Quantifying the Relevance of Cyclones for Precipitation Extremes Based on ERA-Interim Reanalyses

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Precipitation extremes and associated floods may have a huge impact on society. It is thus important to better understand the mechanisms causing these events, also with regard to their variations in a changing climate. Here the importance of a particular category of weather systems, namely cyclones, for the occurrence of regional-scale precipitation extremes is quantified globally, based on the ERA-Interim reanalysis dataset for the period 1989-2009. Such an event-based climatological approach complements previous case studies, which established the physical relationship between cyclones and heavy precipitation.

The advantage of using a reanalysis dataset for this study is its global availability with high, six-hourly time resolution and the fact that circulation patterns (including cyclones, which are identified from sea level pressure fields) are well constrained by observations. It is however not a priori clear if ERA-Interim precipitation extremes, which are obtained from short-term model forecasts, are sufficiently realistic to be used for further, process-oriented studies. This is checked by comparing the reanalysis data with precipitation estimates from the satellite observation-based CMORPH dataset for the years 2003 to 2009. The magnitudes of the precipitation extremes from the two datasets, quantified in terms of the grid-point based 99% percentile of six-hourly accumulated precipitation, agree rather well in the midlatitudes, but not equatorward of 30°, where ERA-Interim typically underestimates the magnitude of the extremes. Nevertheless, for the present study the timing of the extreme events is most crucial. This timing is evaluated by counting the number of coinciding events in both datasets. A good temporal consistency of precipitation extremes is found in the major parts of the extratropics, showing that ERA-Interim properly captures the timing of the events there and is thus well suited for analyzing the relationship between extreme precipitation events and the occurrence of cyclones.

A cyclone is assumed to induce a precipitation extreme if both occur simultaneously at the same grid point (taking into account only the local influence of the low pressure system). The percentage of extreme precipitation events coinciding with a cyclone is then quantified at every grid point. This percentage strongly exceeds the climatological cyclone frequency in many regions. It reaches maxima of more than 80%, e.g., in the main North Atlantic, North Pacific and Southern Ocean storm track areas. Other regional hot spots of cyclone-induced precipitation extremes are found in areas with very low climatological cyclone frequencies, in particular around the Mediterranean Sea, in eastern China, over the Philippines and the southeastern United States. Our results suggest that in these hot spot regions changes of precipitation extremes with global warming are specifically sensitive to variations in the dynamical forcing, e.g., related to shifts of the storm tracks.

Finally, properties of cyclones causing extreme precipitation are investigated. In the exit regions of the Northern Hemisphere storm tracks, these cyclones are on average slightly more intense than low-pressure systems not associated with extreme precipitation events, but no differences with respect to minimum core pressure are found in most other parts of the midlatitudes. The fundamental linkage between cyclones and precipitation extremes may thus provide guidance to forecasters involved in flood prediction, but it is unlikely that forecasting rules based on simple cyclone properties can be established. This study highlights the usefulness of high-quality reanalysis data for investigating processes associated with meteorological extremes.

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