Influences on Subtidal Salinity Variability and Change in the Delaware Estuary

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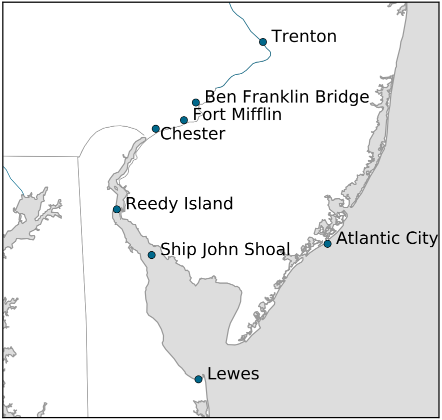
Outline

Salinity variability makes estuaries unique

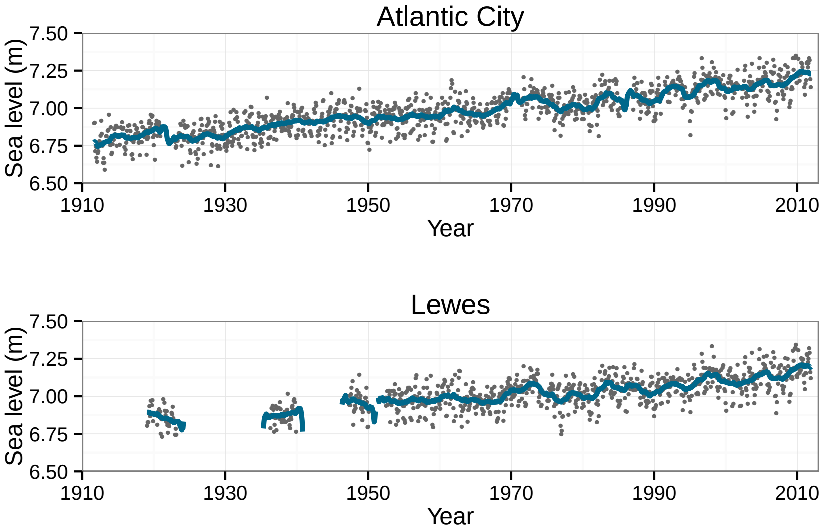
- Tidal and subtidal fluctuations in salinity are a unique feature of estuaries.
- Changes in salinity levels have a wide range of effects on the ecosystem.
  - Oyster disease (Powell et al., 1992)
  - Ammonia-oxidizing bacteria (Bernhard et al., 2005)
  - Phytoplankton blooms (Gallegos and Jordan, 2002)
- Changes caused by climate change and other influences have the potential to influence estuarine salinity.
  - Streamflow
  - Sea level
  - Wind stress
  - Oceanic salinity

These variables have been measured throughout the Estuary

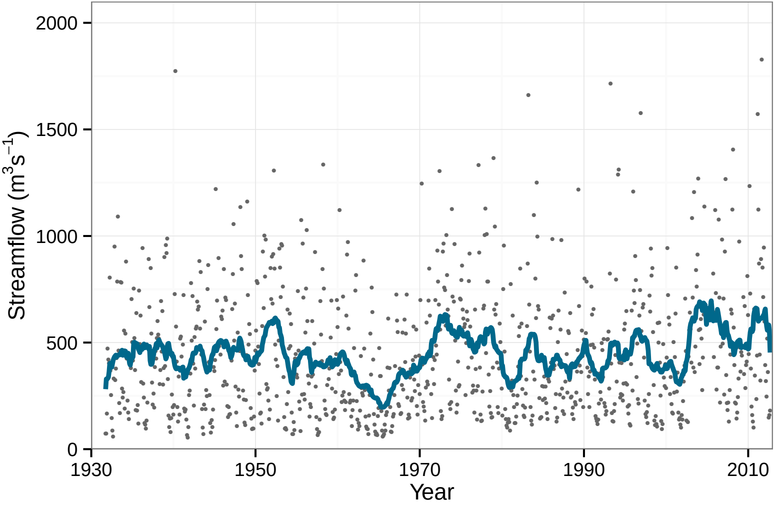
- **Streamflow:** USGS
- **Salinity:** USGS, NOAA/NOS
- **Sea level:** PSMSL (Woodworth and Player, 2003)
- **Oceanic salinity:** Gulf Stream Index (Taylor, 1995)
- **Wind stress:** North American Regional Reanalysis (Mesinger et al., 2006)



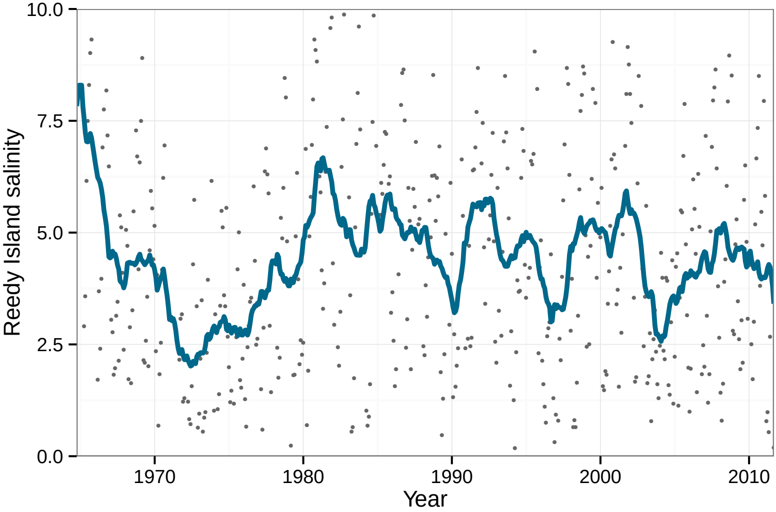
Sea level is rising



Streamflow is increasing



How is salinity responding?



Influences can be determined with statistical models

- Multiple linear regression:

$$\mathbb{E}(S_i) = \beta_0 + \beta_1 Q_i + \beta_2 H_i + \beta_{Month}$$

Influences can be determined with statistical models

Generalized additive mixed model:

$$\mathbb{E}(S_i) = \beta_0 + f_Q(Q_i) + f_H(H_i) + f_M(Month_i)$$

- $f_Q()$, $f_H()$, $f_M()$: Smooth functions that relate streamflow, sea level, and month to salinity.

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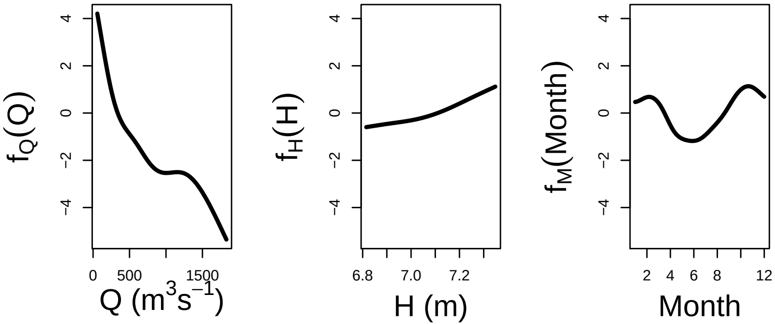
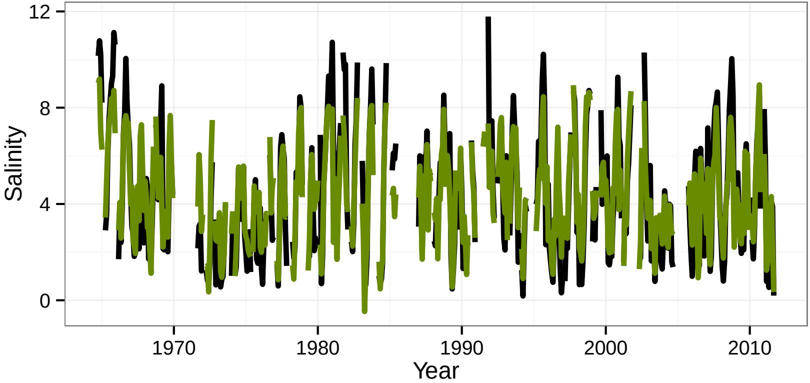


The model handles autocorrelated errors

- Residual lag-1 autocorrelation is roughly 0.4.
- Among other effects, autocorrelation results in decreased degrees of freedom for the smooth functions.
- We assume an AR(1) autocorrelation model.

The model closely fits the observed salinity

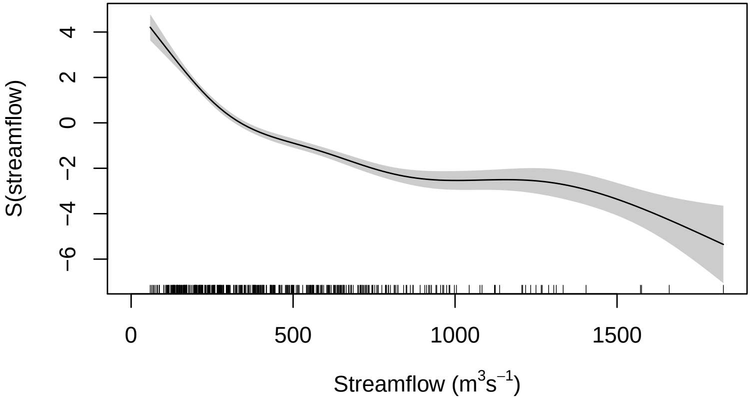
Black: observed Reedy Island salinity. **Green:** modeled Reedy Island salinity.



- The fits upstream in the Estuary are not as good.

Streamflow has the largest effect

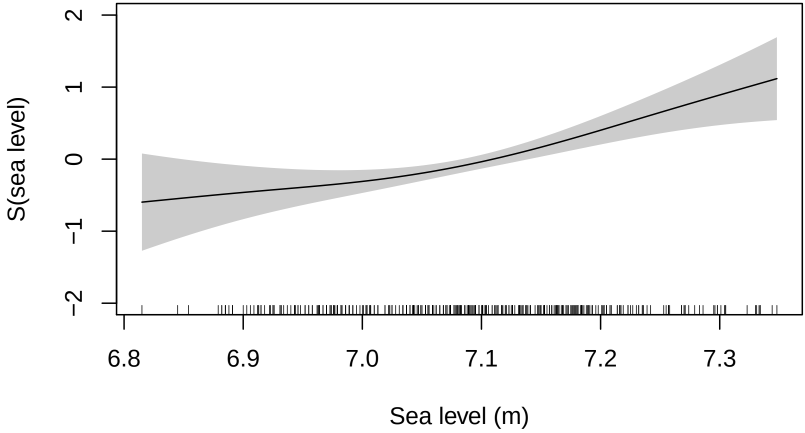
Reedy Island Jetty



- The results are similar at the other locations.

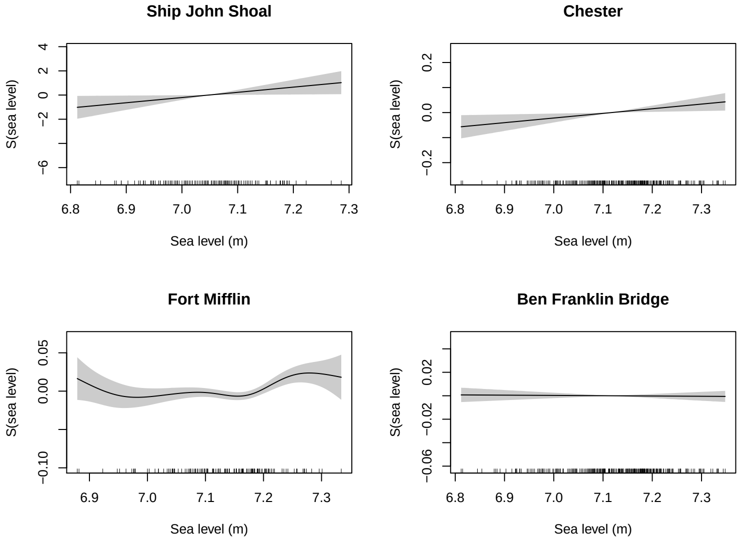
Sea level is also important

Reedy Island Jetty



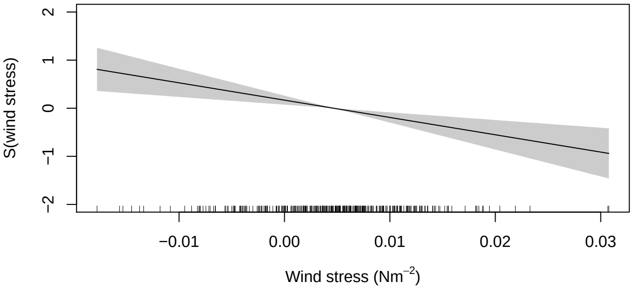
Sea level is also important

Other locations



Alongshore wind stress may be important

Reedy Island Jetty



- Similar result at Ship John Shoal.
- Not significant at upstream locations.

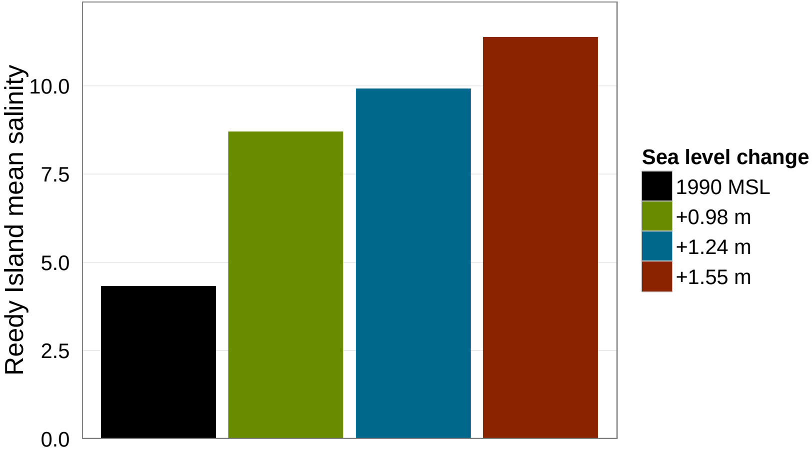
Oceanic salinity is not important

- Oceanic salinity does not have a significant effect at any location, and the signs of the slope of the modeled effect vary.
- This makes sense, since oceanic salinity probably only has an influence over longer time scales.

Sea level will rise significantly

- For the A2 emissions scenario, Vermeer and Rahmstorf (2009) project that mean sea level in 2100 will be 0.98-1.55 m above 1990 MSL with a model mean of 1.24 m above 1990 MSL.
- At Atlantic City, this translates to sea level rising from 7.1 m to 8.3 m (8.0-8.6 m).

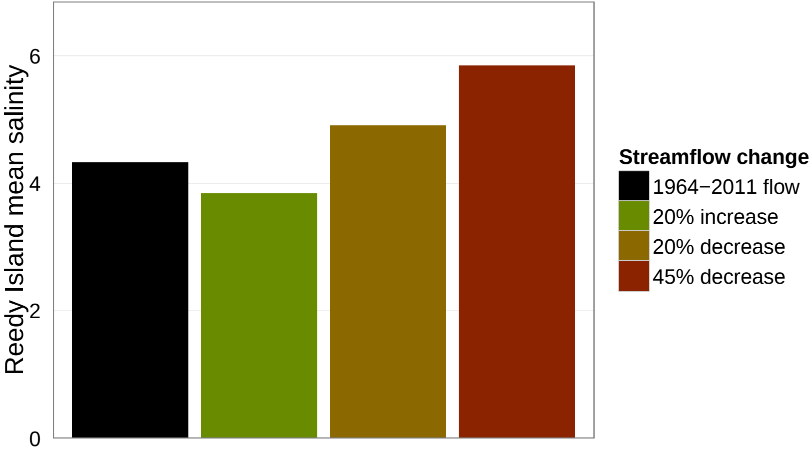
Salinity will increase as a result of sea level rise



Streamflow changes are uncertain

- On average, models predict an increase in precipitation, leading to a 15 ± 20 % change in streamflow by the end of the century for the A2 scenario (Najjar et al., 2009).
- However, a warming of 4°C results in a 15-40% decrease in streamflow due to increased evapotranspiration (Najjar et al., 2009)
- We consider three scenarios:
    1. 20% increase (to 540 $m^3\ s^{-1}$)
    2. 20% decrease (to 360 $m^3\ s^{-1}$)
    3. 45% decrease (to 247 $m^3\ s^{-1}$)

Salinity responds weakly to streamflow change



Summary

- Streamflow has the largest effect on monthly variability of salinity.
- The magnitude of the response to streamflow is relatively weak, so the long term trend in salinity may be dominated by sea level.
- Alongshore wind stress may be important, particularly downstream in the Estuary and Bay.

- Mean salinity will decrease slightly if mean streamflow increases and will increase slightly if mean streamflow decreases.
- Mean salinity will increase significantly if sea level rises as projected.

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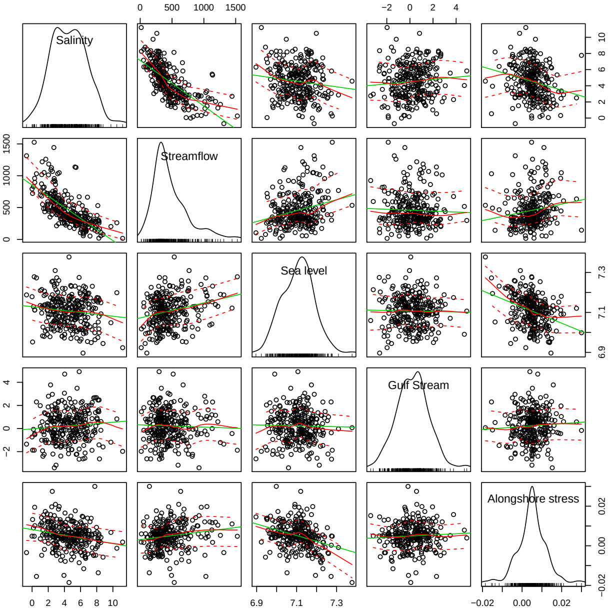
Salinity
Streamflow
Sea level
Gulf Stream
Alongshore stress
0
500
1000
1500
−2
0
2
4
0
2
4
6
8
10
6.9
7.1
7.3
−0.02
0.00
0.02