

Research Institute for Global Change (RIGC) Annual Report FY2023



JAMSTEC

Japan Agency for Marine-Earth Science and Technology



Research Institute for Global Change (RIGC)
Annual Report FY2023
(April 2023–March 2024)

Organization



Research Institute for Global Change (RIGC)

Annual Report FY2023

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I. Research Activities and Results

– Global Ocean Observation Research Center (GOORC) – Success in detecting changes in temperature-salinity relationships in the deep North Pacific

The use of the International Association of Physical Sciences of the Ocean (IAPSO) Standard Seawater (SSW) is essential for salinity measurements to ensure intercomparability. However, batch-to-batch comparisons indicate that the certified Practical Salinity (S_P) may be imprecise by about ± 0.002 , and that imprecision may be too large for reliable detection of slight salinity changes in the deep ocean. Although offsets in certified values can be estimated from batch-to-batch comparisons (Uchida et al., 2024a), the estimation errors can accumulate and cause critical errors in the estimated salinity changes.

We compared a robust and stable reference seawater, the Multiparametric Standard Seawater (MSSW) (Uchida et al., 2024c), with SSW, and found a possible increase in the S_P ($0.1 \times 10^{-3} \text{ y}^{-1}$) of SSW over time, due to the compositional change of IAPSO SSW (Uchida et al., 2024b). We took into consideration this increasing trend to reevaluate the batch offsets of SSW batches P29–P167 (Uchida, 2024). We evaluated the batch correction by applying it to time-series salinity data in the North Pacific from stations K2 (47°N , 160°E) and ALOHA ($22^\circ 45'\text{N}$, 158°W). We found salinity increases on isotherms ($0.29 \pm 0.09 \times 10^{-3} \text{ g kg}^{-1} \text{ decade}^{-1}$ at a potential temperature of 1.09°C) and warming ($3.3 \pm 0.1 \times 10^{-3}^\circ\text{C decade}^{-1}$) at the bottom of station K2 (Fig. 1). The increasing trend

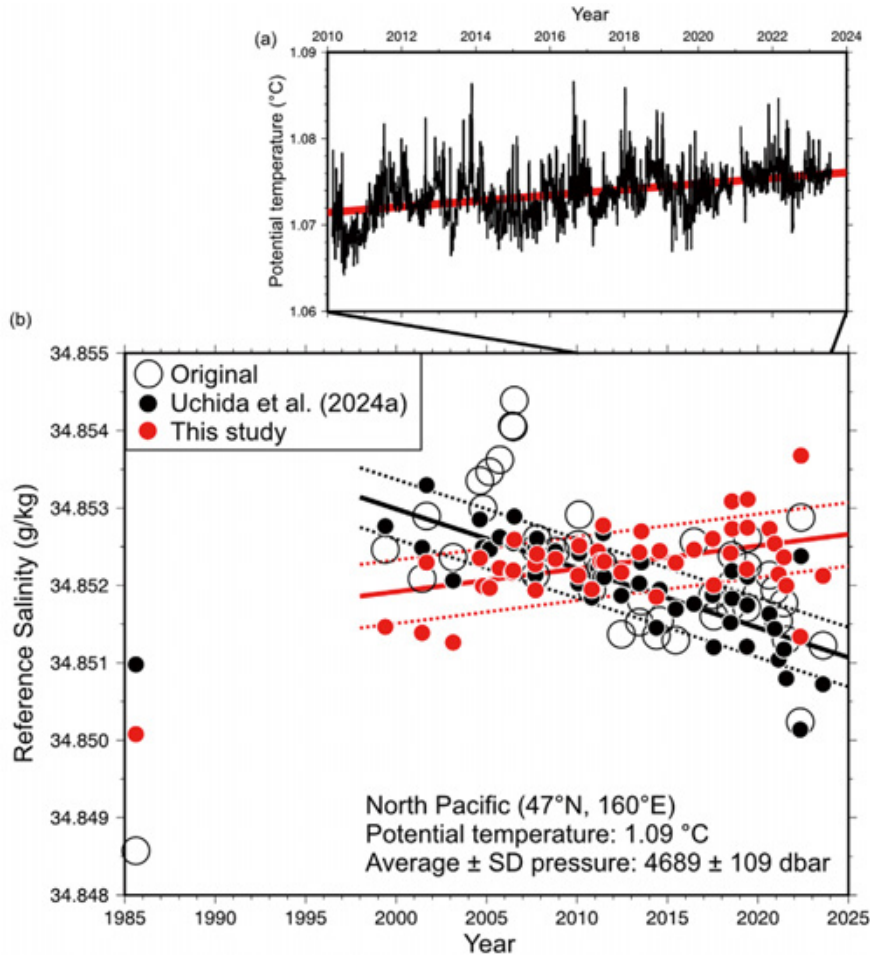


Fig. 1 Time series of (a) potential temperature at 34 m above the seafloor ($\sim 5280 \text{ dbar}$) measured by a moored CTD and (b) Reference Salinity (S_R) at a potential temperature of 1.09°C extracted from the temperature–salinity relationship for the bottom water in the northwestern North Pacific derived from shipboard CTD data (46 profiles) obtained at station K2. The red line in (a) is an ordinary least squares regression line. In (b), open circles represent the original S_R data, black closed circles are S_R data after application of the previous batch offset correction for IAPSO SSW by Uchida et al. (2024a), and red closed circles are S_R data after application of the initial batch offset and the temporal drift correction for IAPSO SSW proposed by this study. The black and red solid lines are the regression lines fitted to the black and red closed circles, respectively, and the dotted lines show their $\pm$ SDs from the regression lines estimated from the data after 1998.

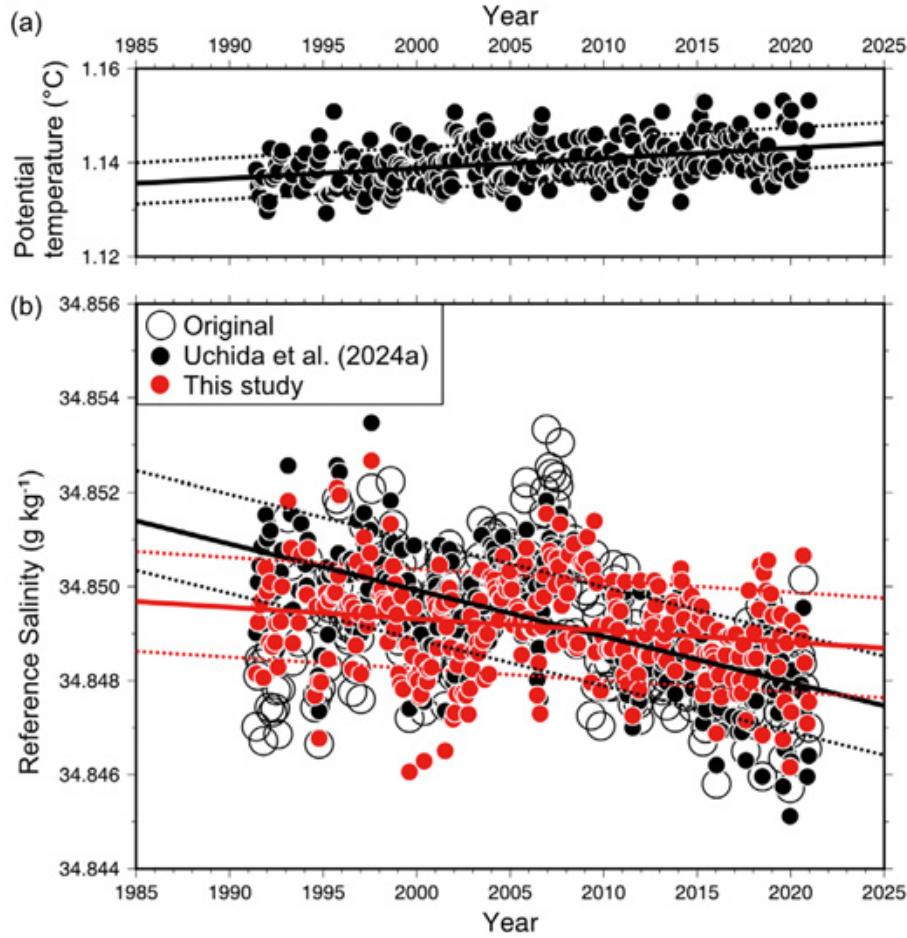


Fig. 2 Time series of (a) potential temperature and (b) Reference Salinity (S_R) averaged for pressures between 3500 and 4700 dbar for the shipboard CTD data obtained at the Hawaii Ocean Time-series (HOT) station ALOHA (22° 45'N, 158°W; water depth 4750 m). For the S_R data, open circles represent the original S_R data, black closed circles are S_R data after application of the batch offset correction proposed by Uchida et al. (2024a), and red closed circles are S_R data after application of the batch offset correction proposed in this study. The black and red solid lines are the regression lines fitted to the black and red closed circles, respectively, and the dotted lines show their $\pm$ SDs from the regression line. The average $\pm$ SD potential temperature was 1.208 ± 0.011 and $1.104 \pm 0.005^\circ\text{C}$ for 3500 and 4700 dbar, respectively. The average $\pm$ SD S_R after applying the batch offset correction proposed in this study was 34.8430 ± 0.014 and $34.8525 \pm 0.0011 \text{ g kg}^{-1}$ for 3500 and 4700 dbar, respectively.

of salinity seen near the seafloor decreased in magnitude as the temperature increased, and no significant trend of salinity was apparent for potential temperatures above about 1.2°C (average pressure of 3509 dbar). We also found warming ($2.1 \pm 0.3 \times 10^{-3}^\circ\text{C decade}^{-1}$) and freshening ($-0.25 \pm 0.08 \times 10^{-3} \text{ g kg}^{-1} \text{ decade}^{-1}$) on pressure surfaces at station ALOHA (pressure ≥ 3500 dbar) (Fig. 2).

Because the slope of the temperature–salinity relationship of the bottom water is $-0.1 \text{ (g kg}^{-1}\text{)}^\circ\text{C}^{-1}$ at stations K2 and ALOHA, those results suggest that pure warming, probably due to slowing of the northward abyssal flow, on pressure surfaces and apparent salinity increases on isotherms occurred in the deep water below a potential temperature of 1.2°C at station K2 (Fig. 3a). However, at station ALOHA, those results suggest that the isotherms were deepened, at least in the deep water below a potential temperature of 1.2°C (Fig. 3b), by internal oceanic waves that were transmitted from the Southern Ocean, which is an area of bottom water formation, and that altered pressure forces and weakened deep-water currents through geostrophic adjustment.

These results are described in details in a submitted manuscript (Uchida, H., Wakita, M., Oe, M., & Santiago-Manduiano, F., Possible increase in the Practical Salinity of IAPSO Standard Seawater. *Journal of Atmospheric and Oceanic Technology*, under 2nd review).

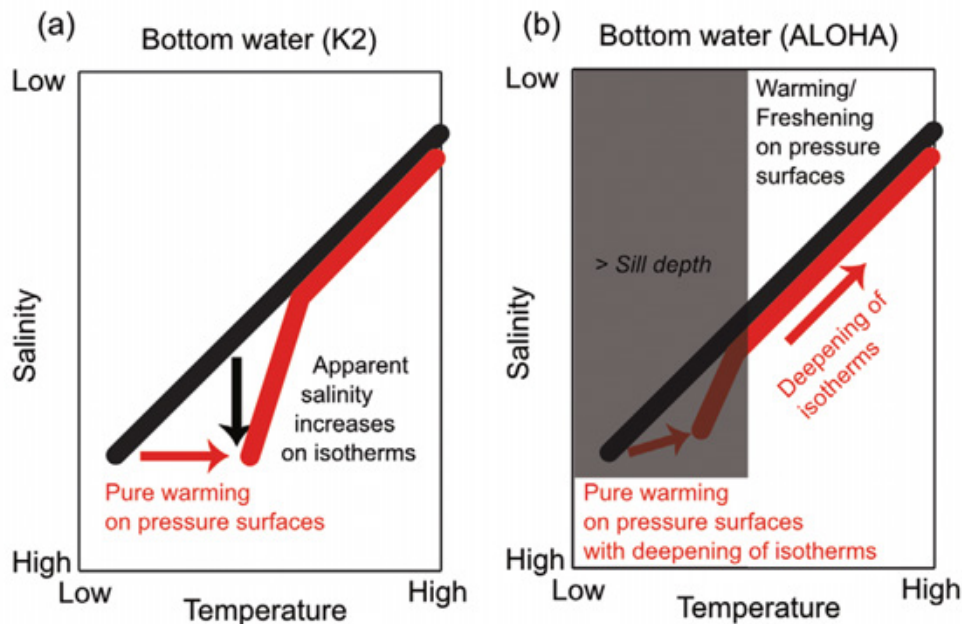


Fig. 3 Schematic plot of temperature–salinity relationships and their temporal changes in the bottom water of the North Pacific. (a) At station K2, strictly warming on pressure surfaces (temperature $\leq \sim 1.2^\circ\text{C}$) and apparent salinity increases on isotherms associated with this strictly warming were detected. (b) At station ALOHA, warming and freshening on pressure surfaces due to deepening of isotherms were detected. The lower part of the bottom water of the Northeast Pacific Basin (gray shading: temperature $\leq \sim 1.08^\circ\text{C}$) cannot extend over the sill region near station ALOHA.

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Antarctic Bottom Water off the Wilkes Land coast in the Australian-Antarctic Basin: its long-term trends and recent modulations

Antarctic Bottom Water (AABW) ventilates the lower limb of the global meridional overturning circulation and plays an important role in the global climate system. Many observational studies have reported that AABW has warmed, freshened, and decreased in volume (i.e., contracted) in recent decades. In particular, AABW in the Australian-Antarctic Basin is considered to have changed more than in other basins in the Southern Ocean. The changes in AABW are expected to be small, and analyses have been based mainly on the highly accurate observations conducted by research vessels under the WOCE/GO-SHIP program. These observations have been

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repeated at intervals of approximately 7–10 years; our knowledge about these changes is very limited.

This study examined the changes in AABW since the 1930s off the Wilkes Land coast (102–123°E), in the central part of the Australian-Antarctic Basin, using a long-term time series of AABW properties reconstructed statistically based on historical hydrographic datasets and recent measurements of Deep Argo floats. Since the 1980s at the latest, AABW off the Wilkes Land coast has contracted by approximately $11\text{--}14\text{ m yr}^{-1}$ and undergone freshening by approximately $-0.6 \times 10^{-3}\text{ yr}^{-1}$ (Figs. 4 and 5). The contraction and freshening of AABW has accelerated slightly over the past few decades, with the former being led by the latter. The contraction of AABW was mainly derived from thinning of the denser layers of AABW, which was partly compensated for by thickening of the upper AABW. This contrast between thinning and compensative thickening has strengthened gradually over time, suggesting that the meridional overturning circulation driven by AABW formation has weakened in the Australian-Antarctic Basin. Dissolved oxygen on isotherms in AABW appears to have remained constant since 1970, except for the possibility of some oxygenation after 2000, which was not statistically significant.

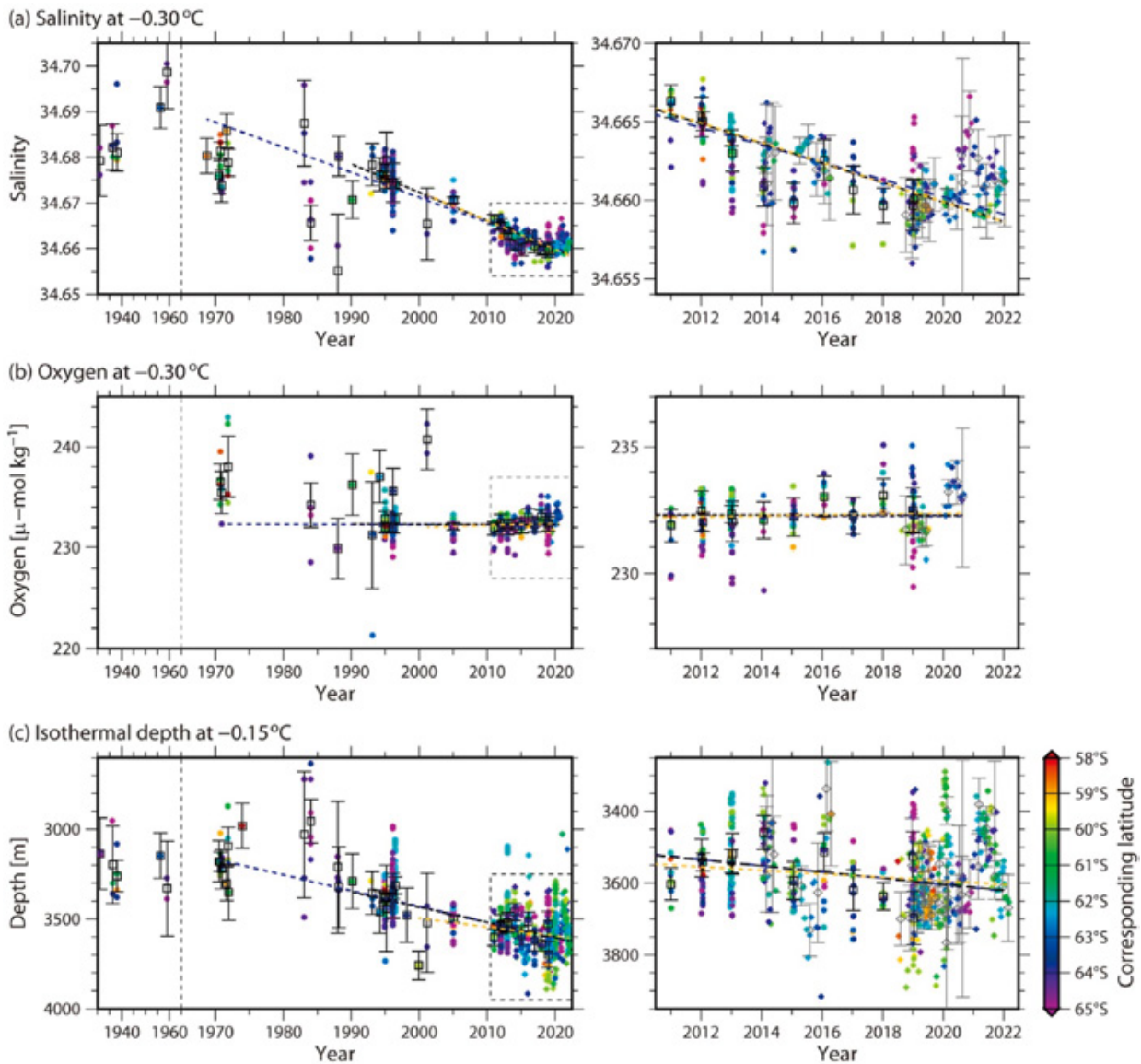


Fig. 4 Reconstructed time series for (a) salinity at $\theta = -0.30^\circ\text{C}$, (b) oxygen at $\theta = -0.30^\circ\text{C}$, and (c) depth of isotherm of $\theta = -0.15^\circ\text{C}$ for 1930–2022. Right panels show the results for 2011–2022, enlarging the region enclosed by the dashed line (inset) in the left panels. The horizontal scale before 1965 is compressed. The circles indicate the observations with the color of the corresponding latitudes for the adjustment. The open squares and diamonds with vertical bars represent the average and standard error for each hydrographic survey and segment of deep float observations, respectively. The dashed blue, black, and yellow lines represent the linear trends for periods 1968–2022, 1990–2022, and 2000–2022, respectively.

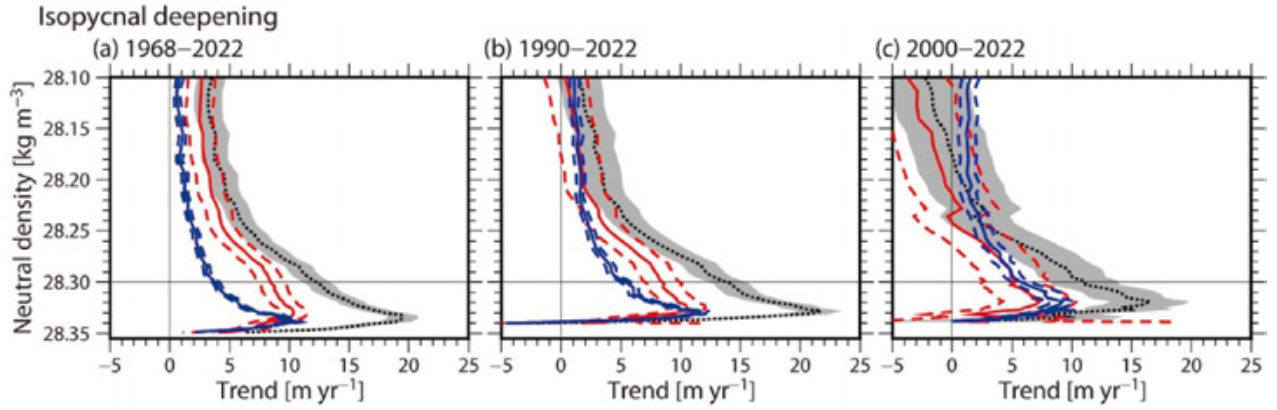


Fig. 5 Trends in isopycnal deepening for $\gamma_n \geq 28.10 \text{ kg m}^{-3}$ for periods (a) 1968–2022, (b) 1990–2022, and (c) 2000–2022. The dotted line with gray shading represents the average and the upper/lower limits of the 95% confidence interval. The warming and freshening component is shown by the red and blue solid lines, respectively, with an envelope of dashed lines for the average and the upper/lower limits of the 95% confidence interval.

After 2010, changes in AABW deviated from the long-term trends, with contraction and freshening of AABW accelerating significantly from 2011 to 2015 and then slowing down from 2015 to 2019. Meanwhile, the bottommost AABW, which is defined as the bottommost 300 m of the water column, increased in salinity significantly in the latter 2010s, mainly in response to contraction of AABW (Fig. 6). These processes have resulted in the recent salinification of the bottommost AABW in the eastern Australian-Antarctic Basin (Aoki et al., 2020), even in areas where the saltier Ross Sea Bottom Water not arrived yet. In 2018, marked freshening and oxygenation of AABW was observed in the 110°E section, probably due to newly formed bottom water in the Vincennes Bay Polynya.

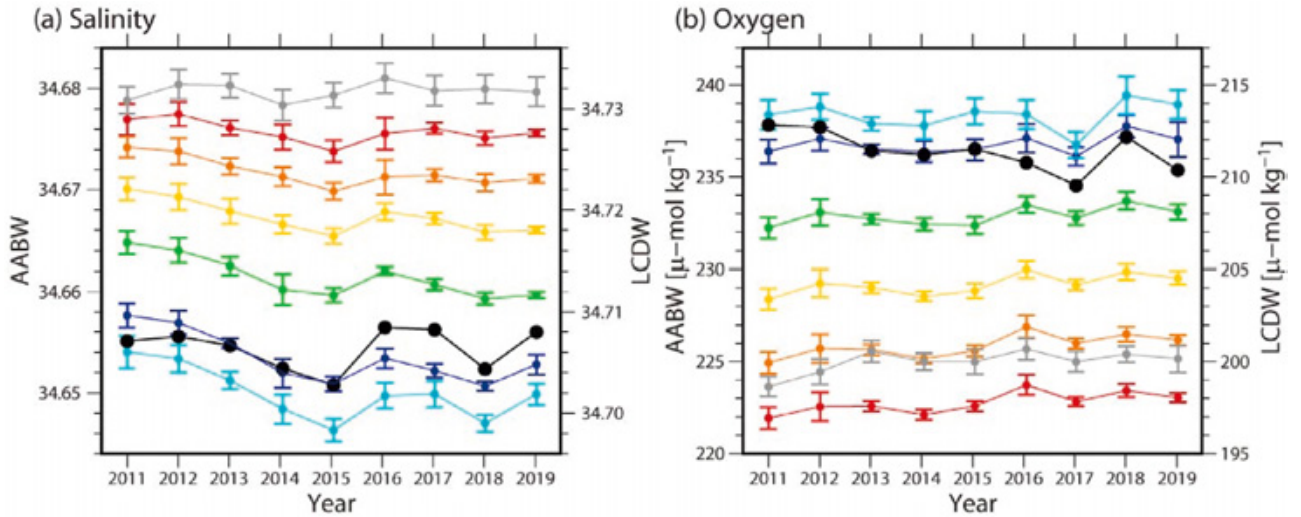


Fig. 6 Change in (a) salinity and (b) oxygen on isotherm for $\theta = 0.0^\circ\text{C}$ (red), -0.1°C (orange), -0.2°C (yellow), -0.3°C (green), -0.4°C (blue), and -0.45°C (cyan) in the KARE section along 110°E . The symbols and error bars represent the average and standard deviation, respectively, for $60\text{--}64^\circ\text{S}$ of the optimal interpolated section. The symbols shown by black and gray represent the average over the bottommost 300 m and the property in LCDW at $\theta = 1.3^\circ\text{C}$ (corresponding to the right axis), respectively.

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– Institute of Arctic Climate and Environment Research (IACE) – Unusually low oxygen and acidified water found in a high seas fishable area of the Pacific Arctic Ocean

Nishino et al. (2023) found unusually low oxygen and acidified water on the Chukchi Plateau (CP), a high seas fishable area on the Pacific side of the Arctic Ocean (Pacific Arctic), for the first time during Japan-Korea-Canada/US joint cruises in 2020 by the Research Vessel (R/V) *Mirai* (Japan), R/V *Araon* (Korea), and CCGS *Louis S. St-Laurent* (Canada) (Fig. 1). The joint cruises were conducted as part of the international Synoptic Arctic Survey (SAS) project, which is a coordinated multiship and multination pan-Arctic ship-based sampling campaign implemented during 2020–2022 to obtain a synoptic view of the totality of hydrographic and ecosystem changes occurring in the Arctic Ocean (Paasche et al., 2019).

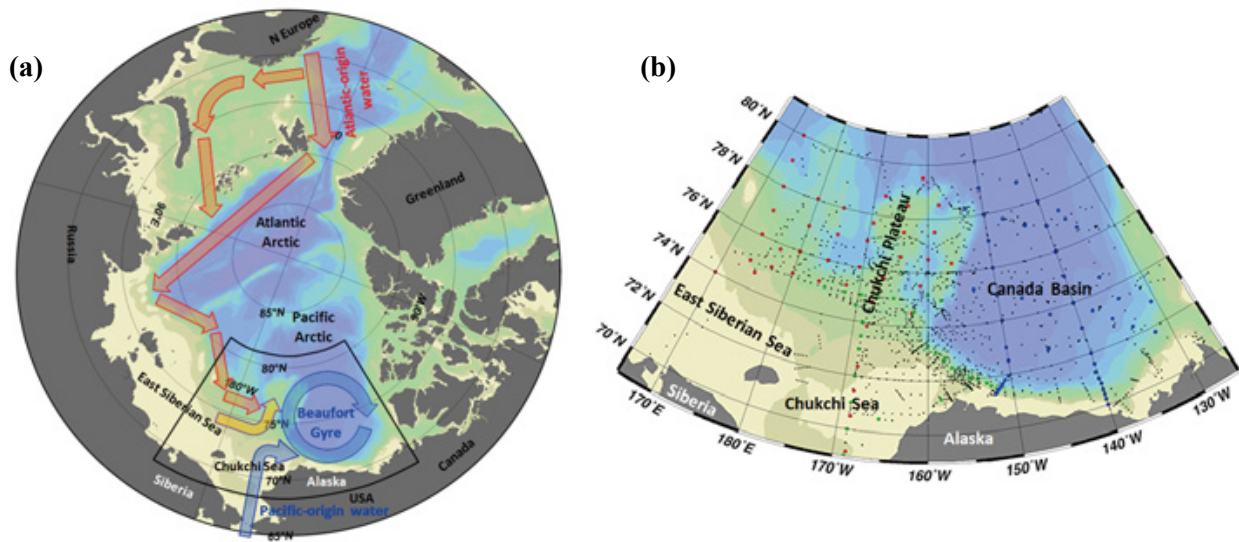


Fig. 1 Maps of (a) the Arctic Ocean and (b) the study area. In (a), blue and red arrows represent flows from the Pacific and Atlantic oceans, respectively, into the study area (surrounded by black lines in a fan shape). A blue circular arrow represents Beaufort Gyre circulation. A yellow arrow indicates the flow from the shelf-slope north of the East Siberian Sea (ESS). This flow transports low oxygen and acidified water from the ESS shelf-slope to the Chukchi Plateau. In (b), an enlarged map of the study area in (a), red, green, and blue dots denote the hydrographic stations conducted by the R/V *Araon* (Korea), R/V *Mirai* (Japan), and CCGS *Louis S. St-Laurent* (Canada), respectively, under the international Synoptic Arctic Survey project in 2020. Black dots indicate other hydrographic stations between 2002 and 2019.

The combined data of the joint cruises show that the Beaufort Gyre in the Pacific Arctic shrinks to the east of the CP and forms a front between the Pacific-origin water within the gyre and the Atlantic-origin water extending from the Atlantic Arctic associated with the recent sea ice loss. That phenomenon triggers a frontal northward flow along the CP. This flow likely transports the low oxygen and acidified water toward the CP; similar biogeochemical properties had previously been observed only on the shelf-slope north of the ESS, where large amounts of terrestrial/marine organic matters are deposited on the bottom (Fig. 2). A high quantity of organic matter decomposition, which consumes oxygen and produces CO₂, results in the formation of low oxygen and acidified water, if the water is not ventilated.

A tracer experiment was conducted using a physical sea ice–ocean general circulation model to evaluate whether the low oxygen water on the ESS shelf-slope was transported to the CP. A virtual passive tracer, which represents the low oxygen water, was continuously provided on the ESS shelf-slope. The tracer distribution shows that the low oxygen water on the ESS shelf-slope is transported to the CP by a northward flow. Associated with this transport, the appearance of low oxygen water passing through the CP has become more pronounced since 2017. The appearance of the water is not continuous throughout 2017 and beyond; instead, it is intermittent on a timescale of several months. Although we observed the low oxygen water on the CP only in October 2020, it

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might also have been present between 2017 and 2019 when observations were not conducted.

The CP is part of a shallow water area in the high seas of the Pacific Arctic Ocean. It is considered that areas shallower than 2000 m are fishable in future ice-free high seas of the Arctic Ocean (Jørgensen & Saitoh, 2021). However, according to the present study, the CP was already occupied by the acidified water. In addition, there will be a threat of deoxygenation. Therefore, this site should be monitored as a bellwether of ecosystem degradation caused by ocean deoxygenation and acidification in the Arctic high seas fishable areas.

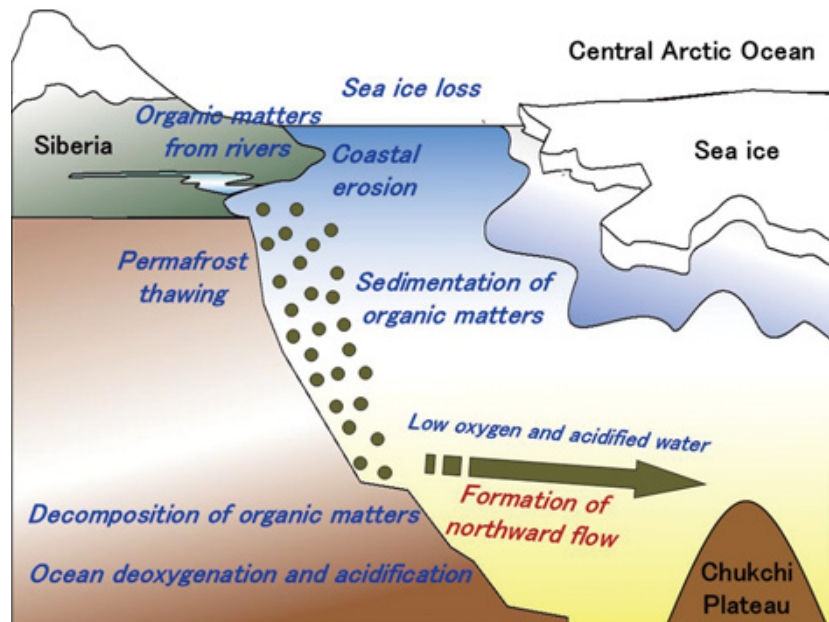


Fig. 2 Schematic of the transport of low oxygen and acidified water from the shelf-slope off Siberia to the Chukchi Plateau. Terrestrial/marine organic matters derived from rivers, coastal erosion, permafrost thawing, and biological production are deposited on the seafloor off Siberia. A high quantity of organic matter decomposition produces low oxygen and acidified water. This water is transported to the Chukchi Plateau with a northward flow caused by a change in large-scale ocean circulation related to the sea ice loss. The organic matter supply from each source is expected to increase in the future, resulting in wider areas of production and spread of the low oxygen and acidified water.

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An assessment of CO₂ uptake in the Arctic Ocean from 1985 to 2018

The Arctic Ocean has previously been estimated to represent a sink for atmospheric CO₂ (Bates & Mathis, 2009; Manizza et al., 2019). The rapid cooling of the inflowing Atlantic and Pacific waters through the

Barents Sea and the Chukchi Sea increases the solubility of CO_2 and hence allows these waters to take up CO_2 from the atmosphere. The air–sea CO_2 exchange is mainly modulated by the partial pressure of CO_2 ($p\text{CO}_2^{\text{ocn}}$) in the ocean surface layer, the wind speed, and the sea ice cover that acts as a barrier for the exchange of gasses across the air–sea interface. While sea ice cover and wind speed are relatively well known from satellite missions and reanalysis products, large uncertainties in $p\text{CO}_2^{\text{ocn}}$ remain and make it challenging to quantify both the direction and magnitude of the air–sea CO_2 exchange (Yasunaka et al., 2018). In the Arctic Ocean, $p\text{CO}_2^{\text{ocn}}$ is influenced by many factors, such as ocean heat loss and gain, the influx of Atlantic and Pacific water masses, biological production and respiration, sea ice formation and melting, river discharge, land–ocean carbon fluxes from rivers and coastal erosion, vertical mixing, and shelf–basin interactions. The combination of these environmental drivers results in large spatiotemporal variations in the Arctic air–sea CO_2 exchange.

As a contribution to the Regional Carbon Cycle Assessment and Processes phase 2 (RECCAP2) project, we present synthesized estimates of the Arctic air–sea CO_2 exchange and their uncertainties from observational products, ocean biogeochemical hindcast and data assimilation models, and atmospheric inversions (Yasunaka et al., 2023). The simulation results from an Earth System Model developed at the Japanese Meteorological Research Institute (MRI–ESM2) and a pan-Arctic regional model developed at the JAMSTEC (Arctic NEMURO-C) in Japan were also analyzed. For the period of 1985–2018, the Arctic Ocean was a net sink of CO_2 of $116 \pm 4 \text{ TgC yr}^{-1}$ in the $p\text{CO}_2$ products, $92 \pm 30 \text{ TgC yr}^{-1}$ in the models, and $91 \pm 21 \text{ TgC yr}^{-1}$ in the atmospheric inversions. The CO_2 uptake peaks in late summer and early autumn, and is low in winter when sea ice inhibits air–sea exchange. The long-term mean CO_2 uptake in the Arctic Ocean is primarily caused by steady-state fluxes of natural carbon ($70\% \pm 15\%$), and enhanced by the atmospheric CO_2 increase ($19\% \pm 5\%$) and climate change ($11\% \pm 18\%$). The annual mean CO_2 uptake increased from 1985 to 2018 at a rate of $31 \pm 13 \text{ TgC yr}^{-1} \text{ dec}^{-1}$ in the $p\text{CO}_2$ products, $10 \pm 4 \text{ TgC yr}^{-1} \text{ dec}^{-1}$ in the models, and $32 \pm 16 \text{ TgC yr}^{-1} \text{ dec}^{-1}$ in the atmospheric inversions (Fig. 3). Moreover, $77\% \pm 38\%$ of the trend in the net CO_2 uptake over time is caused by climate change, primarily due to rapid sea ice loss in recent years. Furthermore, true uncertainties may be larger than the given ensemble standard deviations due to common structural biases across all individual estimates.

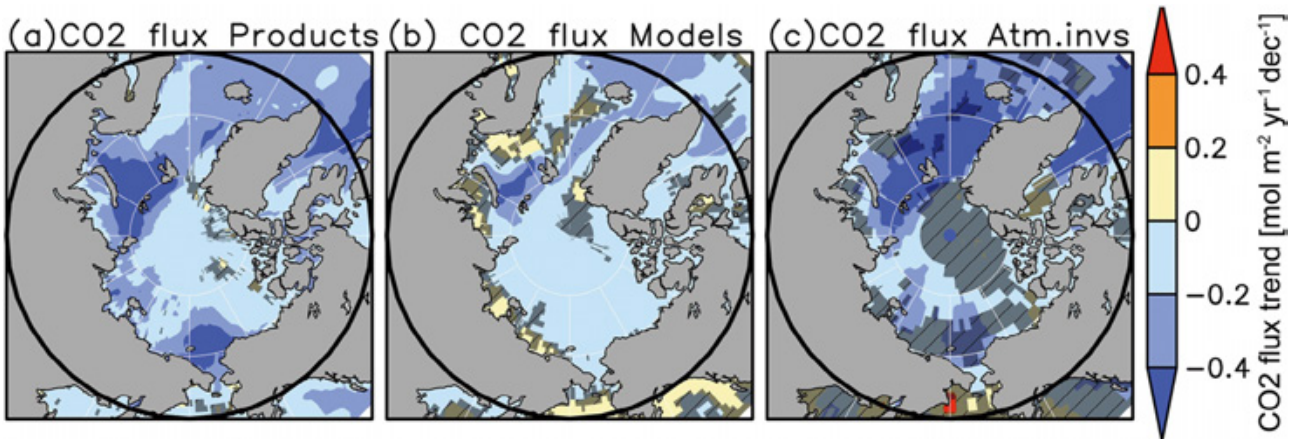


Fig. 3 Trend over 1985–2018 for ensemble mean air–sea CO_2 exchange estimated from the $p\text{CO}_2$ products, the ocean biogeochemical hindcast and data assimilation models, and the atmospheric inversions. Negative values indicate increasing CO_2 uptake into the ocean. Darker hatched areas represent values in grids where less than two third of the estimates show the same sign of the trend. Ensemble means are calculated across the estimates, which cover the full period of 1985–2018.

All individual $p\text{CO}_2$ products are better correlated with observed values (correlation coefficients are 0.7–0.9) than most models (correlation coefficients are lower than 0.6; Fig. 4a). Both the $p\text{CO}_2$ products and the models underestimate the variability of $p\text{CO}_2^{\text{ocn}}$ in time and space. The standard deviations of the $p\text{CO}_2$ products over time and space are about 80% of the standard deviation of the observations. The ensemble means of products and models, tend to slightly better correlate with observations than the individual products and models (the correlation coefficient is 0.88 for the ensemble mean of products and 0.47 for that of models), but this comes at the

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cost of a lower agreement on the magnitude of variability. The uncertainty remains large especially in the $p\text{CO}_2^{\text{ocn}}$ estimates in the East Siberian Sea and the Laptev Sea because of the limited observations in the $p\text{CO}_2$ products and limited or non-existing representation of carbon and nutrient inputs from rivers, coastal erosion, and sediment dynamics (Figs. 4b and 4c). Discrepancies in the seasonal cycle and long-term trend of $p\text{CO}_2^{\text{ocn}}$ between the $p\text{CO}_2$ products and the ocean biogeochemical hindcast and data assimilation models were also observed in many other sub-regions of the Arctic Ocean. Furthermore, the true uncertainties may even be larger than the ensemble standard deviation due to common structural biases across the entire ensemble of estimates. Further model development and more observations are crucially necessary to improve estimates of the Arctic air–sea CO_2 exchange in a time when the Arctic Ocean faces the effects of rapid change, such as sea ice decline, ocean warming, and increasing riverine discharge, that will ultimately also affect ecosystem drivers such as ocean acidification and changing net primary production.

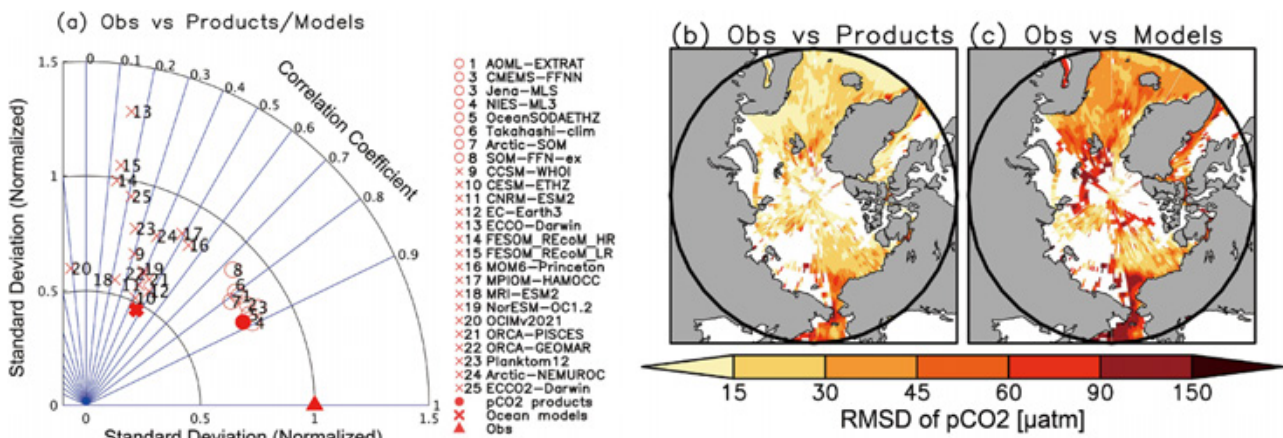


Fig. 4 (a) Taylor diagram of $p\text{CO}_2^{\text{ocn}}$. The radial distance from the origin represents the standard deviation of $p\text{CO}_2^{\text{ocn}}$ in each estimate relative to that of the available observations. The azimuthal angle represents the correlation coefficient of $p\text{CO}_2^{\text{ocn}}$ between the individual estimate and the observation. (b, c) Root mean squared difference between observed and ensemble mean $p\text{CO}_2^{\text{ocn}}$ from (b) $p\text{CO}_2$ products and (c) ocean biogeochemical models. $p\text{CO}_2^{\text{ocn}}$ from $p\text{CO}_2$ products and ocean biogeochemical hindcast and data assimilation models were subsampled at the same time and location as the observations.

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Pioneering initiative for Japan's new research icebreaker to be an "International Research Platform for Arctic Science"

As outlined in the RIGC Annual Report for 2022, JAMSTEC is currently constructing Japan's first research icebreaker for Arctic science, named the "Arctic Research Vessel *Mirai II* (ARV *Mirai II*). ARV *Mirai II* addresses the urgent need for research in sea-ice-covered areas, enabling the collection of new data and knowledge. Unlike the R/V *Mirai*, which has been conducting Arctic Ocean observation cruises since 1998 but cannot enter sea-ice-covered regions due to its classification as an ice-capable vessel rather than an icebreaker, ARV *Mirai II* is specifically designed for these environments. The timeline for the construction of ARV *Mirai II* is as follows:

- ✓ The steel-cutting ceremony was held in March 2023, marking the start of construction.
- ✓ The launching ceremony is planned for March 2025.
- ✓ Delivery of ARV *Mirai II* to JAMSTEC is scheduled for autumn 2026.

Following trial cruises near Japan, the first Arctic observation cruise of ARV *Mirai II* is planned for summer-autumn 2027.

A key objective is to operate the "ARV *Mirai II*" as an international research platform, leading major international projects and fostering the development of the next generation of scientists and engineers. This initiative aims to strengthen and expand collaborations with our international partners. To realize the concept of an "international research platform," the IACE/RIGC has already undertaken several activities together with the Project office for Arctic Research Vessel (PARV) of JAMSTEC. One notable example, as highlighted in the previous report, was the open call for Early Career Scientists' (ECS) proposals for participation in the R/V *Mirai* 2023 cruise. Through this process, we successfully invited six ECSs from foreign countries (Denmark, Portugal, the UK, and the US) to join the cruise.

In addition, we held the first international workshop on Arctic Ocean observation in Tokyo in November 2023. Please note that the organization of this workshop was led by PARV and supported by IACE/RIGC. This workshop provided a valuable opportunity to share and discuss the needs and seeds of science, policy, and other topics related to the Arctic region. It also facilitated discussions on how Japan's new Arctic research vessel can be utilized as an international research platform. The workshop attracted a total of 118 participants, including research scientists, representatives from Arctic Indigenous communities, engineers, shipping operators, and administrative officials from 12 countries. The group photo of this workshop was shown in Fig. 5. The program consisted of five breakout sessions (focusing on early-career scientists, science, engineering, societal interests, and ship operations), a wrap-up session, and a panel discussion. The workshop report is available at the following site: <https://www.jamstec.go.jp/parv/e/event/workshop/>. We are now planning a second workshop, which will be held in Yokohama in October 2025, as part of our preparations leading up to the launch of the new vessel in the fall of 2026.

Regarding future Arctic observation planning, JAMSTEC will succeed the University of Bergen as the secretariat for the international project, Synoptic Arctic Survey (SAS), starting in 2025. In this capacity, JAMSTEC will lead discussions and coordinate implementation efforts for this significant initiative. The SAS project focuses on simultaneous, wide-area observations of the Arctic Ocean conducted by multiple icebreakers and research vessels. The first campaign, carried out between 2020 and 2022, successfully covered much of the Arctic Ocean, while the planned 100% coverage was not achieved due to restrictions imposed by the COVID-19 pandemic. Currently, we are in the synthesis phase of the first campaign, integrating data and findings. At the same time, we have begun planning for the second Synoptic Arctic Survey, which is scheduled for 2030.

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Institute of Arctic Climate and Environment Research (IACE)



Fig. 5 The group photo of the first international workshop on Arctic Ocean observation on November 2023. Referred from the following site, <https://www.jamstec.go.jp/parv/e/event/workshop/>.

– Earth Surface System Research Center (ESS) –

From our recent studies focusing on the interactions between human activities and the natural system, two topics are highlighted here. The first is on climate variability affecting the local ecosystem and fisheries, conducted in collaboration with the Mutsu Institute of Oceanography (MIO). The second topic is the global impact of COVID-19 lockdown on global aerosol reduction and climate, which we informed to the audience in the opportunity of a Japan Pavilion Seminar at COP28, UNFCCC in Dubai, December 2023.

Synoptic climate variability can impact local ecosystem and fishery

Environmental changes such as seasonality, decadal oscillation, and anthropogenic forcing may shape the dynamics of lower trophic-level organisms. In this study, 9-years (2010–2018) of monitoring data on microscopic protists such as diatoms and dinoflagellates, and environmental variables were analyzed to clarify the relationships between plankton and local/synoptic environmental changes.

In May, there were significant positive trends in temperature and $p\text{CO}_2$ (Fig. 1). In August and November, temperature significantly decreased, whereas $p\text{CO}_2$ levels increased with time (Fig. 1). Salinity and nutrients showed the opposite trends compared with temperature indicating that the enhancement of vertical mixing with time in August and November during the study period (Wakita et al., 2021; Sugie et al., 2024). *Chaetoceros* subgen. *Hyalochaete* spp. abundance increased during the study period in all examined months and the abundance of Rhizosoleniaceae increased with time in May and August (Fig. 1).

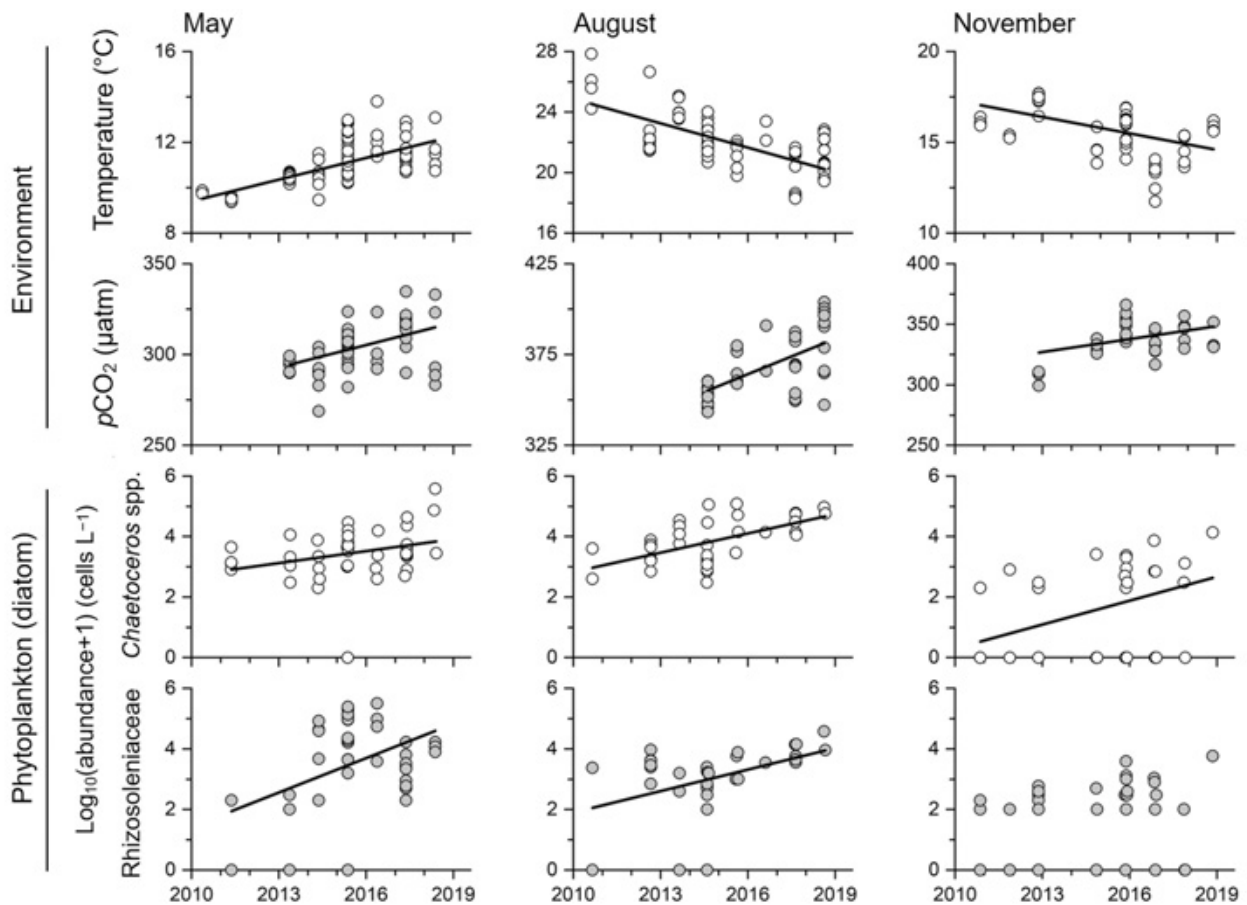


Fig. 1 Temporal changes in (from top to bottom) temperature, partial pressure of CO_2 ($p\text{CO}_2$), abundance of diatoms *Chaetoceros* subgen. *Hyalochaete* spp. and Rhizosoleniaceae in (left to right) May, August and November.

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We found significant linear trends between the PDO index and monthly mean temperatures in February and May (warming) and August and November (cooling) (Fig. 2), similar to the temporal change in seawater temperature (Fig. 1). In addition, the PDO index and scallop soft tissue index (STI) showed a significant positive linear relationship (Fig. 2). Possible underlying mechanisms relating PDO and scallop production is the abundance of diatoms such as Rhizosoleniaceae which is positively correlated to the STI and PDO (Fig. 2). Increasing temperature in spring when nutrients remained could improve food availability for scallop aquaculture by enhancing the growth rate of phytoplankton. In the nutrient-depleted summer, nutrient pulses owing to the increase in turbulent mixing could elevate the carrying capacity of prey (e.g., *Chaetoceros* subgen. *Hyalochaete* spp.) for scallops. In general, seawater temperature around Japan decreases during the positive PDO phase, as we observed that cooling trends in August and November were stronger than warming trends in February and May (Fig. 2). These analyses indicate that the positive phase of PDO is beneficial to scallop aquaculture owing to the increase in diatom production driven by climatologically induced physical and chemical perturbations of seawater.

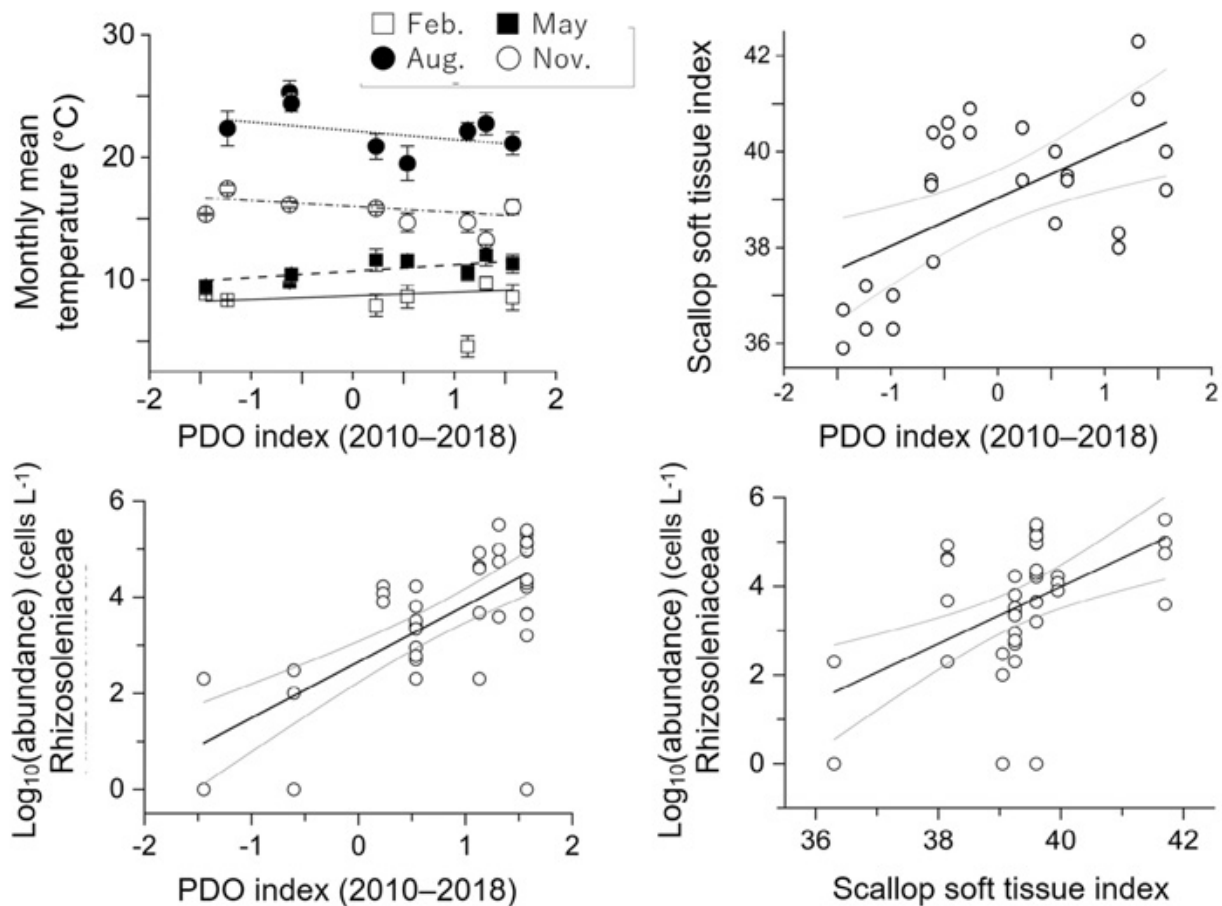


Fig. 2 Relationships (a) between Pacific Decadal Oscillation (PDO) and the monthly mean temperatures in February, May, August, and November, (b) between PDO and scallop soft tissue index (STI), (c) between PDO and Log₁₀(Rhizosoleniaceae) abundance in May, and (d) between STI and Log₁₀(Rhizosoleniaceae) abundance in May.

In conclusion, this study clarified the seasonal and long-term dynamics of microscopic protists in the Tsugaru Warm Current (TWC) ecosystem. The long-term cooling temperature trends in August and November differed from those of global warming, probably due to the change in current volume, which is influenced by synoptic climatic forcing (Nagano et al., 2022; Wakita et al., 2021). The change in the TWC current from 2010 to 2018 positively affected the production of diatoms, and higher prey availability is favorable for the aquaculture of scallops in the Aomori prefecture. The impacts of higher temperature and $p\text{CO}_2$ levels, which often reduce diatoms (e.g., Sugie et al., 2020), may be masked by the increase in nutrient availability induced by enhanced turbulent mixing. Note that the duration of our protist monitoring covered only one PDO cycle. Because the combination of

PDO and ENSO cycles could affect local climatology (Nagano et al., 2022), much longer observation periods are essential for clarifying multi-decadal to centennial ecosystem response.

Regime of Tsugaru Warm Current ecosystem during 2010–2018

- (1) Climate forcing from synoptic-scale decadal oscillation (cf., wind)
- (2) Increase the volume transport
- (3) Nutrient upwelling via intensifying vertical mixing
- (4) Increased large-sized diatom owing to improving nutrient availability
- (5) Increased food availability promoted aquaculture production (scallop)

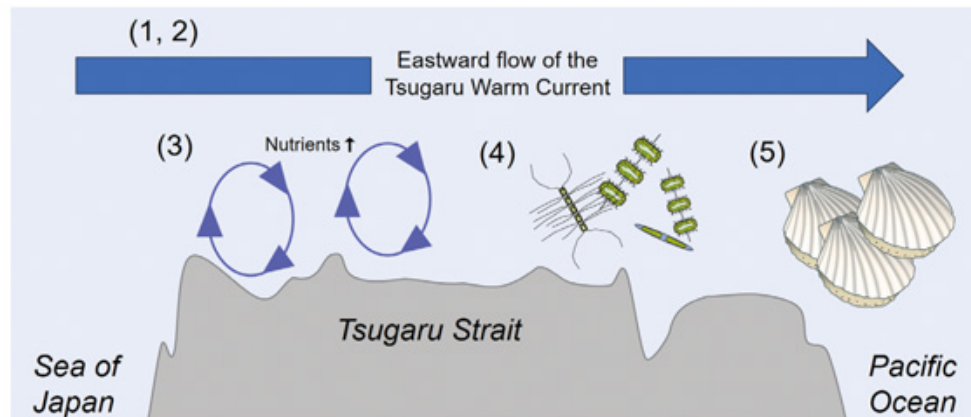


Fig. 3 Cartoon of the changes in the Tsugaru Warm Current ecosystem and aquaculture production during the study period.

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The worldwide COVID-19 lockdown impacts on anthropogenic aerosol reductions and climate

Human activities have an array of impacts on climate and air quality through emissions of greenhouse gases and air pollutants. Specifically, aerosols directly and indirectly play an important role in the Earth's thermal energy balance through the scattering and absorption of radiation, as well as the modification of cloud microphysical properties. Previous research methods based on observation data have assessed changes in the total amount of aerosols, from both anthropogenic and natural sources; however, extracting only the impact of

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changes in human activity due to lockdowns was difficult. Sekiya et al. (2023) addressed this challenge by using a data assimilation analysis system, developed by JAMSTEC and NASA JPL, that can integrate observational information on multiple atmospheric constituents (Miyazaki et al., 2020), as well as satellite observation data from TROPOMI on board Sentinel-5P operated by the European Space Agency (ESA).

This study shows how the reduction in emissions associated with the worldwide lockdown during the COVID-19 pandemic changed the amount of anthropogenic aerosols formed in the atmosphere, and how this affected the Earth's thermal energy balance. We estimated the reductions in the aerosol precursor gas emissions by 14–25% and the amount of anthropogenic aerosols by 8–21% over the major emission regions (East Asia, North America, and Europe) during the COVID-19 pandemic period (Figs. 4 and 5, respectively). This reductions in anthropogenic aerosols correspond to more than 34% of the aerosol optical depth declines derived from satellite observations over the major emission regions, which represent changes in total aerosol amounts from both anthropogenic and natural sources.

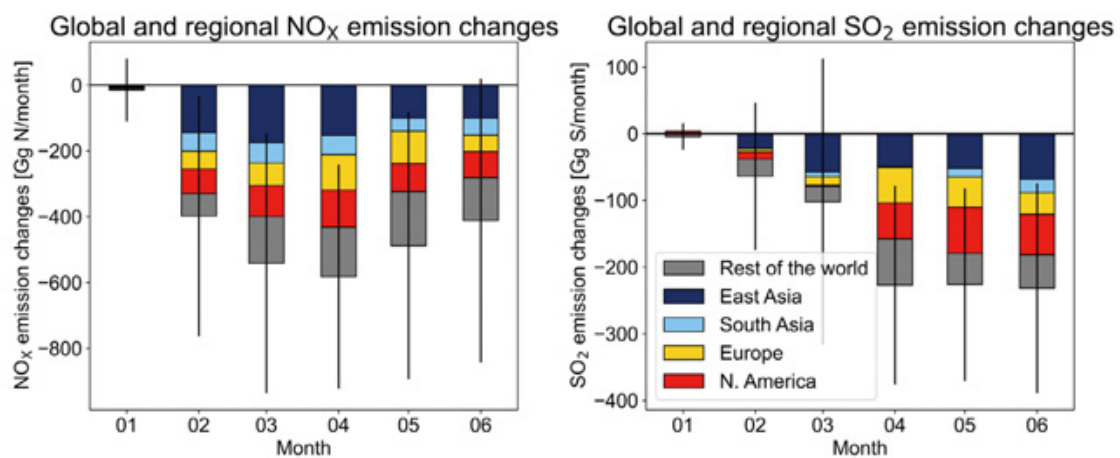


Fig. 4 Reductions in anthropogenic NO_x and SO₂ emissions due to the COVID-19 lockdown. Total monthly mean global and regional changes in NO_x emissions (left) and SO₂ emissions (right) due to the COVID-19 lockdown (i.e., differences between the 2020 and business-as-usual emissions). Regional NO_x and SO₂ emission changes are shown for North America (red), Europe (yellow), South Asia (sky blue), East Asia (blue), and other regions (gray). Error bars represent the uncertainty ranges of emission anomalies estimated from data assimilation calculations for April 2020, with full observation and artificially reduced coverages. The units for NO_x and SO₂ emission anomalies are Gg N month⁻¹ and Gg S month⁻¹, respectively.

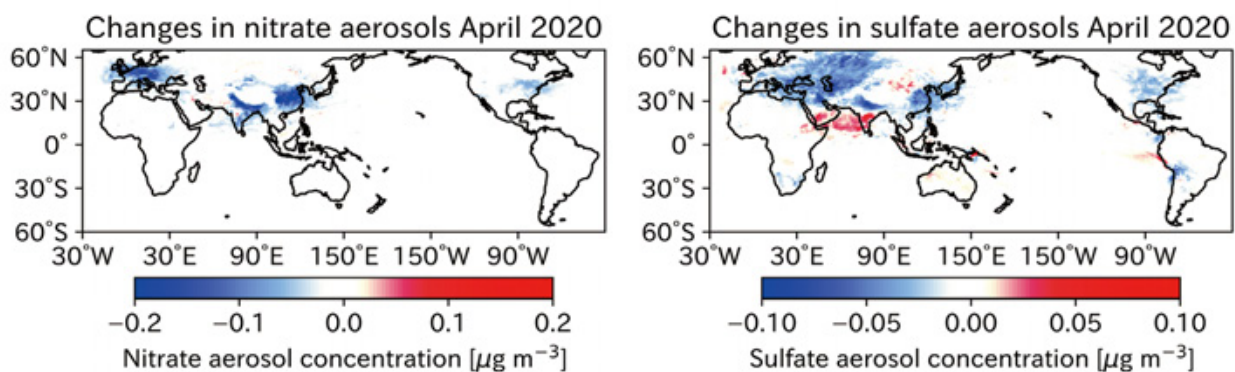


Fig. 5 COVID-19 emission reduction impacts on anthropogenic aerosol columns. Spatial distribution of the monthly column nitrate (left) and sulfate (right) anomalies (in $\times 10^{-6} \text{ kg m}^{-2}$) in April 2020, as estimated from the differences between the simulations using the 2020 and business-as-usual (i.e., normal) emissions.

Furthermore, we assessed the impact of reduced anthropogenic aerosols on the global thermal energy balance and found that this reduction weakened the umbrella effect of aerosols (i.e., scattering solar radiation) and increased the net thermal energy entering the Earth by 0.14 W/m^2 compared to normal periods. This effect

is equivalent to mitigation measures for 6 years under the most aggressively mitigated Shared Socioeconomic Pathway 1-1.9 scenario that includes ambitious aerosol emission mitigation, defined for the Climate Model Intercomparison Project 6.

This study was the first global-scale assessment of climate impacts of anthropogenic aerosol reductions based on realistic estimates in emission reductions during the COVID-19 pandemic period. The warming effect due to the decrease in anthropogenic aerosols was found to exceed the cooling effect (-0.025 W/m^2 , Forster et al., 2020) due to the decrease in fossil fuel CO_2 (FFCO₂) emissions during the same period (Fig. 6). Aerosol and its precursor gas emission reductions are thought to simultaneously occur with FFCO₂ emissions reductions due to climate mitigation measures. Although climate impacts of aerosol and FFCO₂ emission reductions are known to offset each other qualitatively, the present study shows the quantitative relationship regarding the impacts from the reduction of FFCO₂ emissions and the simultaneous reduction in aerosol amounts on the climate. It has important implications for the optimization of climate mitigation measures and climate change projection.

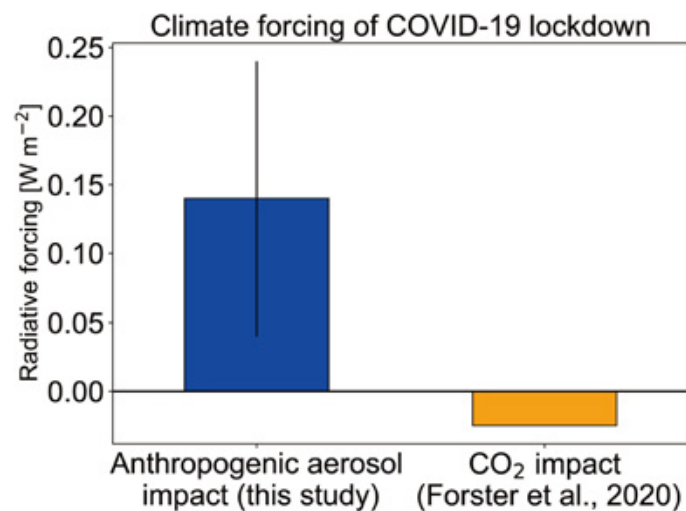


Fig. 6 COVID-19 emission reduction impacts on Earth's thermal energy balance (radiative budget) through anthropogenic aerosol (blue) and CO_2 changes (orange). Global mean changes in net radiation flux at the top of the atmosphere (in watts per square meter) due to COVID-19 emission reductions averaged during April–June 2020. COVID-19 impacts and their ranges were defined as the ensemble mean and spread, respectively, obtained from two sets of ensemble simulations using the 2020 and business-as-usual emissions. Climate forcing due to fossil fuel CO_2 emission reductions was taken from the estimates by Forster et al. (2020).

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– Research Center for Environmental Modeling and Application (CEMA) –

Model development toward global k-scale climate simulation

In the Earth's climate system, moist convection plays an essential role in keeping the energy balance through cloud radiative processes, global atmospheric circulation, and water cycle. The moist convection has a nature of self-organization, and the building block of the organized convection, cumulus clouds, have a 0(1)-km spatial and ~hour temporal scale. Currently, global kilometer (k-) scale global climate simulations acquire high attention as a promising approach to achieve realistic climate and weather simulations avoiding the uncertainties emanating from the implicit representation of cumulus clouds which has been broadly used in conventional general circulation models with horizontal resolution of ~100 km.

With this recognition, we have been developing a global nonhydrostatic model, Nonhydrostatic Icosahedral Atmospheric Model (NICAM) since early 2000's, and demonstrated successful simulation of tropical convective disturbances with subseasonal (~1 month) time scales, such as the Madden-Julian Oscillation (e.g., Miura et al., 2007), and the global climate of clouds (e.g., Kodama et al., 2021). Because the leading physical processes heavily depend on the target phenomena, two representative physical settings have been used: for the simulations of weather events ("MJO" setting) and for the climate simulations ("HRMIP" setting). Toward the realistic simulations of both the individual weather events and global climate, process-oriented improvements in model physics/settings are indispensable.

We conducted sensitivity simulations on several key parameters/physical processes, and specified how these affects the modeled convective disturbances and the mean state (Takasuka et al., 2024). With the "HRMIP" setting, cloud amount is well represented by the updates of the cloud microphysics and radiative processes (Fig. 1b), but convective behavior is rather sporadic and the tropical intraseasonal variability is poorly reproduced (Fig. 2b). In contrast, with the "MJO" setting, in which sedimentation speed of rain, snow, and cloud ice are slowed to

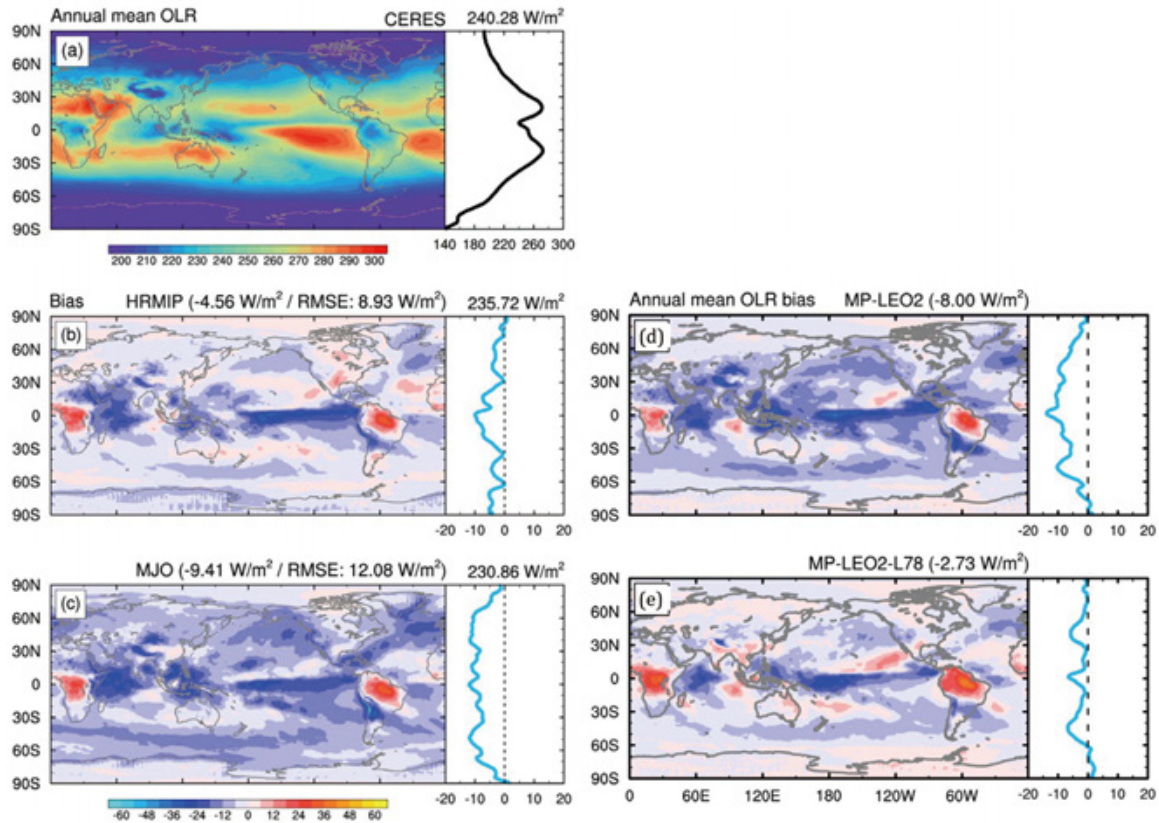


Fig. 1 Horizontal maps of the annual - mean outgoing longwave radiation (OLR) (W m^{-2}) at the top of the atmosphere obtained from the CERES. (b–e) As in (a), but for the OLR bias against the CERES for the (b) HRMIP, (c) MJO, (d) New, and (e) New with 78-vertical levels runs. (reproduced from Figs. 6a-c and 12a-b of Takasuka et al., 2024)

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Research Center for Environmental Modeling and Application (CEMA)

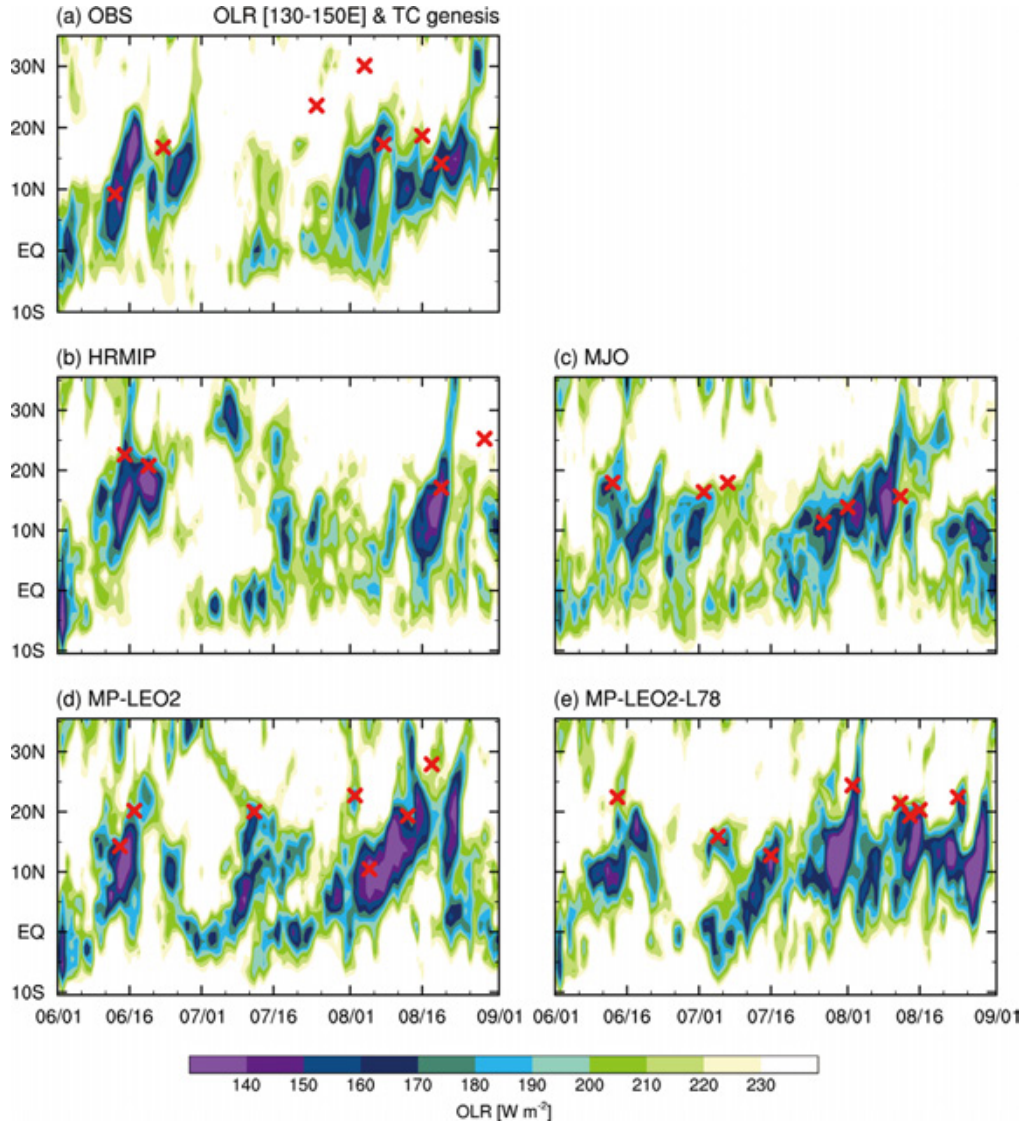


Fig. 2 Time-latitude diagrams of OLR averaged in 130°–150°E (shading) and tropical cyclone genesis points within that longitudinal band (red cross) for the (a) observation and (b) HRMIP, (c) MJO, (d) New, and (e) New with 78-vertical levels runs. (reproduced from Fig. 17 of Takasuka et al., 2024)

enhance convective organization, excessive amount of clouds are formed (Fig. 1c), while it enables realistic simulation of the northward migration of intraseasonal convective envelope and tropical cyclogenesis within it (Fig. 2c). Based on the detailed analysis of these responses to the modification in key physical settings, we worked out a new setting including revisions of the sedimentation speed of the condensates, implementation of new subgrid-scale mixing scheme, and increase in vertical resolution. The new setting successfully reproduces both weather disturbances and climate (Figs. 1d-e & 2d-e). These improvements are applicable to the forthcoming k-scale simulations, and these are expected to lead to more robust and reliable weather and climate predictions.

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Reconstruction of the global carbon cycle

The global carbon cycle, a series of processes in which carbon-based materials is exchanged among the atmosphere, ocean, terrestrial ecosystem, is crucial for maintaining stability of Earth's climate and eco-systems because it determines atmospheric concentrations of CO₂ and other carbon-based greenhouse gases. Intrinsic balance of the global carbon cycle has significantly been disrupted due to increasing anthropogenic CO₂ emission associated with such as fossil fuel combustion and deforestation after the industrial revolution, and the ocean and terrestrial sinks as reservoirs of CO₂ cannot absorb all the anthropogenic CO₂ emission, and thus, the atmospheric loading of the CO₂ amount has been increasing, which results in accelerating climate change known as the global warming. In addition to the above-mentioned changes related to anthropogenic CO₂ emission, the global carbon cycle is fluctuated by internal climate variations. For comprehensive understanding of the global carbon cycle and expected reliable future predictions and projections, near real time monitoring, long-term reconstruction, and clarification of physical/biogeochemical processes are required, focusing on both of human-induced and natural changes and their interactions.

We have challenged to reconstruct the historical global carbon cycle variation with an Earth System Model (ESM) where a system for assimilating observation-based atmosphere and ocean data is implemented, which is built on physical and biogeochemical consistency under interactions in various earth system processes. An ESM used in the present study is MIROC-ES2L (Hajima et al., 2020). JRA55 reanalysis of 6-hourly three-dimensional wind velocity and air temperature and the ocean objective analysis for monthly temperature, salinity, and sea-ice concentration are assimilated with a simple nudging-like method. A full-field assimilation is applied here. Important is that the global carbon exchanges among atmosphere, ocean, land, and human activity is not distorted in our reconstruction because only physical variables are assimilated.

The reconstructed global air-sea CO₂ flux (orange line in Fig. 3) shows an increasing trend of ocean CO₂ uptake with decadal fluctuations that is not represented in the ESM experiment without data assimilation (black).

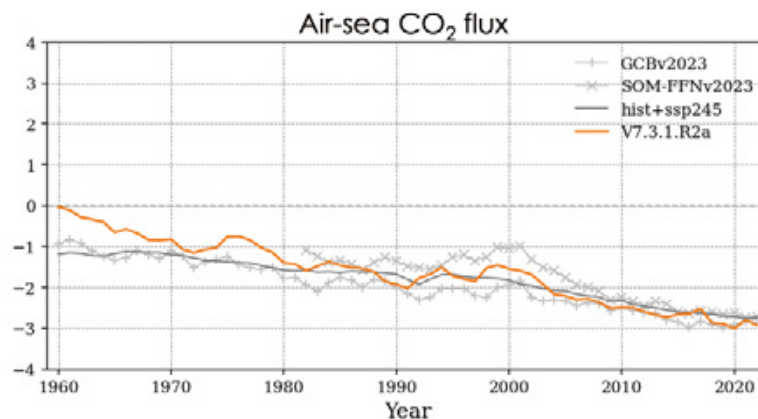


Fig. 3 Timeseries of the global-integral of air-sea CO₂ flux (unit: GtC/yr) for the reconstruction with ESM coupled with/without an data assimilation system (orange/black lines), and GCB2023 (gray with bars).

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An weakening of ocean CO₂ absorption around 2000 in the data product of the Global Carbon Budget (GCB; e.g., Friedlstein et al., 2023; gray with bars), which can be attributed to anomalous CO₂ release from the tropical Pacific caused by enhanced supply of carbon-rich subsurface water to the surface under 1998/1999 La Niña condition, is captured in our system but with smaller amplitude. Looking at the horizontal maps showing correlation coefficients of air-sea CO₂ flux anomalies between observation-based product (SOM-FFN; Landschützer et al., 2014) and ESMs (Fig. 4), advantages of data assimilation in representing historical changes in air-sea CO₂ flux is obvious. In areas with significant internal climate variability, such as the tropical Pacific Ocean and the subarctic North Atlantic, the air-sea CO₂ flux in the ESM with data assimilation is closer to the data product than that without data assimilation. Detailed analysis for the tropical Pacific reveals that climatological-mean vertical gradient of dissolved inorganic carbon (DIC) is shaper when data assimilation is implemented, which contribute to variations in the surface partial CO₂ pressure through wind-induced anomalous equatorial upwelling. It is suggested that not only by synchronizing phases of internal climate variations, but by the improvement in climatological DIC distribution through modification of ocean circulation by assimilating observed temperature and salinity, representation of historical air-sea CO₂ flux variations can be alleviated. However, it should be mentioned that conservation of ocean temperature and salinity is violated during data assimilation procedure. Whether the above-mentioned improvement in DIC is followed by physically valid processes is equivocal, and unreasonable buoyancy gain may lead to spurious improvement of the equatorial DIC. It is necessary to validate on a process basis, not just on a superficial analysis.

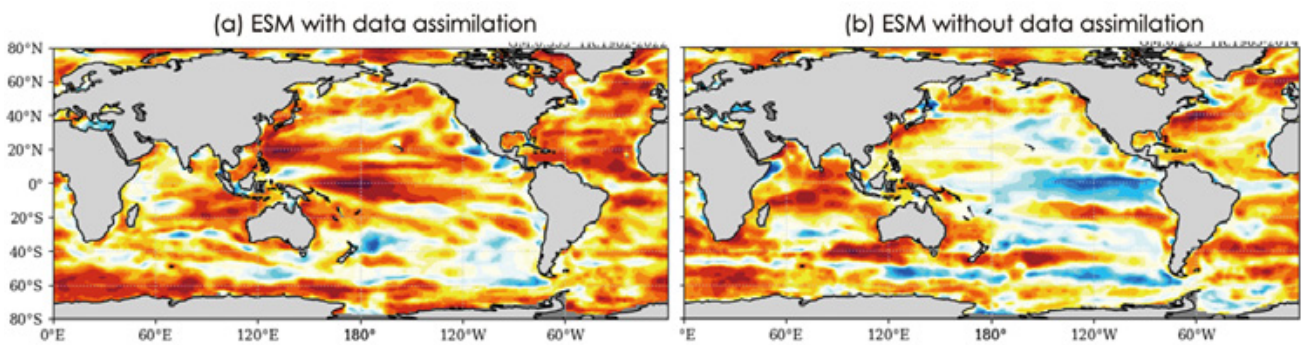


Fig. 4 Horizontal maps for correlation coefficient of annual air-sea CO₂ flux anomalies between observation-based data product and ESM (a) with and (b) without an data assimilation system.

The reconstructions of the global carbon cycle by ESMs including our system are cited for the first time in the latest evaluation of the GCB (Friedlstein et al., 2023). Only four ESM data were cited in GCB2023, and our reconstruction was one of them. The GCB until the 2022 evaluation was a data product of bottom-up estimate based on various methodology such as observations, inversion, machine learning, numerical simulations utilizing stand-alone ocean and land-surface model ensembles. A press conference on the GCB was held at COP28 in December 2023. The findings served as one of the sources of evidence for the decision of the first Global Stocktake, which recognizes that achieving the 1.5-degree target requires substantial greenhouse gas reductions of 43% by 2030 and 60% by 2035, compared to 2019 levels. This will inform the update of each country's greenhouse gas emission reduction targets for 2025. At present, ESM reconstructions are cited in GCB2023 with the same or lower reliability than conventional methods, but the strength of ESM is its ability of global climate and carbon cycle prediction and projections, as well as that it is built on physical and biogeochemical consistency under interactions in various earth system processes. The system introduced here can be also utilized for near-term initialized climate and carbon predictions as well as for quantifying contribution of anthropogenically and internally induced carbon cycle changes in the past, present and future, separately with physical and biogeochemical explanations. Such scientific insights mentioned here contribute to visualizing CO₂ reduction efforts, evaluating progress in emissions reduction, and estimating the remaining carbon budget for achieving mitigation of the Paris Agreement in 2015.

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– Marine Biodiversity and Environmental Assessment Research Center (BioEnv) –

Large amounts of microplastics found in deep-sea sediments – The missing microplastics are in the deep sea off Boso Peninsula–

In order to reduce marine plastic pollution, it is essential to understand the behavior of microplastics (MPs) in the ocean. However, although the deep sea is thought to be the main depositional site, the complex processes by which MPs are transported to the seafloor in the deep sea remain unclear. Therefore, we estimated the transport process based on the distribution information of the number, shape, and material of MPs in Sagami Bay, which is adjacent to Japan's densely populated area, the trench (triple junction) where the trench is connected to Sagami Bay via the Sagami Trough, and the deep-sea abyssal plain directly below the Kuroshio Extension (Fig. 1) (Tsuchiya et al., 2024).

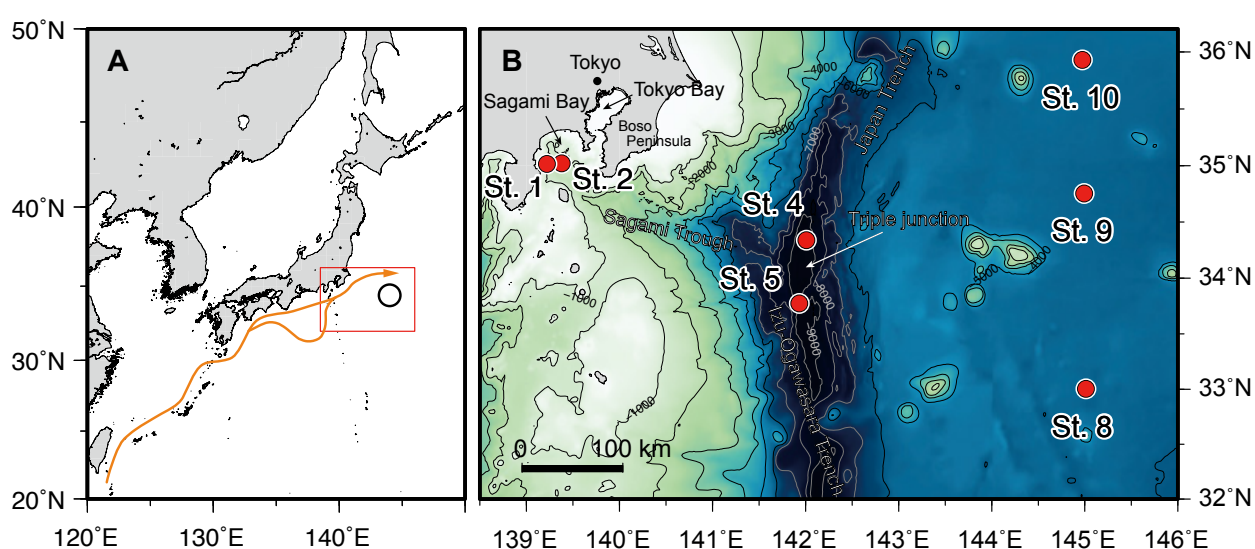


Fig. 1 Sampling locations. The area containing the sampling stations is indicated by the red box (A). Orange arrows in (A) indicate the mean flow of the Kuroshio Current and the Kuroshio Extension, and the meanders of the Kuroshio Current. The black circle indicates the position of the Kuroshio Extension recirculation gyre at the time of sampling (Nakajima et al., 2021) (A). Each sampling station is shown in (B): Stations 1 and 2: Sagami Bay (bathyal); Stations 4 and 5: triple trench junction (hadal); Stations 8, 9 and 10: abyssal plain (abyssal).

MPs in the deep-sea sediments analyzed in this study were more abundant than those in other ocean regions, with more MPs in the abyssal area than in the bathyal stations of Sagami Bay and in the hadal stations of the triple trench junction. MPs in the abyssal area were smaller in size and had a lower aspect ratio than those in the bathyal and hadal stations. The polymer type composition differed between the bathyal/hadal and abyssal stations, with a higher proportion of polypropylene (PP) in the bathyal and hadal stations and a higher proportion of polyethylene (PE) in the abyssal stations, whereas polyamide (PA) was found only in the abyssal stations. In conclusion, MPs discharged to the coastal zone were deposited on the seafloor and transported to the triple junction via the Sagami Trough (similar between bathyal and hadal stations) or deposited from the ocean surface directly above (as observed in the abyssal stations). Considering the similarity in MP properties between bathyal and hadal stations connected by the Sagami Trough, the MPs at the triple junction indicate transport along the submarine canyon (trough) (Fig. 2). Considering the homogeneity (between bathyal and hadal stations) and heterogeneity (between bathyal/hadal and abyssal stations) of MPs in deep-sea sediments at each station, the selection of size and polymer type of MPs during transport may be due to submarine topography and sedimentation events and their magnitude, in addition to their steady-state properties and the influence of severe weather events on the sea surface condition.

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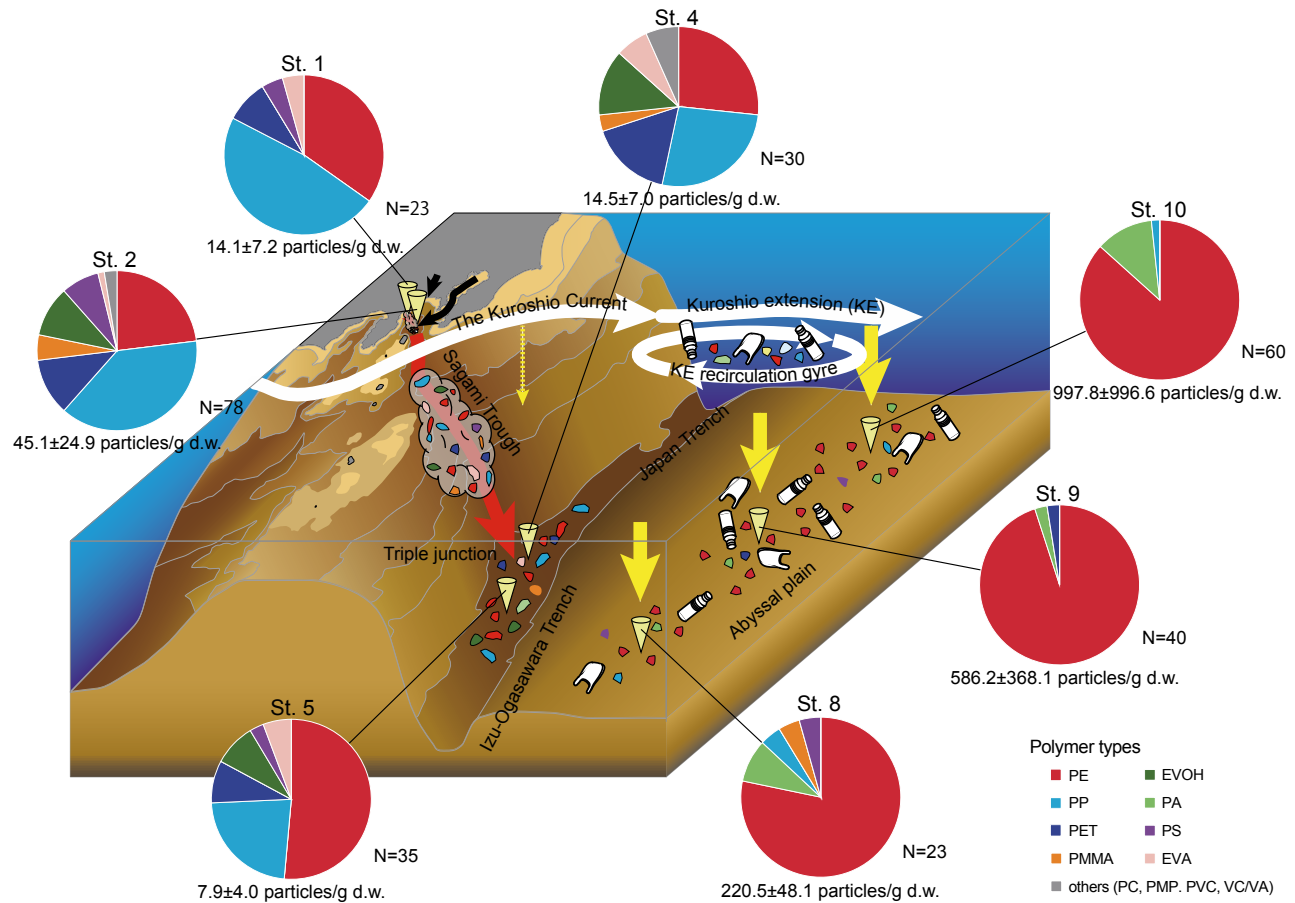


Fig. 2 Schematic transport process of MPs derived from the results obtained in this study and polymer composition at each station. PE, polyethylene; PP, polypropylene; PET, polyethylene terephthalate; PS, polystyrene; PA, polyamide; PMMA, acrylic resin; EVOH, ethylene-vinyl alcohol copolymer; EVA, ethylene-vinyl acetate; PC, polycarbonate; PMP, polymethylpentene; PVC, polyvinyl chloride; VC/VA, vinyl chloride-vinyl acetate copolymers.

Reference

Tsuchiya, M., Kitahashi, T., Nakajima, R., Oguri, K., Kawamura, K., Nakamura, A., Nakano, K., Maeda, Y., Murayama, M., Chiba, S., & Fujikura, K. (2024). Distribution of microplastics in bathyal- to hadal-depth sediments and transport process along the deep-sea canyon and the Kuroshio Extension in the Northwest Pacific. *Marine Pollution Bulletin*, **199**, 115466. <https://doi.org/10.1016/j.marpolbul.2023.115466>

Microplastics: an anthropogenic constituent of the marine particulate pool

Few observational and modeling studies have been performed to delineate the distribution of microplastics (MPs) within the ocean water column and the processes causing their redistribution are still vague. Furthermore, substantial amounts of MPs have become a consequential component of the marine particulate pool. Knowledge of how MPs interact with naturally occurring particulate matters, however, is lacking. Such knowledge is imperative for understanding the immediate and long-term impacts of plastic pollution on the present and predicted future ocean biogeochemical dynamics. In this study, MPs collected via *in-situ* pump filtration in the eastern North Pacific subtropical gyre (Fig. 3a) were quantified by automated interpretation of μ FTIR imaging spectral datasets. Additionally, MPs carbon (C) was estimated and compared to natural particulate organic carbon (POC).

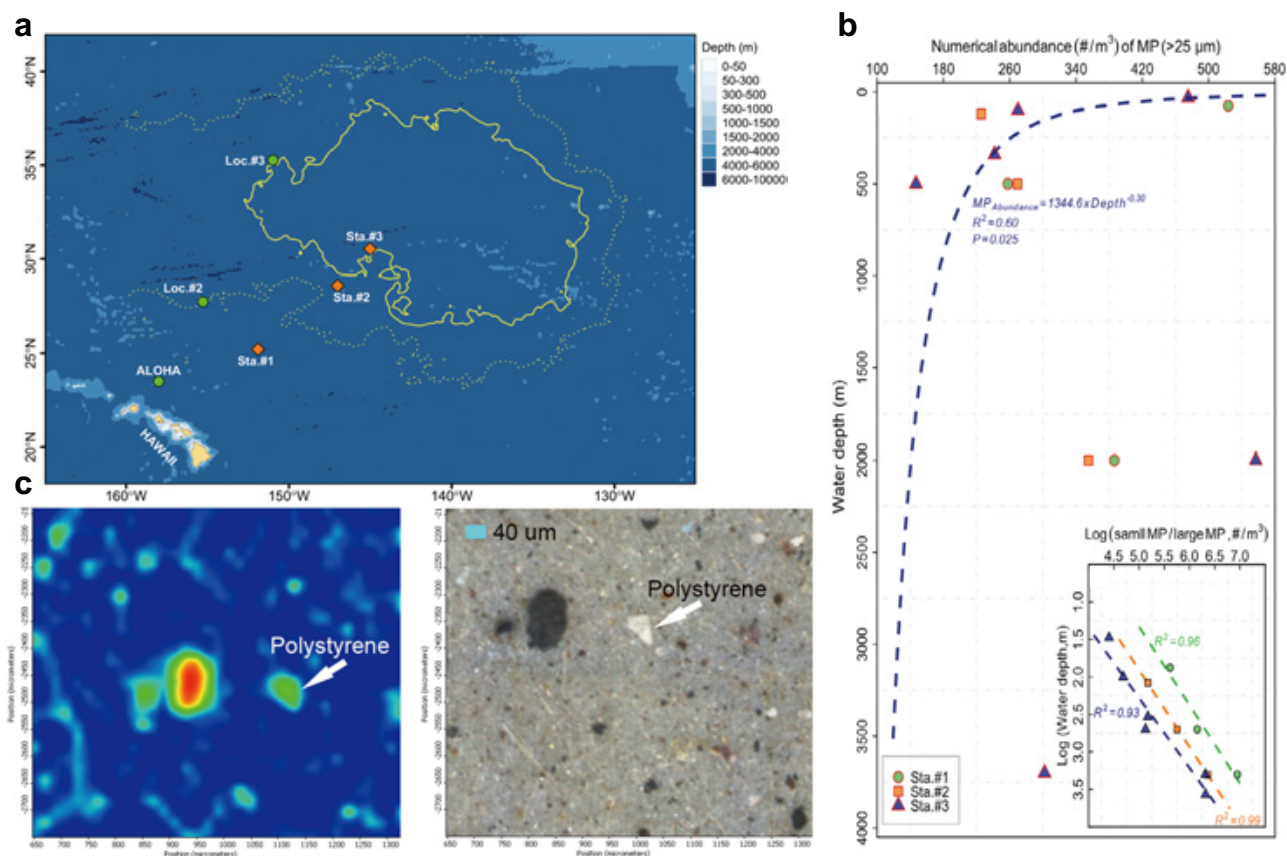


Fig. 3 a) Map of the sampled area within the eastern North Pacific subtropical gyre. Orange-filled diamonds represent MPs stations. Green-filled circles are locations measured the natural POC. Solid and dotted yellow lines represent the predicted inner and outer boundaries of the North Pacific Garbage Patch, respectively. b) The numerical abundances of MP. The inset shows log-log plots of water depth versus the ratios of numerical abundances of small MPs (<100 µm) to large MP. c) An example of small MPs particle <100 µm.

Our results showed exponential declines in plastic abundances within the upper 500 m (Fig. 3b). Small MPs (<100 µm, as shown in Fig. 1c) significantly contribute to the oceanic plastic burden in the deep sea compared to larger MPs (>100 µm, Fig. 3b). The polymer composition was dominated by PE, PP, nylon 6/6.6, PS, and PE-PP copolymer. Dense MPs ($\rho > 1.025$ g/cm³) showed consistent numerical abundance across depths, indicating a uniform vertical distribution (Fig. 4a). Our analysis of ‘Vertical connectivity of water-column MPs’ (Fig. 4b) highlighted that polymers presenting in the top water mass dominate throughout the column, suggesting that most MPs at depth originate those from top water masses. Polymer differentiation by size fraction across three vertical water masses declined with MP size, reflecting a more even distribution of smaller MPs (Fig. 4b). These findings indicate that properties (size and buoyancy) of MPs significantly contribute to their distribution. Small MPs tend to have long lifespan in the water column and represent a heightened risk to marine biome.

Our data also demonstrated that the ratio of MPs-C to natural POC increase with water depth, which can be up to 5% below 2000 m (Fig. 4c). These ^{14}C -depleted plastic particles, declining the fraction of radioactive carbon-14 (denoted as $^{14}\text{C}/\text{C}$) in the marine particulate pool, could therefore hamper radiocarbon dating and lead to an overestimation of the natural POC in high plastic-laden environments.

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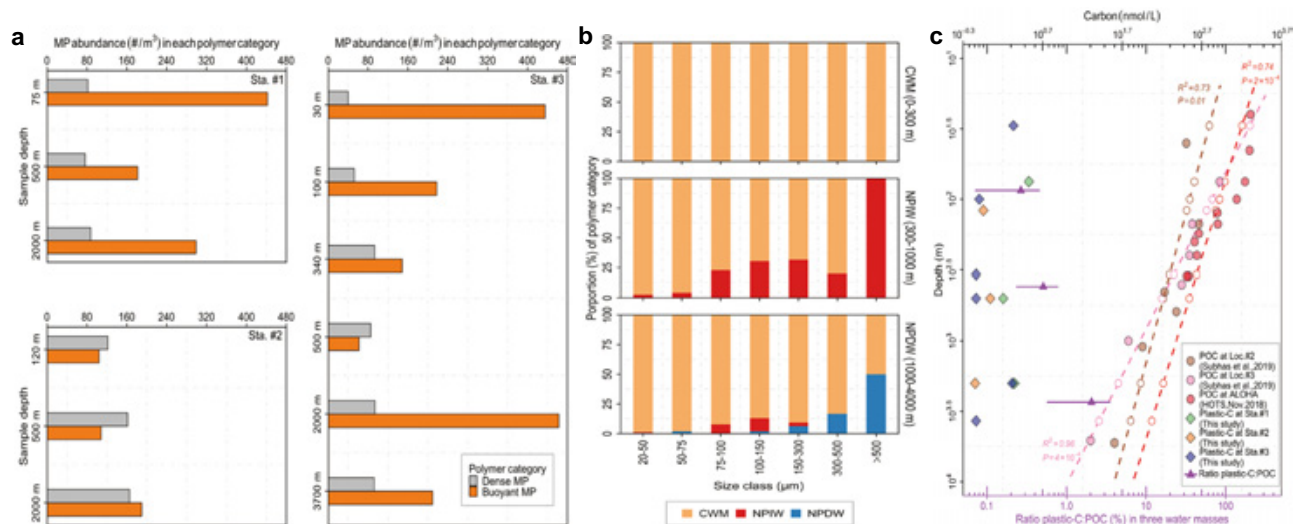


Fig. 4 a) Numerical abundances ($\#/m^3$) of buoyant and dense MP at Sta. #1, Sta. #2 and Sta. #3. Dense MP have theoretical densities which are larger than 1.025 g/cm^3 . The densities of buoyant MP are $< 1.025 \text{ g/cm}^3$. b) Proportion (%) of polymers from the North Pacific Central Water Mass (CWM; 0–300 m), North Pacific Intermediate Water (NPIW; 300–1,000 m), and North Pacific Deep Water (NPDW; 1,000–4,000 m) by size class and water mass, based on their first identification from surface to bathypelagic waters across all stations. c) Comparison of estimated MP-C (filled diamonds) collected and POC (filled circles) previously reported at three stations (ALOHA, Loc.#2 and Loc.#3) from the eastern North Pacific Subtropical Gyre (see Fig. 3a. for geographic reference).

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Zhao, S., Mincer, J. T., Lebreton, L. & Egger, M. (2023). Pelagic microplastics in the North Pacific Subtropical Gyre: A prevalent anthropogenic component of the particulate organic carbon pool. *PNAS Nexus*, 2, 3, pgad070. <https://doi.org/10.1093/pnasnexus/pgad070>

Development of *in situ* Raman spectrometers as a deep-sea geochemical sensing tool

Raman spectroscopy, label-free direct molecular analysis by observing the scattering of a laser light (Raman scattering), is a promising technique to chemically identify targets in oceans. A novel combined system of Raman spectroscopy and digital holography we have developed enables us to do *in situ* chemical and morphological analysis of suspended particles in the water column (Takahashi et al., 2020, 2023a). A device implementing this system could realise fully automated *in situ* measurement for a long term by mounting it on an autonomous platform, which will contribute to understanding the distribution of marine particles, such as plankton and microplastics, with significantly high spatial and temporal resolution. As Raman spectroscopy has a great advantage in measuring the targets with dynamic chemical changes in the water column, we have also developed a deep-sea Raman spectrometer for the measurement of CO_2 -rich fluids emitted from deep-sea hydrothermal vent fields. The behaviour of the CO_2 -rich fluids in the water column, particularly the water depth of the fluid phase transition from liquid to gas, is important to understand the transport system of the volatiles in the fluids as well as the potential impact on ocean acidification. However, no research has been performed to monitor the dynamic chemical change of the fluid due to the lack of measurement techniques. Our 2000 m depth-rated deep-sea Raman spectrometer can be attached to a fluid collection chamber where *in situ* measurement can be performed continuously for the fluid inside, as shown in Fig. 5. High-pressure gas-tight sampling bottles are also attached to the chamber to collect the fluid for later analysis in a laboratory.

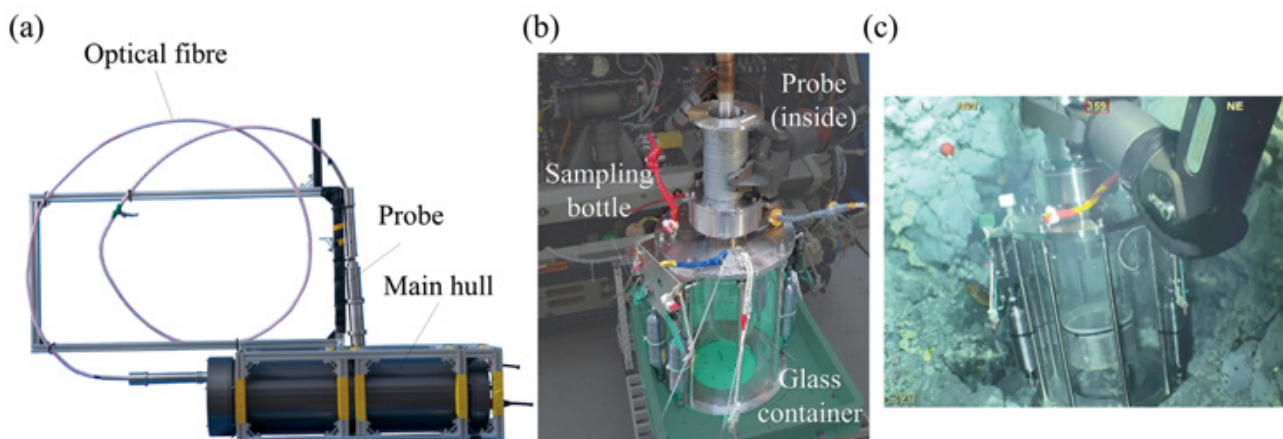


Fig. 5 (a) Deep-sea Raman spectrometer, (b) fluid collection chamber, and (c) collection of the CO₂-rich fluid at the deep sea floor. Adapted with permission from (Takahashi et al., 2023b). Copyright 2023 American Chemical Society.

The deep-sea Raman spectrometer attached to the fluid collection chamber was deployed at CO₂ bubbling sites at different hydrothermal vent fields (two sites in the Mariana Arc in March 2023 and four sites in the Okinawa Trough in September 2023). The CO₂-rich fluid emitted from the seafloor was collected in the chamber by putting it over a vent by holding the upper part of the chamber using the manipulator of the remotely operated vehicle (ROV) as shown in Fig. 5 (c). The Raman measurement revealed that CO₂ in the emitted fluid was gas at the Daikoku mound with a water depth of ~410 m, whereas it was liquid/hydrate at the other sites with a water depth of 1030–1600 m. From the depth profile of the CO₂ peak distance, which indicates the CO₂ phase, the CO₂ phase transition depth from liquid to gas was determined (see Fig. 6).

This study demonstrates the ability of the Raman spectroscopic technique to monitor the dynamic phase and the chemical compositional changes of the fluids in real time on site, showing its ability as a novel geochemical sensing technique in the deep sea.

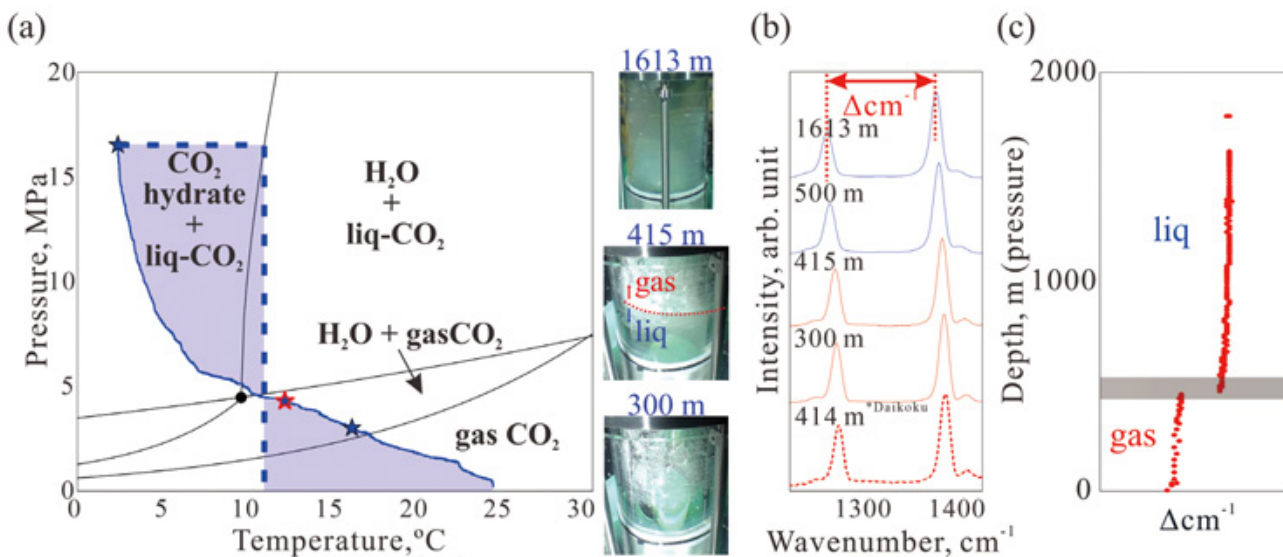


Fig. 6 (a) ROV dive track on the H₂O-CO₂ phase diagram, (b) CO₂ peaks detected in the *in situ* spectra, and (c) depth profile of the CO₂ peak distance, which indicates the CO₂ phase. Adapted with permission from (Takahashi et al., 2023b). Copyright 2023 American Chemical Society.

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– Center for Coupled Ocean-Atmosphere Research (CCOAR) – Diurnal SST warming and the boreal summer intraseasonal oscillation in the Philippine Sea: Contrasts between early and late summer

The tropical western North Pacific (WNP) is a key region for investigating air-sea interaction owing to high sea surface temperature (SST) and its variations in time and space, which affect various atmospheric and oceanic phenomena not only over WNP such as boreal summer intraseasonal oscillation (BSISO; Kikuchi, 2021) but also in higher latitudes through teleconnection (e.g., Nitta, 1987), the Kuroshio current (e.g., Nagano et al., 2014), El Niño and the Southern Oscillation (e.g., Hasegawa & Hanawa, 2007), and so on. Motivated by WNP's important role in climate, we have deployed a moored buoy called the Philippine Sea mooring (PHSMO) at 13°N, 137°E since December 2016 (Nagano et al., 2018). In this study, we investigated the relationship between diurnal fluctuations of SST and BSISO and its difference between early and late summer using four-year (2017–2020) PHSMO data (Seiki et al., 2023).

A strong diurnal cycle of SST is observed frequently during convectively suppressed phases of the BSISO (phases 2 and 3) simultaneously with a weakening of surface winds and enhanced insolation (Fig. 1). In addition, abrupt SST warming along with the strong diurnal cycle occurred in the middle of May in 2018 and 2019, in conjunction with the first BSISO of the year (Fig. 2). Interestingly, the convectively suppressed phases of second BSISO showed small SST warming albeit the strong diurnal cycle, which can be attributed to a deepening of the warm isothermal layer. In the remaining two years, 2017 and 2020, SST increased gradually with small diurnal SST amplitude, which is presumably attributed to continuous surface winds with moderate strengths mixing the upper ocean. Moreover, the first BSISO was observed in late summer. These results suggest that the abrupt SST warming associated with the strong diurnal cycle is linked to the seasonal onset of the BSISO.

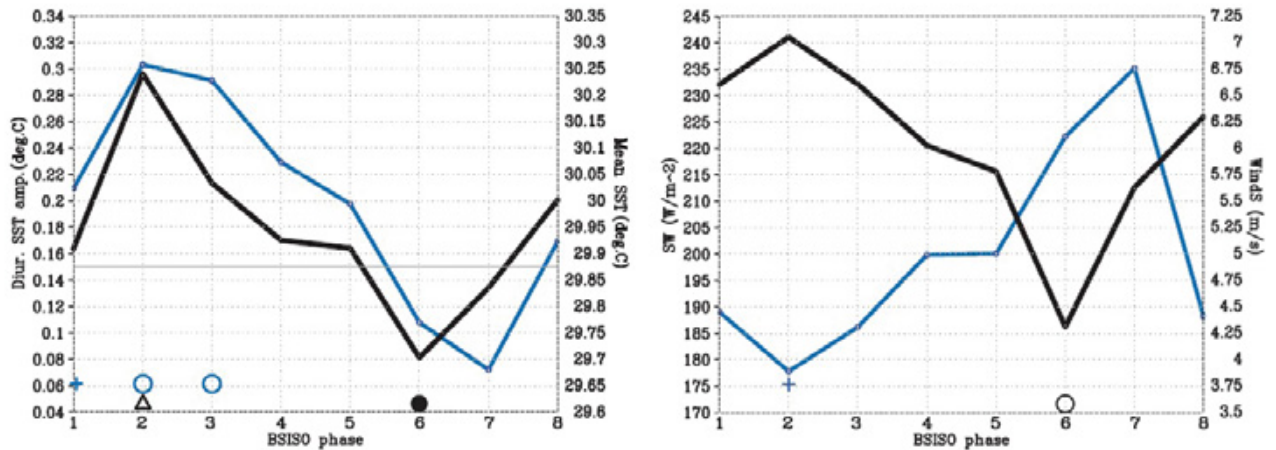


Fig. 1 Composites of (left) diurnal amplitude of SST (black, left axis) and mean SST (blue, right axis) and (right) downward solar radiation at the surface (black, left axis) and surface wind speed (blue, right axis) in each BSISO phase during May - September (MJJAS). Gray line in the left panel represents mean diurnal amplitude of SST averaged for MJJAS. Closed circles, open circles, triangles, and crosses in the bottom represent composite values exceeding the 99%, 95%, 90%, and 80% confidence levels in each phase, respectively.

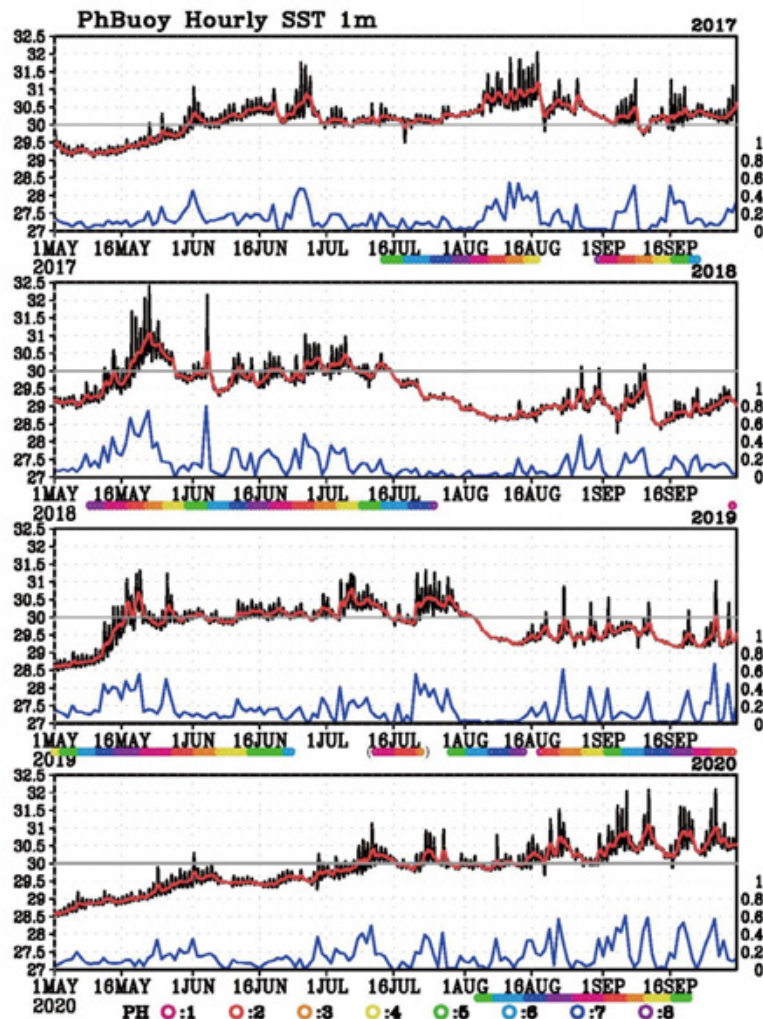


Fig. 2 Time series of hourly SST (°C) observed by the PHSMO buoy during MJJAS shown by black lines (left axis). Red and blue lines show 24-hour running mean SST (left axis) and diurnal amplitude of SST (right axis), respectively. Circles indicate the days of BSISO occurrence and its color represents the phase as shown in the bottom.

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Dual-frequency wind-driven mixed Rossby–gravity waves in the equatorial Indian Ocean

Variability related to mixed Rossby–gravity waves in the Indian Ocean is often referred to as having “biweekly” periods (e.g., Miyama et al., 2006). However, in situ observations in the central equatorial Indian Ocean (0° , 80.5°E) show dual peaks in the spectrum of meridional velocity, one in a high frequency (HF) band ($0.06\text{--}0.1$ cpd; 10–17 days in period) with variance that peaks near the surface, and the other in a low frequency (LF) band ($0.04\text{--}0.06$ cpd; 17–25 days in period) that peaks in the pycnocline (Fig. 3). This study (Nagura and McPhaden, 2023) was motivated by the desire to understand this unusual frequency structure as a function of depth. We used empirical analysis and a wind-forced ocean general circulation model in the Indian Ocean domain validated with in situ velocity measurements to address this problem.

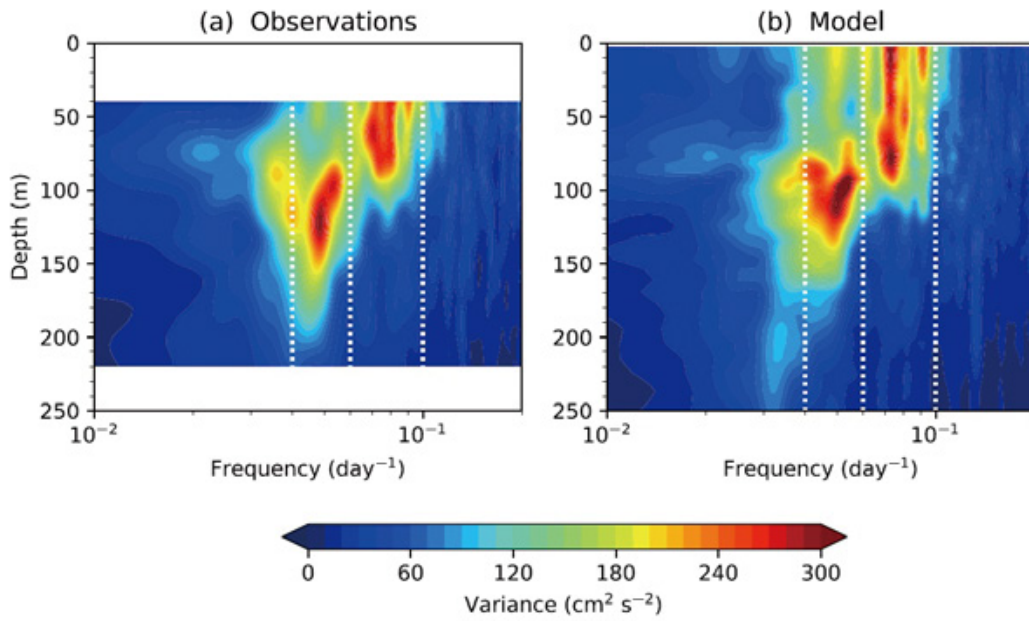


Fig. 3 Variance-preserving spectra of meridional velocity at 0° , 80.5°E as a function of frequency and depth obtained from (a) acoustic Doppler current profiler observations and (b) the control run of the ocean general circulation model. Frequencies of 0.04, 0.06, and 0.1 cpd (periods of 25, 17, and 10 days) are marked by the vertical dotted lines.

Results of statistical analysis show that velocity variability in the HF and LF bands has a similar horizontal structure. However, the wave pattern is meridionally narrower in the LF band than in the HF band and the vertical wavelength is shorter for LF variability than for HF variability. HF variability is characterized by surface-trapped energy, as is pointed out by Pujiana and McPhaden (2021), whereas LF variability exhibits alternating meridional currents with higher vertical wavenumber at depth (Fig. 4). HF variability in meridional velocity along the equator has a large amplitude above 100 m depth, whereas LF variability is largest below the surface east of 70°E . We estimated the zonal and vertical wavelengths using coherence analysis and confirmed that wavelengths of both HF and LF variability are consistent with the dispersion relation of mixed Rossby–gravity waves in an ocean at rest.

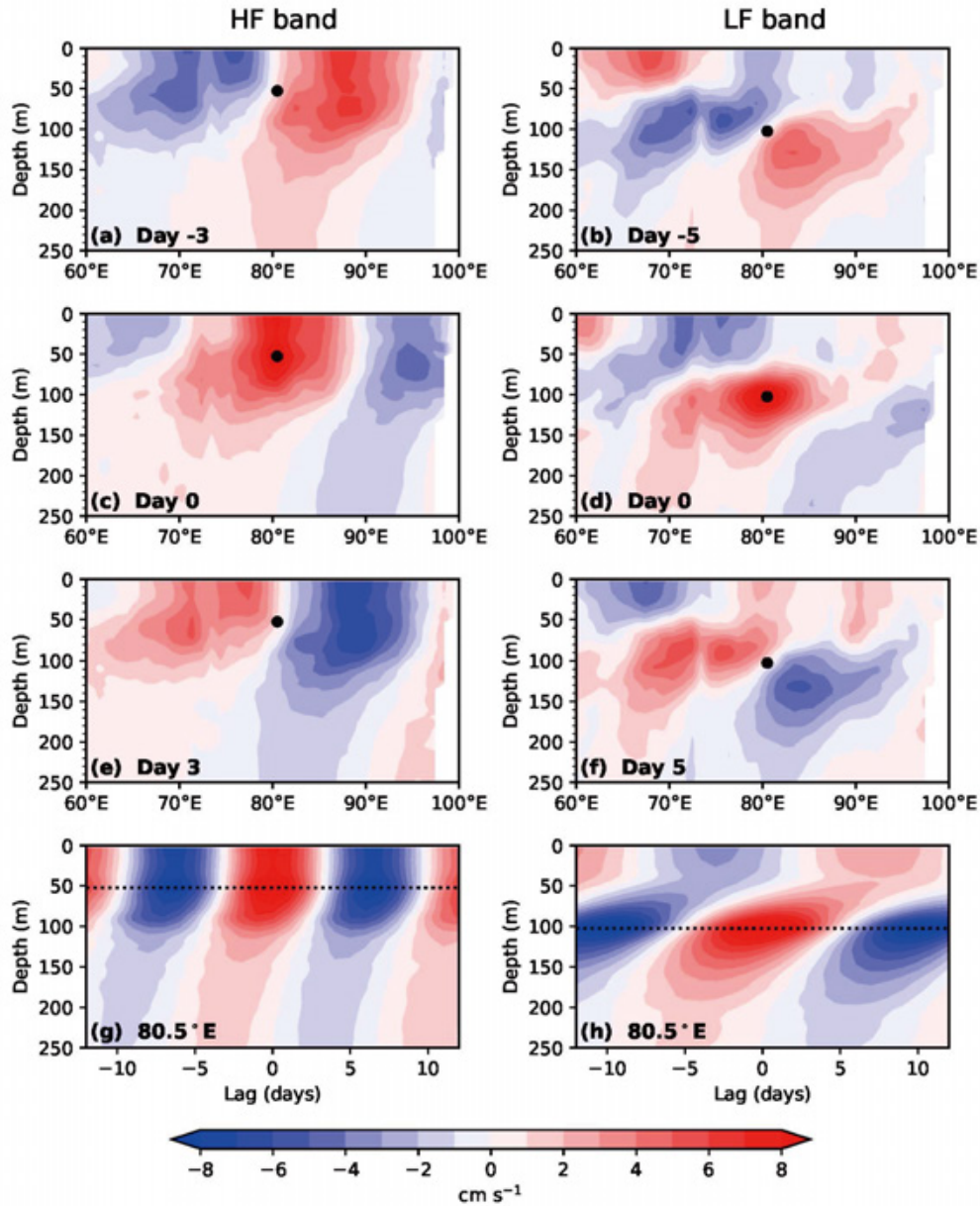


Fig. 4 (a)–(f) Longitude–depth sections of regressed meridional velocity along the equator for (left) HF (0.06–0.1 cpd; 10–17 days in period) and (right) LF (0.04–0.06 cpd; 17–25 days in period) variability. Meridional velocity at 0° , 80.5°E is regressed onto HF meridional velocity time series at 52.5 m depth in (a), (c), and (e) and LF meridional velocity time series at 102.5 m depth in (b), (d), and (f). The location of the index time series is shown by the black dots. Also shown are depth–time sections of (g) HF variability in meridional velocity at 0° , 80.5°E regressed onto the time series at 52.5 m depth and (h) LF variability regressed onto the time series at 102.5 m depth. The depth of the index time series is shown by the dotted lines in (g) and (h).

We conducted sensitivity experiments, in which the model was forced by HF and LF variability in surface wind stress. The results show that HF and LF variability in meridional velocity at the location of the ADCP mooring (0° , 80.5°E) is the response to wind forcing in the central and eastern Indian Ocean consistent with linear equatorial wave theory. The response to HF wind forcing is large in amplitude above the pycnocline, whereas that to LF wind forcing has a peak of energy at the depth of the pycnocline. It is likely that waves excited by LF winds propagate downward from the surface, reflect and are trapped in the pycnocline, generating the energy peak there. We conclude that this process creates the energy peak at the depth of the pycnocline in the LF band. The response to HF wind forcing is large in amplitude near the eastern boundary east of 80°E , whereas the response to LF wind forcing is largest in the central basin between 60° and 90°E .

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– Mutsu Institute for Oceanography (MIO) – Topographically driven vigorous vertical mixing supports mesoscale biological production in the Tsugaru Gyre

The Tsugaru Strait is a critical conduit linking the Sea of Japan and the Pacific Ocean and is characterized by a vigorous eastward current. Here, we use high-resolution surface current data acquired from a high-frequency radar system (e.g., Kaneko et al., 2021; 2022) in conjunction with direct turbulence measurements to show that the large increase in chlorophyll-*a* within a hundred kilometre-scale anticyclonic gyre is driven by the intensification of turbulence, extraordinarily high diffusive nitrate fluxes and divergent flow fields limited to a very narrow area.

Enhanced mixing and nutrient fluxes are caused by the presence of a distinct topographic feature—an underwater seamount—within the path of the Tsugaru Strait water flow. Our long-term datasets revealed a positive correlation between recurring submesoscale divergence related to the topographic features and the downstream distribution of chlorophyll-*a*. This finding reinforces the significant role of the underwater seamount in enhancing the productivity of the downstream anticyclonic gyre. The results of this study emphasize the importance of re-evaluating nutrient supply processes with respect to submesoscale interactions with underwater seamounts for large-scale enhanced biological productivity.

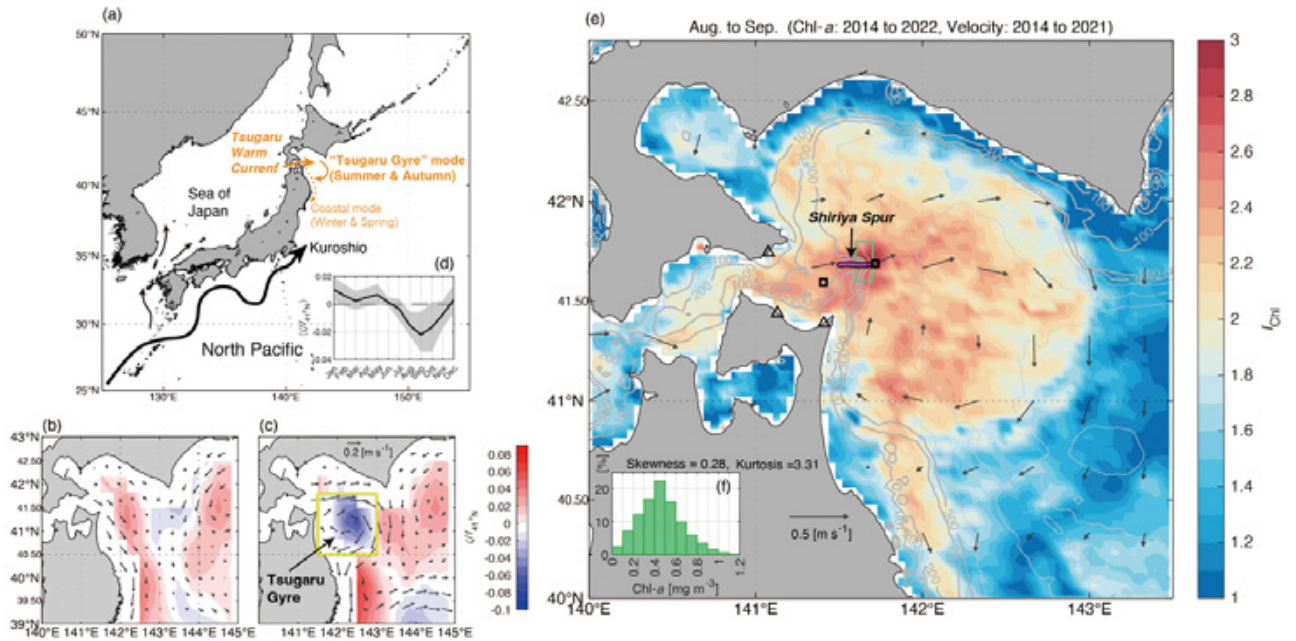


Fig. 1 Observational site. (a), Location of the Tsugaru Strait. (b), (c), Mean surface velocities and relative vorticity (2014–2021) for December and January–June (b) and July–November (c), respectively, derived from OSCAR surface velocities. (d), Monthly (2014–2021 average) time series of relative vorticity (normalized to an inertial frequency of 41°N) derived from the Ocean Surface Current Analysis Real-time (OSCAR) surface velocities in the regions indicated by the yellow rectangles in (c). The black line and shaded range represent the bootstrap mean and 95% confidence interval, respectively. (e), Distribution of the pixelwise arithmetic mean surface chlorophyll-*a* data for August and September from 2014 to 2022, divided by the root of its pixelwise temporal variance relative to the arithmetic mean, defined as an index of $I_{chl}: I_{chl}(x,y) = (chl(x,y))_t / [\frac{1}{n-1} \sum \{chl(x,y) - \langle chl(x,y) \rangle_t\}^2]^{1/2}$, where x , y , and n denote longitude, latitude, and the number of data at each pixel, respectively, and t denotes time. The vectors in (e) represent the mean current velocities for August and September from 2014 to 2021, sourced from OSCAR. The magenta points and squares represent stations where the turbulence measurements were deployed and where a carousel water sampler was used, respectively (26th August 2021). The grey contours denote bathymetry. The upward triangles indicate the location of the antenna of the high-frequency radar system. (f), The frequency distribution of chlorophyll-*a* for August and September from 2014 to 2022 is shown in the light green rectangle in (e).

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I. Research Activities and Results

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I. Research Activities and Results

Publication List

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II. Related Activities

Research Collaboration

1. Domestic Research Collaboration

(1) JFE Advantech Co., Ltd.

Theme: Evaluation of the deep ocean fluorometer and turbidity meter

Program: Global Ocean Observation Research Center

(2) Iwate University

Theme: Research on a snow crawler robot for the EM lighthouse

Program: Institute of Arctic Climate and Environment Research

(3) National Institute of Information and Communications Technology (NICT)

Theme: Application study of Underwater Electromagnetics

Program: Institute of Arctic Climate and Environment Research

(4) Chuo University

Theme: Basic Research on Sea Ice Drilling Robot

Program: Institute of Arctic Climate and Environment Research

(5) Sony Group Corporation

Theme: EM Wave Propagation in the Sea, on the Sea Surface, and in the Sea Bottom and its Applications

Program: Institute of Arctic Climate and Environment Research

(6) Chiba University / Tohoku University / Niigata University

Theme: Technology development for under-ice measurement in the Arctic Ocean

Program: Institute of Arctic Climate and Environment Research

(7) Japan Aerospace Exploration Agency (JAXA)

Theme: Verification for the GCOM-W & AMSR3-based snowfall, snowpack and soil moisture retrievals in the Arctic and elucidation of water and material balance in large northern river basins using an ecohydrological model and satellite data assimilation method

Program: Institute of Arctic Climate and Environment Research

(8) Japan Aerospace Exploration Agency (JAXA)

Theme: Development of the voxel-based plant canopy radiative transfer and estimation and validation of large-scale ecosystem parameters from SGLI

Program: Institute of Arctic Climate and Environment Research

(9) Snow and Ice Research Center, National Research Institute for Earth Science and Disaster Resilience (NIED)

Theme: Change in snow surface roughness length due to irregular snow surface

Program: Institute of Arctic Climate and Environment Research

II. Related Activities
Research Collaboration

(10) National Maritime Research Institute (NMRI), National Institute of Maritime, Port and Aviation Technology (MPAT) / Graduate School of Frontier Sciences, The University of Tokyo / KITAMI Institute of Technology / Japan Radio Co., Ltd.

Theme: Research on the application of observation methods for sea ice characteristics and waves around ships

Program: Institute of Arctic Climate and Environment Research

(11) National Institute for Environmental Studies (NIES) / National Institute of Information and Communications Technology (NICT)

Theme: Nitrogen dioxide concentration observations by the Global Observing Satellite for Greenhouse gases and Water cycle: Development of derivation algorithms, data processing schemes, product validation systems and data utilization methodologies

Program: Earth Surface System Research Center

(12) Kobe University

Theme: Combined study of observation and modeling for atmosphere-ocean material circulation over the Asian region

Program: Earth Surface System Research Center

(13) Japan Aerospace Exploration Agency (JAXA)

Theme: GCOM-C SGLI-based near-real-time observing system for monitoring ocean color in Asian waters

Program: Earth Surface System Research Center

(14) Tokai University Research & Information Center (TRIC)

Theme: Research and Development of Asian Coastal Ocean Color Monitoring Based on GCOM-C SGLI Observations

Program: Earth Surface System Research Center

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

Theme: Assessing the Flexible Phytoplankton Functional Type (FlexPFT) model using two different Ocean General Circulation Models

Program: Earth Surface System Research Center

(16) Tokyo University of Marine Science and Technology / Tsurumi-Seiki Co., Ltd.

Theme: Development of a profiling float equipped with a fast repetition rate fluorometer and a CO₂/pH sensor

Program: Earth Surface System Research Center

(17) City of Mombetsu

Theme: Cooperative research for development of real-time monitoring station on the oceanic carbonate systems, Assessing the Flexible Phytoplankton Functional Type (FlexPFT) model using two different Ocean General Circulation Models

Program: Earth Surface System Research Center

(18) National Institute of Maritime, Port and Aviation Technology (MPAT)

Theme: Observations of air pollutants and greenhouse gases over Tokyo Bay: Research use of Tokyo Wan Ferry

Program: Earth Surface System Research Center

- (19) 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: Research Center for Environmental Modeling and Application
- (20) Japan Aerospace Exploration Agency (JAXA)**
Theme: Contribution to satellite products development by sharing needs and results of a climate change research project
Program: Research Center for Environmental Modeling and Application
- (21) Japan Aerospace Exploration Agency (JAXA)**
Theme: Application of the observed strong dependence of snow growth on atmospheric temperature to the emergent constraint of climate projection and intense rain prediction
Program: Research Center for Environmental Modeling and Application
- (22) Thermo Fisher Scientific K.K.**
Theme: Development of semi-automated microplastic analyzer using reflectance IR spectroscopy
Program: Marine Biodiversity and Environmental Assessment Research Center
- (23) KANSO TECHNOS CO., LTD.**
Theme: Development of an automatic classification system for meiobenthos
Program: Marine Biodiversity and Environmental Assessment Research Center
- (24) Kitasato University**
Theme: Analysis of secondary metabolites produced by deep-sea derived fungi
Program: Marine Biodiversity and Environmental Assessment Research Center
- (25) The University of Tokyo / SHIMADZU CORPORATION**
Theme: Development of an in situ Raman spectrometer towards the applications to deep-sea explorations
Program: Marine Biodiversity and Environmental Assessment Research Center
- (26) BioJet Co., LTD**
Theme: Detailed phylogenetic classification of marine-derived *Aspergillus* by comprehensive genome sequencing and utilization of their useful genome information
Program: Marine Biodiversity and Environmental Assessment Research Center
- (27) Kindai University**
Theme: Observational study on improvement of the global air-sea flux measurements
Program: Center for Coupled Ocean-Atmosphere Research
- (28) Electronic Navigation Research Institute (ENRI), National Institute of Maritime, Port and Aviation Technology (MPAT)**
Theme: Collaborative study on air traffic control ADS-B data acquisition and its application as meteorological information
Program: Center for Coupled Ocean-Atmosphere Research

II. Related Activities
Research Collaboration

(29) Mitsubishi Electric Corporation

Theme: Applied research on atmospheric observations using the Centimeter Level Augmentation Service (CLAS) of the Quasi-Zenith Satellite System (QZSS)
Program: Center for Coupled Ocean-Atmosphere Research

(30) University of the Ryukyus

Theme: A study on material transport from surface to upper stratosphere by high-altitude radiosonde observations
Program: Center for Coupled Ocean-Atmosphere Research

(31) Aomori Prefectural Industrial Technology Research Center

Theme: Collaborative research on coastal environment change around the Tsugaru Strait and Aomori Prefecture
Program: Mutsu Institute for Oceanography

(32) Japan Marine Science Foundation

Theme: Joint research on changes in the Tsugaru Warm Current
Program: Mutsu Institute for Oceanography

(33) Kumamoto University

Theme: Studies on technology development and value-added information generation through the expansion of the high-frequency radar observation system around the Tsugaru Strait
Program: Mutsu Institute for Oceanography

(34) Tokai University / The University of Tokyo / Kagoshima University

Theme: Actual usage of marine environmental data on MORSETS by the local fishermen in Eastern Tsugaru-strait
Program: Mutsu Institute for Oceanography

2. International Research Collaboration

A. Interagency agreement (*extracted based on the areas of cooperation related to Research Institute for Global Change)

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

Theme:

- Study of Ocean General Circulation and Climate
Program: Global Ocean Observation Research Center
- Research into Marine Biogeochemical Cycles
Program: Global Ocean Observation Research Center / Earth Surface System Research Center

(2) 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 and IndoOS (Scientific and Technology Development Cooperation)
Program: Center for Coupled Ocean-Atmosphere Research
- Arctic Observation and Research
Program: Institute of Arctic Climate and Environment Research
- Ocean, Climate and Biogeochemical Research in the North Pacific; Cooperation in Developing and Maintaining JAMSTEC and PMEL Contributions to the North Pacific Surface Mooring Network
Program: Earth Surface System Research Center
- Computer Modeling for Global Environment Research
Program: Research Center for Environmental Modeling and Application

(3) University of Hawai'i (UH), USA

Theme:

- Studies on carbon chemistry in the Pacific
Program: Earth Surface System Research Center
- Study on Climate Change and Variability in the Asia-Pacific region
Program: Research Center for Environmental Modeling and Application / Center for Coupled Ocean-Atmosphere Research

(4) University of Alaska Fairbanks (UAF), USA

Theme:

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

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

Theme: Physical Oceanography (The Argo Programme)

Program: Global Ocean Observation Research Center

II. Related Activities

Research Collaboration

(6) The Ministry of Earth Sciences (MOES), India

Theme: Marine Plastics

Program: Marine Biodiversity and Environmental Assessment Research Center

Theme: Glacial Hydrology

Program: Institute of Arctic Climate and Environment Research

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

Theme: Ocean Biogeochemistry in the Indian Ocean and Impact on Ocean Climate

Program: Global Ocean Observation Research Center

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

Theme: Marine Meteorology and Climate Studies over the Maritime Continent

Program: Center for Coupled Ocean-Atmosphere Research

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

Theme:

- Heat, Carbon and other Material Transports through Ocean Circulation and their Variability

- 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: Global Ocean Observation Research Center

- Planktonic Community Comparisons, including those of the Continuous Plankton Recorder, in Australasian and Japanese regions

Program: Marine Biodiversity and Environmental Assessment Research Center

(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) 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

- Abrupt climate change, Modeling Intercomparison Projects, Earth system modeling incl, ice sheets

Program: Research Center for Environmental Modeling and Application

- Paleoceanography and paleoclimate

Program: Earth Surface System Research Center

(12) University of Tromsø – The Arctic University of Norway (UiT), Norway

Theme: Marine biology, biogeochemistry, and ice-covered sea observation with ice-breakers

Program: Institute of Arctic Climate and Environment / Research Earth Surface System Research Center

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

Theme:

- Ocean Monitoring

Program: Global Ocean Observation Research Center

- Marine Debris

Program: Marine Biodiversity and Environmental Assessment Research Center

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

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

Theme: Joint Research Activity on Arctic Environment and Ecosystem Changes under Arctic Warming

Program: Institute of Arctic Climate and Environment Research

(2) University of Hawai'i (UH), USA

Theme:

- Developing Automated Nutrient and Trace Metal Sampling and Methodology using Programmable Flow Injection

Program: Institute of Arctic Climate and Environment Research

- Joint Research Activities on Climate Change and Variability in the Asia-Pacific Region

Program: Research Center for Environmental Modeling and Application / Center for Coupled Ocean-Atmosphere Research

(3) National Research and Innovation Agency (BRIN), Indonesia

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

Program: Center for Coupled Ocean-Atmosphere Research

(4) The PM2.5 Research Center (PM2.5 Research Center), The Gwangju Institute of Science and Technology (GIST), Korea

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

Program: Earth Surface System Research Center

(5) Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) of the Department of Science and Technology (DOST), The Philippines

Theme: Monsoon Experiment in the Republic of the Philippines

Program: Center for Coupled Ocean-Atmosphere Research

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

Theme: Cooperative Research for Weather and Climate over the Indonesian Maritime Continent

Program: Center for Coupled Ocean-Atmosphere Research

II. Related Activities
Research Collaboration

(7) Viet Nam Meteorological and Hydrological Administration (VNMHA), Viet Nam

Theme: Research Collaboration on Asian Monsoon Observation over Viet Nam

Program: Center for Coupled Ocean-Atmosphere Research

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

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

Program: Earth Surface System Research Center

(9) The Université de Lorraine (UL), France / The Centre National de la Recherche Scientifique (CNRS), France / Universität Greifswald (UG), Germany

Theme: Enhanced Data stream Analysis

Program: Global Ocean Observation Research Center

(10) Federal Research Centre "The Yakut Scientific Centre (YaSC) of the Siberian Branch of the Russian Academy of Sciences", Russia

Theme: Cooperative Research on Black Carbon in the Eastern Siberia

Program: Earth Surface System Research Center

Funded Research Projects

- (1) EnhanceD Data stream Analysis (EDDA): combining the signature method and machine learning algorithms (FY2020-2023)**
Fund: Core Research for Evolutional Science and Technology (CREST)
Funding institution: Japan Science and Technology Agency (JST)
Program: Global Ocean Observation Research Center
- (2) Elucidation of CO₂ absorption and storage mechanism of subtropical mode water by Argo (FY2023-2025)**
Fund: Core Research for Evolutional Science and Technology (CREST)
Funding institution: Japan Science and Technology Agency (JST)
Program: Global Ocean Observation Research Center
- (3) Arctic Challenge for Sustainability II (ArCS II) (FY2020-2024)**
Fund: National flagship project funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT)
Funding institution: National Institute of Polar Research (NIPR)
Program: Institute of Arctic Climate and Environment Research
- (4) Research study on the perturbation of the meteorology and soil radioactivity levels associated with the explosion of the "Little Boy" (FY2022-2025)**
Fund: Collaborative Research Fund
Funding institution: Ministry of Health, Labour and Welfare (MHLW)
Program: Institute of Arctic Climate and Environment Research
- (5) Observation and research collaboration to strengthen Arctic sea ice-ocean environment research capabilities (FY2022-2024)**
Fund: National flagship project funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT)
Arctic Challenge for Sustainability II (ArCS II), International Research Exchange Program
Funding institution: National Institute of Polar Research (NIPR)
Program: Institute of Arctic Climate and Environment Research
- (6) Nitrogen dioxide concentration observations by the Global Observing Satellite for Greenhouse gases and Water cycle: Development of derivation algorithms, data processing schemes, product validation systems and data utilization methodologies (FY2020-2024)**
Fund: Collaborative Research Fund
Funding institution: National Institute for Environmental Studies (NIES)
Program: Earth Surface System Research Center
- (7) Evaluation of global GHG budget change by top-down method (FY2021-2023)**
Fund: Environment Research and Technology Development Fund (ERTDF): SII-8-2
Funding institution: Environmental Restoration and Conservation Agency (ERCA)
Program: Earth Surface System Research Center

II. Related Activities
Funded Research Projects

- (8) Prompt estimation of country-based emissions using field/satellite observations and data assimilation models (FY2022-2024)**
Fund: Environment Research and Technology Development Fund (ERTDF): 2-2201
Funding institution: Environmental Restoration and Conservation Agency (ERCA)
Program: Earth Surface System Research Center
- (9) Effectiveness assessment of GHG emission reduction using Earth system model (FY2021-2023)**
Fund: Environment Research and Technology Development Fund (ERTDF): SII-8-2
Funding institution: Environmental Restoration and Conservation Agency (ERCA)
Program: Research Center for Environmental Modeling and Application
- (10) Quantitative Assessment of Atmospheric Water Cycle Change by Short-Lived Climate Forcers (FY2021-2025)**
Fund: Environment Research and Technology Development Fund (ERTDF): S-20-1
Funding institution: Environmental Restoration and Conservation Agency (ERCA)
Program: Research Center for Environmental Modeling and Application
- (11) System Research Team (26 Weather/Climate Science Application Area) (FY2022-2024)**
Fund: Feasibility Studies on Next-Generation Supercomputing Infrastructures
Funding institution: Ministry of Education, Culture, Sports, Science and Technology (MEXT)
Program: Research Center for Environmental Modeling and Application
- (12) Biogeochemical modeling and climate simulations for carbon budget assessment (FY2022-2026)**
Fund: Advanced Studies of Climate Change Projection (SENTAN)
Funding institution: Ministry of Education, Culture, Sports, Science and Technology (MEXT)
Program: Research Center for Environmental Modeling and Application
- (13) Predictive understanding of Earth system changes based on physical evidence (FY2022-2026)**
Fund: Advanced Studies of Climate Change Projection (SENTAN)
Funding institution: Ministry of Education, Culture, Sports, Science and Technology (MEXT)
Program: Research Center for Environmental Modeling and Application
- (14) Diagnosis of the impacts of typhoons on large-scale environment using numerical simulation data (FY2022-2026)**
Fund: Moonshot Research and Development Program
Funding institution: Japan Science and Technology Agency (JST)
Program: Research Center for Environmental Modeling and Application
- (15) Development of a novel technology for monitoring benthic plastic debris using imagery (FY2023-2025)**
Fund: Environment Research and Technology Development Fund (ERTDF): SII-10-1
Funding institution: Environmental Restoration and Conservation Agency (ERCA)
Program: Marine Biodiversity and Environmental Assessment Research Center

**(16) Data integration and indicator development to capture changes in biodiversity over time –
Demonstrating the effect of conservation and management (FY2023-2025)**

Fund: Environment Research and Technology Development Fund (ERTDF): 4-2302

Funding institution: Environmental Restoration and Conservation Agency (ERCA)

Program: Marine Biodiversity and Environmental Assessment Research Center

**(17) Development of a model for assessing biodiversity and ecosystem services in marine areas
(FY2023-2027)**

Fund: Environment Research and Technology Development Fund (ERTDF): S-21-1

Funding institution: Environmental Restoration and Conservation Agency (ERCA)

Program: Marine Biodiversity and Environmental Assessment Research Center

(18) Deep-sea Archaic Refugia in Karst (D-ARK) (FY2023-2027)

Fund: Ocean Shot Research Grant Program

Funding institution: Sasakawa Peace Foundation

Program: Marine Biodiversity and Environmental Assessment Research Center

**(19) Development of innovative atmospheric observation network for future extreme weather
(FY2021-2027)**

Fund: Fusion Oriented REsearch for disruptive Science and Technology (FOREST)

Funding institution: Japan Science and Technology Agency (JST)

Program: Coupling of Ocean-Atmosphere-Land Research Program

(20) Development of Virtual Mooring (VM) Technology for Stormy Environments (FY2022-2024)

Fund: Moonshot Research and Development Program

Funding institution: Japan Science and Technology Agency (JST)

Program: Center for Coupled Ocean-Atmosphere Research

(21) Test operation under stormy environment in the tropical northwestern Pacific Ocean (FY2022-2024)

Fund: Moonshot Research and Development Program

Funding institution: Japan Science and Technology Agency (JST)

Program: Center for Coupled Ocean-Atmosphere Research

(22) Development of Atmosphere-Ocean Sensors for Stormy Environments (FY2022-2024)

Fund: Moonshot Research and Development Program

Funding institution: Japan Science and Technology Agency (JST)

Program: Center for Coupled Ocean-Atmosphere Research

Awards

- **The 16th National Maritime Award (Prime Minister's Award)**

- Dr. Kentaro Ando (Research Institute for Global Change)**

- Enhancing Japan's international presence through the activities of the IOC/WESTPAC and other organizations
(August, 2023)

- **Kamide Lecture Award, Asia Oceania Geosciences Society (AOGS)**

- Dr. Yoko Yamagami (Research Center for Environmental Modeling and Application)**

- Arctic Sea-Ice Reduction and Gulf Stream Warming under Global Warming: Implication for the Further Development of GCMs
(August, 2023)

- **JpSAC Young Scientist Award, The Japan Society of Atmospheric Chemistry**

- Dr. Takashi Sekiya (Earth Surface System Research Center)**

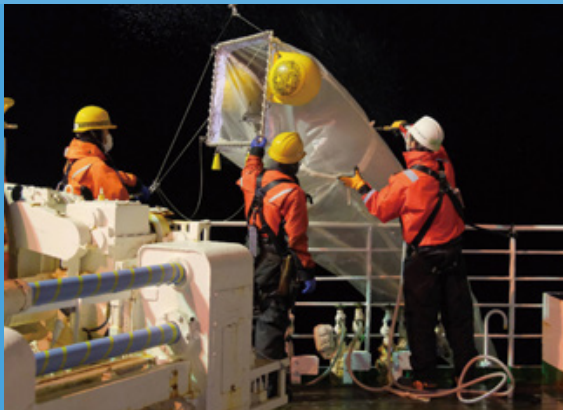
- Studies of atmospheric trace components and their variations by extending the chemistry-climate model CHASER
(November, 2023)

- **Iwate Prefecture Governor's Award for the FY2023 Iwate Prefecture Sanriku Sea Area Research Paper**

- Dr. Takahito Ikenoue (Marine Biodiversity and Environmental Assessment Research Center)**

- Study on Radioactive Iodine-129 Concentration Indicators in Seawater Using Kelps from the Coastal Waters of Northern Japan
(December, 2023)

Published by: Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
Publication Date: February 2025
ISBN: 978-4-901833-55-4



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