Project: **970**

Project title: **TARANTO**

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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, we have set up 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. We adapted the model to two sets of newly generated reanalysis atmospheric forcing: the 3-hourly ERA-20C atmospheric data (ECMWF's first atmospheric reanalysis of the 20th century: 1901-2010, Poli et al. 2013, **denoted as ERA20C below**) and the 3-hourly NOAA-CIRES product 20CRv2c (NOAA-CIRES 20th Century Reanalysis version 2c: 1851-2010, Compo et al. 2011, **denoted as NOAA20C below**). The model has been tuned to adjust to the Mediterranean system and has been spun up for 1000 years separately with the two data sets. In this report three experiments will be mentioned: (1) NOAA20C-MCR: simulation forced by NOAA20C atmospheric forcing and fixed river input corresponding to the year 2000; (2) ERA20C-MCR: simulation forced by ERA20C atmospheric forcing and fixed river input corresponding to the year 2000; (3) ERA20C-VR: simulation forced by ERA20C atmospheric forcing and time-varying river input.

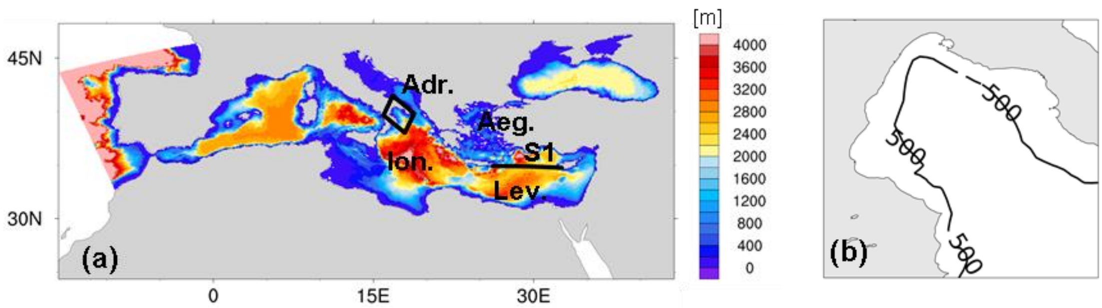

Fig.1 (a) Model domain and the bathymetry (m). Adr: Adriatic Sea, Aeg: Aegean Sea, Ion: Ionian Sea, Lev: Levantine Sea. Black box marks the location of the Gulf of Taranto. The black line (S1) connecting the Cretan Island and Cyprus represents the transect through which the water transport is calculated. (b) The detailed map of the Gulf of Taranto with contour line of the 500m isobath.

Both simulations with different atmospheric forcing reproduce substantial interannual variability in the Mediterranean Sea. The most prominent example is the East Mediterranean Transient (EMT) in the early 1990's, which is characterized by a temporary switch of the main location of the eastern Mediterranean deep-water (EMDW) formation from the Adriatic Sea to the Aegean Sea. Fig. 2 shows the annual mean transport rate through a transect spanning between the Cretan Island and Cyprus following the calculation of Eq.1, where v represents the annual mean meridional horizontal velocity field at each location x, y and depth level z, $-H$ is the bottom of the sea, W and E are the lower and upper bound of the integration in the west and east. Only in selective years there was a southward transport below 2000m, which indicates the formation and spreading of the Cretan Deep Water (CDW) that forms the EMDW. Both simulations with different atmospheric forcing data sets capture the early 1990's event as shown in Fig.2(a) and (b). The simulations forced by the ERA20C data reproduce other EMT-like events in 1950's and/or in 1910's (Fig.2 (b) and (c)).

$$\Psi(y,z) = \int_{-H}^{z} \int_{W}^{E} v(x,y,z)\,dx\,dz \qquad \text{(Eq.1)}$$

The contribution of river input to the climate variability of the Mediterranean Sea has been investigated with sensitivity experiments as shown by ERA20C-MCR and ERA20C-VR. In those experiments, the simulation with fixed river input (river discharge and nutrient load) taken from the Realistic Hydrology Model Run (Global NEWS 2) corresponding to the state of year 2000 (Mayorga et al., 2010) was compared with results driven by transient river input obtained from Ludwig et al. (2009). The differences can be seen in Fig.2 (b) and (c). Simulation with anthropogenic-induced reduction of river discharge (ERA20C-MCR) produces more EMT-like events in the early 20th century. On the other hand, when considering the transient evolution of the river discharge (ERA20C-VR), the 1990's EMT happened earlier and last longer than driven by a constant river input.

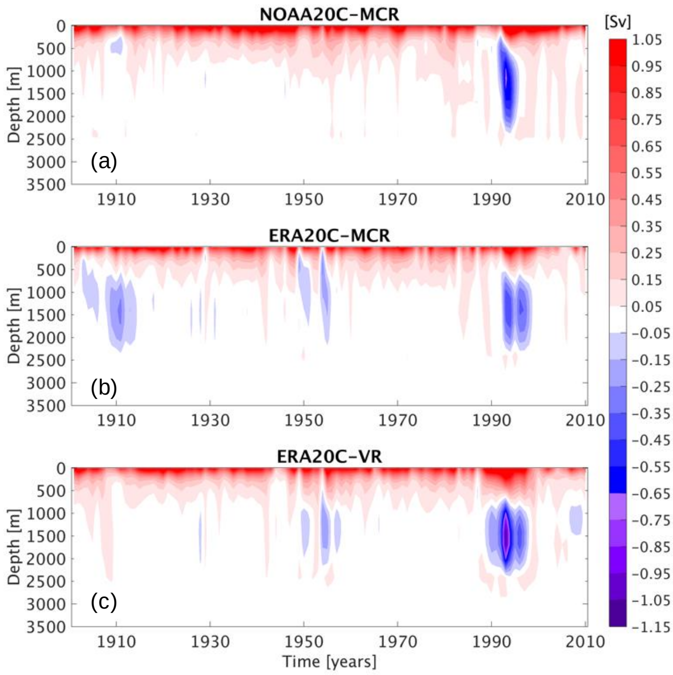

Fig.2 Hovmöller diagrams of the annual mean water transport rate through the transect S1 (shown in Fig.1) for the period of 1901-2010. Positive value represents northward transport and negative value represents southward transport. MCR implies that models are run with fixed modern river discharge corresponding to the year 2000. VR implies the simulation with time-varying river input obtained from Ludwig et al., (2009).

To consider the anthropogenic influence on the variability of the biogeochemistry, we run the model with transient nutrient input from rivers and atmospheric deposition (Experiment ERA20C-VR). Fig.3 shows the simulated yearly maximum primary production in the Gulf of Taranto. The time series shows a clearly increasing tendency over the whole simulation period, which can be attributed to the enhanced anthropogenic imposing. Significant decadal and interannual variability overlay this general tendency (Fig.3). We found a good coincidence between high primary production and the Adriatic dense water outflow events (figure not shown here) and to some extent with the EMT events (Fig.2(c)). This implies that local variations of the primary production might be related to changes of the large-scale physical state in the Mediterranean Sea, which will be further investigated.

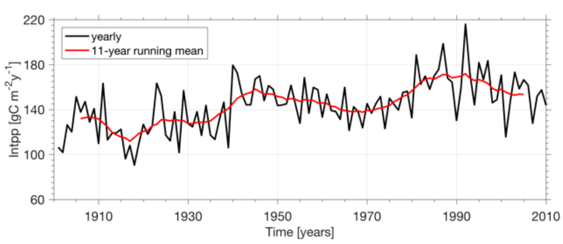

Fig.3 Time series of the yearly maximum integrated primary production averaged over the Gulf of Taranto with simulation of ERA20C-VR (black line). Red line represents the 11-year running mean.

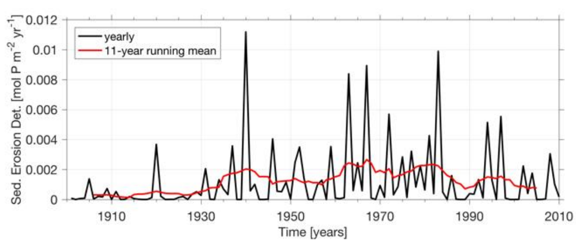

Fig.4 Time series of annual mean sediment erosion rate of detritus in the Gulf of Taranto with simulation of ERA20C-VR (black line). The calculation is restricted to areas shallower than 500m. Red line represents the 11-year running mean.

The sediment module has also been adapted to allow the recording of sediment variations with a high spatio-temporal resolution (vertically 12 levels). Fig.4 shows the preliminary results of the simulated sediment erosion rate in the Gulf of Taranto. In this region, erosion only takes place in shallow coastal areas (generally shallower than 500m, Fig.1(b)). High erosion rates are found in selective years. There is no clear correlation between the erosion and the ocean physical variability like EMT, nor between the erosion and the biogeochemical process like primary production. This implies that the erosion might be regulated by local processes. The sediment module has not reached the quasi steady state yet and tuning needs to be continued. After a series of runs for parameter optimization and spin up, we will investigate the main drivers of the sediment variability and to compare simulated sediment proxy data with observations. We have also implemented isotopes in water column and sediment, which is a frequently measured proxy data and allows a direct comparison between simulated and observed distributions (results not shown). It requires further tuning as well.

In summary, a regional version of the ocean general circulation model MPIOM and the marine biogeochemical model HAMOCC with an advanced sediment component has been set up for the Mediterranean Sea and the Black Sea with two types of reanalysis atmospheric forcing. The model is able to reproduce the mean state and the variations of the physical pattern in the Mediterranean Sea, such as the EMT. The contributions of the river input and the anthropogenic influence were investigated, which help to understand the relative importance of atmospheric forcing, river input and atmospheric deposition on the climatic and biogeochemical variability. Simulated sediment erosion shows certain interannual variability. However, the sediment module and the representation of isotopes need further tuning and analysis.

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