UCLA
UCLA Previously Published Works

Title

Compound weather and climate events in 2025

Permalink

https://escholarship.org/uc/item/1hd273gx

Journal

Nature Reviews Earth & Environment

Authors

Raymond, Colin
García-Martínez, Ivonne M
Rogers, Cassandra DW
et al.

Publication Date

2026-06-03

DOI

10.1038/s43017-026-00797-9

Copyright Information

This work is made available under the terms of a Creative Commons Attribution-NonCommercial-ShareAlike License, available at https://creativecommons.org/licenses/by-nc-sa/4.0/

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Compound weather and climate events in 2025

Colin Raymond[1], Ivonne M. García-Martínez[2], Cassandra D. W. Rogers[3], Yang Chen[4], Weiqing Han[5], Renata Libonati[6,7], Nicholas P. Simpson[8], Christopher J. White[9], and Jakob Zscheischler[10,11]

[1]Joint Institute for Regional Earth System Science and Engineering, University of California, Los Angeles, Los Angeles, California, USA
[2]Department of Physical Oceanography, Centro de Investigación Científica y de Educación Superior de Ensenada, Ensenada, Mexico
[3]Bureau of Meteorology, Melbourne, VIC, Australia
[4]Chinese Academy of Meteorological Sciences, Beijing, China
[5]Department of Atmospheric and Oceanic Sciences, University of Colorado-Boulder, Boulder, Colorado, USA
[6]Department of Meteorology, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
[7]Instituto Dom Luiz, University of Lisbon, Lisboa, Portugal
[8]African Climate and Development Initiative, University of Cape Town, Cape Town, South Africa
[9]Department of Civil and Environmental Engineering, University of Strathclyde, Glasgow, UK
[10]Department of Compound Environmental Risks, Helmholtz Centre for Environmental Research — UFZ, Leipzig, Germany
[11]Department of Hydro Sciences, TUD Dresden University of Technology, Dresden, Germany

*Email: csraymond@ucla.edu

Key Points

1) Events exhibiting spatial, temporal, and multivariate compounding interactions drove devastating floods and wildfires in Asia and North America in 2025.
2) Severe flooding in North and South America resulted from heavy precipitation following both anomalous wet spells (temporal compounding) and dry spells (preconditioning).
3) Heat events compounded with biological extremes to damage marine ecosystems near Australia, and with drought to stress food and energy systems in Mesopotamia.

The spatiotemporal layering of weather and climate events produces impacts often greater than those associated with individual hazards[1]. Such compounding interactions have contributed to some of the most high-impact disasters so far this century, partly owing to ever-increasing temperatures and an intensified hydrological cycle. In 2025, multiple compound events affected built and natural systems, with both commonalities and differences relative to high-impact compound events of 2024 (ref.[2]). Compound-event typologies include nonlinearly interacting combinations of events across space (spatial compounding) and across time (temporal compounding); events contingent on a pre-existing Earth-system state (preconditioning); and events with multiple co-occurring hazards or drivers (multivariate interactions) (Fig. 1). We also note compound events with cross-cutting typologies, which fundamentally combined aspects of

two or more of the above typologies. Here, we present a selection of well-documented, high-impact compound events in 2025.

[H1] Spatially compounding events

Whereas notable spatially compounding marine heat waves occurred in 2024 (ref.[2]), 2025 lacked such events, partly because fewer regions experienced record-warm annual surface air and water temperatures. The numerous large-scale wildfires in central Canada throughout spring and summer were the most prominent case of spatial compounding in 2025. With nearly 9 million ha of forest and prairie burned, 2025 was Canada's second-worst wildfire year by area, following 2023 and surpassing 2024. Prolonged periods of hot, dry, and windy weather — including a May heatwave that reached 37°C — combined with long-term drought to prime the landscape for numerous ignitions. Approximately 85,000 people were evacuated (versus 230,000 in 2023), and property losses exceeded 1 billion USD. The volume of smoke from all the fires combined caused major cities in Canada and the northern USA to experience poor air quality recurrently throughout the summer, echoing 2023.

[H1] Temporally compounding events

Extraordinary flooding, as occurred in eastern Mexico from 6–9 October, is a typical manifestation of high-impact temporal compounding. Following an unusually wet period, Hurricane Priscilla and Tropical Storm Raymond in the Pacific Ocean and Tropical Disturbance 90E in the Atlantic Ocean fueled additional rainfall of up to 700 mm, a sequence reminiscent of Hurricane Helene in 2024 (ref.[2]). The exceptional precipitation totals led to floods and landslides that claimed 83 lives, damaged over 100,000 homes, and isolated hundreds of communities. The affected area spanned about 200,000 km^2, representing 10% of Mexico, and the flooding strained emergency services and infrastructure networks. Floodplain development contributed to the catastrophe, which disproportionately affected remote and Indigenous communities[3]. A much more localized temporally compounding flood struck Bahía Blanca in northern Argentina on 7 March, when about 300 mm of rainfall followed a week-long precipitation event that had already delivered 80 mm and saturated soils. The resulting urban floods caused 17 deaths and infrastructure damage of about 400 million USD.

[H1] Preconditioned events

Preconditioned compounding encompasses sets of hazards whose ultimate impacts depend on the order of occurrence[1]. A devastating compound event of this type occurred in the south-central USA in July, when Tropical Storm Barry and Hurricane Flossie drenched the region with 250-500 mm of precipitation (approximately one-third of the mean annual total); the rain fell on a drought-parched landscape, limiting infiltration rates. The rapid runoff caused deadly flash floods, with the Guadalupe River in Texas rising by 6 m in one hour and killing at least 135 people[4]. Heavy monsoonal rainfall on dry soils caused similarly deadly flash flooding in New Mexico several days later. As they involved a spring drought–summer flood sequence with severe impacts, these events resembled those in eastern China in 2024[2].

Preconditioning can also involve temperature extremes. In Türkiye, following a balmy March with +3°C mean-temperature anomalies that led to early flowering of fruit trees, widespread hail and severe cold struck orchards in April. This 'false spring' caused >50% losses in fruit crops, more than doubling fruit prices for months and causing substantial economic pain for farmers and consumers.

The greater temporal memory of the ocean relative to the atmosphere can make marine ecosystems especially vulnerable to preconditioned events. Off southern Australia, extreme ocean temperatures in 2024 and 2025 triggered a record-setting harmful algal bloom, which is likely to have been preconditioned by excess nutrients lingering from the 2022–2023 Murray River flood events and by 2023–2024 anomalous upwelling activity. This bloom, ongoing as of early 2026, has spanned 20,000 km^2 and killed millions of marine animals across hundreds of species[5]. Separately, a nine-month marine heatwave off Western Australia from 2024 into 2025 caused record-setting coral bleaching and severe coral mortality across a 1,500 km swath[6]. Above-average tropical-cyclone activity in 2025 further damaged the already weakened reefs.

[H1] Multivariate events

Storm Éowyn in the northern British Isles in January can be viewed as a multivariate event, as it simultaneously caused heavy rain, heavy snow, and winds gusting over 80 kt. Transportation, power, and telecommunications links were interrupted owing to both direct damage from winds and coastal flooding and indirect damage from snowdrifts and downed trees[7] — similar to what was observed during Storm Henk in January 2024 (ref.[2]). Other sets of hazards can mutually amplify on a seasonal timescale, as occurred in 2025 in Mesopotamia: pre-existing drought conditions were worsened by a spring with less than half of normal precipitation, and contributed to raising May–July mean temperatures above +2 standard deviations. This hot-dry combination triggered wildfires and crises in food, water, and power supplies, reflecting complex regional natural- and human-system dynamics. Syria, Iran, and Iraq felt the most severe impacts, with 2025 being the driest year in Iraq since at least 1933.

[H1] Events with cross-cutting typologies

Some of the most notable compound events of 2025 comprised particularly complex sets of physical interactions across space and time that lacked a single dominant typology, but rather emerged from the interplay of multiple typologies.

In early January, excessive fuel loads due to a preconditioning sequence of wet winters and then dry winters combined with a warm dry airmass and strong downslope winds to produce intense wildfires in Southern California[8]. Two large wildfires within Los Angeles County rapidly overwhelmed local emergency-response capacities owing to their rapid growth rate, the sheer size of their spatially compounded threat to lives and property, and the accompanying strong winds that prevented usage of firefighting aircraft. The combination of seasonal-scale preconditioning, multivariate extreme weather, and spatial compounding of wildfires was regionally unprecedented and led directly to 24 hours of nearly unchecked destruction. The final tally came to 440 deaths, about 16,000 destroyed buildings, and approximately 200 billion USD in economic losses. These wildfires were even deadlier and costlier than those that devastated Chile in 2024[2].

Several storm clusters with multivariate, temporally compounding, and spatially compounding elements affected Southeast Asia in autumn 2025, an event type which occurred more prominently in 2025 compared with 2024 (ref.[2]). Multiple tropical cyclones struck southern China and northern Vietnam in September and early October, with flooding and high winds causing hundreds of deaths and billions of USD in economic losses. In the Philippines, Typhoons Kalmaegi and Fung-wong made landfall a few days apart in November, generating high winds and flooding that killed about 300 people, displaced millions, and challenged national-scale emergency response as the storms together affected nearly the entire archipelago. Typhoon Senyar struck Sumatra, Indonesia, in November and triggered floods and landslides, causing about 1,000 deaths and 880,000 people displaced. Nearly 10% of remaining Tapanuli orangutans may also have been killed. In Thailand, successive rounds of monsoon- and tropical-cyclone-related flooding throughout autumn left little time for water levels to subside before the next storm arrived; 185 people were killed and 220,000 displaced.

Summary

The most prominent compound events of 2025 reflect the nonlinearities of extreme weather events and rapid climate change. When colliding with human societies and physical, biological, or ecological thresholds, the nonlinearities in impacts become even sharper. These characteristics emphasize the need for compound events to be incorporated into adaptation plans and to be systematically studied and monitored, with special attention paid to addressing large geographic gaps in observational data, inconsistencies in media reports, and imprecise definitions. That numerous destructive events in 2025 involved multiple compound-event typologies points both to the value of the compound-event framing and the need for evolution toward a conceptual hierarchy spanning from intense univariate events, through compound events comprising several distinct hazards, to a new frontier of deeply complex events involving numerous contingent hazards and system interactions.

Figure

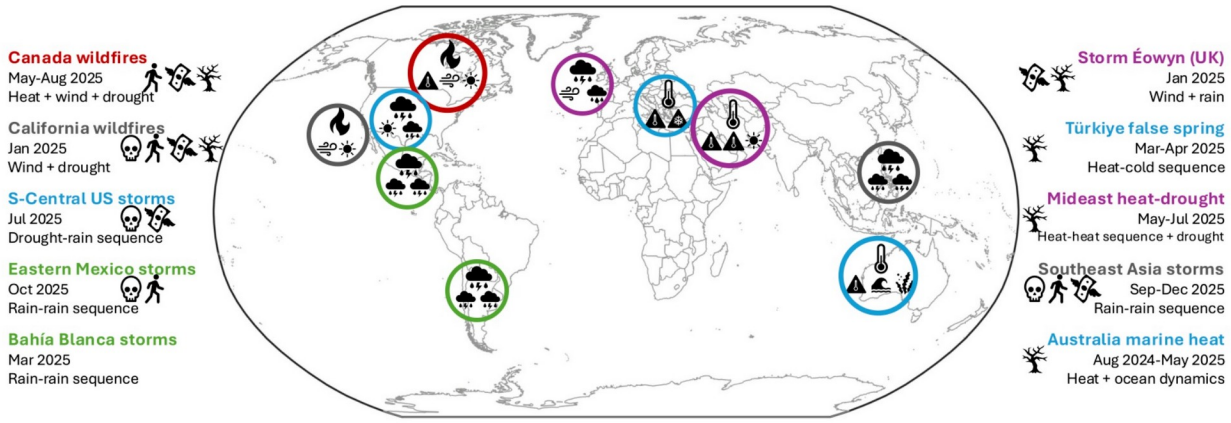


Fig. 1. ***The most prominent compound events in 2025.*** *Spatially compounding (grey), temporally compounding (blue), preconditioned (yellow), multivariate (pink), and cross-cutting (purple) events are listed alongside the sequences of hazards involved and their confirmed impacts, if exceeding the following thresholds: mortality of >50 people, displacement of >10,000 people, or economic cost of >1 billion USD. The ecosystem category is assessed qualitatively. These hazards and impacts illustrate the range of compound interactions shaping the critical extremes of the climate system.*

Acknowledgements

Y.C. acknowledges support from the National Natural Science Foundation of China (42375041). I.M.G.M. acknowledges the support of SECIHTI through Project CBF-2025-I-1037. R.L. acknowledges the Brazilian National Council for Scientific and Technological Development (Cnpq - grants 443285/2023-3 and 3083145/2025-5) and Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ grant E-26/200.424/2026). C.D.W.R. is supported by funding from the Australian Climate Service. N.P.S. received support through Schmidt Sciences. C.J.W. acknowledges the COST Action ANTICIPATE: extended-range multi-hazard predictions and early warnings (CA24144), supported by COST (European Cooperation in Science and Technology).

Competing interests

The authors have no competing interests to report.

References

1. Zscheischler, J., et al. A typology of compound weather and climate events. *Nature Reviews Earth and Environment, 1,* 333–347 (2020). https://doi.org/10.1038/s43017-020-0060-z.
2. Zscheischler, J., et al. Compound weather and climate events in 2024. *Nature Reviews Earth and Environment, 6,* 240-242 (2025). https://doi.org/10.1038/s43017-025-00657-y.
3. Barnes, C., et al. Heavy rainfall leading to widespread flooding in eastern Mexico disproportionately impacts highly exposed Indigenous and socially vulnerable communities. World Weather Attribution (WWA) scientific report no. 77 (2025). https://doi.org/10.25560/125455.
4. Gerlich, J., et al. From dust to deluge: Weather whiplash devastates Texas. National Oceanic and Atmospheric Administration. https://www.drought.gov/news/dust-deluge-weather-whiplash-devastates-

texas-2025-07-23. Accessed 6 Feb 2026.
5. Stokstad, E. (2025). Australia's toxic algal bloom has a surprise culprit. *Science*, *390* (6774). https://doi.org/10.1126/science.z41uwyq.
6. Western Australia Bleaching Group. Worst bleaching event on record for WA coral reefs following long lasting and widespread marine heatwave. Australian Institute of Marine Science. https://www.aims.gov.au/information-centre/news-and-stories/worst-bleaching-event-record-wa-coral-reefs-following-long-lasting-and-widespread-marine-heatwave (2025). Accessed 1 Mar 2026.
7. Cha, Y., et al. Assessing the cascading impacts of natural hazards on Critical National Infrastructure (CNI) using Scotland as a case study. *npj Natural Hazards, 2,* 108 (2025). https://doi.org/10.1038/s44304-025-00161-9.
8. Guirguis, K., et al. Compound atmospheric drivers of the catastrophic 2025 Los Angeles urban firestorm. *npj Natural Hazards, 2,* 103 (2025). https://doi.org/10.1038/s44304-025-00155-7.