Modelling the role of dust particles in Fe speciation and residence time

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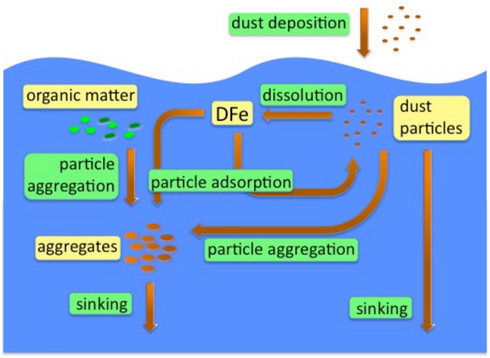
I. Role of dust particles in the biogeochemical cycle of iron

Natural dust deposition is the most important iron source for marine systems in remote offshore regions. On the one hand, considerable iron is input into the surface waters by dissolution from dust particles; on the other hand, dissolved iron is removed by adsorption onto dust particles. Thus, Fe speciation and bioavailability are strongly controlled by particle dynamics in the water column.



III. Particle classification and aggregation in the model

Sinking fluxes in the ocean interior are often dominated by larger aggregates, while fine particles dominate Saharan dust (~1.8 µm). Therefore, particle classification and modelling particle aggregation become necessary for describing reasonable sinking fluxes in our model.

Sinking particles are split into 3 classes by their size and settling velocity:
1) fine dust particles, 2) small particles, and 3) large particles. Small and large particles contain an organic and inorganic fraction. Typical size of particles is shown in the table below. The sinking velocity of dust particles is assumed to be 1 m d^{-1}, of small particles 5 m d^{-1} and of large particles 50 m d^{-1}.

Tab.1

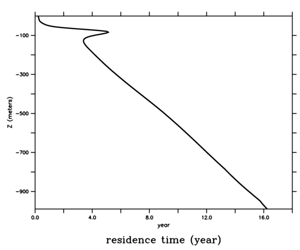
particle class	typical size (µm)	estimated aggregation rate (kg^{-1} L s^{-1})		
		brownian motion	turbulence shear	differential settling
dust & small particles	2 & 10	0.82	4.25E+03	9.43E+03
small & small particles	10 & 10	0.27	2.56E+04	0
small & large particles	10 & 50	2.13E-02	8.76E+03	3.32E+04
dust & large particles	2 & 50	0.12	3.60E+03	2.20E+04

Particle encounter is explained by 3 different mechanisms: Brownian motion, turbulent shear and differential settling. Aggregation rates of modelled particles are estimated for these mechanisms using coagulation kernels by Burd and Jackson (2009). The green marked aggregation rates describe the most important mechanisms between different particles.

Some shortcomings of the estimation are: ignoring the different stickiness of particles in the calculation leads to an overestimate of aggregation rates, certainly for dust particles. Furthermore, the coagulation kernels are strictly valid for a fine resolved size distribution of particles.

V. Estimated residence time of dissolved iron

Based on the particle classification and choice of aggregation rates, the annual averaged residence time of dissolved iron in our model ranges from 80 days in the surface waters to ca. 16 years at 1000 m, which is comparable to the estimate by Croot et al. (2004) based on the measurements during a longi-tudinal transect at 10ºN in Atlantic. This indicates a strong removal of dissolved iron by particle adsorption.



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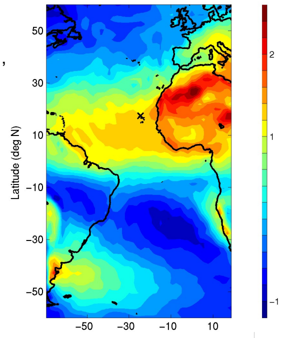
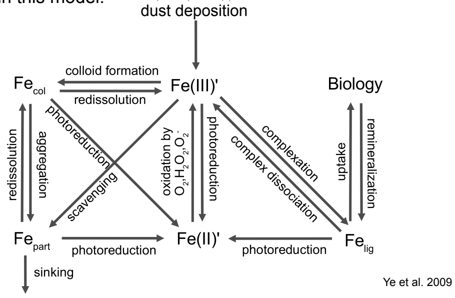
II. A model of Fe speciation for TENATSO

The Tropical Eastern North Atlantic Time-Series Observatory (TENATSO) north of the Cape Verde Islands (17°N, 24.5°W) is strongly influenced by Saharan dust events.



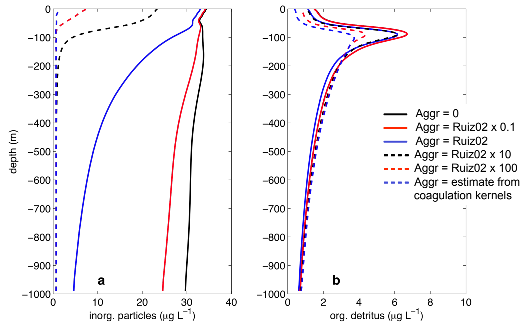
Logarithmic modelled dust deposition by Mahowald et al. 2003, in g m^{-2} a^{-1}.

A one-dimensional model of the biogeochemistry and speciation of iron is coupled with the General Ocean Turbulence Model (GOTM) and a NPZD-type ecosystem model. Modelled Fe species and processes are shown in the diagram. For a better understanding how dust particles impact the vertical distribution of iron, a complex description of particle dynamics in the water column is introduced in this model.



IV. Sensitivity study with respect to aggregation rates

The estimates from the coagulation kernels are some orders of magni-tude higher than the empirical estimates e.g. by Ruiz et al. (2002) and Gruber et al. (2006). Therefore, we ran the model with different aggre-gation rates (*Aggr*) changing the aggregation rates between different particle classes in parallel, maintaining their relative magnitude from the table 1.



The vertical distribution of inorganic particles is strongly influenced by varying aggregation rates (Fig. a), whereas the impact on the sinking flux of organic material is relatively small (Fig. b). Inorganic particles show higher concentration than organic fraction throughout the water column. Compared to the observed lithogenic and POC flux at 1000 m (Ratmeyer et al. 1999, Fischer and Wefer 2000, Lutz et al. 2002 and Bory et al. 2001), the set of aggregation rates based on Ruiz et al. (2002) is best compatible (solid blue line).

VI. Conclusions

A complex description of particle aggregation and sinking is introduced in a 1D model of Fe speciation at TENATSO. Inorganic particles show a high sensitivity to varying aggregation rates. Using the aggregation rates based on Ruiz et al. (2002), modelled sinking fluxed are comparable to observations and dominated in the upper waters by fine dust particles and deeper in the water column by large aggregates. This assumption of aggregation rates results in a annual averaged residence time of DFe ranging from 80 days to 16 years in the upper 1000 m.