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A high-resolution picture of Euro-Atlantic climate variability during the Late Maunder Minimum

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The Late Maunder Minimum (LMM, 1685-1715) denotes the climax of the Little Ice Age (LIA, cf. 1400-1700), which was one of the coldest periods in the last millennium. The LMM is a period of great interest since it was one of the few cold periods in recent centuries that persisted for several decades.
Here, we present the first direct instrumental evidence of the daily atmospheric circulation over the eastern Atlantic during the LMM based on wind direction observations taken aboard ships over the English Channel. To do so, we derived two sets of monthly atmospheric circulation indices based on the persistence of the wind direction in the four cardinal directions and in 8-point wind roses for the 1685-2014 period. They provide the longest observational records of the atmospheric circulation to date, allowing us to explore the variability of the atmospheric circulation in a wide range of time-scales.
The analysis of these indices indicate that the LMM was characterized by a pronounced meridional circulation and a marked reduction in the frequency of westerlies all year round, as compared to the present (1981-2010). The winter circulation contributed the most to enhance the cold conditions through an overall increase of northerly winds. Nevertheless, our findings also show a LMM more heterogeneous than previously thought, displaying contrasting spatial patterns in circulation and temperature, as well as large decadal variability.
Based on the circulation characteristic of each winter, we provide a new observational-based catalogue of winters for the LMM, reassessing the indirect evidences available in the literature about the temperature conditions of the LMM. Our assessment confirms the majority of extremely cold winters documented in the literature, but also uncovers the existence of additional undocumented cold winters and a substantial number of mild winters that had been unnoticed so far. The outcomes also suggest a non-stationarity of the North Atlantic Oscillation (NAO) pattern within the LMM, which has not been reported before, with extremely cold (moderate) winters being associated to negative phases of a “high-zonal” (“low-zonal”) NAO pattern.

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