Equilibrium Solutions for Marine Food-chain to Bottom-up and Top-down Controls

*Yutaka Isoda[1]

1. Hokkaido University

Using a simple four-level food-chain model (N: nutrient, P: phytoplankton, Z: zooplankton and F: fish), the equilibrium solutions are investigated under the nutrient supply (bottom-up control) and the loss-parameter of fish (top-down control). The solutions of bottom-up control suggest that Z stock is always stabilized, while those of top-down control reveal the phase relation between [N, Z] and [P, F] is out of phase.

Keywords: Bottom-up control, Top-down control, Marine food-chain, Volteraa equation

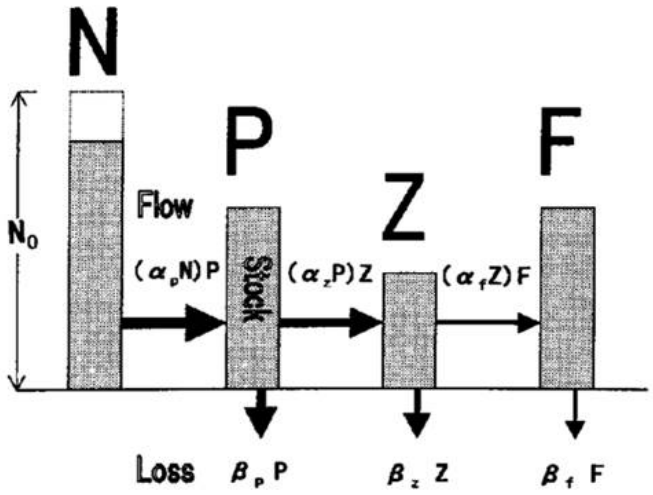

Fig. 1. Diagram of the dynamics of our food-chain model with four stock levels: N (nutrient), P (phytoplankton), Z (zooplankton), and F (fish).

Tidal changes in the Tokyo Bay during the last 10,000 years estimated from a numerical model

*Katsuto Uehara[1]

1. Kyushu University

Many major inner bays in Japan such as Tokyo Bay, Ise Bay south of Nagoya City and Osaka Bay have experienced a specific pattern of morphological changes during the Holocene: a rapid expansion of bay areas during the early Holocene due to the inundation of incised valleys in accord to the postglacial sea-level rise, which was followed by a gradual progradation of shorelines as a result of sediment depositions more apparent during mid- to late-Holocene when the sea level was stable or fallen by several meters. The current study estimated tidal changes taken place during the last 10ka in Tokyo Bay, where most of the modern bay area exposed subaerially during the earliest Holocene while the length of the bay axis extended up to about twice as large as the modern setting during the mid-Holocene. The estimation has been undertaken by compiling a series of paleobathymetry (every 1ka from 10kaBP to 4kaBP) using various sources and by conducting numerical experiments. It was found that the maximum tidal level at the head of the bay may have increased by 52%-93% compared to the present value during the maximum transgression period (7kaBP). The increase in the tidal prism during the transgressive stage have given rise to a significant increase in the tidal current strength at the mouth of the bay. During the early Holocene, strong tidal currents were also observed at around the modern head of the bay, which might be correlated to the coarse sediments observed at the base of the Holocene layer in this area. These features could be explained qualitatively by employing a simple resonance theory with two parameters, i.e., the water depth and the length of the bay.

Keywords: Holocene, paleotides, numerical simulation, Oku-tokyo Bay, Sea-level change

Possible oceanic signals of the 18.6-year period modulation of tide-induced vertical mixing

*Satoshi Osafune[1]

1. Japan Agency for Marine-Earth Science and Technology

Bi-decadal variability is one of the prominent features of the decadal to multi-decadal ocean and climate variability in the North Pacific. This has received considerable attention, because this is seen in many societally important variables such as air temperature, precipitation, and even fishery resources. However, while several possible mechanisms underlying this variability have been proposed, it has not been fully understood. The 18.6-year nodal tidal cycle related to the precession of the moon’s ascending node is a possible one. It is known that the diurnal tides induce strong vertical mixing around steep topographies like sills in the Kuril Straits and the Aleutian Passes, and this strong mixing is thought to play important roles in water-mass modification. The 18.6-year cycle largely modulates the amplitudes of the major diurnal tidal constituents by 11% and 19% for K_1 and O_1, respectively. Thus, it is hypothesized that the modulation of mixing contributes to the bi-decadal variability in water-masses in the North Pacific and its marginal seas. Using the historical ocean observation data, I found various bi-decadal variations downstream of the strong mixing regions, which can be explained qualitatively by the modulation of vertical mixing, although it is difficult to prove whether those are really the 18.6-year period signals by using only the limited observation data.

Keywords: bidecadal variability, 18.6-year nodal tidal cycle, tide-induced vertical mixing

Holocene changes of the Japan Sea Proper Water (JSPW) inferred from marine plankton (radiolarian) fossil records

*Takuya Itaki[1], Ken Ikehara[1]

1. Geological Survey of Japan, AIST

The Sea of Japan has its own deep-circulation system, with its deeper parts occupied by cold and highly oxygenated water formed by winter convection in the northwestern part of the sea. According to recent observations, such deep convection has been weakened with the global warming. How was in the past warming before the historical period? For example, it is well known the warmer climate during the Jomon period (ca. 7,300 years ago) in the mid-Holocene. Here, we will discuss about the deep-circulation changes in the Japan Sea during the past 12,000 years (Holocene) based on marine plankton (radiolarian) fossil records.

Radiolarians are planktonic Protozoans widely distributed in the world ocean, and their skeletons composed of opal are preserved in marine sediments. Many radiolarian species are restricted to discrete depth intervals and the depths at which they dwell are closely related to the vertical water structure. As a result, radiolarian fossils prove to be useful indicators not only in the reconstruction of the surface water conditions, but also for the conditions of the water masses at intermediate and deeper depths. In the Sea of Japan, investigations based on plankton tows and surface sediments revealed that *Cycladophora davisiana* occurs in a depth interval between 1,000 m and 2,000 m (deep layer of JSPW = Japan Sea Proper Water), and *Actinomma boreale* group in depths below 2,000 m (bottom layer of JSPW).

The study of six sediment cores located in water depths ranging from 300 to 3,600 m show that the radiolarian assemblages have varied during Holocene, indicating changes in water-ventilation strength in this marginal sea. Bottom-water ventilation has been dependent on high-salinity inflow through the Tsushima Strait in the south and winter cooling in the northwestern part of the Sea of Japan. Deep water was being actively formed in the early Holocene. This bottom-water formation has resulted in relatively constant water composition since 9 cal ka BP, with the overall increase in high-salinity oceanic-water inflow, although the latter decreased transiently from 7,000 to 5,000 years ago in concert with climatic warming.

Keywords: Paleoceanography, Microfissil, water structure

Collaboration study of paleoceanography and physical model in the Japan Sea

*Takuya Sagawa[1], Xinyu Guo[2]

1. Institute of Science and Engineering, Kanazawa University, 2. Center for Marine Environmental Studies, Ehime University

The Japan Sea is semi-enclosed marginal sea that is connected with adjacent seas with shallow narrow straits. During the last glacial maximum (LGM) sea level was ~130 m lower than today, which is similar to the sill depths of Tsushima and Tsugaru straits. Therefore, the Japan Sea was almost isolated from adjacent seas, and the Tsushima Warm Current (TWC) did not flow into the Japan Sea. Microfossil records suggest that the Oyashio Current flowed into Japan Sea first followed by the TWC as the sea level rose through the deglaciation. However, the deglacial reorganization of Japan Sea current system in relation to global eustatic change is not well understood in terms of physical oceanography. In this talk, we'll introduce our vision of collaboration research between paleoceanography and physical oceanography.

Keywords: Japan Sea, Paleoceanography, Physical Ocenography

Reconstruction of vertical temperature structure in the East China Sea to better understand the past Kuroshio variability

*Yoshimi Kubota[1], Katsunori Kimoto[2], Ryuji Tada[3]

1. National Museum of Nature and Science, 2. Japan Agency for Marine-Earth Science and Technology, 3. University of Tokyo

The East China Sea (ECS) is a marginal sea, located in western edge of the Pacific and the Kuroshio is one of the major current systems in the ECS and has a crucial impact on water properties in the ECS (Chen et al., 2010; Guo et al., 2012). Because the position of the Kuroshio in the ECS is relatively stable (standard deviation is ~10 km) compared with the outside ECS (Andres et al., 2008), it is suitable to investigate long-term variations in the Kuroshio without the consideration of meandering of the main axis. However, there has been ongoing debate about the variability of the Kuroshio in the past in the East China Sea. One argument is, like the Ryukyu Current today, the Kuroshio main axis migrated to be outside of the Okinawa Trough during the last glacial maximum (LGM)(e.g., Ujiié et al., 1991; Ujiié and Ujiié, 1999; Diekmann et al., 2008). Another argument is that the Kuroshio main axis remained located in the Okinawa Trough even at the lowest sea level stand (e.g., Kawahata and Ohshima, 2004; Lee et al., 2013). Based on a comparison of planktic foraminifera assemblages inside and outside the Okinawa Trough, Ujiie et al. (2003) advocated “outside Okinawa Trough”. Their comparison revealed the appearance of cold water species inside the Okinawa Trough during LGM, despite only minimal variation in assemblage-derived sea surface temperature (SST) outside the Okinawa Trough. However, a recent study based on comparison of Mg/Ca-derived SST records demonstrated that there was no significant difference in SST between inside and outside the Okinawa Trough, suggesting the entrance of the Kuroshio inside the Okinawa Trough during the LGM (Lee et al., 2013). Although there are many studies focusing on reconstruction of surface hydrology in the Okinawa Trough since the MIS 3 or LGM using planktic foraminifera assemblages (Li et al., 2001; Ujiie et al., 2003; Xu and Oda, 1999) and alkenon-derived SST (Ijiri et al., 2005; Yu et al., 2009), and Mg/Ca-based SST (Chen et al., 2010; Kubota et al., 2010; Sun et al., 2005), information concerning water properties at subsurface and intermediate depth is sparse, which is important as variations in the Kuroshio velocity and transport have a greater impact on temperature and salinities at subsurface and intermediate depths rather than those at surface (Oka and Kawabe, 1998). In this study, we reveal temperature structure in the Okinawa Trough since the late MIS 3 and discuss how we understand the Kuroshio variability in the past.

Keywords: Kuroshio , East China Sea , Last Glacial period

Temporal variations of productivity at low trophic levels over the past 150 years in the western Seto Inland Sea, Japan, revealed by sedimentary records

*Narumi Tsugeki[1], Michinobu Kuwae[2], Yukinori Tani[3], Xinyu GUO [2], Koji Omori[4], Hidetaka Takeoka[2]

1. Law Faculty, Matsuyama University, 2. CMES, Ehime University, 3. Department of Environmental and Life Sciences, School of Food and Nutritional Sciences, University of Shizuoka, 4. Faculty of collaborative Regional Innovation, Ehime University

We examined fossil pigments in a ^{210}Pb-dated sediment core to document the temporal variations in phytoplankton biomass over the past 150 years in a semienclosed bay, Beppu Bay, in the western Seto Inland Sea, Japan. The flux of fossil pigments was used as an index of phytoplankton biomass, which we reconstructed after removing the effect of post-burial degradation on the concentrations of fossil pigments.
The flux doubled from the 1960s to the early 1970s, decreased or remained stable in the early 1980s, and increased again from the late 1980s to the early 1990s. The first increase in phytoplankton biomass during the 1960s was likely caused by eutrophication due to an increase in terrestrial nutrient fluxes from watersheds. The decreasing phytoplankton biomass in the early 1980s was likely related to the establishment of a sewage treatment system that reduced the terrestrial nutrient fluxes to the sea. However, the terrestrial nutrient fluxes could not explain the second increase from the late 1980s to the early 1990s. Intensification of the influx of nutrients from the shelf slope to the sea was likely the cause of the second increase in phytoplankton biomass. This is supported by the inverse relationship between phytoplankton biomass and sea level at the shelf slope, the latter being an index of the intensity of the influx of oceanic nutrients from the shelf slope to the sea. The supply of oceanic nutrients may be therefore a critical factor in the determination of primary production in the western Seto Inland Sea.

Keywords: Primary production, fossil pigment, Seto Inland Sea, Kuroshio current, Palaeoceanography, Eutrophication

Evidence for multiple redox zones in early Cambrian ocean

*Zihu Zhang[1,2], Meng Cheng[1], Chao Li[1,2]

1. School of Geosciences, China University of Geosciences Wuhan, 2. State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences

Ocean redox state is basically controlled by the balance between oxidizers and reductants. In theory, in addition to conventional oxygen and sulfate, Mn-Fe oxides and nitrate can serve as the oxidizer, whose reductions have been hypothesized to have generated manganous-ferruginous and nitrogenous zones between oxic and sulfidic zones in a highly stratified ocean of early Earth (>520 Ma; Li et al., 2015). To test this hypothesis, we conducted a high-resolution Fe-S-C-N and trace-element geochemical study of the early Cambrian Qingxi Formation in a deep-water setting at Silikou, Guangxi Province, South China. Integrated Fe-Mo-S-C-N data demonstrate an overall marine redox transition at Silikou from euxinic to oxic conditions up section, which is consistent with the gradual oxygenation of early Cambrian ocean observed widely in South China (Jin et al., 2016). However, our data also clearly reveal the developments of manganous-ferruginous and nitrogenous conditions during the transition as suggested by higher sedimentary Mo concentrations relative to U due to the adsorption to Mn-Fe oxides and subsequent reductions(i.e., the activity of Mn-Fe shuttle) and the abrupt increase of the organic N isotope from +2 ‰ to +5 ‰. The occurrence of these redox zones reflects the successive use of oxygen, nitrate, Mn-Fe oxides and sulfate as the oxidizers in early Cambrian oceans. Thus our study for first time provides direct evidence for the existence of these hypothesized redox zones in early Earth’ s oceans, which is of significance to our understanding of elemental biogeochemical cycles in early Earth’ s oceans and their impacts on biological evolutions.

References

Chao Li, Meng Cheng, Thomas J. Algeo, ShuchengXie. A theoretical prediction of chemical zonation in early oceans (>520 Ma). Science China Earth Sciences, 2015, 58(11): 1901-1909.

Chengsheng Jin, Chao Li, Thomas J. Algeo, Noah J. Planavsky,Hao Cui,Xinglian Yang,Yuanlong Zhao,Xingliang Zhang,ShuchengXie. A highly redox-heterogeneous ocean in South China during the early Cambrian (~529-514 Ma): Implications for biota-environment co-evolution, Earth and Planetary Science Letters, 2016, 441:38-51.

Keywords: Early Cambrian, Redox Condition, Early Animals, Oceanic Stratification

Chukchi and Bering Sea shelves contribution to Mn enrichment in the Arctic deep basin

*Liming Ye[1], Yeping Bian[1], Xiaoguo Yu[1]

1. Second Institute of Oceanography. SOA

A key role of the Siberian Arctic shelves has been suggested to play in the enrichment of Mn over all Arctic deep basins. On the orbital timescale, Mn records from the Alpha Ridge core 08B85-D displayed a close correlation to the Relative Sea Level changes on the independent age model. A threshold of -60 m sea level seems to be able to shift the Mn transportation from shelves to deep basins. This phenomenon in the core records was supported to some extent by the Mn distributions in the surface sediments with extremely low values over the Chukchi Sea and Bering Sea shelves and with relatively high values over the areas deeper than 60 m water depth. Another independent proxy Ce anomaly also shown the similar distributions as the Mn both in the core and the surface sediments, and suggested that the main transportation of Mn might occurred at the Chukchi Sea and Bering Sea shelves, rather than the Eastern Siberian Sea and Laptev Sea shelves. Especially the Contributions from the Bering Sea shelf should be considered to account for the Mn enrichment in the Arctic deep basins.

Keywords: Mn enrichment, Chukchi Sea shelf, Bering Sea shelf, Ce anomaly

Capturing extreme river runoff events from oceanic sediment distribution

*Shinichiro Kida[1], Yusuke Okazaki[2], Jon Woodruff[3]

1. Research Institute for Applied Mechanics, Kyushu University, 2. Department of Earth and Planetary Sciences, Kyushu University, 3. Department of Geosciences, University of Massachusetts - Amherst

A significant amount of the freshwater discharges around Japan occurs through extreme weather events. Capturing the event in the ocean, however, has been observationally difficult because of the strong currents and its random occurrence. Moreover, the low salinity signal often disappears after a few days since the majority of the rivers in Japan are directly connected to the open ocean and thus is strongly affected by its circulation. Regional-scale numerical oceanic models are becoming capable of resolving the dynamics of freshwater discharges but we have so far lacked a tool to test them from observations. We will introduce an observational project based on the Ariake Sea that aims to investigate the dynamics of the extreme freshwater discharges from oceanic sediments. The discharge following the Kumamoto Earthquake is likely associated with sediments that entered the rivers through the various landslides and thus contain a detectable record compared to previous years. The Ariake Sea is one of the few estuaries that is large to capture the discharge signal and not directed altered by the open oceanic circulation.

Keywords: river runoff, sediment, earthquake

Response of Japanese sardine and anchovy abundances to orbitally driven climate changes during the Holocene

*Michinobu Kuwae[1], Masanobu Yamamoto[2], Keiji Takemura[3], Ken Ikehara[4], Keitaro Yamada[3], Kohei Ishishita[5], Yuko Takamatsu[5], Takashige Augimoto

1. Center for Marine Environmental Studies, Ehime University, 2. Faculty of Environmental Earth Science, Hokkaido University, 3. Institute for Geothermal Sciences, Kyoto University,, 4. Research Institute of Geology and Geoinformation, Geological Survey of Japan, 5. Faculty of Science, Ehime University

There remains one of the questions how pelagic fish stocks respond to orbital-scale climate change during the Holocene. Long-term relationship between pelagic fish abundances and climate change could help us to understand their responses to future climate changes. Here we present fish scale abundance records of Japanese sardine and Japanese anchovy for the last 7000 years. The record of sardine scale deposition rates showed an increasing trend before around 3,500 calendar year BP and a decreasing trend from the time period toward the present. On the other hand, anchovy scale deposition rates showed an increasing trend after 3,500 cal. yr BP. Observational studies demonstrated that growth rates of Japanese sardine and Japanese anchovy are high at ~16˚C and ~22˚C with a unimodal response to water temperatures. Only one or two degree lower and higher temperature than the optimal temperature may results in depletion of larvae’ s growth rate and recruitment failure, resulting in species alternation from sardine to anchovy and back (Takasuka et al., 2007). This is called 'optimal growth temperature' hypothesis (Takasuka et al., 2007). In fact, the equivalent temperature rise occurred in association with Pacific Decadal Oscillation, resulting in a population decrease up to ~90 part of the highest value recorded in 1988. Since mean temperatures in the spawning ground of Japanese sardine (off southern coast of Japan) during 1980s were around 17˚C, 1˚C higher than the optimal temperature, 1˚C lower than that during the present ‘sardine regime’ can be expected higher growth rates and increase in abundance. Model simulation results obtained under orbitally driven solar isolation forcing (Lorenz et al., 2006; Ohgaito et al., 2013) indicate that SST in Kuroshio extension, an area distributing sardine larvae, shows an increase trend with ~0.7˚C/6 kys in winter. The temperature at 6 cal. kyr BP is likely close to the optimal temperature for sardine larvae. Therefore, past temperature change can be expected to be a long-term decrease trend in population. However, our result suggests a decrease trend only for the last 3,500 years, but showing an increase trend before 3,500 cal. yr BP. One of the most plausible reason for this contradiction may be due to underestimation of the increasing rates of temperature for the last 6 kyrs in the narrow route 0˚ to 0.5˚ north of the Kuroshio axis and the Kuroshio Extension axis as an important nursery ground, which might be due to relatively low spatial resolution in the models used. If the past thermal condition in the route was 2˚C lower temperature than that in the present sardine regime (1˚C lower than the optimal temperature), the observed depletion in sardine abundance at 6 cal. kyr BP, which is comparable to the present day level, can be explainable by 'optimal growth temperature' hypothesis. The increasing trend in anchovy abundance can also be explained by this hypothesis. There may be a new challenge for collaboration between oceanography and paleoceanography regarding this issue.

Keywords: Japanese sardine and Japanese anchovy, climate change, Holocene, Northeast Pacific

Multiple equilibria and overturning variability of the Aegean-Adriatic Seas

*Yael Amitai[1,2], Yosef Ashkenazy[2], Hezi Gildor[1]

1. The Hebrew Univ., 2. Ben-Gurion Univ., BIDR

The Eastern Mediterranean Transient (EMT) –a transition and amplification of the Eastern Mediterranean Sea deep water source from the Adriatic Sea to the Aegean Sea –was observed in the mid-90′ and stimulated intense research. We demonstrate, using an oceanic general circulation model, that the meridional overturning circulation of the Eastern Mediterranean has multiple equilibria states under present-day-like conditions, and that the water exchange between the Aegean and the Adriatic Seas can drastically affect these states. More specifically, we found two stable states and a hysteresis behaviour of deep water formation in the Adriatic Sea when changing the atmospheric (restoring) temperature over the Aegean Sea. In addition, the overturning circulation in both seas exhibits large decadal variability of the deep water formation. The Aegean-Adriatic relationship can be summarized as follows: warm and saline water of the Aegean can either flow in the sub-surface to the Adriatic, switching “on” deep water formation in the Adriatic by increasing its salinity, or the Aegean water can feed the deeper layer of the Ionian and Levantine basins, turning “off” the deep water formation in the Adriatic. The “off” steady state resembles some aspects of the EMT in which the Adriatic source of deep water was weakened when the Aegean source became active. Another noticeable finding of this work is the minor to none dense water outflow from both the Aegean and Adriatic Seas in some of the simulations. When none of the seas produce dense enough water, the Levantine basin deep layers are not ventilated and a sapropel-like period is enabled, as is evident in the Eastern Mediterranean sediments record.

Keywords: Mediterranean Sea, Meridional overturning circulation, Multiple equilibria, Adriatic Sea, Aegean Sea, Eastern Mediterranean Transient

30-year variation of temperature and salinity in the Seto Inland Sea isolated from the climate change in the surrounding ocean

*Atsuhiko Isobe[1]

1. Research Institute for Applied Mechanics, Kyushu University

Using oceanographic data archived in the Marine Information Research Center Ocean Dataset 2005, linear trends of both temperature and salinity from 1963 to 1993 were computed at each grid cell with a horizontal scale of 1/6° over the Seto Inland Sea, Japan. The linear trends were thereafter multiplied by 31 years to compute the increments of temperature and salinity during this period. Over the course of 31 years, summer temperatures decreased significantly both at the sea surface (−1.2 ˚C/31y averaged over the area) and the bottom (−1.7 ˚C/31y), while salinity increased at the sea surface (0.46/31y) and bottom (0.41/31y). In addition, it was found that steric heights computed using temperature and salinity in summer (see Methods) mostly decreases over the Seto Inland Sea during the 31 years (−0.57 mm/y).
It is unlikely that these 31-year trends were caused by surface heat and freshwater fluxes through the sea surface. Of particular interest is the salinity increase, which was revealed in the bottom layer as well as the surface layer. Apparently, this is unlikely to be caused by a secular trend of freshwater flux into the upper layer (precipitation minus evaporation, and/or river runoff). The reasonable explanation is that the dense (cool and saline) Kuroshio intermediate water, uplifted near the coast over the period 1963 through 1993, intruded into the bottom layer of the Seto Inland Sea. The above-mentioned trends were restricted within the Seto Inland Sea. The temperature increment south of Japan was mostly zero during the same period in summer. Moreover, the sea surface height (SSH) within the same area in summer showed an increase of 0.2 (2.0) mm/year during the same period.
In the southwestern Japan Islands, the oceanographic properties of shallow coastal waters exposed to the south are vulnerable to Kuroshio fluctuations that act as outer boundary conditions. The reconstructed SSH data (ReSSH; Hamlington et al., 201, 2112) map averaged over 10 years from 1963 to 1972 suggests that a cold eddy was located off the Kyushu and Shikoku Islands, Japan. However, in the ReSSH map averaged over the period 1984−1993, the cold eddy identified 20 years earlier had mostly disappeared, and it was replaced with a warm eddy. The transition to the warm eddy suggests that the surface speed (hence, volume transport) of the Kuroshio Current south of Japan had increased during the period 1963−1993, because of the recirculating geostrophic flow around the eddy. A geostrophic adjustment associated with the increasing Kuroshio transport results in the thermocline tilting and resultant temperature decreases (salinity increase) close to the Japan Islands. This is consistent with the temperature decrease (salinity increase) in the Seto inland Sea, potentially caused by the subsurface intrusion of the Kuroshio intermediate water. It is however a difficult task to uncover the possible cause(s) of the eddy transition south of Japan; Note that the Kuroshio meander off the Enshu Nada was apparently not a cause, because it is located far east of the Seto Inland Sea. To uncover the cause(s) of the 31-year eddy activity south of Japan, we have to investigate the secular SST/SSH variation, at least, ten times longer than the period in the present study, and it is unfortunately beyond the scope of the conventional physical oceanography.

Keywords: 30-year variation of temperature and salinity, Seto Inland Sea

Formation of bottom water and its variability in the Sea of Japan

*Kiyoshi Tanaka[1]

1. University of Tokyo

The downslope descent of dense shelf water in the northwestern part of the Sea of Japan is investigated from a dynamical point of view. Before 1980, the shelf water in Peter the Great Bay sometimes descended far down the continental slope, at least partly reaching depths in excess of 3000 m (the foot of the continental slope). After 1980, however, the shelf water did not descend as far; it either descended only moderately or not at all. In Winter 2001, however, the dense shelf water again descended to depths greater than 3000 m, resulting in the formation of bottom water. Descents of more than 3000 m are due to low temperatures coupled with high salinities, whereas the moderate descents of the late 20th century were purely related to the low temperature of the shelf water. The formation of bottom water is greatly influenced by interannual atmospheric variability; thus in Winter 2001 a combination of the strengthened Siberian High (especially in its northern part) and the Aleutian Low advected very cold air into northeast Asia, producing dense shelf water and resulting in the formation of bottom water.

Keywords: Sea of Japan, Formation of Bottom Water, Interannual variability, Hydrodynamic Modeling