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Introduction to the special issue on South China Sea Two-Island Monsoon Experiment (SCSTIMX): Observation, simulation, and projection

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ABSTRACT

The South China Sea (SCS) Two-Island Monsoon Experiment (SCSTIMX) is the field experiment of an integrated project: 'Interaction of convection over the Maritime Continent-SCS with large-scale flow'. The project aims to study convective and large-scale dynamic processes over the SCS in cooperation with the international project: 'Years of Maritime Continent' (YMC). Special observations were made during the intensive observation periods (IOPs) including December of 2017 and March and May of 2018 at Taiping Island and Dongsha Island within the extended observation period (EOP) of 2017 - 2019. Atmospheric conditions were observed using upper-air soundings, wind profilers, and surrounding buoys from these two islands and other places in the SCS, and *in-situ* measurements from research vessels for air-sea interaction studies. Research results accomplished by the PIs of the integrated project supported by Ministry of Science and Technology (MOST), Taiwan, for 2016 - 2019 are reported in this special issue. The overall results provide a better understanding of convective and moistening processes, large-scale dynamic processes, and convection-dynamic interactions over the SCS and surrounding regions by observations and model simulations across multiple time scales ranging from diurnal, synoptic, intraseasonal, and beyond.

The South China Sea (SCS) is a marginal sea to the far west of the western North Pacific (WNP). It is situated south of China, east of the Indochina Peninsula, and north of the Maritime Continent (MC). Weather and climatic events originating in these surrounding regions may extend into the SCS, resulting in distinct meteorological features in the SCS. Salient features affecting the SCS include westward-moving tropical cyclones (TCs) from the WNP (Chen et al. 2017b, 2019a; Tan et al. 2019) and the southwesterly monsoon across the Indochina Peninsula (Wang and Lin 2002; Ding 2004) in the warm season, the northeasterly monsoon passing China (Ding 1994; Chang et al. 2006; Chen et al. 2017a) in the cold season, convection organized in cloud clusters and mesoscale convective systems (MCSs) along with equatorial waves around the MC (Liebmann and Hendon 1990; Chang et al. 2005; Hung and Sui 2018) throughout the entire year.

Climatologically, the SCS and tropical western Pacific are characterized by warm, rainy conditions associated with major ascending branches of the tropical Walker circulation around the MC. The convective heating acts as a major source of tropical forcing affecting large-scale circulations via the so-called Matsuno-Gill type response (Matsuno 1966; Gill 1980) or the Pacific-Japan teleconnection or wave-train patterns (Nitta 1987, 1989; Wang and Fan 1999; Lu 2001). The SCS and MC are thus considered hot spots for inducing variability in large-scale circulation phenomena in the Asian-Pacific region, leading to variability in the spatial pattern and intensity of the monsoon trough and western North Pacific subtropical high (Chen et al. 2018a; Tu and Chen 2019). Changes in the large-scale circulations influence different meteorological phenomenon in the SCS-MC region including rainfall and convection patterns, TCs, convectively coupled equatorial wave (CCEW) activity, and monsoon variability (Chang et al. 2004, 2016; Peatman et al. 2014; Chen et al. 2019a, b; Tan et al. 2019). These phenomena exhibit variability on different time scales across

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synoptic, intraseasonal, seasonal, and interannual time scales. Having a good understanding and reliable representations of forcing mechanisms in the SCS-MC region is key to determining the performance of weather forecasting and climate simulations in this region and the globe (Neale and Slingo 2003; Ahn et al. 2020). In addition, knowing how large-scale dynamic processes influence variability of TCs and rainfall activity in the SCS and its surrounding regions is an area of great interest for further studies. Similarly, understanding mutual interaction patterns between large-scale processes and synoptic activity is another area of study very worth pursuing.

The SCS has a pronounced seasonal cycle in the Asian monsoon system with the earliest onset around mid-May in the SCS (Chang and Chen 1995; Chen and Chen 1995), followed by the East Asian (EA) monsoon over China, Japan, and Korea in June and July and the western North Pacific monsoon over the tropical WNP-Philippine Sea region in August (e.g., Chen 1994; Ding 1994; Kang et al. 1999; Li and Wang 2005). The onset of the SCS summer monsoon is described by a change from easterly flows to westerly flows in the central SCS associated with an eastward retreat in the western North Pacific subtropical high and emergence or intensification of the southwesterly monsoonal flows (Chen and Chen 1995). In addition, monsoonal rains and their life cycle are mostly modulated by two modes of intraseasonal oscillations (ISO): 30-60-day and 10-24-day ISO (Hartmann et al. 1992; Chen and Chen 1995; Chen et al. 2000; Mao and Chan 2005; Ding 2007). The convective/non-convective phase of ISO propagates into the SCS to enhance/suppress rainfall activity. These ISO modes also serve as large-scale environments modulating TC activity, including genesis frequency and movement tracks. In general, TCs tend to have increased genesis or higher genesis rates under the convective ISO phase (Hall et al. 2001; Barrett and Leslie 2009; Klotzbach 2014; Chen et al. 2018b). Their movement tracks tend to follow the propagation of the 10-24-day ISO (Feng et al. 2013) within a favorable large-scale background of enhanced moisture convergence and vorticity provided by the 30-60-day ISO (Chen et al. 2018a). The ISO-TC and ISO-monsoon interactions still have research aspects very worth exploring.

Other than the 10-24-day and 30-60-day ISOs, TC genesis is also effectively modulated by the CCEW activity, including the equatorial Rossby wave (ERW), mixed Rossby gravity wave (MRGW), tropical disturbance (TD), and Kelvin wave (KW). These waves exhibit evident activity in the SCS-MC region. The enhanced convection caused by CCEWs acts to facilitate TC genesis (Ritchie and Holland 1999; Schreck et al. 2012). About 79 - 83% of TC genesis cases are assisted by enhanced convection from one or two-coexisting waves (Wu and Takahashi 2018; Zhao et al. 2019). The relative importance of CCEWs on the modulation of TC genesis in the SCS remains a complicated issue to resolve.

In addition to TCs, the MCS is another important rain-producing sub-synoptic system. The origin of such rainfall events and their source of moisture supply or convection by lower-frequency modes, such as ISO and CCEW, needs to be comprehensively examined. The 30-60-day ISO during the warm season initiates in the Indian Ocean and propagates eastward into the SCS. After that, it results in parallel development in circulation and convection over the SCS migrating northward while also extending and propagating eastward into the tropical western Pacific (Wheeler and Hendon 2004). Propagation of the 30-60-day ISO is separated into eight phases. Each phase contains different convection and circulation patterns whose impact on local rainfall varies accordingly. The continuous evolution of ISO is considered as a potential predictability source for extended-range (10-30-day) forecasting (Van Den Dool and Saha 1990; Zhang 2013). Another factor affecting MCSs is southwesterly monsoonal flows across the SCS. These flows are warm and moist in nature. Initiated by such monsoonal flows, MCSs readily develop over hot oceanic regions and follow the monsoonal flows toward downstream regions, such as Taiwan. Severe rainfall events often occur in Taiwan during the southwesterly monsoon season. Issues relating to moisture transport by monsoonal flows and convective systems coupled with rainfall events developing over the SCS and Taiwan need further research efforts to better delineate causative factors.

The reviews given above demonstrate the importance of many salient meteorological features in tropical regions over the SCS and MC. A better understanding of the convective and dynamic processes in these regions is key to improving weather forecasting and climate prediction. One solution to improving our understanding of complex variability in weather and governing climate is to learn from the truth of what is happening specifically in given locations through intensive regional observations. To this end, the international 'Years of Maritime Continent' (YMC) project has been organized by Chidong Zhang (U. of Miami) and Kunio Yoneyama (JAMSTEC) to facilitate and consolidate cooperation among countries around the MC (Indonesia, Malaysia, Philippines, Singapore). Major field campaigns were planned to execute intensive observations of weather-climate systems of the MC for the period 2017 - 2020. To assist the YMC, Taiwan was invited to make parallel observations to the north of the MC over the SCS at two islands, Dongsha and Taiping. An integrated project "Interaction of convection over the Maritime Continent-SCS with large-scale flow" was sponsored by Ministry of Science and Technology (MOST), Taiwan, to investigate weather and climate in the SCS and MC through a variety of studies. The scientific objective of this integrated project is two-fold: observing convective and moistening processes and the associated large-scale dynamic processes over the SCS, and modelling combined special observations and all existing observations to better understand the convective-dynamic interactions in weather and climate over the SCS and its vicinity. To achieve this, an observational experiment named: 'The South China Sea Two- Island Monsoon Experiment' (SCSTIMX) was carried out to conduct intensive observations over land and via research vessels for the periods of December 2017 and March and May of 2018 (Sui et al. 2020).

The purposes of this special issue are to document the observed data collected by soundings, wind profilers, and shipborne observations by the SCSTIMX that are valuable for future research, and to report research results for tropical convection, precipitation, tropical cyclone, boundary flows and their interactions with large-scale processes (on intraseasonal to interannual time scales) in the SCS and surrounding East Asia and western North Pacific. Furthermore, this special issue aims to attract greater research interest into the analyses of the SCSTIMX observational data to enhance our understanding of regional and large-scale convective and dynamic processes in this tropical region.

Papers collected in this special issue are separated into three major subject areas: convection and rainfall events, SCS monsoon systems, and tropical cyclone activity. Specific topics are focused on variability of monsoonal coastal convections (Su et al. 2020), heavy rainfall events in Taiwan due to moisture transported from the SCS (Tu et al. 2020), factors determining rainfall characteristics of MCS in the SCS (Wu et al. 2020b), modulations of ISOs and CCEWs on winter peak rainfall in the SCS and MC (Tsai et al. 2020), impacts of SST-convection interactions (Kuo et al. 2020) and sub-seasonal oscillations (Lu et al. 2020) on the SCS summer monsoon onset, impacts of CCEWs on TC genesis (Lai et al. 2020), seasonal and ISO modulations on tracks of SCS-formed TCs (Chen et al. 2020), and comparison between local and non-local TCs in the SCS (Wu et al. 2020a). Interactions among meteorological phenomena with different temporal and spatial scales are addressed. This special issue should serve as a handy reference to those researchers interested in tropical meteorology over the SCS and MC. These results also benefit the whole meteorological community by giving better understanding of this energetic zone and its role as an important center of action in climate and weather variability.

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