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SIMULTANEOUS OCEAN-ATMOSPHERE *IN SITU* OBSERVATIONS AT THE BRAZIL-MALVINAS CONFLUENCE REGION.

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1. INTRODUCTION

The Brazil-Malvinas Confluence (BMC) region (Figure 1) is acknowledged as one of the most energetic regions of the World's Ocean (Chelton et al. 1990). This region is characterised by the meeting of two opposing boundary currents: the Brazil and the Malvinas currents. At the Confluence, tropical warm and saline waters, transported by the Brazil Current (BC), interact with subantarctic cool and less saline waters of the Malvinas Current (MC), forming an active and non-steady meandering frontal region.

The surface thermal contrasts between distinct water masses in the ocean are known to contribute towards the generation of intense momentum gradients and energy vertical fluxes at the ocean and atmosphere interface (Pezzi et al. 2004). These fluxes affect the dynamical and thermodynamical structure of both ocean and atmosphere. In addition to that, the turbulent processes occurring in small spatial and temporal scales may induce variations on the evolution of large scale processes

The large scale processes have

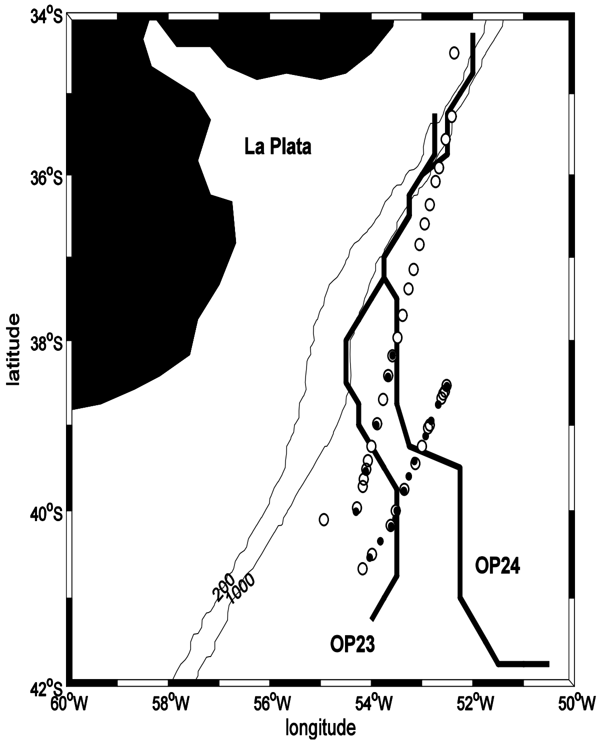

Figure 1. Study area with cruise routes and thermal fronts. The XBTs launching positions are white circles while the radiosondes are black circles for OP23 (upper) and OP24 (lower) routes. Thicker lines are BC-MC thermal front extracted from AMSR-E satellite images at 28 October 2005 (OP23) and 2 November 2005 (OP24).

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Direct influence on the meteorological and marine phenomena affecting the South American coastal region. Moreover, due to the BMC closeness to the continent, its impact over the regional climate may be significant, although this issue has not been extensively investigated.

This work presents a preliminary analysis of simultaneous *in situ* ocean-atmosphere data taken at the BMC on board the Brazilian Navy R/V Ary Rongel. Two research cruises have been made during Antarctic Operations, starting in November 2004 (OP23) and end of October 2005 (OP24). To our knowledge, these were the first simultaneous observation of the Marine Atmospheric Boundary Layer (MABL) and the Ocean Boundary Layer (OBL) in the BMC region.

2. DATA AND METHODOLOGY

As part of the Brazilian Antarctic Program (ProAntar), the Brazilian Navy, Research Ship (RS) Ary Rongel departs from Brazil towards Antarctica every year. Here we analyse data from OP23 and OP24. The study area is comprised between 30°S and 50°S, 50°W and 60°W (Figure 1).
Prior to the vessel's departure from port the BMC front was mapped, which drove the route followed by OSS Ary Rongel while heading towards Antarctica. The study region was covered during 2-3 November 2004 and 28-29 October 2005. The strong surface thermal gradients between BC and MC in the region were determined through synoptic Sea Surface Temperature. Here we show both gradients found during OP23 and OP24 in Figure 1 (thicker lines) extracted from AMSR-E images at 28 October 2005 (OP23) and 2 November 2005 (OP24).

2.1 In situ data collection

While crossing the BMC front, Expandable Bathy-Thermographers (XBTs) were launched from the RS Ary Rongel in order to measure the water temperature as a function of depth along the ship's route (Figure 1) during OP23 and OP24. When at the close vicinity of the BMC front a number of Vaisala RS80 atmospheric radiosondes were also launched in both years. The radiosondes measured pressure, temperature, humidity, wind speed and direction in the atmosphere. Other atmospheric variables were automatically derived by the radiosonde equipment onboard the vessel while the observations were being collected: potential and dew point temperature, ascension rate, geopotential height and mixing ratio. The ship's crew during both OP23 and OP24 also took ship-borne independent meteorological measurements. These informations were used as independent data for validating the data collected by the radiosondes at sea surface level.

2.2 Turbulent fluxes calculation

The turbulent fluxes of latent heat (Q_e) and sensible heat (Q_h) were calculated from the ship-borne meteorological data following the scheme proposed by Fairall et al. (1996). In our calculations we do not correct fluxes due to cool skin effects. It is important to mention that this scheme was originally developed to be used on turbulent fluxes at the warm pool in the western Pacific Ocean. It might not be the best choice to extra-tropical studies with the presence of cold waters. Nevertheless, the method is largely used by others authors, e.g. Rouault et al.

(2000) and Pezzi et al. (2005). Similarly to Tokinaga et al. 2005 we have also calculated the stability parameter SST-T_{air}, where SST is the bulk sea temperature and T_{air} is the ship-borne measured air temperature.

3. RESULTS

3.1 Stability, winds and heat fluxes

Figure 2 shows the ship-borne meteorological data collected and derived during OP23 and OP24 cruises. The panels display the stability parameter (upper panel), surface wind (middle panel) and heat fluxes (lower panel). From those panels we can see the surface wind adjustment to the narrow and strong ocean front.

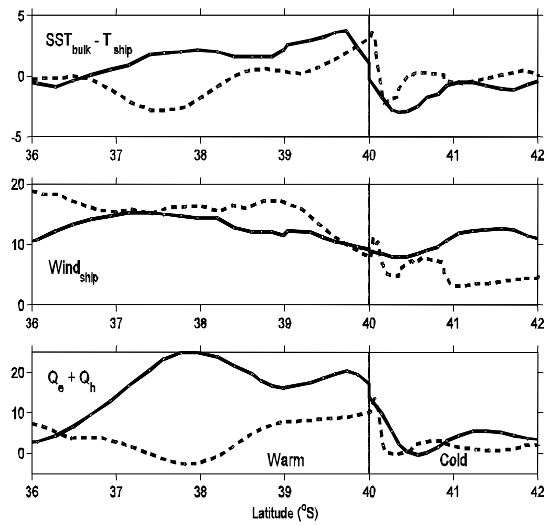

Figure 2. Upper panel: Sea surface temperature minus air temperature in °C. Middle panel: Wind speed in ms^{-1}. Lower panel: Latent + sensible heat fluxes in $x10^2$ Wm^{-2}. All the data are along the cruise route while crossing the BMC region during OP23 (dotted line) and OP24 (solid line).

This figure shows that air-sea exchanges are closely correlated with the SST fields. Heat flux calculations range from 250 $W.m^{-2}$ over warm waters down to 0 $W.m^{-2}$ over cold waters (Figure 2). High values of heat flux and air-sea temperature differences are associated with relatively strong near-surface winds. Consistent with Pezzi et al. (2005) findings, on the absence of strong large-scale synoptic systems, our observations suggest that MABL is modulated by the strong local sea surface thermal gradients. These measurements have shown that OA exchanges are closely related to the SST fields: weak (strong) winds are observed over cold (warm) waters in a cool (warm) atmosphere, which indicates a stable (unstable) MABL. This suggests that the MABL is modulated at the synoptic temporal and spatial scale by strong surface thermal gradients between the warm Brazil and the cool Malvinas currents. This process has been documented at the synoptic scale for other regions around the world (Xie 2004), but the description of a similar process is yet incipient for the BMC region. The first observational analysis based on synoptic *in situ* data was made by Pezzi et al. (2005) using only OP23 data. The prevailing mechanisms between the local forcing, which induce the MABL-OBL interaction, and the large scale on modulating the air-sea interaction are still an open issue and deserve further investigation.

The results presented here are consistent with previous studies (e.g. Chelton et al. (2001); Hashizume et al. (2002); Xie (2004); Tokinaga et al. (2005) and Pezzi et al. (2005)) which suggested that the atmosphere tends to adjust to the narrow oceanic fronts. MABL goes in a vertical stratification transition from unstable condition over warmer waters to a stable condition over cold waters. This will result on stronger surface winds over the warmer side of the front while weaker winds will occur over the cold side of the front. Tokinaga et al. (2005) have analysed a high resolution annual-mean surface wind climatology and it is important to note that (contrary to their results) our *in situ* observations show a clear signal of the SST effects on the surface winds. In Tokinaga et al. (2005) results, the SST frontal effect on annual-mean scalar wind speed was unclear. The data collected for this paper is not expected to be modulated by large scale systems, as during OP23 and OP24 no atmospheric phenomena such as frontal system or ciclogenesis were present over the study region.

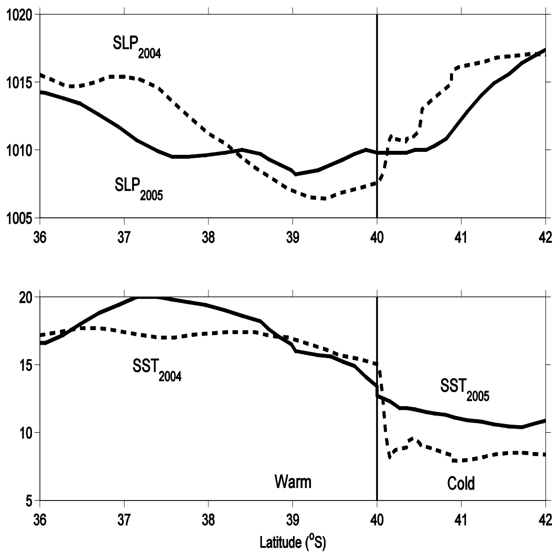

Figure 3. Sea Level Pressure and Sea Surface Temperature collected by the ship instruments along the cruises route while crossing the BMC region during OP23 and OP24.

3.2 Atmospheric pressure

The oceanic front is also playing a role on the MABL hydrostatic equilibrium. Figure 3 shows the ship-borne Sea Level Pressure (SLP) measurements from both OP23 and OP24 cruises. The figure shows that over warm waters the SLP values decrease while at the cold side of the front the surface pressure increases. The lower pressure region is coincident with the stronger wind speeds at warm waters (Figure 2). On the other hand, over cold waters where MABL is stratified stable the SLP increases while wind speed decreases.

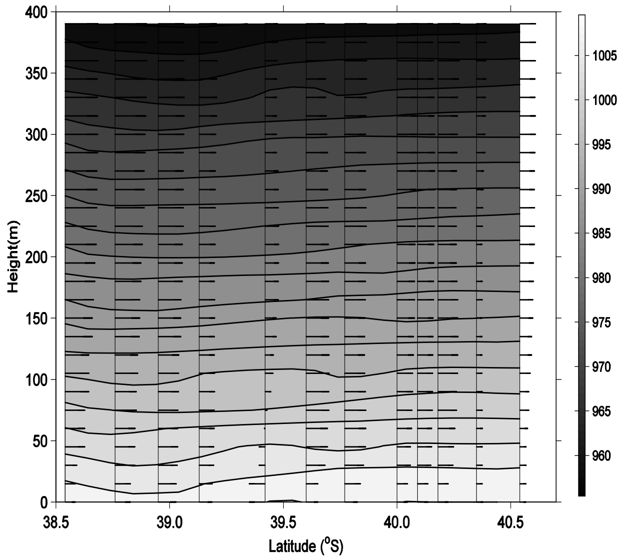

Figure 4. Pressure field (hPa) with wind (ms^{-1}) vectors superimposed. Radiosonde data collect along the OP24 cruise route while crossing the BMC region.

Tokinaga et al. (2005) results did not clearly show the SLP modulation in their annual climatology. Our results suggest that the BMC frontal region is modulating the SLP. Figure 4 shows a vertical section displaying the pressure field measure by the radiosondes launched during OP24. It is possible to see that over the warmer side of the BMC front the pressure is being modulated where lower pressure values are seen. This extends from sea surface up to 400 meters height. Different situation is observed over the cold side of the front where higher SLP values are found. The larger effects on pressure field are seen at surface level. These results are in agreement at some extent with Small et al. 2003. These authors have shown that pressure gradient, vertical mixing and advection are the dominant terms when analysing the Tropical Instability Waves (TIW) impacts on MABL from a momentum budget analysis. TIW produce SST gradients similar to those observed at the BMC region.

4. FINAL REMARKS

The MABL interaction with the sea surface at frontal oceanic regions has been quite well documented at the synoptic scale for other regions of the world but not yet for the BMC region. The prevailing mechanisms between the local forcing, which induce the MABL-OBL interaction, and the large scale on modulating the air-sea interaction are still an open issue deserving further investigations. An important step towards this objective is now taken through OCAT-BM project, which has funded part of the field experiment during OP24. New cruises are already planned to be done in November 2006 and November 2007 under INTERCONF project when the same sampling strategy will be repeated. A better understanding air-sea interaction processes based on observations and theoretical studies is important. The BMC is a storm-track region in southern South America. A better understanding of the air-sea processes taking place at this region will reflect on an improvement of weather and climate forecasting for South American countries.

ACKNOWLEDGEMENT

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