
Midwest
Northeast
Washington, DC
Southwest
Southern Great Plains
Southeast
Hawai‘i and Pacific Islands
Caribbean

Projected Changes in Key Climate Variables Affecting Agricultural Productivity



Climate Downscaling for NCA

Why Downscaling?

- **Actionable** regional/local climate information
- Climate assessment: **top-down** and **bottom-up** approaches
- Climate **extremes**

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Derived Variables

Annual number of days > 86F
Annual number of days > 90F
Annual number of days > 95F
Annual number of days > 100F
Annual number of days > 105F
Annual number of days > 110F
Annual number of days > 115F
Annual number of days Tmin < 28F
Annual number of days Tmin > 75F
Annual number of days Tmin > 80F
Annual number of days Tmin > 85F
Annual number of days Tmin > 90F
Annual number of days > 1 inch
Annual number of days > 2 inches
Annual number of days > 3 inches
Annual number of days > 4 inches
Annual maximum number of consecutive dry days
Annual maximum number of consecutive wet days
Annual maximum 1-day precipitation
Annual maximum 5-day precipitation

Annual number of icing (Tmax < 32F)days
Annual number of frost (Tmin < 32F)days
Annual highest 5-day maximum temperature
Annual lowest 5-day minimum temperature
Annual lowest 5-day minimum temperature
Annual highest 1-day maximum temperature
Annual lowest minimum temperature
Annual lowest minimum temperature
Cooling degree days
Heating degree days
Growing degree days, base 50 (F)
Date of the first fall freeze
Date of the last spring freeze
Length of the frost-free season
Length of the growing season (28F threshold)
Length of the growing season (41F threshold)

Annual number of days with precipitation greater than the 99^{th} percentile
Annual total precipitation greater than the 99^{th} percentile
Annual number of days with maximum temperature lower than the 1^{st} percentile
Annual number of days with maximum temperature greater than the 99^{th} percentile
Annual number of days with minimum temperature lower than the 1^{st} percentile
Annual number of days with minimum temperature greater than the 99^{th} percentile

Climate Extremes

- projected changes for future 30-year periods, respect to the reference period of 1976-2005, using multi-model ensemble.

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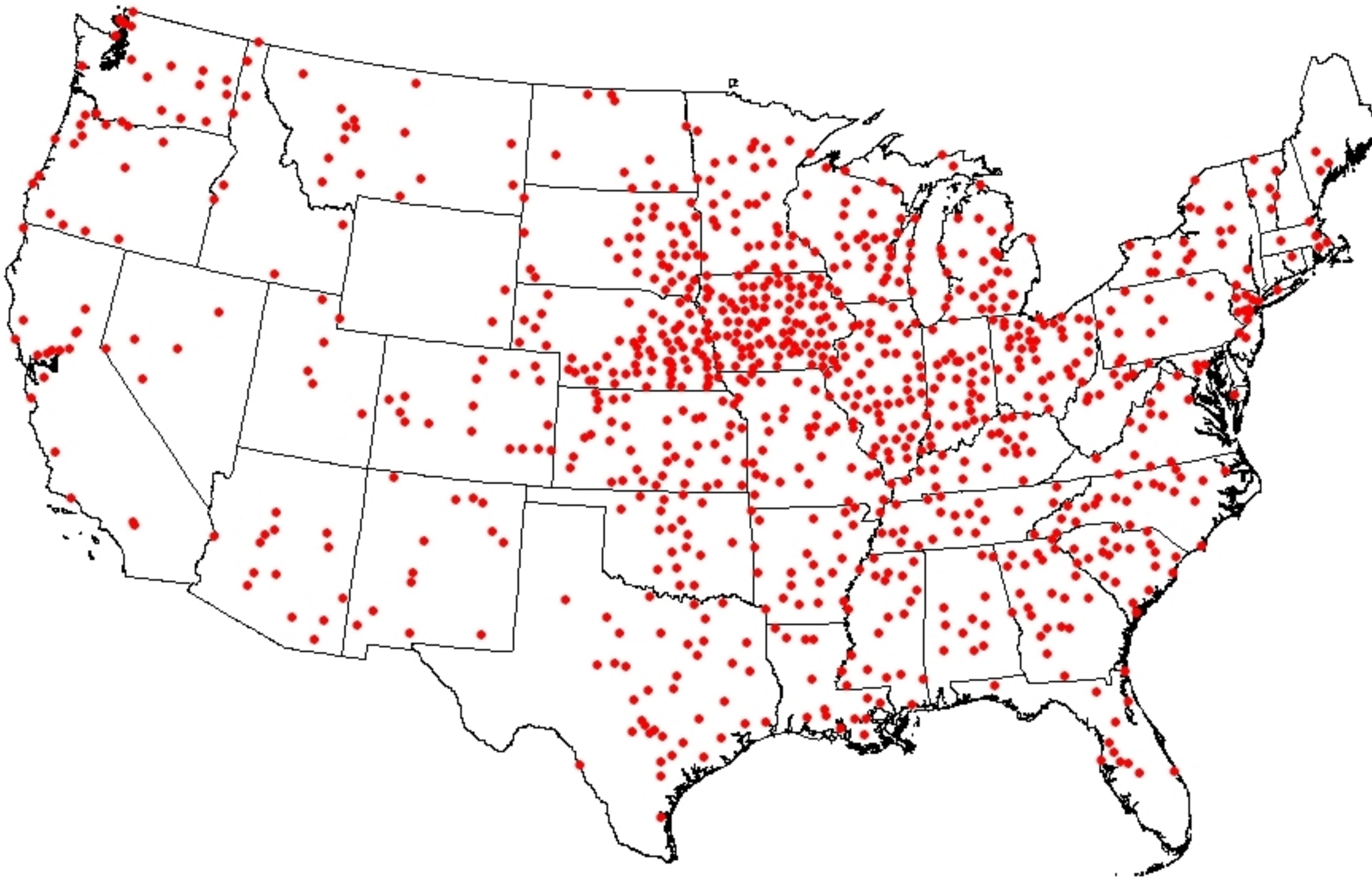
Climate Data

- National Weather Service's Cooperative Observer Network (COOP)
- NA-CORDEX
- LOCA

Long-term Precipitation Stations -

adequacy of data to detect and understand the past changes



NA-CORDEX Simulations

	CRCM5 (UQAM)	CRCM5 (OURANOS)	RCA4	RegCM4	WRF	CanRCM4	HIRHAM5		
ERA-Int	0.44° 0.22° 0.11°	0.44° †	0.44°	50km 25km	50km 25km	0.44° 0.22°	0.44°	RCP	ECS (°C)
HadGEM2-ES								4.5	4.6
				50km 25km	50km 25km			8.5	
CanESM2	0.44°		0.44°			0.44° 0.22°		4.5	3.7
	0.44°	0.22° †	0.44°			0.44° 0.22°		8.5	
MPI-ESM-LR	0.44°							4.5	3.6
	0.44° † 0.22° †	0.22° †		50km* 25km*	50km† 25km†			8.5	
MPI-ESM-MR								4.5	3.4
	0.44°							8.5	
EC-EARTH‡			0.44°					2.6	~3.3
			0.44°				0.44°	4.5	
			0.44°				0.44°	8.5	
GFDL-ESM2M								4.5	2.4
		0.22° †		50km 25km	50km 25km			8.5	
Access	PoC	PoC	ESGF	PoC	PoC	CCCma	ESGF		
Institution	UQAM	OURANOS	SMHI	Iowa State *NCAR	U Arizona	CCCma	DMI		
Modeler	K. Winger	S. Biner	G. Nikulin	R. Arritt *M. Bukovsky	C. Castro, H-I Chang	J. Scinocca	O. Christensen		

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https://na-cordex.org/simulation-matrix

Scripps Localized Constructed Analogs (LOCA) dataset

- 32 CMIP5 models
- Historical: 1950-2005. RCP 4.5 and RCP 8.5: 2006-2100 (2099 some models)
- Climatological period: 1950-99
- Interpolated model calendars to standard calendar w/leap days
- North America 24.5 N to 52.8 N at 1/16th degree resolution
- Daily Tmin, Tmax, Precip

ACCESS1-0
ACCESS1-3
CCSM4
CESM1-BGC
CESM1-CAM5
CMCC-CM
CMCC-CMS
CNRM-CM5
CSIRO-Mk3-6-0
CanESM2
EC-EARTH
FGOALS-g2
GFDL-CM3
GFDL-ESM2G
GFDL-ESM2M
GISS-E2-H
GISS-E2-R

HadGEM2-AO
HadGEM2-CC
HadGEM2-ES
IPSL-CM5A-LR
IPSL-CM5A-MR
MIROC-ESM
MIROC-ESM-CHEM
MIROC5
MPI-ESM-LR
MPI-ESM-MR
MRI-CGCM3
NorESM1-M
bcc-csm1-1
bcc-csm1-1-m
inmcm4

Slide from D. Pierce

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Weighting Method

Weighting

- Independence Weights - Inter-model distances computed as simple root mean square differences are used to calculate independence weights
- Skill Weights - The RMSE distances between each model and the observations are used to calculate skill weights
- An overall weight is then computed as the product of the skill weight and the independence weight.

Variables

1. Surface Temperature (seasonal)
2. Mean Precipitation (seasonal)
3. TOA Shortwave Flux (seasonal)
4. TOA Longwave Flux (seasonal)
5. Vertical Temperature Profile (seasonal)
6. Vertical Humidity Profile (seasonal)
7. Surface Pressure (seasonal)
8. Coldest Night
9. Coldest Day
10. Warmest Night
11. Warmest day
12. Seasonal max. 5-day total precip.

Sanderson *et al.* 2016

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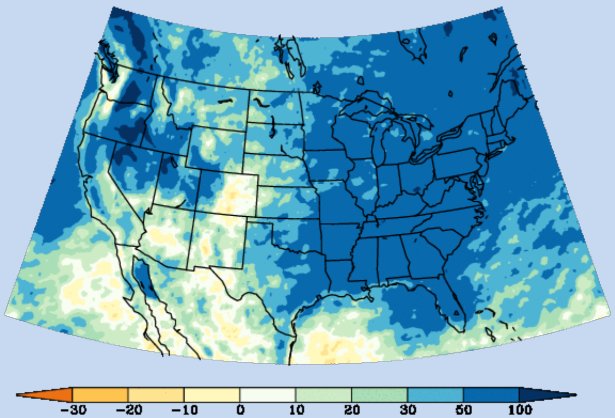
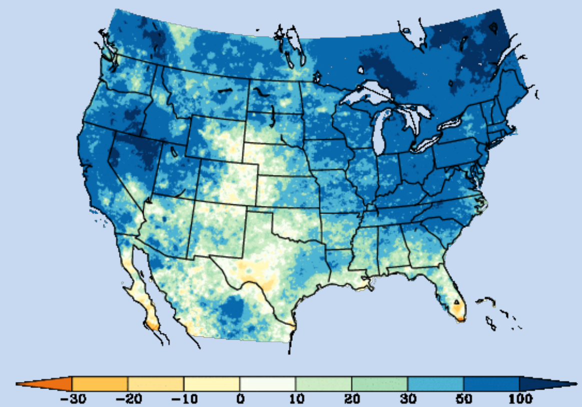
Change (%) in annual total precipitation greater than the 99th percentile

RCP8.5: 2070-2099 minus 1976-2005

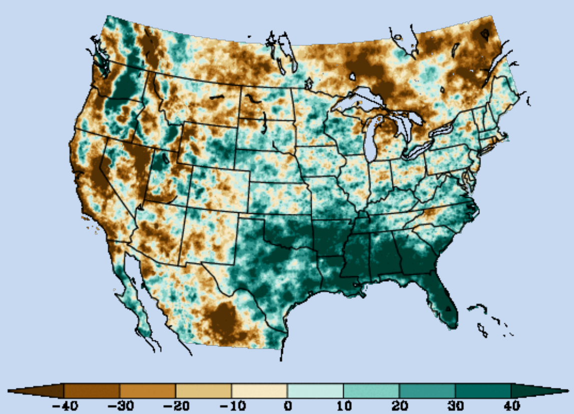
NA-CORDEX



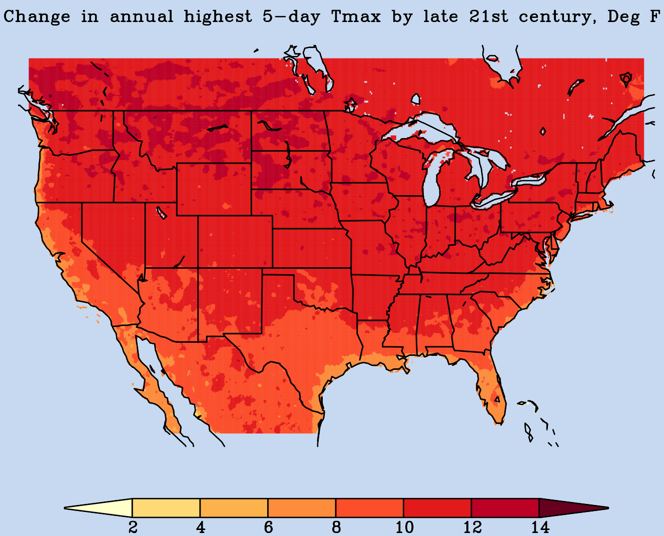
LOCA

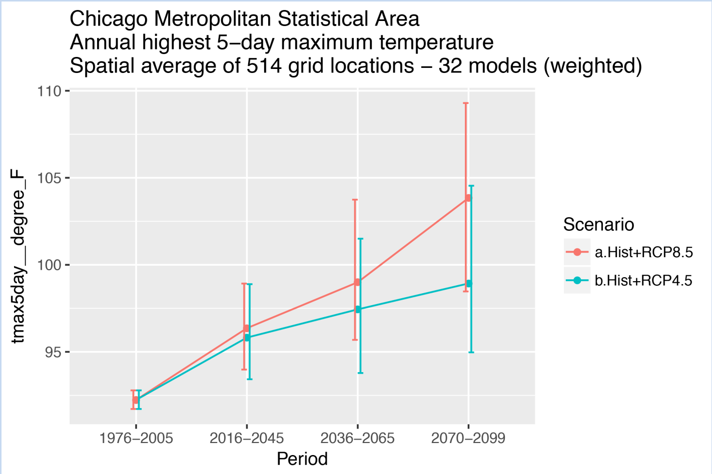


Difference

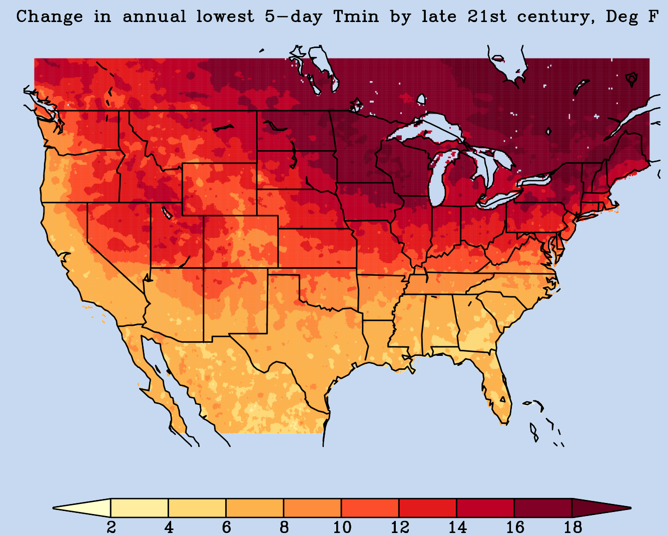


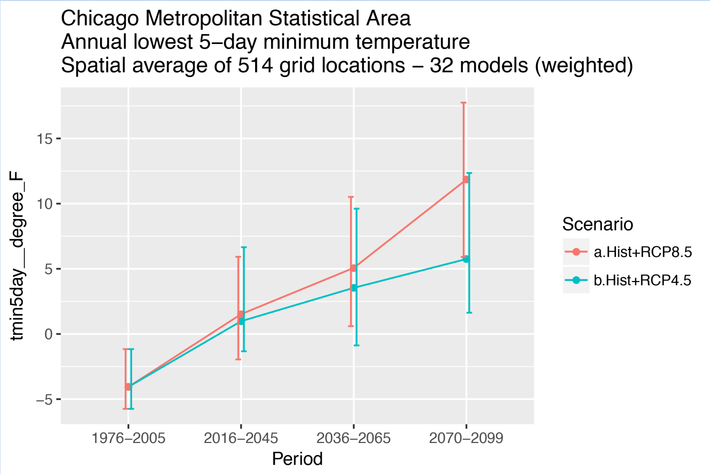
Annual highest 5-day maximum temperature



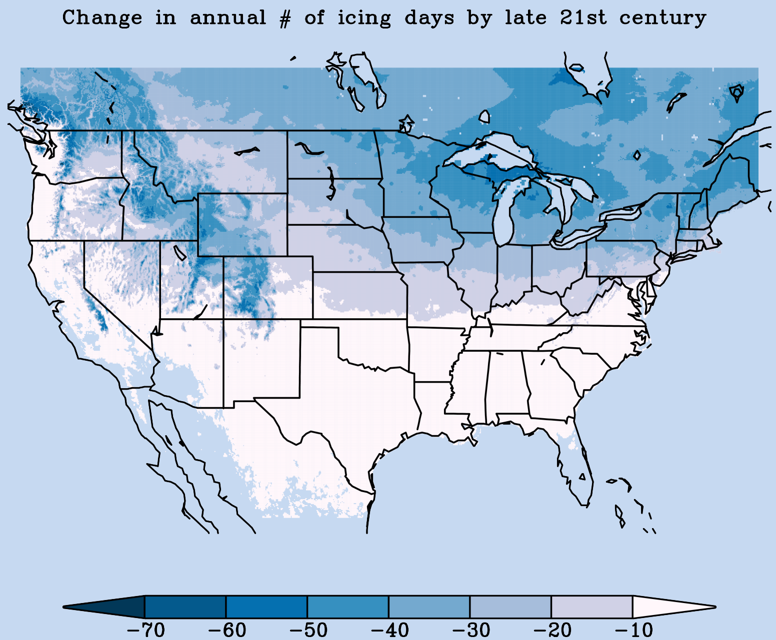


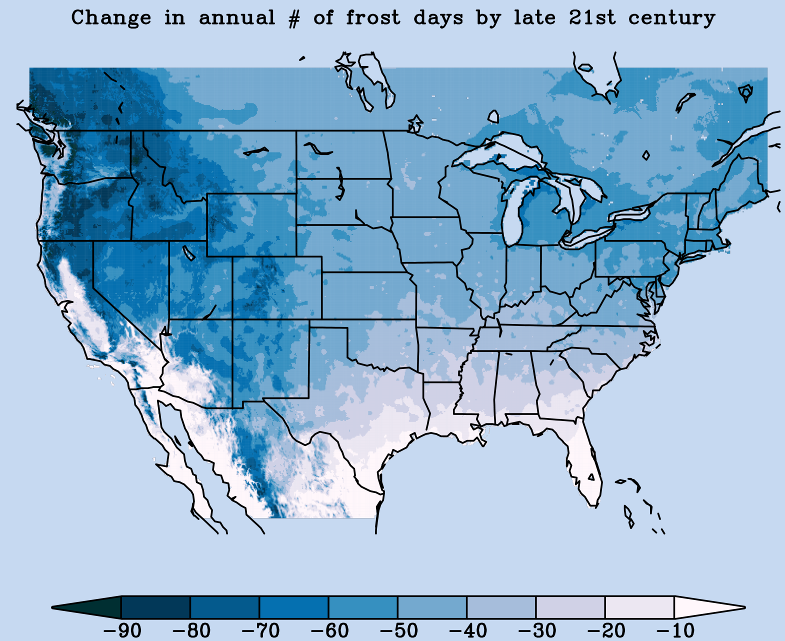
Annual lowest 5-day minimum temperature

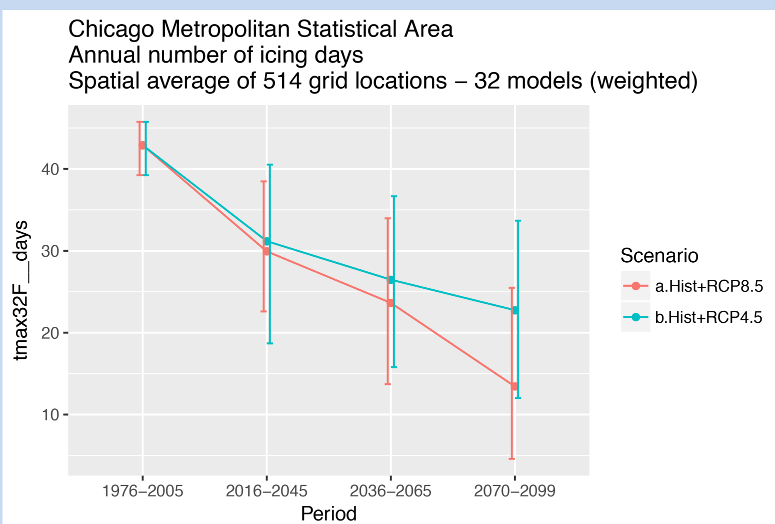


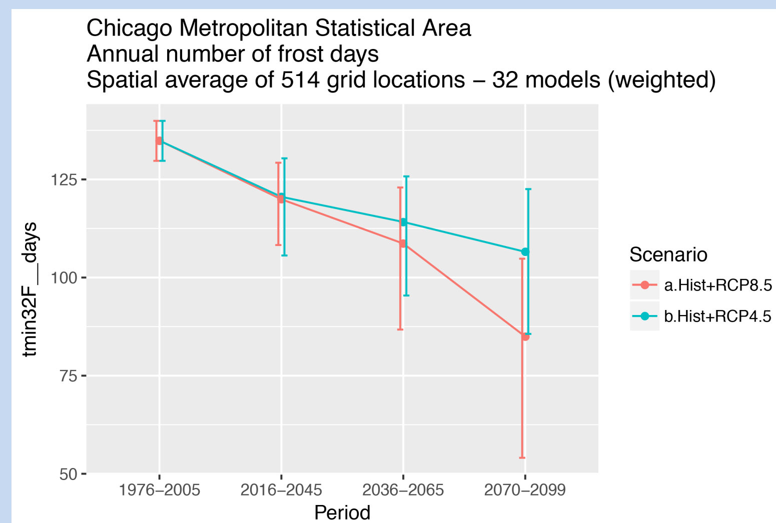


Annual number of icing/frost days

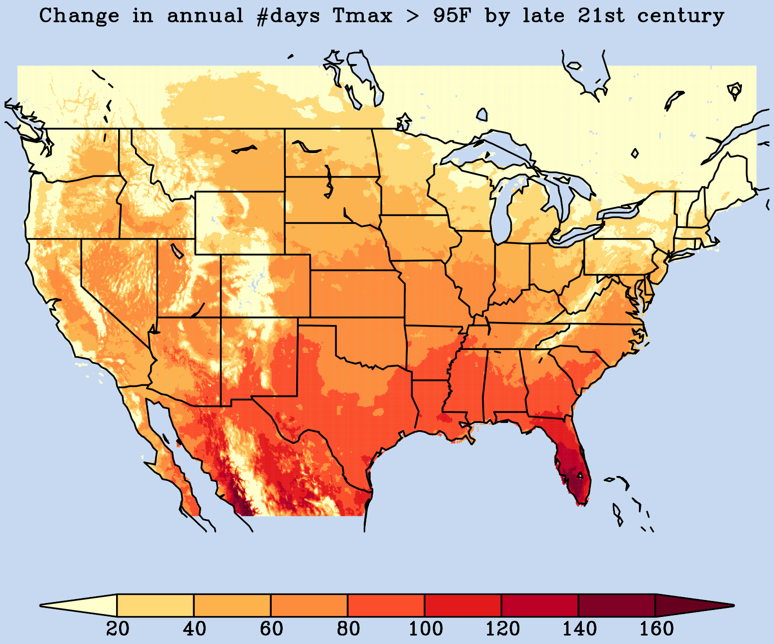




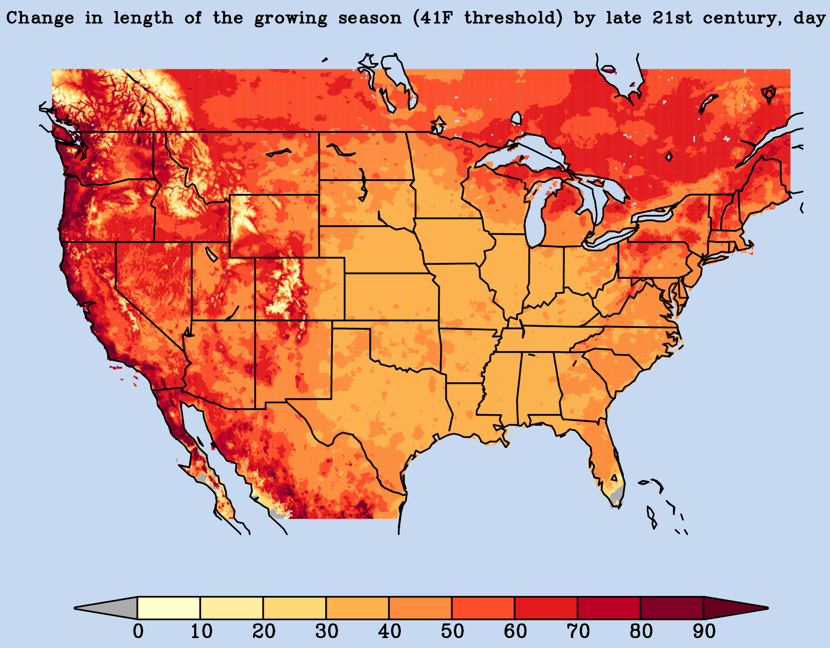




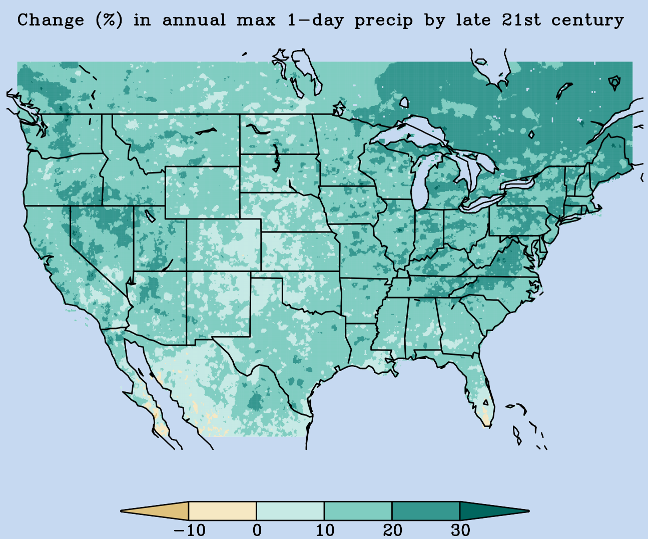
Annual number of days when max temperature > 95°F

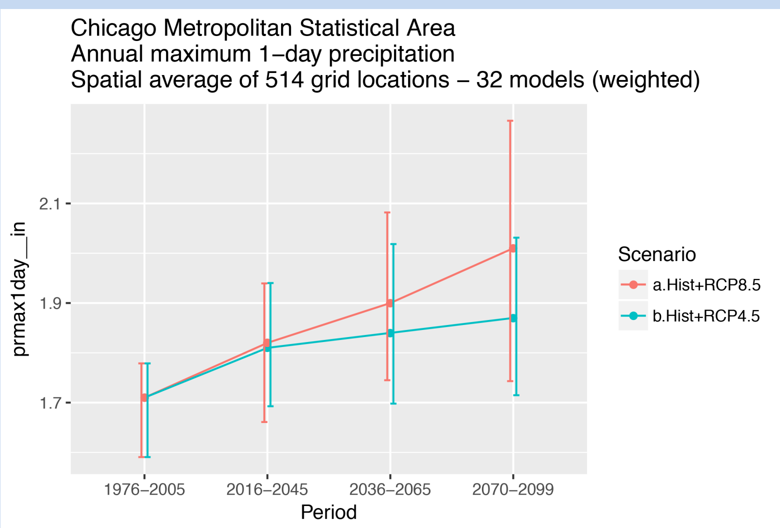


Length of the growing season (41°F threshold)

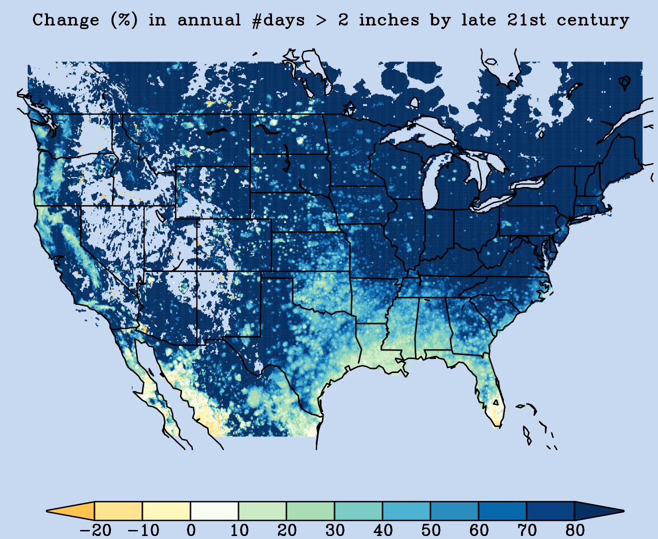


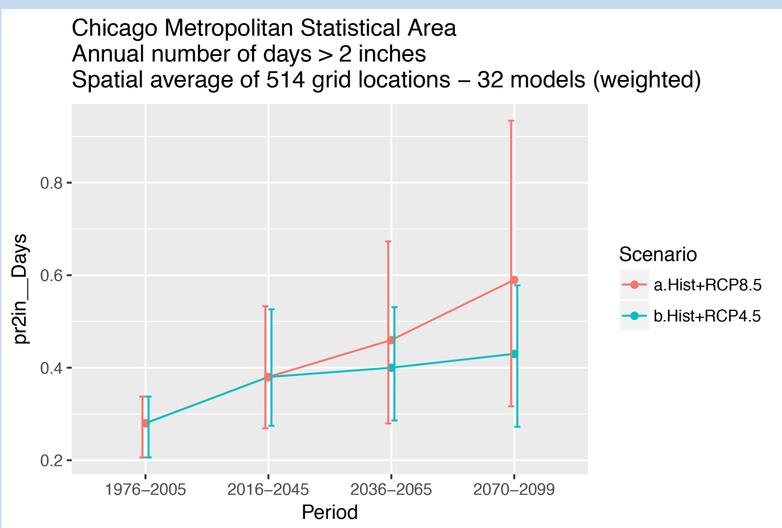
Annual Maximum 1-day precipitation (%)





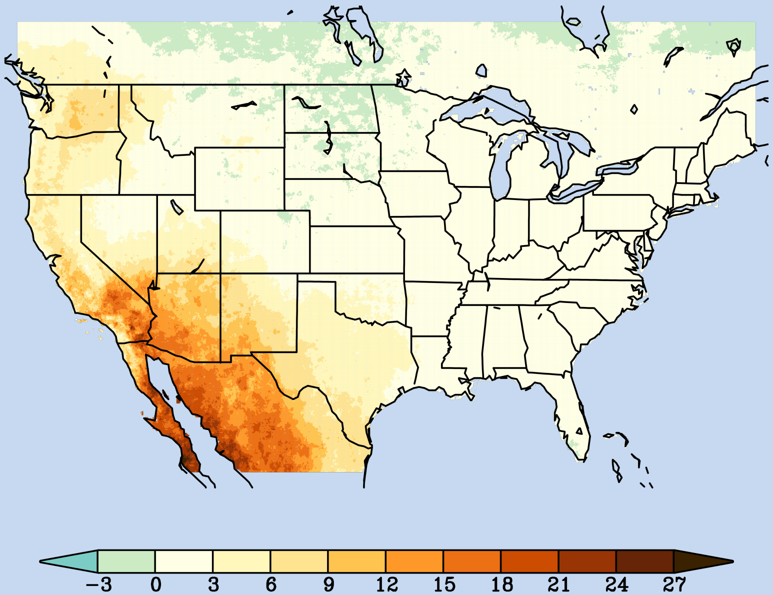
Annual number of Days > 2 inches



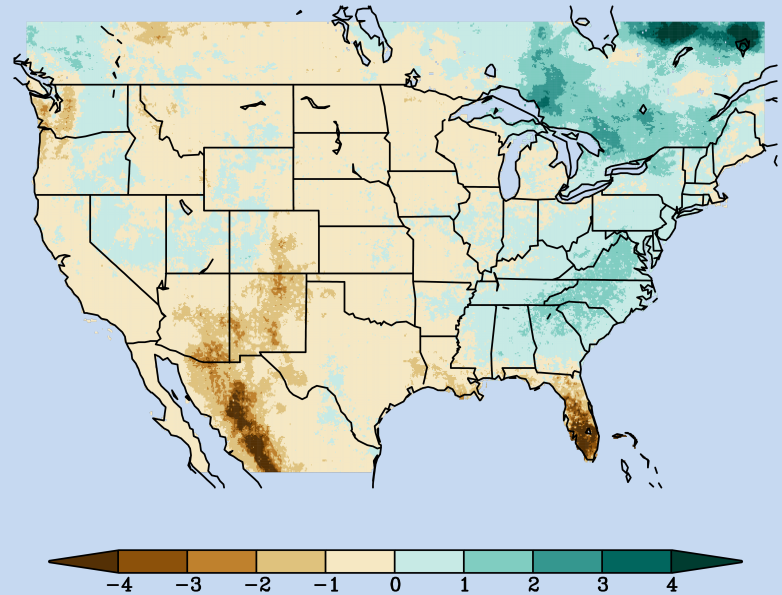


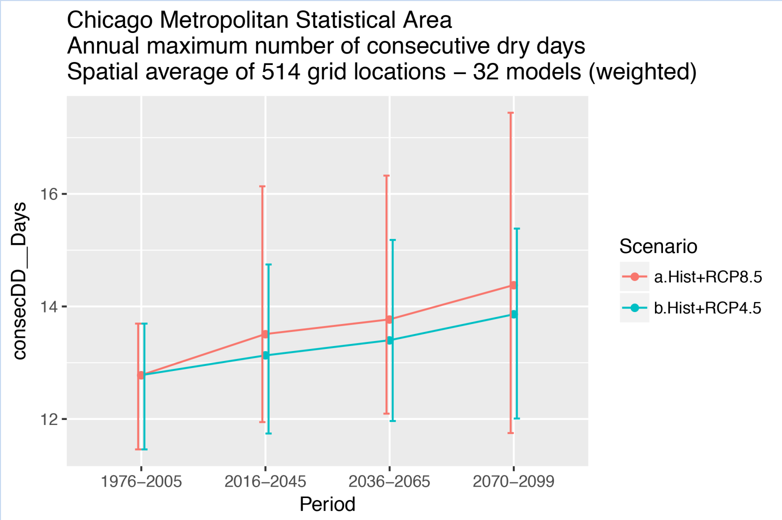
Annual Maximum Number of Consecutive Dry/Wet Days

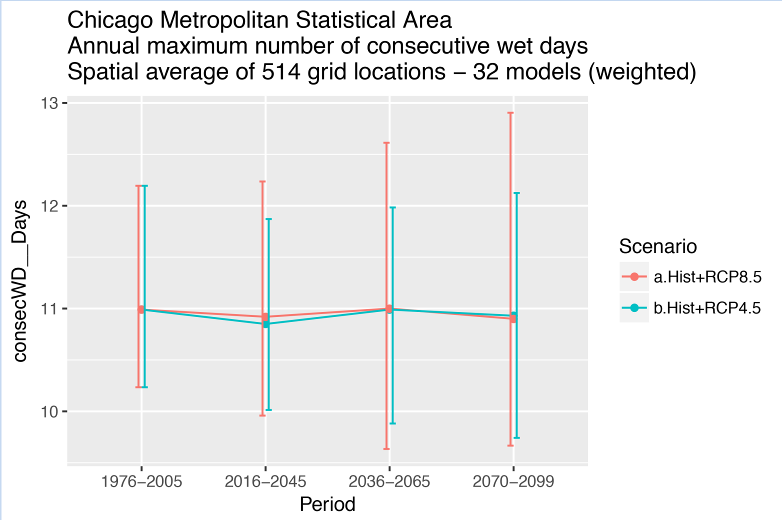
Change in annual max # of consecutive dry days by late 21st century



Change in annual max # of consecutive wet days by late 21st century







Challenges and Paths Forward

"Regional" focus of NCA imposes significant scientific and technical challenges.

1. Right-scaling climate models – Downscaling tools should be thoroughly evaluated.
2. Matching model outputs to sectorial needs - Identifying appropriate climate data and climate information for vulnerability and impact assessments and impacts-related research.
3. Attribution of climate extremes – linking the extremes to weather systems
4. Uncertainty – Identifying the ensemble size for regional models
   - Ensemble size varies with the variables of interested

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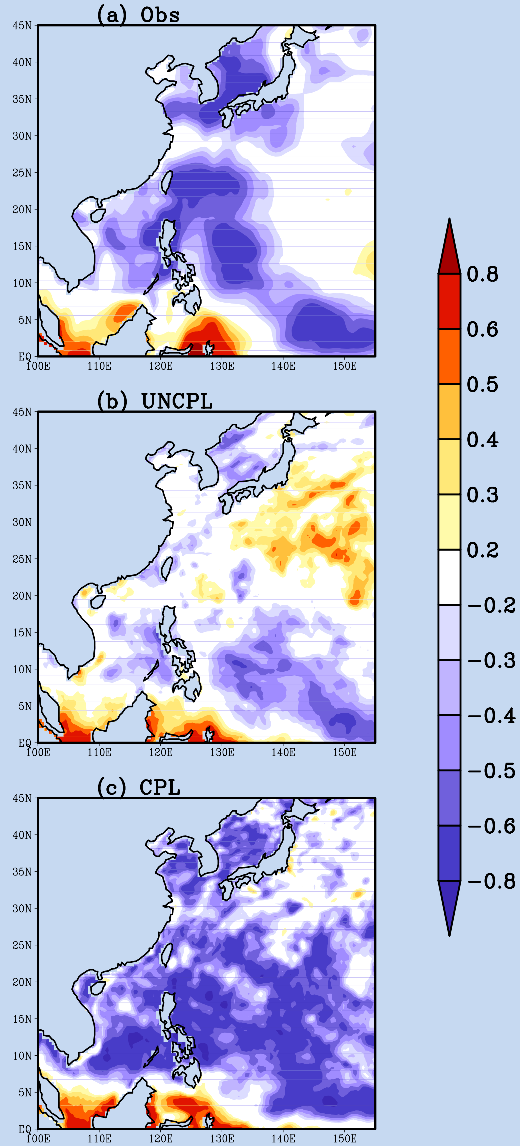
Correlation between SST and precipitation



Li, Sun and Dai 2017

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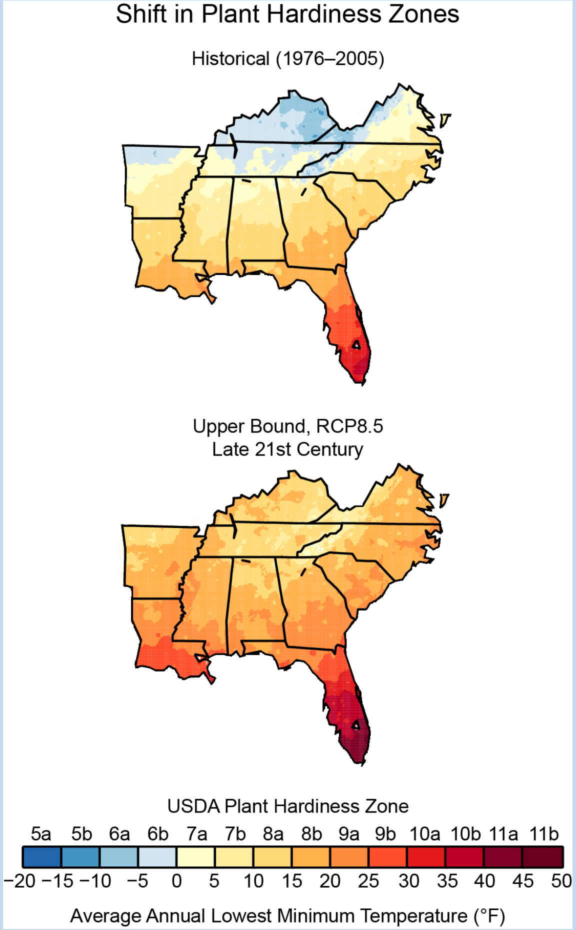
Plant hardiness Zones



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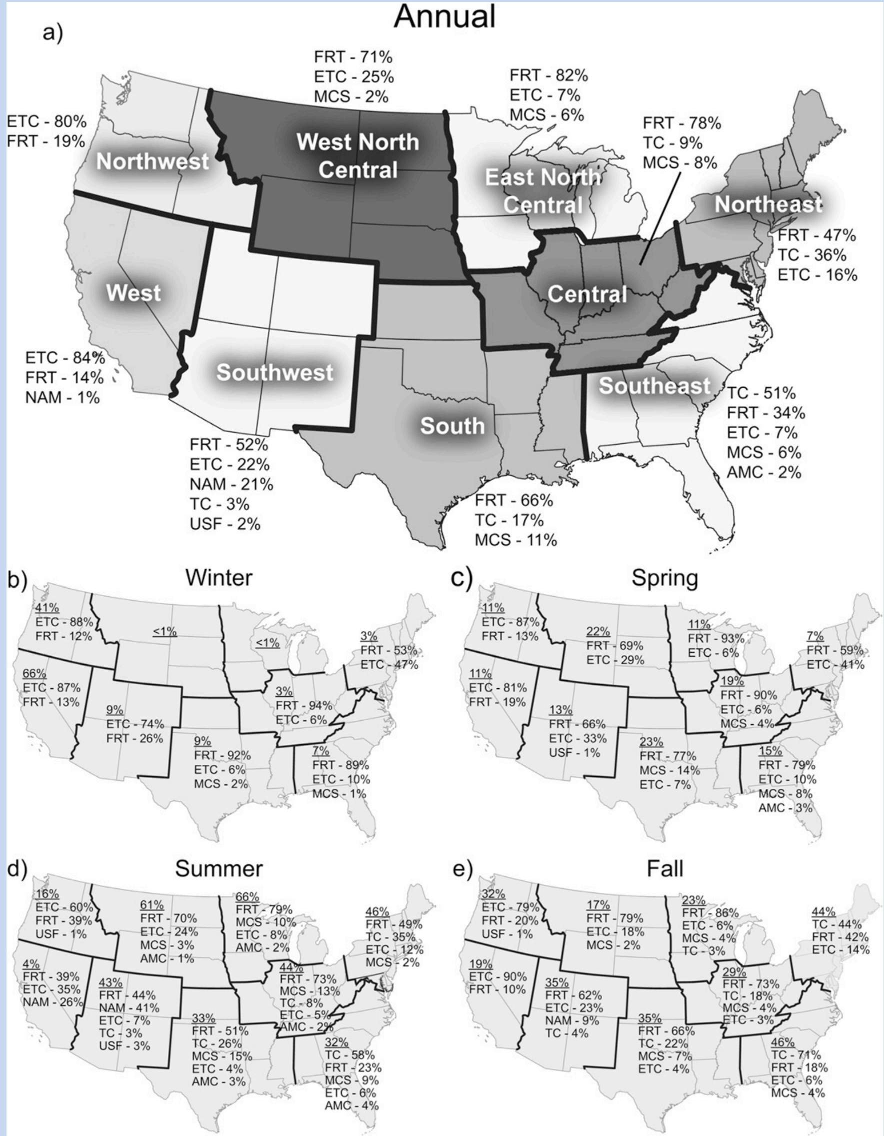
Causes of major extreme precipitation events



Kunkel *et al.* 2012

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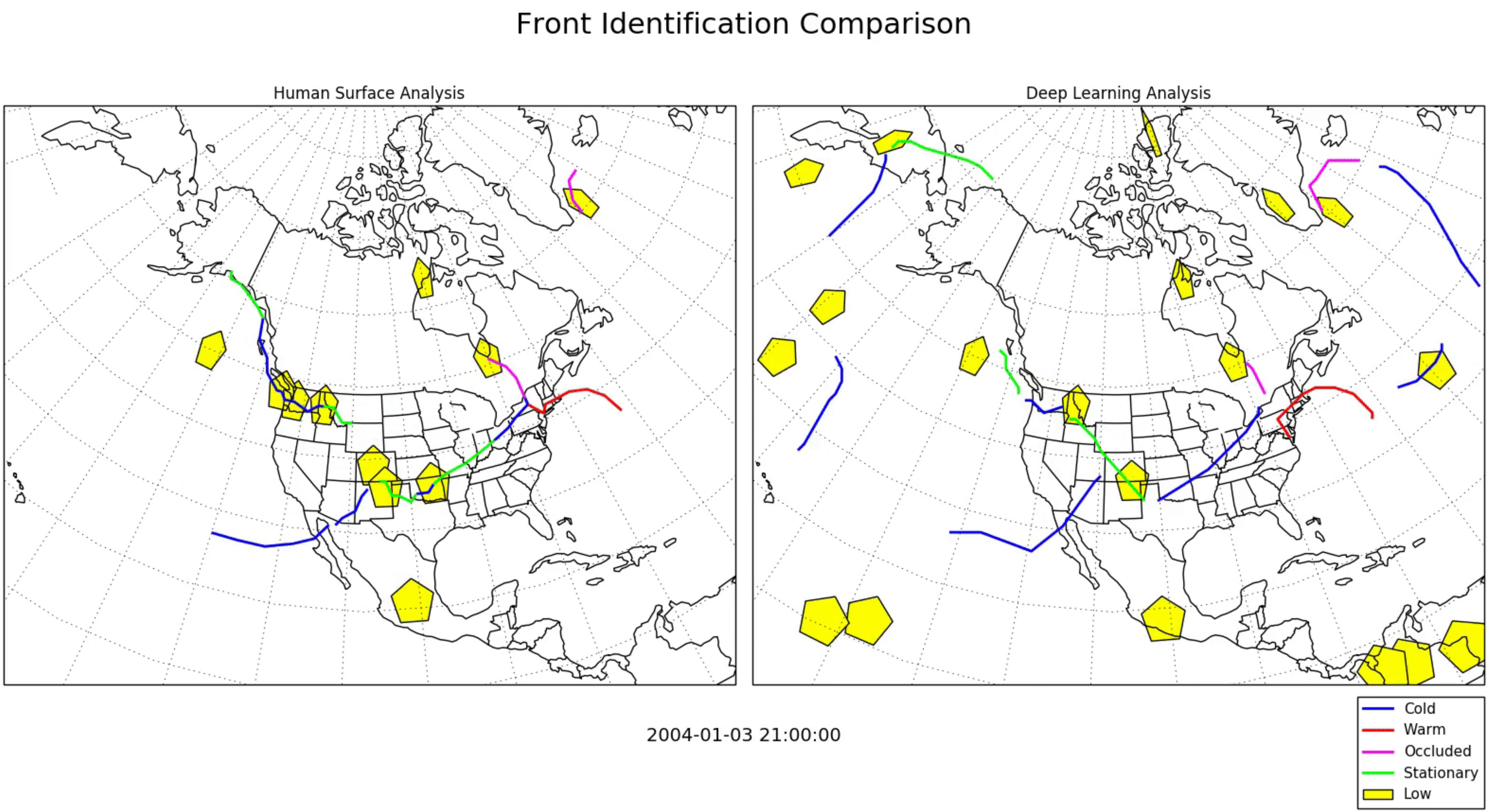
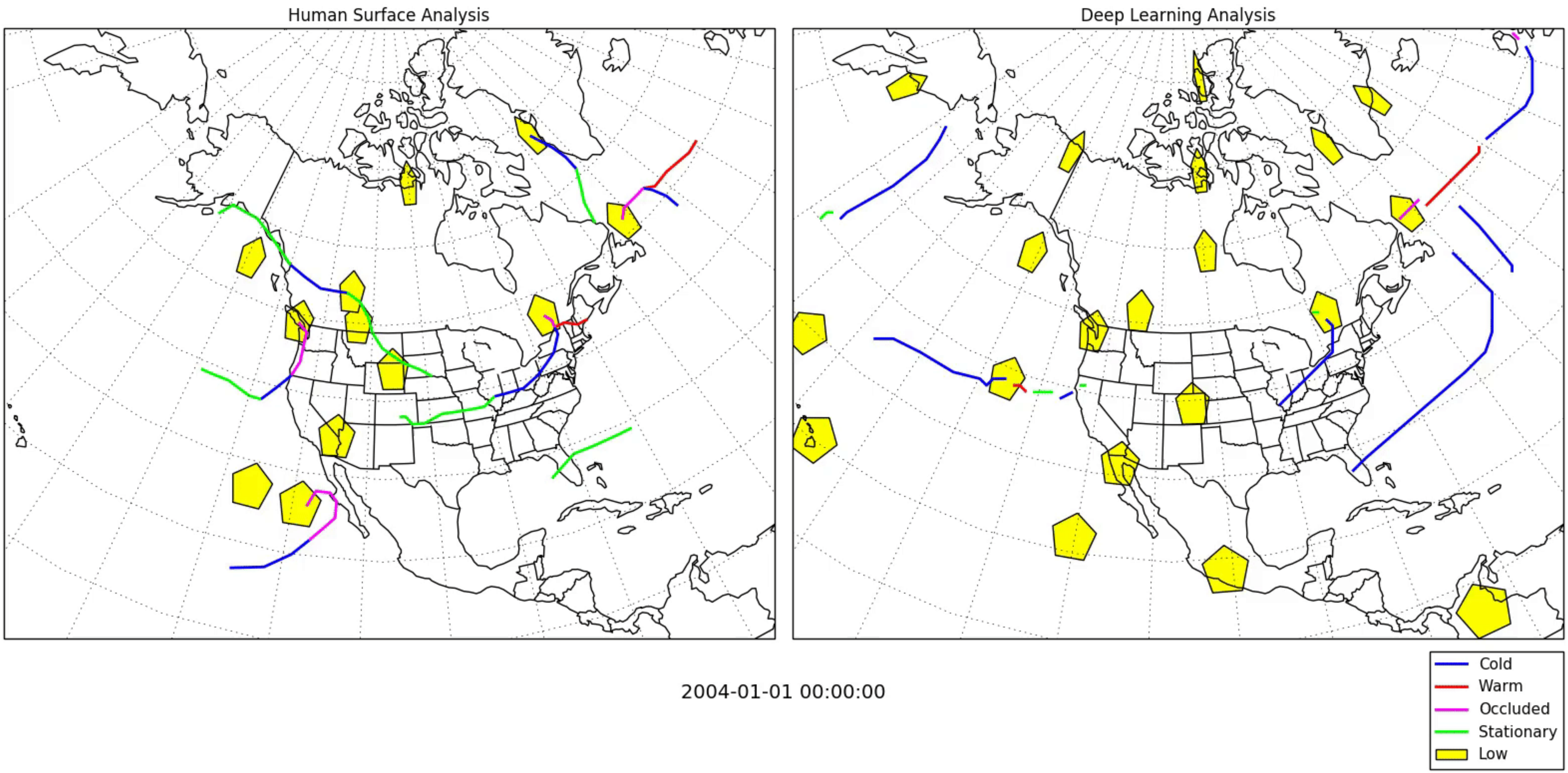
Fronts

- Deep learning neural network
- Inputs: surface values of
  - air pressure
  - air temperature
  - specific humidity
  - west-east and south-north wind velocity components
- Training dataset: 14-year set of fronts manually drawn by the National Weather Service and digitized into polylines
- Grid cell values of the probability of the presence of five types of frontal boundaries (cold, warm, stationary, occluded, and trough)

Front Identification Comparison Example



Front Identification Comparison



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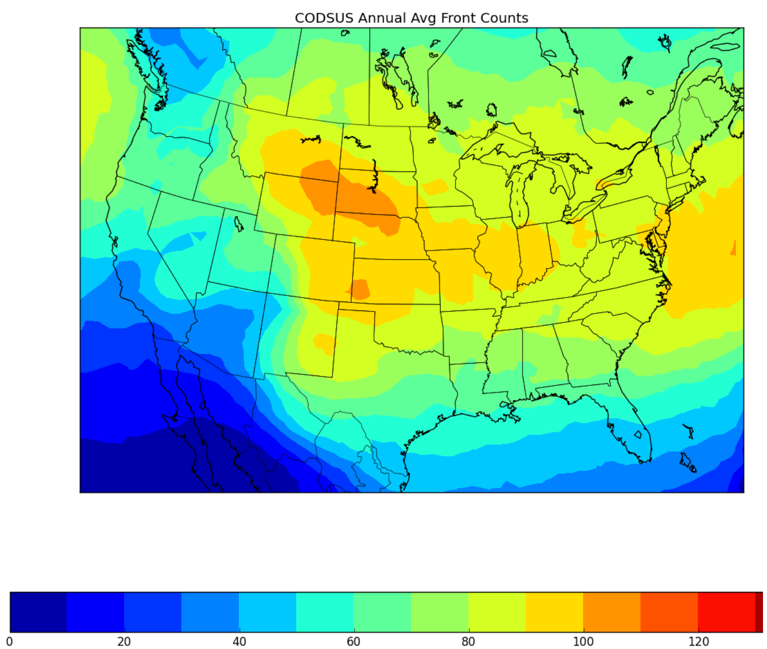
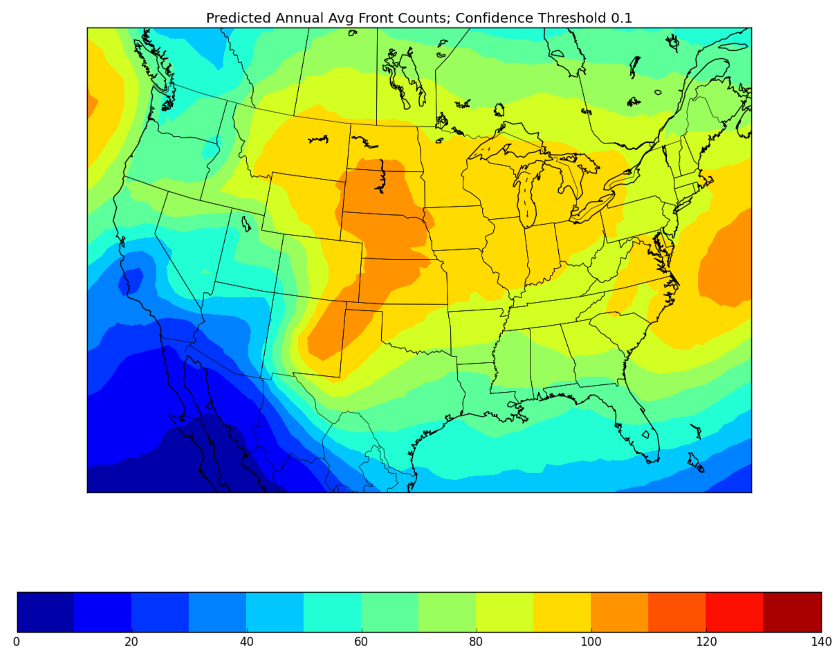
Cold Front Climatology (2003-2016)

National Weather Service Manually Analyzed Fronts (2004-2016)

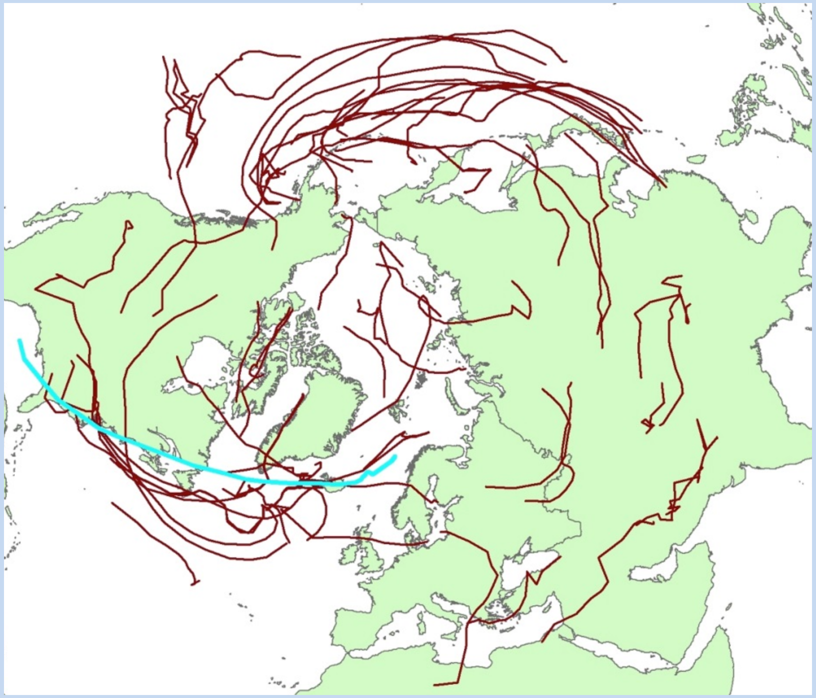


Deep Learning Neural Network automated front detection



CMIP5 ETC analysis

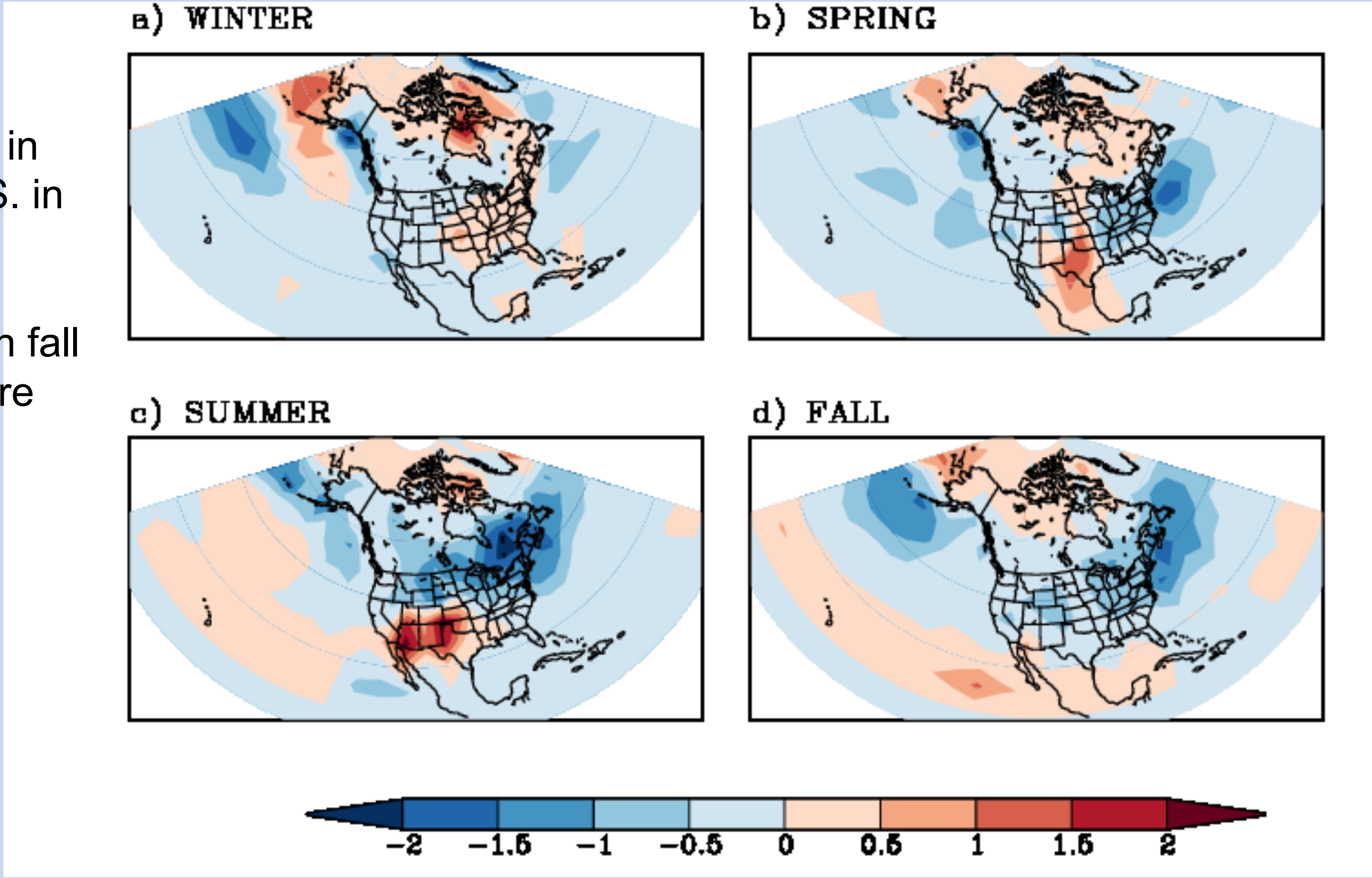
Perform extensive analyses of CMIP5 model simulations, identifying the occurrence of ETCs causing heavy precipitation for historical and future simulations.



Extratropical Cyclone Future Change: 2070-2099

Increases in eastern U.S. in winter

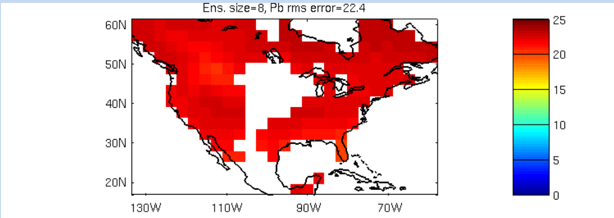
Decreases in fall everywhere



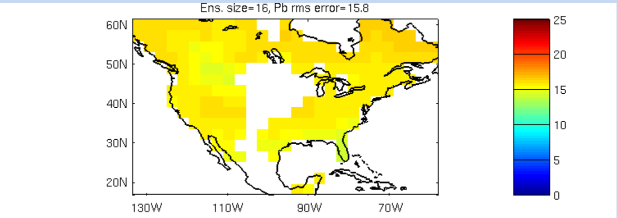
How to choose the number of ensembles?

SAMPLING ERRORS

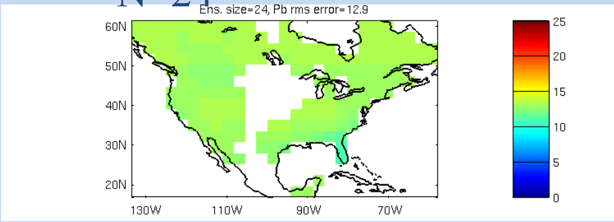
N=8



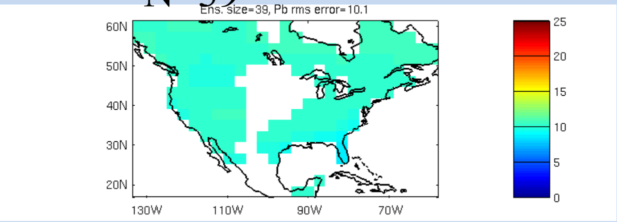
N=16

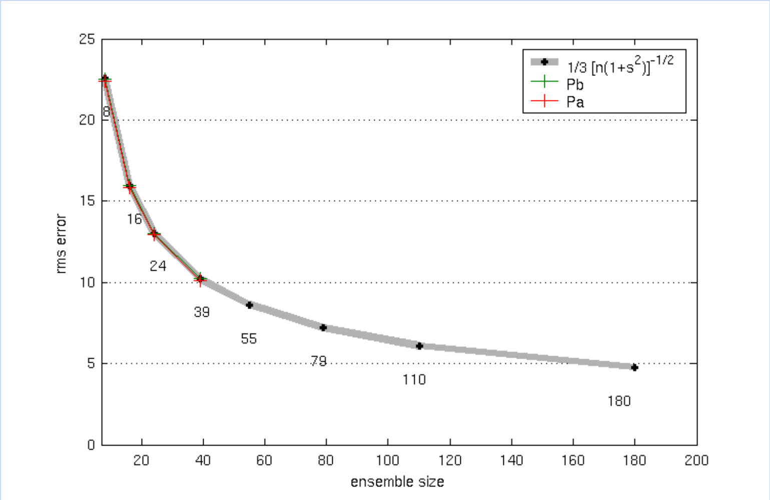


N=24



N=39





Converges like

$$\frac{2}{3\sqrt{N}}\frac{1}{\sqrt{1+S^2}}$$

S = Signal-to-noise ratio

N = ensemble size

“True” rms divide by $\sqrt{2}$

M. Tippett

Summary

- Climate Downscaling has been extensively used in the National Climate Assessment.
  1) Temperature extremes are most directly affected by the climate change: heat waves are projected to increase in frequency, intensity, and duration, and cold snaps are projected to diminish in their frequency, but not necessarily in their intensity.
  2) Precipitation extremes are projected to become more frequent and more intense
  3) annual maximum number of consecutive wet days will significantly increase in the eastern U.S. and annual maximum consecutive dry days will significantly increase in the western U.S.

Summary (cont'd)

- The possibility exists to enhance climate information and increase our confidence in future climate change using dynamical downscaling
  1) Focus on climate variables that are both relevant and adding values by regional models. RCMs can resolve the topographic features and many physical processes such as convectively driven storms and monsoon-topography interaction at very high resolution. We do anticipate that RCMs will provide a realistic indication of how the characteristics of weather events will change in a warming world.
  2) Focus on the physical mechanisms of regional/local climate changes. The full set of dynamical fields available from RCMs will allow diagnostic investigation of these changes to complement the GCM projections.

Climate Explorer 2.0

- The Climate Explorer offers customizable graphs and maps of observed and projected temperature, precipitation, and related climate variables for every county in the contiguous United States.

https://toolkit.climate.gov/climate-explorer2/

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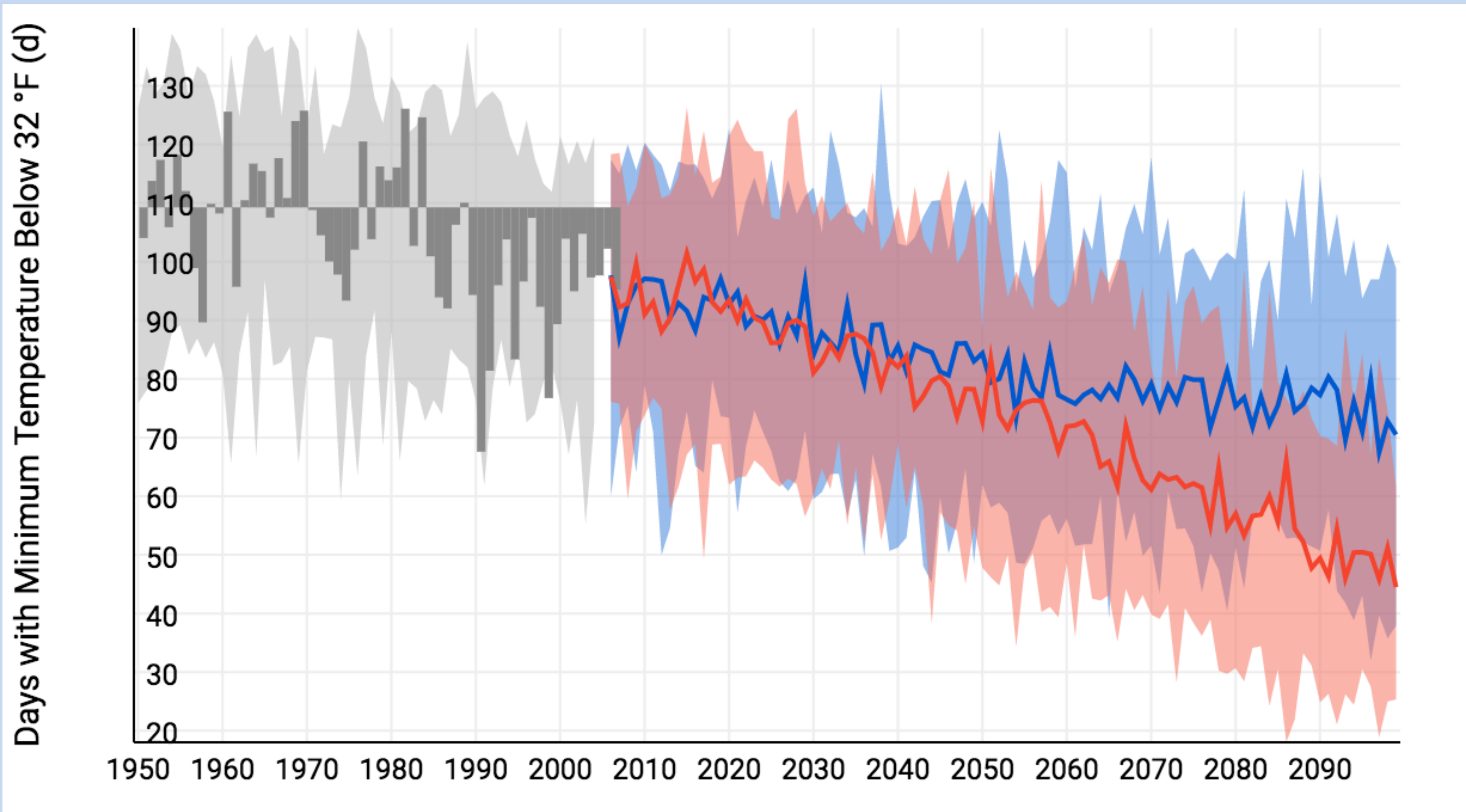
Buncombe County



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THANKS

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