Hydrol. Earth Syst. Sci. Discuss., 9, C6431–C6439, 2013
www.hydrol-earth-syst-sci-discuss.net/9/C6431/2013/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Global multi-scale segmentation of continental and coastal waters from the watersheds to the continental margins" *by* G. G. Laruelle et al.

G. G. Laruelle et al.

goulven@geo.uu.nl

Received and published: 23 January 2013

Authors'reply to Interactive comment on "Global multi-scale segmentation of continental and coastal waters from the watersheds to the continental margins" by G. G. Laruelle et al.

Anonymous Referee #1 Received and published: 12 November 2012

The authors of this paper have collected a wealth of information on continental and coastal waters and combined several layers of data to compile the dataset

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

presented. I have serious questions about this paper. The authors have not managed to explain what the purpose of the dataset is, for what kind of research it would be useful, and how it can be used. To me it seems that the static approach to describing continental and coastal waters may not be useful to modellers who are interested in the dynamic nature of these systems. For example, people interested in fisheries, foodwebs or biogeochemistrywill not benefit from the data.

[1] We are grateful for the reviewer's comments and acknowledgement of the amount of information provided in our study. It appears, however, that we did not manage to explain clearly enough the importance and usefulness of our work. In particular, the reviewer does not see how the scientific community could benefit from the data we produced. We believe that the dataset can serve a broad community with quite diverse research interests. Thus, instead of focusing on our own research goals, we had made the choice not to be very specific about its purpose and range of applications. However, following the reviewer's comment, we have now restructured the paper around our own major research objective (the construction of regional biogeochemical budgets) and we have included a new section where the multi-scale segmentation is used to build a regionalized budget of estuarine CO2 fluxes. The introduction and conclusion have been rewritten and the scope of the revised paper is now much more focused. Nevertheless, we still believe that the segmentation and information on continental and coastal waters presented here could be used by researchers addressing quite different research goals. Many global and regional biogeochemical budget calculations and analyses rely on the definition of environmentally relevant spatial units which require quantitative estimates of surface areas and volumes (Borges and Abril, 2011, Chen et al., 2011, Cai et al., 2011, Seiter et al., 2005, Wanninkhof et al., 2012, Mayorga et al. 2010, Laruelle et al., 2010). However, precise estimates of surface areas for estuaries and continental shelves were only available for a handful of well studied regions of the world while for the rest only first order estimates were available (Woodwell et al., 1973), leading to significant uncertainties in biogeochemical budgets. For instance, one of the first global evaluations of air-water CO2 exchange for continental shelf

seas (Borges et al., 2005) attributed about 25% of the global total surface area to the wrong climatic zone, as shown in Laruelle et al. (2010). Similarly, the only available global estimate of the estuarine surface area has long been that of Woodwell et al. (1973). This value was used in several global budget calculations (Borges et al., 2005, Abril and Borges, 2004) and in global box models (Ver, 1998, Mackenzie et al., 1993, Rabouille et al., 2001, Slomp and Van Cappellen, 2004, Laruelle et al., 2009). The recent use of advanced GIS tools allowed to revise numbers down by 40% (Durr et al. in 2011), with significant consequences for biogeochemical budget calculations (Borges and Abril, 2011, Laruelle et al., 2010).

In this contribution, a much more complete data set of surface areas is provided for the entire land-ocean continuum (watersheds, estuaries and coastal ocean). It not only includes revised estimates for all regions in the world (see also Comment #5, Reviewer #2) but also provides a suite of consistent spatial segmentations using increasing scales to match the resolution of different environmental databases (see also Comment #3, Reviewer #2). As explained in the revised introduction, the level 1 of the segmentation allows integrating global gridded datasets at 0.5 or 1 degree resolution. This includes climatological forcings (Atlas of the world, Da Silva 1994, Levitus et al., 1998), coastal typologies (LOICZ, Durr et al., 2011), model outputs (GLOBALNEWS, Seitzinger et al., 2005, Mayorga et al., 2010) and high resolution datasets (Regnier et al., submitted). The level 2 is suitable for global or regional datasets of non gridded data like the SOCAT (Pfeil et al., 2012) or GLORICH (Hartmann et al., 2011) databases which includes sampled water chemistry data. The level 3 is well suited for regionalization when smaller datasets (several tens or hundreds of points) are available (Borges and Abril, 2012, Laruelle et al, 2010, Seiter et al., 2005, see also Comment #4, Reviewer #2). In the revised manuscript, the latter is used to estimate regionalized estuarine CO2 fluxes through the air-water interface at the global scale (see new section 3.5) and to perform a broad regional analysis of the routing of freshwater through different estuarine types at the global scale. Both applications are novel and provide further insight on processes and fluxes along the Land Ocean Continuum. GIS files will be provided as supplementary material. **The updated sections of the manuscript (introduction, section 3.5, conclusions and outlook) are available in a PDF as supplementary material to this letter.**

A further problem is the presentation of the fresh water residence times. For example, the authors themselves confess on page 11336 that ”residence time is somewhat skewed by the very large contribution of Antarctic shelves to the total” and ”the intensity of upwelling processes varies greatly in space and time and the water can locally be renewed in just weeks”. These are exactly the reasons why the freshwater residence time is not useful. Why have the authors not considered to describe all these currents and fluxes beween ocean boxes? Perhaps this would be material for another paper, but presenting these freshwater residence times, in my opinion, does not make much sense.

[2] The second issue raised by the reviewer refers to the final paragraph of section 3.4 of the manuscript and the calculation of Fresh Water Residence time on continental shelf waters because we did not take into account the oceanic currents connecting the boxes nor the upwelling fluxes. An exhaustive collection of lateral water fluxes connecting the MARCATS with the open ocean and one to another would certainly be of great value. However, to our knowledge, such information is only available in selected regions of the world and a comprehensive global assessment is thus beyond the scope of this paper. The purpose of our fresh water residence time analysis was to provide a qualitative measure of the potential role of terrestrial inputs on the coastal dynamics. For instance, narrow shelves fed by large rivers such as the Amazon or the Congo River exhibit fresh water residence times of only a few years while the voluminous arctic shelves lead to a freshwater residence time as high as several thousands of years. This wide range should be compared with single, globally averaged values used in e.g. global box models (Ver, 1999, Mackenzie et al, 1993, Rabouille et al., 2001, Laruelle et al., 2009). The Fresh Water Residence Time calculation also allows recognition of re-

HESSD

9, C6431–C6439, 2013

Interactive Comment

gions around the world where the terrestrial influence is likely to be a dominant forcing on the coastal biogeochemistry (regions corresponding to small ratios of continental shelf volumes to fresh water discharge), although we fully recognize that the terrestrial influence alone is not sufficient to constrain the coastal biogeochemical dynamics. These limitations are again reiterated in the revised shortened section 3.4:

"*For each COSCAT and MARCATS, the ratio between the shelf volume and the corresponding riverine discharge has been calculated (Fig 5a-5f). Globally, the comparison between the volume of continental shelf seas (3860 103 km3) and the annual fresh water input into the ocean (39 103 km3 yr-1) yields an average value of ~100. However, this "fresh water residence time" is somewhat skewed by the very large contribution of Antarctic shelves to the total (figure 6). If they are excluded from the calculation, the fresh water residence time drops to ~55 years which remains significantly higher than the average residence time of ~8-10 years calculated on the basis of the exchange with the open ocean through upwelling fluxes (Brink et al., 1995; Rabouille et al., 2001; Ver, 1998). Therefore, our results reveal that the renewal of continental shelf waters by fresh water inputs is 5-7 times slower than through upwelling fluxes on average. It should however be noted that the globally averaged box-model calculations for upwellings fluxes do not account for the significant spatial and temporal variability in intensity of upwelling processes which can locally renew coastal waters in just weeks (Gruber et al., 2011). Furthermore, neither the box model nor our calculations resolve the lateral transport by along-shore coastal currents. The ratio of fresh water discharge to continental shelf volume varies significantly from one region to the other, from 2 years (for COSCAT 1103 where the Amazon flows) to several thousands of years in many arid regions. Only 17 of the 149 COSCATs have fresh water residence times shorter than 10 years and the cumulative annual fresh water input of these 17 COSCAT segment amounts to 16 103 km3, which corresponds to 41% of the global water flux. These regions can be identified as coastal waters under strong riverine influence and bear resemblance, in that respect, to the RiOMAR which are defined as continental margins over which biogeochemical processes are* *dominated by riverine influences (McKee et al., 2004).*"

A minor issue is the fresh water input to the Gulf of Mexico (page 11335), which exceeds the global freshwater input to the ocean (page 11336).

[3] This was a typo. The value has been corrected.

References:

Abril G, Borges AV (2004) Carbon dioxide and methane emissions from estuaries. Greenhouse gases emissions from natural environments and hydroelectric reservoirs: fluxes and processes, Chapter 7: 187-207. Tremblay A., Varfalvy L., Roehm C. and Garneau M. (eds.). Environmental Science Series, Springer, Berlin, Heidelberg, New York.

Borges A.V. and G. Abril (2011) Carbon Dioxide and Methane Dynamics in Estuaries, In: Editors-in-Chief: Eric Wolanski and Donald McLusky, Treatise on Estuarine and Coastal Science - Volume 5: Biogeochemistry, Academic Press, Waltham, 2011, Pages 119-161, ISBN 9780080878850, 10.1016/B978-0-12-374711-2.00504-0.

Borges AV, Delille B, Frankignoulle M (2005) Budgeting sinks and sources of CO2 in the coastal ocean: Diversity of ecosystems counts. Geophys Res Lett 32: L14601.

Brink, K. H., Abrantes, F. F. G., Bernal, P. A., Dugdale, R. C., Estrada, M., Hutchings, L., Jahnke, R. A., Muller, P. J. and Smith, R. L.: Group report: How do coastal upwelling systems operate as integrated physical, chemical, and biological systems and influence the geological record?, in Upwelling in the Ocean: Modern Processes and Ancient Records edited by C. P. Summerhayes, K.-C. Emeis, M. V. Angel, R. L. Smith and B. Zeitzeschel, 103-124, 1995.

Cai WJ (2011) Estuarine and coastal ocean carbon paradox: CO2 sinks or sites of terrestrial carbon incineration? Annu Rev Mar Sci 3: 123-145. Chen CTA, Huang TH, Fu YH, Bai Y, He X (2012) Strong sources of CO2 in upper estuaries become sinks of CO2 in large river plumes. Curr Opin Environ Sustain 4: 179-185.

DaSilva A., A. C. Young, and S. Levitus, "Atlas of surface marine data 1994, volume 1.: Algorithms and procedures.," Tech. Rep. 6, U.S. Department of Commerce, NOAA, NESDIS, 1994.

Durr HH, Laruelle GG, van Kempen CM, Slomp CP, Meybeck M, Middlekoop H (2011) Worldwide Typology of Nearshore Coastal Systems: Defining the Estuarine Filter of River Inputs to the Oceans. Estuar Coast 34: 441-458.

Gruber, N., Lachkar, Z., Frenzel, H., Marchesiello, P., Munnich, M., McWilliams, J. C., Nagai, T. and Plattner, G.-K.: Mesoscale eddy-induced reduction in eastern boundary upwelling systems. Nature Geosciences, 4, 787-792, 2011.

Hartmann, J., Lauerwald, R., Moosdorf, N, Amann, t., Weiss, A. (2011) GLORICH: GLobal RIver and estuary CHemical database. ASLO, San Juan, Puerto Rico, 2011-02-13 to 18.

Laruelle, G. G., Durr, H. H., Slomp, C. P., and Borges, A. V.: Evaluation of sinks and sources of CO2 in the global coastal ocean using a spatially-explicit typology of estuaries and continental shelves, Geophys. Res. Lett., 37, L15607, doi:10.1029/2010GL043691, 2010.

Laruelle G. G., V. Roubeix, A. Sferratore, B. Brodherr, D. Ciuffa, D. J. Conley, H. H. Durr, J. Garnier, C. Lancelot, Q. Le Thi Phuong, J.-D. Meunier, M. Meybeck, P. Michalopoulos, B. Moriceau, S. Ní Longphuirt, S. Loucaides, L. Papush, M. Presti, O. Ragueneau, P. A. G. Regnier, L. Saccone, C. P. Slomp, C. Spiteri, P. Van Cappellen. The global biogeochemical cycle of silicon: role of the land-ocean transition and response to anthropogenic perturbation. Global Biogeochemical Cycles. 23 GB4031, doi:10.1029/2008GB003267, 2009.

Levitus, S., T.P. Boyer, M.E. Conkright, T. O' Brien, J. Antonov, C. Stephens, L. Stathoplos, D. Johnson, R. Gelfeld, 1998: NOAA Atlas NESDIS 18,World Ocean Database 1998: VOLUME 1: INTRODUCTION, U.S. Gov. Printing Office, Wash., D.C., 346pp.

Mayorga, E., Seitzinger, S. P., Harrison, J. A., Dumont, E., Beusen, A. H. W., Bouwman, A. F., Fekete, B. M., Kroeze, C. and Van Drecht, G.: Global Nutrient Export from WaterSheds 2 (NEWS 2): Model development and implementation. Environmental Modelling and Software 25(7):837-853, doi:10.1016/j.envsoft.2010.01.007, 2010.

Mackenzie F. T., Ver L. M., Sabine C., Lane M., and Lerman A. (1993) C, N, P, S global biogeochemical cycles and modeling of global change. In Interactions of C, N, P and S Biogeochemical Cycles and Global Change (eds. R. Wollast, F. T. Mackenzie, and L. Chou), pp. 1-62. Springer-Verlag.

McKee, B. A., Aller, R. C., Allison, M. A., Bianchi, T. S. and Kineke, G. C.: Transport and transformation of dissolved and particulate materials on continental margins influenced by major rivers: Benthic boundary layer and seabed processes. Continental Shelf Research 24: 899-926, 2004.

Pfeil, B., Olsen, A., Bakker, D. C. E., Hankin, S., Koyuk, H., Kozyr, A., Malczyk, J., Manke, A., Metzl, N., Sabine, C. L., Akl, J., Alin, S. R., Bellerby, R. G. J., Borges, A., Boutin, J., Brown, P. J., Cai, W.-J., Chavez, F. P., Chen, A., Cosca, C., Fassbender, A. J., Feely, R. A., Gonzalez-Davila, M., Goyet, C., Hardman-Mountford, N., Heinze, C., Hood, M., Hoppema, M., Hunt, C. W., Hydes, D., Ishii, M., Johannessen, T., Jones, S. D., Key, R. M., Kortzinger, A., Landschutzer, P., Lauvset, S. K., Lefevre, N., Lenton, A., Lourantou, A., Merlivat, L., Midorikawa, T., Mintrop, L., Miyazaki, C., Murata, A., Nakadate, A., Nakano, Y., Nakaoka, S., Nojiri, Y., Omar, A. M., Padin, X. A., Park, G.-H., Paterson, K., Perez, F. F., Pierrot, D., Poisson, A., Rios, A. F., Santana-Casiano, J. M., Salisbury, J., Sarma, V. V. S. S., Schlitzer, R., Schneider, B., Schuster, U., Sieger, R., Skjelvan, I., Steinhoff, T., Suzuki, T., Takahashi, T., Tedesco, K., Telszewski, M., Thomas, H., Tilbrook, B., Tjiputra, J., Vandemark, D., Veness, T., Wanninkhof, R., Watson, A. J., Weiss, R., Wong, C. S., and Yoshikawa-Inoue, H.: A uniform, quality controlled Surface Ocean CO2 Atlas (SOCAT), Earth Syst. Sci. Data Discuss., 5, 735-780, doi:10.5194/essdd-5-735-2012, 2012.

Rabouille, C., Mackenzie, F. T., and Ver, L. M.: Influence of the human perturbation on carbon, nitrogen, and oxygen biogeochemical cycles in the global coastal ocean. Geochimica et Cosmochimica Acta 65: 3615-3641, 2001.

Regnier P., Arndt S., Goossens N., Volta C., Laruelle G. G., Lauerwald R., Hartmann J. Modeling estuarine biogeochemical dynamics: from the local to the global scale, Submitted to Aquatic Geochemistry

Seiter, K., Hensen, C., and Zabel, M.: Benthic carbon mineralization on a global scale. Global Biogeochemical Cycles, 19, GB1010, doi:10.1029/2004GB002225, 2005.

Slomp, C. P., and P. Van Cappellen. 2004. Nutrient inputs to the coastal ocean through submarine groundwater discharge: controls and potential impact. Journal of Hydrology, 295 (1-4):64-86.

Ver L. M. (1998) Global kinetic models of the coupled C, N, P, and S biogeochemical cycles: Implications for global environmental change. Ph.D. dissertation, University of Hawaii.

Wanninkhof R, Park GH, Takahashi T, Sweeney C, Feely R, Nojiri Y, Gruber N, Doney SC, McKinley GA, Lenton A, Le Quere C, Heinze C, Schwinger J, Graven H, Khatiwala S (2012) Global ocean carbon uptake: magnitude, variability and trends. Biogeosci Discuss 9.

Woodwell, G. M., Rich, P. H., and Hall, C. A. S.: Carbon in estuaries. in: Carbon and the biosphere, edited by G. M. Woodwell and E. V. Pecan, 221-240, Springfield, Virginia, 1973.