

Impact of intensified Indian Ocean winds on mesoscale variability in the Agulhas system

^{1,2}Björn C. Backeberg, ^{3,2}Pierrick Penven and ^{1,2}Mathieu Rouault

¹Nansen-Tutu Centre for Marine Environmental Research, University of Cape Town, South Africa

²Department of Oceanography, MA-RE Institute, University of Cape Town, South Africa

³LMI ICEMASA, Laboratoire de Physique des Océans, UMR 6523 (CNRS, IFREMER, IRD, UBO), France

S1. Reanalysis product comparison of mean wind stress curl and trend

To assess the robustness of the wind trends for the period 1993-2009, the zonally averaged mean wind stress curl and trend from four reanalysis products are compared (Figure S1): NCEP1¹, NCEP2², ERA-interim³, and CFSR⁴.

The zonal average wind stress curl is calculated from 15°-120°E for the period 1993-2009.

Considering the zonal average, there is good agreement between the products. In all four products, the latitude of zero wind stress curl in the subtropics is near 17°S and in the extratropics near 49°S. Moreover, in all products a maximum wind stress curl, of approximately $130 \times 10^{-9} \text{ N.m}^{-3}$ lies between 35° and 40°S.

While there are some differences in the decadal trend from the four products between 1993-2009, the documented increase in the trade winds⁵ is evident in all four reanalysis products. In particular between 18° and 25°S, where trends up to and exceeding (depending on the product) $10 \times 10^{-9} \text{ N.m}^{-3} / 10 \text{ years}$ occur.

South of 40°S the decadal trend in the westerly winds shows considerable variations. A positive trend and southward shift is evident in both NCEP1 and NCEP2, the mean from 2003-2009 (dotted line) located further to the south compared to the mean of 1993-1999 (dashed line). In agreement with NCEP1 and NCEP2, CFSR also indicates a positive trend in the westerlies, although it is more limited in its latitudinal extent. However, the respective means of 1993-1999 and 2003-2009 suggest that the westerlies have shifted northward, in this case agreeing with ERA-interim, which also suggests a northward shift and a negative trend from 1993-2009.

The uncertainty regarding these changes in the Southern Hemisphere westerlies can be attributed to a lack of observations with which to constrain the models used in these reanalysis products, highlighting the need for a temporally and spatially coherent observing system in the Indian and Southern Ocean. Moreover, such differences have significant implications in our interpretation of ocean dynamics and influence the numerical solutions of ocean models forced by these reanalysis products.

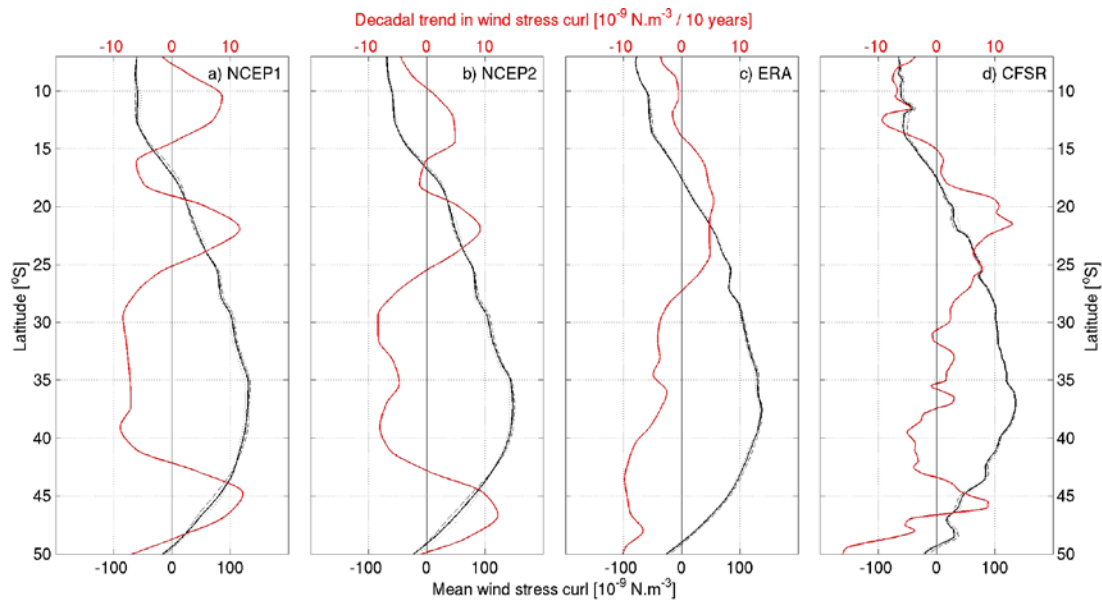


Figure S1: **Comparison of the zonally averaged wind stress curl and trend from four reanalysis products for 1993-2009.** The zonal average was calculated from 15°-120°E and the mean from 1993-2009 is given by the bold black. The red line indicates the decadal trend, and the dashed and dotted lines the means for 1993-1999 and 2003-2009, respectively.

References

1. Kalnay et al. (1996). The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, 77:437-470.
2. Kanamitsu et al. (2002). NCEP-DEO AMIP-II Reanalysis (R-2). *Bull. Amer. Meteor. Soc.*, 1631-1643, doi:10.1175/BAMS-83-11-1631.
3. Simmons et al. (2007). ERA-Interim: New ECMWF reanalysis products from 1989 onwards. Technical report, Newsletter 110 - Winter 2006/07, ECMWF.
4. Saha et al. (2010). The NCEP Climate Forecast System Reanalysis. *Bull. Amer. Meteor. Soc.*, 91:1015-1057, doi: <http://dx.doi.org/10.1175/2010BAMS3001.1>
5. Han et al. (2010). Patterns of Indian Ocean sea-level change in a warming climate. *Nat. Geosci.*, 3:546-550.