The horizontal circulation, upwelling and heat budget of the Weddell Gyre: an observation perspective

Krissy Anne Reeve*, Torsten Kanzow, Mario Hoppema, Olaf Boebel, Volker Strass, Walter Geibert and Rüdiger Gerdes

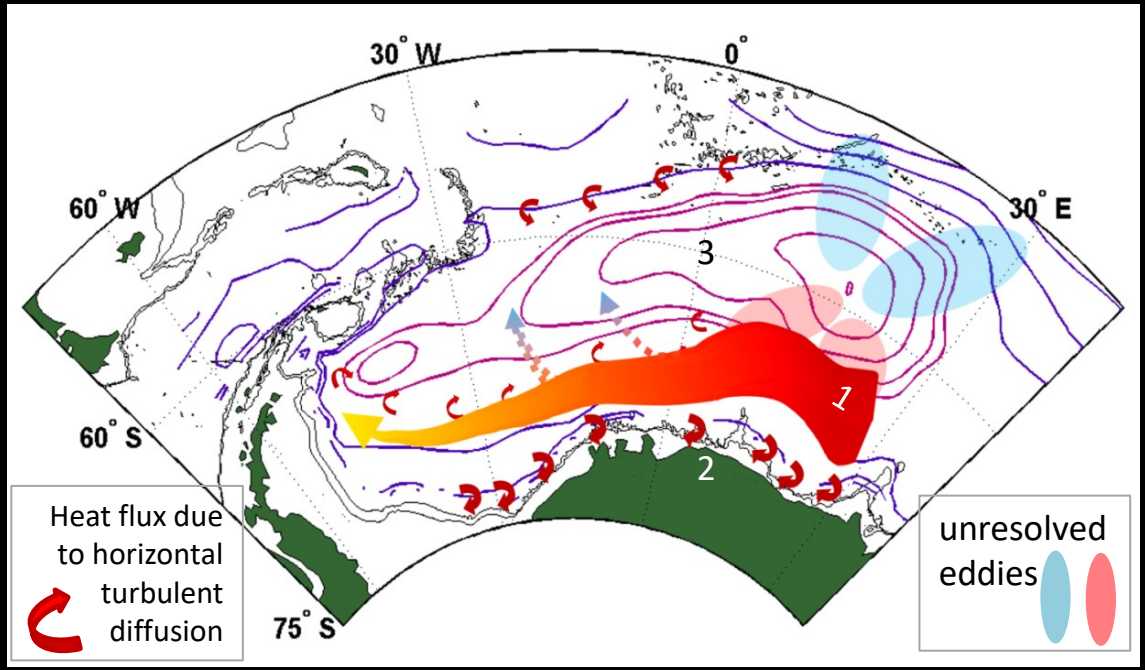
The horizontal circulation and heat budget for a layer within the Warm Deep Water were obtained using observations from Argo floats

Take-home Message

While heat primarily enters the gyre by horizontal advection (1), horizontal turbulent diffusivity appears to play a role in removing heat from the southern limb of the Weddell Gyre, towards the shelves (2) and towards the interior where upwelling takes place (3).

Open Question

What is the role of upwelling in the distribution of heat within the Weddell Gyre?



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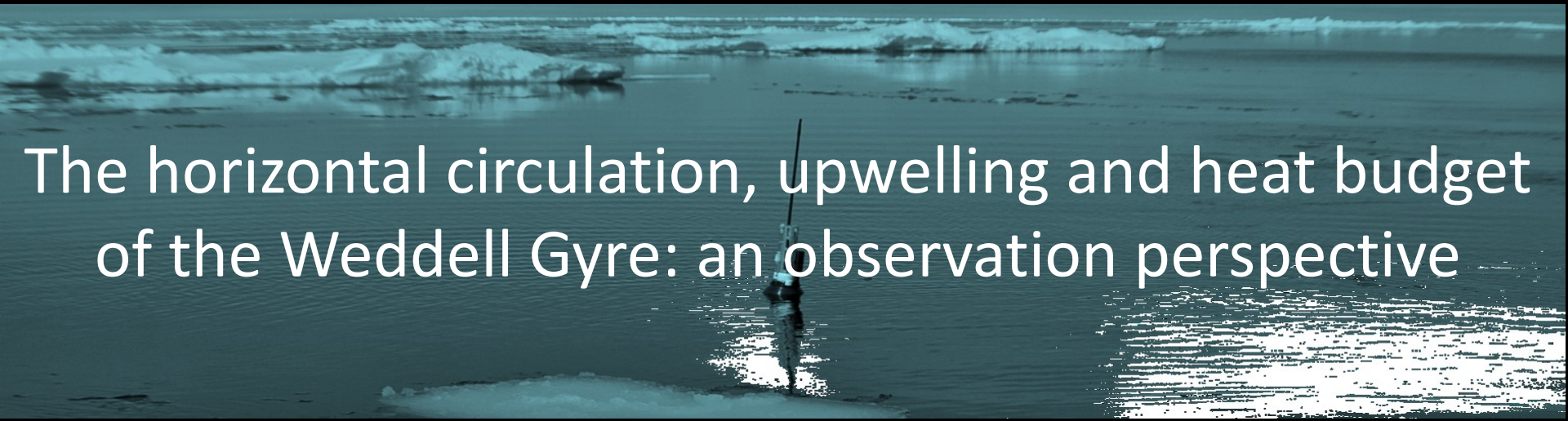

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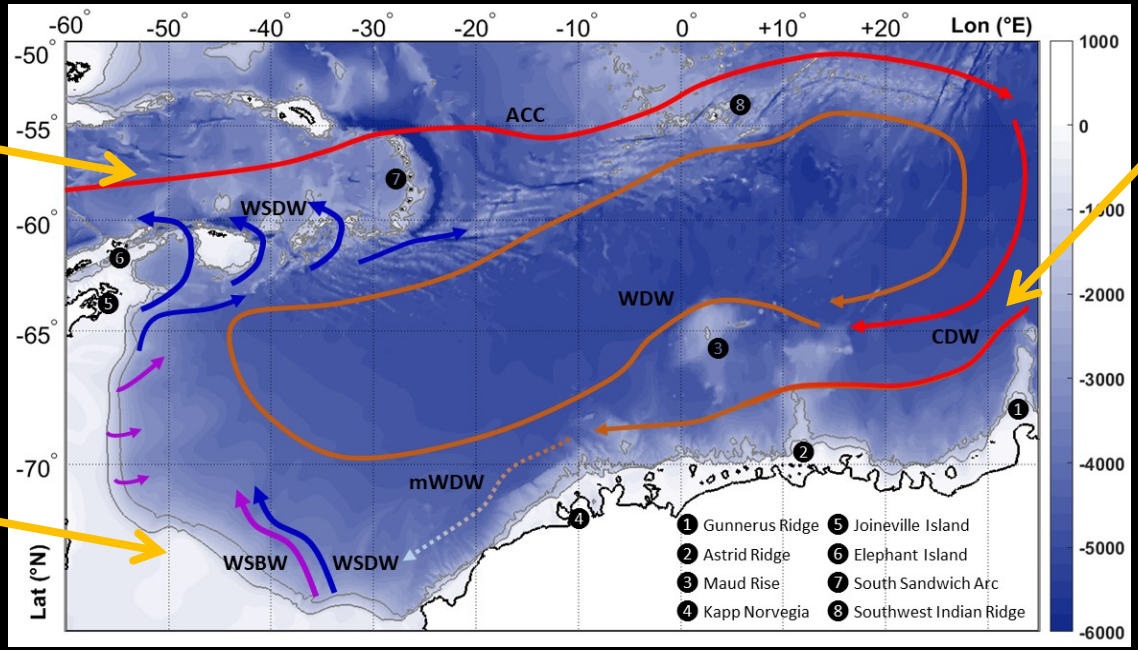
The Weddell Gyre is an important region in that it feeds source water masses (and thus heat) toward the ice-shelves, and exports locally and remotely formed dense water masses to the global abyssal ocean.

Export of locally (Weddell Sea Deep Water) and remotely formed Antarctic Bottom Water (AABW)

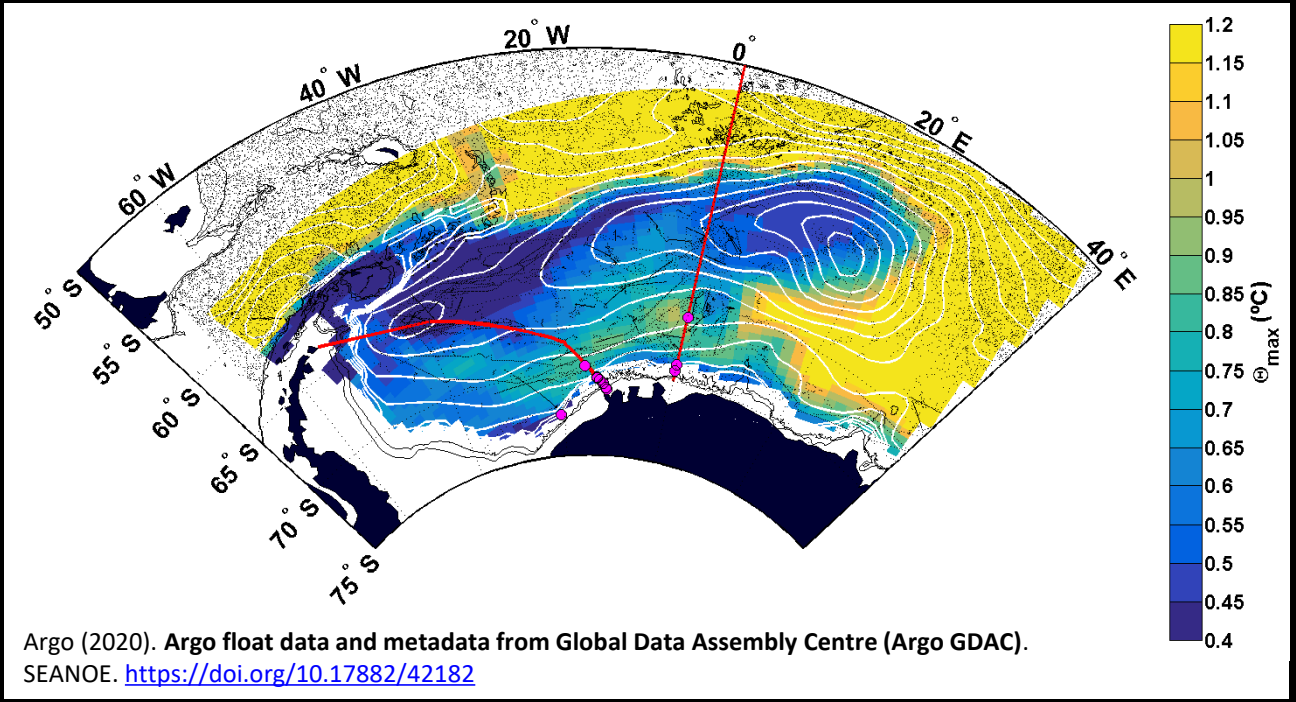
Weddell Sea Deep- and –Bottom Water formation within the gyre



Circumpolar Deep Water, warm and salty source water that enters the gyre from the ACC (Antarctic Circumpolar Current) which is then modified within the gyre

Bathymetry data: from the general bathymetric chart of the oceans (GEBCO, IOC et al., 2003)

Argo float profiles and trajectories were implemented to capture the large-scale, long-term mean circulation of the entire Weddell Gyre, from which the heat budget has been diagnosed for a layer within Warm Deep Water (WDW), the main heat source to the Weddell Gyre.

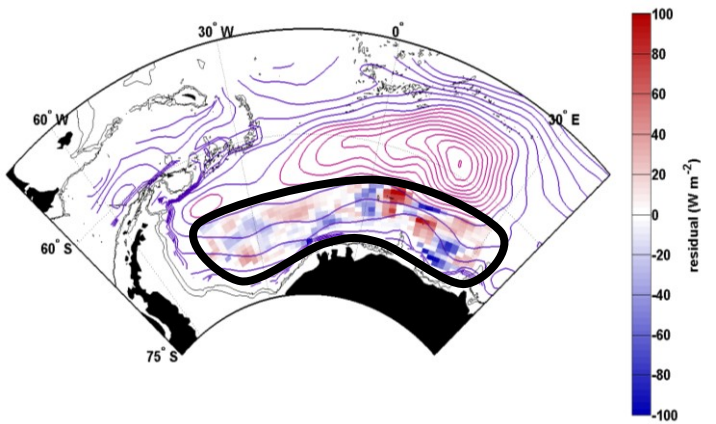


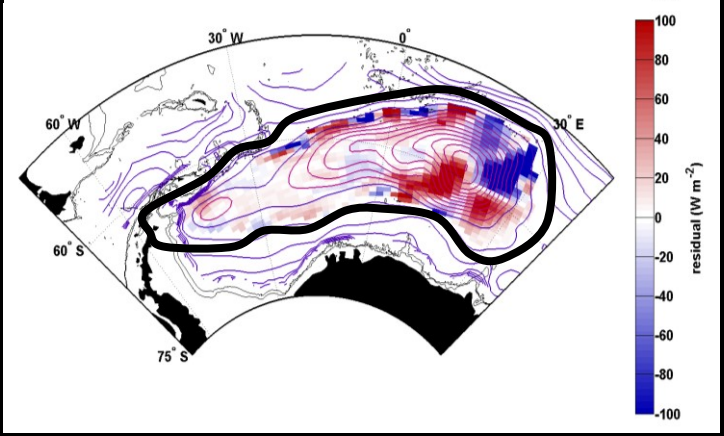
Argo (2020). **Argo float data and metadata from Global Data Assembly Centre (Argo GDAC)**. SEANOE. https://doi.org/10.17882/42182

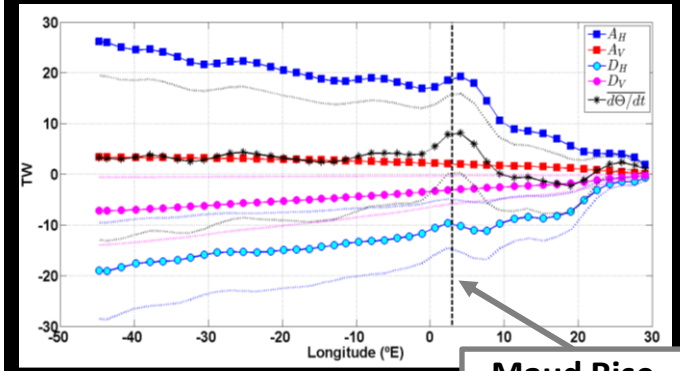
Black dots: Argo float profile from 2002-2016
Red lines: repeat ship transects
Pink circles: moorings

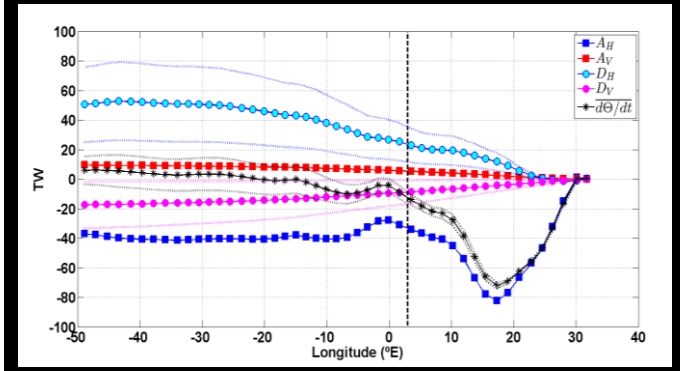
Colour: Sub-surface temperature maximum (i.e. the core of WDW), which is cooled as it circulates the gyre.

White contours: the streamlines for 50-2000 dbar, showing the double cell, elongated cylclonic circulation









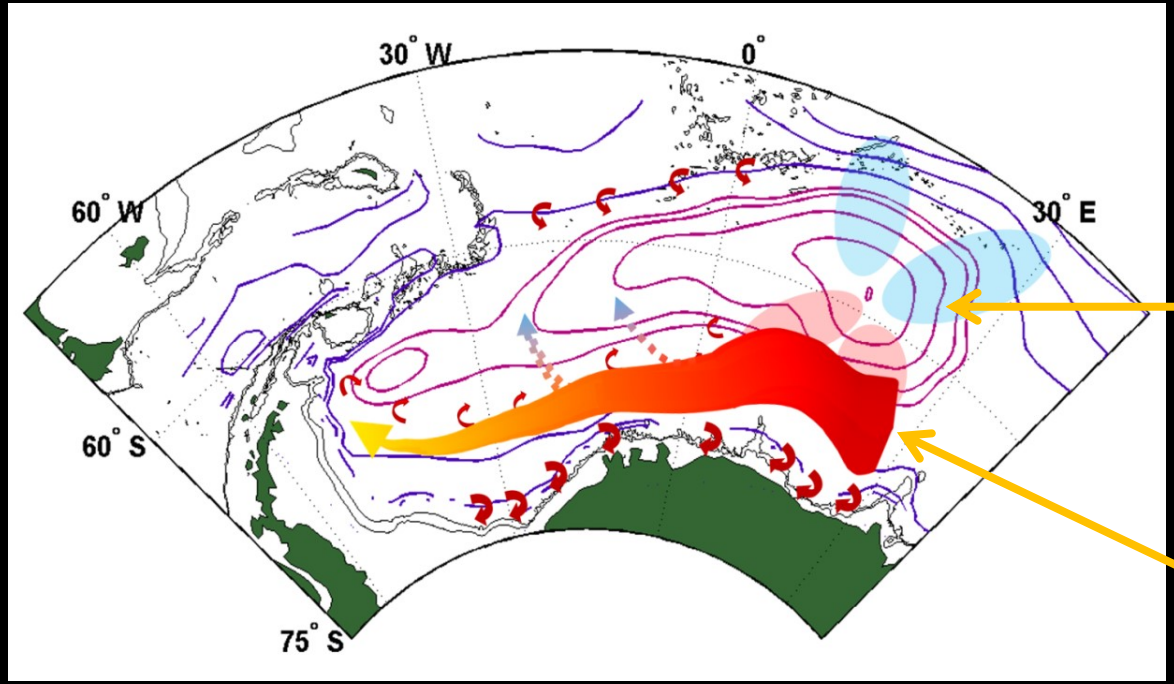
Heat budget horizontally integrated from East to West for the southern limb of the gyre and for the interior where streamlines form a fully enclosed circuit.

Heat budget nearly closes when integrated over large scales, but not for individual grid cells

Heat tendency

Horizontal mean advection	**Vertical mean advection**
Horizontal turbulent diffusion	**Vertical turbulent diffusion**

Heat is horizontally advected into the southern limb of the Weddell Gyre, and then removed from the southern limb by horizontal turbulent diffusion (1) northwards towards the gyre interior, and (2) southwards towards the ice shelves.

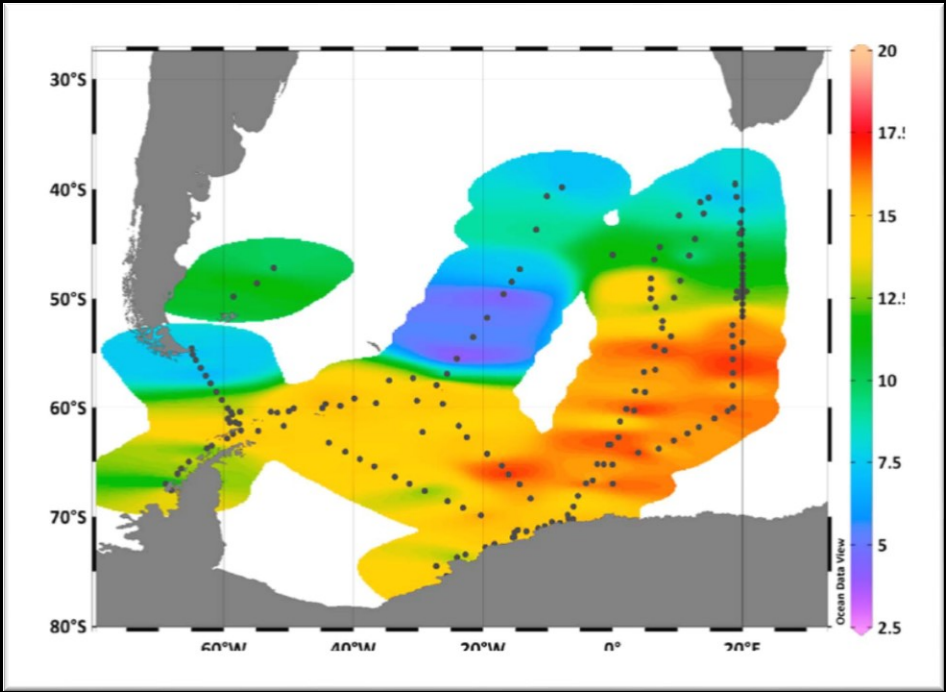


Heat flux due to horizontal turbulent diffusion

Red and blue ellipses indicate unresolved eddies, interaction between “cold” and “warm” regime WDW waters

Advective pathways of heat along the southern limb (1) towards the southern and western Weddell Gyre, and (2) northwards towards the interior east of 30°E

Since the gyre is cyclonic, the heat that is turbulently diffused into the gyre interior is subsequently brought closer to the surface by upwelling. Upwelling is thus an important yet poorly understood feature of the dynamics of the Weddell Gyre.

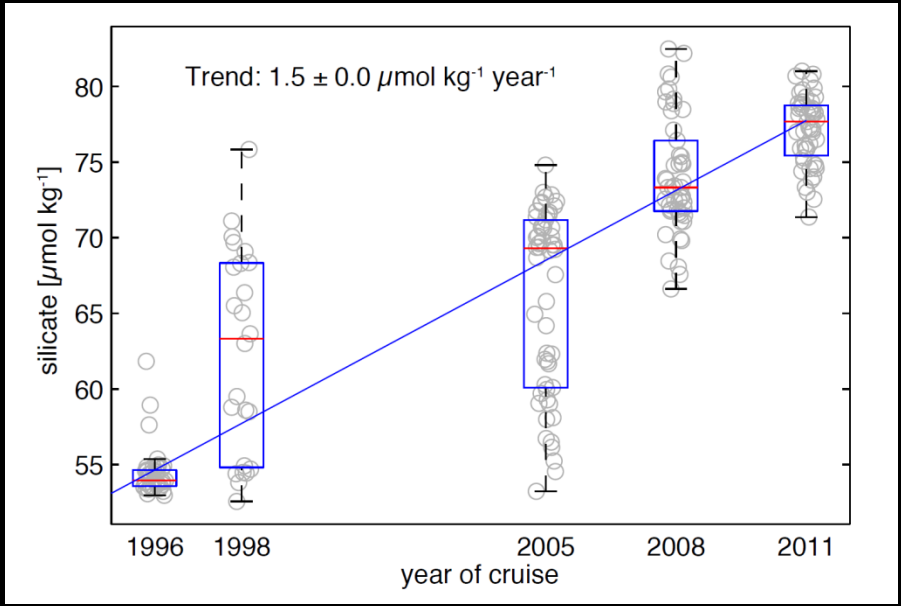


Distribution of 226Ra (dpm/100-kg seawater) in the surface layer of the Weddell Gyre, whose main source is the deep-sea floor (half life, 1600 years; data from Hanfland, 2002; Schlitzer, R., Ocean Data View, odv.awi.de, 2018). Its distribution reflects the effect of deep upwelling, which is more pronounced in the eastern part.

From Vernet et al. 2019

The work presented marks the beginnings of a project focused on improved understanding of the role of upwelling and of turbulent diffusion in redistributing heat towards the central gyre interior, as well as towards the ice shelves of Antarctica.

Silicate trend in surface water 40ºW–20ºW; 0–80 m
Hoppema et al., 2015:



Could increased surface nutrient concentrations in recent years be caused by increased upwelling of nutrient rich sub-surface waters within the Weddell Gyre?

increase in 15 years: nitrate 1.5 μmol kg^{-1}
phosphate 0.05 μmol kg^{-1}

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