# The Atlantic EUC at $0^{o}$ N, $23^{o}$ W: comparing results from a high horizontal resolution ocean model forced by daily winds with PIRATA project observations

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**RESUMO.** Neste trabalho, a subcorrente equatorial atlântica (sigla “EUC” em inglês) em $0^{o}$ N, $23^{o}$ W é mostrada com ajuda de um modelo oceânico forçado por ventos diários e de observações obtidas do projeto PIRATA. O período de tempo compreende o ano de 2002 e de fevereiro de 2004 a maio de 2005. Em geral, o núcleo da EUC se desloca em direção às profundidades mais rasas entre janeiro e maio, atingindo a superfície, e se aprofunda gradativamente de maio a dezembro, atingindo sua posição mais profunda entre outubro e dezembro. A configuração do modelo utilizada, com 1/8 de grau de resolução latitudinal e longitudinal no Atlântico tropical, é capaz de reproduzir esta variação sazonal da EUC, embora o núcleo tenha ficado em uma posição mais rasa do que a observada nos dados do PIRATA entre outubro e dezembro de 2004.

**ABSTRACT.** In this work, the Atlantic Equatorial Undercurrent at $0^{o}$ N, $23^{o}$ W is shown with the aid of an ocean model forced by daily winds and of observations from the PIRATA project database. The time period considers the whole year of 2002 and from February 2004 to May 2005. In general, the undercurrent core moves upward between January-May, reaching the surface, and moves downward from May to December, reaching its deepest position in October-December. The model configuration used, with 1/8 degree of latitudinal and longitudinal resolution in the tropical Atlantic, is able to reproduce this seasonal variability of the undercurrent, although in October-December 2004 the model undercurrent core is placed in a shallower position that that observed in the PIRATA data.

**Palavras-chave:** subcorrente equatorial atlântica, modelo oceânico, projeto PIRATA

## INTRODUCTION

Ocean currents are water flows in the ocean along a definable path. Surface currents are mainly wind driven, because they are induced by wind stresses over the ocean. Examples of surface currents in the tropical Atlantic are the eastward North Equatorial Countercurrent, which is bounded by the westward flows of the South Equatorial Current and the North Equatorial Current. Besides the surface currents, there are the so called “subsurface currents” or “undercurrents”.

Subsurface currents are ocean currents placed below surface currents, therefore not in direct contact with the atmosphere, although they are also wind driven indirectly. They flow at a different speed and even in the opposite direction of the surface currents. The Equatorial Undercurrent (EUC) is an eastward current which flows along the equator in the opposite direction of the trade winds. In the Atlantic, it is called “Atlantic EUC”.

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The Atlantic EUC has been studied with the aid of both numerical model results and observational data, from programs such as the ‘‘Pilot Research moored Array in the Tropical Atlantic’’ (PIRATA) project (Servain et al., 1998).

In Giarolla *et al.* (2005), the temporal variability of the Atlantic EUC at $0^{o}$ N, $23^{o}$ W during 2002 was investigated, based on measurements from a PIRATA ADCP (Acoustic Doppler Current Profiler) data and on results from an ocean general circulation model forced by daily wind fields. In this paper, the zonal ($u$) component of the EUC is shown, with two new aspects in relation to the Giarolla *et al.* (2005) work: (1) For the period January to December 2002, results from a new model configuration, with 1/8 degree of horizontal resolution, will be shown and compared with the PIRATA data and with the former 1/4 degree resolution model results, and (2) the ADCP data for the period from February 2004 to May 2005 will be presented and also compared to the model results.

**PIRATA DATA AND MODEL DESCRIPTION**

The PIRATA ADCP daily data at $0^{o}$ N $23^{o}$ W, covering the year 2002 and from February 13, 2004 to March 28, 2005, was smoothed with a 10 day running mean average to filter out high frequency variability. The current profile reaches a depth of approximately 140 m. The original vertical grid is 5 m spaced, and was averaged to match the model grid.

The model used here was the “Modular Ocean Model” (MOM) version 3 from the Geophysical Fluid Dynamics Laboratory (GFDL). The region modeled was the Atlantic ocean, limited approximately at $65^{o}$ N and $55^{o}$ S. For the vertical resolution, 20 levels were adopted, 7 of them in the first 100 m, spaced by 15 m. An eddy-resolving grid was set for the Tropical Atlantic, with 1/8 degree for latitudinal and longitudinal resolution between $15^{o}$ N, $5^{o}$ S and $60^{o}$ W, $12^{o}$ E, decreasing uniformly to about 3 degrees out of this area. The model was forced by monthly means of wind stress from the NCEP/NCAR reanalysis (Kalnay et al., 1996) for the period January 1971 to December 1995. From January 1996 to December 2005, daily NCEP/NCAR reanalysis wind stress data was used to force the model. Climatological solar radiation from Oberhuber (1988) was considered, and  the surface heat flux was parameterized according to Rosati and Miyakoda (1988) bulk formulas. Daily model outputs for 2002 were also subjected to a 10 day running mean average.

**RESULTS**

Figure 1 shows the $u$ velocity component at $0^{o}$ N, $23^{o}$ W during 2002 as revealed by the PIRATA ADCP. In general, values closer to the surface are negative because the surface current at this position is typically westward (north branch South Equatorial Current and central brunch South

Equatorial Current). The positive values found at deeper levels are related to the EUC eastward flow.

Between January and May the undercurrent moves upward, reaching the surface and reverting the surface flow. The core of the EUC moves then from 90 to 60 m depth. Conversely, from May to December, the EUC core gradually moves downward. The maximum current speed is over 100 cm/s and is reached during October–November at the depth of 80 m.

In Figure 2, the *u* component from Giarolla *et al.* (2005) model results is reproduced. In their work, with 1/4 degree of latitudinal and longitudinal resolution in the tropical Atlantic, the simulated EUC was not as strong as that shown by PIRATA data, reaching speeds of up to 90 cm/s at slightly deeper depths when compared to the observed data. Yet, some of the seasonal features were reproduced: the shallowing of the EUC between January and May, the decrease of the EUC magnitude in February and September, and the intensification of the EUC core in March, June, August, October, and November.

Figure 3 shows the *u* component obtained by the model in this work. Using this new configuration, including higher horizontal resolution, the model is able to reproduce stronger EUC flows, reaching over 120 cm/s in October-November. Besides, in a general aspect, the EUC reproduced in this simulation agrees better with the observed EUC than the one simulated by Giarolla *et al.* (2005).

Figure 4 depicts new PIRATA ADCP *u* component data, for the period February 18, 2004 to May 23, 2005. In this period, the upward displacement of the EUC in April-May is observed as in 2002. However, concerning the downward displacement of the EUC in October-December, in 2004 the undercurrent core is deeper than that in 2002, reaching depths of over 100 m. Consequently, the surface westward flow also reaches deeper positions than those in 2002. In this case, the model is not able to reproduce this deepening of the EUC core (Figure 5), although the values of the velocity at 80 m depth, of about 80-100 cm/s, had been reached by the model in October-December. Apart from this period, the model results seem to agree well with the observations.

## SUMMARY AND CONCLUSIONS

The zonal (*u*) component data provided by the ADCP at the 23$^{o}$ W, 0$^{o}$ N PIRATA site allowed a description of the EUC variability during 2002 and from February 2004 to May 2005. An ocean model, forced by daily winds and parameterized surface fluxes, was used to simulate the EUC in the same time periods. The results were also compared to those obtained by the Giarolla *et al.* (2005) work.

As a whole, the model results agree well with the PIRATA ADCP data, except in October-December 2004, when the EUC core reached a position over 100 m depth. The reasons why the model EUC core can not reach this depth will be investigated in a future paper.

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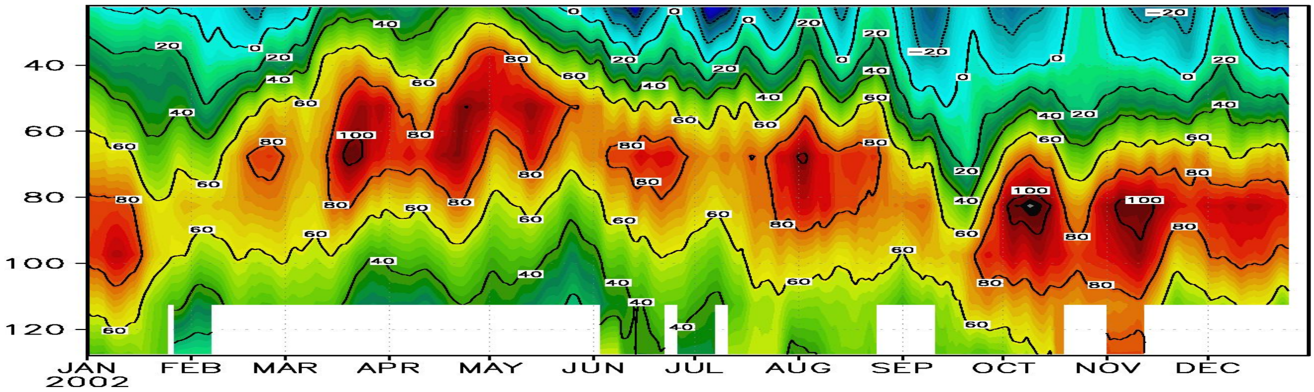


**Figure 1:** 10-day averaged PIRATA zonal velocities (cm/s) at $0^{o}$ N $23^{o}$ W from 6 January to 20 December 2002. Positive values are related to eastward flow.

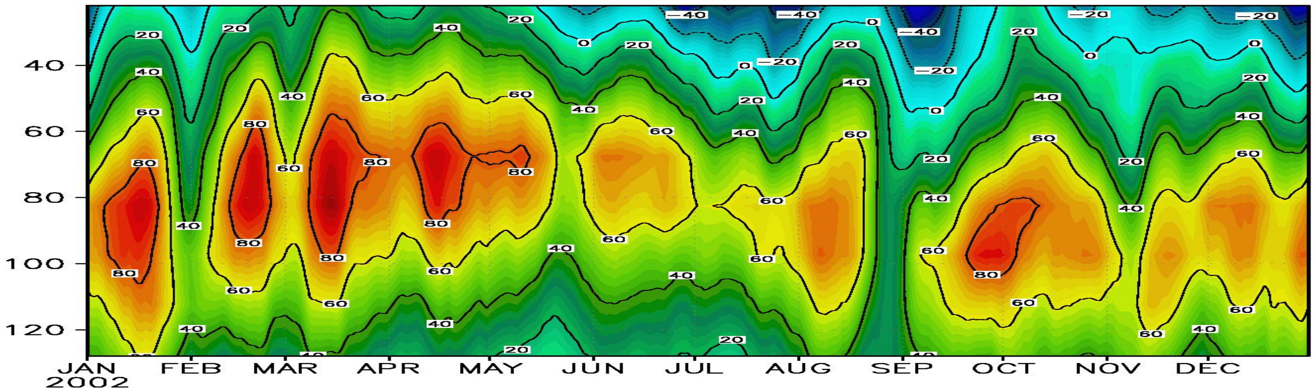


**Figure 2:** Same as Figure 1 but for the ocean model results obtained by Giarolla *et al.* (2005)

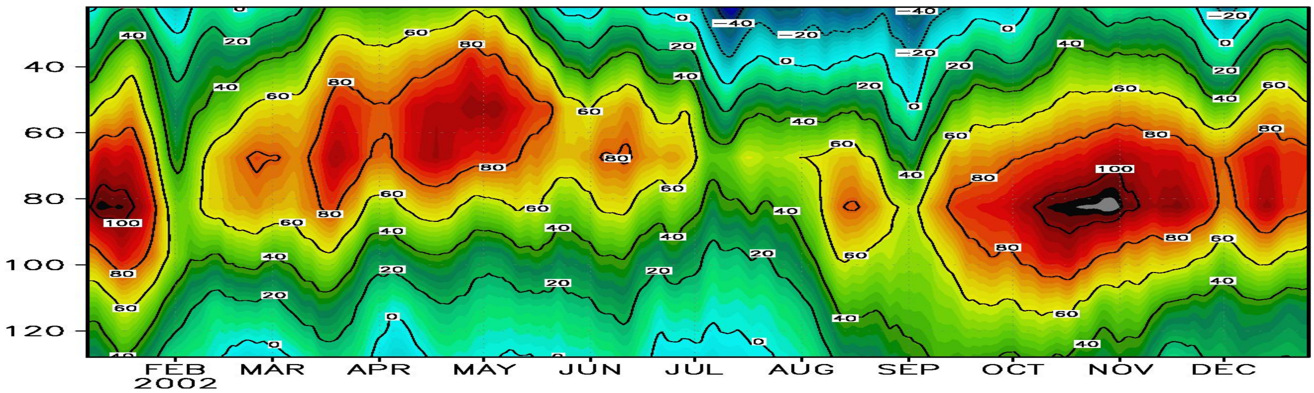


**Figure 3:** Same as Figure 1 but for the ocean model results with higher horizontal resolution in the tropical Atlantic.

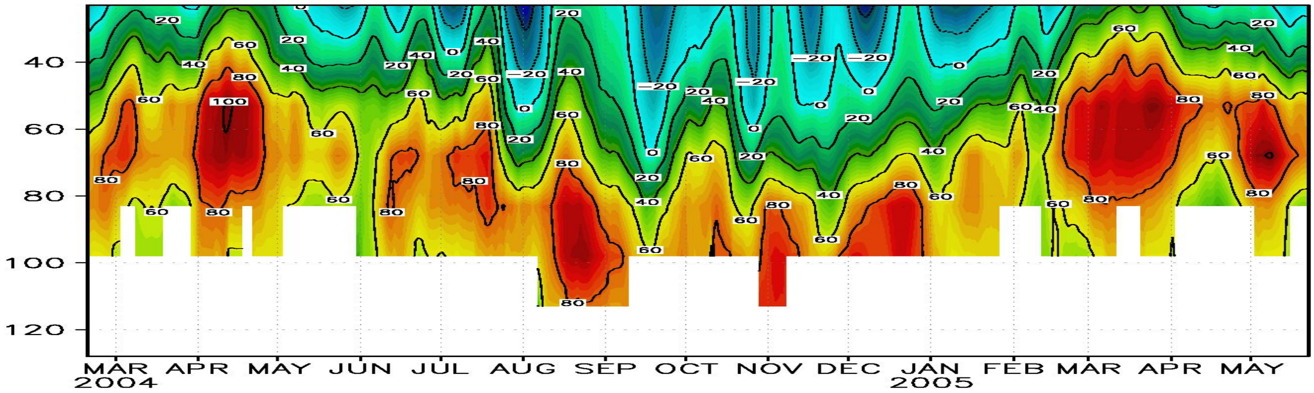


**Figure 4:** 10-day averaged PIRATA zonal velocities (cm/s) at $0^o$ N $23^o$ W from February 18, 2004 to May 23, 2005. Positive values are related to eastward flow.

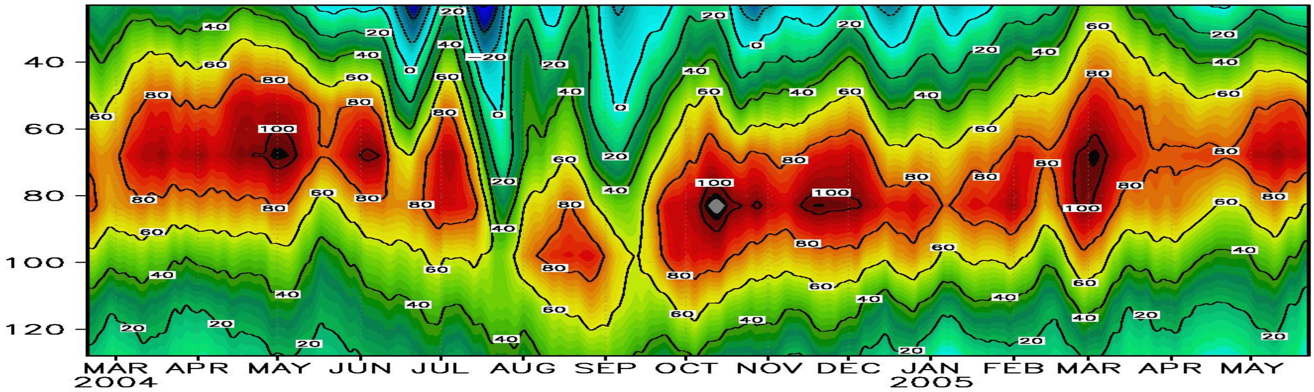


**Figure 5:** Same as Figure 4 but for the ocean model results.