Synoptic analysis and hindcast of an intense bow echo above Western Europe: The Pentecost storm 2014

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1. Abstract

On Pentecost Monday of 2014, a severe **mesoscale convective system** (MCS) hit Belgium and Western Germany. The synoptic analysis shows that the outflow of a decaying MCS above Northern France triggered the storm, which exhibited the typical features of a **bow echo,** like a **bookend vortex** and **rear inflow jet**. This resulted in **hurricane-force wind gusts** (reaching 40 m s^{-1}).

The forecast potential of the storm is evaluated using **sensitivity experiments** with **COSMO-CLM**. Moreover, the synoptic scale and mesoscale characteristics of this storm are analyzed.

Operational NWP models mostly failed to forecast the storm, but the high-resolution **COSMO-CLM hindcast** enabled a **more realistic** simulation of the storm.

The **sensitivity experiments** reveal that the development of the bow echo is particularly sensitive to the **initial wind** field and the **lower tropospheric moisture content**. Correct initial and boundary conditions are therefore elementary for realistic numerical forecasts of such a bow echo event.

2. Synoptic situation

- 2014 Pentecost, 09 June 2014
- Western Europe between an upper level trough and a ridge
- Quasi-stationary front and an easterly convergence line over Spain through Western France
- Ingredients for deep moist convection (Johns and Doswell,1992):

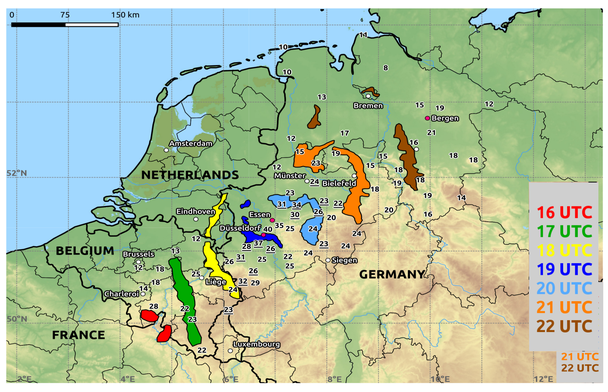


Illustration of the storm propagation based on radar reflectivity above 40 dBz at the leading edge of the storm system.

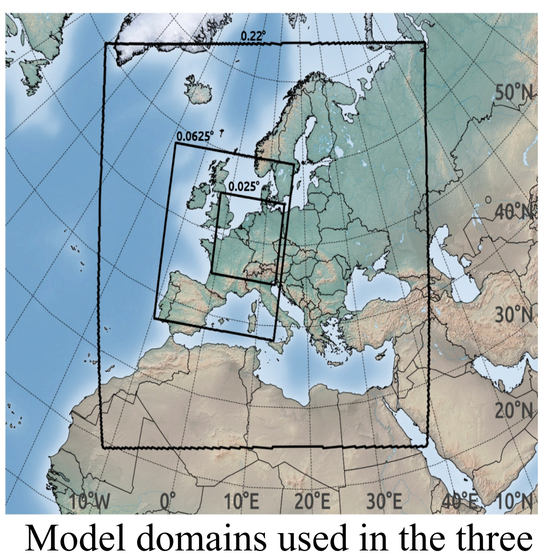
- Moisture in the boundary layer
- Steep lapse rate
- Vertical wind shear
- Lifting (in this case the outflow of a decaying convective system)

Most **operational NWP models** were **not** able to predict the Pentecost storm **adequately in advance**, despite the favorable ingredients.

3. Data & Model

Observations

- Synoptic stations (DWD, MeteoGroup)
- Sounding station, Bergen-Hohne
- Radar from Essen
- Satellite images
- Lightning data



Model domains used in the three step nesting approach for the hindcast simulations.

CCLM hindcast simulations

- COSMO-CLM v5
- Three step nesting (0.22°- 0.0625°- 0.025°)
- Start 09 June 2014, 06 UTC
- Driven with:
  - **ERA-Interim (80 km)**
  - **ECMWF Analysis (16 km)**
- **Sensitivity studies**
  initial conditions from ECMWF analysis with one variable from ERA-Interim data (QV, T, U and V, QC, QI,P, T_SO, W_SO)

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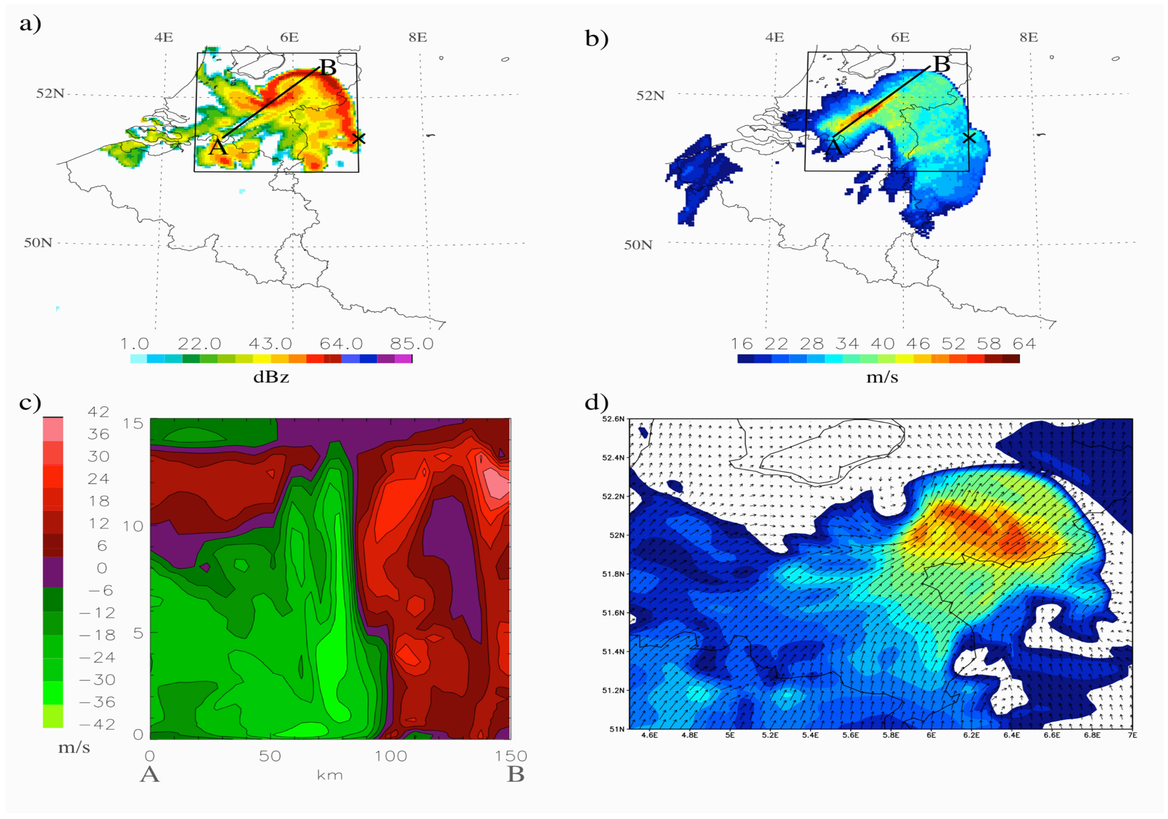
5. Conclusions

- The ERA-Interim driven **CCLM simulation** produced a MCS with a developing **bow echo** featuring similar mesoscale characteristics as those observed in reality (e.g., northern bookend vortex, mid-level rear inflow jet, swath of severe winds).
- The **timing** of the simulated storm **coincides** with the development of the observed system, although the **track** of the simulated system was **shifted** northwestward by about 50 to 100 km.
- **Sensitivity studies** revealed that the bow echo formation is particularly sensitive to the **wind** field and the **moisture content** in the ambient environment and initial conditions.
- The **initial and boundary conditions** played a crucial role in case of our simulations.

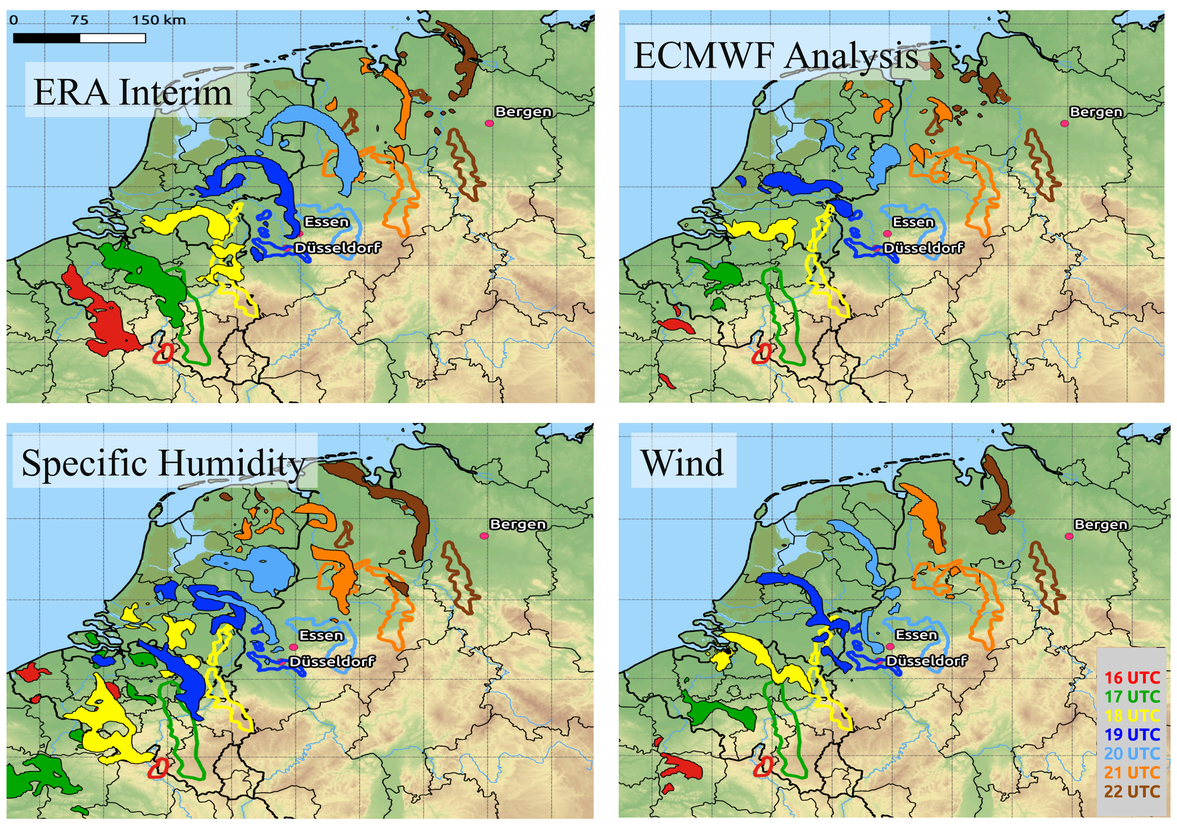
4. CCLM simulations

Modeled Bow Echo



Results from the ERA-Interim driven **CCLM simulation** at 19 UTC:
(a) Low-level (ca. 1.3 km) radar reflectivity,
(b) 10 meter maximum wind,
(c) cross section of radial wind component with respect to the Essen radar station (marked by a cross in (a) and (b)),
(d) wind speed (shading) and direction (arrows) at 2.8 km altitude, in the rectangle denoted in (a) and (b).

Sensitivity Studies



Simulated radar reflectivity (shaded) over the 50 dBz threshold at approximately 1.3 km altitude and observed 0.8° radar reflectivity (colored isolines) over the 40 dBz threshold in consecutive time steps (see legend, 09 June 2014 16 UTC to 22 UTC). Note that the simulated and observed reflectivity are not fully consistent due to the different heights (model level vs. elevation angle).