Sink or Swim:  
Facing Climate Change Challenges in Portsmouth
Climate Change in New England: Past, Present, and Future

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Climate Change Adaptation Roadmap 2014

climate change is a “threat multiplier” because it has the potential to exacerbate many of the challenges we are dealing with.

Report to Congress, July 2015

National Security Implications of Climate-Related Risks

The DoD sees climate change as a present security threat, not strictly a long-term risk.

Climate Change Adaptation and Resilience Directive, January 2016

provide the DoD with the resources necessary to assess and manage risks associated with the impacts of climate change.

Improve climate preparedness and resilience;
Safeguard US economy, infrastructure, environment, & natural res.
Temperature & Carbon Dioxide

Lüthi et al. (2008) Nature

Carbon Dioxide (ppmv)

Years before 2100 AD

Lüthi et al. (2008) Nature
Temperature & Carbon Dioxide

Lüthi et al. (2008) Nature

deltaD

Carbon Dioxide (ppmv)

Years before 2100 AD

Lüthi et al. (2008) Nature

An image of ice crystals with annotations for temperature and carbon dioxide concentration.

- CO₂ concentration
- Antarctic Temperature

Graph showing changes in deltaD and Carbon Dioxide concentration over years before 2100 AD.
Temperature & Carbon Dioxide

Lüthi et al. (2008); IPCC 2013

-400
-300
-200
-100
0
200
400
600
800
1000

0
200,000
400,000
600,000
800,000

deltaD

Carbon Dioxide (ppmv)

CO₂ concentration

Antarctic Temperature

Business as Usual

Current

Years before 2100 AD

Lüthi et al. (2008); IPCC 2013
Temperature & Carbon Dioxide

Lüthi et al. (2008); IPCC 2013

-400-300-200-1000 0 200,000 400,000 600,000 800,000
deltaD

Carbon Dioxide (ppmv)

-200-300-400

CO₂ concentration

-400

Antarctic Temperature

800,000 600,000 400,000 200,000 0
Years before 2100 AD

Lüthi et al. (2008); IPCC 2013

Business as Usual
Clean Energy and Efficiency
Current

Data from the DOE Carbon Dioxide Information Analysis Center
http://cdiac.ornl.gov/
Average Global Surface Air Temperatures 1880 – 2015 (From NASA GISS)
Minimum Arctic Sea Ice Extent

1979-2010 Average Sea Ice Minimum (yellow line)

2012 Sea ice Minimum
achieve the ideal situation where our control points were all measured with GPS at the same time as the SAR data collection, other sources of error would make it difficult to detect change in velocity in the interior regions, where any such change is expected to be small (<10 m a\(^{-1}\)). In these slow-moving, interior regions, we do not assign any significance to differences in the velocity field. Along the ice margin (e.g. below about the 2000 m contour), where points on bedrock provide most of the control, control-related errors in flow speed are small (<10 m a\(^{-1}\)) relative to variations in ice-flow speed (10 m a\(^{-1}\)).

There are several other sources of error in addition to those related to control points. One major source of inaccuracy is error introduced during the matching procedure used to determine the speckle-tracked offsets, which are determined by the degree of correlation between images. These errors are estimated from the image statistics and are included in our formal error estimates (Joughin, 2002). Height errors in the digital elevation model (DEM) used for topographic correction in the processing can cause velocity errors (Bamber and others, 2003), but their effect is usually small relative to the large displacements observed over the 24 day period between images. Some small degree of such error is visible on the rocky areas because DEM-induced errors are much larger over rough terrain. The DEM also introduces errors in the velocity estimates through errors in surface slope, which yields absolute errors of up to about 3% of speed (Joughin, 2002). Since our two datasets were acquired from nearly identical imaging geometries, however, these errors nearly cancel when evaluating changes in velocity.

Ionospheric variability causes errors in the azimuth component of the speckle-tracked displacement fields (Gray and others, 2000). This yields a distinctive 'streaked' pattern of noise in the velocity field with magnitudes of up to several tens of m a\(^{-1}\). These are spatially variable, making it difficult to derive quantitative estimates of their magnitudes. The distinctive noise pattern, however, often makes these errors visually identifiable so they can be accounted for in the interpretation of the data.

### 3. RESULTS

Figure 1 shows the velocity measurements we generated for 2000/01 and 2005/06. A subset of the 2000/01 RADARSAT data was also processed by Rignot and Kanagaratnam (2006) at coastal locations, but their 2005 dataset was acquired during the winter prior to our 2005/06 data. As noted above, there are gaps in coverage near the southern end of the ice sheet. Other gaps are the result of poor coherence between images, typically in areas with high snowfall, such as in the southeast. The 2000/01 data were collected near the solar maximum (Richardson and others, 2001) when the level of auroral-zone ionospheric disturbances was higher, which yields the much larger 'streak' errors visible in the 2000/01 velocity map (Gray and others, 2000), particularly in the southeast.

There are a few modest speed-ups on land-terminating glaciers in this region, in particular in the area around Russell Glacier. We examined a 3 year time series in this region (Joughin and others, 2008a) and found a seasonal variation in speed on the lower part of this glacier (roughly the same area where speed-up is visible in Figure 7). In this time series over the course of the winter, the speed increases by roughly 50–100 m a$^{-1}$ near the margin, following a minimum speed at the end of the melt season. Since the 2000/01 data were acquired on average roughly 3 months earlier than the 2005/06 data, the changes at Russell Glacier and near the termini of some of the other slow-moving glaciers may represent a seasonal effect. This effect does not extend far inland, and other sites near 1000 m elevation show a much more subdued winter speed-up (Joughin and others, 2008a; Van de Wal and others, 2008).

3.3. Eastern Greenland

As on the west coast, we have subdivided the east coast into southern, central and northern sub-regions.

3.3.1. Southeast coast

Figure 8 shows ice flow along the southeast coast of Greenland where, as described above, high accumulation rates make it difficult to measure interior flow speeds. This region of the ice sheet is far steeper than the west coast, with a more abrupt transition near the heads of fjords between the slow ice-sheet flow and fast, channelized outlet glacier flow. Recent increases in speed and the accompanying rapid, dynamic thinning contribute to making this the region of greatest current ice loss from Greenland (Rignot and Kanagaratnam, 2006; Velicogna and Wahr, 2006; Howat and others, 2008a). Our data (Fig. 8) confirm the previously reported speed-ups of numerous glaciers in this region (Fig. 6).

Jakobshavn Glacier: Dramatic Increase in Surface Velocity since 2000

Chasing Ice video:
https://www.youtube.com/watch?v=hC3VTgIPoGU
Global Mean Sea Level from Satellite Radar Altimeters (TOPEX & Jason)

Inverse barometer applied, GIA corrected

Rate = 3.3 ± 0.4 mm/yr
Seasonal signals removed

http://sealevel.colorado.edu
New Hampshire Climate Assessments
ClimateSolutionsNE.org
Southern NH: Average Annual MINIMUM Temperature 1895 – 2012
Monthly data from US Historical Climatology Network

Temperature (°F)

1900 1920 1940 1960 1980 2000

Keene
Durham
Hanover
CLIMATE CHANGE IMPACTS IN THE UNITED STATES

1: OVERVIEW AND REPORT FINDINGS

Prolonged periods of high temperatures and the persistence of high nighttime temperatures have increased in many locations (especially in urban areas) over the past half century. High nighttime temperatures have widespread impacts because people, livestock, and wildlife get no respite from the heat. In some regions, prolonged periods of high temperatures associated with droughts contribute to conditions that lead to larger wildfires and longer fire seasons. As expected in a warming climate, recent trends show that extreme heat is becoming more common, while extreme cold is becoming less common. Evidence indicates that the human influence on climate has already roughly doubled the probability of extreme heat events such as the record-breaking summer heat experienced in 2011 in Texas and Oklahoma. The incidence of record-breaking high temperatures is projected to rise.

2

Human-induced climate change means much more than just hotter weather. Increases in ocean and freshwater temperatures, frost-free days, and heavy downpours have all been documented. Global sea level has risen, and there have been large reductions in snow-cover extent, glaciers, and sea ice. These changes and other climatic changes have affected and will continue to affect human health, water supply, agriculture, transportation, energy, coastal areas, and many other sectors of society, with increasingly adverse impacts on the American economy and quality of life.

3

Some of the changes discussed in this report are common to many regions. For example, large increases in heavy precipitation have occurred in the Northeast, Midwest, and Great Plains, where heavy downpours have frequently led to runoff that exceeded the capacity of storm drains and levees, and caused flooding events and accelerated erosion. Other impacts, such as those associated with the rapid thawing of permafrost in Alaska, are unique to a particular U.S. region. Permafrost thawing is causing extensive damage to infrastructure in our nation's largest state.

4

Some impacts that occur in one region ripple beyond that region. For example, the dramatic decline of summer sea ice in the Arctic – a loss of ice cover roughly equal to half the area of the continental United States – exacerbates global warming by reducing the reflectivity of Earth's surface and increasing the amount of heat absorbed. Similarly, smoke from wildfires in one location can contribute to poor air quality in faraway regions, and evidence suggests that particulate matter can affect atmospheric properties and therefore weather patterns. Major storms and the higher storm surges exacerbated by sea level rise that hit the Gulf Coast affect the entire country through their cascading effects on oil and gas production and distribution.

5

Water expands as it warms, causing global sea levels to rise; melting of land-based ice also raises sea level by adding water to the oceans. Over the past century, global average sea level has risen by about 8 inches. Since 1992, the rate of global sea level rise measured by satellites has been roughly twice the rate observed over the last century, providing evidence of acceleration. Sea level rise, combined with coastal storms, has increased the risk of erosion, storm surge damage, and flooding for coastal communities, especially along the Gulf Coast, the Atlantic seaboard, and in Alaska. Coastal infrastructure, including roads, rail lines, energy infrastructure, airports, port facilities, and military bases, are increasingly at risk from sea level rise and damaging storm surges. Sea level is projected to rise by another 1 to 4 feet in this century, although the rise in sea level in specific regions is expected to vary from this global average for a number of reasons. A wider range of scenarios,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 c).

Observed Change in Very Heavy Precipitation

Change in amount of rain falling in large 1% of events 1958-2012

National Climate Assessment 2014
4 Inch Precipitation Events by Decade 1963 – 2012

Events per Decade


Durham
Federal Expenditures on FLOOD RELATED Presidentialy Declared Disasters And Emergency Declarations in NH

2005: Alstead/Keene Floods (Oct)
2006: Mother’s Day Flood (May)
2007: Patriots Day Flood (April)
2011: Irene
2012: Flooding; Sandy

http://www.fema.gov/disasters
Global Greenhouse Gas Emission Scenarios

Key Input for GCM projections of future climate change

CO2 Emissions (Billion Metric Tons Carbon)

Higher Emissions (A1Fi)

Lower Emissions (B1)

IPCC 2007
Projecting Future Climate Change for the Northeast: Downscale Global Projections to Regional Level

Projections from 4 different global climate models:
- NOAA – GFDL
- UKMO – HadCM3
- NCAR – PCM
- NCAR – CCSM3
Southern NH: Average Summer MAXIMUM Temperature 1960-2099
Average of statistically downscaled simulations from 4 GCMs

Higher Emissions (A1fi)
Lower Emissions (B1)
Southern NH: Number of Days Hotter than 90°F (30 year averages)

Average of statistically downscaled simulations from 4 GCMs

- Lower Emissions (B1)
- Higher Emissions (A1fi)
Southern NH: Average Annual Precipitation 1960-2099
Average of statistically downscaled simulations from 4 GCMs

Graph showing the average annual precipitation in Southern NH, with two lines representing higher emissions (A1fi) and lower emissions (B1). The x-axis represents the years from 1960 to 2100, and the y-axis represents precipitation in inches. The graph indicates a trend where higher emissions lead to increased precipitation in the future.
Southern NH: Precipitation Events >4” in 48 hrs per Decade
Average of statistically downscaled simulations from 4 GCMs

Events per Decade


- Lower Emissions (B1)
- Higher Emissions (A1fi)
Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: 

GLOBAL SEA LEVELS HAVE BEEN RISING AND ARE EXPECTED TO CONTINUE RISING WELL BEYOND THE END OF 21ST CENTURY.

http://ClimateSolutionsNE.org
Sea Level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Trends

**SEA-LEVEL RISE SCENARIOS AT 2050 AND 2100**

- **OBSERVED**
- **SCENARIOS**
  - HIGHEST: +6.6 feet sea level
  - INTERMEDIATE HIGH: +3.9 feet sea level
  - INTERMEDIATE LOW: +1.6 feet sea level
  - +2.0 feet sea level
  - +1.3 feet sea level
  - +0.6 feet sea level

Figure modified from NH Coastal Risks and Hazards Commission, Science and Technical Advisory Panel Report (2014).
Global sea levels have been rising and are expected to continue rising well beyond the end of 21st century.

Where there is little tolerance for risk, communities should commit to manage for **4.0 feet** of sea level rise by 2100, but be prepared to manage for as much **6.6 feet**.
Portsmouth NH Flood Depths with 0.3 foot storm surge + 6.8 foot SLR Equivalent to 11.5 feet above NAVD 88 OR 7.1 feet above MHHW
Portsmouth NH Flood Depths with 11.2 foot storm surge + 6.8 foot SLR Equivalent to 18 feet above NAVD 88 OR 13.6 feet above MHHW

http://www.planportsmouth.com/cri/
Solutions?

Mitigation & Adaptation

Climate Change is the Innovation Opportunity of the 21st Century
2015 Paris Agreement on Climate Change

• 195 countries negotiated an agreement in Paris in Dec 2015
• Goal: Limit planetary warming to well below \(2\, ^\circ C\) \((3.5\, ^\circ F)\)
  Nations urged to pursue even stricter target of \(1.5\, ^\circ C\) \((2.7\, ^\circ F)\)
• Pledges from developed & developing countries
• Transparent system for measuring, reporting & verifying emissions
• Wealthy nations provide >US$100 billion/yr by 2020 to poorer nations
Percent Coal, Oil, and Gas (Global Reserves) That Must NOT BE BURNED to Prevent Climate Change of More than 2°C

Regional Reserves That Must Not be Burned

<table>
<thead>
<tr>
<th>Region</th>
<th>Coal</th>
<th>Oil</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>92%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>China &amp; India</td>
<td>66%</td>
<td>25%</td>
<td>63%</td>
</tr>
<tr>
<td>Arctic</td>
<td>0%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Annual Global Investment in Renewable Energy

Net Generating Capacity Added Globally in 2015
Renewable (without large hydro) 53%
Coal 17%
Gas 16%
Large hydro 9%
Nuclear 6%
The Clean Power Plan: A Climate Game Changer

Environmental Protection Agency finalized new rules (standards) that will reduce carbon emissions from US power plants.
Emissions reduction will reduce growing consequences of climate change and improve public health.
Supported by both NH Senators (Ayotte & Shaheen)
• One of the largest, most diverse collections of leading NH citizens
• Promotes growth of new jobs and renewable energy development
• Reduces energy costs
• Identifies 67 recommended actions
  - buildings
  - electricity generation,
  - transportation & land use
  - natural resources
  - government action
  - adaptation
• Reduce greenhouse gas emissions
  - 44% below 2005 levels by 2025
  - 86% below 2005 levels by 2050
NH Gross State Product Vs. Greenhouse Gas Emissions

GSP data from US DOC Bureau of Economic Statistics; GHG data from US Energy Information Administration
Community Investment in Energy Efficiency & Renewable Energy
NH Coastal Risks & Hazards Commission (RSA 483-E)

Membership: 39 representatives; coastal municipalities, state legislature, state agencies, regional planning commissions, UNH

Purpose: Recommend legislation, rules and other actions to prepare for projected sea level rise and other coastal watershed hazards . . .

Recommendations:

Our Economy
Built Environment
Natural Resources
Our Heritage

http://nhcrhc.stormsmart.org/draft-for-comment/
Reduce Your Risk, Reduce Your Premium
FEMA National Flood Insurance Program

Under the Flood Insurance Reform Act of 2012, You Could Save More than $90,000 over 10 Years if You Build 3 Feet above Base Flood Elevation*

- **PREMIUM AT 4 FEET BELOW BASE FLOOD ELEVATION**
  - $9,500/year
  - $95,000/10 years

- **PREMIUM AT BASE FLOOD ELEVATION**
  - $1,410/year
  - $14,100/10 years

- **PREMIUM AT 3 FEET ABOVE BASE FLOOD ELEVATION**
  - $427/year
  - $4,270/10 years

*based on $250,000 single family, one story structure without a basement

From FEMA Brochure: Build Back Safe and Stronger
City of Portsmouth, New Hampshire

COASTAL RESILIENCE INITIATIVE

Climate Change Vulnerability Assessment and Adaptation Plan

April 2, 2013

Get Involved

Portsmouth 2025 Master Plan – NOW!

Capital Improvement Plan

This project was funded by the Gulf of Maine Council through a grant from the National Oceanic and Atmospheric Administration (NOAA).
**Bipartisan Bill on Accessory Dwelling Units (SB 146)**
Signed into Law by Governor Hassan on 16 March 2016

Findings: There is growing need for more diverse affordable housing opportunities for the citizens of New Hampshire . . .

Allows an Accessory Dwelling Unit (ADU) attached to a single-family home as a matter of right through a conditional use permit or by special exception.

Effective date of June 2017 to give municipalities the necessary time to make zoning adjustments if needed.

Increase affordable housing options for young professionals and seniors in NH
Life isn’t about waiting for the storm to pass. It’s about learning how to dance in the Rain.

Vivian Greene