COMPARATIVE VERIFICATION OF DIFFERENT NOWCASTING SYSTEMS TO SUPPORT OPTIMISATION OF SEVERE WEATHER WARNINGS

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I. INTRODUCTION

Severe weather associated with deep convection pose a significant threat to life, property and economy. Fatalities, injuries and damages might be caused by lightning, gusts, hail, heavy precipitation or tornadoes. Therefore the provision of accurate and timely nowcast information, i.e. warnings provided by the national meteorological services, is essential for the general public as well as special users like emergency services and aviation.

Several algorithms exist which detect and nowcast deep convection. Most of them are based on either radar reflectivity measurements, like KONRAD (CONvection evolution in RADar products, Lang et al. 2003), CellMOS (Cell Model Output Statistics, Hoffmann 2008) and Rad-TRAM (Radar TRAcking and Monitoring, Kober and Tafferner 2009) or on satellite measurements like RDT (rapid developing thunderstorm, Morel et al. 2000) and Cb-TRAM (Cumulonimbus TRAcking and Monitoring, Zinner et al., 2008).

Due to their small horizontal extent, severe weather phenomena resulting from deep convection are rarely entirely and uniquely captured by current observation systems which hamper verification efforts. However, verification is needed to assess the quality of the algorithms, to determine their strengths and weaknesses and consequently to lead to improvements. Given that several nowcasting systems exist and could be used in the warning process these should not only be verified independently but also comparatively using the same method.

The use of consistent verification methods is crucial to compare the different systems. Of particular interest is the question how these algorithms can optimally be used to issue warnings of thunderstorms as well as accompanying specific phenomena like gusts or hail. Nowcast verification experiments have been performed e.g. during the WWRP Forecast Demonstration Projects during the Sydney and Beijing Olympic Games (Ebert et al., 2004, May et al. 2004, Wilson et al. 2010) which compared nowcast provided by different national meteorological services. In the study presented here we show the results of verification of the nowcast systems operated at DWD. Furthermore we discuss some challenges of convection verification.

II. VERIFICATION METHOD AND RESULTS

The nowcasting algorithms verified in this study are CellMOS and KONRAD. They are both based on 2D radar data using thresholds of 37dBZ and 46 dBZ respectively. Additionally CellMOS uses lightning and model data applying a model output statistics approach. Both systems run operationally every 5 minutes.

Verification of a nowcast system can be done by comparing the location (and category) of the nowcast and the analysis. E.g. such a verification of the KONRAD system showed that for all cells during MJJAS 2010 which lived at least 30min, the cell position of the +30min nowcast was on average 11km (±11km) away from the location of the analysis. The displacement error of the +60min nowcast of all cells with a lifetime of at least 120min was 14km (± 12km. Such studies test the consistency and tracking quality of a system.

However, these results do not sufficiently indicate whether the system provides adequate support for the warning process. The nowcast system should be verified against the warning criteria / categories (see Tab. I for an overview of the DWD thunderstorm warning categories).

Thunderstorms (attributes listed below)	Level
Strong Gusts (Bft. 7)	Moderate
Storm Force Gusts (Bft. 8-10)	Strong
Heavy Rainfall (10-25mm/h)	Strong
Storm Force Gusts, Heavy Rainfall	Strong
Storm Force Gusts, Heavy Rainfall, Hail	Strong
Hurricane Force Gusts (Bft. 11-12)	Severe
Storm Force Gusts, Very Heavy Rainfall	Severe
Storm Force Gusts, Very Heavy Rainfall, Hail	Severe
Hurricane Force Gusts, Very Heavy Rain, Hail	Severe
Very Heavy Rainfall (25-50mm/h)	Severe

TABLE I: Overview of DWD warning criteria related to thunderstorm.

However, observations of severe convective weather phenomena are rare. E.g. during JJAS 2010 only five times convective gusts with ≥11 Bft were measured at German SYNOP stations. Furthermore, the SYNOP data usually provides information about the highest gust that occurred within an hour; not knowing the exact time of the gust complicates the attribution of the gust to a specific cell during days with numerous cells. Additionally, strong gusts may occur in the surroundings of cells (and not directly close to the highest reflectivity as detected by the algorithms) which further complicates the correlation of observations and nowcast. The comparative verification for gusts > 14 m/s and gust > 18 m/s showed that nowcasts of CellMOS (which uses a model output statistics approach incorporating NWP model output) are superior to KONRAD (which bases its gust nowcast only on the estimated cell movement speed). However, in general 2D radar data based algorithms have limited capability in analysing gust speed. The same is true for hail. 3D radar is currently provided only in 15 min interval within the German radar network. For the short lifecycle and rapid development of convection this observation frequency is not sufficient. Thus the current algorithms are based on 5 minute 2D data. However, 3D data will be available at 5 min intervals in the future.

The problem of low numbers of observations also exists for hail. E.g. during the summer of 2010 German SYNOP stations observed hail just about 20 times. The European Severe Weather Database (ESWD) provides very useful data for events with hailstones having a diameter of 2 cm or more and smaller hailstones that form a layer of 2 cm thickness or more. Comparison of observations with nowcast show that for most of the summer 2010 ESWD hail reports in Germany a CellMOS (not shown) and a KONRAD (see Fig. 1) cell has been detected (<20km, +/-5min of the event) which had a hail probability of >75% or hail warning flag, respectively. However caution has to be applied when working with this data with the purpose of deriving thorough statistics, because several data base entries exist for a single event (e.g. a cell in NE Germany had 21 entries (out of 82 entries (ESWD Quality Control level QC1 and QC2) in total for April to September 2010) in the ESWD, cause it was analysed to have hit several villages. Other cells might just have a single entry in the data base which either means that the cell didn't leave a long hail path or that the strong extent of the hail event wasn't observed in its full extent. It also has to be considered that the hail observations only provide information on "positive events", no entry in the data base or no measurements at a station does not mean that no hail occurred, i.e. the "hits" and "misses" can be determined but not the "false alarms" and the "correct negatives". Thus a strategy has to be developed how to work best with this data.

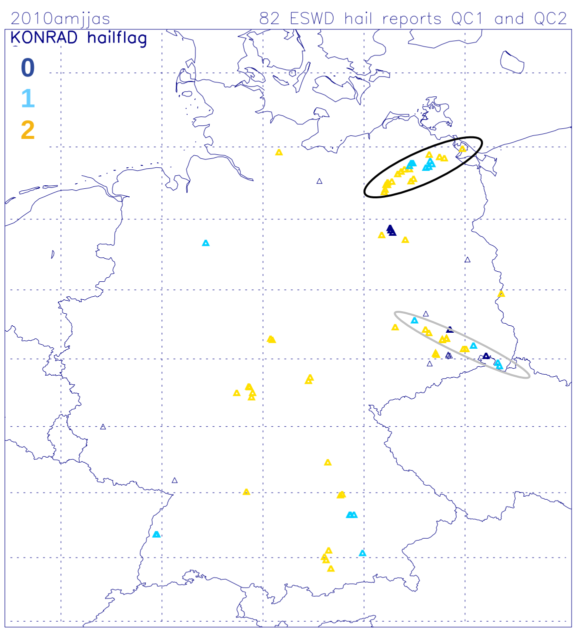

FIG. 1: KONRAD hailflag (thick dark blue, light blue and yellow triangles) for all QC1 and QC2 hail entries (AMJJAS 2010) in the ESWD. Thin triangle show hail reports with no KONRAD cell within 20km and +/-5min. Black (11.06.2011 07:19-09:05UTC) and grey (24.5.2010 13:45-15:05 UTC) ellipses show hail reports related to the same convective event.

The verification of thunderstorms without considering accompanying phenomena seems to be much easier due to the high temporal and spatial coverage of lightning data. However, certain aspects have to be addressed when designing a verification methodology. Various verification methods are possible, e.g. definition of a maximum distance in space and time between nowcast cell and observations allowed for a "hit", definition of areas that are affected by observed and nowcasted convective events and assessment of their overlap, considering each individual lightning or cell clusters. The most suitable method depends on the definition of a "good forecast". A "good forecast" might vary for different users of the warning. The calculated scores depend on the method as well as on the chosen thresholds. Additionally, the maximal possible score of the nowcast also depends on the verification method and the mean cell lifetime (in nowcast systems cells usually don't dissolve, but are extrapolated in the future for the duration of the nowcast time frame). As an example of cell lifetimes the KONRAD statistics show that in MJJAS 2010 40 % of the cells were detected just once and 14 % of the cells lived longer than 30 min.

As an example of thunderstorm nowcast verification, the results of the verification based on the comparison of all observed lightning strokes to detected cells is shown in Tabs. II-IV.

Analysis	**CellMOS**	**KONRAD**	**C ∩ K**	**C ∪ K**
Cell size	62%	31%	29%	64%
10 km	70%	56%	51%	75%
20 km	82%	68%	67%	84%

TABLE II: Percentage of lightning strokes that occurred (JJAS 2010) in the given distance of cells detected by CellMOS, KONRAD, CellMOS and KONRAD, CellMOS or KONRAD. "Cell Size" is based on the assumption of a circular cell where the number of radar pixels above the applied threshold is distributed equally around the cell centre.

+30 min	**CellMOS**	**KONRAD**	**C ∩ K**	**C ∪ K**
10 km	44%	42%	26%	61%
20 km	72%	66%	58%	79%

TABLE III: Percentage of lightning strokes that occurred (JJAS 2010) in the given distance of cells detected and nowcasted for +30min by CellMOS, KONRAD, CellMOS and KONRAD, CellMOS or KONRAD.

+60 min	**CellMOS**	**KONRAD**	**C ∩ K**	**C ∪ K**
10 km	25%	24%	9%	40%
20 km	51%	50%	34%	67%

TABLE IV: Percentage of lightning strokes that occurred (JJAS 2010) in the given distance of cells detected and nowcasted for +60min by CellMOS, KONRAD, CellMOS and KONRAD, CellMOS or KONRAD.

These results show that a considerable part of lightning strokes occurred in cells with less than 9 km² of dBZ values of at least 46 and thus no KONRAD cells were detected. Furthermore, some lightning strokes occurred in cells with less than 9 km² of dBZ values of at least 37 or were to far away from the cell centre and thus no corresponding CellMOS cells were detected.

This comparison also show the decrease of the detection rate with longer lead times and more restrict distance thresholds. Furthermore, it is shown that the combination of different algorithms improve the quality of the nowcast. This is due to the different reflectivity threshold applied of the algorithms as well as on additional data in CellMOS.

III. CONCLUSIONS AND OUTLOOK

In this study the challenges of comparative nowcast verification are discussed and some verification results for thunderstorms, gusts and hail are presented.

It is shown that the combination of different algorithms improve the quality of the nowcast. The low number of observations of rare events, e.g. severe gusts and hail, hampers thorough verification. For a summer season only very few events might be captured by observations however nowcasting algorithms need to be verified especially if they are new and no long statistics are available.

The results presented here provide an overview of ongoing work. It is planned to extend this study by using a larger data set, verifying additional phenomena, such as heavy precipitation, and integrating further nowcasting systems in the comparative verification.

IV. ACKNOWLEDGMENTS

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