

The Influence of Intraseasonal Oscillation on Landfall Tropical Cyclones in East Asia

Qiong Chao¹, Xinhua Huang^{1*}, Jing Wang¹, Xuanyu Zhang¹, Bingyu Zhao¹, Qi Guo², Liangui Xiao¹

¹Qinghai Meteorological Data Center, Xining 810001, Qinghai, China

²Qinghai Meteorological Observatory, Xining 810001, Qinghai, China

*Corresponding author: Xinhua Huang, xhuahi@163.com

Copyright: © 2026 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: This paper illustrates the effect of the boreal summer intraseasonal oscillation on the subseasonal variability of landfalling tropical cyclones (TCs). The paper describes the climatological distribution of landfalling TCs in East Asia and how the modes of BSISO1 and BSISO2 could modulate the number of landfalling TCs in East Asia. The ratio of the number of landfalling tropical cyclones in active and inactive phases is 2:1. During the active phase of the two modes of BSISO, the large-scale environmental field is generally conducive to TC activity. The promotion effects of low-level convergence, upper-level divergence, upward motion of the atmosphere, and sufficient water vapor in the middle level can offset the strong vertical wind shear and lower sea surface temperature that inhibit landfalling TCs. During the inactive phase, the opposite trend is observed. Low-level divergence, upper-level convergence, the subsidence motion of the atmosphere, and less water vapor in the middle level are generally not conducive to TC activity.

Keywords: Boreal summer intraseasonal oscillation; Landfalling tropical cyclones; Intraseasonal variabilities

Online publication: October 21, 2026

1. Introduction

Tropical cyclones (TCs) refer to a type of large-scale, intense cyclonic vortex with a warm core structure that occurs over tropical or subtropical oceans. The disasters caused by TCs are among the most destructive. During their landfall, TCs often accompany strong winds, heavy rain, and storm surges, which can easily trigger secondary disasters and cause significant harm to the natural environment, society and economy, and human lives. Therefore, studying the generation, development, and extinction process of TCs, as well as the activity characteristics and patterns of TCs during their landfall, is of great significance for TC warning, disaster prevention, and mitigation ^[1].

Compared with numerical weather forecasting and climate prediction for TCs, the forecasting skills for extended-range (2 weeks to 2 months) forecasts of TCs are relatively low, and there are also fewer related forecasting systems. This is because the physical mechanisms underlying the seasonal variations of TCs have

not yet been fully revealed. Previous studies have explored the regulatory mechanism of Boreal Summer Intraseasonal Oscillation (BSISO) on the seasonal activities of TCs, but the mechanism of the intraseasonal oscillation of landfalling TCs has not been fully clarified^[2–7]. Therefore, clarifying the influence mechanism of BSISO on the intraseasonal oscillation of landfalling TCs can provide a certain physical basis for the further establishment of extended-range forecasting systems for landfalling TCs.

2. Data and methods

2.1. Data sources

- (1) ECMWF ERA5 reanalysis data (1981–2021, June–October), variables include 850 hPa relative vorticity, 200 hPa divergence, 500 hPa vertical velocity, 200–850 hPa vertical wind shear, 600 hPa relative humidity, and sea surface temperature. The horizontal resolution is $1^\circ \times 1^\circ$.
- (2) BTrACS best track dataset, containing the maximum wind speed and longitude/latitude of the TC center every 6 hours.

2.2. Methods

To study the impact of the two modes of BSISO on the landfalling TC, this paper uses the BSISO index defined by Lee et al. (2013) to define the phase and intensity of BSISO^[8]. The analysis of statistical data on the large-scale environmental factors of TCs in this paper is based on anomaly field synthesis. During the synthesis analysis, significance tests are conducted to indicate whether the anomalies are statistically significant. The main method used is the Student's *t*-test to verify the synthesis analysis results.

3. The influence of BSISO on the intraseasonal oscillation of the landing rate of TCs

3.1. Distribution of climate state of landing TCs in East Asia

Analysis of the distribution of TC climatic states during the period 1981–2021 based on the trajectories and intensities of each TC that made landfall shows that TCs mainly form over the western Pacific Ocean, with a few originating from the Bay of Bengal and the eastern waters off the Philippines. The movement paths of TCs can be broadly classified into three categories: one is TCs formed over the western Pacific Ocean that continuously move westward; another is TCs formed over the western Pacific Ocean that continuously move northwestward and reach the eastern coast of China; the last is TCs formed over the western Pacific Ocean that first move westward or northwestward, and then their trajectories suddenly change direction and move northward or northeastward when they reach the area between 20° – 40° N and 120° – 140° E^[9]. During the movement process, the intensity of TCs changes from increasing to decreasing. When TCs reach the landing area, their intensity decreases, and among the TCs that make landfall, the number of strong typhoons is relatively small. Analyzing the landing points of TCs, the landing points are mainly concentrated in the southeastern coastal areas of China, the Republic of Korea, Japan, and the Malay Archipelago, among which the number of TCs landing near the South China Sea region is the largest.

3.2. The regulation of TC landings in East Asia by BSISO

In order to study the impact of the two modes of BSISO on the TCs that land in the East Asian region, this

paper has statistically analyzed the average number of TCs that land in East Asia during the summer (June–October) of the years from 1981 to 2021 for each of the eight phases of the two modes of BSISO. According to the statistics, the average number of TCs landing in East Asia on days corresponding to the 5th–7th phases of BSISO1 and the 3rd–5th phases of BSISO2 was higher, with the maximum phase averaging approximately 0.1 per day, classified as an active phase; on the days corresponding to the 1st–3rd phases of BSISO1 and the 6th–8th phases of BSISO2, the average number of TCs landing was lower, with the minimum phase averaging approximately 0.04 per day, classified as an inactive phase^[10]. By comparing the average daily number of TCs landing on the active and inactive phases of BSISO1 and BSISO2, it was found that the ratio of TCs landing in each of the two phases was 2:1^[11].

3.3. The physical mechanism by which BSISO influences the entry of TCs into East Asia

During the active phase of the BSISO two-mode, the large-scale environmental field distribution is the same as the convective distribution. Therefore, at 850 hPa in the convective maintenance area, the relative vorticity is a positive anomaly, and there is low-level convergence, while at 200 hPa, it is an anticyclonic circulation, with high-altitude divergence. Under this configuration of high and low levels, the entire atmosphere is in an ascending motion. The vertical velocity at 500 hPa shows a negative anomaly, and the convective maintenance area is entirely a significant ascending area. At 600 hPa in the convective maintenance area, the relative humidity field has abundant water vapor. These thermodynamic and dynamic conditions are all conducive to the activity of TCs landing in the Northwest Pacific^[12–13]. However, larger vertical wind shear and lower sea surface temperature are not conducive to the activity of TCs landing in the convective maintenance area. Overall, during the active phase of BSISO, the number of landing TCs is higher, which is beneficial to the activity of landing TCs. During the inactive phase of BSISO, the thermodynamic and dynamic conditions are not conducive to the activity of TCs, so the number of landing TCs is lower.

During the active phase of BSISO1, an abnormal cyclonic circulation exists over the southeastern ocean surface of China. TCs are influenced by the northward guiding airflow from the north side of the cyclonic circulation and move west/northwestward, making them more likely to make landfall in eastern China and the regions of Japan and the Republic of Korea. During the active phase of BSISO2, an abnormal cyclonic circulation exists over the Northwest Pacific Ocean. The trajectory of TC is affected by the southwesterly guiding airflow from the southeast side of the cyclonic circulation and moves northward, which is conducive to making landfall in East Asia. Moreover, previous studies have revealed that the meridional wind of the guiding airflow changes from east wind to west wind during the active phase of BSISO2, thus facilitating the movement of TC towards the northeast direction in the later stage of BSISO2, resulting in more TCs making landfall in East Asia^[14]. During the inactive phases of the two modes, the guiding airflow influenced by the anticyclonic circulation is unfavorable for TCs to move westward.

4. Conclusions and discussion

This paper discusses the regulatory effects of two modes of BSISO on the number of landfalling TCs, and further analyzes the synthesis of the large-scale environmental fields related to TC formation in the active/inactive phases of BSISO 1 and BSISO 2. It indicates that in the active phases of the two BSISO modes, where there are more landfalling TCs, the large-scale environmental fields show stronger low-level convergence and high-level divergence, more abundant mid-level moisture, and stronger upward movement

compared to the inactive phases, where the frequency of landfalling TCs is lower. Favorable large-scale background fields can give rise to more TCs. This suggests that both modes of BSISO can influence the number of landfalling TCs by regulating the changes of low-frequency large-scale fields, thereby posing a threat to the coastal areas of East Asia. The guiding airflow helps TCs move northwest/westward and further invade the East Asian region. In the future, it is possible to further explore the influence of the circulation fields of the two BSISO modes on the movement paths of landfalling TCs and the regulatory patterns^[15]. In future forecasts, the signals of the two BSISO modes can be used as one of the sources of forecastability for the movement paths of landfalling TCs.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Xu BQ, Wei P, Qian YT, et al., 2024, A Hybrid Dynamic-statistical Prediction Model for Tropical Cyclone Frequency over the Western North Pacific and Its Evaluation. *Transactions of Atmospheric Sciences*, 47(1): 65–79.
- [2] Madden RA, Julian PR, 1971, Detection of a 40–50 day Oscillation in the Zonal Wind in the Tropical Pacific. *Journal of Atmospheric Sciences*, 28(5): 702–708.
- [3] Zhao HK, Jiang X, Wu L, 2015, Modulation of Northwest Pacific Tropical Cyclone Genesis by the Intraseasonal Variability. *Journal of the Meteorological Society of Japan. SER. II*, 93(1): 81–97.
- [4] Xu ZM, Li TM, 2024, Relative Contributions of Thermodynamic and Dynamic Environmental Conditions to the Intensification of Tropical Cyclones with Similar Tracks to Haiyan (2013) in the Western North Pacific. *Transactions of Atmospheric Sciences*, 47(3): 1–13.
- [5] Zhang CY, 2019, Analysis on the Characteristics of Typhoon Disaster Risk Associated with Landfall in Coastal China. Nanchang: Jiangxi University of Science and Technology, 2019: 48–49.
- [6] Wang ZK, Yong B, 2023, Analysis of Characteristics of Typhoon Disasters in Coastal Areas of China. *Water Resources and Power*, 41(4): 22–26.
- [7] Sridhara N, Tetsuya T, 2023, Statistical Analysis of the Characteristics of Typhoons Approaching Japan from 2006 to 2019. *Geomatics, Natural Hazards and Risk*, 14(1): 2208722.
- [8] Lee J, Wang B, Wheeler CM, et al., 2013, Real-time Multivariate Indices for the Boreal Summer Intraseasonal Oscillation over the Asian Summer Monsoon Region. *Climate Dynamics*, 40(1–2): 493–509.
- [9] Zheng S, 2023, Spatial and Temporal Distribution Characteristics of Landfalling Tropical Cyclones in China in Recent 23 Years and Their Impacts. *China Water Transport*, 23(11): 55–57.
- [10] Li CY, Pan J, Tian H, et al., 2012, Typhoon Activities over the Western North Pacific and Atmospheric Intraseasonal Oscillation. *Meteorological Monthly*, 38(1): 1–16.
- [11] Pan J, Li CY, Song J, 2003, The Modulation of Madden-Julian Oscillation on Typhoons in the Northwestern Pacific Ocean. *Chinese Journal of Atmospheric Sciences*, 34(6): 1059–1070.
- [12] Gray WM, 1968, Global View of the Origin of Tropical Disturbances and Storms. *Monthly Weather Review*, 96(10): 669–700.
- [13] Zhou WC, Shen HB, Zhao HK, 2015, Effect of Tropical Intraseasonal Oscillation on Large-scale Environment of Typhoon Genesis over the Northwestern Pacific. *Transactions of Atmospheric Sciences*, 38(6): 731–741.

- [14] Wu PC, Ling Z, He HL, 2023, The Effects of Intraseasonal Oscillations on Landfalling Tropical Cyclones in the Philippines During the Boreal Summer. *Frontiers in Earth Science*, 2023(11): 1606291.
- [15] Tao L, Li SJ, Han Y, et al., 2012, Impact of Intraseasonal Oscillations of Tropical Atmosphere on TC Track Change over the Western North Pacific. *Journal of Tropical Meteorology*, 28(5): 698–706.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.