Evaluation of climate and biochemical models using Argo data

Nikolaos Michalopoulos

Environmental Chemical Processes Laboratory (http://ecpl.chemistry.uoc.gr)

Department of Chemistry, University of Crete

(mihalo@chemistry.uoc.gr)

Abstract The use of ARGO floats as sensors for monitoring biological and chemical changes in the oceans will provide amongst other parameters, chlorophyll (Chl) and dissolved oxygen (DO) data for the eastern Mediterranean basin. The main objective of the present work was to explore the potential benefits of including biochemical sensors in the floats, and the exploitation of the corresponding data for the study of biogeochemical cycles in the eastern Mediterranean and the Greek sees and the climate change in the area. Both Chl and DO are parameters that are sensitive to climatic fluctuations. Chl is a biomass indicator for phytoplankton in marine ecosystems which contributes to the CO_2 removal from the atmosphere. DO is an indicator of the changes that take place in the marine environment, affected both by physical and biological processes. The Mediterranean basin is of special interest for both its marine and atmospheric environment. The Mediterranean Sea is an oligotrophic system, especially in its Eastern basin. However, it is also located at a transboundary location meaning its atmosphere is affected by emissions from both natural sources (i.e. sea salt, desert dust) and anthropogenic sources (i.e. urban and industrial pollution). The interaction of the sea and the atmosphere is an important process in the region, as is the contribution of nutrients from the atmosphere to the marine ecosystem. Future projections suggest that the Mediterranean region will be significantly affected by climate change, and under continuously growing anthropogenic pressures. In the present study we (a) explored the nutrient input from the atmosphere to the marine environment in the eastern Mediterranean, (b) explored how representative are the remote sensing techniques for the surface observations and (c) investigated how useful ARGOdata can be for the study of the climate change. Since no biochemical data from the Greek Argo network were available until this study took place, data from the Euro-Argo networkwere used.

Nutrients from the atmosphere to the marine environment in the eastern Mediterranean

Each year the Mediterranean region receives huge amounts of desert dust originating from northern Africa and the Middle East. Desert dust particles contain significant amounts of nutrients such as nitrogen, phosphorus, and iron. It has been shown that dust input to a marine ecosystem can contribute to its productivity. However, mixing of dust and pollutants in a complex environment such as the Mediterranean atmosphere results in changes to the water solubility and hence the bioavailability of dust. The Finokalia station (http://finokalia.chemistry.uoc.gr/) is the atmospheric research station of the University of Crete. Particulate matter concentrations are being monitored continuously and it has been shown in several studies that enhanced concentrations (daily averages above 50 $\mu g\ m^{-3}$), especially during spring and autumn, are directly linked to dust transport from Sahara desert. Taking into account the percentage of total iron that can be bioavailable (can reach up to 80% of total) we calculated an influx of 5.94–12.25 $mg\ m^{-2}$ to the marine environment, whilst in the atmosphere, during a dust event, its concentration may be 2 to 20 $\mu g\ m^{-3}$. It is expected that because of the climate change, larger amounts of desert dust may be transported towards the eastern Mediterranean due to drier conditions prevailing. The biochemical data collected from ARGOfloats may provide important information on the contribution of desert dust to marine productivity and its evolution due to climate change.

Remote sensing observations are a valuable tool for earth observation and necessary for obtaining a global perspective. It is an open question however, how representative the satellite data are for the surface layer. We explored satellite data over the Mediterranean to investigate how representative these data are for the estimation of dust transport and hence the nutrients' availability for the marine environment. Once again we used data from the Finokalia station to investigate how dust transport is detected on the surface and how well it is observed from the space. We concluded that on average the annual variability of atmospheric particles loading is well captured from the satellites, and that the enhanced concentrations observed during dust events are also well observed. However, for low and medium intensity events, the satellite data are not representative for the surface measurements. When comparing aerosol loading and Chl concentrations, only weak correlations are observed. In any case, these correlations refer to periods with medium intensity events, with are linked to limited marine productivity, and not during the high intensity events that may result in enhanced toxicity of surface waters due to the abundance of metals in the dust. Thus, remote sensing techniques are not adequate for monitoring the response of the marine ecosystem to the changes observed, and in-situ techniques are necessary.

Comparison with ARGO data

For the marine environment, and especially at great depths, in situ-measurements are difficult to perform. In situ measurements are necessary for the validation of satellite data and the validation of climate and biogeochemical models as well. We refer to the work of Lazzari et al., 2012 to compare model calculations with observations from the ARGO floats. We used Chl data of 8 floats fromthe Euro-Argo network that were deployed east of 18^{o} E and may be considered as representative for the eastern Mediterranean marine environment, for the years 2008-09 and 2013-15. Although the model refers to a different period than the measurements (1999-2004) we wanted to compare annual variability that was expected to prevail over inter-annual variations. The annual average for Chl was measured 0.1 mg m^{-3} and it was the same as the model (3D- OPATM-BFM) predicted. The average depth that maximum concentrations were observed was 110m, once again in agreement with the model. Looking at the annual variation of the depth occurrence of the maximum concentrations, we observed that maximum values are observed at greater depths during the summer and closer to the surface in winter (Figure 1). As for the annual variability of Chl concentrations, obtained via the ARGOdata we observed higher concentrations in spring and minimum from October to March (Figure 1). Although the maximum was predicted from the model, the minimum was not captured by the model and not observed from the satellite data either. The satellite data suggests higher Chl concentrations when the depth of occurrence of the maximum concentrations is smaller, and thus phytoplankton is more visible from space, thus emphasizing the need for systematic in-situ measurements in the marine environment. For DO, ARGO data provide a very clear picture of oxygen minimum zone (OMZ) in the Mediterranean Sea. Especially for the eastern Mediterranean, OMZ in medium depths does not decrease below 180 μmol kg^{-1}. Observing the variability of DO will provide important information regarding OMZ and its variations resulting from climate change.

Conclusions

Overall, the biochemical sensors on ARGO floats can provide valuable information for the study of Greek seas and the eastern Mediterranean in general. These data can be used as: input and validation data for climate and biogeochemical models; supplements for satellite observations; and in the long term ARGO float data can be used to observe fluctuations of the marine environment related to climate change.

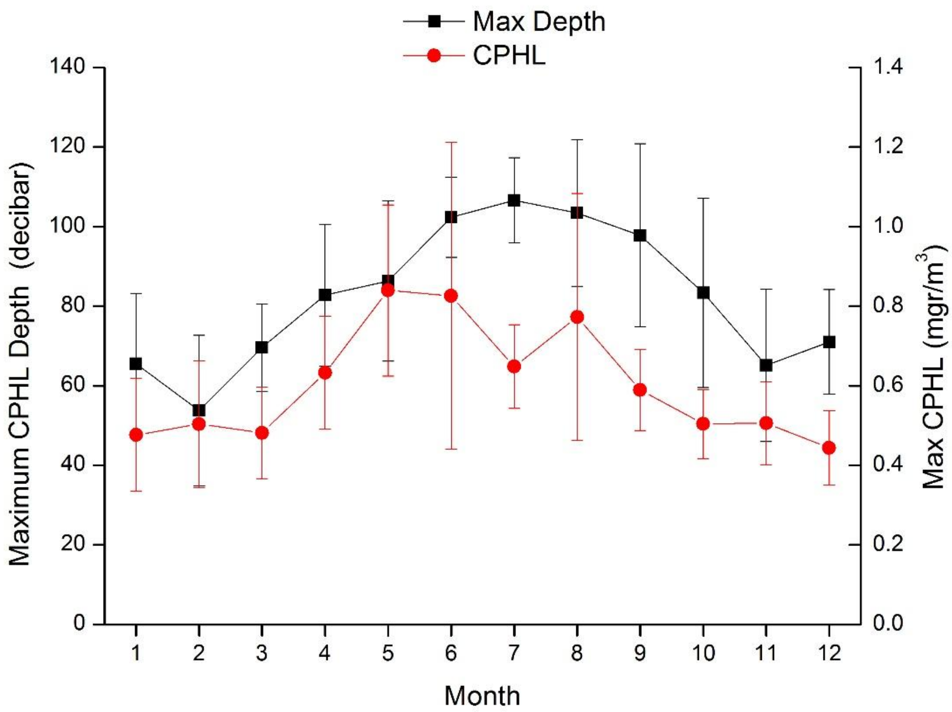

Figure 1: Annual variation of the depth of the maximum concentration of Chl (CPHL) and the maximum concentration observed in eastern Mediterranean.

References

Bennington, V., G. A. McKinley, S. Dutkiewicz, and D. Ullman (2009), What does chlorophyll variability tell us about export and air-sea CO_2 flux variability in the North Atlantic?, Global Biogeochem. Cycles, 23, GB3002, doi:10.1029/2008GB003241

C. Theodosi, Z. Markaki, N. Mihalopoulos, Iron speciation, solubility and temporal variability in wet and dry deposition in the Eastern Mediterranean, Marine Chemistry, 2010, 120, 1-4, 100

Lazzari, P., Solidoro, C., Ibello, V., Salon, S., Teruzzi, A., Béranger, K., Colella, S., and Crise, A.: Seasonal and inter-annual variability of plankton chlorophyll and primary production in the

Mediterranean Sea: a modelling approach, Biogeosciences, 9, 217-233, doi:10.5194/bg-9-217-2012, 2012.

Grimm, R., Maier-Reimer, E., Mikolajewicz, U., Schmiedl, G., Müller-Navarra, K., Adloff, F., Grant, K.M., Ziegler, M., Lourens, L.J., Emeis, K.-C. Late glacial initiation of Holocene eastern Mediterranean sapropel formation. Nature Communications. 6:7099. doi: 10.1038/ncomms8099 (2015).