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Excessive Tibetan Plateau spring warming found to cause catastrophic June 2024 heavy rainfall in China

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When catastrophic rainfall began in early June 2024 in southern China (S. China)—an event that caught worldwide attention due to its devastating consequences—no plausible explanation had yet been proposed. This research was inspired by the finding of the international project "Global Energy and Water Cycle Exchanges/Impact of Initialized Land Surface Temperature and Snowpack on Subseasonal-to-Seasonal Prediction" (GEWEX/LS4P), which identified a lagged relationship between spring land temperatures over the Tibetan Plateau (TP) and downstream summer precipitation over East Asia. Specifically, the findings indicated that when the TP experienced a warm/cold spring, southern China (S. China) was likely to experience a wet/dry summer, respectively.

By examining the record-breaking warm spring land temperatures over the TP in 2024—the warmest TP spring since 1980—the researchers conjectured that this extreme TP warming and the subsequent heavy rainfall in S. China were consistent with the LS4P hypothesis. This study was initiated during the 2024 GEWEX Open Science Conference (July 7-12) in Japan. A group of scientists participating in the LS4P project, including experts from UCLA, the Institute of Atmospheric Physics, Chinese Academy of Sciences (IAP/CAS), the Chinese Meteorological Administration (CMA), the Earth System Science Interdisciplinary Center (ESSIC) at the University of Maryland, College Park, and other institutions, voluntarily collaborated in response to an initiative by LS4P Co-Chair Professor. Yongkang Xue of UCLA. Their goal was to provide a timely explanation for the scientific and public communities.

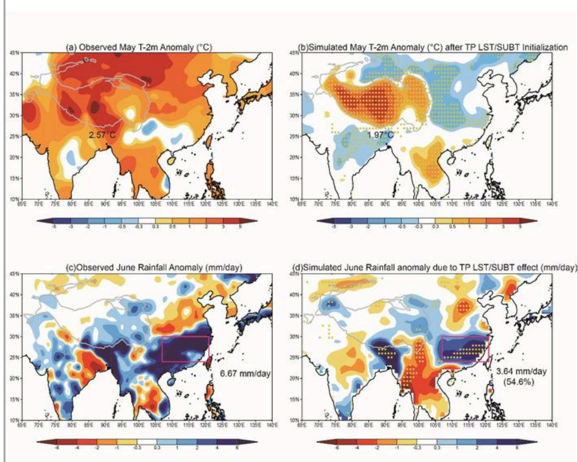

IMAGE:

(A) OBSERVED MAY T-2M DIFFERENCE BETWEEN 2024 AND THE CLIMATOLOGY REFERENCE; (B) GFS/SSIB2 SIMULATED MAY T-2M ANOMALY AFTER SOIL TEMPERATURE INITIALIZATION OVER TP. (C) SAME AS (A), BUT FOR THE JUNE 2024 PRECIPITATION ANOMALY. (D) SIMULATED JUNE PRECIPITATION ANOMALY DUE TO TP LST/SUBT EFFECT. NOTE: (1). THE DOTTED GRIDS DENOTE THE STATISTICAL SIGNIFICANCE BASED ON THE STUDENT T-TEST AT THE *P* < 0.1 LEVEL. (2). THE GREY BOLD 4000M CONTOUR LINES ILLUSTRATE THE APPROXIMATE TP GEOGRAPHIC LOCATION. (3). THE NUMBERS IN PANELS ARE AVERAGES OF CORRESPONDING VARIABLES OVER THE TP IN PANELS (A) AND (B) AND OVER THE RED BOX IN PANELS (C) - (D).

view more ›

The ESM developed by the National Center for Environmental Research (NCEP) and UCLA was used for this study. Since the study was conducted in close to real-time during an ongoing event, Mr. Ratko Vasic of NCEP provided valuable assistance in obtaining initial conditions for model simulations. Drs. Qian Li and Xianghui Kong of the IAP, Chinese Academy of Sciences, promptly produced all numerical experiment results and conducted preliminary analyses.

One of the most challenging aspects of this study was reproducing the observed extreme warm temperatures over the TP in the ESM. Initially, the ESM failed to reproduce the homogeneous extreme warm May temperatures over the TP and underestimated the heavy June rainfall in S. China, exhibiting a severe dry bias. After improving the land temperature initialization for the TP, the ESM successfully reproduced most of the observed TP May 2-meter temperature (T-2m) anomalies and simulated approximately 55% of the observed extraordinary June rainfall anomaly in S. China. The results passed a more stringent field significance test, indicating these results did not occur by chance.

Additionally, the experiment realistically simulated other observed anomalies, including the heavy rainfall in Bangladesh, where an extraordinary June flood occurred and was widely reported in the media, as well as abnormally wet conditions over the eastern TP and southern Japan, and dry conditions over northern China.

The study also assessed the influence of sea surface temperature (SST), traditionally used in climate and weather predictions. Results showed that May and June 2024 global SSTs, with only moderate anomalies, contributed about 17% of the observed rainfall anomaly.

Subseasonal-to-seasonal (S2S) precipitation prediction for late spring and summer, which involves a substantial number of extreme hydroclimate events, has remained stubbornly low in accuracy for years. To tackle this persistent challenge, the World Meteorological Organization (WMO) launched a joint S2S Prediction Project, aimed at improving predictions ranging from 2 weeks to 3 months. Among various factors, land initialization and configuration have been identified as one of key areas with the potential to significantly enhance S2S predictions. While many land variables, such as albedo, soil moisture, snowpack, and vegetation, have been utilized for climate and weather predictions since the 1970s, the memory effect of land temperature on predictions has been largely underappreciated until the inception of LS4P. This is surprising given that the T-2m measurements have the highest quality among land variables, with the longest meteorological observational records, global coverage, and dense measurement networks.

The LS4P group, comprising many of the world's leading climate and weather prediction and research centers, has made great strides in demonstrating the critical role of high mountain land temperature anomalies in S2S predictions. They have published many peer-reviewed papers within the field. “This represents a significant contribution of GEWEX to the S2S prediction that is scientifically challenging and highly relevant to society,” emphasized Professor Xubin Zeng, Co-Chair of the GEWEX. Dr. Aaron Boone of Meteo France asserts this work opens new avenues for improving S2S prediction for operational applications, which is increasingly important given the rising frequency of anomalous meteorological events observed worldwide.

Despite its promise, this approach has yet to gain full recognition within the broader scientific community, where traditional SST-based methods continue to dominate. Historically, it has often taken years to identify the causes of climate-related catastrophic events. The new and exciting results from this study, completed in such a short timeframe, underscore the robustness of this innovative approach. This study demonstrates that excessive TP spring land heating was the primary factor driving the catastrophic June 2024 rainfall in S. China. Yongkang acknowledged that, while there remain many unresolved challenges with this approach, the team hopes their paper in *Science Bulletin* will inspire further research using diverse methodologies to advance S2S prediction of extreme hydroclimate events and increase public awareness of the latest advancements in this field made by LS4P scientists.

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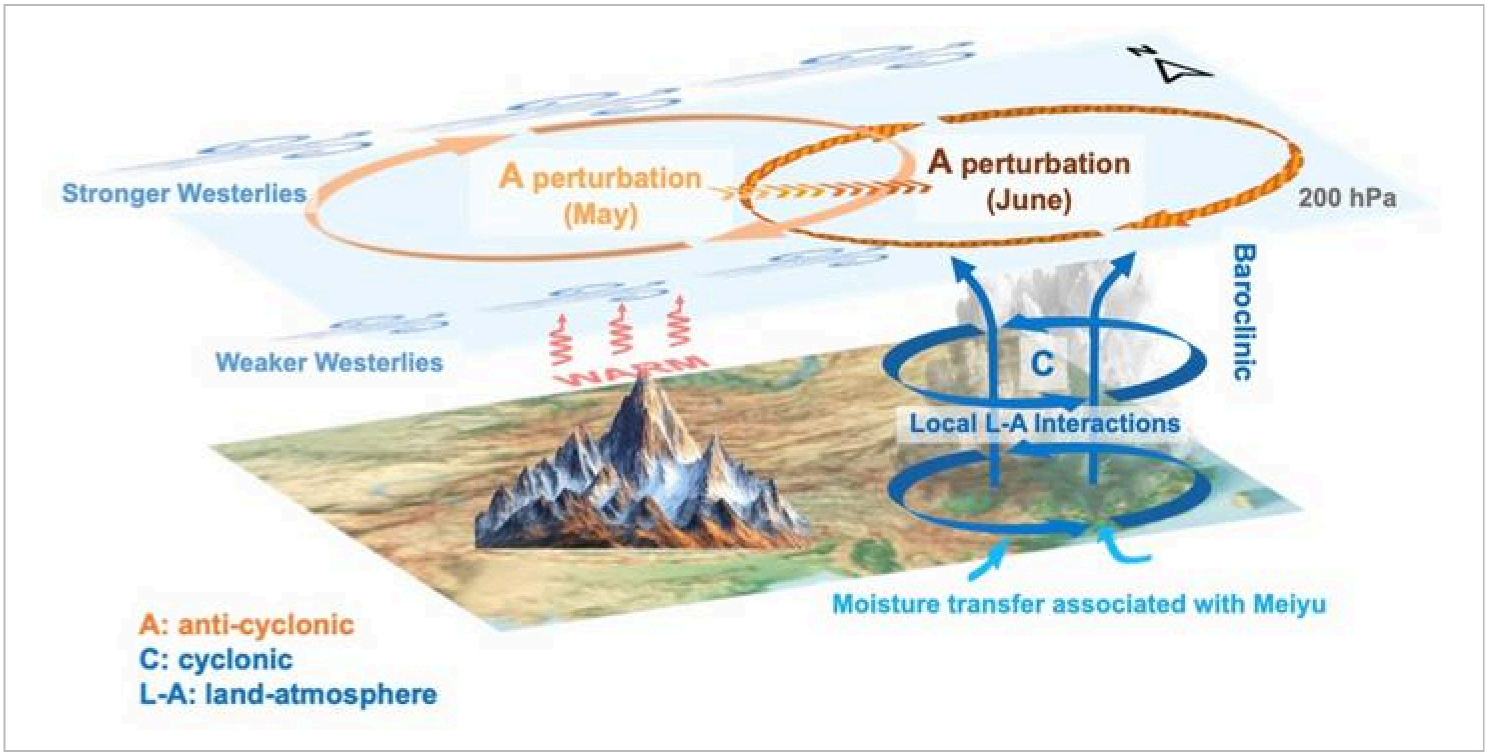
Mechanisms Schematic diagram (IMAGE)



CAPTION

The subseasonal processes associated with the remote effect of Tibetan Plateau spring land temperature anomaly affecting downstream summer precipitation. Yongkang Xue, William Lau, and Zhijiong Cao developed this schematic diagram.

CREDIT

Yongkang Xue, William Lau, and Zhijiong Cao developed this schematic diagram.

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