THE GREAT EASTERN MEDITERRANEAN DEEP-WATER TRANSIENT

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Abstract
Around 1990 large volumes of Aegean Sea overflow began to be deposited in the near-bottom waters around the Cretan Arc. The resulting, transient situation contrasts with a quasi-steady state situation prevailing previously in which the depth range below about 1200 m depth was dominated by waters of Adratic origin. In the course of the transient the distribution of all properties changed drastically through the entire Eastern Mediterranean. The salinity of the outflow through the Sicily Channel was lowered and nutrient concentrations in the upper waters were raised. In this communication we provide a description of the changes, address the causes and the initiation of the transient and name certain of its implications. The transient represents a unique oceanographic event which warrants detailed studies also in the future.

key-words: deep waters, circulation, Eastern Mediterranean

Introduction

The textbook descriptions of the Mediterranean thermohaline circulation, which go back to the work of Wüst [1] and Lacombe and Tschernia [2], among others, depict it as a rather static anti-estuarine system (the so-called Mediterranean conveyor belt). The conveyor consists of Atlantic surface water entering through the Strait of Gibraltar, above outflowing high-salinity Mediterranean water (exchange flow on the order of 1 Sverdrup, or 106 m^3/s [3]), driven by a high net evaporation that increases the salinity, and hence the density, of the Mediterranean waters. A predominant water mass is the Levantine Intermediate Water (LIW) generated southeast of the island of Rhodes in the Levantine Sea, which forms a subsurface salinity-maximum layer that seemingly carries the bulk of the subsurface westward return flow. The textbooks also name the principal formation areas of the deep waters, *i. e.* the Gulf of Lions for the Western Mediterranean and the South Adriatic for the Eastern Mediterranean, while the role of the Aegean Sea remained controversial. This sea, quite like the Adriatic, is a marginal sea with a rather continental environment to the north of the Eastern Mediterranean proper, so that also here dense waters are generated [4]. More recent work revealed a slow, rather steady salinity and temperature increase in the Mediterranean subsurface waters. This drift is due to a changing fresh-water budget, for example by the cutoff of the Nile discharge [5], but left the principal thermohaline structure unaffected. Furthermore it was found that the deep waters have an active part in the subsurface return flow of the conveyor [6].

A big step forward was achieved through new, coordinated Mediterranean observation programs. For the Eastern Mediterranean a prominent one is POEM (Physical Oceanography of the Eastern Mediterranean [7], later on renamed POEM-BC, *i. e.* POEM including biology and chemistry [8]). Furthermore the Mediterranean programs of the European Union (EU-MAST) were developed, which lately have made up the bulk of the physical and biogeochemical work in the whole Mediterranean Sea. A specific new result is a determination of the formation rate of deep water of Adriatic origin of about 0.3 Sverdrup [9] from observations during a cruise of the German F/S *Meteor* in the summer of 1987. This rate is equivalent to an Eastern Mediterranean deep water residence time of approximately 120 years, and means that the renewal is equivalent to as much as about 30% of the conveyor belt flow. Furthermore the role of the Aegean Sea was clarified. The *Meteor* data proved that outflow from the Aegean through the straits of the Cretan Arc formed an intermediate-depth layer (termed Cretan Intermediate Water, CIW). CIW was found to be most prominent in the eastern Ionian Sea and south of Crete where it is centered in about 700 m [10, 11], thus replenishing what has often been called the "transition layer" between the LIW and the deep waters.

Although in 1987 the deep waters of the Eastern Mediterranean appeared to represent a well defined system near to a steady state, it was evident that the static stability between these waters and the Adriatic waters filling the Eastern Mediterranean from the bottom up to about 1200 m was a rather marginal one. In the years following there were indications that the situation was perhaps changing [12, 13], including surprising observations such as a reversed temperature gradient in the upper few meters of sediment in a region west of Crete [14]. During about the same period there was moreover a paradigm change in the physical oceanographic community towards questioning a view of the ocean circulation as a system that was basically stable [15].

A further Eastern Mediterranean cruise of F/S *Meteor* (successor of the previous ship of the same name) in January 1995, organized in connection with both the EU-MAST program and POEM-BC, was begun with the aim to investigate the situation as found in 1987 in more detail, but alerted by the findings mentioned. It came as a big surprise that the deep waters of the Eastern Mediterranean had in fact changed fundamentally, in that a large volume of Aegean outflow waters had entered the bottom and deep waters of the Eastern Mediterranean lifting the water column of the entire sea by several hundred meters within just a few years [16]. The nature of the change, its causes, and some implications are adressed in the following, primarily on the basis of observations of the two *Meteor* cruises mentioned.

Nature of the changes

Figures 1 and 2 compare the distributions of salinity and CFC-12 for the two surveys on a section along the entire Eastern Medi-

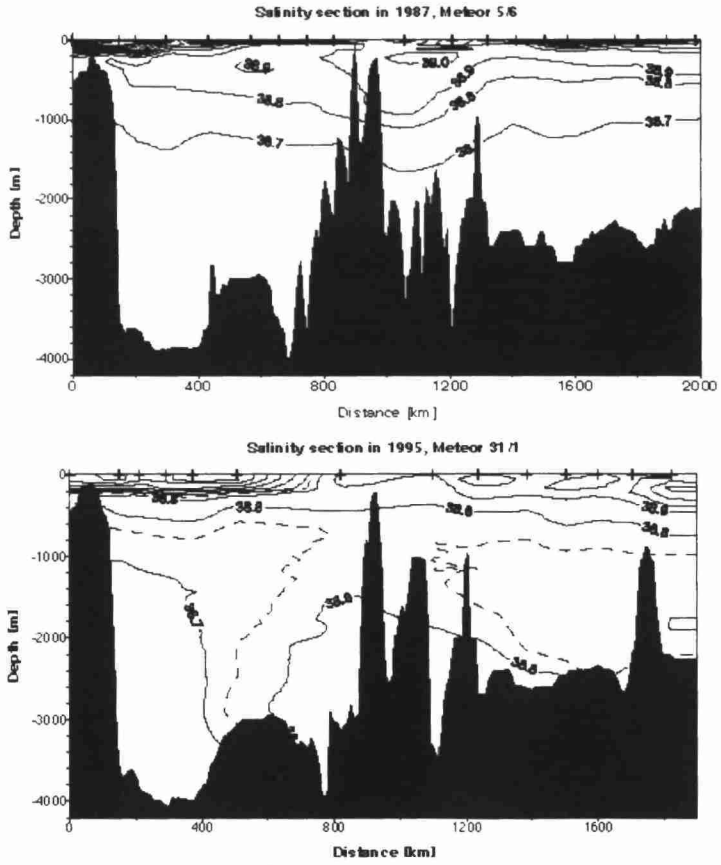

Fig. 1: Salinity isolines (psu) 1987 (Fig. 1a, upper panel) and 1995 (fig. 1b, lower panel) on sections along the entire Eastern Mediterranean as indicated in Fig. 3.