Interactions between the upper ocean and the lower atmosphere in the Brazil-Malvinas Confluence region

Marta Masdeu[1], Josep L. Pelegrí[1] & Pablo Sangrà[2]

[1] Departament d'Oceanografia Física i Tecnológica, Institut de Ciències del Mar, CSIC, Barcelona
[2] Departamento de Física Aplicada, Universidad de Las Palmas de Gran Canaria, Las Palmas de Gran Canaria

ABSTRACT

Recent studies have shown that sea surface temperature (SST) and surface wind speed (SWS) are directly related at ocean mesoscales (10-100 km). Here we examine this relationship in the Brazil-Malvinas Confluence region, where we find one of the most intense regional-scale SST gradients in the world's oceans. We analyze SST and SWS collected in situ during an oceanographic cruise done in March 2015. Data is processed to emphasize the variability of SST and SWS associated with oceanic fronts, both at regional and mesoscalar scales, taking into account the latitudinal SST gradients, the passage of atmospheric synoptic disturbances, and the diurnal variability of SWS. We observe that SST has an influence on SWS – a temperature raise of 1ºC involves a wind-speed increase of 0.36 m s^{-1}, with a correlation coefficient of 0.43 and a 95% confidence level – a relationship that is corroborated using wind data from the European Copernicus Project. Finally, we assess the influence of SST on the lower atmosphere through the changes in sensible and latent heat fluxes across the front. The results point at the existence of significant coupling between the upper ocean and the lower atmosphere.

INTRODUCTION

Ocean and atmosphere have different synoptic scales: in the atmosphere these are ~1000 km and a few days but in the ocean they are ~100 km and weeks. This means that we usually think on the atmosphere as influencing the ocean's variability only at short time and long spatial scales, but playing little or no role at spatially short scales. However, this argument ignores the possibility of feedback mechanisms. Indeed, recent work [1, 2] has pointed at the potential importance of these feedback mechanisms, in such a way that changes in the sea surface temperature (SST) would affect the structure of the lower atmosphere and alter the surface wind speed (SWS), hence potentially affecting back to the upper ocean. Our study seeks to explore precisely this interaction in a region where the oceanic system exhibits an intense and well defined surface front: Brazil-Malvinas Confluence (BMC) region.

The BMC is the encountering region between the Malvinas Current (MC), a northward branch of the Antarctic Circumpolar Current, and the Brazil Current (BC), a southward western boundary current of the South Atlantic subtropical gyre. The thermal contrast between these two currents, or surface front, makes the BMC as an ideal area to study the short-space coupling between the upper ocean and lower atmosphere: the surface waters of the MC are cold (<7ºC during the austral summer), much more than the warm waters (>26°C) of the surface BC [3]. In particular, we expect that this thermal front (some 15ºC in about 30 km) will drive substantial spatial variations in ocean-atmosphere heat exchange [1, 3, 4, 5]. Hence, our objective is double: first, to take advantage of such a unique setting in order to determine the existence of significant SST-SWS relationships and, second, to compute the heat fluxes between ocean and atmosphere that could drive the changes of the lower atmosphere and hence the intensity of the SWS.

MATERIAL AND METHODS

The research vessel BIO Hesperides carried out the TIC-MOC cruise from 5 to 30 March 2015, departing from Ushuaia (Argentina) and arriving at Salvador de Bahia (Brazil). The BMC was sampled from 12 to 22 March, crossing the surface front 11 times.

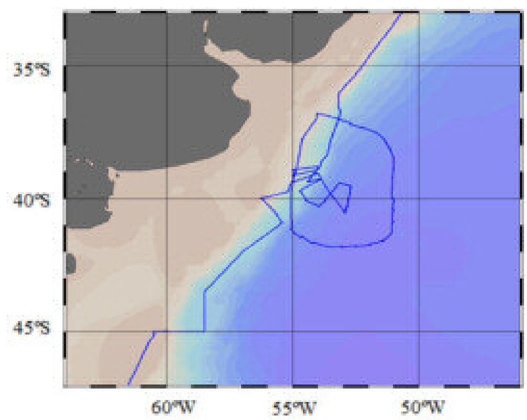

Fig. 1. Trajectory by BIO Hesperides, from SW to NE.

The study area is located between 36ºS-43ºS and 51ºW-57ºW, approximately southeast of Rio de la Plata, outside of the continental shelf and continental slope. The cruise included an initial outer transect followed by an inner mesh (Fig. 1). For our calculations we use the SST data as obtained from the ship's thermosalinograph and the meteorological data as determined by the ship's met-station (at a reference level of 10 m above sea level).

We process the data in order to reduce all those factors that may influence the SST and SWS values at other scales different from the frontal scales: the SST changes because of the ship's motion from high to low latitudes, and the SWS varies as a result of both the passage of frontal systems and the diurnal wind cycle. With this purpose, we follow two steps. First, we search for a low-frequency polynomial filter that removes the synoptic and long-term variations. A key aspect of this calculation is to select the correct polynomial order, such that it properly represents the variability related to atmospheric processes but does not follow the abrupt SST and SWS changes associated with ocean front; from the correlation between the original and adjusted series, we choose a polynomial of order 6 for the SWS and of order 3 for the SST as the best options. The residual time series is then obtained by subtracting the original series to the polynomial adjustment. Second, we average three days of the residual time series prior to arriving to the confluence region so as to produce a daily cycle. We then consider this cycle as characteristic for the entire BMC region, and subtract it to the residual time series in order to produce a new residual time series.

The sensible heat flux (SHF) and latent heat flux (LHF) are calculated from standard bulk formulae [6]. These expressions depend on the SST as well as on variables determined with the ship's meteorological station (wind speed, air density, specific and saturation specific humidity, air temperature, mean surface wind speed.

RESULTS AND DISCUSION

We focus our analysis on the 17-19 March, when the vessel sampled the frontal region with major intensity. During this time period, the residual SWS and SST time series display similar patterns, with coincident SST and SWS minima (Fig. 2). The Pearson correlation coefficient between both variables is 0.428 (calculated with a confidence level of 95%); a Pearson correlation coefficient between 0.3 and 0.5 reflects the existence of a moderate relationship [7].

We conclude that the large contrasts in SST between the subtropical and subantarctic waters lead to substantially different heat fluxes from the ocean to the atmosphere, increasing over the warmer waters. This affects the stability of the marine atmospheric boundary layer (the greater the fluxes the larger the vertical mixing) and therefore produces an increase in SWS.

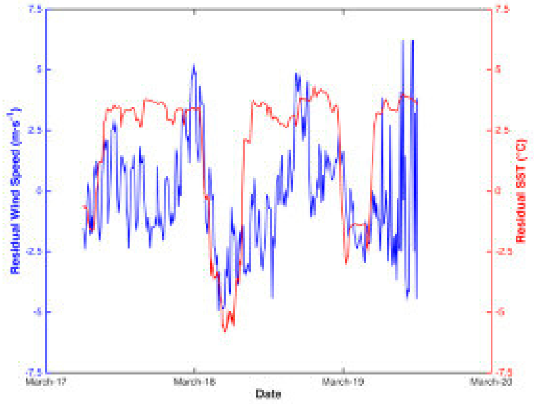

Fig. 2 . Residual SST time series (ºC, red line) and residual SWS (m s^{-1}, blue line) over the frontal region.

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