



Background

Climatic drivers of diverse trends in terrestrial water storage in North American drylands

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Most North American drylands have been unusually dry over the last two decades due to low precipitation and high temperatures (1-2). This has led to a consistent decline in terrestrial water storage (TWS), which was exacerbated by an exceptional drought in 2021 (1). In contrast, TWS in the central North American drylands (2), known as the northern Great Plains, had been increasing due to greater-than-average precipitation between 2003 and 2020. Notably, the drying regions of TWS gradually expanded to the central North American drylands after 2020, leading to a reduction of wetting regions by 1.6 M km² by 2025. Climatic drivers of the diverse trends of TWS and the “wetting-to-drying” regime shift in North American drylands remain unclear. Here, we apply a combination of satellite observations, reanalysis climate data, and a Lagrangian particle dispersion model to investigate how interactions between regional land-atmosphere feedbacks and large-scale water vapor and heat circulations determine the unique spatiotemporal patterns of TWS in North American drylands. Since the Great Plains play a key role in the global food supply, understanding these mechanisms is essential for stakeholders and governments to develop strategies to ensure global food security in response to the regime shift.

Phenomenon: diverse trends in TWS in North American Drylands

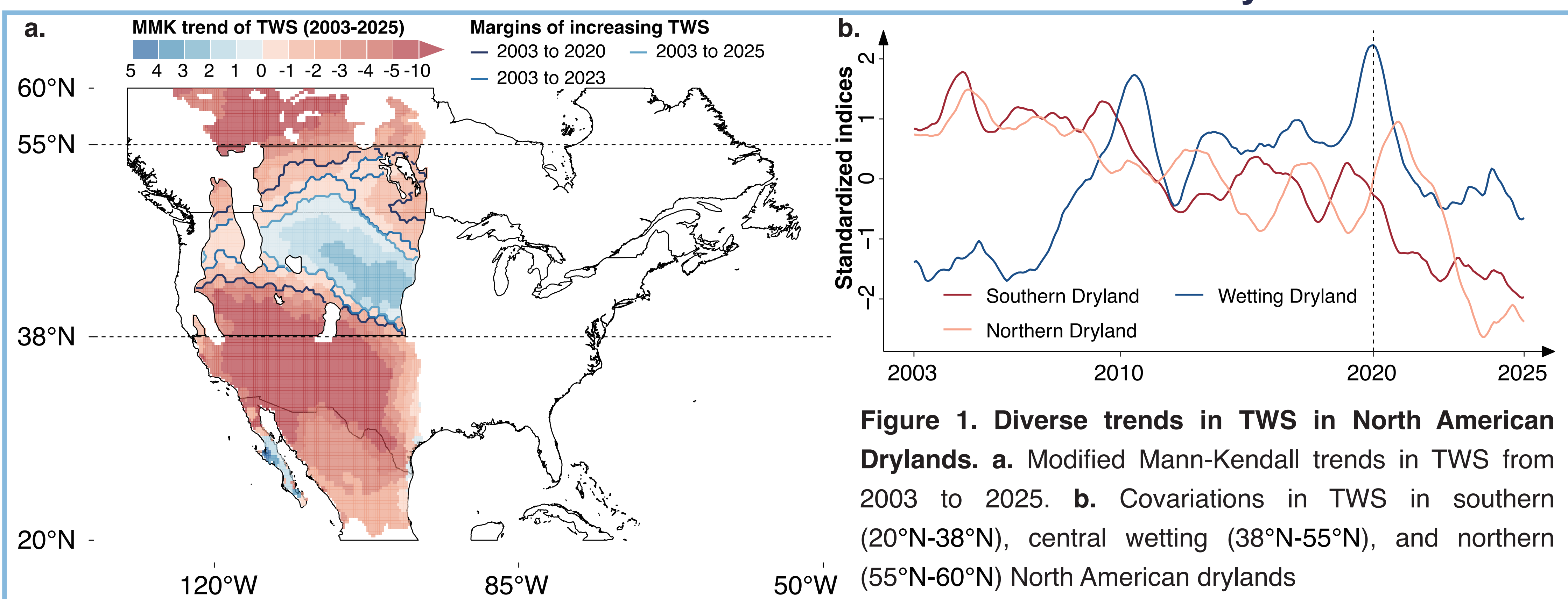


Figure 1. Diverse trends in TWS in North American Drylands. a. Modified Mann-Kendall trends in TWS from 2003 to 2025. b. Covariations in TWS in southern (20°N-38°N), central wetting (38°N-55°N), and northern (55°N-60°N) North American drylands

Wetting regions are shrinking in North American drylands

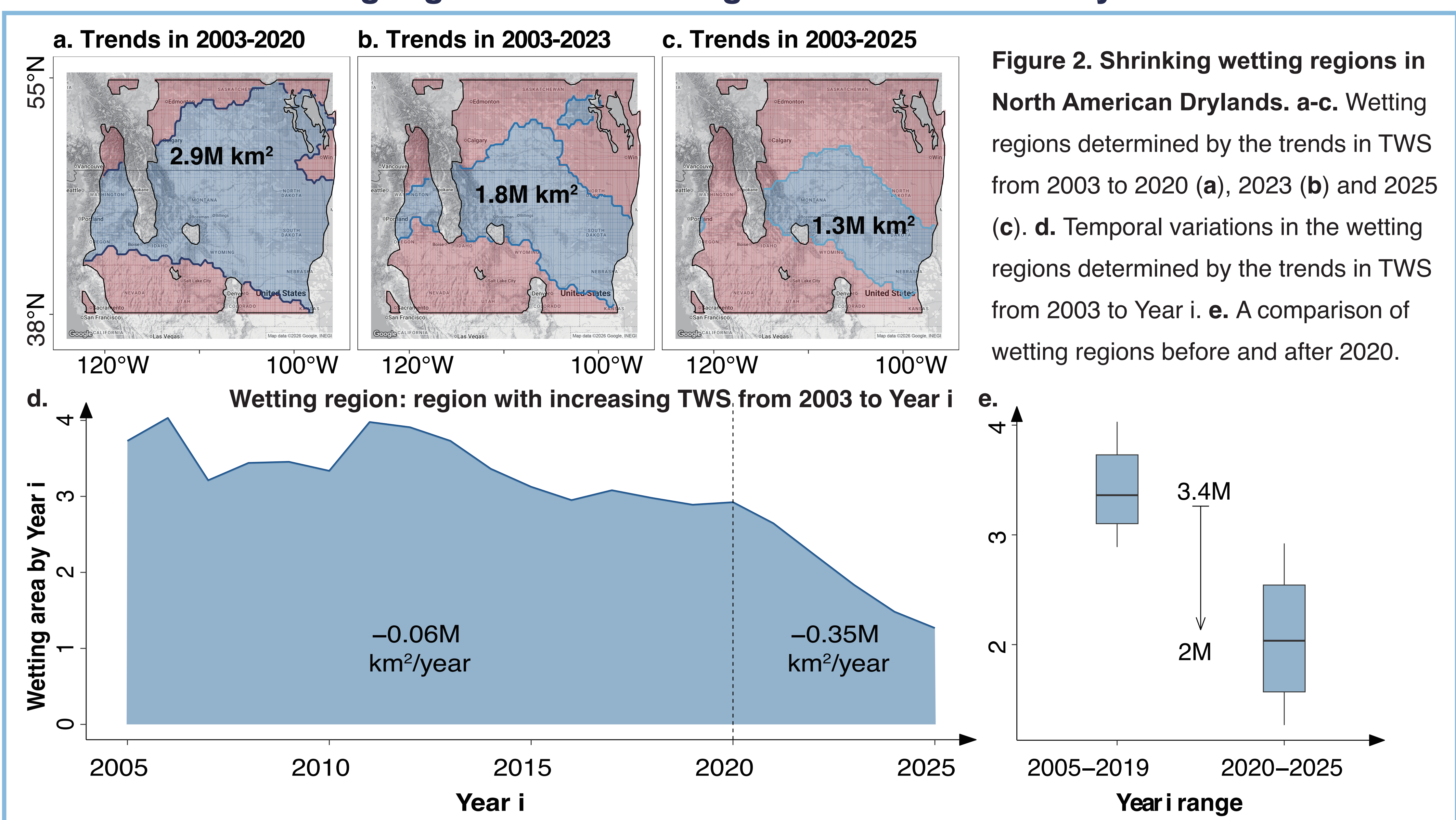


Figure 2. Shrinking wetting regions in North American Drylands. a-c. Wetting regions determined by the trends in TWS from 2003 to 2020 (a), 2023 (b) and 2025 (c). d. Temporal variations in the wetting regions determined by the trends in TWS from 2003 to Year i. e. A comparison of wetting regions before and after 2020.

Jump-over heat led to diverse trends in TWS in North American drylands

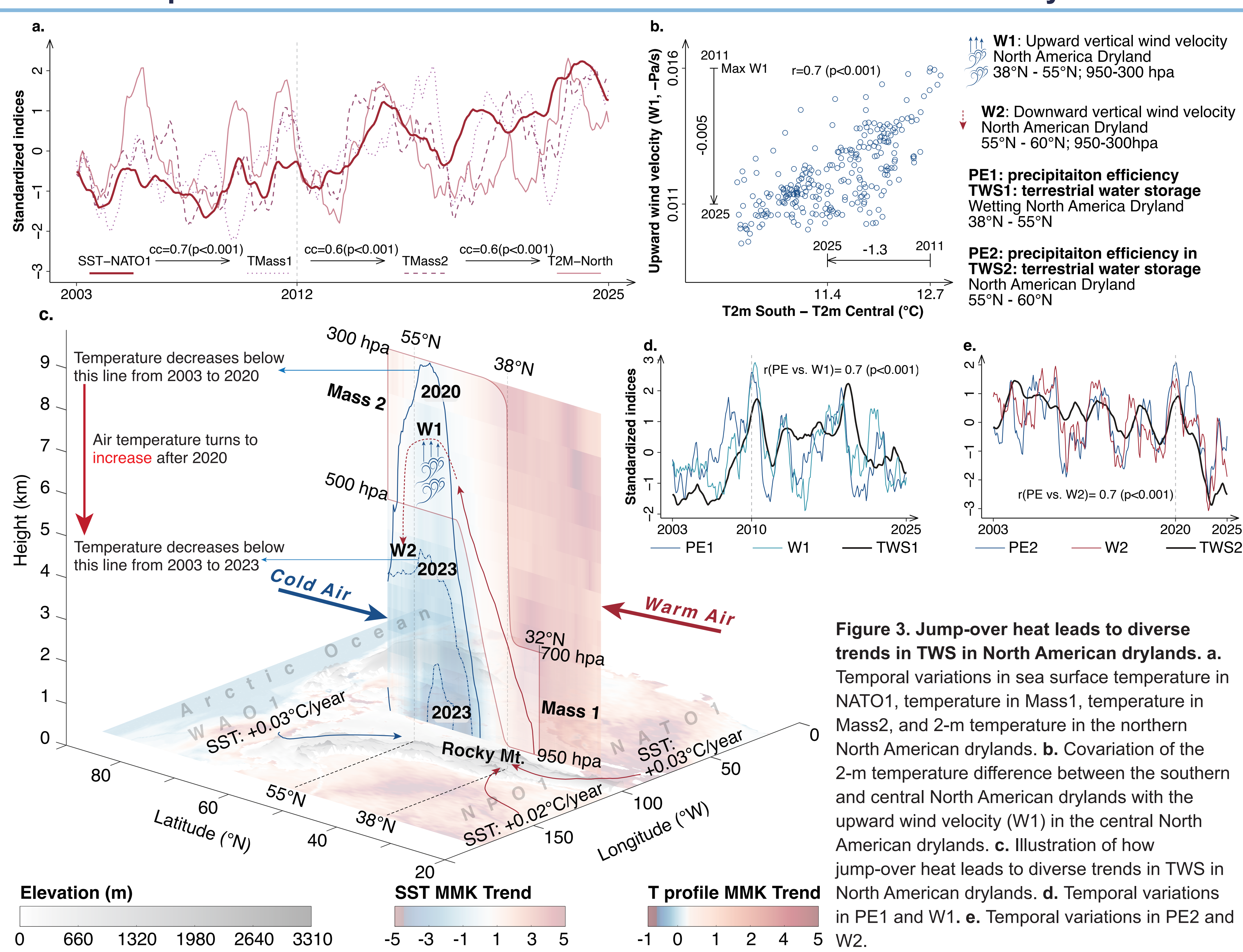


Figure 3. Jump-over heat leads to diverse trends in TWS in North American drylands. a. Temporal variations in sea surface temperature in NATO1, temperature in Mass1, temperature in Mass2, and 2-m temperature in the northern North American drylands. b. Covariation of the 2-m temperature difference between the southern and central North American drylands with the upward wind velocity (W1) in the central North American drylands. c. Illustration of how jump-over heat leads to diverse trends in TWS in North American drylands. d. Temporal variations in PE1 and W1. e. Temporal variations in PE2 and W2.

Key Takeaways

Phenomenon

- Divergent trends in TWS in North American drylands.** The TWS in the southern and northern North American drylands has been declining from 2003 to 2025, while the TWS in the central regions shows increasing trends.
- Wetting regions are shrinking in North American drylands.** After 2020, wetting regions sharply shrank. Its area reduced from 2.9M km² to 1.3M km² from by 2025.

Mechanism: Jump-over heat led to diverse trends in TWS in North American drylands

- Jump-over heat exacerbated atmospheric dryness in the southern and northern drylands, further leading to the decline in TWS.
- Upward vertical wind (W1) blocks the heat flow into the central drylands, which reduces the atmospheric dryness there and thereby increases precipitation efficiency and, in turn, TWS.

Reference

- Williams, A.P., Cook, B.I. & Smerdon, J.E. Rapid intensification of the emerging southwestern North American megadrought in 2020–2021. Nat. Clim. Chang. 12, 232–234 (2022). <https://doi.org/10.1038/s41558-022-01290-z>.
- Rodell, M., Famiglietti, J.S., Wiese, D.N. et al. Emerging trends in global freshwater availability. Nature 557, 651–659 (2018). <https://doi.org/10.1038/s41586-018-0123-1>