AFTER DEEP WATER FORMATION: SINKING AND SPREADING OR REORGANISING PHASE, INCLUDING UPWELLING?

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Abstract
Oceanographic data obtained by mid spring at open sea in the central part of the NW Mediterranean reveal evidences that almost two months after the open sea Deep Water Formation (DWF) process, there are still energetic mechanisms reorganising the water mass structure. Among those, clear indications of a relevant upwelling below the thermocline, that would contribute to maintain the early spring open sea phytoplankton bloom

Keywords: Circulation, Blooms, Deep sea basins, North-Western Mediterranean, Upwelling

Traditional description of the DWF cycle in the Western Mediterranean involves a final phase of sinking and spreading of the newly formed deep water. At the same time, the upper level is progressively recovering its stratification. Both mechanisms are well known. While the first has been obviously observed in the deep layers, the latter has been identified as the main driver for the typical phytoplankton blooms, especially in those areas where deep water formation was previoulsy active. These descriptions assume that on slacking the thermohaline DWF forcing, exerted by strong, dry and cold winds, the sea recovers its typical circulation patterns. Then, vertical motions are almost negligible and horizontal current intensity is decaying with depth, at least in the upper and intermediate layers. Spring phytoplankton blooms developing during this stage can stand for a couple of months, often depending on the intensity of the former DWF process and the, not so scarce, early spring storms [1]. However, to our knowledge, nothing has been reported about possible upwelling of intermediate waters into the upper layer as a mechanism contributing to sustain and perhaps extend the period of blooming.

Within the framework of the "Famoso" project (Fate of the Northwestern Mediterranean Open sea Spring bloom) two cruises were carried out in the NW Mediterranean, in March and early May 2009 respectively. Winter 2009 was considered to be "normal" to "cold" in terms of DWF [2]. At the beginning of the March cruise DWF was still active and, at the end of the cruise the phytoplankton bloom was clearly growing. In early May, several patches of high chlorophyll were still present in the vicinity of the formerly active DWF areas. A closed box around one of these chlorophyll patches was surveyed with the on-board ADCP and a SeaSoar towed system covering the upper 400 meters of the water column. The box was almost closed, from late 29 April to 2nd May, and the flow across the boundaries was estimated in two layers above and below the 29.0 isopycnal. Surprisingly, the results show that in the upper 400 m outflow was much higher than inflow (Figs 1 and 2). One can easily assume that the missing flow through the opening at the N corner of the box should compensate the output on its western side, since it falls under the path of the well know slope current. However, even with this assumption the outflow still remained much higher than inflow. Since the shape chlorophyll distribution at surface evidences that the SE corner of the box was almost at the centre of a cyclonic eddy, another part of the uncompensated flow could be explained if the eddy were moving towards the SW during the survey. However such situation would compensate not more than an additional 20%. Thus the remaining ~50% could only be explained assuming an additonal inflow from below 400 m. Although most of this flow left the box below the 29.0 σ_t surface, part of which would reach the upper layer above that isopycnal (~60-100 m) within the photic zone. In addition to this surprising result, during the cruise there were additional evidences (not shown) for relatively strong currents at depths below 400 m as well as the presence of LIW at less than 200 m depth in several stations. The region thus, at early May, was still involved in a reorganising phase after DWF.

Summarising, the results show evidences that the last phase of the DWF would not only include sinking and spreading of the newly formed DW but also other energetic processes leading to the reorganisation of the dynamic structures, including upwelling pulses that would contribute to maintain the spring phytoplaknton bloom in NW Mediterranean open sea.

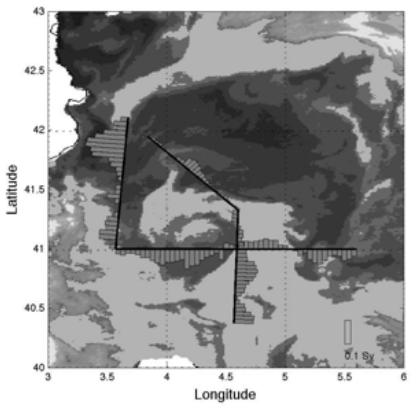

Fig. 1. Surface chlorophyll image from Modis Aqua (2/05/2009) and transport across the boundary estimated through ADCP and SeaSoar data through the Box Inverse method (upper layer above the 29.0 isopycnal)

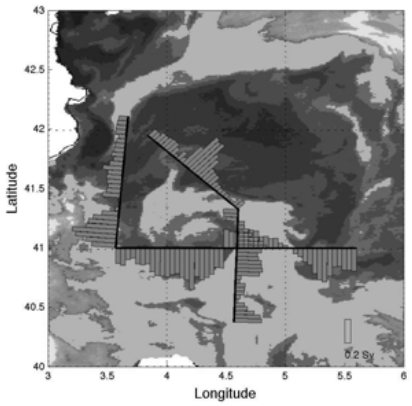

Fig. 2. Idem Fig. 1 with transport between 29.0 isopycnal and 400 m depth.

References

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