Wind changes above warm Agulhas Current eddies

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Sea-surface temperature (SST), altimetry derived sea-level anomalies (SLA) and surface current are used south of the Agulhas Current to identify warm core mesoscale ocean eddies presenting a distinct SST perturbation superior to 1ºC to the surrounding ocean. The analysis of 960 twice daily instantaneous charts of equivalent stability neutral wind speed estimates from the SeaWinds scatterometer onboard the QuikScat satellite collocated with SST during the lifespan of six warm eddies show stronger wind speed above those warm eddies than surrounding water for half of the cases. For cases where the wind is stronger above warm eddies, there is no relationship between the increase in surface wind speed and the SST perturbation. Mean wind increase is about 15 % at 1.8 m.s^{-1}. Wind speed increase of 4 to 7 m.s^{-1} above warm eddies is not uncommon. Average eddy radius is 100 km and SST perturbations range from 1ºC to 6ºC

1 Introduction

Microwave radiometry and altimetry allow making observations in the Southern Ocean with unprecedented spatial and temporal resolution. This is a real advantage in the latitudes between 35ºS to 50ºS south of Africa where persistent cloud cover previously was a perennial problem in this regard. In addition, equivalent stability neutral instantaneous wind speed estimates from the SeaWinds scatterometer onboard the QuikScat satellite is available from July 1999 (Chelton et al., 2004) to November 2009 at a quarter of a degree resolution along a wide swath. Chelton et al. (2004) used 4 years of filtered QuikScat data to show a ubiquitous picture of mesoscale ocean atmosphere interaction linked to SST heterogeneity such as fronts, western boundary currents and tropical instability waves. In general, using satellite estimates of wind speed, wind stress and SST and moorings, there is a linear relationship between SST perturbation and wind speed or wind stress especially evident for SST perturbation from the surrounding ocean between -1 ºC and 1 ºC (Chelton et al., 2004, O'Neill et al, 2005).

Several mechanisms can explain the phenomena that encompass a high range of SST and wind speed wind speed. It is thought that the increase or decrease of surface wind speed along SST gradient is due to the change in the latent and sensible turbulent heat fluxes and associated change in surface atmospheric stability. Consequently there is a substantial modification of the constant flux layer and of the height and structure of the marine atmospheric boundary layer above the surface layer.

2 Data

SST was derived from the AMSR-E, launched in 2002 by NASA. It is a passive microwave radiometer. In this investigation, we use weekly data at a resolution of 56 km. We used twice daily equivalent stability neutral surface instantaneous wind speed and direction estimated by the SeaWinds scatterometer on the QuikScat satellite. It is available in 25 Km Swath Grid. Weekly sea-level anomalies (SLA) were obtained from Centre national d'études spatiales (CNES) and surface current were obtained from Globcurrent. Globcurrent product is an optimal analysis of surface current at two different depth (surface and 15 m depth) at 1/4° resolution three hourly.

3 Wind speed acceleration above eddies

We looked for eddies with SLA of +15 cm and SST perturbation > 1°C. The selected eddies shed from the Agulhas Retroflection and the Agulhas Return Current, were identified in an area ranging from 35°S to 45°S latitude and 15°E to 25°E longitude. Most eddies that we are studying stayed quite close to the Agulhas Return Current for a few months and were re-absorbed by the Agulhas Retroflection or the Agulhas Return Current. AMSR-E SST was therefore instrumental in corroborating the location of warm eddies and their trajectories. Our period of study was July 2002-June 2004. Using SST and altimetry data in this region, we selected six warm eddies that had a significantly different thermal expression at the sea surface compared to ambient waters. The record represents a total of 22 months of clear-cut, identifiable eddies. We have cases for all seasons with a variety of SST (19ºC to 12ºC) and SST perturbations of up to 6 °C. Figure 1 shows four examples of cases showing high wind acceleration above warm eddies of up to 10 m/s and deceleration downstream. We note that the warm Agulhas Current is found to the north of the domain. In the four selected cases, the wind speed increase is superior to 5 $m.s^{-1}$ and relatively homogeneous eddies.

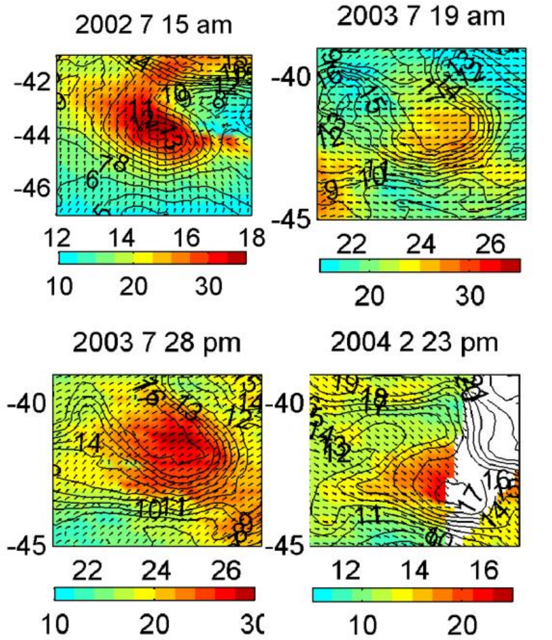

Figure 1: Clockwise from top left, Instantaneous estimate of QuikScat wind speed in in $m.s^{-1}$ (color) and directions (arrows) and AMSR microwave sea-surface temperature in ^{o}C (contours) south of the Agulhas Current system in the "Roaring forties" on the 15 07 2002 (morning path) 19 07 2003 (morning path), 23 02 2004 (evening path) and 28 07 2003 (evening path) showing strong and homogeneous increase and decrease in wind speed collocated with increases and decrease of sea surface temperature.

Not all instantaneous morning and evening paths display a clear increase above eddies but eddies have a strong imprint on the wind field when averaging the wind field data for at least a week at the spatial scales of the eddies. We then systematically plotted the instantaneous SeaWinds wind speed and direction for morning and evening passes with corresponding interpolated SST and SLA for a period of two years and examined those images. We selected 904 cases. However 20 % of the scenes had no data above eddies mainly because the satellite path does not cover the all globe or due to rainfall contamination. This left us with 711 cases.

Increase in wind speed above warm eddies and decrease downstream were a clear feature for 340 cases, about 50% of all. Wind speed, SST and SLA where also digitally saved in a common latitude longitude matrix format. To quantify the relationship between SST perturbation, wind speed increase above eddies and wind speed decrease downstream, we looked at the statistics of the merged dataset of cases that presented a wind speed increase above eddies and a decrease downstream and cases that did not. We considered only SST perturbation > 1^{o}C. For each case, we extracted SST, SLA, and wind speed at three positions along the wind flow: a) just before the border (large SST gradient) of the eddy upstream of the center b) in the middle of the eddy c) downstream of the eddy border. In order to have robust results, we used a stretch of 4 points encompassing 100 km just before and around the eddy, 4 points at the eddy center in the direction of the wind and a stretch of 4 points just after and around the eddy border downstream of the eddy center. SST, wind speed and direction and SLA for those 3 locations were then averaged and stored with time and date. The eddy SST centers ranged from 19^{o}C to 12^{o}C with SST perturbation of up to 6^{o}C for a mean gradient of 2.5^{o}C per 100 km. Altogether, the average SST at the center of the eddies is 15.9^{o}C while average SST at the eddy border is 13.2^{o}C upstream and 13.3^{o}C downstream. This leads to a mean perturbation of 2.65^{o}C. Increase in wind speed above warm eddies and decrease downstream were a clear feature for 340 cases, about 50% of all cases with available data.180 cases did not show an increase above the warm eddies and 191 cases did not show a decrease downstream of the eddies center.

Figure 2 presents a scatter plot of the instantaneous wind speed increase versus the SST perturbation. Figure 2 does not show any clear linear relation between those parameters for SST perturbation > 1. This seems to contradict a number of similar studies. Wind speed increase of 4 to 7 $m.s^{-1}$ above warm eddies is not uncommon.

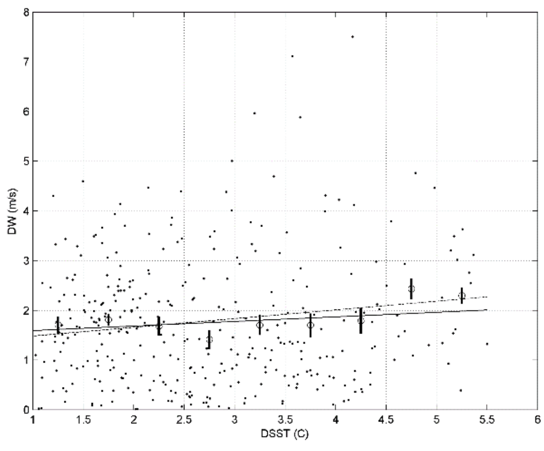

Figure 2: scatter plot of SST perturbation (DSST) versus wind speed increase (DW) in $m.s^{-1}$ for the 340 cases when the wind increased above warm core eddies and decrease downstream and for SST perturbation from the surrounding ocean > 1 ^{o}C. Solid line is a linear fit. The circle represent the means within each 1^{o}C bin and the error bars represent +/-1 standard deviation of the wind differences within each bin divided by the square root of the number of sample within each bin. The

dashed line is a linear fit of the means within the bins.

4 Conclusions

Our study provides instantaneous values of wind changes above warm core eddies for the first time because we did not filter or average the data. Wind speed, increase substantially above warm SST perturbations by about 20 %. With increases of more than 4 $m.s^{-1}$ in eddies not uncommon, the warning should be taken seriously when sailing in the “Roaring Forties”. At last, this study questions the hypothesis that there is a ubiquitous linear relationship between SST perturbation and wind speed modification for large SST perturbation > 1 ºC as we did not find a linear relationship between SST perturbation and wind increase across warm eddy.

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