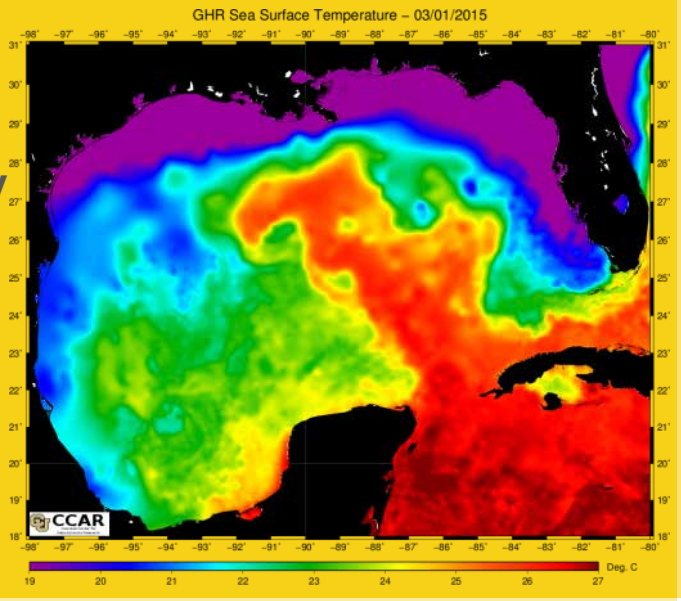
SHELL'S EXPERIENCE USING GLIDERS FOR OBSERVATIONAL OCEANOGRAPHY

The Australian Forum for Operational Oceanography

21 July 2015



Vogel[1], Perry[1], Brzuzy[1], Leung[1], McCall[2], Martin[3], Vandermuelen[3]

1-Shell Oil Co., 2-NOAA National Data Buoy Center, 3-University of Southern Mississippi

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Reserves: Our use of the term “reserves” in this presentation means SEC proved oil and gas reserves.

Resources: Our use of the term “resources” in this presentation includes quantities of oil and gas not yet classified as SEC proved oil and gas reserves. Resources are consistent with the Society of Petroleum Engineers 2P and 2C definitions.

Organic: Our use of the term Organic includes SEC proved oil and gas reserves excluding changes resulting from acquisitions, divestments and year-average pricing impact.

Resources plays: Our use of the term ‘resources plays’ refers to tight, shale and coal bed methane oil and gas acreage.

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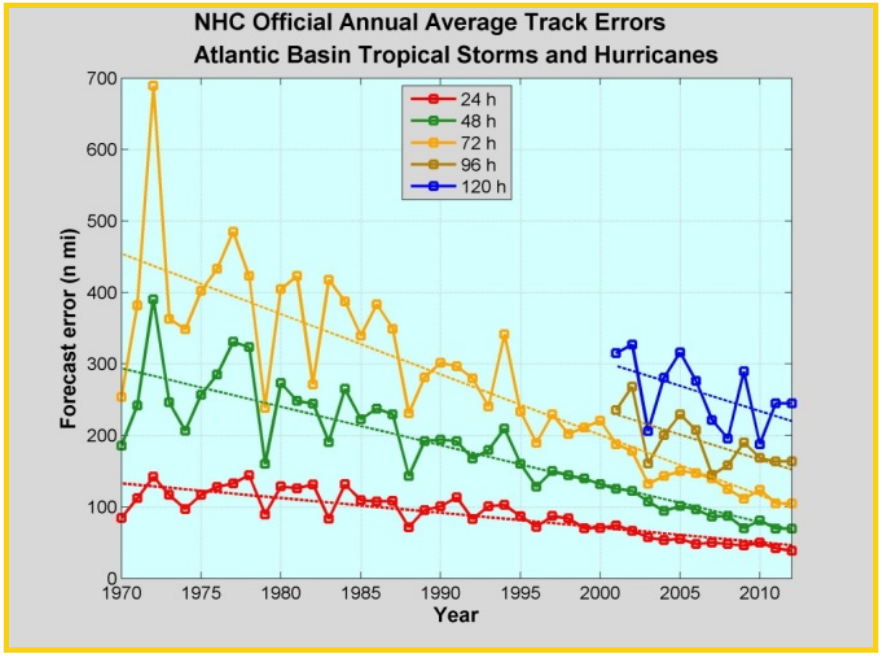
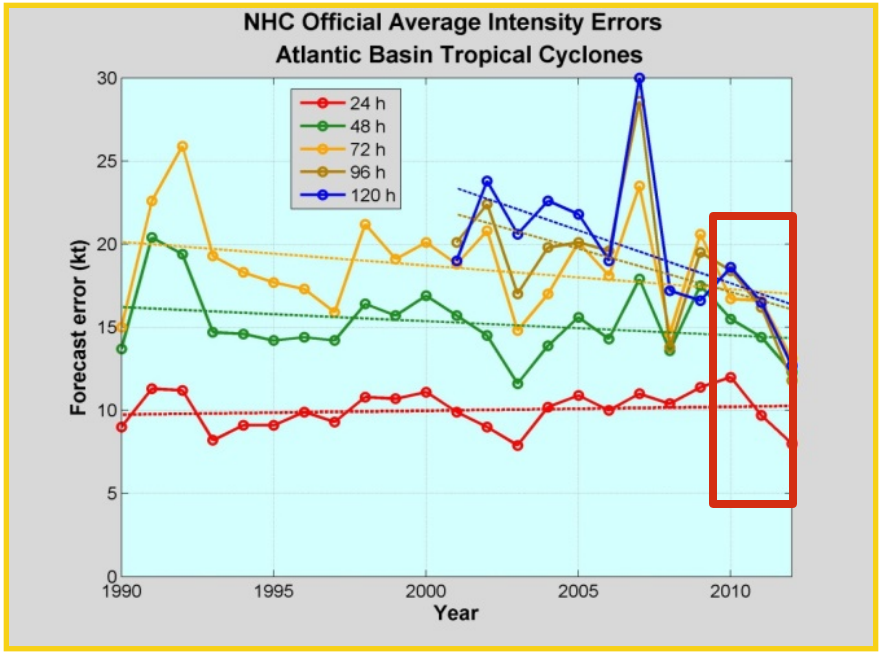
PRESENTATION OUTLINE

- Background/Motivation
- Initial Partnership Strategy
- Present Partnership Strategy
- Glider Missions & Observations
- Conclusions & Next Steps

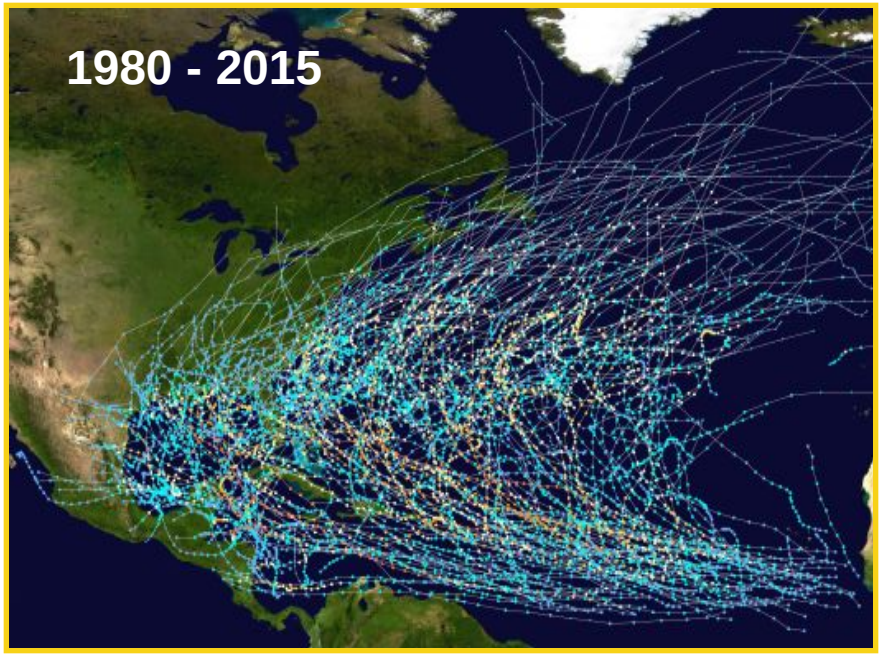
BACKGROUND/MOTIVATION

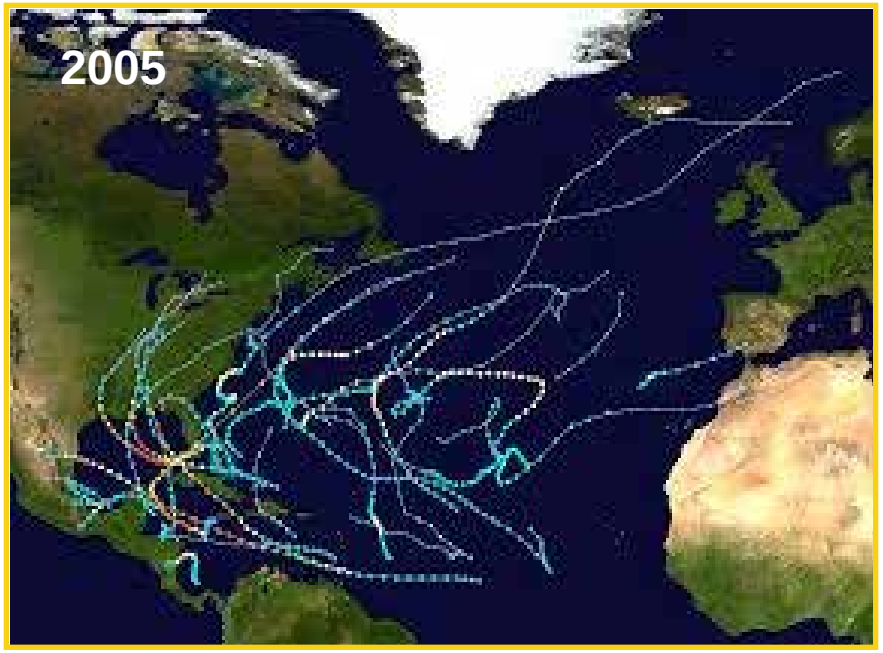




In 2008, Shell signed a Memorandum of Agreement with NOAA to collaborate on ways to improve tropical cyclone intensity predictions in the Gulf of Mexico

NEED FOR GULF HURRICANE MONITORING





10.1 storms occur each season

Average of 5.9 storms become hurricanes (2.5 greater than Category 3)

28 cyclones formed in 2005 (15 of which were hurricanes)

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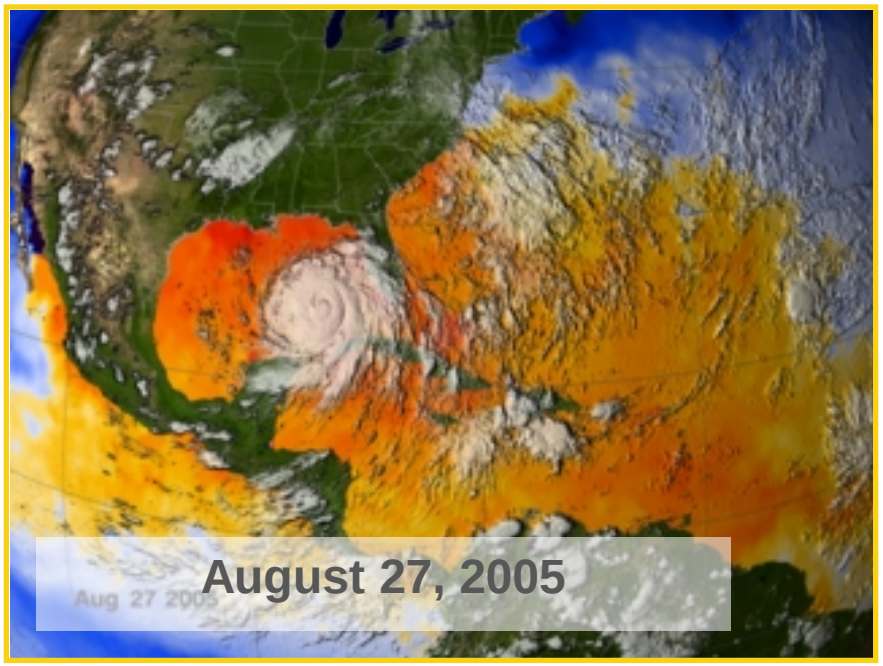
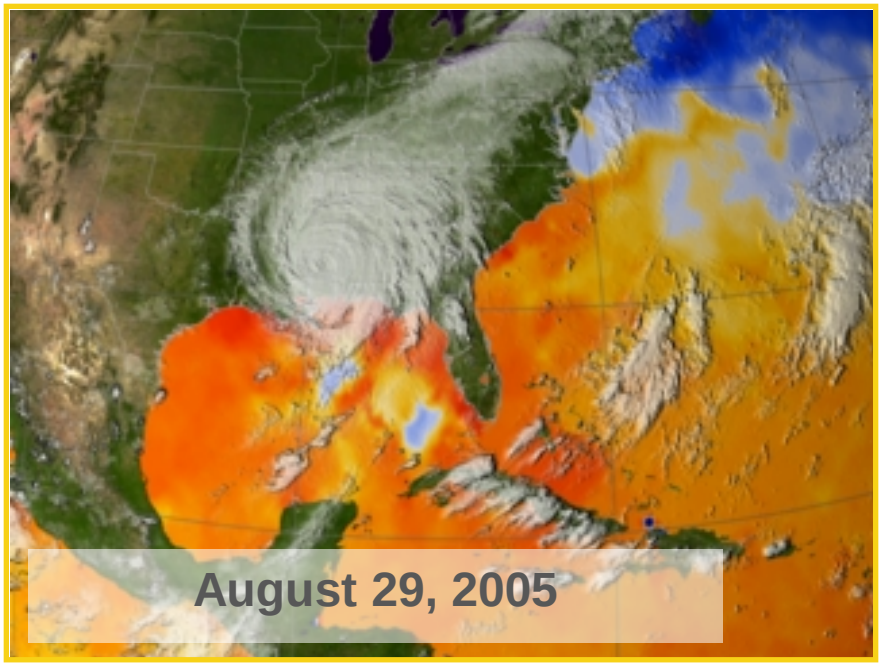




AMSR-E on NASA Aqua Satellite

Decrease in sea surface temperature following the passage of Katrina

WHY GLIDERS?

- Upper ocean heat content drives tropical cyclone intensification.
- Initial concept was to deploy thermistor strings from Shell's deepwater assets.
- Retrofitting strings problematic and the limited number of platforms reduces odds of path of storm
- Gliders offer established method of obtaining T-S profiles and are mobile

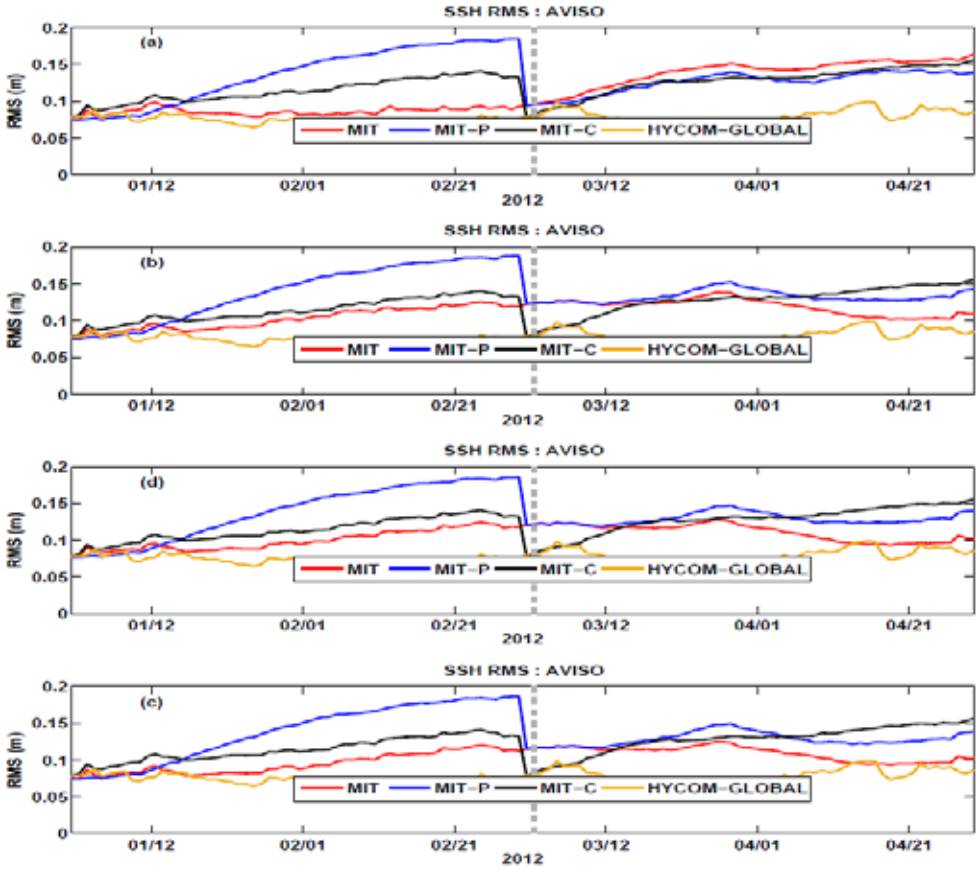
Bullwinkle Platform

WHY GLIDERS?

Other objectives include:

- Biological/chemical baselines to support environmental protection & risk mitigation
- Effective long term monitoring programs utilizing public-private collaboration
- Loop Current/Eddy mapping
- Improved ocean numerical model forecasting with assimilation

WHY GLIDERS?



Assimilation of glider T-S data into numerical ocean models indicates improvements in model hindcast/forecast of Gulf of Mexico Loop Current

(Rudnick, Gopalakrishnan, Cornuelle. *JPO* (2015): 313-326.)

DEVELOPMENT OF THE COLLABORATION

2005 → 2006 → 2008 → 2012 → 2014

Early Discussions

Hurricanes Rita & Katrina

NOAA & Shell initiate conversations to add to NOAA's data collection efforts using Shell's offshore assets

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Research Goals

State of the Gulf Summit

Research goals formalized between NOAA & Shell

- Improve understanding of hurricanes & tropical storms in GoM

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2012

1st Glider Deployed

Shell purchases Seaglider

Deployed by Shell

Piloted by NOAA NDBC

USM joins in the MoA

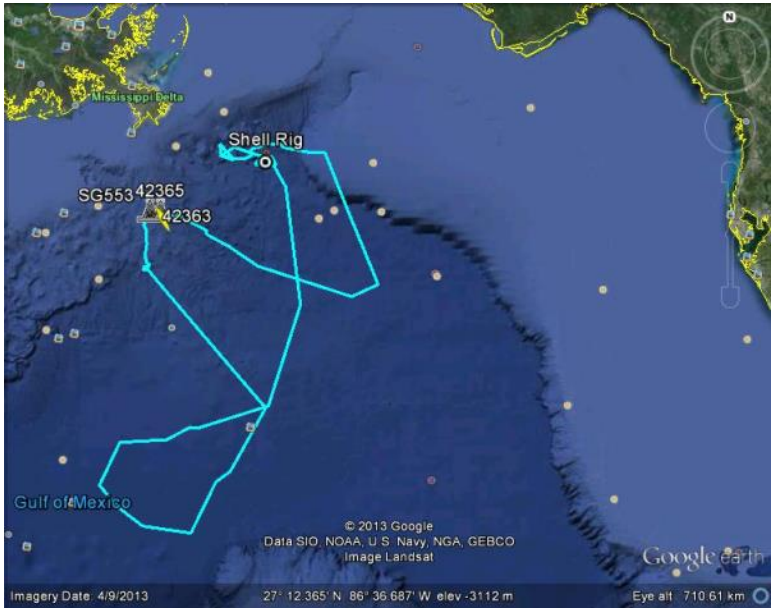
2014

INITIAL OPERATIONAL COLLABORATION STRATEGY

- Shell purchases IRobot Seaglider
- NOAA NDBC serves as mission control center to pilot and manage missions
- Shell uses OSV fleet with ROVs to recovery and deploy glider
- Glider missions developed to address mutual objectives of Shell/NOAA

PRESENT STRATEGY

- Oct 2013 glider lost at sea due to recovery failure after operating from 5 July collecting 1080 profiles
- Univ. of Southern Mississippi joins MoA
- Shell no longer owns gliders, instead supports partners including NDBC, USM, and Gulf of Mexico Coastal Ocean Observing System (GCOOS)
- Data transmitted directly through GTS for public access



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Mission Results

Shelf & OCS gliders operating

To date:

5,000+ miles flown

3000+ profiles collected

2015 underway

GLIDER MISSION OVERVIEW

2012

- Kongsberg Seaglider
- Covered 900 miles
- Collected 1000 profiles
- **Successfully flew in Hurricane Isaac**
- Flew near & in Loop Current

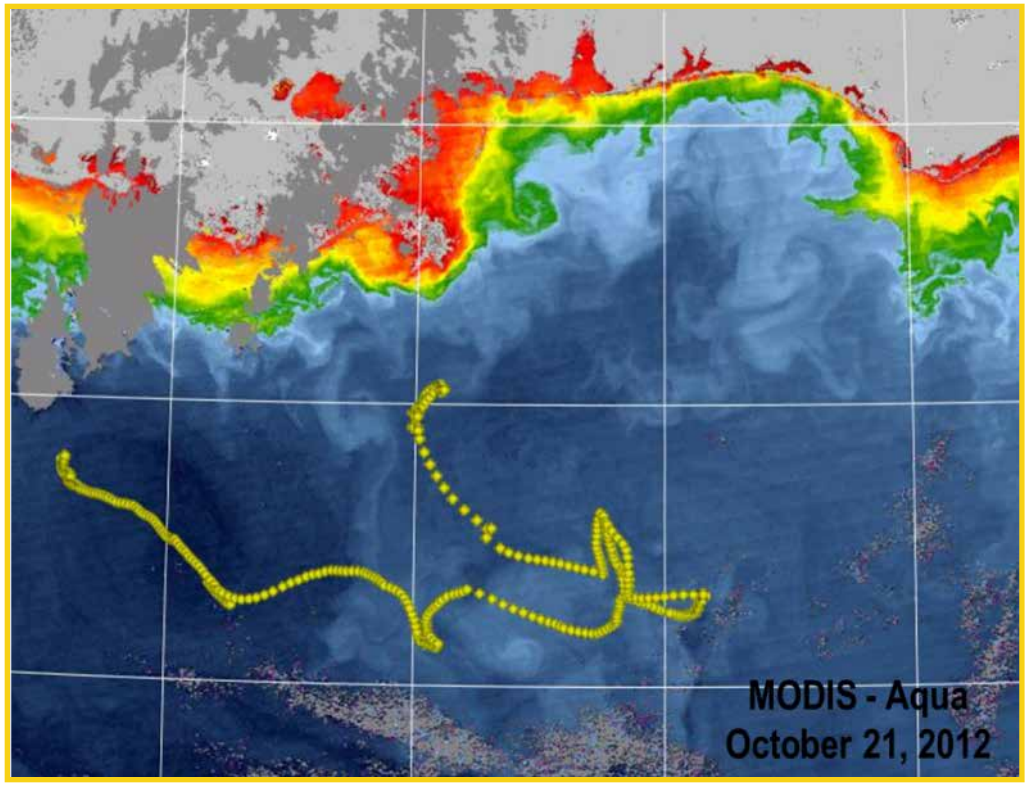
2013

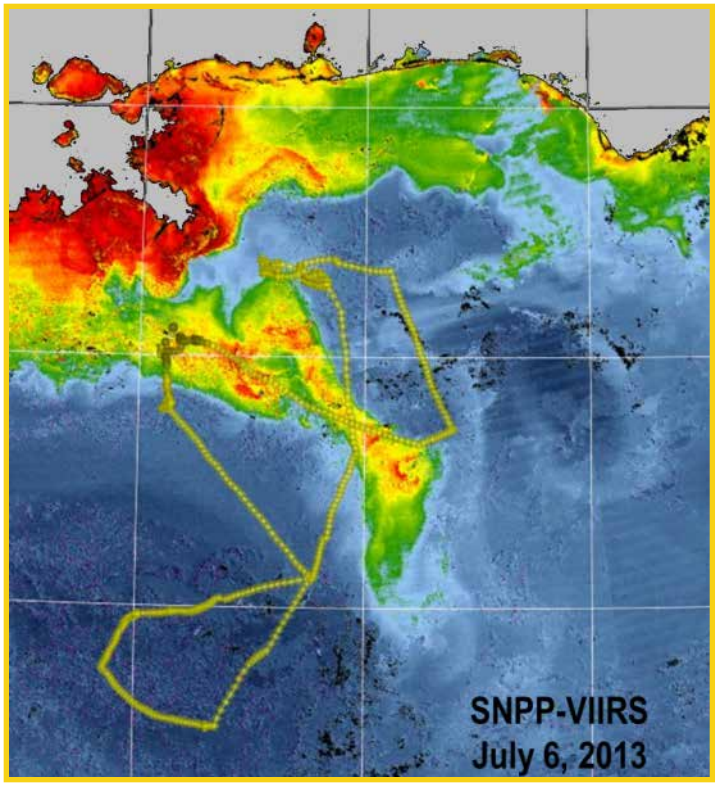
- Kongsberg Seaglider
- Covered 1100 miles
- Collected 1000 profiles
- **No hurricanes**
- Flew in Loop Current & associated eddies

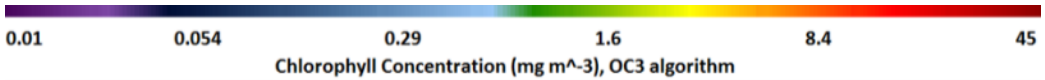
2014

- Kongsberg Seaglider & Teledyne Webb glider
- Covered 3000 miles
- Collected 2800 profiles
- **No hurricanes**
- Flew in Loop Current & associated eddies and at shelf break

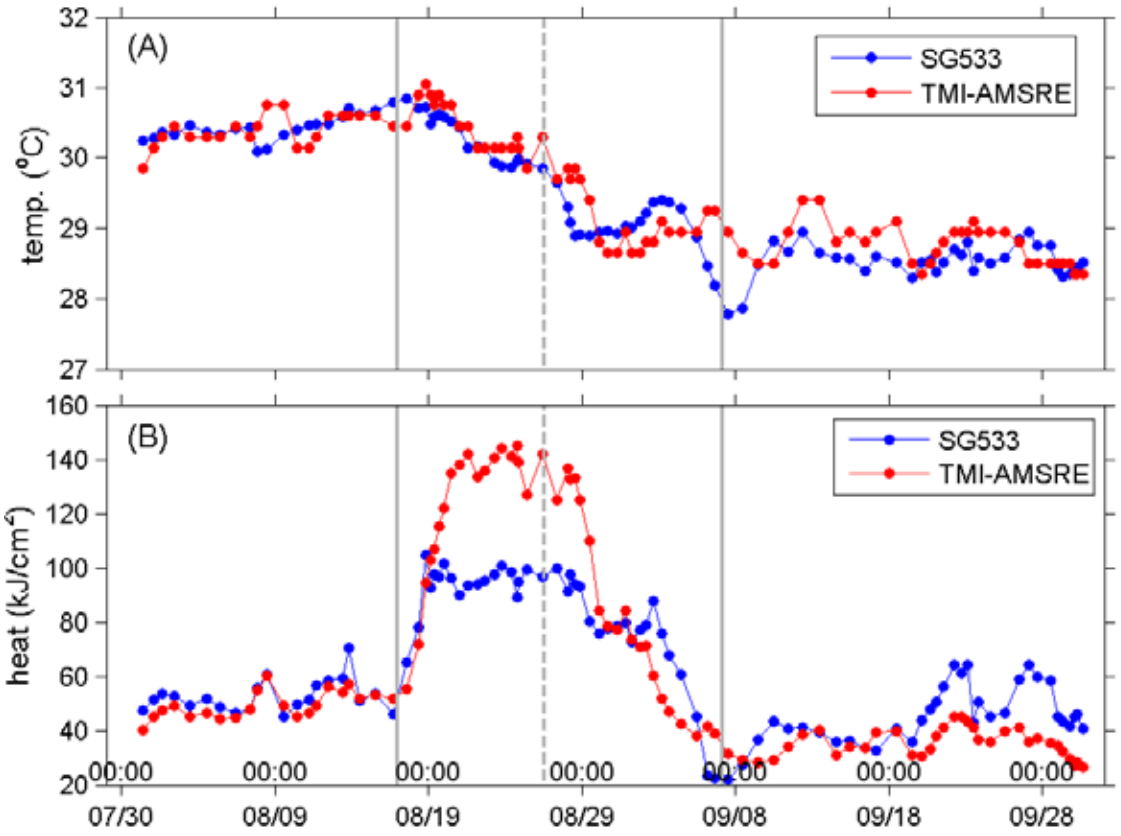
2012 & 2013 GLIDER TRACKS







2012 GLIDER DATA & SATELLITE RESULTS



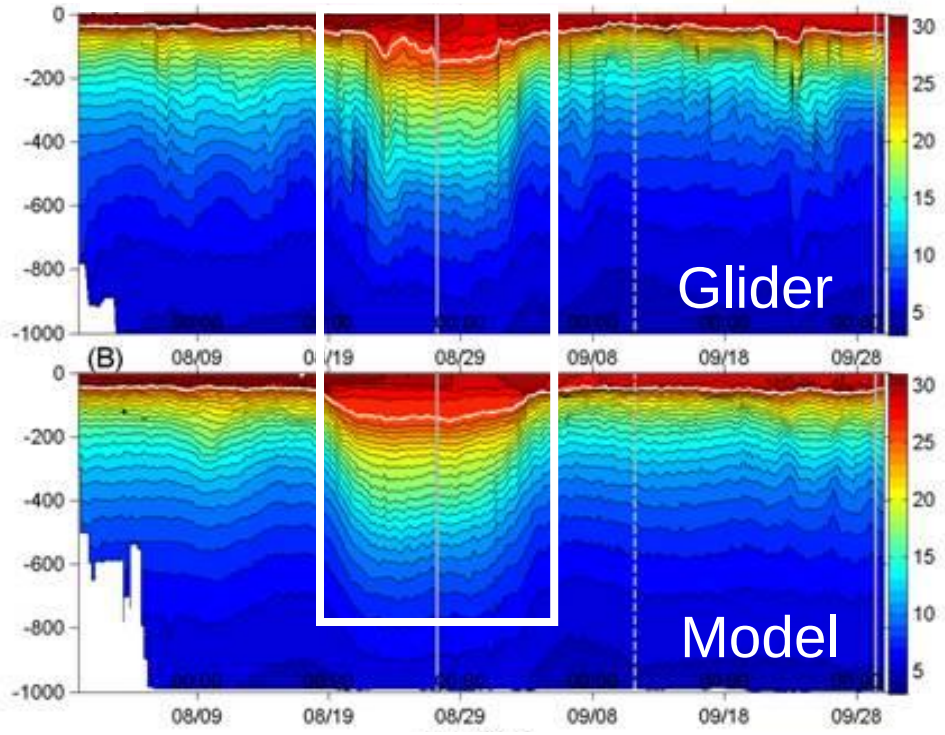
Glider Mean = 29.42 C °
Satellite Mean = 29.54 C °
RMS = .4 C °

Satellite @ surface
Glider @ top 5m

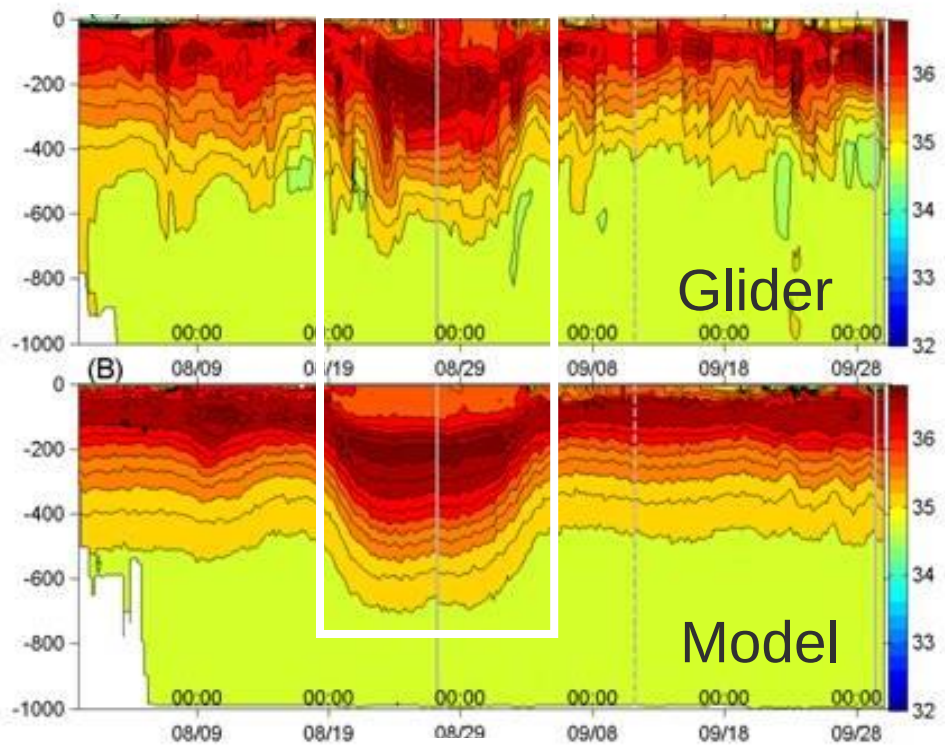
Glider Mean = 62.88 kJ/cm2
Satellite Mean = 65.55 kJ/cm2
RMS = 21 kJ/cm2

Satellite underestimated surface cooling from Isaac

2013 VERTICAL PROFILE COMPARISON

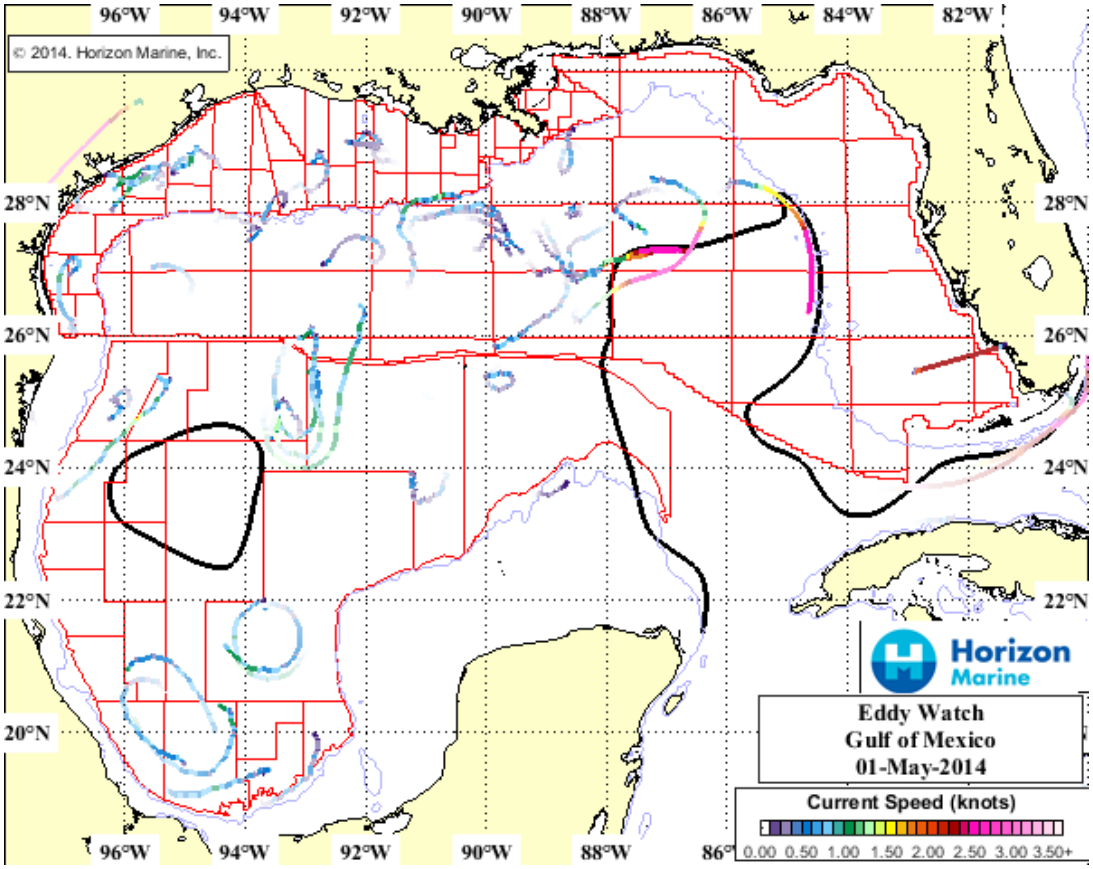


Temperature



Salinity

2014 LOOP CURRENT/EDDY ACTIVITY

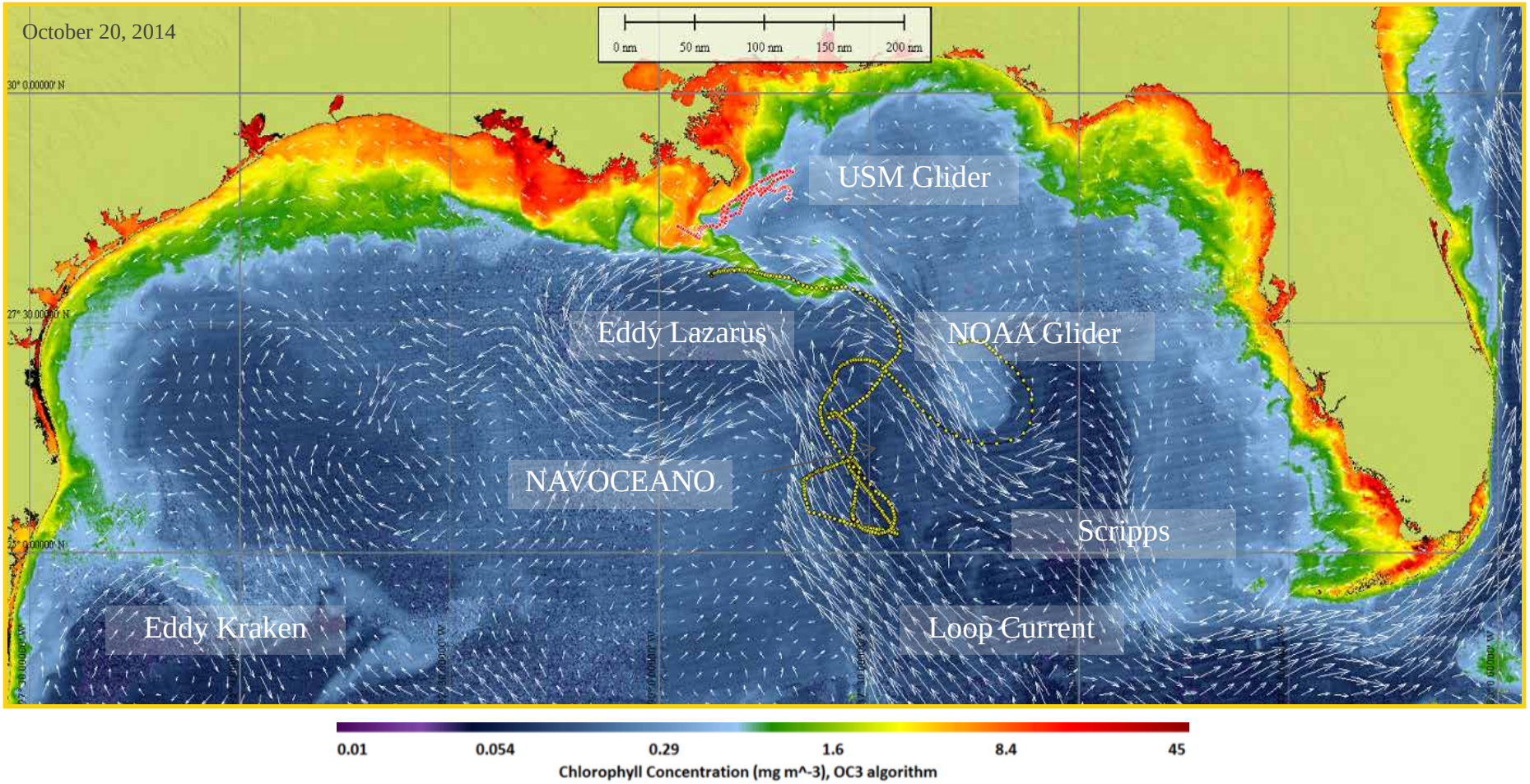


Loop Current dynamics

Evolution and separation of eddies (Kraken, Michael)

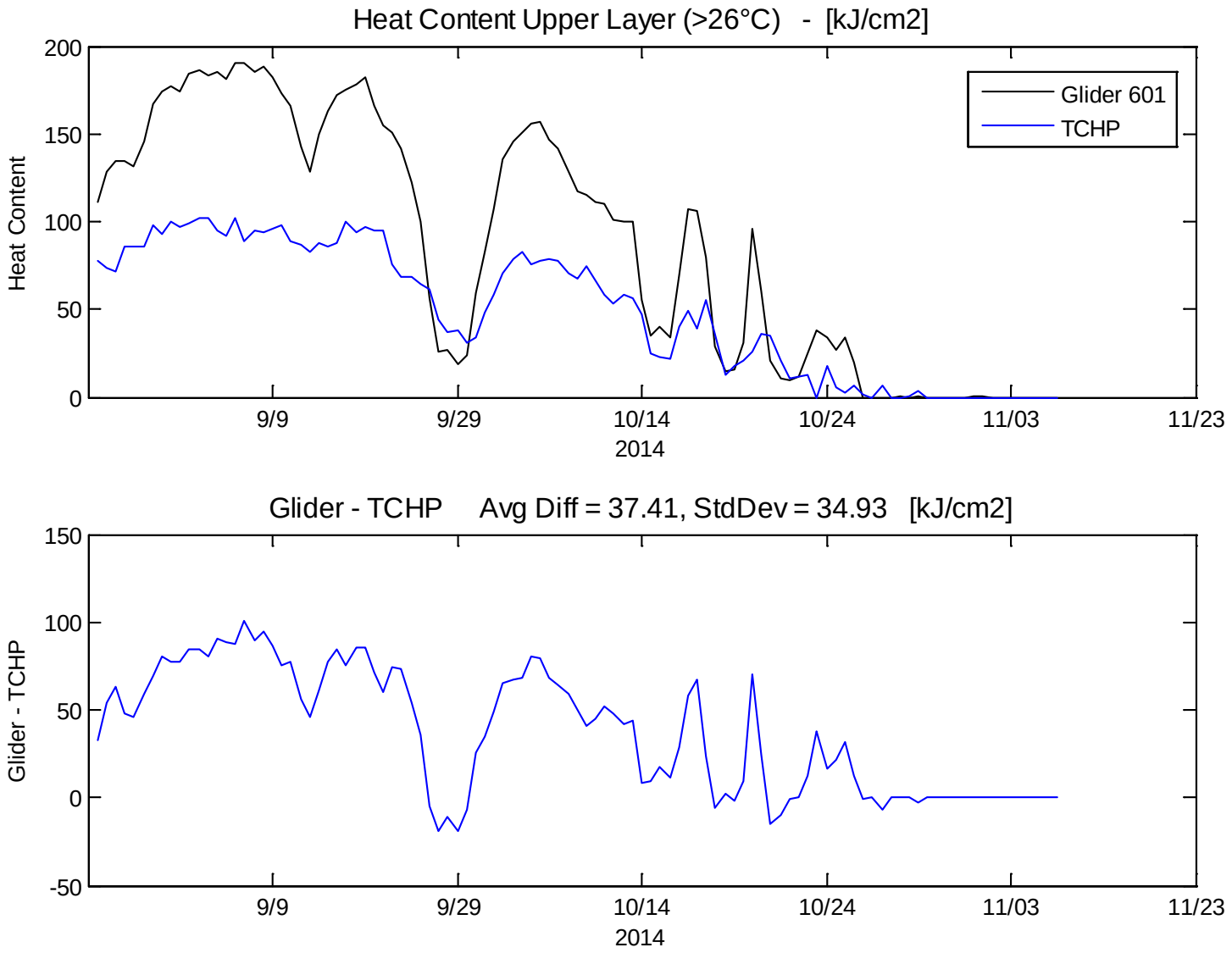
Horizon Marine

2014 GLIDER OBSERVATIONS – SHELF & DEEP WATER

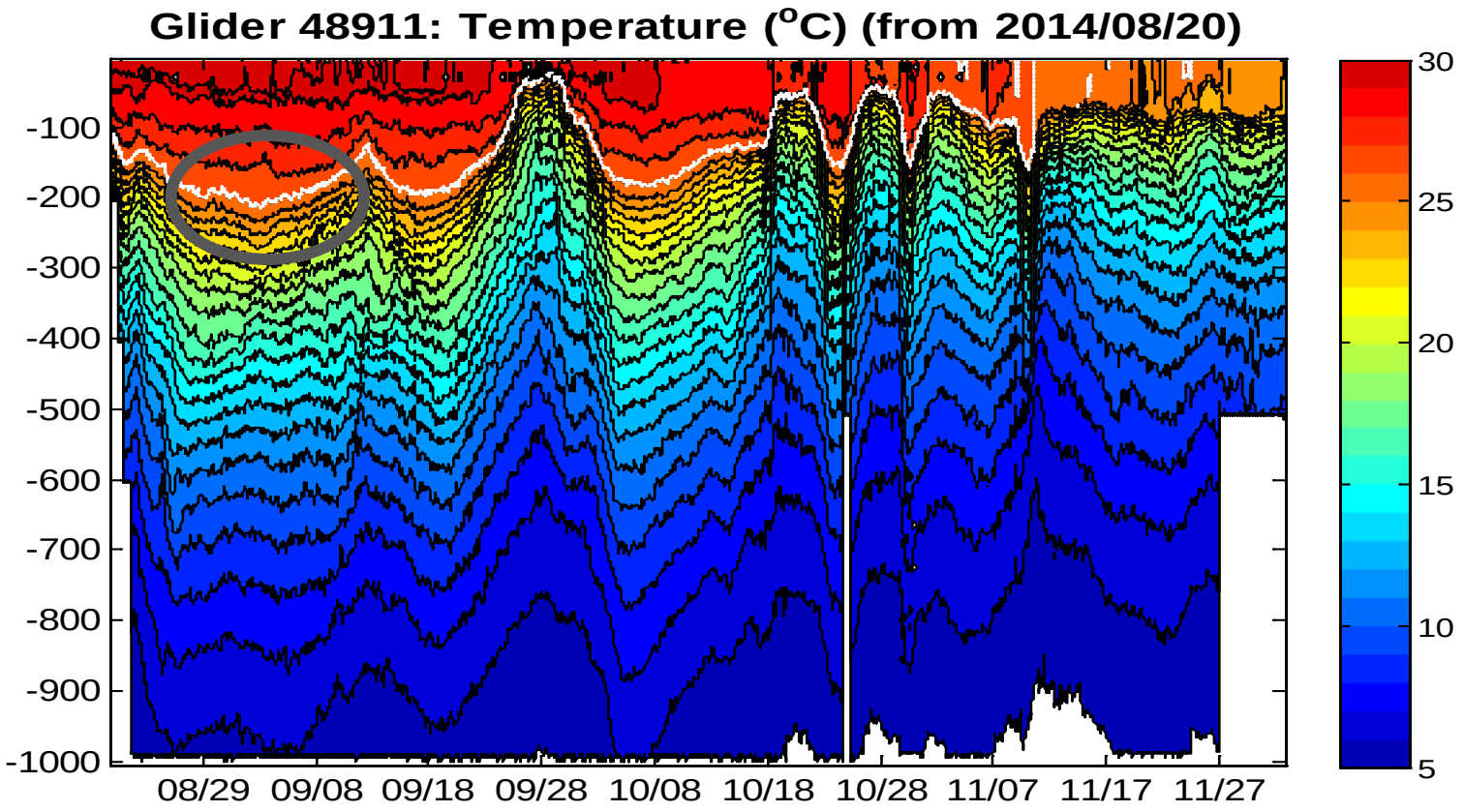


Multiple glider operations in the area monitoring Loop Current and entrainment of coastal waters

2014 GLIDER DATA & SATELLITE RESULTS



2014 GLIDER PROFILE DATA



26° isotherm depth greater than 200m (high OHC values)

CONCLUSIONS

- Industry/Government/Academic partnerships critical for success:
  - Respective strengths of each organization yield a robust measurement program with public data transmission/access and mutually aligned scientific objectives
- Gliders are ideal platforms to supplement existing network of industry offshore measurements and can acquire data through ocean features
- Glider observations provide key tool for improvement in ocean model prediction for:
  - Loop Current position, structure, and dynamics
  - Coupled Ocean-Hurricane interaction

NEXT STEPS

- Sensor & platform additions (*e.g. dissolved oxygen, acoustics, water quality*)
- OHC model hindcasts & algorithm improvement
- Assimilation of data to investigate biological environment
- Assimilation of data into Naval Research Lab Gulf of Mexico Ensemble Forecast System
- Expanding federal-academic-private collaboration