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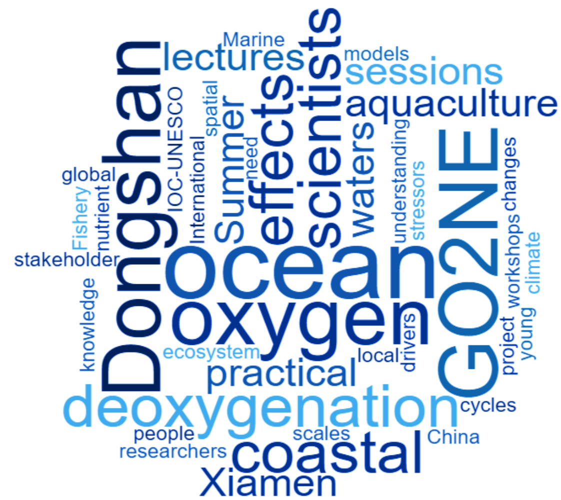
The 1st Global Ocean Oxygen Network (GO2NE) International Summer School

2 - 8 September 2019
Xiamen, China



From 2 - 8 September the 1st International Summer School from the Global Ocean Oxygen Network (GO_2NE) from the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) took place in Xiang'an Campus of Xiamen University, China, hosted by Prof. Minhan Dai, Director of the State Key Laboratory of Marine Environmental Sciences. The summer school was sponsored by IOC UNESCO, GO_2NE, the International Ocean Carbon Coordination Project (IOCCP), the Collaborative Research Center 754 (SFB754), the State Key Laboratory of Marine Environmental Science (MEL) of China, the French National Centre for Scientific Research (CNRS), the National Fund for Scientific Research (FNRS), University of Liège, SOLAS, the European Geosciences Union (EGU), the Ocean Carbon and Biogeochemistry (OCB) program, the National Oceanic and Atmospheric Administration (NOAA) and the Scientific Committee on Oceanic Research (SCOR), and by several other individual advisors and institutes.

Declining oxygen in the world's ocean and coastal waters is reducing suitable habitat, alter-

In this report

Figure 1: The students and lecturers of the 1st GO$_2$NE International Summer School at Xiamen University, Xiamen, China. © Lei Chen

ing biogeochemical cycles, and may cause feedbacks that further exacerbate deoxygenation and global warming (Isensee *et al*., 2016; Breitburg *et al*., 2018). Major advances have been made in understanding patterns, drivers, and consequences of ocean deoxygenation, but there is a need to improve predictions at different spatial and temporal scales important to project the provision of ecosystem services provided by the ocean. Improved numerical models of oceanographic processes that control oxygen depletion and the large-scale influence of altered biogeochemical cycles are the basis to predict the magnitude and spatial patterns of deoxygenation in the open ocean, as well as its feedbacks to climate. Developing and verifying the next generation of these models will require increased *in situ* observations and improved mechanistic understanding at a variety of scales, including how changes in stratification and circulation might affect oxygen content in the water column. Models useful for managing nutrient loads can simulate oxygen loss in coastal waters with some skill, but their ability to project future oxygen loss is often hampered by insufficient data and climate model projections on drivers with an appropriate resolution. Predicting deoxygenation-induced changes in ecosystem services and human welfare needs information based on scaling effects that are measured on individual organisms to populations, food webs, and fish stocks, considering combined effects of deoxygenation and other ocean stressors, and increased research emphasis in developing nations. Reducing effects of other stressors may increase species resilience negatively affected by low oxygen conditions. Ultimately, though, limiting deoxygenation and its negative effects can be only achieved by a dramatic global decrease in greenhouse gas emissions as well as reductions in nutrient discharges to coastal waters (Isensee *et al*., 2016; Breitburg *et al*., 2018; IOC-UNESCO Technical Series 137).

GO$_2$NE places particular emphasis on capacity building, as the development of the current generation of young researchers is vital to make immediate significant progress in response to the pressing environmental and societal challenges.

The GO$_2$NE Summer School 2019 connected young researchers with leading scientists in different components of GO$_2$NE research, and scientists from SMEs not only in a theoretical framework, but also through practical exercises, laboratory experiments and special sessions. The GO_2NE vision is to provide scientific knowledge and educate the younger generation of scientists for 'the Ocean we need for the Future we want' (IOC-UNESCO brochure - International Decade of Ocean Science for Sustainable Development).

The summer school was composed of a mix of lectures and practical workshops, implemented as follows: two full days of lectures followed by two days of practical workshops, one day of stakeholder engagement activities and another two full days of lectures. The 2019 school brought together 37 PhD students and early career scientists from 19 countries across all continents and 14 world-leading international scientists from 12 countries. A balanced geographic representation together with a proper gender balance has been respected. General lectures included open ocean deoxygenation, closed seas and coastal waters deoxygenation, introduction to modelling ocean physics, introduction to modelling ocean biogeochemistry, ocean observing systems design in relation to the deoxygenation issue, effects of ocean deoxygenation including biological responses, etc. In addition, the first two evenings were devoted to poster sessions so that all students got to know each other and the topic of research each one was carrying out. Special sessions included Ethics in Science and How to interact with the press and social media and NGOs.

During the last two days of the school, each student gave a 5 minute presentation in front of the whole school as part of the Practical Workshop on Communication. Rewards for the Best Oral Presentation and Best Cruise Report were given at the end of the school.

During the cruise aboard the research vessel Tan Kah Kee from Xiamen University, students were introduced on how to use the most recent oxygen sensors of the market together with performing Winkler titrations and using a CTD with Niskin bottles, and plankton nets.

The stakeholder engagement activity was centered, after the abalone aquaculture farm visit on Dongshan island, around a dialogue between the Deputy Director General from the Dongshan county Marine and Fishery Bureau and personnel from the Dongshan county Fishery Technology Promotion Station, the Dongshan Yishui abalone farm, the Dongshan Haibao abalone farm and the Dongshan Haitian breeding co. LTD. Questions from the students included: What is the contribution of freshwater versus seawater aquaculture in China? What were local people doing before the abalone aquaculture took off in 1991? How local people got the knowledge for abalone farming? Why did you develop abalone farming - To release stress from overfishing or to add another source of proteins? How do you co-design between scientists and stakeholders?

Prof. Minhan Dai's team is warmly thanked for its support which was key to the success of the GO_2NE Summer School.

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References

Breitburg, D., Levin, L., A., Oschlies, A., *et al*. (2018). Declining oxygen in the global ocean and coastal waters, *Science*, 359, eaam7240.

IOC-UNESCO (2017), The ocean is losing its breath: declining oxygen in the world's ocean and coastal waters. IOC Technical Series, 137.
IOC-UNESCO brochure
http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/IOC_Gatefold_Decade_SinglePanels_PRINT.pdf

Isensee, K., Levin, L. A., Breitburg, D., *et al*. (2016). The Ocean is losing its breath in Ocean and Climate Scientific notes. (www.ocean-climate.org, ed. 2, 2016), pp. 20-32.

Photo gallery of the GO_2NE Summer School

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Yosra Khammeri completed a Master degree in Marine Ecosystems in Tunisia, at the University of Carthage, in 2012. Actually she is a PhD student at National Institute of Marine Sciences and Technologies, Tunisia, to investigate at the single cell level, the response of phytoplankton and heterotrophic bacteria to atmospheric dust deposition in the Mediterranean Sea.

The dynamics of microphytoplankton abundance related to PM10 and meteorological conditions in the Gulf of Gabès

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The Mediterranean Sea is a typical low nutrient-low chlorophyll (LNLC) ecosystem characterised by a decreasing gradient of nutrients and primary production from west to east (Moutin and Raimbault, 2002). From an oceanographers' point of view, nutrient deposition has been pointed out as an important source of the new primary production, particularly for oligotrophic waters (Markaki *et al*., 2003; Herut *et al*., 2005; Paytan *et al*., 2009). Among these areas, the Gulf of Gabès is located in the North African coast which is widely considered as the Earth's largest source of dust (N'Tchayi *et al*., 1997; Prospero *et al*., 2002). It is characterised by a shallow continental shelf with a gentle slope extended 250 kilometers offshore, weak currents, high temperature, and high salinity. However, the hot and sandy Saharan air coming from the southwest is generally transported into the ocean (Bouaziz *et al*., 2003).
In contrast with the oligotrophic feature of the Eastern Mediterranean Basin, the Gulf of Gabès has the peculiarity of being highly productive due to high nutrient availability (Bel Hassen *et al*., 2009; Khammeri *et al*., 2018).

Recently, studies have pointed out the effects of atmospheric dust on phytoplankton growth. The composition and forms of dust in the air vary with sources. In terms of solid particles, particulate matter (PM) 10 are fine atmospheric particulate matter (< 10 micrometre), made up of particles of many different sizes and chemical composition, from a wide range of natural and anthropogenic sources. The interaction of wind direction with dust sources is also important. The long range transport air masses and the back trajectories analysis indicate that high PM10 values detected in Europe is due to Saharan dust advection.
However, in this study, Principle Component Analysis (PCA) was performed to relate the microphytoplankton abundances to PM10 and meteorological variables. PCA demonstrates that diatoms and dinoflagellates abundances were positively influenced by PM10 concentrations, and negatively influenced by wind speed. Linked to the wind speed and directions, PM10 were presented in important amounts when the wind direction is from the South and North West (Figure 2). The important industrial activities and ge-

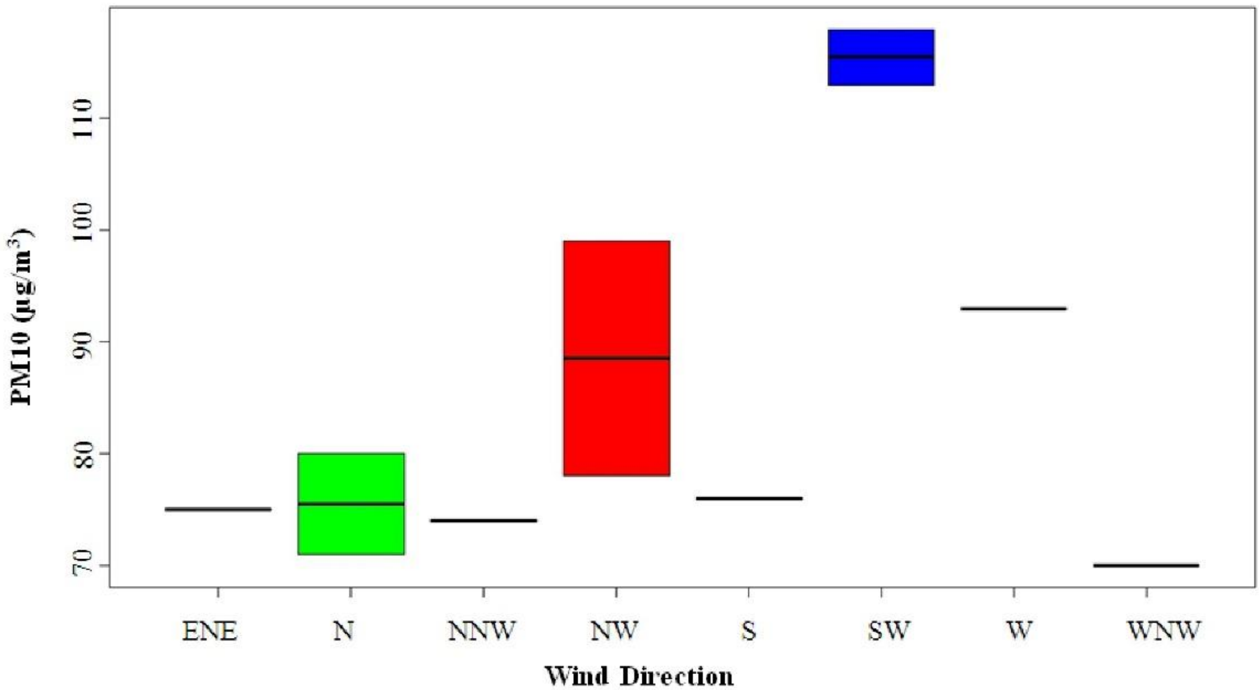

Figure 2: Boxplot of PM10 in micrograms per cubic meter (µg/m^3) depending on wind direction in the Gulf of Gabès.

ographical situation of the Gulf of Gabès suggest the dominance of two types of dusts, anthropogenic dust caused by the massive human and industrial activities in this region, and the Saharan dust due to the dominance of South West air masses trajectories coming from the near desert.

References

Bel Hassen, M., Hamza, A., Drira, Z., *et al*., (2009). Plankton-pigment signatures and their relationship to spring summer stratification in the Gulf of Gabes. *Estuarine Coastal & Shelf Science*, 83 (3), 296-306.

Bouaziz, S., Jedoui, Y., Barrier, E., *et al*., (2003). Néotectonique affectant les depots marins tyrrhéniens du littoral sud-est Tunisien: implications pour les variations du niveau marin. *Comptes Rendus Géoscience*, 335 (2), 247-254.

Herut, B., Zohary, T., Krom, M. D., *et al*., (2005). Response of East Mediterranean surface water to Saharan dust: on-board microcosm experiment and field observations. *Deep Sea Research Part II: Topical Studies in Oceanography*, 52 (22-23), 3024-3040.

Khammeri, Y., Hamza, I. S., Bellaej-Zouari, A., *et al*., (2018). Atmospheric bulk deposition of dissolved nitrogen, phosphorus and silicate in the Gulf of Gabès (South Ionian Basin); implications for marine heterotrophic prokaryotes and ultraphytoplankton. *Continental Shelf Research*, 159, 1-11.

Markaki, Z., Oikonomou, K., Kocak, M., *et al*., (2003). Atmospheric deposition of inorganic phosphorus in the Levantine Basin, eastern Mediterranean: Spatial and temporal variability and its role in seawater productivity. *Limnology and Oceanography*, 48, 1557-1568.

Moutin, T. and Raimbault, P. (2002). Primary production, carbon export and nutrients availability in western and eastern Mediterranean Sea in early summer 1996 (MINOS cruise). *Journal of Marine Systems*, 33-34, 273-288.

N'Tchayi, G. M., Bertrand, J. J., Nicholson, S. E. (1997). The Diurnal and Seasonal cycles of wind-borne dust over Africa North of the equator. *Journal of Applied Meteorology and Climatology*, 36, 868-882.

Paytan, A., Mackey, K. R. M., Chen, Y., *et al*., (2009). Toxicity of atmospheric aerosols on marine phytoplankton. *Proceedings of the National Academy of Sciences USA*, 106, 4601-4605.

Prospero, J. M., Ginoux, P., Torres, O., *et al*., (2002). Environmental characterization of global sources of atmospheric soil dust identified with the Nimbus 7 Total Ozone Mapping Spectrometer (TOMS) absorbing aerosol product. *Reviews of Geophysics*, 40(1), 2-31.

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I also would like to thank SOLAS for funding my participation to the GO_2NE international summer school at Xiamen University.

Most Israt Jahan Mili completed a Master degree in Oceanography at University of Dhaka, Bangladesh in 2017. She started a career as lecturer in the Department of Marine Fisheries and Oceanography at Patuakhali Science and Technology University in 2018. Later on, she joined as a lecturer at Bangabandhu Seikh Mujibur Rahman Maritime University, Department of Oceanography and Hydrography. Her Master of Science work is on nutrients cycling and productivity of ocean.

Productivity of the Bay of Bengal

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Productivity of many coastal marine systems is limited by nutrient availability and the input of additional nutrients increases primary production. The Bay of Bengal (BoB) is traditionally considered to be a less productive basin than the Arabian Sea (Kumar *et al.,* 2002). Coastal regions are the most productive ecosystems of the world, exemplified by the fact that coastal habitats provide feeding and reproduction ground for approximately 90% of the world's marine fish catch (Pramanik and Mohanty, 2016). In tropical aquatic basins where sunlight is not usually a limiting factor except during overcast conditions, the biological production is limited by the availability of nutrients. Numerous measurement methods are typically used for primary production. Some of these methods rely on variations in oxygen concentration, carbon dioxide (CO_2) assimilation (the carbon-14 method), or estimation by different models using satellite data.

Among these models, the Vertically Generalized Production Model (VGPM) is used here for estimating depth-integrated primary productivity. The VGPM model was first described by Behrenfeld and Falkowski (1997) and is a commonly used algorithm for estimating regional to global ocean Net Primary Productivity (NPP). The foundation of the VGPM and other chlorophyll-based models is that NPP varies in a predictable manner with chlorophyll concentration (chl). Remote sensing data of chl-a are derived from MODIS from the ERDDAP (Environmental Research Division's Data Access Program) site with a spatial resolution of 4 kilometer (km), 8-day composite data. Sea Surface Temperateure (SST) and other ancillary data were taken from Aqua MODIS with a spatial resolution of 4 km, 8-day composite data. Jason-2 Sea Surface Height Anomalies (SSHA) data was downloaded from AVISO which was launched in 2008 and providing data till now. We examined the 4 months (December, January, February, March) period over an archive of five years from 2012 to 2016. Estimation of P^B_{opt} following the parameterisations of Behrenfeld and

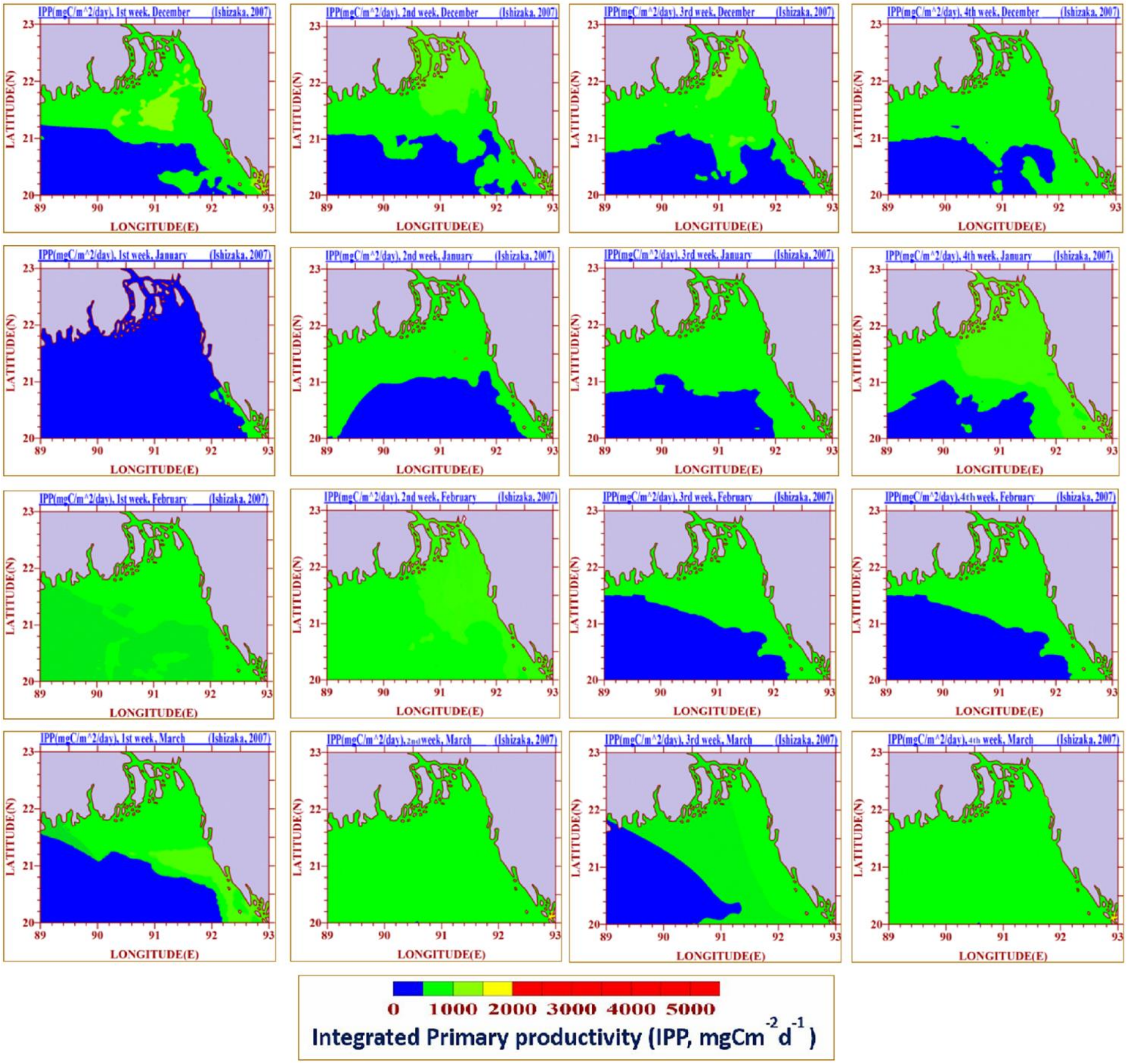

Figure 3: Schematic diagram for in-situ and model derived Primary Productivity in the north-eastern part of the Bay of Bengal.

Falkowski (BF) and Kameda and Ishizaka (KI) were poorly correlated with in situ P^B_{opt} and a new formulation for P^B_{opt} was considered by (Ishizaka, 2007) following a second- order polynomial temperature dependence:

P^B_{opt} = (- 12.2 + 1.17T – 0.025T^2)/ Chl + (13.3 – 0.916T + 0.0191T^2)
Where, P^B_{opt} is the photosynthesis rate (mg m^{-3}).

Estimated P^B_{opt} following Ishizaka (2007) showed a smaller variation than the in-situ data. However, the estimation was slightly better than the one obtained following Kameda and Ishizaka (2005), indicating the validity of the formulation.
Thus, the original formula was fitted to estimate the light dependency parameters of the VGPM with in situ IPP, P^Bopt, PAR, Z_{eu} and C_{opt} and the following equation was obtained:

IPP = 4.19 × P^Bopt × [E_0 / (E_0+ 336)] × Z_{eu} × C_{opt} × D_{irr}
Finally, this was followed to estimate primary productivity for this study.

Where, IPP = Integrated Primary Production ($mgCm^{-2}d^{-1}$), P^B_{opt} =Photosynthesis rate (mg m^{-3}), E_0= PAR (mol quanta $m^{-2}day^{-1}$), Z_{eu}= Euphotic depth (m), C_{opt}= Chlorophyll (mg m^{-3}), D_{irr}= Daylength (hr). In-situ primary productivity was measured following the oxygen method using light and dark bottles at three different sampling stations.

Results revealed that the mouth of the BoB was experienced with low temperature waters covering both the eastern and western parts. It is observed that the northern mouth of the BoB is characterised with upwelling for three months including December, January, and February, and frequently downwelling occurring in March with high sea level anomalies. The model derived PP ranged from 250-1000 $mgCm^{-2}d^{-1}$ where in-situ pp was 8-400 $mgCm^{-2}d^{-1}$. High productivity is found in the upwelling zone in the northern area while lower productivities are observed in the southward region (Figure 3). Eddy formation and presence were also observed in March whereas they totally disappear in consequent months.

References

Behrenfeld, M. J. and Falkowski, P. G. (1997). Photosynthetic rates derived from satellite-based chlorophyll concentration. *Limnology and Oceanography*, 42(l), 1-20.

Ishizaka, J., Siswanto, E., Itoh, T., *et al*. (2007). Verification of Vertically Generalized Production Model and Estimation of Primary Production in Sagami Bay, Japan. *Journal of Oceanography*, 63, 517-524.

Kameda, T. and Ishizaka, J. (2005). Size-Fractionated Primary Production Estimated by a Two-Phytoplankton Community Model Applicable to Ocean Color Remote Sensing. Journal of Oceanography, 61, 663-672.

Kumar, S. P., Muraleedharan, P. M., Prasad, T. G., *et al*. (2002). Why is the Bay of Bengal less productive during summer monsoon compared to the Arabian Sea? *Geophysical Research Letters*, 29(24), 2235.

Pramanik, D. S. and Mohanty, S. S. (2016). Seasonal variation of primary productivity of Bay of Bengal at Chandipur-on Sea, Odisha. *International Journal of Fisheries and Aquaculture*, 4(2), 331-336.

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Florian Ricour completed a Master's degree in Oceanography at the University of Liège, Belgium, in 2018. He has started his PhD in 2019 at the same university in the Modelling for Aquatic SysTems (MAST) research group. The aim of his research is to better understand the evolution of the oxygen content of the global ocean since 1960.

Building a revised assessment of the ocean health with a focus on oxygen

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In the definition of its sustainable development goals, the United Nations have recognised the preservation of the health of the oceans as a priority and a crucial economic development issue. The global and coastal ocean is rapidly changing as a result of warming, acidification, and deoxygenation, with overuse and destruction of marine habitats. In particular, different analyses conclude that the global ocean oxygen content has decreased by 1-2% (i.e. 38-77 billion tons) since the middle of the last century (Bopp *et al*., 2013; Schmidtko *et al*., 2017). Regions with historically low oxygen concentrations are expanding and new regions are now exhibiting low oxygen conditions. Global warming is expected to have contributed to this decrease directly because the solubility of oxygen in warmer waters decreases and indirectly through changes in the physical and biogeochemical dynamics.
Although model simulations and data analyses consistently conclude that the global ocean oxygen inventory has decreased, they do not agree in terms of spatial distribution of the decrease and the last estimates from data analyses (Schmidtko *et al*., 2017) showed a global decrease of 2% which is twice the amount estimated from model simulations.
In this project, I propose to revise those estimates based on an updated data analysis protocol using high quality data and an advanced interpolation tool based on variational data analysis, more adapted to the scarcity of biogeochemical observations (Figure 4). Also, the advent of

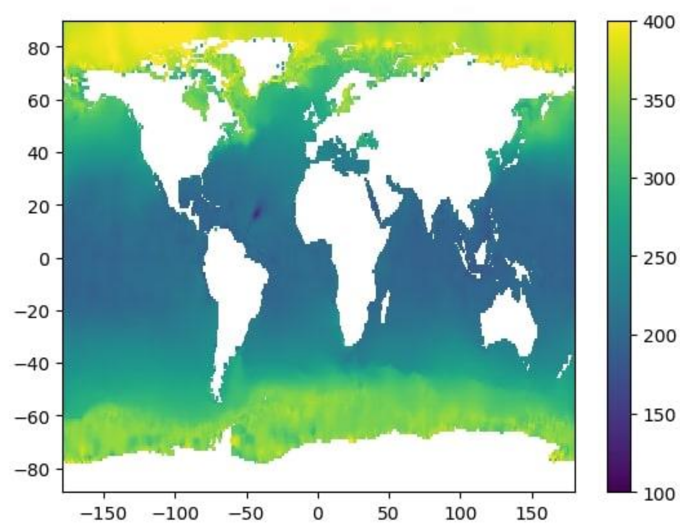

Figure 4: Result of the data interpolation using only bottle data at the surface (analyzed with the method of Winkler). The scale is in micromol/kg.

autonomous profilers such as Biogeochemical Argo floats (Figure 5) offers a wealth of information for refining the estimation of deoxygenation yet not taken into account so far.

Today, the number of oxygen profiles from such floats is outnumbering profiles taken on research cruises but they are still underexploited due to technical and data quality issues (e.g. sensor drift). Thus, a huge effort will be done to correct those data in order to integrate them in our oxygen climatology. Finally, there are more and more evidences that the mesoscale dynamics plays a key role in the ocean heat and biogeochemical budget.

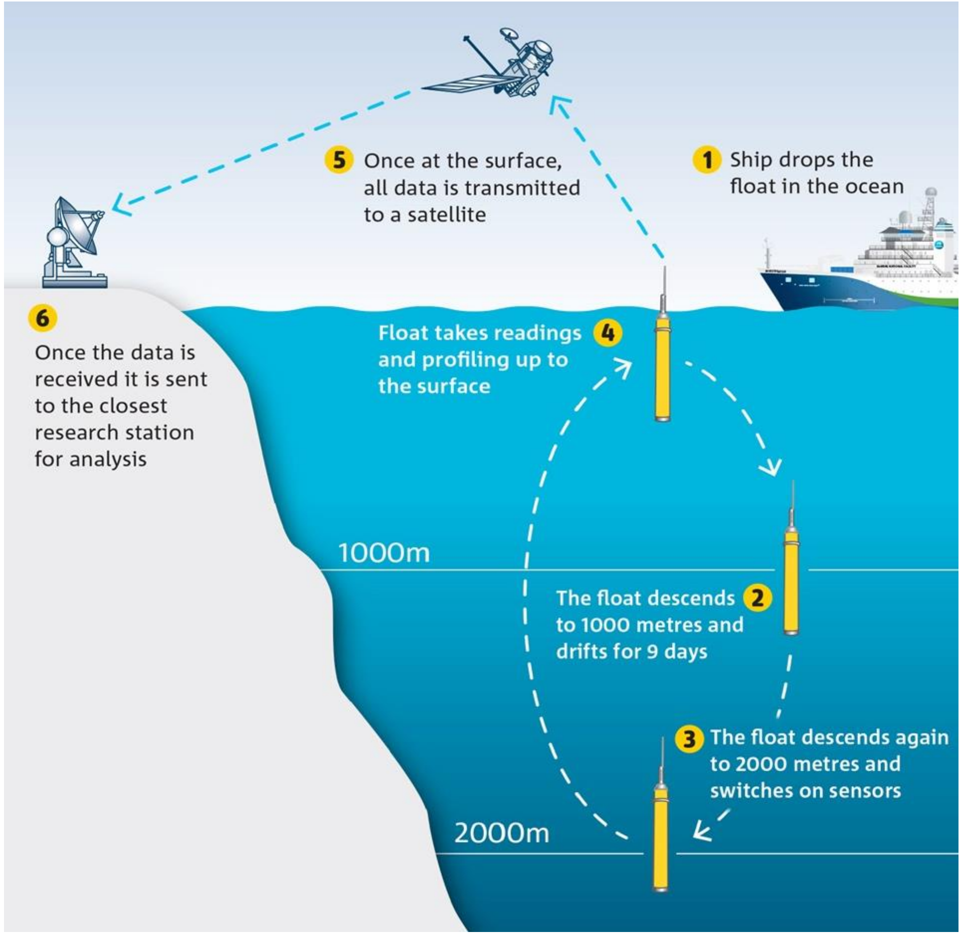

Figure 5: Representation of a Biogeochemical Argo float cycle. (source: www.csiro.au)

However, the role of meso- and sub-mesoscale (i.e. scales of 1 to 100 km) structures in the ocean heat and carbon sequestration (e.g. Pascual *et al*., 2017) is fundamental but still poorly quantified, in particular, at global scales. As concerns oxygen, the global role of mesoscale eddies in shaping its dynamics is still elusive: Schütte *et al*. (2016) found that coherent vortices contribute to reinforce the lowering of oxygen due to an intense production of organic materials inside their core while Bettencourt *et al*. (2015) proposed that mesoscale structures contribute to ventilate low oxygen regions by injecting rich oxygen water by stirring mechanism. The plethora of earth observations provided by the new generation of satellites and autonomous platforms offers an opportunity to elucidate the role of mesoscale structures in oxygen dynamics. Therefore, using machine learning techniques (e.g. neural networks, causal inference), I will analyse multiple observations from satellites, ships, and autonomous platforms for understanding the oxygen dynamics in connection with physical and biogeochemical variables to identify an oxygen signature of mesoscale structures, to infer patterns and causal relations. In the end, using the newly computed three-dimensional oxygen climatology, I will be able to review the deoxygenation trend currently taking place in the global ocean, both at a global and regional scale.

References

Bettencourt, J. H., López, C., Hernández-García, E., *et al*. (2015). Boundaries of the Peruvian oxygen minimum zone shaped by coherent mesoscale dynamics. *Nature Geoscience*, 8, 937-940.

Bopp, L., Resplandy, L., Orr, J. C., *et al*. (2013). Multiple stressors of ocean ecosystems in the 21st century: projections with CMIP5 models. *Biogeosciences*, 10, 6225-6245.

Pascual, A., Ruiz, S., Olita, A., *et al*. (2017). A multiplatform experiment to unravel meso-and submesoscale processes in an intense front (AlborEx). *Frontiers in Marine Sciences*, 4, 39.

Schmidtko, S., Stramma, L., Visbeck, M. (2017). Decline in global oceanic oxygen content during the past five decades. *Nature*, 542(7641), 335-339.

Schütte, F., Karstensen, J., Krahmann, G., *et al*. (2016). Characterization of "dead-zone" eddies in the eastern tropical North Atlantic. *Biogeosciences*, 13, 5865-5881.

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