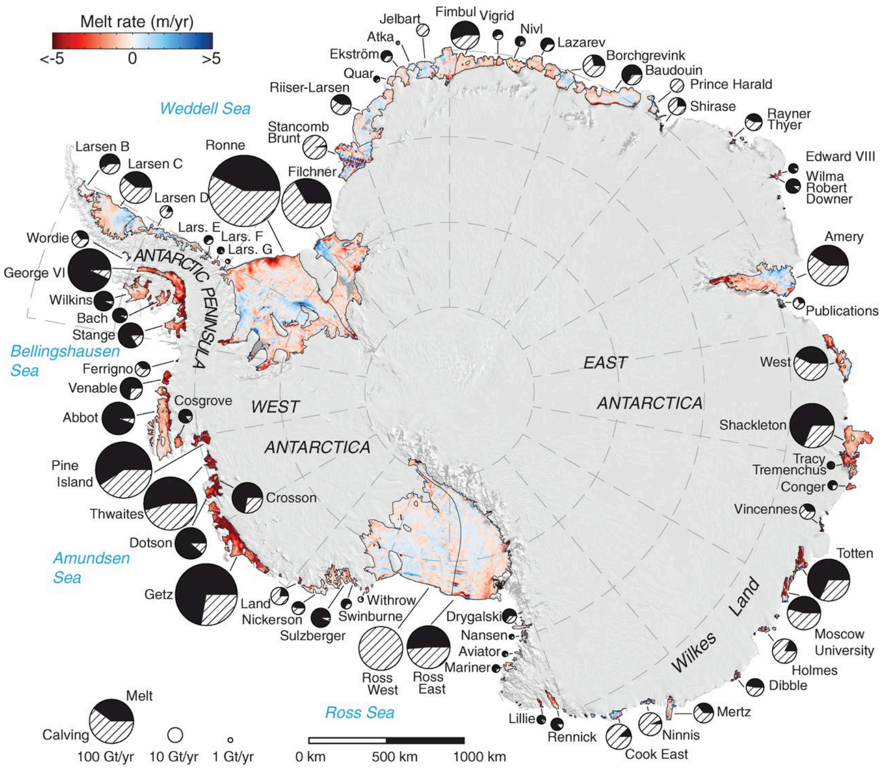
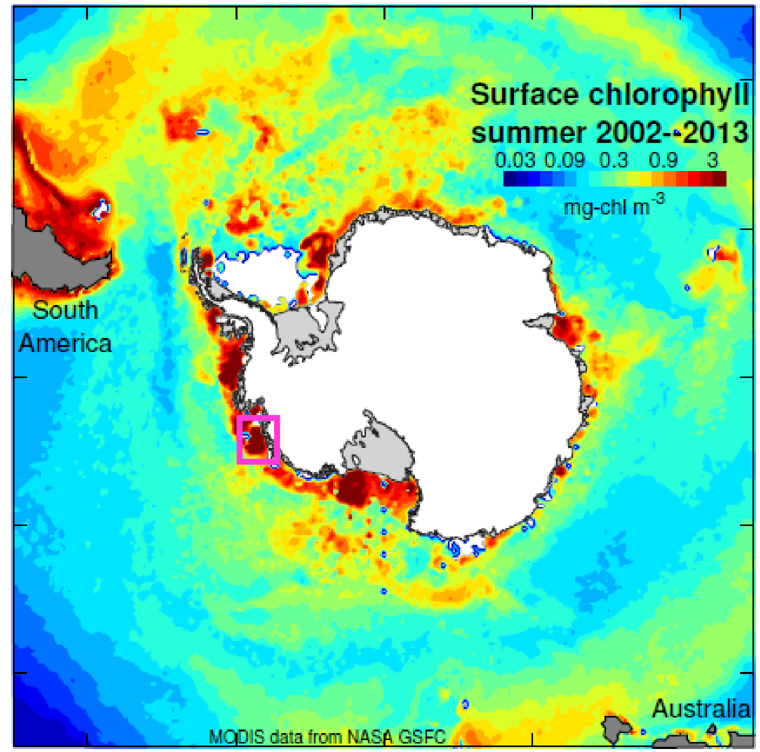
Rationale for GEOTRACES GP 17 Amundsen Sea Transect

Why the Amundsen Sea sector?



Rignot et al., 2013



~50% of net melting from 10 small warm-cavity ice shelves in the SE Pacific that account for 8% of the ice shelf area

Amundsen Sea polynya has highest net primary production per unit area on the Antarctic continental margin

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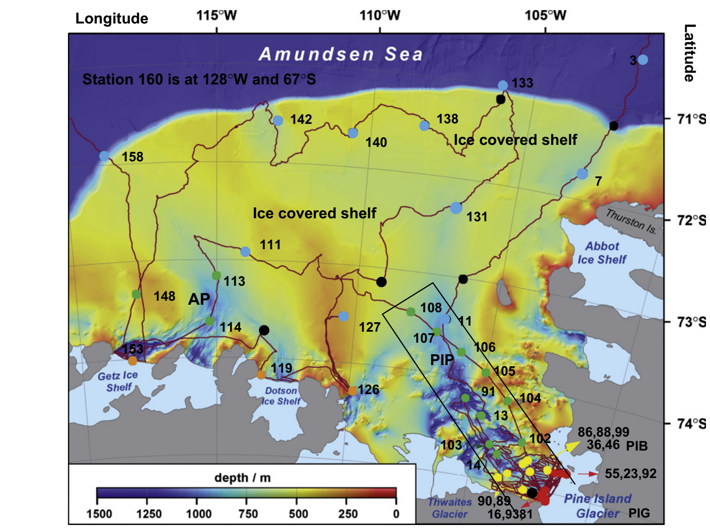

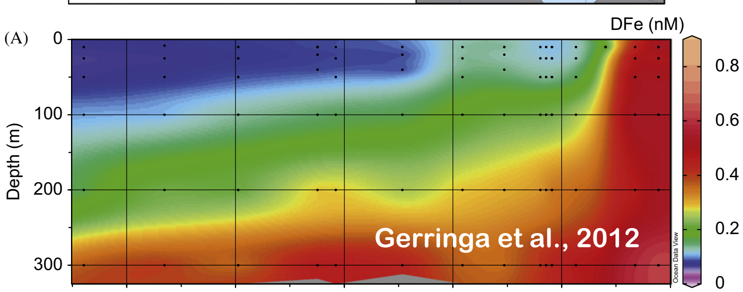

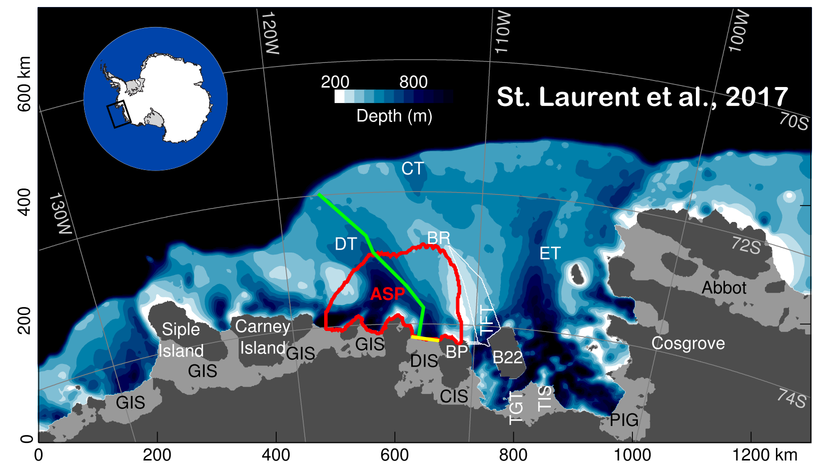

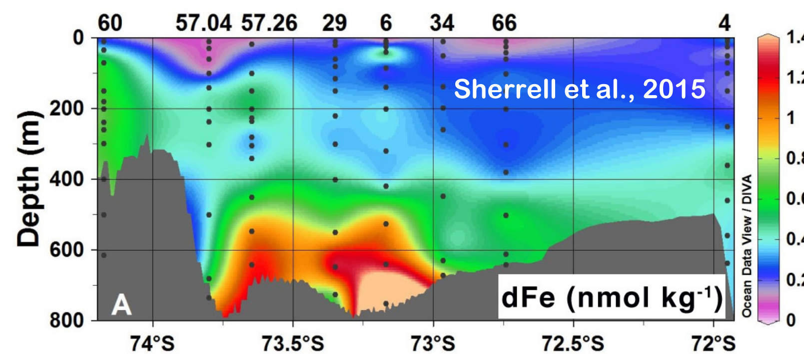

DynaLiFe (left) and ASPIRE programs (right) documented elevated dissolved Fe adjacent to ice shelves and seafloor in Pine Island and Amundsen Sea polynyas, inferred to fuel the intense phytoplankton blooms in these locations

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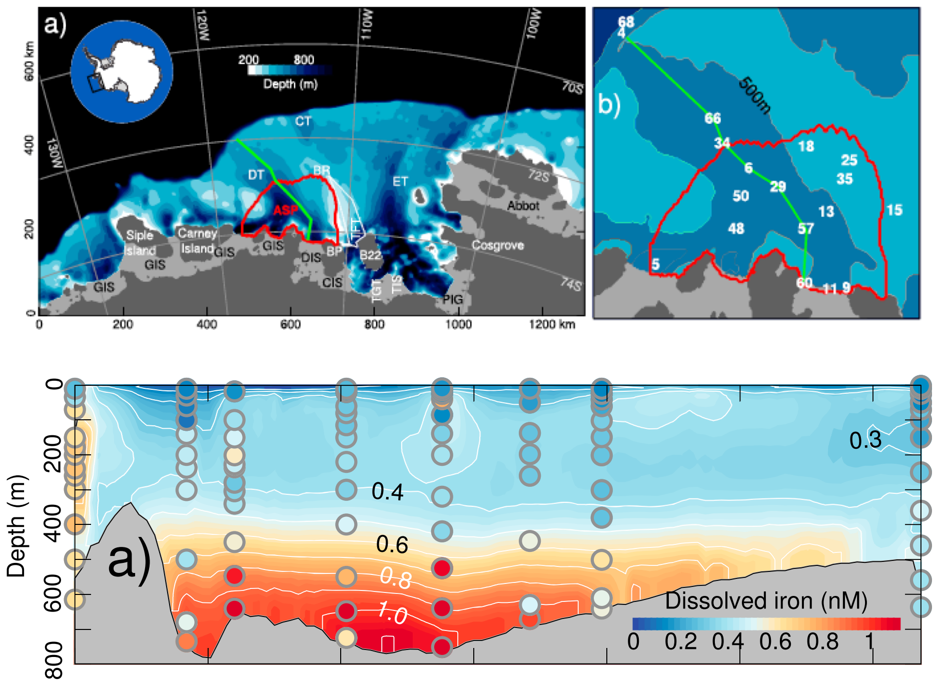
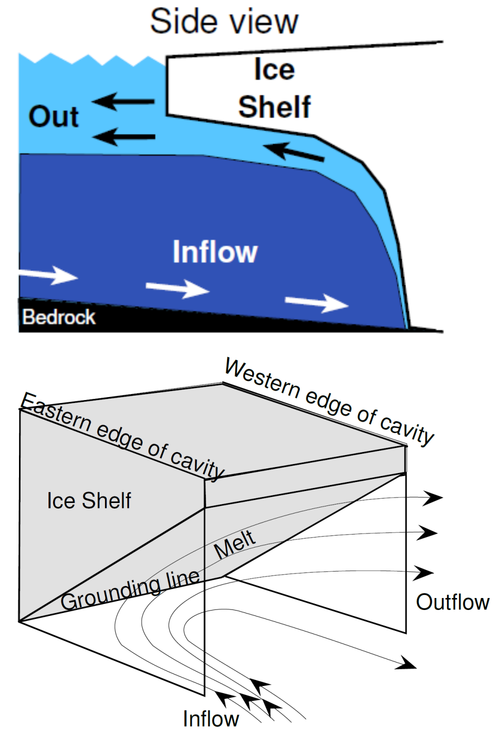


St. Laurent et al. (2019)



Figures: Mike Dinniman

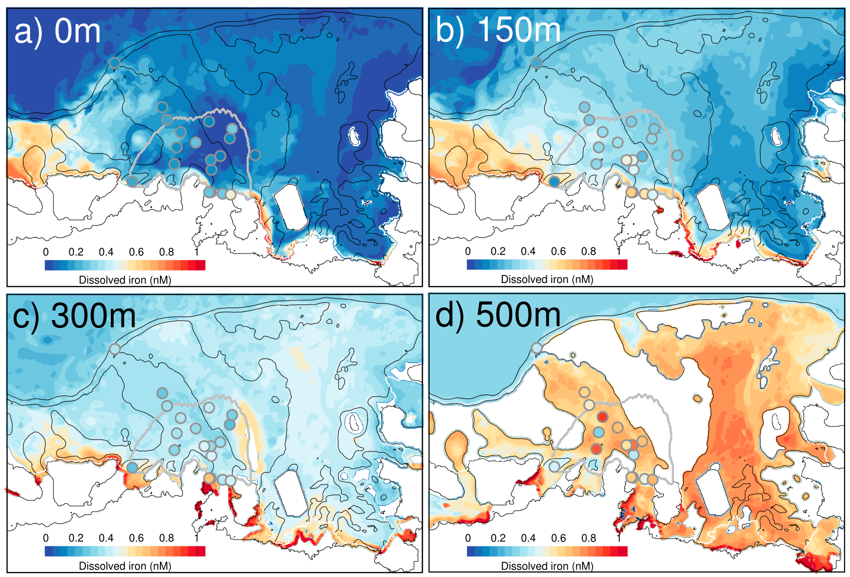
Subsequent modeling work by St. Laurent et al. (2017, 2019) has examined sources of dissolved Fe and impacts on surface waters in and around ASPIRE project domain

Model results suggest that glacial and benthic inputs dominate, and are facilitated by buoyancy- driven “meltwater pump” associated with melting ice shelves

Rationale for GEOTRACES GP 17 Amundsen Sea Transect

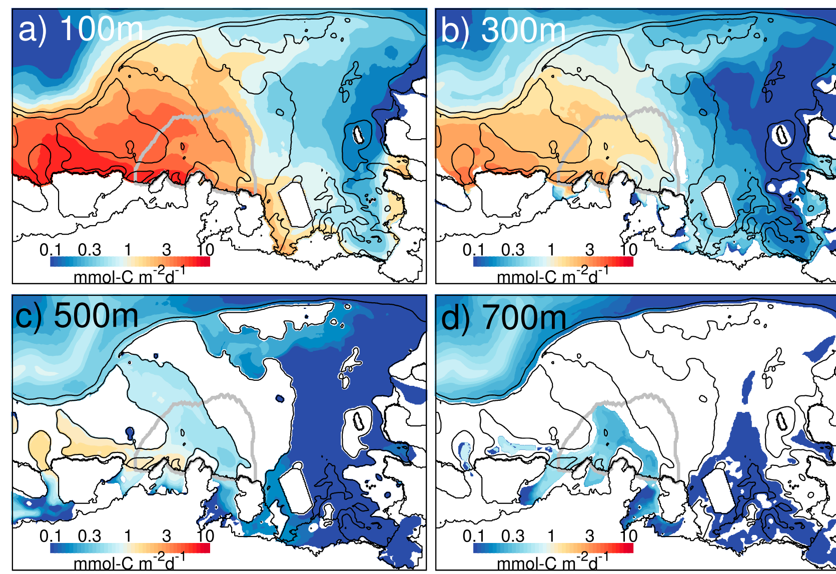
Important implications of modeling work by St. Laurent et al. (2019):

- **westward transport of dissolved Fe from 'upstream' (PIP) contributes to ASP bloom**
- **dissolved Fe and biogenic carbon flux are elevated over shelf 'downstream' of ASP**



St. Laurent et al. (2019)

dissolved Fe



St. Laurent et al. (2019)

carbon flux

Rationale for GEOTRACES GP 17 Amundsen Sea Transect

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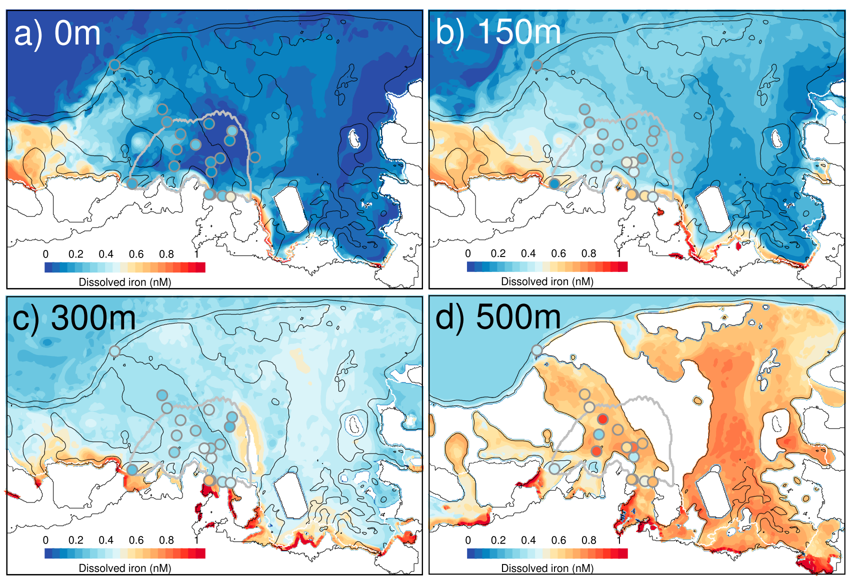


St. Laurent et al. (2019)

<u>Limitations</u> – *No empirical constraints on:*

1) Fe supply (processes or rates)

2) Fe loss (biological uptake, scavenging)

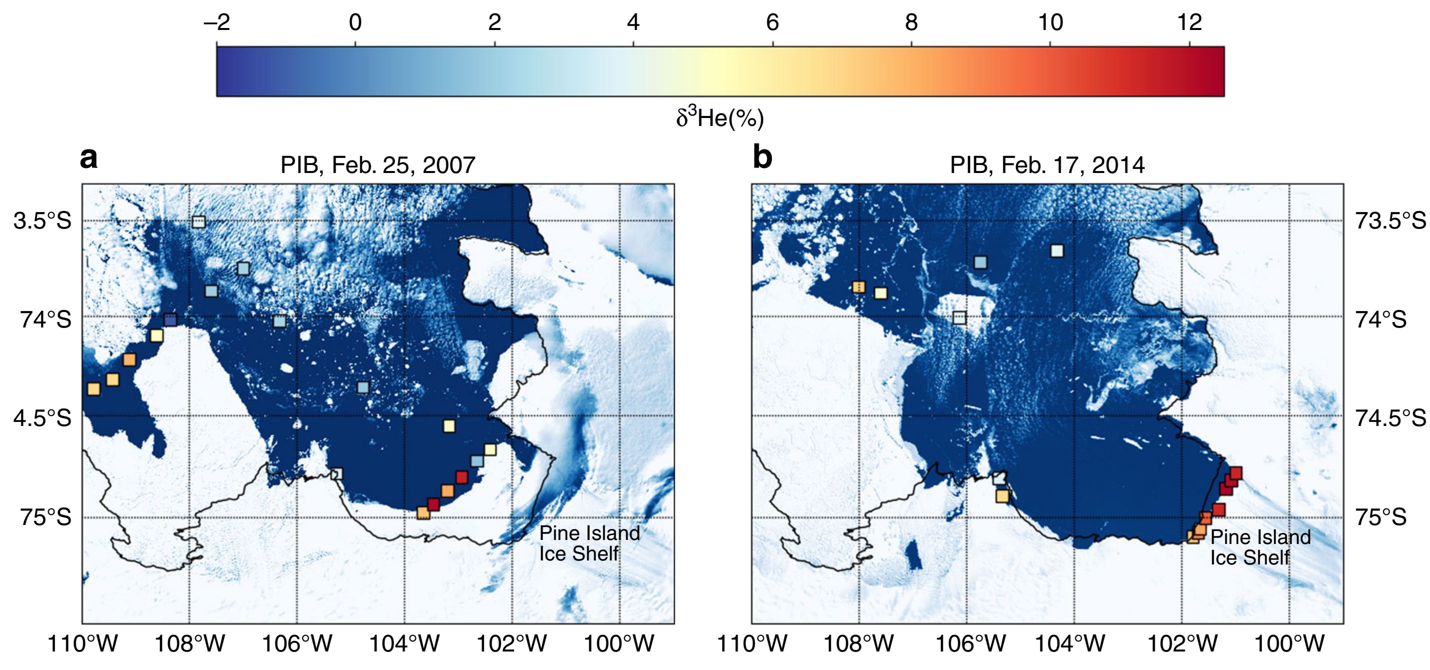
3) Regeneration

4) Cell stoichiometry

5) Fe stress

6) Upstream boundary conditions

Rationale for GEOTRACES GP 17 Amundsen Sea Transect

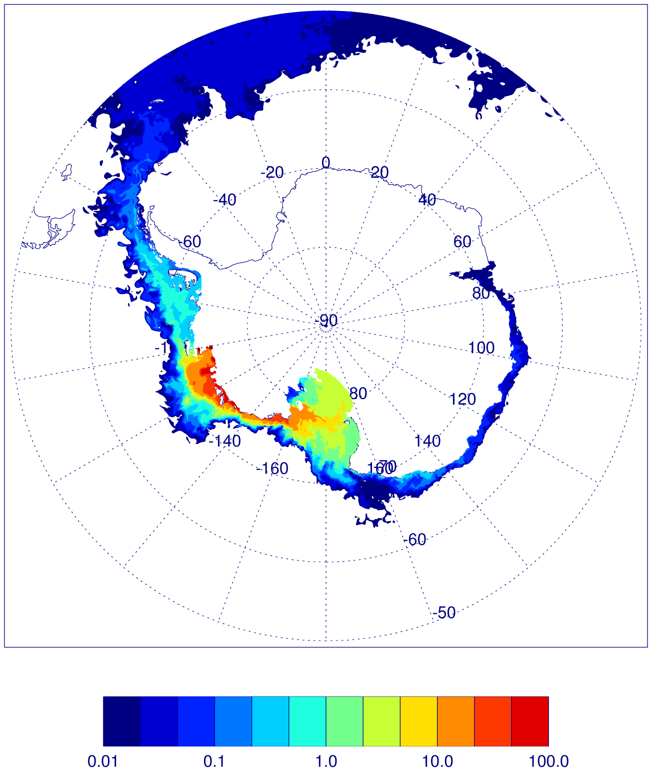


Loose et al. (2018)

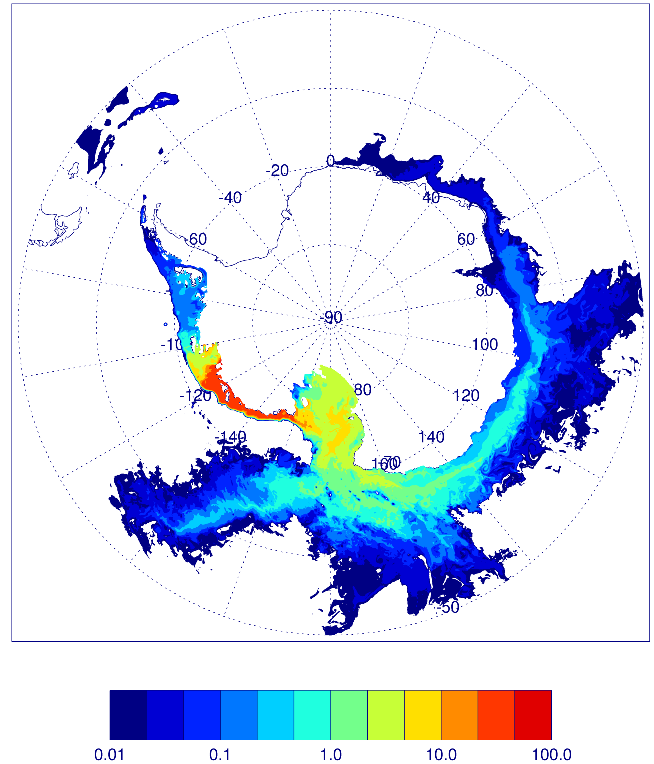
Also, observations provide evidence of volcanic He-3 inputs in association with glacial meltwater near Pine Island ice shelf, raising possibility of hydrothermal TEI inputs

Rationale for GEOTRACES GP 17 Amundsen Sea Transect

surface



bottom



Figures courtesy of Mike Dinniman (unpublished results)

Pan-Antarctic ROMS modeling indicates potential influence of ice shelf melt water (fresh water, Fe, other TEI's): figures show conservative melt water tracer derived from Amundsen Sea sector in surface and bottom model layers after 7 years

Rationale for GEOTRACES GP 17 Amundsen Sea Transect

To robustly address these questions, GEOTRACES would bring measurements of:

1) **noble gases (glacial ice melt sources)**
2) **multi tracers (sea ice melt sources)**
3) **δ^3He (hydrothermal sources)**
4) **Ra (sediment sources)**
5) **δ^{56}Fe (sediment source processes)**
6) **ε_{Nd} (sediment source provenance)**
7) **Th (scavenging and export)**
8) **pFe + cell quotas (uptake, regeneration & scavenging)**
9) **dissolved Cd & Zn, AOU (regeneration)**
10) **Fe speciation (bioavailability and scavenging behavior)**
11) **BioGEOTRACES (e.g., physiological status)**

Rationale for GEOTRACES GP 17 Amundsen Sea Transect

Additional information to be gained by combining results from Antarctic shelf and offshore Southern Ocean waters:

(1). Water mass end-member TEI composition:

- **Essential boundary conditions for coastal models**
- **Use in optimum multiparameter water mass analysis (OMPA) of sources and sinks**

(2). Large-scale lateral concentration gradients:

- **Needed to characterize continent as net source or sink of TEIs for open-ocean**

(3). Multi-tracer distributions (e.g., Ra isotopes, ε_{Nd}, REE patterns, δ^3He, stable metal isotopes)

- **Needed to constrain sources and identify processes for those TEIs for which the Antarctic continent serves as a net source to the open ocean**

26 June 2019

Captions for Presentation on Proposed Amundsen Sea GEOTRACES Cruise

Slide 1. With regard to the supply of trace elements to the ocean, the Amundsen Sea sector of Antarctica is of interest because it supplies ~50% of glacial meltwater to the Antarctic continental margin, sourced from 10 small, rapidly melting warm-cavity ice shelves (left). This region is also among the most biologically productive areas in the Southern Ocean, with the Amundsen Sea polynya having the highest net primary production per unit area around the Antarctic continental shelf (right). This may, in part, reflect supply of biologically available iron and other trace elements from (or associated with) the melting of glacial ice.

Slide 2. Elevated dissolved iron has been documented adjacent to glacial ice shelves by NSF-funded programs DynaLiFe (Pine Island Glacier; Gerringa et al., 2012, left panels) and ASPIRE (Dotson Ice Shelf; Sherrell et al., 2015, right panels). From these and associated biological observations, it has been inferred that these iron sources fuel intense summer phytoplankton blooms in the Pine Island and Amundsen Sea polynyas, respectively (compare with Ross Sea, where glacial iron inputs are low and primary production is seasonally limited by iron supply; e.g., see McGillicuddy et al., 2015).

Slide 3. As follow-up to the ASPIRE project, studies by St. Laurent et al. (2017, 2019) simulate sources, transport and biological impacts of dissolved iron in Amundsen Sea region. These model results (left panels) suggest that glacial melt and benthic sources dominate dissolved iron supply to surface waters in the region, facilitated by buoyancy-driven “meltwater pump” (physical circulation feature, right panels) that is associated with these rapidly melting ice shelves.

Slide 4. Two important implications of this modeling work is that the westward transport of dissolved iron from ‘upstream’ on the shelf (e.g., Thwaites and Pine Island glaciers) are significant contributors to the iron that supports the Amundsen Sea polynya bloom, and that both dissolved iron (left panel) and biogenic carbon flux (right panel) are elevated over areas of the shelf located ‘downstream’ (to the west) of the Amundsen Sea polynya.

Slide 5. However, these model results, and their broader biological and biogeochemical implications, are limited by a lack of observations from this region, including measurements or empirical estimates of iron supply (processes and rates); iron loss via biological uptake and scavenging, dissolved iron regeneration, cellular elemental stoichiometry, degree and impacts of physiological iron/irradiance stress, and ‘upstream’ boundary conditions for the system. Measurements that are routinely made as part of GEOTRACES program cruises would provide such data (see slide 8).

Slide 6. In addition to glacial and benthic sources of iron and other trace elements, a recent study by Loose et al. (2018) reveals elevated helium-3 isotopic abundance in the upper ocean adjacent to the Pine Island Glacier, suggesting volcanic inputs in association with glacial meltwater. This raises the possibility of trace element inputs in the region via submarine hydrothermal emissions and/or discharge of subglacial meltwater (as distinct from glacial melt).

The latter has yet to be directly sampled entering the ocean on the Antarctic margins. The GEOTRACES program would provide geochemical measurements that can uniquely identify and discriminate between these processes, in addition to glacial melt, sea melt, and sedimentary inputs.

Slide 7. Beyond the Amundsen Sea sector, high-resolution pan-Antarctic circulation models (M. Dinniman et al., in preparation) suggest that ice shelf meltwater and associated physical circulation processes may transport substantial fresh water, trace elements such as iron, and other dissolved species as far as the Ross Sea in the west and the Bellingshausen Sea/West Antarctic Peninsula in the east, over a timescale of years. Such transport has important biogeochemical and physical implications (e.g., ocean uptake of atmospheric carbon dioxide, formation of Antarctic Bottom Water).

Slide 8. Shown here are measurements that are routinely made as part of GEOTRACES program cruises that would allow us to robustly address questions concerning the sources, transport and biogeochemical impact of trace elements in and beyond the Amundsen Sea sector of the Antarctic continental margin.

Slide 9. In addition, results of the GEOTRACES program have demonstrated the disproportionate influence of marginal seas and ocean boundaries on the trace element composition of open-ocean waters, including the potential for trace elements and isotopes to provide tracers of water mass transport and ocean processes. For the Southern Ocean and beyond, GEOTRACES measurements from the Amundsen Sea sector would provide information on (1) water mass end member composition and evolution, including associated input and removal processes, (2) large scale concentration gradients that are needed to establish the role played by the Antarctic continent in oceanic trace element budgets, and (3) the combined distributions of multiple geochemical tracers that are required to identify the sources and processes that supply trace elements to the ocean.

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