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Statistical characterization of simulated wind ramps

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Wind ramps, or rapid changes in wind speed, are a crucial aspect of atmospheric dynamics and have significant implications for various wind energy applications. For example, wind ramps tend to increase uncertainty in power output predictions. Furthermore, they also induce fatigue damage
to wind turbines.

In a recent study, DeMarco and Basu (2018; Wind Energy) used long-term observational data from four geographical locations to characterize the tails of the wind ramp probability distribution functions (pdfs). They showed that the pdfs from these various sites (ranging from offshore to complex terrain) portray quasi-universal behavior. The tails of the pdfs are much heavier than the Gaussian pdf and decay faster with increasing time increments. The tail-index statistics, computed via the so-called Hill plots, exhibited minimal height dependency up to approximately one hundred meters above the land or sea surface level. However, wind ramp statistics at higher altitudes at Cabauw (the Netherlands) were quite distinct.

In the present study, we investigate if state-of-the-art reanalysis datasets capture the intrinsic traits of wind ramp pdfs. Specifically, we make use of the newly released Copernicus European Regional ReAnalysis (CERRA) dataset in conjunction with the popular fifth-generation ECMWF reanalysis (ERA5) dataset. These datasets allow us to describe the characteristics of wind ramp pdfs at high altitudes (up to 500 m). Given the disparity of the spatial resolution of CERRA (~5.5 km) and ERA5 (~32 km) datasets, we are also able to demonstrate the impact of spatial resolution on simulated tail index characteristics. Lastly, the influence of natural climate patterns such as El-Nino and La-Nina on wind ramp pdfs are examined.