LAND-OCEAN INTERACTIONS IN THE COASTAL ZONE

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# LOICZ NEWSLETTER

## RISING $CO_2$ AND MARINE CALCIFICATION

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One of the systemic changes in the total earth system that is most representative of global change is the inexorable increase in atmospheric $CO_2$ concentration. $CO_2$ has risen from a base of 280 ppmv before the industrial revolution to 370 ppmv at present, and is projected to reach 560 ppmv ($2xCO_2$) by 2065. These anthropogenically-forced changes are superimposed on a high point in the natural $CO_2$ cycle, and the atmospheric $CO_2$ is probably already higher today than any concentration experienced in the last several million, and possibly tens of millions, of years.

The carbon cycle is a major focus of IGBP attention, and increasing $CO_2$ is extensively studied as a contributor to global climate change, as a possible 'fertilizer' of photosynthesis, and in many other ways. One major role, however, has received little attention until recently -- the effect of atmospheric $CO_2$ on marine biogeochemistry and ocean ecosystems. The ocean contains close to 90% of the earth's "exchangeable carbon," but it mixes only slowly, and the surface layer has an inorganic carbon inventory similar to the atmosphere's and a residence time somewhat longer. Because the ocean is buffered at a pH of about 8, the dominant species of inorganic carbon is the bicarbonate ion, $HCO_3^-$, with only minor amounts of carbonate ion ($CO_3^=$) and aqueous $CO_2$ (dissolved $CO_2$ and $H_2CO_3$, carbonic acid).

The surface ocean equilibrates rapidly with the atmosphere, however, so each new increment of $CO_2$ is reflected in a transient increase in surface ocean carbonic acid concentration --

This is the eighth newsletter of the Land Ocean Interactions in the Coastal Zone (LOICZ) International Project of the IGBP. It is produced quarterly to provide news and information regarding LOICZ

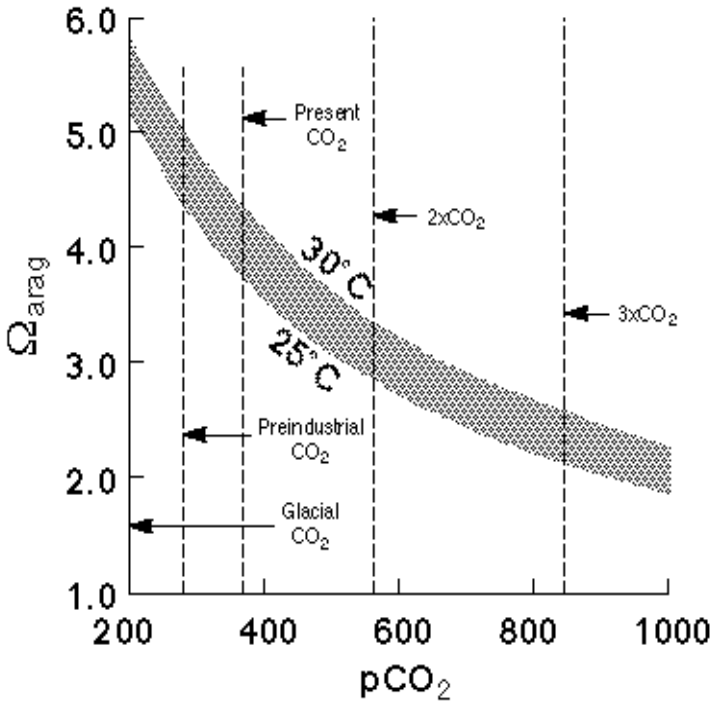


Figure 1. The effect of rising atmospheric $CO_2$ on the saturation states aragonite. (Changes in ½-aragonite as a function of $pCO_2$ and temperature for the range of temperatures most often associated with coral reef development, and the range of probable recent past and future $pCO_2$ values.)

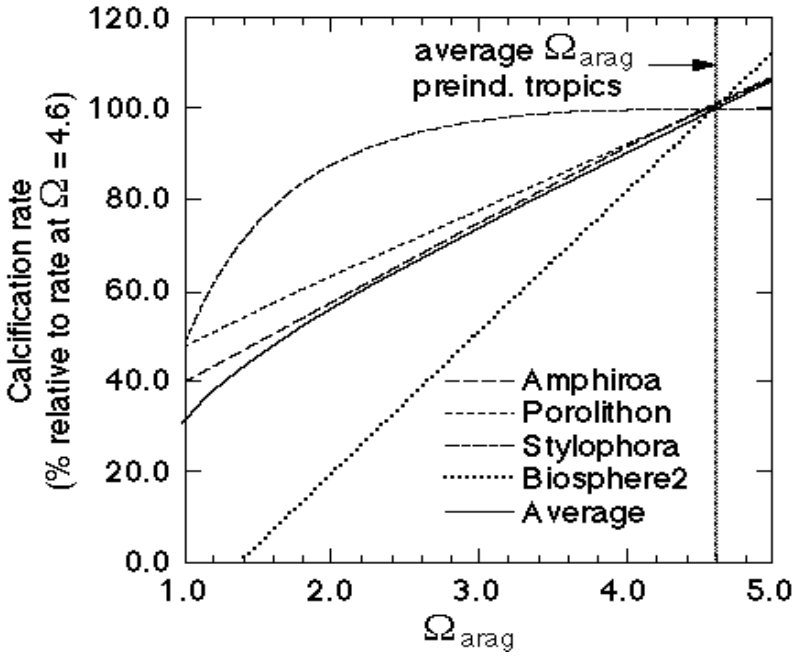


Figure 2. Strong dependence of both organism and community calcification rates on saturation state. (Summary of experimental results (4) on calcification as a function of saturation state for 2 tropical algae, a coral, and a mesocosm of reef-related species. Average rate relative to the calculated preindustrial rate was used to estimate recent past and probable future calcification changes.)

transient, because the inorganic carbon system re-equilibrates in a way represented by the equation $H_2CO_3 + CO_3^{=} \rightarrow 2HCO_3^{-}$. Thus, rising atmospheric $CO_2$ results in an increase in total inorganic carbon (and bicarbonate ion) in the surface ocean, an increase in aqueous $CO_2$, and a significant decrease in carbonate ion concentration. This in turn affects the calcium carbonate mineral saturation states of the surface ocean; because $Ca^{++}$ concentration is much larger than carbonate ion concentration and nearly constant, it is the $CO_3^{=}$ concentration that controls the ion activity (concentration) product $[Ca^{++}]*[CO_3^{=}]$.

If we define Ω as $[Ca^{++}]*[CO_3^{=}]/K_{sp}$, where $K_{sp}$ is the product of concentrations that result in neither precipitation not dissolution of calcium carbonate, then Ω < 1 reflects an undersaturated (dissolution-promoting) condition; and Ω > 1 represents supersaturation (conducive to precipitation). At present the world's surface oceans are all supersaturated with respect to calcite, the least soluble mineral form of calcium carbonate. Aragonite supersaturation is greatest in the tropics and diminishes toward the poles, and high-magnesium calcite (the most soluble form) is strongly supersaturated only in lower-latitude waters. The effect of rising atmospheric $CO_2$ on the saturation state of aragonite is shown in Figure 1, which illustrates the dependence of Ω on the partial pressure of $CO_2$ over the range of $CO_2$ concentrations from glacial maxima to extreme anthropogenic greenhouse conditions.

Although there is geological evidence for saturation state control of mineral distributions and accumulations (1) and the saturation state dependence on $CO_2$ is strong, little marine biological research has focused on the effects of $CO_2$, presumably because Ω is projected to remain > 1 in the foreseeable future, and it is known that all or most calcifying organisms possess active ion transport and concentration mechanisms that enable them to precipitate minerals in an undersaturated environment.

Recent LOICZ-supported investigations into coral reef responses to global change (2) have revealled the importance of saturation state responses in these ecosystems, which produce predominately the more soluble carbonate minerals. Both research (3) and review of the literature (4) have shown a strong dependence of both organism and community calcification rates on saturation state (Figure 2). Although the data base is limited and the mechanisms are not fully understood, the strength and consistency of the signal suggest that calcification rates of reefs and benthic calcifying communities have already decreased by 6-11%, and that a doubling of $CO_2$ will result in a total decrease of 17 to 35%. This will be reflected in shifts in community composition and metabolism, and at the organism level reduced calcification potential may result in weaker skeletons (with greater vulnerability to bioerosion and physical damage) and/or reduced extension rates (implying reduced ability to compete for benthic resources). Additional support for these predictions comes from a recent statistical analysis of the relationships among environmental variables and coral reef biogeography (5); the findings indicate that temperature, light, and saturation state all exercise a significant degree of control over reef distribution.

In addition to future shifts in organism and ecosystem dominance or survival, the findings suggest important considerations for research into paleo-environments and the functioning of the carbon cycle. It is common to interpret past variations in organism or mineral abundances in terms of organic productivity and temperature. Recognition that carbonate accumulation rates, indicator fossil abundances, or organic/inorganic burial ratios can be affected directly by the marine chemical consequences for calcification of atmospheric $CO_2$ concentration changes may help to resolve uncertainties and apparent contradictions, and to develop more useful hypotheses concerning feedbacks in the carbon and carbonate cycles.

This perspective on the saturation-state mediated role of $CO_2$ change in the ocean opens a variety of new avenues for research and integration. It is the first finding of a direct negative biotic effect of rising $CO_2$ on a major ecosystem, it provides an altered perspective on the future of shallow-water and coastal marine ecosystems, especially in tropical and subtropical waters, and on a broader basis it raises significant questions about paleo-environmental interpretations and carbon cycle models based on sedimentary and fossil evidence.

REFERENCES

(1)Opdyke, B. N., and B. H. Wilkinson. 1993. Carbonate mineral saturation state and cratonic limestone accumulation. American Journal of Science 293: 217-234.

(2) SCOR Working Group 104 -- Coral Reef Responses to Global Change: The Role of Adaptation. Co-sponsored by LOICZ.

(3) Gattuso, J.-P. , M. Frankignoulle, I. Bourge, S. Romaine, and R. W. Buddemeier. 1998. Effect of calcium carbonate saturation of seawater on coral calcification. Global and Planetary Change 18: 37-46.

(4) Gattuso, J. P., D. Allemand, and M. Frankignoulle. Interactions between the carbon and carbonate cycles at organism and community levels on coral reefs: a review of processes and control by the carbonate chemistry. submitted to American Zoologist, 1998.

(5) Kleypas, J. A., J. W. McManus, and L. A. B. Meez. 1999. Environmental limits to coral reef development: where do we draw the line? American Zoologist 39: (in press)

**LOICZ**
**4th Open Science Meeting To be held in Bahía Blanca, Argentina in the period 8-19 November 1999. The first announcement and circular will be included in the next Newsletter and posted to the LOICZ Web-**

## HAVE YOU SEEN.....

**World Delta Symposium** (August 1998) An overview of the 8 major global deltaic systems discussed at the Symposium is in the Journal & Coastal Research 14 (3); 695-915 1998

**Internet Mangrove & Coral Reef** Homepage at: http://ibm590.aims.gov.au

**Sea Level Processing Software for IBM PC's.** University of Hawaii Sea Level Centre, with National Oceanographic Data Centre have prepared a software purchase for Sea Level Data Processing designed for IBM PC (DOS). It is "command line" mode, not Windows. Contact Patrick Caldwell (UHSLC) at caldwell@soest.hawaii.edu

**Coral Reefs and Global Change: Adaption, Acclimation, or Extinction?** Abstracts and titles of the meeting (Boston, January 1998) published in American Zoologist 37 (5) 1998.

**About the Global Carbon & Nutrient issues.** Two recent and Topical publications in Science 281 (5374) 10 July 1998 - Chemistry & Biology of the Oceans: T.D. Jickells (pp. 217-222) - "Nutrient biogeochemistry of the coastal zone", and C.M. Duarte & S. Agusti (pp. 232-236) - "The $CO_2$ balance on unproductive aquatic ecosystems".

**LOICZ Website - Revised!!!** LOICZ Website (http://www.nioz.nl/loicz/) has been revised and repackaged. We continue to evolve its content, emphasising science information.

- Contributions of biochemical budgets are strongly encouraged.
- Databases for LOICZ Typology developments and direction to other coastal zone scientific information is posted.
- LOICZ position papers on key issues are being developed and will be posted soon.
- Your use, comments and contributions are welcome.

## LOICZ Liaison Officer

Maarten Scheffers has been appointed as the Liaison Officer between LOICZ and the Coastal Zone Management Centre (CZMC) of the Netherlands. The CZMC is located at the National Institute for Coastal and Marine Management (RIKZ) of the Ministry of Transport, Public Works and Water Management. Maarten will be a member of the staff of the International Project Office and will split his time between The Hague (CZMC) and Texel, based in The Hague.

Maarten was born in Eindhoven in the Netherlands and has an MSc in Physical Oceanography from Utrecht University. Practical experience includes involvement in a large project with sea research was gained during a large the North Sea project and a term as oceanographer with the Royal Netherlands Navy.

In 1991, Maarten was appointed as executive secretary of the Council on Physical Oceanographic Research in the North Sea (RvO). He was also a senior policy officer of a collaborative structure on Policy Linked Ecological Research (BEON) in the Netherlands. This work gave him experience in the transfer of knowledge between research, policy and management.

Maarten's major task will be to further the application of LOICZ science, in particular linking environmental and socio-economic research in an international framework.

## ANNOUNCEMENTS

**Workshop: River Basins and the Coastal Region**

Focus 1 and Focus 4 are organising a workshop on river basins and the coastal regions. The workshop is hosted by the Institute for Environmental Studies in Amsterdam and is planned for November 11-12, 1998. The workshop aims to make an inventory of European research dealing with the interactions between river basins and coastal regions and explore possibilities for integrated research programs. The socio-economic dimension of materials flow to the coastal region and the integration of natural- and socio-economic models will be emphasised. Workshops for other regions are planned.
Please contact Wim Salomons (wim.salomons@gkss.de) or Kerry Turner (r.k.turner@uea.ac.uk) for further details.

**Land Ocean Interaction Study**

The UK-based LOIS program (1992-8) has been quantifying flux, tansformation and effects of materials (sediments, nutrients, contaminants) from freshwater to coastal seas. While the main program is completed, the Integrated Modelling initiatives are continuing, addressing the land-ocean interface under a range of environmental scenarios. A series of CD-ROM is in progress, with the overview already released. For publication information visit the LOIS homepage: http://www.npm.ac.uk/pml/loisa

**AVAILABLE - GRATIS -**
LOICZ REPORTS & PUBLICATIONS

LOICZ IPO has a wide holding of scientific reports and science/implementation plans. Details are on the LOICZ Website.
Do you want copies for information or for use as teaching aids (e.g. LOICZ Modelling Guidelines)? Copies are freely available from LOICZ IPO.

## LOICZ CALENDAR

- LOICZ Executive Committee Meeting, 25-26 September 1998, Texel, Netherlands.
- Australasian Estuaries Biogeochemical Budgets Workshop, 12-14 October 1998, Canberra, Australia.
- Advanced Typology Workshop, 16-18 October 1998, Honolulu, Hawaii.
- European River Basins and the Coastal Regions Workshop, 11-12 November 1998, Amsterdam, Netherlands.
- START/IOC/LOICZ Workshop: Climate changes and coastal processes in West-Africa. 23-25 November 1998, Cotonou, Republic of Benin.
- SARCS/WOTRO/LOICZ Workshop, 7-12 December 1998, Suratthani, Thailand.
- Mexican & Central American Coastal Lagoons Biogeochemical Budgets Workshop, 12-16 January 1999, Merida, Mexico.
- LUCC Data Expert Meeting on Coastal Zones of Southern India (LUCC-DIS, in collaboration with LOICZ), 7-9 April 1999, Goa, India.
- 2nd IGBP Congress and SSC9 Meeting, 6-13 May 1999, Yokohama, Japan.
- LOICZ 4th Open Science Meeting, 8-19 November 1999, Bahía Blanca, Argentina.
- South American Estuaries Modelling Workshop, November 1999, Bahía Blanca, Argentina.
- IGBP Open Science Millennium Conference, April or May 2001, (proposed) Washington, USA.

## OTHER MEETINGS

- Second Annual Scientific ELOISE Conference 30th September - 3rd October 1998, Huelva, Spain.
- JGOFS International Scientific Symposium, Biogeochemistry of the Arabian Sea: Synthesis and Modelling, 18-20 January 1999, Bangalore, India.
- Conference on Marine Environment, the Past, Present and Future, 26-28 January 1999, Kaohsiung, Taiwan.
- 1999 Open Meeting of the Human Dimensions of Global Environmental Change Research Community, 24-26 June, Kanagawa, Japan.

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