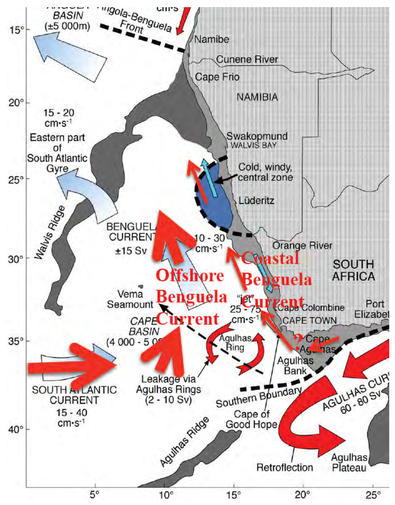
Coastal Circulation in the Southern Benguela Current

Ted Strub[1], Corinne James[1], Ricardo Matano[1], Vincent Combes[1], Juliet Hermes[2] , Charine Collins[3] ,Frank Shillington[3]

[1]College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR U.S.A.

[2]South African Environmental Observation Network, [3]University of Cape Town

Schematic of the Benguela Current System, from Field and Shillington (2006)



How is transport from the southern upwelling and spawning regions to the northern nursery areas accomplished?
How does transport along the west coast change seasonally?

Transport between the Agulhas Bank along the southern coast of South Africa and the SW coast of South Africa is a necessary part of the life history of the small pelagic fish that make up a significant part of the fishery in this region.

Wind Forcing:

The seasonal movement of the wind systems creates a system of upwelling centers:

- **North of Luderitz: Seasonal upwelling maxima in winter (July-September)**
- **Luderitz: Permanent upwelling, year-round**
- **Cape Town and the SW Coast (33°-35°S): Seasonal upwelling maxima in spring-summer (October-March)**

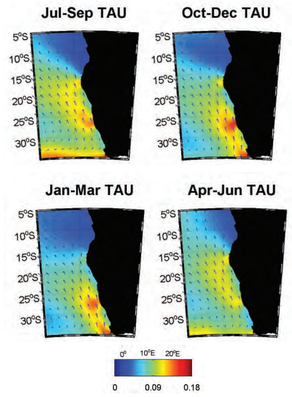
Large-Scale Currents:

- **Agulhas and Agulhas Retroflection: These are extremely energetic, generating large, strong eddies of both signs that move to the northwest, sometime interacting with the shelf along western South Africa and Namibia, drawing long filaments of coastal water far offshore.**
- **South Atlantic Current: A relatively steady eastward flow turning into the northward Offshore Benguela Current.**

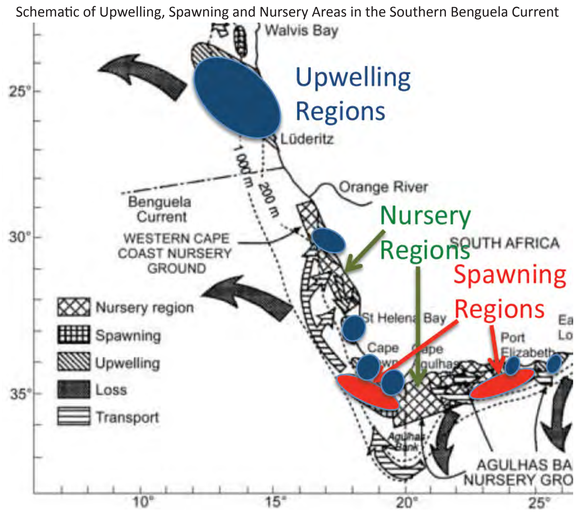
Expectation:

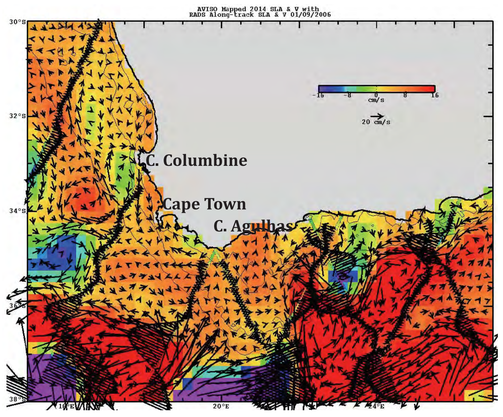
- **Coastal Benguela Current: Equatorward flow, strongest during austral spring and summer, with some connection to the shelf along the southern coast of Africa, inshore of the Agulhas Current. Larval and juvenile stages of the fish are expected to stay over the shelf in this current in order to reach the spawning areas within and north of St. Helena Bay near Cape Columbine.**
- **Offshore Equatorward current present year-round, connecting to the South Atlantic Current.**

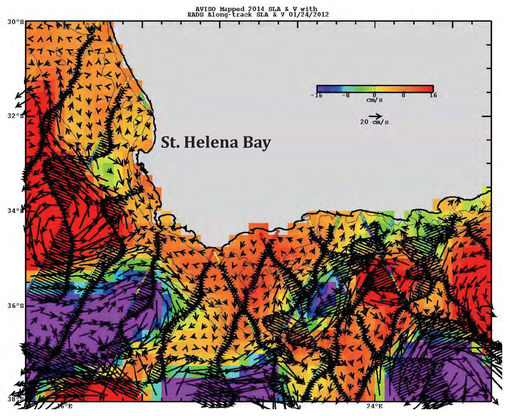
QuikSCAT Seasonal Wind Stress
(Risien and Chelton, SCOW)



Schematic of Upwelling, Spawning and Nursery Areas in the Southern Benguela Current





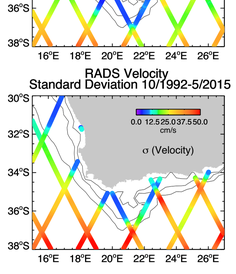


Variability in the Offshore Deep Ocean is Extreme; Variability is Reduced Over the Shelf

The left two panels show examples of the Sea Level Anomaly (SLA) fields for two January periods. Withouth the Mean Dynamic Topography (MDT) fields, meanders appear as eddies. The main point is that variability in SLA and associated geostrophic currents is very large in the Agulhas, the Agulhas Retroflection, and the eddy field to the west of the shelf off SW Africa. Over the shelf, however, variability is much reduced. The 100m, 200m isobaths mark the middle and edge of the shelf. The 1000m isobath marks the upper slope.

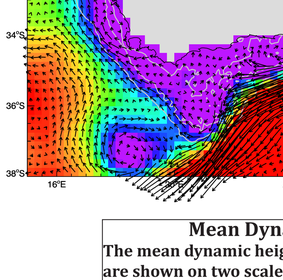
Six Years of Interleaved Data

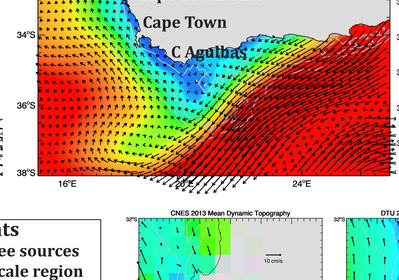
During six years, two reference missions (TOPEX, Jason-1/2) flew in interleaved orbits, along with other satellites (ERS/Envisat, GFO) to give the best resolution of mesoscale features. The standard coverage (left) and interleaved coverage (right) of the reference tracks are shown in the two examples.

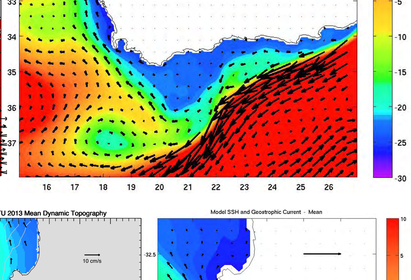


Lower Shelf Variability

Along the standard tracks, using 22 years of data, we show standard deviations of the SLA (top) and cross-track geostrophic velocities (bottom). Inshore of the 100m, 200m and 1000m isobaths varaibility is reduced, allowing better resolution of the mean circulation.



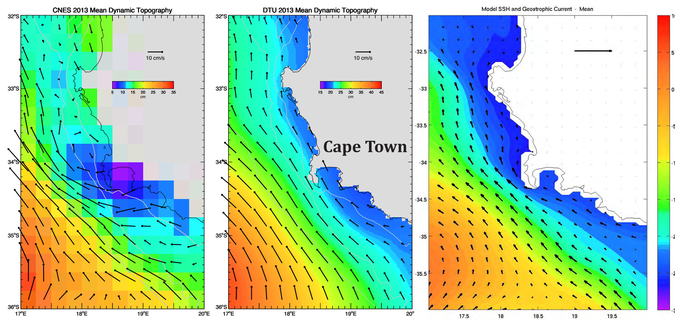


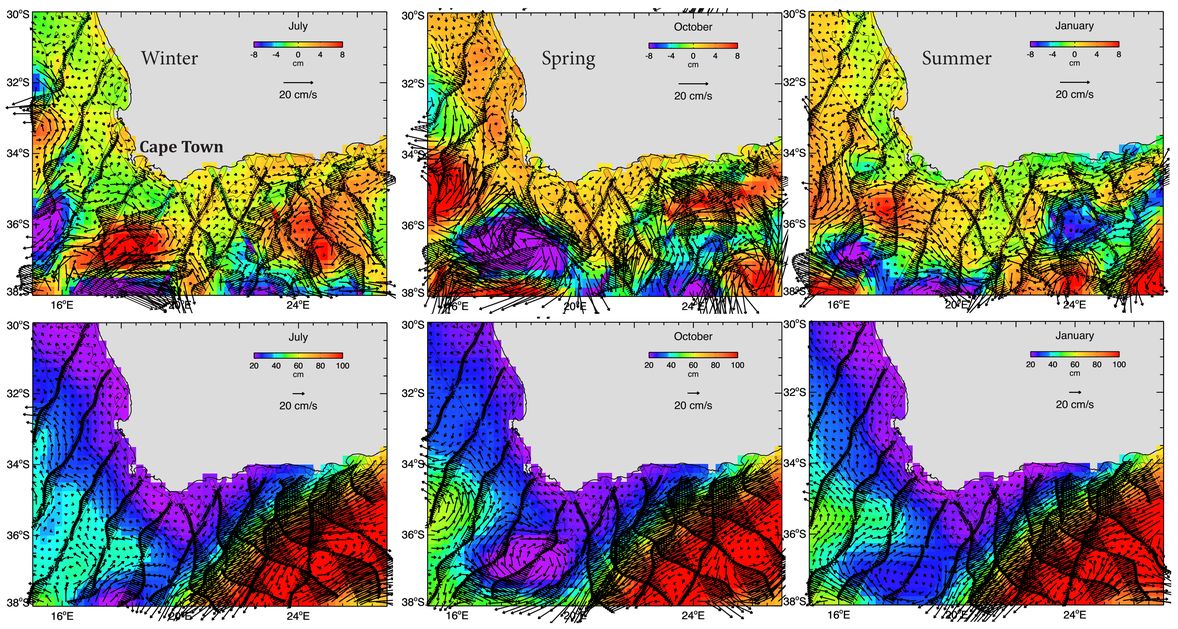


Mean Dynamic Heights

The mean dynamic heights from three sources are shown on two scales, the large-scale region showing the Algulhas Retroflection and the small-scale region along the SW coast of South Africa. We are interested in both regions but will finally focus on the smaller region. The sources of the fields are CNES13 (left), DTU13 (middle) and a ROMS model with ~5 km grid spacing.

Both DTU13 and ROMS show continuous flow along the west coast, while CNES13 shows an inshore countercurrent between 33°-34°. This is a feature of interest.





Altimeter Results

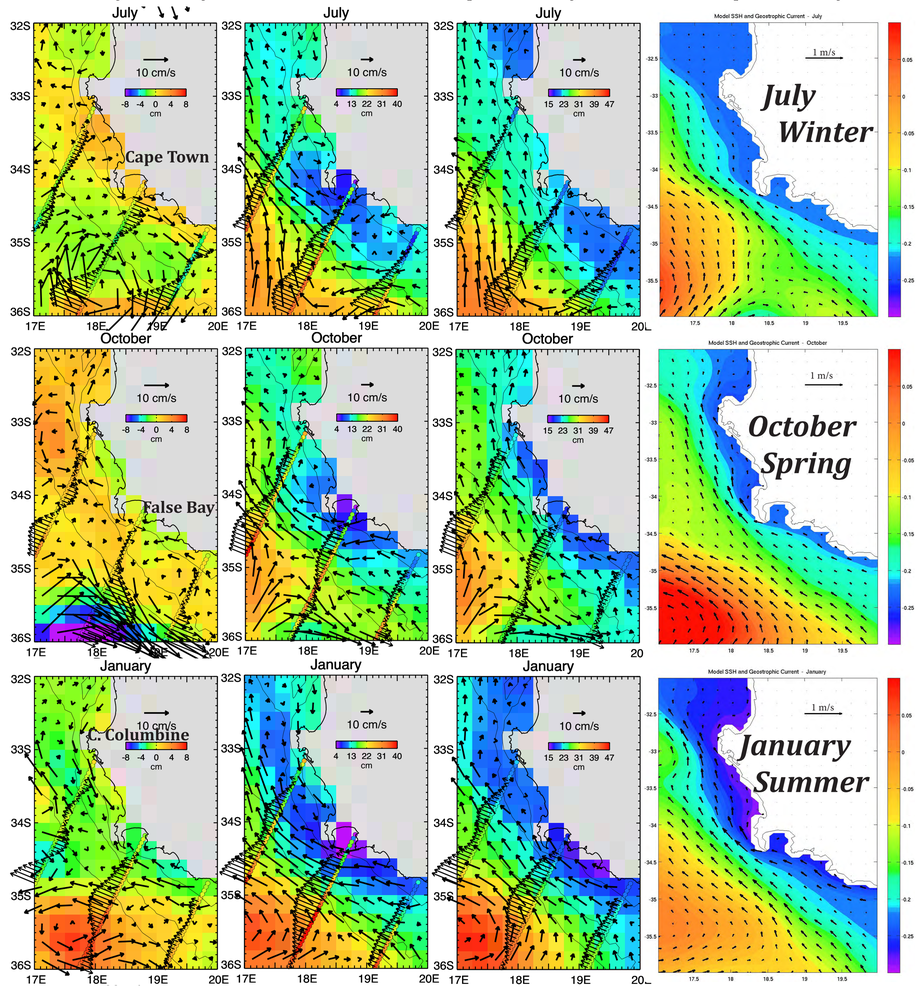
SW Corner, Cape Agulhas (left): Focusing on the shelf (ignore the eye-catching large velocities in the deep ocean), the anomaly fields (top left) show greater eastward flow around Cape Agulhas (SW corner) during winter, greater westward flow in spring and summer. When the DTU13 MDT is added, the absolute geostrophic velocities continue to show pattern, adding a mean westward flow around the corner that weakens/strenthens the eastward/westward flow during winter/spring-summer.

West Coast, 32°-35° (right): Velocity anomalies are:

- **poleward in winter south of Cape Town,**
- **equatorward everywhere in spring (forming two anticyclonic gyres separated by False Bay,**
- **poleward between Cape Town and False Bay in summer, continuing equatorward south of there.**

Whether the absolute currents between 33°-34° are poleward or equatorward depends on the mean that is added to the anomalies.

The model fields show equatorward flow at all times.



Conclusions

- ***Variability over the shelf off SW Africa is less than over the slope and deep ocean, allowing a resolution of the surface current anomalies by altimeter SLA fields.***
- ***Connections between the SW coast and the southern shelf just east of Cape Agulhas are seen in the velocity anomalies: more eastward during June-August and more westward during January-March.***

- ***Along the west coast between 33-35S (Cape Columbine to Cape Agulhas), anomalous currents are:***
  - ***Equatorward during October-December; these currents move offshore north of Cape Town in January***
  - ***** Continuing Equatorward south of Cape Town during January-March but poleward next to the coast north of Cape Town***
  - ***Poleward south of Cape Town during May-August (especially June-July) and disorganized north of Cape Town during this time.***

- ***** Whether the absolute currents become poleward next to the coast north of Cape Town during summer remains a primary research question. Evidence for a poleward coastal current is provided by previous observations (current meter and ADCP).***

- ***Model results indicate a shallowing or surfacing of the poleward undercurrent during summer and autumn***

- ***** HYPOTHESIS: Shallowing of the undercurrent creates a nearshore poleward surface current in summer. Future observations and models are needed to address this.***

- ***The region is a potential site for SWOT Cal/Val efforts, especially during the 1-day repeat which will cover the important upwelling centers.***

Evidence for Poleward Flow Between 33°-34° In Situ Observations

Fig. 20.9. Schematic current flow field derived from ADCP measurements made on the shelf between November 1989 and January 1992. (After Boyd and Shillington, 1994.)

Fig. 20.12. Spatial distribution of current meter deployments (depth in meters) and progressive current vectors measured in the southern Benguela region. Broad arrows depict general advective characteristics of the flow. (After Nelson and Pollex, 1987.)

Schematic interpretations of ADCP measurements (left) and current meter deployments (right) both suggest poleward currents between Cape Columbine (33°) and Cape Town (34°) in a "Coastal Poleward Current". This may be similar to a "Inshore Coastal Countercurrent" found off Central California in summer after the upwelling system moves off the shelf.

Evidence for Poleward Flow Between 33°-34° Model Section at 33.5°

A section across the coast at 33.5°S (left) shows north-south velocities (northward is red, southward is blue-white) for spring, summer and autumn. The poleward undercurrent is evident as blue contours, under equatorward flow. Between spring (October) and autumn (April) the undercurrent strengthens, and surfaces in the coastal region.

Hypothesis - The appearance of the Coastal Poleward Current in the 20-40 km next to the coast in summer is due to the strengthening and movement of the undercurrent from the slope to the inner shelf and from beneath 200m to the surface.

Cal/Val Testbed for SWOT?

This system will be one of the few upwelling systems that will be sampled by SWOT during its initial 1-day repeat period. That sampling includes an offshore diamond in the Retroflection area and swaths that cross the coastal upwelling system north of Cape Columbine and St. Helena Bay. The region offshore of a year-round upwelling center near Luderitz will also be sampled during the 1-day repeat.

During these periods and the rest of the mission, this region provides a natural laboratory in which to test SWOT's ability to resolve complex mesoscale and sub-mesoscale circulation features in both deep-water and coastal systems.

The South African oceanographic community is developing an observational and modeling capability that could be enhanced to make the best of use of this region in the SWOT project.

Acknowledgements

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