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Power-law frequency scaling of surface temperature spatial degrees of freedom – estimated from instrumental data, reanalysis and climate model simulations

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What is the spatial scale of climate fluctuations, and how does this scale depend on the timescale under consideration? To answer this question, the spatio-temporal correlation structure of global surface temperature fields is characterized, for the period 1850-present, by estimating frequency spectra of the effective spatial degrees of freedom (ESDOF). These ESDOF spectra serve as a simple summarizing metric of the frequency-dependent spatial auto-correlation function. ESDOF spectra are estimated from: (a) the HadCRUT global gridded temperature anomaly dataset, based exclusively on instrumental measurements, and including detailed error variance estimates; (b) the NOAA 20th Century Reanalysis; and (c) a large ensemble of CMIP historical climate model simulations. When comparing (i) error corrected ESDOF spectra from the instrumental data to (ii) those obtained from the reanalysis and the model simulations, with HadCRUT data gaps imposed, results are found to be highly consistent among the three data sources. When the analysis is applied to the entire globe, the ESDOF spectra exhibit an almost uniform power-law frequency scaling with about 100 ESDOFs at monthly timescales and only about 2 ESDOFs at multidecadal timescales. Second-order differences in this scaling behaviour are found when the analysis is restricted to various spatial subdomains of the globe, namely, the tropics, extra-tropics, land areas, and ocean areas. A few implications of the diagnosed ESDOF reduction towards the longer timescales are briefly discussed.