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A novel method for objective identification of weather-relevant 3-D potential vorticity anomalies

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Potential vorticity (PV) analysis plays a central role in studying atmospheric dynamics and in particular in studying the life cycle of weather systems. The three-dimensional (3-D) structure and temporal evolution of the associated PV anomalies, however, are not yet fully understood. An automated technique to objectively identify 3-D PV anomalies can help to shed light on 3-D atmospheric dynamics in specific case studies, as well as facilitate statistical evaluations within climatological studies. Such a technique to identify PV anomalies fully in 3-D, however, does not yet exist.

This study presents a novel algorithm for the objective identification of PV anomalies. The algorithm is inspired by morphological image processing techniques and can be applied to both two-dimensional (2-D) and 3-D fields on vertically isentropic levels.

The method maps input data to a horizontally stereographic projection and relies on an efficient computation of horizontal distances within the projected field. Candidates for PV anomaly features are filtered according to heuristic criteria, and feature description vectors are obtained for further analysis. The generated feature descriptions are well suited for subsequent case studies of 3-D atmospheric dynamics, or for generation of climatologies of feature characteristics.

We evaluate our approach by comparison with an existing 2-D technique, and demonstrate the full 3-D perspective by means of meteorological case studies comprising tropical cyclogenesis and a subtropical extreme rainfall event. These case studies demonstrate the complexity and variations in the 3-D structure of the detected PV anomalies. Such anomalies are often insufficiently captured by a 2-D method. We discuss further advantages of using a 3-D approach, including elimination of temporal inconsistencies in the detected features due to 3-D structural variation, and elimination of the need to manually select a specific isentropic level on which the anomalies are assumed to be best captured.