US Hurricanes Since 1990

$916.2 Billion in Damages
57% of Billion Dollar Disasters

Track Improvement: Factor of 2-4
Intensity Improvement: Marginal

“On average, intensity error may represent one category difference above or below the actual hurricane intensity.” - NHC
The Ocean Affects Hurricane Intensity

**Essential Ocean Features (EOFs)**
- Linked to rapid intensification and weakening
- Occur close to populated and vulnerable coastlines.

**Key Point**
EOFs are challenging for models because:
1) Highly dynamic nature
2) Very limited sub-surface observations to initialize models

**Glider Operations**
Real-time ocean observations to **improve initialization** of numerical forecast models
- **Sustained and targeted obs**: Gliders have demonstrated to reduce error in hurricane intensity forecasts
Simulating realistic conditions with the assimilation of combined ocean observations reduces intensity forecast error by 54%.

Underwater gliders: Largest contributor (40%) of total error reduction that resulted by assimilating All Obs 24 hrs before landfall.

Le Henaff et al. 2021
Hurricane Michael (2018) OSE

Domingues et al. 2021
Hurricane Maria (2017)
2021 Operations Overview

2021 Completed
3,667 Glider Days
118,563 GTS Profiles

2021 Goal
~ 2,500 Glider Days
~ 130,000 GTS Profiles

Annual Glider Profiles & Days

2021 Goal
~ 2,500 Glider Days
~ 130,000 GTS Profiles
Partnerships Make it Possible

<table>
<thead>
<tr>
<th>Region</th>
<th>Operator Support</th>
<th>Lead by</th>
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<tbody>
<tr>
<td>Tropical Atlantic &amp; Caribbean</td>
<td>MARACOOS, CARICOOS, CIMAS</td>
<td>THE G. UNGER VETLESEN FOUNDATION</td>
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<tr>
<td>Mid-Atlantic Bight</td>
<td>Rutgers University of Delaware, UMass, VIMS, William &amp; Mary, University of Virginia</td>
<td>IOOS, Integrated Ocean Observing System</td>
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<tr>
<td>Gulf of Mexico</td>
<td>GCOOS, NGSO</td>
<td>USF, University of South Florida</td>
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<tr>
<td>South Atlantic Bight</td>
<td>SECOORA, Skidaway Institute of Oceanography, University of Georgia</td>
<td>USF, University of South Florida</td>
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<td>Regional Association of Coastal Ocean Observing Systems (RACCOOS)</td>
<td>Integrated Ocean Observing System (IOOS)</td>
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- 79 missions in the Atlantic basin contributed data
- 82% success, determined by ≥ 15 days at sea
- 44 Hurricane Gliders deployed, collectively acquiring data for 2,359 combined days at sea
- IOOS Glider Data Assembly Center (GDAC) allowed NOAA to leverage data from an additional 35 gliders (1,308 Days)
- 15+ Institutions provided data in support of the project
- 118,563 ocean profiles were submitted to the GTS by the IOOS GDAC in support of this project
Glider data are assimilated into operational RTOFS

>95% of glider profiles collected pass QC and are delivered to the GTS and used in ocean forecast models

Glider profile data collected by provider

Data access and visualization

IOOS DAC

AOML OceanViewer

Regional coupled hurricane models
(HMON, HWRF and HAFS)
Storm Highlight: Ida - *Ocean Features and Intensity*

Storm was forecast to track across Gulf of Mexico Essential Ocean Features:
- The Loop Current, a Loop Current Eddy, and Freshwater Barrier Layer

- Ida began to rapidly intensify over the warm and deep Loop Current, reaching peak intensity over coastal waters with a freshwater barrier layer
Vertical black lines = approximate eye-passage time
Initial (left of black line) ocean temperature and salinity compared well between the model and glider
Saildrone-Glider co-location

First quasi-collocated / quasi-simultaneous observations of upper ocean and meteorological parameters from fully autonomous, uncrewed vehicles for hurricane studies and forecasts
Challenges

- Ad-hoc & Sporadic Funding
  - Funding cycles out of phase with hurricane season operations
  - Recapitalization is a growing challenge
- Manufacture bottleneck creates delays
- Community access to operational models and the DA increments for storm simulation studies
  - More multi-platform OSEs and OSSEs needed to optimize pre-storm conditions.
- Getting ocean information to NHC forecasters during hurricane season
2022 plans

- Deployments similar locations to 2021
  - 2022 Disaster Supplemental funding
- Continue Navy-NOAA glider coordination (OMAO)
- Coordination with Saildrone project
- Contribute to Global Ocean Monitoring and Observing (GOMO) 2022 Integrated Field Campaign
Questions