Meteosat Third Generation (MTG): Lightning Imager and its products

EUMETSAT

Jochen Grandell

Topics

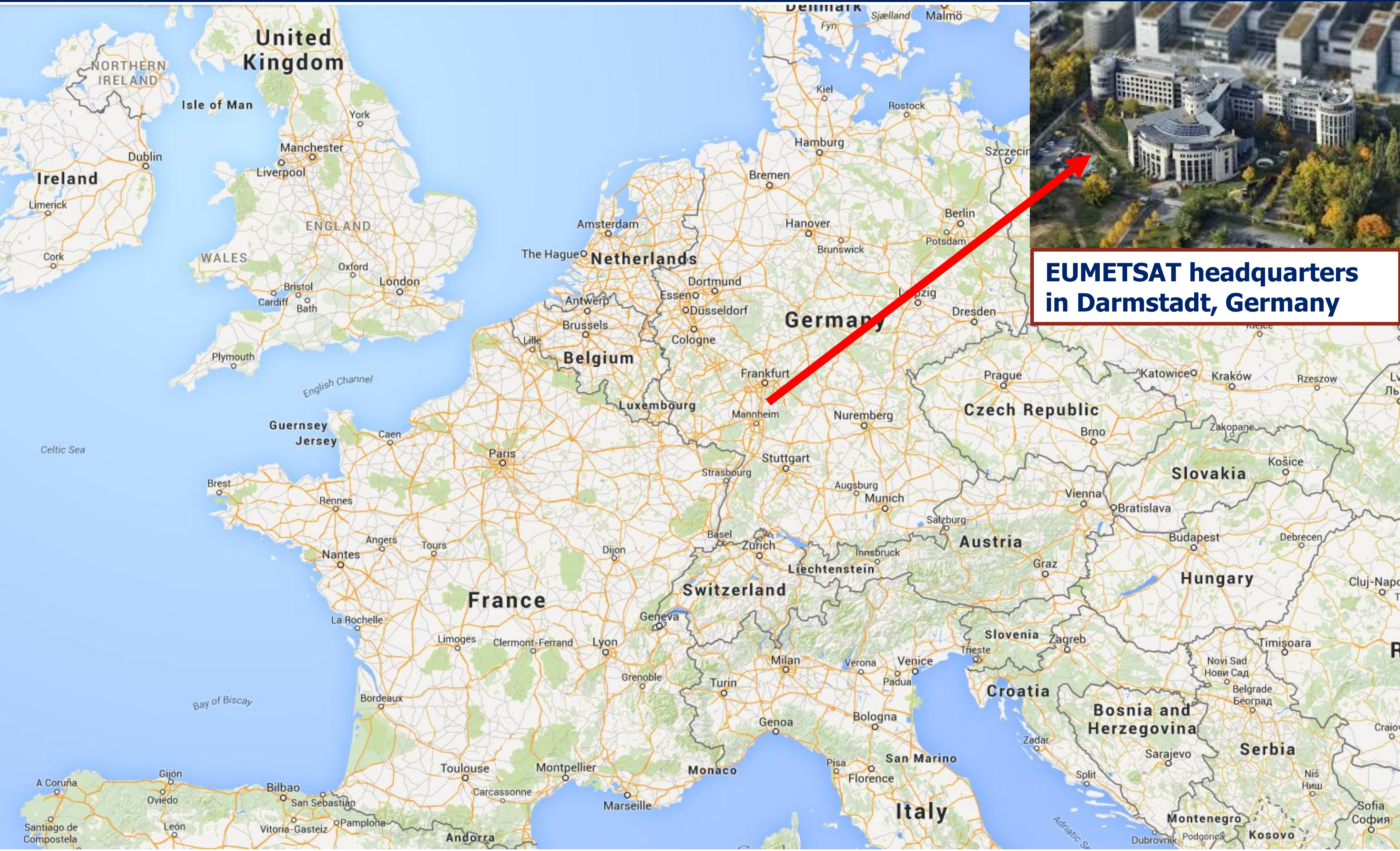
- Putting Meteosat Third Generation (MTG) into context
- Lightning monitoring from space – how does the concept work
- MTG Lightning Imager
  - **Design and characteristics**
  - **User products**
- Proxy data development
- Summary

Who am I...

- Jochen Grandell
  - Finnish
  - With EUMETSAT since 2002
  - Until very recently MTG Lightning Imager mission scientist
  - Now Atmospheric and imagery applications manager

(it was cold while taking this picture...)

Where am I...



EUMETSAT headquarters in Darmstadt, Germany

Where I would like to be...

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MTG to Secure Continuity and Evolution of EUMETSAT Services

1977 — 2002 — 2019 and 2021

MOP/MTP
MOP/MTP

MSG
MSG

MTG-I and MTG-S

Observation mission:
- MVIRI: 3 channels

Spinning satellite
Class 800 kg

Observation missions:
- SEVIRI: 12 channels
- GERB

Spinning satellite
Class 2-ton

Observation missions:
- Flex.Comb. Imager: 16 channels
- Infra-Red Sounder
- Lightning Imager
- UVN (*)
3-axis stabilised satellites
(two-satellite configuration)

(*) Ultraviolet Visible Near-infrared spectrometer (UVN-S4) via GMES Sentinel 4

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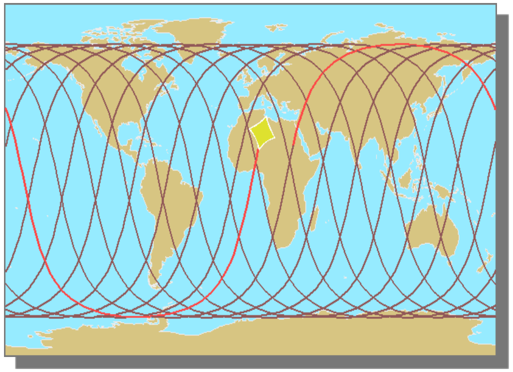
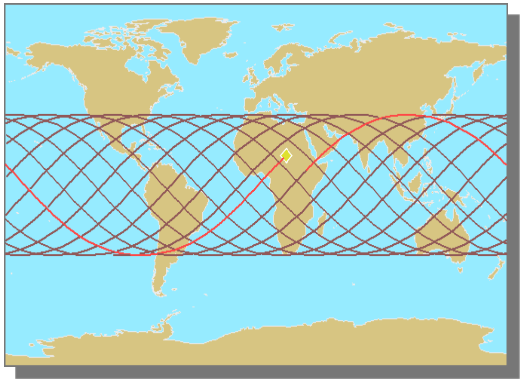
Lightning Detection from Space – from LEO to GEO

Feasibility of lightning detection from space by optical sensors has been proven by NASA instruments since 1995 on low earth orbits (LEO)

Optical Transient Detector (OTD) 1995-2000

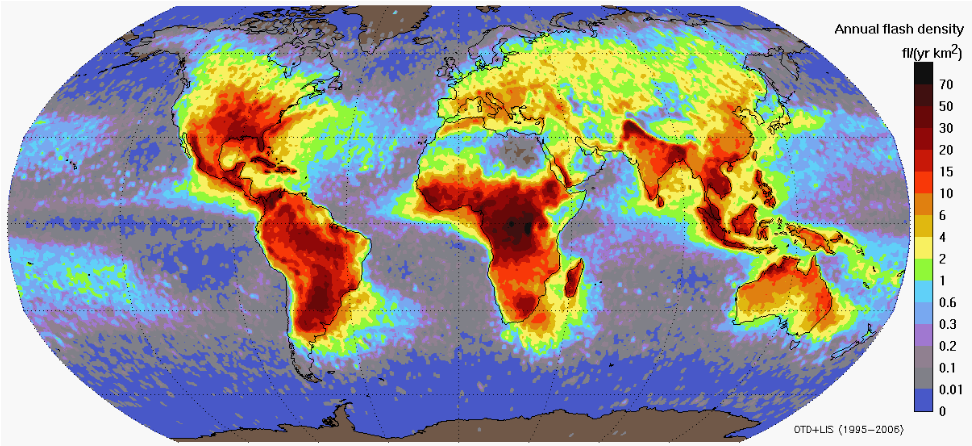


Lightning Imaging Sensor (LIS) 1997-present



Results from LIS/OTD: Global lightning distribution

Annual flash density



Geostationary lightning imaging – objectives and benefits

The LI on MTG measures Total Lightning:
Cloud-to-Cloud Lightning (IC) and Cloud-to-Ground Lightning (CG)

Main benefit from GEO observations:
homogeneous and continuous observations delivering information on location and strength of lightning flashes to the users with a timeliness of 30 seconds

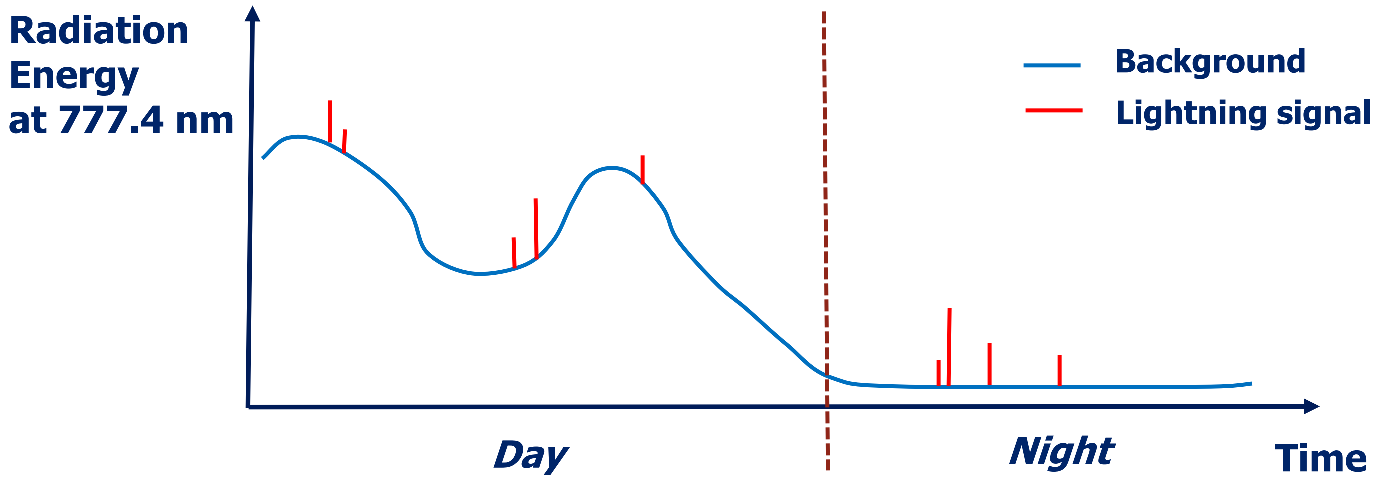
→

Main objectives are to detect, monitor, track and extrapolate in time:

- **Development of active convective areas and storm lifecycle**
- **Lightning climatology**
- **Chemistry (NOx production)**

Detection of a Lightning Optical Signal

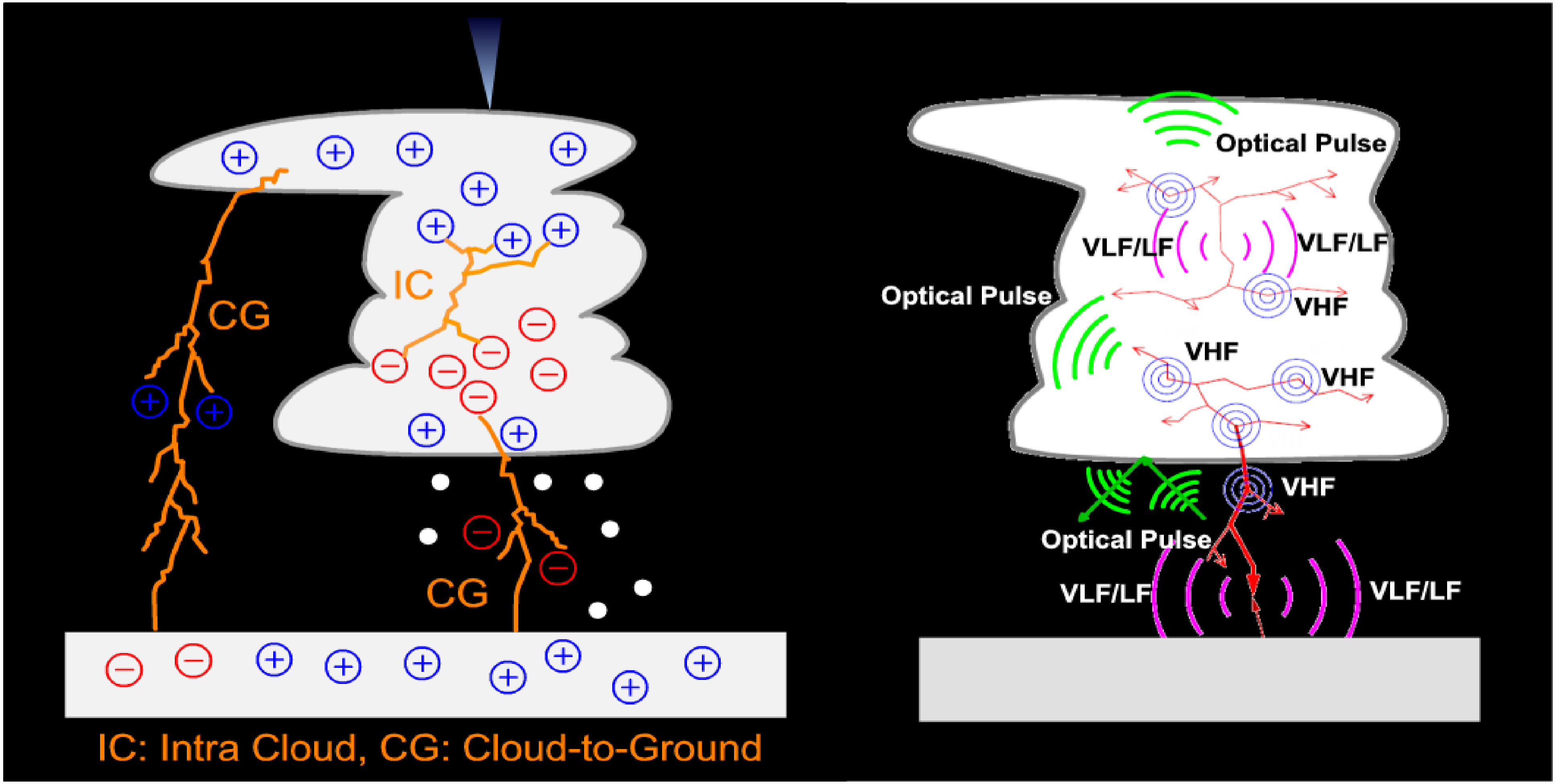
- Lightning with a background signal (bright clouds) changing with time:



- Lightning is **not recognized by its bright radiance alone, but by its transient short pulse character** (also against a bright background)

- Variable adapting threshold has to be used for each pixel which takes into account the change in the background radiance

Thunderstorm Electrification
Lightning and its Emissions



- VHF – Very High Frequency, (V)LF – (Very) Low Frequency

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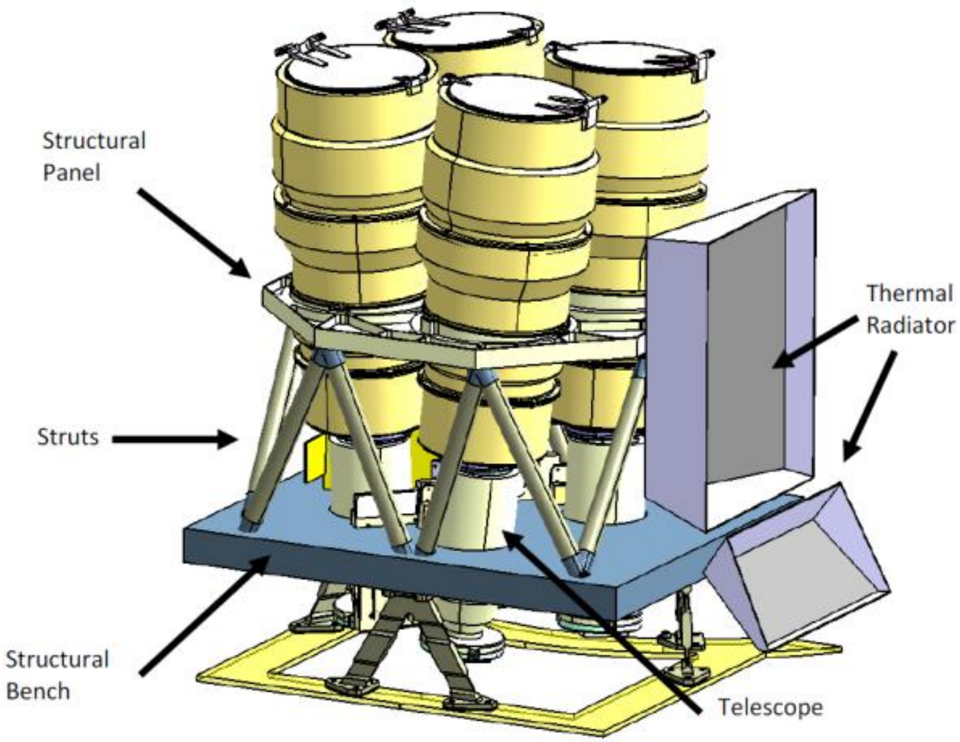
Lightning Imager (LI) design



CMOS Back-thinned backside illuminated detectors with integrated ADCs

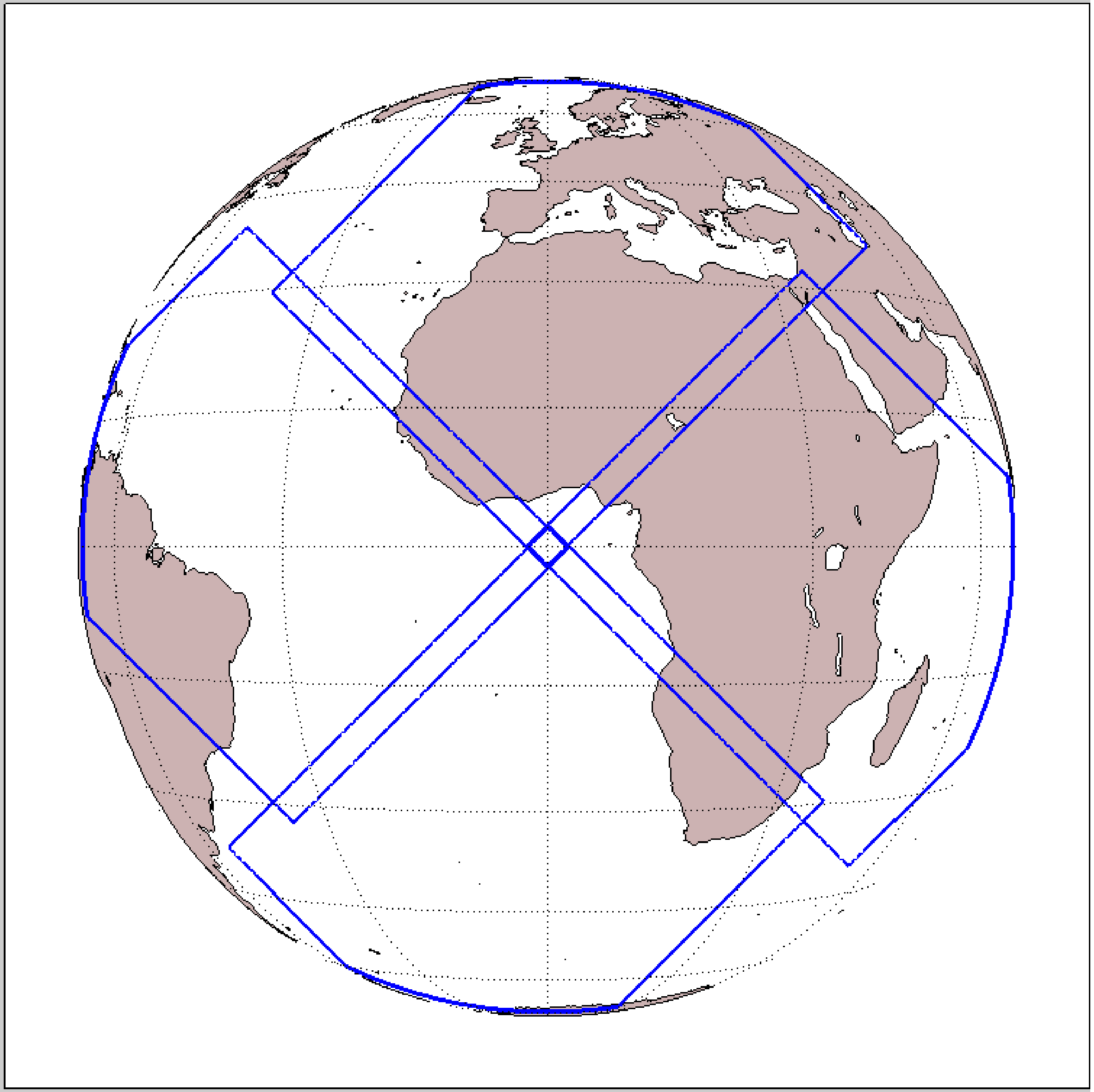
The baseline for the LI is a 4-camera solution

1170 x 1000 pixels per camera

Lightning Imager (LI) – Main Characteristics

- **LI main characteristics:**
  - **Measurements at 777.4 nm**
  - **Coverage close to visible disc**
  - **Continuous measurements of (lightning) triggered events**
  - **Ground sample distance at sub-satellite point ~4.5 km**
  - **Integration time per frame 1 ms**
  - **Background subtraction and event detection in on-board electronics**

LI coverage – full disk view



Four identical detectors with small overlaps

End-users (Level 2) will not see the “detector structure”

However, data contains information on from which detector(s) the observation is origination from

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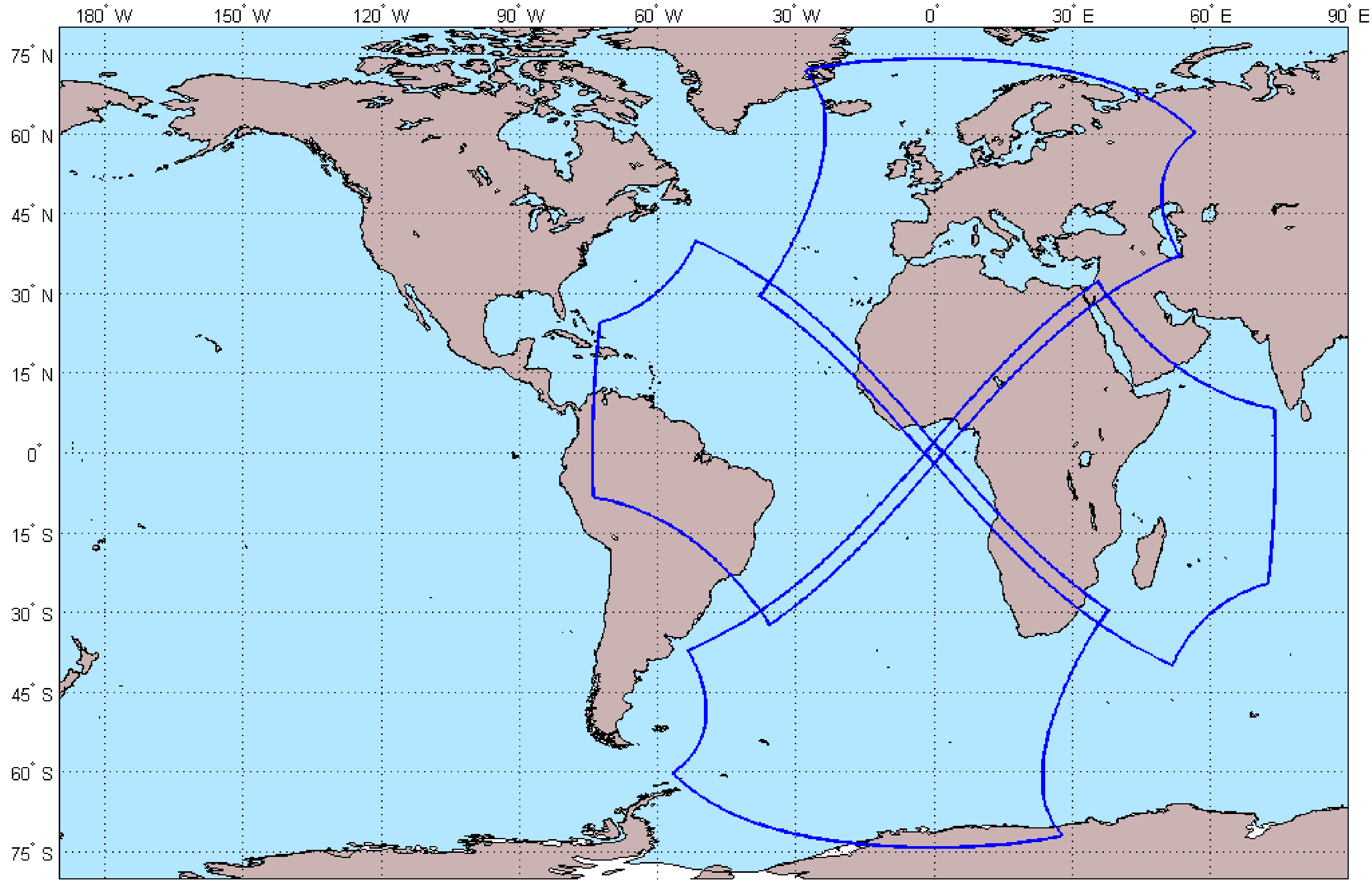
LI coverage – another projection



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Product terminology same as for LIS/GLM

- ***Events:*** **what the instrument measures, a triggered pixel in the detector grid**
- ***Groups:*** **collection of neighbouring triggered events in the same integration period (1 ms), representing a lightning stroke in nature**
- ***Flashes:*** **a collection of groups in temporal and spatial vicinity (XX km, YY milliseconds), representing a "geophysical" flash.**

Lightning Imager (LI) – User Products

- **“LI Initial Processing”**
  - **Point data in nature in the LI grid**
  - **Groups (strokes) & Flashes with geographical coordinates**
- **“Accumulated products”**
  - **Product density shown in the fixed MTG-FCI (*) imager grid (same grid as for the FCI IR channels in the 2 km FDHSI resolution)**

(*) FCI = Flexible Combined Imager on MTG

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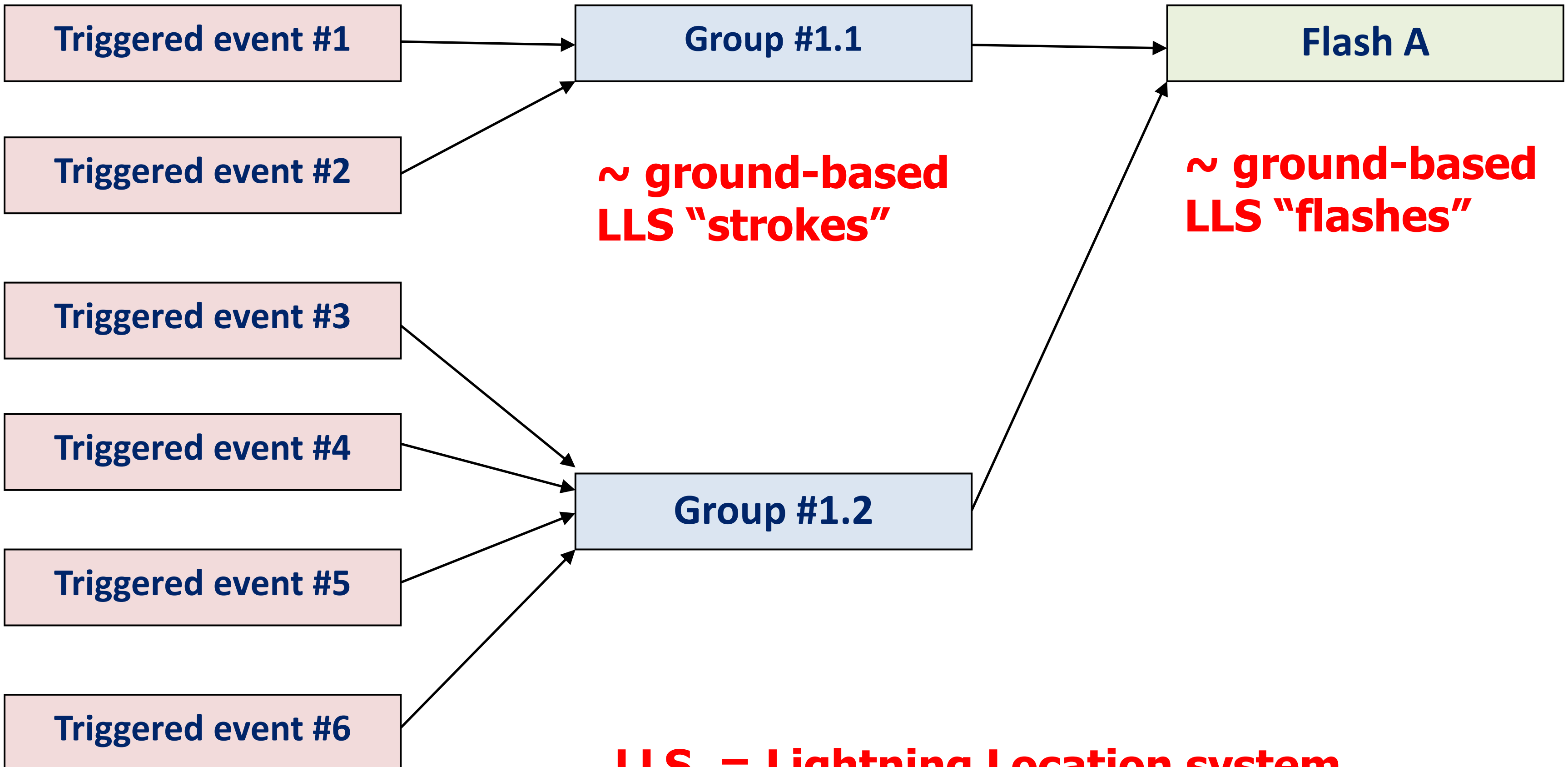
L2 Flashes/Groups/Events

The “Flash tree” combining the events and the groups into one flash

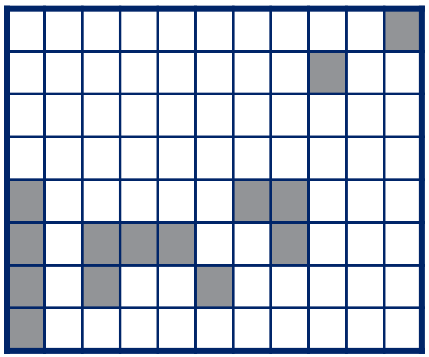


LLS = Lightning Location system

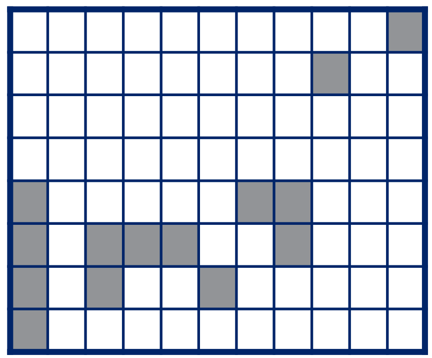
Groups and Flashes

Example/Conceptual representation of a L2 processing sequence:

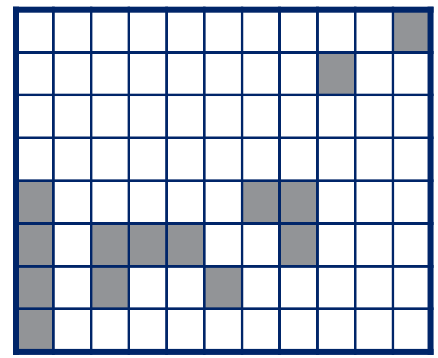
LI grid of 4.5 km at SSP



LI grid of 4.5 km at SSP



LI grid of 4.5 km at SSP



SSP = Sub-Satellite Point

Groups and Flashes

Example/Conceptual representation of a L2 processing sequence:

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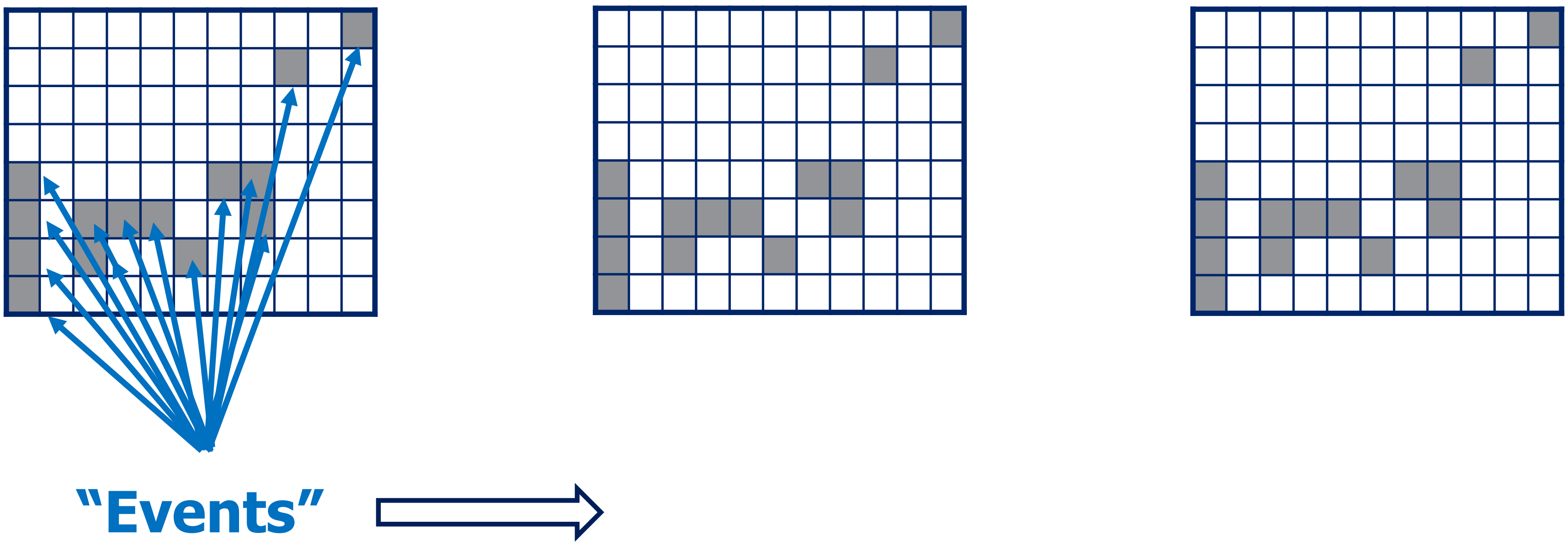
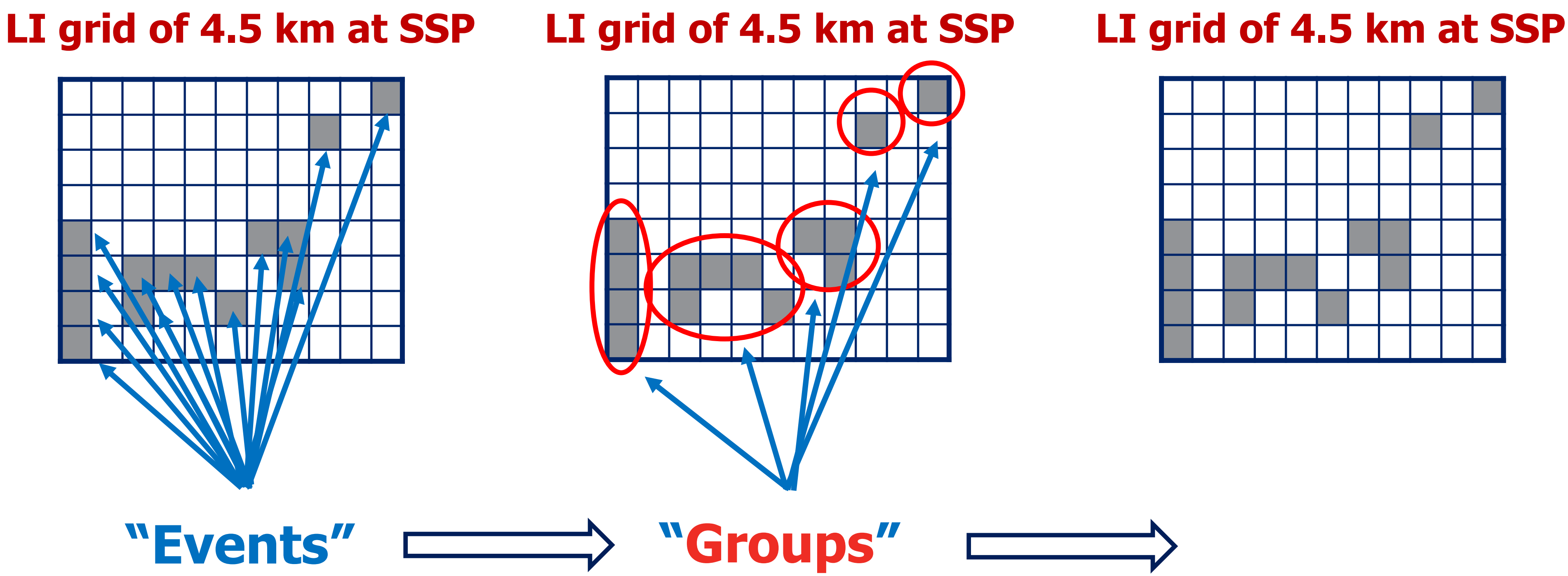


SSP = Sub-Satellite Point

Groups and Flashes

Example/Conceptual representation of a L2 processing sequence:



SSP = Sub-Satellite Point

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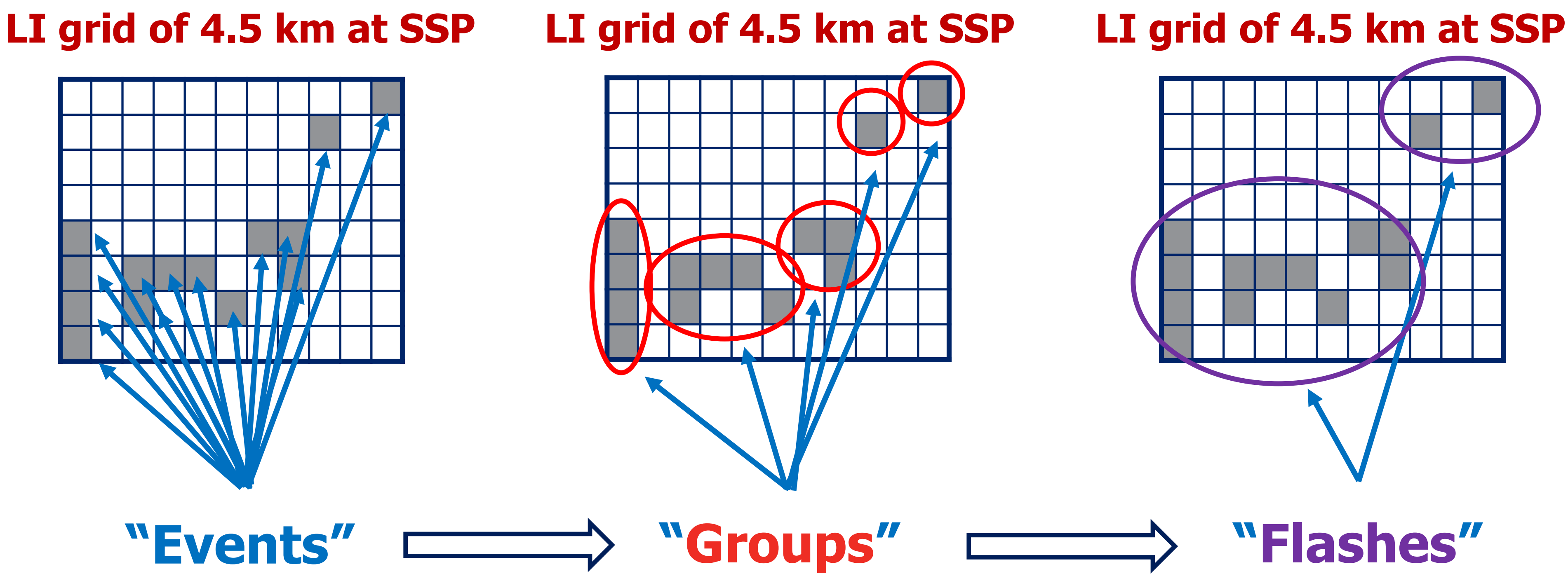


SSP = Sub-Satellite Point

L2 Accumulated Products

- **Accumulated products:**
  - **Collecting samples from a 30 second buffer**
  - **Presented in the same 2-km grid as the imager IR channel data for easier combining with imager information**
  - **Events define the extent in the products**
  - **Flashes define the values in the products**

  - **For a longer temporal accumulation, the 30 second products can be stacked according to users' preferences**

Background to accumulated products

- Current understanding has been that EUMETSAT users are mostly interested in:

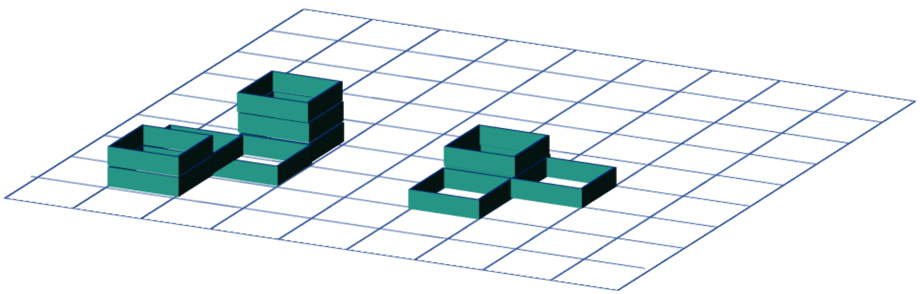
  a) **Flashes**
  b) **Understanding of "what kind of a flash" it is they are getting ("strength", duration, extent)**

⇒ Real-time users would be well served with the flashes (groups) and a supporting accumulated product coming from events

⇒ The periodicity of the product should be short enough that it fits well for any further application allowing stacking of data (30 seconds)

Accumulation status at *t* = 10s

 = Events in Flash #1



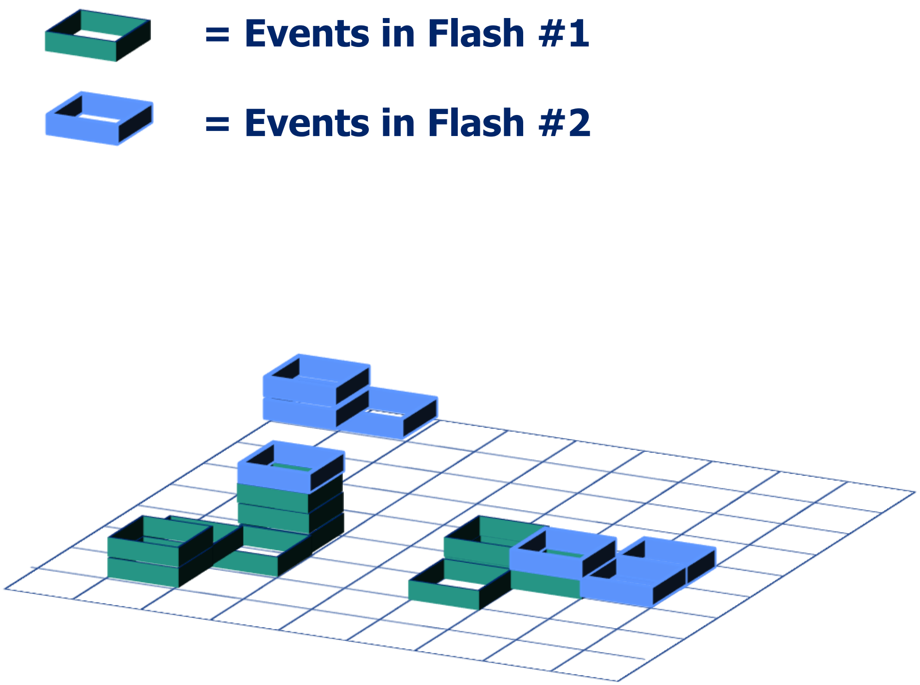
Event count in density buffer (and density grid)

		3			2	1		
	1	1			1			
	2							

Flash count in density buffer (and density grid)

		1			1	1		
	1	1			1			
	1							

Accumulation status at *t* = 20s



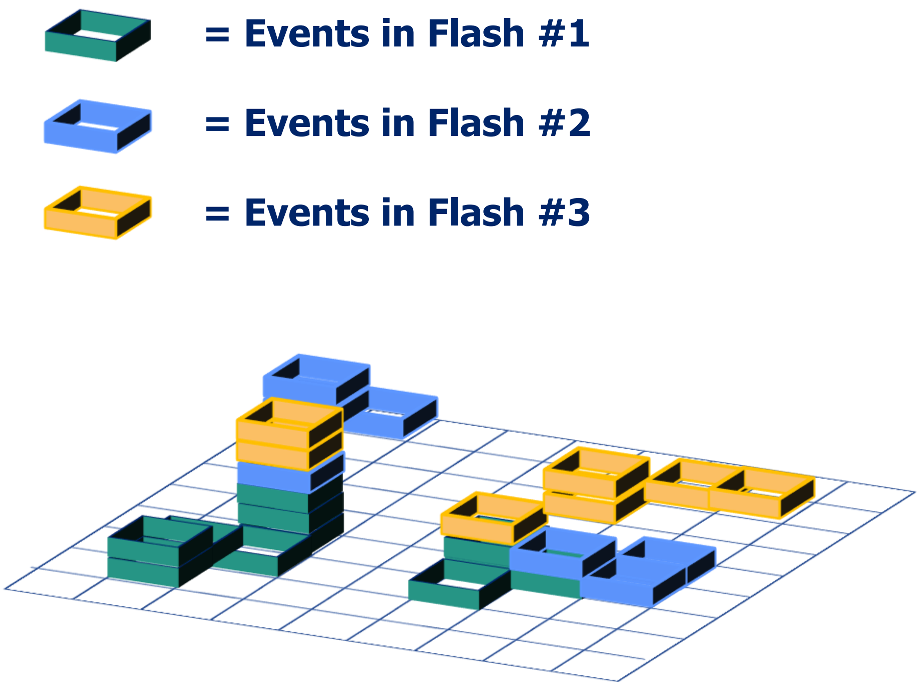
Event count in density buffer (and density grid)

2	1							
							1	
		4			2	2	1	
	1	1			1			
	2							

Flash count in density buffer (and density grid)

1	1							
							1	
		2			1	2	1	
	1	1			1			
	1							

Accumulation status at *t* = 30s



Event count in density buffer (and density grid)

2	1							
						1	1	
					2			
							1	
		6			3	2	1	
	1	1			1			
	2							

Flash count in density buffer (and density grid)

1	1							
						1	1	
					1			
							1	
		3			2	2	1	
	1	1			1			
	1							

Accumulated product stacking

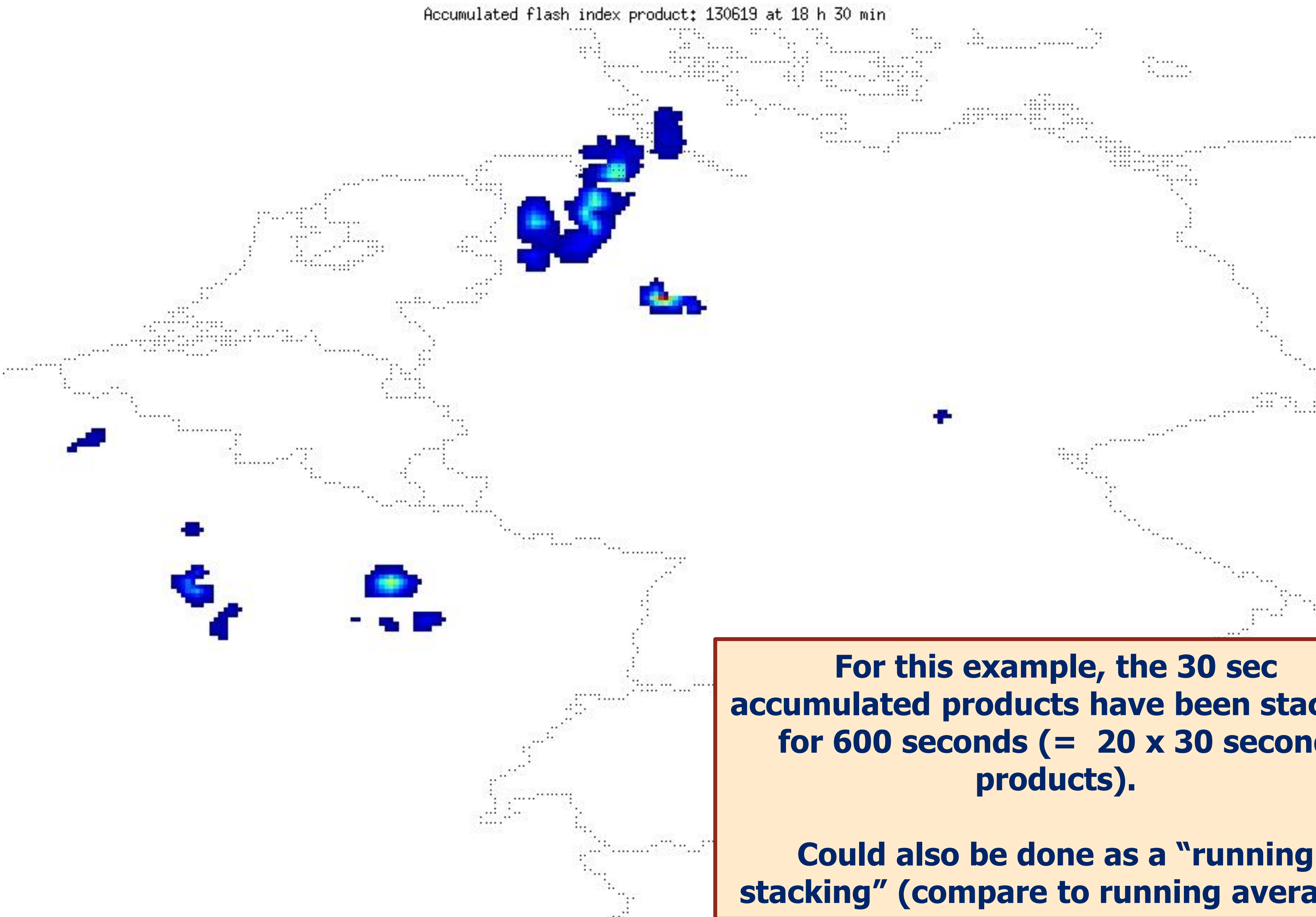
The original 30 sec product stacked into several longer time periods depending on application

Original 30 second product

Accumulated flash area product

- **stacking 5 products** — Accumulated flash area product → **2.5 min (= FCI Rapid Scanning Service FDC/4)**
- **stacking 10 products** — Accumulated flash area product → **5 min (= FCI Rapid Scanning Service FDC/2)**
- **stacking 20 products** — Accumulated flash area product → **10 min (= FCI Full Disk Scanning Service FDC)**

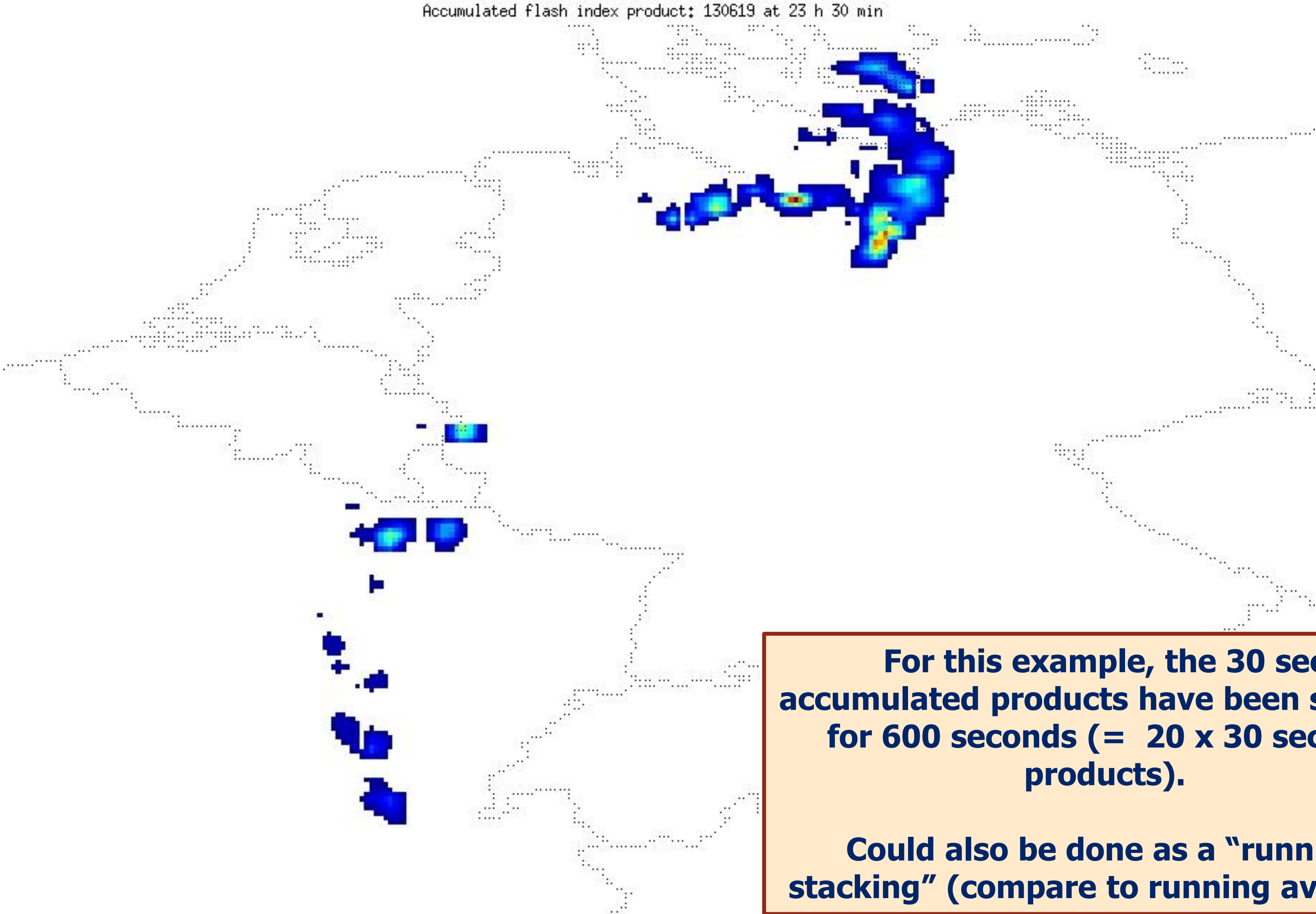
Example accumulated product: 19 June 2013 at 18:30



For this example, the 30 sec accumulated products have been stacked for 600 seconds (= 20 x 30 second products).

Could also be done as a "running stacking" (compare to running average)

Example accumulated product: 19 June 2013 at 23:30



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MTG LI Proxy Data – data available before launch

- MTG LI is without heritage in GEO orbit, and the closest comparison is the Lightning Imaging Sensor (LIS) on TRMM – currently still in operation
  - **However, LIS flying on LEO orbit can only monitor storms for less than 2 minutes at a time (and without European coverage)**

- Use of ground-based Lightning Location System (LLS) networks as a source of proxy data is not straightforward, as they are based on Radio Frequency (RF) observations of lightning and depending on the RF band (VHF, VLF, LF) they are sensitive to different parts of the lightning process

- A combination of **optical + RF** observations has been selected for proxy data generation

MTG LI Proxy Data – current approach

- The best compromise is to use ground-based lightning data, but converted to optical pulses based on case study comparisons with LIS data.
- One of the networks in operation in Europe (LINET) is currently the main source of such proxy data for the LI activities.
- LINET data has been compared in measurement campaigns to other ground-based systems and to LIS
- As an outcome, a model for transforming the LINET stroke data into optical emission ("pulses") has been created

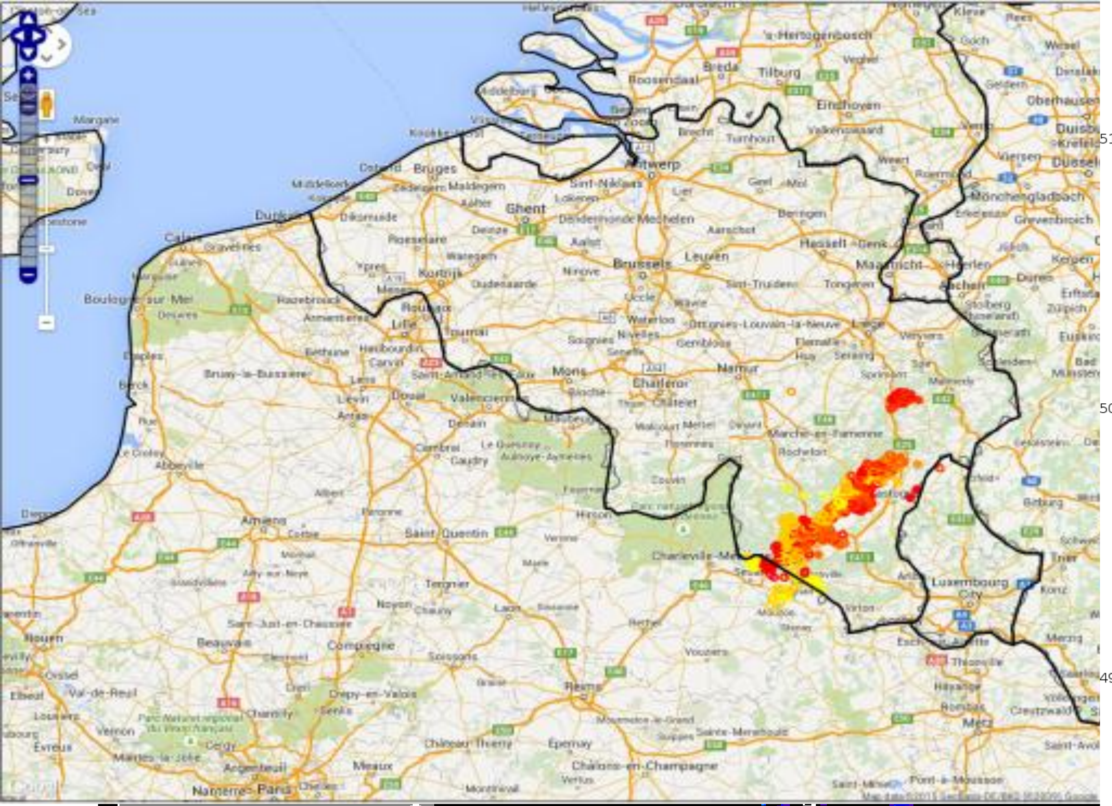
Proxy data examples

- In the following slides a comparison created by RMI (Belgium) is shown. It consists of:

- Top-right panel:
  - **RMI ground-based data: combination of SAFIR and LS700x sensors placed in Belgium and also in France, Netherlands and Germany.**

- Top-left panel:
  - **LI proxy data (L2 accumulated product)**
  - **Based on LIS/LINET transformation statistics, taking into account the varying DE of LINET in the coverage area**

- Bottom panel:
  - **Weather radar composite**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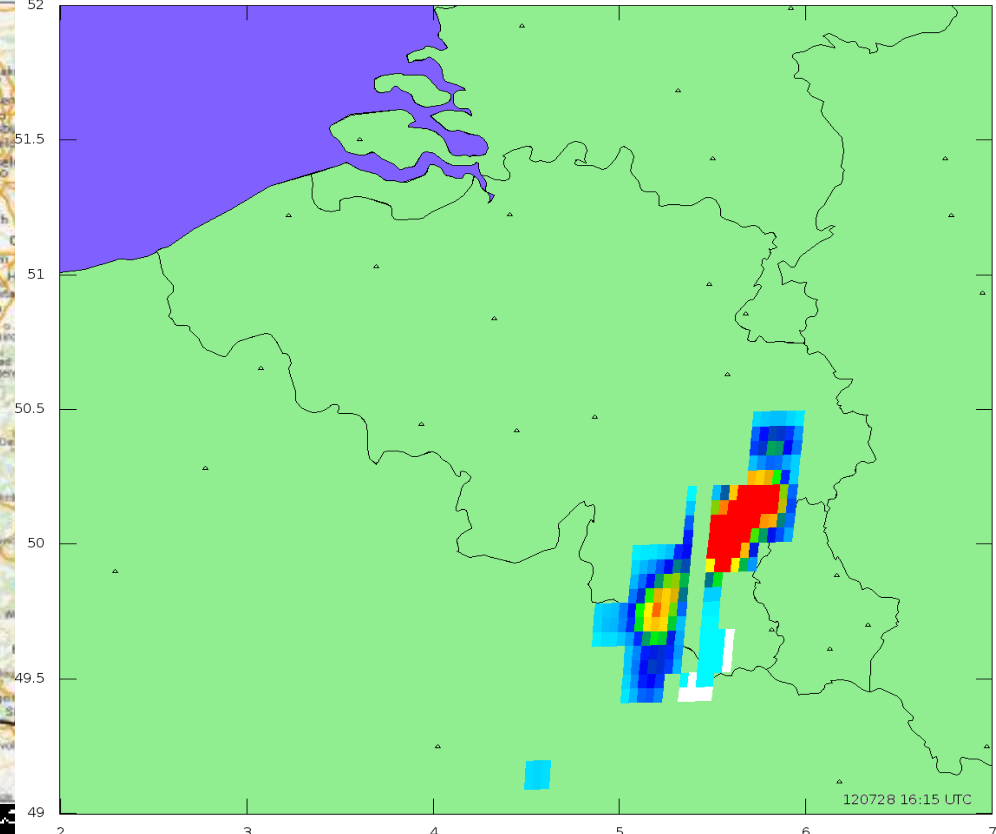
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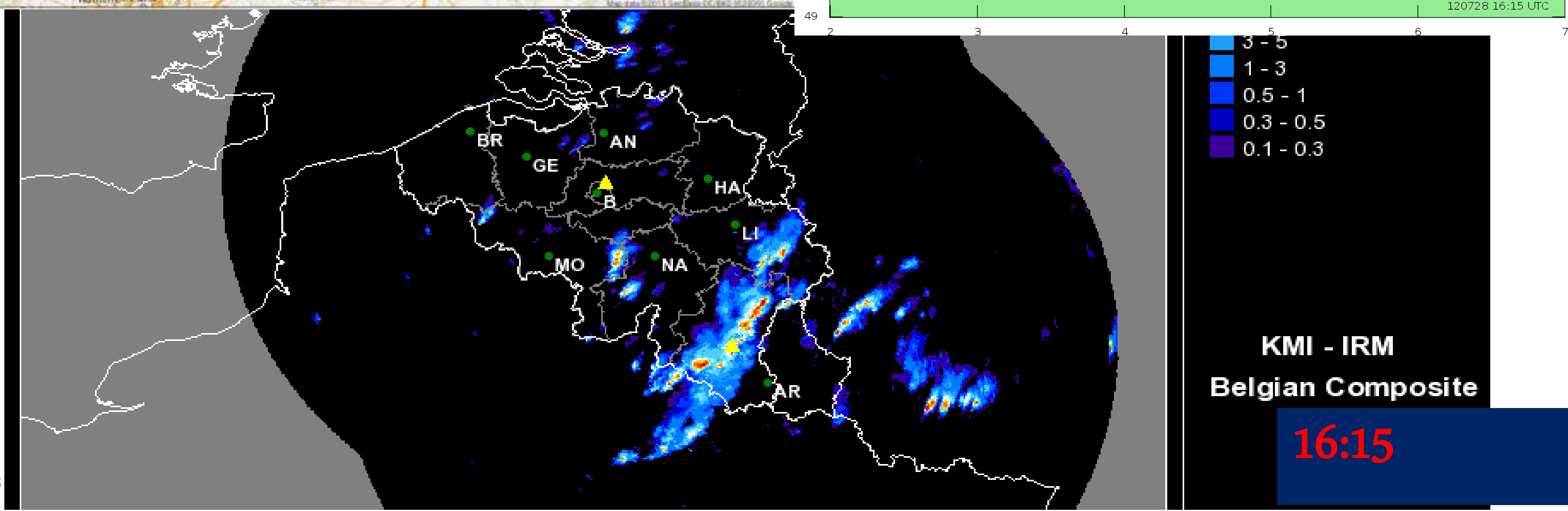
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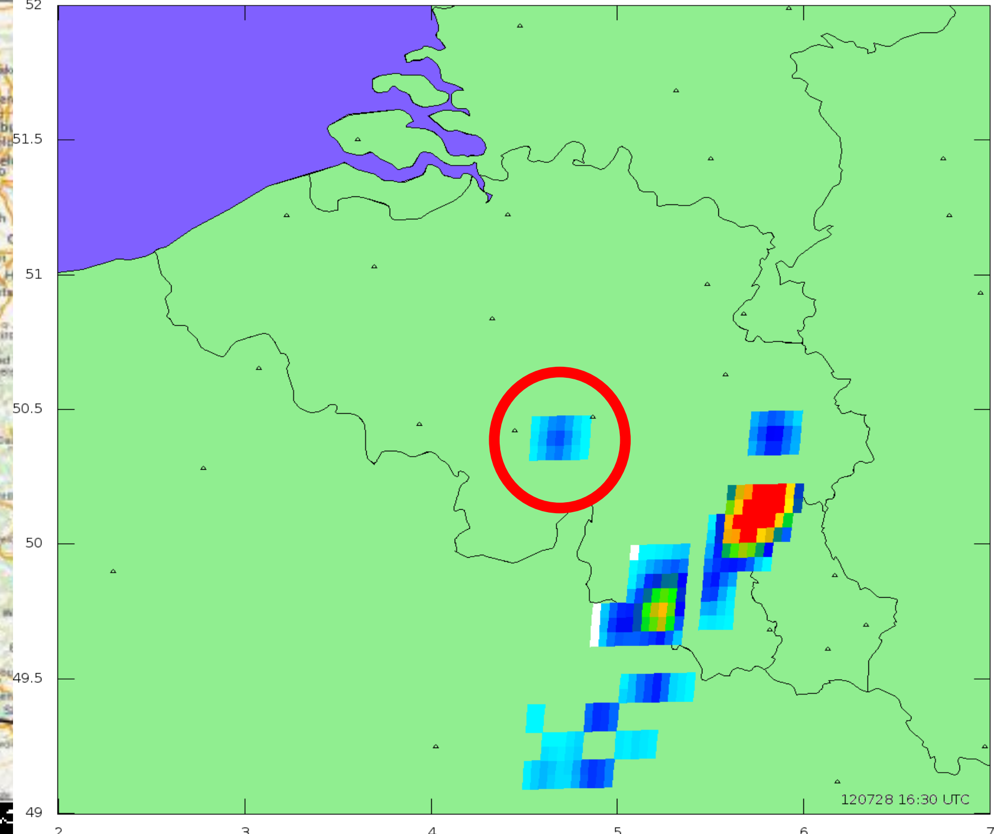

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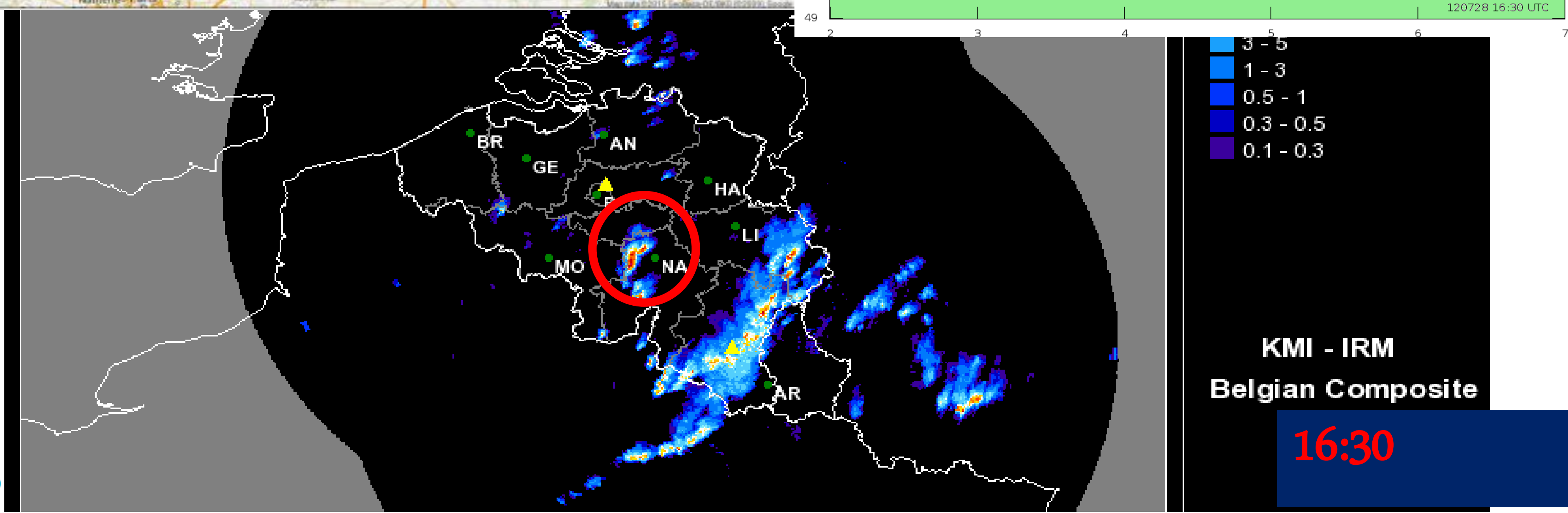

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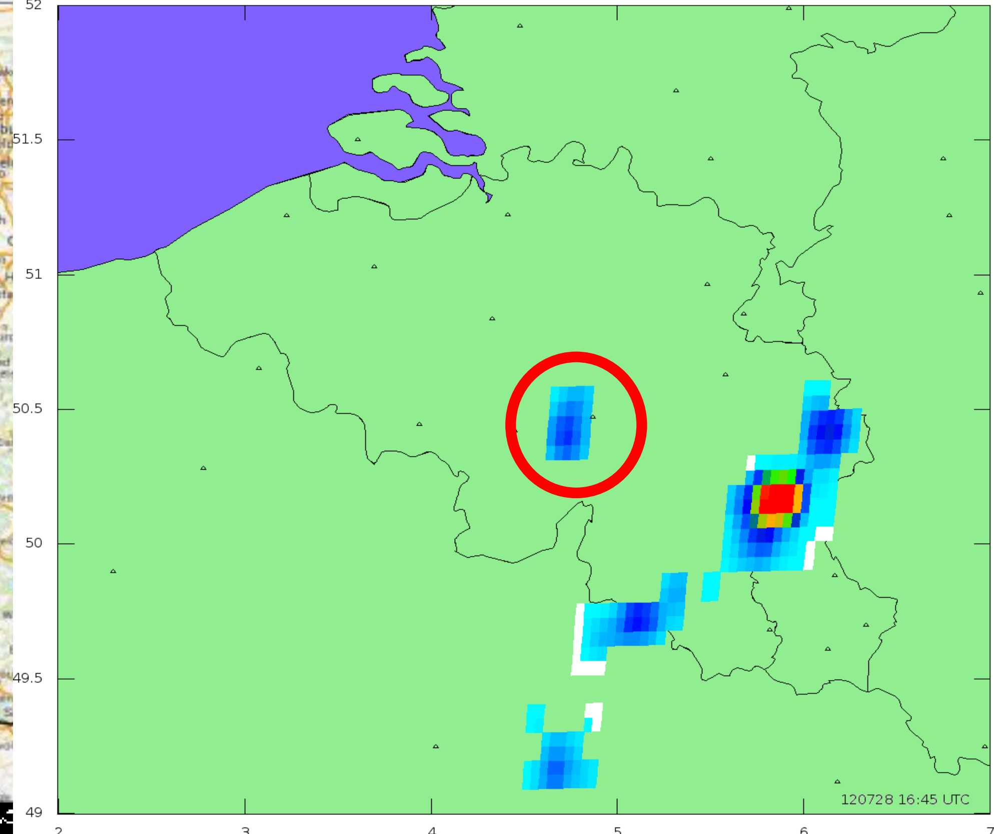

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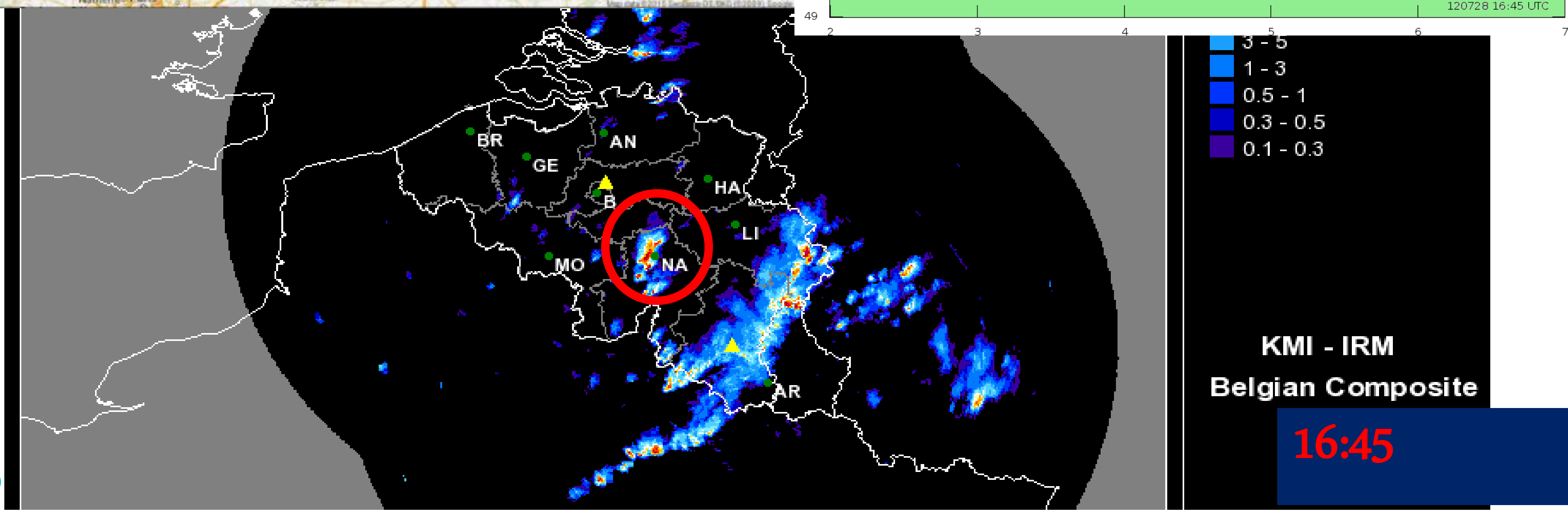

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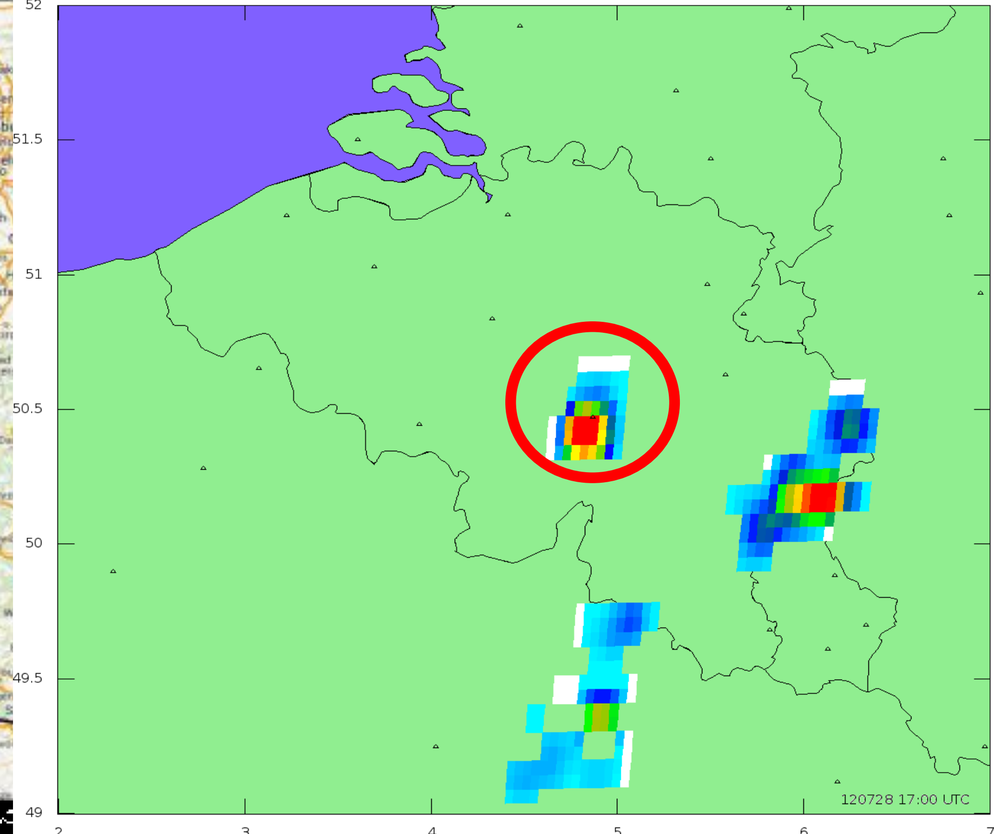

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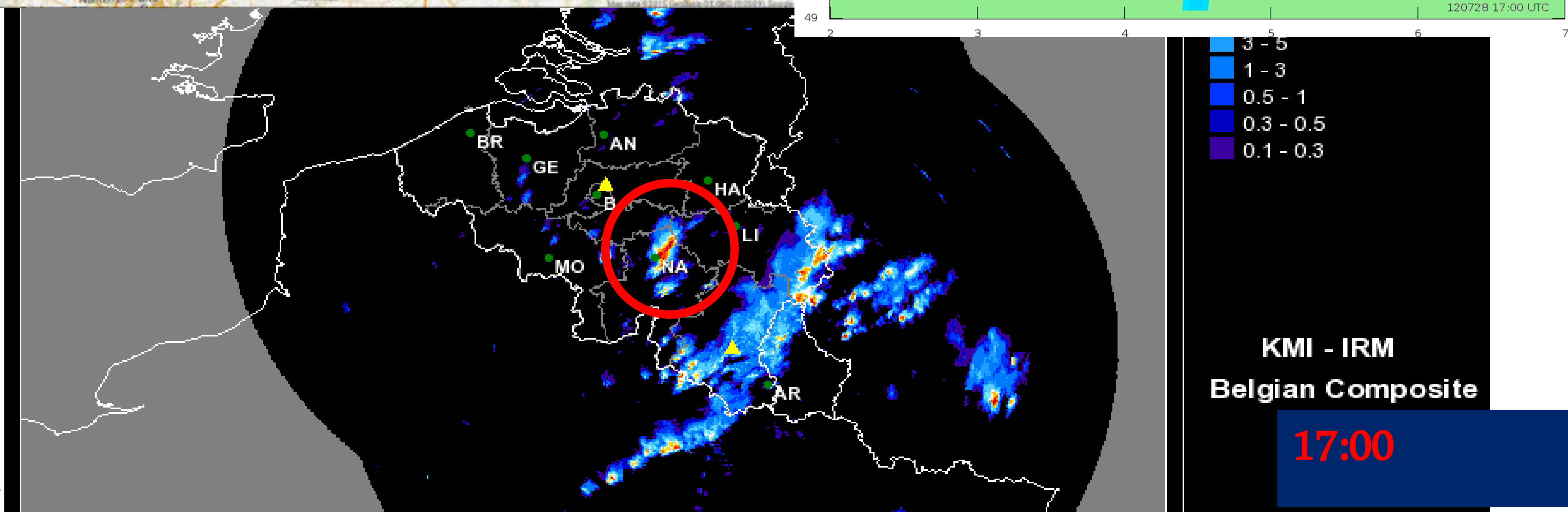

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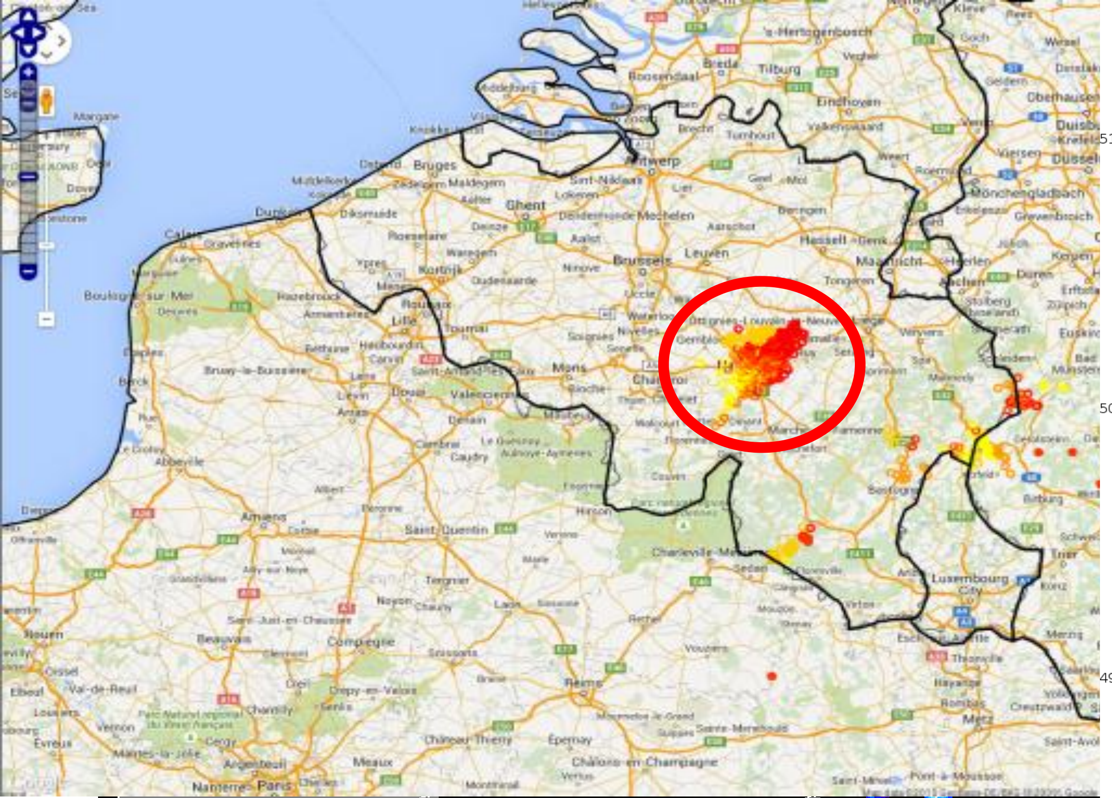
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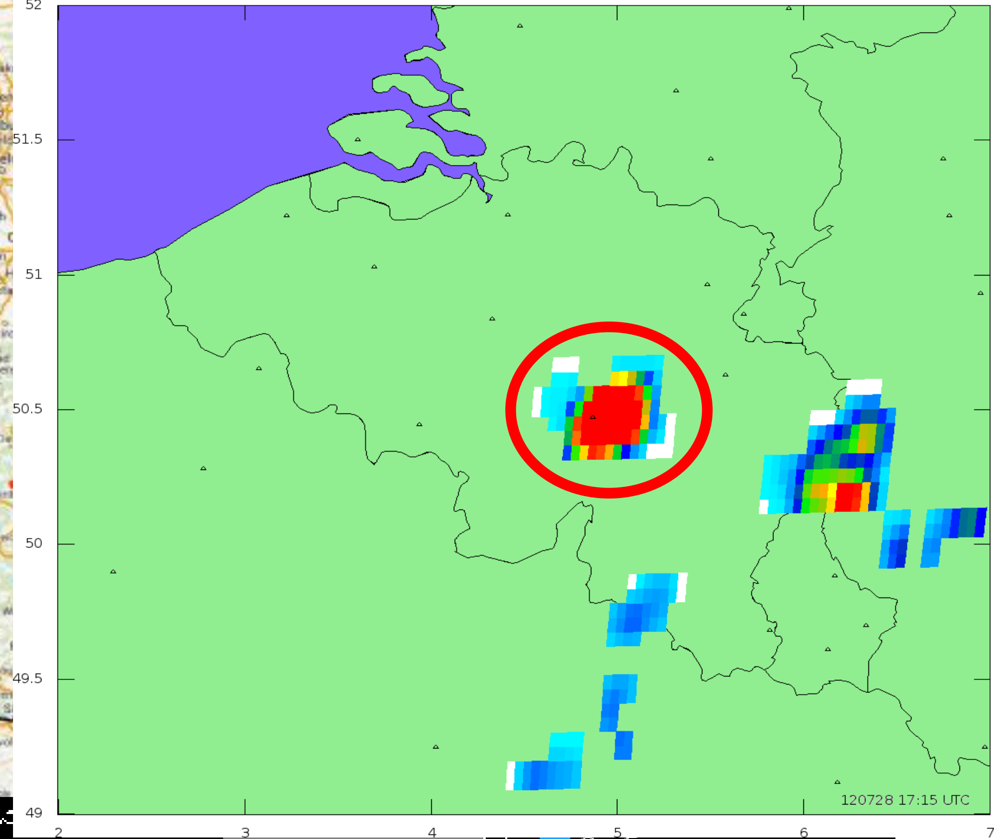
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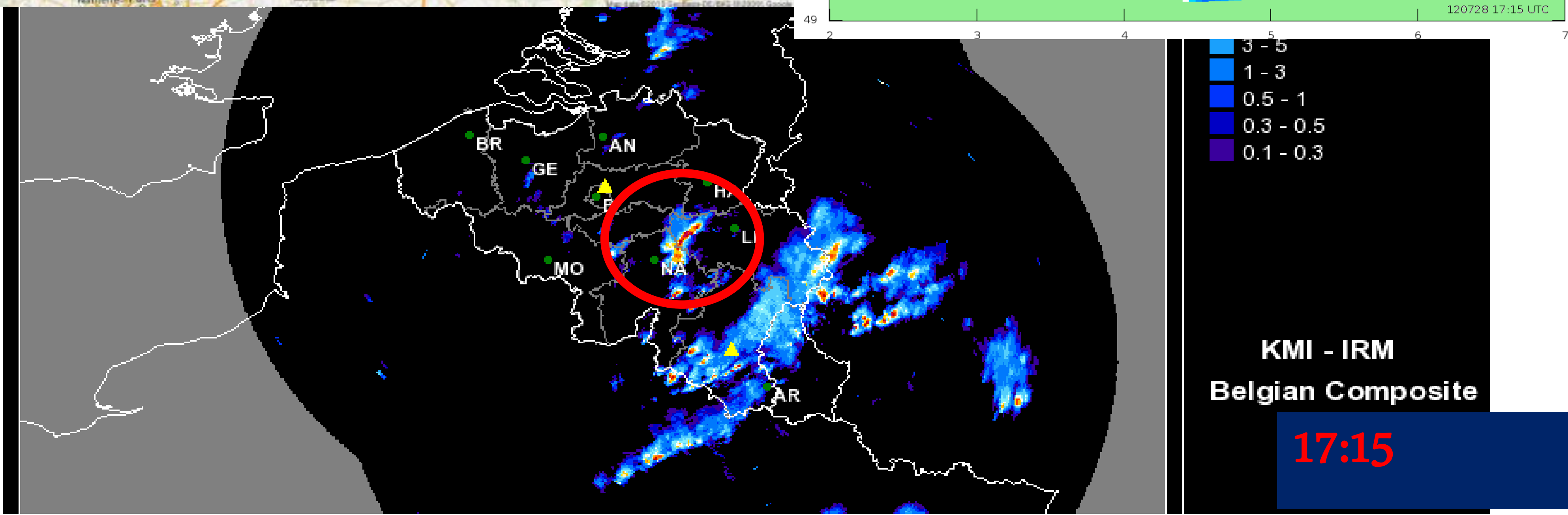
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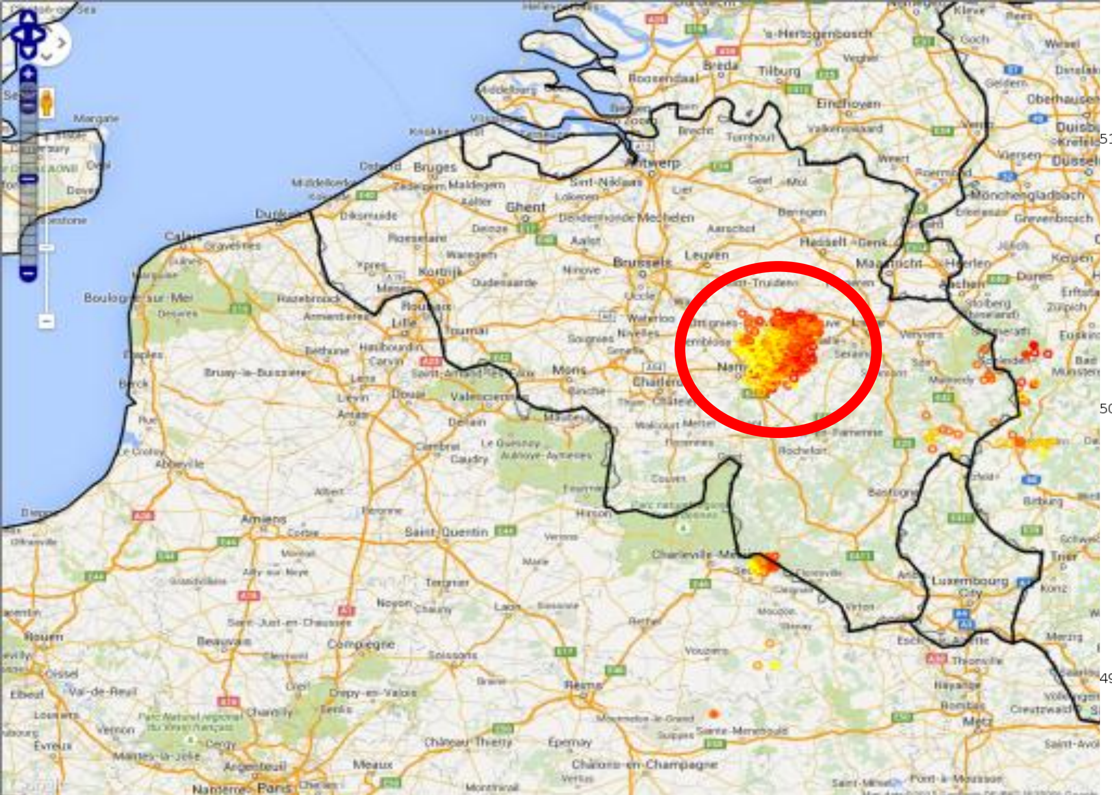
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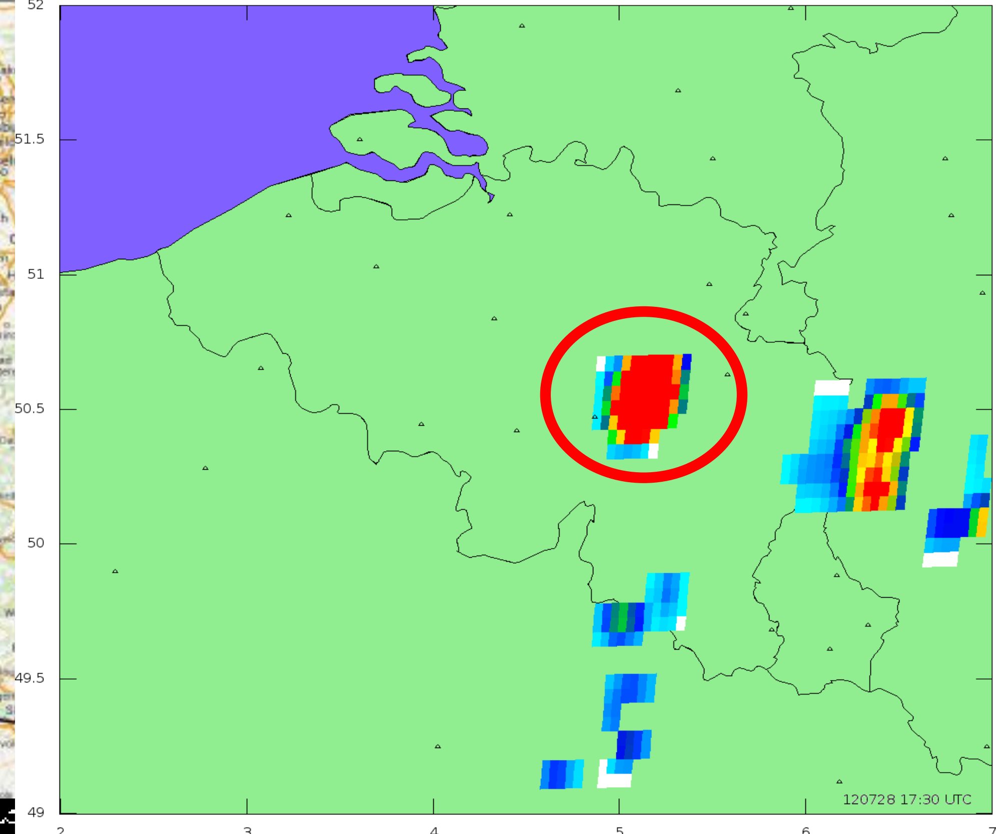
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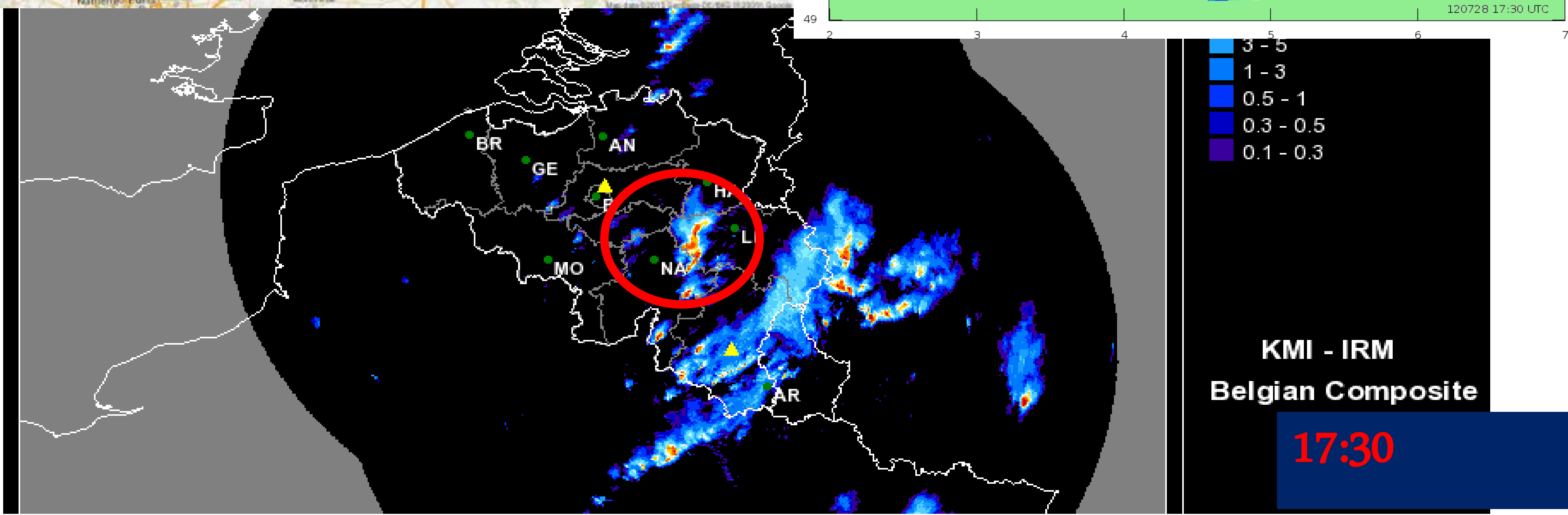
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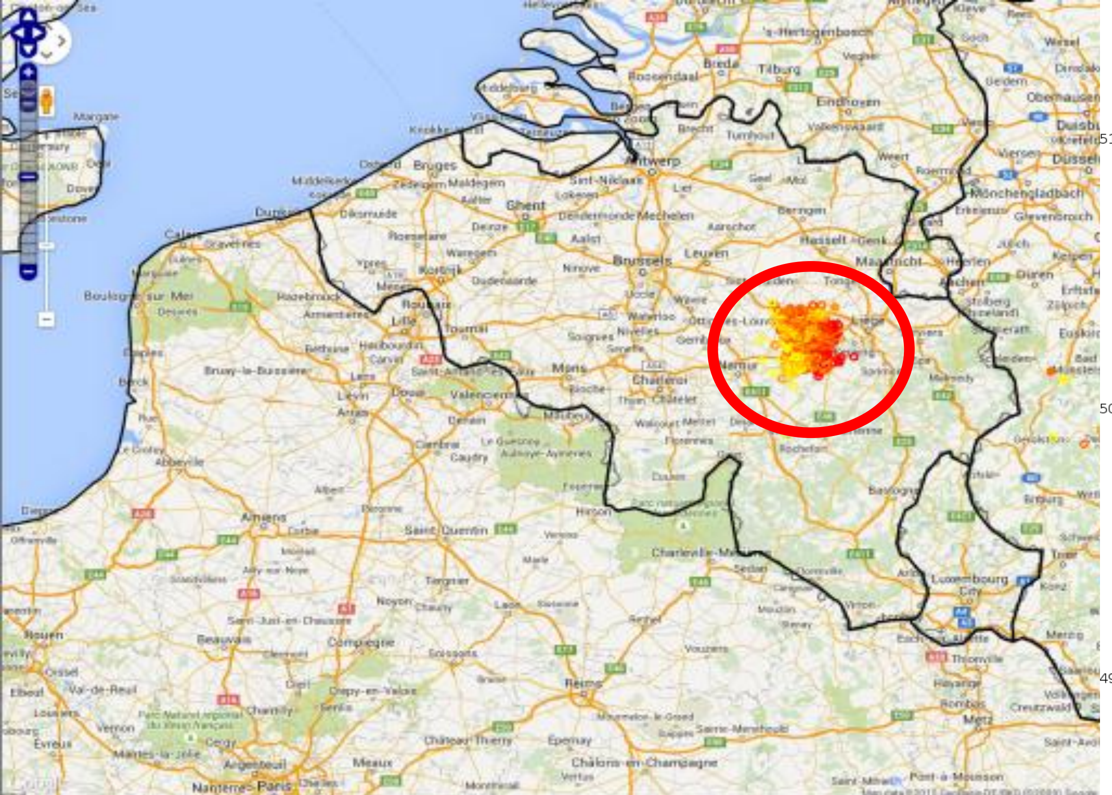

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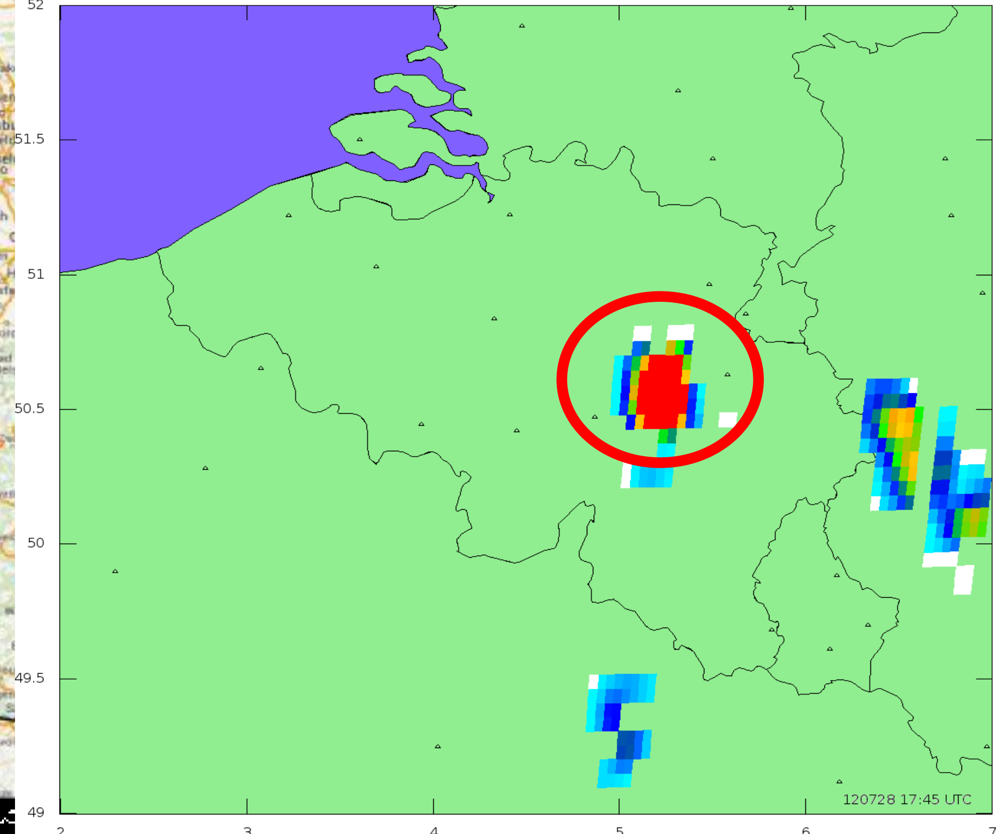

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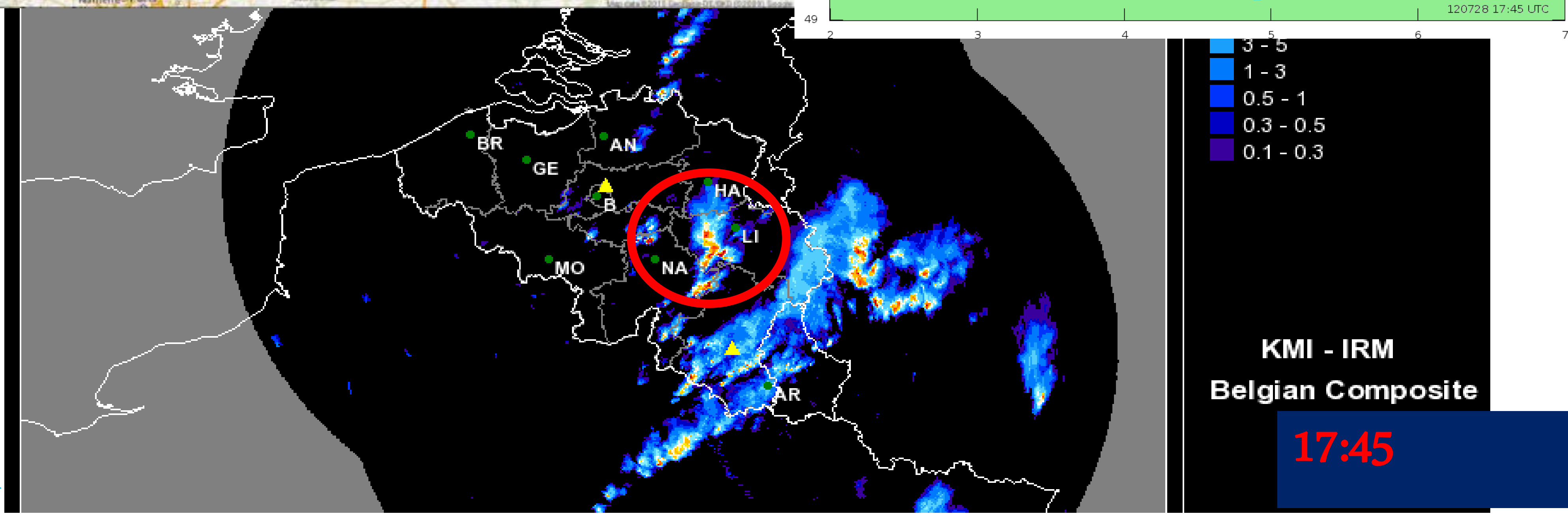

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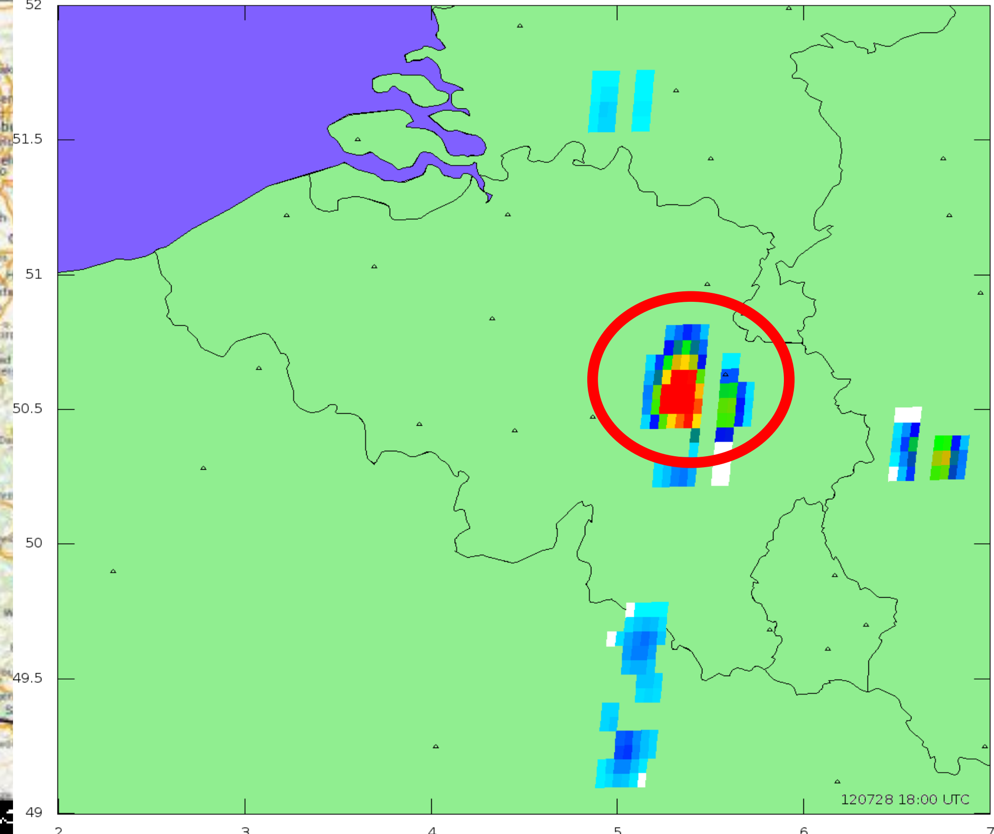
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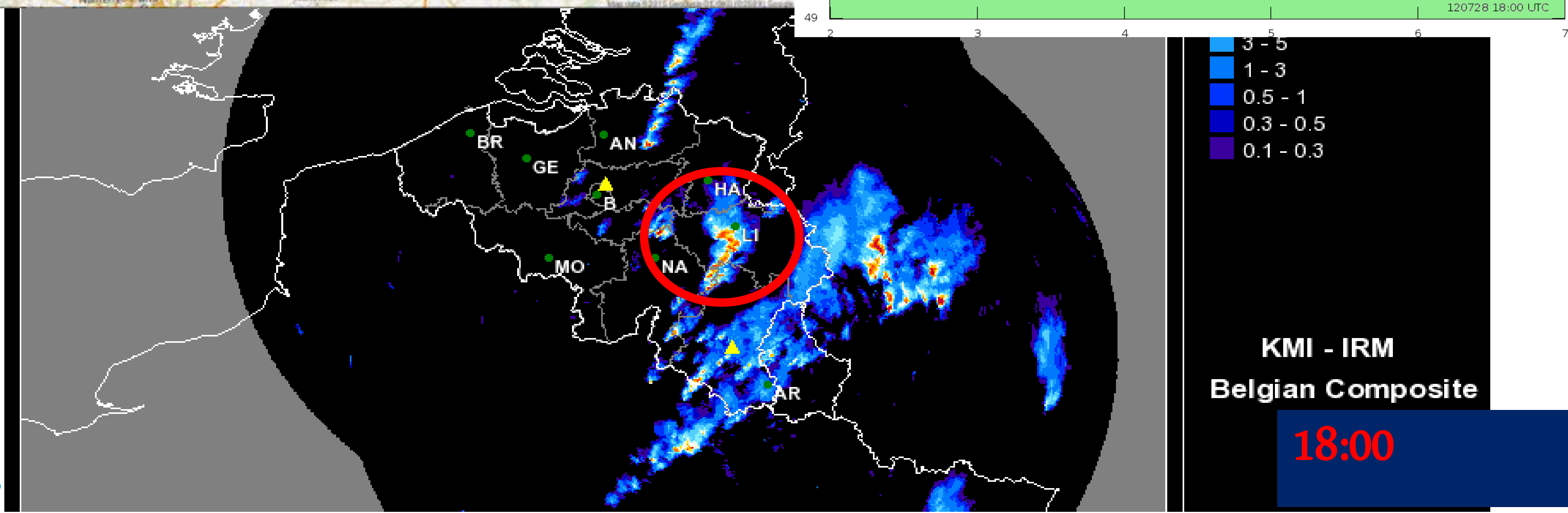
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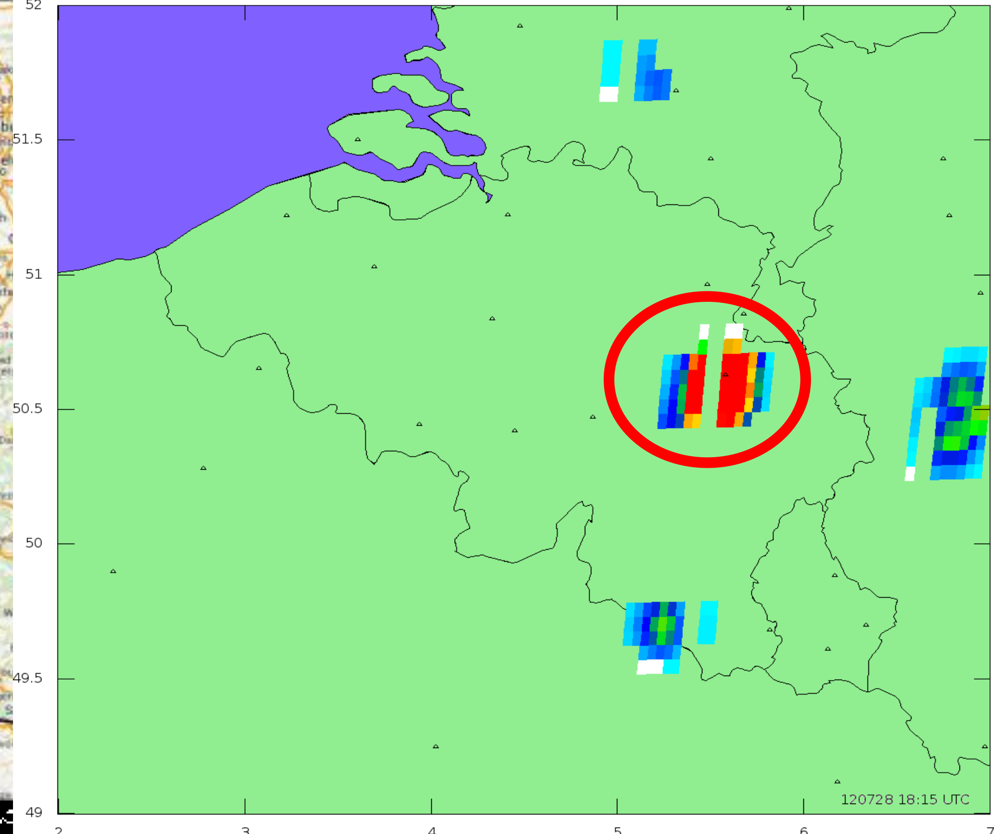
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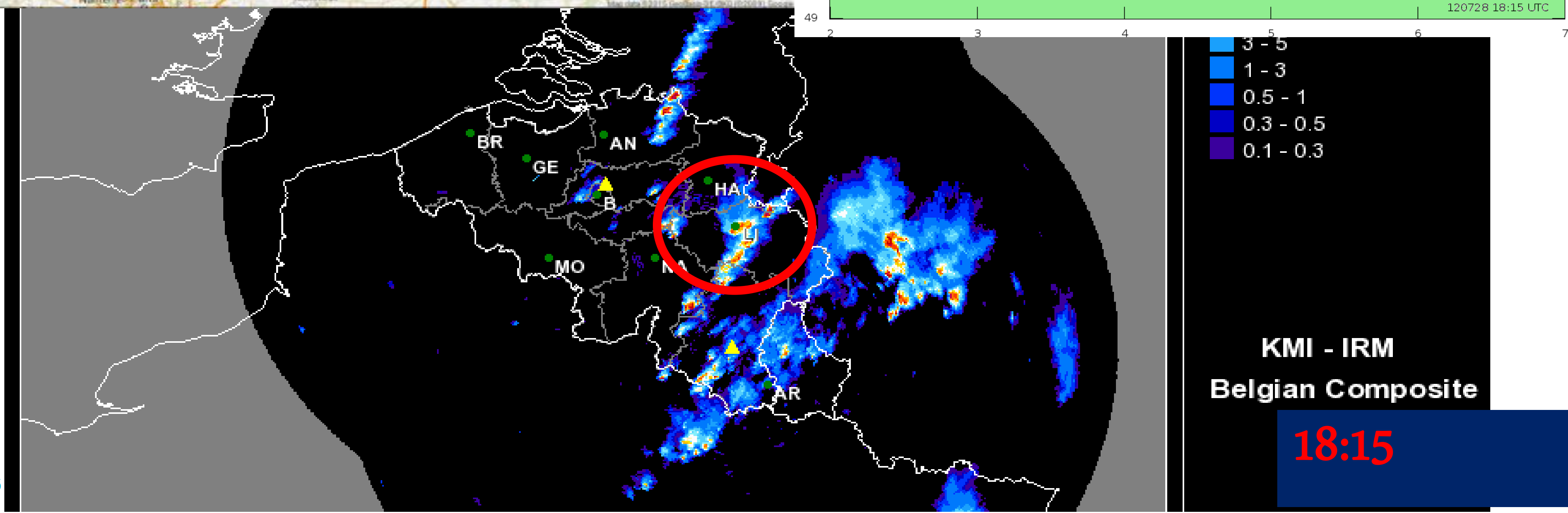
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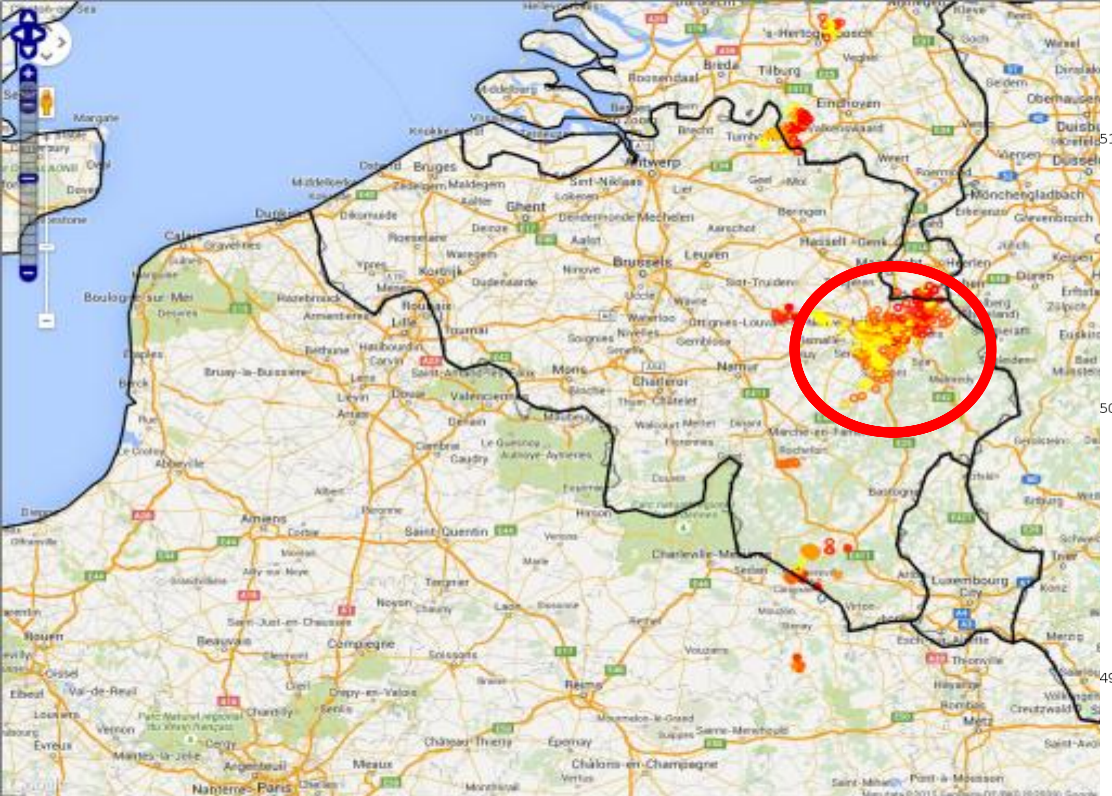

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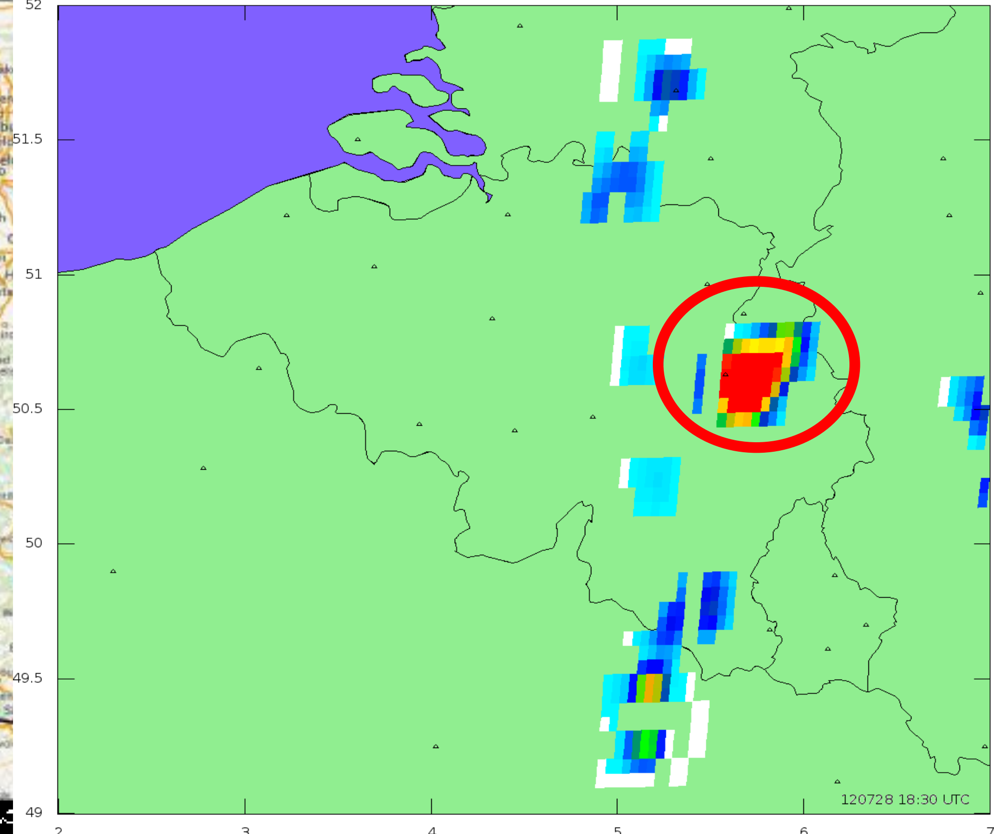

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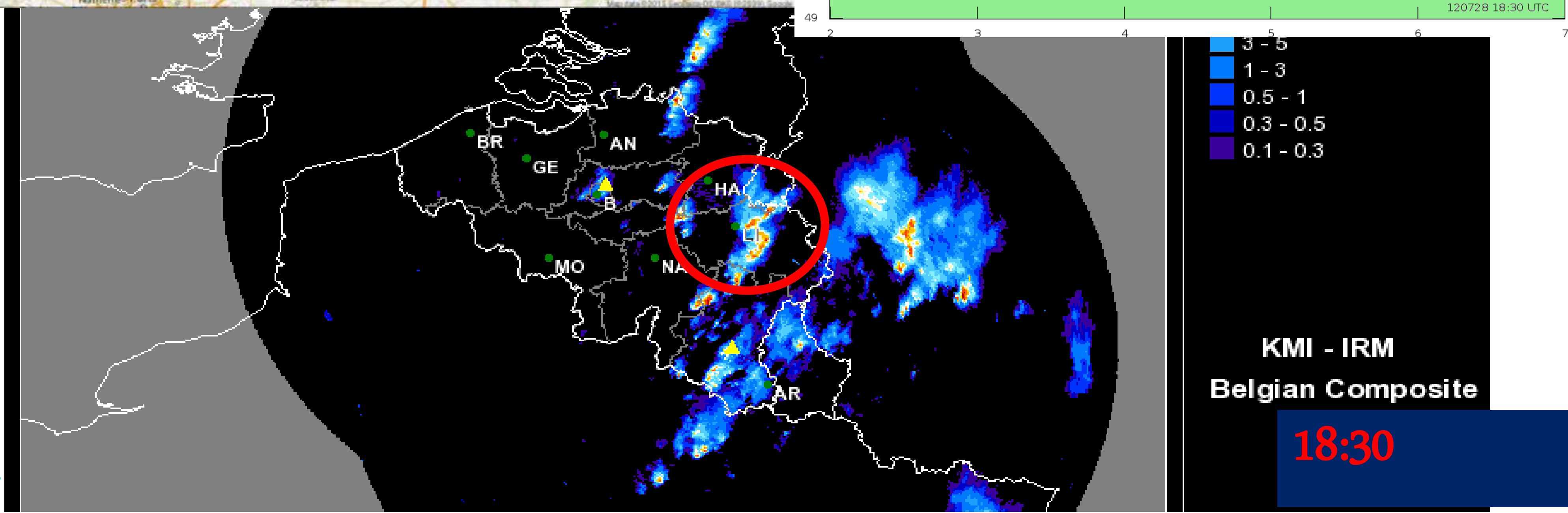

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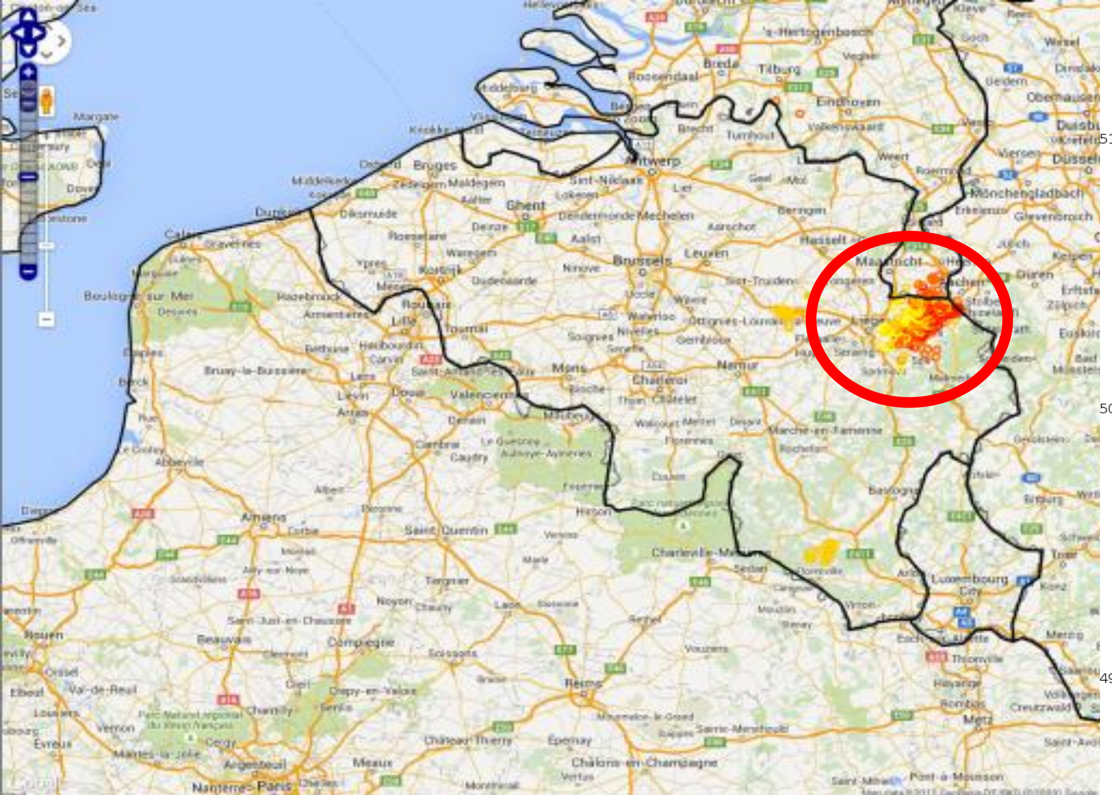

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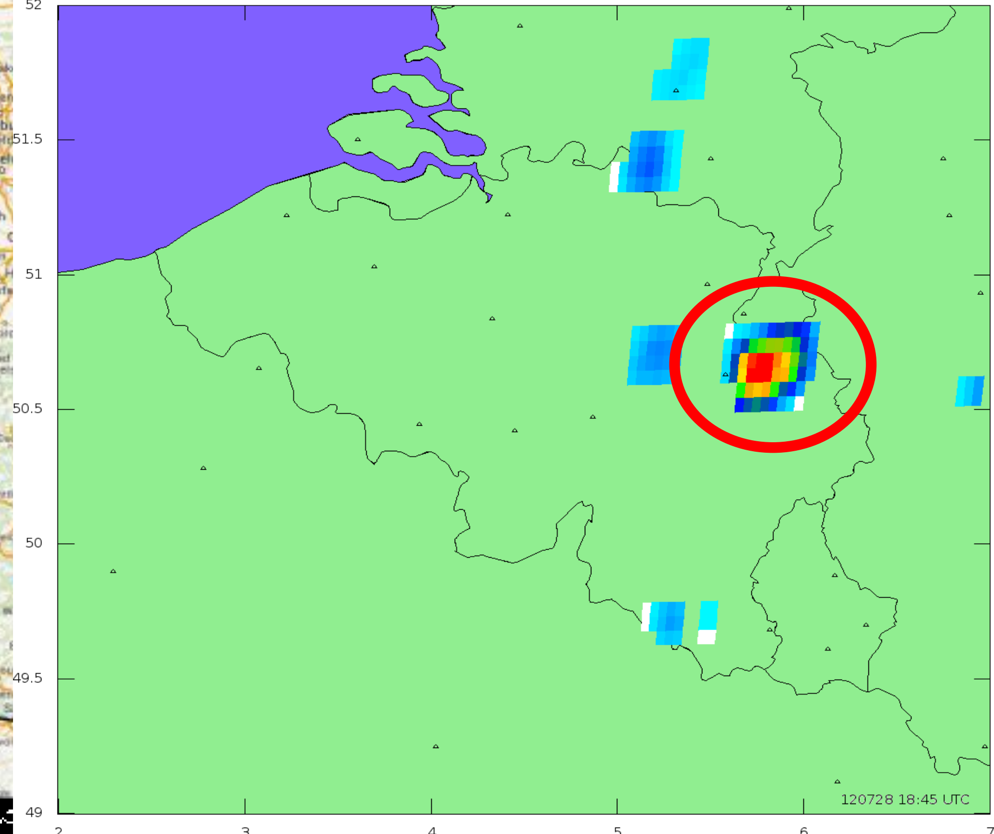

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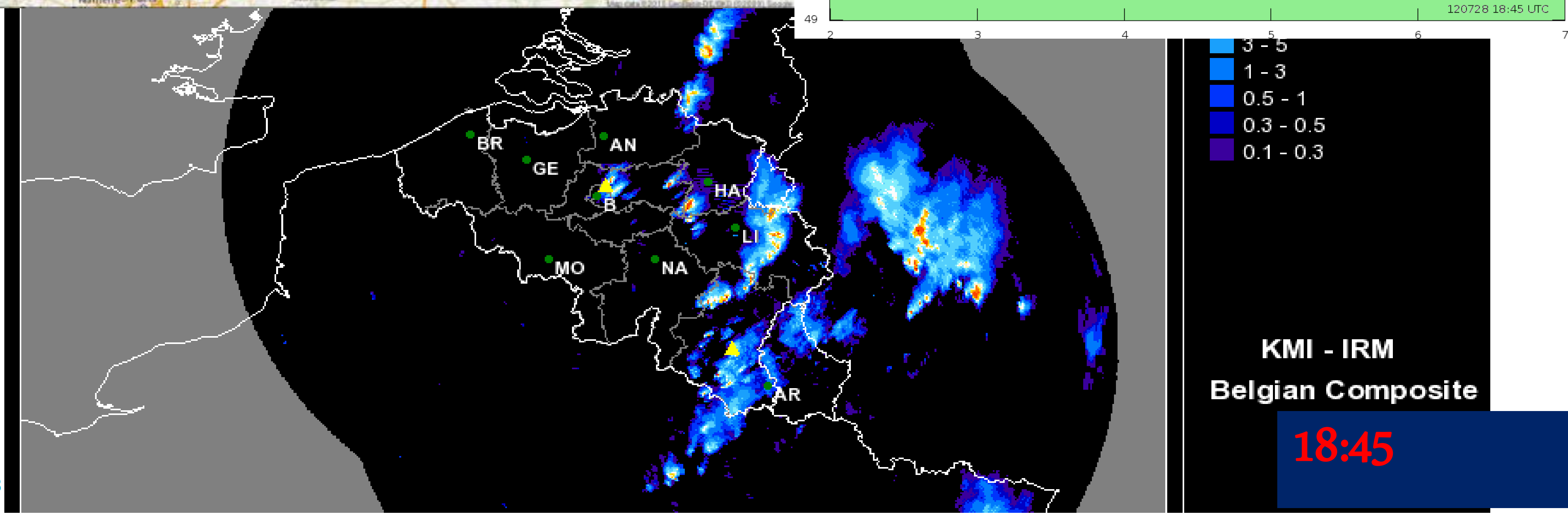

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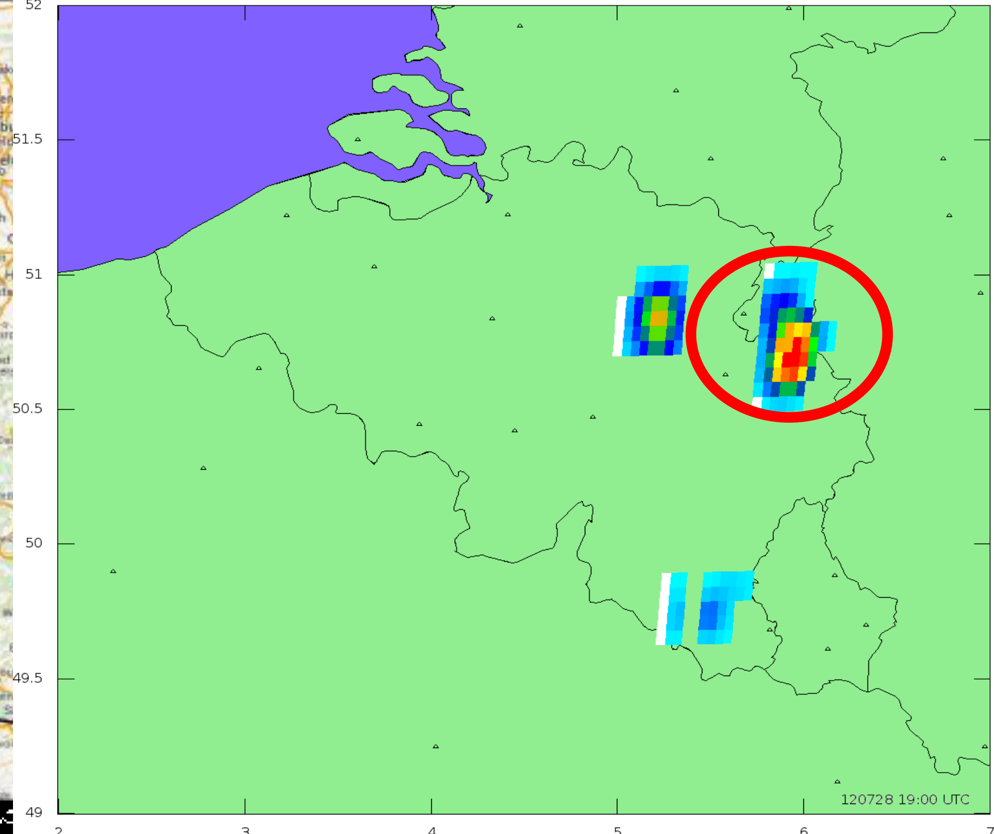
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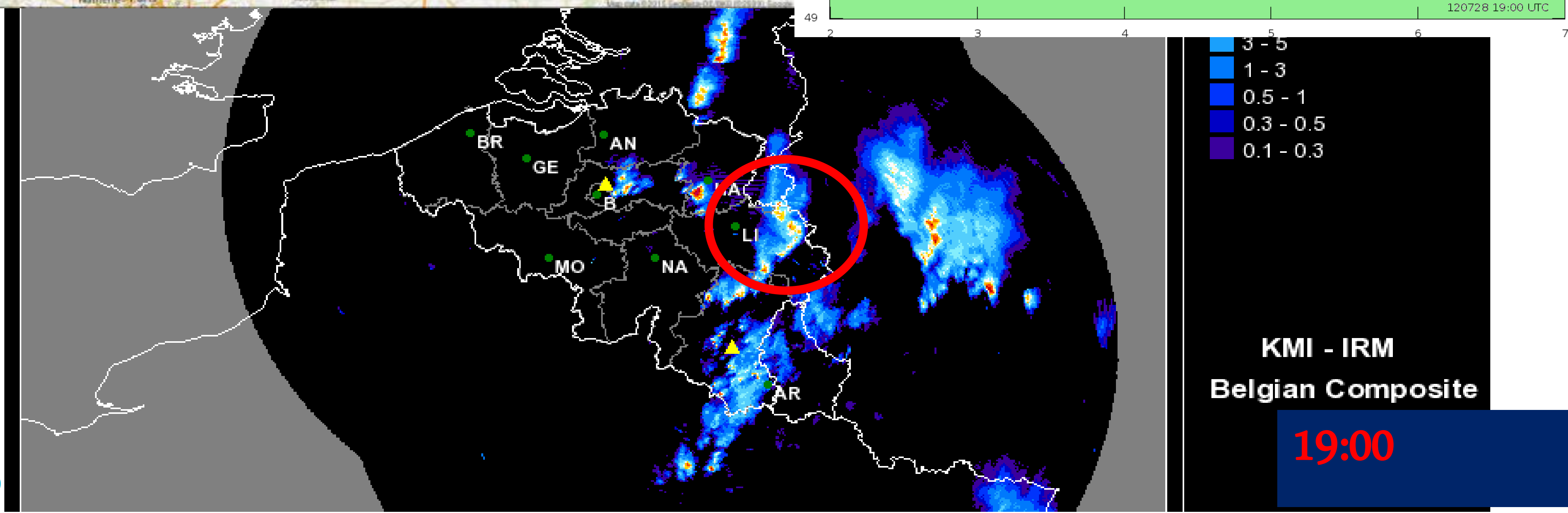
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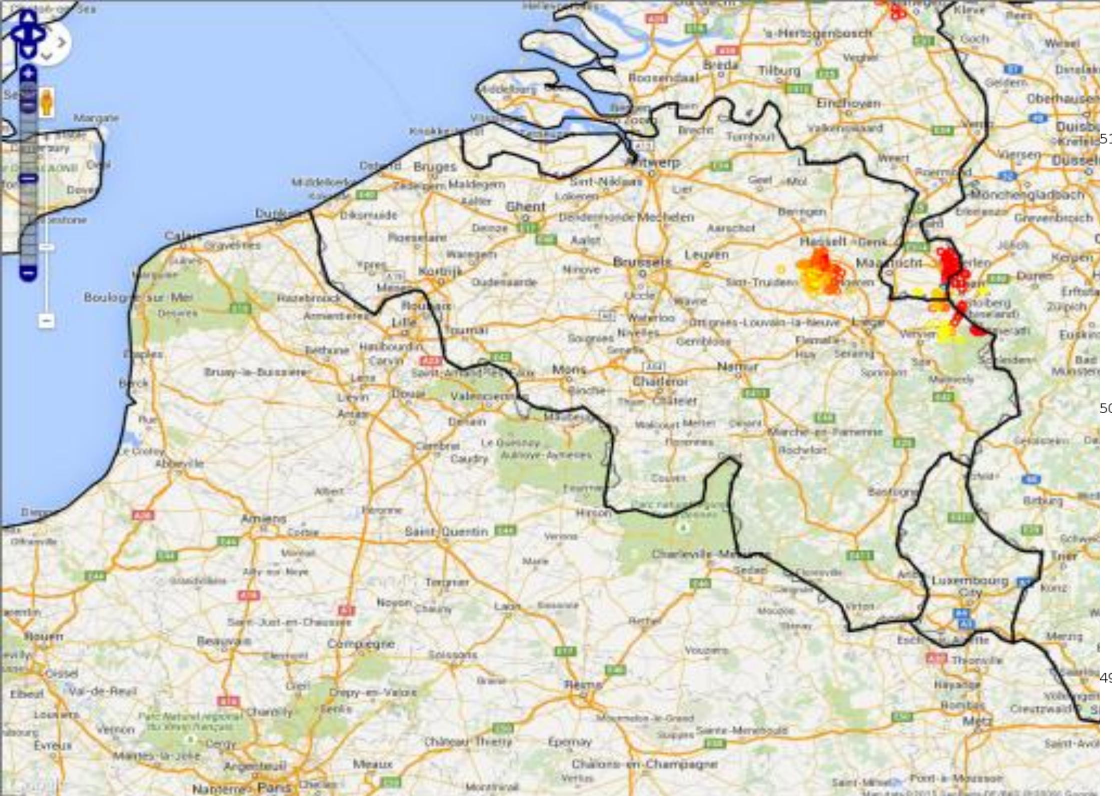
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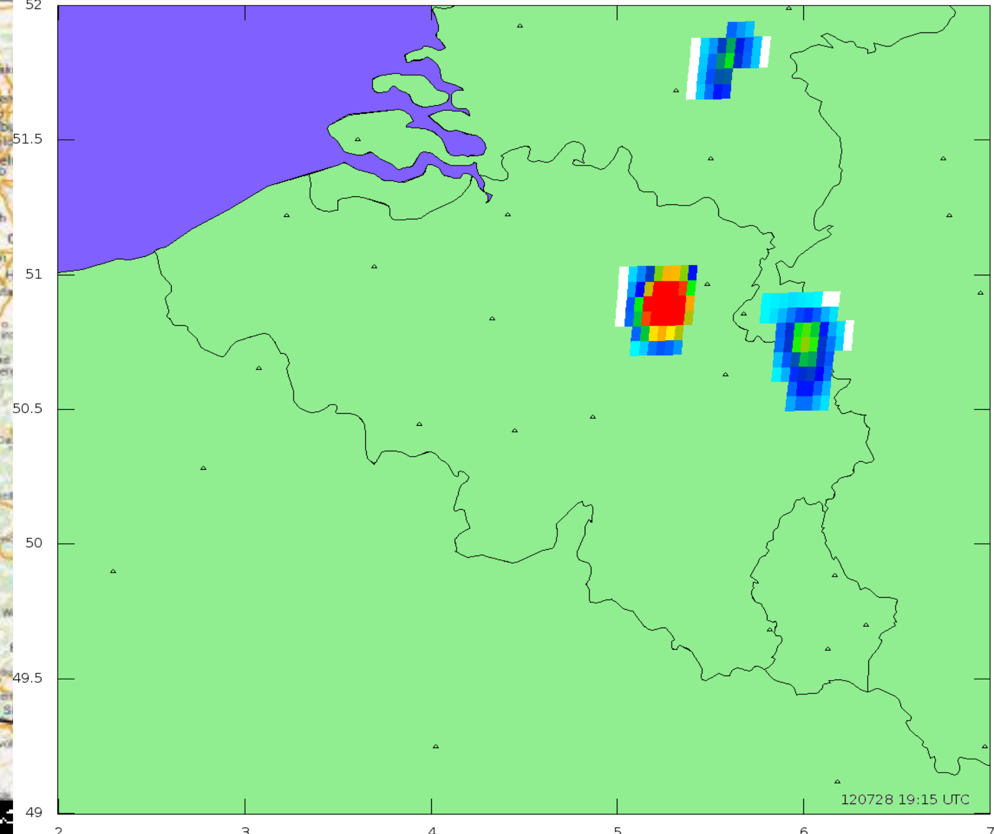
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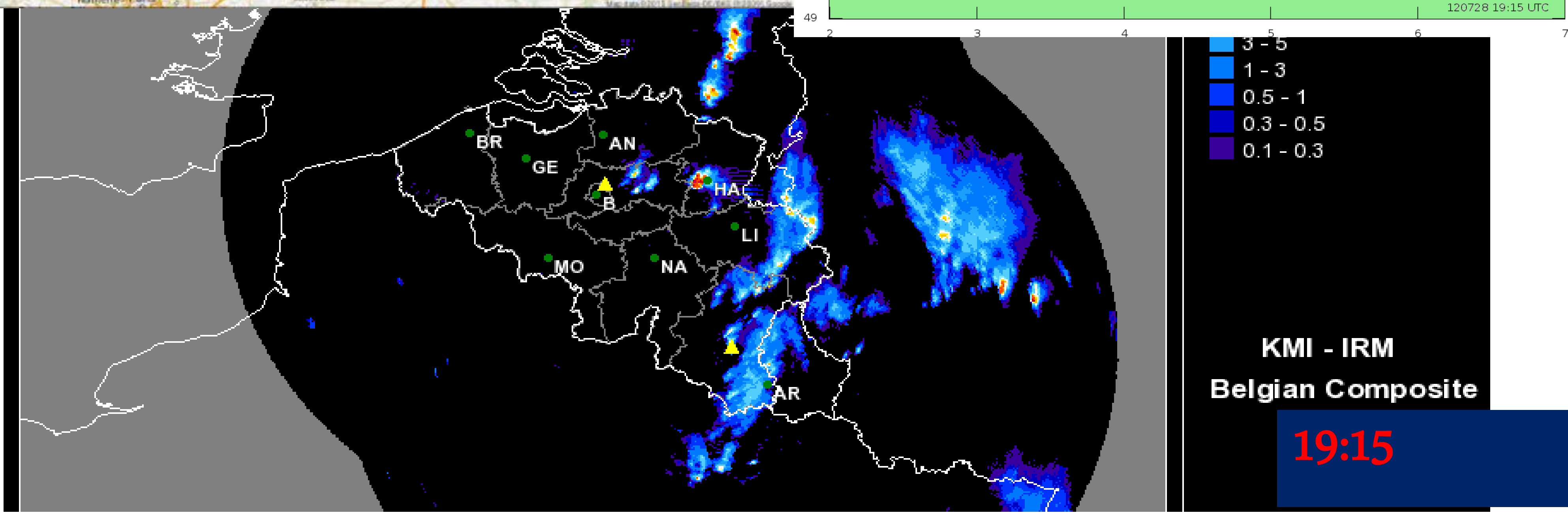
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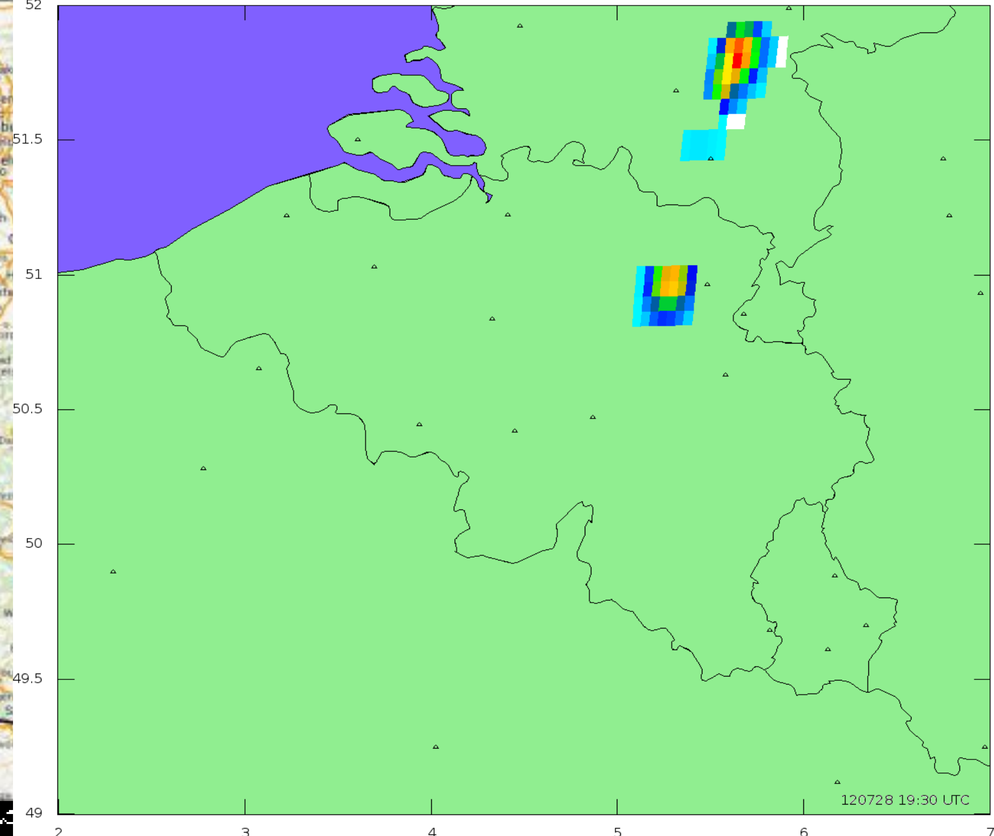
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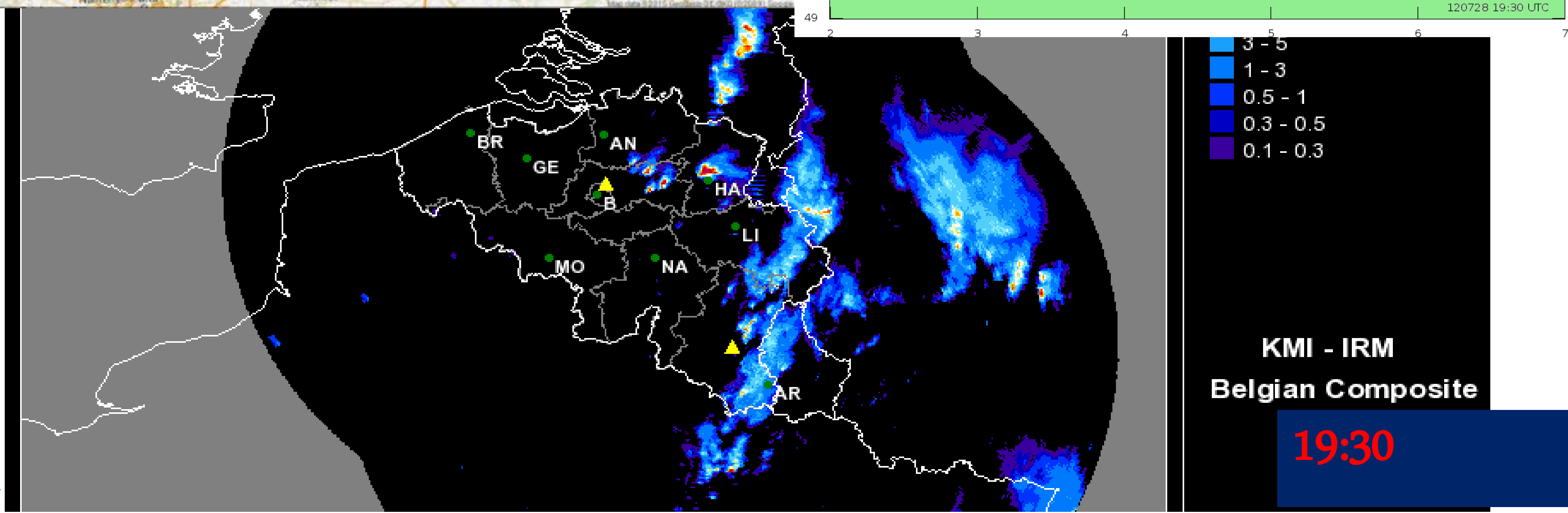
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Topics

- Putting Meteosat Third Generation (MTG) into context
- Lightning monitoring from space – how does the concept work
- MTG Lightning Imager
  - **Design and characteristics**
  - **User products**
- Proxy data development
- Summary

Summary

- The Lightning Imager is a new mission on Meteosat Third Generation, with no heritage in Europe (first GEO mission will be on GOES-R in 2016)
  - **(almost) Full disk coverage with 4 different detectors**
  - **Homogeneous and continuous observations of lightning flashes with a timeliness of 30 seconds**
  - **To be launched in 2019**

- User products consist of
  - **Initial processing data (groups and flashes)**
  - **Accumulated product data**

- Proxy data for LI available from 2015 onwards (continuous development)