Masterarbeitsthemen AG Atmosphärische Dynamik (Stand: 15.02.2018)

1) The Ouagadougou flood: Modelling extreme convection in the Sahel (Fink, Knippertz)

The capital of Burkina Faso, Ouagadougou, was hit by an extreme precipitation event that brought more than 260 mm of rainfall in the morning hours of 01 September 2009. This resulted in catastrophic flooding and several fatalities. This event exceeded the largest 24-hour rainfall accumulation of the last 100-years by nearly 100 mm, underpinning its extreme nature. In a recent manuscript (submitted to the J. Hydrometeorology), Engel et al. show that this event was also exceptional from a thermodynamic and dynamical point of view: A succession of two slow-moving African Easterly Waves (AEWs) caused record-breaking values of tropospheric moisture. The second AEW, one of the strongest in recent decades, provided the synoptic forcing for the nighttime genesis of Mesoscale Convective Systems (MCSs).

Using the ICON model, the role of MCSs and synoptic-scale AEW dynamics shall be compared against each other. This will be achieved by first conducting a nested ICON control run with convection permitting resolution at 2.8 km grid spacing at the highest resolution. Model output of this run will be analyzed in terms of the degree and type of convective organizations, with a particular focus on the role of cold pools in generating new cells, and in terms of the role of the AEW vortex in providing moisture advection/convergence, shear and lifting. The results will be compared with ERA-Interim analyses and results of Engel et al. (2017). Sensitivity experiments with ICON will be carried out by, for example, inhibiting the generations of cold pools or by enhancing background moisture and vorticity. These sensitivity experiments will serve two purposes: (a) the understanding of the role of convective dynamics and (b) the potential for even stronger extremes in a warmer world with stronger AEW vortices.

2) Dynamics of a synoptic-scale dusty vortex in Arabia (Pante, Knippertz)

In April 2015 a spectacular dust storm originated from the northern part of Saudi Arabia and covered the entire Arabian Peninsula and the adjacent Indian Ocean on the following days. Dynamics and predictability of such events are only little understood so far. First investigations of this case suggest convective processes to be one important component for the generation of a strong vortex with very high vorticity values throughout the atmosphere during the initial stage of the storm. Surprisingly, a comparison between surface station measurements and operational ECMWF analyses suggest that the analysis underestimates the strength of the vortex, which is also evident in the dust movement in satellite imagery. It is conceivable that convective vertical mixing and vortex stretching have both contributed to the strong rotation at low levels. In this MSc thesis, calculations of the vorticity budget from ECMWF data and own high-resolution model runs will be employed to understand the mechanisms leading to this extraordinary event. The model system ICON-ART, which includes a sophisticated dust module, will be used for simulations of this storm. Sensitivity experiments with the model in different resolutions and configurations, e.g. with and without convection parameterisation, will reveal the importance of single processes for the generation and the predictability of this dust storm.

3) Predictabiliy of tropical waves (Schlüter, Fink)

Planetary- to synoptic-scale tropical waves are key elements in the weather dynamics of the low latitudes and strongly couple with deep convection and thus precipitation. Examples of those waves are the Madden-Julian Oscillation, African easterly waves and Kelvin waves. The predictability of tropical rainfall on synoptic to sub-seasonal timescales is mainly limited

by the correct representation of tropical waves in numerical weather prediction (NWP) models. Due to their strong coupling with convection, models largely fail to capture the wave signals found in reality. Little research has been dedicated to the validation of tropical dynamics in NWP models. The aim of this MSc thesis is the assessment of tropical waves in the ECMWF operational forecasts (or even the S2S multi-model ensemble). For this purpose, the tropical waves will be filtered in the forecast data using using an available Equatorial Wave Filtering Tool. The properties of the waves in the NWP models will be compared to observed characteristics and the forecast horizon will be estimated. Finally, the underlying reasons for the misrepresentation will be analyzed. The thesis will be conducted in the framework of TransRegio 165 „Waves to Weather“ (http://w2w.meteo.physik.uni-muenchen.de).

4) Dynamics and predictability of the West African monsoon onset (Knippertz, Fink)

The short Sahelian rainy season is of crucial importance to the livelihood of millions of its inhabitants. In most years, the onset of the summertime monsoon rains occurs abruptly as a consequence of a change in the continental-scale circulation. It heralds the beginning of the next growing season. For decades, predicting this onset several weeks in advance has been a goal of national and international weather services but with relatively little success so far. Often the assumption is made that persistent anomalies in sea-surface temperatures provide enough predictive signal to be exploited using statistical or dynamical models. In individual years, however, profound extratropical disturbances have been documented to affect the circulation over West Africa around the onset time. In this Master thesis, the dynamical mechanisms relating extratropical disturbances and monsoon onset will be explored and implications for predictability inferred. The investigations will be based on ECMWF analysis data and satellite estimates of precipitation. The predictability aspect could be further examined based on ensemble predictions from the ECMWF.