CASE STUDY: DERECHO EVENT IN ESTONIA 08 AUGUST 2010

MODELLING DERECHO DYNAMICS WITH NWP MODEL HARMONIE

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I. INTRODUCTION

On the 8-th of August 2010 derecho-type thunderstorm moved over Estonia, causing widespread wind damage. The strongest wind gusts measured in automatic stations were up to 35 m/s and more than 15 m/s in larger area. Operational model in Estonian Meteorological and Hydrological Institute was unable to predict it. Case study of this situation has been carried out using HARMONIE model, derecho dynamics is investigated.

II. PRESENTATION OF RESEARCH

Progressive derecho moved along quasi-stationary polar front in area with high convective available potential energy (CAPE ≥ 2000 J/kg), high humidity content ($T_{dewpoint, 2m} \geq 20$ ºC) and convergent flow near ground. High pressure area was situated to the East of Estonia in Russia (Figure 1). Troposphere in midlevel was relatively drier (Figure 2) and moisture was pooling near ground (Figure 3) which are characteristics of warm season bow echo development according to Johns (Johns 1993).

Synoptic situation on 08.08.2010 was similar to situation during derecho outbreak in Finland on 5 July 2002 (Punkka et al 2006). Derecho moved in both cases along meridionally situated polar front and developed close to the short wave trough.

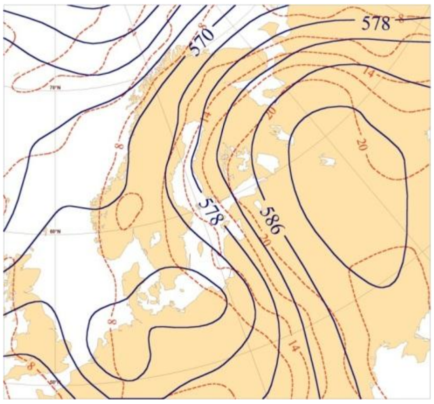

FIG. 1: ECMWF analysis 2010.08.08 12 UTC 500 hPa gph (dam) and 850 hPa temperature (ºC).

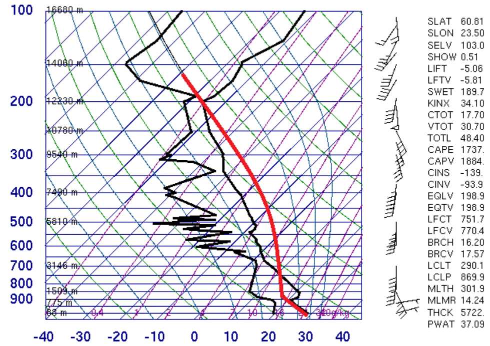

FIG. 2: 08.08.2010 12 UTC sounding in Jokioinen, Finland (University of Wyoming).

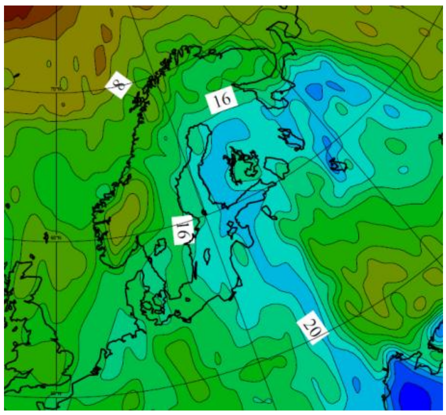

FIG. 3: ECMWF analysis 2010.08.08 12 UTC 2 m dewpoint temperature (ºC).

Numerical simulations were carried out in order to investigate predictability and dynamics of the storm. HARMONIE model was run with AROME physics and high horizontal resolution (2.5 and 1 km) resolving deep convection explicitly (Seity et al 2011).

HIRLAM model analyses and forecasts were used as initial and boundary conditions, no data assimilation in HARMONIE forecast was performed. Boundary conditions were obtained from operational HIRLAM output from Estonian Meteorological and Hydrological Institute (EMHI-ETA) and from Regular Cycle of the Reference Hirlam (RCR). Influence of different boundary conditions on modelling results is investigated. Initialized 00 UTC simulations are quite similar comparing RCR and EMHI-ETA initalizations (Figure 4).

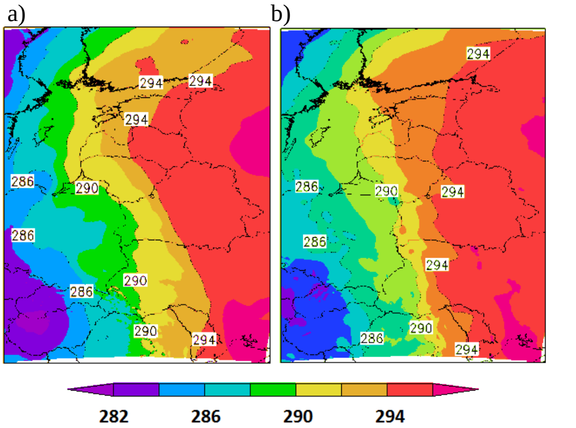

FIG. 4: 850 hPa temperature (K) 00 UTC a) RCR initialization b) EMHI-ETA initalization.

HARMONIE is not able to simulate derecho successfully using EMHI-ETA boundaries (initialization 00 UTC 08.08.2010). Starting forecast at 12 UTC instead of 00 UTC results in storm system over Estonia. Updates of the initial state improve the forecast because of better representation of the derecho environment at later time.

Increasing spatial resolution from 2.5 to 1 km results in more intensive storm system, although geographical location of the storm remains the same. Simulated wind gusts are stronger and area of strong gusts is wider with 1 km horizontal resolution (Figure 5).

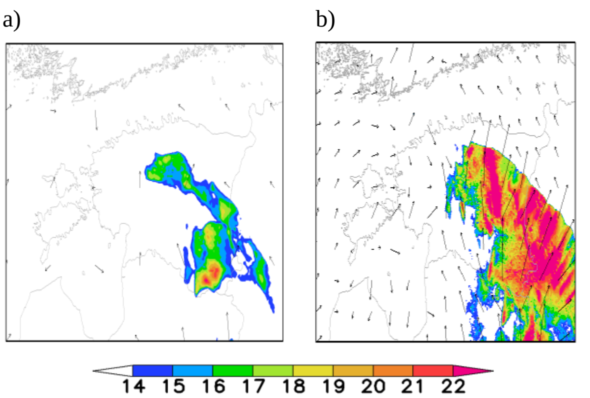

FIG. 5: Modelled 10 m wind gusts (m/s) in last 30 minutes 19 UTC using EMHI-ETA boundaries a) 2.5 km resolution b) 1 km resolution.

Using RCR boundaries realistic derecho evolution is seen in model output (Figure 6). Derecho is similarly simulated using RCR analyses or forecasts as boundary and initial conditions. Approximate speed of northward movement of the storm was 25 m/s, similarly in model and radar observations.

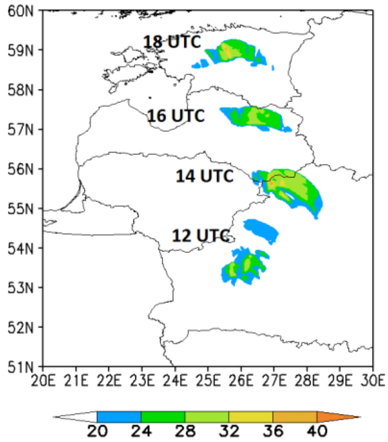

FIG. 6: Path of derecho as seen by the model 12-18 UTC presented by 10 m wind gusts (m/s) in last 30 minutes.

Modelled accumulated precipitation during 08.08.2010 was over 10 to 15 mm in the storm area. More than 10 mm 24h accumulated precipitation was measured also in several automated stations. Modelled instantaneous convective precipitation rate was from 1 to more than 9 mm/h. Radar reflectivity derived precipitation rate exceeds 20 mm/h. Stratiform precipitation is weak in simulation (Figure 7).

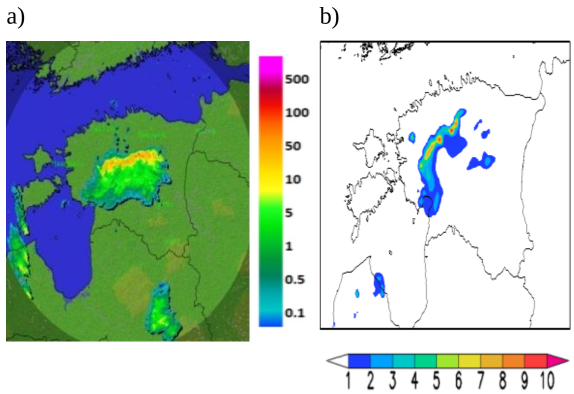

FIG. 7: a) Radar rainfall rate (mm/h) 16.45 UTC and b) modelled instantaneous rainfall rate (mm/h) 18 UTC.

Simulated wind gusts are 25-35 m/s, similar to radar maximum winds, which are seen at gust front (Figure 8). Area with strong gusts in last 30 minutes is approximately the path of gust front in this time. The strongest gust measured in automatic station was 36.5 m/s.

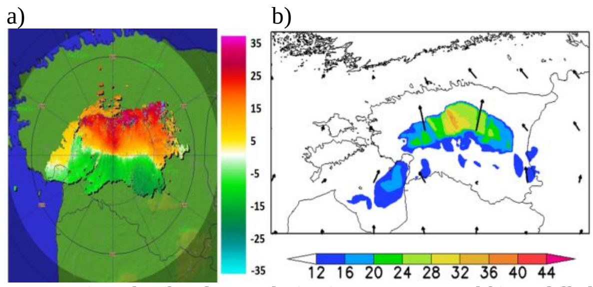

FIG. 8: a) Radar doppler winds (m/s) 16.20 UTC and b) modelled 10 m wind gusts (m/s) 18 UTC.

After convection is initiated convective cells form the squall line. Convective organization is favoured by wind share (15 m/s modulus between 700 hPa and 1000 hPa pressure levels) in area of derecho movement. As convective precipitation evaporates downdrafts are formed. Near ground behind gust front cold pool is formed (Figure 9) and convection is regenerated. Storm relative vortex around low pressure forms in mid-troposphere in storm area (Figure 10).

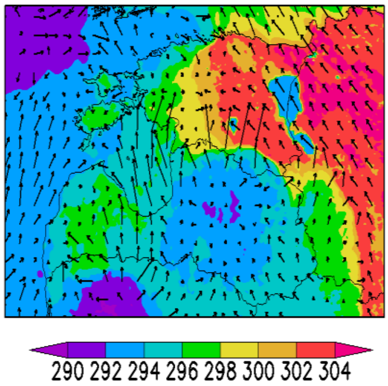

FIG. 9: Simulated 2 m temperature (K) 16.30 UTC, cold pool behind gust front.

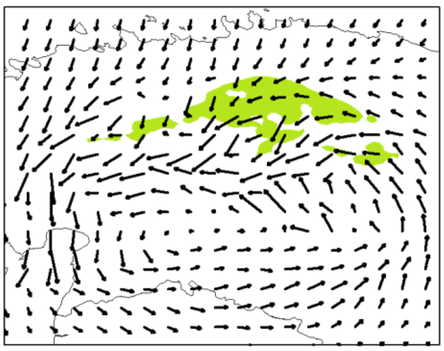

FIG. 10: Storm relative horizontal winds on 500 hPa pressure level, vortex around low pressure (area of 10 m gusts in green).

Updraft vertical wind speed is up to 10 m/s (Figure 11). 2 m temperature in cold pool is up to 10 ºC cooler than air in front of the storm. High pressure is formed near ground in cold pool and low pressure at mid-troposphere. Storm relative rear inflow jet (RIJ) (more than 5 to 10 m/s relative speed) is seen in model output, what enhances the strength of wind gusts generated by downbursts (Figure 12). RIJ was also detected in radar images.

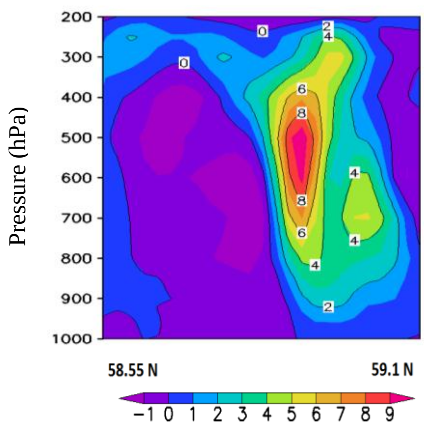

FIG. 11: Modelled vertical velocity (m/s) in vertical cross section on pressure levels on south-northerly line 18 UTC, updraft and downdraft.

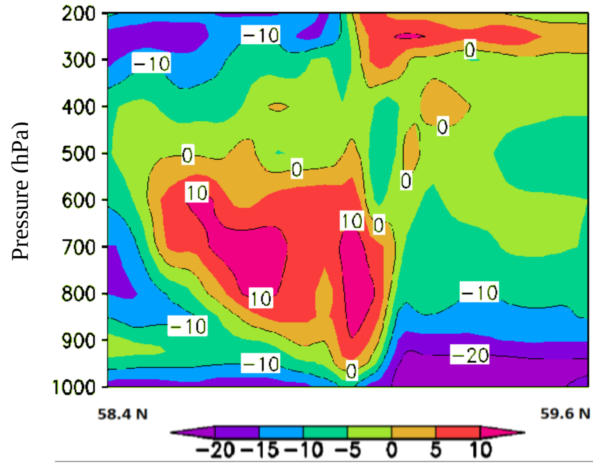

FIG. 12: Modelled storm relative horizontal wind speed (m/s) in vertical cross section on pressure levels on south-northerly line 18 UTC, rear inflow jet.

III. RESULTS AND CONCLUSIONS

In this work dynamics of derecho in Estonia on 8-th of August 2010 is simulated with NWP model HARMONIE (AROME physics, 2.5 km horizontal resolution) which solves deep convection explicitly. Preliminary results of the simulations show capability of HARMONIE model to predict severe convective storm and reliably represent the dynamics of the storm.

Model resolution increase has an impact on representation of storm intensity and dynamic details but 2.5 km horizontal resolution appears sufficient for reliable forecast. Modelling results depend strongly on initial data. With appropriate initial data realistic derecho evolution is forecasted and dynamics of the storm can be analysed.

Common features of severe convective storm such as convectively driven updrafts and downdrafts, strong wind gusts, high pressure and cold pool near ground, low pressure in midtroposphere and rear inflow jet are seen in the model output. Simulated wind gusts (25-35 m/s) are very similar to strongest gusts measured in automatic stations (35 m/s) and radar maximum winds. The wind damage could have been foreseen using HARMONIE model and appropriate warning about the storm in Estonian Meteorological and Hydrological Institute could have been issued.

It is possible to forecast this type of storm with high accuracy with HARMONIE model, but the quality of initial data is crucial. Effect of HARMONIE data assimilation and assimilation of different kinds of data needs to be investigated further.

IV. ACKNOWLEDGMENTS

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V. REFERENCES

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