Diagnostic and modelling of two derecho events over European Russia in summer 2010

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INTRODUCTION

The summer of 2010 in the European part of Russia (ER) is known as the hottest during the instrumental observations history. The unusually persistent atmospheric blockings resulted in unprecendent heat wave, widespread forest and peat fires and severe drought. Moreover, a number of powerful convective storms happened on a northwestern flank of the blockings, which received less attention of the scientific community.

Two most remarkable storms formed on June 27 and July 29 in north-east and north-west of ER, respectively. Both storms resulted in casualties and injures in Russia and produced exceptional damage to forest cover. Both storms had exceptionally long (> 500 km) and wide (30-70 km) damage tracks and can be classified as derechos, that is a large-scale and long-lived straight-line convective windstorm, i.e., a family of downbursts, producing by a mesoscale convective system.

In this study, we analyze the synoptic- and mesoscale environments of the formation and evolution of derecho events on June 27 and July 29 of 2010 using ground-based and satellite data, and performed high-resolution simulation with the WRF atmospheric model. We also present the unified data on stand-replacing windthrows caused by these two storms in Russia and Finland.

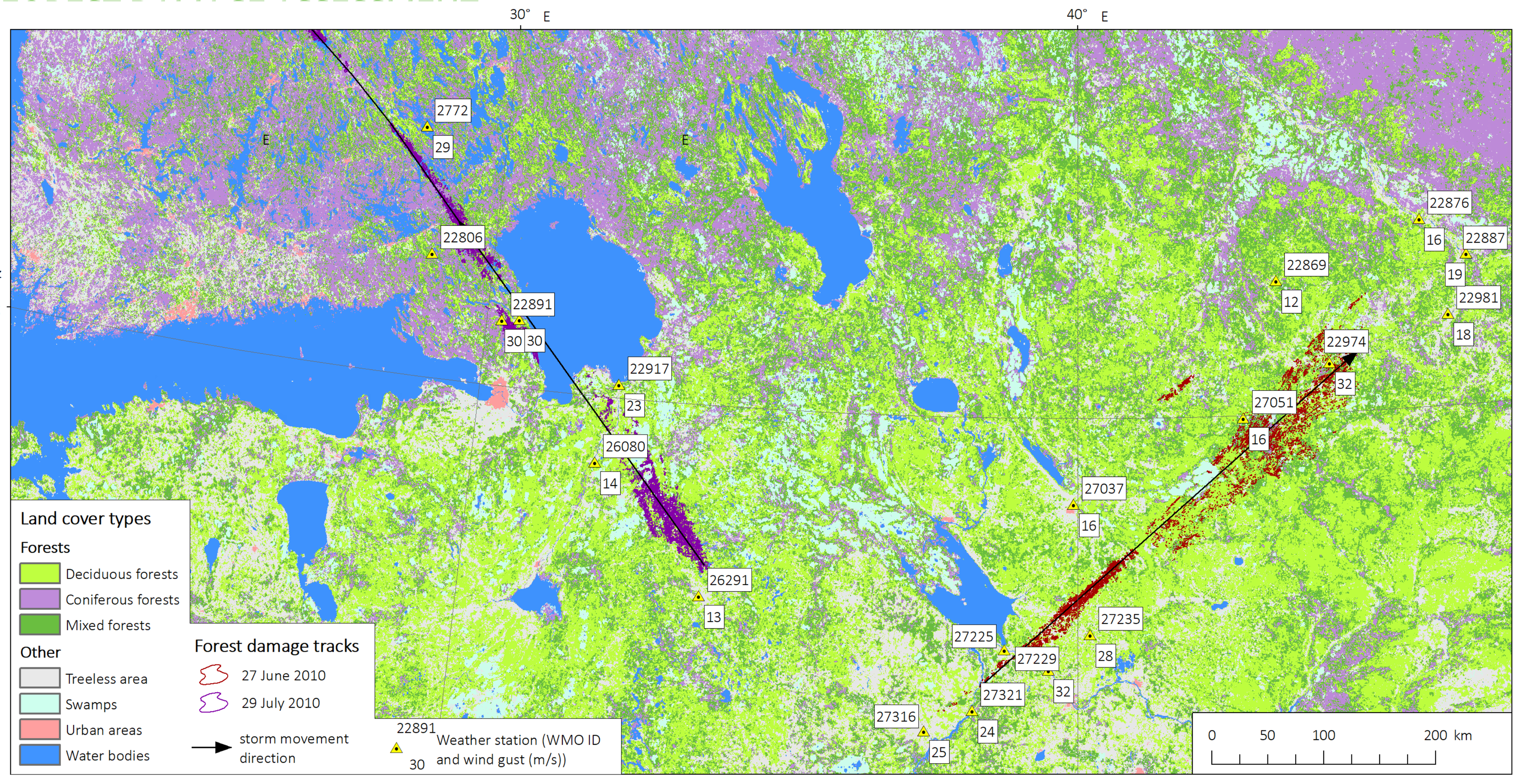

Figure 1. Geographical location of the storm tracks 27 June 2010 and 29 July 2010. Land cover types are shows according to (Bartalev et al., 2016)

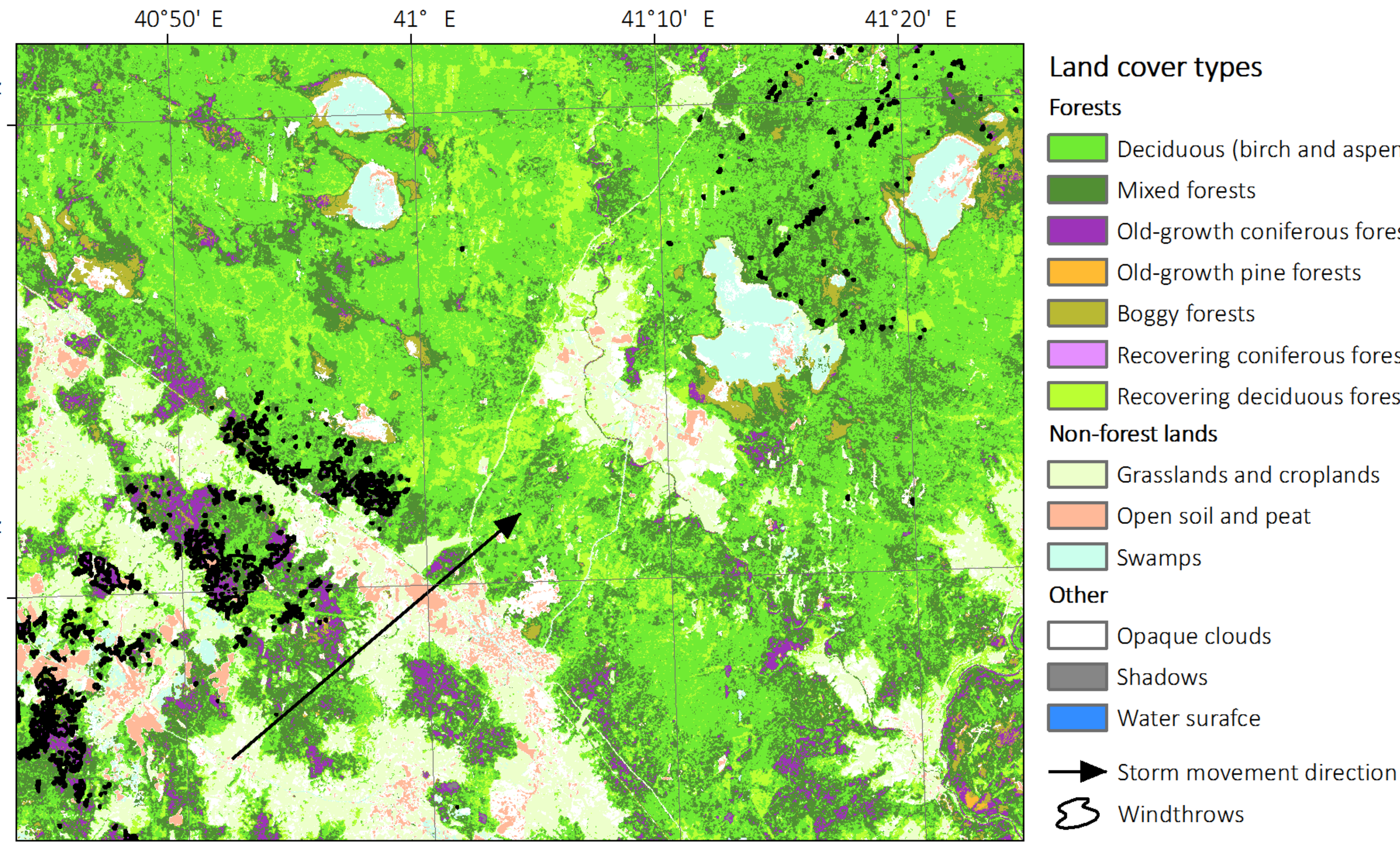

Figure 2. Variations of forest damage degree along the storm track of 27 June 2010, related to the dominant tree species (classified by Landsat images)

INITIAL DATA

- Weather stations data of Roshydromet, storm reports from ESWD, information on storm-related damage from the media. Maximum reported wind gust was 32 m/s at 27 June 2010 and 30 m/s at July 29, 2010
- CFSR and ERA-5 reanalysis data for synoptic-scale analysis and calculating convective instability indices.
- Meteosat-8/SEVIRI and Terra/Aqua MODIS satellite images to assess the development of storm-producing MCSs, identify the signatures of intense updrafts on the cloud top, and validate the results of high-resolution simulation
- Global Forest Change Data and Landsat images obtained before and after the storm events, for windthrow delineation and classification of forest species composition
- High-resolution (3 km) simulation with Weather research and Forecasting (WRF) atmospheric model version 4 (with ARW dynamic core. The model started on CFSR and ERA-5 initial conditions.

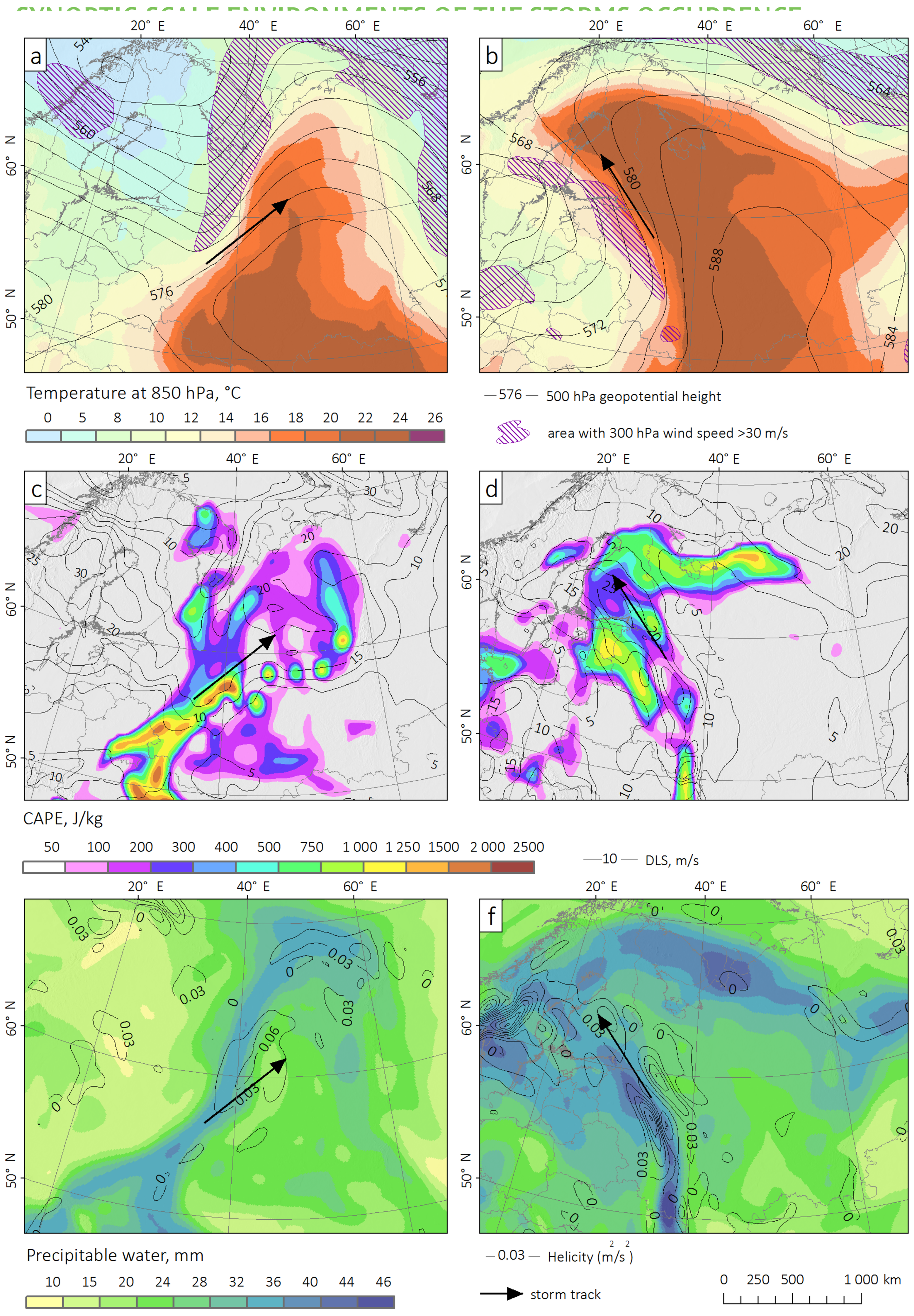

Figure 3. Synoptic-scale environments of the formation of the storms 27 June 2010 (a, c, e) and 29 July 2010 (b, d, f): 850 hPa temperature, 500 hPa geopotential height and jet stream at 300 hPa (line 1); CAPE and DLS (line 2), precipitable water and helicity (line 3)

WRF MODEL SIMULATION RESULTS

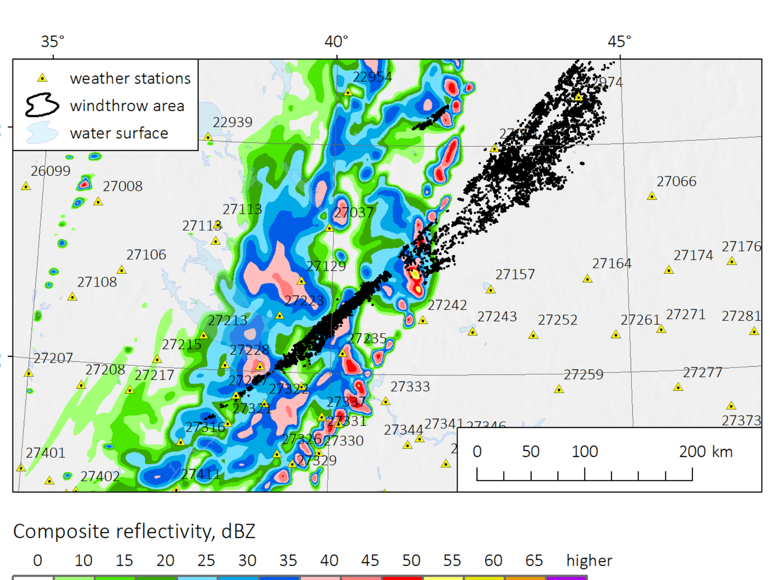

Fig. 4 Sumulated maximum reflectivity at 12.00 27 June 2010 (with ERA-5 initial data)

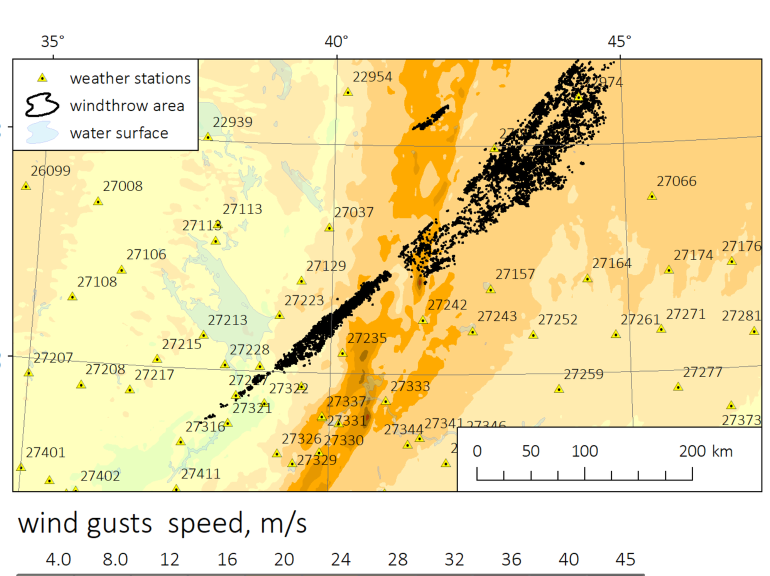

Fig. 5 Sumulated wind gust at 12.00 27 June 2010 (with ERA-5 initial data)

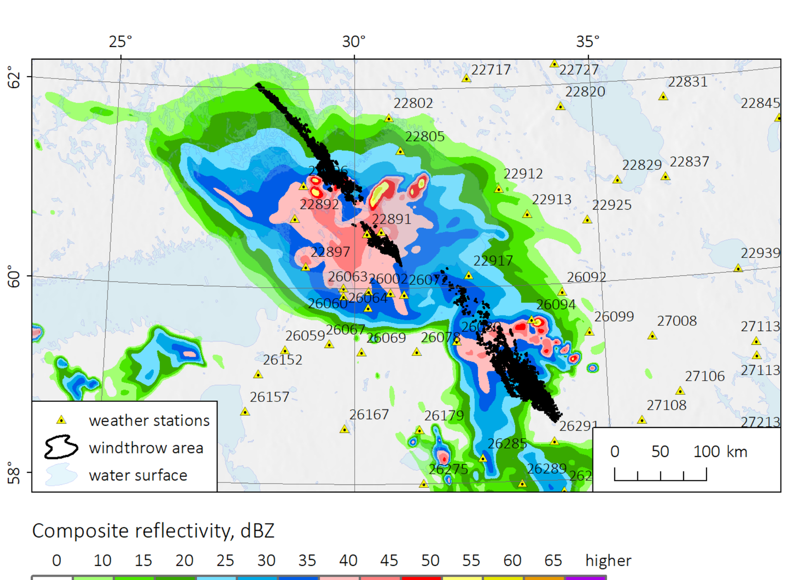

Fig. 6 Sumulated maximum reflectivity at 21.00 29 July 2010 (with ERA-5 initial data)

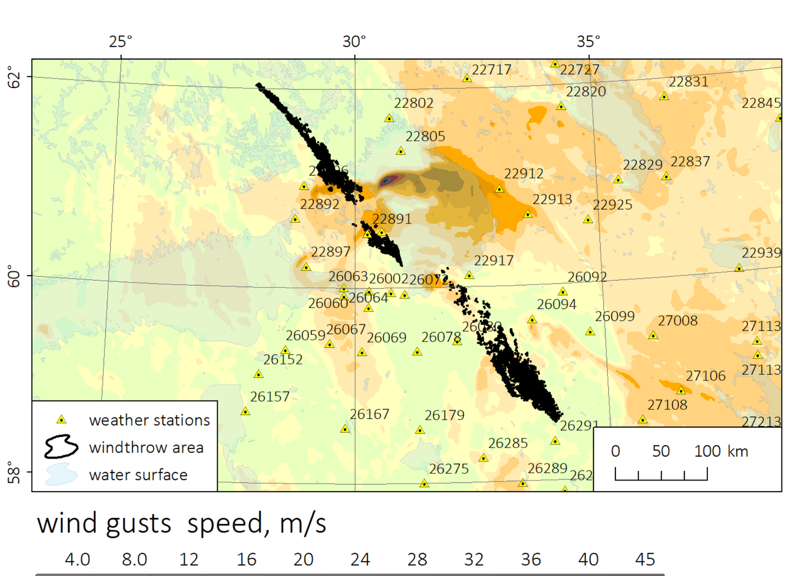

Fig. 7 Sumulated wind gust at 21.00 29 July 2010 (with ERA-5 initial data)

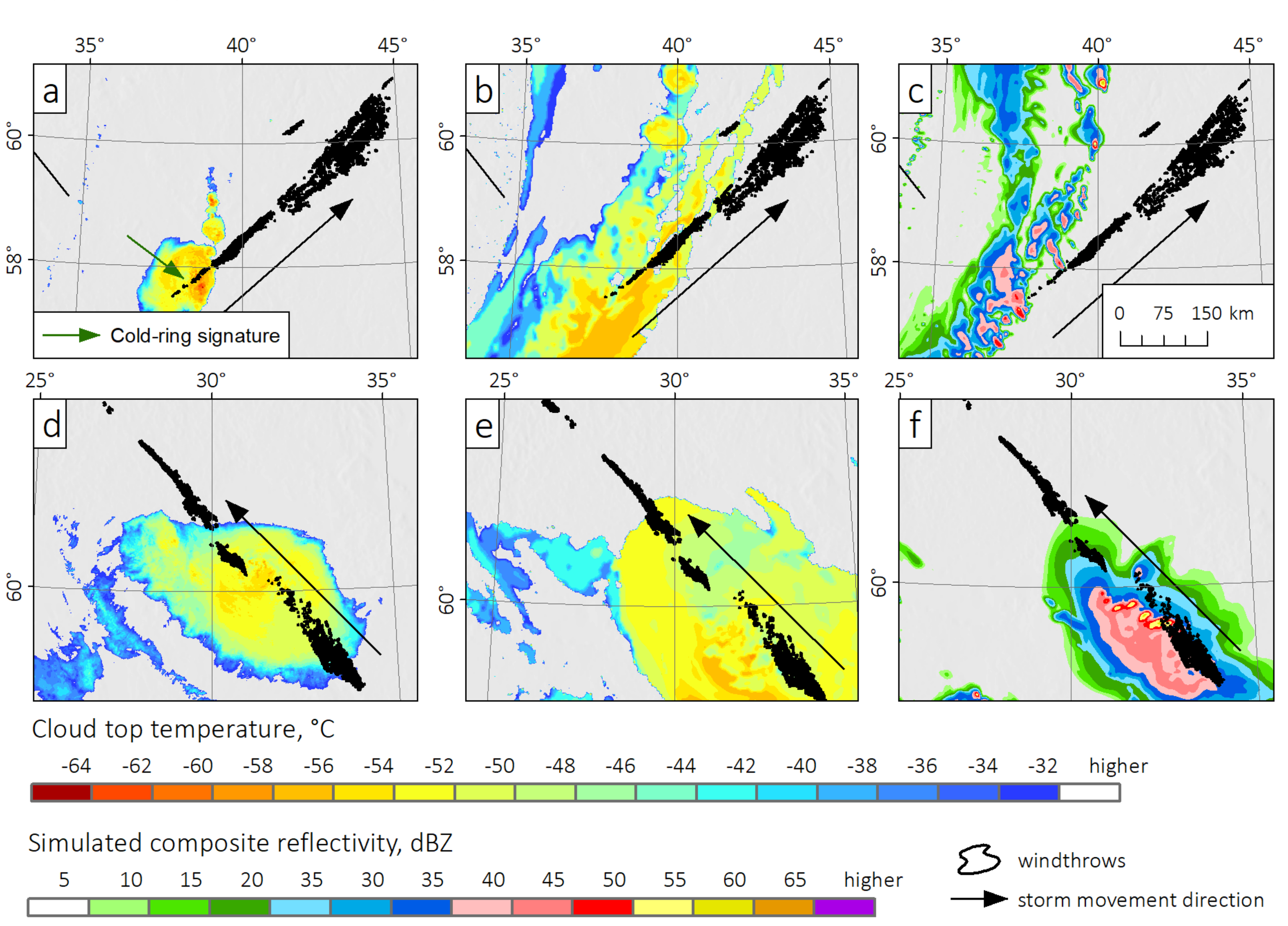

Figure 8. Satellite-observed and WRF-simulated (with ERA-5 initial data) derecho-producing MCSs at 10.00 UTC 27 June 2010 (line 1) and 19.30 UTC 29 July 2010 (line 2): cloud top temperature by Aqua/MODIS data (a, d), WRF-simulated cloud top temperature (b, e) and composite reflectivity (c, f)

CONCLUSION

The storms 27.06 and 29.07 caused catastrophic forest damage in the European Russia and Finland, with a total area of stand-replacing windthrows > 1250 km². In both cases, dark-coniferous forests were most susceptible to windthrow, and deciduous forest were least damaged. In Finland, forest damage was several times higher than the same induced by previous derecho occurred July 5, 2002. In European Russia, these two storms are responsible for 38.4% of the total area of stand-replacing windthrow over the period 1986-2017.

Synoptic-scale environments of both storms formation have many similarities. Storms occurred in a transition zone between long-lived blocking and a deepening trough on the west side of it. In both cases, the storms propagation over warm and moist underlying surface contributed to maintaining their intensity for an unusually long time. Also it is interesting, that the dates of storms formation coincide with the same of termination of the blocking events (Lupo et al., 2012).

Both storms formed on the cold fronts with strong temperature gradients, under moderate thermodynamic instability (CAPE > 1000 J/kg) and precipitable water, but high vertical wind shear (> 18 m/s).

The WRF model started on the ERA-5 initial data reproduced both storms more successfully than the same with CFSR initial conditions. At the storm 27.06, both simulations not reproduced the main derecho-producing storm in a squall line, and wind gusts are underestimated. On the contrary, the life cycle of the storm 29.07 is successfully reproduced by the model. Wherein, CFS-based simulation underestimated wind speed and affected area, and ERA-5 based simulation show wind gusts up to 41 m/s.

Shikhov A.N., Chernokulsky, A.V., Azhigov, I.O. and Semakina A.V. (2020) A satellite-derived database for stand-replacing windthrows in boreal forests of the European Russia in 1986–2017. ESSDD., https://doi.org/10.5194/essd-2020-91, in review.