기후 분과 / 기후 5-1

On the spatial double peak of the 2023-24 El Niño event

Jong-Seong Kug

Seoul National University, Seoul, South Korea

The recent 2023-24 El Niño has raised widespread concern in scientific and public communities. Here, using latest observational reanalysis, we show that this event matured with two distinct spatial peaks of sea surface temperature (SST) anomaly in the equatorial central and eastern Pacific, respectively. Like other double-peaked (DP) El Niños, the central Pacific SST peaked in winter due to zonal advective and thermocline feedbacks. However, the eastern counterpart matured asynchronously in autumn and then stopped growing. This peculiar behavior results primarily from a cooling zonal advection by the anomalous westward current in the eastern Pacific during the autumn of 2023, which is associated with the local wind-driven sea surface height (SSH) meridional concavity. We further propose that the relatively stronger and more eastward-displaced autumn precipitation in the Pacific intertropical convergence zone in 2023, compared to other DP El Niños, is the primary cause of this distinct wind and SSH pattern.

Key words: El Nino, Double peak, air-sea interaction

기후 분과 / 기후 5-2

Sub-seasonal ENSO Impact on the Indian Ocean Dipole Development

Hyo-Jin Park[1], Soon-Il An[1,2,3], Jae-Heung Park[4], Young-Min Yang[5] and Soong-Ki Kim[2]

[1]Department of Atmospheric Sciences, Yonsei University
[2]Irreversible Climate Change Research Center, Yonsei University
[3]Division of Environmental Science and Engineering, Pohang University of Science and Technology
[4]School of Earth and Environmental Sciences, Seoul National University
[5]School of Civil, Environmental, Resources and Energy Engineering, Jeonbuk National University

The Indian Ocean Dipole (IOD) is a dominant interannual climate variability in the tropical Indian Ocean that influencessurrounding weather patterns and marine ecosystems. The evolution of IOD from spring to fall is known to significantly affected by ENSO. Here, we examine impact of ENSO on IOD development from a sub-seasonal perspective using a simple IOD model with observational-reanalysis datasets. We revealed that the ENSO impact, determined by both the sensitivity of IOD to ENSO and the intensity of ENSO, intensifies sharply after the early summer due to the semi-annual pattern of the sensitivity and developing ENSO. The sensitivity of IOD growth to the ENSO remarkably reduces in May and June, while it enhances in April and August. The reduced sensitivity in early summer is due to ENSO-induced positive wind stress curl in the western Indian Ocean, in association with northward movement of ITCZ. This effectleads to a negative Ekman feedback that disrupts IOD growth in May and June. Consistent results are also observed in mLBM experiments. Our study underscores the necessity in understanding of IOD evolution on sub-seasonal time scales.

Key words: Indian Ocean Dipole, evolution, Sub-seasonal impact, El Niño – Southern Oscillation (ENSO)

기후 분과 / 기후 5-3

Significant Winter Atlantic Niño effect on ENSO and its future projection

Jae-Heung Park[1], Jong-Seong Kug[1], Young-Min Yang[2], Yoo-Geun Ham[3], Hyun-Su Jo[3], Hyo-Jin Park[4], So-Eun Park[4], Chao Liu[4],Gagan Mandal[4], Soon-Il An[4]

[1]School of Earth and Environmental Sciences, Seoul National University
[2]School of Civil, Environmental, Resources and Energy Engineering, Jeonbuk National University
[3]Environmental Planning Institute, Seoul National University
[4]Department of Atmospheric Sciences/Irreversible Climate Change Research Center, Yonsei University

The Atlantic Niño, a primary climatic variability mode in the equatorial Atlantic Ocean, exhibits pronounced variability not only in boreal summer but also in winter. However, the role of Winter Atlantic Niño in trans-basin interactions remains underexplored compared to its summer counterpart. Through analysis of observational reanalysis data since the mid-twentieth century, here we found that Winter Atlantic Niño significantly influences the development of El Niño–Southern Oscillation (ENSO), surpassing the impact of Summer Atlantic Niño with a longer lead time. This effect is reasonably captured in the CMIP6 historical simulation from a multi-model ensemble perspective. Further analysis of the global warming scenario projects that the influence of Winter Atlantic Niño on ENSO will persist into the future, contrasting with a reduced impact of Summer Atlantic Niño. Therefore, these findings underscore the importance of further investigating Winter Atlantic Niño for a comprehensive understanding of trans-basin interactions and their future change.

Key words: Atlantic Niño, El Niño–Southern Oscillation (ENSO), Trans-basin Interaction

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기후 분과 / 기후 5-4

엘니뇨-남방 진동(ENSO)에 의한 습윤 정적 에너지 수송의 변동성 분석

홍채은, 유창현, 정다정, 허이제

이화여자대학교 기후에너지시스템공학과

본 연구는 엘니뇨-남방 진동(El Niño - Southern Oscillation)에 따른 습윤 정적 에너지(Moist Static Energy) 수송의 변동성에 대한 분석을 진행하였다. 습윤 정적 에너지 수송은 평균 자오면 순환(Mean Meridional Circulation)과 소용돌이(Eddy)로 나뉘며, 소용돌이는 정체 에디(Stationary Eddy)와 일시 에디(Transient Eddy)로 분류된다. 위와 같은 세 가지 수송 방법을 각각 살펴봄으로써 ENSO에 따른 습윤 정적 에너지 수송의 변동성에 대한 기여도를 분석하였다. 기후학적으로 습윤 정적 에너지는 극 방향으로 수송되지만, ENSO가 발생하였을 때 15°-40°N사이에서는 수송이 약화되었고, 이 외의 지역에서는 수송이 강화되었다. 이러한 습윤 정적 에너지 수송의 변동은 평균 자오면 순환이 가장 크게 기여하는 것으로 나타났다. 중위도에서 정체 에디와 일시 에디 모두 큰 변동성을 보이지만, 두 에디가 서로 크게 상쇄되어 기여도가 낮아진다. 지오포텐셜 에너지(Geopotential Energy)는 ENSO와 관련된 습윤 정적 에너지 수송의 변동에서 가장 중요한 요소로 나타나며, 평균 자오면 순환이 지오포텐셜 에너지 수송을 대부분 설명한다. 중위도에서의 에디에 의한 습윤 정적 에너지 수송의 변동성은 주로 현열(Sensible Energy)과 잠열(Latent Energy)의 에디에 의한 수송의 변동성으로 설명된다. 평균 자오면 순환을 통한 습윤 정적 에너지 수송의 변동은 주로 해들리 순환의 변동으로 영향을 받는다. 정체 에디의 경우 ENSO에 따른 남북 풍(Meridional Wind)의 변화와 에너지 구성요소의 변화 둘 다 변동성에 영향을 끼친다. 반면, 일시 에디에 의한 습윤 정적 에너지 수송의 변동성의 경우 에너지 확산(Diffusive) 관점에서 이해할 수 있다.

Key words: 습윤 정적 에너지, 에너지 수송, 엘니뇨-남방진동(ENSO), 평균 자오면 순환, 에디

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기후 분과 / 기후 5-5

The changes in the impact of ENSO on global economical growth under climate mitigation scenarios

Geon-Il Kim, Dong-Kyu Park, Jong-Seong Kug

School of Earth and Environmental Sciences, Seoul National University

The El Niño-Southern Oscillation (ENSO) is a climate phenomenon that affects global extreme weather events, often with significant economic impacts. It is of utmost importance to understand the extent of these impacts on the economy and how they will change in response to anthropogenic forcing. In this study, we quantify the economic impact of ENSO by fitting observations using a nonlinear climate-economic model that accounts for both the strength and spatial asymmetry of El Niño and La Niña. The extreme El Niño events of 1997-98 and 2015-16 resulted in global economic losses of $2.3 trillion and $3.7 trillion, respectively. In contrast, the effects of La Niña are asymmetrical and weaker, with the 1998-99 extreme La Niña event generating only a modest economic gain of $0.15 trillion. Furthermore, the economic losses associated with El Niño are exacerbated by climate change. Despite reductions in atmospheric CO_2 levels due to mitigation strategies, the increased economic losses decline at a slower rate because of the rise in ENSO teleconnections and amplified variability over the eastern Pacific. The results highlight the urgency of implementing effective climate mitigation strategies to prevent escalating economic losses from climate variability.

Key words: ENSO, Economy, Carbon mitigation, Climate change

Geographical Distribution of Convectively Unstable Regions and Its Response to Global Warming

Rok Seong, Namyoung Kang

Department of Geography, Kyungpook National University

Due to global warming, there is an overall increase in ocean temperatures results in higher levels of water vapor in the atmosphere. This has raised concerns regarding convective precipitation. The present study introduces the concept of the environmental conditions that trigger convections. The primary objective of this study is to examine the geographical distribution of convective instability and its response to global warming. For investigation, thermodynamic variables at the lower and upper troposphere were chosen, including the dew point temperature at 850hPa in the lower troposphere and the temperature at 500hPa in the upper troposphere. Spatial standardization and principal component analysis are employed to analyze these variables, effectively illustrating the spatial distribution of thermodynamic environments. The two principal components, i.e. in-phase and out-of-phase variations, are utilized as indicators of entire thermodynamic energy and convective instability, respectively. The study area covers the inland region of East Asia (100°E-180°, 0-50°E) as well as encompassing the western North Pacific.

This study effectively identifies the distribution of convective instability and its response to global warming through the application of spatial standardization and principal component analysis. The analysis during the climatological period (1991 – 2020) exhibits the areas of significant convective instability due to continental heating in summer, which is distinctive from the stable regions under the subtropical highs. While the results indicate an overall increase in convective instability in low-latitude regions due to global warming, stabilization is evident in a broader area in mid-latitude regions, including the Korean Peninsula.

Key words: Convective instability, Global warming, Principal component analysis