OD19 Daily convective precipitation maps

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I. Introduction

Hazardous weather, such as severe rainfall, hail and other dangerous phenomena associated with convective storms show clear signatures in radar data. Those events may affect public safety, cause property damage, and/or induce economic losses. Therefore, the goal of the OD19 work package is to produce an a posteriori daily overview of all areas in Europe affected by severe convective phenomena, which could be of interest to many stakeholders.

Pan-European weather radar composites are available through the EUMETNET Operational Programme for the Exchange of Weather Radar Information (OPERA). As such, daily pan-European maps can be produced based on the aggregation or accumulation of the 15 minute maximum reflectivity and rainfall OPERA products. However, the most hazardous convective storms are generally producing lightning activity and hail. To identify such convective storms, it is useful to complement radar data with lightning observations. To this end, a thunderstorm daily map using data from the European-wide lightning detection network EUCLID (European Cooperation for Lightning Detection) is used to improve the mapping of convective precipitation over Europe. Lightning, radar rainfall and radar-derived hail products are combined for a selection of convective episodes simultaneously affecting several countries in Europe. The benefits of combining the two sources of observations are being explored.

II. Data

1. OPERA

The OPERA Data Center collects volume radar data from national weather services and produces Pan-European weather radar composites. In 2018, 152 radars from 24 countries are regularly included in the composites (Fig. 1). Three composites are generated every 15 minutes: (1) the surface reflectivity/rainrate composite (PAAH), (2) the maximum reflectivity composite (PABH), and (3) the hourly accumulation composite (PASH). The surface reflectivity/rainrate composite is used in the present study. The rainfall accumulations are derived from the rainrate composite by temporal integration.

2. National hail products

Hail detection products can be produced from volume reflectivity data (e.g. Holleman, 2001, Delobbe and Holleman, 2006; Lukach et al., 2017; Nisi et al., 2018; Saltikoff et al., 2010). The

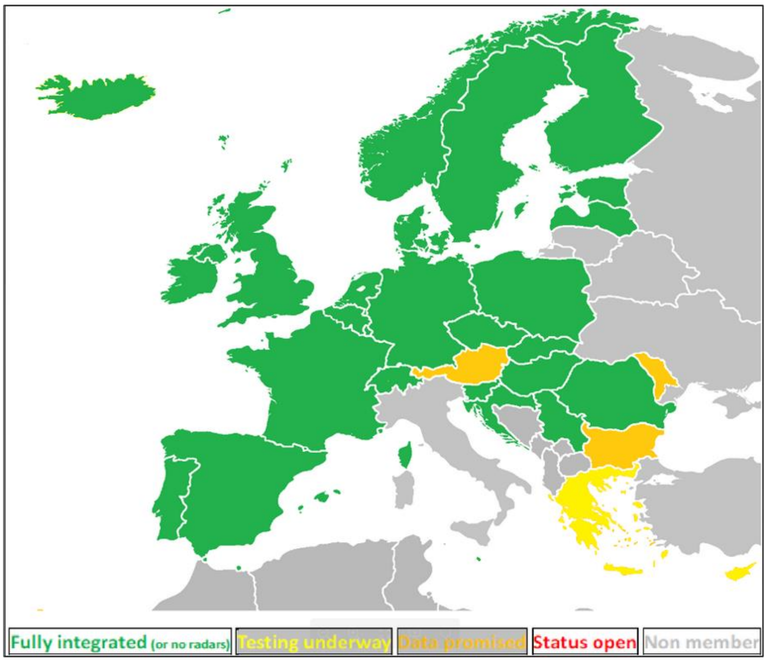

Fig. 1: Countries sending reflectivity data to OPERA Data Center (situation in June 2018).

probability that a convective storm is producing hail is generally estimated based on the analysis of the vertical profiles of reflectivity complemented with temperature information. The most common algorithm is based on the height difference between the echotop-45 dBZ and the freezing level (Waldvogel et al., 1979). Hail detection products are generally produced every 5 minutes and are used in real-time for nowcasting and warning purpose. Based on these products, daily maps of hail have been produced for many years in several weather services. Such daily products are very useful in several application fields like insurance, climate studies or media.

In this particular study, daily hail products from MeteoSwiss, KNMI (Netherlands) and RMIB (Belgium) have been used. The three weather services make use of the Waldvogel algorithm. Note that RMIB products are single-radar products, whereas those from KNMI and Meteoswiss are composites based on 2 and 4 radars, respectively. In regions covered by multiple radars, the maximum probability of hail (POH) is taken. Subsequently, the daily POH for a given pixel is taken as the maximum value over the day.

The original OD19 plan included the possible use of SESAR hail data. The 3D composite produced in SESAR forms indeed a natural basis for convection identification, and in particular for hail detection. Unfortunately, at the time of this study the European-wide 2D hail composite field was not yet available. Therefore, SESAR data are not included.

3. EUCLID

The European Cooperation for Lightning Detection network has been operational since 2001 and processes in real-time data of 164 lightning detection sensors to provide European-wide lightning observations of high and nearly homogeneous quality (Schulz et al., 2016; Poelman et al., 2016). Note that those sensors belong to independent national lightning detection networks. All the partners employ dedicated technicians to supervise and maintain the network and to react immediately in case of sensor or communication problems. All of the sensors operate over the same low frequency (LF) range and provide amongst others timing and angle information. The individual raw sensor data are sent in real time to a single processor, calculating the electrical activity at any given moment, i.e. cloud-to-ground (CG) as well as intracloud (IC) lightning discharges. The locations of the EUCLID sensors are displayed in Fig. 2. The network has been tested continuously over the years against ground-truth data from direct lightning current measurements at the Gaisberg tower in Austria (Schulz et al., 2016), Peißenberg tower in Germany (Heidler and Schulz, 2016) and Säntis tower in Switzerland (Romero et al., 2011; Azadifar et al., 2016) as well as data from E-field measurements and video recordings in Austria, France and

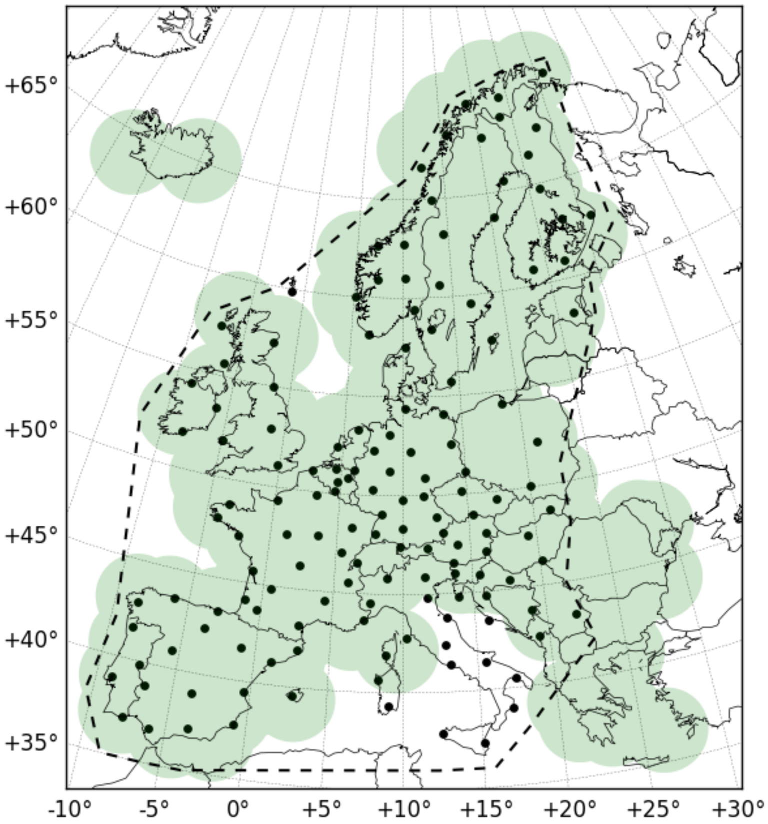

Fig. 2: Lightning detection sensor locations (dots) within the EUCLID network, as well as the EUCLID coverage (dashed line). The extent of the ODC coverage is indicated in green. As can be seen, there is a good match between the coverage of EUCLID and ODC.

Belgium (Schulz et al., 2016). The latest comprehensive performance analysis of the EUCLID network based on those measurements revealed that the flash detection efficiency (DE) for negative cloud-to-ground (CG) discharges is greater than 93%, while for positive events those are greater than 87 % (Schulz et al., 2016). In addition, Schulz et al. (2016) showed that the location accuracy (LA) dropped steadily over the years down to the present LA in the range of 100m within the majority of the network.
EUCLID supports research aimed at improving scientific understanding of lightning and meteorological uses of lightning information. Hence, archived data was made freely available on our request to support this particular study.

III. Approach

First of all, a couple of interesting days with convective activity are selected within 2014-2017. The selection is based on the amount and spread of electrical activity in Europe, as observed by EUCLID. This resulted in a collection of 25 days. Subsequently, for those particular days ODC, EUCLID and hail data are processed to produce various daily overview products aimed at identifying and characterizing convective precipitation over Europe.

Three types of daily maps can be derived from ODC reflectivity/rainrate data only: (1) daily accumulation [mm], (2) convective accumulation [mm], i.e. only reflectivity values larger than 40 dBZ are included in the rainfall accumulation, and (3) maximum reflectivity [dBZ], i.e. for each pixel the maximum reflectivity observed during the entire day is extracted. Subsequently, maximum reflectivity maps with a certain dBZ threshold can be made. The extraction of daily convective precipitation based on a reflectivity threshold is a very simple approach. It must be noticed that more sophisticated techniques for discriminating convective from stratiform precipitation are available (e.g. Biggerstaff and Listemaa, 2000; Steiner et al., 1995; Yang et al., 2013).

The presence of hail in summer is a clear signature of convective precipitation. The maximum probability of hail along the day can be used as an indicator of the severity of atmospheric convection. Using hail information for mapping convective precipitation is not straightforward since it is available as a probability. The selection of a threshold, above which it is considered that hail was present, is generally required. Note that the national POH data use site-specific projections and grids as defined in the HDF5 files. In this work, no attempt was made to convert the POH data to the Odyssey grid.

Lightning, as observed by EUCLID, is the third dataset used in this study. The locations of all lightning discharges observed along the day can be extracted, as well as the lightning density (i.e. the number of discharges per km^2). Lightning is also a clear indicator of atmospheric convection. However, occasionally lightning activity is sometimes observed in dry thunderstorms. This occurs when thunderstorms form at relatively high altitudes with rainfall evaporating in dry air below the cloud base before it reaches the ground. On the other hand,

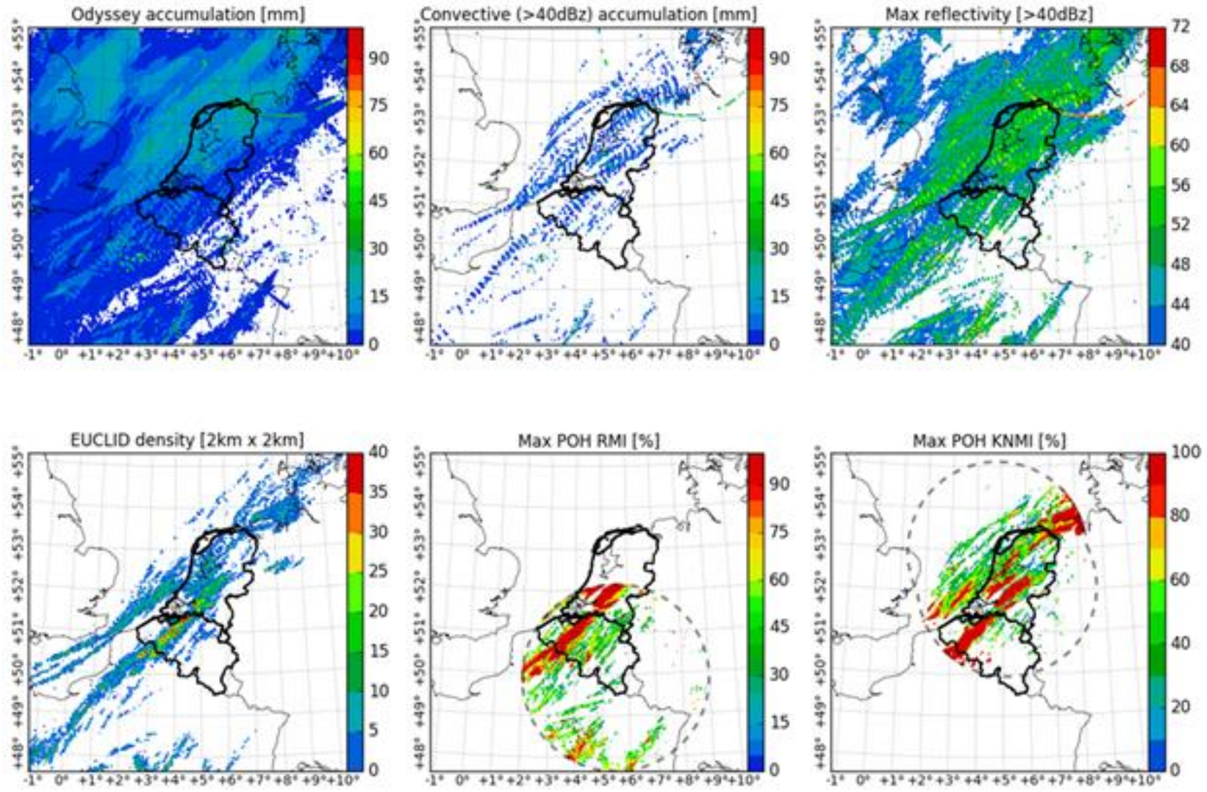

Fig. 3: Top panels depict different types of daily maps as derived from the ODC reflectivity/rainrate data centralized on the Benelux on 2015/08/31. Corresponding maps of the EUCLID lightning density and national POH of RMI and KNMI are plotted in the lower panels.

convective precipitation is not always accompanied with lightning. Showers produced by shallow convective clouds do not produce lightning activity. Like hail, lightning information cannot be used alone for mapping the full extension of convective precipitation over Europe. However, it can be used as an indicator of the severity of convection.

IV. Results

In the following, focus is on two selected days, being 2015/08/31 and 2016/06/24, representative of large-spread convective activity in Europe. Similar plots can be produced for the other selection of days.

Fig. 3 and 4 plot the (1) daily Odyssey accumulation [mm], (2) convective accumulation [mm], (3) maximum reflectivity [dBZ], (4) EUCLID lightning density and (5) the maximum POH [%] for 2015/08/31 (zoomed-in on the Benelux) and 2016/06/24 (zoomed-in on Switzerland), respectively. It is clear that the regular accumulation map is not a good indicator of convective precipitation since it combines stratiform and convective precipitation. Hence, in order to extract regions with convective activity based on the radar observations one can make use of the convective accumulation or maximum reflectivity plots. Those show similar patterns as to what

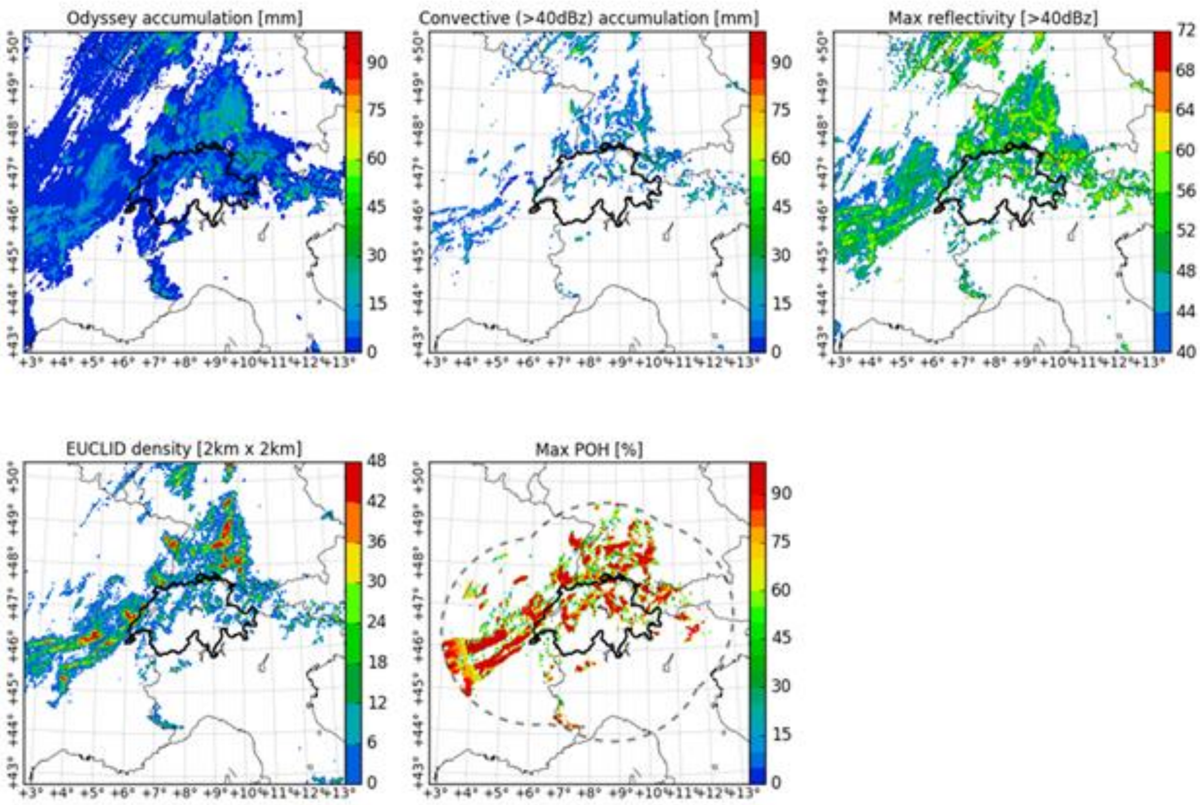

Fig. 4: Top panels depict different types of daily maps as derived from the ODC reflectivity/rainrate data centralized on Switzerland on 2016/06/24. Corresponding maps of the EUCLID lightning density and national POH of MeteoSwiss are plotted in the lower panels.

is observed within the EUCLID network. Additionally, the POH field, with maximum POH exceeding 60%, overlaps closely with the spatial EUCLID density distribution and can be therefore used as an indicator of convective activity. The fact that high POH and lightning activity are closely linked is not surprising, since collisions between hydrometeors drive the electrification processes within the clouds.

On a European scale the differences and similarities become even clearer when comparing the EUCLID density plots with the convective accumulation and maximum reflectivity, as seen in Fig. 5 and 6. While in some areas there is a good overlap amongst the different fields, there are places where EUCLID detects lightning activity but with no clear sign in the radar observations, and vice versa. Hence, the EUCLID observations complement the radar observations in order to distinguish where the convective activity took place.

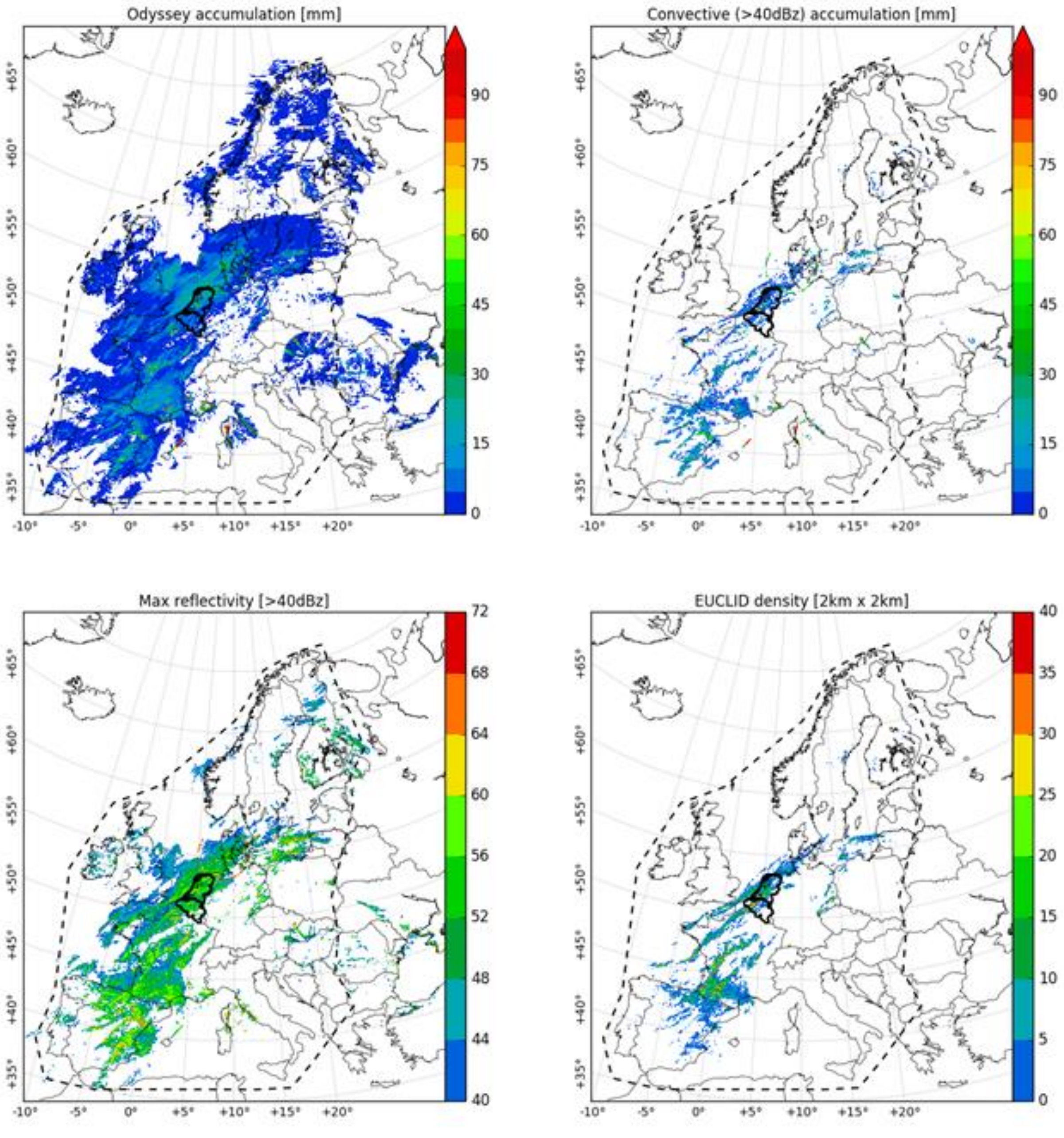

Fig. 5: Different panels depict three types of daily maps as derived from the ODC reflectivity/rainrate data as well as the EUCLID lightning density over Europe on 2015/08/31. EUCLID lightning observations are restricted within the dashed-dotted polygon.

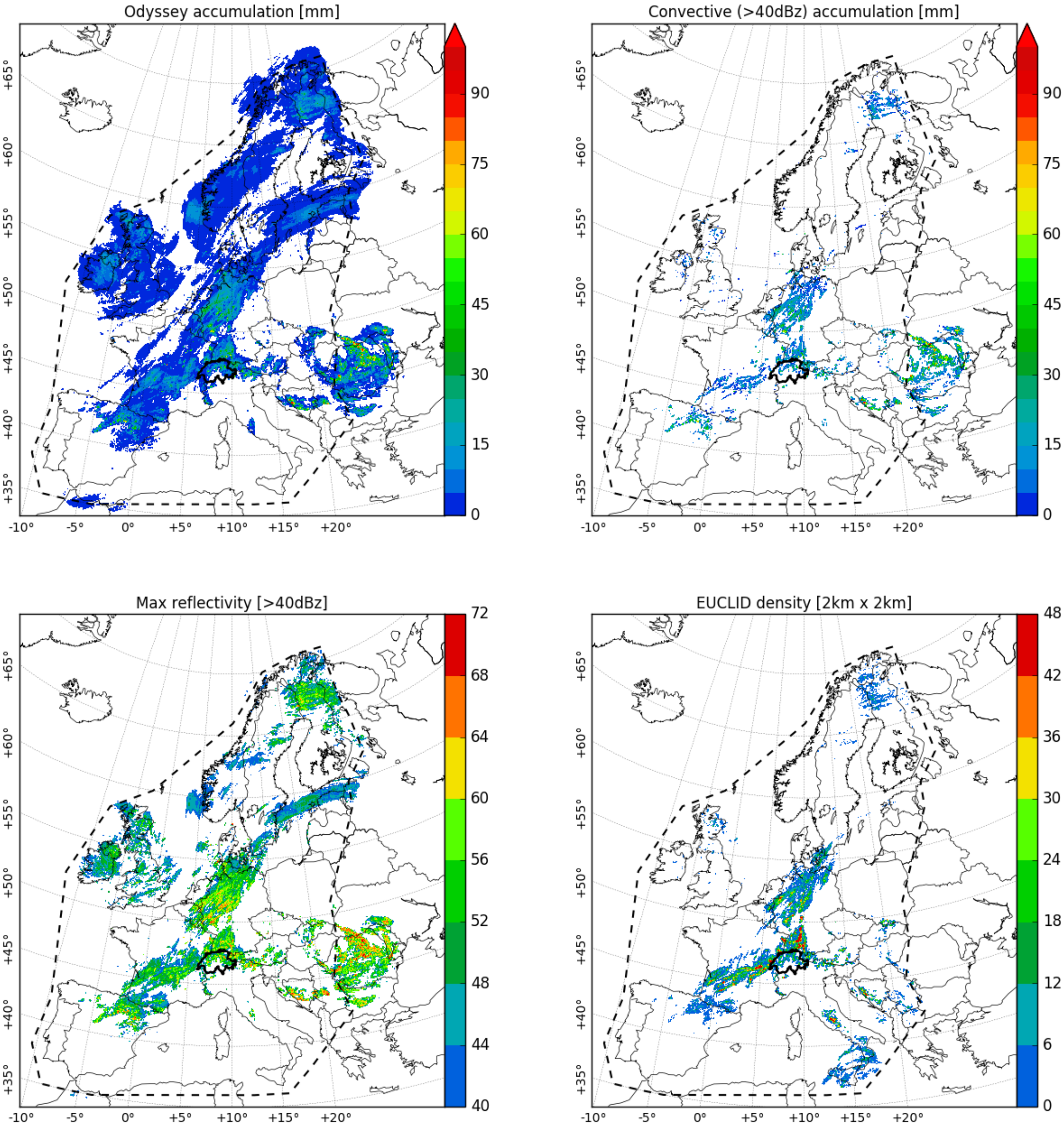

Fig. 6 Different panels depict three types of daily maps as derived from the ODC reflectivity/rainrate data as well as the EUCLID lightning density over Europe on 2016/06/24. EUCLID lightning observations are restricted within the dashed-dotted polygon.

Finally, ODC derived products and EUCLID data are combined to create so-called convective precipitation maps (Fig. 7 and 8). Pixels in grey indicate areas where either the maximum reflectivity (Zmax) is observed to be larger than 40 dBz or where lightning activity has been observed. On top of that two fields are superimposed, i.e. pixels where Zmax exceeds 40dBz (/48dBz) and where lightning is observed are plotted in green (/red). In this way, daily maps are created which can be used to distinguish between different levels of convective activity. While it is highly possible that no lightning was observed, but convective precipitation occurred (grey areas), the green and red areas are an indicator of more severe convective activity that took place

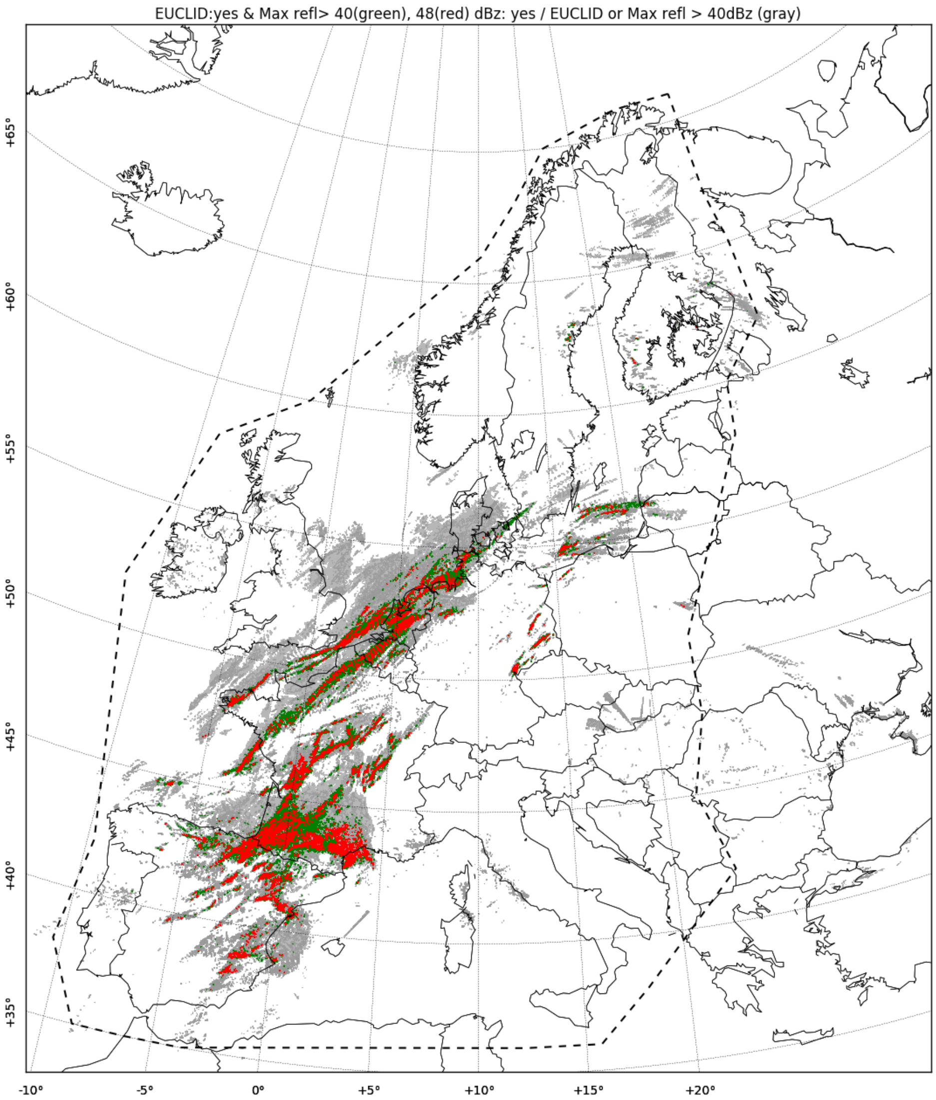

Fig. 7: Mapping of convective precipitation over Europe on 2015/08/31. Areas with lightning activity or max reflectivity larger than 40 dBZ are indicated in grey, whereas regions with lightning activity and max reflectivity larger than 40 and 48 dBZ are plotted in green and red, respectively. Note that EUCLID lightning observations are restricted within the dashed-dotted polygon.

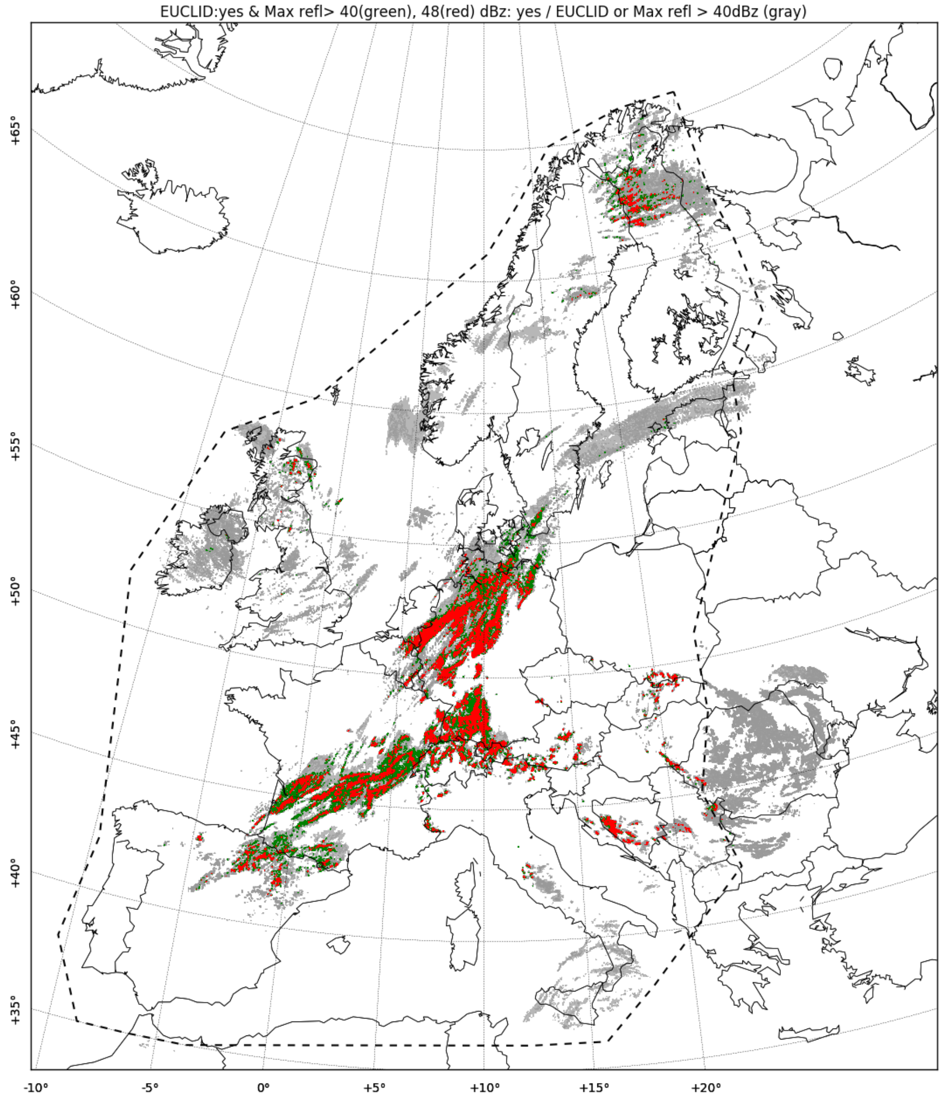

Fig. 8: Mapping of convective precipitation over Europe on 2016/06/24. Areas with lightning activity or max reflectivity larger than 40 dBZ are indicated in grey, whereas regions with lightning activity and max reflectivity larger than 40 and 48 dBZ are plotted in green and red, respectively. Note that EUCLID lightning observations are restricted within the dashed-dotted polygon.

during the day. Maps created in this way, can be used in the future on a daily basis to investigate in more detail where convection took place in Europe.

V. Conclusions and perspectives

In this study, the possibility of using OPERA radar products, hail detection products and EUCLID lightning data is explored in order to produce daily overviews of convective precipitation over Europe. Daily rainfall accumulations, convective rainfall accumulations (including only rainfall with reflectivity larger than 40 dBZ) and maximum reflectivity products have been produced from

OPERA rainfall composites. Daily lightning density products (number of discharges per km^2) have been generated from EUCLID data. These radar-derived and lightning products were generated for a selection of 25 days with substantial convective activity over Europe. For some of these days, national hail detection products from Switzerland, Netherlands and Belgium were collected as well. European hail detection products, as produced by SESAR, were not available for the present study.

Comparisons at national level show similar patterns in convective accumulation, max reflectivity and lightning density. Besides, a very good match is obtained between areas with probability of hail larger than 60 % and areas with lightning activity. Comparisons at European level indicate that radar-derived products and lightning data are complementary. Patterns are similar but differences in spatial extension of convective precipitation are observed. The results indicate that a combination of several products will allow a better mapping of convective activity. Maps combining maximum reflective and lightning information have been produced to distinguish between three levels of probability/severity of convective precipitation. Such maps allow to visualize in a straight-forward manner the convective precipitation over Europe.

Further improvement can be expected from a better identification of convective versus stratiform precipitation based on radar data only. Such improvement can be obtained by analyzing the three dimensional spatial texture of the radar reflectivity field. This can be performed on volume data from single radars or can be based on 3D European radar composites. Additional hail information on a European scale would improve the estimation of the severity of convective precipitation. We conclude that the combination of lightning observations and radar-derived convective precipitation and hail products has the potential to produce a reliable mapping of the presence and severity of convective precipitation over Europe.

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