Classification of extratropical cyclogenesis events based on a set of precursors

Michael Sprenger, Michael Graf, and Heini Wernli

ETH Zurich, Atmospheric and Climate Science, Zurich, Switzerland (michael.sprenger@env.ethz.ch)

Many studies indicate that extreme weather events are often associated with extra-tropical cyclones. In this study, we consider the genesis of these systems, which has been shown to exhibit a large variability of the physical processes (so-called precursors) involved. More specifically, potential precursors for cyclogenesis are systematically and comprehensibly investigated on a statistical basis. For this reason, cyclones are objectively identified during the time period 2000-2011 in the ERA-interim dataset and then tracked along their life cycle. The starting points of these tracks are considered as the points of cyclogenesis.

In the environment of these cyclogenesis locations a set of about 30 potential precursors is determined. The set includes the following parameters: (a) the surface conditions and fluxes (e.g., sensible and latent heat fluxes, sea surface temperature); (b) characteristic conditions in the troposphere (e.g., vertically integrated water vapor, amplitude of low-level potential vorticity); (c) measures of baroclinic and convective stability (e.g., horizontal temperature gradients, convective available potential energy, Eady growth rate); and (d) flow patterns and forcings from upper-tropospheric and stratospheric levels (e.g., jet streams and streaks, potential vorticity anomalies). In addition to simple Eulerian characterisations, more advanced diagnostic approaches are applied: Lagrangian backward trajectories, averaged time since oceanic moisture uptake of involved low-level air parcels, and layerwise quasi-geostrophic forcing for vertical motion.

In the phase space of these potential precursors - determined for a multitude of cyclones and suitably normalized - a principal component analysis is performed. The first two principal components are used subsequently for the separation of the cyclogenesis events in five classes. Composites of each class are constructed in order to represent the averaged spatial pattern of the precursors. This statistical approach reveals that the most important separating mechanisms are upper-level forcing and moist processes.

The classification of Petterssen and Smebye is reproduced, if enhanced moisture values are present. But also other physical mechanisms can be detected (e.g., diabatic Rossby waves). The classification approach is additionally applied to a selection of cyclones, which caused high-impact weather during their lifecycle.