VARIABILITY OF CARBON DIOXIDE PRODUCTION RATES IN THE WATER MASSES OF SOUTHERN ADRIATIC PIT IN THE PERIOD 1993-2014

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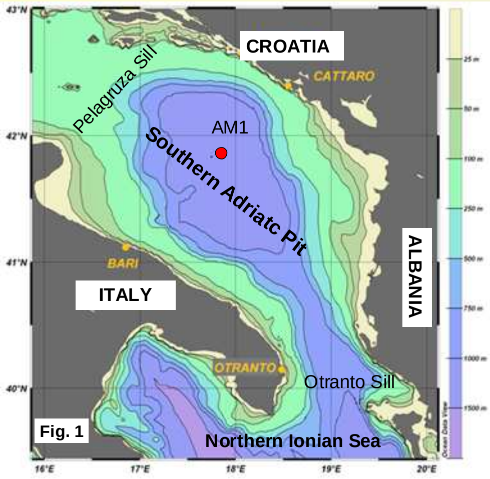

Fig. 1

During the last century, the global increase in fossil fuels consumption together with the reduced capacity to remove CO_2 due to deforestation, have caused a dramatic input of carbon dioxide into the atmosphere. The resulting enhancement of the natural Greenhouse Effect is partially balanced by the sequestration of CO_2 in the deep oceanic waters. In fact, topical studies have supported the significant role of the oceanic biological pump with respect to atmospheric CO_2 build-up. In the marine ecosystem the biological pump controls the export of biogenic carbon from the surface layers down to the deep. In brief, this mechanism transforms in the euphotic zone, through photosynthesis processes, carbon dioxide into organic matter; the latter sinks to the waters below and at the same time is consumed by respiration with the production of metabolic CO_2. However, during the formation of dense waters, a significant quantity of organic products is conveyed from the surface within the water mass and remineralized inside it, thereby altering the normal flow of the biological pump. This study presents the temporal variability of respiratory rates assayed by microbial Electron Transport System activity (ETSa) in a deep convection site (Fig. 1) of Eastern Mediterranean Sea (the Southern Adriatic Pit).

Our data, collected from 1993 to 2014 during several cruises in the context of various scientific projects (AM3, MATER, SINAPSI, VECTOR, SESAME, PERSEUS), shed light on the seasonal variability of the microbial respiration.

"BIOLOGICA PUMP"

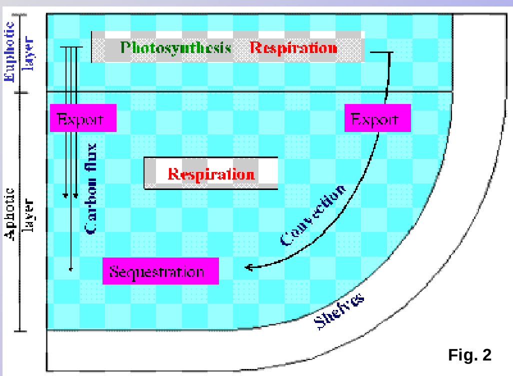

Fig. 2

Moreover, the binding of the oxidation of organic matter in the deep water with the formation or non-formation of deep water during these 21 years in the study area is investigated. In fact, in the years in which the deep water formation was documented, a supply of preformed C transported was observed within the deep water masses. Such C supply was reflected in a high oxidation of organic matter in the deep waters, that was not justified by the normal sink of organic matter conveyed by the Biological Pump (Fig. 2).

Material and Methods

The study was performed at one deep station (1200 m deep) located in the Southern Adriatic Pit (Fig. 1: st.AM1: 41°50'N; 17°45'E) and a total of nine cruises were conducted from August 1993 to February 2014. Respiratory rates were obtained according to the tetrazolium reduction technique (Packard, 1971, 1985), as modified by Kenner and Ahmed (1975) for the microplankton community. The ETS assay allows an estimate of the maximum velocity (Vmax) of the dehydrogenases transferring electrons from their physiological substrates (NADH, NADPH and succinate) to a terminal electron acceptor (O_2) through their associated electron transfer system. Briefly, sub samples for the analysis were pre-filtered through a 250 mm mesh size net to remove large particles and concentrated on GF/F Whatmann glass fiber membranes at reduced pressure (< 1/3 atm). The filters were folded into cryovials and immediately stored in liquid nitrogen until analysis in the laboratory (<45 days) to prevent enzymatic decay (Ahmed et al., 1976). The ETS was corrected for in situ temperature with the Arrhenius equation using a value for the activation energy of 15.8 kcal/mol (Packard et al., 1975). Potential carbon dioxide production rates (CDPR) were calculated from ETS Vmax utilizing the Takahashi oxygen–carbon ratio (Takahashi et al., 1985).

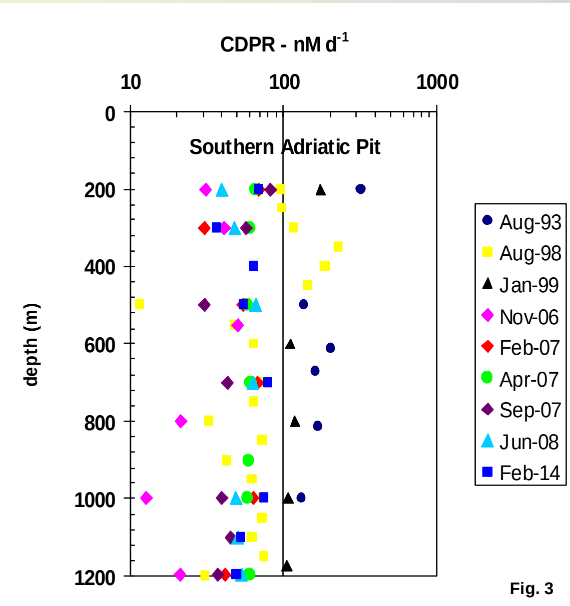

Fig. 3

Results and Discussion

In Figure 3, the CDPR determined in the south Adriatic Sea are reported. During August 1993, in the depth range between 200 and 1200 m, CDPR ranged between 131.8 and 319.8 nM d-1 and were the highest of time series. In August 1998, CDPR decreased (range 11.6–188.0 nM d-1), mostly because of the decline of the respiratory activity with depth. In January 1999, CDPR increased (range 104.7–174.4 nM d-1) with a slight increase below 600 m. The relative maximum of CDPR in 1998 at about 400-m depth was associated to a salinity of 38.73 and a potential temperature of 13.6 °C, with values in the underlying layer (400–800 m) all below 75.0 nM d-1 (θ < 13.5°C, S < 38.7), whereas the profile in 1999 was basically homogeneous around the value of 110 nM d-1 with a negative gradient in both S (down to 38.58) and θ (down to 12.75°C). These evidences suggest a close relationship between hydrological properties and ETS. In 2007 CDPR were lower than in previous years, probably because the winter convection in 2007 was lacking. Moreover, the highest values were determined in February and March 2007 in the period of algal bloom, and the lowest in September. CDPR slightly higher were determined in June 2008. Since deep respiration occurs at the expenses of POC and DOC, in Figure 4 we compare our south Adriatic values to the estimates of CDPR for the same area during the period 1992–1999 (Civitarese and Gacic, 2001). The convective mixing of the water column occurring during winter 1991–1992 induced - in spring 1992 - an averaged New Carbon Production (NCP) of about 120 mg C d-1 m-2 over a 4-month period. This was followed by a fast decrease for the next 2 years before the period 1995–1997, when the new production values were negligible and at their minima values. There were two reasons for that: the winter heat fluxes were dumped by the milder winters (Civitarese and Gacic, 2001; Gacic et al., 2002), and the salt supply from the eastern Mediterranean decreased, due to lower salinity waters upwelled from deeper layers in the Ionian. These concomitant events limited the capacity of the Adriatic to produce dense water (Klein et al., 2000) so that the convective mixing was weak or absent, and the nutrient supply from the deep reservoir to the surface highly reduced (Civitarese and Gacic, 2001).

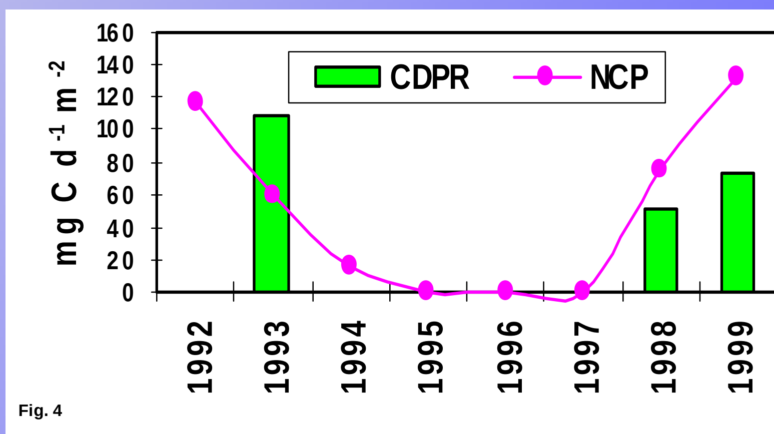

Fig. 4

During winter 1998 only, the winter convection occurred again, though reaching only the 400-m depth horizon (Gacic et al., 2002). In the same year the CDPR along the water column was lower than 1993 value (51 mg C d-1 m-2), and lower than the one expected for the estimated NCP. The reason for this low integrated value was the very low contribution to CDPR by the layer underneath 400 m, which was not affected by the convection. Therefore it is reasonable to assume the following. The relatively shallow convective event caused a pulse of export production without a parallel transfer of DOC to the deep layer (Gacic et al. 2002). On the other hand, the lack of significant convective events in the previous years had probably reduced the amount of respirable matter at depth, and consequently, the CDPR was at its minimum in the site. In the following winter (1999), NCP increased (133 mg C d-1 m-2) (La Ferla et al. 2003). Our measurements (January 1999) preceded the deep convective event of late winter 1999; thus our values did not reflect that process. It has clearly been proven that in 1998 the deepwater formation in the southern Adriatic was restored as prior to 1993 also because of the atmospheric forcing (Klein et al., 2000). The same forcing was also responsible for the cooling of different water types in the northern Adriatic (Malanotte-Rizzoli et al., 1997), which frequently produces dense waters, which may carry a significant carbon load from the eutrophic northern areas (Vilibić and Supić 2005). Therefore we interpret the potential respiration measured during early winter 1999 as mostly due to the contribution of the northern Adriatic, not excluding additional contributions from the neighboring shelves.

Conversely, in the year when convective phenomenon was not observed (2007), the variability of prokaryotes oxidative metabolism was governed by the seasonal cycle of the organic matter, while in June 2008 the dynamics of deep water ventilation influenced again the trend along the water column (Azzaro et al., 2012).

These findings are the starting point for the ADREX experiment in the frame of PERSEUS project.

Acknowledgments

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PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS