

## Ocean Heat Balance in the ACCESS Ocean Model: Regional variability of dominant mechanisms of heat uptake over the historical period.

\*Simon James Marsland<sup>1,2,3,4</sup>, Fabio Boeira Dias<sup>1,2,3,4</sup>, Catia Motta Domingues<sup>2,3,4</sup>

1. CSIRO Oceans and Atmosphere, Aspendale, VIC, Australia, 2. Australian Research Council Centre of Excellence for Climate System Science (ARCCSS), 3. Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC), University of Tasmania, Australia, 4. Institute for Marine and Antarctic Studies (IMAS), University of Tasmania, Australia

The Australian Community Climate and Earth System Simulator (ACCESS) is being prepared for a forthcoming submission to the Climate Model Intercomparison Project - phase 6 (CMIP6). In addition to the entry-level CMIP6 submission requirements (DECK and historical simulations), we plan for participation in a number of the 21 additional CMIP6 Model Intercomparison Projects (MIPS). Of particular relevance to ocean climate study is participation in the Ocean Model Intercomparison Project (OMIP) and the Flux Anomaly Forced Model Intercomparison Project (FAFMIP). In preparation for the ACCESS submissions, a detailed analysis of the ocean heat budget, and the dominant mechanisms of heat transport is being undertaken with the ACCESS Ocean Model (ACCESS-OM). Ocean heat uptake along with its vertical and lateral redistribution are one of the main factors contributing to the large intermodel spread in the magnitude and regional patterns of sea level rise projections for the 21<sup>st</sup> century. Here, we perform a heat budget analysis to quantify the physical processes involved in ocean heat uptake and redistribution in contemporary simulations utilising ACCESS-OM. The model is forced with atmospheric reanalyses from the Coordinated Ocean-Sea ice Reference Experiments (CORE-II, 1948-2007) and the Japanese Reanalysis (JRA-55, 1958-2015). Our results show that the global vertical heat balance proposed by Munk (1966) between downward flux by diffusion and upward flux by the mean advection is only held at the tropics and has a small global impact. In the top 500 m, warming from vertical diffusion is balanced by cooling from mixed-layer physics. Below 500 m, regardless of depth level, warming due to mean advection and vertical diffusion counteracts cooling due to isoneutral diffusion and mesoscale eddies. Overall, the global balance is largely dominated by ocean processes in high latitude areas of the North Atlantic and Southern Ocean but with regional differences. The heat balance in the North Atlantic is mostly explained by an advective balance between the mean circulation (warming) and mesoscale eddies (cooling), within the 400-2000 m depth interval. In the Southern Ocean (south of 30°S), mean advection plays a major role below the mixed layer down to 4000 m, and is mainly counterbalanced by isoneutral diffusion above 900 m and mesoscale eddies below 900 m. We note, however, that within the Southern Ocean, the balancing terms vary depending on latitude band (30°-45°S and poleward of 50°S). The Subantarctic zone holds a similar balance as found in the Southern Ocean despite a stronger advective downward flux above 2000 m, which drives a warming tendency at intermediate depths with significant contribution to the model drift. South of 50°S, the vertical diffusion of heat changes its sign due to convective processes and cools the ocean interior, resulting in a consistent deep ocean cooling drift which subsequently penetrates into other ocean basins. The subtropics also play a role in the model drift, where a warming trend occurs above 500 m due to intense positive convergence of heat driven by vertical diffusion.

Keywords: Australian Community Climate and Earth System Simulator (ACCESS), Ocean heat uptake, CORE-II, JRA-55-do

# Projected sea level rise, gyre circulation and water mass formation in the North Pacific: CMIP5 inter-model analysis

\*Mio Terada<sup>1</sup>, Shoshiro Minobe<sup>1</sup>

1. Hokkaido University

Spatial dependency of sea level (dynamic sea level; DSL) change attracts much attention, because it directly impacts on the human society. Relatively large sea-level rise is expected to occur in the western North Pacific. It is suggested that wind stress change and heat flux change contribute to DSL change there. However, there is no comprehensive study of DSL dealing with both surface forcings and subsurface ocean using multi-models. In this study, DSL changes over the North Pacific and the associated changes of the subsurface ocean and surface forcings are investigated until 2300 under two greenhouse-gas emission scenarios (RCP4.5, RCP8.5) by analyzing the output from CMIP5 models. The DSL changes in the North Pacific until 2100 are characterized by a DSL rise in the western North Pacific around the Kuroshio Extension (KE), as also reported by previous studies in both the scenarios. From 2100 to 2300, DSL rises most of the North Pacific with the large positive DSL change located on the KE front only in RCP8.5. DSL changes little after 2100 in RCP4.5 related to the faster stabilization of the radiative forcing than that of RCP8.5. Subsurface density analysis indicates that DSL rise around the KE is associated with decrease in density of subtropical mode water (STMW) and with northward KE migration, while the density decrease of STMW (northward KE migration) is relatively strong between 2000 and 2100 for both RCP4.5 and RCP8.5 (2100 and 2300 for RCP8.5). A large regional density decrease in the STMW is due to a large heat uptake of the STMW related to an excess downward heat flux in the south of the KE. A regional density decreases around the KE front by 2300 induced by the northward migration of the KE, which is related to the northward migration of the zonal wind stress. These features are commonly found in multi-model ensemble means and the relations among representative quantities produced by different climate models.

Keywords: Sea Level, CMIP5 Climate Models, Kuroshio Extension, Subtropical Mode Water

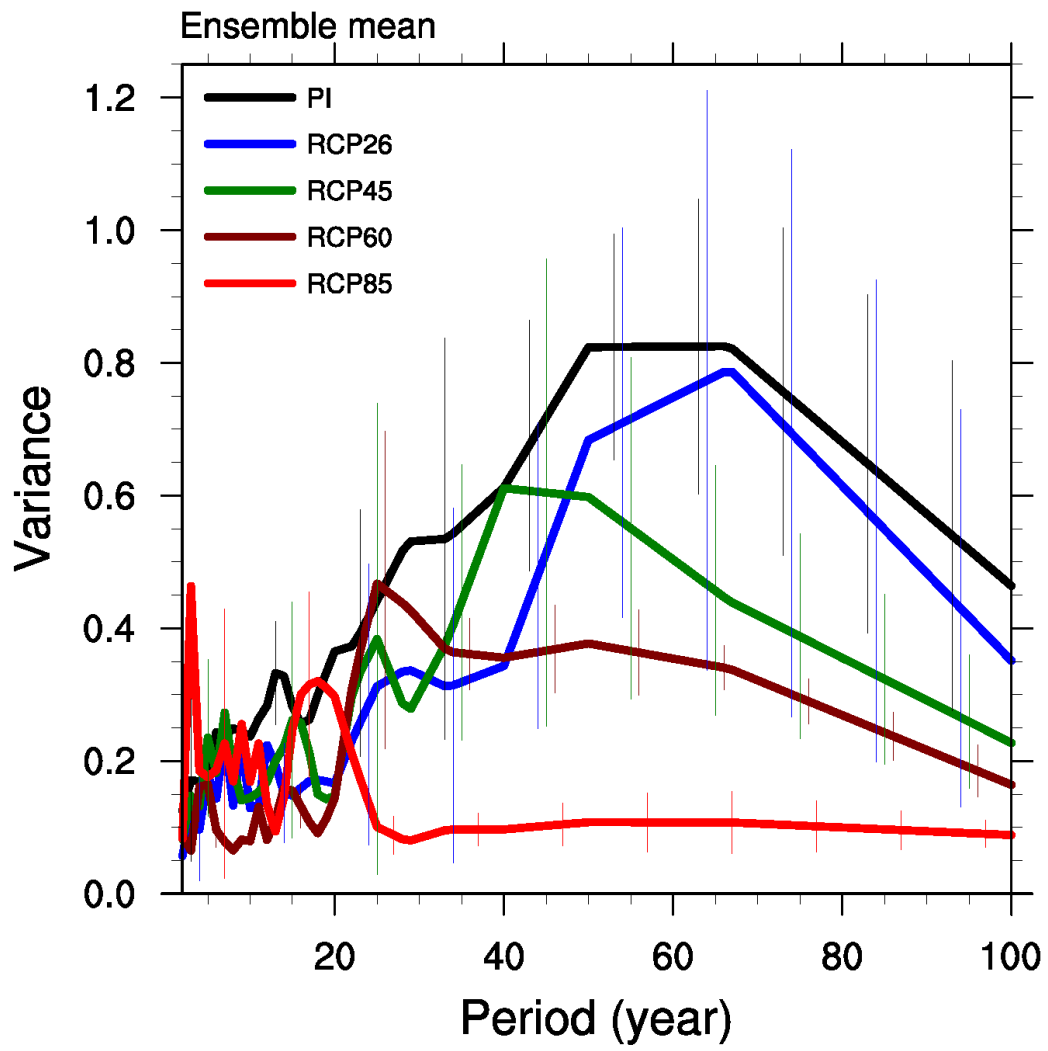
# Reduced interdecadal variability of Atlantic Meridional Overturning Circulation under global warming

\*Jun Cheng<sup>1</sup>, Zhengyu Liu<sup>1</sup>

1. NUIST Nanjing University of Information Science and Technology

Interdecadal variability of the Atlantic Meridional Overturning Circulation (AMOC-IV) plays an important role in climate variation and has significant societal impacts. Past climate reconstruction indicates that AMOC-IV has likely undergone significant changes. Despite some previous studies, responses of AMOC-IV to global warming remain unclear, in particular regarding its amplitude and time scale. In this study, we analyze the responses of AMOC-IV under various scenarios of future global warming in multiple models and find that AMOC-IV becomes weaker and shorter with enhanced global warming. From the present climate condition to the strongest future warming scenario, on average, the major period of AMOC-IV is shortened from  $\sim 50$  y to  $\sim 20$  y, and the amplitude is reduced by  $\sim 60\%$ . These reductions in period and amplitude of AMOC-IV are suggested to be associated with increased oceanic stratification under global warming and, in turn, the speedup of oceanic baroclinic Rossby waves.

Keywords: global warming, AMOC, interdecadal variability



## Impacts of interannual ocean circulation variability on Japanese eel larval migration in the western North Pacific Ocean

\*Yu-Lin Eda Chang<sup>1</sup>, Jinyu Sheng<sup>2</sup>, Kyoko Ohashi<sup>2</sup>, Mélanie Béguer-Pon<sup>2</sup>, Yasumasa Miyazawa<sup>3</sup>

1. Institute of Marine Environmental Sciences and Technology, National Taiwan Normal University, Taiwan, 2. Department of Oceanography, Dalhousie University, Canada, 3. Application Laboratory, Japan Agency for Marine-Earth Science and Technology, Japan

The Japanese eel larvae hatch near the West Mariana Ridge seamount chain and travel through the North Equatorial Current (NEC), the Kuroshio, and the Subtropical Countercurrent (STCC) region during their shoreward migration toward East Asia. The interannual variability of circulation over the subtropical and tropical regions of the western North Pacific Ocean is affected by the Philippines–Taiwan Oscillation (PTO). This study examines the effect of the PTO on the Japanese eel larval migration routes using a three-dimensional (3D) particle tracking method, including vertical and horizontal swimming behavior. The 3D circulation and hydrography used for particle tracking are from the ocean circulation reanalysis produced by the Japan Coastal Ocean Predictability Experiment 2 (JCOPE2). Our results demonstrate that bifurcation of the NEC and the strength and spatial variation of the Kuroshio affect the distribution and migration of eel larvae. During the positive phase of PTO, more virtual eels ( “v-eels” ) can enter the Kuroshio to reach the south coast of Japan and more v-eels reach the South China Sea through the Luzon Strait; the stronger and more offshore swing of the Kuroshio in the East China Sea leads to fewer eels entering the East China Sea and the onshore movement of the Kuroshio to the south of Japan brings the eels closer to the Japanese coast. Significant differences in eel migration routes and distributions regulated by ocean circulation in different PTO phases can also affect the otolith increment. The estimated otolith increment suggests that eel age tends to be underestimated after six months of simulation due to the cooler lower layer temperature. Underestimation is more significant in the positive PTO years due to the wide distribution in higher latitudes than in the negative PTO years.

Keywords: Japanese eel larvae, 3D particle tracking, Western Pacific, PTO, JCOPE2

# Studying potential link between phytoplankton and water cloud microphysics at high latitudes using 11 year CALIPSO lidar measurements

\*Yongxiang Hu<sup>1</sup>

1. NASA Langley Research Center

CALIPSO satellite started taking lidar measurements of the atmosphere and ocean since 2006. The lidar measurements provide unique information about high latitude water cloud microphysics (Hu et al., 2007) and ocean subsurface measurements (Behrenfeld et al., 2013; Behrenfeld et al., 2016) all year round. Lidar can make measurements of ocean subsurface at high latitudes all season, including winter, since it provides its own light and it can measure ocean subsurface from holes between clouds (Behrenfeld et al., 2016). Lidar also provide unique water cloud microphysics measurements since its depolarization ratio measurements are sensitive to droplet number concentration and extinction coefficient. This study investigate correlations of high latitude cloud microphysical property anomaly and ocean phytoplankton carbon anomaly during the last 11 years in order to evaluate the link between ocean biogeochemistry and cloud radiative forcing.

Reference:

Behrenfeld, M. J., Y. Hu, C. Hostetler, G. Dall' Olmo, S. D. Rodier et al., 2013: Space-based lidar measurements of global ocean carbon stocks, **GRL**, 40, 4355–4360, doi:10.1002/grl.50816.

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Hu, Y., M. Vaughan, C. McClain, M. Behrenfeld et al., 2007: Global statistics of liquid water content and effective number concentration of water clouds over ocean derived from combined CALIPSO and MODIS measurements, **Atmos. Chem. Phys.**, 7, 3353–3359.

Keywords: lidar, cloud, phytoplankton

## Ecosystem effects of ocean acidification

\*Ben Harvey<sup>1</sup>, Sylvain Agostini<sup>1</sup>, Shigeki Wada<sup>1</sup>, Koetsu Kon<sup>1</sup>, Kazuo Inaba<sup>1</sup>, Jason M Hall-Spencer<sup>1,2</sup>

1. Shimoda Marine Research Center, University of Tsukuba, 2. Marine Biology and Ecology Research Centre, University of Plymouth, UK

Our oceans cover 70% of the planet, provide 90% by volume of its biosphere, support 50% of global primary production and provide vital ecosystem services, including the recycling of nutrients, carbon sequestration and the provision of protein, on which large proportions of the global population rely. These marine systems are, however, now under threat from both climate (e.g. ocean acidification and global warming) and non-climate stressors (e.g. fishing pressure, invasive species) with negative impacts expected overall for biodiversity, ecosystem functioning, and the goods and services the world's oceans provide. While there is increasing evidence for the impacts of climate change at the individual level, much less is known about how species' likely idiosyncratic responses may alter ecological interactions within a community. Given the importance of ecological interactions in structuring marine communities, future climate change is likely to have major consequences for community composition and the structure and function of ecosystems.

My research currently involves carrying out collaborative international research into CO<sub>2</sub> seeps located on Shikine-Jima (Izu Islands, Japan) as a first assessment of the likely ecosystem-level effects of ocean acidification in warm temperate waters –located at a biogeographic boundary where canopy-forming macroalgae and zooxanthellate scleractinian corals coexist. Areas with naturally high seawater pCO<sub>2</sub> can be used as natural laboratories for investigating such long-term (multi-generational) effects of ocean acidification on entire communities. To date, studies at CO<sub>2</sub> seeps have demonstrated a few positive species' responses whereby some organisms can adapt to long-term ocean acidification –some can build their skeletons even faster at higher CO<sub>2</sub> levels –and others have protective tissues that allow them to survive. However, in the majority of cases ocean acidification will reduce the overall biodiversity and the density of marine biogenic habitats and therefore negatively impact the structure and complexity of coastal marine ecosystems. Overall, it is anticipated that it will be a combination of direct effects and community-mediated indirect effects caused by ocean acidification that will drive ecosystem changes in future oceans.

Keywords: Ocean Acidification, CO<sub>2</sub> Seeps, Marine Ecosystems, Ecological Interactions, Marine Food Webs

## Ocean acidification trend in the Canada Basin since the 2000s

\*Yuanxin Zhang<sup>1</sup>, Michiyo Yamamoto Kawai<sup>1</sup>

1. Tokyo University of Marine Science and Technology

With the increasing release of anthropogenic carbon dioxide, ocean acidification has been recognized as an important issue in research of global environmental change. Calcium carbonate undersaturation of seawater is one of the most serious threat of ocean acidification. In the Arctic Ocean, known as an extremely sensitive region to ocean acidification, calcium carbonate undersaturation of surface water has been observed in the Canada Basin since 2008. In this study, we have analyzed observations between 2008 and 2016 obtained during the Joint Ocean-Ice Project in the Canada Basin and have found that calcium carbonate saturation state in surface water does not grow steadily worse with the continuing increasing of atmospheric CO<sub>2</sub>. The sharp drop in sea ice coverage in 2007-2008 induced a great amount of fresh water discharge into the surface of Canada basin, which accounted for the decrease of calcium carbonate undersaturation. However, after 2009, sea ice coverage decline has slackened and a net export of freshwater to outside of the Canada Basin or to deeper layers has increased salinity and alkalinity of the surface water. This resulted in a rebound in calcium carbonate saturation state in surface water after 2009, transient good news for the marine ecosystem in the arctic.

Keywords: Ocean acidification, Calcium carbonate saturation state, Rebound, Sea ice melt, Arctic Ocean



## Response of sea surface fugacity of CO<sub>2</sub> to the Southern Annular Mode (SAM) shift south of Tasmania

\*Liang Xue<sup>1</sup>, Libao Gao<sup>1</sup>, Weidong Yu<sup>1</sup>, Meng Wei<sup>1</sup>

1. FIO, SOA, China

Using observational data collected south of Tasmania during 14 austral summer cruises during 1993-2011, we examined the response of sea surface fugacity of carbon dioxide ( $f\text{CO}_2$ ) to the Southern Annular Mode (SAM) shift, which occurred around 2000. In the southern part of the Southern Ocean (SO) or the Polar Zone (PZ) and the Polar Frontal Zone (PFZ),  $f\text{CO}_2$  increased faster at the sea surface than in the atmosphere before the SAM shift, but not after the shift. In the northern part of the SO or the Sub-Antarctic Zone (SAZ), however, surface  $f\text{CO}_2$  increased faster than atmospheric  $f\text{CO}_2$  both before and after the shift. The SAM shift had an important influence on the surface  $f\text{CO}_2$  trend in the PZ and PFZ, but not in the SAZ, which we attribute to differences in regional oceanographic processes (upwelling vs. non-upwelling). The SAM shift may have reversed the negative trend of SO CO<sub>2</sub> uptake.

Keywords: Southern Ocean, Southern Annular Mode shift, Carbon cycling

## Coupling of Surface Ocean Heat and Carbon Perturbations under Global Warming

\*Keith Bradley Rodgers<sup>1</sup>, Masao Ishii<sup>2</sup>, Thomas Frölicher<sup>3</sup>, Richard Slater<sup>1</sup>

1. AOS Program, Princeton University, 2. MRI, Tsukuba, Japan, 3. Environmental Physics, Institute of Biogeochemistry and Pollutant Dynamics, ETH Zürich, Switzerland

The ocean is the principal integrator in the climate system on multi-decadal to centennial timescales, modeling anthropogenic climate change by absorbing approximately 30% of anthropogenic carbon ( $C_{\text{ant}}$ ) emissions. Under global warming, coupled climate model simulations and theoretical arguments indicate that the capacity of the ocean to absorb  $C_{\text{ant}}$  will be reduced relative to what would be absorbed for an unperturbed physical state of the ocean, with this constituting a positive ocean carbon-climate feedback. Recent studies emphasize the importance of the North Atlantic and/or the Southern Ocean in sustaining such feedbacks. Here we use simulations with an Earth system model under a “business-as-usual” (historical/RCP8.5) concentration pathway to show that the coupling of heat and carbon in surface waters of the low-latitude shallow overturning circulation plays a first-order role in sustaining global ocean carbon-climate feedbacks. For an approximately 2°C average warming over 45°S-45°N, solubility perturbations alone would be expected to produce an 8% increase in surface ocean pCO<sub>2</sub>. The fact that the increase in pCO<sub>2</sub> is only 2% by the end of the 21<sup>st</sup> century indicates that the response is more nuanced than just a solubility response. The amplitude of the surface warming prescribes a reduction of surface DIC concentrations of approximately 6 mmol/kg/°C, resulting in an 8% reduction in surface DIC concentrations relative to what one would expect in the absence of warming by the end of the 21<sup>st</sup> century. The reduction by 8% in surface DIC concentrations over 45°S-45°N constitutes a positive carbon-climate feedback. The consistency of this 8% reduction in average surface ocean DIC concentrations and the time-integrated reduction by 8% in spatially integrated CO<sub>2</sub> uptake by the ocean over the same latitude band indicates that it is the perturbations to the buffering capacity of seawater rather than perturbations to ocean ventilation rates that determine the amplitude of the carbon-climate feedbacks over 45°S-45°N. This stands in contrast to the drivers of carbon-climate feedbacks over the high latitudes, which tend to be driven by ocean circulation changes perturbing the natural carbon cycle.

Keywords: Carbon cycle, Earth system model, Carbon-climate feedback

# Uncertainty in Detecting Trend: A New Criterion and Its Applications to Global SST

\*Tao Lian<sup>1</sup>

1. Second Institute of Oceanography

In most parts of the global ocean, the magnitude of the long-term linear trend in sea surface temperature (SST) is much smaller than the amplitude of multi-scale internal variation. One can thus use a specific period in a much longer record to arbitrarily determine the sign of long-term trend, which is statistically significant, in regional SST. This could lead to a controversial conclusion on how global SST responded to the anthropogenic forcing in the recent history.

In this study, the uncertainty in the linear trend due to multi-scale internal variation is theoretically investigated. It is found that the “estimated” trend will not change its sign only when its magnitude is greater than a theoretical threshold that scales the influence from the multi-scale internal variation. Otherwise, the sign of the “estimated” trend may depend on the period used. The new criterion is found to be superior over the existing methods when the de-trended time series is dominated by the oscillatory term. Applying this new criterion to a global SST reconstruction from 1881 to 2013 reveals that the influences from multi-scale internal variation on the sign of “estimated” linear trend cannot be excluded in most parts of the Pacific, the southern Indian Ocean and the northern Atlantic; therefore, the warming or/and cooling trends found in these regions cannot be interpreted as the consequences of anthropogenic forcing. It's also suggested that the recent hiatus can be explained by combined uncertainty from internal variations at the interannual and decadal time scales.

Keywords: ordinary least-square, linear trend, internal variation

## Ocean Macronutrient Fertilisation –An enhanced natural carbon sink?

\*Daniel P Harrison<sup>1</sup>

1. University of Sydney

In order to meet the goal of limiting global average temperature increase to less than 2 °C, it is increasingly apparent that anthropogenic CO<sub>2</sub> sinks of up to 10 Pg C yr<sup>-1</sup> 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<sub>2</sub> 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<sup>-1</sup>. If N and P were used in combination to fertilise the ocean, the size of the CO<sub>2</sub> 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<sup>-1</sup> sequestration and consume 0.07% yr<sup>-1</sup> 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 CO<sub>2</sub> flux in the Arctic with the use of the chlorophyll-a concentration

\*Sayaka Yasunaka<sup>1</sup>, Eko Siswanto<sup>1</sup>, Are Olsen<sup>2,7</sup>, Mario Hoppema<sup>3</sup>, Eiji Watanabe<sup>1</sup>, Agneta Fransson<sup>5</sup>, Melissa Chierici<sup>4</sup>, Akihiko Murata<sup>1</sup>, Naohiro Kosugi<sup>6</sup>, Siv Kari Lauvset<sup>7</sup>, Jeremy Mathis<sup>8</sup>

1. Japan Agency for Marine-Earth Science and Technology, 2. University of Bergen, 3. Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, 4. Institute of Marine Research, 5. Norwegian Polar Institute, 6. Meteorological Research Institute, 7. Bjerknes Centre for Climate Research, 8. NOAA Arctic Research Program

We examined the relationship between partial pressure of CO<sub>2</sub> in the surface water ( $p\text{CO}_{2w}$ ) and chlorophyll-a concentration (Chl-a) in the Arctic. The relationship between  $p\text{CO}_{2w}$  and Chl-a is negative where  $\text{Chl-a} < 1 \text{ mg m}^{-3}$ , but there is no significant relationship where  $\text{Chl-a} > 1 \text{ mg m}^{-3}$ . In the Greenland/Norwegian Seas, a relationship between  $p\text{CO}_{2w}$  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  $p\text{CO}_{2w}$  and Chl-a is found in the Barents Sea in summer when Chl-a values decline while  $p\text{CO}_{2w}$  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  $p\text{CO}_{2w}$  and Chl-a water in the coastal region.

We estimated monthly air-sea CO<sub>2</sub> 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,  $x\text{CO}_{2a}$ , and geographical positions. The addition of Chl-a as a training parameter enables us to improve the estimate of  $p\text{CO}_{2w}$  through reproducing its decline in spring by biological production. A significant CO<sub>2</sub> uptake of  $180 \pm 130 \text{ TgC yr}^{-1}$  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<sub>2</sub> data.

Keywords: CO<sub>2</sub> flux, Arctic, chlorophyll-a, SOCAT

## Reef Refugia to Climate Change

\*Haruko Kurihara<sup>1</sup>, Atsushi Watanabe<sup>2</sup>, Asami Tsugi<sup>1</sup>, Takashi Kawai<sup>1</sup>, Izumi Mimura<sup>1</sup>, Chuki Hongo<sup>1</sup>, Marine Gouezo<sup>3</sup>, Yimnang Golbuu<sup>3</sup>

1. University of the Ryukyus, 2. Tokyo Institute of Technology, 3. Palau International Coral Reef Center

### 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<sub>2</sub> vent studies also revealed that high CO<sub>2</sub> 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 Woerik 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 ( $\Omega_{\text{arag}}$ ) 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 ( $\Omega_{\text{arag}}$ ) 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<sub>3</sub> m<sup>-2</sup> d<sup>-1</sup> 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  $\Omega_{\text{arag}}$ . 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  $\Omega_{\text{arag}}$ , while turf algae density decrease with  $\Omega_{\text{arag}}$ . Reciprocal transplantation and tank experiment indicated that the calcification rate of coral *P. cylindrica* collected from both out and within the bay decrease with  $\Omega_{\text{arag}}$  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

\*Chung-Chi Chen<sup>1</sup>, Gwo-Ching Gong<sup>2</sup>

1. National Taiwan Normal University, Taipei, Taiwan, 2. National Taiwan Ocean University, Keelung, Taiwan

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

\*Tzu-Ling Chiang<sup>1</sup>

1. National Taiwan Normal University

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

\*Yi-Chia Hsin<sup>1</sup>

1. Academia Sinica

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

\*Zhe-Wen Zheng<sup>1</sup>

1. National Taiwan Normal University, Institute of Marine Environmental Science and Technology

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

\*Shin-ichi Ito<sup>1</sup>, Coleen Moloney<sup>2</sup>, Enrique Curchitser<sup>3</sup>

1. Atmosphere and Ocean Research Institute, The University of Tokyo, 2. University of Cape Town, 3. Rutgers University

One of the most important marine ecosystem services is provision of food, the rate of which 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

\*Michio Kawamiya<sup>1</sup>

### 1. Japan Agency for Marine-Earth Science and Technology

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 5<sup>th</sup> phase of coupled model intercomparison (CMIP5), which has made essential contributions to the 5<sup>th</sup> 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