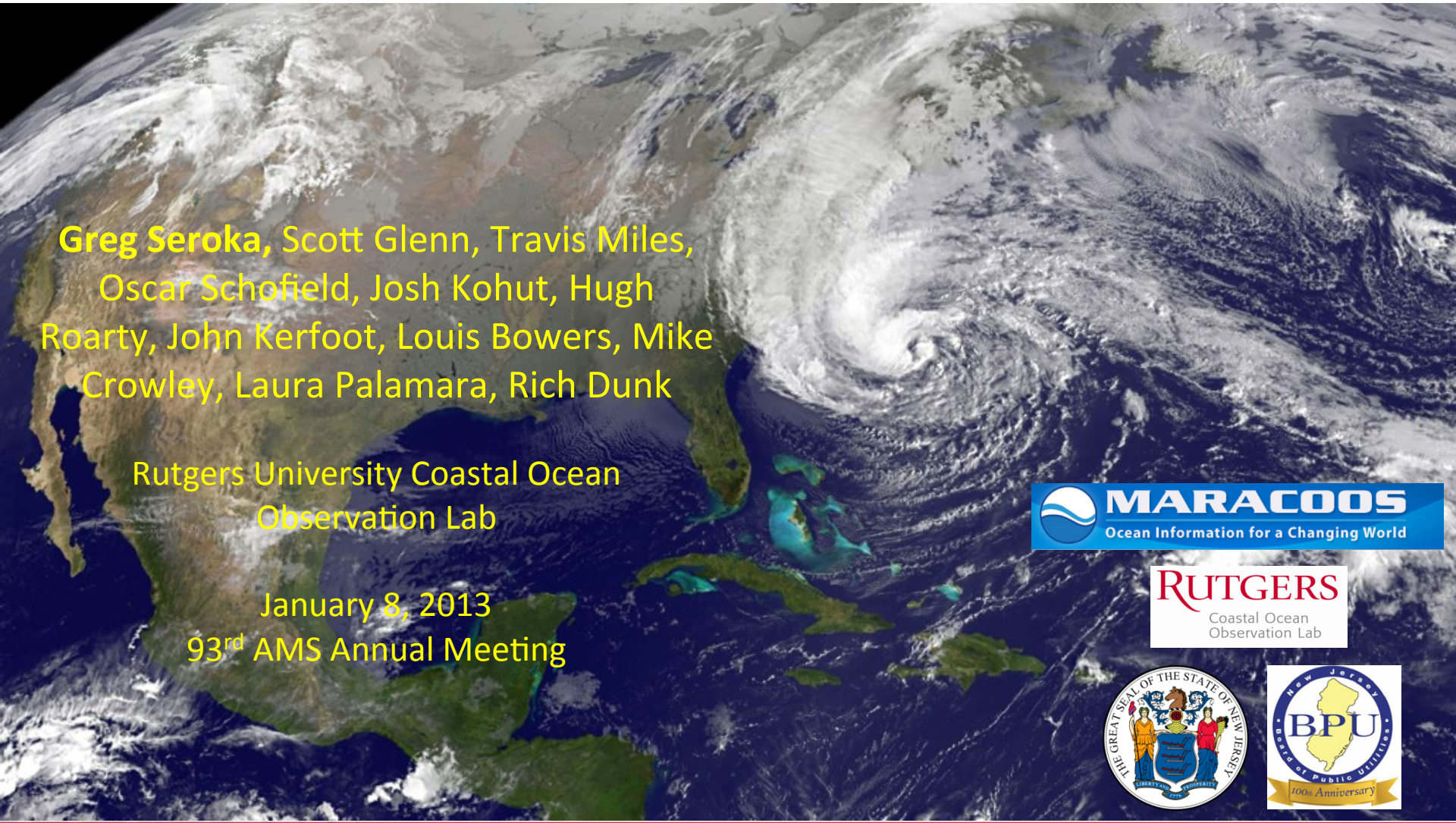
Impact of Ocean Observations on Hurricane Irene and Hurricane Sandy Forecasts



Greg Seroka, Scott Glenn, Travis Miles, Oscar Schofield, Josh Kohut, Hugh Roarty, John Kerfoot, Louis Bowers, Mike Crowley, Laura Palamara, Rich Dunk

Rutgers University Coastal Ocean Observation Lab

January 8, 2013
93rd AMS Annual Meeting

MARACOOS
Ocean Information for a Changing World

RUTGERS
Coastal Ocean Observation Lab

BPU
New Jersey Board of Public Utilities
100th Anniversary

Background

- Hurricane intensity prediction remains key area of research (e.g. Bender and Ginis, 2000)
- Measurements of upper ocean limited (Emanuel, 2003)
- **Hurricanes Irene (2011)** and **Sandy (2012)** are key events to study coastal ocean mixing and feedback onto hurricane intensity
- Unique coastal ocean observations collected before, during and after both storms


Hurricane Irene (2011)
N41°
N39°
N37°
N35°
N33°
N31°
W85°
W83°
W81°
W63°
W61°
Bermuda
© 2011 Europa Technologies
© 2011 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
©2010 Google

Bloomb

The Miami Herald > We

Hurrica

Sunday, 02.19.12 Wel

HOME | NEWS | SP

Miami-Dade | Brow

Posted on Friday, 09.02.1

HURRICANE SEASON

Intensity

Like 1

The National Hu
it wasn't the first
the increasing s

BY CURTIS MORGAN
MORGAN@MIAMIHERALD.

RUTGERS

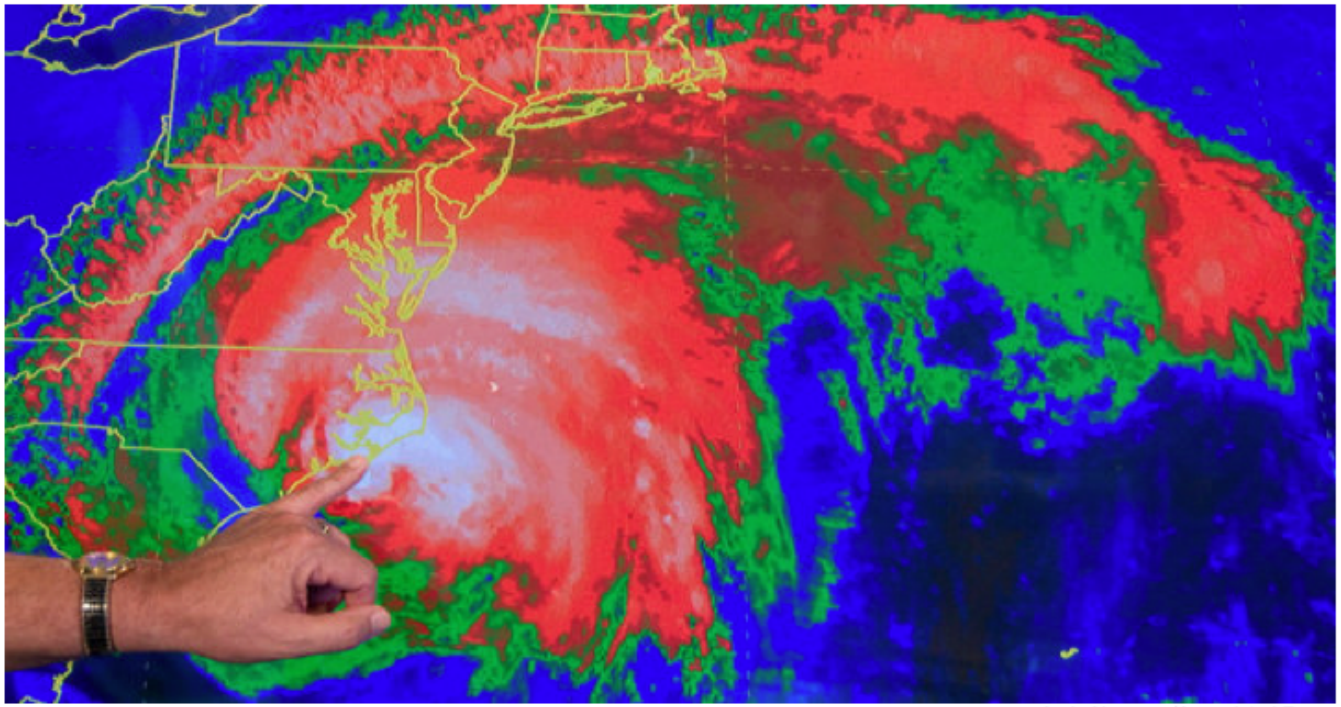
The New York Times

U.S.

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION

POLITICS | EDUCATION | BAY AREA | CHICAGO | TEXAS

Challenges in Predicting the Intensity of Storms

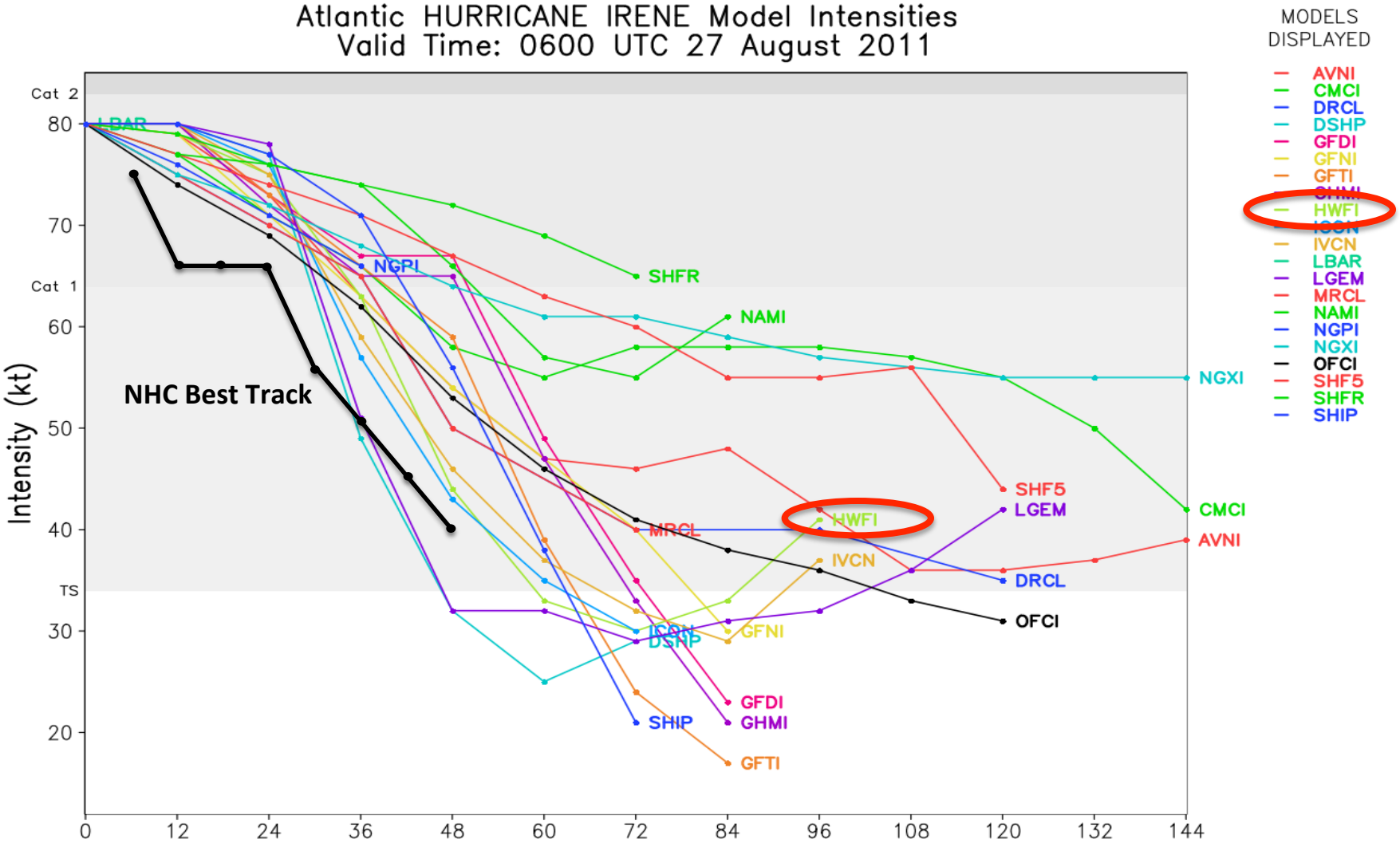


Andy Newman/Associated Press

Scientists say that it is much easier to accurately predict what path a hurricane will take.

By HENRY FOUNTAIN
Published: August 27, 2011

Even coupled models (e.g. HWRF) overpredicted Irene



Could the ocean be a major player?

MARACOOS
MIDDLE ATLANTIC REGIONAL ASSOCIATION COASTAL OCEAN OBSERVING SYSTEM

1000 km
Cape to Cape

CT
RI
MA
Cape Cod
NY
10 States
PA
NJ
MD
DE
VA
NC
Cape Hatteras

Regional Association – 2004

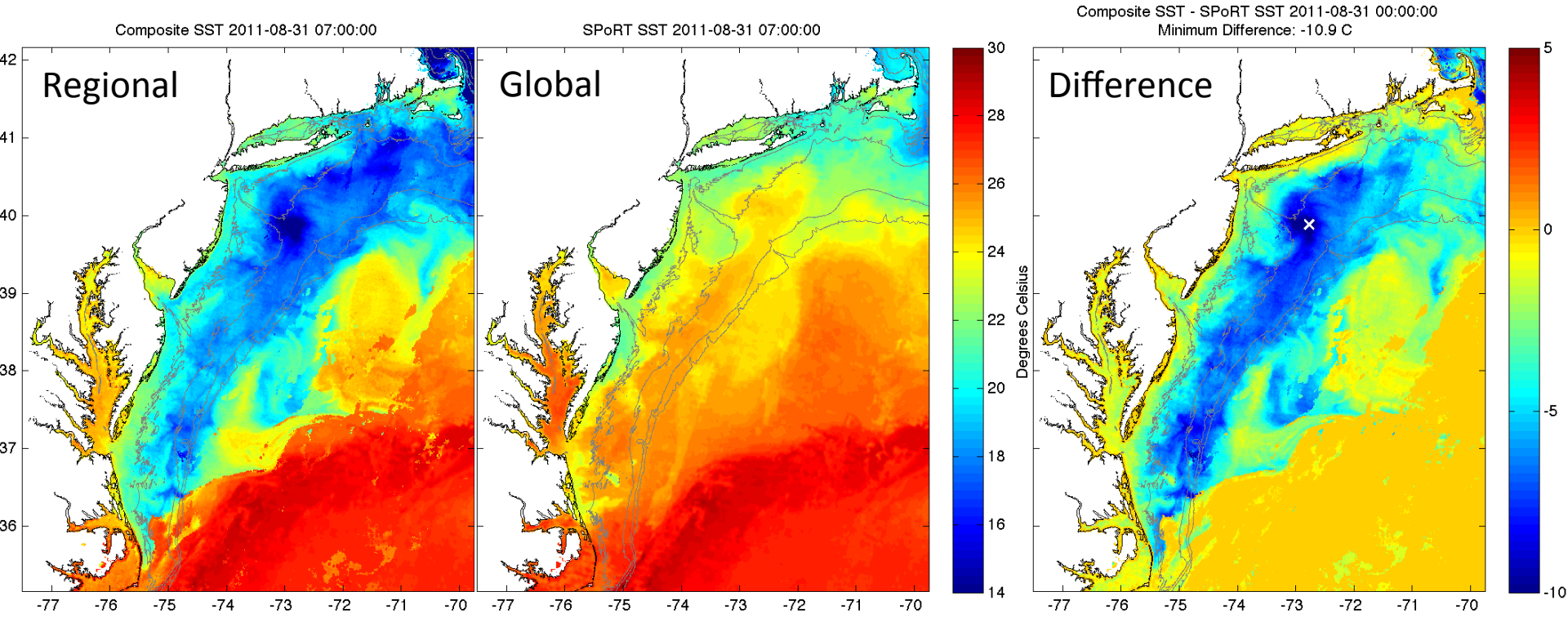
Regional Coastal Ocean Observing System – 2007

CODAR | L-Band | X-Band | Gliders | Forecasts

New MARACOOS De-clouded SST Composite

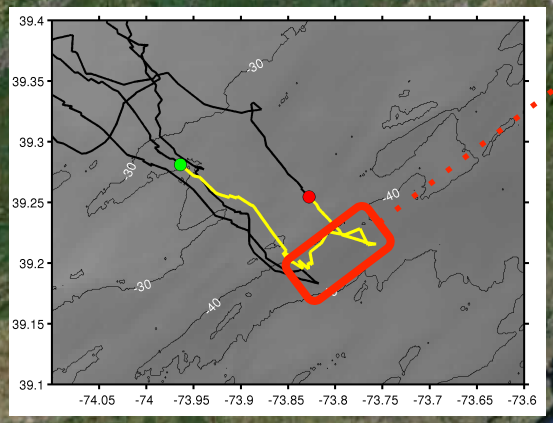
1. De-cloud 1-km resolution AVHRR data using various temperature and near IR thresholds
2. 3-day *coldest* dark pixel composite of de-clouded AVHRR scans
3. Then, coldest pixel composite with SPoRT SST to fill in remaining cloudy gaps
4. Result: high resolution in space and time, resolves cold wake

Post-Hurricane Irene Sea Surface Temperatures (°C)



But when did the 6-8°C **surface** cooling occur?
And what did **subsurface** mixing look like?

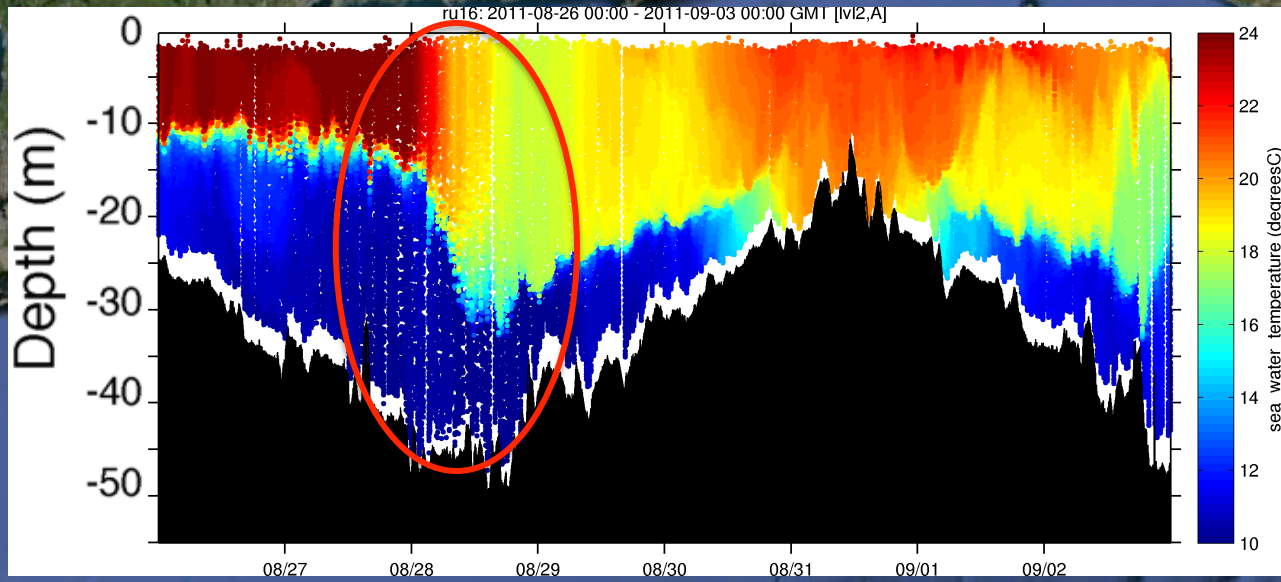
RU16 Glider



Hurricane Irene

Buzzards Bay

Vineyard Sound



Did forecast models resolve surface cooling correctly?

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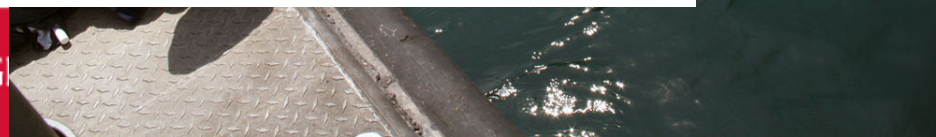
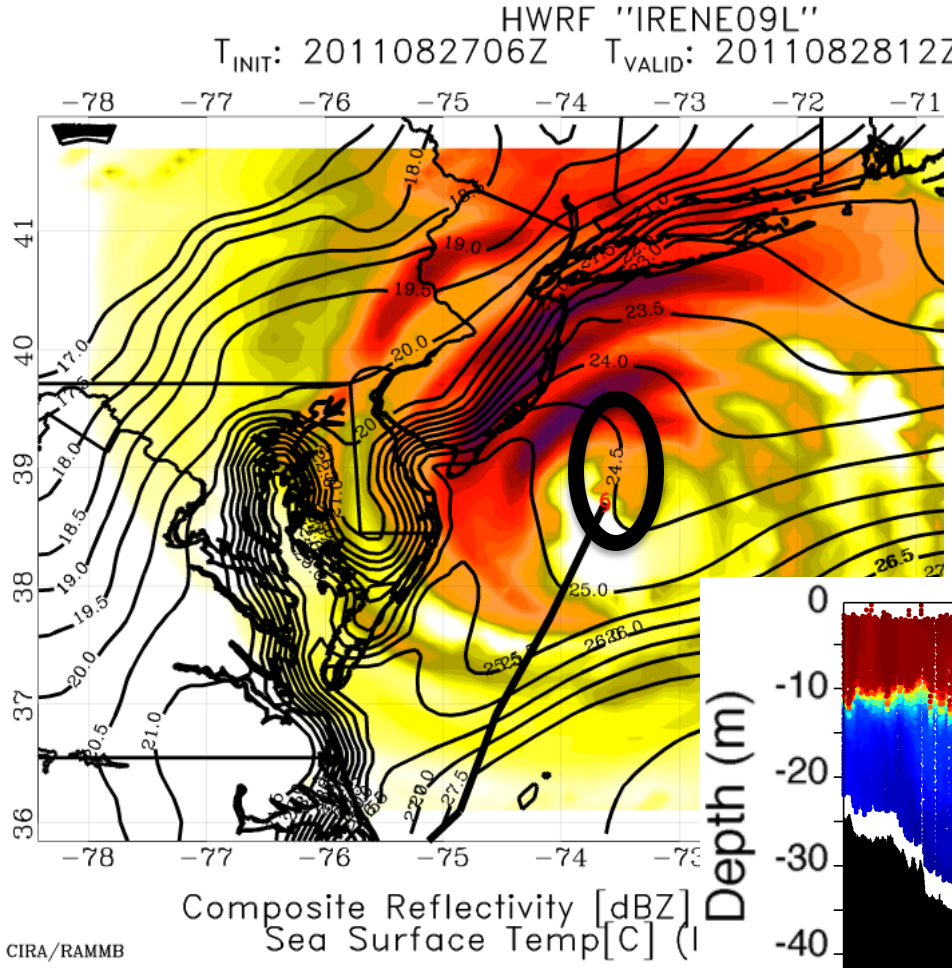
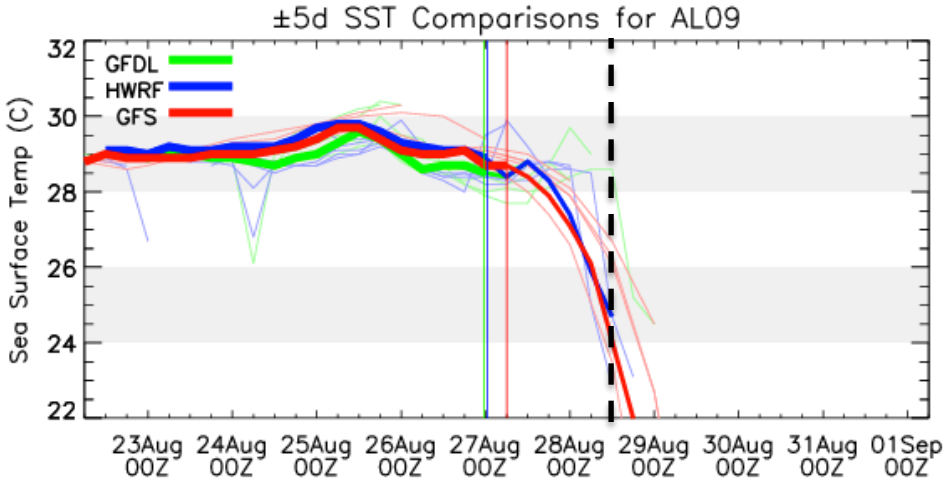
JERSEY ROOTS, G

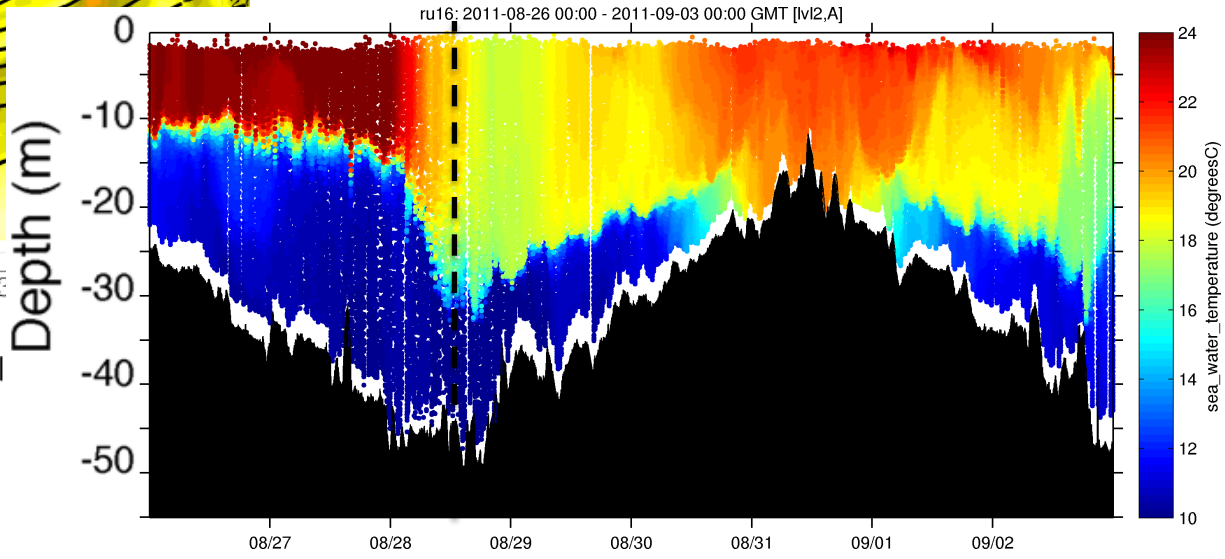


HWRF, GFDL SST during Irene



Courtesy of CSU/CIRA



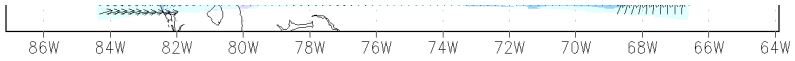


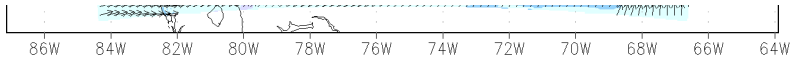
Model Setup

- Weather Research and Forecasting (WRF) model, Advanced Research core (ARW) (Michalakes et al., 2001)
- **Horizontal Resolution:** 6km
- **Vertical Resolution:** 50 levels, focused near surface
- **Lateral B.C.:** NAM 12km / GFS 0.5 degree
- **Microphysics:** Thompson (6-class with graupel)
- **Planetary Boundary Layer (PBL) scheme:** Mellor-Yamada-Janjic (MYJ)
- **Land surface model:** Noah Land Surface Model
- **Longwave radiation:** Rapid Radiative Transfer Model (RRTM-G)
- **Shortwave radiation:** RRTM-G
- **Bottom B.C. (Sea Surface Temperature, SST):** Variant

Hurricane Irene SST Sensitivity Hindcast

- Using observed variations in SST reduced modeled intensity of Irene—in some cases by 15 knots—to more closely match NHC best track and available obs.
- 1D ocean mixed-layer model in Advanced Hurricane WRF only slightly decreased errors
- Fully coupled atmosphere-ocean models even overpredicted intensity→ critical need for **correct ocean simulation of coastal mixing, esp. bottom boundary layer**

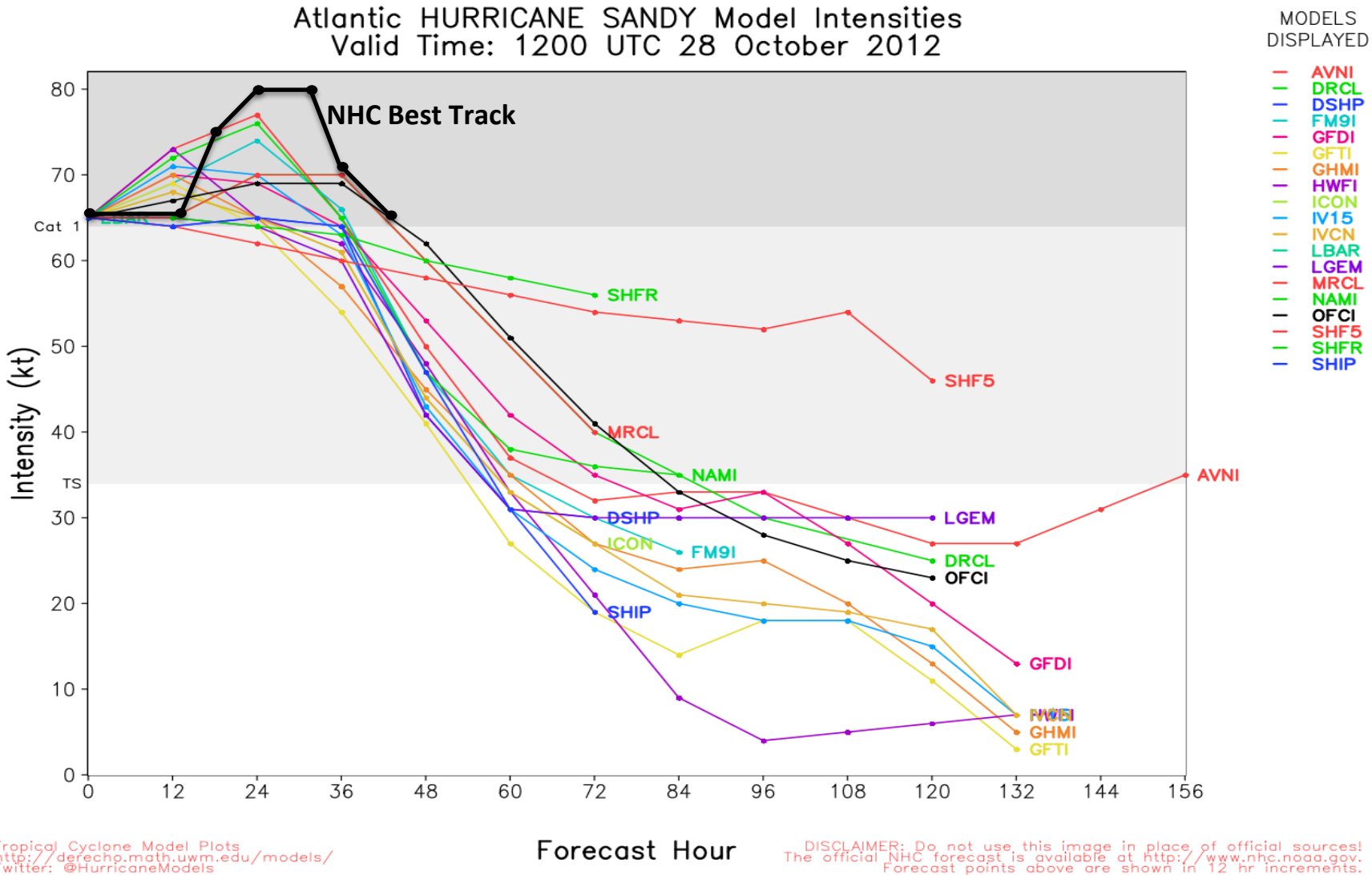




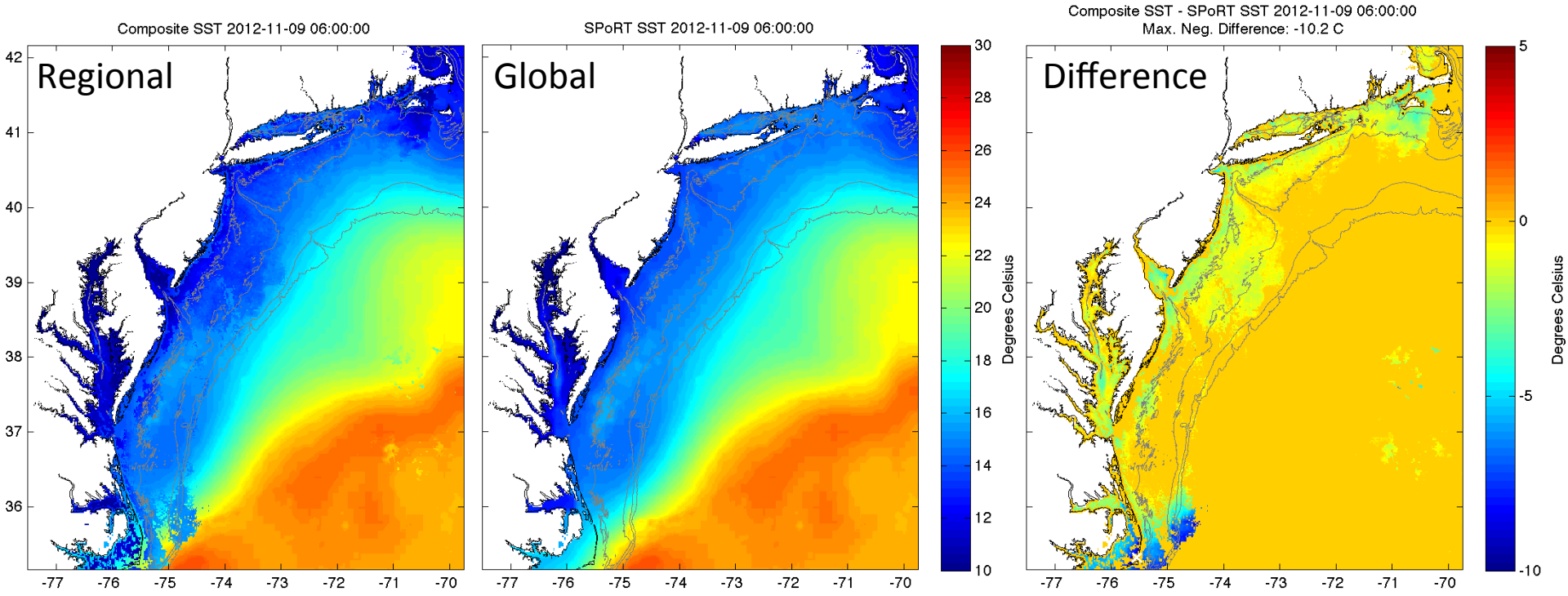
Maximum Wind Speed Skill Score	*Official Forecast*	*Warm SST Hindcast*	*Warm SST + OML Model Hindcast*	*Cold SST Hindcast*
RMS Error (knots)	9.43	7.13	7.09	3.61


Hurricane Sandy (2012)
N55°
N45°
N35°
N25°
W135°
W125°
W115°
W105°
W95°
W85°
W75°
W65°
W55°
W45°
W25°
Current Speed (cm/s)
0
10
20
30
40
60
© 2009 GeoBasis-DE/BKG
© 2012 Google
US Dept of State Geographer
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth

Sandy intensity predictions can be improved…

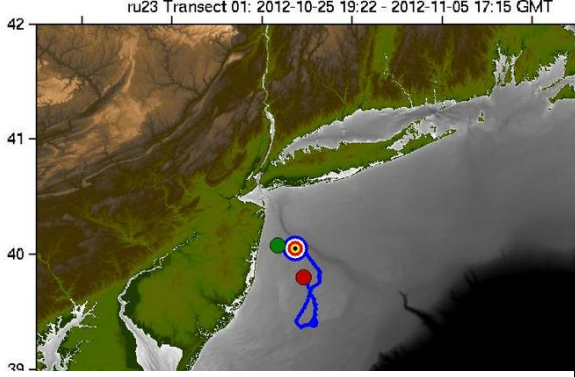


Post-Hurricane Sandy Sea Surface Temperatures (°C)



Persistent clouds post-Sandy prevented clear satellite view…

RU23 Glider


ru23 Transect 01: 2012-10-25 19:22 - 2012-11-05 17:15 GMT
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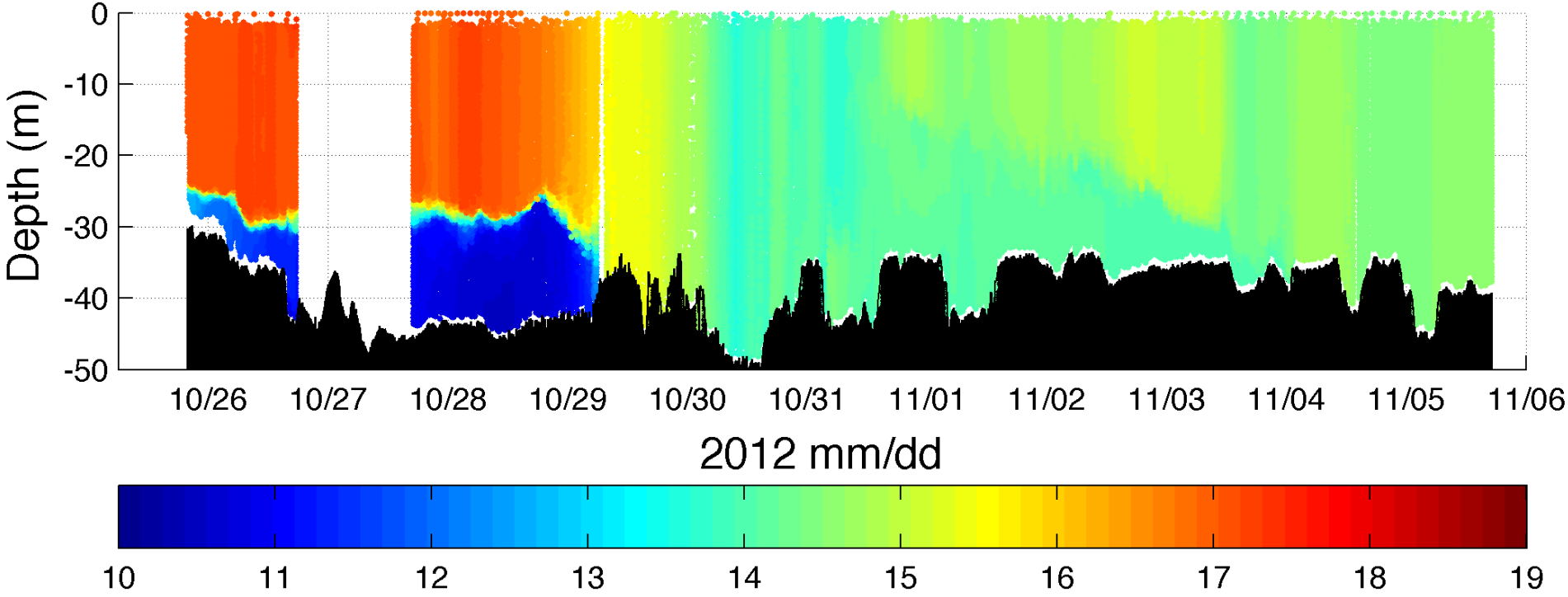
41
40


Depth (m)
0
-10
-20
-30
-40
-50
10/26
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10/29
10/30
10/31
11/01
11/02
11/03
11/04
11/05
11/06
2012 mm/dd
10
11
12
13
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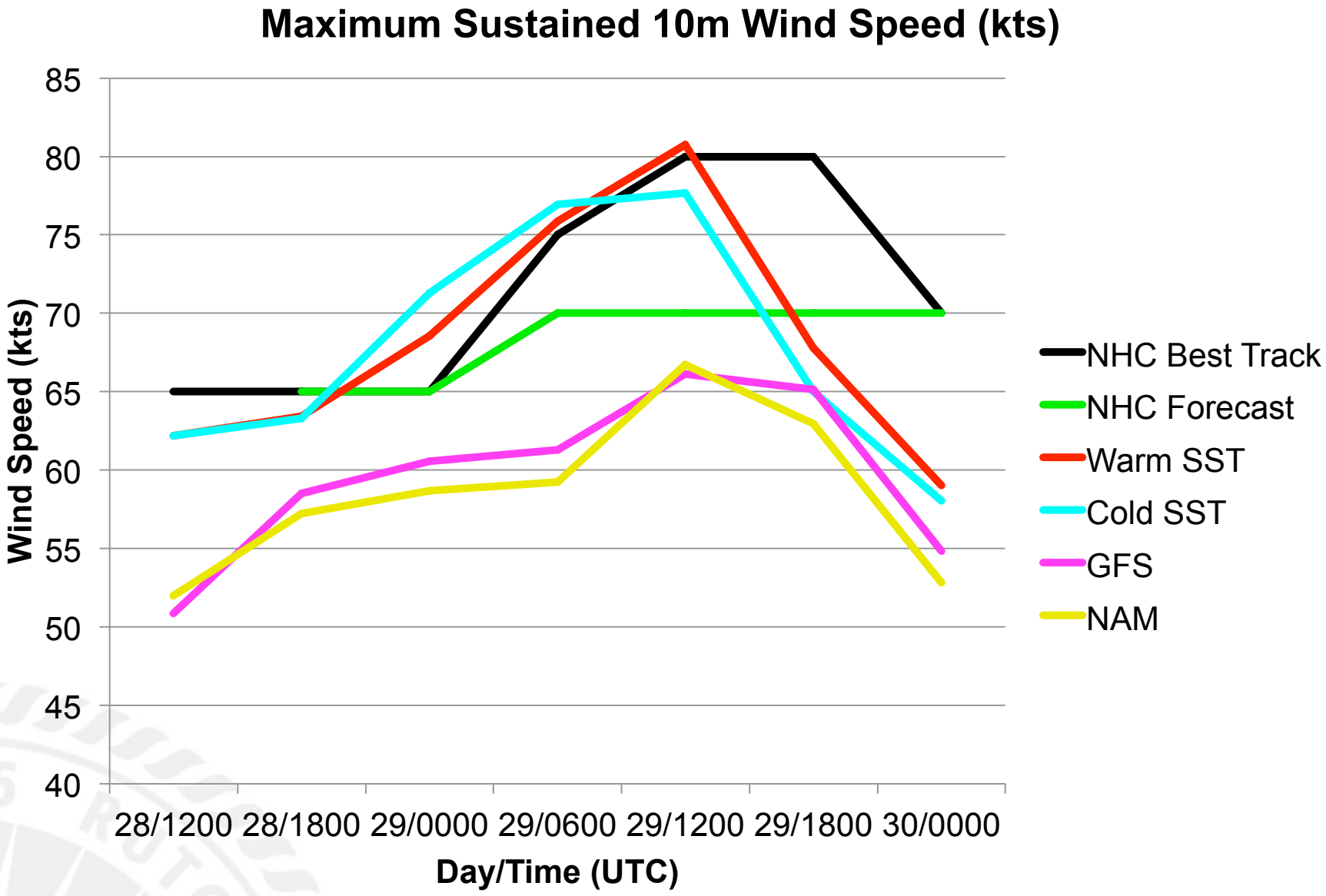
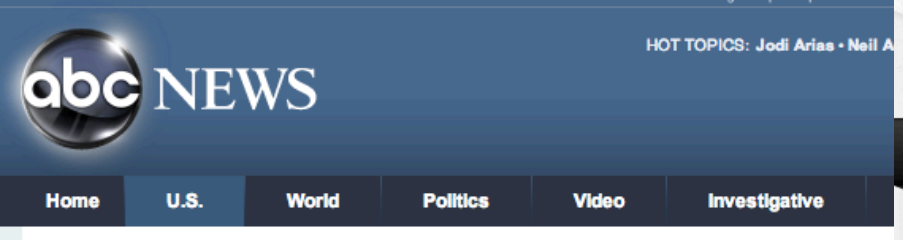
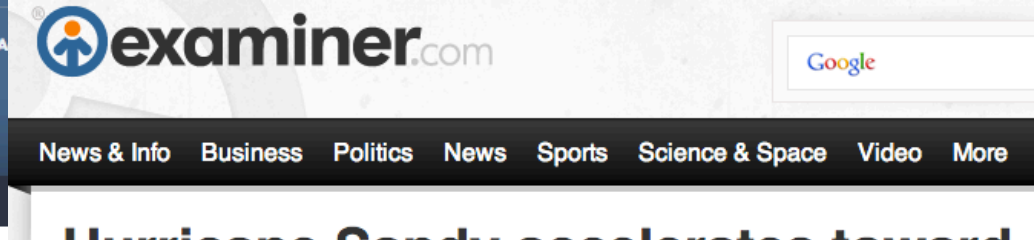
19

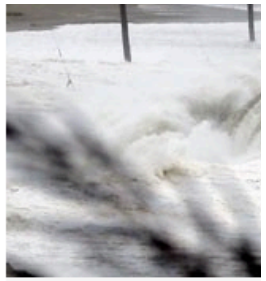
Hurricane Sandy Hindcast: Intensity



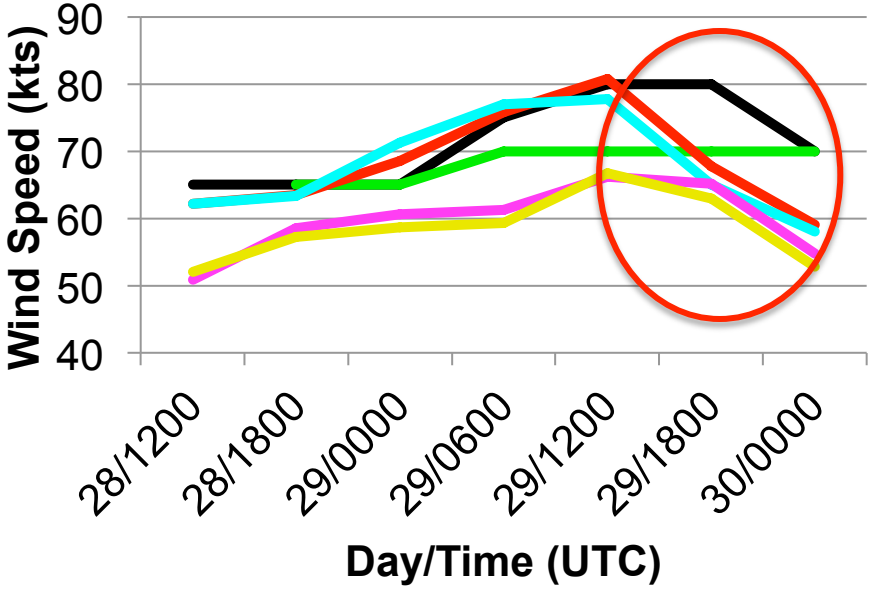


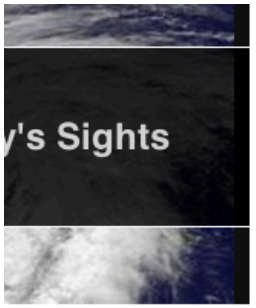


- What caused acceleration toward landfall? Phasing?
- Could accurate acceleration improve intensity forecast 6-12 hours prior to landfall?
- Hindcasts are being ingested into **storm surge models** to improve sea level prediction



Ocean waves kick up near h
2012. (Elise Amendola/AP Phot





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strengthened to a
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a bit faster than
andfall is now
during the next few hours
ersey.

Conclusions

- **Hurricanes Irene (2011)** and **Sandy (2012)** key events to study coastal ocean mixing during tropical/ subtropical storms
- Unique coastal ocean observations (satellite, glider) collected before, during and after both storms
- Data used to improve hindcast intensity (Irene) and speed (Sandy) and storm surge (Sandy)
- Next steps:
  - ***Predict** storm mixing (Irene) with accurate ocean model
  - Investigate why acceleration was underpredicted (Sandy)
  - Provide storm surge model with better wind fields (Sandy)

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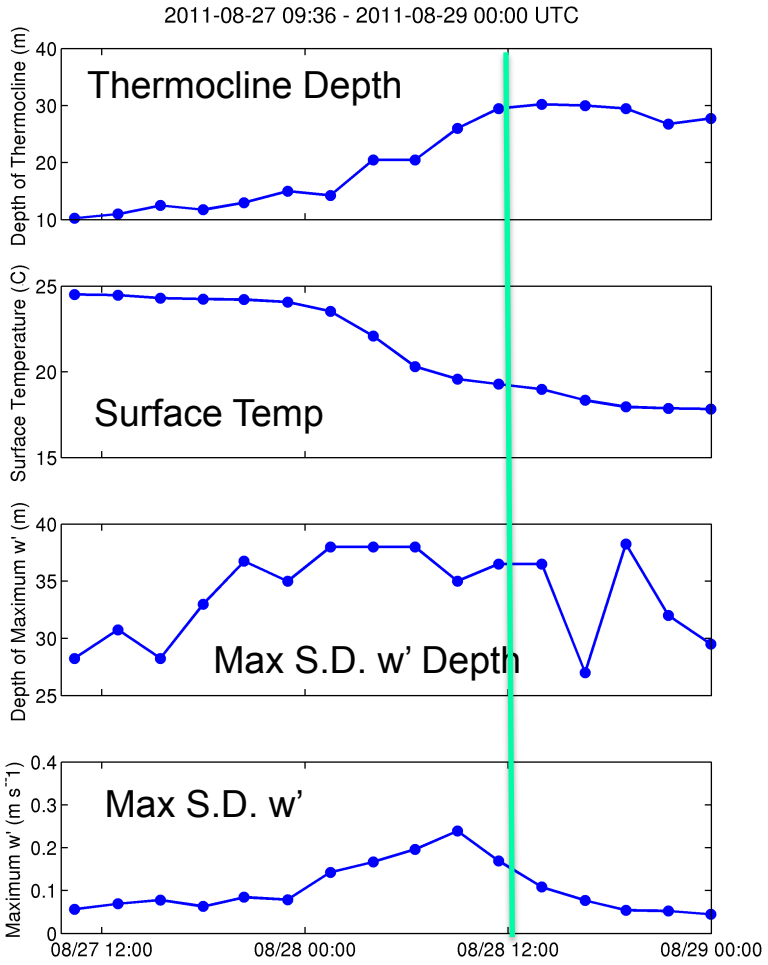
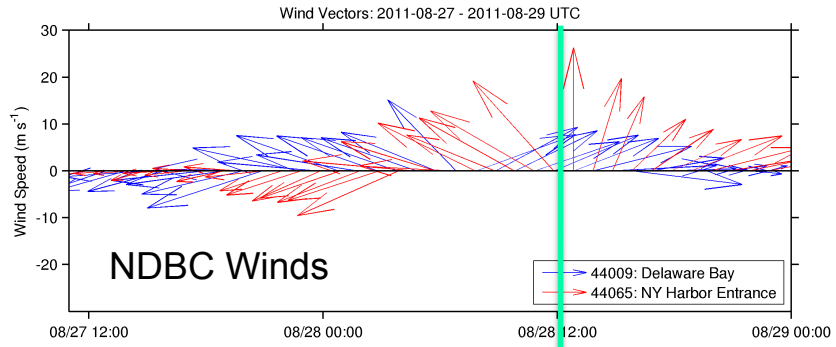
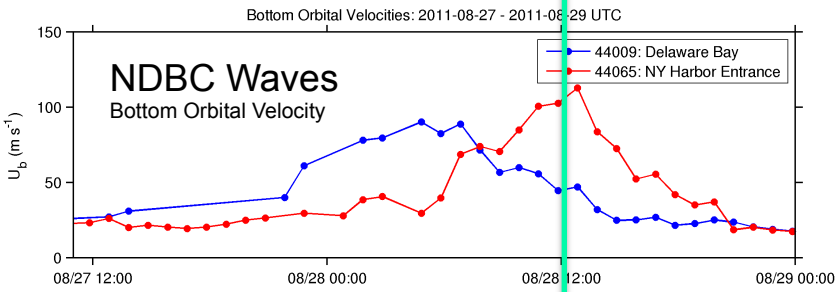
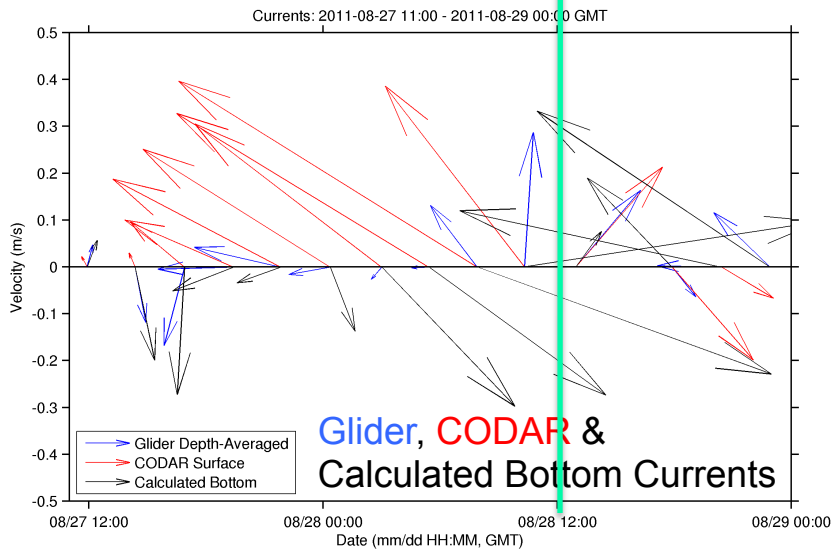
MARACOOS Network Observations:
Hurricane Irene



Glider RU16

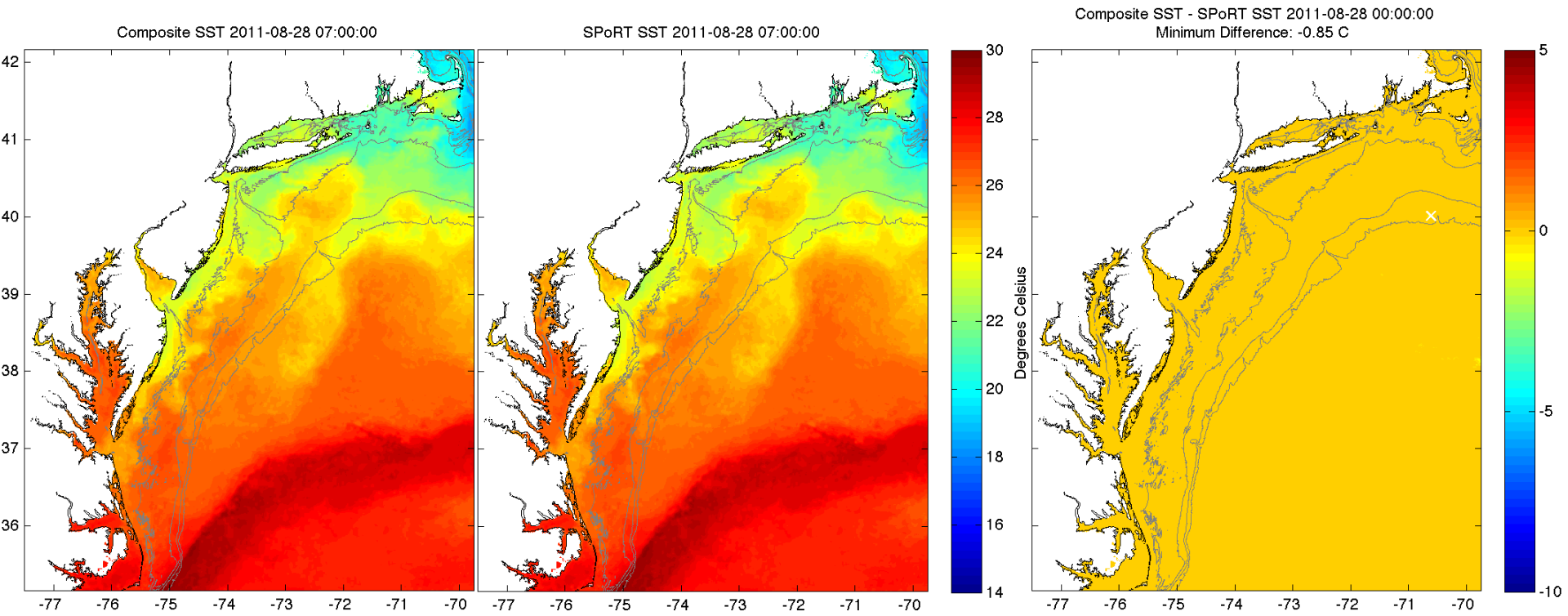






RU-COOL De-clouding Thresholds

- Visible and near IR thresholds empirically derived by season and location
- E.g. Mid-Atlantic Bight, summer/fall:
  - <10°C removed (cloud)
  - near IR albedo >2.3% removed (clouds)
  - Other tests on changes (within ~3km X 3km grid boxes) of SST (1°C) and near IR albedo (0.15%)


Composite SST 2011-08-28 07:00:00
SPoRT SST 2011-08-28 07:00:00
Composite SST - SPoRT SST 2011-08-28 00:00:00
Minimum Difference: -0.85 C
Degrees Celsius
42
41
40
39
38
37
36
-77
-76
-75
-74
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-71
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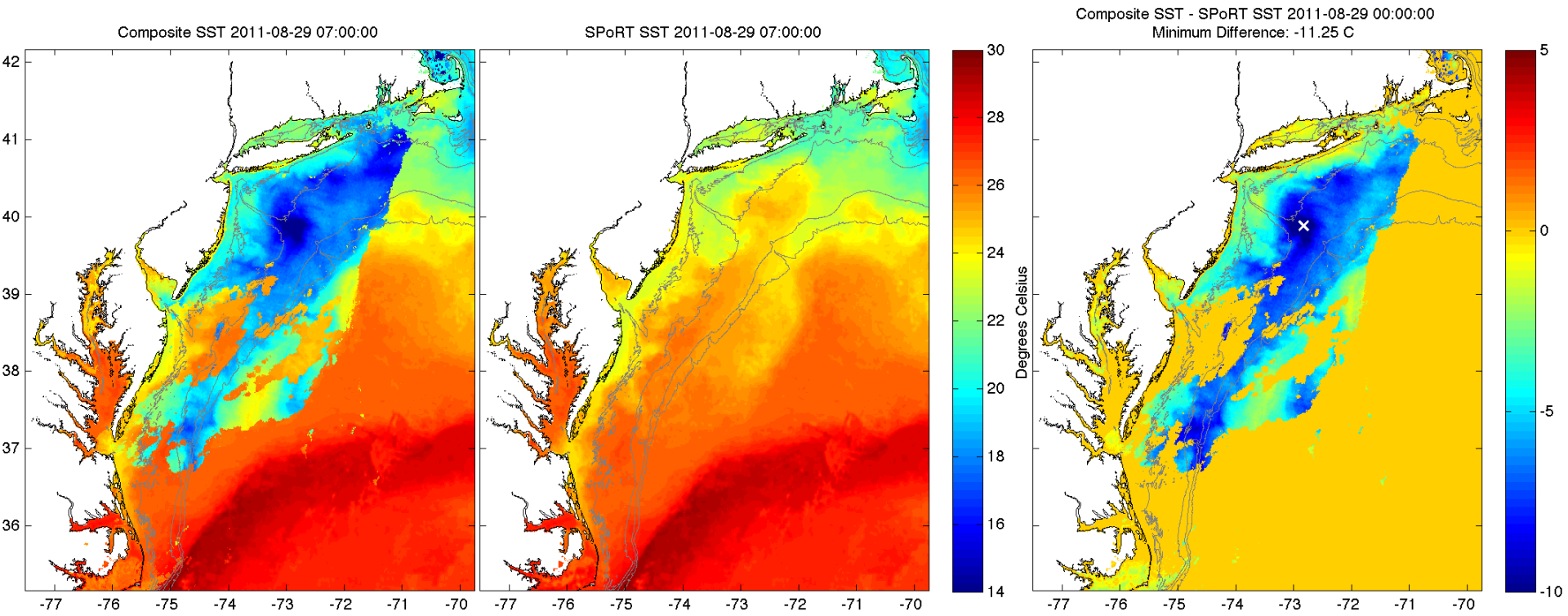
-5
-10


Composite SST 2011-08-29 07:00:00
SPoRT SST 2011-08-29 07:00:00
Composite SST - SPoRT SST 2011-08-29 00:00:00
Minimum Difference: -11.25 C
Degrees Celsius
42
41
40
39
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37
36
-77
-76
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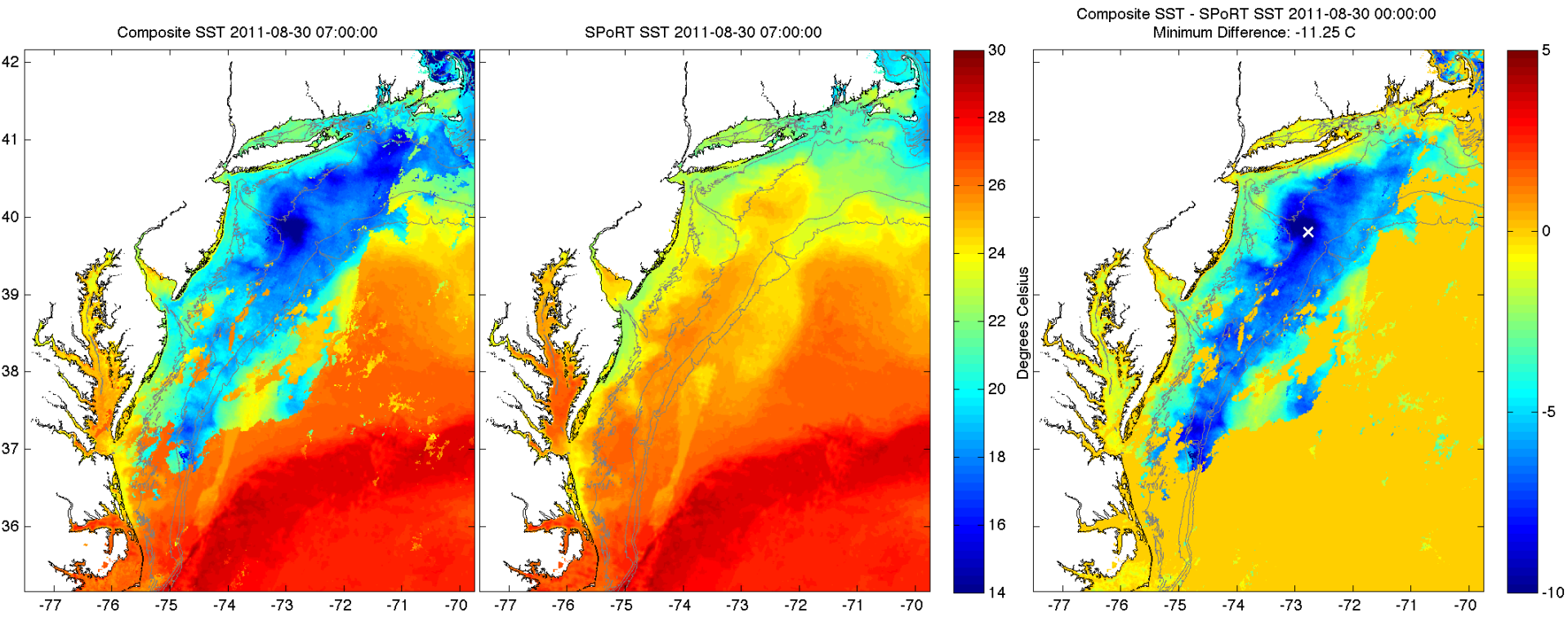
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SPoRT SST 2011-08-30 07:00:00
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Degrees Celsius
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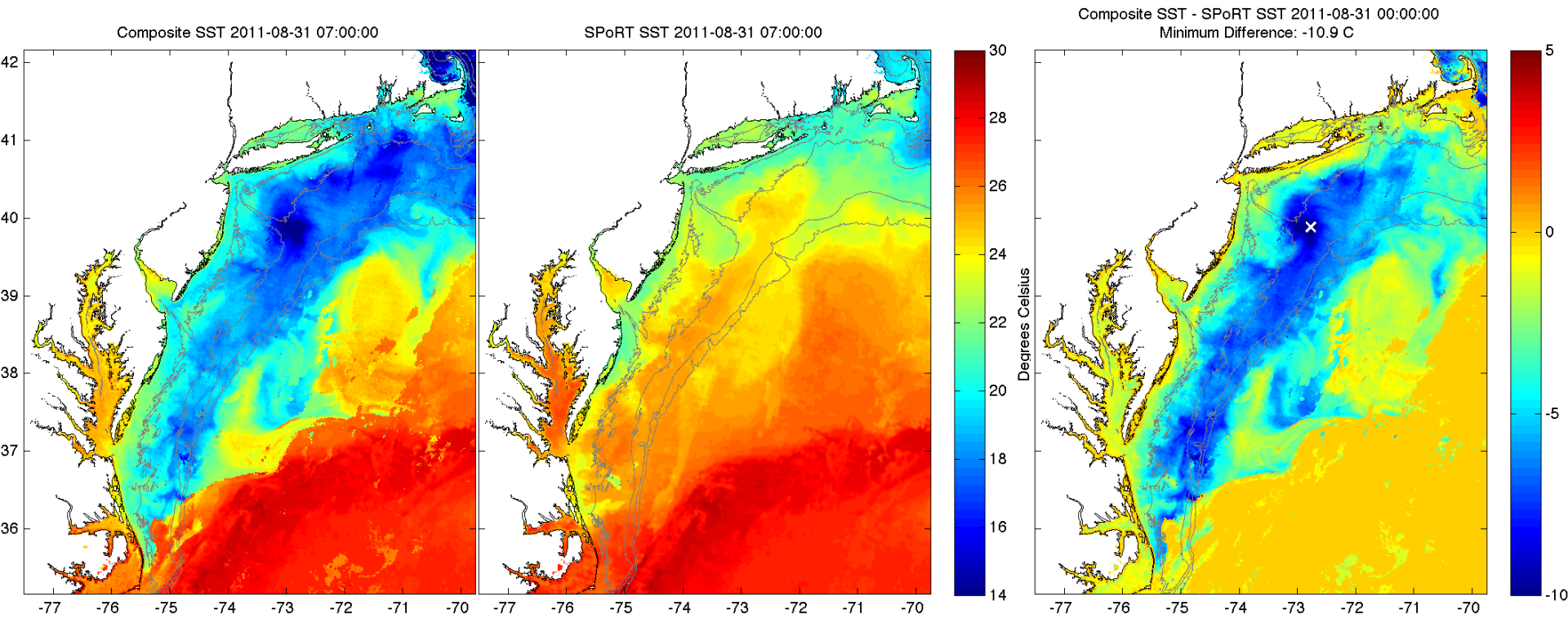
Composite SST 2011-08-31 07:00:00
SPoRT SST 2011-08-31 07:00:00
Composite SST - SPoRT SST 2011-08-31 00:00:00
Minimum Difference: -10.9 C
Degrees Celsius
42
41
40
39
38
37
36
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-72
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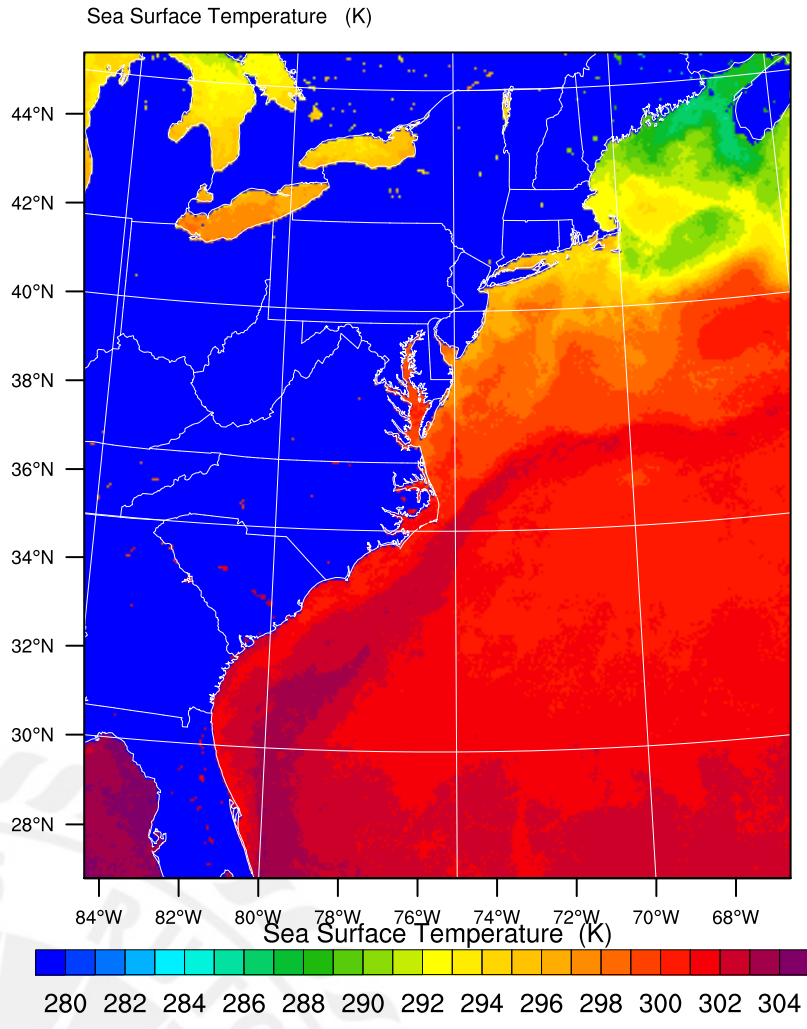
WARM: RTG+SPoRT(8/27) Init: 2011-08-27_00:00:00

27/1200→28/0600



RTG,SPoRT(9/06)+AVHRR(8/31) Init: 2011-08-28_06:00:00

28/0600→29/0600