The marine heatwaves variations in South China Sea

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South China Sea (SCS) is influenced by complex weather and climate variations and the air-sea interaction processes are active. The apparent marine heatwaves (MHWs) are prominent at synoptic, intra-seasonal, seasonal, interannual, decadal and long-term trends, as a consequence to the extreme weather, anomalous monsoon, El Niño/La Niña, Pacific Decadal Oscillations, and even the long-term climate change. The intensive inter-basin connections further makes the local SCS MHWs complex and difficult to predict. On the other hand, around SCS is the critical interface between human and nature, which is the most densely-populated, economically active and richest in nature and culture. As one example, SCS is worldly known for its most diverse coral reef species. However, the coral reef in SCS and around its coastal waters are facing more and more bleaching threatens in response to the severe MHWs. These massive bleaching events load devastating impacts on the national and regional economics and likelihood. It is therefore crucial to promote our understanding on the poorly known MHWs, particularly its regionality, seasonality and predictability. For this purpose, the substantial cooperation within SCS is urgently needed, including the coastal and deep ocean survey, cruise and laboratory research, education and capacity building. Through such multi-lateral cooperation, it is expected that we have better scientific knowledge, stronger capacity of MHW monitoring and risk assessment, in more advance preparedness and more effective policy. The utmost goal is that we jointly develop our world-level advanced excellence in science and technology to safeguard our regional sustainable development.

The Challenging on the Improvement of Ocean Forecasting System

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The Indonesian Maritime Continent (MC) territory has unique characteristics of weatherclimate variation due to its geographical position, which is covered by the ocean and has deep convection processes. Weather and climate dynamic factors that influence, especially in areas near the equator along the 90 o – 160o E, involve superposing interaction among the global mean circulation and variability on inter-annual, seasonal intra-seasonal, synoptic, diurnal, and convective scales. However, marine observation data in the MC is limited, especially inside Indonesian waters.

Since 2017, Indonesia Agency for Meteorology Climatology and Geophysics (BMKG) has developed the Ocean Forecast System to support the information needs of the weather and marine climate in Indonesia. Our capability to utilize met-ocean observational data is limited, mainly analyzed using statistical methods or primarily used as a model driver/verification. Thus, it serves as a challenge for BMKG to improve atmosphere and ocean conditions analysis capability through increased observation network density and numerical weather and forecast model accuracy through the strengthening of Marine Meteorological System (MMS) program during 2020 – 2024. The MMS extends the capability of the OFS to develop innovative weather and ocean coupling models predictions to improve early detection of high impact met-ocean phenomena. Otherwise, MMS develop accurate and timely forecast and warning services, integrated and relevant to the marine sector, policymakers and the public. For limited marine observation, MMS increases the spatial & temporal resolution of Risk Based Warning information and develop operational capacities of BMKG and international cooperation.

Capacity building under UN Ocean Decade: Past and future

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The 75th session of the UN General Assembly deliberated and approved the "Ocean Decade" Plan in 2020. The "Ocean Decade" was officially launched in January 2021, The vision of the "Ocean Decade" is to "build the science we need for the ocean we want" and aims to "promote transformative ocean science solutions for sustainable development, connecting people and our ocean". It's an important UN resolution to promote sustainable ocean development and the most important global Marine science initiative in the coming decade. In the marine filed, Chinese marine and oceanographic deeply feel the importance and sense of mission of contributing China's wisdom and strength, actively responding to the "Ocean Decade" initiative, and constantly promoting innovation in marine science and technology and marine governance, so as to contribute to the sustainable development of the ocean. As the first RTRC of the UNESCO/IOC, ODC aims to promote the international cooperation and enhance the research capacity and capability in WESTPAC region on ocean dynamics, air-sea interactions, climate change and numerical modeling through the provisions of international annual training courses and workshops to junior scientists and doctoral/master students mainly from the member states of IOC in the Western Pacific. More than ten years of training and forum activities held by ODC Center have become an international exchange platform for young scholars in the field of oceanography and climate. World-renowned oceanography and climate experts and young scholars from all over the world have formed a network to learn and develop together, promoting the realization of the vision of the "Ocean Decade". In the future, ODC Center will organize more relevant training activities in accordance with the goals of "Ocean Decade", aiming to achieve the oceans we want.

Climate and Ocean: Variability, Predictability and Change (CLIVAR)

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Established in 1995, the Climate and Ocean: Variability, Predictability and Change (CLIVAR) is one of the six core projects of the World Climate Research Programme (WCRP). Within WCRP, CLIVAR works closely with its sister WCRP core projects, including the two new WCRP core projects: the Regional Climate Information for Society (RifS) and the Earth System Modelling and Observational Capabilities (ESMO), in particular in the implementation of the WCRP Lighthouse Activities.

Malaysian Meteorological Department Marine Forecasting System

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Malaysia has a unique geography with long coastlines, large maritime Exclusive Economic Zones (EEZs), and continental shelves in the South China Sea and the Sulu Sea. Most of the nation's large economic resources are found in its maritime zones and Malaysian's export of commodities and manufactured products relied heavily on maritime transportation. Therefore, marine weather forecasting is important to ensure these economic activities can be carried out safely. Malaysian Meteorological Department (MetMalaysia) is tasked to provide marine weather forecasts in Malaysian water and its surrounding sea up to seven days. The marine forecasts are provided with the aid of various numerical models. For the sea conditions forecast, the forecast is provided with the aid of wind-wave model while for surface weather condition forecast, it is provided by WRF-MMD model. In addition, the MetMalaysia also provides warning such as storm surge prediction, and oil spill or floating object trajectory during search and rescue missions. MetMalaysia also provides monitoring and alert for tsunami waves. Current challenges include resources for more observations and modeling at higher resolution.

Development of the Operational Marine Environment Forecast System of 21st-Century Maritime Silk Road

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Focusing on the protecting marine environment and provide the information support along the "maritime silk road", the Marine Environment Forecast System of 21st-Century Maritime Silk Road is established. The system consists six sub-systems, a service platform for navigation safety and a channel for maritime silk road at www.oceanguide.org.cn, and the domain encompasses the North Indian Ocean, part of South Indian Ocean and South China Sea with a horizontal resolution of 9km for atmosphere and 5km for wave and current. It can provide high resolution products of atmosphere temperature, sea surface temperature, sea surface wind, wave height, wave period, water temperature, salinity and current. In addition, based on the prediction and traceability analysis models for multiple types of marine target, the oil spill and hazardous chemicals drift and diffusion prediction models, machine learning method and multi-model intelligent optimization technology, the system can also provide some derivative and analytical products, including oil spill and hazardous chemicals drift path, impact range, diffusion concentration, search and rescue forecast guarantee products and so on. With the NMEFC's continuous improvements for numerical forecasting technologies on models, multi-source data fusion and assimilation methods and products releasing, the system is used in marine environment security missions. The sub-system for ship-borne marine environment forecast information was packaged and put into trial operation during the 12th Arctic expedition voyage of Xuelong 2. And the sub-system for the key areas and shipping routes search rescue emergency forecasting ensured the drift test of the wrecked object in the Pearl River Estuary in the northern part of the South China Sea in 2021.

Interannual variation of Malacca Strait throughflow and controlling mechanism

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The Malacca Strait (MS), located between Malay Peninsula and the Sumatra Island, is a conduit for the water to transport from the South China Sea (SCS), Pacific Ocean (PO), to the Andaman Sea (AS), Indian Ocean (IO). Economically, it is also one of the most important shipping lanes of the world, promoting economy in the region. In this paper, we formulated a quasi-steady model for a narrow channel with a constant depth to estimate interannual flow through the strait as well as investigating the controlling mechanism. Results suggest that, at interannual timescale, the flow anomaly varies between -10 and 20 cm/s, primarily driven by sea level difference between two sides of the strait each of which is associated with different climate variabilities. El Nino Southern Oscillation (ENSO) induces interannual sea level on the south of the strait, and Indian Ocean Dipole (IOD), via long wave propagation, plays significant role in interannual sea level variation on the north of the strait.

Current understanding of marine heatwaves and future research needs in the Bay of Bengal

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In recent years, extremely oceanic warm water events, also known as marine heatwaves (MHWs), exert devastating impacts on marine ecosystems. Thus, the study of MHWs has attracted great scientific interests and public concerns. Numerous studies have been carried out in the global ocean (mainly in Pacific and Atlantic oceans) to understand physical drivers, characteristics and ecological impact of MHWs. Although the Bay of Bengal (BoB) is one of the regions with the fastest warming rate among tropical oceans, the status of MHWs over the BoB and its potential impacts on marine ecosystems is still poorly understood. Based on the analysis of the spatiotemporal variations using daily sea surface temperature (OISST) data, we find that in recent 40 years, marine heatwaves are increasing in the BoB, with much larger increase observed over the offshore waters around Myanmar, southern Bay and Andaman Sea, the places which are of abundant coral reef. From the observation data obtained by the China-Myanmar joint survey cruise in January 2020, a coral bleaching event is recorded in the coastal waters off Chaung Tha for the first time. The bleaching is primarily induced by the strong MHW event during 2019 fall. Considering the increasing impacts of MHWs on marine ecosystems and economic development under the warming background, there is an urgent need for the collaborative investigation in the BoB. Further research is needed to develop a more robust understanding of the MHW mechanisms through process-based joint surveys, which may contribute to its prediction and ecological impact assessment.

Evolution of Extreme Indian Ocean Dipole in 2019 and Its Impact on Forest Fire in Indonesia

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Extreme positive Indian Ocean Dipole (pIOD) took place in the tropical Indian Ocean during the late boreal summer to early winter of 2019. The patterns of anomalous sea-surface temperature (SST) revealed a typical pIOD characteristic: cooling (warming) in the southeastern (western) tropical Indian Ocean. Based on the Dipole Mode Index (DMI), evolution of the event started in the early August and gradually strengthened with abrupt weakening in the early September before came to its peak in the late October/early November. It quickly weakened in November and then it terminated in late December. During the peak phase of the event, SST anomaly in the southeastern (western) tropical Indian Ocean reached –2.2 ℃ (+1.4 ℃). The pattern of anomalous SST was followed by anomalous pattern in precipitation: increased (decreased) precipitation over the western Indian Ocean – East Africa (eastern Indian Ocean – Indonesia and western Australia). Dry condition associated with the 2019 pIOD event created a favourable condition for a forest fire in southern Sumatra and west Kalimantan. The number of hotspots has increased significantly during the peak phase of the event. In addition, anomalously strong upwelling forced by strong southeasterly wind anomalies along the southern coast of Java and Sumatra had induced surface chlorophyll-a bloom in this region. High surface chlorophyll-a concentration was collocated with the negative SST anomalies, which were observed off southwest Sumatra coast and off south Java.

Hypoxia in the East China Sea: A rising ecosystem issue varying with multiple drivers

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Hypoxia, one of the most attractive marine ecosystem issues, was frequently observed off the Changjiang Estuary in the East China Sea since 1960s. The depletion of oxygen is a result of overwhelming consumption of organic matter produced by massive phytoplankton blooms. The blooms were triggered by eutrophication attributed to riverine and oceanic nutrients. This presentation revealed how the cross-shelf exchange of nutrients and dissolved oxygen affect the hypoxia extent based on a serial numerical experiment. Increase in nutrient in the river loading and the Kuroshio both led to an expansion of hypoxic water during the summer period. An increase in Kuroshio DO concentrations by 25% would result in a decrease of the maximum hypoxia extent (MHE) in the ECS by 76%, while a 25% decrease in Kuroshio Current DO would increase the MHE by up to 219%. Changes in phosphate and nitrate concentrations by 25% in the Kuroshio would change the MHE by up to 30% and 18%, respectively. Our results showed the relative importance for the Kuroshio transport, i.e., DO > phosphate > nitrate > silicate, in terms of modifying the hypoxic water area. Historical hypoxia events were also compared, indicating that hypoxia was severely enhanced by tremendous fresh water discharge related to El Niño event. Our results suggest that variation of hypoxia in the East China Sea is probably driven by multiple causes. (presentere: zhoufeng@sio.org.cn)

Observed seasonal and tidal variability of sea level and current on Andaman Shelf

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The Andaman shelf is a board continental shelf extending in a north-south direction along the eastern boundary of the Andaman Sea (AS). While the Andaman shelf has been investigated for a long time, the fundamental understanding on the shelf dynamics is still limited largely due to the scarcity of long-term oceanographic observation. Under a collaborative framework between Thailand and China, an acoustic Doppler current profiler (ADCP) was deployed on the shelf for a year, providing long-term in situ observation. By analyzing the ADCP and tide-gauge observations, the sea level and current variations on seasonal and tidal timescales were investigated during the study period. Our analyses showed a clear seasonal pattern of sea level corresponding to monsoon winds. Current, in contrary, exhibited a weak seasonality and were likely influenced by remote forcings from the Equatorial Indian Ocean (EIO). Our observation highlights the connection between the AS and the EIO. In addition, tides are semi-diurnal with M2 and S2 being the most predominant tidal constituents, followed by N2 and K1. Tidal currents for the two major constituents exhibited a clockwise rotation with major semi-axis lengths oriented toward northeastward direction.

Storm Surge Modeling in the Southern of Java using Coupled 4D-VAR Circulation-Waves Model

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Indonesian Maritime Continent is a complex substance with the highest of mean high-water datum on the coastal area throughout the years. There are 2 research focuses: (1) Improving the initials of the input system in the ADCIRC-SWAN model. The assimilation was applied based on the in-situ observations data for improving the accuracy. The research of storm surge modeling in the southern coastal of Java was carried out by the integration of the 4DVAR assimilation technique of the surface observation and JASON-3 altimetry data into the Advanced Circulation and Simulating Waves Nearshore (ADCIRC-SWAN) model. The finite-volume grid domain pattern with domain density of 150 meters and use of S2 and M2 diurnal tidal components for open boundaries. The output of the ADCIRC-SWAN model is tidal flooding and inundations. The deep-water wave pattern as the output of the WaveWatch 3 model is used to analyze its influence on the formation of fully-developed sea propagation and the swell in the coastal area. The increase in water level and peak surge is dominantly caused by the friction effect from the strong wind-driven intensity on the sea surface. It causes a fluctuation in tides of 20-30 cm during the Ernie tropical cyclone event on April 6-10, 2017. (2) The verification of EnsembleKF uses 5 member verifiers and JASON-3 satellite data is used as a comparison to the SWAN model output of shallow water with in-situ observation.