



Research and Development on Marine and Global Environmental Change Annual Report FY2015



**Research and Development on Marine and Global
Environmental Change Annual Report FY2015
(April 2015-March 2016)**

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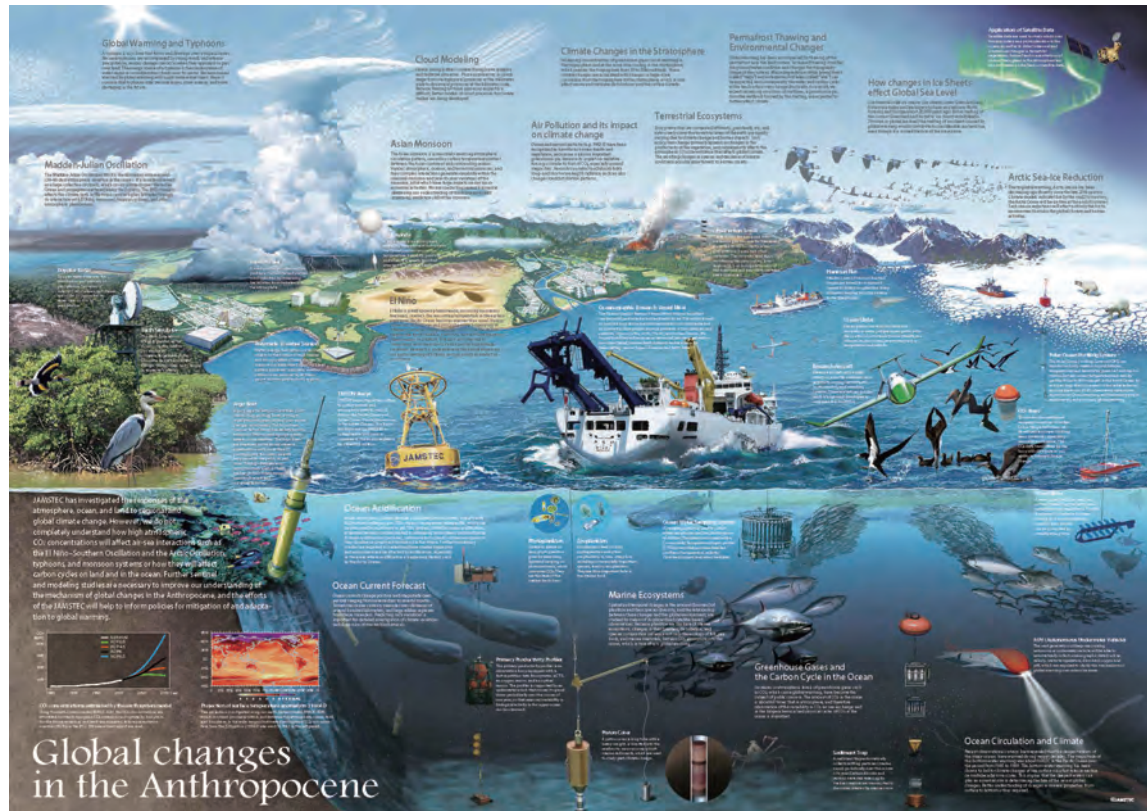
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I. Research Activities and Results

Changing Oceans

– Research and Development Center for Global Change (RCGC) –

Research and Development Center for Global Change (RCGC) was established in April 2014. The purpose of the center is to explore the oceans to know their state and to detect signal of global environmental changes. The center is consisted of four groups which cover wide area of studies such as physical, chemical, biogeochemical and biological processes in the oceans, tropical climate and sub-arctic environment. Several major achievements in this fiscal year are highlighted as follows.



Development of a new Flexible Phytoplankton Functional Type (FlexPFT) model

Developing a new model that can explicitly represent the functional diversity in plankton ecosystems is essential in order to evaluate correctly the marine ecosystems' response to various environmental changes caused by human activities and to make projections of expected future changes. However, most existing models that address this challenge require a great many calculations and include many parameters (increased model complexity). Based on the theoretical concept of optimality, expressed in terms of eco-physiological trade-offs, we have developed a new Flexible Phytoplankton Functional Type (FlexPFT) model, which represents the dynamic physiology and associated adaptive capacity of phytoplankton, in a simplified way that requires only one differential equation for the dynamics of biomass. This model also accounts for the functional diversity of phytoplankton, including for example differences in size, growth rate, and amount of chlorophyll per cell.

A study was conducted testing the results of this model (FlexPFT) against observations from time-series stations K2 and S1 in the North Pacific, including the application of data assimilation. The results were successfully published [Smith et al. *J. Plankton Res.*, 2015], demonstrating that the flexible response of phytoplankton communities does impact the modeled size diversity in a 0-D model of the upper ocean forced by realistic physical conditions. Compared to existing models, which do not account for this flexibility, this FlexPFT model gives quite different results concerning phytoplankton size diversity under realistic seasonal changes of environmental conditions (Fig. 1).

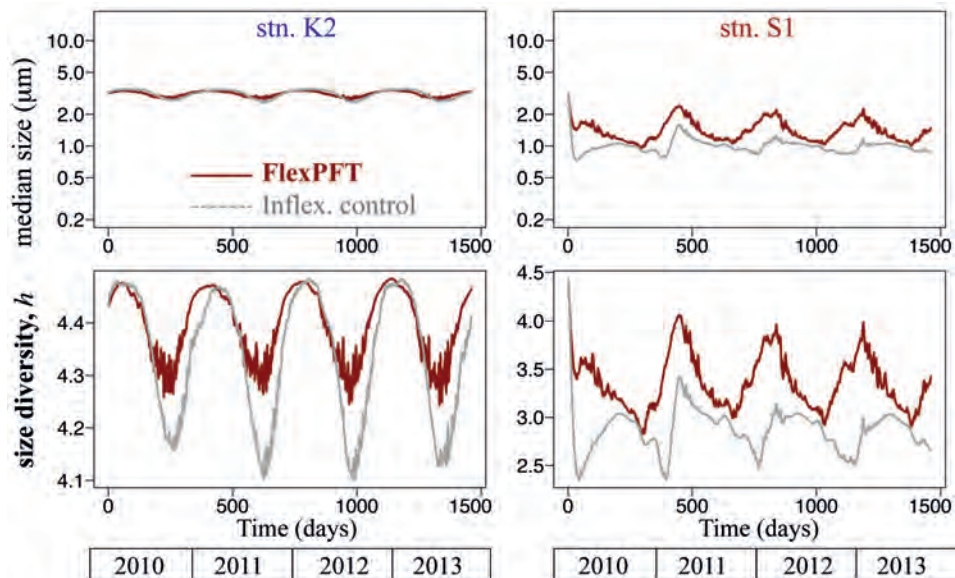


Fig. 1 Median (log-mean) size and continuous size diversity index (h). Simulation results were obtained using 200 FlexPFTs representing phytoplankton of different size for time-series observation stations K2 (left) and S1 (right).

The simplicity of this new model makes it possible for the first time to combine the flexible response and the size distribution of phytoplankton within large-scale (3-D) models, in order to examine the dynamics of biodiversity at the regional and global scale, as we are beginning to do in our on-going research. In the future, coupled with different models of the physical environment at various spatio-temporal scales, this new ecosystem model is expected to provide useful information for addressing many problems confronting human society as the result of changes in the marine environment and ecosystems.

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Smith S. L., M. Pahlow, A. Merico, E. Acevedo-Trejos, Y. Sasai, C. Yoshikawa, K. Sasaoka, T. Fujiki, K. Matsumoto, and M. C. Honda (2015), Flexible Phytoplankton Functional Type (FlexPFT) model: Size-scaling of traits and optimal growth, *Journal of Plankton Research*, doi:10.1093/plankt/fbv038.

A Wake due to the Maldives in the eastward Wyrтки jet

The North Indian Ocean is enclosed by landmasses to the north, west and east. Heat coming across the sea surface is exported to the south across the equator in the North Indian Ocean. Despite of its important role in maintaining the heat balance, the cross equatorial current is dynamically peculiar and difficult to understand. This is owing to the breakdown of the conservation law of potential vorticity, which is assumed to be valid in many theories which account for mid latitude circulations. To cross the equator, a water particle must obtain or lose vorticity, which requires it to pass in the surface or western boundary layers. Due to difficulty in parameterizing frictional effects, models (either theoretical or numerical) do not always reproduce boundary currents, and thus in-situ observations of those currents are valuable.

In this study [Nagura and Masumoto, 2015], the dynamics of cross-equatorial currents were studied using in-situ observations from two acoustic Doppler current profilers (ADCPs) at 80.5°E and 90°E on the equator and also numerical simulation results. Meridional velocity observed at 0°, 80.5°E (Fig. 2a) exhibits annual variability above 50-m depth, which is driven by friction due to local monsoonal winds [e.g., Horii *et al.*, 2013]. On the other hand, meridional velocity at about 100-m depth shows semiannual variability, showing southward velocity in the northern spring (March to May) and the northern fall (October to December). This semiannual current variability cannot be explained by local wind forcing, nor has it been pointed out by previous studies. Semiannual

variability was not observed at 0° , 90°E , which indicates that it is a localized feature.

A similar variability was also found in output from a high resolution ocean general circulation model, OFES, which was driven by satellite winds (Fig. 2b). The zonal section of meridional velocity simulated by OFES revealed that southward currents observed by ADCP is a part of a wavy structure that spans about 1500 km along the equator (Fig. 3). The wavy structure of meridional velocity is seen east of 73°E in the northern spring and fall, which is the longitude of the Maldives islands. In the northern spring and fall, westerly winds along the equator drive an eastward equatorial jet, which are called the Wyrtki jet. We hypothesized from these results that the Wyrtki jet hits the Maldives and meanders, which is observed as a wavy structure in meridional velocity. We conducted an idealized numerical simulation using a 1.5-layer model, in which an eastward jet flows in along the equator from the domain end and hits an island that is similar in shape to the Maldives. The meandering of the equatorial jet and a related wavy pattern in meridional velocity are observed east of the model island, which has similar magnitude and wavelength to those simulated by OFES. In the 1.5-layer model, an equatorward western boundary current is driven along the eastern coast of the model island, which joins the eastward equatorial jet and flows away to the east of the island on the equator. Analysis of the momentum budget and potential vorticity showed that the dynamics of the meandering of the equatorial jet was similar to those of the western boundary current extension region in mid latitude.

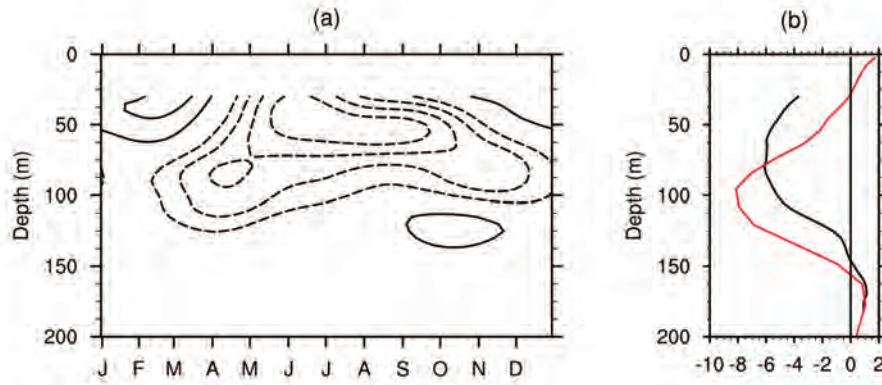


Fig. 2 (a) 3-day climatologies for meridional velocity observed at 0° , 80.5°E by ADCP. Contour intervals are 2 cm s^{-1} . Solid and dashed lines are for positive and negative values, respectively. Contour lines for zero have been omitted. Time series is smoothed by applying a 90-day triangle filter twice. (b) Vertical profiles of climatological meridional velocity in May at 0° , 80.5°E . Black and red lines are for measurements by ADCP and for simulation results from OFES, respectively.

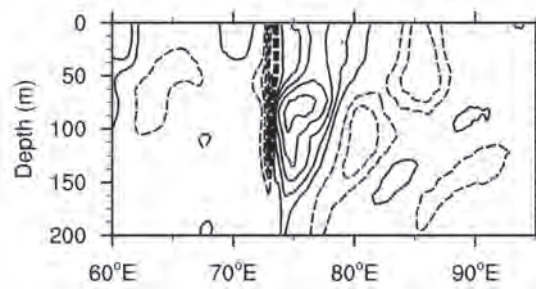


Fig. 3 Climatological meridional velocity along the equator in April obtained from OFES. Contour intervals are 3 cm s^{-1} . Solid and dashed lines are for positive and negative values, respectively. Contour lines for zero have been omitted.

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A New Approach to El Niño Prediction

Accurate El Niño forecasts are of vital importance to the global community. Yet our predictive capabilities were once more shown to be inadequate when the 2014 El Niño, an event widely predicted by international climate centers, failed to materialize. We have developed a new prediction scheme for the El Niño phenomenon based on the discovery of new types of tropical climate variation [Masuda *et al.*, 2015].

At first, we reassessed El Niño energetics (Goddard and Philander, 2000) by focusing on the exchange of kinetic energy between the atmosphere and ocean, which significantly affects El Niño development. The results showed that the role played by tropical seasonality in the evolution of the El Niño is changing on pentadal (five year) to decadal timescales. Within this background, we newly constructed a prediction scheme by using a coupled data assimilation system and a forecast system which incorporated these decadal influences directly to constrain modeled seasonal variability.

The data assimilation system was originally constructed within the JAMSTEC K7 consortium [Sugiura *et al.*, 2008] for use in climate research studies. The assimilation is based on a 4-dimensional variational (4D-VAR) adjoint approach, in which adjoint codes of the AGCM and OGCM are applied to seek the best possible temporal trajectory of the model variables on the basis of observational data. As a result, high-quality analysis fields are produced as forecasts from the initial conditions. In addition, the temporal evolution of the ocean-atmosphere coupled state is partly controlled by some of the coupling parameters in this system. The parameters are determined through statistical optimization on the basis of model dynamics and observational data.

By using this system, we showed El Niño predictions through the opaque and poorly understood “spring predictability barrier” (SPB) would inevitably be uncertain if the tropical seasonality [e.g., Wright, 1979] is inadequately specified and particularly if the decadal modulations are not reflected explicitly in the climate model.

Figure 4 shows hindcasted NINO 3.4 sea surface temperature (SST) anomaly. This shows the seasonal control enables us to generate more accurate hindcasts through the SPB for the El Niño. The similar experiments for other periods generate accurate hindcasts for all the 7 major historical El Niños for the period of 1970s-2000s. The error value between predicted and observed SST in NINO 3.4 area can consequently be reduced by 0.4 Kelvin for one-year predictions over a specific pentadal/decadal phase. This correction is quite substantial since an "El Niño" is confirmed when the SST anomaly becomes greater than +0.5 Kelvin. Our 2014-2015 forecast is in line with the observed development of the tropical climate (Fig. 5). These results show that the seasonal variability of one key component of the energy delivered by the atmosphere to the tropical ocean is modulated on pentadal to decadal timescales.

Here we showed a new coupled climate simulation technique which incorporates these long-term influences directly generates both accurate hindcasts for the major historical El Niños on the Earth Simulator and more accurate predictions of El Niño beyond boreal spring. Overall the work will contribute to a better understanding of climate fundamentals and further improvements in the predictability of the El Niño phenomenon.

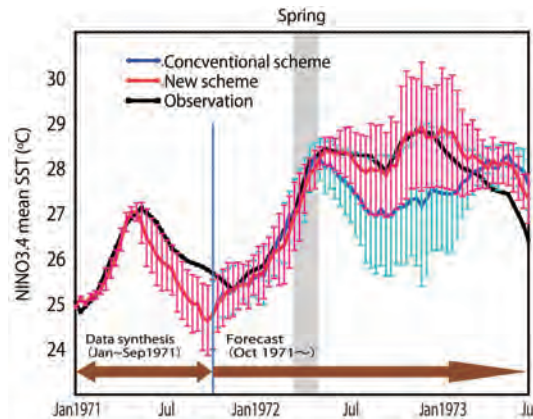


Fig. 4 Predicted NINO 3.4 (5°N–5°S and 170°–120°W) SST (sea surface temperature) anomaly (red and blue curve) as compared with observed SST anomaly (black). The values are for hindcast experiments during 1971–1973 derived from the conventional case without seasonal control (blue) and the new case using a seasonal adjustment factor (red). Grey shaded regions denote the boreal spring periods.

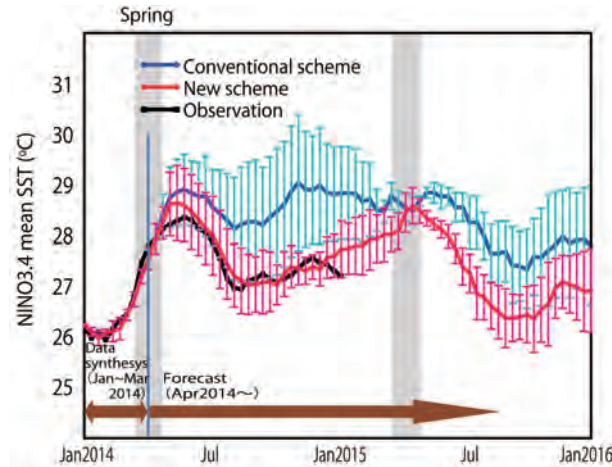


Fig. 5 The same as Fig. 4 but for the period of 2014-2016.

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Observational evidence of eastward propagations of decadal salinity anomalies along the subarctic gyre in the North Pacific

The profiling float array, maintained under the Argo project, clearly revealed eastward propagation of the decadal salinity changes in the subsurface and deep neutral density (γ) layers of 27.0–27.6 γ along the subarctic front in the North Pacific after 2000 (Fig. 6). While such propagation was previously inferred from water property variations along a few observation lines and from numerical simulations, mainly for shallow layers, the propagations were captured by actual observations for the first time in this study. In the western North Pacific, the phases of the changes (positive before 2007 and negative after 2007) were the same on and below the 27.0 γ . The changes were propagating eastward approximately with the geostrophic current speeds on each isopycnal surfaces. As the current speeds in the shallower layers (ex. 27.0 γ) were faster than those in the deeper layers (27.4 γ), the phase of the changes were

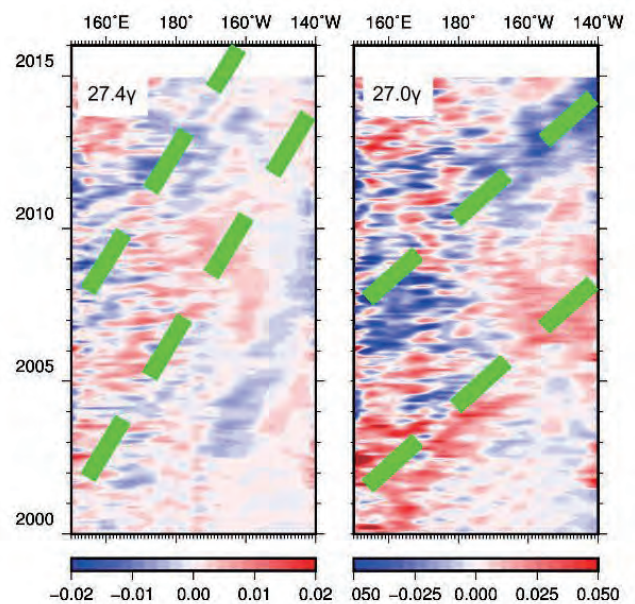


Fig. 6 Salinity changes propagation along the subarctic front (left: 27.4 γ ; right: 27.0 γ). The changes along the were calculated on the isopycnal surfaces from the decadal mean (2001-2015)

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opposite in the eastern North Pacific (Fig. 6). The variation revealed by the float array was similar to those associated with a decadal changes observed along repeat ship-based observation lines (along 165°E maintained by JMA and Line P maintained mainly by DFO), and they were also associated with changes in apparent oxygen utilization. The small salinity changes in the deeper layers inferred from the float array were also detected as decadal differences in highly accurate trans-basin observations (along 47°N in Fig. 7). The pattern of the changes in the vertical section in the eastern part of 47°N line, that were the vertically layered negative and positive changes, were mainly due to the phase shift of the changes in propagating with vertical geostrophic shear. Furthermore, because the extension of small changes into the subtropical gyre was also captured by the float and ship-based observations (not shown along 30°N), the influence of the decadal changes on the isopycnal surfaces off the coast of Japan could appear relatively quickly, even in deeper near oxygen minimum layers (27.0–27.4 σ_t) in the North Pacific.

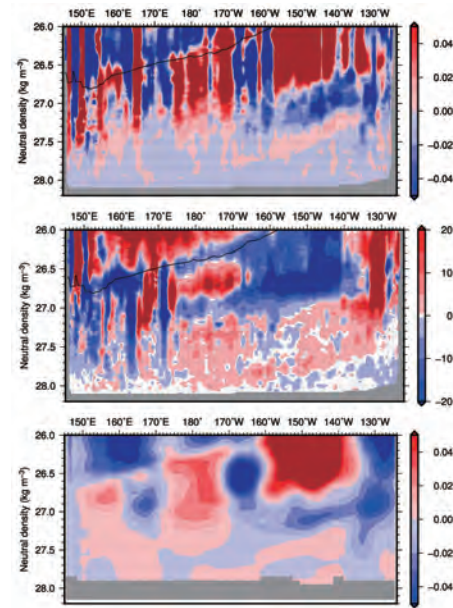


Fig. 7 Changes in the vertical section along 47°N in the North Pacific. The top and middle figures show the salinity and oxygen differences from 2007 to 2014 based on ship-based observations under GO-SHIP. The salinity changes revealed by the Argo float array along 47°N were shown in the bottom figure.

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Microbiological process in pelagic ecosystems

– Marine Functional Biology Group / Research and Development Center for Marine Biosciences –

Prokaryotes (Bacteria and Archaea) play important roles in major biogeochemical processes, such as nutrient cycles and organic matter fluxes of the oceans. However the dynamics of prokaryotes are not well considered as parameters in global organic matter cycle models. To embed the contribution of prokaryotes into a global organic matter cycle model, it is necessary to determine high-resolution geographical variations of prokaryotic abundance, production and community composition of functional groups in the global pelagic systems. In this project, we examined prokaryotic abundance and activity with depth and across regions to clarify organic carbon delivery and prokaryote-mediated carbon flux mechanisms in the pelagic systems.

In FY2015, we conducted water sampling from the water columns in the eastern Indian Ocean along 110 degrees east line from 25 degrees to 10 degrees south during MR15-05 cruise, in order to reveal geochemical and geophysical impacts of this pelagic realm on microbial ecosystems as follows.

- 1) To determine the microbial abundance, diversity and activities throughout the water columns.
- 2) To estimate the impacts of biogeochemical cycles in the surface layer to the meso- and bathypelagic layers.

Microbiological processes throughout water column of the eastern Indian Ocean

Prokaryotes play a major role in marine biogeochemical fluxes. Microbially mediated biogeochemical transformation rate is one of the major research topics in microbial ecology. However the linkages between prokaryotes activity and biogeochemistry in the surface, meso- and bathypelagic layers are not systematically clarified despite of the efforts that highlighted the role of microbes in the cycling of organic matter. In FY2015, we determined microbial abundance in water samples taken along the water columns in the eastern Indian Ocean transect of MR15-05 cruise. We here highlight a part of results of FY2015 research that distribution pattern of prokaryotic abundance and the relationship among primary production, ocean circulation and pelagic microbial ecosystems.

The prokaryotic abundance distribution pattern in the surface, meso- and bathypelagic layers of the eastern Indian Ocean along the 110 degrees east.

The results showed that prokaryote abundance distributions in the surface, meso- and bathypelagic zone of the eastern Indian Ocean display similar vertical patterns of stations along with the WOCE I10 line and generally reflect the primary production regime (Fig. 1).

I. Research Activities and Results

Marine Functional Biology Group / Research and Development Center for Marine Biosciences

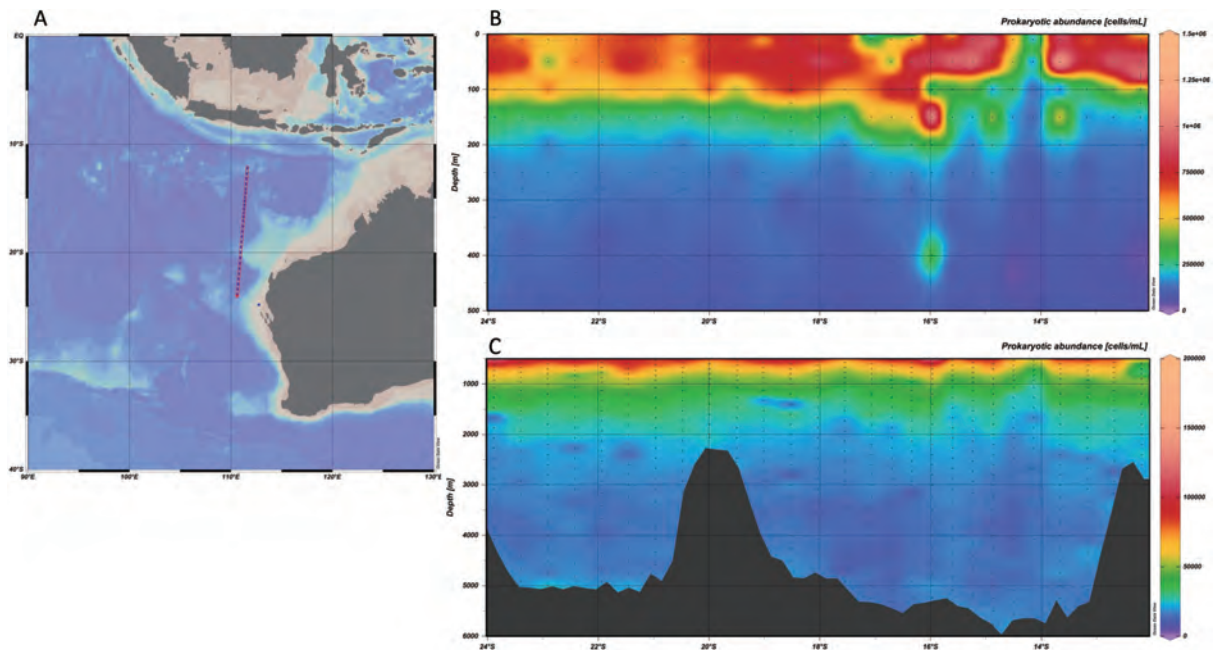


Fig. 1 Sampling stations during MR15-05 cruise (A), and depth profile of prokaryotic abundance in surface waters (<500 m) (B), and in deep waters (> 500 m) (C) in the eastern Indian Ocean. These figures were created using Ocean Data View (<http://odv.awi.de/>).

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- De Corte, D., E. Sintes, T. Yokokawa, I. Lekunberri, and G. J. Herndl (2016), Large-scale distribution of microbial and viral populations in the South Atlantic Ocean, *Environ. Microbiol. Rep.*, 8, 305–315.
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Climate and ocean variability prediction and its societal applications

– Application Laboratory –

The major aim of the laboratory is to study the variability and the predictability of ocean and climate. Focusing on predictability and understanding of the ocean and climate variability with temporal scales ranging from few days to a decade, we are developing various kinds of ocean/climate modeling, data analysis, and data assimilation techniques. The accumulated information and discovery of new phenomena from the dedicated research help to improve the real-time predictions of ocean and climate variations (Fig. 1). This year, since February 2015, the SINTEX-F climate model has correctly predicted a return of El Niño condition (following the El Niño of 2014) in the boreal-summer of 2015. This is clearly seen in the predictions of the global sea surface temperature (SST) anomalies (Fig. 1a). The global predictions are then used in several application studies. We are also producing fine-resolution predictions using dynamical and statistical downscaling of those predictions for providing detailed information to contribute to various needs of the society. In addition, the finer-scale simulations and predictions are used in finding inter-relationships among ocean/climate variability, fishery, agriculture, water resources, human health and other economical/social phenomena (Fig. 1b).

In this fiscal year, we have concluded several high-level studies and published research articles in reputed international journals. The topics of our research outcomes ranged from the discovery of the Dakar Niño/Niña to the predictability of winter wheats in Australia. We have also demonstrated that ocean circulation patterns could be markedly different even under slightly changed conditions despite the identical wind-forcing variability. In addition, studies led by different research teams investigated the effect of mesoscale eddies on the Taiwan Strait Current, potential sources of decadal climate variability over southern Africa, stability of the atmospheric jets, moisture variability over the Indo-Pacific region, the influence of the Gulf Stream on wintertime European blocking and impacts of interannual ocean circulation variability on Japanese eel larval migration.

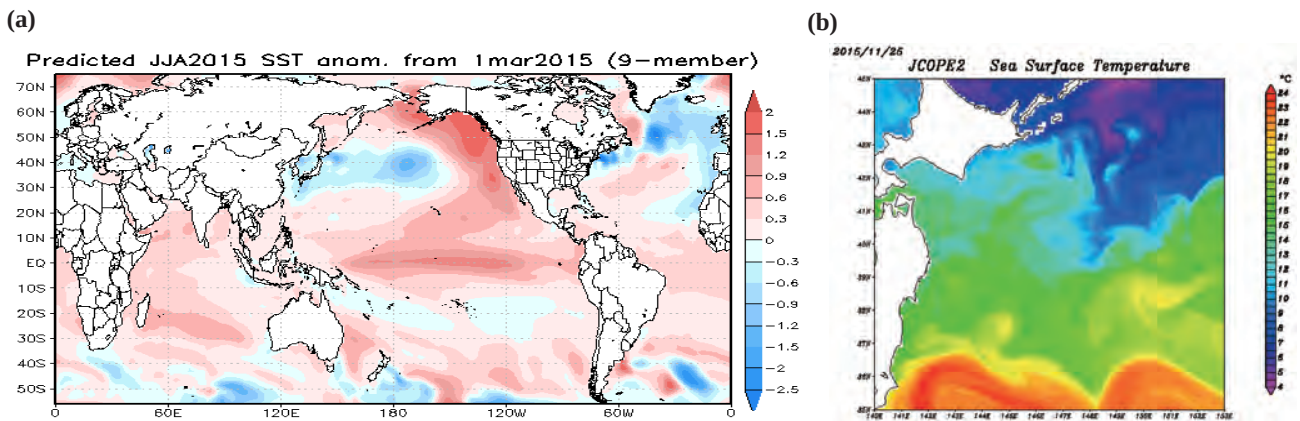


Fig. 1 (a) SST anomaly showing the boreal-summer evolution of 2015 El Niño, predicted on 1 March 2016 using the SINTEX-F climate forecast system (<http://www.jamstec.go.jp/frcgc/research/d1/iod/e/seasonal/outlook.html>).

(b) SST distribution showing the anomalously high temperature in the Oyashio region associated with an event of the northward intrusion of a branch of the Kuroshio Extension reproduced by the JCOPE2 ocean forecast system (http://www.jamstec.go.jp/jcope/htdocs/e/kow/151207/KOWatch_20151207.html#s3).

Discovery of Dakar Niño/Niña

Recently, team members of our laboratory have discovered coastal Niño/Niña phenomena off Western Australia and Baja California. Pursuing it further from this new point of view of the regional ocean-land-atmosphere interaction, on the western boundaries of continents, Pascal Oettli, Yushi Morioka and Toshio Yamagata [Oettli *et al.*, 2016] have discovered yet another coastal Niño/Niña in Dakar region off the northwestern Africa.

The phenomenon evolves in boreal late fall, peaks in spring and decays thereafter. It is found that the interannual variability of the mixed-layer temperature anomaly off the Dakar coast is associated with the alongshore wind anomaly, mixed-layer depth anomaly and cross-shore atmospheric pressure gradient anomaly in a local ocean-land-atmosphere coupled feedback process. The associated anomalies in sea surface temperature in the coastal area affects the air temperature immediately above, which in turn causes the pressure difference between the land and the sea leading to coastal wind anomalies and their influences on the coastal upwelling as well as the sea surface temperature. During a warm (cold) event, northerly (southerly) alongshore wind anomalies are associated with weaker (stronger) than normal coastal upwelling. For the period 1982–2011, six warm events (1983, 1984, 1997, 1998, 2008 and 2010) and five cold events (1985, 1986, 1999, 2003 and 2009) are identified. Following the conventions of other Niño/Niña, the coupled warm (cold) event is named as Dakar Niño (Niña).

In Dakar coast, sea surface temperature is normally kept low due to coastal upwelling. Therefore, the anomalous phenomenon plays an important role not only for regional climate but also for regional marine ecology. Because of its effect on the coastal upwelling, marine ecosystems are adversely affected during the occurrences of a Dakar Niño influencing the worldwide fishery market.

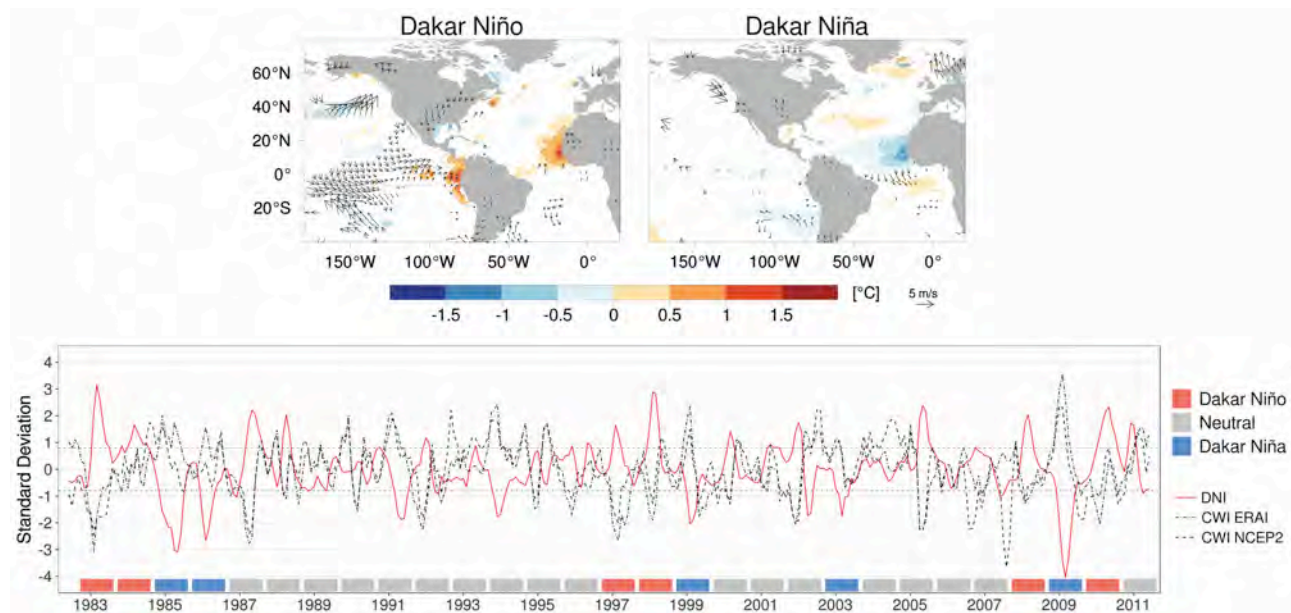


Fig. 2 Upper panel: composite analysis of SST (contour and shading) and surface wind (vector) anomalies for the period 1982–2011, during (left) Dakar Niño and (right) Dakar Niña. Only wind values significant at the 95% confidence level according to a two-sided Hotelling's T2-test are displayed. Significant SST values at the 95% confidence level (according to a two-sided Student's t-test) are shaded. Lower panel: time series of the standardized coastal SST index (red line), standardized coastal wind index based on NCEP/DOE AMIP II (black two-dash line) and on ERA Interim (black dashed line) in the region [21°–17°W, 9°–14°N] for the period 1982–2011. Colors correspond to identified warm (red), neutral (dark grey) and cold (blue) events. Horizontal dotted lines denote the $\pm 0.8\sigma$ (0.57°C).

Predictability of winter wheat yields of Australia based on links to IOD, ENSO and ENSO Modoki

In a study focused on the wheat yields of Australia, Chaoxia Yuan and Toshio Yamagata [Yuan and Yamagata, 2015] for the first time have clarified the respective roles of climate modes of the Indo-Pacific Oceans on the interannual variations of the winter wheat yields. Australia is one of the major wheat producers in the world and accounts for 10–15% of the global wheat trades. Several countries in the world imports wheat from Australia. A fifth of Japan's imports are from Australia. Therefore, the understanding of the climate impact on the wheat yields particularly the winter wheat yields are very important for food management not only in Australia but also in many other countries.

Over the years it has been observed that the winter wheat yield undergoes considerable interannual variations despite fairly consistent consumer demands. These variations are seen to be mainly driven by climate factors. Especially interannual variations in precipitation and surface temperature play important roles in wheat growing seasons spanning from May to November. Tropical climate modes such as flavors of El Niño/Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) are known to influence the above climatic factors in Australia. Meanwhile, in the recent couple of decades the tropical Pacific has seen more of ENSO Modokis, which influence Australia differently as compared to canonical ENSO. Yuan and Yamagata [2015] in their novel study have illustrated the dominant role of IOD on the Australian wheat yield variation compared to the two types of ENSO in the recent decades.

It is found that the average anomalies in the wheat yields in general are significantly positive in the negative IOD years (Fig. 3). The correlation coefficient is -0.38 between DMI in September-November and the Western Australian wheat yield, significant at the 95% confidence level. Based on this promising result, Yuan and Yamagata [2015] have constructed a regression model to predict wheat yield variations. The model based on either observed or SINTEX-F predicted IOD indices shows promising skills. In addition, it is noted that some of the years with exceptions are linked to climate variations in the middle and higher latitudes. Therefore, improving skills for predicting the impacts of the mid-high latitude climate systems is also important for better estimation of the wheat yield variations in Australia.

This study provides a great potential to access the food security of a large population with similar simple approaches of modeling the future crop yields in Asia-Oceania regions.

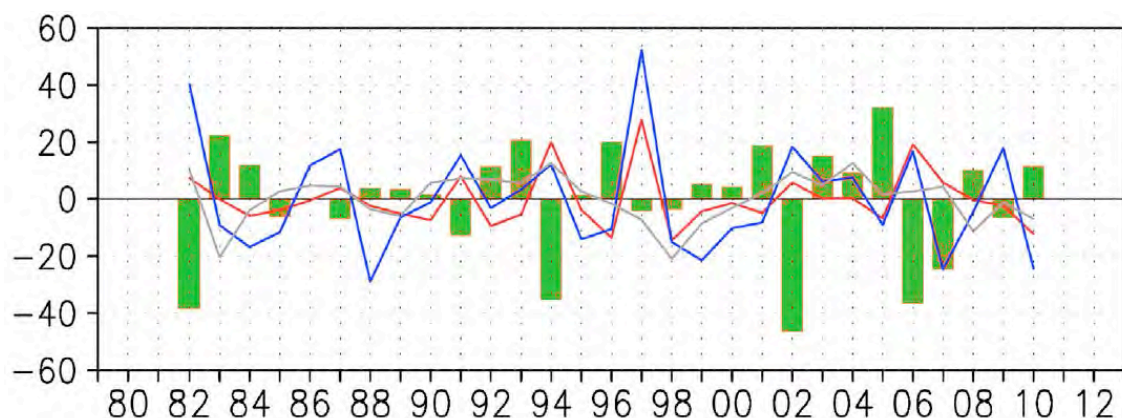


Fig. 3 Inter-annual percentage anomalies of Australian winter wheat yield (green bar), Indian Ocean dipole (red line), ENSO (blue line) and ENSO Modoki (gray line) phenomena.

Publication List

Publication with Peer Review (Published)

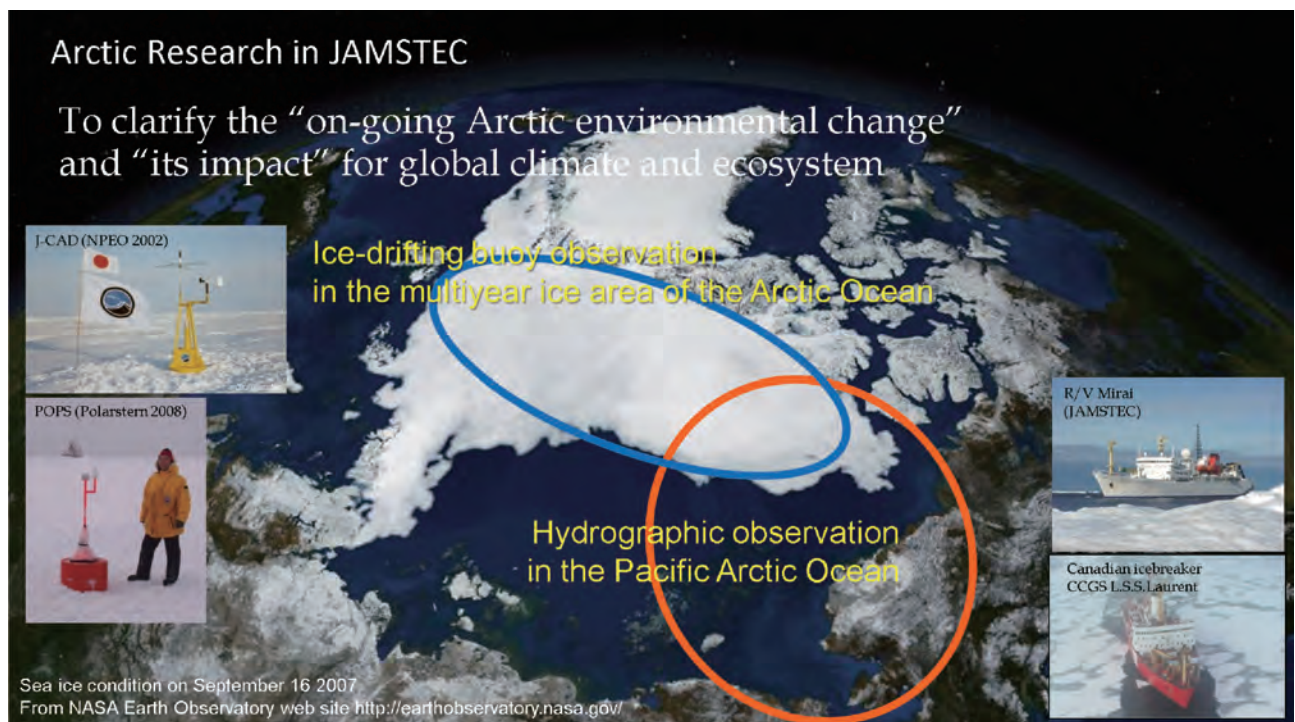
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Changing Arctic

– Institute of Arctic Climate and Environment Research –

The decrease of Arctic sea ice is attributed to the effects of “global warming.” The Arctic is the world region that is warming the most. Warming in the Arctic will proceed at least twice as fast as the world average. Such rapid change will not only reduce sea ice, but also drive the melting of permafrost, glaciers, and ice sheets. Further, this is having impacts on not only the Arctic Ocean and its surrounding region, but also on oceans and countries around the world, including Japan. Change in the Arctic climate will bring about change in the ecosystems of marine organisms living there. In fact, changes occurring in the Arctic Ocean, where the effects of global warming are quickly manifested, could at some time occur in the world’s other oceans. Arctic problems are no longer confined to countries bordering the Arctic Ocean; so, we must think of these problems as global, affecting the whole world. The Japan Agency for Marine-Earth Science and Technology (JAMSTEC), which had been conducting Arctic research since the 1990s, established the Institute of Arctic Climate and Environment Research (IACE) in April 2015 to further expedite its Arctic research and to broadly benefit international society.



Arctic Marine Biological Hotspot Supported by Underwater Storage House of Organic Matters

In the Arctic Ocean, phytoplankton blooms occur when light irradiance necessary for photosynthesis increases with sea ice melting. Because of a large phytoplankton bloom in spring as a source of food for benthic organisms in the southern Chukchi Sea, this area is known as a biological hotspot, where various kinds of living organisms exist with feeding relationships. However, seasonal variations of phytoplankton biomass, especially after the spring bloom, and its relation to maintenance mechanisms of the biological hotspot have not been well studied. To examine seasonal changes in water characteristics and phytoplankton biomass in the biological hotspot, we installed a mooring with various sensors near the bottom of Hope Valley in the southern Chukchi Sea during July 16, 2012 to July 19, 2014 (Fig. 1). Furthermore, we conducted hydrographic and biogeochemical surveys across the biological hotspot using the JAMSTEC's research vessel (R/V) *Mirai* during September to October in 2012 and 2013 to understand a maintenance mechanism of the biological hotspot (see also Fig. 1).

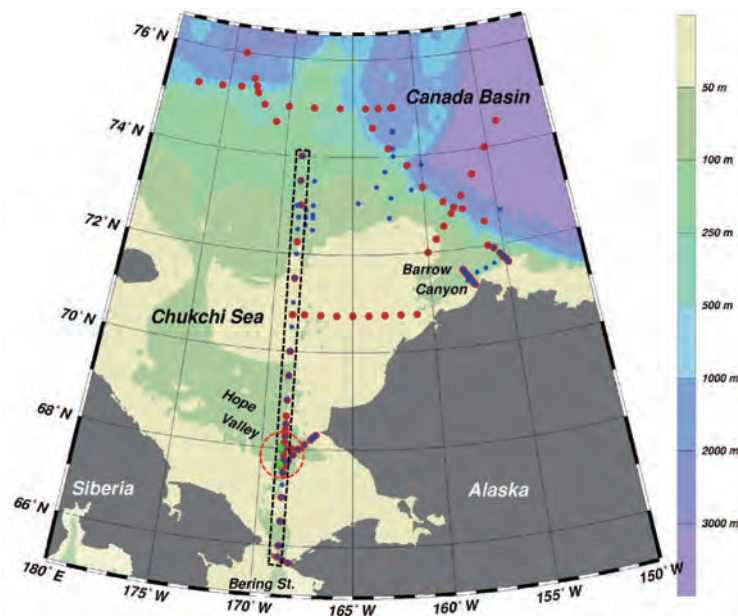


Fig. 1 Map showing the bathymetric features of the study area and the hydrographic stations for the R/V *Mirai* cruises in 2012 (red dots) and 2013 (blue dots). Green diamonds indicate mooring sites. Data from the stations enclosed by black dotted lines were used for the illustrations of vertical sections shown in Fig. 3. The area enclosed by the red dotted circle is the southern Chukchi Sea biological hotspot, where a mooring was deployed and detailed hydrographic surveys were carried out.

The mooring data showed seasonal variations of phytoplankton biomass (chlorophyll *a* concentration), and also captured phytoplankton blooms in autumn (Fig. 2). During this autumn bloom an annual maximum of turbidity and minimum of dissolved oxygen (DO) were found, suggesting accumulations of particulate organic matters (increase in turbidity) and their decomposition consuming DO (decrease in DO) that occurred significantly in autumn. In addition, the ship-based observation data from the R/V *Mirai* indicated that bottom water in Hope Valley formed a dome-like structure (Fig. 3), suggesting ocean circulation in a counter-clockwise direction and converge of deep water there. By combining the mooring data with the data obtained from the R/V *Mirai*, it was indicated that the autumn bloom was triggered by regenerated nutrients (ammonium) associated with the decomposition of particulate organic matters, which were transported and stored at the bottom of the valley (Fig. 4). In other words, Hope Valley was becoming a storage house of organic particles, in which nutrients for the phytoplankton growth were produced to maintain the biological hotspot until autumn. It is the first time such annual variations in phytoplankton were identified in Hope Valley. The work [Nishino *et al.*, 2016] was carried out in collaboration with researchers from Hokkaido University and Research Organization of Information and Systems, as part of GRENE Arctic Climate Change Research Project by Green Network of Excellence (GRENE).

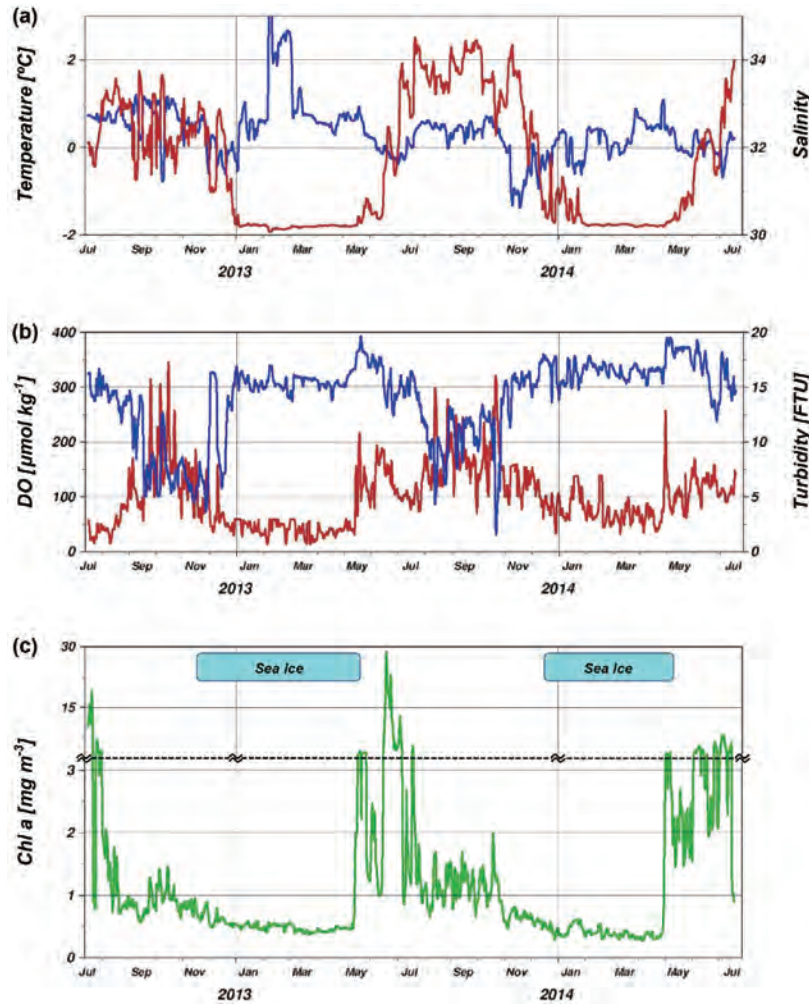


Fig. 2 Time series of (a) temperature (red) and salinity (blue); (b) turbidity (red) and dissolved oxygen (DO; blue); and (c) chlorophyll *a* (Chl *a*; green). The vertical axis scale in the (c) below the dotted line is exaggerated where the concentration is $< 3 \text{ mg m}^{-3}$. Periods when sea ice concentration was $> 50\%$ at the mooring site are indicated by blue bars. In the (c), time series of chl *a*, phytoplankton blooms are occurring both in spring and autumn in the southern Chukchi Sea. As shown in the (b), autumn blooms are observed with increased turbidity and decreased DO, which suggest particulate organic matters are transported and accumulated in Hope Valley (turbidity increase) and decomposed using DO (DO decrease) with regeneration of nutrients. Such environments are considered to be triggering autumn blooms.

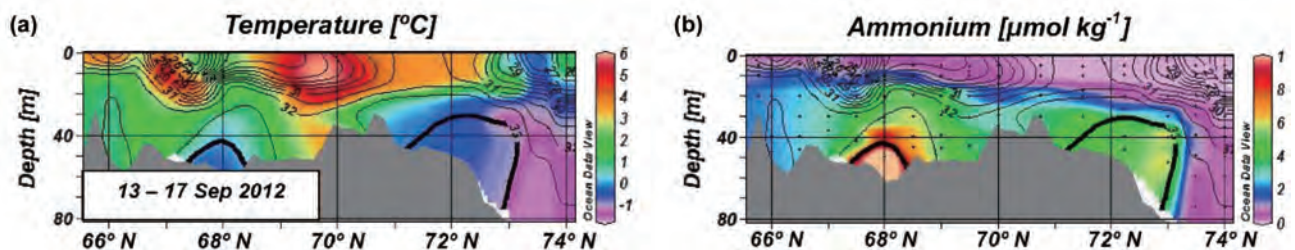


Fig. 3 Data obtained during the R/V *Mirai* cruise from September 13 to 17 in 2012 on (a) temperature and (b) ammonium (observation data from stations enclosed by black dotted lines in Fig. 1 are used). The contour lines indicate distribution of salinity. A dome-like structure of water mass with low temperature, high salinity, and high concentration of ammonium is identified near latitude 68° north.

Marine ecosystems are considered to be largely affected by changes in phytoplankton as it is located in the base line of the oceanic food chain. To grasp and clarify changes in plankton is highly important to understand how biological hotspots are formed and maintained. Further study will be carried forward to explore how these phytoplankton changes affect higher-trophic level ecosystems.

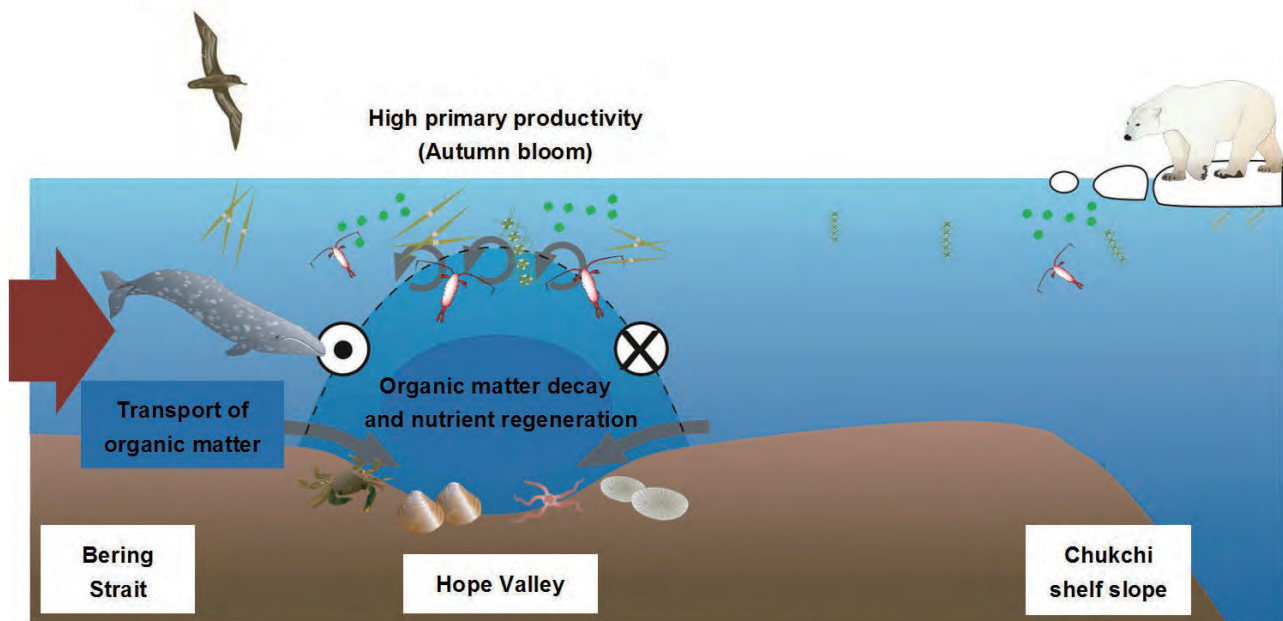


Fig. 4 Schematic of autumn bloom in Hope Valley in the southern Chukchi Sea. Circles with a dot and x represent flows from the back to the face of the figure and from the face to the back of the figure, respectively. Over the Hope Valley, there is a dome-like structure of the bottom water, suggesting ocean circulation in a counter-clockwise direction and converge of deep water there. The autumn blooms are, therefore, likely to be associated with particulate organic matters transported into the bottom of the valley, where nutrients such as ammonia are produced to increase phytoplankton with the organic matter decomposition.

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Predictability of a drastic reduction in Arctic sea ice using APPOSITE experiment data

The Arctic Ocean is one of the most vulnerable ocean areas to global warming. Since the recent rapid decline in Arctic summer sea ice is likely associated with the severe cold winter in the Northern Hemisphere mid-latitudes and the Northern Sea Route, the retreat of sea-ice cover has been of concern in the light of socio-economic activity as well as science. Previous studies have implied that the potential predictability for sea-ice extent and volume are 1-2 and 3-4 years, respectively, which are robust features of multi-climate models. In contrast, predictability of a drastic reduction in sea ice, such as the years 2007 and 2012, has not fully been discussed in the previous studies.

In this study, we focus on the predictability and mechanism of a drastic reduction in sea ice, using a control simulation that was run as part of the Arctic Predictability and Prediction On Seasonal to Inter-annual Timescales (APPOSITE) project by a climate model MIROC version 5.2. The control experiment does not include a global warming trend because of radiative forcings fixed at the year 2005. Nevertheless, the time series in sea-ice area, extent, spatial distribution of sea ice is characterized as extreme negative anomalies from the Russian coast to near the North Pole, which are similar to the spatial patterns observed in September 2007. Considering that a sea level pressure (SLP) dipole pattern with positive anomaly over the Beaufort Sea and negative anomaly over the Kara Sea is formed in late-spring to summer (Fig. 5h), it is inferred that sea ice drifts offshore with winds associated with the SLP dipole anomaly, leading to the large retreat of ice edge throughout July to August (Fig. 5d).

To examine the predictability of extreme sea-ice loss, we conducted a series of perfect model ensemble prediction experiments started in 1 January, 1 April, and 1 July chosen from the control run, and then compared to the control run. Forecast started in July successfully predicted the sea-ice distribution in the year when sea ice drastically decreased in the control run (Figs. 5c and 5d). This is because the SLP anomaly pattern was well predicted (Figs. 5g and 5h). Similarly, the April-started forecast roughly predicted the sea-ice distribution due to the weak SLP anomaly pattern (Figs. 5b and 5f). In the January-started forecast, however, sea ice remained near the Russian coast (Fig. 5a). This is partly because winds associated with the SLP anomaly were not formed (Fig. 5e).

In the present study, the key implications regarding the predictability of drastic reduction in sea ice are as follows. The SLP dipole anomaly could be a crucial factor for predicting the sea-ice distribution in the year when sea ice anomalously decreases. In addition, the Arctic sea ice could extremely retreat only by internal variability without the global warming trend. Therefore, the relationship between sea ice and other important modes of climate variability (ENSO, AMO, PDO, AO, and so on) should be investigated to further improve the predictability of internal variability.

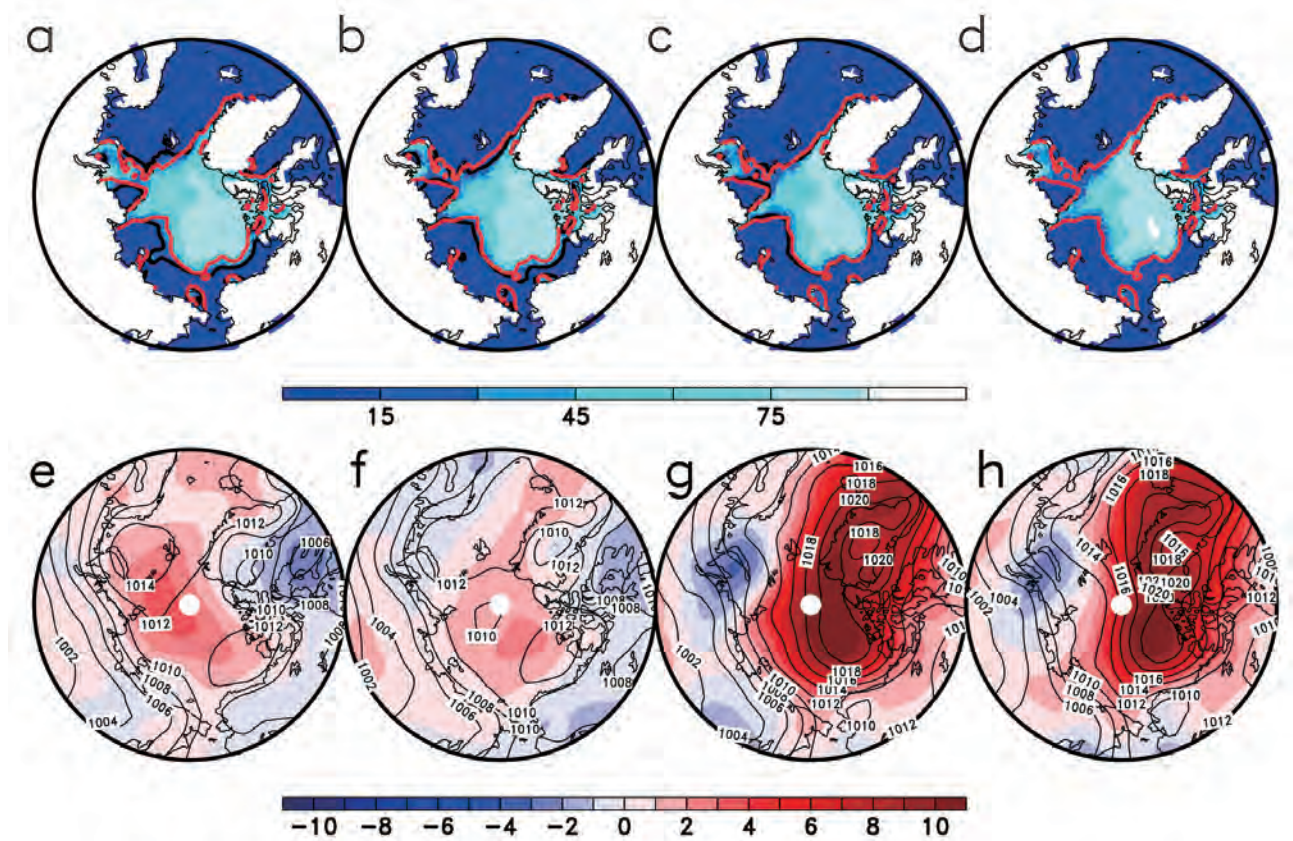


Fig. 5 September sea-ice concentration (shaded, %) in a year of a drastic reduction for forecast runs started in (a) 1 January, (b) 1 April, (c) 1 July, and (d) that for a control run. Red and black lines indicate the sea-ice edge defined as the sea-ice concentration of 15% for control and forecast runs. (e-h) as in (a-d), but for the SLP anomaly (shaded, hPa) and SLP (contour, hPa), averaged over June-August.

Publication List

Publication with Peer Review (Published)

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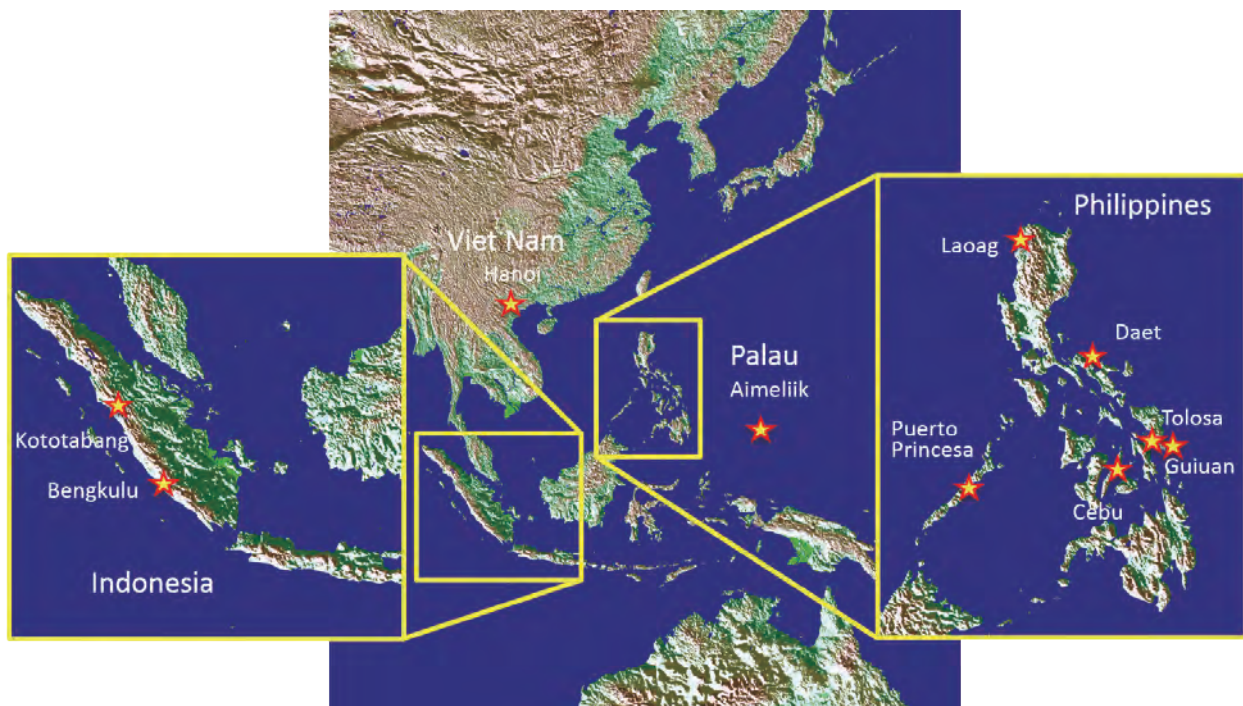
Chasing what's happening in the tropics

– Department of Coupled Ocean-Atmosphere-Land Processes Research –

The Maritime Continent (MC) and adjacent seas host a source of the global atmospheric circulation owing to the huge amount of heat release from cumulus convections. Since this region is characterized with complicated topography with steep mountains and surrounding warm waters, interactions among ocean, land, and atmosphere are thought to play a critical role in regulating weather and climate systems, which have impacts onto not only the tropics but also higher-latitudes. Our research goal is to improve our understanding of weather and climate in this region through observations from the viewpoints of ocean-atmosphere-land interactions. In particular, we have set to conduct two major activities during this mid-term (FY2014 - 2018). One is the international field campaign called “Years of the Maritime Continent (YMC)”, and the other is the boreal summer monsoon study.

The YMC is an international framework which engages to conduct field campaign starting from July 2017 for two years. Their ultimate goal is to expedite the progress of improving understanding of local multi-scale variabilities of the MC weather-climate system and its global impact. Currently over 70 institutes/universities from 19 countries and regions have expressed their participation will in this campaign. Since JAMSTEC is one of the founding and leading institutes of the YMC, we developed the Memorandum of Understanding (MOU) and Implementing Agreement (IA) with the Agency for Meteorology Climatology and Geophysics (BMKG) and the Agency for Assessment and Application of Technology (BPPT) in FY2015 and 2016, respectively. Its field campaign consists of long-term measurements and several intensive observations. As part of the YMC, we have proposed to conduct intensive observations around west coast of Sumatra Island, Indonesia in November - December 2017. To accomplish this campaign, we have also conducted a pilot study in 2015.

As for the monsoon study, we have developed an IA with the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) of the Republic of the Philippines in February 2015, and with Aero-Meteorological Observatory of National Hydro-Meteorological Service (AMO/NHMS) of the Socialist Republic of Viet Nam in March 2015, respectively. Then, we have continued observations there based on the collaboration with those agencies.



Major observation sites (red stars), where DCOP deploys their instruments or conducts intensive observations.

Pilot Study for the YMC

Many previous studies indicated that most precipitation occurs near the coast. Recently, *Ogino et al.* [2016] showed its evidence using satellite data. Figure 1 indicates the annual mean precipitation observed by the satellite Tropical Rainfall Measuring Mission (TRMM) over the MC region and most precipitation concentrates in the coastal region. Indeed, Figure 2, which shows precipitation amount as a function of distance from the coastline, indicates sharp decrease of rainfall amount beyond 300 km from the coastline. Based on this result, we focus on the precipitation mechanism study over the coastal region.

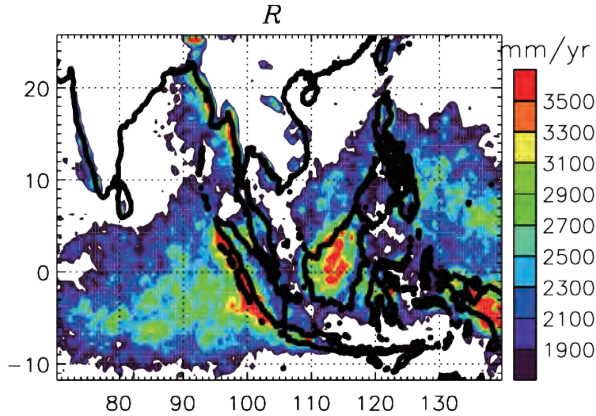


Fig. 1 Annual mean precipitation observed by TRMM during December 1997 to January 2011. [Ogino et al., 2016]

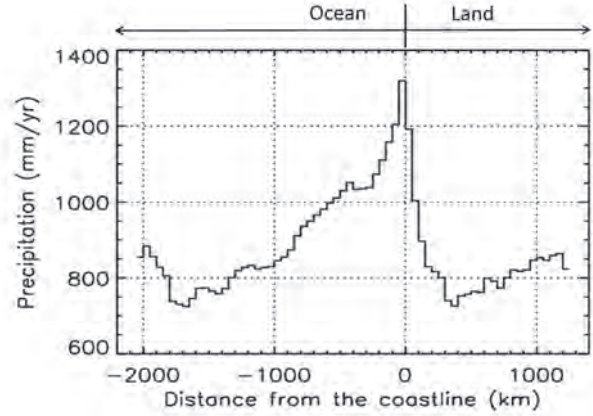


Fig. 2 Precipitation observed by TRMM as a function of distance from the coastline. [Ogino et al., 2016]

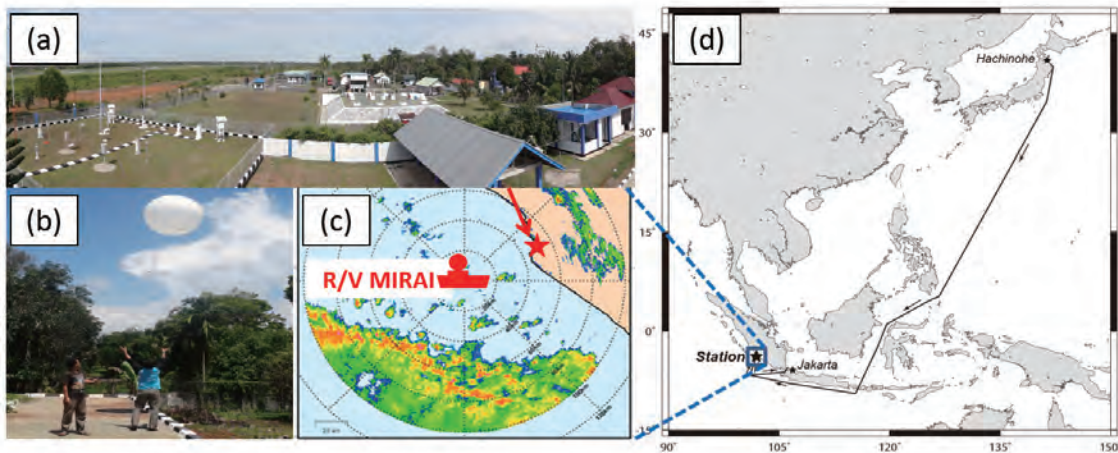


Fig. 3 Pre-YMC campaign in November - December 2015. (a) Bengkulu site, (b) radiosonde sounding by local staff, (c) location of Mirai and Bengkulu sites over the radar reflectivity distribution, and (d) R/V Mirai cruise track.

In November - December 2015, we conducted an intensive observation to study precipitation mechanism on and off Bengkulu in the west coast of Sumatra Island, Indonesia. We call this campaign as “Pre-YMC” since it aims at not only scientific understanding but also obtaining the knowledge of logistics to perform the observation in the Indonesian External Economic Zone as well as within territorial waters, as part of the forthcoming international field campaign YMC. To confirm various procedures, not only observational research departments but also numerical research groups as well as operational centers in JAMSTEC were involved.

We deployed our observational instruments such as Polarimetric X-band Doppler radar, automated weather station, sky camera, videosonde, and radiosonde in collaboration with the Indonesian agencies BPPT and BMKG during November 9 through December 25 (47 days) in Bengkulu (Figs. 3a, b). We also deployed the research vessel *Mirai* off Bengkulu (about 50 km away from the coastline). Onboard the *Mirai*, various atmospheric and oceanic observations have been carried out, they include radiosonde, Polarimetric C-band Doppler radar, lidar, ceilometer, surface meteorology, CTD, water sample, and so on (Figs. 3c, d). By deploying

these platforms near the coast, we tried to capture the precipitation clouds which develop owing to the diurnal cycle of solar radiation heating over the coastline and then propagate into offshore region from both land-based and ship-based sites.

In particular, this period was chosen because large-scale cloud systems associated with the Madden-Julian Oscillation (MJO) often appear and the interaction between the local diurnal cycle rain and the MJO is one

of main topics of the YMC study. Indeed, during the Pre-YMC campaign, we could encounter the MJO convection which developed over the central-eastern Indian Ocean and propagated eastward (Fig. 4). Based on significant changes of various meteorological parameters (not shown here), the center of MJO convection passed the observational site on December 13, 2015. So-called MJO index also indicates the development of cloud system on the same day and moves eastward (Fig. 5). Currently, data analyses have been actively performed. For example, while diurnally-induced rain developed over the coastline and then propagates offshore-ward during the evening before December 13, this feature is changed and such diurnal cycle rain becomes obscure after the MJO convection passed (not shown).

Finally it should be noted as a special remark. YMC adopts open data policy with timely release and easy access. Since this campaign was conducted as part of the YMC, we will follow this regulation. Thus, it is expected that quality controlled data will be available in the early 2017 from JAMSTEC YMC site at <http://www.jamstec.go.jp/ymc/>. It is expected that those data will be a basis for the coming YMC campaign.

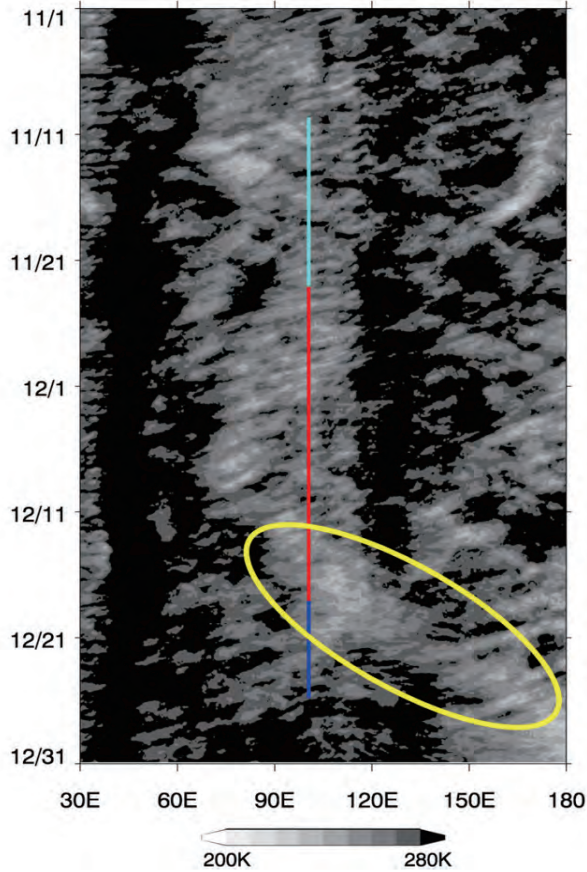


Fig. 4 Time-longitude diagram of infrared radiation brightness temperature along the equator. Vertical line indicates when the R/V *Mirai* observation period (light blue and blue indicate before and after the stationary observation; thus location is not correct, while red indicates on station). Yellow indicates rough MJO convection region.

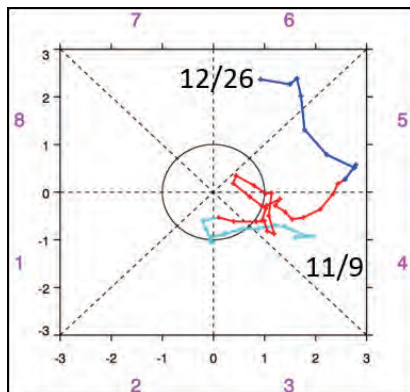


Fig. 5 The Wheeler and Hendon (2004) MJO index. Colors (light blue, blue, and red) correspond to those in Fig. 4. Numbers (1-8) indicate the rough location along the equator from western Indian Ocean (1) to African region (8) via the MC (4-5).

Acknowledgments.

This Pre-YMC campaign was conducted under the permission of the Indonesian government. We'd like to express our sincere thanks to the responsible agency RISTEKDIKTI (Ministry of Research, Technology, and Higher Education) and the help from BPPT as well as the Embassy of Japan in Indonesia.

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Exploring geochemical cycle across atmosphere, land, and ocean: a key factor in global environmental change

– Department of Environmental Geochemical Cycle Research –

In the atmosphere, land, and ocean, various geochemical materials, as well as water and energy, are cycled continuously, dominating the climate and environment of the earth. Carbon dioxide (CO₂), a representative greenhouse gas (GHG) released mainly by fossil fuel combustion (FFC) and cement production, is absorbed and sequestered by the land and ocean. This process moderates the addition of CO₂ to the atmosphere, reducing its increase by approximately half of the potential contribution from FFC and cement production emissions.

Ocean and land ecosystems play an important role in geochemical cycle dynamics, such that the seasonal variation in atmospheric CO₂ concentration is controlled by the seasonal variation in forest ecosystem CO₂ cycling over high latitude regions in the Northern Hemisphere. Carbon dioxide is also absorbed by ocean surfaces and transported to deep sea depths within sinking particles produced by biogeochemical marine ecosystem processes.

In addition to CO₂, aerosols generated during wildfires and human activities, and methane (CH₄) from paddy fields or wetlands strongly influence changes to the earth's climate and environment. A current challenge is to elucidate the dynamics of emission, transport, and accumulation (deposition), as well as the transformation of such geochemically active materials in the atmosphere, land, and ocean, based on *in-situ* observations, satellite data, and numerical modeling.

The 2015 fiscal year marked the second year of the five-year midterm plan of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). We conducted a study of environmental geochemical cycles with respect to five themes (atmosphere, land, atmosphere–ocean interaction, land–atmosphere interaction, and ocean–atmosphere–land interaction), which had been established in the previous year. Most of the 33 department members (as of April, 2015) have been involved in one or more of these themes. We organized a steering group consisting of five scientists, with both scientific research and administrative/management responsibilities.

Interdisciplinary seminars, assembling all members of the department, were held four times during the year, at which scientific results were presented and knowledge exchanged. In addition to these seminars, a discipline-based seminar series was also created to engender more in-depth discussion. All seminars were open and announced to all JAMSTEC members, and provided opportunities to disseminate scientific information outside of the department.

The following abstracts present highlights of the departmental research results for the 2015 fiscal year.

Ship-based Observation of Black Carbon Particles over the Arctic Ocean

Black carbon (BC), which is formed through the incomplete combustion of fossil fuels, biofuels, and biomass, has positive radiative forcing properties and is a major component of the light-absorbing particulate matter in the atmosphere. To further understand the global distribution and temporal variation of BC, we conducted ship-based observations on the research vessel (R/V) *Mirai* and ground-based observations at Fukue Island. To compare measurements with ground-based BC observation points, we decided sites at Poker Flat in USA and Yakutsk in Russia (Fig. 1).

We have published the results of our ship-based observation of BC mass

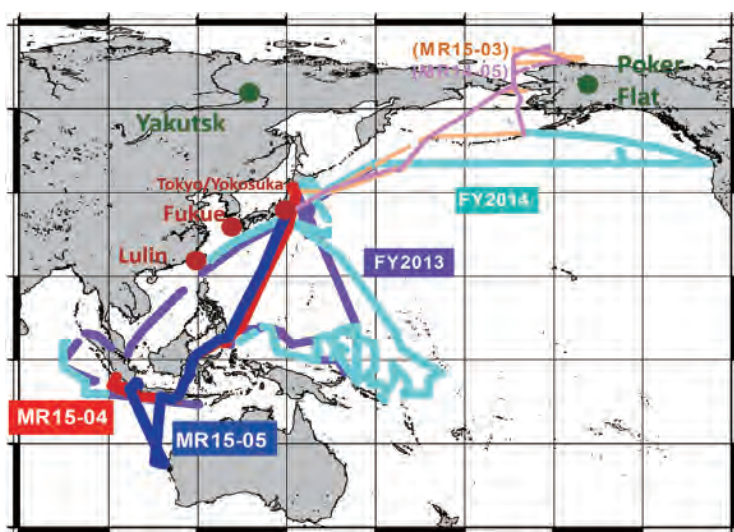


Fig. 1 Black carbon (BC) observation sites (circles) and cruise routes (lines).

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concentration, size distribution, and mixing state during Arctic Ocean cruise MR14-05 [Taketai *et al.*, 2016]. This research involved the world's first ship-based observation of atmospheric BC particles over the Arctic Ocean. Observations were conducted aboard the R/V *Mirai* between August 31, 2014 and October 9, 2014, between the ports of Dutch Harbor, Alaska, USA (53.90° N, 166.53° W) and Yokohama Port, Kanagawa, Japan (35.45° N, 139.64° W), via the Arctic Ocean. Observations were carried out at a stationary point in the Arctic Ocean (74.75° N, 162.00° W) from 6 to 25 September, 2014. Measurements of BC particles were performed by a highly sensitive online instrument, a single particle soot photometer (SP2).

Figure 2 shows the geographical distribution and time series of BC mass concentrations observed over the Arctic Ocean, Bering Sea, and North Pacific Ocean during the cruise. To avoid the influence of ship exhaust (the ship's funnel is located near the rear of the sampling inlet), we used only data recorded when the wind direction and speed relative to the ship's course were within $\pm 60^\circ$ from the bow and > 3 m/s, respectively. The range in BC mass concentration spanned four orders of magnitude (10^{-2} – 10^2 ng/m³); measurements taken in the Arctic region yielded the lowest values. The mean BC concentration over the Arctic Ocean in the region $> 70^\circ$ N was 1.0 ± 1.2 ng/m³. Long-term ground-based observations of BC concentrations at Barrow (71° N, 156.6° W), at a location approximately 450 km from the ship's position, on 6–25 September, displayed strong seasonal trends. In summer, BC concentrations were at their lowest (approximately 10 ng/m³); however, this concentration was still much higher than our result (1.0 ng/m³). These BC data will be the benchmark for global chemical transport models.

Figure 3 shows the normalized mass distribution of BC measured in the Arctic Ocean, the Bering Sea, and the North Pacific Ocean. In the Arctic region, the median values of mass equivalent diameter (MED) were approximately 170 nm. Median MED values over the Bering Sea and the North Pacific Ocean were also in the range of 170–190 nm, suggesting that this BC particle size was dominant within the observed masses. The mixing state of BC-containing particles can influence their optical properties and removal processes in the atmosphere. Our analysis indicated that there were three significant types of BC-containing particles over the Arctic Ocean: BC particles attached to the surfaces of non-BC material, bare BC particles, and BC particles coated with non-BC material. In contrast, there were only two types of BC-containing particles over the Bering Sea and North Pacific Ocean: bare BC particles and BC particles coated with non-BC material. We found that BC particles attached to the surface of non-BC material contributed approximately 20% of the total BC over the Arctic Ocean. We also analyzed the morphology and components of these particles using a transmission electron microscopy

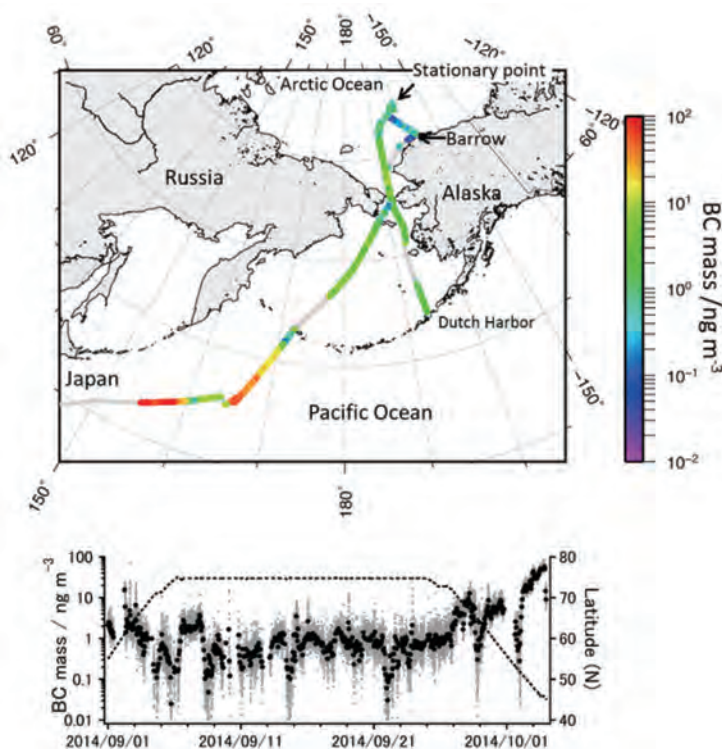


Fig. 2 Top: Black carbon (BC) mass concentration observed over the Arctic Ocean. The gray line shows the cruise route, and colored lines indicate the BC mass concentration. The BC mass concentration over the Arctic Ocean ranged from 0.1 (blue) to 10 (green) ng/m³. Higher BC concentration levels ranged between 10 (yellow) and 100 (red) ng/m³ at latitudes of 50 degrees north or below, probably due to impacts from the Eurasian continent. Bottom: Time-dependent variation in the BC mass concentration. Gray and black dots show the BC mass concentration averaged at 1 min and 1 h, respectively. The dotted line indicates the latitude at the time of observation (right axis). During observations at the stationary point (74.75° N, 162.00° W) from 6 to 24 September, 2014, the BC concentration ranged from 0.01–20 ng/m³. A slightly higher BC level was observed around September 7, 2014, seemingly due to emissions from BC observation sites on land and cruise routes.

with energy-dispersive X-ray spectroscopy (TEM-EDX). Figure 4 shows a TEM-image of BC particles attached to the surface of non-BC material, bare BC particles, and BC particles coated with non-BC material, all collected over the Arctic Ocean. Even at low BC concentrations, we found that several BC particles had attached to the surfaces of non-BC material, in addition to the bare and coated BC found via TEM-EDX analysis. These non-BC materials typically consisted of Na, S, O, and Cl. From these constituents and the particle shapes, we inferred that the attached non-BC material was likely sea salt, suggesting that such particles may have been produced by coagulation. Because the mass absorption cross-section of an individual BC-containing particle depends on its morphology, mass, and the amount of internally-mixed non-BC compounds, mixing status information provided by our observations was critical in estimating the regional radiative balance.

We are currently developing an advanced BC model that can treat the BC mixing state. We plan to combine the resulting model and observed data to better understand the source and transportation processes of BC particles.

This study has been performed with the Arctic Geochemical Cycle Research Unit, Institute of Arctic Climate and Environment Research (IACE).

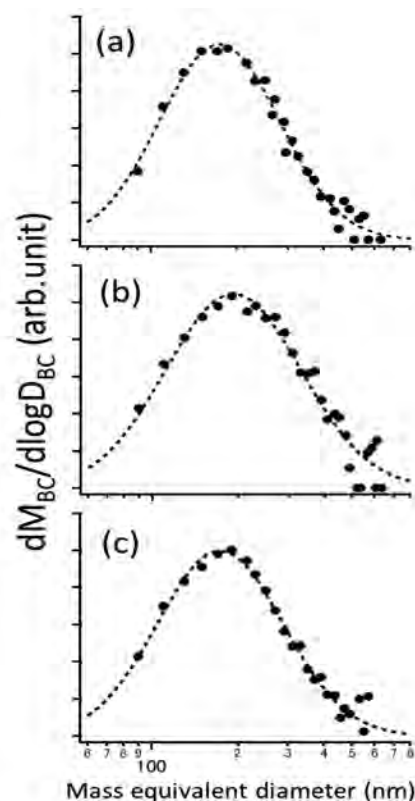


Fig. 3 Normalized mass distributions of black carbon (BC) particles over (a) the Arctic Ocean, (b) the Bering Sea, and (c) the North Pacific Ocean. Dashed lines denote lognormal fits to observed results using data from 90–400 nm.

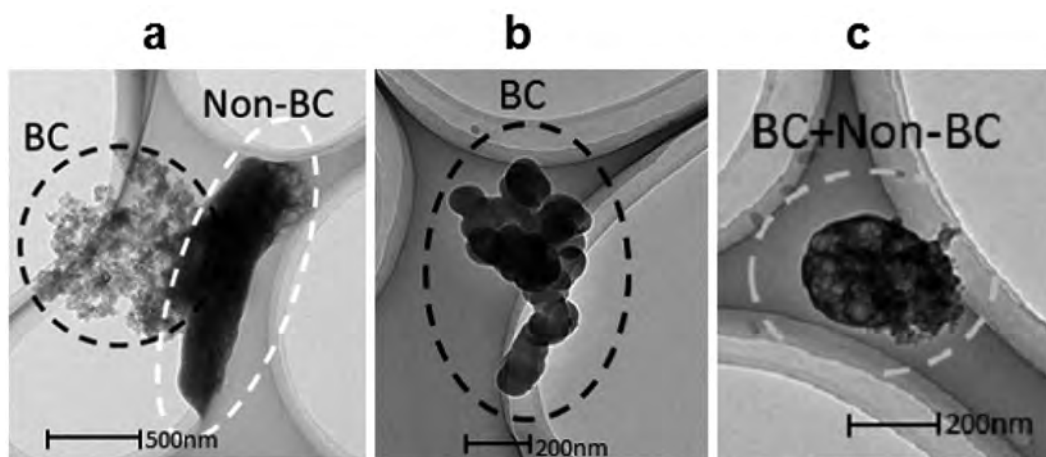


Fig. 4 Transmission electron microscopy (TEM) images of black carbon (BC). (a) BC particles attached to the surface of non-BC material, (b) bare BC particles, (c) BC particle coated with non-BC material. Depending on the BC type, BC absorption of sunlight varies; e.g., light absorption increases when BC particles are coated with non-BC material. A greater understanding of BC types present in the air could therefore lead to a better assessment of climate variations. These results identified the (a) type of BC present at a significant levels over the Arctic Ocean BC observation sites and cruise routes.

Reliable Estimation of Terrestrial CO₂ Exchange Using Ground and Satellite Observations

This study is the first attempt to evaluate two different approaches (i.e., top-down and bottom-up) for the data-driven estimation of terrestrial CO₂ exchanges, with the aim of elucidating the impact of satellite and ground observations of net CO₂ exchange. The top-down approach uses a forward-running atmospheric transport

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model and *a priori* initial estimates of the surface fluxes (CO_2 exchange for land, ocean, and other CO_2 emission attributions, e.g., biomass burning and fossil fuel emissions) to predict concentrations and to estimate terrestrial CO_2 exchange while seeking consistency between simulated and observed CO_2 concentrations [e.g., *Chevallier et al.*, 2005; *Peters et al.*, 2007]. The bottom-up approach can be classified into two broad categories: process-based model simulation and empirical upscaling. Process-based models simulate the ecosystem-scale carbon cycle by considering the internal biochemical mechanisms of carbon flows (e.g., photosynthesis, respiration and decomposition) for each prescribed vegetation type [e.g., *Thornton et al.*, 2002; *Sitch et al.*, 2003; *Sato et al.*, 2007; *Ito*, 2008]. Empirical upscaling is driven by empirically-obtained relations between CO_2 flux and environmental factors (e.g., air temperature, precipitation, radiation, and vegetation parameters) as appropriate input data [e.g., *Saito et al.*, 2009; *Beer et al.*, 2010]. Since the early 2000s, the research community has invested substantial effort in the development of bottom-up and top-down approaches to the estimation of CO_2 exchange; however, current estimates of terrestrial CO_2 exchange yielded by these two approaches remain inconsistent for global terrestrial regions [*Ciais et al.*, 2013].

We examined the consistencies and inconsistencies between terrestrial CO_2 exchanges estimated by data-driven top-down and bottom-up approaches over 42 global terrestrial regions between June 2009 and October 2011. Top-down CO_2 exchange estimates were based on atmospheric CO_2 concentrations measured by the Greenhouse gases Observing SATellite (GOSAT) "IBUKI" [*Maksyutov et al.*, 2013], and bottom-down estimates were based on empirical eddy flux upscaling with a support vector regression (SVR) model [*Ichii et al.*, 2010; *Saigusa et al.*, 2010; *Ueyama et al.*, 2013]. The data-driven top-down CO_2 exchange was estimated by Bayesian inverse modeling, in which both ground and satellite observations were incorporated with corresponding

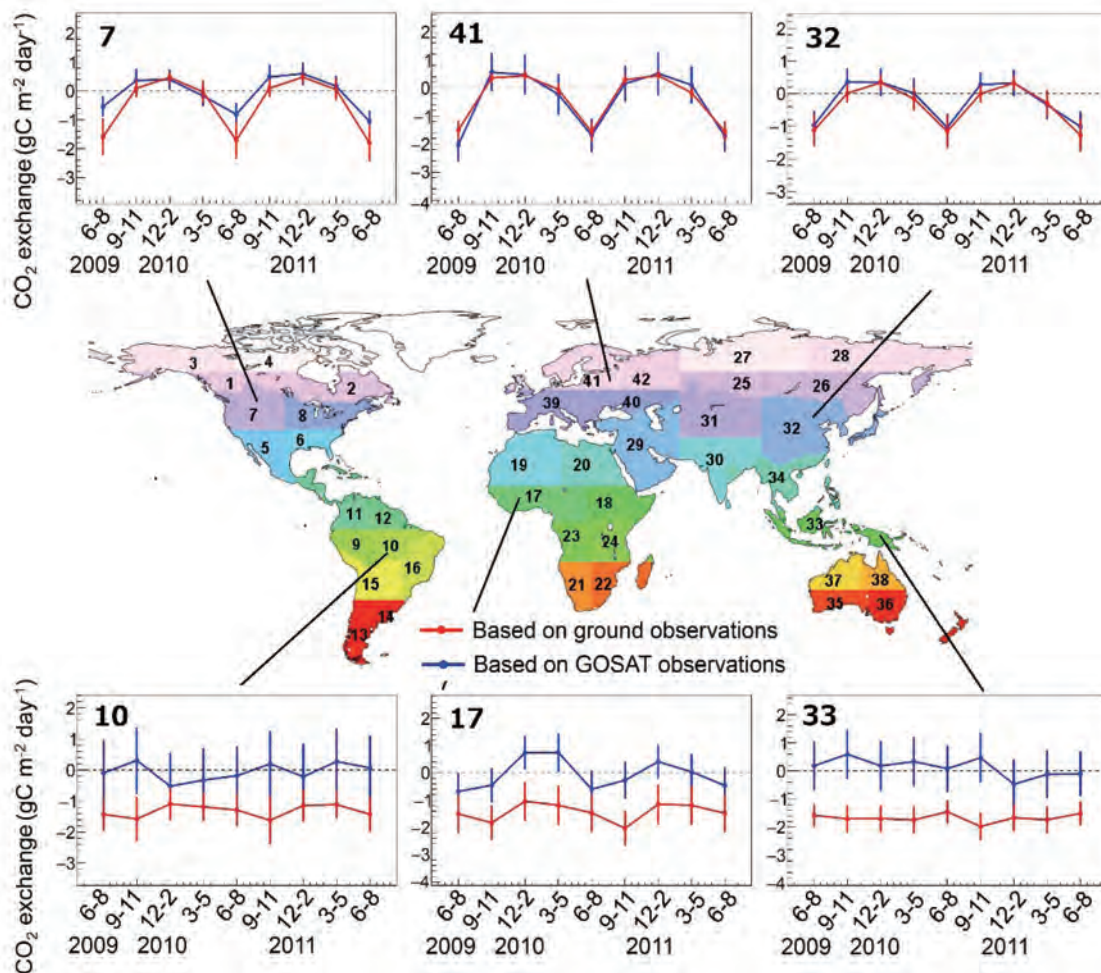


Fig. 5 Seasonal variation (three-month average) in CO_2 exchange via Greenhouse gases Observing SATellite (GOSAT) observations (biosphere flux, blue) and the ground observation network support vector regression (SVR) model (biosphere flux, red) for selected regions in the Northern Hemisphere (regions 7, 32, and 41) and tropics (10, 17, and 33).

predictions from an atmospheric transport model [Maksyutov *et al.*, 2013]. Compared with common top-down approaches, this method has the advantage of integrating into the inversion process satellite-based atmospheric CO₂ concentration measurements obtained from high-resolution shortwave infrared (SWIR) spectra onboard the GOSAT satellite (hereafter, GOSAT biosphere flux). Data-driven bottom-up CO₂ exchange was estimated via an empirical upscaling technique using machine learning-based regression (SVR), which was used to obtain spatiotemporal variation in surface CO₂ fluxes from 144 eddy-covariance observation sites registered as Free Access FLUXNET data (hereafter, SVR biosphere flux).

We identified that the seasonal variation in CO₂ exchange estimated by the two approaches agreed well in boreal and temperate regions across the Northern Hemisphere (Fig. 5). In addition, we confirmed that both estimates commonly show strong anomalous signals in response to the contrasting anomalous spring temperatures observed in North America and boreal Eurasia. This result indicates that the CO₂ concentration data integrated into the GOSAT biosphere flux and eddy-covariance observations in the SVR biosphere flux are equally effective in producing spatiotemporal variation in CO₂ exchange. Meanwhile, large differences in seasonality were found in subtropical and tropical South America, Southeast Asia, and Africa. The GOSAT biosphere flux displayed seasonal variation that pivoted around CO₂-neutral, while the SVR biosphere flux showed seasonal variation that tended toward a CO₂ sink. Thus, a large difference in the CO₂ budget occurred between the two approaches in subtropical and tropical regions. Examination of the integrated data revealed that the large tropical CO₂ sink in the SVR biosphere flux was an artefact caused by underrepresentation of the biosphere fluxes predicted by limited eddy flux data for tropical biomes.

Due to the global coverage of CO₂ concentration data, the GOSAT biosphere flux is a better estimate of continental CO₂ exchange than the SVR biosphere flux in the Southern Hemisphere. However, one shortcoming of GOSAT data is that its application is limited to recent events because of its short temporal coverage (29 months between June 2009 and October 2011 for the current version). Although the excessively large CO₂ sinks in subtropical and tropical regions require improvement, empirical upscaling by SVR still has an advantage over the GOSAT biosphere flux due to its longer temporal coverage (2001–2010). The reliable seasonal variation in boreal and temperate regions indicates that long-term trends and anomalous events during the past 11 years over North America and Eurasia can be analyzed with the SVR biosphere flux. Thus, despite the issues relating to the global budget, both methods of CO₂ exchange estimation can be useful within appropriate research fields and can provide new insights in terrestrial CO₂ exchange.

In predicting climate change caused by global warming, it is important to obtain accurate estimates of CO₂ absorption/emissions from the land. These research findings can be applied to improve process models for future climate change prediction, contributing to a more accurate determination of global warming effects.

Resuspension and Lateral Transport of Radiologically-Contaminated Seafloor Sediment Near the Fukushima Daiichi Nuclear Power Plant

In order to investigate the behavior of particulate radiocesium emitted from the Fukushima Daiichi Nuclear Power Plant (F1NPP), time series sediment traps were deployed at 500 and 1000 m at station F1, located on the continental shelf slope approximately 100 km southeast of F1NPP in the ocean (Fig. 6), and settling particles were collected. Time series observations made over approximately three years (July, 2011 – July, 2014) revealed that radiocesium emitted from F1NPP (Cs-134 and Cs-137, both with an activity ratio of ~1) were collected mainly in 2011 and early 2012; thereafter, collection decreased with time (Fig. 7). However, radiocesium was still detected in July 2014, with activity tending to increase in autumn. A major component of the settling particles collected by sediment traps was lithogenic (mineral) material. Temporal variability in the settling particles was not synchronized with the variability in the satellite-based chlorophyll concentration (marine primary productivity) in the upper layer. In addition, ratios of radiocesium (Cs-137) to excess radiolanthanum (Pb-210) were similar to those of the seafloor sediment near F1NPP. Based on these observations, we suspect that the time series sediment trap collected mainly radiologically-contaminated seafloor sediment that was resuspended and

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laterally transported to the continental shelf slope and open ocean. Several typhoons passed near F1NPP or station F1 in the autumn during the observation period. An increase in the radiocesium flux during the autumn was likely due to more active resuspension / lateral transport of seafloor sediments by these typhoons. Based on the Cs-137 inventory within seafloor sediment shallower than 200 m (< 200 m) and Cs-137 export flux from the seafloor < 200 m, we estimated the residence time of Cs-137 in seafloor sediment < 200 m to be approximately 60 years. For more precise estimates of residence time, the dissolution of seafloor Cs-137 into ambient water and dilution of Cs-137 by the bioturbation should be taken into account.

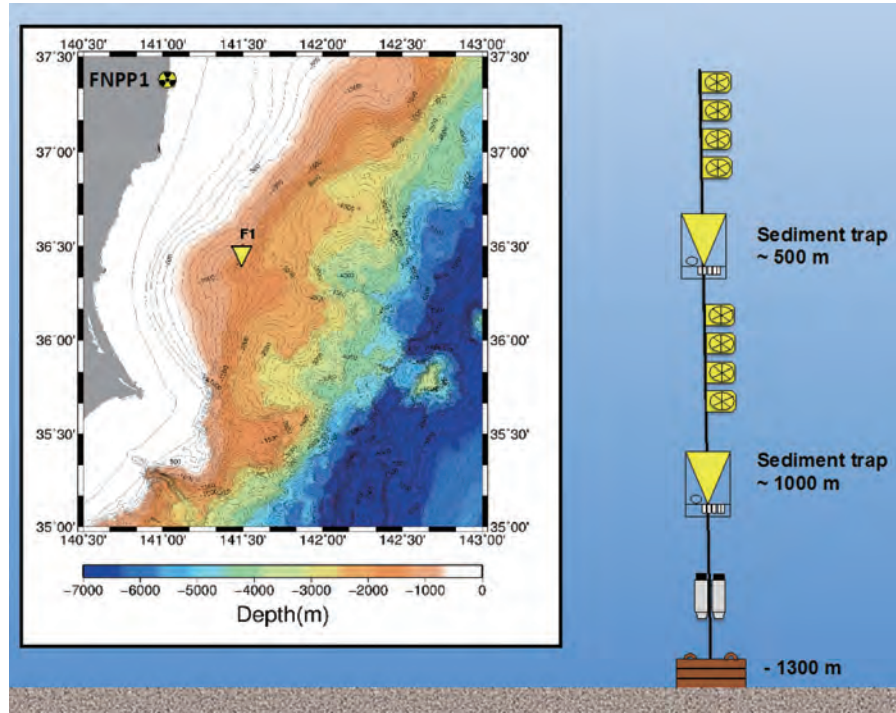


Fig. 6 Location of station F1 (left) and the sediment trap mooring system (right). FNPP1 denotes the location of the Fukushima Daiichi Nuclear Power Plant.

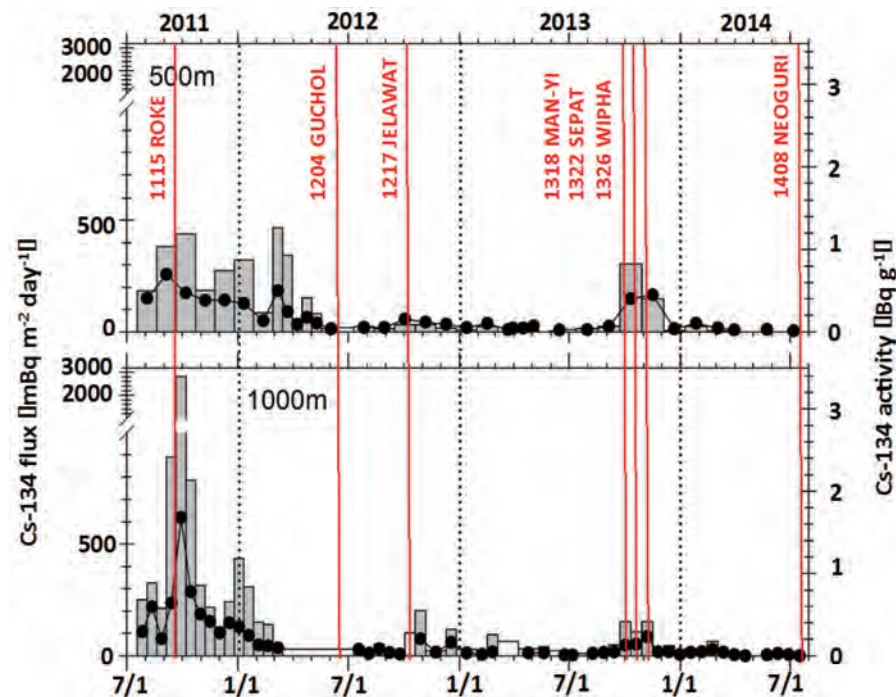


Fig. 7 Time-series for Cs-134 flux (bars) and Cs-134 activity (solid circles) at 500 m (upper) and 1000 m (lower) at station F1, between July, 2011–July, 2014. The Cs-134 activity is decay-corrected to the middle day of the respective sampling interval. Red lines indicate typhoons passing near F1NPP or station F1.

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Toward Comprehensive Projection of Global Change – Department of Integrated Climate Change Projection Research & Project Team for Risk Information on Climate Change –

Department of Integrated Climate Change Projection Research works on researches on mechanism for oceanic and atmospheric variations including water and biogeochemical cycles, and assessment of human impacts on those variations. Our main research tools include an atmosphere-ocean coupled model dealing with physical variables such as temperature and precipitation, and an earth system model (ESM) incorporating oceanic and terrestrial biogeochemical dynamics important for formation of the global environment. Activities also include observational research on permafrost, in order to develop a land process module to be a part of the ESM. It is hoped that our researches lead to contribution to the society in addition to improved understanding on how the nature works.

JAMSTEC has been undertaking "Program on Risk Information on Climate Change" funded by Ministry of Education, Culture, Sports, Science and Technology (MEXT) since FY 2012 by establishing a dedicated project team. Based on the protocol for global change projection experiments being discussed by scientists from across the world (CMIP6 protocol), we perform projection experiments using the models developed at JAMSTEC. This annual report includes results obtained under this program.

This year, we estimated the rate at which permafrost is diminishing and changes in the carbon cycle by joining Permafrost Carbon Network, an international project on permafrost dynamics. Results are documented and submitted to scientific journals. Also, an ice sheet model, which is an important tool for investigation tipping elements and irreversibility of the global environment, was improved and its uncertainties have been estimated. Factors generating model-model differences in projection of future Greenland ice sheet have been clarified, which has been published in a scientific journal.

MIROC, coupled general circulation model (CGCM) that we have been developing, has been refined in order to meet the standard of CMIP6. The shallow convection scheme has been introduced to MIROC which resulted in a better reproducibility of present climate. Thus, scientific achievements have been successfully obtained in accordance with the mid-term plan, and preparation for CMIP6 is progressing smoothly. It can be concluded that FY 2015 is a fruitful year.

Irreversible changes in permafrost zones under global warming

This year we focused on thermal and hydrological changes in the Northern Hemisphere high latitude permafrost zones. The climate-vegetation-permafrost-snow subsystem has a long climatological time constant, whereas its changes under warming can lead to quasi-irreversible processes such as melting of ground ice, decomposition and release of stored soil carbon, and surface subsidence. Composition of the released greenhouse gases is subject to the ambient hydrological conditions. MIROC-ESM warming experiments with doubled/tripled/quadrupled CO₂ concentration showed warming of average permafrost temperatures by 6.1 °C, 9.3 °C 13.4°C, respectively, with degradation over 100 years in all the cases. Ratio of ground ice decreased following degradation, whereas liquid moisture content increased relatively, implying wetting of the ground (i.e., favorable to methane production).

We also participated in an international Permafrost Carbon Model Intercomparison study (retrospective for 1960 to 2000, with 9 terrestrial, biogeochemical models). Of the outcomes, *Peng et al.* [2015] reported that all the models show warming permafrost, whose trend varies from 0.010 ± 0.003 to 0.031 ± 0.005 °C yr⁻¹ (at 20cm depth), and that the area underlain by near-surface permafrost (with seasonally thawing depth less than 3 m) is lost at the rate of $-2.80 \pm 0.67 \times 10^6$ km² K⁻¹ with reference to 1-m ground temperature.

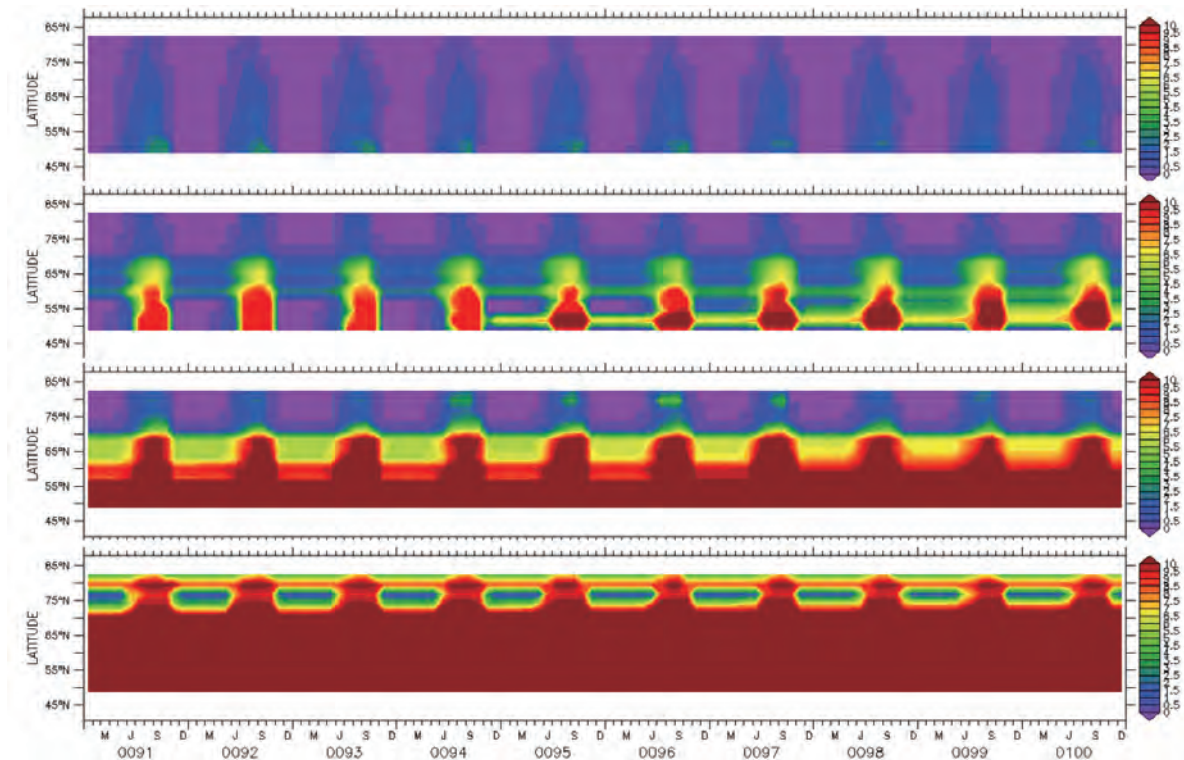


Fig. 1 Thaw depth changes by latitude (N of 50N). Ground freezes totally in winter and thaws up to 3 m in summer in Control experiment (top). 2xCO₂(2nd from top), 3xCO₂(3rd), and 4xCO₂(bottom) show proportional deepening of thaw layer, and increase in freeze-free layer in low-latitude, with general wetting of ground.

MIROC 6 development

Development of the climate model, MIROC6, has been ongoing in order to contribute to the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC) and to provide information on climate change prediction for political decision makers. In this fiscal year, physical parameterization for shallow convective systems has been implemented.

Shallow clouds, whose cloud top height is 2 km at most, are frequently observed over the tropical and subtropical oceans. These clouds are formed associated with atmospheric boundary layer processes, and lower-tropospheric water vapor around the clouds is efficiently transported upward and mixed with relatively dry air in the free atmosphere through vertical turbulence. Consequently, dry biases in the free atmosphere, which is remarkable in the previous version of our climate model, has been much reduced in MIROC6 and resultant increase in convective available potential energy leads to development of deep convective clouds. Correspondingly, summer time precipitation over the western tropical and subtropical Pacific, which was underestimated so far, has been better represented (Fig. 2).

Representing shallow convective process leads also to improvement of the mid-latitude climate. Upward transport of the lower tropospheric water vapor to the free atmosphere results in reduction of the low-level clouds in the tropics and subtropics. Because clouds reflect the incoming solar radiation, the decrease of the low-level cloud amount results in tropospheric temperature rise over the low-latitude oceans. In general, characteristics of the mid-latitude westerly jet is determined by the temperature difference between low-latitudes and mid- and high-latitudes, suggesting that larger the temperature difference stronger the westerly jet and so is the wintertime storms track activity. By implementing the shallow convective parameterization, the wintertime mid-latitude westerly jet and storms, which were underestimated, have been better represented in MIROC6 (Fig. 3).

As the global warming progresses, evaporation from the ocean to the atmosphere is considered to increase and so does the low-tropospheric water vapor. In the previous version of our climate model where the shallow convections cannot be represented, low-level clouds over low-latitude oceans are significantly increased

under the global warming, and thus, the cooling effect due to the cloud radiative feedback processes is considered to be overestimated, also implying uncertainties of transient responses of the mid-latitude westerly and storms to the global warming. Representation of the shallow convective processes in MIROC6 could result in reducing uncertainties and errors in global-scale climate predictions.

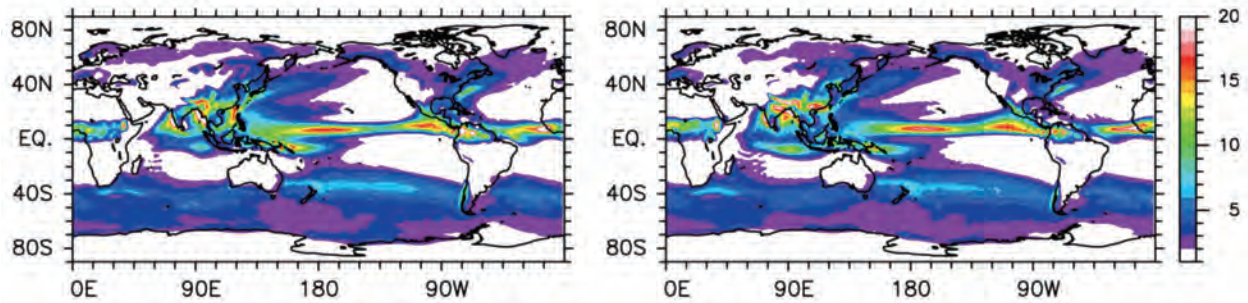


Fig. 2 Climatological summertime precipitation in MIROC6 (left) and MIROC5 (right) which was an official model for the IPCC-AR5. Unit is mm/day

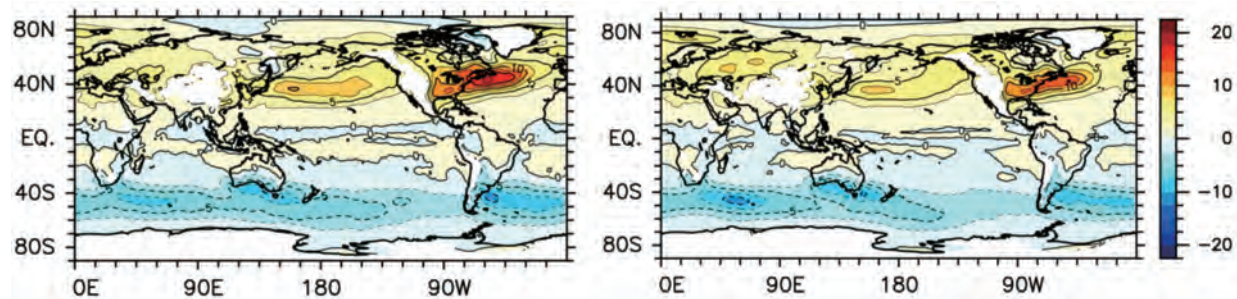


Fig. 3 Meridional atmospheric eddy heat transport at the 850 hPa level for MIROC6 (left) and MIROC5 (right). Unit is $K\ ms^{-1}$. Here, eddies are defined as transient waves whose periods are shorter than 8-days.

Development of a numerical ice-sheet model: Structural uncertainties in ice-sheet simulation

Ice sheet, in the nature of its dome-shape, is expected to collapse drastically when the surface temperature exceeds a certain threshold. Thus response of the Greenland ice sheet to future global warming has been focused in terms of a tipping element. Uncertainties of simulated response by numerical models become large when the warming is close to the threshold, therefore, it is an important subject to evaluate the structural uncertainties in ice-sheet simulation. Sea-level Response to Ice Sheet Evolution [SeaRISE, *Bindschadler et al.*, 2013] is an international project which focuses on the ice-sheet evolution under future global warming using numerical ice-sheet models. Several scenarios for 500 years from the present-day are prepared by the project, and eight ice-sheet models participated to the intercomparison of the Greenland ice sheet response. One experiment in SeaRISE is A1B scenario experiment, which forces ice-sheet with changes in the precipitation and temperature obtained by GCMs. The projections of the different SeaRISE participants show dispersion, which range from 5.4cm to 38.7cm (in the sea level equivalent) at 500 years from the present. The reason of this spread has not examined in detail. *Saito et al.* [2016] present a series of sensitivity experiments using the Ice-sheet model for Integrated Earth-system Studies (IcIES) by replacing one or more formulations of the model parameters with those adopted in other model(s). The figure shows simulated Greenland ice-sheet evolution over 500 years in terms of the sea level change obtained by 6 model configuration, O, A, B, B', D', and E'. The reference experiment O corresponds to that used for submission to the SeaRISE by IcIES, and A, B, B', D', E' correspond to that replacing bedrock, basal sliding formulation, surface mass balance formulation, initialization method, and formulation of ice-margin advance step by step, with a method used by the other participants. The vertical gray bars indicate the range of results summarized in the SeaRISE at 100, 200 and 500 years. It is concluded that the initialization methods and

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the surface mass balance methods have equal largest impact on the results, and that the treatment of ice-sheet margins in the simulation has a secondary impact on the dispersion.

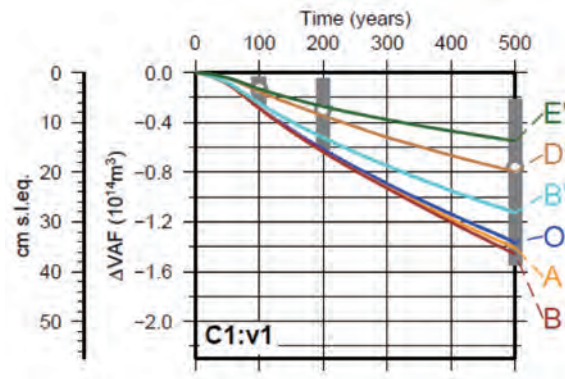


Fig. 4 Simulated changes in Greenland ice-sheet volume above flotation obtained by future-climate runs under A1B climate forcing using IcIES for 500 years, in terms of the difference relative to the result of corresponding constant-climate experiments. [Saito *et al.*, 2016]

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From Localized Heavy Rain Fall to Global Environmental Change – Department of Seamless Environmental Prediction Research –

We have been increasingly feeling the abnormality of daily weather in recent years: severe natural disasters, caused by unprecedented torrential rain and strong winds, have been occurring frequently, as well as extreme weather events such as heat waves (on the one hand,) and heavy snowfall (on the other hand).

It has been pointed out that part of these changes in weather and climate may be attributed to the global environmental change such as global warming. It is not easy, however, to predict the extreme events that have never been observed in the past and to prepare for disasters and changes in daily life.

We, the Department of Seamless Environmental Prediction Research, address the research and development on atmosphere-ocean coupled global cloud-system-resolving model that can predict events on extensive spatiotemporal scales ranging from cloud system causing localized torrential rain, to El Niño phenomena affecting global extreme weather events. We also address the research and development on downscaling technology to generate future projection information about finer-scale local climate change.

Furthermore, we aim to establish a platform for generating and providing seamless environmental prediction information, which would quickly meet the needs of current and future societies, through verifying and upgrading the prediction model systems using observational data and elementary process resolving models. It is also important to elucidate the cloud-precipitation process with multiple structure, which potentially plays a key role to improve reliability in prediction. Below a selected research topic of our department this year.

Global cloud-permitting forecasts for the Pre-YMC campaign on the ES

The Maritime Continent (MC) is known as one of the most convectively active regions over the globe. The MC convection has a broad impact on the world weather and climate, especially over the Asian countries, and hence it has been a major research topic. However, the multi-scale multi-process nature of the MC region makes it difficult to fully understand; ranging from diurnal variation associated with local processes forced by steep orography to inter-annual ocean-atmosphere variation, such as El Nino and Indian Ocean Dipole phenomena. Because of this complexity, numerical simulation and prediction of the MC phenomena are challenging tasks. Lack of observational data also retarded the progress. To deal with this problem, JAMSTEC Department of Coupled Ocean-Atmosphere-Land Processes Research (DCOP) and Research and Development Center for Global Change (RCGC) Ocean-Atmosphere Interaction Research Group conducted the intensive field campaign “Pre-YMC” over the southwest Sumatra during November–December 2015. Many research departments and Research and Development centers in JAMSTEC joined this campaign. Department of Seamless Environmental Prediction Research (DSEP) was in charge of the modeling activity in the “Pre-YMC”. A real-time forecast system using a global nonhydrostatic model (Nonhydrostatic Icsahedral Atmospheric Model, NICAM; [Satoh *et al.*, 2014]) was constructed and operated on the Earth Simulator (ES) throughout the campaign. A major advantage of NICAM is seamless representation of local weather and global climate in a uniform framework, which is suitable to the investigation and prediction of the atmospheric phenomena over the MC. In DSEP NICAM has been developed as a seamless environmental prediction model. Here, we report the outline of the forecast system, the real-time operation on the ES, and highlights of the Pre-YMC campaign.

The design of the forecast system was determined after careful examination of the computational time and minimization of the time for the pre- and post-processes. The month- (week-) long forecasts using the global 14- (7-) km mesh size twice a week (once a day) were realized on the upgraded ES in the FY2015. The horizontal resolution was finer than those of the global operational models (≥ 20 km), marginally resolving mesoscale convective systems, with the explicit treatment of moist convection in NICAM. The computational cost of the forecast system amounts to 100 times that of the old version [Nasuno, 2013], which was operated during the CINDY2011 campaign [Yoneyama *et al.*, 2013] on the PC cluster system. Aiming at understanding the impact of the ocean surface conditions on the atmospheric variability, two-member ensemble runs were made varying the sea surface temperature (SST) setups. The use of the 7-km mesh allowed successful simulation of the primary

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aspects of the diurnal convection which is specific to the MC region, but with a systematic phase delay. The month-long ensemble simulations showed 2~3 weeks prediction skill associated with the intraseasonal variability (e.g., the Madden-Julian Oscillation, MJO; *Madden and Julian* [1971, 1972]). The ensemble spread increased after 2~3-weeks lead time, implying the importance of large ensemble members. The forecasts were initialized using the National Centers for Environmental Prediction (NCEP) global final analysis at around 18 JST, run on the ES (4~6 hours), and after the post-processes (2~3 hours) forecast charts were released on the web and by e-mail. The daily updates were achieved in tight cooperation with the Center for Earth Information Science and Technology (CEIST) on the operational schedule of the ES. The real-time forecasts described above was used for the field operation in grasping the status at the observational site within the large-scale variation including the forthcoming period.

Figure 1 compares the time series of the zonal wind profiles in the radiosonde observation and in the 7-km mesh forecasts. During November 2015, the center of the convective activity and the equatorial lower-tropospheric westerlies persisted over the Indian Ocean, while in the southwest Sumatra diurnal and 4–5-day period variations were pronounced (Fig. 1). An abrupt change occurred around 13 December, when the westerlies rapidly intensified over the MC (Fig. 1), and migrated eastward. The westerlies largely meandered over the western North Pacific in mid-December, and subsequently shifted to the southern hemisphere over the broad

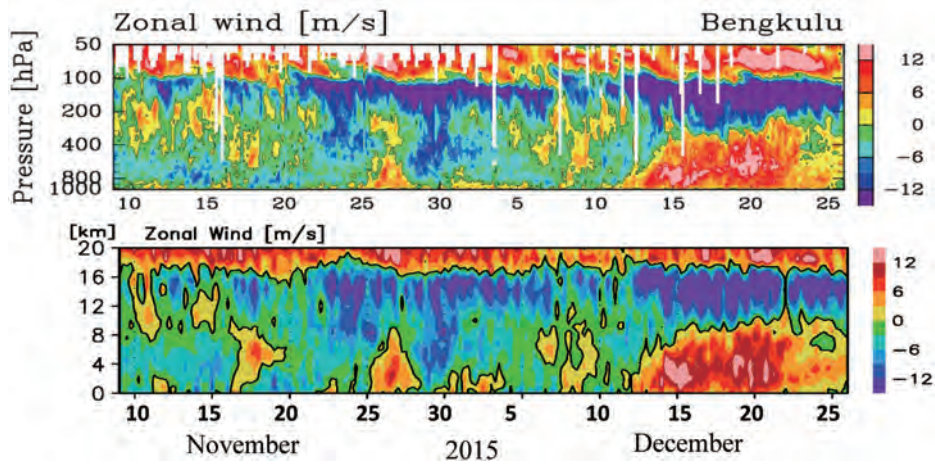


Fig. 1 Time series of zonal wind profiles in (top) the radiosonde observation at Bengkulu station and (bottom) the 7-km mesh NICAM forecasts (the 1-day lead time).

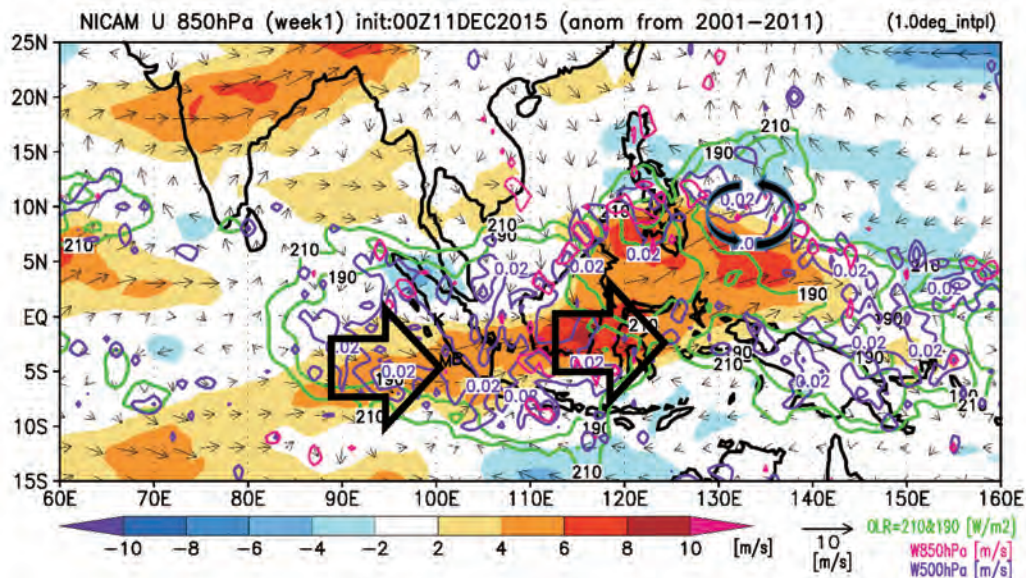


Fig. 2 850-hPa zonal wind anomaly (color) and wind vector, outgoing long wave radiation (green lines), 500-hPa (purple lines) and 850-hPa (magenta lines) vertical velocity in the 14-km mesh NICAM forecasts (11–17 December average).

domain. Such drastic change in the large-scale zonal wind fields was associated with a rapid intensification and propagation of the MJO event under the seasonal march (e.g., *Miura et al.* [2015]). During the intensification of the lower-tropospheric westerlies (Fig. 1), meridional convergence associated with the Rossby wave-like flow fields increased over the MC (Fig. 2), and heavy precipitation was observed on the research vessel *Mirai* and at the Bengkulu station. The month-long forecasts using NICAM successfully simulated these large-scale tendencies 2–3 weeks in advance. The 7-km mesh forecasts showed a significant change in the morphology and behavior of the convective systems associated with the large-scale variability. Before the intensification of the MJO event, westward-propagating synoptic-scale rotational disturbance (corresponding to the 4–5-day period variations in the wind fields, Fig. 1) repeatedly appeared, and the diurnal convection was clear. After the MJO intensification, overall intensification of convective activity dominated the diurnal variation, and eastward-propagating arrow-shaped convective disturbance was pronounced. According to the spectral analysis of satellite data, these disturbances are interpreted as convectively coupled equatorial waves.

In summary, typical diurnal variation over the MC and its variation associated with equatorial disturbances and the MJO were successfully observed and simulated during the Pre-YMC campaign, which serve as a pilot study for the forthcoming YMC campaign (2017–2019). Considering that the Pre-YMC period corresponded to the peak El Niño (JAMSTEC news http://www.jamstec.go.jp/j/jamstec_news/20151104/), the obtained data was useful in probing the ENSO impact on the MC convection and the MJO. In the forthcoming studies in the FY2016, we plan to analyze the observation and simulation data, to deepen our understanding of the relationship between local convection and large-scale variation over the MC.

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Understanding of marine nitrogen cycle based on stable isotope analysis and modeling

– Department of Biogeochemistry –

One of the purposes of this group is to understand key processes and regulation mechanisms of nitrogen cycle including nitrous oxide (N_2O) in the ocean. For this purpose we made various kinds of water sampling for nitrogen isotope analysis and measured nitrogen isotope ratios of individual components of marine nitrogen cycle (Fig. 1), such as phytoplankton, chlorophylls, nitrate, ammonium, particulate organic nitrogen, nitrous oxide, and so on, with our elemental analyzer–isotope ratio mass spectrometer specifically modified to analyze small samples. By using these measured values, we developed marine ecosystem isotope models (Green part in Fig. 1) to comprehensive and quantitative understand the marine nitrogen cycle. Furthermore, based on these marine ecosystem isotope models, we had developed a box-type marine ecosystem isotopomer model last year, which can predict sea-to-air N_2O emissions directly. In this FY, we newly added a nitrite compartment and extended this model to a one-dimensional model. We are planning to further extend to a global ocean model, and conduct global warming experiments with our model in the future.

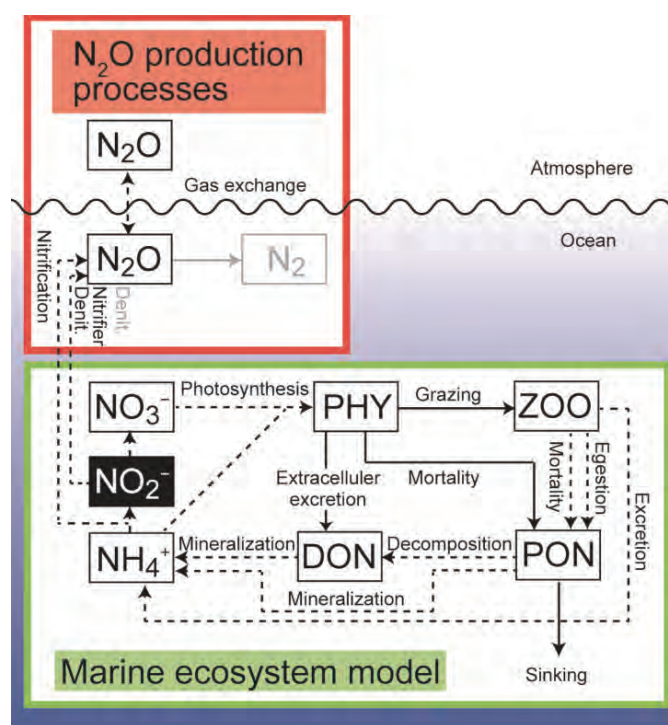


Fig. 1 A schematic representation of the marine ecosystem isotopomer model, which consists of a marine ecosystem model based on Yoshikawa *et al.* [2005] and the N_2O production processes with nitrogen isotopomers based on Yoshikawa *et al.* [2016]. The symbols NO_3^- , NO_2^- , NH_4^+ , PHY, ZOO, PON, and DON represent the nitrate, nitrite, ammonium, phytoplankton, zooplankton, particulate organic nitrogen, and dissolved organic nitrogen concentrations, respectively. The nitrate is newly added. The dashed and solid arrows indicate nitrogen flows with and without isotopic fractionation, respectively. The gray arrows indicate processes not represented in this study.

Insight into nitrous oxide production processes in the western North Pacific based on a one-dimensional marine ecosystem isotopomer model

Nitrous oxide (N_2O) is a greenhouse gas that also destroys the stratospheric ozone. Therefore, it is important to estimate accurately the global N_2O budget in order to better understand the factors that influence atmospheric N_2O concentrations, to develop global warming countermeasures, and to protect the ozone layer. Because estimates of total N_2O emissions vary widely (from 8.1–30.7 Tg N yr^{-1} [IPCC, 2013]), it is necessary to reduce the uncertainty in the estimate of each emission source. Previous models have indirectly predicted marine N_2O emissions from the apparent oxygen utilization (AOU), based on the observed inverse relationship between the dissolved oxygen and N_2O concentrations in the ocean [Suntharalingam and Sarmiento, 2000; Jin and Gruber, 2003; Schmittner and Galbraith, 2008; Rickels et al., 2010; Zamora and Oschlies, 2014]. A model that simulates ammonium oxidation, nitrite reduction, and N_2O reduction explicitly and separately had yet to be reported in the literature.

The two main types of marine N_2O production are ammonium oxidation during nitrification and nitrite reduction during nitrifier denitrification and denitrification. The main marine N_2O consumption process is N_2O reduction during denitrification. Different microbes with distinctive substrates and enzymes mediate each of these processes. Hence, the N_2O production rate for each process has a different environmental dependency. N_2O isotopomers, the differences in the abundance of $^{14}\text{N}^{15}\text{N}^{16}\text{O}$ and $^{15}\text{N}^{14}\text{N}^{16}\text{O}$ (site preference [SP]) and the average nitrogen isotope ratio [$\delta^{15}\text{N}$] are useful tracers to distinguish the various N_2O production processes and have been used in different oceanic environments [e.g., Toyoda et al., 2002; Popp et al., 2002; Yamagishi et al., 2007]. To accurately estimate current and future marine N_2O emissions, we developed a model, which explicitly includes these processes by evaluating observed nitrogen isotope/isotopomer values.

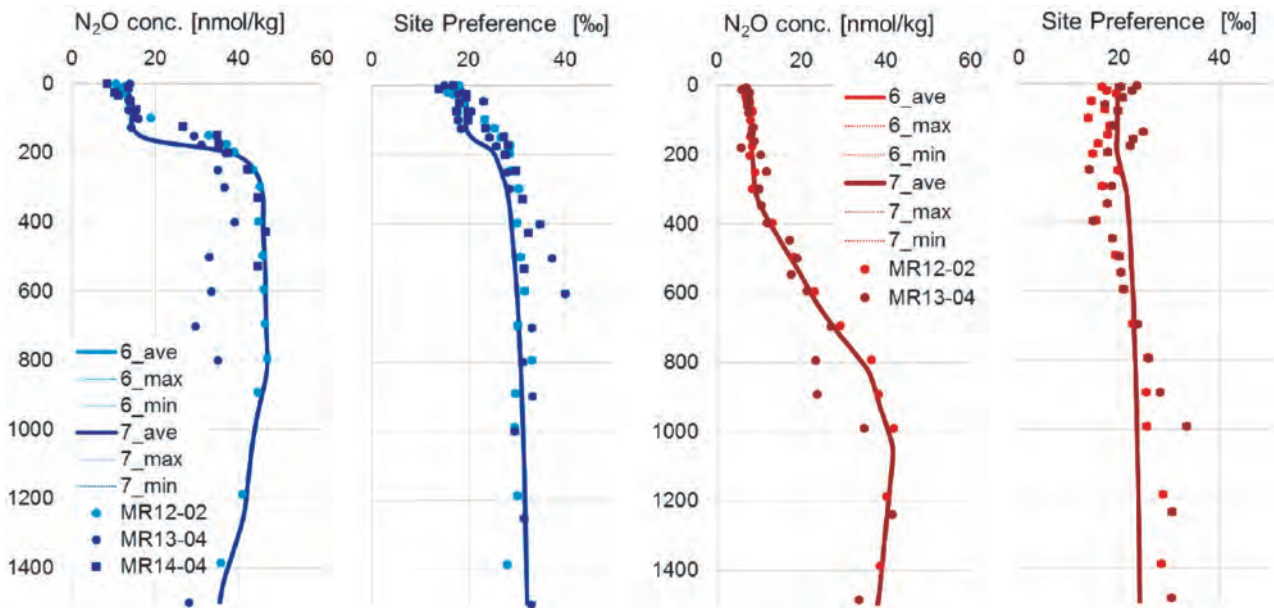


Fig. 2 Simulated (lines) and observed (symbols) vertical distributions of concentrations and site preference values of dissolved N_2O at K2 and S1 in June and July. The observed values are referred from Breider et al. [2005].

We had developed a box-type marine ecosystem isotopomer model in the last year [Yoshikawa et al., 2016]. In this year we added a nitrite compartment, which is a precursor of N_2O , to this model and expanded to a one-dimensional model applied to subarctic K2 and subtropical S1 stations in the western North Pacific. The model was validated with observed seasonal and vertical variations of nitrogen concentration and nitrogen isotope datasets including nitrite. Figure 2 shows the simulated vertical distributions of concentration and site preference value of dissolved N_2O at K2 and S1 in the summer time. The model was also successfully simulated the higher N_2O concentrations, higher $\delta^{15}\text{N}$ values, and higher site preference values for N_2O at K2 compared with S1. Figure 3

shows the seasonal variations of concentration and site preference value of dissolved N_2O at K2 and S1. The N_2O is produced at the bottom of euphotic layer from late autumn to winter in concurrence with the progress of nitrification especially in K2. The produced N_2O is emitted from the ocean to the atmosphere during winter. The annual mean N_2O emissions were estimated to be $41.9 \text{ mg N m}^{-2} \text{ yr}^{-1}$ at K2 and $2.6 \text{ mg N m}^{-2} \text{ yr}^{-1}$ at S1.

Using this model, we conducted two case studies: 1) the case without in-situ biological N_2O production, 2) the case without nitrite reduction. The results of case studies estimated the annual mean N_2O efflux by in-situ biological N_2O production to be $28.6 \text{ mg N m}^{-2} \text{ yr}^{-1}$ at K2 and $2.6 \text{ mg N m}^{-2} \text{ yr}^{-1}$ at S1 and the annual mean N_2O efflux by nitrite reduction to be $2.3 \text{ mg N m}^{-2} \text{ yr}^{-1}$ at K2 and $0.9 \text{ mg N m}^{-2} \text{ yr}^{-1}$ at S1. It is suggested that N_2O was mainly produced via ammonium oxidation at K2 but was produced via both ammonium oxidation and nitrite reduction at S1.

We applied the marine N_2O isotopomer model to an aerobic ocean environment. The next step in improving the estimate of the global ocean N_2O emission will be the addition of denitrification processes to our model and the application of the model to oxygen-deficient zones.

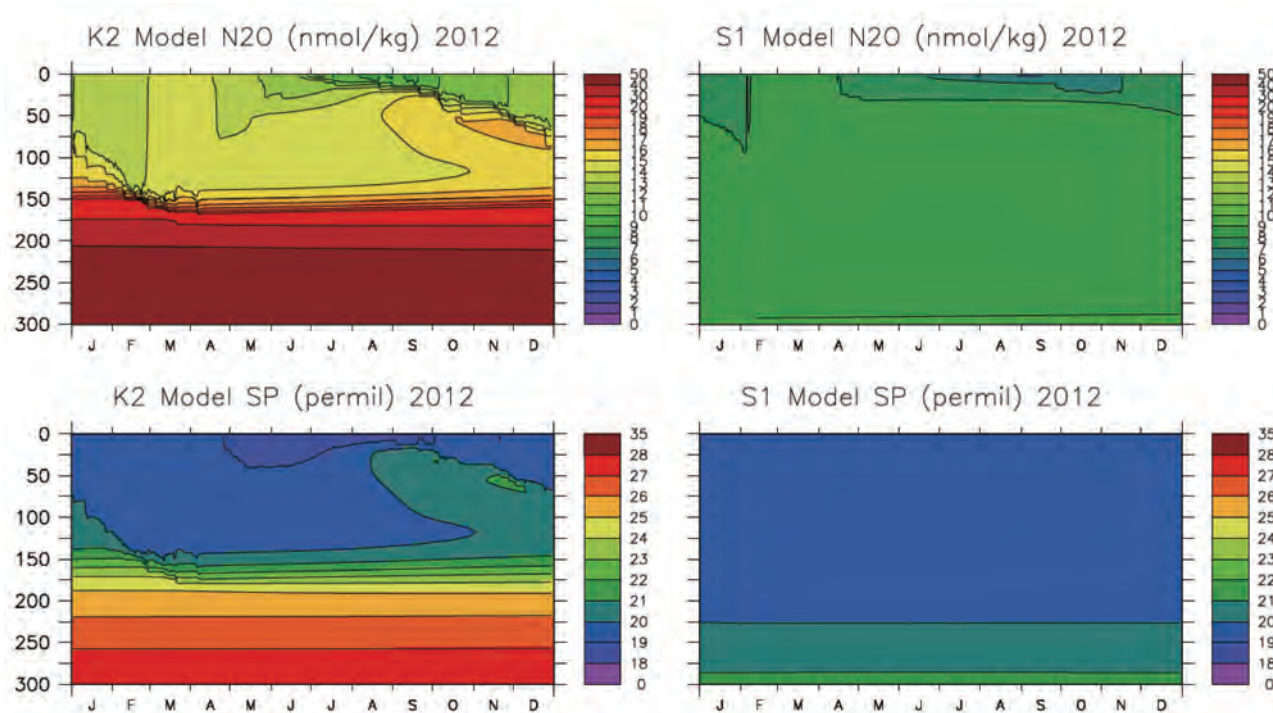


Fig. 3 Simulated seasonal variations of concentration and site preference value of dissolved N_2O in K2 and S1.

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Research of Coastal environment change

– Mutsu Institute for Oceanography –

The research program of the Mutsu institute for oceanography (MIO) aims at investigating coastal environment changes and biogeochemical cycle in coastal area which area might be affected by the global warming and the increasing carbon dioxide concentration. For this purpose, MIO is conducting observational studies around the eastern Tsugaru Strait under the collaborative agreements with the Hokkaido University and the Aomori Prefectural Industrial Technology Research Center.

Our main researches are the measurement of current speed and direction the hydrographic observation in the Tsugaru strait. The current direction and rate are measured continuously using the HF radar which has been installed and operated in April, 2014. These obtained current patterns are distributed to fishermen and others through web site, MORSET (MIO Ocean Radar data Site for Easter Tsugaru Strait, <http://www.godac.jamstec.go.jp/morsets/>) from September 2015. The hydrographic observation by the training ship of Hokkaido University was started in 2009 and it is conducted 4 times a year. The monitor of surface water temperature out of the Sekinehama port is continued from 2002. The hydrographic observations were also started on the pier of Sekinehama Port after we observed the cold Oyashio Water in 2014.



Fig. 1 Schematic of MIO research program

Validation and publishing of HF radar data

We use the HF radar to observe surface current speed and direction around the Eastern Tsugaru Strait. It is needed to validate the observed data because the radar observation is a remote sensing technique. In order to obtain in-situ data, compact sensors (electromagnetic current meters and CTDs) were deployed inside of the radar observation area for 1month (3 September - 1 October, 2015).

The topmost sensor data (~2.5 m below the sea surface) was compare with HF radar data (Fig. 1). In the meridional component (V), very close time series variations were found between radar data and in-situ current measurement (Figs.2a, c). In the zonal component (U), amplitude of current variation of radar data was smaller than that of in-situ data although variation pattern was close in both measurements (Figs. 2b, d). The radar data is calculated by vector synthesis of radial vectors from two radar site. The radial vector from each radar site is

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obtained by least-squares fitting to the original radial vectors in an averaging circle area.

In order to check there are any problems in original radial vectors or not, the in-situ current vector was decomposed into each radial angle, and compared with original radial vectors (Fig. 3). Although the radar data is somewhat noisy, the observations from both stations are close to the in-site data. It means that there would be some problems in calculation processes from original radial vectors to total vectors.

A possible cause of the problem is inappropriate parameters for spatial least-square fitting of radial vectors. The radius of the averaging circle is set to 6km that is factory-recommended value. This radius could be too large to estimate current velocity in the Tsugaru Strait in which complex structure of current is observed. We are undertaking the tuning of these parameters.

Although there is dissatisfaction as underestimate of U component, the quasi real-time current data will be essentially useful for the safe navigation of the ship, fishery activities, and so on. We have cooperated with CEIST-JAMSTEC to build a data publishing site named "MORSETS (MIO Ocean Radar data Site for the Eastern Tsugaru Strait)" (Fig. 4). The current map is updated every 30 minutes and anyone can see changes in current conditions over the past 48 hours via the internet (PC and mobile terminal device). For academic and educational purposes, authorized users can download numerical current data set archived in MORSETS.

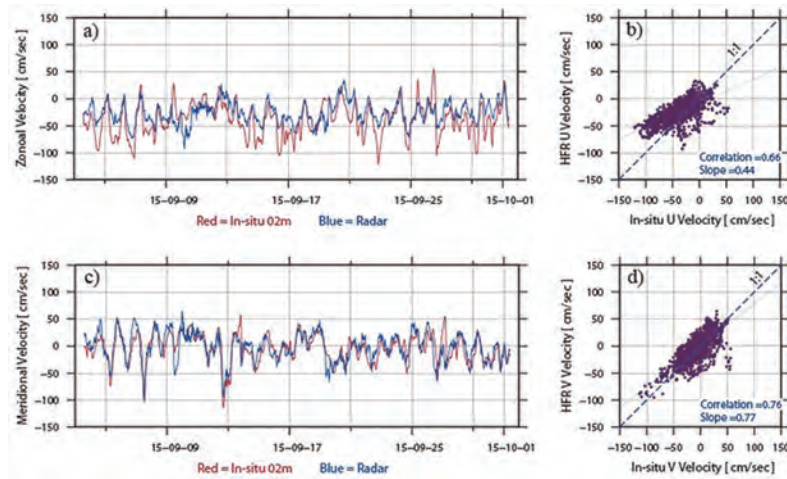


Fig. 2 Comparison of in-situ current observations at 41.48°N, 141.29°E and HF radar data at 41.485°N, 141.291°E (most close station). (a) and (c) are time series comparison for meridional (V) and zonal (U) components, respectively. The red line is in-situ data. The blue line indicate radar data. (b) is plot of radar data against to in-situ data for V component. (d) is same as (b) but for U component.

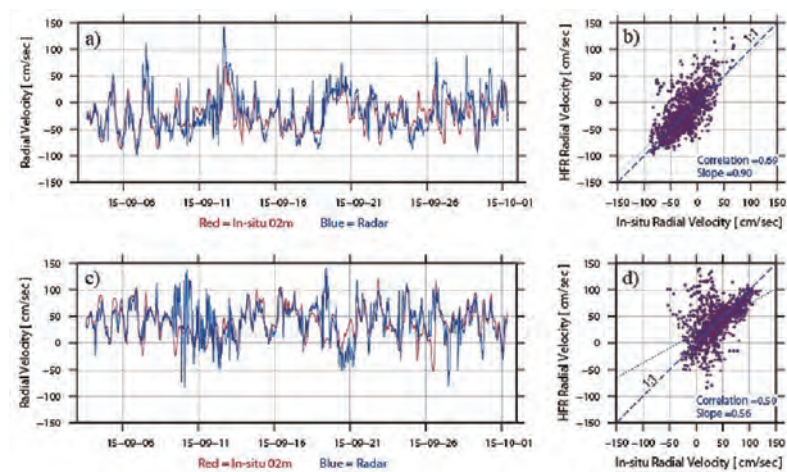


Fig. 3 Comparison of in-situ current observations at 41.48°N, 141.29°E and radial velocity from each HF radar site at most close station. The in-situ observation vector is decomposed into each radial vector angle. (a) and (c) are time series comparison for Shiriya and Ohata stations, respectively. (b) is plot of radial data against to in-situ data for Shiriya site. (d) is same as (b) but for Ohata site. Symbols used in the panels are same manner as Fig. 1.

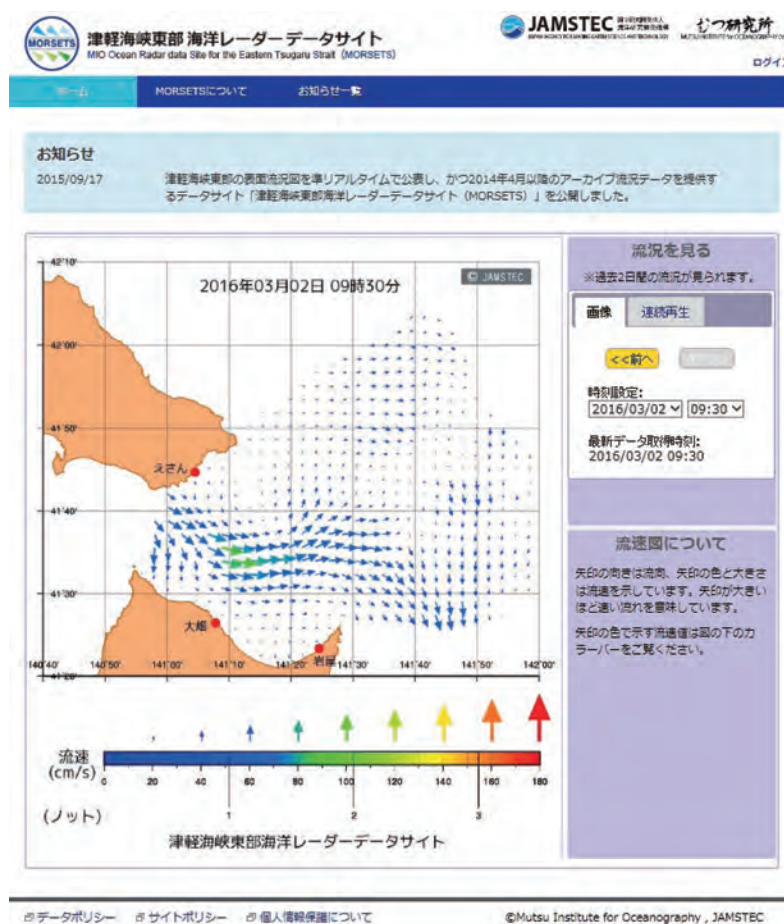


Fig. 4 Example of data site " MORSETS" (at the moment Japanese only).

URL: <http://www.godac.jamstec.go.jp/morsets/j/top/> (same for PC and mobile).

Coastal ocean acidification monitoring in the Tsugaru Strait of northern Japan

Currently, approximately 30 % of the total amount of CO_2 released to the atmosphere by human activities, the anthropogenic CO_2 , is accumulating in the ocean [IPCC, AR5]. Oceanic uptake of anthropogenic CO_2 has resulted in acidification of surface waters which the observed decrease in ocean pH of 0.1 since the beginning of the industrial era [IPCC, AR5]. This ocean acidification has increased the hydrogen ion (H^+) concentration (i.e., lowered the pH) and lowered the CaCO_3 saturation state (Ω), by decreasing the carbonate ion (CO_3^{2-}) concentration. These changes in carbonate chemistry affect marine organisms and ecosystems, calcifying species, throughout the open ocean and coastal seas [Doney *et al.*, 2009]. The changes in pH and Ω have long-term and gradual direct (and indirect) impact on coastal environment strongly characterized by high rates of primary production and export of organic carbon [e.g., Bates *et al.*, 2013]

As there is little ocean acidification monitoring site in the coastal zone of Japan, we started the monitoring to clarify the progression of coastal ocean acidification and carbon cycling on the Tsugaru Strait. We have collected water samples at the pier of Sekinehama Port once a week and measured temperature, salinity, nutrients, dissolved inorganic/organic carbon, total alkalinity, total dissolved nitrogen and $^{18}\text{O}\text{-H}_2\text{O}$ from February 2014. In addition, ship-based observations around the Tsugaru Strait have been carried out every season since summer in 2012.

In the winter of 2014, the coastal Oyashio water have reached to the eastern Tsugaru Strait for the first time in 30 years. This will be caused by the subsurface water in this strait originated from northern Sea of Japan water, although subsurface usually characterized Tsugaru warm current. Then, pH and Ω with respect to the CaCO_3 minerals forms of aragonite ($\Omega_{\text{aragonite}}$) in the winter of 2014 (the coastal Oyashio water) were very lower

I. Research Activities and Results

Mutsu Institute for Oceanography

than those in 2015 and 2016. This unexpectedly and suddenly declines of Temperature, pH and $\Omega_{\text{aragonite}}$ in 2014 might affected on anglerfish and scallop in the eastern Tsugaru Strait. To detect temporal ocean acidification and the impact on the carbon cycle will require more accurate and longer time-series data in future.

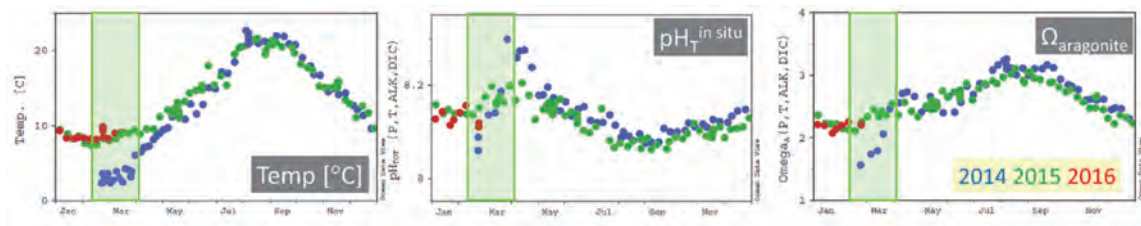


Fig.5 Seasonal variations of sea surface temperature, pH and $\Omega_{\text{aragonite}}$ in the Sekinehama Port of in the Mutsu Institute for Oceanography from 2014 to 2016.

II. Related Activities

Research collaboration

1. Domestic research collaboration

(1) Atmosphere and Ocean Research Institute (AORI), The University of Tokyo

Theme: A Pilot Study of Microstructure Measurements with Fast-response Thermistors Attached with a Rosette Water Sampler During Basin-scale Hydrographic Observations

Program: Research and Development Center for Global Change

(2) Institute of Low Temperature Science, Hokkaido University

Theme: Study of Mechanism to Sustain Primary Productivity and Biogeochemical Cycle in the Subarctic North Pacific Including its Marginal Seas such as Okhotsk and Bering Seas

Program: Research and Development Center for Global Change

(3) National Institute for Environmental Studies (NIES)

Theme: Improvement of the Shipboard Lidar Observation to Study Oceanic Water Vapor, Cloud and Aerosol

Program: Research and Development Center for Global Change

(4) National Institute of Technology, Ibaraki College (NITIC)

Theme: Fundamental Study for Developing the Ultra-precision Paleoproxy by the Microscale Stable Isotope Analysis of Cultured Foraminiferal Shells

Program: Research and Development Center for Global Change

(5) National Institute of Polar Research (NIPR)

Theme:

- Studies on Greenhouse Gas Cycles in the Arctic and their Responses to Climate Change

- Ecosystem Studies on the Arctic Ocean Declining Sea Ice

Program: Research and Development Center for Global Change

- Projection of Sea Ice Distribution and Arctic Sea Routes

(7-2) Coordinated observational and modeling studies on the basic structure and variability of the Arctic sea ice-ocean system

Program: Project Team for Risk Information on Climate Change

- Atmospheric Studies on Arctic Change and its Global Impacts

Program: Application Laboratory

- Changes in Terrestrial Ecosystems of the Pan-Arctic and their Effects on Climate

- The Role of Arctic Cryosphere in Global Change

Program: Department of Environmental Geochemical Cycle Research

- Improvement of Coupled General Circulation Models Based on Validations of Arctic Climate

Reproducibility and on Mechanism Analysis of Arctic Climate Change and Variability

Program: Department of Integrated Climate Change Projection Research

(6) Kyoto University Graduate School of Advanced Integrated Studies in Human Survivability (GSAIS)

Theme: Advanced Ocean Modeling Combined with River Discharge Information

Program: Application Laboratory

II. Related Activities
Research collaboration

(7) National Institute for Agro-Environmental Sciences (NIAES)

Theme: Pilot Study on Developing a Coupled Climate and Large Scale Process-based Crop Model for the Assessment of Crop Productivity Impact Caused by Extreme Climate
Program: Application Laboratory

(8) Institute of Tropical Medicine, Nagasaki University

Theme: Establishment of an Early-warning System for Infectious Diseases in Southern Africa Incorporating Climate Predictions
Program: Application Laboratory

(9) Kobe University

Theme: Studies on Model Expression to Better Describe Atmospheric Ozone Behavior Using Observations as Target
Program: Department of Environmental Geochemical Cycle Research

(10) National Agriculture and Food Research Organization (NARO) / National Research Institute for Earth Science and Disaster Resilience (NIED) / Akita University

Theme: Domestic Observations on Thermal and Hydrological States on and Below Surface
Program: Department of Integrated Climate Change Projection Research

(11) Meteorological Research Institute (MRI), Japan Meteorological Agency (JMA)

Theme: Ultrahigh Precision Meso-Scale Weather Prediction
Theme: Improvement of mesh meteorological data accuracy using a regional climate model
Program: Department of Seamless Environmental Prediction Research

(12) RIKEN

Theme: Collaborative Research for the Evaluation of the Common Platform for Climate Simulation
Program: Project Team for Risk Information on Climate Change

(13) Kyushu University, Institute for Advanced Study

Theme: Deposition of aerosol particles on the North Pacific and the Arctic region
Program: Research and Development Center for Global Change

(14) National Institute of Advanced Industrial Science and Technology (AIST)

Theme: Evaluation of a densitometer based on refractive index measurement
Program: Research and Development Center for Global Change

2. International research collaboration

A. Interagency agreement (*extracted based on the areas of cooperation related to Research and Development on Marine and Global Environmental Change)

(1) The Woods Hole Oceanographic Institution (WHOI), USA

Theme:

- Arctic Research
Program: Institute of Arctic Climate and Environment Research
- Physical Oceanography and WOCE Hydrographic Lines Revisits
Program: Research and Development Center for Global Change
- Biogeochemistry and the Carbon Cycles
Program: Mutsu Institute for Oceanography
- Extra-tropical Ocean-Atmosphere variability and predictability
Program: Application Laboratory

(2) Scripps Institution of Oceanography (SIO), USA

Theme: Study of Ocean General Circulation and Climate

Programs: Research and Development Center for Global Change

(3) The Trustees of Columbia University in New York, Lamont-Doherty Earth Observatory (LDEO), USA

Theme: Climate Change in Relation to Dynamics of Marine Ecosystem and Biogeochemical Cycles

Program: Department of Environmental Geochemical Cycle Research

(4) The Office of Oceanic and Atmospheric Research (OAR) of the National Oceanic and Atmospheric Administration (NOAA), USA

Theme:

- Indo-Pacific Tropical Ocean and Climate Research (Scientific and Technology Development Cooperation)
Program: Research and Development Center for Global Change
- Cooperation in Maintaining JAMSTEC and PMEL Contributions to Indian Ocean Observing System (IndOOS) (Cooperation with other countries, e.g., Indonesia, France)
Program: Research and Development Center for Global Change
- Ocean and Climate Research in the North Pacific; Cooperation in Developing and Maintaining JAMSTEC and PMEL Contributions to the North Pacific Surface Mooring Network
Program: Research and Development Center for Global Change
- Arctic Observation
Program: Institute of Arctic Climate and Environment Research
- CO₂ and other Autonomous Biogeochemical Sensors
Program: Mutsu Institute for Oceanography
- Computer Modeling for Global Environment Research
Program: Department of Integrated Climate Change Projection Research
- Ocean Acidification
Program: Research and Development Center for Global Change

(5) The University of Hawaii (UH), USA

Theme: Study on Climate Change and Variability in the Asia-Pacific region

Program: Application Laboratory

(6) The University of Alaska Fairbanks (UAF), USA

Theme:

- Greenhouse Gas Dynamics of Boreal Forest and Tundra Ecosystems Vulnerability to Arctic Warming
Program: Department of Environmental Geochemical Cycle Research
- Arctic Ocean Observation Research
Program: Institute of Arctic Climate and Environment Research
- Northern Fresh Water Cycle and Changing Atmospheric Pattern
Program: Department of Environmental Geochemical Cycle Research

(7) The National Oceanography Centre (NOC) and The University of Southampton (UoS), UK

Theme:

- Geology and Geophysics (Palaeoceanography)
Program: Department of Biogeochemistry
- Physical Oceanography (The Argo Programme, Global Ocean Circulation)
Program: Research and Development Center for Global Change

(8) Agency for the Assessment and Application of Technology of the Republic of Indonesia (BPPT), Indonesia

Theme:

- Tropical Ocean Climate Observational and Modeling Studies
Program: Research and Development Center for Global Change
- Climate Dynamics Research over the Maritime Continent
Program: Department of Coupled Ocean-Atmosphere-Land Processes Research

(9) The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Theme:

- Heat, Carbon and other Material Transports through Ocean Circulation and their Variability
- Planktonic Community Comparisons, including those of the Continuous Plankton Recorder, in Australasian and Japanese regions
- Ocean Modelling and Data Assimilation
- Real-time Monitoring of the Global Ocean, including Polar and Deep-water Extensions
- Indo-Pacific Ocean and Atmosphere Dynamics
Program: Research and Development Center for Global Change

(10) Department of Fisheries and Oceans (DFO), Canada

Theme:

- Observing and Modeling Ocean Climate Variability in the upper 200-300m layer of the Arctic Ocean
- Observing and Modeling Physical, Chemical and Biological Processes of Shelf/Basin Interaction
- Determining the Freshwater and Chemical Budgets of the Bering, Chukchi and Beaufort Seas
- Monitoring and Modeling the Evolution of Ice-Thickness Variability in both Shelf and Offshore Domains
Program: Institute of Arctic Climate and Environment Research

(11) Korea Institute of Ocean Science and Technology (KIOST), Korea

Theme:

- Western Pacific Ocean Circulation and Air-Sea Interaction
Program: Research and Development Center for Global Change
- Nonlinear Wave Interaction
Program: Application Laboratory

(12) The Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), Germany

Theme:

- Polar Research and Technology
Program: Institute of Arctic Climate and Environment Research
- Atmospheric Research
Program: Application Laboratory

(13) L'Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), France

Theme:

- Ocean Monitoring
Program: Research and Development Center for Global Change
- Simulation Research with the Earth Simulator
Program: Application Laboratory

(14) Council of Scientific and Industrial Research – National Institute of Oceanography (NIO), India

Theme:

- Upper Ocean Dynamics and Air-Sea Interactions in the Tropical Indian Ocean
Program: Research and Development Center for Global Change
- Ocean Biogeochemistry in the Indian Ocean and Impact on Ocean Climate
Program: Research and Development Center for Global Change

(15) Agency for Meteorology, Climatology and Geophysics of the Republic of Indonesia (BMKG), Indonesia

Theme: Marine Meteorology and Climate Studies over the Maritime Continent

Program: Department of Coupled Ocean-Atmosphere-Land Processes Research

B. Research cooperation agreement between each research program and foreign institute on specific theme

(1) The University of Alaska Fairbanks (UAF), USA

Theme: Greenhouse Gas Dynamics of Boreal Forest and Tundra Ecosystems Vulnerable to Arctic Warming
Program: Department of Environmental Geochemical Cycle Research

(2) The University of Hawaii (UH), USA

Theme:

- Sub-seasonal Predictability of Tropical and Extratropical Climate Modes

Program: Application Laboratory

- High-resolution Atmospheric Modeling and Diagnosis

Program: Department of Seamless Environmental Prediction Research

- Mid-Latitude Ocean-Atmosphere Variability

Program: Application Laboratory

- Climate/biogeochemical Interactions in the North Pacific during the past 18,000 Years

Program: Research and Development Center for Global Change

- Unraveling the Coupled Air-Sea Interaction Processes in CFES in Shaping the Monsoon-Indian Ocean Basic States

Program: Application Laboratory

(3) Department of Fisheries and Oceans (DFO), Canada

Theme: Pan-Arctic Climate Investigation

Program: Institute of Arctic Climate and Environment Research

(4) Agency for the Assessment and Application of Technology of the Republic of Indonesia (BPPT), Indonesia

Theme:

- Research Collaboration in Climatology, Meteorology, and Hydrometeorology over Indonesian Maritime Continent

Program: Department of Coupled Ocean-Atmosphere-Land Processes Research

- Tropical Ocean Climate Observational Studies

Program: Research and Development Center for Global Change

(5) Anhui Institute of Optics and Fine Mechanics (AIOFM), Chinese Academy of Sciences, China

Theme: Research Cooperation of Atmospheric Composition Change related to Environmental and Climate Change

Program: Department of Environmental Geochemical Cycle Research

(6) Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences, China

Theme: Research Cooperation of Atmospheric Composition Change related to Environmental and Climate Change

Program: Department of Environmental Geochemical Cycle Research

(7) Advanced Environmental Monitoring Research Center (ADEMRC), Gwangju Institute of Science and Technology, Korea

Theme: Research Cooperation of Atmospheric Composition Change related to Environmental and Climate Change

Program: Department of Environmental Geochemical Cycle Research

- (8) **Center for Oceanographic Research in the eastern South Pacific (COPAS) of Universidad de Concepción (UDEC), Chile**
Theme: Basic Research on Paleoceanography, Biogeochemistry, Biology and Physical Oceanography in the Coastal Area off Chile
Program: Research and Development Center for Global Change
- (9) **Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) of the Department of Science and Technology (DOST), Philippines**
Theme: Monsoon Experiment in the Republic of the Philippines
Program: Department of Coupled Ocean-Atmosphere-Land Processes Research
- (10) **Aero-Meteorological Observatory of National Hydro-Meteorological Service (AMO/NHMS), Vietnam**
Theme: Research Collaboration on Asian Monsoon Observation over Vietnam
Program: Department of Coupled Ocean-Atmosphere-Land Processes Research
- (11) **A.M. Obukhov Institute of Atmospheric Physics (IAP), Russian Academy of Sciences, Russia**
Theme: Research Cooperation of Atmospheric Composition Change related to Environmental and Climate Change
Program: Department of Environmental Geochemical Cycle Research
- (12) **Institute for Biological Problems of Cryolithozone (IBPC), Siberian Branch of Russian Academy of Sciences, Russia**
Theme: Observational Study of Vegetation, Energy and Water in Eastern Siberia towards Elucidation of Climate and Carbon Cycle Changes
Program: Department of Environmental Geochemical Cycle Research
- (13) **Melnikov Permafrost Institute (MPI), Siberian Branch of Russian Academy of Sciences, Russia**
Theme: Observational study of Permafrost, Vegetation, Energy and Water in Eastern Siberia towards Elucidation of the Impact of Climate Change in the Geochemical Cycle
Program: Department of Environmental Geochemical Cycle Research
- (14) **Departement Oceanographie et Dynamique des Ecosystemes, L'Institut Français de Recherche pour l'Exploitation de la Mer (ODF/IFREMER), France**
Theme: Scale Interactions and Material Transport using Output from High-resolution Ocean Simulations
Program: Application Laboratory
- (15) **Agency for Meteorology, Climatology and Geophysics of the Republic of Indonesia (BMKG), Indonesia**
Theme: Weather and Climate over the Indonesian Maritime Continent
Program: Department of Coupled Ocean-Atmosphere-Land Processes Research

Funded research projects

(1) Development of a New Ecosystem Model to Represent the Adaptive Capacity of Plankton Communities in the North Pacific (FY2012-2017)

Fund: Core Research for Evolutional Science and Technology (CREST)

Funding institution: Japan Science and Technology Agency (JST)

Program: Research and Development Center for Global Change

(2) Validation Experiments of GPM/DPR on the Pure-oceanic Precipitating Clouds by Instruments on board R/V Mirai (FY2013-2015)

Fund: 7th Precipitation Measuring Mission (PMM) Research Announcement

Funding institution: Japan Aerospace Exploration Agency (JAXA)

Program: Research and Development Center for Global Change

(3) Validation of GPM DPR Rainfall Products with Long-term Observations in Palau (FY2013-2015)

Fund: 7th Precipitation Measuring Mission (PMM) Research Announcement

Funding institution: Japan Aerospace Exploration Agency (JAXA)

Program: Research and Development Center for Global Change

(4) Commissioned business of measurement of certified reference material of nutrients (FY2015)

Institution: The General Environmental Technos Co., Ltd.

Program: Research and Development Center for Global Change

(5) Research on use and improvement of ocean database (FY2015-2017)

Fund: Environment Research and Technology Development Fund (ERTDF)

Funding institution: Meteorological Research Institute (MRI), Japan Meteorological Agency (JMA)

Program: Research and Development Center for Global Chang

(6) Production of Wave and Ocean Current Reanalysis Data (FY2013-2015)

Fund: Research and Development of the Renewable Energy Conversion including Utilization of Atmospheric and Oceanic Phenomena, Focusing on Implementation of Oceanic Power Generation Systems

Funding institution: New Energy and Industrial Technology Department Organization (NEDO)

Program: Application Laboratory

(7) Common basic research on ocean energy power generation: estimation of energy potential (FY2014-2015)

Fund: Research and Development of the Ocean Renewable Energy Conversion

Funding institution: New Energy and Industrial Technology Department Organization (NEDO)

Program: Application Laboratory

(8) Establishment of an Early-warning System for Infectious Diseases in Southern Africa Incorporating Climate Predictions (FY2014-2016)

Fund: Science and Technology Research Partnership for Sustainable Development (SATREPS)

Funding institution: Japan Agency for Medical Research and Development (AMED)

Program: Application Laboratory

(9) Prediction of newly found climate phenomena and its societal application (FY2014-2016)

Fund: Environment Research and Technology Development Fund (ERTDF)

Funding institution: Ministry of the Environment

Program: Application Laboratory

(10) Study of scientific data and forecast systems for the information infrastructure (FY2015)

Institution: The Sasakawa Peace Foundation (SPF)

Program: Application Laboratory

(11) Assimilation of high-resolution satellite sea surface temperature data, including Himawari-8, into numerical ocean models and validation of the products (FY2015-2018)

Fund: A contract research funded by Japan Aerospace Exploration Agency

Funding institution: Japan Aerospace Exploration Agency (JAXA)

Program: Application Laboratory

(12) Arctic Challenge for Sustainability (ArCS) (FY2015-2019)

Fund: National flagship project funded by the Ministry of Education, Culture, Sports, Science and Technology

Funding institution: Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Program: Institute of Arctic Climate and Environment Research

(13) Climatic Changes and Evaluation of their Effects on Agriculture in Asian Monsoon Region (FY2011-2015)

Fund: Green Network of Excellence (GRENE) Program; Environmental Information Project

Funding institution: Graduate School of Agricultural and Life Sciences, The University of Tokyo

Program: Department of Coupled Ocean-Atmosphere-Land Processes Research

(14) Multi-scale Climatology of Coastal Heavy Rainbands over the Indonesian Maritime Continent using Satellite and Ground Based Radar Observations (FY2013-2015)

Fund: 7th Precipitation Measuring Mission (PMM) Research Announcement

Funding institution: Japan Aerospace Exploration Agency (JAXA)

Program: Department of Coupled Ocean-Atmosphere-Land Processes Research

(15) Was the Typhoon Yolanda strongest in the observation history in the Philippines? (FY2014-2015)

Fund: J-RAPID

Funding institution: Japan Science and Technology Agency (JST)

Program: Department of Coupled Ocean-Atmosphere-Land Processes Research

(16) Studies on effects of large-scale tropical disturbances upon climate in East Asia (FY2015-2017)

Fund: Environment Research and Technology Development Fund (ERTDF)

Funding institution: Atmosphere and Ocean Research Institute (AORI), The University of Tokyo

Program: Department of Coupled Ocean-Atmosphere-Land Processes Research

(17) Mapping and Spatio-temporal Change Detection of Biodiversity and Ecosystem Functions by Remote Sensing (FY2011-2015)

Fund: Environment Research and Technology Development Fund (ERTDF)
Funding institution: Tohoku University
Program: Department of Environmental Geochemical Cycle Research

(18) Improvement of terrestrial carbon cycle estimation by effective use of various GCOM-C1 SGLI products (FY2013-2015)

Fund: Global Change Observation Mission (GCOM) Research Announcement
Funding institution: Japan Aerospace Exploration Agency (JAXA)
Program: Department of Environmental Geochemical Cycle Research

(19) Development of Integrative Information of the Terrestrial Ecosystem (FY2013-2015)

Fund: Global Change Observation Mission (GCOM) Research Announcement (RA102)
Funding institution: Japan Aerospace Exploration Agency (JAXA)
Program: Department of Environmental Geochemical Cycle Research

(20) Tropospheric ozone pollution over East Asia by synergism of innovative satellite observations, in situ measurements and models (FY2014-2015)

Fund: Joint research under JSPS's bilateral programs (Japan-France Integrated Action Initiatives (SAKURA))
Funding institution: Japan Society for the Promotion of Science (JSPS) / Ministère des Affaires étrangères et du Développement international (MAE)
Program: Department of Environmental Geochemical Cycle Research

(21) Integrated carbon observation and analysis system for early detection of carbon cycle change in global and Asia-Pacific region

Developing an optimal combination of an atmospheric transport model and CO₂ inversion/assimilation method towards an integrated analysis system (FY2014-2016)

Fund: Environment Research and Technology Development Fund (ERTDF)
Funding institution: National Institute for Environmental Studies (NIES)
Program: Department of Environmental Geochemical Cycle Research

(22) Evaluation of spatio-temporal patterns in terrestrial carbon budget based on integrated land observation data (FY2014-2016)

Fund: Environment Research and Technology Development Fund (ERTDF)
Funding institution: National Institute for Environmental Studies (NIES)
Program: Department of Environmental Geochemical Cycle Research

(23) Regional-scale aerosol observations and model evaluations (FY2014-2016)

Fund: Environment Research and Technology Development Fund (ERTDF)
Funding institution: Graduate School of Science, The University of Tokyo
Program: Department of Environmental Geochemical Cycle Research

(24) Estimation of Asian CH₄ emission and evaluation of emission reduction by inverse modeling (FY2015-2017)

Fund: Environment Research and Technology Development Fund (ERTDF)
Funding institution: Nara Women's University
Program: Department of Environmental Geochemical Cycle Research

(25) Impacts of Short-Lived Climate Pollutants from Asia on the Arctic Climate and Environment (FY2015-2017)

Fund: Environment Research and Technology Development Fund (ERTDF)
Funding institution: National Institute for Environmental Studies (NIES)
Program: Department of Environmental Geochemical Cycle Research

(26) Effective utilization of new satellite observations on air pollution at km-class spatial resolution for frontier science and policy on ozone and PM_{2.5} issues (FY2015-2017)

Fund: Coordination Funds for Promoting AeroSpace Utilization
Funding institution: Ministry of Education, Culture, Sports, Science and Technology (MEXT)
Program: Department of Environmental Geochemical Cycle Research

(27) C budget of ecosystems and cities and villages on permafrost in eastern Russian Arctic (COPERA) (FY2015-2019)

Fund: Strategic International Research Cooperative Program “Belmont Forum”
Funding institution: Japan Science and Technology Agency (JST)
Program: Department of Environmental Geochemical Cycle Research

(28) Elucidating variability of stratospheric circulations associated with a global warming (FY2015-2017)

Fund: Environment Research and Technology Development Fund (ERTDF)
Funding institution: Atmosphere and Ocean Research Institute (AORI), The University of Tokyo
Program: Department of Integrated Climate Change Projection Research

(29) Climate change projection contributing to stabilization target setting promotion for climate change research and linkage coordination (FY2012-2016)

Fund: Program for Risk Information on Climate Change
Funding institution: Ministry of Education, Culture, Sports, Science and Technology (MEXT)
Program: Project Team for Risk Information on Climate Change

(30) Prediction and Diagnosis of Imminent Global Climate Change (FY2012-2016)

Fund: Program for Risk Information on Climate Change
Funding institution: Atmosphere and Ocean Research Institute (AORI), The University of Tokyo
Program: Project Team for Risk Information on Climate Change

(31) Analysis for Climate Change in Water Vapor Variation (FY2013-2015)

Fund: Environment Research and Technology Development Fund (ERTDF)
Funding institution: Ministry of the Environment
Program: Department of Seamless Environmental Prediction Research

II. Related Activities

Funded research projects

(32) Impact of Short Lived Climate Pollutants on Global Water Cycle (FY2014-2018)

Fund: Environment Research and Technology Development Fund (ERTDF)

Funding institution: Kyushu University

Program: Department of Seamless Environmental Prediction Research

(33) Meteorological and Agricultural Information System (FY2014-2018)

Fund: Cross-ministerial Strategic Innovation Promotion Program

Funding institution: Central Region Agricultural Research Center (CARC), National Agriculture and Food Research Organization (NARO)

Program: Department of Seamless Environmental Prediction Research

(34) Development and improvement of the method for isolation and purification of various organic compounds to evaluate the dynamics of marine ecosystems and material cycling (FY2013-2018)

Fund: Core Research for Evolutional Science and Technology (CREST)

Funding institution: Japan Science and Technology Agency (JST)

Program: Department of Biogeochemistry

Awards

- **The Geochemical Journal Award 2015, Goldschmidt 2015**

Dr. Haruna Sugahara (Department of Biogeochemistry)

Glycine Oligomerization up to Triglycine by Shock Experiments Simulating Comet Impacts
(August, 2015)

- **The Japanese Society of Snow and Ice Technology Prize 2015**

Dr. Hironori Yabuki (Department of Environmental Geochemical Cycle Research)

Development of cryosphere data archive and analysis system
(September, 2015)

- **JSST2015 International Conference on Simulation Technology Outstanding Presentation Award**

Dr. Kazuyoshi Oouchi (Department of Seamless Environmental Prediction Research)

Extraction, Classification and Visualization of Cloud simulated by Atmospheric General Circulation Model
(February, 2016)

- **Research Award of Society of Genome Microbiology, Japan**

Dr. Takuro Nunoura (Research and Development Center for Marine Biosciences)

Molecular Environmental Microbiology in Marine and Subsurface Environments
- Visualization of Geochemical Cycles with Microbial Genomic Signatures-
(March, 2016)

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Research and Development on Marine and Global Environmental Change

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