Proposal for a SCOR Working Group on

Studying Ocean Acidification Effects on Continental Margin Ecosystems

Abstract

The increase in atmospheric CO_2 concentrations caused mainly by fossil fuel combustion is changing ocean carbonate chemistry equilibrium and decreasing seawater pH [1]. On continental margins these changes are less clear, which could be due to a variety of reasons, among them ***i)*** the extreme ecosystem heterogeneity, ***ii)*** the fact that carbonate chemistry is strongly regulated by riverine and open ocean delivery of nutrients and biological processes in these areas, ***iii)*** natural variation of pH in these areas at daily and/or seasonal timescales [2], and ***iv)*** lack of observations and the inadequacy of global biogeochemistry models in resolving these areas [3]. The extent of ocean acidification effects on continental margin ecosystems, and the interaction of carbonate chemistry with other human-induced changes like eutrophication need to be better constrained [4]. This Working Group (WG) proposal focus on an integrated effort to put together the current knowledge on ocean acidification effects on continental margins (including boundary zones – e.g. coastal areas and shelf slope zone) to identify common features, regional contrasts, and sensitive areas. The WG Members will, over the 4-year period, ***a)*** *synthesize the current knowledge* of impacts of ocean acidification on continental margin ecosystems; ***b)*** *identify gaps* in current knowledge, taking into consideration the physical and biogeochemical variability of ecosystems; ***c)*** propose *best practices for observing and modeling ocean acidification impacts in these ecosystems*, including an intercalibration exercise for marine carbonate chemistry in continental margin areas; and ***d)*** *publish* the results of the working group either as a special issue of a peer-reviewed international journal or a book by a major world publisher.

Rationale

The absorption by the oceans of the excess atmospheric CO_2 changes the carbonate equilibrium of seawater, lowering the pH and carbonate ion concentrations, a process widely known as Ocean Acidification [1,5]. Field datasets have shown a clear decreasing trend in surface, open ocean pH [6] while in coastal seas and adjacent shelves this trend is not that clear and may be due to a variety of reasons including distinct dynamics over the continental shelf when compared to the deep ocean regime, the different biogeochemistry (i.e. higher and variable rates of primary production and respiration), and regional drivers such as nutrient input from riverine, atmospheric, and anthropogenic sources or upwelling of nutrient-rich water masses [4,7–9]. *The multiple factors controlling carbonate chemistry in continental margins imply that procedures commonly applied in ocean acidification research in deep waters cannot be simply translated to shelf regions* [10]. Moreover, the fact that these processes are dependent not only on the biogeochemistry but also on the physics make it necessary to have integrated studies on changes in the marine carbonate chemistry to eutrophication and ocean physics (e.g. circulation and seawater warming) [11]. Because of the socio-economic importance of continental margins (e.g. fisheries, tourism, biodiversity), it is important to integrate efforts on ocean acidification effects in these areas in order to enable near-future adaptation or mitigation strategies.

A SCOR Working Group is the best strategy to coordinate an international research group focusing on the issue of ocean acidification effects on continental margin ecosystems. There is a strong consensus in the scientific community about their socio-economic importance for the world

population and the regional diversity of this land ↔ ocean interface area. The scientific rationale for this working group comes from the timeliness of an integrated effort to put together the existing knowledge on carbonate chemistry over continental margin ecosystems so that the common features, regional contrasts, and ocean acidification and man-made impacts can be identified through observational and modeling studies. A sponsorship from SCOR will help regional groups to attract financial support from national research funding agencies, especially *for those countries where ocean acidification research is still at an early stage*.

Scientific background

Because of their proximity to land and large metropolitan areas, continental margin ecosystems are at present threatened by human exploitation of their resources as well as by impacts associated to climate change: warming of the oceans, expansion of low-oxygen areas, and ocean acidification [12,13]. Continental margins have a disproportionately large contribution to the global cycle of essential elements of marine biogeochemistry. Although they occupy approximately 8% of the oceanic global area their contribution to global primary production ranges from 19-28% [14].

Ocean acidification is caused when the excess CO_2 in the atmosphere is absorbed by seawater and causes a disequilibrium in the aquatic inorganic carbon (carbonate) system [1,9]. This disequilibrium leads to lower seawater pH, lower concentration of ion carbonate [CO_3^{2-}], and reduces the saturation state of the biominerals aragonite and calcite, upon which aquatic calcifying organisms build their shells [15] , and affects the physiology of marine organisms [1].

Continental margin areas have their carbonate chemistry strongly regulated by riverine and open ocean delivery of nutrients and biological processes [7,16]. However, there are (few) available datasets for the coastal oceans do not reveal the trends in changing carbonate chemistry as for open ocean areas [4,6]. Changes in nutrient delivery to the coastal ocean, and hence to primary production and organic matter remineralization, may enhance the impacts of ocean acidification on the continental margin carbonate system [2,4].

Several studies show that continental margins currently play a role as carbon sinks (~ 0.2 – 0.3 Pg C yr^{-1}) [16–19]. Additionally, continental margins house large benthic calcifying, reef building organisms, comparable to marine calcifying phytoplankton [20,21]. Despite the large ecosystem heterogeneity, these areas can be divided into near-shore (including estuaries and bays) and distal portions [22]. The former would act as net CO_2 sources to the atmosphere while the latter are net atmospheric CO_2 sinks. Concomitantly, geographical position also affects the sea ↔ air CO_2 fluxes. Temperate and sub-polar continental shelves would act as atmospheric CO_2 sinks while tropical and subtropical shelves would act as a source of CO_2 to the atmosphere [22,23]. *It is timely to understand the response of this "continental shelf pump" [24] to the combined effects of ocean acidification and eutrophication, both globally and regionally.*

There is a need for assessing ocean acidification (OA) effects on coastal and continental margin ecosystems, together with the current efforts to understand OA impacts in the open ocean carbonate system. For instance, recent technological developments now enable scientists to measure parameters (e.g. pCO_2, pH) of the marine carbonate system using moored equipment in continental margin areas [21]. Modeling efforts are also a valuable tool for assessing regional changes in the carbonate chemistry over continental margins because both physical and biogeochemical processes can be coupled to understand natural variability and predict future changes. Marine biogeochemistry models may have different levels of spatial resolution and complexity, both in the ecosystem (e.g. plankton functional types) and biogeochemistry processes representation [8].

The challenge of understanding ocean acidification effects in such heterogeneous portion of

the world ocean cannot be achieved by isolated studies. It requires an integration of long term observational data (e.g. from regional studies) and ecosystem-biogeochemistry models. This is the main purpose of creating this SCOR Working Group. Lastly, this proposed Working Group should also encourage the adoption of best practices for carbonate system measurements in the coastal and continental shelf oceans, especially for early stage research groups interested in ocean acidification.

Terms of reference

The proposed Working group would:

1. Synthesize the current knowledge of impacts of ocean acidification on continental margin ecosystems (Year 1);
2. Identify gaps in current knowledge, taking into consideration the physical and biogeochemical variability of ecosystems in distinct biogeochemical provinces (Years 1 and 2);
3. Propose best practices for observing and modeling ocean acidification impacts in these ecosystems, including an intercalibration exercise for marine carbonate chemistry in continental margin areas (Years 2 to 4); and
4. Publish the results of the working group either as a special issue of a peer-reviewed international journal or a book by a major world publisher (Year 4).

Working Group Membership

The tasks proposed in this document would be carried out by the proposed Full Members and Working Group Associate Members. The full and associate members listed here below have already accepted to participate to the working group in case it is funded by SCOR. Additional Associate Members may be nominated during the first Working Group Meeting. The proposed full and associate member lists here below would ensure a broad geographic coverage, including experts in Marine Biogeochemistry, Physical, Chemical and Biological Oceanography and Ecosystem Modeling.

Full Members

1. Leticia Cotrim da Cunha – (UERJ, Brazil, co-chair) – Coastal Ocean Biogeochemistry
2. Arne Koertzinger – (GEOMAR, Germany) – Chemical Oceanography
3. Paulo Calil (FURG, Brazil) – Ocean Biogeochemistry Modeling
4. Peter Croot (Univ. Galway, Ireland) – Marine Chemistry
5. Gwenaël Abril (Univ. Bordeaux, France) – Estuarine and Coastal Ocean Biogeochemistry
6. Claudine Hauri – (Univ. Alaska, USA) – Ocean Biogeochemistry Observations
7. Zouhair Lachkar – (ETH Zürich, Switzerland, co-chair) – Ocean Biogeochemistry Modeling

Associate Members

1. Rodrigo Kerr – (FURG, Brazil) – Physical Oceanography, carbonate system observations
2. Marcelo F. Landim de Souza – (UESC. Brazil) – Coastal Ocean Biogeochemistry

3. Katrin Meissner – (Univ. New South Wales, Australia) – Ocean-Atmosphere Interactions
4. Óscar Melício (INDP, Cape Verde) – Biological and Fisheries Oceanography

Working Group Activities

If approved, the WG would organize its first meeting in 2014 during a large marine science meeting (e.g. Ocean Sciences Meeting). At the first meeting, WG Members will have the opportunity to meet and present their research activities, and discuss about the division of tasks in the WG (according to the main terms of reference). Another important topic to be discussed during the first Meeting is the potential names for new Associated Members. The activities proposed here could be linked to many global ocean research projects, especially LOICZ, SOLAS, IMBER, GLODAP, EUROCEANS and GOOS. The WG will strongly encourage that all observational data generated within this framework to contribute to global ocean databases such as SOCAT, PANGAEA, and IODE.

WG Meetings

It is proposed that WG Meetings will take place annually before or during large related events such as the Ocean Sciences Meeting, or the EGU Meeting. The WG Agenda, the following meetings, the strategy for the intercalibration and modeling exercises, and the preparation of the final WG publication will be set up during this first meeting.

Capacity building

The proposed best practices and intercalibration results will be a helpful tool for all scientists (confirmed and especially the newcomers) studying ocean acidification effects in coastal and continental shelf areas. The WG will strongly encourage the exchange of scientists (e.g. learning new analysis techniques, modeling efforts, manuscript preparation) by seeking financial support from national funding agencies (e.g. CNPq, DAAD, NSF, COST, CNRS).

The aspect of capacity building could be further improved by hosting a session during a WG meeting to discuss the real needs and capabilities of countries bordering sensitive continental margin areas with respect to future strategies to face ocean acidification effects.

The proposed WG will create a web-based platform to post the documents (analytical procedures and recommendations) and results from intercalibration exercises and modeling efforts executed by different international groups.

References

1. Doney, S. C., Fabry, V. J., Feely, R. A. & Kleypas, J. A. Ocean Acidification: The Other CO2 Problem. *Annual Review of Marine Science* **1**, 169–192 (2009).

2. Cai, W.-J. *et al.* Acidification of subsurface coastal waters enhanced by eutrophication. *Nature Geoscience* **4**, 766–770 (2011).

3. Giraud, X., Le Quéré, C. & Da Cunha, L. C. Importance of coastal nutrient supply for global ocean biogeochemistry. *Global Biogeochemical Cycles* **22**, (2008).

4. Borges, A. V. & Gypens, N. Carbonate chemistry in the coastal zone responds more strongly to eutrophication than ocean acidification. *Limnology and Oceanography* **55**, 346–353 (2010).

5. Dickson, A. G. The carbon dioxide system in seawater: equilibrium chemistry and measurements. *Guide to best practices for ocean acidification research and data reporting.* 17–40 (2010).

6. Orr, J. C. Recent and Future Changes in Ocean Carbonate Chemistry. *Ocean Acidification* (2011).

7. Hofmann, G. E. *et al.* High-frequency dynamics of ocean pH: a multi-ecosystem comparison. *PloS one* **6**, e28983 (2011).

8. Hauri, C. *et al.* Spatiotemporal variability and long-term trends of ocean acidification in the California Current System. *Biogeosciences* **10**, 193–216 (2013).

9. Feely, R. A. *et al.* The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. *Estuarine, Coastal and Shelf Science* **88**, 442–449 (2010).

10. Duarte, C. M. *et al.* Is Ocean Acidification an Open-Ocean Syndrome? Understanding Anthropogenic Impacts on Seawater pH. *Estuaries and Coasts* **36**, 221–236 (2013).

11. Gazeau, F., Martin, S., Hansson, L. & Gattuso, J.-P. Ocean acidification in the coastal ocean. *LOICZ INPRINT* **3**, 5–14 (2011).

12. Levin, L. A. & Dayton, P. K. Ecological theory and continental margins: where shallow meets deep. *Trends in ecology & evolution* **24**, 606–17 (2009).

13. Rees, A. P. Pressures on the marine environment and the changing climate of ocean biogeochemistry. *Philosophical transactions. Series A, Mathematical, physical, and engineering sciences* **370**, 5613–35 (2012).

14. Longhurst, A., Sathyendranath, S., Platt, T. & Caverhill, C. An estimate of global primary production in the ocean from satellite radiometer data. *Journal of Plankton Research* **17**, 1245–1271 (1995).

15. Riebesell, U., Fabry, V. J., Hansson, L. & Gattuso, J.-P. (Eds. . *Guide to best practices for ocean acidification research and data reporting.* 260 (Publications Office of the European Union: Luxembourg, 2010).

16. Chen, C.-T. A. & Borges, A. V Reconciling opposing views on carbon cycling in the coastal ocean: Continental shelves as sinks and near-shore ecosystems as sources of atmospheric CO(2). *Deep-sea Research Part Ii-topical Studies In Oceanography* **56**, 578–590 (2009).

17. Cotrim da Cunha, L., Buitenhuis, E. T., Le Quéré, C., Giraud, X. & Ludwig, W. Potential impact of changes in river nutrient supply on global ocean biogeochemistry. *Global Biogeochemical Cycles* **21**, (2007).

18. Frankignoulle, M. & Borges, A. V Blooms of Emiliania huxleyi are sinks of atmospheric carbon dioxide: A field and mesocosm study derived simulation. *Global Biogeochem. Cycles* **15**, 569–576 (2001).

19. Gattuso, J. P., Frankignoulle, M. & Wollast, R. Carbon and carbonate metabolism in coastal aquatic ecosystems. *Annual Review of Ecology & Systematics* 405 (1998).

20. Amado-Filho, G. M. *et al.* Rhodolith beds are major CaCO3 bio-factories in the tropical South West Atlantic. *PloS one* **7**, e35171 (2012).

21. Vecsei, A. A new estimate of global reefal carbonate production including the fore-reefs. *Global and Planetary Change* **43**, 1–18 (2004).

22. Borges, A. V Do we have enough pieces of the jigsaw to integrate CO(2) fluxes in the coastal ocean? *Estuaries* **28**, 3–27 (2005).

23. Cai, W.-J., Dai, M. & Wang, Y. Air-sea exchange of carbon dioxide in ocean margins: A

province-based synthesis. *Geophysical Research Letters* **33**, L12603 (2006).

24. Chen, C.-T. A. Exchanges of Carbon in the Coastal Seas. *The Global Carbon Cycle: Integrating Humans, Climate, and the Natural World* 341–351 (2004).