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 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 influence of global warming in Antarctica.

Ocean research is conducting using satellite remote sensing, numerical simulations, and in situ observations. We also performing synthesis studies of physical and biogeochemical processes in the ocean and their interactions with the atmosphere and climate. In particular, we are investigating 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 are also investigating how variations in ocean circulation, mixing processes, and air–sea fluxes influence marine ecosystems where phytoplankton is a primary producer. Moreover, we are interesting the possible impact of the marine ecosystem on physical processes and climate in the ocean and atmosphere.

Main Activities in FY2019

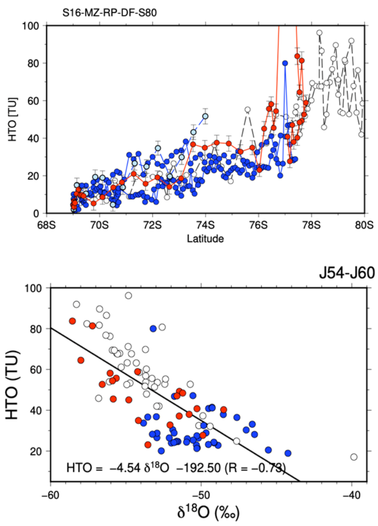
Canopy-scale methane flux measurements in a larch forest in eastern Siberia

Focusing on a larch forest in eastern Siberia, canopy-scale methane fluxes measured using an eddy covariance method were compared with previously obtained methane fluxes measured using a chamber method. In previous warm seasons, the methane fluxes obtained using the chamber method showed negative values (i.e., methane absorption) in the forest floor. However, chamber methods cover a limited area, and do not represent canopy-scale fluxes. Thus, we applied an open-path eddy covariance methane flux measurement system to the larch forest. The canopy-scale methane flux results showed positive values (i.e., methane emission) in the warm season. This is because there are humid wetlands in the vicinity of the eddy covariance flux tower. In addition, there could be methane emitted from above-ground vegetation (i.e., trees including trunks, branches, and leaves). Recently, methane emissions from above-ground vegetation were also observed in tropical rain forests. We need to collect long-term methane flux measurements in several forests with different climates.

(Reference: Nakai, T., T. Hiyama, R. E. Petrov, A. Kotani, T. Ohta, and T. C. Maximov, 2020. Application of an open-path eddy covariance methane flux measurement system to a larch forest in eastern Siberia. *Agric. For. Meteorol.*, 282–283, 107860, doi:10.1016/j.agrformet.2019.107860.)

Understanding of the spatial distribution of oxygen isotopic composition in surface snow over East Antarctica

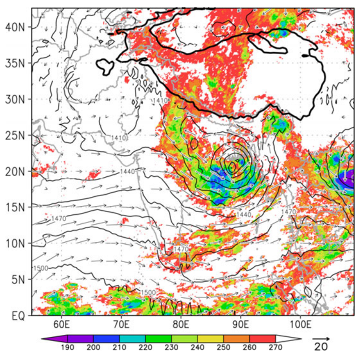
We launched a new project entitled "Factors controlling isotopic variability of snow over East Antarctica." This was selected as a challenging exploratory research direction for the current Japanese Antarctic Research Project (JARE) Phase IX. The purpose of this research is to understand the physical mechanisms of the experimental relationship between surface temperature and oxygen isotopic composition in the snow over Antarctica. This year, we completed the first assessment research using snow samples collected along the traverse route from near Syowa station to Dome Fuji station in East Antarctica by the 2018/2019 summer campaign of the 60th JARE. The total number of samples is 227. The stable water isotopes of the snow were measured by cavity ringdown spectroscopy (L2130-I, Picarro Inc.). We also measured HTO concentration using a liquid scintillation counter (Quantulus 1220, Perkin-Elmer Inc.). Both instruments are registered as joint-use resources of ISEE. The top Figure shows the spatial variation of HTO between the coastal site and the interior station. There is a clear increase of HTO and then a rapid increase occurs over the plateau region exceeding an altitude of 3500 m. This means that moisture transport from the surrounding ocean is not a dominant contributor over the Antarctic plateau. It is well known that clear-sky deposition of diamond dust is frequently observed at inland stations, such as Dome Fuji. Thus, we speculate that local moisture may largely contribute to inland snowfall. Interestingly, the spatial features of HTO correspond well to those of oxygen isotopic composition (see bottom Figure). This enables us to set the following hypothesis: the spatial distribution of oxygen isotopic composition may largely reflect the relative contribution of both local Antarctic moisture (High HTO and low oxygen isotopic content) and moisture transported from the surrounding ocean (Low HTO and heavy isotopic content). To verify this hypothesis, a quantitative explanation is necessary. Thus, we are developing a new water transport model incorporating HTO and stable water isotopes.



HTO distribution from coastal site to inland station (Top), The relationship between HTO and oxygen isotopic composition of snow over the Plateau in East Antarctica (Bottom).

A study on monsoon depressions over South Asia

Synoptic-scale monsoon low-pressure systems contribute a large fraction of total summer monsoon rainfall, especially over land in South Asia. We investigated the three-dimensional structure of the mesoscale precipitation systems in the different stages of the life cycle of a monsoon depression, using observational data from multi-satellite sensors and a cloud-resolving regional model. The effects of latent heating from the precipitation system and the Bay of Bengal (BoB) on the development of the monsoon depression were also evaluated in sensitivity experiments using the model. In the rapid development phase, satellite observations revealed mesoscale convective systems with deep convective precipitation cells and stratiform precipitation near the head of the BoB. Extremely deep and intense convective cells appeared along a ring-like rain band when closed cyclonic circulation became obvious around the northernmost part of the BoB. Sensitivity experiments revealed that both cloud/precipitation processes and evaporation from the BoB are essential for the rapid development of monsoon depressions over the BoB.

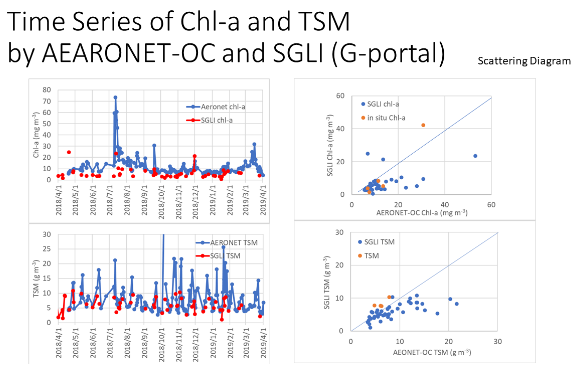


A monsoon repression that generated over the Bay of Bengal on 17 August 2016.

(Reference: Fujinami et al., 2020, Mesoscale precipitation systems and their role in the rapid development of a monsoon depression over the Bay of Bengal. *Q. J. R. Meteorol. Soc.*, 146, 267– 283, doi:10.1002/qj.3672.)

Variation of chlorophyll-a and total suspended matter in Ariake Bay and GCOM-C validation

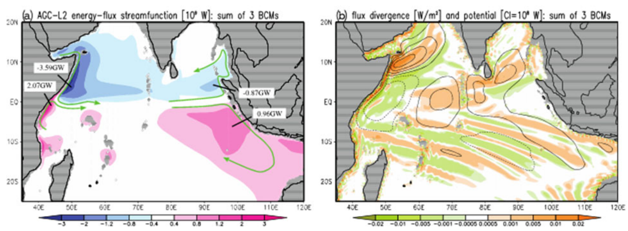
Global Change Observation Mission–Climate (GCOM-C) was launched in December 2017, and the global observation of visible and infrared radiation, including ocean areas, with 250 m resolution and a two day interval was started. The new high frequency data with 250 m resolution is expected to be useful for coastal applications. To use the ocean color data, frequent sea-truth data is required, although it is difficult to obtain at sea. The aerosol robotic network–ocean color (AERONET-OC) is a network of spectral radiometers, which are modified from the radiometers developed for the observation of aerosols from land, to also observe sea surface radiance. For GCOM-C validation, ISEE set a JAXA-owned AERONET-OC on the Ariake Tower of Saga University from April 2018 (ISEE Newsletter 6). Chlorophyll-a (Chl-a), which is an indicator of phytoplankton biomass, and total suspended matter (TSM) were estimated from the AERONET-OC radiance data between April 2018 and March 2019 and compared with the GCOM-C data (Figure). Chl-a and TSM varied with the spring–neap tidal cycle, and were high at neap and spring tide, respectively. TSM is expected to increase with the resuspension of bottom sediments by the strong tidal current during spring tide and the reduced light limits phytoplankton growth. Chl-a also showed peaks in July and March after the high river discharge events. Similar variation was seen in the GCOM-C data. Both the Chl-a and TSM AERONET-OC data showed significant correlations with the relevant GCOM-C data, and the AERONET-OC data also showed consistency with water sampling data, while GCOM-C was underestimated. JAXA is currently improving the GCOM-C data to Version 2.



Time series (left) of Chl-a (top-left) and TSM (bottom-left) from AERONET-OC and GCOM-C, and scatter diagrams (right).

Energy circulation of ocean surface wave motion by the seasonal winds of the Indian Ocean

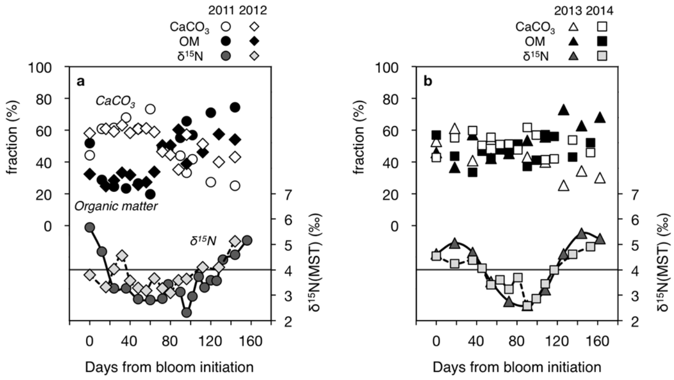
A significant task in climate and geophysical sciences is to clarify the role of synoptic-scale waves in the atmosphere and ocean by analyzing, for example, the global transfer routes of wave energy. This problem remained unsolved because conventional diagnostic schemes could not handle the tropics and mid-latitudes continuously. A recent theoretical work has developed a seamless diagnostic scheme for all latitudinal bands, which has the advantage of identifying the distribution of group velocity vectors, even in mixed gravitational and planetary wave situations. Li and Aiki (2020) have used this new scheme to perform the first analysis of the life cycle of seasonal waves in the upper layer of the Indian Ocean, and found that the eastward energy flux of Kelvin waves culminates when the equatorial zonal flow anomalies are maximized eastward and westward by the monsoon, and this occurs four times a year. Near the western boundary of the Indian Ocean, seasonal variations in the Somali jet and the East African coastal current led to equatorially oriented energy fluxes along the African continental coastline, forming a localized cyclonic circulation of wave energy in each hemisphere. These results are the foundation for a deeper understanding of tropical–extra-tropical interactions.


Circulation and budget of wave energy in the Indian Ocean revealed by the numerical experiments and analysis in this study. (a) Streamfunction and (b) divergence (shading) and potential (contours).

(Reference: Li, Z., and H. Aiki, 2020, The life cycle of annual waves in the Indian Ocean as identified by seamless diagnosis of the energy flux. *Geophysical Research Letters*, 47, e2019GL085670. doi:10.1029/2019GL085670)

Seasonal and interannual variations in nitrogen availability and particle export in the North Pacific subtropical gyre

Nutrient availability limits primary productivity in the low and mid-latitude oceans. This constrains the export of sinking biogenic particles, which removes carbon from the atmosphere, the so-called biological pump. We examined temporal variations in nitrogen availability and particle export in the northwestern North Pacific subtropical gyre (NPSG), using sediment trap time-series observations at 200 m depths between 2010 and 2014. We found that the nitrogen isotopic ratio ($\delta^{15}N$) of trapped particles varied according to the external input of "new" nitrogen. About 86–93% of the "new nitrogen" was nitrate supplied from subsurface waters. The reduced $\delta^{15}N$ of the high particle fluxes every winter indicated that nitrate was mainly supplied via convective mixing, triggering phytoplankton blooms. Interestingly, the magnitude of the convective nitrate supply varied from year to year, depending on winter monsoon intensity. This not only controls particle fluxes but also their composition. Stronger mixing in 2011–2012 than 2013–2014 enhanced $CaCO_3$ export, thus reducing the organic carbon to inorganic carbon export ratio, R(POC:PIC). Such interannual changes of winter R(POC:PIC) can affect air–sea CO_2 fluxes by modulating seawater CO_2 partial pressure in the northwestern NPSG.

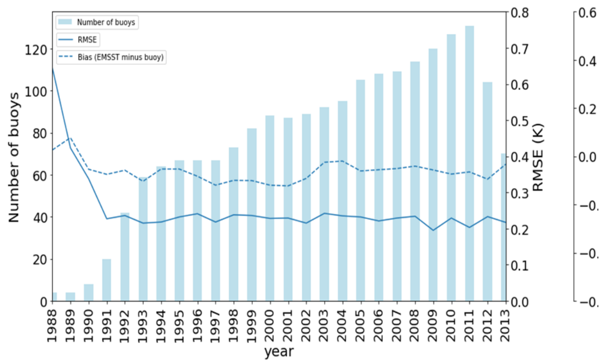


Influences of Changjiang river and upwelling water on phytoplankton community structure. Top: years with high anthropogenic nitrogen input from Changjiang river, Bottom: years with high influence of upwelling.

(Reference: Mino et al., 2020, Seasonal and interannual variations in nitrogen availability and particle export in the northwestern North Pacific subtropical gyre. *JGR-Oceans,* doi.org/10.1029/2019JC015600.)

Long-term consistency of a global satellite-derived air–sea flux dataset

Accurate estimation of global air–sea flux is indispensable to understanding the complex air–sea interactions in the climate system. We have released a new air–sea flux dataset, based on satellite observations over the past 25 years, through the use of multi-satellite observation data and the development of advanced estimation technology (J-OFURO3). Since such a long-term observational dataset is expected to be used for climate research, it is necessary to confirm the reliability of the data, as well as its long-term consistency. This study confirmed the long-term consistency of the dataset by establishing a verification system that comprehensively included in-situ observations in the global oceans. The Figure summarizes the verification results for sea surface temperature, which is the basis for estimating air–sea heat flux. Except for the first few years where the number of in-situ observations were extremely small, the root mean squared error and bias of the in-situ observations were very stable, approximately 0.2 K and -0.1 K, respectively. Similar comparisons were also conducted for surface winds (Koizumi et al., 2020). These results support the application of the dataset to climate research.



Verification results for J-OFURO3 daily mean sea surface temperature data. The bars show the number of observations from in situ buoys in the verification system, and the solid (dashed) line shows the yearly change in RMS error (bias), compared with the buoy data.

(Reference: Koizumi, A, M. Kubota, and H. Tomita, 2020, *Int. J. Remote Sens.* doi:10.1080/01431161.2019.1706113)