

**Dawn of ecosystem sampling using autonomous gliders**

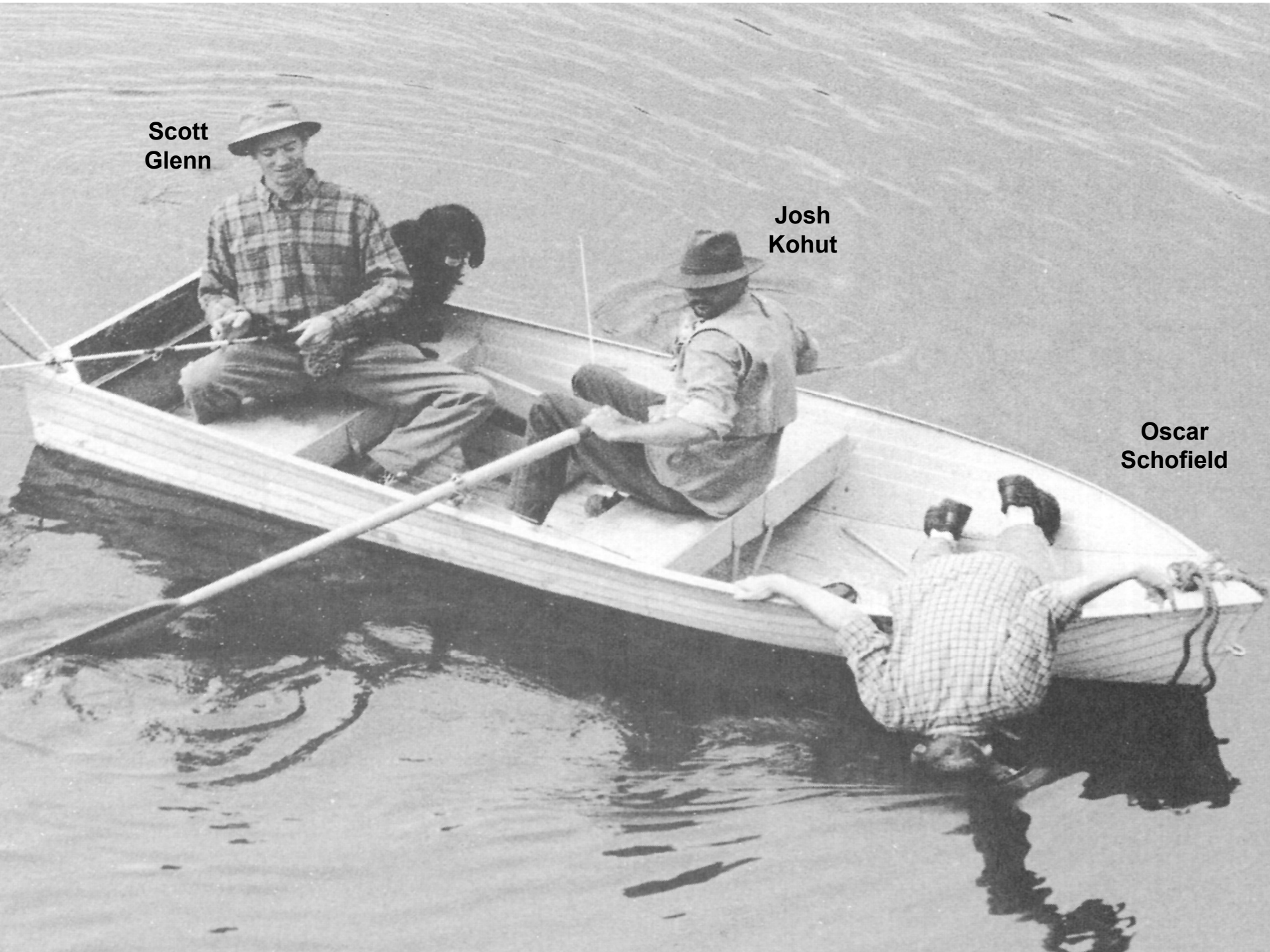
Oscar Schofield on behalf of many



**Scott  
Glenn**

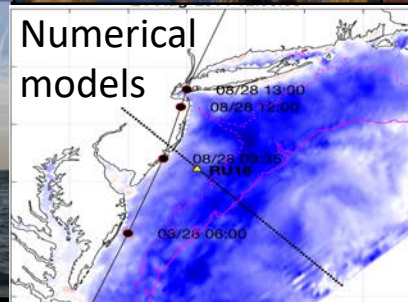
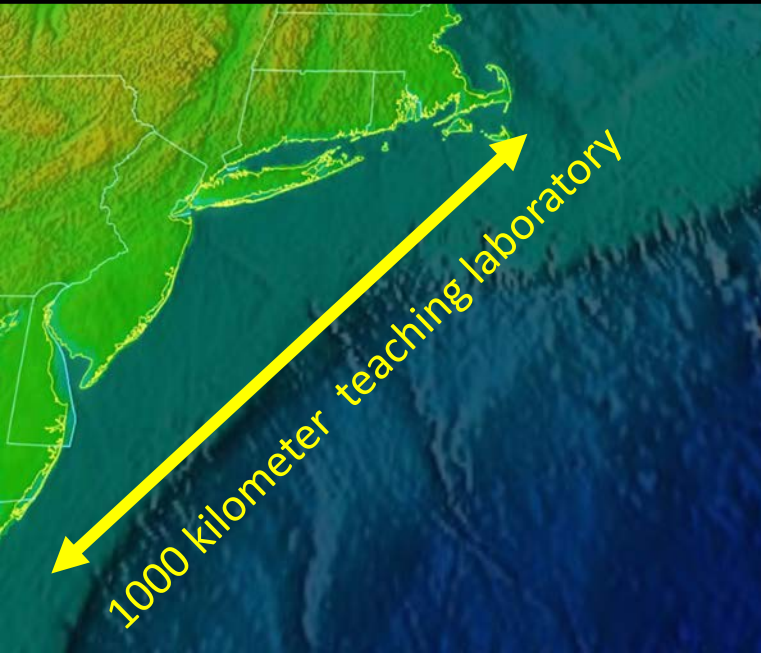
**Josh  
Kohut**

**Oscar  
Schofield**

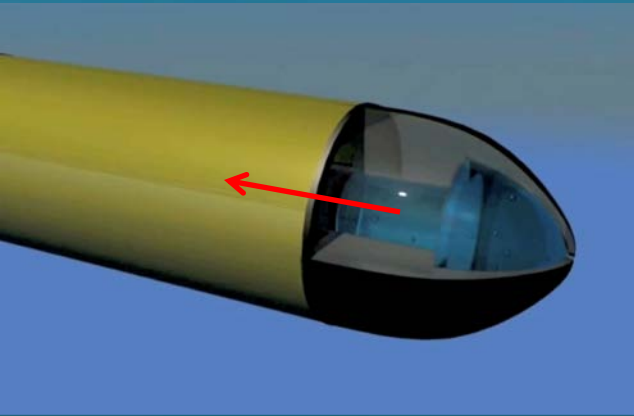


# The Path Forward: 24:7 365 4-D sampling of the system, make the ocean your lab

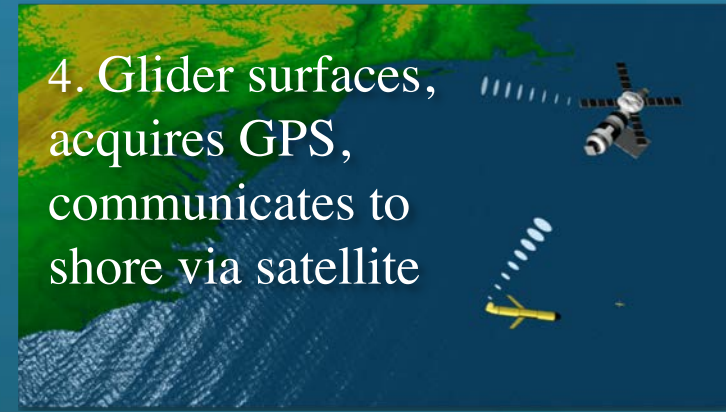
Rutgers University's Coastal Ocean Observation Lab (RU COOL)



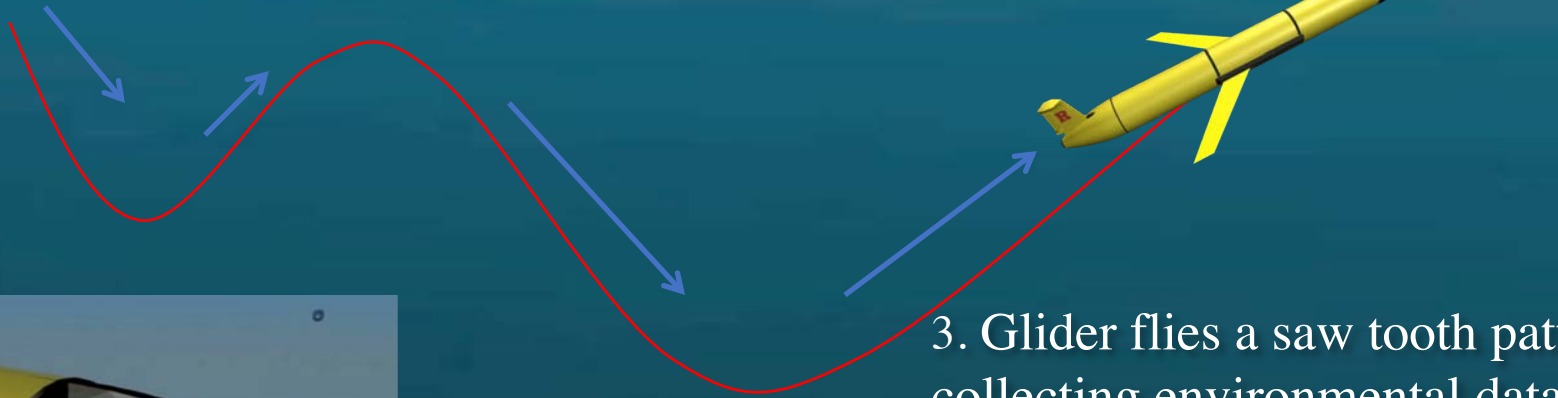
# How an underwater Glider works...



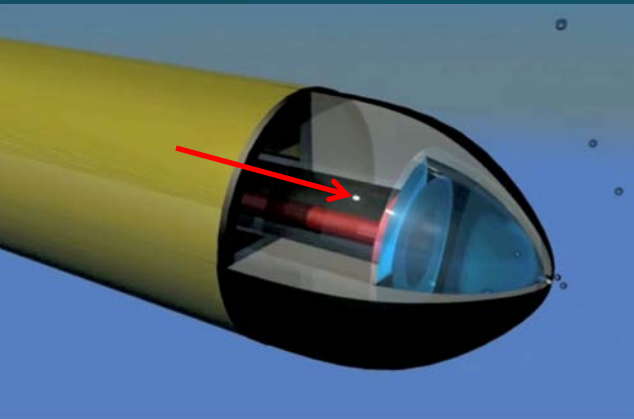
1. At surface, pump/diaphragm decreases volume, Glider descends



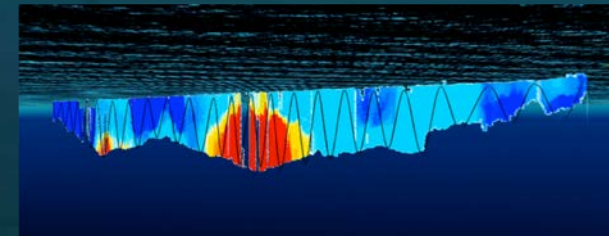
4. Glider surfaces, acquires GPS, communicates to shore via satellite



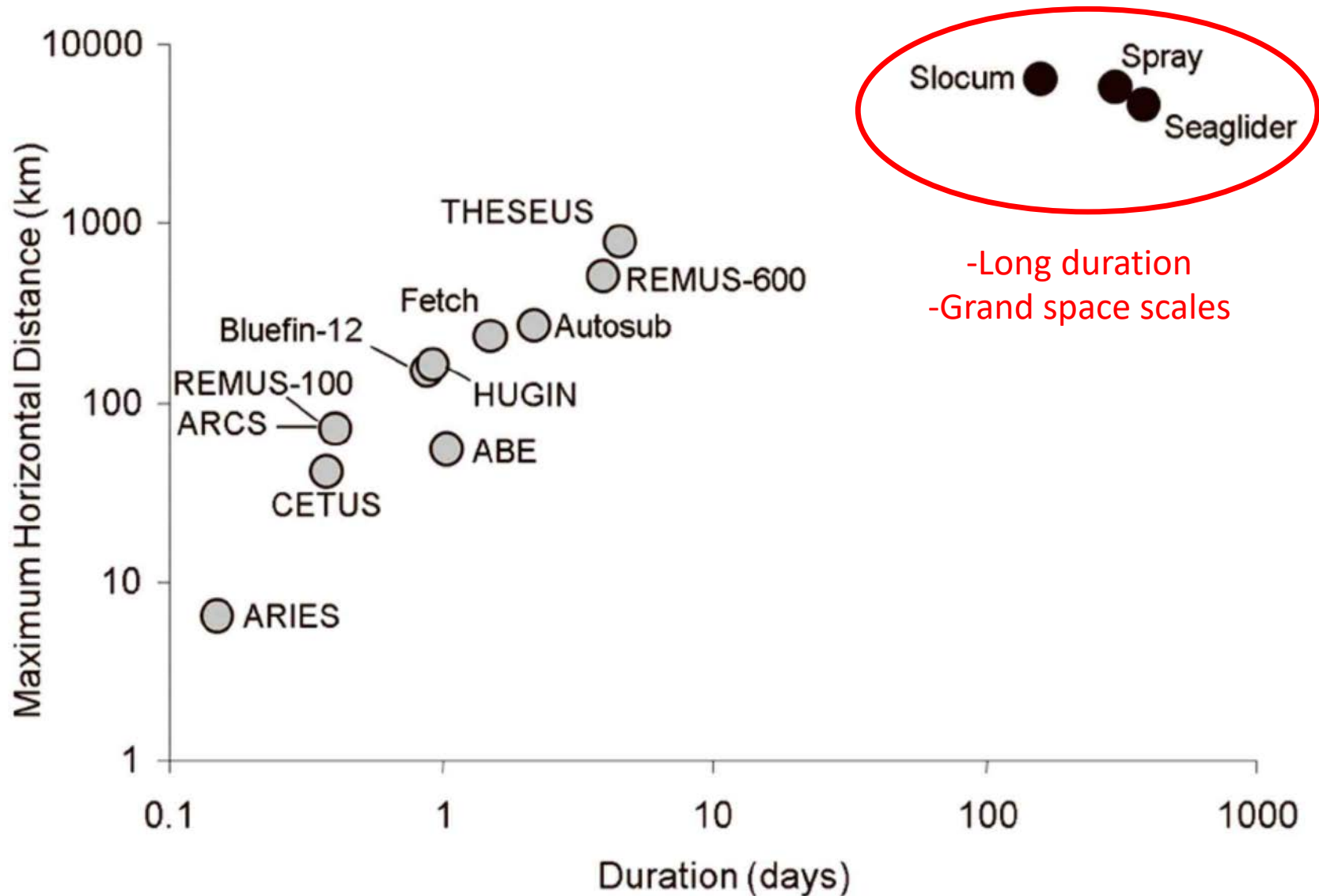
3. Glider flies a saw tooth pattern, collecting environmental data along it's path



2. At depth pump/diaphragm increases volume, Glider ascends

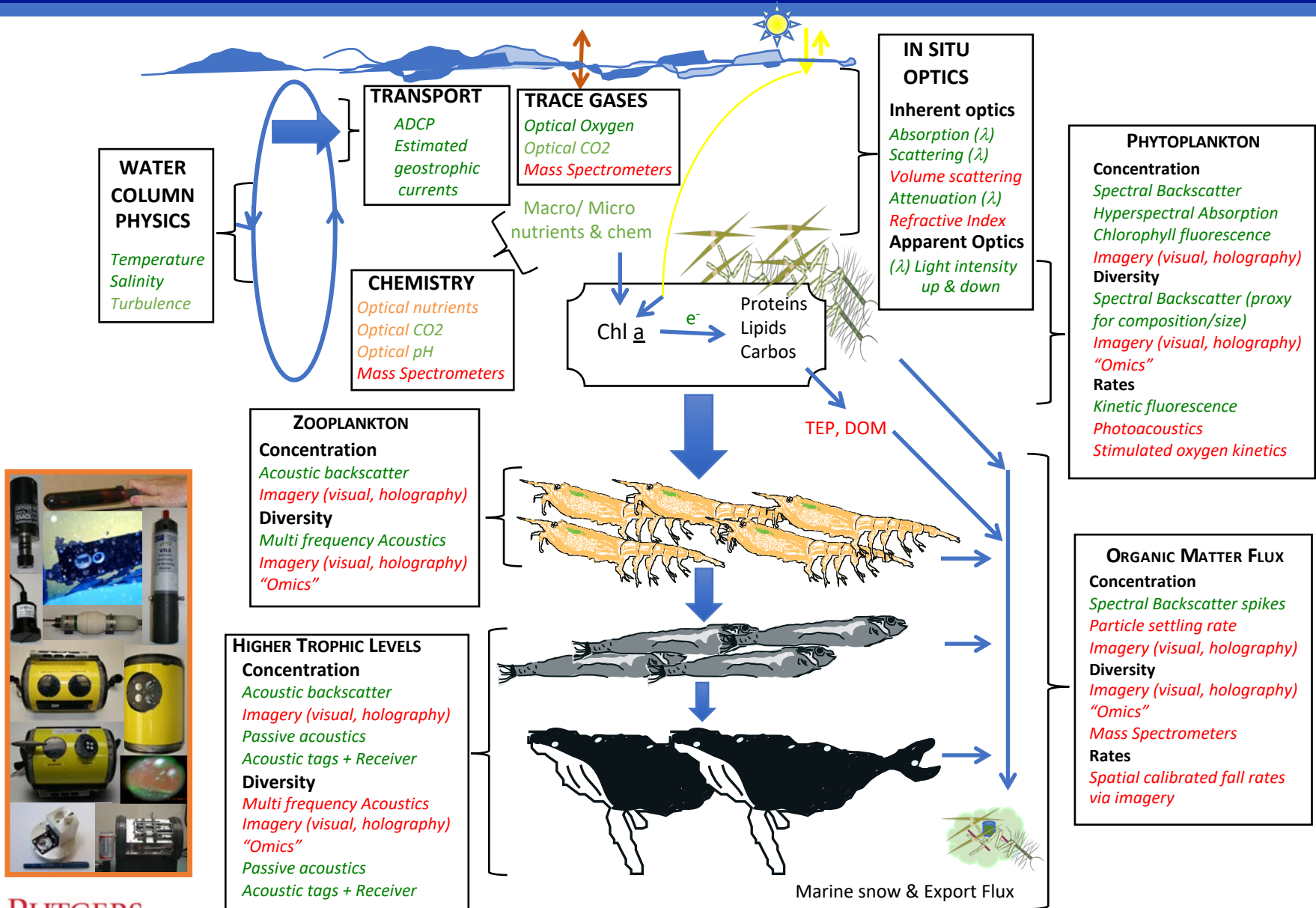


# Glider's are "steerable" underwater vehicle with real-time communications that can cover great distances over long periods

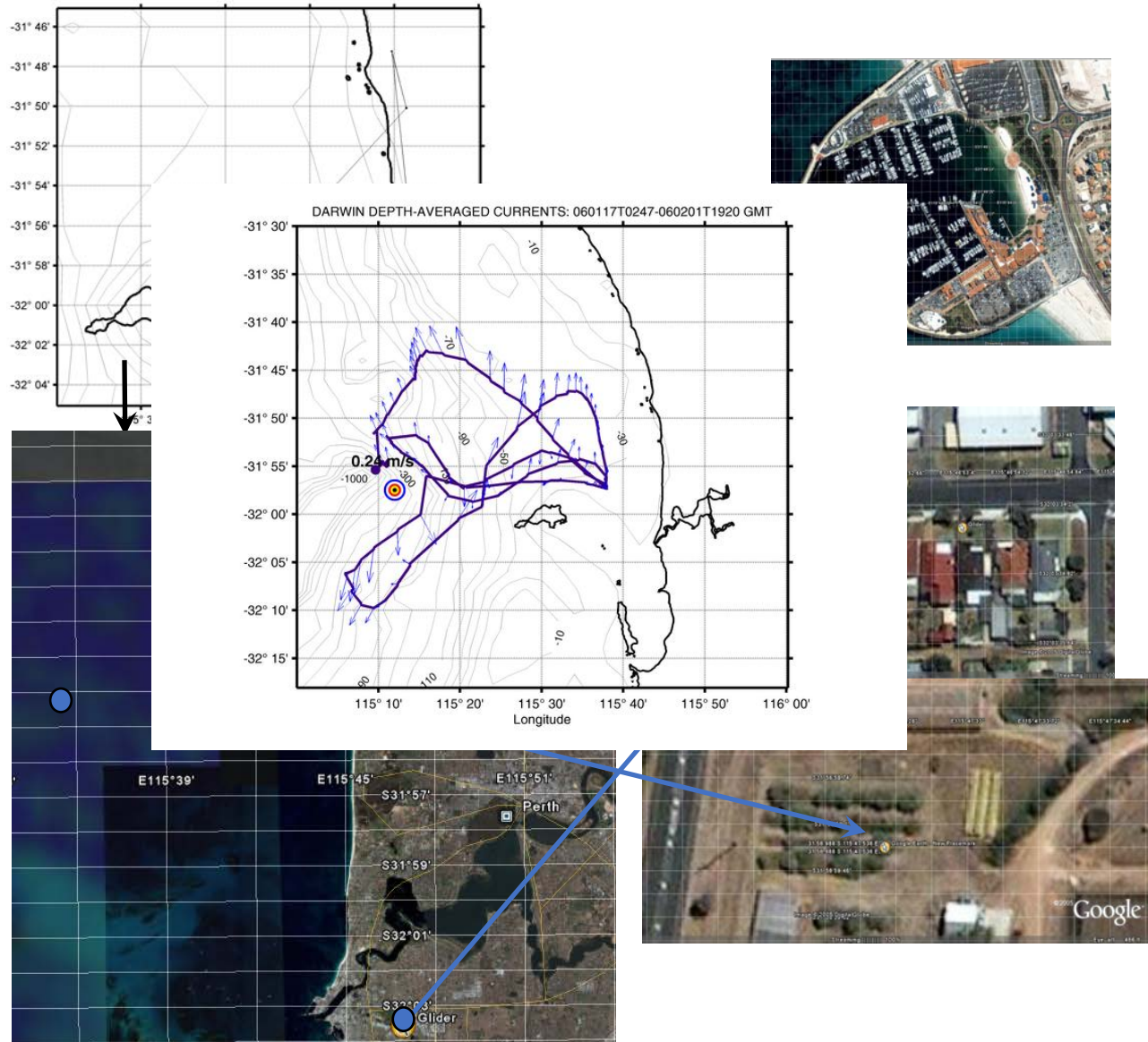


-Long duration  
-Grand space scales

# What can science data can be collected by gliders?



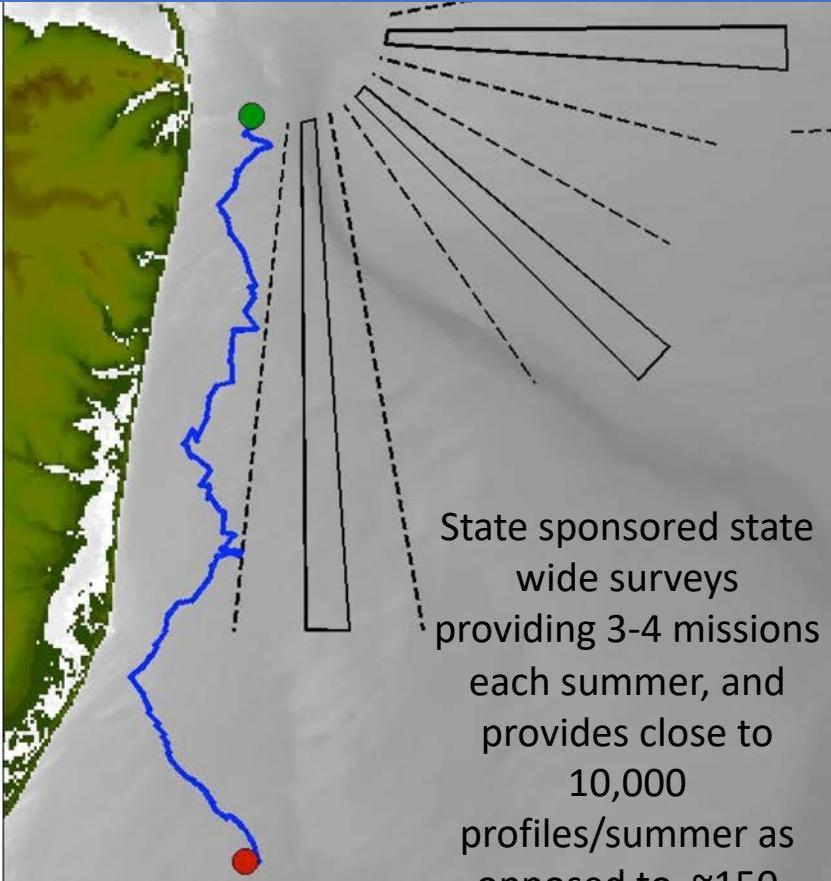
# Darwin's Odyssey



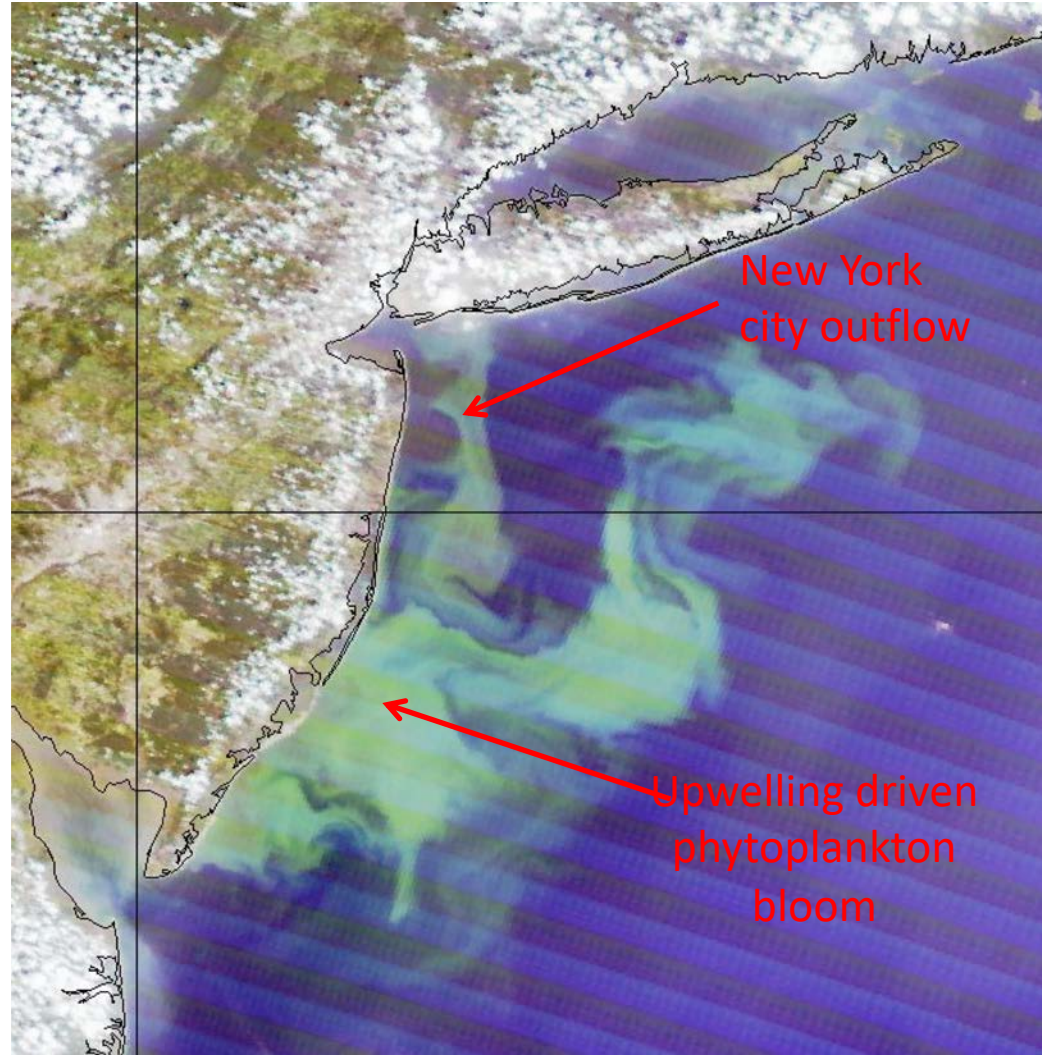
# Ability to link phytoplankton to watercolumn biogeochemistry



State of New Jersey is now using gliders to map summer water quality. Is low bottom water oxygen due to outflows from the New York city or is a naturally driven by natural dynamics.

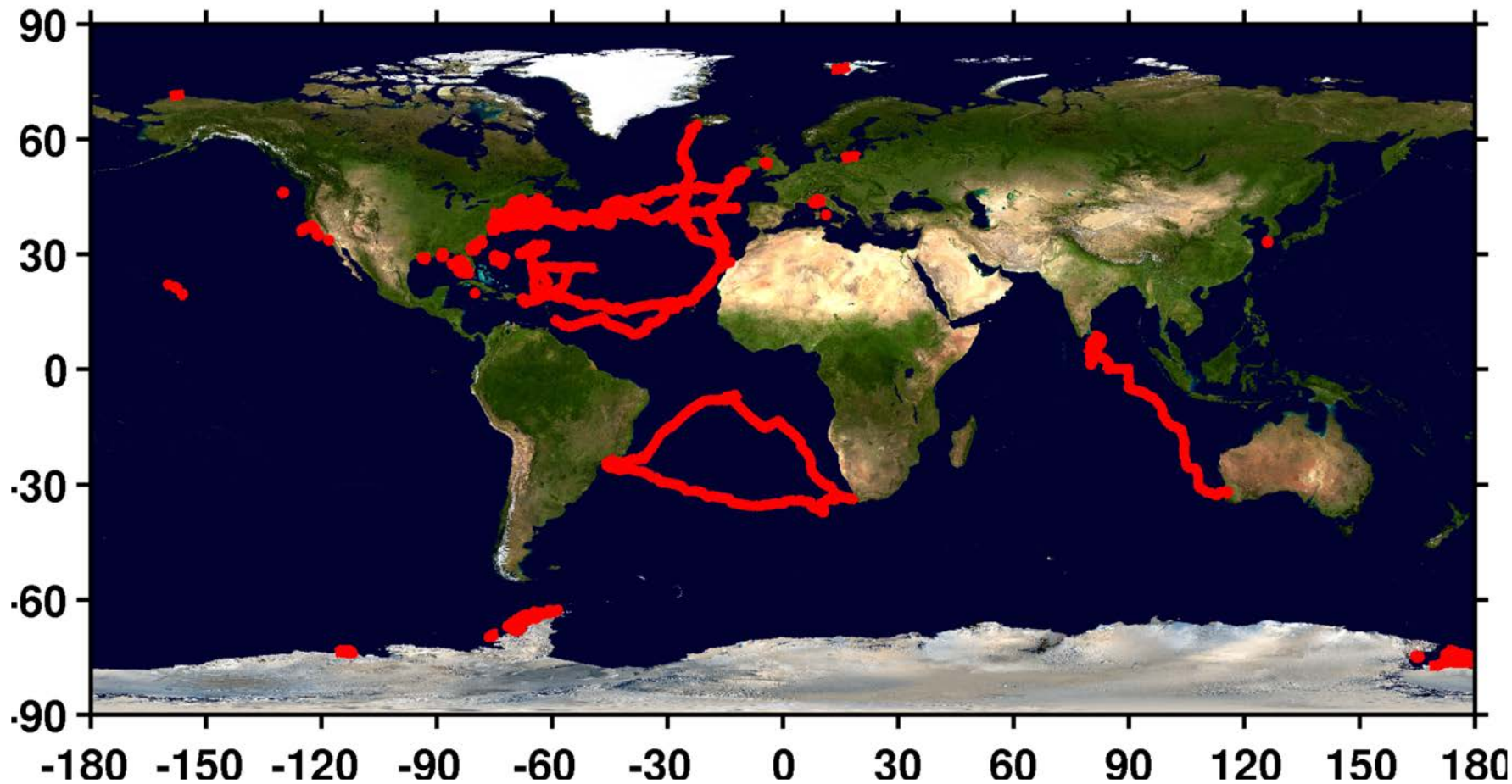


State sponsored state wide surveys providing 3-4 missions each summer, and provides close to 10,000 profiles/summer as opposed to ~150 profiles/summer by ship/





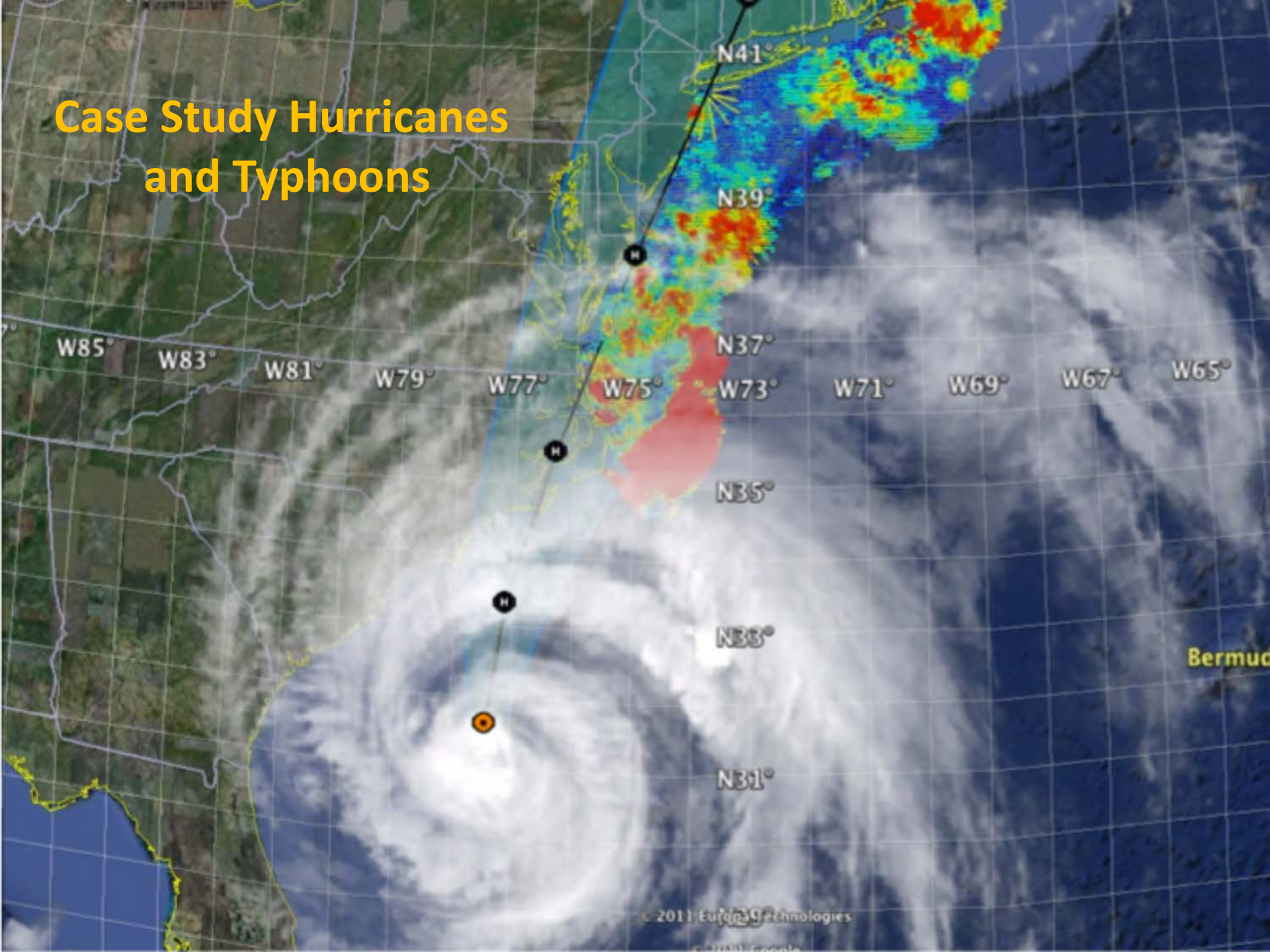
504 deployments - 250691.69km flown - 13414 days



Since 2003

Represents 36 years at sea  
6 times around the planet

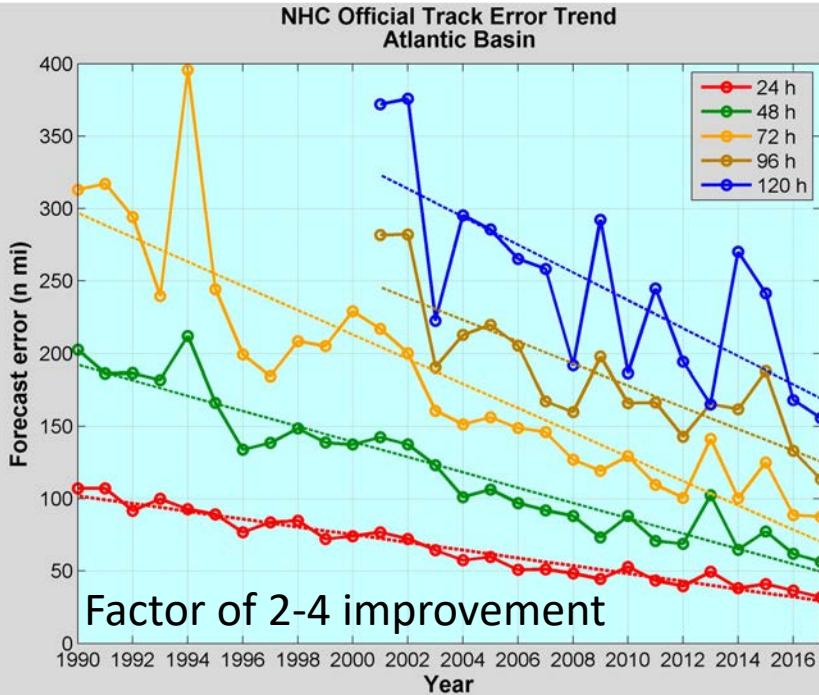
# Case Study Hurricanes and Typhoons



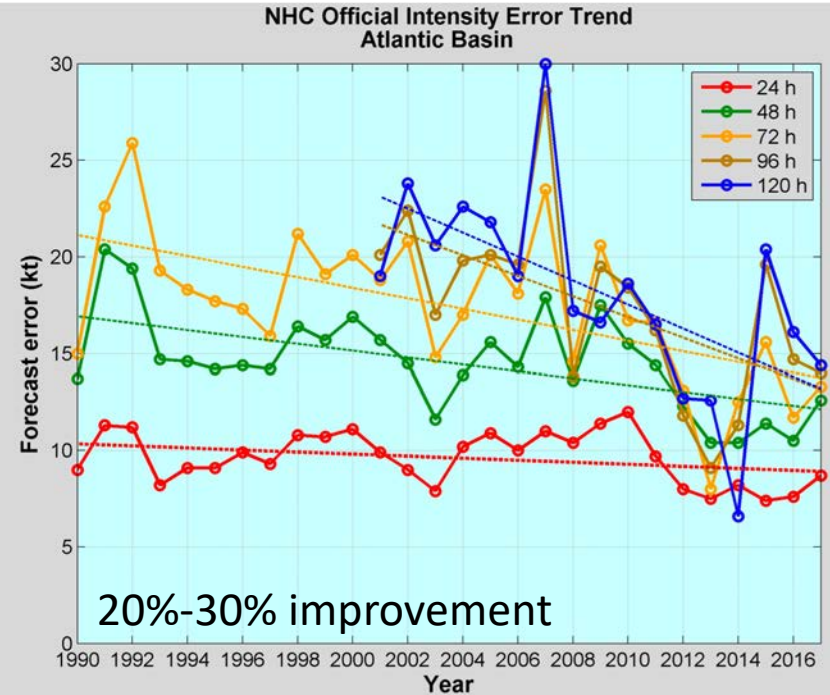


# NOAA Annual Operational Suite Review

## Average Track Errors: Atlantic Basin



## Average Intensity Errors: Atlantic Basin



**Evacuate vs Shelter-In-Place** decisions are often made 3-5 days ahead based on the forecast intensity at landfall

*Close the gap from both sides: forecasting and response*

# Tropical Cyclone Heat Potential - Rapid Intensification Proxy

But published research shows ...

Irene & Sandy \$87 B

Glenn et al., 2016 Nature Comms

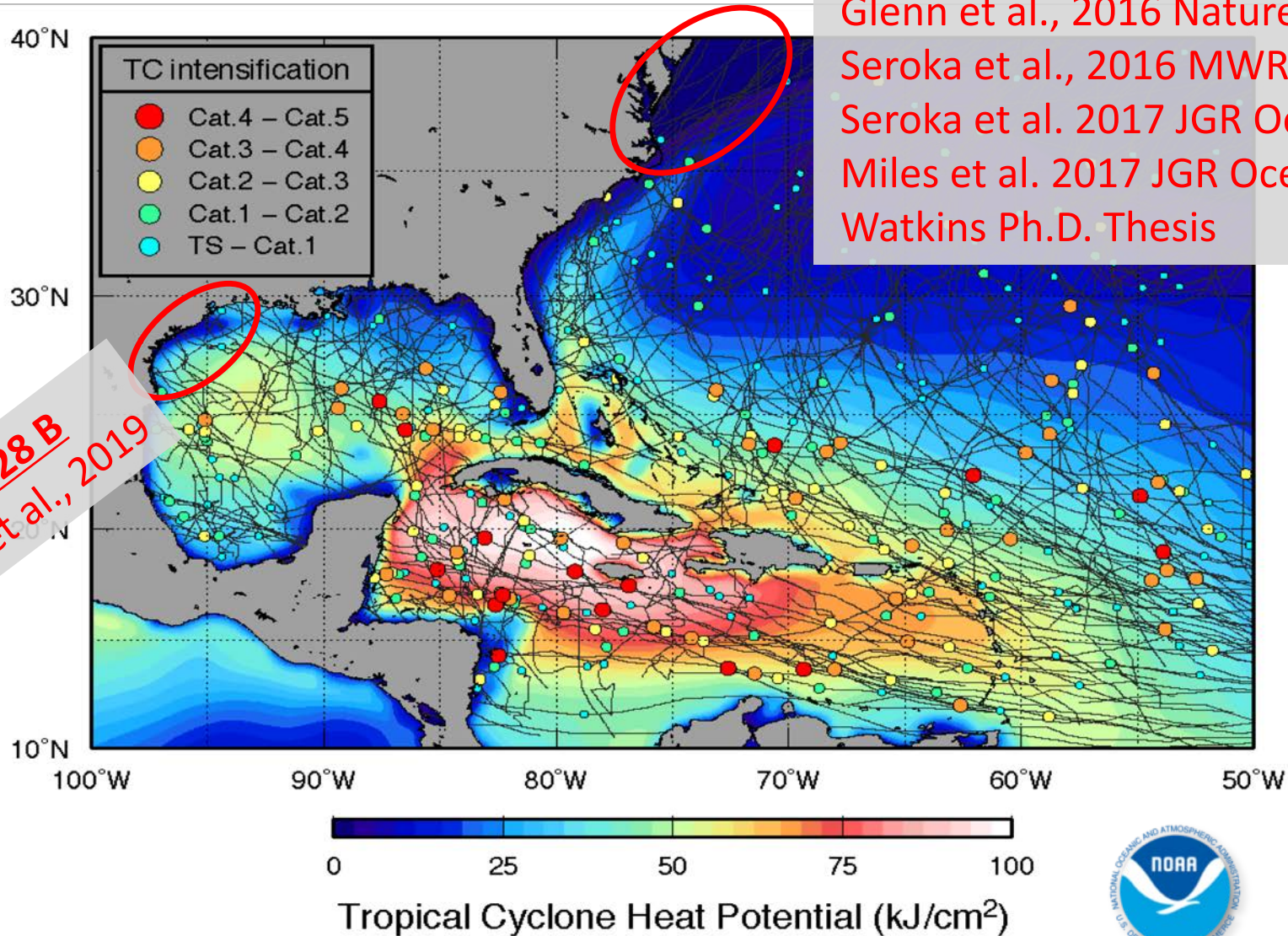
Seroka et al., 2016 MWR

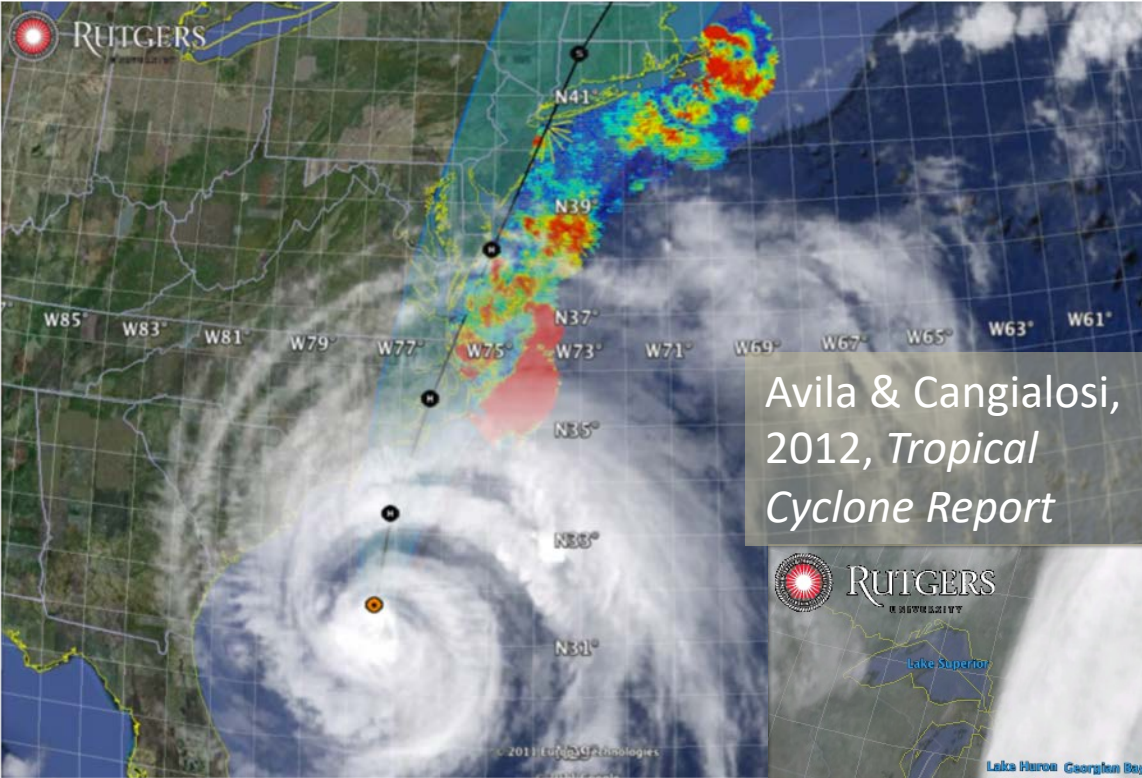
Seroka et al. 2017 JGR Oceans

Miles et al. 2017 JGR Oceans

Watkins Ph.D. Thesis

Harvey \$128 B  
Potter et al., 2019





**Hurricane Irene**  
August 28, 2011

NOAA/NHC Damage:  
>\$15 Billion, #15.

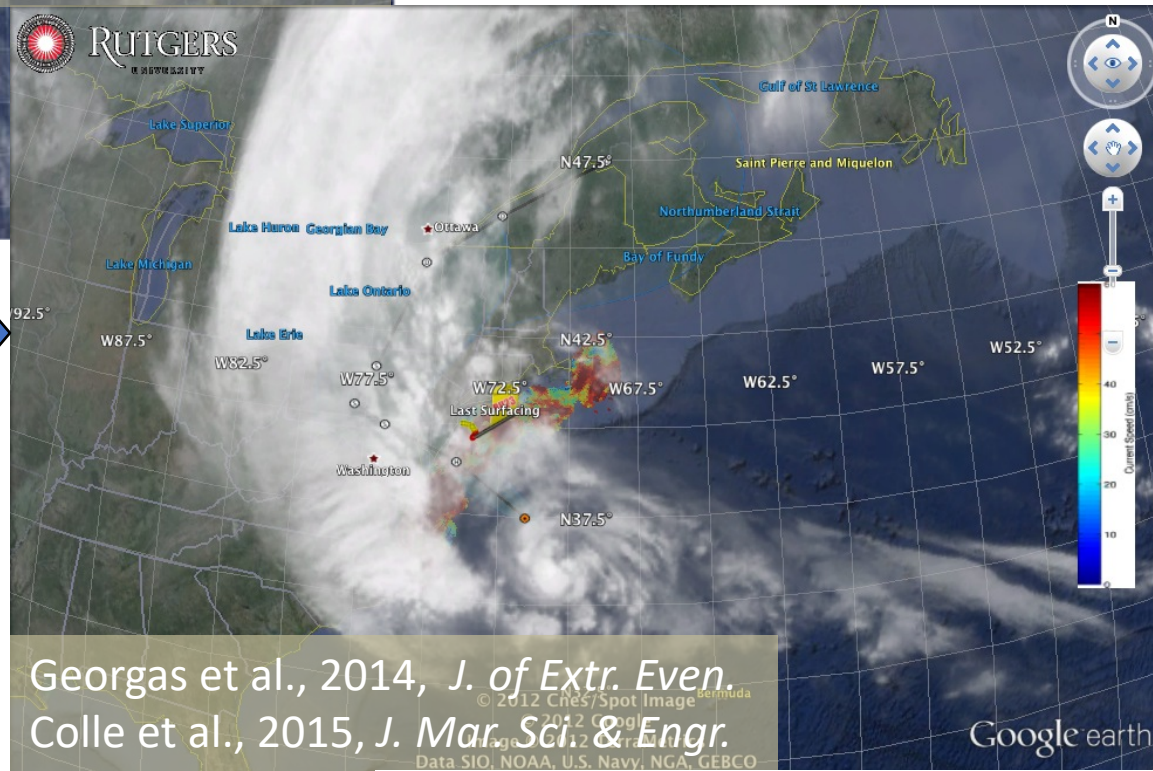
Track Accurate;  
Intensity Over-predicted.

Avila & Cangialosi,  
2012, *Tropical  
Cyclone Report*

**Hurricane Sandy**  
October 29, 2012

NOAA/NHC Damage:  
>\$72 Billion, #4.

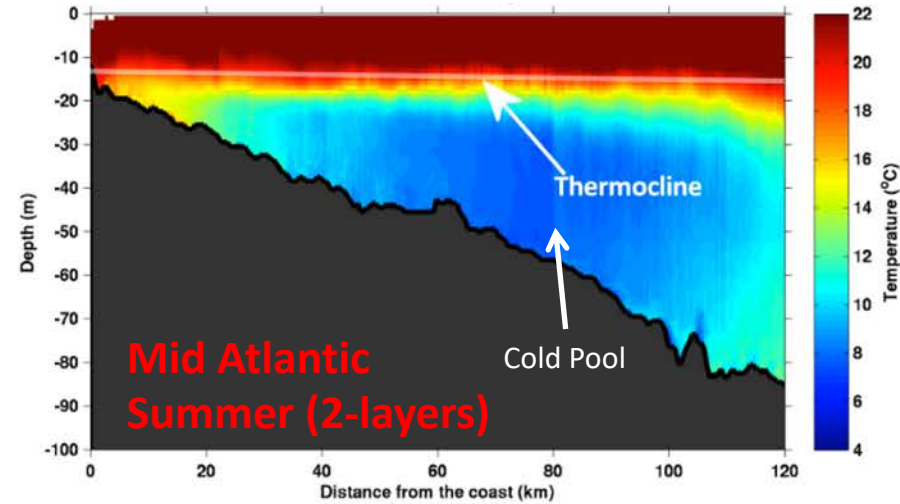
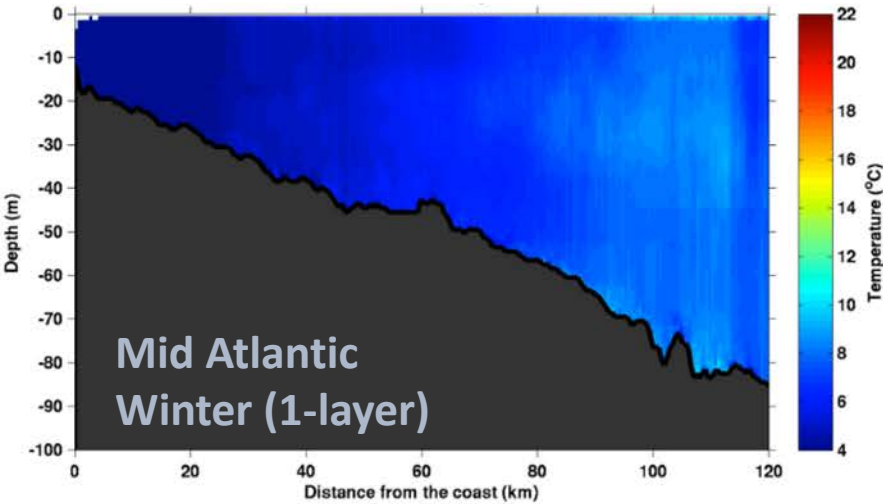
Track Accurate;  
Impacts Under-predicted.



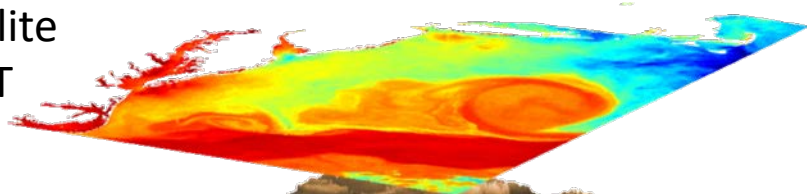
Georgas et al., 2014, *J. of Extr. Even.*  
Colle et al., 2015, *J. Mar. Sci. & Engr.*

# Essential Ocean Feature - Mid-Atlantic's Cold Pool

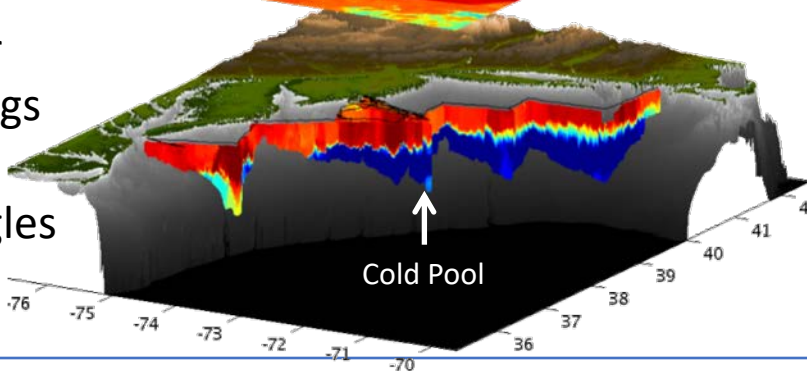
A continental shelf-wide cold bottom layer beneath a warm summer surface layer



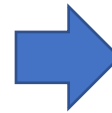
Satellite  
SST



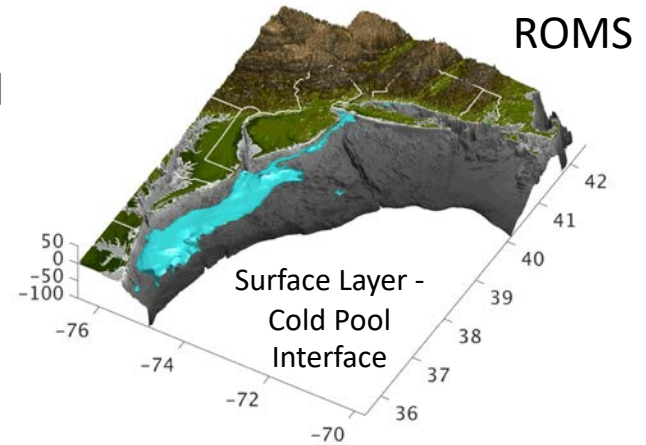
Glider  
Zig-Zags  
or  
Triangles



Assimilated  
into Regional  
Ocean  
Models



12° C on May 15, 2017



**The Cold Pool is not monitored from space – we use Gliders, HF Radar, and Models**

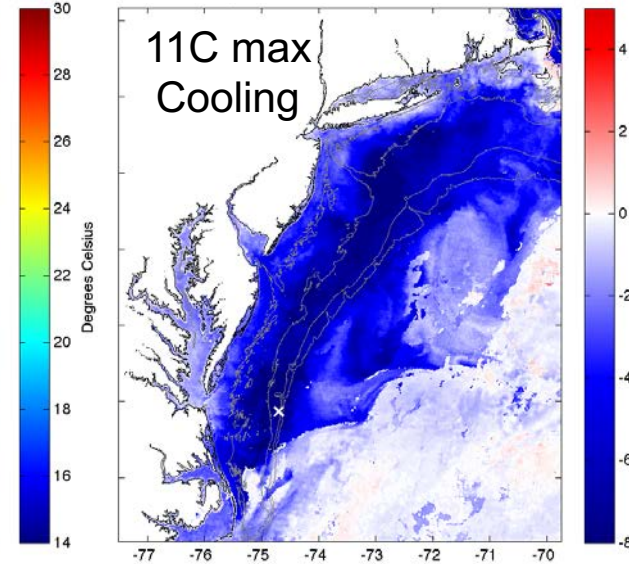
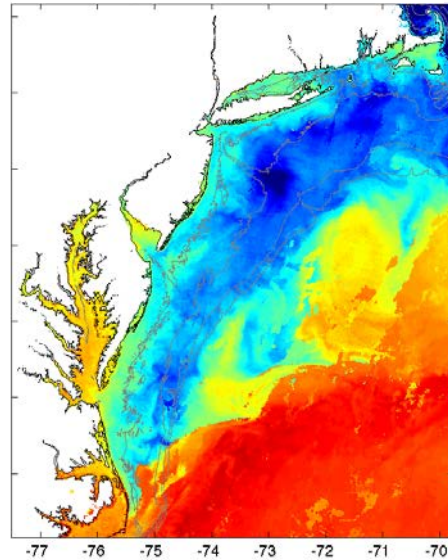
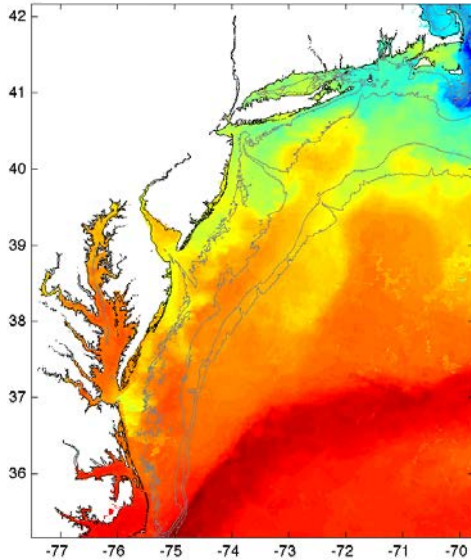
Pre-Irene

Post-Irene

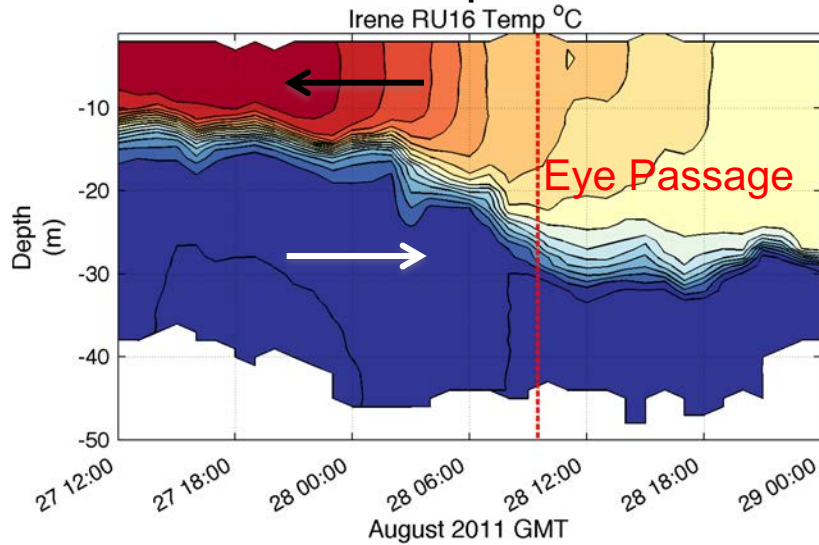
Difference

WHAT?

Satellite  
SST



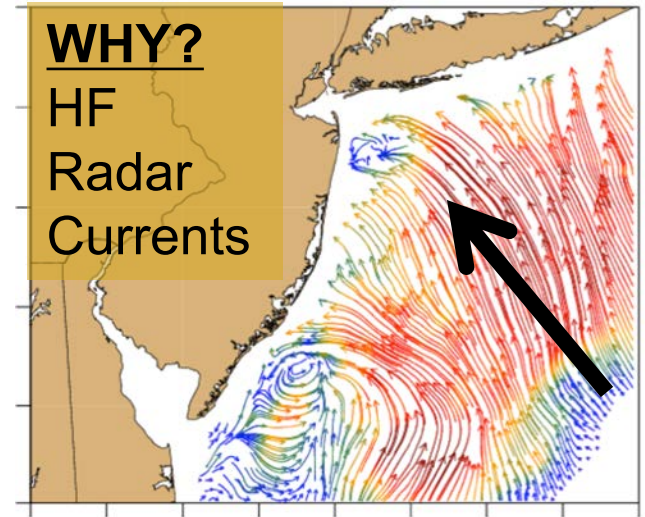
WHEN? Glider Temperature



Surface Current Field: 2011-Aug-28 06:00 GMT

WHY?

HF  
Radar  
Currents

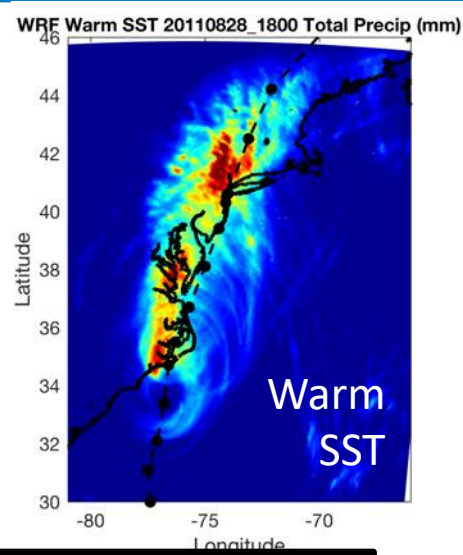
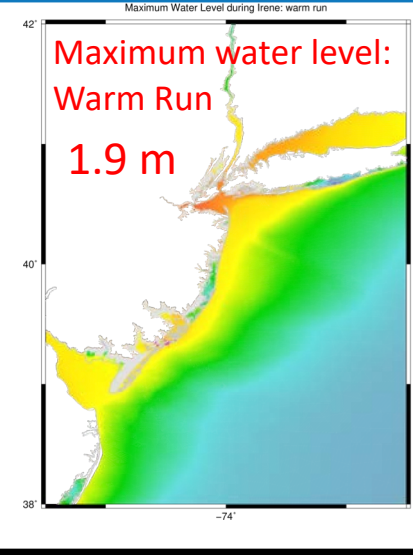
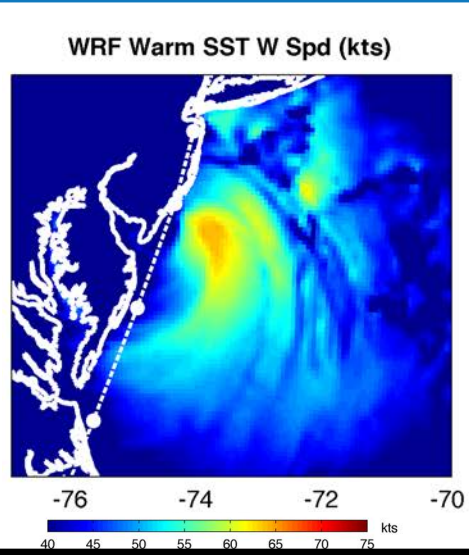
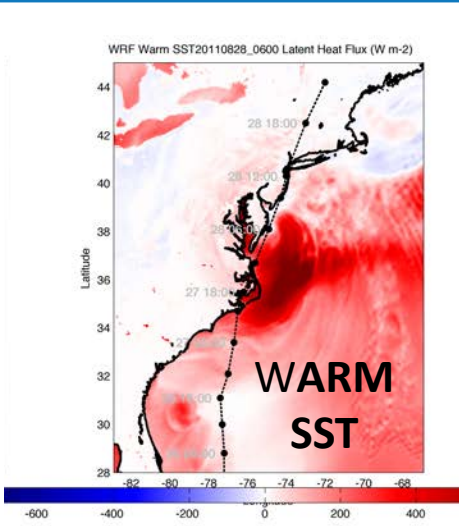


Glenn et al., Nature Comms, 2016

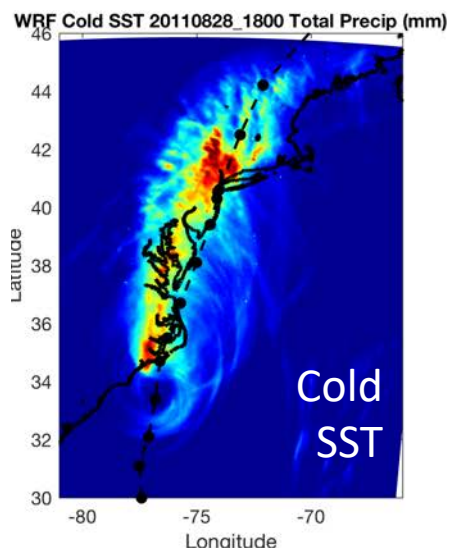
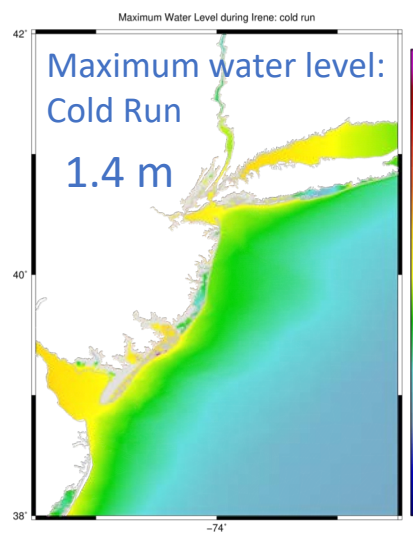
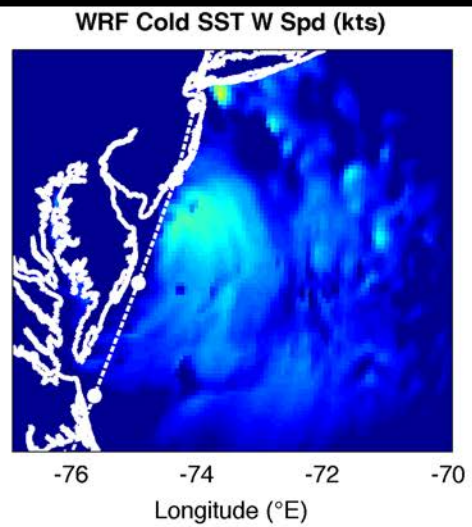
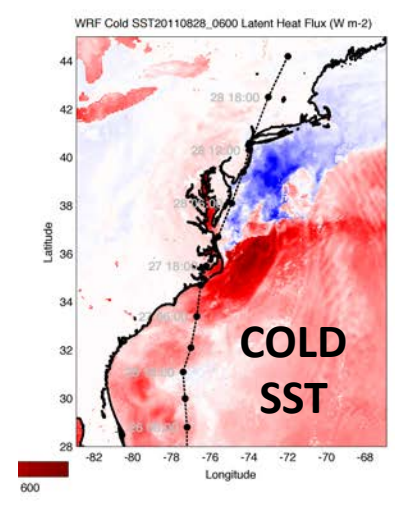
**Essential Ocean Processes in Hurricane Irene:**

**Ahead of eye center – Vertical Shear > Mixing > Cooling > Weakening**

# Irene - Impacts of Warm (top row) vs Cold (bottom row) SST



**Surface Heat Flux      Wind Speed      Storm Surge      Total Rainfall**



Sign Change as observed

10 knot reduction to observed

0.5 m reduction to observed

35 mm reduction to observed

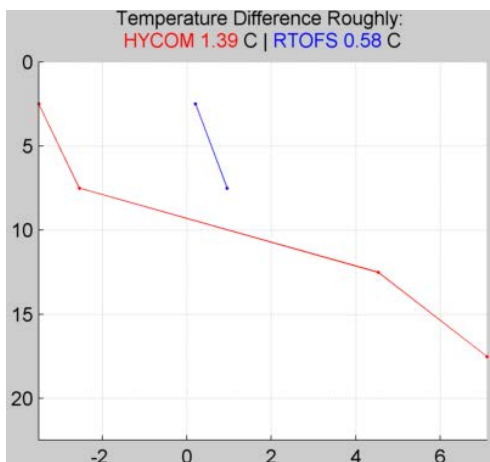
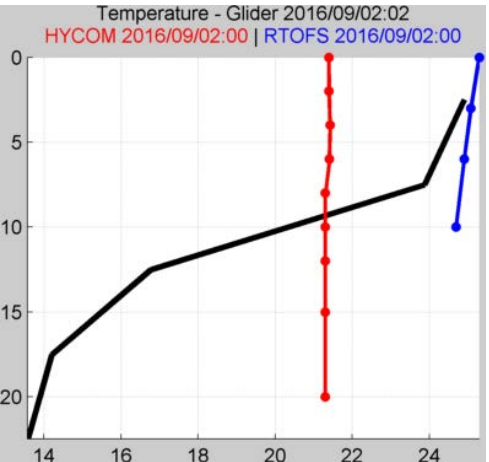
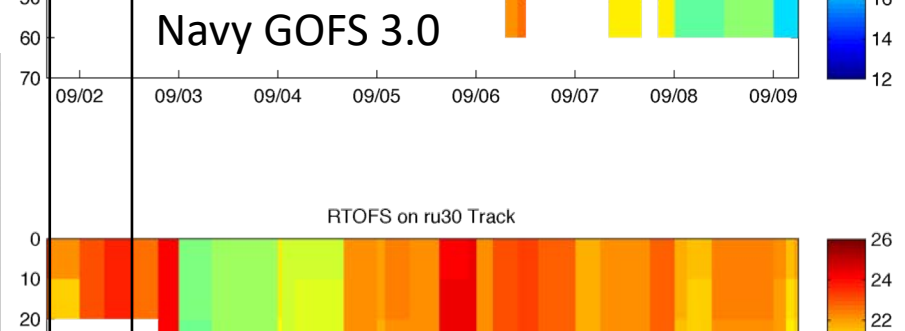
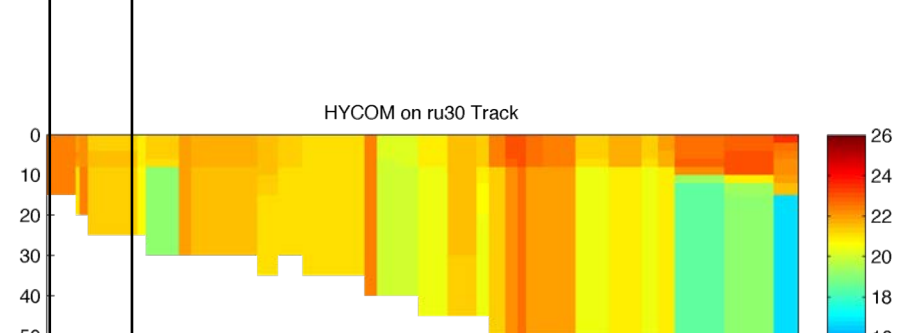
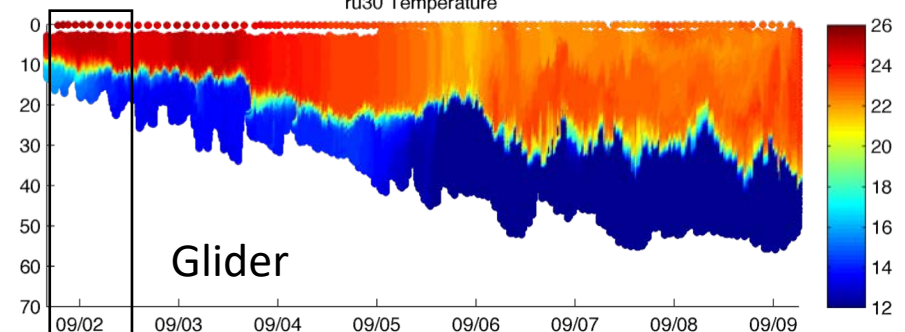
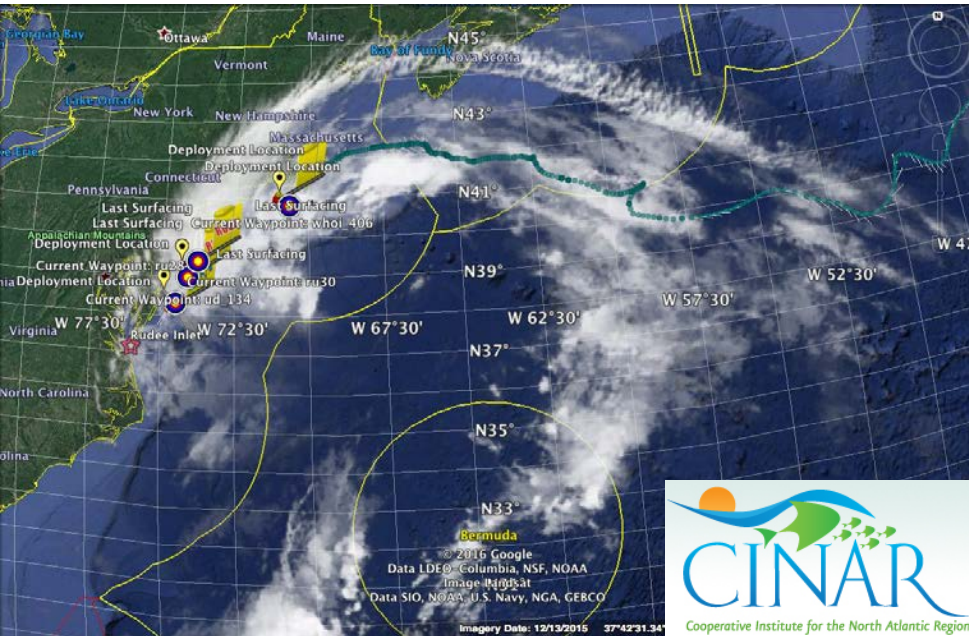




**One year later...**  
**Superstorm Sandy**  
*October 2012*



# Hurricane Hermine Response: CINAR/MARACOOS Glider Fleet Launched, 9/2016



GOFS 3.0 = Navy's operational Global Ocean Forecast System  
 RTOFS = NOAA's operational global Real Time Ocean Forecast System



# 2018 FIFA WORLD CUP RUSSIA™

14 JUNE - 15 JULY

FIFA WORLD CUP  
RUSSIA 2018

MATCHES

TEAMS

GROUPS

PLAYERS

STATISTICS

DESTINATION

FAN ZONE

AWARDS

TICKETING

CLASSIC



## HURRICANE HUNTERS

Since  
1946

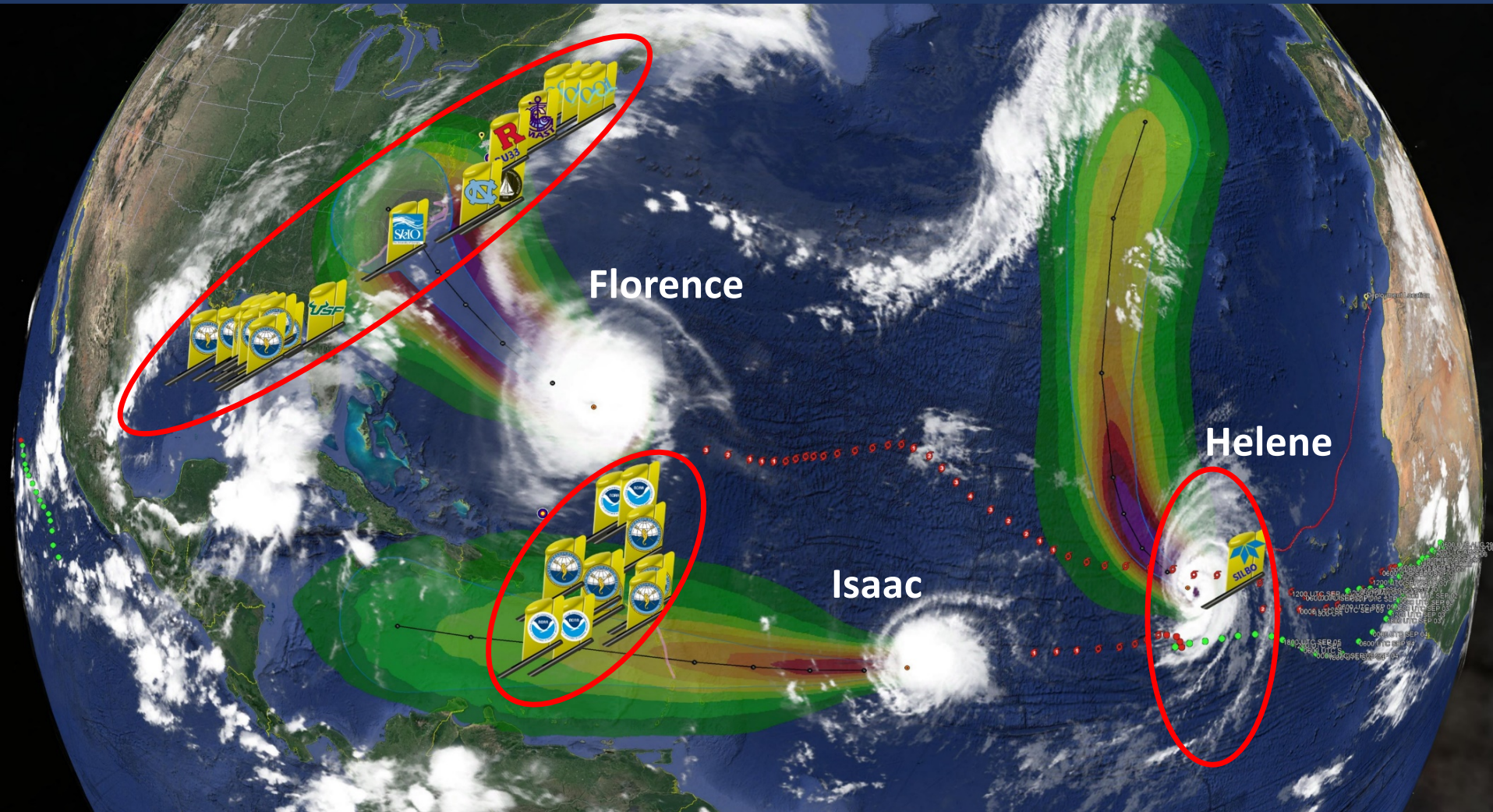


## HURRICANE GLIDERS

Starting  
2018

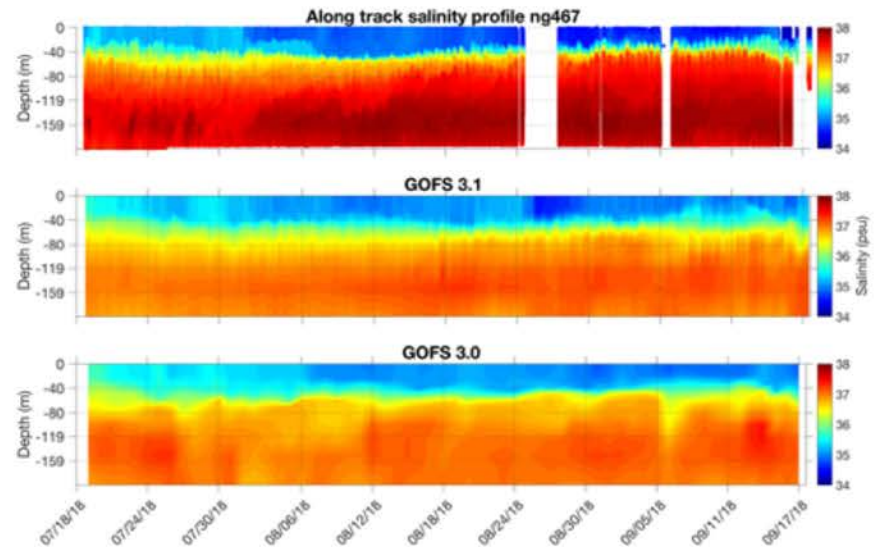
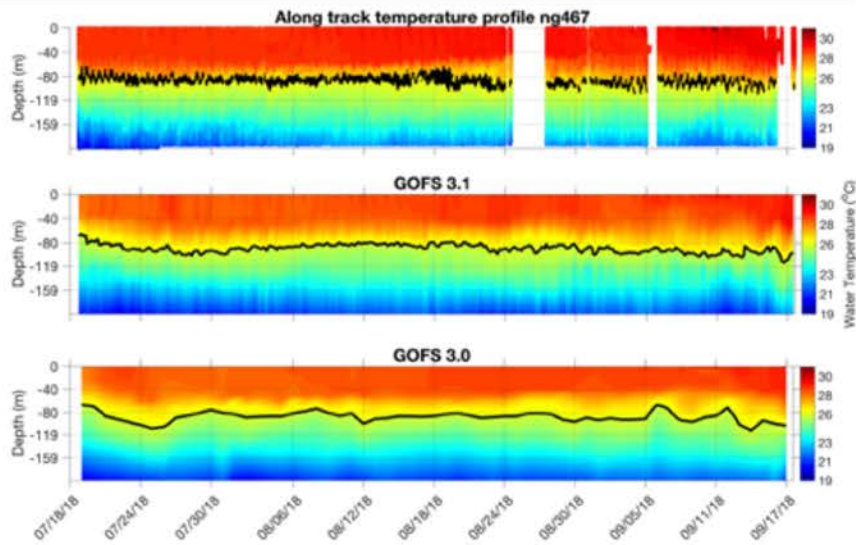
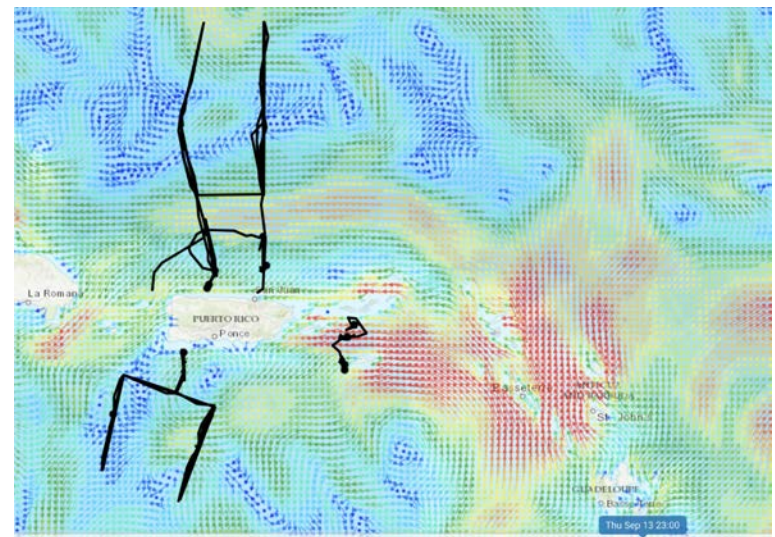
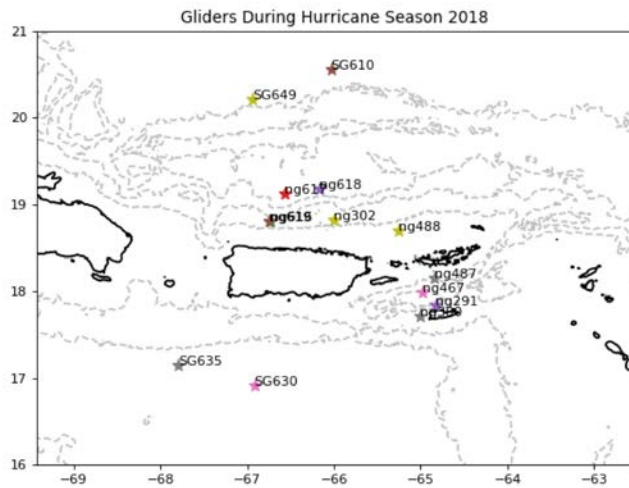


# 2018 Community Gliders deployed in 3 Picket Lines

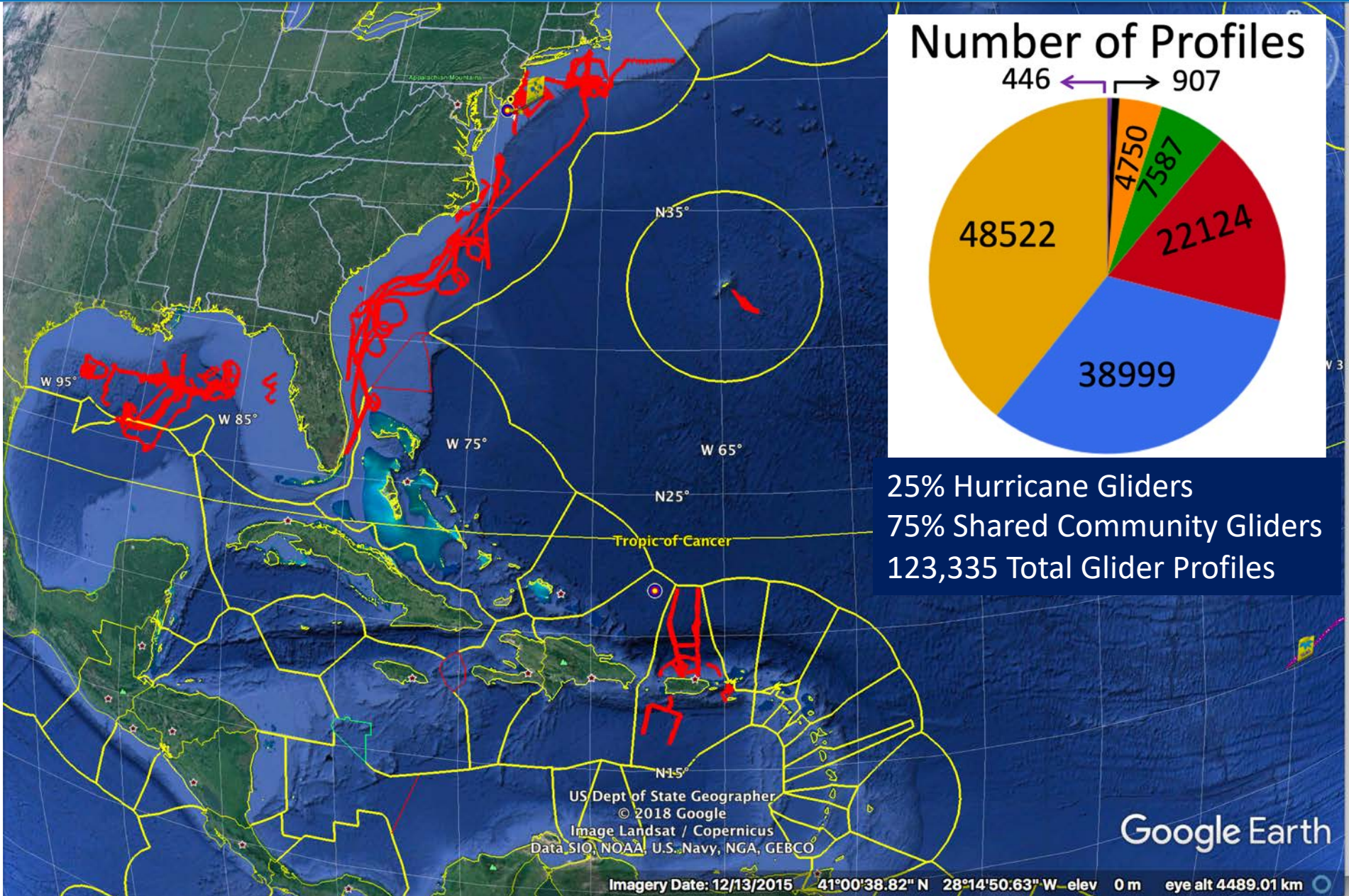


>30 Hurricane Sentinel Gliders from the Navy, NOAA, NSF, Academic & Industry Partners reporting ocean conditions through the U.S. IOOS Glider Data Assembly Center (DAC) ahead of Hurricanes Florence, Isaac and Helene on September 11, 2018.

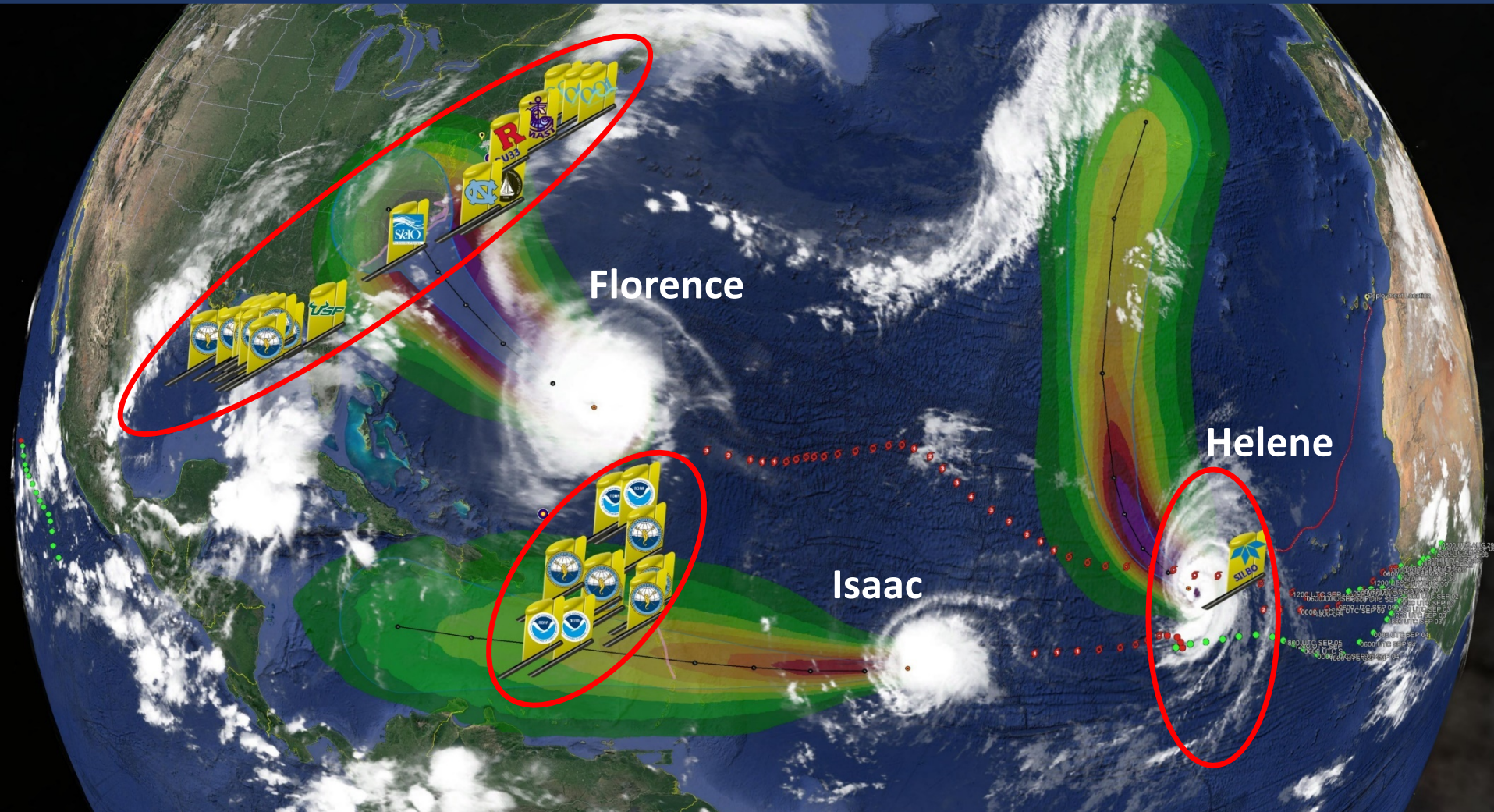
# Caribbean – NG467



# 2018 Hurricane Season – 62 Gliders in IOOS Glider DAC

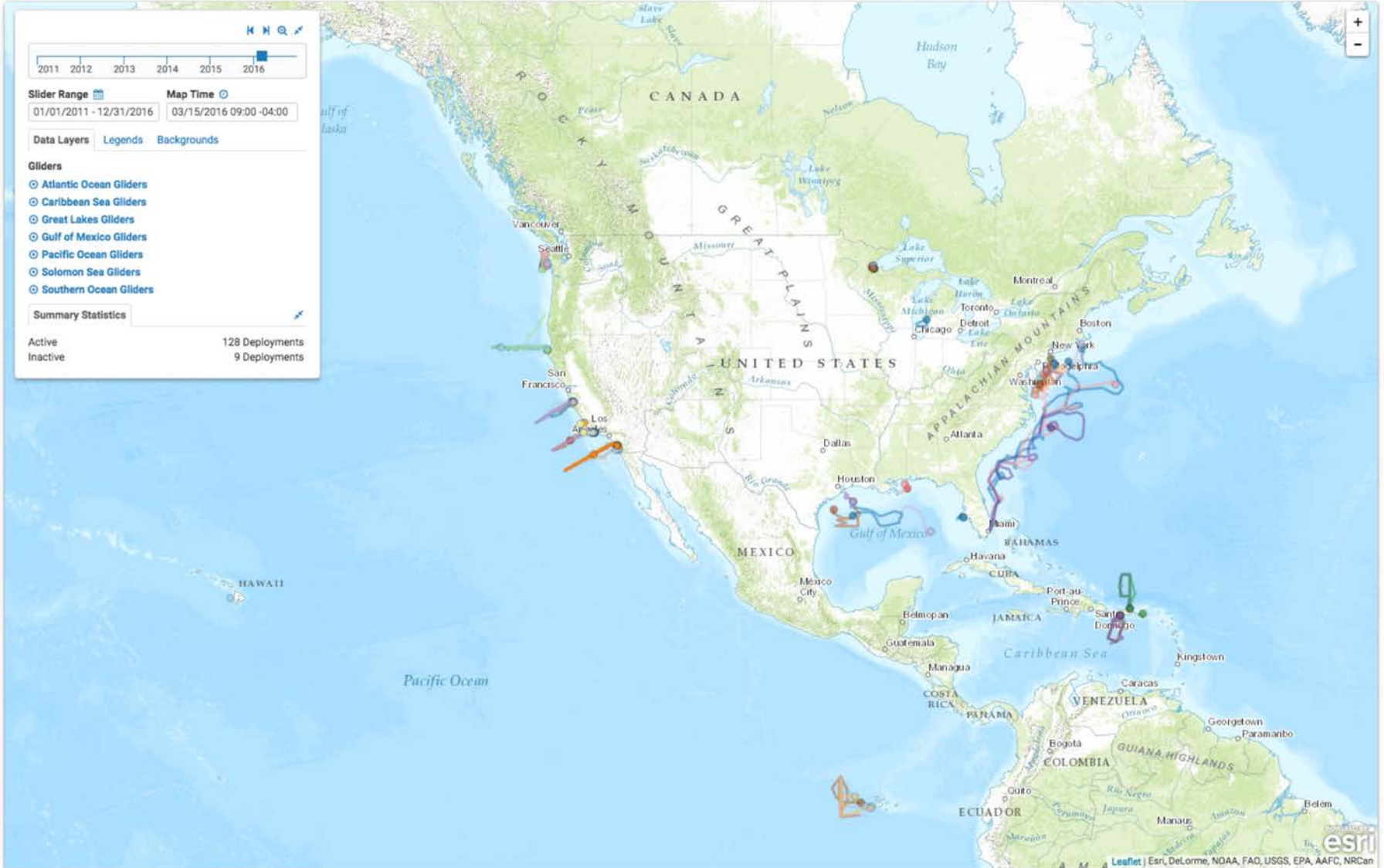


# Hurricane Sentinel Gliders deployed in 3 Picket Lines



>30 Hurricane Sentinel Gliders from the Navy, NOAA, NSF, Academic & Industry Partners reporting ocean conditions through the U.S. IOOS Glider Data Assembly Center (DAC) ahead of Hurricanes Florence, Isaac and Helene on September 11, 2018.

# Data Availability





# Leveraging Global Tropical Cyclone Expertise



Asia-Pacific

National Oceanography Centre  
NATURAL ENVIRONMENT RESEARCH COUNCIL

NOAA RESEARCH  
National Oceanic and Atmospheric Administration  
National Centers for Environmental Prediction

UMass RPS asa  
MAINE  
NERACOOS  
Orsted  
OOL  
CINAR  
RUTGERS  
MARACOOS  
Ocean Information for a Changing World  
Mid-Atlantic Regional Association Coastal Ocean Observing System  
TELEDYNE MARINE  
Everywhere you look  
BIOS

IOOS | Integrated Ocean Observing System

SECOORA  
Southeast Coastal Ocean Observing Regional Association

Drawn from an expanding  
Global Network

58 Institutions

Indian Ocean

NIO  
understanding the seas

BMKG

THE UNIVERSITY OF WESTERN AUSTRALIA

CARICOOS

UPR  
Universidad de Puerto Rico

University of the Virgin Islands

OCOVI  
supporting CARICOOS in the Virgin Islands

IOCARIBE

INSMET

ICIMAR  
INSTITUTO DE CIENCIAS DEL MAR

USEF  
UNIVERSITY OF SOUTH FLORIDA  
National Data Buoy Center  
Center of Excellence in Marine Technology

Atlantic Oceanographic & Meteorological Laboratory  
National Oceanic & Atmospheric Administration

Skidaway Institute of Oceanography  
UNIVERSITY OF GEORGIA

VIMS  
VIRGINIA INSTITUTE OF MARINE SCIENCE  
WILLIAM & MARY

UNIVERSITY OF DELAWARE  
CENTER FOR ENVIRONMENTAL SCIENCE

USGS  
Science for a Changing World

GULF OF MEXICO COASTAL OCEAN OBSERVING SYSTEM

U.S. NAVAL RESEARCH LABORATORY  
National Center for Environmental Prediction

ATM

Shell

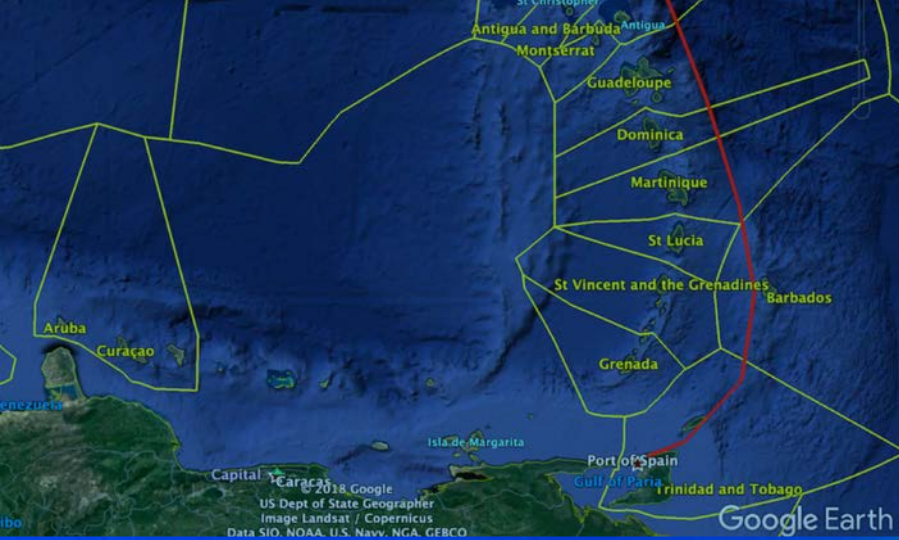
U.S. NAVAL RESEARCH LABORATORY

CICESE

UNAM

IOOCAN

UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA



- Moving
- 1) Maximize collaboration and partnerships
  - 2) Capacity Building