# Glider Observations of Hurricane Passages near Bermuda in 2014 and 2015


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MAGIC
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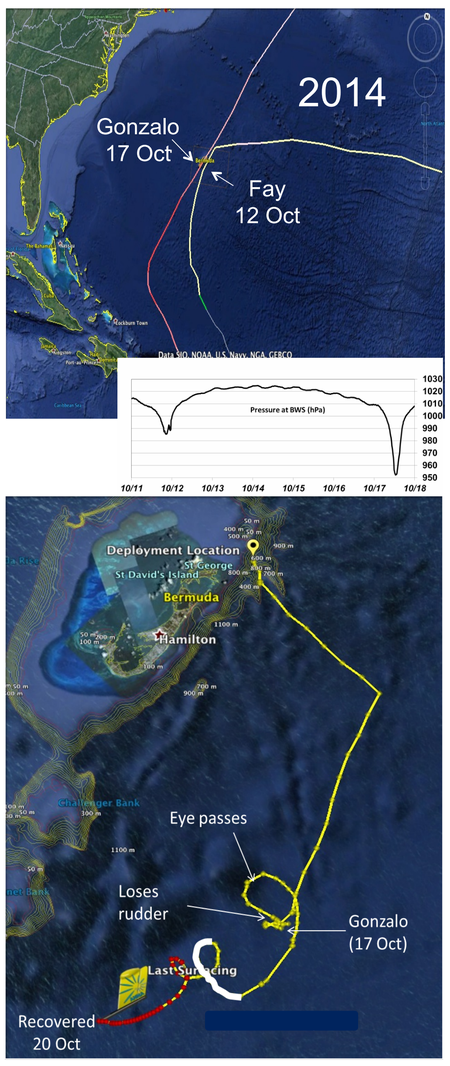
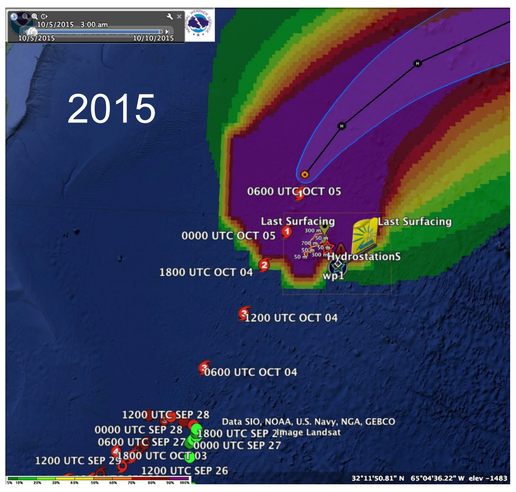
## Three hurricanes in 2 years…

In October 2014, Hurricanes Fay and Gonzalo hit Bermuda within a single week. BIOS deployed a deep Slocum glider ('Anna') within 2 days of Fay's passage and it was positioned directly under the eyewall of Gonzalo, a Category 3 hurricane, as it passed overhead. The glider recorded the evolution of the cold wake created by the two storms, including a 4°C surface temperature drop, deepening of the mixed layer, and breaking internal waves at the base of the mixed layer. By varying dive depths during the mission, estimates of the near surface inertial current speeds were obtained.

As the winds rose toward their peak on Oct 17, the glider's tail rudder was sheared off. Unable to steer, Anna effectively became a profiling drifter, tracking the strong inertial currents that developed in the surface mixed layer. The vehicle's pitch, roll and heading characteristics reflected turbulence and vertical shear in the mixed layer and its underlying boundary which exhibited 50 meter vertical oscillations with a period of ~23 hours corresponding to the local inertial frequency. These internal waves are caused by wind gusts imparting mechanical energy to the ocean which resonates at near-inertial frequencies.




Anna's track line from deployment to recovery (Oct 14-20), the encounter with Gonzalo and loop-de-loop pathway tracing inertial currents created by the storm's transfer of momentum to the ocean.

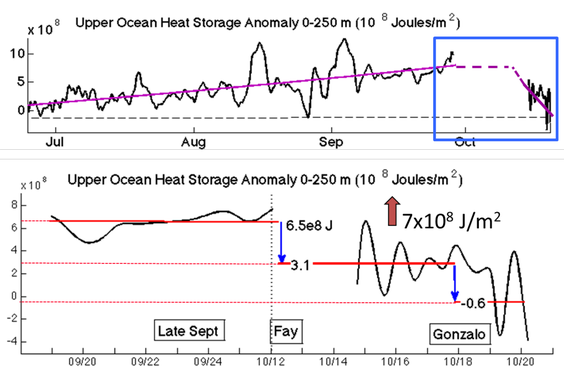



A year later on Oct 4/5 2015, Hurricane Joaquin passed about 60 miles to the west of the island as a Category 1 storm. BIOS had gliders 'Jack' and 'Minnie' in the water ~50 miles SSE of the island profiling before, during and after the event. Because of the distance from the storm center, the gliders recorded a greatly reduced ocean response compared to Fay and Gonzalo.

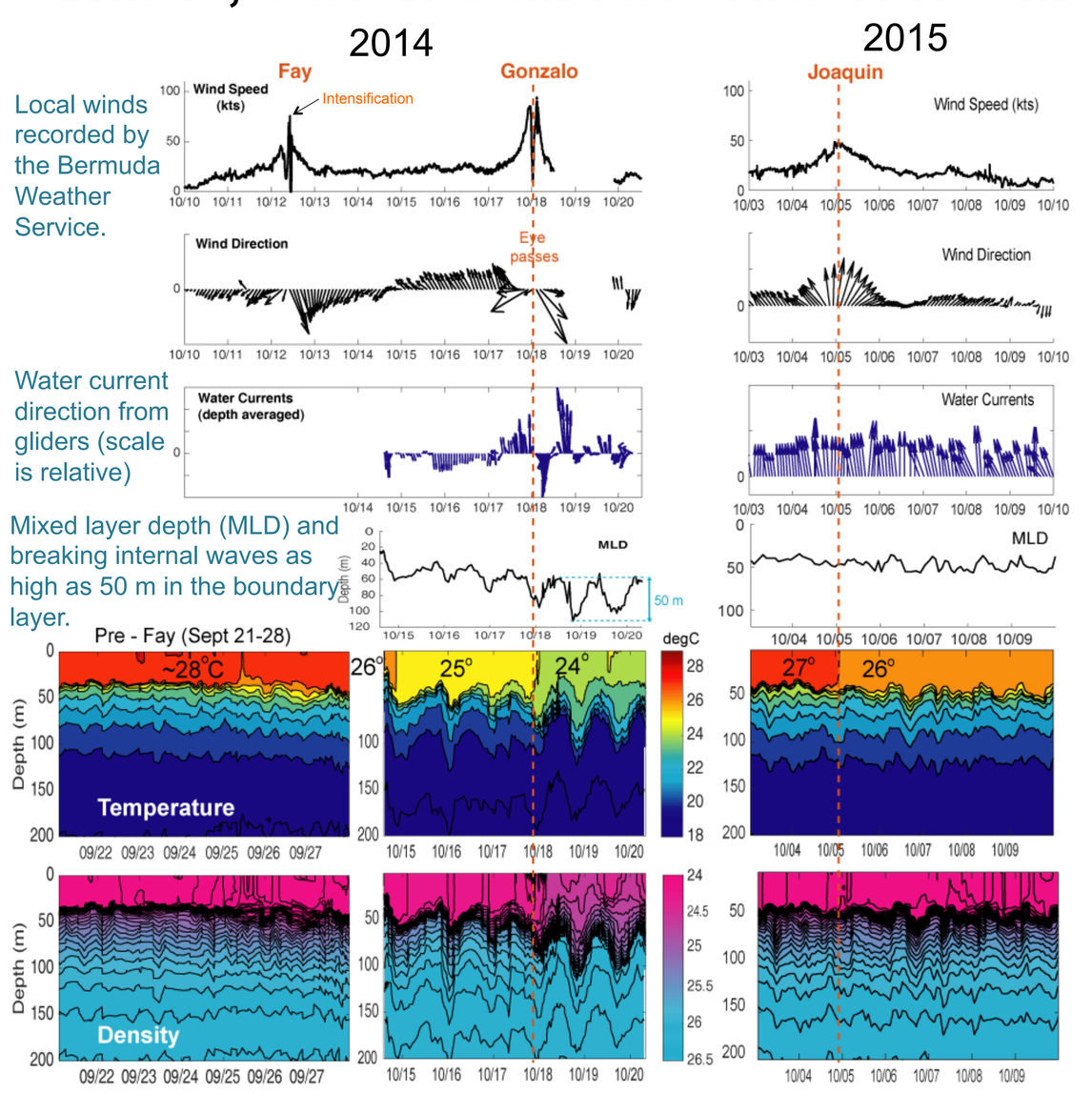
## The cold wake of Fay & Gonzalo

Upper ocean heat content gains measured by Anna over the summer of 2014 were removed in 1 week by the 2 tropical storms.

Each resulted in heat storage reductions of ~3-4 J $m^{-2}$ in the 0-250 m layer. Surface heat flux was a factor causing Fay to intensify from a T.S. to hurricane as it passed Bermuda. Gonzalo actually weakened as it passed over Fay's cold wake just before it reached the island. Mixing of surface and deeper layers contributed to the overall reduction in heat content.

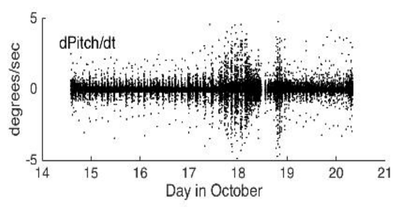



## Winds, currents and internal waves...

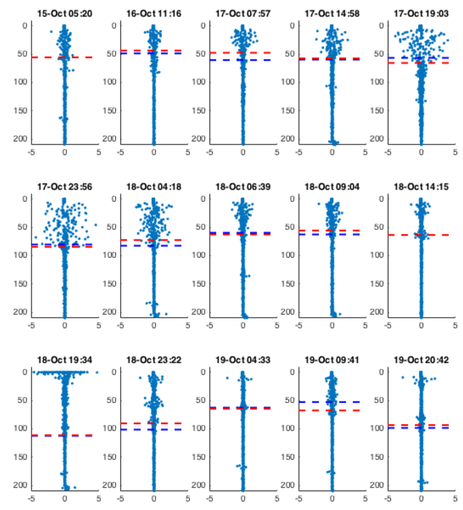



Glider-measured time series of temperature and density recorded a 4-deg C cooling and density increases associated with the 2014 storms. A stable ocean structure in the last week of Sept (left panels) contrasted sharply with the internal waves and turbulent mixing following Fay and Gonzalo (middle panel). In 2015, Joaquin registered a much smaller response (right panel) as the hurricane's center passed ~80 km to the west of the glider's location.

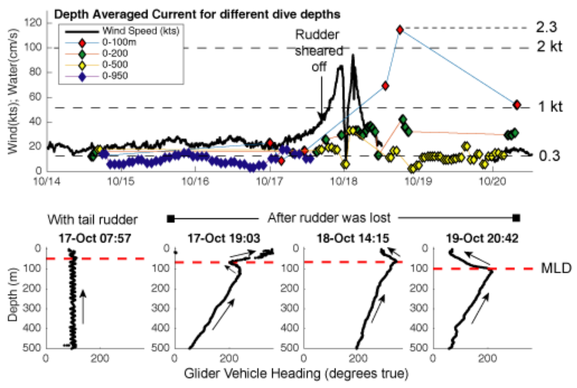
## Glider pitch characteristics reflect turbulent mixing above the base of the mixed layer …




Time series of dPitch/dt during the Gonzalo deployment (above) and individual yo profiles from the mission (right) with corresponding date/time annotated. Mixed Layer Depth for dives (blue) and climbs (red) are denoted by dashed lines




## … water currents measured for different dive depths and heading changes reflect strong vertical shear



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