YEARS OF THE MARITIME CONTINENT
Boreal Summer Monsoon Study 2020

SCIENCE PLAN
(ver. 1.2)

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TABLE OF CONTENT

PREFACE

This science plan has been written by four principal investigators (PIs), who are responsible for each site/observation, with some input from their colleagues including members of DCOP (Dynamic Coupling of Ocean-Atmosphere-Land Research Program of JAMSTEC) and others as well as Science Plan of the Years of the Maritime Continent (YMC) (http://www.jamstec.go.jp/ymc/docs/YMC_SciencePlan_ver2.pdf). It should be noted that this document describes their original ideas and scientific needs prior to the occurrence of COVID-19 pandemic, and their field campaign was arranged based on their original plan. However, we have to cancel or postpone some observational components. Thus, while the field campaign in the boreal summer of 2020 is conducted, some plans cannot be carried out in the same framework. Currently, PIs are making and rearranging their alternative science and implementation plan, which will be documented separately from this volume.

EXECUTIVE SUMMARY

The Years of the Maritime Continent or YMC is designed to improve our understanding and prediction skill of weather-climate systems over the Maritime Continent (MC), where hosts various unique phenomena, and their global impact. YMC is a multi-year and multi-national program, which consists of many field campaigns and numerical study efforts in addition to special use of original high-resolution operational observations such as radiosonde, weather radars, and surface meteorology provided by the participating regional responsible meteorological agencies. Here, we focus on the boreal summer monsoon study from various viewpoints.

Boreal summer intraseasonal oscillations (BSISOs), generally characterized by eastward and northward propagating cloud clusters over the warm pool, has significant impacts on daily weather not only in countries surrounding the warm pool, but also in midlatitudes through its influence on monsoon transition and tropical cyclone genesis.

Atmospheric deep convection penetrating the tropopause over the MC makes it a primary spot for vigorous stratosphere-troposphere interaction. Horizontal and vertical transports of minor constituents are important in the view point of stratosphere-troposphere exchange and midlatitude-tropics interaction related with Asian summer monsoon.

Under the YMC framework, Boreal Summer Monsoon Study 2020 (YMC-BSM 2020) aims to investigate boreal summer monsoon by conducting various observations at selected sites, where local unique phenomena are often observed.

YMC-BSM 2020 includes three science themes and intensive observations:

Theme 1: BSISO over the western Pacific. Intensive observation campaign will be conducted over the western Pacific using the Research Vessel *Mirai* and the network of intensive upper-air observations at Legazpi (Philippines), Palau, and Yap (Federated States of Micronesia; FSM).

Theme 2: Interaction between diurnal convection and synoptic waves off the northern coast of New Guinea. Intensive observations consisting of radiosonde soundings, C-band precipitation radar, and wind profiler will be conducted at Biak in Indonesia.

Theme 3: Stratosphere-Troposphere Interaction. Intensive special sonde observation equipped with ozone-sensor and high accurate hygrometer will be conducted at Laoag in Philippines.

1. INTRODUCTION

The Maritime Continent (MC) of the Indian and Pacific Oceans is a unique mixture of land and ocean. Sitting in the middle of the warm pool, the MC plays an unmatched role in the weather-climate continuum of the region and the world (Ramage 1968). The MC is at the center of global multi-scale interactions involving the global mean circulation and variability on a wide range of timescales including convective, diurnal, synoptic, intraseasonal, seasonal, interannual, decadal, and longer periods (McBride 1998; Chang et al. 2004a).

Both the summer and winter East Asian/Australian monsoons have their footprints over the MC (Meehl 1987; Wang 1994). With its complex coastal lines and terrain, the MC causes asymmetry in both latitudinal extension and temporal transition of the two monsoons (Chang et al 2005). The seasonal march of the monsoon onset and withdrawal appears from both the west (Indochina) and east (Australia) as seen in cloud activity (Matsumoto 1992; Murakami and Matsumoto 1994).

Boreal summer intraseasonal oscillations (BSISOs) are generally characterized by eastward propagating cloud clusters from the equatorial Indian Ocean to western Pacific with pronounced northward propagation over Indian Ocean, MC, and western Pacific (e.g. Lau and Chan 1986; Nitta 1987; Wang and Rui 1990; Kikuchi et al. 2012; Lee et al. 2013). Some mechanisms including the interaction among the mean seasonal flow, intraseasonal perturbations, and small-scale phenomena have been proposed to explain northward propagation of the BSISO (Jiang et al. 2004; Drbohlav and Wang 2005, Bellon and Sobel 2008, Kang et al. 2010, Hsu and Weng 2001; Fu et al. 2003; Fu and Wang 2004; Bellon et al. 2008).

Frequent deep atmospheric convection penetrating through the tropopause over the MC makes it a primary spot for vigorous stratosphere-troposphere interaction. Approximately 83% of the global tropospheric air mass that enters into the tropical tropopause layer and 71% that enters the stratosphere does so over the MC and western Pacific (Fueglistaler et al. 2004). This marks the importance of the MC in large-scale stratospheric variations, such as stratospheric sudden warming, polar vortex intensification, the quasi-biennial oscillation, the semi-annual oscillation (SAO), etc., all having great global impacts.

The main goal of YMC-BSM 2020 is designed to investigate boreal summer monsoon by conducting various observations at selected sites, where local unique phenomena are often observed.

The YMC-BSM 2020 science themes are introduced and discussed in section 2. The scientific objectives and activities of YMC-BSM 2020 are summarized in section 3. References are in section 4.

2. SCIENCE THEMES

2.1 Atmospheric convection

2.1.1 BSISO over the western Pacific

The intraseasonal variability is known as one of the dominant large-scale variability in cumulus convective activity over the Indo-Pacific warm pool domain. Its behavior is different in different seasons. The BSISO is characterized by northward migration of convectively active area over the Bay of Bengal and western Pacific (Yasunari 1980; Murakami et al. 1984), which is quite different from the behavior of the boreal winter counterpart. The BSISO has significant impacts on daily weather in countries surrounding the Indo-Pacific warm pool, including Japan. In south and southeast Asia, the BSISO is one of the atmospheric disturbances that induce onset of rainy season. During the rainy season, the BSISO causes interchange of monsoon active and break periods. Furthermore, the BSISO can modulate frequency of tropical cyclone genesis over the western Pacific (Liebmann et al. 1994; Nakano et al. 2015), and thus it can indirectly affect occurrence of severe weather in Japan and other east Asian countries.

Despite such widespread impact, detailed physical processes and dynamics of the BSISO are still elusive. For example, how the BSISO disturbance can develop and sustain its amplitude, what determine its periodicity and direction and speed of its propagation, and how the BSISO interacts with shorter-scale disturbances such as tropical depressions and tropical cyclones are important but open questions for understanding the BSISO.

In order to collect detailed information of the atmosphere and underlying ocean that are helpful for addressing these questions, we plan to conduct intensive observation campaign over the western Pacific in boreal summer of 2020. The main component of the campaign is shipborne observation using the Research Vessel (R/V) *Mirai* of JAMSTEC. We plan to deploy her over the tropical western Pacific near Palau to perform a variety of atmospheric and oceanographic observations. Our observation targets include air-sea interaction processes related to the BSISO, and ~100km-scale horizontal contrast in oceanographic condition that may have an impact on cumulus convection. In addition to the shipborne observation include upper-air sounding, we plan to ask meteorological agencies in charge of routine upper-air observations at Palau, Yap (Micronesia), and Legazpi (Philippines) to increase the frequency of the upper-air observation. The network of intense upper-air observations will enable us to perform energy and moisture budget analysis via a method proposed by Yanai et al. (1973) and then improved by many researchers.

2.1.2 Interaction between diurnal convection and synoptic waves off the northern coast of New Guinea

New Guinea is the world's second largest island after Greenland and the influence of New Guinea on the Pacific warm pool region is an important issue for understanding the diurnal cycle of convection and air-sea interaction over the tropical western Pacific. Generally, the horizontal scale of land-sea breeze circulation in the tropics is larger than that in the midlatitudes (Rotunno, 1983; Sun and Orlanski, 1981; Yan and Anthes, 1987) and could affect the diurnal cycle of convection over adjacent oceans. For instance, Yang and Slingo (2001) showed that strong diurnal signals over land spread out over adjacent oceans for several hundred kilometers.

Liberti et al. (2001) investigated the influence of landmasses on the diurnal cycle of clouds over the Pacific warm pool region using satellite infrared data. They depicted that the coherent signals of the diurnal convection from New Guinea prevailed up to 600 km off the island's coast. The genesis of the propagating cloud systems could be due to low-level convergence between large-scale flow and a land breeze. Various studies have noted the influence of land breezes in the vicinity of the islands of Borneo and Sumatra (Houze et al., 1981; Johnson and Kriete, 1982; Ohsawa et al., 2001; Mori et al., 2004; Sakurai et al., 2005).

Moteki et al. (2008) revealed that a meso-scale convective system observed in the vicinity of Palau islands was originated from a land breeze front from New Guinea. They concluded that the influence of New Guinea can prevail farther northward (700–800 km) depending environmental conditions of the positions and features of synoptic disturbances over the tropical western Pacific.

However, high-frequency in-situ observations on such processes are required because the analyses of the previous studies are based on satellite and low-frequency radiosondes that are insufficient to depict the physical mechanisms of the diurnal convection. In order to collect detailed information of such processes, we plan to conduct intensive radiosonde observation at Biak island that is located off the northern coast of the mainland of New Guinea. Collaborating with BMKG, observations of high-frequency radiosondes (4–8 times per day), C-band precipitation radar, and wind profiler should be conducted to detect the formation processes of land breeze and initial convection from New Guinea.

2.2 Stratosphere-Troposphere Interaction

Horizontal and vertical transports of minor constituents occur as typically seen in ozone and water vapor variations in the upper troposphere and the lower stratosphere due to the Asian summer monsoon-related phenomena, such as the anti-cyclonic circulation associated with Tibetan High, the active convections, and atmospheric waves induced by the convections. Such transports are important in the viewpoint of stratosphere-troposphere exchange and mid-latitude-tropics interaction (e.g., Dunkerton, 1995; Holton, 1995; Randel and Jensen, 2013), which can change the global climate through dynamical, chemical, and radiative processes. In particular, the northwestern Pacific is one of the most active regions of convection, and the material transport and mixing must actively occur there associated with the active convections.

However, the nature of the material transport in this region has not fully understood due to the lack of observation: First, scarce in-situ material observations have been carried out over this region, and second, although the satellite observations provide useful information on the horizontal variation of the minor constituents, they have limitations in vertical resolution and coverage, and observation time. The ozone and water vapor sounding in this region will reveal the effect of the active convections and their complexes, such as the northward propagating intra-seasonal variation and typhoons, and convection-induced atmospheric waves, such as gravity waves and Rossby waves, over the northwestern Pacific on the material distribution and dynamical field in terms of advection (Randel and Park, 2006; Ogino et al., 2013), wave-induced transport (Holton 1995, Kinoshita et al., 2016), and dehydration (e.g., Fueglistaler et al., 2009, Suzuki et a., 2013).

The wave disturbances transmitted from the active convections in the troposphere can propagate through the stratosphere. Most of the standard meteorological balloons reach up to about 30 km height. However, the waves can reach higher altitudes and affect the dynamics and chemical distribution there. It is useful to measure the higher elevations by a convenient method (for example, a radiosonde with a larger balloon can reach about 40 km as shown by Kinoshita et al., 2020, submitted) for clarifying the properties of convection-induced waves above 30 km with fine vertical resolution.

3. OBJECTIVES and MAIN ACTIVITIES

YMC-BSM is designed to study boreal summer monsoon by conducting various observations at selected sites, where local unique phenomena are often observed.

Objective 1: *Reveal physical processes and dynamics of the BSISO and its relation to air-sea interaction.* R/V *Mirai* will be deployed over the tropical western Pacific near Palau in boreal summer of 2020 and a variety of atmospheric and oceanographic observations will be performed. In addition, radiosonde soundings will be enhanced to four times per day at Legazpi (Philippines), Palau, and Yap (FSM) for almost the same period. The network of intense upper-air observations will enable us to examine energy and moisture budget quantitatively.

Objective 2: *Detect the formation processes of land breeze and initial convection from New Guinea.* Intensive observations consisting of radiosonde soundings (4–8 times per day), C-band precipitation radar, and wind profiler will be conducted at Biak in Indonesia.

Objective 3: *Reveal the material transport and interaction between upper troposphere - lower stratosphere*. Intensive special sonde observation equipped with ozone-sensor and high accurate hygrometer will be conducted at Laoag in Philippines.

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