DIRECT ESTIMATE OF WATER, HEAT AND SALT TRANSPORT THROUGH THE STRAIT OF OTRANTO

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Abstract
Water, heat and salt transport across the Strait of Otranto are estimated. Historical data sets (from December 94 through November 95) are used in this study [1, 2]. A new methodology (Variational Inverse Method [3]) is used to reconstruct the current, temperature and salinity fields over a regular grid, from the sparse measurements across Strait of Otranto. The direct method [4], which is simply spatial integration of production of current, potential temperature, specific heat capacity and water density over the transect area, is applied to gridded data to calculate the transport rates. The air-sea heat fluxes are calculated for the period of study to compare with heat advection through the Strait. The fresh water budget is estimated as well.
Keywords: Adriatic Sea, Strait Of Otranto, Water Transport, Heat Budget

The water, heat and salt transports through the Strait of Otranto are estimated applying direct method to historical current and hydrographical data (from December 94 through November 95). A variational inverse method based on a variational principle and a finite element solver is used to reconstruct the current, temperature and salinity fields across the Strait section from sparse measurements. Characteristics of the current field obtained by this new application are comparable to the historical studies [2]. The main features, such as the existence of the horizontal anticlockwise shear in the strait with inflow (northward currents) on the east and outflow (southward currents) on the west, and a two-layer system in the central deep portion (with inflow in the surface and outflow in the bottom layer) are reproduced. The mean annual inflow and outflow water transport rates are estimated as 0.901±0.039 Sv and -0.939±0.315 Sv, respectively, and the net transport is equal to -0.032±0.208 Sv. Thus, on a yearly time interval, the inflow and the outflow are practically compensated. The seasonal variation of water transport across the Strait of Otranto shows that the maximum exchanges take place during winter and spring, while the minimum exchanges are in summer. The errors of the inflow transport rates are almost always less than 10%, while the errors of outflow transport rates have large values 30%-50%. This is due to low spatial resolution of the current measurements in the lower layer of the central part of the cross section, which is located mostly in the outflow region. Consequently, the higher error on outflow influences the net transport rates and finally these estimations are associated with larger errors.

The heat and salt transports due to advection process are calculated for the first time. These estimations are carried out for five monthly periods, namely December 1994, February, May, August and November 1995. Considering these five periods representative of the seasonal cycle during the year (Autumn 1994 and four seasons of 1995), their average values show that there is a net heat advection into the Adriatic Sea on a yearly basis. The estimated value of advected heat and the corresponding error are 2.408±0.490 TW, which is equivalent to a heat gain of 17.37±3.53 W m^{-2} for the whole basin. The heat exchange through the air-sea interface is estimated by applying the bulk formulas to the meteorological data, namely the ERA-40 reanalysis data set extracted from European Centre for Medium-Range Weather Forecasts (ECMWF). The average surface heat flux for the study period is estimated as a heat loss of -36±152 (std) W m^{-2} through the air-sea interface over the Adriatic Sea. The final estimates of the advected heat through the Strait of Otranto are compared and discussed with the relationship to air-sea heat exchange over the Adriatic Sea. The two values are expected to balance each other in order to close the heat budget of the basin. The possible reasons for a difference to occur are discussed. On an annual time scale the advected heat should be compensated with the air-sea heat loss. However, on a seasonal time scale a significant disagreement might be expected. This is due to seasonal variation of the heat content of the Adriatic Sea, seasonal cooling or warming. Moreover, it can be related to the fact that the heat advection and surface heat exchange are basically two different mechanisms in time and space. Therefore, the spatial and temporal scales of these processes are different. Consequently, they can not balance each other on a short time scale as monthly or even a seasonal one. The potential temperature distribution indicates that the upper layer (first 200 m from the surface, including thermocline layer) is associated with higher temperature and elevated variability, while the lower layers are associated with lower temperature and smaller variability. This fact may set up the different role that each of the two layers plays in transporting heat. To examine this, the heat transport rates are then calculated for the two layers separately: the upper layer from sea surface down to 200 m depth and the lower layer from 200 m depth to bottom. The results show that the upper layer has larger contribution to the heat transport into the Adriatic Sea (heat gain), and as the net heat transport, the inflow of heat prevails in this layer. The lower layer contributes significantly to the heat transport away from the Adriatic Sea (heat loss). In fact, the net heat transport rates are negative, which means that the outflow of heat dominates in this layer.

The effect of temporal variation of the temperature field, which remains unsolved by using hydrographic surveys, is examined by simultaneous time series of current and temperature measurements. The contribution of eddy heat fluxes to total heat advection is estimated. The contribution is less than 6% [5]. Therefore, by calculating the heat transport from averaged current and temperature distributions, we asses the major part of the total heat transport, and consider it as representative of the total heat due to advection. The direct estimation of heat transport can be used as a constraint for validating the air-sea heat fluxes [6]. Therefore, by considering the advected heat as a reference, one can tune the bulk formulas to modify the estimation for the air-sea heat fluxes.

On a yearly basis, the salt transport is estimated as an input of salt equal to 0.05×10^{6} Kg s^{-1}. The average annual fresh water budget is estimated as -0.002 Sv, equivalent to 0.45 m yr^{-1} for the entire Adriatic Sea. The import of salt that is less than the gain of fresh water is in agreement with the fact that the Adriatic Sea is a dilution basin. The brief results of water, heat, salt and freshwater transports are presented in Table 1 [5].

Table 1. Water, heat, salt and freshwater transports across the Strait of Otranto [5]. Units are in Sv (10^{6} m^{3} s^{-1}), TW (10^{12} Watts) and MKg/s (10^{6} Kgs^{-1}).

Period	Water (Sv)	Heat (TW)	Salt (MKg/s)	Freshwater (Sv)
Dec. 94	0.045 ± 0.182	2.068 ± 0.148	0.007 ± 0.086	-0.001
Feb. 95	0.163 ± 0.206	2.633 ± 0.259	0.033 ± 0.091	-0.001
May 95	0.055 ± 0.232	1.718 ± 0.293	0.065 ± 0.058	-0.002
Aug. 95	-0.118 ± 0.177	3.287 ± 0.151	0.079 ± 0.048	-0.002
Nov. 95	0.104 ± 0.274	2.338 ± 0.207	0.049 ± 0.053	-0.001
Mean	-0.032 ± 0.208	2.408 ± 0.490	0.046 ± 0.031	-0.002

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