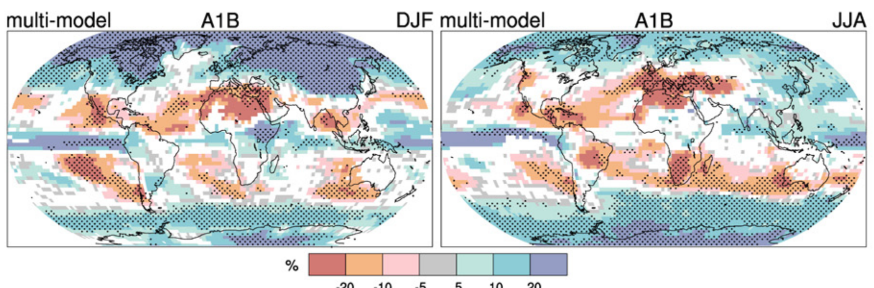
CAC.C Clemson Architecture Center in Charleston

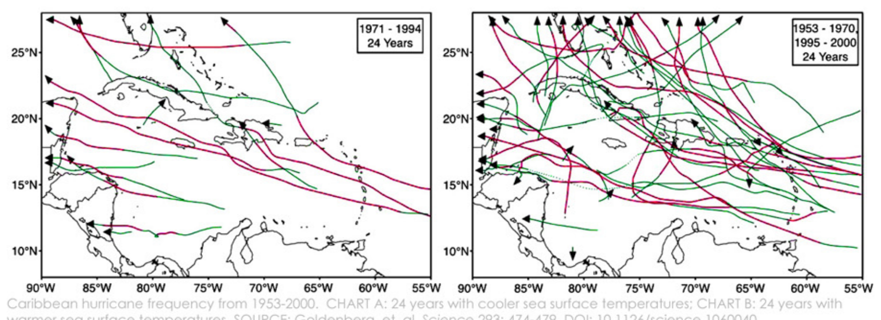
global climate change

peninsular perspective

PRECIPITATION vs. STORM INTENSITY



Relative changes in precipitation predicted for 2090–2099 (relative to 1980–1999). LEFT: Multi-model averages based on the SRES A1B scenario for December to February; RIGHT: June to August. White areas (including Charleston) indicate less than 66% agreement among models; stippled areas indicate more than 90% agreement. SOURCE: IPCC 2007:WG1-AR4



Caribbean hurricane frequency from 1953-2000. CHART A: 24 years with cooler sea surface temperatures; CHART B: 24 years with warmer sea surface temperatures. SOURCE: Goldenberg, et. al. *Science* 293: 474-479. DOI: 10.1126/science.1060040

precipitation

The increased atmospheric moisture associated with global warming is expected to lead to increased mean precipitation. Global annual land precipitation showed a small, but uncertain, upward trend over the 20th century of approximately 1.1 mm per decade. Significantly increased precipitation has been observed in eastern parts of North and South America, northern Europe, and northern and central Asia from 1900-2005. Drying has been observed in the Sahel, the Mediterranean, southern Africa and parts of southern Asia.

Greenhouse gas increases are expected to cause enhanced horizontal transport of water vapour that is expected to lead to a drying of the subtropics and parts of the tropics, and a further increase in precipitation in the equatorial region and at high latitudes. Mid-latitude summer drying is another anticipated response to greenhouse gas forcing, and drying trends have been observed in the both hemispheres since the 1950s.

A larger change in extreme precipitation than mean precipitation is expected. Climatological data show that the most intense precipitation occurs in warm regions and diagnostic analyses have shown that, even without any change in total precipitation, higher temperatures lead to a greater proportion of total precipitation in heavy and very heavy precipitation events. As total precipitation increases a greater proportion falls in heavy and very heavy events.

Modeling of the South Carolina coast is generally uncertain regarding total net precipitation; what we should anticipate are more intense storms.

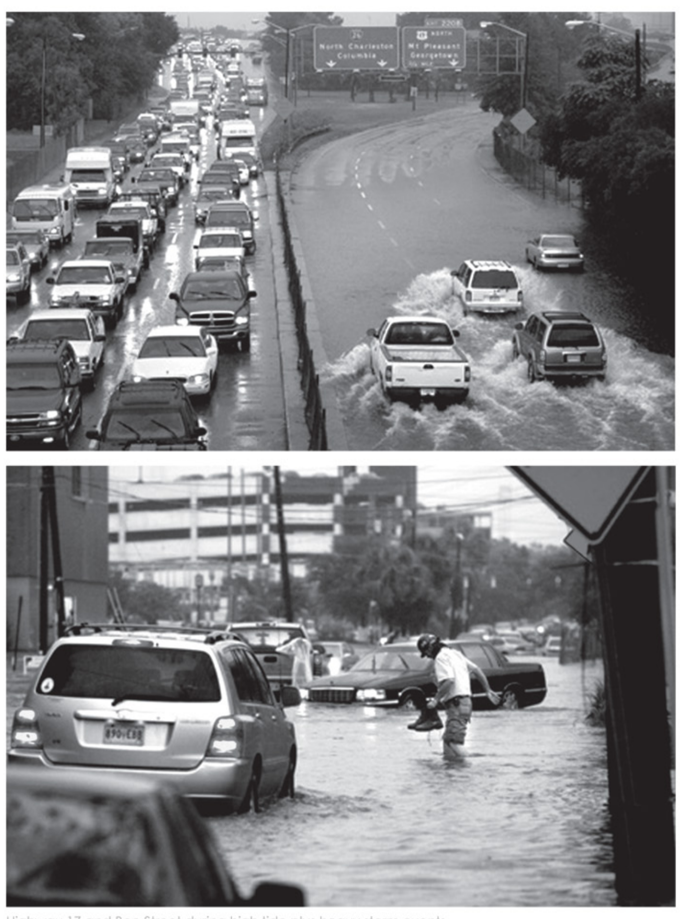
hurricanes

The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapour. There is observational evidence for an increase in intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures.

It is very likely that hot extremes, heat waves, and heavy precipitation events will continue to be more frequent. It is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with higher peak wind speeds and heavier precipitation associated with increases in sea surface temperatures. The number of cyclones is less certain; there is less confidence in projections of a global decrease in numbers. The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period.

drainage

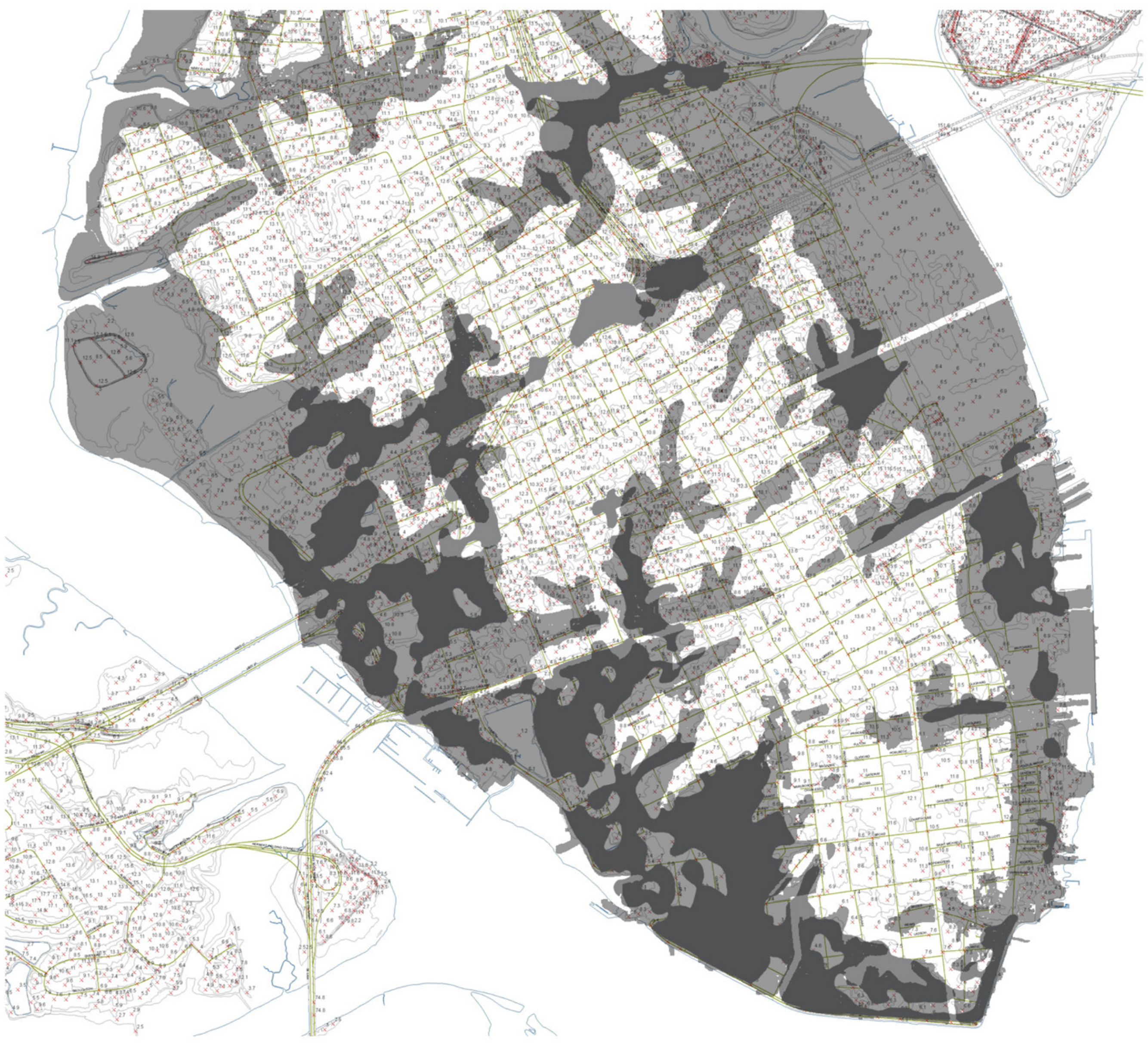
The peninsula's stormwater drainage system is inadequate to handle current severe storm events. It is also incapacitated by peak tides, which infiltrate the system and create in-land ponding. As storm and hurricane severity increases and sea level rises under global climate change, storm water management will be a significant problem. Not only will property be threatened, but access to and by emergency services will be compromised as will evacuation routes.



Highway 17 and Bee Street during high tide plus heavy storm events.

HISTORY & TOPOGRAPHY

Maps showing the correspondence between the original peninsula shoreline and today's low-lying and flood-prone areas.

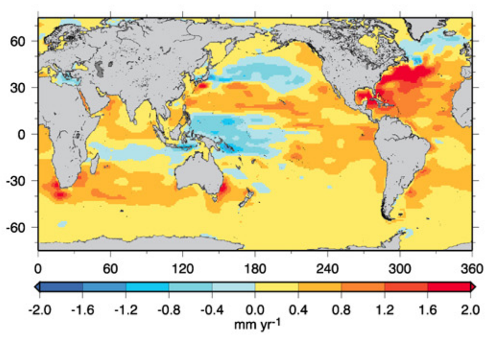


To trace the areas where the Charleston floods today is to trace the peninsula's history. Over the past two-hundred years the City has grown into the Ashley and Cooper Rivers, and this fill continually settles—as it will over the coming centuries (as sea level rises). Internal flood-prone areas, such as Market Street, were originally creek beds that remain low conduits for stormwater. In a situation where land is sinking and water rising, the shoreline along with areas of historical fill will become an increasing problem for saving the City.

ASSUMPTIONS & CONDITIONS

To test the implications of global climate change on the peninsula, we adopted the two most extreme IPCC Special Report on Emission Scenarios (SRES). B1 models an ecologically-responsive future with correspondingly minimal global warming; A1FI models a modified "business as usual" approach where economic interests trump other considerations (see "emission scenarios (SRES)" on panel A). Given that sea level rise and severe precipitation events are likely to be the most dramatic effects of global climate change on the peninsula, and as both factors may be under-represented in the SRES models, we modified the scenarios to make some allowance for for ice sheet melt (see "ice sheet melt uncertainty" on panel A and graphs below). Our modified scenarios are indicated with a PLUS (as in B1+ and A1FI+).

The difference between scenarios is really just a matter of time, as far as this study is concerned. Magnitude M1 is likely by 2075 under A1FI, by 2050 under both B1+ and A1FI+. M2 is predicted under both of our scenarios; magnitudes M3 and M4 under an A1FI+ world. See below.



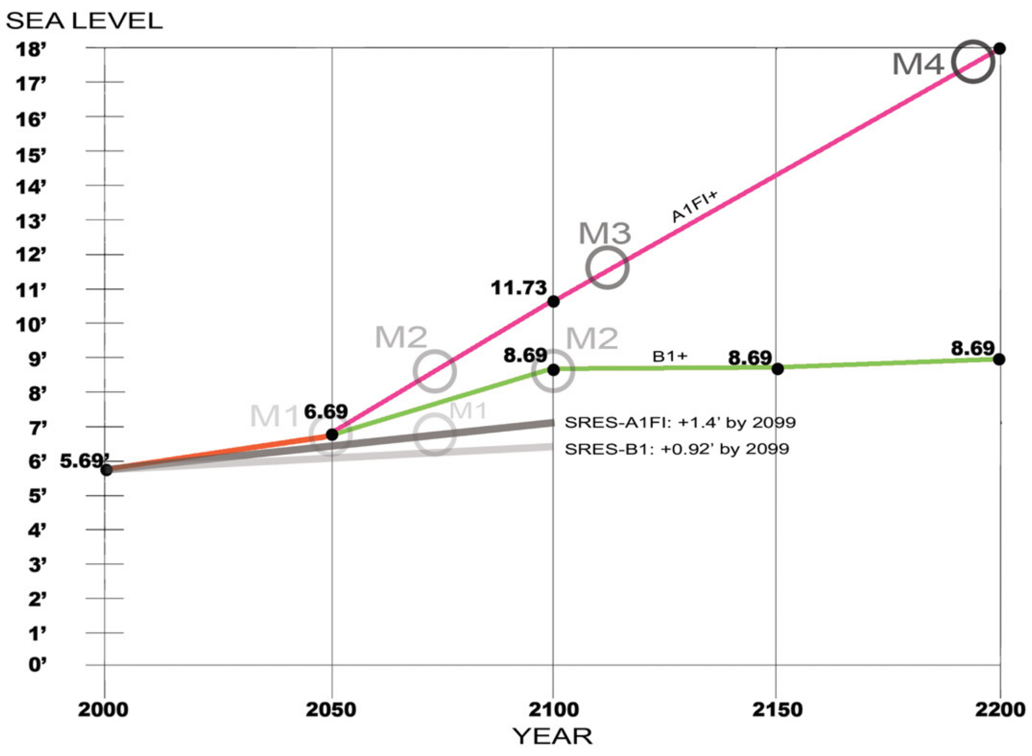
sea level isn't

Sea level varies in elevation at various places around the globe. These variations also change. Climate models, satellite data, and hydrographic observations show that sea level is not rising uniformly around the world. In some regions, rates are up to several times the global mean rise, while in other regions sea level is falling.

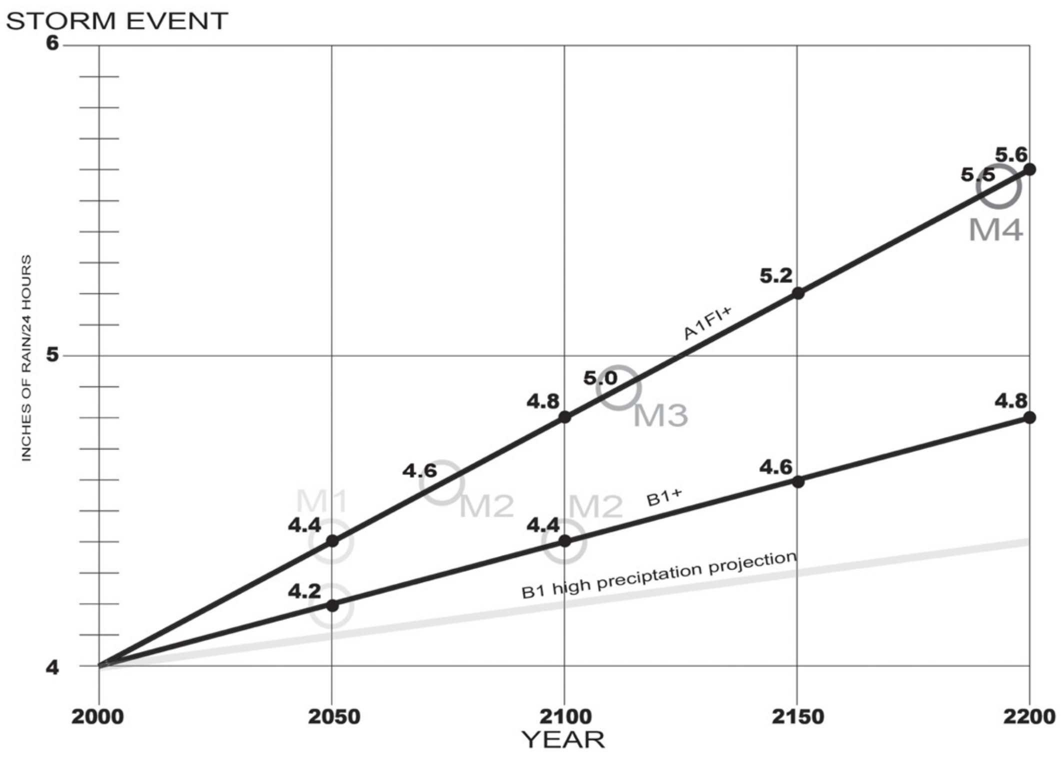
Thermal expansion is projected to contribute more than half of the average future rise. The map, left, shows trends in thermal expansion for 1955 to 2003. The coast of South Carolina is among the highest in the world.
SOURCE: IPCC 2007:WG1-AR4

Geographic distribution of linear trends in thermal expansion (mm yr–1) for 1955 to 2003 (based on temperature data down to 700 m). SOURCE: IPCC 2007:WG1-AR4

2-scenarios



THE WATER LEVEL IN THE CHARLESTON HARBOR is currently 5.69' above sea level. According to the SRES models, which do not take into account the full effects of changes in ice sheet flow (see "ice sheet uncertainty" in panel A), sea level will rise an average of 0.92' (B1) to 1.4' (A1FI) by 2100. There is reason to believe that thermal expansion off the coast of South Carolina, and thus sea level, will be higher than average (see "sea level isn't," panel B). The CAC.C study takes a more aggressive (some would say "realistic") estimate of ice melt by doubling the IPCC's rate per decade. Accordingly, sea level would increase to the order-of-magnitude benchmarks as follows:
M1-1' rise= ELE 6.69' by 2050 in B1+ and A1FI+
M2-3' rise= ELE 8.69' by 2100 in B1+ and 2075 in A1FI+
M3-6' rise= ELE 11.69' by 2115 in A1FI+
M4-12' rise= ELE 17.69' by 2190 in A1FI+



THE 90TH PERCENTILE OF A 50-YEAR STORM for the Charleston area is approximately 6" preciptation in 24 hours. The CAC.C study assumes that percolation and the existing stormwater infrastructure will handle 2"/day, leaving 4"/day still to be handled. While the IPCC notes the unreliability of weather modeling, it shows predictions for some SRES models and offers a 5% increase by 2100 as a high projection under a B1 world (SOURCE: IPCC 2007:WG1-AR4). There is no projection for the severity of storms, which are expected to get worse even if total precipitation drops (see "preciptation and storm intensity," panel B).

In terms of urban design, the critical issue is managing water during severe storms. As it is unrealistic to plan for the worst potential event, we have planned for the 90th percentile of a 50-year storm. We have assumed a steady increase of 0.1% per year in a B1+ world, and 0.2% per year in an A1FI+ world, for the targeted 90th percentile 50-year storm.

4-orders of magnitude

Whenever it comes, rising sea level will threaten the peninsula in stages. Up to a 12" increase (M1), the peninsula can operate much as it does today; when sea level reaches the elevation of the historic Battery (M3), Charleston will be a completely different City. This study imagines the peninsula coping with global climate change at four orders-of-magnitude based on sea level rise.

inflow vs. outflow

The opposing demands of sea level rise and increasingly severe precipitation will put the peninsula in a bind: *a wall that keeps seawater out keeps rainwater in*. Rising sea level means a rising groundwater table. Below-grade stormwater piping will increasingly be subject to infiltration; gravity-run drainage systems will run out of "drop" between land-surface and sea. Increasing quantities of stormwater will have to be temporarily stored as the stormwater system loses its current (inadequate) capacity to drain.

M1

Sea level will rise 1 foot above the 2000 level, at which point 3.5% of the 2000 peninsula footprint will be under water unless protective measures are taken.

A1FI+ Severe storm events will increase 10% over 2000 levels by 2050; a 50-year storm will be 4.4 inches/24 hours yielding 84,358,897 ft^3 over M1 land area.

B1+ Precipitation will increase 5% over 2000 levels by 2050; a 50-year storm will be 4.2 inches/24 hours yielding 80,524,402 ft^3 over M1 land area.

M2

Sea level will rise 3 feet above the 2000 level, at which point 9% of the 2000 peninsula footprint will be under water unless protective measures are taken.

A1FI+ Severe storm events will increase 5% over M1 levels by 2075; a 50-year storm will be 4.6 inches/24 hours yielding 88,193,392 ft^3 over M2 land area.

B1+ Severe storm events will increase 5% over M1 levels by 2100; a 50-year storm will be 4.4 inches/24 hours yielding 84,358,898 ft^3 over M2 land area.

M3

Sea level will rise 6 feet above the 2000 level, at which point 34% of the 2000 peninsula footprint will be under water unless protective measures are taken.

A1FI+ Severe storm events will increase 8% over M2 levels by 2115; a 50-year storm will be 5.0 inches/24 hours yielding 95,862,383 ft^3 over M3 land area.

M4

Sea level will rise 12 feet above the 2000 level, at which point 77% of the 2000 peninsula footprint will be under water unless protective measures are taken.

A1FI+ Severe storm events will increase 15% over M3 levels by 2190; a 50-year storm will be 5.5 inches/24 hours yielding 105448620 ft^3 over M4 land area.