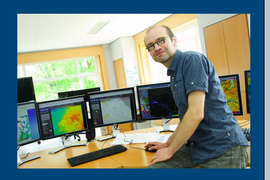
Development and verification of a lightning nowcast in the nowcasting system INCA-BE



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Motivation

At the Royal Meteorological Institute of Belgium (RMI), the current systems are in place and fully operational:

- Nowcasting system INCA-BE provides deterministic nowcasts, including a precipitation nowcast for 4 hours ahead, with a 10 minute time step and a spatial resolution of 1x1 km^2.
- The total lightning location system BELLS provides accurate real-time intracloud and cloud-to-ground lightning observations.

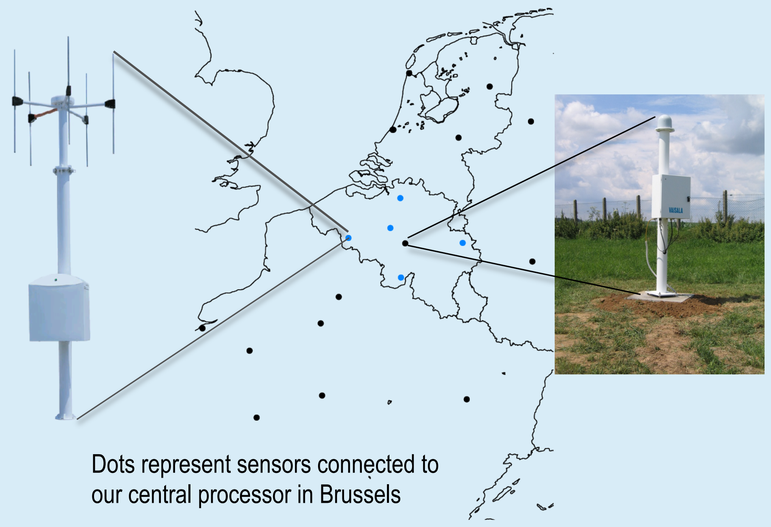
The combination of both tools gives us the opportunity to set up and test a lightning nowcast.

Belgian Lightning Location System (BELLS)

Total lightning network: detection of

- Cloud-to-ground (CG) lightnings with low frequency sensors
- Inter- and intracloud (IC) lightnings with very high frequency sensors

Location by optimal combination of methods: time-of-arrival (TOA), direction finding (DF) and interferometry.



Dots represent sensors connected to our central processor in Brussels

Terminology and method

Definitions

LA(t) — Observed lightning activity at time t
defined as 1 if at least one lightning (CG or IC) is observed in INCA-BE grid box between (t - 10min) and t, 0 elsewhere

LS(t) — Smoothed LA(t)
A Gaussian smoothing with a kernel bandwidth σ = 2 pixels is applied on field LA; isolated lightnings are eliminated, and adjacent lightnings are connected

LF(t+x) — Forecast of LS issued at time t with valid time t+x

adv(x,Y) — Advection of field Y with x minutes
Advection field is taken from INCA-BE precipitation nowcast

LA, LS and LF are binary (yes/no) fields.
LS and LF are to be interpreted as risk zones where lightning can possibly occur.

Forecast Method

Method LAG0

$LF(t+x) = adv(x, LS(t))$

Lightning forecast is based on lightnings in the last 10 minutes

Method LAG1

$LF(t+x) = adv(x, LS(t) + adv(10, LS(t-10)))$

Lightning forecast is based on lightnings in the last 20 minutes

Method LAG2

$LF(t+x) = adv(x, LS(t) + adv(10, LS(t-10)) + adv(20, LS(t-20)))$

Lightning forecast is based on lightnings in the last 30 minutes

Verification

LF is intended to be a prediction of LS, so verification is done against LS, and not against LA. LF and LS are binary (yes/no) fields, so verification is done by the classical categorical scores

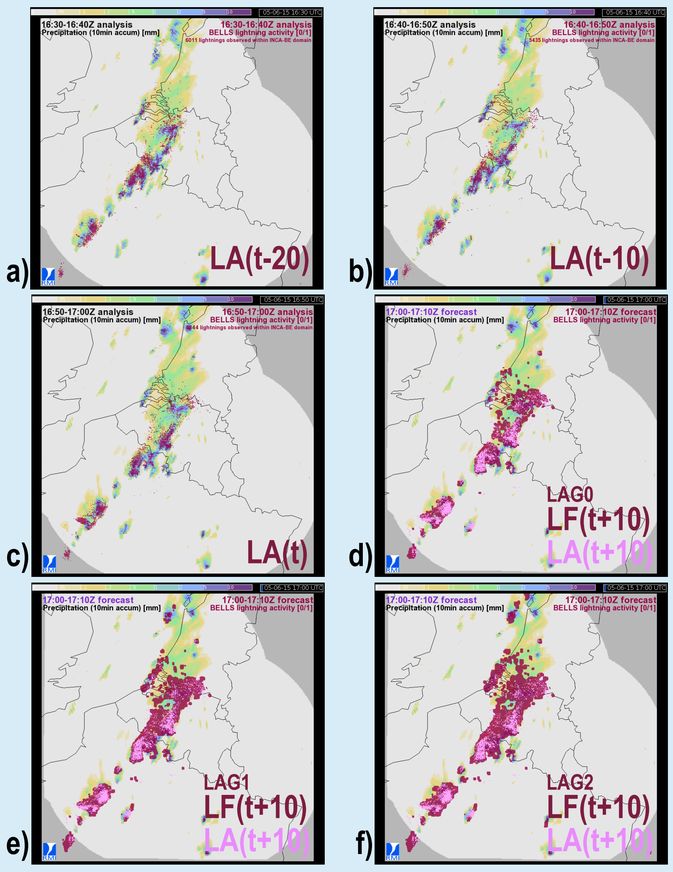
$$POD = \frac{hits}{hits + misses}, FAR = \frac{false\ alarms}{hits + false\ alarms}, CSI = \frac{hits}{hits + misses + false\ alarms}$$

with hit: LF=1 and LS=1
miss: LF=0 and LS=1
false alarm: LF=1 and LS=0

Case study 05-06-2015

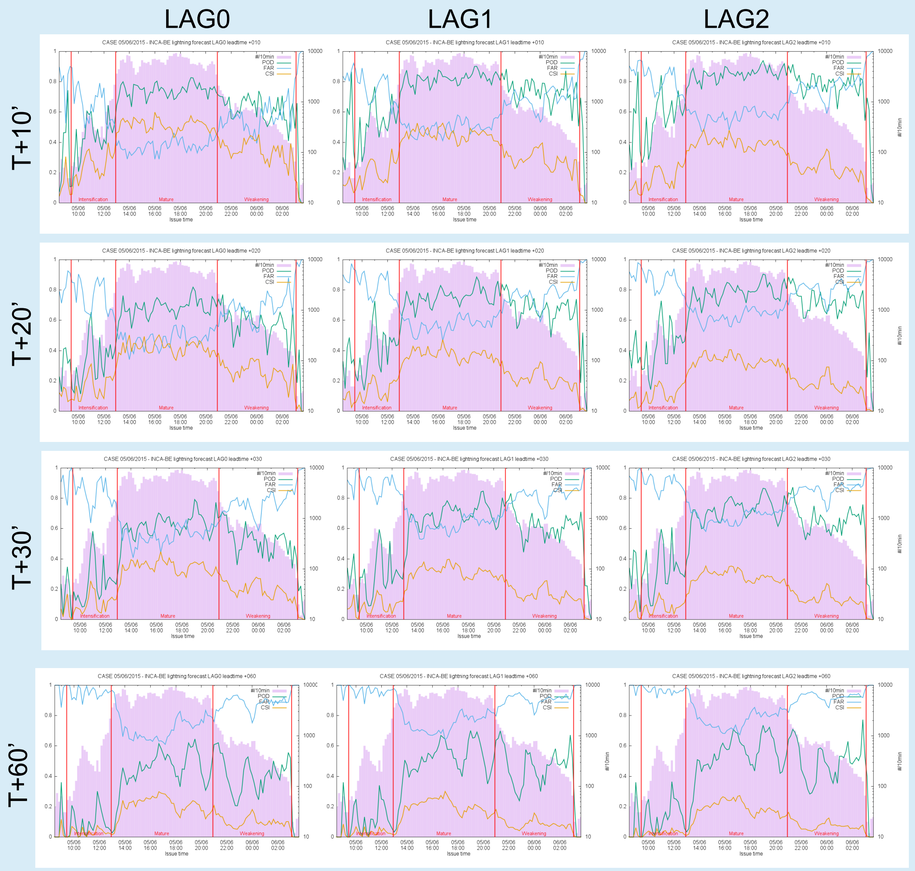
Snapshot at 17:00 UTC

In Figures **a**, **b** and **c**, three consecutive analysis images are given. The colour scale on top is for the precipitation, the observed lightnings (LA) are overplotted in purple (■). In **d**, **e** and **f** this color is used for the lightning forecast (LF), while the observed lightnings are shown in pink (■).



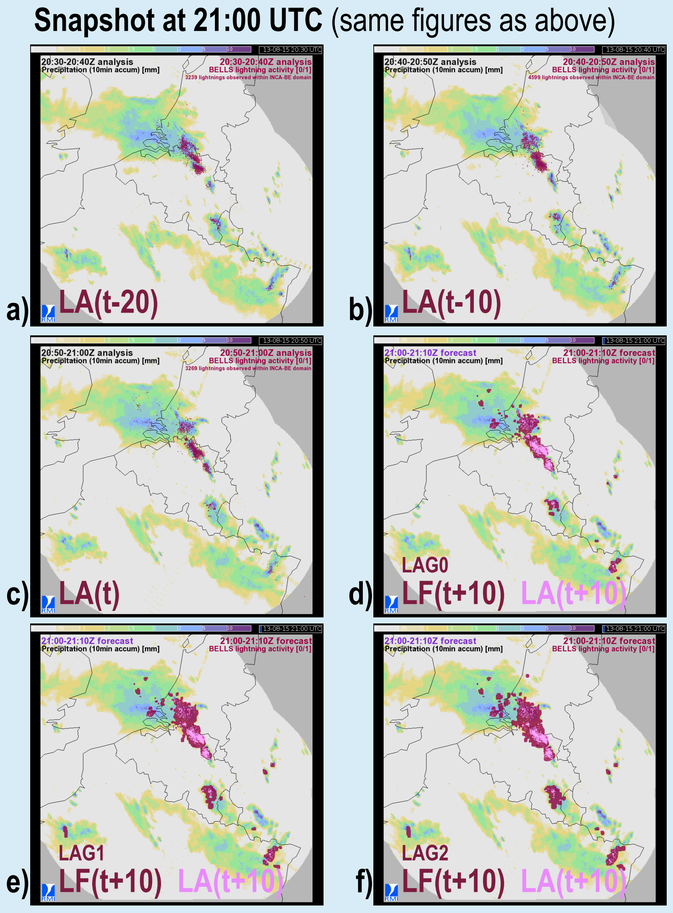
Lightning forecast verification

POD (green line), FAR (blue line) and CSI (beige line) are calculated for each time step during the whole episode, and for the three different methods. In the background, a bar plot with logarithmic scale shows the number of lightnings (CG+IC) registered by BELLS within the INCA-BE domain.

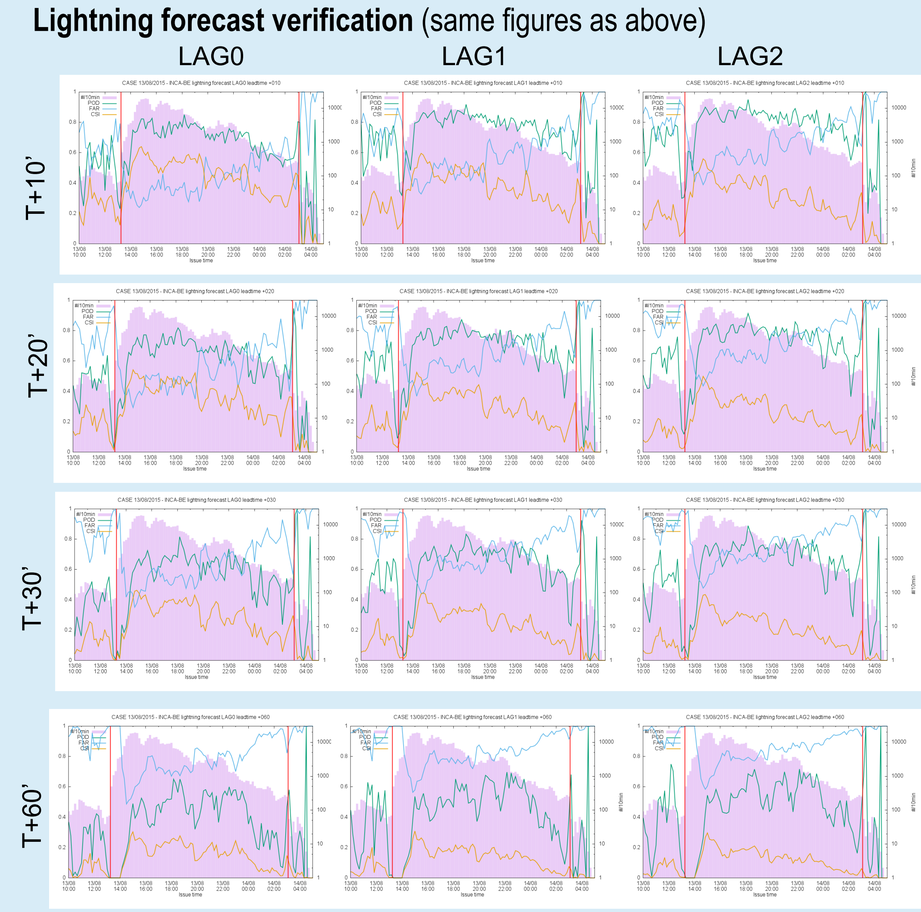


Case study 13-08-2015

Snapshot at 21:00 UTC (same figures as above)

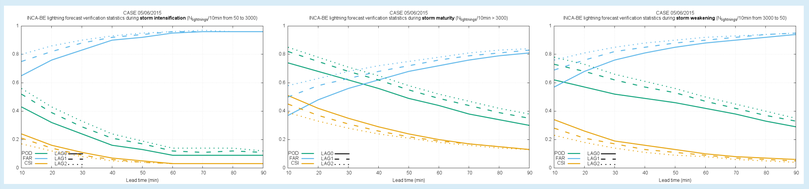


Lightning forecast verification (same figures as above)



Forecast verification summary

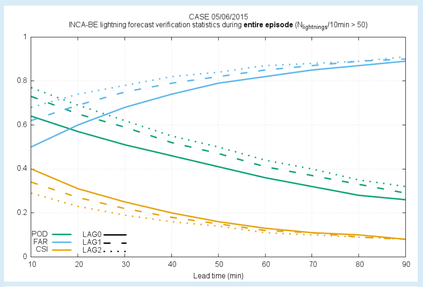
POD, FAR and CSI are shown as a function of lead time for the two cases above. For the 05-06-2015 case, the results are also stratified according to the development stage of the overall lightning activity within the INCA-BE domain (intensification – mature – weakening).

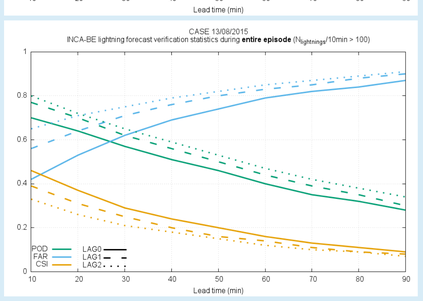


Since there is no prediction of lightning initiation, the verification scores during thunderstorm development are rather low.

A forecast with more "memory" results in a higher detection probability (POD), but unfortunately the number of false alarms is increasing even more. The net effect are CSI scores that are slightly decreasing for more conservative forecasts :
$CSI_{LAG0} > CSI_{LAG1} > CSI_{LAG2}$

Nevertheless, for critical applications (eg. airports), one can image to prefer the LAGged forecast, due to its higher probability of detection.





Conclusions

A lightning nowcast was developed in the framework of the INCA-BE nowcasting system.

A detailed verification study of two recent episodes revealed an overall good performance of the nowcast, except in the early stages of storm development. It was also shown that the Probability of Detection (POD) can be considerably increased when we add more "memory" into the system (lagged approach). Unfortunately, the False Alarm Ratio (FAR) inevitably increases then as well.

The question of which forecast is "better" (a higher POD at the expense of a higher FAR, or a lower FAR at the expense of a lower POD) is a trade-off depending on the end-user and related to his risk tolerance.

The LAG0 forecast is taken as the default in the operational version of INCA-BE, which means that the lightning forecast is derived from the lightning activity of the past 10 minutes.

Contact information

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