Regionalizing Sea-level Rise Projections for Urban Planning

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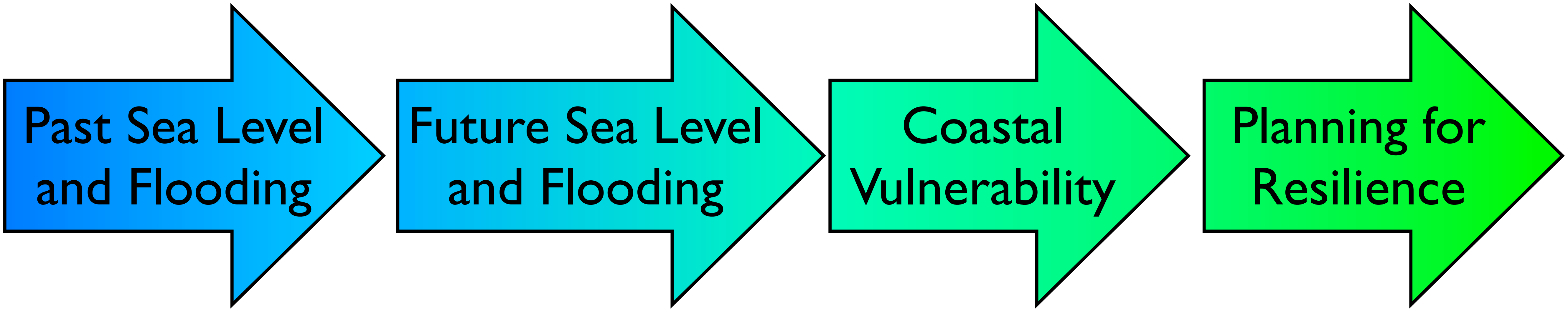
Students and Postdocs: Carling Hay, Eric Morrow (Harvard)

DIMACS/CCIADA Workshop on Urban Planning for Climate Events
23 September 2013

The coastal impacts, vulnerability and adaptation knowledge chain



Coastal Climate Change Research for Resilience

Past Sea Level and Flooding → Future Sea Level and Flooding → Coastal Vulnerability → Planning for Resilience

Institute of Marine & Coastal Sciences

Bloustein School of Planning & Public Policy

Earth & Planetary Sciences

Geography

Center for Advanced Infrastructure & Transportation

Environmental Science

Walton Center for Remote Sensing & Spatial Analysis

Jacques Cousteau National Estuarine Research Reserve

CCICADA

Past Sea Level and Flooding → Future Sea Level and Flooding → Coastal Vulnerability → Planning for Resilience

This talk

Greenberg

Andrews

Lathrop

Ship Bottom, NJ

→ N

2008 (Ken Miller)

The Philadelphia Inquirer

philly.com

Wednesday, Oct. 31, 2012 ★ 2012 Pulitzer Prize Winner ★ $1

Death Toll Hurricane claims 50 on East Coast.

New York City Devastating blow cripples Big Apple.

Powerless Fallen trees leave millions in dark.

Swath of Destruction

Deluged Shore towns face daunting cleanup

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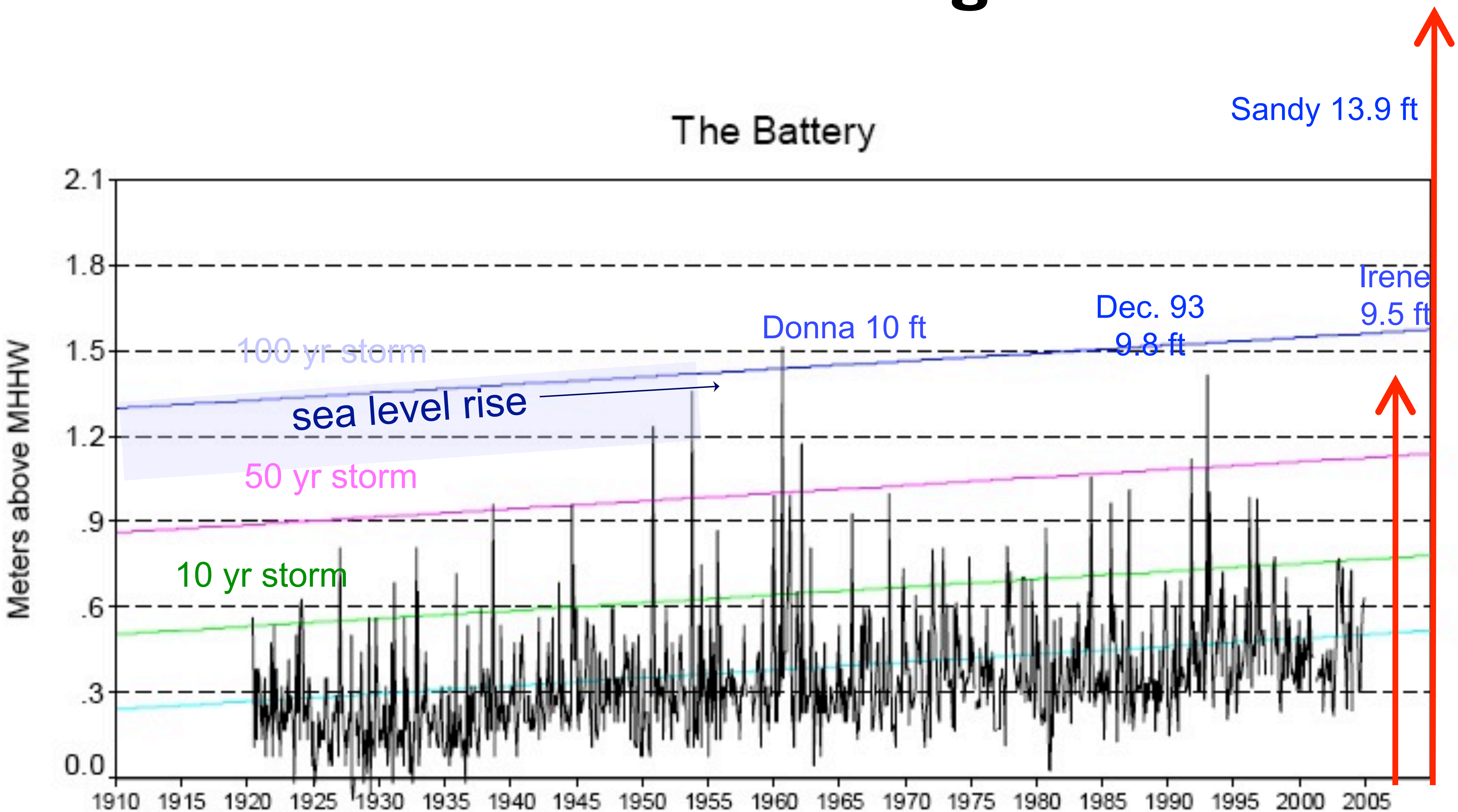
October 31, 2012

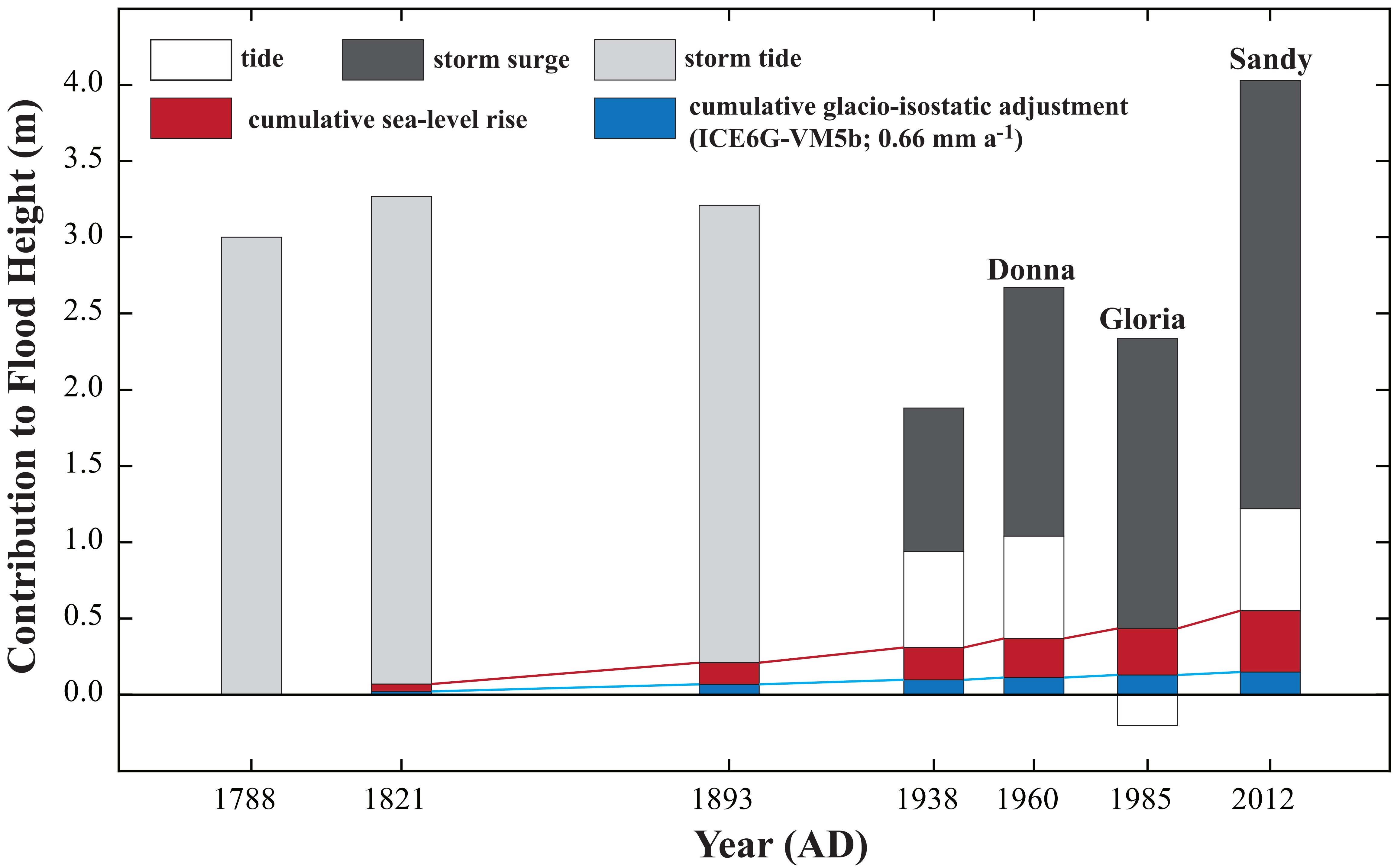
Storm surges take place in a context of sea-level change



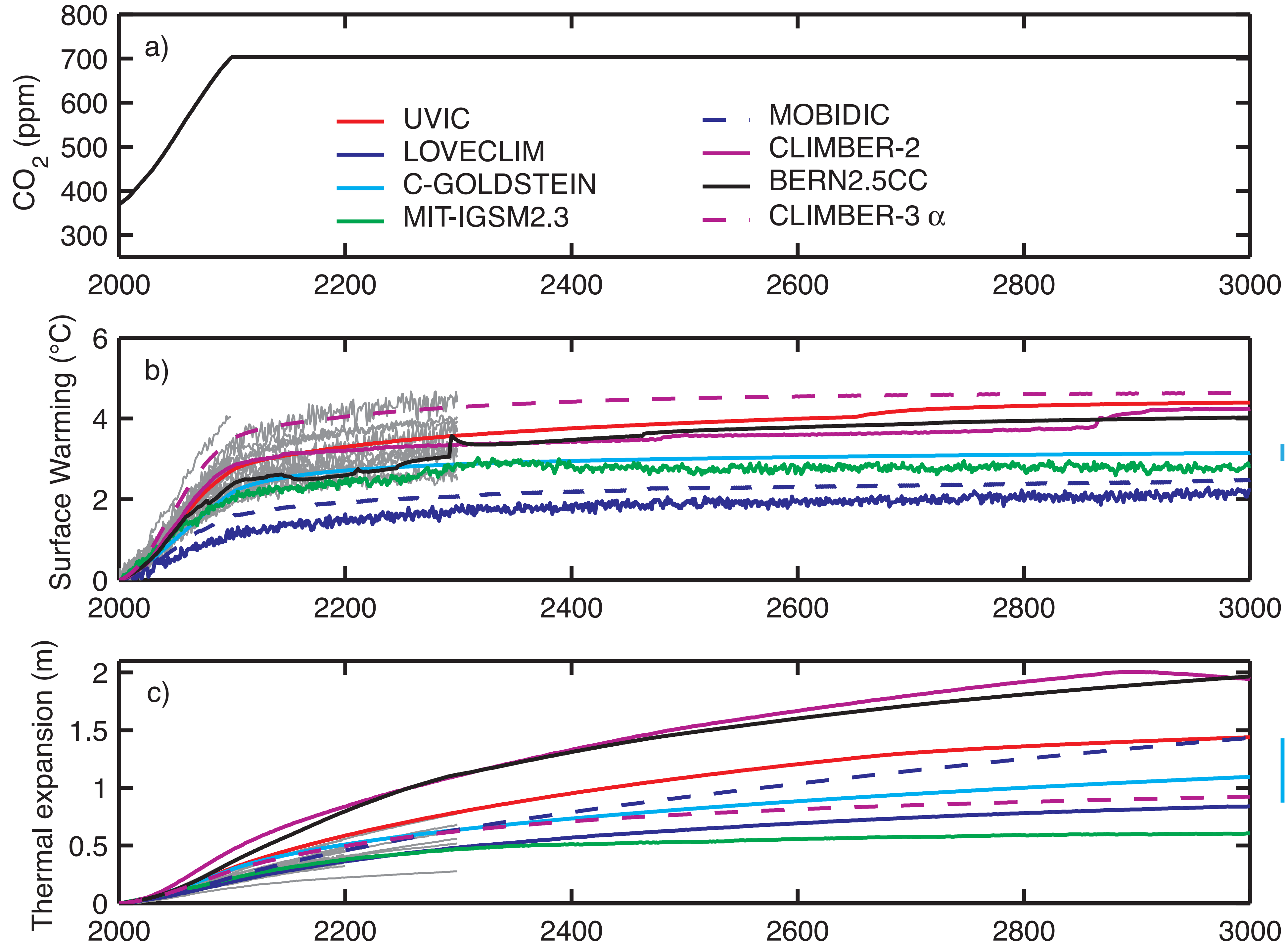
Heights in blue relative to MLLW (FEMA standard)

Miller; modified after Zervas (2005)

Kemp & Horton (2013) estimates of the contribution of historical sea-level rise to flooding at the Battery



Dominant factors in global sea level rise: 1. Thermal Expansion

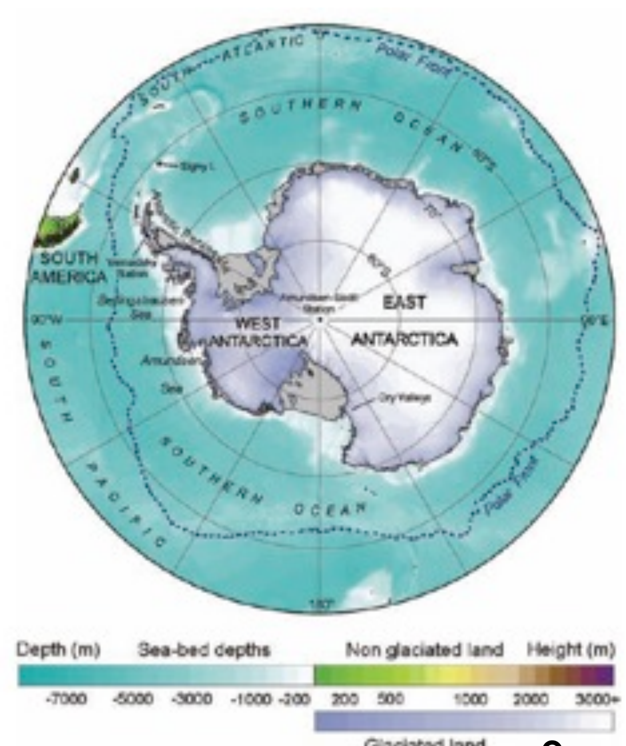


Compare observed thermal expansion of about 1.0 mm/yr from 1983-2003 (Domingues et al., 2008)

Meehl et al. (2007)

Dominant factors in global sea level rise: II. Glacier and ice sheet melt

	Total Hazard
Non-polar glaciers and ice caps	0.26 ± 0.11 m
Greenland & Antarctic glaciers and ice caps	0.46 ± 0.17 m
Greenland Ice Sheet	7 m
West Antarctic Ice Sheet	5 m
East Antarctic Ice Sheet	52 m



Maps by P. Fretwell (British Antarctic Survey)

Lemke et al. (2007); Bamber et al. (2001); Lythe et al. (2001)

Road map

- Why does regional sea level differ from global sea level?
- What sort of regional sea level variations do we see?
- How can we incorporate these into projections?
- [How can understanding past sea level help us move beyond informed expert judgment for projecting ice sheet behavior?]

Why does regional sea level differ from global mean sea level?

Global Sea Level change is not the same as local sea level change

- Ocean dynamic effects
- Mass redistribution effects: Gravitational, elastic and rotational
- Natural and groundwater withdrawal-related sediment compaction
- Long term: Isostasy and tectonics

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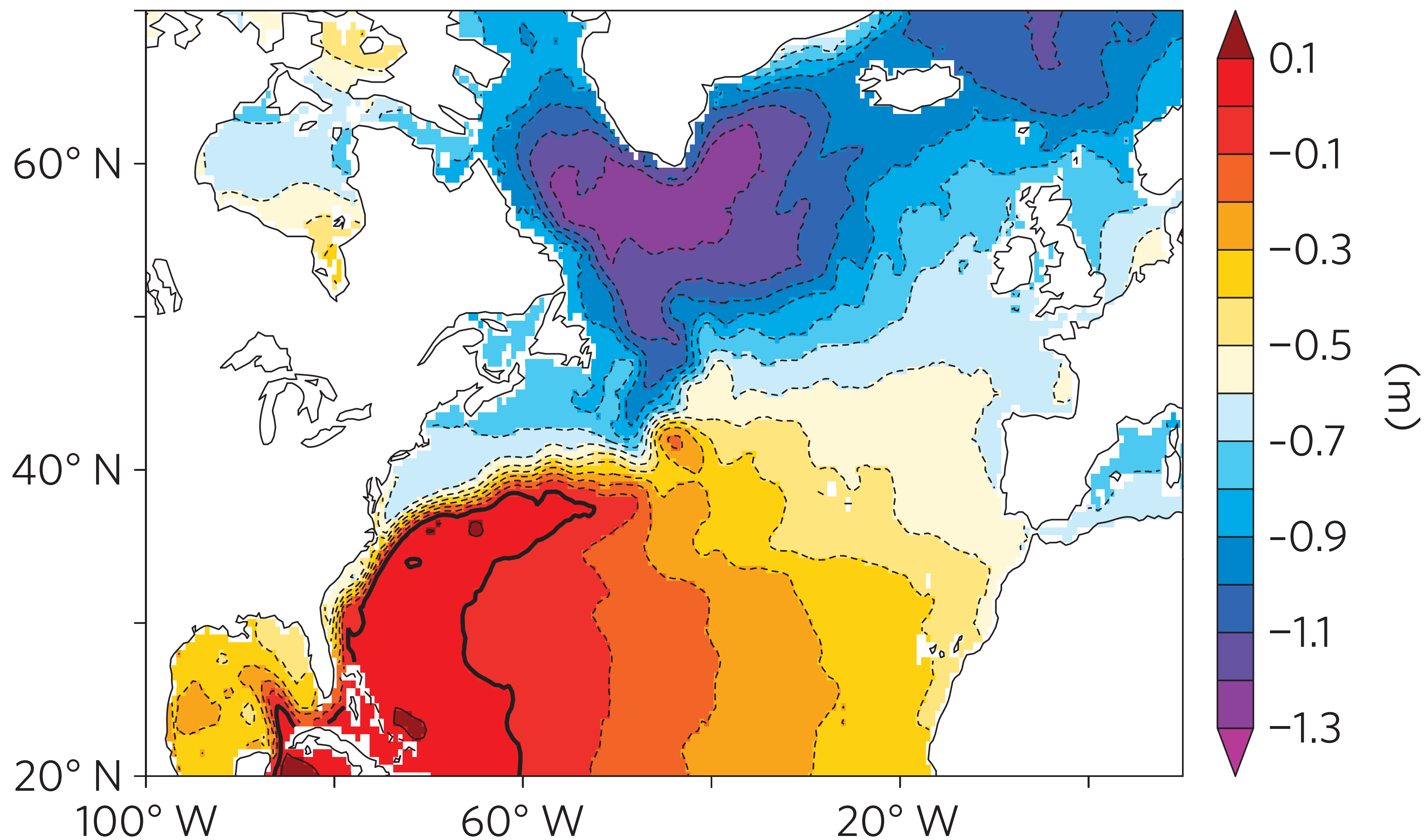

SSH, 1992-2002

Yin et al. (2009)

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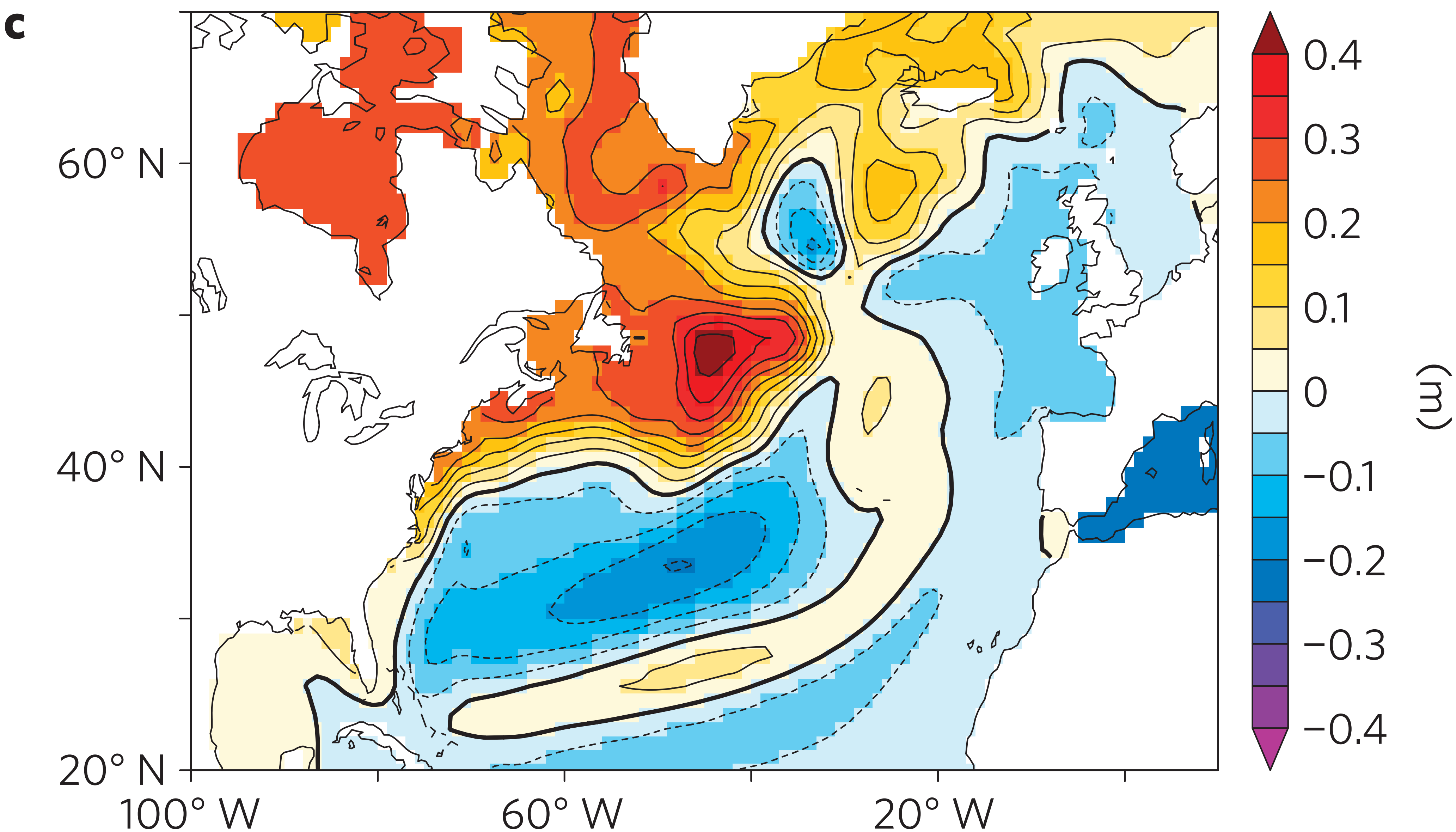

Projected dynamic sea level anomalies from changes in the Atlantic Meridional Overturning Circulation in A1B in 2091-2100, relative to 1981-2000

Yin et al. (2009)

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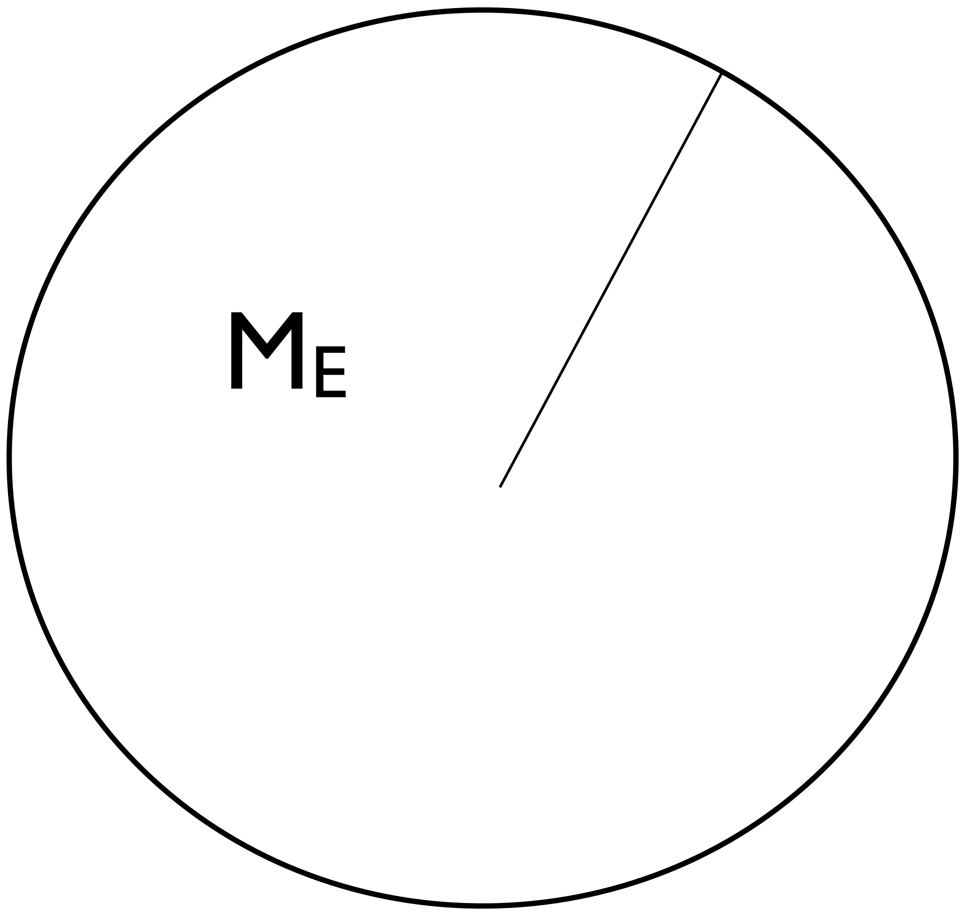

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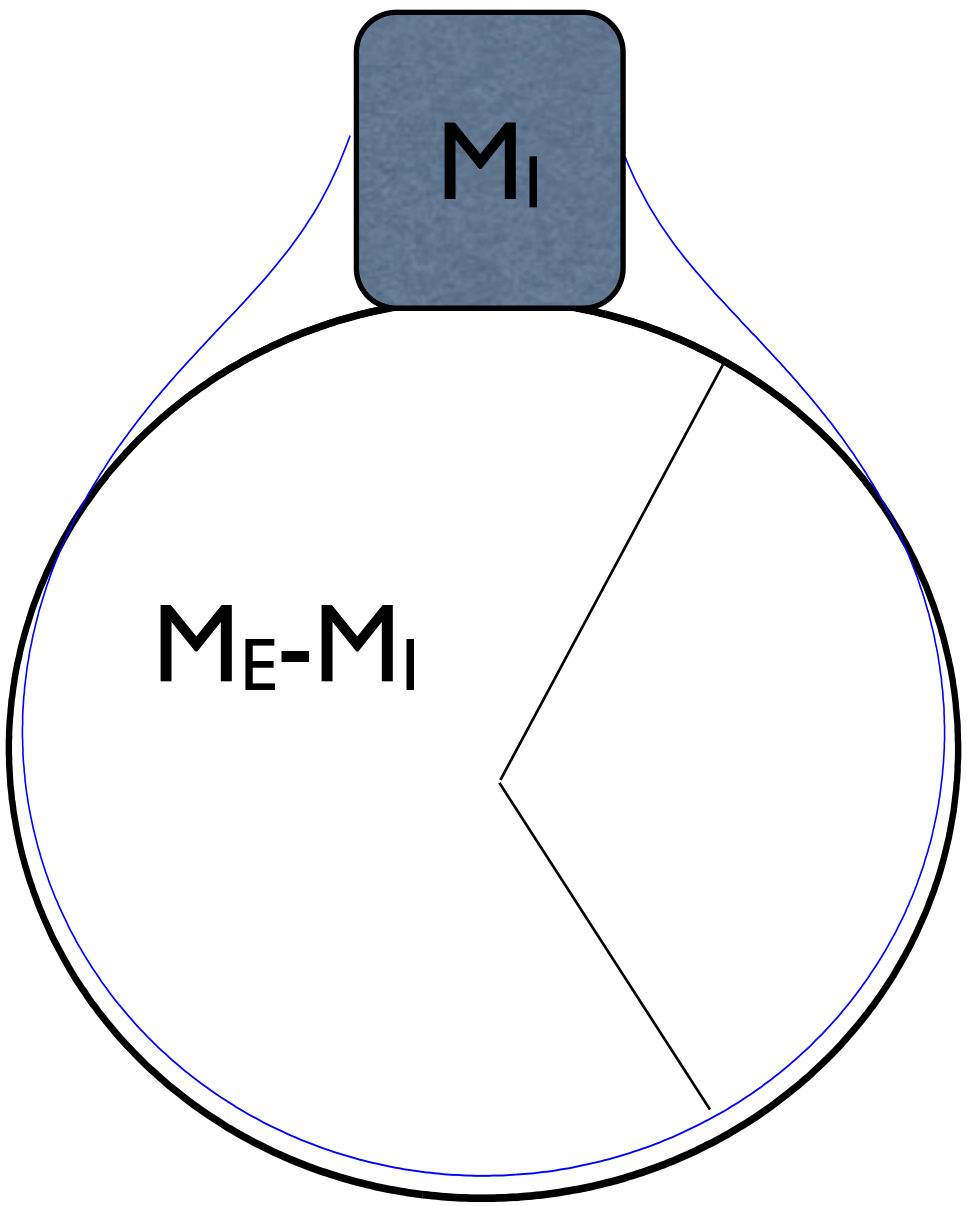

Not to scale!

Farrell & Clark (1976), after Woodward (1888)

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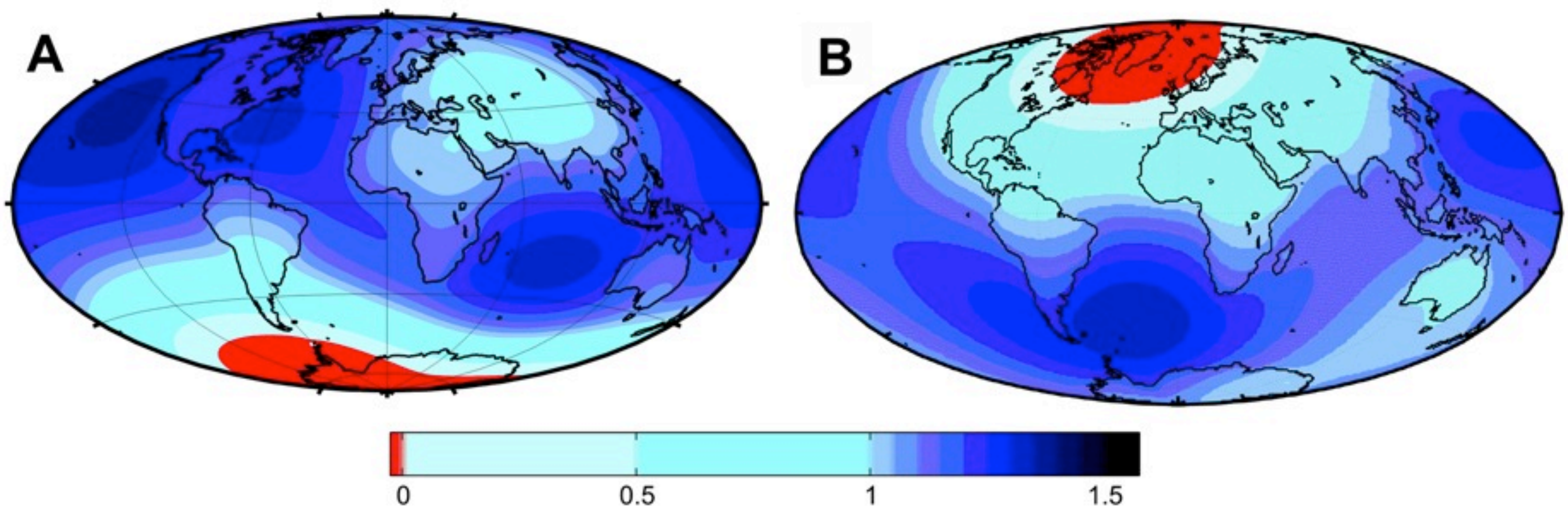
Gravitational-Elastic-Rotational Fingerprints of Greenland and WAIS melting, per meter GSL rise

West Antarctica *Greenland*



Mitrovica et al. (2011)

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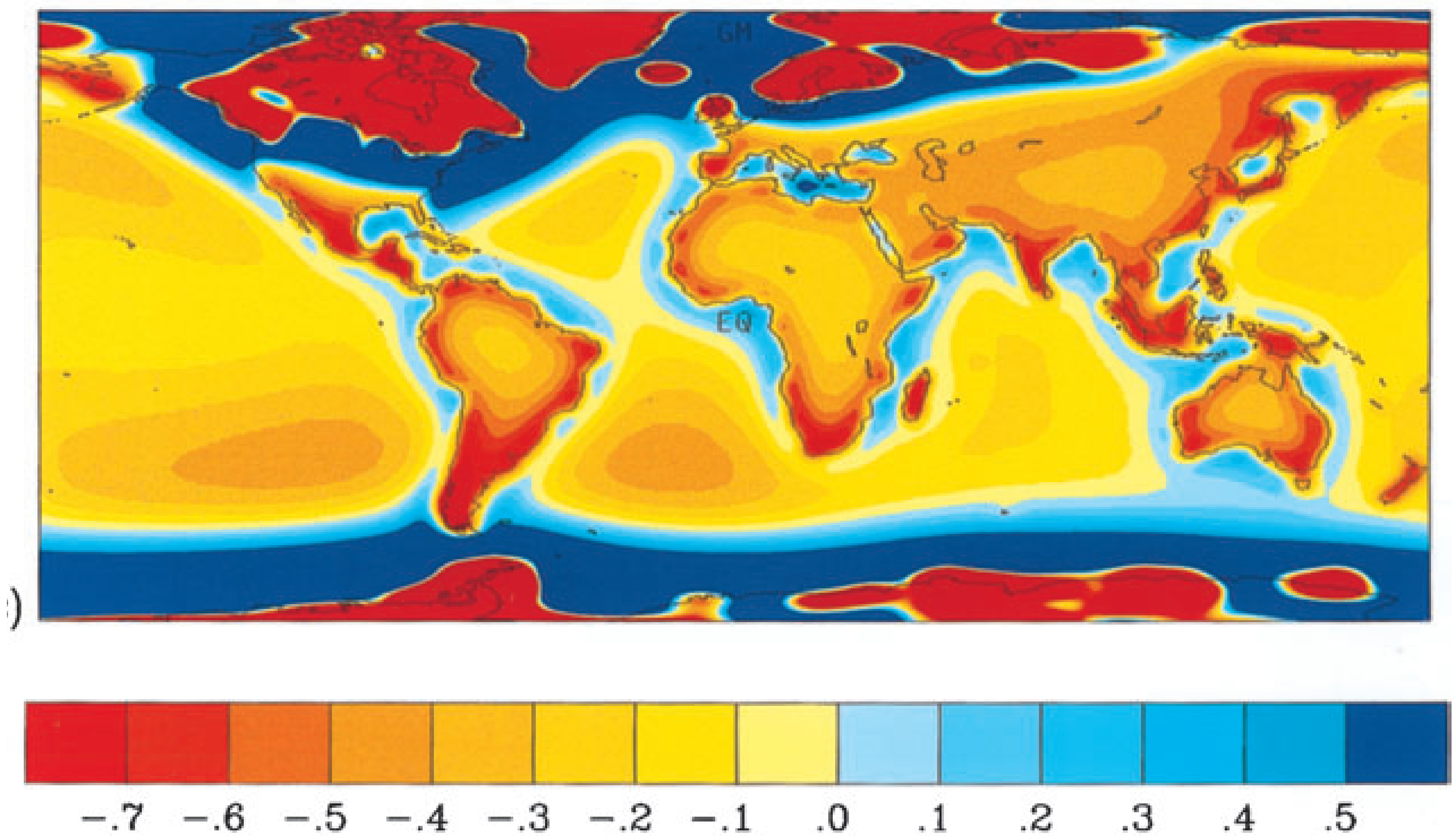
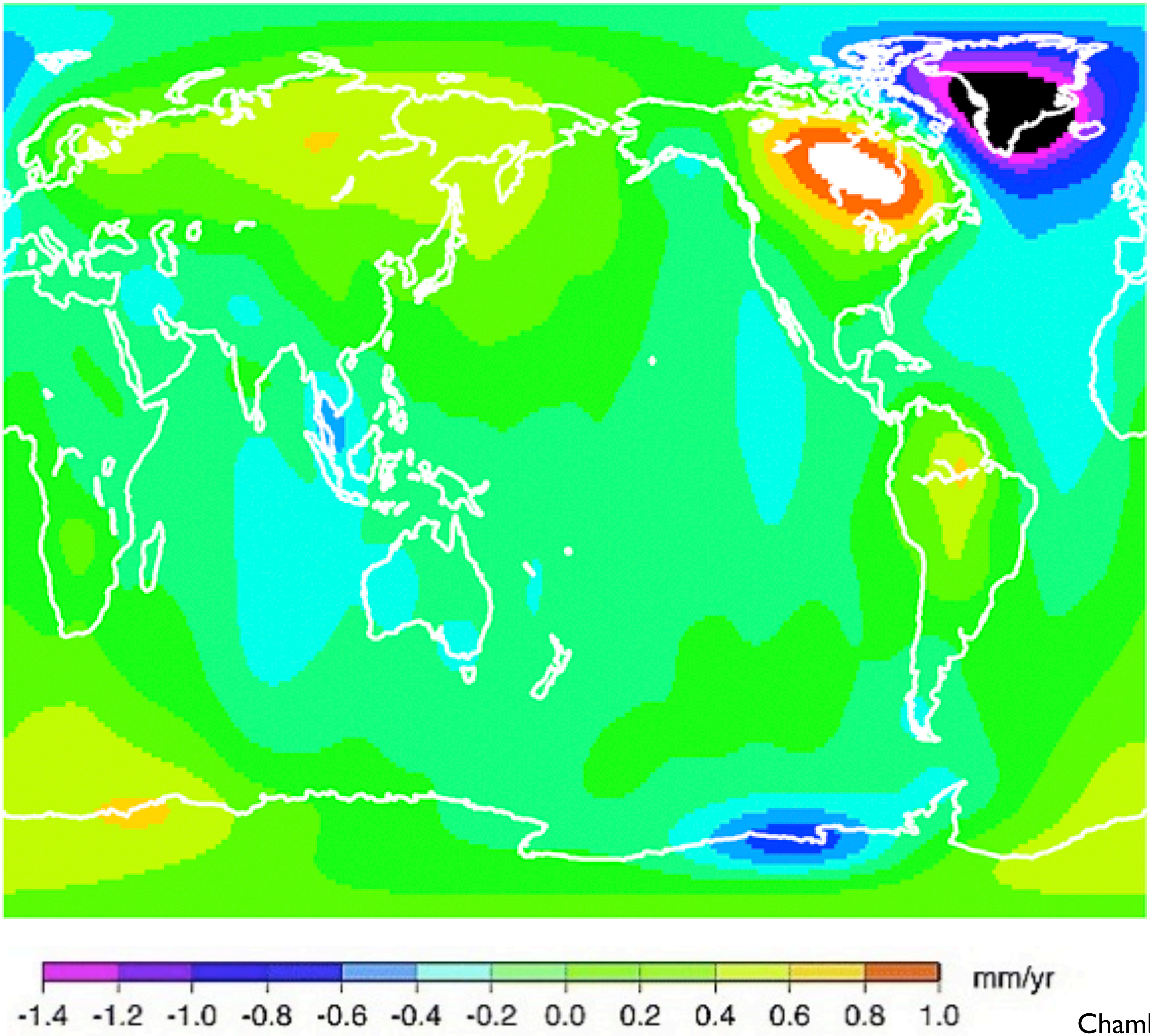


Sea-level rise due to GIA (mm/y)

Mitrovica et al., 2001

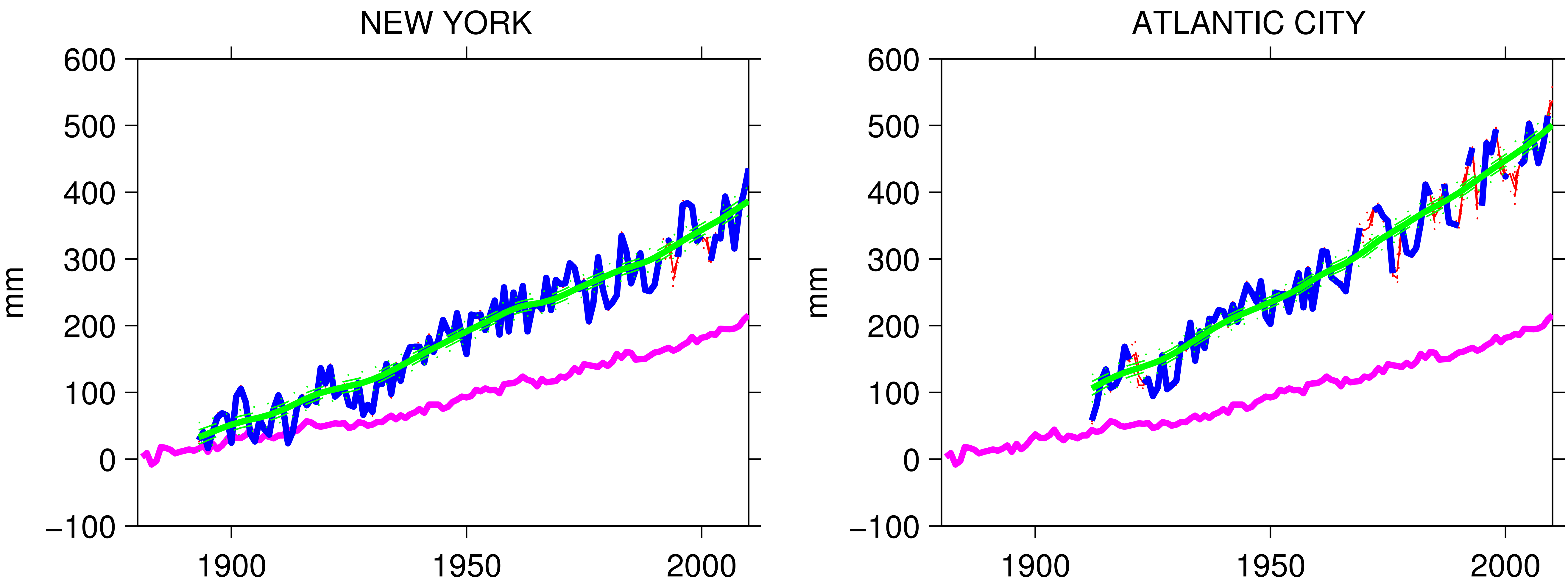
Geoid trends inferred from GRACE, 2002-2009



Chambers et al. (2010)

What sort of regional variations do we see?

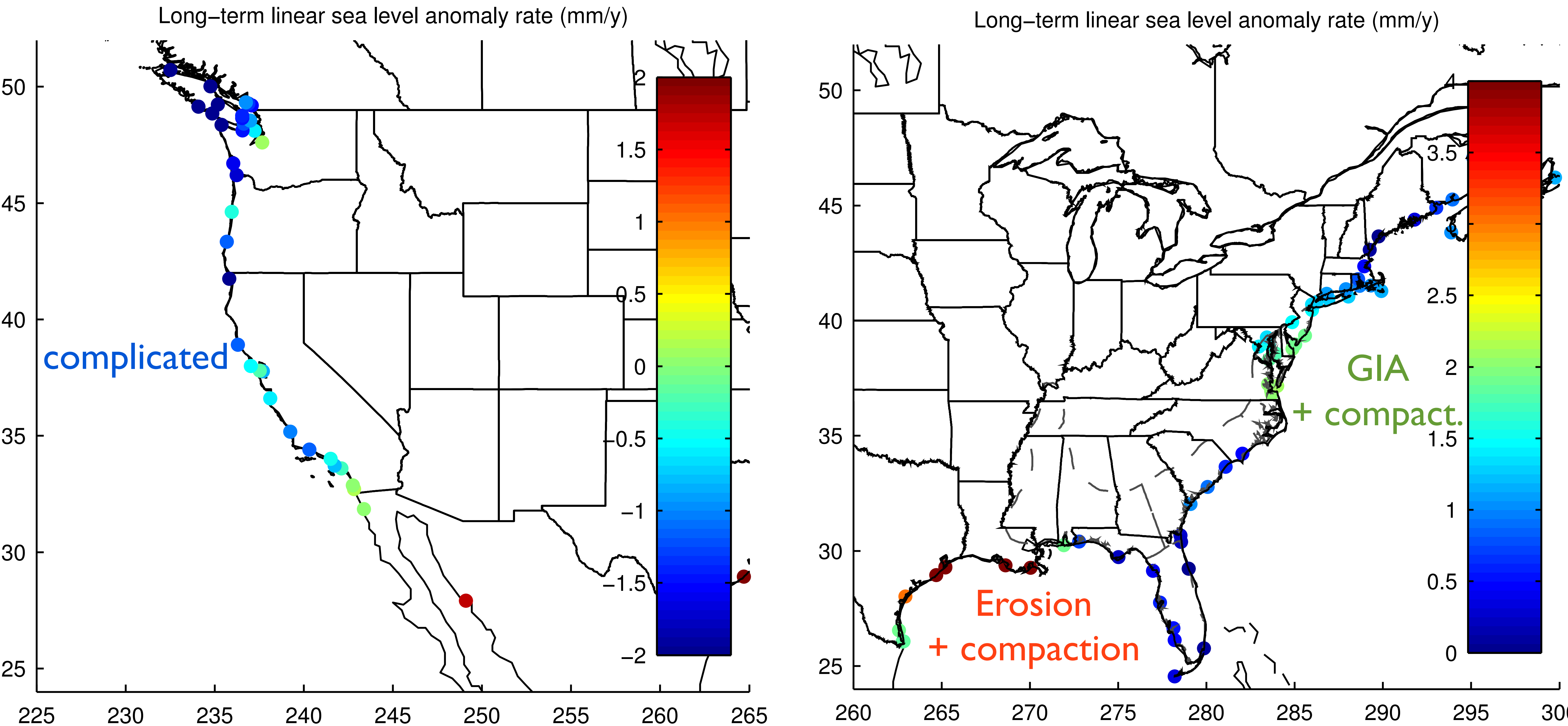
What do we actually see?



Purple: Church & White (2011) GSL
Blue: Tide gauge data
Green: Long-term sea-level signal

~1.3 mm/y GIA
An additional ~1 mm/y on the shore
Interannual variability of ~10 cm

Local long-term ~linear sea-level anomaly rate (mm/y)



after Kopp (2013)

nature climate change

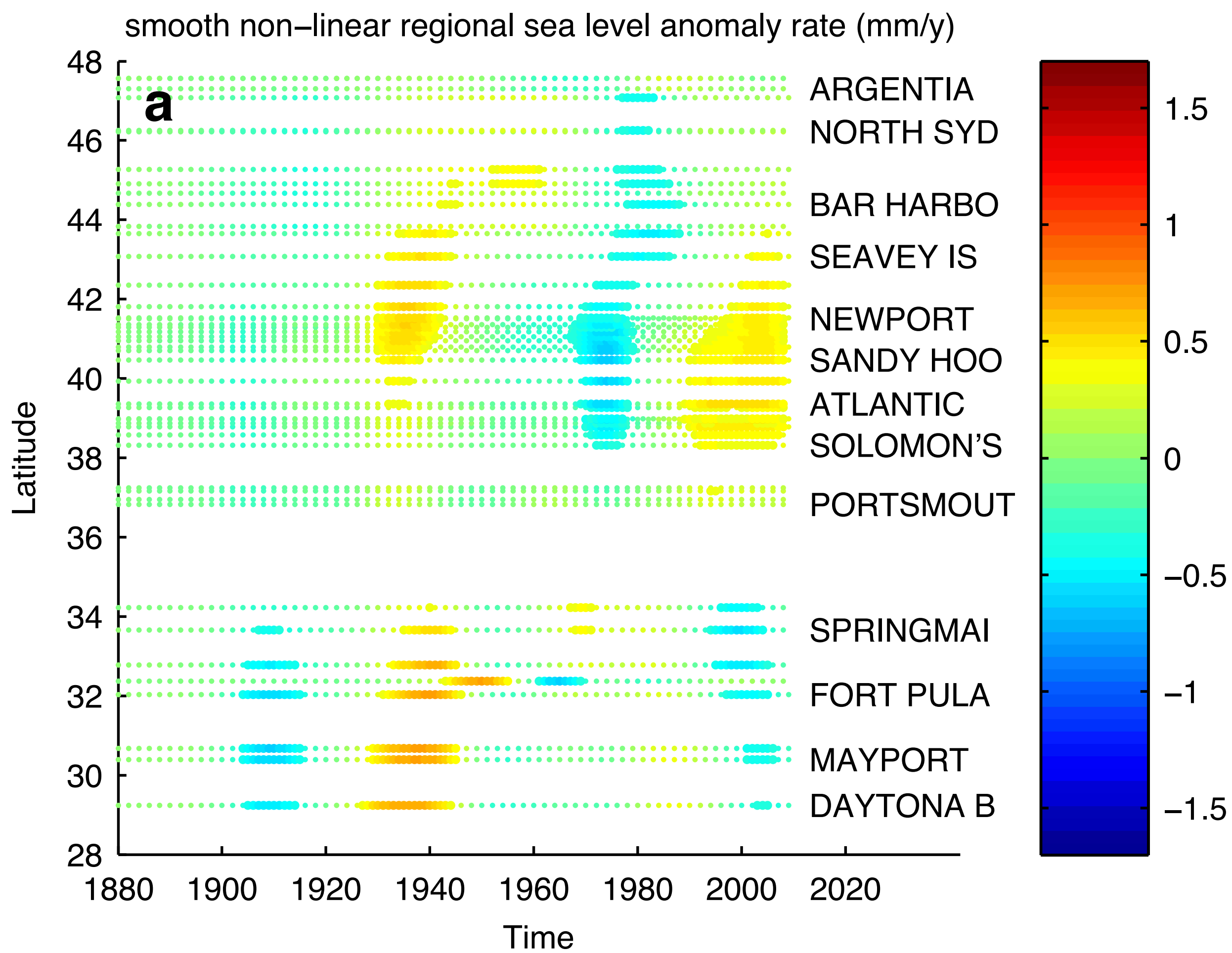
LETTERS

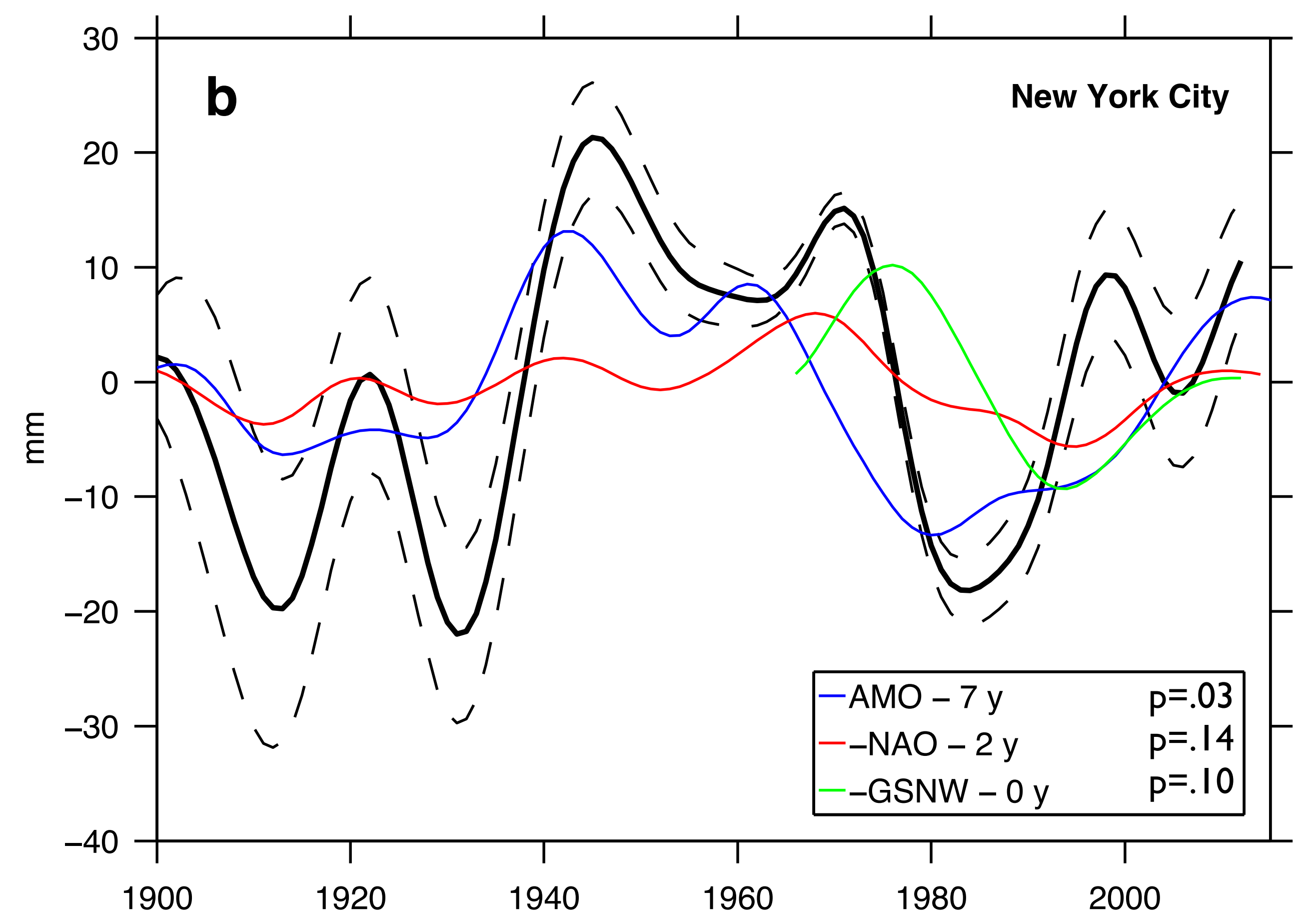
PUBLISHED ONLINE: 24 JUNE 2012 | DOI: 10.1038/NCLIMATE1597

Hotspot of accelerated sea-level rise on the Atlantic coast of North America

Asbury H. Sallenger Jr*, Kara S. Doran and Peter A. Howd

Really? Yes, but it's too early to tell if it goes beyond natural variability (but it will likely, eventually)...





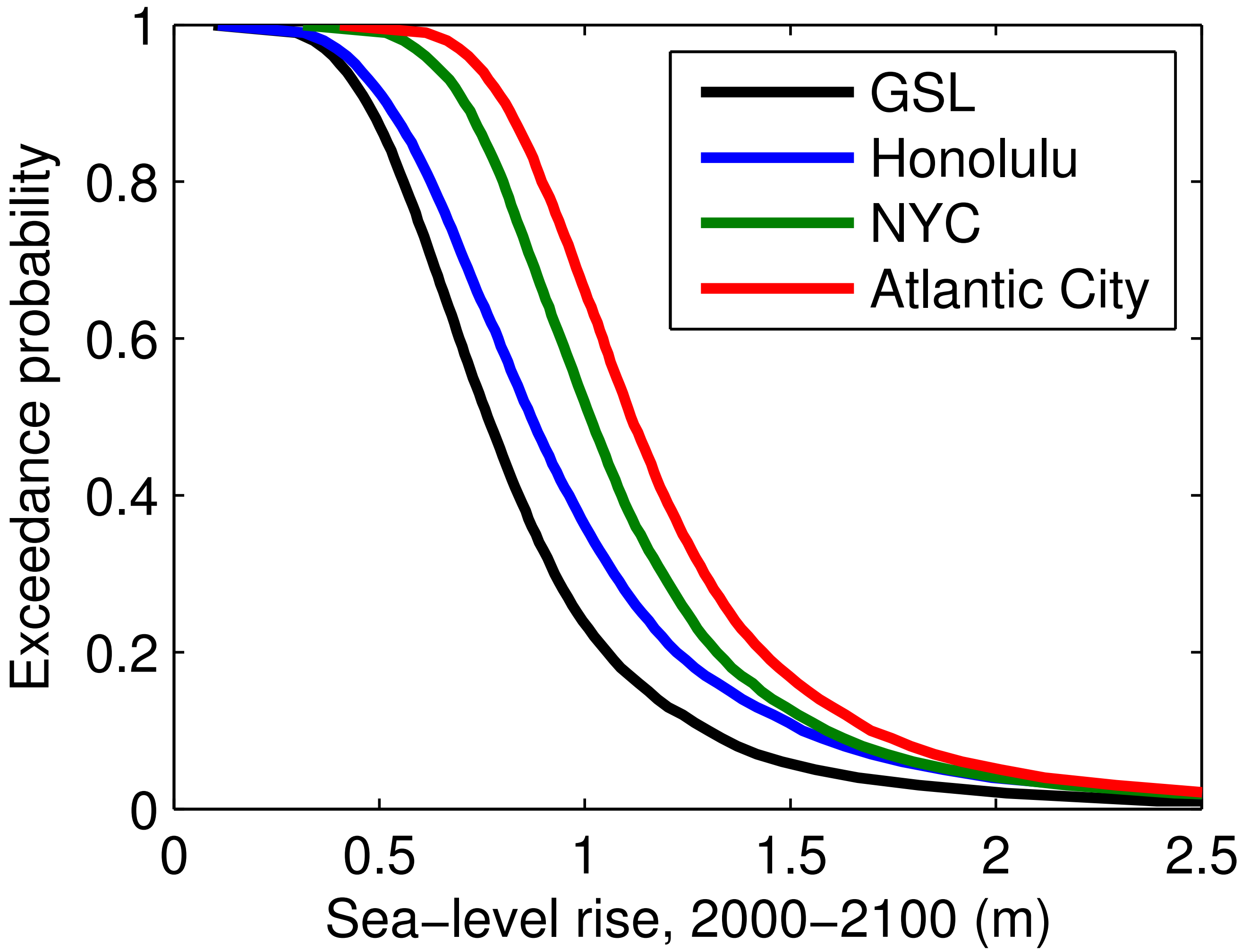
How can we incorporate these into projections?

Scenario-based localization example: SLR scenarios for NYC and New Jersey

	Global effects				**Regional effects**			**Local eff.**	**Totals**		
	Thermal cm	Glaciers cm	GIS cm	AIS cm	Ocean dynamics cm	Mass redist. cm	GIA cm	Coastal subsidence cm	Global cm	NYC cm	Shore cm
2030 best	**5**	**3**	**3**	**2**	**6**	**-1**	**4**	**3**	**13**	**22**	**25**
2030 low	2	3	1	1	2	-1	3	2	8	15	18
2030 high	11	4	4	6	8	-1	5	4	21	30	33
2030 higher	11	4	4	6	8	-1	5	4	24	36	40
2050 best	**10**	**6**	**8**	**2**	**10**	**-4**	**7**	**5**	**25**	**38**	**43**
2050 low	4	5	2	1	3	-1	5	4	16	27	32
2050 high	19	7	10	9	13	-3	9	6	39	52	57
2050 higher	19	7	10	9	13	-3	9	6	45	62	68
2100 best	**24**	**14**	**27**	**8**	**20**	**-13**	**13**	**10**	**73**	**93**	**103**
2100 low	10	13	4	2	5	-3	9	8	40	64	74
2100 high	46	19	35	33	25	-11	17	12	117	139	149
2100 higher	46	19	35	33	25	-11	17	12	133	164	176

after Miller et al. (in rev.)

Probabilistic localization example



cm	**95%**	**50%**	**33%**	**5%**	**1%**
GSL	47	77	89	151	233
Honolulu	50	87	102	181	288
NYC	67	101	115	186	286
Atlantic City	77	112	125	196	298

using Bamber & Aspinall (2013) for ice sheets: 30 cm (10-103 cm, 90% range)
Glaciers from Radic et al. (2013): 20 cm (10-30 cm)
Thermal expansion from NRC (2012): 24 cm (10-46 cm)
Dynamic sea level from Yin et al. (2009)
GIA and subsidence from Kopp (2013)
Fingerprints from Mitrovica

Seaside Heights, NJ

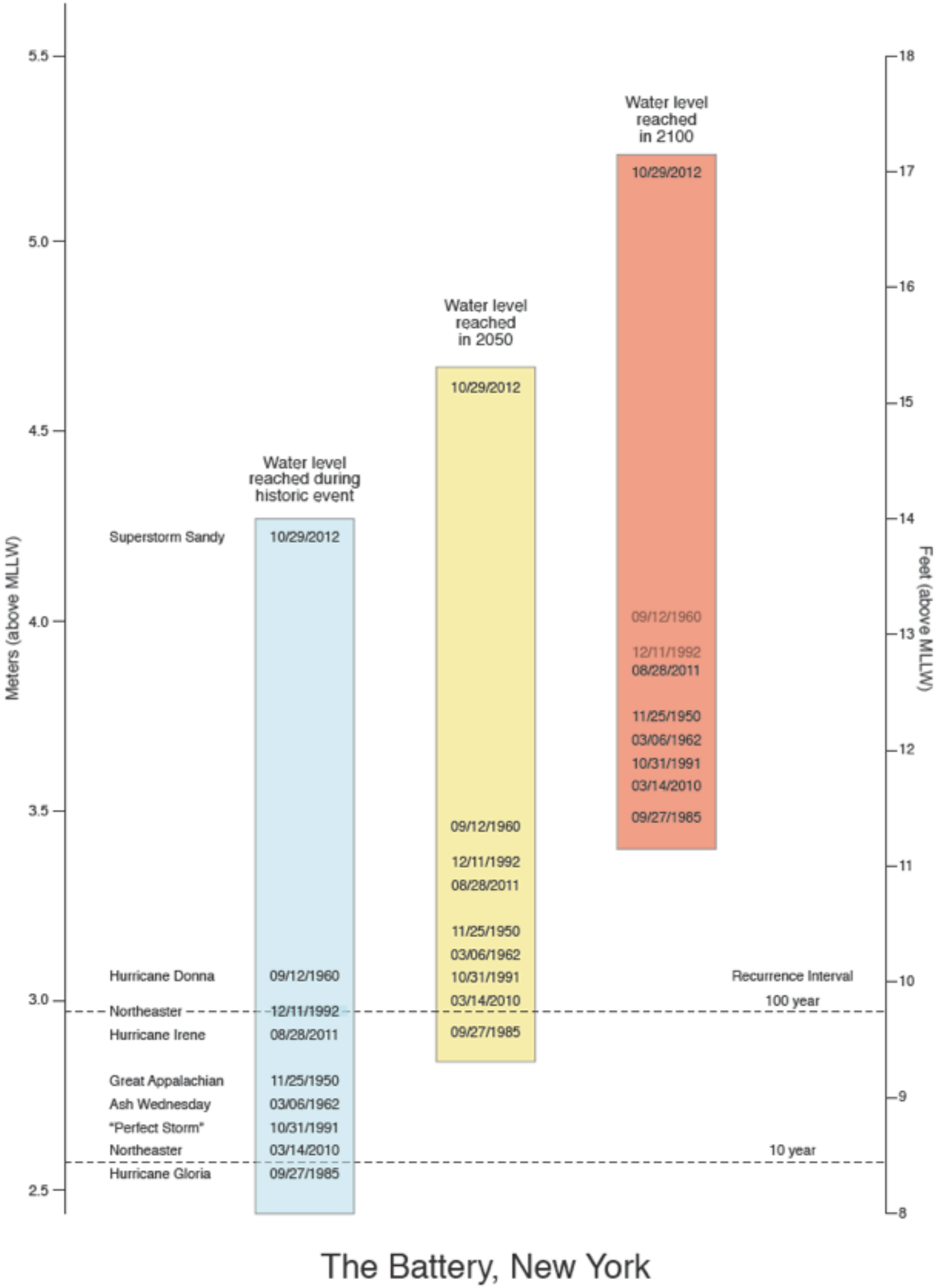
1 foot
(likely by ~2040)

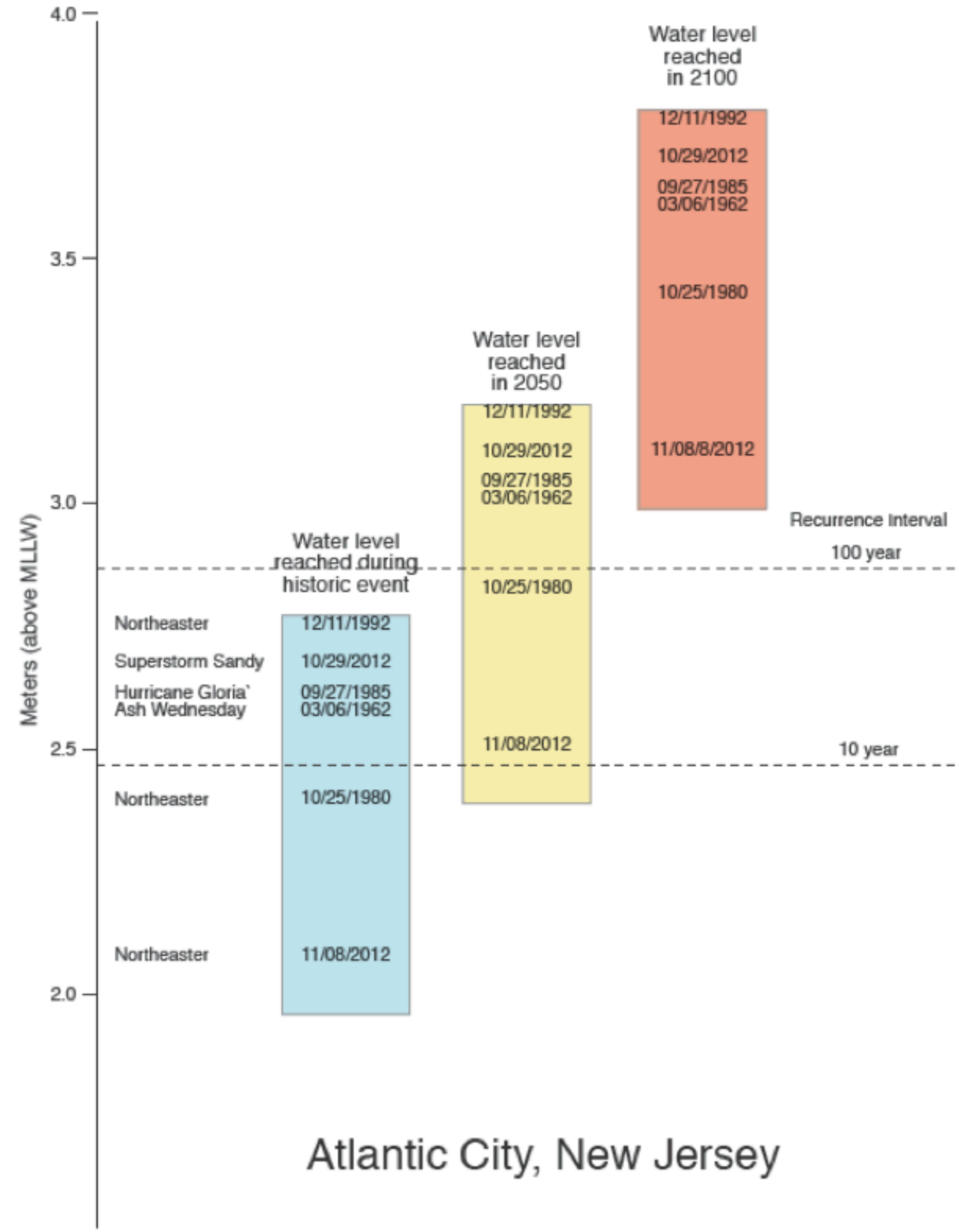
3 feet
(likely by 2090s)

6 feet
(~5% chance by 2100)

Maps available from http://slrviewer.rutgers.edu/ and http://sealevel.climatecentral.org/

Influence of moderate SLR on historical flood levels





Miller et al. (in rev.)

Take-aways

- Regional sea-level rise differs from global mean sea-level rise due to a variety processes; we must understand these processes in order to generate sea-level rise projections that are maximally useful for local decisionmakers.
- Our current best estimates project >1 foot more sea-level rise on the Jersey shore than the global average by 2100, leading to a most-likely projection of ~3.5' on the Shore by 2100, and about a 5% probability of sea-level rise in excess of 6' by 2100.
- These estimates are ultimately informed expert judgment, though informed by modeling output and the historical record. Better pre-historical records, combined with better physical and statistical models, can allow us to advance further.