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 FY2021

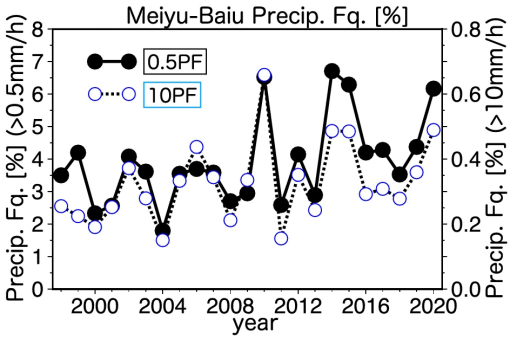
Impact of Arctic warming and abnormally high precipitation on vegetation activity of Siberian larch forests

The fate of a boreal forest may depend on the trend in its normalized difference vegetation index (NDVI), such as whether NDVI has been increasing significantly over the past few decades. We analyzed the responses of two Siberian larch forests at Spasskaya Pad and Elgeeii in eastern Siberia to various waterlogging-induced disturbances using satellite-based NDVI and meteorological data for the period 2000–2019. The forest at Spasskaya Pad experienced waterlogging (i.e., flooding events caused by abnormal precipitation) during 2005–2008, which damaged canopy-forming larch trees and increased the abundance of water-resistant understory vegetation. In contrast, the forest at Elgeeii did not experience any remarkable disturbances, such as tree dieback or changes in the vegetation community. Significant increasing NDVI trends were found in May and June–August in Elgeeii, whereas no significant trends were found in Spasskaya Pad. NDVI anomalies in May and June–August at Elgeeii were significantly associated with precipitation or temperature, depending on the season, whereas no significant relationships were found at Spasskaya Pad. Thus, the 20-year NDVI trend and the NDVI–temperature–precipitation relationship differed between the two larch forests, although no significant trends in temperature or precipitation were observed. These findings indicate that non-significant NDVI trends for Siberian larch forests may reflect waterlogging-induced dieback of larch trees with a

concomitant increase in water-resistant understory vegetation.
(Reference: Nagano, H., A. Kotani, H. Mizuochi, K. Ichii, H. Kanamori, and T. Hiyama (2022): Contrasting 20-year trends in NDVI at two Siberian larch forests with and without multiyear waterlogging-induced disturbances. *Environmental Research Letters*, 17, 025003, doi:10.1088/1748-9326/ac4884)

Recent decadal enhancement of Meiyu–Baiu heavy rainfall

We investigated recent decadal trends in Meiyu–Baiu rainfall over the last two decades using 23-year satellite precipitation radar (TRMM-PR and GPM-DPR) data. We also explored the variability of atmospheric circulation, such as water vapor transport and uppertropospheric circulations, related to the trend using the JRA-55 reanalysis. The frequency of heavy precipitation along the Meiyu–Baiu front has increased over the past 22 years. In particular, heavy precipitation (10 mm/h) increased by 24% between 1998 and 2008 and 2009–2019, which likely led to the recent enhancement in Meiyu–Baiu heavy rainfall. The decadal enhancement of the Meiyu–Baiu rainfall is associated with both tropical and mid-latitudinal influences. Along with the westward expansion of the western North Pacific subtropical high, more water vapor was transported to the Meiyu–Baiu front. Simultaneously, the upper-level trough over the East China Sea, associated with wave trains along the subtropical jet, intensifies the transport of water vapor and upward flow. These changes in atmospheric circulation are physically consistent with the increase in rainfall at the Meiyu–Baiu front.



Interannual variations in the frequency of Meiyu–Baiu band precipitation.

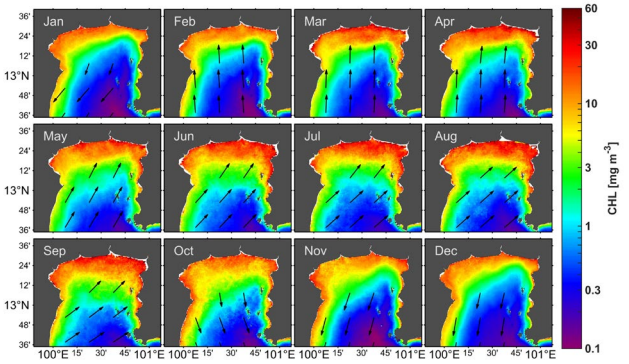
(Reference: Takahashi, H. G. and H. Fujinami, (2021): Recent decadal enhancement of Meiyu–Baiu heavy rainfall over East Asia. *Scientific Reports*, 11, 13665, doi:10.1038/s41598-021-93006-0)

Calibration of the surface temperature measurement biases on the Antarctic Plateau

Near-surface air temperature measurements over the Antarctic Plateau (AP) are important for climate change monitoring and model validation. Owing to their remoteness and harsh environment, automatic weather stations (AWSs) were installed on the AP. However, it is difficult to obtain accurate temperatures because most temperature measurements are subject to systematic errors owing to solar radiative heating. Owing to the shortage of power supplies, naturally ventilated (NV) sensors are often used in Antarctica instead of mechanically force-ventilated (FV) sensors. When ventilation is inadequate to remove the influence of radiative heating, NV temperature measurements result in higher values than FV measurements. In this study, we examined the radiative heating error of NV measurements on the East Antarctic Plateau using both the newly installed AWSs at NDF and Relay Station and the existing AWSs at Relay Station and Dome Fuji. In austral summer, the temperature bias between the FV and NV sensors never reached zero owing to continuous sunlight. The hourly mean temperature errors reached 8 °C at noon on a sunny day with weak wind conditions. The errors increased linearly with increasing reflected shortwave radiation and decreased nonlinearly with increasing wind speed. These features are consistent with those reported in previous studies. Thus, to quantify radiative errors, we applied an existing correction model based on the regression approach. We found that this approach successfully reduced radiative biases by up to 70%. This indicates that we can use the corrected temperature data instead of quality-controlled data, which removes the warm bias during weak winds in inland Antarctica.
(Reference: Morino, S., N. Kurita, N. Hirasawa, H. Motoyama, K. Sugiura, M. A. Lazzara, D. Mikolajczyk, L. Welhouse, L. Keller, and G. Weidner (2021): Comparison of ventilated and unventilated air temperature measurements in inland Dronning Maud Land on the East Antarctic Plateau. *J. Atmos. Oceanic Technol.*, 38, 2061–2070, doi:10.1175/JTECH-D-21-0107.1)

Seasonal and interannual variations of chlorophyll-a in the upper Gulf of Thailand

Seasonal and interannual variations in the total phytoplankton biomass in the upper Gulf of Thailand (uGoT) from 2003–2017 were investigated using the chlorophyll-a (Chl-a) of the Moderate Resolution Imaging Spectroradiometer (MODIS) on Aqua. The accuracy of Chla was first verified and improved by the local tuning of the empirical algorithm. The seasonal variation was mostly related to the monsoon variability, the non-monsoon (NOM), southwest-monsoon (SWM), and northeast-monsoon (NEM) seasons, of the environmental parameters. High and low Chl-a corresponded with high and low precipitation and river discharge during the SWM and NEM, respectively. Chl-a was generally low during NOM because of the low precipitation. Chl-a was generally higher in the north where the river discharge was high, especially from the Chao Phraya and Tha Chin Rivers. The high Chl-a area was shifted to the east and west and was related to the wind direction, resulting in the current and probable freshwater distribution during SWM and NEM, respectively. Interannual variations in Chl-a were related to variations in precipitation, river discharge, and wind patterns caused by El Niño-Southern Oscillation rather than the Indian Ocean Dipole. Positive and negative SWM Chl-a anomalies corresponded to high and low precipitation and river discharge during La Niña and El Niño, respectively. Positive and negative NEM Chl-a anomalies corresponded to high and low river discharge and strong and weak winds during La Niña/El Niño. A positive NOM Chl-a anomaly appears to be related to the higher wind speed and precipitation during El Niño.



Mean MODIS Chl-a (2003–2017) and wind distributions of upper Gulf of Thailand.

(References: Luang-on, J., J. Ishizaka, A. Buranapratheprat, J. Phaksopa, J. I. Goes, H. Kobayashi, M. Hayashi, E. R. Maúre, and S. Matsumura (2021): Seasonal and interannual variations of MODIS Aqua chlorophyll-a (2003–2017) in the Upper Gulf of Thailand influenced by Asian monsoons. *J. Oceanogr.*, doi:10.1007/s10872-021-00625-2)

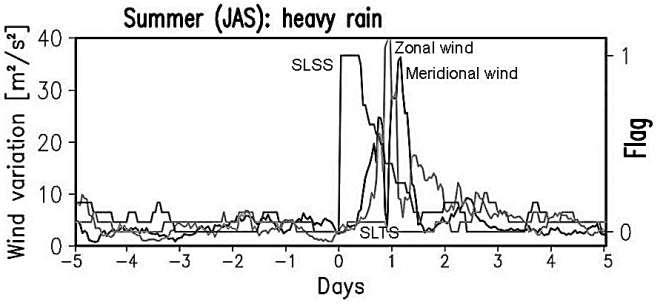
High-resolution vertical observations of phytoplankton groups derived from an *in-situ* multiple excitation fluorometer in the East China Sea and Tsushima Strait

Few studies have used multiple excitation fluorometers to understand the variability in coastal phytoplankton groups. We used a multiple excitation fluorometer to understand the high-resolution vertical distributions of phytoplankton composition in the East China Sea (ECS) and Tsushima Strait (TS) where the Changjiang River diluted water (CDW), Kuroshio water (KW), and Tsushima water (TW) during the summers of 2011, 2012, and 2014. The multiple excitation fluorometer was calibrated with phytoplankton group data derived from high-performance liquid chromatography (HPLC) analysis of the water samples. We found clear differences in the distribution of phytoplankton in CDW, KW, and TW. Brown algae were generally dominant (~60%) in the CDW, although cyanobacteria (>40%) and green algae plus cryptophytes (>40%) were abundant above and below the subsurface chlorophyll maximum, respectively. Brown algae were also dominant in the water column (>60%), including the subsurface chlorophyll maximum (>80%) of TW, and cyanobacteria were dominant in the surface water. Cyanobacteria were abundant (>40%) at the surface while brown and green algae dominated (>60%) below 40 m in the KW. These results are related to the nutrient distributions in these areas. A multiple excitation fluorometer, which was calibrated using phytoplankton group data derived from HPLC analysis of some water samples, can efficiently supply high-resolution vertical distribution of phytoplankton group distribution.

(References: Xu, Q., S. Wang, C. Sukigara, J. I. Goes, H. d. R. Gomes, T. Matsuno, Y. Zhu, Y. Xu, J. Luang-on, Y. Watanabe, S. Yoo, and J. Ishizaka (2022): High-Resolution Vertical Observations of Phytoplankton Groups Derived from an *in-situ* Fluorometer in the East China Sea and Tsushima Strait. *Front. Mar. Sci.*, 8, 756180, doi: 10.3389/fmars.2021.756180)

Statistical analysis of the impact of typhoons and other strong wind precipitation events on the oceanic mixed layer

The Kuroshio Extension Observatory (KEO) buoy has been measuring air-sea interaction quantities since 2004. The KEO buoy records contain sporadic low-salinity signals (SLSSs) in the mixed layer when using, for example, the tropical cyclone approach. SLSSs cannot be reproduced by one-dimensional turbulence closure models, which have been used as a part of three-dimensional ocean circulation models in previous studies. In the western North Pacific, precipitation is substantial in both the Baiu and autumn front seasons, around June and November, respectively. SLSS events can be terminated by entrainment of saltier subsurface water parcels to the mixed layer in response to storms (Figure). The discovery of wind velocity subdiurnal variation peaks following SLSS commencement is the reason the present study adopted a time scale of 1-day wind velocity analysis. The present study illustrates how to extract the features of marine weather events that produce SLSSs in the oceanic mixed layer. This new and concise approach will be useful for identifying SLSS events in other regions of the global ocean to provide the necessary information for improving air-sea flux formulations.



Composite time series of SLSS flag, sporadic low-temperature signal flag, and wind variance for 18 SLSS events in summer with heavy rainfall.

(References: Kameyama et al. (2022): Sporadic low salinity signals in the oceanic mixed layer observed by the Kuroshio Extension Observatory buoy. *Front. Clim.*, 4, 820490, doi:10.3389/fclim.2022.820490)

Enhanced oxygen consumption results in summertime hypoxia in Mikawa Bay, Japan

The spread of coastal hypoxia ("dead zones"), whose occurrence has increased rapidly since the latter half of the 20th century, is having a serious impact on ecosystem functions. Six shipboard observations were conducted in Mikawa Bay from May to August 2014 to investigate the spatiotemporal variation in the oxygen consumption rate (OCR) of the bottom layer. The OCR was determined from the dark incubation of sample waters using an optical oxygen sensor, which showed a range of 5.7–38.3 μM d^{-1}. A high OCR was observed at the inner-most station, where higher concentrations of nutrients and chlorophyll a than at the other stations were found and bottom hypoxic water appeared during the observation period after late June. These OCRs can deplete the oxygen dissolved in water within a week. Overall, OCR showed a highly significant positive correlation with particulate organic carbon concentrations in the bottom water. Considering the relatively low carbon-to-nitrogen mole ratio (6.4~7.6) and high carbon isotope ratio (between −20.2‰ and −18.8‰) of particulate organic matter at the stations, the supply of fresh organic matter produced in the bay as opposed to land may have affected the OCR by acting as a substrate for microbial aerobic respiration. High temporal resolution data from two automated observation buoys near the bay mouth and the inner area captured increases in Chl-a a at both sites in response to typhoon events, along with the subsequent appearance of bottom hypoxic water at the inner site and its expansion at the mouth. This supports our hypothesis that enhanced organic matter production due to nutrient input to the surface layer through vertical mixing would increase the bottom OCR, resulting in hypoxia. The apparent oxygen decline in the bottom layer from the buoy data was consistent with incubation-based OCRs during the observation period. Therefore, it is essential to properly model the OCR in numerical simulations of hypoxia, to which the variability characteristics that we revealed make a significant contribution.

(References: Sukigara, S., Y. Mino, A. Yasuda, A. Morimoto, A. Buranapratheprat, and J. Ishizaka (2021): Measurement of oxygenconcentrations and oxygen consumption rates using an optical oxygen sensor, and its application in hypoxia-related research in highly eutrophic coastal regions. *Cont. Shelf Res.*, 229, 104551, doi:10.1016/j.csr.2021.104551)