Assessing Unstoppable Change: Ocean Heat Storage and Antarctic Glacial Ice Melt

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Motivation

Role of Antarctic glacial melt recently shown to be accelerating to the point of contributing as much to global sea level rise as Greenland. Acceleration has been attributed to warm deep ocean waters melting base of ice shelves of the ice streams draining West Antarctic Ice Sheet. ***Long term objective: what is source of the deep ocean heat, its pathway to west Antarctic coastline and its potential for future sea level rise (i.e., can it be stopped).***

Project Goals

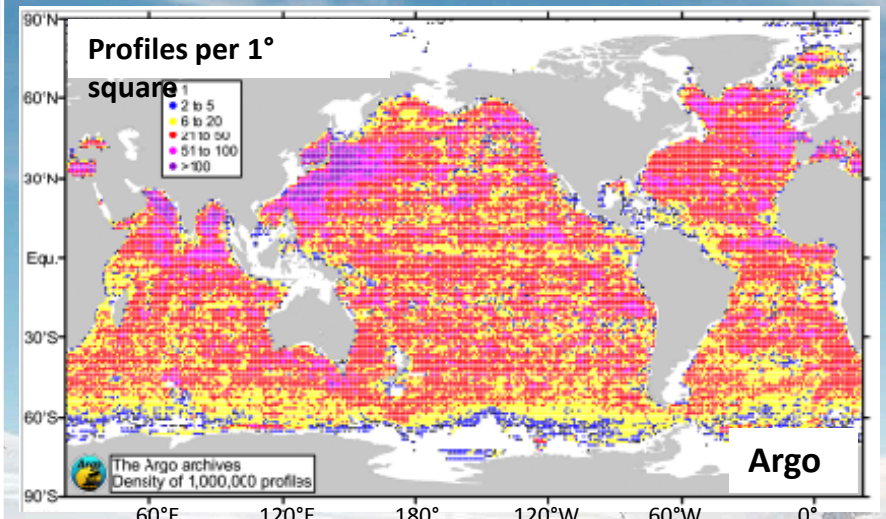
Warm deep water is: ***UPPER CIRCUMPOLAR DEEP WATER (UCDW)*** presumed to form somewhere in the South Pacific.

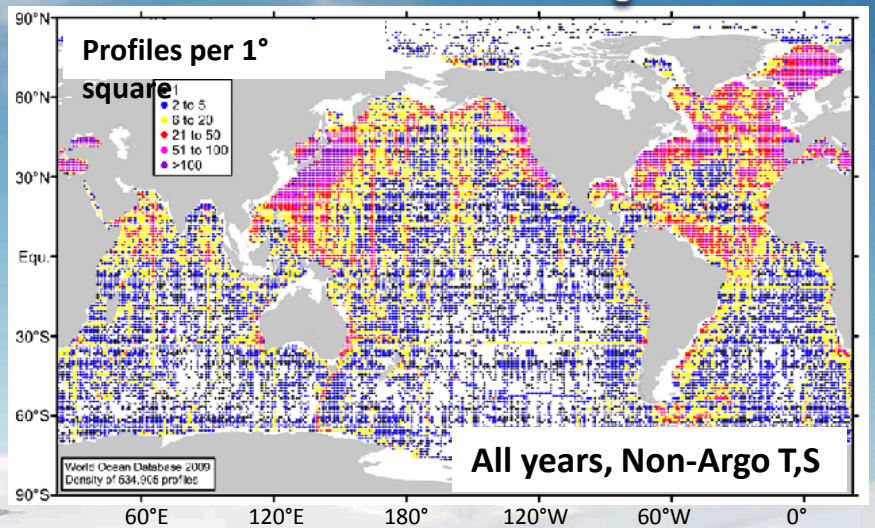
#1 What is ***transport*** of water from South Pacific to the south.

#2 How has UCDW warmed, what are the paths for delivery to continental shelves, and ***mechanisms*** for getting onto the shelves for access to ice shelves near coast.

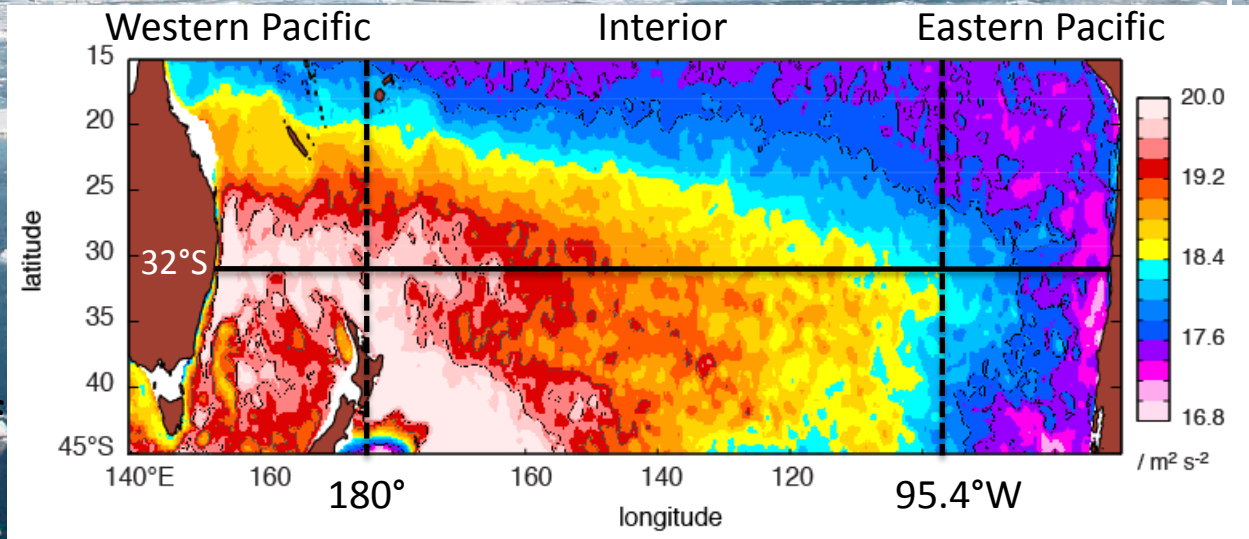
Goal #1

≥2000m volume and mass transport



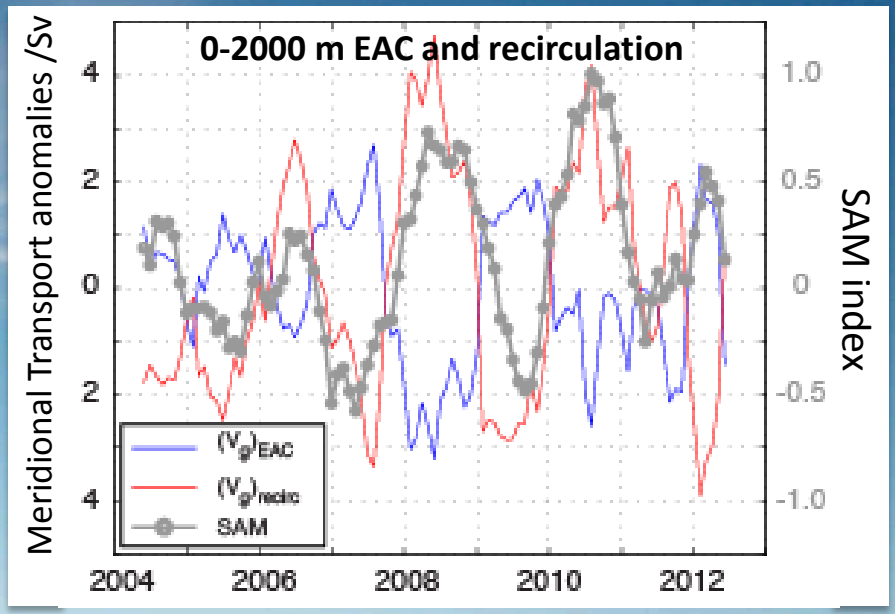


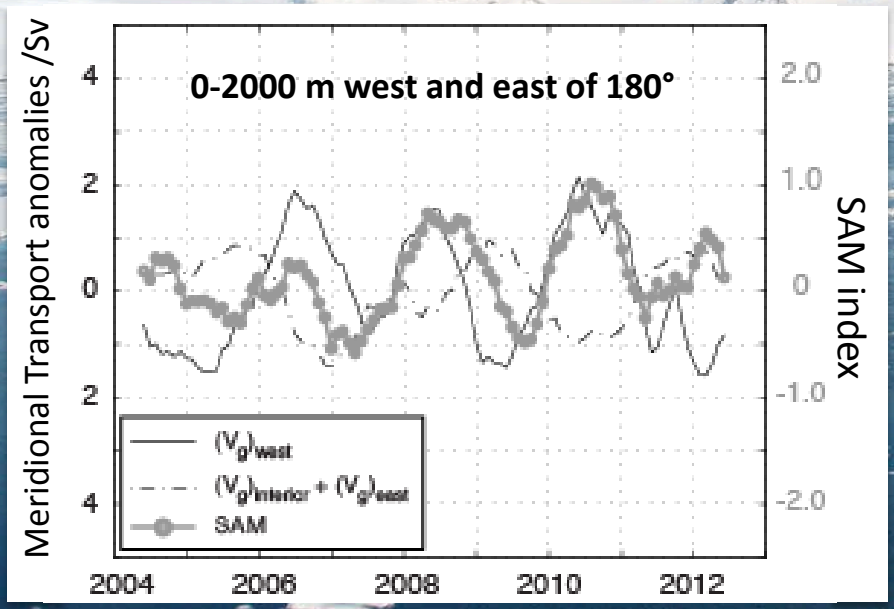
- **Method: Argo and Altimetry data (AVISO)**
- **Improve estimate of ≥2000 m volume and mass transport across 32˚S**
- **Investigate time-variability of estimate 2004-2012 using Argo and Altimetry.**

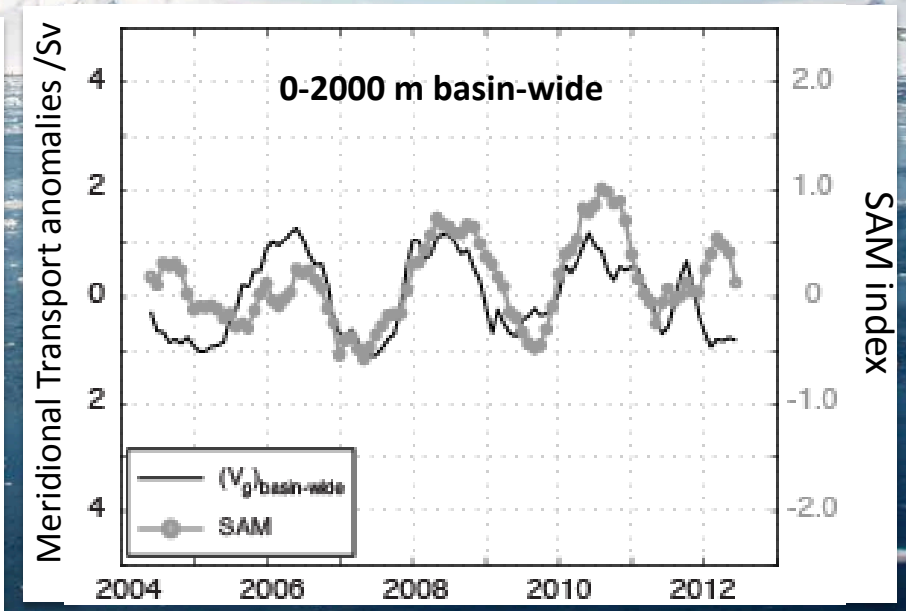


0-2000 m geostrophic transport anomalies at 32°S

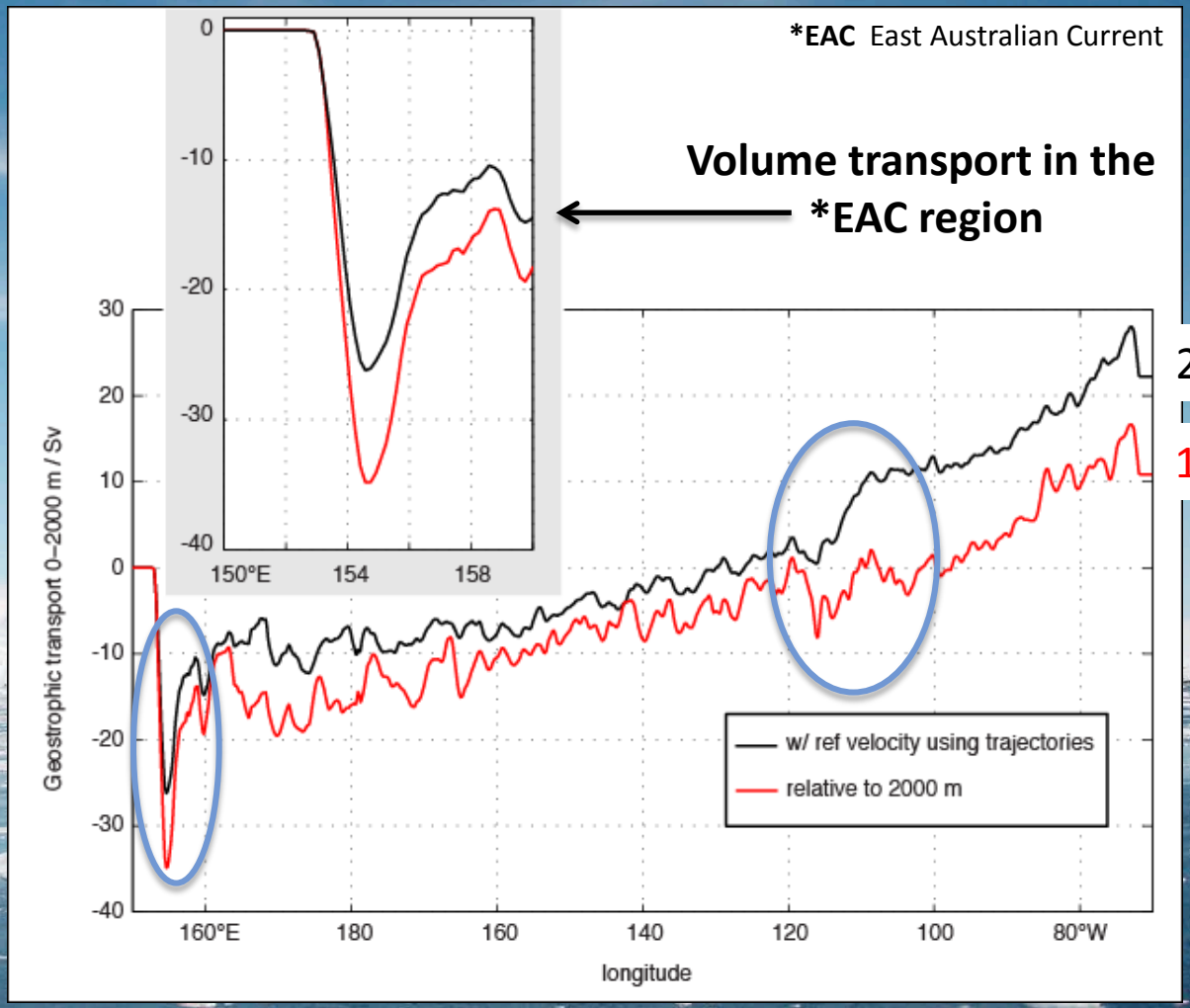
All locations covary with SAM





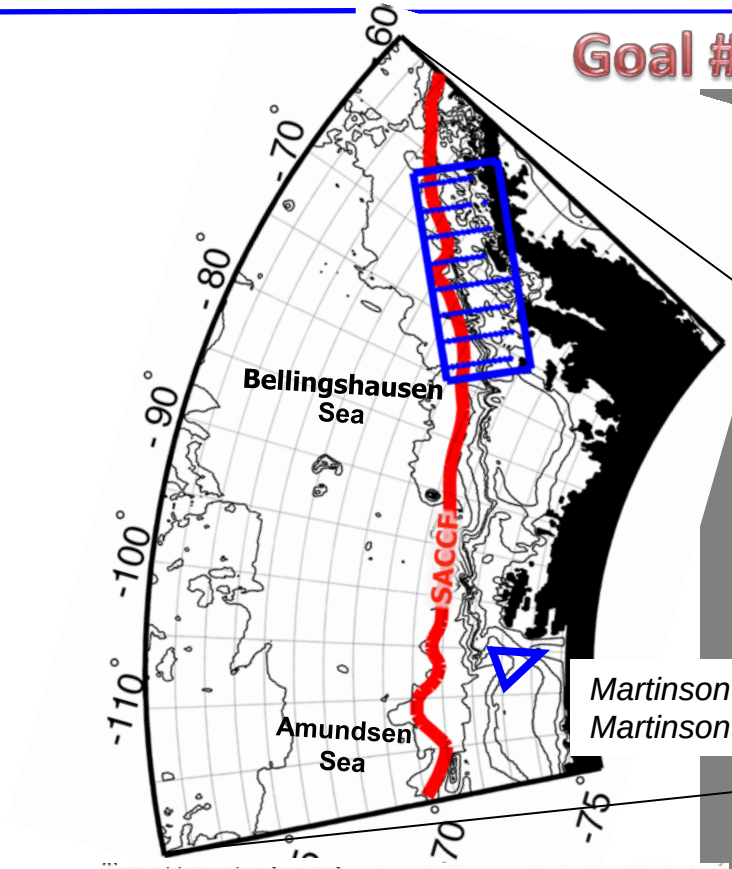


2004-2012 mean volume transport at 32°S

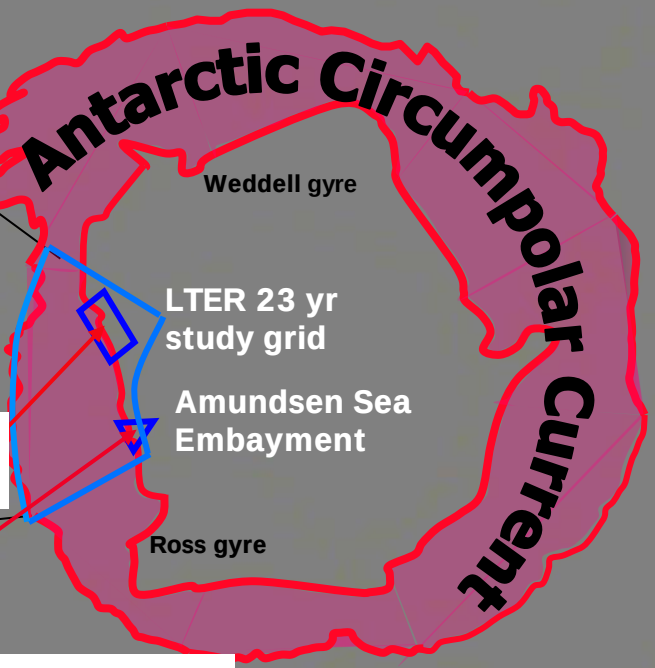


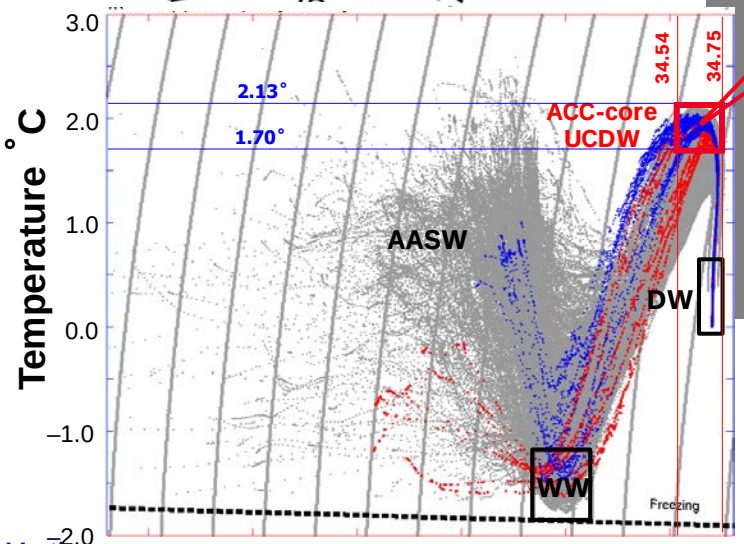
Basin-wide 0-2000 m volume transport with level of no motion at 2000 m depth is 11.4 Sv lower than computed using float trajectories.

Goal #2: UCDW delivery to WA and onto shelf



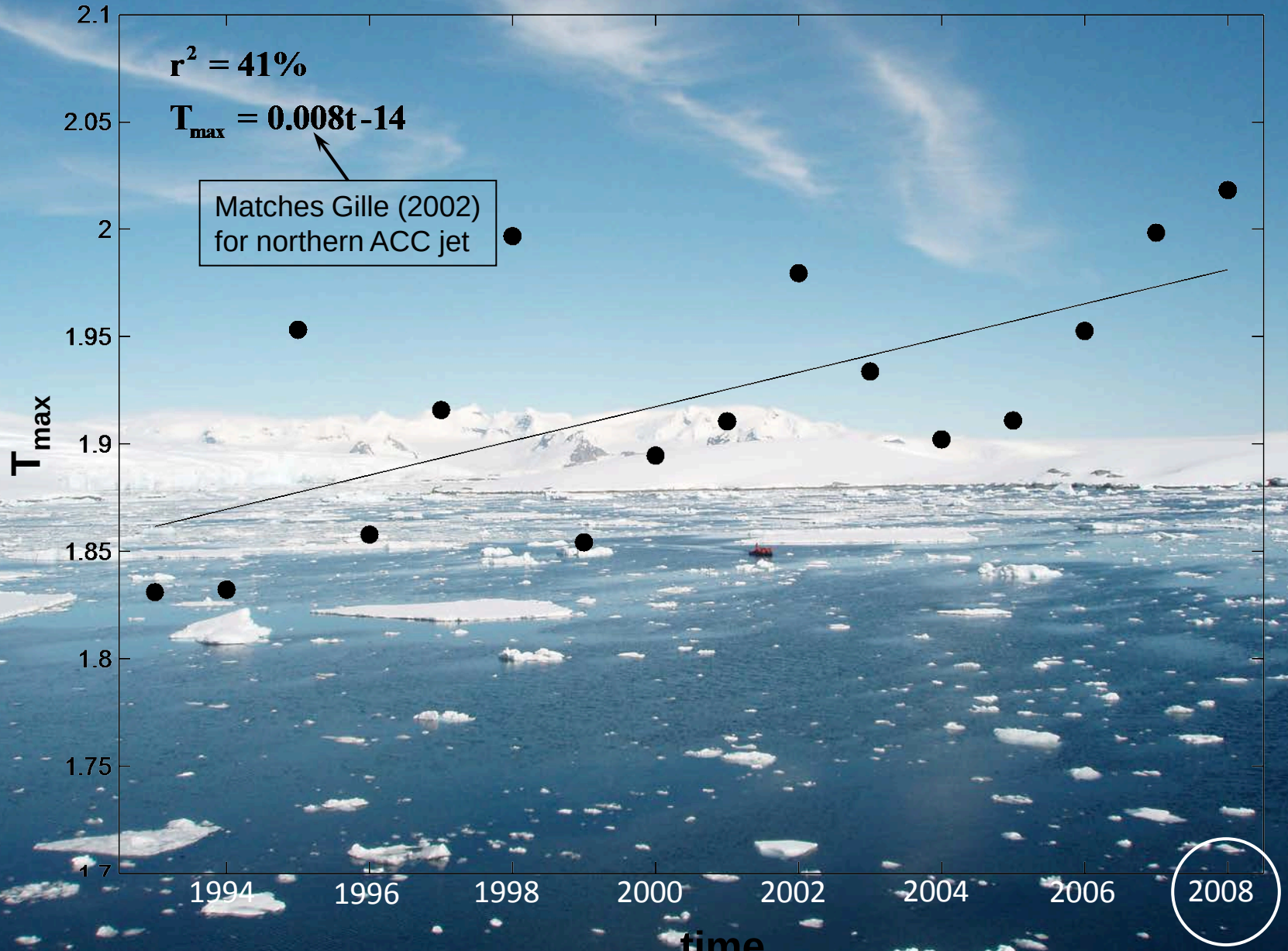
Martinson et al., 2008
Martinson & McKee, 2012

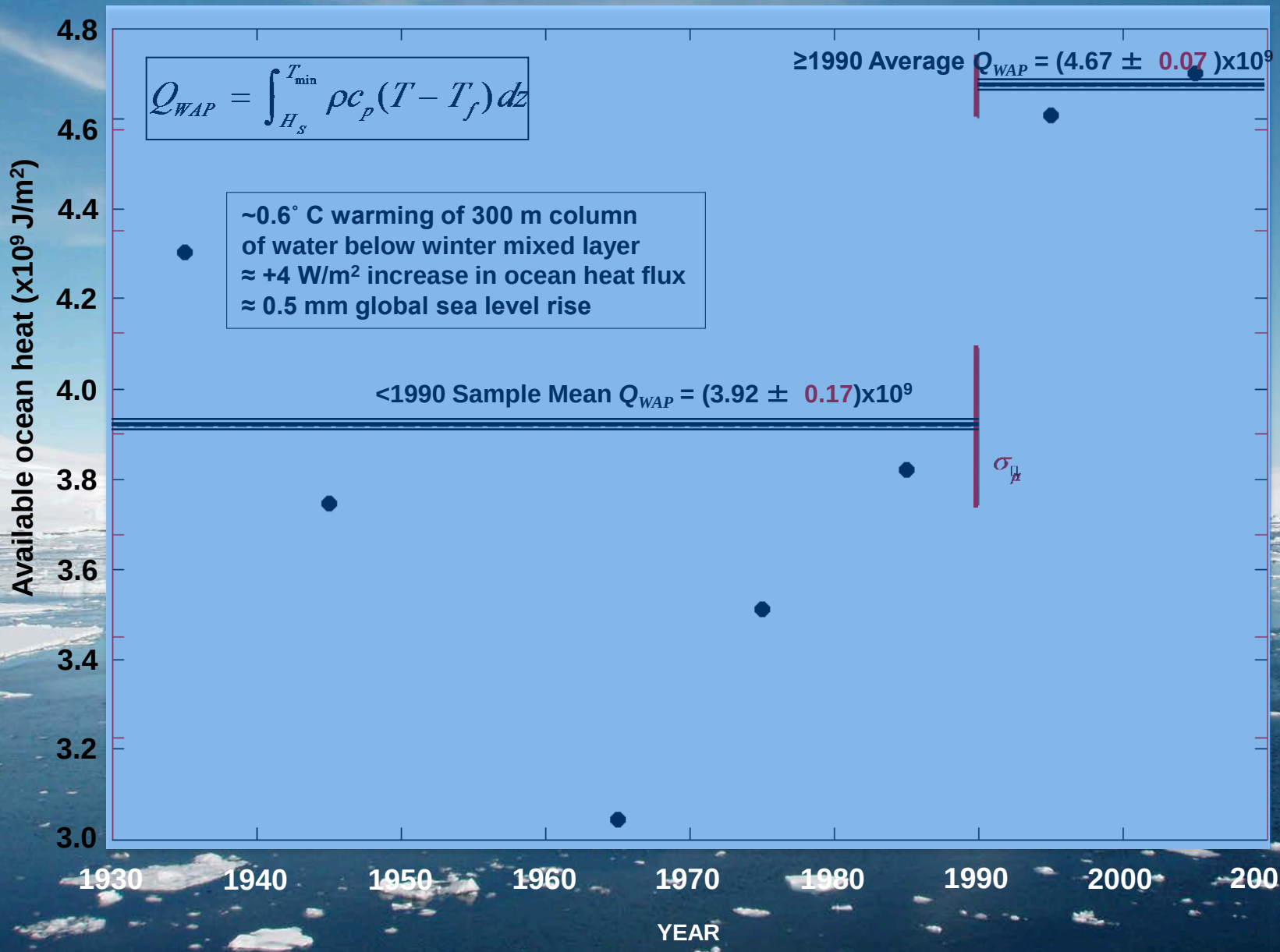




Jacobs and Hellmer, 1986
Payne et al., 2004
Shepherd et al., 2002
Thoma et al., 2008
Jacobs et al., 2011

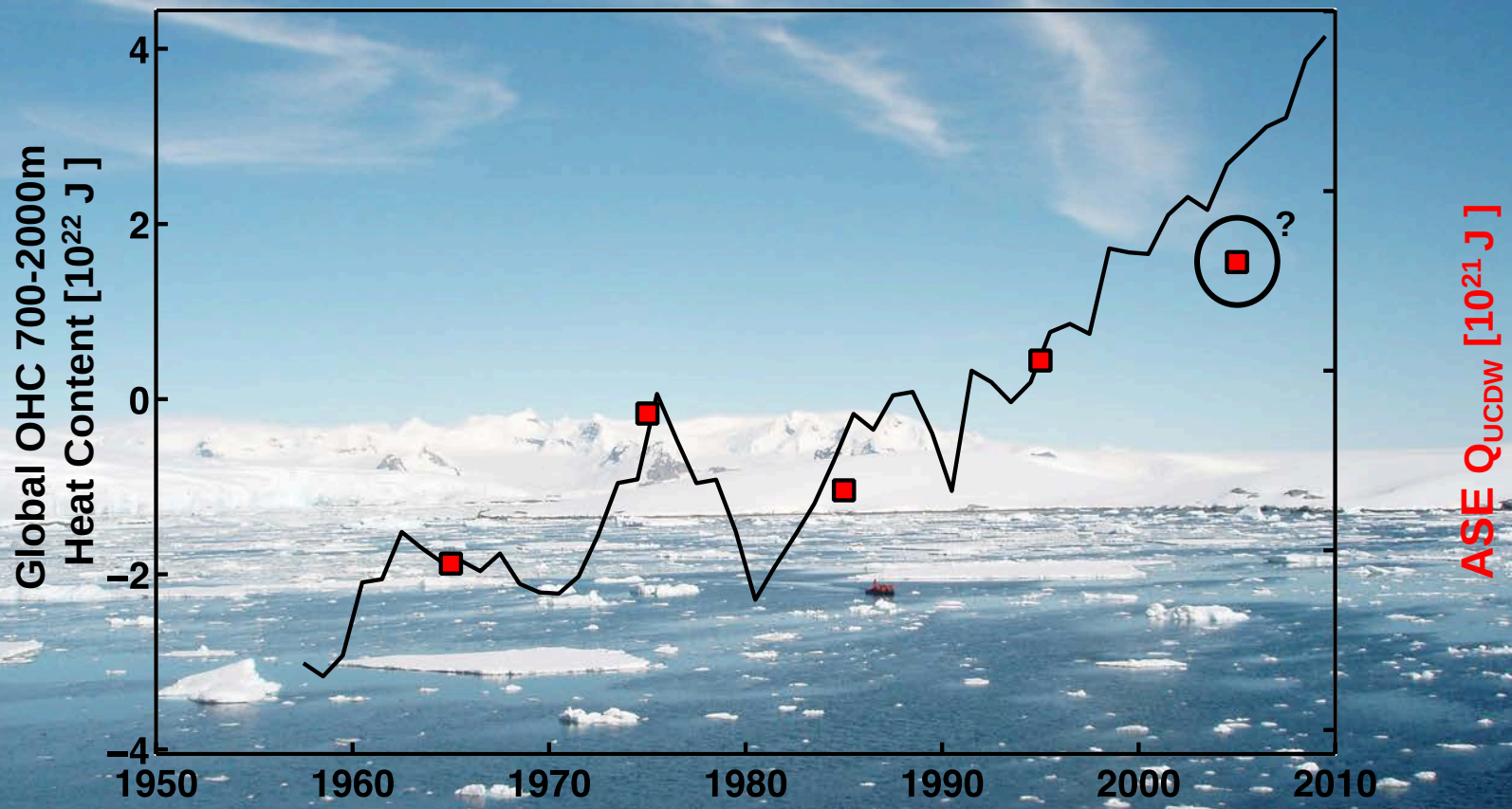
UCDW warming with time (as delivered by ACC)





Q from *Martinson et al.*, 2008

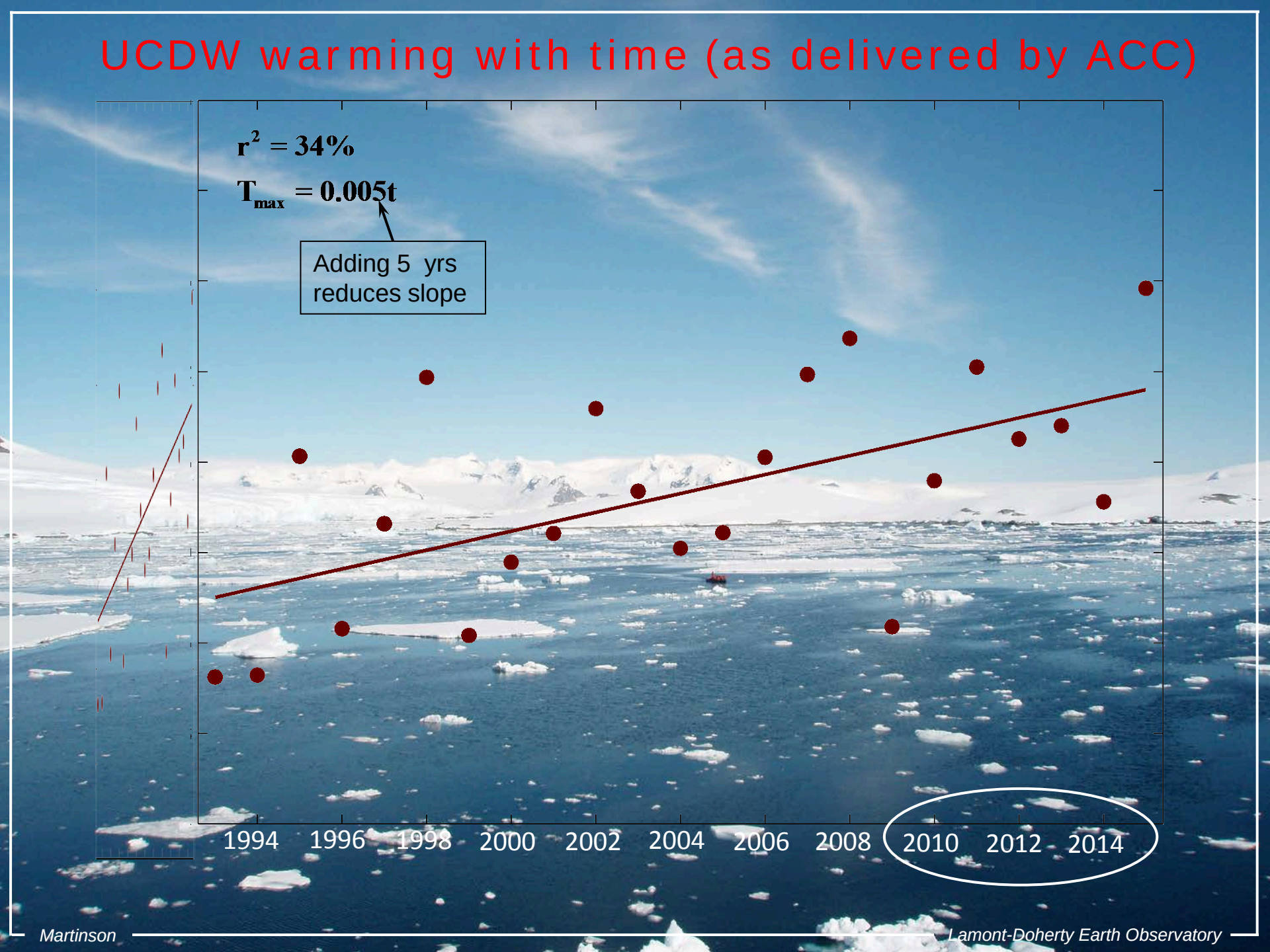
New 700-2000m Global Ocean Heat Content (vs ASE)



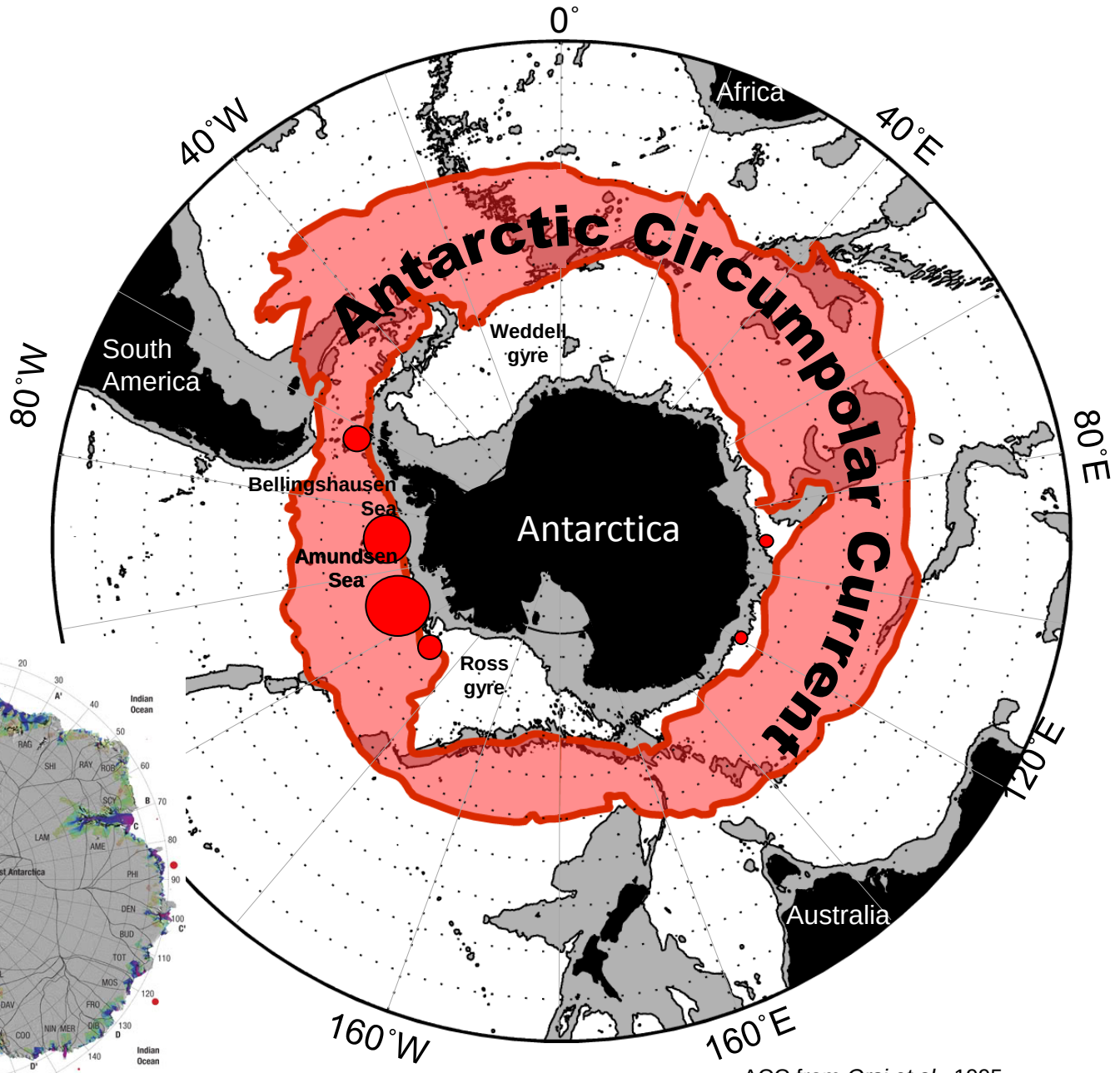
NOAA/NESDIS/NODC Ocean Climate Laboratory
Levitus et al., 2012

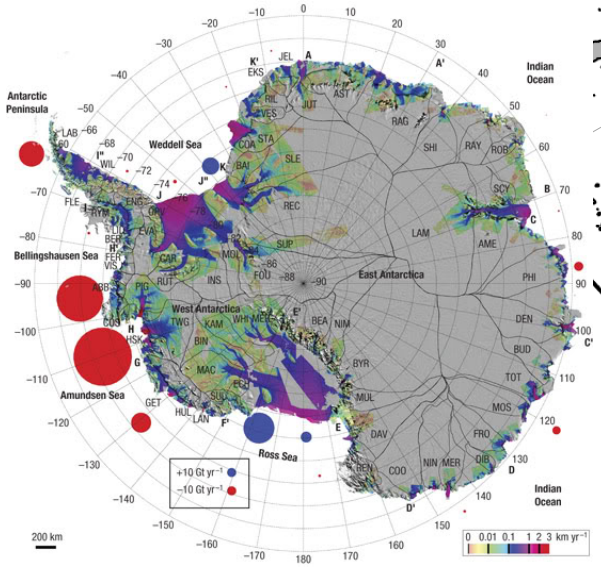
$$Q_{UCDW} = \int_{WW}^{-300} \rho c_p [T(z) - T_f] \, dz$$

UCDW warming with time (as delivered by ACC)

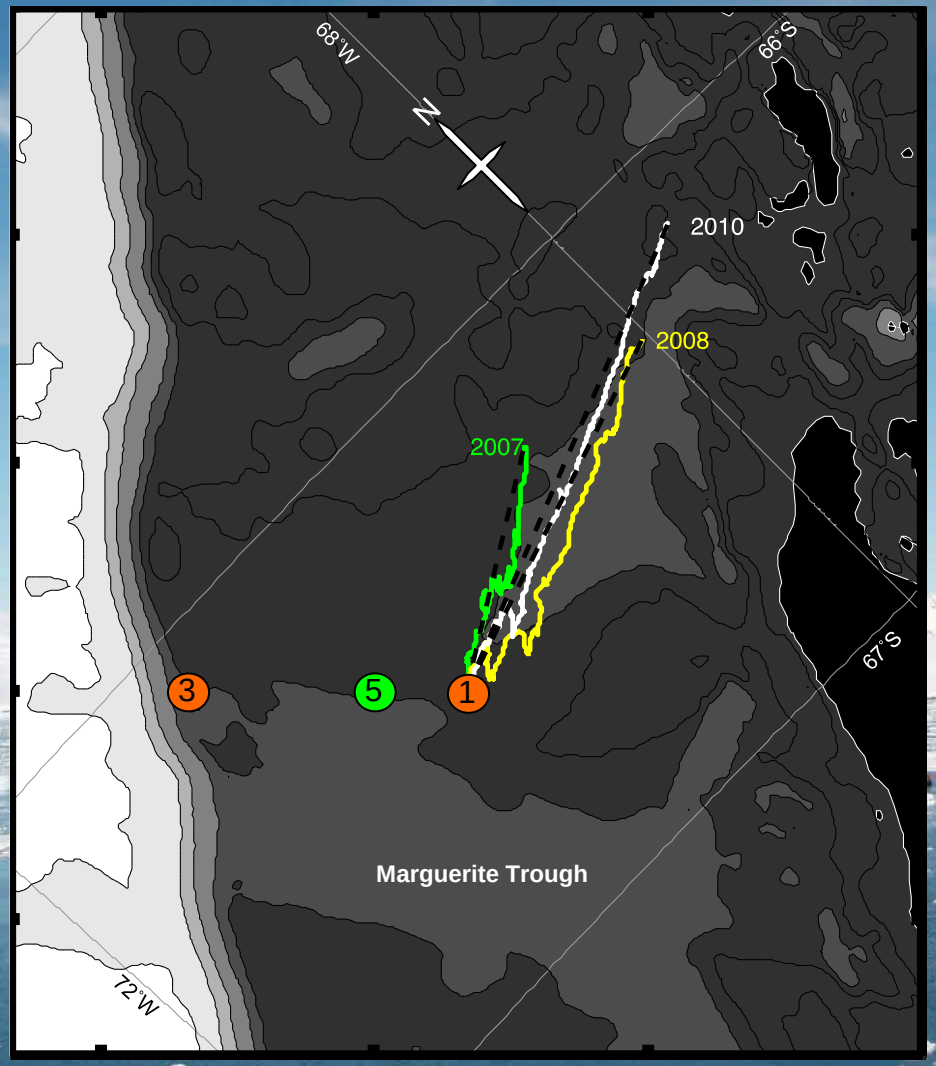


10 gigatons per year





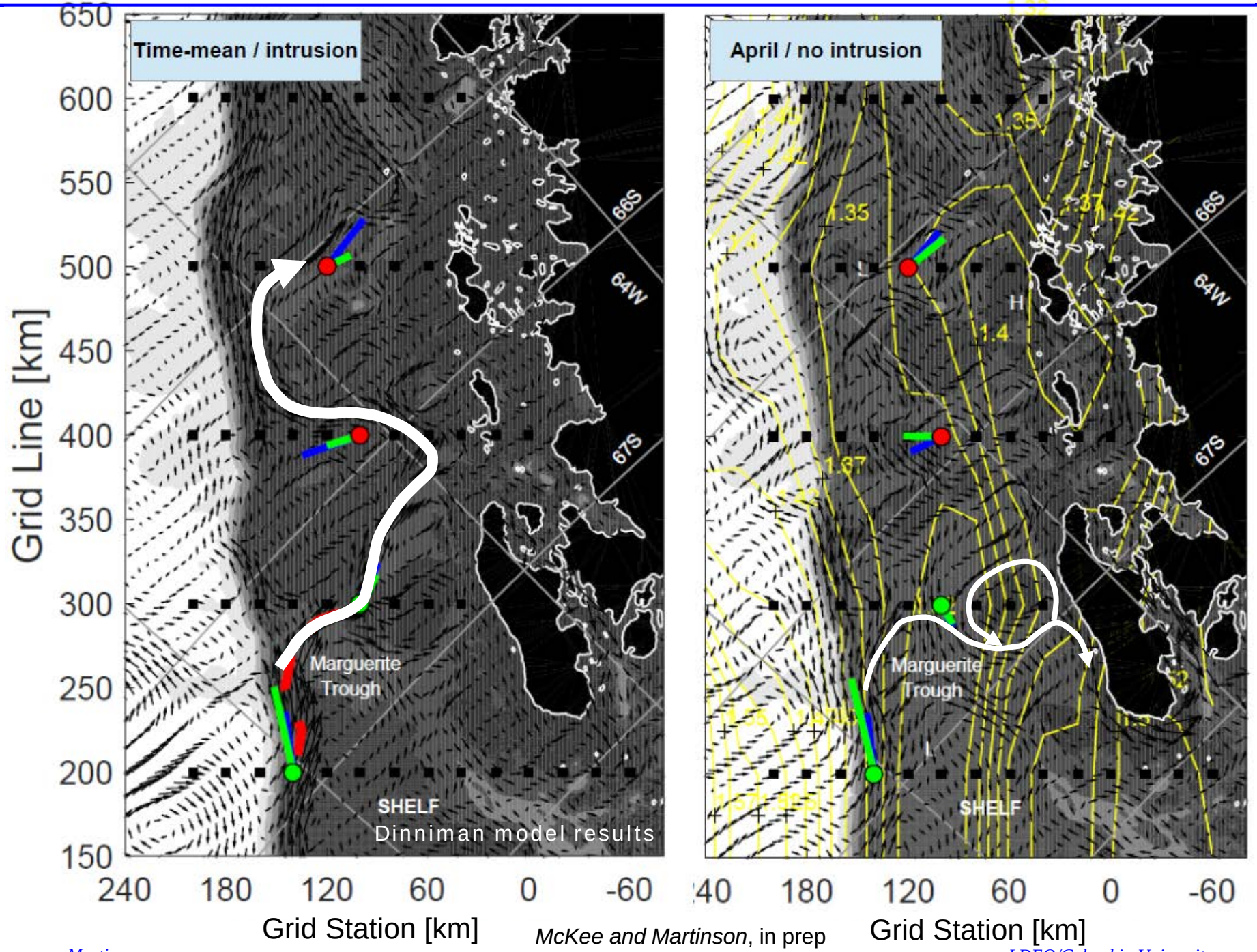
ACC from *Orsi et al.*, 1995
Glacial melt from *Rignot et al.*, 2008



Wind bursts drive UCDW onto continental shelf via intrusions that enter Marguerite Trough near midpoint of our sampling grid. Nonlinear terms ( ) associated with the advective burst allows flow to cross *f/h* contours and enter shelf proper steered to the north.

In absence of intrusions, water stays in trough, cutting across shelf through Marguerite Bay to deep south, ineffective to getting to southern shelf (though other canyons may allow entry to southern shelf farther south; need better bathymetry to know).

Martinson and McKee, Ocean Science, 2012
McKee and Martinson, in prep.



McKee and Martinson, in prep

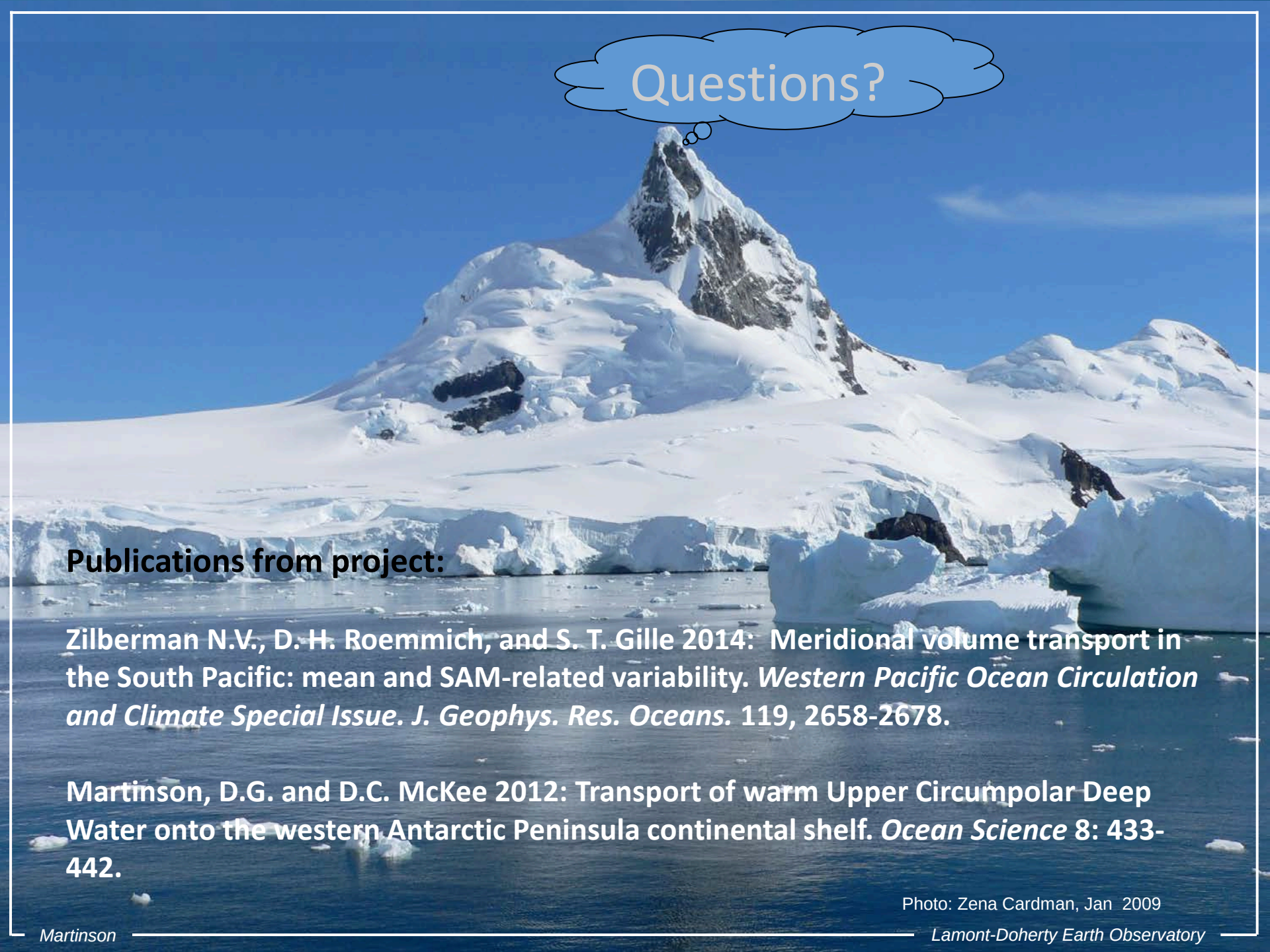
Conclusions:

Results #1: **Argo floats give improved estimates of 0-2000 m transport in midlatitude South Pacific, showing 20-26 Sv toward the south in the EAC, or 20.8±6 SV basin-wide (10 Sv larger than previous estimates).**

East Australian Current and it recirculation covary with wind-stress curl tied to the SAM.

Results #2: **Marine glaciers in western Antarctica are accelerating in their melt rate due to warm underlying waters. 1300 km downstream, along the Antarctic peninsula, these same deep waters are delivered to the continental slope via the ACC, and onto shelf via intrusions associated with a major canyon cutting through the shelf-slope break.**

Warming of global ocean deep water has considerable potential for long term melting of Antarctic glacial ice — even if global warming is stopped, unlimited ocean heat is available for endless melt (a previous stable level)!



Publications from project:

Zilberman N.V., D. H. Roemmich, and S. T. Gille 2014: Meridional volume transport in the South Pacific: mean and SAM-related variability. *Western Pacific Ocean Circulation and Climate Special Issue. J. Geophys. Res. Oceans.* 119, 2658-2678.

Martinson, D.G. and D.C. McKee 2012: Transport of warm Upper Circumpolar Deep Water onto the western Antarctic Peninsula continental shelf. *Ocean Science* 8: 433-442.

Photo: Zena Cardman, Jan 2009