Severe convective storms and wind damage assessment over northwestern Poland

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Introduction

Severe convective storms can generate damaging weather conditions ranging from severe winds to hail and floods. Over Poland these events occur mostly from May to September as seen in the distribution of cloud-to-ground lightning flashes (Fig. 1) .
The expected increase in their frequency and intensity over the century (Rädler et al., 2019) represents a primary concern for insurers.

We study the losses caused by strong winds (Fig. 2) over a region located in northwestern Poland (Fig. 3).

Three dates are selected for their high convection-related damages. Wind gusts are studied over 8 weather stations, 2 numerical weather model and the ERA5 reanalysis. The location of strong lightning density is also considered.

Relating a single weather variable to an observed damage is challenging. In the discussion section, we display some preliminary results.

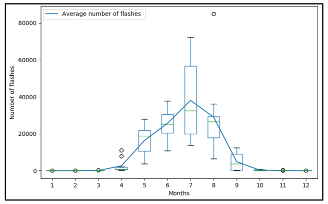

Figure 1. Monthly distribution of the number of cloud-to-ground lightning over northwestern Poland during May-September 2009-2019.

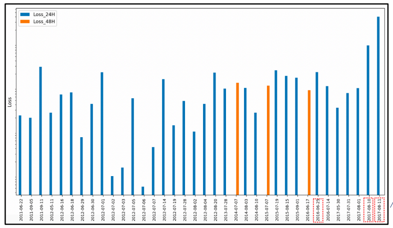

Figure 2. Cumulative losses per day over northwestern Poland during May-September 2011-2017.

Data

Reanalysis and NWP models:
- ERA5 reanalysis (0.25° resolution)
- ECMWF-IFS (0.1° resolution)
- UKMO (0.04° resolution)

Weather stations (Fig. 3, Table 1)
Lightning data: NOWCAST

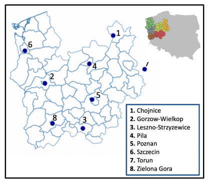

Figure 3. The main weather stations in northwestern Poland (8)

Table 1. Historical wind gusts values per weather station [2009-2019].

Station	Gust <= 10m/s	10 < Gust <= 15m/s	15 < Gust <=20m/s	Gust > 20m/s
1	31 %	55 %	12 %	2 %
2	52 %	42 %	5.5 %	0.5%
3	29 %	54 %	14 %	3 %
4	55.5 %	40.5 %	3.5 %	0.5 %
5	25 %	58 %	14 %	3 %
6	26.5 %	57.5 %	14 %	2 %
7	55 %	41 %	3.5 %	0.5 %
8	47 %	45 %	7 %	1 %

Case Study : Three days of damaging convective weather

1. Wind gust : 8 weather stations

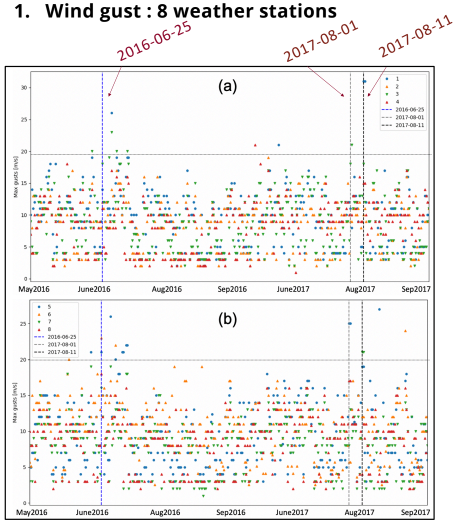

Figure 4. Maximum daily wind gusts (m/s) during May-September 2016-2017 period on 8 weather stations. (a) Stations: 1 to 4, (b) Stations 5 to 8.

2. Wind gusts: weather model data

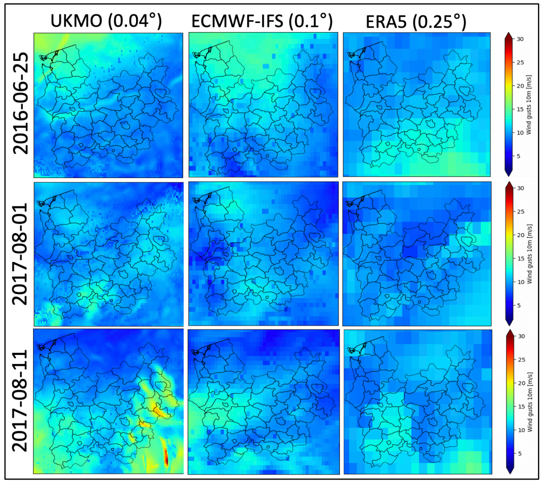

Figure 5. Maximum wind gusts (m/s) in 3 days of the highest losses for UKMO, ECMWF-IFS and ERA5.

3. Lightning Data

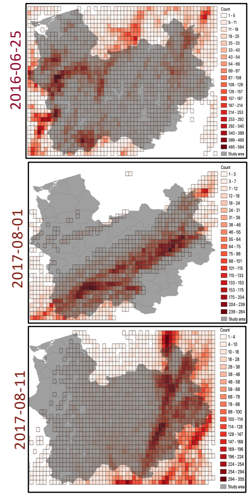

Figure 6. Lightning occurrence for the 3 days studied in 10km x 10km grid cells.

Three days of damaging convection-related winds were chosen based on **the losses that resulted from severe wind gusts**. A comparison between wind gusts observed over 8 weather stations covering the domain (Fig. 3 and 4) and numerical weather models (Fig. 5) is performed. The lightning flash density (Fig. 6) offers a perspective on the localization of the thunderstorm:

- **June 25th 2016:** Two weather stations registered winds > 20m.s-1. The Szczecin station, located in the northwest, displayed the strongest gust. Similarly, the UKMO and IFS models produced stronger gusts over the northwest. Lightning activity is also intense over the west.
- **August 1st 2017:** Only the Poznan station registered winds > 20m.s-1. All models show a southwest-northeast axis of stronger gusts, similarly to the location of high lightning density.
- **August 11th 2017 :** The two eastern-most weather stations (Chojnice and Torun) registered winds > 20m.s-1. Only the UKMO model produced stronger gusts over the east part of the domain, in agreement with the lightning activity.

Weather stations record local high wind gusts but are too spread-out to catch the full extent of potential damages. High resolution models show better skills than reanalysis at generating local wind gusts over locations where lightning density is very high.

Discussion and next steps

1. Correlation with damage

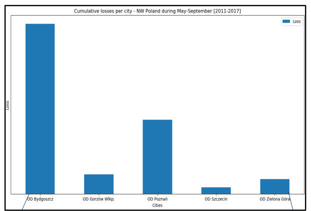

Figure 6. Cumulative loss per city over northwestern Poland during May-September 2011-2017.

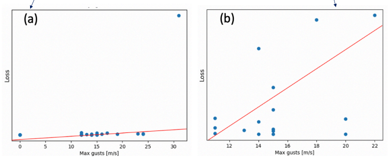

Figure 7. Correlation between loss and maximum wind gusts from weather stations in two cities. (a) Bydgoszcz, (b) Zielona Gora (correlation coefficient=0.45).

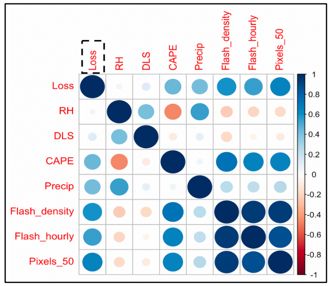

Figure 8. The correlation matrix between ***Loss*** : The daily global losses (our predictand), ***RH*** : Average relative humidity from the 850, 700 and 500 hPa layers, ***DLS*** : Deep-layer wind shear between 10m and the 500 hPa level, ***CAPE*** : Convective Available Potential Energy, ***Precip*** : Daily total Precipitation, ***Flash_density*** : Number of daily flashes, ***Flash_hourly*** : The hourly number of flashes, ***Pixels_50*** : The percentage of pixels (10 km x 10 km) covered with a number of flashes exceeding 50.

Losses recorded over specific cities (Fig. 6) are correlated with wind gusts over the corresponding weather station : Bydgoszcz (Fig. 7a) and Zielona Gora (Fig. 7b).

As illustrated in the correlation matrix (Fig. 8), the daily global summer losses are correlated with large scale indicators of convection (CAPE) in the ERA5 reanalysis and with the total daily precipitation generally associated with the thunderstorm downdrafts. **The losses are also correlated with the flashes density** (*Flash_density*) **and their spatial and temporal extent** (represented by the two parameters *pixels_50* and *flash_hourly*).

Also, a **Linear Model with interactions** applied to the predictors (R-squared=0.89) shows that the parameter *Pixels_50* (representing the spatial extent of flashes density) and its interaction with the *CAPE* was statistically significant.

The next step is to correlate global damages with a storm severity index that will be determined.

The lightning activity could be an interesting source of information on the severity of a convective storm.

References

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Taszarek, M., B. Czernecki, and A. Kozioł, 2015: A cloud-toground lightning climatology for Poland. Mon. Wea. Rev., 143, 4285–4304
Tadeusz Chmielewski, Jacek Szer & Piotr Bobra (2020) Derecho wind storm in Poland on 11–12 August 2017: results of the post-disaster investigation, Environmental Hazard