RECENT OBSERVATIONS OF SEASONAL VARIABILITY OF THE MEDITERRANEAN OUTFLOW IN THE STRAIT OF GIBRALTAR

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Abstract

Recent observations of the outflow collected near the bottom in key points of the Strait of Gibraltar within the Spanish funded project INGRES (REN03-01608/MAR), suggest the existence of a seasonal cycle of temperature and density with warmer and lighter waters leaving the Mediterranean Sea in winter and cooler and denser waters in spring early summer. The amplitude of the signal is around 5 10^{-2} °C for potential temperature and 1.5 10^{-2} for potential density, salinity hardly showing any seasonal fluctuation. The outflow also shows a seasonal cycle with maximum volume transport in April, in coincidence with the signal of potential temperature.

Keywords : Strait Of Gibraltar, Western Mediterranean, Monitoring, Deep Waters, Water Transport.

The experimental data of this study were collected in Espartel (ES, 35° 1.7'N, 5° 58.6'W) and Camarinal (CS, 35° 54.8'N, 5° 44.70'W) sills in the Strait of Gibraltar (Figure). The bulk of data come from ES station, which started working in September 2004 and continues collecting data. The station has an uplooking ADCP at 20 m above sea floor, a RCM9 and a MicroCat CT at around 15 and 10 m above sea floor, respectively, all instruments recording every 30 min. From February to May 2006 a second mooring line with the same configuration as ES line was deployed in CS with the aim of comparing simultaneous observations at both sills. ES station is linked to Hydro-Changes initiative and is aimed to monitor the properties of the Mediterranean outflow on the long term. Presently the station has collected data over two years and has provided useful information to investigate annual variability, which is analysed in this contribution.

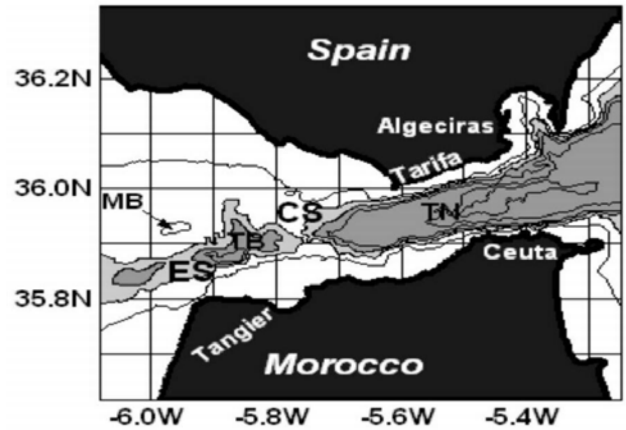

Fig. 1. Map of the Strait of Gibraltar showing the main topographic features. CS and ES indicates Camarinal and Espartel sills, MB is the submarine ridge of Majuan Bank, TB is the Tangier Basin and TN is Tarifa Narrows. The plotted isobaths are 100 m, 290 m (the light-shaded contour chosen to highlight CS, -297 m), 400 m (the medium-dashed contour), and 500 m, 700 m and 900 m.

Hydrological observations are largely modified by semidiurnal tidal flow. To remove tides, the original series were divided into pieces one semidiurnal tidal cycle long and the absolute minimum of potential temperature (T-pot), and maxima of salinity and sigma-theta within each piece were identified. The resulting series of extremes represent the properties of the less-mixed Mediterranean water that is able to overflow the sills during a given tidal cycle, and they are suitable for seasonal variability studies. Extreme values in CS are mainly observed between 2 and 3 hours after the maximum tidal outflow. This is an encouraging finding because the flow over CS is able to suction water residing at the eastern side of the Strait from depths of 700 m or more [1], where Mediterranean water is less mixed and maintains purer T/S characteristics. Maximum suction will coincide with maximum outflow and, from this time onwards, the water crossing the sill will exhibit purer and purer Mediterranean characteristics until the internal bore formed downstream of CS during the flood tide [2] occurs. It happens around one hour before high tide, that is, nearly three hours after the maximum outflow, which should be the time when the less mixed Mediterranean water is expected to be overflowing CS. It is also important to say that while the original series of T-pot and S behave differently in both sills, the time series of extremes do not, thus ensuring that low frequency signals can be analysed using data either from CS or from ES.

The series of extremes and computed outflow from ADCP observations in ES have been fitted to a harmonic function of annual and semiannual frequencies in order to investigate seasonal variability. The clearest seasonality is found in T-pot with warmer water flowing by the end of the year. A non-negligible semiannual signal, arising from the fact that T-pot drops rapidly after reaching the seasonal maximum and increases slowly towards the next maximum, combines with the annual one to produce the coldest flow around March. Salinity hardly has seasonal signal while sigma-theta shows a signal induced by T-pot. The computed outflow exhibits enhanced winter variability due to the stronger meteorological forcing in this season but also a seasonal signal whose phase agrees with previously reported values [3, 4] and coincides with the time of the year when T-pot is at its lowest value.

The behaviour depicted above suggests that the seasonal variability is closely related to the process of formation of WMDW in the manner put forward by Bormans et al. [5]. Winter deep convection would replenish the reservoir of WMDW (or WMDW plus other intermediate waters overlying this water mass, such as the Tyrrhenian Dense Water) in the western Mediterranean basin, rising the hypothetical interface some tens of meters and making colder water available for suction over CS. Coincidentally with this fact, the outflow would increase, in agreement with the observations. Should this be the explanation, the seasonal cycle would be strongly dependent on the winter conditions in the WMDW formation areas. Mild winters would lead to a reduced seasonal signal (the case of the winters in early 2000's) while hard winters, like those of 2005 and 2006, would produce noticeable signals.

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