Iron Model Intercomparison Project

SCOR WG 151

Co-chairs: Alessandro Tagliabue (UK) and Stephanie Dutkiewicz (USA)

Other Full Members: Tatiana Ilyina (Germany), Kazuhiro Misumi (Japan), Fanny Monteiro (UK), J. Keith Moore (USA), Yeala Shaked (Israel), Marcello Vichi (South Africa), Christoph Völker (Germany), Mustafa Yücel (Turkey)

Associate Members: Olivier Aumont (France), Alex Baker (UK), Philip Boyd (Australia), Fei Chai (China-Beijing), Peter Croot (Ireland), Christel Hassler (Switzerland), Eun Young Kwon (Korea), Jun Nishioka (Japan), Maite Maldonado (Canada), Mark Moore (UK), Andy Ridgwell (USA), Benjamin Twining (USA)

Goals and context

- FeMIP is concerned with the representation of the ocean iron cycle within global ocean models
- These are often coupled to earth system models to make climate change projections or address questions of contemporary ocean functioning, biogeochemical cycling and ecosystem dynamics
- There are key challenges around external inputs and internal cycling, especially around the feedbacks with biology
- WG goal was to deliver new datasets, new tools and new understanding and constraints

Terms of Reference

1. How complex does the iron cycle need to be in global models?
2. How can we assess model skill in an undersampled system and benchmark progress?
3. Intercompare sensitivity to dust deposition and constrain ocean residence times in global models
4. Review the role of biological activity in driving the iron cycle

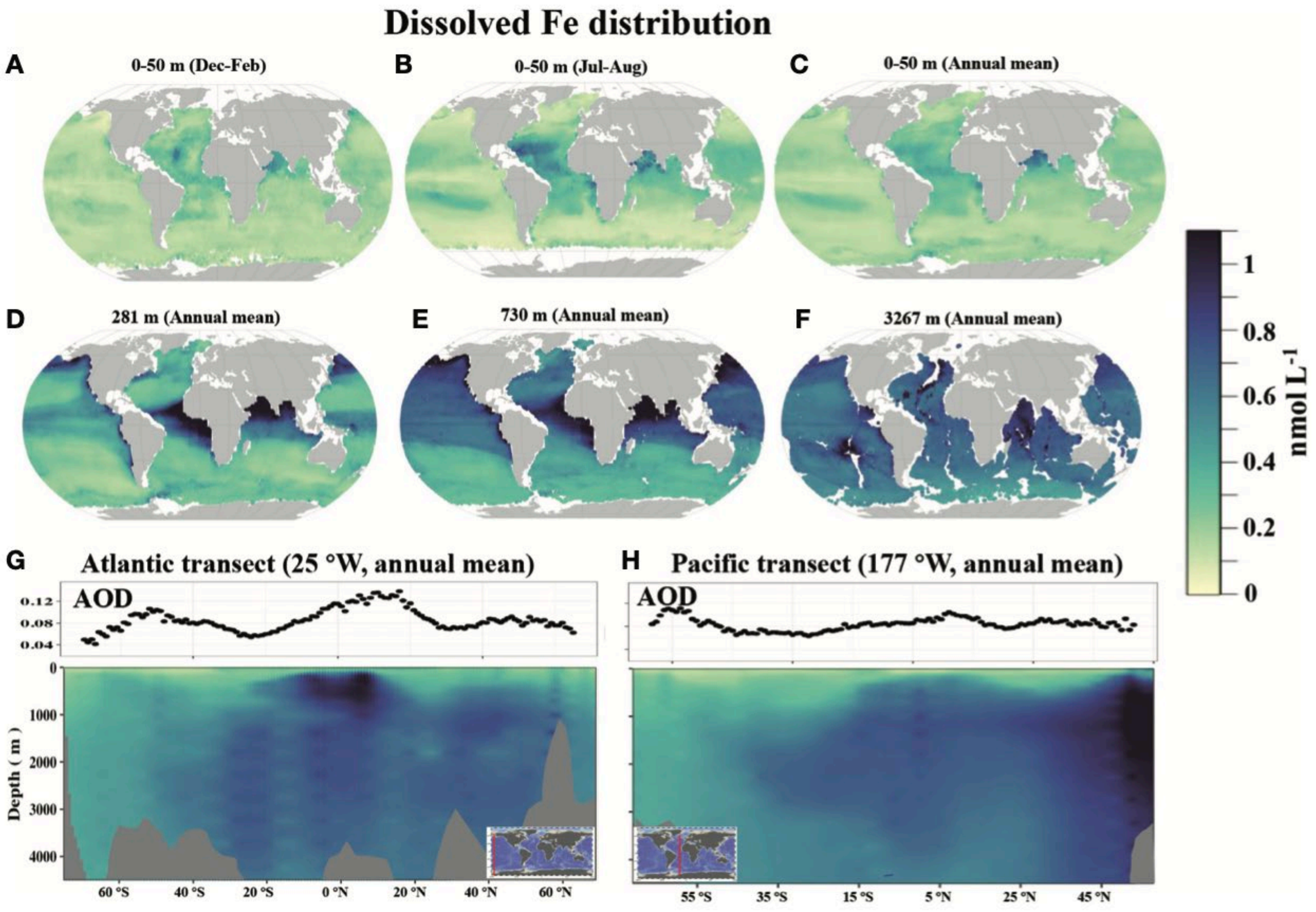
Outputs – new datasets

Data-Driven Modeling of Dissolved Iron in the Global Ocean

*Yibin Huang[1], Alessandro Tagliabue[2] and Nicolas Cassar[1,3]**

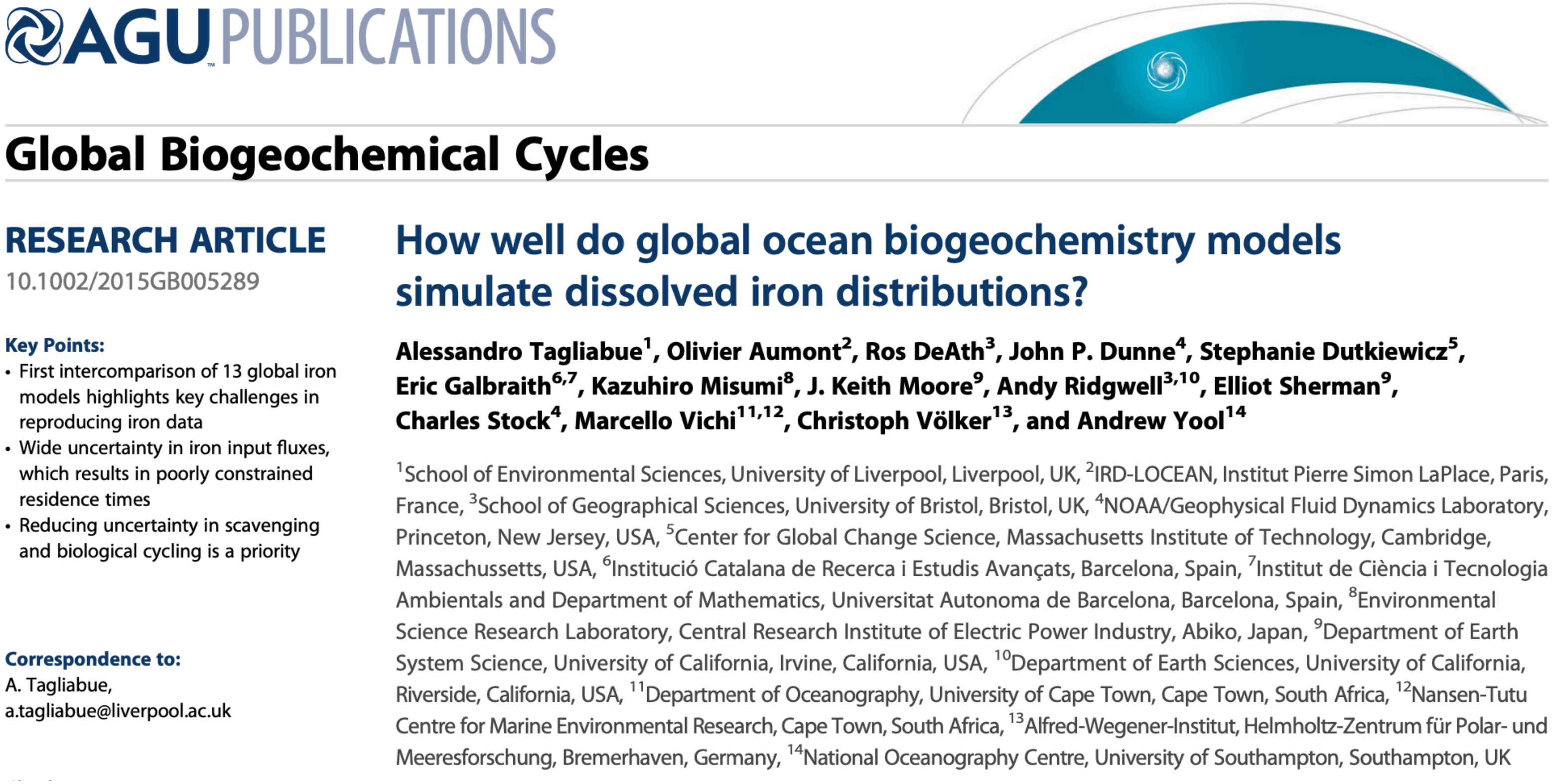
[1] Division of Earth and Climate Sciences, Nicholas School of the Environment, Duke University, Durham, United States, [2] School of Environmental Sciences, University of Liverpool, Liverpool, United Kingdom, [3] CNRS, Université de Brest, IRD, Ifremer, LEMAR, Plouzané, France

- **New 2022 DFe climatology based on all available DFe data (including IDP2021)**
- Machine learning tools linked to a range of covariates to generate global and seasonal dataset
- Facilitates model initialisation/evaluation
- Freely available: https://zenodo.org/record/6994318
- 138 downloads



Outputs – new datasets

- **Global model datasets from large scale model intercomparison assembled and available**
- Freely available with doi: https://zenodo.org/records/5827909
- 11 downloads



AGU PUBLICATIONS

Global Biogeochemical Cycles

RESEARCH ARTICLE

10.1002/2015GB005289

How well do global ocean biogeochemistry models simulate dissolved iron distributions?

Alessandro Tagliabue[1], Olivier Aumont[2], Ros DeAth[3], John P. Dunne[4], Stephanie Dutkiewicz[5], Eric Galbraith[6,7], Kazuhiro Misumi[8], J. Keith Moore[9], Andy Ridgwell[3,10], Elliot Sherman[9], Charles Stock[4], Marcello Vichi[11,12], Christoph Völker[13], and Andrew Yool[14]

[1]School of Environmental Sciences, University of Liverpool, Liverpool, UK, [2]IRD-LOCEAN, Institut Pierre Simon LaPlace, Paris, France, [3]School of Geographical Sciences, University of Bristol, Bristol, UK, [4]NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey, USA, [5]Center for Global Change Science, Massachusetts Institute of Technology, Cambridge, Massachussetts, USA, [6]Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain, [7]Institut de Ciència i Tecnologia Ambientals and Department of Mathematics, Universitat Autonoma de Barcelona, Barcelona, Spain, [8]Environmental Science Research Laboratory, Central Research Institute of Electric Power Industry, Abiko, Japan, [9]Department of Earth System Science, University of California, Irvine, California, USA, [10]Department of Earth Sciences, University of California, Riverside, California, USA, [11]Department of Oceanography, University of Cape Town, Cape Town, South Africa, [12]Nansen-Tutu Centre for Marine Environmental Research, Cape Town, South Africa, [13]Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany, [14]National Oceanography Centre, University of Southampton, Southampton, UK

Key Points:
- First intercomparison of 13 global iron models highlights key challenges in reproducing iron data
- Wide uncertainty in iron input fluxes, which results in poorly constrained residence times
- Reducing uncertainty in scavenging and biological cycling is a priority

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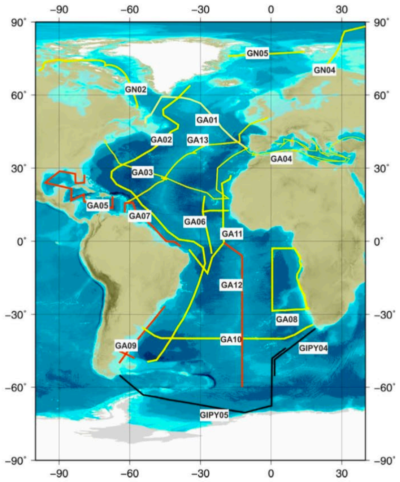
Outputs – new tools

Example output for one GEOTRACES section:



Source: www.geotraces.org

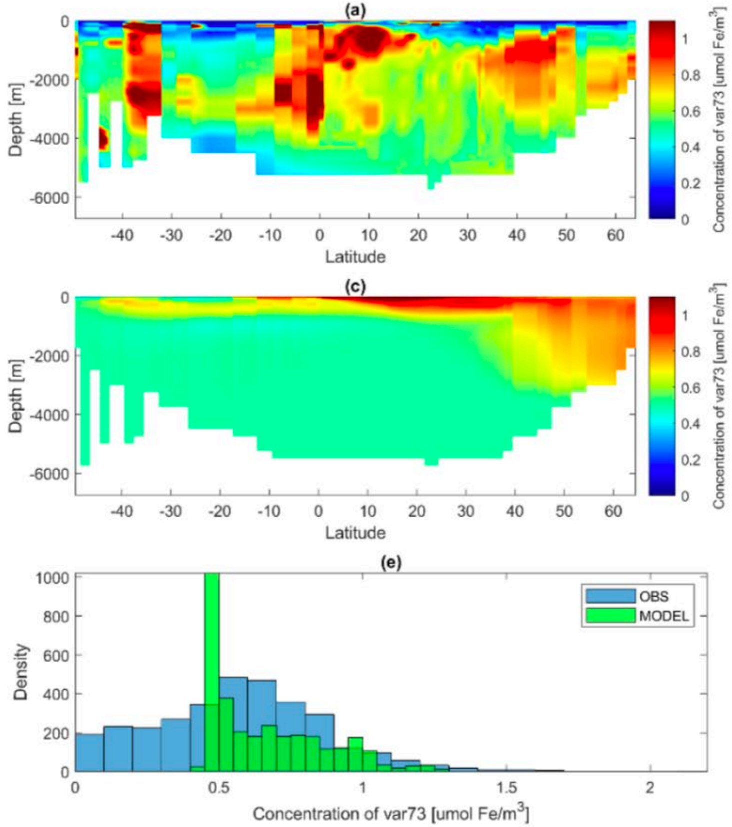
FeMIP – Iron model intercomparison project- SCOR WG151

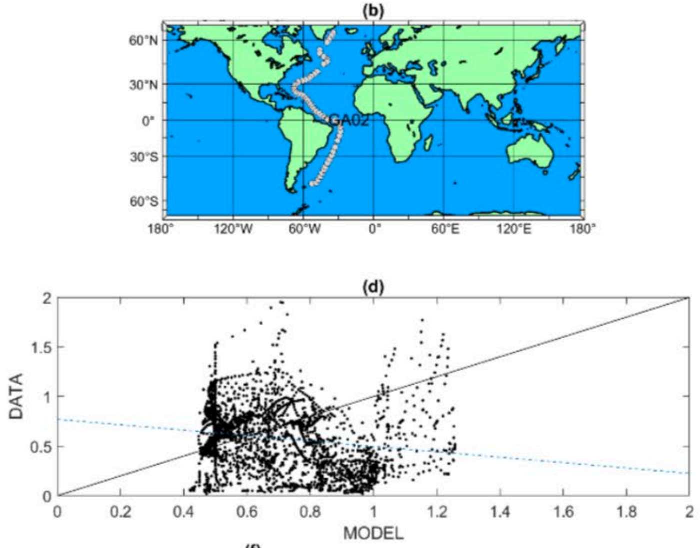
FeMIPeval

Iron model evaluation tool with GEOTRACES IDP2017

MATLAB version

Jonathan Rogerson
Marcello Vichi
University of Cape Town, South Africa





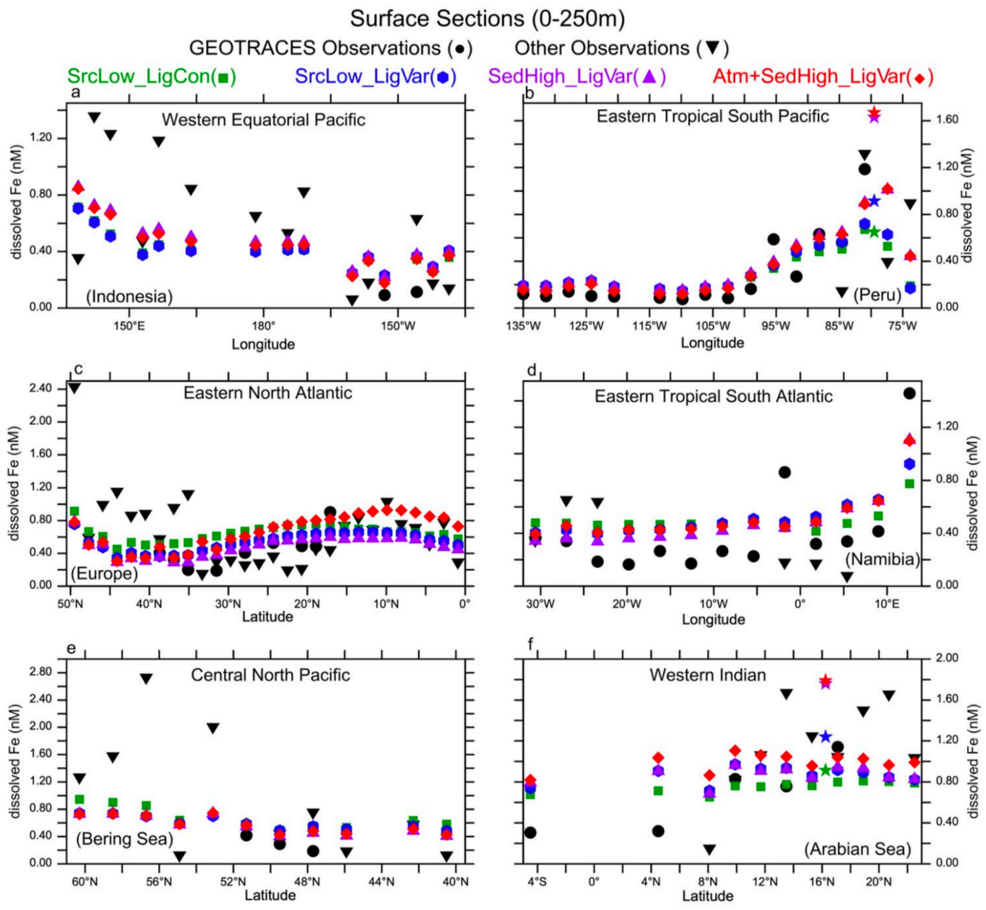
(f)

	Concentration of var73 [umol Fe/m^3]
Model mean	0.6684
Obs mean	0.5876
Model std	0.1968
Obs std	0.3811
Pearson r	-0.1408
RMSD	0.4600
B	0.0808
AAE (MAE)	0.3272
RMSD_CP	0.4528
MEF	-0.4569
RI	2.5148

- **New tool, FeMIPeval, for model skill assessment**
- Freely accessible tool for model-data assessment and skill scores
- Facilitates a reproducible approach across different models
- Freely accessible: https://github.com/RGRJON002/FeMIPeval

Outputs – new papers

Model - data assessments in the upper 250m for different regions:



AGU ADVANCING EARTH AND SPACE SCIENCE

Global Biogeochemical Cycles

RESEARCH ARTICLE
10.1029/2021GB006948

Key Points:

- Global marine iron model tests varying levels of atmospheric deposition, sedimentary release, ligand distributions, and scavenging rates
- Simulations that best reproduce observations include variable ligands and high rates of atmospheric deposition and sedimentary release
- Simulations with high iron sources require high scavenging rates resulting in short residence times

Constraining Global Marine Iron Sources and Ligand-Mediated Scavenging Fluxes With GEOTRACES Dissolved Iron Measurements in an Ocean Biogeochemical Model

Christopher J. Somes[1], Andrew W. Dale[1], Klaus Wallmann[1], Florian Scholz[1], Wanxuan Yao[1], Andreas Oschlies[1], Juan Muglia[2], Andreas Schmittner[3], and Eric P. Achterberg[1]

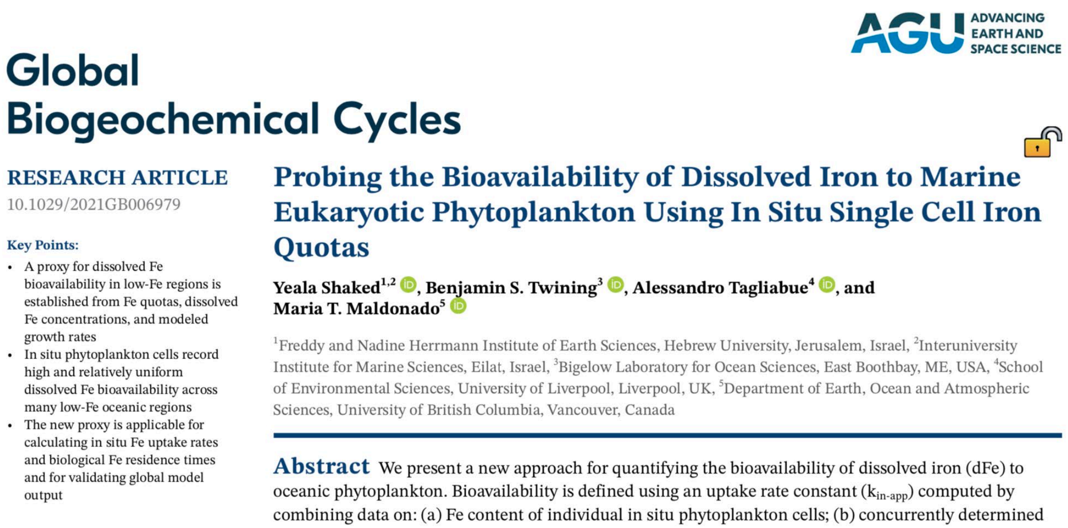
[1]GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, [2]Centro para el Estudio de los Sistemas Marinos, CONICET, Puerto Madryn, Argentina, [3]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA

Abstract Iron is a key micronutrient controlling phytoplankton growth in vast regions of the global ocean. Despite its importance, uncertainties remain high regarding external iron source fluxes

- **Combining GEOTRACES data with a suite of model experiments to address key processes in the ocean Fe cycle**

- Model experiments addressed: dust and sediment sources, as well as ligand dynamics
- System requires high scavenging rates and low residence times
- Substantial biases with respect to observations remain

Outputs – new constraints



AGU ADVANCING EARTH AND SPACE SCIENCE

Global Biogeochemical Cycles

RESEARCH ARTICLE

10.1029/2021GB006979

Key Points:

- A proxy for dissolved Fe bioavailability in low-Fe regions is established from Fe quotas, dissolved Fe concentrations, and modeled growth rates
- In situ phytoplankton cells record high and relatively uniform dissolved Fe bioavailability across many low-Fe oceanic regions
- The new proxy is applicable for calculating in situ Fe uptake rates and biological Fe residence times and for validating global model output

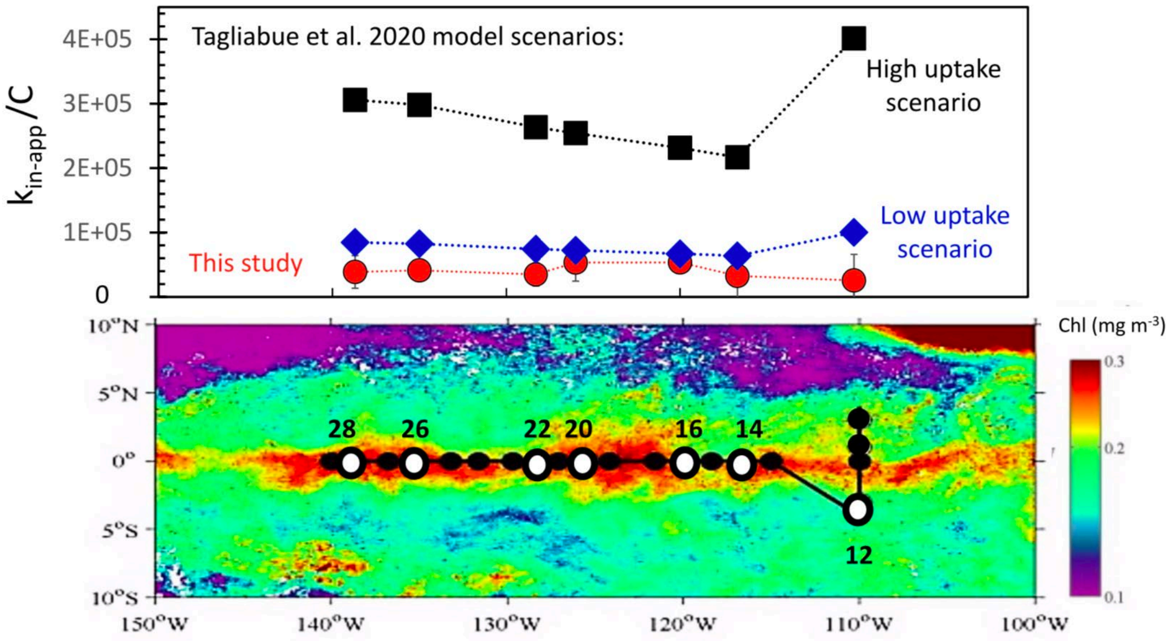
Probing the Bioavailability of Dissolved Iron to Marine Eukaryotic Phytoplankton Using In Situ Single Cell Iron Quotas

Yeala Shaked[1,2], Benjamin S. Twining[3], Alessandro Tagliabue[4], and Maria T. Maldonado[5]

[1]Freddy and Nadine Herrmann Institute of Earth Sciences, Hebrew University, Jerusalem, Israel, [2]Interuniversity Institute for Marine Sciences, Eilat, Israel, [3]Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA, [4]School of Environmental Sciences, University of Liverpool, Liverpool, UK, [5]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada

Abstract We present a new approach for quantifying the bioavailability of dissolved iron (dFe) to oceanic phytoplankton. Bioavailability is defined using an uptake rate constant ($k_{in\text{-}app}$) computed by combining data on: (a) Fe content of individual in situ phytoplankton cells; (b) concurrently determined

Assessing agreement with high/low Fe uptake scenarios from ESM projections:



- Large data synthesis effort led by Yeala Shaked (full member)
- **New means to constrain Fe bioavailability from field measurements and constrain different model scenarios**
- Calculation of Fe uptake rates and residence times in the upper ocean
- New horizons for modelling Fe uptake and bioavailability

Newly completed ToR4 ....

- Guidelines for biological cycling in Fe models assessed
- Responses from 9 modelling groups
- Paper writing in progress

	Process	Least Complexity	Moderate complexity	Most Complexity
	Model setup			
1	Physics – model resolution	>1 degree	1 degree	<1 degree
2	Typical run length	Years-decades	Decades-centuries	Centuries-millenia
3	Iron sources	Dust	Dust+Sediments	Dust+Sediments+Hydrothermal vents+ rivers
	Fe speciation			
4	DFe-Ligand speciation	Threshold-based (i.e. scavenging occurs above set concentration)	Empirical (i.e. one ligand calculated based on DOC or other tracers)	Specific ligand classes (i.e. prognostic simulation of one of more ligand)
6	Abiotic DFe loss	Fixed scavenging rates	Particle dependant scavenging rates	Particle dependant scavenging and colloidal pumping
7	Photochemistry	None	simple implicit effects	Multiple roles – speciation, ligand degradation, particle Fe dissolution
	Biological Fe cycling			
8	Iron bioavailability	All dFe	Differential bioavailability of Fe' and FeL	Differential bioavailability of specific dFe and pFe complexes
9	Iron uptake kinetics	Coupled to C or N (i.e. fixed C/Fe ratios)	Explicit Michaelis Menten (i.e. Fe uptake rates calculated)	Multiple interacting components (i.e. including feedbacks around iron limitation and cell size)
10	Iron limitation model	Monod	Quota (fixed required quota)	Quota (dynamic required quota)
12	Regeneration of grazed Fe	Constant proportion of grazed Fe (i.e. fixed gross growth efficiency)	Comparison of prey and predator Fe/C ratios (i.e. variable gross growth efficiency)	Specific trophic pathways and/or variable zooplankton Fe quotas
13	Role of Bacteria	Implicit role - Fe regeneration	Implicit role - Fe regeneration and uptake	Explicit Fe regeneration and uptake
	Particulate Fe cycling			
14	Downward PFe export	Martin Curve	Explicit sinking particulate Fe	Multiple interacting specific particulate Fe pools (biogenic, lithogenic, authigenic etc)
15	Particle flux attenuation	Single b value	Explicit sinking and regeneration of pFe pools with emergent b values	Multiple particle size spectra and attenuation
16	DFe release from settling particles	Fixed rate of release	Rate of release dependant on bacterial activity, oxygen etc	Release rates also modified by ligands and lithogenic particle load

- Working group efforts completed, many thanks to SCOR for their support (and patience)
- New avenues to deploy some of the tools developed during the life of this WG as part of GEOTRACES plans going forward