Means, Extremes and the Changing Character of Maine’s Climate

Bradfield Lyon

Climate Change Institute and School of Earth and Climate Sciences, University of Maine, Orono

2016 Maine Sustainability & Water Conference

Augusta Civic Center, Augusta, Maine
29 March, 2016
Outline

• Changes in the mean can affect changes in extremes:
  → Temperature
  → Atmospheric Moisture and Precipitation

• A warmer climate increases precipitation intensity AND the severity of drought (i.e., an enhanced hydrologic cycle)

• Impacts of extremes:
  → Extreme precipitation
  → Extreme temperature
  → Tipping Points

• Conclusions
Means and Extremes -- Temperature

Maine’s Climate Zones

Distribution of Monthly Temperature Departures from Average 1981-2010 (all Maine climate zones)

Source: www.manomet.org

Source: climatenexus.org
Means and Extremes -- Temperature

Now consider temperature departures from an 1896-2015 average for the two periods 1896-1955 and 1956-2015 separately…

[Graph showing temperature departures]

Compute the differences between the two distributions:

- Fewer cold months
- More warm months

Divide the number of months in each category: latest period/earlier period

A +10F departure is 16x more frequent…
Means and Extremes -- Temperature

Number of Days with Maximum Temperature > 90 deg. F

Source: National Climate Assessment 2014
Means and Extremes -- Precipitation

**Difference:** Recent/Earlier Period

**Ratio:**

- Precipitation Departure (inches)
- Number of Months

---

**Graphs:**
- Histogram showing the number of months with different precipitation departures.
- Bar graph showing the ratio of recent to earlier periods.
Means and Extremes

Consider changes in 20-yr moving averages (mean & variability)

**Temperature (all months)**

**Precipitation (all months)**
Atmospheric Water Vapor

A Warmer Atmosphere can Hold More Moisture

Atmospheric Water Vapor

Increases ~7% for every 1°C of warming

Trenberth et al. (2005)
Atmospheric Water Vapor

Low-Level temperature and Water Vapor Content over Maine 1979-2014
Atmospheric Water Vapor -- Reminder

Water vapor may travel large distances before arriving in Maine...
Atmospheric Water Vapor -- Conceptual

More water vapor = Heavier Precipitation
Atmospheric Water Vapor -- Models

- The climate model energy results in fewer light precipitation days and more heavy and extreme precipitation days. It takes more time to “recharge” the atmospheric water vapor content to its normal level.

Figure 3.6: Projected changes in the intensity of precipitation, displayed in 5% increments, based on a suite of models and three emission scenarios. As shown here, the lightest precipitation is projected to decrease, while the heaviest will increase, continuing the observed trend. The higher emission scenarios yield larger changes. Figure courtesy of Michael Wehner.

Figure Source: US Climate Change Science Program
Observed trends in precipitation over the past 50 years show an increase in the amount of precipitation occurring during extreme events...

Percent changes in the amount of precipitation falling in very heavy events (the heaviest 1%) from 1958 to 2012 for each region. There is a clear national trend toward a greater amount of precipitation being concentrated in very heavy events, particularly in the Northeast and Midwest. (Figure source: updated from Karl et al. 2009.)

Source: National Climate Assessment 2014
Drought

Maine State Average of the Palmer Drought Severity Index 1895-2015

A warming climate exacerbates drought... Additional atmospheric heating further dries the surface, increases temperature.
Drought -- What Lurks Below the Surface


http://pubs.usgs.gov/fs/2004/3021/
Changing Character of Maine’s Climate

Maine Hardiness Zones, 1990 and 2006

Figure 20: The Arbor Day Foundation (2006) revised plant hardiness zones used by farmers and gardeners, based on data from 5,000 National Climatic Data Center cooperative stations across the continental United States. A northward shift in zones reflects a warming climate.

Source: Maine’s Climate Future 2009, University of Maine
Changing Character of Maine’s Climate

Climatological Snowfall

Change in SWE/Total Prcp

Projected Change in Snow

Source: Portland Press Herald

Huntington et al. 2004
Journal of Climate

Map showing the predicted change or difference in total accumulated winter snow by climate zone from 1995–2014 to 2035–2054. The greatest changes are predicted to be along the coast, where many winters of the future will bring rain instead of snow. Map derived from an ensemble simulation of the IPCC A2 emissions scenario.
Impacts -- Extreme Rainfall

Urban Flooding

Flooding in Portland, ME Aug 13, 2014
Photo Source: earthsky.org

Water Quality (DOC)

From Tilburg et al. 2015

Balch et al., 2016

Impacts -- Extreme Rainfall

Erosion

Fecal Coliform Bacteria

From Tilburg et al. 2015
During the height of last month's heat wave, millions of people in northern New England were urged to conserve energy... at the same time, at least two wind farms in Maine and Vermont were ordered to reduce the amount of electricity they provided. ...weakness in the rural system linking wind turbines to the power grid mean wind companies are routinely taken offline or have their output reduced.
Conclusions

• Changes in the mean may accompany changes in the full distribution of a climate variable: changes the probability of extremes.

• A warmer atmosphere can hold more water vapor (7%/deg. C) → Increased rainfall → Increased extreme rainfall

• A warming climate is associated with an enhanced hydrologic cycle: heavier precipitation and exacerbated drought

• Impacts are numerous and varied: erosion, water quality, flooding, heat stress,...

• Tipping points: Non-extremes can have substantial impacts (e.g., power generation, dissolved O$_2$, SLR,...)
Supplemental Slides
Water Vapor Trends (SSMI)

a) Column Water Vapour, Ocean only: Trend, 1988-2004

b) Global ocean mean (%)  
1.2% per decade

IPCC Fourth Assessment Report
Maine’s drought declared as worst

By THE ASSOCIATED
This story was published on News

AUGUSTA – The drought is severe to hit the state Thursday by the U.S. Department of Agriculture.

Although the dry conditions have been widespread since 2002.

http://waterwatch.usgs.gov/
Climate models are able to capture this effect...
How is Precipitation Changing in Maine by Season?
Look at 20-yr changes in the average & variability