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AtmoDist as a new pathway towards quantifying and understanding atmospheric predictability

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The predictability of the atmosphere is a classical problem that has received much attention from both a theoretical and practical point of view. In this work, we propose to use a purely data-driven method based on a neural network to revisit the problem. The analysis is built upon the recently introduced AtmoDist network that has been trained on high-resolution reanalysis data to provide a probabilistic estimate of the temporal difference between given atmospheric fields, represented by vorticity and divergence. We define the skill of the network for this task as a new measure of atmospheric predictability, hypothesizing that the prediction of the temporal differences by the network will be more susceptible to errors when the atmospheric state is intrinsically less predictable. Preliminary results show that for short timescales (3-48 hours) one sees enhanced predictability in warm season compared to cool season over northern midlatitudes, and lower predictability over ocean compared to land. These findings support the hypothesis that across short timescales, AtmoDist relies on the recurrences of mesoscale convection with coherent spatiotemporal structures to connect spatial evolutions to temporal differences. For example, the prevalence of mesoscale convective systems (MCSs) over the central US in boreal warm season can explain the increase of mesoscale predictability there and oceanic zones marked by greater predictability corresponds well to regions of elevated convective activity such as the Pacific ITCZ. Given the dependence of atmospheric predictability on geographic location, season, and most importantly, timescales, we further apply the method to synoptic scales (2-10 days), where excitation and propagation of large-scale disturbances such as Rossby wave packets are expected to provide the connection between temporal and spatial differences. The design of the AtmoDist network is thereby adapted to the prediction range, for example, the size of the local patches that serve as input to AtmoDist is chosen based on the spatiotemporal atmospheric scales that provide the expected time and space connections.

By providing to the community a powerful, purely data-driven technique for quantifying, evaluating, and interpreting predictability, our work lays the foundation for efficiently detecting the existence of sub-seasonal to seasonal (S2S) predictability and, by further analyzing the mechanism of AtmoDist, understanding the physical origins, which bears major scientific and socioeconomic significances.