# Increasing probability of simultaneous heat waves due to a quasi-stationary wave 7 teleconnection favored by heterogeneous surface warming

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Since the beginning of the 21st century the northern hemisphere mid-latitudes have experienced an unusual number of severe heatwaves bringing devastating impacts to societies and ecosystems. The magnitude of these extremes exceeded what would be expected solely from an intensified radiative warming due to rising greenhouse gas concentrations in the atmosphere. This increase of summer extremes coincides with large scale changes in the northern hemispheric surface temperature gradients characterized by an over-proportional warming of the Arctic and an enhanced warming of land compared to the oceans. Changes in global temperature gradients can impact the large scale atmospheric circulation in the mid-latitudes and thereby affect the weather patterns in these densely populated regions. Here we show that several of recent European and US heatwaves (e.g. 2003, 2009, 2012, 2015, 2017) were local imprints of a hemispheric circulation pattern of a stationary wave number 7. This teleconnection, characterized by a strongly meandering jet stream, causes hemispheric temperature anomalies, with signals of amplified heat over central North America, Western Europe and the Ural Region, possibly explaining the increase of more stationary and anti-cyclonic weather here. This pattern is favoured by a low meridional temperature gradient and spatially confined by a high land-ocean temperature contrast as well as prominent mountain ranges in the northern hemisphere mid-latitudes. Both - a decreasing meridional temperature gradient and enhanced land warming - are robust global warming signals in the northern hemisphere summer. This suggests that this pattern will likely become more frequent in the future, further adding to the increase of persistent heatwaves in the aforementioned regions.

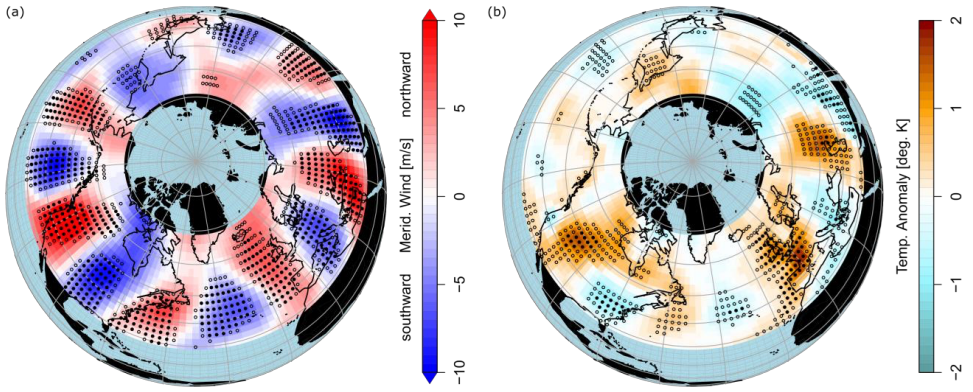


**Figure 1 | Hemispheric circulation and surface weather during wave 7 events. a)** Meridional wind speeds (northward: red; southward: blue) during the 40 weeks of high wave 7 amplitudes (>1.5 σ) in summer (JJA) over the NH mid-latitudes (30°N - 67.5°N) observed over the period 1979 - 2016. **b)** Composite plot of daily surface temperature anomalies over the NH mid-latitudes (30°N - 67.5°N) during those 40 events. The filled stippling in a) and b) indicates grid-cells with significant deviations from JJA climatology using a significance test that accounts for the false discovery rate (FDR) associated with multiple testing, while the grid-points marked with hollow stippling indicate local significance.