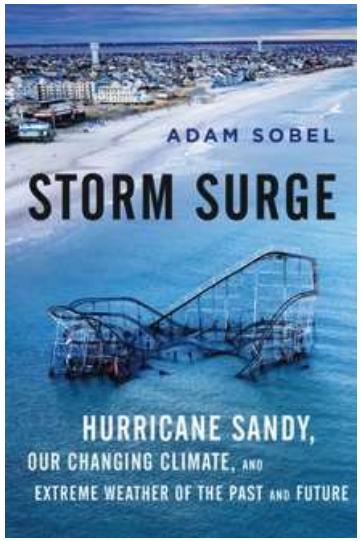
MEOPAR

STORM SURGE

Hurricane Sandy, our Changing Climate, and Extreme Weather of the Past and Future



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Hurricane Sandy and climate change: predictions and responses

Adam Sobel
Columbia University

ICLR
Toronto, ON
September 3, 2015

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

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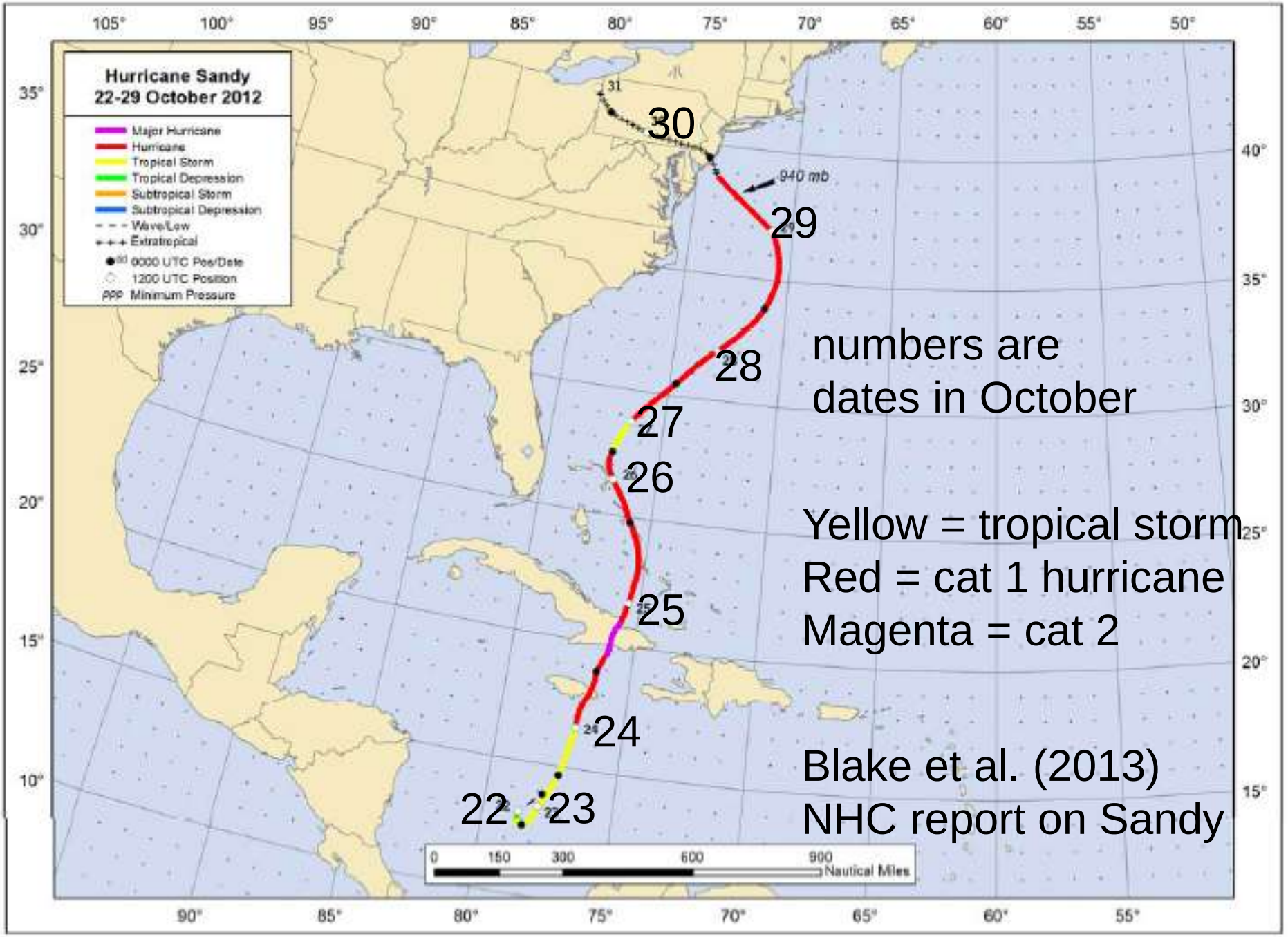
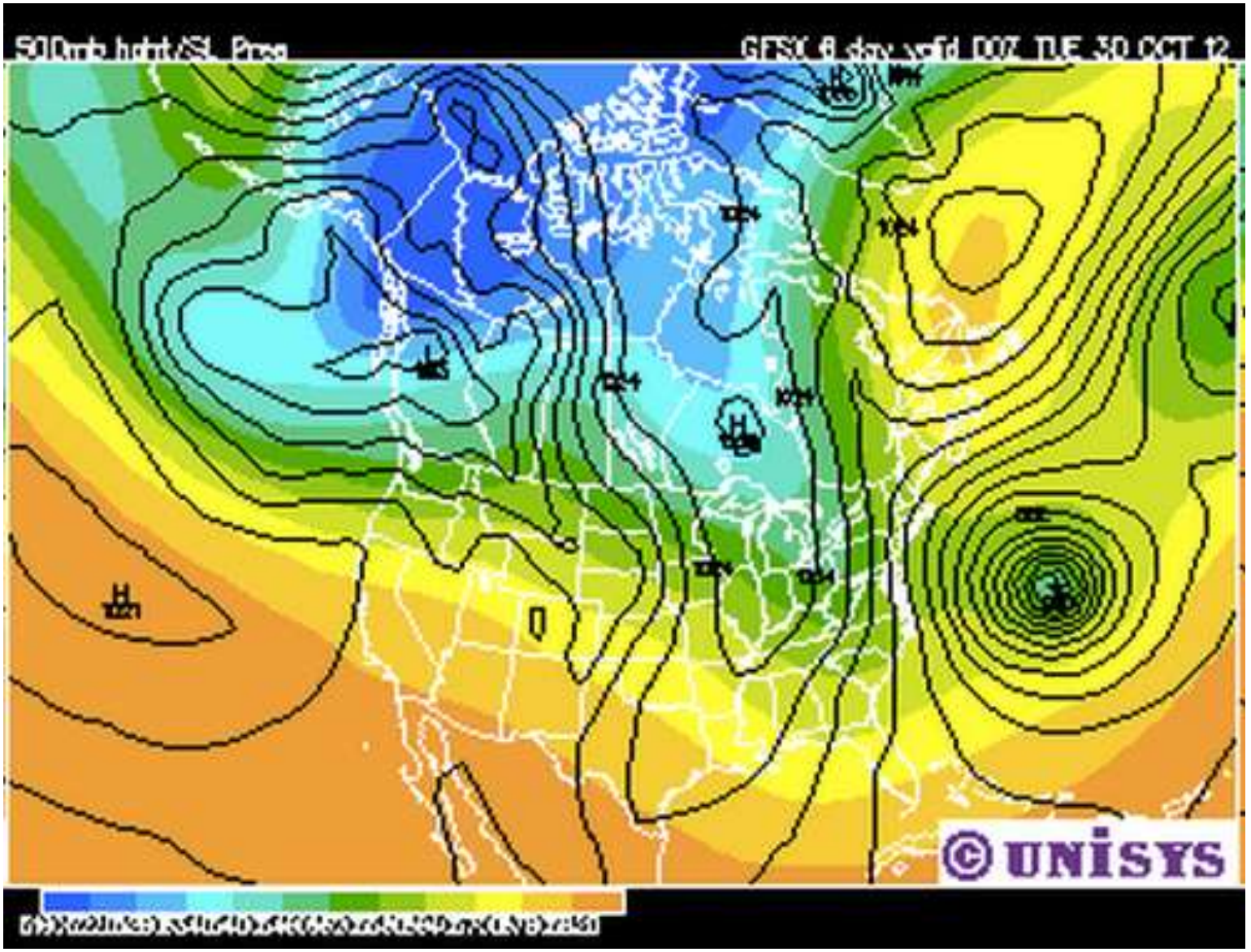

Hurricane Sandy
22-29 October 2012
Major Hurricane
Hurricane
Tropical Storm
Tropical Depression
Subtropical Storm
Subtropical Depression
Wave/Low
Extratropical
0000 UTC Pos/Date
1200 UTC Position
Minimum Pressure
940 mb
numbers are
dates in October
Yellow = tropical storm
Red = cat 1 hurricane
Magenta = cat 2
Blake et al. (2013)
NHC report on Sandy
0 150 300 600 900
Nautical Miles

Deterministic GFS 6-day forecast for Monday night 10/29, made Wed. 10/24



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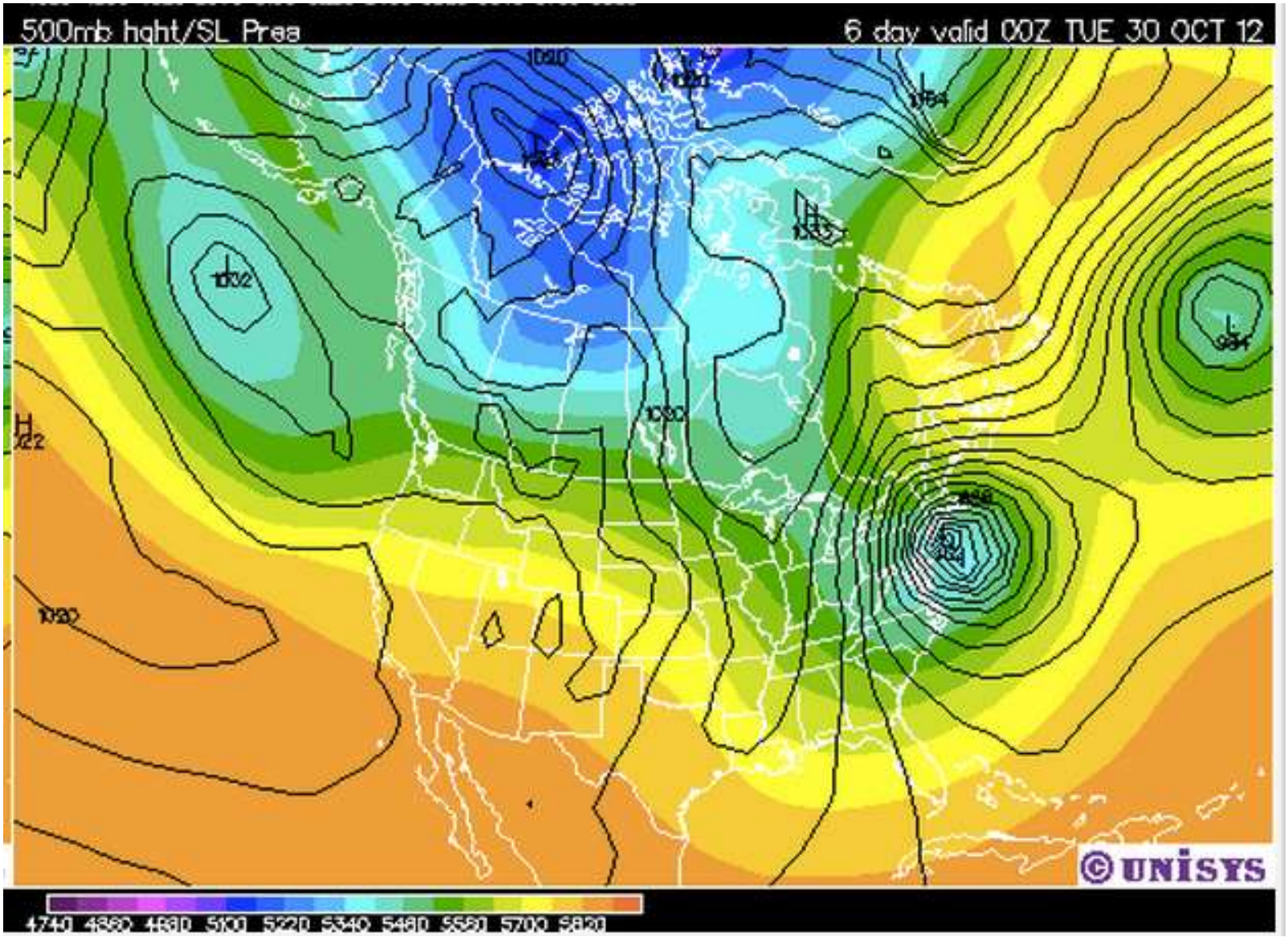
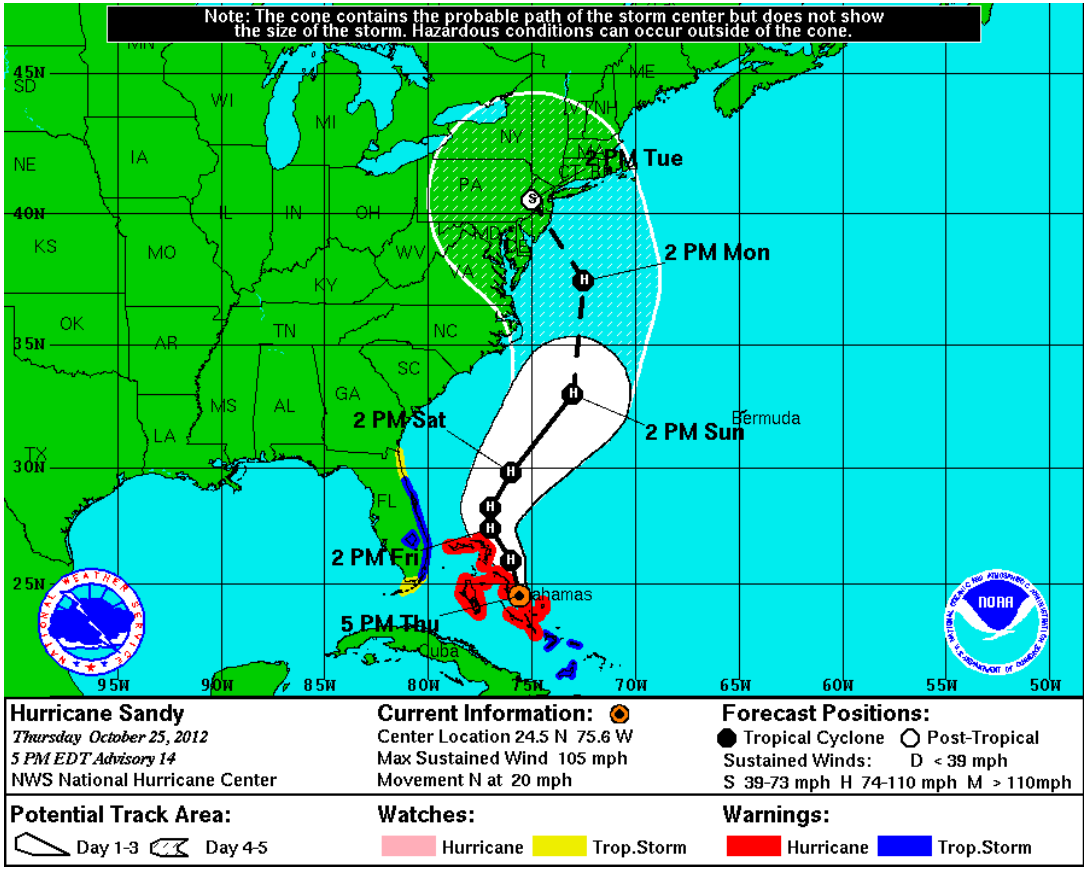
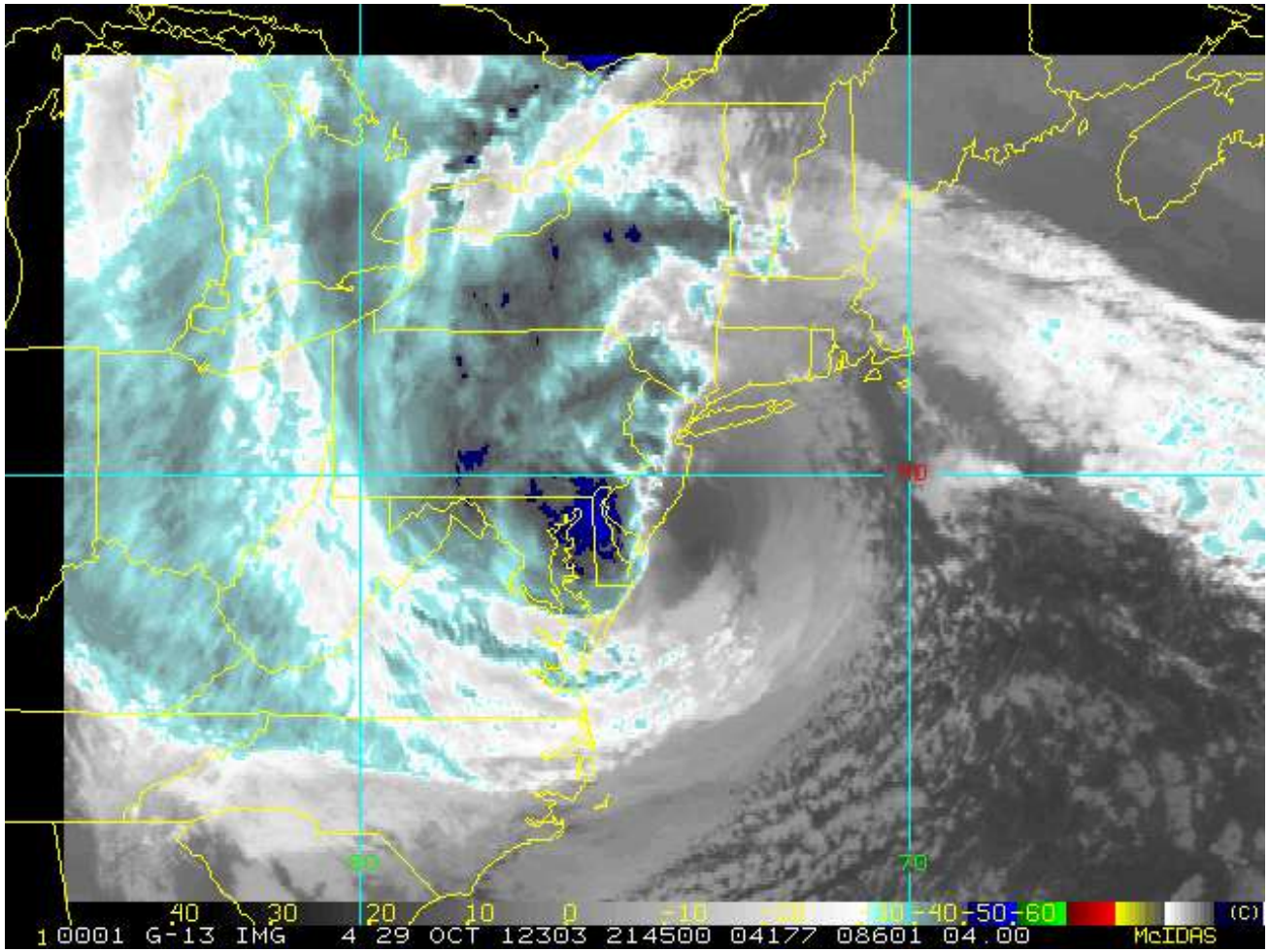


By Thursday, NHC's 5-day forecast was dead on (except the precise timing)



Sandy near landfall was declared “post-tropical” – note high asymmetry (false color IR)



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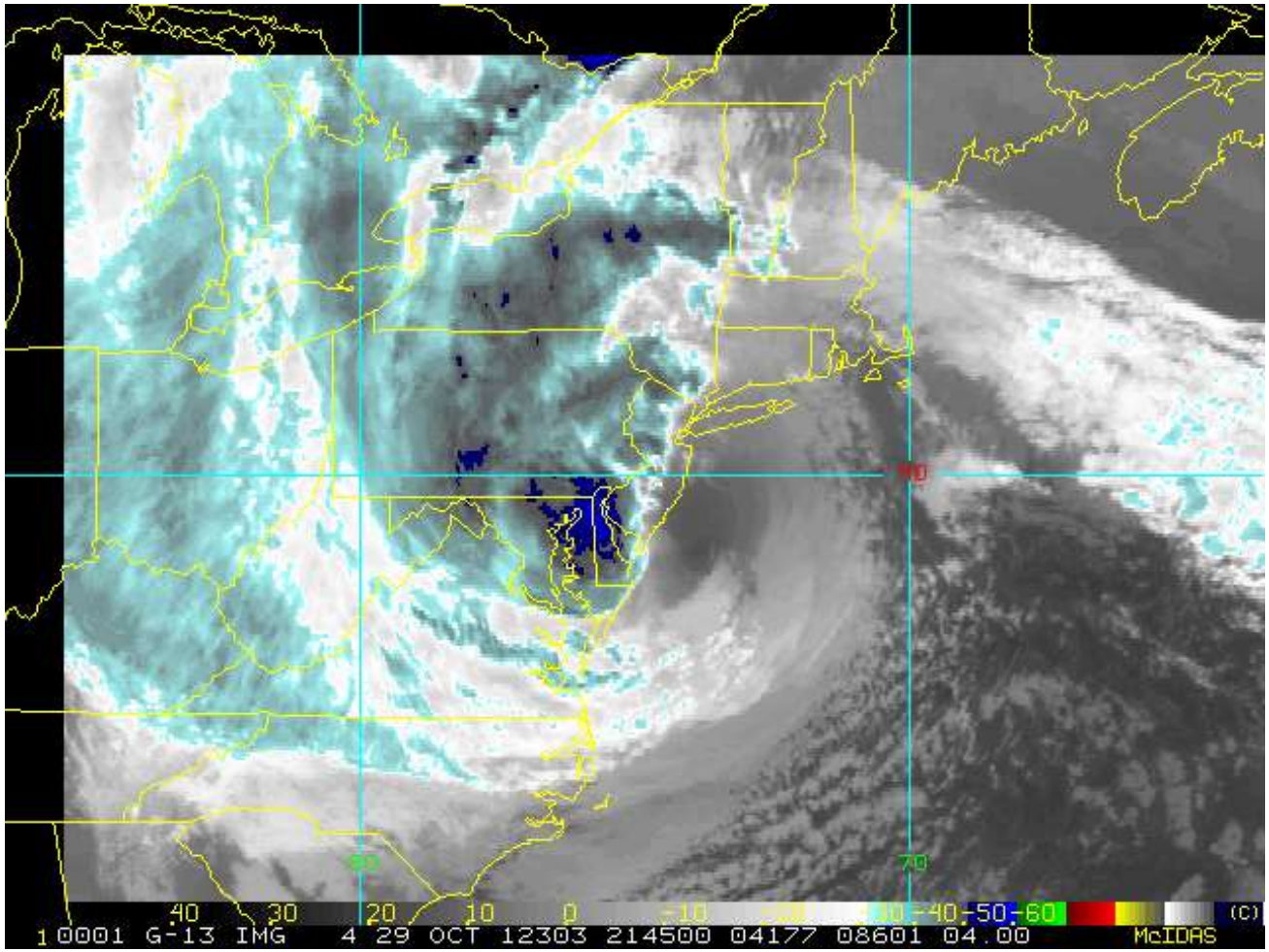


Because of this, no hurricane warnings were issued north of NC, causing some confusion…

NHC Advisory 8 AM EST Sunday 10/28

SUMMARY OF WATCHES AND WARNINGS IN EFFECT...

A TROPICAL STORM WARNING IS IN EFFECT FOR...
* CAPE FEAR TO DUCK NORTH CAROLINA
* PAMLICO AND ALBEMARLE SOUNDS
* BERMUDA

HIGH WIND WATCHES AND WARNINGS FOR HURRICANE-FORCE WINDS ARE IN EFFECT FOR PORTIONS OF THE MID-ATLANTIC STATES. OTHER WATCHES AND WARNINGS ARE IN EFFECT FOR MUCH OF NEW ENGLAND. SEE STATEMENTS FROM LOCAL NATIONAL WEATHER SERVICE FORECAST OFFICES.

Bloomberg press conference, 5pm Saturday 10/27

“Let me tell you first we are not ordering any evacuations as of this time for any parts of the city. We’re making that decision based on the nature of this storm. Although we’re expecting a large surge of water, it is not expected to be a tropical storm or hurricane-type surge. With this storm we’ll likely see a slow pile-up of water, rather than a sudden surge, which is what you would see from a hurricane.”

-Mayor Michael Bloomberg, October 27, 2012

Pre-storm preparation as of Sunday

- Evacuations (Zone A in NYC, as of Sunday)
- Nursing homes & adult care facilities not evacuated
- Transit system shutdown
- Attempts to protect low-lying infrastructure, e.g. boarding up transit tunnels; signals removed from subways
- Partial pre-emptive power grid shutdown
- FEMA had been moving assets into place for a few days

Summary of impacts

- 117 deaths in US per CDC
- Perhaps more indirect deaths (e.g., nursing homes).
- $50-65B in economic damage, incl. lost economic activity

Mantoloking, NJ – similar up and down the Jersey shore, and the NY barrier islands

Doug Mills/Associated Press

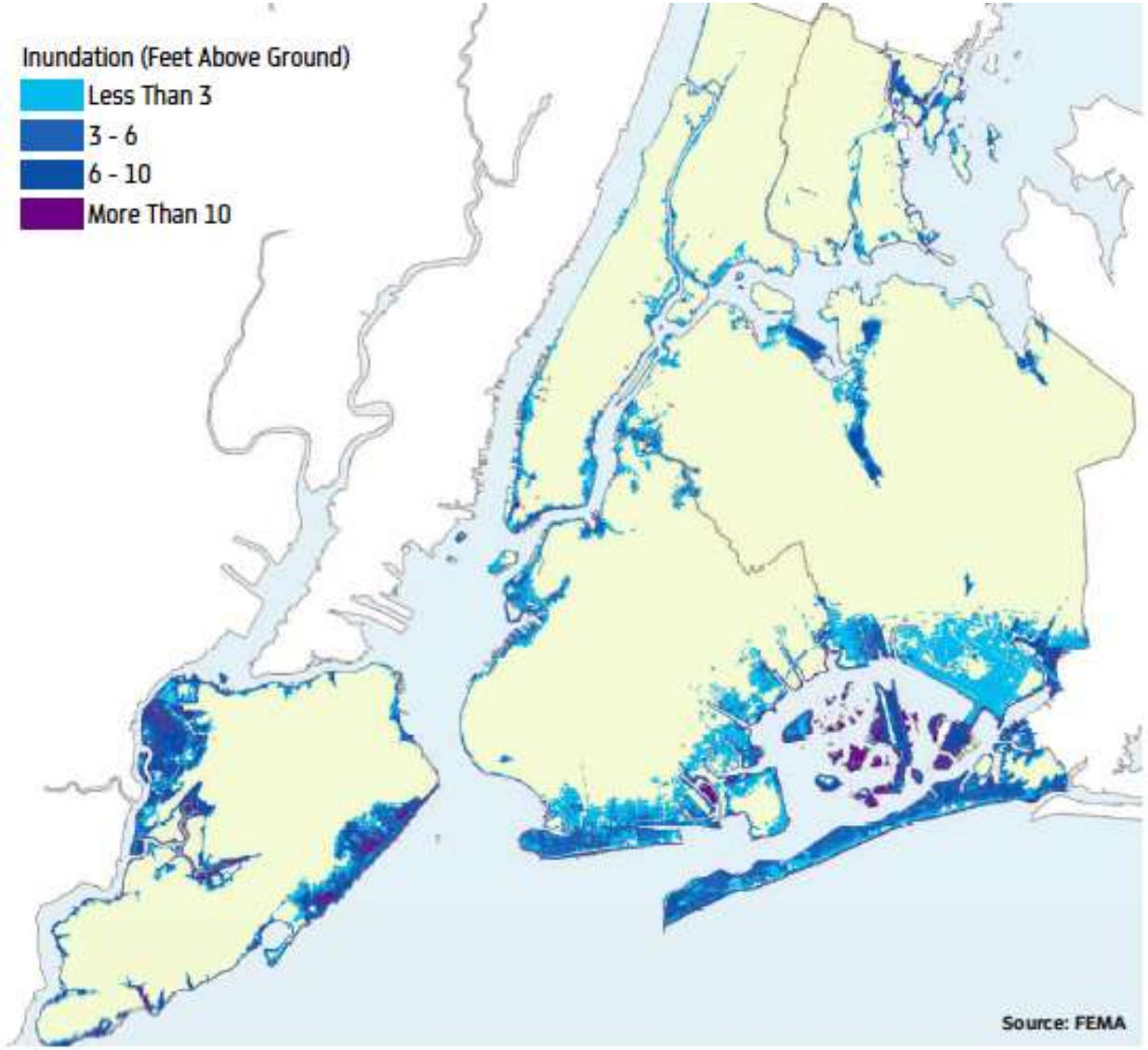
Hoboken, NJ

Charles Sykes/Associated Press

Hoboken, NJ PATH station

Port Authority

Inundation map, NYC



Breezy point, Queens

Mark Lennihan/Associated Press

Oakwood Beach, Staten Island

Bill Lyons/Staten Island Advance

Oakwood Beach, Staten Island

Bill Lyons/Staten Island Advance

Half of Manhattan dark for most of a week (and some areas for much longer)

Iwan Baan/Getty Images

Jamaica, Queens – gas lines lasted for weeks, as supply chains were disrupted

Craig Ruttle/Associated Press

Many wise short-term decisions were made in the days before landfall, saving many lives (evacuations) and property (removing signals from subways).

Many wise short-term decisions were made in the days before landfall, saving many lives (evacuations) and property (removing signals from subways).

But the region's infrastructure was clearly completely unprepared. It was not designed to withstand a Sandy. Did we think it couldn't happen?

South Ferry Station, opened 2012, cost $550M, totaled

U.S. Army Corps of Engineers • FEMA
National Weather Service
NY/NJ/CT State Emergency Management

INTERIM TECHNICAL DATA REPORT

November 1995

METRO NEW YORK HURRICANE TRANSPORTATION STUDY

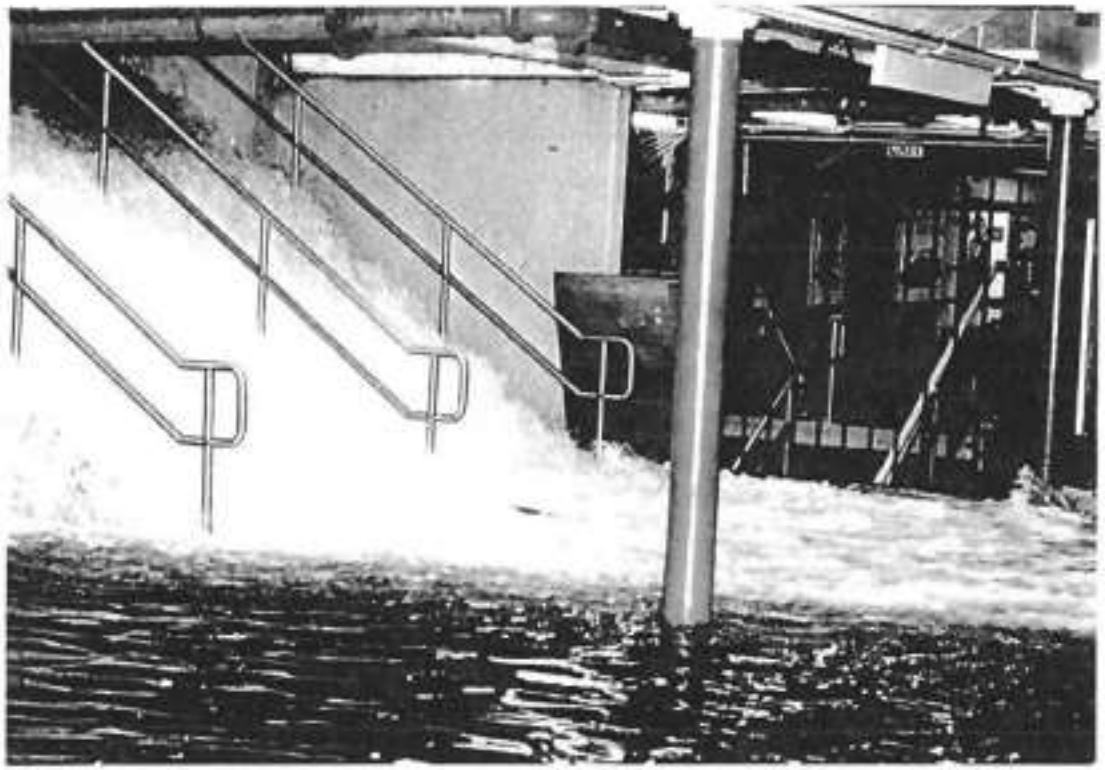


FIGURE 11

Floodwater cascades into the Hoboken PATH Station
December 11, 1992

The NHC ran some storm surge simulations to estimate what could happen

FIGURE 17 - Potential Category 2 hurricane surge at South Ferry (Battery) Subway Station

US Army Corps, 1995

The USACE report addressed evacuations and other short-term measures, emphasizing that the transit system would need to be shut down ahead of time.

This was done first in Irene (2011) and then in Sandy.

The report also made long-term infrastructure recommendations.

“….
there is no doubt that moderate flood proofing measures in strategic locations would yield substantial dividends in terms of protecting transportation facilities and the public. A coordinated effort … to flood proof vulnerable tunnel openings and raise roadways to a reasonable level could provide valuable insurance against shallow flooding… Protection from coastal storm surge should be a consideration in all capital programs planning.”

USACE et al., 1995

Sandy was a rare event, but no serious scientific assessment could have said it was impossible

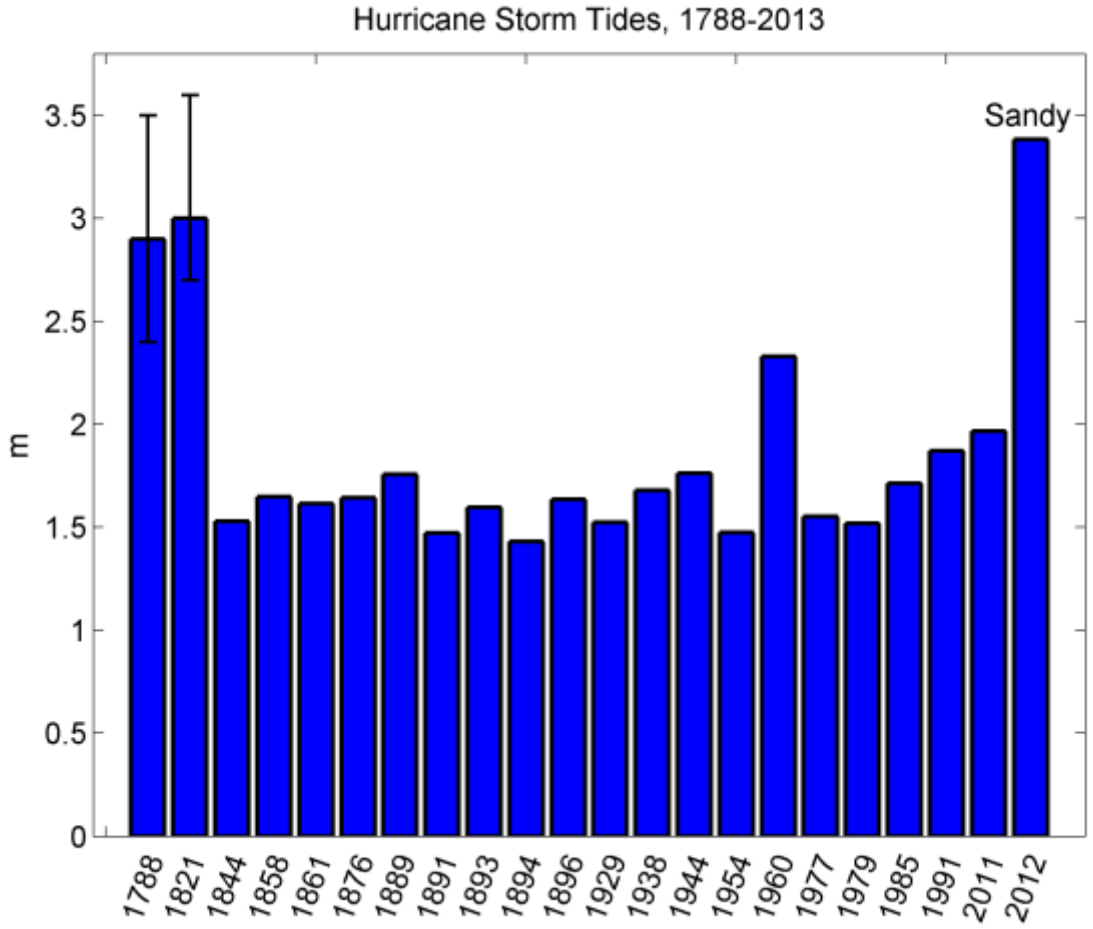


Figure courtesy of Stefan Talke and Philip Orton

No matter what scientists tell us *could* happen – or even *eventually will* happen – we as a species seem unable to make long-term investments in prevention or mitigation until it actually has happened at least once.

The psychologists call this *availability bias* (D. Kahneman, *Thinking Fast and Slow*)

1953 Delta Flood, Netherlands
~1800 deaths, massive economic damage

Getty images, archive.wired.com

The 1953 flood led almost immediately to the “Delta Plan” (also to the Thames barrier in the UK)

Maeslant barrier, Netherlands

Credit: Rijkswaterstaat, part of the Dutch Ministry of Infrastructure and the Environment (http://www.keringhuis.nl/index.php?id=39)

Was Sandy related to climate change?

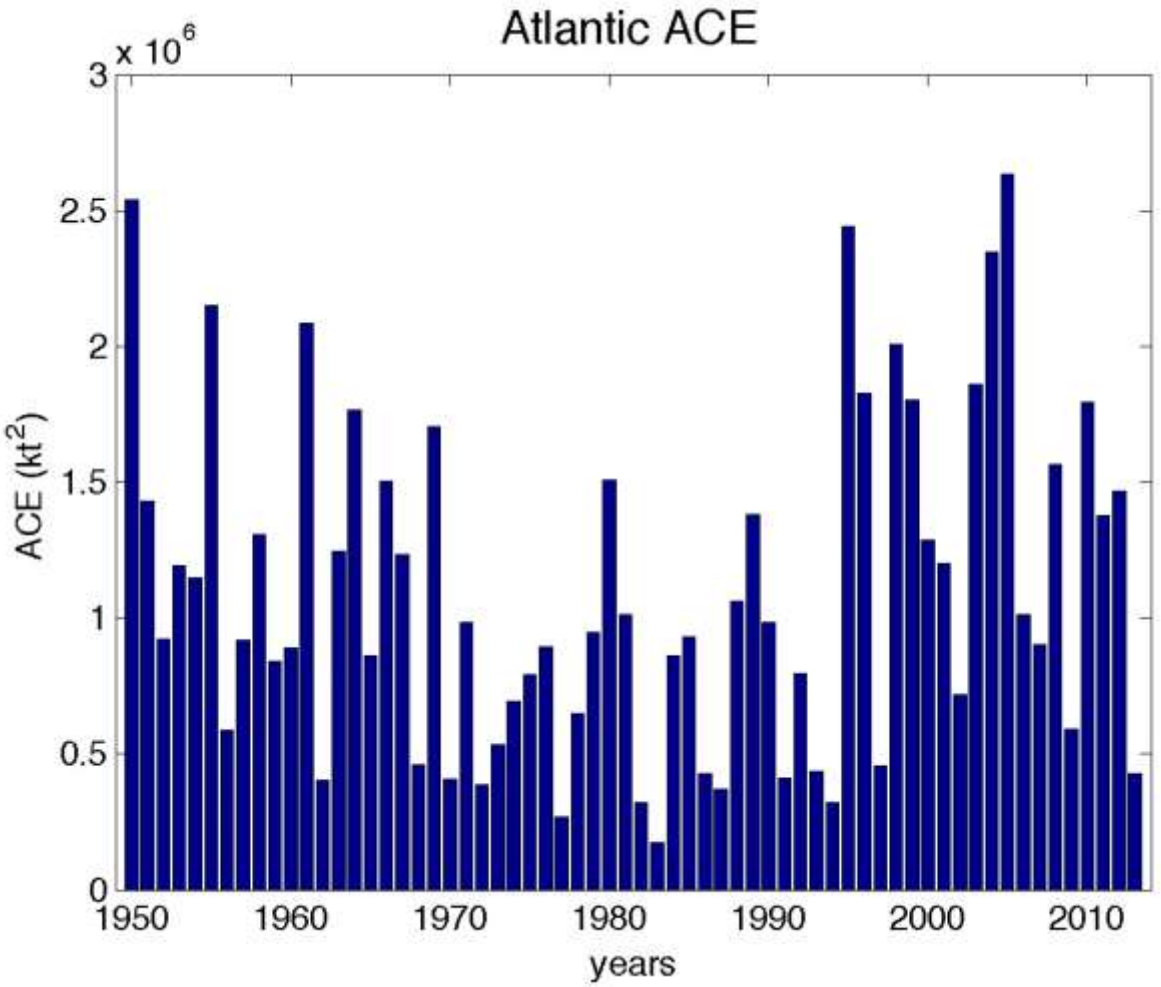
Graffiti on a sea wall in Rockaway Beach, N.Y., implies that global warming is to blame for the devastating Superstorm Sandy that struck the area on Oct. 29, 2012. Many homes along the beach front ended up destroyed after being hit by the resulting storm surge. Photo by Mike Pedersen

http://www.sbujdrive.com/rockaways/photo/landscape/

Bloomberg Businessweek

IT'S GLOBAL WARMING, STUPID

We cannot yet clearly detect a human influence on hurricanes in the observations.

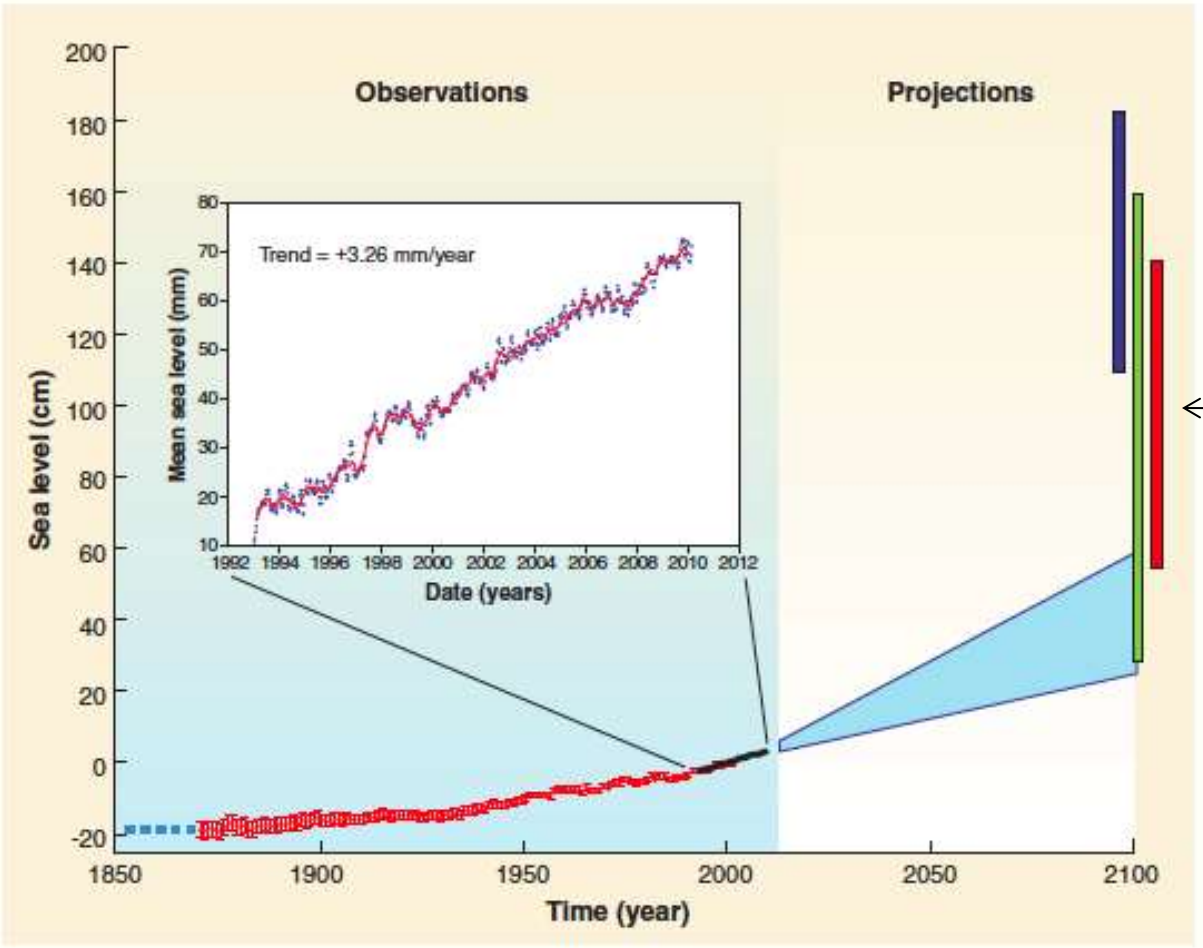


Suzana Camargo, LDEO

Effect of climate change on hurricanes based on models and theory

- TC frequency seems more likely to decrease than increase, based on latest models, but that is still uncertain esp. at level of individual basins (e.g., Atlantic)
- Intensity likely to increase
- *Little known about how the factors that were most important in Sandy will respond to climate change: size, track, extratropical transition*

The really clear and simple link to climate is via sea level rise.



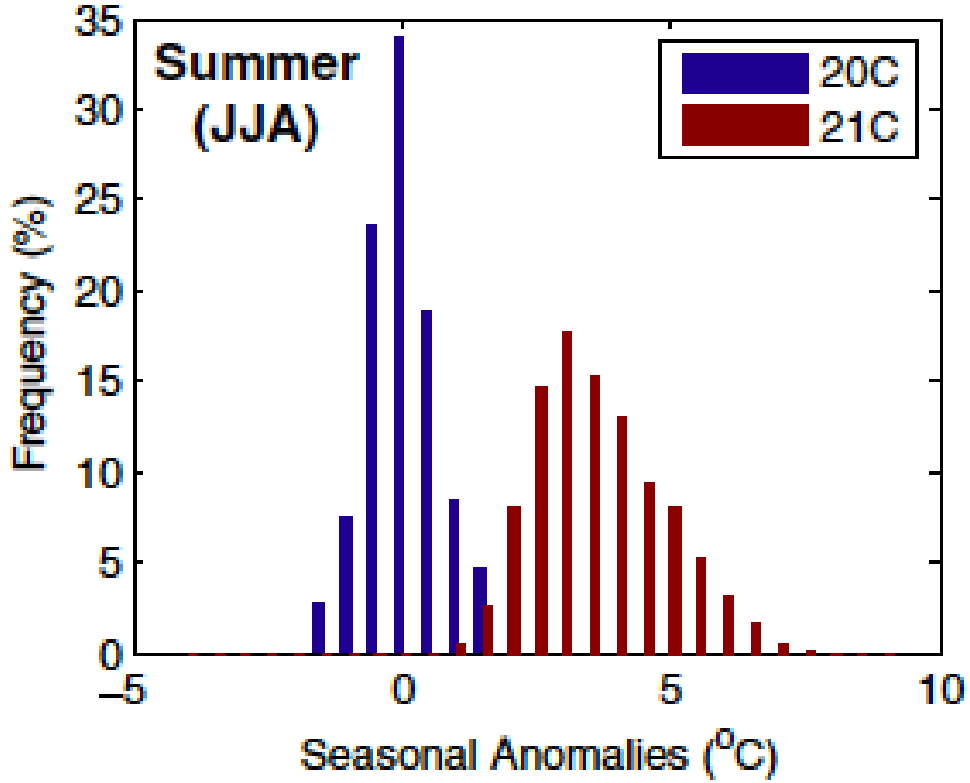
Nicholls and Cazenave, 2010, *Science*

Perhaps the most important link between Sandy and climate change is not anything about how warming influences storms, but about what it says about our ability to prepare for things outside our experience.

The climate to come will, before too long, be outside our experience in a number of ways.

The coolest summers at the end of the century will likely be as warm as the warmest summer experienced by anyone alive.

US Gulf states summer mean temps,
from Biasutti et al. (2012, *Climatic Change)*



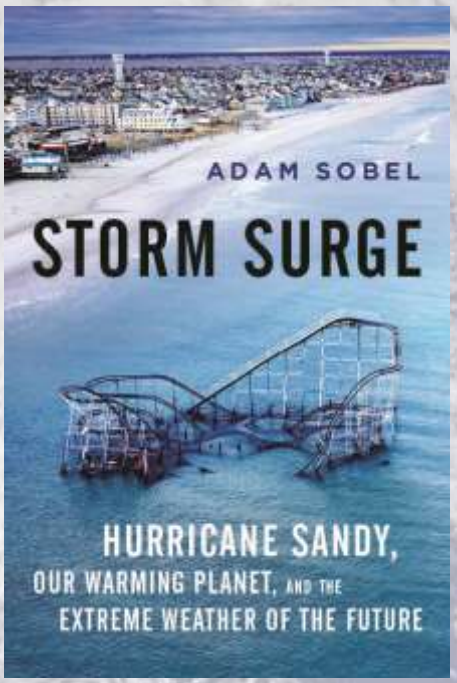
Willful denialism is the most acute problem we face in dealing with global warming (at least in the US and Canada).

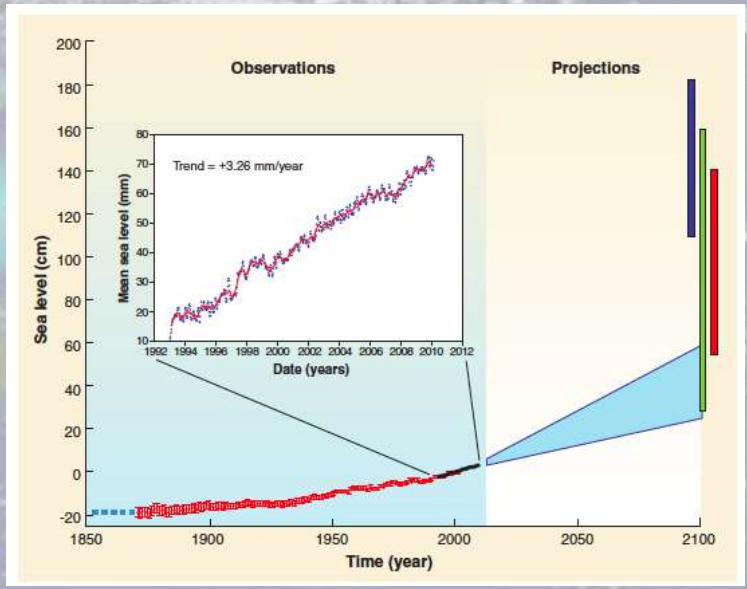
But our difficulty in taking long-term, unfamiliar risks seriously – the availability bias – may be just as much of a hindrance to action.

Waiting til all the worst impacts have arrive to make mitigating investments is an even worse strategy for global warming than it was for hurricane risk.

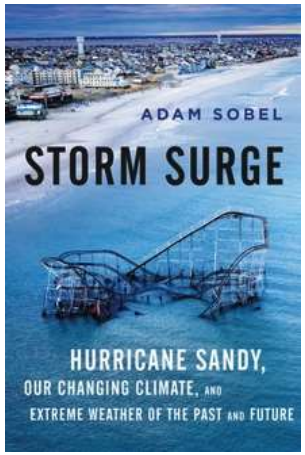
Columbia page: www.columbia.edu/~ahs129/home.html
Blog: adamsobel.org
Facebook: www.facebook.com/adam.sobel
Twitter: @profadamsobel

Columbia Initiative on Extreme Weather & Climate:
extremeweather.columbia.edu





Questions?



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Marine Environmental Observation Prediction and Response Network
Dalhousie University | Halifax, NS
t. (902) 494-4384 | info@meopar.ca
@MEOPAR_NCE
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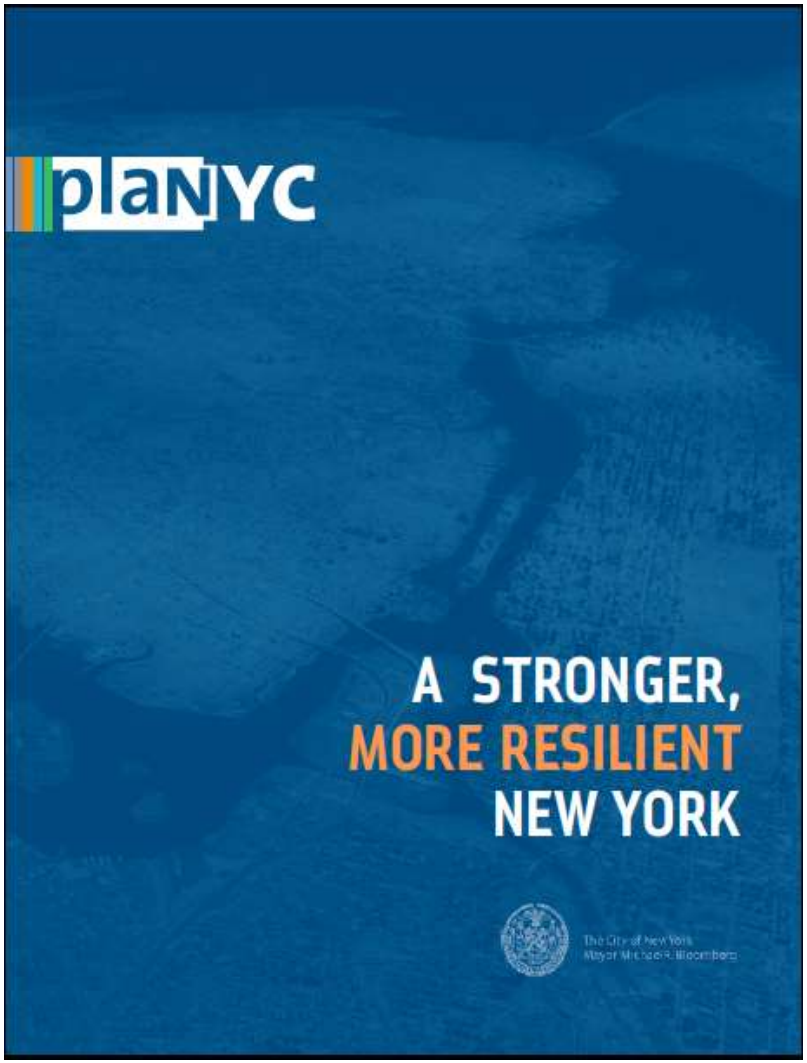
Strengthening Canada's capacity to anticipate and respond to marine risk

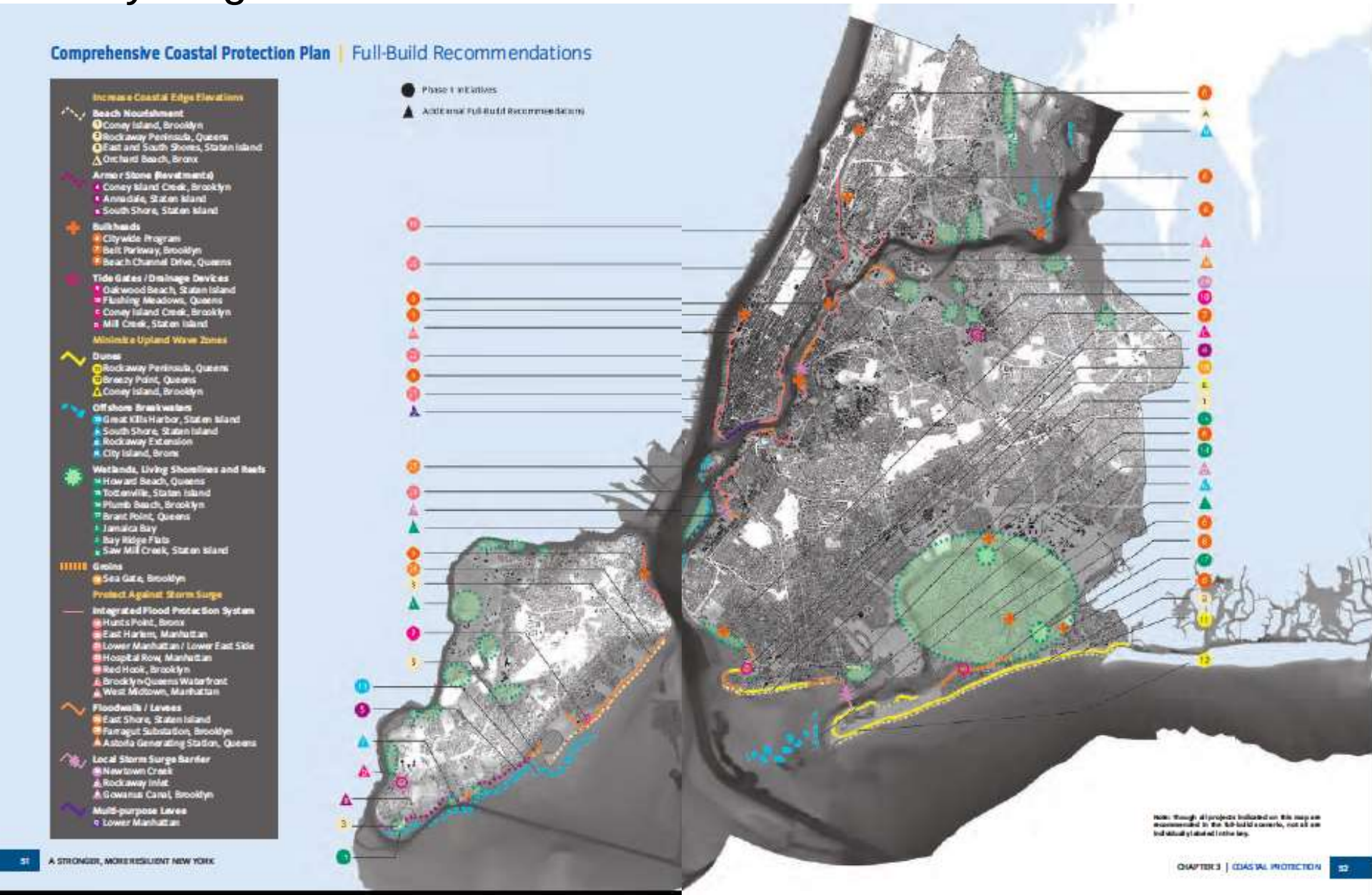
So what will happen now, post-Sandy?

ARCADIS

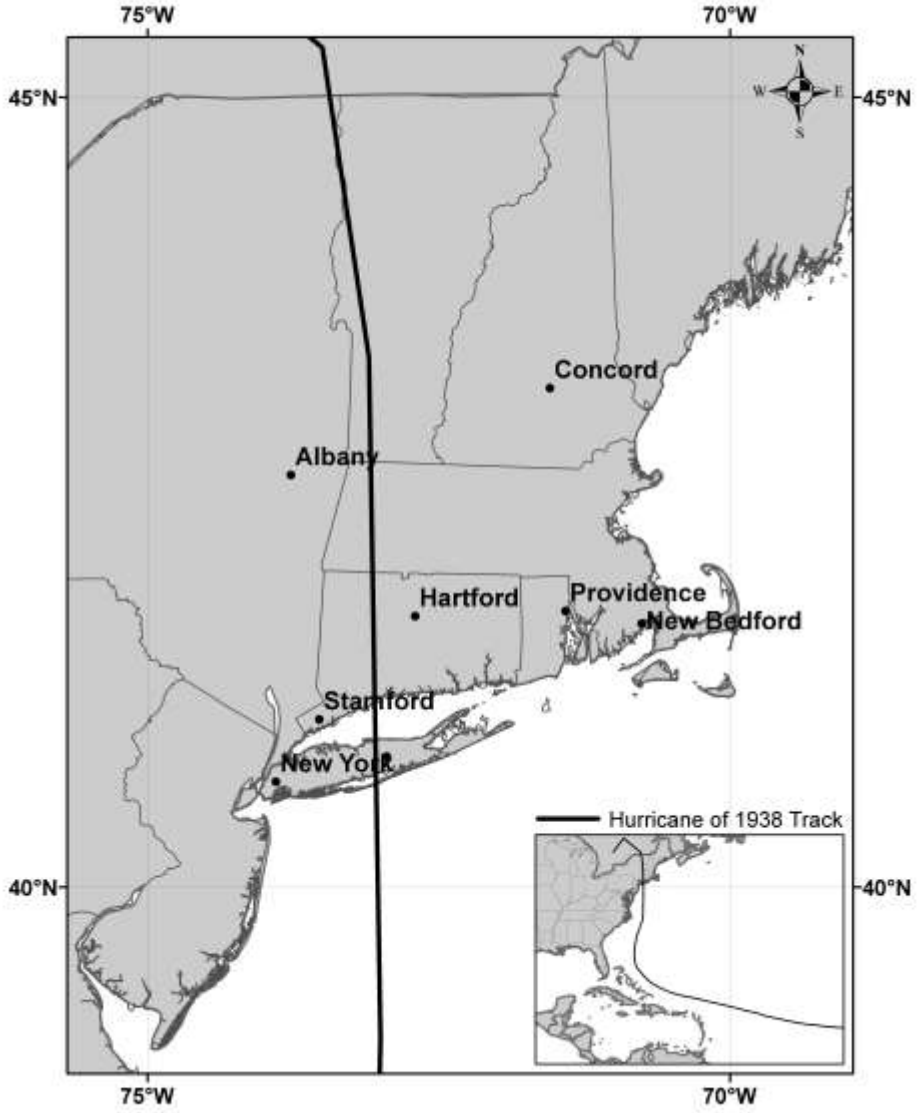
Comprehensive plan prepared by the Bloomberg administration

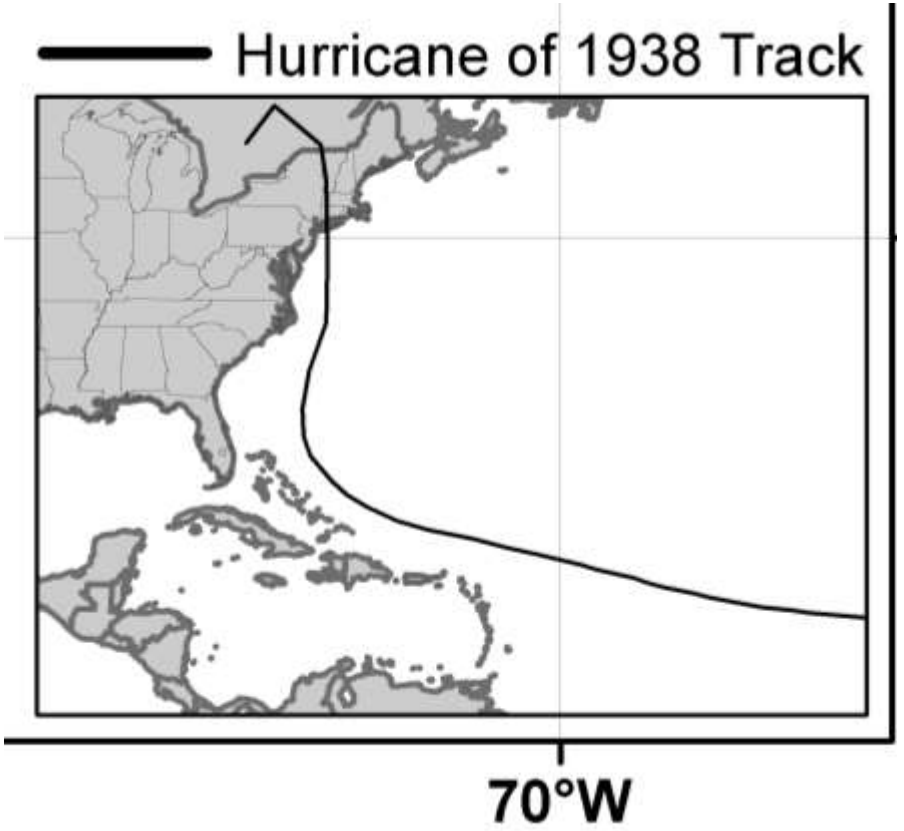


No giant storm surge barriers across the harbor, but nearly everything else



There have been disastrous storms in our area in living memory

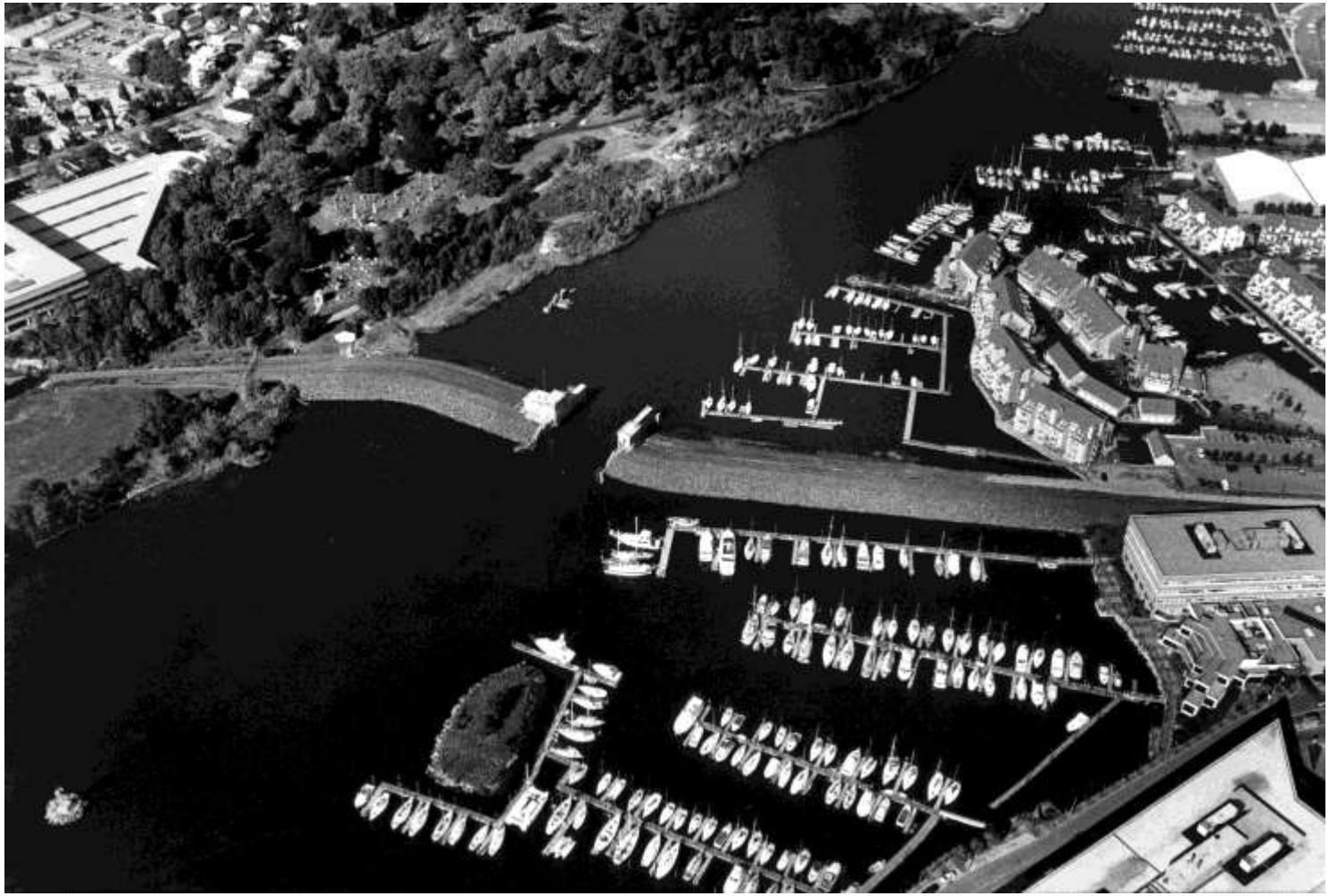




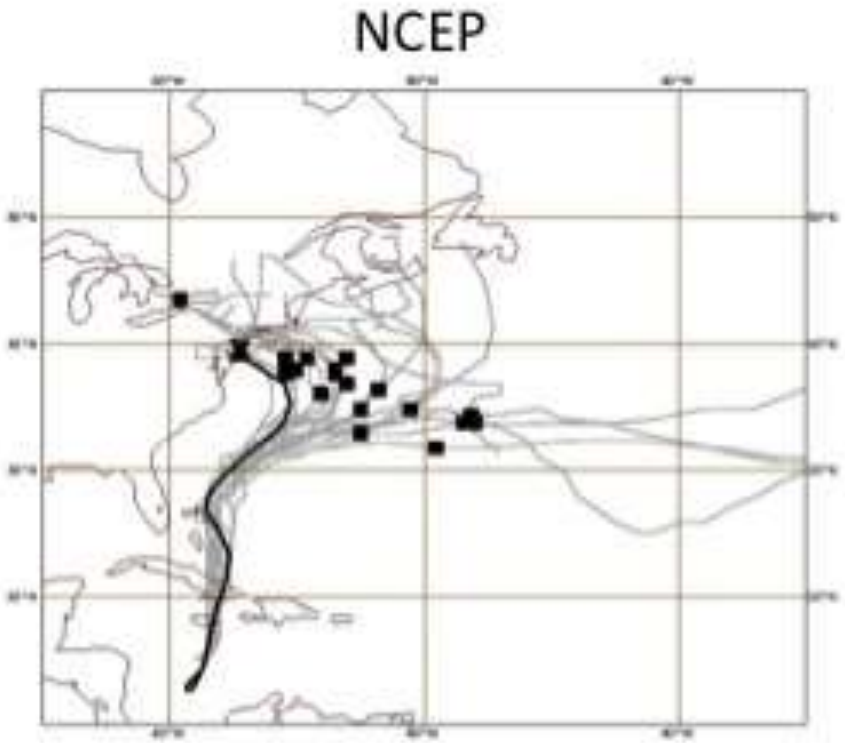
Maps by Andrew Kruczkiewicz and Sunny Ng

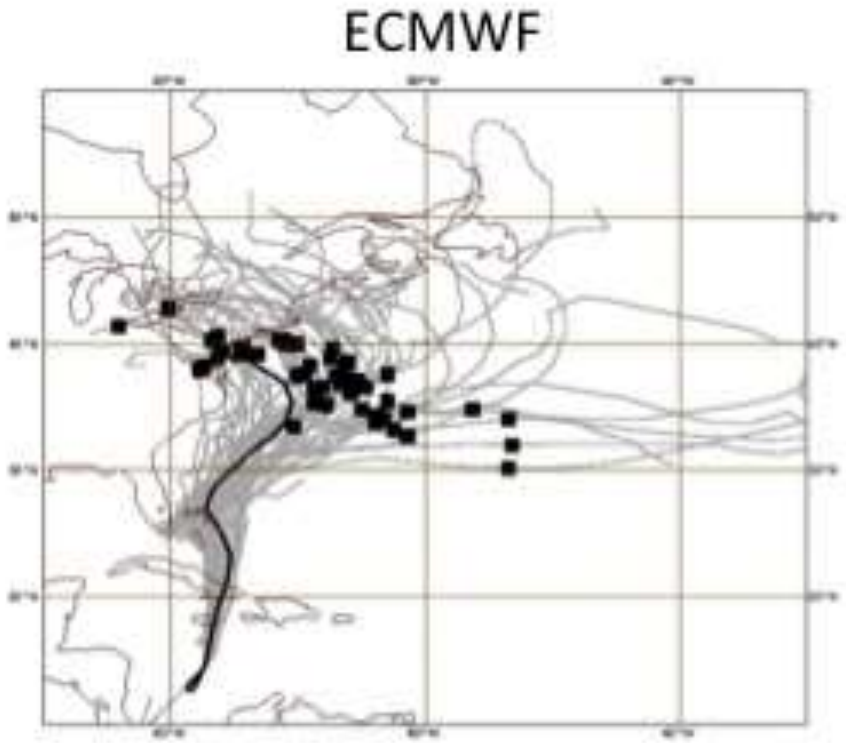
Poorly forecast, the 1938 storm killed over 600, and was the most expensive natural disaster to date

Stamford, CT Hurricane Barrier



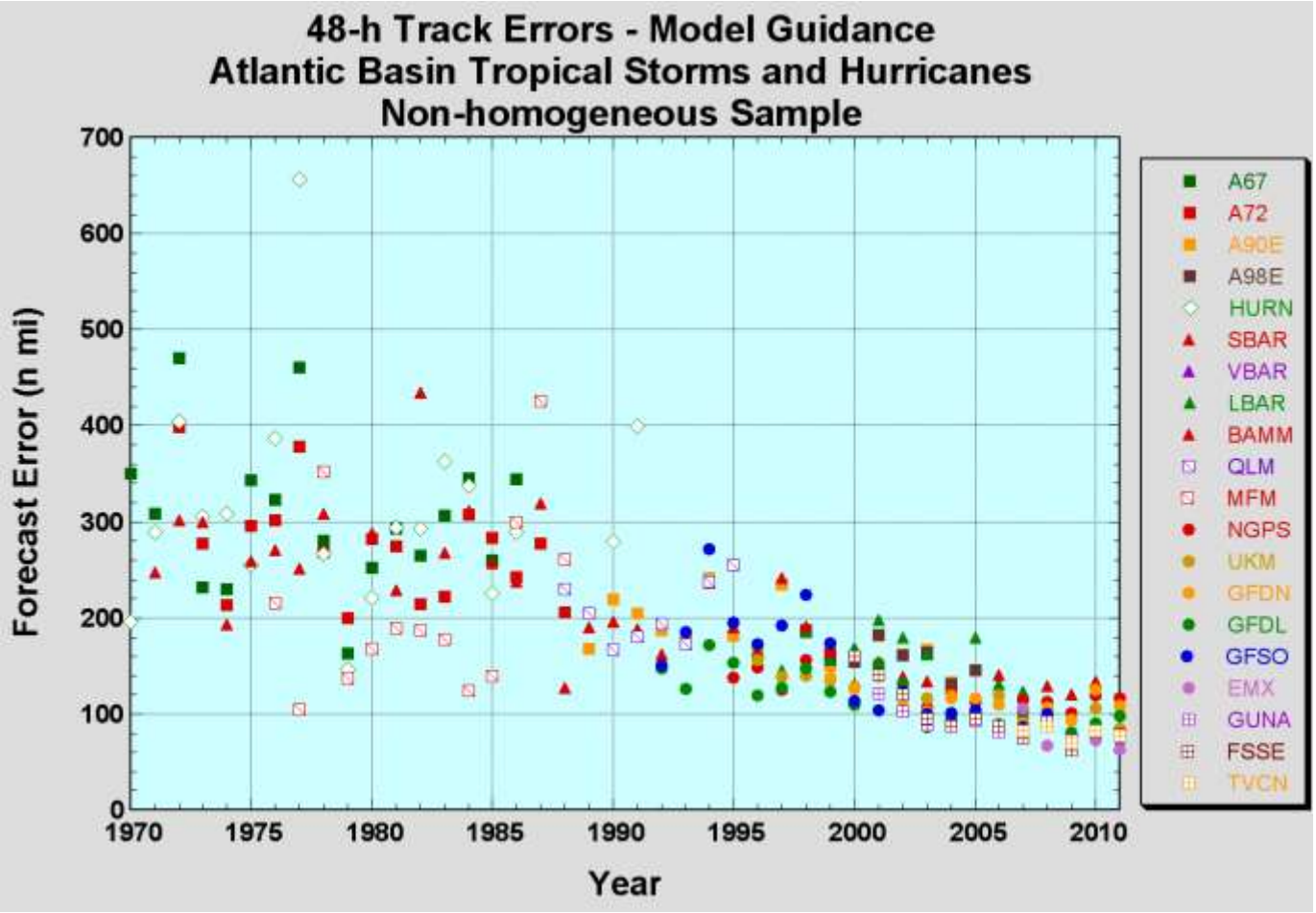
On Wednesday, forecast model ensembles still indicated uncertainty about whether the storm would make landfall.





Linus Magnusson, ECMWF

Such forecasts are remarkable scientific achievements, resulting from decades of steady progress



National Hurricane Center, NOAA

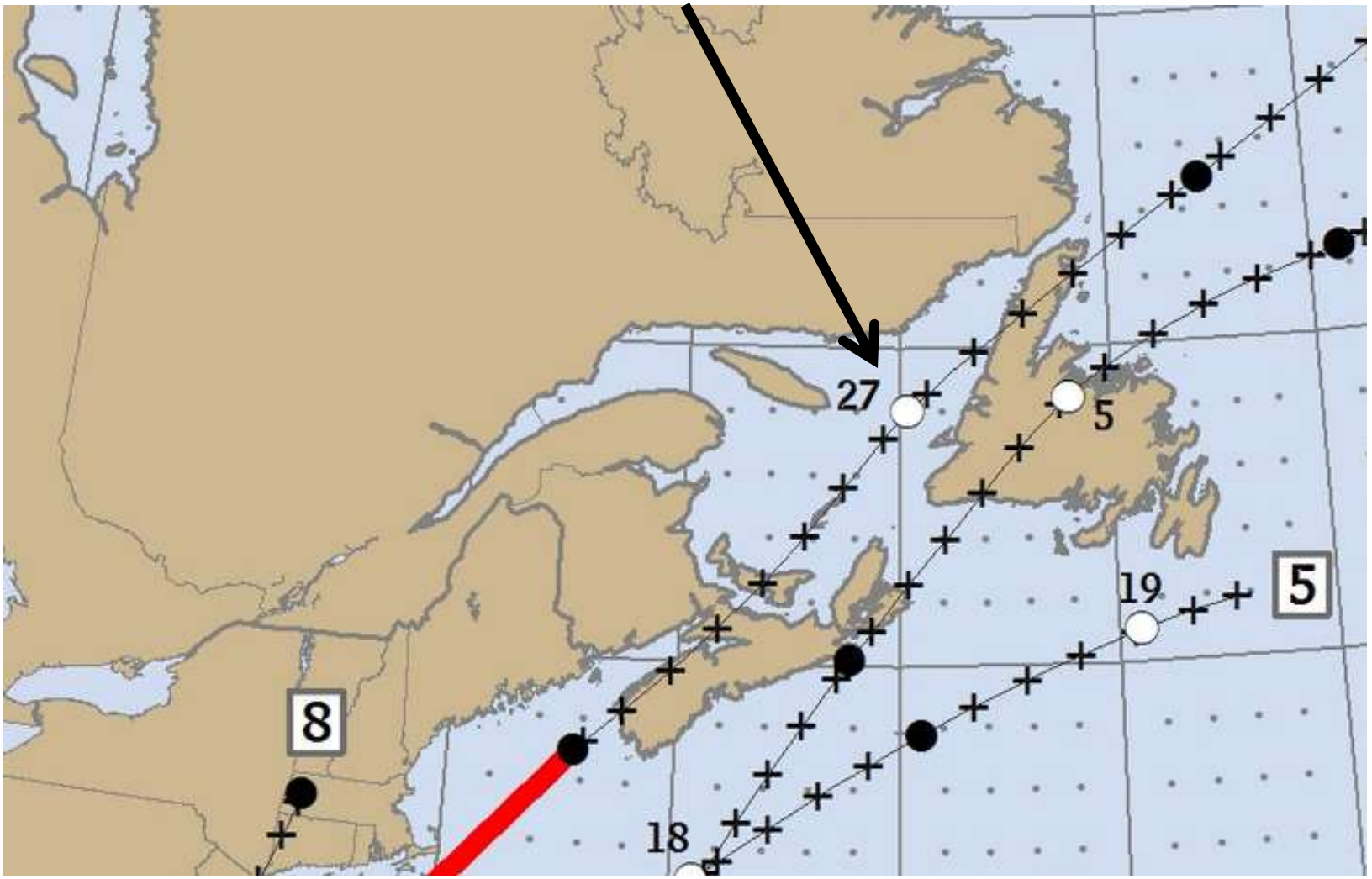
In the old Saffir-Simpson scale (which still included surge) 3 ft increase in surge = 1 category increase

Saffir-Simpson Scale

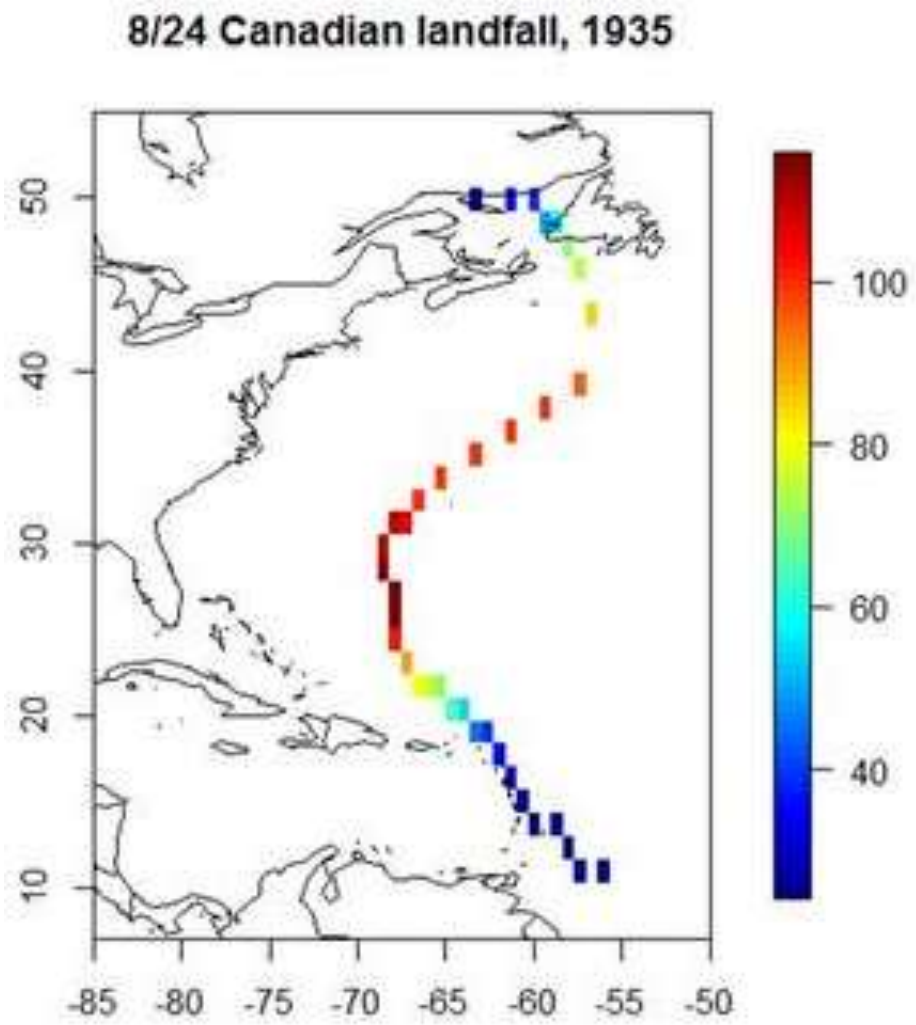
Saffir-Simpson Category	Maximum sustained wind speed			Minimum surface pressure	Storm surge	
	mi/h	m/s	kt	mb	ft	m
1	74-95	33-42	64-82	greater than 980	3-5	1.0-1.7
2	96-110	43-49	83-95	979-965	6-8	1.8-2.6
3	111-130	50-58	96-113	964-945	9-12	2.7-3.8
4	131-155	59-69	114-135	944-920	13-18	3.9-5.6
5	156+	70+	136+	less than 920	19+	5.7+

http://www.unc.edu/~rowlett/units/scales/saffir.html

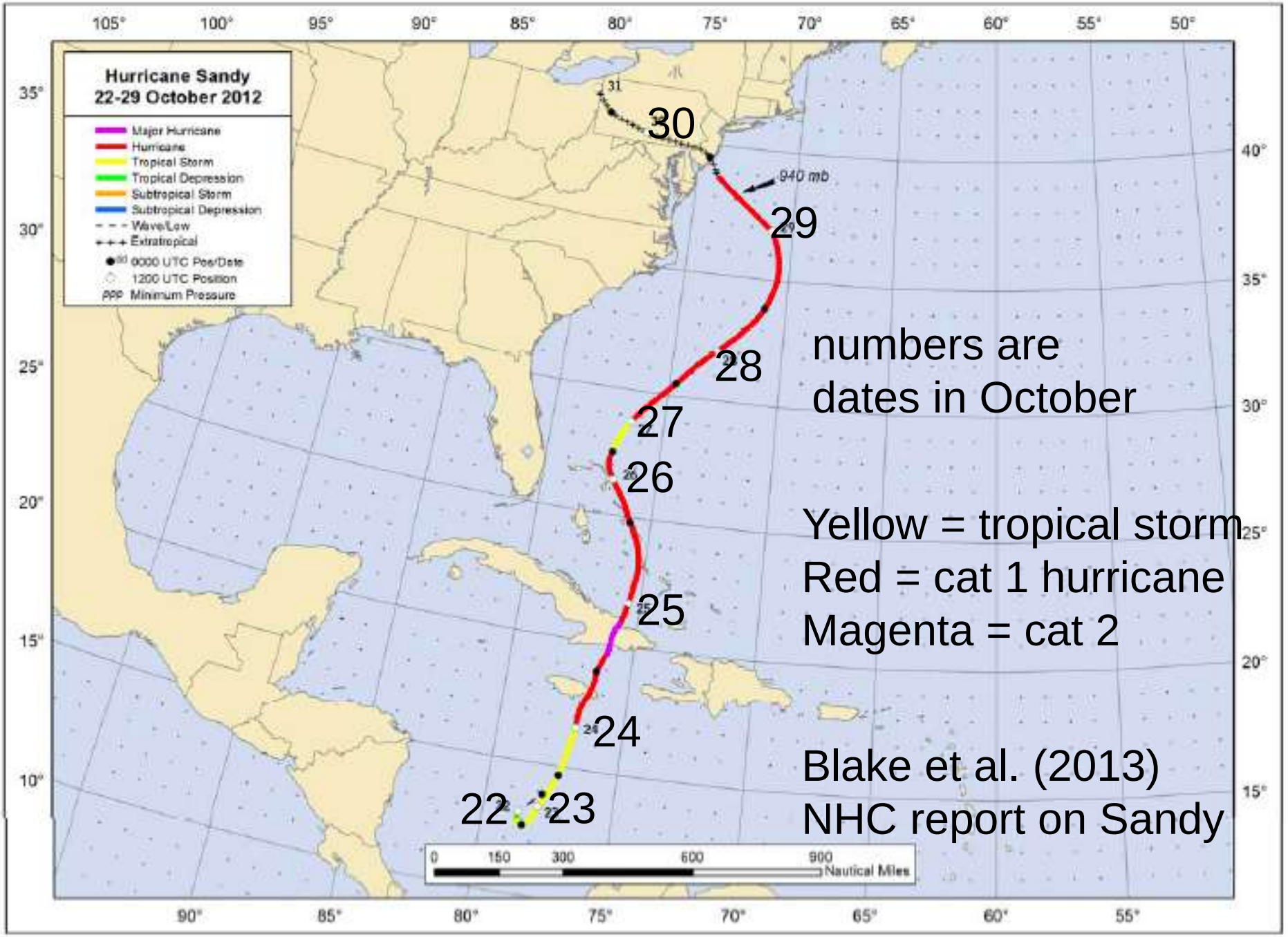
August 27, 1924



80 years ago today:
The 1935 Newfoundland August Gale



Plot courtesy of
Suz Tolwinski-Ward,
AIR


Hurricane Sandy
22-29 October 2012
Major Hurricane
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