Sustainable ocean carbon and biogeochemistry observing system in the era of warming, acidification and deoxygenation.

*Masao Ishii[1]

1. Meteorological Research Institute, Japan Meteorological Agency

The importance of studies on the impacts of human activities on marine biogeochemical cycles is increasing recently from multiple aspects of climate change mitigation, ocean health conservation as well as the sustainable use of marine resources. The ocean is absorbing about a quarter of anthropogenic CO_2 being released to the atmosphere by human industrial activities and is reducing the rate of atmospheric CO_2 increase thereby mitigating the global warming. To project the change in its role as a result of the changes in oceanic CO_2 storage, ocean circulations and marine ecosystems is one of the challenges in reducing the uncertainty in the projection of climate change. The human societies are also being threatened by the ocean acidification and deoxygenation being caused by the oceanic anthropogenic CO_2 uptake, warming and eutrophication through their adverse impacts on marine ecosystems. They are among the important issues being addressed in recent IPCC WGI's assessment reports and in the UN Decade of Ocean Science for Sustainable Development (2021-2030). In addition, ocean acidification has been defined as one of the targets of Sustainable Development Goal 14.

Studies on marine carbon cycle have been developed significantly in 1990s through international projects such as Joint Global Ocean Flux Study. Thereafter, International Ocean Carbon Coordination Project (IOCCP) and Global Ocean Acidification Observing Network (GOA-ON) were established and are playing an impoertant role for the coordination of ocean carbon observations and studies on ocean acidification, respectively, by acting closely with Global Ocean Observing System (GOOS). On the contrary, the studies of ocean carbon cycles have been rather fragmented into projects such as SOLAS for air-sea interactions, IMBeR for ocean biosphere, and CLIVAR for ocean modelings. However, their linkages have been reinvigorated recently under the auspices of UNESCO-IOC to establish the "value chain" of ocean carbon cycle researches being comprised of coordination and implementation of observations, their open data assess and integrated data analyses, data assimilations, numerical modelings and disseminations of scientific products and outcomes to contribute to the "UN Decade". In the field of ocean observation as a component of this "value chain", the networking of sustainable ocean observing networks including ship-board high-precision multi-parameters measurements from the surface to the near bottom (e.g. GO-SHIP), surface ocean CO_2 measurements (SOCONET) and the emerging networks of profiling floats (Argo) and under water gliders installed with biogeochemical sensors are critical to gain the 4-D view of ocean biogeochemistry by establishing the broad sensor calibration system with high precision data from ship-board measurements.

Recently, the decadal variability in the regional ocean CO_2 uptake being associated with the variability in ocean circulation is being found in repeat sections of ship-board measurements. The networking of sustainable ocean observing networks and their data integration will help much better assessments of changes and variability of ocean biogeochemistry in space and time, and thereby help improve our knowledge about carbon-climate feedbacks, declining CO_2 buffering capacity of seawater, impacts of ocean biogeochemical changes on marine ecosystems and so on. The benefits of the developments of ocean observing networks and their integration will not be confined to the studies of ocean biogeochemistry but will be given over ocean sciences across the disciplines.

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