Carbon and Nutrient Cycles on Continental Shelves - Current Advances and Thoughts for Future Research

1. Brief summary of N-based productivity measures.
2. Thoughts for future studies of the ocean margin carbon system in relation to some interesting new results.

Sources

Reviews:

Galloway, J.N. et al. 2004. *Biogeochemistry* 70: 153-226.

Ivanov, V.V. et al. 2004. *Prog. Oceanogr*. 60: 47-98.

Ducklow, H.W. and S. L. McCallister. 2005. *The Sea*, Vol. 13.

Manuscripts:

Thomas, H. et al. 2004. *Science*. 304: 1005-1008.

Wang and Cai. 2004. *Limnol. Oceanogr*. 49: 341-354.

Hales et al. 2005. *Global Biochem. Cycles* 19: doi whatever

Muller-Karger et al. 2005. *Geophys. Res. Lett*. 32 doi whatever

Table References

1. Walsh, J.J. 1991. Nature 350: 53-55.
2. Wollast, Roland. 1993. NATO ASI Series, Vol 14.
3. Nixon, S.W. et. al. 1996. Biogeochemistry 35: 141-180.
4. Muller-Karger, F.E. 2005. Geophys. Res. Lett. 32:
5. Galloway, J.N. et. al. 2004. Biogeochemistry 70: 153-226.

Units: Tg N (=10^{12} g)/year	Ref. 1	Ref. 2	Ref. 3 (N.Atl)	Ref. 4	Ref 5 1860	Ref 5 1990s	Ref 5 2050
New Production – Margins	570	265		630			
						Δ 25	Δ 54
New Production Open Ocean		670		490			
Ocean DIN Flux to Margins	560	200	84				
River DN Flux to Margins	110	62	8.8		27	48	63
Atmos DN Flux to Margins		9	1.9				
					14	39	70
Atmos DN Flux to Open Ocean		33					
N-Fixation Margins		15	0.3		15	15	15
N-Fixation Open Ocean		5			121	121	121
Denitrification Margins	50	70	20		172	193	210
Denitrification Open Ocean		5			129	129	129
Margin Export to Open Ocean	570	200	76	120			

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Three Broad Science Questions Related to Carbon and Nutrient Cycles on the Ocean Margins

1. What are the important processes controlling the margin's role in the ocean carbon cycle, and how significant are these processes?
2. What is/has been the potential for ocean margins to affect CO_2 released by human activities?
3. How could ocean margins affect the fate of CO_2 released by human activities in the future?

Units: Tg N (=10^{12} g)/year	Ref. 1	Ref. 2	Ref. 3 (N.Atl)	Ref. 4	Ref 5 1860	Ref 5 1990s	Ref 5 2050
New Production – Margins	**570**	**265**		**630**		**+**	**+**
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Coincidence?

Potential ocean margin new production from increases in river and atmospheric N sources (minus increase in denitrification) since 1860 - **ca. 0.2 Pg C/year.**

Current estimate of ocean margin atmospheric CO_2 sink (Cai – this meeting) - **ca. 0.2 Pg C/year.**

Three Broad Science Questions Related to Carbon and Nutrient Cycles on the Ocean Margins

1. What are the important processes controlling the margin's role in the ocean carbon cycle?
2. What is/has been the potential for ocean margins to affect CO_2 released by human activities?
3. How will the potential for ocean margins to affect the fate CO_2 released by human activities change in the future?

Thoughts for Process Studies based on recent studies of ocean margin carbon system and nutrient cycles.

1. Rates of new production versus warming rates of upwelled waters (i.e. lower solubility, degassing) in the coastal upwelling systems of Eastern Boundary Currents (EBC).

   See: Hales, B. et al. 2005. *Global Biogeochem. Cycles* 19: GB1009.

Hales et al. 2005 showed:

During the upwelling season off Oregon, shelf waters are a net sink of CO_2 because:

1. Complete autotrophic utilization of all respiration-derived and preformed nitrate, with concurrent stoichiometric drawdown of CO_2.
2. Modest warming of upwelled waters thus sustaining a negative sea-air difference for the shelf.

and…..

3. Assuming removal of CO_2-enriched waters during the downwelling season, and assuming similar conditions in other EBC coastal upwelling systems, this ***pathway may play an important role in the global carbon cycle***.

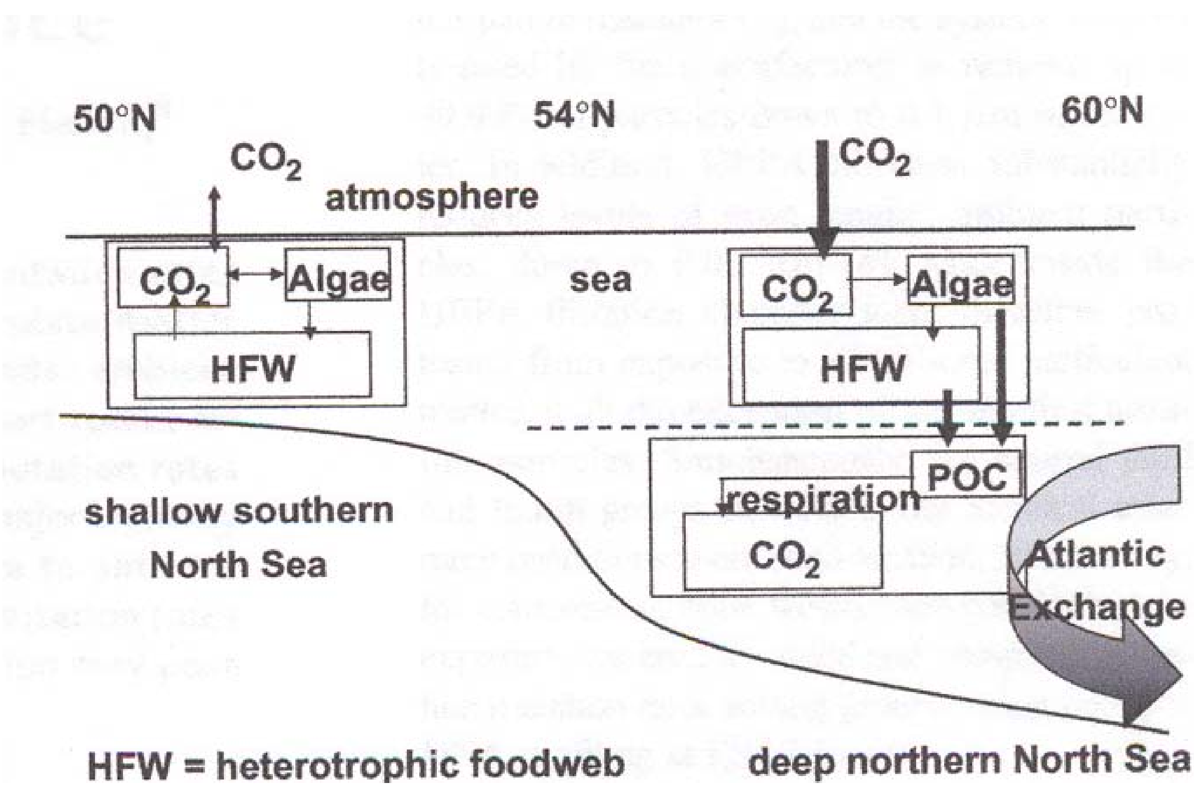
Those assumptions lead directly to hypotheses for an EBC/coastal upwelling-focused process study.

Background for second Process Study suggestion

Continental Shelf Pump – CO_2-enriched shelf waters, either introduced at the coast (e.g. Cai's *salt marsh pump*) or enriched with CO_2 owing to respiration of *in situ* produced organic matter (e.g. North Sea, MAB), are injected into or below the ocean thermocline at the shelfbreak.

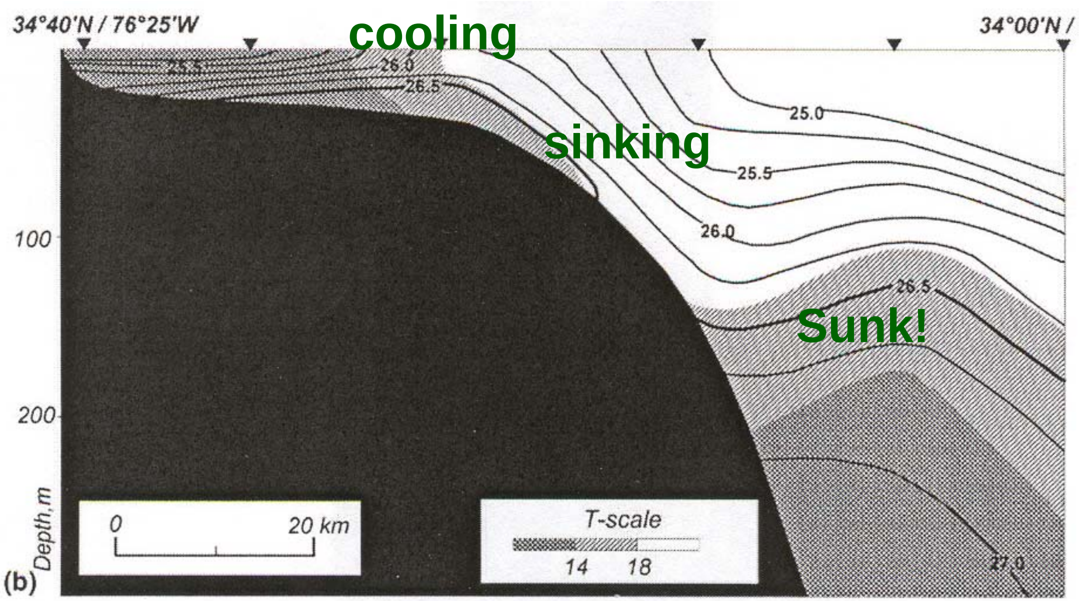
See: Falkowski et al. 1988, Walsh 1991; Liu et al. 2000, Thomas et al. 2004, Wang and Cai 2003, Yoder and Ishimaru 1989 and others.

For the North Sea, Thomas et al. 2004 showed:



Continental Shelf Pump

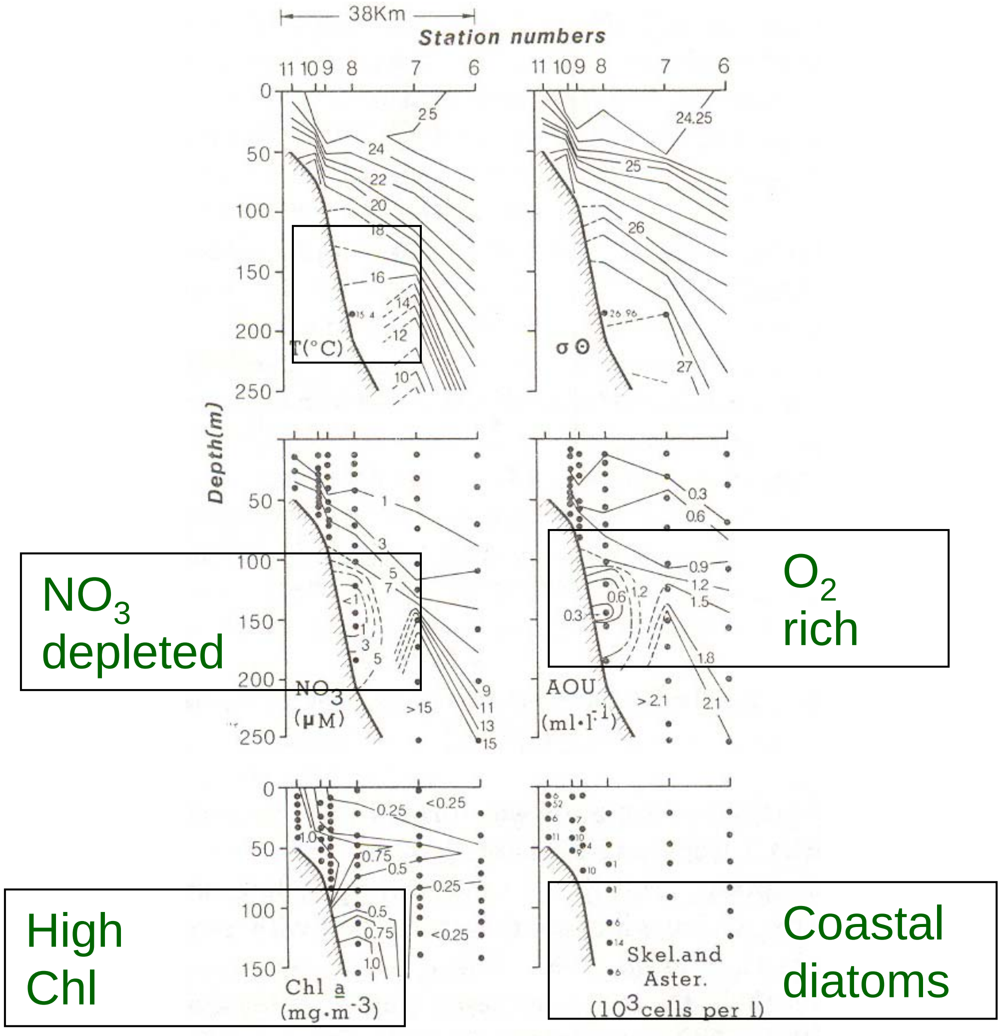
But what about surface waters on the margins? In the absence of wind-driven downwelling, how can CO_2-enriched surface waters on continental shelves, become sufficiently dense to be injected into or below the ocean thermocline? **One possibility is by "cascading" (**see review by Ivanov et al. 2004**).**



February, off N. Carolina. From Stefannson et al. 1971, reproduced by Ivanov et al. 2004. *Prog. Oceanogr*. **60**: 47-98

Example showing productive waters that first cooled and then cascaded off the Georgia shelf.

(Yoder and Ishimaru. 1989. *Cont Shelf Res* **9**: 547-553).



How important is the “cascade” process?

Ivanov, V.V. et al. 2004. *(Prog. Oceanogr*. 60: 47-98) calculate that cascading leads to a mean off-shelf water flux of **0.05-0.08 Sv per 100 km of shelf length.**

Example: For a continental shelf of 100 km wide and 50 m deep, an 0.05 Sv along a 100-km shelf length would **remove all shelf waters 3 times per year.**

Thoughts for Process Studies based on recent studies of ocean margin carbon system and nutrient cycles.

2. Generalized *Continental Shelf Pump* study to include a focus on how CO_2-DOC-POC-enriched waters are removed, e.g. by cascading.

Hypotheses could be developed for both surface and subsurface layers, including processes leading to enriched CO_2-DOC-POC, and for removal processes.

Conclusion

Results obtained in the past few years propose a significant role for the ocean margins in the global ocean carbon cycle. However, extrapolating these new results to all margins is questionable given our current state of knowledge. Future margin process studies could resolve these questions and lead to a better understanding of the role of ocean margins in the ocean carbon cycle and predictions as to how the ocean margins will respond to future human perturbations of the carbon and nutrient cycles.