Characterization of export and regeneration in models*, including recommendations for new data and model-data comparisons

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models = global ocean and Earth System Models

Particulate Export and Regeneration in Models

Highly parameterized, empirical relationships.

Assumed sinking speed and remineralization rate defines the remineralization vs. depth profile.

The length scale is assumed to increase with depth (average sinking speed and/or remin rate increases as a function of depth), a la the Martin Curve

Other factors can modify the remin curve including oxygen concentration, temperature, and mineral ballast components (bSi, $CaCO_3$, lithogenic).

Typically tuned to best match obserbed global mean phosphate or nitrate profiles.

Not Explicitly Included in the Models

Twilight Zone Biota (hetero-bacteria, zooplankton)
Surface ecosystems relatively well developed, built on the JGOFS legacy.

Full particle size spectrum and physical aggregation and disaggregation processes.

Most models have only one or two sinking particulate size classes. CESM has implicit sinking particles (no lateral transport, sink and regenerate where formed).

Progress has been limited by data availability and computational constraints.

Generating the Sinking Particulates

Biogenic Fluxes

Surface ecosystem models generate the sinking POM, bSi (diatoms), and $CaCO_3$ (coccolithophores) fluxes.

Primary route through grazing losses. Often assumed that large phytoplankton export more efficiently (larger fraction of grazed material routed to sinking pools).

Secondary route through aggregation losses (simple function of biomass, or biomass^2).

Lithogenic Fluxes

Most include sinking mineral dust particles (less small fraction that dissolves at deposition). GFDL models also include lithogenic particles from rivers/shelf.

Trace Element Particle Scavenging in Models

dFe scavenging is a linear function of sinking mass (or in models without ballast components, sinking POC).

dFe is released when sinking particles remineralize, based on the prescribed remineralization curves.

A constant desorption rate for dFe on particles is also imposed. Can observations help constrain this?

Models assume much lower scavenging rates on dFe bound to ligands than "free" Fe. How much iron is really "free" given a spectrum of weaker and weaker Fe-binding ligands?

The scavenging rate on dFe in excess of the (assumed) ligand concentration is set high, such that all the "free" iron was removed in a single time step (~instantly, < 1-3 hours).

Is this too fast?

Recent simulations in our group suggest a lower rate on the unbound Fe can improve simulated dFe in areas with large iron inputs (dust plumes, hydrothermal vents).

Dynamic ligand-Fe models recently developed by Tagliabue and Völker, and currently for CESM (Sherman et al., in prep.).

Explicit treatment of L1 ligands with dynamic sources and sinks.

Elevated L1 ligands were observed at the margins on GAO3. Was this due to higher organic matter export?

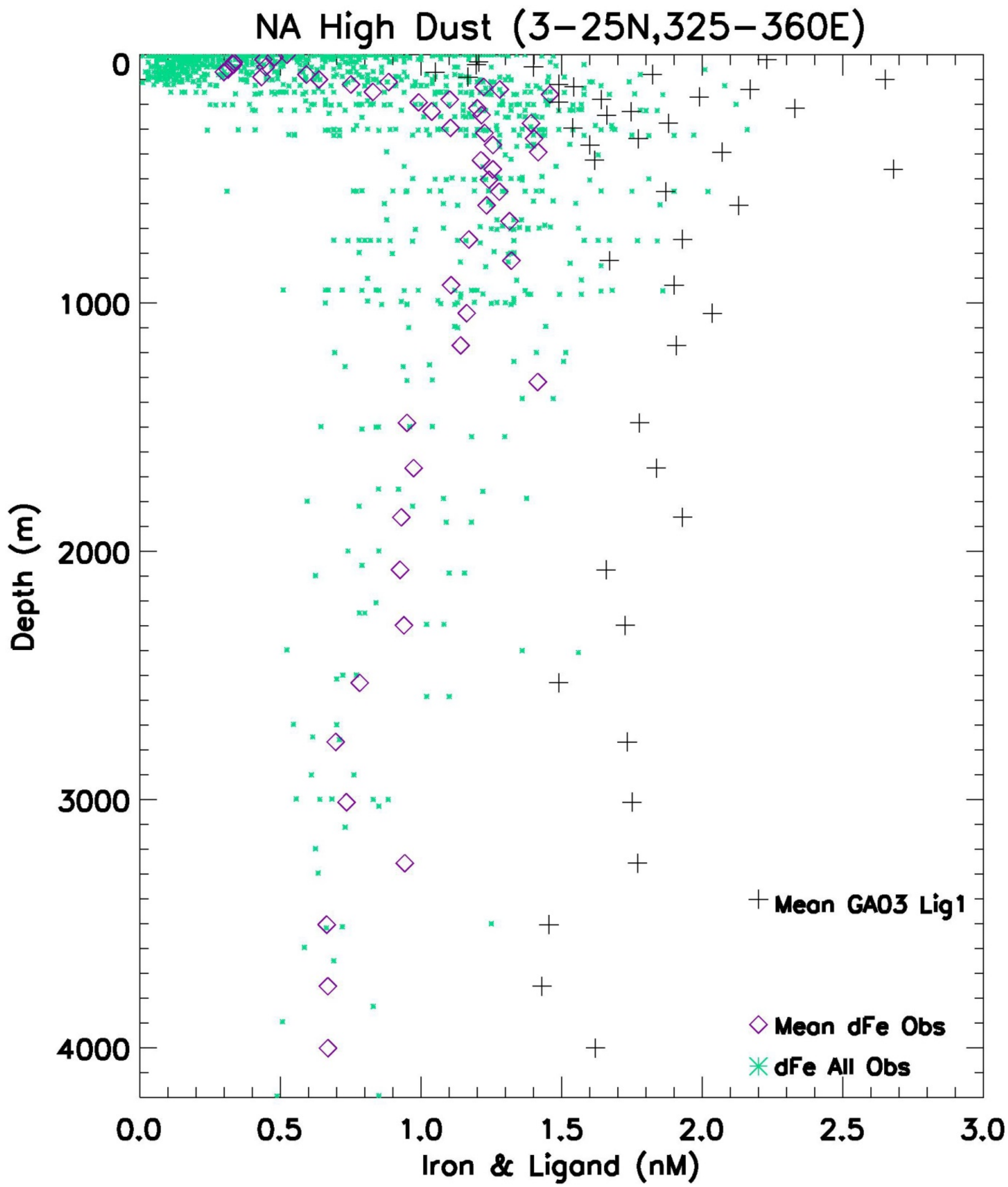
Can synthesis efforts derive a ligand produced / POM remin ratio?

Relatively high dFe scavenging rates are required to match observations (especially sub-euphotic zone 100-500m).

This has to include scavenging removal of ligand-bound iron.

Some aggregation-scavenging of colloidal ligands likely occurs.

But is there also scavenging loss of Fe to particles that doesn't remove the ligands? Particles steals Fe from ligand or during dynamic cycling.



North Atlantic High Dust Region Profiles

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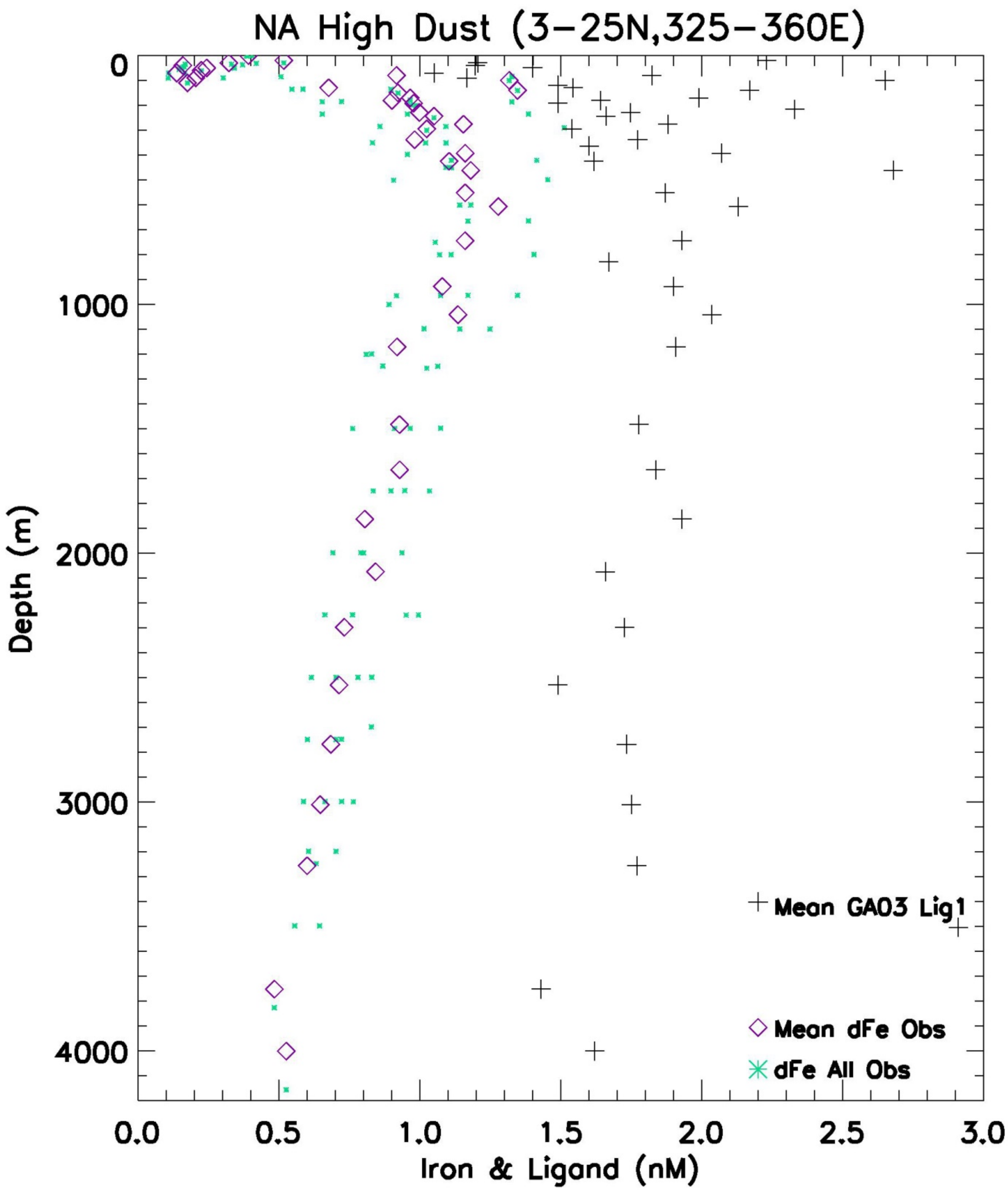


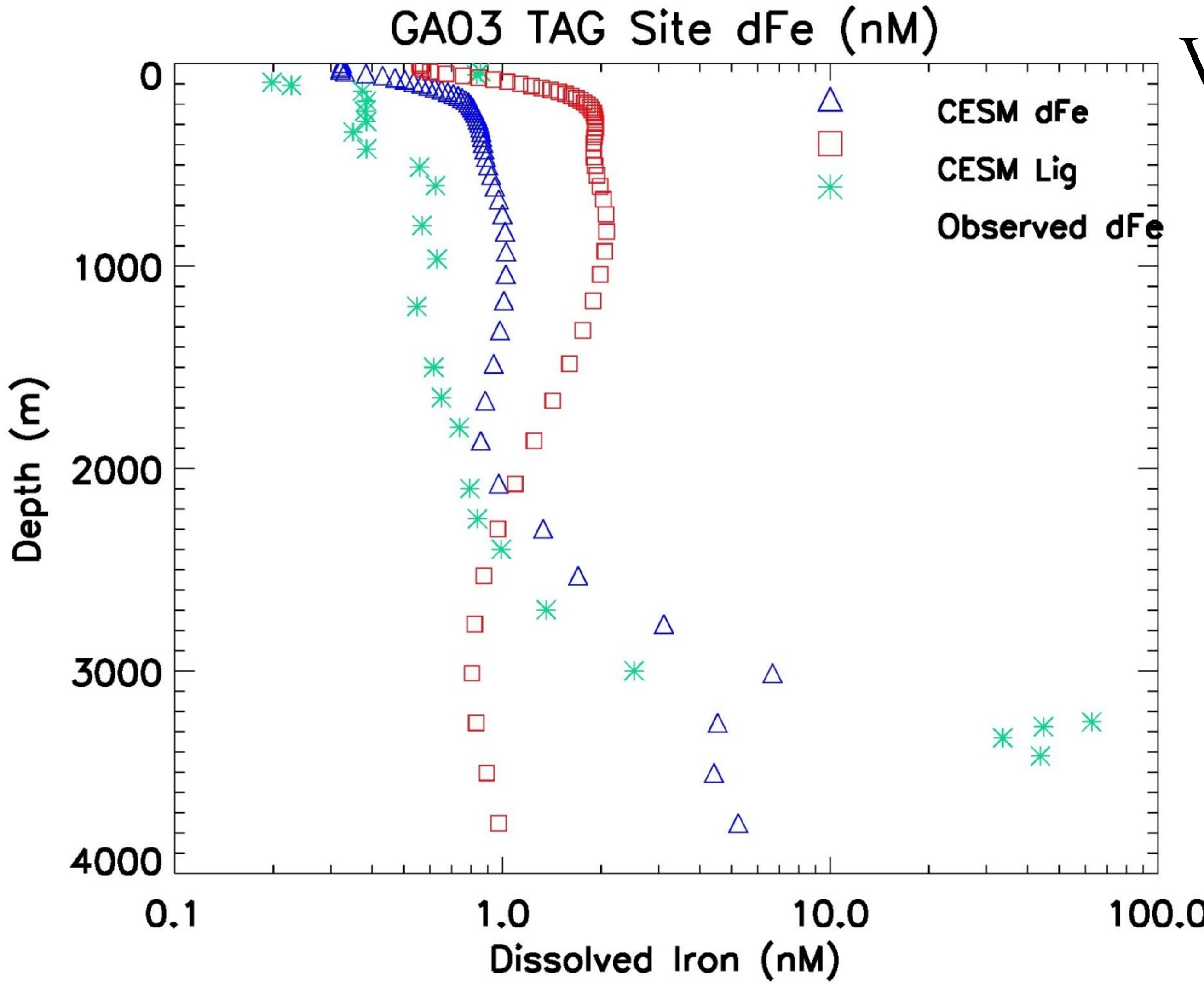
Constraining Particle Scavenging and Export

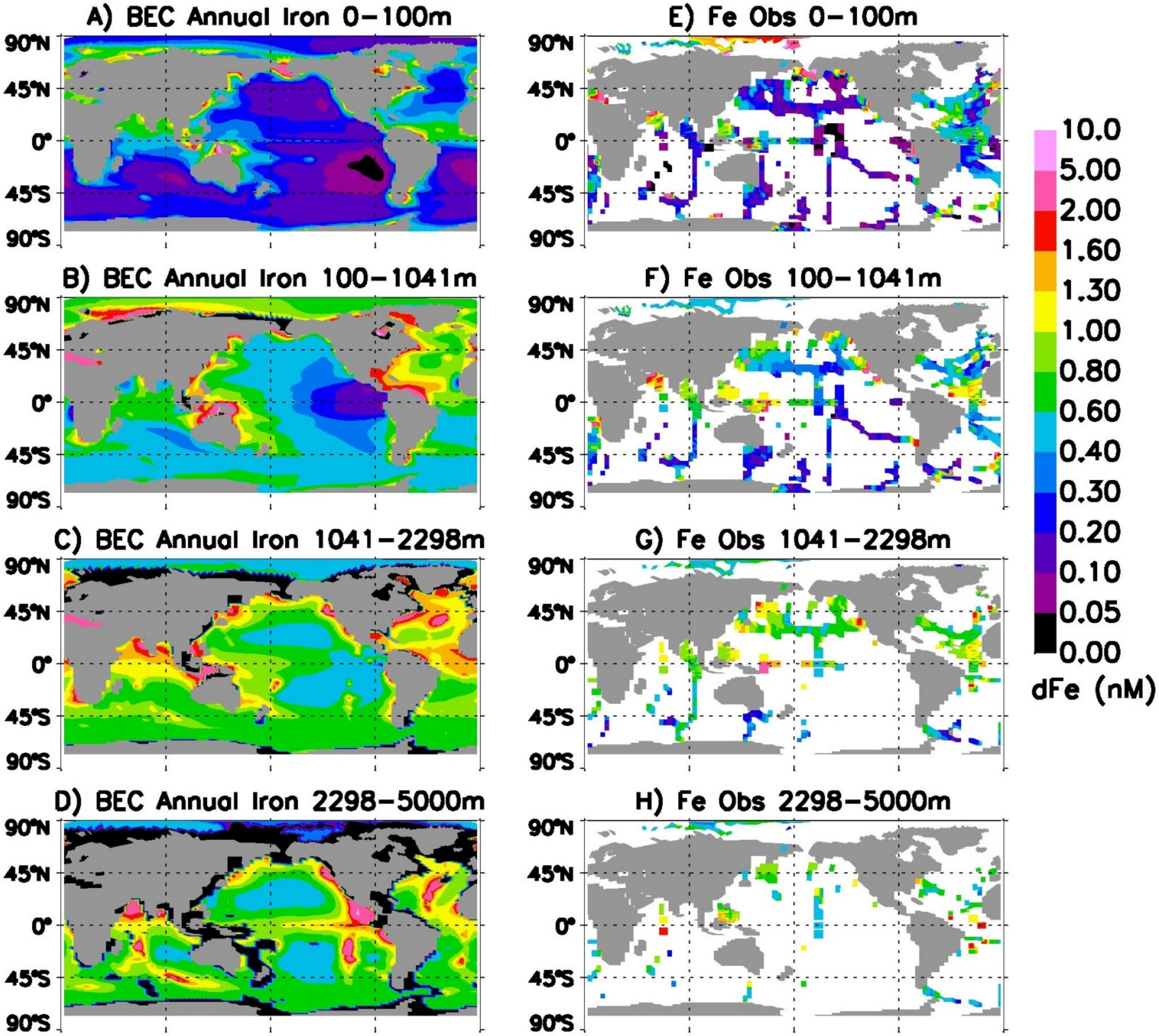
GEOTRACES and other new observational datasets are already driving development of more explicit models of particle dynamics and twilight zone biogeochemistry, but these will take time.

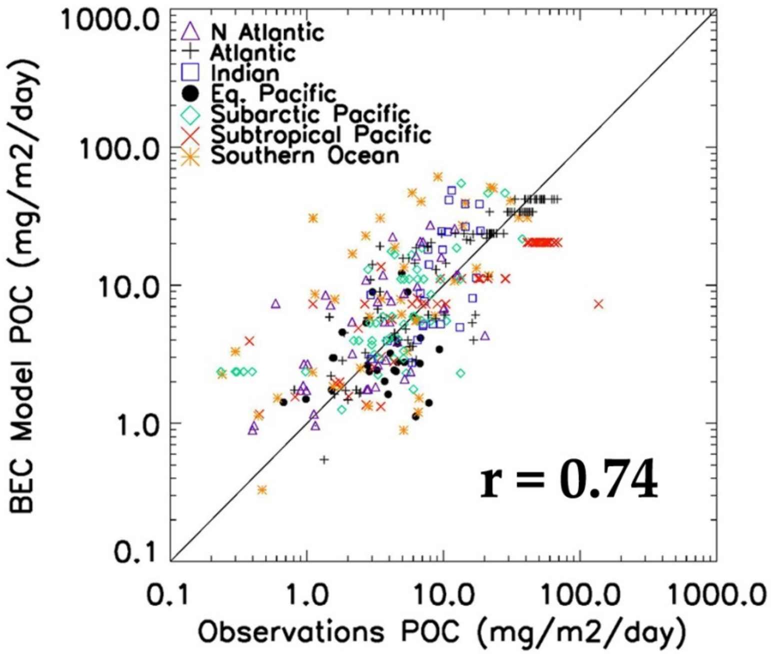
Current generation models could be improved with observational constraints on the relation between sinking mass flux (currently in models) and trace element particle scavenging and export.

Sinking speeds and mean particle size (decreasing S/V) may increase with mass flux, leading to decreasing scavenging efficiency. Particle composition may also modify scavenging efficiency.

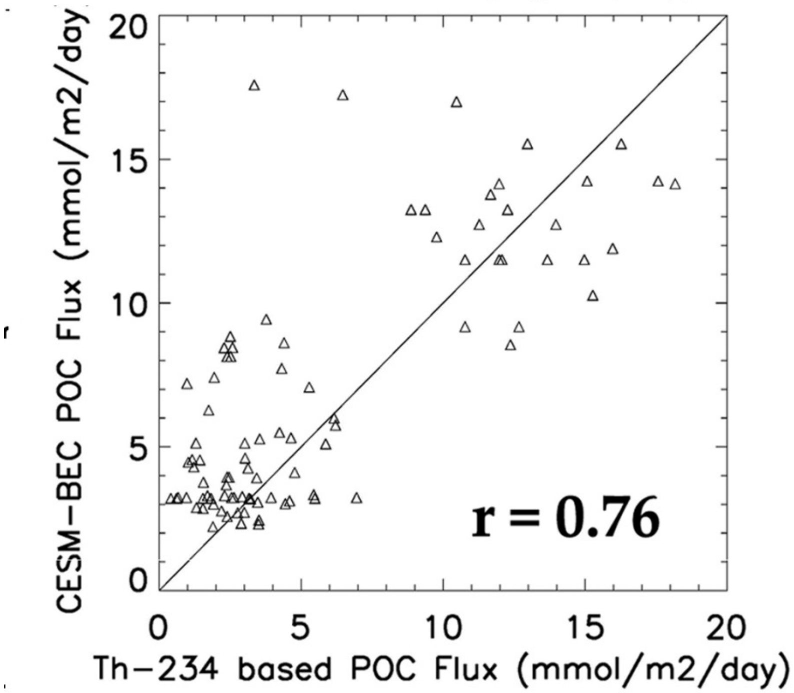
Vertical Profiles at GA03 TAG Site



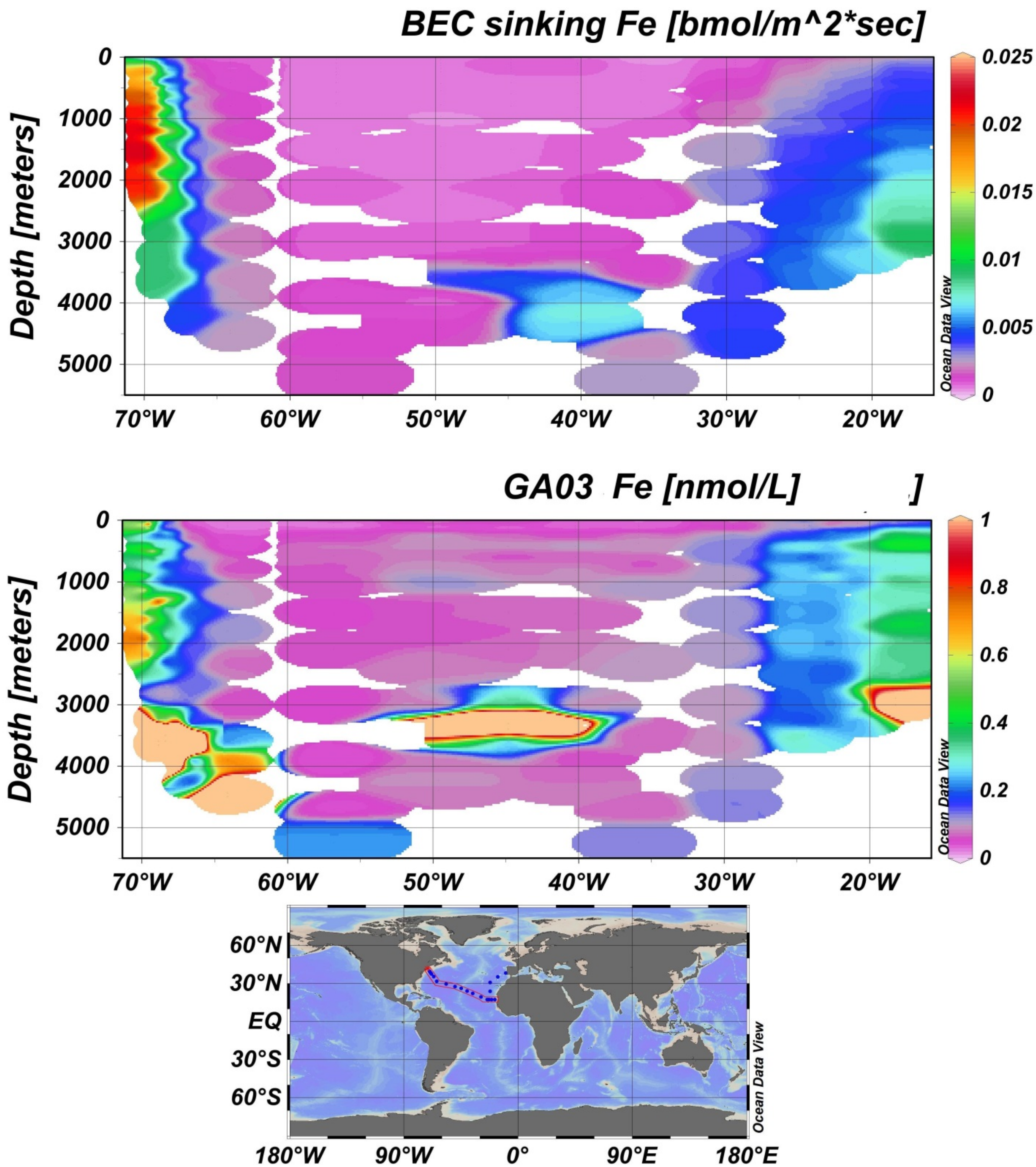

A) BEC Annual Iron 0-100m
B) BEC Annual Iron 100-1041m
C) BEC Annual Iron 1041-2298m
D) BEC Annual Iron 2298-5000m
E) Fe Obs 0-100m
F) Fe Obs 100-1041m
G) Fe Obs 1041-2298m
H) Fe Obs 2298-5000m
90°N
45°N
0°
45°S
90°S
10.0
5.00
2.00
1.60
1.30
1.00
0.80
0.60
0.40
0.30
0.20
0.10
0.05
0.00
dFe (nM)



Sediment trap carbon flux measurements compared with CESM-BEC output.



Th-234 based carbon export measurements (Buesseler et al., 2009; Owens et al. 2015) compared with CESM-BEC output.


BEC sinking Fe [bmol/m^2*sec]
Depth [meters]
0
1000
2000
3000
4000
5000
70°W
60°W
50°W
40°W
30°W
20°W
0.025
0.02
0.015
0.01
0.005
0
Ocean Data View
GA03 Fe [nmol/L]]
Depth [meters]
0
1000
2000
3000
4000
5000
70°W
60°W
50°W
40°W
30°W
20°W
1
0.8
0.6
0.4
0.2
0
Ocean Data View
60°N
30°N
EQ
30°S
60°S
180°W
90°W
0°
90°E
180°E
Ocean Data View

Model Constraints from GEOTRACES

Marine Fe Cycle - Lots of uncertainty, but not independent uncertainty. Progress constraining the rates of iron particle scavenging, would also help constrain iron inputs. Similarly, constraints on dust input and iron release, also constrains scavenging. Iron isotopes will help constrain sources.

Particle Export and Stoichiometry - New tracers for particle, carbon export, and new measurments of particle stoichiometry, including the TEIs. Supports efforts to move away from Redfield C/N/P stoichiometry and to include to TEIs in ecosystem and biogeochemical models.
Improve models of particle scavenging.