9-1. Research Divisions
Division for Land-Ocean Ecosystem Research

Research topics and keywords

- 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

Introduction to Division for Land–Ocean Ecosystem Research

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 of how on-going 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 works 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 the climate, and the detection of early signs of the influence of global warming in Antarctica.

Ocean research is performed using satellite remote sensing, numerical simulations, and *in-situ* observations. We perform synthetic studies of physical and biogeochemical processes in the ocean and their interactions with the atmosphere and climate. In particular, we investigate the manner in which 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 also investigate how variations in ocean circulation, mixing processes, and air–sea fluxes influence marine ecosystems where phytoplankton is a primary producer. Moreover, we are interested in the possible impact of the marine ecosystem on physical processes and climate in the ocean and atmosphere.

Main Achievements in FY2017

1. Measurement of methane flux over a larch forest in eastern Siberia

The role of forests in methane cycling is not well understood, in part because of difficulties in assessing methane fluxes at the canopy scale, while previous chamber measurements at the forest floor show that many forest soils provide a methane sink. In particular, even though about 70 percent of boreal forest is in Eurasia, mostly in the Russian Federation, canopy-scale methane fluxes over such forests have not been reported. Thus, we measured the methane flux over a larch forest in eastern Siberia using the eddy covariance technique. The canopy-scale methane flux was calculated to be positive (methane emission), while the forest floor of this site was reported to be a methane sink by a previous study. However, since the absolute value of the methane flux is generally small over forests, it is necessary to pay sufficient attention to the accuracy of instruments and the quality of data for a better understanding of methane fluxes.

2. Modeling of larch forest dynamics in eastern Siberia under a changing climate

According to a projection from an earth system model under the RCP8.5 scenario, the boreal forest in eastern Siberia is predicted to experience significant changes in climate, with a positive change in mean annual air temperature and a twofold increase in annual precipitation by the end of the 21st century. Since the forest in this region is underlain by continuous permafrost, increases in both temperature and precipitation will affect forest dynamics through soil-water processes. To investigate such effects, we applied a newly developed terrestrial ecosystem dynamics model named 'S-TEDy' to a larch forest in eastern Siberia. By considering coexisting liquid water and ice under freezing temperatures, the seasonal variation in liquid soil water content was reproduced, and the above-ground biomass of larch trees calculated by S-TEDy agreed well with the values reported by previous studies.

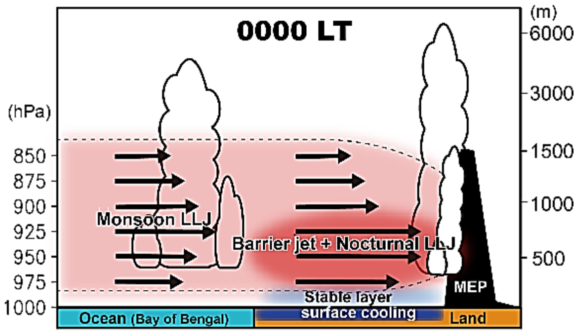
3. Interpretation of ENSO-related precipitation changes in northern Borneo

The rainfall in Borneo exhibits an inter-annual variability related to the El Nino-Southern Oscillation (ENSO). However, there is not yet any comprehensive explanation of how the ENSO influences the year-to-year rainfall in Borneo. Here, we employed a new approach based on the oxygen isotope ratio ($\delta^{18}O$) to investigate ENSO-related rainfall variability. The values of $\delta^{18}O$ can be used to identify dominant factors controlling the ENSO-related Borneo rainfall variation, since its relative concentration is related to the moisture sources of precipitation. In this study, we merged three oxygen isotopic datasets available in Borneo into a single rainfall $\delta^{18}O$ dataset and created a 7-year long record from 2004 to 2011. We found that large negative $\delta^{18}O$ excursions are associated with synoptic-scale convective activity over the SCS, and the frequency of the convective activity is closely linked to the ENSO. Along with the significant correlation between $\delta^{18}O$ variations and Borneo rainfall variations on an inter-annual timescale, we concluded that ENSO-related Borneo rainfall variations can be chiefly attributed to changes in the frequency at which synoptic-scale convective activities occur.

4. Role of land surface processes on summer heavy rainfall over South Asia

The Meghalaya Plateau of northeast India, with a maximum elevation of approximately 2000 m, is one of the wettest places in the world. Precipitation over the southern slope of the plateau is enhanced at nighttime under the westerly regime (WR) in the windward area over Bangladesh. Under the WR, a strong southwesterly low-level jet (LLJ) with a core of less than 1,500 m across Bangladesh encounters the southern slope of the plateau, and localized strong low-level southerlies running parallel to the Arakan Mountains (i.e., the barrier jet) also blow toward the plateau, concentrating convective unstable air onto its southern slopes. This situation provides favorable conditions for high orographic precipitation around the plateau. Atmospheric boundary layer processes over the plain of Bangladesh change the structure of the LLJ toward the plateau and cause a diurnal variation. The vertically well-mixed layer over land decelerates the prevailing low-level wind toward the plateau during the daytime and breaks up the LLJ structure, resulting in reduced daytime rainfall over the southern slopes. In contrast, the wind speed toward the southern slopes accelerates at night and exhibits a clear LLJ structure from 950 to 925 hPa above the surface stable layer, resulting in very high nocturnal rainfall.

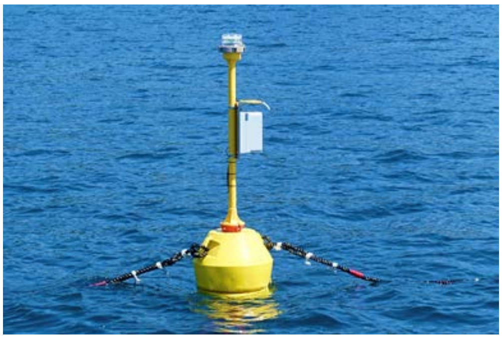
(Reference: Fujinami, H., T. Sato, H. Kanamori and F. Murata, 2017: Contrasting features of monsoon precipitation around the Meghalaya Plateau under westerly and easterly regimes. *J. Geophys. Res. Atmospheres*, 122, 9591-9610, DOI: 10.1002/2016JD026116.)



A schematic of the low-level jet (LLJ) and atmospheric boundary layer from the Bay of Bengal to the Meghalaya Plateau during nighttime under the WR.

5. New Instrument for Joint Research at ISEE: Sea Spray Aerosol Optical Particle Counter

Some of recent numerical studies on tropical cyclones have adopted an atmosphere-ocean surface-wave coupled model to incorporate the evolution of surface waves (Aiki et al. 2015). This surface wave information allows for advanced versions of bulk formulae for air-sea fluxes, such as wind stress and heat fluxes, to be used. It is necessary to develop yet further our understanding of microscopic material transport mechanisms, such as the distribution of sea-spray particles, associated with wind wave breaking. We have developed an optical particle spectrometer probe that can measure size-resolved particle concentrations in 8 bins spanning the diameter range between 0.3 and 15 micrometers at a rate of 10 Hz. The probe is also equipped with a 3-axis accelerometer to monitor basic marine-meteorological conditions as well as the phase of surface wave breaking. Preliminary measurements of sea spray have been performed in both Otuchi Bay in Iwate prefecture and Tanabe Bay in Wakayama prefecture, the latter of which successfully captured the passage of Tropical Cyclone Noru at 15 JST on August 7th, 2017, with a wind speed of 23 m/s and a wave height of 3.8 m. The sea-spray spectrometer probe has been registered as a new instrument for Joint Research at ISEE, and is expected to yield a series of new studies spanning the fields of meteorology, atmospheric chemistry, physical oceanography, and marine engineering. We have also promoted the study of surface waves by holding an annual workshop for the community, and by publishing a textbook on wave-mean-flow interaction theories for the ocean and atmosphere (Aiki, 2018).

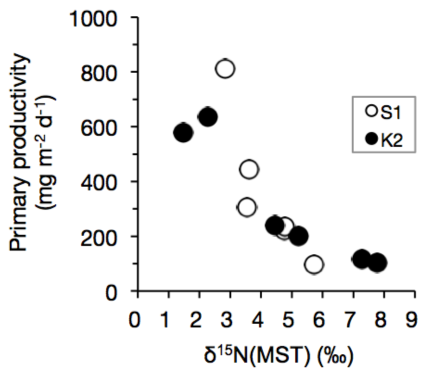


Sea-spray spectrometer probe on a mooring buoy.

(Reference: Aiki, H. 2018: Waves, eddies and mean flows in the ocean – the background and outlook of interaction theories –, Meteorological Research Note (published by Meteorological Society of Japan), vol. 235, 175 pp.)

6. Seasonal variations in δ^{15}N of settling particles in the western North Pacific

The isotope delta of particulate nitrogen δ^{15}N(PN) in the upper ocean is governed by both δ^{15}N in substrates and isotopic fractionation during PN formation. δ^{15}N for particles incorporated into sediments have frequently been used to reconstruct paleo-nutrient conditions and primary productivity (PP). δ^{15}N(PN) variations observed so far in the modern ocean are, however, still incompletely explained. We examined the δ^{15}N time-series of settling particles collected using a moored sediment trap (MST) in subtropical station S1 (30°N, 145°E) and subarctic station K2 (47°N, 160°E), to investigate the factors controlling δ^{15}N variation, and to assess its use as a proxy for the upper oceanic condition. These MST experiments revealed distinct seasonal patterns of δ^{15}N(PN) at both sites. Analyses with hydrographical data concluded that i) δ^{15}N(PN) variations in S1 were attributable to changes in nitrate supply into the euphotic zone from below, via mixing, while ii) those in K2 were due to light-controlled ammonium consumption by nitrifiers and, thereby, depended on light conditions within the mixed layer. Furthermore, significant correlations were found between δ^{15}N(PN) and PP in both sites (Figure). This implied that productivities in S1 and K2 would vary, dependent on nitrate and light availabilities, respectively. For both sites, even with contrasting oceanographic conditions, similar δ^{15}N(PN) vs PP relationships support the utility of δ^{15}N for estimating PP. However, it is not clear why the differences in resources limiting PP is not reflected, and this should be resolved to establish theδ^{15}N proxy for productivity.

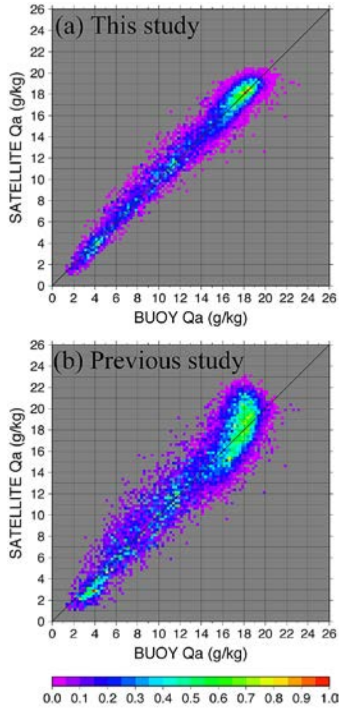


Relationship between δ^{15}N of MST particles and primary productivity in subtropic region S1 and subarctic region K2.

7. Improved satellite estimation of global near-surface air specific humidity

Near-surface air specific humidity is designated as an Essential Climate Variable (ECV) and a key variable in the estimation of air-sea latent heat flux and evaporation from the ocean surface. An accurate estimation over the global ocean is required. Current satellite remote sensing techniques are problematic and a major source of errors in flux and evaporation. This study proposes a new method for estimating surface humidity, using satellite microwave radiometer instruments, based on new findings on the relationships between multi-channel brightness temperatures measured by satellite microwave radiometers, surface humidity, and the vertical moisture structure. Satellite estimations using the new method were compared with *in situ* observations to evaluate the method, and confirmed that satellite estimations could be significantly improved (Figure). Moreover, this improvement has a significant impact on estimation of the latent heat flux. In particular, significant improvements were found in the western boundary current region where the world's largest heat release from the ocean is observed. Application to wide-range climate and air-sea interaction studies is expected.

(Reference: Tomita et al. 2018, Improved satellite estimation of near-surface humidity using vertical water vapor profile information. *Geophys. Res. Lett*., 45, doi: 10.1002/2017GL076384)

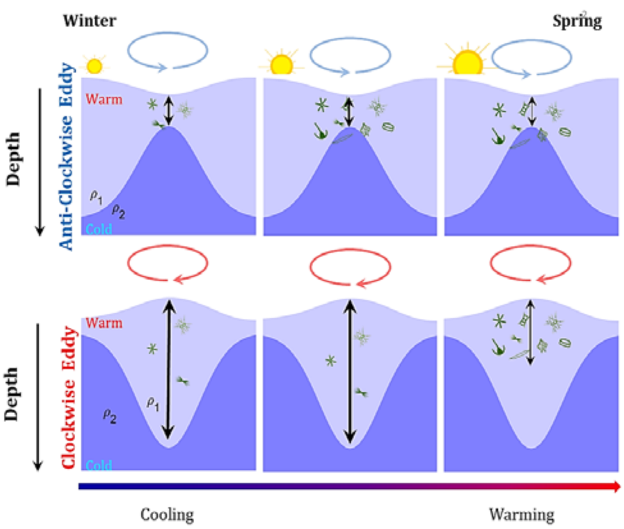


Comparison with *in situ* buoy observation for (a) this study and (b) previous study. Color means normalized data density.

8. Phytoplankton spring bloom: early anti-clockwise eddy and late clockwise eddy

It is known that abundance of phytoplankton increases during spring in temperate ocean. It is also known that oceanic currents forms eddy structures, like cyclone and anti-cyclone which correspond anti-clockwise and clockwise in the northern hemisphere, respectively. However, there have been no previous investigations of the influence of eddies on the spring phytoplankton bloom. In the Japan Sea, where eddy activity is intense, seasonal changes in phytoplankton, in the eddies, were observed using satellite data from 2002 to 2011. Satellite sea surface height data indicate the presence of frequent clockwise and anti-clockwise eddies, with diameters of 100 km near the Noto Peninsula. Satellite chlorophyll-a data showed that, in anti-clockwise eddies, phytoplankton increases in late February when the water temperature is still decreasing whereas, in clockwise eddies, phytoplankton increases in early April when the water temperature is increasing. In anti-clockwise eddies, the mixed layer is shallow and phytoplankton populations can increase with a slight increase in sunlight, whereas in clockwise eddies, the mixed layer is deep and the mixing conditions must be weakened for phytoplankton development. This is the first study showing the differences of the timing and the mechanism of the phytoplankton spring bloom with different types of eddies.

(Reference: Maúre et al., 2017, Mesoscale eddies control the timing of spring phytoplankton blooms: A case study in the Japan Sea. *Geophys. Res. Lett*., 44, 11,115–11,124., doi:10.1002/2017GL074359)



Mechanism of phytoplankton spring bloom in anti-clockwise (upper) and clockwise (lower) eddies.