Water Level Variability Along the North Carolina Coast

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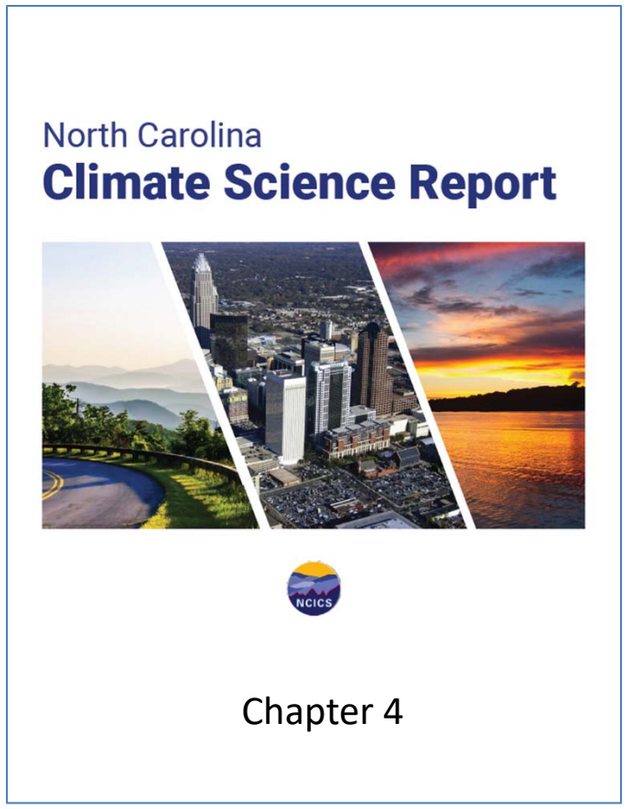


https://ncics.org/programs/nccsr/

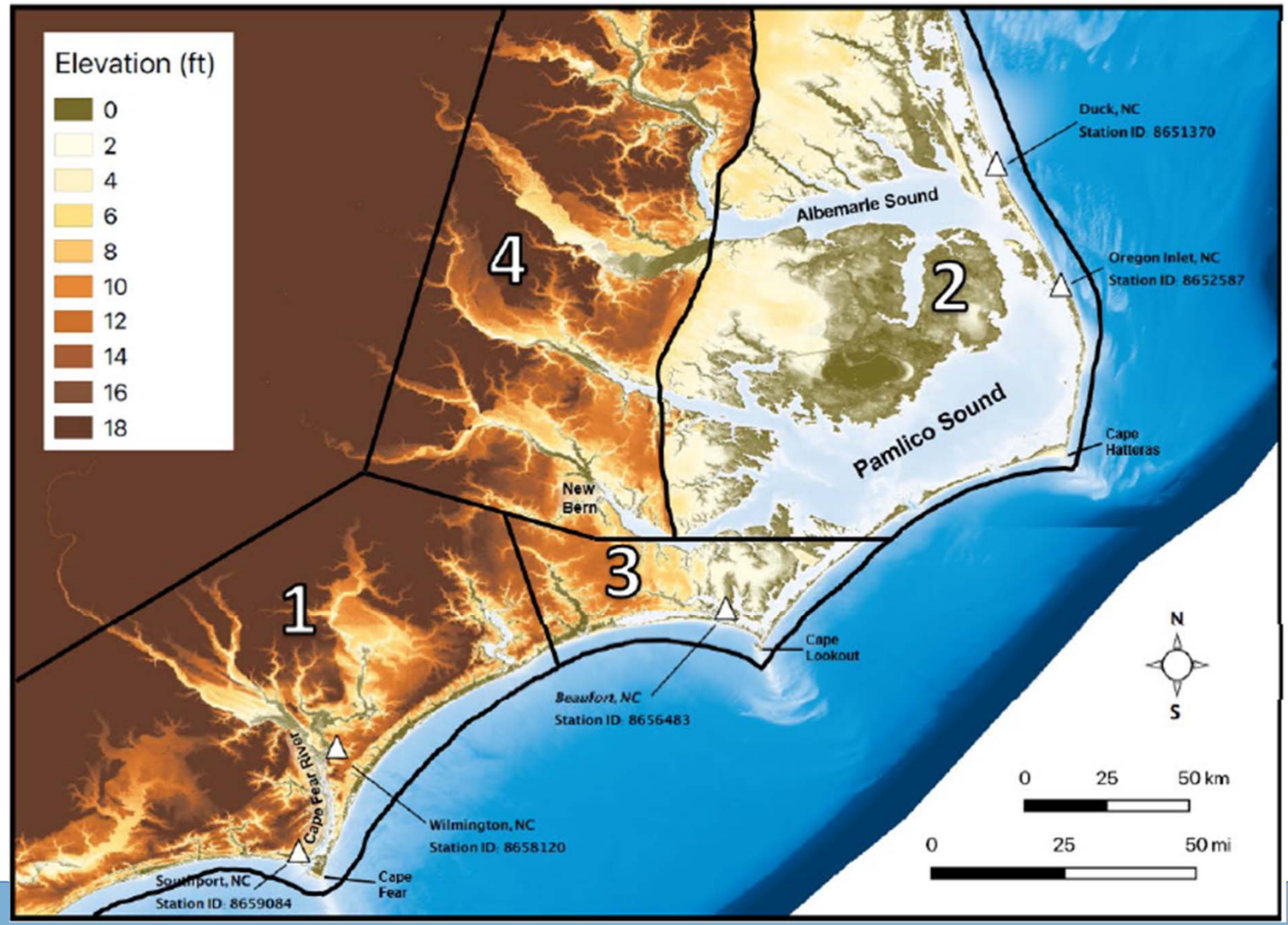
Why Ocean Water Level Matters in Coastal NC

Major portions of coastal NC only a few ft above sea level

- Water level impacts safety, property, livelihoods, economies

Fragile barrier islands

- Major degradation could lead to significant change in flood hazards and ecosystems in adjoining sounds



Drivers of Water Level Variability

Wind waves & swell

- Generated by winds
- Cause shoreline and dune erosion
- Cause structural damage
- Future wave conditions depend largely on climate affects on storms
- Few studies on future wave conditions - no strong trends along NC coast
- Waves affected by changes in water level

Drivers of Water Level Variability

Astronomical tides

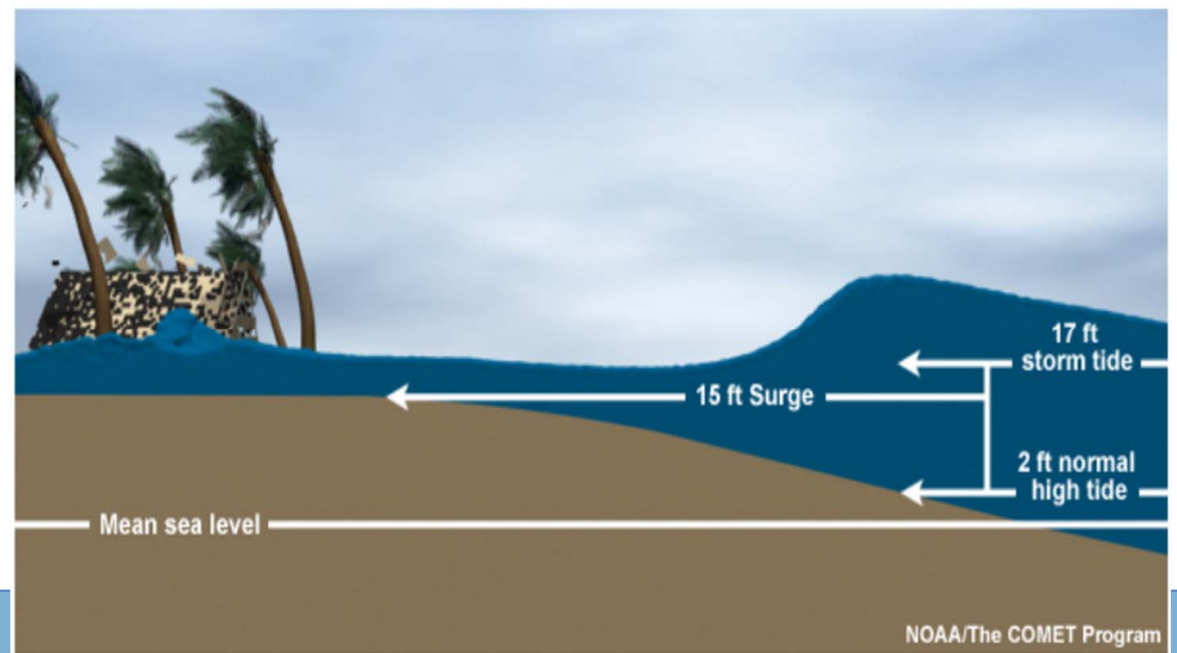
- Due to gravitational attraction of sun, moon and earth
- Along the NC coast
  - Twice daily high and low tides - Low to high tide range = 3.7 ft in NE to 5.5 ft in SE
  - 14-day spring neap cycle
  - King Tides – highest high tides of year
    nckingtides.web.unc.edu
  - Longer period tides: 4.4 yr – 18.6 yr cycles ~5-10% change in dominant tides
- Future changes in tides can be due to
  - near shore coastal change (dredging) – doubling of tidal range in Wilmington in 20th century
  - other water level change

Drivers of Water Level Variability

Coastal Storms – storm surge / storm tide

- Extratropical Cyclones – winter Nor'easters
  - Northeast NC coast averages ~14.5 per year causing storm surge > 1 ft
  - No clear pattern in future climate
- Tropical Cyclones - hurricanes
  - NC coast averages a hurricane every 2-3 years
  - Hurricane Hazel (1956) – storm tide ~ 18 ft open coast
  - Hurricane Florence (2018) – storm surge ~ 10 ft New Bern
  - Hurricane Dorian (2019) – storm surge ~ 6-7 ft Ocracoke
  - Stronger storms predicted in future climate
  - Surge affected by other depth/water level change

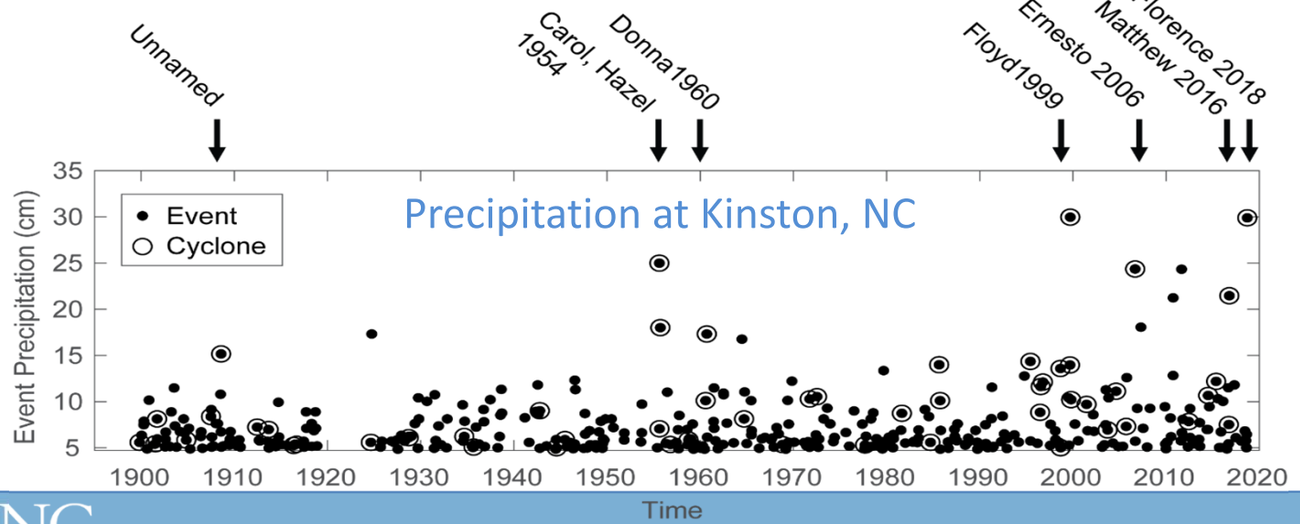
What are Storm Surge / Storm Tide?



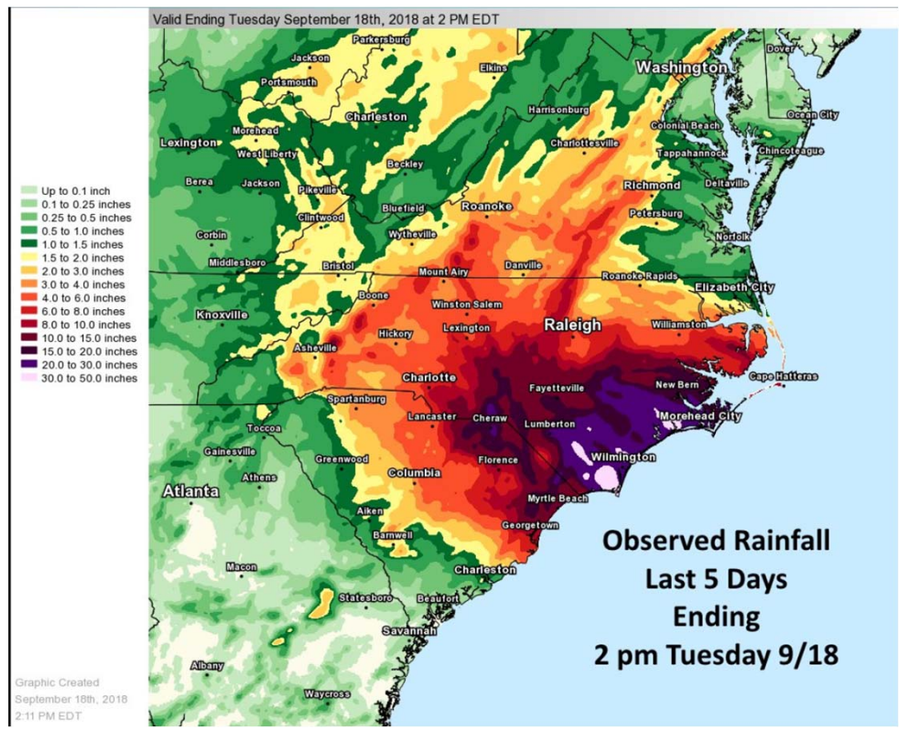
Drivers of Water Level Variability

Coastal Storms – extreme precipitation

- Dominated by tropical cyclones
- Increasing over time: future climate = wetter storms
- Widespread precipitation based coastal flooding usually occurs after storm surge
- Florence (2018) storm surge & precipitation flooding were coincident = ***compound flooding***



Hurricane Florence (2018) Precipitation Totals



Drivers of Water Level Variability

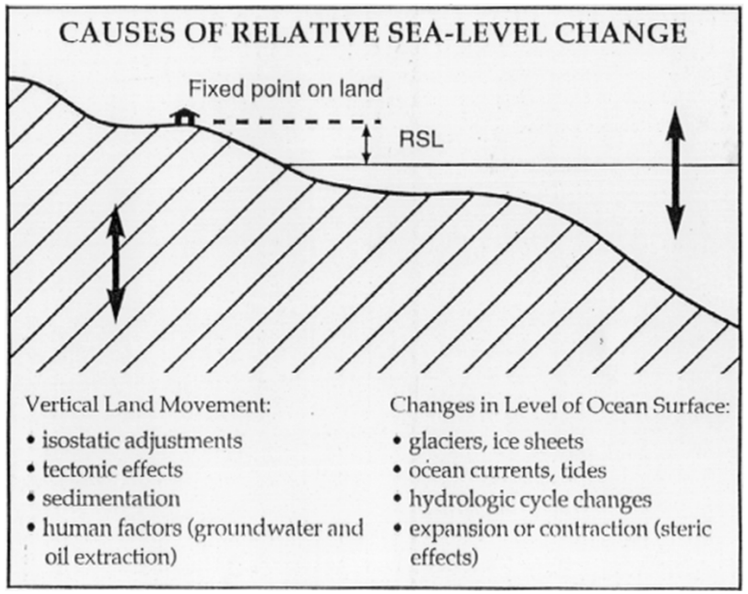
Oceanic Processes

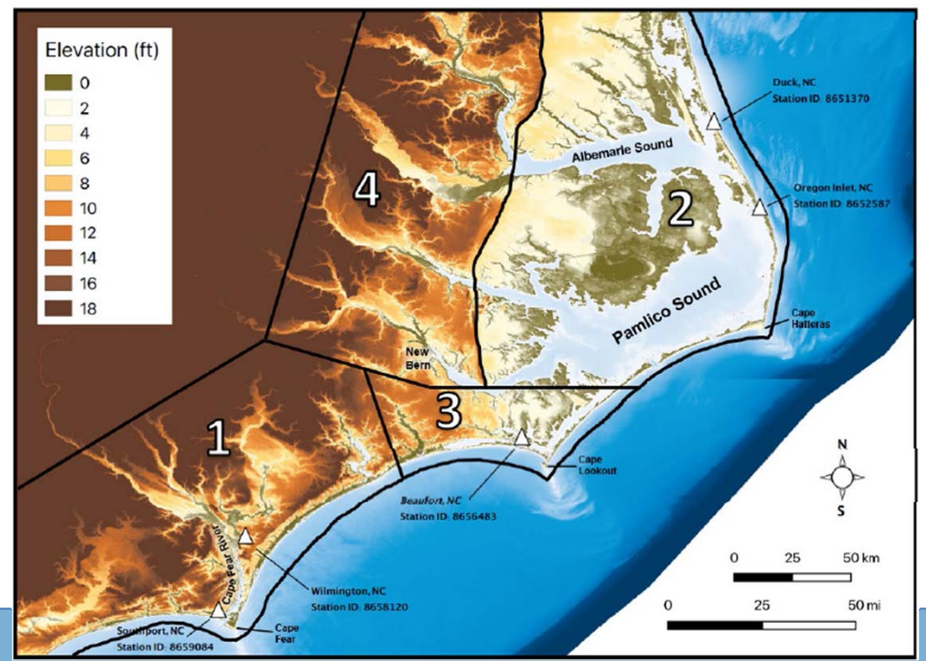
- Steric Effect
  - Annual heating and cooling cycle ~ 0.5 ft
  - Global mean sea level rising due to overall warmer ocean
- Gulf Stream
  - Slowing of Gulf Stream = elevated water levels along adjacent coast (~ 1ft) over days to weeks
  - 2-5 year cycle in position
  - Future climate may weaken Atlantic meridional overturning circulation which GS is part of
- Other Ocean – Atmospheric Processes
  - El Nino – Southern Oscillation, Atlantic Multidecadal Oscillation, etc
  - 1 year to decadal cycles
  - Response level small, but cumulative with other processes
  - Unclear about relationship to future climate

Relative Sea Level Change

Land elevation change + Ocean elevation change

- North Carolina land elevation change
  - Southern province (#1) rising + 0.01 in/yr
  - Northern province (#2) sinking - 0.04 in/yr
  - Central province (#3) sinking intermediate

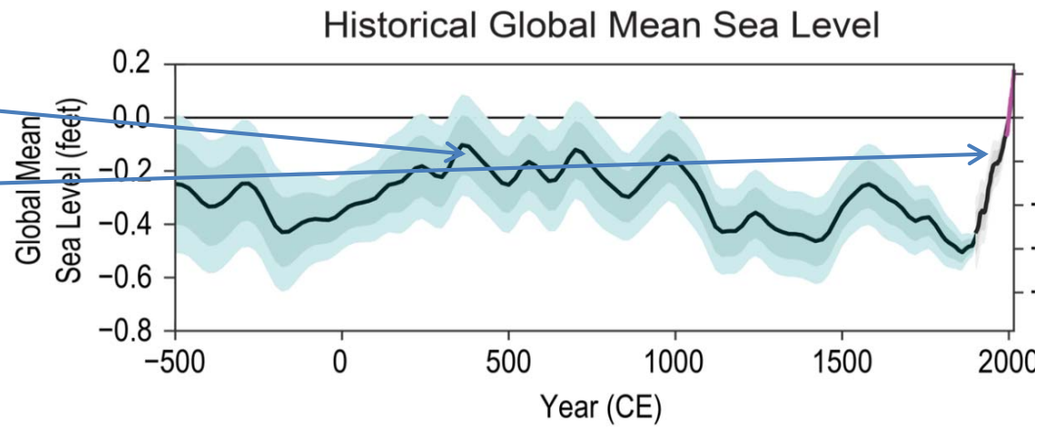




Relative Sea Level Change

Land elevation change + Ocean elevation change

- Global Mean Sea Level (GMSL)
  - Historically constant ± 3.5 in for 2400 years
  - GMSL Rising since beginning of 20th century
  - Rate of GMSL rise is increasing
    - 1901 – 1990 0.06 in/yr
    - 2005 – 2015 0.14 in/yr



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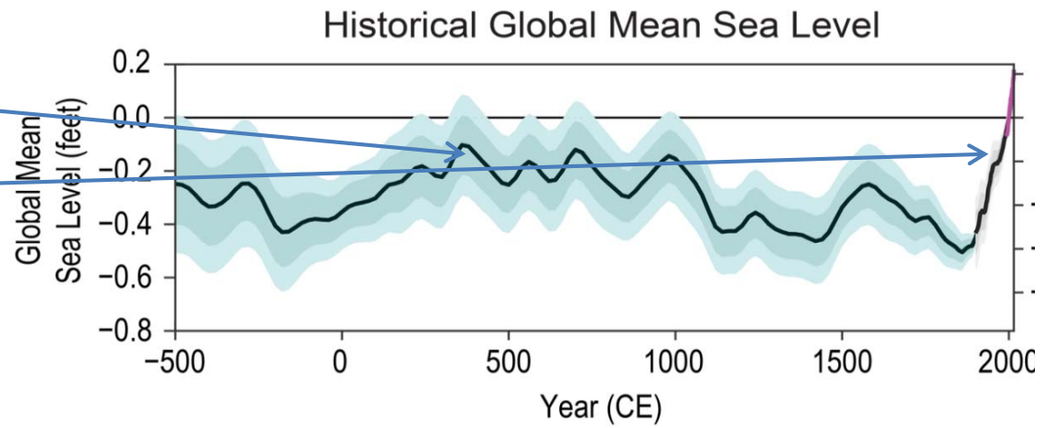
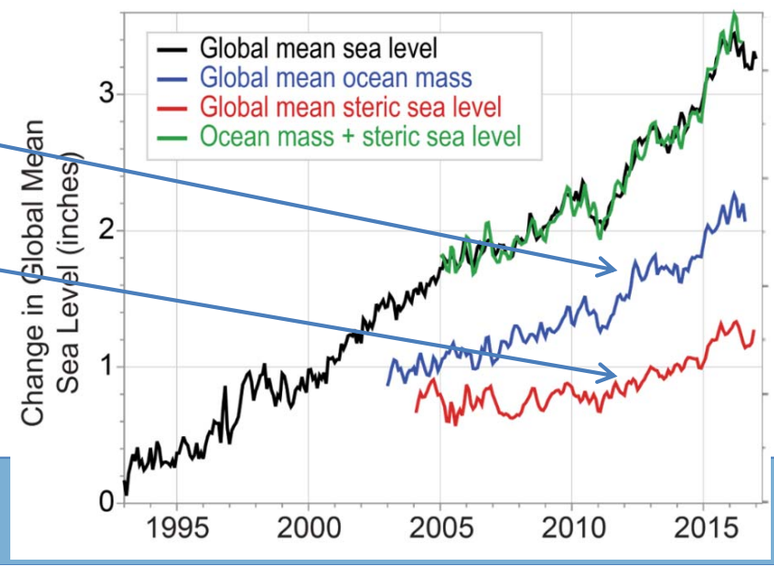
  - GMSL caused by
    - Melting ice sheets and land-based glaciers
    - Steric effects





Relative Sea Level Change

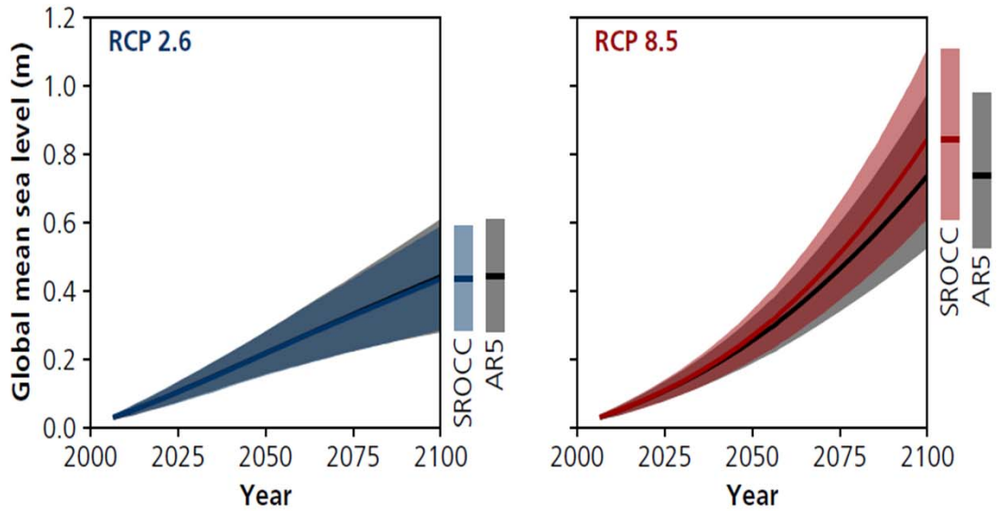
Land elevation change + Ocean elevation change

- Global Mean Sea Level (GMSL)
  - GMSL In 2100
    - Rising @ 0.16 - 0.35 in/yr
    - Elevated 0.9 – 1.9 ft vs 2000

    } RCP2.6: greenhouse gas emissions peak in 2020 and decline thereafter

    - Rising @ 0.39 – 0.79 in / yr
    - Elevated 2 – 3.6 ft vs 2000

    } RCP8.5: greenhouse gas emissions increase through 21st century

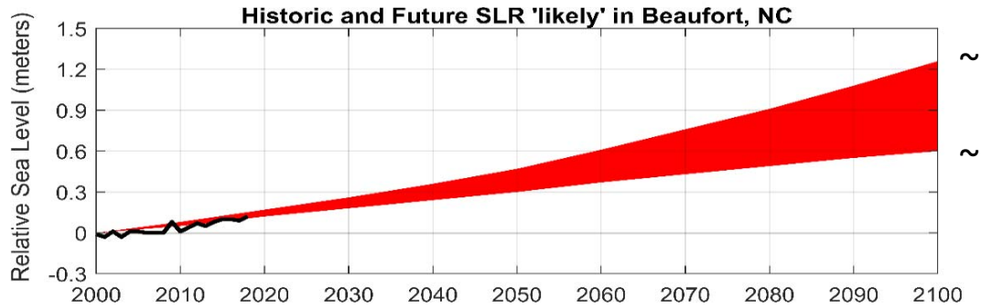


IPCC SROCC 2019

What does this mean for coastal NC?

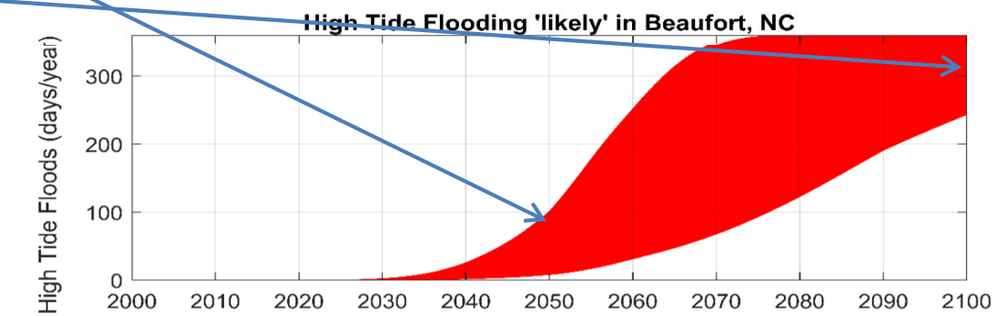
High tide or sunny day flooding

- Happens occasionally now
- As often as 2x per week in 2050
- Every 1-2 days in 2100

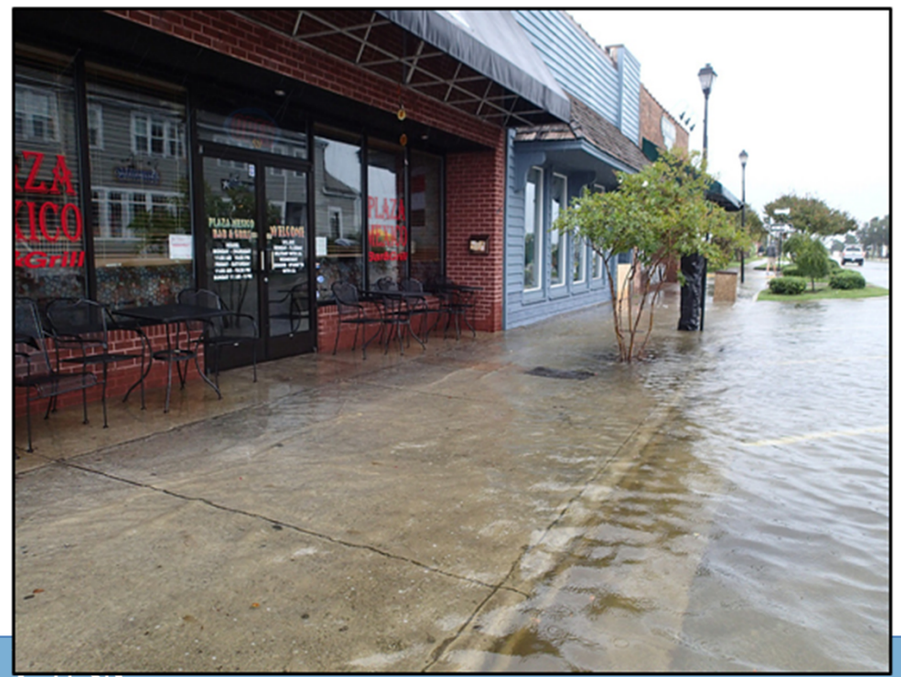


~ RCP8.5

~ RCP4.5



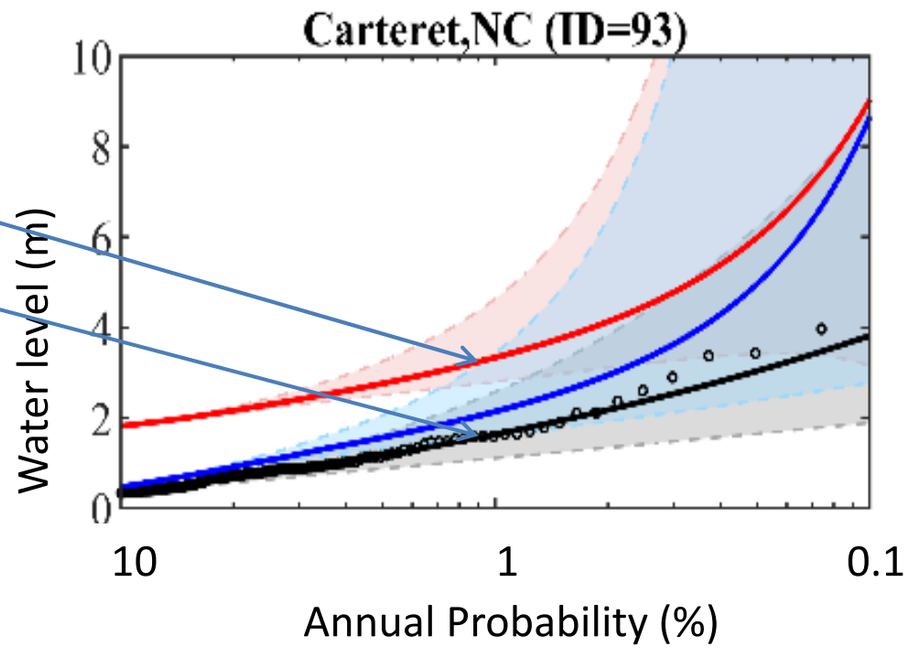
HTF=1.8ft > MHHW



What does this mean for coastal NC?

Tropical Cyclone water levels

- 1980-2005 vs 2070-2095 (RCP8.5)
  - Recent 1% annual prob water levels ~30% or greater annual prob near end of century
  - Effect of SLR 2-3x effect of change in TCs in coastal NC



Marsooli et al 2019

Conclusions

- It doesn't take a large change in water level to impact significant portions of coastal NC – inches matter, feet can be catastrophic
- *Summing the many drivers of water level variability + relative sea level rise = significant high tide/sunny day flooding in 2nd half of 21st century*
- Coastal NC is highly vulnerable to major storm surge / flooding from hurricanes
- Climate change is causing GMSL rise and strengthening tropical cyclones – GMSL 2-3 times more important than stronger hurricanes on future storm surge in coastal NC
- *Hurricane driven water levels that recently had a 1% chance of occurring each year may have 30% or greater chance of occurring each year near the end of the 21st century.*
- Growing concern about precipitation based coastal flooding and compound flooding