Modeling the impacts of aerosol deposition on the biogeochemical cycles of the Mediterranean Sea

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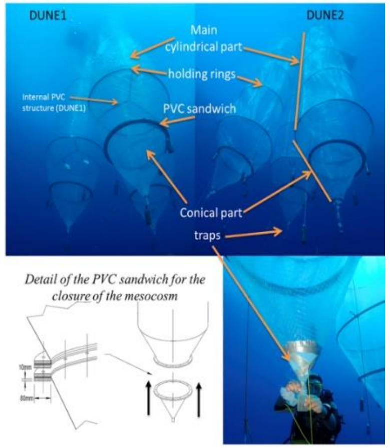
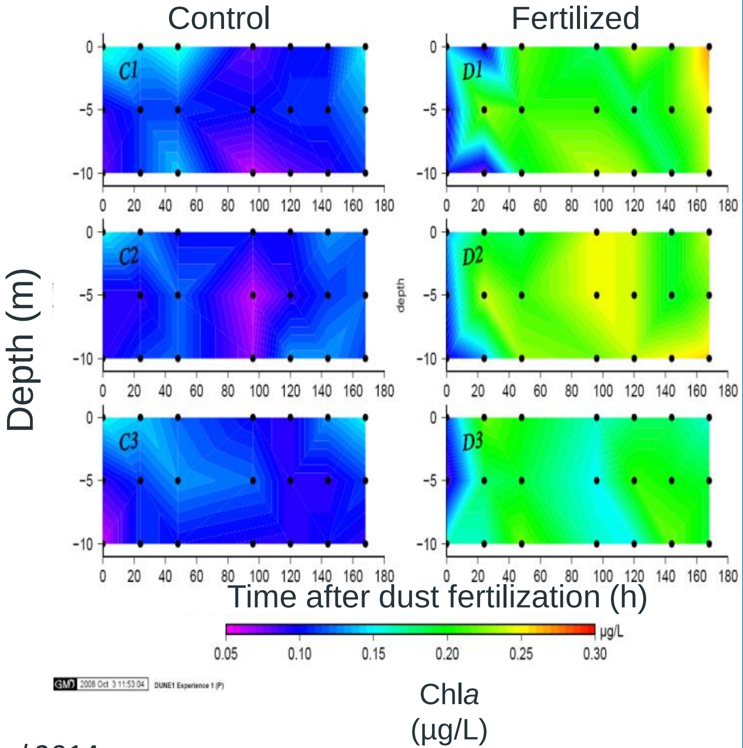
The Mediterranean Sea is an oligotrophic basin. Its biogeochemistry relies on the external supply of nutrients. Many observations show important great quantities of nutrients supplied to the Mediterranean.

Recent experimental work showed that aerosols can fertilise the surface Mediterranean waters, thereby increasing surface productivity (DUNE and PEACETIME projects, Guieu *et al.* 2010, Wuttig *et al.* 2013) .

Global modeling studies showed that natural dust deposition events can trigger increases in surface productivity in the LNLC regions up to 36% (Guieu *et al.* 2014).

- ➢ What are the impacts of aerosol deposition on the Mediterranean surface biogeochemistry?
- ➢ Which sources have the most influence?





Guieu *et al* 2014

- ➢ Mesocosm experiments in the Western Mediterranean show a clear fertilization of surface water by Saharan dust.

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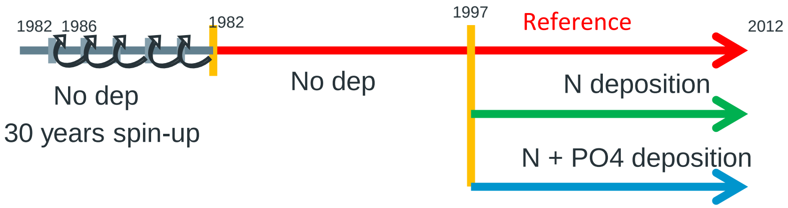
Ocean model: High resolution dynamical NEMOMED12/PISCES (1/12° horizontal resolution, 6-8km)
75 vertical levels

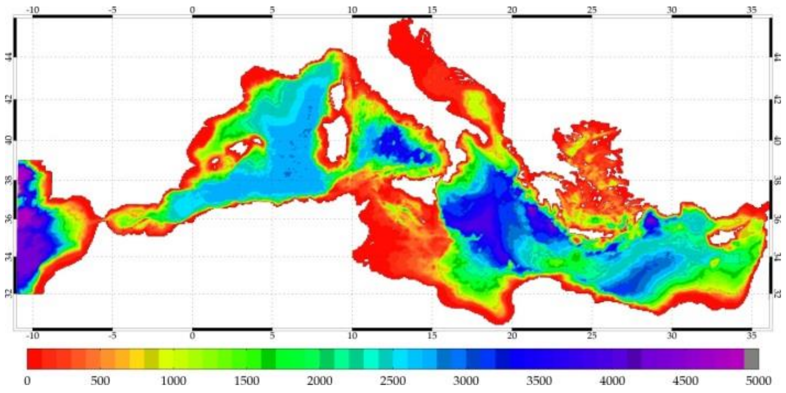
Biogeochemical model PISCES (Aumont et al.): 24 tracers (including 6 nutrients, 2 phytoplankton and 2 zooplankton groups)
Redfieldian
External nutrient forcings: Rivers, Gibraltar

We perform the first long term simulations at the basin scale with this coupled model using high resolution aerosol deposition forcings

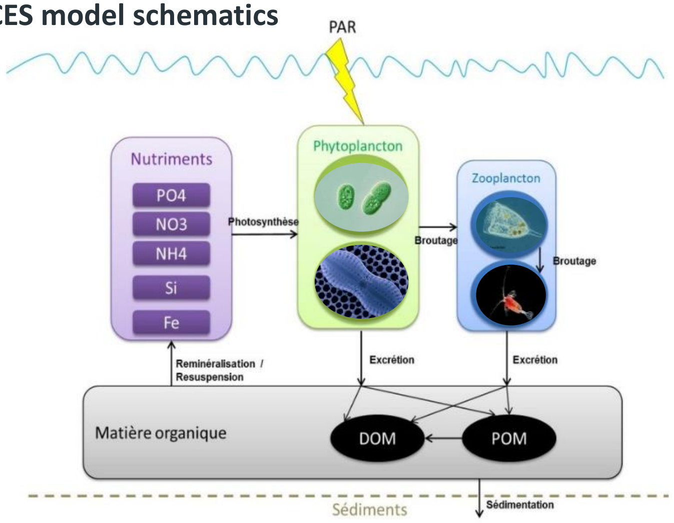


Simulation strategy

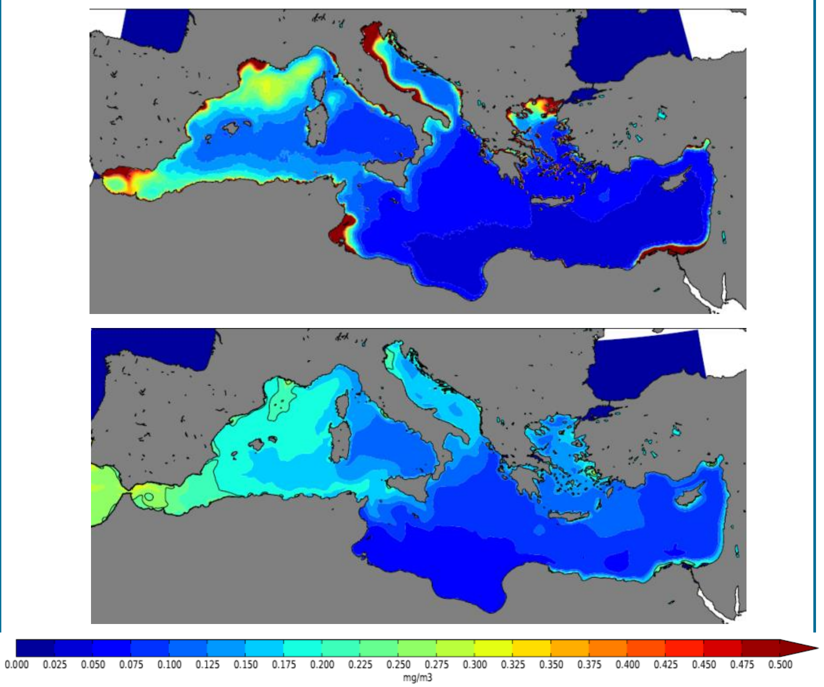
NEMO- MED12 Bathymetry



PISCES model schematics



Model evaluation: Comparison of satellite (SeaWifs, top) and modelled (down) surface chl a concentrations for the period 1997-2012)



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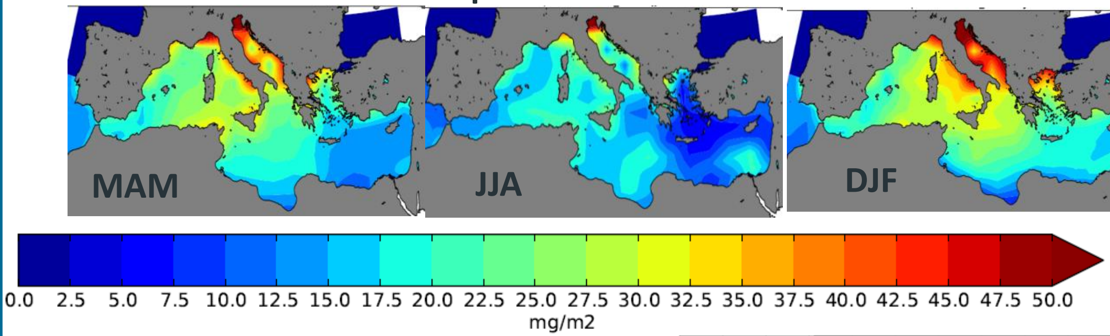
Nitrogen aerosol deposition forcings: LMDZ-INCA (Hauglustaine *et al.* ACP 2014) Global low-resolution model

- Temporal resolution: 1 month
- Spatial resolution: 200 km

- Dry+Wet deposition
- Nitrogen: $NO_3 + NH_4$, Solubility=100% (Wang *et al.*)
- N from natural + anthropogenic sources

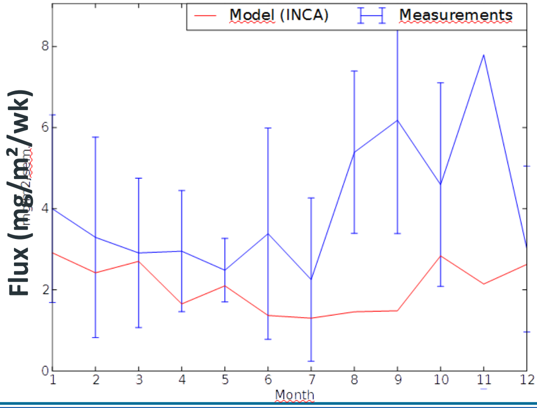
Simulated seasonal N deposition



1^{e-3} gN/m^2

N depositon simulated and measured at the Galeria Station (France)

Desboeufs *et al.*

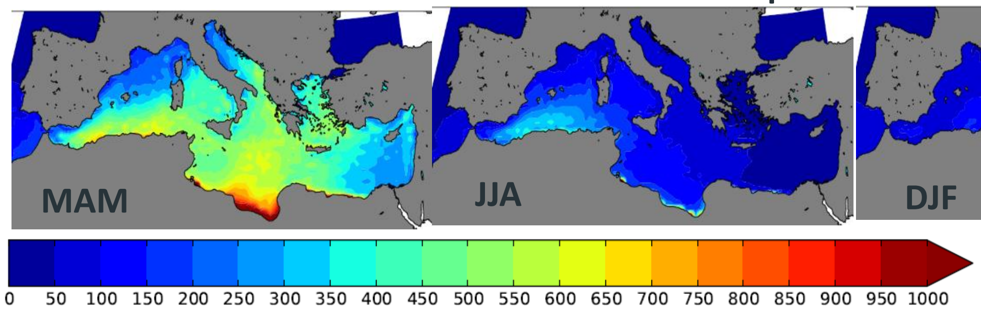


ALADIN-Climat (Nabat *et al.* ACP 2012) High resolution regional model

- Temporal resolution: 3h
- Spatial resolution: 50 km

- Wet + dry deposition
- PO_4 from dust: 735ppm, solubility: 10% (Desboeufs *et al.*, Mahowald *et al.*)

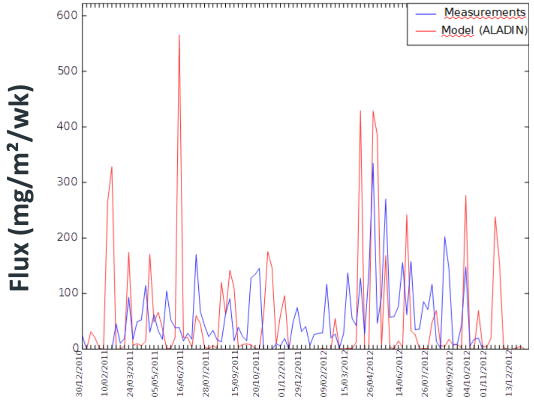
Simulated seasonal P deposition



1^{e-6} gPO_4/m^2

Dust depositon simulated and measured at the Frioul Station (France)

Bergametti *et al.*



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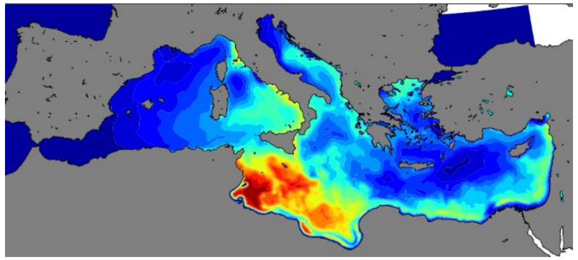
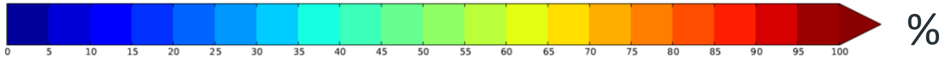
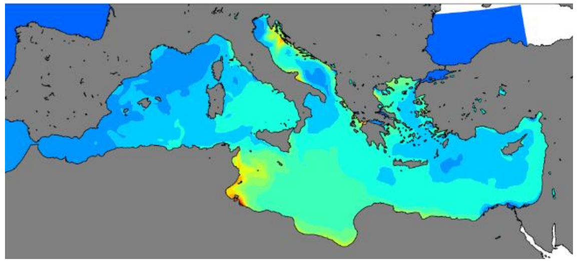
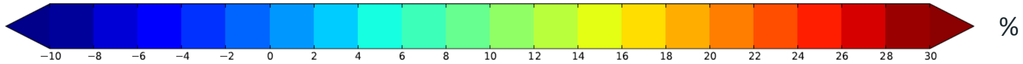
Relative surface [NO3] changes induced by N deposition





Relative surface [PO4] changes induced by P deposition

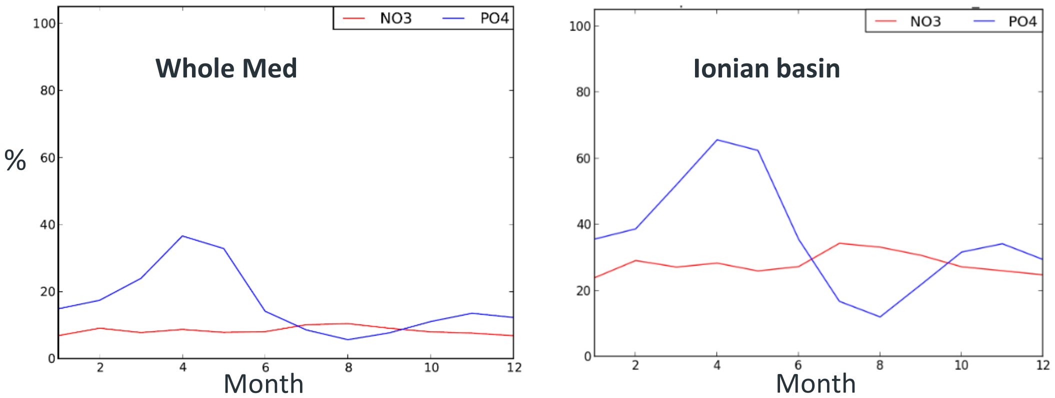




Atmospheric contribution to the total nutrient input (%)

	Krom *et al* 2010 (east)	Bergametti *et al.* 1992	Western Basin	Eastern Basin	Ionian
NO3	60	/	8-18	5-10	35-45
PO4	28	36	5-25	2-25	20-80

% of NO_3 et PO_4 brought by aerosols compared to rivers + Gibraltar (1997-2012 average)



- Aerosol deposition may increase surface nutrient concentrations from a few % to 100%. The southern part of the Mediterranean is particularly sensitive to aerosol deposition.
- General agreement between our model and in situ estimates of the atmospheric contribution to nutrient inputs.
- The atmosphere can become the major source of nutrients for the surface Mediterranean, in particular in the Ionian basin during spring.

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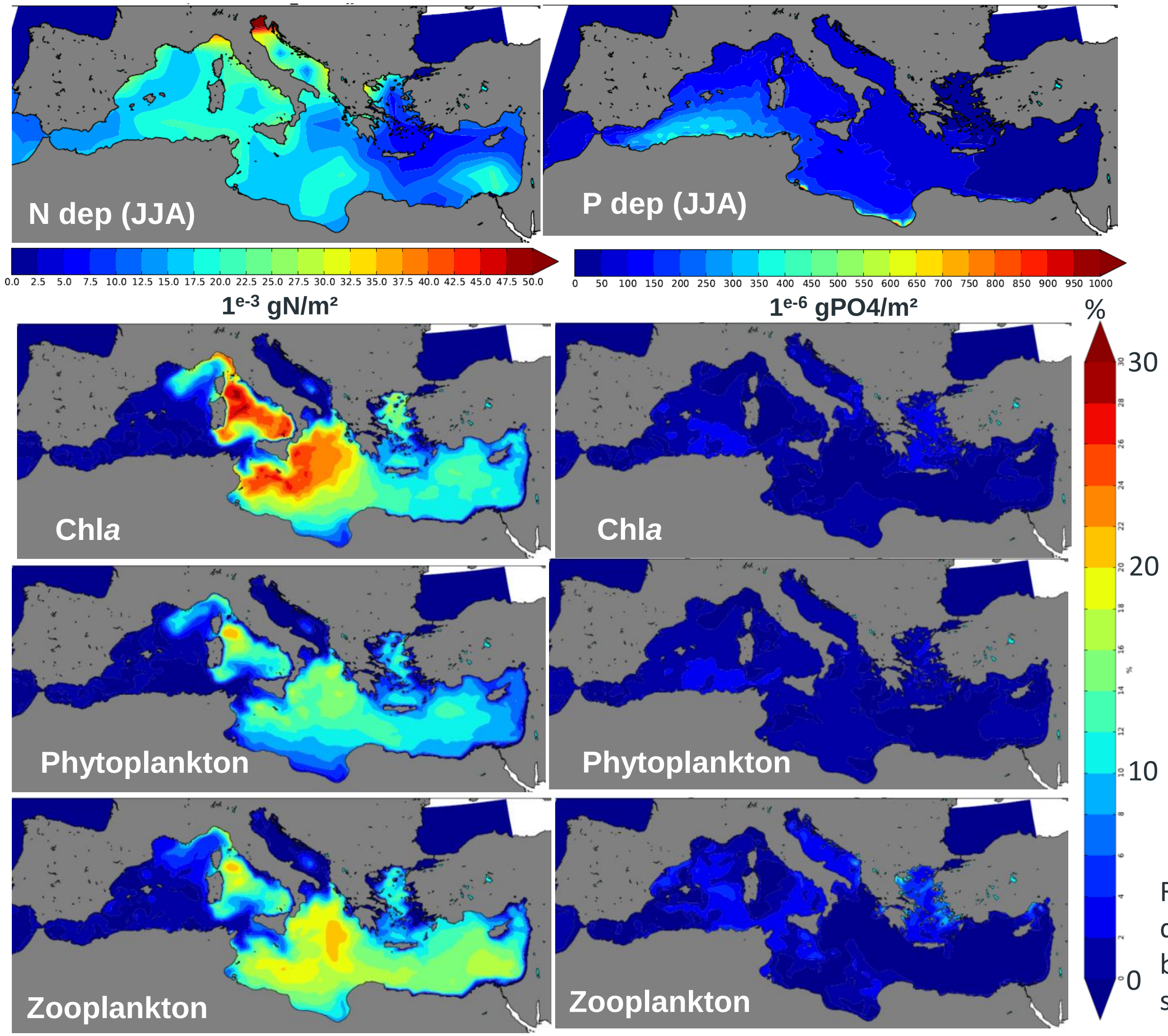

Relative impacts of aerosol deposition on surface biogeochemical tracers in summer.

The relative impacts of aerosol deposition on the Mediterranean biogeochemistry are maximal during summer. This is because, in spite of the low deposition fluxes, the stratified conditions lead to surface nutrient depletion. Therefore, even a small deposition flux of nutrients is rapidly utilized and translates into increased productivity.

The impacts of N deposition are larger than that of P and mostly located in the eastern basin.

P deposition is very low and its effects are small and located in the southern part of the basin. However, we observe some increased productivity in the Aegean basin, in spite of very low P deposition. This indicates that even a small deposition flux alleviates P limitation in the region and increases surface productivity.

Finally, the impacts of aerosol deposition are transmitted along the trophic chain.

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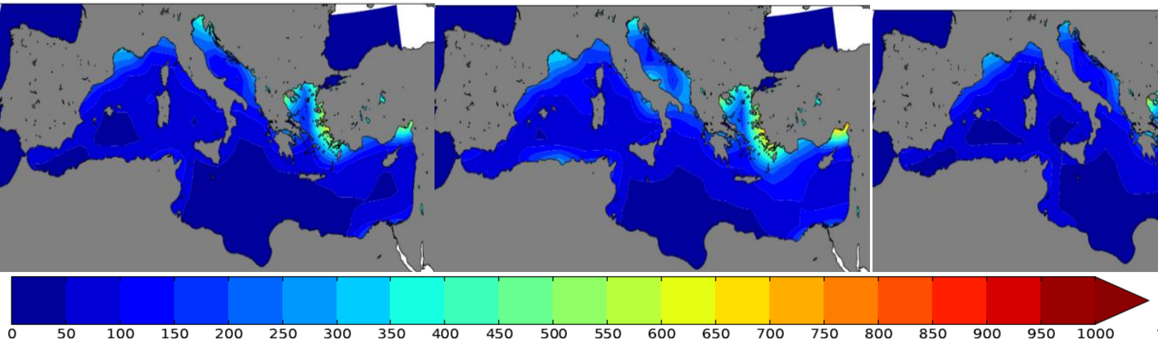
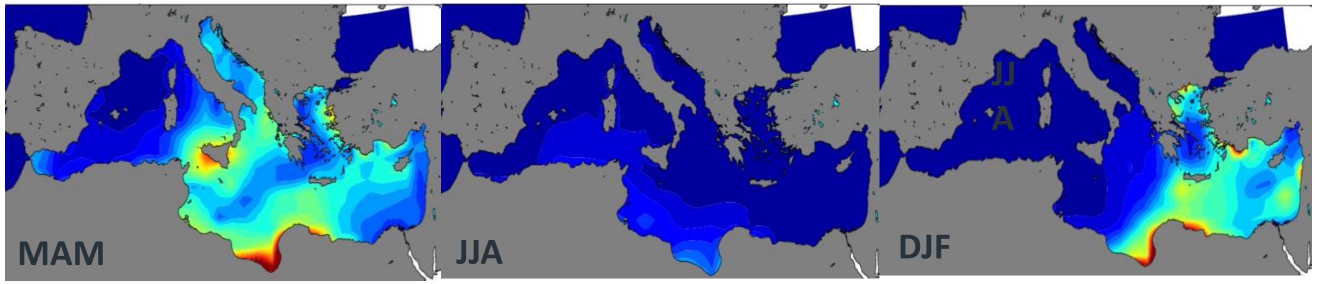
Comparison of the impacts of anthropogenic and natural P deposition

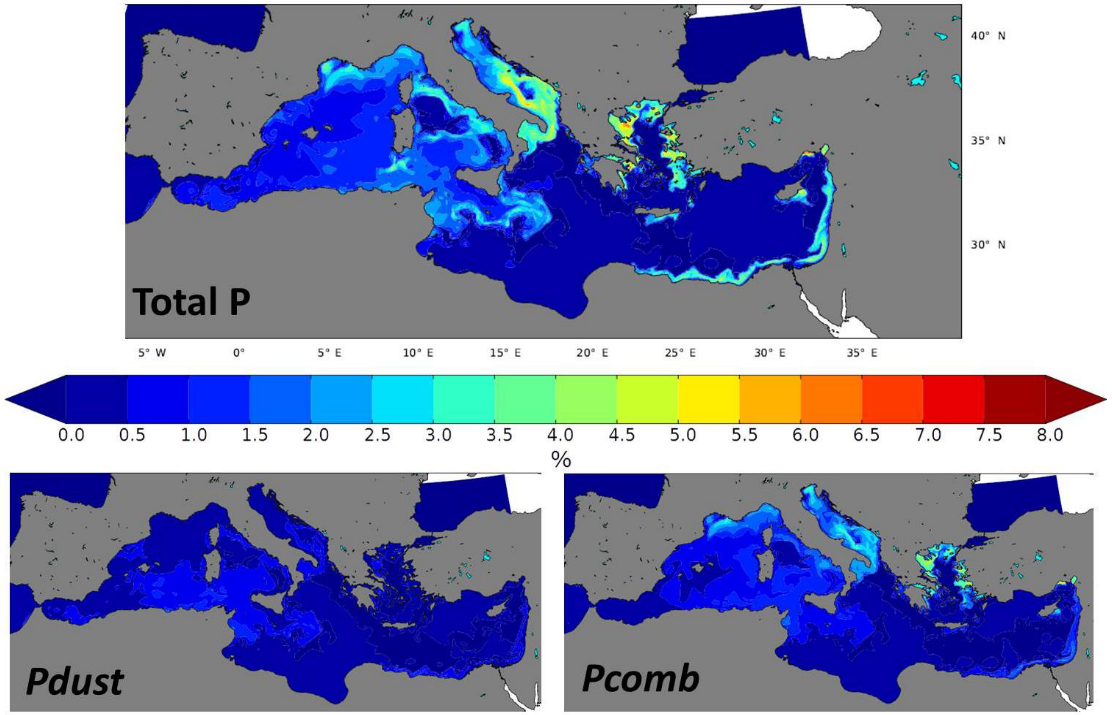
Combustion-derived P (anthropogenic fossil fuels + forest fires) :
solubility = 54% (Longho et al. 2014)



1^{e-6} molPO4/m²



Natural (Dust) P: solubility = 10%



Average relative effects of total P, P from dust and P from combustion deposition on surface (0–10 m) chlorophyll a concentration for June 2005.

Forcings from the LMDz-INCA model, year 2005
Spatial reslution: 0,94°x1,28° (dust) 1,27°x2,5° (combubstion)

- Impacts of P from combustion located in the northern basin, close to the sources
- Combustion aerosol are more soluble than dust aerosol and may have more impacts on surface biogeochemistry

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- Our simulations show that the atmosphere is an important source of nutrients for the Mediterranean (Up to 65% of PO4 in the Ionian Basin is supplied by aerosols).
- Effects of aerosol deposition greater during stratified period
- Different regional distribution for P and N impacts. Larger biological impacts for nitrogen deposition in the Eastern basin (up to 50% Chl a increase following N deposition).
- Additional significant impacts of PO4 deposition from desert dust on Chl a (6-10%, 30% max.)
- The impacts of aerosol deposition are transmitted along the biological chain
- Including a new source of P deposition showed that P deposition from natural dust only accounts for 30% of total P deposition.
- Combution-derived P deposition mostly impacts the north of the basin (up to 10% increase in PP) whereas P deposition from dust impacts the south of the basin (2-3% of PP increase).