Future Earth ~Human Impact~

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Abstract
Human activities have significant contributions to the Earth's surface environments and climatic change recently. Therefore the investigation of Earth's environmental and climatic change has attracted an attention all over the world at the moment. For better future environments we should reconstruct paleo-environments, understand the natural processes deeply and have a future perspective for the global climate. Especially carbon cycle study is one of the key issues for the environmental study because the increase in atmosperhic CO2 concentration would lead to global warming and also should bring ocean acidification in near future. Both environmental disasters will make an impact on energy problem, food supply, tourism and other economic issues. Also the climatic change in Holocene has affected the development of civilization. The mid-Holocene is well known for having a warmer climate than the present as is cited as Hypsithermal period (Holocene Climatic Optimum) around 50ka. The population showed a maximum during this period in Japan. After that, the population was decreased, which corresponds to the decline of other civilization. IODP will provide the high-resolutional Holocene record to reconstruct the linkage between climatic change and human development.

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1. Global carbon cycle and global warming

The observed increase in global average temperatures since the mid-20th century could be due to the observed increase in anthropogenic greenhouse gas (GHG) concentrations. GHG includes carbon dioxide, methane, freon gases and others. Both natural and anthropogenic drivers of climate change includes the chain from GHG release to atmospheric concentrations to radiative forcing to climate responses and effect. It is very important for us to understand climatic forcing processes in natural system for future prediction of climatic and environmental change.

During glacial-interglacial cycles in late Quaternary, the atmospheric concentrations of CO2 rises from180 to 280–300 p.p.m.v. and that of CH4 rises from 320–350 to 650–770 p.p.b.v.. In contrast, the mid-Cretaceous represents one of the warmest climate intervals during the entire Phanerozoic (Veizer et al., 2000). Maximum sea surface temperatures (SSTs) of 31°C, which is ~6°C higher than that at an oceanic site at comparable latitude today. Also, intermediate-deep water temperatures are suggested to be ~12°C higher during 99–100 Ma than that at present. Some believe that the mid-Cretaceous greenhouse warming may have been linked to the CO_2 derived from the enormous volcanic episode associated with the Cretaceous superplume. Although atmepheric CO2 concentration is quite important for global warming, the atmospheric concentration is deeply controlled by ocean reservoir because ocean reservoir is more than 50 times of that of atmosphere and 16 times of terrestrial reservoir. Therefore it is important to investigate the carbon cycle in the ocean.

The practical role of the oceans in the global carbon cycle is an important subject of discussion, especially with respect to their capacity to buffer anthropogenic release of CO2 to the atmosphere (e.g. Tans et al. 1990). In particular, photosynthetic carbonate-producing organisms widespread in the marine environment have a potentially important effect on the global carbon cycle. In the ocean, the principal groups of photosynthetic, calcifying organisms are symbiotic reef-building corals that are replete with algae, calcareous algae that are often associated with coral reef communities, planktonic foraminifera that have symbiotic algae and coccolithophores.

Coccolithophores and coral reefs produce carbonate in association with the production of organic carbon. Generally, elevated rates of calcification are made possibly by high rates of photosynthesis, although the detailed interaction between the two processes is not well understood. Photosynthesis is a short - term sink for atmospheric CO_2 ($CO_2 + H_2O$ -> $CH_2O + O_2$) while respiration/degradation releases the fixed CO_2 to the ambient water or atmosphere. On the other hand, calcification raises the CO_2 fugacity in seawater (PCO_{2w}) as follows:

$Ca^{2+} + 2HCO_3^-$ -> $CaCO_3 + H_2O + CO_2$.

A bloom of the coccolithophore Emiliania huxleyi in the northeast Atlantic appeared to raise pCO_2 by a mean of 50 micro-atm, due to the effect of calcification (Holligan et al., 1993). On the contrary, Sikes and Fabry (1993) proposed that photosynthetically enhanced coccolith formation works as a sink of atmospheric CO_2. The controversy mainly comes from whether the integrated effects of photosynthesis-respiration and precipitation-dissolution of $CaCO_3$ increase or decrease pCO_2.

Generally speaking, continental shelves are net sinks of CO_2 due to the intense primary production and coastal processes such as river input and upwelling (e.g., Kempe and Pegler, 1991). However, according to Kawahata et al. (2000), since the dissolved inorganic C:P ratio is anomalously high in terrestrial waters compared to the mean C:P ratios of primary production in a Shiraho fringing coral reef of Ishigaki Island, excess carbon supplied by terrestrial input could be released into the atmosphere. Therefore, IODP should reconstruct the paleo-environments in both coastal and open oceans in future for a long term.

2. Ocean acidification

Ocean acidification has become the biggest threat to calcifying marine organisms in recent years. Previous studies have reported that calcification rate of calcareous marine organisms (e.g., corals, foraminifers, coccolithophores, pteropods, mussels, and oysters) changes in response to lowering pH levels even waters oversaturated with respect to calcite. The rising level of partial pressure of carbon dioxides in seawater is making the world's oceans more acidic. The pH could drop from 8.15 at the pre-industrial 1800 through 8.06 at modern to 7.9 by the end of this century. Previous DSDP/ODP expeditions have provided lines of evidence indicating a contemporaneous carbonate dissolution event associated with sever ocean acidification across the Paleocene/Eocene boundary, which would have been triggered by massive dissociation of methane and subsequent elevation of atmospheric pCO_2. The carbonate sediments will buffer pH by dissolution of carbonate. However, deep (~>4 km) seafloor in the Pacific is covered with red clay sediments without carbonate, which is more affected by acidification, due to aragonite and/or calcite undersaturation by little chemical buffering and pressure effects. In 2nd phase of IODP, we would like to investigate the process and degree of ocean acidification in the past and buffering effect on pH by deep-sea carbonate dissolution, terrestrial weathering and others processes.

3. High resolution Holocene to understand the linkage between human development and climatic change

The Holocene is a geological epoch, which started about 11,700 years ago and characterized by Human civilization and increase in anthropogenic activities. Holocene climate has been much more stable than that during the deglaciation and glacial periods. It is supported by no evidence of millennial-scale fluctuations in $d^{18}O$, methane concentrations, and snow accumulation in Greenland ice cores during the Holocene, except for a brief cooling about 8.2 ka. However recent evidences from Greenland ice core [O'Brien et al., 1995] and sediments retrieved from the northern North Atlantic [Bond et al., 1997] suggested that the climate during the Holocene has been punctuated by millennial-scale events. Bond et al. [2001] inferred that solar-induced atmospheric changes might be amplified and transmitted globally through North Atlantic thermohaline overturning. On the other hand, the mid-Holocene is well known for having a warmer climate than the present as is cited as Hypsithermal period (Holocene Climatic Optimum) around 50ka. Currently, it is important to increase our understanding of modern climatic variability and its socioeconomic impacts as a function of increased concentrations of greenhouse gases. Also interestingly these climatic change in Holocene has made an impact on the population values and civilization. In Japanese islands, the population showed a large maximum at Holocene Climatic Optimum (an increase from 20 thousand people at 10 ka to 260 thousand at 50 ka). However, the temperature suddenly decreased at 4.2 ka, when the population definitely declined to 80 thousand people. The timing of the abandonment is consistent with the timing (around 4.0–4.3 cal. kyr B.P.) of the decline of civilizations in north Mesopotamia and along the Yangtze River.. We think it very important that IODP will drill into thick Holocene sediments near continental margin with high sedimentation rate to evaluate naturally-induced global warming and the rise/fall of the civilizations in the world in response to climatic change.