G3OS | **Ocean Observing Co-Design**
by The Global Ocean Observing System

Co-Designing Ocean Observing Systems for Improving Tropical Cyclone Forecasts and Warnings

Scott Glenn – *Rutgers University*

Cheyenne Stienbarger – *NOAA*

2024 IOCARIBE Working Group Meeting
8 November 2024

NOAA P3 Hurricane Hunter Track in **Hurricane Beryl** over Hurricane Glider RU29 in the Caribbean.

GOOS | At the heart of the Ocean Decade

GOOS Ocean Observing Co-Design Programme

Initial Exemplar Projects

Carbon Cycle

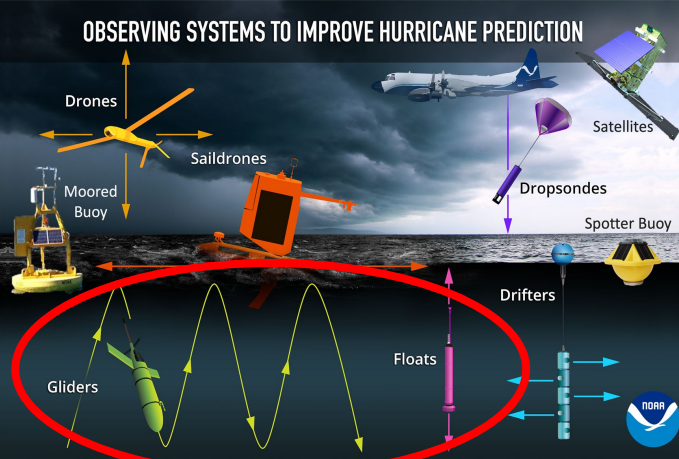Tropical Cyclones

Marine Life 2030

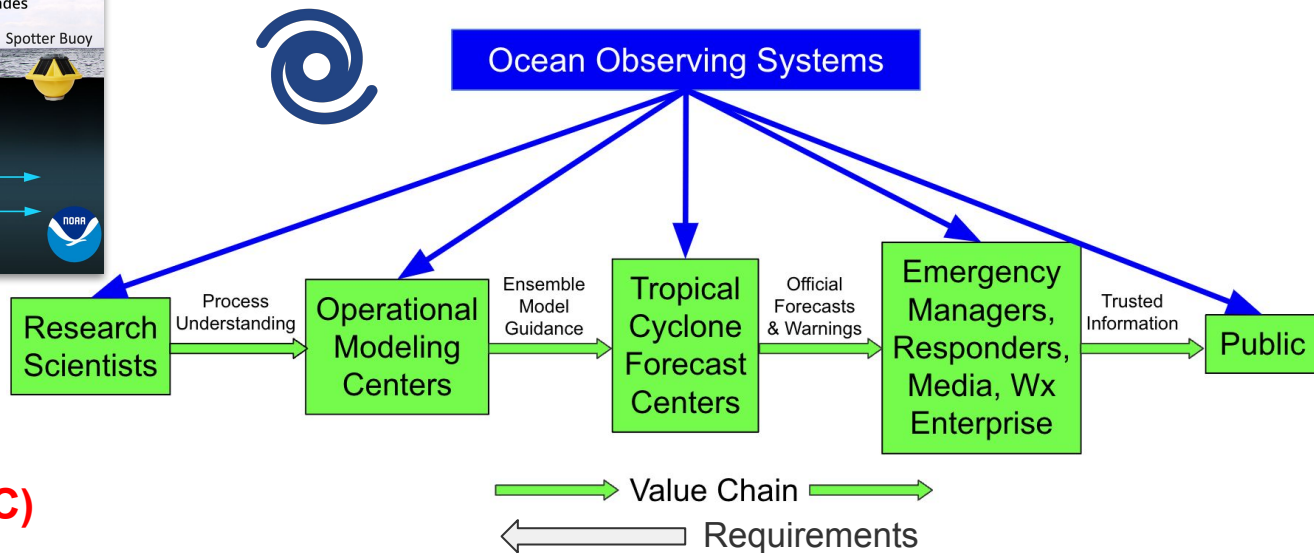Storm Surge

Marine Heatwaves

Boundary Currents

Operational services

Climate

Ocean health

Accelerate GOOS Implementation through Exemplars

OBSERVING SYSTEMS TO IMPROVE HURRICANE PREDICTION

Drones
Saildrones
Moored Buoy
Satellites
Dropsondes
Spotter Buoy
Drifters
Floats
Gliders

THE CO-DESIGN PROCESS: Defining the Value Chain and the reverse flow of Requirements

"There is a dearth of subsurface profile data"
- **NOAA Environmental Modeling Center (EMC)**

Ocean Observing Systems

Research Scientists → *Process Understanding* → Operational Modeling Centers → *Ensemble Model Guidance* → Tropical Cyclone Forecast Centers → *Official Forecasts & Warnings* → Emergency Managers, Responders, Media, Wx Enterprise → *Trusted Information* → Public

→ Value Chain →
← Requirements

Requirements are fed back through the value chain starting with public needs:

- **Public** requires trusted information to make evacuate vs shelter in place decisions

- **Emergency Managers** require forecasts and warnings with sufficient accuracy and lead time to guide decisions

- **Forecast Centers** require improved numerical model guidance products to make better forecasts

- **Modeling Centers** require more and better ocean observations to improve Earth System model guidance

- **Observing System Operators** prioritize deployment of the most critical observing systems to improve models

The International Best Track Archive for Climate Stewardship (IBTrACS) stores global tropical cyclone information.

Tropical Cyclone Tracks

Saffir-Simpson Hurricane Wind Scale

Intensity Missing — Category 1
Tropical Depression — Category 2
Tropical Storm — Category 3
— Category 4
— Category 5

Pilot Study Regions

ACCELERATING GOOS IMPLEMENTATION: Five Regional TC Pilot Studies

Tropical Americas and Caribbean (TAC)
Capacity building for the most damaging TCs

North Pacific Ocean and Marginal Seas (NPOMS)
Coupled air-sea science in the most intense TCs

Bay of Bengal, Indian Ocean
Fostering national networks for the most deadly TCs

Southwest Indian Ocean (SWIO)
Co-designing the response to the triple threat of changing boundary currents, MHWs, & TCs

Pacific Islands – *New*
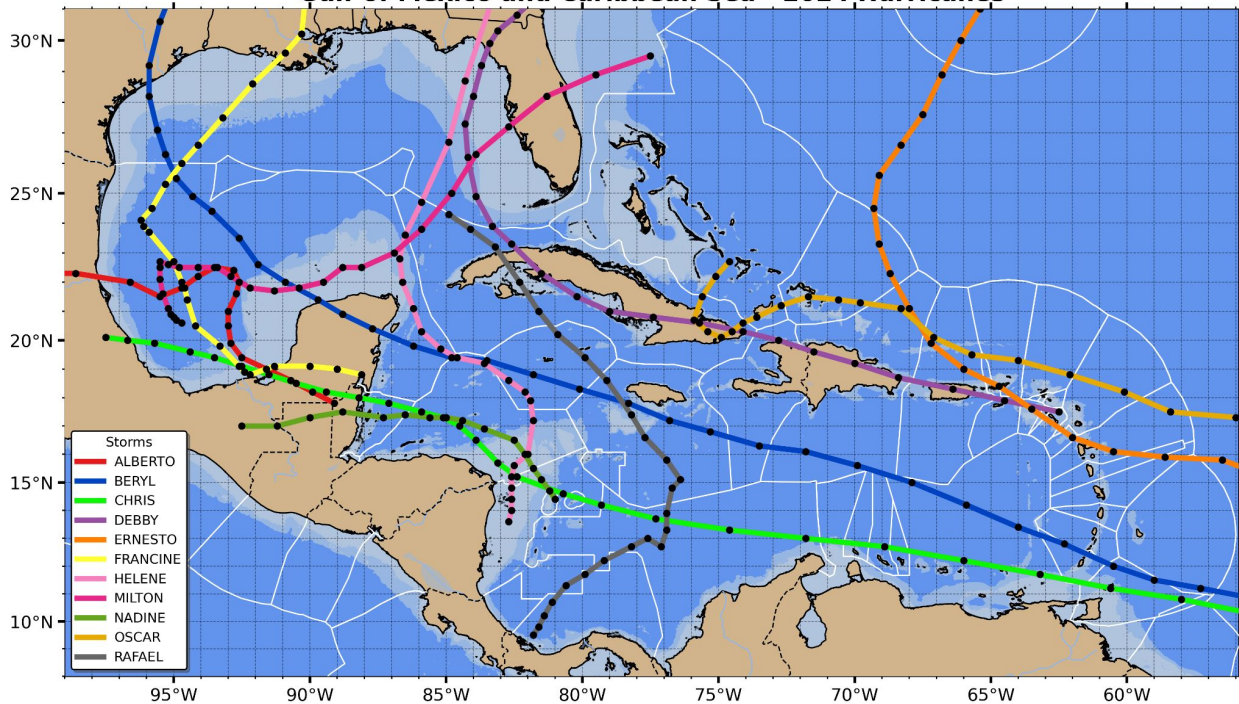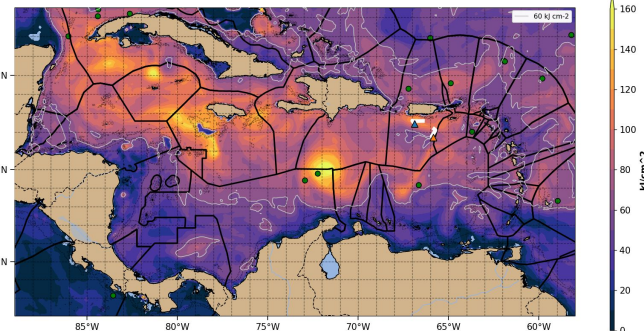Initial co-development of regional stakeholder needs

2024 Tropical Cyclone Tracks
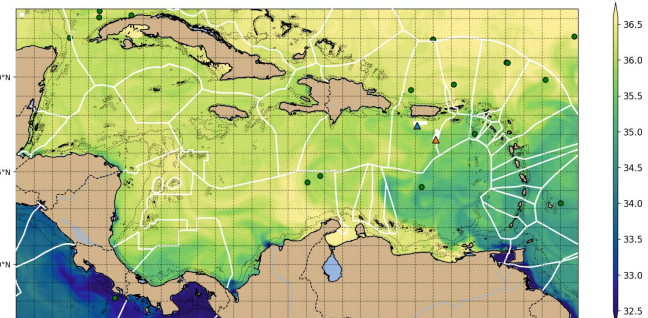
Gulf of Mexico and Caribbean Sea - 2024 Hurricanes

Storms
- ALBERTO
- BERYL
- CHRIS
- DEBBY
- ERNESTO
- FRANCINE
- HELENE
- MILTON
- NADINE
- OSCAR
- RAFAEL
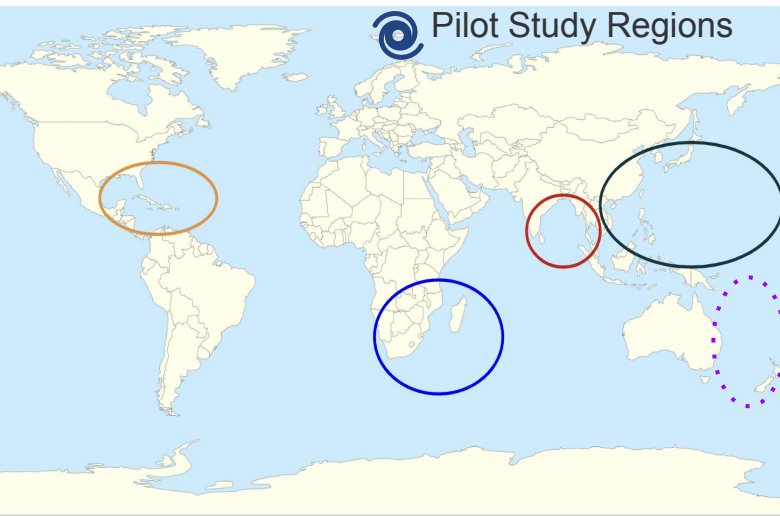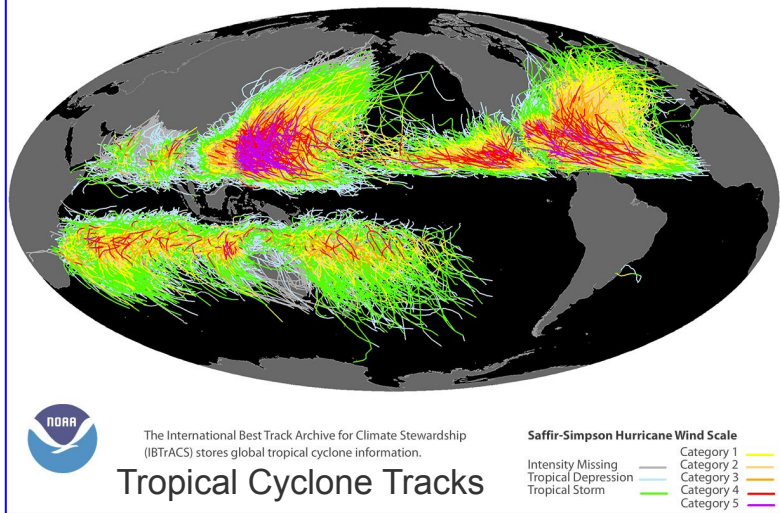
Essential Ocean Features
Ocean Heat Content

Ocean Heat Content - RTOFS - 2024-07-02 12:00:00

60 kJ cm-2

kJ/cm^2

Salinity - RTOFS - 2024-07-02 12:00:00

Surface Salinity for Barrier Layers

GeoS

Profile Data Available for Assimilation

2024	Gulf of Mexico	Caribbean Sea
Surface Area	1.55M km^2	2.75M km^2
Argo Profiles	2,264	1,117
Glider Profiles	31,110	12,828

Gulf of Mexico Assets - January 1, 2024 to November 5, 2024

Water Depth
0-100m
100-1000m
1000+m

Profile Statistics
Argo (#): 42
Profiles: 2264
Gliders (#): 33
Profiles: 31110

Caribbean Assets - January 1, 2024 to November 5, 2024

Water Depth
0-100m
100-1000m
1000+m

Profile Statistics
Argo (#): 53
Profiles: 1117
Gliders (#): 20
Profiles: 12828
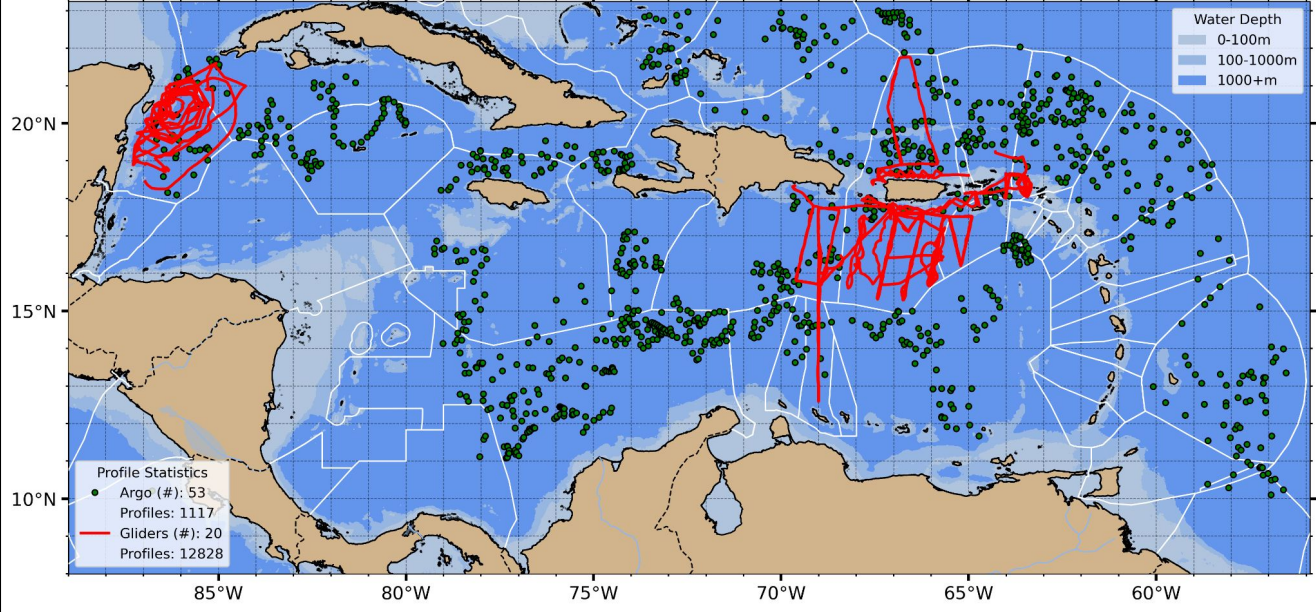
Glider   Argo

— WMO Engagement

- **WMO Region IV Hurricane Committee**
  - March 2024 - Panama - Ocean Panel
  - Caribbean is undersampled for TCs
  - Expand beyond Marine Scientific Research permissions for uncrewed systems
  - Demonstration projects for capacity building
- **WMO Impact of Observing Systems**
  - May 2024 - Sweden - TC Exemplar/TAC
- **WMO Region V Cyclone Committee -**
  - July 2024 - Australia - TC Exemplar/TAC
- **WMO TECO (Technical Conf for Observations)**
  - Sept 2024 - Austria - Yucatan HF Radar
- **WMO** - Co-Design Pilot Studies Best Practices
- **DCC & WMO - NPOMS/TAC Collaborations**
  - Spring, 2025 - Japan

WMO Region IV Hurricane Committee

46th RA IV Hurricane Committee,
City of Panama, Panama, 18-22 March 2024
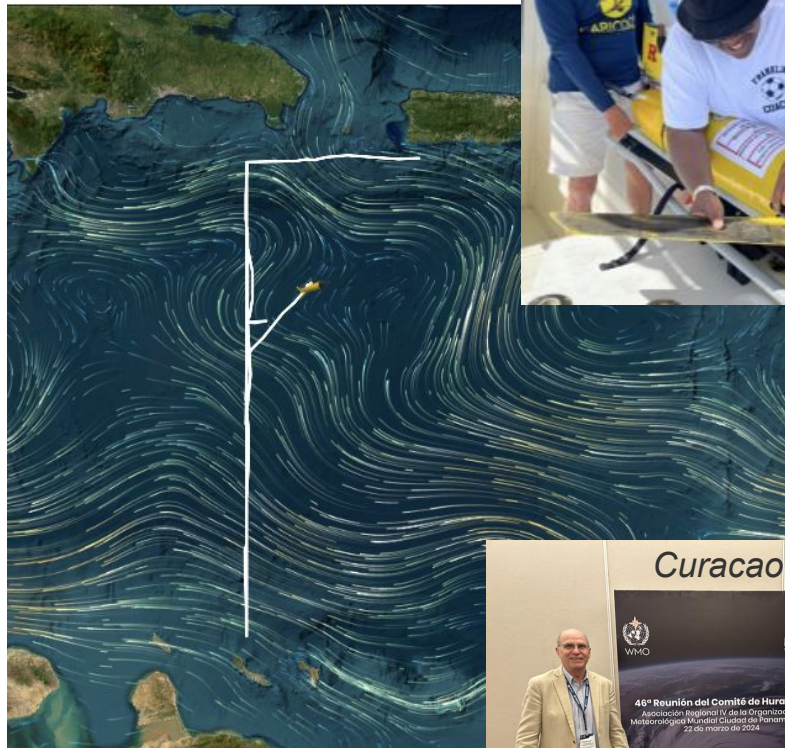
WMO Region IV Ocean Panel
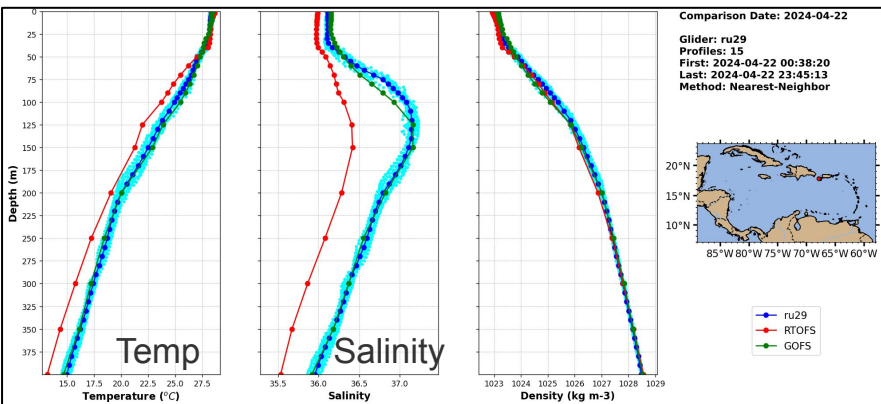
Caribbean Throughflow Glider Mission
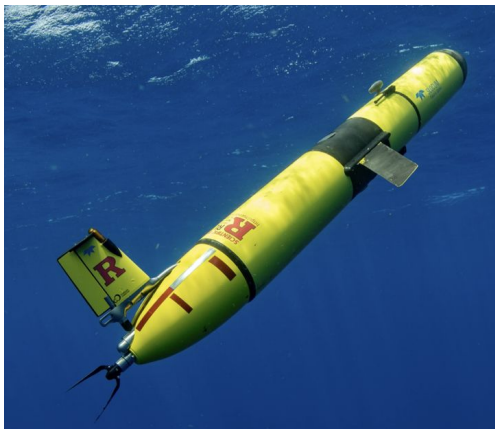
Exploratory Repeat Transect: *Puerto Rico to Dominican Republic to Curacao*
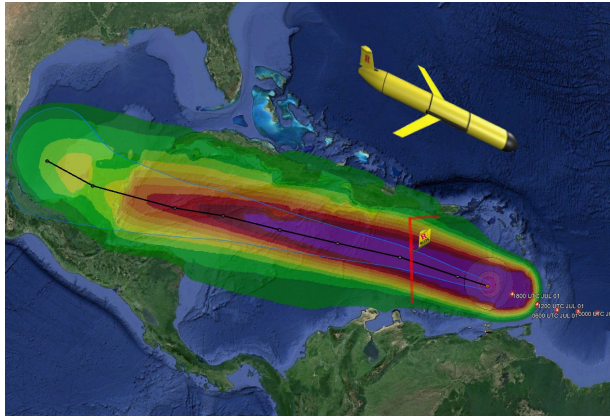
THE
G. UNGER VETLESEN
FOUNDATION

Puerto Rico

Before **Glider Data** Assimilation -
ROTFS Operational Model is Biased Cold & Fresh

Comparison Date: 2024-04-22

Glider: ru29
Profiles: 15
First: 2024-04-22 00:38:20
Last: 2024-04-22 23:45:13
Method: Nearest-Neighbor

Temp   Salinity

ru29
RTOFS
GOFS

Curacao

WMO Region IV
Coordination

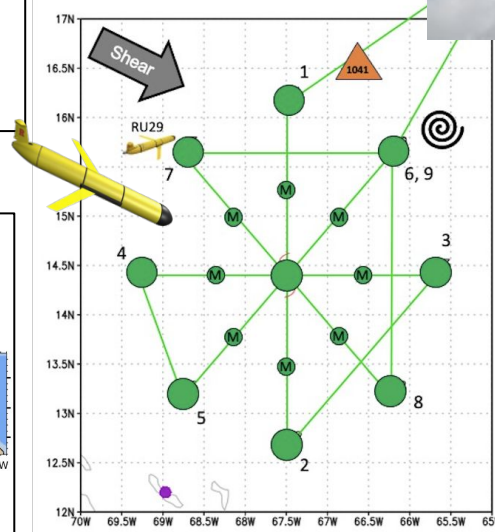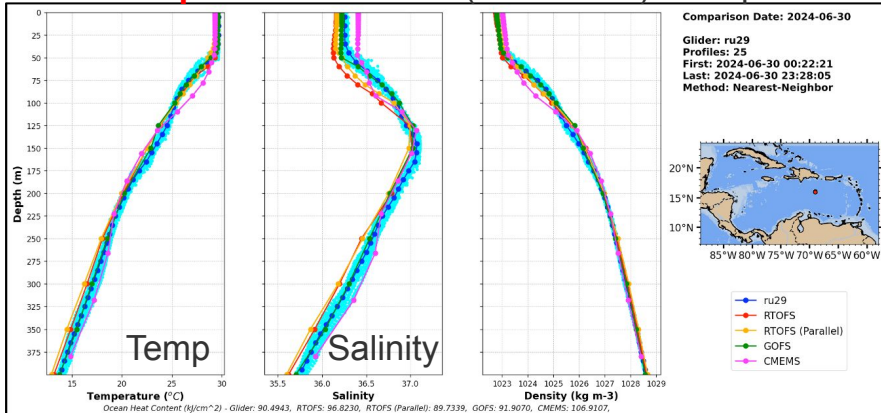# BERYL - Hurricane Hunter & Hurricane Glider Coordination

Glider data is shared on the GTS in real time and assimilated in operational ocean models used for hurricane forecasts

World Record: Closest approach of any uncrewed system to a hurricane eye.
*-   NOAA*

After **Glider Data** Assimilation -
ROTFS Operational Model (and others) all improved

NOAA P3 Hurricane Hunter dropsonde deployments coordinated with underwater glider RU29 location in Cat 5 Hurricane Beryl

2025 Planned Caribbean Glider Missions (Ovals)

Combined with Argo floats deployed across the Caribbean provide real-time profile data for assimilation by hurricane forecast models

Caribbean Sea

Water Depth
- 0-100m
- 100-1000m
- 1000+m
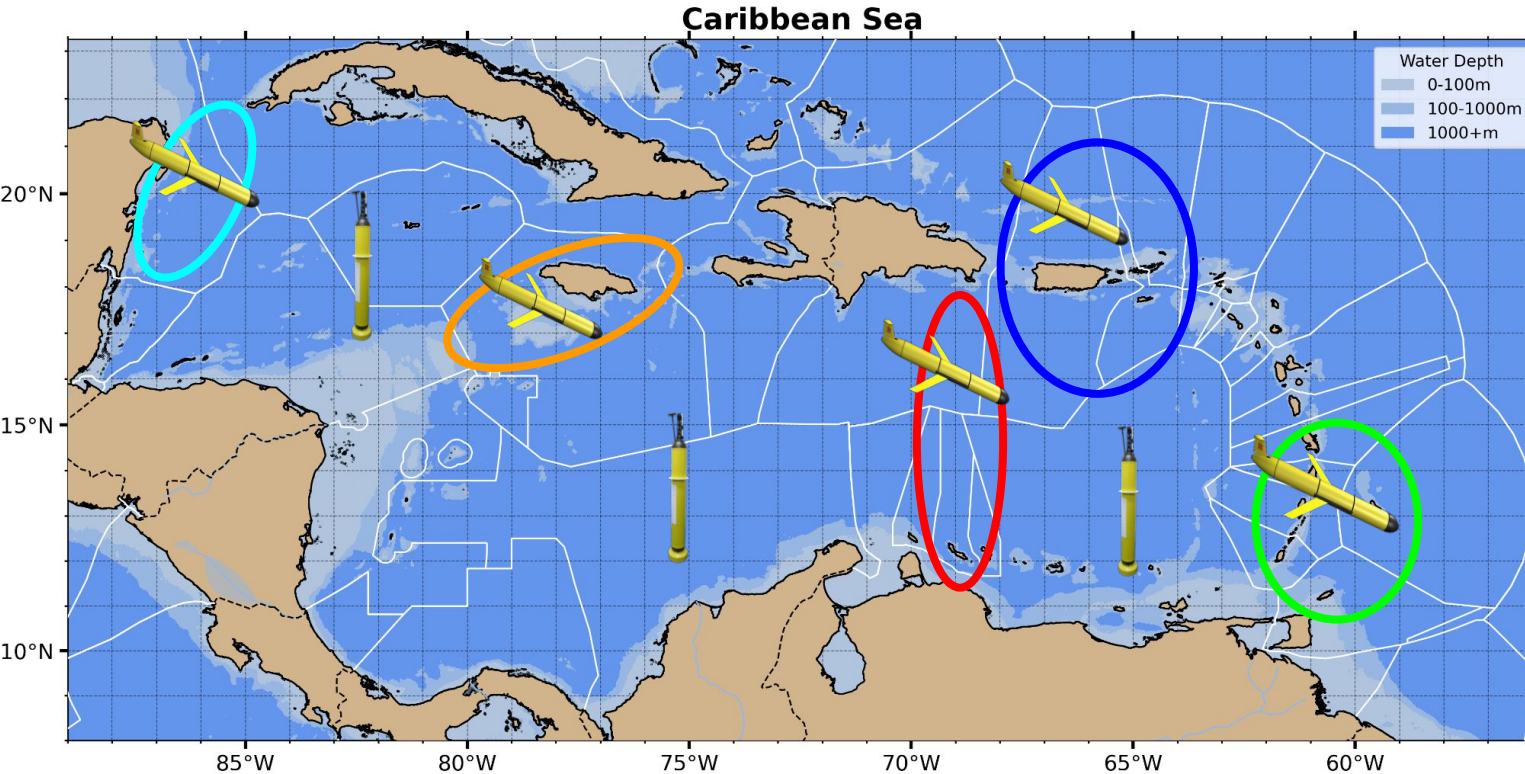
North Atlantic Inflow - PR-USVI-BVI (US Hurricane Gliders)

Throughflow - DR to Curacao (2024 Vetlesen to US NSF)

Throughflow - Nicaraguan Bank (US NSF)

Yucatan Outflow - Mexico (US NAS UGOS)

South Atlantic Inflow - Barbados - (2025 Vetlesen Proposal)

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Thank You for being part of the TC Exemplar

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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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