Historical analysis of global distribution of and trends in wind droughts

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What are wind droughts and why are they important?

Wind power is one of the critical low-carbon energy sources that is expected to play a substantial role in decarbonizing electricity generation.

Under some energy transition scenarios, onshore and offshore wind will provide more than one-third of global electricity needs by 2050.

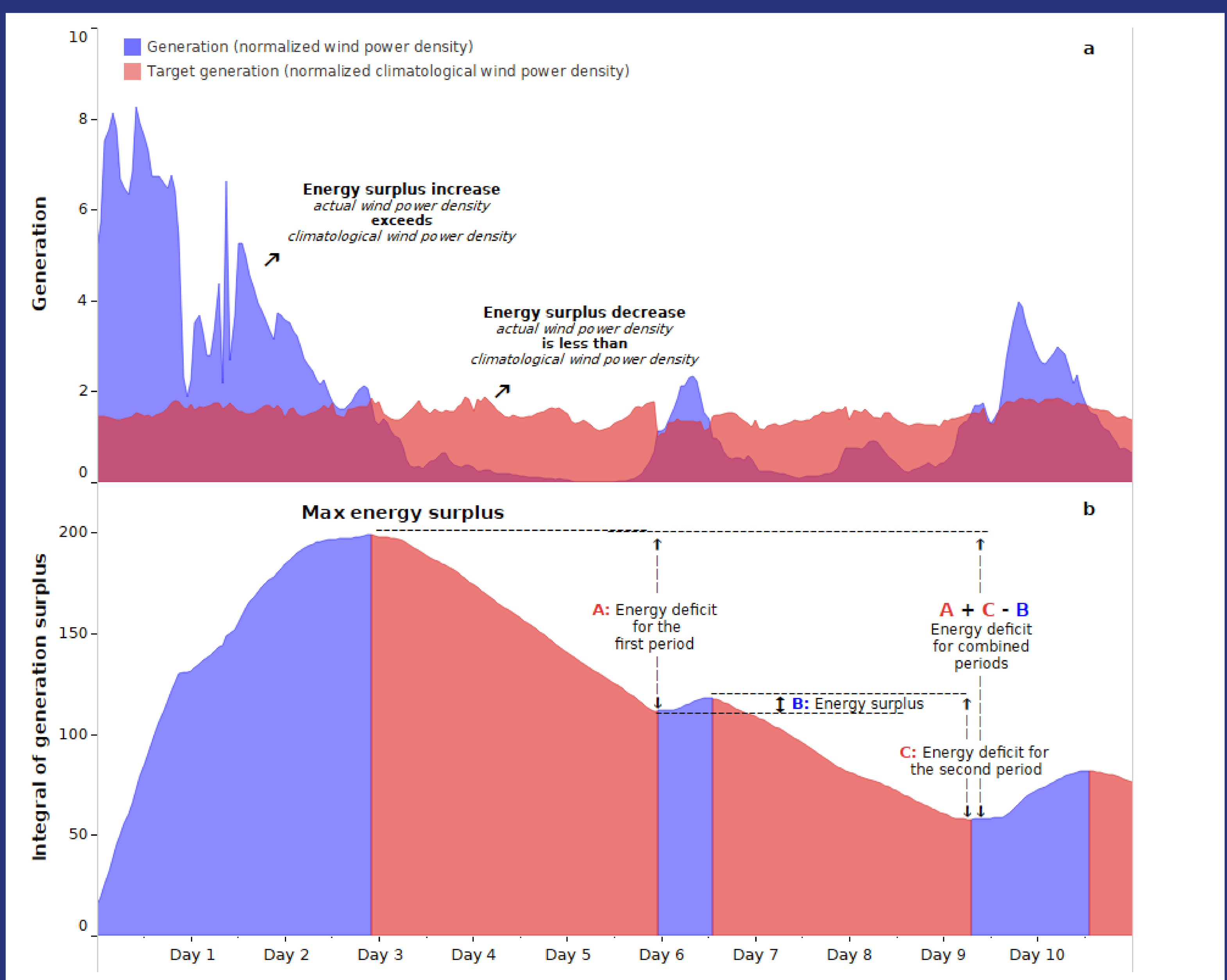
Wind droughts, or prolonged periods of low wind speeds, can be a severe issue for electricity systems that are largely reliant on wind generation.

The increasing use of this intermittent source can exacerbate the exposure of national power systems to meteorological variability, potentially requiring emergency intervention by the system operators.

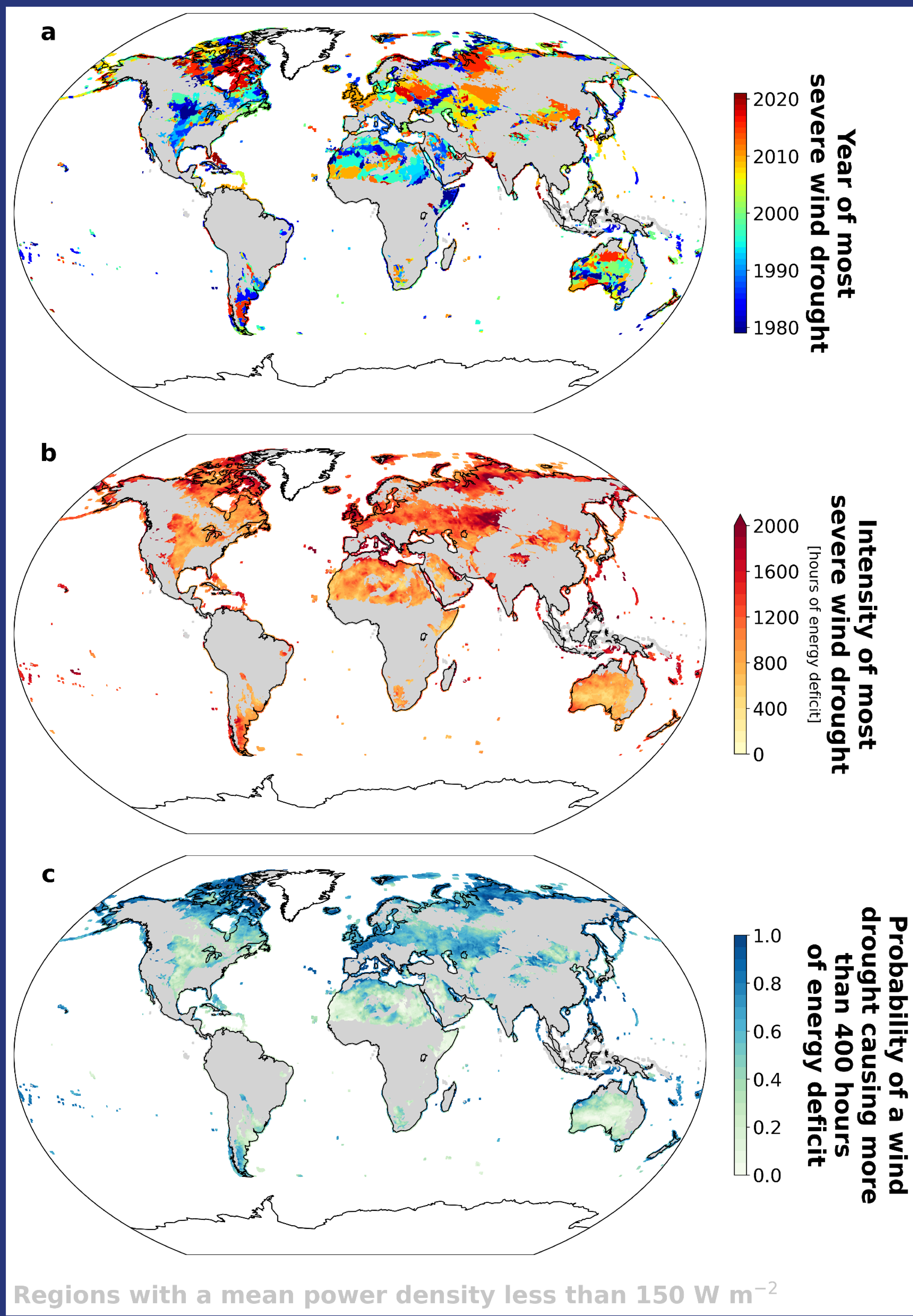
How did we characterize them?

We analyzed the ERA5 weather reanalysis (the fifth-generation atmospheric reanalysis of the global climate by the European Center for Medium-Range Weather Forecasts) for the period from 1979 through 2021, using an energy deficit metric that integrates the depth and duration of wind droughts over an annual temporal scale.

This metric quantifies the energy deficit of a wind-based power system over an annual time scale when we set a target generation profile.



Our historical analysis of wind droughts



The maps show the year of the most severe wind drought (panel a), the length of the most severe wind drought in hours of energy deficit (panel b), and the probability of having a year with a wind drought causing more than 400 hours of deficit (panel c).

Only places on land or coastal areas and with a mean power density greater than or equal to 150 W m^{-2} are plotted. Grid cells that have a mean power density greater than 150 W m^{-2} account for approximately 46% of the total grid cells over land and coastal areas, excluding Greenland and Antarctica.

What did we find?

We found that the most promising areas for power generation from winds are the American Midwest, Australia, the Sahara, Argentina, parts of central Asia and southern Africa, which have relatively high power densities, relatively low amounts of climatological seasonal variability, and relatively low weather variability.

We also found less ideal regions with high power densities but high weather variability, such as northern Europe, characterized by more frequent wind droughts.

Our analysis shows that the most severe wind droughts in many places occurred well before wind power generation contributed substantially to power systems.

This prevalence of wind droughts in the historical record, combined with little evidence for strong trends in their prevalence, suggests a statistical analysis of weather reanalysis products could provide valuable guidance in designing electricity systems reliant on wind power that are robust to wind droughts.

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