

Seasonality of particulate Iron and Manganese in the Southern Ocean

Antoine Ringard
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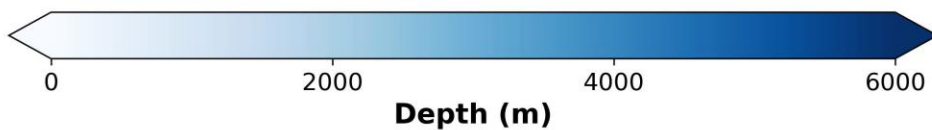
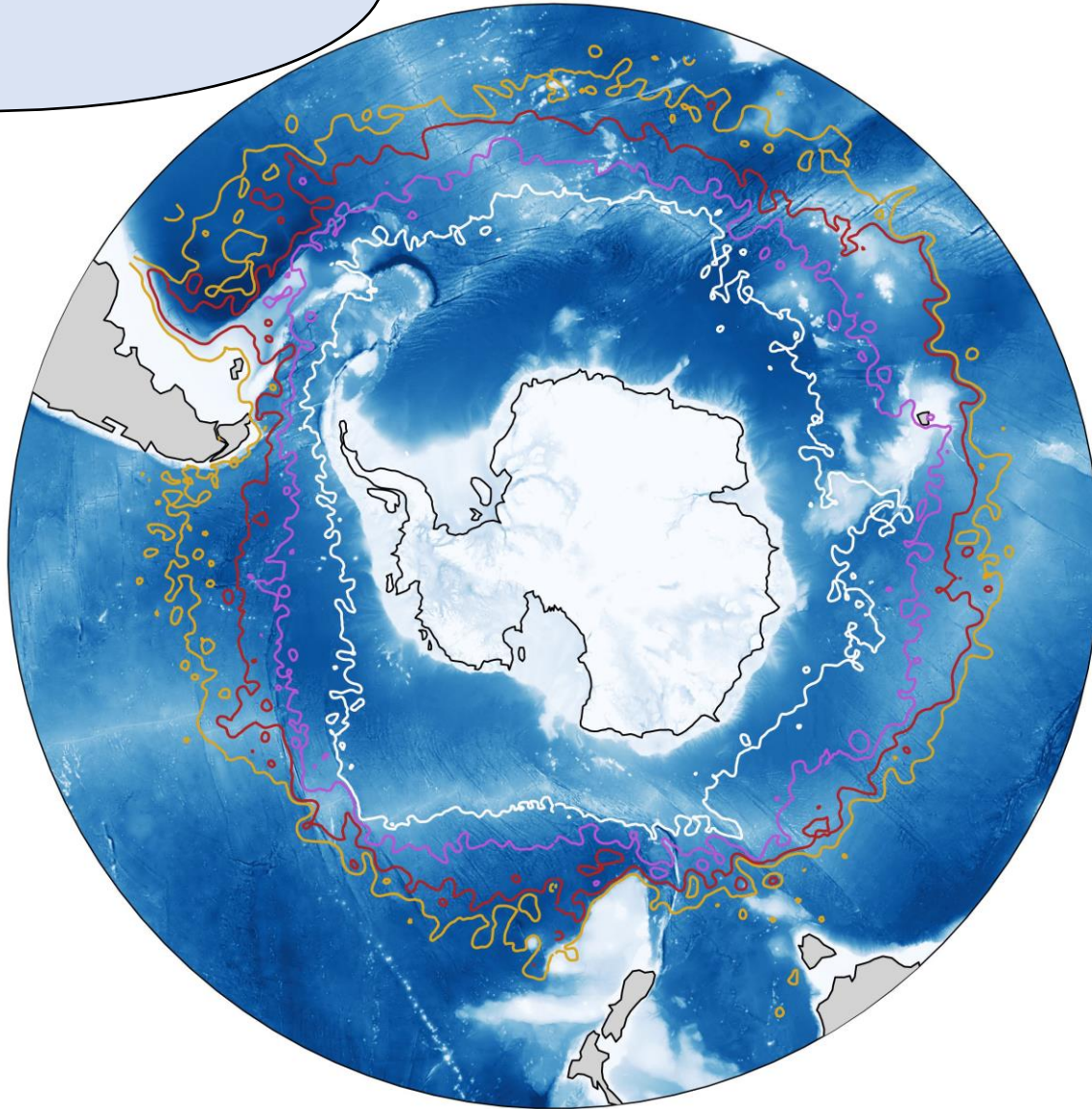
2nd year PhD student

Supervisors:
Hélène Planquette and Eva Bucciarelli

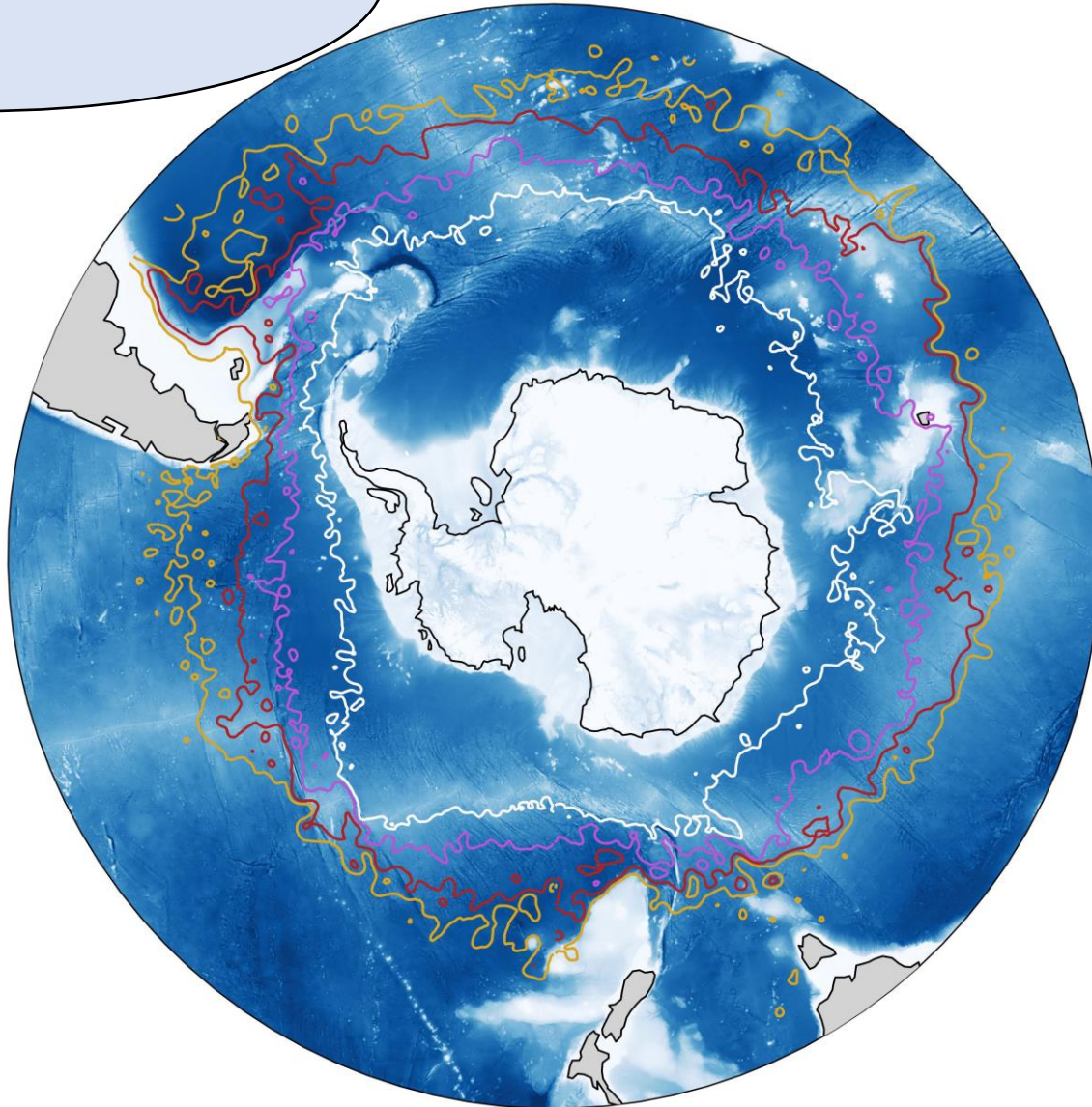
Journées Polaires 2025

Southern Ocean

- Antarctic Circumpolar Current (ACC) transport occurs along hydrographic fronts:

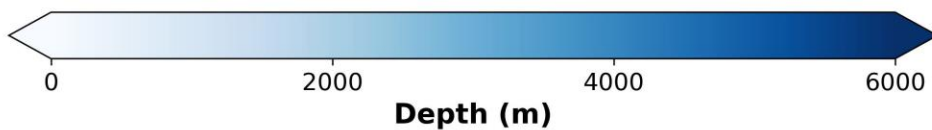


Southern Ocean

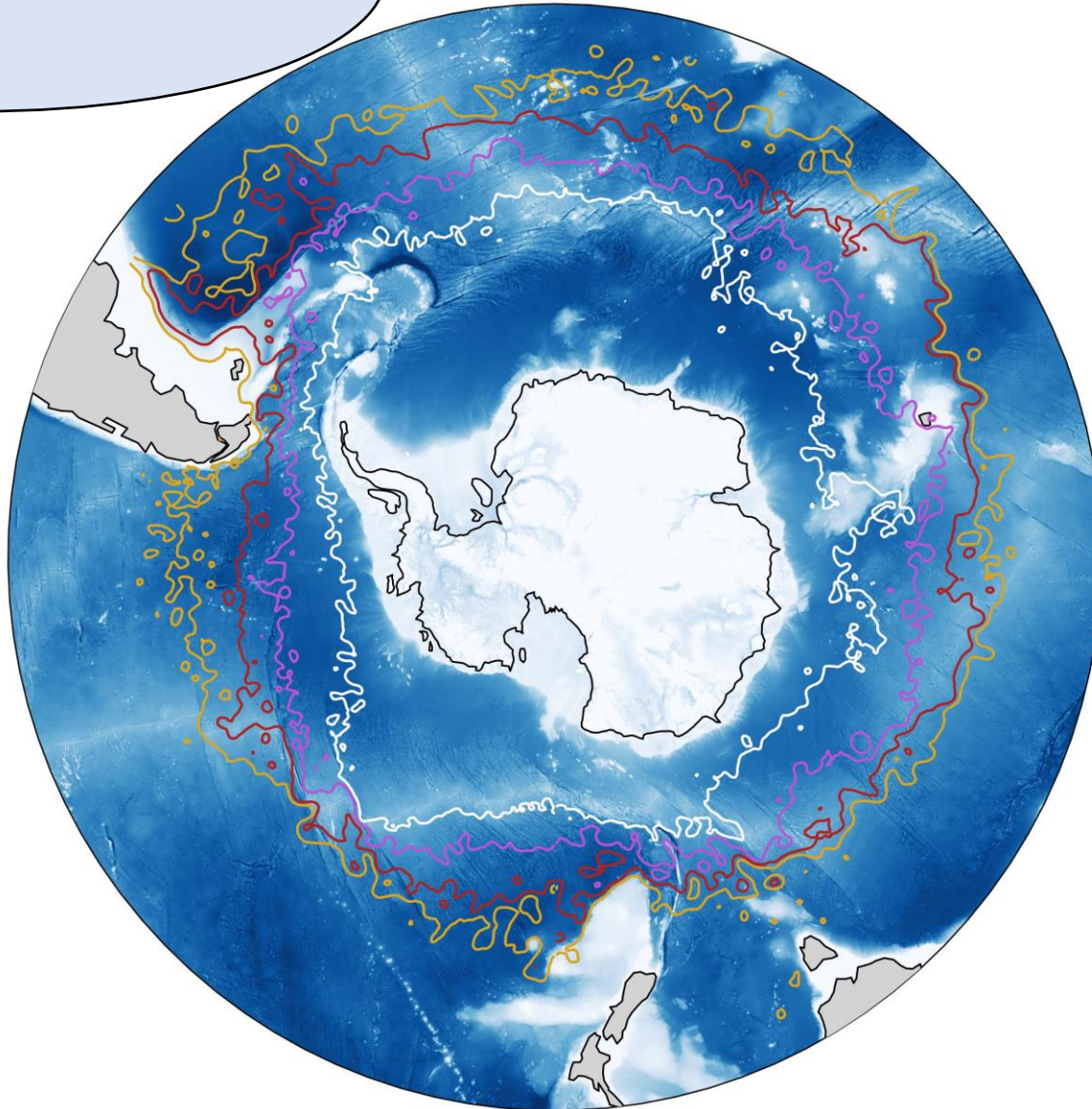


- Antarctic Circumpolar Current (ACC) transport occurs along hydrographic fronts:

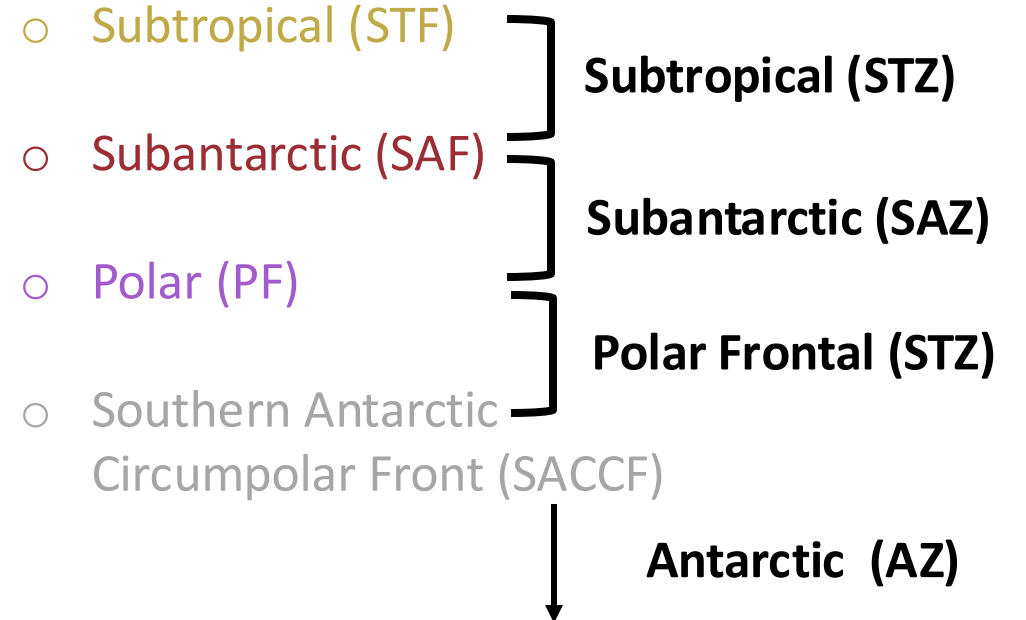
- Subtropical (STF)
- Subantarctic (SAF)
- Polar (PF)
- Southern Antarctic Circumpolar Front (SACCF)



Southern Ocean



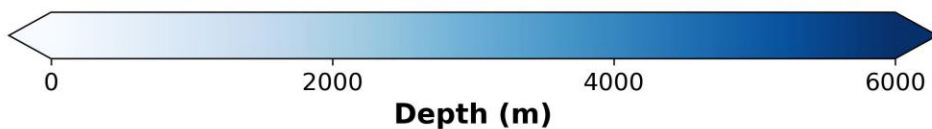
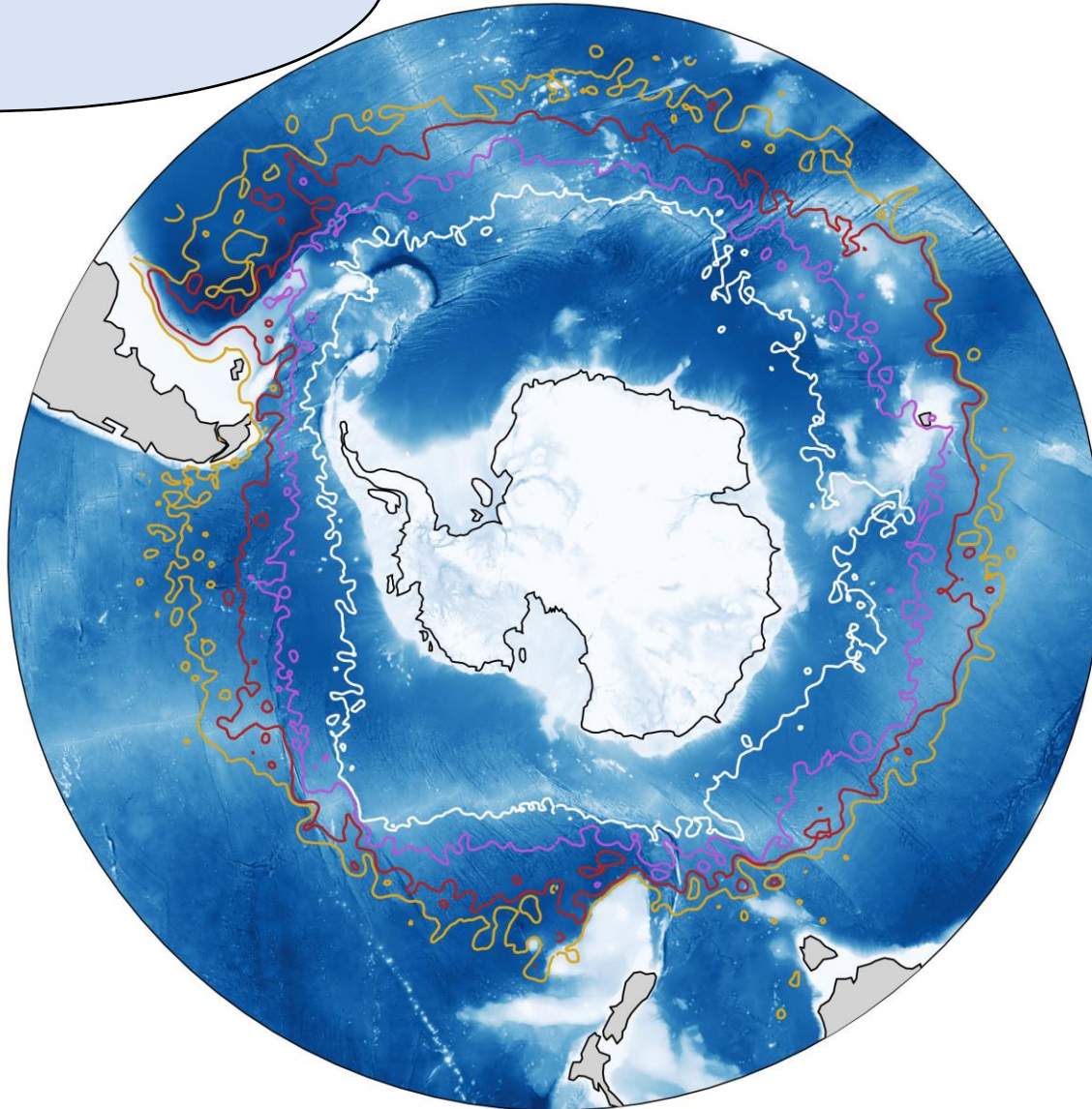
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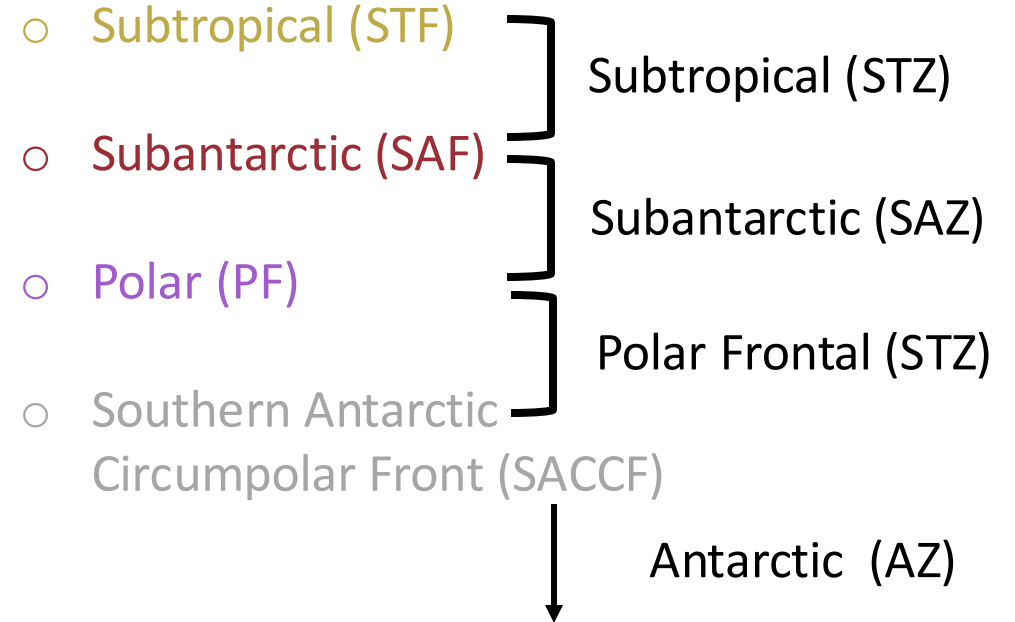
- Divide the Southern Ocean into distinct biogeochemical zones



Southern Ocean

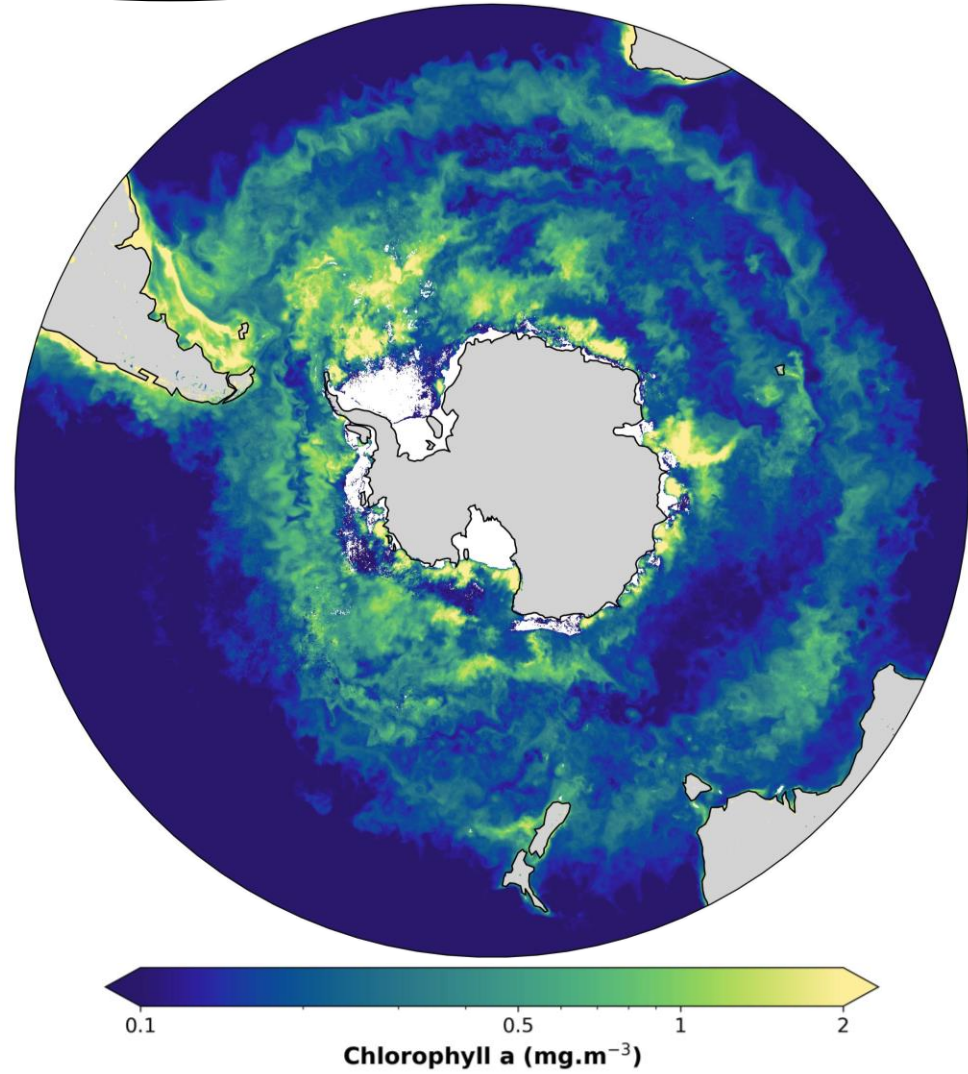


- Antarctic Circumpolar Current (ACC) transport occurs along hydrographic fronts:



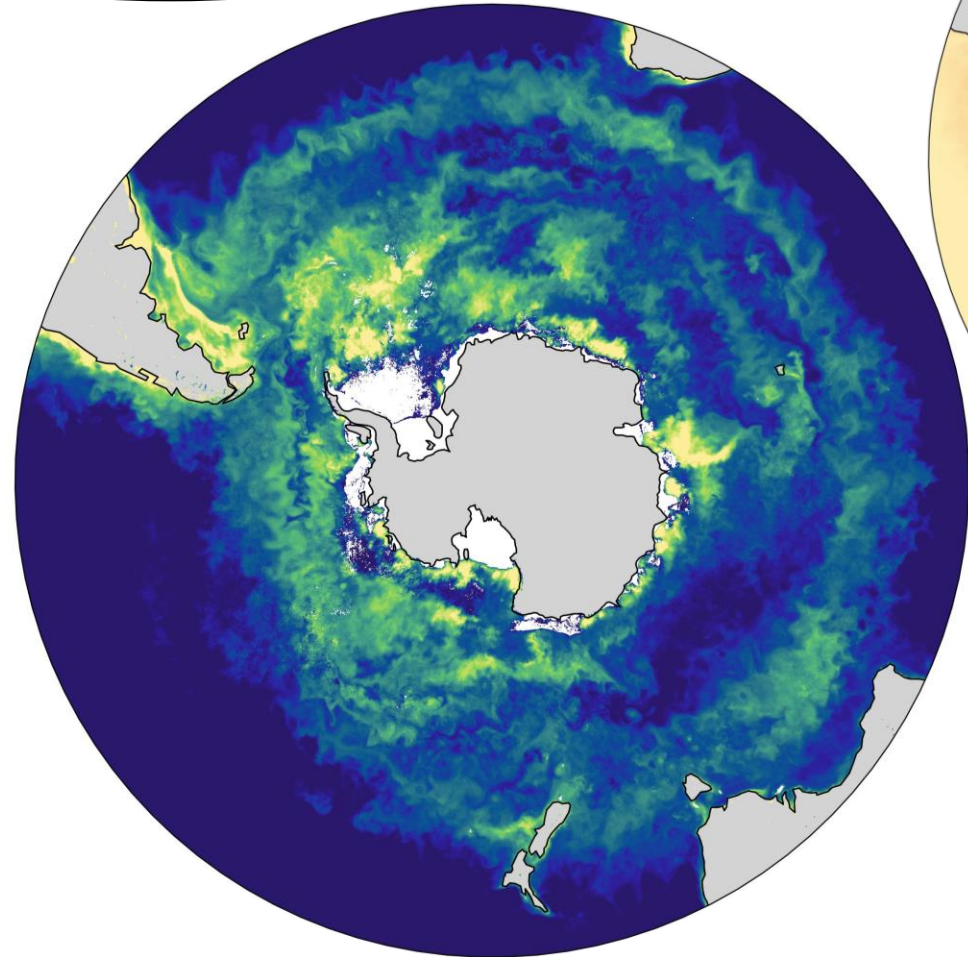
- Divide the Southern Ocean into distinct biogeochemical zones
- **30-40% of the anthropogenic CO₂ uptake by the Southern ocean via physical and biological pumps** (DeVries 2014)

Iron hypothesis

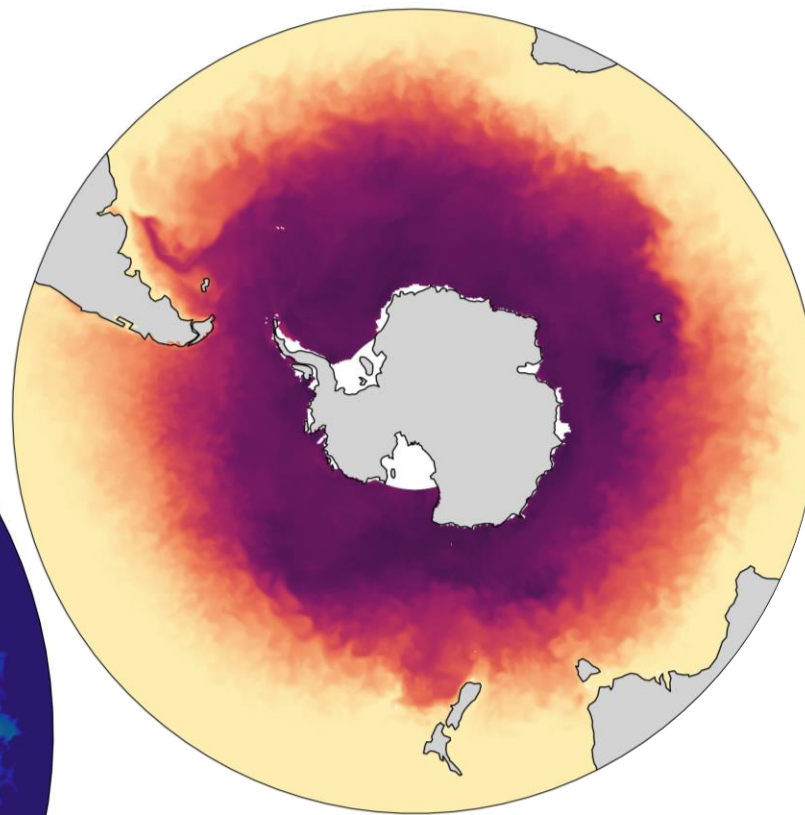


→ Low chlorophyll a concentrations ($< 0.5 \text{ mg}\cdot\text{m}^{-3}$)

Iron hypothesis



0.1 0.5 1 2
Chlorophyll a ($\text{mg}\cdot\text{m}^{-3}$)

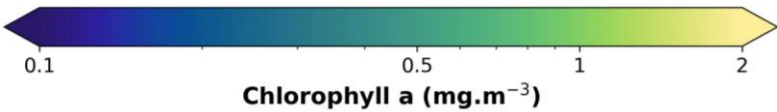
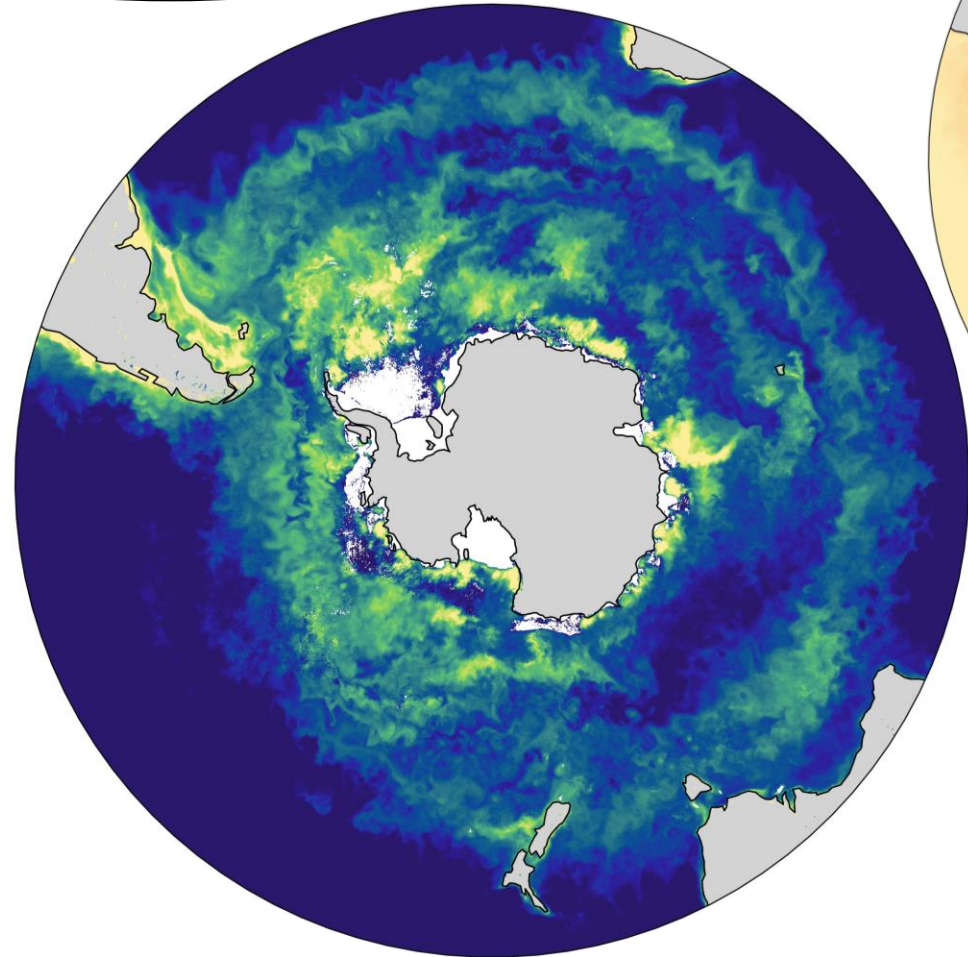


0 10 20 30
Surface Nitrate ($\text{mmol}\cdot\text{m}^{-3}$)

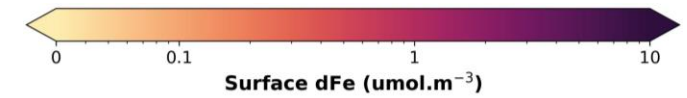
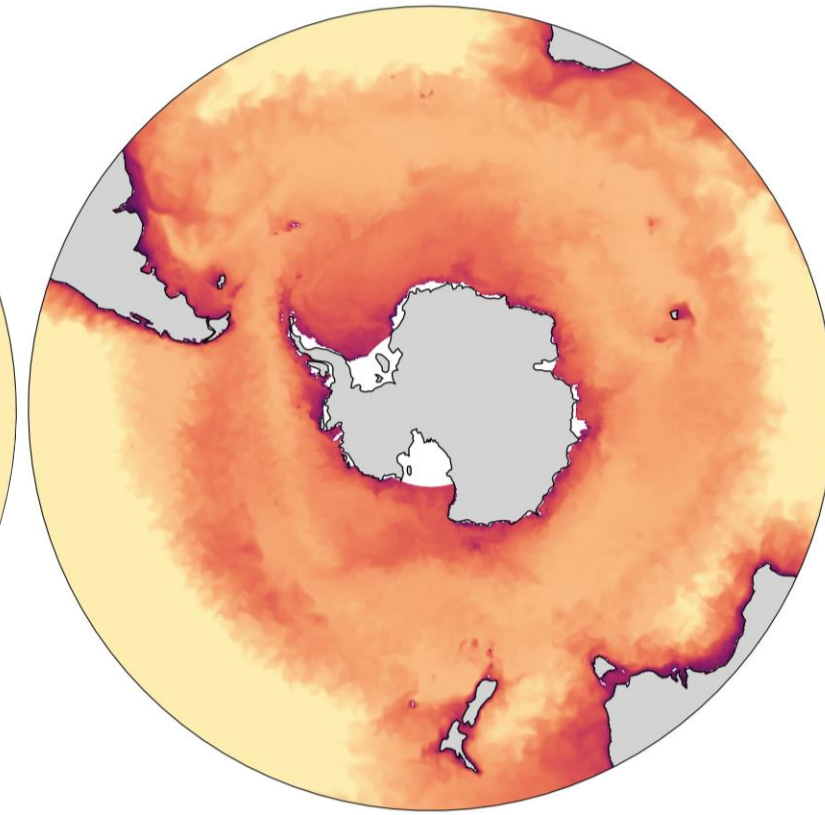
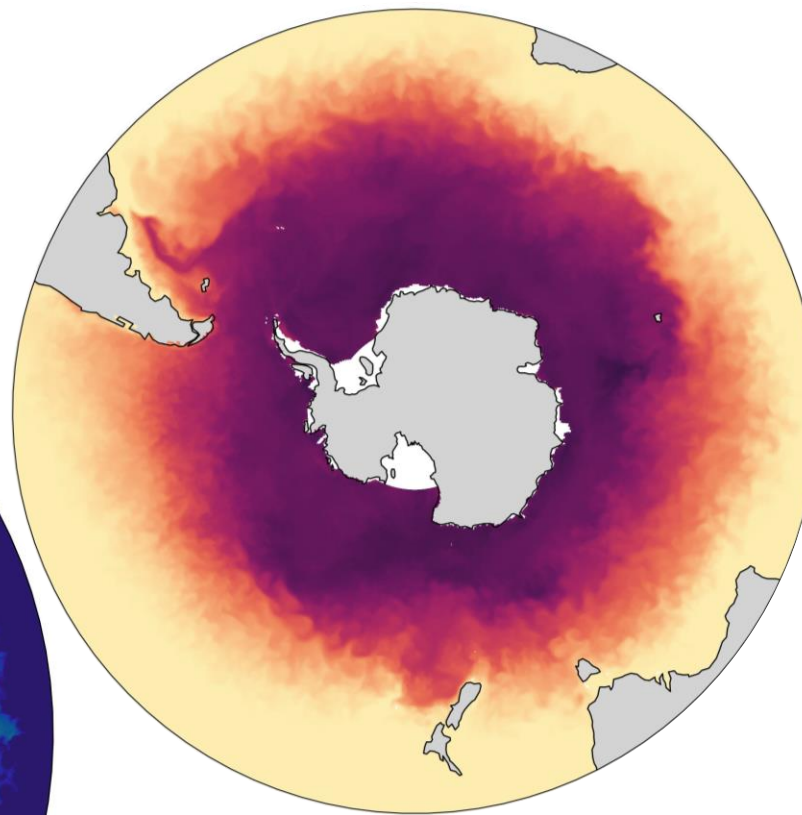
- High macronutrient concentrations contrast with Low chlorophyll concentrations
→ HNL zone (High Nutrient Low Chlorophyll)

→ Low chlorophyll a concentrations ($< 0.5 \text{ mg}\cdot\text{m}^{-3}$)

Iron hypothesis

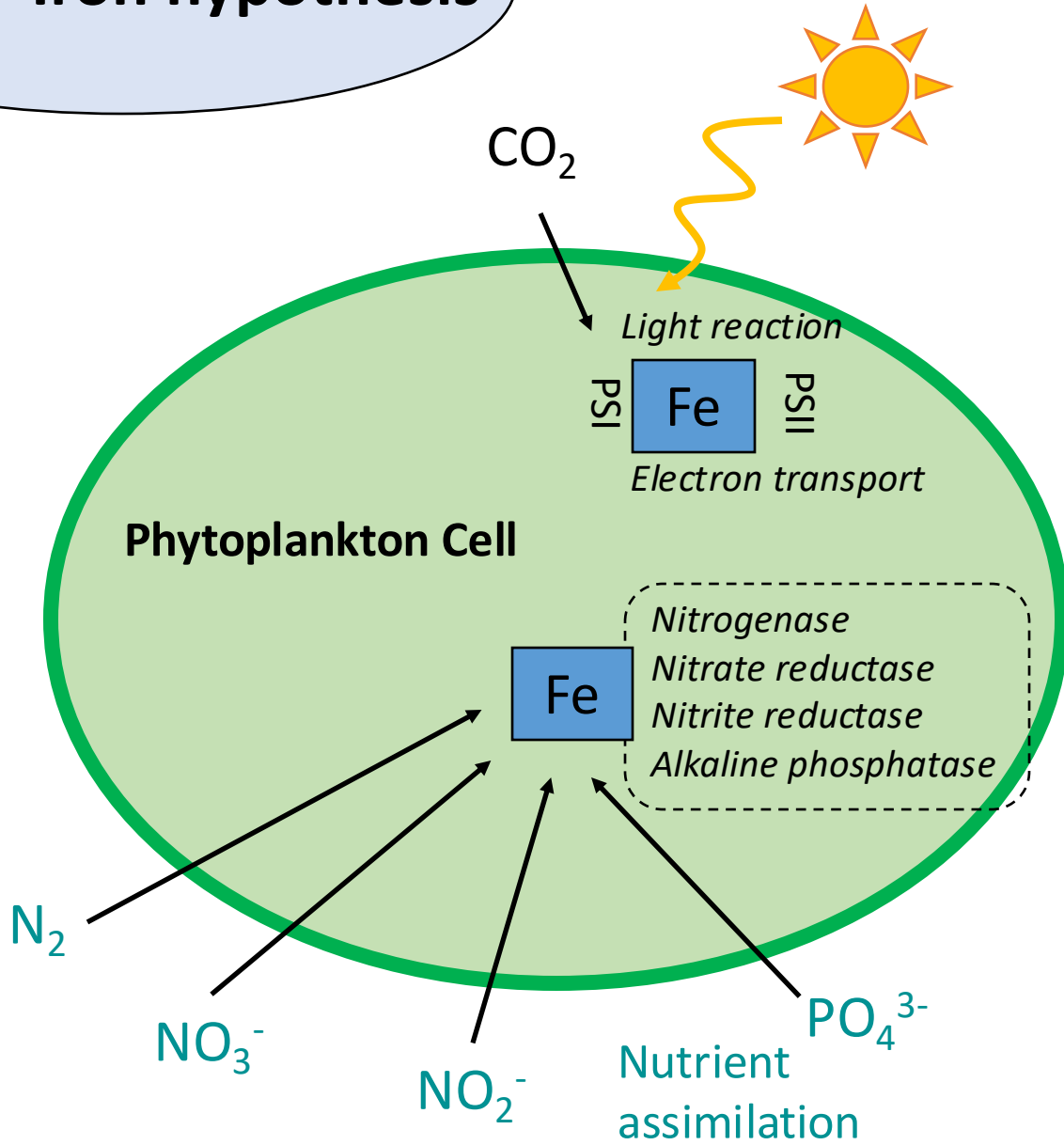


→ Low chlorophyll a concentrations ($< 0.5 \text{ mg}\cdot\text{m}^{-3}$)



- High macronutrient concentrations contrast with Low chlorophyll concentrations
→ HNLC zone (High Nutrient Low Chlorophyll)
- **Low concentrations of iron limit phytoplankton growth in the Southern Ocean (Martin, 1990)**

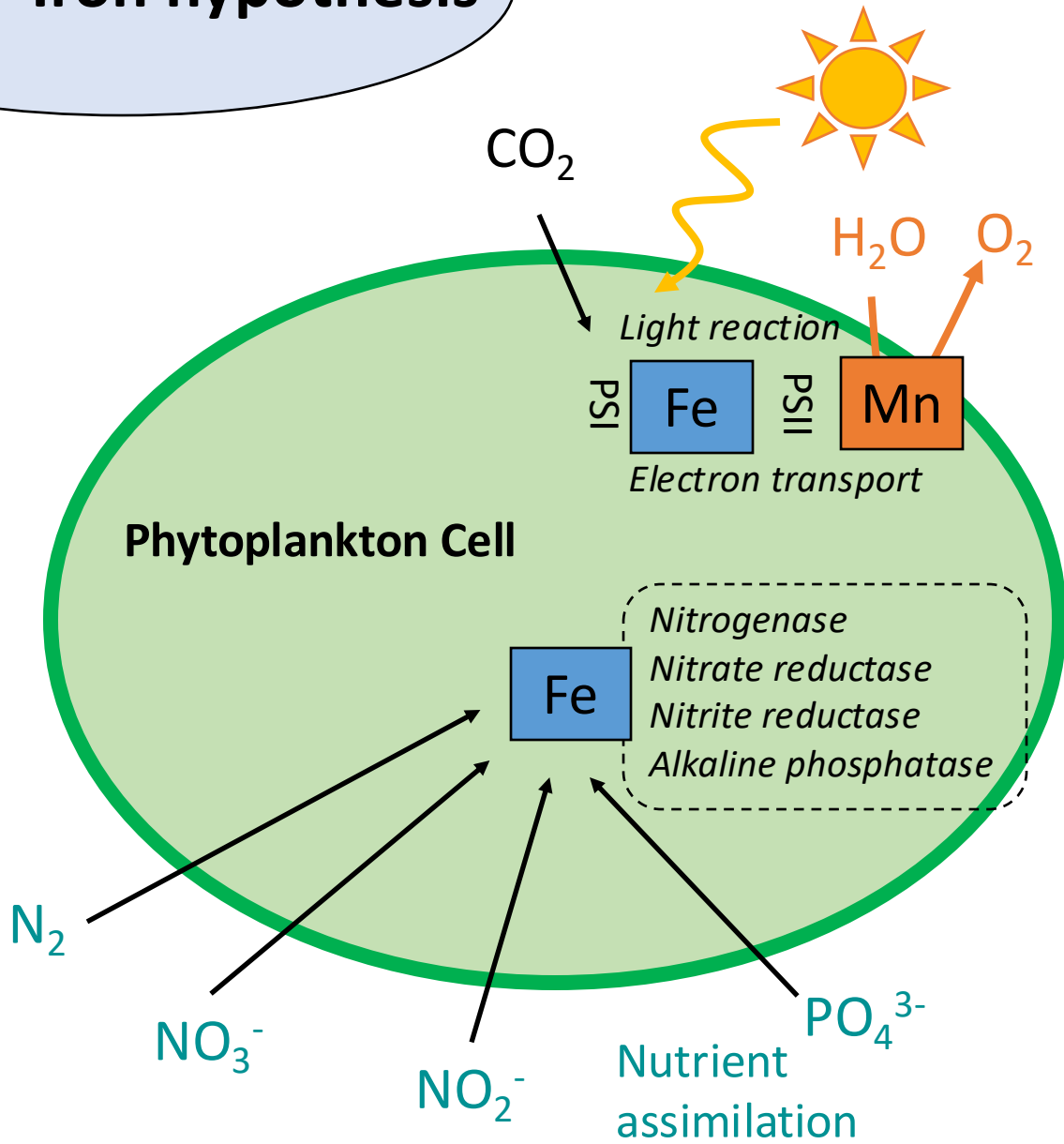
Iron hypothesis



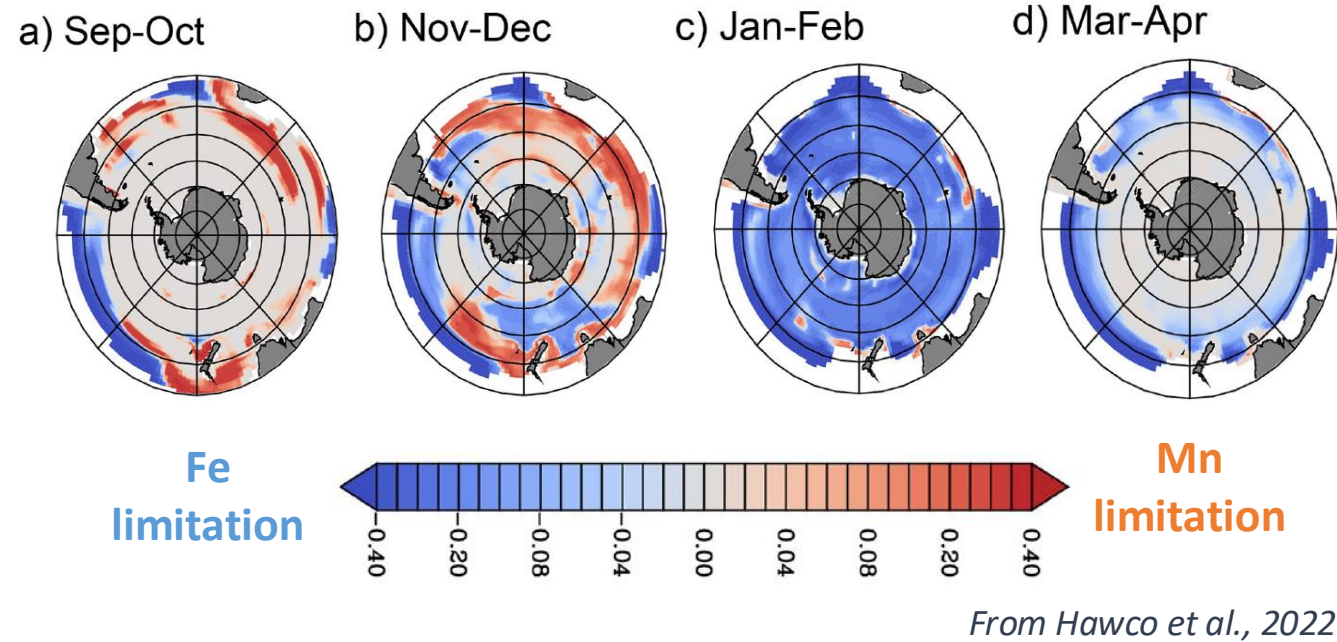
- **Iron:** Micronutrient present in very low concentrations in the open Southern Ocean. Essential for the metabolism of phytoplankton cells (*Twining and Baines, 2013*)

figure based on Lohan and Tagliabue, 2018

Iron hypothesis



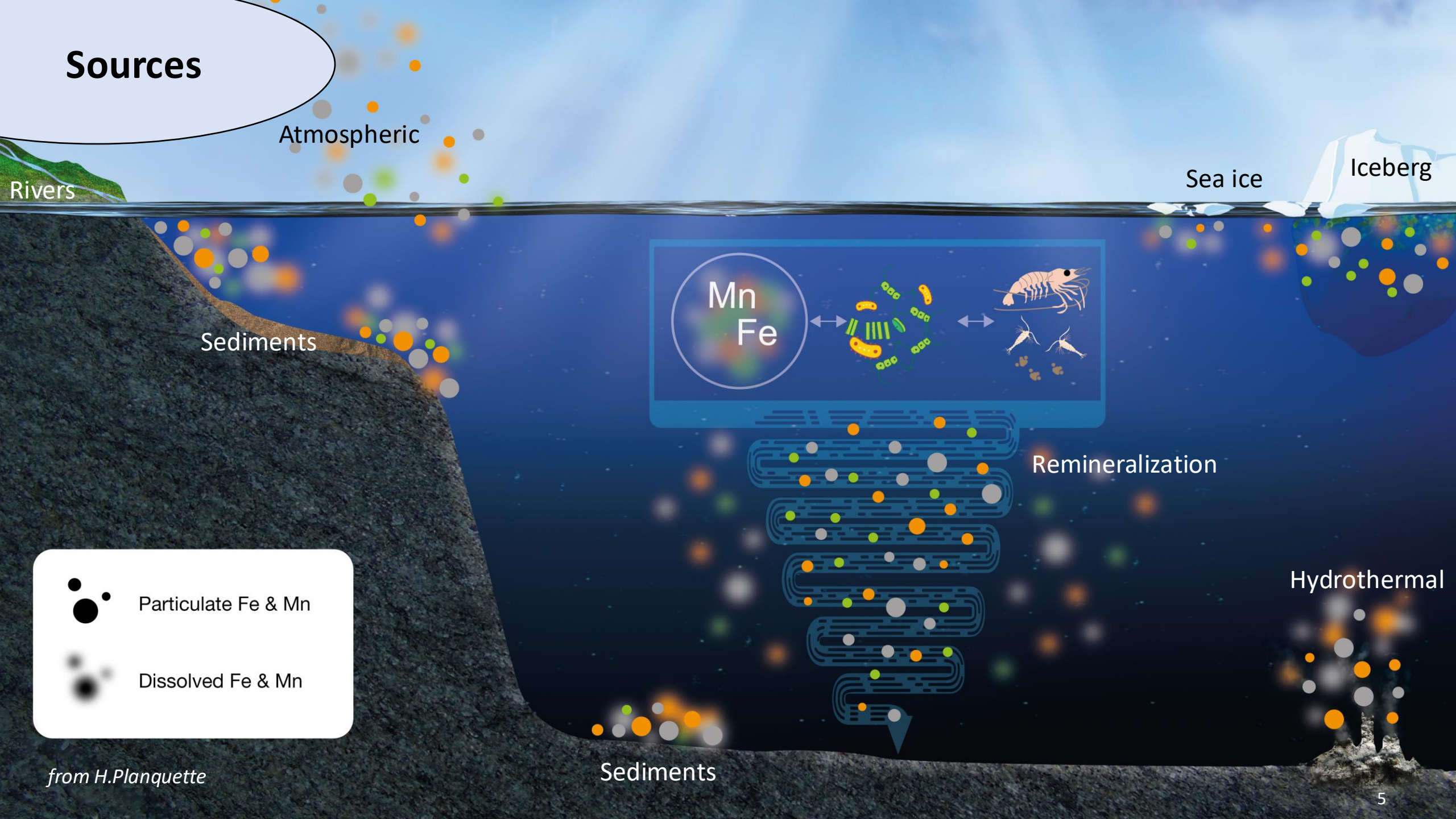
- Iron:** Micronutrient present in very low concentrations in the open Southern Ocean. Essential for the metabolism of phytoplankton cells (Twining and Baines, 2013)



- Manganese:** Essential for the metabolism of phytoplankton cells (Twining and Baines, 2013). Limiting or co-limiting nutrient in some areas (Browning and Moore, 2023; Hawco et al., 2022)

figure based on Lohan and Tagliabue, 2018

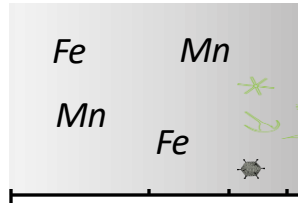
Sources



from H. Planquette

Physical speciation

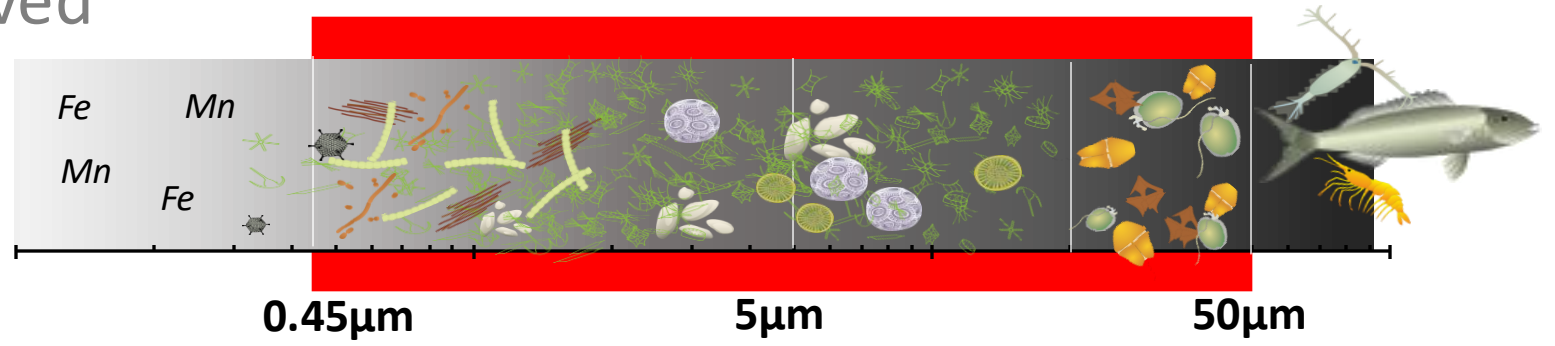
dissolved



Physical speciation

dissolved

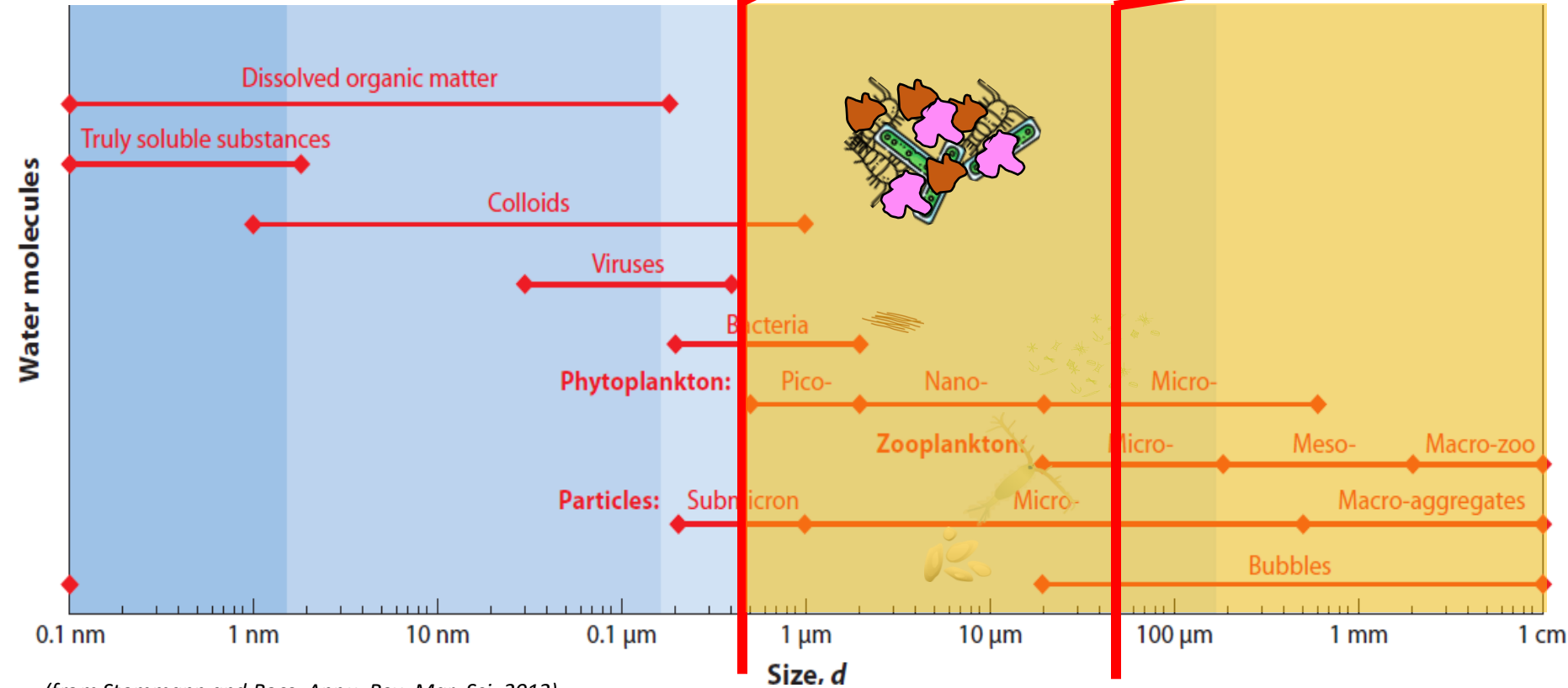
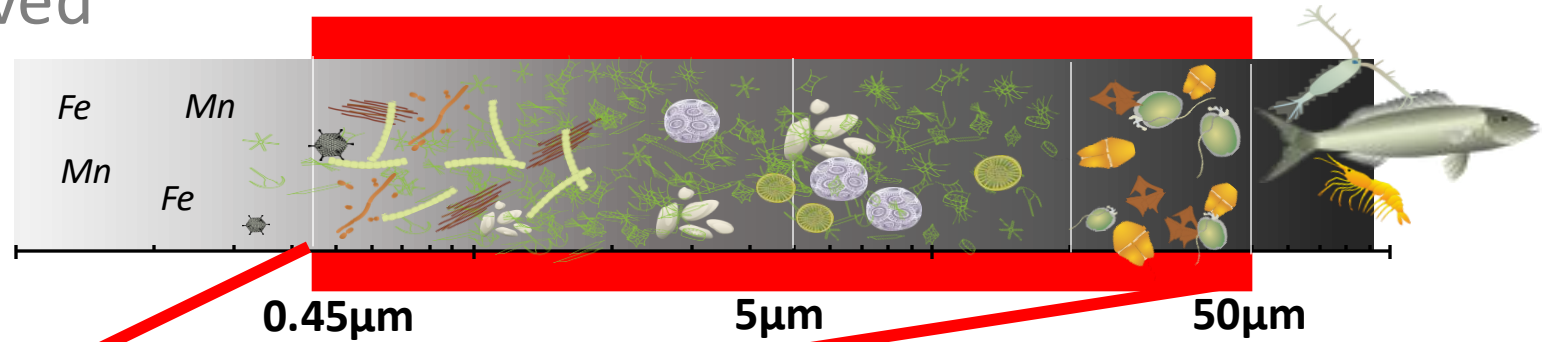
particulate



Physical speciation

dissolved

particulate



Fe and Mn can be associated with:

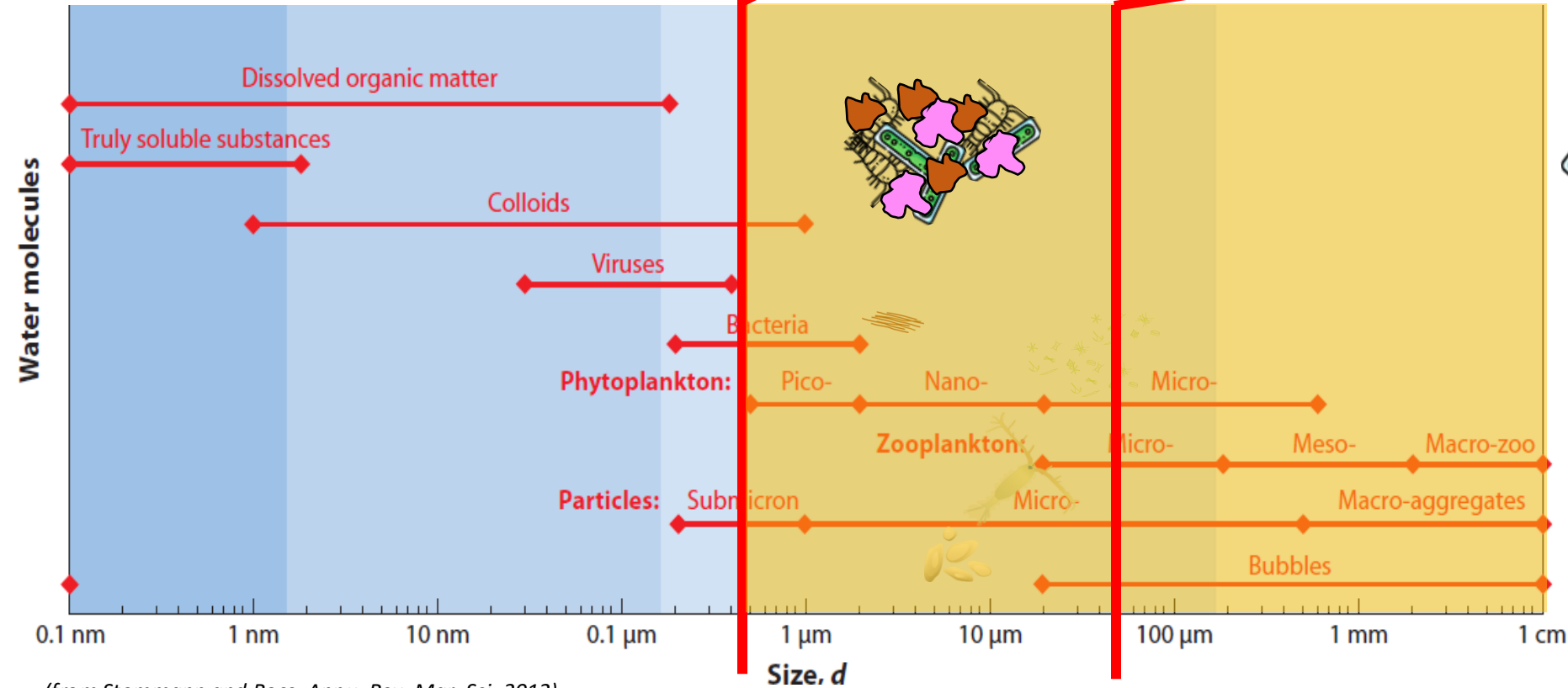
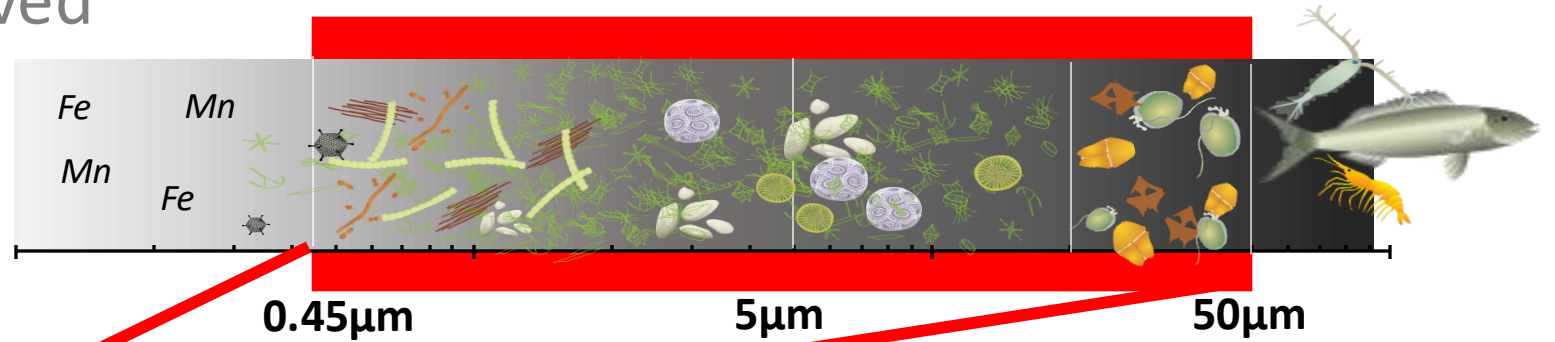
(from Stemann and Boss, *Annu. Rev. Mar. Sci.*, 2012)

0.45 μm

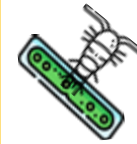
Physical speciation

dissolved

particulate



Fe and Mn can be associated with:



Biogenic particles

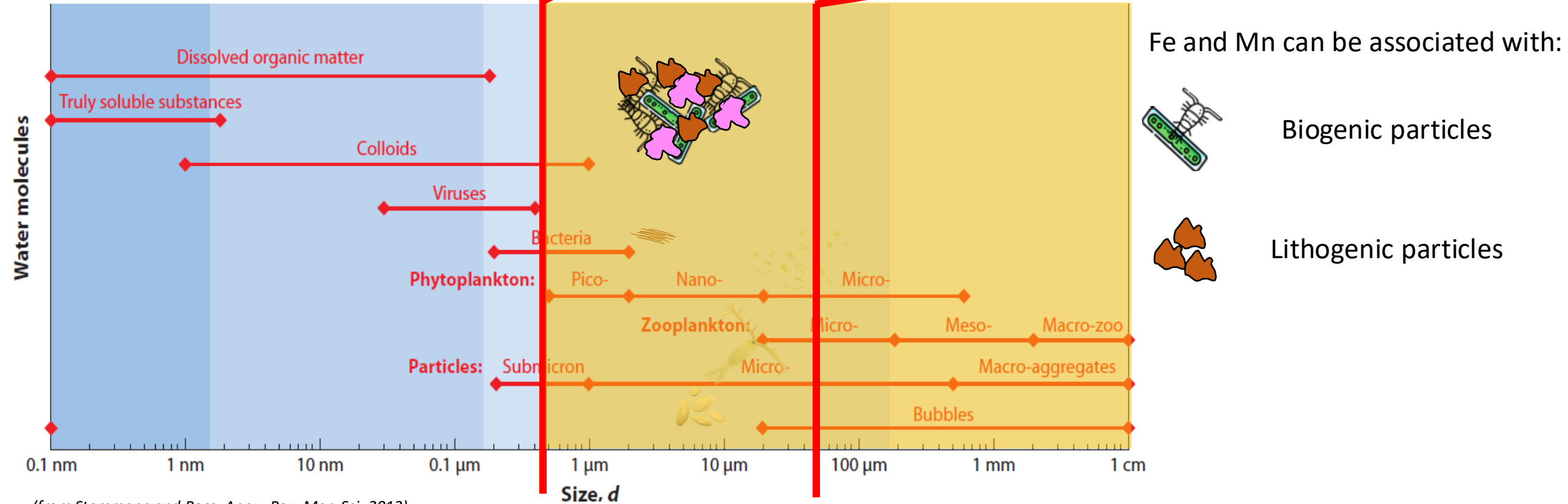
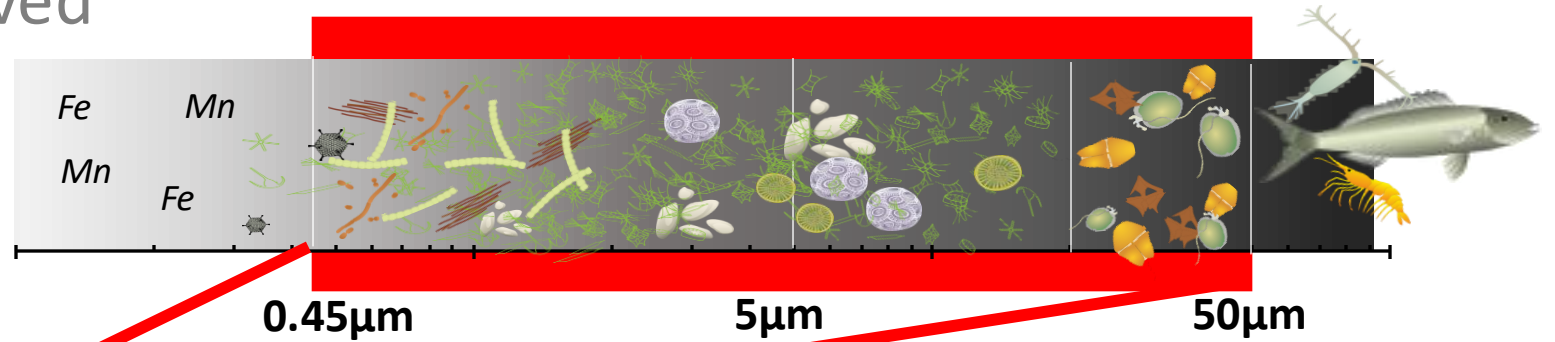
(from Stemann and Boss, *Annu. Rev. Mar. Sci.*, 2012)

0.45 μ m

Physical speciation

dissolved

particulate



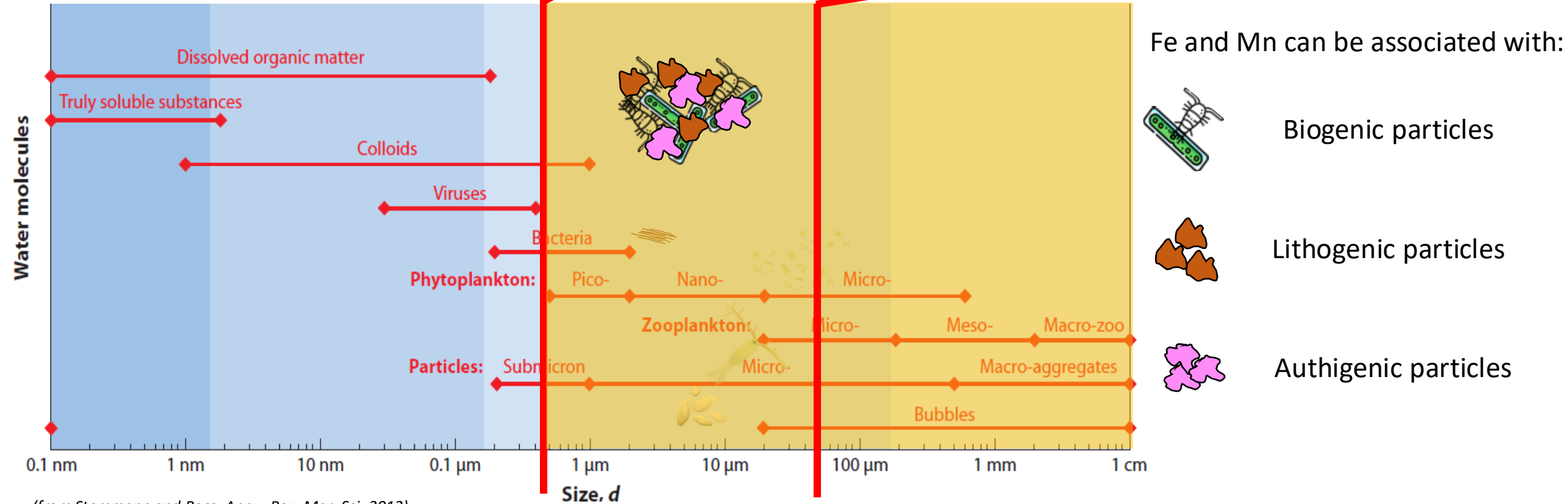
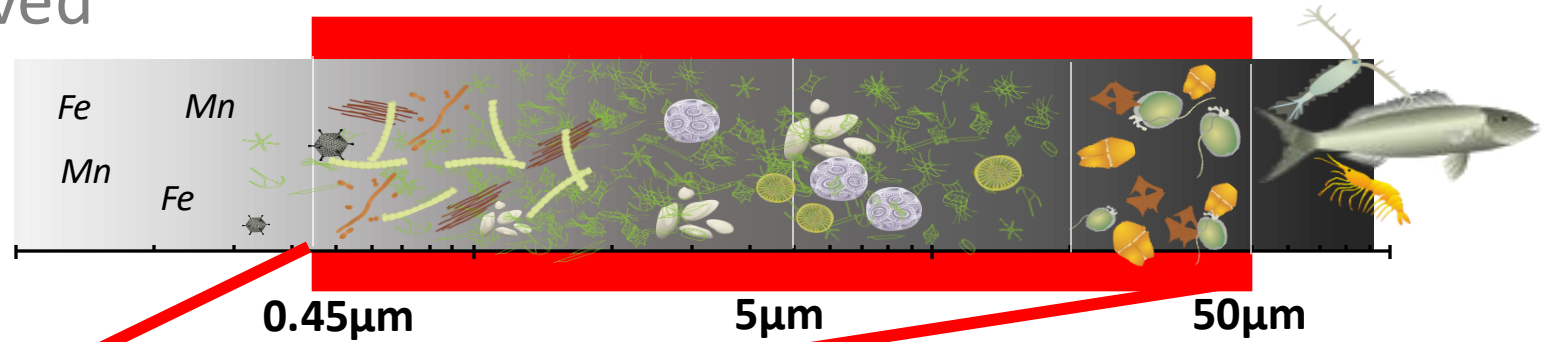
(from Stemann and Boss, *Annu. Rev. Mar. Sci.*, 2012)

0.45 μm

Physical speciation

dissolved

particulate



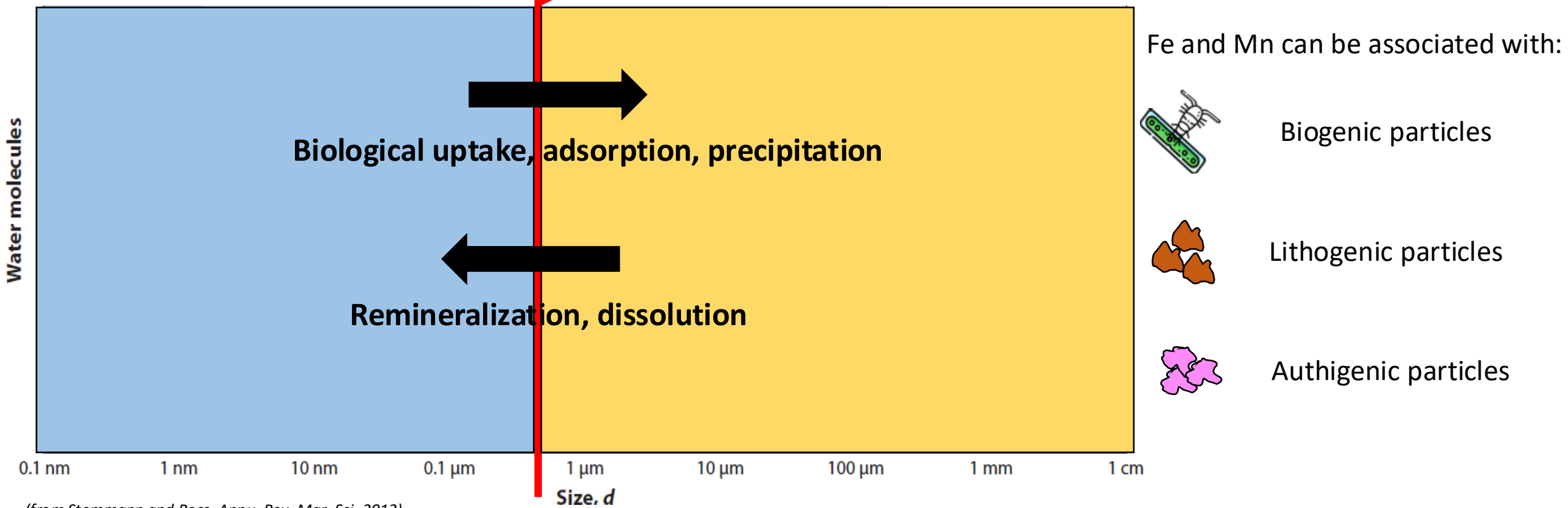
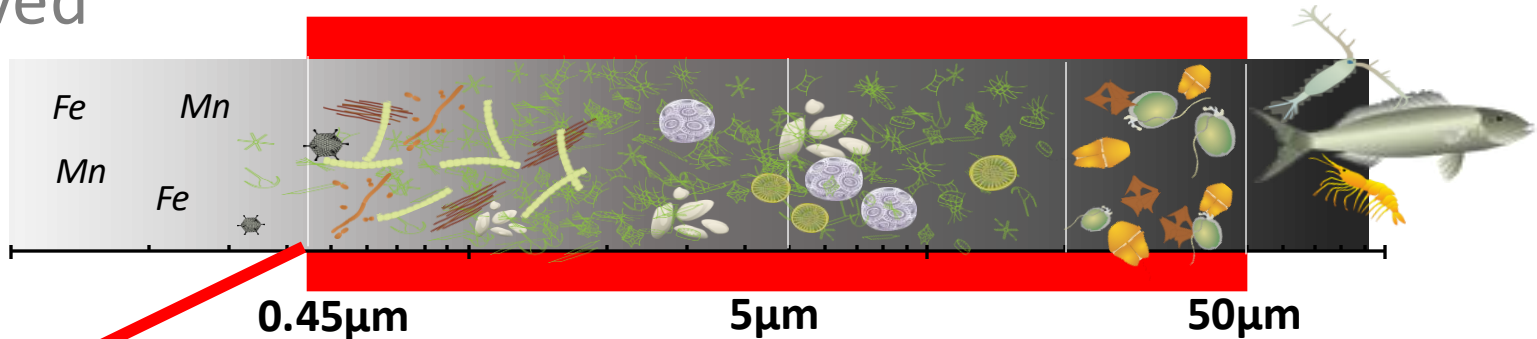
(from Stemann and Boss, *Annu. Rev. Mar. Sci.*, 2012)

0.45 μm

**Physical
speciation**

dissolved

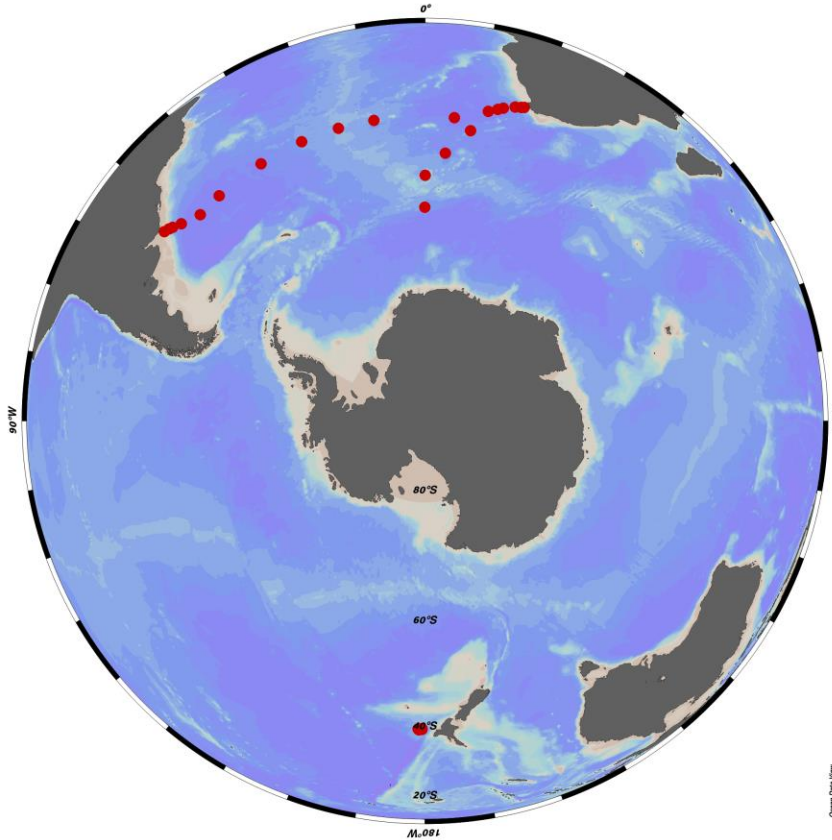
particulate



(from Stemmann and Boss, *Annu. Rev. Mar. Sci.*, 2012)

0.45 µm

Winter Data



*pFe and pMn data available
on the GEOTRACES IDP 2021 V2*

Marine Chemistry 346 (2022) 104161
Contents lists available at ScienceDirect
Marine Chemistry
Journal homepage: www.elsevier.com/locate/marchem

The role of the Dotson Ice Shelf and Circumpolar Deep Water as driver and source of dissolved and particulate iron and manganese in the Amundsen Sea polynya, Southern Ocean

Biogeosciences, 7, 455–468, 2010
www.biogeosciences.net/1551-0091/
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the Creative Commons Attribution 3.0 License.

An iron budget during the natural iron fertilisation experiment KEOPS (Kerguelen Islands, Southern Ocean)
E. Chaver^{1,2}, G. Sarthou^{1,2}, E. Bouverneville^{1,2}, S. Blain^{3,4}, and A. B. Poindexter⁵
¹Université Européenne de Bretagne, 35000 Rennes, France
²Université de Bretagne Occidentale, 29200 Plouzané, France
³Laboratoire Océanographie et Atmosphères Biogéochimie, 66050 Banyuls-sur-Mer, France
⁴Laboratoire de Chimie des Éléments de Trace, 13288 Marseille Cedex 9, France
⁵Department of Earth and Planetary Sciences, Rutgers University, 713 Frelinghuysen Road, Piscataway, NJ, USA

AGU PUBLICATIONS
Journal of Geophysical Research: Oceans
RESEARCH ARTICLE
10.1002/2017JC013068
Distributions, sources, and transformations of dissolved and particulate iron on the Ross Sea continental shelf during summer
Dennis J. McGillicuddy Jr.¹, and Peter N. Sedwick¹
¹Department of Earth and Atmospheric Sciences, Skidaway Institute of Oceanography, 1406 Bay Pines Drive, Marietta, Georgia, USA
Chris M. Marsay², and
²Department of Earth and Atmospheric Sciences, Skidaway Institute of Oceanography, 1406 Bay Pines Drive, Marietta, Georgia, USA

Marine Chemistry
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Particulate iron delivery to the water column of the Amundsen Sea polynya
Hélène Planquette^{a,b}, Robert M. Sherrell^c
^aInstitute of Marine and Coastal Sciences, Rutgers University, 713 Frelinghuysen Road, Piscataway, NJ, USA
^bDepartment of Earth and Planetary Sciences, Rutgers University, 713 Frelinghuysen Road, Piscataway, NJ, USA
^cInstitute of Arctic and Alpine Research, University of Colorado Boulder, Boulder, CO, USA

Marine Chemistry
Contents lists available at ScienceDirect
Journal homepage: www.elsevier.com/locate/marchem

Controls on dissolved and particulate iron distributions in surface waters of the Western Antarctic Peninsula shelf
Anber L. Annett^a, Jessica N. Fitzsimmons^{a,b}, Marie J.M. Séguret^{a,c}, Maria Lagerstrom^a, Michael P. Meredith^a, Oscar Schofield^a, Robert M. Sherrell^{a,c}
^aDepartment of Marine and Coastal Sciences, Rutgers University, Piscataway, NJ, USA
^bBritish Antarctic Survey, Cambridge, UK
^cDepartment of Earth and Planetary Sciences, Rutgers University, Piscataway, NJ, USA

Deep-Sea Research II
Contents lists available at ScienceDirect
Journal homepage: www.elsevier.com/locate/der2

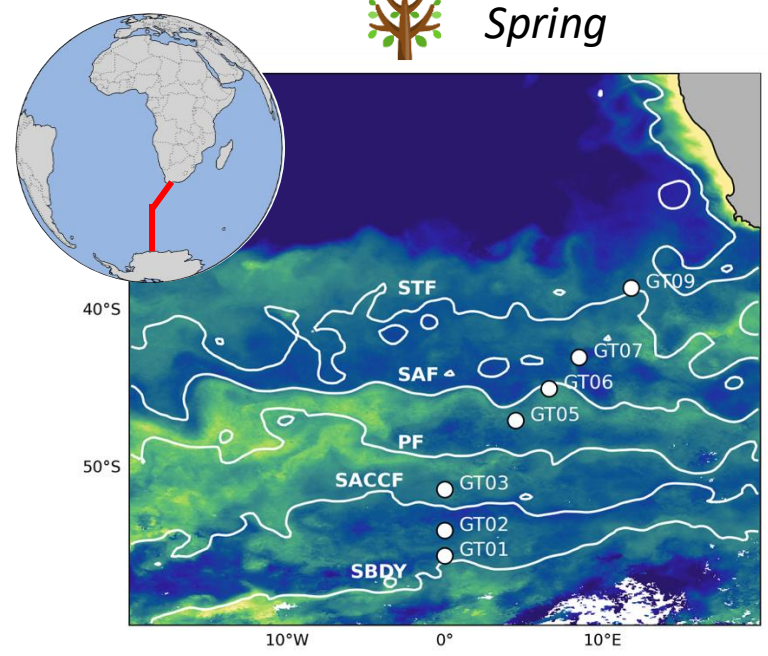
Iron budgets for three distinct biogeochemical sites around the Kerguelen Archipelago (Southern Ocean) during the natural fertilisation study, KEOPS-2
A. R. Bowie^{1,2,3}, P. van der Merwe¹, F. Quéroué^{1,2,3}, T. Trull^{1,4}, M. E. F. Chaver^{3,5}, A. T. Townsend⁶, I. Obernosterer⁵, T. M. Martin⁷
¹Antarctic Climate and Ecosystems Centre, University of Tasmania, Hobart, Tasmania, Australia
²Department of Earth and Atmospheric Sciences, Skidaway Institute of Oceanography, Marietta, Georgia, USA
³Department of Earth and Planetary Sciences, Rutgers University, Piscataway, NJ, USA
⁴Department of Earth and Atmospheric Sciences, Skidaway Institute of Oceanography, Marietta, Georgia, USA
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⁶Department of Earth and Atmospheric Sciences, Skidaway Institute of Oceanography, Marietta, Georgia, USA
⁷Department of Earth and Atmospheric Sciences, Skidaway Institute of Oceanography, Marietta, Georgia, USA

Distributions of dissolved and particulate iron in the sub-Antarctic and Polar Frontal Southern Ocean (Australian sector)
Delphine Lannuzel^{a,b,*}, Andrew R. Bowie^a, Tomas Remenyi^a, Phoebe Lam^c, Ashley Townsend^d, Enitan Ibasanni^e, Edward Butler^f, Thibaut Wagener^g, Véronique Schoemann^h
^aAntarctic Climate & Ecosystems CRC, University of Tasmania, Private Bag 80, Hobart, Tasmania 7001, Australia
^bInstitute for Marine and Antarctic Studies, University of Tasmania, Private Bag 129, Hobart, Tasmania 7001, Australia
^cWoods Hole Oceanographic Institution, Woods Hole, MA 02543, USA
^dCentral Science Laboratory, University of Otago, Dunedin, New Zealand
^eCentre for Australian Weather and Climate Research, GPO Box 1538, Hobart, Tasmania 7001, Australia
^fCentre for Australian Weather and Climate Research, CNRS UMR 7093 Caserne Nicolas, Quai de la Darse, 06238 Villefranche sur Mer, France
^gLaboratoire d'Océanographie et Atmosphères Biogéochimie, Université de Bordeaux, Campus de la Plaine, CP221, 66 du Tromphe, B-1050 Brussels, Belgium
^hEcologie des Systèmes Aquatiques (ESA), Université Libre de Bruxelles, Faculté des Sciences, Campus de la Plaine, CP221, 66 du Tromphe, B-1050 Brussels, Belgium

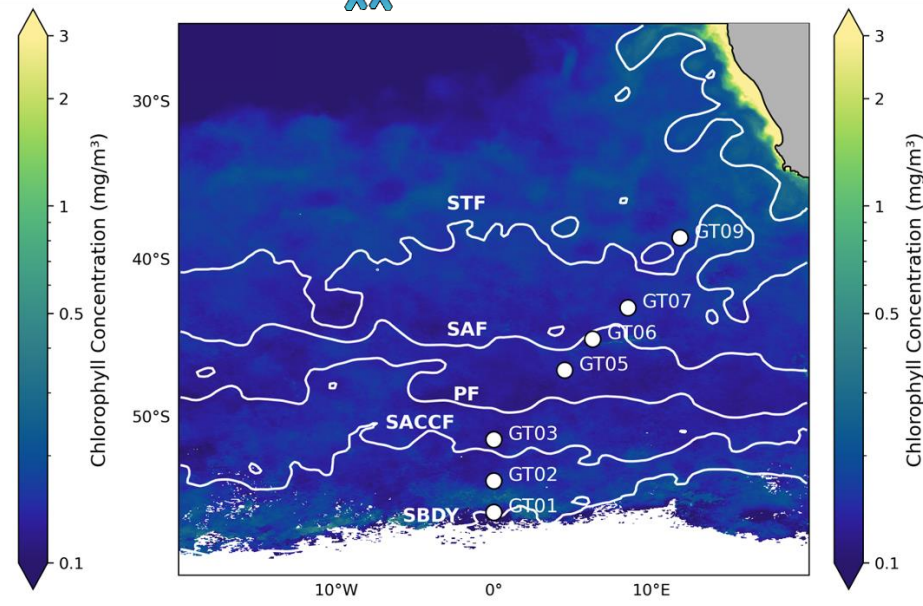
➔ Particulate Fe and Mn data in the Southern Ocean are scarce with no winter data

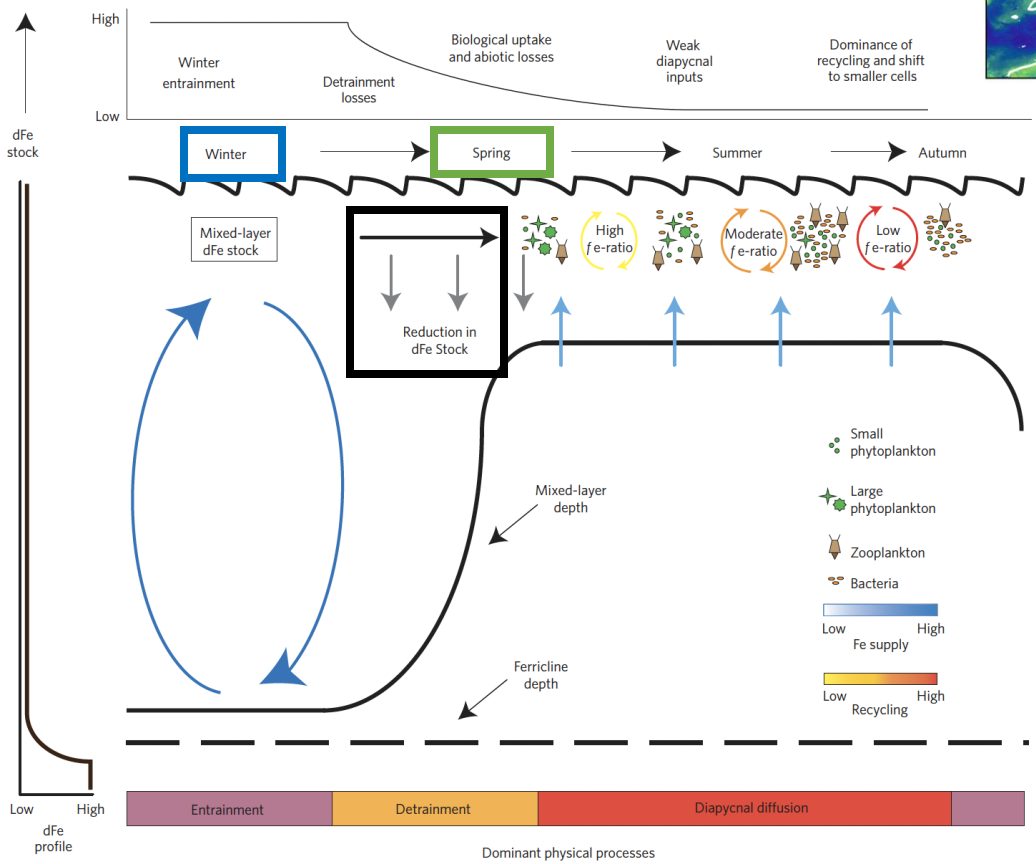
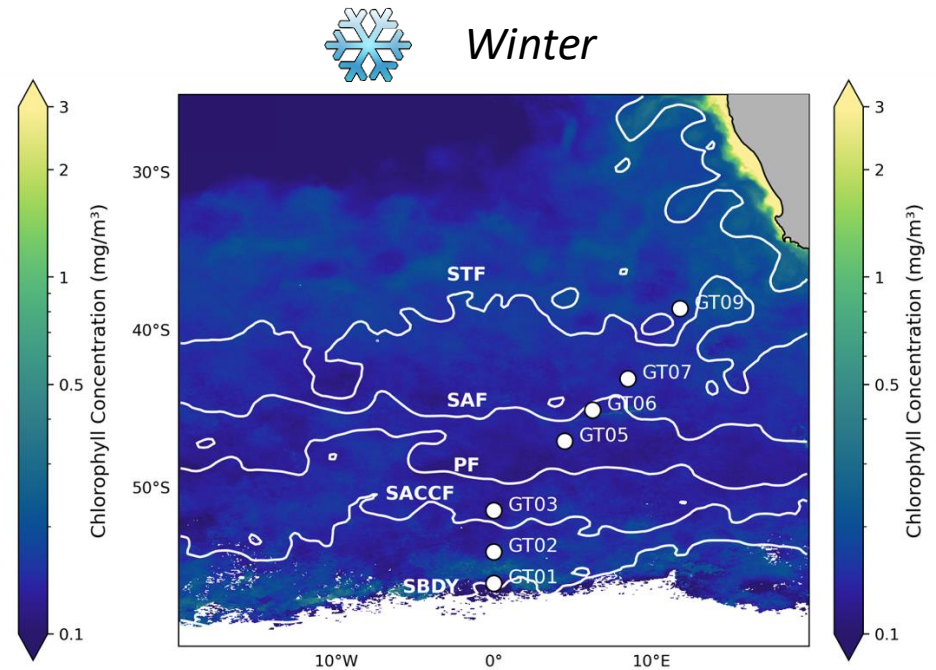
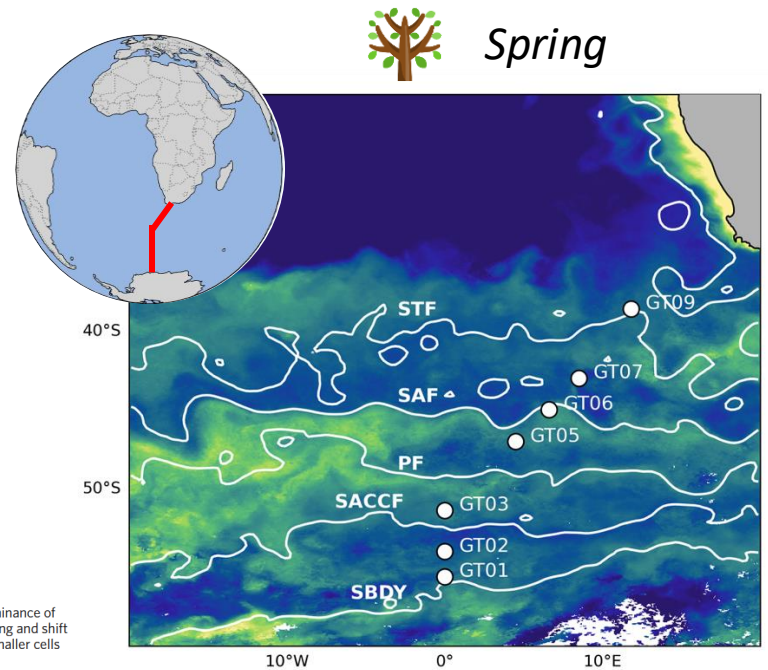


 *Spring*



 *Winter*

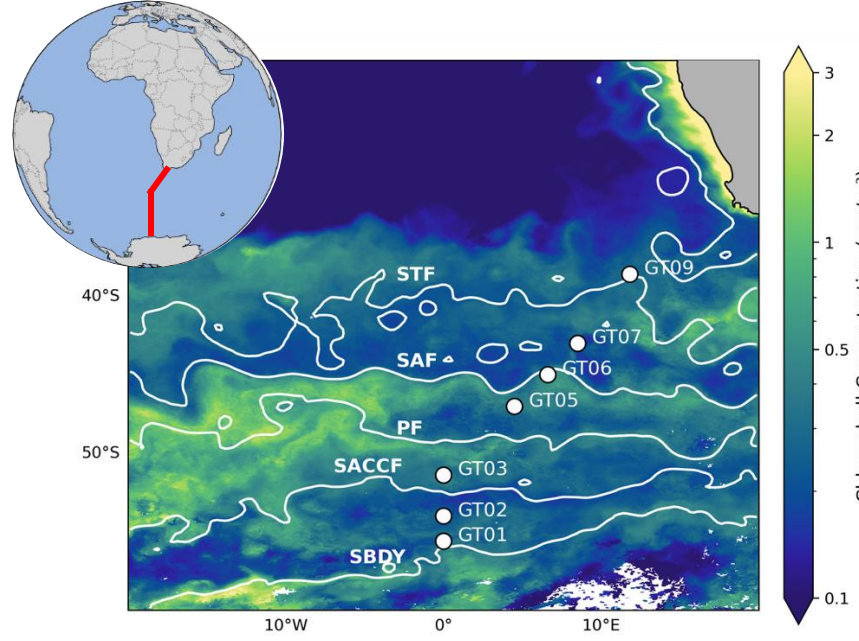




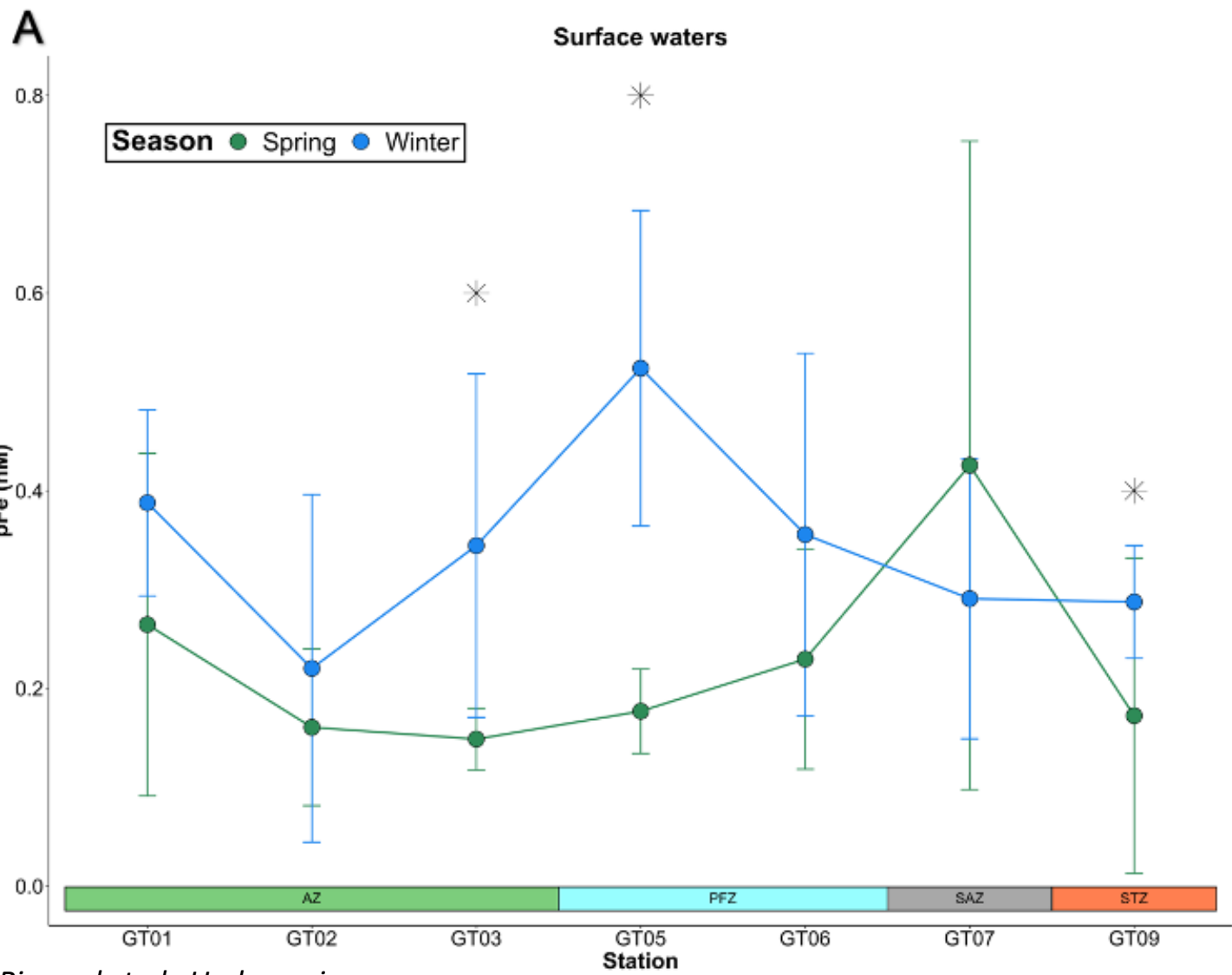
Hypothesis:

The loss of dFe in surface should contribute to more pFe in *spring* compared to *winter* due to biological uptake

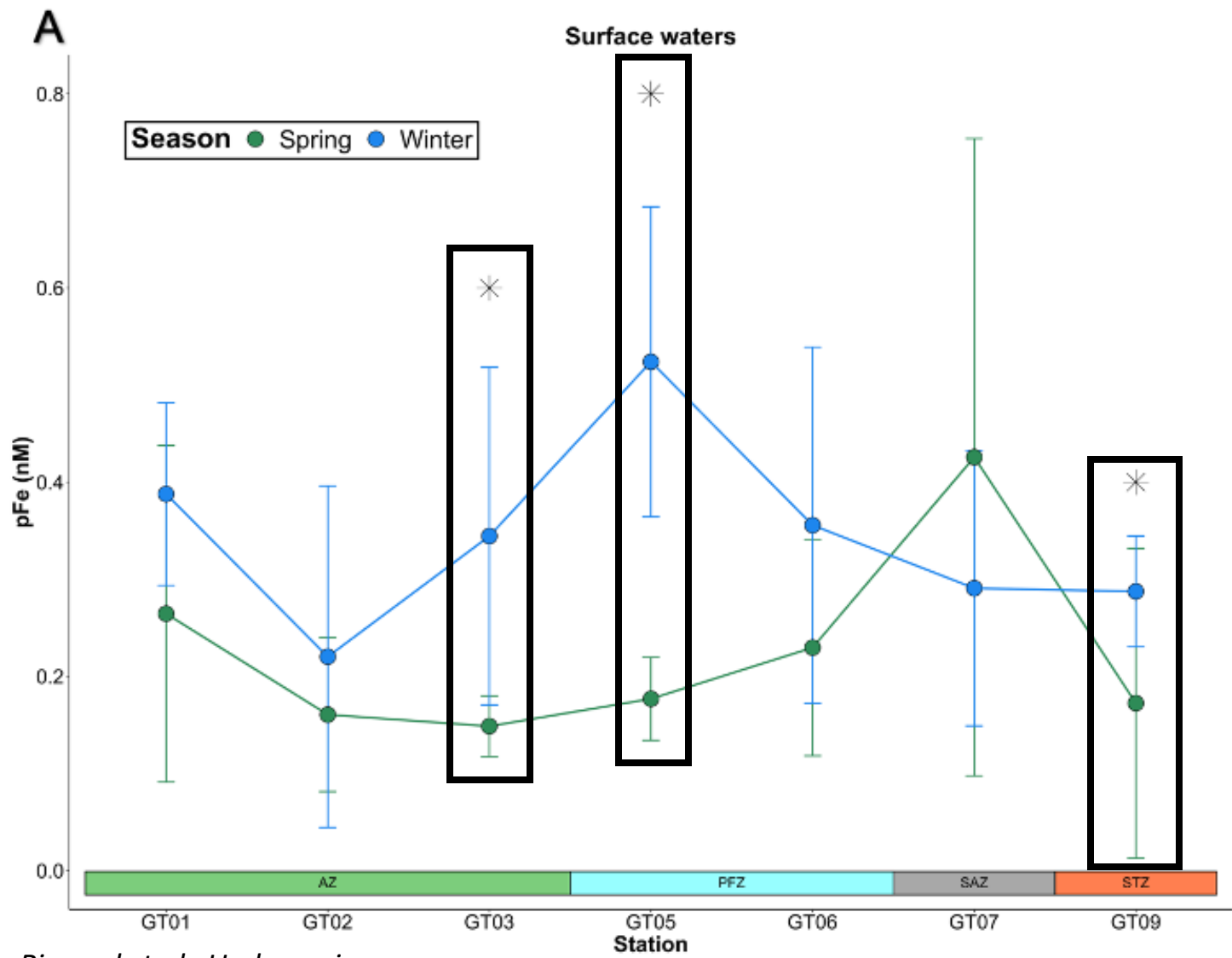
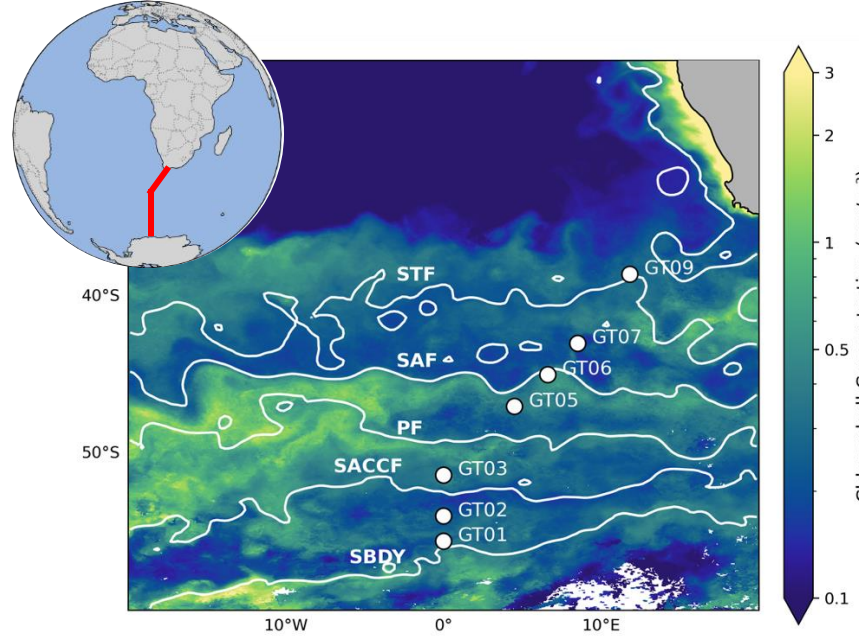
Total pFe



- pFe content in surface waters of each station for both seasons



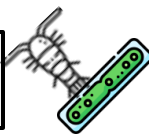
Total pFe



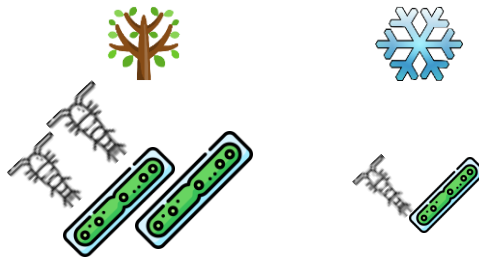
- pFe content in surface waters of each station for both seasons
- **mean pFe in winter** > **mean pFe in spring** (significantly different p-value < 0.05)
- Opposite result to what was expected

→ Origin of these differences ?

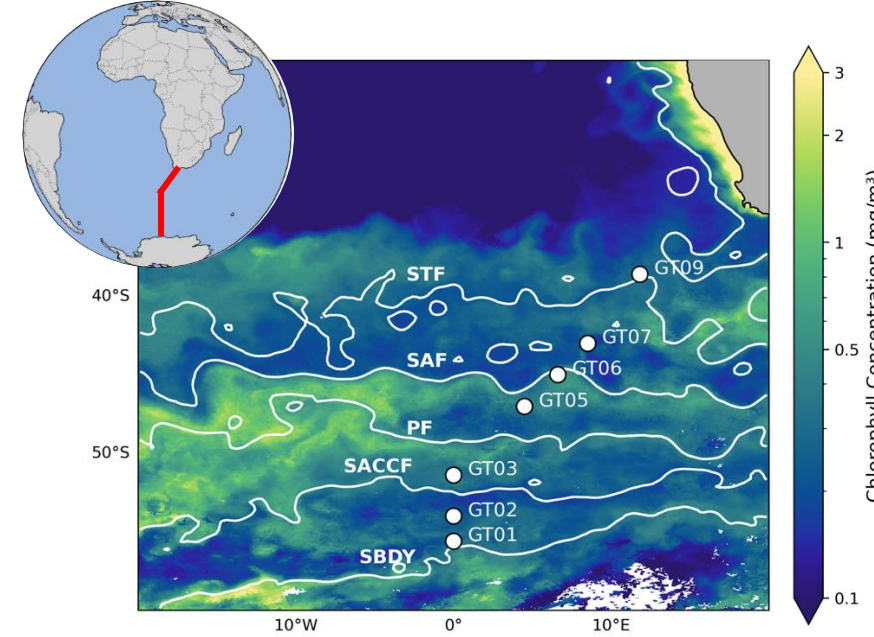
Biogenic pFe



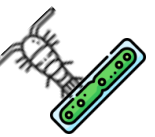
- Minor contributor to total pFe (< 20%)



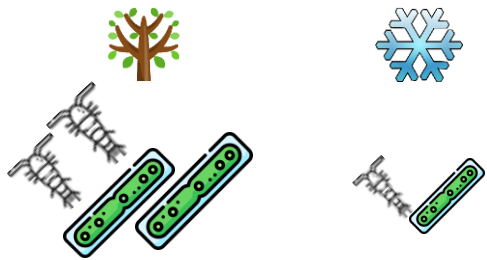
→ Biological processes do not drive seasonal variations of surface pFe



Biogenic pFe



- Minor contributor to total pFe (< 20%)

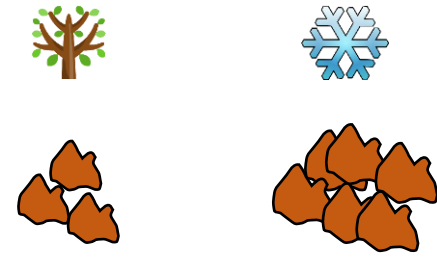


→ Biological processes do not drive seasonal variations of surface pFe

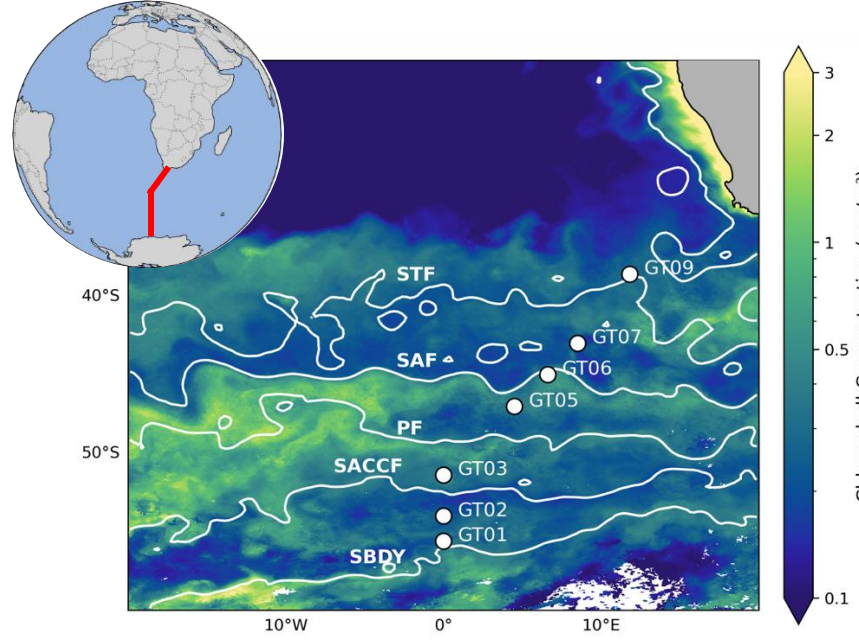
Lithogenic pFe



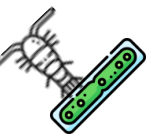
- Significant contributor to total pFe (> 20%)
- Variations followed those of total pFe



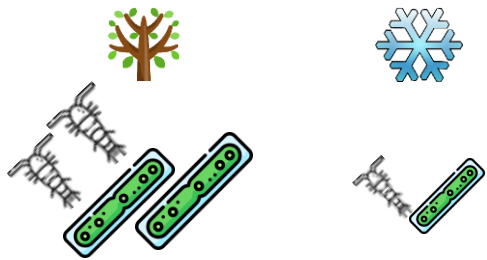
→ External episodic inputs of lithogenic particles drive seasonal variations of surface pFe



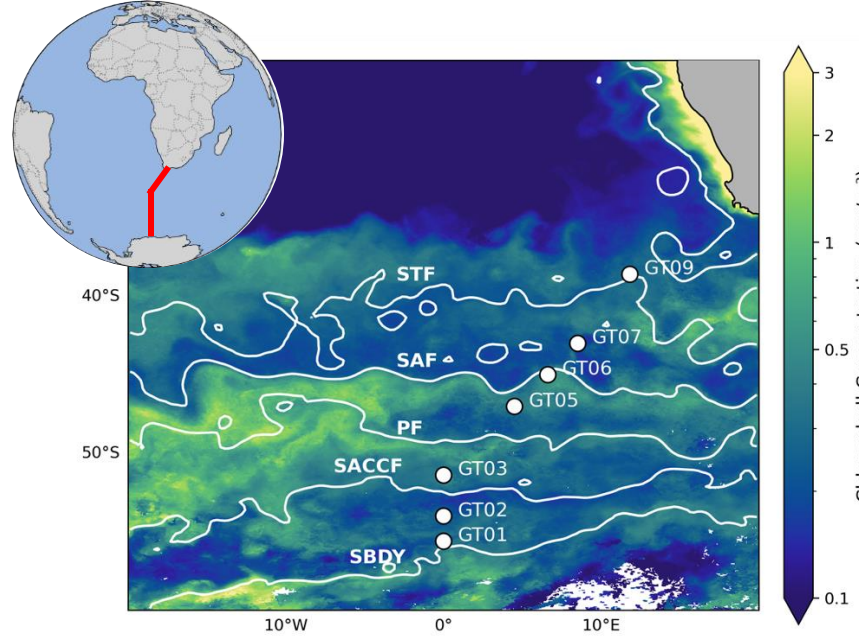
Biogenic pFe



- Minor contributor to total pFe (< 20%)



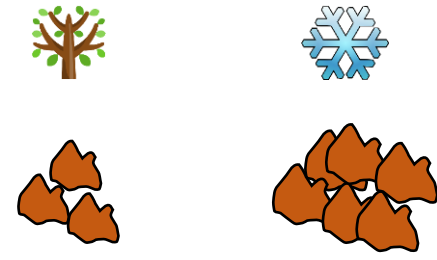
→ Biological processes do not drive seasonal variations of surface pFe



Lithogenic pFe



- Significant contributor to total pFe (> 20%)
- Variations followed those of total pFe



→ External episodic inputs of lithogenic particles drive seasonal variations of surface pFe

- STZ: Winter dust pFe > Spring dust pFe (*Kangueehi, 2021*)
- PFZ: Stronger winter ACC inputs (*Hatta et al., 2013; Measures et al., 2013*)
- AZ: Dust deposition from Patagonia (*Erickson III et al., 2003; Mahowald et al., 2006; Meskhidze et al., 2007*)

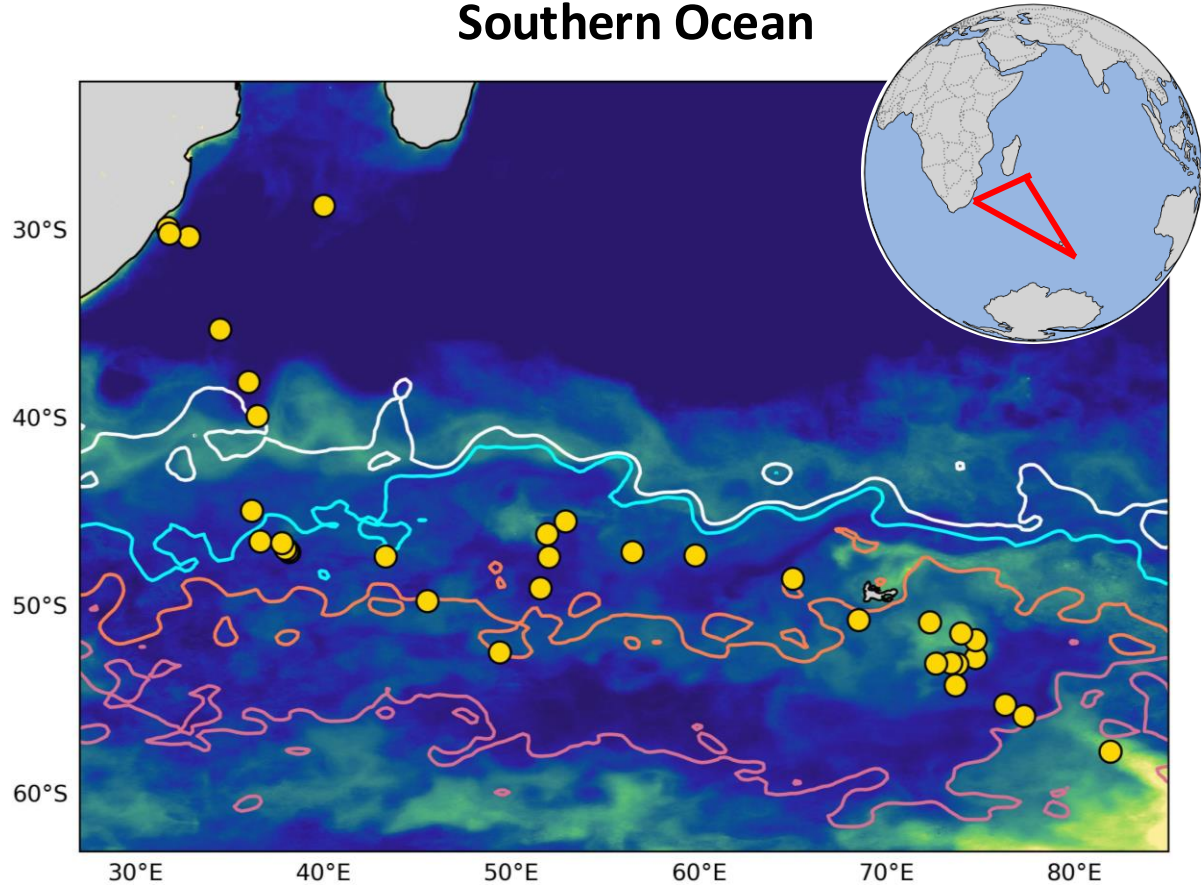
Other polar projects

SWINGS



- *PIs: Catherine Jeandel and H el ene Planquette*
- *January – March 2021*
- *Ship: Marion Dufresne II*

➔ GEOTRACES section in the South Indian and Southern Ocean



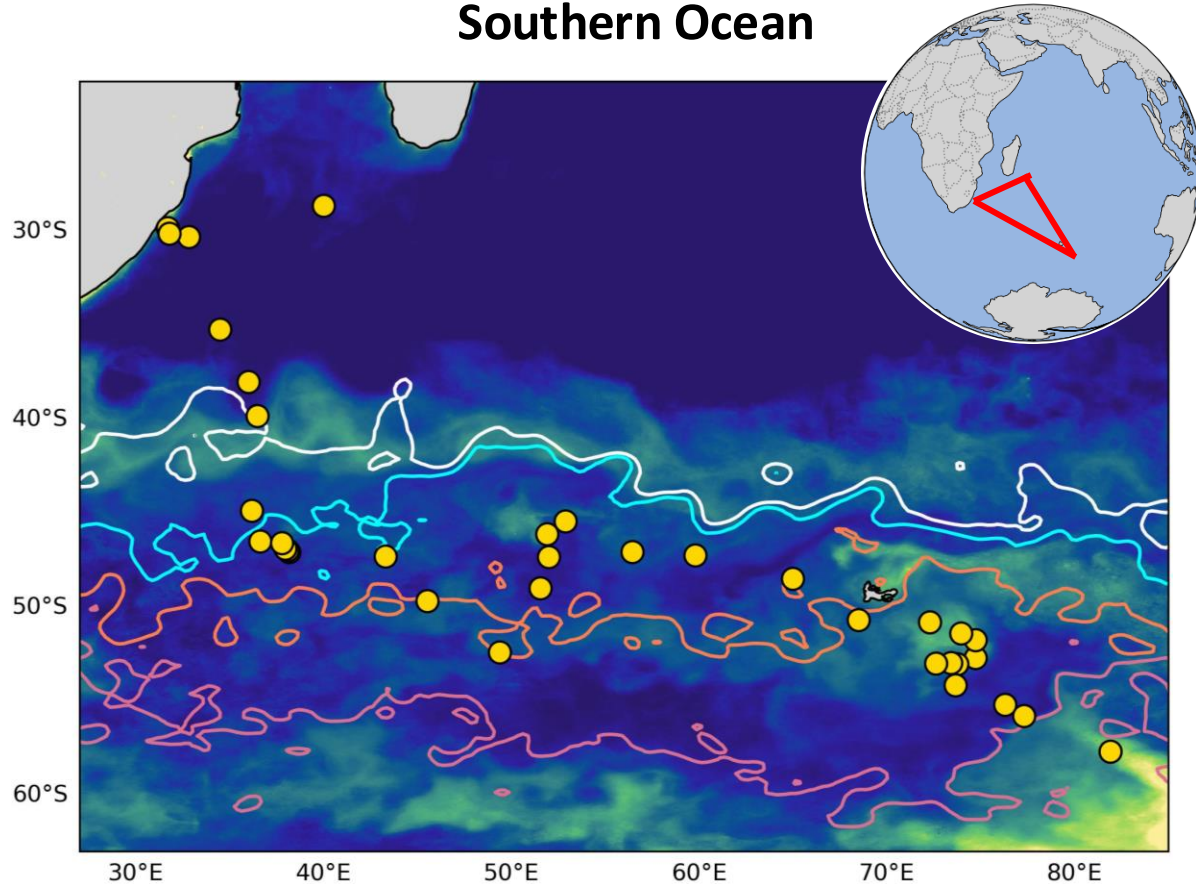
Other polar projects

SWINGS



- *PIs: Catherine Jeandel and H el ene Planquette*
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➔ **GEOTRACES section in the South Indian and Southern Ocean**



MARGOCEAN



- *PIs: St ephane Blain*
- *January – March 2024*
- *Ship: Marion Dufresne II*

➔ **Transport of matter from glacial origin to the open ocean (Kerguelen)**



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