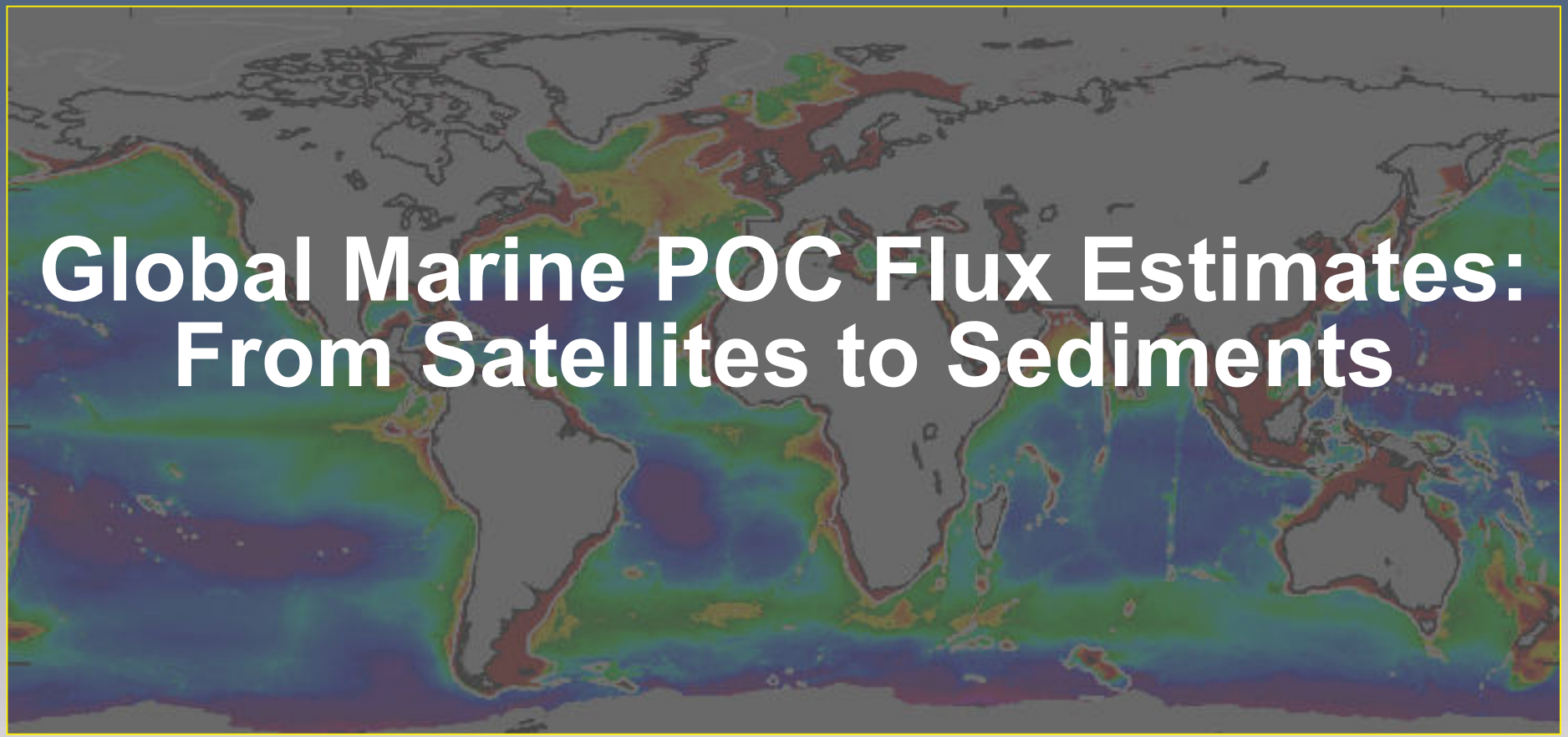

Global Marine POC Flux Estimates: From Satellites to Sediments

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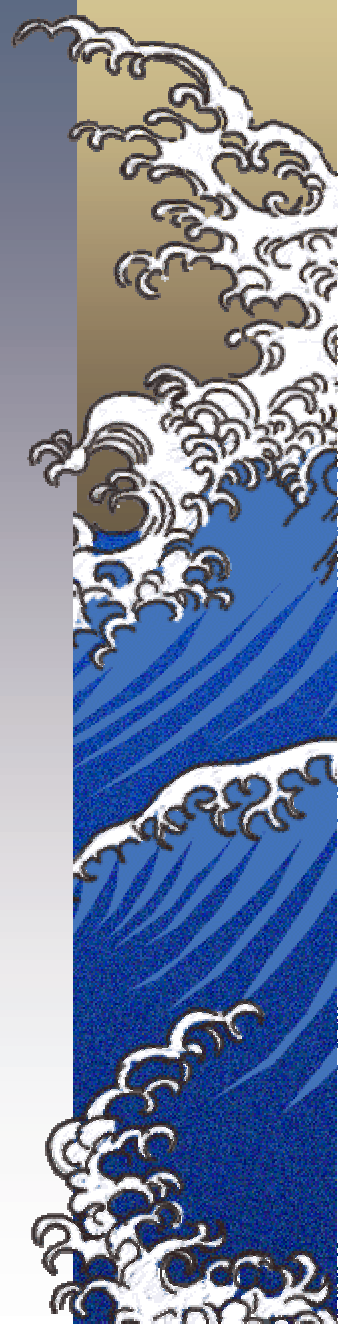
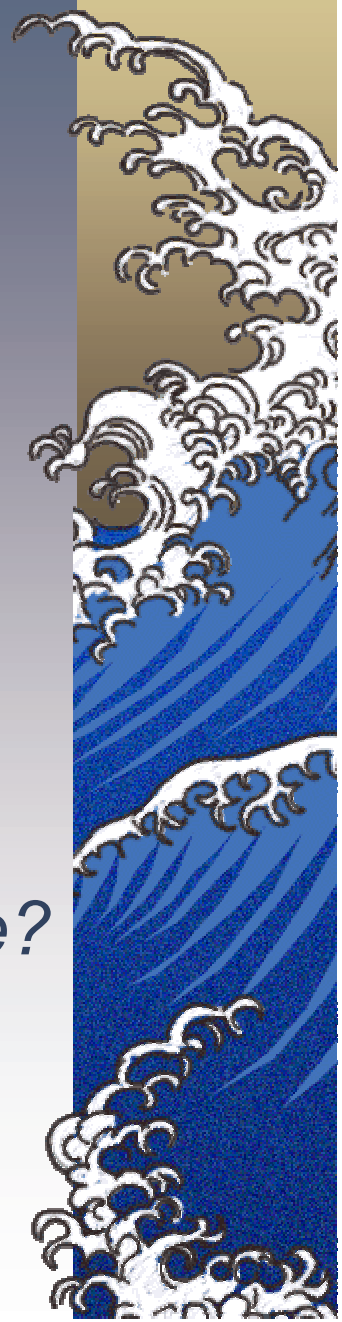
Outline

- Purpose of study
- Ocean productivity estimates
- Vertical POC flux estimates
- Global ocean POC flux
- Issues
- Recommendations for future research



PURPOSE OF STUDY

- *How much carbon is fixed by photosynthesis in the ocean and how much is sequestered?*
- *Do continental margins play a significant role?*

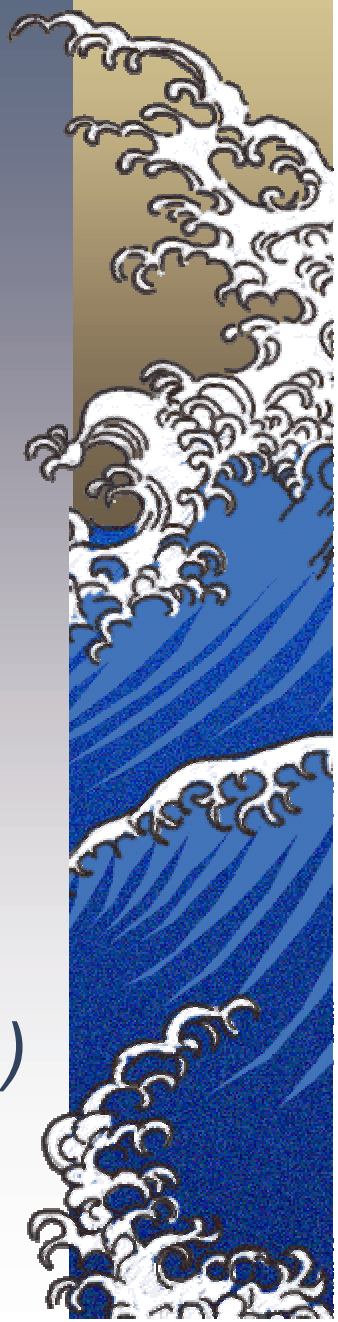


Global distribution of phytoplankton primary production
[mgC m^{-2} d^{-1}. White is > 500. Black is <100]
(Walsh et al., 1988; after Koblenz-Mishke et al., 1970)

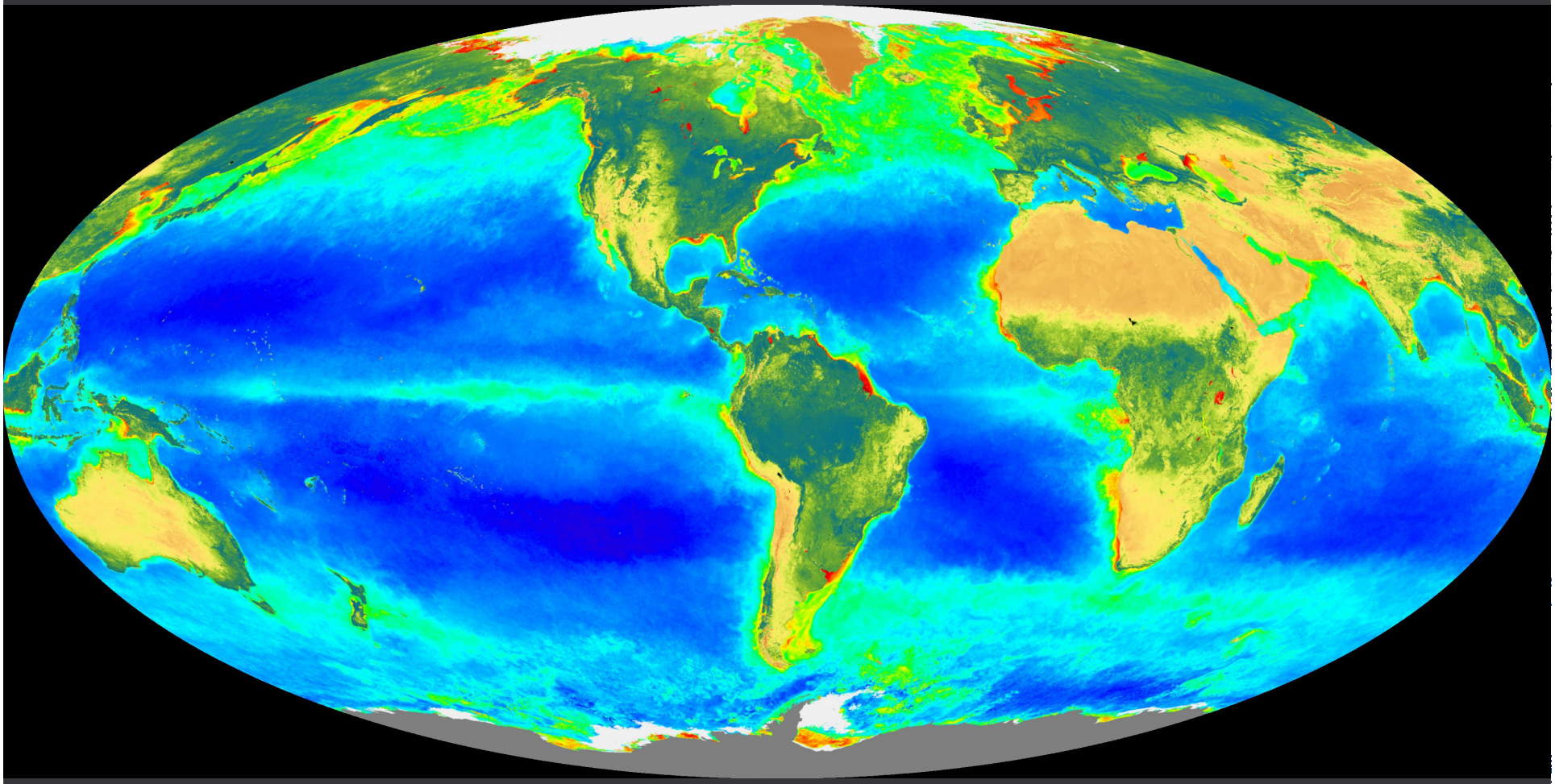
Productivity of Oceans

- *Approximately 1/2 of world's annual photosynthesis occurs in the oceans*
- *Traditional estimates:*
  - *~48 Pg C y^{-1}*

    (1 Pg = 1 petagram = $1x10^{15}$ g = 1 GTon)



Does global NPP vary over long periods of time?



Annual mean ocean chlorophyll concentration

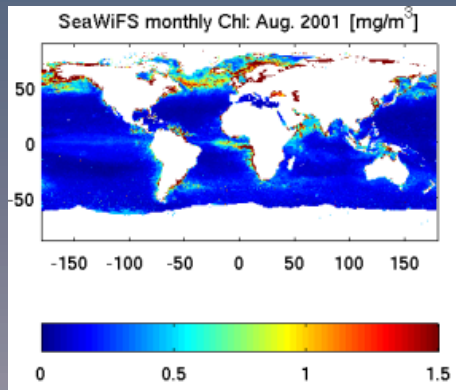
Depth Integrated Net Primary Productivity from remote sensing data

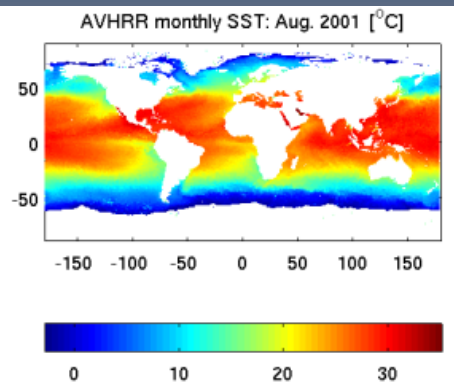
$$PP_{eu} = 0.66125\ P_{opt}^{B}\ \frac{E_o}{E_o + 4.1}\ C_{SAT} \times Z_{eu} \times D_{IRR}$$

- *Behrenfeld and Falkowski, 1997*

PBopt is difficult to estimate and is very variable.
-It is a source of great uncertainty
(Behrenfeld and others now advocate C-based approach

SeaWiFS CHL





AVHRR SST

SeaWiFS PAR

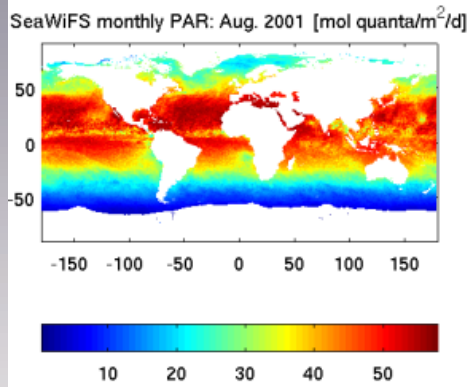
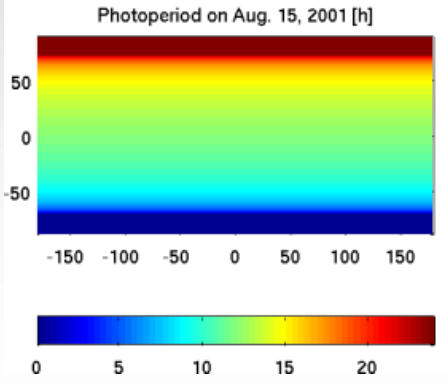
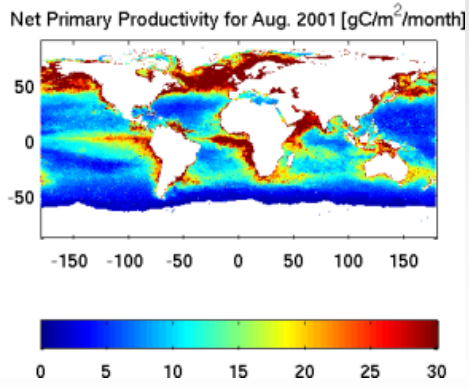


Photo-period





Monthly Net Primary Production

Global Oceans Primary Production

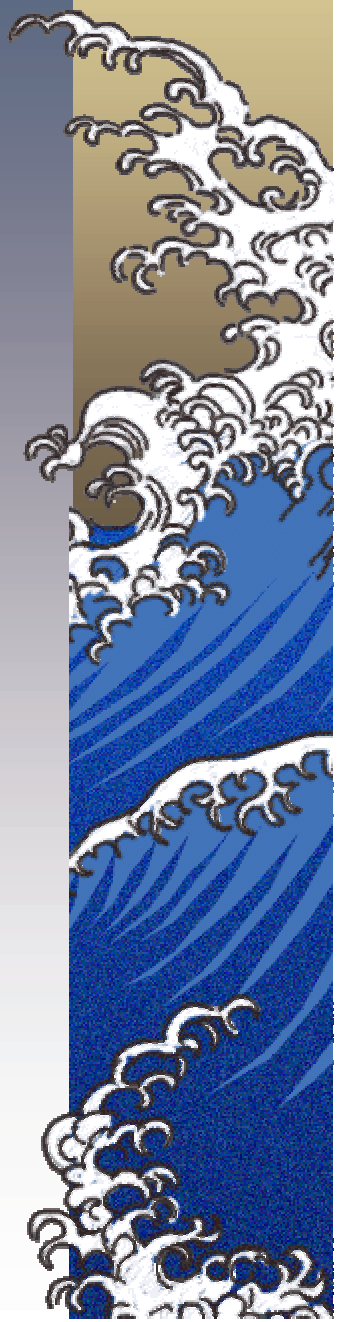
	Global	Deep water		Margins
Net PP [Pg*]	**47.91**	**38.92** (81%)		**8.99** (19%)

Interannual variation of global NPP was ~2% (4 years)

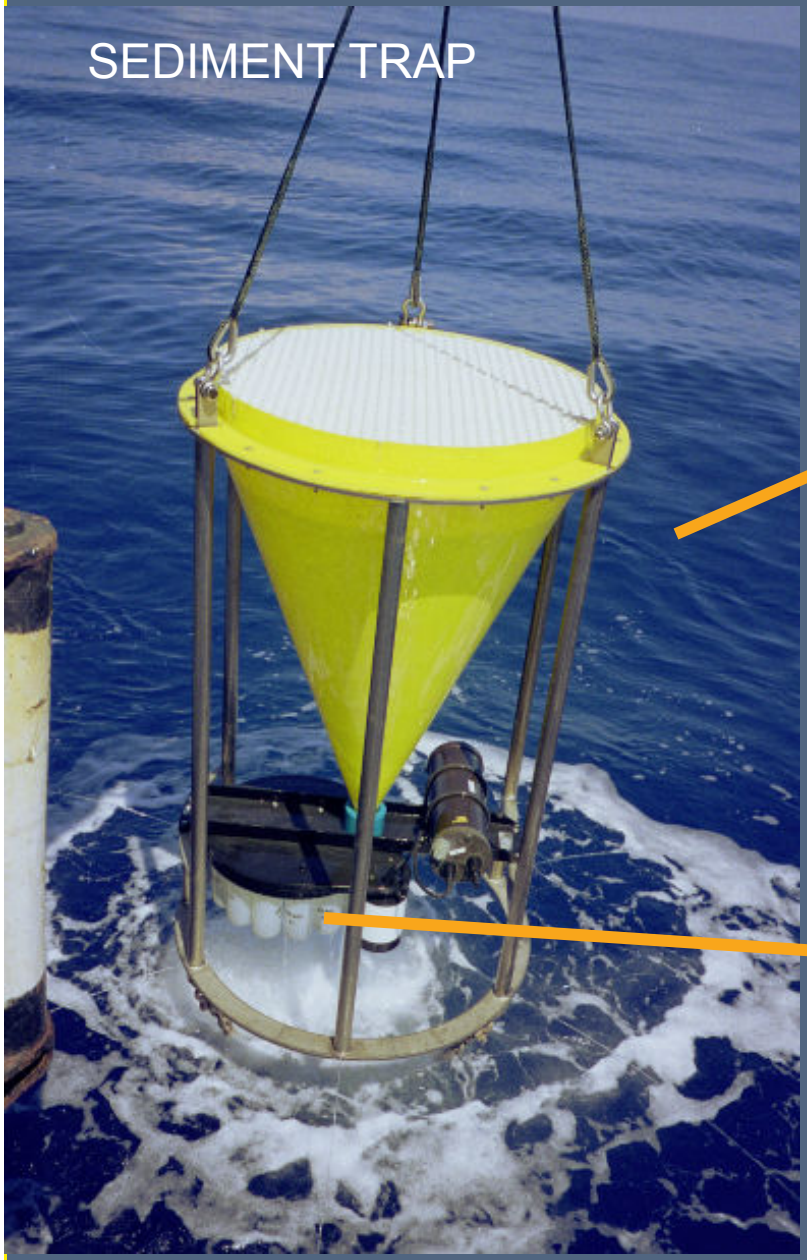
- *Continental margins (bottom < 2000 m)*
  - *shelves and slopes*
  - *5.8×10^7 km^2 → ~15% of world's oceans*
- *Deep ocean waters*
  - *31×10^7 km^2 → ~85% of world's oceans*

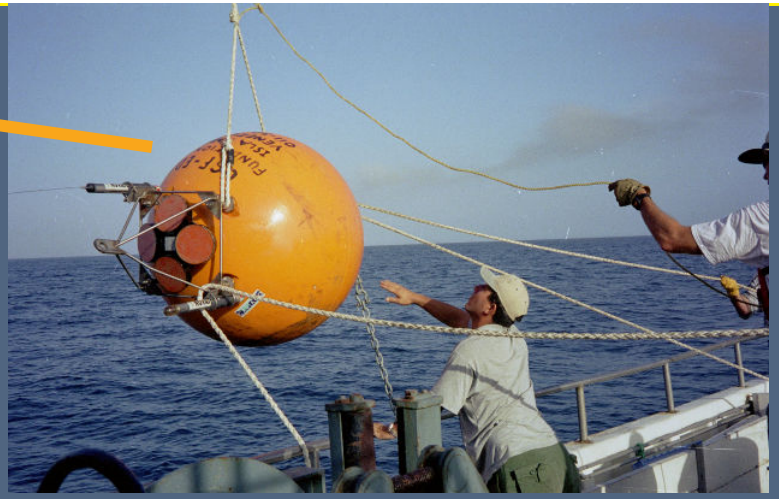
ISSUES

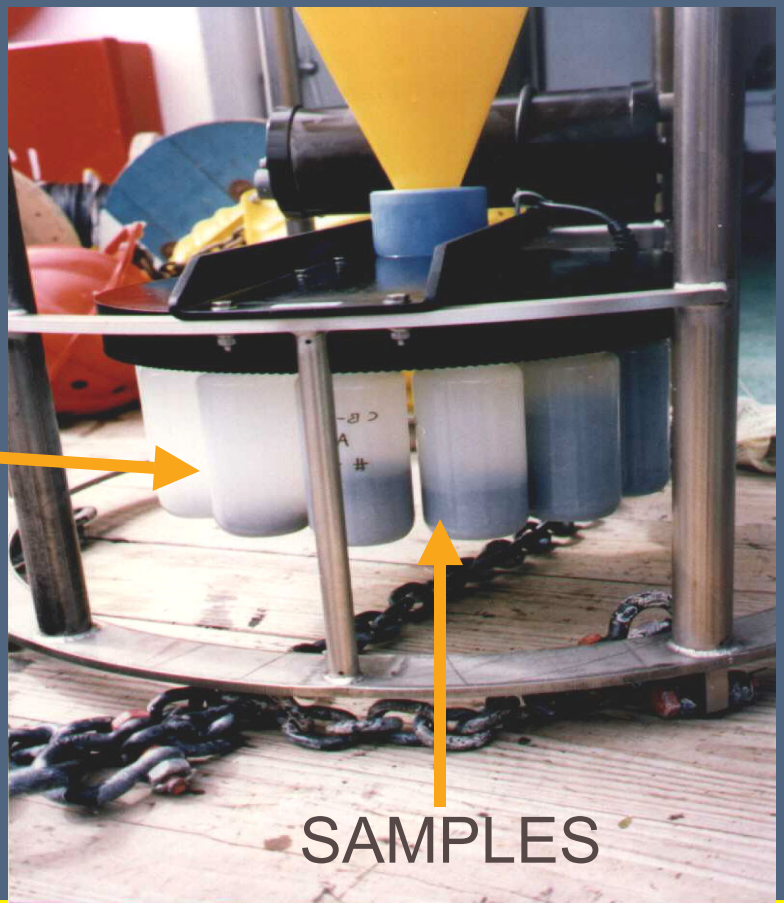
- *Behrenfeld et al. (GBC, 2005):*
  - *Carbon-based production models should be better*
    - *(but estimated global NPP > 60 Pg)*
- *Mouw and Yoder (L&O, 2005)*
  - *Satellite PP may "miss" 30% NPP in MAB*



Particulate organic carbon (POC) flux



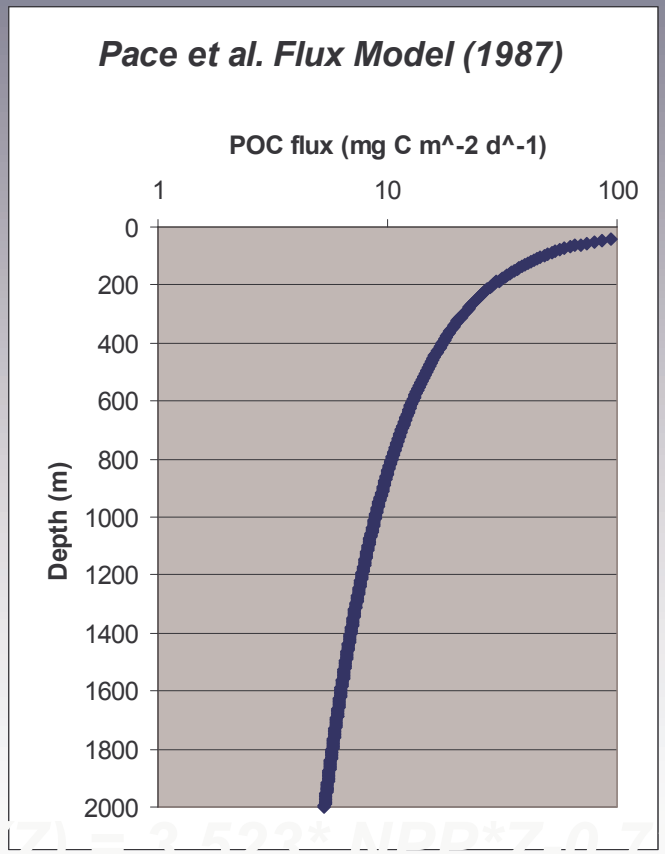




SEDIMENT TRAP MOORING

POC flux as function of NPP and depth

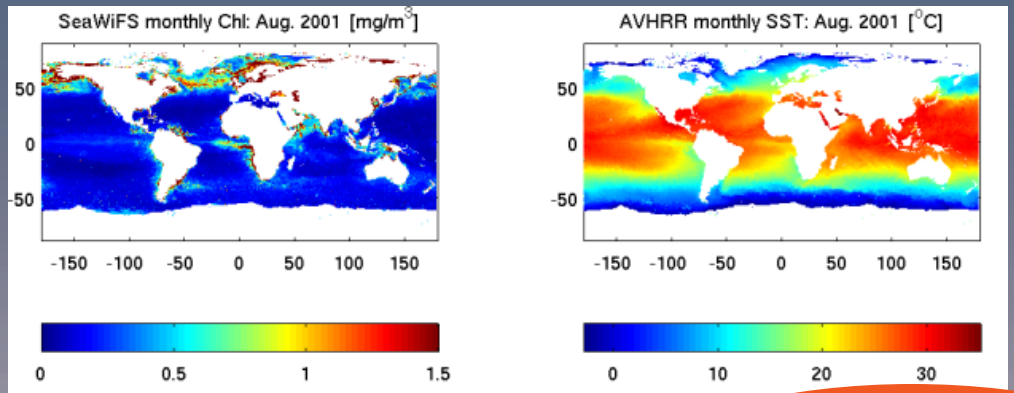
- *Pace, M., G. Knauer, D. Karl and J. Martin. Primary production, new production and vertical flux in the eastern Pacific Ocean. Nature. 325, 803-804 (1987)*
- *See also:*
  - *Francois, Honjo, Krishfield and Manganini, GBC 16:4, 2002*
  - *Lutz, Dunbar, Caldeira. GBC. 16:3. 2002*



Estimating Global POC Flux

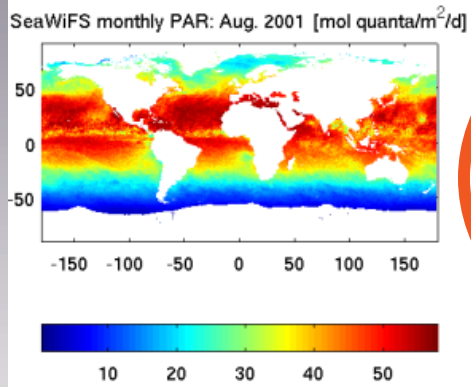
- *We applied Pace et al. (1987) to monthly SeaWiFS-derived global NPP estimates*
- *Constrained by:*
  - *Case Study 1: Thermocline*
    - *500 m where bottom < 2000 m*
    - *800 m where bottom > 2000 m*
  - *Case Study 2: Global bathymetry*

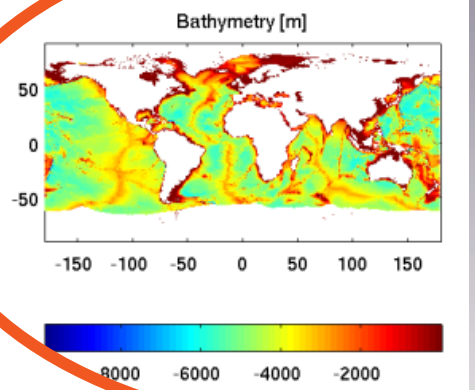
SeaWiFS CHL



AVHRR SST

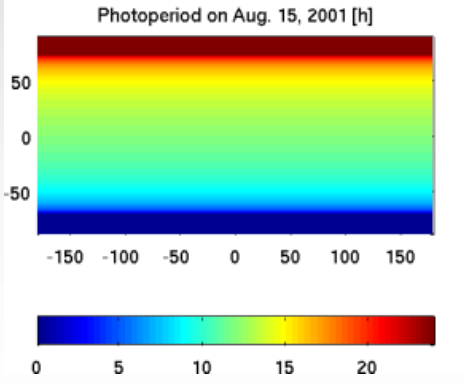
SeaWiFS PAR

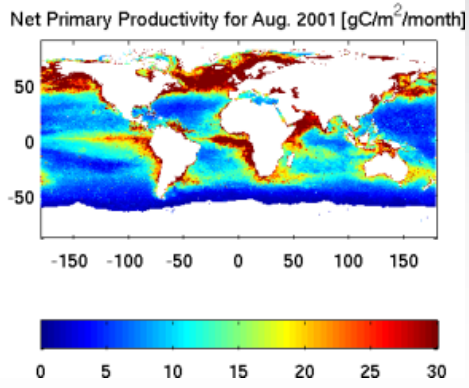




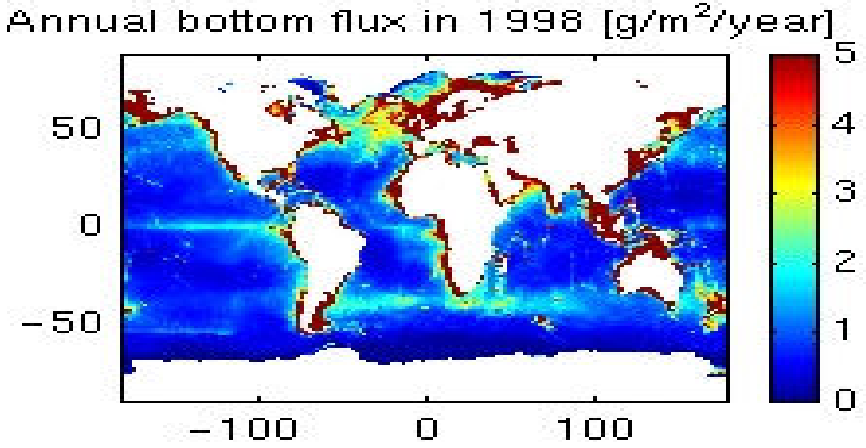
Bathymetry

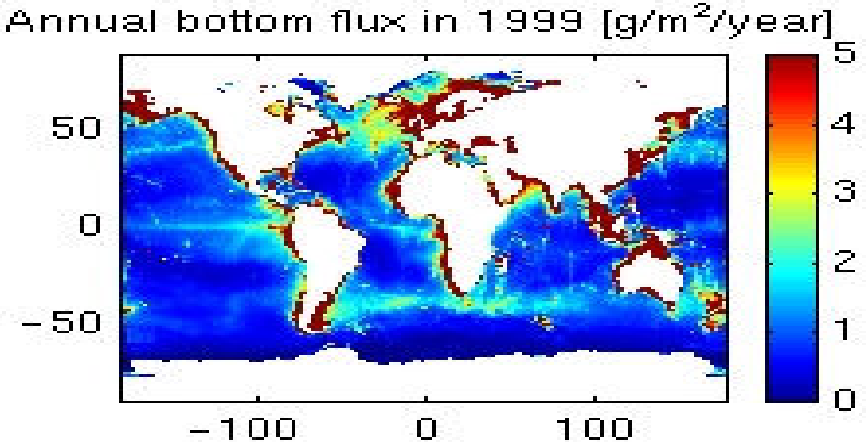
Photo-period

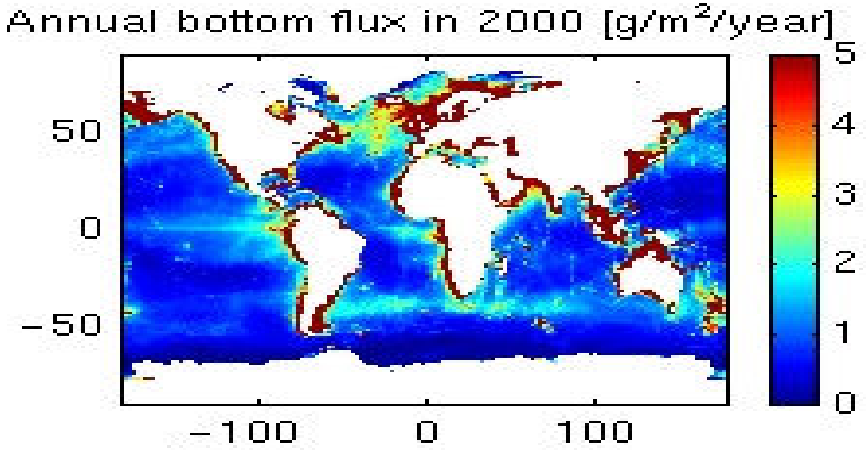


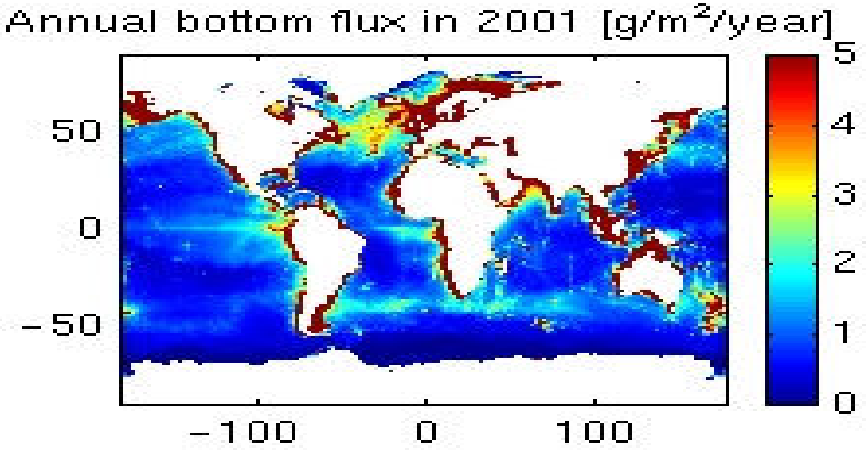


Monthly Net Primary Production





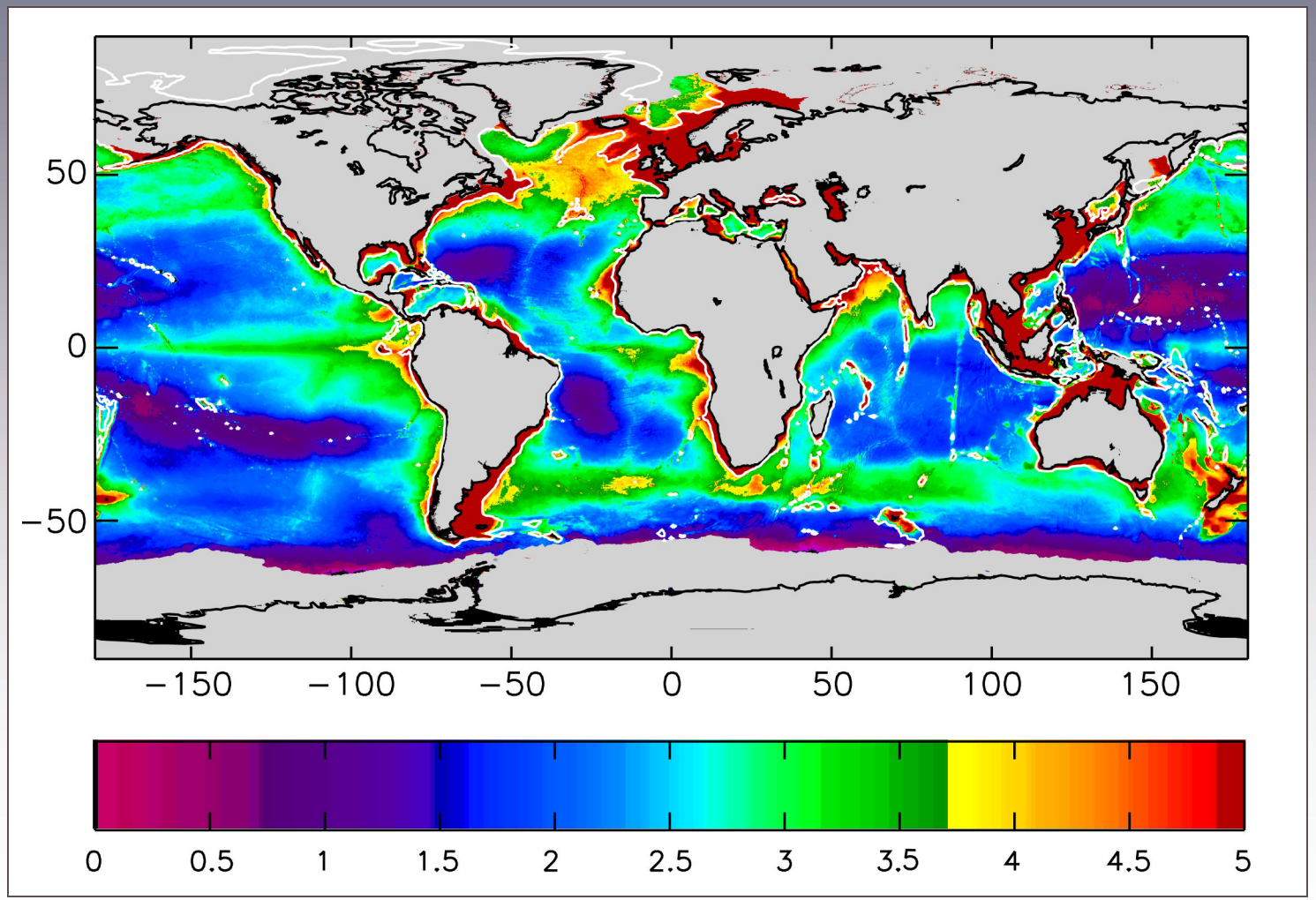




Annual bottom POC flux [g m-2 y-1] (1998 – 2001)

Interannual variation of global flux to bottom was ~1% (4 years)

Average annual bottom POC flux [g m-2 y-1] (1998 – 2001)

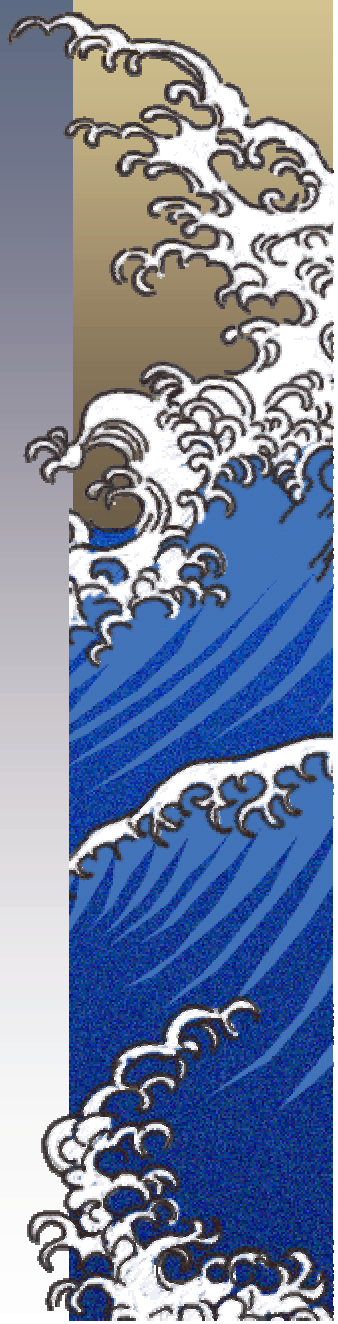


Global POC flux analysis

	Global (flux to bottom)	Deep water (flux to bottom)	Deep Water (flux to 800 m)	Margins (flux to bottom)	Margins (flux to 500 m)
Net PP [Pg*]	47.91	38.92		8.99	
Flux [Pg]	0.93	0.31	1.01	0.62	0.68
		33%	60%	67%	40%

Conclusions

- *Considering flux to thermocline:*
  - *Oceanic biological pump sequesters 60% of C in the deep ocean, 40% on margins*
  - *Carbon on margins could also move laterally into the deep ocean along isopycnals*
  - *This is a minimum estimate of flux on margins*
- *Note: using PP or Export Production gives about same answers (see also Lutz et al., 2002)*

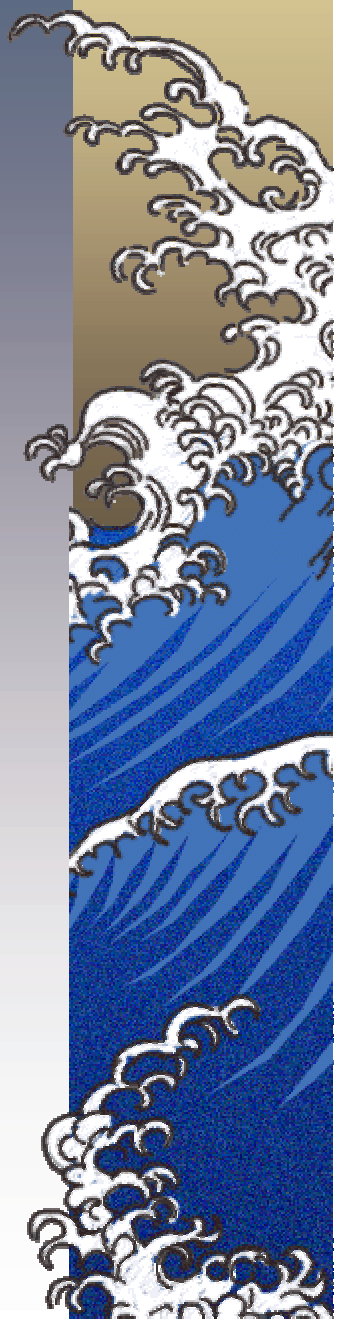


Conclusions

- *POC reaching bottom*
  - *Largest flux over shelves, ridges, mounts*
  - *Margins: receive 60% of global flux to bottom (again, a minimum estimate)*

Estimating burial

- *To estimate the amount of carbon buried in sediments, we assumed:*
  - *~30% POC burial efficiency in the deep sea (Jahnke, 1996; Dymond and Lyle, 1994)*
  - *~10% on margins (Jahnke, personal comm.)*



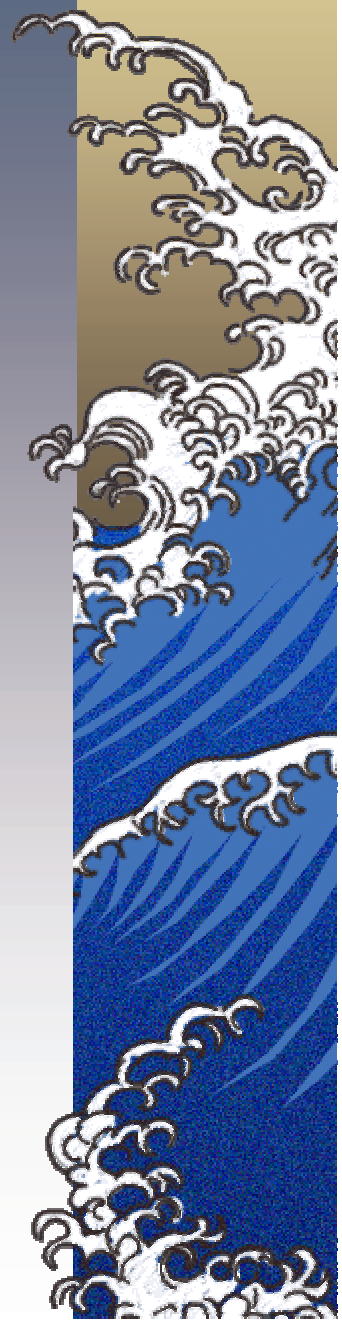
Global POC flux analysis

	Global (flux to bottom)	Deep water (flux to bottom)	Deep Water (flux to 800 m)	Margins (flux to bottom)	Margins (flux to 500 m)
Net PP [Pg*]	47.91	38.92		8.99	
Flux [Pg]	0.93	0.31	1.01	0.62	0.68
C buried [Pg]	0.15	0.09		0.06	

60% 40%

Conclusions

- *Burial:*
  - *>40% global ocean annual buried POC flux is on margins*

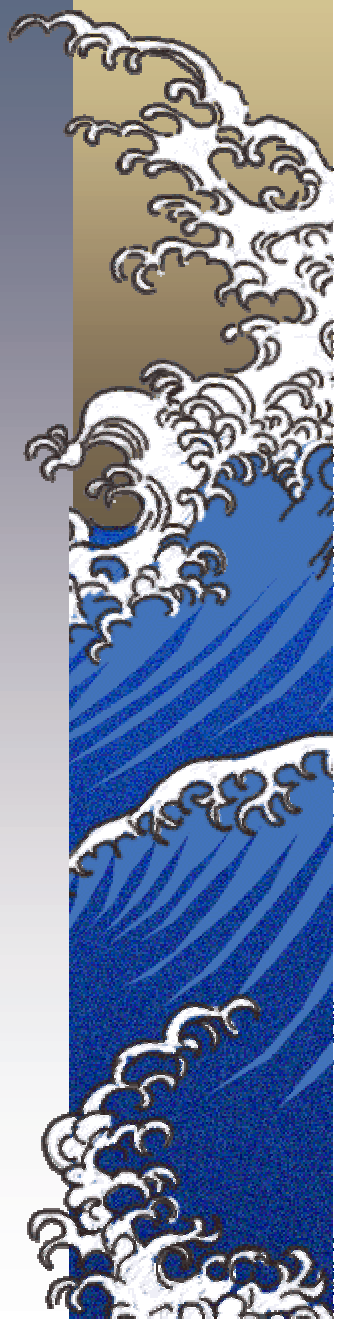


Example of Implications

- *Chris Sabine's estimate of oceanic sink for anthropogenic CO2:*
  - *Assumption is that NPP and vertical POC flux don't change*
- *Gregg et al. (GRL 30:15, 2003):*
  - *suggested that deep ocean NPP decreased 2.8 Pg C per decade between the late 1980's and the early 2000's.*
  - *This would lead to a decrease of perhaps 0.007 Pg C y^{-1} in the carbon sequestered to >800 m in the deep open ocean.*
  - *In contrast, just the year-to-year variation in POC reaching the sea floor over margins (±2%) is larger.*
  - *Even crude estimate of burial on shelves is ~0.06 Pg C y^{-1}.*

Major Conclusion

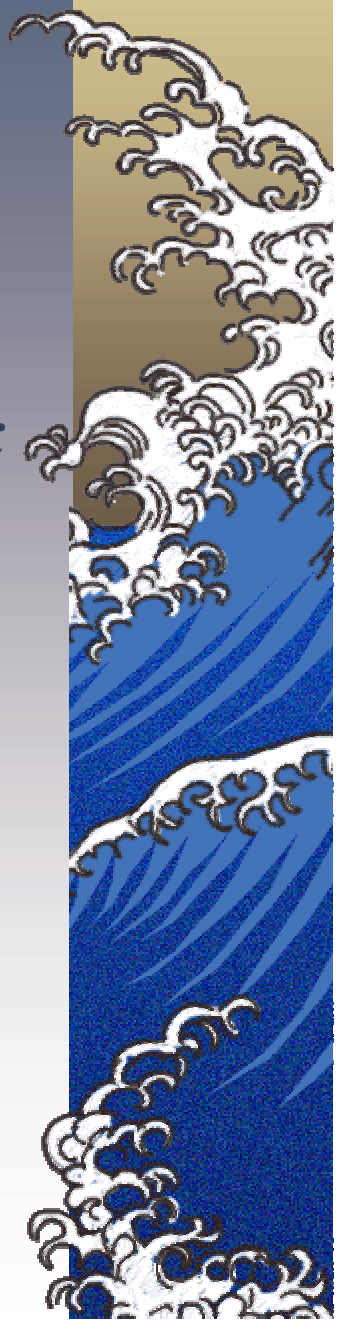
- *Margins cannot be ignored in global ocean carbon models!*



ISSUES

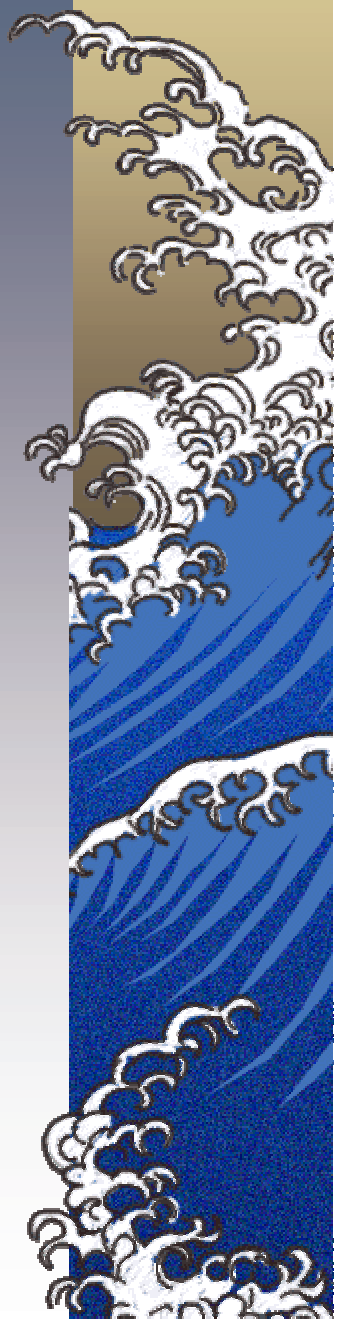
- *Exponential flux relationship overestimates flux observed with sediment traps by x8-30*
  - *(Lutz, Dunbar, Caldeira. GBC 16:3. 2002)*
  - *Biggest problem between ~2-4 km depth*
  - *At greater depths, model approximates observations*

- *Implication: model underestimates regeneration*



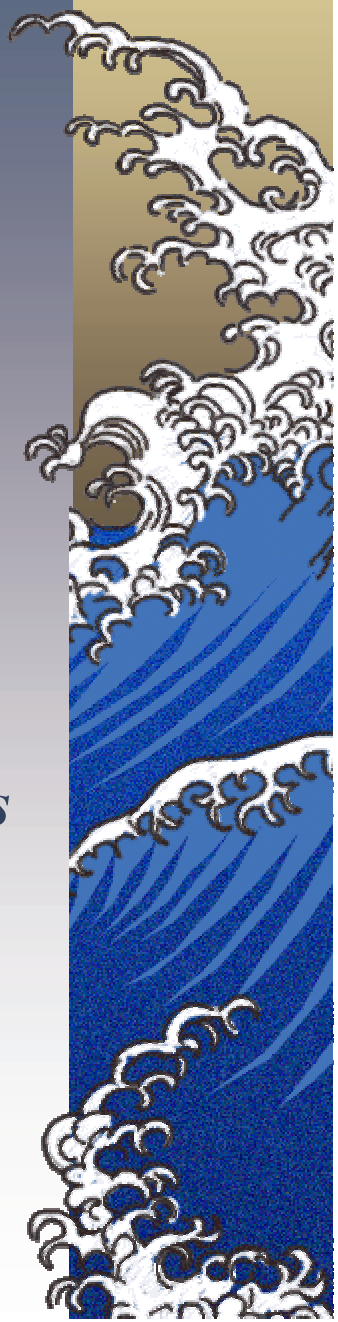
ISSUES

- *However:*
  - *^{234}Th shows traps underestimate by x2*
    - *Buesseler et al. SCOR WG. Submitted PIO*
- *Therefore:*
  - *Pace et al. (1987) model may not be that bad after all!*



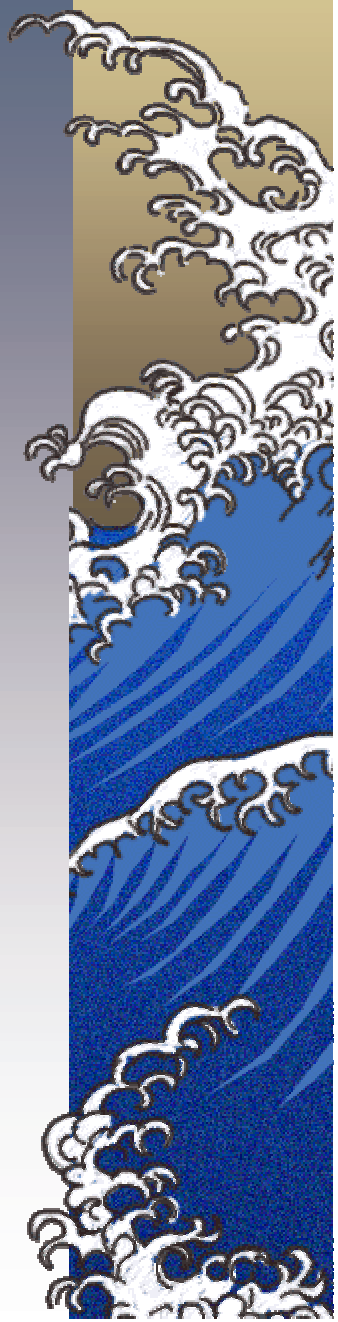
ISSUES

- *Geographic variability in regeneration*
  - *We don't know much*
  - *Francois, Honjo, Krishfield, Manganini (2002):*
    - *Productive regions in low –latitudes may be more effective in POC export than high-latitude regions*



Topics for future research

- *Improve ocean productivity estimates*
  - *Understand issues with various schemes proposed*
  - *Find ways to avoid using CHL (or C:CHL)*
  - *Driving forces*



Topics for future research

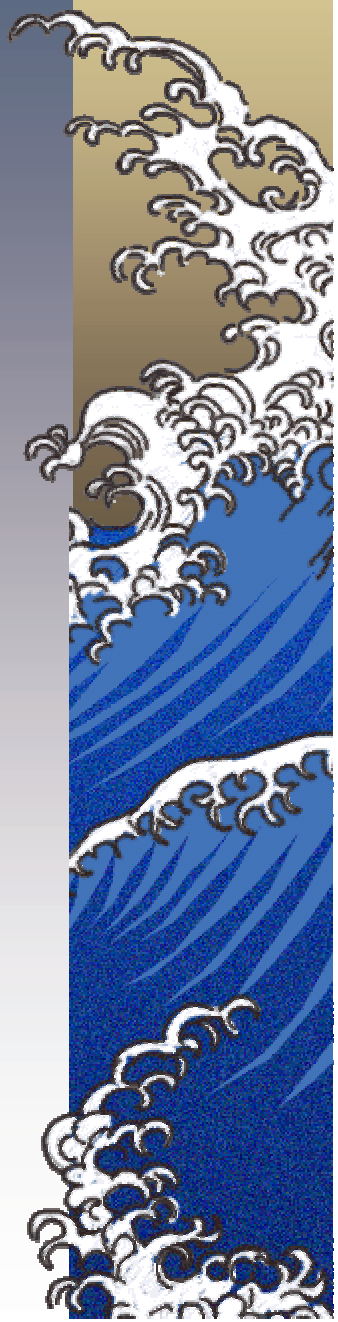
- *Sediment fluxes:*

  We need better estimates of:

  - *Trapping efficiency*
  - *Geographic variability in flux*
  - *Export efficiency as related to environmental forcing*
    - *Lateral transport*
    - *Biological production*
    - *Consumption*
    - *Zooplankton migration*
    - *Seasons*

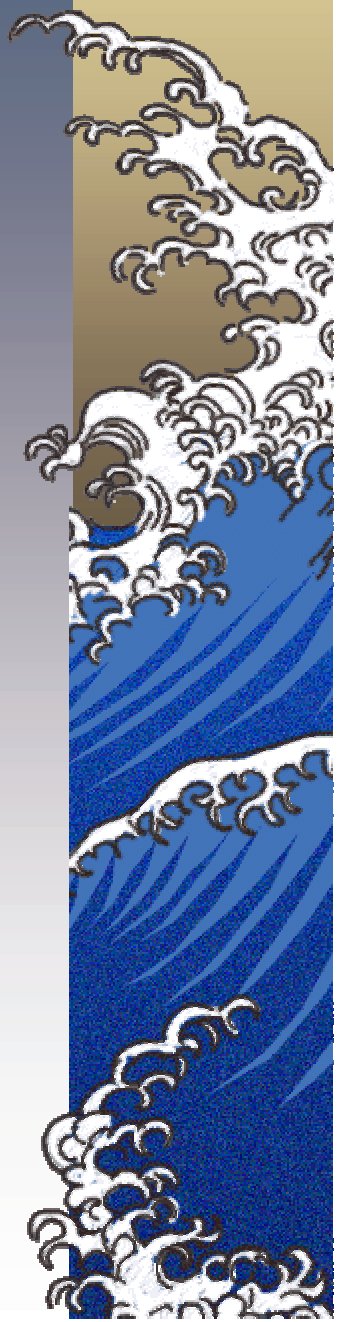
Topics for Future Research

- *Remote sensing research:*
  - *Focus on understanding connections between:*
    - *"observables"*
      - *(Sea Spectral Reflectance, SST, Winds, Currents)*
    - *variability in the vertical flux and*
    - *regeneration profile*



Recommendations

- *Identify locations for oceanographic time series studies and include sediment flux/regeneration observations*
- *Integrate remote sensing when planning process and time series studies, develop strategies to scale findings to globe*
- *Use the **OOI/Orion** and **IOOS/GOOS/GEOSS** to advance OCCC strategic plans*



Collective Action

- *Community needs to show unity and coherence in pushing for research program*
- *Each individual needs to communicate to elected representatives in Congress and the Executive about importance of OCCC and investing in ocean research*