WATER TRANSPORT VARIABILITY IN THE AEGEAN SEA AND ITS CONNECTION WITH NORTH SEA CASPIAN PATTERN (NCP)

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ÖZET

The relationship between water transport in the Aegean Sea and the North Sea Caspian Pattern (NCP) index is investigated. Calculated meridional mass transport in the Aegean Sea, a possible proxy for the Eastern Mediterranean Transient (EMT), shows significant correlation with the NCP index, especially in winter. It was found that the EMT may have happened during the consistent positive phase of the NCP index. Two different wind regimes corresponding to the positive and negative phases of the NCP suggest that atmospheric condition defined by NCP over the Euro-Mediterranean region may play significant role to trigger the EMT event.

***Anahtar Kelimeler*:** Aegean Sea, Eastern Mediterranean Transient (EMT), Climate Indices, North Sea Caspian Pattern (NCP)

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2. INTRODUCTION

In the Mediterranean Sea, there are preferred dense water formation regions. The Aegean Sea, with wide shelf areas subject to strong atmospheric activity, is known to be one of the Mediterranean regions suitable for dense formation. (Fig. 1) [1], [2]. The amount of dense water formed in the Aegean Sea changes dramatically, depending on the climatic conditions over the region [3]. An important climatic change in the early 1990s in the Eastern Mediterranean region was the shift in the main dense water formation site from the Adriatic Sea to the Aegean Sea [4], leading to modified properties of the Eastern Mediterranean deep water, known as Eastern Mediterranean Transient (EMT). There has been a number of studies investigating the possible mechanism behind this event; [5] attributed it to the change in the strength and direction of the wind stress field over the Aegean Sea, [6] suggested that reduced Black Sea water outflow into the North Aegean facilitate dense water formation, [7] proposed that the significant cold conditions over the Aegean Sea would be capable of switching the formation site to the Aegean Sea.

The atmospheric connections leading to the EMT are not clearly identified yet. [8] tried to find connection between EMT and North Atlantic Oscillation (NAO), but did not find any significant correlation between Aegean Sea surface heat fluxes and the NAO, and speculated that another atmospheric pattern could be responsible for EMT. [9] have shown the North Sea Caspian Pattern (NCP) (an upper layer atmospheric circulation defined by two centers at 500 hPa geopotential height) to be an important tele-connection pattern influencing air-sea fluxes of Euro-Mediterranean seas, possibly related with the EMT. Later [10] have also found the East Atlantic / West Russia (EA/WR) pattern, an analogue of the NCP, to be the pattern with the highest correlation with the winter heat loss in the region leading to the EMT.
Although the sequence of events leading to the EMT, its recurrence and the fate of the generated dense water masses are not very clear, various studies have investigated the physical processes that could have contributed [11-13]. The aim of the present study is to investigate the possible connection between NCP and water transport in the Aegean Sea. In section 2, the source of the data and methods are described, and in section 3, the results from correlation analyses are discussed.

2. DATA AND METHOD

The Aegean Sea meridional velocity data of the INGV Ocean Analysis data set has been obtained from the data archives of the EU-funded project ENSEMBLES [14] (The ultimate aim of the project is to develop an ensemble prediction system by using the available regional atmospheric and oceanic models over the European Seas.This study uses the meridonal velocities created by the ocean climate simulations of an ocean model with 1° horizontal resolution and 72 vertical levels, covering the 1960-2005 period (46 years).

The NCP index is based on monthly mean geopotential height data at the 500 hPa atmospheric pressure level [15]. The geopotential height data are averaged over two centers: the North Sea (0° – 10°E, 55°N), and the North Caspian (50° – 60°E, 45°N). The NCP index is calculated by the normalized difference in mean geopotential between these two centers.

Meridional mass transport *M* was calculated by integrating the meridional velocity $v(x,z)$ over the whole water column and on east-west oriented sections across the Aegean Sea (between longitude limits 23°E to 28°E):

$$\boldsymbol{M} = \int_{z=surface}^{z=bottom} \int_{x=23^{\circ}E}^{x=28^{\circ}E} v(x,z)\,dx\,dz.$$

3. RESULTS

Meridional mass transport is chosen as a proxy for the EMT event, since it is believed that the new dense water formed over the Northern Aegean Sea is expected to move south [2].

Table 1 shows the correlation coefficient computed between the mass transport ***M*** at different latitudes and the NCP index for different time windows. In general, the correlation coefficient has higher values in winter months, and reaches a maximum value at 37°N latitude. Annual mean (December-January-February (DJF)) time series of NCP index and mass transport at 37°N is shown in Figure 2 (a). In general, these two time series shows strong similarity during the investigated period, confirmed by a correlation coefficient value of $r = -0.58$. In Figure 2 (b), the annual mean time series are filtered by a boxcar filter of 3 years in length. The correlation coefficient increase to $r = -0.73$ after filtering.

The NCP index shows persistent positive values during the early 90s, which corresponds to the EMT period. It has been suggested [8, 17] that other anomalous cooling events in the period 1972–1976 besides the EMT in the 1990s, which may have produced conditions conducive to deep water formation in the Aegean Sea. NCP time series in Fig. 2 (b), indicates consistent positive values in mid 1970s, confirming these events.

The wind velocity at 10m for the years when NCP index is positive (Figure 3(a)) and when NCP index is negative (Figure 3(b)) were calculated. It shows clear distinction in winds between the two periods. While the positive NCP index phase shows a stronger southward wind over the Aegean Sea, the negative phase reflects rather calm conditions over the Aegean Sea.

4. CONCLUSIONS

In this study, the possible connection between the water transport and a tele-connection pattern is investigated. It is found that the water transport over the Aegean Sea is strongly correlated with the atmospheric pattern over the region of interest. The connection is stronger in winter months. While the consistent positive phase of the NCP corresponds to the very strong southward winds over the Aegean Sea, corresponding to the dense water formation periods, the negative phase of the NCP corresponds to rather calm conditions.

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Table 1 Correlation coefficient between the mass transport anomaly (averaged over $23^{\circ}E$ to $27^{\circ}E$ and from surface to bottom) and NCP index. The two time series (1960-2005) filtered with a boxcar filter with a length of 3 years. First column show the latitude of the section that mass transport calculated, the other columns are months (i.e. jfm: January-February-March etc.)

Lat	jfm	fma	mam	amj	mjj	jja	jas	aso	son	ond	ndj	djf
35°N	0.34	0.16	-0.24	-0.29	-0.39	-0.19	-0.10	-0.23	-0.27	-0.10	0.27	0.45
36°N	-0.18	0.11	**-0.50**	-0.18	-0.32	-0.15	-0.20	-0.20	-0.11	0.06	-0.36	-0.37
37°N	**-0.57**	-0.34	**-0.53**	-0.06	0.09	-0.11	-0.35	-0.13	0.00	0.02	**-0.65**	**-0.73**
38°N	-0.12	0.26	0.08	0.21	-0.05	0.09	0.15	-0.10	0.12	0.05	-0.29	-0.17
39°N	0.13	0.36	**0.52**	**0.54**	-0.28	0.26	0.38	0.05	0.09	0.18	-0.08	-0.09
40°N	0.05	-0.02	0.05	-0.37	-0.33	-0.17	0.00	-0.20	-0.37	0.11	**0.55**	0.42

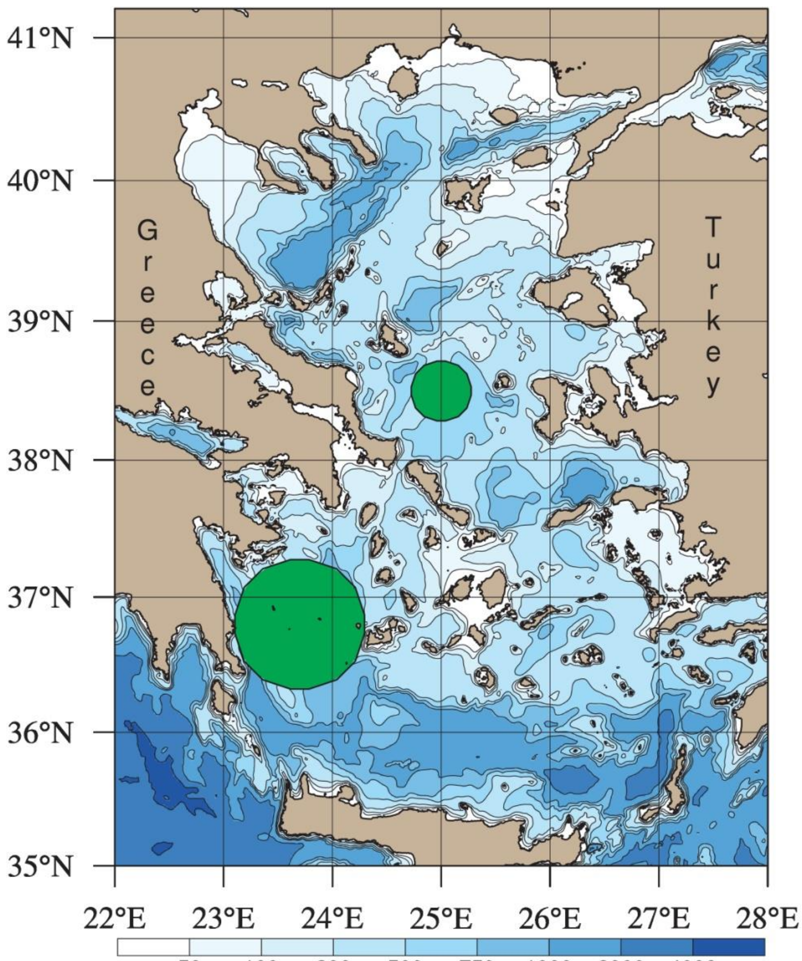

Figure 1. The bottom topography of the Aegean Sea. The winter convection areas are shown by green circles [1], [2].

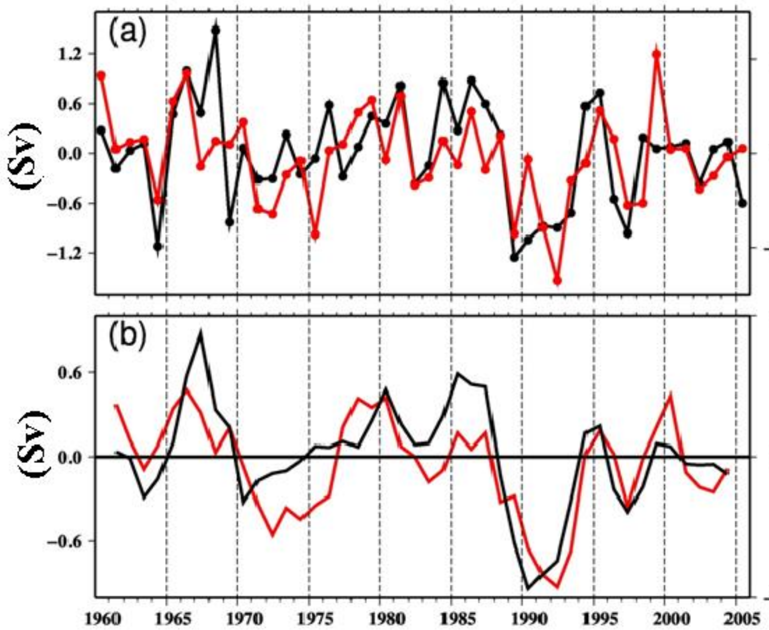

Figure 2. (a) Time series of annual mean mass transport (black line, scale on the left, in Sverdrups) at 37° *N* and NCP index (red line, multiplied by -1, scale on the right) over the December-January-February (DJF) months. (b) Boxcar filtered time series with a filter length of 3 years. The correlation coefficient is -0.58 in (a), the correlation coefficient is increased to -0.73 after boxcar filtering in (b).

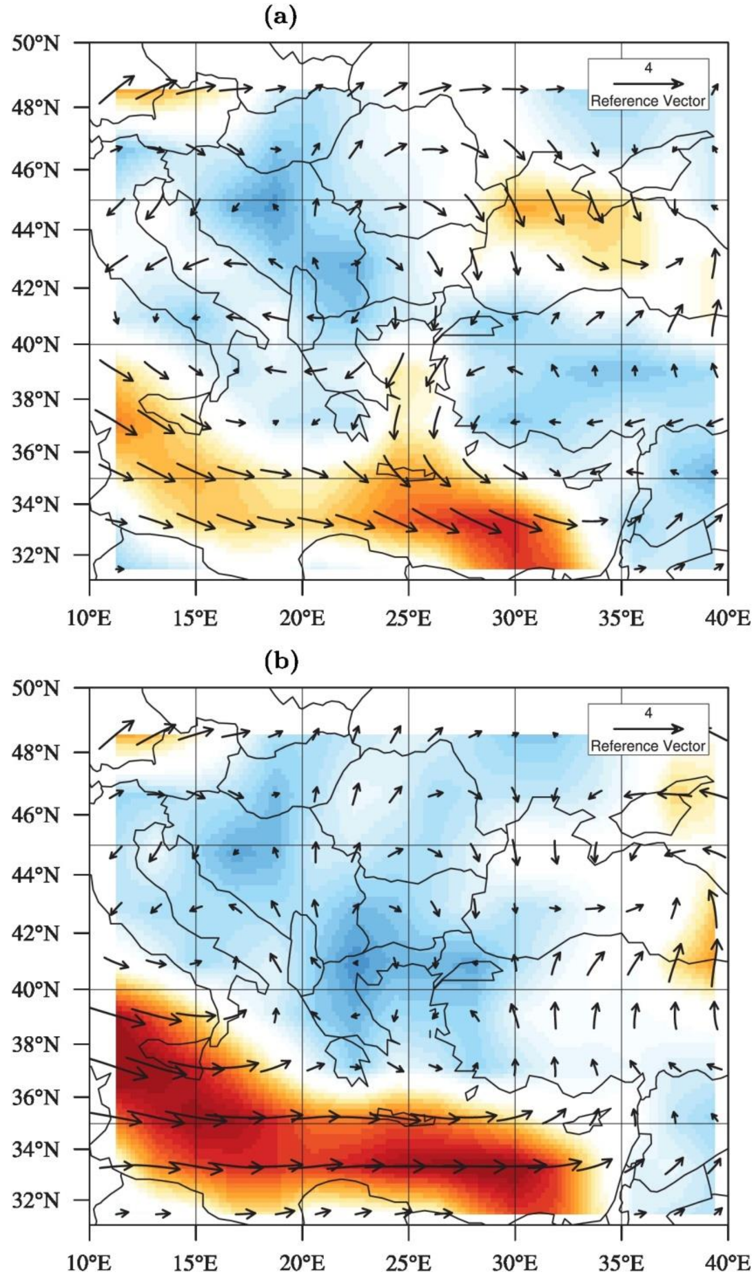

Figure 3. Velocity vectors (m/s) at 10 m (a) Averaged over the years when NCP is positive (i.e. 1964, 1967, 1971-1975, 1980, 1982, 1983, 1985, 1987, 1990-1994, 1997, 1998, 2002, 2003 (b) Averaged over the years when NCP is negative (i.e. 1965, 1966, 1968-1970, 1976-1979, 1981, 1984, 1986, 1988, 1995, 1996, 2000, 2001).