Historical Sea level Rise

**Causes:**
- Land sinking (glacial warping, impact crater)
- Ocean Currents (position of the gulf stream)
- *Ocean Volume (thermal expansion, ice melt)

- ~1 mm/yr
- ~3 mm/yr

Mid-Atlantic region even faster!

Source: Kemp et al., 2009
Factors that control wetland size

- Transgression (elevation/connectivity)
- Vertical Maintenance or Submergence
- Edge Erosion

Virginia Coast Reserve LTER - SET Locations

- Mid elevation
- Low elevation
- High elevation

Source: Linda Blum, UVA + LTER
Vertical Dimension: Marshes tend to be resilient

Feedbacks between sediment transport, plant growth, and hydrodynamics allow coastal wetlands to adapt to changes in sea level.

Elevation change at Phillips Creek (Linda Blum)

Elevation change rates increase with flooding frequency!

Mainland marshes keeping up
Accretion rate increases with sea level rise!

Modelled threshold rates

- Threshold rate of SLR increases with sediment concentration and tidal range
- In general, marshes survive rates > 10 mm yr⁻¹
- Measures local SSC

Source: Kirwan and Kolker

Kirwan et al., 2010
Factors that control wetland size

- Transgression (elevation/connectivity)
- Vertical Maintenance or Submergence
- Edge Erosion

Average erosion rates at 10 sites along the mainland marsh-bay boundary from 1957 - 2009

Average erosion rate along entire mainland marsh-bay boundary from 2002-2009 is 0.2m/y.

Source: McLoughlin, Wiberg et al. 2011
Edge Erosion - Response to SLR:

Wave height tends to increase with sea level rise
But, erosion maximum for a specific water level relative to marsh level (Fagherazzi et al.)

Important factors:
- Height of marsh relative to water level
- Timing of storms relative to tide level

Sea level rise means bigger waves but not necessarily more erosion

Factors that control wetland size

- Transgression (elevation/connectivity)
- Vertical Maintenance or Submergence
- Edge Erosion
Pictures of active marsh migration

Dying Loblolly Pine forest
Marsh under trees

Will look like this in a decade or 2

Photo: Matthew Kirwan
Photo: S. Temmerman
Marsh Response to Sea Level Rise

\[ f(\text{wind, water depth, fetch}) \quad f(\text{sea level rise, upland slope}) \]

Kirwan et al., in prep
Marsh Response to Sea Level Rise

Kirwan et al., in prep
Sea Level Rise Rate (mm yr$^{-1}$)

- Expansion, then drowning
- Expansion rate related to slope
- No migration case - marsh loss inevitable
- Erosion even if marsh is keeping up vertically!

For a given wind speed, fetch, sediment supply

Kirwan et al., in prep

How much land available for marsh migration?

(\text{Green} = \text{potential land for new marsh under 1m of SLR})

Entire continental U.S.
1m SLR = 11,000 km$^2$ new intertidal area
Existing marshland = 16,000 km$^2$
(Morris et al., 2012)

Enough to compensate for almost complete loss of existing marshland. But...

Source = Chris Bruce, TNC

Fraser River Delta, BC
Conclusions/Discussion Points

- Mainland marshes tend to be **stable** in vertical dimension (i.e. build elevation with sea level rise). Survive > 10mm/yr.

- Inherently **unstable** at seaward and landward boundaries (erosion + migration)

- Enough adjacent land to accommodate severe loss of existing marsh

- Loss not inevitable, expansion possible

So, whether marshes will expand or contract in response to future SLR depends on how we ourselves defend against SLR