Past and present inundation episodes on the US East Coast: Short-term variability and adaptation to long-term sea level rise

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Abstract

Many global processes drive coastal sea level variability, e.g., melting land-based ice, crustal subsidence due to glacial isostatic adjustment, and steric effects on sea-surface height, but the societal impacts of coastal sea level rise are often local issues. Documentation of past and current inundation in specific areas may enhance outreach regarding the need for coastal adaptation. For example, many coastal cities now publicize "king tides" during the predicted yearly maxima of astronomical tides.

We use tide gauge data to show increased coastal inundation in recent years. We informally define inundation episodes as times when water levels remain >10 cm above local Mean Higher High Water for one or more hours. High water during storms is nothing new for coastal residents, but fair-weather coastal flooding has become more frequent and observable. A LIDAR-generated hypsometric curve of topography shows that the most frequently flooded (lowest elevation) areas occur along bays, sounds and estuaries, not the sandy barrier beachfronts. We also note that the stepped nature of coastal topography implies that the increase in flooded coastal areas will not be a smooth function of sea level rise magnitude.

To place sea level rise in a long-term context, we use published data from regional Holocene sea level reconstructions to explicitly illustrate the contribution of ongoing crustal subsidence due to glacial isostatic adjustment (GIA) at East Coast sites. In North Carolina crustal subsidence has been the dominant cause of sea level rise for most of the last 2000 years. Presently, however, GIA-driven crustal subsidence accounts for only about 1/3 of the sea level rise seen on the NC coast, whereas about 2/3 of the rise rate now being observed is due to anthropogenic warming.

Western boundary current (*e.g.*, Gulf Stream) variability also affects coastal inundation. Rapid changes in East Coast water levels (± 25 cm in a few days) accompany changes in Gulf Stream speed and position, and thus can exacerbate coastal flooding due to sea level rise. We demonstrate the inverse relationship between Florida Current Transport rate and coastal water levels at many East Coast tide gauges, and show that brief (8-10 day) intervals of reduced Florida Current Transport increase coastal inundation during both fair weather and storms.

Study Area

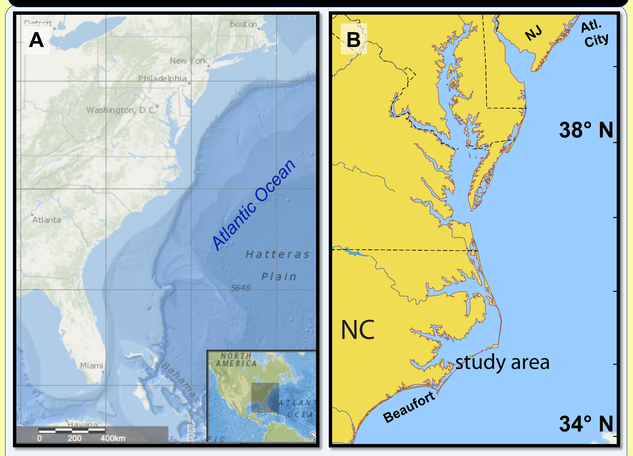


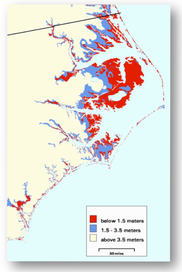
Figure 1 A: US East Coast. **B**. Beaufort, NC and Atlantic City, NJ.

Low-elevation regions of US East Coast affected by sea level rise now and in near future.

NC: 1,288 km² of coastal land less than 1 m above MHW; but only 59,000 people live there.

NJ: Area <1 m above MHW is only 174 km²; but its population is 155,000.

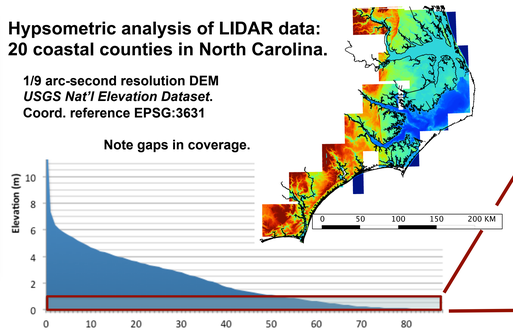
[data from Strauss *et al.* 2012, *Environ. Res. Lett.* based on 2010 census]



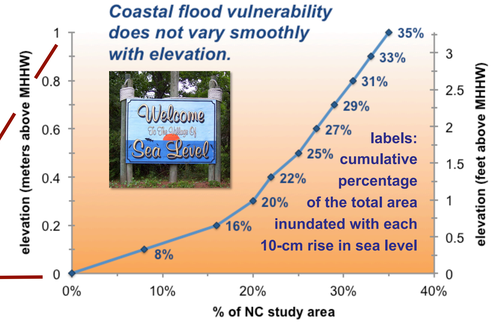
Hypsometric analysis of LIDAR data: 20 coastal counties in North Carolina.

1/9 arc-second resolution DEM
USGS Nat'l Elevation Dataset.
Coord. reference EPSG:3631

Note gaps in coverage.

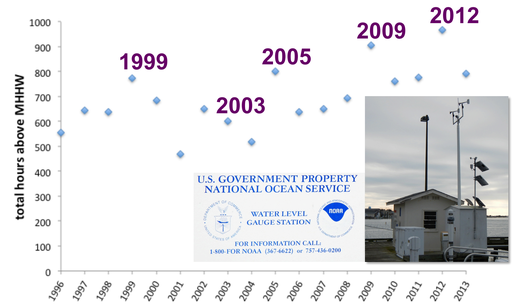


Coastal flood vulnerability does not vary smoothly with elevation.

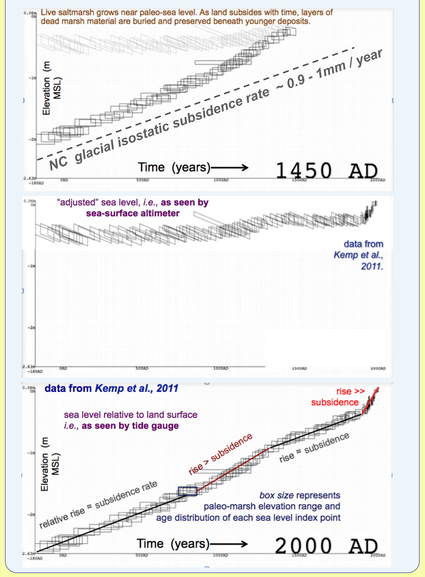


Frequency of high water events

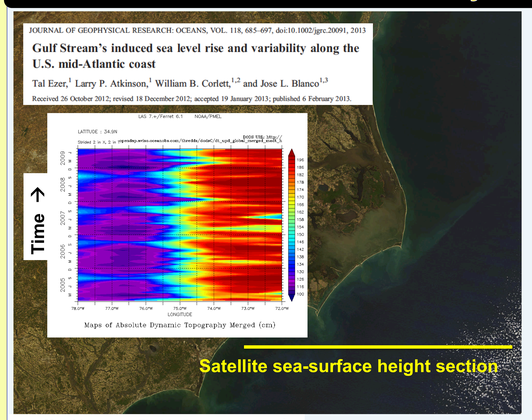
But coastal flooding is getting worse, *as shown by NOAA inundation analysis: Total hours per year when water level was above MHHW as measured by the tide gauge at Beaufort, NC.*

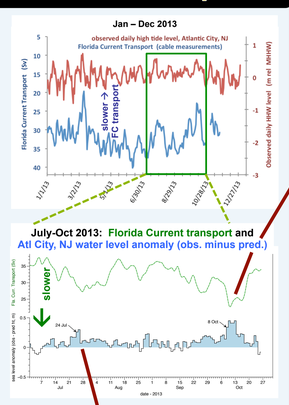


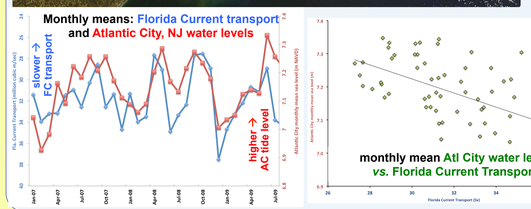
Sea level rise & long-term regional subsidence



Coastal water level varies inversely with Gulf Stream speed







Sea level rise on US East Coast… Good news & Bad news:

- The most frequently flooded (lowest elevation) areas are along the bays and sounds, not sandy barrier beachfronts.
- Coastal topography is stepped, thus land area subject to flooding is not a smooth function of sea level rise (SLR).
- Coastal flooding has become more frequent / observable.
- Post-glacial isostatic subsidence dominated SLR for most of last 2000 years, but presently on NC coast, ~2/3 of observed SLR rate is due to 20th century warming.
- Western boundary current (Gulf Stream) variability is associated with rapid changes in coastal water levels (± 25 cm in a few days) that can exacerbate coastal flooding.

Implications for the future?

US East Coast must adapt to increasingly frequent and severe inundation resulting from the sum of multiple processes influencing sea-level change:

ancient global warming
recent / future warming
??
recent / future warming

- Regionally varying land subsidence—geophysical response to Canadian ice sheet disintegration 16,000 years ago.
- Melting polar ice sheets & glaciers adding water to ocean.
- Sea-surface slope changes due to variations in western boundary currents (Gulf Stream & Florida Current).
- Mass transfer onto shelf as deep ocean warms & expands.*
- Gravitational movement of water away from shrinking ice masses.*

* Topics not presented here.

Acknowledgments

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