Progress report on
Monsoon Onset Monitoring and Its Social and Ecosystem Impacts

1. Introduction and justification

Asian Monsoon plays a significant role in the agriculture, economy and the livelihood of people in South Asian, Southeast Asian, and East Asian regions since it exhibits the significant dry-wet contrast between the boreal winter and summer seasons with the predominant rainfall occurring in the summer season. Naturally, the Asian Monsoon exhibits multiscale variability due to the complex land-ocean-atmosphere interactions, which are not fully resolved. External drivers, such as El Nino, Indian Ocean Dipole and even the North Atlantic Oscillation, load the remote forcing on Asian Monsoon and make it more dynamic. Once it deviates from its normal pattern (i.e. climate mean condition), it causes severe disasters such as floods and droughts, leading to the severe disruption of agricultural production and the displacement of inhabitants. Furthermore, the extraordinary late monsoon onset leads to an extended persistence of high sea surface temperature (SST), which increases the risk of coral bleaching and causes marine ecosystem impacts, such as the massive coral bleaching and high coral mortalities over Southeast Asian Seas in the year 2010. In this regard, it is vital to improve the understanding, monitoring and predicting capability of monsoon onset and its seasonal march in the wider Southeast Asia region for societal and ecosystem benefits. To this end, the IOC Sub-Commission for the Western Pacific (WESTPAC) initiated one pilot project entitled “Monsoon Onset Monitoring and its Social and Ecosystem Impact” (MOMSEI) in 2009 under the framework of Southeast Asia Global Ocean Observing System (SEAGOOS), whose objectives are to enhance the regional scientific knowledge base on the abrupt monsoon onset, to develop its monitoring capacity and to explore the better science-policy interface towards the application of disaster reduction. The priority region of MOMSEI includes the Bay of Bengal, Andaman Sea, and the Southeastern tropical Indian Ocean, where monsoon onset depicts peculiar features associated with air-sea interaction and marine ecosystem.

2. Timeframe and objectives

MOMSEI project is running since 2009, breaking into three phases as below.

(1) YR2009 - YR2010: Teaming up and prioritizing the goals

This initial phase aims to collect the regional interests in the monsoon onset study, understand the local impacts associated the anomalous late monsoon onset and prioritize the project targets.

(2) YR2011 - YR2015: Building capacity and moving into implementation

This second phase aims to build the scientific and technological capacity through workshops, where experts from and beyond the region are invited to share knowledge and identify the gaps,

and summer schools, where the students and early career scientists from the region are trained. This second phase also aims to build the regional partnership toward the project implementation through bilateral and multilateral cooperation.

(3) YR2016 - YR2022: Promoting science-policy linkage

The third phase aims to dive deeply into the scientific processes behind the monsoon onset and its late anomalies that lead to massive coral bleaching. One step further is expected to establish the science-policy linkage in order to help regional efforts combat the disastrous coral bleaching and its ecological impacts with the science-informed policy.

3. Major activities, outputs & outcomes over the last intersessional period (May 2021- April 2023)

In general, MOMSEI activities were heavily constrained by the covid-19 pandemic during the last intersessional period, particularly no personnel exchanges were realized.

However, the project participants have tried to keep working through emails and online meetings. MOMSEI group focused on the data analysis, process study, and modeling work, which resulted in three outcomes, including:

(1) Through the partnership between MOMSEI and Thailand-China Joint Laboratory for Climate and Marine Ecosystem, MOMSEI supports the demonstration of the pilot early warning system for coral bleaching which was developed in Phuket Marine Biological Center.

(2) MOMSEI continues its work with the Indonesian Agency of Marine and Fishery Research (AMFR) through the virtual system.

(3) Four (4) research papers were published, whose main findings are summarized below.

(3.1) Illustrating the low frequency modulation of the zooplankton diel vertical migration by the monsoon cycle and remote Kelvin wave forcing, which shows the physical-biological coupling feature in the Andaman Sea.

(3.2) Highlighting the close relationship between coral bleaching, monsoon onset and internal wave, which lays down the scientific basis to establish the early warning system for coral bleaching in the Andaman Sea.

(3.3) Demonstrating artificial intelligence (AI) in monitoring the large amplitude internal wave in the Andaman Sea, which opens the big potential for future development.

(3.4) Identifying the role of the internal tides in mixing up the water properties in the Andaman Sea, which connects the physical process with the bio-geo-chemical ones and calls for further multi-disciplinary study.

The four papers are listed below.

Liu, Y., J. Guo, Y. Xue, C. Sangmanee, H. Wang, C. Zhao, S. Khokiattiwong, W. Yu (2022), Seasonal variation in diel vertical migration of zooplankton and micronekton in the Andaman Sea

observed by a moored ADCP. Deep Sea Res. I, vol. 179, 103663, https://doi.org/10.1016/j.dsr.2021.103663.

Liu, Y., L. Putchim, K. Li, H. Gao, L. Sun, S. Khokiattiwong and W. Yu (2022), Late monsoon threatens coral refugia in the Andaman Sea. Environ. Res. Lett., 17, 034038, https://doi.org/10.1088/1748-9326/ac4a30.

Zhang, X., Wang, H., Wang, S., Liu, Y., Yu, W., Wang, J., Xu, Q. and Li, X. (2022). Oceanic internal wave amplitude retrieval from satellite images based on a data-driven transfer learning model. Remote Sensing of Environment, 272, https://doi.org/10.1016/j.rse.2022.112940.

Peng, S., Liao, J., Wang, X., Liu, Z., Liu, Y., Zhu, Y., Li, B., Khokiattiwong, S. and Yu, W. (2021). Energetics-based estimation of the diapycnal mixing induced by internal tides in the Andaman Sea. J. Geophys. Res. - Oceans. https://doi.org/10.1029/2020JC016521.

4. A summary of key achievements since its establishment

MOMSEI has struggled to achieve most of its goals even though the covid-19 pandemic since 2019 brought many difficulties. The key achievements are summarized below.

(1) The most important achievement is to build up a regional network and significantly improve the regional capacity for the study, monitoring and application of monsoon onset related ocean-atmosphere interactions, climate local impacts with a particularly focus on the late monsoon impact on the massive coral bleaching. MOMSEI has conducted 9 workshops and 6 summer schools, significantly enhancing the regional understanding of monsoon onset loading on the ocean and marine ecosystem.

(2) The partnership promoted by MOMSEI is a valuable asset for the region. MOMSEI develops its close cooperation with Indian Ocean Observing System (IndOOS), particularly its buoy array RAMA. The rich data stream from IndOOS helps MOMSEI develop its science and application. Also, MOMSEI works closely with Thailand and Indonesia, through Thailand-China Joint Laboratory for Climate and Marine Ecosystem hosted by Phuket Marine Biological Center (PMBC) and Indonesia-China Joint Center for Ocean and Climate hosted by Indonesian Agency of Marine and Fishery Affairs (AMFR). Also, MOMSEI conducted workshops and/or summer schools in the Philippines, Myanmar, Thailand, Malaysia, Indonesia, and China. Institutions and universities from the above countries made a huge contribution to promote MOMSEI. The spirit of partnership and engagement from MOMSEI is a big legacy for the region.

(3) MOMSEI significantly promotes the understanding of monsoon onset over the Asian region and results in a series of published papers. Particularly, MOMSEI research provides the common physical framework of ocean-atmosphere interaction of the Asian monsoon onset over the Bay of Bengal and the Indonesian-Australian monsoon onset. Furthermore, MOMSEI

research identifies the close linkage between ENSO and monsoon onset anomalies over the Bay of Bengal and the Andaman Sea and links its application to the disaster reduction of massive coral bleaching.

(4) As one of the most important legacies, MOMSEI pioneered the science-policy interface development. MOMSEI supports the demonstration of the pilot early warning system for coral bleaching, which was developed at Phuket Marine Biological Center. This pilot endeavor will have long-term impacts on the science-informed policy in the region.

5. Self-assessment on implementation against objectives

The project has achieved most of its objectives, which could be broken down into several key aspects.

(1) Regional collaborative network

MOMSEI successfully builds up its regional collaborative network, and the participating countries include Thailand, Indonesia, Myanmar, Malaysia, Vietnam, Philippines and Cambodia. MOMSEI implementation has two strong partners, including the Thailand-China Joint Laboratory for Climate and Marine Ecosystem hosted by Phuket Marine Biological Center (PMBC) and the Indonesia-China Joint Center for Ocean and Climate hosted by the Indonesian Agency of Marine and Fishery Affairs (AMFR). MOMSEI implementation also has strong international partners such as CLIVAR-GOOS Indian Ocean Panel (IOP) and its project of IndOOS.

(2) Regional capacity building

MOMSEI successfully promotes regional capacity building on monsoon climate-related research, ocean observation and data processing, physical-biological interactions, etc. This capacity building mainly targets students and early career scientists. MOMSEI, along with other collaborative projects, supports the implementation of the Chinese Government Scholarship on Marine Science. Quite a number of young students from the region are awarded master and PhD scholarships to study in China.

(3) New knowledge

MOMSEI successfully generates new knowledge on the monsoon onset over the Asian-Australian monsoon region, where a unified framework is suggested from the point of view of ocean-atmosphere interaction. This understanding is further extended to establish the linkage between the late monsoon onset and the massive coral bleaching in response to the elevated thermal pressure due to the heatwave resulting from the delayed monsoon onset. It is also identified that the internal waves in the Andaman Sea play a critical role in mixing the oceanic interior water, in sheltering coral from thermal stress.

(4) Science-informed policy

MOMSEI is moderately successful in this aspect. MOMSEI supports the demonstration of the pilot early warning system for coral bleaching, which was developed at Phuket Marine Biological Center. This is a very critical development towards the science-policy interface. Due to the covid-19 pandemic constraints, this development is not fully advanced as expected. However, the regional dissemination of this pilot demonstration's good experience and best practices is still immature.

6. Problems encountered and recommended actions

Covid-19 brought rather difficulties. After 2019, it is hard to carry out any in-person actions.

7. Objectives to be achieved, if applicable, over the next intersessional period (May 2023-April 2025)

The MOMSEI project has fulfilled its goals and will be terminated in April 2023.

8. Planned activities for May 2023- April 2025

None