EcoSystem Indicator Partnership

Information on change in the Gulf of Maine

Climate Change in the Gulf of Maine

Climate change is anticipated to have wide-ranging effects on many elements of the Gulf of Maine region, including its ecosystems, habitats, and coastal communities. The Earth's climate system is driven by several factors, including the amount of incoming sunlight, volcanic activity, land use changes, and the atmospheric concentrations of greenhouse gases and other pollutants. Over the last century, average global temperature has increased by about 1°F (0.7°C) (Intergovernmental Panel on Climate Change [IPCC]), in part due to increasing greenhouse gases from human activities.

Organizations such as the IPCC project a global atmospheric temperature increase ranging from 2°F to 11.5°F (1.1°C to 6.4°C) by 2100 compared to temperatures in the 1980s and 1990s (IPCC AR4, 2007). A rise in temperature of this magnitude and rate is likely to affect global patterns of storms and precipitation, raise global sea levels by thermal expansion of the oceans and the melting of continental ice, increase ocean temperatures, reduce ocean salinity, and affect ocean chemistry. All of this will affect ecosystems and human settlement. The extent of these global climate impacts will be influenced by many regional and local factors in the Gulf of Maine. In addition, these pressures will interact with each other and with other non-climate related pressures, such as coastal development, habitat degradation, pollution, and changes in natural resources.

Potential changes in the aquatic environment in the Gulf of Maine as a result of climate change include increases in water temperature, decreases in salinity, and changes in freshwater quantity. Among other things, these changes will likely affect the sustainability of fisheries. If these changes occur, for example, conditions may no longer be favorable for some local species, while exotic species may find a niche to colonize and out-compete native species at adaptation. Rising temperatures will likely also cause increases in diseases in both natural and commercial populations of shellfish and finfish. Sea level rise will also be an important pressure on coastal habitats and ecosystems, causing additional fragmentation and loss of coastal wetlands.

In 2006 the Gulf of Maine Council on the Marine Environment formed a partnership to assess the health of the Gulf of Maine ecosystem through the use of indicators. The EcoSystem Indicator Partnership (ESIP) formed as a direct result of the recognized need to understand ecosystem status and trends in the Gulf of Maine. The Council has many efforts that look at the health of the Gulf of Maine through monitoring and restoration. ESIP is an attempt to bring together information from these and other efforts in the region.

Why use indicators?

Simply put, indicators are one of the best tools for understanding the complexities of the Gulf of Maine/Bay of Fundy. Like lights on the dashboard of a car, indicators can work in concert with each other to provide an essential look at the larger system. They can be combined into complex calculations or be relatively simple. Simple indicators are often driven by complicated pressures and responses. The three indicators that ESIP has chosen for climate change in the Gulf of Maine region are:

1. **Sea level**
2. **Air temperature trends, with an emphasis on seasonality**
3. **Precipitation trends, with an emphasis on extreme weather**

Photo: Genevieve Hofmann

Bay of Fundy

Climate change mitigation and adaptation are recognized as essential strategies to reduce the vulnerability of the Gulf of Maine to these climatic changes.

Sea Level

Indicator 1

Sea level fluctuations on a global scale are a normal part of the geologic record. Since the last glacial period ended 12,000 years ago, global sea level has been fluctuating and has risen approximately 1.7 mm/year. Climate change and associated melting of ice sheets is further increasing the rate of sea level rise globally, making sea level a significant indicator for assessing climate change effects in the region and around the world.

The Gulf of Maine has some of the longest tide gauge datasets of recorded sea level in the world with certain sites monitored for 100 years. Data from all of the records in and around the Gulf of Maine are presented in the table with sites experiencing 0.5-3.2 mm increases in sea level each year. Changes of 1.8 mm/year or greater are significant because many of the region's beaches, dunes, and coastal wetlands formed when the rate of sea level rise was significantly lower. When combined with impacts from human activities, the rise in sea level is often further amplified.

Sea level rise, coupled with a potential increase in the intensity and frequency of extreme storm events, will place pressure not only on the functionality of the natural coastal environments such as wetlands, beaches, and dunes, but also on coastal communities and associated infrastructure. An increase in the frequency and intensity of extreme events is expected to lead to more flooding, coastal erosion, deposition, and impacts on water management, transportation, and other infrastructure that communities rely upon.

Photo: Stephen M. Dickson, Maine Geological Survey

Flooding in Saco, Maine

Photo: John Cannon, National Weather Service

Patriot's Day Storm

Site	Increase/ Decrease	Annual Rate of Change (mm/ year)*	Length of Record	Rate of Change 1974–2004 (mm/ year)
Buzzards Bay, Mass.	↑	0.5	20 years	‡
Woods Hole, Mass.	↑	2.9	74 years	2.8
Cape Cod Canal, Mass.**	↑	2.0	20 years	‡
Boston, Mass.	↑	2.7	85 years	2.7
Seavey Island, Maine	↑	1.8	58 years	‡
Portland, Maine	↑	1.8	94 years	0.07
Bar Harbor, Maine	↑	2.1	58 years	1.0
Cutler II, Maine	↑	1.4	24 years	‡
Eastport, Maine	↑	2.1	76 years	1.3
Saint John, New Brunswick	↑	2.9	70 years	‡
Yarmouth, Nova Scotia	↑	2.9	37 years	3.8
Halifax, Nova Scotia**	↑	3.2	109 years	2.4
Gulf of Maine Averages	↑	2.2	60 years	2.0

* This table presents relative sea level. Relative sea level takes into account not only the influence of global sea level changes, but also how the land mass is moving in relation to the sea. For example, crustal rebound in some locations in response to the last glacial period is causing lower relative sea level changes, while subsidence in other areas is causing higher relative sea level changes (in relation to the global average). Sites were selected both within the Gulf of Maine watershed and nearby to increase the amount of data available.

** Sites outside the Gulf of Maine.

‡ These sites did not have complete data for 1974–2004.

Obtaining Data: Indicator Reporting Tool

All data used for the three indicators discussed in this fact sheet are available for graphing and downloading via ESIP's Indicator Reporting Tool (**www2.gulfofmaine.org/esip/reporting**). The reporting tool uses familiar mapping programs to enable users to locate climate change data in the region and build graphs for the time periods of interest. The snapshots that the tool produces can provide critical information in a timely fashion for those faced with making decisions quickly. Questions such as the following can be answered using the tool:

- Is sea level rising more quickly in the Boston area versus Yarmouth, Nova Scotia?
- How many extreme precipitation events were there in my area in 2007?
- Has air temperature risen more quickly in the last 15 years than in the previous 50 years?

To see the answers visit the ESIP webpage: **www2.gulfofmaine.org/esip**.

Air Temperature

Indicator 2

Changes in climate, as indicated by mean air temperature, have a major impact on our daily lives and our region's economy in a number of ways, including human health, tourism, transportation, and agriculture. Air temperature, therefore, is one of the most frequently used indicators of climate change around the world and is currently recorded at more than 100 stations in the northeastern United States and the Canadian Maritime region.

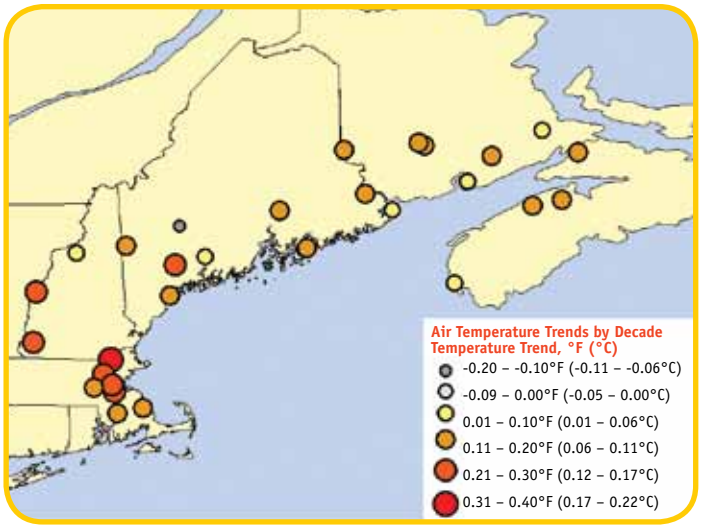
The climate of the Gulf of Maine region reflects global influences, but regional temperature is also influenced by regional and local aspects of the climatic system including topography, the passage of different weather systems, fluctuations in the jet stream, and warming and cooling sea surface temperatures.

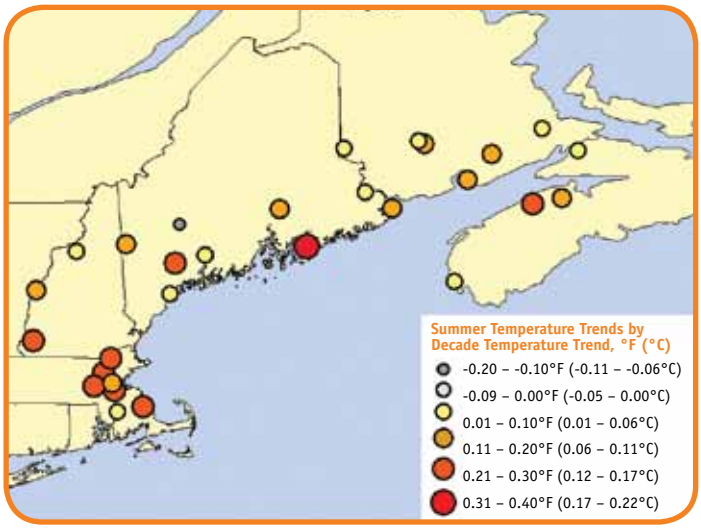
Across the region, average air temperatures have been on the rise over the past three decades at 13 out of 14 sites. Most sites have exhibited 1–2°F (0.5–1°C) per century increase (comparable to the observed increase in global temperatures) while several sites increased by 4°F (2.2°C). If we examine the trends by season, winter trends of as much as 0.5°F (0.3°C) per decade are observed at several sites in Maine.

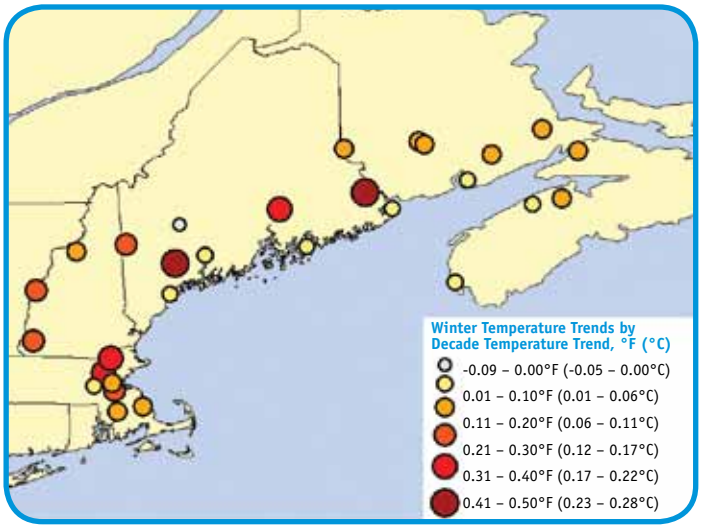
Analysis of air temperature trends in North America by the IPCC over the past 100 years found that the warming trend from 1950 to 1999 cannot be explained by natural climate variation alone. Rather, the observed trends are consistent with the combination of natural variability and anthropogenic forcing from increasing levels of greenhouse gases and sulfate aerosols in the global climate system.

Photo: <No data from link>

Ice cutting on Sebago Lake







Precipitation

Indicator 3

Precipitation is critical for sustaining human well-being and quality of life, as well as Gulf of Maine ecosystems. Ecological systems depend on precipitation for hydration, while human communities depend on the replenishment of water sources for residential, municipal, and industrial water supplies and for growing crops. In addition, precipitation patterns are important for the region's tourism economy. Generally speaking, more snow in winter is better for winter tourism, and fewer rainy days during the warm season is better for summer tourism.

Climate change will likely lead to changes in precipitation and atmospheric moisture, mainly due to changes in atmospheric circulation, a more active hydrological cycle, increased evaporation and plant transpiration, and increases in the water-holding capacity of the atmosphere.

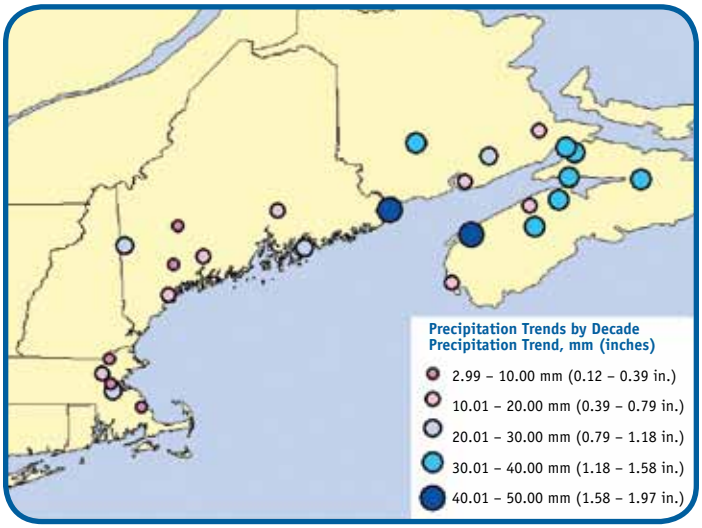
Photo: Casco Bay Estuary Partnership

Combined sewer overflow pipe

Temperature and precipitation are intricately linked in the climate system. In the past century there has been a 2% increase in global precipitation, but that change has not been uniform over time or geography. Precipitation tends to be much more variable over short distances when compared to temperature, and this is reflected in both global and regional records.

In the Gulf of Maine, annual average precipitation has increased by approximately 5%. However, this increase is seasonal and dependent on location with some sites showing small decreases over the same time period. Extreme precipitation events have also been on the increase (see text box on impact of extreme precipitation).

On average, all sites across the region show increasing precipitation over the period of record. Some sites show increases of as much as 50 mm (~2 inches) per decade in annual precipitation. At the same time, sites in the more northern portions of the region indicate lessening snow cover. This can be attributed to the increase in average temperature and more seasonal precipitation falling as rain, combined with more vigorous and earlier spring melt.



Extreme precipitation trends and impacts on wastewater systems

Intense precipitation events, such as those that result in more than 50 mm (~2 inches) of rain in 48 hours, have the potential to significantly affect the region's agriculture, infrastructure, wastewater treatment, and streams and rivers. The average number of extreme precipitation events for all sites in the region has increased over the period of record.

Intense precipitation events are complex phenomena that can result from several different types of weather events. Some examples include strong frontal systems where there is a large temperature contrast between air masses, tropical systems (including hurricanes) which gain their energy from warm sea surface temperatures, and air mass instability leading to the buildup of large cumulonimbus clouds.

In general, a storm with more energy and more moisture will tend to increase its severity and, therefore, the amount of precipitation. When these events occur, especially with heavy rainfall, they have direct physical impact on water management systems. Most communities have inadequate or antiquated water management structures that are vulnerable to intense events. When communities have a combined storm and waste water piping system, for example, they are particularly vulnerable to intense rain events. In these instances, when extreme rainfall events occur, they may be handled by the storm portion of the pipe design, but in general overwhelm the existing wastewater system. The result is flow-through of untreated waste into aquatic systems impacting water quality and species in those environments. With an increase in intense precipitation events predicted, communities need to plan to address the likely accompanying increase in overflow events that will follow.

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www2.gulfofmaine.org/esip

For more information on any of the ESIP products, please visit our website at www2.gulfofmaine.org/esip. You may also contact the ESIP Program Manager at ESIPmail@gulfofmaine.org. We always welcome new members to our work.

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Gulf of Maine Council on the Marine Environment

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