

# Dissolved Organic Carbon in Ocean Export Production

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## Acknowledgements

Support -

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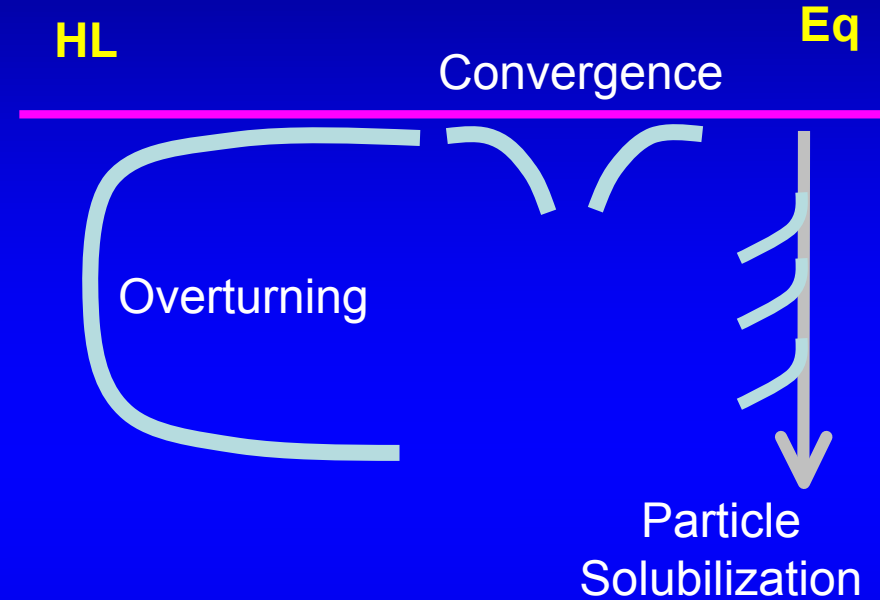
Collaborators -

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Prof. Reiner Schlitzer (Alfred Wegener Institute)

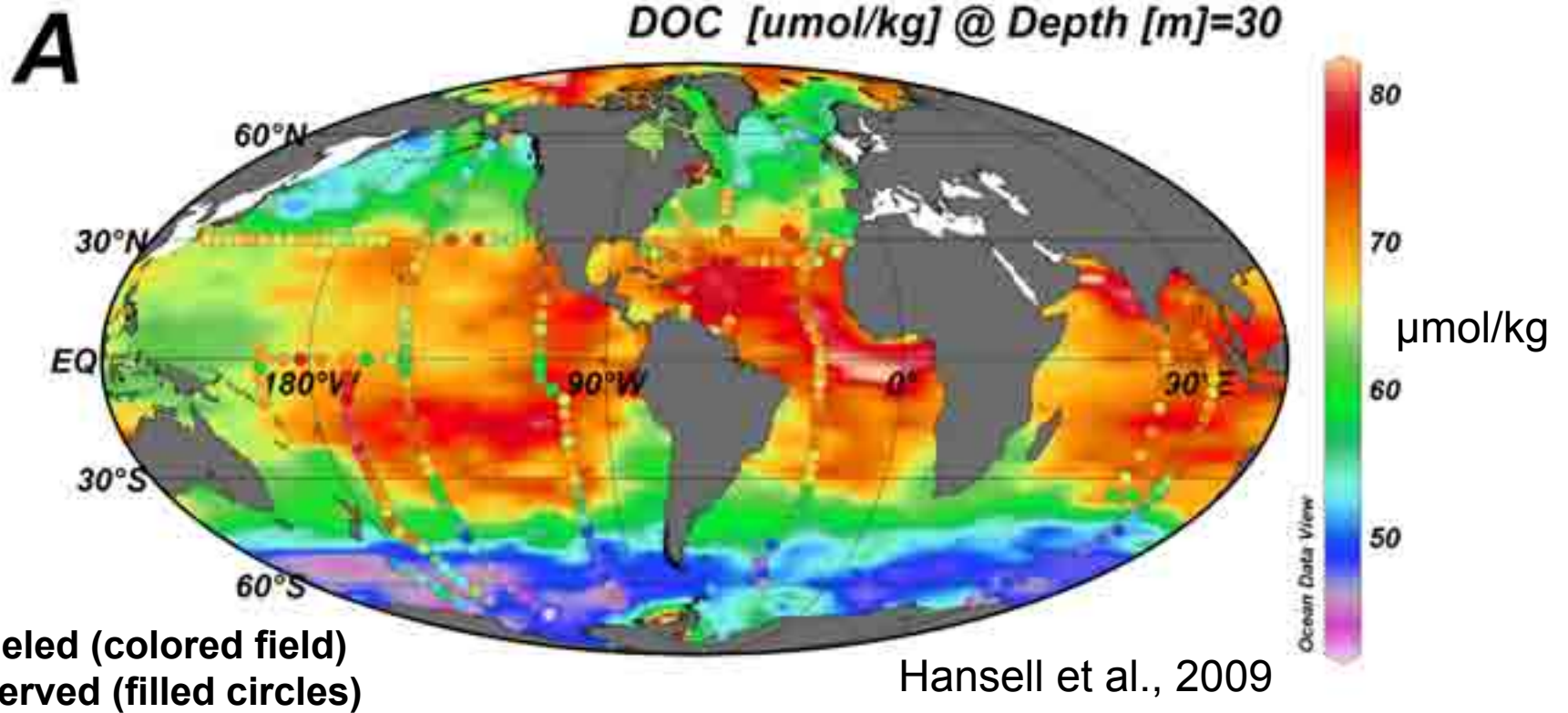
# Outline

- 1) Context: Mass characterization of the DOC pool (inventories, distributions, production rates)
- 2) DOC export (highlights)
- 3) DOC as residue of particle export (highlights)
- 4) Consideration of the GFP-OOI opportunity



**One new message:** vertical flux is not the only process of relevance in export; need to consider both **export** and **'accumulation of export residue'** at depth

# View from the top.....

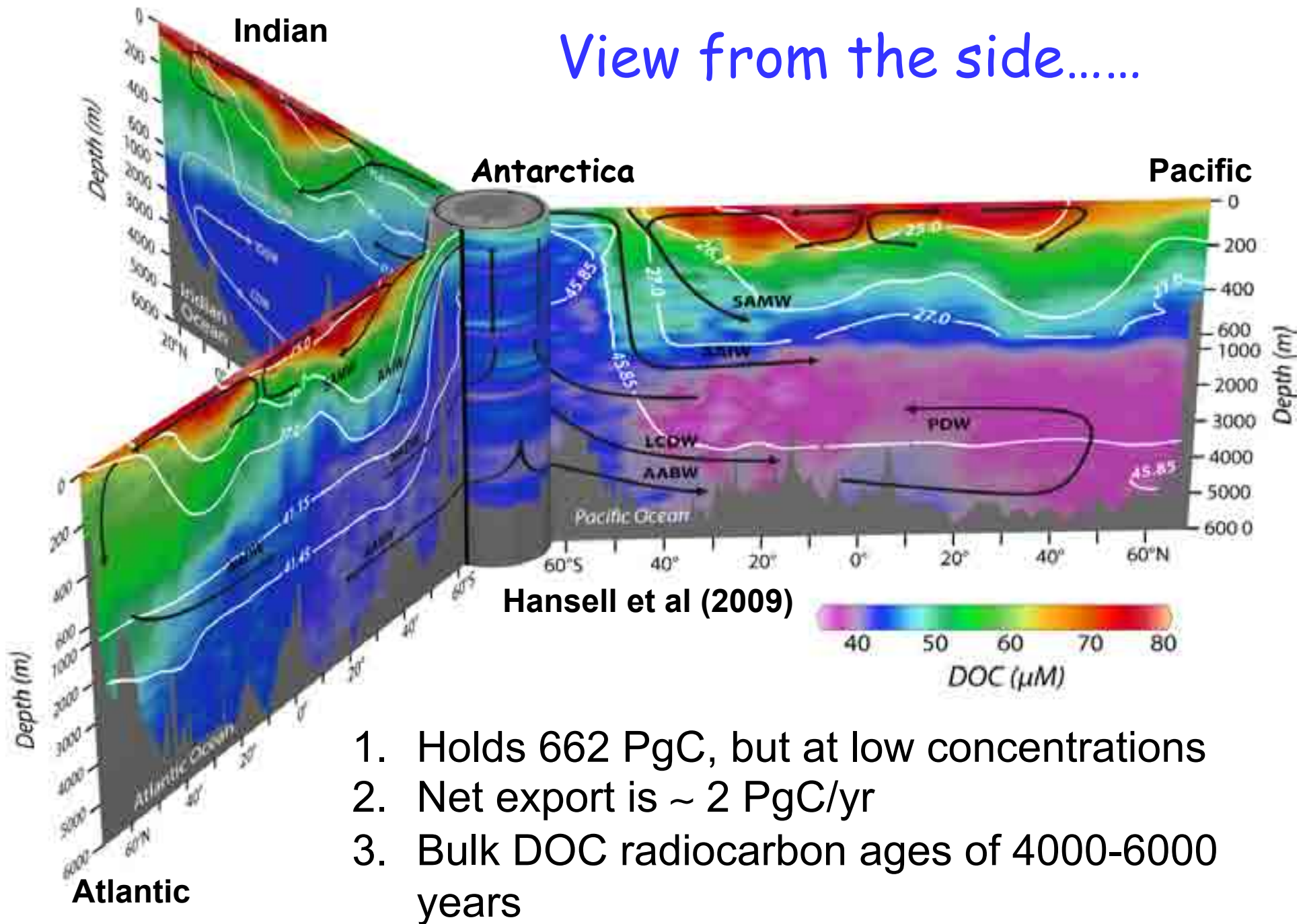


## Features

Gross production:  $\sim 25$  PgC/yr ( $\sim 50\%$  of PP)

Net production:  $\sim 2$  PgC/yr ( $\sim 20\%$  of NCP)

# View from the side.....



Hansell et al (2009)

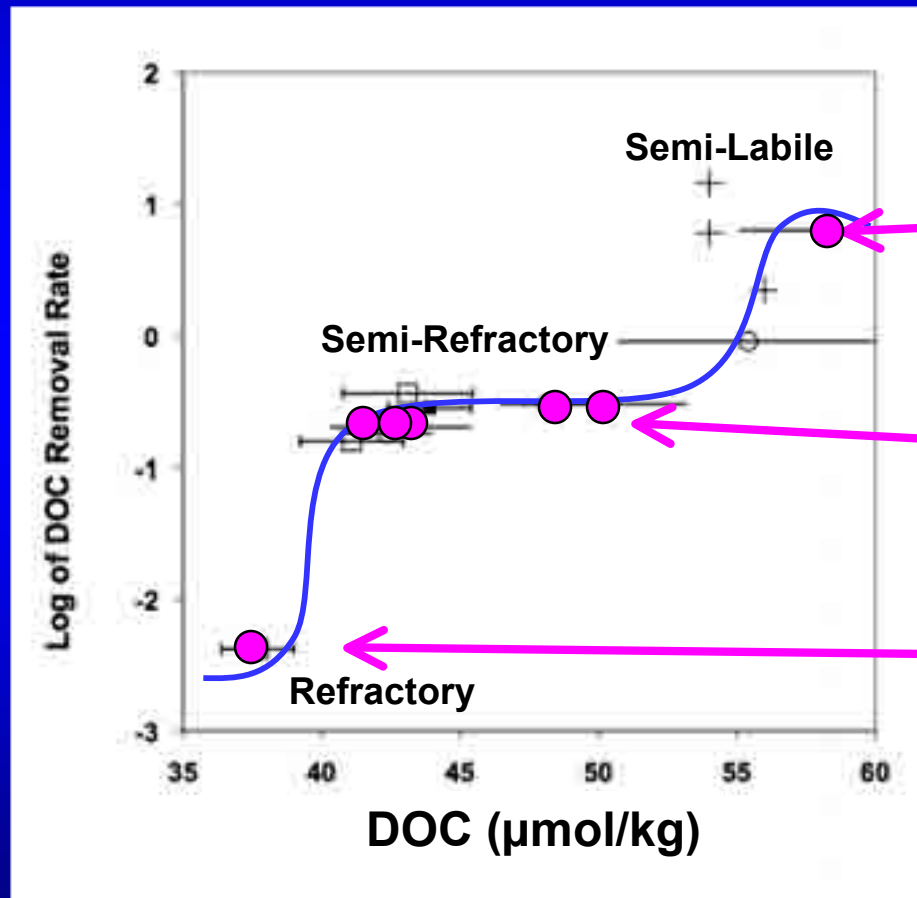
1. Holds 662 PgC, but at low concentrations
2. Net export is  $\sim 2$  PgC/yr
3. Bulk DOC radiocarbon ages of 4000-6000 years

## 2. DOC Export

### Exported DOC Net Removal Rates

$\text{Log}_{10}$  DOC removal rate ( $\mu\text{mol}/\text{kg}/\text{yr}$ )

Multi-compartment model, with each fraction defined by continuity of reactivity



BATS

N. Atlantic

Pacific LCDW

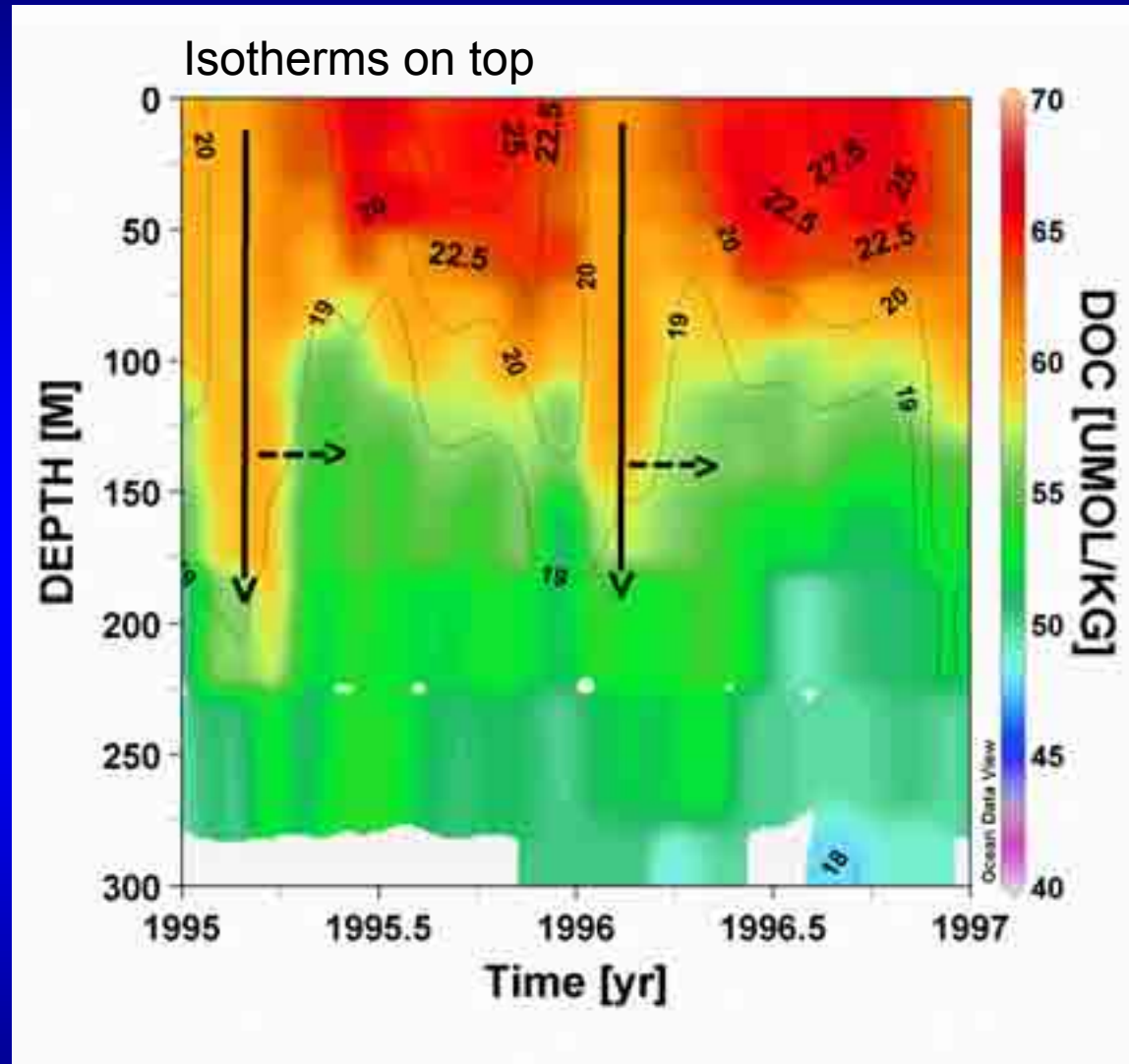
Hansell et al (in review)

# BATS DOC

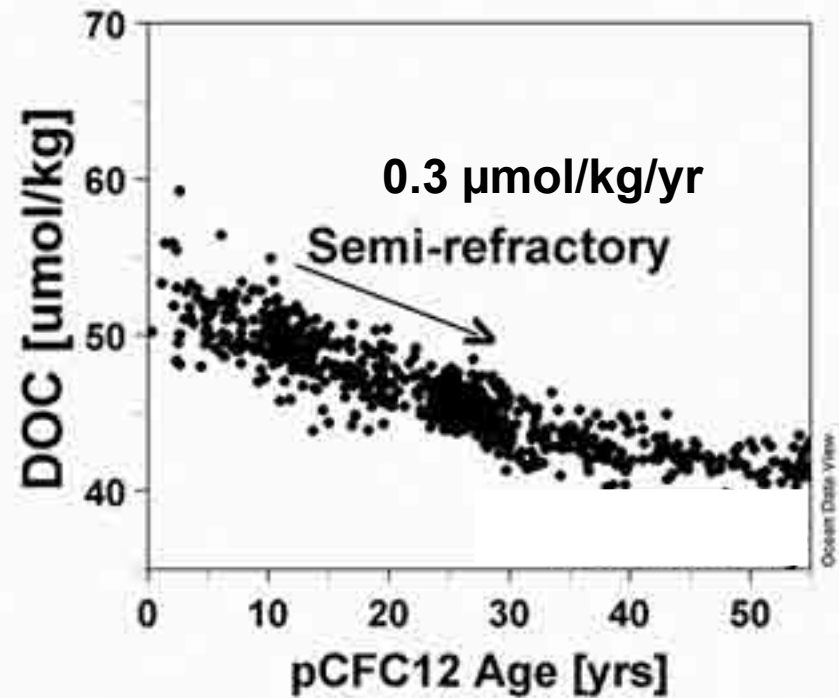
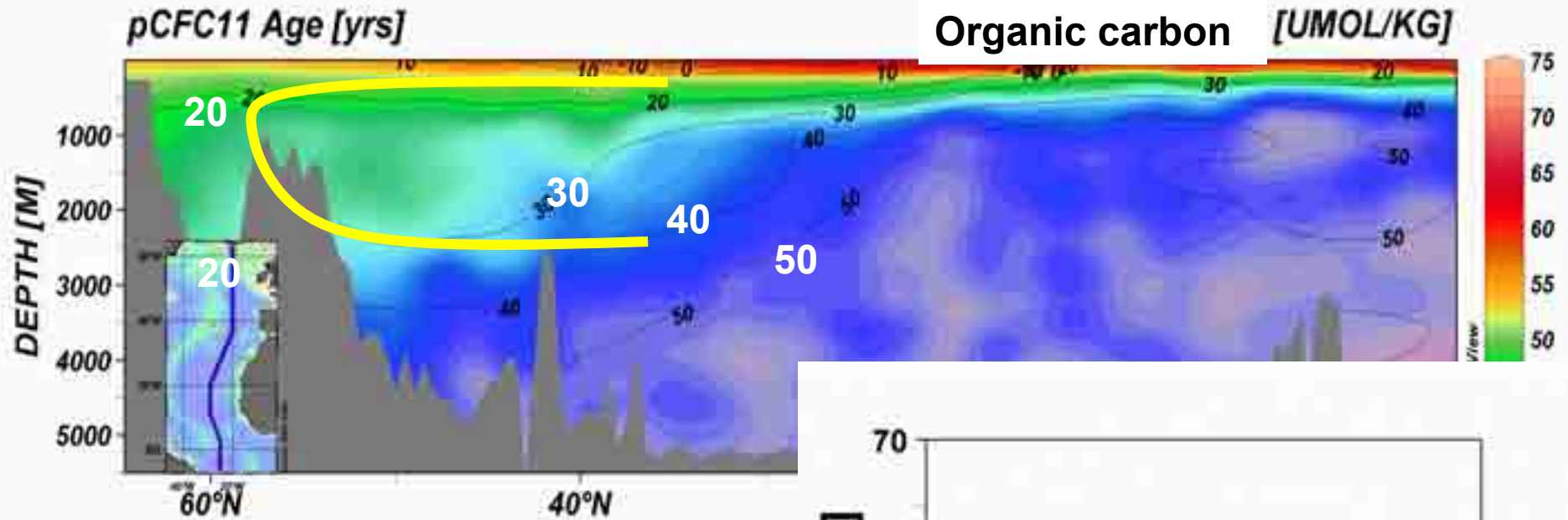
**Dashed lines indicate periods of convective overturn in winter, with export of DOC; it is then removed.**

**~6  $\mu\text{mol C/kg/yr}$**

Hansell and Carlson, 2001

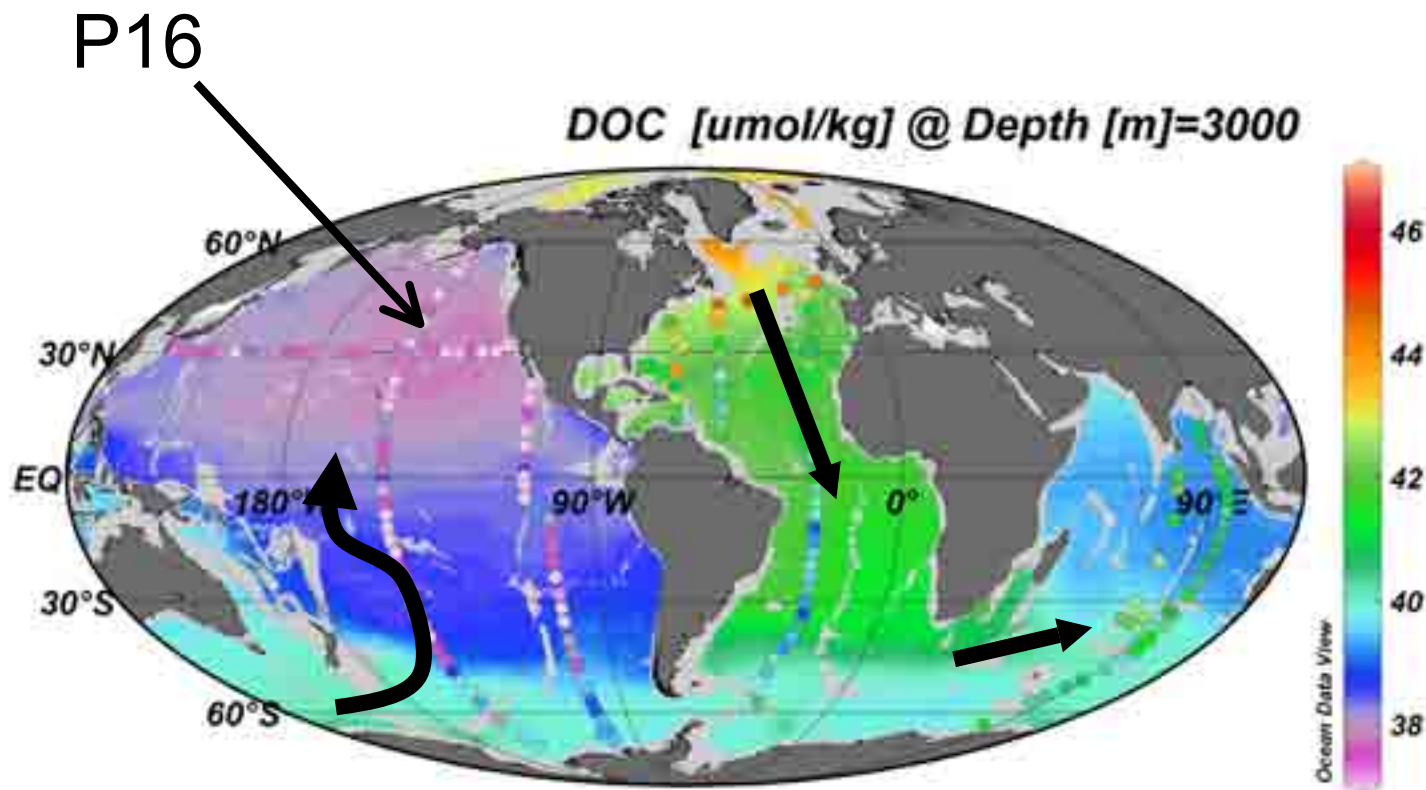


# Overturning circulation delivers DOC to depth



Carlson et al., 2010

# DOC at 3000 m

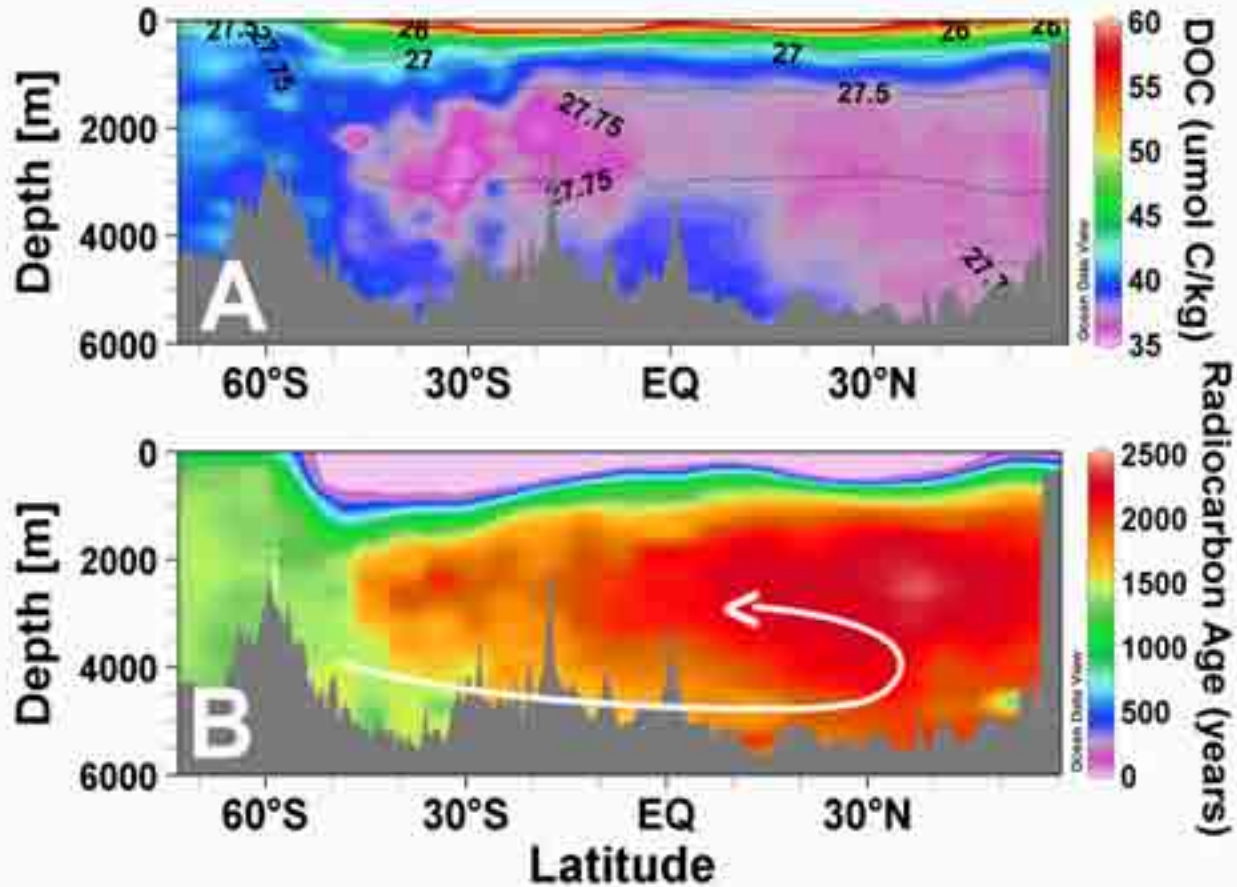
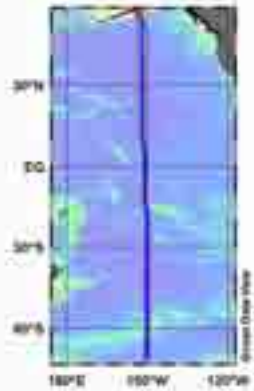


Modeled (colored field)  
Observed (filled circles)

Hansell et al., 2009



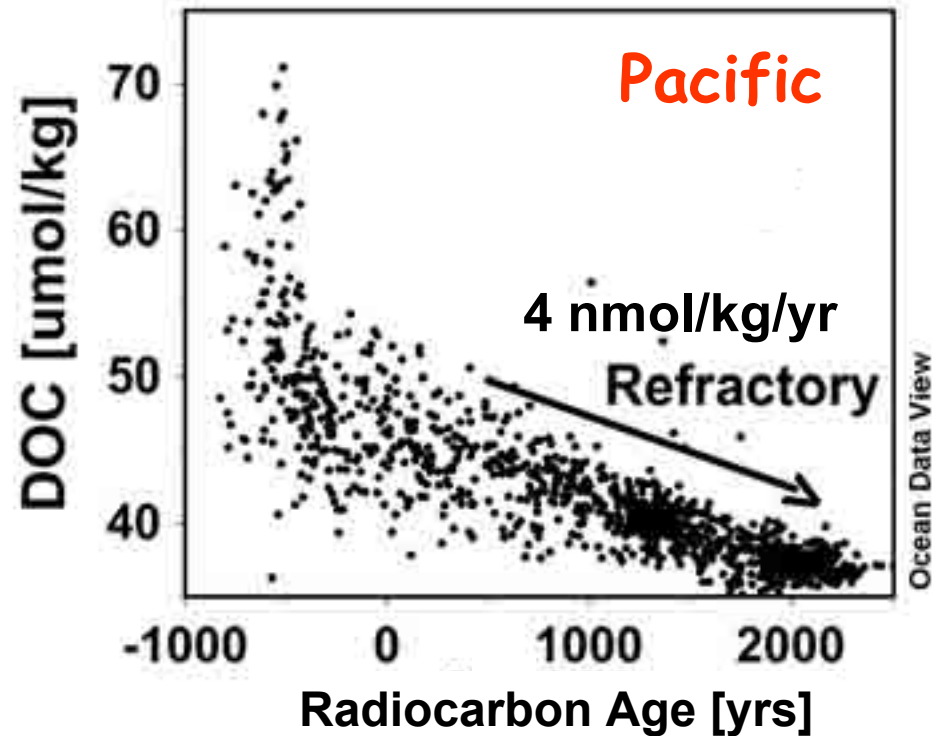
# DOC in the Pacific Ocean (CLIVAR P16)



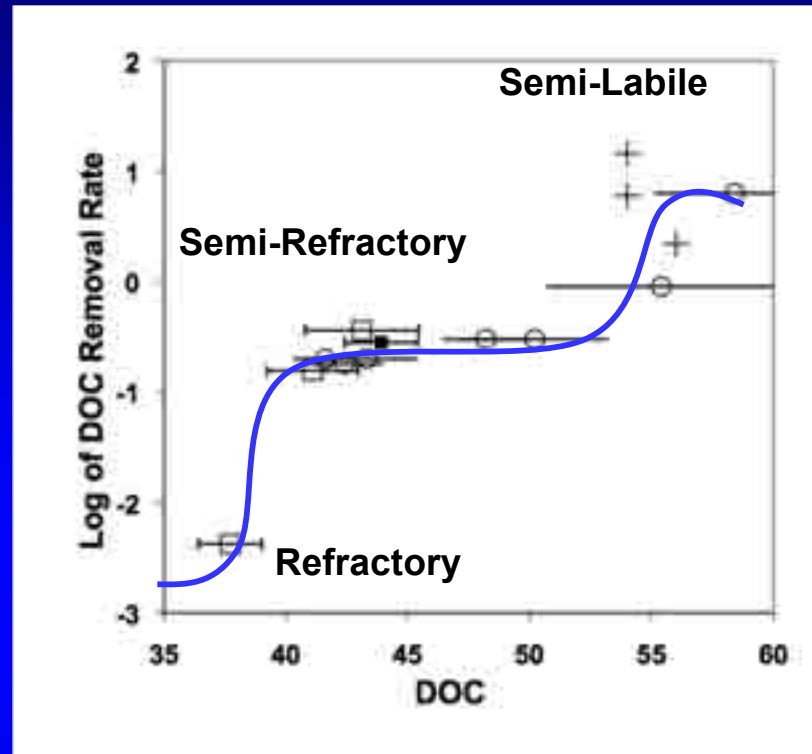
DOC  
( $\mu\text{mol/kg}$ )

TCO<sub>2</sub> Radio-  
carbon  
Age (yrs)

## DOC/age regressions in the Pacific



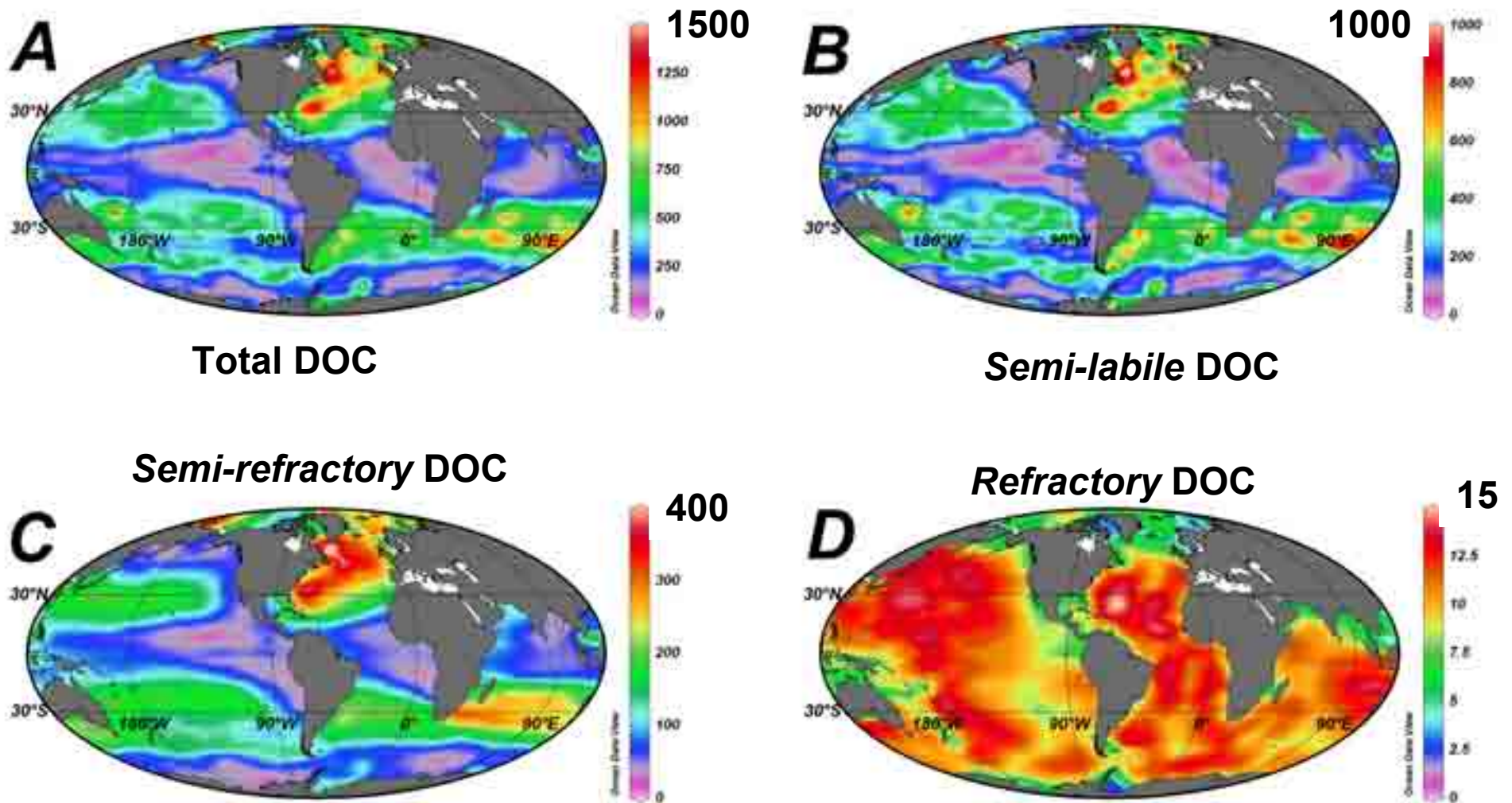
# DOC Export



Fraction	Global	Lifetime	
	Inventory (Pg C)	Observed (years)	Model (years)
Semi-labile	5.8	1-4	1.5
Semi-refractory	13.8	10-25	20
Refractory	642.4	-	16,000

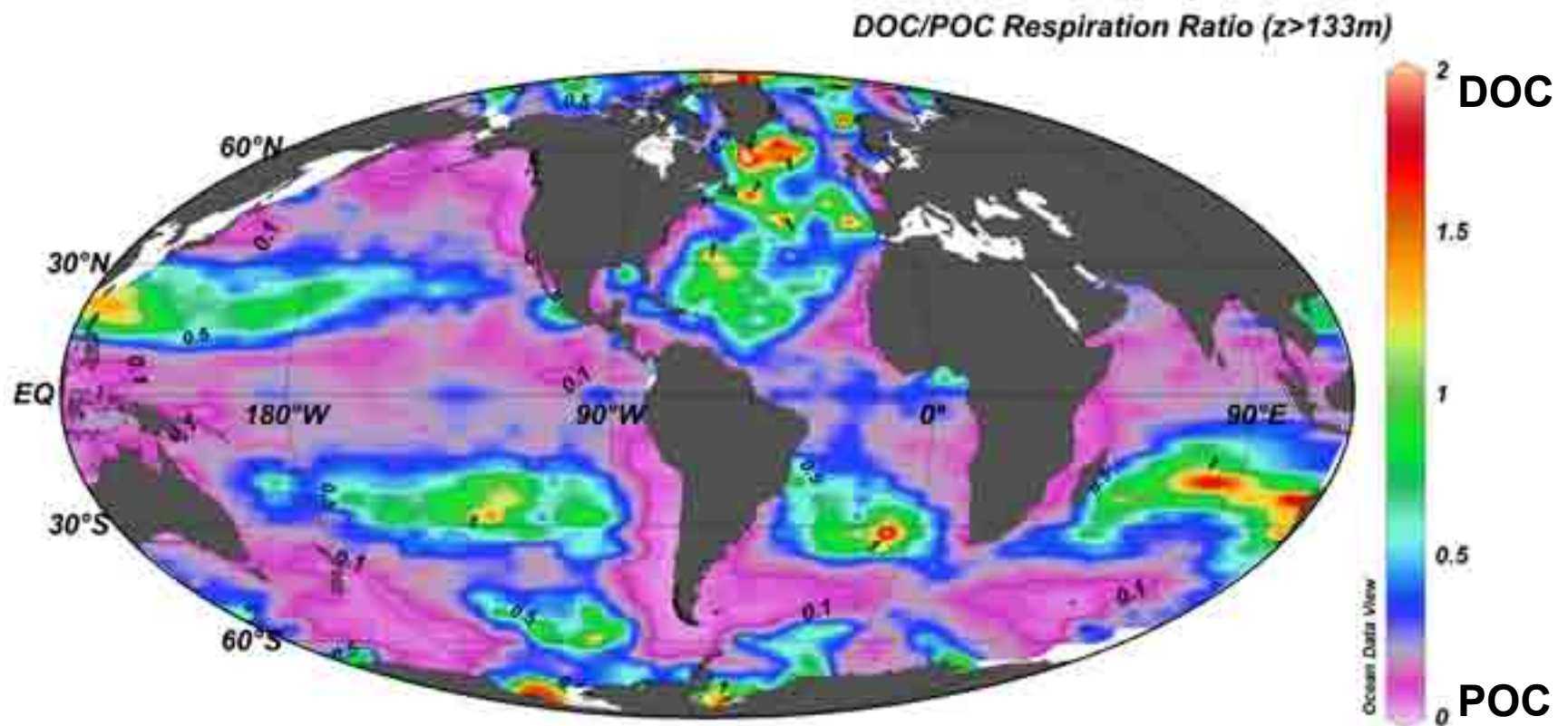
Hansell et al. in review

## Integrated rates of exported DOC removal ( $>130$ m; $\text{mmol C m}^{-2} \text{ yr}^{-1}$ ).



Modeled DOC is decomposed into three pools (*semi-labile*, *semi-refractory*, and *refractory* DOC) with lifetimes of 1.5, 20, and 16k years, respectively.

# DOC:POC removal ratio (>133 m)



**DOC export maxima in convergence zones;  
POC export maxima in divergence zones;  
Net DOC production maxima in the divergence zones.**

“We ..... know there are known unknowns; that is to say we know there are some things we do not know.”

Donald Rumsfeld, February 2002

1. DOC removal can occur both by biotic and abiotic processes; when/where does each occur? Who/what are the agents of removal?
2. Observed DOC removal rates are net rates: DOC accumulates at depth as a residue of sinking particles

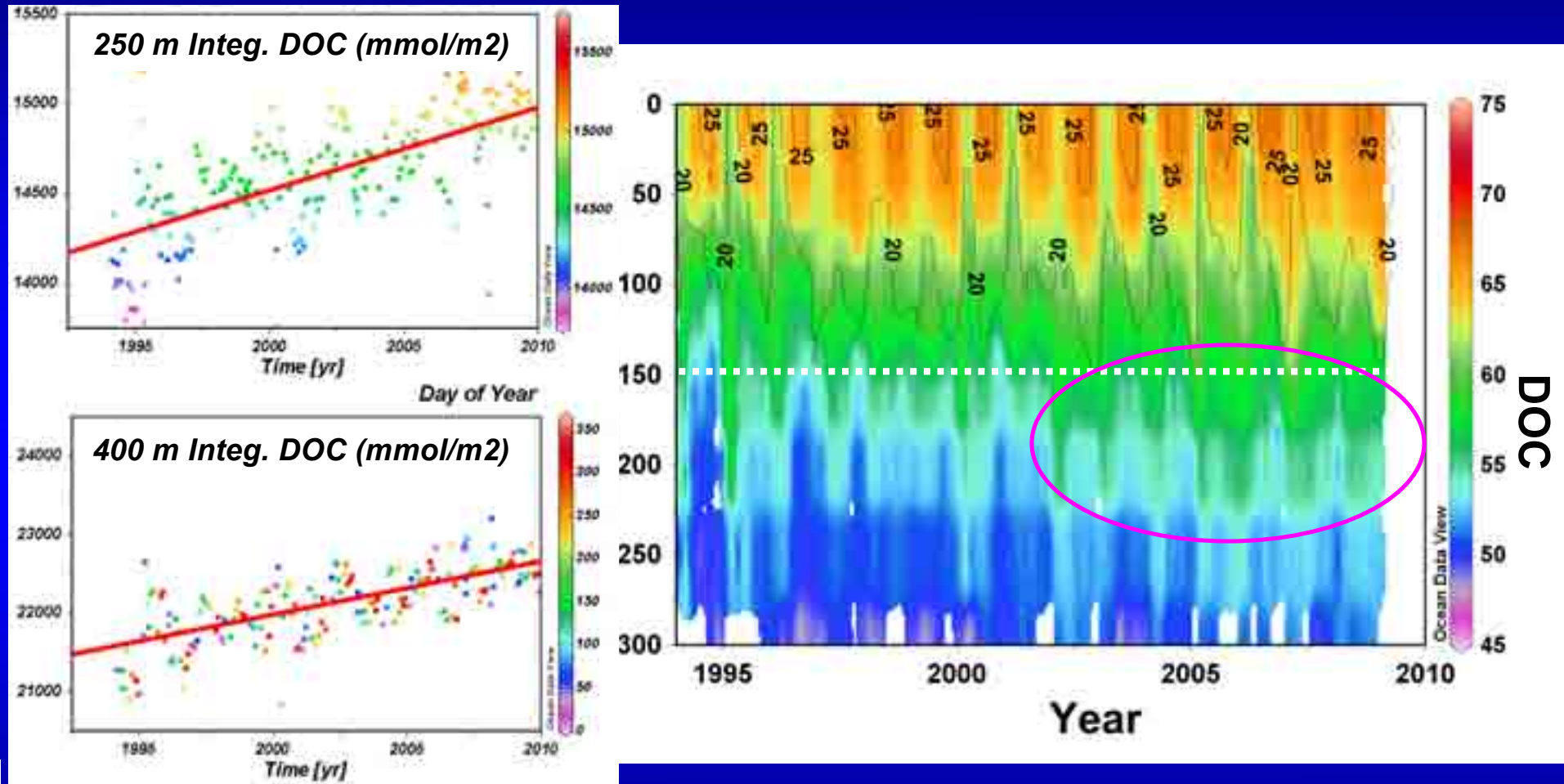
## 3. DOC as residue of particle export

### Observed.....

1. Subeuphotic zone accumulation of DOC at the BATS site
2. (C)FDOM associated with sinking particle remineralization
3. “RubisCO” distributed throughout the water column under high particle export systems
4. DOC enhancements deep under equatorial waters

# DOC as residue of export

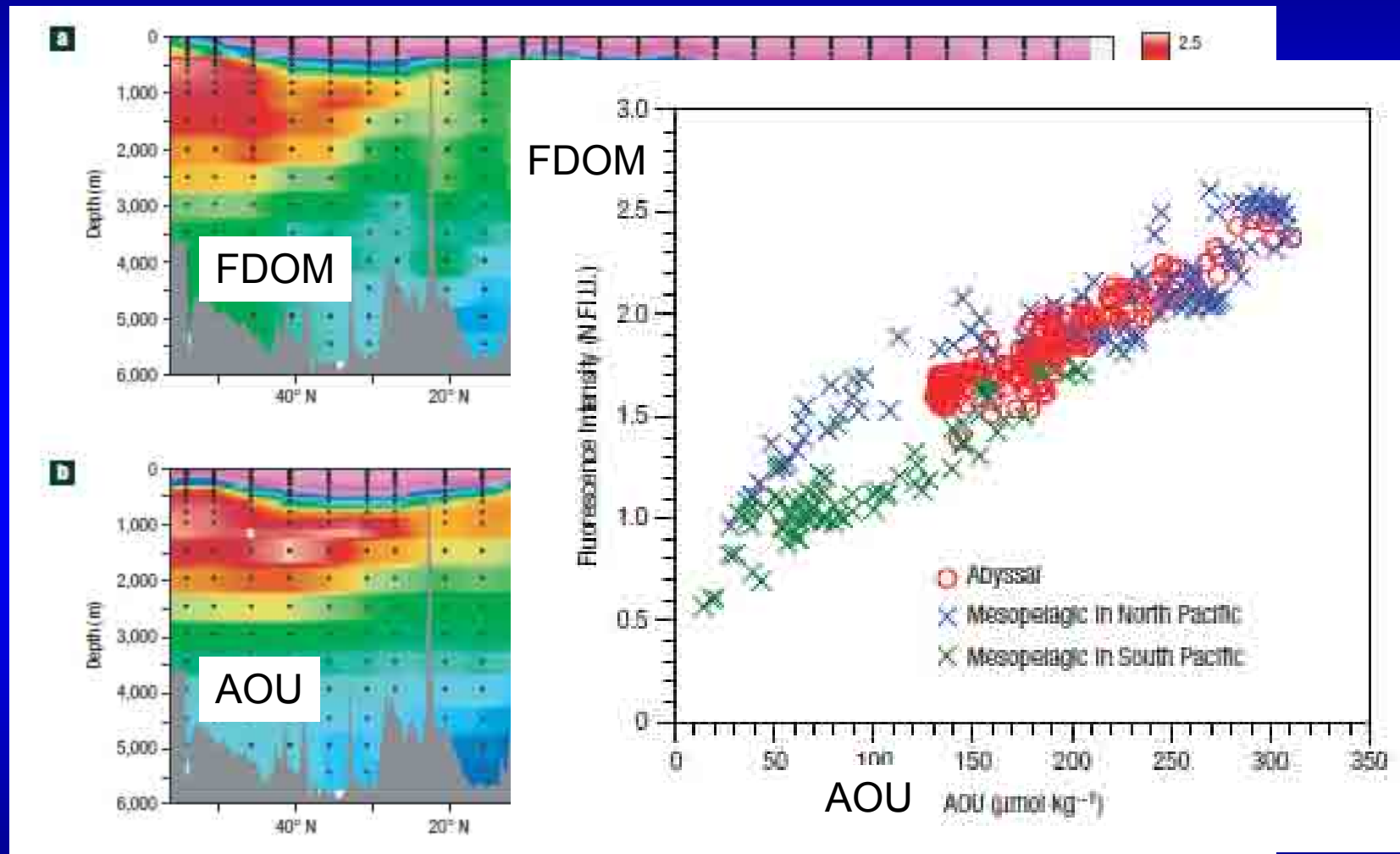
- subsurface accumulation of DOC at BATS



Increase of **1 mol/m<sup>2</sup>** DOC in the upper 400 m of the water column, apparently associated with shift in NAO in 1996 (see Lomas et al., 2010)



# DOC as residue of export FDOM in the OMZ of the North Pacific

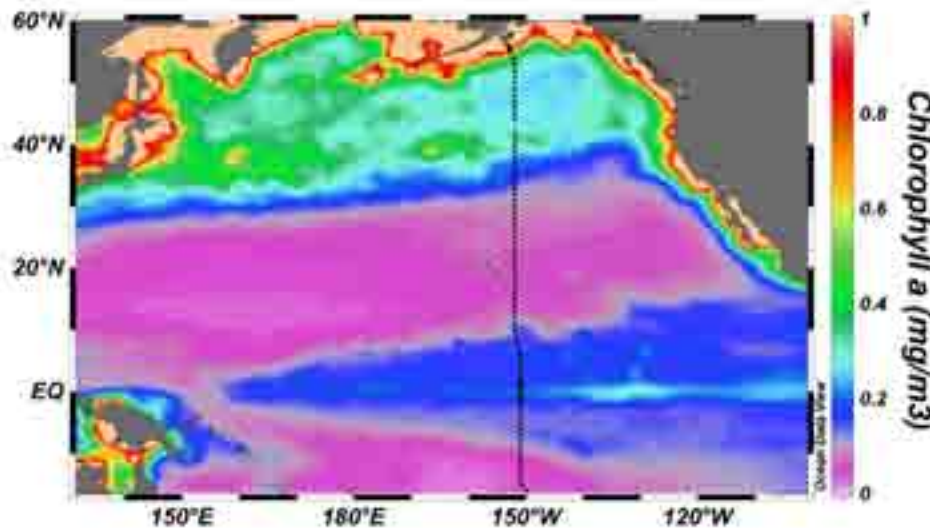
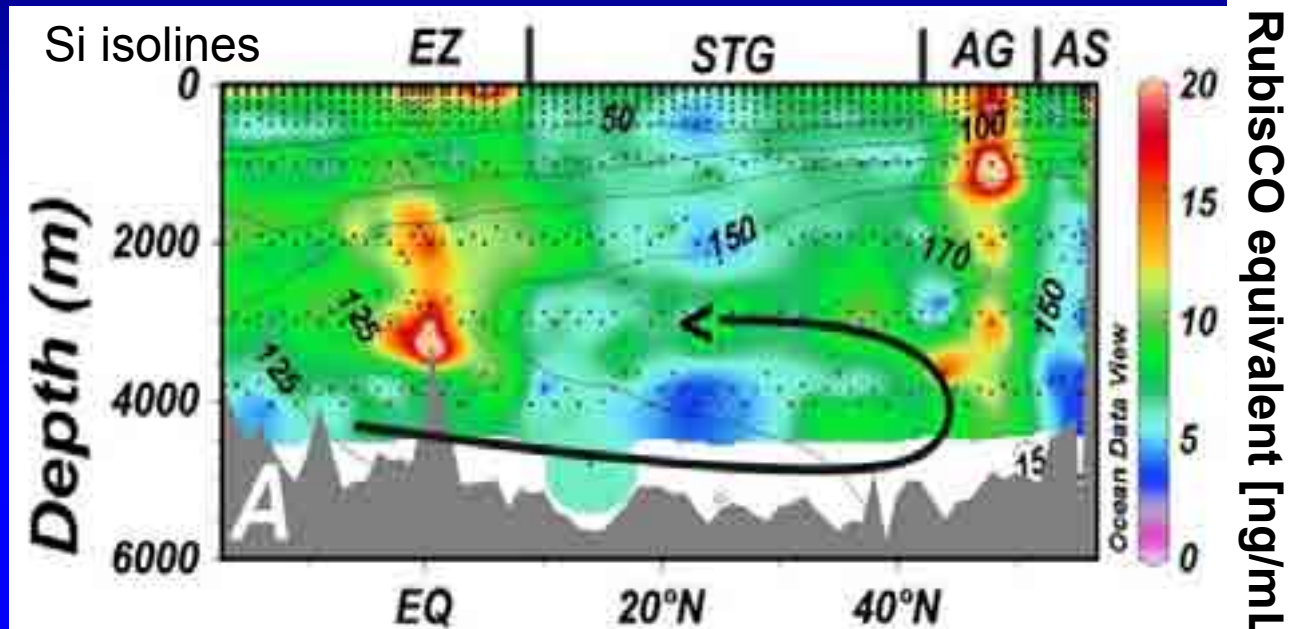


160/170°W (Yamashita and Tanoue, 2008)

# DOC as residue of export

Organic matter that is reactive to a RubisCO antibody

Tracer of export residue

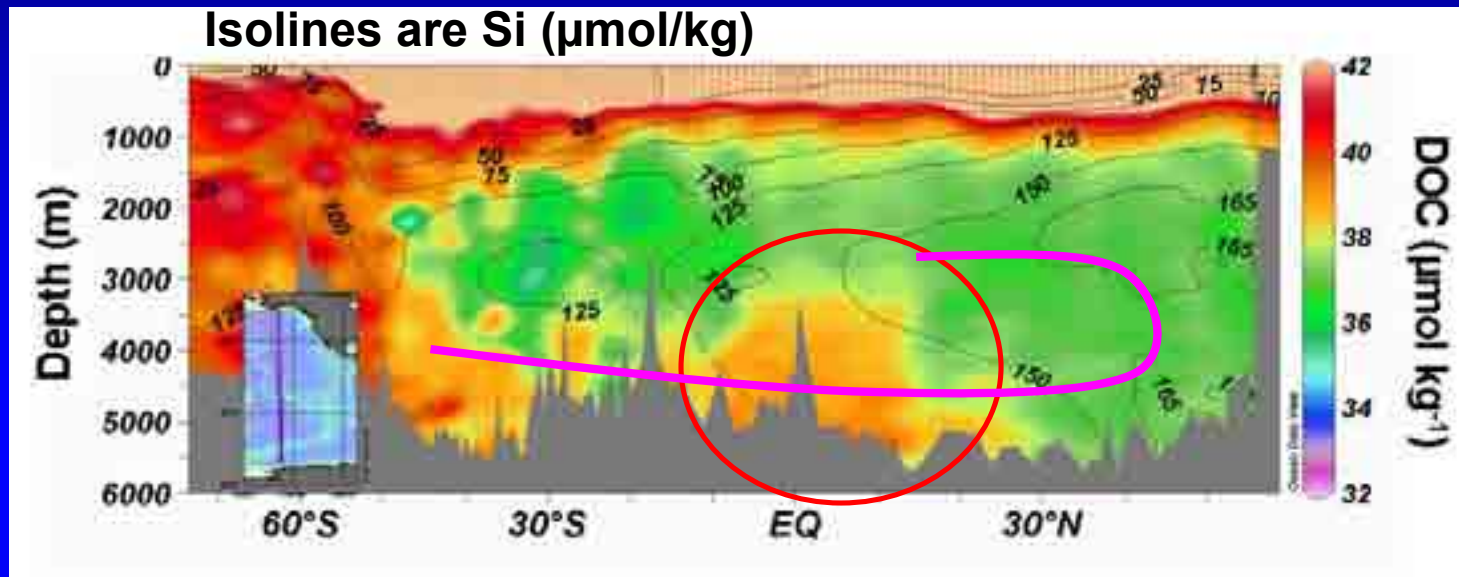


Orellana and Hansell (unpublished)

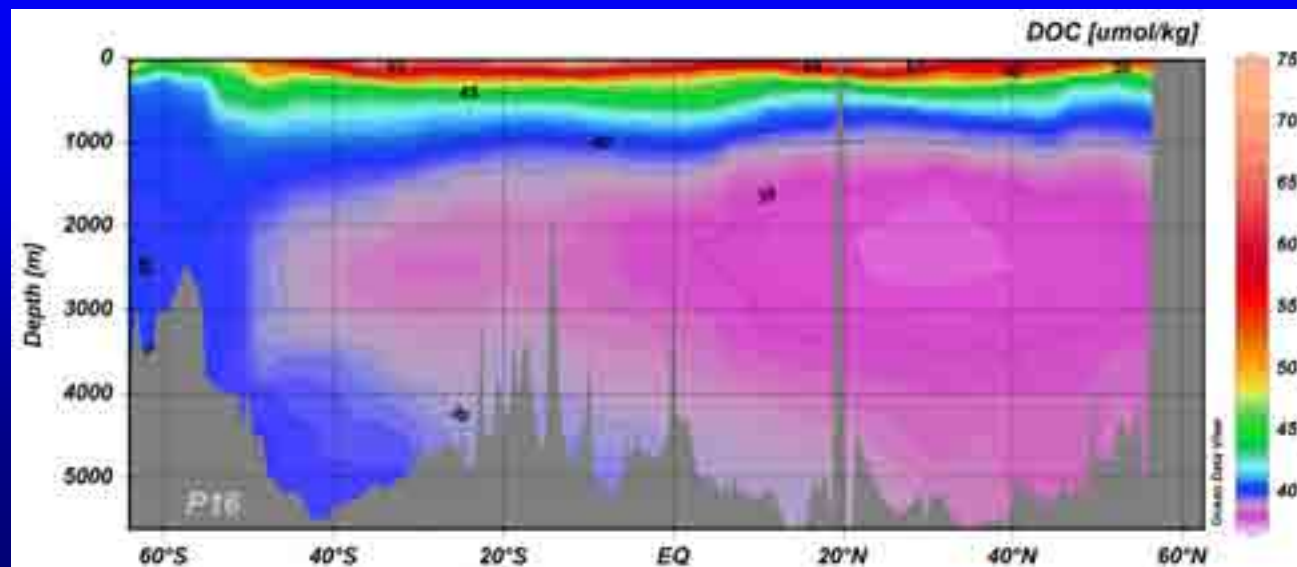
# DOC as residue of export

- Accumulation of DOC deep under equatorial waters

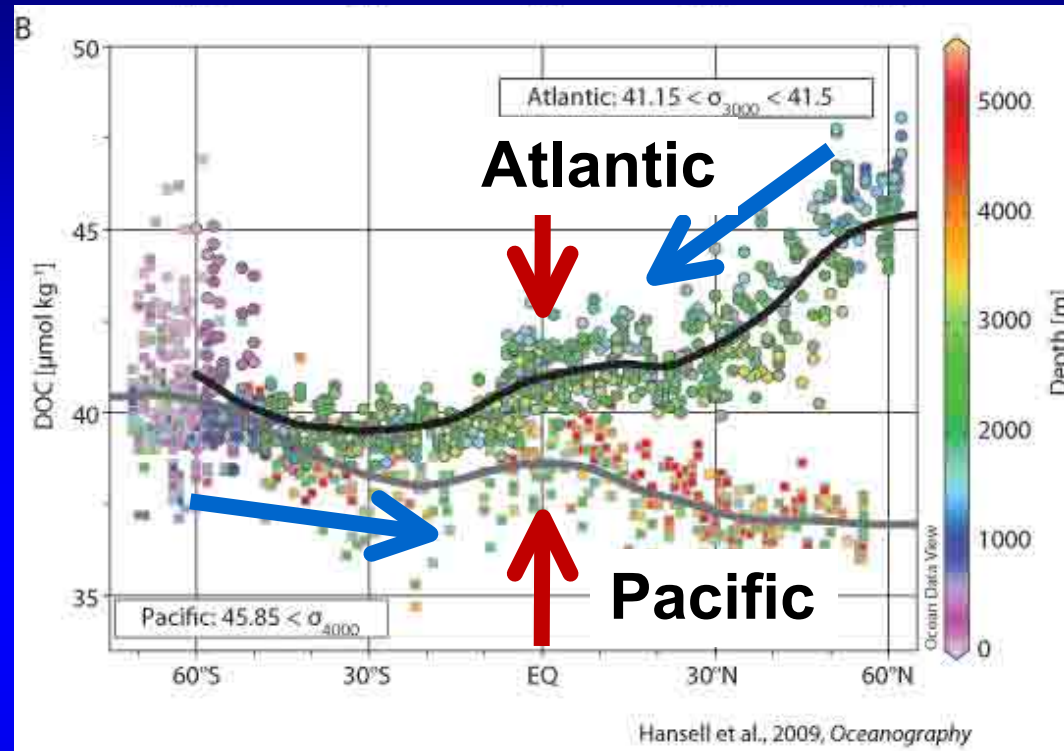
P16  
Obs.



Modelled  
Pacific  
DOC  
(removal  
only)



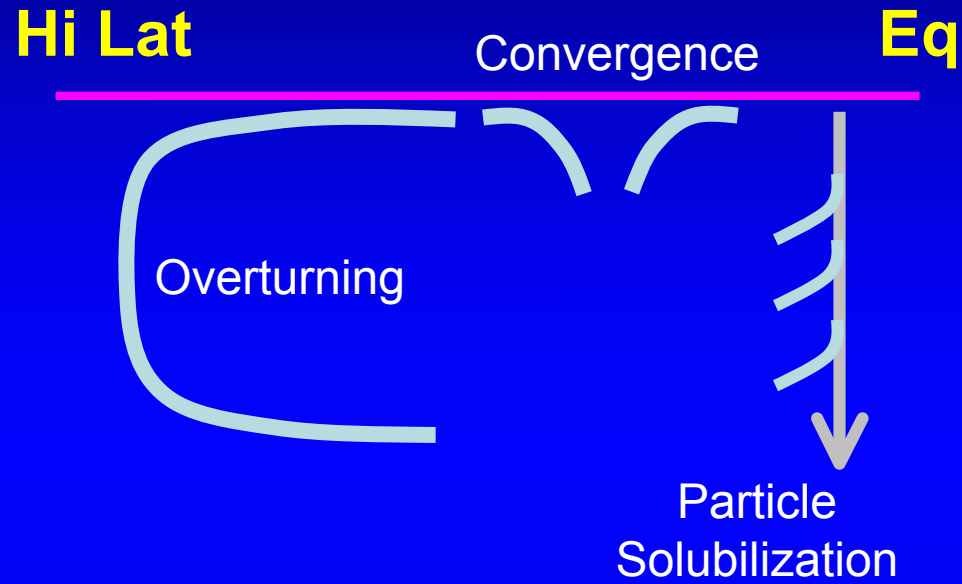
**DOC on deep  
isopycnal  
surfaces**



**Deep  
and  
bottom  
waters**

**Inputs are apparent near  
the equator**

# DOC in Export



# DOC in Export

- For DOC export, look to the convergence zones globally, and deep water formation in the North Atlantic.
- For net DOC production in surface waters, look in high productivity systems.
- For DOC production as residue of exported particles, look under high productivity systems.

**Questions?**

## 5. Consideration of the GFP-OOI opportunity

- DOC export occurs with overturn of the water column. At present we do not have sensors specific to DOC, but proxies for mixing of surface waters to depth may be useful meanwhile.

In convergence zones, temperature may work:

a) Onset of winter, cooling first without overturn.....

b) then at threshold temperature, vertical instability results in DOC export.....

