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EDITORIAL

Subseasonal-to-seasonal predictability of extreme precipitation and land forcing

Yongkang Xue[1] · William K-M Lau[2]

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It is well-known that the root cause of extreme hydroclimate events, i.e., heatwave, droughts, and floods, under climate change is in the variability of precipitation at subseasonal-to-seasonal(S2S) time scales. Improved S2S prediction of precipitation over land is among the top priorities in the mitigation of disastrous impacts of climate change on human society. Yet, the skill of S2S precipitation prediction over land, especially in the late spring-to-summer months when extreme hydroclimate events frequently occur, has remained poor to date. To tackle the "weather–climate prediction desert ranging from two weeks to three months" (Merryfield et al. 2020), a joint S2S Prediction Project of the World Climate Research Programme (WCRP) and the World Weather Research Programme (WWRP) of the World Meteorological Organization (WMO) has been launched. The S2S precipitation predictability has been attributed to various mechanisms, among which sea surface temperature (SST) has long been considered as a major source of predictability. However, observational data analyses and modeling studies have consistently shown that SST alone only partially explains the phenomena of predictability. Additional emphases on atmosphere-land interactions are needed to close the gap on S2S precipitation predictability.

This special issue includes recent research using both observational data and/or Earth System Models (ESM) or Regional Climate Models (RCM) to seek explanations beyond current traditional SST approaches by exploring the role of land-induced forcing in S2S predictability/prediction with following themes: (1) Contributions to improving understanding of the role of land-induced forcing/atmosphere interactions in high-mountain and other regions in S2S variability, and impacts on prediction of precipitation and heatwaves, especially droughts and floods in downwind regions. (2) Mechanisms of dynamic and physical processes and hydroclimate feedback associated with the land forcing-induced S2S predictability; relative roles and uncertainties of land processes compared to those of SST in S2S prediction. (3) Application of observational and assimilation data and remote sensing products providing a pathway for evaluation and improvement of S2S prediction modeling and advancing understanding the roles of land processes in S2S predictability. (4) Evaluation of RCM downscaling ability in simulating water and energy cycle and atmospheric conditions in high-mountain regions, e.g., the Tibetan Plateau (TP), including their variability, and potential contribution to S2S predictability.

Most papers in the special issue are from the Global Energy and Water Exchanges (GEWEX)/ Impact of Initialized Land Temperature and Snowpack on Sub-seasonal to Seasonal Prediction (LS4P) project (Xue et al. 2021). LS4P is the first international effort to explore the possibility that spring land surface and subsurface temperature (LST/SUBT) over high mountain areas is a crucial factor that can lead to significant improvement in S2S precipitation prediction through the remote effects of land/atmosphere interactions. More than 40 institutions including many major climate and weather prediction centers worldwide participate in this project. The first phase (LS4P-I) has been focused on the effect of the spring LST/SUBT in TP on the global summer precipitation variability. The spring and summer 2003 have been selected for the case study, when the TP had a very cold spring and the southern Yangtze River basin had a severe drought, which cause had never been identified. Xue et al. (2023) summarizes the major results from the LS4P-I ESM ensemble mean regarding the S2S predictability. In addition to the southern Yangtze River basin, another 7 hotspot regions over Northern Hemisphere have been identified where the TP spring LST/SUBT had significant impact on the dry or wet conditions, which are also

✉ Yongkang Xue
yxue@geog.ucla.edu

1 University of California, Los Angeles, CA, USA

2 Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD, USA

consistent with the observed anomalies. Furthermore, the Tibetan Plateau-Rocky Mountain Circumglobal wave train (TRC) has been found to be highly associate with the TP LST/SUBT's global scale effect. Among 8 hotspots regions, 5 are along the TRC and one is in its extension. Zhang et al. (2024) and Xue et al. (2023) in this special issue analyzed the possible mechanisms for TP's influence in global circulation and East Asian monsoon, respectively. The TRC's role in the TP's remote effect has been further confirmed by Ardilouze and Boone (2023) and Qin et al. (2023).

Several researchers presented their research and results that extend the LS4P-I original scope (Qi et al. 2022; Xu et al. 2022; Yang et al. 2022; Saha et al. 2023). Xu et al. (2022) integrated the model for 8 months starting in April and found the TP LST/SUBT serves as a charged capacitor to modulate the planetary atmospheric circulation and affect the East Asian summer's seasonal prediction through influencing the South Asian High and shifting the East Asian jet. Since LS4P-I did not simulate South Asian monsoon well, using the observational data and five LS4P-I ESMs' results, Saha et al. (2023) found a mode that is linked the spring LST around the Western Third Pole (WTP), i.e., the western Tibetan Plateau and Iranian Plateau, during the early phase (May-June) of the South Asian monsoon. Diallo et al. (2022) carried out prototype research for LS4P Phase II (LS4P-II) to investigate how observed warm spring TP in 1998 caused summer flood in downstream East Asian monsoon region. Yang et al. (2022) investigate the influence of spring LST/SUBT over Central Asia on summer LST variability and prediction over Northeastern China.

To properly simulate the LST/SUBT effect, the key is to reproduce the observed LST anomaly. This requires adequate LST initial condition. Due to lack of observational data over high mountains, such as TP, the LST in reanalysis data, which are used by many ESMs for initial conditions may not represent reality well (Xue et al. 2021). A number of papers investigate methodologies to improve the LST initial conditions. Ardilouze and Boone (2023) found that when they adjust both initial soil temperature and soil moisture under constraint of enthalpy conservation, a more realistic LST anomaly can be produced by the models. Qin et al. (2023) applied a nudge approach to generate better initial LST condition and CRT wave train. Furthermore, how different land models cause the uncertainty in simulating the land memory is also investigated (Qiu et al. 2022).

RCM plays a crucial role in the S2S prediction (Xue et al. 2018). Tang et al. (2023) reported 8 LS4P RCMs intercomparison for their performance over the TP and identified different downscaling characteristics for the RegCM4 type and WRF type models. The study showed that varying land and cumulus schemes are the main cause for large precipitation differences over the TP. The role of convective activity in the S2S prediction has also been addressed in Sugimoto et al. (2022) and Risanto et al. (2022).

The papers in this special issue present the latest advances in S2S prediction using the land forcing. This special issue reports the first community effort in exploring the high mountain LST/SUBT' tele-connected impact on summer precipitation S2S predictability over midlatitude and tropical hotspots regions. Despite the progress that has been achieved, approaches to finding additional predictability sources based on LST/SUBT condition over high mountains are still in the incipient and exploratory stages. There are more issues to be addressed and further research is imperative to achieve a comprehensive understanding. For instance, land-atmosphere interaction studies performed so far have been focused on the local land surface/atmosphere feedback with remote SST forcing at the background. With the recognition of remote effect of land forcing, it is important to study the combined remote effects from the high mountain LST/SUBT and local feedback from vegetation and soil moisture to further improve S2S predictions. Furthermore, there are only a few studies to explore the cause of the LST/SUBT anomaly and memory in high mountains (Zhang et al. 2019; Liu et al. 2020; Takaya et al. 2024). The above two issues are just examples among many challenging issues. The published studies represent a starting point for further investigation. We hope this special issue can stimulate more research on land-induced forcing and S2S and long-term predictability/prediction.

References

Ardilouze C, Boone AA (2023) Impact of initializing the soil with a thermally and hydrologically balanced state on subseasonal predictability. Clim Dyn. https://doi.org/10.1007/s00382-023-07024-x

Diallo I, Xue Y, Chen Q, Ren X, Guo W (2022) Effects of Spring Tibetan Plateau Land temperature anomalies on early summer Floods/Droughts over the monsoon regions of South East Asia. Climate Dynamics. https://doi.org/10.1007/s00382-021-06053-8

Liu Y, Xue Y, Li Q, Lettenmaier D, Zhao P (2020) Investigation of the variability of near-surface temperature anomaly and its causes over the Tibetan Plateau. J Geophy Res Atmos 125:e2020JD032800. https://doi.org/10.1029/2020JD032800

Merryfield WJ Current and Emerging Developments in Subseasonal to Decadal Prediction, Am B et al (2020) Me-teorol. Soc., 101, E869–E896, https://doi.org/10.1175/BAMS-D-19-0037.1, 2020

Qi X, Yang J, Xue Y, Bao Q, Wu G, Ji D (2022) Subseasonal warming of surface soil enhances precipitation over the eastern tibetan Plateau in early summer. J Geophy Res Atmos 127:e2022JD037250. https://doi.org/10.1029/2022JD037250

Qin Y, Tang Q, Xue Y, Liu Y, Lin Y (2023) Improved subseasonal–to–seasonal precipitation prediction of climate models with nudging approach for better initialization of Tibetan Plateau–Rocky Mountain Circumglobal wave train and land surface conditions. Clim Dyn. https://doi.org/10.1007/s00382-023-07082-1

Qiu Y, Feng J, Wang J, Xue Y, Xu Z (2022) Memory of land surface and subsurface temperature (LST/SUBT) initial anomalies over

Tibetan Plateau in different land models. Clim Dyn. https://doi.org/10.1007/s00382-021-05937-z
Risanto C, Chang H-I, Luong TM, Dasari HP, Attada R, Castro CL, Hoteit I (2022) Retrospective sub-seasonal forecasts of extreme precipitation events in the Arabian Peninsula using convective-permitting modeling. Clim Dyn. https://doi.org/10.1007/s00382-022-06336-8
Saha SK, Xue Y, Krishnakumar S, Diallo I, Shivamurthy Y, Nakamura T, Tang Q, Chaudhari H (2023) A Dominant Mode in the First Phase of the Asian summer Monsoon Rainfall: role of Antecedent Remote Land Surface temperature. Clim Dyn. https://doi.org/10.1007/s00382-023-06709-7
Sugimoto S, Xue Y, Sato T, Takahashi HG (2022) Influence of convective processes on Weather Research and forecasting model precipitation biases over East Asia. Clim Dyn. https://doi.org/10.1007/s00382-022-06587-5
Takaya Y et al (2024) A sub-monthly timescale causality between snow cover and surface air temperature in the Northern Hemisphere inferred by Liang–Kleeman information flow analysis. Clim Dyn. https://doi.org/10.1007/
Tang J, Xue Y, Long M, Ma M, Liang X–Z, Sugimoto S, Yang K, Ji Z, Hong J, Kim J, Xu H, Zhou X, Sato T, Takahashi HG, Wang S, Wang G, Chou SC, Guo W, Yu M, Pa X (2023) Regional climate model intercomparison over the Tibetan Plateau in the GEWEX/LS4P phase I. Clim Dyn. https://doi.org/10.1007/s00382-023-06992-4
Xu H, Liang X-Z, Xue Y (2022) Regional climate modeling to understand Tibetan heating remote impacts on East China precipitation. Clim Dyn. https://doi.org/10.1007/s00382-022-06266-5
Xue Y, Diallo I, Li W, Neelin JD, Chu PC, Vasic R, Guo W, Li Q, Robinson DA, Zhu Y, Fu C, Oaida CM (2018) Spring land surface and subsurface temperature anomalies and subsequent downstream late spring-summer droughts/floods in North America and East Asia. J Geophy Res: Atmos 123:5001–5019. https://doi.org/10.1029/2017JD028246
Xue Y, Yao T, Boone AA, Diallo I, Liu Y, Zeng X, Lau WK-M, Sugimoto S, Tang Q, Pan X, van Oevelen PJ, Klocke D et al (2021) Impact of Initialized Land Surface temperature and snowpack on Subseasonal to Seasonal Prediction Project, Phase I (LS4P-I): Organization and experimental design. Geosci Model Dev 14:4465–4494. https://doi.org/10.5194/gmd-14-4465-2021
Xue Y, Diallo I, Boone AA, Zhang Y, Zeng X, Lau WKM, Neelin JD, Yao T, Tang Q, Sato T, Koo M-S, Vitart F, Ardilouze C, Saha SK et al (2023) Remote effects of tibetan Plateau spring land temperature on global subseasonal to seasonal precipitation prediction and comparison with effects of sea surface temperature: the GEWEX/LS4P phase I experiment. Clim Dyn. https://doi.org/10.1007/s00382-023-06905-5
Yang Z, Zhang J, Liu Y, Li K (2022) The substantial role of May soil temperature over Central Asia for summer surface air temperature variation and prediction over Northeastern China. Clim Dyn. https://doi.org/10.1007/s00382-022-06360-8
Zhang Y, Zou T, Xue Y (2019) An Arctic-Tibetan connection on subseasonal to seasonal time scale. Geophy Res Let 46:2790–2799. https://doi.org/10.1029/2018GL081476
Zhang Y et al Near-global Summer Circulation Response to the Spring Surface Temperature Anomaly in Tibetan Plateau ---- The GEWEX/LS4P Phase I experiment, Climate Dynamics. https://doi.org/10.1007/s00382-024-07210-5.