Development of the Southeast Asia Ocean Forecast System

Changshui Xia
First Institute of Oceanography, Ministry of Natural Resources, China
xiacs@fio.org.cn

The construction of marine environment prediction and disaster early warning system in Southeast Asia is a systematic project integrating marine observation, model development, prediction service, disaster early warning and regional cooperation. It mainly includes five parts: the construction of wave tide current coupled numerical prediction system, the verification of marine observation and prediction model system, the operational operation of prediction system and the release of service products Prediction and early warning of marine environmental disasters and emergencies, disaster assessment, capacity-building, popularization and application.

A wave tide current coupled numerical marine environment prediction and prediction system in Southeast Asia is established in the way of triple nesting of the world, Southeast Asian waters and offshore waters of Southeast Asian countries, with horizontal resolutions of 10km, 4km and 1km respectively. After three years of independent third-party test, the prediction accuracy of the prediction system has reached the international level of ocean prediction system with the same resolution.

Relevant prediction products have been released in the host country and the Western Pacific branch of IOC through network and mobile phone. At present, the forecasting system has become the official marine forecasting system of Thailand and is published on the official website of the National Meteorological Administration of Malaysia. After the shipwreck in Phuket, Thailand in July 2018, the project team timely started the disaster response mechanism of the prediction system, quickly provided the scope and direction of search and rescue, and won high praise from the Thai government.

China-Indonesia Joint observation in Indonesian seas during the past decades

Tengfei Xu
First Institute of Oceanography, and Key Laboratory of Marine Science and Numerical Modeling, Ministry of Natural Resources, China
xutengfei@fio.org.cn

The Indonesian seas is significantly important as it is the convergence region for both oceanic energy and atmospheric circulation, and is the only pathway for inter-ocean water transport at tropical region. Since 2007, researchers from China and Indonesia have completed The SITE and TIMIT international collaboration projects, which focus on the South China Sea-Indonesian seas water exchange, and the Indonesian Throughflow, as well as their impacts on marine ecosystem. The ongoing TRIUMPH project was initiated in 2018 with focus on the ITF, Java upwelling and mixing physics in the Indonesian surrounding waters. So far, a total of 23 joint expedition cruises have been conducted for the SITE, TIMIT and TRIUMPH projects, by which longterm time series of temperature, salinity and current in the Karimata, Sunda, Makassar, Lombok, Alas, and Badung straits, and lots of geology and biochemistry samples were obtained. Here, we will overview the China-Indonesia collaboration during the past decades. Some scientific recognizations based on these data are also summarized.

The complexity of South China Sea summer monsoon onset

Tian Ma
School of Atmospheric Sciences, Sun Yat-Sen University, Zhuhai Campus
matian@mail2.sysu.edu.cn; yuwd@mail.sysu.edu.cn

Most of the South China Sea (SCS) summer monsoon (SCSSM) onsets are triggered by the10-25-day intraseasonal oscillation (HISO) and 30-60-day ISO (LISO), and the SCSSM can also be established without the effects of the ISOs, but the date would be put off. In this study, the characteristics and mechanisms of the ISOs are investigated.

The mean easterly trade winds are considered as the main reason for the HISO that can successively propagate westward from the western North Pacific along 10 ℃N until the SCSSM onset. Based on the budget analysis of column-integrated moist static energy, the interaction between the trade winds and the zonal gradient of MSE anomalies account for 62% in the MSE tendency anomaly when the HISO triggers the SCSSM onset. The SCSSM onset is always triggered by the second wet phase of the HISO propagates into the SCS. The first one is considered as an implication that the influence of western North Pacific subtropical high is weaken in the SCS and the SCSSM onset will be triggered by the next HISO or LISO within 15 days.

For the typical northward-propagating LISO of triggering the SCSSM onset, the positive sea surface temperature anomaly (SSTa) ahead of the convention center is of prime importance， followed by the barotropic southerly. In the budget analysis, the SSTa-induced turbulent heat flux and the interaction between mean southerly and the meridional gradient of MSE anomaly account for 54% and 39% respectively.

Relationship between dinoflagellate cysts and water eutrophication and ENSO index in the Changjiang River estuary

Xinfeng Dai
Key Laboratory of Marine Ecosystem Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, China
daixinfeng@4io.org.cn

Dinoflagellate cysts, as micro-fossil, could be used to trace environmental change history, such as water eutrophication and climate change. But there is controversy on how to indicate water eutrophication, and also it is a problem how to differ the signals between water eutrophication and climate change in dinoflagellate cysts. In order to address these problems, we collected four sediment cores in the Changjiang River estuary and analyzed their dinoflagellate cysts. Results showed that eutrophication could lead to the increase of total dinoflagellate cysts and Paralytic Shellfish Poisoning (PSP) productive dinoflagellate cysts abundance. And the ratio of hetero/autotrophic dinoflagellate cysts decreased, which implied that the eutrophication mainly resulted from agriculture and domestic sewage in the Changjiang River estuary. Because of water plume, the eutrophication signal was relatively weak near estuary, strong in middle distance and almost none in far distance. Seasonal change of dinoflagellate cysts was observed in the high sediment sinking area in the estuary, with the lowest production in winter as a result of low temperature. ENSO events will lead to the peak and valley value of dinoflagellate cysts abundance by affecting nutrient input which is transferred by river downloading. Moreover, the signal also varied with the distance: valley and peak value of dinoflagellate cysts present because of strong and weak river runoff pulse near estuary, peak and valley value of dinoflagellate cysts and runoff overlapped and were clear in middle distance, and peak value of dinoflagellate cysts was obvious in far distance but the domain reason was complex. These findings are of great significance to environment history reconstruction, study of red tide history and ENSO events.

Smart Tsunami Information Process System at South China Sea Tsunami Advisory Center

Hongwei Li
National Marine Environmental Forecasting Center, MNR
lihw@nmefc.cn

Tsunami Decision Support system is very important to tsunami warning, it can save several minutes if it is well designed. Decision support system Smart Tsunami Information Process System (STIPS) started to develop from 2018, it is developed based on python, open-source and well-maintained, and its trial operation will start this year.

There are six modules in the system: data receiving module, information display module, earthquake analysis module, tsunami forecasting module, sea level observation module and products publishing module. Data receiving modules receives sea level observation data and earthquake bulletins. Sea level data is mainly from GTS and Website, whereas earthquake bulletins are from both local earthquake monitoring system and earthquake agencies. These data are collected and saved into local database which is also the media each module communicate with each other. We can use the earthquake analysis module to give reasonable parameters of the earthquake and do the tsunami forecasting using these parameters. Sea level data module can be used to pick tsunami wave height at the same time. At last we can generate variable types of products and send the products to people though multiple ways.

Different versions of STIPS have been deployed in Guangdong, Macau and Hong Kong. it will be improved in stability and fluency in future.

Sea Surface Temperature and Chlorophyll a variability in the vicinity of Natuna Sea : Role of cold surge during east asian winter monsoon 2020/2021

Yosafat Donni Haryanto
Indonesian State College of Meteorology Climatology and Geophysics
yosafatdonni@gmail.com

Cold surge is a phenomenon of cold air outbrakes originating from the highlands of Asia during the winter in the Northern Hemisphere. It is known that the variability of sea surface temperature (SST) and chlorophyll-a (chl-a) is influenced by the presence of monsoon winds. However, the cold surge which is part of the monsoon phenomenon is not yet fully known whether it has a significant influence or not. This study aims to analyze the effect of cold surge on the variability of SST and chl-a during the 2020/2021 Asian winter around the waters of the Natuna Sea which is an area of cold surge propagation. The SST data were obtained from satellite observations using the Advanced VeryHigh-Resolution Radiometer (AVHRR) sensor with a resolution of $0.05^{o} \times 0.05^{o}$ and the chl-a data obtained from the Aqua Moderate-resolution Imaging Spectroradiometer (MODIS) satellite observation with the 4×4 km resolution. The results of the analysis show that SST gradually cools from November (28 – 30 ℃) to February (25-27 ℃). When cold surge occurs, SST experiences overall cooling in the study area with an anomaly of more than -1 ℃ for strong cold surge cases. Overall, there are differences in the distribution of chl-a which is influenced by cold surge. An increase in the concentration of chl-a occurred in most of the waters of the Natuna Sea with a significant distribution of values in the waters close to the mainland.

Tsunami Warning and Mitigation System in the South China Sea Region

Zongchen Wang
National Marine Environmental Forecasting Center
wangzc@nmefc.cn; shijy@nmefc.cn

South China Sea Tsunami Advisory Center (SCSTAC), hosted by China and authorized by International Oceanographic Commission of UNESCO, began its full operation after 10-year cooperative constructions on 5th November in 2019. The SCSTAC provides 24-hour service on tsunami detection and alerts to nine countries in the SCS and adjacent regions, including Brunei, Cambodia, China, Malaysia, Indonesia, Philippines, Singapore, Thailand and Vietnam.

The operational regional earthquake and tsunami detection systems have been established by more than 100 seismic stations and nearly 20 tidal gauges. On average, the rapid earthquake message can be obtained within 3-5 minutes. A scenario database is in use for fast tsunami hazard analysis after obtaining preliminary earthquake parameters. When the focal mechanism is produced for tsunami source by the real-time W-phase inversion system, the on-the-fly tsunami forecast model is capable of accomplishing 15-hour simulation in less than 5 seconds by means of GPU accelerators. The model has been validated by 9 major historical tsunamis in the Pacific region. And, the hindcast accuracy of threat levels is acceptable in terms of tsunami alert purpose, with 80% of results falling into the corresponding levels. Furthermore, a SOP-based decision supporting system is operating to assist watch-stander for tsunami evaluation and products making, as well as issuing. During the last three years, the average elapsed time for the first tsunami message is less than 10 minutes in terms of earthquake occurrence time.

The Short-Term Climate Prediction System FIO-CPS v2.0 and its Prediction Skill in ENSO

Yajuan Song
First Institute of Oceanography, and Key Laboratory of Marine Science and Numerical Modeling, Ministry of Natural Resources, Qingdao, China
songyj@fio.org.cn

The climate model is an important tool for simulating and predicting the mean state and variability of the climate system. The First Institute of Oceanography-Climate Prediction System (FIO-CPS), built on a climate model with the oceanic observation initialization, has been updated from version 1.0 to 2.0, with a finer resolution and more reasonable physical processes. Previous assessments show that the mean state was well simulated in version 2.0, and its influence on the prediction was further analyzed in this study. Hindcast experiments were conducted using FIO-CPS v1.0 and v2.0, and their prediction abilities based on 27 years (1993 to 2019) experiment data were analyzed. The results show that the sea surface temperature (SST) biases over the eastern Pacific and the Southern Ocean are improved in the initial condition of FIO-CPS v2.0. Moreover, this new system has a higher skill for predicting El Niño-Southern Oscillation (ENSO). Furthermore, the improvement of the prediction skill changes seasonally, featured by the ACC significantly increasing in the boreal winter and early spring. The improvement in the annual mean SST prediction over the Equatorial Pacific mainly contributes to the enhanced ENSO prediction skill in FIO-CPS v2.0. These results indicate that a state-of-the-art climate model with a well-simulated mean state is critical in improving the prediction skill on the seasonal time scale.

Extreme sea level rise off the northwest coast of the South China Sea in 2012

Lin Liu
Center for Ocean and Climate Research, First Institute of Oceanography, MNR, Qingdao, China
liul@fio.org.cn

Tide gauge data are used to investigate sea level variability off the northwest coast of the South China Sea (SCS) in 2012, and a significant sea level elevation with a magnitude approaching 79 mm is observed. Analysis suggests that an abnormal sea surface heat flux and freshwater flux may have contributed to this abnormal rise in sea level, together with the remote influence of an ENSO event. Further investigation shows that the event was dominated by the positive freshwater flux, where large volumes of water entered the ocean, and a maximum is centered to the south of Guangdong province, China. Simultaneously, a positive anomalous heat flux occurred in the northwestern part of the SCS, which is considered to have made a positive contribution to the high local sea level elevation. In addition to the heat flux, the ENSO event also had a significant effect on the event, where the La Niña-induced northwest Pacific cyclone contributed to sea level rise over the northwestern SCS through dynamic and thermodynamic interactions.

Model Description and Evaluation of FIO Earth System Model (FIO-ESM) version 2.0

Ying Bao
First Institute of Oceanography, Ministry of Natural Resources, Qingdao, China
baoying@fio.org.cn; qiaofl@fio.org.cn

The First Institute of Oceanography Earth System Model (FIO-ESM) version 2.0 was developed and participated in the Climate Model Intercomparison Project phase 6 (CMIP6). In comparison with FIO-ESM v1.0, all component models of FIO-ESM v2.0 are updated, and their resolutions are fined. In addition to the non-breaking surface wave-induced mixing (Bv), which has also been included in FIO-ESM v1.0, there are three more distinctive physical processes in FIO-ESM v2.0, including the effect of surface wave Stokes drifts on air-sea momentum and heat fluxes, the effect of wave-induce sea spray on air-sea heat fluxes and the effect of sea surface temperature (SST) diurnal cycle on air-sea heat and gas fluxes. The FIO-ESM v2.0 has conducted the CMIP6 Diagnostic, Evaluation and Characterization of Klima (DECK), historical and futrue scenario experiments. The results of pre-industrial run show the stability of the climate model. The historical simulation of FIO-ESM v2.0 for 1850-2014 is evaluated, including the surface air temperature (SAT), precipitation, SST, Atlantic Meridional Overturning Circulation (AMOC), El Niño-Southern Oscillation (ENSO), etc. The climate changes with respect to SAT and SST global warming and decreasing AMOC are well reproduced by FIO-ESM v2.0. In particular, the large warm SST bias at the east coast of tropical Pacific from FIO-ESM v1.0, which is a common challenge for all climate models, is dramatically reduced in FIO-ESM v2.0 and the ENSO period within the range of 2-7 years is well reproduced with the largest variation of SST anomalies occurring in boreal winter, which is consistent with observations.

On the First Observed Wave-induced Stress over the Global Ocean

Sheng Chen
First Institute of Oceanography, Ministry of Natural Resources, Qingdao, China
rain@fio.org.cn

Despite many investigations/studies on the surface wave-induced stress, the global feature of the wave-induced stress has not been obtained previously as that requires a simultaneous observation of wave spectra and wind on a global scale. The China France Oceanography Satellite (CFOSAT) provided an opportunity for the first time to evaluate the global wave-induced stress and its contribution to the total wind stress. In this study, the global spatial distributions of wave-induced stress and its correlated index for August to November in 2019 are presented using the simultaneous ocean surface winds and wave spectra from the CFOSAT. The main results show that the wave-induced stress is fundamentally dependent on the wind and wave fields on a global scale and shows significant temporal and spatial variations. Further analyses indicate that there is an upward momentum flux under strong swells and low wind speeds (below approximately 5 m/s), and an anti-correlation between the dimensionless wave-induced stress and the proportion of swell energy to the total. Finally, the variations of the surface wave induced wind stress are clear asymmetric between northern and southern hemispheres in late summer but symmetric in late fall, which are closely associated with the seasonal changes in large-scale atmospheric circulation.

Could CMIP6 climate models reproduce the early-2000s global warming slowdown?

Meng Wei
First Institute of Oceanography, and Key Laboratory of Marine Science and Numerical Modeling, Ministry of Natural Resources, Qingdao, China
weimeng@fio.org.cn; qiaofl@fio.org.cn

The unexpected global warming slowdown during 1998–2013 challenges the existing scientific understanding of global temperature change mechanisms, and thus the simulation and prediction ability of state-of-the-art climate models since most models participating in phase 5 of the Coupled Model Intercomparison Project (CMIP5) cannot simulate it. Here, we examine whether the new-generation climate models in CMIP6 can reproduce the recent global warming slowdown, and further evaluate their capacities for simulating key-scale natural variabilities which are the most likely causes of the slowdown. The results show that although the CMIP6 models present some encouraging improvements when compared with CMIP5, most of them still fail to reproduce the warming slowdown. They considerably overestimate the warming rate observed in 1998–2013, exhibiting an obvious warming acceleration rather than the observed deceleration. This is probably associated with their deficiencies in simulating the distinct temperature change signals from the human-induced long-term warming trend and/or the three crucial natural variabilities at interannual, interdecadal, and multidecadal scales. In contrast, the 4 models that can successfully reproduce the slowdown show relatively high skills in simulating the long-term warming trend and the three key-scale natural variabilities. Our work may provide important insight for the simulation and prediction of near-term climate changes.

Different influencing mechanisms of two ENSO types on the interannual variation in diurnal SST over the Niño 3 and 4 regions

Xiaodan Yang
First Institute of Oceanography, and Key Laboratory of Marine Science and Numerical Modelling, Ministry of Natural Resources, Qingdao, China
yangxiaodan@fio.org.cn; songroy@fio.org.cn

In this paper, the different effects of the eastern equatorial Pacific (EP) and central equatorial Pacific (CP) El Niño-Southern Oscillation (ENSO) events on interannual variation in the diurnal sea surface temperature (SST) are explored in both the Niño 3 and Niño 4 regions. In the Niño 3 region, the diurnal SST anomaly (DSSTA) is negative during both EP and CP El Niño events and becomes positive during both EP and CP La Niña events. However, the DSSTA in the Niño 4 region is positive in El Niño years and negative in La Niña years, which is opposite to that in the Niño 3 region. Further analysis indicates that the incident shortwave radiation (SWR), wind stress (WS), and upward latent heat flux (LHF) are the main factors causing the interannual variation in the DSST. In the Niño 3 region, the decreased/increased SWR and the increased (decreased) LHF lead to the negative (positive) DSSTA in EP El Niño (La Niña) years. In addition, the enhanced (reduced) WS and the increased (decreased) LHF cause the negative (positive) DSSTA in CP El Niño (La Niña) years. In the Niño 4 region, the reduced (enhanced) trade wind plays a key role in producing in the positive (negative) DSSTA, while the decreased (increased) SWR has an opposite effect that reduces/increases the range of the DSSTA during both EP and CP El Niño (La Niña) events.

Recent development of the global 1/32 °surface wave-tide-circulation coupled ocean model: FIO-COM32

Bin Xiao
First Institute of Oceanography, and Key Laboratory of Marine Science and Numerical Modeling, Ministry of Natural Resources, Qingdao, China
xiaobin@fio.org.cn; qiaofl@fio.org.cn

Model resolution and physical processes are two of the most important factors that determine the realism of the ocean model simulations. Recently, a brand new global 1/32 °surface wave-tide-circulation coupled ocean model FIO-COM32 is developed and validated. Promotion of the horizontal resolution from 1/10 °to 1/32 °lead to great improvements of the simulated surface eddy kinetic energy (EKE), fine structures of sub-mesoscale to mesoscale movements and global tide accuracy. The non-breaking wave induced mixing is proved to be an important contributor that improves the agreement of the simulated summer mixed layer depth (MLD) of the new 1/32 °model and the Argo observations. Internal tide (IT) can be explicitly simulated in this new model and is compared with the satellite observations. Comparisons using along-track of Jason3 sea surface height (SSH) wave-number spectrum shows that IT induced SSH undulations is an important factor that contribute to improved agreement of model and satellite observations.

Transport and dispersion scenarios of tritium from the radioactive water of the Fukushima Daiichi nuclear plant

Chang Zhao
First Institute of Oceanography, Ministry of Natural Resources, Qingdao 266061, China
zhaoc@fio.org.cn; qiaofl@fio.org.cn

Japan recently announced plans to discharge over 1.2 million tons of radioactive water from the Fukushima Daiichi Nuclear Power Plant (FDNPP) into the Pacific Ocean. However, the contaminated water can poses a threat to marine ecosystems and human health depending on their concentrations. To estimate the impact of the plan, here, we developed a three-dimensional global model to track the transport and dispersion of tritium released from the radioactive water of the FDNPP. The pollution scenarios for four release durations (1 month, 1 year, 5 years, and 10 years) were simulated. The simulation results showed that for the short release-duration scenarios (1 month and 1 year), the peak plume with high tritium concentration shifted with the currents and finally reached the northeastern Pacific. For the long release scenarios (5 years and 10 years), the peak plume of the contaminated water was confined to coastal regions east of Japan.

Microplastic pollution in the Beibu Gulf-the Northern of the South China Sea

Zuhao Zhu
Fourth Institute of Oceanography, Ministry of Natural Resources, Beihai 536000, PR China
zhuzuhao@4io.org.cn

Microplastics were sampled and analyzed from 75 surface seawater stations and 66 surface sediment stations during July to August in 2020, in the Beibu Gulf, the northern of the South China Sea. The abundances of microplastics in seawater (according to the Manta net sampling) and sediment (based on dry weight) were found to be 0.669 particles/m^3 and 4.33 particles/kg, respectively. The abundances of microplastics in coastal area were found to be greater than those in off coastal area, indicating that the important contribution of human activities, especially higher microplastic abundances were found in the seawater and sediment adjacent to the urban area. The shape, color, size and composition of the microplastics were also determined. In seawater the fragments contributed the most as 92.38%, and 56.0%, 44.0%, 53.23% of white color, 1-2 mm size distribution, polystyrene (PS). In sediment the most abundant microplastics were fibre (82.93%), Black (66.83%), 0-1 mm size distribution (50.04%) and PY (39.54%). There were no significant correlations between the distributions of microplasics in the seawater and sediment, and the abundances of microplastics in off coastal sediment were only slightly lower than that in the coastal sediment, indicating that microplastic is readily to transport and bury in open area sediment. This study provides data of microplastics in the Beibu Gulf, supporting further investigation of transportation fate and the behavior of this emerging pollutant from coastal zone to the South China Sea.

New Gridded Product for the Total Columnar Atmospheric Water Vapor over Ocean Surface Constructed from Microwave Radiometer Satellite Data

Weifu Sun
Marine Physics and Remote Sensing Research Department, First Institute of Oceanography, Ministry of Natural Resources
sunweifu@fio.org.cn; wupeiqiang@fio.org.cn

Analyzing and understanding the spatial and temporal patterns of water vapor are thus crucial for global climate change. In this study, multisource remote sensing water vapor observation data from SSMIS, WindSat, AMSR-E, ASMR2, and HY-2A microwave radiometers are used to develop an extended daily water vapor multisource remote sensing fusion product based on the OI algorithm. The merged daily available product features a high spatial resolution of 0.25 ° from 2003-2018. Then, the accuracy of the produced global ocean atmospheric water vapor fusion products was examined using radiosonde observations. The main conclusions are summarized as follows.

(1) Over the past 16 years, the *RMSE* and *Std* of satellite-derived atmospheric water vapor fusion products in the global ocean combined with radiosonde data have generally been better than 3 mm. *Bias* has shown a positive deviation and is generally smaller than 0.6 mm. *MAD* has generally been better than 2 mm, and *R* has been stronger than 0.98. The errors of remotely sensed water vapor are normally distributed and slightly skewed to positive values from 2003 - 2018.

(2) The possibility of replacing AMSR-E data with AMSR2 and HY-2A microwave radiometer data was studied after the data service of AMSR-E ceased. The findings showed that the fusion products obtained by combining AMSR2 and HY-2A microwave radiometer data show higher accuracy compared with the water vapor fusion products using AMSR-E data based on the *Bias*, *Std*, and *RMSE* results. Thus, AMSR-2 and HY-2A microwave radiometer data can be used to replace AMSR-E data.

Thermohaline conditions and circulation in the gulf of Thailand during the northeast monsoon

Jingsong Guo
First Institute of Oceanography, Ministry of Natural Resources, Qingdao 266061, China
gjings23@fio.org.cn

Hydrographic data from the Gulf of Thailand (GoT) reveal two bottom saline water areas with Salinity (S) ≥ 33.0 psu (BSWA1 and BSWA2) and where the water columns are highly stratified during December-January. Observational results from a seafloor Acoustic Doppler Current Profiler (ADCP) verify that the current is dominated mainly by the barotropic current. The monthly average sea-level-anomaly (SLA) and barotropic current vector maps confirm a cyclonic circulation in the northern GoT during November-January. The BSWA1 is located near the center of the cyclonic circulation. The BSWA1 and cyclonic circulation simultaneously enter their weakening phases, which suggests that the cyclonic circulation convergence plays a key role in maintaining the BSWA1. The BSWA2 occurs as a narrow strip concentrated along the eastern slope of the basin in the southern GoT during December-January. The southern GoT also has higher SLA and forms a congregation area of diluted water with S<31.0 psu that enters from the north and south of this region during December-January.

Interdecadal Differences in the Interannual Variability of the Winter Monsoon Over the South China Sea

Baochao Liu
Center for Ocean and Climate Research, First Institute of Oceanography, Ministry of Natural Resources, Qingdao 266061, China
liubc@fio.org.cn

We investigate interdecadal differences in the interannual variability of the South China Sea (SCS) Winter Monsoon (SCSWM) since 1950. The SCSWM is influenced by both the East Asian Winter Monsoon (EAWM) over the mid–high latitudes and the anomalous anticyclone over the western North Pacific (WNPAC). The EAWM tends to cause a positive linear correlation of wind speeds between the northern SCS (NSCS) and the southern SCS (SSCS). Because the cold surge of the EAWM can make wind speeds over the NSCS and SSCS increase simultaneously. While, the WNPAC tends to weaken this positive correlation (corNS) because anomalies associated with the WNPAC will decrease wind speeds over the NSCS but exert a small or even an opposite influence on wind speeds over the SSCS. The interannual variation of the EAWM before the late 1970s is greater than that after the early 1990s. And the WNPAC was weak and confined to the east of the SCS before the late 1970s but became strong and expanded towards the SCS after the early 1990s. As a result, the positive corNS was significant at the 95% confidence level before the late 1970s but became insignificant after the early 1990s.

Observations on Surface Ocean Acidification in the eastern Indian Ocean

Liang Xue
First Institute of Oceanography, Ministry of Natural Resources, Qingdao, China
xueliang@fio.org.cn

Since the Industrial Revolution, increasing human activities has caused substantial rises in atmospheric carbon dioxide levels from ~280 ppm (parts per million) to over 420 ppm today. This has induced rapid declines in pH and calcium carbonate mineral saturation states (Ω), a process coined ocean acidification (OA), which may exert negative impacts on marine organisms. However, compared to the Pacific and Atlantic Oceans, the status of OA and its relevant parameter is not well understood. Here we show the temporal changes of surface pH and Ω in the eastern Indian Ocean observed during the past few years. We find OA not only occur in a CO_2 sink region that absorbs CO_2 from the atmosphere, but also in a CO_2 source region that releases CO_2 to the atmosphere, such as the eastern equatorial Indian Ocean. Also, we observe large variabilities of pH induced by natural processes. In the Andaman sea, for example, internal wave is an important process that can induce large-amplitude variations in pH as large as 0.2 units within several minutes. And in the Java upwelling region, the Indian Ocean Dipole (IOD) can cause a strong interannual variability of OA parameters by driving upwelling strengths. We expect that more observations are needed to detect anthropologic OA particularly in the areas with strong natural variabilities.

Modulation of Environmental Conditions on the Significant Difference in the Super Tropical Cyclone Formation Rate during the Pre- and Post-Monsoon Transition Periods over the Bay of Bengal

Zhi Li
First Institute of Oceanography, MNR
lizhi@fio.org.cn

Unlike other tropical ocean basins, the Bay of Bengal (BoB) uniquely has two tropical cyclone (TC) seasons: a pre-monsoon transition period (Pre-MT) and a post-monsoon transition period (Post-MT). More importantly, the global maximum and minimum formation rates of super tropical cyclones (STCs, category 4 and 5) occur in Pre-MT and Post-MT, respectively, over the BoB during the period of 1981-2016.

The Butterworth filter, the box difference index (BDI) and a quantitative diagnosis were utilized to detect what and how background environmental factors cause the significantly different STC formation rates between Pre- and Post-MT. The diagnosis revealed that the vertical temperature difference (VTD) mainly determines whether TCs can develop into STCs during Post-MT, similar to Pre-MT. However, unlike that during Pre-MT, the VTD during Post-MT is controlled by the low-level temperature instead of the upper-level temperature.

The analysis results also revealed that the background sea surface temperature is much warmer in Pre-MT than in Post-MT and forces higher 1000 hPa-level temperatures. Additionally, more water vapor is gathered by the cyclonic anomaly circulation associated with warmer sea surface temperatures in Pre-MT, inducing a high specific humidity (SH) in the boundary layer. The differences in the low-level temperature and SH cooperate to predominantly contribute to the significant difference in V_{pot}^2, which denotes the maximum TC potential intensity, eventually leading to the remarkably different STC formation rates between Pre- and Post-MT over the BoB.

Equatorial Moisture Dynamics of the Quasi-Biweekly Oscillation in the Northwestern Pacific

Kuiping Li
First Institute of Oceanography, Ministry of Natural Resources
likp@fio.org.cn

The pronounced summertime quasi-biweekly oscillation (QBWO) in the tropical northwestern Pacific usually originates from equatorial convective anomalies (ECAs) in the western Pacific. In this study, ECAs in relation to the QBWO are investigated in terms of the equatorial moisture dynamics. The results show that the development of ECAs is preconditioned by significant moisture anomalies associated with zonal moisture advection along the equator. Prior to initiation, an equatorially westward-moving moisture precursor at a speed of approximately 5° longitude per day could be traced back to 140°W. A moisture budget analysis indicates that the successive westward movement of the moisture precursor is primarily due to the interaction between the zonal gradient of moisture anomalies and the mean easterly trade winds. The equatorial moisture dynamics likely maintain the quasi-biweekly variability of ECAs regarding the QBWO in the tropical northwestern Pacific.

An Interannual Perspective on the Devastating 2017-2019 Australian Drought during Austral Spring

Yiling Ma
School of Atmospheric Sciences, Sun Yat-sen University, Zhuhai, Guangdong, China.
mayling5@mail2.sysu.edu.cn; dongwj3@mail.sysu.edu.cn; yuwd@mail.sysu.edu.cn

Much of Australia was in severe drought from 2017 to 2019. Here we link this prolonged drought to the Pacific and Indian Ocean sea surface temperature (SST) mode associated with Central Pacific (CP) El Niño and Indian Ocean Dipole (IOD) based on clustering analysis. Compared to traditional eastern Pacific (EP) El Niño, the CP El Niño has increasing occurrence frequency over the last 20 years. The original Australian rainfall forecasting skills developed for EP El Niño are now facing new challenges. This study extends the previous understanding of EP El Niño-Australian rainfall teleconnections, exhibiting that CP El Niño can bring much broader and stronger rainfall deficiencies than EP El Niño during austral spring (September-November) over the northern Australia (NA) and eastern Australia (EA), in which the CP El Niño-Australian rainfall correlation coefficient generally exceeds 0.4 even without the covariance of IOD. In particular, we demonstrate that the CP El Niño can affect extratropical eastern Australian rainfall via the Pacific-South American (PSA) pattern no matter whether it co-occurs with IOD, while the influence of EP El Niño is only confined in equatorial Australia because its PSA pattern sits far too east to convey the variability of EP El Niño. With the development of ENSO diversity since 2000, the footprint of El Niño on Australian rainfall has become more complex. Therefore, particular attention need to be paid to rainfall in NA and EA when doing forecasts on El Niño-related rainfall in the future.

Can summer intraseasonal easterly wind bursts stall 2014 El Nino?

Xia Zhao
CAS Key Laboratory of Ocean Circulation and Waves, and Center for Ocean Mega‐Science, Institute of Oceanology, Chinese Academy of Sciences, Qingdao, China
zhaoxia@qdio.ac.cn

The relationship between the tropical Indian Ocean basin mode (IOB) of sea surface temperature anomalies (SSTA) during winter and the central Pacific (CP) ENSO during the following fall-winter is investigated in observations. Results show that the positive (negative) IOB is one possible contributor to the initiation of CP La Niña (El Niño) about one year later, especially during 1980-2002. However, the forcing of positive IOB events on the CP La Niña events is more significant, compared to the weak impact of negative IOB on the CP El Niño. Warming in the tropical Indian Ocean during winter produces easterly wind anomalies over central-to-western Pacific, which results in cooling in the central Pacific during the following summer-winter. This result implies that the positive IOB in the tropical Indian Ocean is one import factor in generation of the CP La Niña, which contributed to the asymmetry of the CP ENSO.

Observational and numerical study on the deep circulation in the South China Sea

Xiaolong Zhao
North China Sea Marine Forecasting Center, Ministry of Natural Resources of the People's Republic of China, Qingdao, P. R. China.
zhaoxiaolong@ncs.mnr.gov.cn

The South China Sea (SCS) is the largest marginal sea of the northwest Pacific Ocean and plays a significant role in thermohaline circulations of the Pacific and Indian Ocean. Three moorings equipped with 10 current meters and 7 CTDs were deployed in the Bashi Channel, the main deep connection between the northwestern Pacific Ocean and the SCS, from August 2010 to April 2011 to investigate the deepwater overflow of the North Pacific Deep Water through it. Deep western boundary current (DWBC) was observed for the first time by an array of 6 current meter moorings in the SCS deep basin southeast of the Zhongsha Islands during the period from August 2012 to January 2014. Deep circulation in the SCS is investigated using results from mesoscale-eddy-resolving, regional simulations using the Hybrid Coordinate Ocean Model (HYCOM) verified by continuous current-meter observations. Analysis of these observational and numerical results provides a detailed spatial structure and temporal variability of the deep circulation in the SCS.