2017 CLIVAR International Symposium on Boundary Currents

The “2017 CLIVAR International Symposium on Boundary Currents” was successfully held in Qingdao, China on 5-7 June 2017. At the symposium, about 200 oceanographers and young scholars congregated and discussed the recent advances and challenges towards understanding of the Boundary Current dynamics and interactions. The symposium covered 3 themes: 1) mechanism and interaction of multi-scale processes of the oceanic Boundary Currents; 2) role of Boundary Current systems in climate variability and change; 3) interactions between Boundary Currents and marginal seas, as well as their footprint in ecosystem response.

Session 1: Mechanism and interaction of multi-scale processes of the oceanic boundary currents

With the development of science and technology, both oceanic observation capability and model simulation experienced significant improvement. Based on these, marine scientists have conducted a lot of theoretical analysis and formed consensuses on the interaction of multi-scale processes in the ocean. This session focused knowledge at present and in the following years.

Prof. Bo Qiu (University of Hawaii) reported the predictability of the Kuroshio Extension (KE) with 5-6 years ahead and its mechanism: 1) Rossby wave adjustment in the KE area, 2) variability of the KE triggering a negative feedback in the atmosphere, which further enhances the variability of the KE within a time scale of 10 years. This report had great scientific significance and sparked heated discussions.

Prof. Bishop (NC State University) introduced the latest research on air-sea interaction in mid-latitudes, especially near the western boundary. His research demonstrated that the variability of sea surface temperature (SST) with time scale longer than months is caused by interior oceanic processes. Moreover, impact of oceanic processes (such as eddies) increases with its time scale but decreases with its spatial scale. This conclusion challenges the traditional view which speculated that low-frequency variability of SST is determined by heat exchange between ocean and atmosphere and variability

of atmosphere, providing new development direction for coupled models.

Dr. Yongchui Zhang (an early career scientist from National University of Defense Technology) introduced the case of a vertical southward-titling eddy south of the Kuroshio in 2006 and analyzed the transformation processes from mesoscale eddies to submesoscale turbulence. Based on the observations, he found that this transformation processes are not sensitivity to depth. This work reflects the characters of eddies in the real oceans, sparking heated discussions.

Dr. Yu Liu (an early career scientist from Nanjing University of Information Science and Technology) introduced research on the eddy characters in the East China Sea. Based on both observations and high-resolution model output, his team analyzed the asymmetry of two submesoscale eddies with focus on the horizontal shear and found the unique characters of eddies in the western boundary area.

Based on observations of temperature and salinity in the northern South China Sea during four seasons, Dr. Hongyang Lin (a young scholar from Ximen University) analyzed the seasonal variability of submesoscale turbulence in the upper ocean. He found that the development of submesoscale turbulence is accompanied by the deepening of mixing layer, weakening of the stratification and smaller Richardson number. Dr. Yu Liu (a young scholar from Nanjing University of Information Science and Technology) discussed the energy cascade in the nonlinear hydrodynamics, which is widespread in ocean and atmosphere.

Session 2: Role of Boundary Current systems in climate variability and change

Over the recent two decades, climate change has arisen as one of the hottest topics faced by human society in general and geophysical researchers in particular. This session focused on the interaction and impacts between boundary currents and the overlying atmosphere. In this session, the critical climatic factors related to human living and society, especially the boundary currents were discussed explicitly by experts and scholars.

Prof. Wenju Cai (the principal investigator from QNLM) presented a

review of the main progresses that have been made in the last decade to improve our understanding of the Pacific western boundary circulation and its connection with tropical climate variability. These progresses were achieved in large part because of several international programs, such as Northwest Pacific Ocean Circulation and Climate Experiment (NPOCE), Southwest Pacific Ocean Circulation and Climate Experiment (SPICE), and the CLIVAR Pacific Panel, which have been galvanizing international efforts by providing research and logistics coordination. Much is yet to be learnt, in the pan-Pacific context though, for example, in the following areas:

- Characteristics, dynamics, and climatic impact of deep western boundary currents;
- Quantification, pathway and dynamics of the south and north Pacific exchange, involving the Indonesian Throughflow;
- The role of low-latitude western boundary currents in the heat, freshwater and mass balance of the equatorial Indo-Pacific, particularly the maintenance and variability of the western Pacific warm pool;
- Dynamics of the Pacific equatorial cold tongue, its representation in climate models, and alleviation of the common bias;
- Tropical and extratropical interactions and their role in climate variability.

In the end, Prof. Cai pointed out, that the knowledge of how the above processes may respond to greenhouse warming, or what difference the 1.5°C warming target of the Paris agreement will make to that under the business-as-usual scenario, deserves further research.

Prof. Shangping Xie (the Sverdrup Gold Medal winner from Scripps Institution of Oceanography) delivered the impacts of boundary currents on typhoon activities and possible mechanisms. He proposed that, the thermocline shoals in the South China Sea (SCS) relative to the tropical northwest Pacific Ocean (NWP) can explain the difference of typhoon ocurrences between the SCS and western Pacific. It is found that over the past 37 years, typhoons that strike Asia have intensified by 12-15%. The reason for the increased intensity of landfalling typhoons is suggested to be associated with the enhanced warming over the subtropical western boundary currents proposed by Lixin Wu.

Prof. Ping Chang (Texas A&M University) introduced the dynamics of mesoscale SST in the KEJ region. It is found that mesoscale SST is far more sensitive to SSH changes north of the KEJ than along the KEJ, suggesting that the mesoscale eddies north of the KEJ are much more effective to produce mesoscale SST anomalies. Further analysis indicates that the enhanced sensitivity of mesoscale SST to SSH north of the KEJ mainly results from three major factors：1) the smaller thermal expansion coefficient due to the colder seawater；2) the compensation effect by sea-surface salinity due to the strong salinity gradient; 3) the shallower eddy vertical structure due to the stronger stratification. This novel results provide new ideas for the ocean-atmosphere coupling mechanisms in the western boundary currents region.

Prof. Hisashi Nakamura (the university of Tokyo) introduced the influence of western boundary currents and the associated oceanic frontal zones on the overlying atmosphere. Prof. Chunzai Wang (the South China Sea Institute of Oceanology) delivered the topic of variability of tropical cyclones in the western North Pacific. Prof. Niklas Schneider (the university of Hawaii) introduced the dynamics of the wind stress response to ocean mesoscale surface temperature over the Agulhas Retroflection. Prof. Shoshiro Minobe (Hokkaido University) presented the storm-track response to SST fronts in the Northwestern Pacific region in an AGCM. Prof. Minobe said that it’s the third time that He participates in the “International Symposium on Boundary Current Dynamics” and spoke highly of this meeting. He considered the meeting as an excellent platform for academic discussion and international research cooperation and he sincerely looks forward to the next few sessions.

Session 3: Interactions between Boundary Currents and marginal seas, as well as their footprint in ecosystem response

In recent decades, with improvement of in-situ observation, remote sensing, high-resolution numerical models, as well as theoretical exploration and laboratory experiments, our understanding of the dynamics of boundary currents and their impacts on open-ocean and marginal-sea exchanges and interactions has significantly advanced. In this session, the achievements in

relevant scientific researches were reviewed, and latest scientific findings were discussed.

Prof. Dong-Ping Wang, famous for research study of Gulf Stream Dynamics, reviewed the exchange processes between the Middle Atlantic Bight (MAB) off the U.S. East Coast, and the Gulf Stream. He pointed out that the occasional impinging of warm rings could have major impact on the cross-shelf exchange. The inner shelf water, on the other hand, is less affected by the frontal processes. It is ultimately entrained into the Gulf Stream at the southern end of MAB, and subducted in cold, cyclonic eddies. He emphasized that the study of interaction between deep-ocean and marginal seas has advanced from large scale (thousands of km), bypassing meso-scale (on the order of 10-100 km), to sub-mesoscale with typical horizontal scale of 1km, and fluids dynamics extend from quasi two dimensional to complex fully three dimensional. Hydrodynamics theories changes a lot and becomes much more complicated. This is a problem that shall be solved immediately on practical application and academic research level, and is a hot research topic all over the world as well as a great challenge.

Prof. Jianping Gan, an expert on study of marginal sea hydrodynamics and biogeochemical cycle from Hong Kong University of Science and Technology, showed his simulation results for Marginal China Seas by a carefully designed hydrodynamical-biogeochemical-coupled Regional Ocean Modelling System, and the validation compared with in-situ ocean observations. The SCS and East China Sea (ECS), where intense interaction and exchange with Kuroshio Current and Western Pacific Ocean take place, are highlighted in his presentation. The three-layered ocean current structure, its driving mechanism and the water exchange characters between SCS and Western Pacific are analyzed. Not only accurate numerical simulation is demonstrated, but also clear dynamical explanations are proposed. Furthermore, in close connection with realistic application especially those related to human near-shore activities, Prof. Gan discussed the associated biogeochemical influences. This work provides a nice platform and software system for studying physical and biogeochemical environments in China Marginal Seas.

Internationally well-known expert in biogeochemical research area, Prof. Minhan Dai from Xiamen University talked about their systematic research products on the biogeochemical conduit of the western ocean boundary current in the ocean-margin exchange. He analyzed the biogeochemical cycle in the SCS, especially Carbon budgets. Taking nutrients as a target, Prof. Dai discussed the relative importance of local source and sink, compared with advective transports by Kuroshio intrusion from Luzon Strait. Kuroshio is characterized by extremely low nutrients but high dissolved organic carbon (DOC) concentrations along with different microbial community composition. The intrusion of Kuroshio waters into the SCS would thus bring about a significant amount of DOC. Their incubation experiments revealed that the degradation rate of Kuroshio DOC was substantially enhanced when inoculated with the SCS bacteria, suggesting that the biodegradation of Kuroshio DOC was altered when entered in the SCS with a different microbial community regime. Because of its great realistic significance, Prof. Dai's systematic and innovative research results bring heated discussion.

Prof. Isobe (Kyushu University) introduced their research about Kuroshio variability south of Japan and further upstream in ECS. When Kuroshio advances its journey interacting with ECS topography, strong water mass and energy exchanges happen. This not only affects hydrological environment in ECS, but also has great impacts on climates and fishery resources, hence it is always a key problem causing lots of research discussion. Prof. Isobe analyzed Kuroshio's influences on near-shore hydrological environment at three typical time scales: Decadal, Seasonal, and Synoptic. Through theoretical modeling combined with numerical simulation and in-situ observation, he revealed the different dynamic characters and physically dominating mechanism: at synoptic time scale the dominating factor is Kuroshio frontal eddies and unusual tide events; at seasonal time scale, coastal trapped waves and gravity waves from the "north" dominates; at decadal time scale, it is highly connected to the intrinsic chaotic fluctuations of subtropical gyre and nonlinear western boundary current system.

There were also several wonderful discussions, given by early career scientists, about boundary layer flow dynamics, physical generation

mechanism of yellow sea warm current and so on.

This meeting brings together scientists of international scientific community working in the field of ocean and climate, with the support from the CLIVAR. It explores frontier scientific issues such as response of western boundary system and offshore dynamic process to climate change, which further promotes the international cooperation in basic ocean and climate research and provides scientific support to deal with climate change. As event with great influence, this meeting has attracted extensive attention and received recognition from home and abroad.

Group Photo