ACM 2017

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S1D Presentation

S1D-1 (Invited Talk)

Super El Ninos and their dynamics

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Super El Ninos are strong and extremely powerful El Ninos with distinct spatial and temporal structures. The distinguishing spatial signature is its extreme SST amplitude at the far eastern Pacific. Its evolution is characterized by rapid growth and termination. Distinct from normal El Ninos, they have a disproportionately large impact on economies, societies and ecosystems through their powerful impacts. Projections with global warming scenarios have suggested that super El Ninos will become more frequent over the next decades and centuries. Despite their great importance, we do not fully understand why and how super El Ninos develop, and why they have a unique spatio-temporal structure. In this talk, we first discuss what is and what is not a super El Nino. In particular we will argue why the extremely warm El Nino of 2015/16 is not a super El Nino. We then proceed to discuss the dynamical reasons for why super El Ninos cannot develop from inherent coupled variations within the tropical Pacific alone. This is shown to be a consequence of the equatorial atmospheric response over the tropical Pacific in combination with the annual cycle of cooling over the cold tongue region. Through these considerations we show that ENSO dynamics on its own is self-limited and prevents strong SST variations from developing over the eastern Pacific. We then introduce a role for the Indian Ocean Dipole. Using dynamical reasoning and numerical simulations, we show that IOD on its own can force a significant SST anomaly over the tropical Pacific mediated by the atmospheric Kelvin response to eastern Indian Ocean convection. We then proceed to demonstrate how all salient features of a super El Nino develops as a result of interaction between Indian Ocean dipole and ENSO dynamics.

S1D-2

Coherent climate anomalies over the Indo-western Pacific in post-El Nino summer

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El Nino typically peaks in boreal winter, and the associated equatorial Pacific sea surface temperature (SST) signal dissipates before subsequent summer. Its impact, however, outlasts until boreal summer in the Indo-western Pacific, featuring basin-wide Indian Ocean warming and tropical Northwestern Pacific cooling accompanied by the Pacific-Japan (PJ) teleconnection pattern with surface anomalous anticyclone (AAC) extending from the Philippine Sea to the northern Indian Ocean. Two formation mechanisms have been proposed for these climate anomalies in post-El Nino-Southern Oscillation (ENSO) summer. One hypothesis invokes the wind-evaporation-SST (WES) feedback in the tropical Northwestern Pacific, while the other points to inter-basin feedback between the Indian Ocean and tropical Northwestern Pacific. Based on a coupled model experiment, we propose an ocean-atmosphere coupled mode that synthesizes the two mechanisms. This Indo-western Pacific Ocean capacitor (IPOC) mode evolves seasonally from spring to summer under seasonal migration of background state. In spring, the WES feedback is operative in association with the tropical Northwestern Pacific cooling, whereas in summer the Indian Ocean warming and the inter-basin interaction maintains the AAC. While the IPOC mode is independent of ENSO in mechanism, ENSO can drive this mode in its decay phase, bringing seasonal predictability to the summertime Northwestern Pacific.

S1D-3

Impact of the ocean front on the climate variability over the Korean peninsula in summer

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The ocean is known to be able to induce variation of the atmospheric circulation through the interaction by exchanging heat energy, in particular, the Korean peninsula can be affected by marginal sea, because it surrounded by ocean. In addition, the Korean peninsula is located in mid-latitude and has the largest meridional gradient of sea surface temperature along with the Gulf Stream region which can be affected by the ocean front. However, research on the relationship between climate variability and the ocean front on the Korean peninsula has yet to be actively studied.

In this study, the effects of the marginal ocean front on summer temperature and precipitation over the Korean peninsula are examined. In order to evaluate effect of the ocean front, we defind the marginal ocean front index as the difference of sea surface temperature between Korean marginal sea (120-140 ˚E, 30-40 ˚N) and Western North Pacific (120-140 ˚E, 20-30 ˚N), where correlation related to climate on the Korean peninsula are reversed.

The ocean front and climate on the Korean peninsula is found to be significantly related. The ocean front and marginal sea surface temperature are negatively correlated and positively with Western North Pacific which mean meridional gradient of sea surface temperature become strong. In addition, it increases the meridional gradient of atmosphere temperature because of changing sensible and latent heat flux and the atmospheric pressure instability. In the region where has high baroclinic instability, westerly wind blows which can be explained for thermodynamic reasons. It causes an anomalous low pressure flow over the Korean peninsula and a high pressure in the Western North Pacific region. It means that the North Pacific high which affects the climate of the Korean peninsula in the summer has not risen. As a result, the temperature over the Korean peninsula tends to be lower than normal and precipitation is higher. In order to quantitatively examine the effect of the ocean on the Korean climate in summer, a composite analysis is conducted. During the analysis period of 31 years (1982-2012), six samples are extracted and composited according to the high and low ocean front index. When the ocean front is strong, the temperature over the Korean peninsula is about 1 ºC lower than normal and the precipitation is about 1.1mm/day more than normal. On the other hand, then the ocean front index is weak, the temperature over the Korean peninsula is about 0.8ºC higher than normal and the precipitation is about 1.3mm/day lower than normal in summer and it is a significant difference at 95% confidence level.

S1D-4

Unraveling El Niño's impact on the East Asian Monsoon and Yangtze River summer flooding

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Strong El Nino events are followed by massive summer monsoon flooding over the Yangtze River basin (YRB), home to about a third of the population in China. Although the El Nino-Southern Oscillation (ENSO) provides the main source of seasonal climate predictability for many parts of the Earth, the mechanisms of its connection to the East Asian monsoon remain largely elusive. For instance, the traditional Nino3.4 ENSO index only captures precipitation anomalies over East Asia in boreal winter but not during the summer. Here we show that there exists a robust year-round and predictable relationship between ENSO and the Asian monsoon. This connection is revealed by combining equatorial (Nino3.4) and off-equatorial Pacific sea surface temperature anomalies (Nino-A index) into a new metric that captures ENSO's various aspects, such as its interaction with the annual cycle and its different flavors. This extended view of ENSO complexity improves predictability of YRB summer flooding events.

S1D-5

Comparison of the Convective Boundary Layers of the Atmosphere and the Ocean

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The convective boundary layer (CBL) in the atmosphere, generated under surface heating, is characterized by the well-mixed layer with strong entrainment at the inversion layer, which is driven by large-scale convective eddies. The existence of almost uniform temperature within the CBL makes it difficult to parameterize the vertical mixing based on eddy diffusivity, as it causes the counter-gradient heat transport. Therefore nonlocal mixing is often introduced to cope with this difficulty, as in the case of the K-profile model (Troen and Mahrt 1986). The CBL is also characterized by asymmetry of the vertical velocity field; that is, strong updrafts covering a relatively small fraction of the area, with weak downdrafts in between.

The CBL in the ocean, generated under surface cooling, is also driven by large-scale convective eddies, and thus shows many similar characteristics to the CBL in the atmosphere; i.e., the well-mixed layer with strong entrainment at the mixed layer depth. Therefore the same model as used in the atmospheric boundary layer (ABL), such as the K-profile model, has been also applied to the ocean mixed layer (OML). Nonetheless the presence of the free surface makes the OML fundamentally different from the ABL in many aspects. It generates many features unique in the OML such as wave breaking, Langmuir circulation, and inertial oscillation. For example, wave breaking causes the turbulent kinetic energy (TKE) becomes very large near the surface in the OML, whereas it becomes very small in the ABL. Therefore, it may not be guaranteed that the same model used in the ABL can be applied to the OML as it is.

Therefore, with an aim to understand the difference in the mixed process between two CBLs, we compare the CBLs of the atmosphere and the ocean, by analyzing LES results obtained under various conditions with different surface heat flux, wind stress, Coriolis parameter, Langmuir parameter, and initial profile. We compare various physical features of the CBL, including the profiles of TKE, velocity, temperature, stratification, shear, and heat flux, the TKE budget, the entrainment rate, the effect of the Coriolis force, and the probability distribution of vertical velocity. It is found that, in the CBL of the ocean, the effect of the Coriolis force is stronger, the role of nonlocal mixing is weaker, and the probability distribution of vertical velocity is more symmetric. Based on the comparison of the CBL, we suggest the modification of the K-profile model for the OML.