Project: 970 Project title: TARANTO Project members: Uwe Mikolajewicz, Katharina Six, Feifei Liu (MPI-Met), Gerhard Schmiedl, and Kay Emeis (CEN, Uni HH) Report period: 2018-01-01 to 2018-12-31

The aim of our project is to reconstruct records of climate and related biogeochemical cycles in the Gulf of Taranto (southern Italy) for the past few centuries and the late Holocene. To achieve this goal, we will derive a novel spatio-temporal transfer function that defines the relationships between proxy data and environmental parameters both in the spatial and temporal domain from model simulations. We will combine proxy records (CEN, Uni HH) with an advanced physical/biogeochemical model (MPI-Met).

In the last year, the major task of the project has been finished. The model has been adjusted to the Mediterranean system. The long-term simulation allows us a comprehensive analysis of the impact of climate on biogeochemical cycles as well as the related sediment processes in the areas of interest. Here we focus our analysis on the Gulf of Taranto and the South Adriatic Sea since there are available sediment cores for comparison.

The model that we are using is the ocean circulation and biogeochemistry model (MPIOM-HAMOCC) for the Mediterranean Sea and the Black Sea with the horizontal resolution of approx. 9km and 30 layers in the vertical. Fig.1 shows the model domain and the bathymetry. The model is forced by the 3-hourly ERA-20C atmospheric data (ECMWF's first atmospheric reanalysis of the 20th century: 1901-2010, Poli et al. 2013). In the simulations we will present below, the external nutrient source refers to the preindustrial riverine nutrient input and atmospheric deposition.



Fig.1 Model domain and the bathymetry (m). Adr: Adriatic Sea, Ion: Ionian Sea. Red box is the Gulf of Taranto. Black box marks the area over which the zonal current velocity is calculated. The black line shows the Strait of Otranto. The red dots show the locations of three sediment cores where alkenone-derived SST is available.

We found the biogeochemistry of the Gulf of Taranto is strongly influenced by the reversals of the North Ionian Gyre (NIG) upper layer circulation which is tightly coupled to the Bimodal Oscillating System. Fig.2(a) shows the vertical profiles of phosphate concentration in the upper 700m depth of the Gulf of Taranto in winter from 1910 to 2010. The nutricline shown by the black line is fluctuating on a decadal time scale. This variability is in good phase with the oscillation of the NIG circulation, which is illustrated by the zonal velocity averaged over the upper 100m depth in the northern Ionian Sea (Fig.2(b)). Positive velocity represents an anti-cyclonic circulation while negative velocity is related with a cyclonic mode. The NIG circulation oscillates between the two modes on a decadal time scale. The uplifting of the nutricline coincides with the anticyclonic circulation and vice versa. This can be explained by the vertical displacement of the density interfaces that is introduced by the NIG circulation. When the NIG shows a cyclonic circulation, the upwelling in the center of the Ionian Sea will cause a downwelling at the border of the NIG, resulting in a deepening of the nutricline. On the other hand, an anti-cyclonic circulation causes a downwelling in the center but an upwelling at the edge of the gyre, leading to an uplifting of the nutricline.

The nutricline dynamics also show a good correlation with the Adriatic Deep Water (AdDW) outflow, as show in Fig.2(c). During the strong outflow event periods, a large amount of dense water flows out Adriatic Sea across the Strait of Otranto and spreads along the bottom into the Gulf of Taranto. The old deep water in this area is therefore uplifted and leads to a shallow nutricline depth. Here should be noted, the NIG circulation reversal is interacted with the AdDW outflow variations, which refers to as Bimodal Oscillating System.



Fig.2 (a) Hovmöller diagram of the winter phosphate concentration in the upper 700m depth of the Gulf of Taranto. Black line represent the nutricline (PO4=0.15 mmol m⁻³). (b) Zonal velocity component averaged over the upper 100m in the area denoted by the black rectangle in Fig.1 (c) Hovmöller diagram of the annual mean water transport across the Strait of Otranto (black line in Fig.1) for the period of 1910--2010. Positive value represents southward transport and negative value represents northward transport.

Climate variability is imprinted in the sediment. We have implemented a temperature tracer to record the local temperature at times of organic matter production. This tracer allows for a direct comparison to surface temperatures estimated from sediment records. Fig.3 shows the comparison of the modelled temperature recorded in sediment flux of detritus with the alkenone-derived SST in three core sites in the Adriatic Sea (Jalali et al., 2018). In general, the simulation shows a negative temperature bias in all three core sites. Nevertheless, the temporal evolutions are comparable. In both model and reconstructions, temperature in the core site of SW104-ND-14Q shows hardly any trend. The modelled temperature in core CSS00-07 agrees well with the reconstructions in the later part of the record matching the cold period around 1960 and an increase of the temperature after 1980. However, the model shows a warm period in 1920s which is not represented in reconstructions. In the core site INV12-15, both the reconstructed SST and the simulated temperature tracer show a generally decreasing tendency from 1905 to 1978, but discrepancies appear after 1980. This might indicate a deficit of the model to resolve shallow coastal points due to its coarse vertical resolution.



Fig.3 (a) Alkenone-derived SST in three Adriatic Sea core records. The locations of the cores are displayed in Fig.1 with red dots. (b) Modelled temperature tracer recorded in sediment flux of detritus at the same locations. Bold lines are 11-year running mean.

Based on the analysis above, we conclude that the Mediterranean Sea is subject to strong decadal variability. The biogeochemical cycles in the Gulf of Taranto is strongly influenced by the large scale physical variations, for instance, the NIG circulation reversals and the Adriatic Deep Water outflow events. By resolving the processes in the sediment, we gain insights of the imprint of climate variability on the sediment. For instance, the temperature tracer, which records SST, will be a good diagnostic tool to support the construction of the transfer function.

References

Poli, P., et al., (2013), The data assimilation system and initial performance evaluation of the ECMWF pilot reanalysis of the 20thcentury assimilating surface observations only (ERA-20C).

Jalali, B., et al., (2018), Deltaic and Coastal Sediments as Recorders of Mediterranean Regional Climate and Human Impact Over the Past Three Millennia. *Paleoceanography and Paleoclimatology*, 33: 579-593.