Ocean Macronutrient Fertilisation –An enhanced natural carbon sink?

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In order to meet the goal of limiting global average temperature increase to less than 2 ˚C, it is increasingly apparent that anthropogenic CO_2 sinks of up to 10 Pg C yr^{-1} will be needed before the end of the century. Ocean iron fertilization, although controversial has been shown to be one of the few technologies with a large capacity for removing CO_2 from the atmosphere. Here I present the findings of a study to assess the capacity of an alternate form of ocean fertilization, Ocean Macronutrient Fertilisation (OMF). Sufficient phosphate exists outside the iron limited surface ocean to support once-only sequestration of up to 3.6 Pg C by fertilization with nitrogen. Ongoing sequestration using nitrogen fertiliser is estimated at 1.07±0.27 Pg C yr-^{1}. If N and P were used in combination to fertilise the ocean, the size of the CO_2 sink thus created is limited by societies willingness to utilize phosphate resources. Doubling current phosphate production would allow an additional 0.9 Pg C yr^{-1} sequestration and consume 0.07% yr^{-1} of known global resources. Environmental risks have received little quantitative evaluation; however it is likely they could also limit the scale of implementation.

Keywords: Ocean fertilisation, Sequestration, Carbon Sink

Multi-year estimate of the air-sea CO2 flux in the Arctic with the use of the chlorophyll-a concentration

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We examined the relationship between partial pressure of CO_2 in the surface water (pCO_{2w}) and chlorophyll-a concentration (Chl-a) in the Arctic. The relationship between pCO_{2w} and Chl-a is negative where Chl-a < 1 mg m^{-3}, but there is no significant relationship where Chl-a > 1 mg m^{-3}. In the Greenland/Norwegian Seas, a relationship between pCO_{2w} and Chl-a is strongly negative in spring and weakly negative in summer. Chl-a is higher in summer than in spring, while nutrient concentration is high in spring and low in summer there. A positive relationship between pCO_{2w} and Chl-a is found in the Barents Sea in summer when Chl-a values decline while pCO_{2w} remains at a relatively constant low level. In the Kara and East Siberian Seas and the Bering Strait, the relationships are positive because of high pCO_{2w} and Chl-a water in the coastal region.
We estimated monthly air–sea CO_2 flux in the Arctic north of 60°N from 1997 to 2014 by applying a self-organizing map technique with Chl-a, SST, SSS, SIC, xCO_{2a}, and geographical positions. The addition of Chl-a as a training parameter enables us to improve the estimate of pCO_{2w} through reproducing its decline in spring by biological production. A significant CO_2 uptake of 180 ±130 TgC yr^{-1} in the Arctic Ocean was obtained. This estimate has been much improved compared to a previous estimate thanks to the use of Chl-a, but to some extent also due to a higher number of CO_2 data.

Keywords: CO2 flux, Arctic, chlorophyll-a, SOCAT

Reef Refugia to Climate Change

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Introduction:

Climate change including global warming and ocean acidification is suspected to have profound impacts on the marine ecosystems at a global scale (IPCC 2011). Among them, coral reef ecosystem is suspected to be principally affected by the climate change (Hoegh-Guldberg et al. 2007). Number of experiment and field studies demonstrated that the increase of seawater temperature and seawater acidity induces coral bleaching and decrease of net calcification. CO_2 vent studies also revealed that high CO_2 could cause shifts in reef community structure and decrease of biological diversity (Fabricius et al. 2011, Inoue et al. 2013, Enochs et al. 2015). However, recent studies have indicated the possible existence of some reef system that could work as a refugia to the climate change (Manzello et al. 2012, Yates et al. 2014, Cacciapaglia and van Woesik 2015, Barkley et al. 2015). Here, we examined the water chemistry and reef community within an inner reef bay (Nikko bay) in Palau that show natural low pH and high temperature gradient and high coral cover community to understand the factors generating the resilience of this community. Transplantation and tank experiments using the coral *Porites cylindrica* was also conducted to evaluate the potential local adaptation to warmed and acidified environment.

Methods

Nikko Bay is a highly sheltered bay with spatially heterogeneous seawater chemistry due to the complex topography and high water residence time. We conducted a fine scale carbon chemistry measurement including pH, total alkalinity (TA), dissolved inorganic carbon (DIC), aragonite saturation (Ω_{arag}) salinity and temperature, and water quality measurement including nutrient, Chl-*a*, turbidity and dissolved oxygen (DO) within the bay. For the evaluation of the effect of pH/temperature at community level, we conducted benthic community surveys at 7 sites along the gradient of the seawater pH and temperature. Reciprocal transplantation experiment and tank experiment using the coral *Porites cylindrica* collected from different sites was performed to study the possible adaptation of the corals to high temperature and low pH condition.

Results and discussion

The seawater chemistry was spatially highly heterogenic and seawater pH within the bay ranges from 7.6 to 8.1 (average 7.8), aragonite saturation (Ω_{arag}) from 1.8 to 3.6 (2.4) and the temperature from 30 to 33˚ C (average 32˚C). Coral density range from 38 to 82% with the average of 60%, and show the highest coverage among the benthic communities. Net calcification rate was calculated to be 22 mmol $CaCO_3$ m^{-2} d^{-1} which value was higher than the value measured out of the bay. Coral community structure differ between sites however, coral biodiversity increase with the decline of $\Omega_{arag.}$ The coral *Porites cylindrica* show the highest coverage within whole bay, which percentage account for 50% of whole coral community. There was no significant change on macroalgae, sea grass and calcareous algae density with Ω_{arag}, while turf algae density decrease with $\Omega_{arag.}$ Reciprocal transplantation and tank experiment indicated that the calcification rate of coral *P. cylindrica* collected from both out and within the bay decrease with Ω_{arag} and temperature. However, the corals originated from the lowest pH and highest temperature site show higher resilience to the low pH and temperature compared to the corals out of the bay, suggesting acclimatization for these corals to warmed and acidified environment. We will further

discuss for the mechanisms underlying this possible refuge system to the future climate change.

Keywords: Climate change, Ocean acidification, Coral Reef, acclimatization, Refugia

Effects of the Changjiang (Yangtze) River plume magnitude on organic carbon consumption in the East China Sea in summer

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Understanding how freshwater discharge influences coastal ecological processes is an important factor in exploring global carbon cycling in the adjacent seas. Especially, under the current conditions of climate change, such heavy freshwater discharge events are predicted to become even more pronounced in the near future because of the dramatic increases in extreme rainfall events and floods predicted to occur throughout the world. However, few studies have focused on the effects of freshwater discharged magnitude on organic carbon consumption in continental shelf ecosystems, especially which influenced by large river, e.g., the Changjiang River. In this study, the effects of the Changjiang River plume magnitude on the East China Sea ecosystem were examined by using over a decade of summer data set. Results show that the amount of organic carbon consumption was positively related to the area of the Changjiang diluted water (ACDW; sea surface salinity < 31; $p < 0.001$). Interestingly, the rate of organic carbon consumption (per m^3) was however negatively regressed to the ACDW ($p < 0.001$). As expected, the rate of plankton community respiration was also significantly related to plankton biomass, especially phytoplankton. The growth of phytoplankton seemed limited by light intensity in the plume region. In addition, the whole ecosystem in the plume region was more phosphate limitation when using all pooled data. This unprecedented data might help to better understand how ecosystems response to variant magnitude to the river plume.

Keywords: Plankton community respiration, organic carbon consumption, East China Sea, The Changjiang River, River plume, Phytoplankton

Long-term changes of typhoon-related ocean condition: South China Sea vs. tropical northwest Pacific Ocean

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The ocean condition has been proposed to play a key role in the activity of typhoon. Effect of global warming on ocean variability differs from place to place. Via the air-sea interaction, the climate-related oceanic changes can in turn affect the formation and development of typhoon. The ocean characteristics on both sides of the Luzon Strait are quite different. By analyzing the underlying ocean properties relevant to typhoon’ s evolution (e.g. sea surface temperature and tropical cyclone heat content), this study discusses the variation of surface and subsurface oceanic condition for typhoon in the South China Sea versus tropical Northwest Pacific Ocean.

Keywords: Typhoon, Global Warming, Tropical Cyclone Heat Content

Dynamical study on interannual variation of the summertime upwelling in the South China Sea

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Upwelling off the southern Vietnamese coast is one the most important summertime features in the South China Sea. It remarkably contributes to the abundance of fishery resources and has a great influence on heat distribution. By analyzing the sea surface temperature (SST), sea surface wind, and altimeter-based geostrophic current, the interannual change of the upwelling in summers of 1990-2015 is investigated. Based on the analyses, three upwelling areas are identified in this study. One is in offshore region and two are along the Vietnamese coast. An upwelling index derived from SST at the upwelling center and the background SST is introduced to quantitatively explore the change of upwelling intensity. The possible processes relevant to wind field and eastward-flowing jet for the three upwelling areas are proposed as well.

Keywords: Upwelling, South China Sea, Interannual variability

Influences of coastal upwelling on the regional winds system off east Vietnam

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The impacts of coastal upwelling off southeast Vietnam (CUEV) on local wind field using numerical simulations are elucidated based on atmospheric model of Weather Research and Forecasting (WRF). Several scenarios are simulated by forcing identical model configurations with different SST fields. Based on simulation outputs, the relationship between CUEV and reduction of wind forcing is identified. The local wind speeds can drop to less than 70% of original level while the influence of a typical cold patch with a temperature drop attains to 3-5 ˚C. We find that the mechanism of response of the wind reduction to CUEV is associated with the enhancement of sea-breeze driven wind modulation. Onshore sea-breeze will enhance, while the contrast between land and sea is even more striking due to the contribution of a distinct coastal upwelling. This implies that air-sea-land interaction dominates the process of local wind system modulation in response to transient CUEV. This result sheds a new light on the air-sea interaction process off southeast Vietnam.

Keywords: coastal upwelling, sea-breeze, air-sea interaction, WRF

Our challenges for full marine food web modelling and future projections

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One of the most important marine ecosystem services is provision of food, the rate of which is has increased over recent decades. Global food fish supply increased at a average annual rate of 3.2 % over the last 50 years, outpacing the world population growth. However, the Earth is facing global change impacts and it is an urgent task to assess marine ecosystem responses to future global climate change. To assess marine ecosystem responses to climate forcing, it is essential to understand mechanistic linkages from physics to phytoplankton to zooplankton to fish. Recent improvements in ocean model spatial resolution and data assimilation techniques have enabled us to conduct realistic simulations to test marine ecosystem responses to climate forcing. However, for projections of future states, typical climate model resolution is a half to one degree in latitude/longitude for the ocean model component, which makes it difficult to represent many ocean structures and phenomena important to marine ecosystems (e.g. upwelling, western boundary currents, eddies). Coastal areas are some of the most productive and biodiverse regions, and are dominated by mesoscale phenomena, which cannot be properly resolved by these climate models. Full life-cycle migratory fish models have also been developed using high-resolution circulation models. However, knowledge gaps in physical, biogeochemical and biological processes and especially in trophic linkages are preventing improvement of full food web modelling of marine ecosystems. This presentation will 1) compare the ecosystem structures of two high biological production areas: the Benguela Current system and the western North Pacific, and 2) discuss our challenges for full food web modelling and future projections.

Keywords: ecosystem model, fish growth-migration model, climate change

Summary of SOUSEI-B: Five-year research program on earth system modeling

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The Program for Risk Information on Climate Change (SOUSEI) is a national project for projection of global change, with an aim to provide information for adaptation and mitigation, based on scientific evaluation of changes in extreme events and carbon cycle etc. This project began in FY2012 and comes to an end in March, 2017. Amongst other themes of the SOUSEI program, Theme B (SOUSEI-B) focuses on earth system modeling incorporating sophisticated carbon and nutrient cycles, and its application for examining future socio-economic pathways of mitigation. MIROC-ESM, an earth system model (ESM) developed under SOUSEI-B has been significantly improved since the 5th phase of coupled model intercomparison (CMIP5), which has made essential contributions to the 5th Assessment Report of Intergovernmental Panel on Climate Change (IPCC AR5). New features for the ocean geochemistry part include: explicit iron and phosphate cycle, nutrient deposition via atmosphere, and nutrient transport by rivers from land to ocean. Besides these model improvements, understandings have been obtained regarding ocean’s role in regulating the earth system response to, and impacts on the ocean from, anthropogenic forcings, such as those on mechanism of acidification in the middle layer in the western North Pacific, impact of ocean heat uptake on transient climate response to emission (TCRE), and identification of uncertainty sources for sea level rise due to ice sheet melting. Besides, SOUSEI-B yielded many results for other fields than oceanography, including multi-model estimates of the effect of geoengineering, impact of earth system uncertainty on future cost for global change mitigation, and dependence of precipitation change on aerosol emission scenario. It is hoped that these results will contribute to IPCC’s special reports and subsequent Working Group I assessment report. Although the SOUSEI program come to an end quite soon (as of February, 2017), the community has been striving to establish a follow-on program so scientists can further contribute to the next phase of CMIP (CMIP6). By the time of presentation, outline of the new program should be clear and will be explained in the presentation.

Keywords: Earth System Model, Global Warming, Intergovernmental Panel on Climate Change (IPCC), Ocean Acidification, Transient Climate Response to Emission (TCRE), Geoengineering

