# Freshwater inputs at the Antarctic Peninsula: spatial and temporal changes, and biogeochemical impacts

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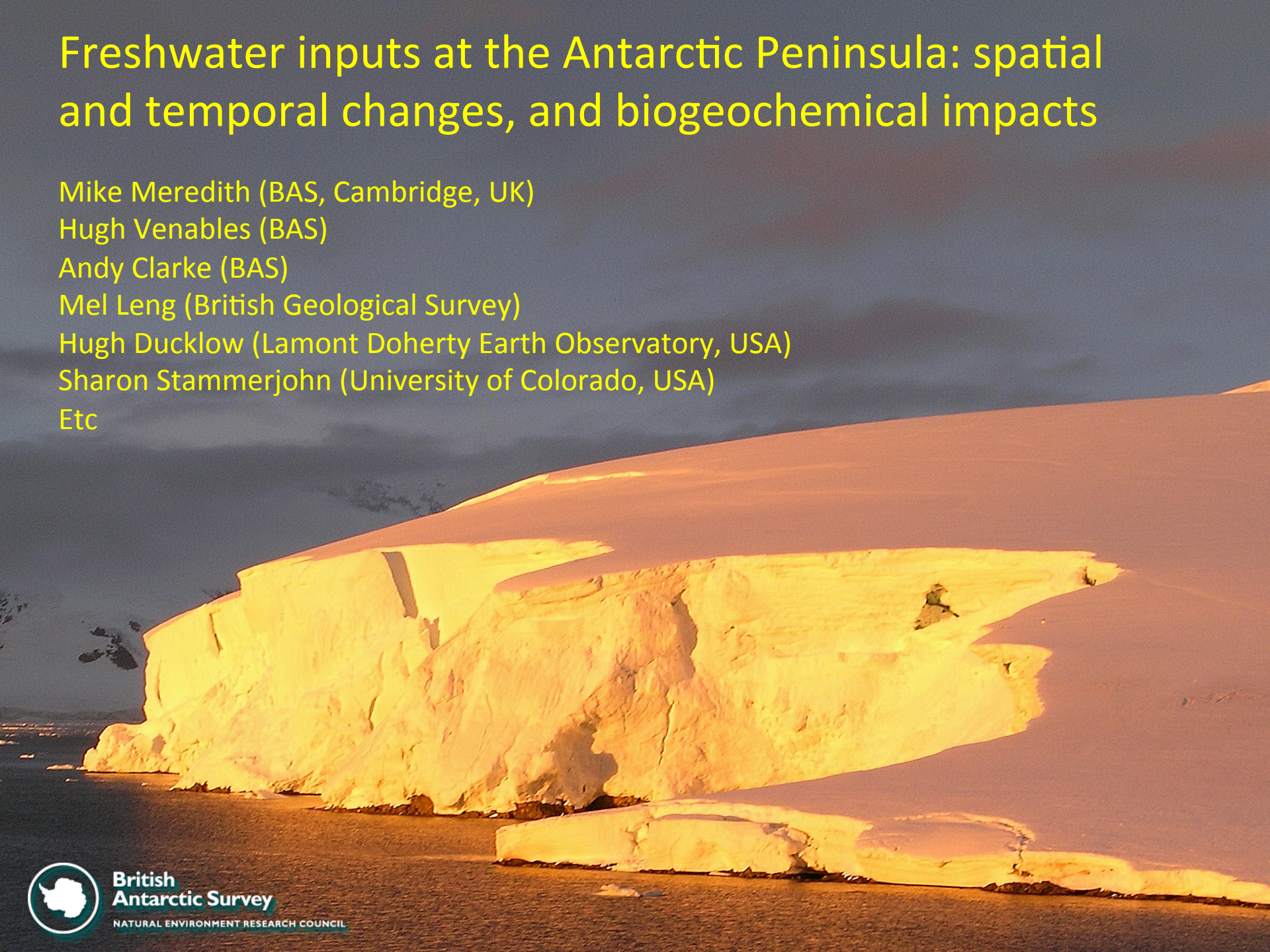

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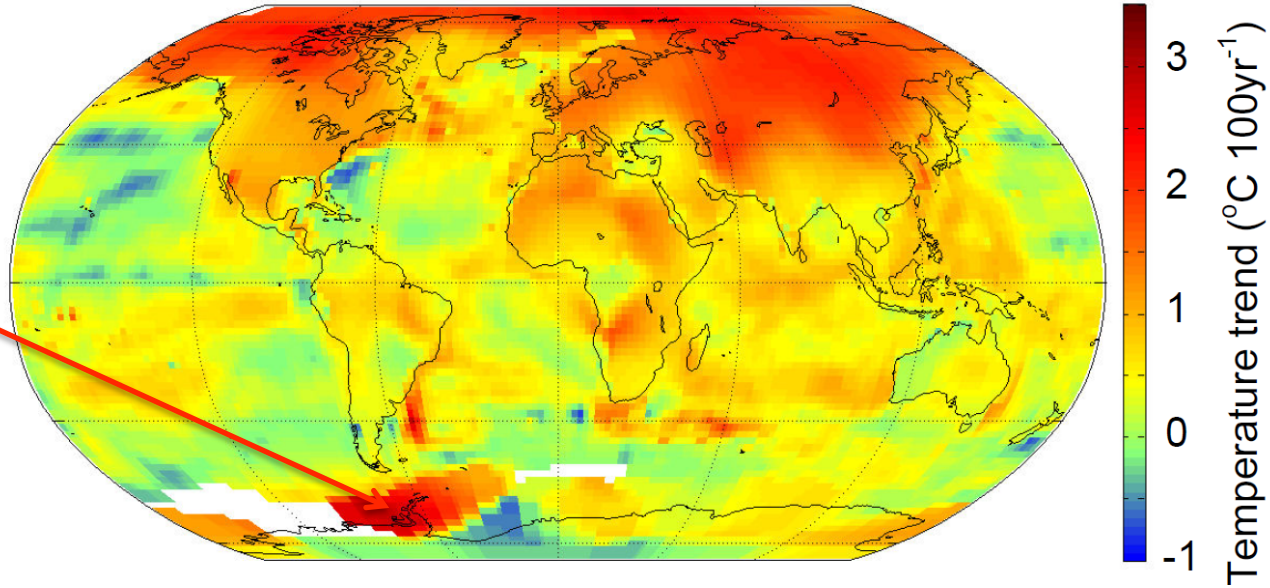
# Where is the Antarctic Peninsula, and why do we care about it…?

Most rapidly warming region in Southern Hemisphere.




The Antarctic Peninsula is a superb “natural laboratory” to study the effects on climate change on the ocean, the feedbacks between the atmosphere ocean and ice, and the impacts on marine biology.

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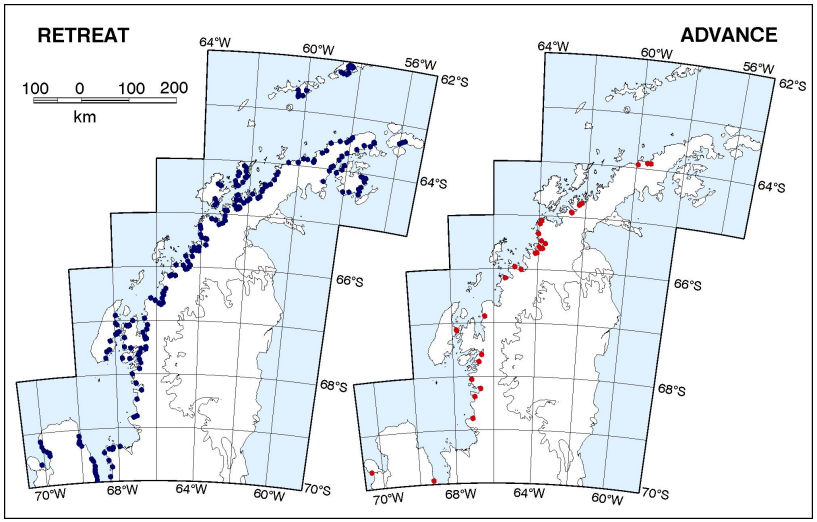
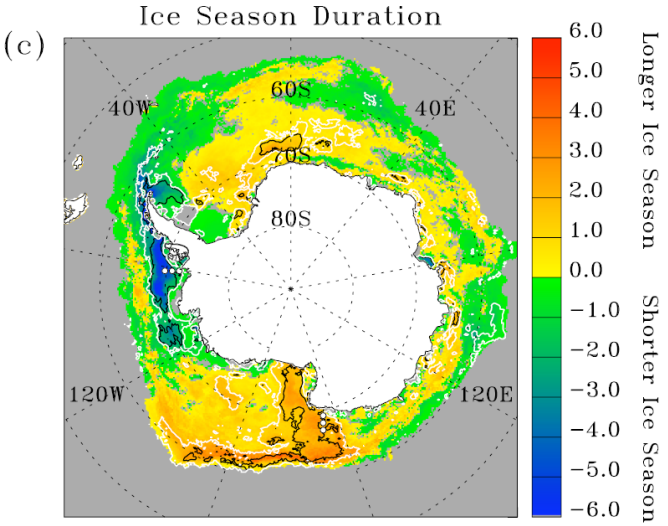
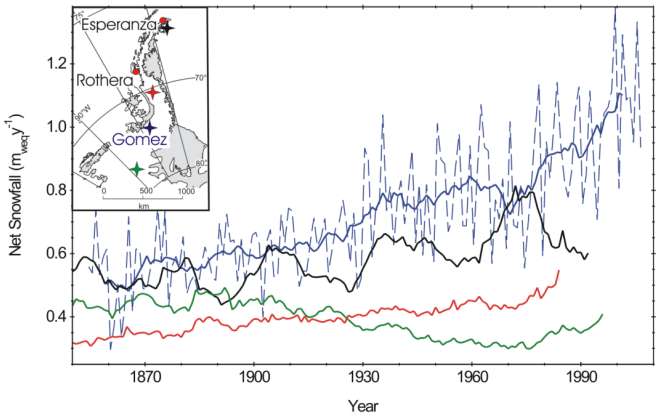
# Peninsula climate is changing rapidly; freshwater system is inherent in that change




Glaciers are predominantly retreating, and retreat rates are accelerating (e.g. Cook et al., *Science*, 2005)




Sea ice is retreating, and length of sea ice season is shortening (e.g. Stammerjohn et al., *Deep-Sea Research,* 2008)




Precipitation has increased over last century (e.g. Thomas et al., *Geophys. Res. Lett.,* 2008)

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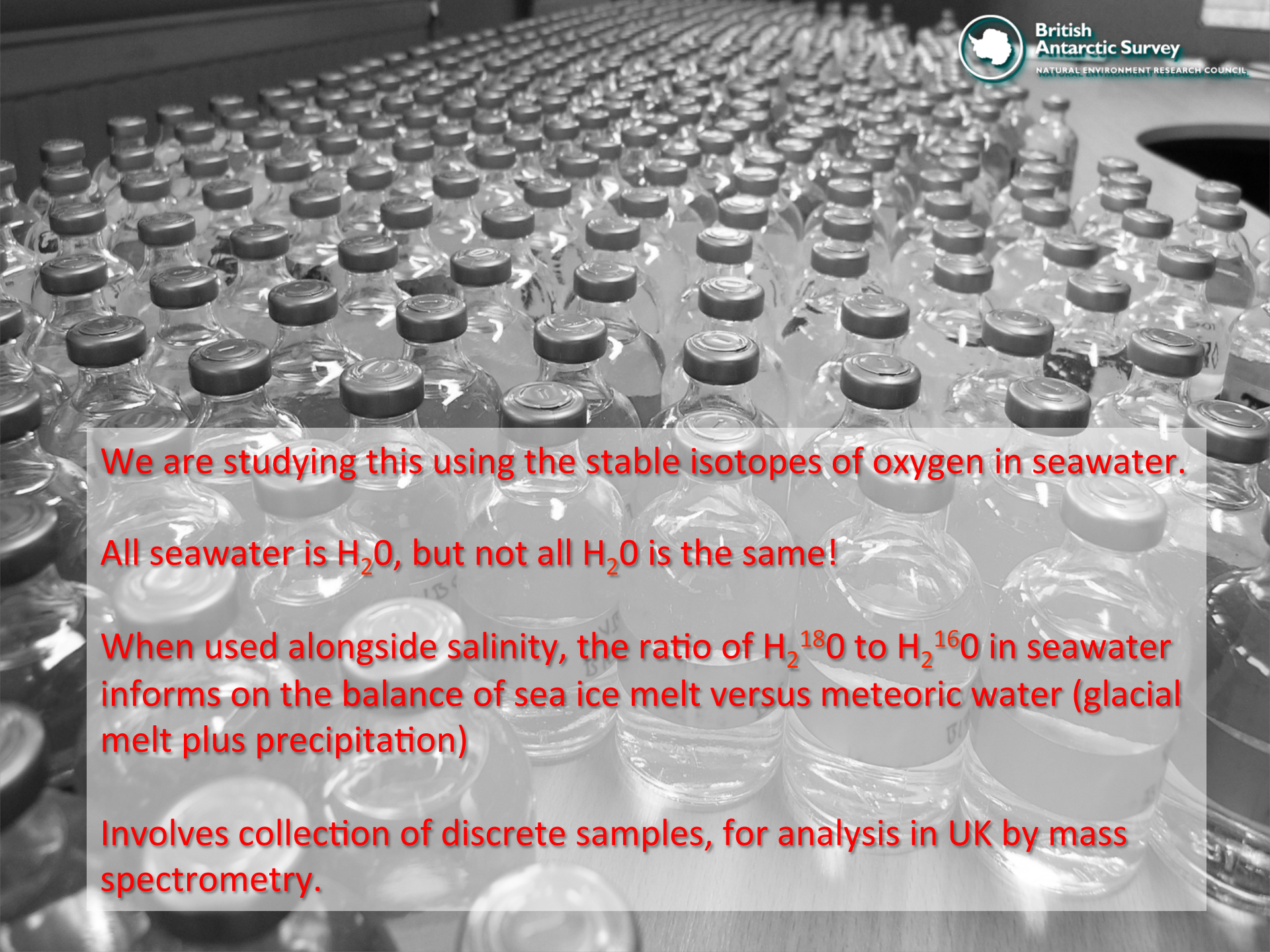
# Of interest to marine scientists because …

- Ocean salinity dominates density at low temperature, therefore freshwater inputs control stratification, geostrophic flow, etc etc.
- Inputs from glaciers have capacity to add bioavailable micronutrients (e.g. iron) to surface ocean.
- Sea ice controls light levels, productivity etc etc etc.
- Persistent organic pollutants (POPs) can reach polar regions via long-range atmospheric transport, and enter marine ecosystem via glacial runoff.
- Sea level - WAP is currently adding 0.16 ± 0.06 mm/y of sea level rise, equivalent to all Alaskan glaciers.
- Etc etc.

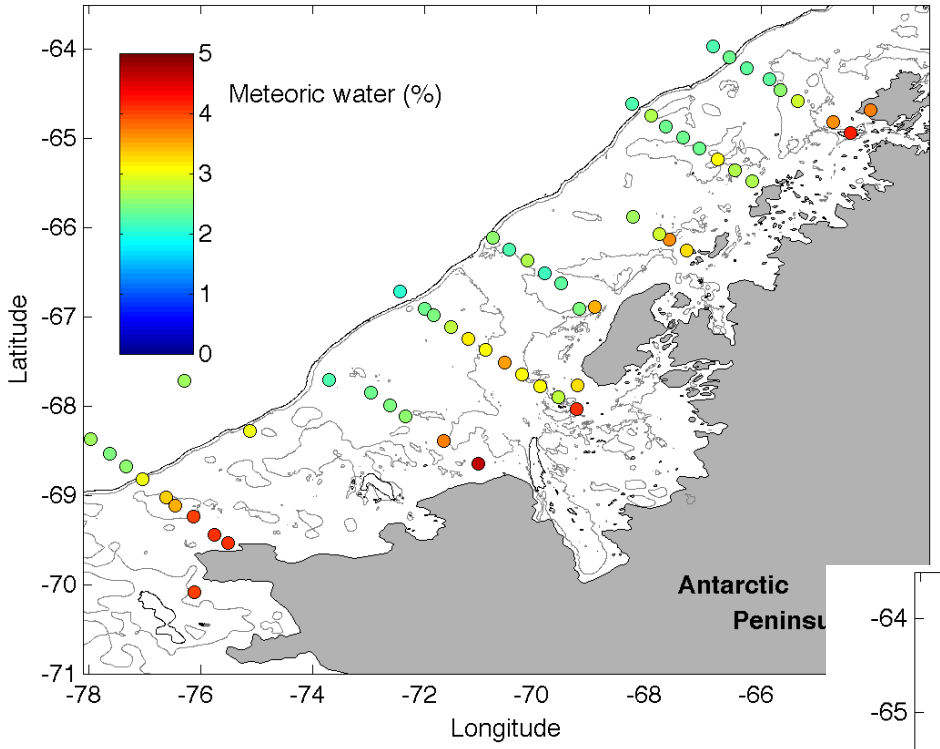



We are studying this using the stable isotopes of oxygen in seawater.

All seawater is $H_20$, but not all $H_20$ is the same!

When used alongside salinity, the ratio of $H_2{}^{18}0$ to $H_2{}^{16}0$ in seawater informs on the balance of sea ice melt versus meteoric water (glacial melt plus precipitation)

Involves collection of discrete samples, for analysis in UK by mass spectrometry.

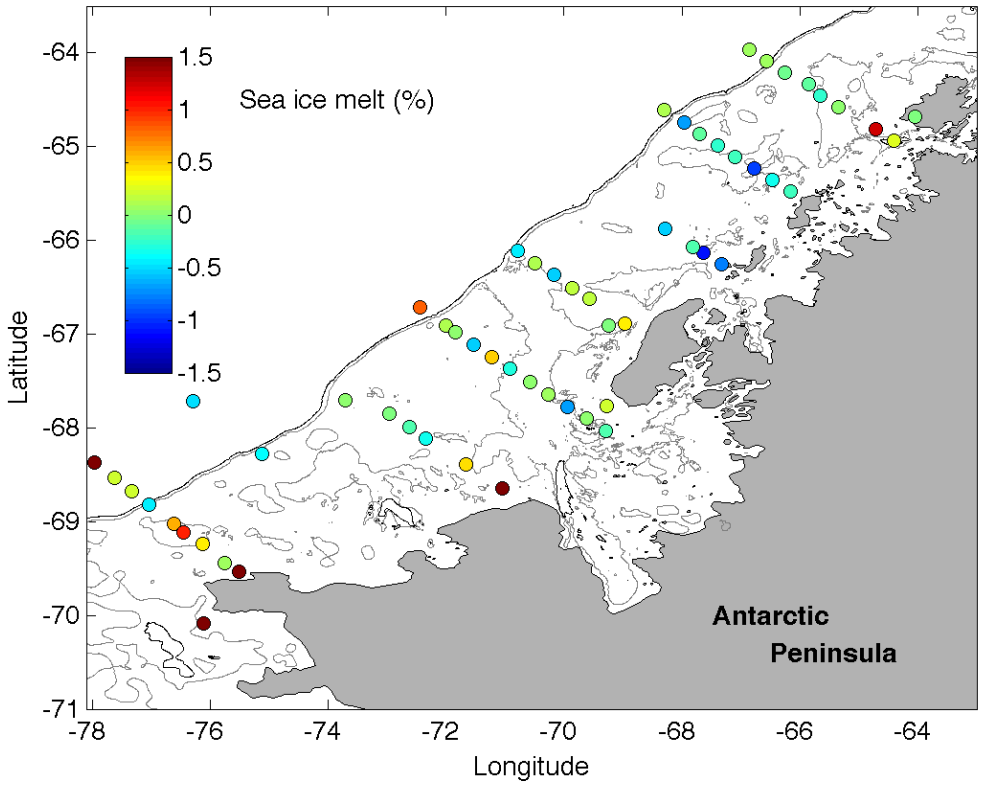



What does it look like at the western Peninsula?

Meteoric water concentrations are higher near-shore, due to glacial inputs and elevated precipitation.

Sea ice melt concentrations are lower, and more scattered.
Note can be negative as well as positive.

(Data from Jan 2011 Palmer LTER cruise)

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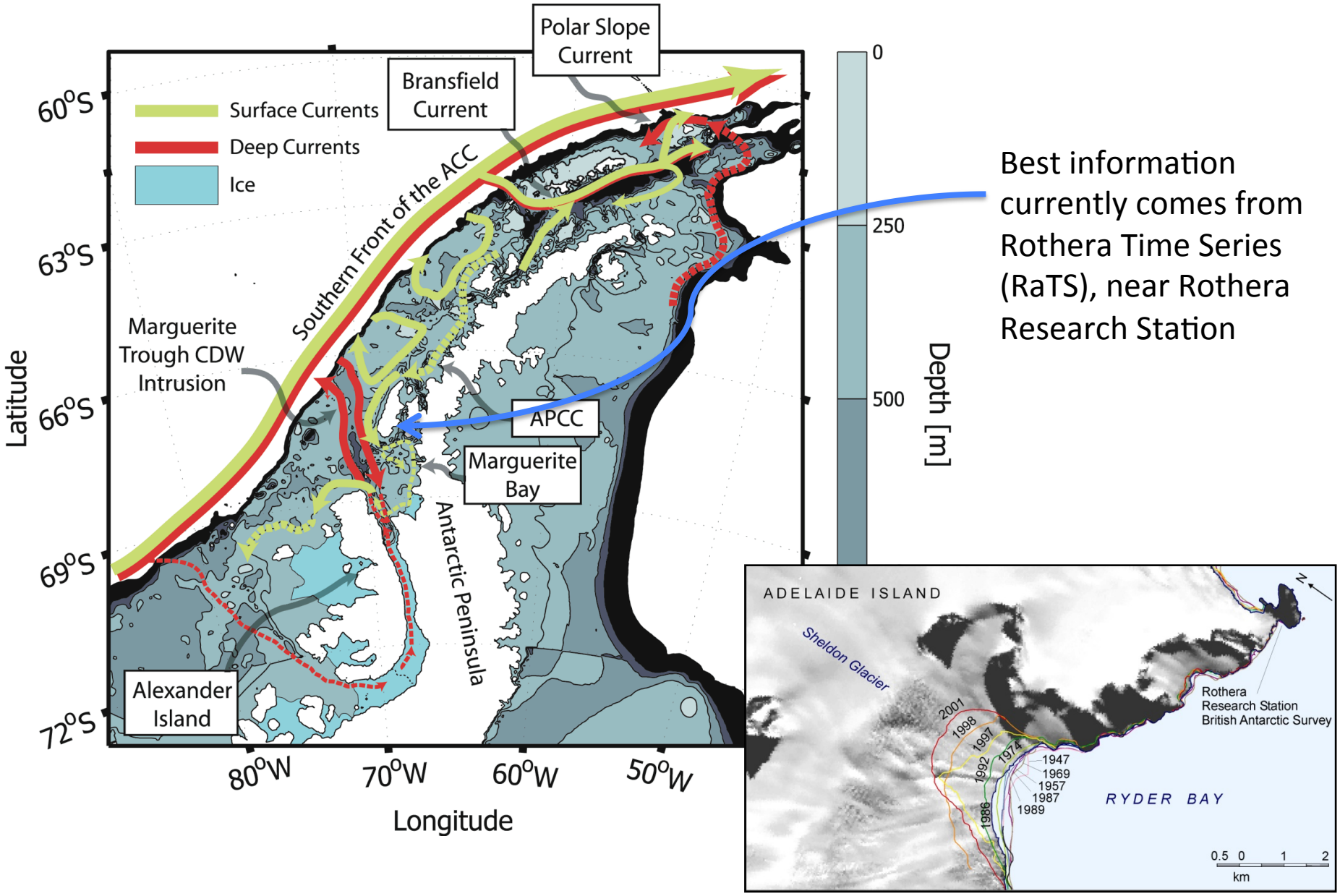
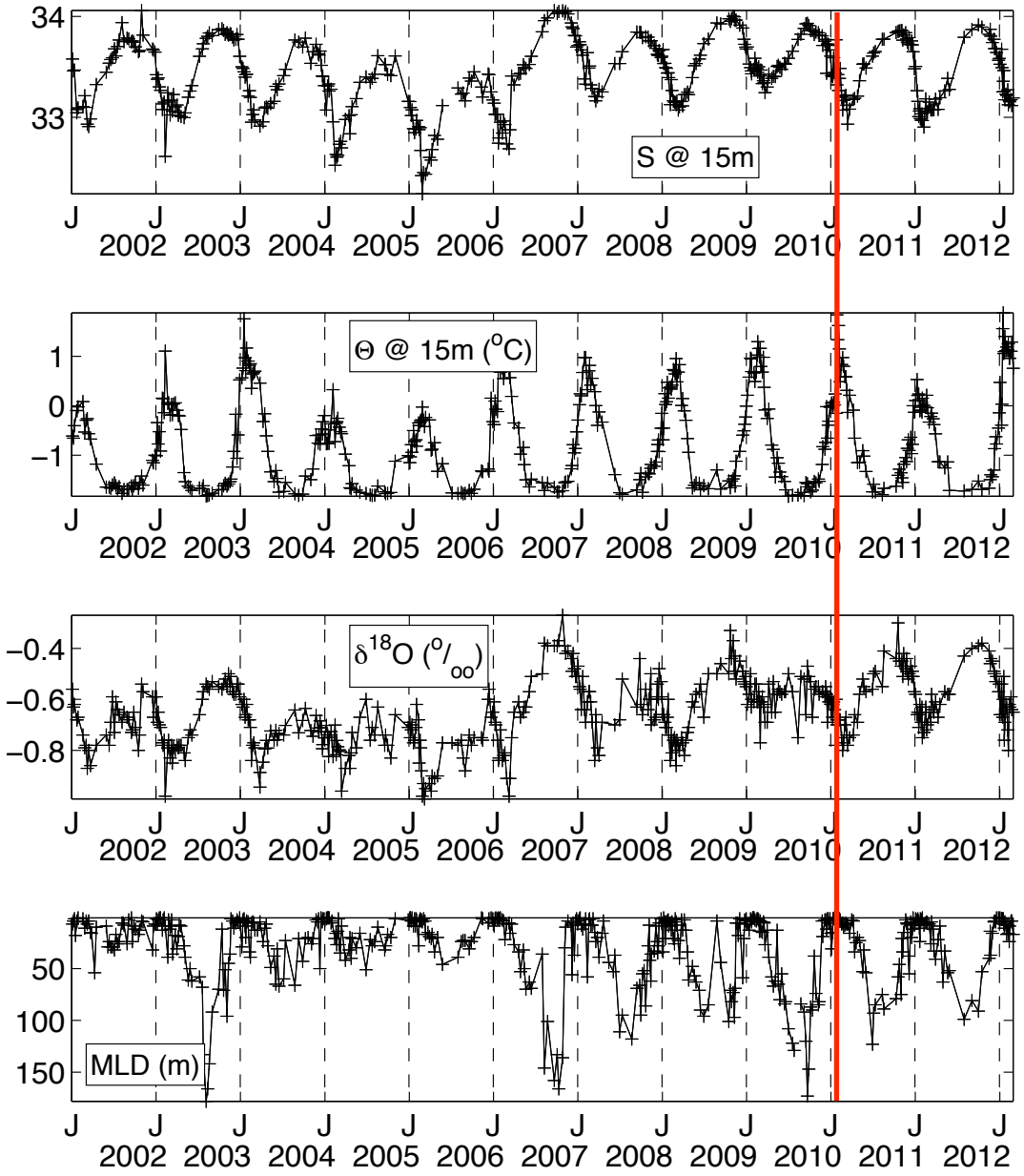
# But how are these things changing over time?






Data from quasi-weekly sampling at 15m depth at the RaTS site. Now >10 years data.

Naively, one might expect falling $\delta^{18}O$ (as precipitation and glacial discharge increase) - but does not appear to be the case.

(Note the deep mixed layers in winter 2003 and 2007 onwards…)

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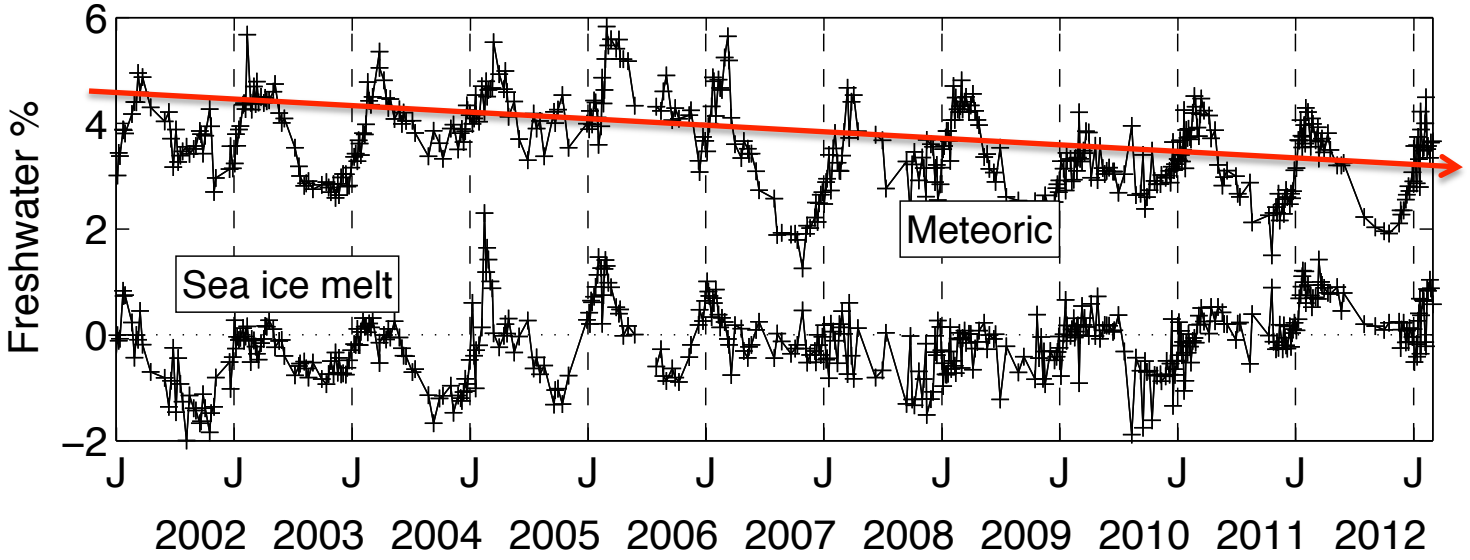
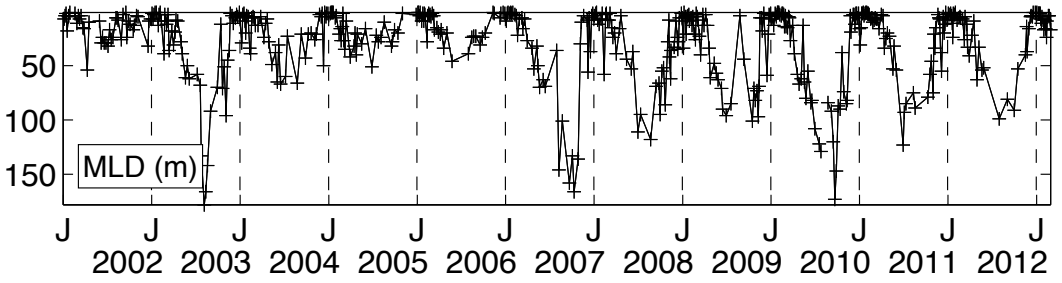
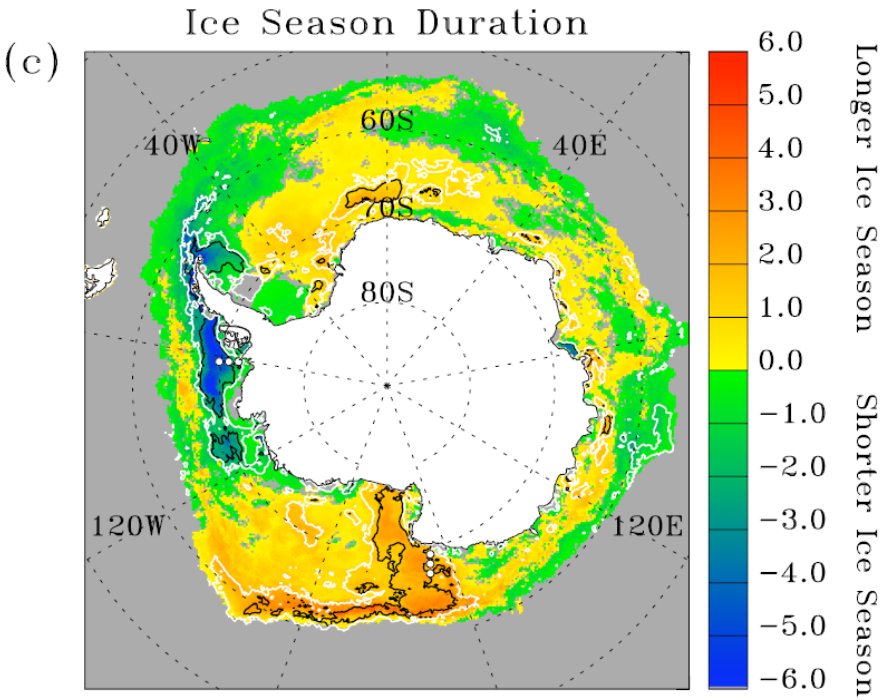



- Data allow quantification of the freshwater inputs as functions of time.
- Dominance of meteoric water input is confirmed year-round, and seasonality is as high as that of sea ice melt (and now higher?)
- *Falling* meteoric water percentages (even in summer). Why?

# Why is the meteoric water concentration *falling*?




Reduced sea ice cover allows greater ocean mixing. This distributes any material input over a greater vertical extent, including glacial melt.




This pattern is probably localised at the Peninsula at present, but …

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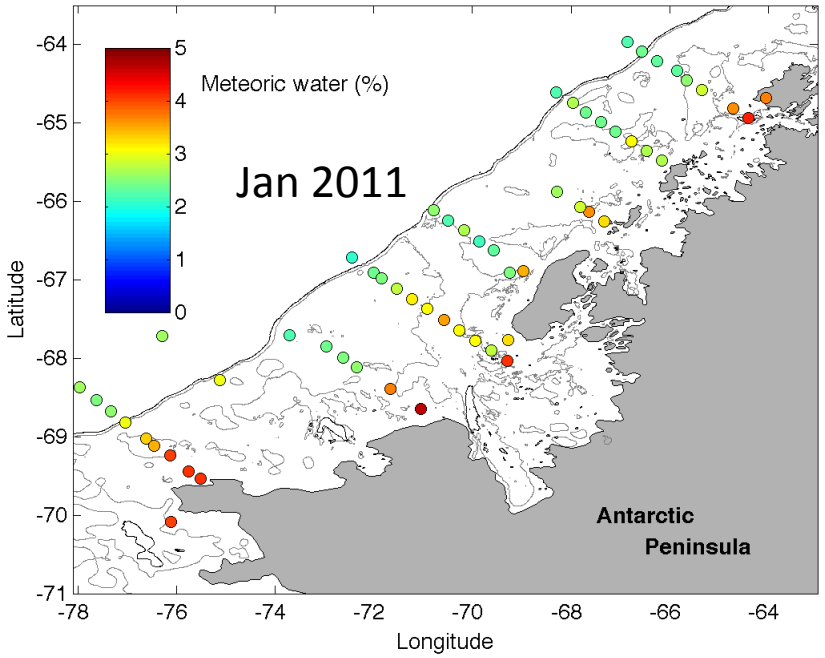
# Why does this matter…? Lots of reasons; here's one:-

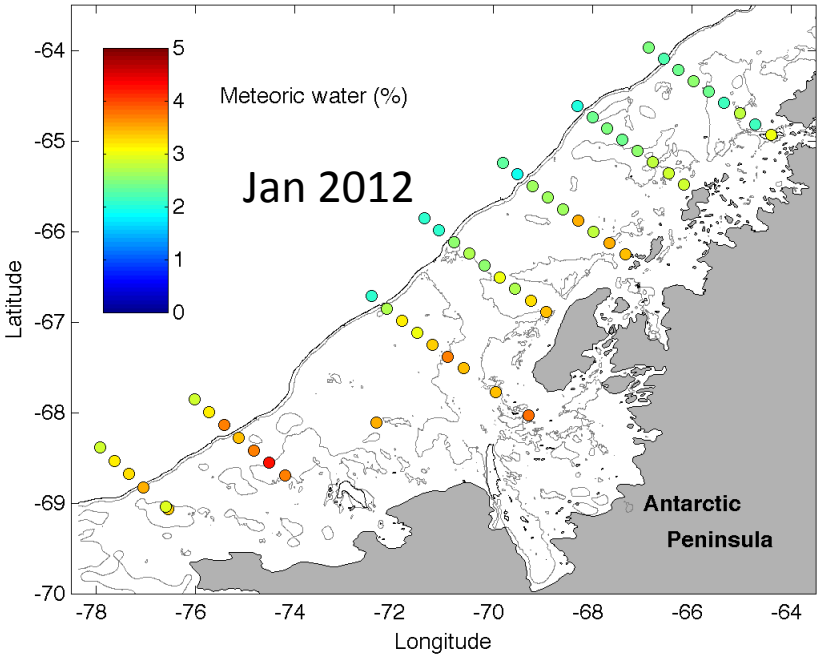
Recall that Southern Ocean glacial ice supplied to the ocean via melting icebergs can fertilise blooms (e.g. Raiswell et al., 2008), and Greenland & Antarctic glaciers can be a source of bioavailable iron for the ocean (e.g. Bhatia et al., *Nature Geoscience*, 2013).

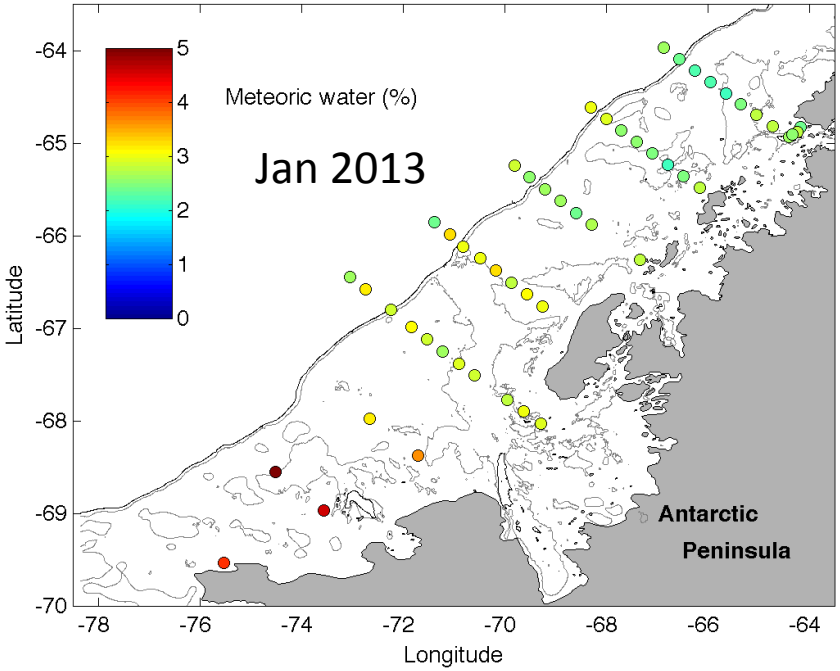
Several people have speculated how this might change in future, e.g.:-

"It is likely that ice sheets will provide a greater flux of bioavailable Fe to coastal regions as larger quantities of meltwater are exported to the oceans in a warmer climate"
(Hawkings et al., *Nature Comms.*, 2014)

Our work has shown that at the WAP, where we know there are increasing inputs from melting glaciers, the concentrations of the meltwater in the euphotic zone is *decreasing*, not increasing – because the ocean stratification is changing more rapidly.




Now getting large-area spatial information on how things are changing over time, from repeat Palmer LTER cruises….

Note the big decline in meteoric water in Jan 2013, c.f. 2011 and 2012. Why?

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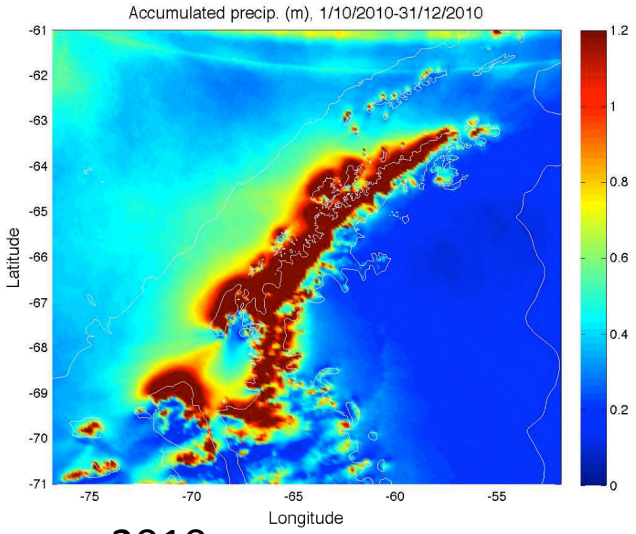
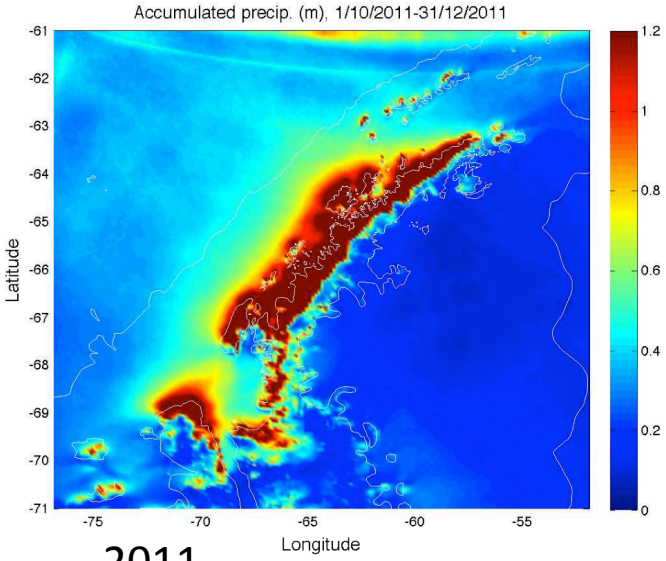


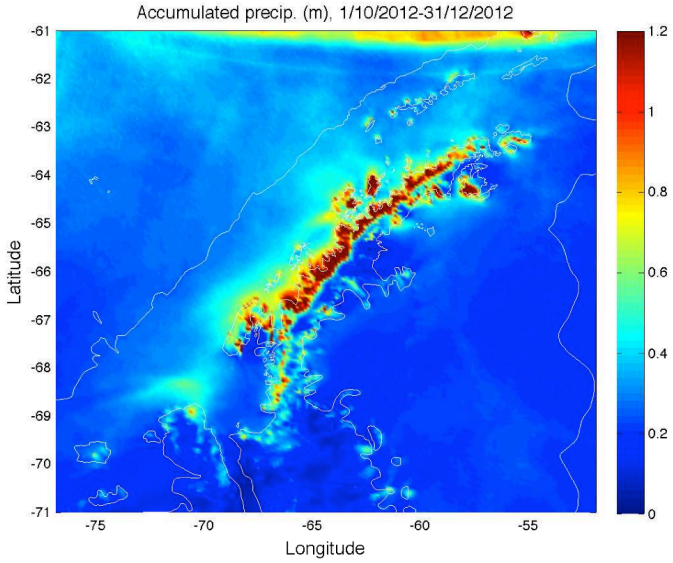

2010




2011

Accumulated precipitation

2012




Most likely explanation is the change in precipitation in the 3 months preceding the cruises……

Note the much smaller values in 2012 (c.f. 2010, 2011), associated with drier, southerly winds that predominated at this time.

⇒ Dialling down the precipitation can have a significant, rapid impact on the $\delta^{18}O$ fields.

⇒ Cannot assume that all meteoric water changes, even big ones, are due to glacial melt

# Summary

• The climate of the Antarctic Peninsula is changing very rapidly, and the freshwater system is a key component of this.

• Each of the freshwater inputs is changing differently, and needs to be understood individually if predictive skill concerning impacts is to be garnered.

• Meteoric water is more significant than sea ice melt, both in terms of mean levels and seasonality…

• Rapid deglaciation and precipitation increases at the western Peninsula are currently overcompensated by greater ocean mixing, with counter-intuitive results for where the freshwater ends up, and the impact it might have.

• This pattern is probably constrained to the Peninsula at present, but…?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Can we hear from
Nicolas now…?