

Abstract

[Project Title]

Comprehensive study on multi-scale monitoring and modeling of greenhouse gas budgets

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[Abstract]

Reliable and comprehensive monitoring of greenhouse gases (GHGs), such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), is crucial in accomplishing the long-term goals of the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement, with special emphasis on temperature rise below 1.5°C from the preindustrial level. The global stocktake is an important 5-year milestone to facilitate the collective progress for mitigation by revising the Nationally Determined Contributions toward an increasingly ambitious direction. The global stocktake must be performed using the best available science; therefore, it has become an essential and urgent task for the research community to provide reliable data and perform practical analyses. The research community of Japan has a long experience in monitoring atmospheric GHG in the Asia–Pacific region and was therefore highly expected to contribute to the global stocktake and associated international activities. From April 2021 to March 2024, the SII-8 project entitled “Comprehensive Study on Multi-scale Monitoring and Modeling of Greenhouse Gas Budgets,” funded by the Environmental Restoration and Conservation Agency and the Ministry of the Environment, Japan, was conducted to enhance the contributions of Japan to the global stocktake. The project is composed of three research components: (1) high-level observation and top-down estimation of GHG budget, (2) evaluation of the effect of GHG mitigation using an Earth system model, and (3) bottom-up estimation of GHG budget. Every year, the research outcomes of the project are summarized in a concise report, “Bulletin of Multi-scale Estimation of Greenhouse Gas Budgets.” In March 2022 and 2023, the reports were submitted to the UNFCCC portal for the information collection and technical dialogue phases of the global stocktake, followed by the consideration of the outcome at the COP28 in Dubai.

Theme 1 leveraged an observational network of GHGs across the Asia–Pacific region using various platforms, such as ground-based stations, ships, aircraft, and satellites. To estimate GHG budgets on multiple spatial scales from a global to a city scale, a global high-resolution inverse analysis system was developed, and a high-resolution atmospheric CO₂ transport simulation was performed. Furthermore, a new portable GHG measurement system was developed and installed at Chiba in 2023

to better constrain the flux estimate for the Great Tokyo area. Shipboard observation along the Pacific Belt Zone in Japan also started in 2022 to efficiently capture GHG emission signals from other large cities. A global sea–air CO₂ flux data product was also produced by integrating the newly produced data product for marginal seas in the northwestern North Pacific with the existing product for the open ocean.

Theme 2 estimated the regional/global budgets of three GHG species (CO₂, CH₄, N₂O) with the top-down approach, and the outcomes contributed to international scientific discussions. Budget information was also used to validate and improve Earth system model performance. The improved model was used to assess the effectiveness of emission reduction efforts in the future, suggesting that the earlier emergence of a decrease in atmospheric CO₂ concentration will require more enhanced emission reduction.

Theme 3 developed a bottom-up method to spatially and explicitly evaluate GHG budgets using emission inventories, biogeochemical models, and satellite products. Technical developments were achieved for paddy field and termite CH₄ emissions and anthropogenic emissions. Satellite image analyses were conducted for the early detection of anomalies in surface GHG budgets. Individual sources and sinks were aggregated to evaluate national and regional GHG budgets, contributing to the global stocktake and Intergovernmental Panel on Climate Change reports.

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