특별세션 1 / English Session 1-1

Seasonal Prediction of Wintertime North Pacific Blocking: What Are We Capturing and Missing?

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During boreal winter, atmospheric blocking, which is characterized by persistent, quasi-stationary high-pressure anomalies, often drives the occurrence of cold extremes in remote regions through cold horizontal advection and anomalous surface radiative flux. However, due to the chaotic nature of the extratropical atmospheric circulation and errors in state-of-the-art climate models in the simulation of blocking, the prediction of blocking remains a challenging task. In this study, by leveraging both observational data and a state-of-the-art seasonal prediction model developed at the Geophysical Fluid Dynamics Laboratory, SPEAR (Seamless System for Prediction and Earth System Research), we investigate the prediction skill of North Pacific wintertime blocking frequency and its linkage to downstream cold extremes.

The observational results show that the climatological blocking frequency during boreal winter has a local maximum over the central North Pacific Ocean and that the occurrence of North Pacific blocking drives significant cold anomalies over northwestern North America within a week. These observed features of North Pacific blocking are well reproduced by the model. Regarding the blocking prediction skill, the model results show that the frequency of the western North Pacific blocking nearby the subtropical jet exit region can be skillfully predicted at the shortest forecast lead, but skill drops off rapidly with lead time. In observation, these western North Pacific blocking events are triggered by localized tropical convection anomaly over the tropical Indian Ocean and central tropical Pacific Ocean, which excites a poleward propagating Rossby wave train and decelerates the subtropical jet accompanied by its equatorward shift. Prompted by skillful seasonal prediction of sea surface temperature variability, a hybrid dynamical-statistical model of winter blocking frequency using SPEAR-forecasted predictors is constructed and shows the potential for skillful predictions up to seven months. Our results indicate that an improvement in the seasonal prediction skill of winter North Pacific blocking frequency may be achieved by the representation of the links among sea surface temperature anomalies, tropical convection, and the ensuing tropical-extratropical interaction that initiates North Pacific atmospheric blocking.

특별세션 1 / English Session 1-2

Recovery of the warm Arctic – cold Eurasia relationship by CO_2 removal

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Cold temperature anomaly over central Eurasia (CE) is often associated with warm temperature anomaly over the Barents-Kara Seas (BKS) on intraseasonal to interannual timescales. This phenomenon, termed the warm Arctic-cold Eurasia (WACE) relationship, has been shown to weaken as CO_2 concentrations keep increasing. Here, its reversibility is examined by analyzing a carbon dioxide removal experiment where atmospheric CO_2 concentrations are quadrupled then reduced to the initial levels. As CO_2 concentrations increase, the co-variability between the BKS and CE surface air temperatures weakens, on both intraseasonal and interannual time scales. This weakened relationship recovers when CO_2 concentrations are reduced. The spatial pattern of co-variance between CE and BKS surface air temperatures anomalies at the end of CO_2 removal becomes consistent with that of the initial state. It is shown that the temporal changes in WACE-like co-variability are largely modulated by the baroclinity changes which are mostly due to the meridional temperature gradient changes. This finding suggests that the weakening of the intraseasonal and interannual WACE relationship in a warming climate can be recovered by CO_2 mitigation.

Keywords: temperature co-variability, warm Arctic – cold Eurasia pattern, carbon dioxide removal, meridional temperature gradient

특별세션 1 / English Session 1-3

The North Atlantic Climate Predictability on Interannual – to Decadal Timescales.

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External forcings, such as slowly varying greenhouse gases and the natural variabilities internal to the Earth's system, serve as the primary sources of climate predictability. It is essential to distinguish between the internal and external components to enhance our understanding of climate change and improve predictions, particularly regarding the predictability linked to natural variabilities. The North Atlantic is peculiar due to its profound natural variabilities across various timescales, making it a region with notable long-term climate predictability. Among these variabilities, the Atlantic Multidecadal Variability (AMV) and the Atlantic Meridional Overturning Circulation (AMOC) are the key contributors to this long-term predictability. Here, we investigate the Interannual to Decadal (I2D) predictability of the North Atlantic climate associated with these prominent natural variabilities. A major challenge lies in defining indices that accurately represent this variability while isolating the effects of external forces. In this study, we analyze and compare several widely used indices to assess their applicability in the context of North Atlantic climate predictability. Additionally, we examine the importance of temperature and salinity information for initialization using a newly developed multi-year prediction system based on the CESM2 model (CESM2-MP). Our findings indicate that certain indices effectively describe natural variability from a predictability viewpoint. Furthermore, improved representation of temperature and salinity in the initialization, particularly salinity, significantly enhances the hindcast skill in North Atlantic climate predictions.

특별세션 1 / English Session 1-4

Data-driven AI for identifying diverse AMOC evolution

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Tipping elements—components of the Earth system that can undergo abrupt transitions near critical thresholds—raise concerns about whether ongoing climate change could drive them toward collapse, and if so, how fast and how severe such changes might occur. However, traditional anticipation is usually not applicable to those elements, suggesting deep learning-based strategies. In this study, we employ recent Earth system model experiments simulated bifurcation characteristics of Atlantic Meridional Overturning Circulation (AMOC), build a convolutional neural network that successfully distinguishes the collapsed and recovered ensemble members. The data-driven model is also utilized to understand the mechanisms and processes underlying the AMOC behavior, highlighting the salinity structure as a key feature from which the CNN extracts higher-order statistical information, consistent with theoretical expectations. Finally, the salinity bias between observations and model simulations—likely contributing to the over-stable AMOC in models—suggests that the critical threshold may lie closer than model-based projections currently indicate.

Keywords: AMOC, Tipping, stability, Deep learning

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특별세션 1 / English Session 1-5

Changes in Tropical Cyclone Seed Predictor over the Western North Pacific under Carbon Dioxide Removal

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Tropical cyclones (TCs) are among the most destructive natural disasters threatening densely populated regions in the western North Pacific (WNP). Understanding their response to climate forcings is thus essential for adaptation planning. While TC changes under global warming have been comprehensively studied, less is known about their potential recovery via climate mitigation, such as carbon dioxide removal (CDR), with only a few recent studies proposing a hysteretic suppression of TC genesis over WNP under CDR. Meanwhile, several recent studies indicate that precursory disturbances of TCs, termed "TC seeds", significantly contribute to variations in TC frequency. However, the response of TC seeds to CDR and their importance in the hysteresis of TC genesis remain unaddressed. In this study, we investigate changes in the TC seed frequency predictor over the WNP basin in a large-ensemble climate model simulation imposed with an idealized symmetric CO_2 pathway. It is found that WNP TC suppression under CDR is primarily attributable to a similar hysteretic decrease in the TC seed frequency predictor. Reduction in the TC seed frequency predictor is consistent with suppressed tropical convection over WNP, which is associated with enhanced longwave radiation loss by reduced cloud cover and internal positive feedback. These changes are presumably linked to anomalous anticyclonic circulation over WNP, possibly induced by El Niño-like sea surface temperature changes. Our results highlight a potentially important role of synoptic-scale disturbances in changing WNP TC genesis and their possible connection with large-scale circulation changes under CDR.

Keywords: Western North Pacific, Tropical cyclone seed, Carbon dioxide removal, Hysteresis

특별세션 1 / English Session 1-6

Improving Tropical Cyclone Intensity Projections Under Climate Change Using the Coupled PGW (Pseudo Global Warming) Approach

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Current studies on tropical cyclone (TC) projections use a storyline approach or pseudo-global warming (PGW) approach, which uses climate deltas to incorporate the future effect of climate change on TCs. However, most of these PGW simulations employ atmosphere-only models, which neglect the ocean feedback mechanisms (e.g., vertical mixing and TC-induced sea surface temperature (SST) cooling) that are a critical process in TC intensification. In this study, we use the Coupled Ocean–Atmosphere–Wave–Sediment Transport (COAWST) modeling system combined with the Pseudo Global Warming (PGW) approach to simulate Typhoons Maysak and Haishen (2020) under the high-emission SSP5-8.5 scenario. COAWST allows a dynamic coupling between the atmosphere and ocean, allowing us to assess how TC-induced vertical mixing modulates future TC intensity. Results show that atmosphere-only PGW runs significantly overestimate storm intensity compared to coupled simulations. On the other hand, the coupled PGW simulations demonstrate that vertical mixing results in SST cooling beneath the cyclone's inner core, reduces surface heat fluxes, and ultimately limits intensification. These findings highlight the critical role of ocean feedback, which varies with storm size and speed, in modulating TC response to climate change. The use of the coupled PGW approach produces more realistic results that reduce the uncertainty in future TC risk assessments. Our findings underscore the necessity of using coupled models for future cyclone simulations, particularly for vulnerable areas where high-risk infrastructure, such as nuclear power plants and coastal flood protection measures, requires accurate and reliable climate projections.