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Atmospheric circulation during the Late Maunder Minimum from ships' logbooks

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We use daily wind direction observations from ships' logbooks over the English Channel to construct atmospheric circulation indices on a monthly basis for the Late Maunder Minimum (LMM, 1685-1715). They include four wind directional indices (one for each cardinal direction) and 8-point wind roses providing the monthly persistence of the wind from a given direction.
Firstly, the indices are used to characterize the atmospheric circulation during the LMM. The results reveal a pronounced increase of the meridional circulation during the LMM and a marked reduction in the frequency of the westerlies all year-round, as compared to present-day (1981-2010). In spite of this overall picture, the LMM hided contrasting spatial patterns in circulation, as well as, large decadal variability. In particular, we report increased northerlies contributing to colder winters in Europe during the first half of the LMM, but enhanced southerlies favoring milder winters in the second half of the LMM.
Second, we infer the dynamically-driven temperature anomalies during the LMM based on flow (8-point wind roses) analogues of the 20th century. The results confirm the majority of the well-documented extremely cold winters. However, the analysis also uncovers other less documented cold winters and a substantial number of mild winters, most of which had been largely unnoticed. Extremely cold winters were associated with negative phases of a "high zonal" North Atlantic Oscillation (NAO) pattern, while moderately cold winter were rather dominated by negative phases of a "low zonal" NAO pattern.
Therefore, our results indicate that the LMM was more heterogeneous than expected, displaying decadal variability, non-stationary signatures of the NAO pattern a relatively frequent mild winters.
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