Toward a global data-based estimate of the oceanic accumulation of anthropogenic CO_2 since the WOCE era

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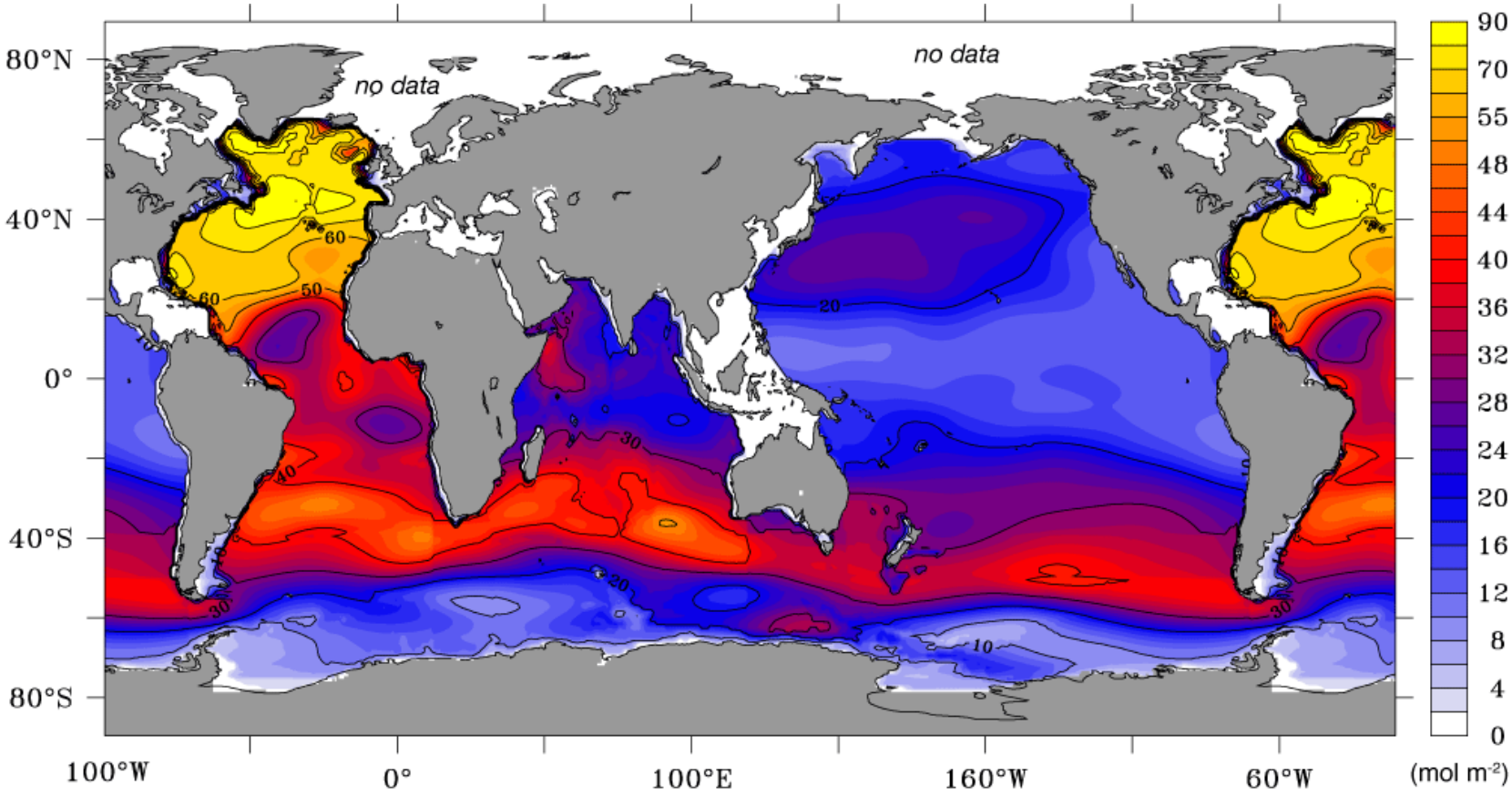
Acknowledgments:

PIs and Co-PIs of repeat hydrography program

Funding from many international funding agencies

IMBER/SOLAS/CLIVAR/IOCCP

Anthropogenic CO_2 inventory for the WOCE era

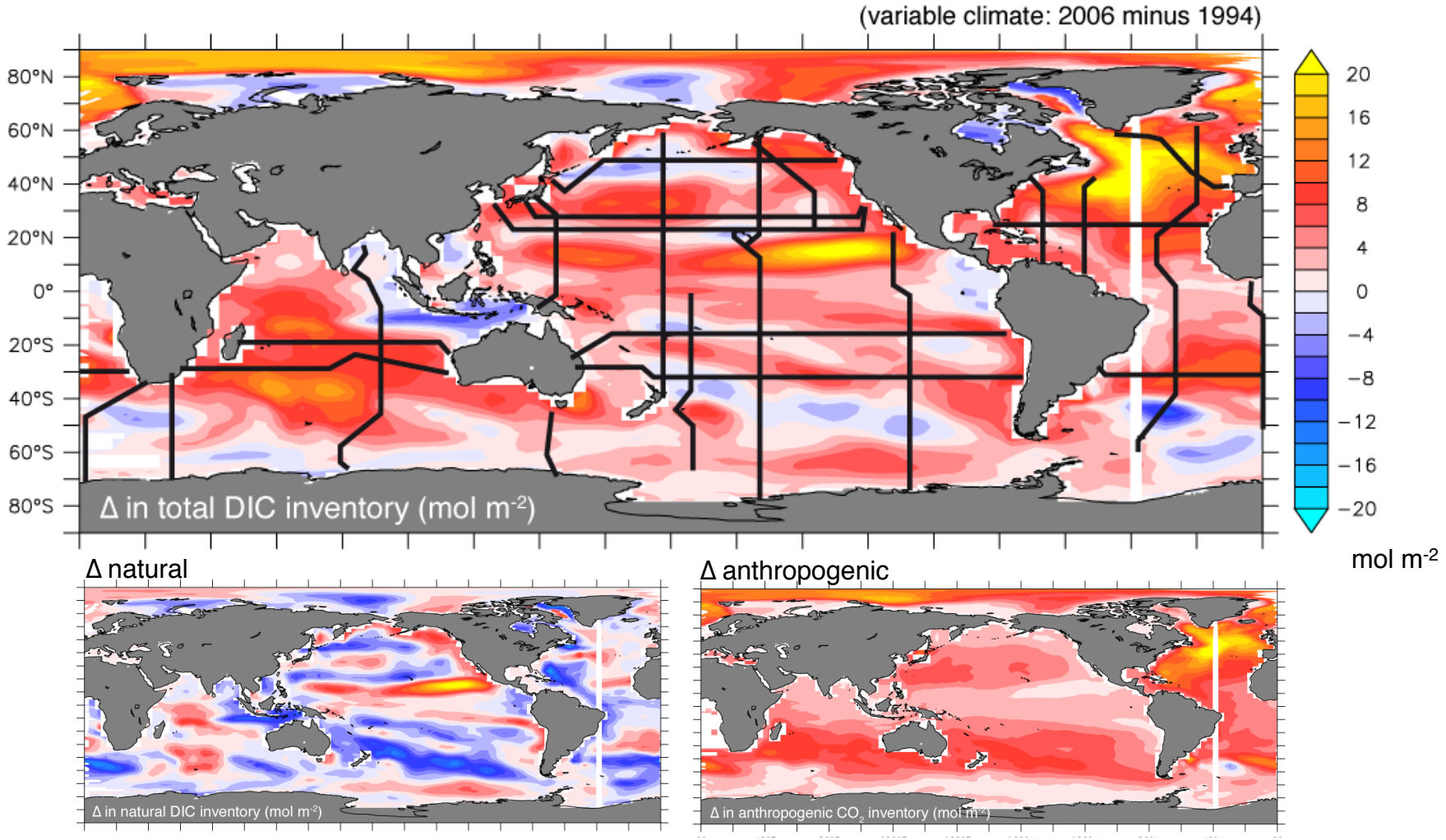


Column inventory of anthropogenic CO_2 (ΔC^* method)

This map represents a major achievement of the global ocean carbon community for their efforts during the WOCE/JGOFS era

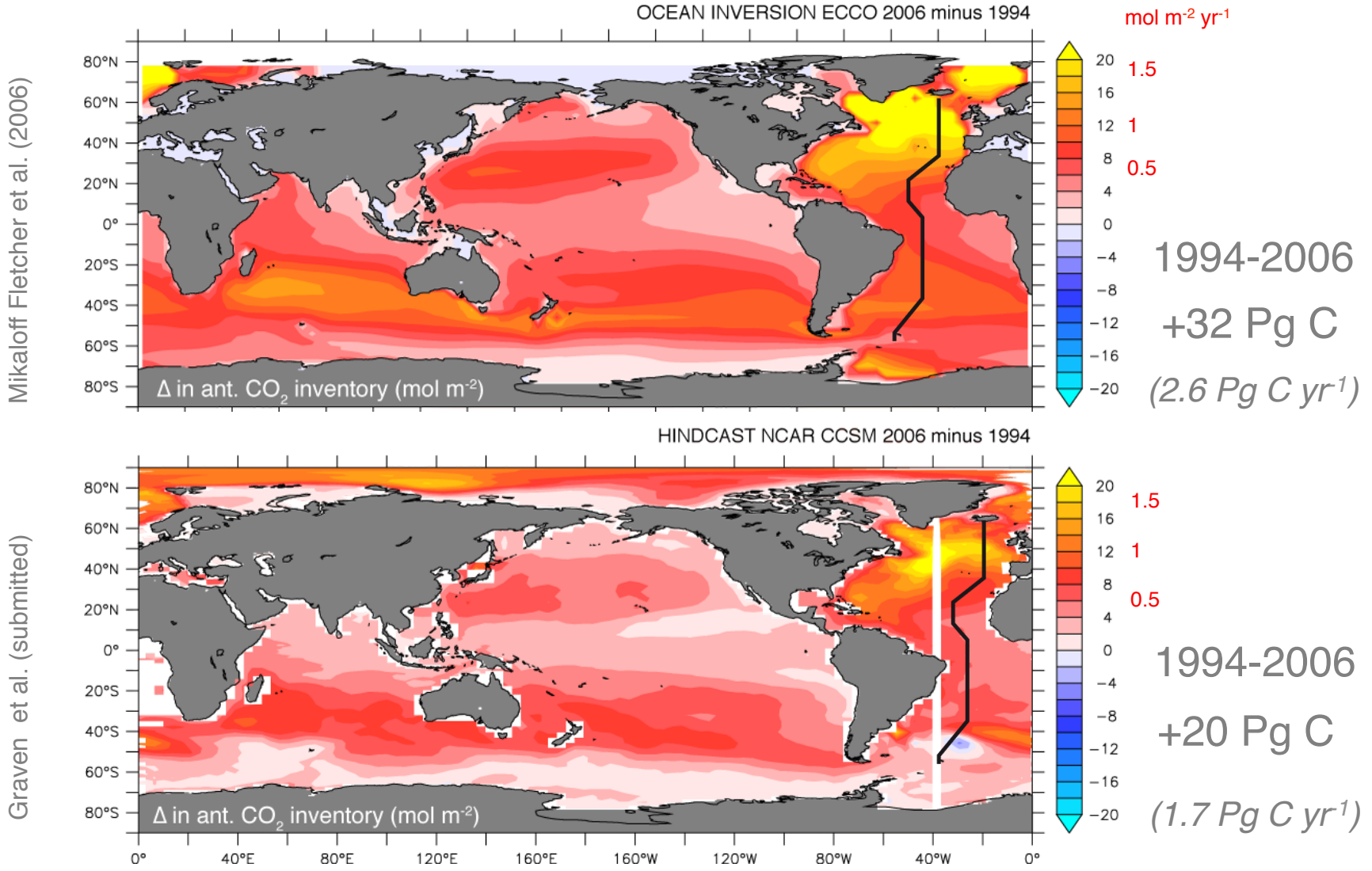
Sabine et al. (2004)

The challenge: determining the DIC inventory change



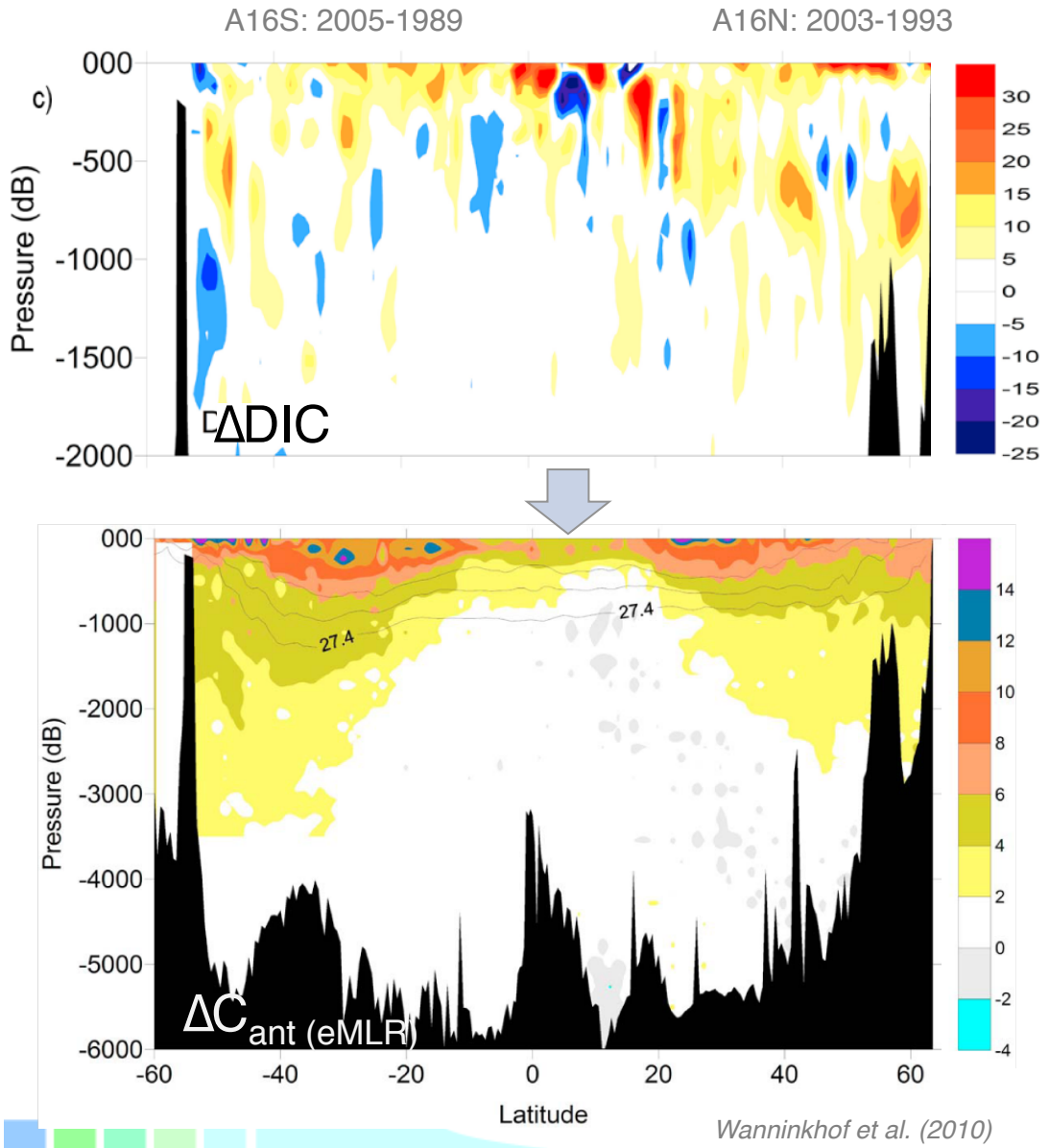
The change in the DIC inventory represents a superposition of changes in natural carbon (mostly internal shifting) and uptake of anthropogenic CO_2 from the atmosphere

The expected changes in C_{ant} (CLIVAR vs WOCE era)



The ocean inversion and the NCAR CCSM model represent an upper and lower bound of the expected uptake

Determining ΔC_{ant} from repeat measurements

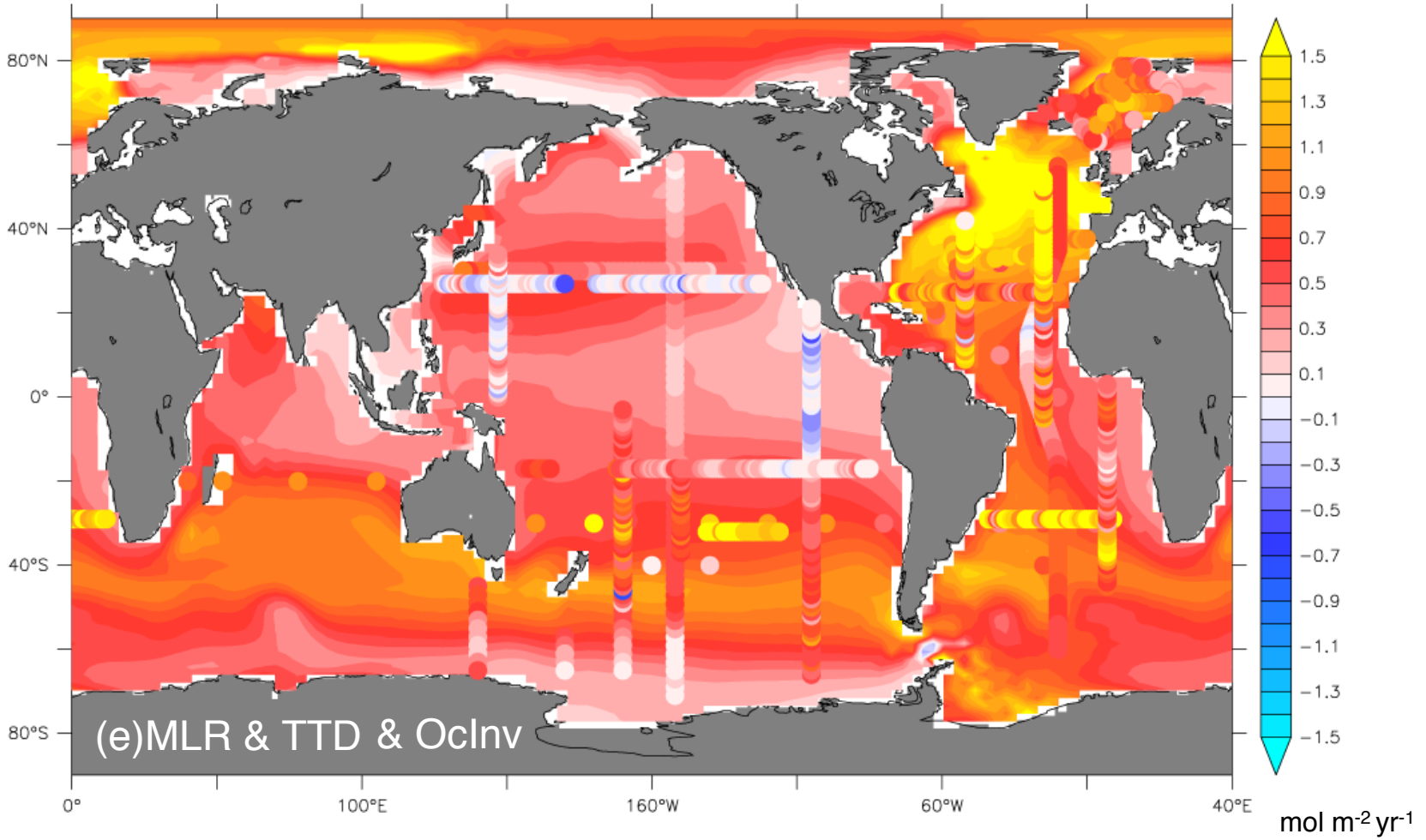


Wanninkhof et al. (2010)

Different techniques are used to determine the total change in DIC, and to split then the anthropogenic CO_2 component, ΔC_{ant} from it:

- Direct differencing (e.g. Murata et al., 2009)
- Multiple linear regression (MLR)
- Extended MLR (eMLR) models (e.g. Wanninkhof et al. 2010)
- MLR and eMLR on C* (e.g. Clement et al.)
- φ-ΔC_T° backcalculation method (e.g. Perez et al.)
- Timeseries residual analysis (van Heuven et al. 2011)
- TTD-based methods (Tanhua et al. 2010)

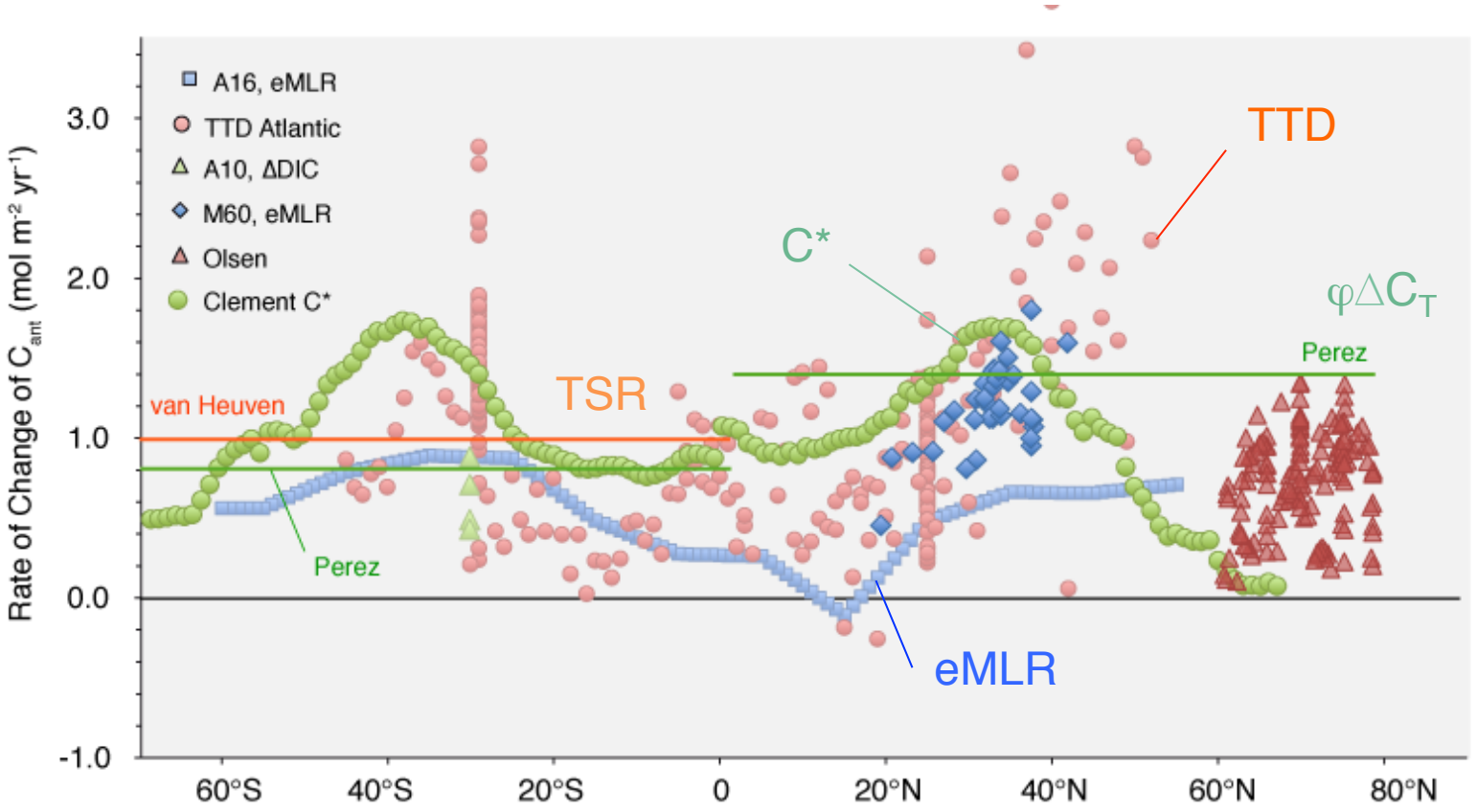
Interior trends of anthropogenic CO_2



Atlantic versus Pacific pattern emerges clearly, but substantial differences exist between different methods

Updated from Sabine and Tanhua (2010)

A more detailed view at the Atlantic: rates of change



Rather different perspectives on the relative uptake ratio between the South and North Atlantic

A first and very rough attempt at determining the global change in the C_{ant} inventory

1994 - 2006

	Atlantic Inventory [Pg C]	Pacific Inventory [Pg C]	Indian Inventory [Pg C]	Other[a] [Pg C]	Global Inventory [Pg C]
Northern hemisphere	2.3 - 5.4*	~3.5	?	?	
Southern hemisphere	3.6 - 5.4*	~5.5	?	?	
Entire basin	6 - 11	~8	~3	?	~17 to 22

* Based on Wanninkhof et al. (2010), Perez et al. (in prep), and van Heuven et al. (in prep)

This (very) rough estimate suggests that the ocean might have taken up CO_2 at a rate that is at the lower end of the spectrum of model based expectations.

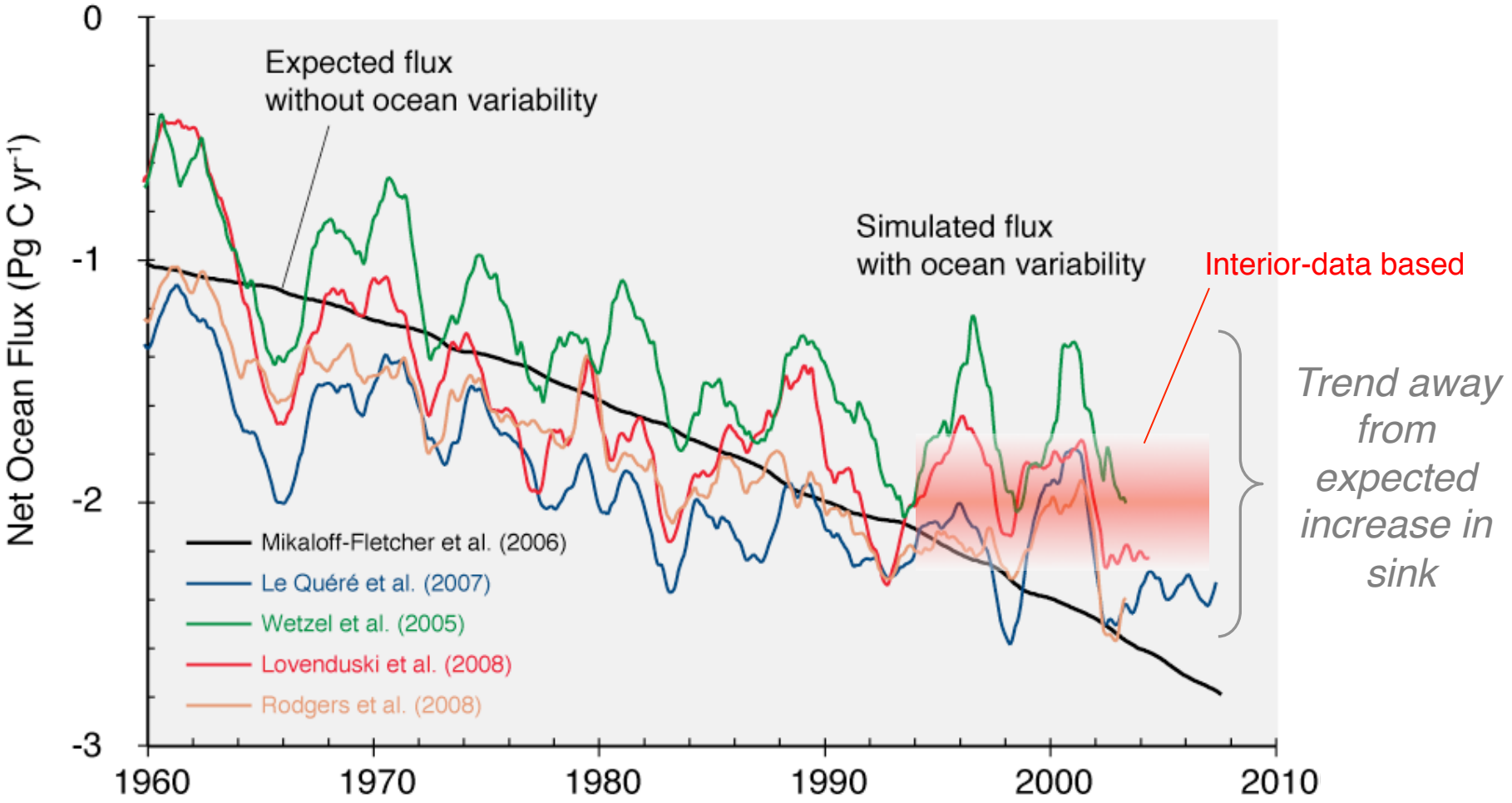
Summary and Conclusions

- The determination of the change in the anthropogenic CO_2 inventory since the WOCE era represents *a formidable challenge*. *Variability* in natural CO_2, as well as the need to *interpolate* the data in time and space are some of the reasons underlying this challenge.

- Different methods agree on the *overall pattern*, but substantial *differences* remain that need to be better characterized and understood.

- A *rough first estimate* suggests a global anthropogenic CO_2 uptake between ~1994 and ~2006 that is at the *lower end* relative to expectations (about 20 Pg C, or less than 2 Pg C yr^{-1}).

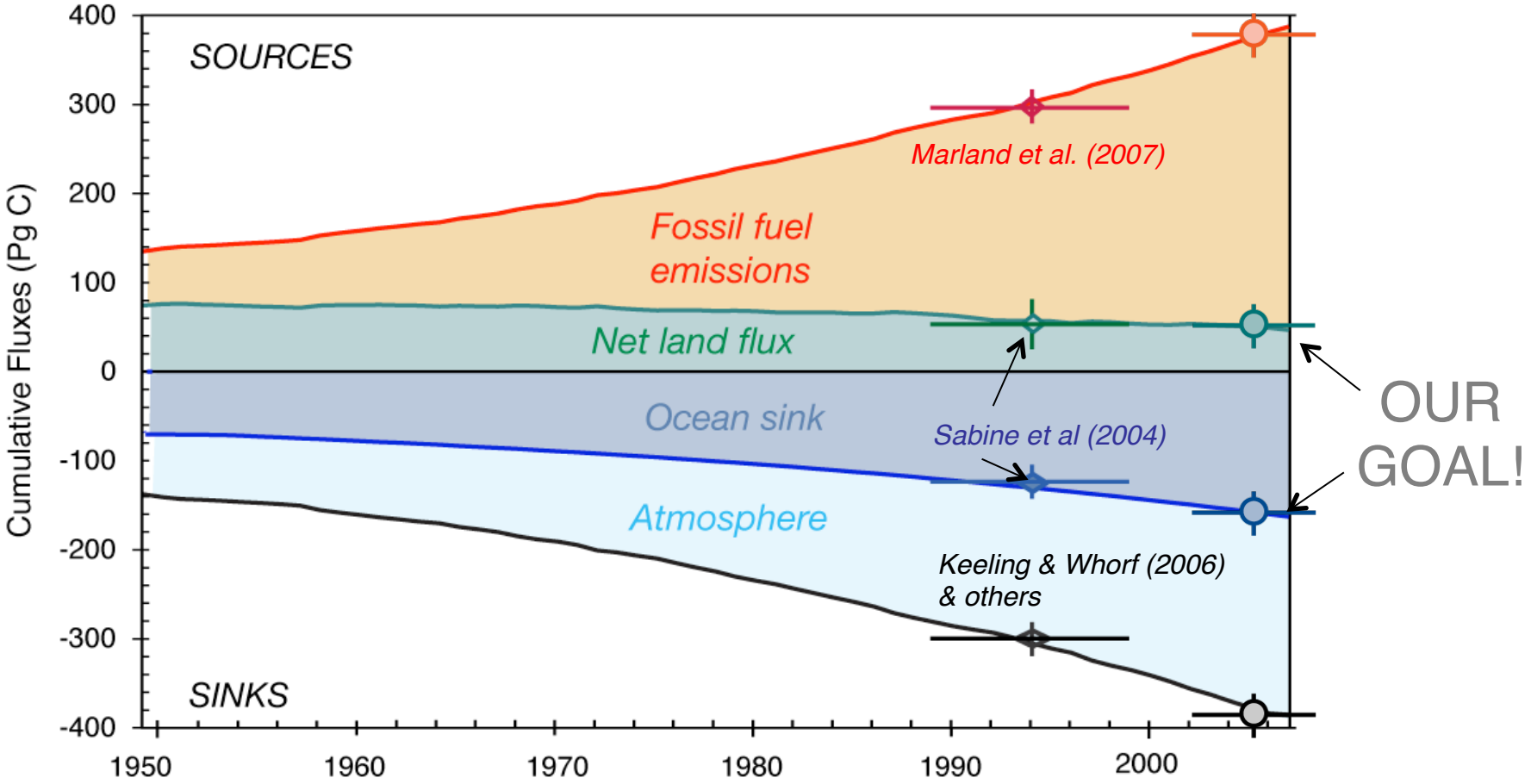
The changing ocean carbon sink



A reduction in the rate of increase of the global ocean carbon uptake!

Sarmiento et al. (2010)

Evolution of cumulative sources and sinks from 1950-2006



The oceanic constraint on the global ant. CO_2 budget provided a powerful means to estimate the net land flux, i.e.,

Net land Flux = FF – $F_{atm\text{-}oc}$ – dN_a/dt

Adapted from Sarmiento et al. (2010)