DUNE : a DUst experiment in a low Nutrient, low chlorophyll Ecosystem

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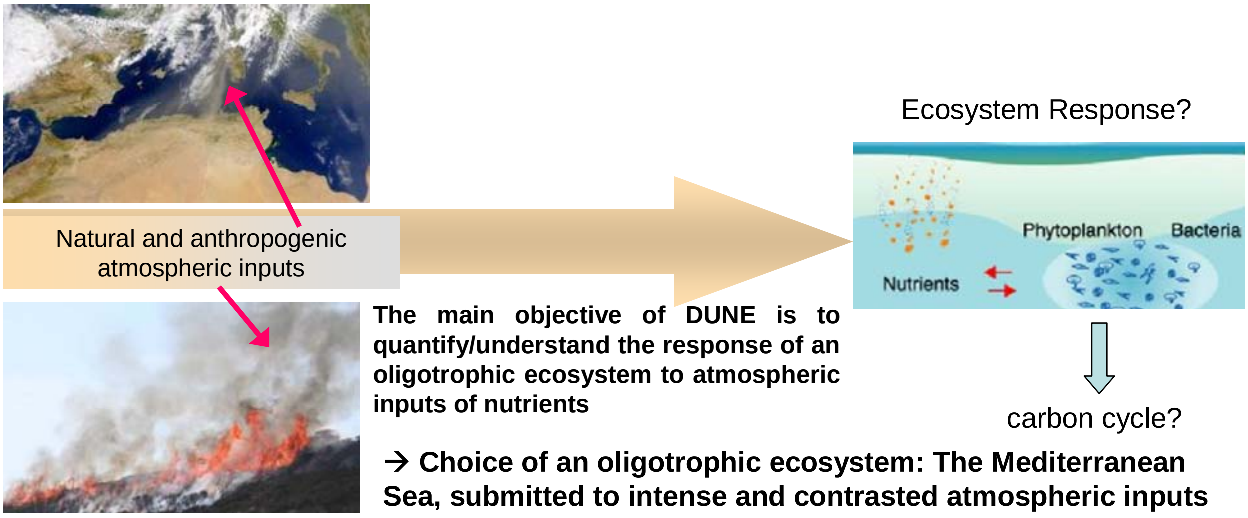
The main goal of DUNE is to estimate the impact of atmospheric inputs on an oligotrophic ecosystem submitted to strong atmospheric inputs. Atmospheric deposition is currently recognized as a significant source of macro- and micro-nutrients for the surface ocean, but the quantification of its role on biological carbon pump is still poorly determined. The main difficulty of such a quantification relies mainly on the diversity of the processes occurring: (1) within atmospheric cycling of particles (from emission processes to deposition onto surface ocean, including physical-chemical transformations occurring during transport) and (2) within the water column (uptake by bacteria and phytoplankton of particle-derived elements of biogeochemical interest, and carbon export resulting from fertilization induced by those inputs). We propose in DUNE to investigate the role of atmospheric inputs on the functioning of an oligotrophic system particularly well adapted to this kind of study: the Mediterranean Sea.



The Mediterranean Sea – etymologically, sea surrounded by land, is submitted to atmospheric inputs that are variable both in frequency and intensity. During the stratification period, only atmospheric deposition is prone to fertilize surface waters which had become very oligotrophic due to the nutrient depletion (after the spring bloom). In order to quantify the impact of both natural (Saharan) and anthropogenic (biomass burning, human activity) inputs on productivity and biogenic carbon sequestration – key concern of international scientific community such as SOLAS - it is necessary to parameterize the processes affecting the ecosystem functioning. In particular, it is important to consider the fixation of atmospheric nitrogen N2, for which dissolved iron, which mainly originates from atmospheric deposition, is one of the limiting elements.

Realistic fertilizations, aiming to mimic natural and anthropogenic events of known intensity, will be performed onto a set of large mesocosms settled in Scandola Marine Reserve, located in North Corsica. Several biological and chemical parameters will be measured before and up to one month after the fertilization, in order to quantify bacteria, phytoplankton and zooplankton response. The mesocosms will be installed during two field campaigns throughout the project. With the ambition to develop large mesocosms allowing accurate measurements of trace elements (Fe, P), DUNE constitutes a veritable technological challenge. The main innovation of our approach, relative to traditional use of microcosms or mono-specific cultures, lies on the fact that these ultra-clean systems will allow for the first time to accurately study over time, the processes stimulated by atmospheric deposition and this will be done within an authentic biogeochemical assemblage which natural physico-chemical conditions will be preserved. Moreover, an accurate quantification of exported matter, collected thanks to this device, will allow to achieve an integrated view of ecosystem responses to a selected external forcing, information needed in flux models. The project has been funded by ANR for 3 years (2008-2010) and in 2007, funding from BQR University Paris VI and from National program 'LEFE' have been devoted to 2 field works necessary to prepare the actions proposed in the main project. (1) a campaign devoted to collection of Saharan soils necessary to seed the mesocosm and (2) a short survey in Scandola in June during which 2 large mesocosms were deployed to insure the feasibility of the seeding experiment : deployment of the structure, filling of the bags, requirements for the divers, control of the structure solidity ; test for simulation of atmospheric deposition in a non-contaminant way ;

test for the 'clean-metal sampling' (sampling and control of the contamination) ; test for the recovery of the sediment traps. Two bags have been deployed during 7 days and a limited number of parameters have been measured.

1. Saharan soils collection in South Tunisia (coordinator F. Dulac). The goal was to collect an atmospheric end-member representative of Saharan aerosol. The campaign took place March 26-April 1 2007, at a site well identified as being a source region of Saharan aerosol for the Mediterranean Sea and far from any anthropogenic contamination.

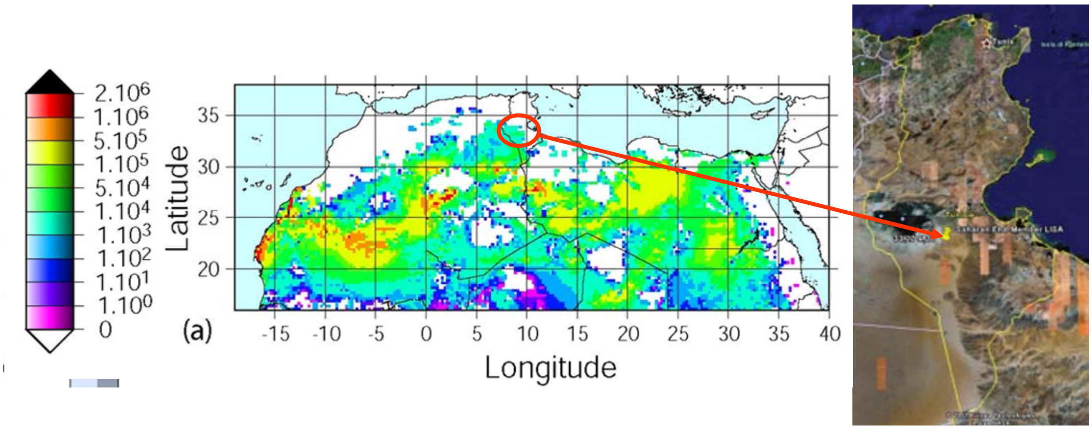


Figure 1. Yearly emissions of desert aerosols (in tons) averaged for 1996-2001. (Thèse B. Laurent, LISA, 2005) and location of the sampling site.

The soils have been sampled under ultra-clean conditions and sieved through successive polyethylene meshes and the fraction < 20µm was stored carefully. Physical and chemical characterizations are in progress at LISA. This dust was then used to fertilize one mesocosm during the pilot phase in June in Scandola.

Figure 2. General view of the sampling site in Tunisia and sieving. (Photo F. Dulac)

2. Deployment of 2 large mesocosms in Scandola: pilot phase in June 2007. The main goal of this survey were to (1) resolve all the logistical aspects related to the deployment aspects for the 2 scheduled large campaigns; (2) demonstrate the feasibility in particular show that the contamination aspects were under control; (3) perform a very reduced seeding experiment by using only 2 mesocosms (1 control + 1 with Saharan dust – no duplicates) and follow during one week a restricted number of parameters. This will allow, among other things to (4) validate the choice of the site regarding biogeochemistry.

It is important to note that this survey would have not been possible without the help of the Parc Naturel Régional de Corse that provided divers and boats with pilots. In addition they provided us with a noticeable logistical assistance (some laboratory space and accommodation for 3 people).

Two mesocosms were successfully deployed, one being fertilized with 30 g of Tunisian soils (fraction <20µm) (this represents a 7 g.m-2 dust deposition, a type of event frequently recorded in the Mediterranean environment). During 5 days after the seeding, a restricted number of parameters have been measured on samples collected at 3 different depths inside the mesocosms and outside of the mesocosms: Chla, pigments, dissolved iron, bacterial abundance, nitrogen fixation, primary production, diazotrophs identification (coll. I. Biegala), nutrients (after a method for measuring nano-levels have been setup at LOV). In addition, several parameters will be measured on sediment traps collected at the end of this short experiment. Hydrological parameters have been measured every day close to the mesocosms and outside of the bay.

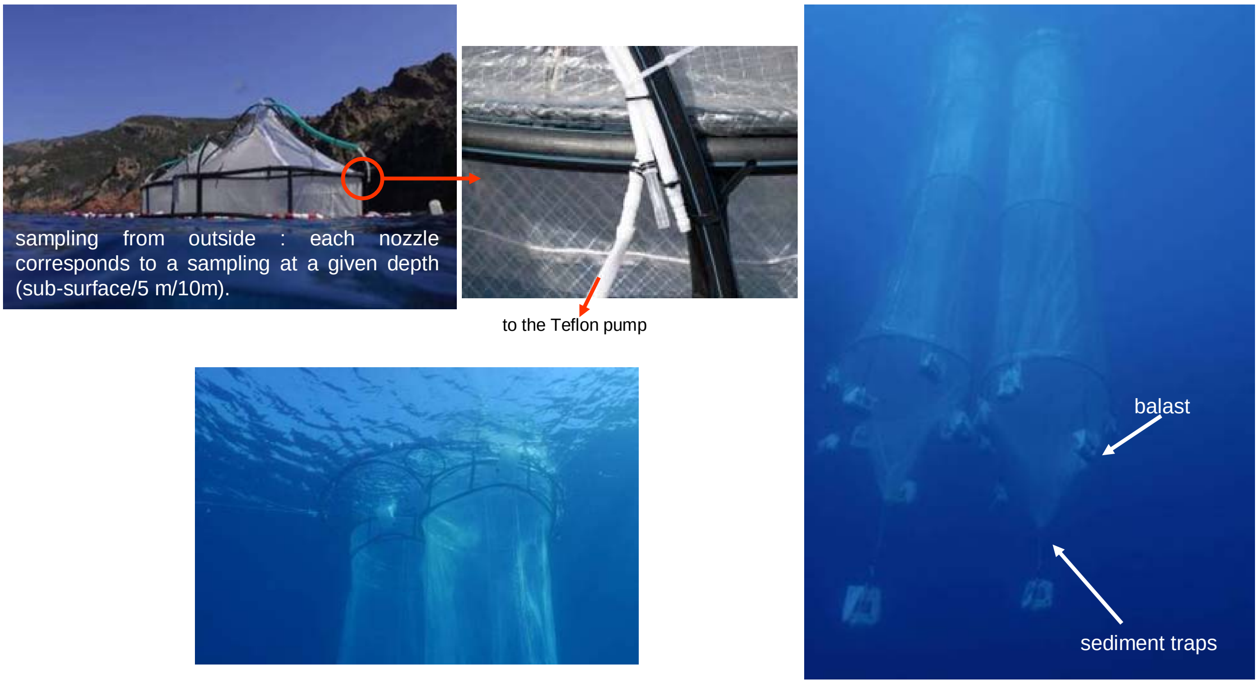


Figure 3. Several views of the two mesocosms (2.3 m diameter; 14 m height; total volume = 33 000 L). The sampling is done at 3 different depths from the outside without any disturbance of the inside body water. (Photos D. Luquet)

Figure 4. Sampling the mesocosms. (Photos D. Luquet)

Preliminary results.

Hydrological data indicate that the site has the same characteristics in surface as the deep-sea site (DYFAMED) for the same period. Chlorophyll concentrations were very low (0.1 µg.l-1) and varied only slightly after the seeding but were always higher in the '+dust' mesocosm.

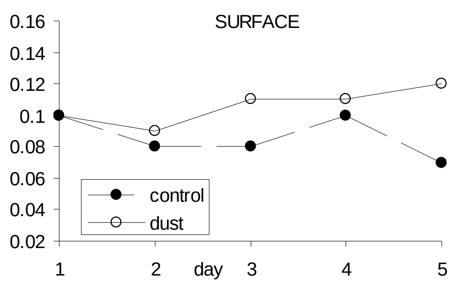


Figure 5. Evolution of the Chla concentrations in surface of the mesocosms ('control': no addition; 'dust': dust addition).

Bacterial abundance was very weak before the seeding (< 400.000 cells/ml) and increased in the +dust mesocosm at all the depths (Figure 6).

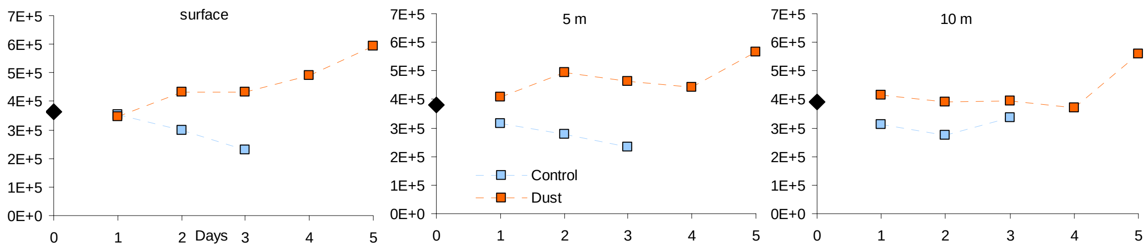


Figure 6. Evolution of the bacterial abundance at 3 depths in the 2 mesocosms (no error bar available: sampling was duplicated but only one sample was analyzed so far).

Concerning nitrogen fixation (PI Céline Ridame), several protocols were tested during the survey: incubation of different volumes, test using different volume of ^{15}N spike; intercomparison of the results obtained on two different mass spectrometers. The very preliminary results indicate a significant ^{15}N enrichment on certain samples and only on samples from the '+dust' mesocosm. Results will be completed with diazotroph identification using molecular biology techniques (coll. I. Biegala) on selected samples.

Dissolved iron concentrations were of the order of 2-2.5 nM inside and outside the mesocosms. None of the samples were contaminated, and all the results are presenting a very good coherence. A slight difference can be observed between the control and the +dust samples and it will be very important to see if this difference can be related to biological assimilation. Outside of the bay where the mesocosms were moored, the [DFe] are very similar to those measured at DYFAMED in July the year before (data: Wagener et al. submitted). In surface, the concentrations are higher and have to be interpreted with the knowledge of atmospheric data (not done yet).

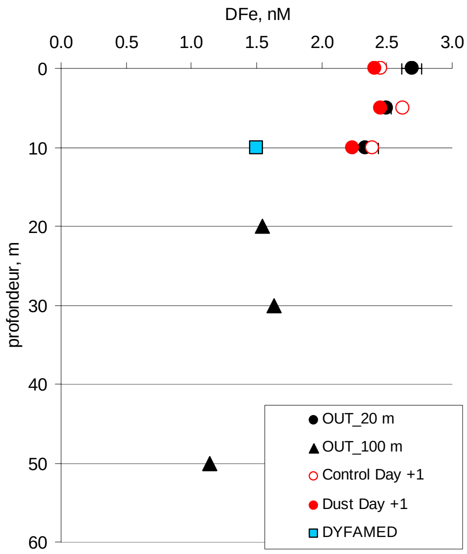


Figure 7. Dissolved iron concentrations : comparison for the same day in each mesocosm (24h after the seeding), close to the mesocosm (OUT_20m) and outside of the bay (OUT_100m).

Finally, on the material collected by the 2 sediment traps located at the bottom of the mesocosms (14m depth) some very preliminary analysis have been performed. It is very interesting to note that less that 24h after the seeding, a strong export of material appearing like thick marine snow with aggregates was observed. The type and amount of material collected at the end was very different between the 2 mesocosms: color, aspect, density of aggregates, type and number of swimmers etc. We also observed that 6 days after the seeding, we didn't retrieve in the '+dust' trap, the amount of dust that was sprayed (added: 30 g of dust: recovered: 10 g, including organic matter).

Figure 8. Sediment traps on July 5 (6 days after the seeding). Left: Control. Right: '+dust' mesocosm.

In conclusion, this pilot phase was helpful to demonstrate the feasibility of the project even with bad meteorological conditions (we have undergone constant high winds and heave). We have been able to setup 2 mesocosms with no contamination regarding metals from the bags themselves and from the sampling system. The site appears to be a good choice for the project. The preliminary results from the pilot phase are very promising indicating a biological response after dust addition. From this experience, we will make some adjustments to improve the system and allow the mesocosms to stay for a period of one month in the water.

The project was recently funded by ANR (Agence Nationale de la Recherche) for 3 years. The first seeding experiment involving 6 large mesocosms will take place in June 2008.

So far, the DUNE project has been presented at several occasions:

Guieu C., Blain S., Dulac F., Obernosterer I., Bergametti G., Desboeuf K., Loÿe-Pilot M-D., Losno R., Pulido-Villena E., Ridame C., 2007, The DUNE project: a DUst experiment in a low Nutrient, low chlorophyll Ecosystem, poster, SOLAS Science 2007, 6-9 Mar 2007, Xiamen, China.

Guieu C., 2007, The DUNE project: a DUst experiment in a low Nutrient, low chlorophyll Ecosystem, SOLAS News, Issue 5, Spring 07, page 19.

Présentation aux journées SOLAS-France, 11 et 12 Septembre 2007 : « Présentation du projet DUNE et de sa phase pilote (juin-juillet 2007, Scandola) »

Présentation à la réunion nationale mésocosmes aquatiques à Sète le 27 septembre 2007 : « les mésocosmes « propres » dans le cadre du projet DUNE ».