Assessment of the current ocean carbon sink and its implications for climate change and mitigation

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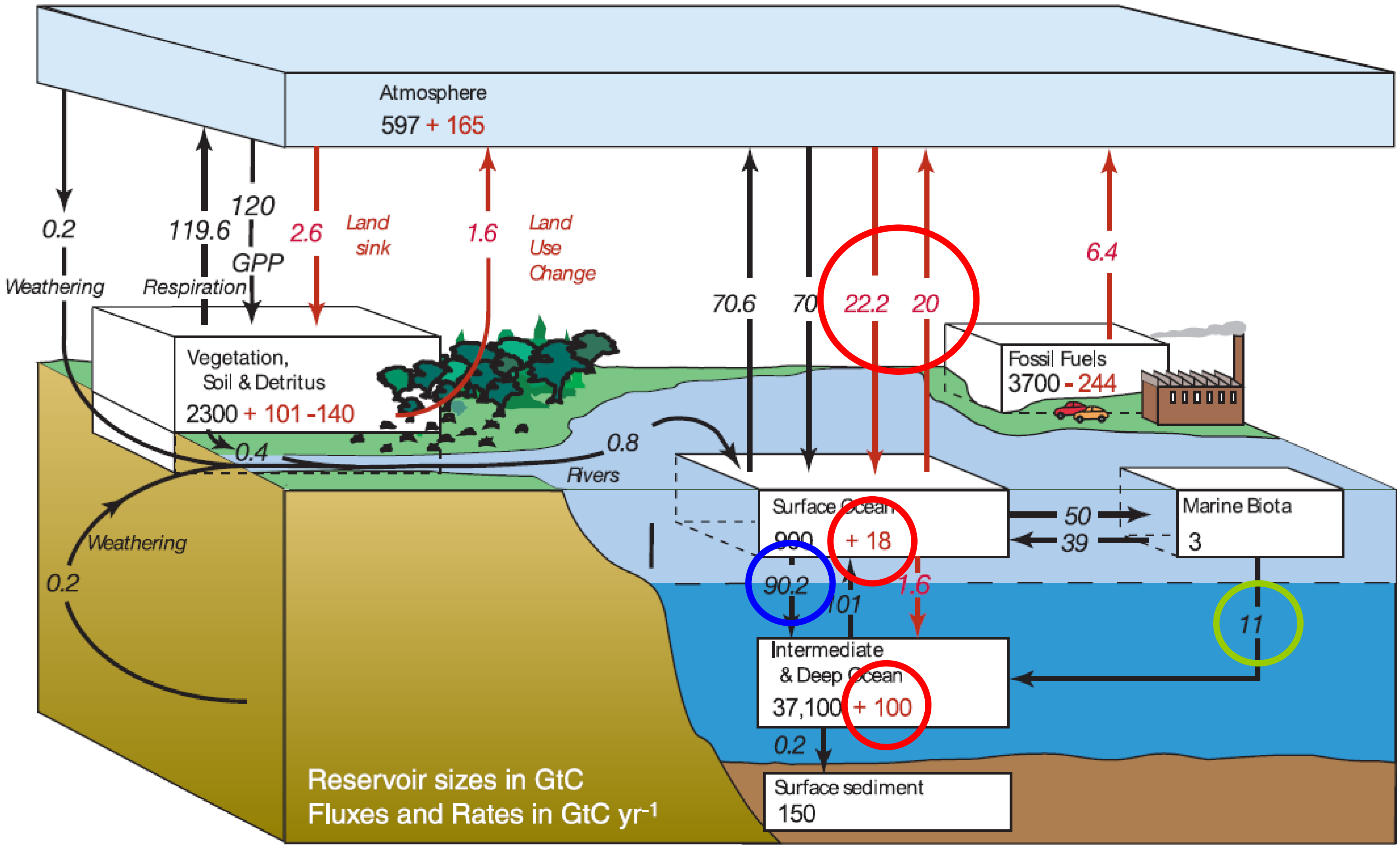
Most relevant CWPs for this topic:

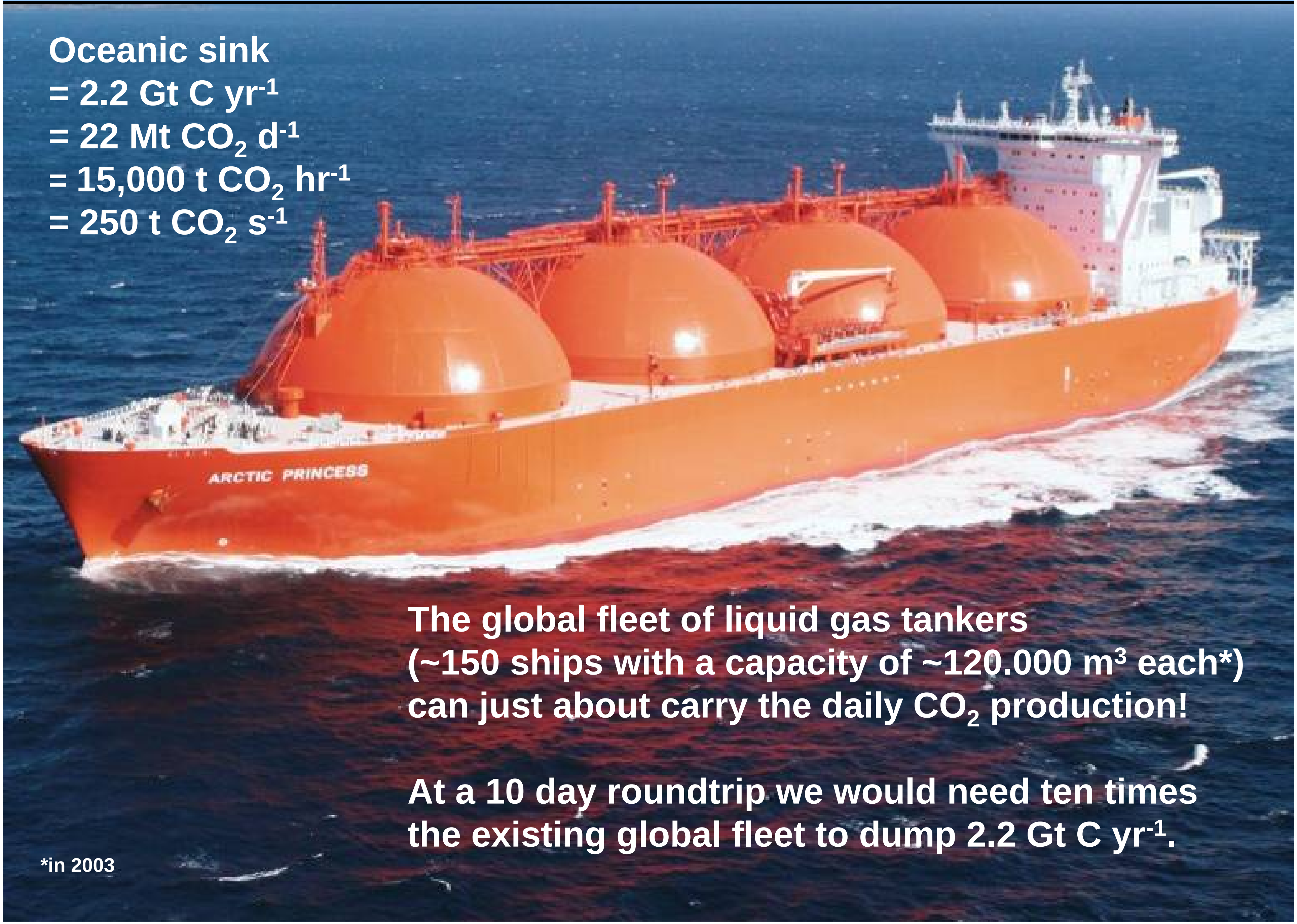
- **Surface *p*CO_2 (VOS) Network: Schuster *et al*.**
- **Repeat Hydrography: Fukasawa/Hood *et al*.**
- **OceanSITES: Send *et al*.**
- **CO_2 sensors: Byrne *et al*.**
- **Oxygen-ARGO: Gruber *et al*.**

The canonical picture of the anthropogenically perturbed global carbon cycle for the 1990s



IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

We are not talking peanuts here...



Oceanic sink
= 2.2 Gt C yr^{-1}
= 22 Mt CO_2 d^{-1}
= 15,000 t CO_2 hr^{-1}
= 250 t CO_2 s^{-1}

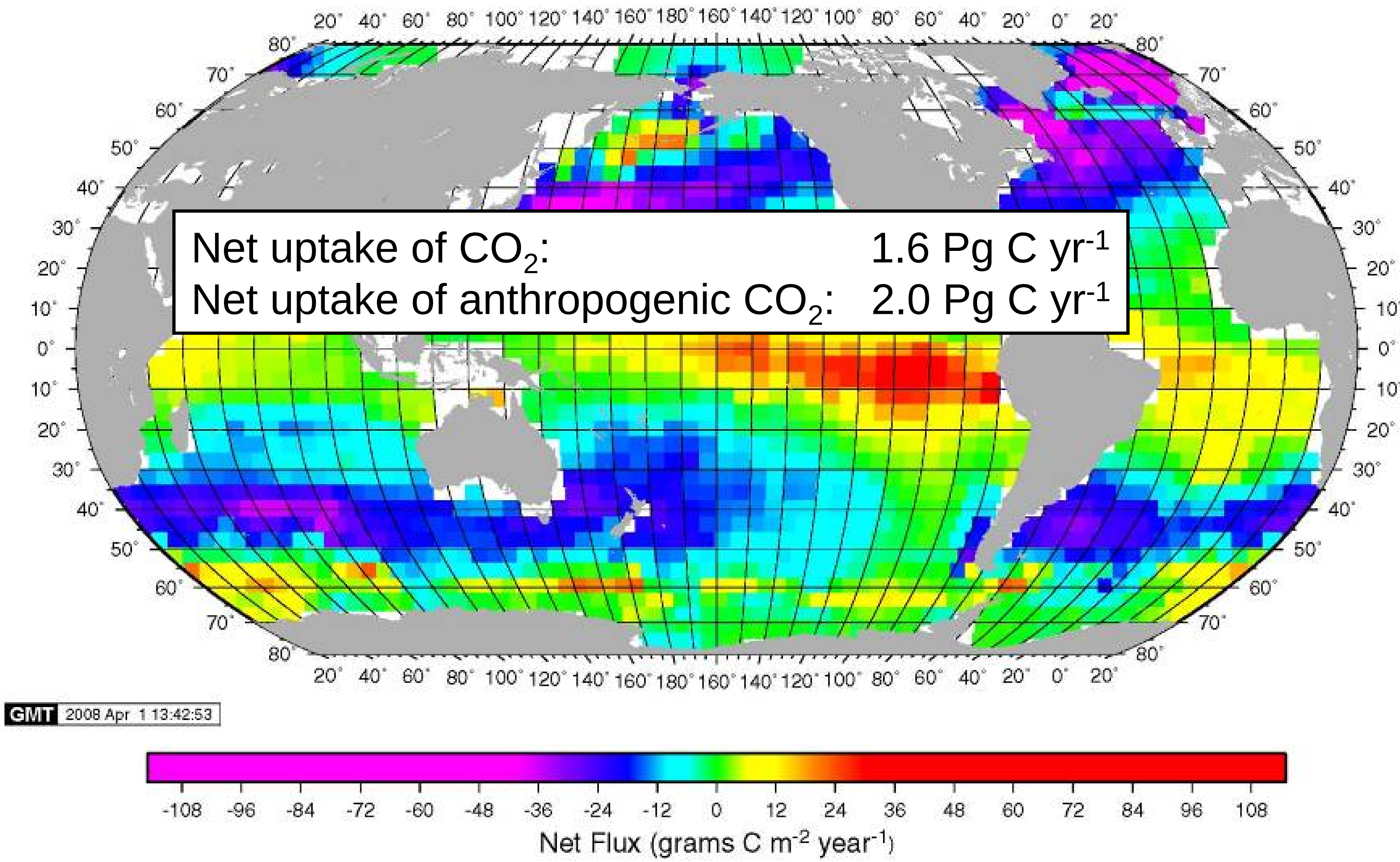
The global fleet of liquid gas tankers (~150 ships with a capacity of ~120.000 m^3 each*) can just about carry the daily CO_2 production!

At a 10 day roundtrip we would need ten times the existing global fleet to dump 2.2 Gt C yr^{-1}.

***in 2003**

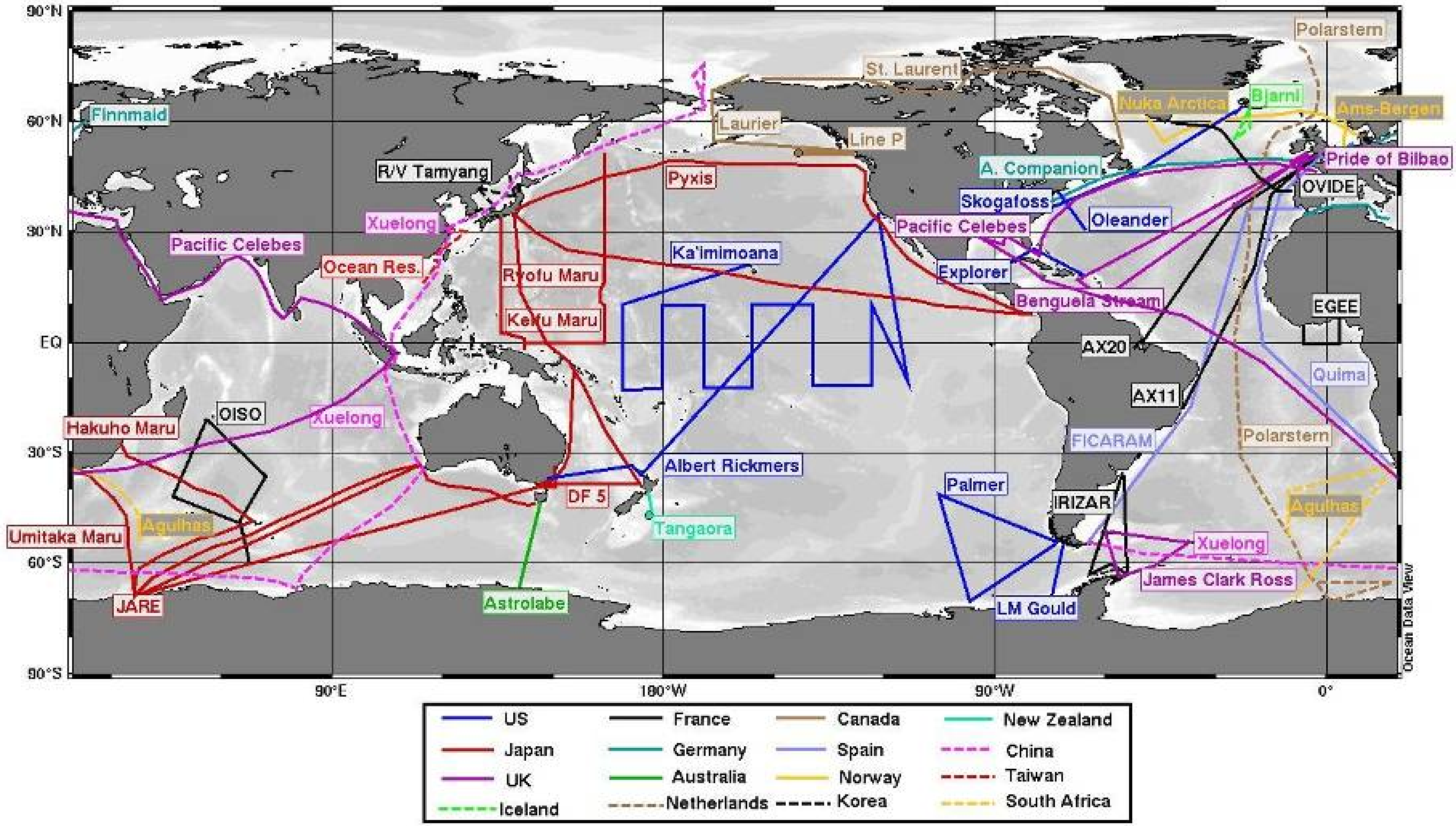
Iconic Map I: Global net air-sea CO_2 flux (= anthropogenic + pre-industrial flux)

Climatological picture based on 3 million measurements taken during 1970-2007 (referenced to year 2000)



Takahashi *et al*. (2009), *DSR II* **56**, 554-577.

Iconic Map I: „Voluntary Observing Ship“ network that forms its basis (CWP: Schuster *et al.*)



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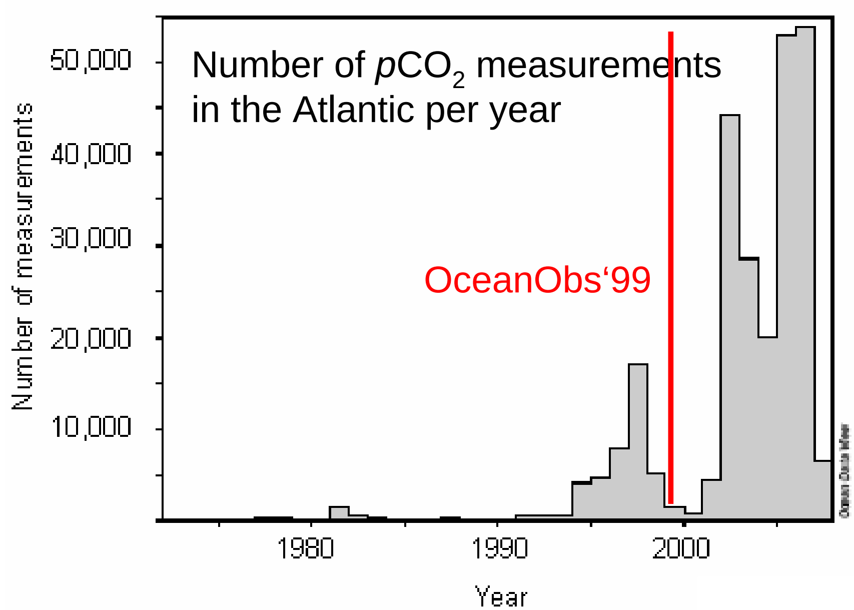
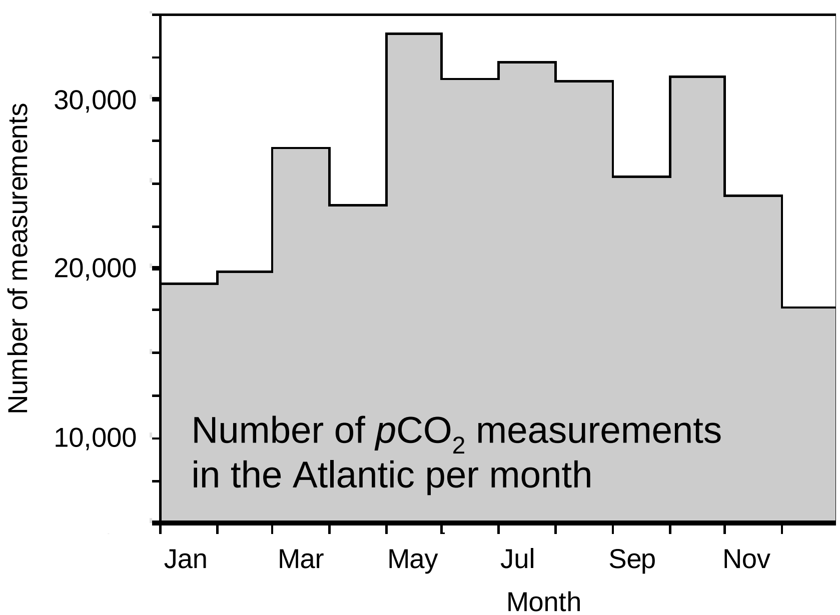
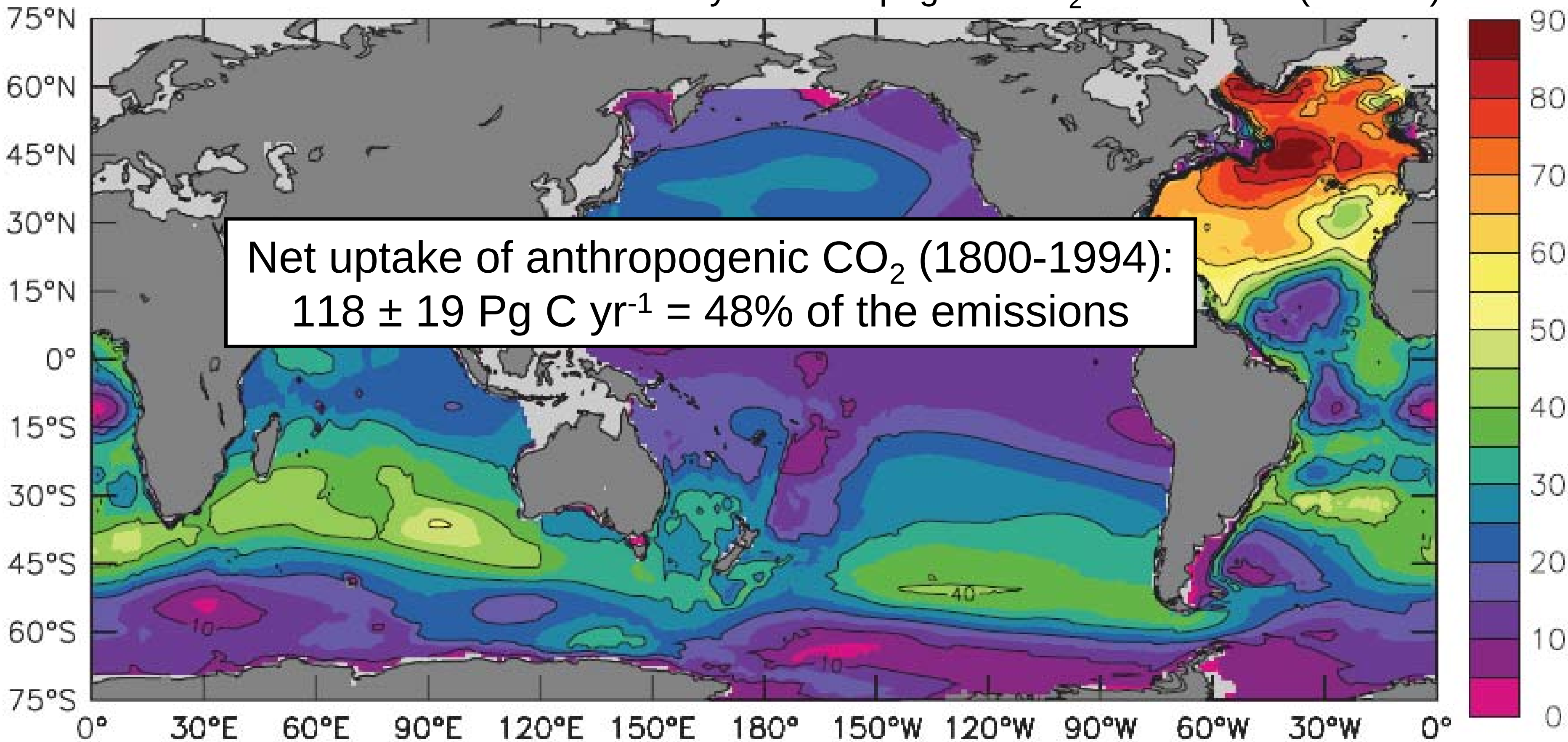




Benjamin Pfeil, CarboOcean

Iconic map II: Oceanic storage of anthropogenic CO_2

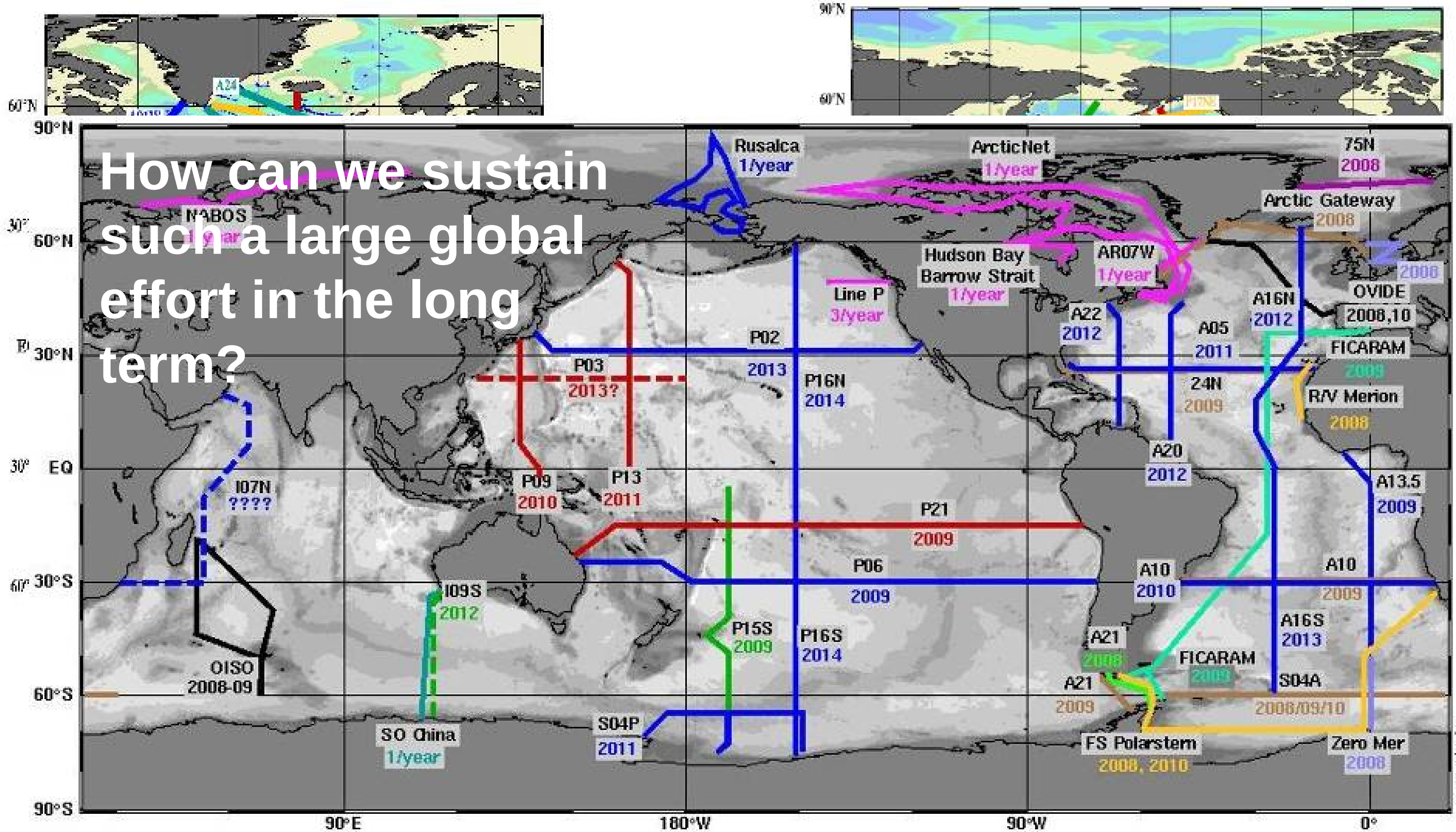
Column inventory of anthropogenic CO_2 in the ocean (mol m^{-2})



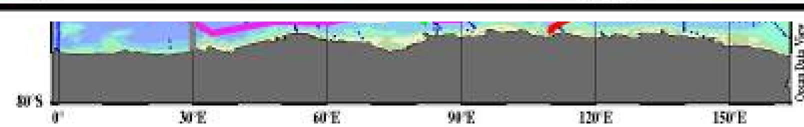
Net uptake of anthropogenic CO_2 (1800-1994):
118 ± 19 Pg C yr^{-1} = 48% of the emissions

after Sabine *et al.* (2004), *Science* **305**, 367-371.

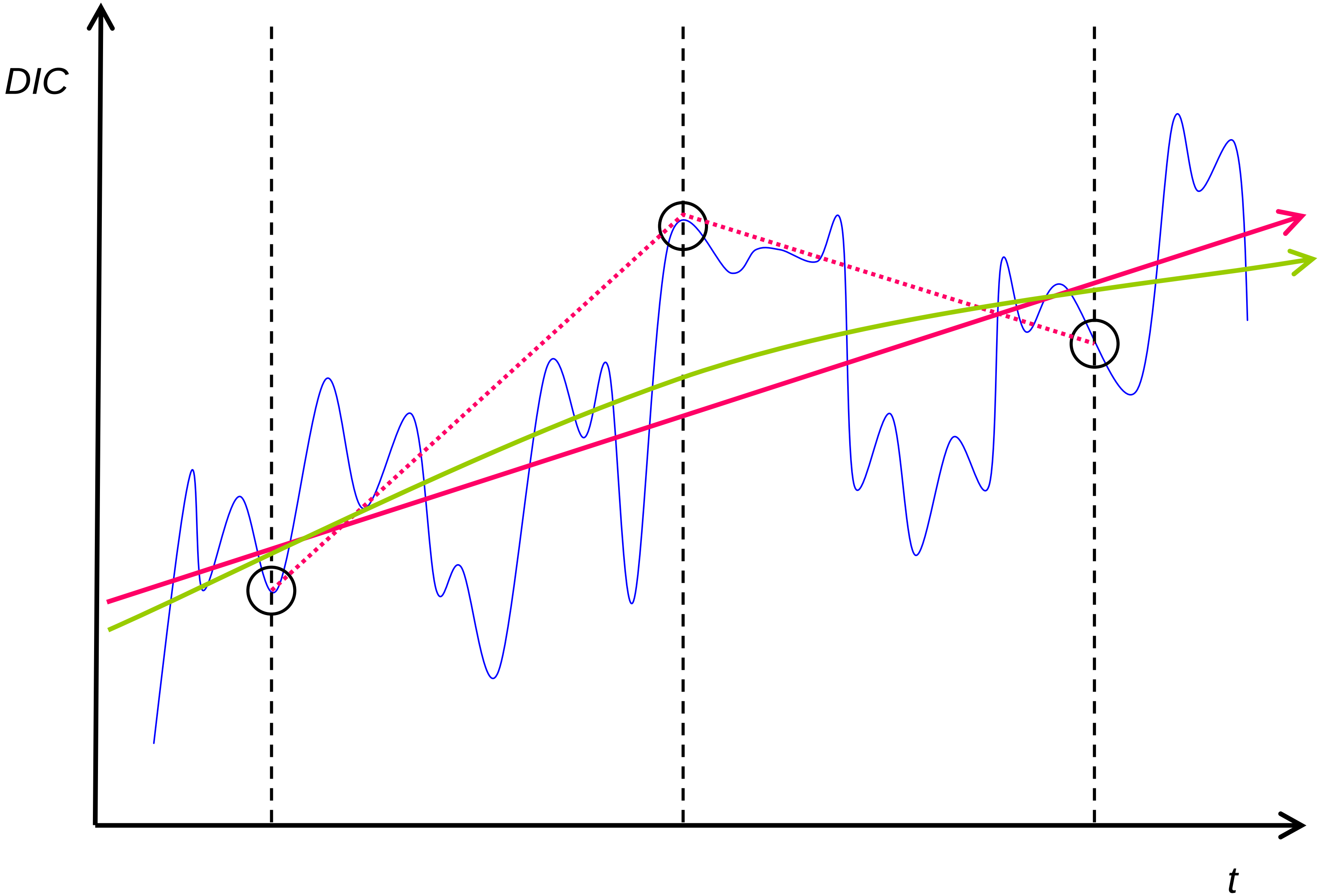
How can we sustain such a large global effort in the long term?



Repeat Hydrography
CO_2 survey
(→GLODAP)

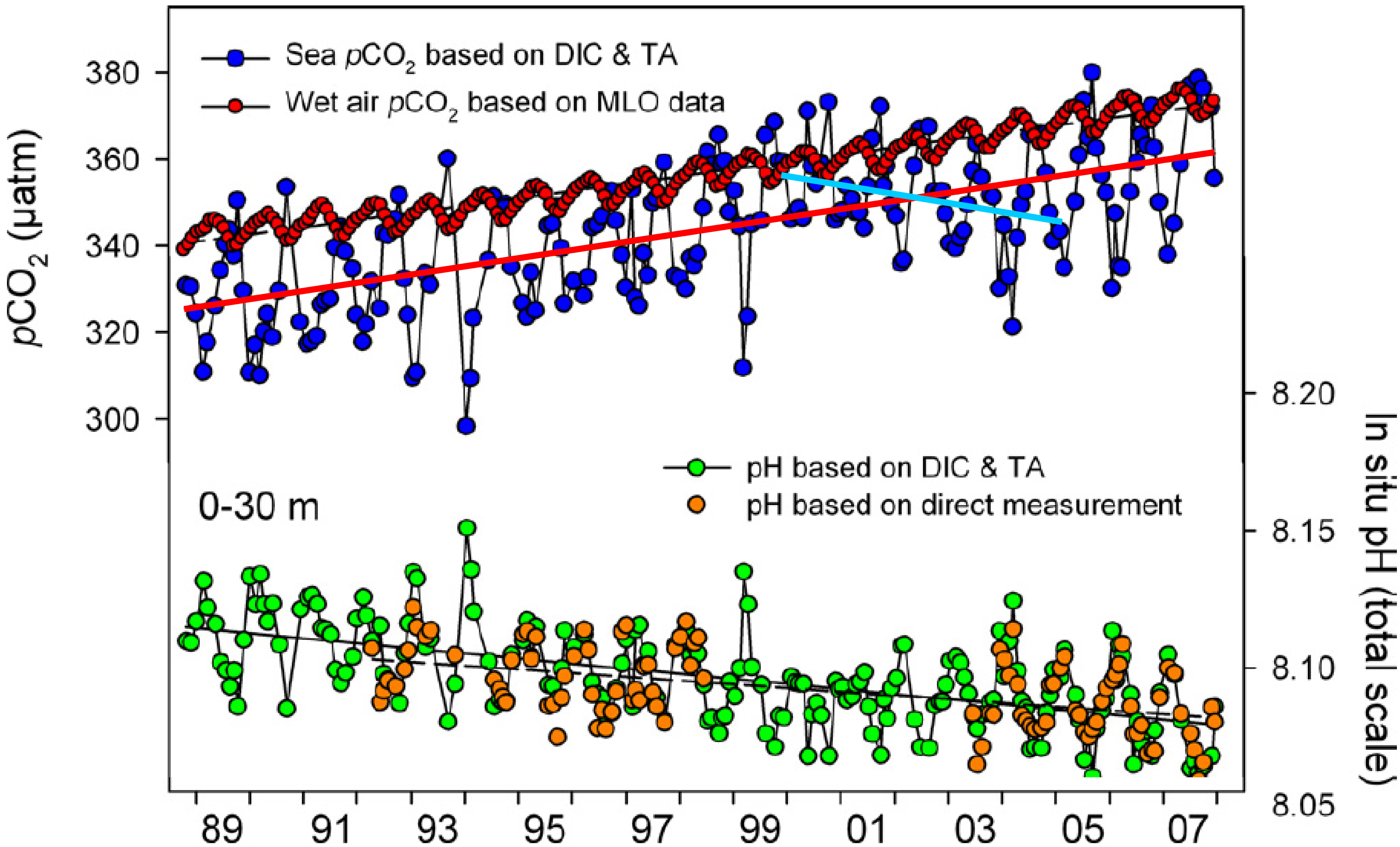


How to detect decadal change against in a system with high internal variability?



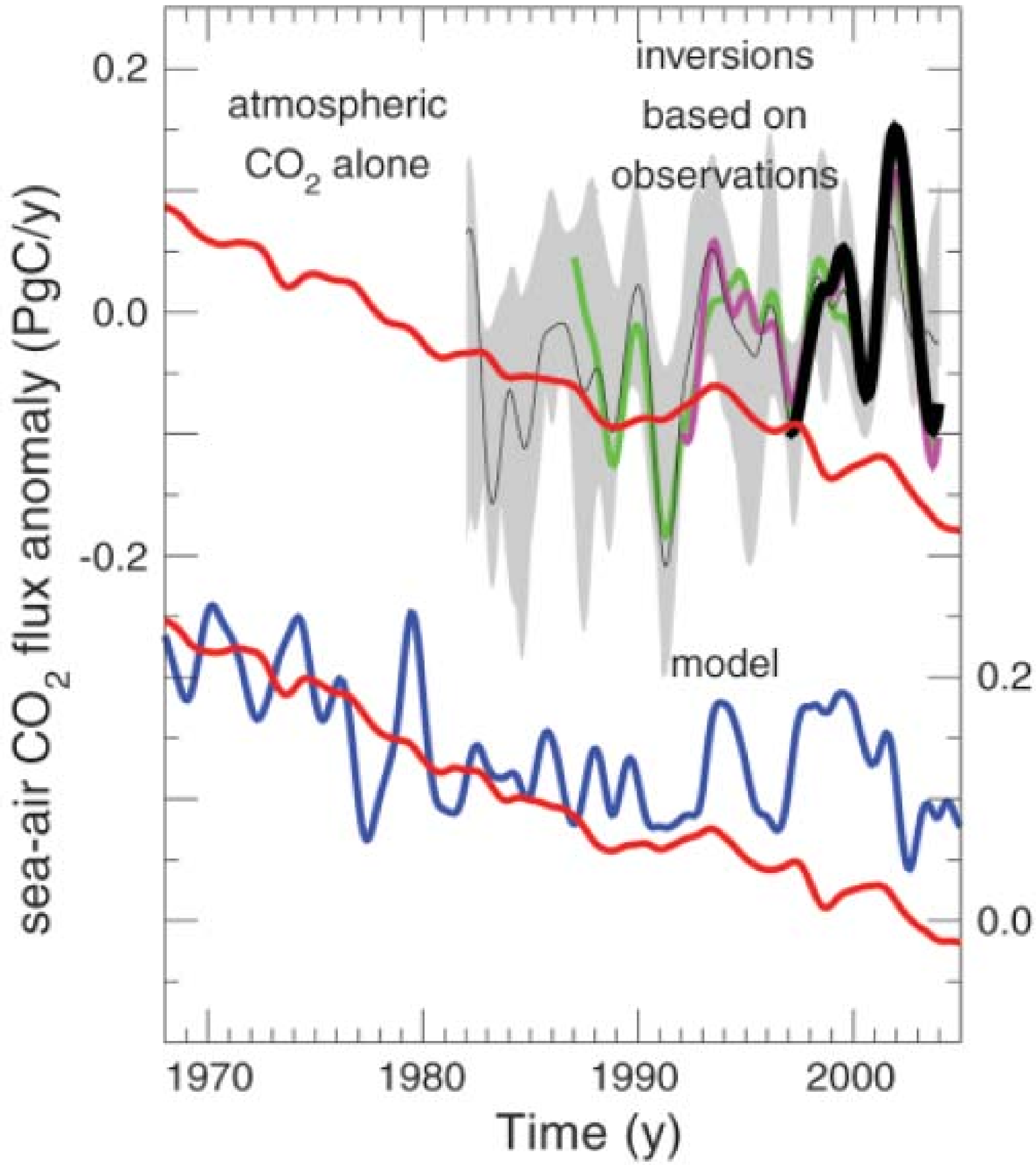
Ocean/coastal time-series sites

Hawaii Ocean Time Series (ALOHA)



Dore *et al.* (2009), *PNAS* **106**, 12235–12240.

Example:
Attenuation of Southern Ocean CO_2 sink



LeQuéré et al. (2007), *Science* 316, **1735-1738**.

Table 1. Biotic responses to sea surface warming and ocean carbonation/acidification and their feedback potential to the climate system

Feedback process	Sign of feedback	Sensitivity	Capacity	Longevity
Responses to ocean warming				
Nutrient supply to oligotrophic ocean		+++	±0	++
Nutrient supply to HNLC areas	negative	++	++	+++
Nutrient utilization efficiency	negative	++	++	+++
Nutrient inventory	positive		++	+++
Organic matter remineralisation	positive			
Responses to ocean acidification				
Calcification	negative	+†	+	+‡
Ballast effect	positive		+++	+++
Stoichiometry	negative	++†	++	++
Extracellular organic matter production	negative	++†	+++	‡
Nitrogen fixation	negative	++†	+	‡

Responses to ocean deoxygenation?

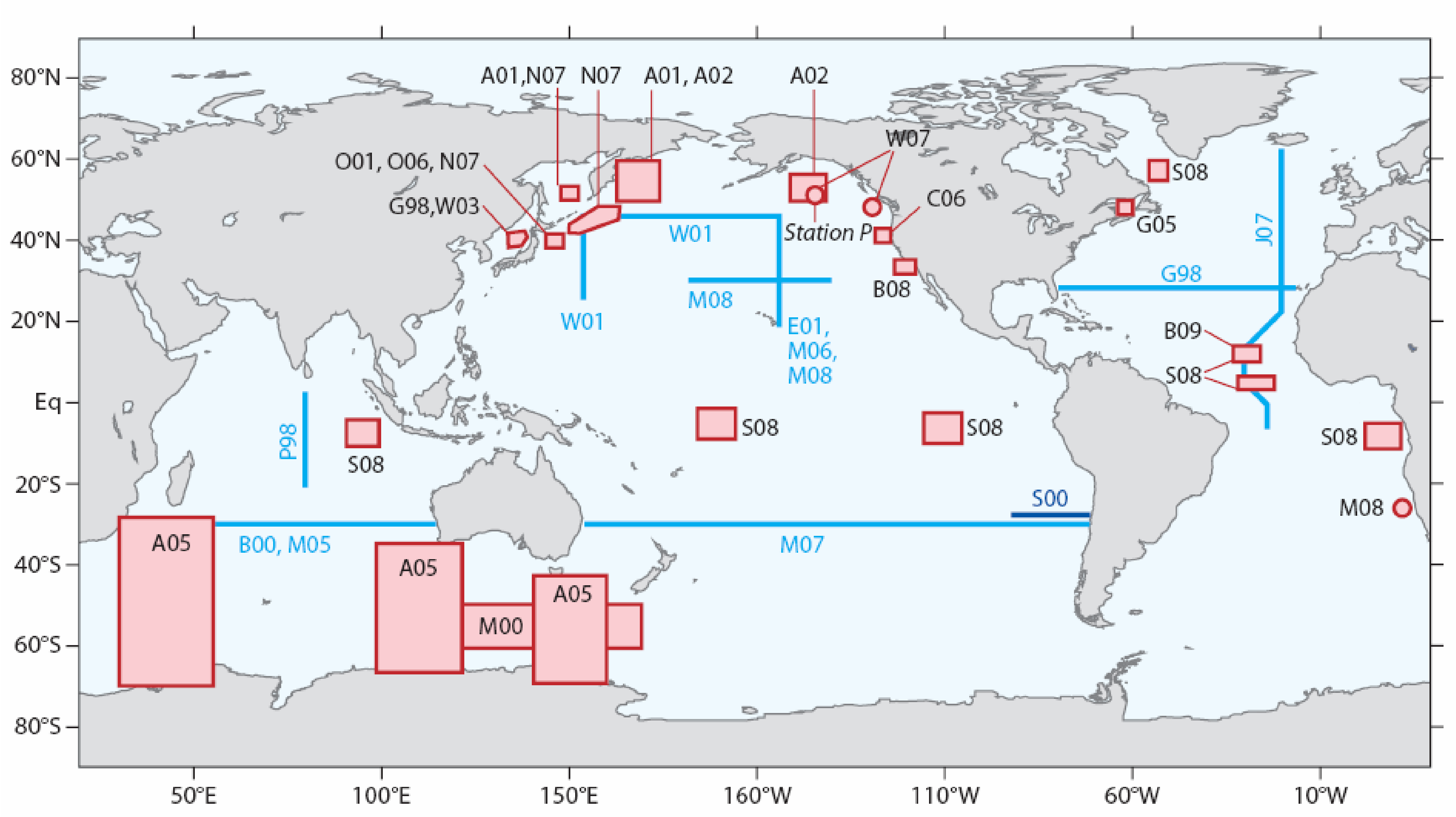
Responses are characterized with regard to feedback sign, sensitivity, capacity, and longevity by using best guesses; we use ±0 for negligible, + for low, ++ for moderate, and +++ for high. Empty boxes indicate missing information/ understanding.

†Available information mainly based on short-term perturbation experiments.

‡Potential for adaptation presently unknown. HNLC, high nutrient, low chlorophyll.

Riebesell, Körtzinger, and Oschlies, *PNAS*, **in press**.

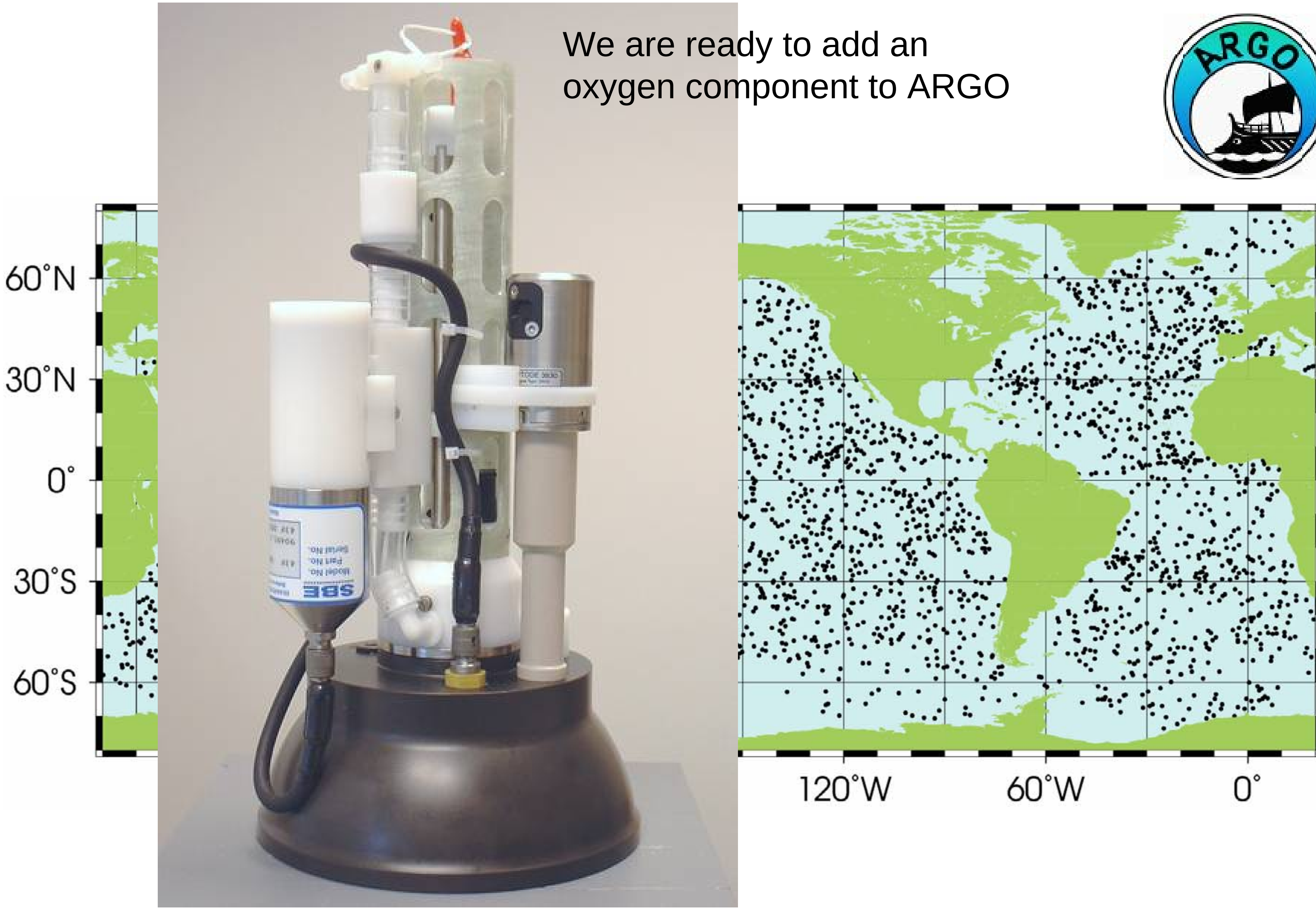
Ocean deoxygenation: Increasing evidence of a near-ubiquitous trend



Keeling, Körtzinger, and Gruber, *Annu. Rev. Mar. Sci.*, in press.

ARGO – an opportunity not to be missed by the carbon community (CWP: Gruber *et al.*)

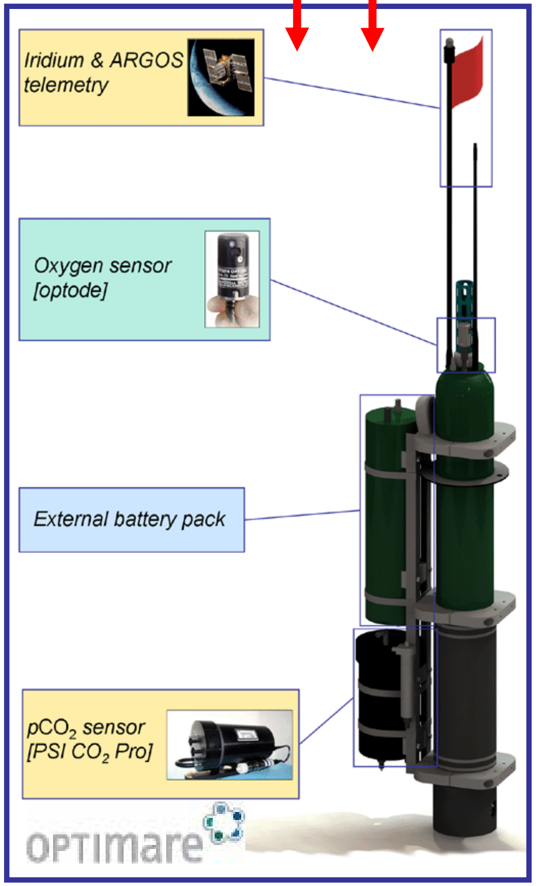
We are ready to add an oxygen component to ARGO

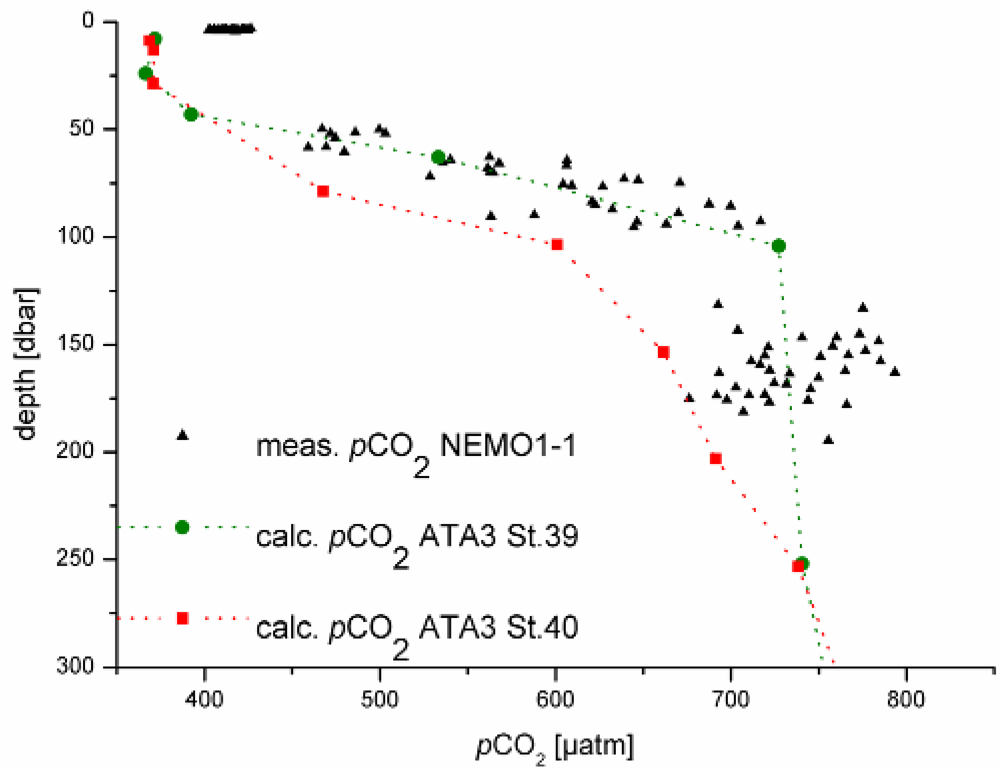


Are we also there with CO_2 sensor technology? – Not really … (CWP: Byrne *et al.*)

CO_2 Sensor

O2 Sensor





<u>We need to</u>

- continue (and perhaps expand) the VOS-based surface pCO_2 network,
- continue the repeat hydrography pro…
- continue the existin… ones i… …ples),
- I… …al fully-fledged component of t… …st,
- Improve CO_2 sensor technology to encompass autonomous observation platforms (e.g., float & gliders)

But how can all this be sustained in the long term?

integrated carbon observation system

ICOS Vision:

To have in place by 2014 an operational network of observation platforms covering Europe and the North Atlantic to provide daily regional greenhouse gas budgets at 10 km resolution

- ~40 ecosystem stations
- ~40 atmospheric stations
- ~10 VOS lines
- ~ 7 oceanic/coastal time-series site
- central facilities for analyses, calibration and quality control
- ~ long term operation (>20 years)

ICOS – Integrated Carbon Observation System (ESFRI)