FINAL REPORT PROGRAM LEFE

Program LEFE/CYBER	MOdelling the Biogeochemical Impact of seDImentary partiCulate iron (MOBIDIC)	Years 2016 – 2017

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***Context* :** Iron is known to be the limiting nutrient for the phytoplankton growth over ~40% of the global ocean. Dissolved iron (DFe) is assumed to be the only form available to phytoplankton while the particulate iron form has mostly been considered for its role in the biogenic iron remineralization. Therefore, most of the studies focused on the DFe external sources to the ocean and among them, the sedimentary sources have lately been shown to be underestimated. However, iron enrichment from sediment has been documented to be often larger in the particle fraction than in DFe and inorganic iron particles of sedimentary origin have been shown to be able to dissolve.

Objectives / scientific questions : This project is intended to document the potential impacts on dissolved iron and phytoplankton biomasses of an iron compartment increasingly considered as a key player in the ocean iron cycle but yet overlooked in biogeochemical models: the inorganic particulate iron of sedimentary origin.

Main results *:* To investigate the potential impacts of particulate iron from sedimentary sources, a biogeochemical model (PISCES) was modified to add a new compartment of inorganic particulate iron (PFe_{Inorg}). Once released by the sediment, its temporal evolution has been made dependent on dissolution and vertical sinking.

We have run three main climatological simulations differing only in the parameterization of the iron flux from the sediments : (i) a classic PISCES simulation with 2 µmol m^{-2} d^{-1} dissolved iron sediment flux hereafter named "D2", (ii) a simulation with an increased dissolved iron flux from 2 µmol m^{-2} d^{-1} to 10 µmol m^{-2} d^{-1} referred as "D10" and (iii) a simulation, named "Pref", with an iron sediment flux constituted from a lithogenic inorganic particulate iron flux set at 8 µmol m^{-2} d^{-1} and a dissolved iron flux of 2 µmol m^{-2} d^{-1} (same overall total coastal iron flux as D10 but separated in two iron pools). The latter simulation (i.e. Pref) used the most plausible parameters (based on the few data available to date) for the dissolution rate (i.e. $3x10^{-3}$ d^{-1}) and the sinking speed (i.e. 0.2 m d^{-1}) of those inorganic particles. Sensitivity tests towards these parameters have been run.

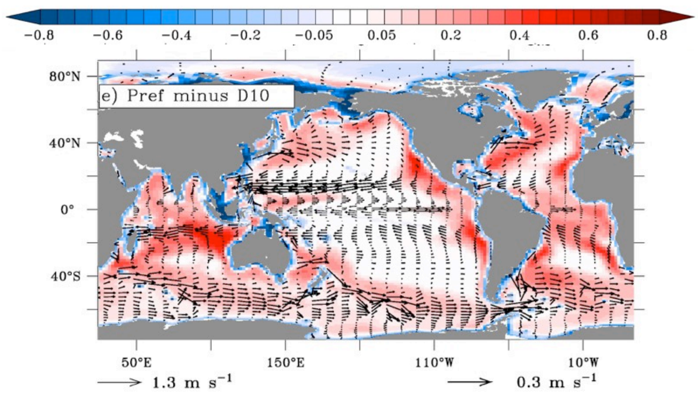

Figure 1: impact of the inorganic particulate iron (Pref-D10) on the annual mean dissolved iron (in nmol L-1) averaged over the top 0-100 m. Vectors represent currents with a small scale in the equatorial band (9°S-°N) and larger one in high latitudes.

The direct quantification of the role of particulate iron sourced from the sediments can be seen by comparing the Pref and D10 simulations and is shown in Figure 1. The impact of a PFe_{Inorg} source, compared to a fully dissolved iron source, is mostly significant in coastal areas and in regions characterized by high horizontal transport (e.g. Gulf Stream, Kuroshio). In the first grid cells close to the topography, the dissolved iron added in D10 is sustaining higher DFe concentration than in Pref. In Pref, only a fraction of the PFe_{Inorg} is dissolving before being transported away from the topography. Thus, DFe concentrations in those very first grid cells close to the topography mirror the intensity of the DFe sediment sources, which are higher in D10 than in Pref. Further away from the topography, DFe concentrations decrease faster in D10 than in Pref while being transported offshore. This is the result of: (i) high scavenging rates in regions characterized by relatively high DFe concentration (i.e. above a 0.7 nmol L^{-1} threshold corresponding to the ligand concentration) and (ii) low vertical export of PFe_{Inorg} due to small sinking velocities relative to the horizontal currents in the surface (i.e. respectively 0.2 m d^{-1} vs. 0.1 m s^{-1}). Consequently, the PFe_{Inorg} can easily escape the sediment source areas while DFe concentrations, well above the ligand threshold, are either scavenged or uptaken by biology, limiting its transport by ocean circulation. PFe_{Inorg} is then transported further offshore while slowly releasing dissolved iron. Therefore, in the surface layer, the impacts of the PFe_{Inorg} on the dissolved iron concentrations mostly mimic the large scale horizontal circulation (Fig. 1).

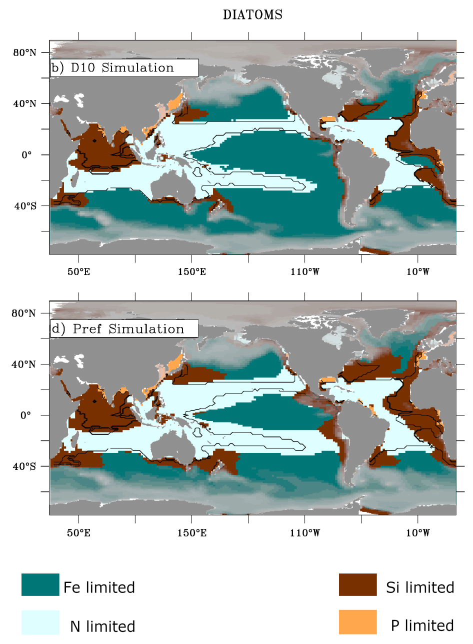

Figure 2: Limitation patterns of the surface diatom growth during the boreal (North Hemisphere) and Southern (South Hemisphere) summer for (b) D10 and (d) Pref.Contours delineate the same limitation regions but for D2.

Our results show that increasing the dissolved iron source by 5-fold is less significant in terms of surface impacts on the global inventory of dissolved iron than a change in the phase of the iron released by the sediments (i.e. particulate phase rather than dissolved).

In turn, these results reflect on the surface phytoplankton biomasses, that are most impacted by the addition of a particulate iron source than increasing the dissolved one. Figure 2 shows that an increase of the sediment flux of dissolved iron only marginally changes the limitation patterns of the primary producers, while the addition of the the PFe_{Inorg} decreases significantly the iron-limited ocean surfaces.

A sediment source of PFe_{Inorg} is then able to significantly change the coast to open ocean gradient as well as the Pacific equatorial upwelling meridional gradient in surface phytoplankton biomasses.

Future of the project :

In the short term, a **second publication focusing on the impact of the inorganic particulate iron on the interannual variability of the phytoplankton** is currently in preparation. It is taking advantage of the same PFe_{Inorg} parameterization than the one used in the JGR publication but with interannual forcings. Indeed, the PFe_{Inorg} has the potential to increase the relative importance of the variability of the transport of the iron from the sediment source

The work achieved in the MOBIDIC project stressed the lack of observations that can be used to constrain model parameters. In-situ observations alone are not sufficient to improve our understanding of the iron cycle. Tailored lab experiments designed in close collaboration between observationalists and modelers are also needed to notably tackle the dependence of those parameters to abiotic (e.g. light, temperature) and biotic (bacterial activity) environmental factors. This led the team gathered by the MOBIDIC project to propose the **"Biogeochemical Impact of Iron released by Marine particles" (BIIM, PI: H. Planquette) ANR project that has been funded (2019-2023)**. Within this project, a postdoc will be specifically dedicated to the refinement of the PFe_{Inorg} parameterization under T. Gorgues guidance and in close collaboration with experimentalists.

Publication :

Potential Impact of inorganic particulate iron on dissolved iron and phytoplankton biomasses, Beghoura, H., Gorgues, T., Aumont, O., Planquette, H., Tagliabue, A. and Auger, P.-A. Submitted to *Journal of Geophysical Research : Ocean.*

Communications :

19th EGU General Assembly 2017; Sedimentary particulate iron : the missing micronutrients ? *Beghoura, H., Gorgues, T., Aumont, O., Planquette, H.*, Vienna, Austria.

1st PISCES Meeting 2017; LOPS – Initiatives *Gorgues, T.*, LOCEAN – UPMC, Paris, France.

1st GEOTRACES summerschool 2017 ; Sedimentary particulate iron : the missing micronutrients ? *Beghoura, H., Gorgues, T., Aumont, O., Planquette, H., Tagliabue, A.*.Institut Universitaire Européen de la Mer (IUEM), Plouzané, France.

2nd PISCES Meeting 2018; Biogeochemical impact of particulate iron of sedimentary origin. *Beghoura, H., Gorgues, T., Aumont, O., Planquette, H., Tagliabue, A.*, LOCEAN – UPMC, Paris, France.

Colloque de Bilan et de Prospective du programme LEFE 2018 ; MOdelling the Biogeochemical Impact of seDImentary partiCulate iron. *Gorgues, T.*, Clermont-Ferrand, France.

ASLO 2019, How abiotic sedimentary particulate iron may impact the dissolved iron distribution and may change our understanding on global ocean biogeochemical cycles ? *Beghoura, H., Gorgues, T., Aumont, O., Planquette, H., Tagliabue, A.*, Puerto-Rico, USA.

Thèse :

Thèse de Houda Beghoura. Soutenance prévue en Novembre 2019 : Le fer particulaire inorganique d'origine sédimentaire : le nutriment manquant ?, Université de Bretagne Occidentale.