GLOBAL RESEARCH IMMERSION PROGRAM FOR YOUNG SCIENTISTS

Grips

Analysis of the Pathway of Arctic Oscillation (AO) and El Niño-Southern Oscillation (ENSO) Influence on South China's First Rainy Season (SCFRS)

[1]Yanhao Peng, [2]Lexi Chen, [3]Min Chung and [4]Qazi Muhammad Yasir

[1]Department of Atmospheric and Oceanic Sciences, Fudan University, Shanghai, China

[2]Department of Data science and Statistics, National University of Singapore, Singapore, Singapore

[3]Department of Interdisciplinary Sciences, Faculty of Arts and Sciences, The University of Tokyo, Tokyo, Japan

[4]Department of Geography, Mary Immaculate College, University of Limerick, Limerick, Ireland

Email: [1]20307110043@fudan.edu.cn, [2]e0969983@u.nus.edu, [3]minchung02@g.ecc.u-tokyo.ac.jp, [4]qazi.yasir@ul.ie

Background Introduction

South China first raining season, which contributes to roughly 40 percent of the yearly precipitation in South China, is of great significance in various aspects of human lives during April to June each year. Different atmospheric circulations in mid-latitude areas, which are highly susceptible to distant signals like Pacific decadal oscillations and Arctic Oscillations, can contribute significantly to South China precipitation by triggering interactions among different air masses.

There are existing researches on the influence of distant signals on the spatiotemporal distribution of the South China first raining season. For example, Qin et al. (2023) concluded that the positive sea surface temperature on the Atlantic Ocean that is one year before South China precipitation may pose crucial influence on the atmospheric circulation in East Asia through ways like PNA and EU. Other researches focus on the influence of signals from the Pacific Ocean to the precipitation in China. High latitude signals like sea ice would also affect South China first raining season through Rossby wave activities and land-atmosphere coupling (Peng et al.,2024).

Considering the intimate relationship between distant signals and South China first raining season, we propose a question: whether Arctic Oscillation and El Nino could jointly affect precipitation in southern China during spring, and what is the mechanism? Our discussion is mainly focused on this issue.

Research Objectives

(1) Explore the possible impacts that distant signals (ENSO/AO) may have on South China precipitation.

(2) With that, judge the predictability of South China's weather pattern, which helps prevent/reduce loss from extreme weathers.

(3) Practice the ability in designing academic poster and writing academic essays.

Data and Methods

For the current study, we sourced monthly precipitation data for South China from the ERA5 reanalysis dataset, which offers a high horizontal resolution of 1° × 1°. This data, covering the period from 1950 to 2020, was selected to provide a detailed and extensive view of climatic anomalies within the region. In addition to precipitation data, we also incorporated global monthly reanalysis data from ERA5 at a 2.5° × 2.5° resolution, including variables such as geopotential height, horizontal wind, sea surface temperature, snow depth, outgoing longwave radiation, and relative vorticity. This comprehensive dataset allowed for a thorough investigation of the atmospheric and oceanic conditions influencing the South China climate.

To explore the relationship between the positive phase of the Arctic Oscillation (AO) and the El Niño Southern Oscillation (ENSO) with the South China first raining season, we employed a combination of correlation and composite analyses. These methods were applied to the data from April to June, the period of the first rainy season in South China and adjacent ocean areas. Our goal was to uncover the underlying mechanisms behind the observed weather patterns and to use these insights for predicting future climatic conditions.

Statistical significance of the observed correlations and anomalies was assessed using the T-test. This step was critical in identifying specific areas within the study region that exhibited statistically significant anomalies. By pinpointing these areas, we were able to focus our analysis on the regions most affected by the positive phase of AO/ENSO, thereby enhancing the precision and relevance of our findings.

Results

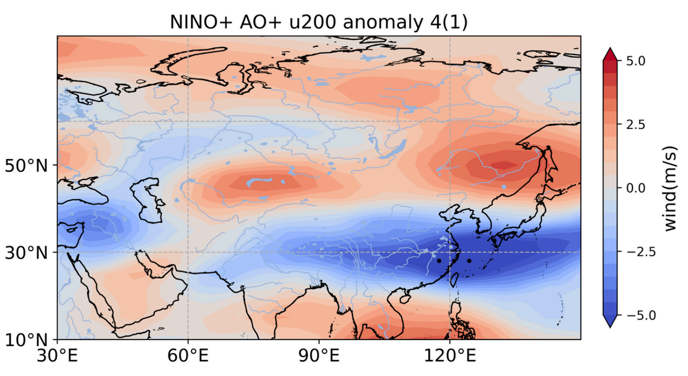

Figure 1. Wind anomaly (in m/s) of April during NINO positive (+) and AO positive (+) phase.

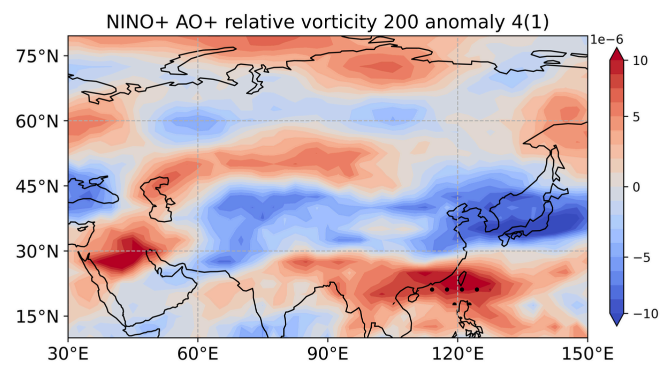

Figure 2. Relative vorticity (at 200hPa) of April during NINO positive (+) and AO positive (+) phase.

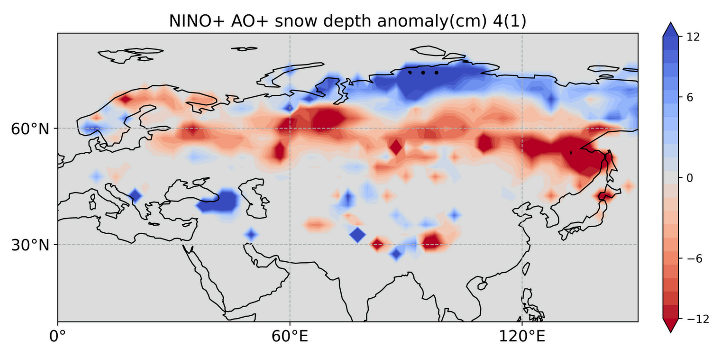

Figure 3. Snow depth anomaly (in cm) of April during NINO positive (+) and AO positive (+) phase.

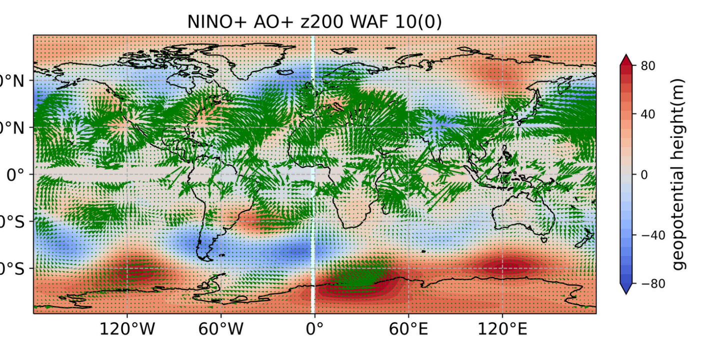

Figure 4. Wave activity fluxes of October during NINO positive (+) and AO positive (+) phase.

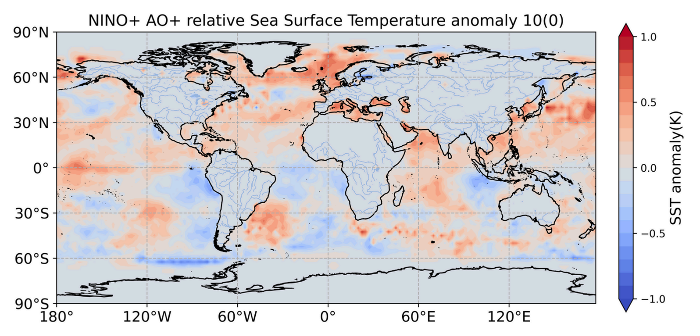

Figure 5. Sea surface temperature anomaly

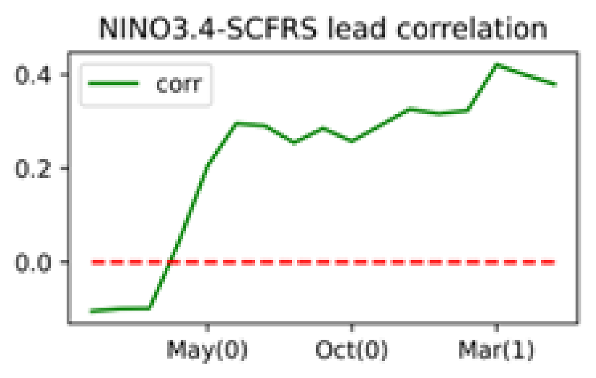

Figure 6. Lead correlation

Conclusion

This research identifies a key pathway linking sea surface temperature (SST) anomalies to wave activity fluxes (WAF) and their subsequent impact on atmospheric conditions. SST anomalies induce Pacific-North American (PNA) teleconnections in October, resulting in positive geopotential height (GPH) anomalies along the east coast of North America. These anomalies initiate eastward-propagating WAF, influencing Northern Eurasia and altering lower-level wind patterns.

The resulting changes affect water vapor transport, triggering anomalous snow depth signals that persist into the spring and impact weather patterns. Notably, WAF generates 200 hPa GPH anomalies, leading to additional wind anomalies and associated precipitation anomalies in the region.

Additionally, the predictability of South China's rainy season precipitation in relation to positive Arctic Oscillation (AO) and El Niño phases from the previous year is analyzed. The signal-to-noise ratio, indicating predictability, is highest in the Yungui Plateau and North Vietnam during April to June (Fig. 7A), with a similar pattern observed for monthly precipitation (Fig. 7B-D). In June, areas of high predictability extend to the northern South China Sea and the Bashi Strait, likely influenced by monsoon and typhoon activities.

The main findings indicate that SST anomalies drive WAF, which creates GPH anomalies that affect snow depth and atmospheric circulation, ultimately influencing precipitation patterns in South China. However, two limitations should be noted: the low significance of the anomalies for snow depth and GPH may undermine the robustness of the conclusions, and further discussion is needed regarding the enhanced South Asia high-pressure system in June and its potential correlation with the monsoon.

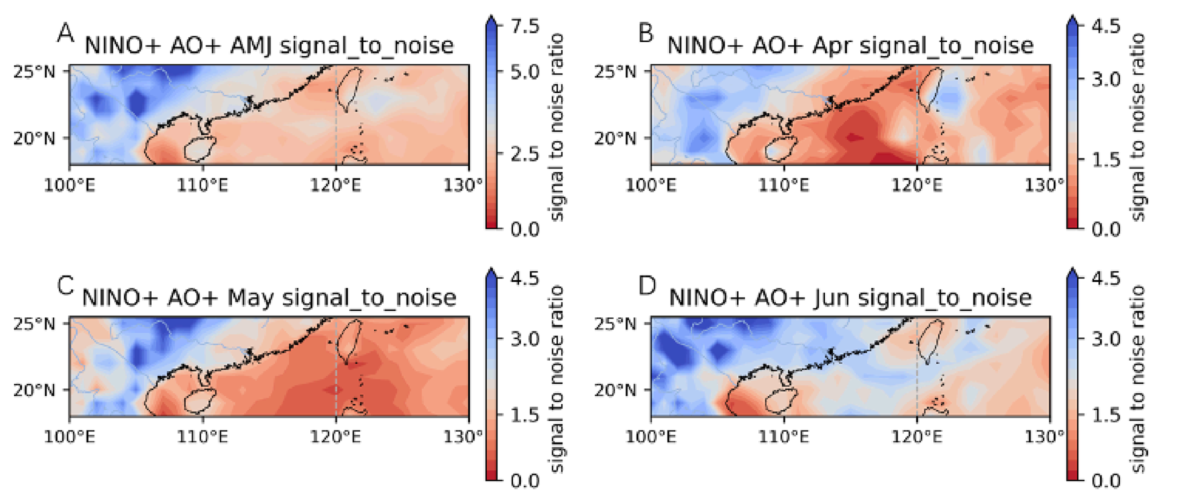

Figure 7. The ratio of mean precipitation to the variance of precipitation

References

1. 强学民，杨修群.华南前汛期降水异常与太平洋海表温度异常的关系[J].地球物理学报，2013，56 (8):2583-3593
2. 覃皓, 伍丽泉, 何慧.夏季热带大西洋海温变化对华南前汛期降水的影响 [J]. 大气科学, 2023，47(5): 1309−1324
3. 彭彦皓, 张若楠. 北极海冰与华南前汛期降水的关联 [J]（未发表）
4. T.R.Li, R.H.Zhang, M. Wei., Impact of ENSO on the precipitation over China in winter half- years[J]. Trop Meteorol, 2015, 21(2): 161-170
5. Qian, D., Huang, Y., Li, H., et al. Decadal variations in the summer precipitation over eastern China associated with spring Arctic Sea ice[J]. Journal of Geophysical Research: Atmospheres, 2023, 128
6. Takaya, K. & Nakamura, H. A formulation of a phase-independent wave-activity flux for stationary and migratory quasigeostrophic eddies on a zonally varying basic flow. Journal of the Atmospheric Sciences, 2001, 58(6), 608–627