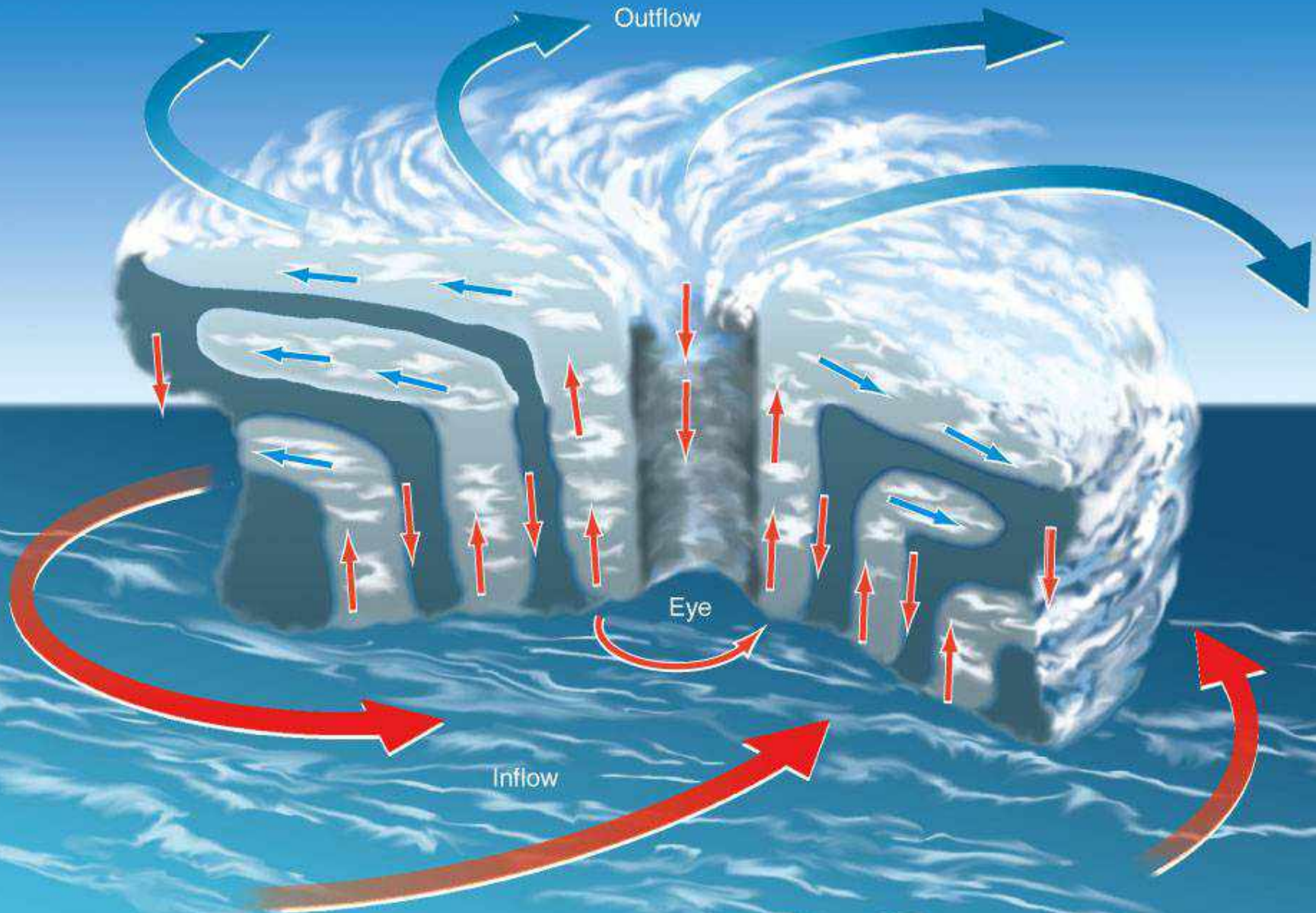


Impact of Hurricanes and Storm Surges on the Chesapeake Bay

Bill Boicourt

University of Maryland
Center for Environmental Science
Horn Point Laboratory

Heat Engine



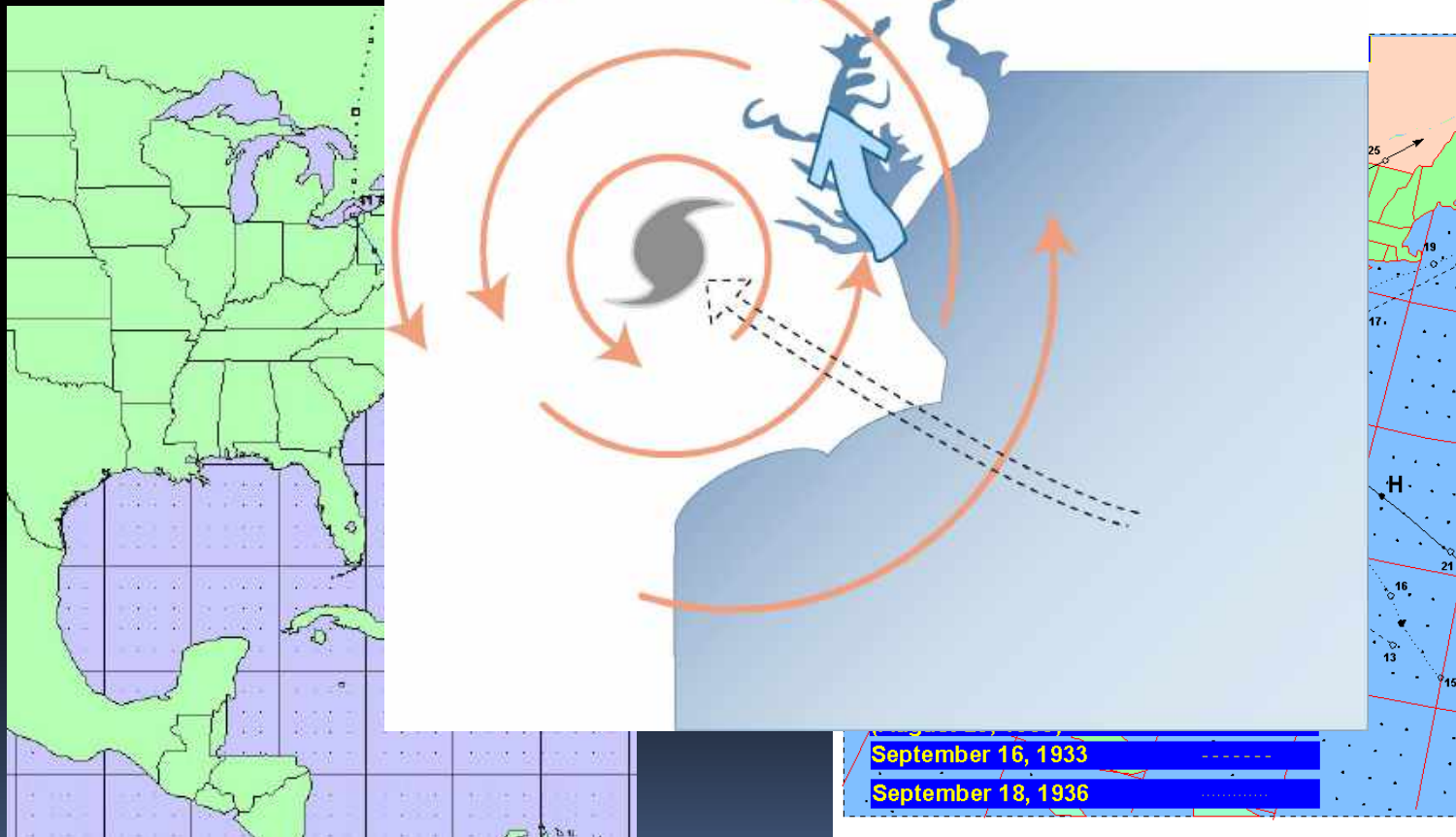
CAPCA Meeting Annapolis 23 September 2019



The Bay: Usually Protection, but Occasionally Entrapment

Isabel

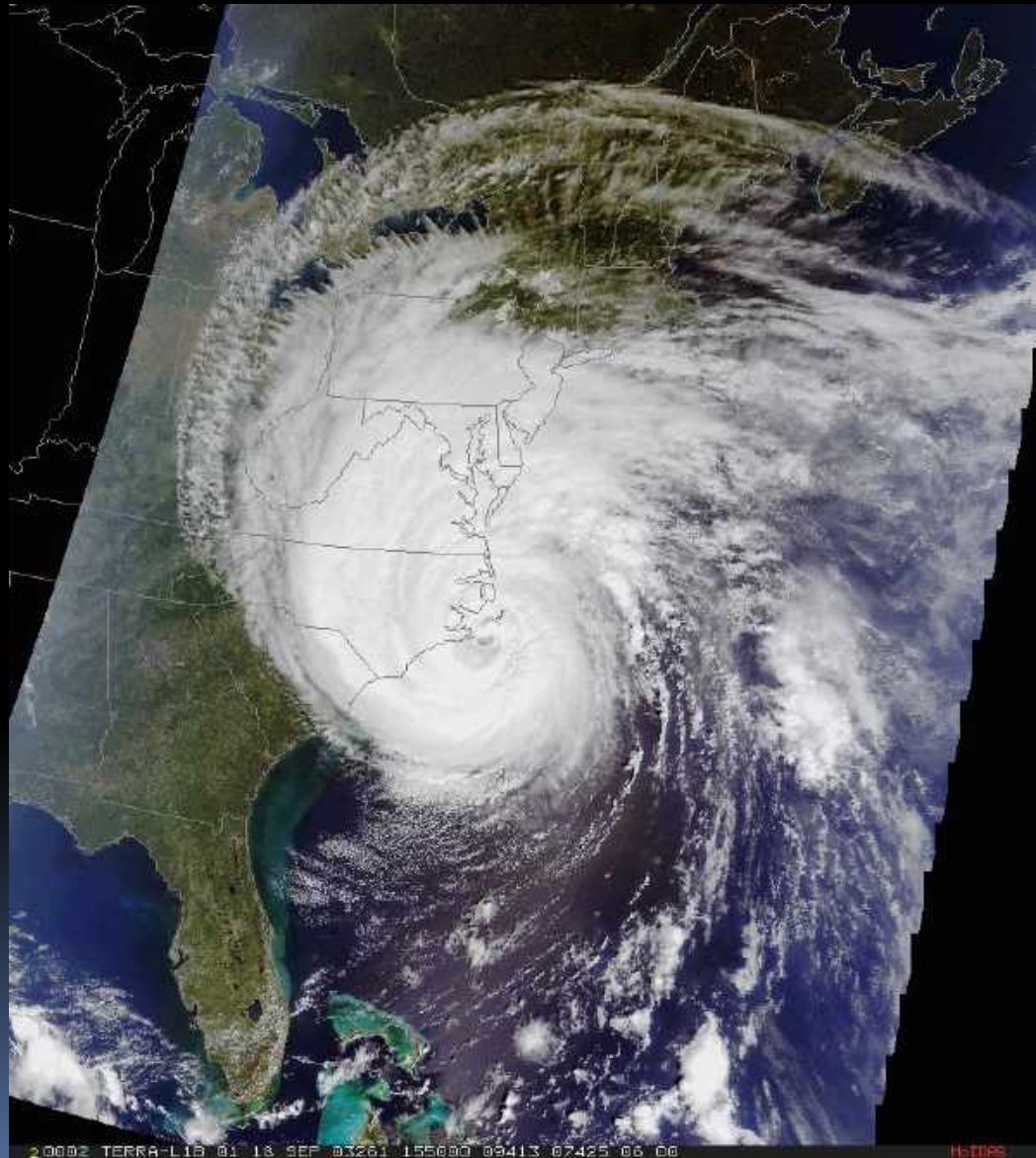
August 1933



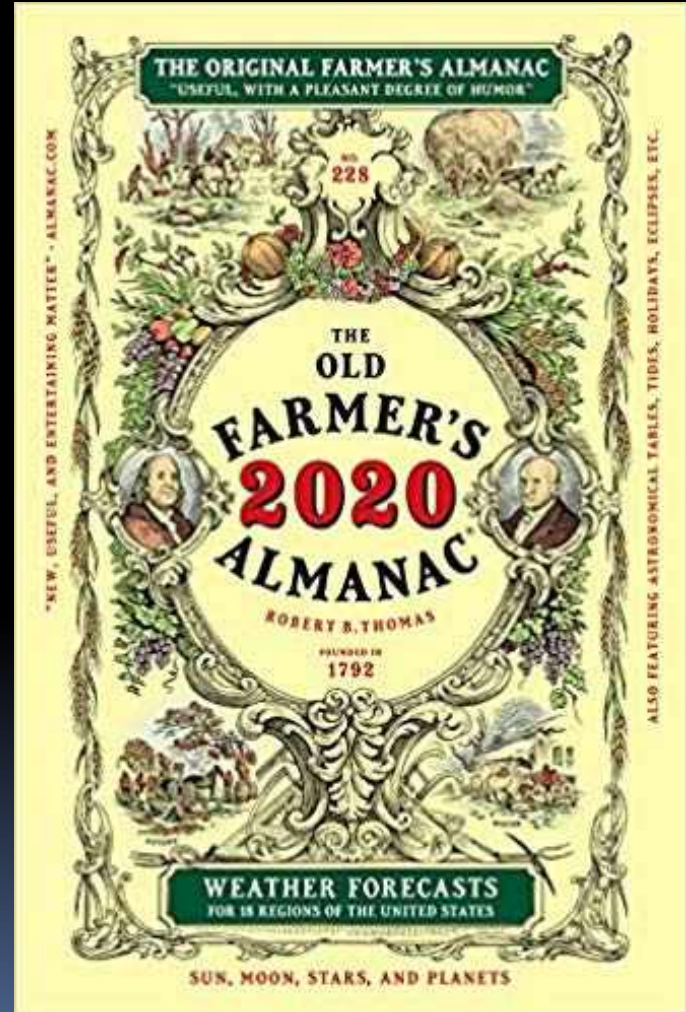
NOAA

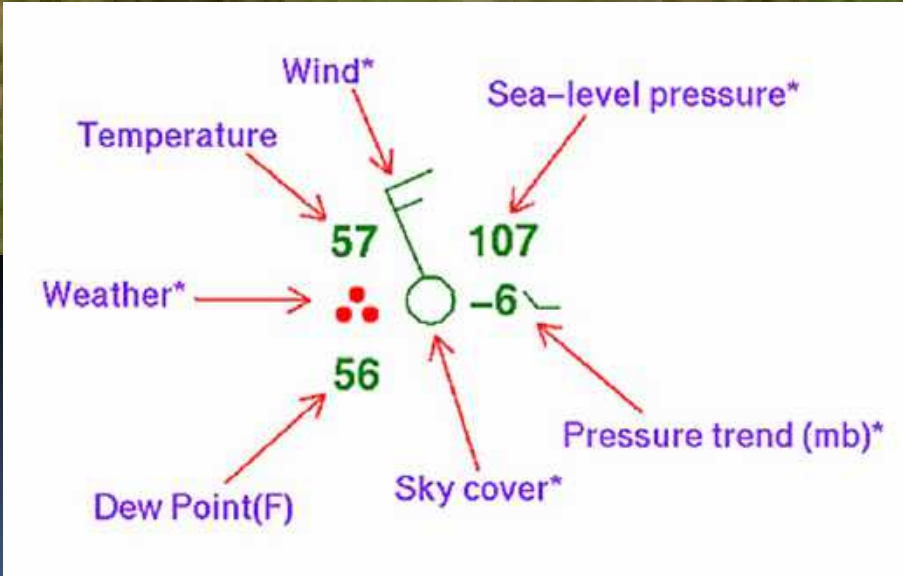
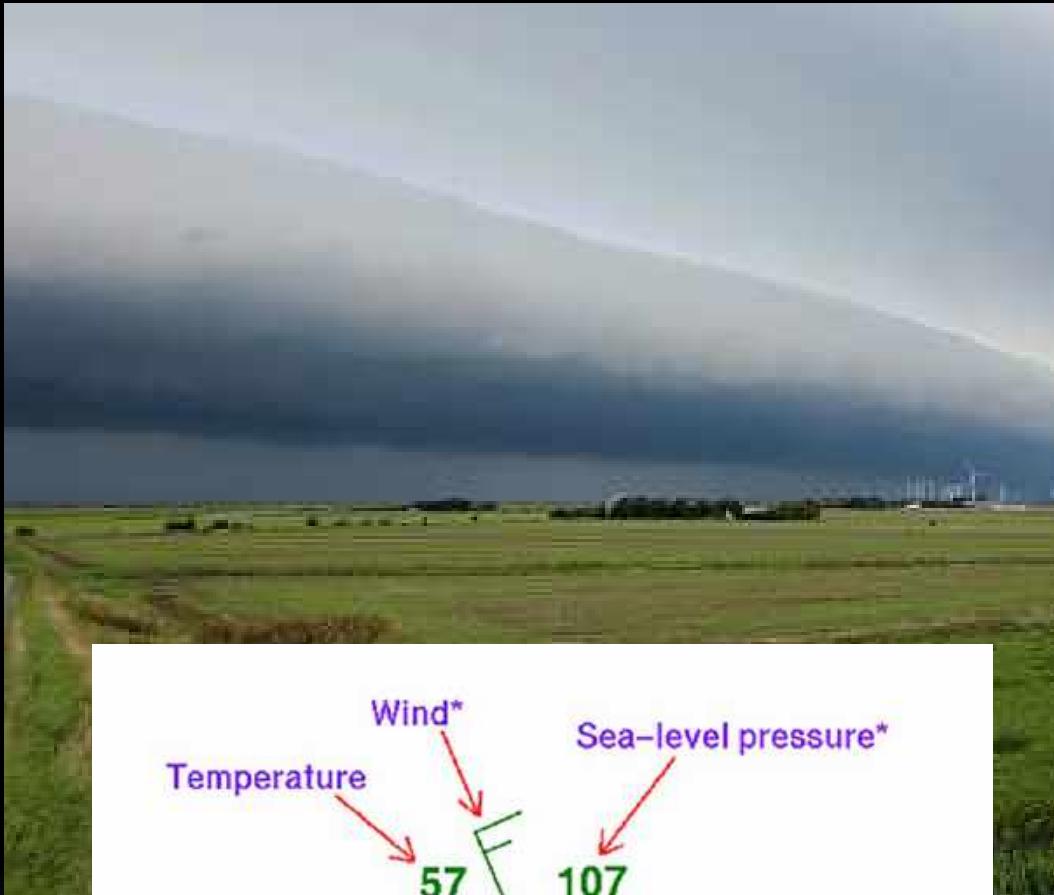
HURRICANE ISABEL 2003

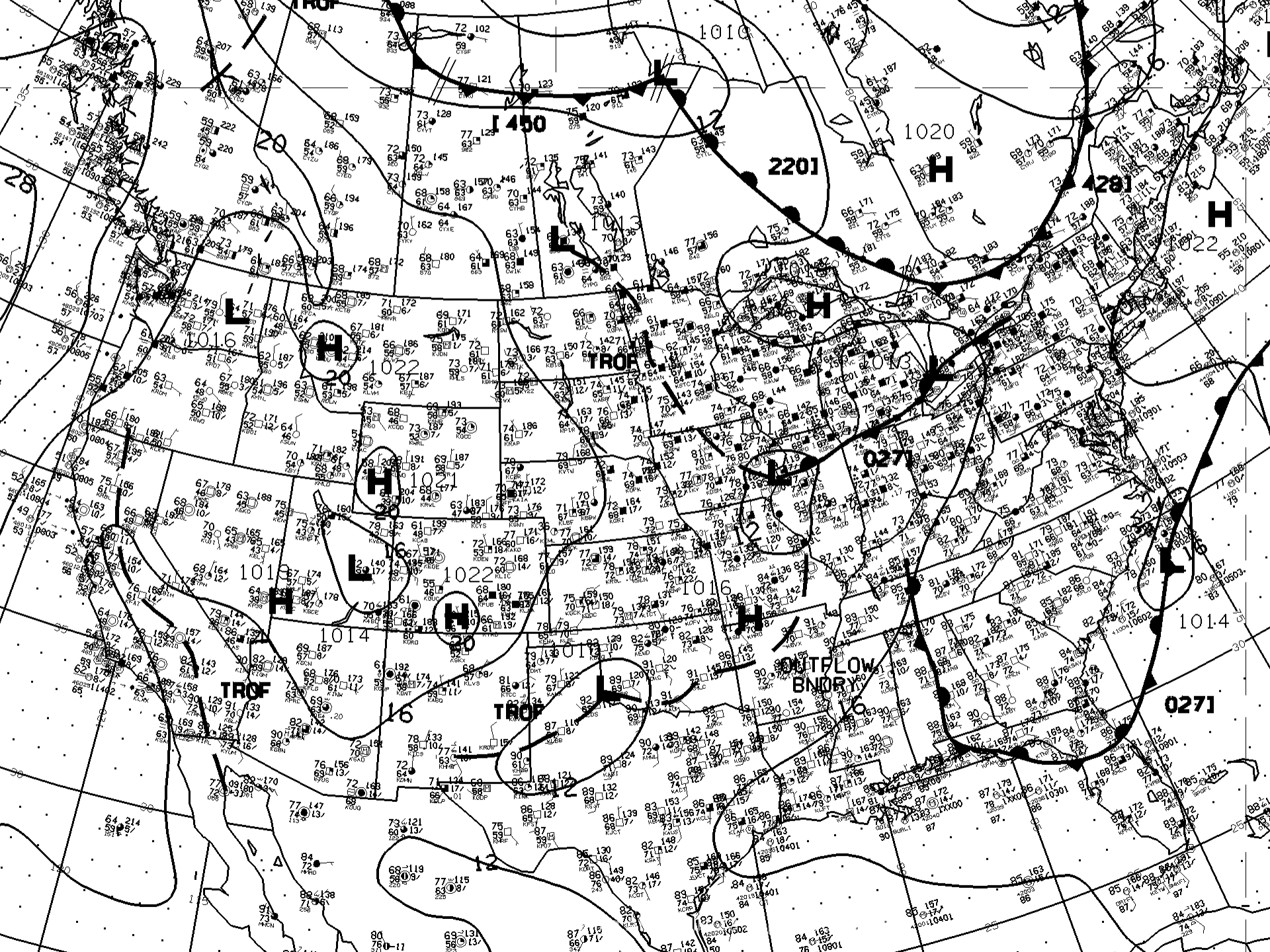
STORM SURGE



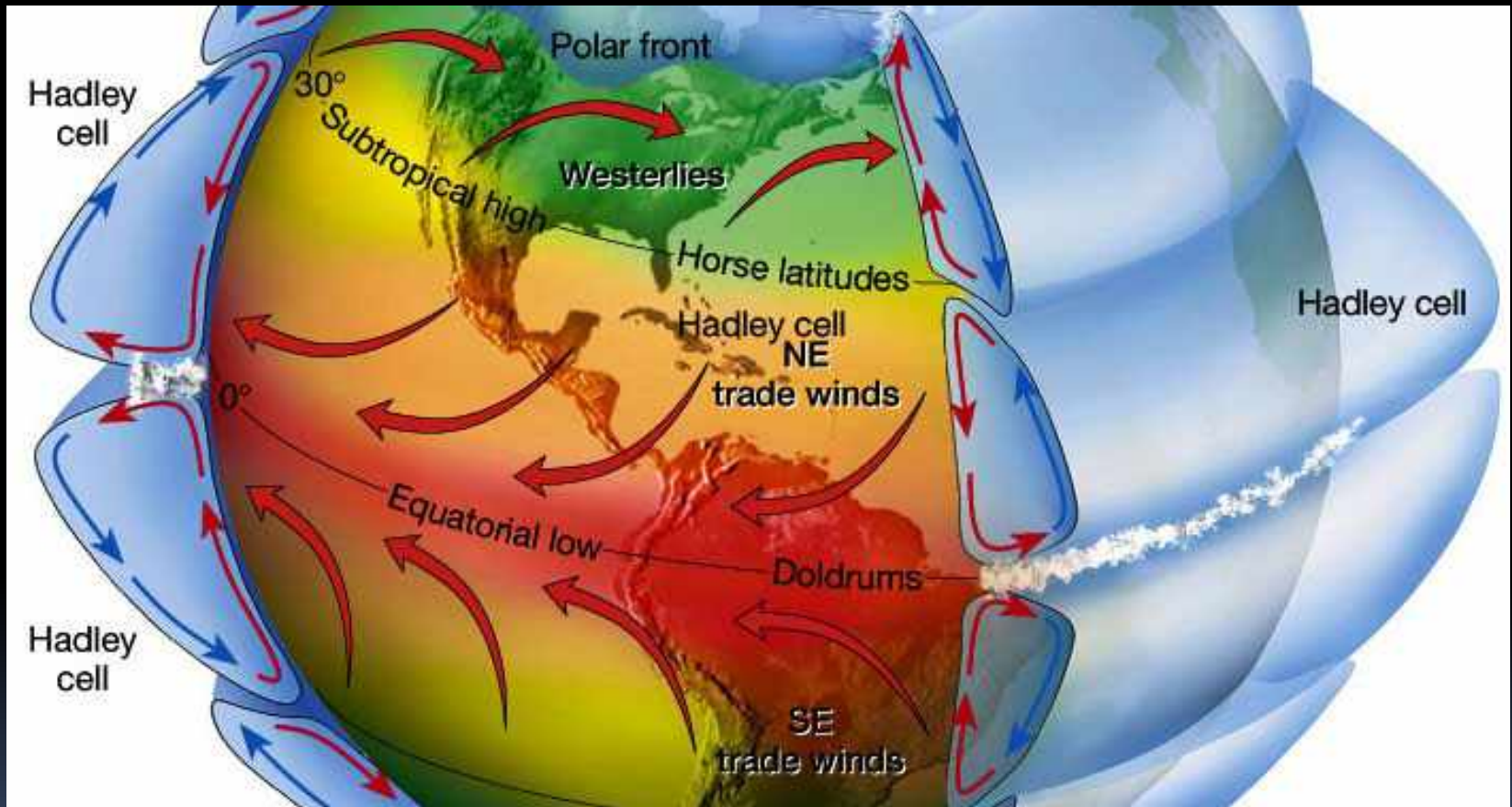
FORECASTING

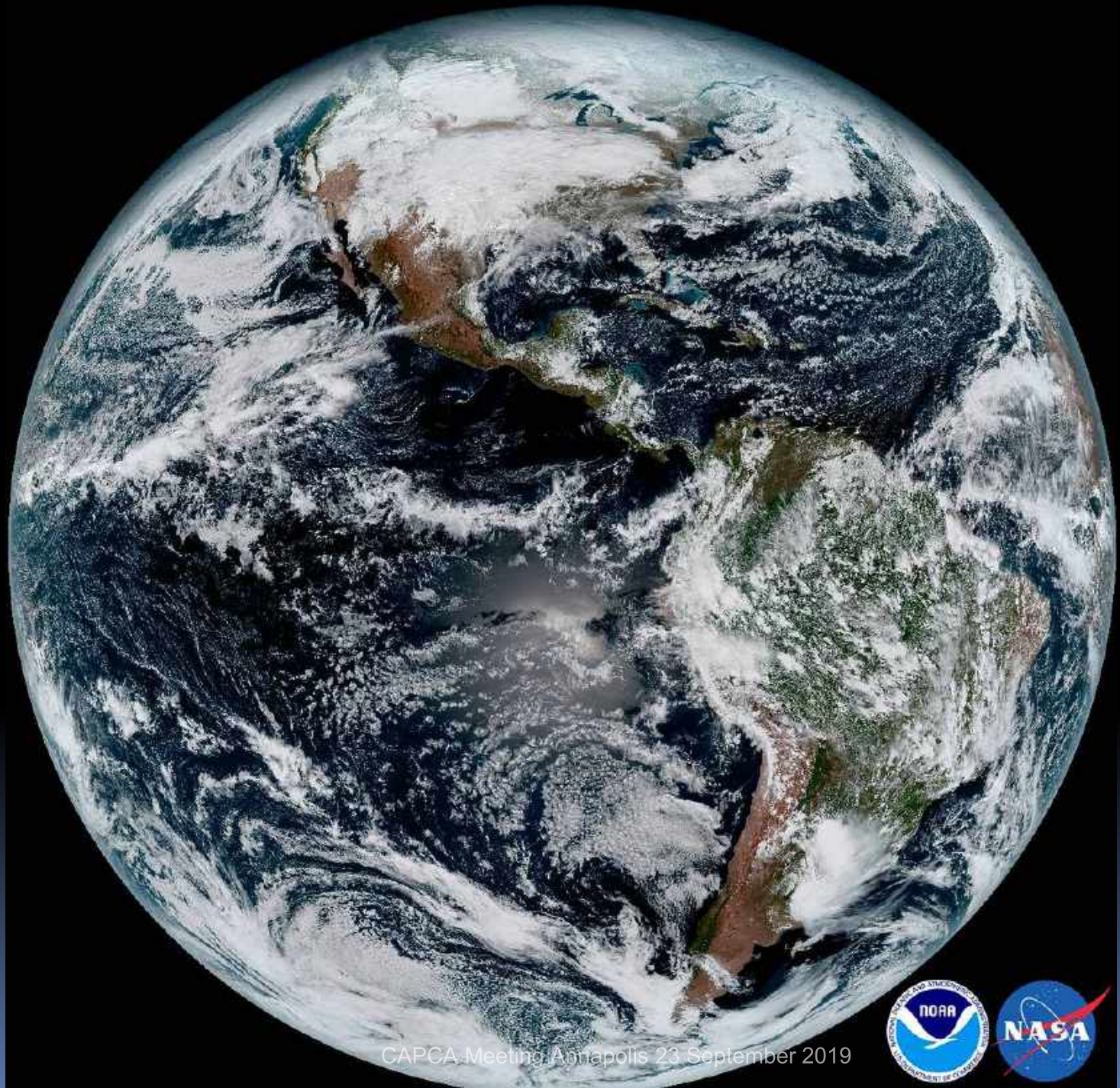






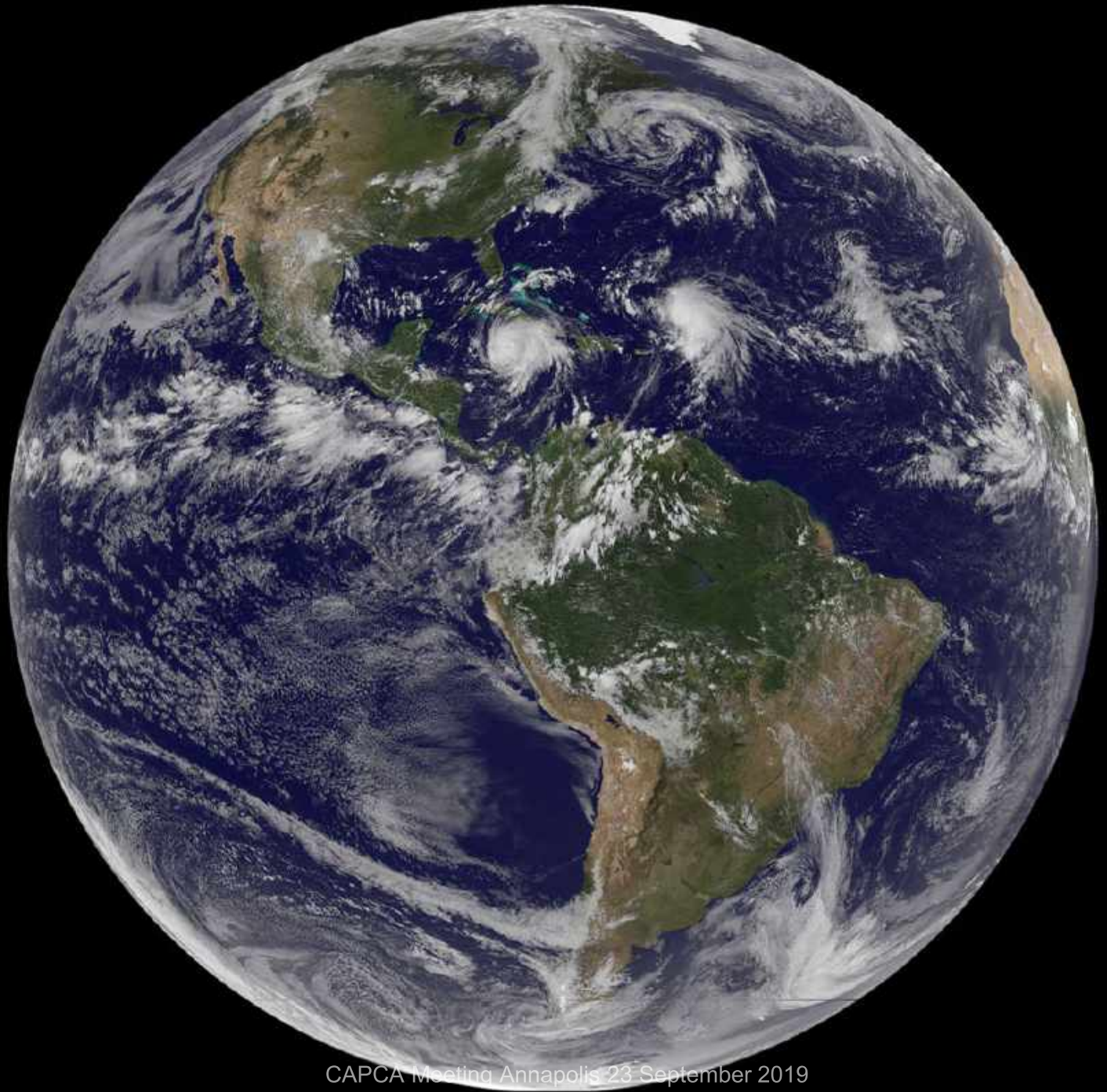
Hadley Cell





CAPCA Meeting Annapolis 23 September 2019





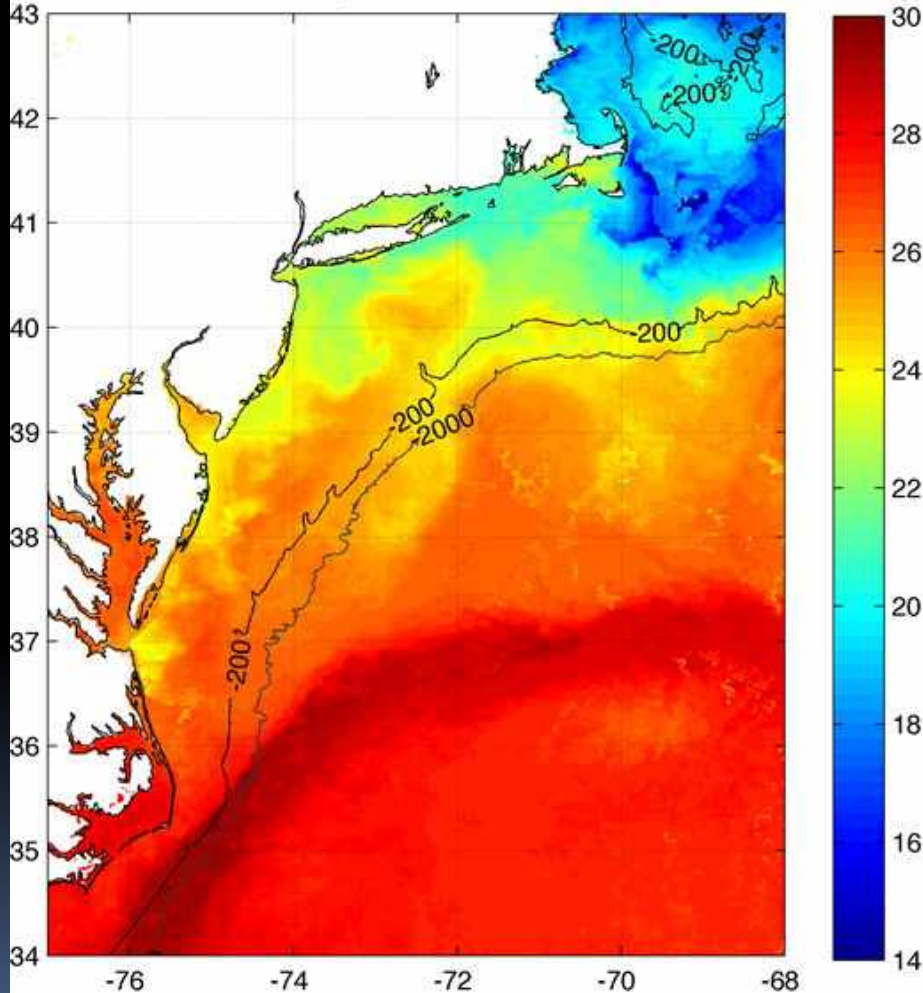
CAPCA Meeting Annapolis 23 September 2019

FORECASTING: IRENE, 2011

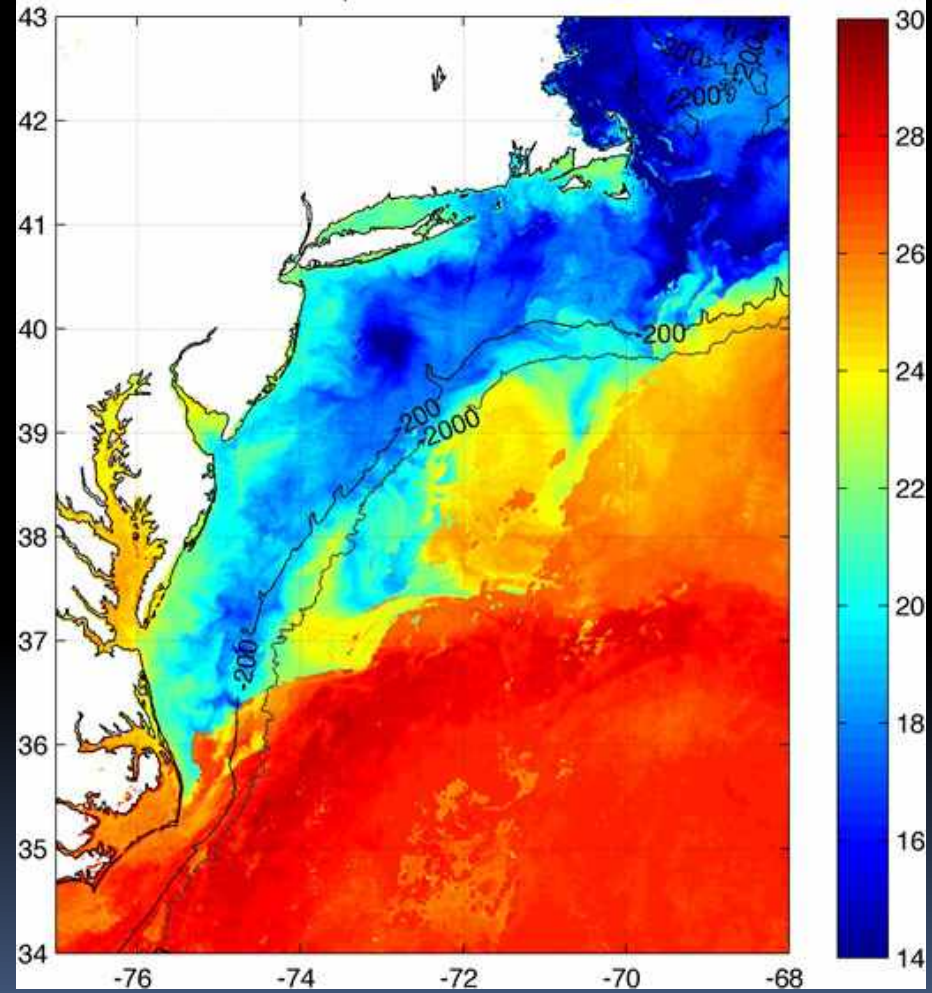
BEFORE

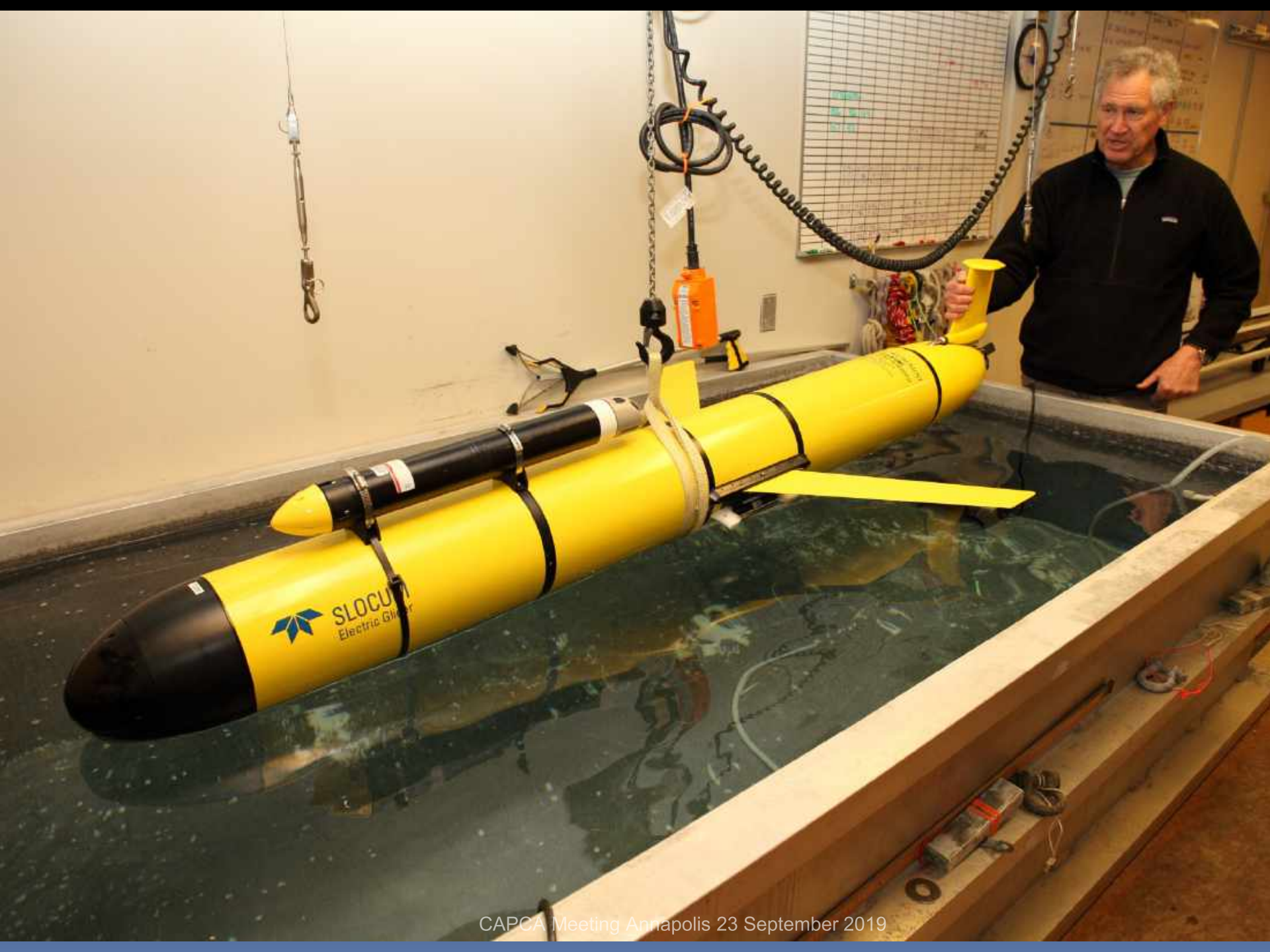
AFTER

AVHRR+sport 20110827T070000



AVHRR+sport 20110831T070000









MARACOOS

Ocean Information for a Changing World

2017 Season

Harvey
Irma
Jose
Maria

Deployment Location

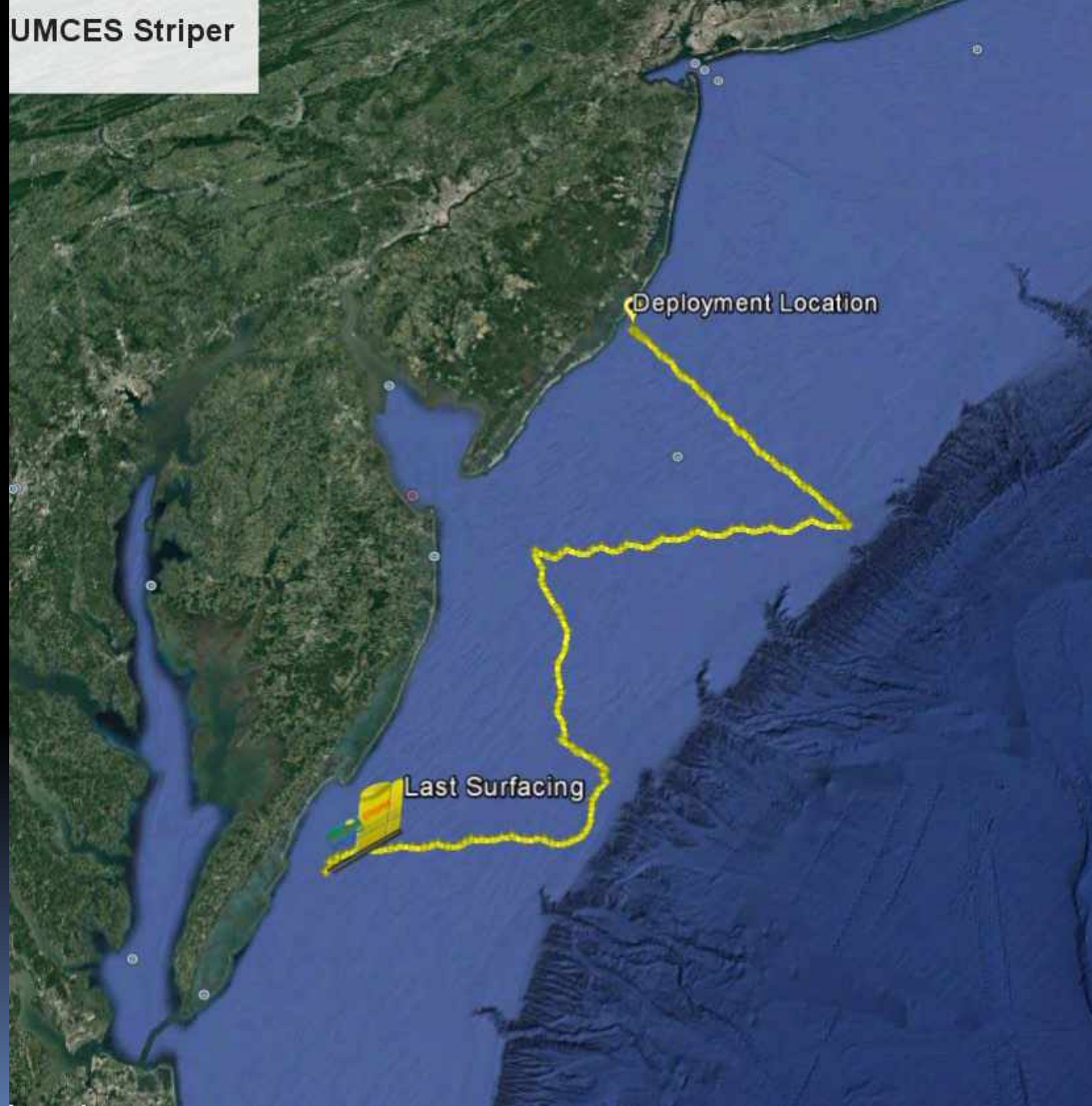
Deployment Location

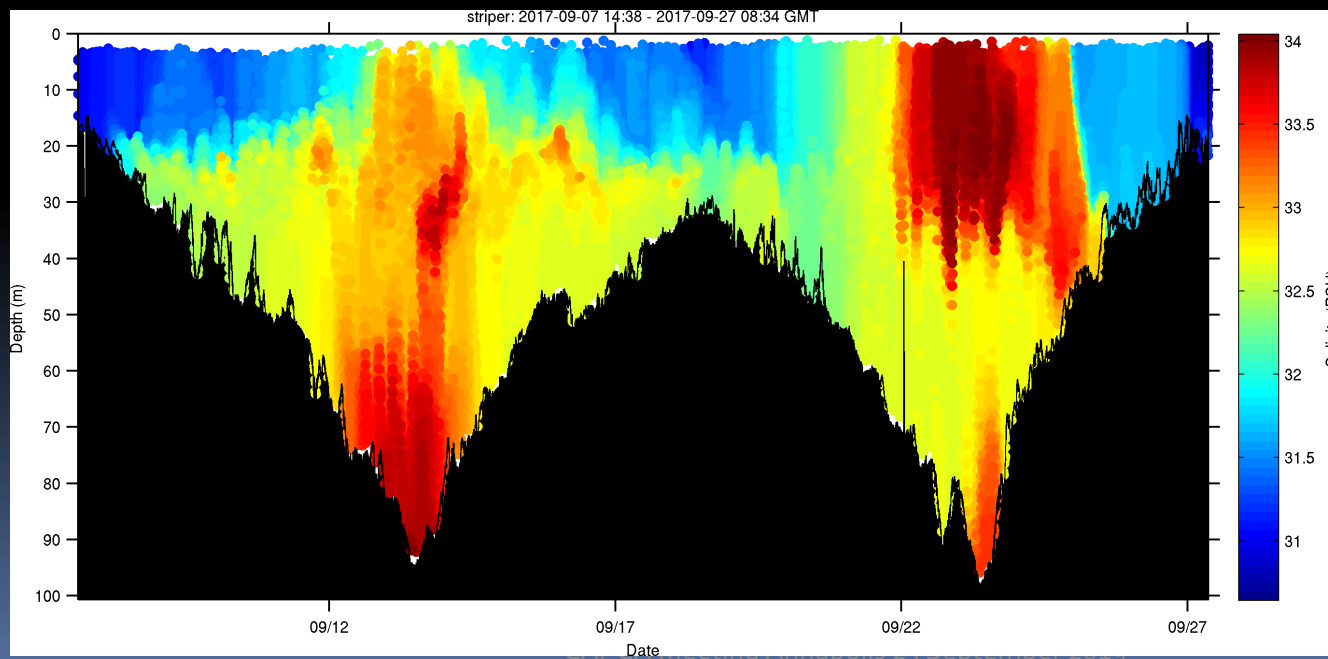
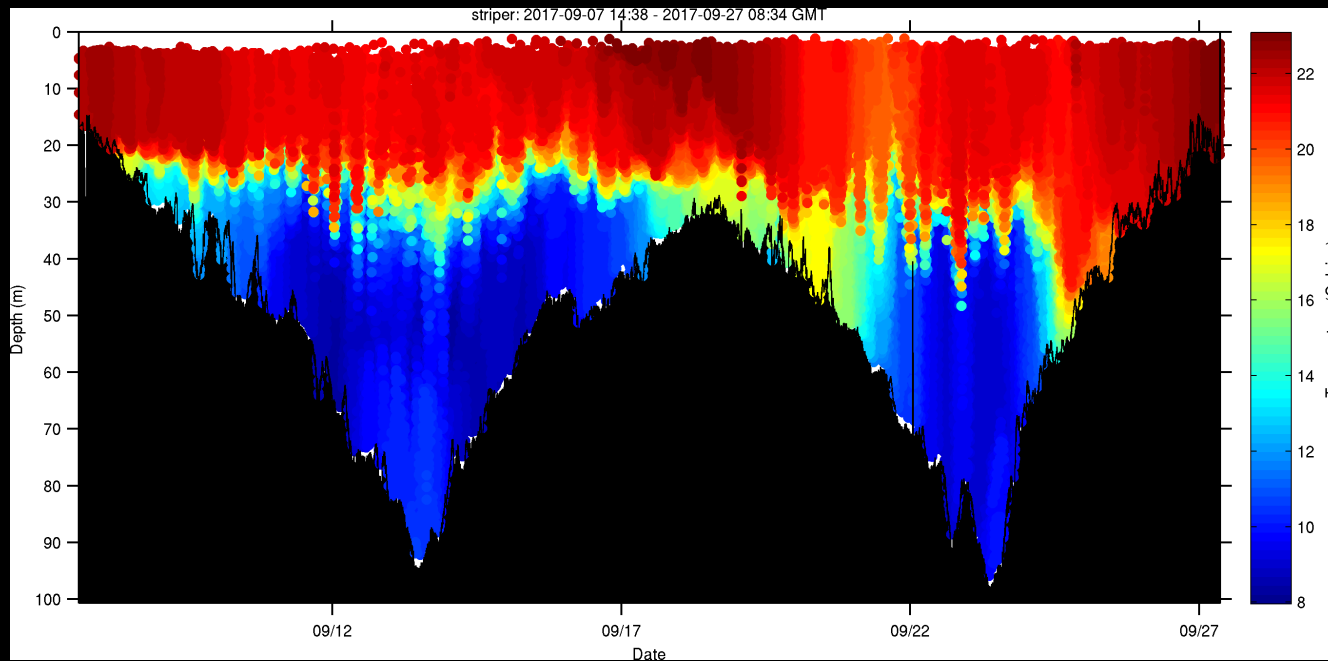
Last Surfacing

Last Surfacing



UMCES Striper



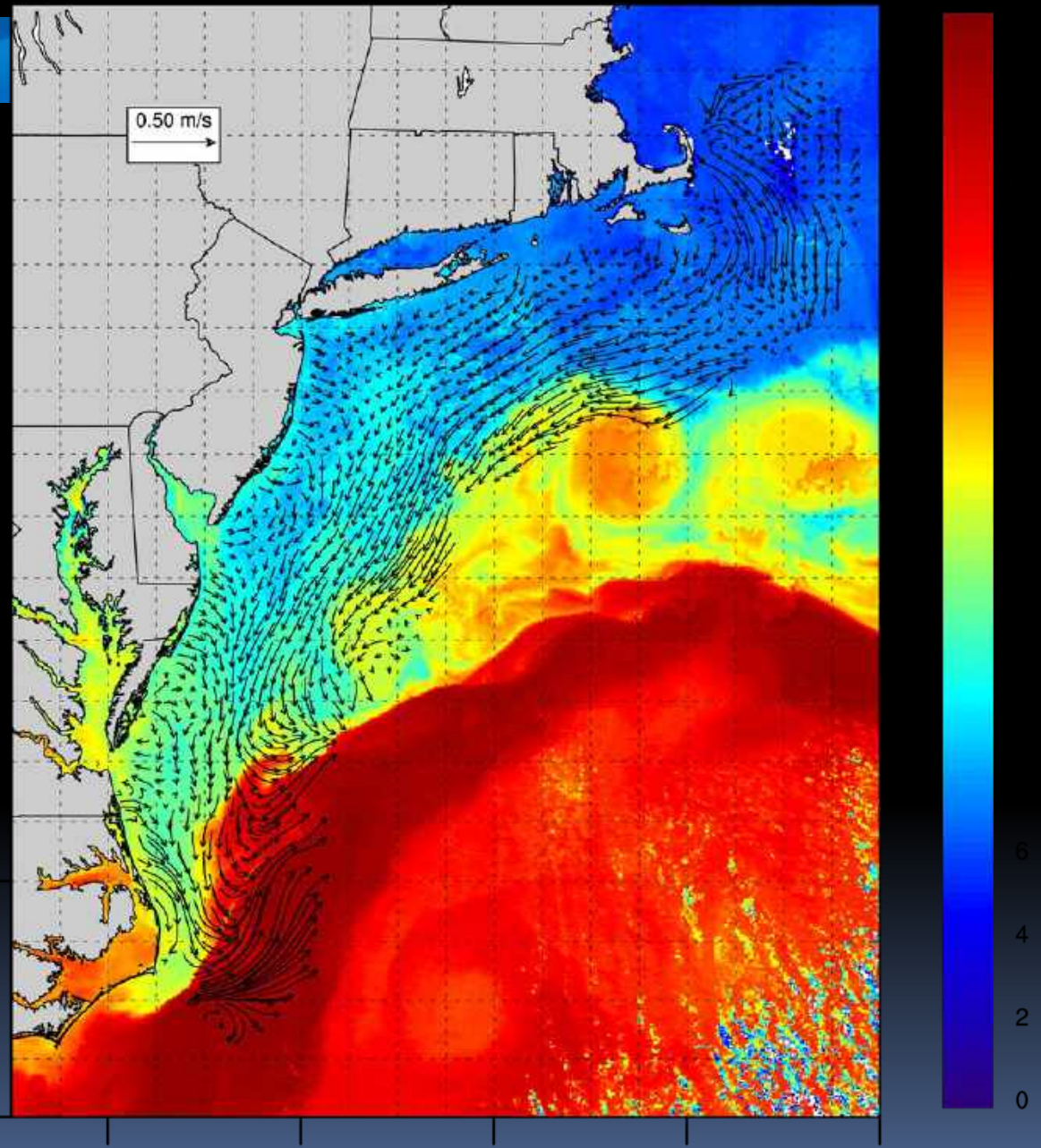




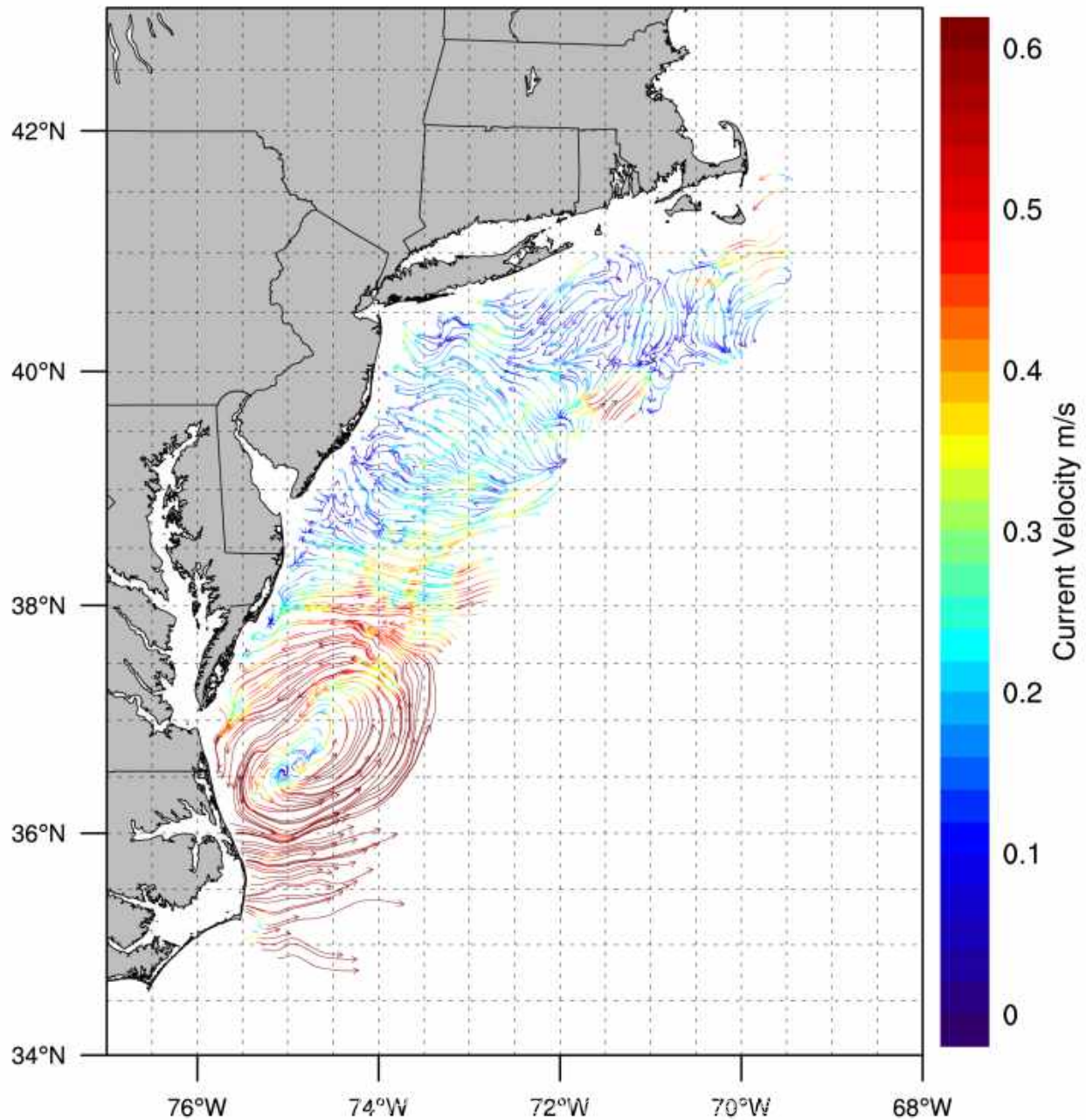
MARACOOS

Ocean Information for a Changing World

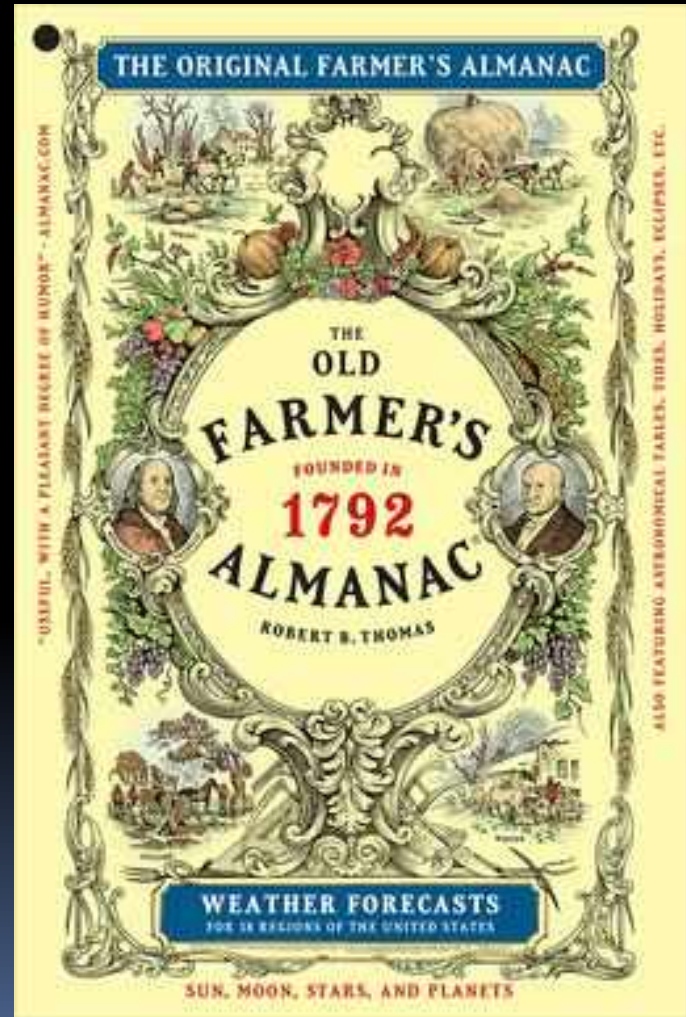
Satellites and HF Radar



Hourly Surface Current Field (5MHz): 2014-Jul-04 13:00



FORECASTING



SHORT HISTORY



Nansen



Bjerknes



Sverdrup



Rossby



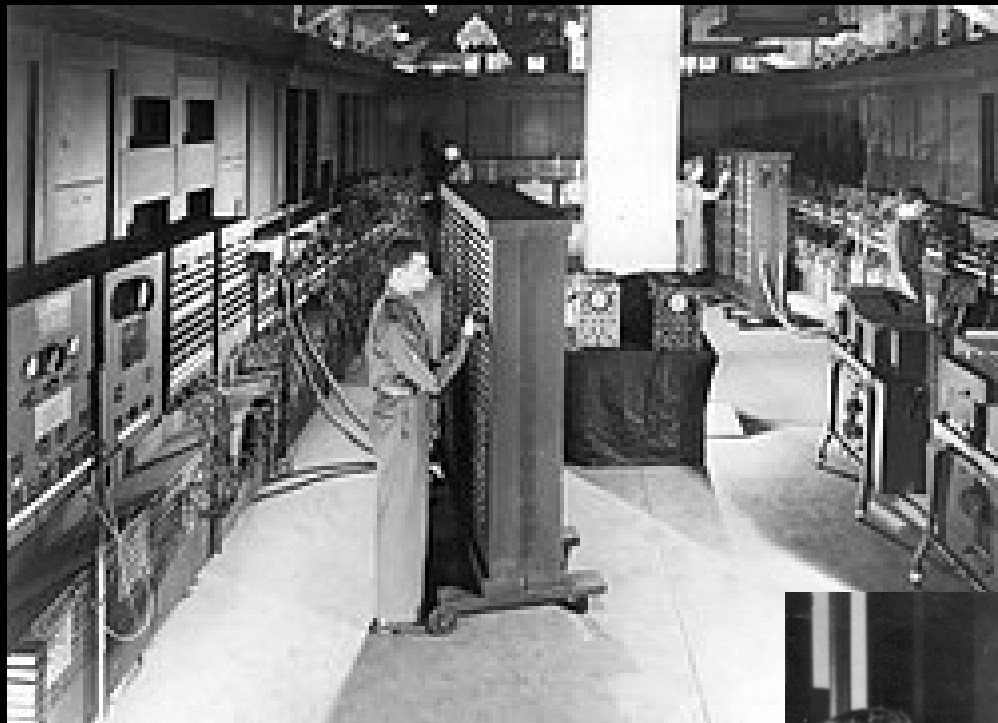
Revelle



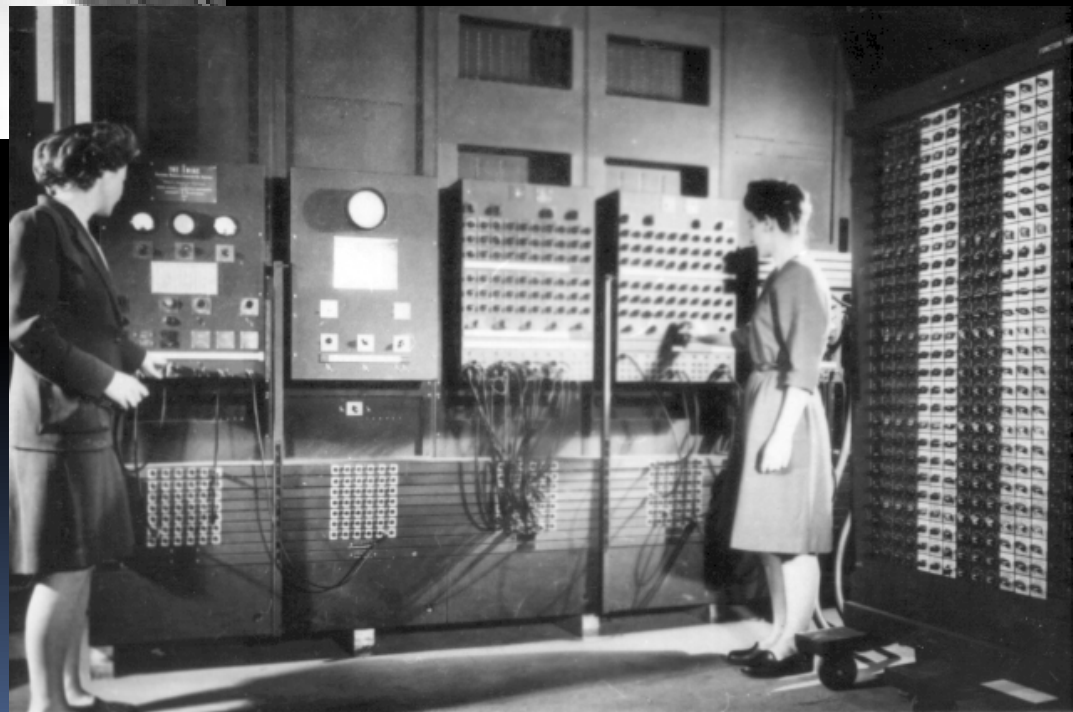
Pritchard



Montgomery

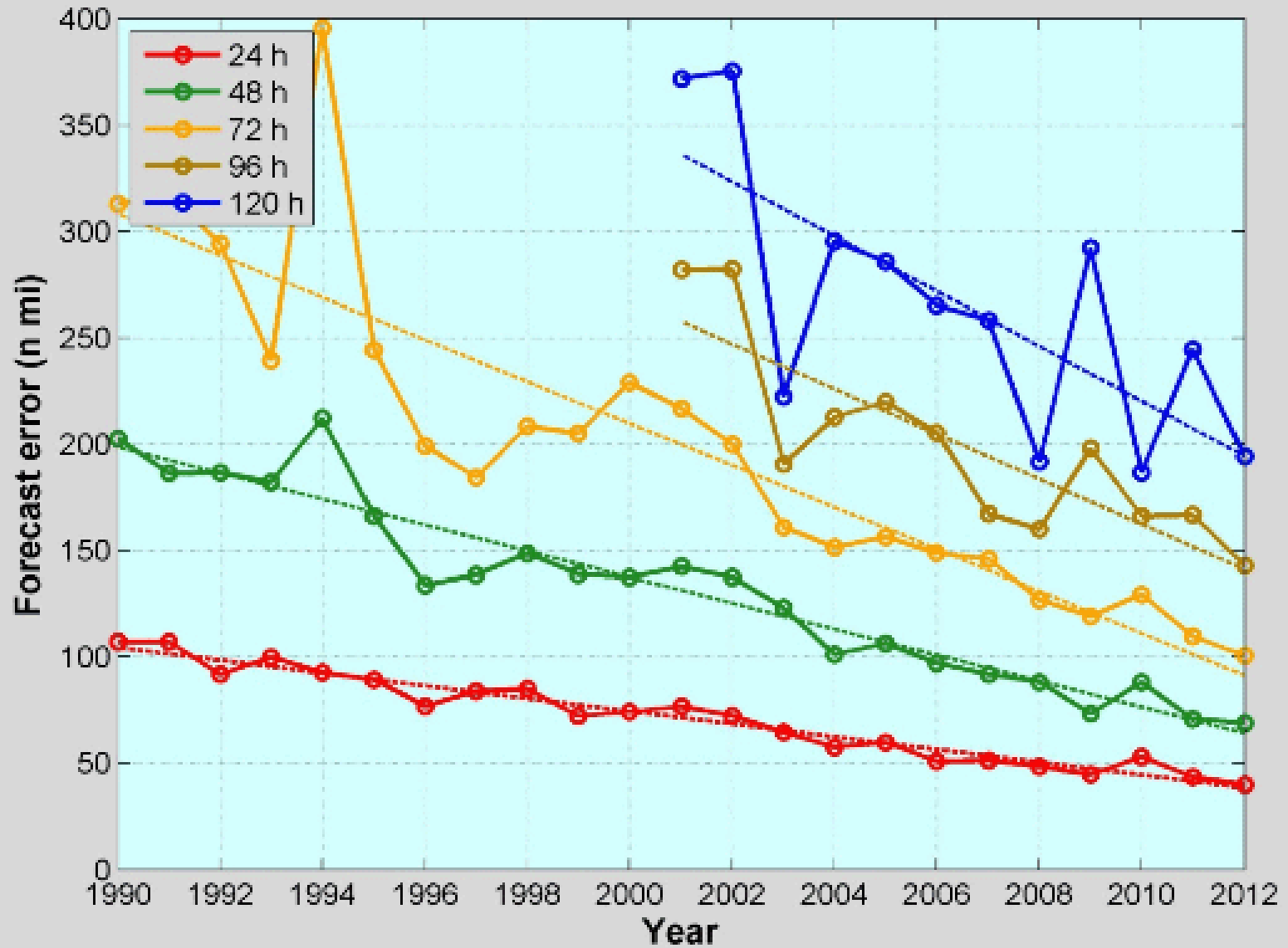


ENIAC



HOW ARE WE DOING IN THE FORECASTING GAME?

NHC Official Track Error Trend Atlantic Basin



HOW ARE WE DOING IN THE
FORECASTING GAME?

The Europeans (ECMWF)
are Still Winning

BUT GFS has made some
Significant improvements

US vs. THEM: Solutions

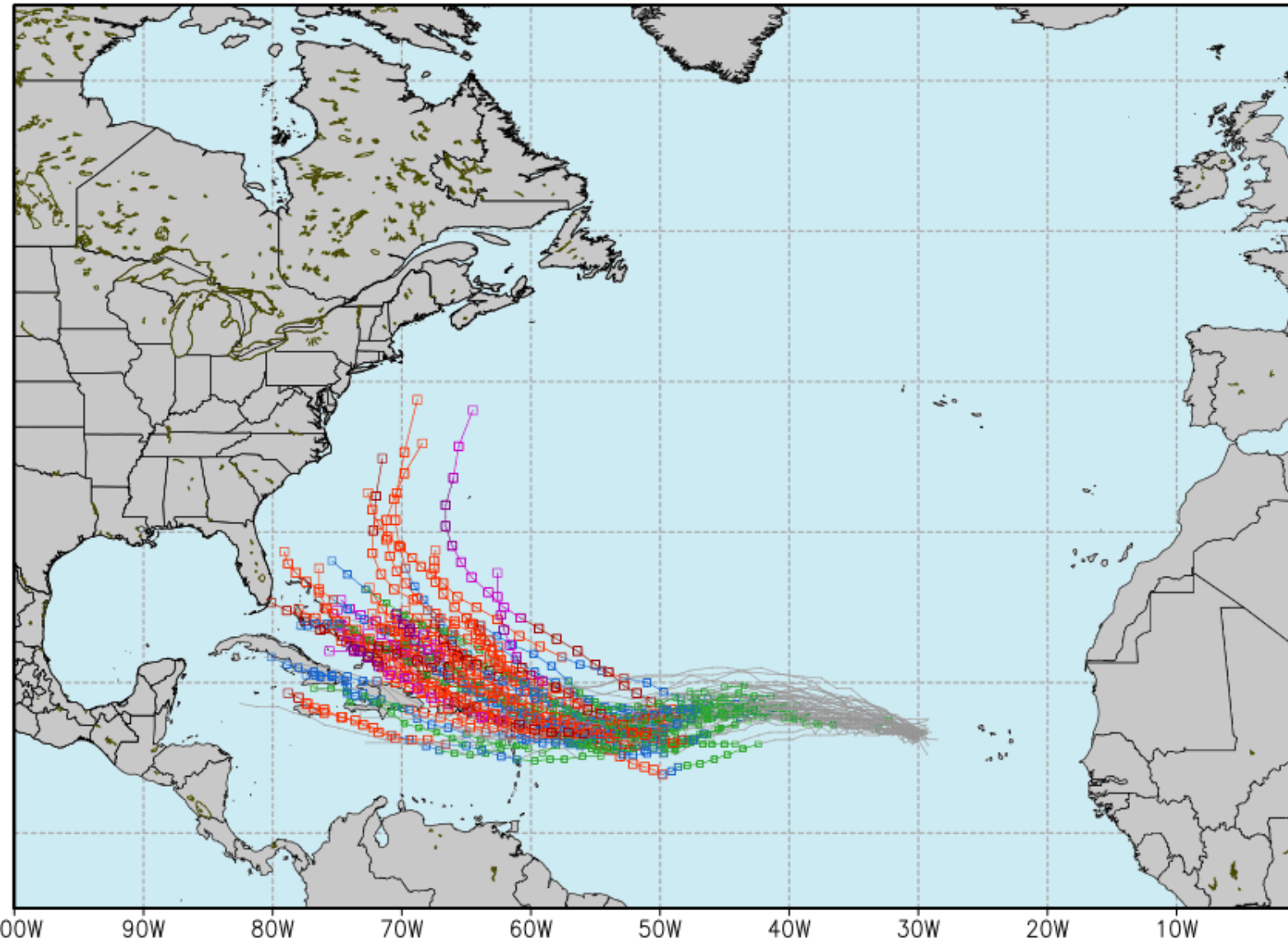
- Resolution
- More Ensembles
- Data Assimilation
- Initial Conditions
- Manpower
- Research-to-Operations



IRMA ECMWF Ensemble Guidance [51-members+deterministic]
 Forecast Init: 2017083012 --> Next 10 days

o-o > 1000 hPa o-o 960 - 979 hPa
 o-o 990 - 1000 hPa o-o 950 - 959 hPa
 o-o 980 - 989 hPa o-o < 940 hPa

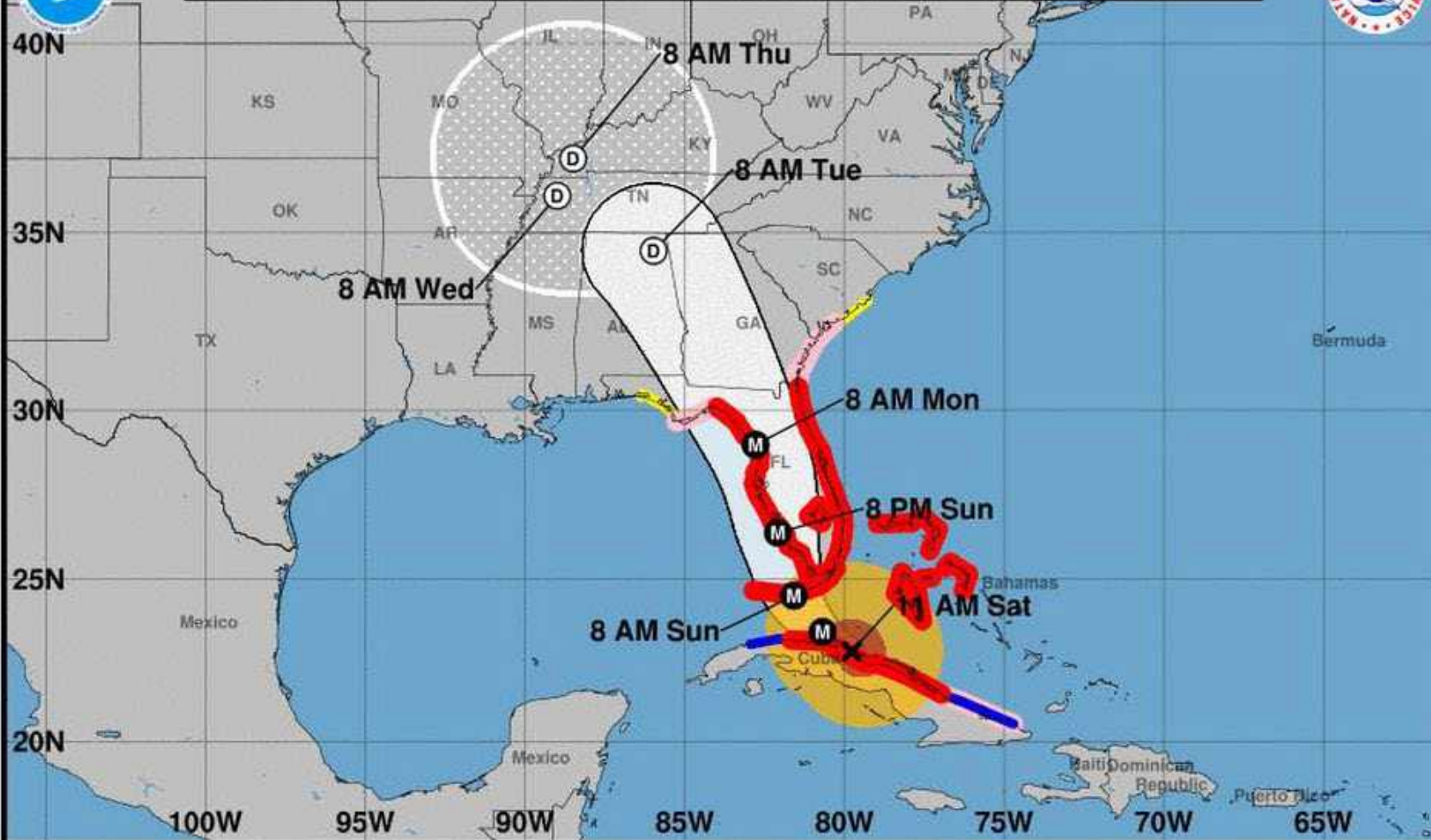
Model Mems



| | | |
|----|-----|------|
| 01 | 228 | 1001 |
| 10 | 240 | 960 |
| 11 | 240 | 972 |
| 12 | 240 | 935 |
| 13 | 240 | 971 |
| 14 | 240 | 957 |
| 15 | 240 | 944 |
| 16 | 240 | 1004 |
| 17 | 240 | 947 |
| 18 | 240 | 959 |
| 19 | 240 | 947 |
| 02 | 240 | 1001 |
| 20 | 240 | 964 |
| 21 | 240 | 981 |
| 22 | 240 | 962 |
| 23 | 240 | 960 |
| 24 | 162 | 1007 |
| 25 | 240 | 962 |
| 26 | 240 | 962 |
| 27 | 240 | 945 |
| 28 | 150 | 1007 |
| 29 | 240 | 977 |
| 03 | 240 | 1002 |
| 30 | 240 | 1004 |
| 31 | 240 | 962 |
| 32 | 240 | 957 |
| 33 | 240 | 941 |
| 34 | 240 | 965 |
| 35 | 240 | 960 |
| 36 | 168 | 1006 |
| 37 | 240 | 942 |
| 38 | 240 | 1003 |
| 39 | 240 | 938 |
| 04 | 240 | 945 |
| 40 | 240 | 968 |
| 41 | 240 | 986 |
| 42 | 240 | 987 |
| 43 | 186 | 1004 |
| 44 | 240 | 963 |
| 45 | 240 | 956 |
| 46 | 174 | 1003 |
| 47 | 240 | 966 |
| 48 | 240 | 950 |
| 49 | 240 | 962 |
| 05 | 240 | 961 |
| 50 | 240 | 983 |
| CN | 240 | 955 |
| HR | 240 | 933 |
| 06 | 240 | 959 |
| 07 | 138 | 1002 |
| 08 | 240 | 931 |
| 09 | 240 | 940 |



Note: The cone contains the probable path of the storm center but does not show the size of the storm. Hazardous conditions can occur outside of the cone.



Hurricane Irma
 Saturday September 09, 2017
 11 AM EDT Advisory 42
 NWS National Hurricane Center

Current information: x
 Center location 22.8 N 79.8 W
 Maximum sustained wind 125 mph
 Movement W at 9 mph

Forecast positions:
 ● Tropical Cyclone ○ Post/Potential TC
 Sustained winds: D < 39 mph
 S 39-73 mph H 74-110 mph M > 110 mph

Potential track area:



Watches:



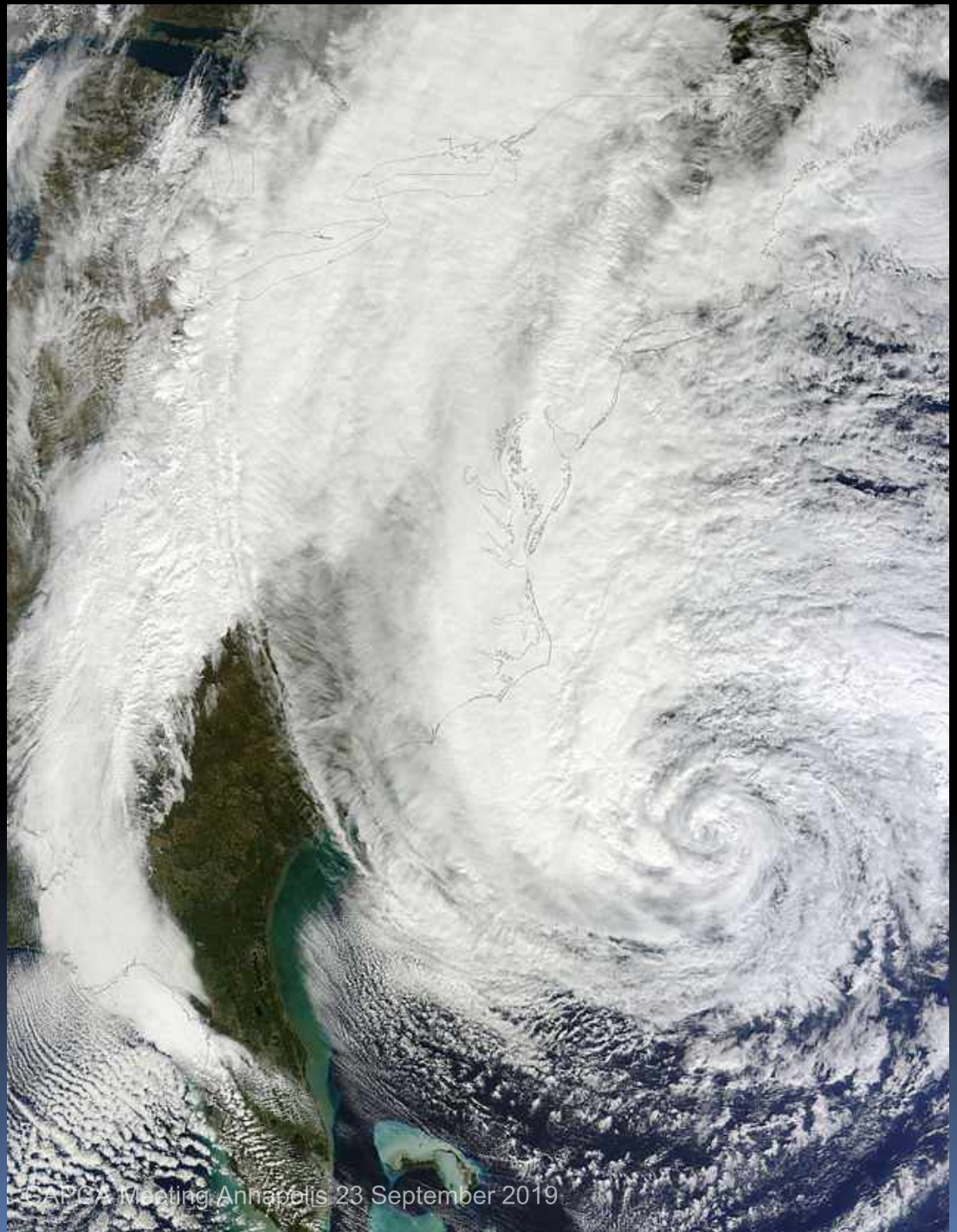
Warnings:



Current wind extent:



SANDY



SANDY: CHESAPEAKE BAY

Tangier, 10:32am, Monday 29 October 2012



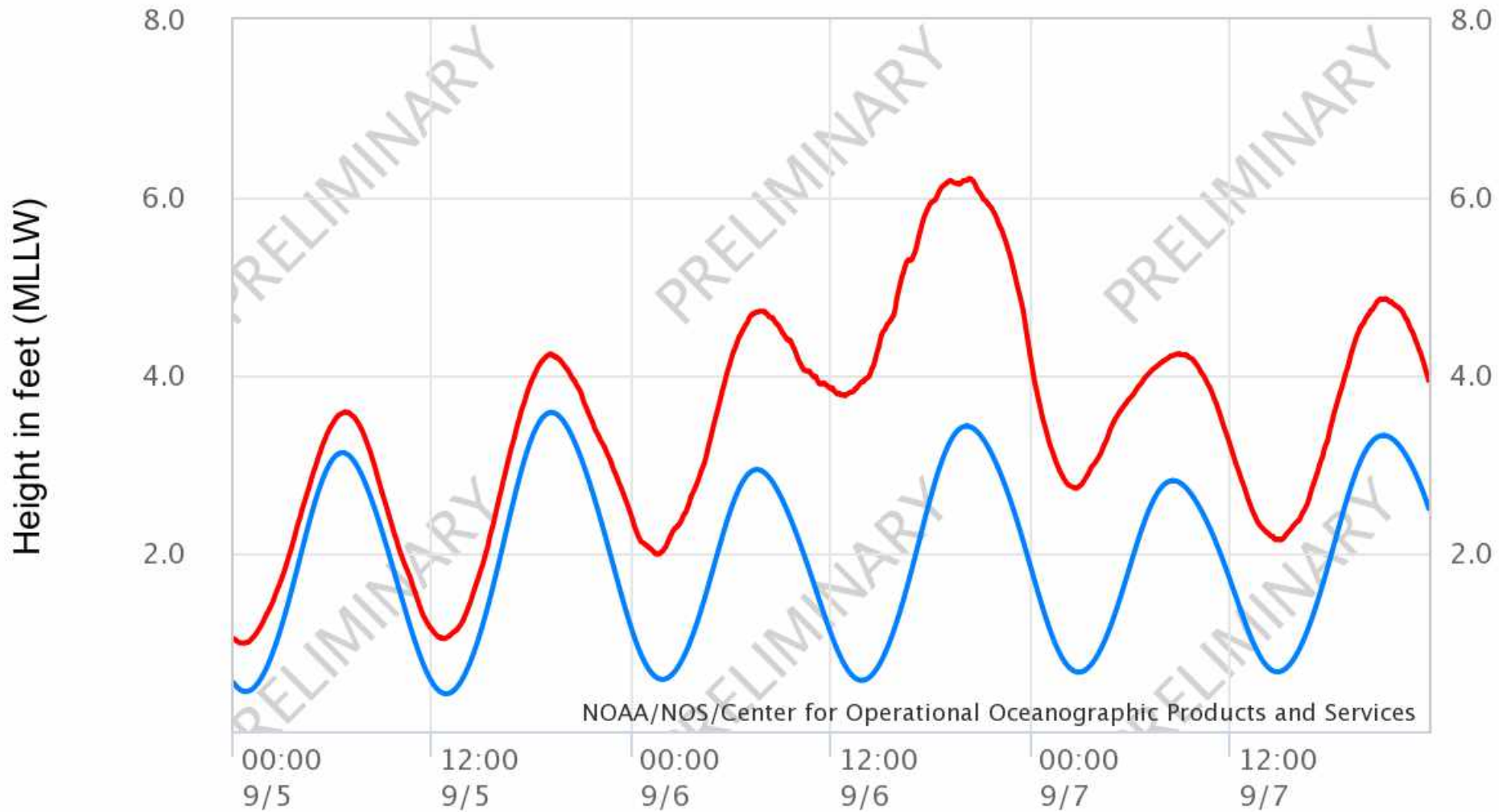
“Tide on Tangier streets, coming up fast, highest in Lonnie's life. Jessie at Bishops Head reports little rise and no problems. Very interesting storm. Thanks again for heads up. Don”





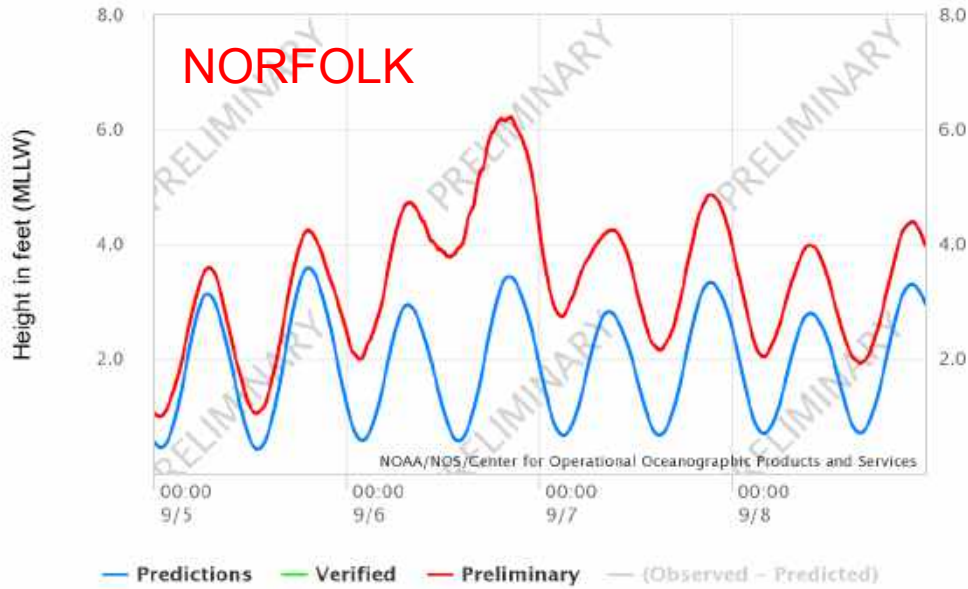
DORIAN

NOAA/NOS/CO-OPS
Observed Water Levels at 8639348, Money Point VA
From 2019/09/05 00:00 GMT to 2019/09/07 23:59 GMT



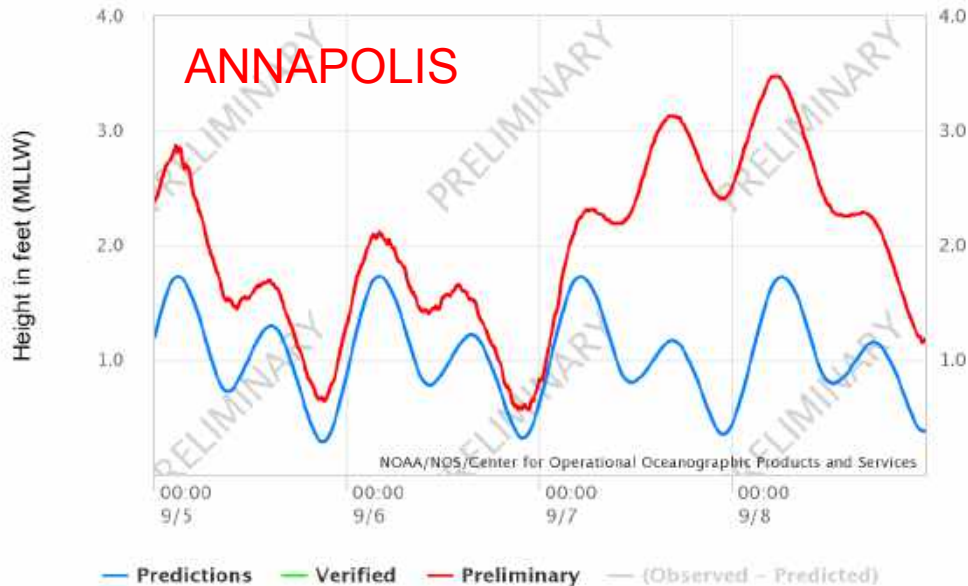
— Predictions — Verified — Preliminary — (Observed - Predicted)

NOAA/NOS/CO-OPS
Observed Water Levels at 8639348, Money Point VA
From 2019/09/05 00:00 GMT to 2019/09/08 23:59 GMT

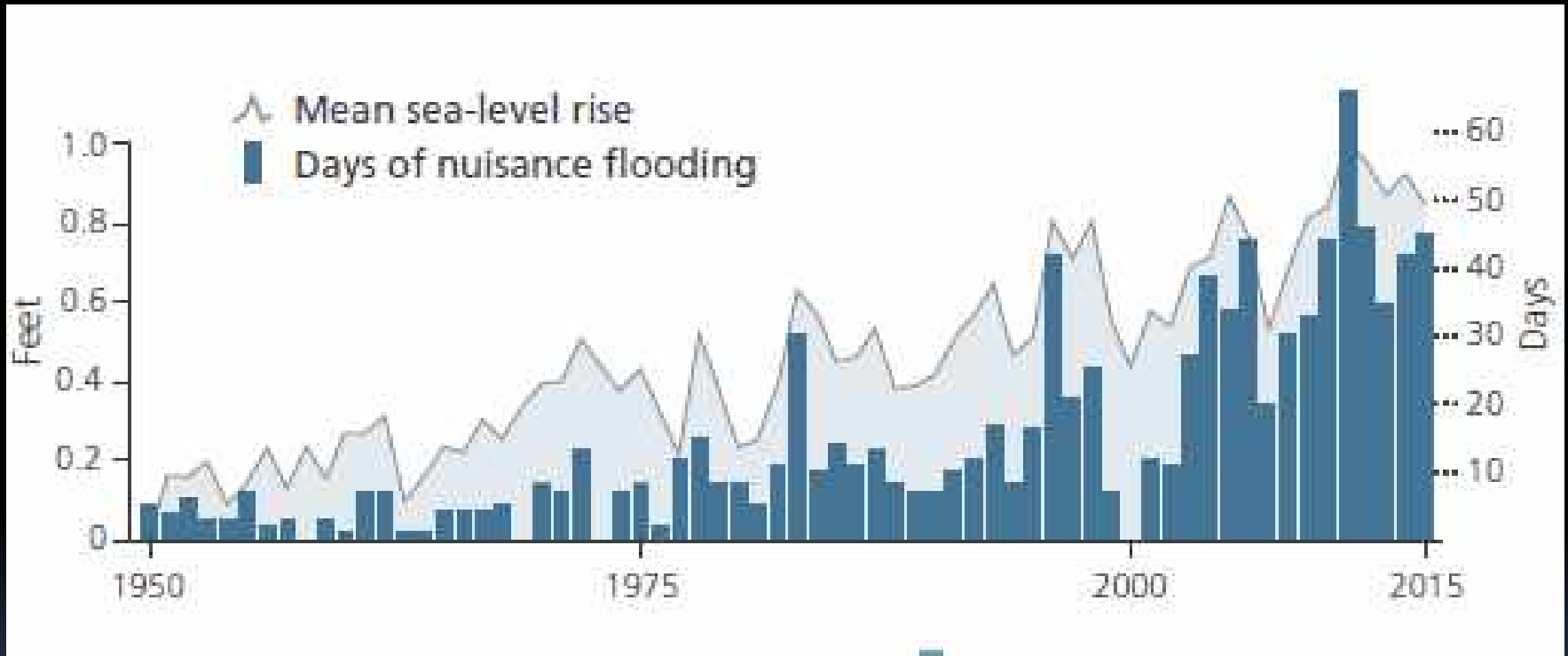


Surge Propagation

NOAA/NOS/CO-OPS
Observed Water Levels at 8575512, Annapolis MD
From 2019/09/05 00:00 GMT to 2019/09/08 23:59 GMT



Nuisance Flooding, Annapolis



Dorchester County, Maryland



David Harp

Dorchester County is "the rural Ground Zero" of sea-level rise in the Chesapeake, where climate change is leaving a mark — not in 25 or 50 years, but now, says Tom Horton, Bay Journal.



Updating Maryland's **Sea-level Rise Projections**



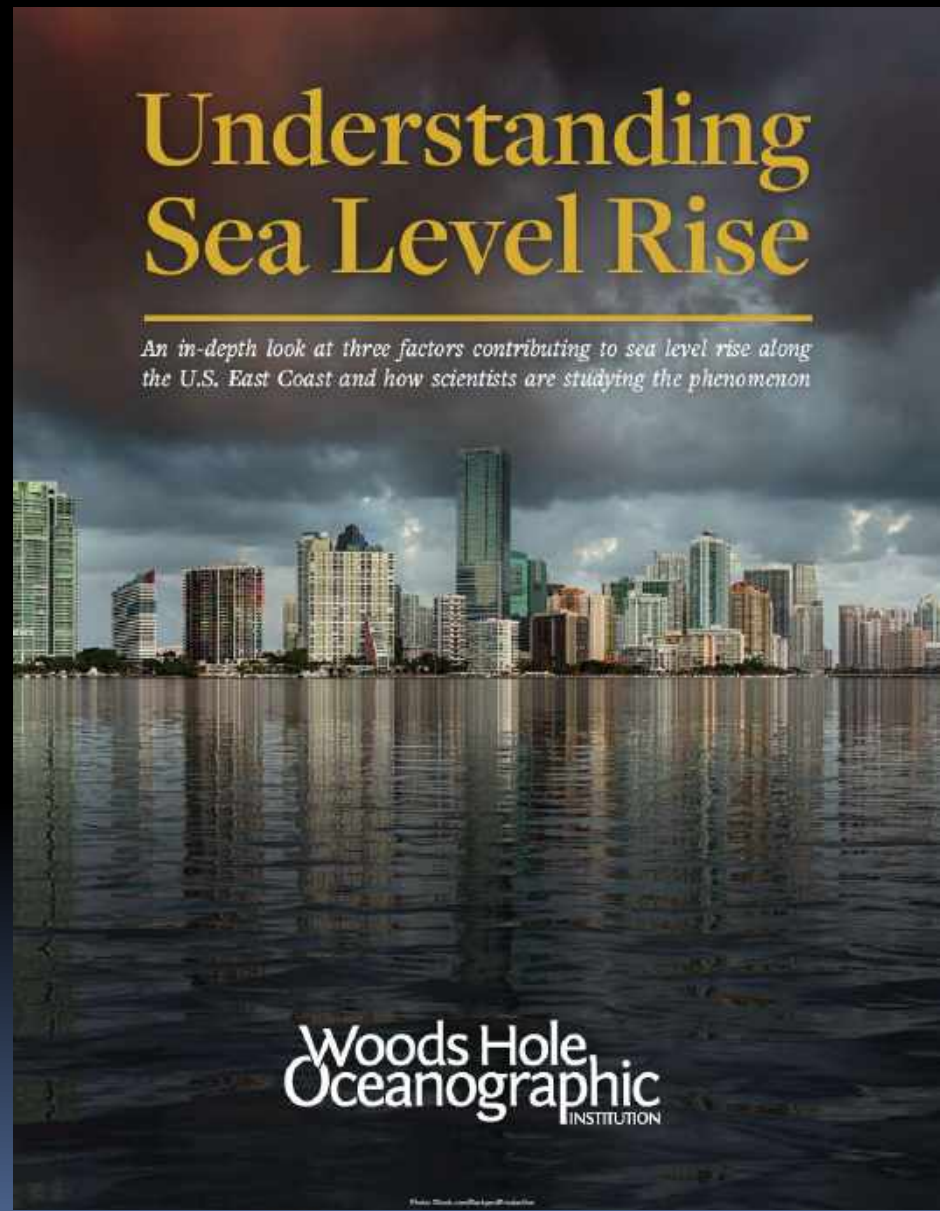
*Scientific and Technical Working Group
Maryland Climate Change Commission*

June 26, 2013

1.4± ft. by 2050

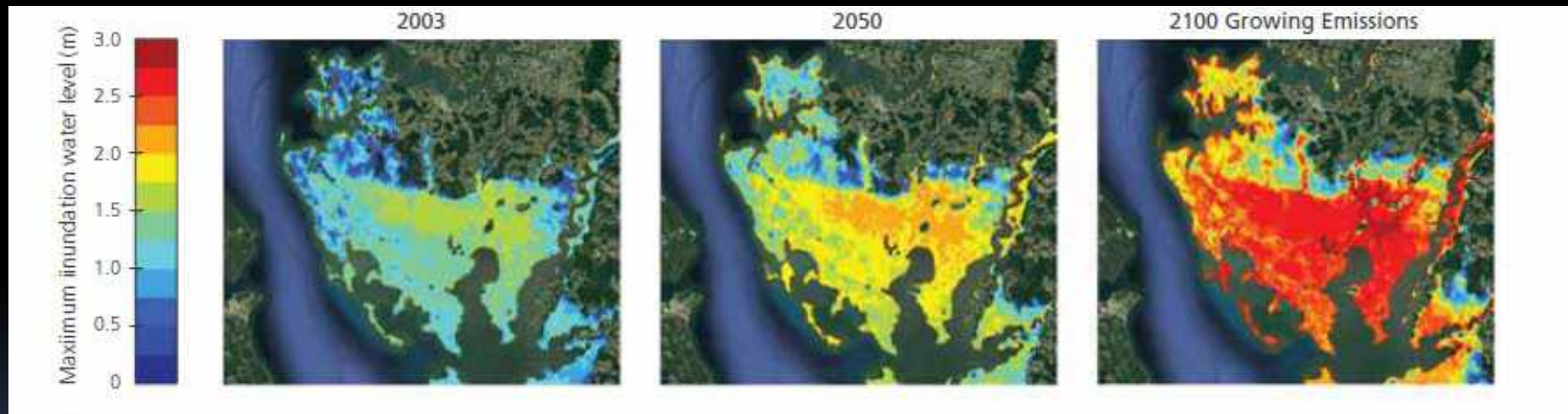
by 2100,
it depends on
emissions and
ice

2018 Update

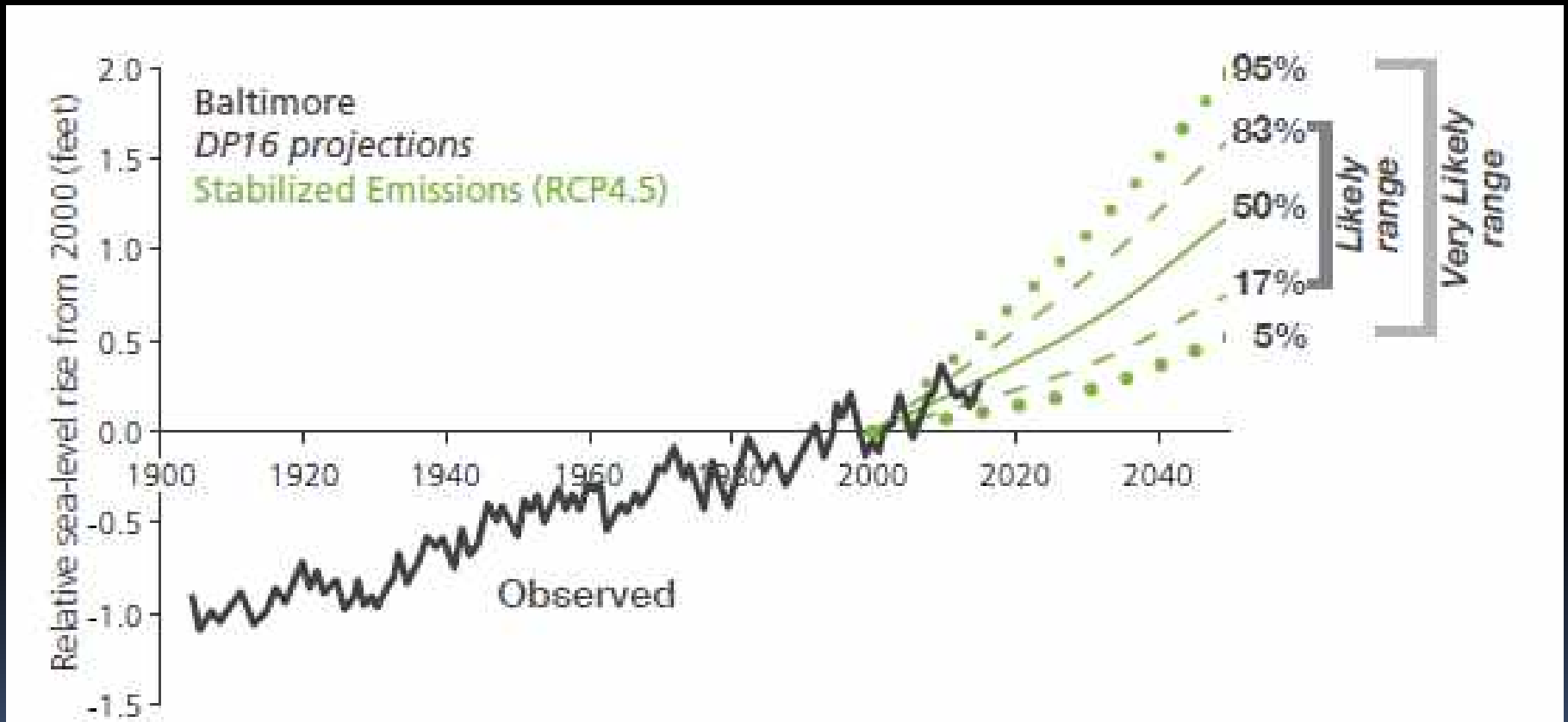


Mid-Atlantic is a Hot Spot for Sea-Level Rise

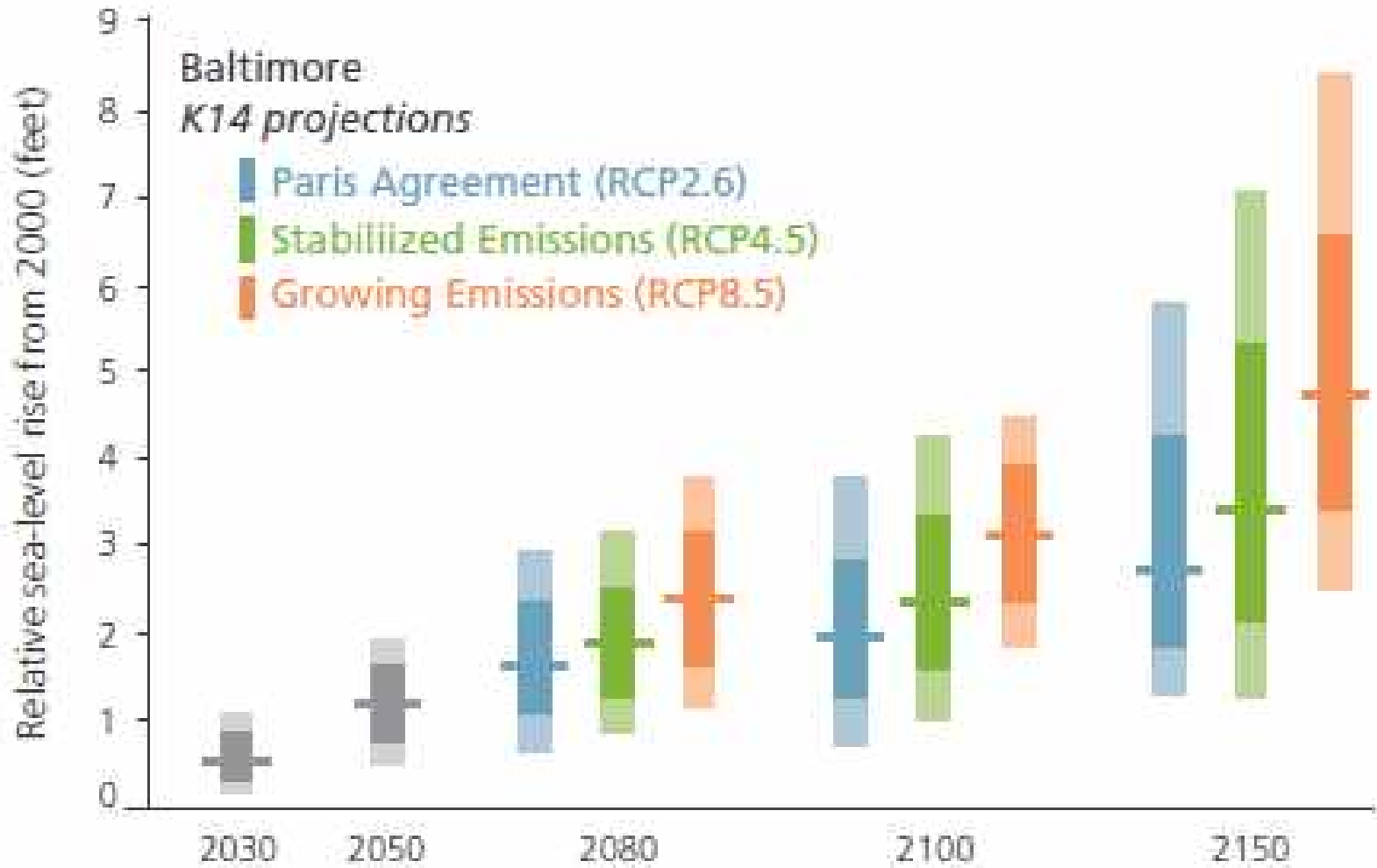
Dorchester County storm surge from an Isabel Storm, past and future



2018 PROJECTION UPDATE: 2050



AND LONGER...



HURRICANES: IT'S NOT JUST THE WIND

- AGNES 1972
- HARVEY 2017
- IMELDA 2019

Are Hurricanes becoming more frequent or more intense?

IMPACTS

- WIND
- SURGE
- RAIN
- ECOSYSTEMS/FISHERIES

“There are known knowns. There are things we know we know. We also know there are known unknowns. That is to say, we know there are some things we do not know. But there are also unknown unknowns, the ones we don't know we don't know.”

Donald Rumsfeld

CERTAINTY AND UNCERTAINTY

THWAITES GLACIER



A hurricane is an absolutely, beautifully smooth-running engine with a very temperamental starter motor—Ed Zipser, University of Utah

Warming will increase the size and intensity of storms, but it will also make them more difficult to form—Kerry Emanuel, MIT

Acceleration

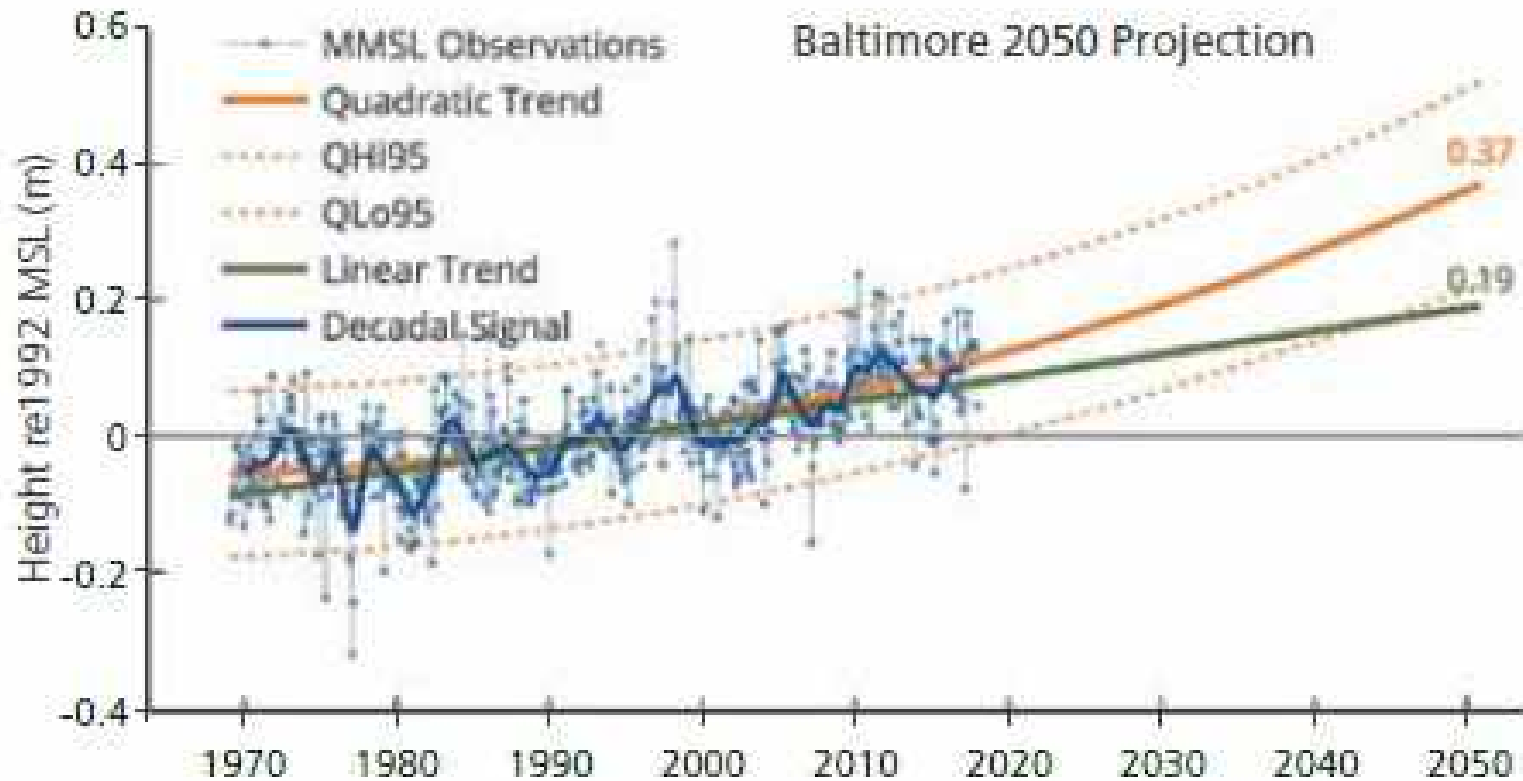


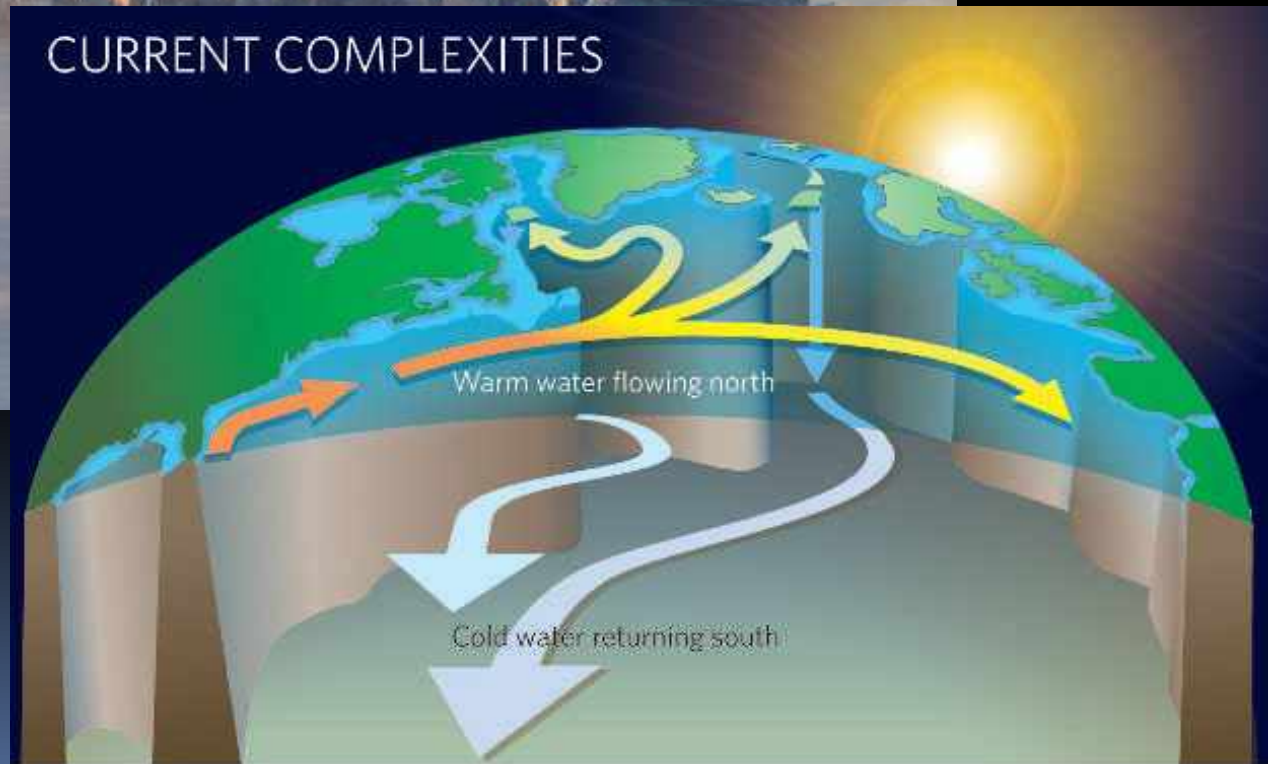
Table 1. Individual contributions to global mean sea-level rise in mm/yr.

| | 1993-2015 | 2005-2015 |
|-------------------|-------------|-------------|
| Thermal expansion | 1.30 | 1.30 |
| Glaciers | 0.65 | 0.74 |
| Greenland | 0.48 | 0.76 |
| Antarctic | 0.25 | 0.42 |
| Residual | 0.37 | 0.28 |
| Total | 3.05 | 3.50 |

The Day After Tomorrow

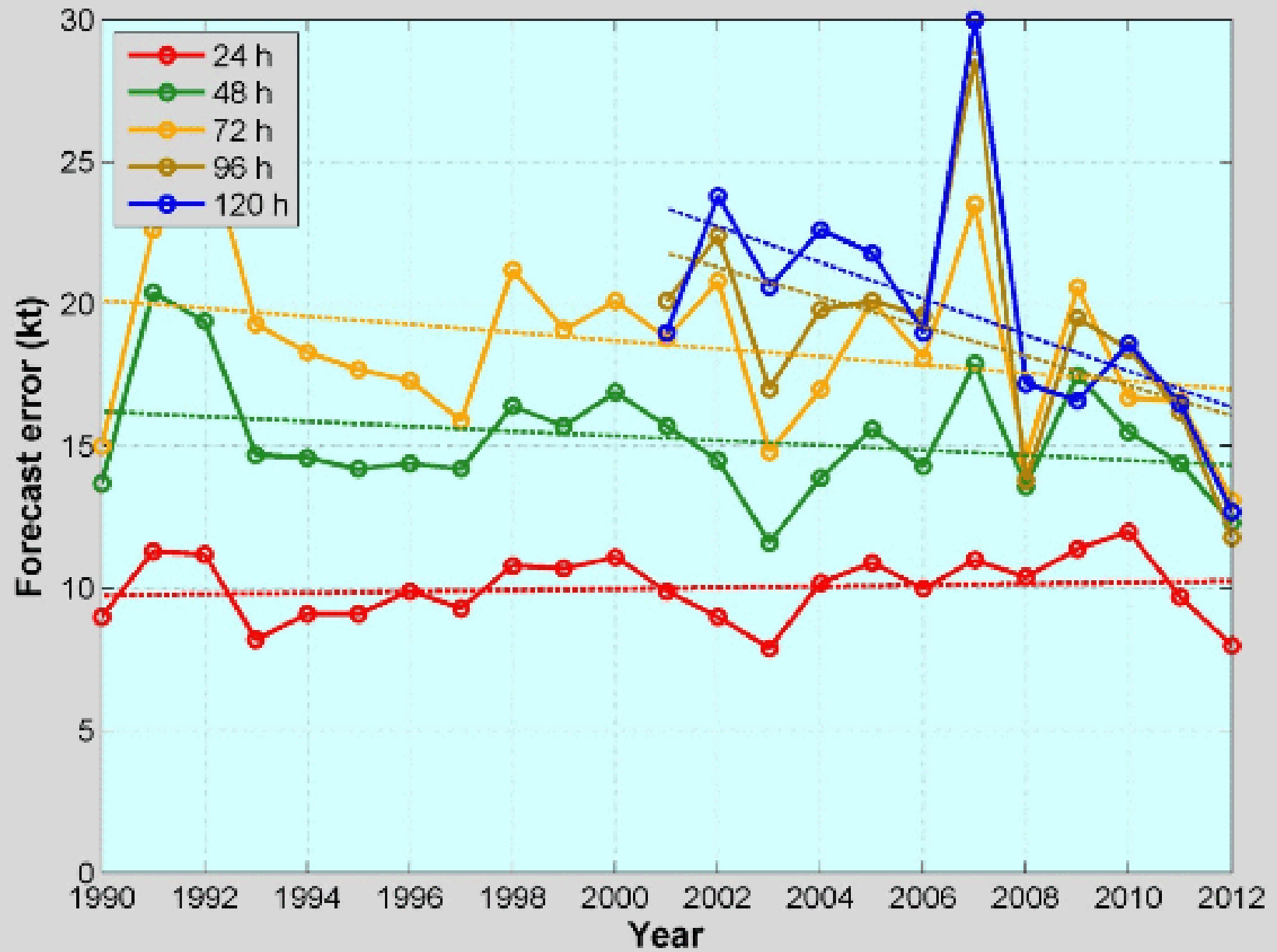


CURRENT COMPLEXITIES





NHC Official Intensity Error Trend Atlantic Basin

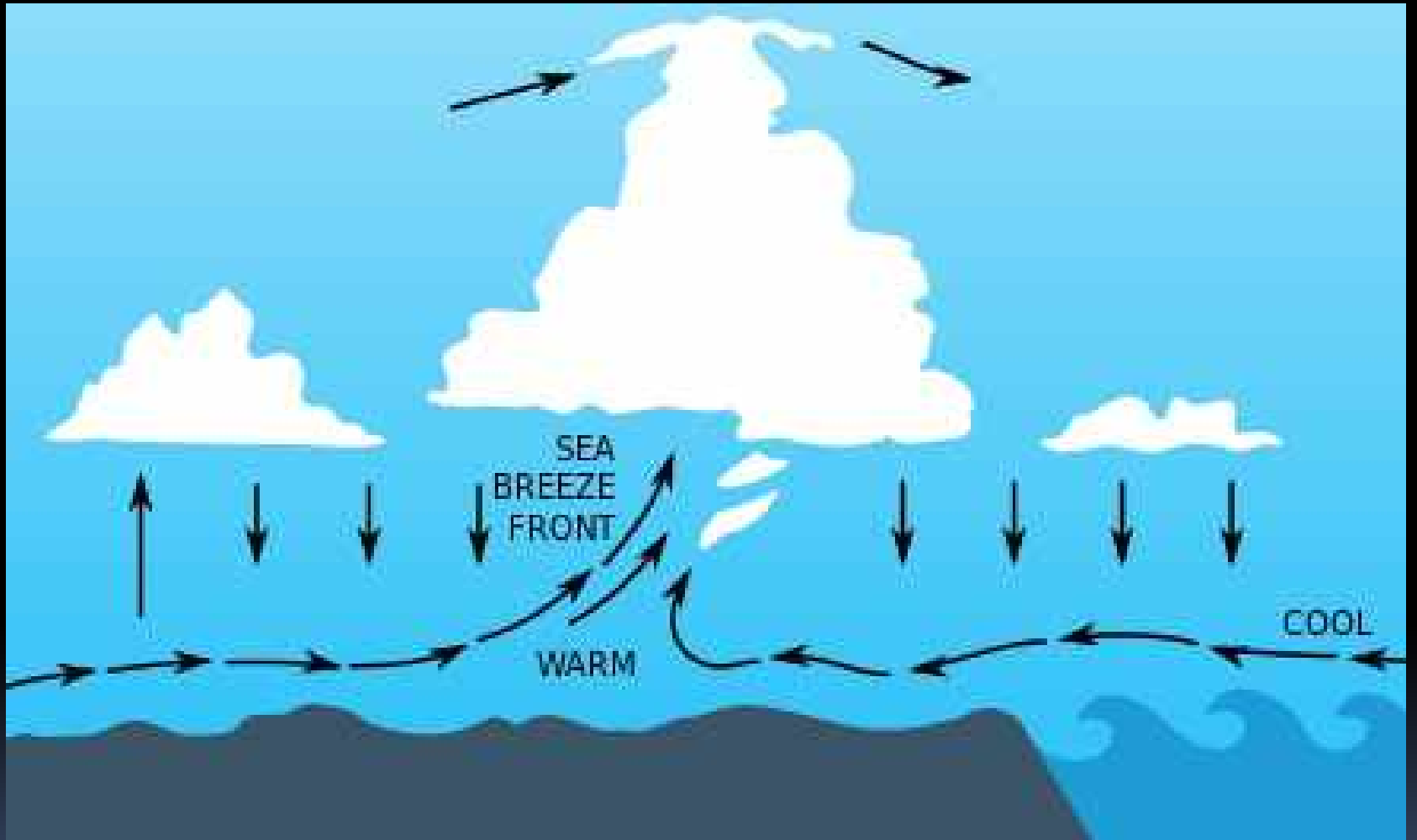


Rise for Bay since 1961:
Mid-Atlantic “Hot Spot”

Global Rise: 1.8mm/yr

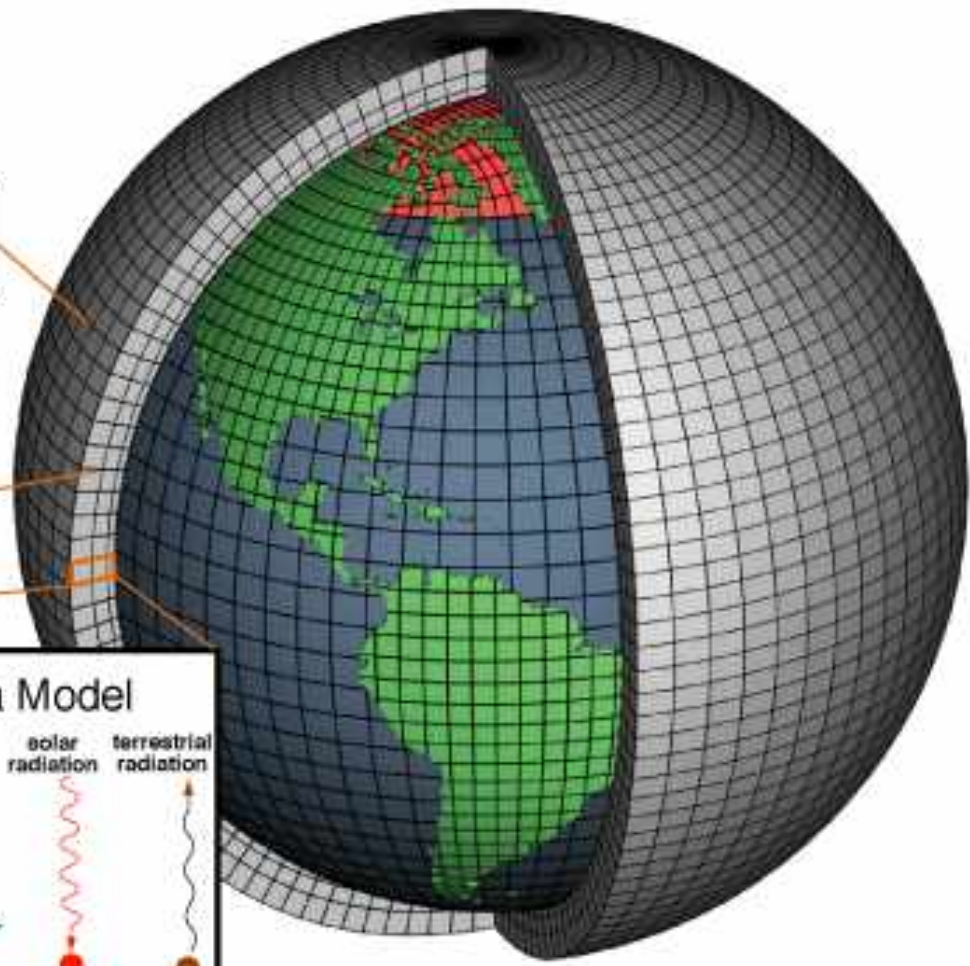
Subsidence: 1.7mm/yr

3.5mm/yr

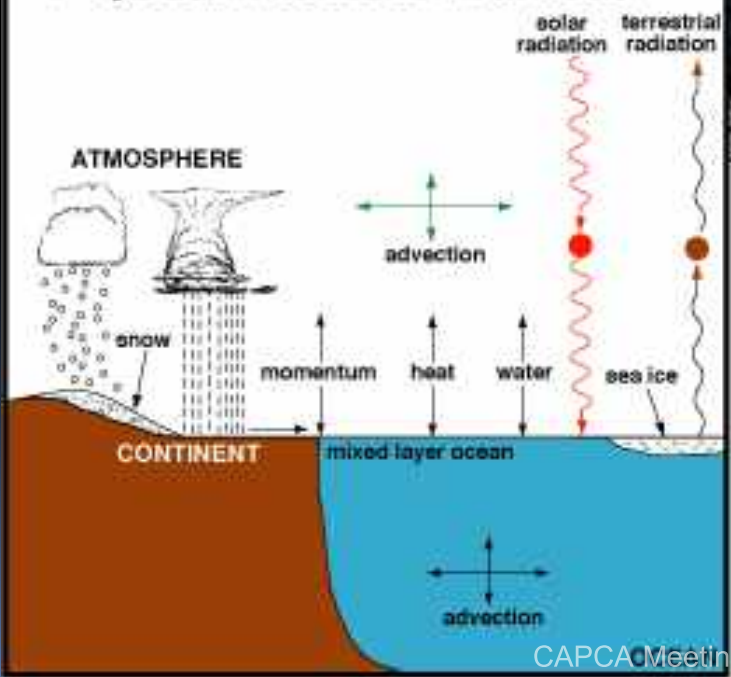


Horizontal Grid
(Latitude-Longitude)

Vertical Grid
(Height or Pressure)



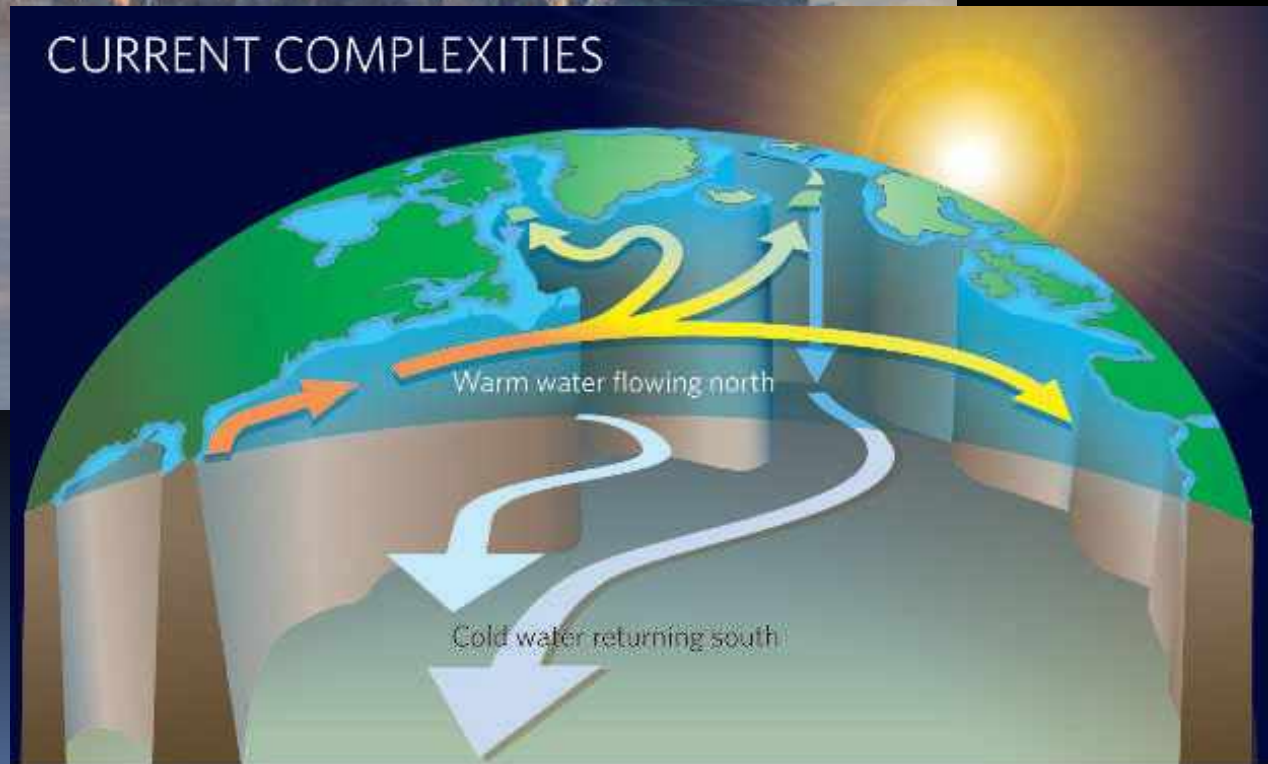
Physical Processes in a Model



The Day After Tomorrow



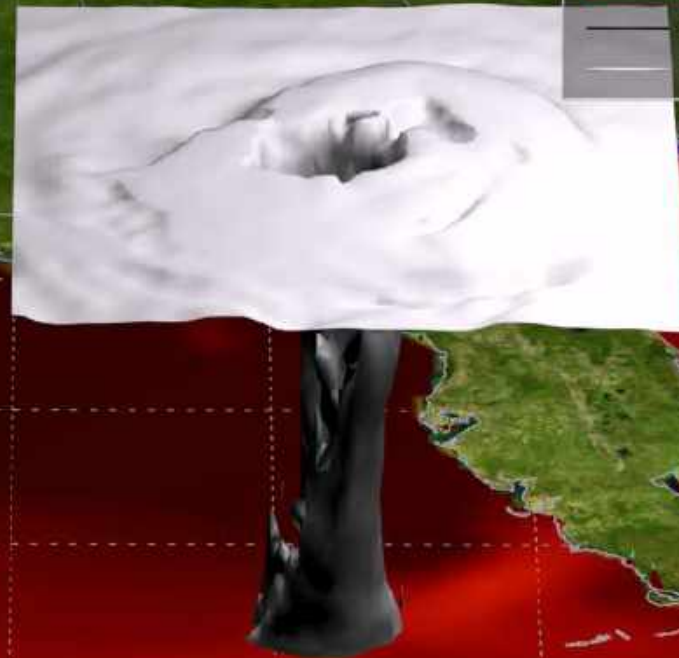
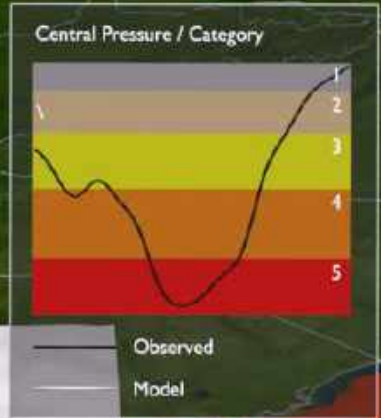
CURRENT COMPLEXITIES



Hurricane Katrina 2005

Hurricane Katrina Coupled Model Forecast

Aug 27 02:30 UTC





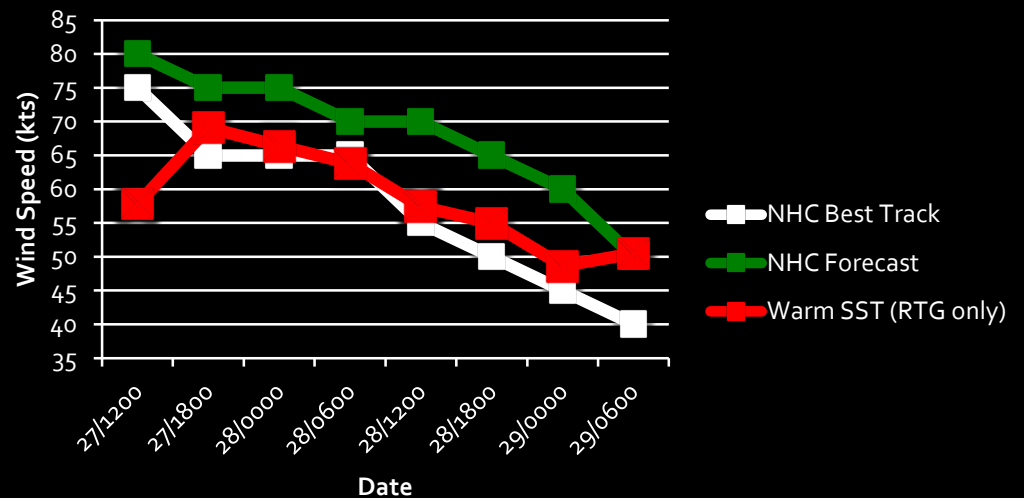
HURRICANE IRENE 2011

RU-WRF
Atmospheric
Forecast Model

Key

- NHC Best Track
- GFS 0.5 deg 06Z
- WRF 6km (Warm SST, 06Z, 06hr)

Maximum Sustained Wind Speed (10m)



Data SIO, NC
© 20

38°07'08.13"

TIMING

Urban Ocean Observatory at the Center for Maritime Systems



Present Conditions

NYHOPS Forecast

NJ Coast (CMN)

Storm Surge

Mobile Stations

CMS Partners

Data & Time Series



Storm Surge Warning System

Plot Series or Download Data

Station: :
Stations are listed from North to South

Start Date:

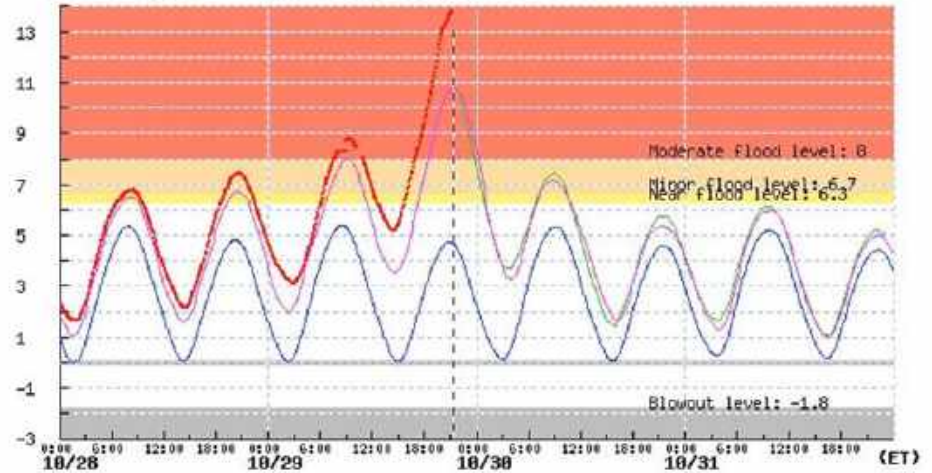
End Date:

Datum: :

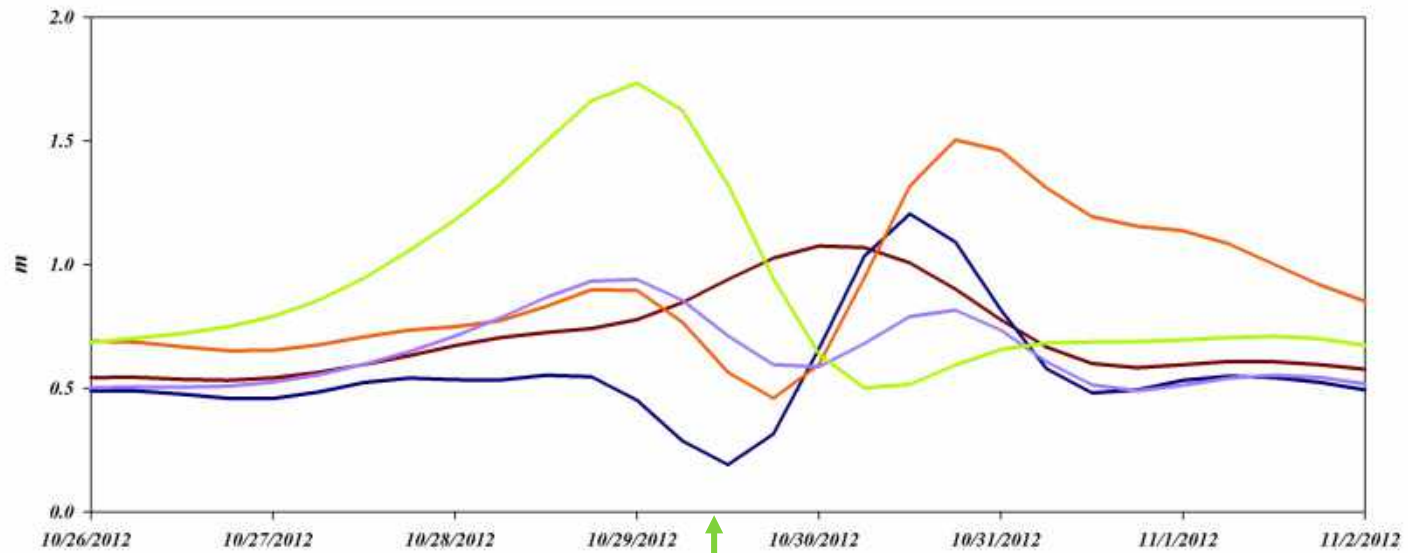
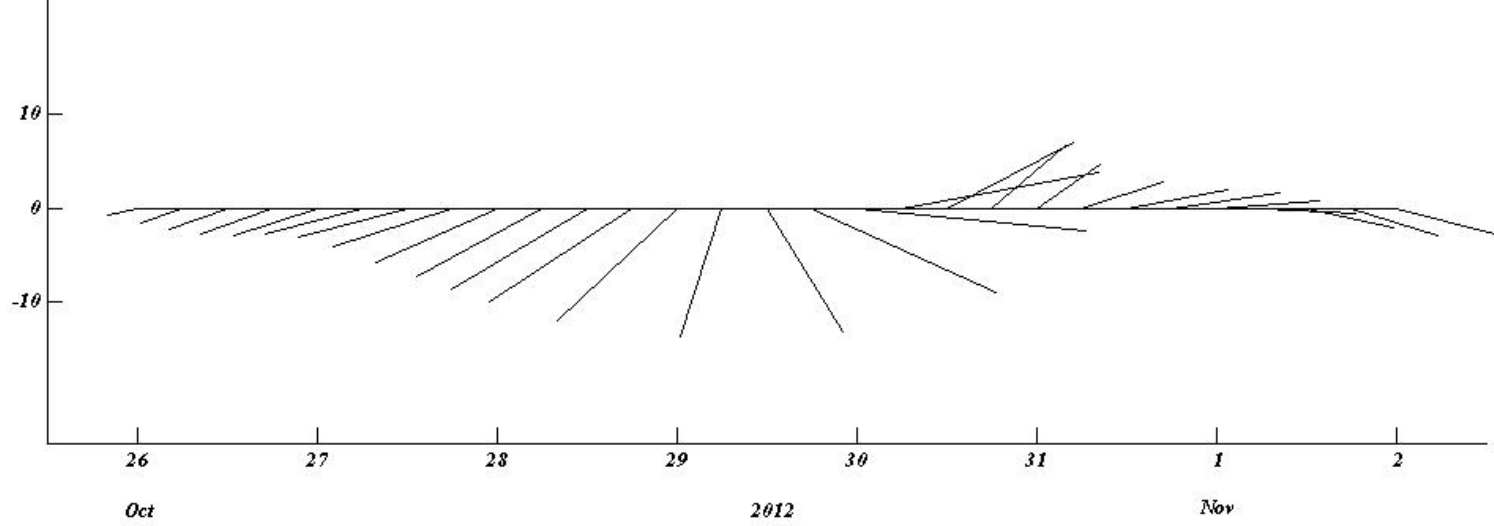
Units: :

Time Zone: :

The Battery NY - Water level relative to MLLW (ft)



- Astron. predictions
- Observations (where available)
- NYHOPS Forecast model
- NOAA Forecast model (where available)



- Bishops Head, MD
- Baltimore, MD
- Date/time EST vs Washington
- Date/time EST vs Lewisetta
- CBBT, VA

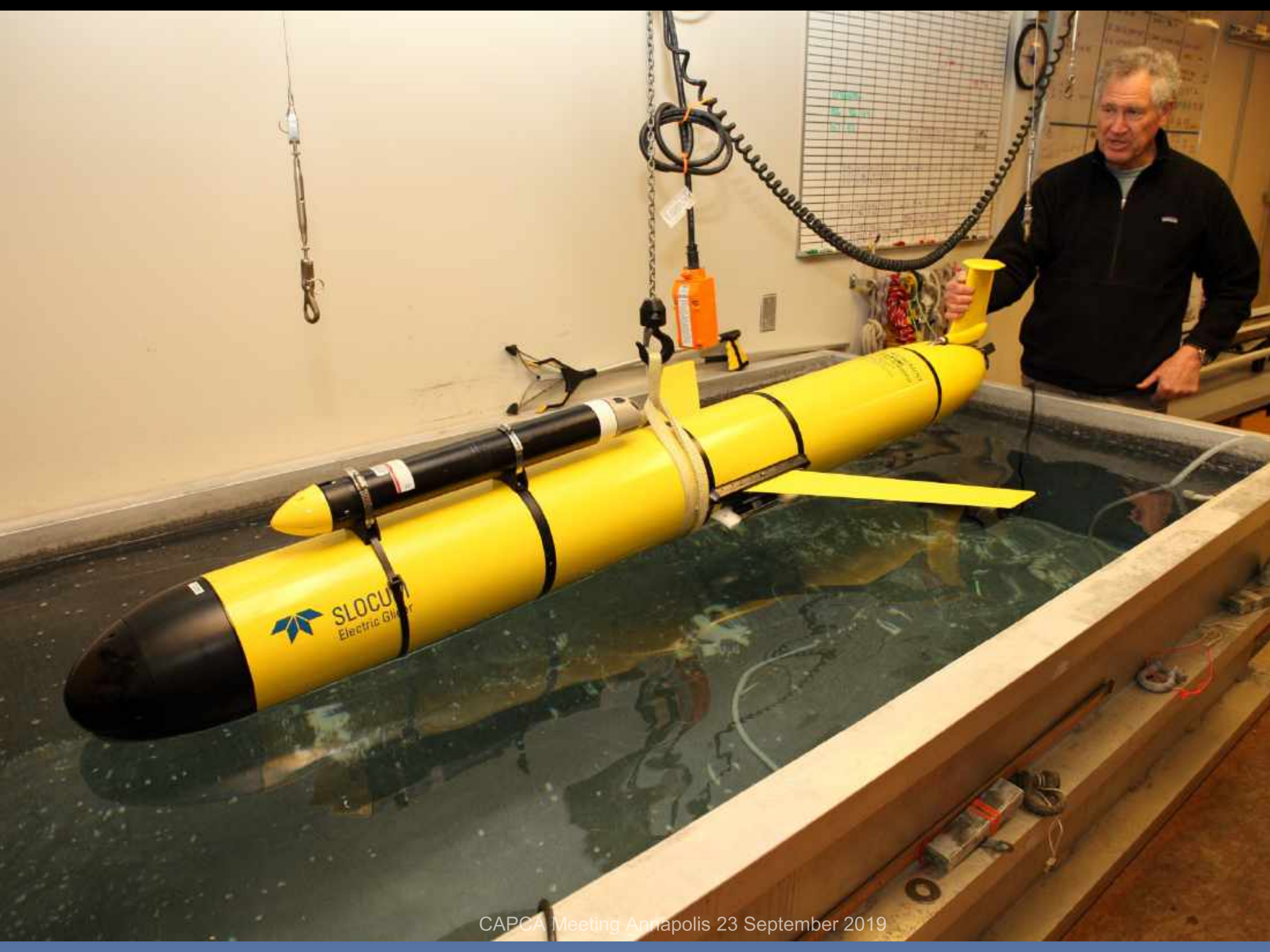




Before the Storm

CAPCA Meeting Annapolis 23 September 2019



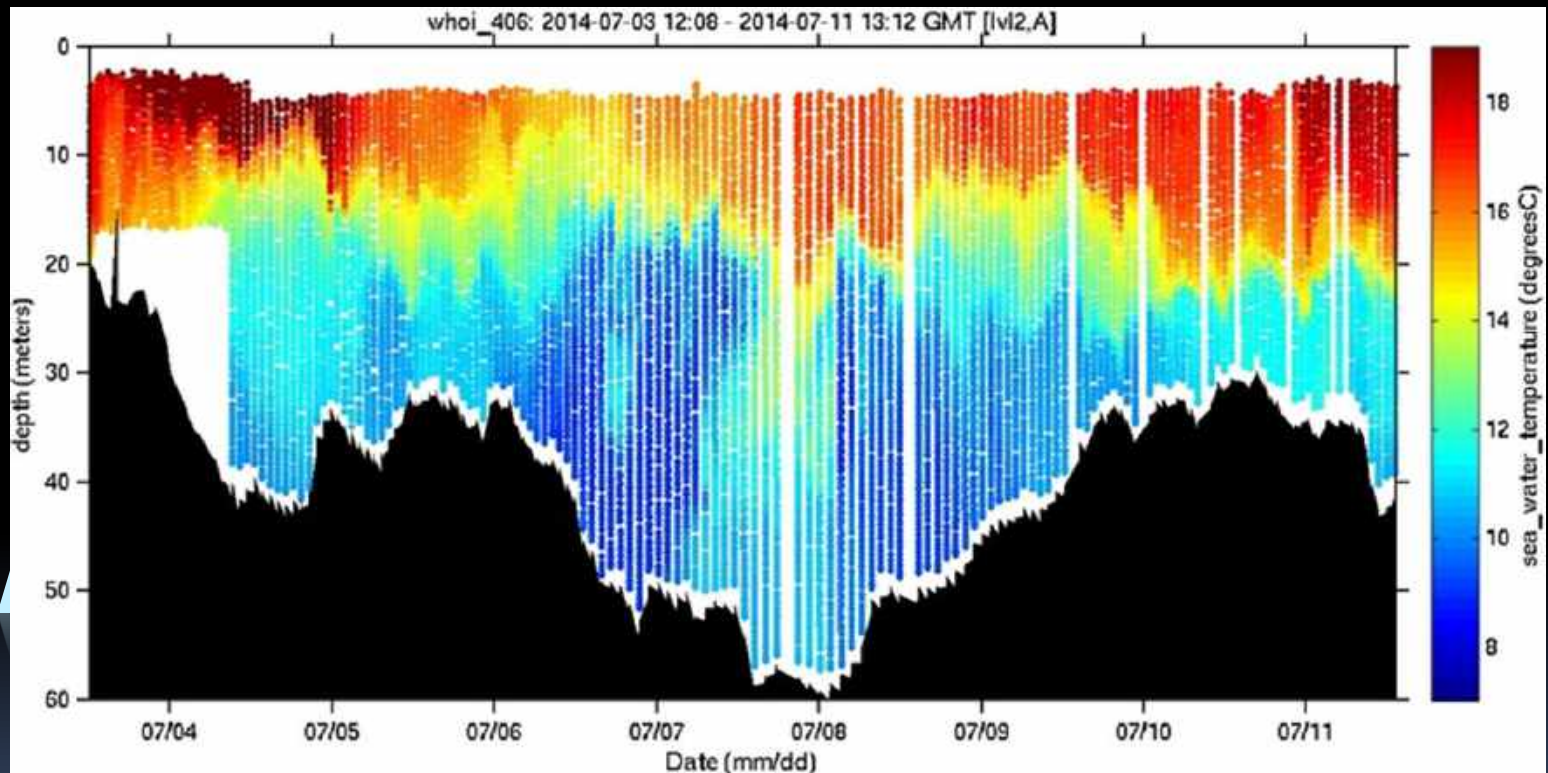




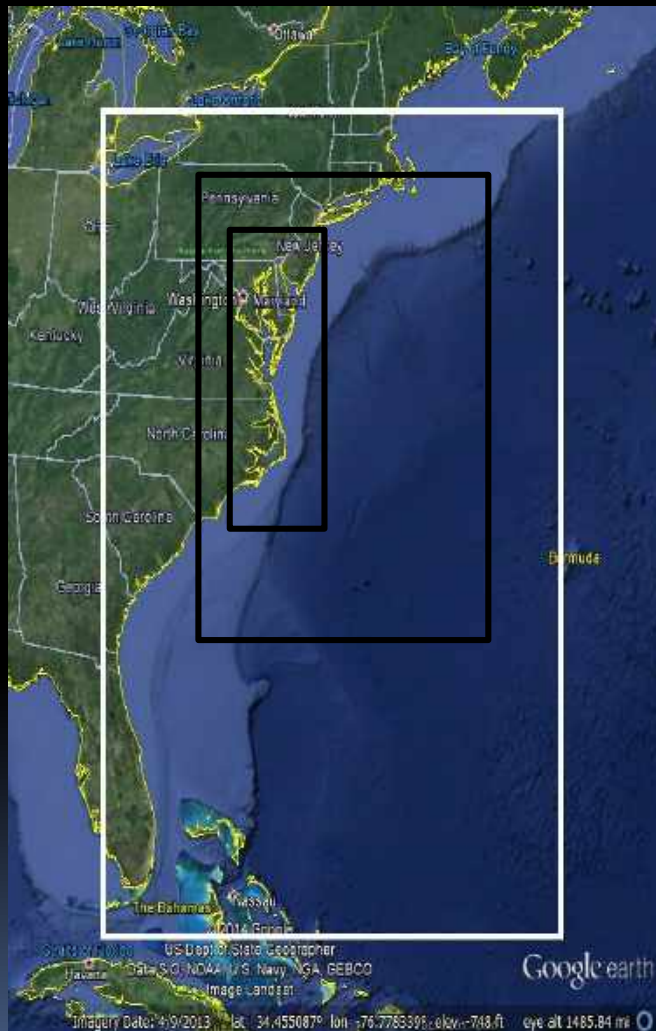
CAPCA Meeting Annapolis 23 September 2019



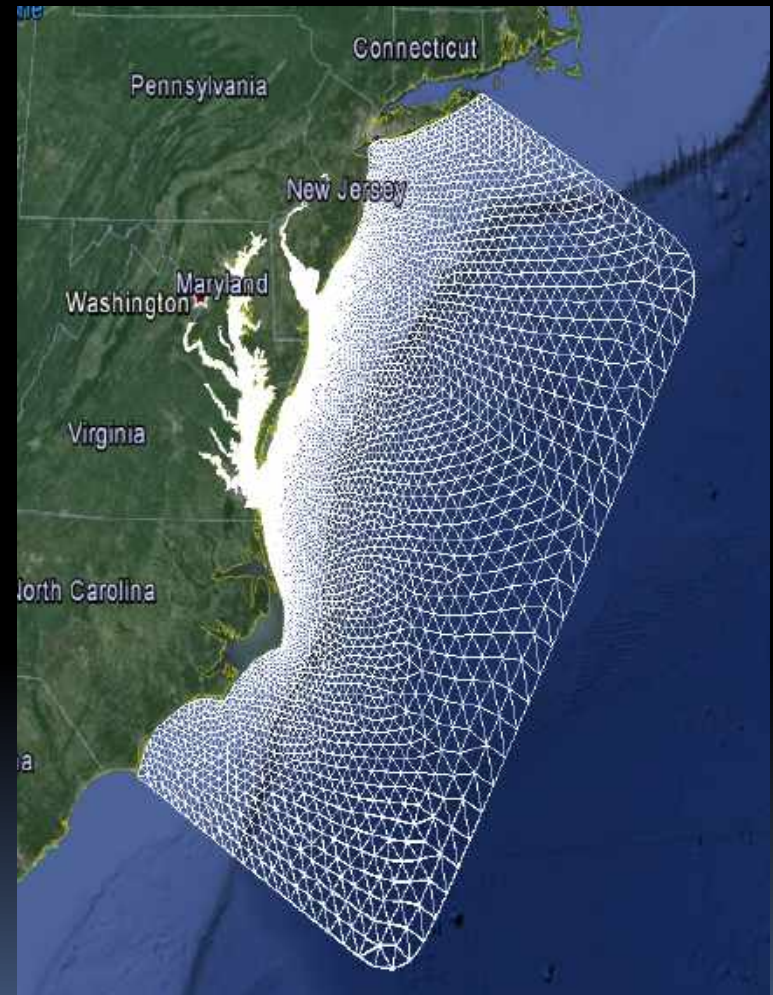
Temperature—Hurricane Arthur



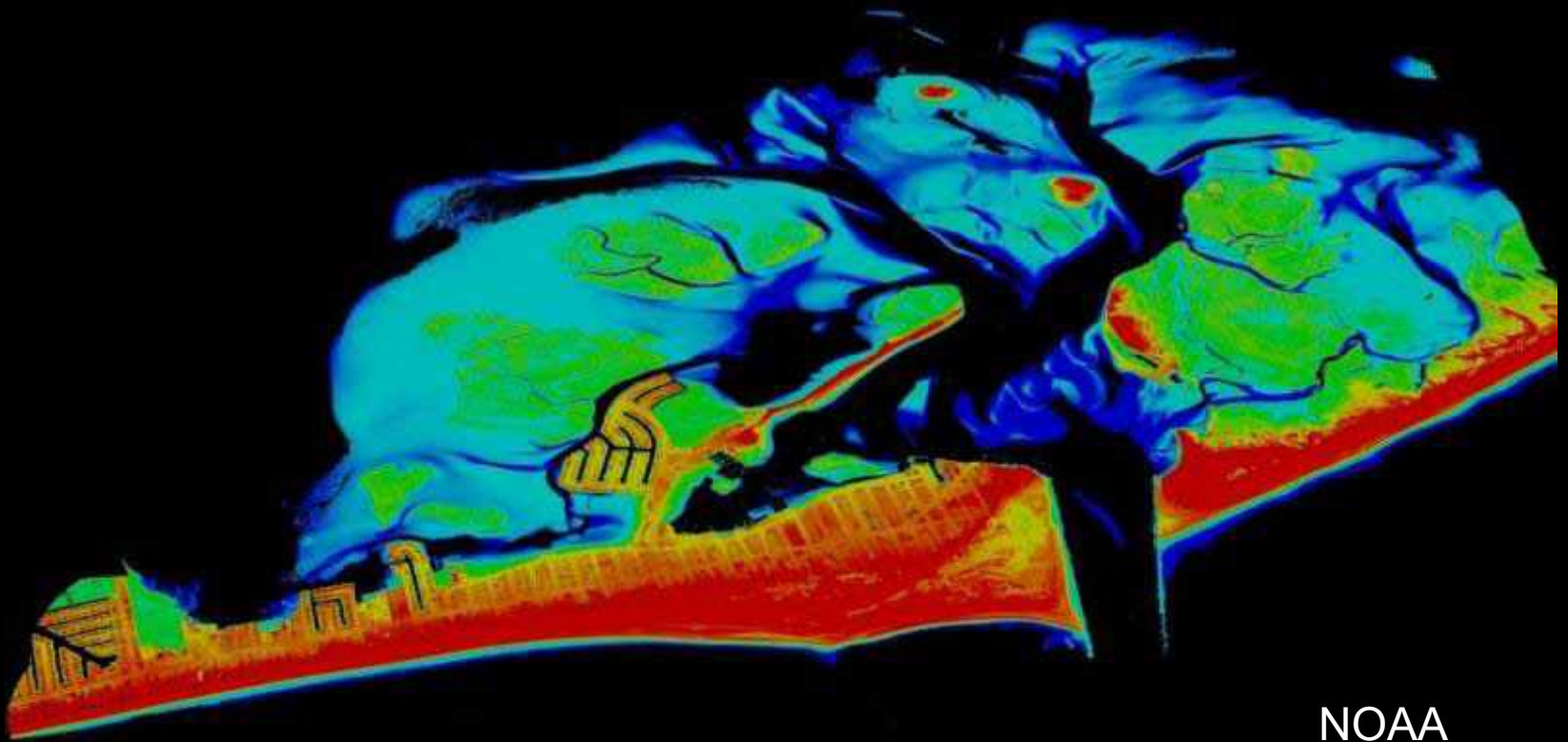
Triply-nested WRF (12km-4km-1.3km)



Unstructured FVCOM (50 m to 20 km)



CINAR-TEMPESTS



NOAA

LIDAR BARNEGAT BAY

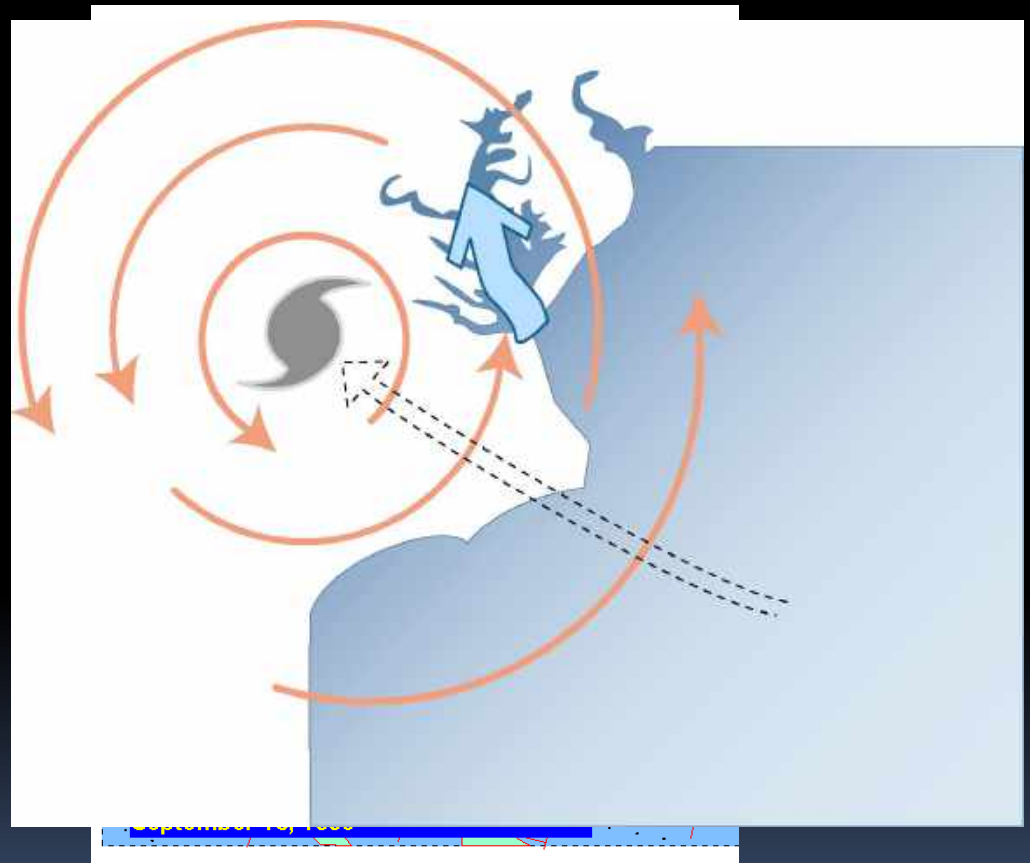
Graphic Visualizations for Street-Level flooding in Cambridge, MD Using GIS and Google Earth



1933, 2003: VULNERABILITY

Isabel

August, 1933



NOAA

A hurricane is an absolutely, beautifully smooth-running engine with a very temperamental starter motor—Ed Zipser, University of Utah

Warming will increase the size and intensity of storms, but it will also make them more difficult to form—Kerry Emanuel, MIT

IMPACTS



David Harp

CAPCA Meeting Annapolis 23 September 2019



CAPCA Meeting Annapolis 23 September 2019

Prospects

- Intensity
- Phasing
- Wetting and Drying
- Transition to Operations
- Partnerships

Last House Standing



Approximate area lost
2006-2014



Photo taken 9/26/2006
© 2006 Gordon Campbell

Gordon Campbell 914-772-6242



©2014 Gordon Campbell / At Altitude Photography

CAPCA Meeting Annapolis 23 September 2019



©2014 Gordon Campbell / At Altitude Photography

CAPCA Meeting Annapolis 23 September 2019

SANDY: CHESAPEAKE BAY

Wakefield, VA
08:57am, Wednesday
31 October 2012

Subject: Tidal Flooding Delmarva From Sandy
From: John Billet <john.billet@noaa.gov>
Date: 10/31/2012 8:57 AM
To: Ming Li <mingli@umces.edu>, William Boicourt <boicourt@hpl.umces.edu>

Hi MIng and Bill,

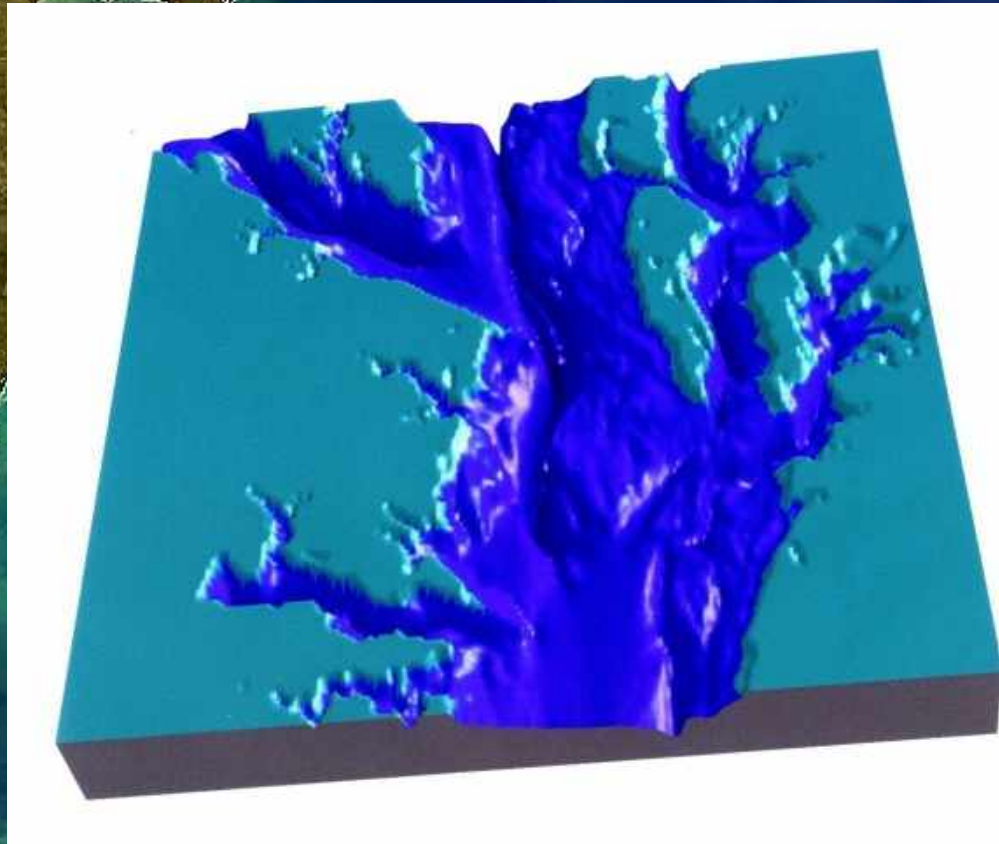
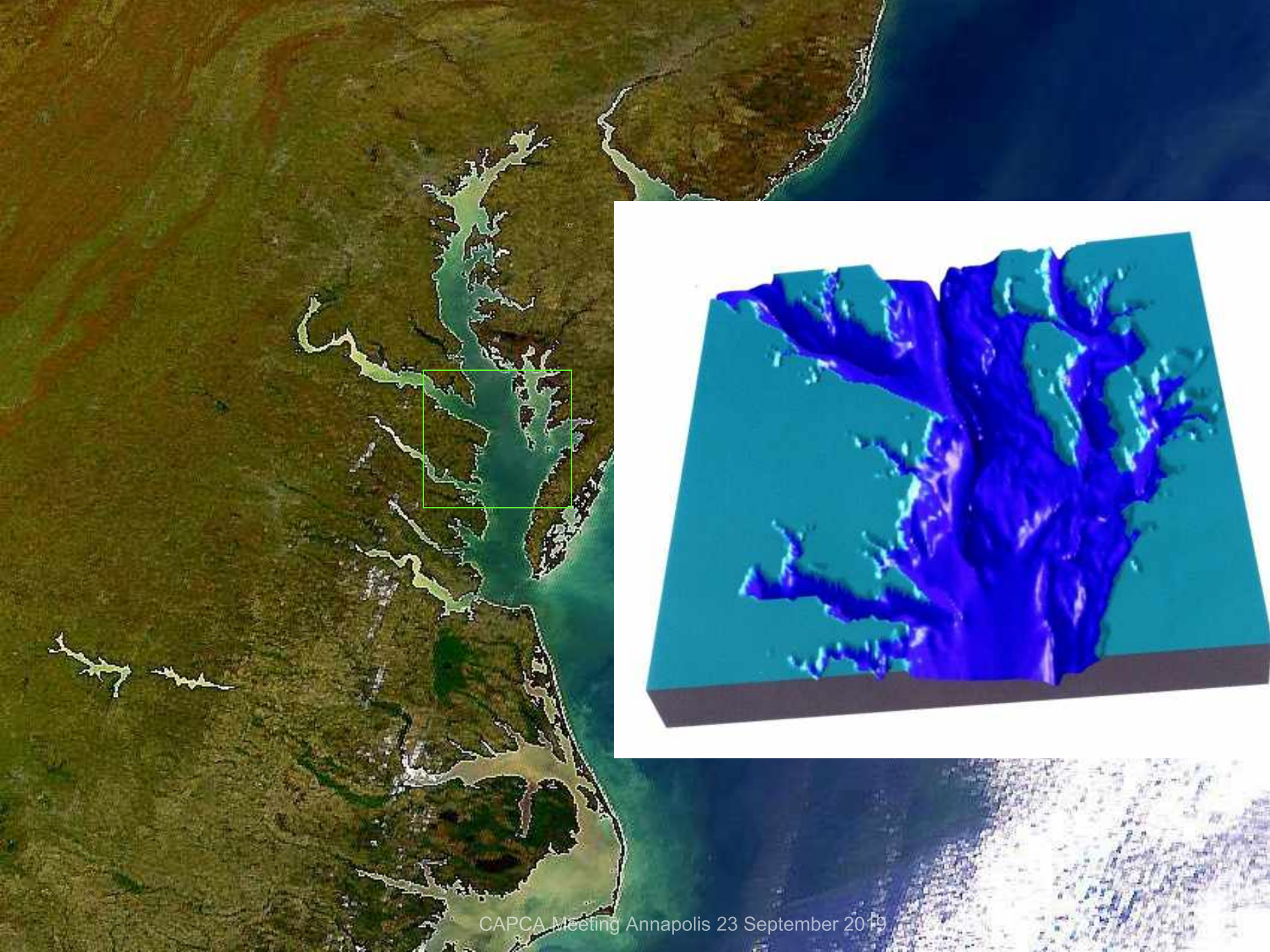
The flooding on the Maryland part of the Delmarva was very confusing from Sandy. We constantly seemed to be under forecasting and had significant trouble relating our gages at Cambridge and Bishop Head to what was actually happening. It seemed that when the wind switched to northwest Monday we got much higher flooding then anticipated on northwest facing areas. Using the two models we get for Cambridge neither model showed the magnitude of the flooding at other Dorchester county locations. The two models were the extra tropical storm surge from NWS and ESTOFS developed by NOAA coastal services. As the event continued models showed the tides coming down but they still remained high or went higher in many areas. These seemed to be topographic related. The coast line is quite complicated up there and I am sure this is causing some of the problems.

I would appreciate any thoughts you might have about this. I would be happy to share any information I have with you. We need to develop methods to improve our forecasts so we can serve our customers better.

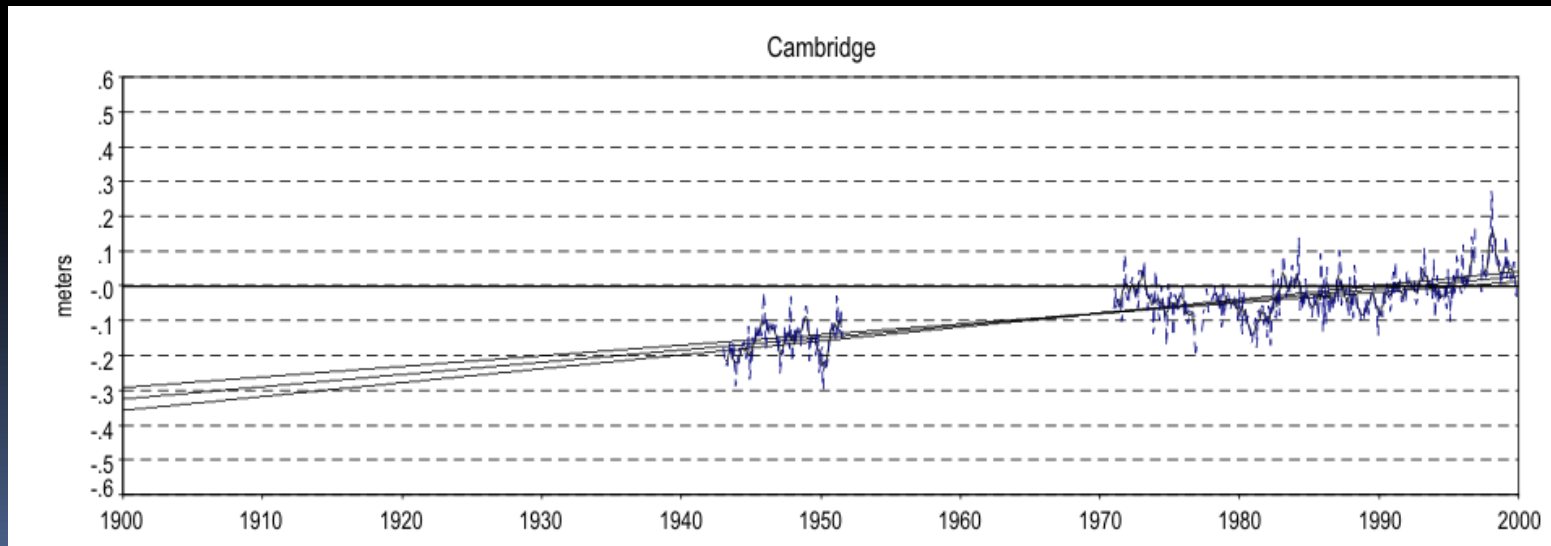
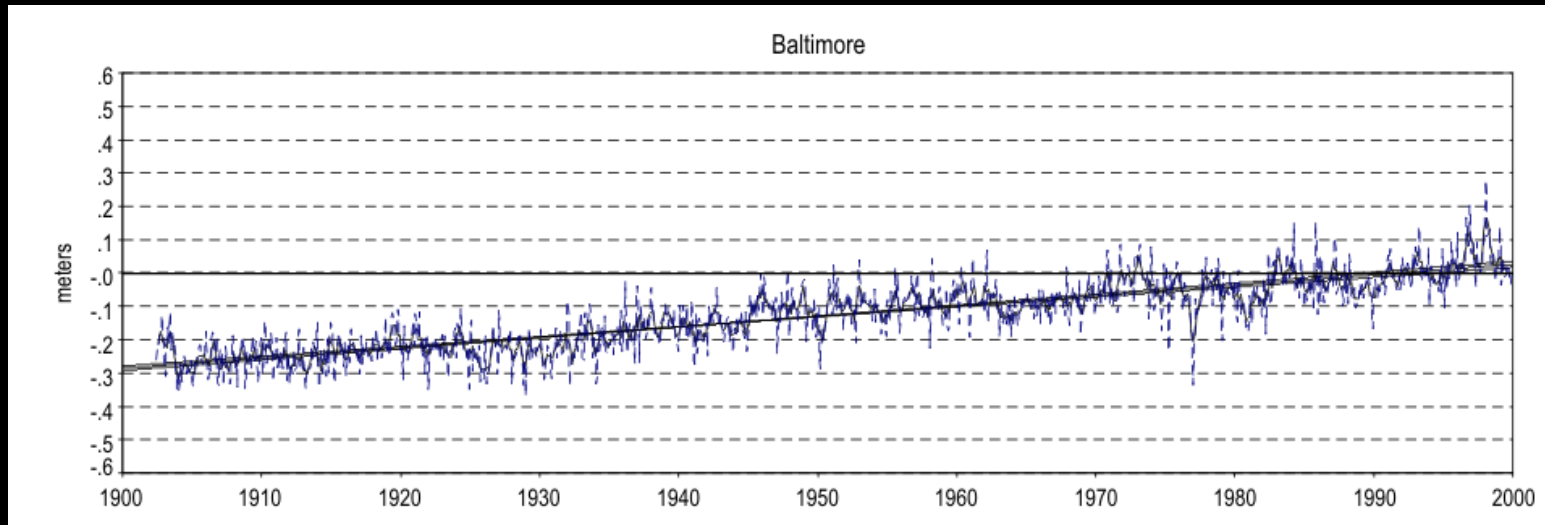
I hope the storm was not to be on you. I know we had reports of 65 mph winds and many places with 10 inches of rain. Thanks for your input.

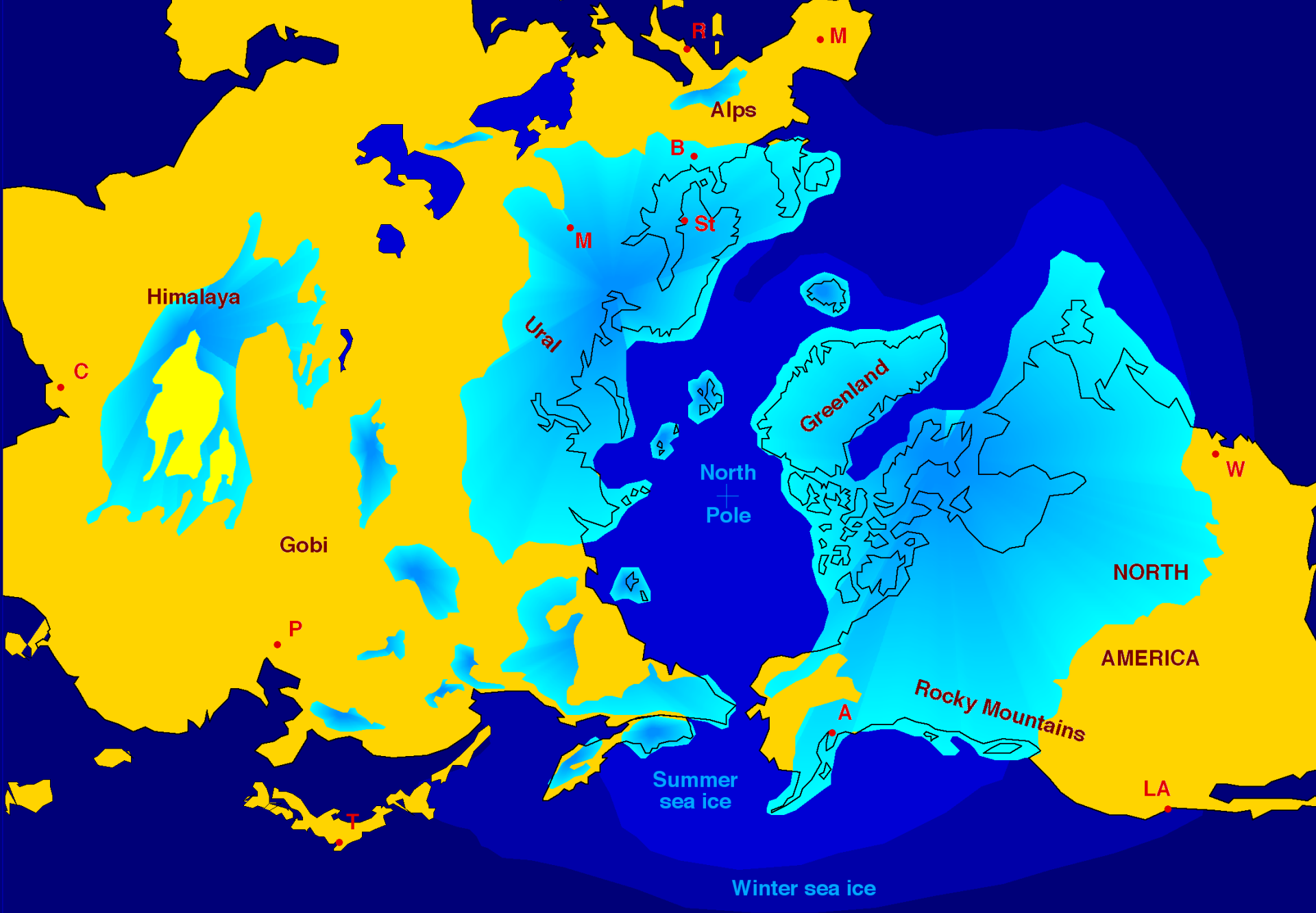
John
--
John Billet
Science Operations Officer

NWS Wakefield VA
10009 General Mahone Hwy
Wakefield, VA 23888
phone 757-899-4200 ext 224



SEA-LEVEL RISE





Prepared in cooperation with the
Hampton Roads Planning District Commission

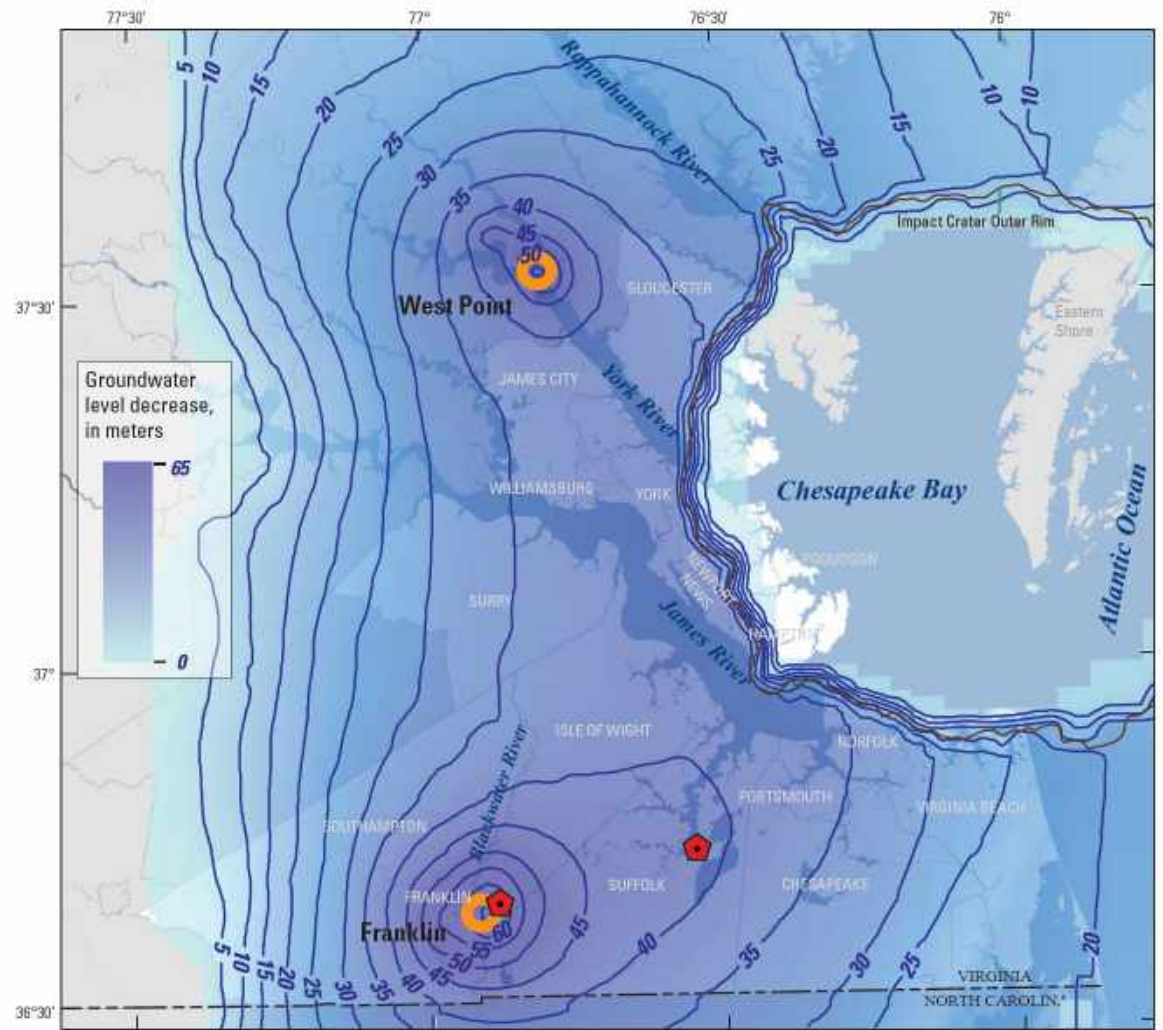
Land Subsidence and Relative Sea-Level Rise in the Southern Chesapeake Bay Region



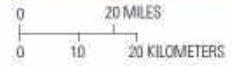
Circular 1392

CAPCA Meeting Annapolis 28 September 2019




Groundwater water-level decreases

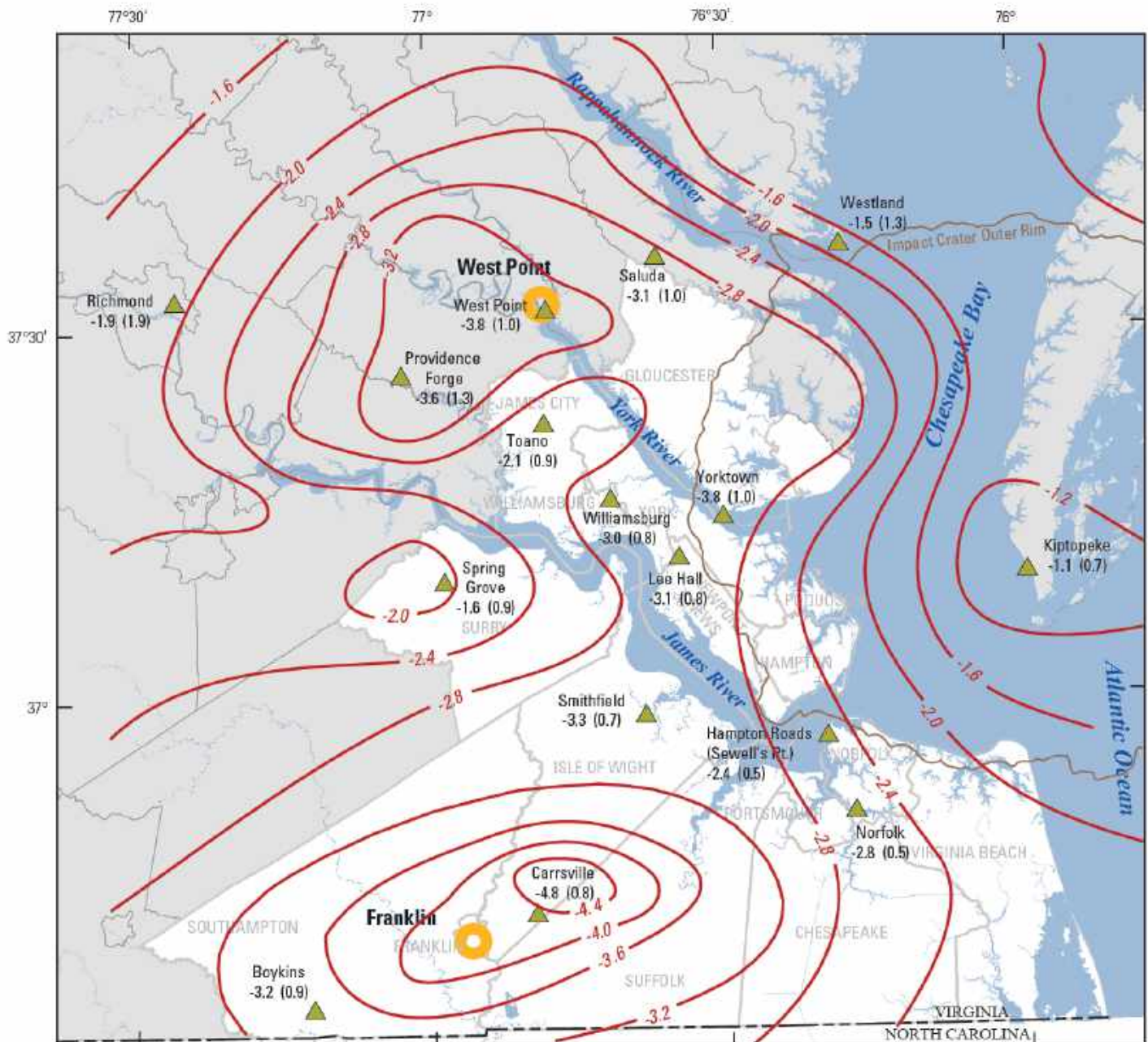


Map made from U.S. Geological Survey and Virginia Department of Game and Inland Fisheries data.
 Virginia State plane projection
 Virginia south Federal Information Processing Standard (FIPS) 4502
 North American Datum 1983 (NAD83)



EXPLANATION

-  **Line of equal groundwater water level decline (predevelopment to 2008)**—Shows change in elevation. Contour interval is 5 meters
-  **Groundwater withdrawal center**
-  **U.S. Geological Survey extensometer station**



Map made from U.S. Geological Survey and Virginia Department of Game and Inland Fisheries data

Virginia State plane projection

Virginia south Federal Information Processing Standard (FIPS) 4502

North American Datum 1983 (NAD83)

0 5 10 15 20 MILES

0 10 20 KILOMETERS

Geoidic leveling from Holdahl and Morrison (1974)

Groundwater extraction vs. Subsidence

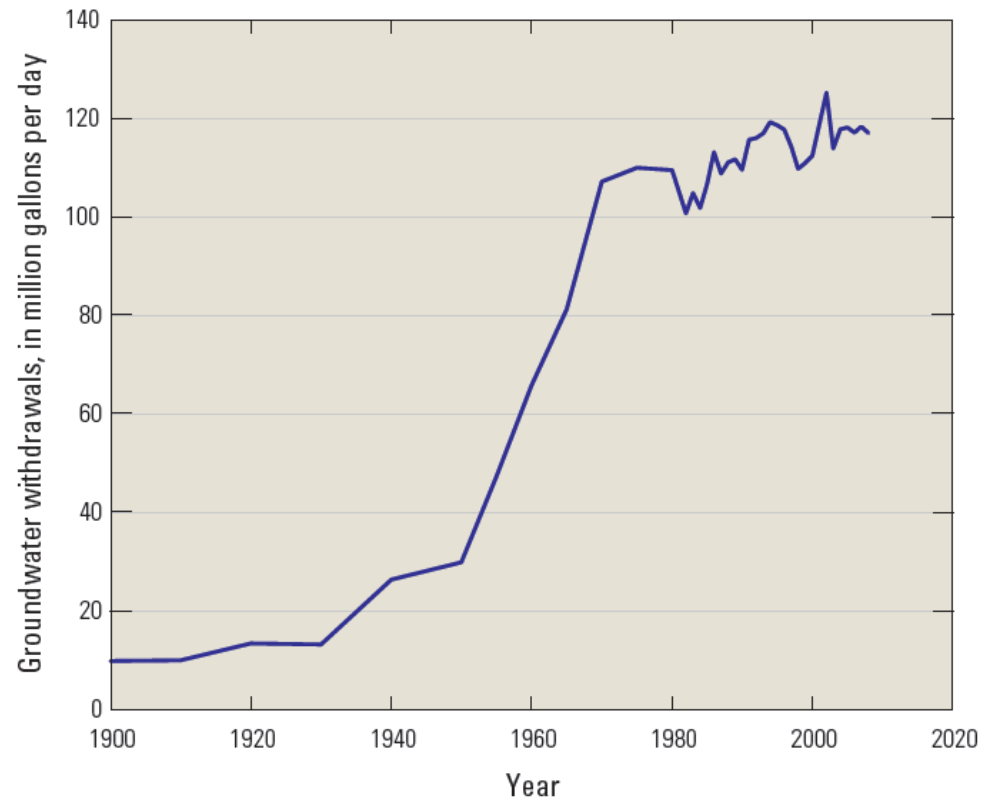
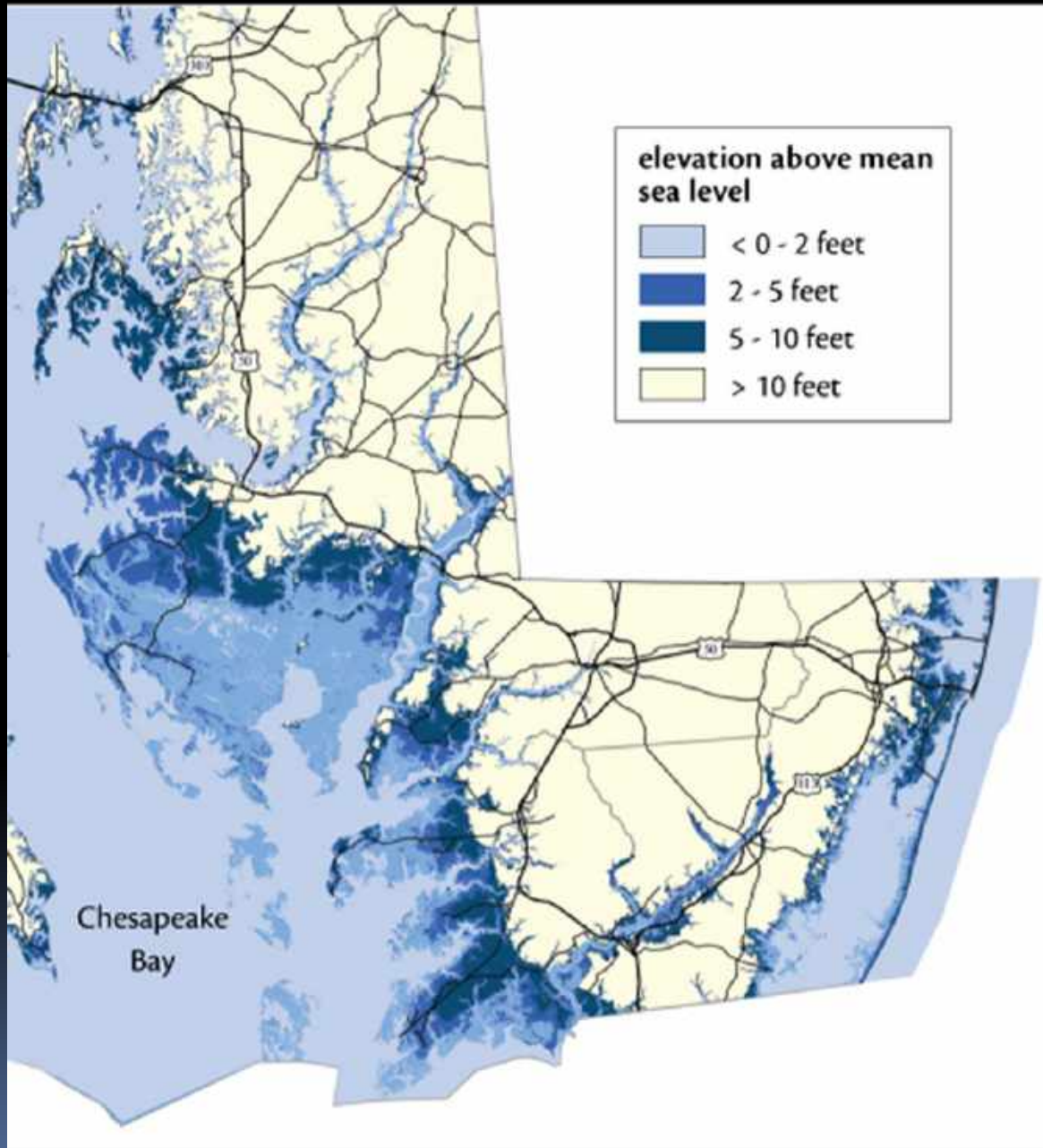
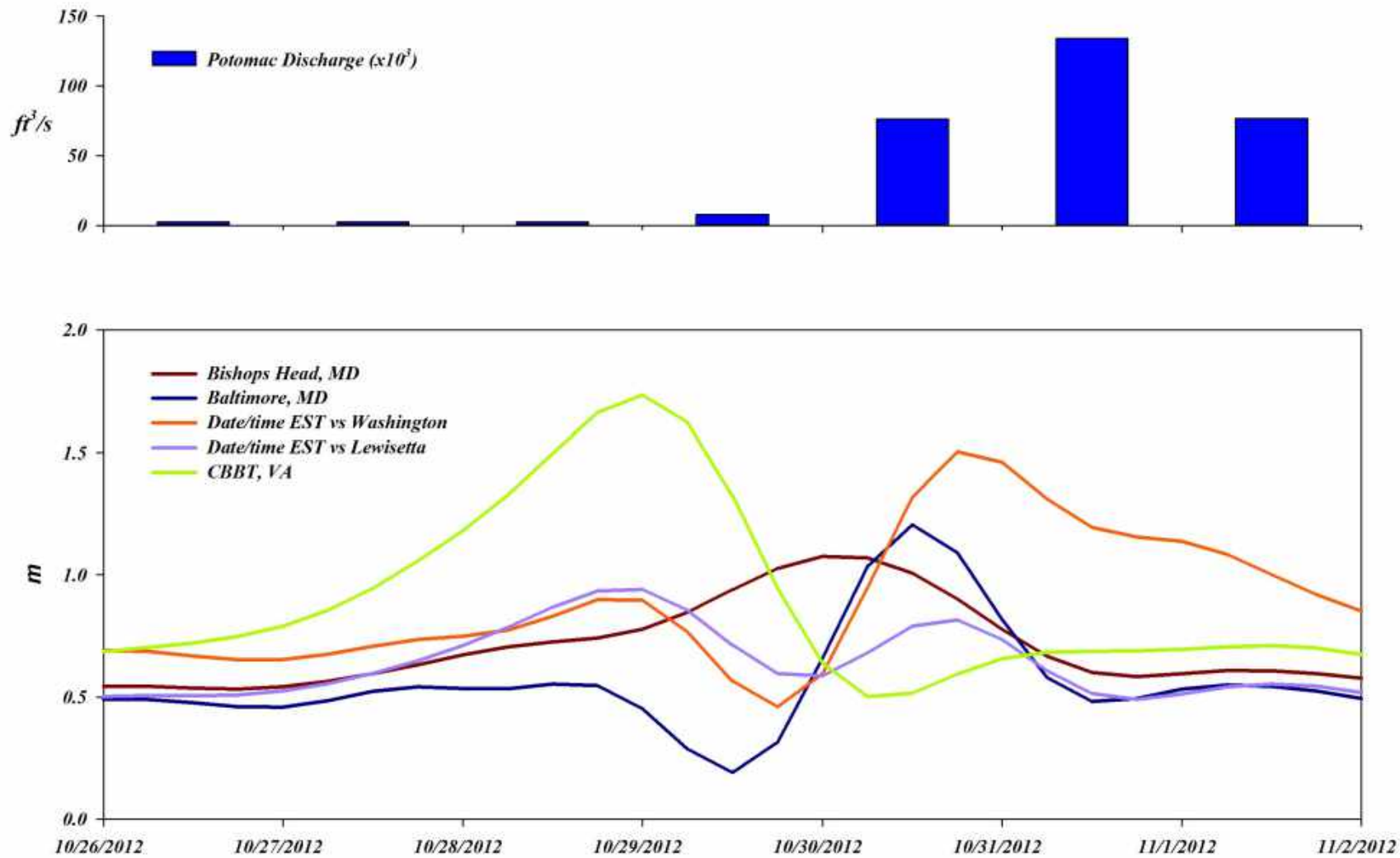


Figure 15. Groundwater withdrawal rates from Virginia Coastal Plain aquifers from 1900 to 2008. Modified from Heywood and Pope (2009).





SEA LEVEL RISE: TECHNICAL
GUIDANCE for DORCHESTER COUNTY



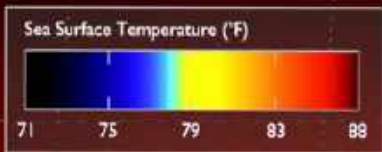
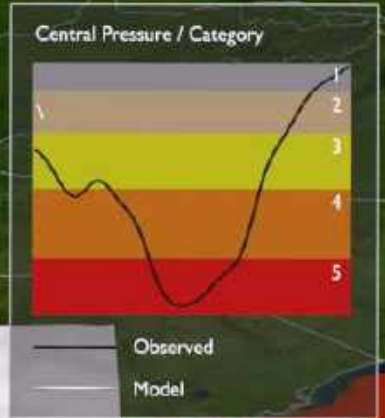
Wanda Diane Cole
Maryland Eastern Shore
Resource Conservation & Development Council

for

Maryland Department of Natural Resources
Coastal Zone Management Division
March 2008

Hurricane Katrina Coupled Model Forecast

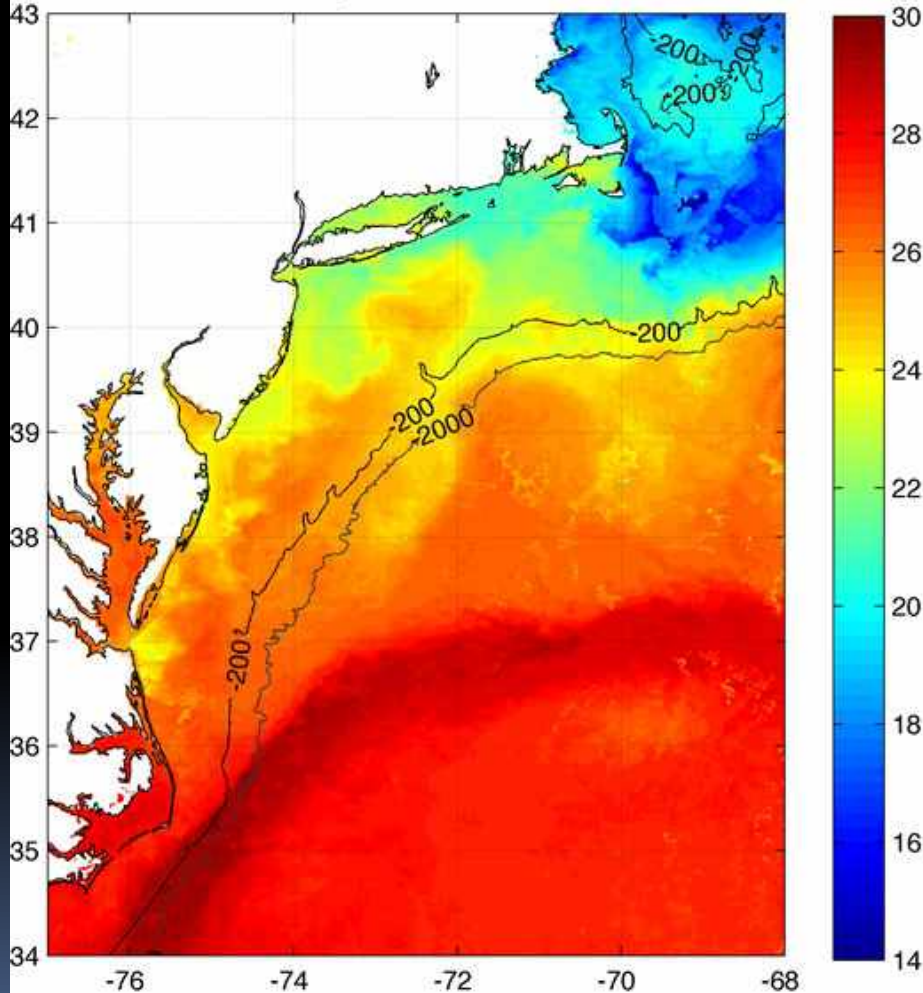
Aug 27 02:30 UTC



2011: IRENE

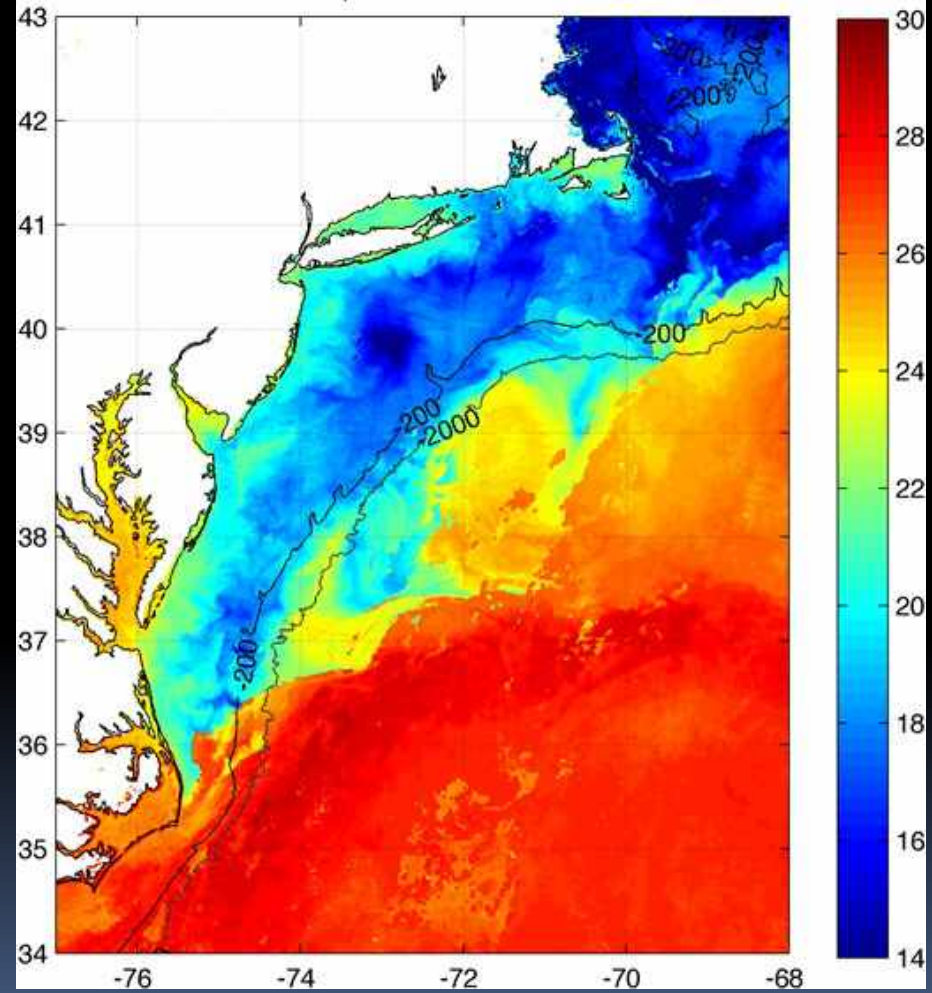
BEFORE

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AFTER

AVHRR+sport 20110831T070000



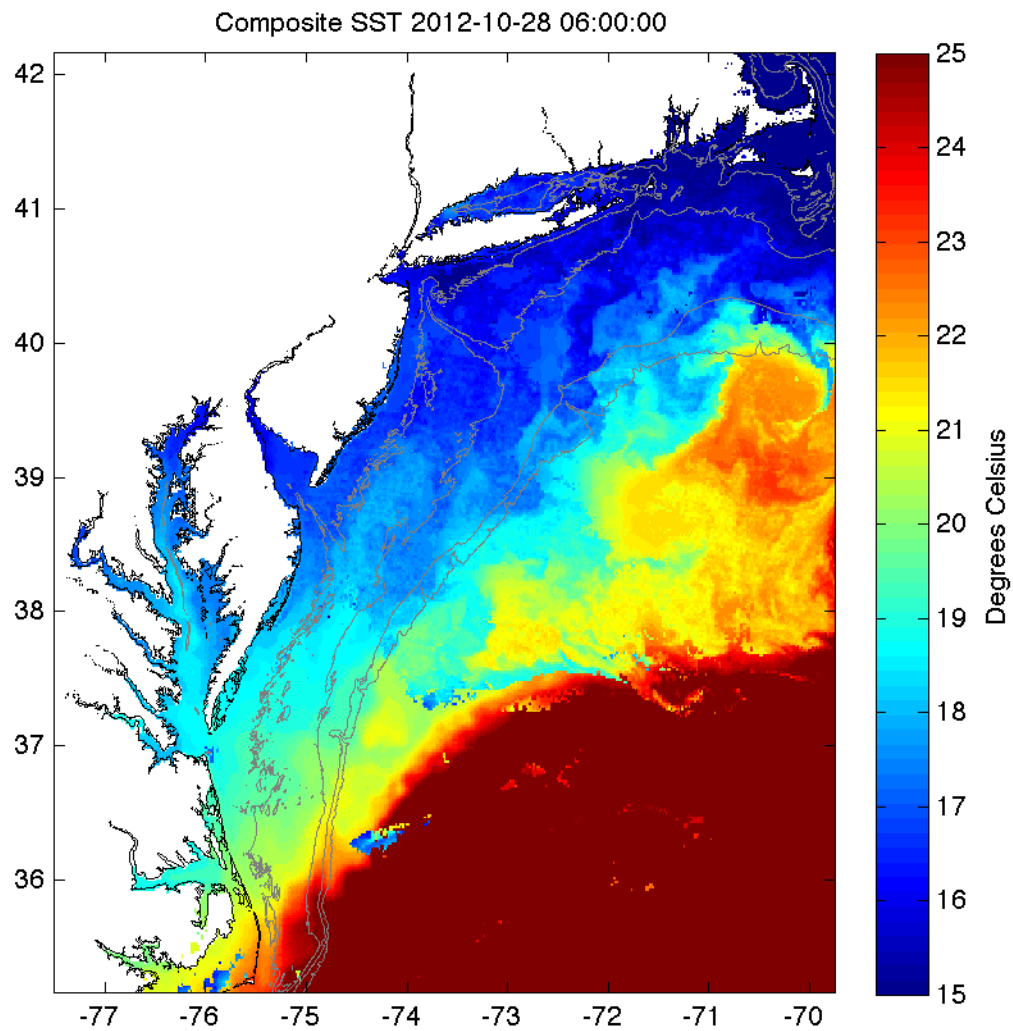
SANDY: NYC'S PREPARATIONS



... SOME WERE NOT ADEQUATE



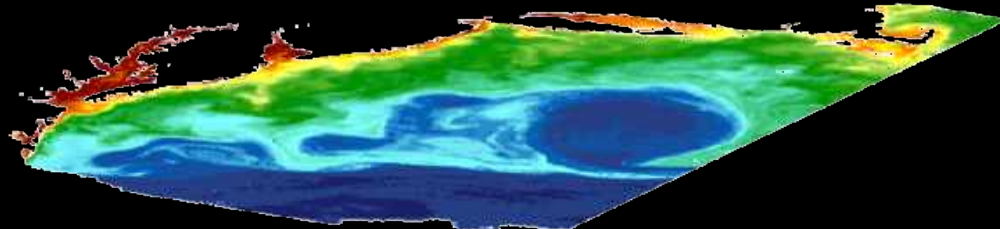
POST SANDY



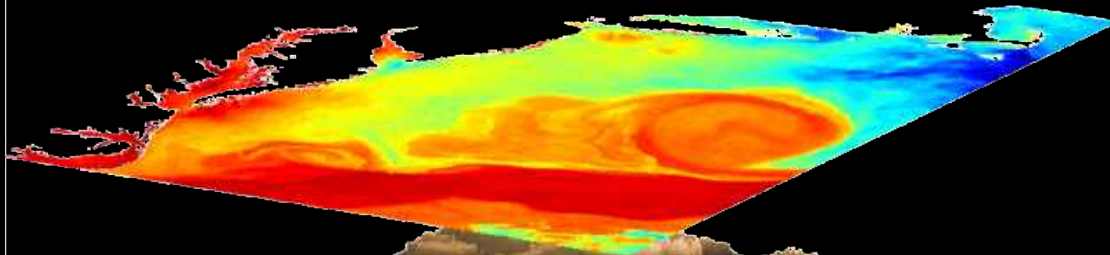


MARACOOS Glider Network

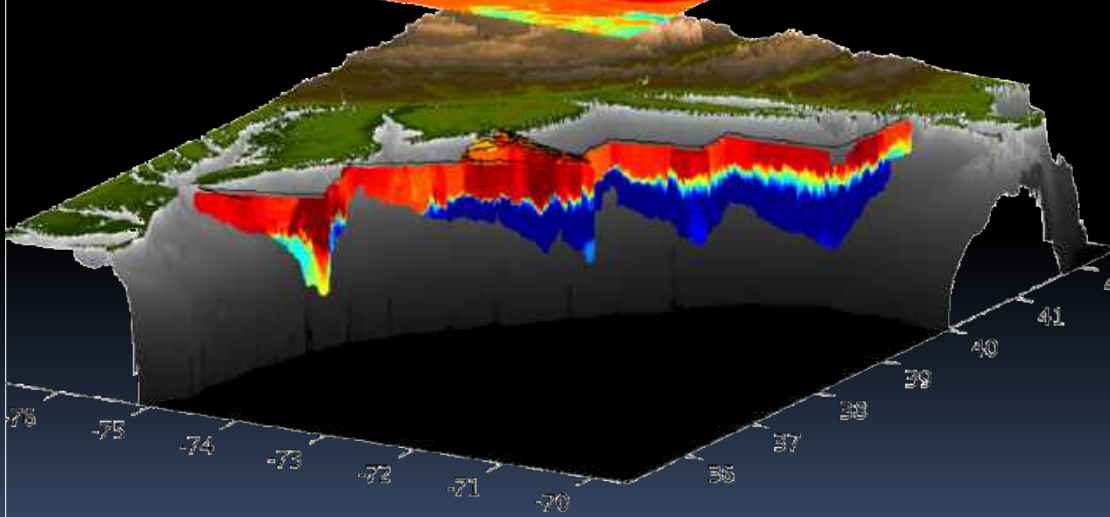
Satellite Ocean Color

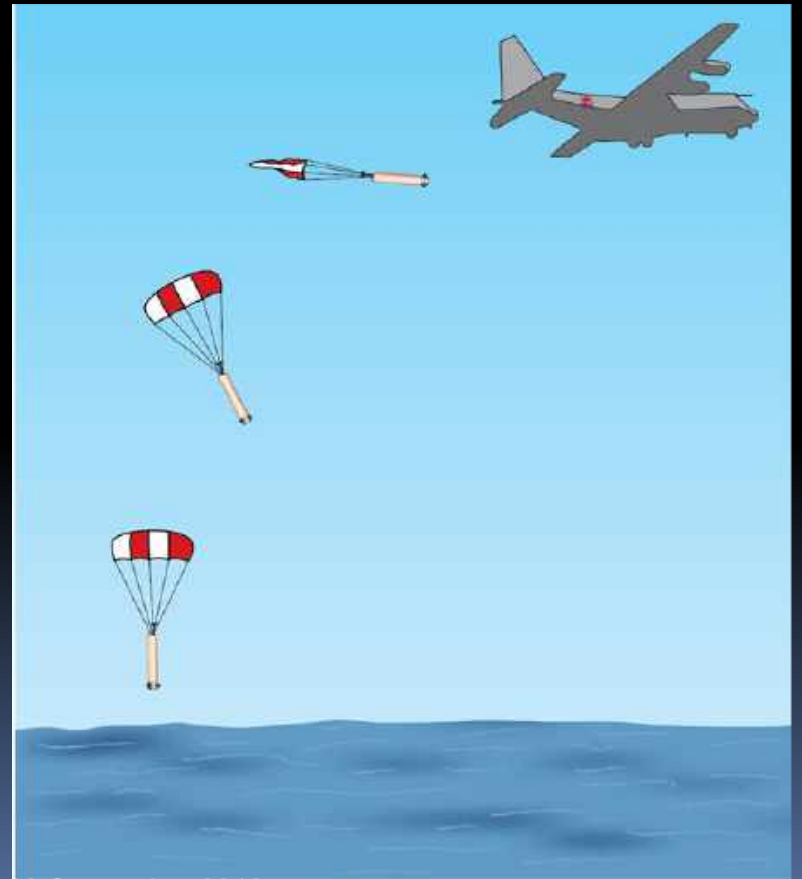


Satellite SST

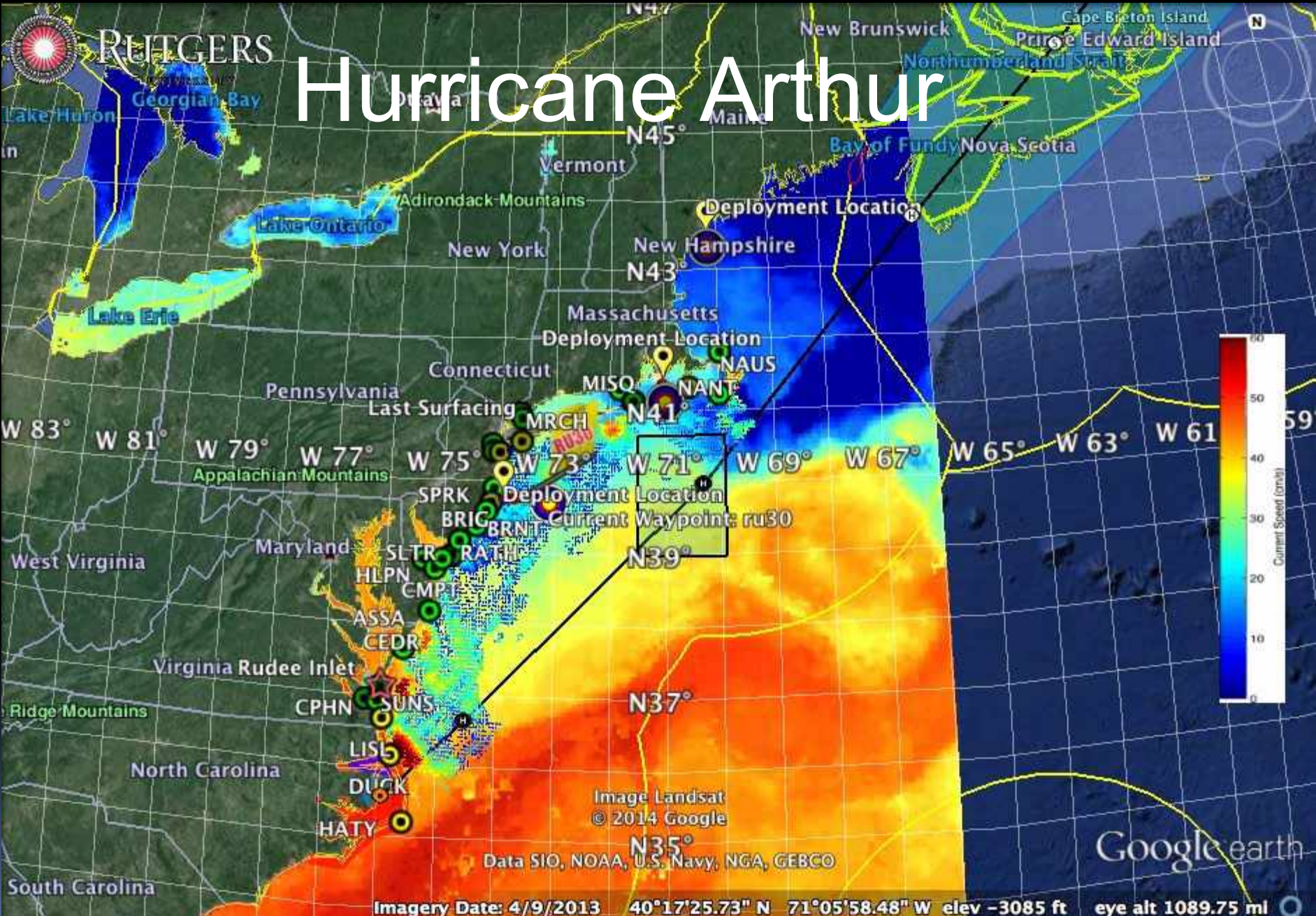


Subsurface
Glider
Data

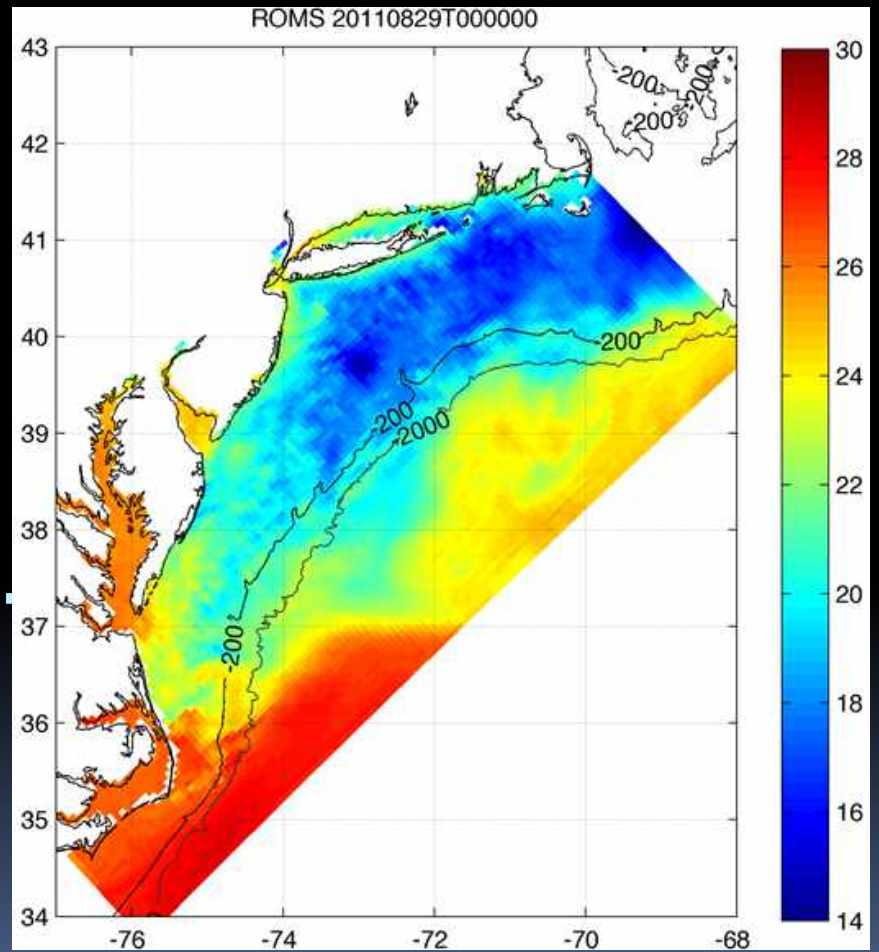
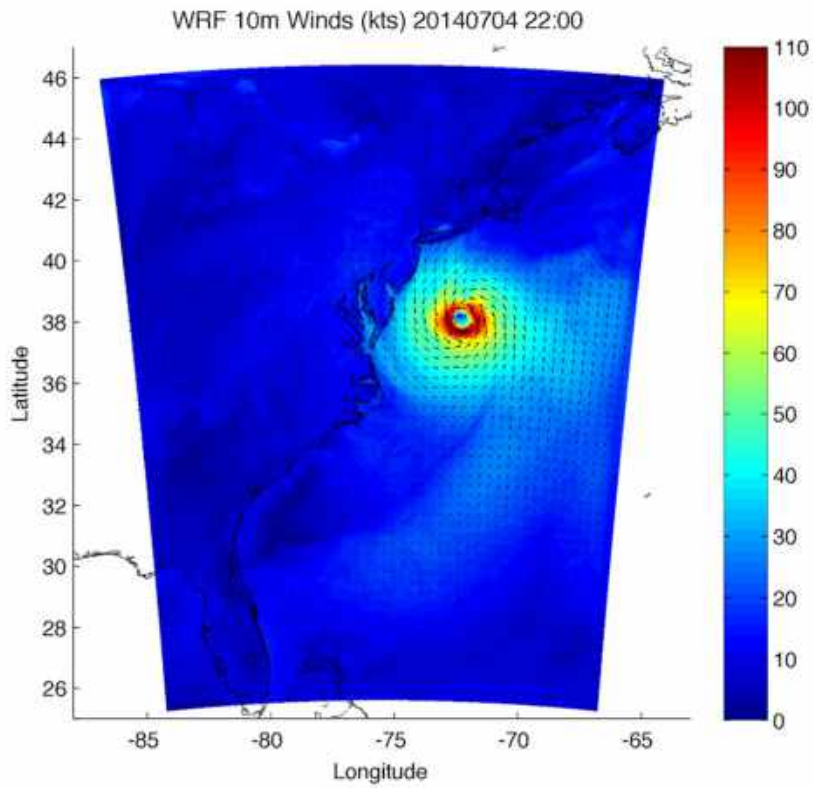


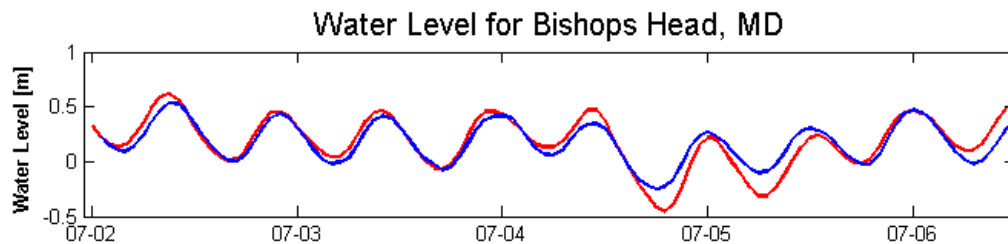
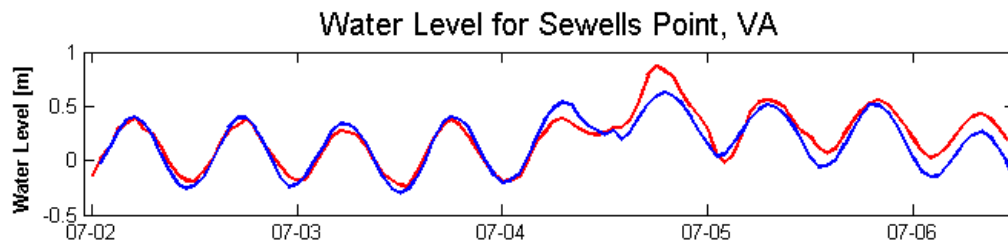
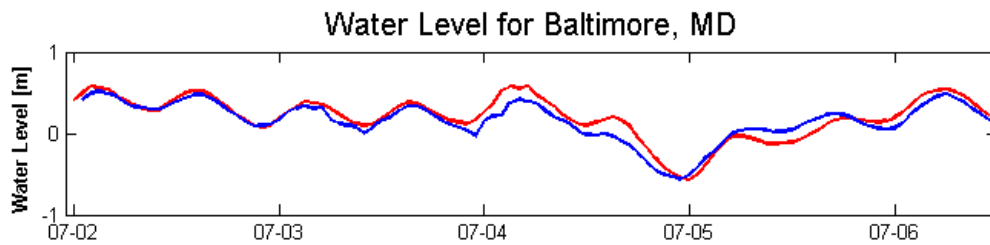
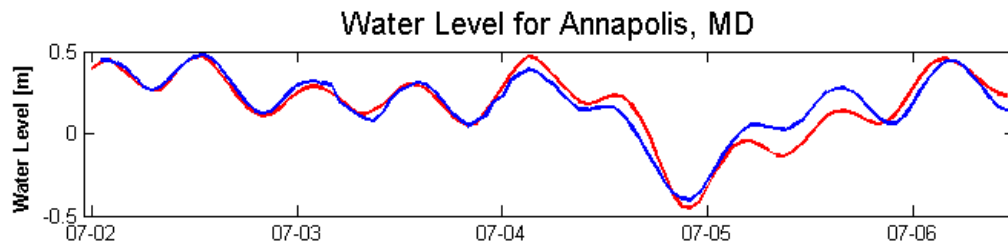


Hurricane Arthur



Imagery Date: 4/9/2013 40°17'25.73" N 71°05'58.48" W elev -3085 ft eye alt 1089.75 mi

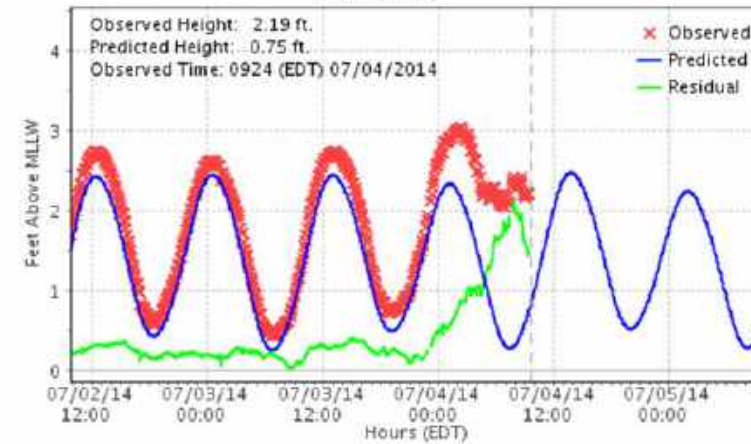




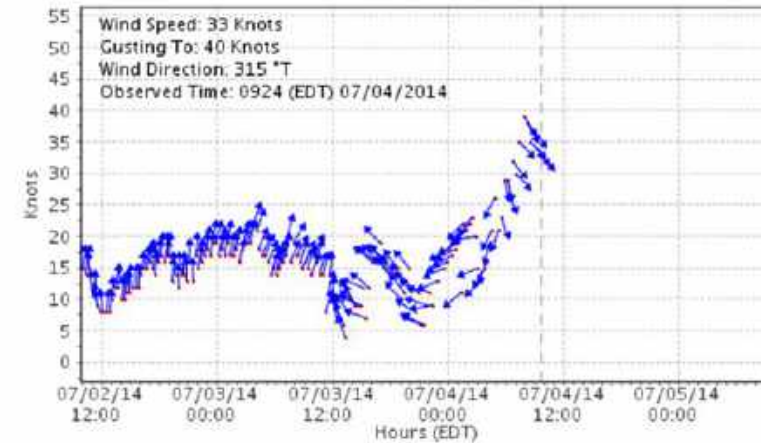
Time GMT (red:FVCOM blue: Observation from NOAA)

8638863 Chesapeake Bay Bridge Tunnel, VA

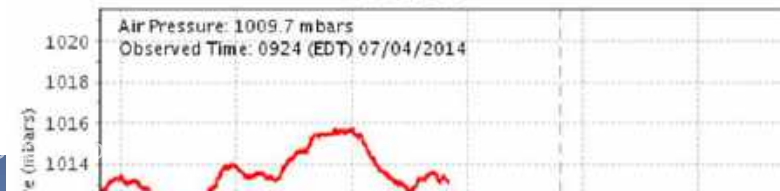
Water Levels



Winds

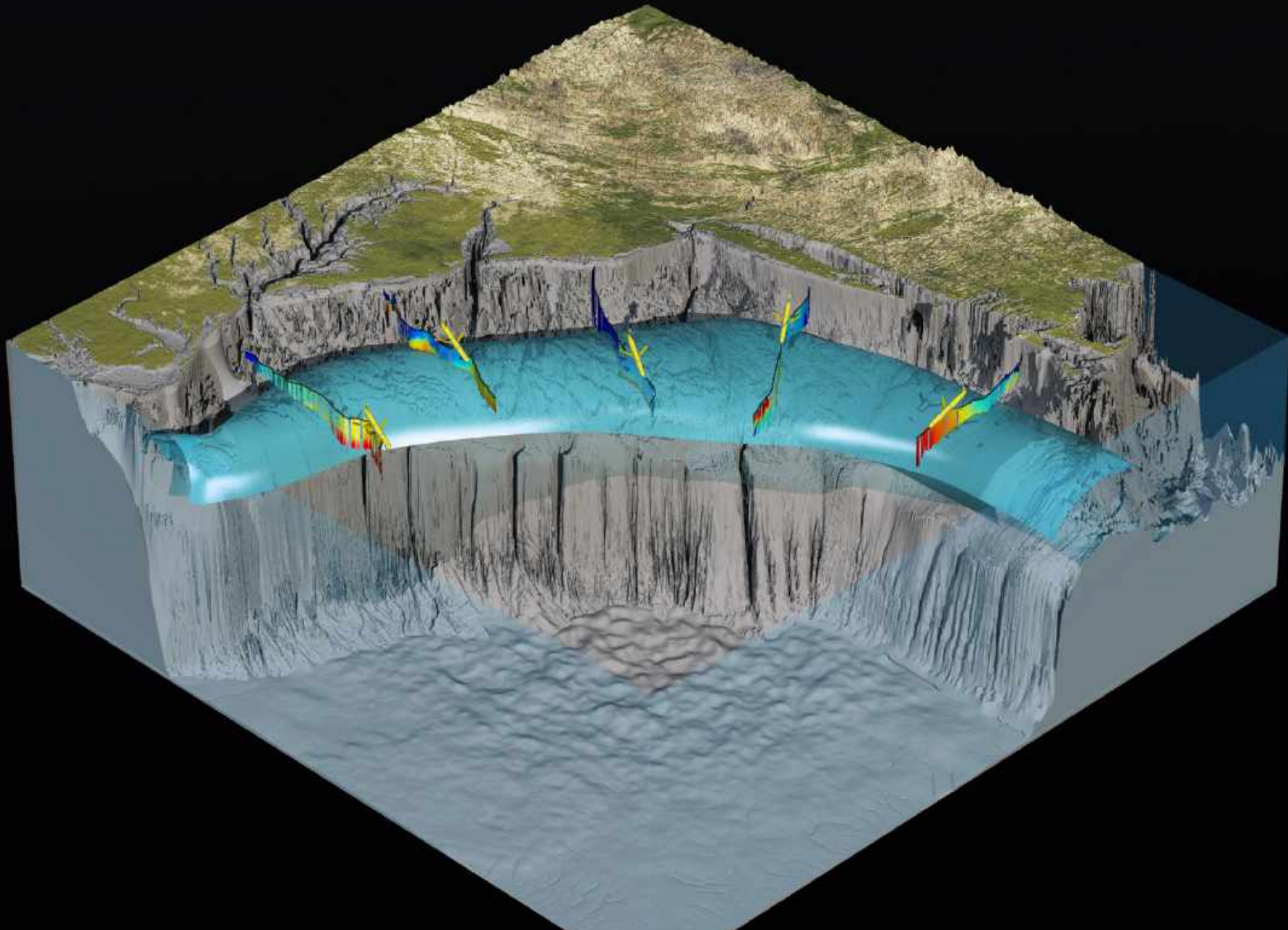


Air Pressure



AUV-REMUS





**SCIENCE
MOVING
RAPIDLY**

ipcc

INTERGOVERNMENTAL PANEL ON climate change

CLIMATE CHANGE 2013

The Physical Science Basis

Summary for Policymakers

WG I

WORKING GROUP I CONTRIBUTION TO THE
FIFTH ASSESSMENT REPORT OF THE
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

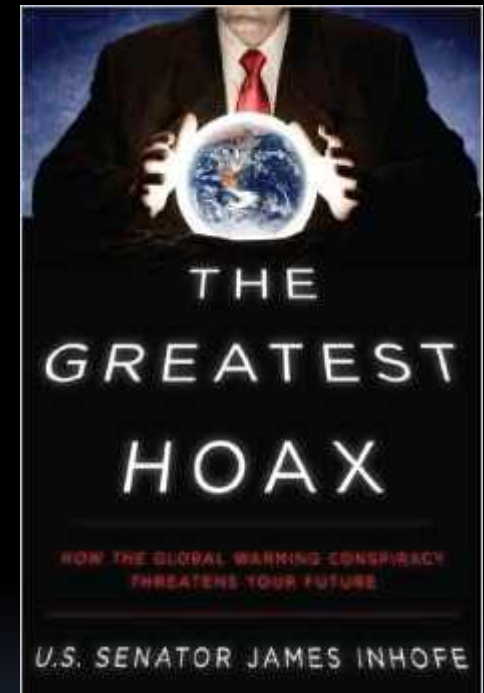


IT'S NOT JUST WARMING AND SEA-LEVEL RISE

- Ocean Acidification and Coral Bleaching
- Permafrost melting.
- Global changes in agricultural production.
- Increases in temperature sensitive diseases.
- Disruption of Ecosystems
- Droughts
- Increase in Forest Fires
- Famine
- Mass Extinctions

A Changing Conversation

- “It’s a Hoax...”
- “It’s not Happening...”
- “It’s just Natural Cycles”
- “I didn’t do it...”
- “I’m not a Scientist...”
- “Tax Carbon”



WHAT CAN WE DO?

- **Advocate for the pricing of carbon**, through tax, trading, or regulation.
- **Support innovation** and the deployment of low-carbon technologies.
- **Conserve**, and help remove barriers to improving energy efficiency
- **Educate and advocate**: do not leave the decisions solely to scientists, economists, and politicians.
- **Support research** to eliminate known unknowns and diminish the number of unknown unknowns.
- **Watch for new scientific discoveries** and evolving understanding of climate future.

IS THERE ANY GOOD NEWS?

Stern Review:

Tackling climate change is the pro-growth strategy for the longer term, and it can be done in a way that does not cap the aspirations for growth of rich or poor countries. The earlier effective action is taken, the less costly it will be.

A SEA LEVEL RISE RESPONSE STRATEGY FOR THE STATE OF MARYLAND



Zoë Pfahl Johnson
NOAA Coastal Management Fellow

for

Maryland Department of Natural Resources
Coastal Zone Management Division
October, 2000

Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change

Phase II: Building societal, economic, and ecological resilience



REPORT OF THE MARYLAND COMMISSION ON CLIMATE CHANGE
ADAPTATION AND RESPONSE AND SCIENTIFIC AND TECHNICAL WORKING GROUPS

Scientists Warn of Rising Oceans From Polar Melt

By JUSTIN GILLIS and KENNETH CHANG

The depletion of large parts of the ice sheet in West Antarctica is almost certainly unstoppable, with global warming accelerating the disintegration, two groups of scientists reported Monday.

<http://www.nytimes.com/2014/05/13/science/earth/collapse-of-parts-of-west-antarctica-ice-sheet-has-begun-scientists-say.html?emc=eta1>

Bipartisan Report Tallies High Toll on Economy From Global Warming

By JUSTIN GILLIS

Treasury secretaries dating to the Nixon years backed a new report predicting a heavy loss of coastal properties, a shift of farming northward, and dangerous outdoor conditions because of climate change.

<http://www.nytimes.com/2014/06/24/science/report-tallies-toll-on-economy-from-global-warming.html?emc=eta1>

“I AM NOT A SCIENTIST...”

U.S. | Political Memo
Why Republicans Keep Telling Everyone
They're Not Scientists

By CORAL DAVENPORT
OCT. 30, 2014

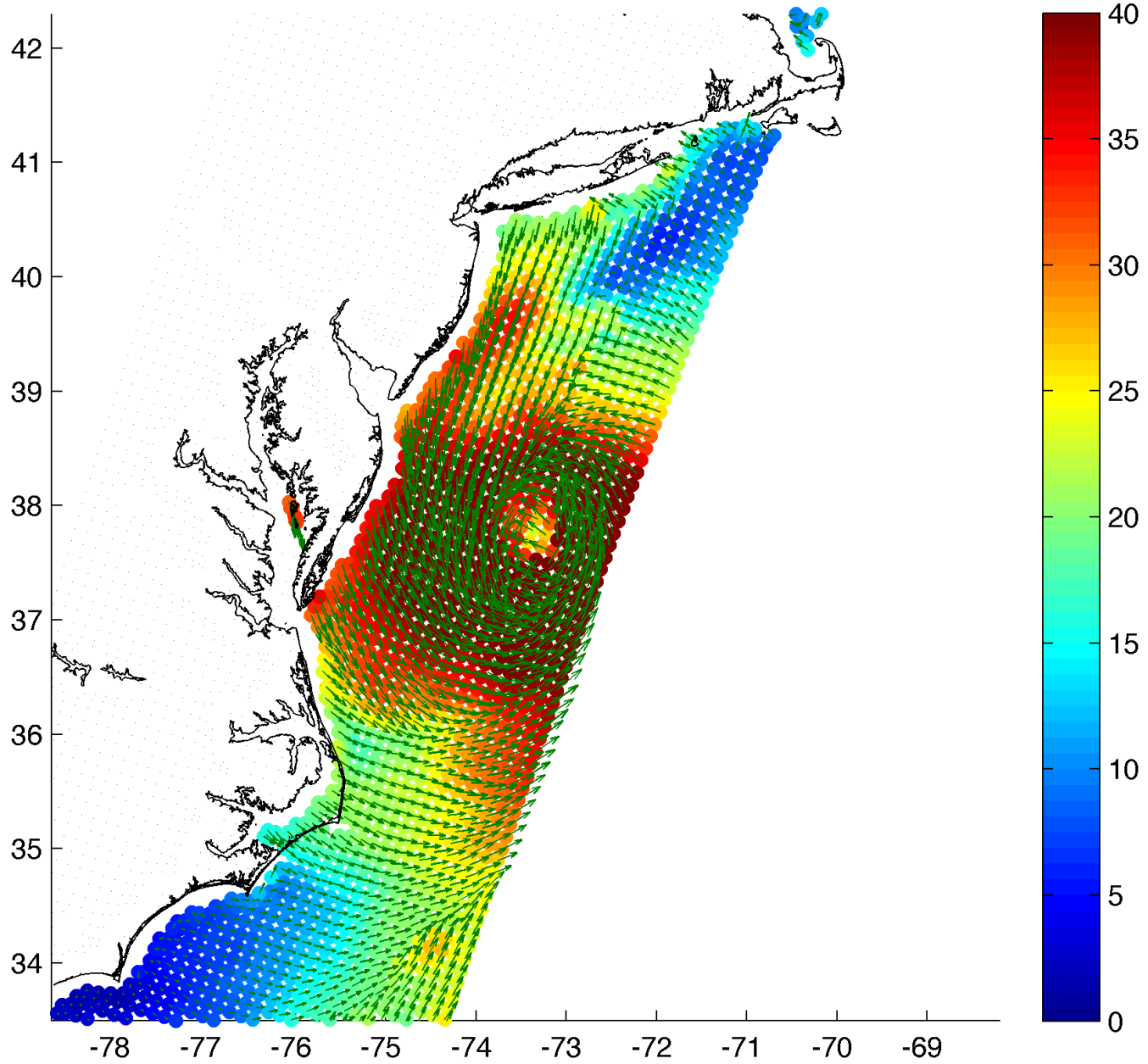
<http://www.nytimes.com/2014/10/31/us/why-republicans-keep-telling-everyone-theyre-not-scientists.html?smprod=nytcore-iphone&smid=nytcore-iphone-share&r=0>

If You See Something, Say Something

By MICHAEL E. MANN

JAN. 17, 2014

should we go full-bore on nuclear power? Invest in and deploy renewable energy — wind, solar and geothermal — on a huge scale? Price carbon emissions through cap-and-trade legislation or by imposing a carbon tax? Until the public fully understands the danger of our present trajectory, those debates are likely to continue to founder.



Improving How Scientists Communicate About Climate Change

PAGES 106–107

Science meets policy in the most important challenge of our time: global warming. Yet even the most basic facts of this issue (e.g., that the world is warming and that human activity is the dominant cause) are obscure to some decision makers who need to understand them. How can climate scientists be more effective at communicating what they know, how they know it, and how sure they are of it?

The need for scientists to communicate more effectively about climate change is urgent. For people to take climate change seriously and support appropriate responses, they need to feel sure it is happening and is caused primarily by humans. But while the rise in global temperature is a fact (see, e.g., *Intergovernmental Panel on Climate Change (IPCC) [2007]*, which calls the warming “unequivocal”), 56% of Americans believe there is a lot of disagreement among scientists about whether global warming is even occurring. And while every authoritative scientific body attributes most of

time. And know your audience; always use Fahrenheit for Americans.

Clearly state the settled scientific conclusions. Do not overdo “weasel words” and caveats. We know it is warming and we know it is due primarily to human activity. Say so. Saying human activity “contributes” to global warming makes it sound like human activity might be only a minor contributor. It would be more accurate to say “most of the warming...”

Clearly distinguish settled science from the details on which scientists frequently focus their attention. Avoid using the word “debate” in connection with climate change. It reinforces the mistaken notion that there is a debate about basic issues that are settled science. When referring to the whole issue, try something like “the urgent challenge of human-induced climate disruption” rather than “climate debate.”

Words That Mean Different Things to Scientists and Lay People

Scientists use many words that mean some-

“CONTINUATION OF HIGH FOSSIL FUEL EMISSIONS, GIVEN CURRENT KNOWLEDGE OF THE CONSEQUENCES, WOULD BE AN ACT OF EXTRAORDINARY WITTING INTERGENERATIONAL INJUSTICE.”

OPEN ACCESS Freely available online

PLOS ONE

Review

Assessing “Dangerous Climate Change”: Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature

James Hansen^{1*}, Pushker Kharecha^{1,2}, Makiko Sato¹, Valerie Masson-Delmotte³, Frank Ackerman⁴, David J. Beerling⁵, Paul J. Hearty⁶, Ove Hoegh-Guldberg⁷, Shi-Ling Hsu⁸, Camille Parmesan^{9,10}, Johan Rockstrom¹¹, Eelco J. Rohling^{12,13}, Jeffrey Sachs¹, Pete Smith¹⁴, Konrad Steffen¹⁵, Lise Van Susteren¹⁶, Karina von Schuckmann¹⁷, James C. Zochos¹⁸

1 Earth Institute, Columbia University, New York, New York, United States of America, **2** Goddard Institute for Space Studies, NASA, New York, New York, United States of America, **3** Institut Pierre Simon Laplace, Laboratoire des Sciences du Climat et de l'Environnement (CEA-CNRS-UVSQ), Gif-sur-Yvette, France, **4** Synapse Energy Economics, Cambridge, Massachusetts, United States of America, **5** Department of Animal and Plant Sciences, University of Sheffield, Sheffield, South Yorkshire, United Kingdom, **6** Department of Environmental Studies, University of North Carolina, Wilmington, North Carolina, United States of America, **7** Global Change Institute, University of Queensland, St. Lucia, Queensland, Australia, **8** College of Law, Florida State University, Tallahassee, Florida, United States of America, **9** Marine Institute, Plymouth University, Plymouth, Devon, United Kingdom, **10** Integrative Biology, University of Texas, Austin, Texas, United States of America, **11** Stockholm Resilience Center, Stockholm University, Stockholm, Sweden, **12** School of Ocean and Earth Science, University of Southampton, Southampton, Hampshire, United Kingdom, **13** Research School of Earth Sciences, Australian National University, Canberra, ACT, Australia, **14** University of Aberdeen, Aberdeen, Scotland, United Kingdom, **15** Swiss Federal Institute of Technology, Swiss Federal Research Institute WSL, Zurich, Switzerland, **16** Center for Health and the Global Environment, Advisory Board, Harvard School of Public Health, Boston, Massachusetts, United States of America, **17** Institut Français de Recherche pour l'Exploitation de la Mer, Ifremer, Toulon, France, **18** Earth and Planetary Science, University of California, Santa Cruz, CA, United States of America

Abstract: We assess climate impacts of global warming using ongoing observations and paleoclimate data. We use Earth's measured energy imbalance, paleoclimate

inertia causes climate to appear to respond slowly to this human-made forcing, but further long-lasting responses can be locked in.

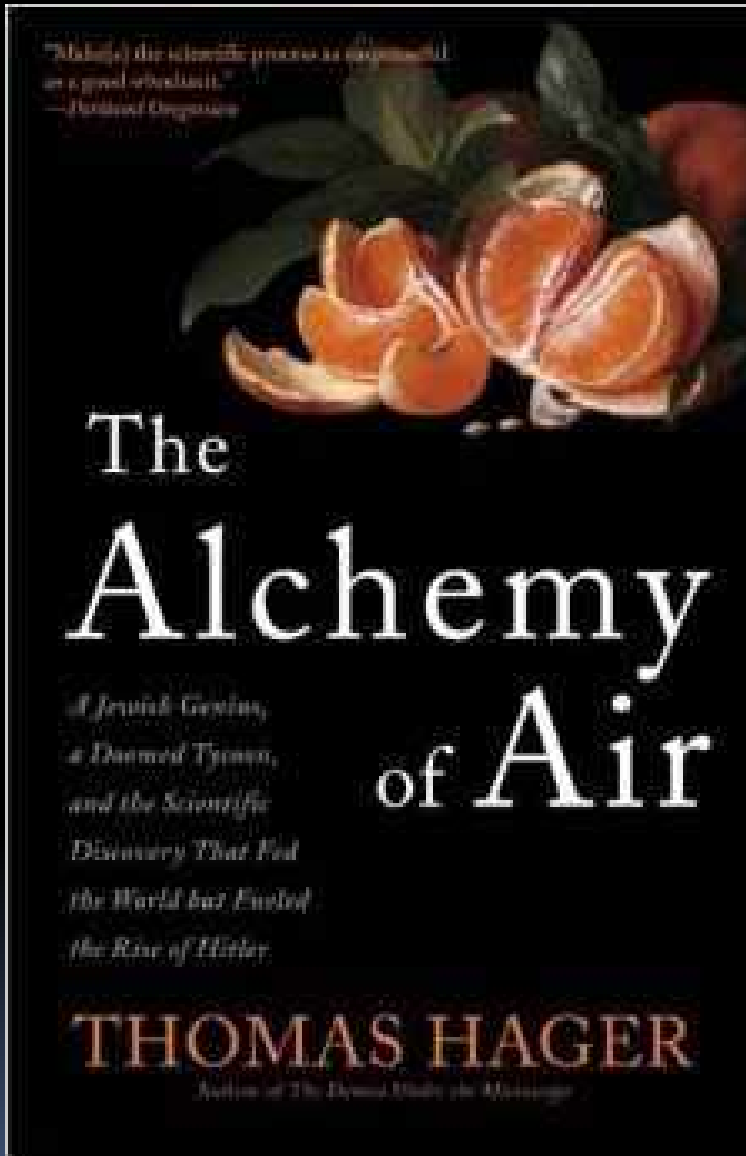
More than 170 nations have agreed on the need to limit fossil fuel emissions to avoid dangerous human-made climate change' as

SIR WILLIAM CROOKES, 1898

“England, and all civilized countries, stand in deadly peril.”

Humans would begin dying of hunger in large numbers somewhere around 1930.

Not enough new farmland, and not enough natural fertilizer: manufacture some.



NITROGEN

The Stern Review: The Economics of Climate Change, Royal Society of London October 30, 2006

[Inaction] over the coming few decades could create risks of major disruption to economic and social activity, later in this century and in the next, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes... Climate change is the greatest market failure the world has ever seen, and it interacts with other market imperfections.

<http://abcnews.go.com/US/north-carolina-bans-latest-science-rising-sea-level/story?id=16913782#.VFDrxwREFlw.email>

<http://wapo.st/100VLQr>

http://www.nytimes.com/2014/06/23/opinion/paul-krugman-conservatives-and-climate-change.html?emc=eta1&_r=0

The Coming Climate Crash

Lessons for Climate Change in the 2008 Recession

By HENRY M. PAULSON Jr. JUNE 21, 2014

<http://www.nytimes.com/2014/06/22/opinion/sunday/lessons-for-climate-change-in-the-2008-recession.html?emc=eta1>

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MAP
OF
TALBOT COUNTY
SHOWING THE
GEOLOGICAL FORMATIONS

MARYLAND GEOLOGICAL SURVEY
W.P. BULLOCK CURRAN, STATE GEOLOGIST
U.S. GEOLOGICAL SURVEY
1892



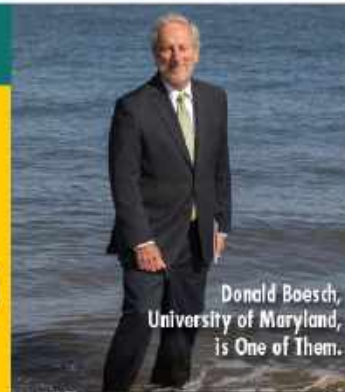
Scientific Consensus on Climate Change:
There's No Debate

ABOUT **97%**
OF CLIMATE SCIENTISTS
— HAVE CONCLUDED —
**HUMAN-CAUSED
CLIMATE CHANGE
IS HAPPENING.**

Citation for 97%: Andersson, W. R. L., Pratt, J. W., Harsh, L., & Schneider, S. H. (2010). Expert credibility in climate change. *Proceedings of the National Academy of Sciences*, 107(17), 12107–12109.

Cook, J., O'Neill, B., Green, S. A., Richardson, M., Winkler, B., Paulding, R., Way, R., Jacobs, P., & Skusek, J. (2013). Quantifying the consensus on anthropogenic global warming in the scientific literature. *Environmental Research Letters*, 8(2), 024029.

Doran, P. T., & Zimmerman, M. R. (2009). Estimating the overall consensus on climate change. *Est. The section American Geophysical Union*, 10(2), 21.



Donald Boesch,
University of Maryland,
is One of Them.



Patricia Delgado at Jug Bay
Wetlands Sanctuary in Maryland
is One of Them.



William Boicourt,
University of Maryland,
is One of Them.

Find Out What They are Learning.

CHANGE IT UP MARYLAND!



**CLIMATE COMMUNICATION
CONSORTIUM OF MARYLAND**