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Biogeosciences
Discussions

Interactive comment on "CO_2 exchange in a temperate marginal sea of the Mediterranean Sea: processes and carbon budget" *by* G. Cossarini et al.

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In this section we reply to all the remarks raised by reviewer#1 (reported in capital letters). A general reply has been added to the main page of the interactive discussion, along with a supplementary file containing the new Appendixes A and B and the new section 3.2.

REVIEWER #1

REVIEW OF THE MANUSCRIPT: CO2 EXCHANGE IN A TEMPERATE MARGINAL

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Interactive Discussion

Discussion Paper

SEA OF THE MEDITERRANEAN SEA: PROCESS AND CARBON BUDGET. G. COSSARINI, S. QUERIN, C.SOLIDORO. SUBMITTED TO BIOGEOSCIENCES THE SUBMITTED MANUSCRIPT ADDRESSES THE IMPORTANT PROBLEM OF DESCRIBING AND QUANTIFYING THE ROLE OF COASTAL SHALLOW SEAS IN MODULATING THE ATMOSPHERE-OCEAN CO2 EXCHANGE IT DOES SO TROUGH THE ADRIATIC SEA IMPLEMENTATION OF A COUPLED PHYSICAL BIOGEOCHEMICAL NUMERICAL MODEL. ALTHOUGH THE ISSUE IS AN IMPORTANT ONE AND THE USE OF THE NUMERICAL TOOL IS NEEDED IN THE ASSESSMENT OF BIOGEOCHEMICAL PROCESSES I DO NOT THINK I CAN RECOMMEND PUBLICATION, AS THE ASSESSMENT OF THE METHODOLOGICAL TOOL IN REPRODUCING FEATURE OF THE ADRIATIC SEA FUNCTIONING IS NOT CARRIED OUT AT SUFFICIENT DEPTH. WITHOUT AN EXTENSIVE QUANTITATIVE ASSESSMENT OF THE RESULTS ALL THE PAPER CONCLUSIONS REMAIN VERY QUESTIONABLE.

The new appendix A reports a detailed description of the coupled model including the full list of the biogeochemical model parameterizations; other details will be added in section 2.1 and 2.2 (these changes are reported in the following points). The new Appendix B describes the ability of the model to reproduce the main features and the most relevant processes occurring in the Adriatic Sea. In particular, satellite MODIS surface chlorophyll-a maps, experimental data from three published climatologies and an extensive review of published data and estimations have been used to validate the dynamics of chlorophyll-a, nutrients (DIP and DOP), dissolved oxygen, carbonate system variables (pCO2, alkalinity and DIC) and the most relevant ecosystem processes (primary production, bacterial production and sinking of organic carbon). A corroboration of the simulated physical dynamics are shown in the companion paper (Querin et al., 2012), now accepted by JGR pending minor revisions, which has been sent (for the editor and reviewers) to the editor.

I LIST BELOW MY MAIN REMARKS AT THE BASE OF THE ABOVE DECISION. 1) THE PHYSICAL MODEL IS BASED ON THE MIT MODEL IMPLEMENTED IN THE

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ADRIATIC SEA. I UNDERSTAND THAT THERE IS ANOTHER (BUT UNKNOWN TO ME) PAPER BASED ON THE RESULTS OF THE PHYSICAL SIMULATIONS, BUT THE SUBMITTED MANUSCRIPT I HAVE AT HAND DOES NOT ALLOW TO ASSESS THE QUALITY OF THE PHYSICAL RESULTS OF THE MODEL IN TERM OF CIRCULATION PATTERNS AND SEASONAL VARIABILITY.

The paper by Querin et al. aims at understanding how dense water masses are produced and how the masses sink and spread along the basin under both “almost normal” and “warmer than normal” winter conditions. The results are obtained using a state-of-the-art, three-dimensional numerical model (MITgcm), corroborated by a comparison with satellite sea surface temperature (SST) data. In particular, we implemented a 1/32° horizontal grid to capture the most important mesoscale structures, which have length scales varying from 5 to greater than 20 km. We also adopted high-resolution wind forcing to properly resolve several peculiar wind-driven features, such as the double gyre circulation induced by the Bora wind in the Northern Adriatic Sea. A copy of the paper, which will undergo a minor revision process, has been attached for the editor and the reviewers.

2) THE SAME SHOULD BE SAID OF THE BIOGEOCHEMICAL MODEL. SUCH MODEL IS DESCRIBED ELSEWHERE AND IT HAS BEEN TESTED IN A 0-D MODE. NO ASSESSMENT IDS PROVIDED HERE (AND THERE) OF THE BEHAVIOUR OF THE MODEL IN A COUPLED MODE.

The new appendix A is dedicated to the description of the biogeochemical model and reports the complete list of model parameterizations. Besides, the section 3.2 has been rewritten to empathize the relevant ecosystem dynamics simulated by the 3D model, which have a relevant role in the carbon pump in the Adriatic Sea. In particular, we identify several moments during which biological processes can contribute to the carbon pump in the Adriatic Sea: the excess of primary production over respiration in the western part of the NA triggered by the river input, the bloom in the central part of the SA during winter deep convection events, and the prevalence of respiration in the

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SA during summer stratification. New section 3.2 has been attached to this reply (A pdf file has been uploaded to the interactive discussion).

3) THE PAPER DOES NOT GIVE ANY INDICATION OF THE NUMERICAL COUPLING TECHNIQUE USED TO PUT TOGETHER THE TWO (PHYSICAL AND BIOGEOCHEMICAL) MODELS. ON-LINE OR OFF-LINE? IF OFF-LINE WHICH FREQUENCY OF THE PHYSICAL FIELDS UPDATE HAS BEEN ADOPTED? OPERATOR OR SOURCE SPLITTING? NUMERICAL SCHEME TO CARRY OUT THE TEMPORAL INTEGRATION? NONE OF THE ABOVE IS MADE KNOWN TO THE READER. THE COUPLING TECHNIQUE ISSUE IS A VERY IMPORTANT ONE AND IT IS RECEIVING INCREASINGLY ATTENTION (SEE FOR INSTANCE, BUT NOT ONLY, BUTENSCHOEN AT AL., 2012)

The simulation is carried out by an on-line coupled physical (MITgcm) and biogeochemical (Cossarini and Solidoro, 2008) model. The coupling of the physical and biogeochemical models uses an “operator splitting” method with an integration time of 300 s for both the models. We are aware that the choice of numerical scheme for model coupling and integration is a tricky point. However, the use of a very short integration time makes the model output a bit less sensitive to such a choice (as said also in the manuscript quoted by the reviewer, which –by the way- was not yet published when we submitted our paper). The following sentence on this issue will be added in the section 2.2 and in the appendix A: “The coupling of the transport and biogeochemical models uses an operator splitting method, with an integration time of 300 s for both the models. Even if it has been suggested that operator splitting schemes can be less accurate than source splitting schemes (Butenschön et al., 2012), the use of a very short integration time (300 s) makes the model output less sensitive to the choice of the scheme”

4) THE ONLY ATTEMPT TO PROVIDE A SORT OF MODEL VALIDATION IS MADE TROUGH THE PRODUCTION OF A TABLE COMPARING SIMULATED AND OBSERVED AVERAGED VALUE CLAIMING “CONSISTENCY” BETWEEN OBSERVA-

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TIONS AND SIMULATIONS. CONSIDERING THAT THE SIMULATED (2007 AND 2008) ARE COVERED BY SATELLITE OBSERVATIONS (OCEAN COLOUR AND SST) A MORE QUANTITATIVE OBJECTIVE COMPARISON AND VALIDATION (E.G. STOW ET AL., 2009) SHOULD HAVE BEEN MANDATORILY CARRIED OUT.

As stated at the beginning of this reply (general comments), the new appendix B is dedicated to the biogeochemical model validation. In particular, satellite MODIS surface chlorophyll-a data, three published climatological datasets (for chlorophyll-a, DIP, dissolved oxygen) and an extensive review of published data (for DIP, DOP, pCO_2, DIC, alkalinity and relevant ecosystem processes) have been used to validate and corroborate the coupled model. The companion paper (Querin et al., 2012), which discusses the physical aspects of the dense water formation and spreading, reports a comparison of the sea surface temperature structures obtained by the physical model and by remotely sensed data. The paper, accepted for publication (pending a few minor revisions), is attached (for the editor and the reviewers) to this reply.

5) THE MODEL LACK OF A FULL SEDIMENT BIOGEOCHEMICAL MODEL (LIKELY TO BE VERY IMPORTANT IN STUDYING THE CO_2 DYNAMICS IN A SHALLOW SEA). THIS LIMITATION IN THE MODEL STRUCTURE CAN SERIOUSLY AFFECT THE FINAL RESULTS. UNFORTUNATELY NOT MUCH IS SAID ABOUT THE ROLE OF THIS LACKING PROCESS IN AFFECTING THE FINAL BUDGETS.

We agree with the reviewer that sediment processes affect the carbon cycle. We add that we do have a parameterization of this (a first order kinetic of sunk organic matter), but acknowledge that it is a very rough -and possibly inadequate- one. Unfortunately, state of the art is not very advanced on that, and examples of fully coupled pelagic-benthic modules are very few (e.g. Vichi et al., 2003 [1D model], Brigolin et al., 2011 [very limited coastal area model]). Even fewer are the validated benthic pelagic (1D) models. And basically no example exists of applications of validated pelagic-benthic models to large 3D basins. On the other hand, the experimental information on the spatial distribution of a number of benthic parameters required to a proper initialization

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of a basin scale 3D model is presently not available for the Adriatic Sea, nor for the majority of the seas. Because of this, the choice of a first-order approximate parameterization (a choice made also in many published studies) seems appropriate and, possibly, unavoidable. Benthic fluxes are important for the very coastal areas influenced by the Po river discharges, whereas observations for the off-shore areas show lower (and also opposite) values of the benthic fluxes (Hammond et al., 1999). Further, it is shown that much of the organic matter remineralization occurs during the sinking (Giordani et a., 2002). Details on the parameterization of the bottom remineralization have been added to the model description (see the appendix A) and the discussion will be enriched by a sentence dedicated to this important issue, which is a source of uncertainty for our model and results (see the point about the source of uncertainty of model results of the reviewer#2).

OTHER ISSUES: SECTION 2.3 PAGE 6 LINES 28-30, PAGE 7 LINES 1-2. WHY USING WIND DATA FROM ALADIN AND HEAT FLUX FROM MFS?. PLEASE EXPLAIN. I MIGHT BE WRONG BUT THIS MAY GENERATE INCONSISTENCY IN THE FORCING.

In the present configuration of the MITgcm model, the wind acts adiabatically on the ocean currents, whereas the total heat fluxes are imposed directly from the MFS dataset. Given the aim of this study (reproducing the formation of dense water and its effect on the carbon pump), the wind stress obtained from the MFS model (1/16° horizontal resolution and daily frequency) would not be sufficiently spatially and temporally fine, therefore ALADIN (0.03° x 0.02°, three hours frequency) guarantees the necessary accuracy in describing the wind field. On the other hand, MFS total heat flux can be considered a good approximation for surface fluxes [Oddo and Guarnieri, 2011] because of the relatively low spatial variability of air temperature, irradiance and humidity compared with wind direction and speed. This aspect will be better explained in section 2.3.

SECTION 3.1 PAGE 7 LINES 9 AND 16. WHAT DO YOU MEAN WITH “NORMAL

CLIMATOLOGY”?PLEASE EXPLAIN YOUR CONCEPT OF “NORMALITY”. . .. . ..

“Current weather climatology (referred to the period 2000-2010)” has been added instead of normal.

SECTION 4.1 DIFFERENCES IN WINTER PP AND NCP SHOULD BE SHOWN (SEE PAGE 11, LINE 11). THE SAME APPLIES TO SPATIAL VARIABILITY (PAGE 11, LINES 17-20).

The new section 3.2 is now reporting a description of the modelled winter and summer integrated primary production and community respiration maps. Section 3.2 has been rewritten to empathize the relevant ecosystem dynamics simulated by the 3D model, which have a relevant role in the carbon pump in the Adriatic Sea. See the attached file of the new section 3.2.

REFERENCES MENTIONED IN THE REVIEW MOMME BUTENSCHÖN, MARCO ZAVATARELLI, MARCELLO VICHI (2012) SENSITIVITY OF A MARINE COUPLED PHYSICAL BIOGEOCHEMICAL MODEL TO TIME RESOLUTION, INTEGRATION SCHEME AND TIME SPLITTING METHOD OCEAN MODELLING, VOLUMES 52–53, AUGUST 2012, PAGES 36-53 CRAIG A. STOW, JASON JOLLIFF, DENNIS J. MCGILLICUDDY JR., SCOTT C. DONEY, J. ICARUS ALLEN, MARJORIE A.M. FRIEDRICHS, KENNETH A. ROSE, PHILIP WALLHEAD SKILL ASSESSMENT FOR COUPLED BIOLOGICAL/PHYSICAL MODELS OF MARINE SYSTEMS JOURNAL OF MARINE SYSTEMS, VOLUME 76, ISSUES 1–2, 20 FEBRUARY 2009, PAGES 4-15

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Interactive comment on Biogeosciences Discuss., 9, 10331, 2012.