

## Reconfiguration of Webb-style Gliders for Routine Turbulence Measurements

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### LONG-TERM GOALS

The long-term goal of this program is to understand the physics of small-scale oceanic processes including internal waves, hydraulics, turbulence and microstructure that act to perturb and control the circulation in coastal oceans and, in doing so, affect the propagation of sound and light. Ongoing studies within the **Ocean Mixing Group** at OSU emphasize observations, interaction with turbulence modelers and an aggressive program of sensor / instrumentation development and integration. This includes extending measurements to new platforms such as gliders so that we can make continued measurements *where* ships cannot go (or *when* they cannot be there, such as during periods of extreme surface forcing).

### OBJECTIVES

Gliders offer a means of making two very valuable types of relatively autonomous measurements in the ocean. The first is the type of repeated routine observation that permits establishment of a climatology from which significant deviations can be identified and addressed. The second is the observation of extreme events (such as hurricanes) that cannot be made from ships. Over the past 20 years, we have established standards of ocean turbulence measurements and have extended our ship-based vertical and horizontal profiling packages to moored mixing measurements. It has been a natural evolution to use this expertise to integrate new sensors into gliders that will both begin to define climatologies of mixing in coastal waters and lead to turbulence measurements in events such as hurricanes and typhoons, for which we have limited or no observation.

In particular, the mechanical design of the Webb Research glider is robust and proven. The prospects for measuring turbulence and surface waves on these gliders have been recently tested by us by strapping a turbulence / motion-sensing package to both OSU and Rutgers gliders. Results have been sufficiently encouraging that we are now reconfiguring two existing gliders (one at Oregon State University, the other at Rutgers University) to achieve the following objectives from an integrated package:

# Report Documentation Page

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- routine and continuous measurement of turbulence in the form of the temperature variance dissipation rate,  $\chi$ , the turbulence kinetic energy dissipation rate,  $\varepsilon$ , and the turbulence diffusion coefficients,  $K_T$  and  $K_\rho$ ;
- routine and continuous measurement of water-column velocity;
- routine measurement and transmission of significant wave height and direction when surfaced using a 6-axis accelerometer package;
- detection of nonlinear internal waves using the same motion package and transmission of wave properties.

## APPROACH

We have added external turbulence pods to gliders. These pods include inertial motion (6 components of acceleration), fast thermistors, shear probes and gust probes (to measure three components of velocity with multiple pitot tubes). The advantage of an external pod is that it can be deployed on any glider of the same design. However, a significant disadvantage is that it slows the glider speed, thereby reducing its range/endurance for a given deployment. External pods also increase the probability of a glider getting tangled in fishing gear. Analyses of the data obtained to date have been used to incorporate the pod into an integrated turbulence package (Figure 1).

## WORK COMPLETED

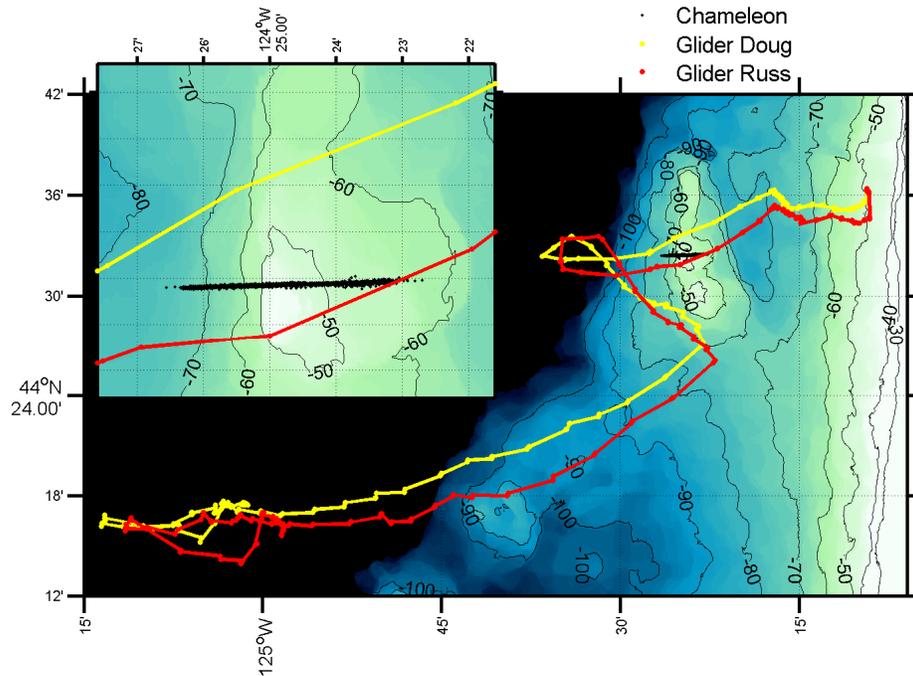
Tests were conducted in June 2008 (external pod), June 2009 and June 2010 (internal pod) over Stonewall Bank on Oregon's continental shelf. These were coordinated with Chameleon turbulence profiling. A glider with an external turbulence package and internal inertial motion package was launched by the Rutgers glider group off NJ in early September 2008 to encounter Tropical Storm Hanna, which it did. This glider was recovered in early October following a successful mission through an energetic storm



*Figure 1 – Photograph of Webb glider with internal turbulence pod upon deployment in June 2009 over Stonewall Bank on Oregon's continental shelf.*

## RESULTS

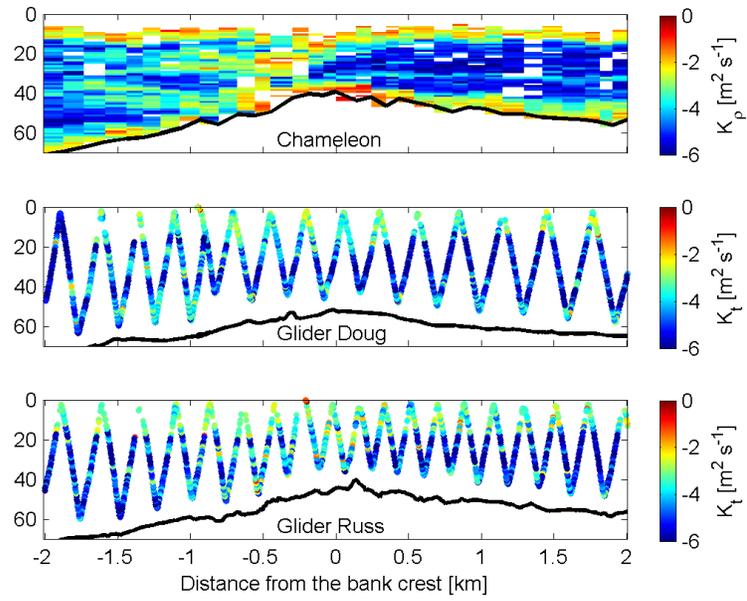
Deployments in June 2010 over Oregon's continental shelf (Fig. 2) provide a basis for direct comparison of turbulence measurements from gliders and Chameleon (Figs. 3,4). These 2 glider deployments tracked each other very well (Fig. 2) and transited Stonewall Bank as turbulence profiling operations using Chameleon were in progress.



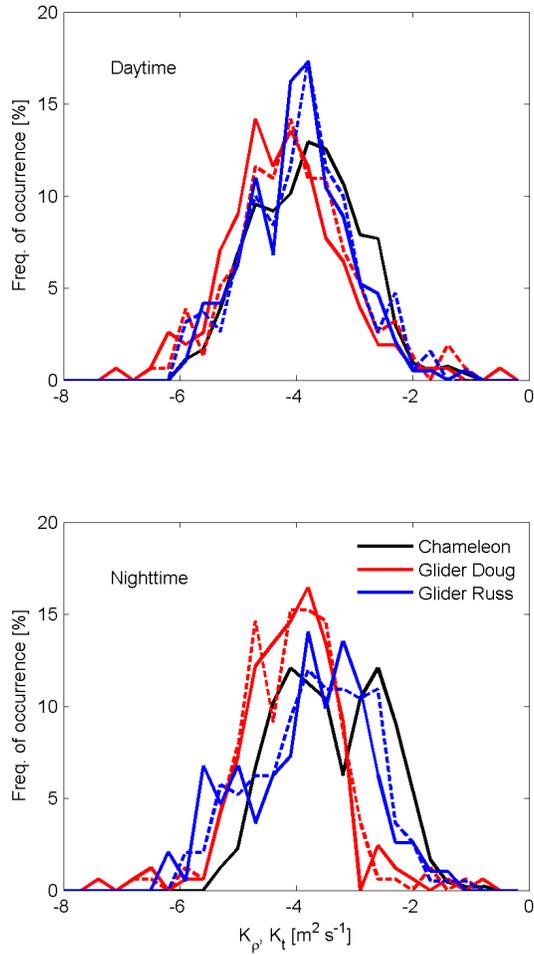
**Figure 2 – Bathymetry of Oregon shelf in the vicinity of Stonewall Bank. During intensive Chameleon profiling (black dots) and lander-based observations of strong bank-related flows in June 2010, gliders Doug (yellow) and Russ (red) were flown directly over the bank while profiling. Full set of glider tracks are shown - bank details are inset.**

Measurements across the bank are shown in Fig. 3. The Chameleon transect took about 40 minutes and crossed over the shallowest part of the bank where the strongest flows are anticipated. Glider transects took about 3 hours; Russ crossed directly over the bank, while Doug steered a course roughly five miles north of its summit. Direct comparisons between the measurements shown in Fig. 3 are specious at best. A better comparison is statistical, as in Fig. 4, based on several 10s of thousands of independent estimates over a 7 day period. This comparison makes several points:

- 1) independent estimates of  $K_T$  from 2 different sensors on the same glider differ from each other far less than they differ from estimates on different platforms.
- 2) estimates of  $K_T$  differ between the 2 gliders. This should not be surprising as they are separated by roughly a few km throughout the deployment.
- 3) Day/night differences differ significantly for all platforms. Nighttime values are higher, as expected due to changes in buoyancy forcing common in the upper 20 m.
- 4) Chameleon values are statistically larger. Pending further investigation, we expect this is due to the more energetic flows found over Stonewall Bank where Chameleon measurements were focused for the full period of comparison.



**Figure 3** — Series of turbulence diffusivity ( $K_T$ ). These are derived from sensors on Chameleon (upper panel), glider Doug (middle panel) and glider Russ (lower panel). Passes over the bank were coincident neither in time nor space.



**Figure 4** — Distributions of  $K_T$  in the depth range 10-20 m from Chameleon, glider Doug and glider Russ over a 7-day period in June 2010. The glider paths were reasonably close to each other (Fig. 2) while Chameleon remained over the energetic Stonewall Bank. Solid and dashed lines represent independent estimates made from 2 different sensors on each glider.