UMassAmherst

CLIMATE CHANGE AND REGIONAL HYDROLOGY ACROSS THE NORTHEAST US: Evidence of Changes, Model Projections, and Remote Sensing Approaches

Michael A. Rawlins
Climate System Research Center
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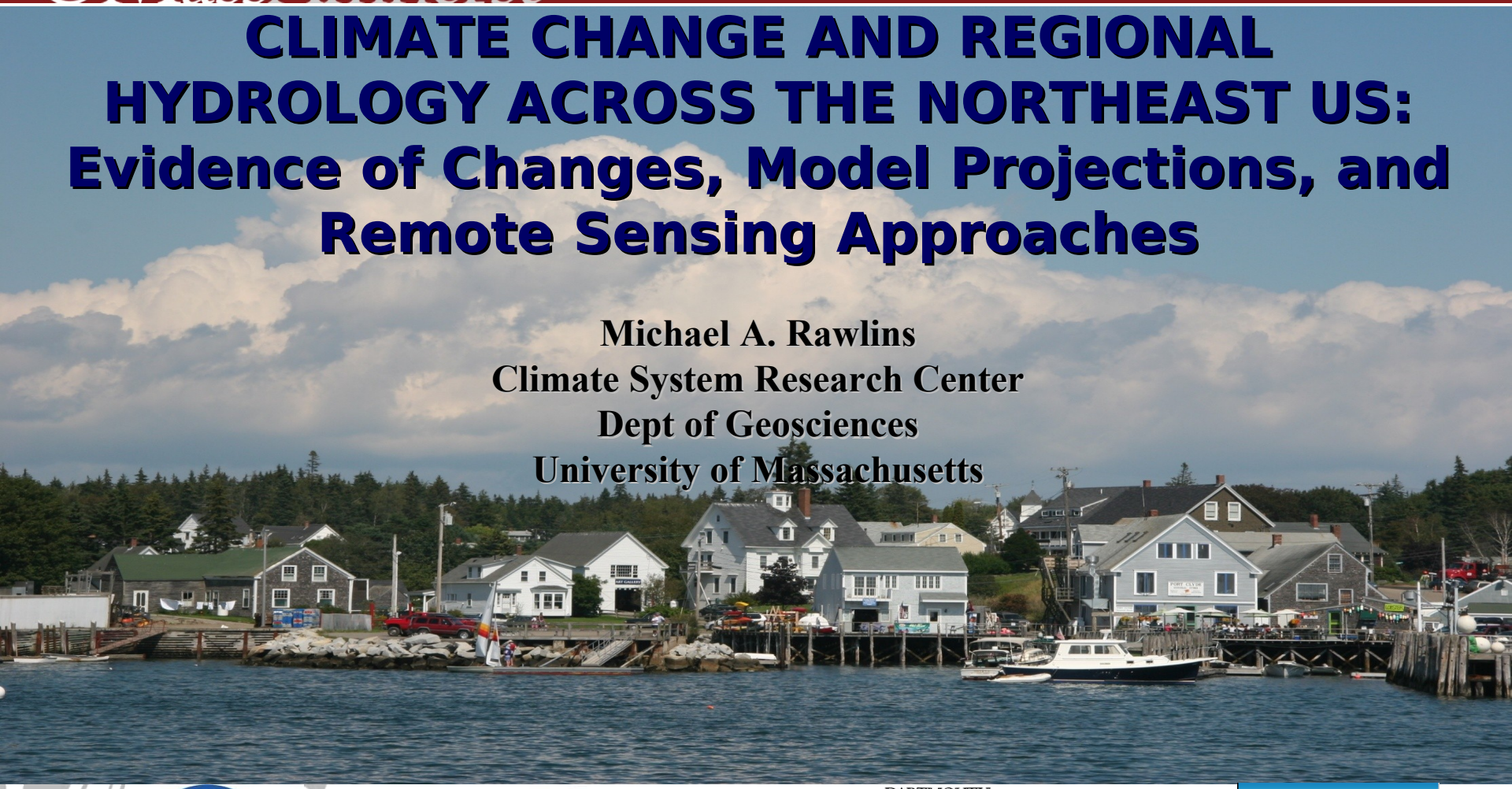
University of Massachusetts



NASA

New Hampshire Space Grant Consortium

DARTMOUTH VOX CLAMANTIS IN DESERTO 1769

CLIMATE SYSTEM RESEARCH CENTER

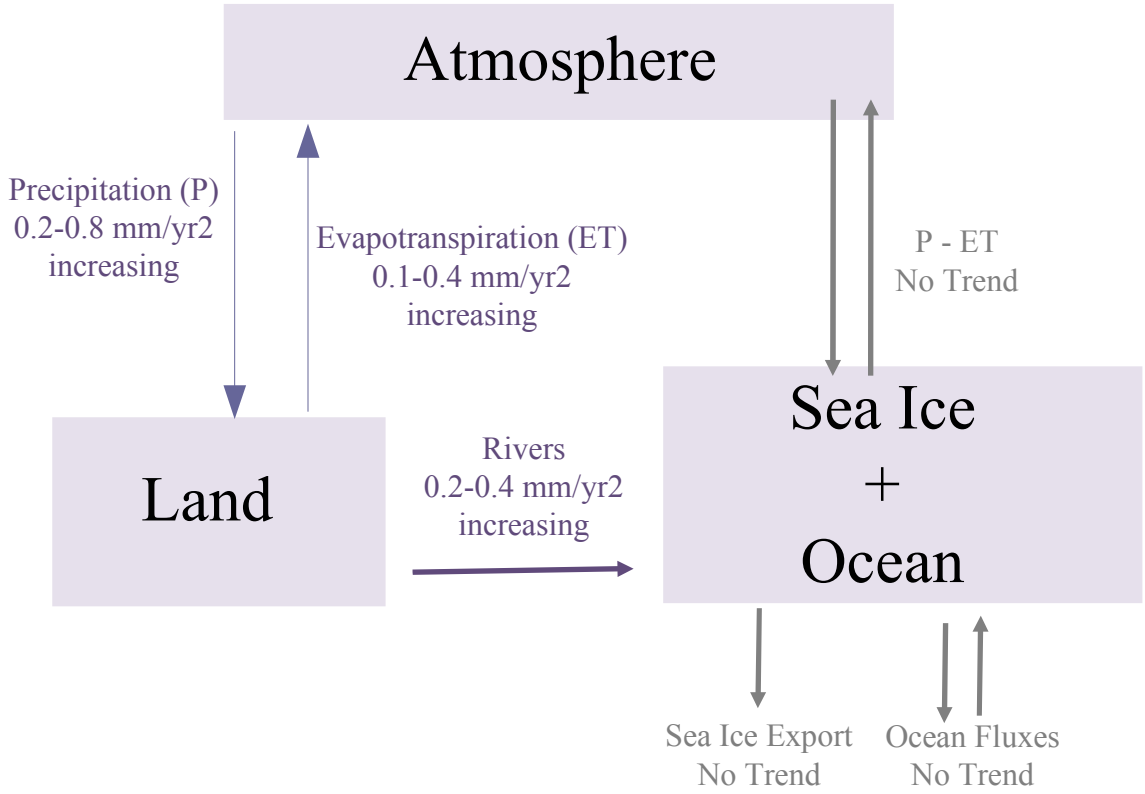
OUTLINE

- **Global Climate Change**
- **Past and Future Changes to Hydrological Quantities Across the Northeast US**
- **Available Remote Sensing Tools**

Freshwater Cycle Intensification in the Arctic System

Rawlins et al., *Journal of Climate*, 2010

Intensification = Increased freshwater (FW) fluxes between atmosphere, land and ocean

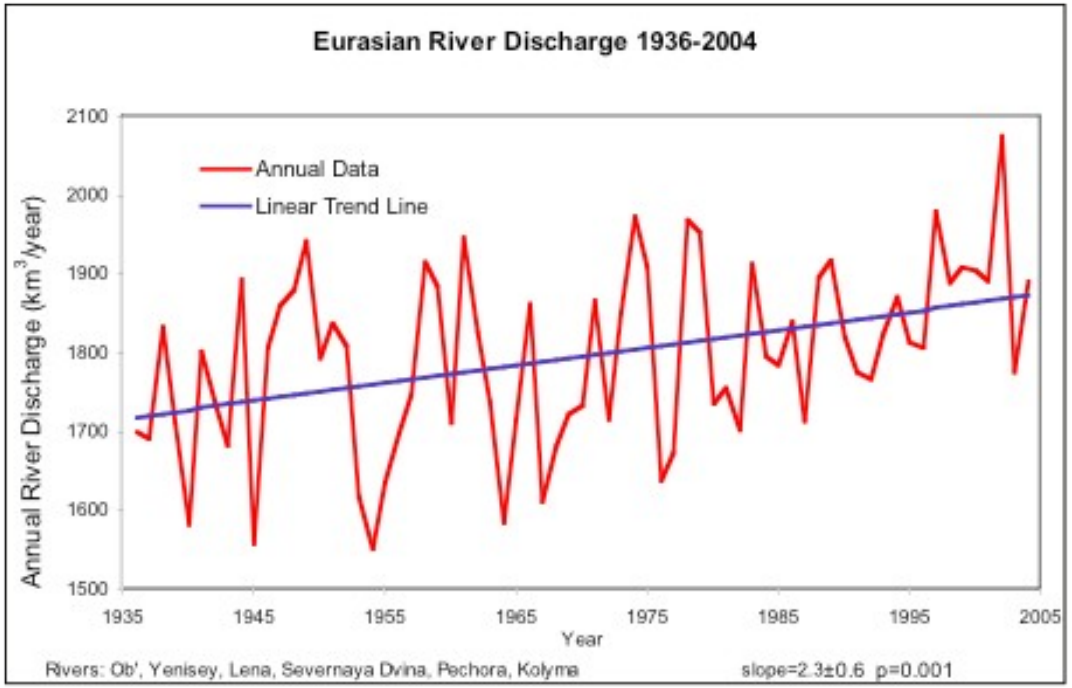


- Both observations and models were used to examine whether intensification is occurring in response to planetary warming
- Global climate models show more significant trends (lower inter-annual variance) than observations
- Intrinsic variability in relatively short times series of observations tends to limit confidence in trend robustness

FW fluxes between atmosphere and land, and river discharge, show clear, positive trends over the last several decades. Sea ice and ocean fluxes do not exhibit any clear trends through 2009, but we expect intensification with further warming.

Discharge to the Arctic Ocean from the 6 largest Eurasian rivers has increased since the 1930s...

… Increased snowfall has been identified as primary driver for this trend

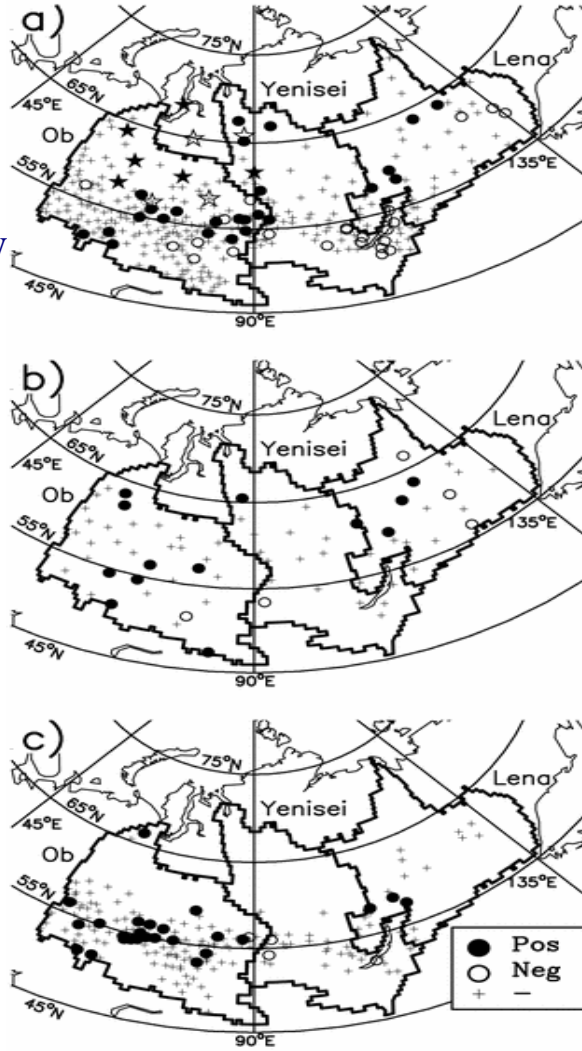


Peterson et al., 2002, Science

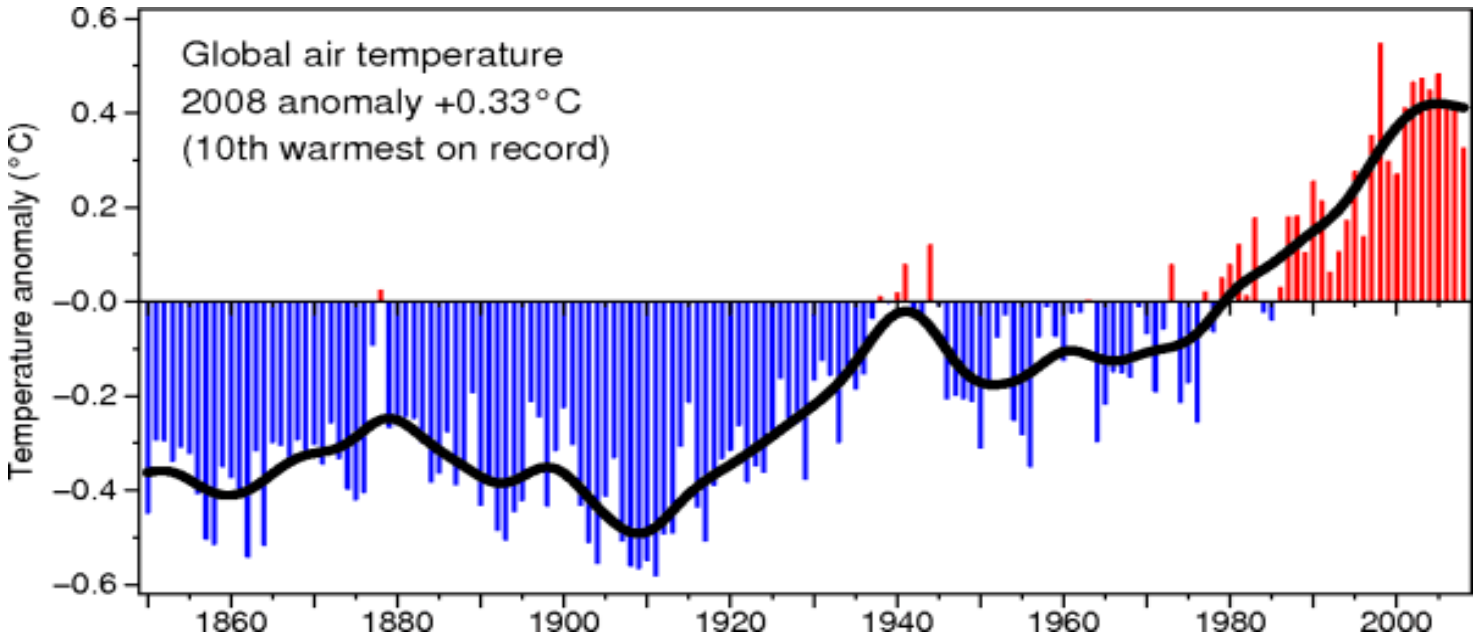
snow fall

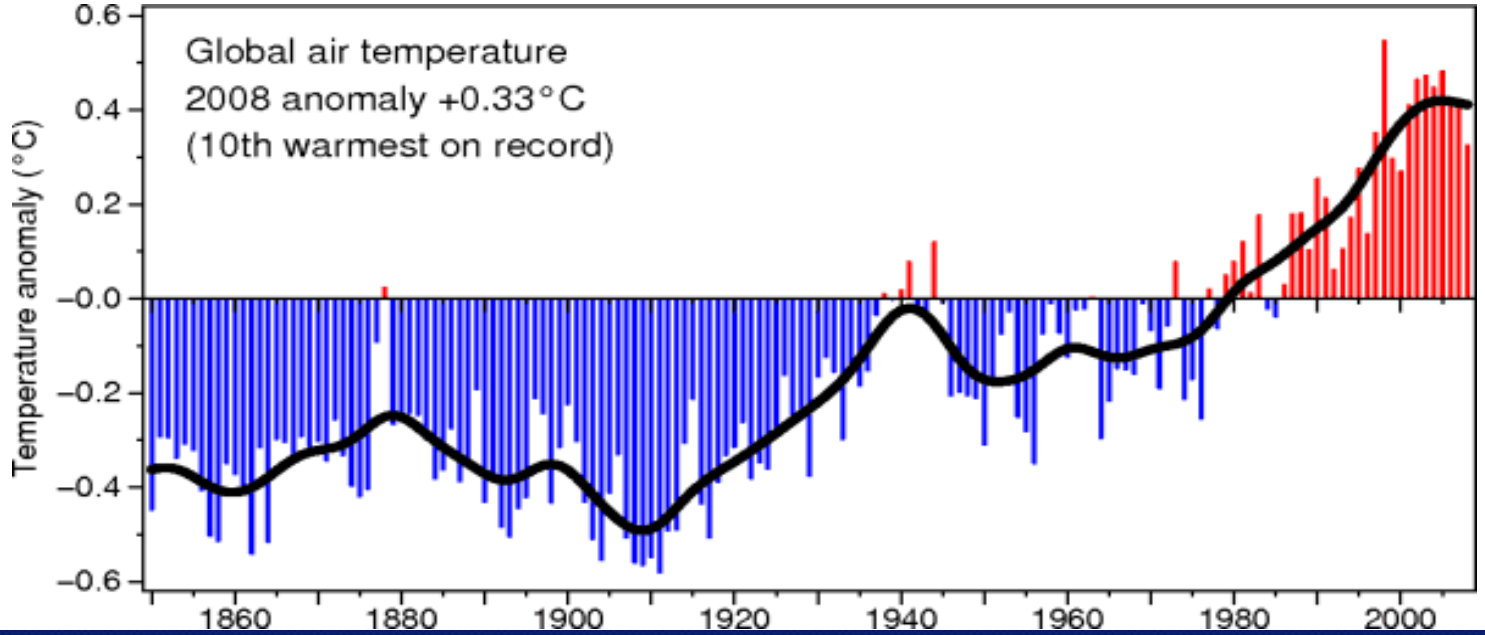
snow depth

swe



Rawlins et al., 2009, JGR


Global air temperature
2008 anomaly +0.33°C
(10th warmest on record)
Temperature anomaly (°C)
0.6
0.4
0.2
−0.0
−0.2
−0.4
−0.6
1860
1880
1900
1920
1940
1960
1980
2000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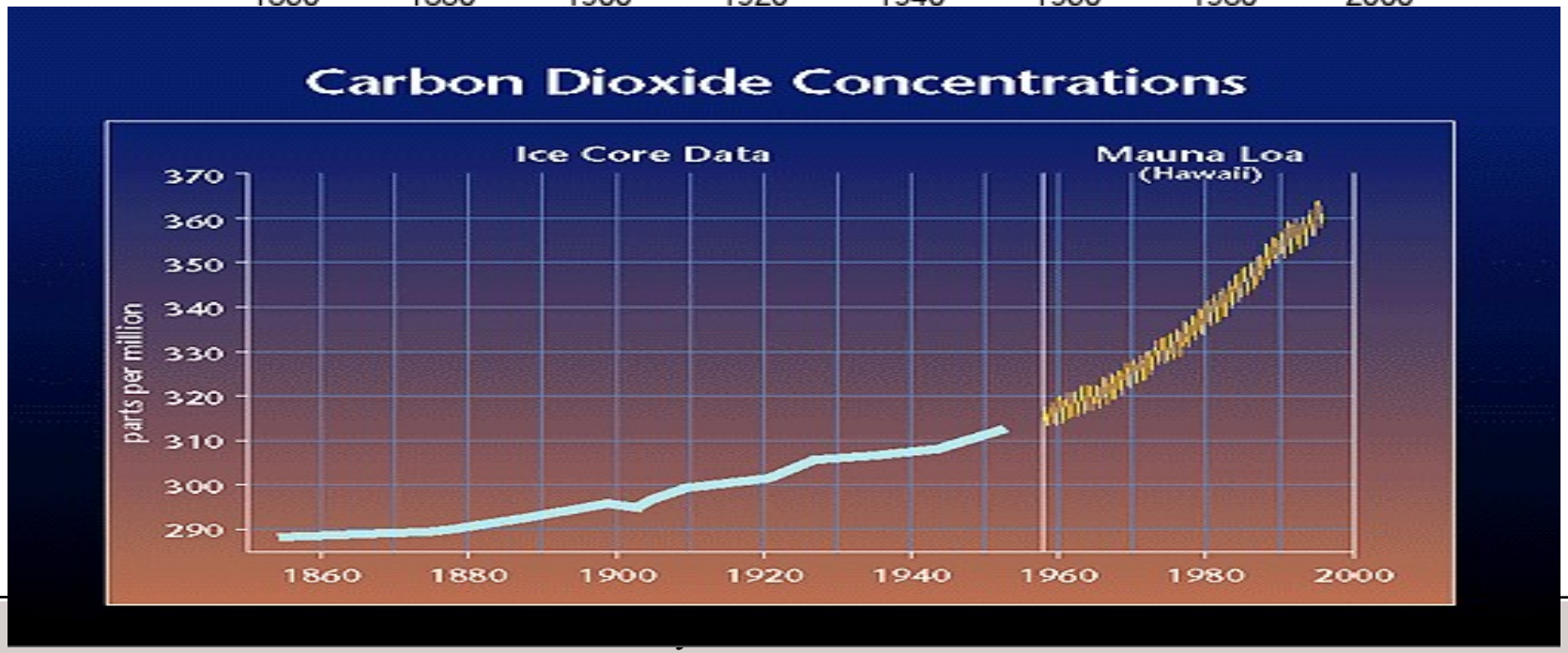
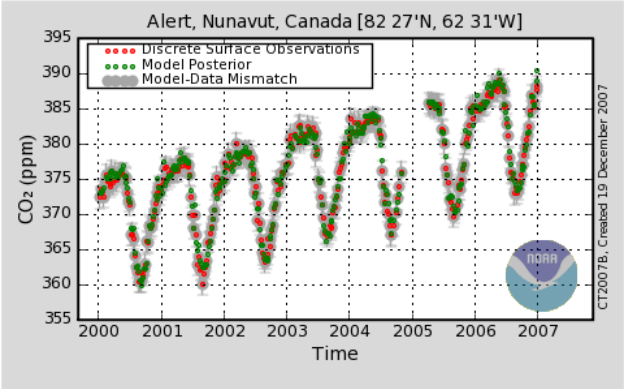
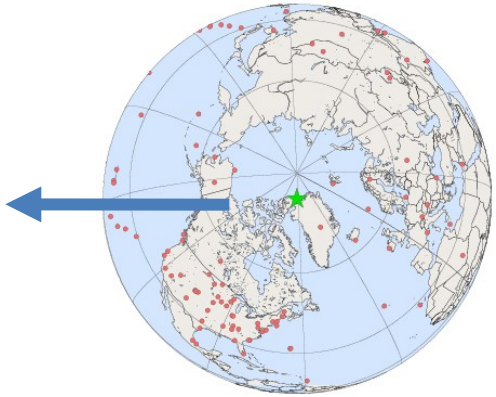
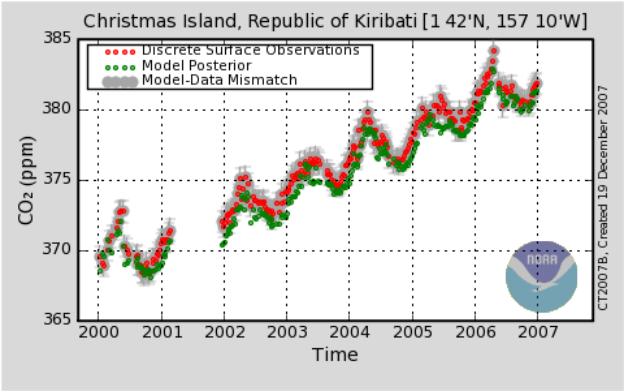
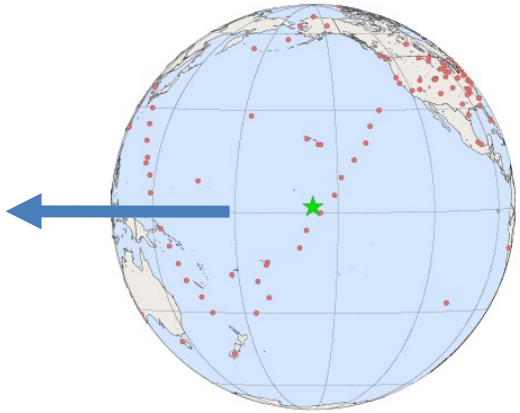
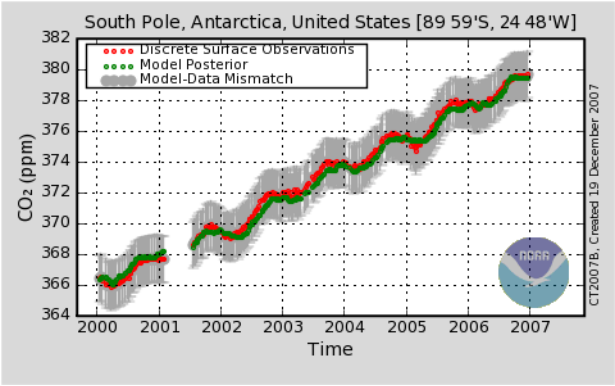

Carbon Dioxide Concentrations
Ice Core Data
Mauna Loa
(Hawaii)
parts per million
370
360
350
340
330
320
310
300
290
1860
1880
1900
1920
1940
1960
1980
2000

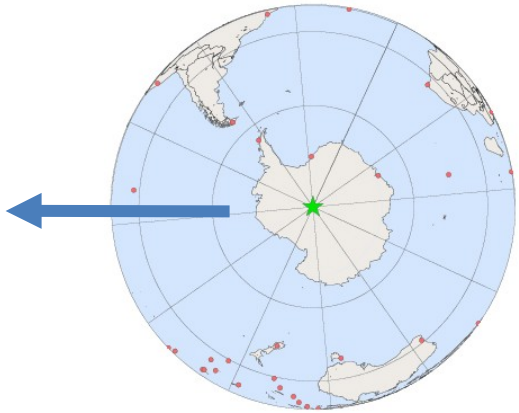

Alert, Nunavut, Canada [82 27'N, 62 31'W]
Discrete Surface Observations
Model Posterior
Model-Data Mismatch
CO₂ (ppm)
Time
CT2007B, Created 19 December 2007

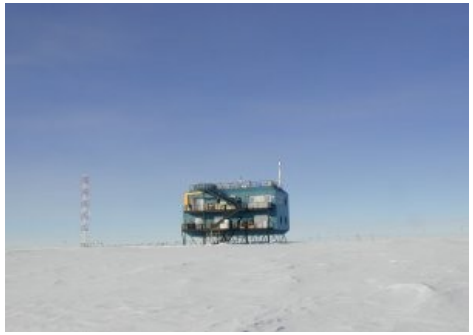



Christmas Island, Republic of Kiribati [1 42'N, 157 10'W]
Discrete Surface Observations
Model Posterior
Model-Data Mismatch
CO₂ (ppm)
Time
CT2007B, Created 19 December 2007

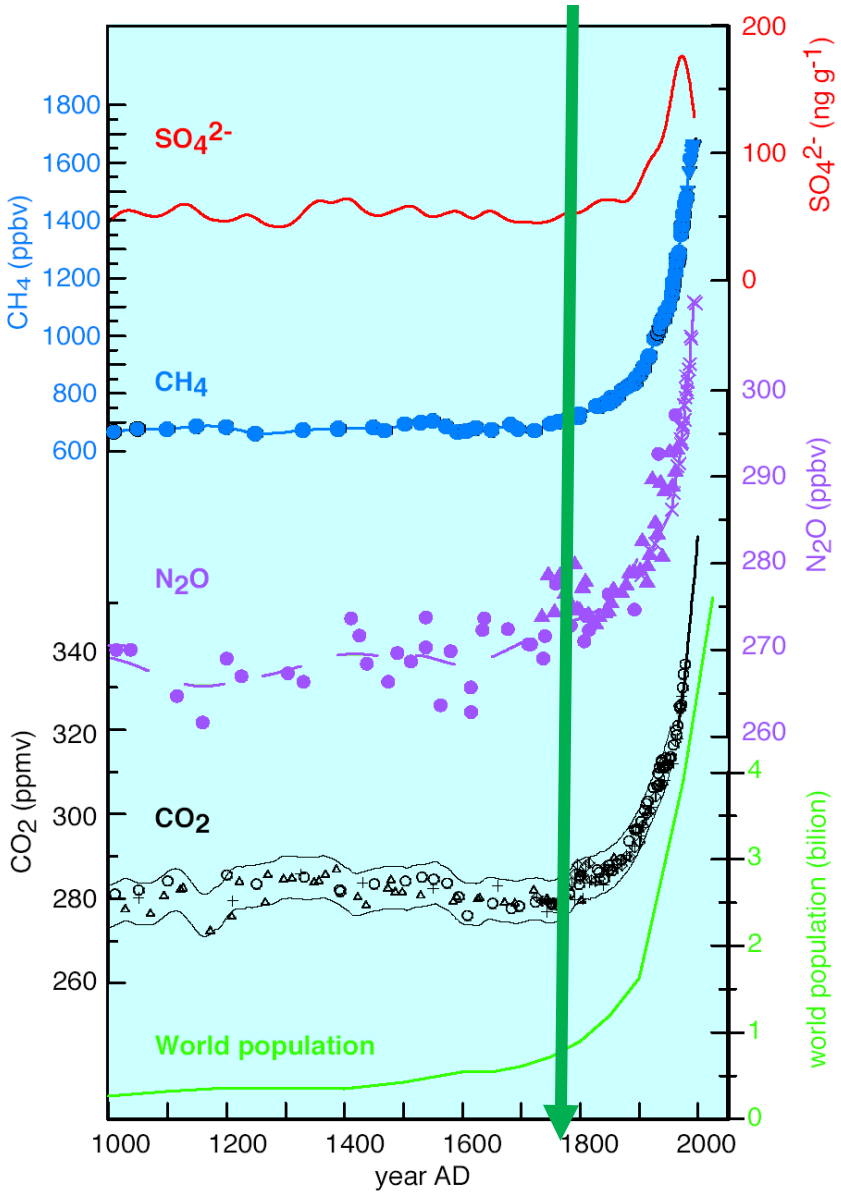



South Pole, Antarctica, United States [89 59'S, 24 48'W]
Discrete Surface Observations
Model Posterior
Model-Data Mismatch
CO₂ (ppm)
Time
CT2007B, Created 19 December 2007





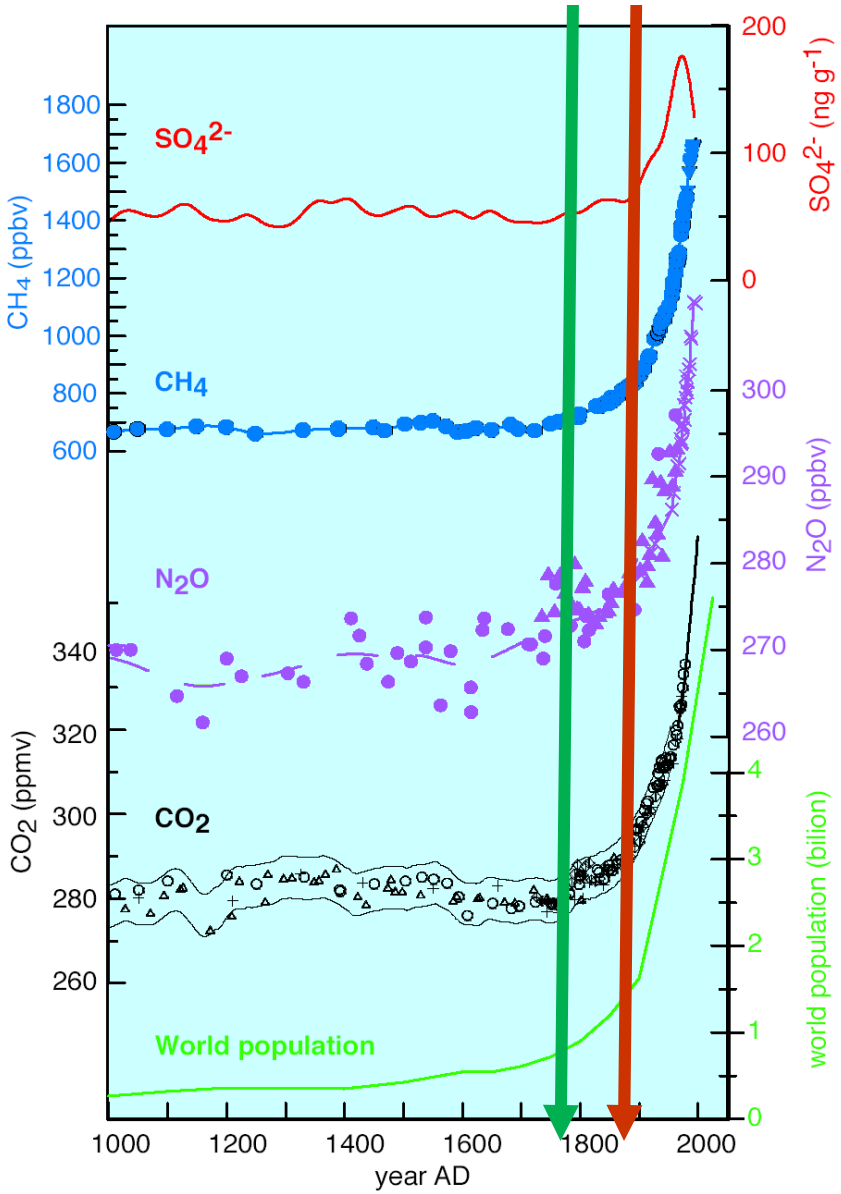
Anthropogenic Increase: Records Over the Last Millennium



Key dates:

1.James Watt's invention of the steam piston engine in 1784

Anthropogenic Increase: Records Over the Last Millennium



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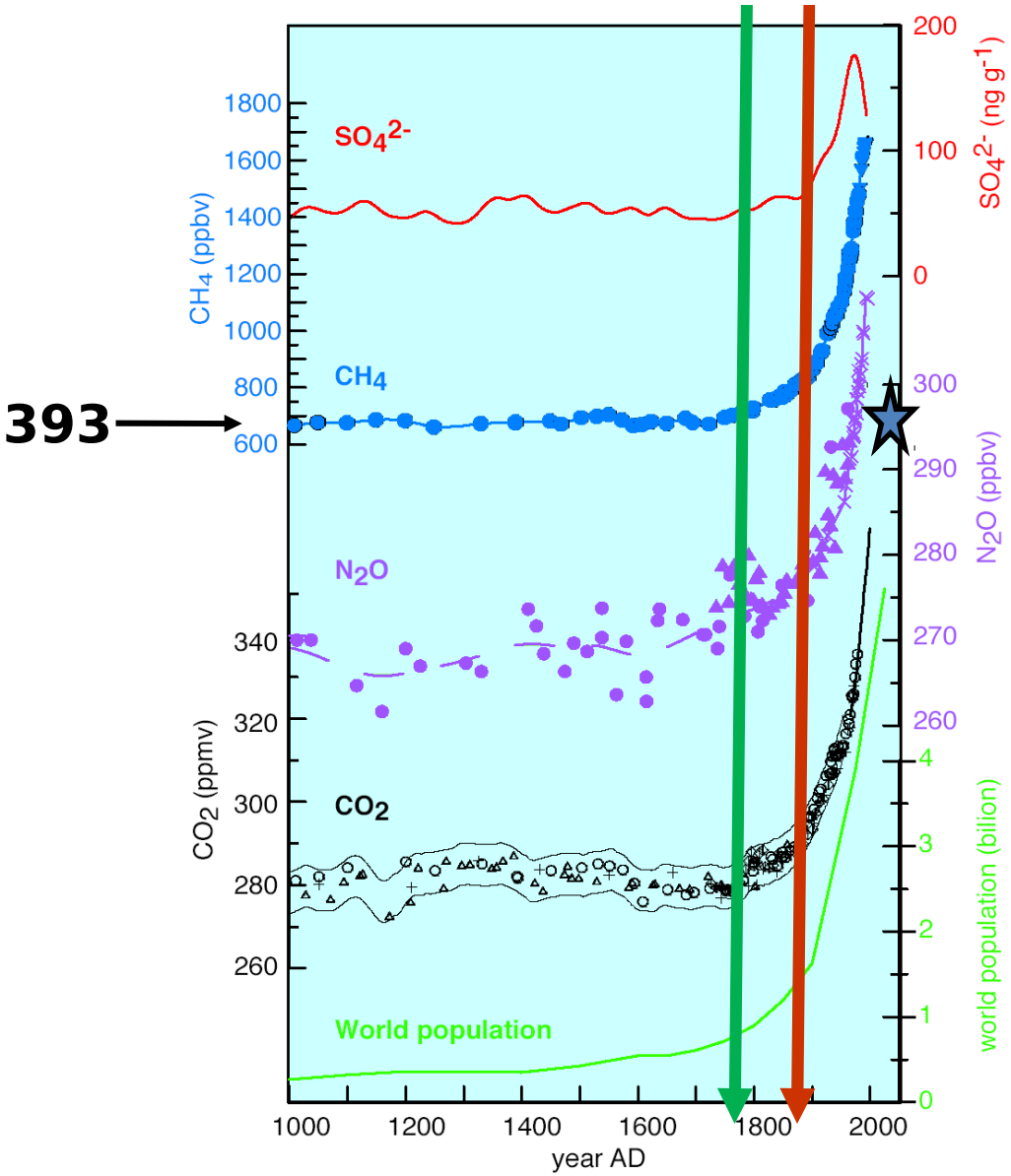
Anthropogenic Increase: Records Over the Last Millennium



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1.James Watt's invention of the steam piston engine in 1784

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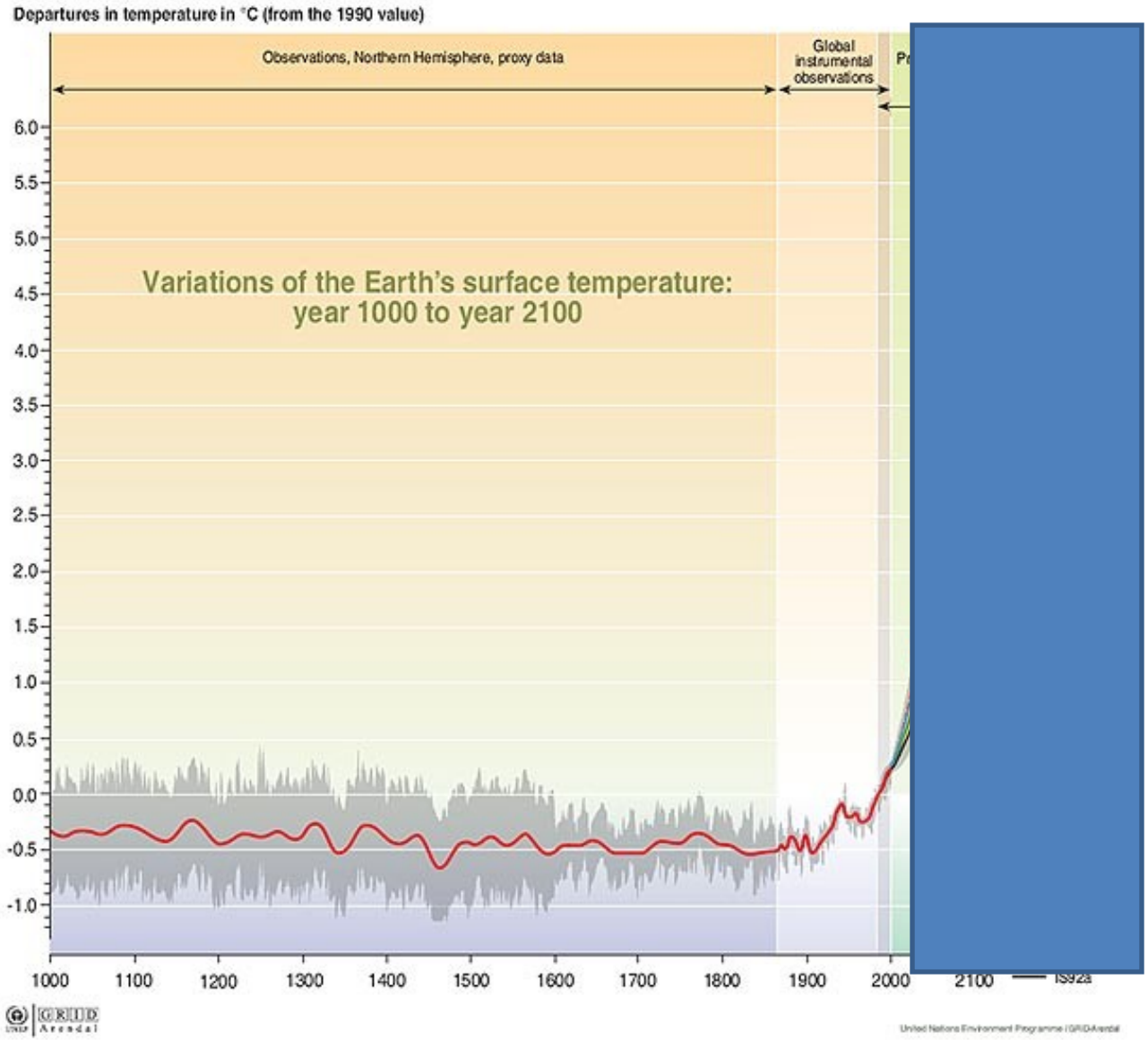
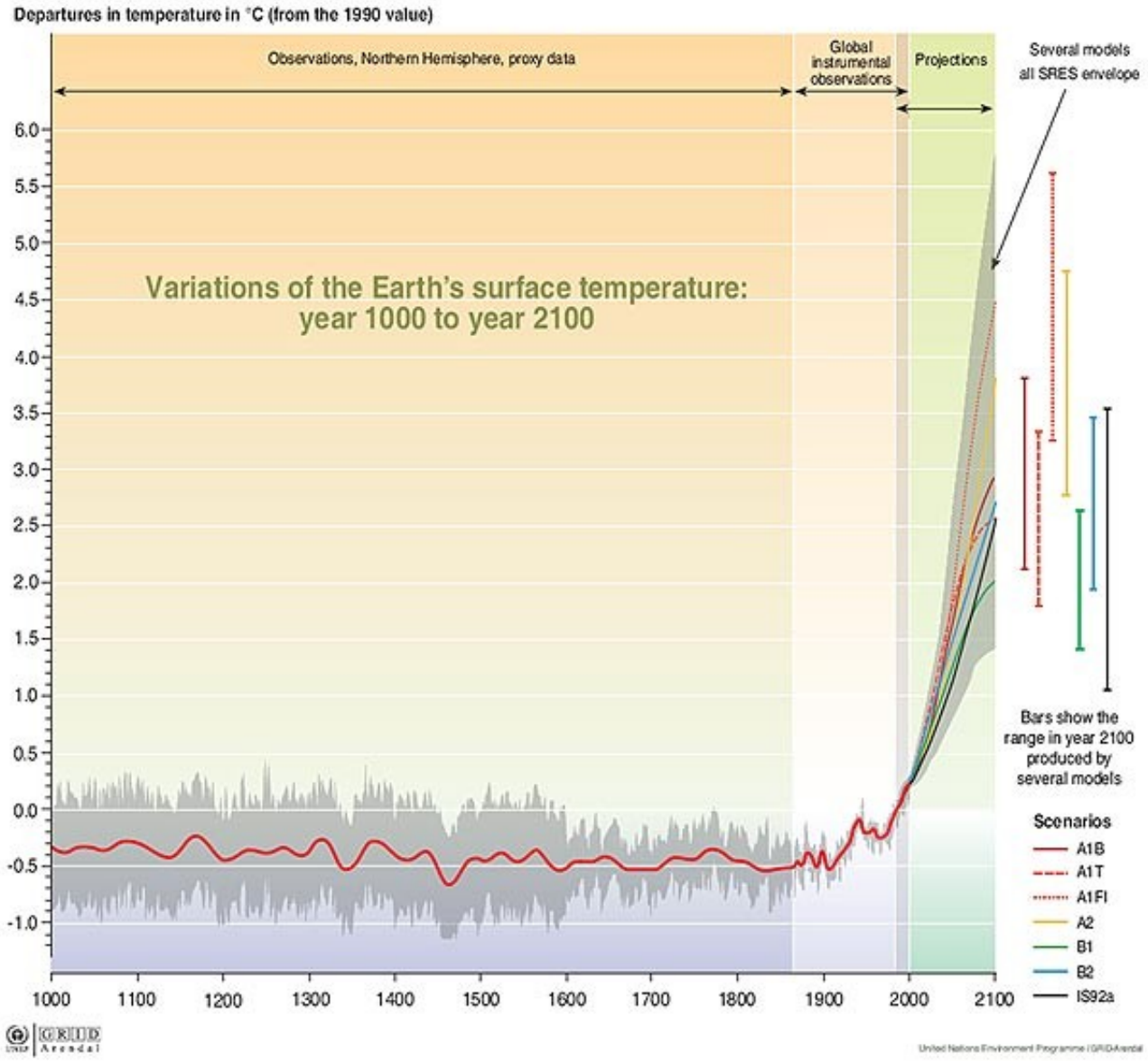
Source: *Raynaud et al., 2003*

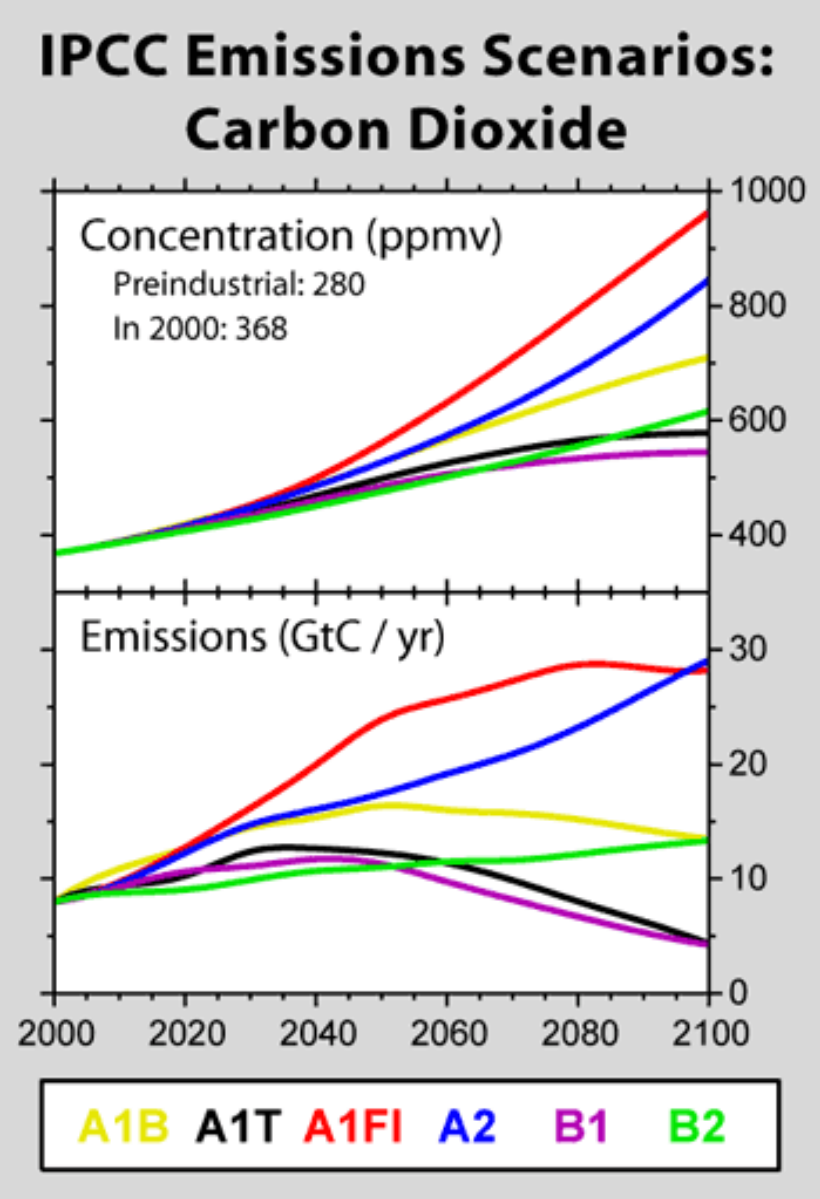

Departures in temperature in °C (from the 1990 value)
Observations, Northern Hemisphere, proxy data
Global instrumental observations
Variations of the Earth's surface temperature:
year 1000 to year 2100
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
IS92a
GRID Arendal
United Nations Environment Programme / GRID-Arendal

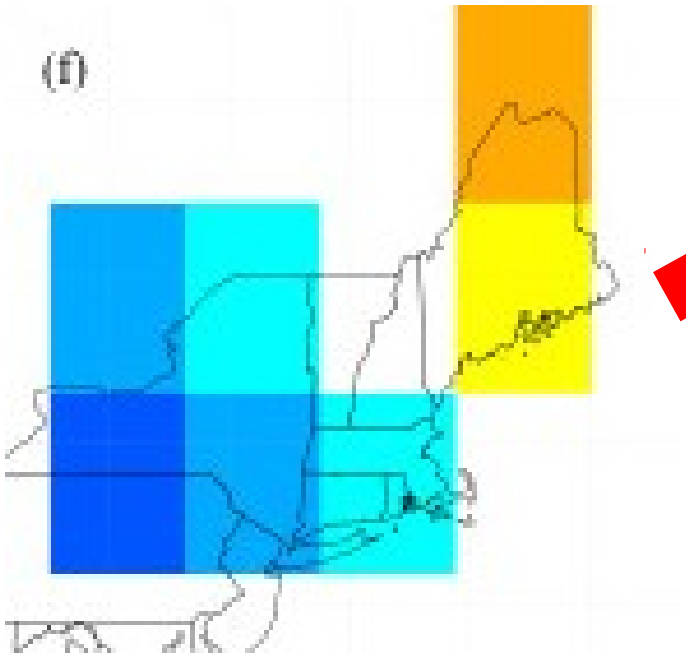

Departures in temperature in °C (from the 1990 value)
Observations, Northern Hemisphere, proxy data
Global instrumental observations
Projections
Several models all SRES envelope
Variations of the Earth's surface temperature: year 1000 to year 2100
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
Bars show the range in year 2100 produced by several models
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a
GRID Arendal
United Nations Environment Programme / GRID-Arendal

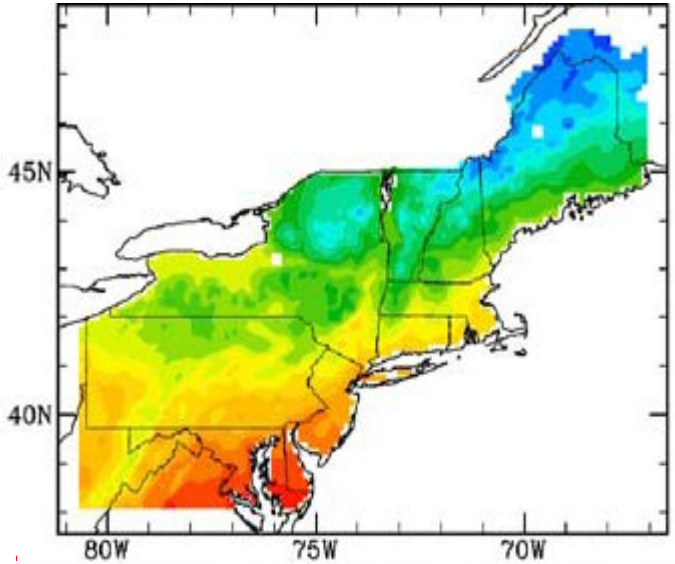
Even under best case (B1) scenario, we will likely reach twice pre-industrial levels (around 550 ppm) by 2100.

To keep CO_2 concentrations below this level, emissions must peak by 2040 and then decline.

8.5 billion metric tons in 2007

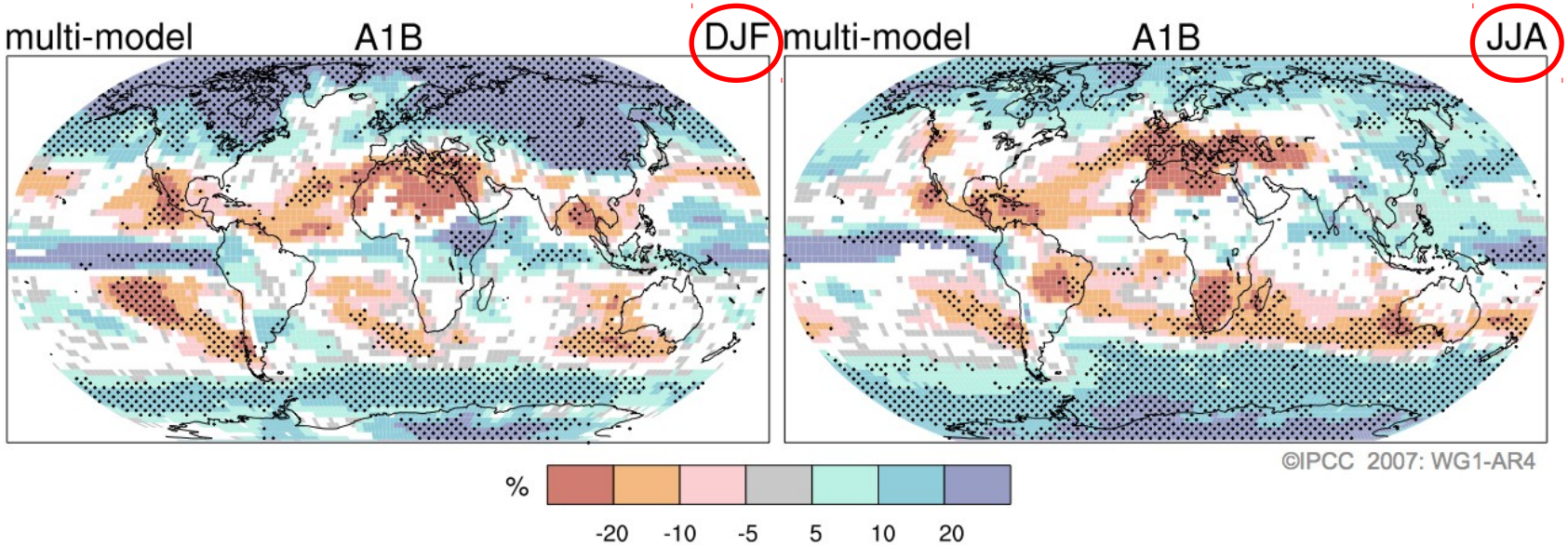



(f)


45N
40N
80W
75W
70W


Change
U.S. Northeast

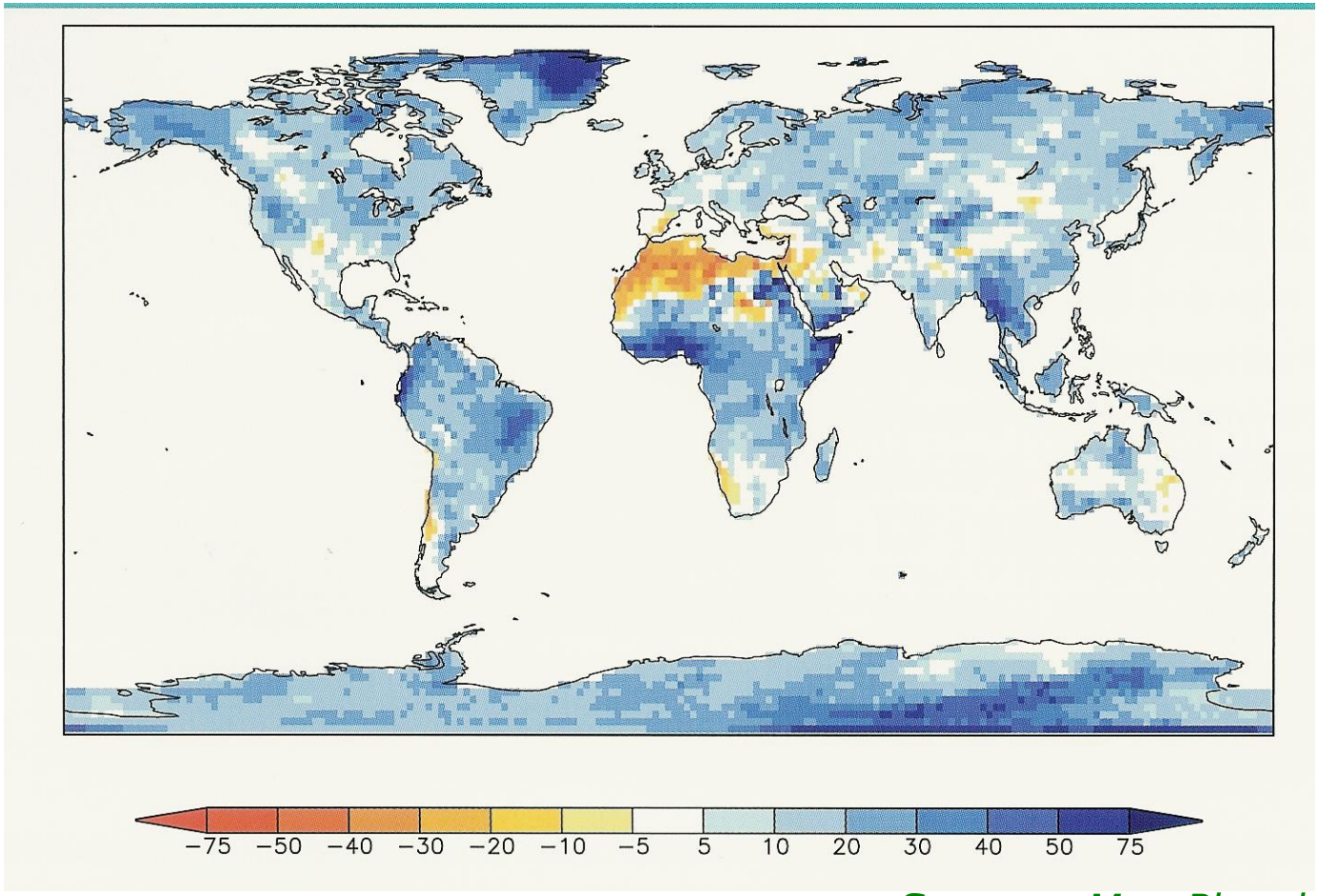
Projected Patterns of Precipitation Changes



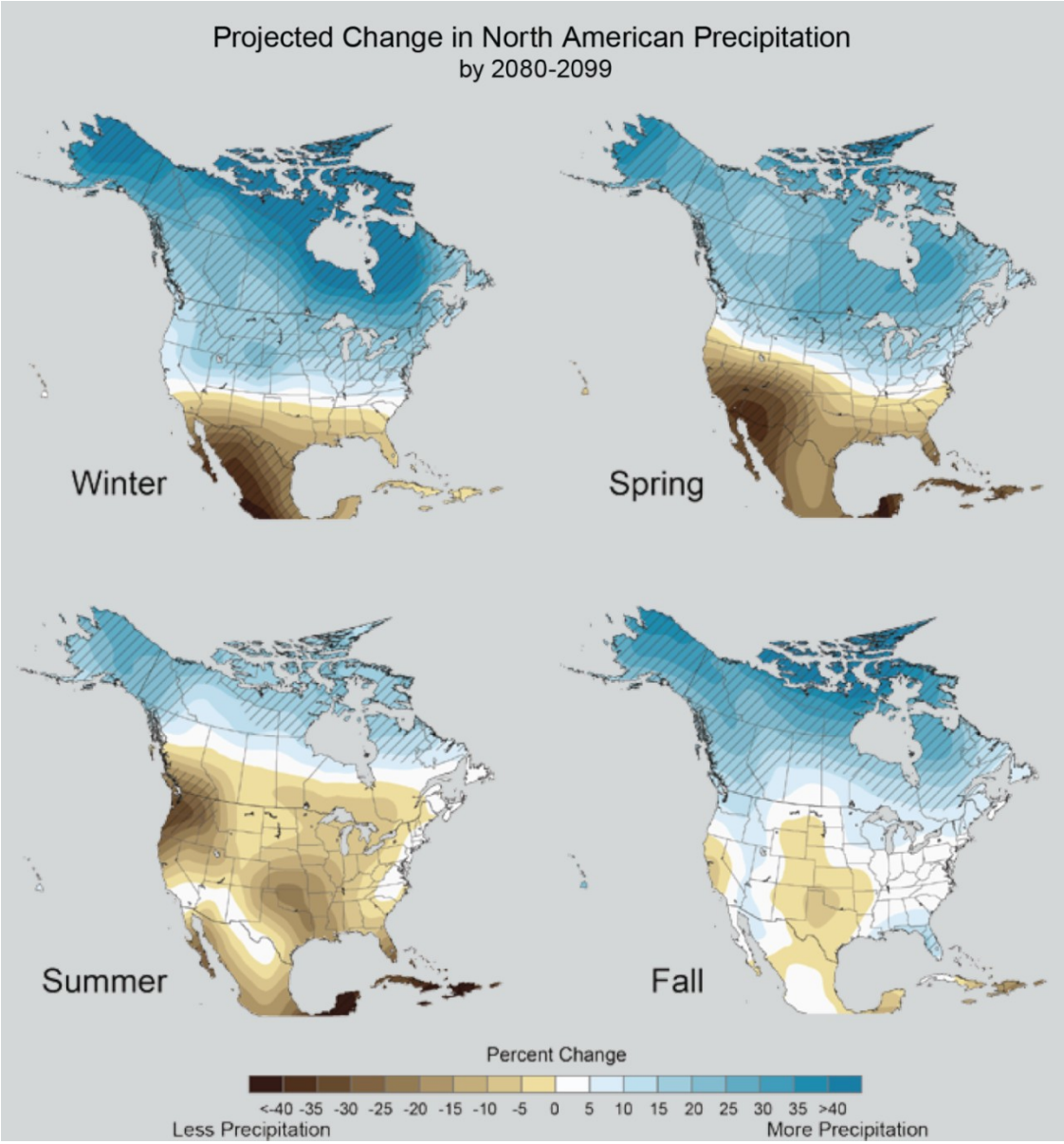
Precipitation increases *very likely* in high latitudes

Decreases *likely* in most subtropical land regions

% Change in Annual Extreme Precipitation for scenario A1B (maximum precipitation in a 5-day period within a year): (2071-2100)-(1961-90)



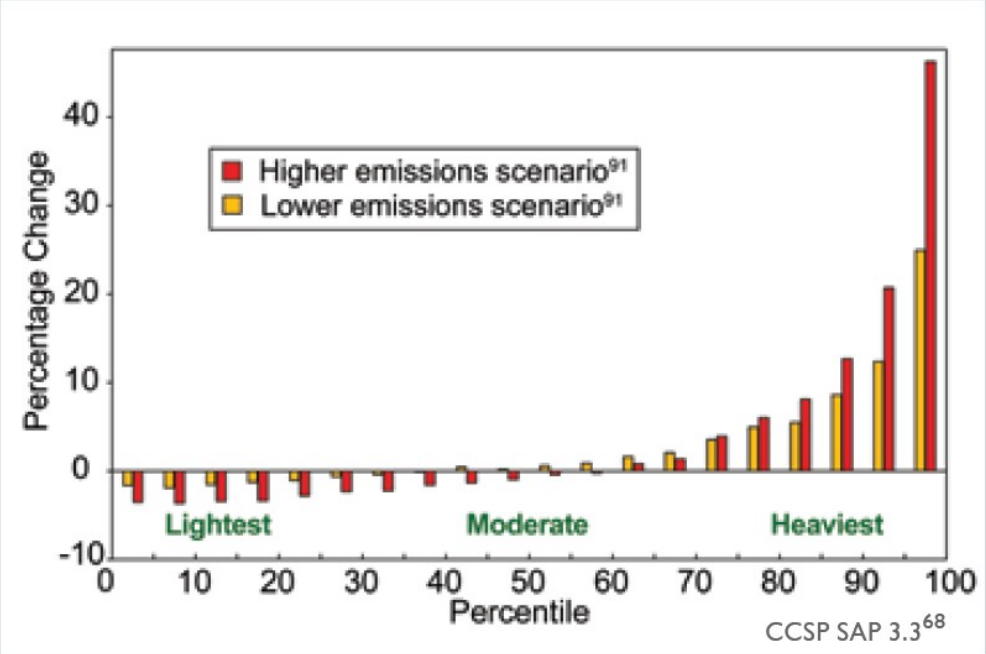
Source: *Max-Planck Institute for Meteorology, Hamburg*



15 model average for scenario A2

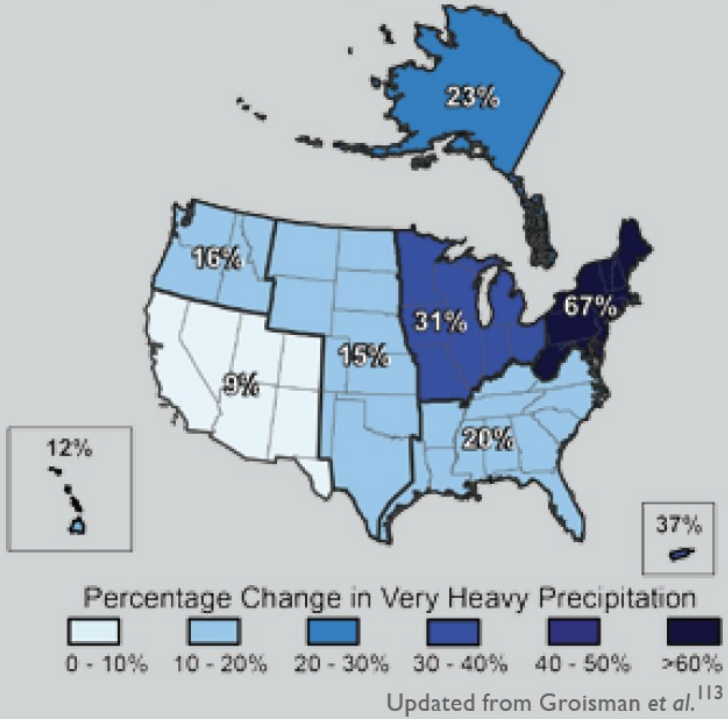
Source: *U.S. GCRP, 2009*

Projected Changes in Light, Moderate, and Heavy Precipitation (by 2090s)



CCSP SAP 3.3[68]

Increases in Amounts of Very Heavy Precipitation (1958 to 2007)



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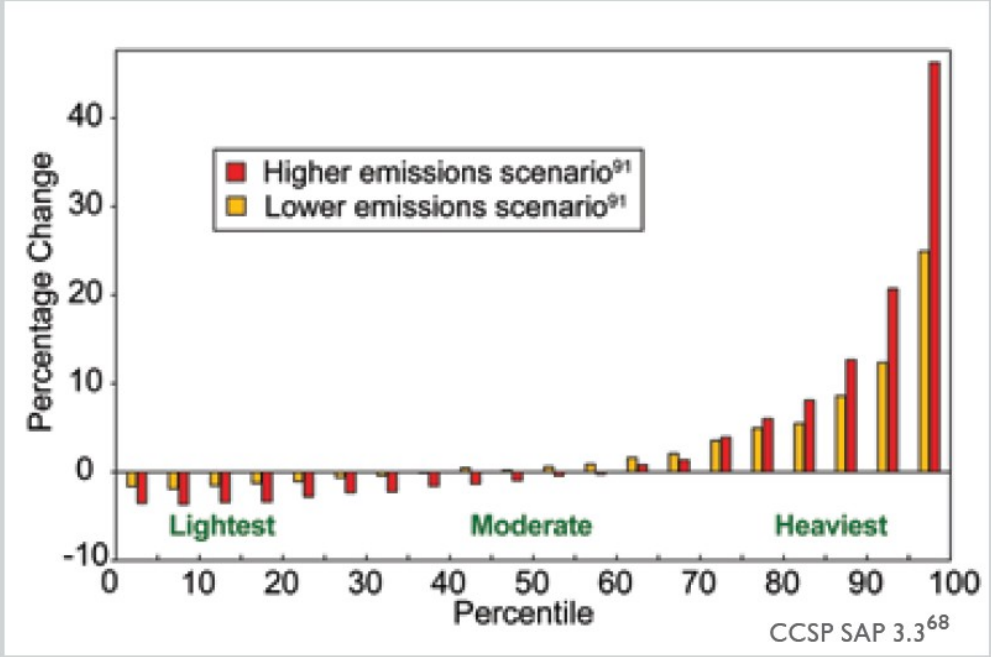
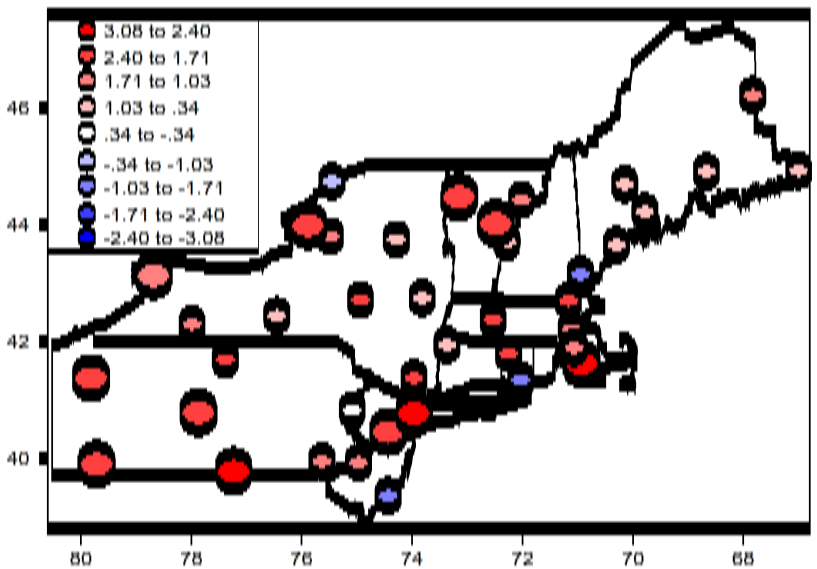


Trends in heavy precipitation amounts 1951-2005

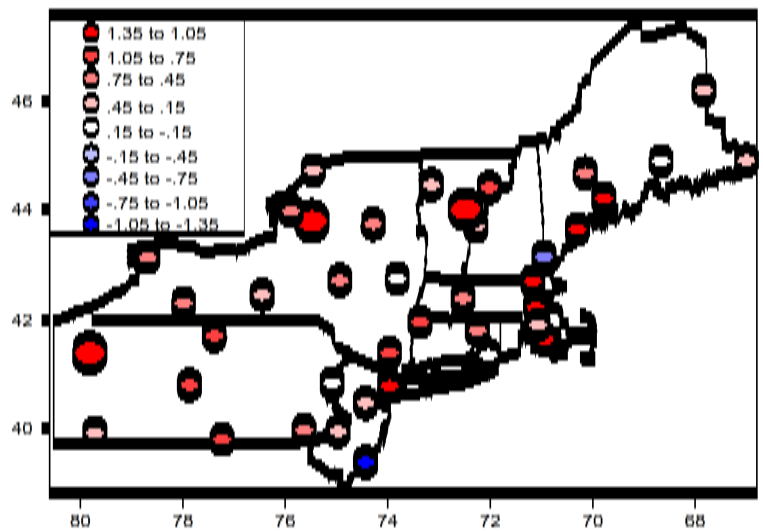
"very wet days"

R95P: 1951-2005



"extremely wet days"

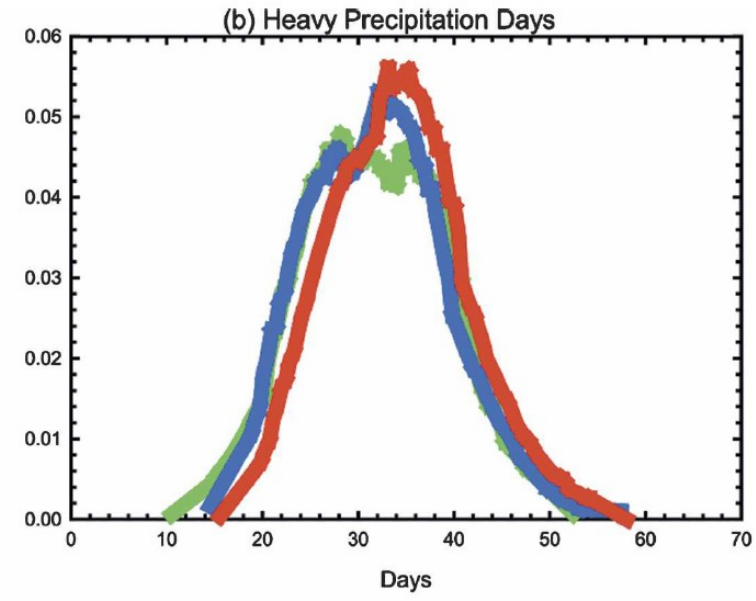
R99P: 1951-2005

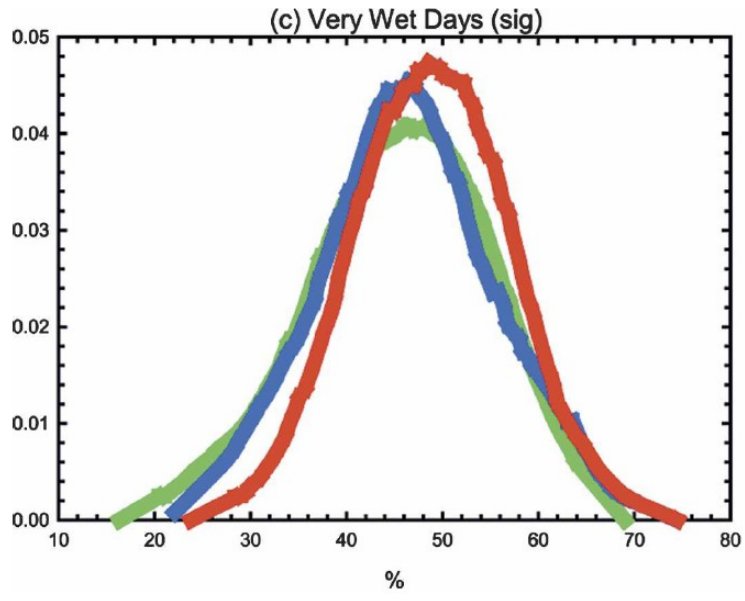


Source: *Brown et al., 2009*

Changes in heavy precipitation across the Northeast

1926-50 1951-75 1976-2000





Number of days with precipitation >10 mm day^{-1}

% of annual total precipitation from events exceeding the 1961–90 95th percentile

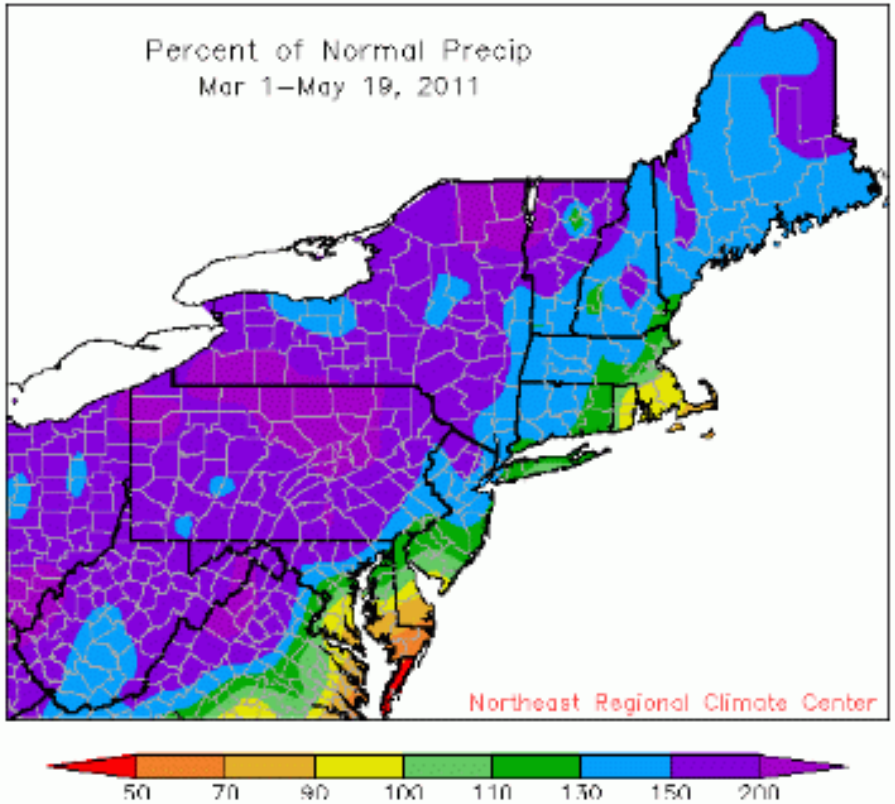
Source: *Griffiths & Bradley, 2007*

Soggy Spring 2011 Across The Northeast

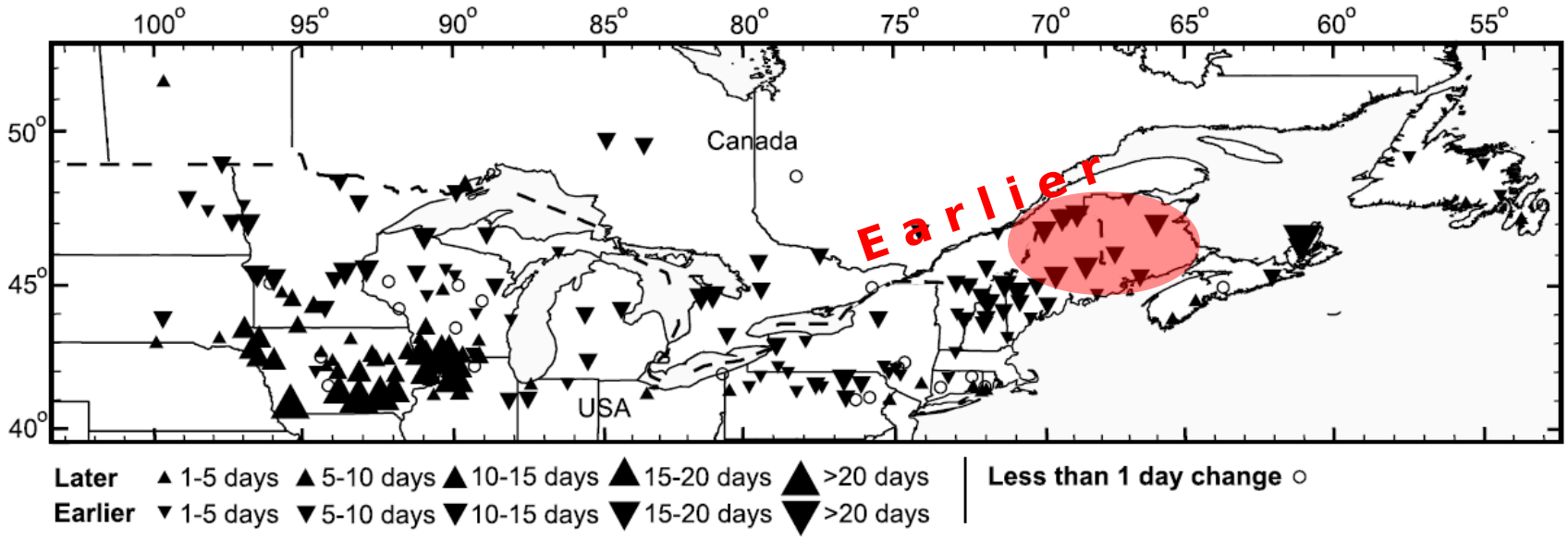
23 of the 35 first order stations in the Northeast are currently ranked in the top ten wettest Mar 1 - May 19 on record. Five have already surpassed their March through May record rainfall amounts.

Climatological Spring Rainfall Rankings (inches)

Name	Rank Mar 1 – May 19	Amount	Wettest Mar 1 – May 19	Year	Wettest Mar 1 – May 31	Year
Huntington, WV	1	20.83	18.36	2002	19.24	1935
Williamsport, PA	1	20.74	14.04	1980	16.13	1919
Harrisburg, PA	1	19.76	15.48	1983	18.18	1983
Binghamton, NY	1	16.94	14.41	2000	14.59	1929
Burlington, VT	1	15.97	12.04	1983	15.46	1983
Erie, PA	1	15.69	13.87	1947	16.73	1947
Buffalo, NY	1	15.36	13.96	1976	16.76	2000
Scranton, PA	2	14.61	14.92	1983	16.38	1947
Syracuse, NY	2	14.43	19.29	1976	20.15	1976
Allentown, PA	3	15.26	18.76	1952	22.64	1952
Albany, NY	3	13.26	18.18	1953	19.54	1983
Rochester, NY	3	11.45	14.69	1873	15.42	1873
Caribou, ME	3	10.33	12.53	2005	14.29	2005
Pittsburgh	5	14.13	14.98	1967	17.60	1901
Dulles AP. VA	5	13.18	16.73	2008	18.07	2008
Charleston, WV	6	15.01	16.42	1908	18.75	1908
Central Park, NY	7	15.95	20.23	2007	22.66	1984
Newark, NJ	7	15.67	23.34	1983	26.50	1983
Elkins, WV	7	15.38	17.94	1996	23.57	1996
Beckley, WV	7	14.90	27.32	1927	29.42	1927



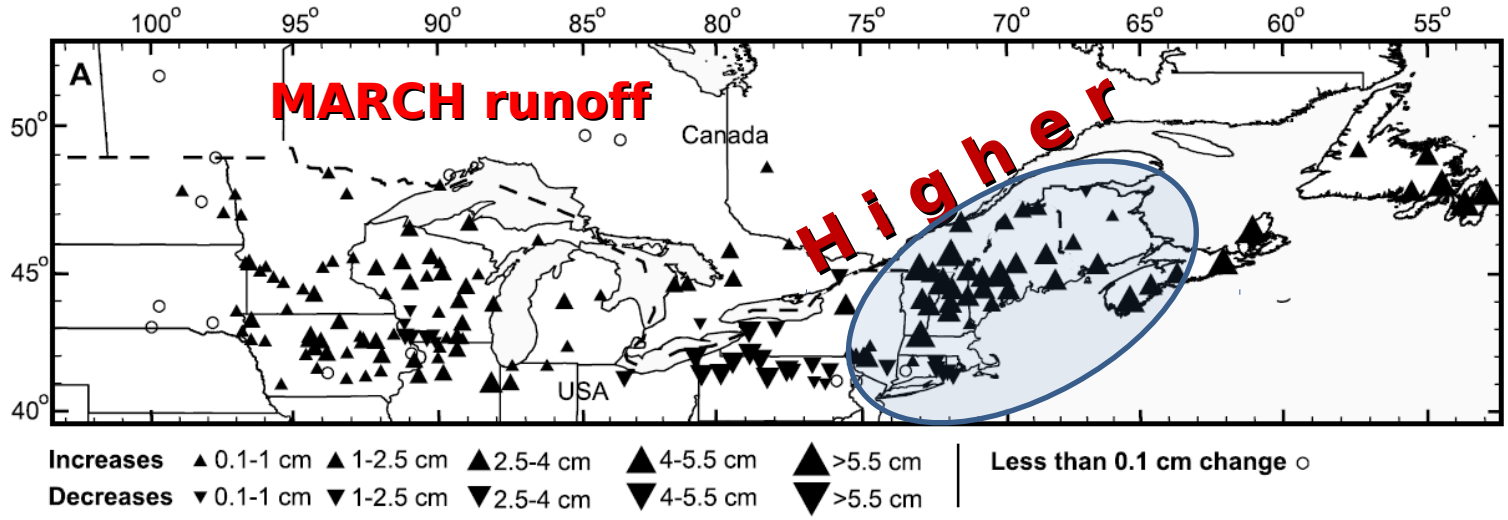
Magnitude and direction of changes in winter-spring streamflow center of volume dates*, 1953–2002.

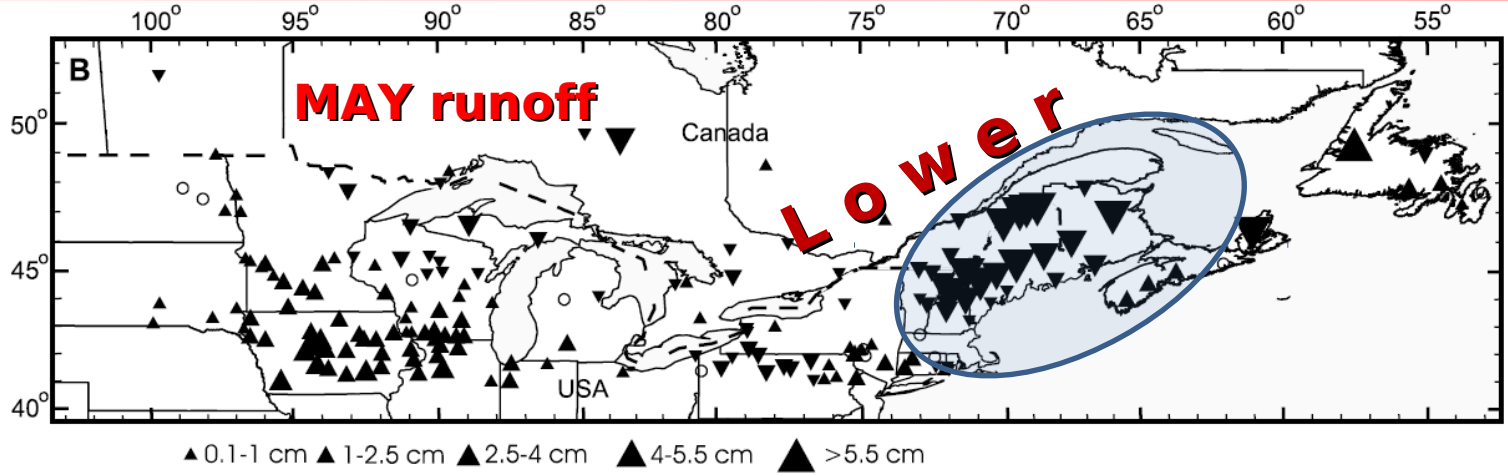


***The CV date is the date, from the start of the year or season, by which half or more of the volume flows by a gaging station.**

Source: *Hodgkins & Dudley, 2006*

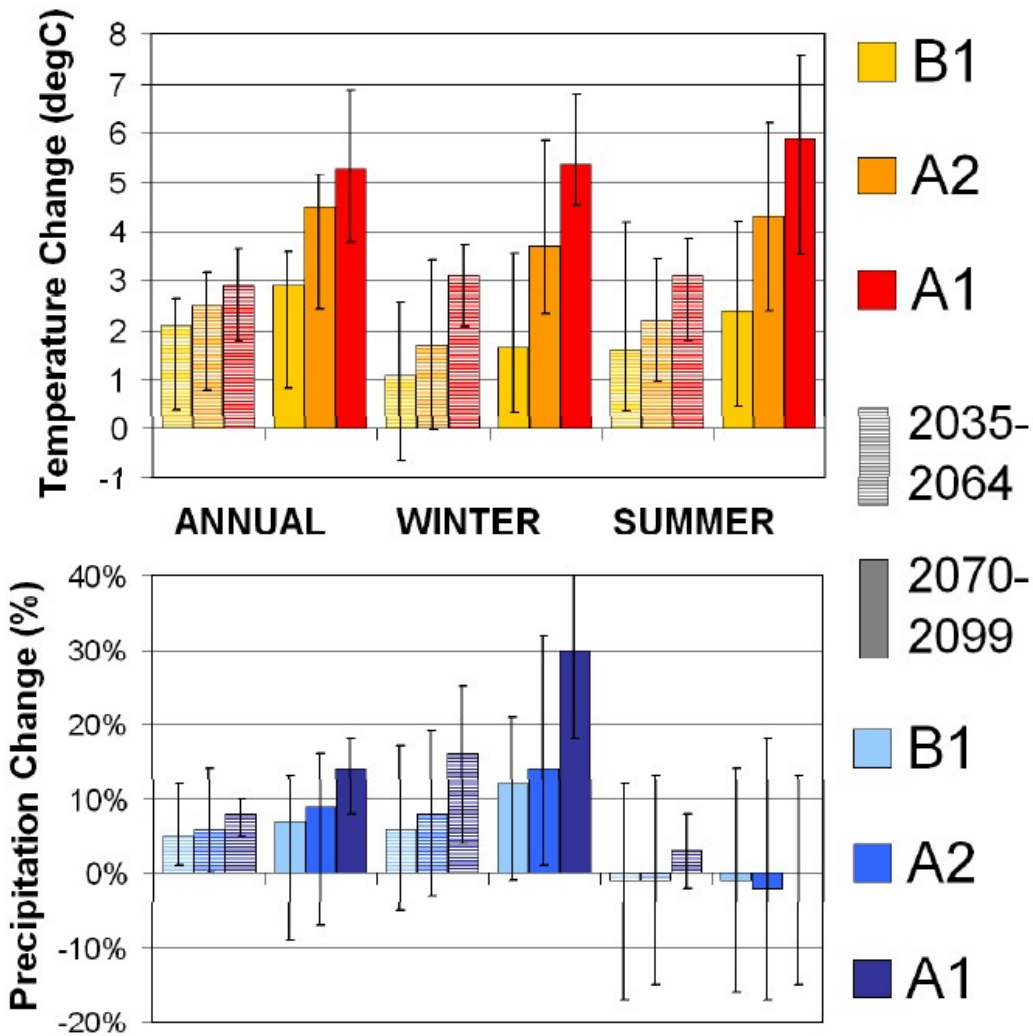
Magnitude and direction of changes in runoff: 1953-2002





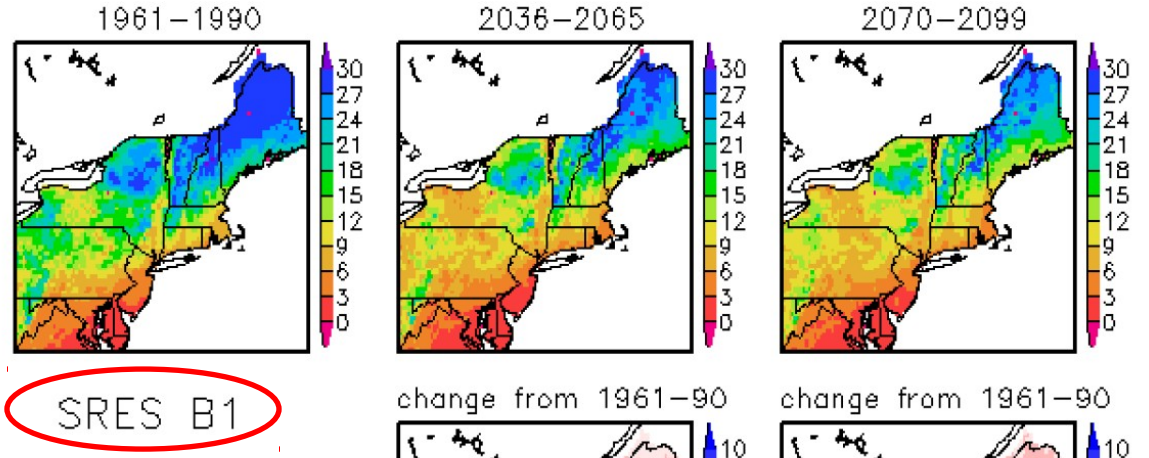
Source: *Hodgkins & Dudley, 2006*

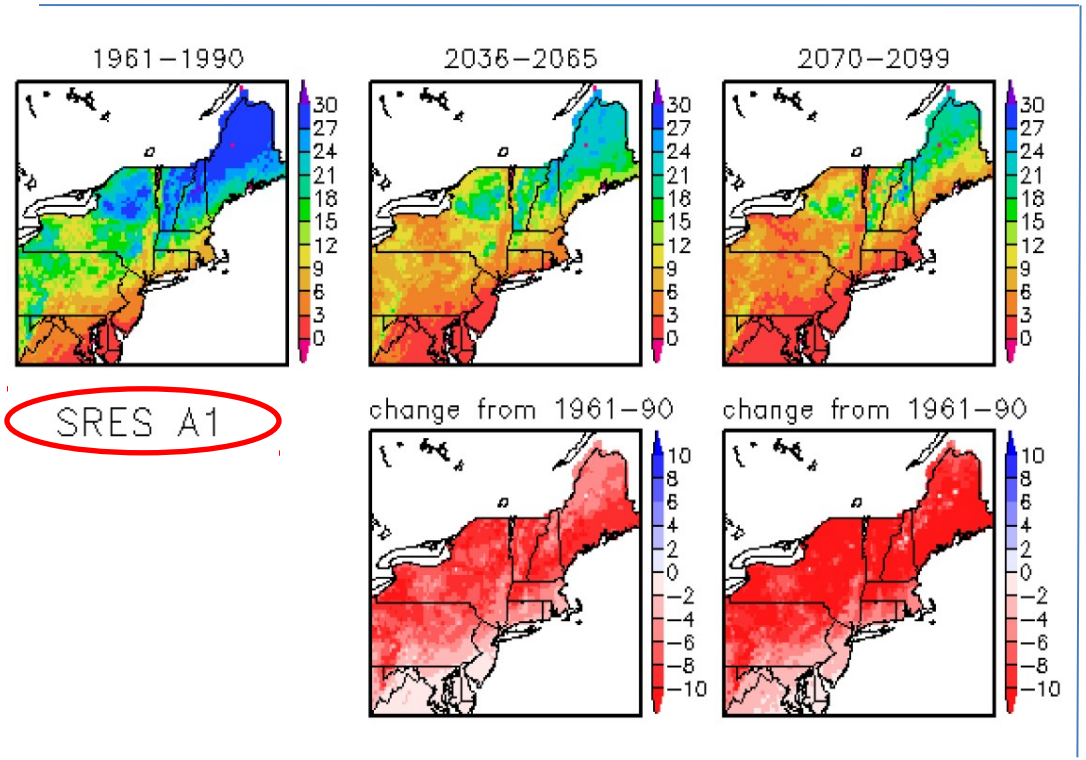
Temperature and Precipitation Changes



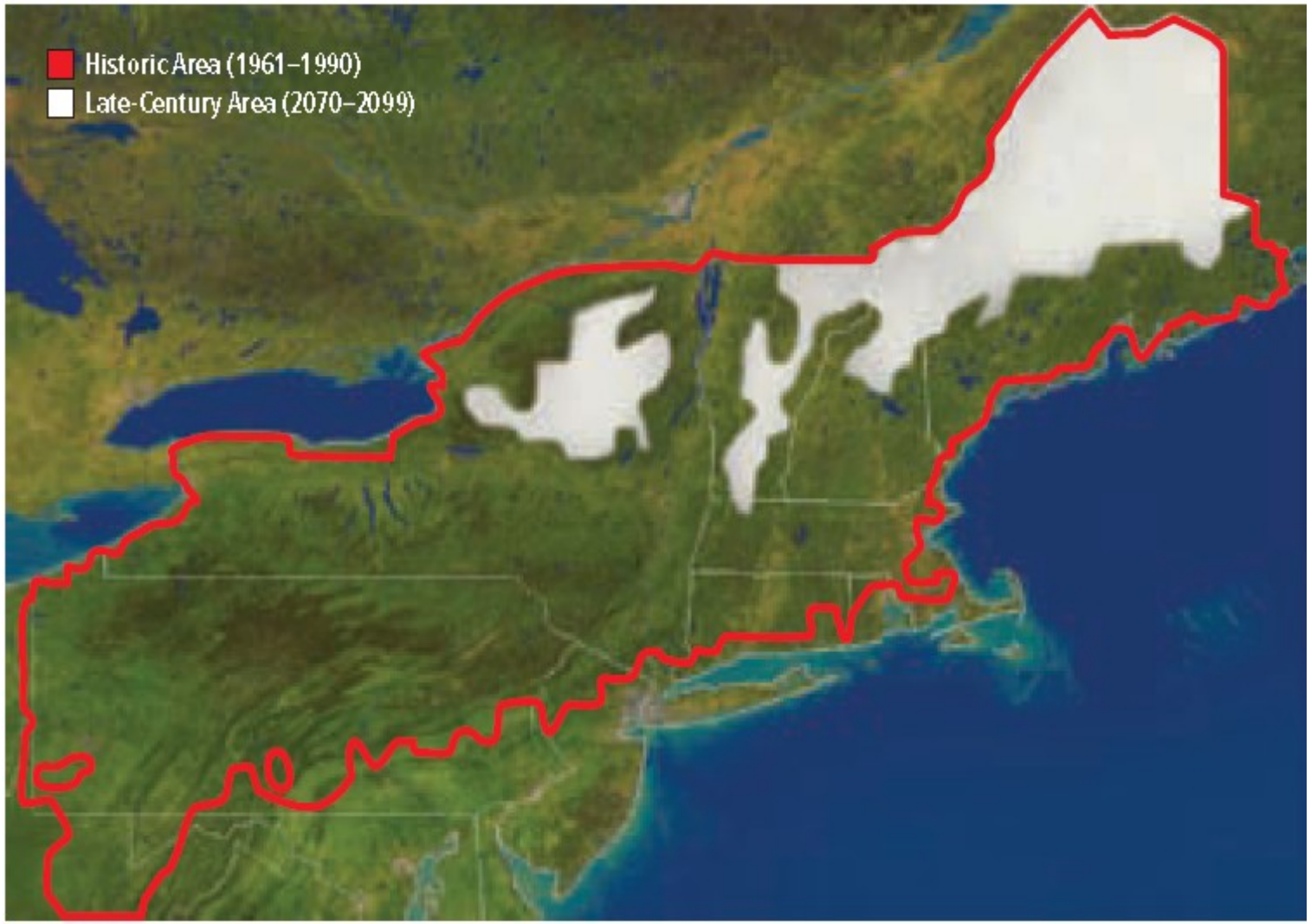
Source: *Hayhoe et al., 2006*

Number of snow-covered days per month for winter (DJF)



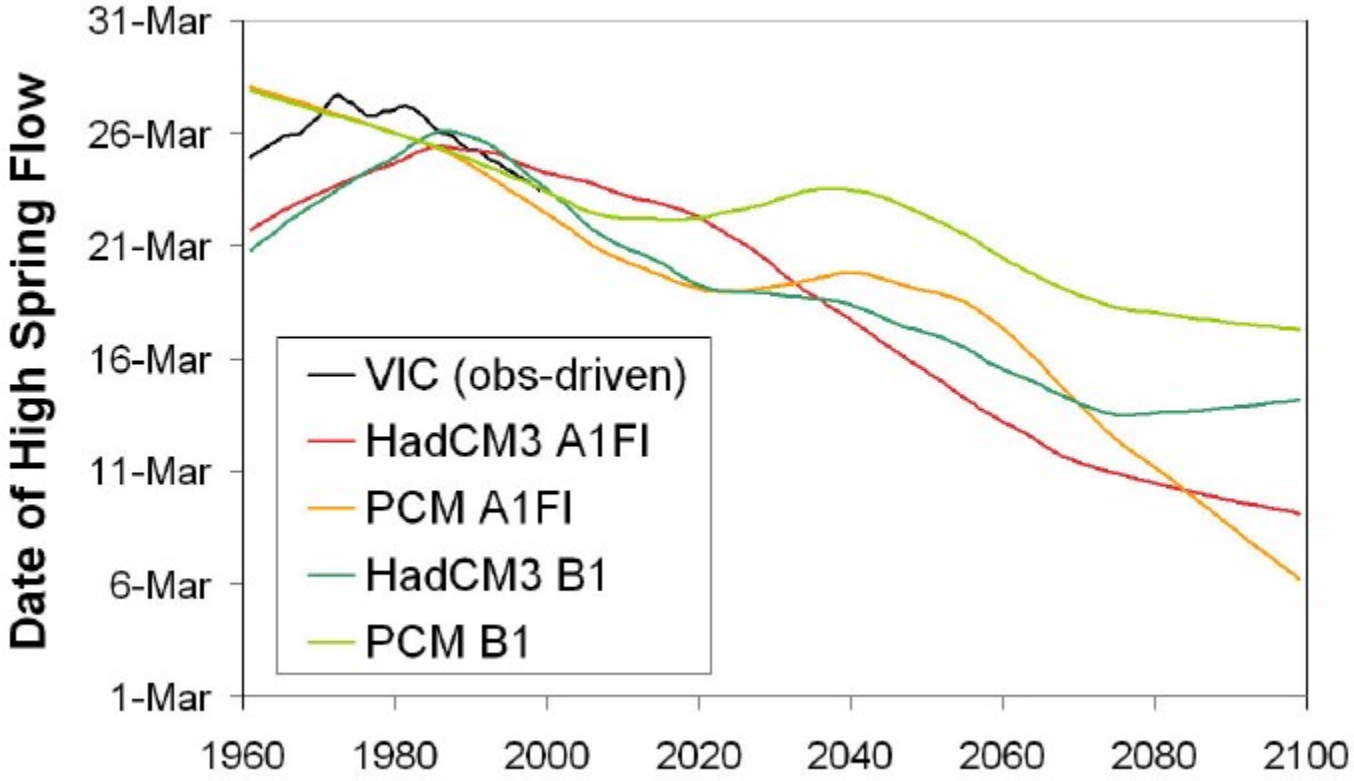


Source: *Hayhoe et al., 2006*



Source: *Union of Concerned Scientists 2007*

Projections of timing of snowmelt-driven high spring flow, (shifts in the center of volume precipitation) 2 models, 2 scenarios…

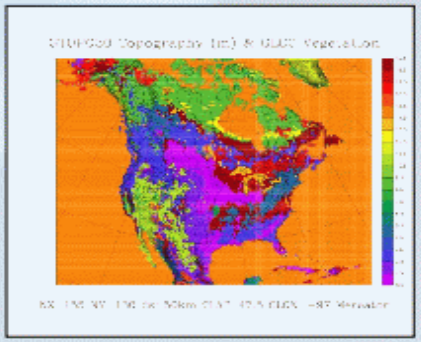


Source: *Hayhoe et al., 2006*

The North American Regional Climate Change Assessment Program (NARCCAP)

NCAR

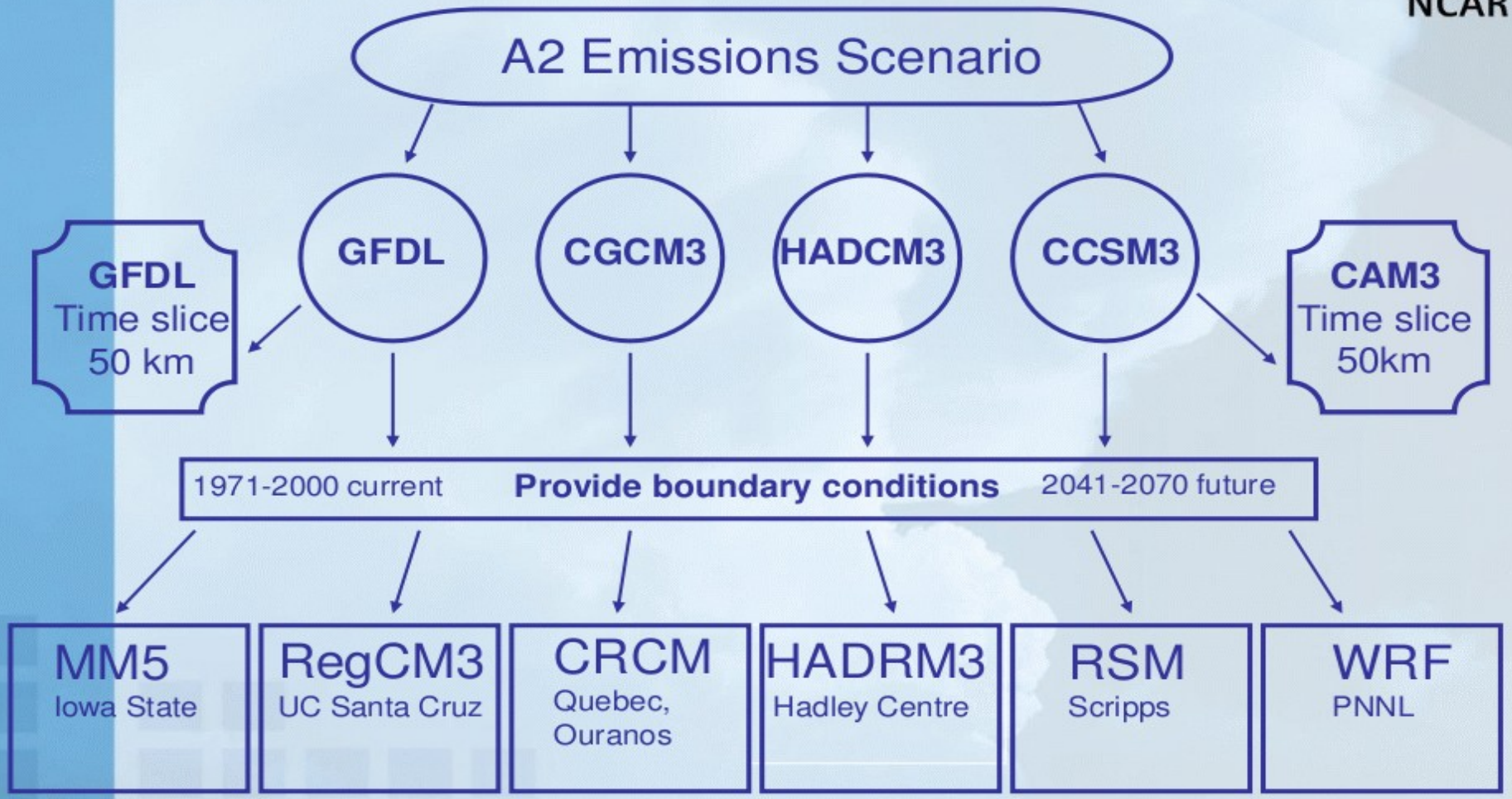
Providing climate scenarios for
the United States, Canada, and northern Mexico

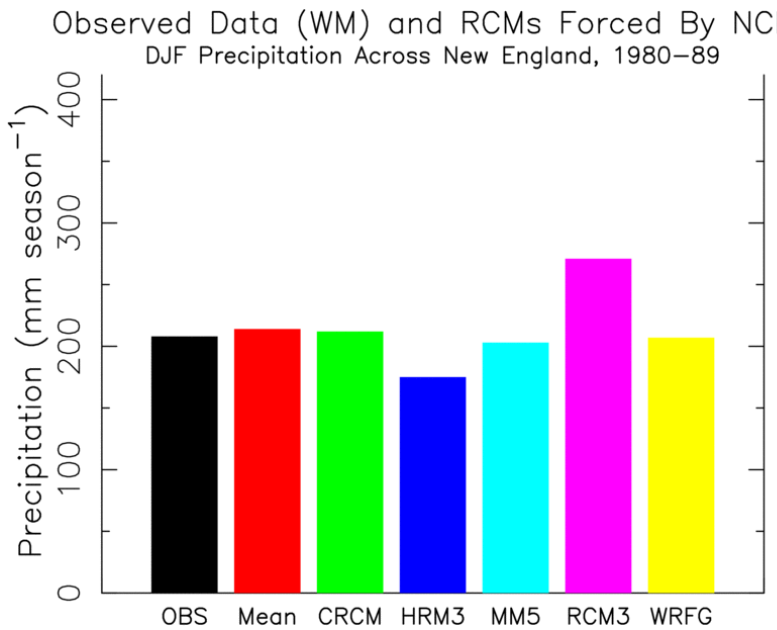


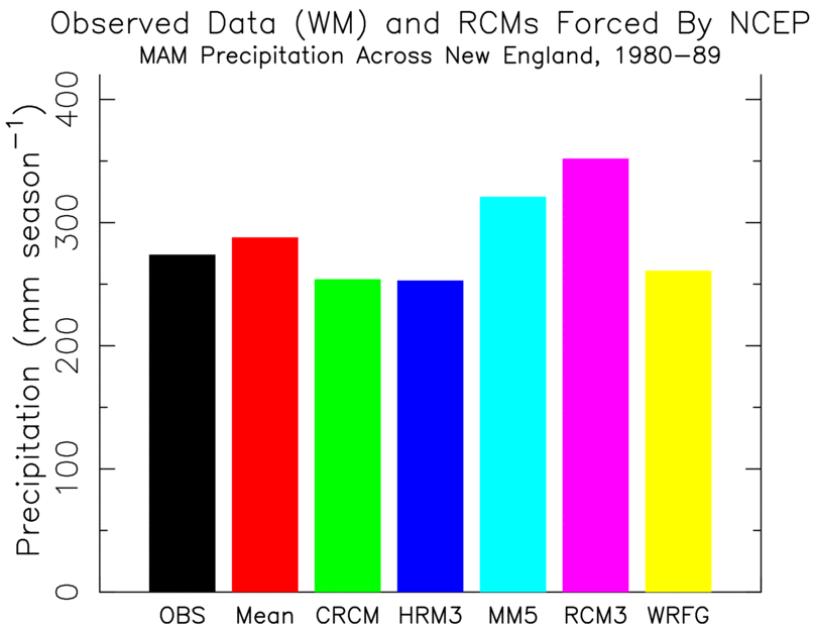
- Explores multiple uncertainties in regional and global climate model projections.
  - 4 global climate models x 6 regional climate models
- Develops multiple high resolution regional climate scenarios for use in impacts assessments.
- Evaluates regional model performance to establish credibility of individual simulations for the future
- Participants: Iowa State, PNNL, LLNL, UC Santa Cruz, Ouranos (Canada), UK Hadley Centre, NCAR
- Initiated in 2006, funded by NOAA-OGP, NSF, DOE, USEPA-ORD – 4-year program

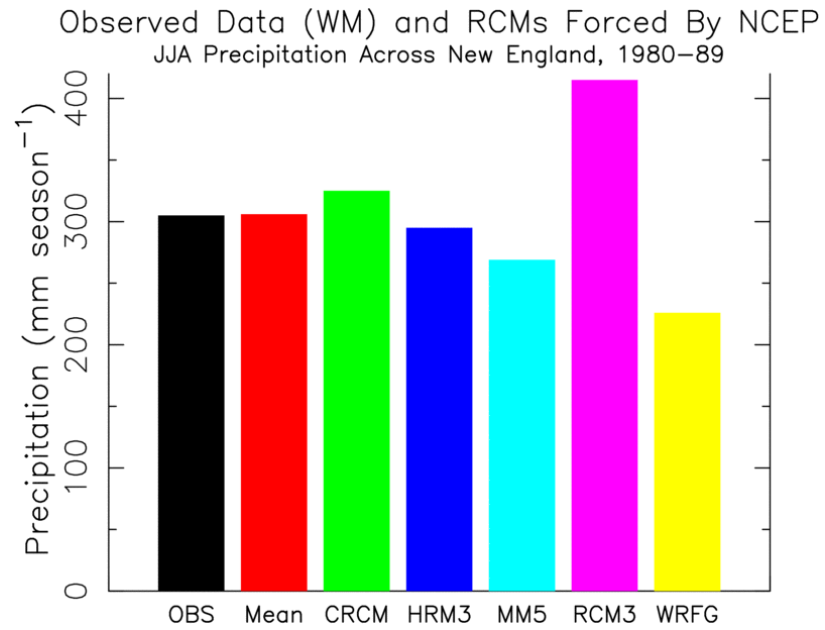
NARCCAP PLAN – Phase II

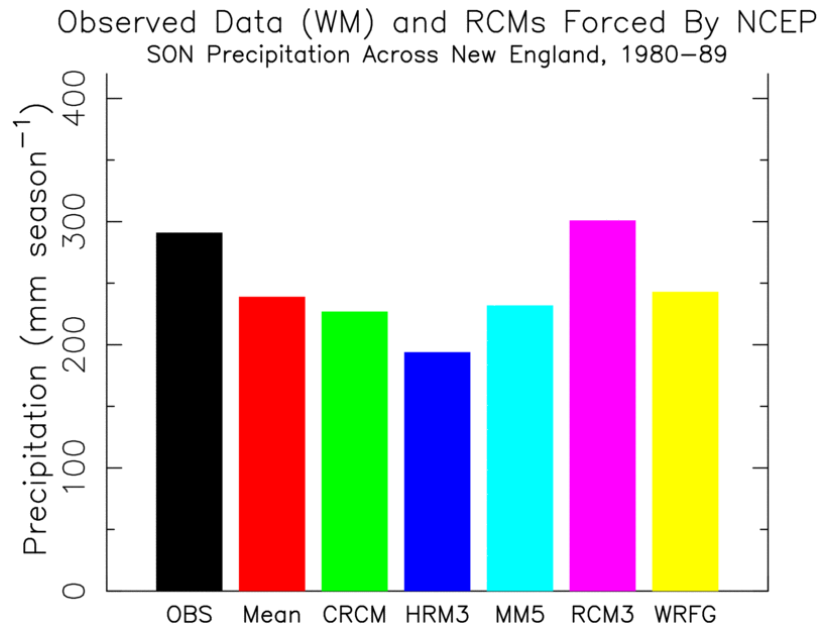
NCAR



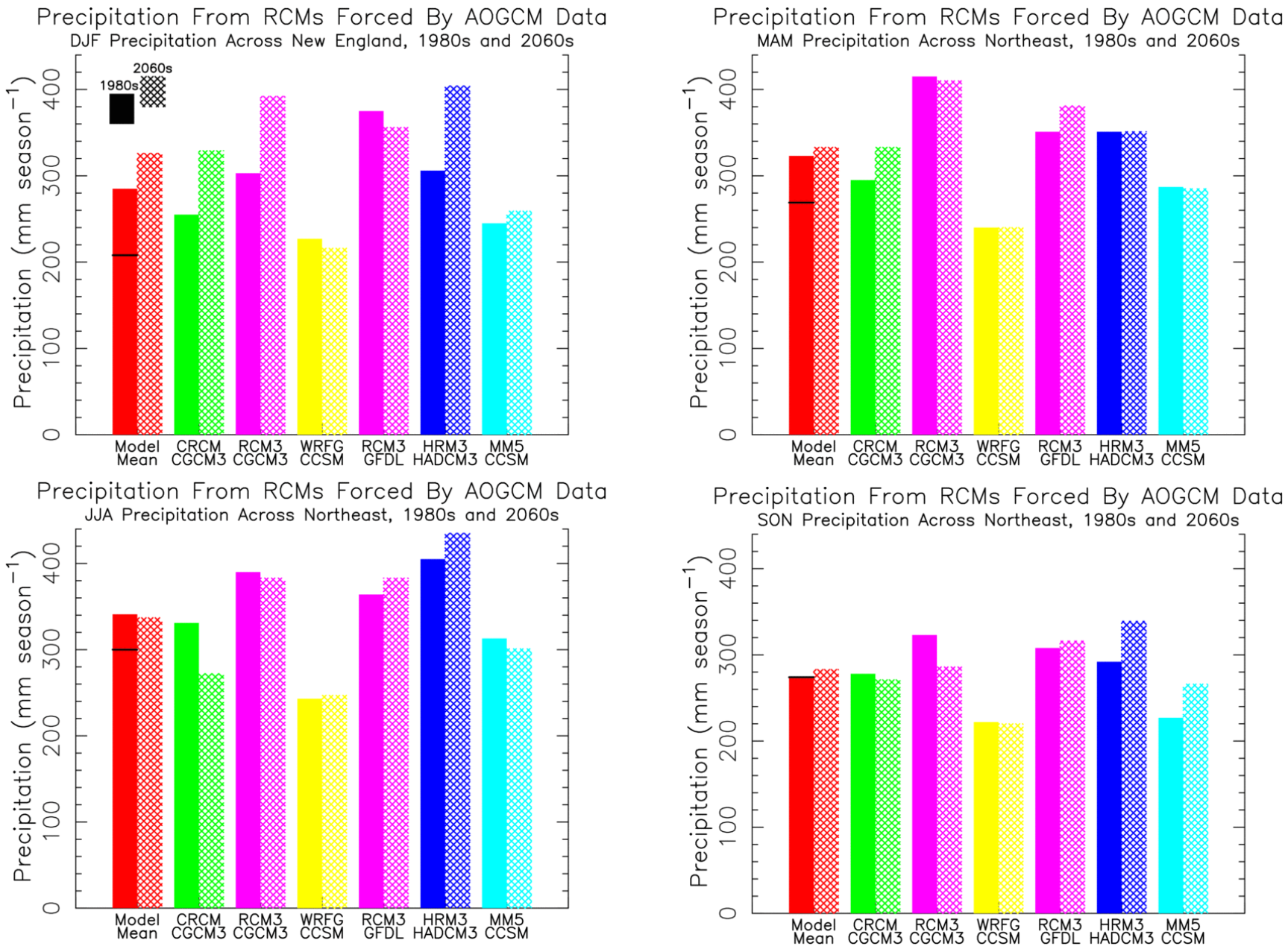




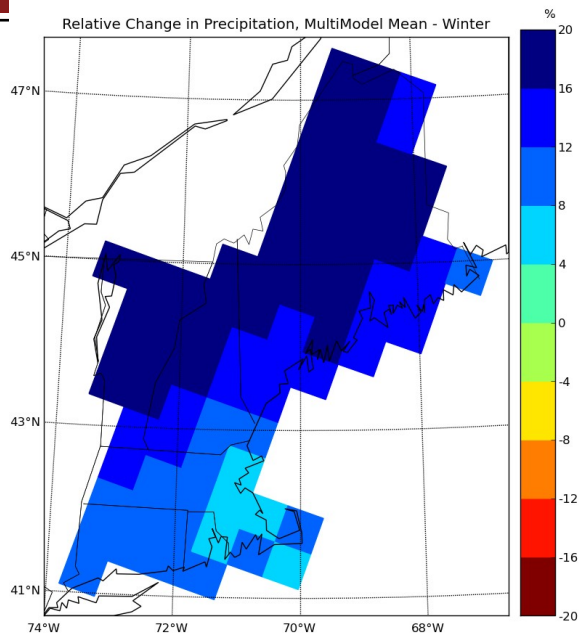


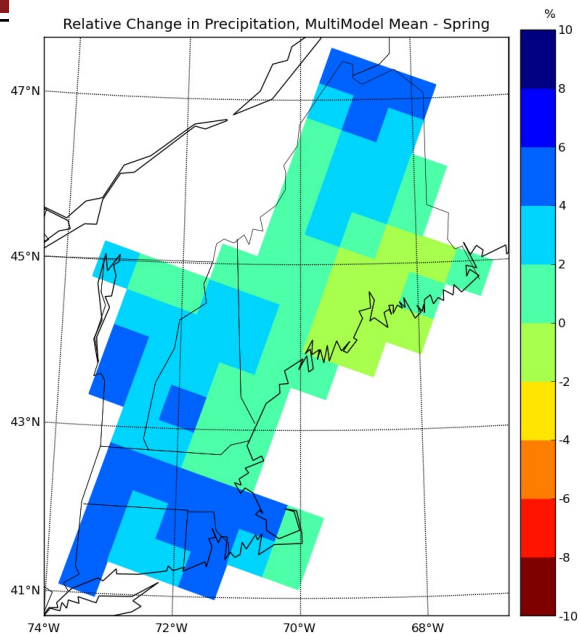


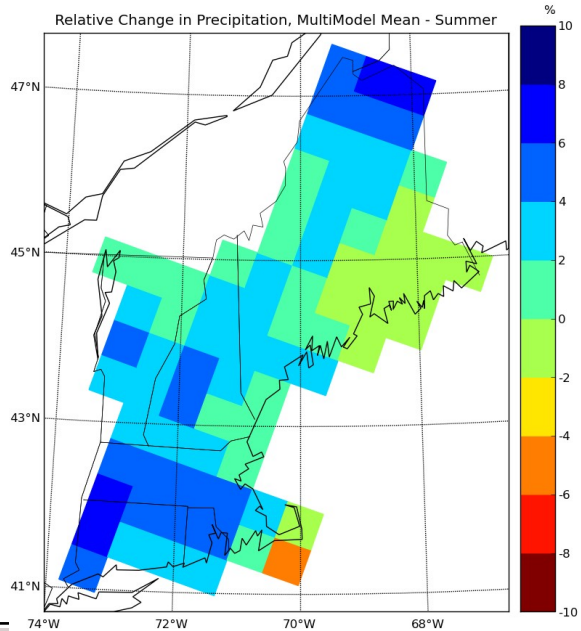
Rawlins et al. in prep

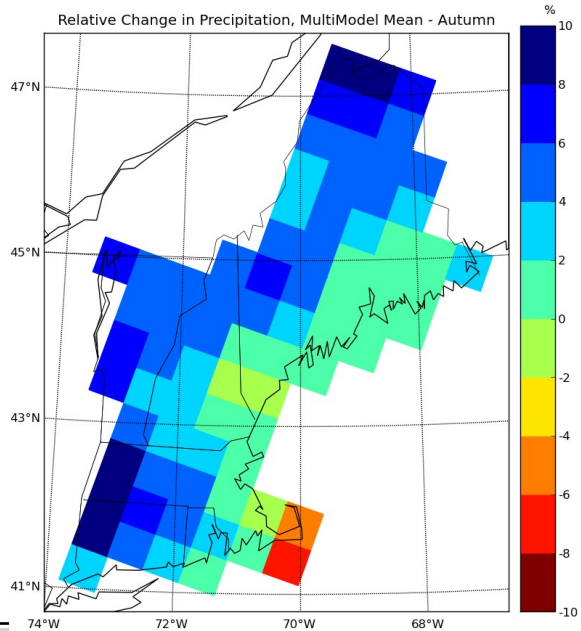


Rawlins et al. in prep



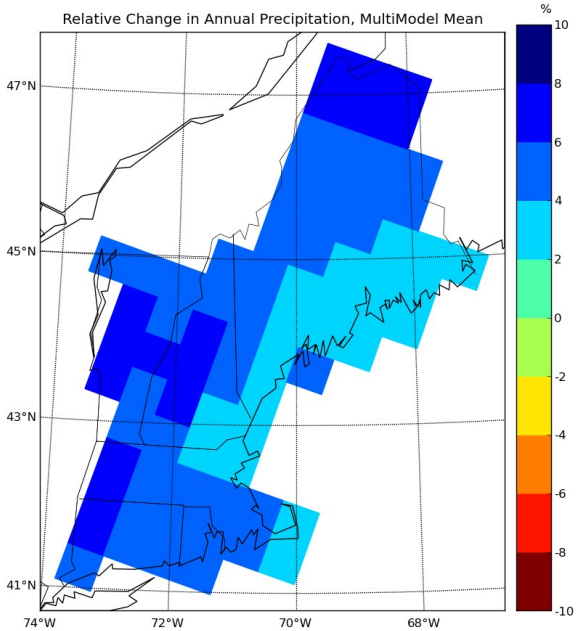






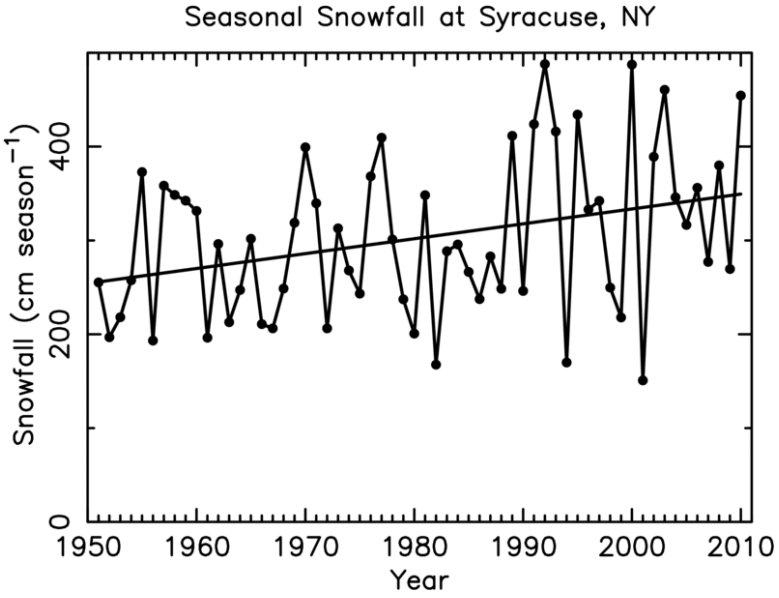
Relative change in precipitation (P) for each season from a six GCM_RCM mean.

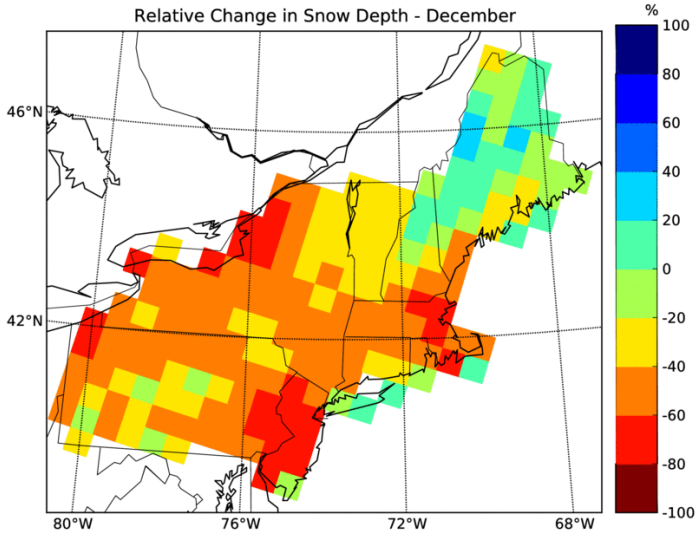
For annual P increases range from around 2-8%. The regional mean is ~5%. Larger increases are found across northwest New England.

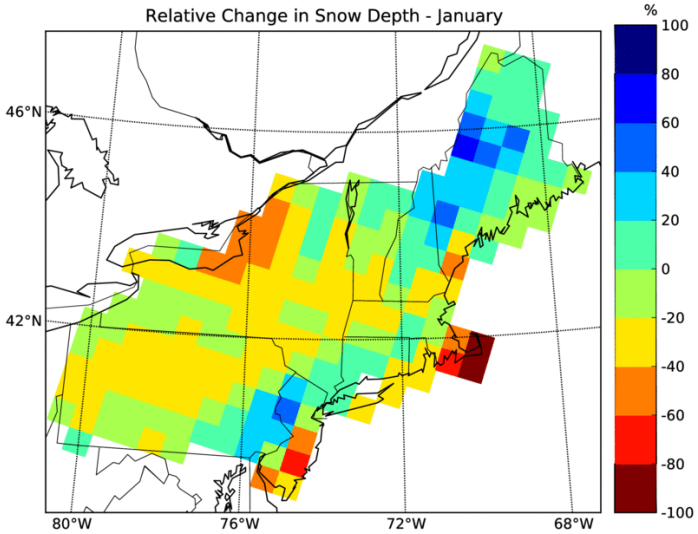


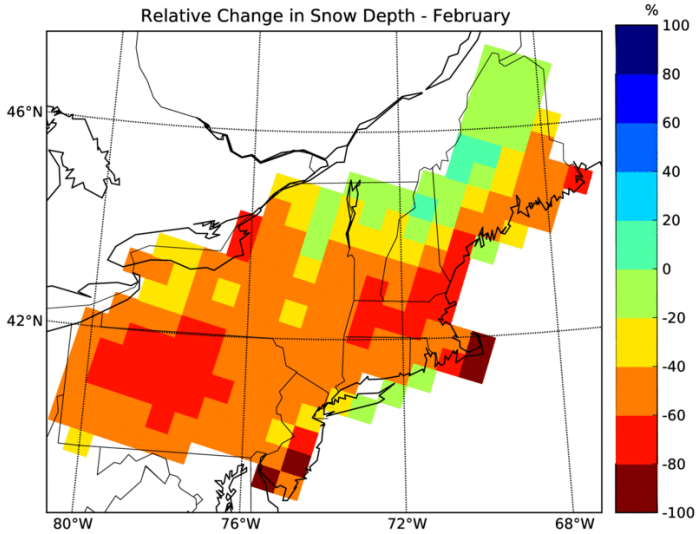
Rawlins et al. in prep

Relative change in snow depth - model mean of three RCMs.









Rawlins et al. in prep

Soil Moisture Active Passive (SMAP)

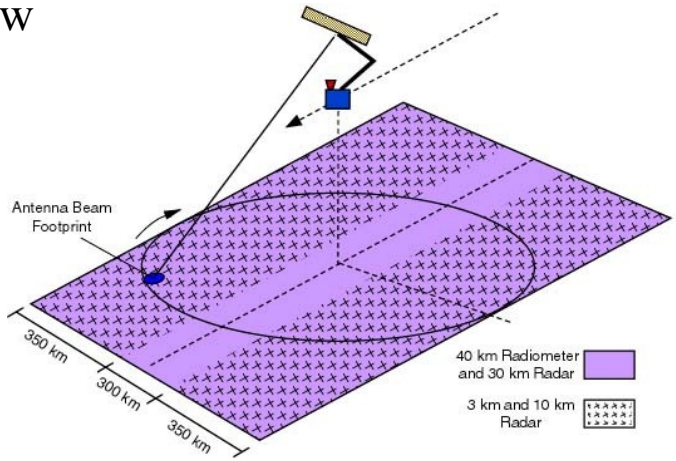
SMAP is one of the four first-tier missions recommended by the NRC Earth Science Decadal Survey Report

Primary Science Objectives:

- Global, high-resolution mapping of soil moisture and its freeze/thaw state to:
  - *Link terrestrial water, energy and carbon cycle processes*
  - *Estimate global water and energy fluxes at the land surface*
  - *Quantify net carbon flux in boreal landscapes*
  - *Extend weather and climate forecast skill*
  - *Develop improved flood and drought prediction capability*

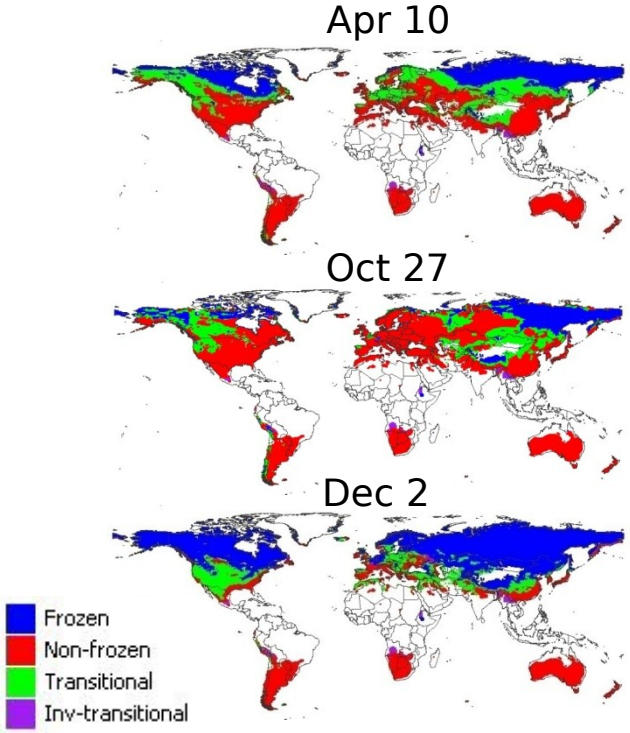
SMAP mission:

- launch: March 2013
- L-band radar, L-band radiometer
- 1000-km wide swatth; 30/40 km footprints
- Soil moisture resolution 10 km, 1-3 km for freeze/thaw

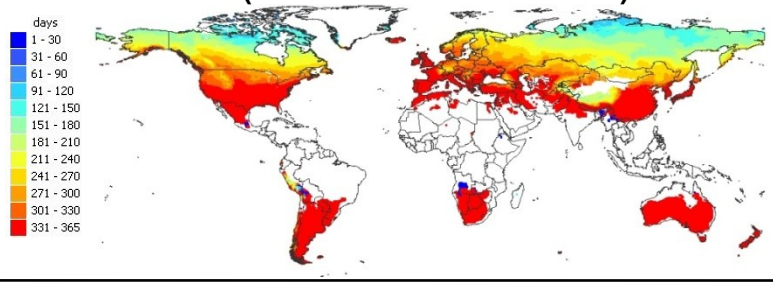


Developing a Global Data Record for Landscape Freeze/Thaw Status

Daily FT Dynamics
(AMSR-E AM/PM 36V GHz, 2004)



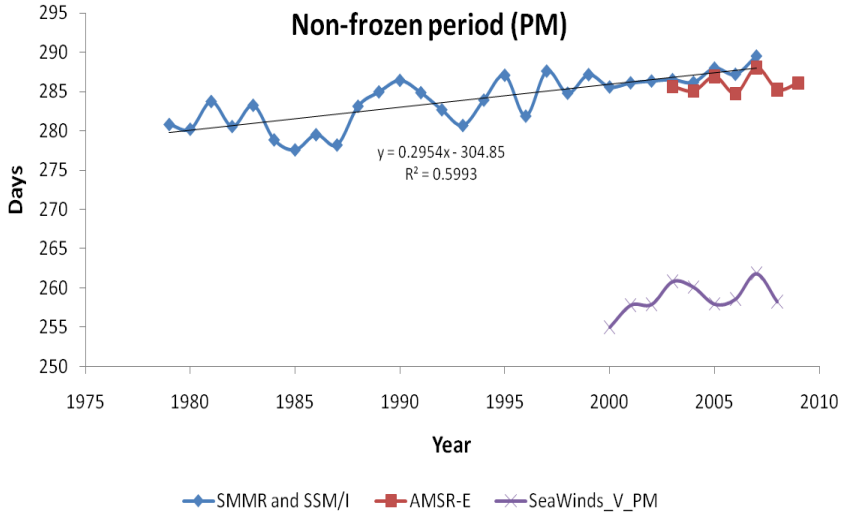
2004 Non-Frozen Period
(AMSR-E 36V GHz)



Goal: **1)** Build a global, long-term (30+ yr) record of daily landscape freeze-thaw state dynamics with well quantified accuracy for climate change studies; **2)** Inform development of similar algorithms & products under NASA SMAP mission.

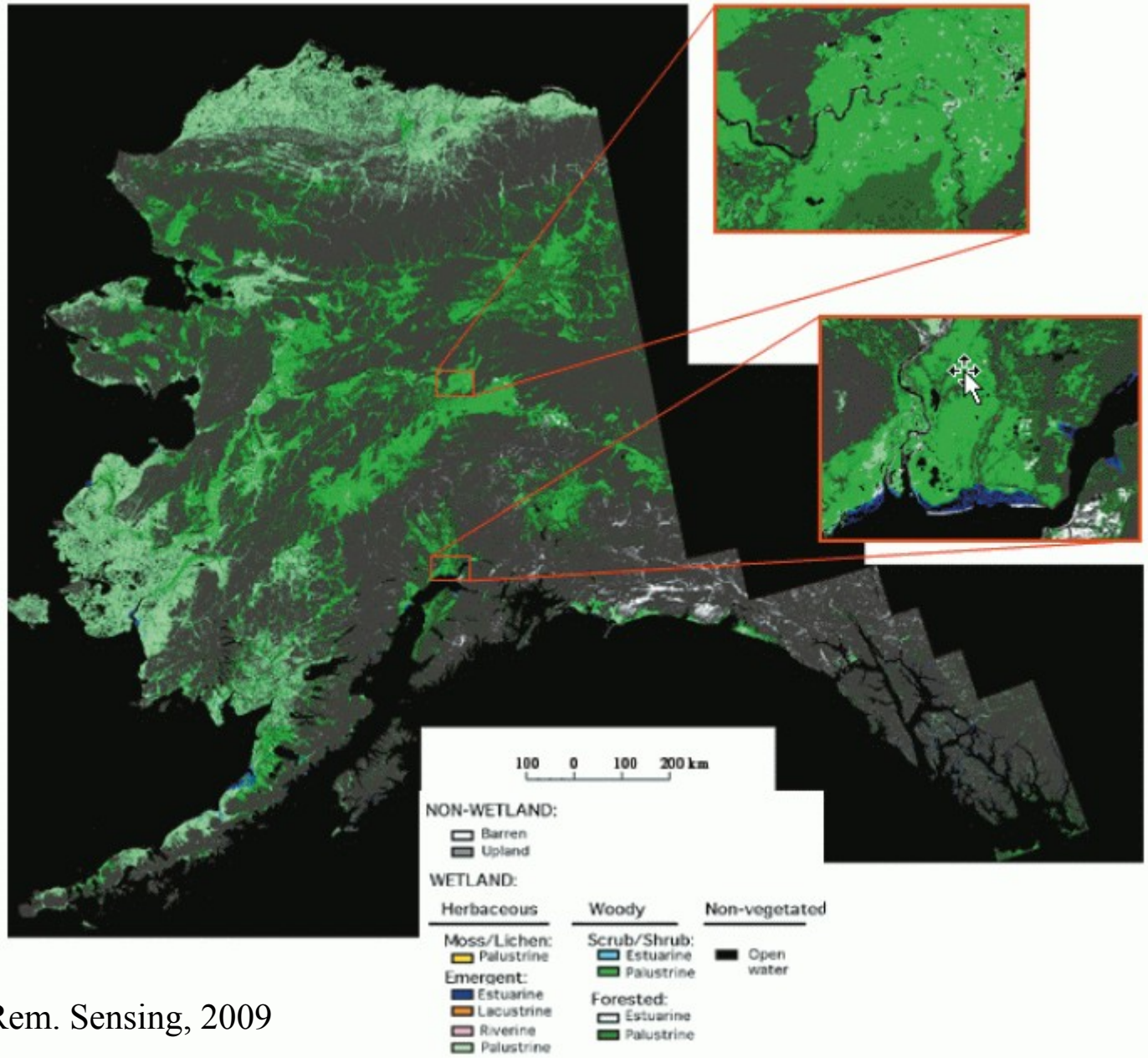
Methods: Temporal change classification of ensemble satellite active & passive microwave remote sensing series; accuracy assessment and uncertainty analysis using global in situ station networks and ancillary geospatial data.

Global Mean Annual Non-Frozen Period.1979-2009



Courtesy John Kimball – U. Montana, NTSG

Wetland map produced from Synthetic Aperture Radar (SAR) aboard the Japanese Earth Resources Satellite 1 (JERS-1).

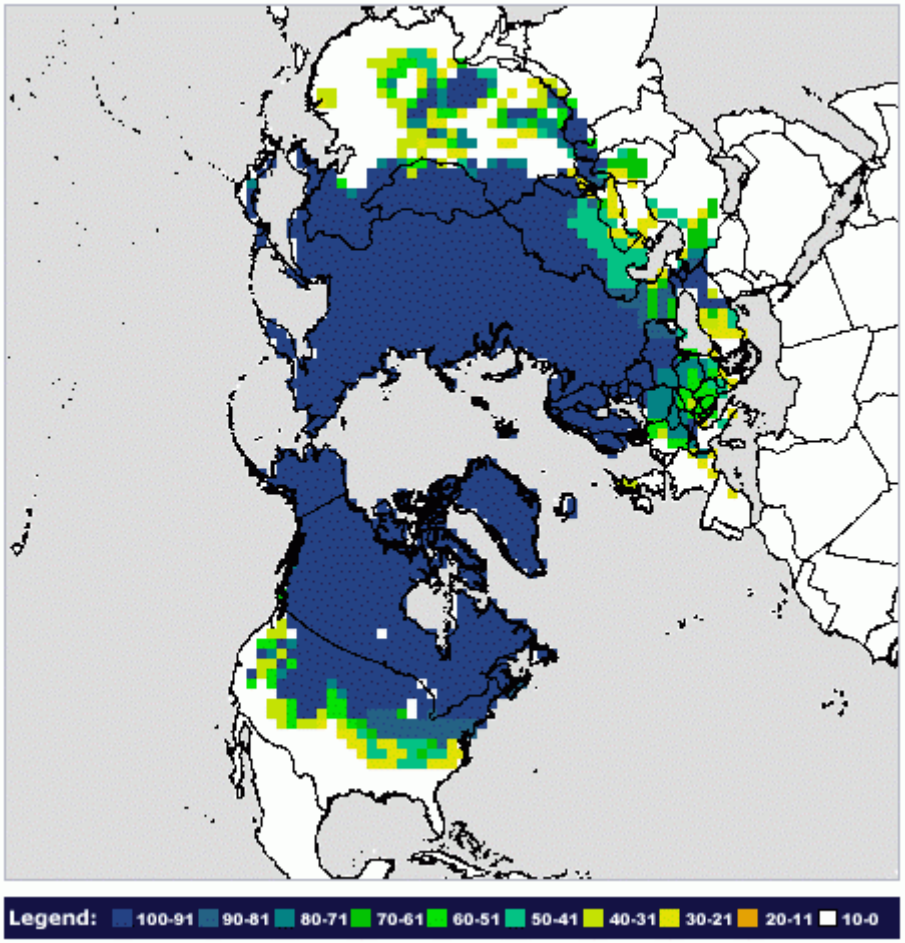


Whitcomb et al., Can. J. of Rem. Sensing, 2009

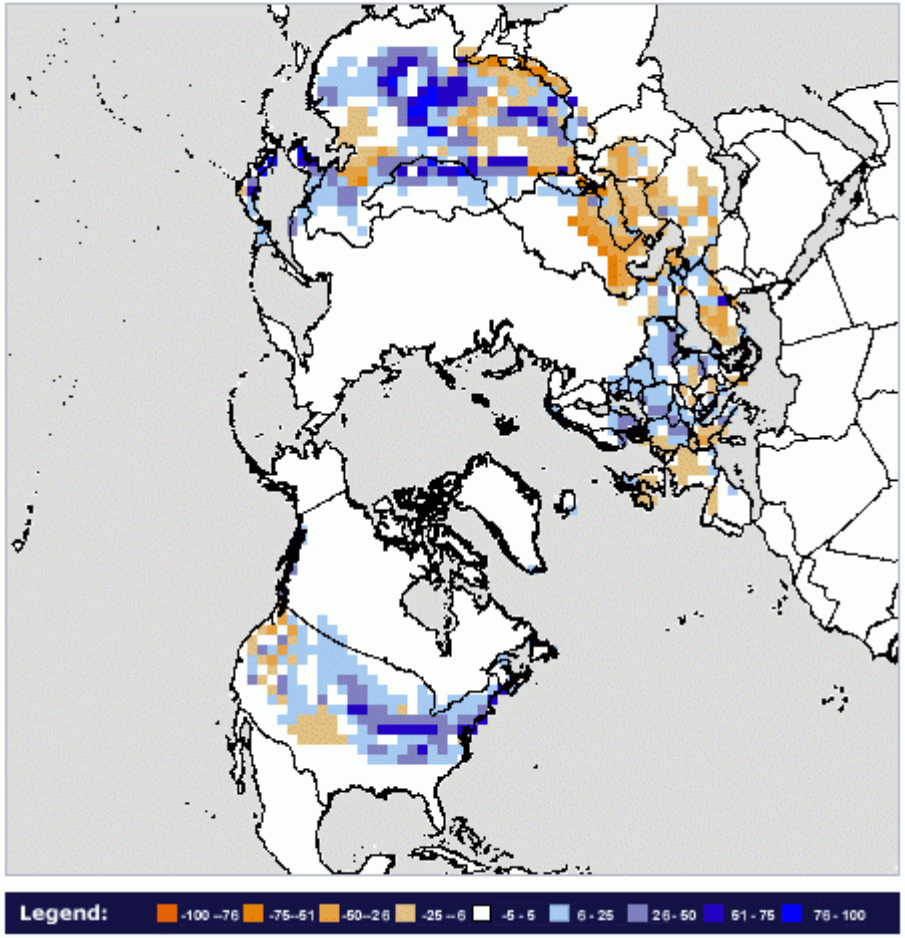
Snow Cover Extent and Anomaly

Visible Satellite Data

Monthly Snow - January 2011



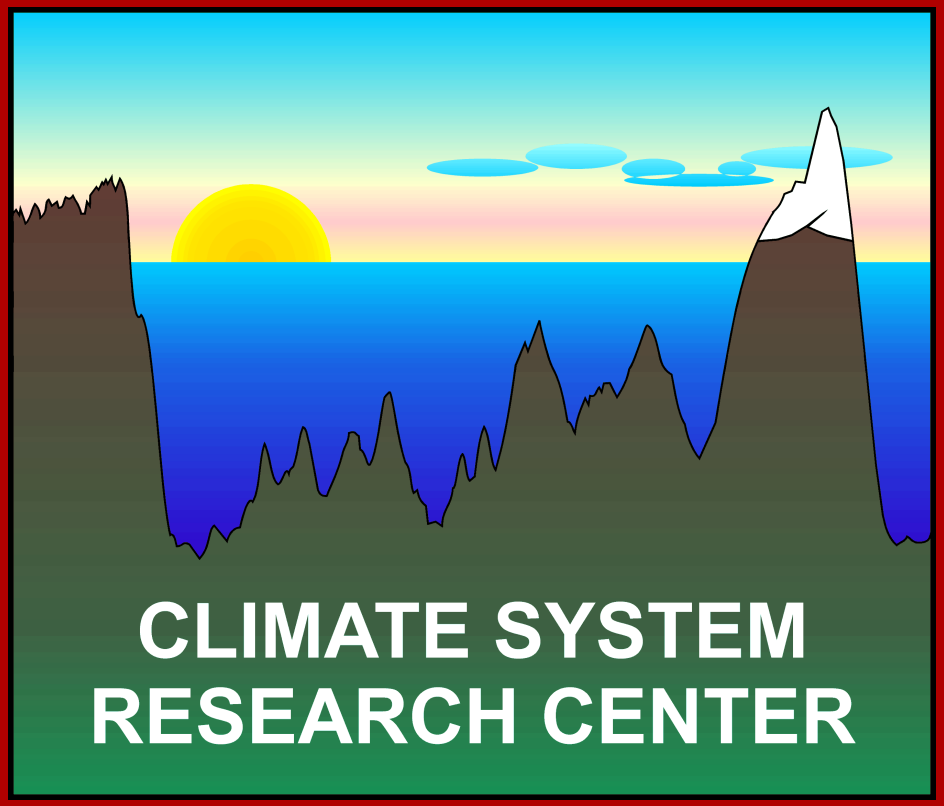
Departure from Normal - January 2011



From Global Snow Lab – Rutgers University

Summary

- Global warming is related to the build-up of greenhouse gases, mainly from the combustion of fossil fuel
- Changes in climate involve more than just temperature
- In New England, more extreme precipitation is expected (& has been observed)
- Snowfall will decline & area of snow-covered ground will be far less
- Peak runoff will be earlier…summer droughts may be more common
- Higher temperatures will be experienced, with more extremely warm days
- Remote sensing tools available for regional monitoring



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www.geo.umass.edu/climate