COLD-SEASON MESOSCALE CONVECTIVE SYSTEMS IN GERMANY

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I. INTRODUCTION

In the winter months, warm air spreading into central Europe is mostly dominated by stable lapse rates as the low level air tends to cool over the land due to weak diurnal heating. However, deep and intense moist convection can also occur along of cold fronts in the winter season. For example, large and long-lived severe mesoscale convective systems (MCS) evolved during the winter storms "Kyrill" and "Emma" in 2007 and 2008. These systems were capable of producing frequent lightning, flash floods, severe wind gusts, and strong tornadoes. Using an ingredients-based methodology, forecasting of this type of cold-season convection can be a problem as latent instability is often not detectable before the event and seems to develop immediately before it is destroyed by the convection due to the strong forcing (Van Den Broeke et al., 2005). As a consequence, lapse rates and low-level moisture may not indicate clearly where and when deep moist convection will be likely.

This work tries to analyze some environmental conditions that enable MCS development in the range of initially stable air masses. Many of these thunderstorms seem to evolve from narrow convective lines that are frequently detected by radar along of cold fronts in mostly saturated air masses. Suggesting that this initial forcing is essential in most of the cases with deep moist convection in warm air masses during the winter season, their thermodynamic environment may show some favourable conditions that allow the shallow convection to become deep.

II. DATA

For this work, radar images of the German radar network operated by the German Weather Service (DWD) were analyzed to detect narrow convective lines. The terminus "narrow" is used in this work for convective lines that have a very large line-parallel extension relative to the line-normal extension. Narrow lines that were likely related to gust fronts of convection rather than synoptic-scale cold fronts were not taken into account. Additionally, convective lines with very weak reflectivity were difficult to detect and therefore had a weaker chance to be taken into account.

Radar images were taken from the winter seasons of 1998/99 until 2008/09 between 1st of November and 10th of March. Within this dataset, about 120 narrow convective lines were analyzed across Germany. Data of the EUCLID lightning network were used to identify electrified lines. WMO wind gust observations and the ESWD data set were used to search for severe weather related to the convection. Reanalysis data of the GFS global model were analyzed to characterize the large scale flow, especially the position of mid-level and low-level jets relative to the convective line. Furthermore, proximity soundings were searched for every convective line that was detected. Soundings were stated to be proximity when they were placed about 100 km or less in front of a convective line crossing the location during the next hour or less. Low-level parameters of the soundings were compared with the environment to check that it was really launched ahead of the narrow lines.

III. RESULTS AND CONCLUSIONS

In 10 years, about 120 narrow convective lines were detected in the radar images. Most of them (90 percent) had a line-parallel extension of at least 200 km; about 50 percent had a length of at least 400 km. The lines occurred in clusters: In the winter season of 2002/03, only 2 cases were found, while 8 lines were detected in only 12 days during the winter of 2007. Although on average most narrow lines occurred in January, a significant trend was not observable. Furthermore, the lines did not indicate to follow a diurnal cycle. Regarding the regional distribution of the narrow lines, they occur rather often in the north-western portions of Germany near the North Sea. The south-eastern quadrant of the country showed to lowest number of events. The propagation direction was from the north-west to the south-east for about 90 percent of the cases. Lines that moved to the north were not detected.

From the lightning network data, about 50 percent of the lines were counted as electrified. 20 percent of the all narrow lines were accompanied by severe wind gust and/or tornadoes. Large hail was not observed, while excessive rain was not taken into account. With respect to the position of the mid-level jet, about two thirds of all narrow lines occurred in the range of the cyclonic flank. These lines did produce more thunder (66 percent) and severe weather (25 percent) compared to narrow lines that were located in the range of the anticyclonic flank of the mid-level jet, where remarkable few lines produced thunder (9 percent) and severe weather was not reported. A strong low-level jet was found for most of the narrow lines (84 percent), and intense convective lines were all associated with strong or very strong (25 m/s) low-level jets.

More than 50 proximity soundings were found. Around ten of them were located near to severe weather reports along the narrow lines. Almost every of these sounding was characterized by at least moist neutral lapse rates, 60 percent showed CAPE, while the average CAPE value was 13 J/kg. The equilibrium temperature was about -6.1°C on average, with -9.3 for electrified lines and -7.6 for severe events. The equilibrium temperature does likely have a significant influence on the electrification process in the convective line (Van Den Broeke et al., 2005). The boundary-layer air was nearly saturated in 24 percent of the cases, while mixed boundary-layers were measured for 20 percent of the events. Severe weather seems predominantly occur with well-mixed low-levels. Low-level vertical wind shear was strong in most of the cases, with the average exceeding 15 m/s in the lowest kilometre.

This work shows that narrow convective lines do occur frequently over Germany. It indicates that the development of these lines is closely related to strong forcing in the range of mid-level jet streaks, while lightning and severe weather may correlate with the position of the cyclonic flank of the mid-level jet. Based on the analysis of proximity soundings, it seems that CAPE is present ahead of these lines. The depth of the unstable layer seems to increase underneath the cyclonic flank of the mid-level jet where more lightning was detected. Future work will discuss these results including international studies on cold-season mesoscale convective systems.

IV. REFERENCES

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