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Signatures of midlatitude heat waves in the global atmospheric circulation

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This work investigates systematic changes of the global atmospheric circulation during midlatitude heat waves in spectral space. The basis functions for the expansion of global data are the eigensolutions of the linearised primitive equations; here, the Rossby waves are represented in terms of Hough harmonics that are defined by their zonal wavenumber, meridional modes and vertical structure functions. Their orthogonality allows diagnostics in terms of energy of the zonal mean flow and wave energies. The diagnostic provides a holistic dynamical picture of the variability spectrum of Rossby waves and allows scale-selective filtering of modes of variability in physical space. The method is applied to reanalysis datasets starting in 1980.

The reconstructed circulation (the inverse projection onto wind and geopotential fields based on selective filtering) during heat waves is dominated by large-scale anticyclonic systems in agreement with previous studies, thereby demonstrating the physical meaningfulness of the applied method. Probability distribution functions of Rossby wave energies are evaluated separately for the zonal mean flow, for the planetary and synoptic zonal wavenumbers with the tropospheric barotropic structure. Time series of wave energies are characterised by a chi-square distribution. The chi-square skewness shows a reduction in the number of involved degrees of freedom for planetary-scale circulation by 50% during the heat waves. This reduction yields a quantitative estimate for the coarse large-scale structure of blocking events and its barotropic structure in the midlatitude troposphere. The robustness of the results is ensured by considering the four reanalyses: ERA5, ERA-Interim, JRA-55 and MERRA datasets.