Division for Land–Ocean Ecosystem Research

- Global warming and changes in terrestrial water-material cycles in the Arctic circumpolar region
- Effects of climate change and anthropogenic forcing on the terrestrial ecosystem
- Cloud/rainfall variability in Asian monsoon regions
- Dynamics of phytoplankton in marginal seas and coastal areas
- Climate variability and changing open ocean ecosystem dynamics and biogeochemical cycle
- Interaction between oceanic waves and climate variations

The Land–Ocean Ecosystem Research Division investigates regional and global energy, water and material cycles, and physical/biogeochemical processes in the land–ocean ecosystem.

The land research group contributes to advancing our understanding of the mechanisms by which ongoing global warming and anthropogenic activity influence the terrestrial water cycle and ecosystem. Using field observations, satellite remote sensing, global meteorological data analysis, laboratory analysis, and model simulation approaches, our group aims to understand the impact of global warming on hydrological and greenhouse gas cycles in the Arctic region, the dynamics of the continental scale water cycle, the processes that drive weather and climate over Asia, the interplay between the terrestrial ecosystem and climate, and the detection of early signs of the influence of global warming in Antarctica.

Ocean research was conducted using satellite remote sensing, numerical simulations, and *in-situ* observations. We also performed synthesis studies of physical and biogeochemical processes in the ocean and their interactions with the atmosphere and climate. In particular, we are investigating how oceanic heat content, circulation, and surface waves interact with atmospheric environments and how they are linked to climate and meteorological phenomena such as tropical cyclones. We are also investigating how variations in ocean circulation, mixing processes, and air–sea fluxes influence marine ecosystems where phytoplankton are the primary producers. Moreover, we are interested in the possible impact of the marine ecosystem on physical processes and climate in the ocean and atmosphere.

Main Activities in FY2022

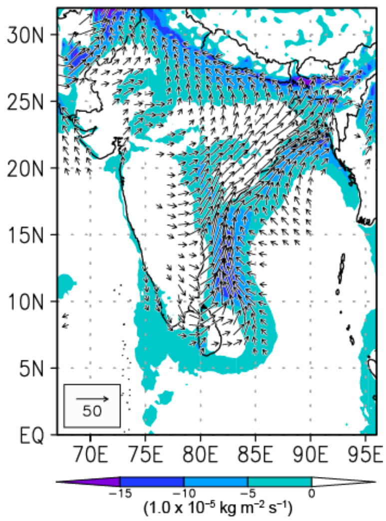
Contribution of summer net precipitation to winter river discharge in permafrost zone of the Lena River basin

Winter discharge from the Lena River in eastern Siberia has increased over recent decades. However, the impact of permafrost thawing and changing hydrological processes induced by climate change on the winter discharge of rivers has not been well quantified. Herein, using a coupled land surface and a distributed discharge model, we performed trend evaluations to examine the sensitivity of winter discharge to permafrost thawing and water budget changes in the Lena River basin from 1979 to 2016. An increasing trend in winter baseflow was found in the upper part of the Lena River basin, where the summer net precipitation demonstrated a statistically significant increase. The increased summer net precipitation resulted in higher soil moisture in the deepened active layer in late summer and early autumn, which was linked to the autumn and winter baseflow. These implications were examined from the perspective of the interrelations among the trends in active layer thickness, soil moisture, and baseflow in the cold season by identifying regions, wherein all variables exhibited positive trends. The identified source regions were primarily in the upper and lower parts of the Lena River basin, although winter baseflow was more dominant in the upper regions owing to the freezing effect of the active layer in the lower region. The thinning of river ice induced by warming temperatures also contributes to an increase in winter river discharge. These results suggest that increased winter discharge was strongly associated with the climate change-related enhancement of permafrost thawing and an increase in net precipitation that affected soil hydrological processes, which will be strengthened further in the context of global warming.

(Reference: Hiyama, T., H. Park, K. Kobayashi, L. Lebedeva, D. Gustafsson (2023): Contribution of summer net precipitation to winter river discharge in permafrost zone of the Lena River basin. *Journal of Hydrology*, 616, 128797, doi:10.1016/j.jhydrol.2022.128797)

Nocturnal southerly moist surge parallel to the coastline over the western Bay of Bengal

Nocturnal precipitation is a well-known phenomenon around the Himalayas and the Meghalaya Plateau in South Asia during the summer. Such precipitation is a major supply source for glaciers in the central and –eastern Himalayas and the headwaters of major rivers, such as the Ganges and Brahmaputra. In this study, we demonstrate that low-level moist southerlies are significantly enhanced at night parallel to the coastline over the western Bay of Bengal (BoB), and then flow onto the Gangetic Plain, enhancing moisture transport toward land and nocturnal precipitation in South Asia. We refer to this phenomenon as a nocturnal southerly moist surge. This nocturnal surge was strongly affected by the diurnal cycle of the thermal and topographic effects of the Indian subcontinent. At night, a strong low-level westerly jet appears above the nocturnal stable layer over the Indian subcontinent. Strong low-level southwesterlies with a low-level jet structure also appear over the western BoB, extending from the strait between the southernmost tip of the Indian subcontinent and Sri Lanka. The low-level westerlies flowing from the subcontinent and the southwesterlies merge into a single strong southwesterly flow, forming the low-level moist surge over the western BoB.

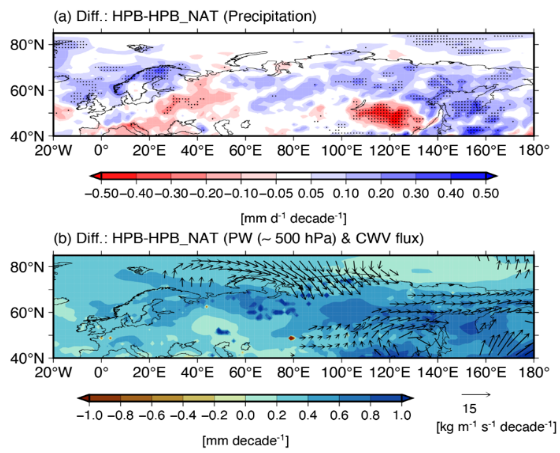


Difference in water vapor flux (vectors) and its divergence (shading) between nighttime (23:00–02:00 LT) and daily mean values

(Reference: Fujinami, H., T. Sato, H. Kanamori, and M. Kato (2022): Nocturnal southerly moist surge parallel to the coastline over the western Bay of Bengal. *Geophysical Research Letters*, 49, e2022GL100174, doi:10.1029/2022GL100174)

Impacts of global warming on summer precipitation trend over northeastern Eurasia during 1990–2010

Summer precipitation in Siberia increased significantly during the 2000s, particularly in eastern Siberia. However, the mechanism controlling this increase in precipitation remains obscure. This study investigated the impact of global warming on summer precipitation over northeastern Eurasia using large-ensemble data from historical warming and non-warming simulations for the period 1990–2010. The positive summer precipitation trends across Siberia reproduced in the ensemble mean of the historical simulation were similar to the observed data; however, the negative trends observed over northeast China and Mongolia were not found in the ensemble mean. An empirical orthogonal function analysis was applied to the summer precipitation trend over Siberia for each

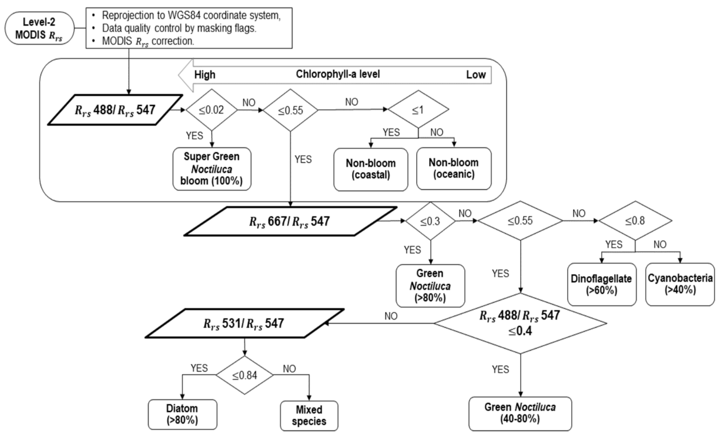


The composite differences in the linear trends of (a) summer precipitation and (b) column water vapor flux and low-level precipitable water between the warming and non-warming experiments contributed to the strength of the westerly moisture flux over eastern Siberia simulation to extract the members with a precipitation trend pattern similar to that of the observations. The first leading mode in each simulation demonstrated an increase (decrease) in precipitation over eastern Siberia (northeast China), which is consistent with the spatial features of the observations. In the extracted members, the spatial pattern of the cyclonic (anticyclonic) circulation trend over the northern parts of eastern Siberia (northeast China), associated with decadal and multidecadal variations, was amplified by global warming, resulting in an increasing trend of the westerly moisture flux into eastern Siberia from western Siberia (Figure). Additionally, surface heating in northeast China, enhanced by global warming, may have concurrently intensified the cyclonic circulation over eastern Siberia. Furthermore, the results suggest that the reduced extent of Arctic sea ice coverage played a role in strengthening the cyclonic circulation over eastern Siberia and enhancing water vapor transport from the Arctic Ocean, which contributed to the strength of the westerly moisture flux over eastern Siberia.

(Reference: Kanamori, H., M. Abe, H. Fujinami, and T. Hiyama (2023): Impacts of global warming on summer precipitation trend over northeastern Eurasia during 1990-2010 using large-ensemble experiments. I*nternational Journal of Climatology*, 43, 615-631, doi:10.1002/joc.7798)

Algorithm development for satellite-based green *Noctiluca* red tide and the seasonal variation in the Upper Gulf of Thailand

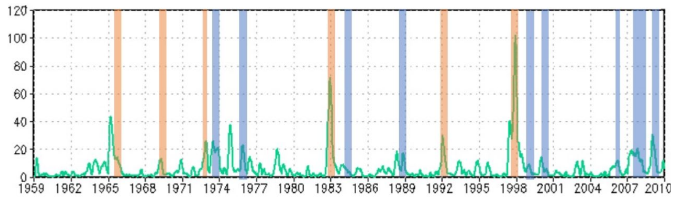
Red tides of diverse species occur in coastal tropical areas, and in recent decades, red tides of green Noctiluca scintillans red tides have been particularly frequent. In this study, we developed a red-tide classification algorithm for a satellite ocean color sensor in the upper Gulf of Thailand (uGoT) to study seasonal variations in red tides. High green *Noctiluca* concentrations demonstrated clear spectral characteristics at blue to green and red to near-infrared wavelengths with *in situ* remote-sensing reflectance observations. According to the red tide spectral characteristics, a classification algorithm using remote sensing reflectance of 488, 531, and 667 nm normalized to the value of 565 nm was developed to distinguish between green *Noctiluca* red tides at three concentration levels and other red tides (dinoflagellates, diatoms, blue-green algae, and mixed species), including offshore and coastal waters in non-red tide conditions (Figure) . Monthly composite data from MODIS from 2003 to 2021 revealed seasonal variations in the surface distribution and frequency of green *Noctiluca* and other red tides during the Southwestern (May–September) and Northeastern (October–January) monsoons. Green *Noctiluca* red tides occurred more offshore from the shore and estuaries than other red tides (dinoflagellates and blue-green algae) and occurred more frequently than other red tides between the mouths of the Tachin and Chao Phraya rivers during non-monsoon periods (February–April). The frequency and distribution of green *Noctiluca* and other red tides varied during the monsoon season. By comparing the red tide distribution identified by the satellite with factors caused by the monsoon (ocean wind, precipitation, and river flow), we were able to elucidate, the spatiotemporal distribution of red tides across the uGoT under Asian monsoon conditions. This study will help us comprehend the impact of climate change on phytoplankton dynamics.



Red tide classification algorithm in the upper Gulf of Thailand

(References: Luang-on, J., J. Ishizaka, A. Buranapratheprat, J. Phaksopa, J. I. Goes, E. R. Maure, E. Siswanto, Y. Zhu, Q. Xu, P. Nakornsantiphap, H. Kobayashi, and S. Matsumura (2023): MODIS-derived green *Noctiluca* blooms in the upper Gulf of Thailand: Algorithm development and seasonal variation mapping. *Frontiers in Marine Science*, 10, 1031901, doi:10.3389/fmars.2023.1031901)

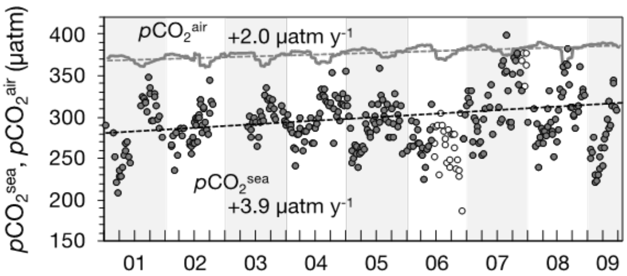
Zonal interaction of interannual oceanic waves in the Tropical Pacific



Peak values of the energy-flux stream function [Watts] in the eastern equatorial Pacific Ocean

This study examined how oceanic upper-layer wave motions associated with El Niño and La Niña events and play a role in the interaction between the western, central, and eastern parts of the ocean basin from the energy circulation perspective. Recent studies have made it possible to trace wave energy circulation paths by tracing group velocity vectors without any borders between the equatorial and mid-latitude dynamics. It is not possible to trace or quantify the generation, transfer, and dissipation of perturbations in a chain simply by displaying the distribution of these energy-flux vectors on a map. To resolve this problem, this study proposes a method to apply Helmholtz decomposition to the energy flux distribution and diagnose the time series of the peak values of the stream function and potential components. This time series implies that the energy flux is integrated across its path, and its time variation can be compared with a well-known index in climate studies called the Niño 3. In making this comparison, we note that the energy fluxes in this study demonstrate eastward transfer events during both El Niño and La Niña events and cannot distinguish between downwelling and upwelling Kelvin waves. However, the Niño 3 index, which represents climatological anomalies in sea surface temperature in the eastern equatorial Pacific, can distinguish between downwelling and upwelling Kelvin waves, whereas its quantitative meaning reflects only the physical component related to potential energy and does not consider the physical component related to kinetic energy. This study aims to resolve these problems and provide useful validation using the output of hindcast simulations for 51 years.

Rapid increase of surface water pCO_2 during 2001–2009 in Sagami Bay



Time series data for (a) pCO_2^{sea} (circle) and atmospheric pCO_2 (pCO_2^{air}, solid line) in the central part of Sagami Bay from 2001 to 2009

Little Little is known about the rate of increase in coastal seawater pCO_2 (pCO_2^{sea}) despite its necessity for evaluating future oceanic CO_2 uptake capacity. We examined temporal changes in pCO_2^{sea} in central Sagami Bay during 2001–2009. The weekly pCO_2^{sea} was reconstructed using a time series of the particulate organic carbon isotope delta (POC-δ^{13}C) of settling particles at 150 m from moored sediment trap deployments. For pCO_2^{sea} estimation, an empirical relationship between suspended POC-δ^{13}C and aqueous CO_2 concentrations from repeated ship observations in 2007 and 2008 was applied to the trapped POC-δ^{13}C. The air–sea CO_2 flux was calculated using the air-sea pCO_2 difference with the gas transfer velocity. The estimated Bay pCO_2^{sea} varied by 190 µatm (mean 294 µatm) and was mostly below atmospheric pCO_2 (pCO_2^{air}), resulting in a mean oceanic CO_2 uptake of 30 g m^{-2} y^{-1}, suggesting that Sagami Bay is an efficient sink for atmospheric CO_2. Meanwhile, carbon sequestration to the mesopelagic layer by particulate carbon export accounted for 60–75% of the CO_2 uptake, with the rest likely removed horizontally via surface water exchange. The pCO_2^{sea} demonstrated an increasing trend of +3.9 µatm y^{-1}, approximately twice that of pCO_2^{air}, resulting in the two converging. Concurrently, a decreasing trend in POC export flux and an increasing trend in the nitrogen isotope delta of the trapped particles were observed. A large summer pCO_2^{sea} increasing rate (+4.9 µatm y^{-1}) was observed accompanied by POC concentration decreasing, which resulted in a decrease in CO_2 uptake over time. Long-term summer nutrient depletion and reduced primary production may increase pCO_2^{sea} in the bay.

(References: Mino, Y., C. Sukigara, A. Watanabe, A. Morimoto, K. Uchiyama-Matsumoto, M. Wakita, and T. Ishimaru (2023): Rapid increase of surface water pCO_2 revealed by settling particulate organic matter carbon isotope time series during 2001–2009 in Sagami Bay, Japan. *Journal of Oceanography,* 79, 317–331, doi:10.1007/s10872-023-00688-3)