The damaging tornado in Luxembourg on 9 August 2019

MeteoLux

LE GOUVERNEMENT DU GRAND-DUCHÉ DE LUXEMBOURG

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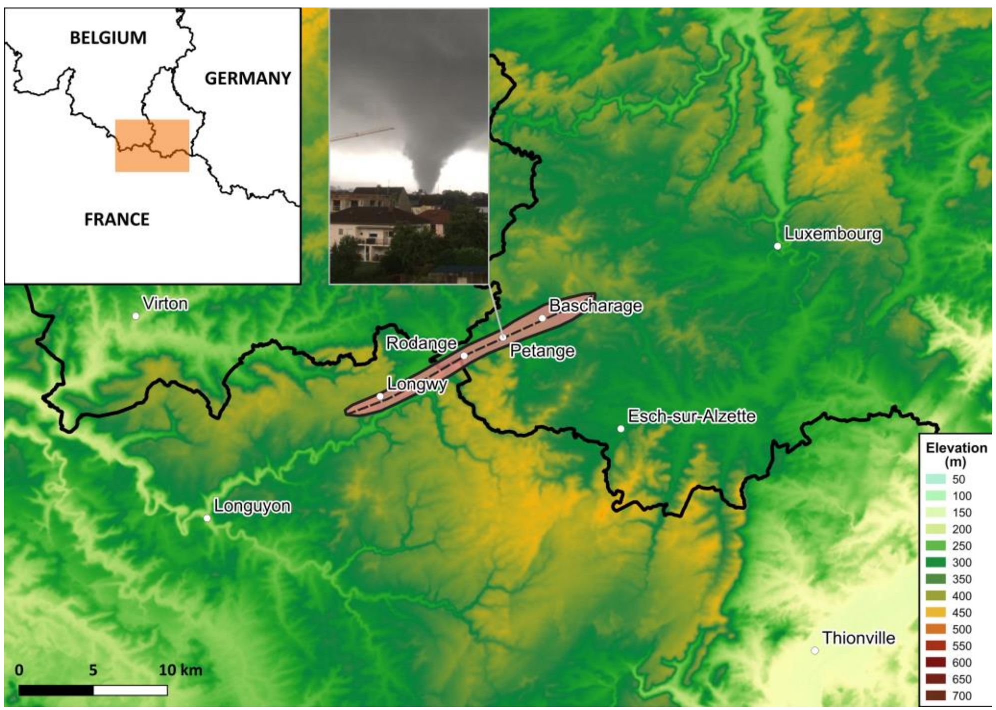
1. Key facts of the event

- 19 people injured, 2 of them severely
- More than 400 trees and 300 houses damaged
- At least 80 people had to be sheltered in hotels or other accommodation
- Total insured losses of at least €100 million



- ➢ Estimated path length: 18 to 20 km
- ➢ Estimated duration: 15 minutes
- ➢ Maximum path width: > 500 m
- ➢ Translation speed: 17 to 19 m/s
- ➢ Maximum intensity: F2+ (241 km/h)

2. Synoptic-scale overview

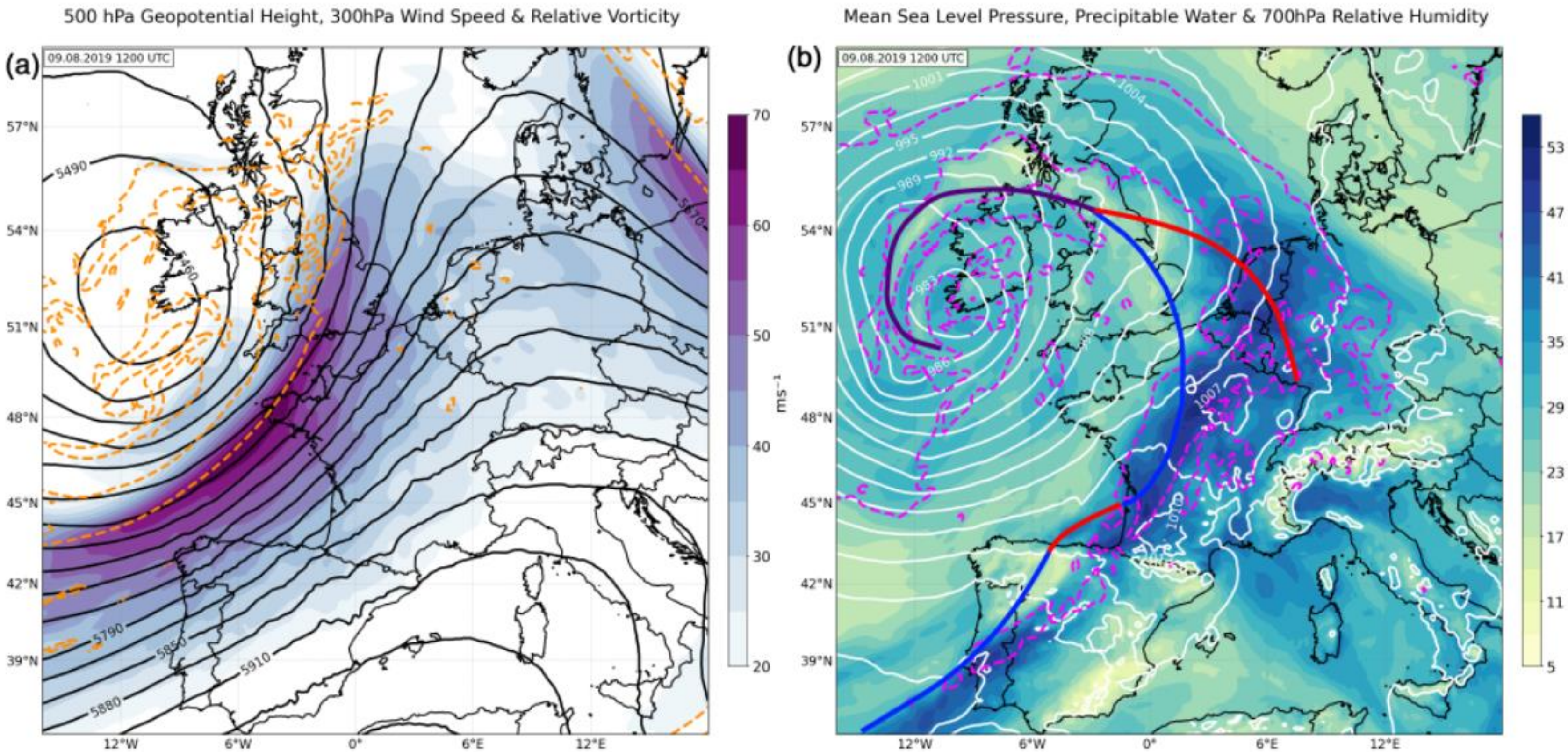


Figure 2. ECMWF analysis of the synoptic-scale conditions on 9 August 2019 at 1200 UTC over Western Europe. (a) 500hPa geopotential height (black lines; gpm), 300hPa wind speed (shaded; ms^{-1}) and areas of 300hPa relative vorticity exceeding $0.00015s^{-1}$ are denoted by the dashed orange lines. (b) Mean sea level pressure (white lines; hPa), precipitable water (shaded; mm) and areas of 700hPa relative humidity exceeding 80% are denoted by the dashed magenta lines. The analysed location of the surface frontal boundaries by the German Weather Service (DWD) is superposed (blue line: cold front, red line: warm front, dark purple line: occluded front).

3. Mesoscale preconvective environment

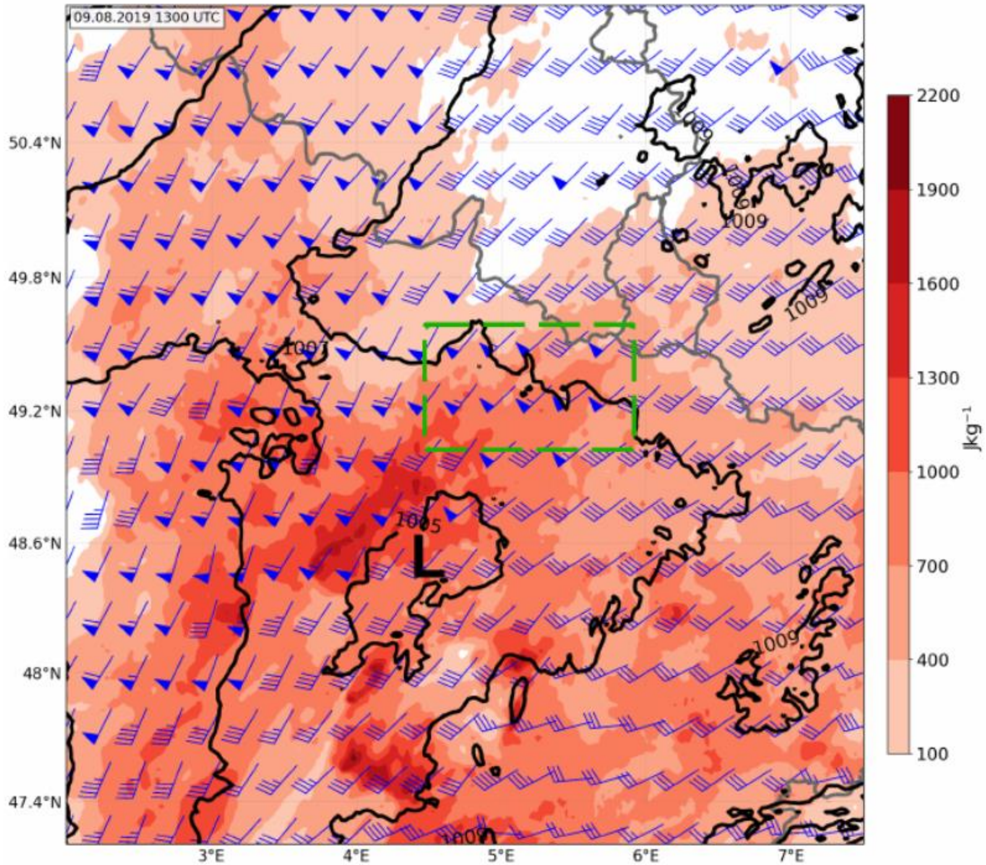


Figure 3. Forecast of the pre-convective environment for 1300 UTC on 9August 2019 by the 1200 UTC run of AROME. Mean sea level pressure (black lines; hPa), most-unstable CAPE (shaded; Jkg^{-1}) and 0–6km shear vector (blue wind barbs; kts). The mesoscale low is denoted by the black 'L' The dashed green outlined box indicates the area considered for the vertical profiles shown in Figure 4.

- Prefrontal mesoscale low-pressure area in a moist and warm air mass
- Backing wind at the surface with the approach of the surface low
- Moderate latent instability with CAPE values between 500 and 1000 J/kg near Luxembourg
- Strong 0–6 km bulk shear with values slightly exceeding 25 m/s

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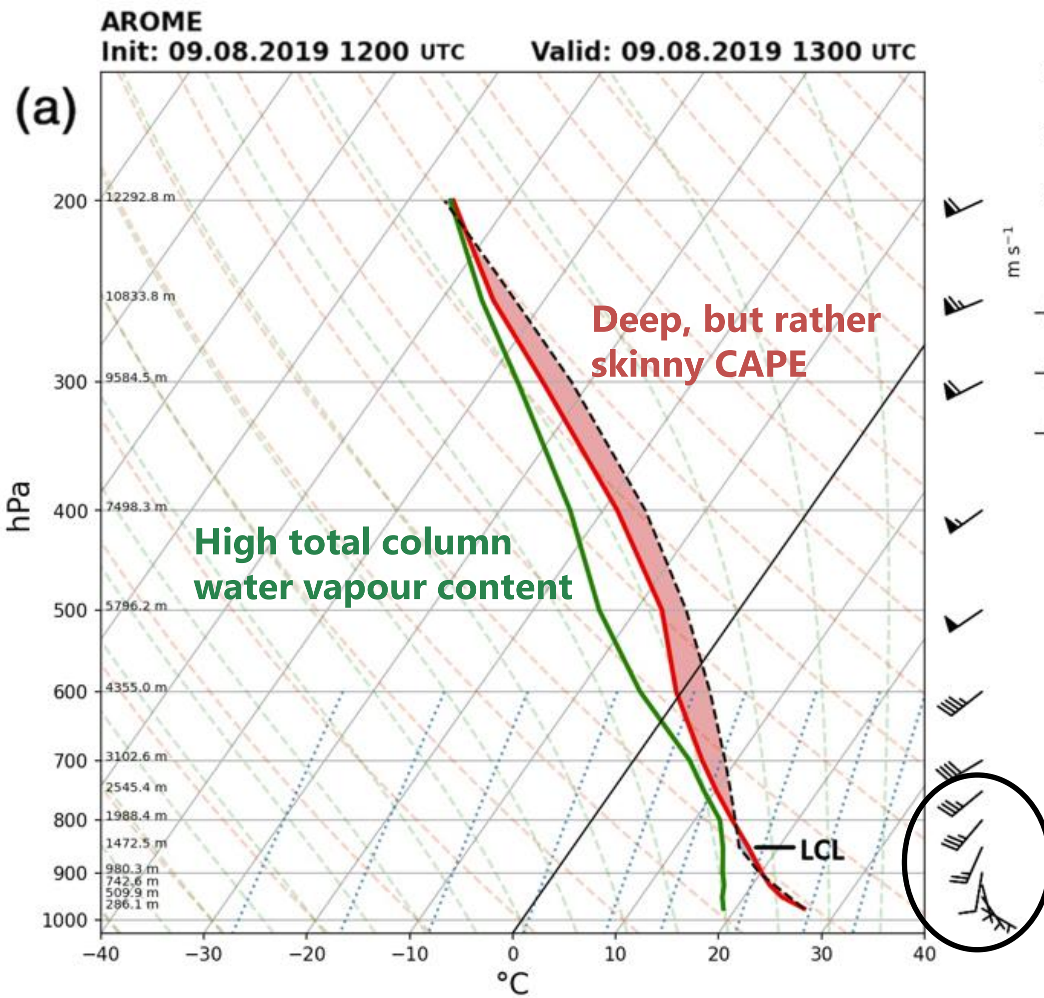
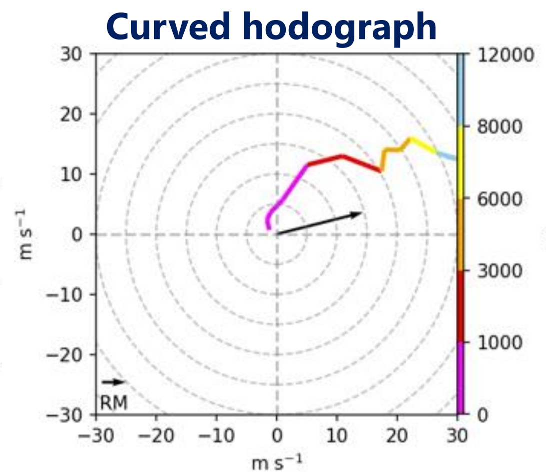
3. Mesoscale preconvective environment





Surface-based CAPE:	893.6 $J kg^{-1}$
Surface-based CIN:	-12.0 $J kg^{-1}$
Most-unstable CAPE:	893.6 $J kg^{-1}$
Most-unstable CIN:	-12.0 $J kg^{-1}$
50-hPa mixed-layer CAPE:	606.5 $J kg^{-1}$
50-hPa mixed-layer CIN:	-43.4 $J kg^{-1}$
0-1 km bulk shear:	10.5 $m s^{-1}$
0-3 km bulk shear:	21.6 $m s^{-1}$
0-6 km bulk shear:	26.6 $m s^{-1}$
0-1 km storm-relative helicity:	131.4 $m^2 s^{-2}$
0-3 km storm-relative helicity:	276.0 $m^2 s^{-2}$
Precipitable water:	46.6 mm
0-500 m mean specific humidity:	13.6 $g kg^{-1}$

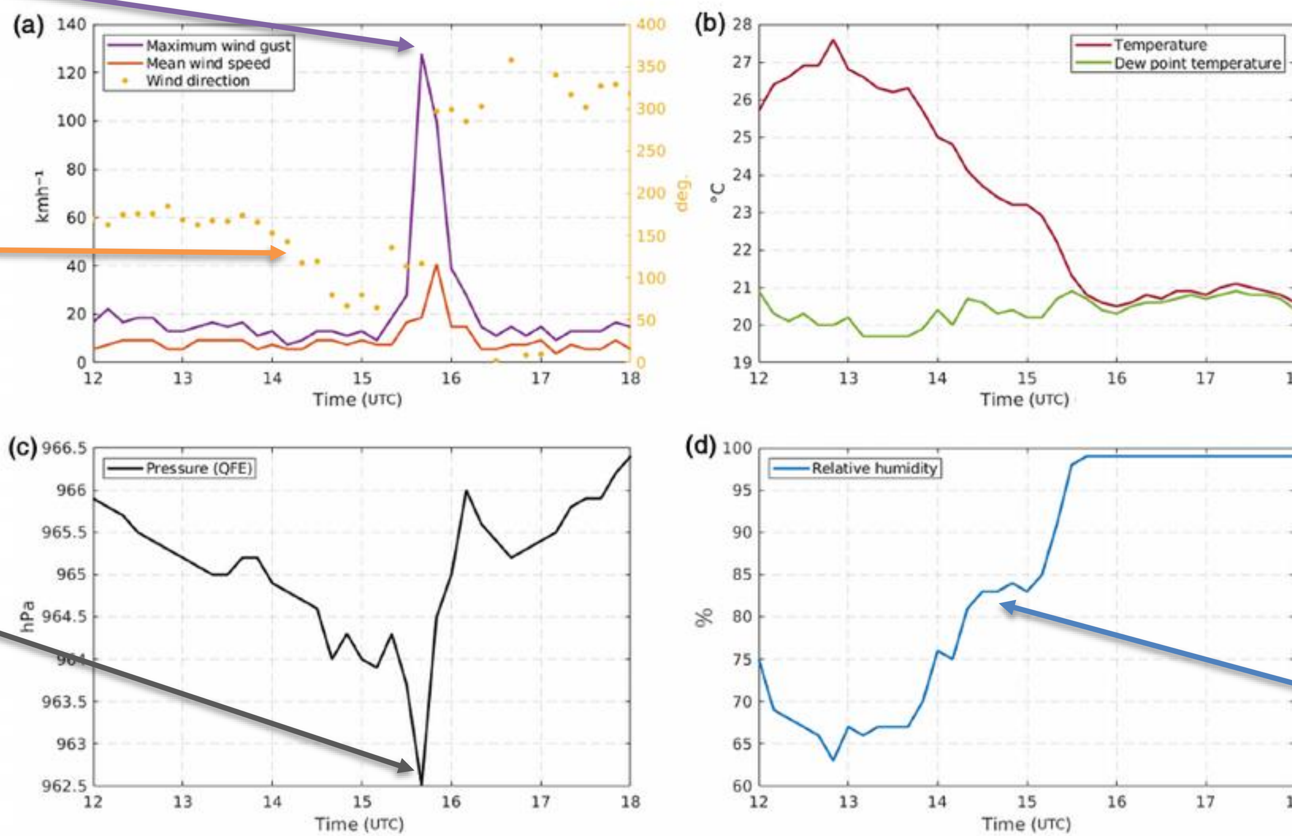
Veering and strengthening wind with height

4. In situ measurements

Peak gust of 35.5 m/s was measured around 15:35 UTC

Backing wind from S to E ahead of the tornadic storm

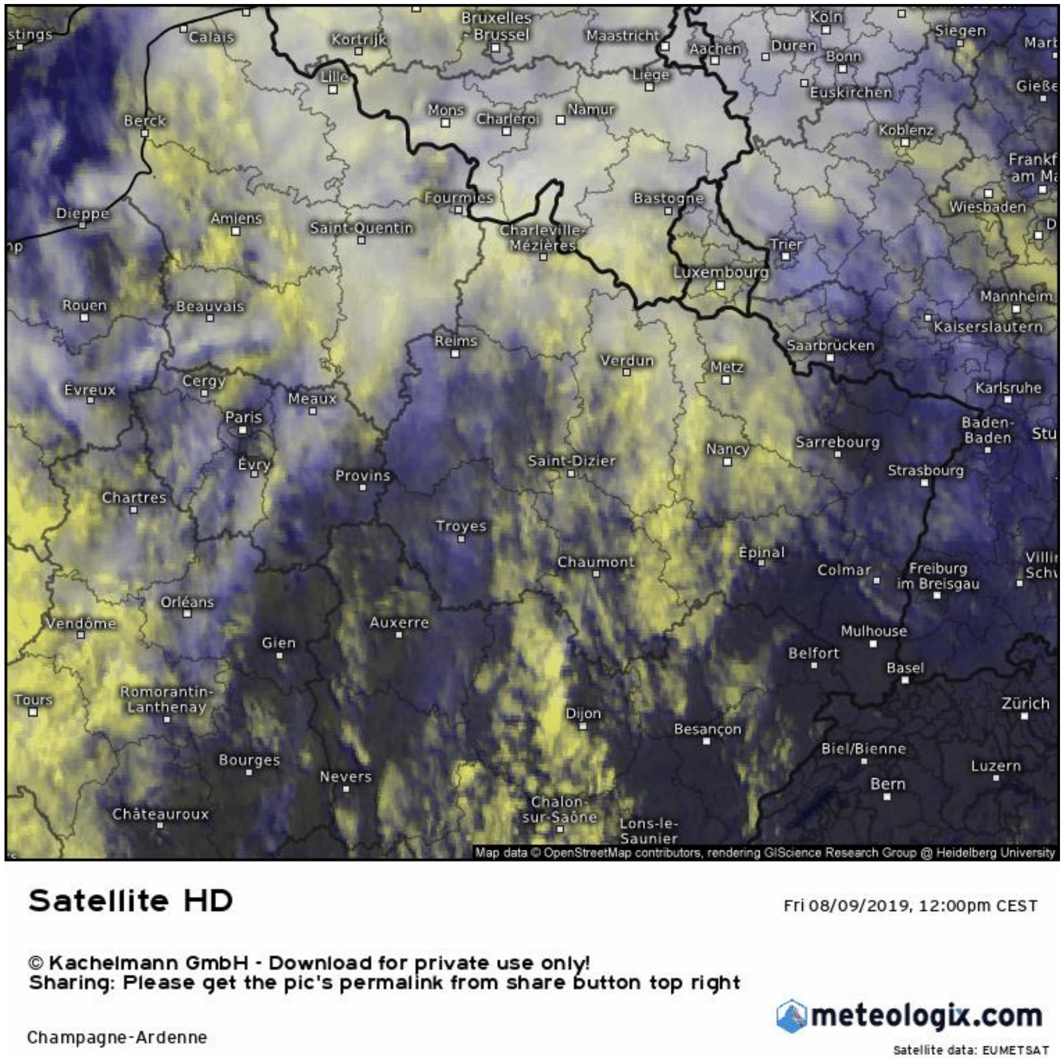
Pressure drop partially caused by the short-term pressure perturbation of the tornadic wind circulation



Increase of RH due to preceding precipitation

Figure 5. In situ measurements with a temporal resolution of 10min from the automated weather station located in Rodange (cf. Figure 1) between 1200 UTC and 1800 UTC on 9 August 2019. (a) Maximum wind gusts (purple line; kmh⁻¹) and mean wind speed (orange line; kmh⁻¹) during the preceding 10min (1kmh⁻¹ = 0.278ms⁻¹), and corresponding mean wind direction (yellow dots; °). (b) Instantaneous temperature (red line; °C) and dew point temperature (green line; °C) measured 2m above the ground. (c) Instantaneous surface pressure (black line; hPa). (d) Instantaneous relative humidity (blue line; %) measured 2m above the ground.

5. Storm cell analysis



5. Storm cell analysis

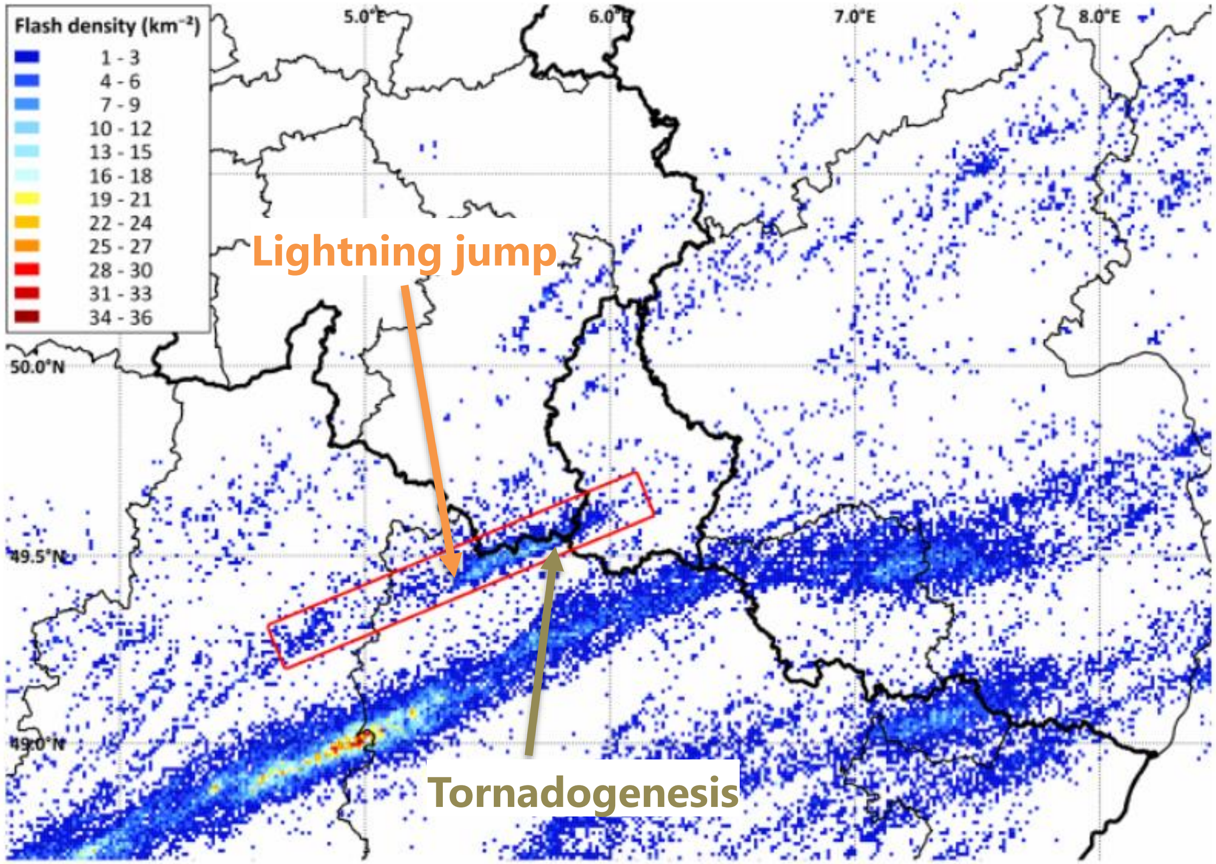


Figure 6. Lightning density (flashes per km^2) measured by the European Cooperation for Lightning Detection (EUCLID; Schulz et al., 2016) network on 9 August 2019. The path of the tornadic supercell is denoted by the red rectangle.

5. Storm cell analysis

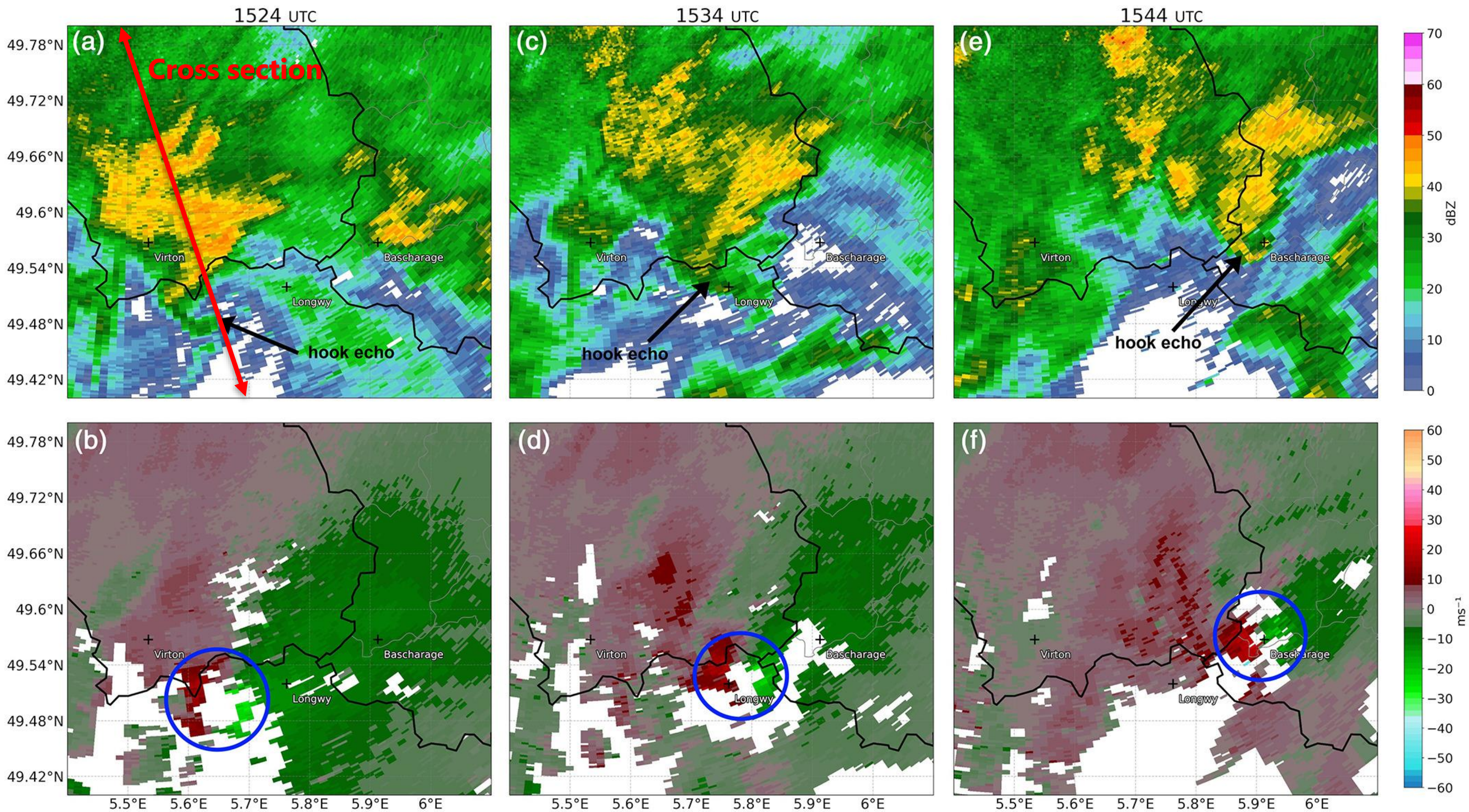
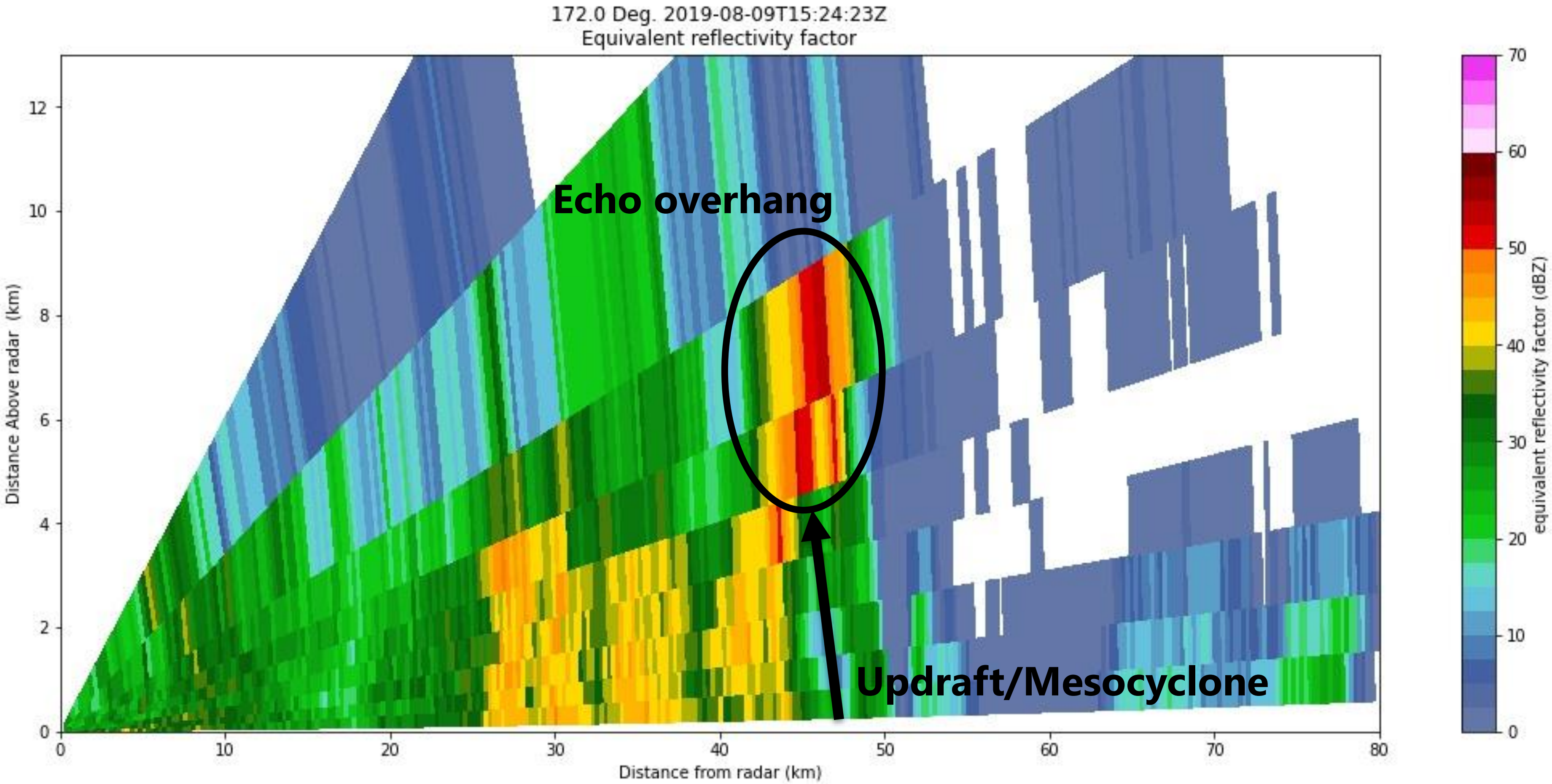


Figure 7. Reflectivity (dBZ; upper row) and radial velocity (ms⁻¹; lower row) measured at 1524 UTC, 1534 UTC and 1544 UTC with an elevation angle of 0.5° by the meteorological radar located in Wideumont (49.9°N, 5.5°E; outside of the area shown) to the north-northwest of the tornadic storm and operated by the Royal Meteorological Institute of Belgium (RMIB). Negative velocities indicate a relative movement towards the radar and positive velocities indicate a relative movement away from the radar. The mesocyclonic circulation is indicated by the blue circle in (b), (d) and (f).

5. Storm cell analysis



6. Predictability

- The 00z AROME run suggested a cluster of four storms with supercellular characteristics over northern France.
- A more isolated, but weaker supercell is evident over far eastern Luxembourg.

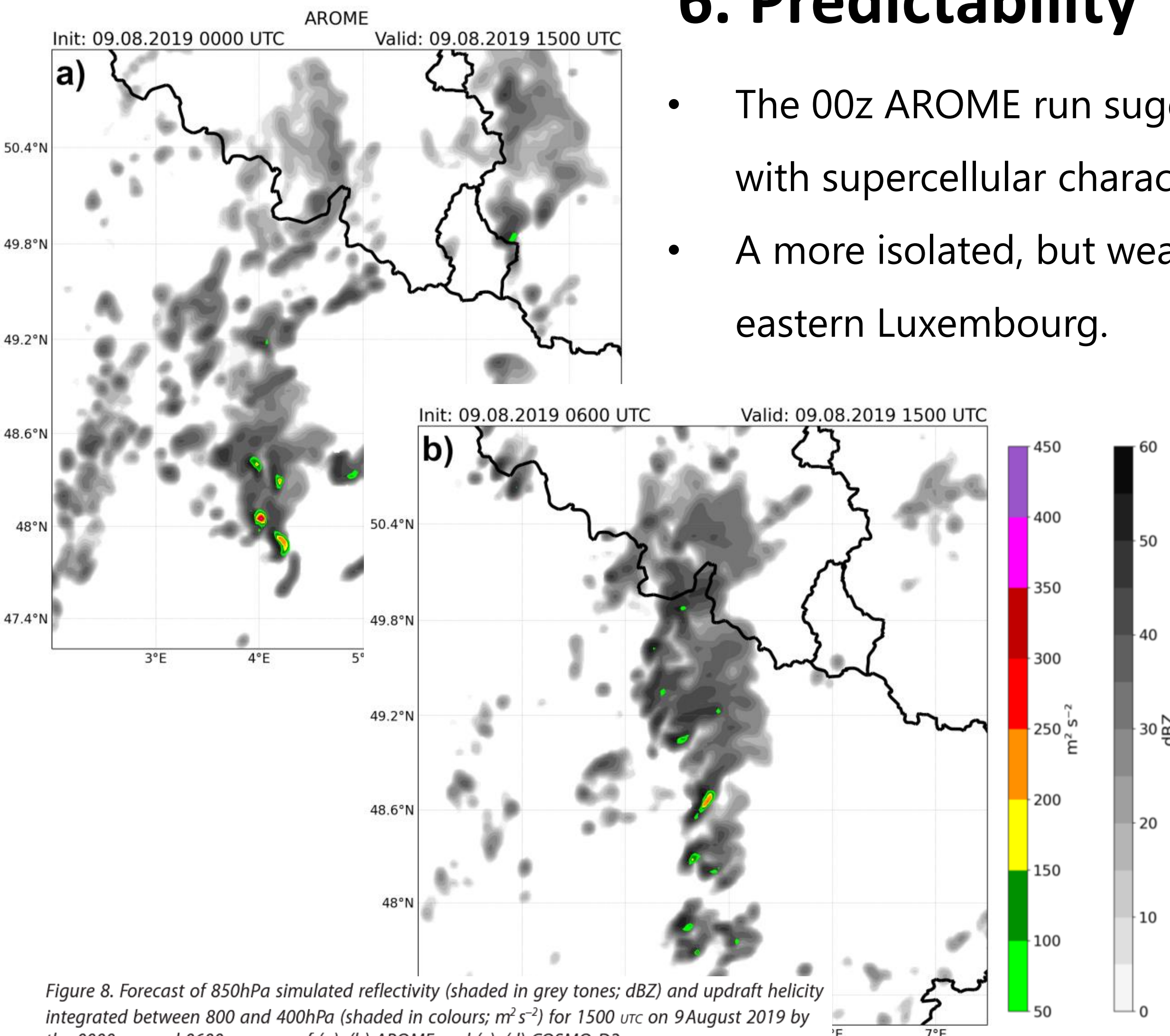


Figure 8. Forecast of 850hPa simulated reflectivity (shaded in grey tones; dBZ) and updraft helicity integrated between 800 and 400hPa (shaded in colours; $m^2 s^{-2}$) for 1500 UTC on 9 August 2019 by the 0000 UTC and 0600 UTC runs of (a), (b) AROME and (c), (d) COSMO-D2.

- The 06z AROME run also simulated widespread storms with embedded supercells.
- AROME suggested an increased potential of supercells, despite being inconsistent with the spatial and temporal evolution of the storm cells.

7. Summary and conclusions

- Atmospheric setting was conducive to the development of discrete and long-lived supercell thunderstorms (overlap of moderate latent instability and strong vertical wind shear).
- Well-defined prefrontal mesoscale surface low was associated with high values of the storm-relative helicity in the lowest 3 km at its northern flank.
- Favourable lower-tropospheric conditions for mesocyclonic tornadogenesis existed.
- The formation of the hook echo signature preceded the tornadogenesis by about 10 minutes.
- Footprints of updraft helicity from operational model output may be very important for forecasters to identify supercells simulated by the model.
- Forecasters should consider multiple deterministic convection-resolving NWP models covering the forecast area or convection-resolving ensemble forecasts of a single model for the evaluation of such dangerous situations.

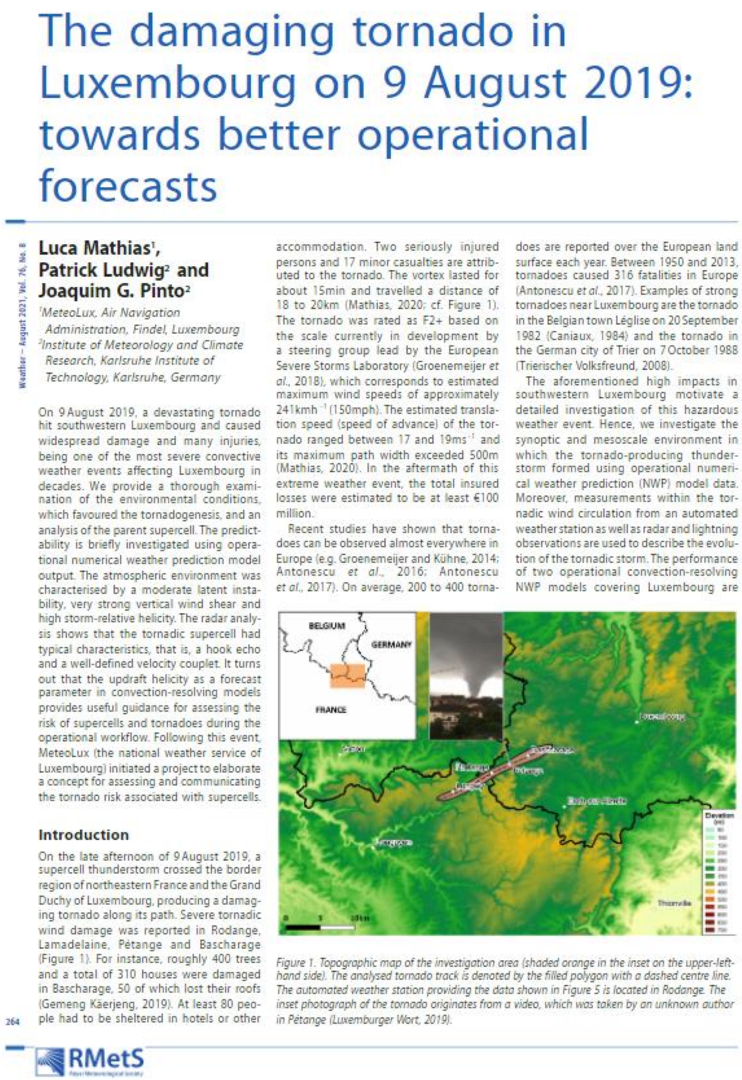
7. Summary and conclusions

Operational concept for assessing the tornado risk in the Greater Region (Luxembourg + border regions) using an ingredients-based forecast methodology since April 2021:

- **Step 1:** Analyse of supercell thunderstorms are likely to occur.
- **Step 2:** Determine if the low-level conditions are favourable for tornadogenesis associated with supercells.
- **Step 3:** Contact warning supervisor to discuss the forecast and further actions (AlarmTILT message sent to HCPN).

5 confirmed (mesocyclonic) tornadoes (4 on 19.06.2021 and 1 on 27.06.2021) within the Greater Region (source: https://eswd.eu)

- ✓ Warning message sent to HCPN on 19.06.2021
- × No warning message sent to HCPN on 27.06.2021



The damaging tornado in Luxembourg on 9 August 2019: towards better operational forecasts

Weather – August 2021, Vol. 76, No. 8

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On 9 August 2019, a devastating tornado hit southwestern Luxembourg and caused widespread damage and many injuries, being one of the most severe convective weather events affecting Luxembourg in decades. We provide a thorough examination of the environmental conditions, which favoured the tornadogenesis, and an analysis of the parent supercell. The predictability is briefly investigated using operational numerical weather prediction model output. The atmospheric environment was characterised by a moderate latent instability, very strong vertical wind shear and high storm-relative helicity. The radar analysis shows that the tornadic supercell had typical characteristics, that is, a hook echo and a well-defined velocity couplet. It turns out that the updraft helicity as a forecast parameter in convection-resolving models provides useful guidance for assessing the risk of supercells and tornadoes during the operational workflow. Following this event, MeteoLux (the national weather service of Luxembourg) initiated a project to elaborate a concept for assessing and communicating the tornado risk associated with supercells.

Introduction

On the late afternoon of 9 August 2019, a supercell thunderstorm crossed the border region of northeastern France and the Grand Duchy of Luxembourg, producing a damaging tornado along its path. Severe tornadic wind damage was reported in Rodange, Lamadelaine, Pétange and Bascharage (Figure 1). For instance, roughly 400 trees and a total of 310 houses were damaged in Bascharage, 50 of which lost their roofs (Gemeng Käerjeng, 2019). At least 80 people had to be sheltered in hotels or other accommodation. Two seriously injured persons and 17 minor casualties are attributed to the tornado. The vortex lasted for about 15min and travelled a distance of 18 to 20km (Mathias, 2020; cf. Figure 1). The tornado was rated as F2+ based on the scale currently in development by a steering group lead by the European Severe Storms Laboratory (Groenemeijer *et al.*, 2018), which corresponds to estimated maximum wind speeds of approximately 241kmh^{-1} (150mph). The estimated translation speed (speed of advance) of the tornado ranged between 17 and 19ms^{-1} and its maximum path width exceeded 500m (Mathias, 2020). In the aftermath of this extreme weather event, the total insured losses were estimated to be at least €100 million.

Recent studies have shown that tornadoes can be observed almost everywhere in Europe (e.g. Groenemeijer and Kühne, 2014; Antonescu *et al.*, 2016; Antonescu *et al.*, 2017). On average, 200 to 400 tornadoes are reported over the European land surface each year. Between 1950 and 2013, tornadoes caused 316 fatalities in Europe (Antonescu *et al.*, 2017). Examples of strong tornadoes near Luxembourg are the tornado in the Belgian town Léglise on 20 September 1982 (Caniaux, 1984) and the tornado in the German city of Trier on 7 October 1988 (Trierischer Volksfreund, 2008).

The aforementioned high impacts in southwestern Luxembourg motivate a detailed investigation of this hazardous weather event. Hence, we investigate the synoptic and mesoscale environment in which the tornado-producing thunderstorm formed using operational numerical weather prediction (NWP) model data. Moreover, measurements within the tornadic wind circulation from an automated weather station as well as radar and lightning observations are used to describe the evolution of the tornadic storm. The performance of two operational convection-resolving NWP models covering Luxembourg are

Figure 1. Topographic map of the investigation area (shaded orange in the inset on the upper-left-hand side). The analysed tornado track is denoted by the filled polygon with a dashed centre line. The automated weather station providing the data shown in Figure 5 is located in Rodange. The inset photograph of the tornado originates from a video, which was taken by an unknown author in Pétange (Luxemburger Wort, 2019).

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https://doi.org/10.1002/wea.3979