Sea Level Rise along the East Coast of the United States

Jianjun Yin

Department of Geosciences
University of Arizona

And many GFDL collaborators

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Outline

- Introduction

  U.S. east coast – a hotspot of sea level rise

- Observations

  - 20^{th} century

  - Past two decades (satellite era)

  - Recent years (2009-10 northeast coast extreme event)

- Model simulations and projections

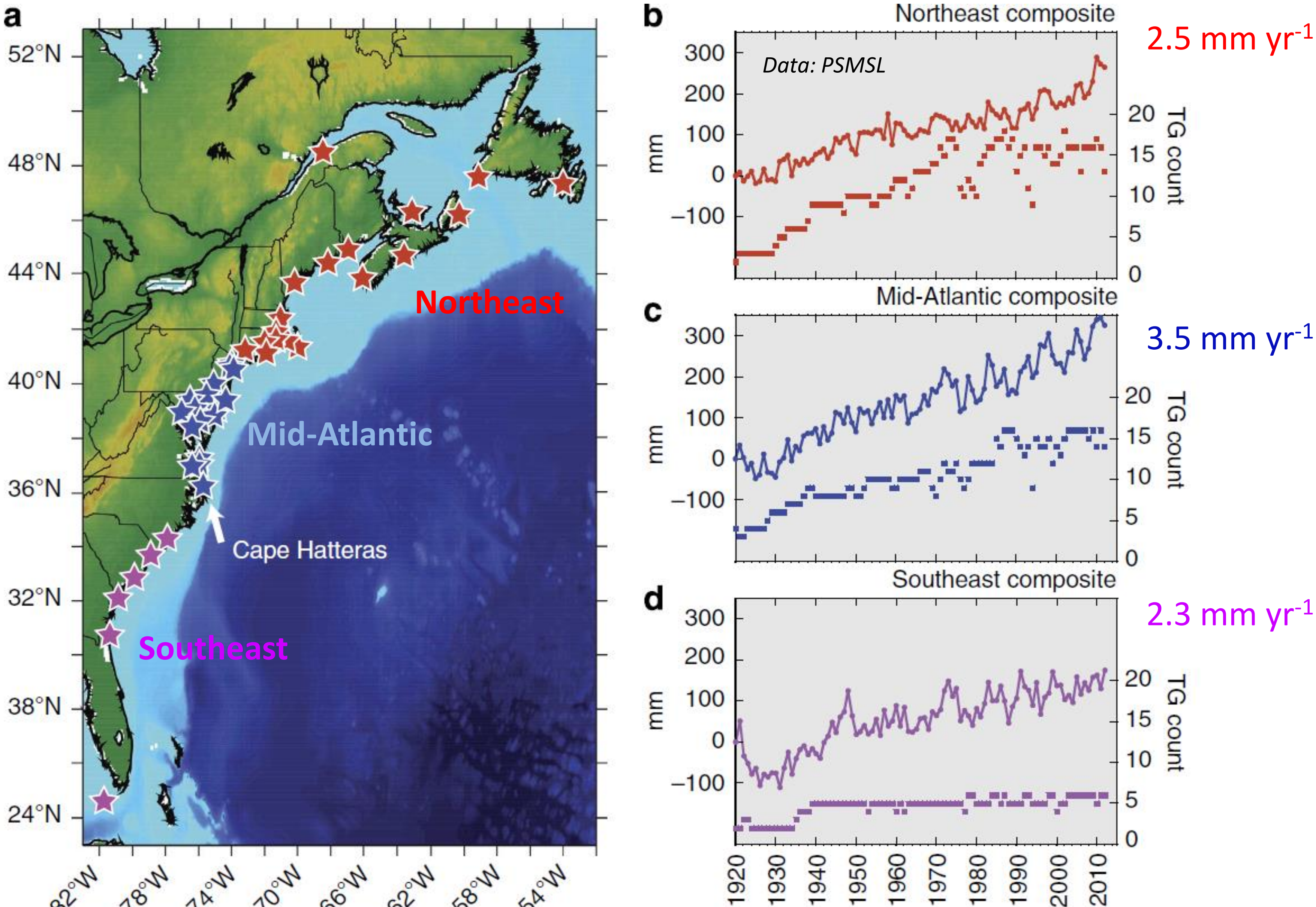
  - CMIP3 models (GFDL CM2.1)

  - CMIP5 models (GFDL ESM2M, ESM2G and CM3)

  - More recent GFDL models (CM2.6, CM2.5, …)

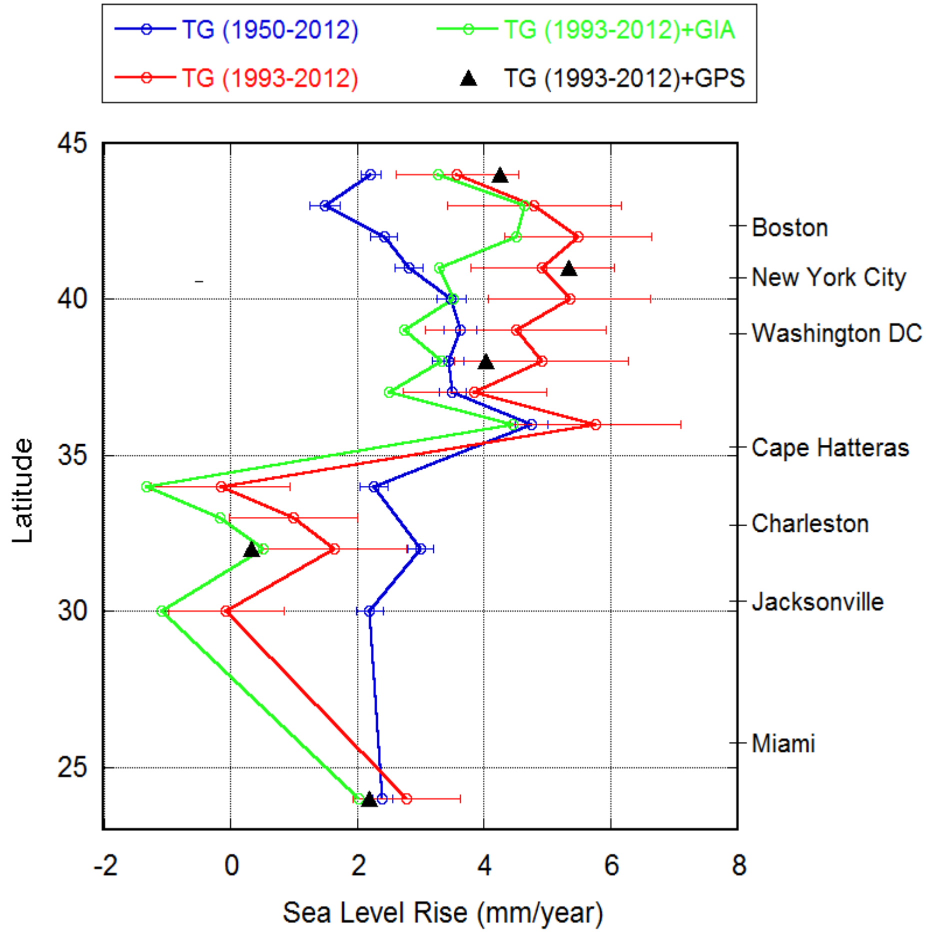
- Summary

Long-Term Sea Level Rise



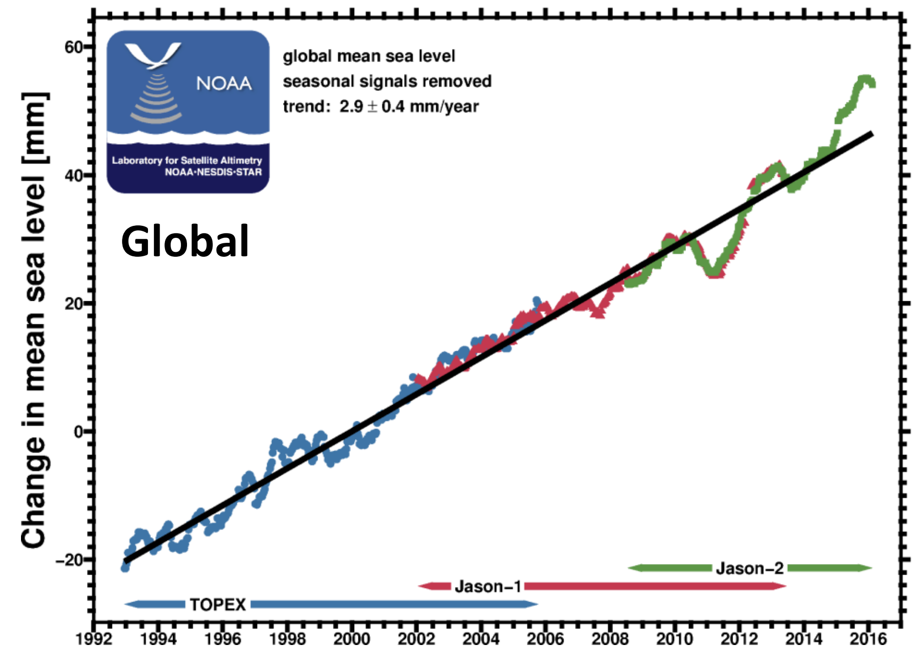
Goddard et al., Nat. Comm., 2015

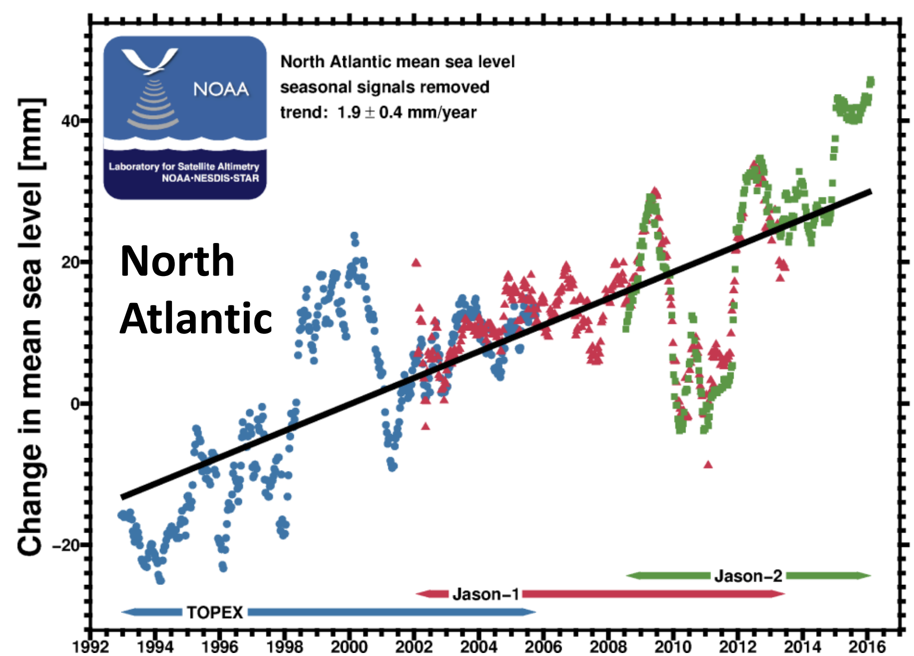
Decadal to Multidecadal



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

Yin and Goddard, GRL, 2013





Global and basin mean sea level

2009-10 Extreme Event

- **Yearly sea level change**

  SLR(t) = [SL(t+1)-SL(t-1)] / 2 ;

  t=1921, 1922, …., 2011

- **Northeast regime**

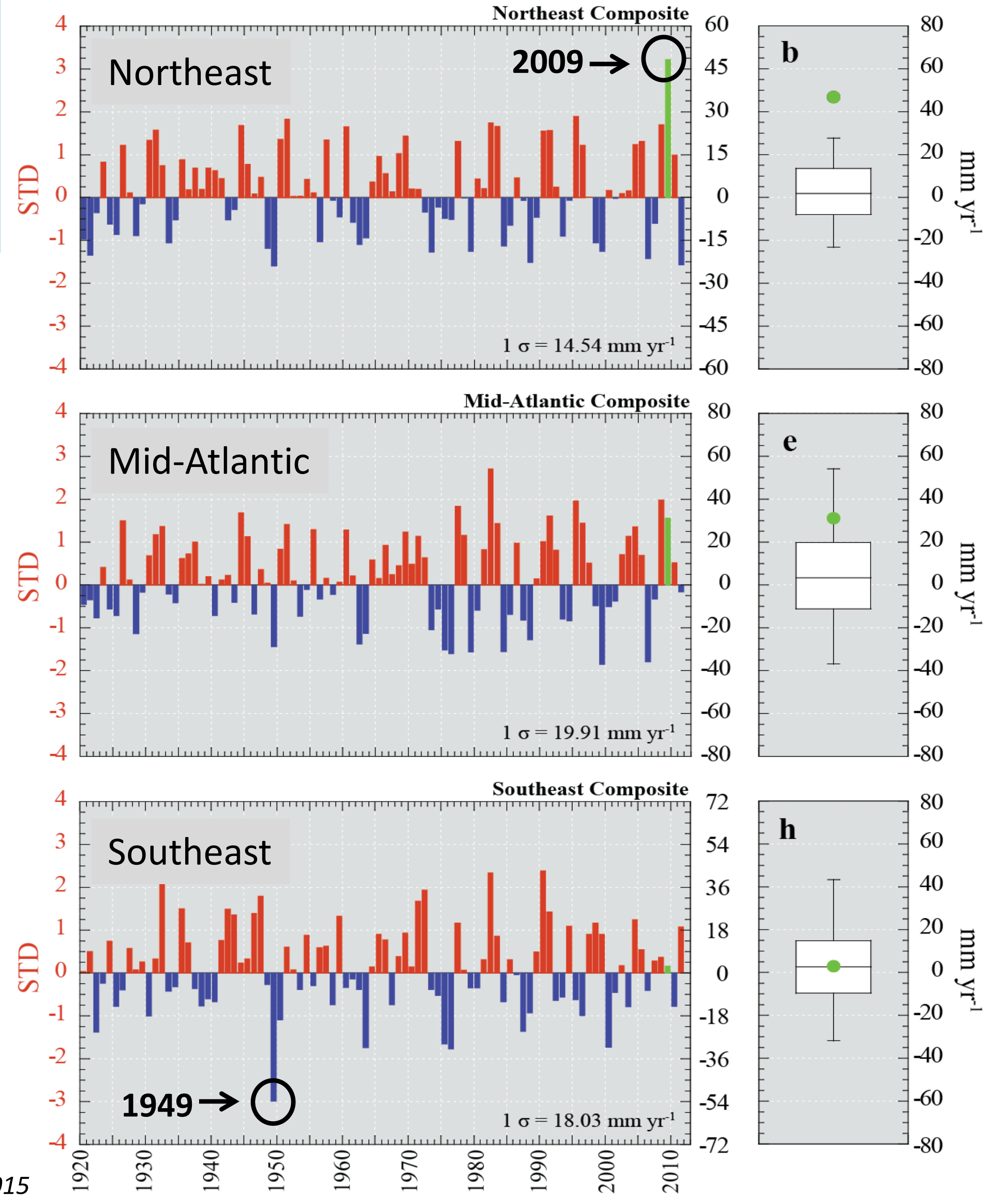
  Yearly rate in 2009 > 3σ

  Probability (1-in-850 year)

  On average, sea level jumped by about 100 mm during 2008-10.

- **Southeast regime**

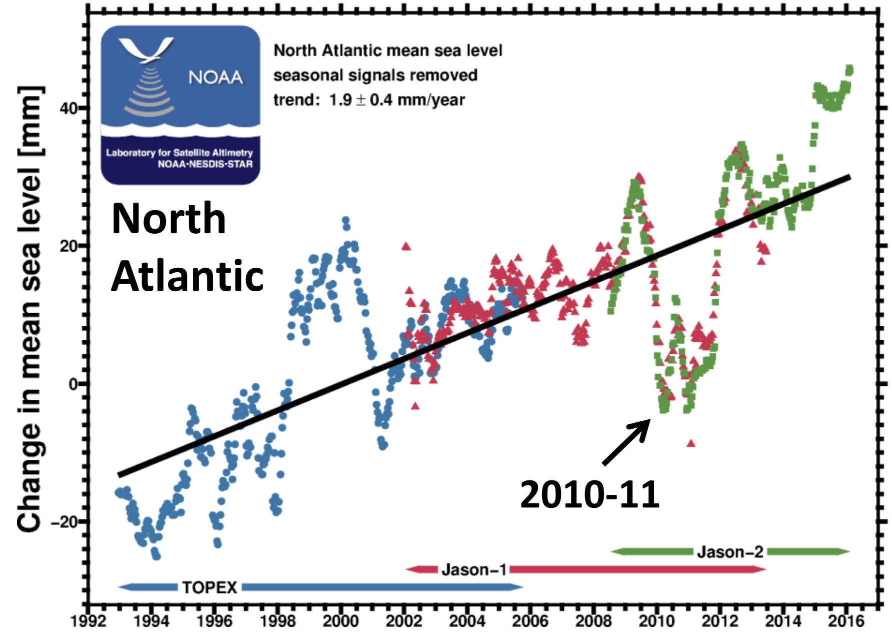
  Extreme event in 1949 ~ 3σ

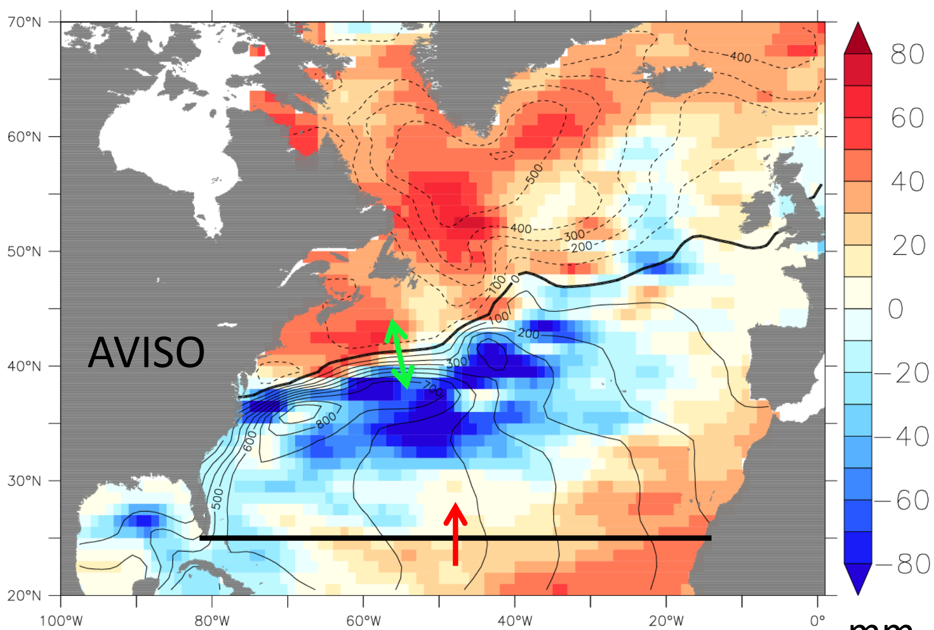


Goddard et al., Nat. Comm., 2015

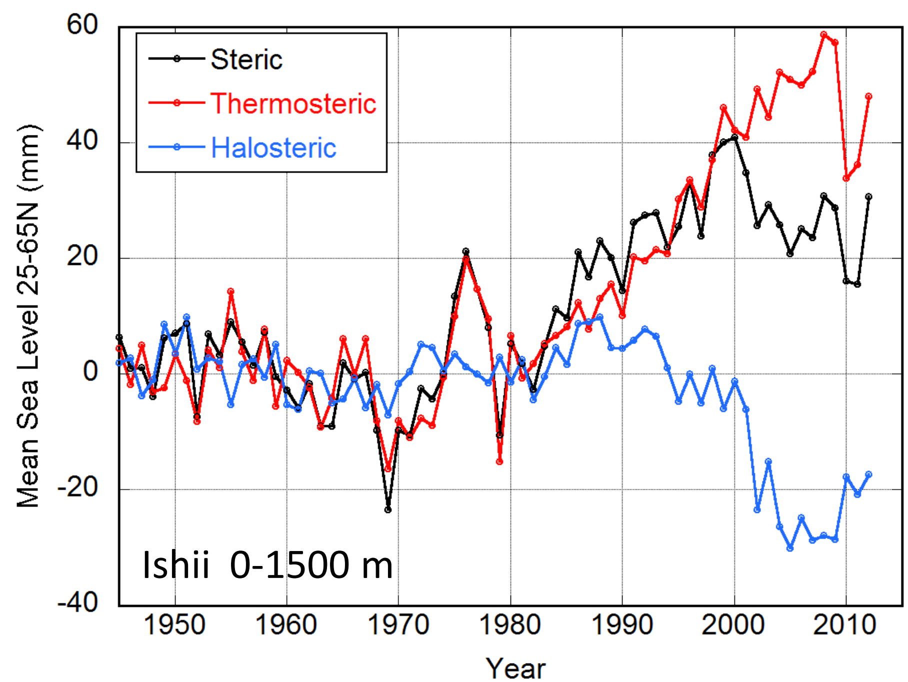
Interannual

- 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.

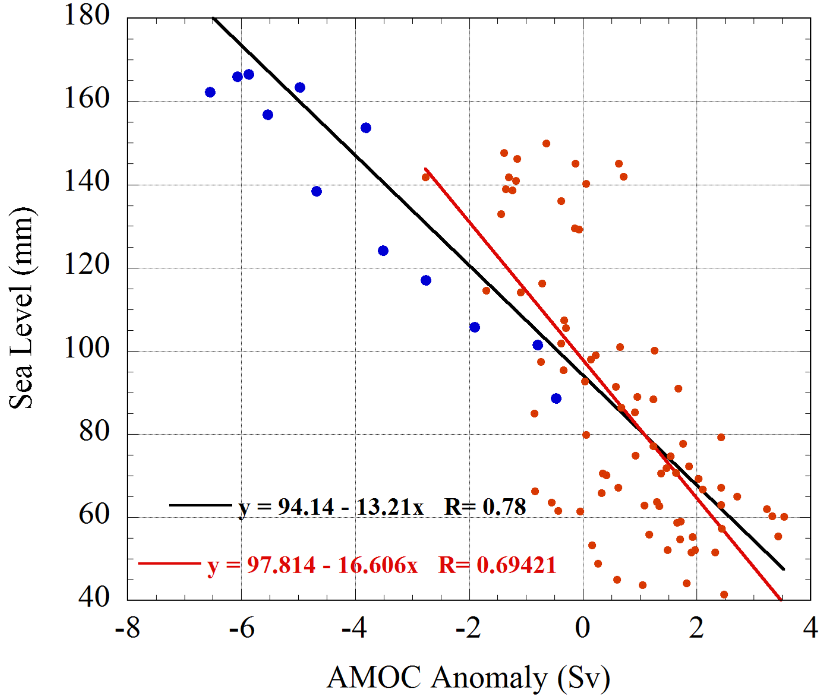


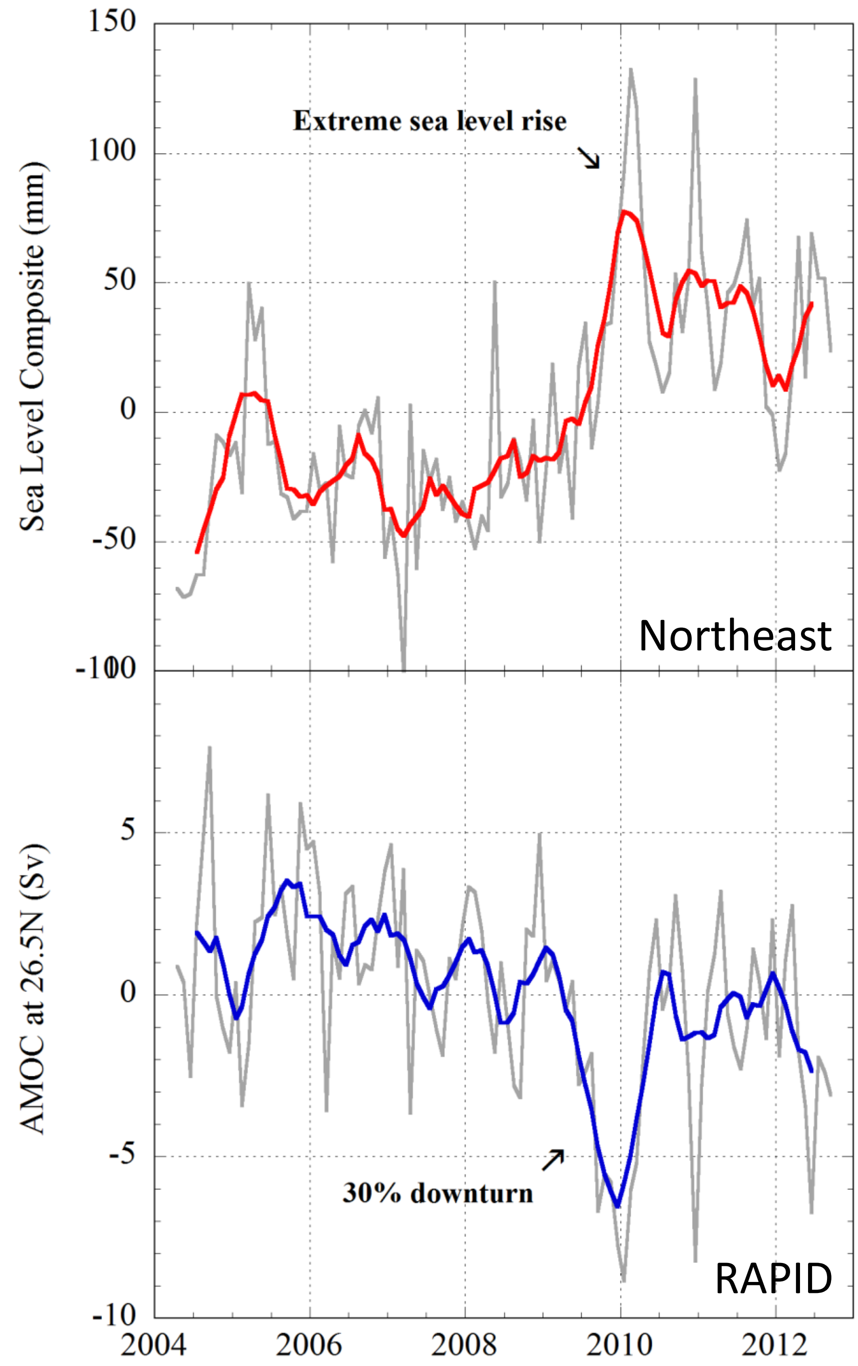


2010 dynamic sea level anomalies relative to long-term mean



Role of AMOC

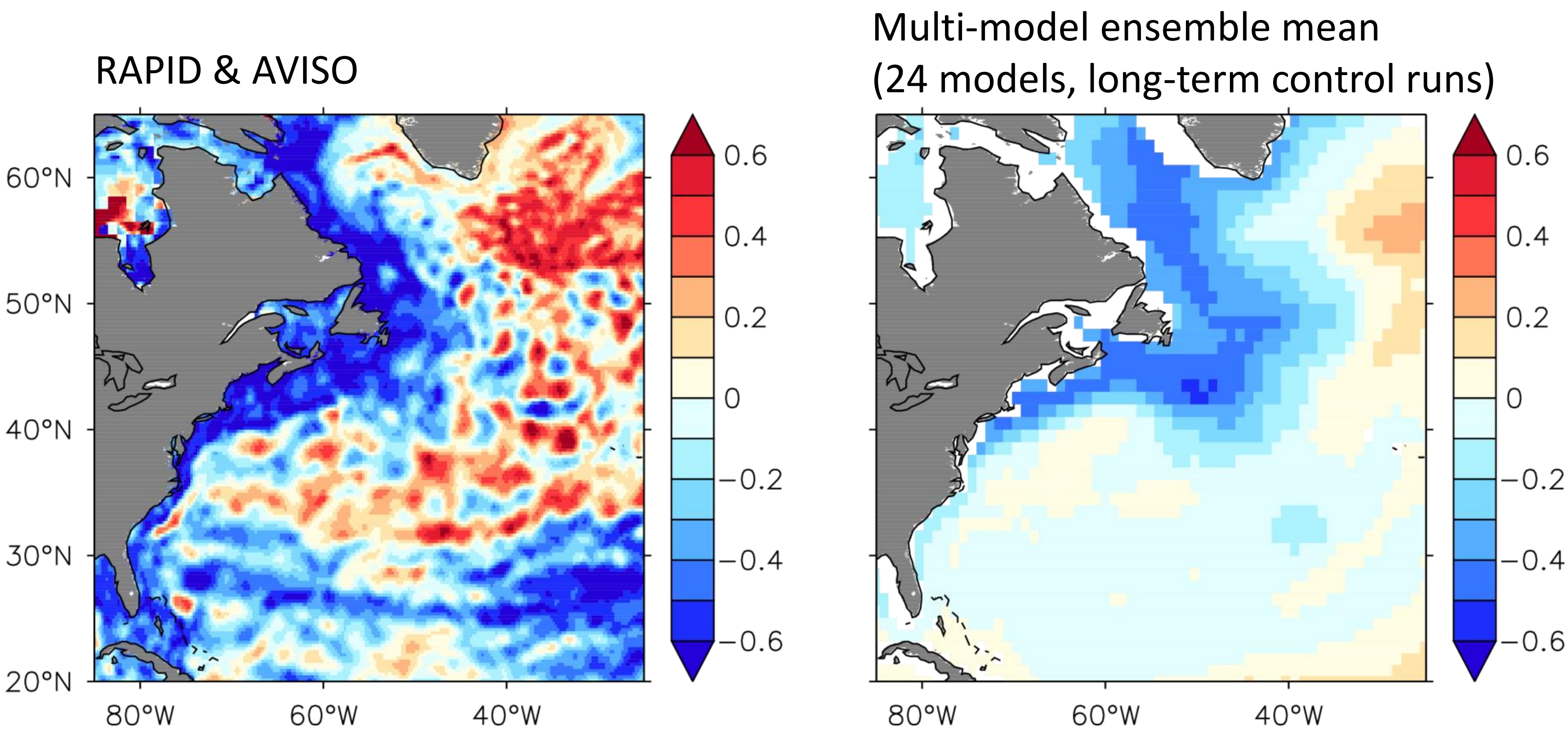




- The AMOC and Northeast sea level composite are well correlated during 2004-2012.
- The regression coefficient suggest a 13-17 mm Sv^{-1} relationship.

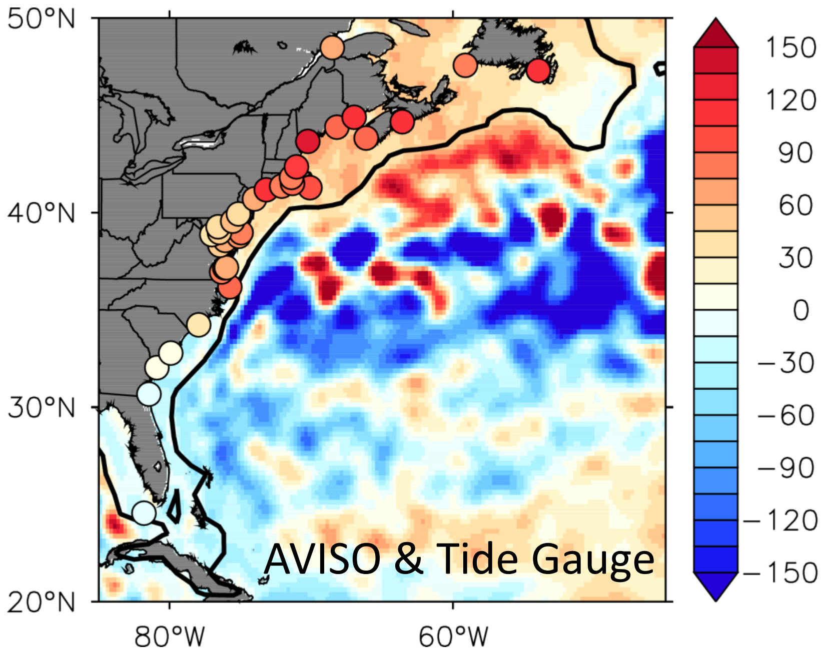
Goddard et al., Nat. Comm., 2015

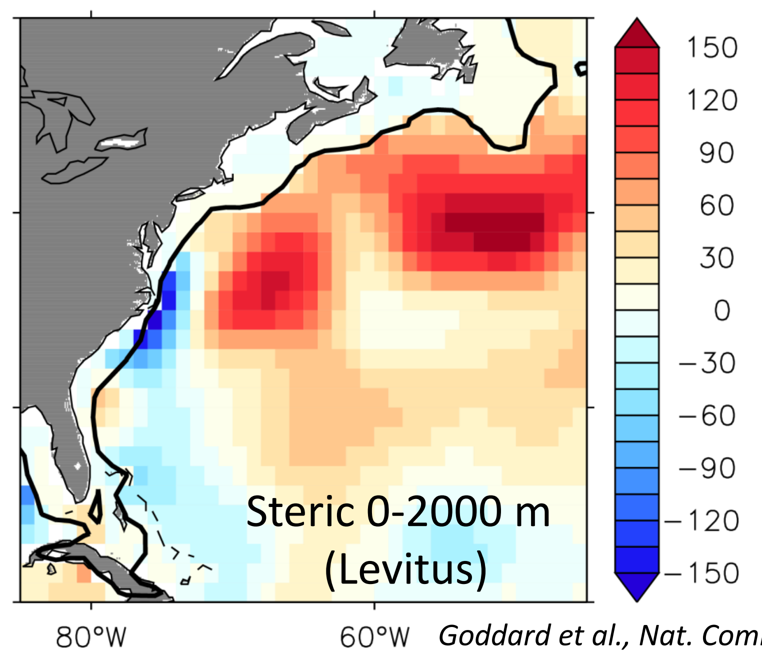
Correlation of AMOC and Dynamic Sea Level



- 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.

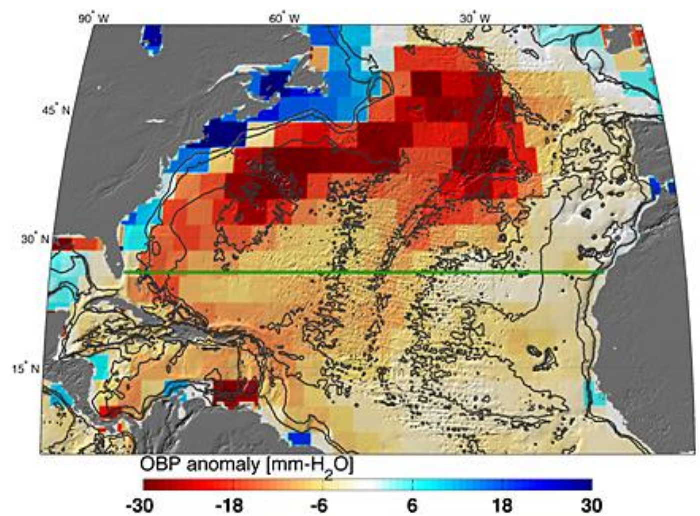
Impact of AMOC on Coastal Sea Level





Goddard et al., Nat. Comm., 2015

- 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.

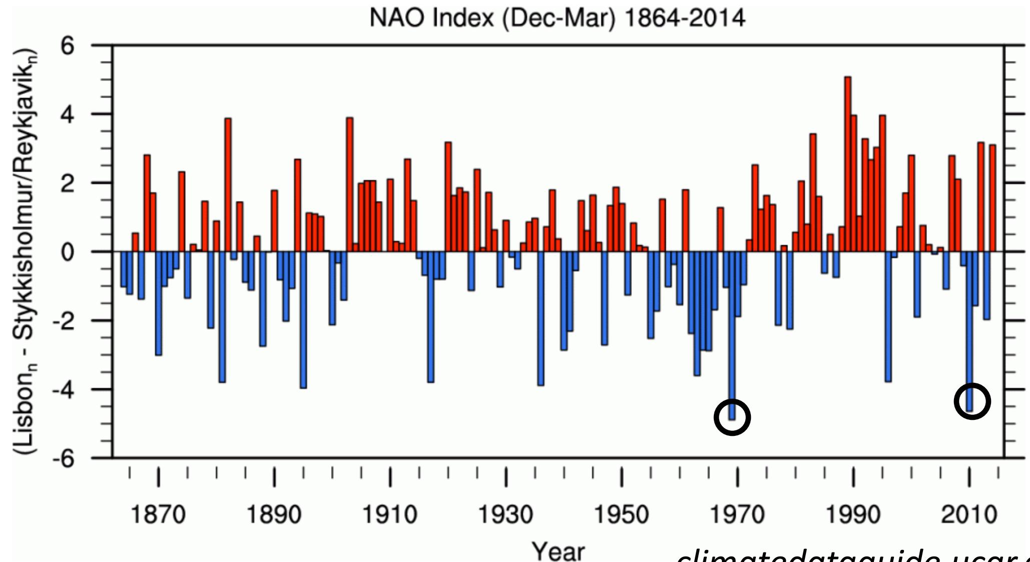


Ocean bottom pressure

Landerer et al., GRL, 2015

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.



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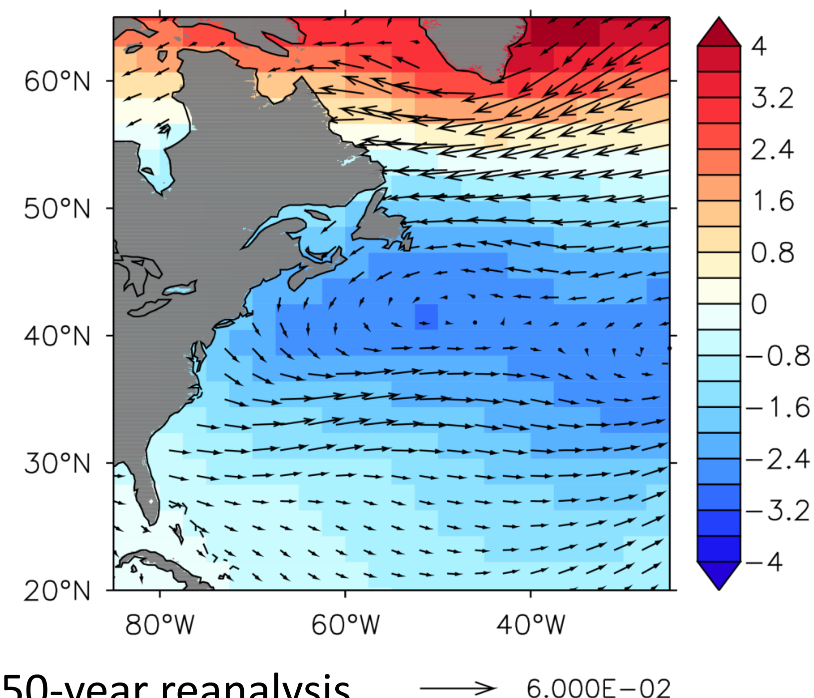

GFDL 50-year reanalysis

Goddard et al., Nat. Comm., 2015

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  - 20^{th} century

  - Past two decades (satellite era)

  - Recent years (2009-10 northeast coast extreme event)

- **Model simulations and projections**

  - CMIP3 models (GFDL CM2.1)

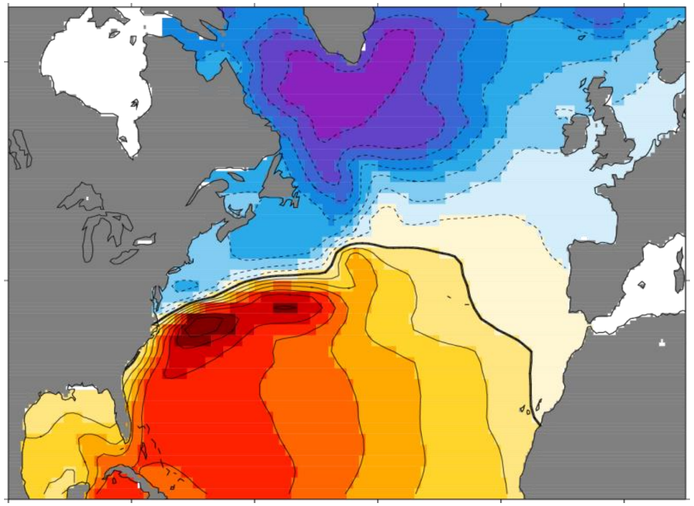
  - CMIP5 models (GFDL ESM2M, ESM2G and CM3)

  - Latest GFDL model suite (CM2.6, CM2.5, …)

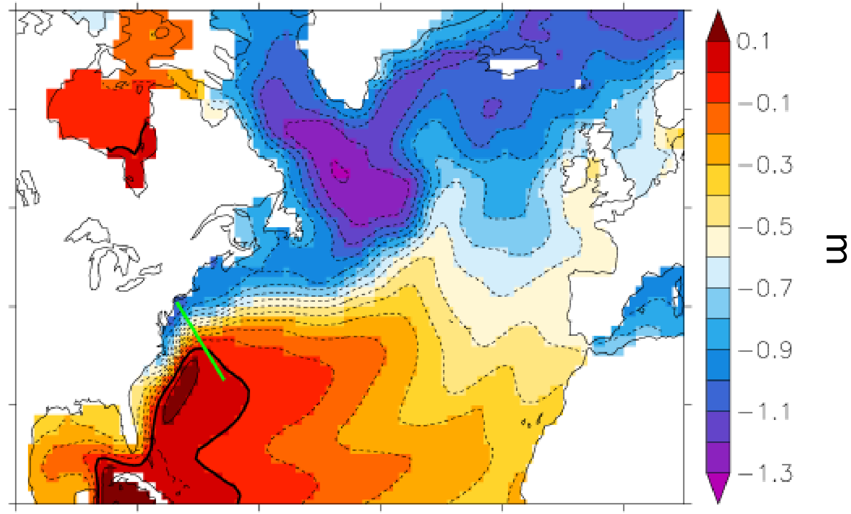
- Summary

21st Century Projection

(a) AVISO

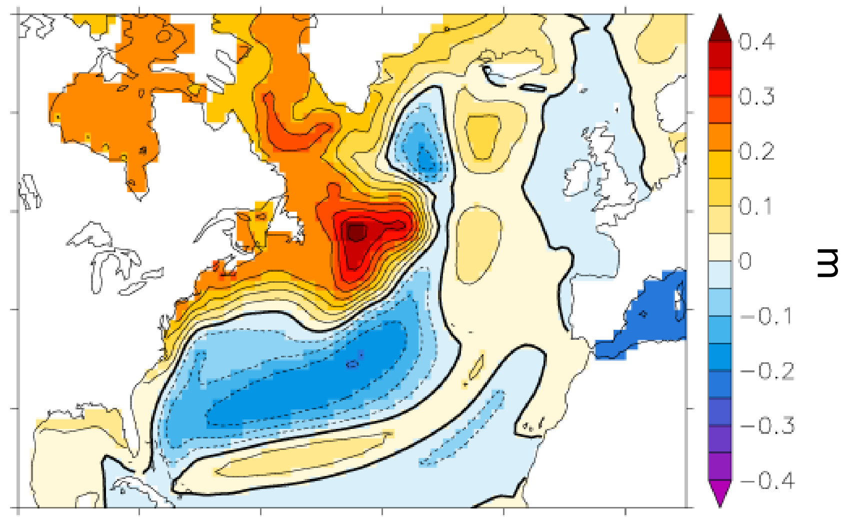


(b) Simulation (1992~2002)



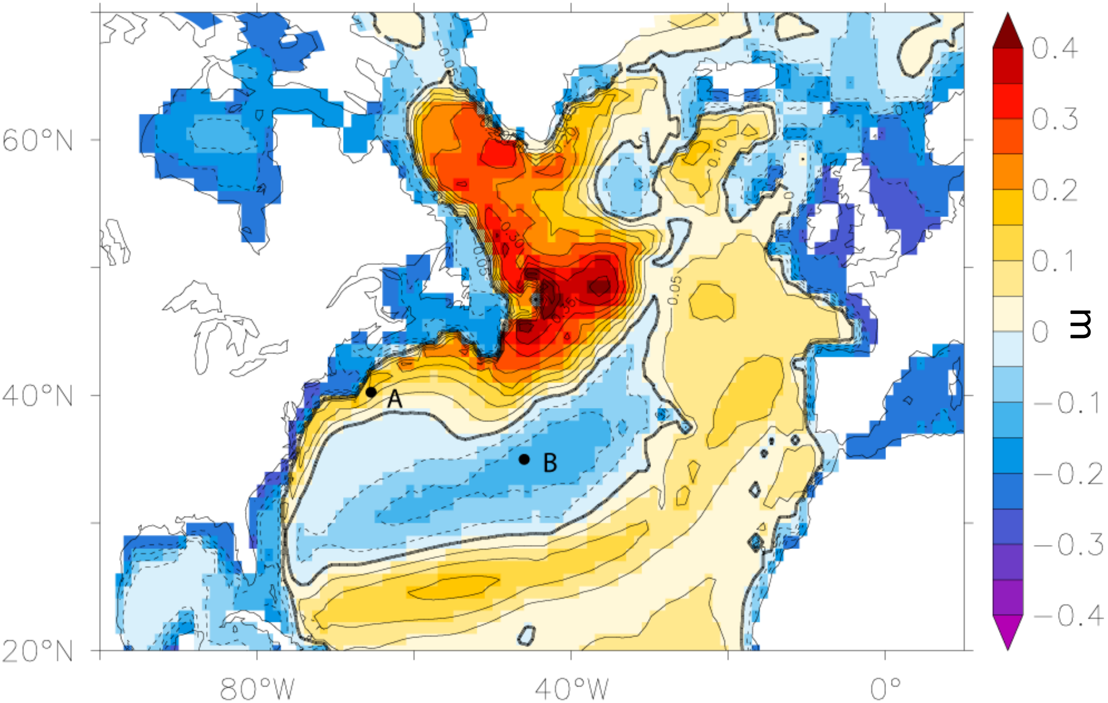
- GFDL CM2.1
- A1B scenario
- Dynamic sea level change during 2091-2100 relative to 1981-2000
- Global mean sea level rise is subtracted.
- ~20 cm dynamic sea level rise at NYC

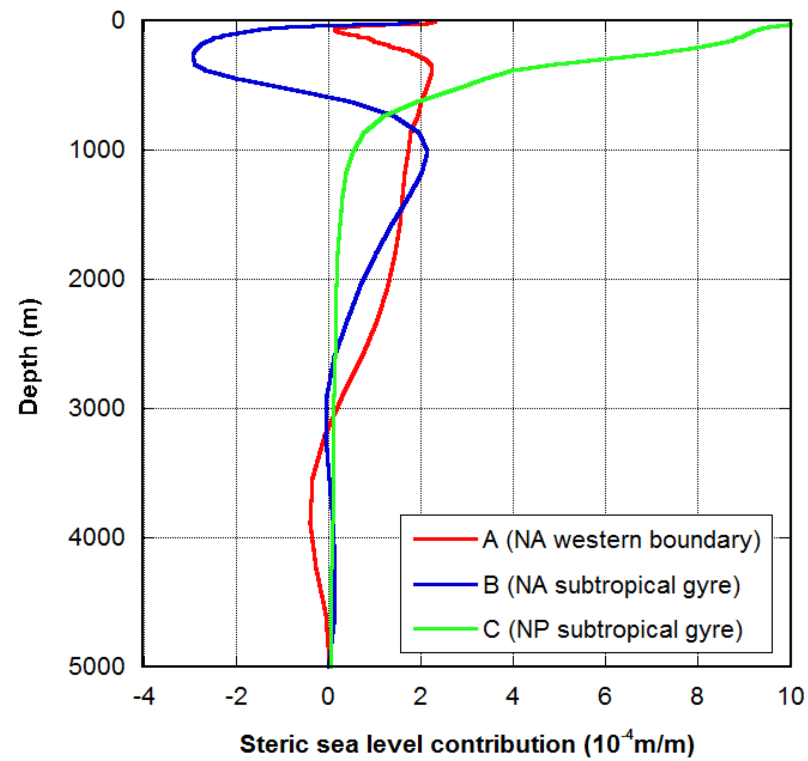
(d) A1B



Yin et al., Nat. Geo., 2009

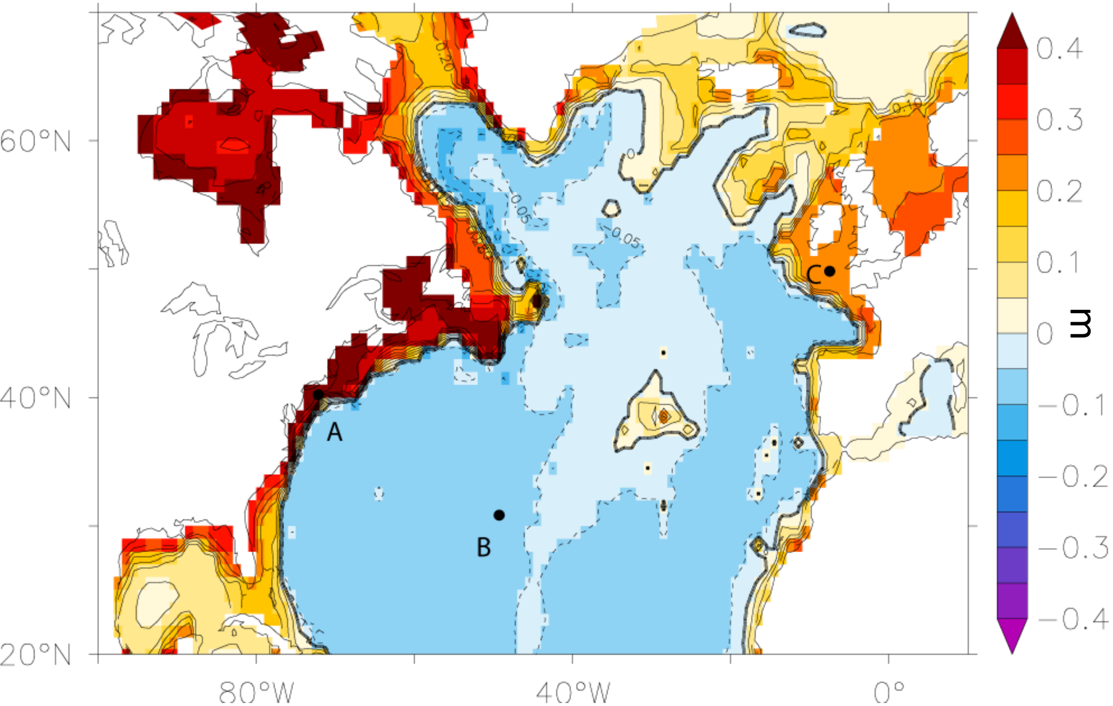
Contribution of Steric Effect

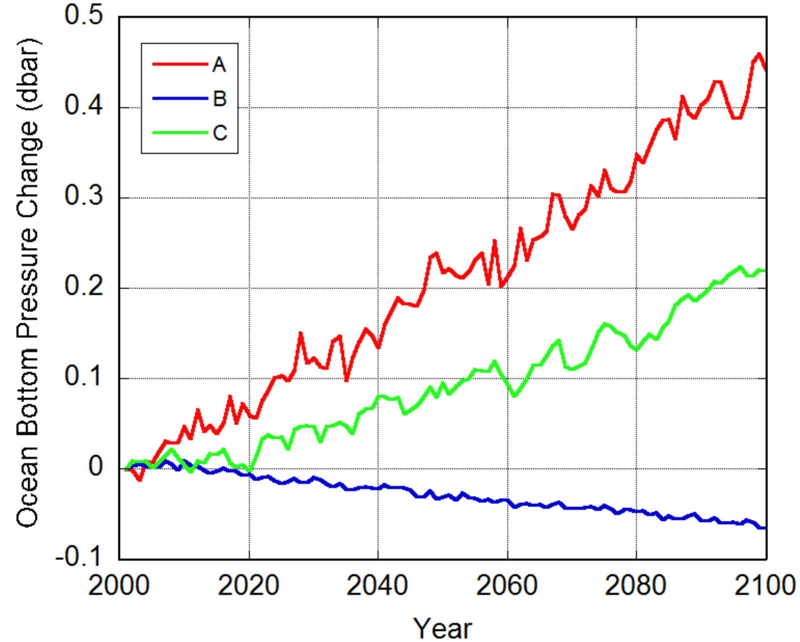




- A1B; 2091-2100 relative to 1981-2000; global steric sea level rise subtracted
- Additional steric sea level rise east of the shelf break – mainly induced by an ocean warming in both the upper and deep oceans

Ocean Mass Redistribution

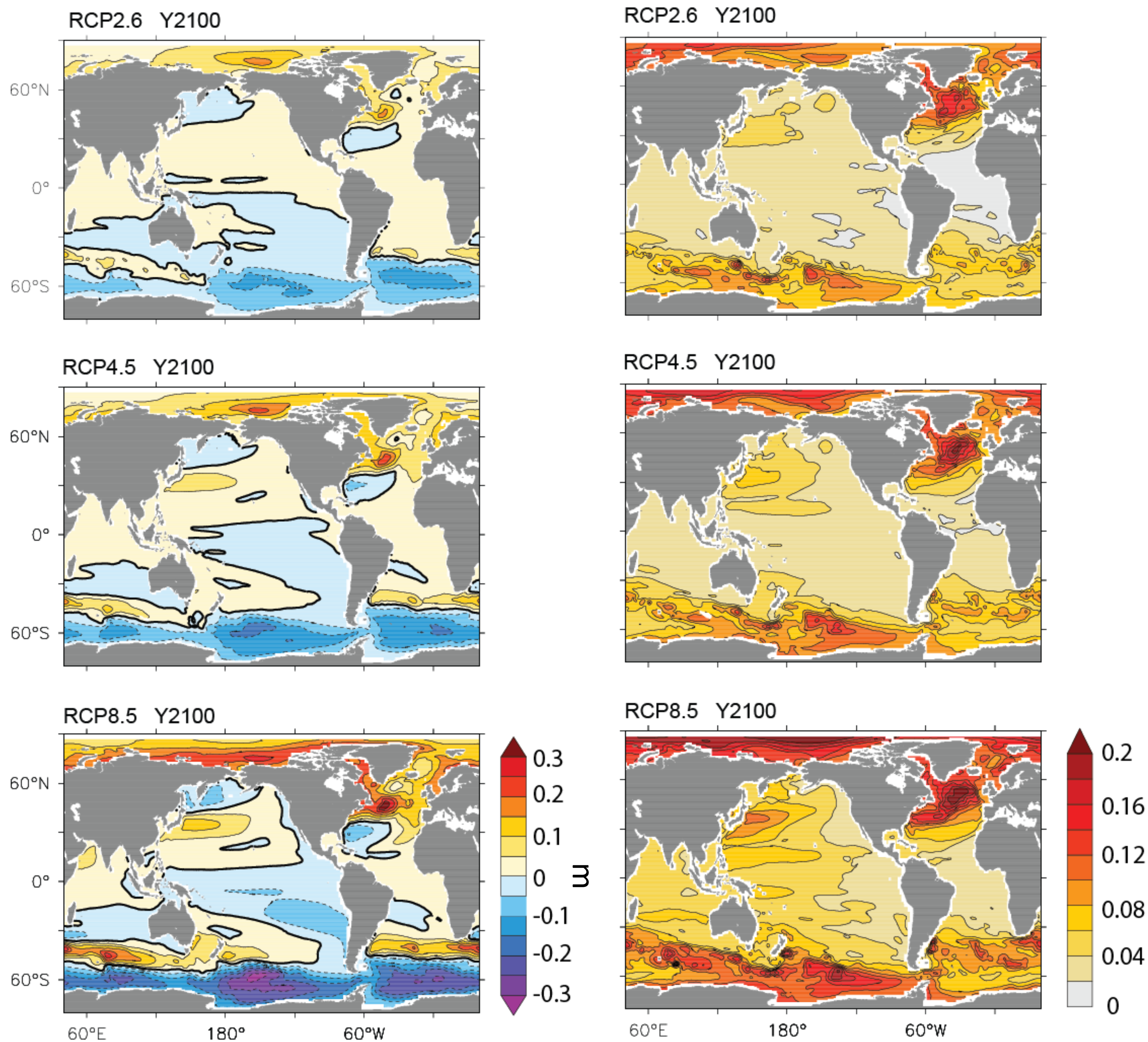




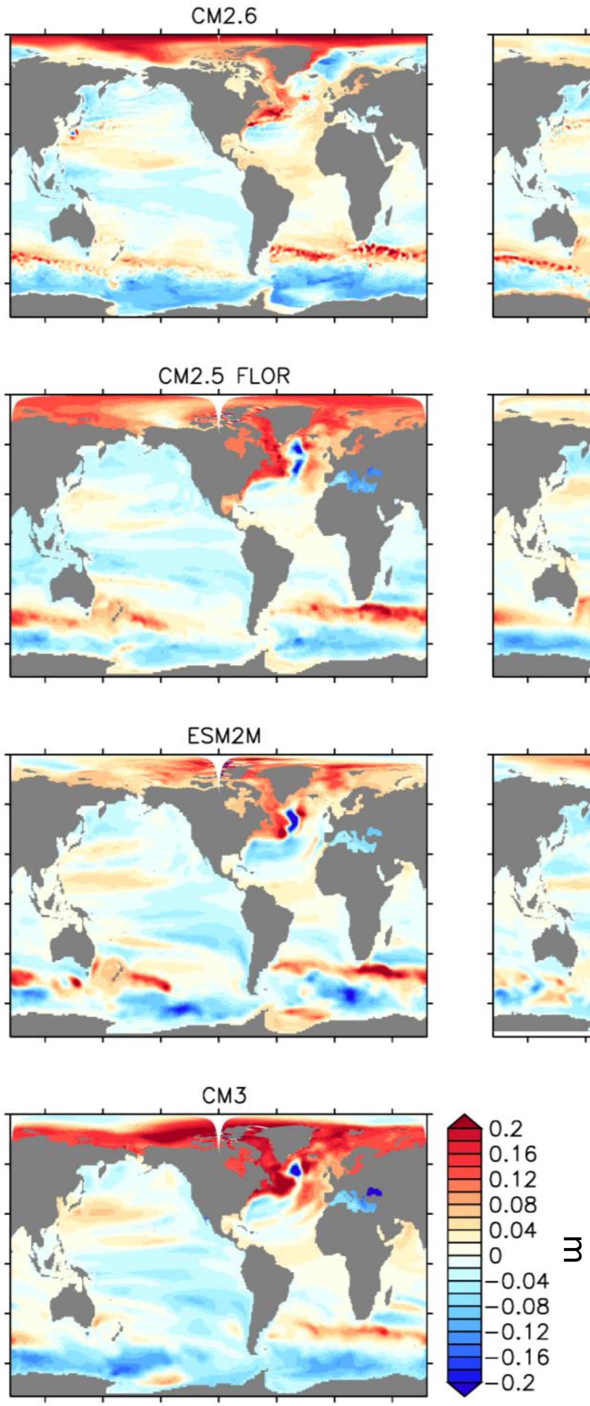
- The global mean value is subtracted.
- Mass moves from ocean interior to the shelf region.
- Ocean bottom pressure increases on the shelf, especially east of the U.S.
- Ocean bottom pressure decreases in ocean interior.

CMIP5 Models

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



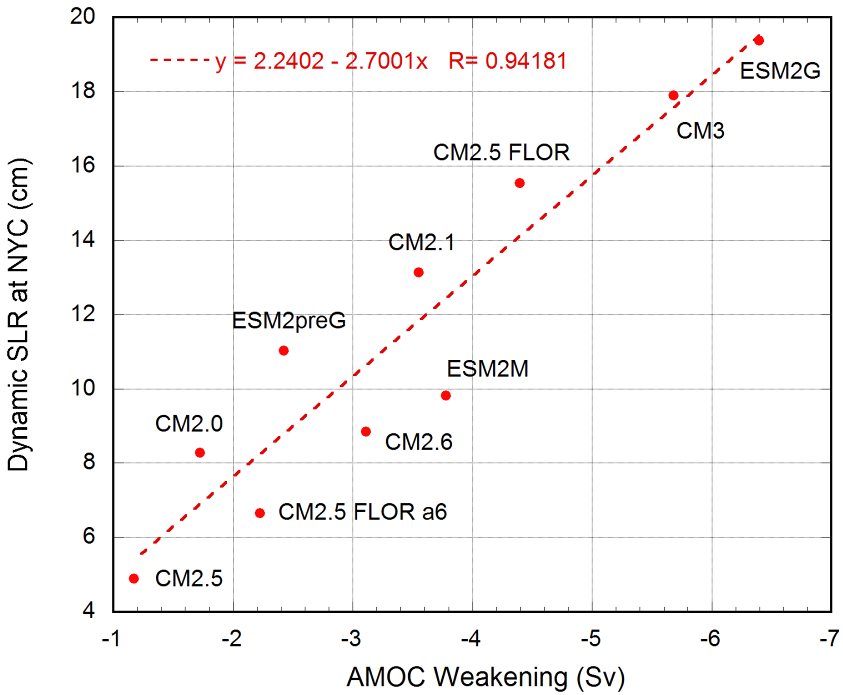
Yin, GRL, 2012

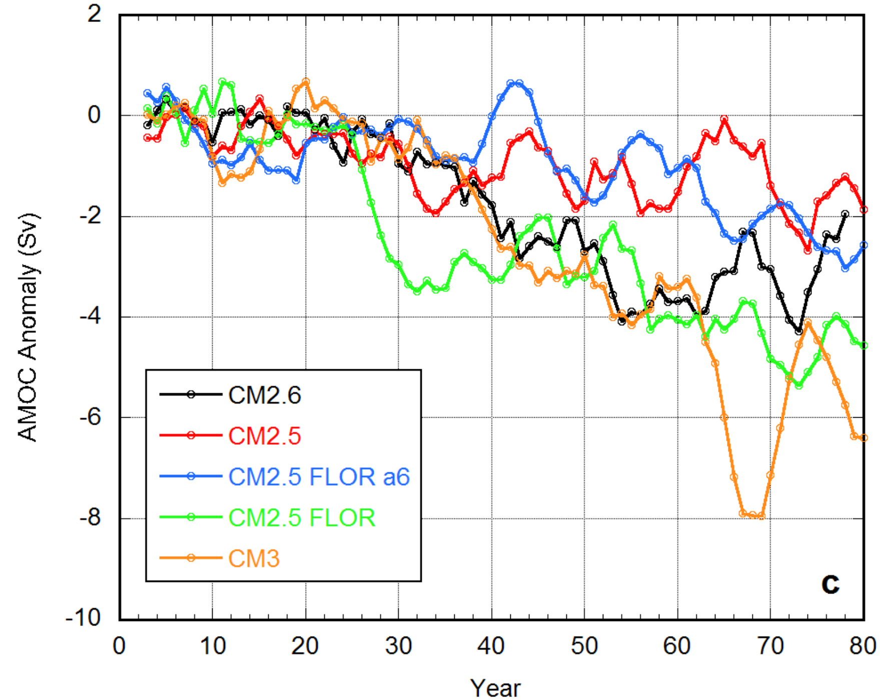


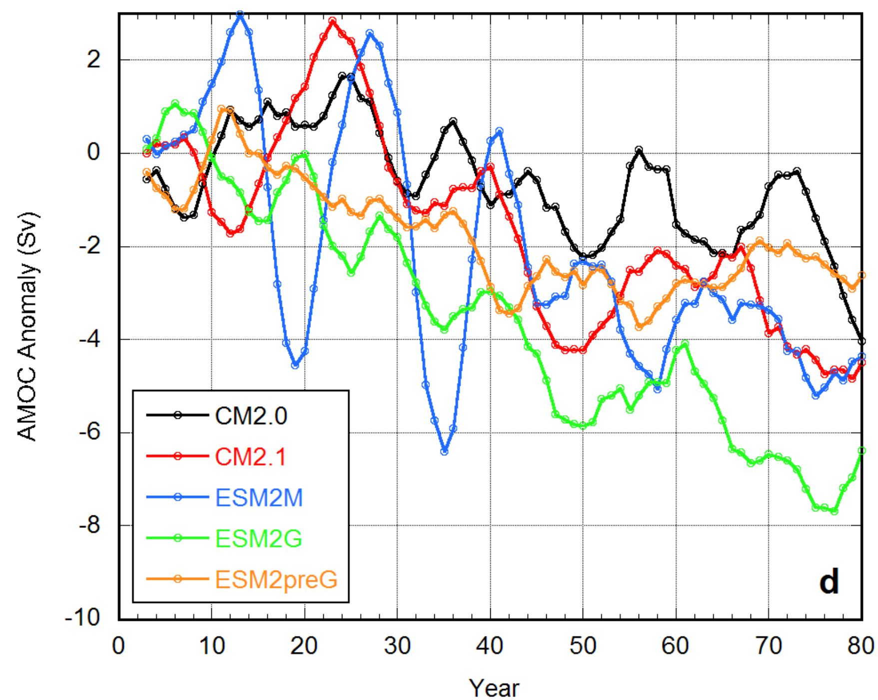
- Ten GFDL models
- 1% yr^{-1} $2xCO_2$ experiments
- Dynamic sea level change relative to the global mean at CO_2 doubling

Yin et al., 2016, in preparation

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.