MECHANISM FOR NEW DEEP WATER FORMATION IN THE AEGEAN SEA

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Abstract

We analyse whether the observed newly formed deep water in the Aegean Sea could be formed locally by the combination of an increase in net evaporation and wintertime water mass transformation. With a simple mixed layer model, we show that an effective increase in net evaporation slowly increases the depth average salinity and decreases the stratification in the Aegean Sea until a severe winter leads to deep convection and new bottom water formation. We argue that the increased amount in net evaporation over the Eastern Mediterranean basin is due to river diversion projects in Russia and Egypt since the 1950´s.

Keywords : Aegen sea, water convection, air-sea interaction, depp-waters.

Introduction

In an experiment to examine wintertime water mass conversion in the Aegean Sea, Charnock and Miller made pre-winter hydrographic stations in October 1961 aboard R/V *Chain* and post-winter stations in March 1962 aboard R/V *Atlantis II*. In 1961-62 the deep water in the Aegean Sea had potential temperature of 14.15°C and salinity of 38.95‰ with a potential density anomaly of 29.25 kg m^{-3}. For both the October and March profiles, the deep water is separated from the surface waters above 500 m depth by lower salinity (38.75‰) called Transition Mediterranean Water by Theocharis et al.[1].

In September 1987 *Meteor* surveyed the Eastern Mediterranean including full-depth profiles in the Aegean Sea. In 1987 the deep water properties in the Aegean were effectively the same as in 1961-62. Notably, the 1987 profiles show a near absence of the low salinity TMW as the minimum intermediate water salinity is about 38.9‰, much higher than the TMW salinity of 38.75‰. Comparison of September 1987 and October 1961 and March 1962 depth-averaged salinities shows an increase in salinity of 0.03‰ to 0.05‰, which would be equivalent to a local net evaporation of 1.5 m to 2.5 m or an average extra net evaporation between 6.3 and 10.7 cm yr^{-1}.

In January 1995, Roether *et al.* [2] made another *Meteor* cruise to survey the modern deep water properties of the eastern Mediterranean. Remarkably, newly formed deep water was found in the Aegean Sea and it was spilling over the connecting sills and spreading out into the deep eastern Mediterranean basins [2]. The new deep water is about 0.2°C colder, 0.12‰ saltier and 0.13 kg m^{-3} denser than the deep water of 1961-62 or 1987. The structure of the vertical stratification, however, had returned to 1961-62 conditions with the reappearance of low salinity intermediate waters (TMW).

Modelling

We develop a simple mixed layer model where the initial profiles are taken to be the March 1962 observations of temperature and salinity (and hence density) versus depth linearly interpolated to 20 m intervals down to 2350 m. In time steps of one year, a net evaporation of 10 cm of freshwater is imposed on the uppermost 20 m layer. We run the model for 25 years, removing a net evaporation of 10 cm yr^{-1}. Then we continued to run the mixed layer model in monthly time steps using monthly anomalies of e-p and air-sea heat exchange anomalies from the SOC climatology [3] from March 1987 to December 1995. In addition we continue to remove a net evaporation at a rate of 10 cm yr^{-1} (0.83 cm $month^{-1}$).

Within the model, deep convection had reached 1950 m depth in March 1987. By March 1988, the entire water column is mixed with a bottom salinity of 38.99‰. After the winters of 1991-92 and 1992-1993 when large wintertime heat and freshwater losses occur over the Aegean, the deep water becomes colder as well as saltier. As a result of mild conditions in 1993 and 1994, no new deep water is found in March 1994 or in March 1995. By 1995, the deep water in the model has a salinity of 39.01‰ and a potential temperature of 14.05°C. The model deep water has cooled by 0.11°C and become saltier by 0.04‰ over the 8 years from 1987 to 1995.

Discussion and Conclusions

The model shows how persistent long-term changes in net evaporation can slowly change the stratification in the Aegean basin until suddenly deep water formation occurs during a severe winter. We attribute the observed increase in depth-averaged salinity from 1961-62 to 1987 to the increase in net evaporation following river diversion for irrigation in Russia and Egypt [4].

The formation of new deep waters in the Aegean is therefore a result of the two processes: a long, slow increase in the salinity due to changes in the water budget and then a catastrophic deep water formation event during a suitable cold, dry winter. The presence of low salinity intermediate waters in 1995 while the newly formed deep waters are still flowing out of the Aegean over the sills into the deep eastern Mediterranean [5] strongly suggests that deep water will not be formed again for several years in the Aegean. On the basis of observations and understanding to date, it appears that salinity initially increases near to where the water balance has changed; salty deep water is then formed in a local deep basin which then spills out over the sills spreading into the greater deep basin; within the local basin the outflowing dense waters are replaced by lower salinity waters which then shut off deep water formation. The cycle may repeat: we eagerly await new observations of the next stage as the Mediterranean becomes saltier and new model simulations brave enough to predict what will happen next.

References

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