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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

Rawlins et al., 2009, JGR
Global air temperature
2008 anomaly +0.33°C
(10th warmest on record)
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Carbon Dioxide Concentrations

Ice Core Data

Mauna Loa (Hawaii)

parts per million
Key dates:

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Source: Raynaud et al., 2003
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Variations of the Earth’s surface temperature: year 1000 to year 2100
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.
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
Projected Change in North American Precipitation by 2080-2099

Winter, Spring, Summer, Fall

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

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

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


(b) Heavy Precipitation Days
Number of days with precipitation >10 mm day$^{-1}$

(c) Very Wet Days (sig)
% 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.

*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

A. MARCH runoff

B. MAY runoff

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)

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
For annual P increases range from around 2-8%. The regional mean is ~5%. Larger increases are found across northwest New England.
Relative change in snow depth - model mean of three RCMs.

Seasonal Snowfall at Syracuse, NY

Relative Change in Snow Depth - January

Relative Change in Snow Depth - December

Relative Change in Snow Depth - February

Rawlins et al. in prep
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 swath; 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))

**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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