Impact of open ocean dissolution of olivine on atmospheric CO_2, surface ocean pH and the biological carbon pump

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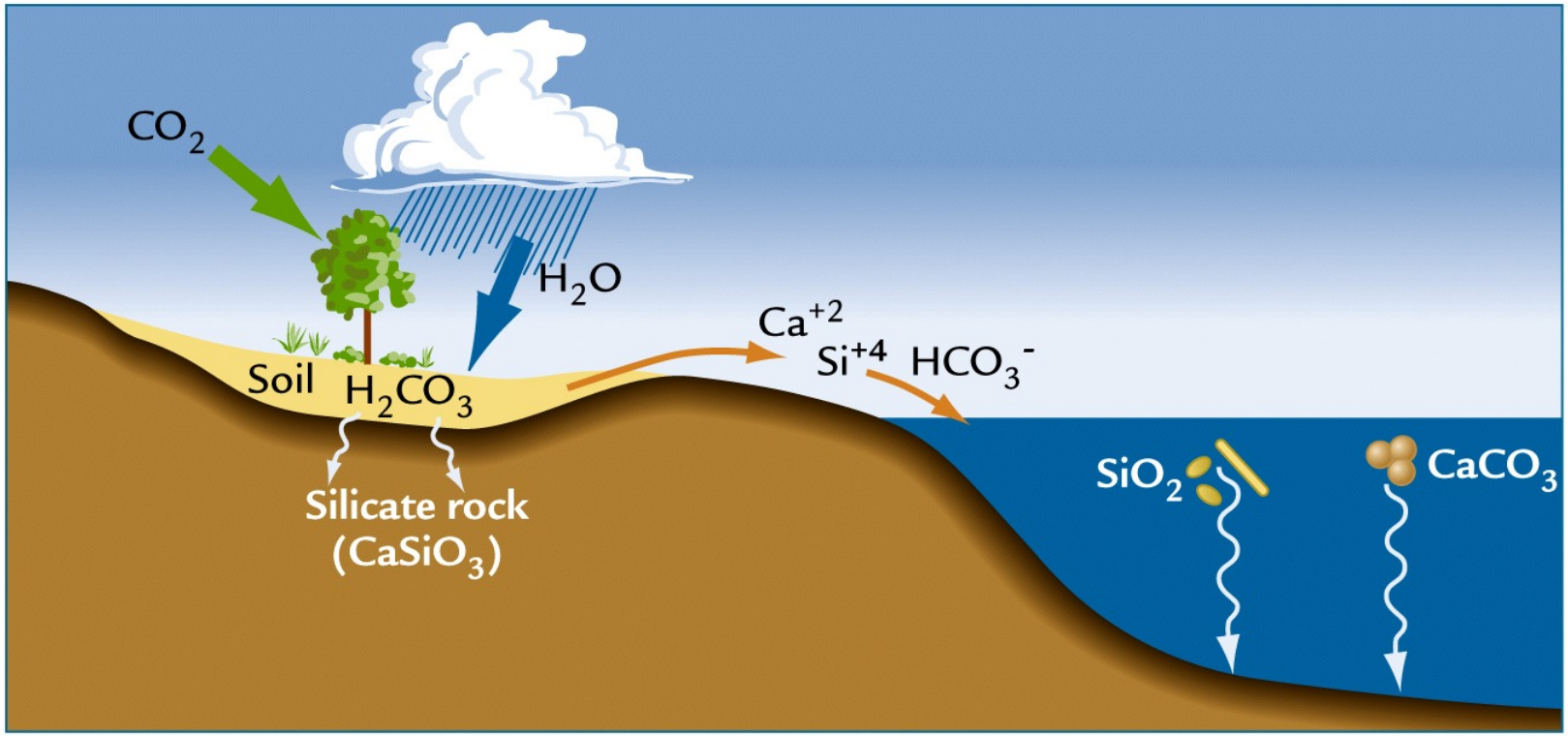
20 August 2014, Climate Engineering Conference 2014, Berlin

SILICATE WEATHERING



$CaSiO_3$ + H_2CO_3

Silicate bedrock + Carbonic acid in soils

Weathering on land

Ca^{+2} Si^{+4} HCO_3^-

Ions dissolved in river water

Transport in rivers

$SiO_2 + CaCO_3$

Shells of ocean plankton

Deposition in ocean

Ruddiman 2001

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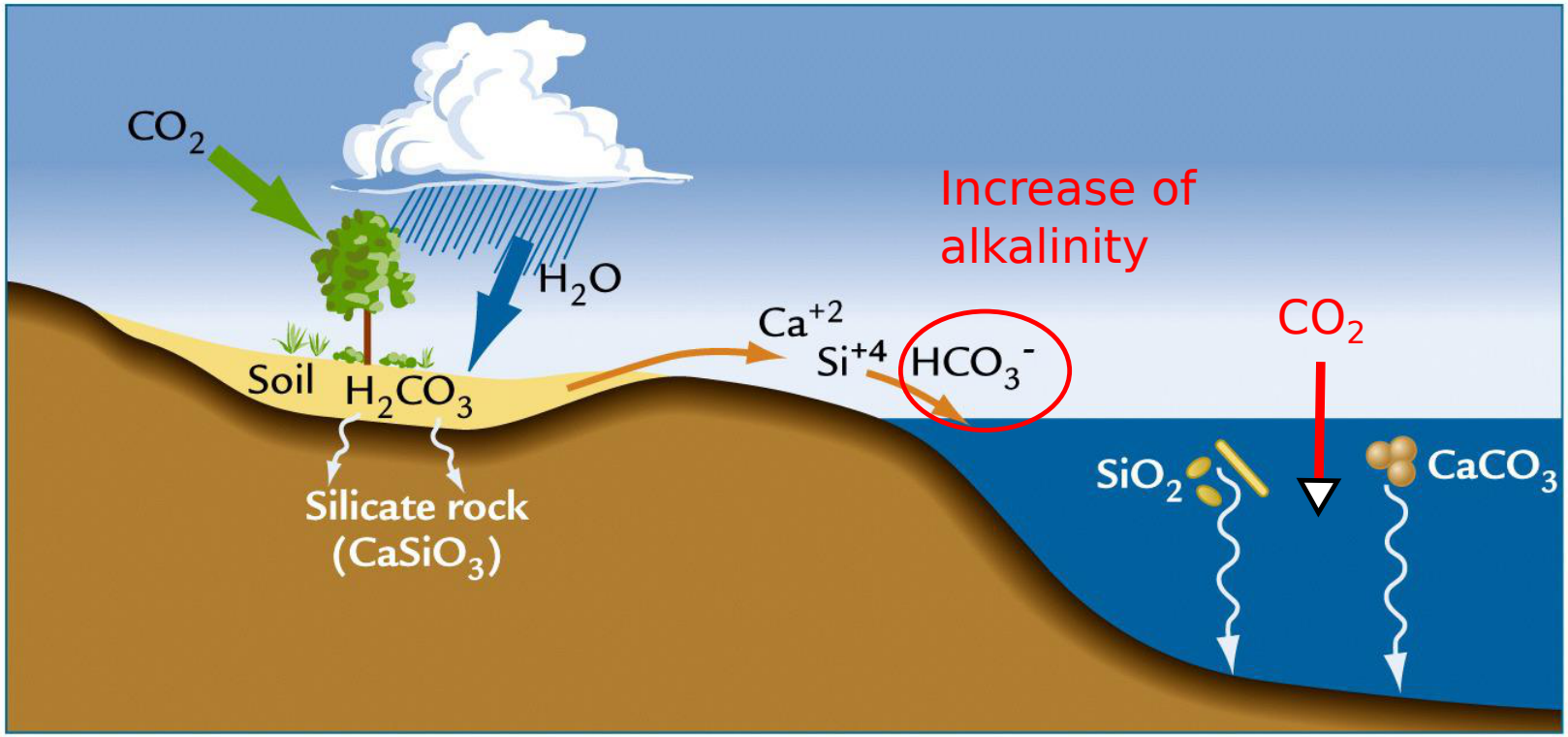

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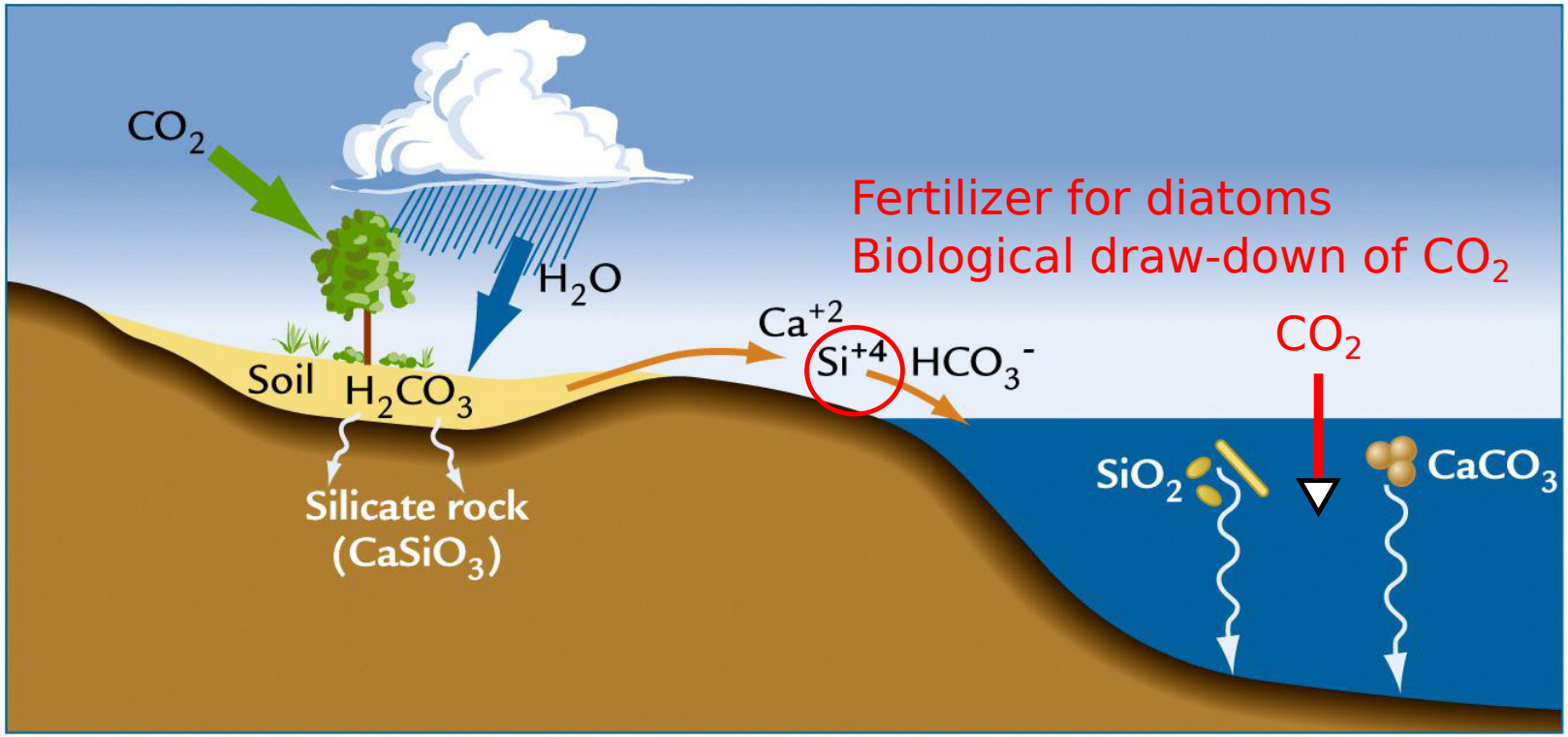

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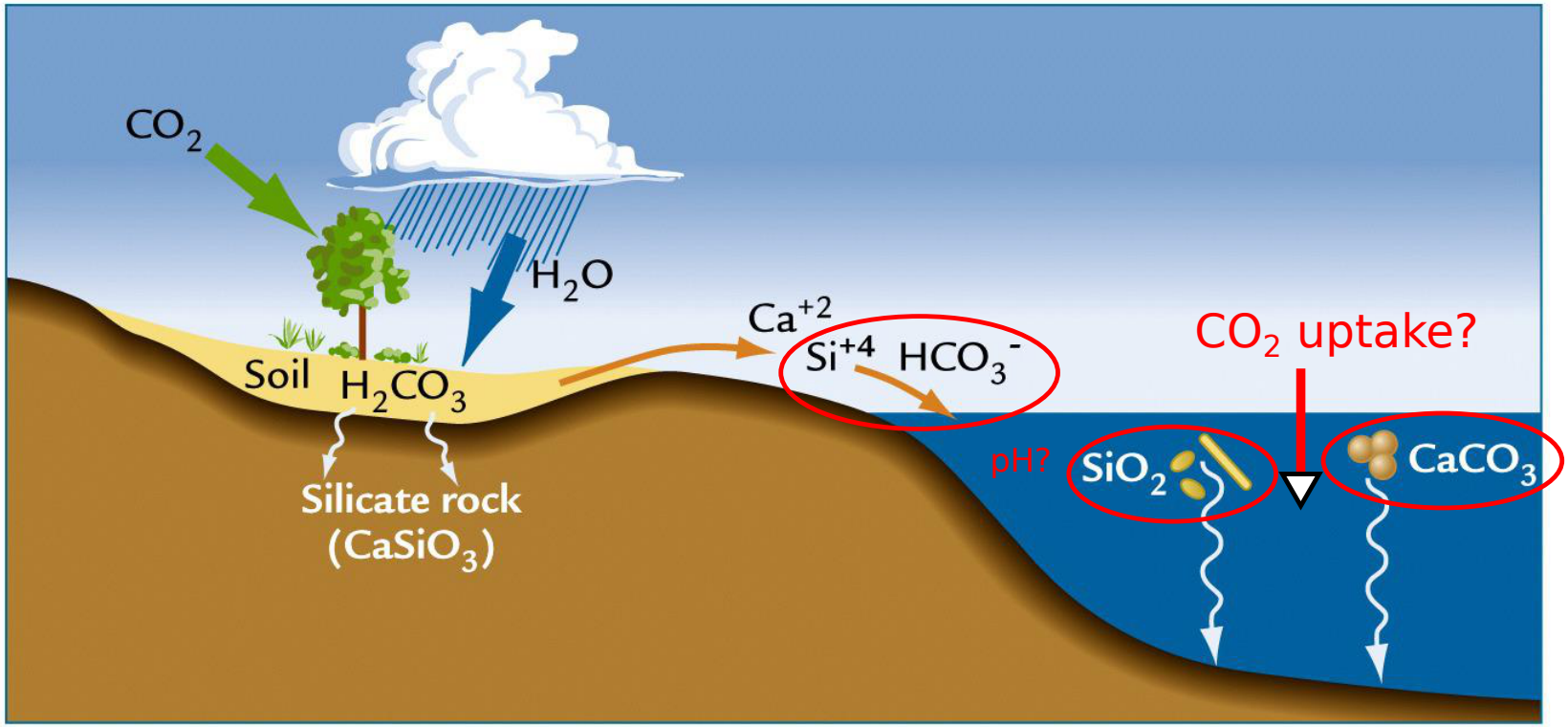

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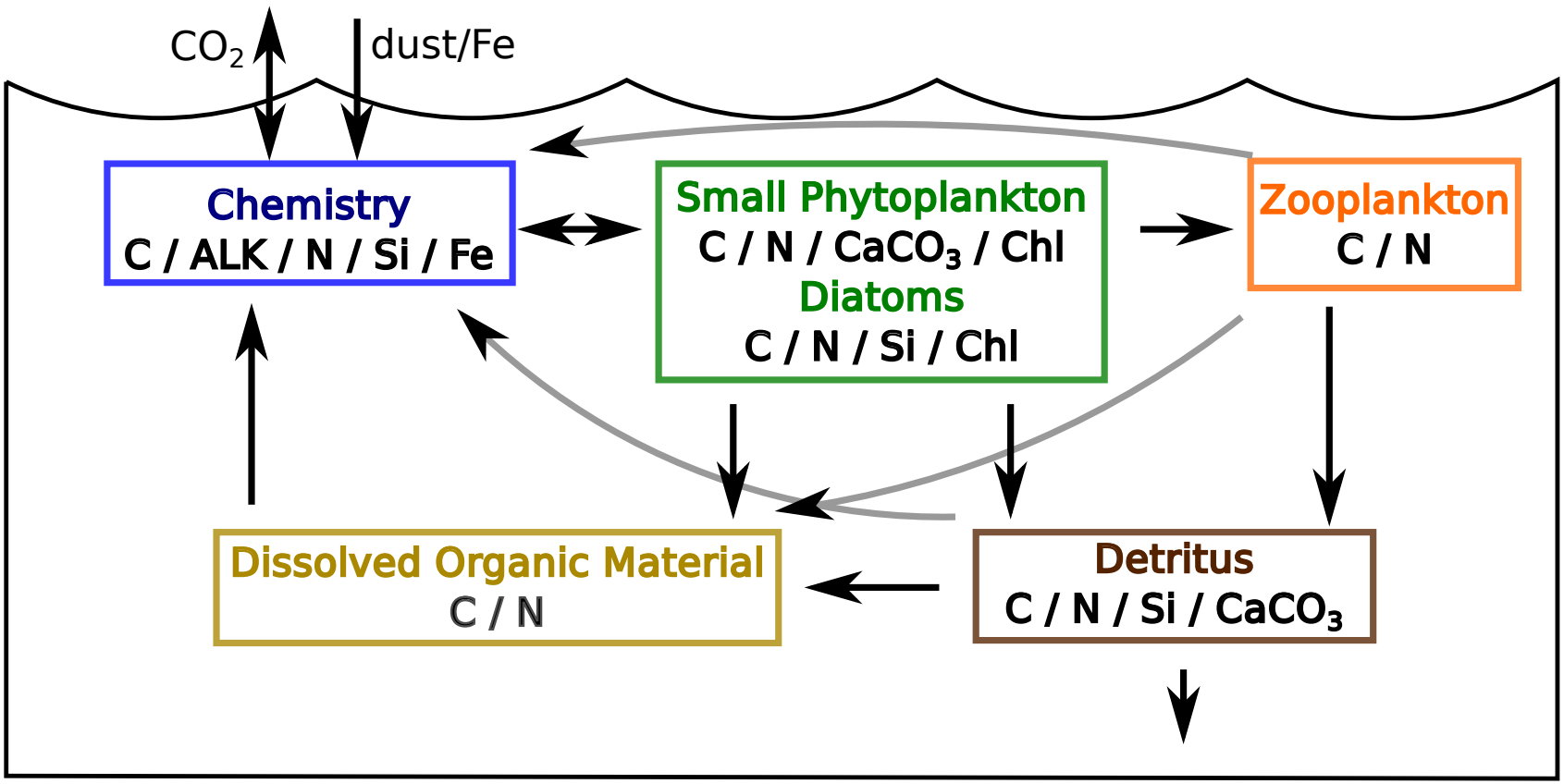

Hauck et al., 2013

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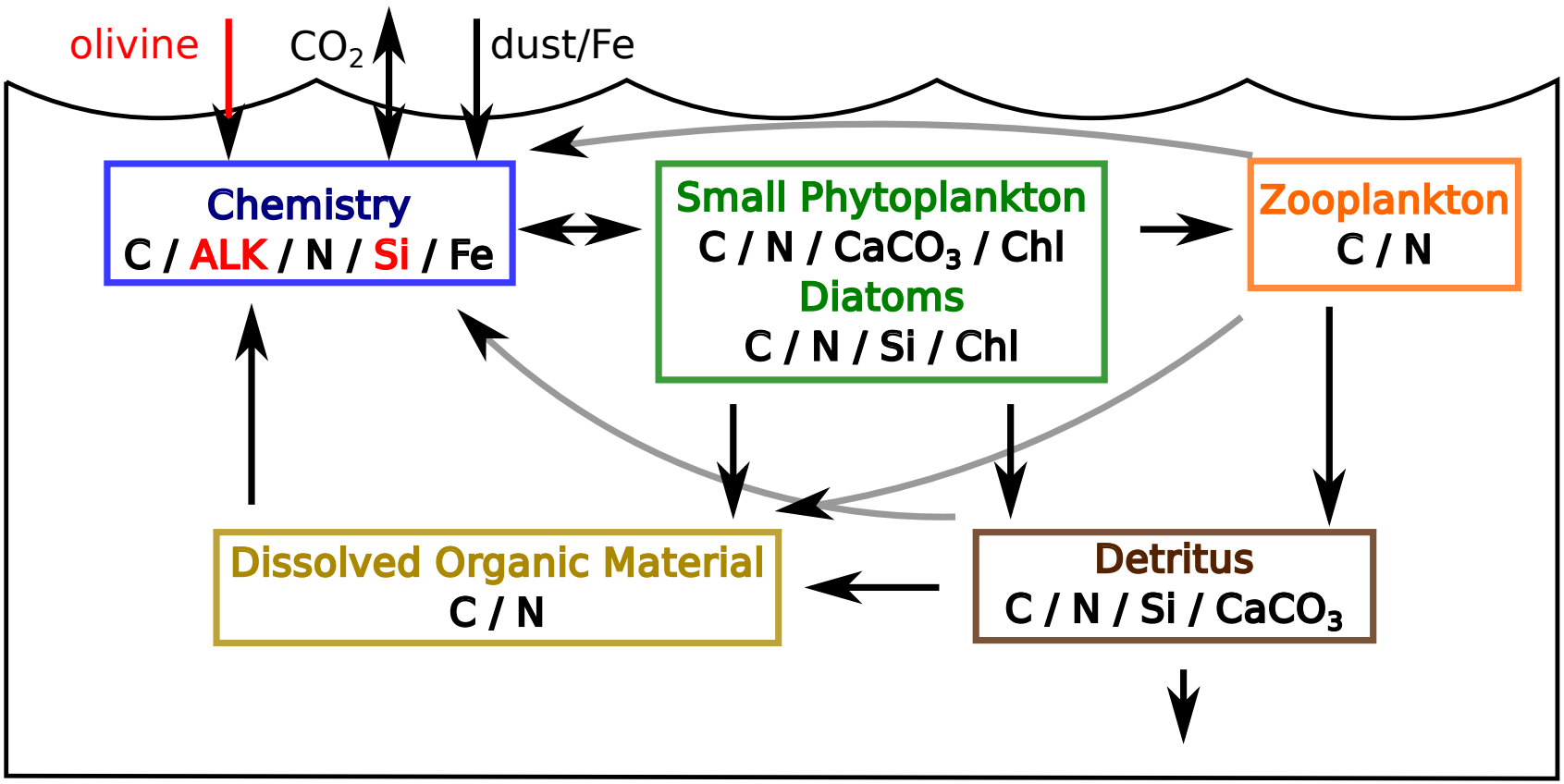


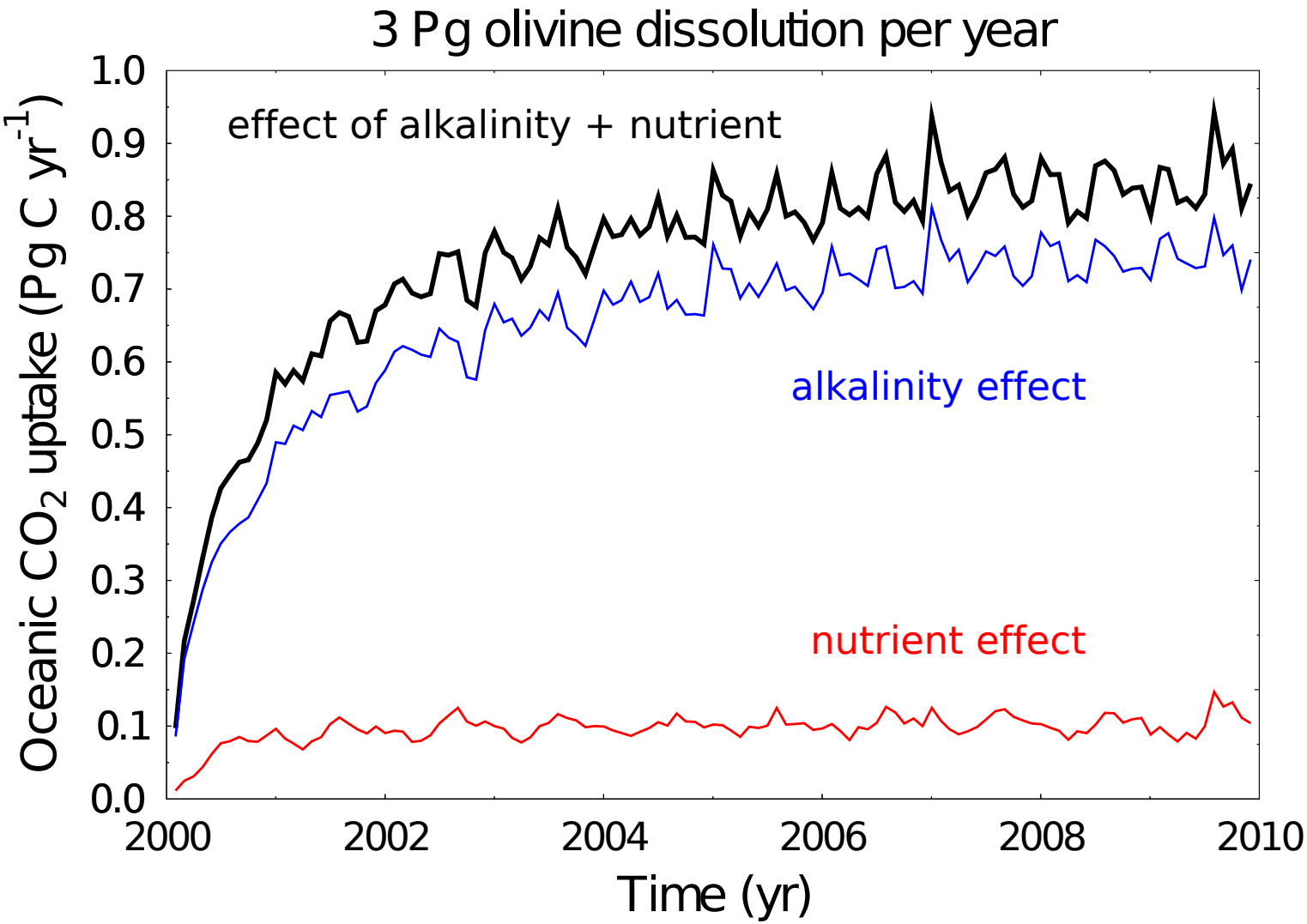
Hauck et al., 2013

Model experiments

Olivine addition

1 Pg per year	3 Pg per year	10 Pg per year
Small	Standard	Large
	Only silicic acid	
	Only alkalinity	
	Ships	

CONTRIBUTION OF ALKALINITY VS NUTRIENTS



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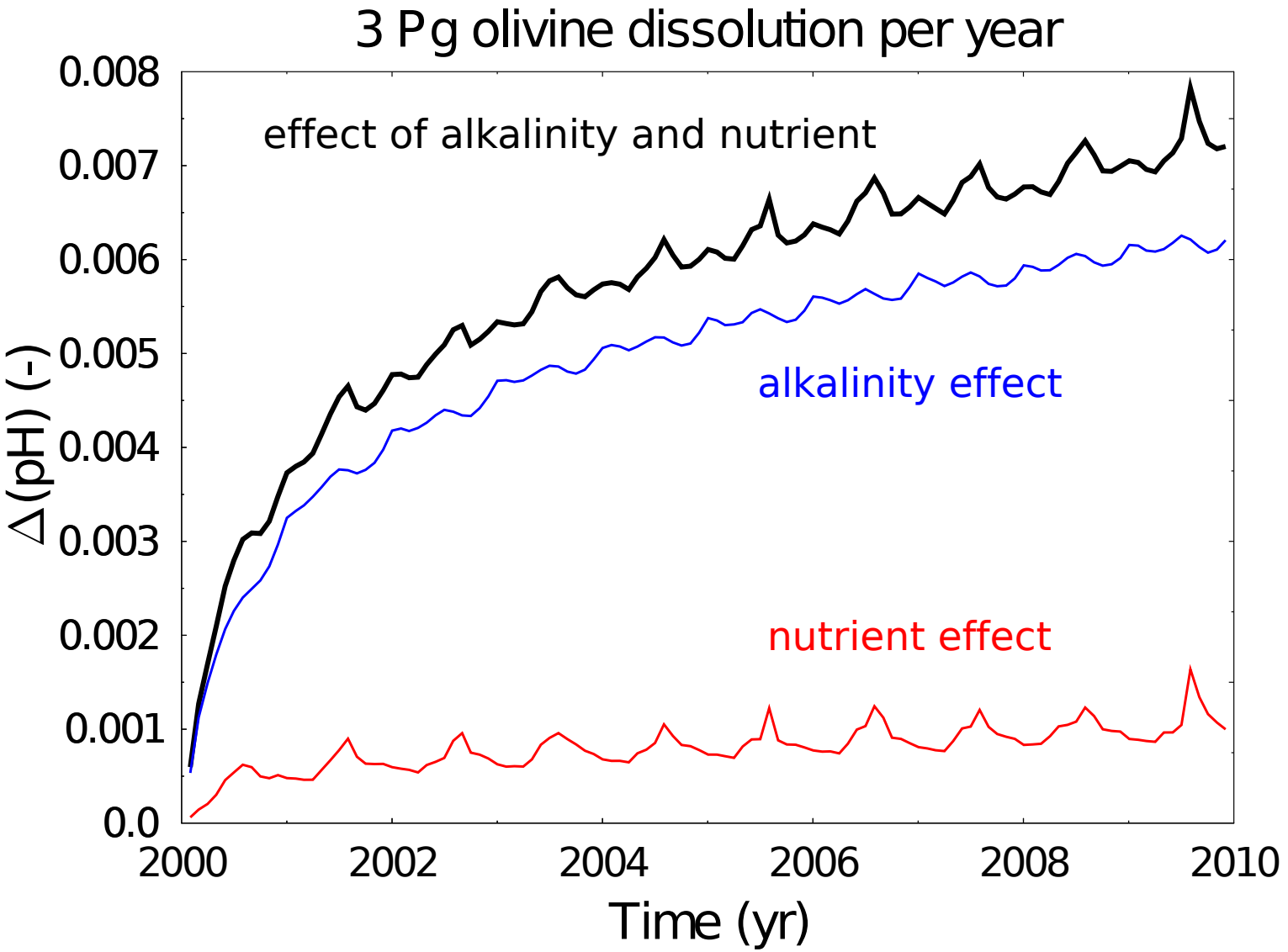
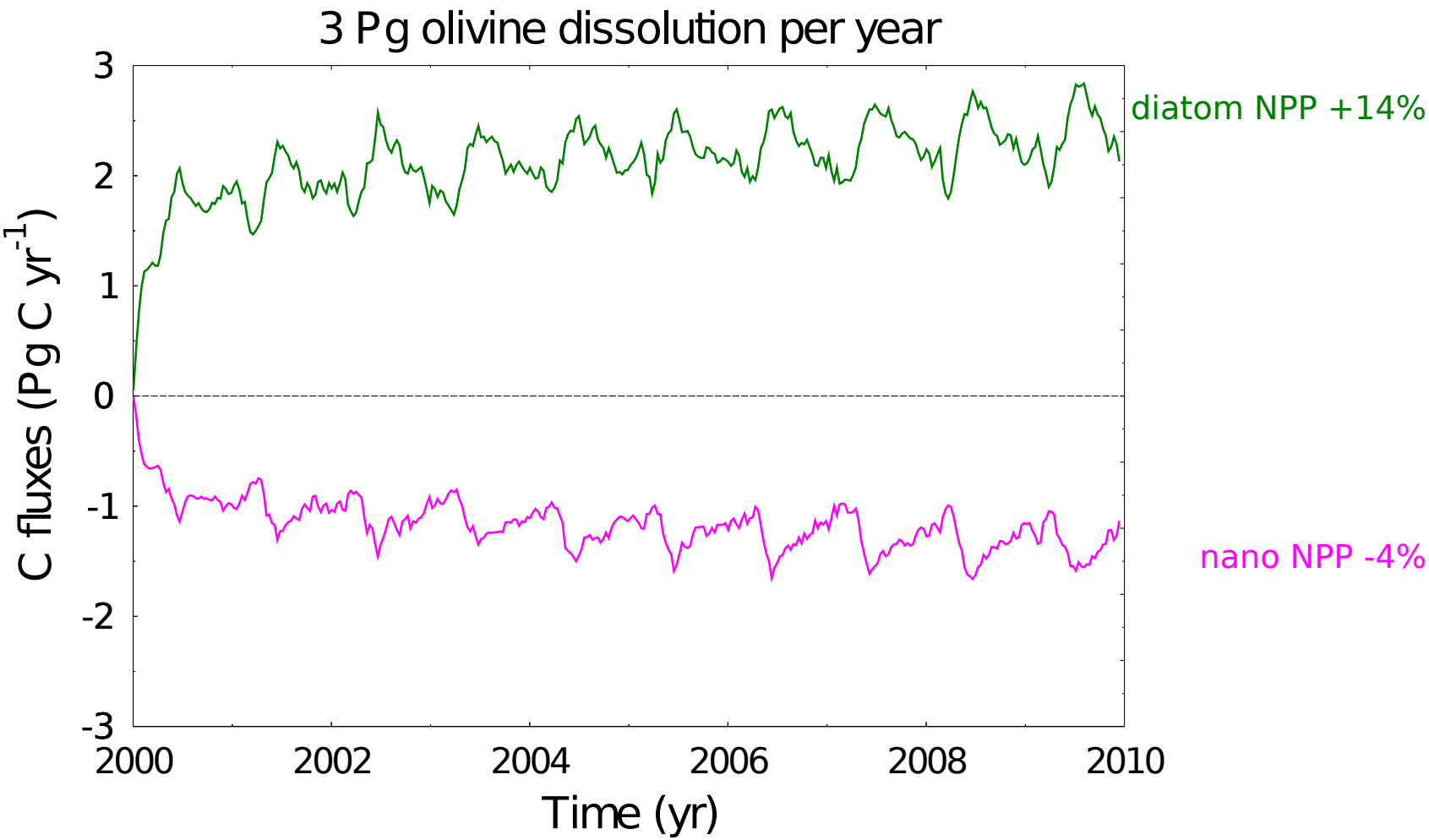


CHANGES IN PRIMARY AND EXPORT PRODUCTION



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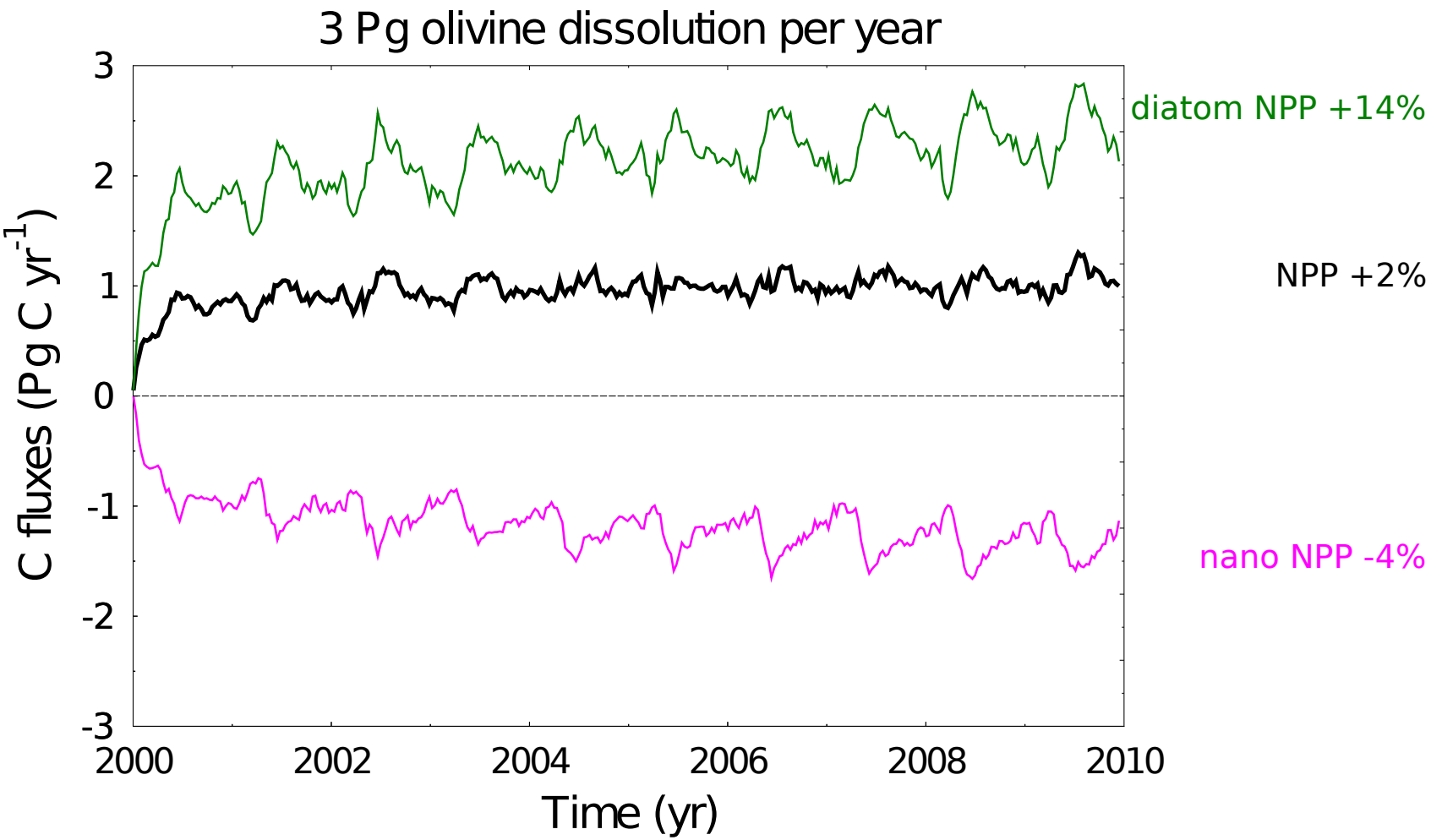

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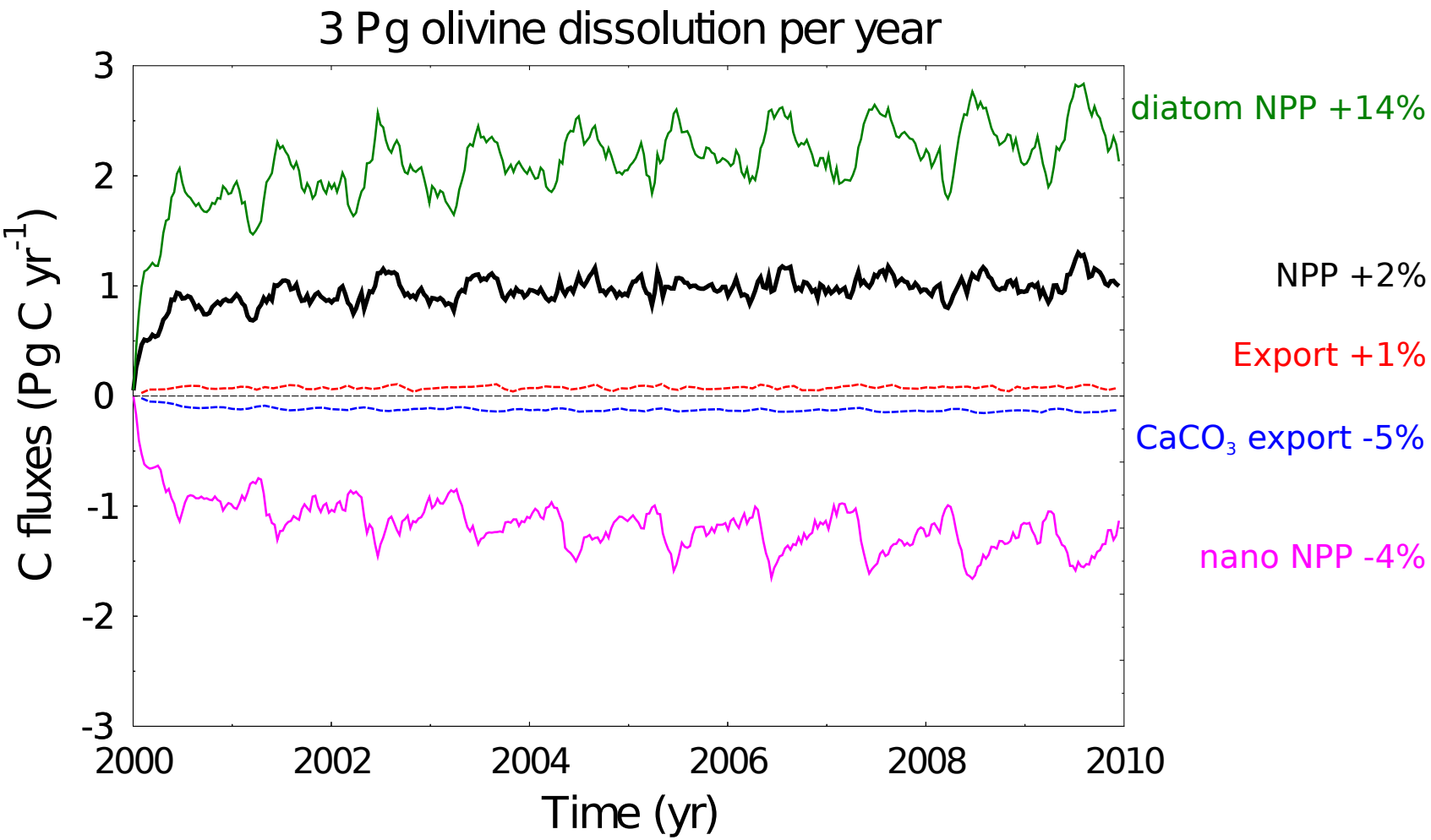
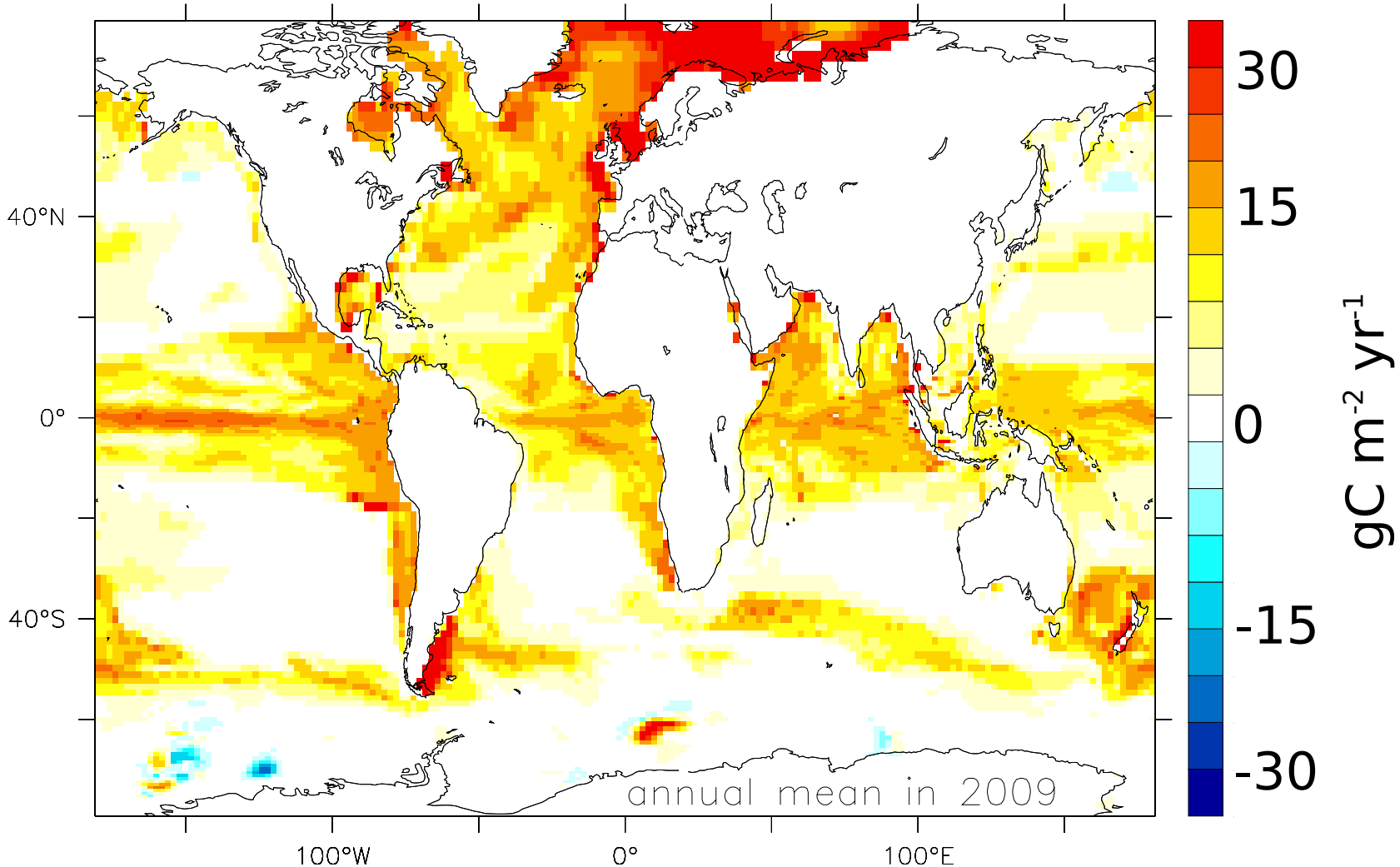
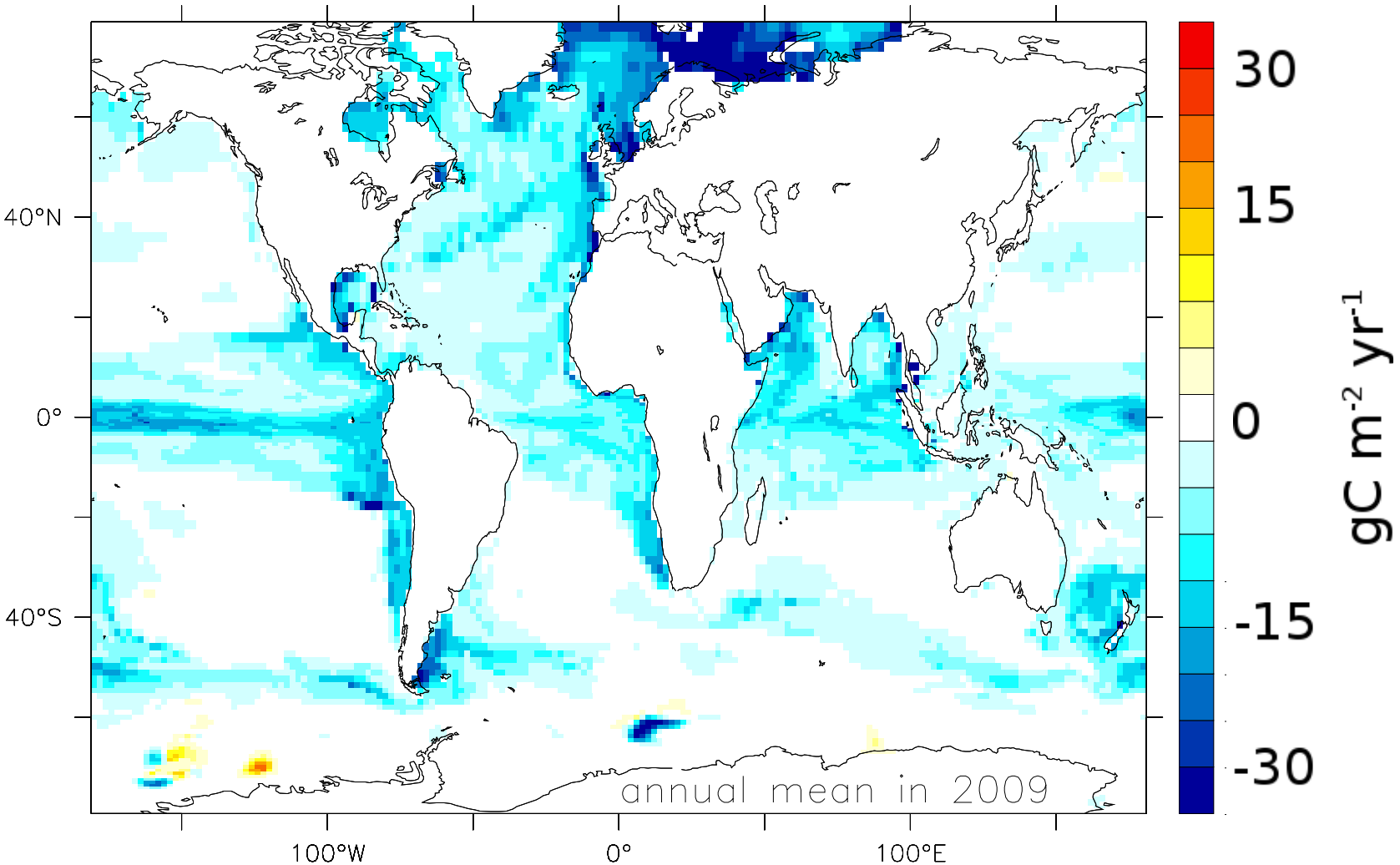


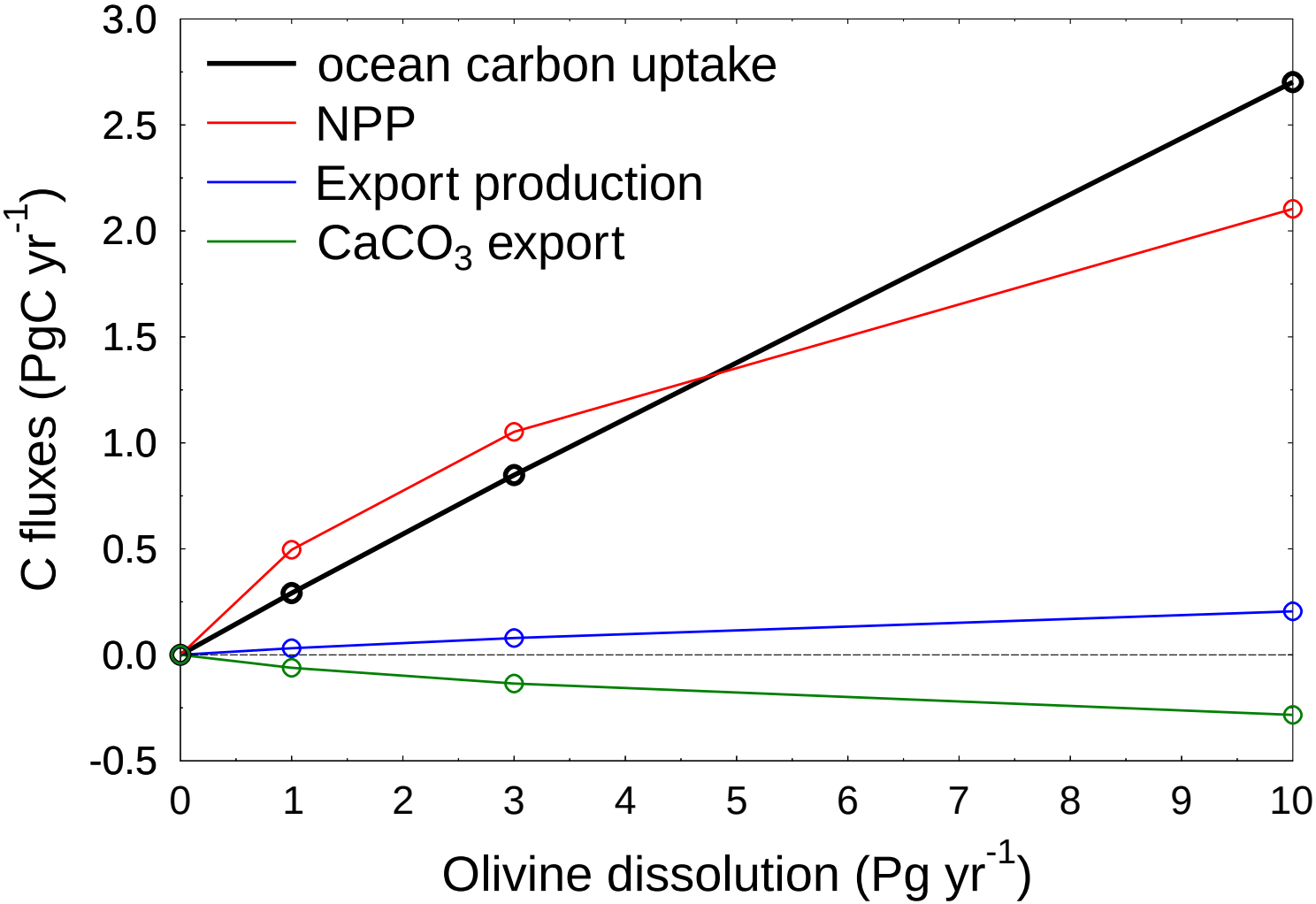
Standard run: Diatom primary production



Standard run: Nano primary production

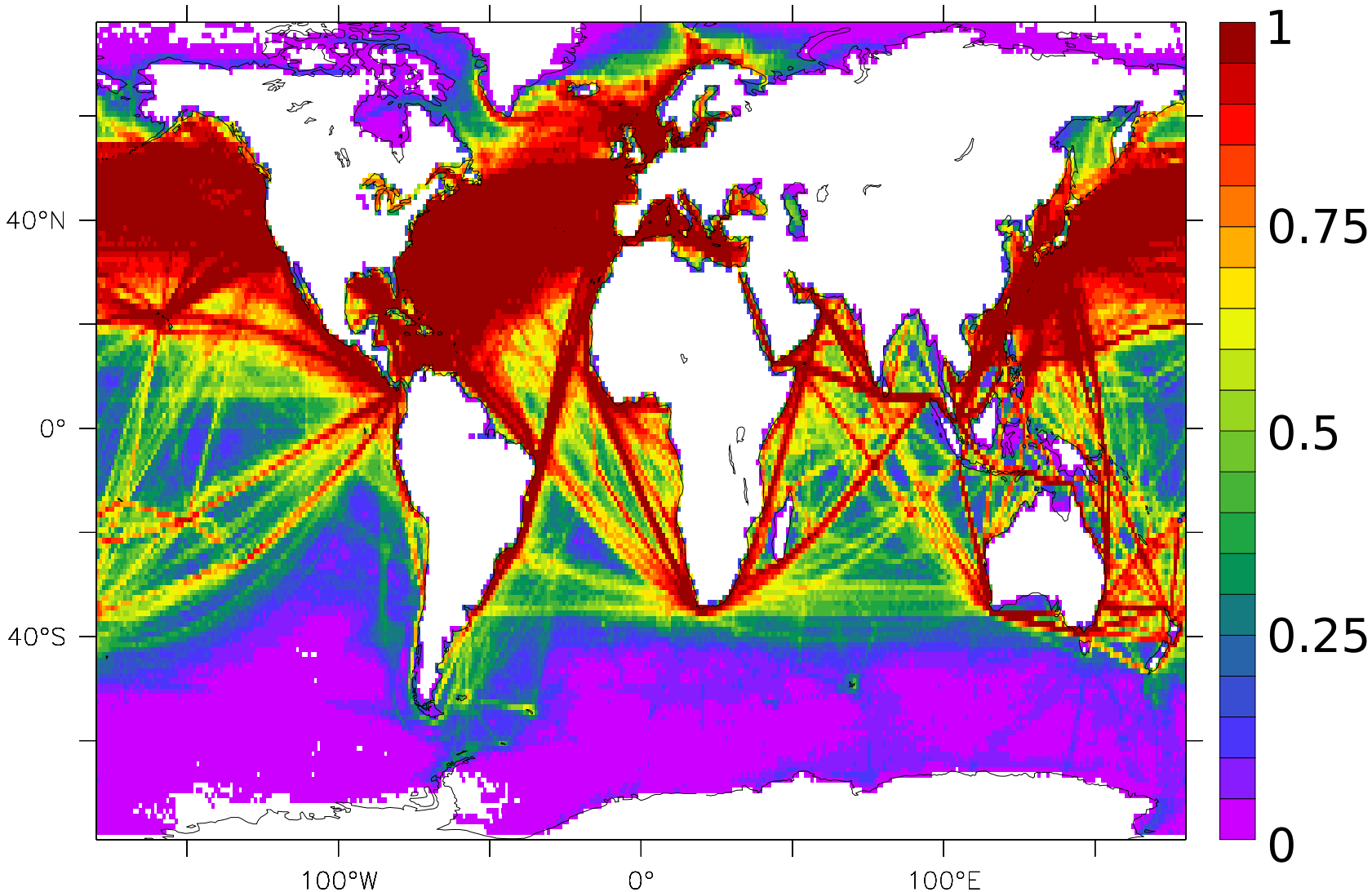


SCALING FACTORS



Distribution via ships

Normalized ship track density



SIZE OF PARTICLES TO DISSOLVE IN MIXED LAYER?

- sinking speed: Stokes' law
- dissolution rate based on Hangx & Spiers, 2009

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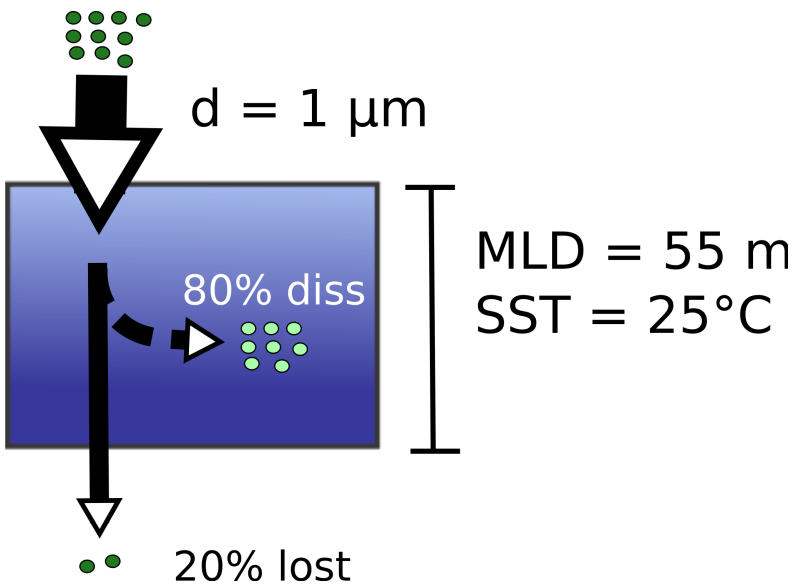
Ideal scenario



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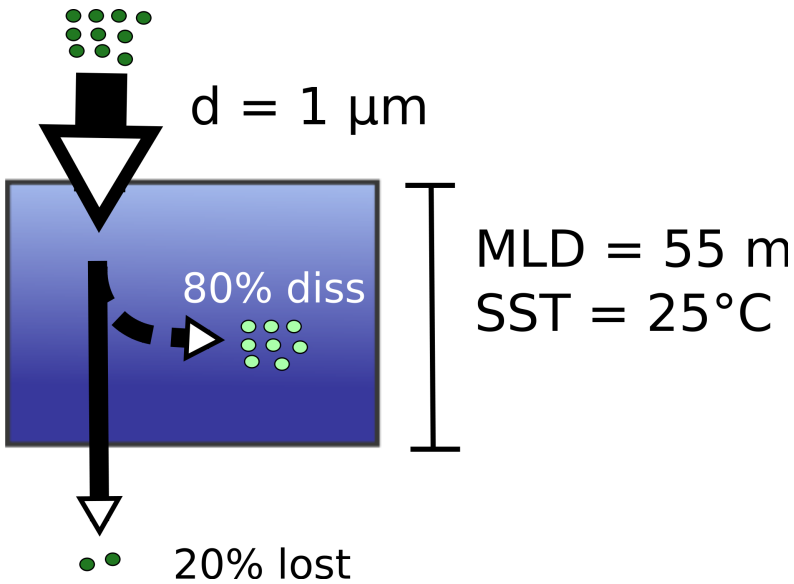
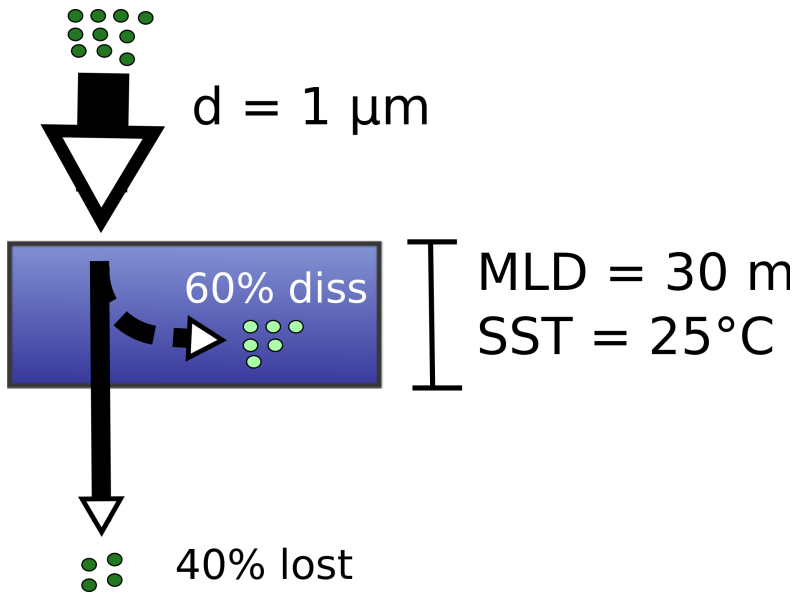


Shallower MLD



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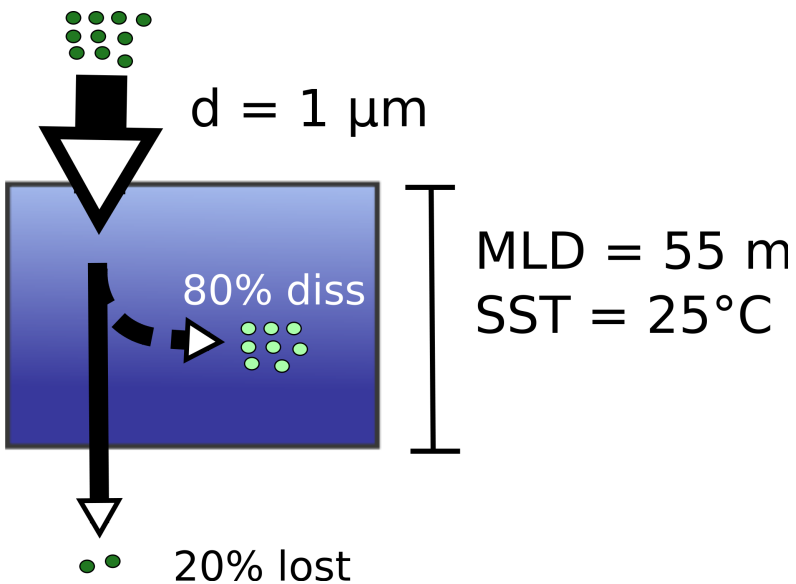
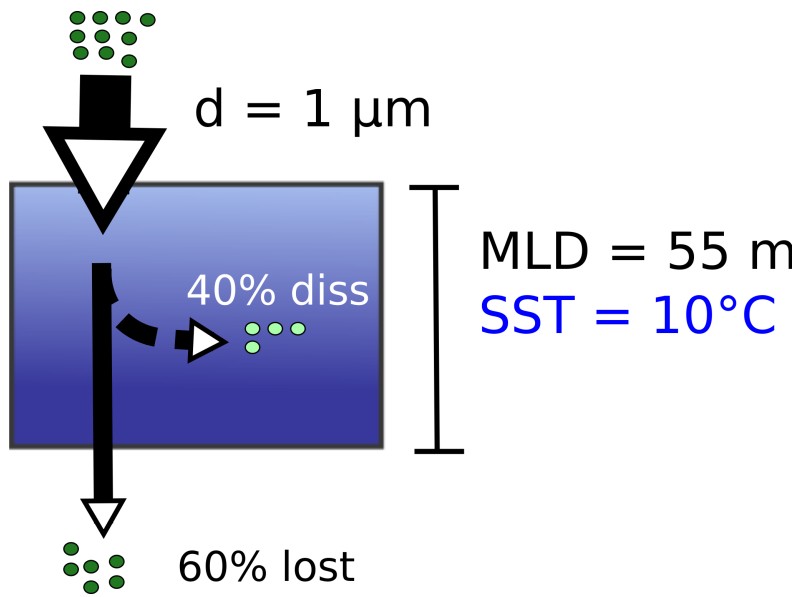


Lower SST



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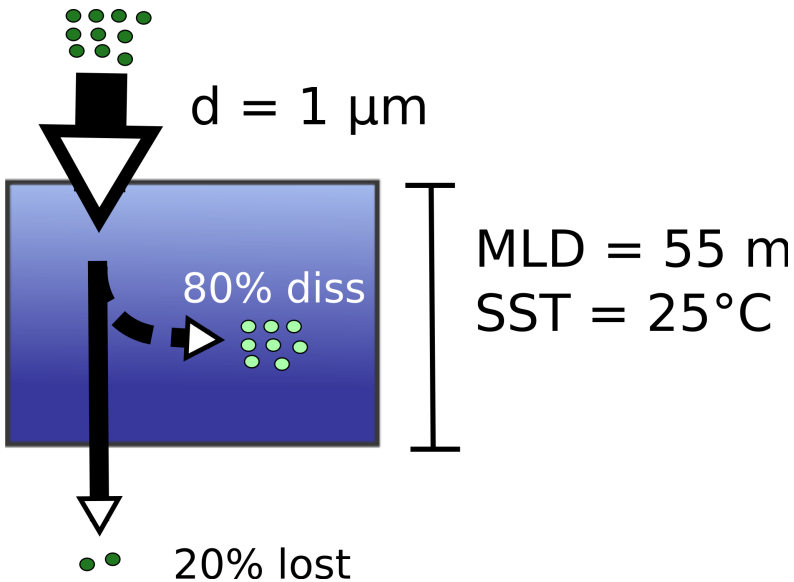
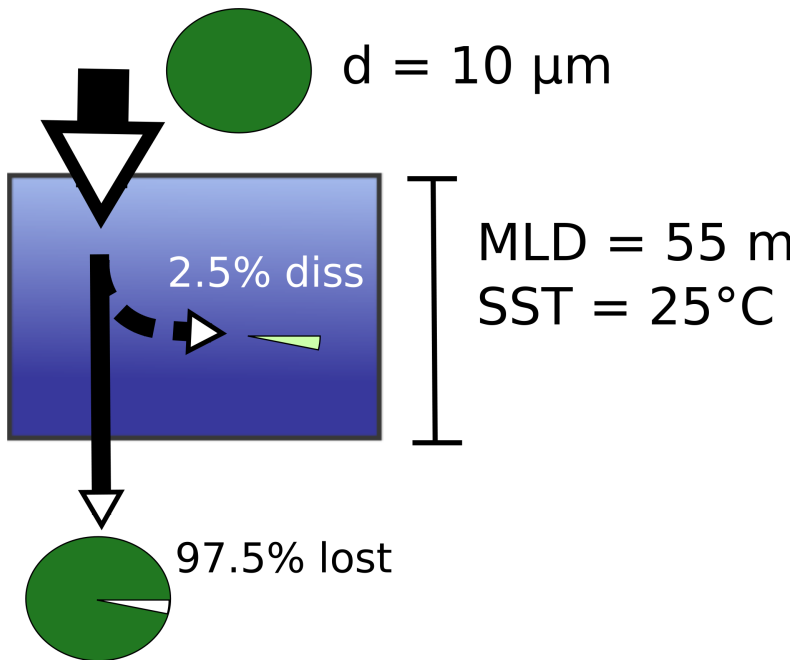
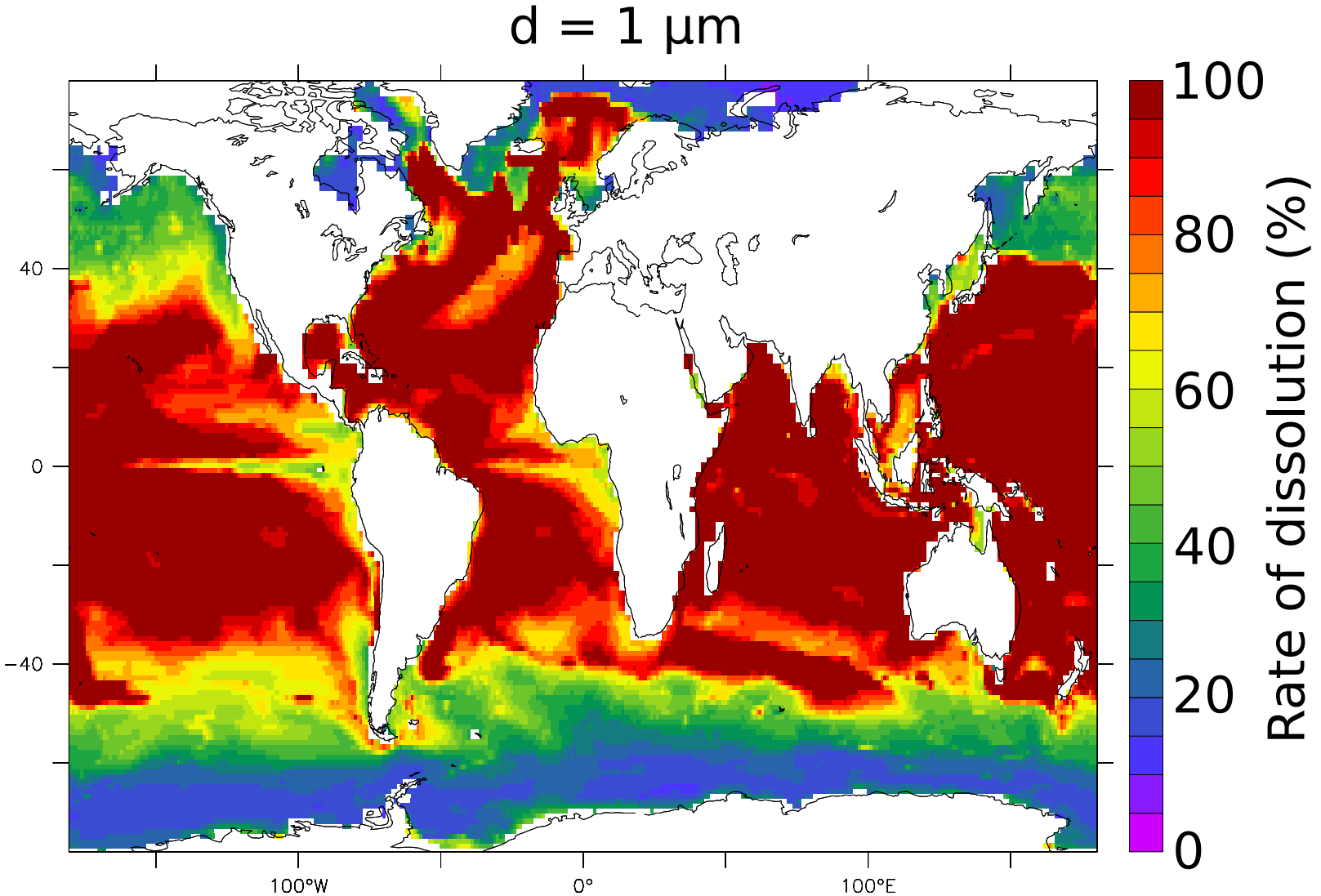


Increased grain size



PARTICLE DISSOLUTION IN REAL OCEAN



LIMITATIONS AND RISKS

- Limitations
  - Distributing 3 Pg olivine per year: full-time commitment of more than 300 large ships → compensation of approx. 9% of anthropogenic CO_2 emissions
  - Ships of opportunity (using ballast water): maximum potential distribution: 0.9 Pg olivine per year
  - Need grain sizes of 1 μm (sinking speed) → grinding reduces carbon sequestration efficiency from approx. 90 to 60%

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- Risks
  - Dissolution of heavy metals possible - toxicity?
  - Impact on marine species distribution
  - Potential for extension of anoxic or suboxic regions
  - Environmental and social problems with mining of olivine

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- Simplifications
  - Effects of iron-addition, reduction of water transparency not considered
  - Impact on oxygen not quantified

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Geoengineering impact of open ocean dissolution of olivine on atmospheric CO_2, surface ocean pH and marine biology

Peter Köhler, Jesse F Abrams[1], Christoph Völker, Judith Hauck and Dieter A Wolf-Gladrow