SCIENTIFIC REPORTS

OPEN

Received: 31 July 2017
Accepted: 9 July 2018
Published online: 27 July 2018

Linking mixing processes and climate variability to the heat content distribution of the Eastern Mediterranean abyss

Vincenzo Artale[1,2], Federico Falcini[2], Salvatore Marullo[1,2], Manuel Bensi[3], Florian Kokoszka[4], Daniele Iudicone[4] & Angelo Rubino[5]

The heat contained in the ocean (OHC) dominates the Earth's energy budget and hence represents a fundamental parameter for understanding climate changes. However, paucity of observational data hampers our knowledge on OHC variability, particularly in abyssal areas. Here, we analyze water characteristics, observed during the last three decades in the abyssal Ionian Sea (Eastern Mediterranean), where two competing convective sources of bottom water exist. We find a heat storage of ~1.6 W/m^2 – twice that assessed globally in the same period – exceptionally well-spread throughout the local abyssal layers. Such an OHC accumulation stems from progressive warming and salinification of the Eastern Mediterranean, producing warmer near-bottom waters. We analyze a new process that involves convectively-generated waters reaching the abyss as well as the triggering of a diapycnal mixing due to rough bathymetry, which brings to a warming and thickening of the bottom layer, also influencing water-column potential vorticity. This may affect the prevailing circulation, altering the local cyclonic/anticyclonic long-term variability and hence precondition future water-masses formation and the redistribution of heat along the entire water-column.

Convection and diapycnal mixing contribute to transfer and redistribute water masses and heat throughout the deep ocean[1–3]. These phenomena act at very different time scales[4,5]. Diapycnal mixing, in particular, increases the potential energy within a stratified fluid by raising the water mass center on a larger time and spatial scale. It is triggered by an external process[4,6] and it is concentrated above seamounts, mid-ocean ridges, and along strong currents[2,3].

Despite its thorough implications in the ocean circulation, the relationship between the intensity of overturning circulation and deep mixing rates is not yet fully understood, particularly, in the Mediterranean Sea[7–11]. Numerical models, in such a context, seems often useless since they are too sensitive to vertical eddy diffusivity and largely affected by inaccuracy at deep layers[12–14]. Consequently, the analysis of *in situ* observations is crucial for understanding the actual role of mixing in the deep ocean circulation and heat content distribution.

The Eastern Mediterranean Transient (EMT), i.e., the first experimental evidence of a non-steady behavior of the deep Mediterranean thermohaline circulation, gave us the opportunity to investigate, experimentally, convective and mixing dynamics[7]. During the EMT (occurred between the end of 80′ and the beginning of 90′), the Aegean Sea turned to be the source of deep water, also causing an increase of surface water temperature, salinity, and density in the Eastern Mediterranean and, in particular, in the Aegean Sea[7,9] (Fig. 1). This dense water feeds the Eastern Mediterranean Deep Water (EMDW), thus replacing (for some years) the Adriatic Sea (Fig. 1) as the main producer of bottom water[7,9,15]. Subsequently, the meridional overturning circulation of the Eastern Mediterranean, as obtained by general circulation models, showed multiple equilibria states[16] under slight perturbations of the present-day-like conditions[17,18]. These findings revealed two stable states and a hysteresis behavior

[1]Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, ENEA — Centro Ricerche Frascati - Dipartimento Sostenibilità dei Sistemi Produttivi e Territoriali (SSPT), Frascati, 00044, Italy. [2]Istituto di Scienze dell'Atmosfera e del Clima, Consiglio Nazionale delle Ricerche, Roma, 00133, Italy. [3]Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, OGS, Trieste, 34010, Italy. [4]Stazione Zoologica Anton Dohrn, Villa Comunale, Napoli, 80121, Italy. [5]Department of Environmental Sciences, Informatics and Statistics, University of Venice, Mestre, 30172, Italy. Correspondence and requests for materials should be addressed to F.F. (email: ffalcini@isac.cnr.it)