SUBINERTIAL VARIABILITY OF THE EXCHANGED FLOWS AT THE WESTERN EXIT OF THE STRAIT OF GIBRALTAR

A. Sanchez-Roman [1], J. Garcia-Lafuente [1], F. Criado-Aldeanueva [1], J. Delgado [1], J. M. Vargas [1], J. Soto-Navarro [1], J. C. Sanchez-Garrido [1], C. Naranjo [1]* and C. Calero [1]
[1] Physical oceanograpy Group. University of Malaga. Malaga, Spain - cristina.naranjorosa@alum.uca.es

Abstract
Four year-long time series of Acoustic Doppler Current Profiler (ADCP) observations at a single station in Espartel sill have been analysed in order to investigate the subinertial flows through the Strait of Gibraltar. Estimated net flow at the western exit of the Strait has been compared with atmospheric pressure over the north eastern Atlantic (parameterised by the NAO index) and sea level pressure and wind-stress in the western Mediterranean. The main driving force is the atmospheric pressure over the Mediterranean Sea, although wind stress in the Atlantic side of the Strait may contribute appreciably to subinertial net flow.
Keywords: Atmospheric Input, Western Mediterranean, Water Transport, Strait Of Gibraltar

The western Mediterranean Sea is dynamically connected to the Atlantic Ocean through the Strait of Gibraltar. The excess of evaporation (E) over precipitation (P) and river runoff (R), together with the conservation of mass and salt in the Mediterranean basin drive the two-layer baroclinic exchange in the Strait. This exchange has been traditionally described as an inverse estuarine circulation [1] with an upper flow Q_1 of about 1 Sv (1 Sv = 10^6 m^3 s^{-1}) of fresh ($S_A \approx 36.2$) and warm Atlantic Water spreading into the Mediterranean basin, and a lower flow Q_2 of relatively cold and salty ($S_M \approx 38.4$) Mediterranean Water. A long term barotropic flow $Q_0 = Q_1 - Q_2$ of the order of 0.05 Sv is necessary to balance the water deficit (E-P-R) of the Mediterranean Sea. The exchange is not steady but highly variable. According to the timescale of the process under study this variability has been traditionally classified into tidal, subinertial and long-term (seasonal and interannual). Subinertial flows, with periods from a few days to a few weeks or months, are mainly driven by meteorological forcing [2, 3] and are related to atmospheric pressure fluctuations over the western Mediterranean [4]. These flows are mainly barotropic (depth independent) although a baroclinic contribution can be identified due to the effects of local winds over the Strait.

In this work, ADCP velocity records collected over Espartel Sill (ES) are used to investigate the subinertial fluctuations of the exchanged flows at the western exit of the Strait of Gibraltar. Data from ES are the most recent recorded in the Strait. This station was placed at 35º 51.70'N, 5º 58.60'W in September 2004 and it is still acquiring information so five year-long time series are now available, this making the analysis of the flow seasonality a feasible task. A four year-long subset (from September 2004 until January 2009) has been used in this work. The ES station is part of the Spanish-funded INGRES project. The two-layer character of the exchange requires an interface definition to compute the transports. The easier and more obvious definition (after removing tidal fluctuations, which distort the two-layer exchange during part of the tidal cycle) is the surface of zero along strait velocity that separates water flowing into the Mediterranean and water flowing out. Subinertial velocities only reverse in very exceptional situations of extreme meteorological forcing. On the other hand, seasonal and interannual variability are always too weak to reverse flows. Therefore, the surface of null along-strait velocity is appropriate to carry out an analysis of the two-way exchange at subinertial frequencies [3]. ADCP data from ES were used to compute the Mediterranean outflow (more details in [5]) whereas the net flow (and hence the Atlantic inflow) were estimated from a mass-balance over the Mediterranean. Finally, atmospheric pressure and wind stress observations collected both in the Alboran Sea and the Strait of Gibraltar have been used together with the NAO index in order to analyse the response of the exchanged flows to the meteorological forcing and its seasonality.

The net flow has a mean value of 0.04 Sv at it presents a seasonal signal of around 0.04 Sv amplitude with maximum in September and minimum in March, similar than that obtained by [3] in the eastern Strait. The time-averaged Mediterranean outflow is -0.77 Sv with a maximum (absolute) value in April and minimum in November [5] (seasonal signal of 0.025 Sv amplitude). The Atlantic inflow was eventually estimated from both transports. It presents a mean value of 0.81 Sv with seasonality quite similar to that of the net flow. Meteorologically induced net flow fluctuations are chiefly driven by atmospheric pressure changes over the Mediterranean Sea showing a negative correlation that turns positive for the Mediterranean outflow due to the baroclinic response of the exchanged flows. Wind stress must be also taken into account since it may appreciably contribute to subinertial net flow.

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