Present status and preliminary results of the Belgian lightning detection network

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I. INTRODUCTION

In this paper, we present some results of a study of the lightning detection network of the Royal Meteorological Institute of Belgium (RMI). At present, two different processors perform calculations in parallel to retrieve the location of the discharge signals. These processors differ from each other in the way it determines in the low-frequency (LF) band of the spectrum the position of the return stroke. Hence, to quantify this difference, data from May–August 2011 are analysed. In addition, the outcome of both processors are intercompared with the lightning data of the overlapping long-range network ATDnet of the United Kingdom Met Office (UKMO).

II. LIGHTNING DETECTION NETWORK

A. Network setup

The RMI has been operating a SAFIR lightning detection system (Système d'Alèrte Foudre par Interférométrie Radioélectrique) since 1992. The sensors were provided by the former *Dimension* and are of type SAFIR-3000. The SAFIR network originally consisted out of four stations in Dourbes, Oelegem, La Gileppe and Mourcourt. Approximately one year ago, an extra fifth sensor has been added at the RMI site in Ukkel. Each sensor, being GPS synchronized, transmits in real-time the data related to a specific event to the central processor.

From the beginning of this year, RMI shares very-high-frequency (VHF, 110–118 MHz) and LF (300 Hz–3 MHz) data with a Vaisala demo-network around Paris in cooperation with Météorage. This non-operational network provides RMI with raw total lightning data from three LS8000 sensors in Evreux, Compiègne and Renardières, see Fig. 1. A fourth sensor is scheduled to be in operation shortly in Chateaudun.

In the near future, RMI will share its data with the four-sensor KNMI network in the Netherlands (3 SAFIR and 1 LS8000 sensor). Once this connection is established, a large total lightning network, covering an area from the South of Paris up to the North of the Netherlands is in place. This will open vast possibilities in total lightning studies.

B. Data Processing

Two different processors are running in parallel to calculate the lightning positions; one in operational mode, the other is in test phase.

1. *Operational processor*

Within the current operational processor (OP) the localisation of lightning discharges is operated in the VHF band, and uses solely the four sensors of the initial network. During the processes that create the lightning channel, vast amounts of VHF radiation is emitted. An interferometric lightning location retrieval method for VHF signals is used to retrieve after triangulation the location of the sources. In addition, the sensors have a capacitive electrical antenna which detects the high-current LF return stroke and allows discrimination between intracloud (IC) and cloud-to-ground (CG) signals. Once a LF signal is detected, the CG stroke is assigned a location using the position of a time-correlated VHF signal. As such, LF and VHF data are combined to develop location information from preliminary breakdown to ground strokes.

2. *Test phase processor*

Besides the OP, RMI runs the Total Lightning Processor (TLP) of Vaisala, combining VHF interferometry with a LF time-of-arrival (TOA) approach for the localization and characterization of total lightning, using data of 8 sensors (5 RMI sensors + 3 sensors of the Paris demo network). The latter TOA technique uses the relative arrival times of a signal from the sensors to form hyperboloids, from which the intersection is then used as the location of the signal.

The effect on the theoretical location accuracy (LA) using the TOA technique for two different network configurations is plotted in Fig. 1. For each position and each combination of three sensors the area enclosed by the intersecting hyperboles is calculated. The extent of the enclosed region is a measure of the location accuracy (LA) of this particular combination. The sensors are allowed to have a $\pm 1.5\,\mu$s timing error, being a realistic value for our network (Vaisala, private communication). Subsequently, the least LA of all the sensor combinations is taken as the LA for that particular position. It is seen that the 5 km LA area increases with increasing sensors. Due to the sensor positions, roughly along the NE-SW axis, the 5 km LA stretches along the NW-SE axis covering large parts of the United Kingdom and Germany. A LA of $\sim$300 m is found across the area in between the sensors.

III. COMPARISON

A. Method

We compare CG flashes over a region covering Belgium with lat $\in$ [49,52] / lon $\in$ [2,7] in the following way. First, a

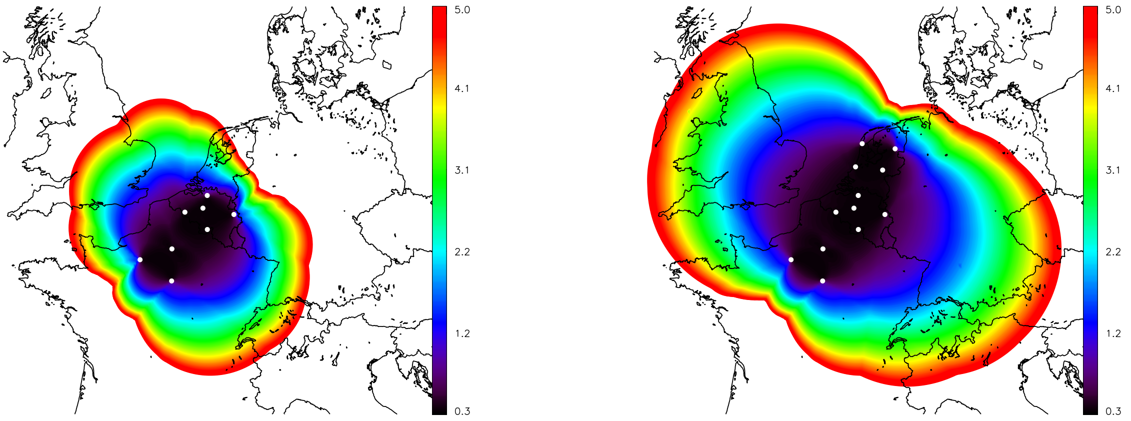

FIG. 1. Theoretical location accuracy [km] based on the TOA technique with a sensor timing error of $\pm 1.5\,\mu$s for the RMI - Paris demo network configuration (*left*) and RMI - Paris demo network - KNMI configuration (*right*). The white dots represent the sensor positions.

common method is used to make CG flashes from individual strokes. Following the methodology in Drüe et al. (2007) and Finke (1999), single point signals can be grouped according to their separation in time and space. It is found that flashes with multiple CG discharges have a temporal separation *dt* less than 1 s and a spatial separation *dr* smaller than 25 km. Hence, signals with $dt > 1$ s and/or $dr > 25$ km originate from a different flash. The location of the flash is then chosen as the position of the last recorded stroke within the flash. Finally, a flash is detected by both processors (or networks) if it meets following criteria: $dt < 1$ s and $dr < 25$ km.

We make use of the probability of detection (POD) concept to evaluate the relative performance of two different datasets by calculating the amount of overlapping events registered by one system assuming the other as the truth, and vice versa. Thus, consider two data sets A and B. Then, POD(A out of B) = N(overlapping flashes)/N(B), with N(B) the total number of events in dataset B.

B. Operational versus test phase processor

Fig. 2 plots the flash density by OP and TLP for the period May–August 2011. The total amount of detected strokes and flashes is presented in Table 1. It is seen that TLP outnumbers OP in stroke detection by a small fraction. However, a larger difference is noticed in the amount of flashes. It should be noted that the rise in flash detection by TLP is not entirely attributed to the enhanced performance when applying the TOA method for localisation, as the amount of sensors used within TLP has increased w.r.t. OP. Besides this, a large(r) fraction of false detections/outliers is found at the moment with the TLP w.r.t. OP, when comparing to ATDnet data.

Fig. 3 plots the POD [%] and corresponding averaged values are listed in Table 1. It is found that TLP recognizes half of the OP flashes, about 10% more then OP identifies out of TLP. This POD is rather low and can be attributed to the difference in the amount of sensors used and in the method to determine the position of a LF signal – corresponding to a CG stroke – between the two processors. In addition, a large spatial difference of ∼8 km is found between the overlapping flashes. This large difference is probably due to the fact that the position of the CG stroke in case of the OP is linked to a corresponding VHF location. Such a VHF signal can be emitted at higher altitude, then is the case for the actual return stroke peak signal. Hence the lightning channel can strike the ground in a different place as one would expect from the VHF signal.

C. RMI versus ATDnet

Similarly as in Sect. III B, we investigate in the following the relative performance of the two RMI processors w.r.t. the long-range ATDnet network of UKMO. The flash density is plotted in Fig. 2 and results are presented in Table 1. One observes an increase of 20% (*40%*) in the amount of flashes w.r.t. TLP (*OP*). It is striking that a long-range network outnumbers the amount of detections of a local network by such a large portion. However, this number can be somewhat reduced by an unknown fraction. As ATDnet does not discriminate between IC or CG, it could be detecting some of the stronger IC signals which emit sufficient VLF radiation and would be categorized by the RMI network as IC (UKMO, pri-

TABLE I. Intercomparison values

	Strokes	Flashes
OP	72736	38257
TLP	76951	51720
ATDnet	92833	65556

POD	Value	POD	Value	Median Deviation
TLP out of OP	49%	OP out of TLP	38%	8.5km
TLP out of ATDnet	39%	ATDnet out of TLP	53%	4.7km
OP out of ATDnet	36%	ATDnet out of OP	62%	9.3km

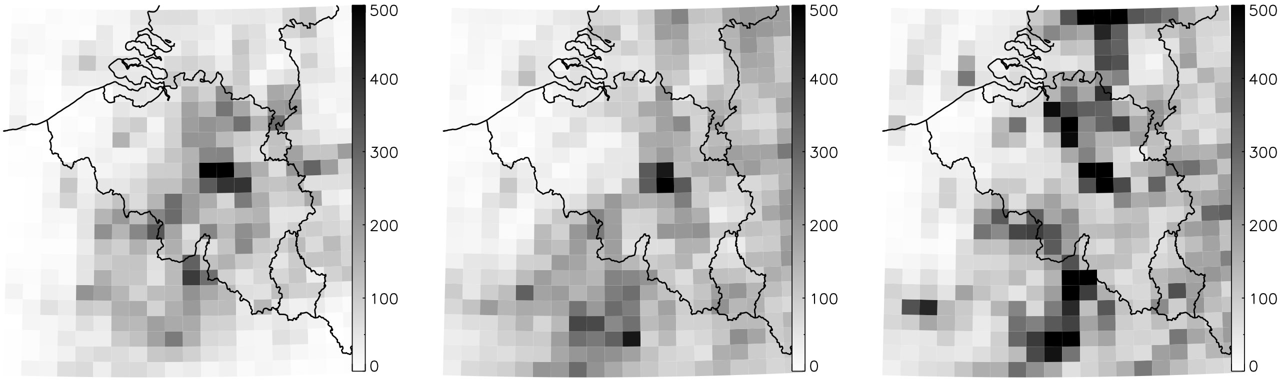

FIG. 2. Number of CG flashes per 0.125°(lat) × 0.25°(lon) detected by the OP (*left*), TLP (*middle*) and ATDnet (*right*) during May–August 2011. Note that all values above 500 are given the same value.

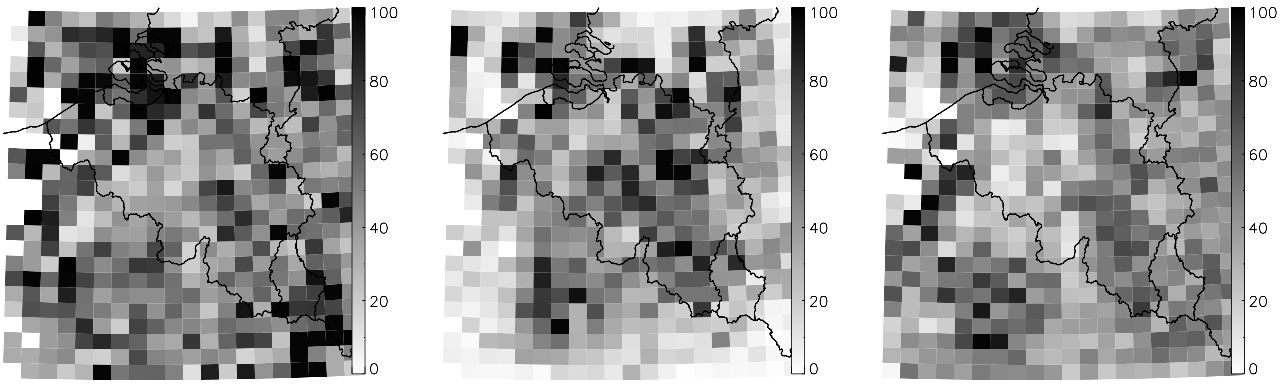

FIG. 3. POD [%] per 0.125°(lat) × 0.25°(lon) for TLP out of OP (*left*), OP out of ATDnet (*middle*) and TLP out of ATDnet (*right*).

vate communication).

Looking at the POD, the RMI processors have a ∼40% overlap with the ATDnet flashes, whereas the ATDnet's POD out of TLP (*OP*) increases with 14% (*26%*). The mean spatial deviation between TLP and ATDnet is 4.7 km, half of the value of OP vs. ATDnet. This value is expected to drop even further as the ATDnet positioning is known to have a slight systematic offset in location (UKMO, private communication). Overall, we find that TLP tends to match slighty better than does OP with ATDnet.

IV. CONCLUSIONS AND OUTLOOK

At the level of CG detections, one notices a quite large difference between the OP and TLP. On the one hand, TLP detects more flashes, albeit with a higher fraction of false detections (not shown in this study). On the other hand, TLP matches closer to ATDnet data. However, both the RMI processors have a lower detection efficiency (DE) compared to ATDnet.

In addition to the connection with the KNMI network, RMI will install in the near future a LS7001 sensor for LF detections in the middle of the network. This is expected to have a significant effect on the total performance of the network; increasing the DE and LA and decreasing the false detection rate. This will be monitored closely in the future.

V. ACKNOWLEDGMENTS

We would like to thank UKMO, and in particular Alec Bennett for making ATDnet data available for this study and for providing useful suggestions. Special thanks go to Laurent Delobbe for fruitful discussions and to Vaisala and Météorage for exchanging sensor data with the RMI network.

VI. REFERENCES

Drüe, C., Hauf, T., Finke, U., Keyn, S., Kreyer, O., 2007: Comparison of a SAFIR lightning detection network in northern Germany to the operational BLIDS network. *Journal of Geophysical Research*, Vol. 112, D18114

Finke, C., 1999: Space-time correlations of lightning distributions, *Mon. Weather Rev.*, 127, 1850–1861