Sea Level Rise along the East Coast of the United States

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Outline

• Introduction
  U.S. east coast – a hotspot of sea level rise
• Observations
  - 20th century
  - Past two decades (satellite era)
  - Recent years (2009-10 northeast coast extreme event)
• Model simulations and projections
  - CMIP3 models (GFDL CM2.1)
  - CMIP5 models (GFDL ESM2M, ESM2G and CM3)
  - More recent GFDL models (CM2.6, CM2.5, ...)
• Summary
Long-Term Sea Level Rise

Data: PSMSL

Goddard et al., Nat. Comm., 2015
Decadal to Multidecadal

Linear trend of sea level along the U.S. east coast

Yin and Goddard, GRL, 2013
2009-10 Extreme Event

- **Yearly sea level change**
  \[
  SLR(t) = \frac{[SL(t+1)-SL(t-1)]}{2} ;
  \]
  \(t=1921, 1922, \ldots, 2011\)

- **Northeast regime**
  Yearly rate in 2009 > 3\(\sigma\)
  Probability (1-in-850 year)
  On average, sea level jumped by about 100 mm during 2008-10.

- **Southeast regime**
  Extreme event in 1949 ~ 3\(\sigma\)

_Goddard et al., Nat. Comm., 2015_
Interannual

- 2010-11 North Atlantic sea level fall
- Reduced northward heat transport and cooling of the subtropical gyre due to a 30% downturn of AMOC during 2009-10.

**2010 dynamic sea level anomalies relative to long-term mean**
The AMOC and Northeast sea level composite are well correlated during 2004-2012.

• The regression coefficient suggest a 13-17 mm Sv\(^{-1}\) relationship.

Goddard et al., Nat. Comm., 2015
• Dynamic sea level shows an instantaneous correlation with AMOC along the east coast of North America, especially near the northeast coast.
• SST signals in the northern North Atlantic usually emerge a few years latter.
The altimetry and tide gauge data are generally consistent in the 2009-10 extreme event, but the magnitude differs.

Ocean temperature and salinity data indicate positive anomalies of steric seal level east of the shelf break in 2009.
Role of NAO

- An extreme negative NAO occurred in 2009-10.
- The northeasterly wind anomalies during 2009-10 could generate onshore Ekman transport.
- The lower atmospheric pressure can further enhance the magnitude through the inverse barometer effect.

Goddard et al., Nat. Comm., 2015
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  - CMIP3 models (GFDL CM2.1)
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  - Latest GFDL model suite (CM2.6, CM2.5, ...)

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21st Century Projection

- GFDL CM2.1
- A1B scenario
- Dynamic sea level change during 2091-2100 relative to 1981-2000
- Global mean sea level rise is subtracted.
- ~20 cm dynamic sea level rise at NYC

Source: Yin et al., Nat. Geo., 2009
• A1B; 2091-2100 relative to 1981-2000; global steric sea level rise subtracted

• Additional steric sea level rise east of the shelf break – mainly induced by an ocean warming in both the upper and deep oceans
• The global mean value is subtracted.
• Mass moves from ocean interior to the shelf region.
• Ocean bottom pressure increases on the shelf, especially east of the U.S.
• Ocean bottom pressure decreases in ocean interior.
CMIP5 Models

- 34 models
- Three RCP scenarios
- Left panels – mean dynamic sea level change by 2100
- Right panels – model spread

Yin, GRL, 2012
• Ten GFDL models
• 1% yr\(^{-1}\) 2xCO\(_2\) experiments
• Dynamic sea level change relative to the global mean at CO\(_2\) doubling
AMOC-DSL Correlation

- Good correlation between AMOC weakening and dynamic sea level rise at NYC

Yin et al., 2016, in preparation
Summary

- The densely populated U.S. East Coast is a hotspot of sea level rise with the rise rate faster than the global and basin mean.
- The AMOC is an important factor in explaining this regional deviation of sea level rise and its temporal behavior.
- In the 21st century model projections, the magnitude of dynamic sea level rise at NYC is proportional to the absolute weakening of AMOC.
- A better understanding of the AMOC and its future evolution is therefore critical for sea level projections along the U.S. East Coast.