CLIMATE CHANGE AND ITS EFFECTS ON HUMANS

STATE OF THE GULF OF MAINE REPORT

Gulf of Maine Council on the Marine Environment

June 2010

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Gulf of Maine Council on the Marine Environment

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The Gulf of Maine Council on the Marine Environment was established in 1989 by the Governments of Nova Scotia, New Brunswick, Maine, New Hampshire and Massachusetts to foster cooperative actions within the Gulf watershed. Its mission is to maintain and enhance environmental quality in the Gulf of Maine to allow for sustainable resource use by existing and future generations.

Cover map (background) courtesy of Census of Marine Life/Gulf of Maine Area Program

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1. Issue in Brief

Accelerated climate change is anticipated to have wide-ranging effects on the future sustainability of the Earth due to adverse ecological, social and economic impacts (Stern 2006; McMullen and Jabbour 2009). The driving force is an increase in the Earth's temperature as a result of human activities (e.g., release of greenhouse gases and changes in landscape characteristics). The Intergovernmental Panel on Climate Change (IPCC) projects a global mean temperature increase of 1.1°C to 6.4°C by 2100, which is likely to affect storms and floods, and lead to a rise in sea level due to the thermal expansion of the oceans and the melting of ice sheets and glaciers (IPCC 2007a). Recent research efforts estimate a global sea level rise of between 50 cm and 190 cm from 1990 to 2100 (see Vermeer and Rahmstorf 2009). There are several parts of the Gulf of Maine coast line that are classified as highly sensitive to the impacts of sea level rise because of risks associated with storm events. The physical extent of climate-related impacts will vary depending on regional and local situations (Burtis 2006). Coastal communities in the Gulf of Maine will be impacted in numerous ways, including: health and well-being of communities (e.g., injury, mortality, migration, crime and security); access to services; design and placement of structures (e.g., buildings, bridges, and utilities); cost of living; loss of livelihoods, and the cumulative magnitude of climate change impacts (see Figure 1). Climate change mitigation and adaptation are becoming increasingly important to community management and there are numerous ongoing federal, provincial/state, county, and municipal plans addressing these issues within the Gulf of Maine.

LINKAGES

This theme paper also links to the following theme papers:

- Climate Change and Its Effect on Ecosystems, Habitat and Biota
- Landuse and Coastal Development

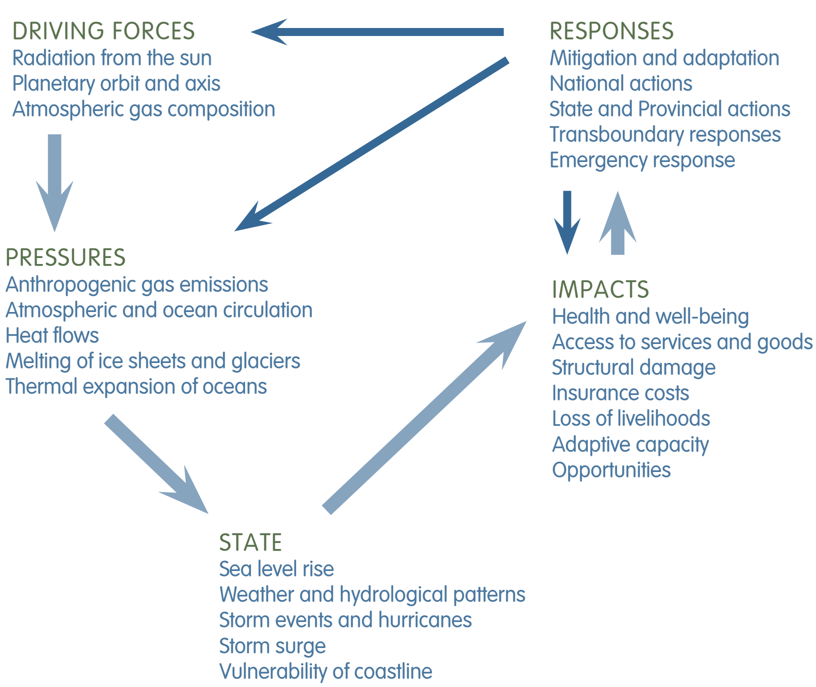


Figure 1: Driving forces, pressures, state, impacts and responses (DPSIR) to climate change and its effects on humans in the Gulf of Maine. The DPSIR framework provides an overview of the relation between the environment and humans. According to this reporting framework, social and economic developments and natural conditions (driving forces) exert pressures on the environment and, as a consequence, the state of the environment changes. This leads to impacts on human health, ecosystems and materials, which may elicit a societal or government response that feeds back on all the other elements.

2. Driving Forces and Pressures

There are many forces responsible for shaping the Earth's climate. Operating and interacting at different scales in time and geographic space, these include (McMullen and Jabbour 2008): variations in radiation emitted from the sun (e.g., sun spot activity), the cyclical behaviour of the Earth's orbit and axis, changes in the gas composition of the atmosphere, volcanism, uplifting and wearing away of land surfaces, shifting distribution of landmasses and oceans caused by plate tectonics, and changes in the characteristics of the Earth's land surface. Evidence indicates that the Earth is currently going through an accelerated period of global warming (IPCC 2007a; see also Figure 2). Increases in anthropogenic emissions of gases (e.g., carbon dioxide, methane) into the atmosphere, and an enhanced greenhouse effect, are considered to be the major driving force behind the accelerated global warming that has taken place over the last century (IPCC 2007a,b). Since the introduction of the United Nations Framework Convention on Climate Change in 1994 few countries have been able to reduce gas emissions according to targets of the Kyoto Protocol (IPPC 2007b). Trends for the states and provinces associated with the Gulf of Maine indicate an increase in GHG emissions over the last decade (Environment Canada 2008; Regional Greenhouse Gas Initiative 2009).

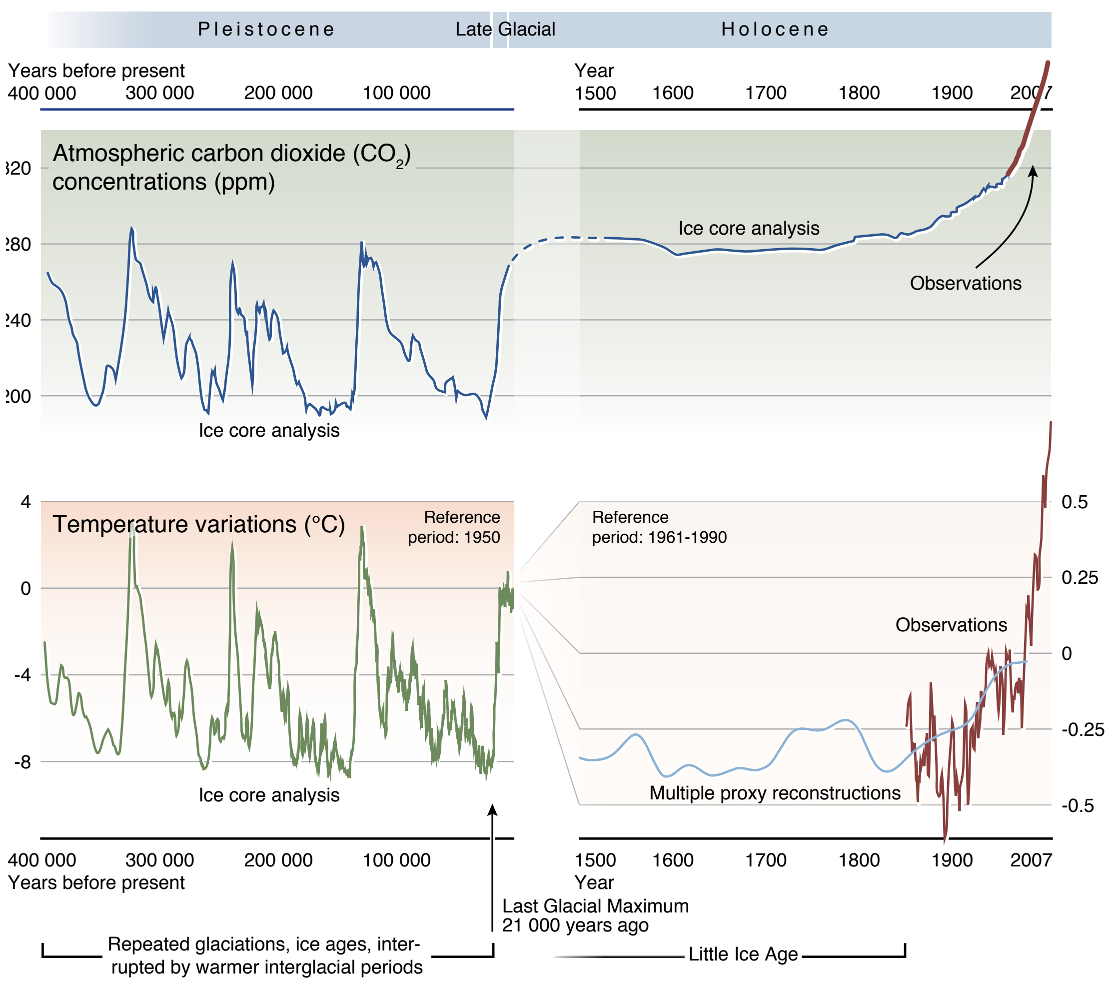


Figure 2: Variations in atmospheric carbon dioxide and mean global surface temperatures for the Earth.

Source: Hugo Ahlenius, UNEP/GRID-Arendal, http://maps.grida.no/go/graphic/historical-trends-in-carbon-dioxide-concentrations-and-temperature-on-a-geological-and-recent-time-scale. Accessed May 7, 2010.

Global climate scenarios examined by the IPCC (2007b) project global mean temperature increases varying between 1.1°C and 6.4°C by 2100. Observations at the regional and local level (North Eastern United States and Canadian Maritimes Cross Border Region) support that a trend in warming is taking place in the Gulf of Maine where monitoring sites in the Gulf of Maine display a trend of an increase in annual average temperature of the order of 0.1°C/decade (Burtis 2006 - see Figure 3).

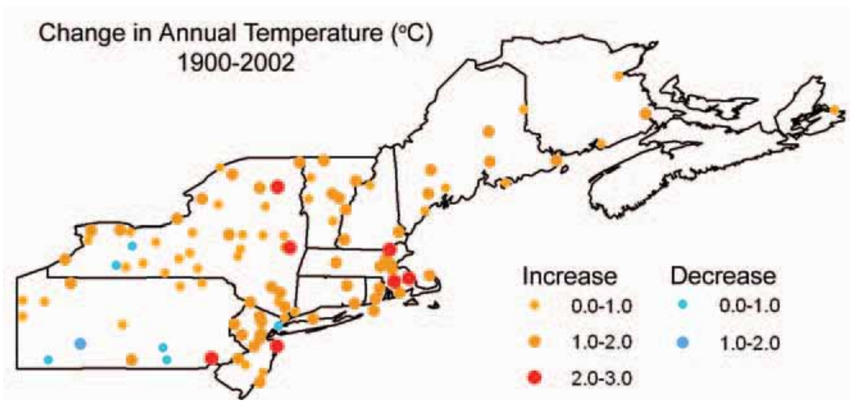


Figure 3: Map illustrating the pattern in annual temperature changes (°C) at sites in the Cross-Border Region for the period 1900-2002. Cooling trends are shown with blue dots, while warming trends are shown with orange and red dots (from Burtis 2006).

Increases in the gas composition of the Earth's atmosphere have an impact on numerous aspects of the planet's physical properties and characteristics, all of which interactively affect changing climate and increasing variability at the regional and local levels (IPCC 2007a). These include:

- The changing thermal properties of the Earth's atmosphere, which contributes to changes (a general increase) in global moisture content and atmospheric water balance (McMullen and Jabbour 2009).
- Changes to the global distribution of heat flows and atmospheric circulation patterns. The differential heating and cooling patterns will influence major regional air flow systems (e.g., the jetstream, North Atlantic Oscillation, Arctic Oscillation) and ocean currents (the Deep Sea Circulation System, Gulf Stream, the Nova Scotian Current etc.), which dictate continental weather patterns over the Eastern United States and Atlantic Canada. It is thought that this could cause an increase in the intensity of storms in the northern hemisphere, as well as a possible northward shift of storm tracks (McCabe et al. 2001, Wang et al. 2006).

Greenhouse Gas (GHG) Emissions for Provinces and States Associated with the Gulf of Maine

GHG emissions in CO_2 equivalents (Mt) for Canadian provinces (1990 and 2006). Source: Environment Canada, 2008.

Province	1990	2006
Nova Scotia	19.0	19.6
New Brunswick	15.9	17.9

CO_2 emissions (Mt) for power plants in US states (2000 and 2007). Source: RGGI, 2009.

State	2000	2007
Maine	3.2	3.4
New Hampshire	5.2	7.6
Massachusetts	25.5	25.4

- Melting of ice sheets, glaciers and warming of ocean waters. The ice caps lock up some 2% of the Earth's water and melting will change the volume, temperature and salinity of the oceans. Observations have shown that since 1979 the Arctic perennial sea ice cover has been declining at 9.6 % per decade (Arctic Climate Impact Assessment 2005). In 2005, the Arctic sea ice extent dropped to 2.05 million sq. miles, the lowest extent yet recorded in the satellite record. The IPCC (2007c) estimates that, since 1993, thermal expansion of the oceans due to rising sea temperature contributed about 57% to sea level rise, while melting of ice caps and glaciers contributed about 28% and losses from the polar ice sheets contributed 15%.
- Land movement and land subsidence, which is a manifestation of the Earth crust's long-term response to the end of the last ice age, referred to as 'glacial isostatic adjustment' (Peltier 2004; Leys 2009). In the Gulf of Maine, subsidence rates are not uniform and are estimated to be from 0 cm to 20 cm/century.

3. Status and Trends

Changes in weather and climate (e.g., temperature, precipitation, drought, timing of thaw, frequency of hurricanes), rising sea level and elevated storm surges are all physical processes that have implications on the development and well-being of human settlements (Lemmen et al. 2008). There is evidence that the Gulf of Maine is experiencing changes that will impact society to varying degrees.

3.1 CHANGES IN WEATHER PATTERNS

Weather patterns in the Gulf of Maine region have shown similar trends to global climate change. Burtis (2006) states that:

- There has been an increase in average summer and winter land temperatures, with increased variability.
- Average precipitation in the United States-Canadian Cross Border Region has increased by an average of 129 mm (12 %) over the past century.
- The post-1970 period has experienced the only four years on record with precipitation greater than 1,400 mm and eight of the ten wettest years on record.
- Severe drought periods have been also experienced, and some sites have shown decreases in average precipitation.

- The average number of extreme precipitation events (more than 50 mm of rain or water equivalent if the storm results in snowfall) during a 48-hour period for the entire region is 2.6 events per year. Sites in parts of Massachusetts have more than 4 events per annum. Of the 51 monitoring stations in the Cross-Border Region, 36 stations showed an increase of greater than 10 % in the number of extreme events since 1949.
- There are indications that the timing of melting and thawing of snow and ice is occurring earlier with resultant changes to the hydrological patterns of rivers flowing into the Gulf of Maine.

3.2 RISING SEA LEVEL

Recent projections (Vermeer and Rahmstorf 2009) estimate a global mean sea level rise of between 50 cm and 190 cm over the period 1990 to 2100. According to Burtis (2006), sea level in Atlantic Canada and the north-eastern United States has risen approximately 25 cm since 1920. Permanent tide gauges have been established in the Gulf of Maine as part of the global network (see http://www.pol.ac.uk/psmsl/). For stations with the most long-term data (Yarmouth NS, Saint John NB, Eastport ME, Bar Harbor ME, Portland ME and Boston MA) average sea level rise is given in Table 1.

Table 1: Average sea level rise for stations in the Gulf of Maine

Station	Start Year	End Year	Average Sea Level Rise (mm/a)
Yarmouth, NS	1929	1999	4.1
Saint John, NB	1967	2007	2.5
Eastport, ME	1930	2007	2.2
Bar Harbor, ME	1948	2007	1.6
Portland, ME	1912	2007	1.2
Boston, MA	1921	2007	2.4

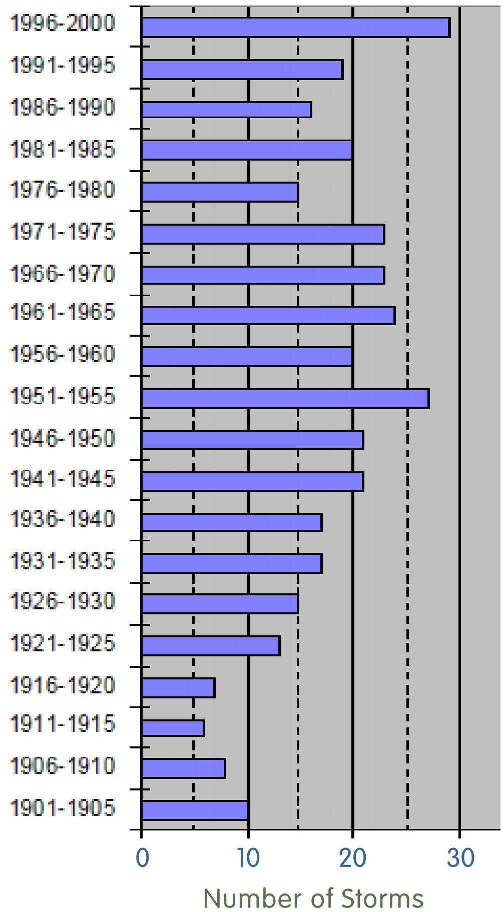
Source: Permanent Service for Mean Sea Level 2010, http://www.pol.ac.uk/psmsl

3.3 STORM EVENTS AND HURRICANES

Tropical storms of hurricane strength carry winds in excess of 100 km/h and wind- and flood-related impacts are always experienced. Eastern Canada and the north eastern US are vulnerable to landfall from tropical cyclones, which arise in the Atlantic. Although no specific long-term trend of increase is apparent over the period 1900 to 2000 (see Figure 4), a cyclical pattern is evident and the Atlantic Basin is currently experiencing an active period. Burtis (2006) reported that the highest frequency of tropical cyclones of any decade on record was for the period 1995 to 2005. The Gulf of Maine is an area that receives between two and five

Figure 4: Five-year tropical storm frequency for the Canadian Hurricane Response Zone 1900–2000.

Source: http://www.ec.gc.ca/Hurricane/default.asp?lang=en&n=BD699ABF-1)



storms per annum. Because of their size and tracking direction, most storms generally have an influence over the whole of the Gulf of Maine coastline, as well as considerable distances inland.

3.4 STORM SURGES

Storm surges are caused by storm winds that pile water onshore, and are influenced by wave setup, possible resonant effects within a bay and the coastal response to all these factors (Parkes et al. 1997). The surge is determined as the height difference between the water level due to astronomical tides and the total water level at the peak of the storm. A rise in sea level allows storm surges to reach further inland. The surges mostly occur during extratropical storms in the fall and winter, but can also be caused by tropical cyclones in the summer and fall. Figure 5 shows an analysis of the 40-year return level of extreme storm surges for the Atlantic coastline. The highest surges around the Gulf of Maine tend to occur at the head of the Bay of Fundy and in Massachusetts. The most damaging storms are those occurring at high tide, or storms of long duration (over several tidal cycles) coinciding with spring tides.

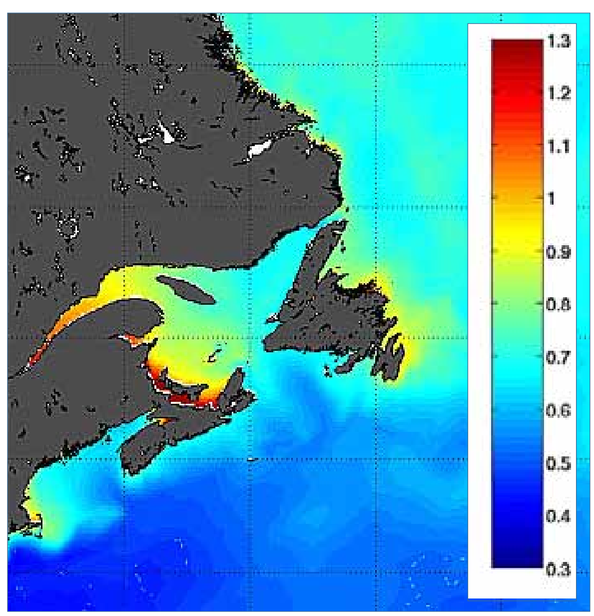


Figure 5: Forty-year return level of extreme storm surges based on a hindcast (reproduced from Bernier and Thompson 2006; Leys 2009). The colourbar indicates the 40-year surge levels independent of tidal elevations.

3.5 VULNERABILITY

Vulnerability (or sensitivity) of coastal areas to sea level rise is the degree to which coastal systems (human and ecological) are susceptible to adverse impacts from sea level rise (see Section 4). The United States has undertaken a nationwide assessment of vulnerability of coastal areas to sea level rise (Thieler et al. 2001, http://woodshole.er.usgs.gov/project-pages/cvi/). The assessment focused on the physical response of the coastline to sea-level rise. The relative vulnerability of different coastal environments to sea-level rise was quantified at a regional scale using a coastal vulnerability index (CVI), based on coastal geomorphology, shoreline erosion and accretion rates, coastal slope, rate of relative sea-level rise, mean tidal range and mean wave height (Thieler and Hammer-Klose 1999). The results of the analysis for the Atlantic Coast, including Massachusetts, New Hampshire and Maine, are indicated in Figure 6. Although the findings indicate that most of the Gulf of Maine coast is considered to have a relatively low risk ranking, there are areas which are of high risk, particularly in the southern parts.

A similar analysis for coastal sensitivity (or vulnerability) to sea level rise has been undertaken for Canadian coastal areas (Shaw et al. 1998). The coastal sensitivity index is based on general relief, rock type, coastal landform, sea level rise trend, shoreline displacement, tidal range and wave height using large-scale 1:50,000 maps (Shaw et al. 1998). Figure 7 depicts the broad regional scale sensitivity of Atlantic Canada to such physical impacts. There is no accounting for small areas of very high sensitivity, so the map should not be used for developing local, site-specific policies.

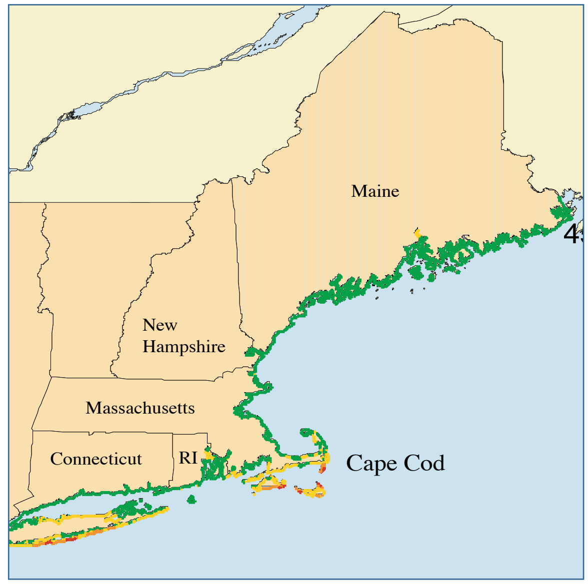


Figure 6: Map of the CVI for Maine, New Hampshire and Massachusetts. The CVI shows the relative vulnerability of the coast to changes due to future rise in sea-level. Areas along the coast are assigned a ranking from low to high risk, based on the analysis of physical variables that contribute to coastal change.

Source: http://woodshole.er.usgs.gov/project-pages/cvi

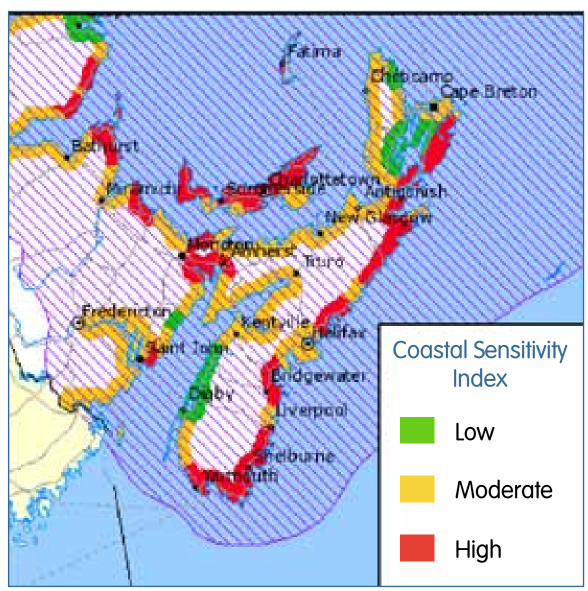


Figure 7: Regional physical sensitivity of coastline to sea level rise in Nova Scotia and New Brunswick.

Source: http://atlas.nrcan.gc.ca/site/english/maps/climatechange/potentialimpacts/coastalsensitivitysealevelrise

4. Impacts

Climate change is a physical process, but because of the dependency of humans on the availability and quality of natural resources (e.g., air, land, water, biota, and materials) any changes in the physical characteristics of the environment will be reflected by cumulative, interacting social and economic impacts. Their intensity and frequency will not be the same due to variations in site-specific characteristics (SNIFFER 2009). Coastal areas and communities will be amongst the highest at risk because of their proximity to the sea.

The direct risks and impacts of climate change will depend largely on the density of human populations and characteristics of settlements on the coastal strip (Lemmen et al. 2008). Average population density along the coastline is relatively low, but high densities occur in coastal cities (e.g., Boston and Portland). The Gulf of Maine has a wide range of human settlements and development over its coastline and population density is expected to increase, particularly in areas close to the larger coastal cities over the next 30 years (Pesch and Wells 2004).

The potential risks and impacts of climate change on human society have been identified at global (IPCC 2007c) and regional levels for both Canada and the United States (Lemmen et al. 2007; Climate Change Science Program 2008; US Global Change Research Program 2009; Jacobsen et al. 2009). These relate to human well-being, disruption of infrastructure and networks, access to goods and services, and adaptive capacity of communities to deal with the issue (Table 2). Not all potential impacts can be classified as negative as there are positive aspects that have been cited.

It is difficult to measure many of the impacts, although some impacts can be evaluated in financial terms. For instance, the costs of storm and hurricane damage on coastal areas can be extremely high, as evidenced by estimates for Hurricane Katrina, the most costly natural disaster in US history, which generated damage in excess of US$100 billion (commercial structure damages of $21 billion, commercial equipment damages of $36 billion, residential structure and content damages of almost $75 billion, electric utility damages of $231 million, highway damages of $3 billion, sewer system damages of $1.2 billion and commercial revenue losses of $4.6 billion) (Burton and Hicks 2005). By comparison, in a less populated area the estimated costs of Hurricane Juan, which passed over Nova Scotia in 2003, amounted to CAD$200 million (Lemmen et al. 2008).

Table 2: Potential socio-economic impacts associated with climate change (not presented in any order of priority - derived from SNIFFER 2009; Lemman et al. 2008; Climate Change Science Program 2008).

HEALTH AND WELL-BEING	
Physical injuries	• Increased injuries and deaths due to flooding, high winds, and storms. • Reduced access to health care due to disruption of services.
General health	• Increased heat-related mortality and morbidity particularly the elderly. • Increase in infectious diseases due to flooding and increase in damp conditions. • Exposure to chemicals from damage and overflow from pipelines and other storage utilities. • Increase in disease vectors resulting from temperature and precipitation shifts.
Mental health	• Anxiety, stress and other mental health problems due to heat, flooding and storm events, as well as possible evacuation or migration.
Safety and crime	• Increased risk of social unrest, crime and violence. • Increased risk of exposure to fires, chemical spillages, electricity.
ACCESS TO GOODS AND SERVICES	
Land	• Loss of land along the coastline and riparian areas for multiplicity of purposes (e.g., housing, agriculture, recreation). • Increased costs of land preparation to prevent flooding along coastline and riparian areas.
Water	• Threat of access to potable water due to saline intrusion of freshwater aquifers. • Threat of access to potable water due to contamination of water supplies and and disruption of treatment works and supply infrastructure. • Risk of sewer overflows.
Food	• Loss of riparian and coastal land area suitable for agriculture. • Reduced availability and increased cost of agricultural (animal, dairy and vegetable) products due to wet weather and flooding. • Reduced availability of fish/shellfish due to water quality.
Housing	• Damage and loss of buildings and property during floods and storms. • Increased cost of housing in coastal areas. • Employment and business opportunities in sustainable construction and design.
Energy	• Disruption to electricity supplies during weather events. • Outages of production lines for manufacturing.
Employment and education	• Opportunities for business, education, skills and jobs relating to climate change. • Loss of business, skills and jobs relating to agriculture and tourism due to business failure and/or costs to business from storm events, etc. • Loss of pupil/teaching days due to storm damage to educational buildings.
Leisure and recreation	• Disruption of sports events and recreational activities. • Reduced access to leisure, cultural facilities and historic buildings and sites. • Opportunities for alternative activities.
Landscapes and nature	• Damage and reduced access to ecosystems, historic and cultural landscapes, green spaces and gardens.
Transport and mobility	• Disruption of transport and communication networks.
Business and finance	• Increased costs for establishing and maintaining business facilities and operations in sensitive areas. • Increased costs of insurance. • Opportunities for new technology and business.
ADAPTIVE CAPACITY	
Social inclusion/cohesion	• Dislocation from family and community through evacuation. Disadvantaged and elderly people are particularly at risk. • Community conflict over resource allocations. • Increases in the sense of community in face of common risks.
Participation in climate change adaptation measures	• Exclusion and/or non-participation of vulnerable groups.

5. Actions and Responses

There are two strategies for responding to the potential risks and impacts of climate change (IPCC 2007c): (1) mitigation, which involves policies and interventions to reduce GHG emissions or enhance the sinks of gases that remove them from the atmosphere (e.g., forests and vegetation), and (2) adaptation, which is based on preparing for, and minimizing, the predicted impacts of climate change.

The current international mechanism for countries to reduce their emissions is the United Nations Framework Convention on Climate Change (UNFCCC), which for many years has been focussing on decreasing gas emissions through the Kyoto Protocol. At the 15th Conference of Parties in Copenhagen, Denmark in 2009 it was agreed that countries would reassess their base years and emission targets for 2020 through the Copenhagen Accord. While there is disagreement about emission targets, and mechanisms to achieve these, there is unanimity about the importance of pursuing adaptation actions as indicated by the clause No 3 in the Copenhagen Accord, which states "[a]daptation to the adverse effects of climate change and the potential impacts of response measures is a challenge faced by all countries. Enhanced action and international cooperation on adaptation is urgently required to ensure the implementation of the Convention by enabling and supporting the implementation of adaptation action". This is reflected by policies and action plans of federal, state, and provincial governments associated with the Gulf of Maine area (Table 3).

The Conference of New England Governors and Eastern Canadian Premiers (NEG/ECP) has committed to a Climate Change Action Plan (August 28, 2001; NEG/CEP 2001) that identifies steps to address those aspects of global warming that are within the region's control. The Plan requires the development of a comprehensive and coordinated regional plan for reducing greenhouse gases, and a commitment by each jurisdiction to reach specified reduction targets for the region as a whole. In particular, the mid-term goal is to reduce regional GHG emissions by 10% below 1990 emissions by 2020.

The impacts of sea level rise and storm events will likely be very site-specific and coastal risk is generally dealt with at a municipal planning level, with assistance from the provincial or state governments, as well as federal agencies (Leys 2009). Strategic decisions will be required by communities and governments, and funds will be needed for programs to protect key public infrastructure and flood and hazard-prone communities (e.g., dyke lands, transportation systems). There is presently little information on current local initiatives to deal with sea level rise.

Emergency response preparedness both at a municipal and provincial/state level will be critical to ensuring minimal damage and loss of life due to impacts of sea level rise. The following legislation is already in place for the various provinces

Table 3: Examples of response activities and actions being undertaken by governments associated with the Gulf of Maine.

JURISDICTION	POLICY	LEGISLATION	ACTION PLAN/ PROGRAMS	COMMENTS
United States of America	✓	✓	✓	House of Representatives passed a climate change bill in 2009, which did not win passage in the Senate. New legislation is being proposed. Federal research being coordinated by the Office of the President through an integrated program. http://www.globalchange.gov
Canada	✓	✓	✓	Climate Change Accountability Bill C-311 passed by Parliament in 2007. National activities on climate change impacts and adaptation are being coordinated by the Department of Natural Resources http://adaptation.nrcan.gc.ca/index_e.php
Massachusetts	✓	✓	✓	Global Warming Solutions Act passed in 2008. Climate change planning and implementation under the Executive Office of Energy and Environmental Affairs. The Office of Coastal Zone Management advancing adaptation through its StormSmart Coasts program. http://www.mass.gov/czm/stormsmart/index.htm
New Hampshire	✓		✓	Climate Change Action Plan published in 2009. Program operated through the Department of Environmental Services. http://des.nh.gov/organization/divisions/air/tsb/tps/climate/index.htm
Maine	✓	✓	✓	Maine legislature passed a bill in 2003 charging the Department of Environmental Protection with responsibility for developing and implementing action plan. http://www.maine.gov/dep/air/greenhouse/
New Brunswick	✓		✓	Climate Change Secretariat within the Department of Environment and an Action Plan 2007-2012 http://www.gnb.ca/0009/0369/0015/0001-e.pdf
Nova Scotia	✓		✓	Action plan being developed and coordinated by the Department of Environment http://climatechange.gov.ns.ca/ActionPlan

and states around the Gulf of Maine:

- New Brunswick – Emergency Measures Act, 1978 (http://www.gnb.ca/0062/PDF-acts/e-07-1.pdf)
- Nova Scotia – Emergency Management Act, 1990 (http://www.gov.ns.ca/legislature/legc/index.htm)
- Maine – Maine Emergency Management Act, 1987 (Maine Revised Statutes Title 37-B, Chapter 13; http://www.mainelegislature.org/legis/statutes/37-B/title37-Bch13sec0.html)

All jurisdictions have provincial/state emergency management and response organizations that are mandated to co-ordinate emergency response at all levels within each province/state. Responsibilities include mitigation of the effects of emergencies by providing assistance in planning before an emergency occurs, by coordinating the provision of resources when an emergency occurs and by assisting with analysis and evaluation after an emergency. These emergency management and response agencies include:

- Nova Scotia Emergency Management Office (http://www.gov.ns.ca/EMO);
- New Brunswick Emergency Measures organisation (http://www.gnb.ca/cnb/emo-omu/index-e.asp);
- Maine Emergency Management Agency, Department of Defense, Veterans and Emergency Management (http://www.state.me.us/mema/);
- New Hampshire Bureau of Emergency Management, Department of Safety, Homeland Security and Emergency Management (http://www.nh.gov/safety/divisions/bem/); and
- Massachusetts Emergency Management Agency (http://www.mass.gov).

National emergencies are dealt with in the US by the Federal Emergency Management Agency (FEMA; http://www.fema.gov/). National policy, response systems and standards for Canada are developed by Public Safety Canada (http://www.publicsafety.gc.ca/ prg/em/index-eng.aspx), which works with provincial emergency management agencies across the country.

INDICATOR SUMMARY

INDICATOR	POLICY ISSUE	DPSIR	TREND*	ASSESSMENT
Average annual land and water temperatures	Global warming	Pressure	–	Poor
Land subsidence	Exacerbates sea level rise	Pressure	–	Fair
Sea level in the Gulf of Maine	Causes inundation and flooding	State	–	Poor
Coastal vulnerability indices	Sensitivity to sea level rise	State	/	Fair
Occurrence of storm events	Worsens impacts from sea level rise	State	–	Poor
Costs of damage	Increasing costs of impacts	Impact	/	Fair

* KEY:
– Negative trend
/ Unclear or neutral trend
+ Positive trend
? No assessment due to lack of data

Data Confidence

- Projected global sea level rise determined through modelling based on scientific research. Sea level rise in the next century ranges from 50 cm to 190 cm, an order of magnitude difference.
- Regional land subsidence estimates are also modelled to determine current subsidence levels. However, these have been verified through values from local sea level gauges.
- Sea level rise at fixed points provide a close estimate of current sea level rise, although future trends are uncertain.
- Comprehensive information is available on storms that have affected the Gulf of Maine, but there is little confidence in future storm predictions.

Data Gaps

- Vulnerability of communities to sea level rise needs to be determined at a local level.
- There is little information on local responses to sea level rise.
- There is little information on any of the possible impacts from climate change. There are few data on cost estimates of events causing damage.

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