Data quantile-quantile plots: model independent quantification of the evolution of the full distribution and application to solar wind turbulence and extremes

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Characterizing turbulence, and complex systems more widely, often requires quantitative characterization of the full distribution of observed variables and how it varies with control parameters or driving of the system. We will discuss data-data quantile-quantile plots which quantify how the underlying statistical distribution of a given observable is changing in time or with scale. Importantly this method does not require any assumptions concerning the underlying functional form of the distribution and can identify multi-component behaviour that is changing. This can be used to determine when a sub-range of a given observable is undergoing a change in statistical distribution, or where the moments of the distribution only are changing and the functional form of the underlying distribution is not changing [1]. The method is quite general and we will apply it to the solar wind which is inherently variable across a wide range of spatio-temporal scales. Embedded in the solar wind flow are the signatures of distinct non-linear physical processes from evolving turbulence to the dynamical solar corona which also shows scaling. In-situ satellite observations of solar wind magnetic field and velocity are at minute and below time resolution and now extend over several solar cycles. Each solar cycle is unique, with different space climatology and we use this methodology to quantify how solar wind turbulence, and extremes respond within, and across, each distinct solar cycle; for this application we use data from the WIND satellite to compare the solar wind across the minima and maxima of solar cycles 23 and 24. We consider in-situ solar wind plasma parameters in fast and slow solar wind such as the magnetic energy density and the Poynting flux. The core of the plasma parameter distributions retains a log-normal functional form simply varying in amplitude with the solar cycles, in agreement with previous work and suggestive of a multiplicative underlying physical process consistent with turbulence. The DQQ method also identifies the threshold energy flux at which solar wind plasma parameters depart from the lognormal regime; this extremal component exhibits its own dependence on the solar cycle which is distinct between fast and slow wind.

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