**Progress Report: OSTST17 Science Team**
**Cross-Shelf Exchanges in the South African EBC/WBC System**

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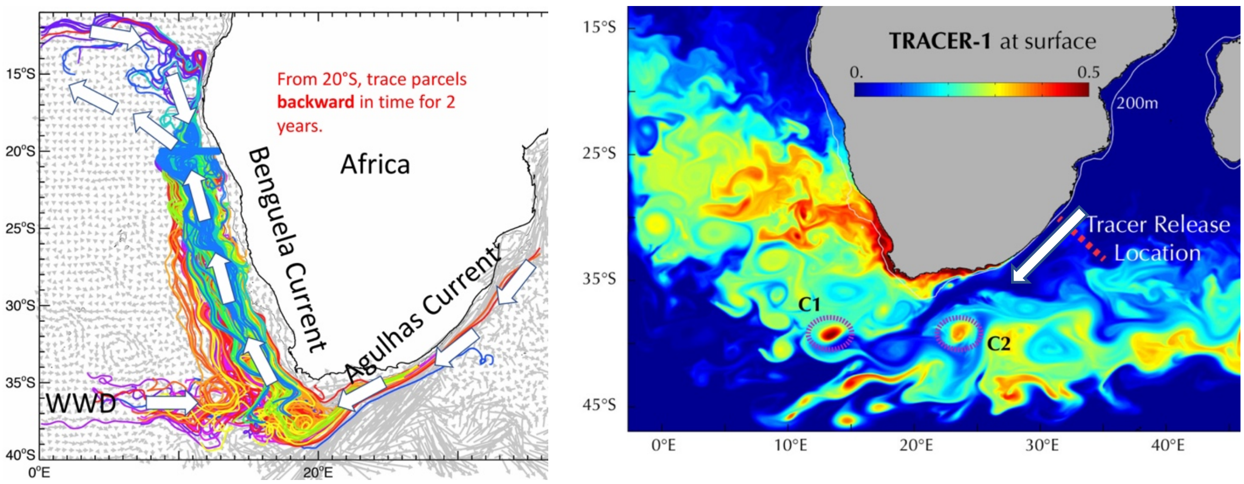



**Two Views of the Agulhas-Benguela System: Altimeter and Model**
***(Left):*** Altimeter-derived trajectories formed by tracing backward in time for two years from water parcels released along the west coast of Africa at 20°S, mapping the sources of the Benguela Current.
***(Right):*** Model mapping of tracers released beneath 200m along a transect (red dots) on the SE side of South Africa, after two years of advection in the Agulhas Current and upwelling on to the Agulhas Bank and southwest shelf and entrainment into the offshore circulation to the northwest.

Our present work on the South African boundary currents began during preparation for the 2016 OSTST proposal, interacting with South African colleagues in preparing preliminary analyses and presentations in 2015-2016 (Strub et al., 2015; Strub et al., 2016). After funding began in March 2017, direct interactions with a larger group of South African oceanographers (observationalists and modelers) occurred during the IAPSO meeting in Cape Town in September 2017 (see references to Strub et al., 2017b; and Risien et al, 2017). These interactions were helpful in identifying several problems in the altimeter analyses, as planned. These involved the use of the 2013 version of the Mean Dynamic Topography (CLS13-MDT) and in our Altimeter-Tide Gauge analysis. To address these problems, we began an investigation of the ALES alongtrack coastal altimeter product as a substitute for the tide gauges and P.T. Strub search for alternate mean surface height and velocity fields from Delft Technical University or global models. These proved less than adequate but Strub contacted CLS and joined the evaluation of the initial version of the 2018 CLS MDT, which eventually provided a solution to the problem.

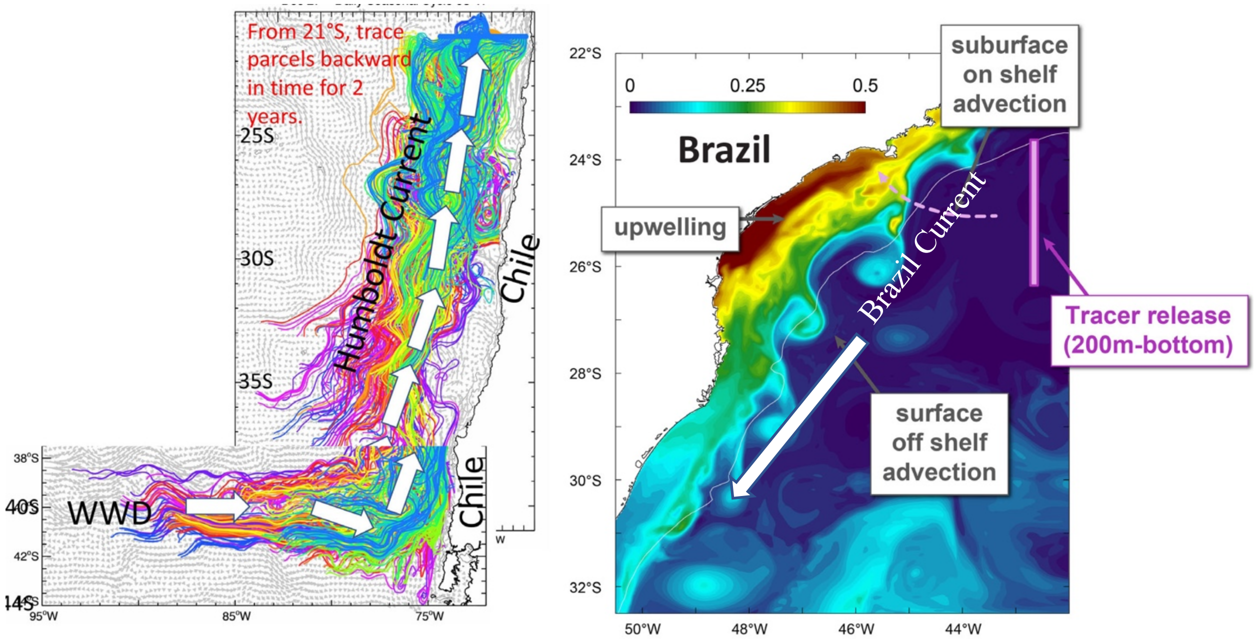
During 2017-18, the high-resolution modeling of the large-scale region around South Africa was completed and analysis commenced, as reported by Matano et al. (2018b) at the OSTST meeting in the Azores and Combes et al. (2019b) at the Chicago OSTST meeting. See also the Matano et al. (2020) presentation here at the OSTST-2020 Large-Scale Circulation session. Manuscripts describing the model analysis of the Agulhas-Benguela circulation and shelf-deep ocean exchanges are in preparation. This analysis shows that the western and eastern shelves of Africa form a quite unique system connected by the inflows of deep ocean waters from the Agulhas Current. Most notably, we found that the interactions driving these inflows also represent a significant contribution to the Indian/Atlantic interocean exchange and hence to the meridional overturning circulation. Preliminary calculations suggest that 10 to 20% of the water mass transformations and exchanges occurring in this region are accounted for by the intense mixing and advection processes that are associated with shelf/deep-ocean interactions.

Attempts to blend the AVISO gridded SLA fields with tide gauges along the Cape Region of SW Africa (as done off the western US by Risien and Strub, 2016) were halted due to the low correlations between the tide gauge and altimeter data, as presented by Risien et al. (2017) and Strub et al. (2017a). This lack of correlation between tide gauge and altimeter data along SW Africa has since been confirmed by others (several posters at the OSTST 2019 Coastal Altimetry session). To substitute for the tide gauge data, we have investigated whether the ALES alongtrack SLA data set improves on the RADS data set, examining the data in detail along the US West Coast, where the correlations are good. A novel approach was devised by M. Fewings, who joined the project in 2018, based on her previous analyses of wind-relaxations along the US West Coast. These relaxations produce coastal trapped waves with relatively small height signals that have long evaded detection by altimeters, due to their rapid phase velocities. But by compositing altimeter data over many events, Fewings et al. (2019) showed that the blended TG/altimeter data set of Risien and Strub (2016) could capture the rise in sea level along the coast poleward of the wind event over the several days following the event. The blended data set captured this result but the standard AVISO gridded altimeter SLA product did not, prompting us to look at the alongtrack data from the ALES and RADS data sets. Strub et al. (2020b) present the results at this OSTST 2020 meeting in the Coastal Altimetry session. The net result of these analyses is that the ALES alongtrack data reproduce the tide gauge results and show the sea level response at the coast as the coastal trapped waves move poleward, if enough events can be sampled and composited. The RADS data are not quite as successful, due to a lower number of data retrievals near the coast. We are proceeding with our analysis of the South African systems using both data sets but with a preference for the ALES data for analysis after 2002 (the beginning of the data set). The RADS data extend back to October, 1992, and so must be used for some analyses.

The problem with the CLS13 MDT is that it produces unrealistic long-term mean velocities (in the wrong direction) in the coastal regions off the southern Benguela and also on the Agulhas Bank. During 2019-2020 P.T. Strub evaluated the more recent CNES-CLS18 MDT height and velocity fields, collaborating with S. Mulet at CLS (Rio et al., 2020). This MDT removes both of the problems found with CLS13 and is now being used in all analyses (it is now the CLS default for everyone). Since the mean velocities are needed to calculate the trajectories, work on the trajectories waited for this more realistic mean velocity field and is now proceeding.

During 2019-2020 we developed the capability to calculate surface water parcel trajectories from the daily AVISO gridded SLA altimeter velocities. Initial results for the exchanges of water parcels between the Agulhas Bank and the Benguela Current were presented at the 2019 OSTST Chicago meeting (Strub et al., 2019b) and we include some of these in our presentation (Large-

Scale Circulation) at this OSTST 2020 meeting (Strub et al., 2020). We have also used the trajectory analysis approach in looking at the source for the warm anomalies in the northern and southern Benguela Current during their interannual "Benguela Niños", also presented in Chicago by Strub et al. (2019b).




**Comparable EBC and WBC Systems**

(***Left):*** Altimeter-derived trajectories tracked backward in time for two years for water parcels released at 21°S and 35°S (cut and paste of two figures), showing source waters for the Humboldt Current.
***(Right):*** Model mapping of tracers released offshore below 200m in the Brazil Current, which upwells over the shelf and moves south, while also advecting off the shelf in eddies.

Given the delays and time spent evaluating new approaches to the analyses in the South African systems, we have put some of our efforts into analyses of comparable systems in the Southwestern Atlantic (the Brazil and Malvinas West Boundary Currents, WBCs, above figure on the right) and in the eastern North and South Pacific (the California Current and the Humboldt Current Eastern Boundary Currents, EBCs, respectively, above figure on the left). This was especially timely in the Pacific, where the 2015-16 El Niño provided a natural comparison to our analyses of the 1997-98 El Niño (Peterson et al., 2017; Strub et al., 2018a, 2018b, 2019a; Saldias et al., 2020). In these analyses, we used 'pseudo-Lagrangian' presentations of 'progressive vector diagrams', which motivated the development of our present methods of using true Lagrangian trajectories to define pathways of interactions (both altimetry and model). These are now being used in our analyses of the South African systems (see the Matano and Strub presentations in the Large-Scale Circulation session) and will be used in the future to look at pathways of water mass exchanges and water mass modifications during periods of more extreme interannual climate variability (ENSO extremes, marine heat waves, etc.), as we have described in our new OSTST20 proposal.

As with our analyses of comparable EBCs in the eastern Pacific, we have investigated the processes that govern shelf-and-deep ocean exchanges in comparable WBCs in the southwest Atlantic, i.e., the Brazil and Malvinas Currents (Matano et al., 2018a, 2019, 2020; Combes and Matano, 2018, 2019). Our attention was focused on the Brazil Current, which is the Atlantic counterpart of the Agulhas Current. We found strong similarities between the two systems: in both cases shelf/deep-ocean exchanges are largely driven by the interactions of mesoscale eddies with the continental slope. The most important difference between these two region is associated with the coastline geometry, which in the case of the South Brazil Bight allows for the development of an alongshelf pressure gradient and, hence, for a geostrophically balanced cross-shelf flow. There is no similar feature in the southern African coastline and, hence, most of the cross-shelf flows are driven by eddies.

Throughout the course of this project, Strub has been engaged in an outreach effort that reached a conclusion and bore fruit in 2019. Strub teamed with a colleague (F. Conway) in the Marine Resource Management group and her student (J. Kuonen) to make the fields from an ocean forecast system available to Oregon fishermen. The ocean forecast model was previously designed for the Oregon coast by A. Kuropov, who implemented a data assimilation process of the near real-time altimeter along track data. This improves the realism of the mesoscale features in the forecast surface fields. The outreach effort consisted of the collaborative development of the web site that makes the data available, in a format designed with the help of the fishermen. This collaborative effort resulted in a web site design that was adopted by the Integrated Ocean Observation System node in Seattle (called NANOOS), now running under their NANOOS Visualization System (available at http://nvs.nanoos.org/Seacast). It also resulted in two papers and several presentations (Kuonen et al., 2019a, 201b; Strub et al., 2019c, 2019d, 2019e).

In summary, a number of investigations have been required to address problems encountered in the satellite analysis early in the project, while the modeling work has proceeded as planned. Additional efforts have been put into investigations of comparable EBC and WBC systems. A highly successful outreach effort has resulted in the availability of a coastal ocean forecasts to the fishing community, using a model that assimilates near real-time altimeter data. The list of papers and presentations below documents the progress to date. The core analyses of the project in the coupled Agulhas and Benguela Current Systems are nearing completion and will be submitted for publication during the remainder of this fourth year. Additional analyses of the interannual variability of the system will be finished and submitted for publication during an expected year of a no-cost extension.

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