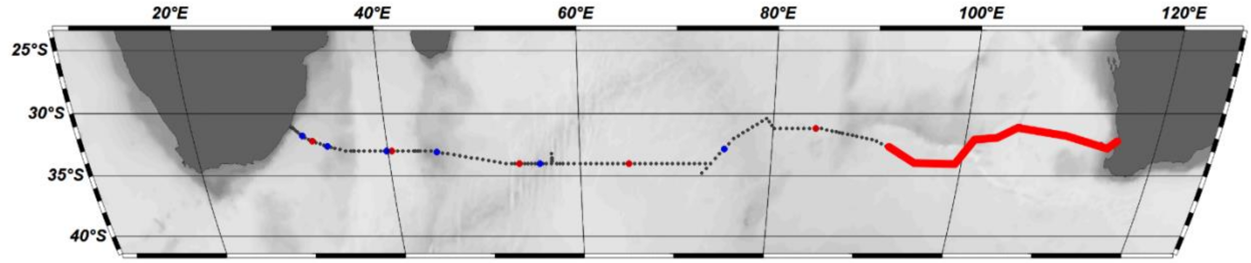
I05_2023 Weekly update 8/6/2023

Update 2 of 7



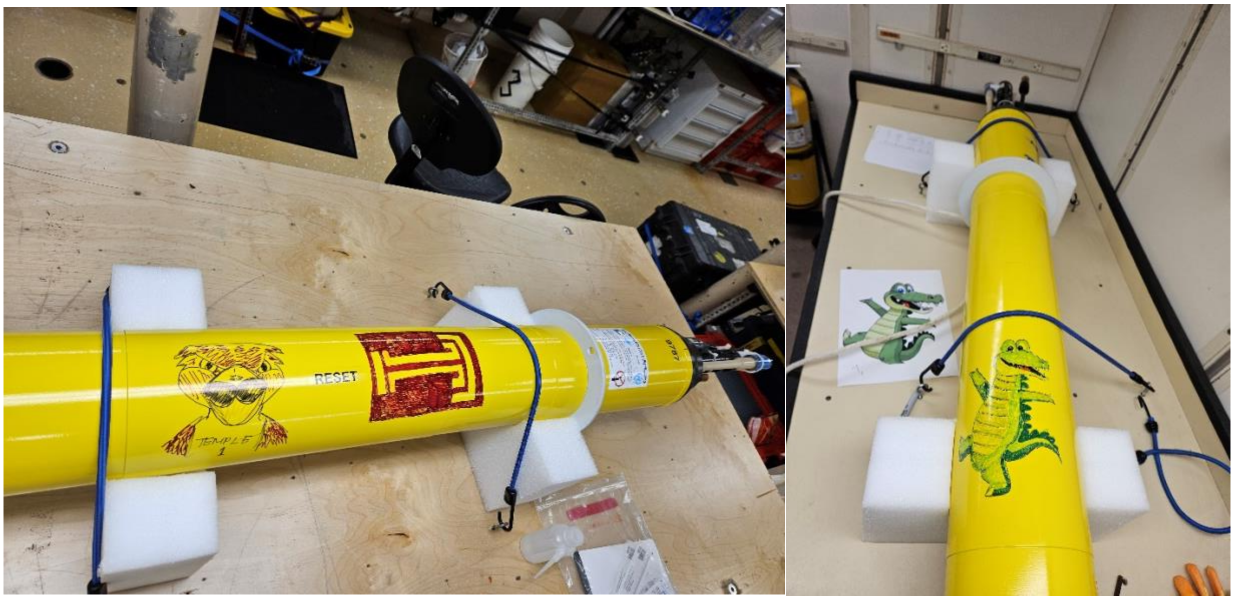
A map of our planned cruise track with the completed stations covered with a red line. Upcoming planned and potential float deployment locations have larger dots.

Highlights (as of 8/6)

- 57 stations (34 new since last update) completed with 15 stations (9 new) with biological measurements
- 4 floats (3 new) and 3 drifters (3 new) deployed: 1 SQUID float, two biogeochemical Argo floats (*Gator* and *Hooter*), 2 "Directional Wave Spectra Barometric Drifters" (DWSBDs), and 1 drifter from the National Oceanographic and Atmospheric Administration (NOAA).
- 21 hours of weather time
- Transient tracer (CFC) team operational again
- Can't get enough I05 updates? Check out the I05 blog with updates from scientists and crew appearing at the bottom as they are written.

We have had a productive week, though we were hit by several days of rough weather, including a 21 hour period in which ~6.8 m (22') waves prevented us from conducting our normal station operations. Then we had several days of calm and now a squall is roaring by just south of us; the boat is currently rocking in 28 knot winds, but thankfully the confused wind direction has only built up 3.6 m (12') waves. Station operations are continuing, though slowly to minimize tension spikes on the 32mm diameter cabled wire that connects the several ton Niskin-rosette/sensor/frame package to our heaving boat.

The I05 cruise has a very ambitious schedule, with a long swath of Indian Ocean to cross and several regions of planned higher resolution sampling. As such, the various weather delays from this week and last already have us thinking about ways to preserve time for future work. We've enacted several measures to save time that leverage the immense 36 bottle capacity of our sampling rosette. However, to explain the rationales behind these measures we should first segue into an explanation of why the I05 cruise track has so many seemingly-random wiggles (see above).



Some of the great volunteer artistry our CTD watchstanders did on behalf of the Adopt-a-Float program, where various school classrooms decorate and name a float, and then incorporate the data from that float into their curriculum. These floats are designed to float at ~1000 m depth, then sink to ~2000 m before rising to the surface, making measurements along the way. Then they report their data by satellite and sink back down to start the cycle again 10 days later. Photo credit: Aurélie Moulin.

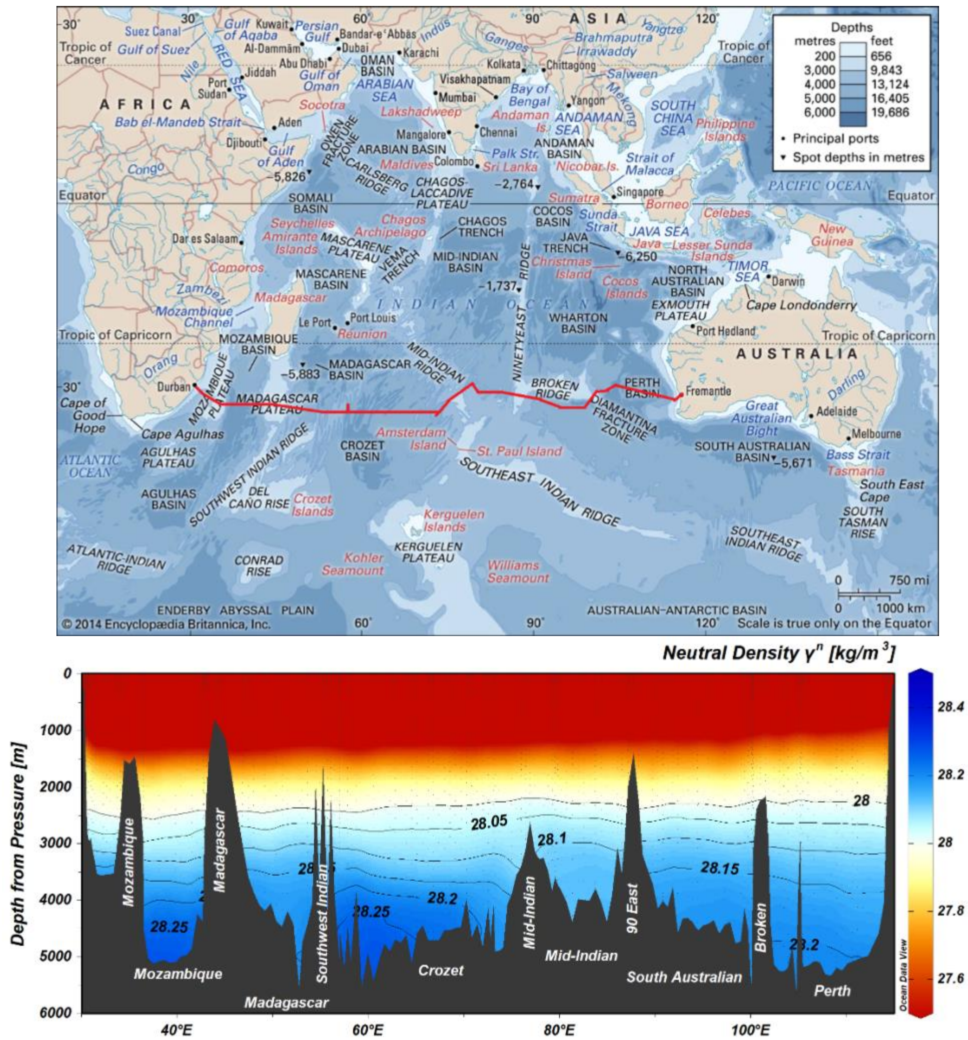
I05 bathymetry and GO-SHIP

The non-linear I05 cruise track is a result of the rugged seafloor of the Indian Ocean. Like most ocean basins, the deep Indian Ocean is carved into deeper basins separated by shallower ridges where the seafloor is currently (or was previously) being ripped apart by tectonic forces.

As GO-SHIP is one of the only measurement programs that permits long-term deep ocean monitoring, it is important that we measure the deepest and densest waters in the ocean wherever possible on our sections. Here, these waters form to the south when surface waters cool and slide down the Antarctic Continental shelf. From there, these “Antarctic Bottom Waters” flow northward hugging the ocean floor, expanding out through the other ocean basins, and sliding below (and mixing with) their slightly warmer and saltier cousin water mass (that originates from salty Gulf Stream waters being cooled by the boreal winter in the far northern reaches of Atlantic Ocean). However, the deep Indian Ocean looks a little bit like an ice cube tray designed by a mad scientist, so these bottom-dwelling deep waters can’t flow directly from one basin to another. Instead, they flow into the various ocean basins and rely on gaps in the ridges that separate the ocean basins to exchange their coldest and deepest waters. Of the basins we cross, the densest waters are found in the Mozambique and Crozet basins, because these two basins have a more or-less unobstructed bottom water path from Antarctica.

The ridges are also important because they interact with the Coriolis force to guide the flows of deep ocean waters, and the rough topography induces vertical mixing between water masses when water masses flow around and over the mountainous subsea ridges (similar to how updrafts and turbulence occur when winds move through mountain ranges). As a chemical oceanographer, a naïve generalization seems to be that few things get physical oceanographers more excited than vertical ocean mixing, which is how deeper dense waters exchange with the overlying more buoyant waters masses. This exchange is a critical piece of the puzzle of how deep waters form, move, and are eventually destroyed in the interior of the ocean, thereby making room for new cold waters to fill the ocean depths.

Given how remote and isolated these deep ocean basins are, it is alarming that scientists have detected both warming and freshening of these water masses over the last several decades using GO-SHIP measurements. The warming is a simple consequence of climate change from heat-trapping human CO_2 emissions to the atmosphere, and the freshening is thought to be due to the input of freshwater from melting Antarctic ice. Human induced climate change is truly a global phenomenon with no part of Earth's surface and oceans untouched. It is part of GO-SHIP's mission to continue to measure these changes, including on I05.



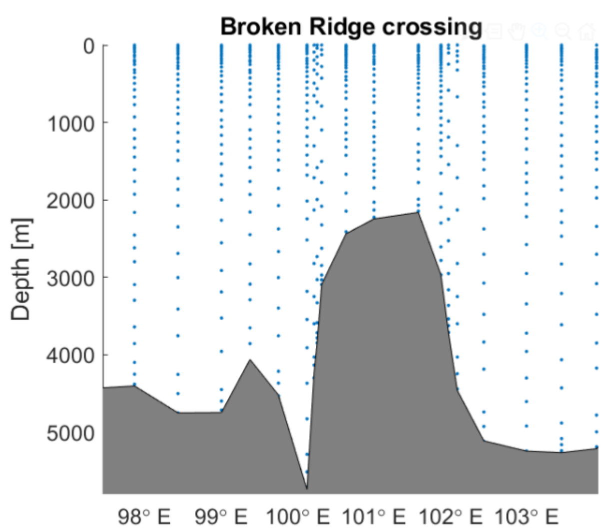
(TOP) Map of the I05 cruise track superimposed over a labeled diagram of the deep Indian Ocean from the online Encyclopedia Brittanica. (BOTTOM) Section of neutral density anomaly along the I05 cruise track as measured in 2009 with the various ridges (vertically labeled) and basins (horizontally labeled) indicated. Neutral density anomaly is used to keep track of the relative density of various water masses.

All of that noted, if our cruise merely went straight from Fremantle to Durban at 32° S, then we would follow along the shallowest parts of the Broken Ridge and miss some of the deepest and most interesting parts of the Perth, South Australian, and Crozet Basins, so instead we wiggle to try to measure seawater changes in these deep basins. In a few places, the result is our cruise track runs over a steep ridge at a nearly right angle like a speed bump. This causes us to slow down a bit by putting our stations closer together: the interesting flows that follow bathymetric features mean that we need to increase our CTD-O_2 (which measures salinity, temperature, depth, and dissolved oxygen content), Chipod (which measures temperature microstructure and allows inferences of turbulence and vertical mixing), and LADCP (which measures subsurface ocean currents) sensor resolution during these ridge crossings.

Time saving measures

The need for higher resolution sampling during ridge crossings is primarily due to our greater need for sensor and (to a lesser degree) bottle samples in the *deep* ocean. However, the reason that we need to slow down during these crossings is because of the need for additional time to sample and analyze the extra bottle measurements that come from all depths of these closely-spaced stations, as well as the time needed to prepare the rosette to go back into the water. Recognizing that the *surface* samples are less of a priority during these ridge crossings, we opt to conduct the stations as normal, but only trigger bottle samples at full vertical resolution from the seafloor to the depths just above the depth of the ridge itself. This allows our analysts to focus on the most interesting parts of the water column while saving time and capacity (e.g., empty bottles) from the upper parts of the ocean for the next station with nominal 30 nautical mile spacing. This also allows our CTD watch standers to have the sensor and bottle package (very nearly) ready for deployment to begin collecting sensor data by the time we get on the next station (which is a shorter wait than usual due to the close station spacing).

Fortuitously, three of our recent biological stations occurred during our four completed ridge crossings. At these stations, we used the Niskin bottles that usually capture surface seawater (for the analyses that were skipped with the close station spacing) to replace the Niskins needed for the biological casts. This saved us the time that we had previously been using to conduct a second biological cast to 1000 m depth.



Sample depths crossing the Broken Ridge in 2023, with higher resolution near the bathymetric changes.

Going forward, we plan to use a similar strategy to claw back some time lost to bad weather, forgoing some of the daily separate biological casts (collocated with ~1/4 of our chemistry stations) by dedicating a subset (currently 4) of our 36 bottles to these biological properties. We are able to do this even on the stations spaced by the nominal 30 nautical miles because the majority of our chemistry analysts cannot sample all the bottles on a 36-position rosette at every station. We will revert to doing separate biological casts if timing permits, which would slow down the rate of sample acquisition and allow our chemistry analysts more opportunity to keep up with our brisk pace.

Data

An upside to the weather delays is that our analysts were able to get fully caught up on measurements and then use some of the remainder of the time to work up and submit their data. Even the Transient Tracer team managed to finish their sample backlog *after* rebuilding many parts of their measurement system in the Hydro Lab (see: last week's wave). Expect some early results in next week's update, but my preliminary dive into the new measurements already has me excited about the high quality of data being produced by this team of amazing scientists.