

# Referee comment on **A study of the variability of the Benguela Current**, by Sudip Majunder and Claudia Schmid.

## General comment

Driven mainly by economic interests, the countries along the west coast of southern Africa have, for many decades, conducted dedicated marine research efforts to survey and understand aspects of the Benguela Current System. Much of the research was spatially and temporally constrained by infrastructure (e.g. research vessels) and funding, and the only long-term data sets that became available included SST observations, tidal records and fisheries/biological parameters.

Ocean topography, ARGO floats and NCEP data is now deployed by the authors to provide a whole new insight ("bigger picture") into the three-dimensional flow and variability of the area. Their approach is therefore novel, and the analysis and presentation are good. The results are therefore considered relevant.

## Suggestions and basic comments

### a. Amendment of title

Much is known about other (non-physical) aspects of the Benguela Current. It is suggested that the title should indicate that the manuscript is confined to the *physical* aspects (current, flow, transport), and maybe even add the years covered.

### b. Suggested links with existing knowledge

The title of the manuscript focuses on the *physical* aspects of the Benguela's variability (currents, volume transport). Considering the strong link that exists between the physics and the fisheries, biochemical and environmental issues of the region, and to indicate that interested readers can follow up on the extensive research that has been conducted and reported in those fields, the Addendum below provides some information.

## Definition of the Benguela and regional features

- It would be of great use to the reader to know how the authors delineate the Benguela in terms of relevant environmental parameters, such as speed, volume transport, flow direction, or latitude/longitude.
- It would also help if some of the geographic features, such as Walvis Ridge, are identified on a chart of the area. A map of the area [such as the one by Shannon V (2006) *A plan comes together*. in: Benguela, Predicting a Large Marine Ecosystem. Large Marine Ecosystems Vol 14, Elsevier BV, p 4] would be very useful for readers not familiar with the local topography and nomenclature.
- p 3 line 2: The reader is uncertain why names like *Cape Frio* and *Cape Agulhas* are mentioned (instead of just their latitudes) without identifying them on a map of the area.
- p 5 line 22 and 23: It seems that the distinction between "steady" and "transient" flow is based on the spatial variability of the flow direction (?). In the absence of a reasonably clear delineation of the Benguela Current there is some confusion whether the "steady flow" is synonymous with the Benguela Current.

- p 5 line 30: "...may occur in two branches." The 15 m flow pattern (Figure 1a) suggests that there is a third contributory branch crossing 35°S northeastward at about 7°E. This seems less distinct in Figure 1b, so it may be largely a surface feature.

## Definitions and clarity of terminology

- The authors tend to use "northward" (e.g. p 2) when the flow is largely northwestward. E.g. is "meridional" the northward component of the NW flow? This confusion between the flow and the flow components must be avoided.
- p 4 line 3: readers may know what Sv means, but as a non-SI unit and for the sake of completeness it should be defined when first used.
- p 6 line 3-6: The vertical sections in Figure 2 display only the meridional component of the flow. Low values do not necessarily mean that the flow as a whole is low, but just that the meridional component is low. It can therefore not be used to differentiate between the "steady" flow and the "transient" flow (i.e the flow with a stronger zonal flow component need not necessarily be less steady).

## Clarity of approach and presentation

- p 6 line 15-18: It is understood that there is data gap in the inshore, shallower regions. However, the authors can only extrapolate the flow eastward into areas shallower than 1000m (in terms of speed and direction) if there is a justifiable basis (e.g. references).
- p 6 line 17-18: Using climatological averages a meridional flow of 1.8-2.0 Sv is derived for the inshore region at the latitudes of 30° and 35° S. So, if there is approximately the same volume of water entering at 35°S than is leaving at 30°S, how is this related to the value of 7 Sv leaving the coastal area westwards (reported in p 7 line 3)?
- p 6 line 20 and further: Considering that the Benguela Current direction is around NW, the volume transports computed along the latitudinal lines at 30°S and 35°S reflect only about 70% of the whole transport. The authors should indicate why lines oriented in a SW-NE direction were not chosen, and the effect on the computed transports. Has the orientation of the lines not perpendicular to the main flow axis of the Benguela been taken into account when comparing the transport results with other authors (line 25-27)?
- p 7 line 3: Flow in shelf area: Figure 1 indicates the location of points B and D, but why are they so far inland? Where exactly is "parallel to the shelf break", or do the authors mean "at the shelf break"?
  - Were the flows reported across AC and BD corrected for their mutual difference in orientation?
  - Visual inspection of Fig 1a and b suggests that the vectors along the eastern perimeter (closest to the shelf edge) are oriented largely parallel to the shelf edge, except in 30/31° and 34/35° where flow is oriented slightly onto the shelf, and at 31/32° where the flow is oriented with an off-shelf component.
  - The net westward (?) flow of 7 Sv at BD therefore seems to be largely associated with the off-shelf flow at 31/32°. The chart of Shannon (mentioned above) indicates a south-eastward flow on the shelf at 30°, creating the possibility of confluence of southward and northward flows and a solution to the transport imbalance.
- p 7 line 5: Shorter-period anomalies: The computation of the climatic volume balance is a huge step forward in the insight of the flow/transport of the area and the Benguela Current (Fig. 4). The authors admit that, at times, the budget is

unbalanced. There seem to be events that not only imbalance the climatology, but are in themselves huge anomalies (of the order of the average condition). The following are examples:

- In 2005 there occurred a westward flow of approximately 20 Sv across AC. This was the largest flow of the data record, and seemed to coincide with an equally large westward flow across the eastern boundary. These flows were 2-3 times the average. While the flow across AB was slightly below average, the flow across CD was about 5 Sv larger than average.
- In 2014 two large flow pulses northward at AB coincided with similar eastward events across AC.

The authors indicated some possible reasons for transport discrepancies. If the events mentioned above occurred more-or-less simultaneously (as they appear) a specific investigation to pin down what happened, is called for.

- p 11 line 12: Impact of local wind forcing: Lutjeharms and Meeuwis (1987, *S Afr J mar Sci* **5**, 51-62) indicated that the coastal area between 25° and 30°S seems to have the highest, upwelling-favourable wind speed of all locations along the southwestern coast of Africa. There is a significant decrease in the vicinity of 34°S.
- p 20: The order of (a),...(d) at the top of the figure need checking?

### Issues of expression, grammar, etc

- p 2 line 5: "...long-term velocity observations" [there are other fisheries-biological data records and satellite SST that continue for many years/decades]
- p 2 line 9: insert of after study
- p 3 line 16: "... two thirds ... contribute..."
- p 4 line 8: "Further east ..." Shouldn't this be west?
- p 4 line 9: conducted
- p 4 line 17: "...no long-term measurements of this current's flow/transport/dynamics.. are available"
- p 4 line 33: "0.5x0.5 grid": It is suggested to change this to 0.5°x0.5° grid"
- p 5 line 8: "...dynamic height does not change.."
- p 5 line 15: insert "and" after coast
- p 5 line 26: The convention is that positions should be reported as (lat, long) and, not as (long, lat).
- p 5 line 32: I don't see any "zonal velocities" in the area indicated by the authors. Do the authors mean "zonal velocity components" when they say "zonal velocity"? This was also mentioned above, and it is suggested that the authors rigorously identify and reword such misnomers.
- p 6 line 9. It is possible that Figure 2b shows a weak signal around 7°E corresponding to the third tributary referred to before (p 5 line 30).
- p 6 line 11-12: So the westward flow at 30°S is still the Benguela Current?
- p 6 line 12: insert "in" after "resulting"
- p 6 line 20: The authors should indicate the origin of the standard deviation.
- p 6 line 32: transports
- p 8 last paragraph: I liked the results concerning the course of Agulhas rings.
- p 9 line 4: cannot
- p 10 and 11: The Summary and conclusions are in order
- p 11 line 2: Vema
- p 16: "...the black straight line marks the depth.."

## Addendum

Without trying to mention all the research papers (especially the most recent ones), I recall that there were 5 compendia (below), based on symposia, where some of the results have been summarised. I draw attention (as examples only) to three papers with their full reference, contained in some of the books:

- *The Benguela and comparable ecosystems* (ed. Payne, Gulland and Brink), 1987, 956pp
- *Benguela trophic functioning* (ed. Payne, Brink, Mann and Hilborn), 1992, 1108 pp. [Shillington FA, L Hutchings, TA Probyn, HN Waldron and WT Peterson (1992) Filaments and the Benguela Frontal zone: Offshore advection or recirculation loops? *S. Afr. J. mar. Sci.* **12**, 207-218.
- *Benguela dynamics. Impacts of variability on shelf environments and their living resources.* (ed. Pillar, Moloney, Payne and Shillington), 1998, 512 pp. [Strub PT, FA Shillington, C James and S Weeks (1998) Satellite comparison of the seasonal circulation in the Benguela and California current systems. *S. Afr. J. mar. Sci.* **19**, 99-112]
- *Ecosystem approaches to fisheries in the Southern Benguela* (ed. Shannon, Cochrane and Pillar), 2004, 328 pp.
- *Benguela: Protecting a large Marine Ecosystem* (ed. Shannon, Hempel, Malanotte-Rizzoli, Moloney and Woods), 2006, Elsevier B V, 410 pp. [Shillington FA, CJC Reason, M Duncombe Rae, P Florenchie and P Penven (2006) Large scale physical variability of the Benguela Current Large Marine Ecosystem (BCLME). p 49-70]

If required, contact may also be taken up with the University of Cape Town and (especially) the Coastal and Oceans Branch of the Department of Environmental Affairs in Cape Town. This Branch and its predecessor *Sea Fisheries Research Institute* has been responsible for the bulk of the multi-disciplinary research in the Benguela region.