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OPERATIONAL PROGRAMME FOR THE EXCHANGE OF LIGHTNING LOCATION DATA: FEASIBLE OR NOT?

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I. INTRODUCTION

The exchange of national weather radar data on European scale has been carried out successfully within the framework of the OPERA network (Huuskonen et al., 2010; Holleman et al., 2008). In a similar manner, data from lightning location systems (LLS) could also be shared and combined and this has actually been done over smaller regions in Europe, e.g., between some neighbouring countries. Larger areas like Europe are also covered by the European Cooperation for Lightning Detection (EUCLID; Diendorfer, 2010) community. However, because of the commercial nature of EUCLID, the data is not available free of charge.

The main reason why lightning location data is more difficult to share and combine compared to weather radar data is that most of the European national meteorological and hydrological services (NHMSs) are not the owners of an LLS, but are customers. This means that an OPERA-style cooperation is much more difficult to establish since it is easily hampered by commercial issues. In addition, the performance and coverage of a national LLS is subject to variations due to differences in network performance and the used technology, which makes a composite challenging.

In this study we explore the methods and requirements on how lightning location data could be shared and combined in Europe between national meteorological services. We also address the question whether such “European lightning composite” is even feasible in practice. The purpose of this study is not to present a method which *should* be used when making a lightning composite over Europe; we purely present ideas how the data *could* be composited, and what are the main difficulties and benefits of such an composite.

II. DATA AND METHODS

In this study, we have used LLS data from eight European countries or regions: Italy, France, Belgium, Croatia, Slovakia, Hungary, Poland and Scandinavia. The LLS data in each region is described here shortly.

Italy (Lampinet): Italian Air Force Meteorological Service set up a lightning network and put it in operation during 2004, based on Vaisala technology with 15 IMPACT ESP sensors. At Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA), the Operational Centre, it is located the LAMPINET Central Suite, based on LP2000 Vaisala processor. The location technique is based both on MDF (Magnetic Direction Finding) and TOA (Time Of Arrival) and during early 2011 a Network Performance and Evaluation Program has been done by Vaisala to bring performances at best. The detection efficiency is 90% on Italy and the location accuracy is 500 m.

France (Météorage): The French national network is owned and operated by Météorage. In France, it is composed of a total of 24 Vaisala LS7001 sensors from Vaisala. It detects low frequency signals generated mainly by cloud-to-ground (CG) lightning. Raw data are exchanged in real time with partners from neighboring countries who are using the same technology. With these exchanges, the level of detection is uniform on France with a detection efficiency of at least 95% for CG flashes; the median location accuracy is below 500 m in France.

Belgium (BELLS): The Royal Meteorological Institute of Belgium (RMIB) has been operating a Belgian lightning location system (BELLS) since 1992, locating cloud-to-cloud (CC) as well as cloud-to-ground (CG) discharges. At first, the network consisted out of four sensors of type SAFIR. Currently, raw data an extra fifth SAFIR sensor and from additional SAFIR and LS-type sensors belonging to KNMI, Météorage and Siemens are used as well by the central processor at RMIB to map the total electric activity from thunderstorms. The performance of BELLS has been tested recently against ground-truth data using video and E-field measurements (Poelman et al. 2012), resulting in a location accuracy (LA) of 1.0km and a stroke and flash detection efficiency (DE) of 64% and 88%, respectively, at the time of the campaign.

Croatia (Linet): Lightning data is provided by the Lightning Location System, a part of the International Lightning Detection Network LINET (e.g., Betz et al., 2009; Höller et al., 2009). The mentioned system covers an area from approximately 30°N 10°W to 65°N 35°E and has more than 100 sensors in 24 countries all over the Europe . The LINET system detects total lightning discharges, but it also separates cloud-to-ground (CG) from intracloud (IC) discharges. For the purpose of this study the data from the area 30°-65°N and 10°-35°E are used.

LINET data provides information about date and time, location (coordinates) and current (kA) of lightning strokes, as well as stroke type (IC or CG), height of lightning (km) and 2D-error of stroke location (km).

Slovakia (SAFIR): The Slovak SAFIR network consists of 3 SAFIR3000 sensors, located in the southern part of the country. There is a real-time data exchange with the Hungarian Met. Service. Data from 3 Slovak sensors and 3 Hungarian sensors are collected and processed by a SAFIR-SCM central unit. The IC strokes are localised by VHF interferometric direction finding. To locate the CG strokes the time-of-arrival method is used based on the data from the LF part of the sensors. Because the LF part of the sensors is functioning only on 4 sensors, the detection efficiency of CG strokes is low, especially in the northern part of the country.

Hungary (SAFIR-HMS): The Hungarian Meteorological Service (OMSZ) has been operating it's own lightning location network since 1997. Until 2011, it consisted of 5 SAFIR 3000 V1. One of them was exchanged with a V2 rack in 2003. Since 2001 OMSZ is cooperating with the Slovak Hidrometeorological Institute (SHMU) in a bilateral agreement to exchange their data. OMSZ has a licence for a 7 sensor managing CPS (old type). This enables it to integrate 2 Slovak sensors beside the 5 Hungarians. CPS only uses triangulation from VHF data and uses LF only for CG discrimination. Time of arrival option is not included. The area covered is 655x655 km square with a centre of N47.5 E19.0. After 2011 - when two of the 5 sensors irreversibly damaged by lightning strikes - the entire network was relocated with a new geometrical configuration and presently operating with 4 VHF sensors, 2 of them completed with LF, and the CPS includes 3 Slovak sensors.

Poland (SAFIR): Polish total lighting detection network is called PERUN. It consists of a total of 9 SAFIR3000 type VHF sensors. It is operated by TLP central processor additionally with old SCM central processor running parallel. Both datasets are archived (SCM from 2002, TLP from 2012). Baseline of PERUN network is about 200 km which causes some lack in IC lightning detection. Performance of the network is centralized around the capital of Poland.

Scandinavia (NORDLIS): The Nordic Lightning Information System is a cooperative network between Norway, Sweden Finland and Estonia (Mäkelä et al., 2010). The network is composed of about 30 Vaisala LF sensors. The raw sensor data from all of the Scandinavian sensors are transmitted to central processors in Norway, Sweden and Finland, which then process the data independently. To the south, the network coverage extends to Northern Germany and in the Baltic countries, although with decreasing performance.

Because all networks provide essentially the same information on located lightning, although with varying performances and regional coverages, the data sets from individual networks can be combined. Here, we are only interested on the temporal and spatial information of lightning. The combining method depends on the desired output, as explained below:

1. Plotting located events on a map (Fig. 2). This is the most trivial method, and does not require any projection changes, because all LLSs report the located events in WGS84 geographical coordinate system. Temporal information can be attached, for example, by colour coding the events according to time. However, to avoid plotting duplicate events, the combined data sets should be removed from common events.

2. Calculating a flash density. This gives practically the same information as method (1) but it indicates better the intensity of the thunderstorms. If this method is used in kilometer-based coordinate system, the data sets should be reprojected uniformly. The difficulty of this method is that the relative performances of each LLS participating into to the composite should be known, and the data should be restricted only to areas with good network coverage.

3. Showing only areas with and without lightning. This method is similar to method (2): we calculate the flash density, and show the result, for example, with values zero (i.e., no lightning observed) and one (i.e., lightning observed). Compared to method (1), now it is not necessary to remove common events, and the data can contain both CG and IC. Also, the method is not as dependent on the performance variations between different networks as method (2). Actually, this method could be termed as *thunderstorm indicator*; we are only interested to see where lightning is occurring, not on the lightning type or its intensity.

Coordinate system	Lambert Azimuthal Equal Area
Ellipsoid	WGS84
Lat 0	55°N
Lon 0	10°E
X-size	1900 km
Y-size	2200 km
SW corner	31.7462°N, -10.4346°E
NW corner	67.0228°N, -39.5358°E
NE corner	67.6210°N, 57.8120°E
SE corner	31.9877°N, 29.4210°E

TABLE I: Projection parameters used in this study for the flash density matrix.

Before compositing the data, we have firstly homogenized it into a common format: the data from each eight LLS is organized into a separate ascii-file, with each row as one located event, and columns indicating the date, UTC-time, latitude and longitude, respectively. If the LLS provides also the event type (i.e., IC or CG), we have considered only CG flashes. Also, if the LLS reports subsequent strokes, we have here used only the first strokes.

Then, depending on the desired end-product, we can plot the combined data set as such (method (1), Fig. 1), or we can further calculate it into a common flash density grid (methods (2)-(3), Figures 2-3). Here, we have used a grid of 10 km x 10 km bins for every 15-minute period. Then, we reproject the data into a Lambertian Azimuthal Equal Area coordinate system, with the parameters described in Table I; these are the same as used in the OPERA weather radar composite.

The next step is to read the LLS data sets one by one into the flash density grid. If a bin is covered by several networks, we use the largest reported flash density value for that bin. Finally, we have a composite flash density matrix of 10 km x 10 km bins for every 15-minute period. In this study we use the archived historical data; in real time operation this method provides the matrix every 15-minutes.

A question arises, how reliable the composite values are because the data set contains data from different types of LLSs whose efficient coverages and relative performances are not known in detail. This is indeed an important question, and should be a topic for another study. In Figures 1-3 the *estimated efficient coverage areas* of the networks used in this study are shown with light-grey colours. As we can see, with the composite of 8 LLSs, large parts of Europe are covered well. Figures also show that lightning is located also beyond the efficient coverages; however, the detection efficiency is poorer in these areas.

In Section III we show examples how the three methods work and how the outcomes looks like.

III. RESULTS

Figure 1 illustrates method (1): each located CG flash from the composite data set on July 28, 2012 is plotted in red. This method shows well the thunderstorms areas and their movement (if used in real time). From the estimated efficient network coverages we can see that the most intense lightning activity has occurred over the composite area. Some flashes are likely missed over Germany, Spain and the Mediterranian.

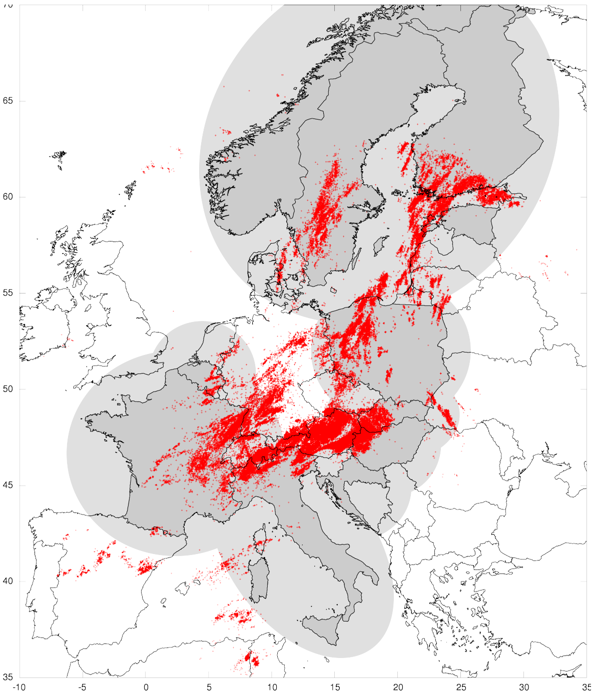

FIG. 1: Located lightning flashes on July 28, 2012 from the LLSs operating in the countries shaded in grey. The light-grey area show the estimated efficient coverage areas of the individual networks used in this study. On the map a total of 203652 flashes.

Compared to Fig. 1, the CG flash density shown in Fig. 2 shows better the most intense thunderstorm areas over the Central Europe, Poland, Sweden and Finland. In real time operations, the flash density can be visualized as an animation of consecutive 15-minute images in similar way as weather radar animations. The biggest uncertainty related to Fig. 2 is that the flash density values might be over- or underestimations. This is caused by the different types and performances of the individual LLSs. Of course, the data could be validated against a reference network (e.g. EUCLID) and efficiency-corrected based on that, but that would be a scope for another study.

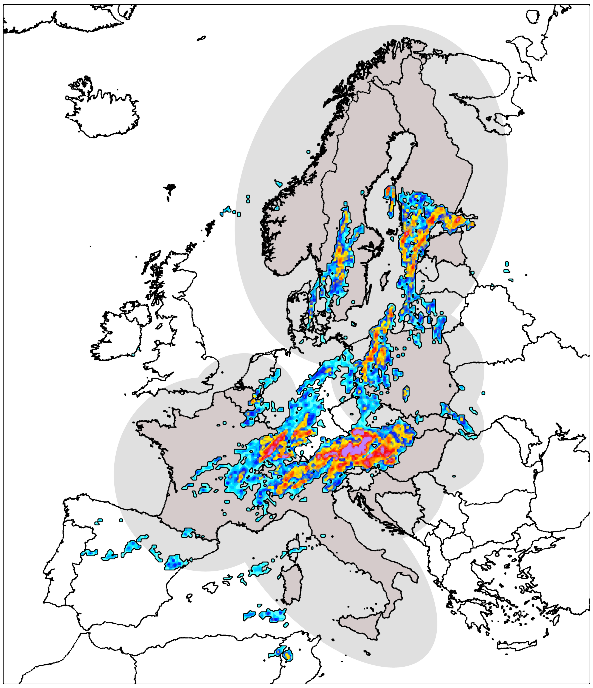

FIG. 2: CG flash density on July 28, 2012. The unit is CGs per 100 km² per 24 hours.

We can also minimize the uncertainties caused by the multitude of different LLSs in the composite: if we are only interested to see the areas with and without lightning, i.e., not the absolute number of flashes or flash density, we set the scale in Fig. 2 from zero to one (Fig. 3). Now we can see the 10 km x 10 km areas in which at least one flash has been located. This method serves well as a warning tool for many end-users. Naturally, this method also suffers over areas with poorer detection efficiency.

IV. DISCUSSION AND CONCLUSIONS

Although practically the whole Europe is covered with lightning location systems (LLSs), a common European composite is not available largely because the commercial use of LLS data makes the interchange of the data difficult. However, as we have shown in this study, such a composite could be easily done even despite the large heterogeneity of the national and regional LLSs. Regarding data communications, processing, storing and visualization, lightning location data composite would be relative easy to make.

As a conclusion, if the European NHMSs or a sub-group of them would indeed show a green light for an operational lightning location data composite, that would be possible to do. Large parts of Europe would be covered and by increasing the number of cooperators into the composite, the coverage and reliability of the composite would increase. One way for distributing the composite would as a table within the OPERA weather radar hdf5-file.

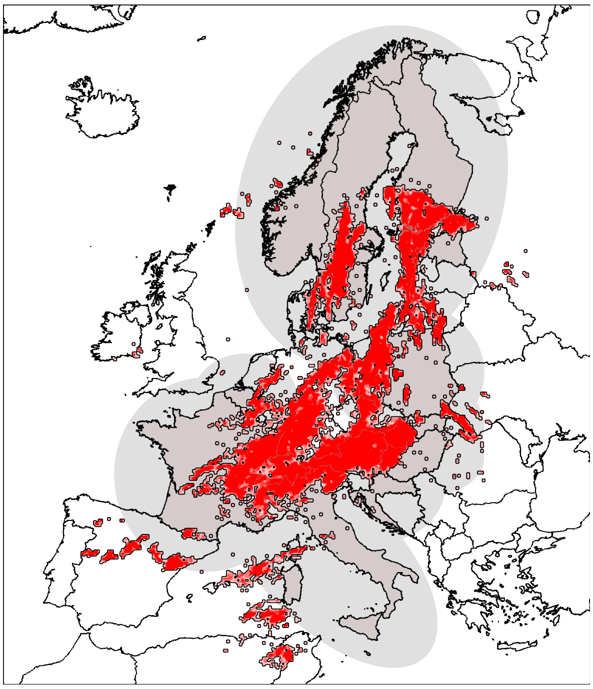

FIG. 3: Map showing 10 km x 10 km areas with lightning (red) on July 28, 2012.

Here we have shown some methods how the data could be composited, what kind of end-products could be made, and what kind of issues need to be considered when making the composite. Our preliminary results presented in this paper could be considered as a first step towards such a composite. Further and more detailed studies should be made to analyze for example the relative performances of neighbouring LLSs which have overlapping coverage.

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V. REFERENCES

Holleman I., Delobbe L., and Zgonc A., 2008: Update on the European weather radar network (OPERA). *Proceedings of ERAD 2008*, 3.3.

Huuskonen, A., Delobbe, L. and Urban, B. 2010: Update on the European Weather radar cooperation (OPERA). *Preprints, 6th European Conference on Radar in Meteorology and Hydrology*, Sibiu, Romania.

Diendorfer, G., 2010: LLS Performance 427 validation using lightning to Towers. *21St International Lightning Detection Conference (ILDC) & 3rd International Lightning Meteorology Conference (ILMC)*, 19-20 April 2010, Orlando, Florida. 15 p.

Poelman D., Schulz W., and Vergeiner C., 2012: Performance characteristics of distinct lightning detection networks covering Belgium. *J. Atmos. Oce. Tech.*, http://dx.doi.org/10.1175/JTECH-D-12-00162.1

Höller, H., Betz, H.-D., Schmidt, K., Calheiros, R.V., May, P., Houngninou, E., Scialom, G., (2009) Lightning characteristics observed by a VLF/LF lightning detection network (LINET) in Brazil, Australia, Africa and Germany. *Atmos. Chem. Phys.* ***9****, 7795–7824*

Betz, H.-D., Schmidt, K., Laroche, P., Blanchet, P., Oettinger, W.P., Defer, E., Dziewit, Z., Konarski, J., (2009) LINET — an international lightning detection network in Europe. *Atmos. Res.*, **91**, 564–573.

Mäkelä A., Tuomi T.J., and Haapalainen J., 2010: A decade of high-latitude lightning location: Effects of the evolving location network in Finland. *J. Geophys. Res.*, 115 (D21).