Preface

The W-PASS (Western Pacific Air-Sea interaction Study) Project 2006–2010 in Japan —Linkages in Biogeochemical Cycles between the Surface Ocean and the Lower Atmosphere—

Global Climate change has a significant impact on biogeochemical cycling in the ocean, on atmospheric chemistry, and on the chemical exchanges between the ocean and the atmosphere. These exchanges include the atmospheric deposition of nutrients and metals that control marine biological activity and, hence, the ocean carbon uptake, and the emission of trace gases and particles from the ocean because of their importance in atmospheric chemistry and climate processes.

To clarify the interaction processes of the boundary between the atmosphere and the ocean, the Surface Ocean-Lower Atmosphere Study (SOLAS) was established as one of the core projects by the International Geosphere-Biosphere Programme (IGBP) under the International Council for Science (ICSU) in 2004. Subsequently, the W-PASS (Western Pacific Air-Sea interaction Study) was funded in the summer of 2006, for 5 years as a part of SOLAS-Japan activity.

The goal of the W-PASS project was to achieve a quantitative understanding of the key biogeochemical key interactions and feedbacks between the ocean and the atmosphere. We aimed to resolve this link through field observation studies over the western Pacific, mainly using research vessels and island observatories. Numerical modeling studies were required for systematic evaluation and quantitative assessment. Our objectives were:

(1) Quantify the transport of natural and anthropogenic materials which contribute to primary production in the marginal and remote oceanic regions, from the Asian continent to the western Pacific.

(2) Determine the responses of marine ecological systems to changes in atmospheric composition over the western Pacific.

(3) Investigate the production and emission of marine biogenic gases that might lead to changes in atmospheric composition, especially in subtropical and subarctic regions of the western Pacific.

(4) Evaluate the contribution of marine biogenic gases to global climate change.

The W-PASS project consisted of 11 main, and 12 supportive, research groups under four primary research programs (see Fig. 1) with 29 research institutional organizations and 89 scientists from Japan.

A01. Dynamics of Atmospheric Composition

Long-term continuous monitoring of nitrogen species, both in gaseous and particulate phases, was carried out with other air pollutants at the National Institute for Environmental Studies (NIES) Atmospheric and Aerosol Monitoring Station of Cape Hedo, at the north end of the Okinawa main Island facing the East China Sea. Simultaneous, comprehensive and high time-resolution continuous monitoring was conducted for the total NO_y and nitrogenous deposition species, particulate NO_3^- and NH_4^+, as well as gaseous HNO_3 and NH_3. Quantifying the annual trend and

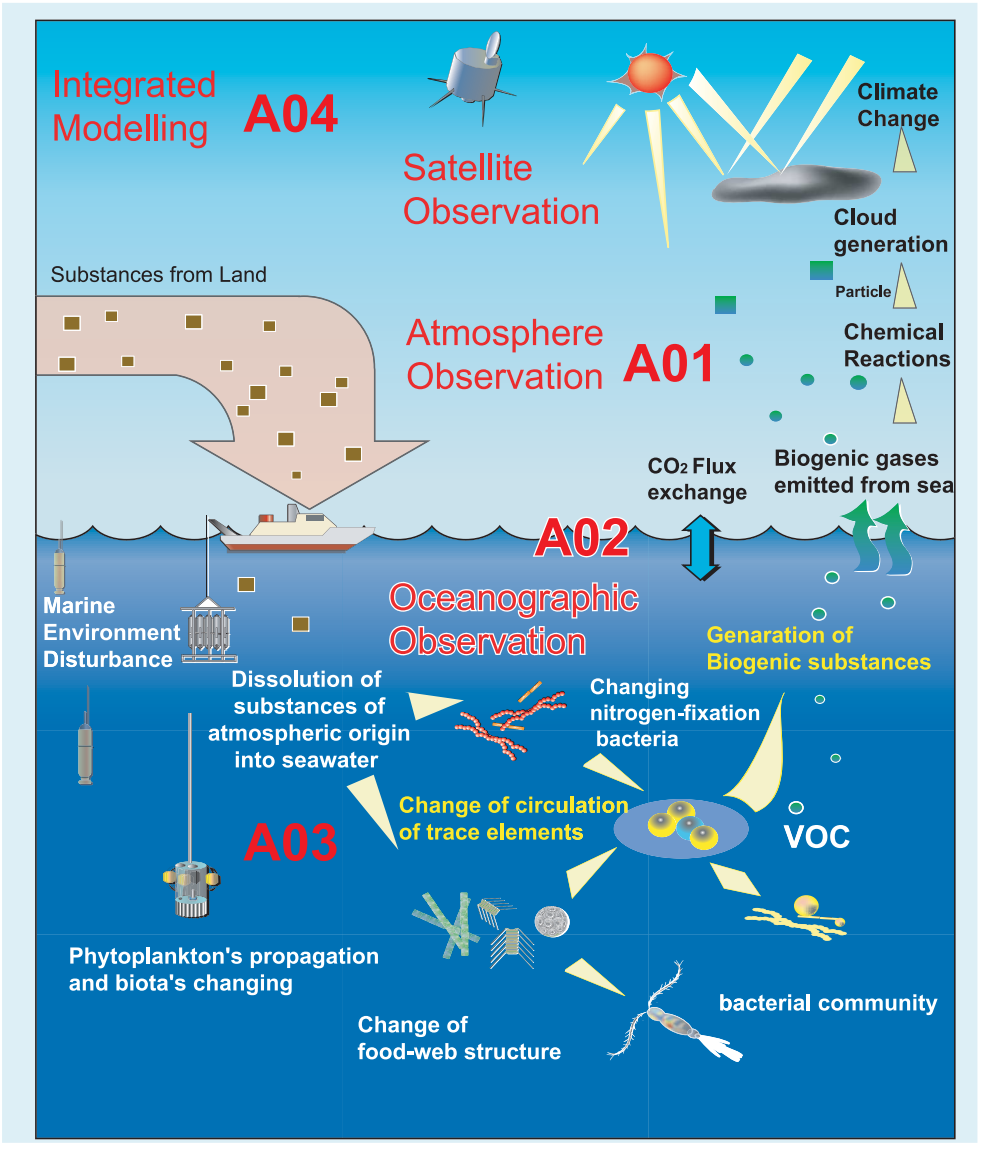

Fig. 1. Overview image of the W-PASS activities. A01: Behavior of atmospheric compositions for air-sea interaction (PI: Y. Yokouchi). A02: Gas exchange between air and sea (PI: Y. W. Watanabe). A03: Behavior of biota in sea after air-sea interaction (PI: S. Takeda). A04: Integrated modeling for air-sea interaction (PI: Y. Yamanaka). See the detail of each activity in the text.

the seasonal variability of atmospheric nitrogen input to the western Pacific enabled us to evaluate the potential impact of the economic growth in East Asia on the marine ecosystem in the marginal seas.

Field measurements of marine VOCs in the air and surface seawater took place with cooperative research on the mechanism and controlling factors of marine VOC production based on the cultivation

of microalgae and molecular biological techniques.

The transport and deposition of particulate major ions, trace metals and organic compounds were measured on-board ship, and at island stations, over the marginal seas of the Asian continent to the western North Pacific. The production and emission of biogenic trace gases and the gas-to-particle processes were determined over the high primary productive regions, especially in the tropical and subarctic regions of the western Pacific. Chemical and physical properties of newly-formed nanoparticles were determined by an Aerosol Time-of-Flight Mass Spectrometer (ATOFMS) on-board ship during the SOLAS research cruises.

A02. Variability of Gas Exchanges at the Air-Sea Interface

Trace organic compounds in seawater were determined by a new technique using PTR-MS. Production of methane in oxic seawater using dual (carbon and hydrogen) isotope tracers was determined, as well as stable carbon isotopecompositions of trace non-methane hydrocarbons (NMHCs). The geochemistry of nitrate and nitrous oxide using the triple oxygen isotope composition was elucidated for the quantitative estimation of atmospheric deposition of nitrogen to the ocean.

For a precise evaluation of air-sea fluxes of trace gases, an eddy-covariance method has been considered to be the direct and most reliable technique. In the project, CO_2 and DMS were possible candidates for the application of the eddy-covariance method. A measurement system of these trace gas density fluctuations, and ship motion correction for the wind velocities, were implemented in this project.

We investigated oceanic parameters for the prediction of greenhouse gas behavior with physical-biogeochemical observations during this project. We also focused on decadal changes in the subarctic/subtropical regions of the North Pacific in order to get a quantification of feedback parameters.

A03. Dynamics of the Marine Ecosystem

To investigate the speciation and bioavailability of trace metals supplied from the atmosphere to the ocean surface, we studied the dissolution rates of trace metals from atmospheric mineral dust and their speciation in seawater.

The detailed distributions of different forms of biophilic elements (C, N, P, Si), and their interactions with microbial processes in the surface water column, have been elucidated in terms of the biogeochemical flux between the atmosphere and the surface ocean.

We examined the ecosystem responses to the dust (iron) input in the subarctic and subtropical Pacific with bottle incubation. We also investigated the effects of a typhoon as a mechanism to enhance the primary production in the subtropical Pacific.

To examine an abrupt change of primary productivity, we generated satellite data set on ocean color and sea surface temperature before, and after, a typhoon passing around Japan. We developed a numerical model of a typhoon to simulate the magnitude of mixing and upwelling in the sub-surface layer and examined the relationship between the moving speed of a typhoon and the magnitude of mixing and upwelling.

A04. Modeling of the Interaction between the Ocean and the Atmosphere

In this project, we attempted to bring together the outputs from the atmospheric chemical transport model and the marine ecosystem model. Results obtained from the field observation projects in the

SOLAS-Japan activities were also combined. In particular, we focused on the responses of the marine ecosystem to sporadic weather disturbances such as a typhoon and a strong extra-tropical cyclone, which deepen the mixed layer and shut down solar radiation over a period of a few days to a week. We also investigated the responses of the marine ecosystem to aeolian dust input using ecosystem models representing iron cycle processes.

Field Observations

High-frequency measurements of methyl halides and DMS were carried out in the marine atmosphere at Hateruma Island in Okinawa, and Cape Ochiishi in Hokkaido, over a period of a year.

We conducted several W-PASS cruises using Japanese research vessels and intensive atmospheric observations on the island station.

SNIFFS (Subtropical Nitrogen Fixation Flux Study) I (2–23 June, 2006) and SNIFFS II (18 May–4 June, 2010) cruises were carried out in the subtropical region of the western North Pacific by R/V Hakuho Maru.

BLOCKS (Bloom Caused by Kosa Study) cruise (16–29 April, 2007) was carried out in the off-Sanriku region of the western North Pacific by R/V Tansei Maru. We investigated various patches of phytoplankton bloom and experienced an intensive dust event on-board ship. A newly-developed surface-water clean sampling system, 'Fish' was used during the R/V Hakuho Maru cruise, 24–29, July 2007, and trace metal sampling was carried out in the surface layer around the Kuroshio Current by R/V Tansei Maru, 21–25 October, 2007.

On the R/V Mirai, eddy-covariance flux measurements were carried out during a longitudinal transect cruise from Japan to North America along 47°N and the subarctic regions during the summer and the fall of 2007, and during cruises from Japan to the equatorial and subarctic regions during the summer and fall of 2008.

In the spring of 2008, intensive marine atmospheric observations, including direct atmospheric deposition measurements, were carried out at the NIES Atmospheric and Aerosol Monitoring Station of Cape Hedo at the north end of Okinawa Main Island facing the East China Sea from 17 March to 13 April, 2008.

In summer 2008, in collaboration with the Japan-IMBER, the SPEEDS (Subarctic Pacific Experiment for Ecosystem Dynamics Study)/SOLAS cruise was carried out in the subarctic to the subtropical region in the western North Pacific by R/V Hakuho-maru from 29 July to 16 September, 2008.

During the R/V Hakuho Maru (KH-09-05) cruise, the W-PASS members collaborated with the GEOTRACES group for an investigation of trace metals and VOCs in the Indian Ocean.

Accomplishments of the W-PASS Project

The accomplishments of the 5-year W-PASS project have been published in the 500 international peer-reviewed academic papers listed in this book. The highlighted exciting research topics will be found in the following chapters.

After the 5-year project, we traced the development of the young scientists involved in the project. Seven students continued with a PhD study from the 37 students who were awarded a master's degree. Eleven scientists who earned a PhD have been working as a post doc or assistant professor. A new PhD got a job in private industry. Among 34 post docs working for the W-PASS project, 7 obtained faculty positions and 22 are keeping their post doc positions. Substantial numbers of young scientist are working in the SOLAS field in Japan.

We wish to express our appreciation to our colleagues in close collaboration with the W-PASS scientists, students and staff for supporting our research activities. We also thank Drs Atsushi Tsuda and Yasushi Narita for operating the secretariat.

We would like to sincerely thank the advisory committee members, Drs Hajime Akimoto, Shiro Imawaki, Isao Koike, Akira Taniguchi and Shizuo Tsunogai for their thoughtful and constructive opinions throughout the period, of this study.

We hope that more new science projects involving collaboration between international communities will be established in this new field after the completion of the W-PASS project for further contributions to global environmental research.

"Science is facts. Just as houses are made of stones, so is science made of facts. But a pile of stones is not a house and a collection of facts is not necessarily science."
Henri Poincaré

March 2014

Mitsuo Uematsu
Yoko Yokouchi
Yutaka W. Watanabe
Shigenobu Takeda
Yasuhiro Yamanaka