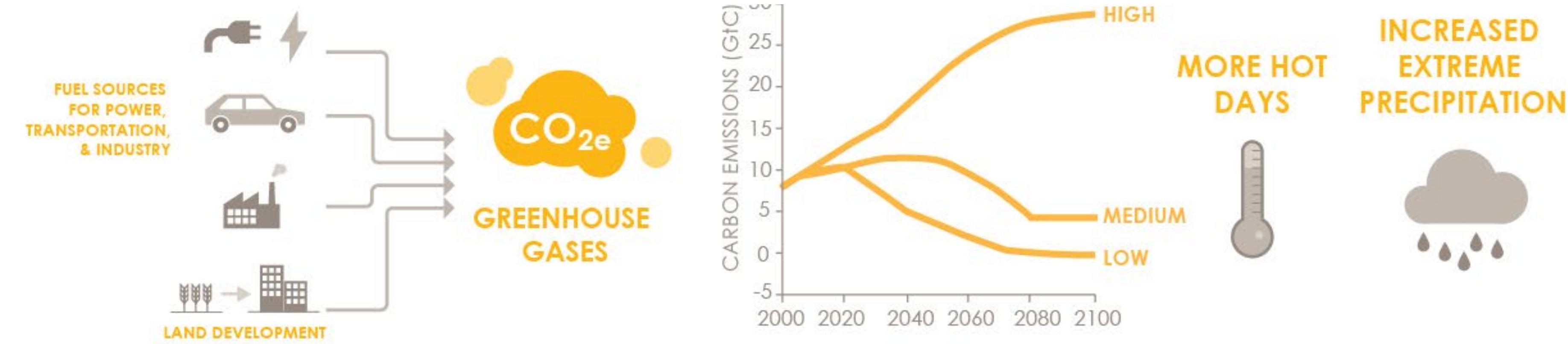
s

stand
e
local
of Boston
Ribbon
onvened
earch
(BRAG),
egion's
entists,
Climate
sensus.

RELATIVE SEA LEVEL RISE

The Climate Projec
how Boston's clim
throughout the tw
on four climate fac
relative sea level ri
and coastal storms
major climate haz
flooding, stormwat
(see Vulnerability A
these hazards and



For Boston to effectively plan for the impacts of climate change, there must be a shared understanding about what these impacts are likely to be. While the Intergovernmental Panel on Climate Change publishes global climate projections, the impacts of climate change vary by location, and therefore local projections are needed for better-informed planning. Since the late 2000s, there have been a number of vulnerability assessments and adaptation plans published for the Boston region, which have included local climate change projections. Because knowledge of climate change is continually growing, the BRAG was charged with identifying and evaluating the most-recent data available for the Boston region on climate change impacts.

The findings reported here reflect a consensus among the scientific community, including a scientific approach to uncertainty. Currently, the largest source of uncertainty related to understanding the future impacts of climate change is our lack of knowledge about the future

scenarios to underlie their climate projections, based on projections about future population growth, development patterns, and energy use. Climate projections for the next few decades are relatively consistent, regardless of their underlying emissions scenario, because the past 200-plus years of human actions have already caused changes to our climate and will continue to do so. However, the projections become increasingly different further into the future, because human actions going forward will have an important and compounding effect on whether climate change accelerates or slows down. Another source of uncertainty is the complexity of natural processes, which scientists are still working to better understand. There is also a certain amount of naturally occurring interannual and interdecadal climate variability (also called "internal variability"). Finally, there appear to be "tipping points" in the climate system, which have the potential to result in larger, more rapid changes, and our understanding of these events is limited.

- A **high-er** characteri usual;
- A **mediur** emissions through 2 in the seco moderate
- A **low-em** emissions their curr zero by ab reduction

The magnitud on our actions transportation the level of gre As greenhouse the impacts of extreme precip we take action

ERATURES
INGS

ge temperatures Northeast have slowly rising for century.

ures in the northeastern ites increased by almost es Fahrenheit between 2011.

f increase in average ures is accelerating. While ast century, temperatures in east rose about two degrees, se over the next century eater than ten degrees.

an area, Boston tends er than surrounding ties that are more or rural. Urban areas tend to be hotter than ral areas because concrete, other building materials re heat than vegetation. omenon, known as heat island effect," is led by climate change.

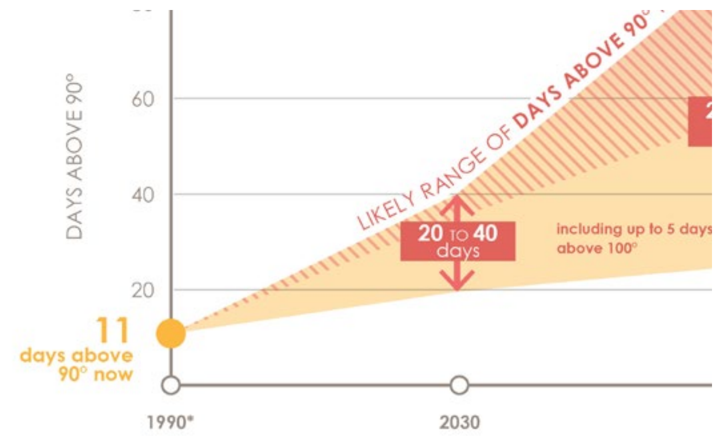
ummers are getting hile the average summer re in Boston from 1981 to

There will be more days of extreme heat. Compared to the period from 1971 to 2000, when an average of 11 days per year were over 90 degrees, there may be as many as 40 days over 90 degrees by 2030 and 90 days by 2070—nearly the entire summer.

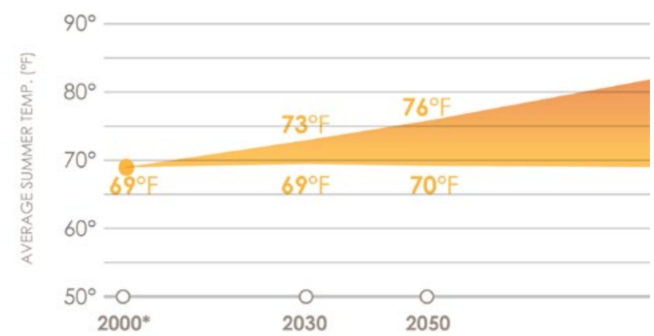
Heat waves will become more common, last longer, and be hotter. The City of Boston defines heat waves as periods of three or more days above 90 degrees, and heat waves are a leading cause of weather-related mortality in the United States.

Although winters will likely be warmer, the risk of frost and freeze damage and cold snaps will continue. While from 1981 to 2010, Boston reached below freezing almost one out of three days per year, by the end of the century, this may happen only around one in ten days.

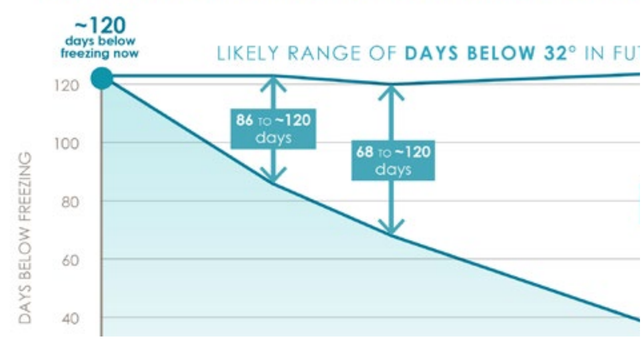
Future temperatures in Boston will depend on how much we are able to cut our greenhouse gas emissions. The rise in temperatures between now and 2030 is largely consistent among all emission scenarios. However, the scenarios show that



AVERAGE SUMMER TEMPERATURES WILL INCR



THE NUMBER OF VERY COLD DAYS MAY DEC



vel rise is caused ombination of ce melting, al expansion, nanges in land storage.

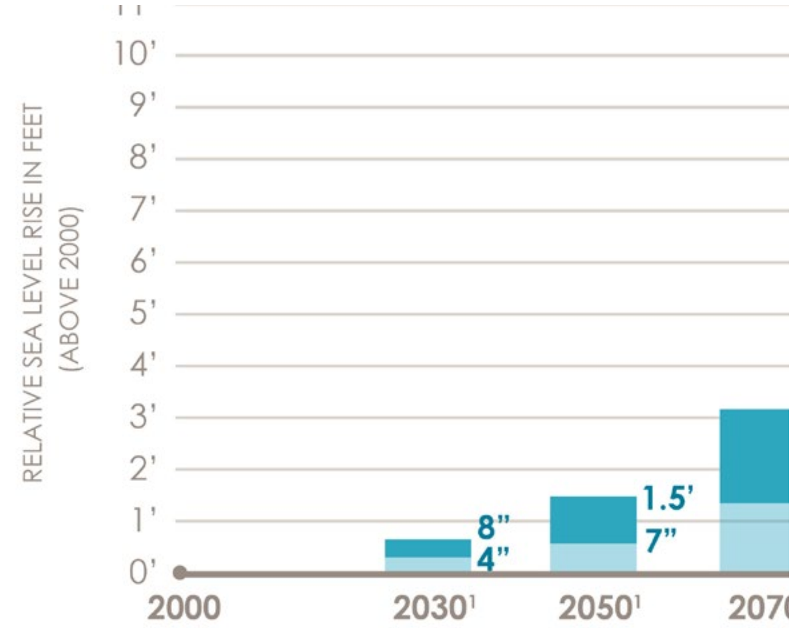
nelting includes the melting in (alpine) glaciers, ice caps, ntinental-scale ice sheets and, West Antarctica, and rctica. Thermal expansion the phenomenon that, as ms, it generally occupies volume. Land water storage activities that affect the water stored on land, such water in reservoirs or behind umping out underground rrigation and use by people.

ve sea level in Boston Harbor over the past century. From l5, the overall trend in relative ise was about 0.11 inches per tive sea level is the difference n between the sea surface surface at a specific place and elative sea level rise can result nbination of changes in the

The pace of relative sea level rise is accelerating. Over the entire twentieth century, sea levels rose about nine inches relative to land. Another eight inches of relative sea level rise may happen by 2030, almost three times faster. By 2050, the sea level may be as much as 1.5 feet higher than it was in 2000, and as much as 3 feet higher in 2070.

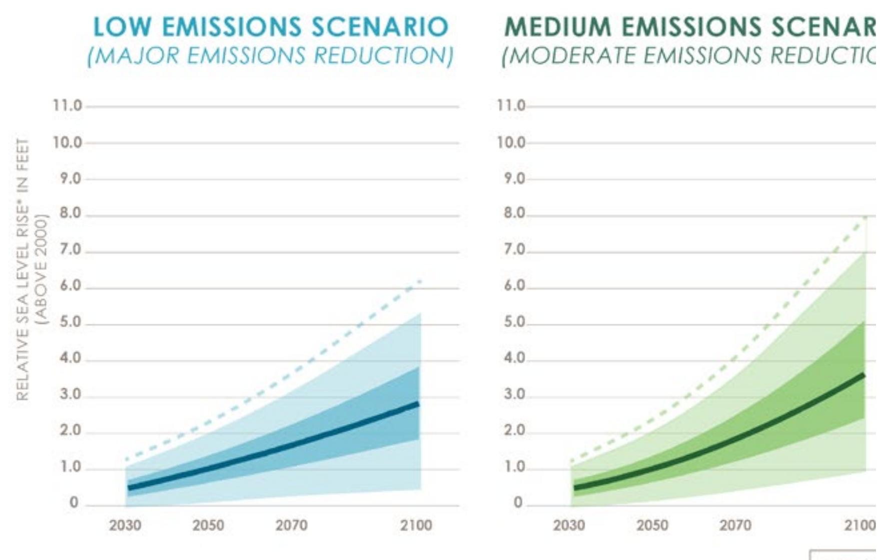
As sea levels rise, a deeper harbor will mean higher and more powerful waves. Although Boston remains relatively protected from Atlantic waves by Winthrop, Hull, and the Harbor Islands, stronger waves are more likely to damage sea walls and erode beaches. The outer islands and peninsula shorelines of Boston Harbor are likely to experience these impacts to a greater extent than the Boston proper shoreline.

A major reduction in global greenhouse gas emissions can have a tremendous impact on the future of Boston Harbor. While sea level rise projections for 2030 are consistent across all emission scenarios, in later years big differences exist between scenarios. With a sharp emissions reduction, we may be able to keep end-of-century sea level rise to under two feet, while higher emissions



1 - Likely under all emission scenarios
2 - Likely under moderate to high emission scenarios
3 - Low probability under high emission scenario

THE AMOUNT OF SEA LEVEL RISE DEPENDS ON GREENH



:IPITATION
INGS

Northeast, there ready been a ırge increase in ensity of extreme ıd snow.

to 2010, there was a 70 crease in the amount of on that fell on the days with st precipitation. ase is greater in the than for any other he country.

ase in extreme precipitation d to continue. As the ırms, more ocean water ; into the air, and warmer ld more water, supporting ecipitation events. Heavy on events will continue in Boston. However, due plexity of the processes g precipitation as well as riability, the magnitude of se is not yet clear.

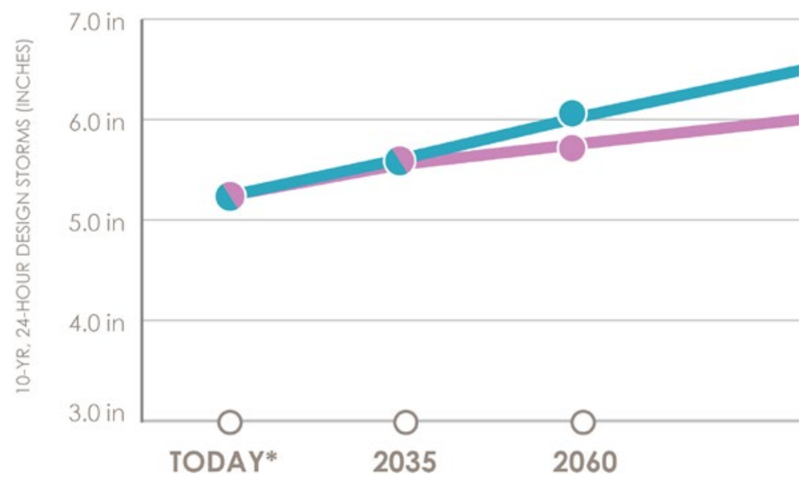
total amount of annual will decrease, there may me heavy snow events

However, changes in daily heavy snowfall events can be quite different from changes in annual snowfall. Expected changes to individual heavy snow events, ice storms, and drought are not clear.

Both stormwater and riverine flooding are affected by extreme precipitation. Boston's stormwater drainage system may be overwhelmed by major rain events. It may be further compromised by sea level rise as drain outlets are flooded by the rising ocean, reducing the ability of the drainage system to convey stormwater to the coast. River flooding is also likely to increase, but there are large uncertainties associated with river flooding due to the complexity of the climate and hydrological systems involved.

If we take action to cut global greenhouse gas emissions, we can prevent the most extreme precipitation projections from becoming a reality. A commonly used measure of major rain and snow events is the amount of precipitation that has at most a one-in-ten annual chance of falling during a 24-hour period. While projections for these events are similar in the

RAINFALL FROM STORMS WILL INCRE



* "Today" baseline represents historical average from 1948-2012
Confidence intervals are not available for these projections but are likely large, so these numbers should be considered as the middle of a large range

ston, the
that are of
st concern are
opical cyclones,
ed by tropical
ies.

cal cyclones, which are mon and longer lasting theast than tropical currently produce most of induced flooding in the gion and will continue to e near future. These are at originate outside of the d are sometimes called s. They can form during of the year but are most in the extended cold-season ropical cyclones are storms ate in the tropics and are ricanes once they reach a wind speed of more than 74 hour.

Current climate projections do not provide a clear projection of how the intensity, frequency, and trajectory (tracks) of tropical and extratropical storms will change. Extratropical storms (like blizzards and nor'easters) have cold air at their centers. Tropical storms, on the other hand, have warm air, which means that they can develop into hurricanes more quickly. There are large uncertainties about how climate change will affect future storms. This is particularly true for extratropical storms. For tropical storms, there is some evidence that their intensity has been increasing. If tropical storm intensity increases, major hurricanes (Category 3 and greater) could occur more frequently, even if the total number of tropical storms does not increase.

Rising sea levels mean that any given storm will cause more flooding in the future than it would today. During a storm, winds can blow ocean water toward the land, creating a "storm surge" on top of the baseline sea level. When storm surge is combined with tidal processes, the result is known as a "storm tide."