

REMOTE SENSING OF SURFACE OCEAN PH EXPLOITING SEA SURFACE SALINITY SATELLITE OBSERVATIONS

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ABSTRACT

The overall process commonly referred to as Ocean Acidification (OA) is nowadays gathering increasing attention for its profound impact at scientific and socio-economic level. To date, the majority of the scientific studies into the potential impacts of OA have focused on models and in situ datasets. Satellite remote sensing technology have yet to be fully exploited and could play a significant role by providing synoptic and frequent measurements for investigating OA processes on global scales. Within this context, the purpose of the ESA “Pathfinders-OA” project is to quantitatively and routinely estimate surface ocean pH by means of satellite observations in several ocean regions. Satellite Ocean Colour, Sea Surface Temperature and Sea Surface Salinity data (with an emphasis on the latter) will be exploited. A proper merging of these different datasets will allow to compute at least two independent proxies among the seawater carbonate system parameters and therefore obtain the best educated guess of the surface ocean pH. Preliminary results of the anomaly and variability of the ocean pH maps are presented.

Index Terms— Ocean Acidification, Ocean pH, Sea Surface Salinity, Sea Surface Temperature, Carbon dioxide.

1. INTRODUCTION

Oceans absorb almost one third of the human-released carbon emissions, acting as a natural carbon dioxide (CO₂) sink and playing a crucial mitigation role in slowing the rate of increase of atmospheric CO₂ concentration. This ocean CO₂ uptake has the overall effect of rising the content of hydrogen ion in the ocean (therefore lowering its pH) and altering chemical speciation of the large reservoirs of inorganic carbon dissolved in seawater, especially by reducing the concentration of the carbonate ion. These processes, referred to as Ocean Acidification (OA), affect

the biogeochemical cycles and threaten marine biodiversity and its commercial exploitation. Ocean Acidification is nowadays gathering increasing attention as one of the major foci of climate-related research [1,2], having profound impact not only at scientific level, but also in its socio-economic dimension. Ocean regions that have shown to be already particularly vulnerable to OA include upwelling areas, the oceans near the poles and coastal regions that receive freshwater discharges.

Growing international efforts are being devoted to develop a coordinated strategy for monitoring OA [3], with an eager need for global and frequent observations of OA-relevant parameters; however, the datasets acquired are currently mostly relevant to in-situ measurements, laboratory-controlled and mesocosm experiments, and models simulations.

Remote sensing technology is yet to be fully exploited and can be integrated by providing synoptic and frequent OA-related observations, upscaling and extending in-situ carbonate chemistry measurements on different spatial/temporal scales; yet, the preliminary products developed so far are only regional, empirical or derived with a limited variety of satellite datasets [4,5].

Within this context, “Pathfinders-OA” is an ESA Support To Science Element (STSE) project, led by the British Plymouth Marine Laboratory and the University of Exeter, meant to exploit Earth Observation (EO) to monitor ocean acidification. This is being addressed by collecting relevant datasets and creating a large database of EO/in-situ matchups, with the objective of developing and validating algorithms to retrieve OA parameters from space in 5 case-study regions (global ocean, Amazon plume, Barents sea, Greater Caribbean, Bay of Bengal). These ocean regions are indicated in the Fig.1.

Overall, the purpose of this study is to quantitatively and routinely estimate surface ocean pH and carbonate saturation states (mainly aragonite) by means of satellite observations,

capitalizing on the recent advent of remotely-sensed salinity measurements [6].

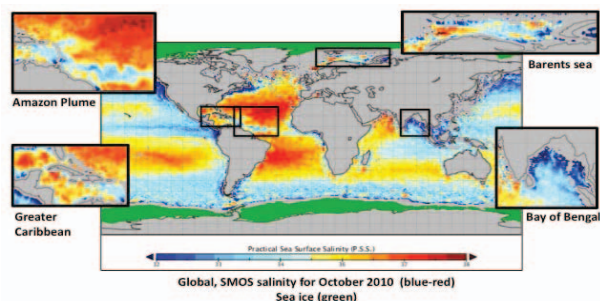


Fig.1. “Pathfinders-OA” ocean case studies. Black boxes indicate the test areas over a satellite salinity map. The study will also be carried out globally.

The overarching objectives are to develop new algorithms and data processing strategies to overcome the relative immaturity of OA satellite products currently available, and to produce a global, temporally evolving, quasi-operational suite of relevant satellite-derived data.

2. METHODOLOGY

Specifically, the objectives will be pursued by exploiting the information content of Ocean Colour (OC) data, Sea Surface Temperature (SST) and Sea Surface Salinity (SSS) parameters (with an emphasis on the latter, as a recent addition to the suite of satellite-derived oceanographic parameters). A proper merging of these different satellites datasets will allow to compute at least two independent proxies among the seawater carbonate system parameters (Fig. 2): namely, the partial pressure of CO₂ in surface seawater (pCO₂); the total Dissolved Inorganic Carbon (DIC) and the total alkalinity (AT). Through the knowledge of these parameters, the final objective is to come up with the currently best educated guess of the surface ocean pH.

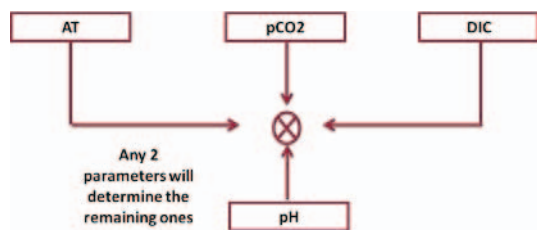


Fig. 2. Schematic view of the carbonate system parameters. By estimating any two of these parameters, the remaining ones can be computed (once temperature and salinity are also known).

The relationships between these satellite parameters and the above-mentioned carbonate systems variables have been studied by some authors (see [5], for a compendium), but mainly at regional scale, using specific satellite datasets or focusing only on a single parameter of the carbonate system.

For instance, information on DIC can be parameterized by Chlorophyll-a and SST; pCO₂ (and the related CO₂ fluxes at the air-sea interface) can be inferred by SST, Chlorophyll-a and Mixed-Layer Depth (MLD) information; lastly, AT could be now derived taking advantage of the recent SSS satellite measurements by SMOS and Aquarius, given concurrent information on SST.

A preliminary effort in this sense was the estimation of monthly surface ocean pH maps using pCO₂ data and computed AT derived from SMOS salinity measurements [7]. In Fig. 3, input fields of SSS (SMOS L3 SSS OI, ascending passes, courtesy of SMOS-BEC, Barcelona), SST (L4 OSTIA product distributed by MyOcean), and pCO₂ (ESA OceanFlux-GHG project climatology) are shown for the sample month of November 2010.

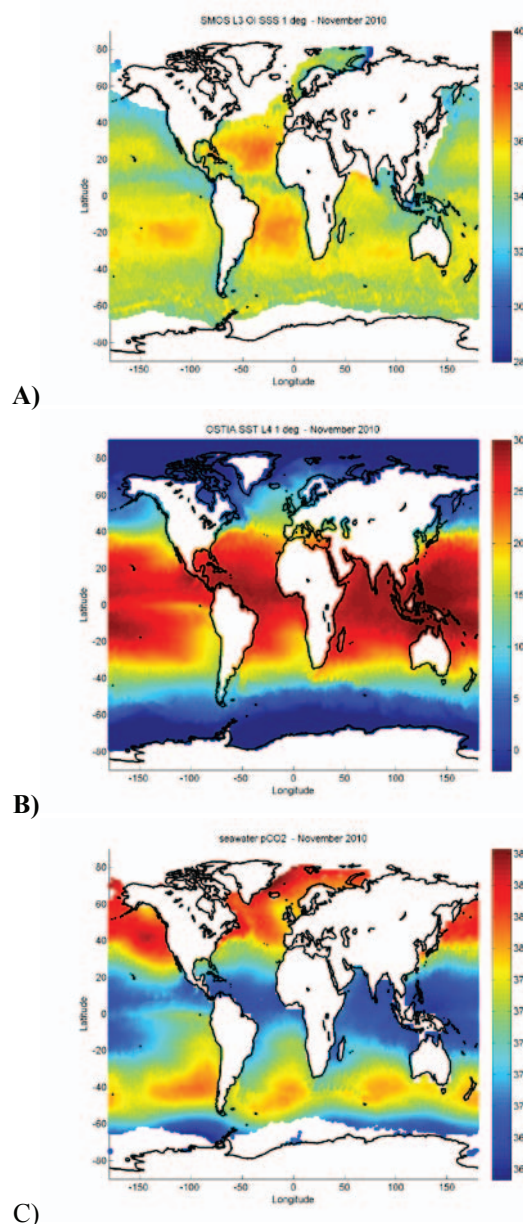


Fig. 3. Input fields for a) SSS (in psu), b) SST (in °C) and c) pCO₂ (in μ atm) for the sample month of November 2010.

3. RESULTS

The study focuses on the year 2010 in the Atlantic ocean, and the AT (Fig. 4) is computed with the parameterizations described in [8]. Higher AT (corresponding to higher capability to “buffer” and neutralize acids) values can be found in the open ocean, whilst the opposite happens along coastlines and in correspondence of freshwater discharges. Finally, the surface ocean pH (Fig. 5) is computed as described above. Lower pH values can be noted in correspondence of the ITCZ (freshwater discharges) and at high latitudes (colder waters).

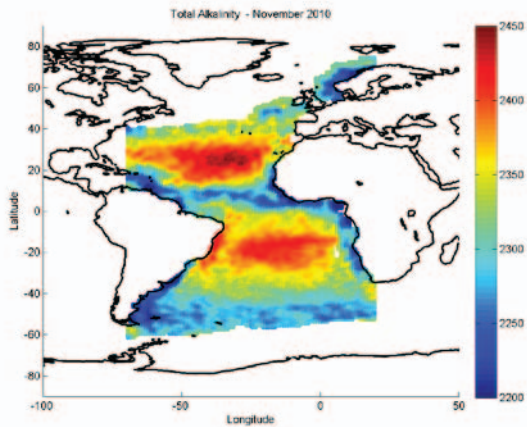


Fig. 4. Total alkalinity (in μ mol/kg), using satellite information and parameterized from SSS and SST as in [8] for the sample month of November 2010.

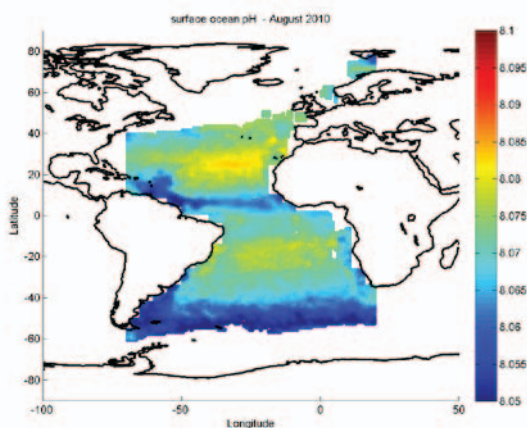


Fig. 5. Surface ocean pH, as derived from AT and pCO₂, for the sample month of November 2010.

If climatological data of SSS and SST from World Ocean Atlas (WOA) 2009 are used in the same processing chain to compute climatological fields of AT and pH, then a

corresponding anomaly can be computed (Figs. 6 and 7, for the same sample month). In noticing the seemingly small differences in terms of pH, it has to be recalled that the pH is a logarithmic scale.

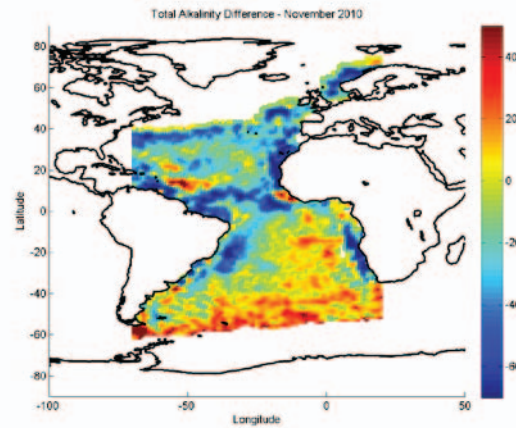


Fig. 6. Total alkalinity anomaly with respect to WOA 2009 for the sample month of November 2010.

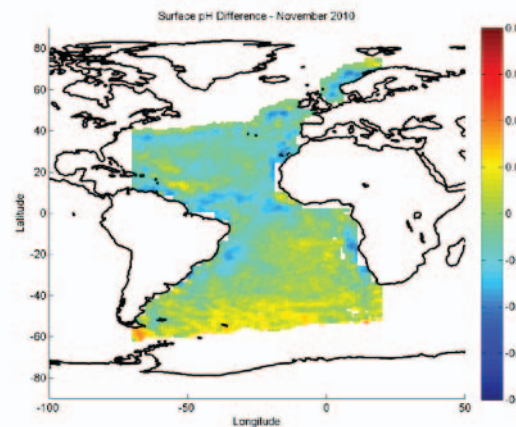


Fig. 7. Surface ocean pH anomaly with respect to WOA 2009 for the sample month of November 2010.

In order to have an idea of the order of magnitudes of fluctuations of both signals, the above mentioned anomalies can be compared with the natural seasonal variability of both At and pH, as described in Figs. 8 and 9. In this case, the variability is obtained by subtracting the November 2010 maps with At and pH values obtained 6 months apart. Despite the mean misfit of these ensembles is different, the associated standard deviations is comparable in both cases (about 27 μ mol/kg for the AT, and about 0.0035 for the pH). Remarkable variability is noticed in the correspondence of the Amazon river plume, where the AT parameterization may present some inaccuracies.

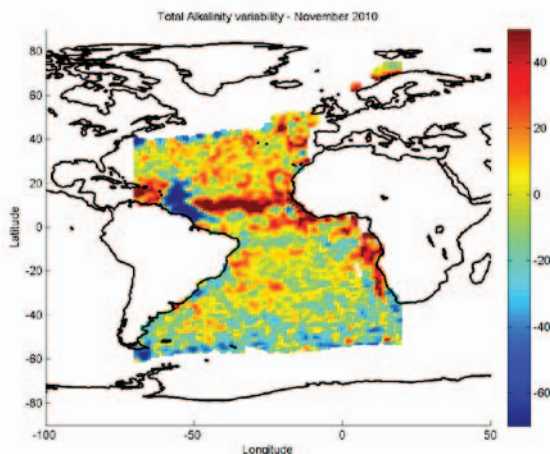


Fig. 8. Total alkalinity variability obtained by subtracting the November 2010 maps with AT values obtained 6 months apart.

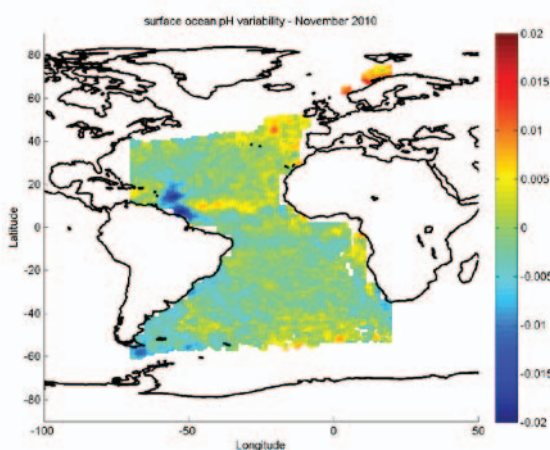


Fig. 9. Surface ocean pH variability obtained by subtracting the November 2010 maps with values obtained 6 months apart.

4. SUMMARY AND FUTURE WORK

Currently, ongoing efforts aim at extending the temporal domain and the geographical analysis, including additional satellite datasets (especially OC-related) and the remaining carbonate system parameters, and performing different permutations (round-robin approach) in view of a systematic ocean pH sensitivity analysis. An effort in assessing the error propagation of satellite inaccuracies along the identified processing chain is ongoing.

An overall validation plan is being devised to verify the consistency, accuracy and robustness of the satellite datasets produced, by quality-controlling the satellite products against in-situ measurements and modelling outputs. The recently developed climatology produced by Takahashi and colleagues in 2014 will be used at this scope [9].

The innovation of this study lies mainly in the effort of unifying fragmented remote sensing studies and generating a novel value-added satellite product: a global and frequent

surface ocean pH “cartography”. This will foster the advancement of the embryonic phase of OA-related remote sensing and will aim at bridging the gap between the satellite and the process studies communities, benefiting from their cross-fertilization and feedback.

5. REFERENCES

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