RainGain international workshop on "fine-scale rainfall nowcasting"
Ramada Plaza Hotel, Antwerp, 31-03-2014

The operational nowcasting system INCA-BE at the Royal Meteorological Institute of Belgium

dr. Maarten Reyniers
Royal Meteorological Institute of Belgium

INCA-BE one-slide summary

- INCA = Integrated Nowcasting through Comprehensive Analysis
- **Nowcasting system** of several meteorological fields:
  temperature, humidity, wind, cloudiness, precipitation, precipitation type and some derived fields (e.g. wind chill, height of freezing level, visibility)
- **High resolution**: 1 km
- Several of these fields are analysed in a **three-dimensional grid**
- Developed by national meteorological institute of Austria (ZAMG)
- **INCA-BE**: implementation of INCA in Belgium

OVERVIEW

- Why nowcasting?
- INCA, INCA-CE, INCA-BE
- INCA-BE input and output
- INCA-BE precipitation forecast
- Applications
- Future developments

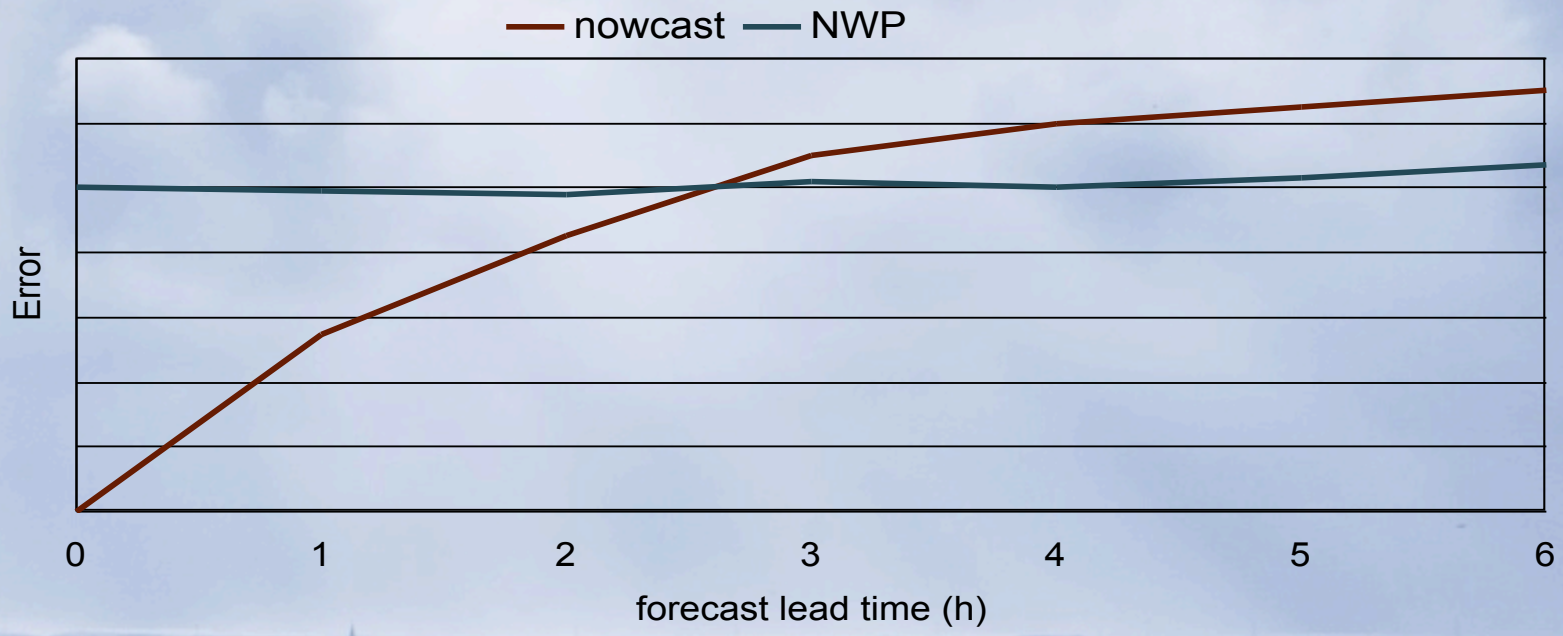
OVERVIEW

- Why nowcasting?
- INCA, INCA-CE, INCA-BE
- INCA-BE input and output
- INCA-BE precipitation forecast
- Applications
- Future developments

Why nowcasting?

Nowcast = real-time forecast for the next couple of hours
with high resolution in space and time
contains some kind of extrapolation of current observations

Numerical models not accurate enough in this time frame, and do not have (yet) the required resolution.



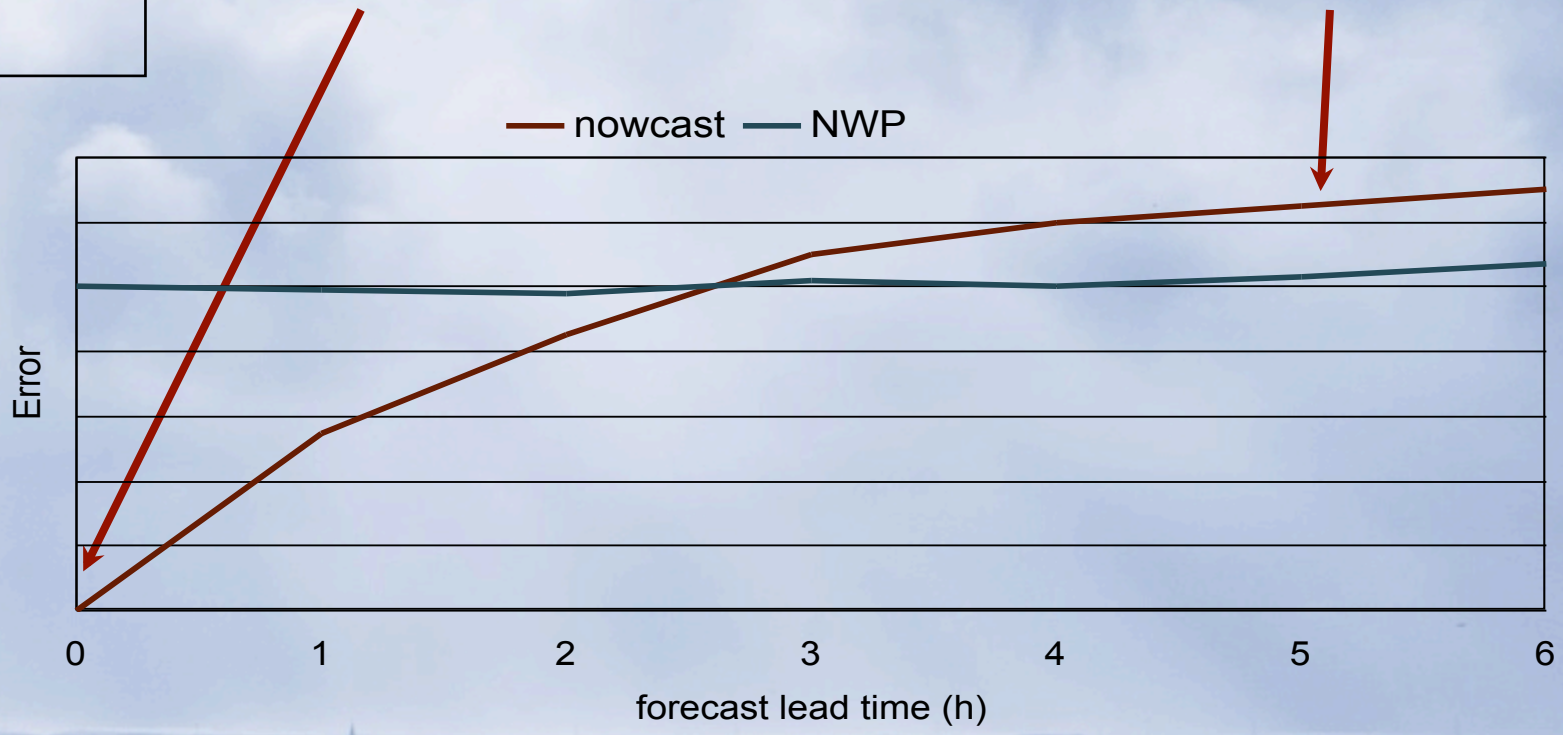
Why nowcasting?

Nowcast =

Radar
AWS
gauges
satellite
...

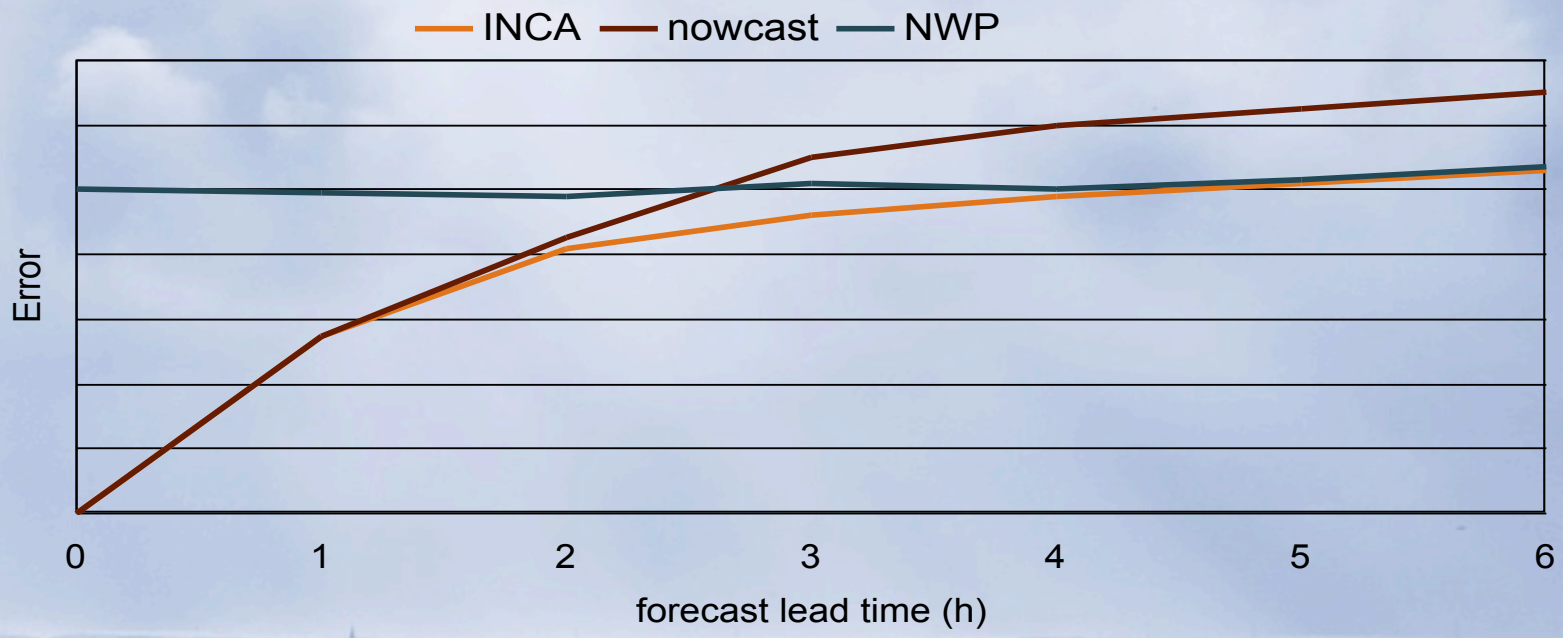
→ nowcast “analysis fields”
accurate representation of
current state of the atmosphere

→ nowcast “forecast fields”
high-resolution extrapolation
for coming hours



Why nowcasting?

Nowcasting system INCA merges both forecasting strategies

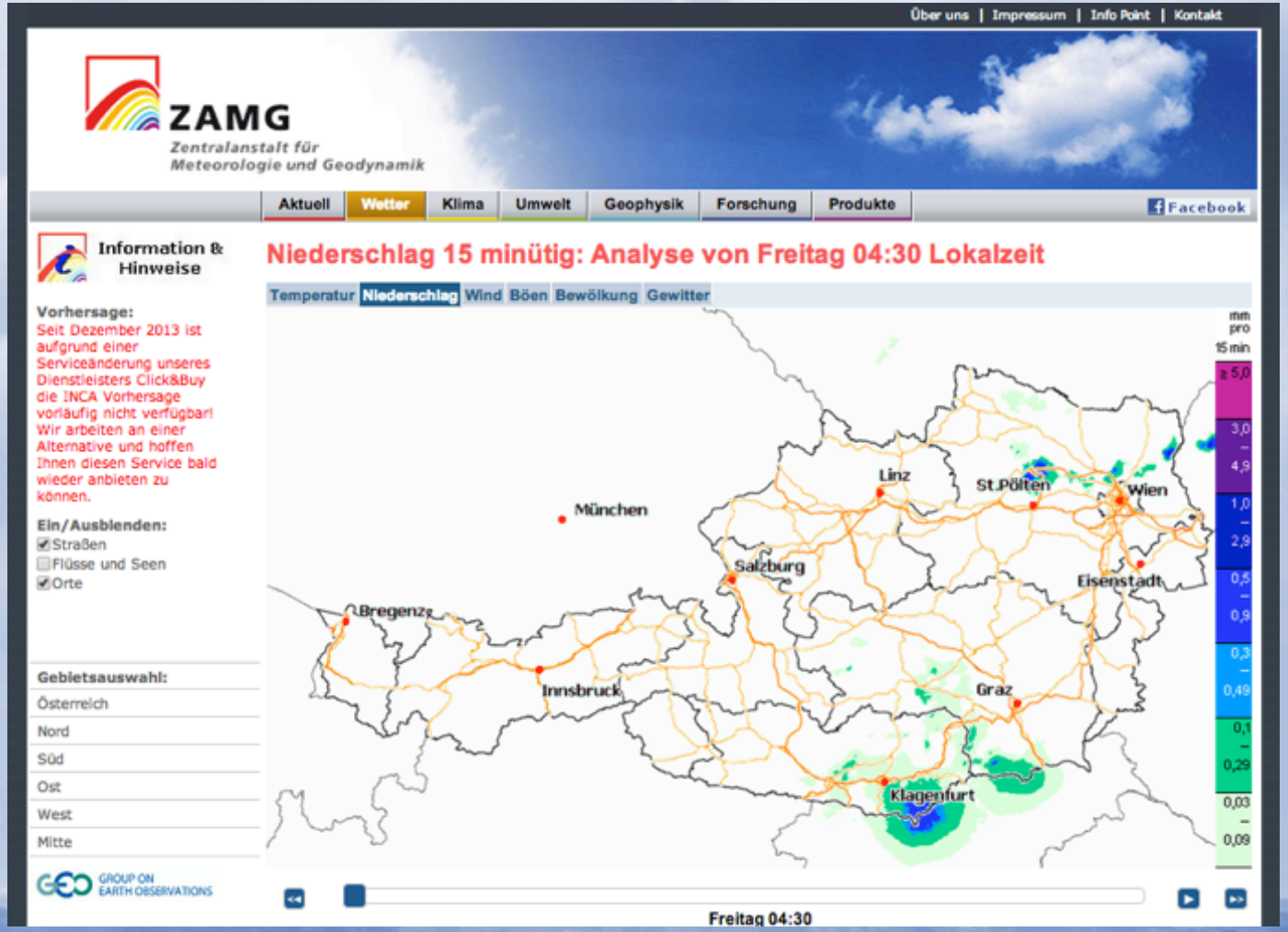


OVERVIEW

- Why nowcasting?
- INCA, INCA-CE, INCA-BE
- INCA-BE input and output
- INCA-BE precipitation forecast
- Applications
- Future developments

INCA at ZAMG

http://www.zamg.ac.at/incaanalyse/



INCA in Europe

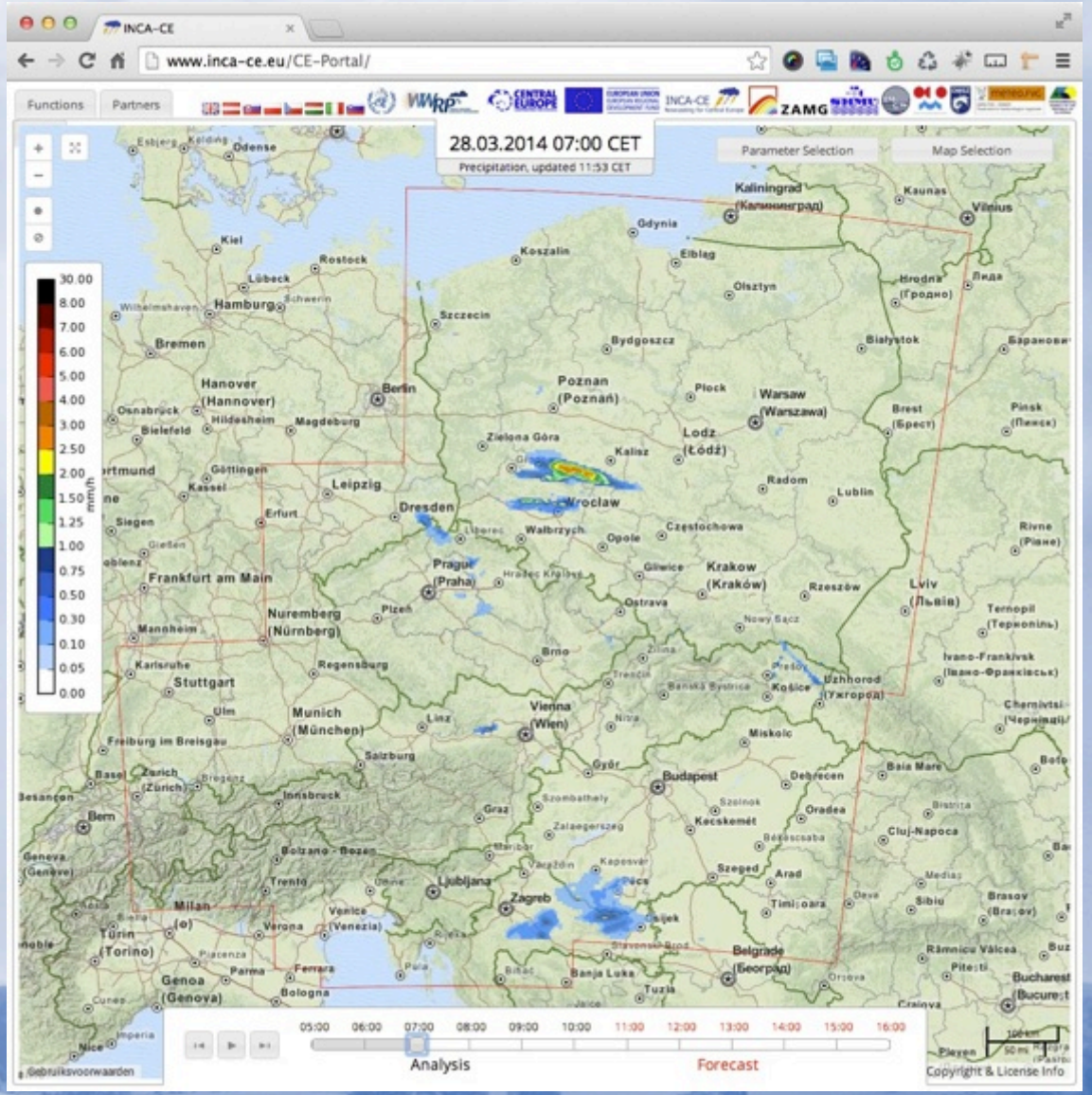
- INCA is growing! More and more countries have adopted (or going to adopt) INCA as their main nowcasting system: Slovakia, Slovenia, Croatia, Poland, Switzerland, Czech Republic, Turkey, Israel and even a province in China

- INCA-CE: ambitious European program to collaborate on improved nowcasting for Central Europe (May 2010 – Sept. 2013)

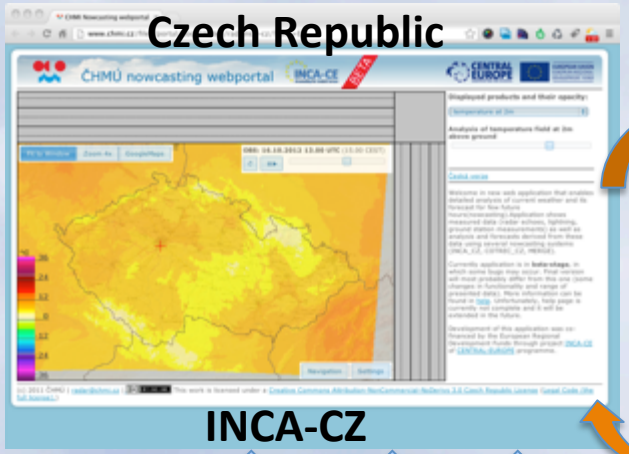
INCA-CE

INCA for central Europe http://www.inca-ce.eu/CE-Portal

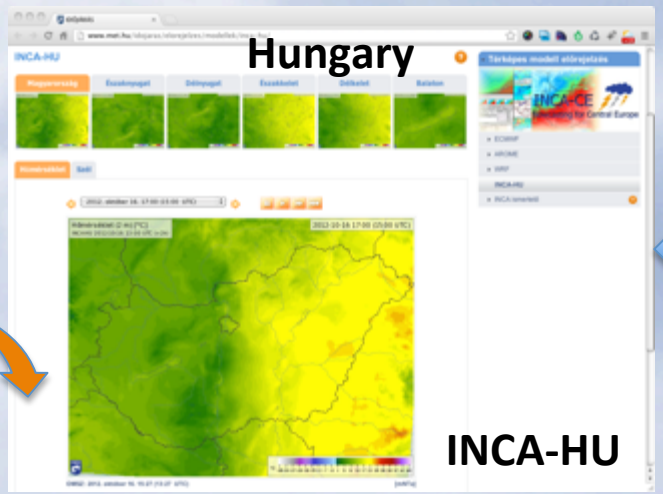
- 4 km resolution
- 6h forecast for
  2m temperature,
  10m wind,
  10m gusts,
  precipitation



INCA-CE project



Exchange of knowledge and data



Hydrological service

Road management

Civil protection

"Pilot implementation"

"Pilot implementation"

Civil protection
Hydrological service
Road management

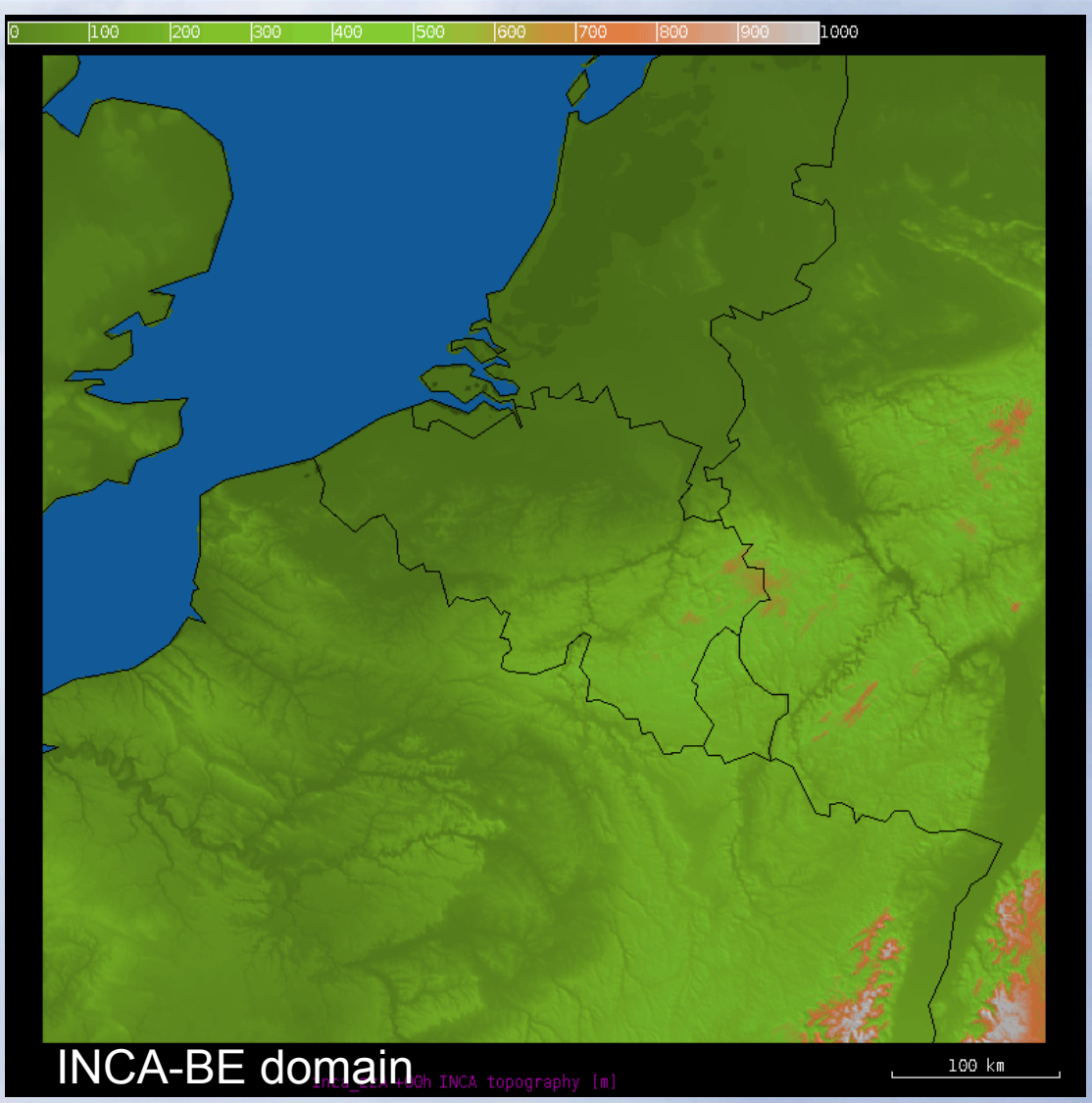
Civil protection
Hydrological service
Road management

INCA-BE

INCA-**BE** is the local implementation of INCA in Belgium

INCA-BE domain

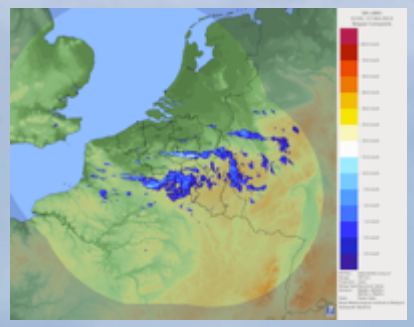
600x590 km, 1km resolution



OVERVIEW

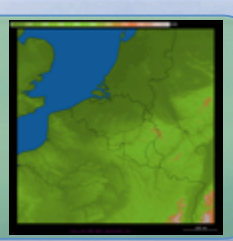
- Why nowcasting?
- INCA, INCA-CE, INCA-BE
- INCA-BE input and output
- INCA-BE precipitation forecast
- Applications
- Future developments

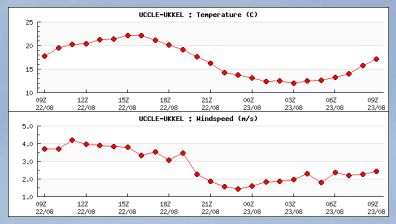
INCA-BE input



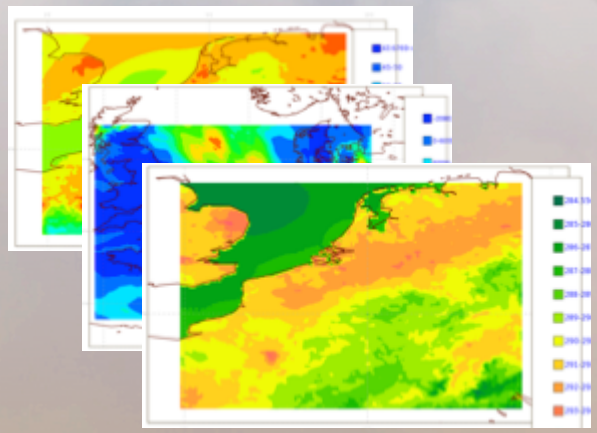
Radar
(Wideumont, Zaventem, Avesnois, Jabbeke)

High resolution
elevation data
(USGS GTOPO30)



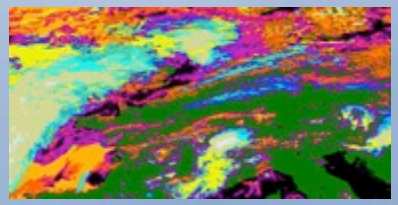


Automatic weather stations, synop
stations and regional gauge networks



NWP (ALARO-4km) – 6h update

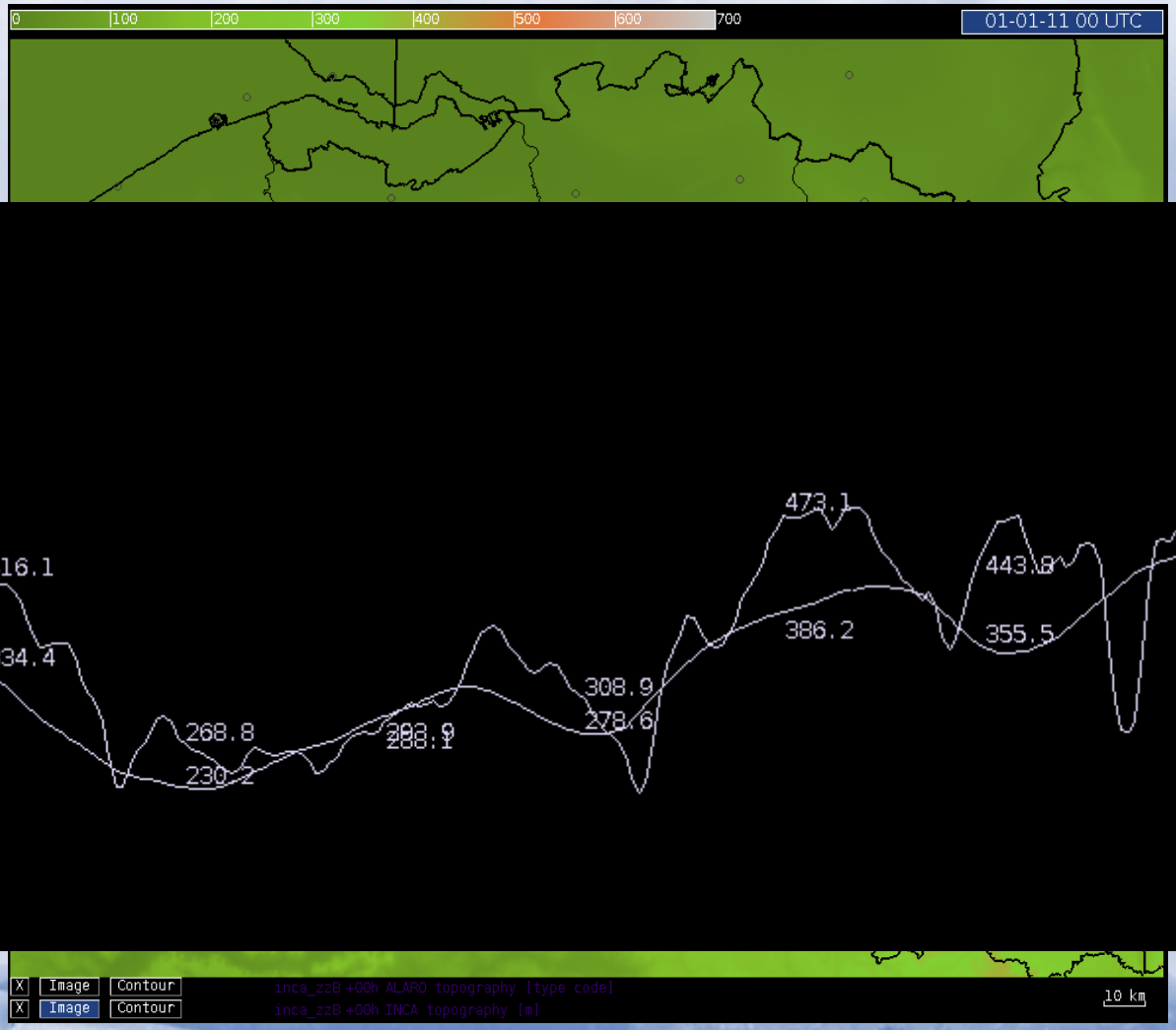
INCA-BE



Satellite data (MSG RSS - SAFNWC)

INCA-BE topography

- ALARO-4km topography compared to INCA-BE topography



Difference up to 100m!

INCA-BE input

NWP

- **ALARO-0 4km**
  4 runs per day
  hourly output, 36h of forecast
  output available roughly 4h after analysis time

OBSERVATIONS

- **Automatic weather stations and synop stations**
  30 stations Belgium (available within 15 min after hour)
  ~120 synoptic stations in neighbour countries within INCA-BE domain
  most of them available after ~20min
- Precipitation (10min time step)
  - **Radar** composite Wideumont + Zaventem + Avesnois + Jabbeke
  - **Rain gauges**
    - our own stations (available every hour)
    - regional hydrological services VMM and Sethy (real-time)
- **Satellite (**10min time step)
  Cloud-type product of **SAFNWC** from **RSS** (real-time)

INCA-BE output

Output grouped into four categories:

Basic fields: **forecast** up to **+12h**, time step 1h, update every hour

2m temperature, 2m dewpoint, 2m relative humidity, snowfall level, freezing level, 10m wind, wind chill, ground temperature

Precipitation: **forecast** up to **+4h**, timestep 10 min, update every 10 min

Precipitation and precipitation type [rain/mix rain+snow/snow/freezing rain]

Convective fields: only **analysis**, time step 1h, update every hour

CAPE, CIN, LCL, Level of free convection, Lifted Index, Showalter Index, Deep Convection Index, Trigger temperature, Trigger temperature deficit, Equivalent pot. Temperature, Moisture convergence, Flow divergence, Precipitable water

Cloudiness fields: only **analysis**, time step 10 min, update every 10 min

Cloudiness and visibility

Runtime information

Hourly fields: basic and convective

	First run	Second run
T2M, TD2M, RH2M, ZSNOW, ZFREEZ	H+16’	H+43’
WIND10M	H+17’	H+44’
TGR	H+18’	H+46’
WCHILL	H+19’	H+47’
Convective analysis	H+20’	H+48’

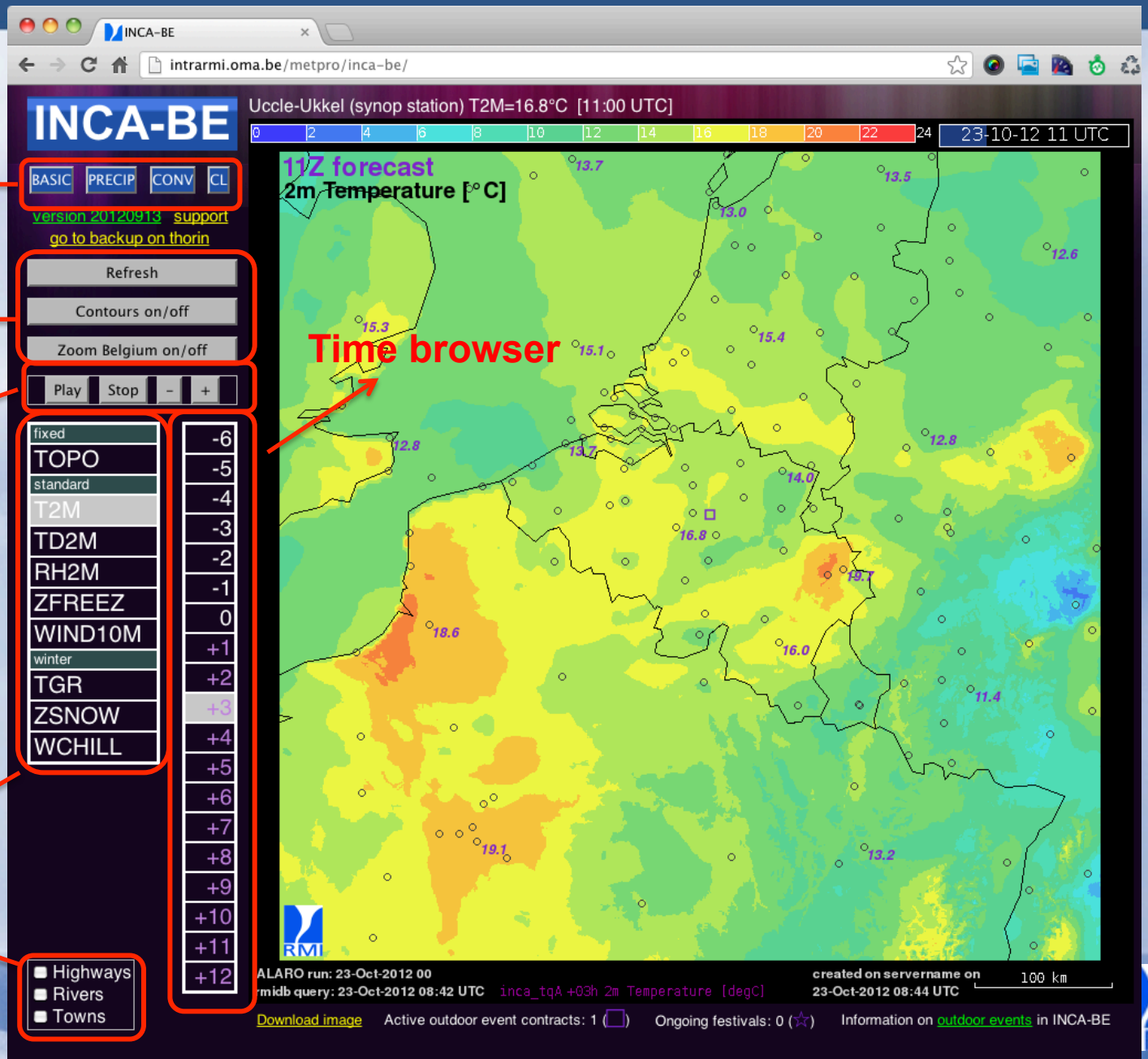
10min fields: precipitation and cloudiness

RR10MIN and PTYP	H+02’,H+12’,H+22’,H+32’,H+42’,H+52’
CLOUD and VIS	H+14’,H+24’,H+34’,H+44’,H+54’
+ rerun last hour	H+04’

Output is available roughly 2 or 3 minutes after launch

➔ **INCA-BE generates 1680 images per hour!**

INCA-BE website on intranet



Sub-page selector

Refresh
Contours
Zoom

Animation

Field browser

Overlays

INCA-BE output

http://intrarmi.oma.be/metpro/inca-be/

Basic fields

forecast up to **12h**

time step 1h

update every hour

2m temperature

2m dewpoint

2m rel. humidity

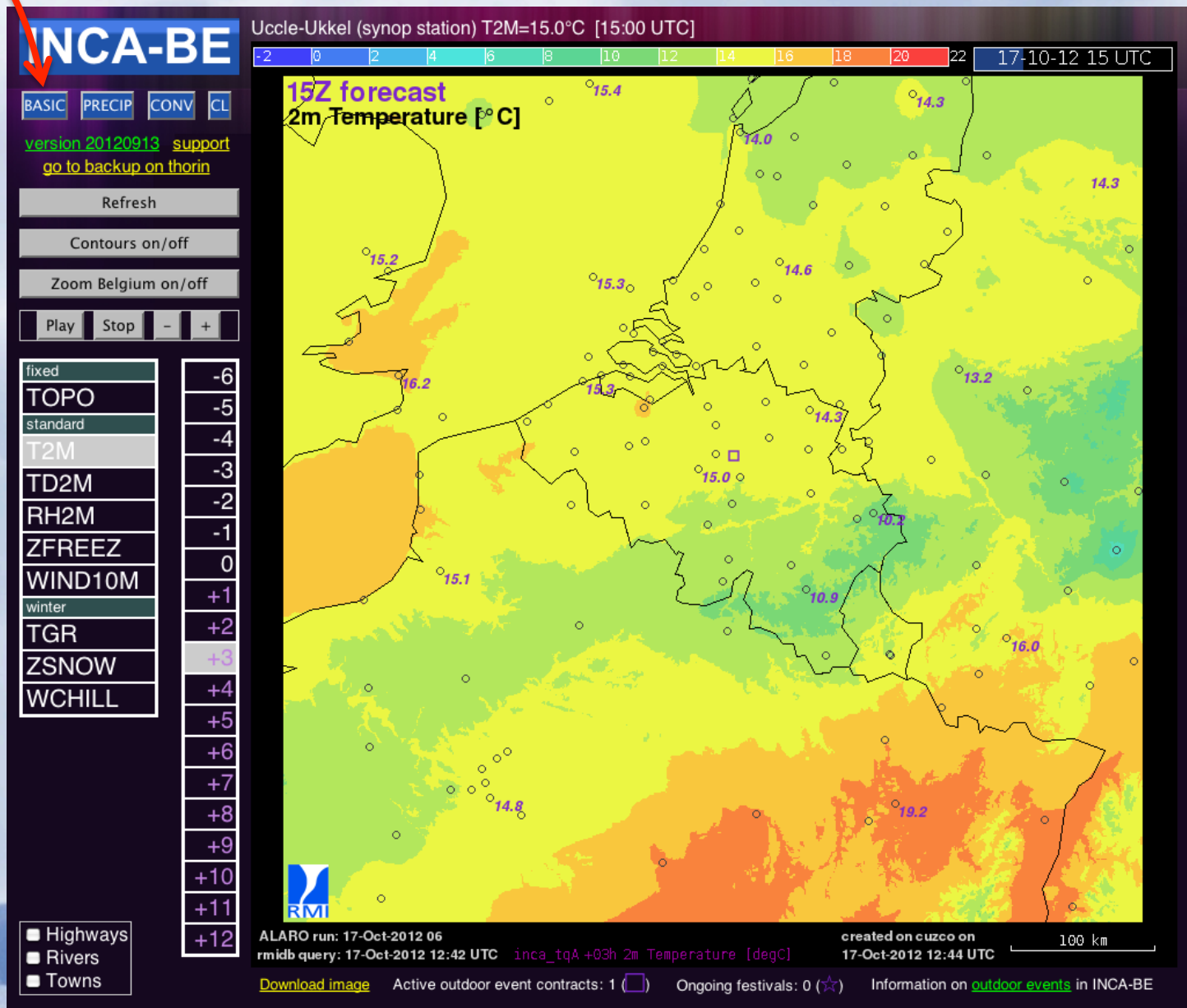
freezing level

10m wind

ground temp.

snowfall level

wind chill

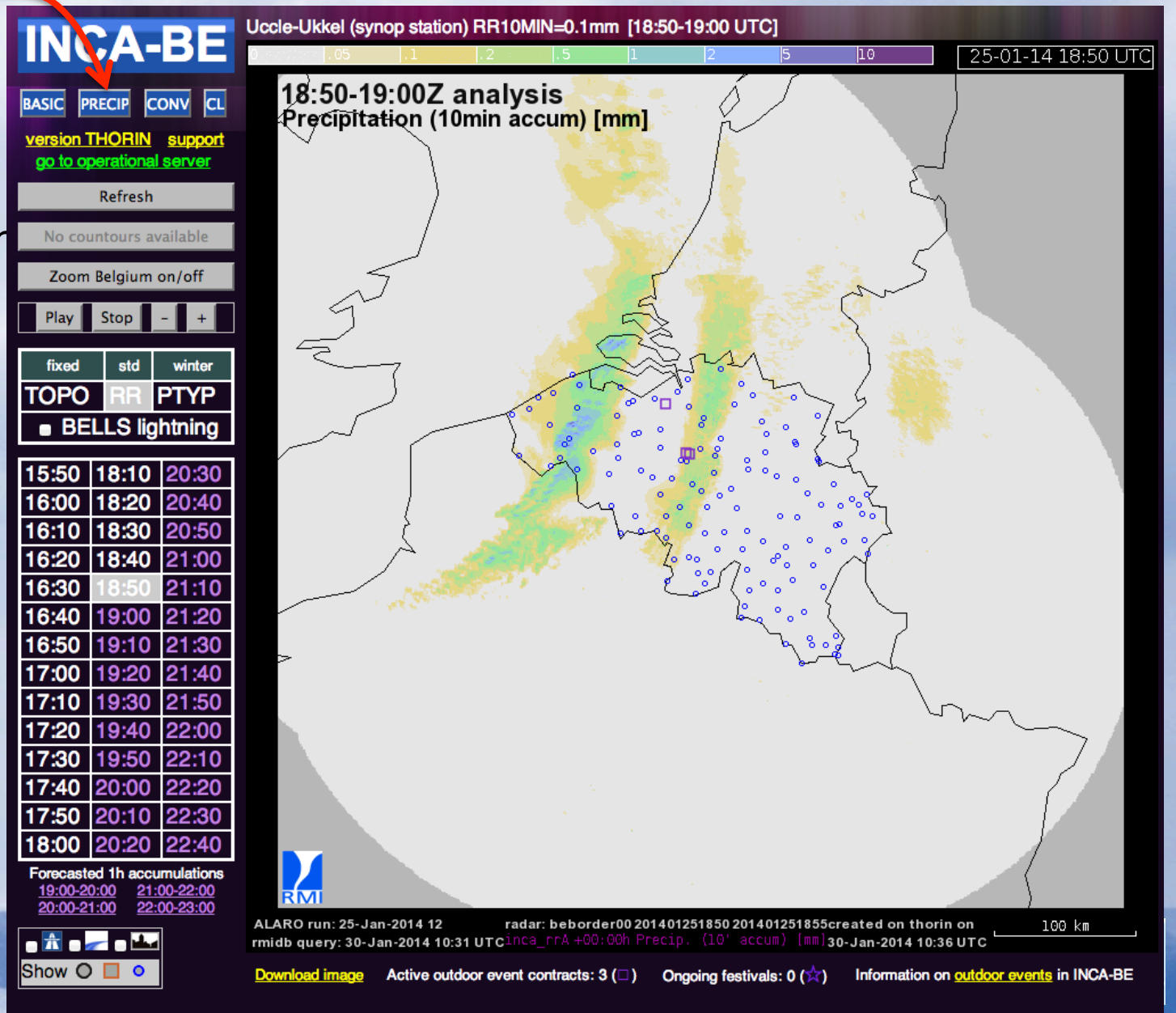


INCA-BE output

Intranet webpage:
http://intrarmi.oma.be/metpro/inca-be/

Precipitation
forecast up to **4h**
time step 10min
update every 10min

Precipitation
(10 min accum)
Precipitation type

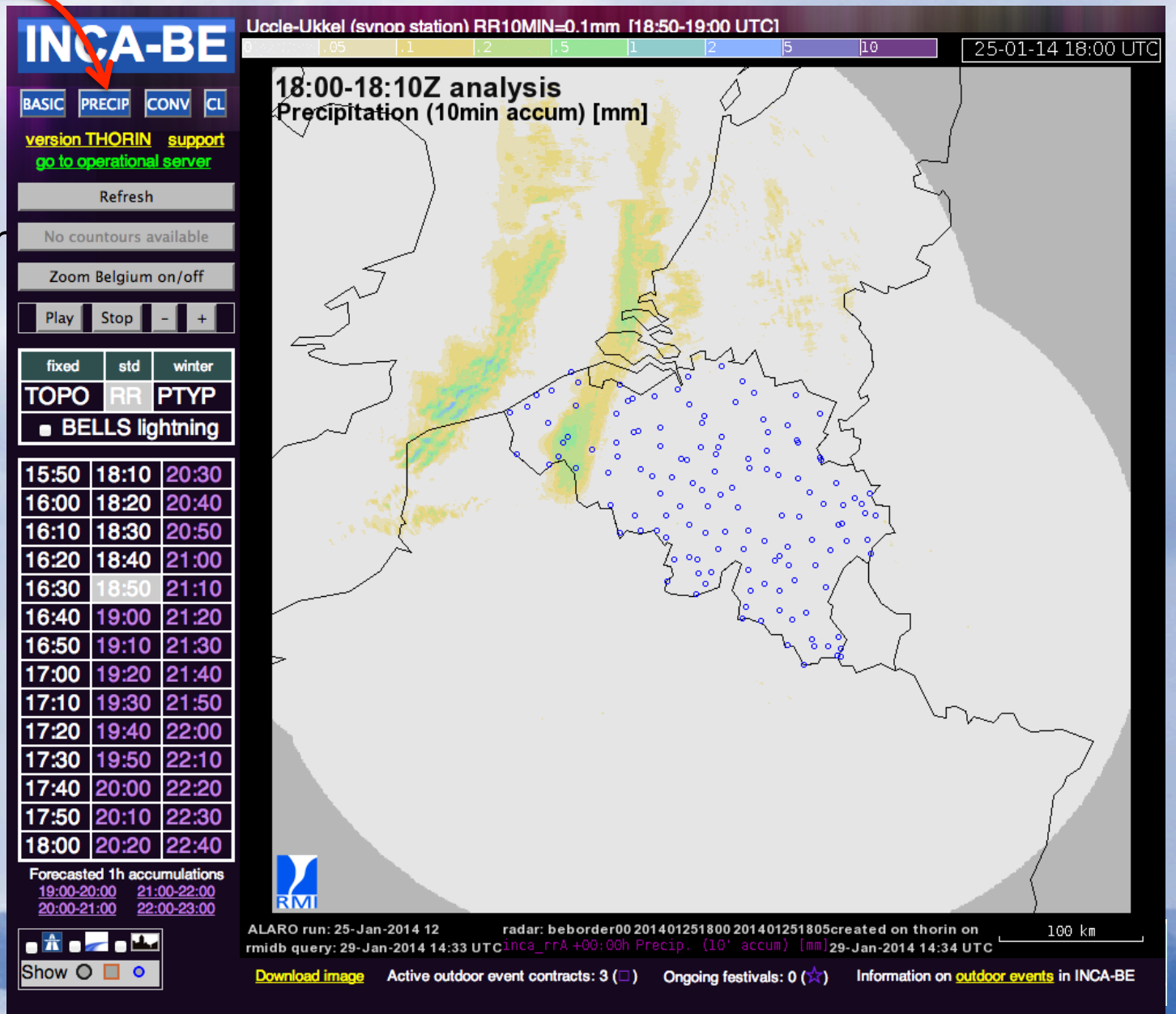


INCA-BE output

Intranet webpage:
http://intrarmi.oma.be/metpro/inca-be/

Precipitation
forecast up to **4h**
time step 10min
update every 10min

Precipitation
(10 min accum)
Precipitation type



INCA-BE output

http://intrarmi.oma.be/metpro/inca-be/

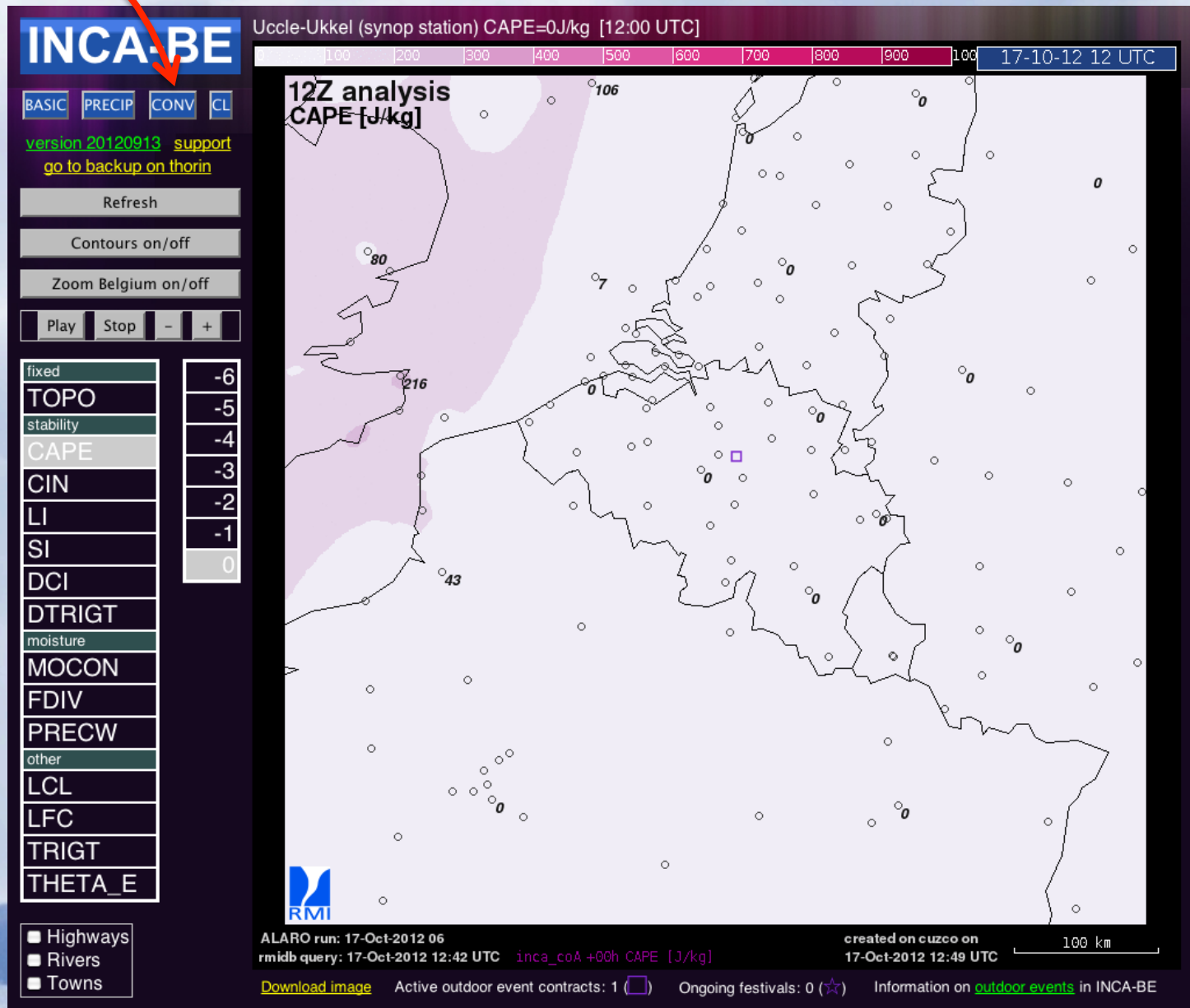
Convective analysis

only **analysis**

time step 1h

update every hour

CAPE, CIN, Lifted Index, Showalter Index, Deep Convection Index, Trigger temperature deficit, Moisture convergence, Flow divergence, Precipitable water, LCL, Level of free convection, Trigger temperature, Equivalent Potential Temperature



INCA-BE output

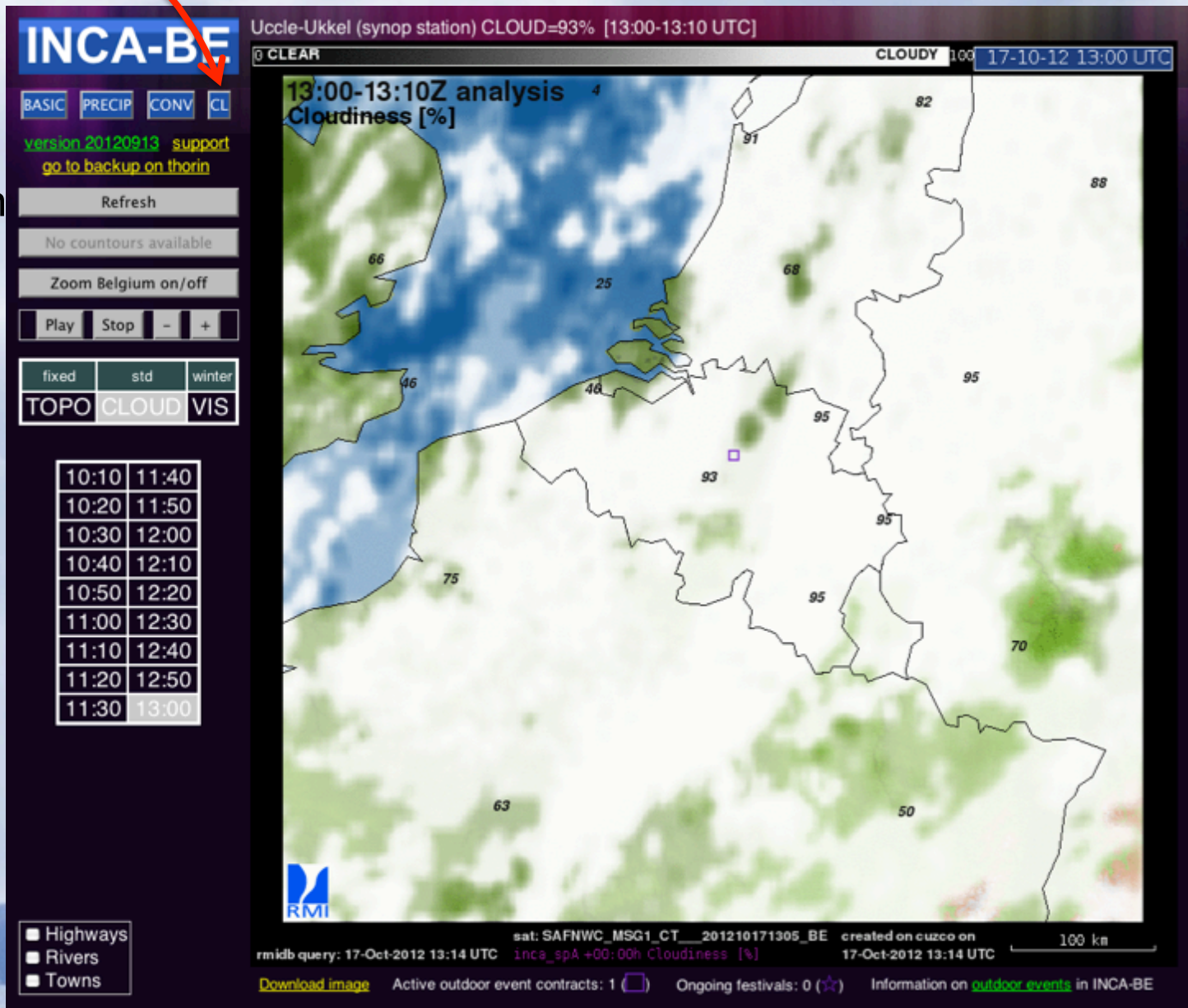
http://intrarmi.oma.be/metpro/inca-be/

Cloudiness fields
only **analysis**
time step 10min
update every 10min

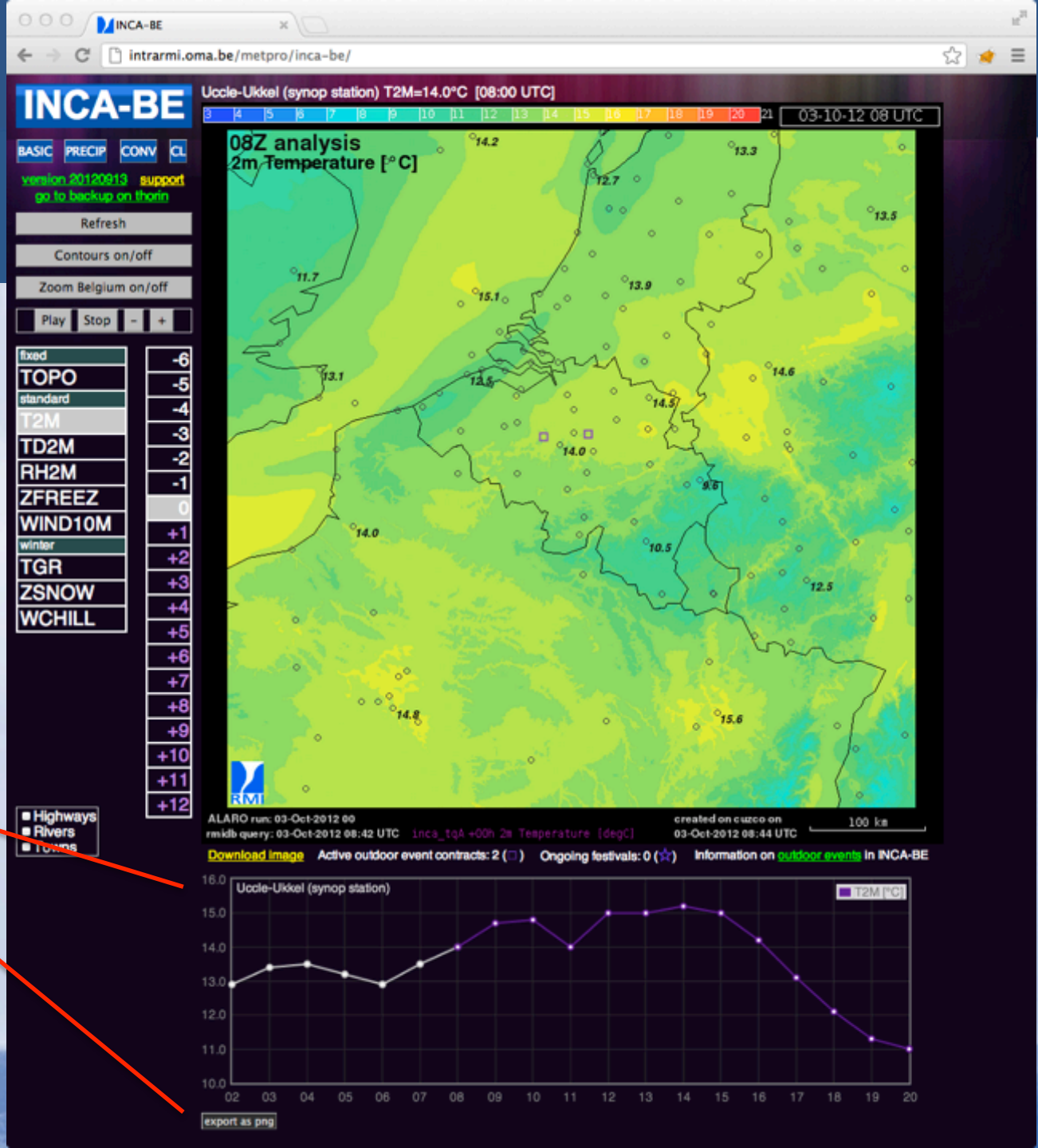
Cloudiness

Visibility (experimental)

Live demo



INCA-BE website on intranet



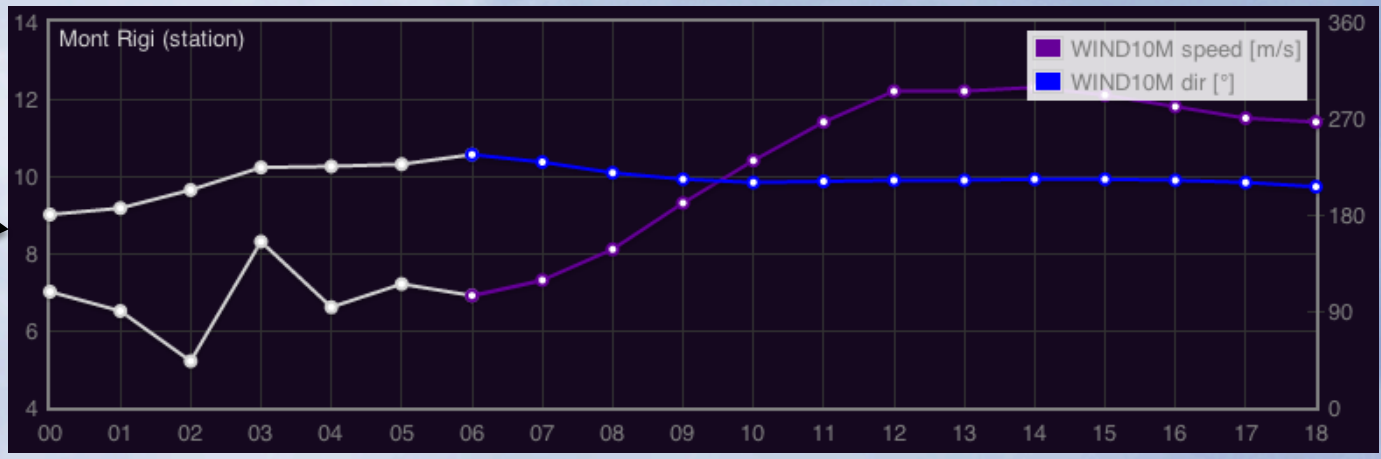
Interactive meteogram

Export meteogram

INCA-BE website on intranet

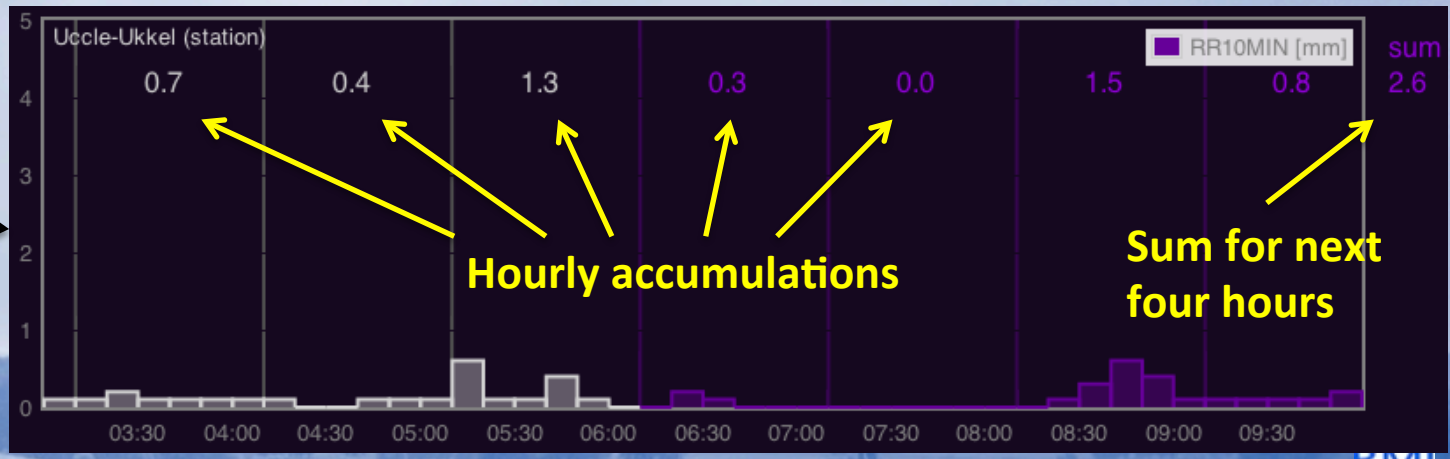
T2M

WIND10M



Examples of meteograms

RR10MIN



INCA-BE info page on intranet

Contents

- Latest news
- How to navigate
- Legend and runtime info
- Test cases
- Notes & known issues
- Changelog
- Documentation
- Further development

INCA-BE

BASIC PRECIP CONV CL

version 20130517 support
go to backup on thorin

INCA-BE is the local implementation of the INCA software from ZAMG adapted for a domain centered around Belgium. INCA-BE runs on an operational machine, but it has not been officially declared operational by the direction, so there is no support by the operators for the moment.

Comments on INCA-BE are very helpful to improve the system: send them to maarten.reyniers@meteo.be.

Separate pages are available for information on the INCA-BE Outdoor Event Forecast, and for the monitoring of the ftp transfer to the external clients currently evaluating INCA-BE.

Latest news

17-May-2013 We are proud to announce two important steps in the implementation of INCA-BE at our institute.

1. The output of INCA-BE is now available in GRIB1 format. Currently GRIB1 files of all the 'basic' and 'precip' fields are generated by the operational server. They are available in real-time in **`/home/inca_op/grb/`** on host **`stratus`** and can be used for the generation of derived products and downstream applications.
2. The GRIB1 files are archived on the EQL NAS of the computer centre and available for all users at the RMI. The archive disk is mounted on **`thorin`** and accessible through **`/mnt/EQL_INCABE/`**. Please contact me for further details if you intend to use these data.

01-Feb-2013 In the coming months, EUMETSAT will carry out some important changes in their satellite management. The Rapid Scanning Service (RSS), on which the **Cloudiness** and **Visibility fields** critically depend, will be suspended until March 5, 2013. From that date Meteosat-9 will gradually take over the RSS, and no more outages will be expected. More information on the planning of this change can be found in the section Notes and known issues.

Furthermore, two new features are added to the **precipitation module** of INCA-BE:

1. One hour accumulation forecast for the next four hours

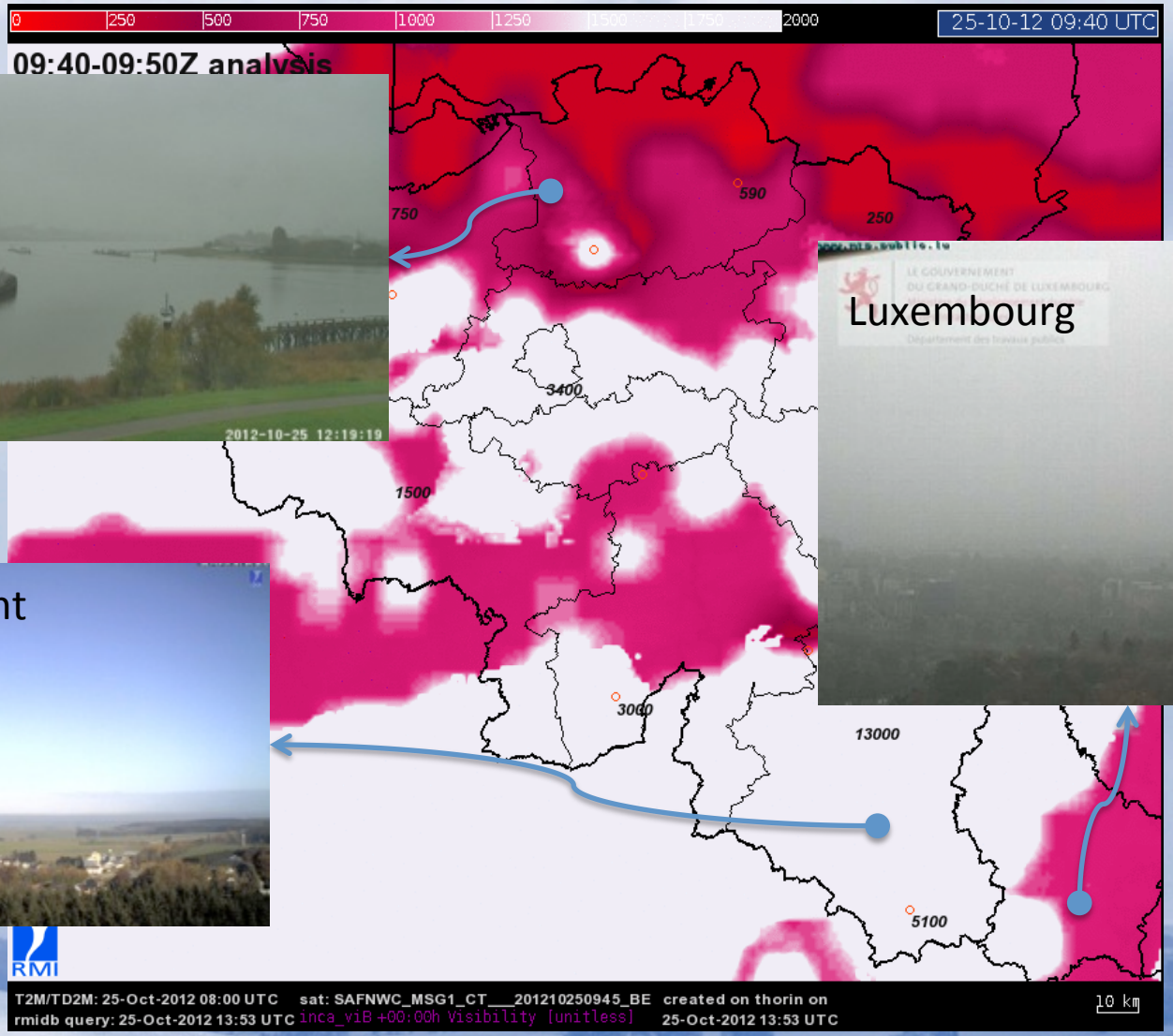
   Upon request of several forecasters, one hour accumulation forecast images are generated on top of the usual 10 min accumulation forecast. These accumulations are updated for every new INCA-BE precipitation run, so every ten minutes. They are available through the links below the time browser on the precipitation page of INCA-BE. Note that the upper limit of the colour scale of these images (20 mm) differs from the one used on the 10 minute images (10 mm).
2. New runtime strategy

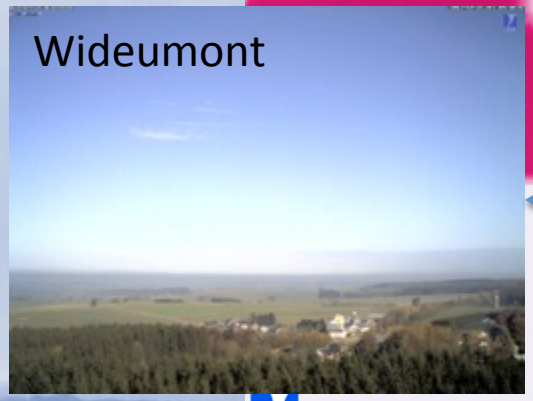
   The simple linear runtime scheme for the precipitation module (launch every 10') has been replaced by a more sophisticated strategy: every ten minutes the 'normal' precipitation module is launched (like before), but in addition the analysis of 10, 20 and 30 minutes ago is recalculated. This strategy has the advantage that the *analysis* is more accurate since the number of available gauges increases with elapsed time.

A last modification is done in Outdoor Event Forecast page: from now on, contracts or events in the past are greyed out in the two tables.

Visibility

Visibility is an **experimental** product with promising results, but with **room for improvement**. Verification difficult.



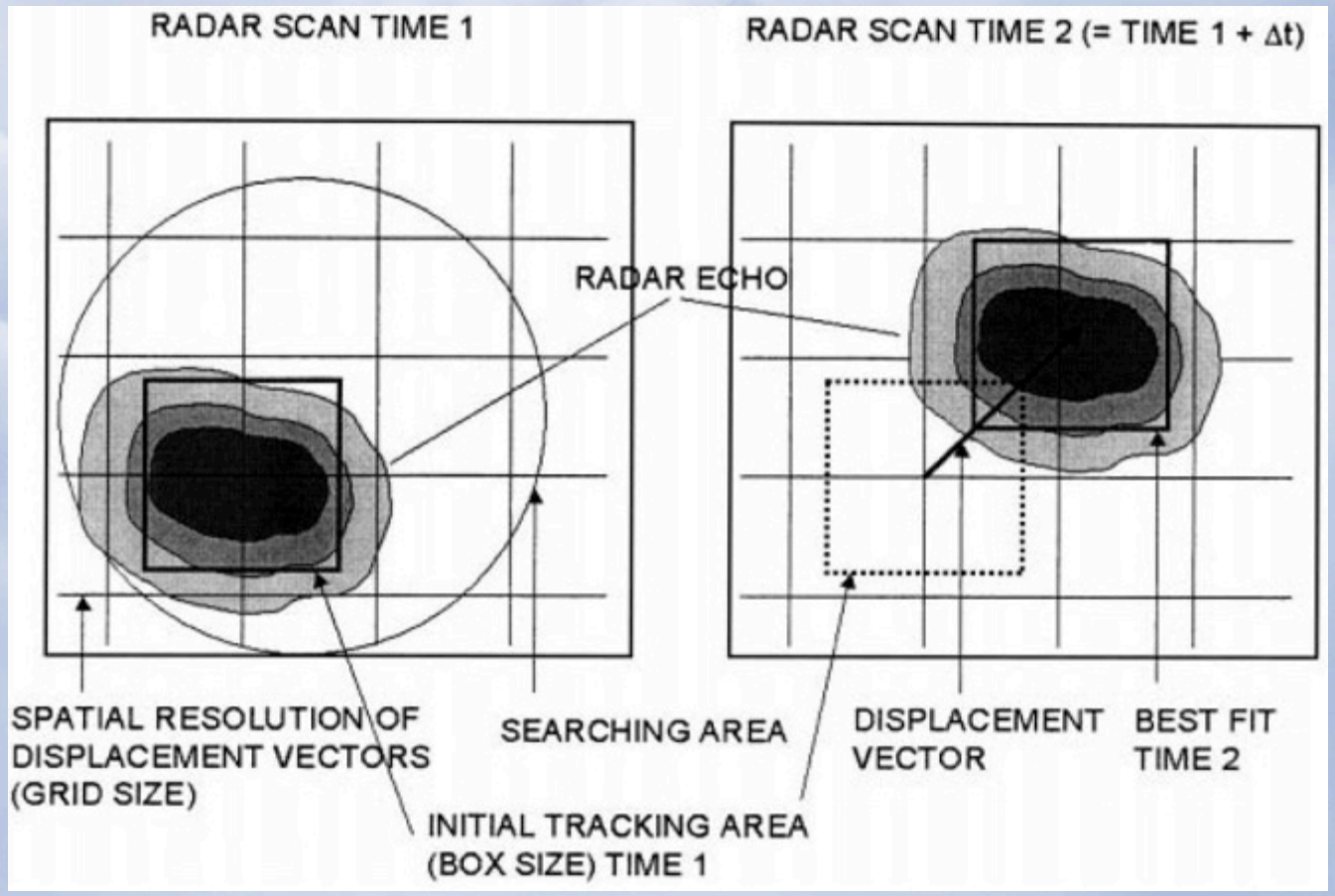


OVERVIEW

- Why nowcasting?
- INCA, INCA-CE, INCA-BE
- INCA-BE input and output
- INCA-BE precipitation forecast
- Applications
- Future developments

INCA-BE precipitation forecast

INCA motion vectors are derived from consecutive INCA precipitation analyses, with an **area tracking** algorithm.

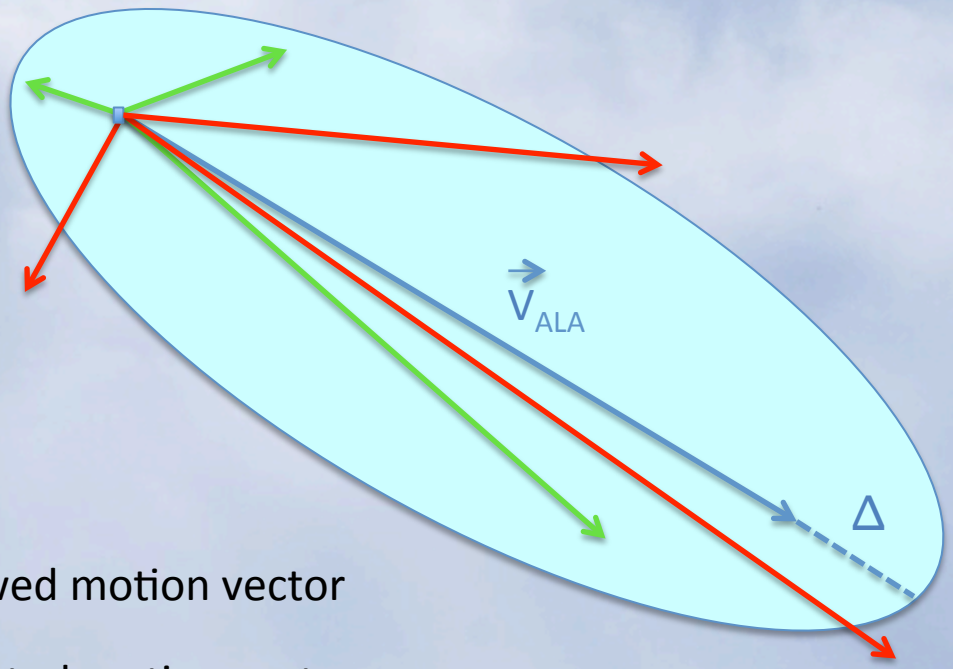


INCA-BE precipitation forecast

INCA motion vectors are filtered by the ALARO wind field at 500 and 700 hPa.

$$\left|\vec{V}_{KORR}\right| + \left|\vec{V}_{KORR} - \vec{V}_{ALA}\right| \leq \left|\vec{V}_{ALA}\right| + 2\Delta$$

5 m/s
(18 km/h)



Allowed motion vector

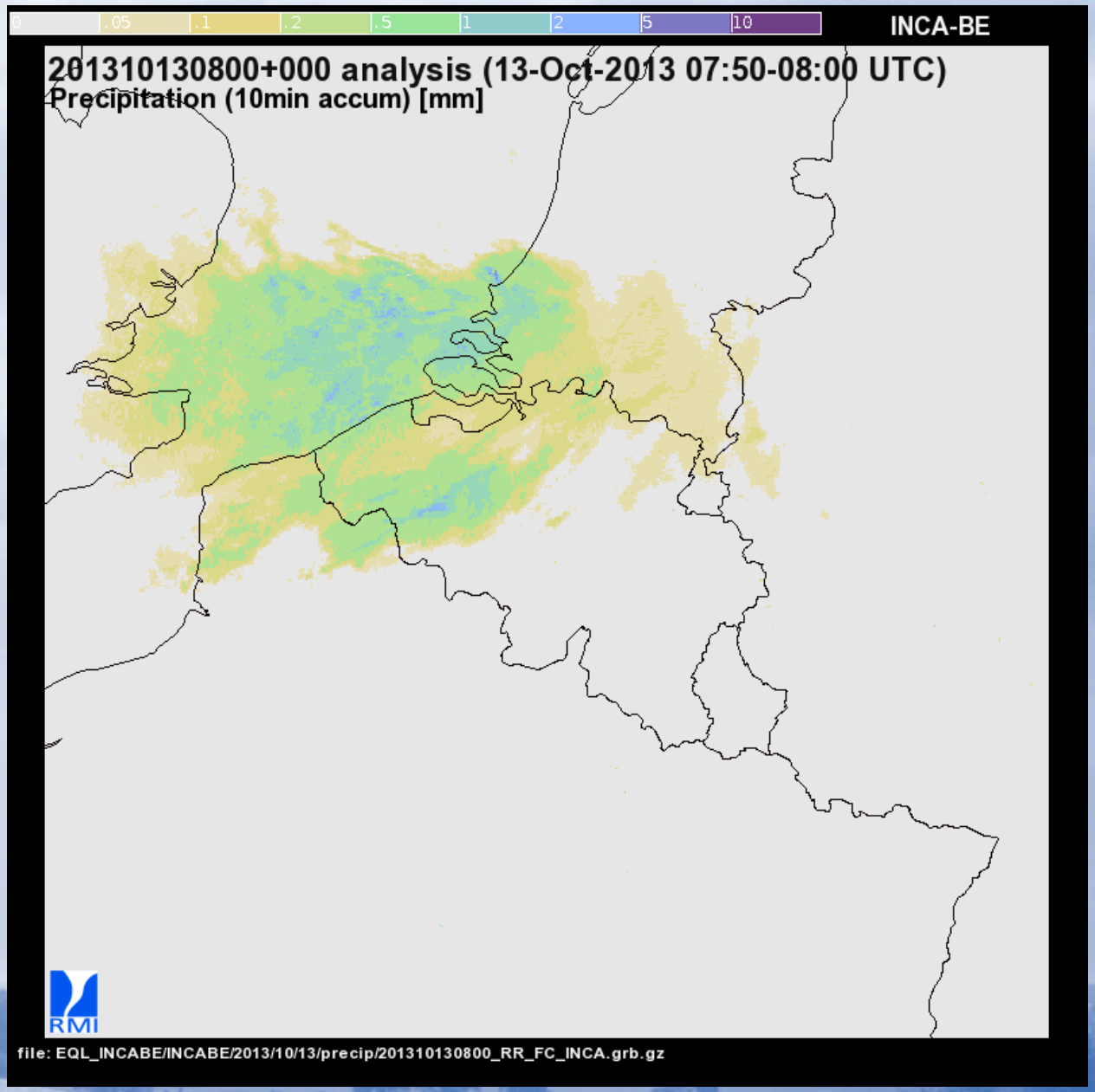
Rejected motion vector

INCA-BE precipitation forecast

0h-2h: pure translational forecast (with motion vectors as explained above)

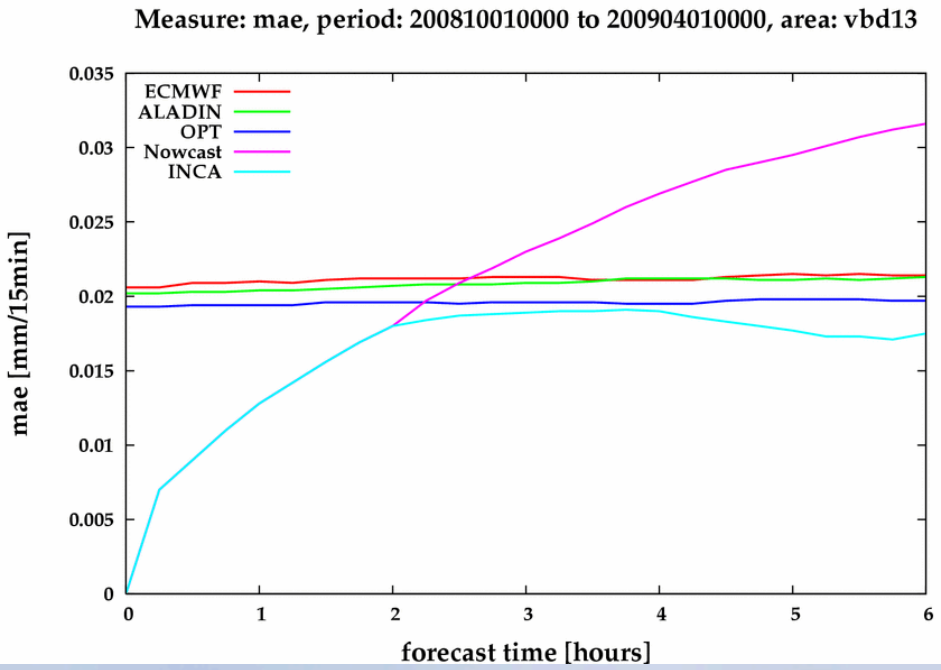
2h-4h: model is injected into forecast.

Small jumps in space can occur in precipitation from ALARO, since this field is only available once per hour.

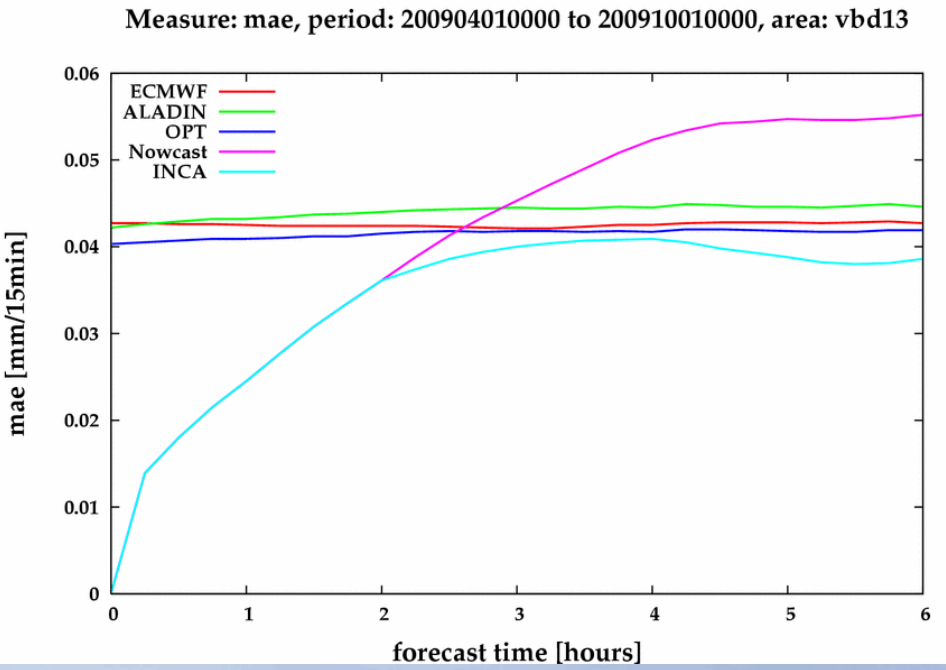


INCA precipitation forecast verification

MAE Winter 2008/2009



MAE Summer 2009



INCA-BE precipitation type algorithm

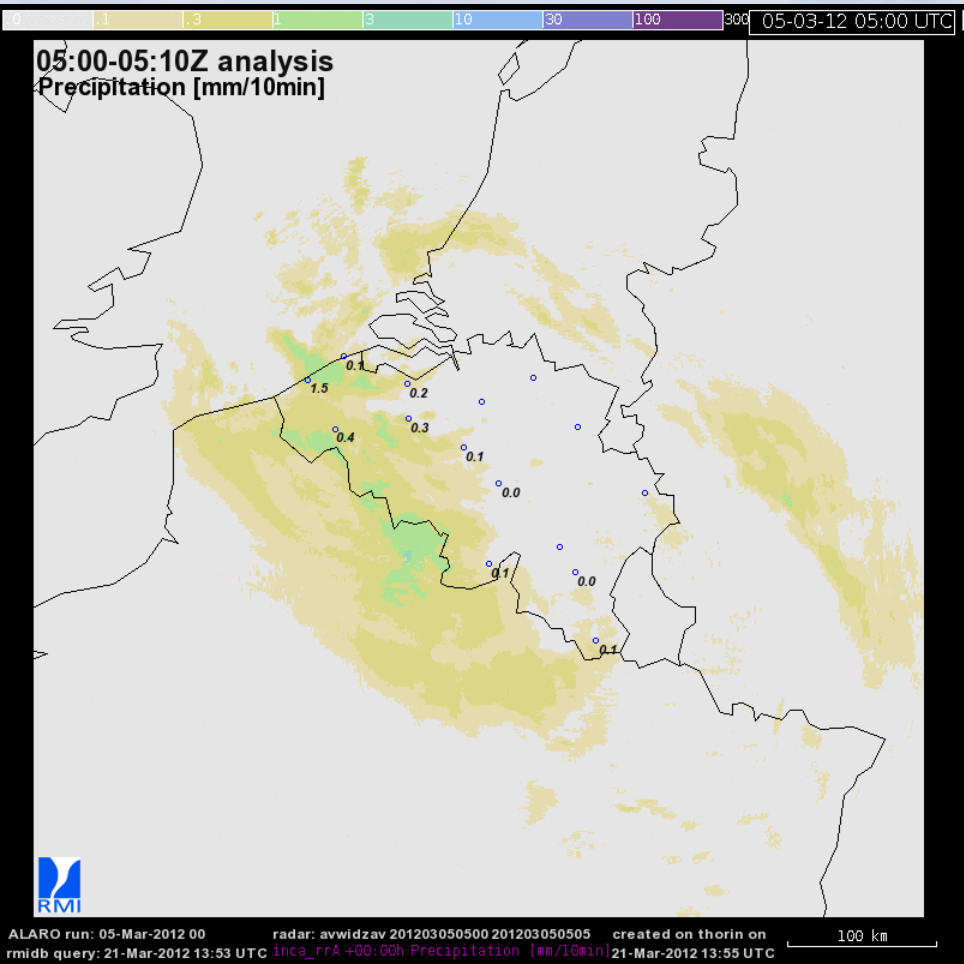
Precipitation type algorithm uses near-surface information (T2M, T_w wet bulb, TGR) and upper-air information (ZSNOW):

1) T_w < +2°C:
   Determine whether surface elevation is
   - *below* (rain),
   - *in* (mix rain/snow) or
   - *above* (snow) ZSNOW level layer.
   Width of melting layer (around ZSNOW) is currently fixed at 200m
2) $T_w \geq$ +2°C: rainfall is diagnosed
3) If rain is diagnosed: extra test for **freezing rain**:
   either air temp. or ground temp. is < 0°C
   (latter case air temp has to be <+2°C as well).

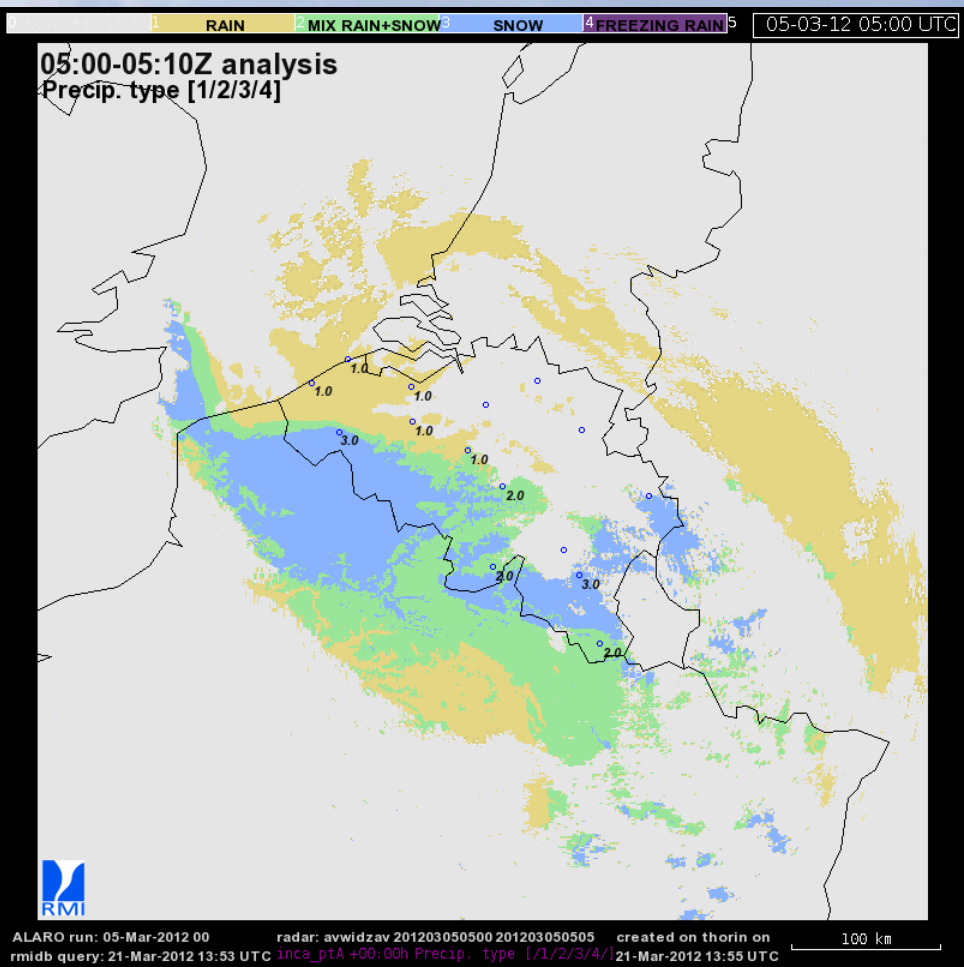
INCA-BE precipitation type example

Example 05.03.2012

Precipitation intensity

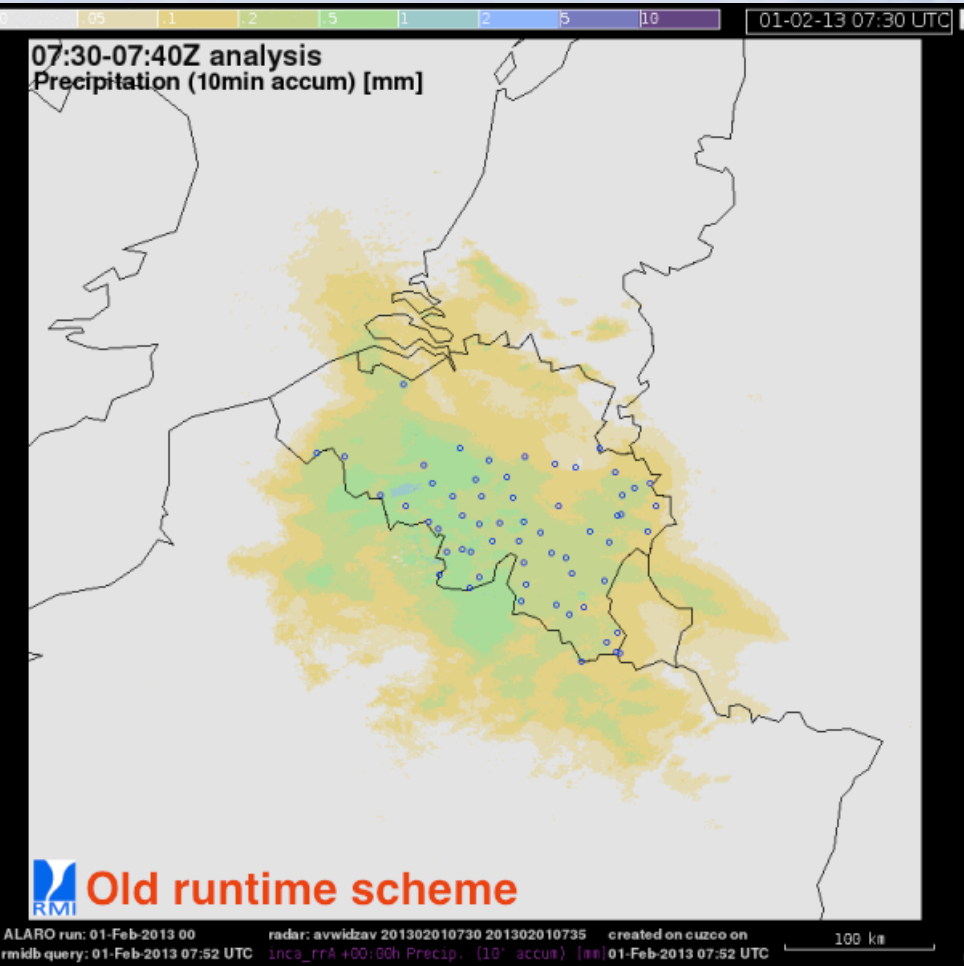


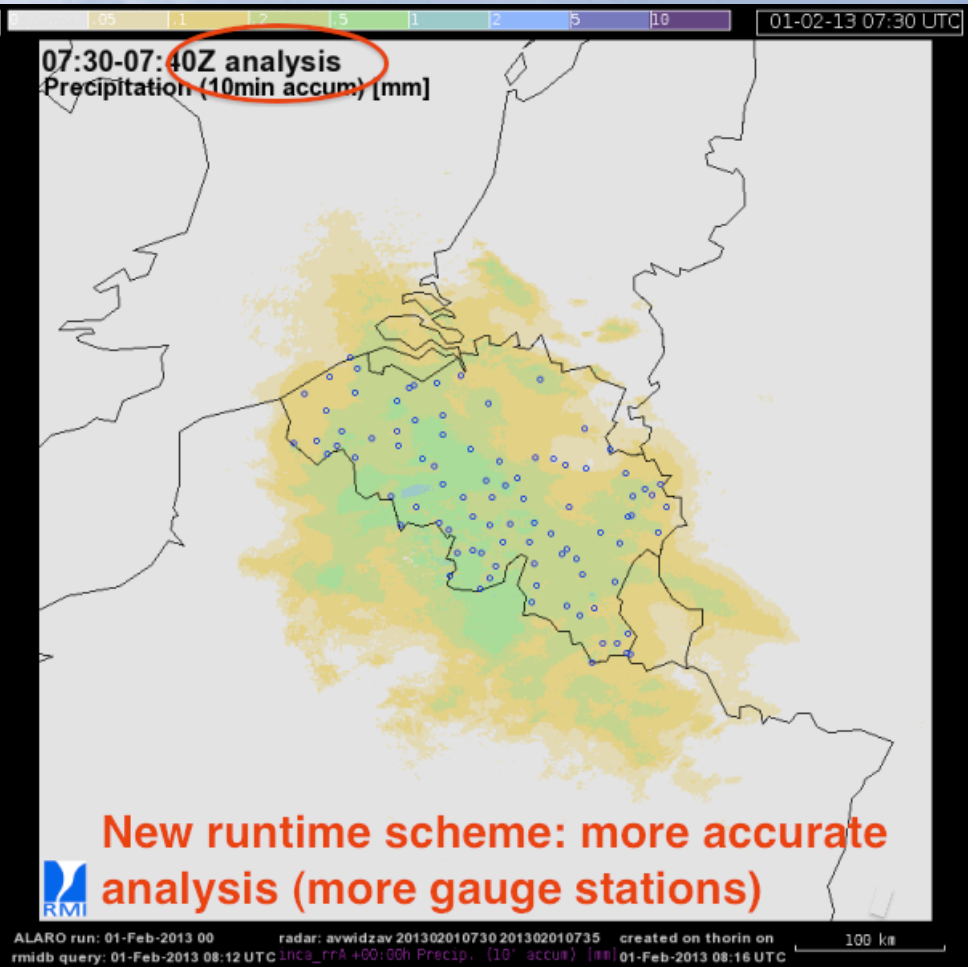
Precipitation type



INCA-BE runtime strategy precipitation

- **Runtime strategy** for the **precipitation** module: for every timestep (every 10 minutes), the precipitation module is repeated four times: respectively for 30, 20, 10 minutes ago and for the current time (also motion vectors are re-calculated).

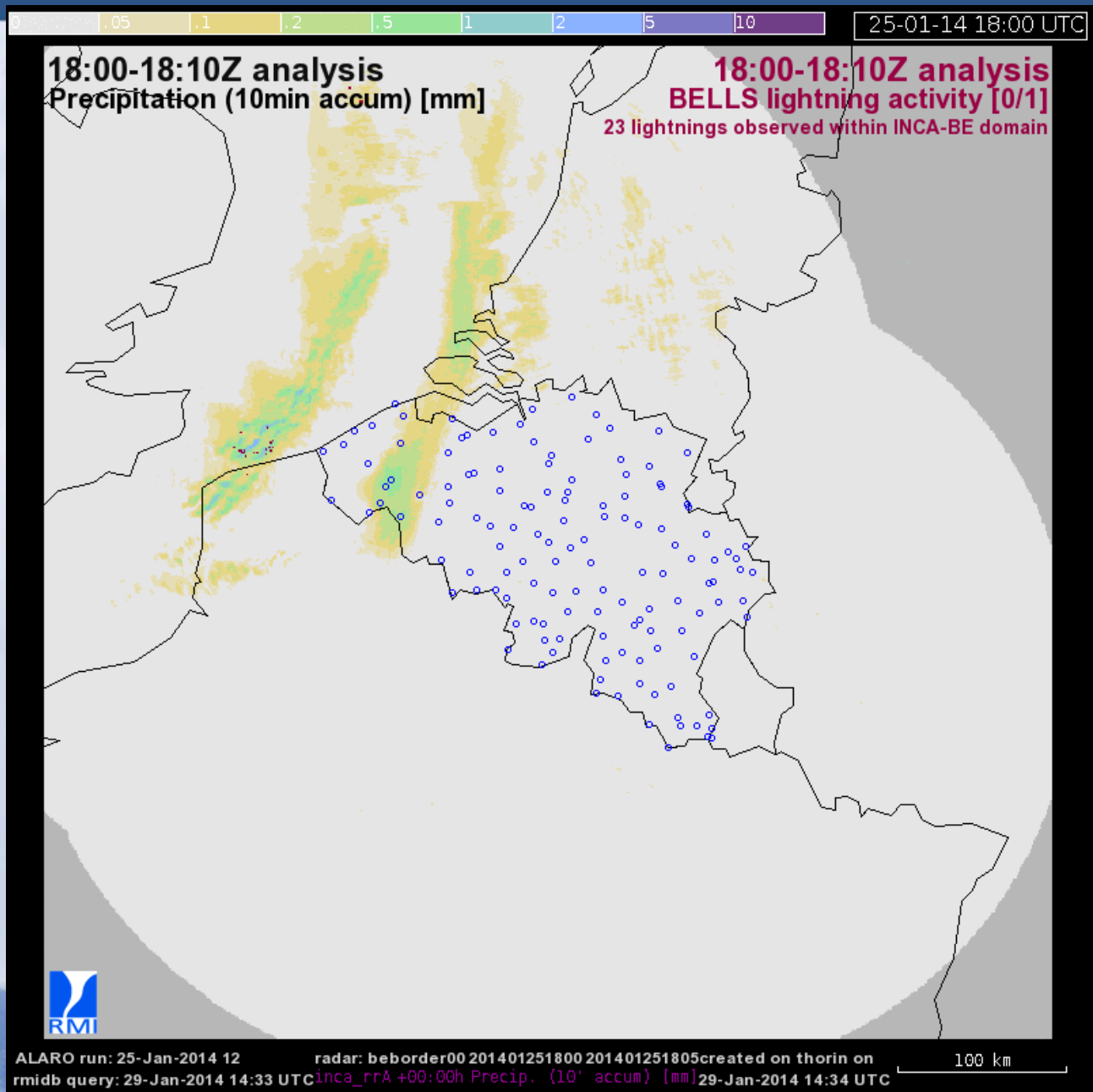




INCA-BE lightning forecast

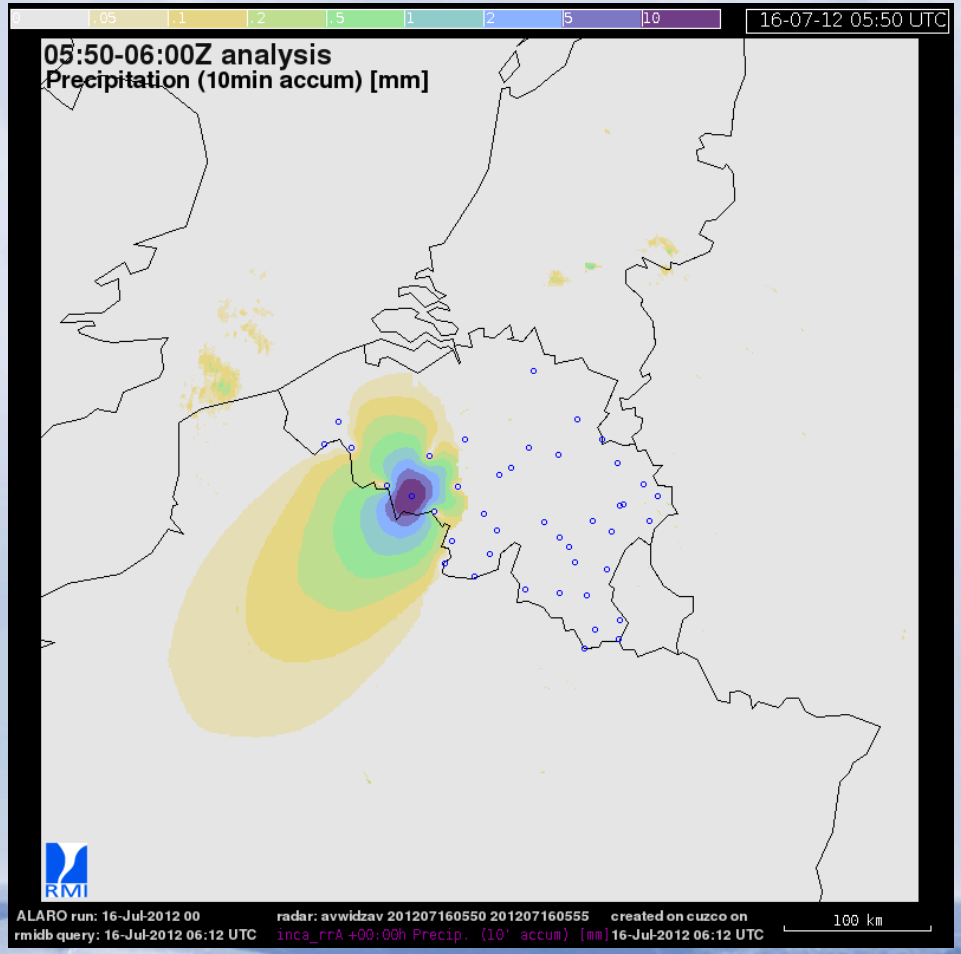
Addition of “lightning activity” field defined as follows: for each INCA-BE gridbox, it is 1 if at least one lightning (intracloud or cloud-to-ground) is observed in that gridbox, 0 otherwhise.

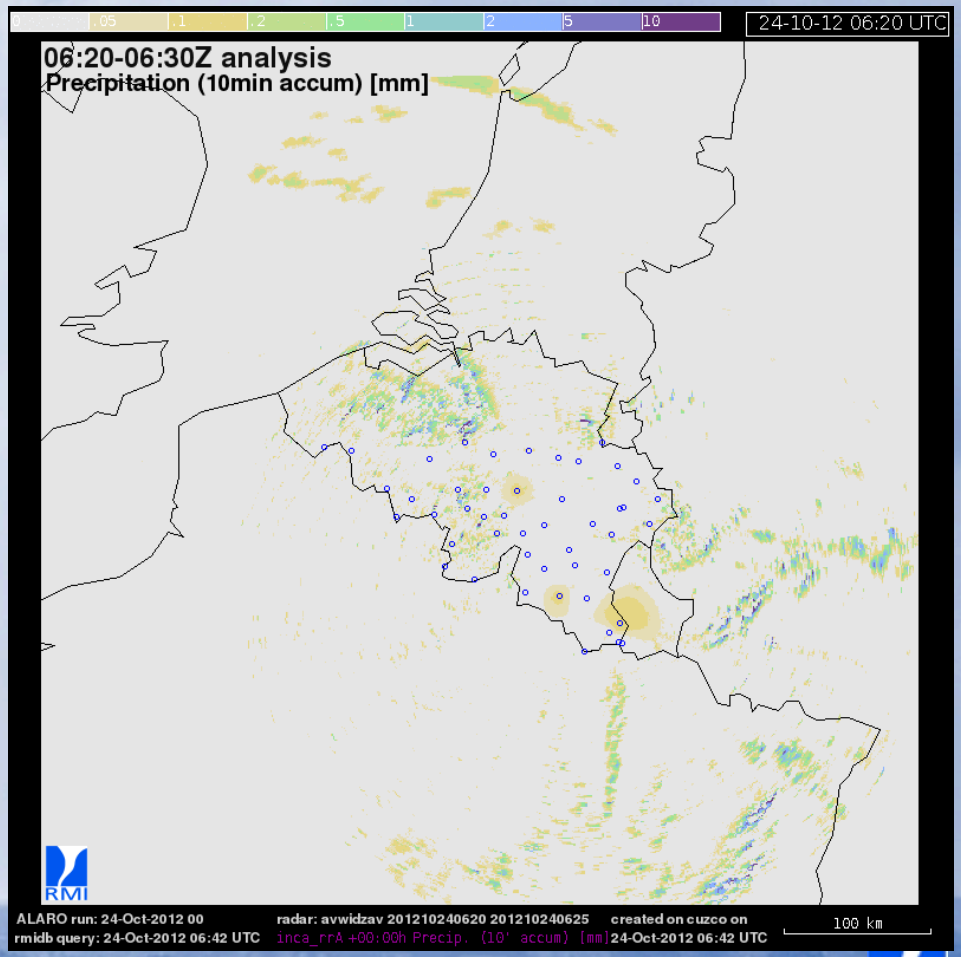
Forecast: advect with precipitation.



INCA-BE precipitation: known issues

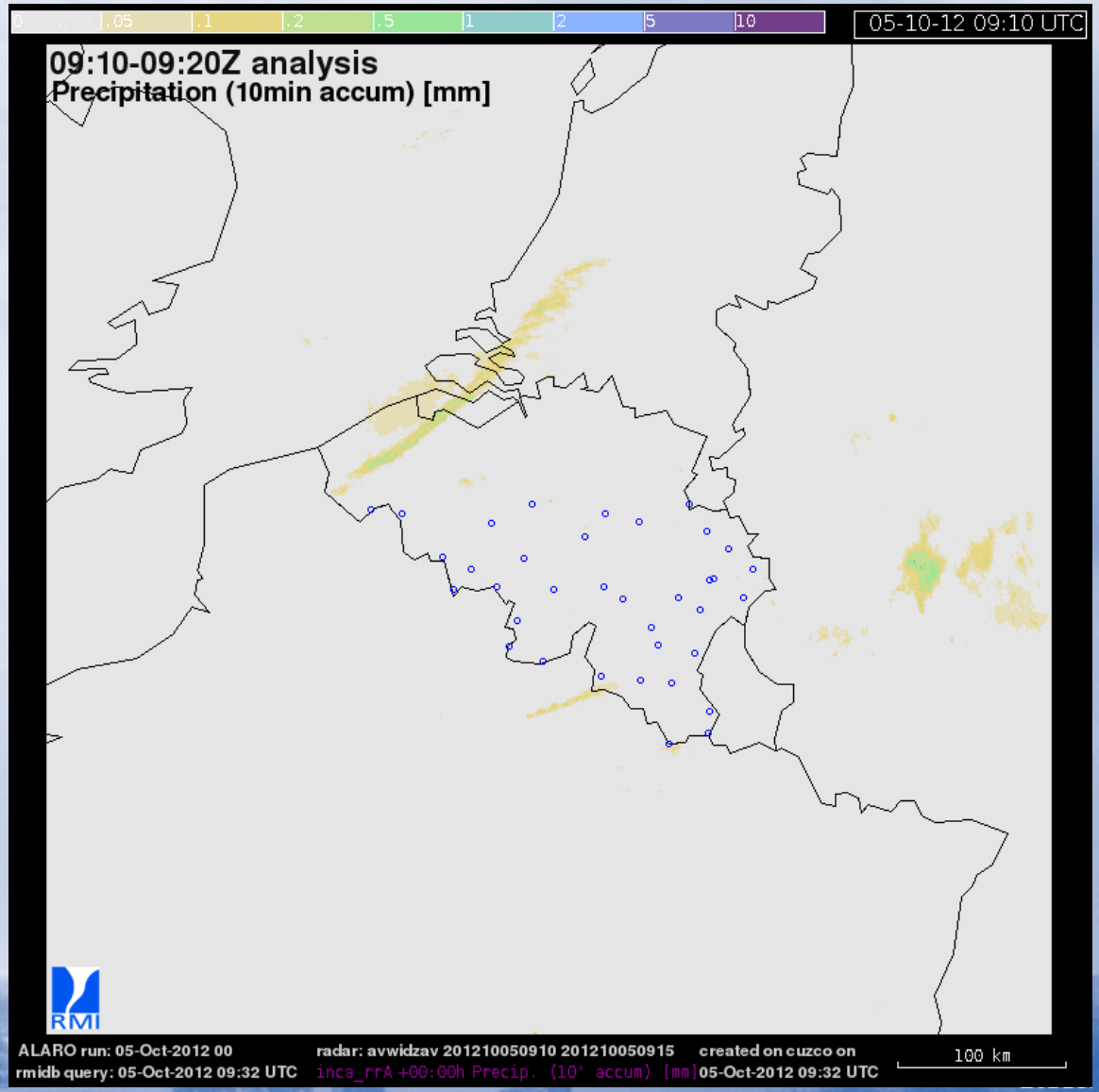
- **Extension stations** towards neighbour countries
- **Quality control of input data** (QC stations, filtering radar)





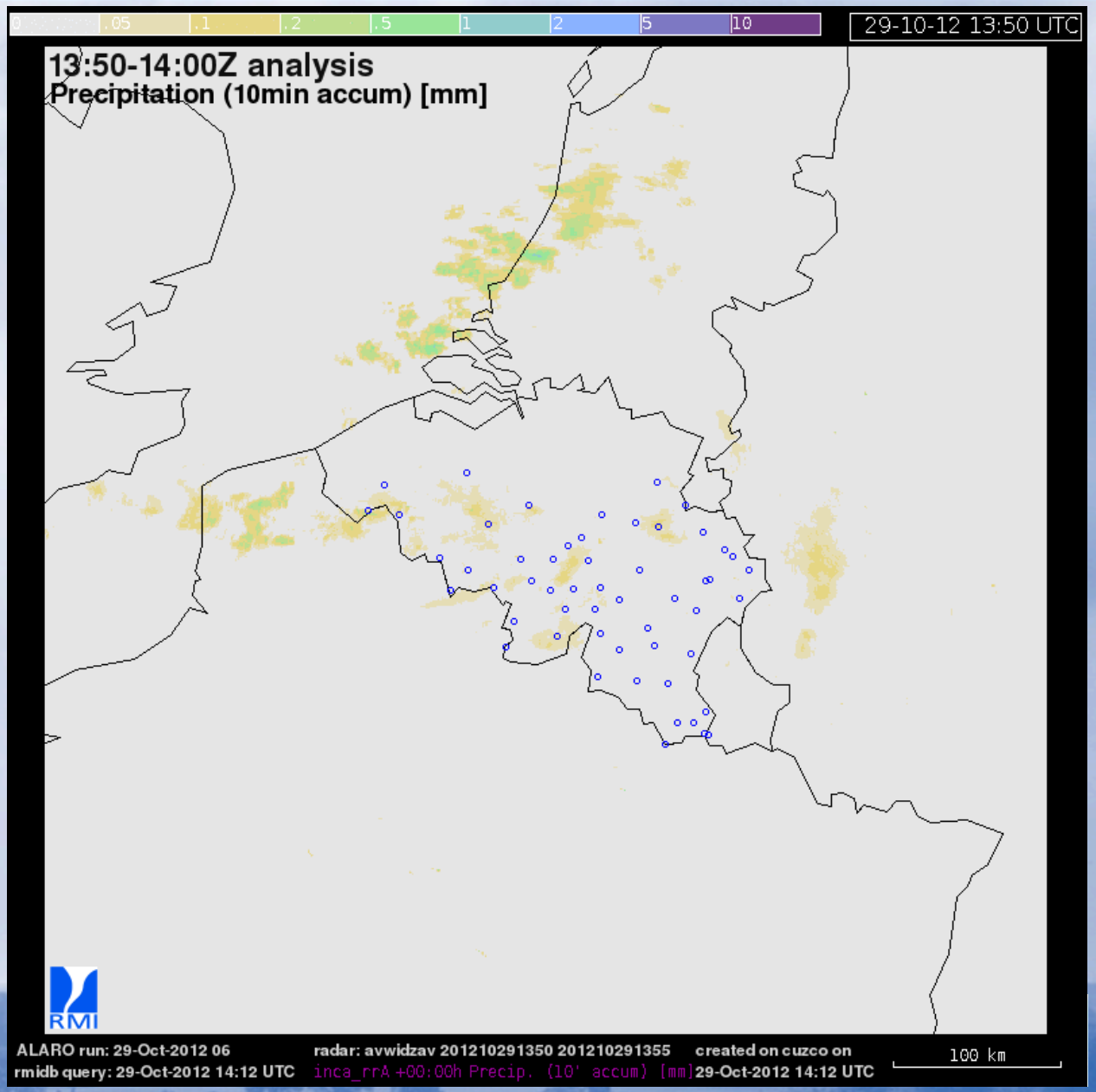
INCA-BE precipitation: known issues

- **Radar-gauge merging** technique can be improved; our group has the expertise (Goudenhoofdt & Delobbe, 2009)



INCA-BE precipitation: known issues

- **Phase shifts** between radar and model can occur



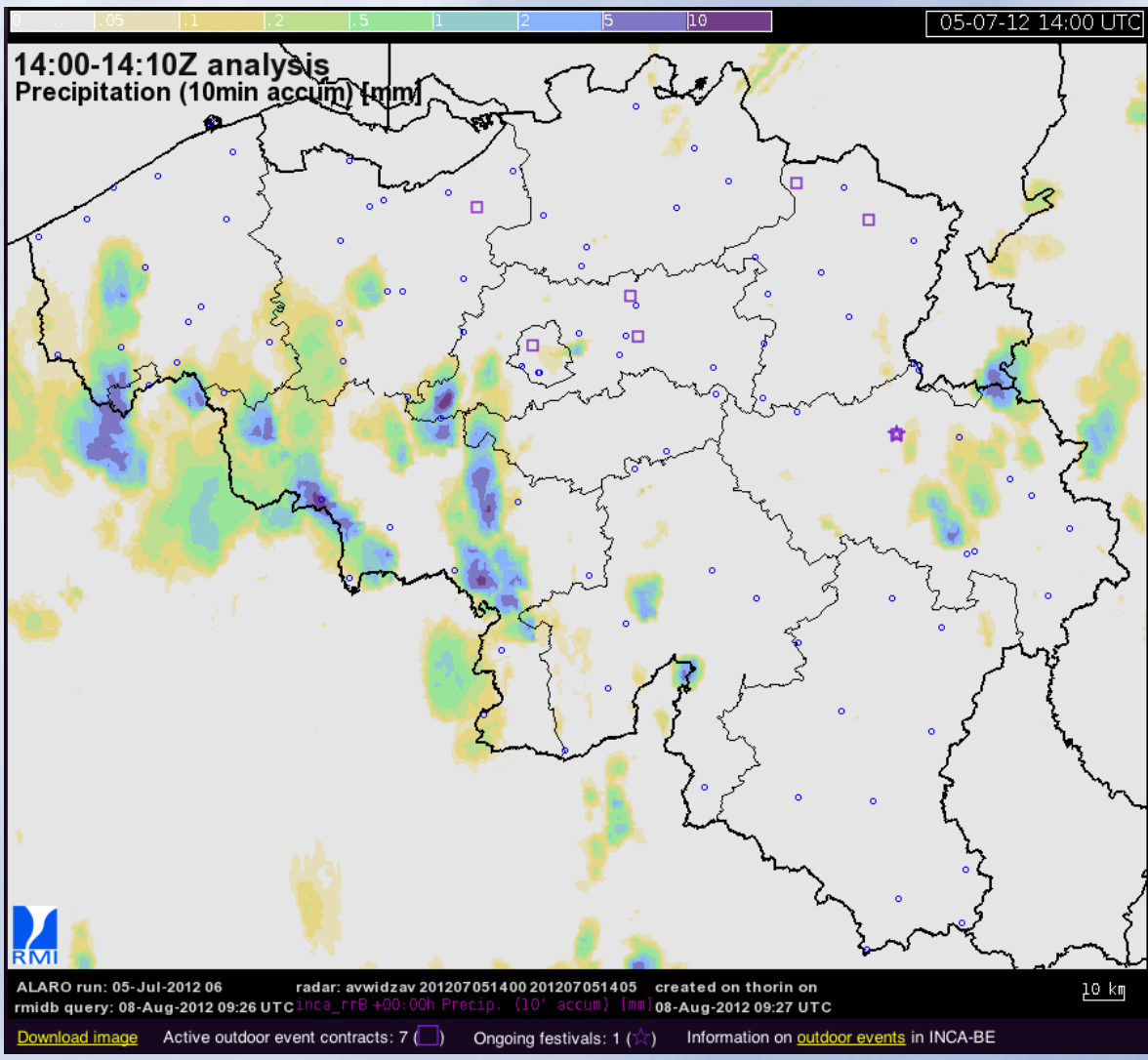
OVERVIEW

- Why nowcasting?
- INCA, INCA-CE, INCA-BE
- INCA-BE input and output
- INCA-BE precipitation forecast
- Applications
- Future developments

Application: Outdoor Event Forecast

The events with contract are integrated in INCA-BE:

- ongoing contracts are marked with □
- ongoing festivals with ☆
- meteograms are generated by clicking on this mark



Application: Outdoor Event Forecast

Outdoor Event Forecast product: package for event organisers.

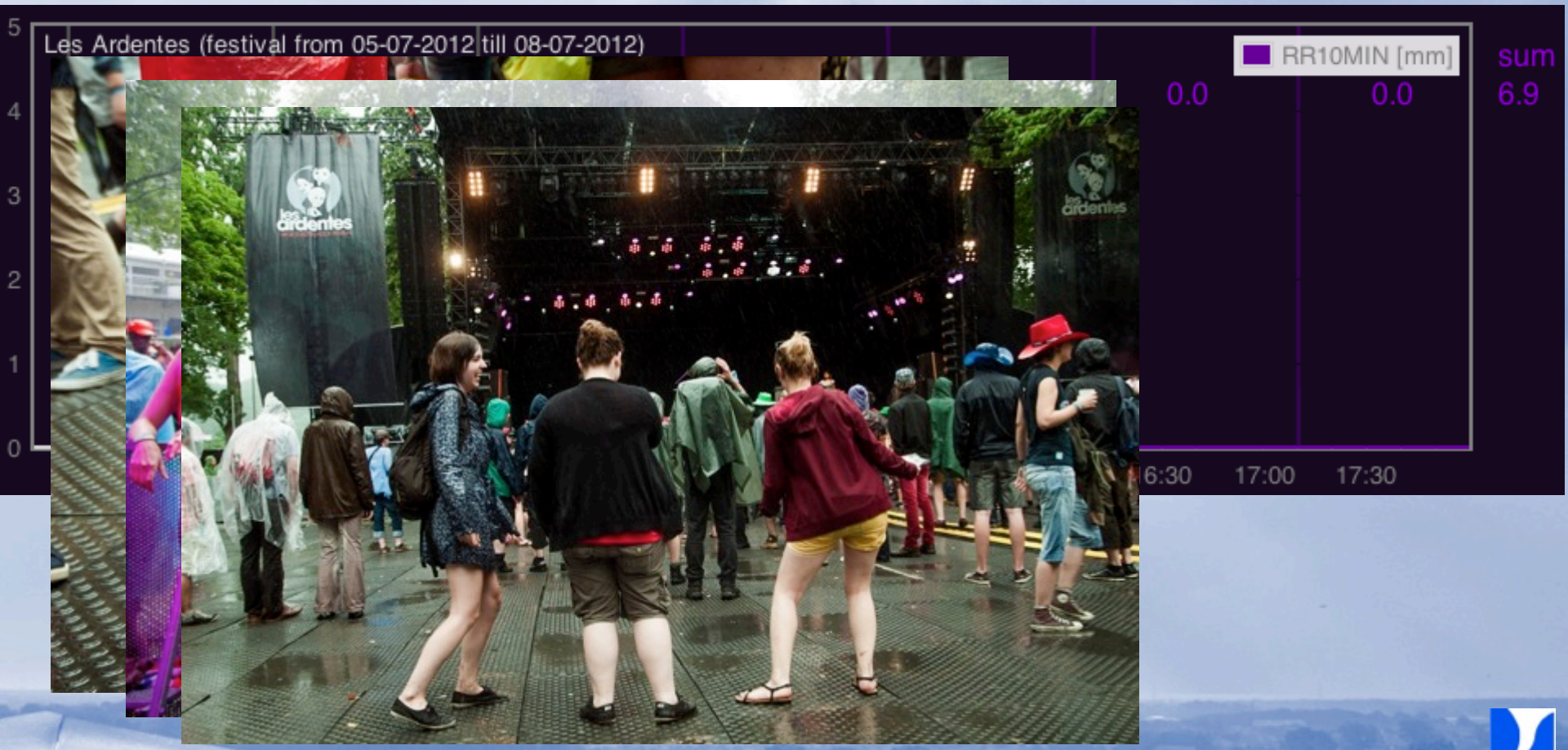
Contains:

- Customized version of MyMeteo
- SMS warning
- At day of event: privileged contact with forecaster by phone

Application: Outdoor Event Forecast

Example: convective cells hitting the Les Ardentes festival (Liège) on 05.07.2012, around 17:00 LT (15:00 UT).

RR10MIN meteogram generated by INCA-BE at 14:00 UT.



INCA-BE application: external clients

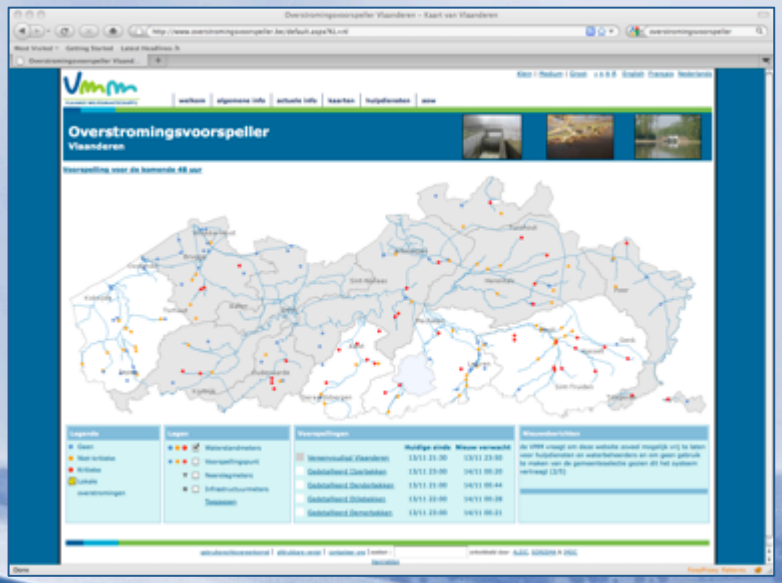
Dissemination to **external clients** since spring/summer 2013

Hydrological services of Flanders and Wallonia: precipitation

Belgocontrol (Belgian aviation agency): all fields

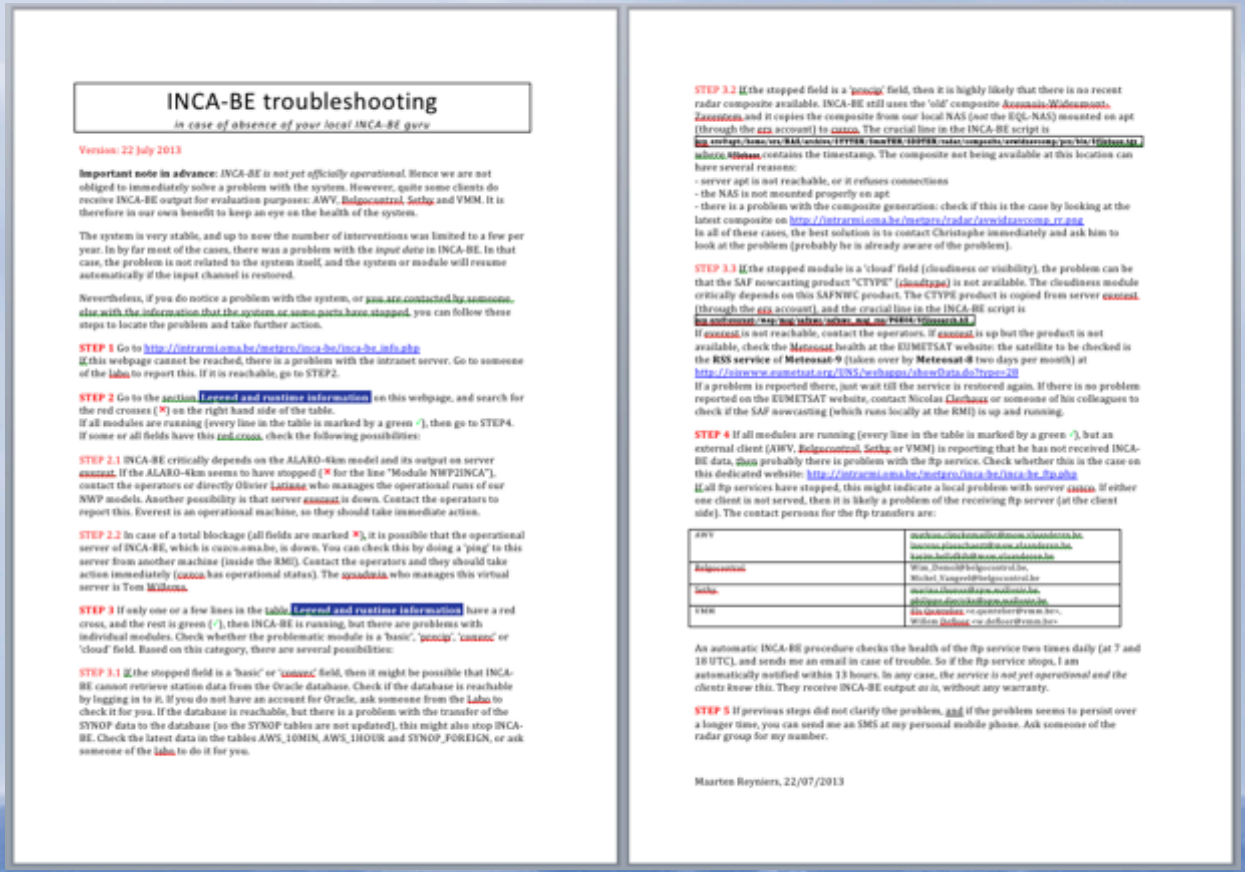
Road management: point forecasts of precipitation to control lighting on highways (4 month test)

Near future: MeteoLux, MeteoWing (Belgian army)



Latest developments

- One-day INCA-BE **training** for our **forecasters** (dec. 2012)
- Created a step-by-step INCA-BE **troubleshooting guide**



INCA-BE troubleshooting

in case of absence of your local INCA-BE guru

Version: 22 July 2013

Important note in advance: *INCA-BE is not yet officially operational.* Hence we are not obliged to immediately solve a problem with the system. However, quite some clients do receive INCA-BE output for evaluation purposes: AWV, Belgocontrol, Sethy and VMM. It is therefore in our own benefit to keep an eye on the health of the system.

The system is very stable, and up to now the number of interventions was limited to a few per year. In by far most of the cases, there was a problem with the *input data* in INCA-BE. In that case, the problem is not related to the system itself, and the system or module will resume automatically if the input channel is restored.

Nevertheless, if you do notice a problem with the system, or you are contacted by someone, else with the information that the system or some parts have stopped, you can follow these steps to locate the problem and take further action.

STEP 1 Go to http://intrarmi.oma.be/metaro/inca-be/inca-be_info.php
If this webpage cannot be reached, there is a problem with the intranet server. Go to someone of the labo to report this. If it is reachable, go to STEP2.

STEP 2 Go to the section **Layered and runtime information** on this webpage, and search for the red crosses (✖) on the right hand side of the table.
If all modules are running (every line in the table is marked by a green ✓), then go to STEP4. If some or all fields have this red cross, check the following possibilities:

STEP 2.1 INCA-BE critically depends on the ALARO-4km model and its output on server everest. If the ALARO-4km seems to have stopped (✖ for the line "Module NWP2INCA"), contact the operators or directly Olivier Latinne who manages the operational runs of our NWP models. Another possibility is that server everest is down. Contact the operators to report this. Everest is an operational machine, so they should take immediate action.

STEP 2.2 In case of a total blockage (all fields are marked ✖), it is possible that the operational server of INCA-BE, which is cuacc.oma.be, is down. You can check this by doing a 'ping' to this server from another machine (inside the RMI). Contact the operators and they should take action immediately (cuacc has operational status). The sysadmin who manages this virtual server is Tom Willems.

STEP 3 If only one or a few lines in the table **Layered and runtime information** have a red cross, and the rest is green (✓), then INCA-BE is running, but there are problems with individual modules. Check whether the problematic module is a 'basic', 'precip', 'convenc' or 'cloud' field. Based on this category, there are several possibilities:

STEP 3.1 If the stopped field is a 'basic' or 'convenc' field, then it might be possible that INCA-BE cannot retrieve station data from the Oracle database. Check if the database is reachable by logging in to it. If you do not have an account for Oracle, ask someone from the Labo to check it for you. If the database is reachable, but there is a problem with the transfer of the SYNOP data to the database (so the SYNOP tables are not updated), this might also stop INCA-BE. Check the latest data in the tables AWS_10MIN, AWS_1HOUR and SYNOP_FOREIGN, or ask someone of the labo to do it for you.

STEP 3.2 If the stopped field is a 'precip' field, then it is highly likely that there is no recent radar composite available. INCA-BE still uses the 'old' composite Accumuls-Wideumont-Zaventem and it copies the composite from our local NAS (not the EQL-NAS) mounted on apt (through the ecs account) to cuacc. The crucial line in the INCA-BE script is
[redacted]
where filedate contains the timestamp. The composite not being available at this location can have several reasons:
- server apt is not reachable, or it refuses connections
- the NAS is not mounted properly on apt
- there is a problem with the composite generation: check if this is the case by looking at the latest composite on http://intrarmi.oma.be/metaro/radar/aswidzzcomp_rr.png
In all of these cases, the best solution is to contact Christophe immediately and ask him to look at the problem (probably he is already aware of the problem).

STEP 3.3 If the stopped module is a 'cloud' field (cloudiness or visibility), the problem can be that the SAF nowcasting product "CTYPE" (cloudtype) is not available. The cloudiness module critically depends on this SAFNWC product. The CTYPE product is copied from server everest (through the ecs account), and the crucial line in the INCA-BE script is
[redacted]
If everest is not reachable, contact the operators. If everest is up but the product is not available, check the Meteosat health at the EUMETSAT website: the satellite to be checked is the **RSS service** of **Meteosat-9** (taken over by **Meteosat-8** two days per month) at http://oiswww.eumetsat.org/IDS/webapps/showData.do?type=28
If a problem is reported there, just wait till the service is restored again. If there is no problem reported on the EUMETSAT website, contact Nicolas Clerbaux or someone of his colleagues to check if the SAF nowcasting (which runs locally at the RMI) is up and running.

STEP 4 If all modules are running (every line in the table is marked by a green ✓), but an external client (AWV, Belgocontrol, Sethy or VMM) is reporting that he has not received INCA-BE data, then probably there is problem with the ftp service. Check whether this is the case on this dedicated website: http://intrarmi.oma.be/metaro/inca-be/inca-be_ftp.php
If all ftp services have stopped, this might indicate a local problem with server cuacc. If either one client is not served, then it is likely a problem of the receiving ftp server (at the client side). The contact persons for the ftp transfers are:

AWV	[redacted]
Belgocontrol	[redacted]
Sethy	[redacted]
VMM	[redacted]

An automatic INCA-BE procedure checks the health of the ftp service two times daily (at 7 and 18 UTC), and sends me an email in case of trouble. So if the ftp service stops, I am automatically notified within 13 hours. In any case, *the service is not yet operational and the clients know this.* They receive INCA-BE output *as is*, without any warranty.

STEP 5 If previous steps did not clarify the problem, and if the problem seems to persist over a longer time, you can send me an SMS at my personal mobile phone. Ask someone of the radar group for my number.

Maarten Reyniers, 22/07/2013

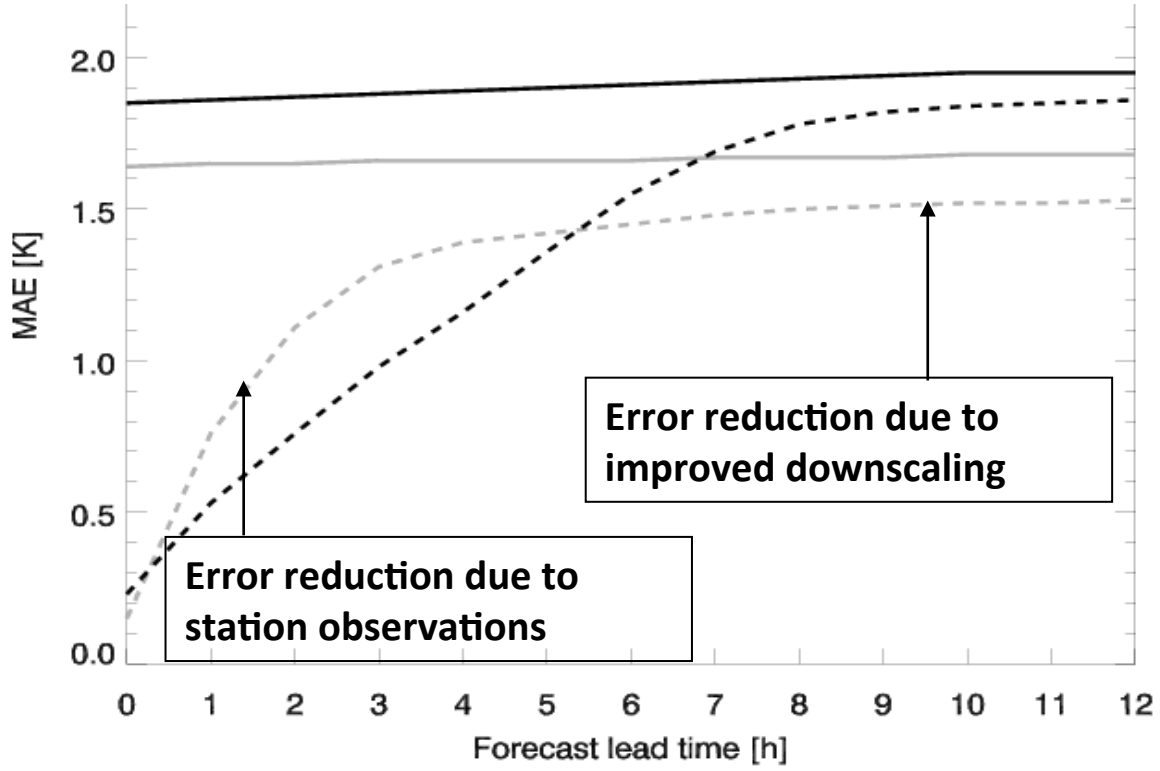
Evaluation

Cloudiness fields

- Here also: implement a more sophisticated **satellite-station merging** technique
- Choice to use RSS implies two days of outages per month
- Visibility still experimental, verification difficult but necessary

Evaluation temperature

INCA-AT (dashed lines) and ALADIN (solid lines) mean absolute forecast errors (MAE) of temperature, averaged over all stations, for July 2009 (grey) and January 2010 (black).



- Overall performance satisfying (quantitative study required)

OVERVIEW

- Why nowcasting?
- INCA, INCA-CE, INCA-BE
- INCA-BE input and output
- INCA-BE precipitation forecast
- Applications
- Future developments

Future work

- **Precipitation (medium term)**
  - Improve quality station and radar data
  - Integrate more real-time station networks (e.g. border stations)
  - Verification studies

- **Precipitation (longer term)**
  - Add other extrapolation strategy (STEPS)
  - Uncertainty estimate on precipitation nowcast
  - (Cell tracker)

PLURISK project (financed by Belgian Science Policy Office)

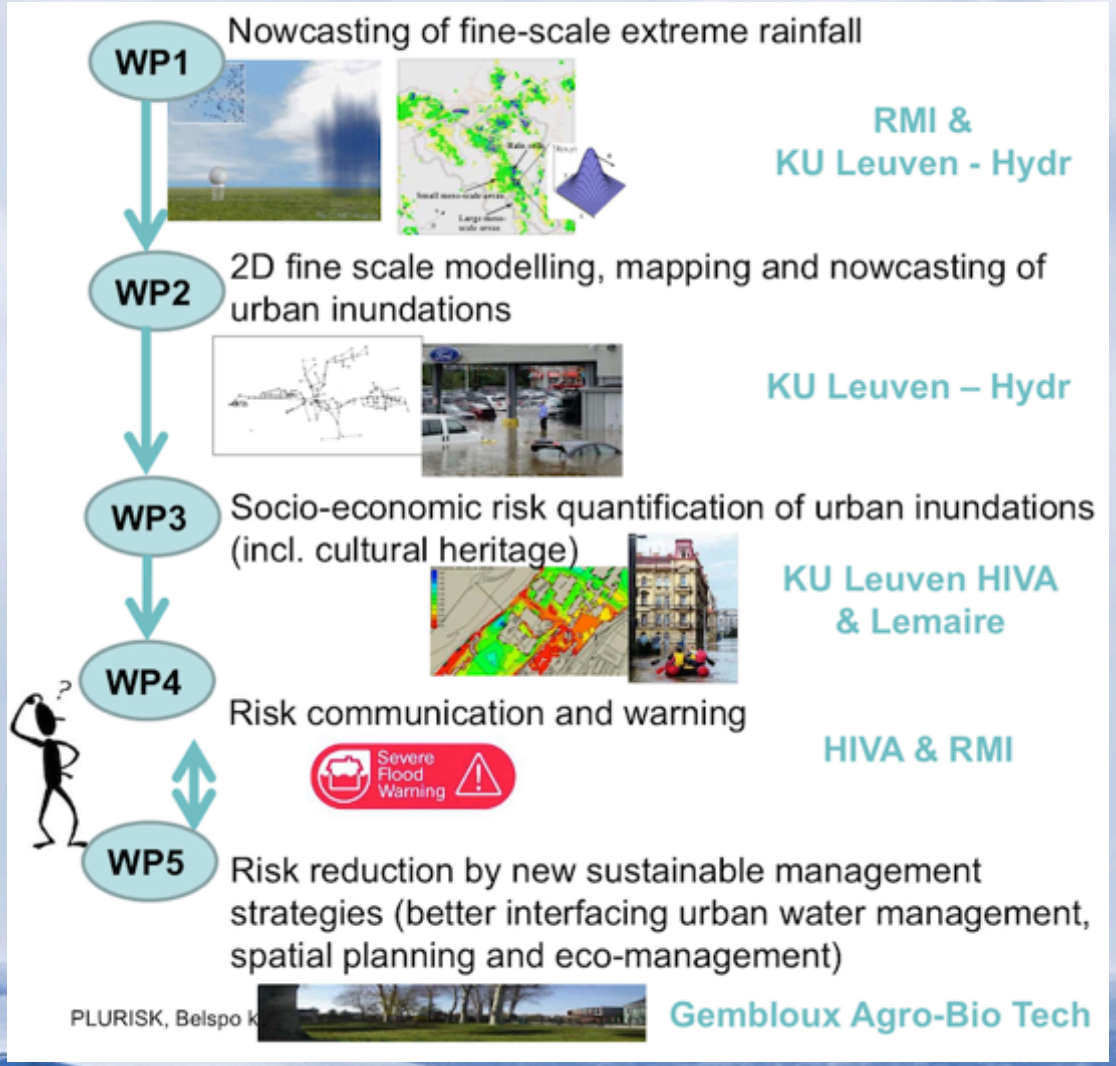
Presentation Loris Foresti

- **Other fields**
  - Implementation of gust module
  - Verification studies
  - Improve visibility field

RMI

PLURISK project

'Forecasting and management of extreme rainfall induced risks in the urban environment' (1 May 2012 – 30 April 2016) €1million



WP1: Nowcasting of fine-scale extreme rainfall

- Using advanced techniques for storm cell tracking
- Integrating:
  - national (C-band) radar technology
  - local (X-band) radar technology
  - numerical weather prediction
  - lightning detection
- Quantification of the uncertainty in the nowcasting

INCA-BE “rolling release”

- System is in **constant development**; there is no “final version”
- However, current implementation is **stable**, and results are satisfying
- Current implementation will be operational version, but improvements will be continuously implemented: **rolling release**
- Output of this version is offered to **external clients** since **spring/ summer of 2013**

Overview current applications

- **Weather office** RMI: refine short-term forecasts and more precise warnings e.g. for outdoor events like festivals
- **Hydrological services**: integration in their flood-predicting software → earlier anticipation on possible high waters and floods
- **Road management**: automatic lighting control for highways to reduce energy costs
- **Aviation**: aviation agency Belgocontrol uses INCA-BE for nowcasts

Conclusions

- **Current version** of INCA-BE is **stable** and results are certainly **usable**
  → results are sent to external clients e.g. hydrological services
- **Gust module** not yet implemented
- Future work mainly in **precipitation module**

  in the context of the **PLURISK** project led by the University of Leuven
  http://www.kuleuven.be/hydr/plurisk