Overshooting tops – satellite-based detection methods and correlation with severe weather conditions

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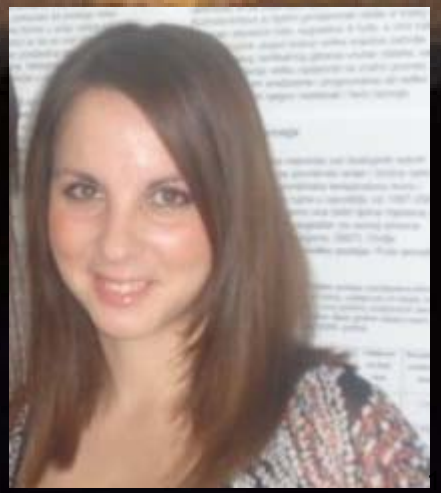


Outline

- Introduction
  - Methods of OT detection using satellite imagery
  - Relationship between OT and severe weather
- Data and methods
- Examples
- Conclusion and future work

Introduction: Overshooting top (OT)

- a domelike protrusion above a cumulonimbus anvil
- forms when a thunderstorm's updraft protrudes its equilibrium level
- exists for less than 30 minutes and has a maximum diametar of ~ 15 km
- penetrating convective storms affect on the transport of various chemical species (especially water vapor) from the troposphere into the stratosphere
- generates gravity waves which can produce significant turbulence

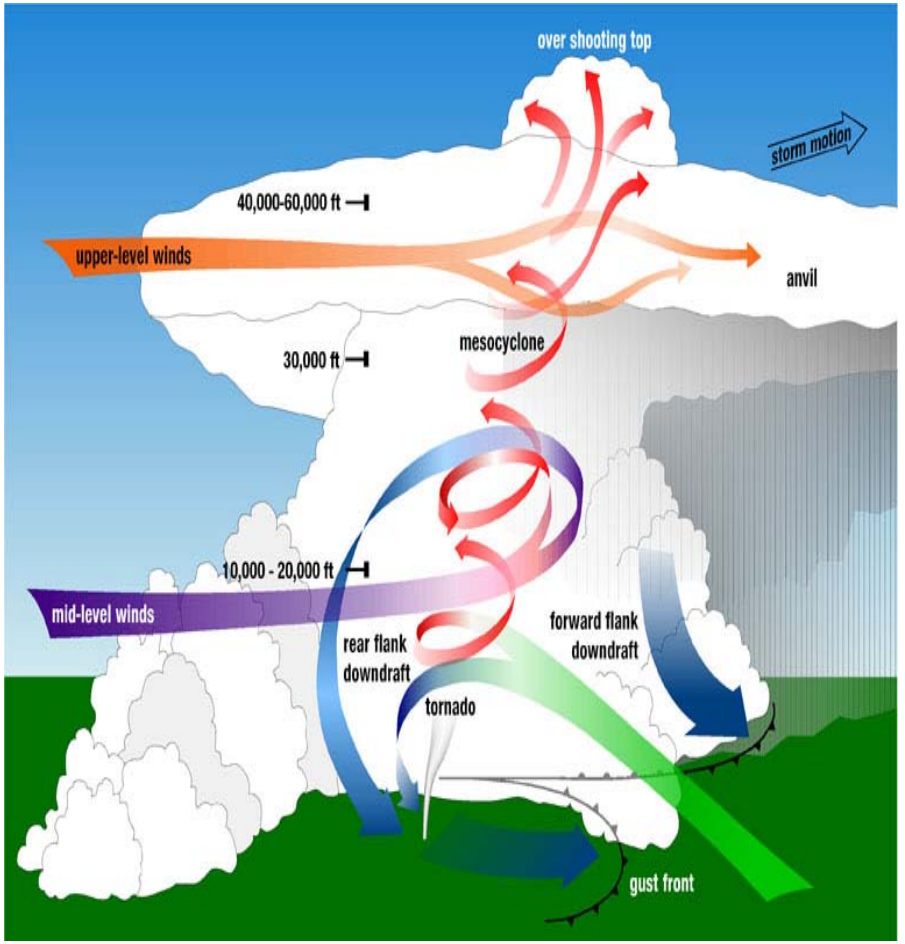
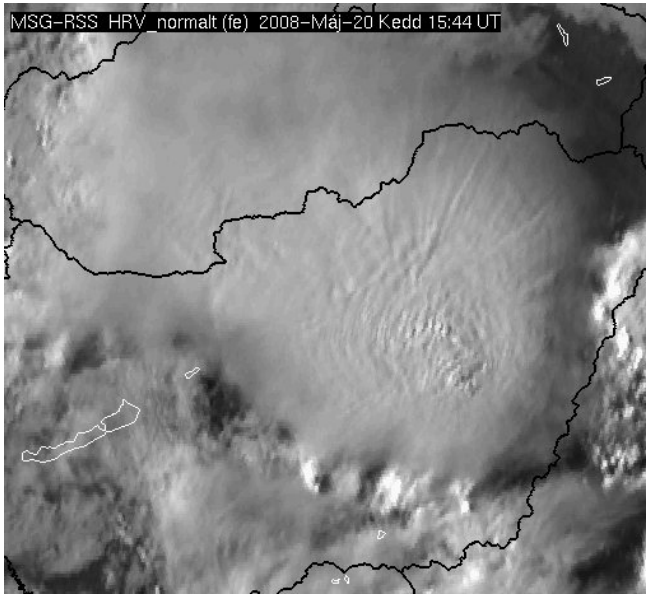


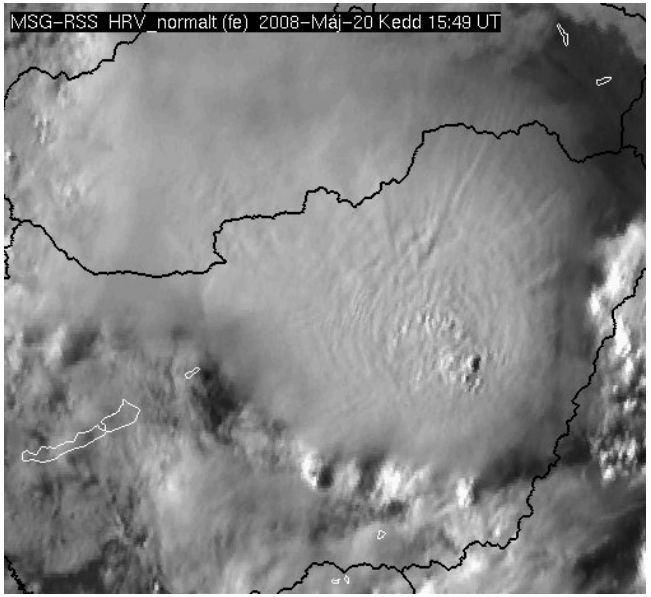
Figure: Diagram of a supercell thunderstorm, which shows the overshooting top rising above the anvil cloud

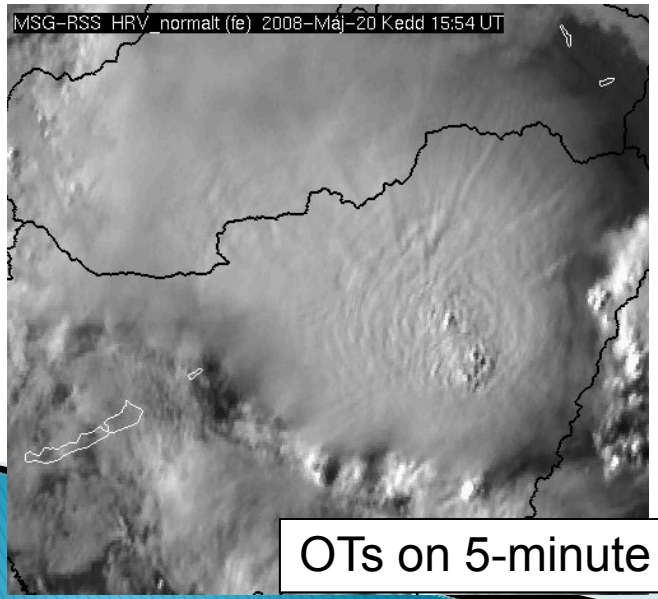
Examples: Overshooting tops

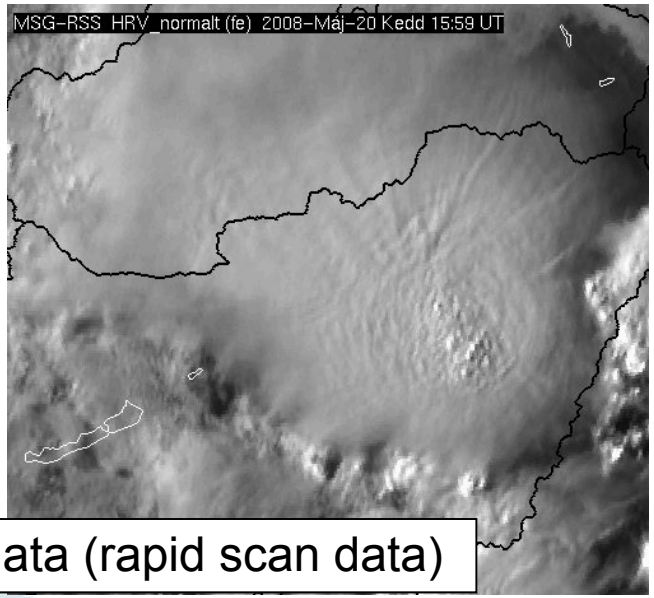
Photo: Supercell thunderstorm with overshooting cloud top and anvil overhang, looking southeast from about 40 miles away. This storm produced baseball hail, but no known tornadoes, along a track in southeast Oklahoma and southwest Arkansas

Photo: Looking east from about 60 miles away, we see a line of towering cumulus clouds and a large supercell storm. Note the great amount of anvil overhang and the large overshooting dome at the summit of the updraft. This particular storm was producing a tornado that stuck downtown Ft. Worth, TX on March 28, 2000.





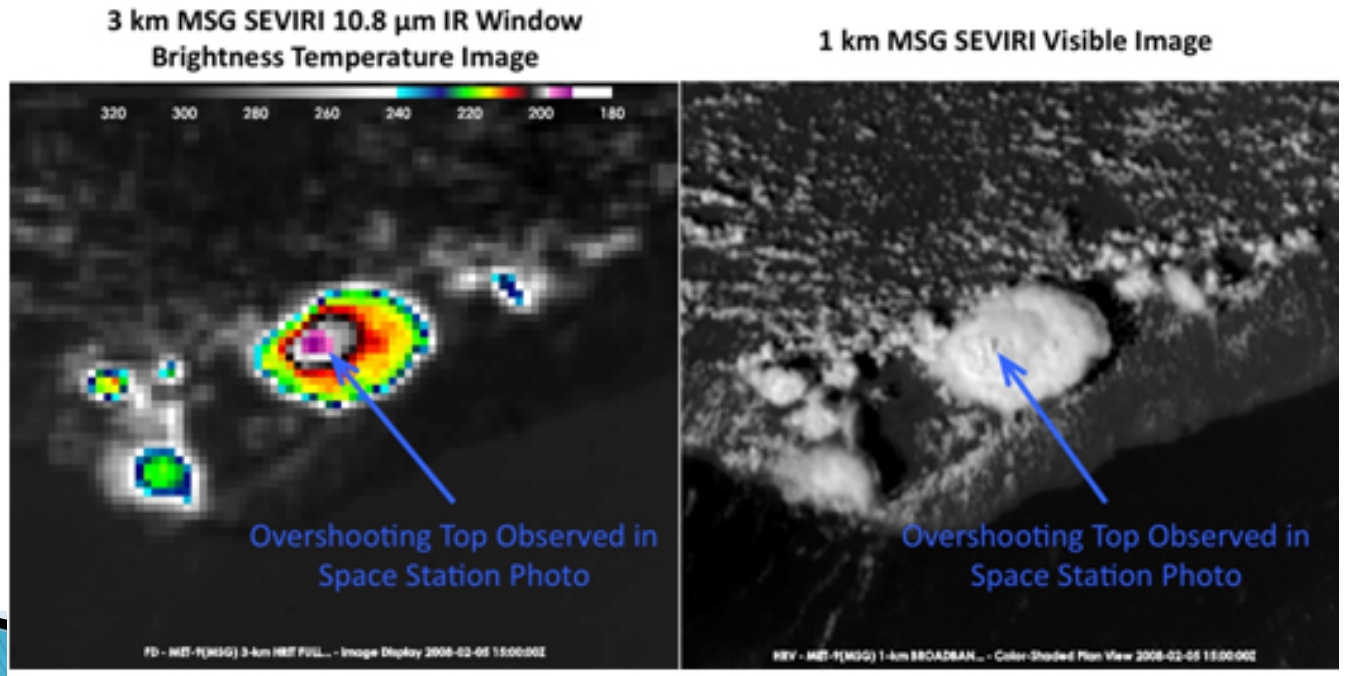




OTs on 5-minute HRV data (rapid scan data)

Introduction: Detection of OT using satellite imagery

- visible channel imagery – OT as the lumpy textured appearance
  - can be observed only during the day

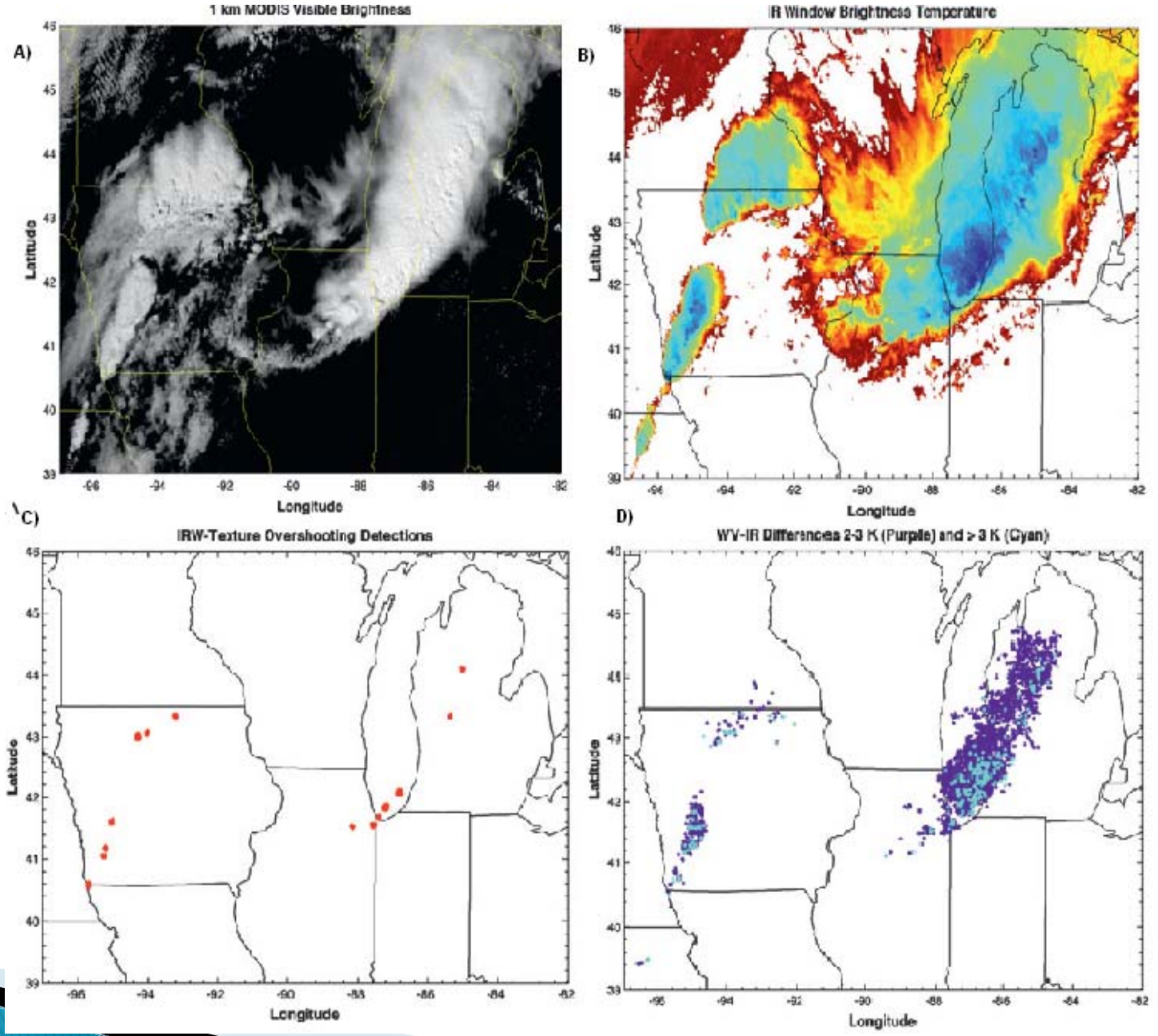


objective satellite – based detection of OT:

- WV–IR BTD (Schmetz,1997; Setvak, 2010)
  - greater than zero degrees are related to convective cloud with high vertical extension
  - often identifies OT regions with a spatial extent that is significantly larger than that of commonly observed OTs
  - often produce a significant number of false OT detection

- "IRW – texture" (Bedka, 2010)
  - combination of 11μm IR channel, a numerical weather prediction model tropopause temperature forecast, OT size and BT criteria (defined through analysis of 450 thunderstorm events)
  - IR brightness temperature minima $< 215K$
  - OT $\leq$ 15 km diameter

Figure :
A) Contrast – enhanced Aqua MODIS 0.65 µm visible channel imagery,
B) Color- enhanced Aqua MODIS IRW imagery,
C) IRW – texture overshooting top detections,
D) WV – IRW brightness temperature differences between 2 and 3 K (purple) and > 3 K (blue) (*Bedka et al., 2010*)



Introduction: Relationship between overshooting cloud top and severe weather

- frequently produce hazardous weather *(Bedka et. Al, 2010)*
- often associated with cloud to ground lightning (*Machado et al., 2009*)
- often associated with significant turbulence (*Lane et al., 2003*)

Table : The number of events where overshooting tops were found to occur near to the location of tornado, severe wind and large hail events recorded within ESWD (SEVIRI European Domain) and SPCD (GEOS – 12 U.S. Domain) (*Bedka, 2010*).

SEVIRI European Domain		GOES-12 U.S. Domain	
Severe Weather Type	**Match Percentage**	**Severe Weather Type**	**Match Percentage**
Tornado	18%	Tornado	56%
Severe Wind	59%	Severe Wind	58%
Large Hail	61%	Large Hail	51%
All Severe Types	49%	All Severe Types	54%

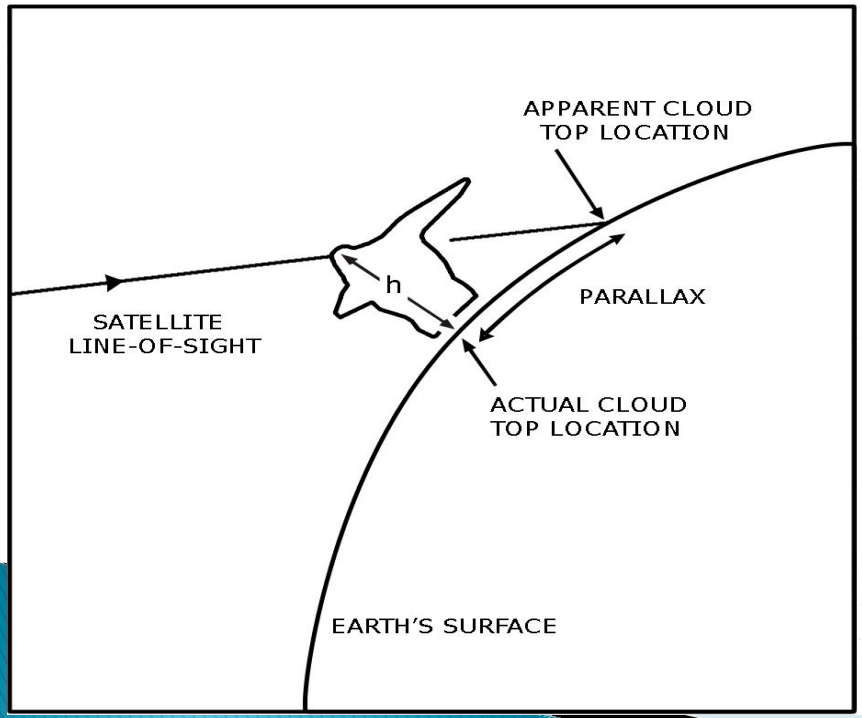
Motivation

- Deep convective storms with OTs often produce hazardous weather conditions, such as heavy rainfall, damaging winds, large hail, cloud-to-ground lightning and tornadoes
- OTs also generate gravity waves which can produce significant turbulence
- These events can cause considerable property damages, influence everyday activities and even endanger the human lives

Data and methods

- The OTs are detected from MSG data using BTD methods
- Compared locations and times of appearance of the OTs with data measured by the automatic stations
- Compared OT detections according the “IRW-texture” with data from automatic stations

- **Parallax correction**



- apperent displacement of cloud location in satellite imagery
- depends on the height of the cloud top (important especially for high Cb clouds), its geographic location and position of the satellite
- Method: each automatic station is shifted by the computed values of parallax shift for certain cloud top height

Parallax correction

- Parallax correction for automatic stations
  (cloud height is constant – based on soundings data)
- MSG satellite position: 0°
- Parallax correction tables for 80 different cloud heights for NE image section for the 0° position (http://www.convectionwg.org/parallax.php)

Parallax shift (°)						
cloud top height (km)	12	12	13	13	12	12
	Croatia	Slovenia	Austria	Slovakia	Hungary	Bosnia and Herzegovina
N	0,14	0,14	0,15	0,16	0,15	0,14
E	0,08	0,07	0,08	0,12	0,11	0,08

Satellite-based overshooting top detection methods

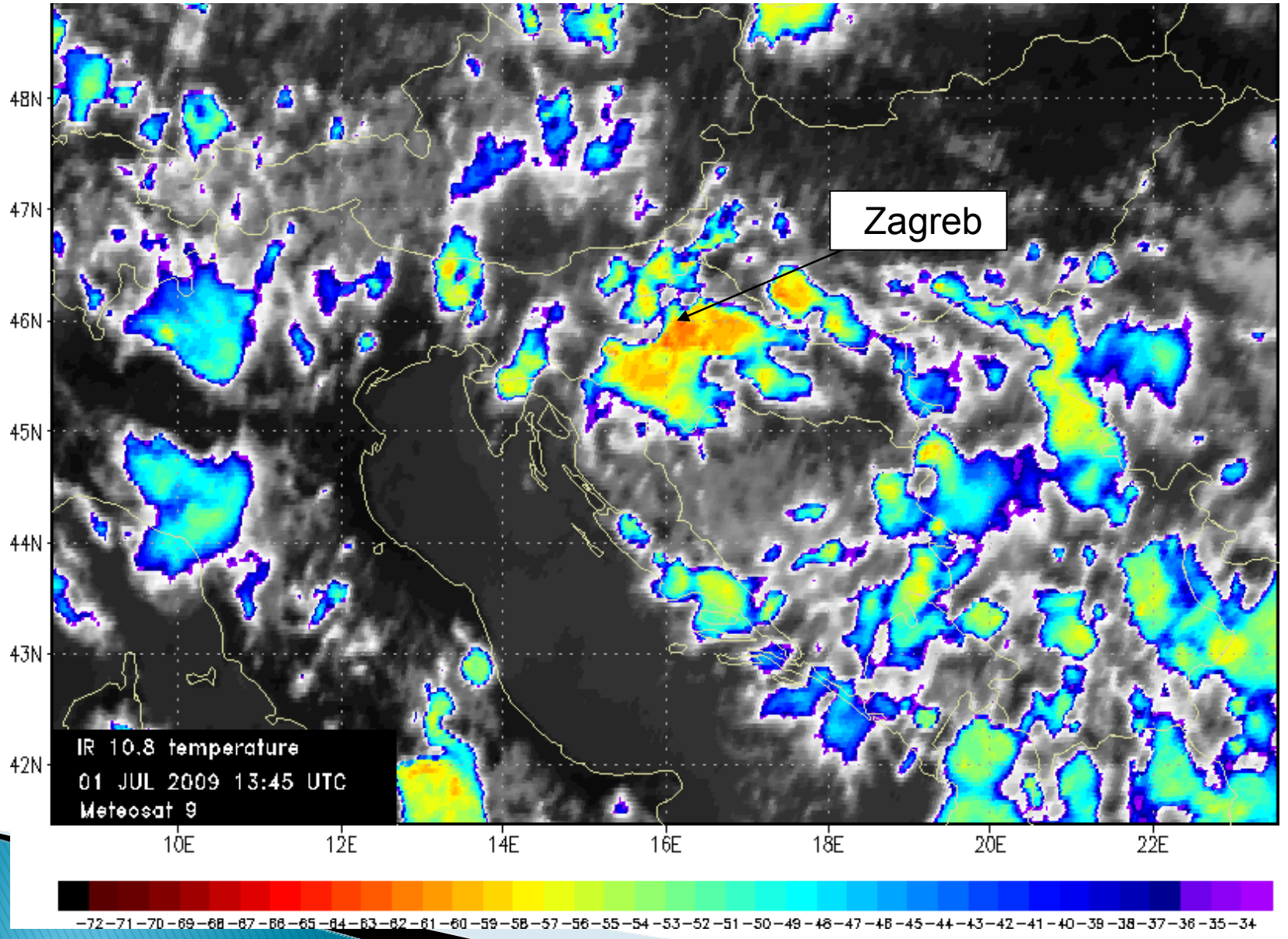
- Brightness temperature difference (BTD) methods:

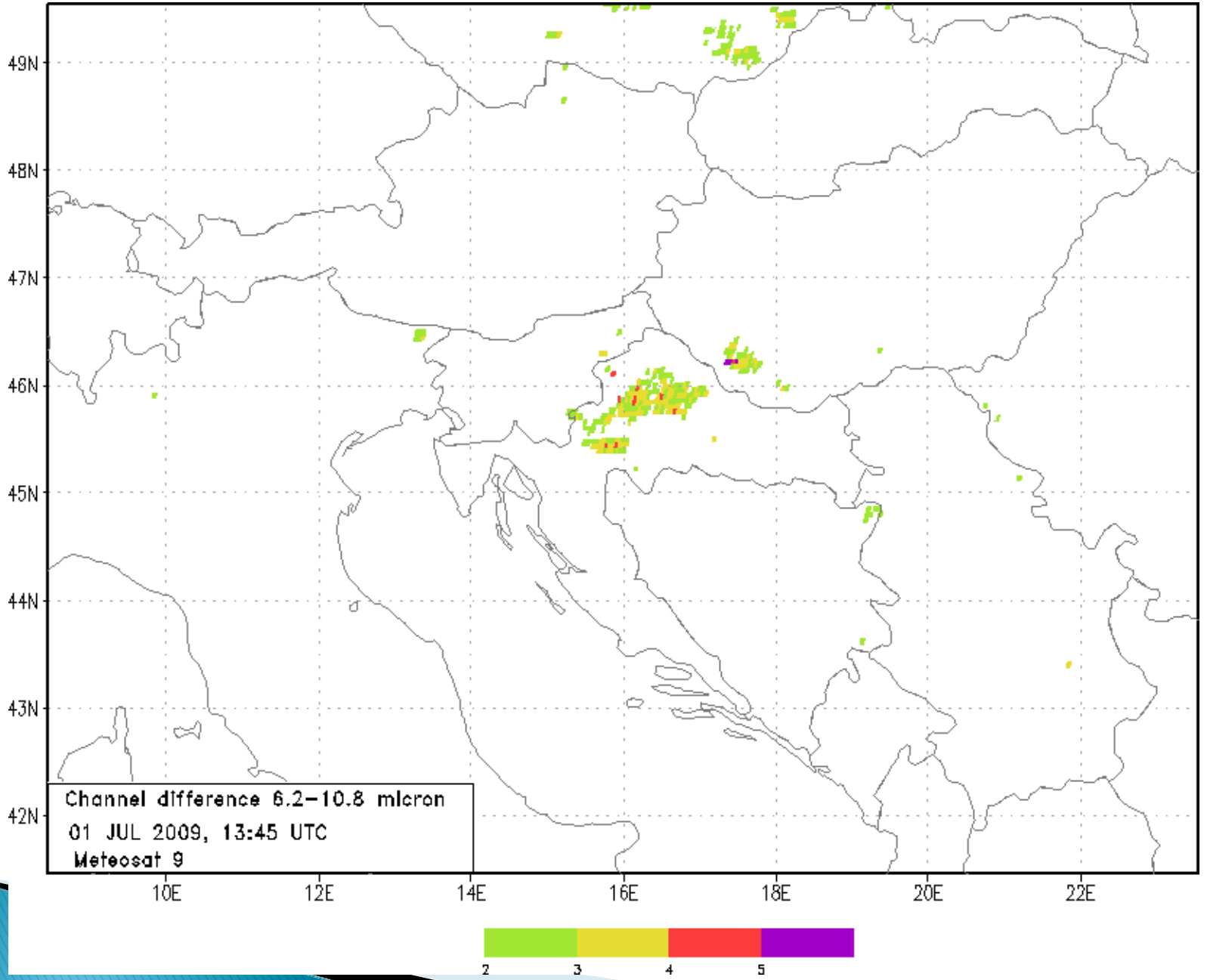
Criteria		
WV-IR	IR brightness temperature < 215K	>4K
O3-IR		>13K
CO2-IR		>3.5K
COMB (WV-IR & O3-IR)		>4K & >13K

- IR=10.8 μm
- WV = 6.2 μm
- O3 = 9.7 μm
- CO2 = 13.4 μm

- some studies showed that this BTD methods are usefull for determining cloud top heights of convective clouds *(Kwon et al.)*

- **OT and their relationship with severe weather conditions**

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Channel difference 6.2−10.8 micron
01 JUL 2009, 13:45 UTC
Meteosat 9
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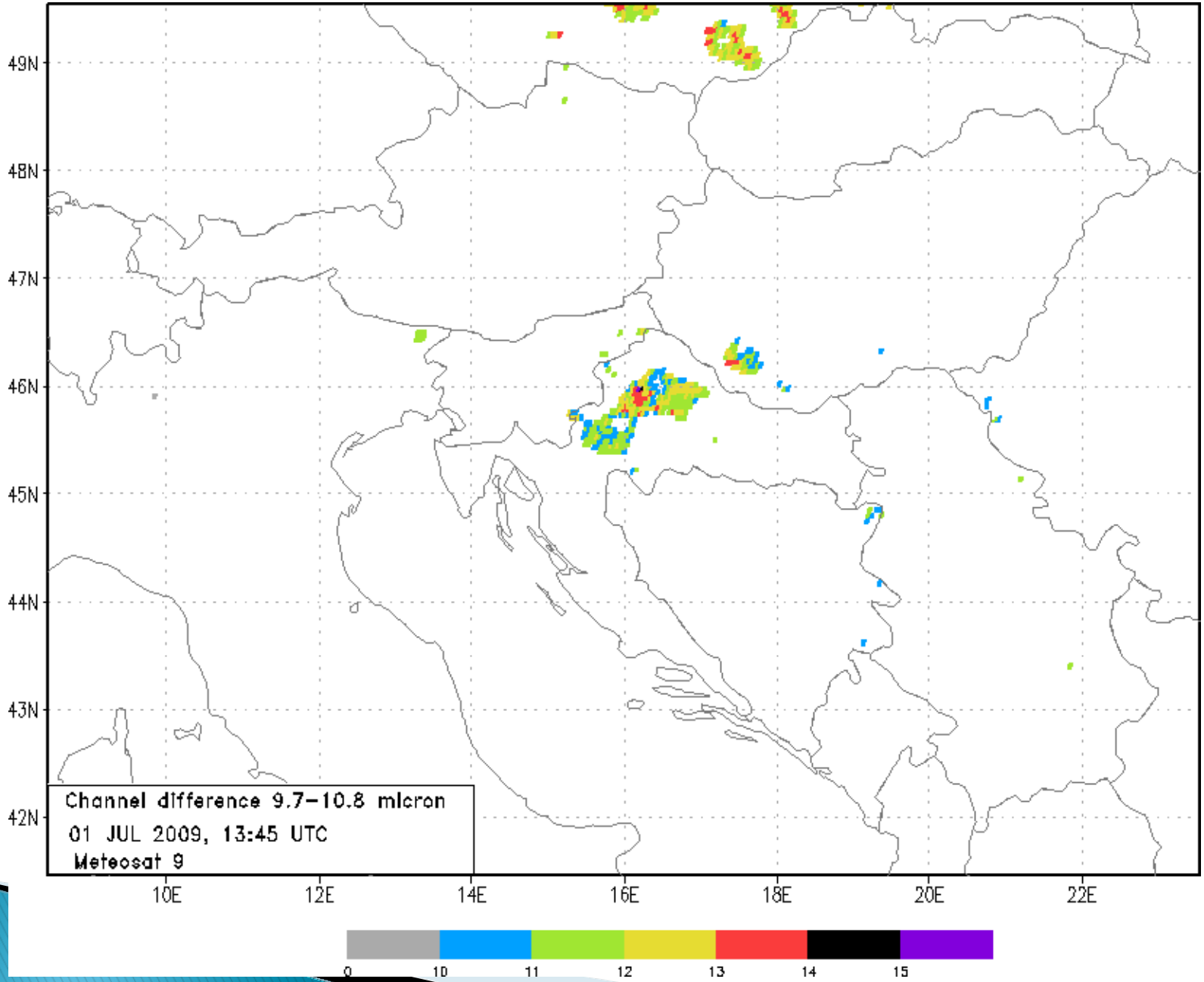
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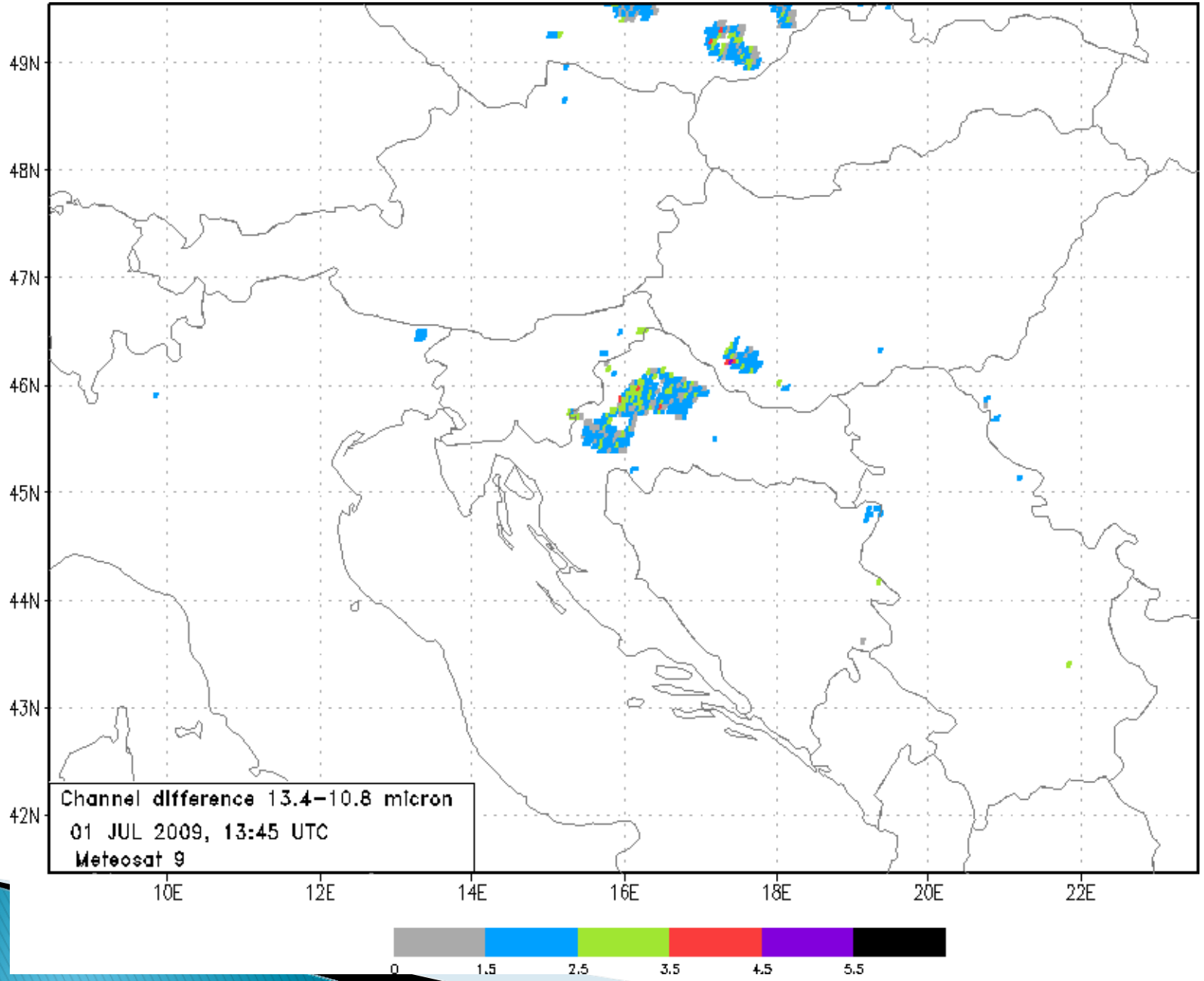
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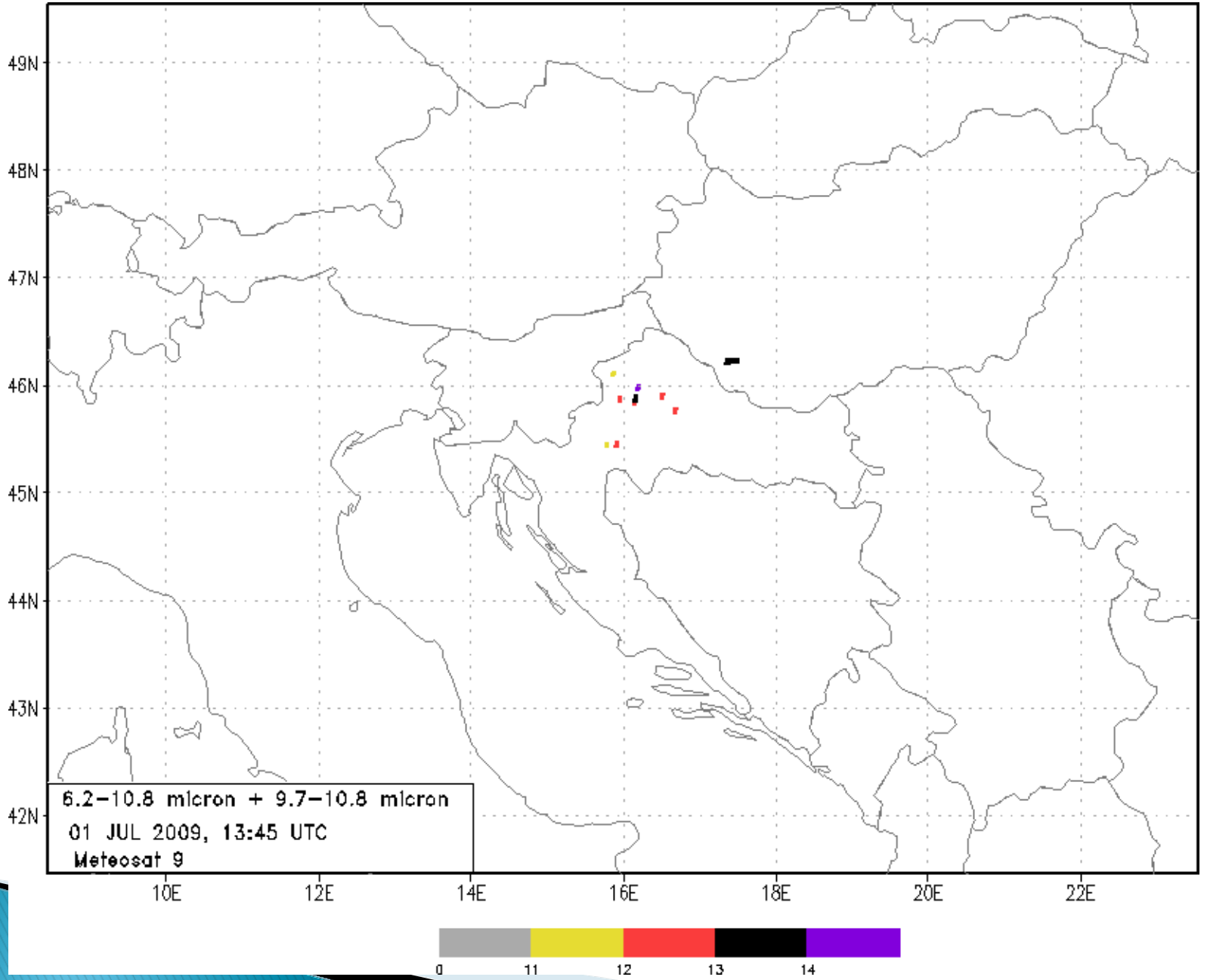
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Example: OT vs. severe weather

Zagreb, 01.07.2009.

OT -13:45 UTC (Bedka, 2010)

Blue: temperature:

23.8°C(13 UTC) – 21.4°C(15 UTC)

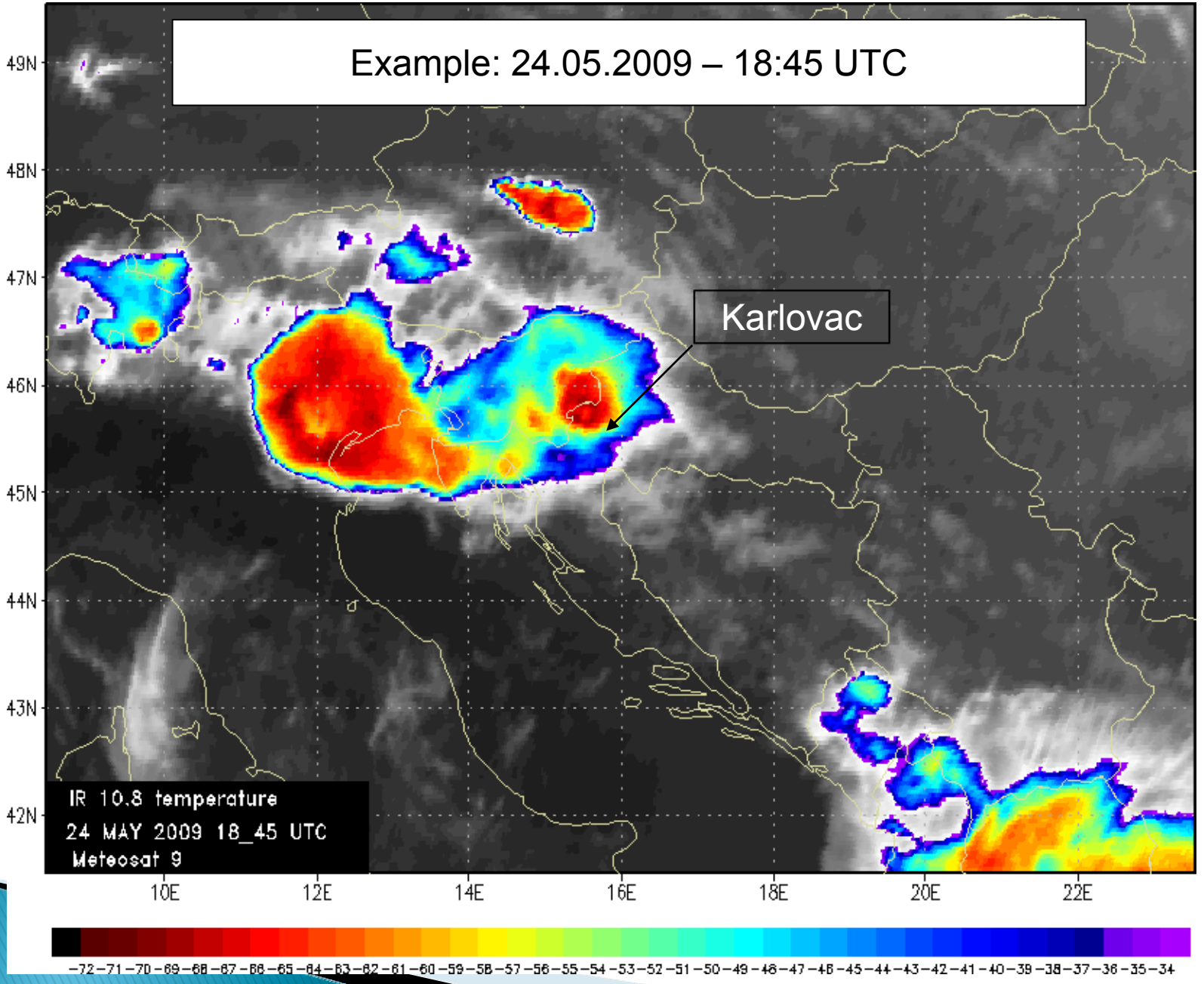
Green: relative humidity

Orange: precipitation:

1.8 mm during 30min

Red: maximum wind speed:

16.2m/s; 14:06 UTC


Example: 24.05.2009 – 18:45 UTC
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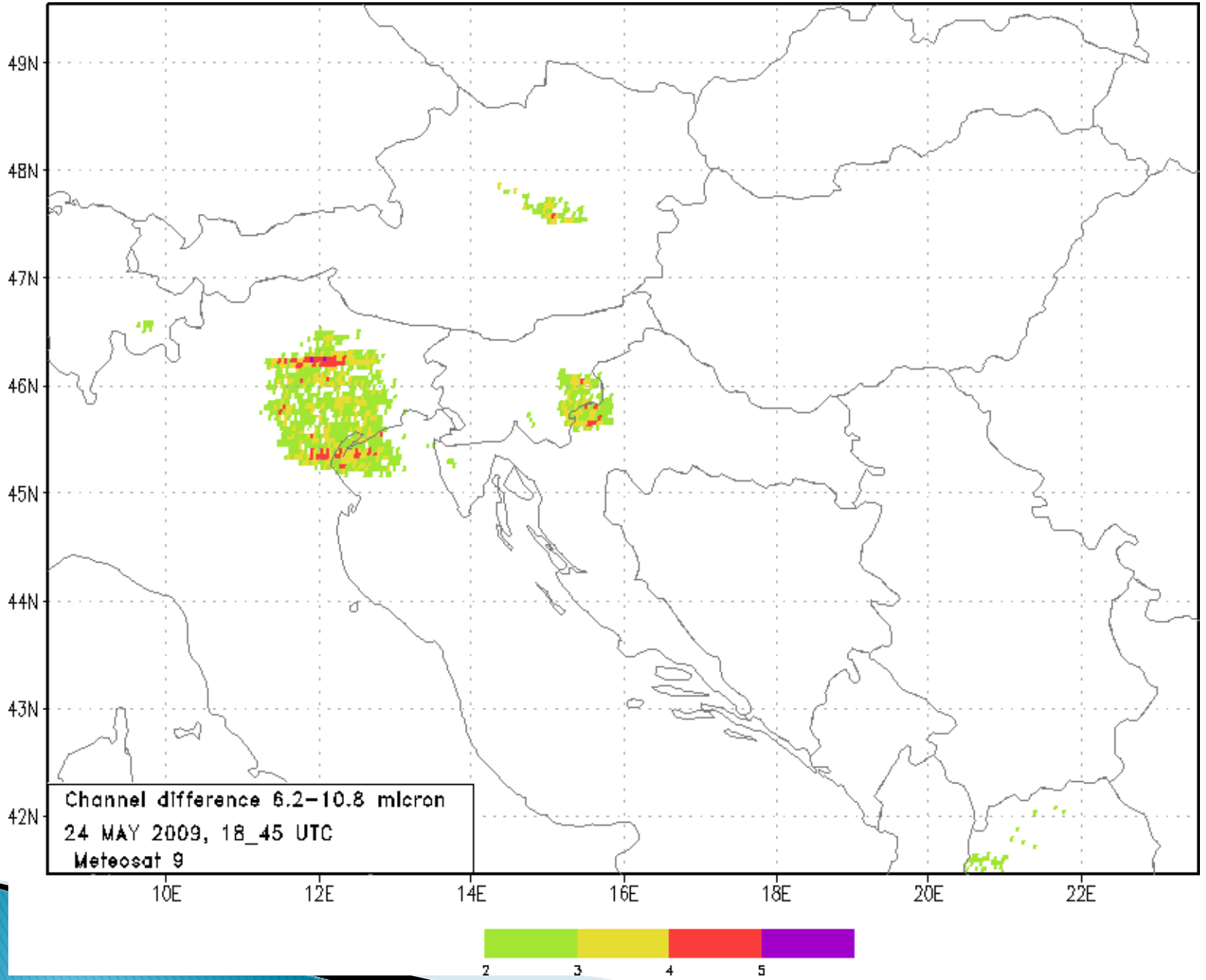
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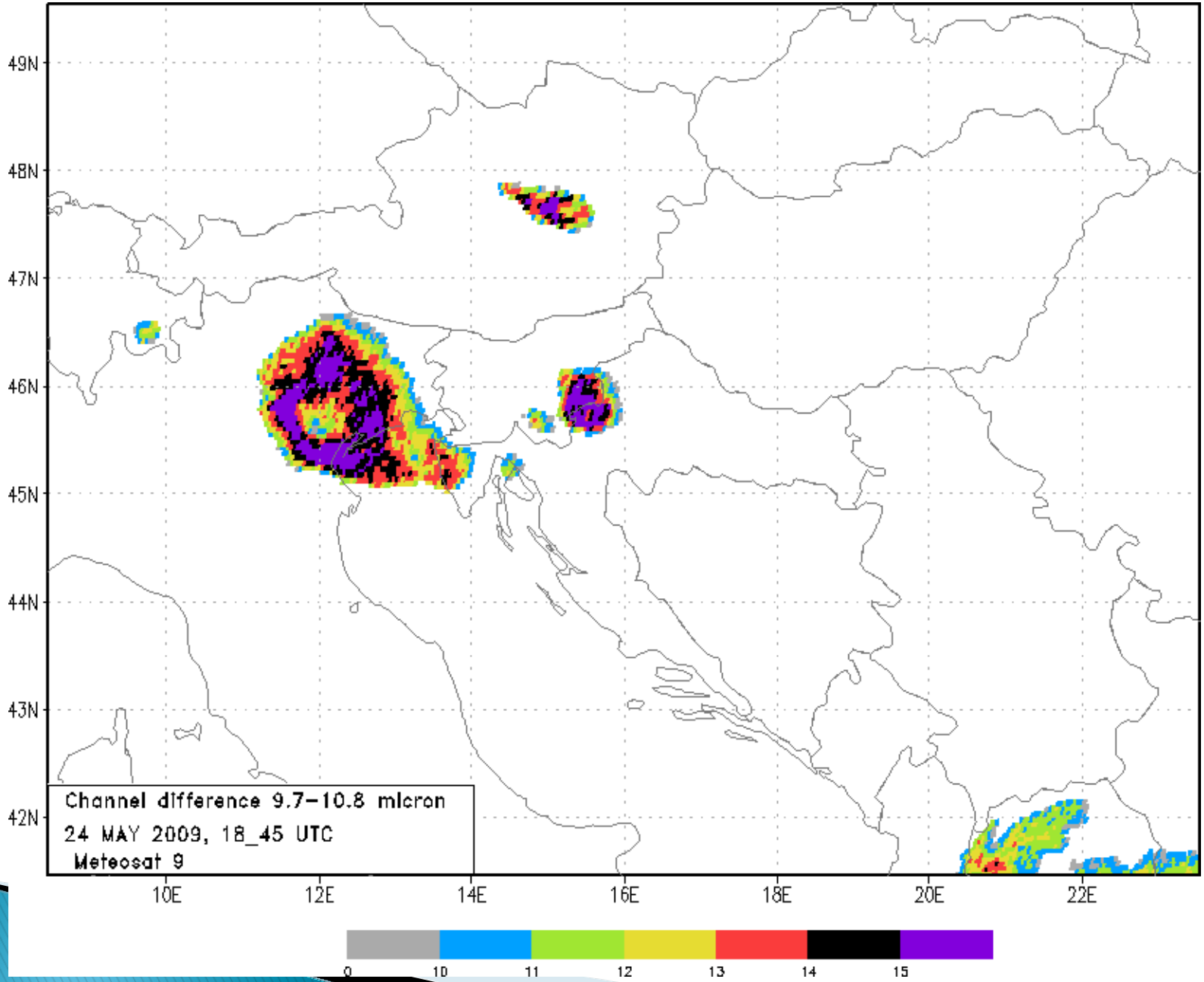
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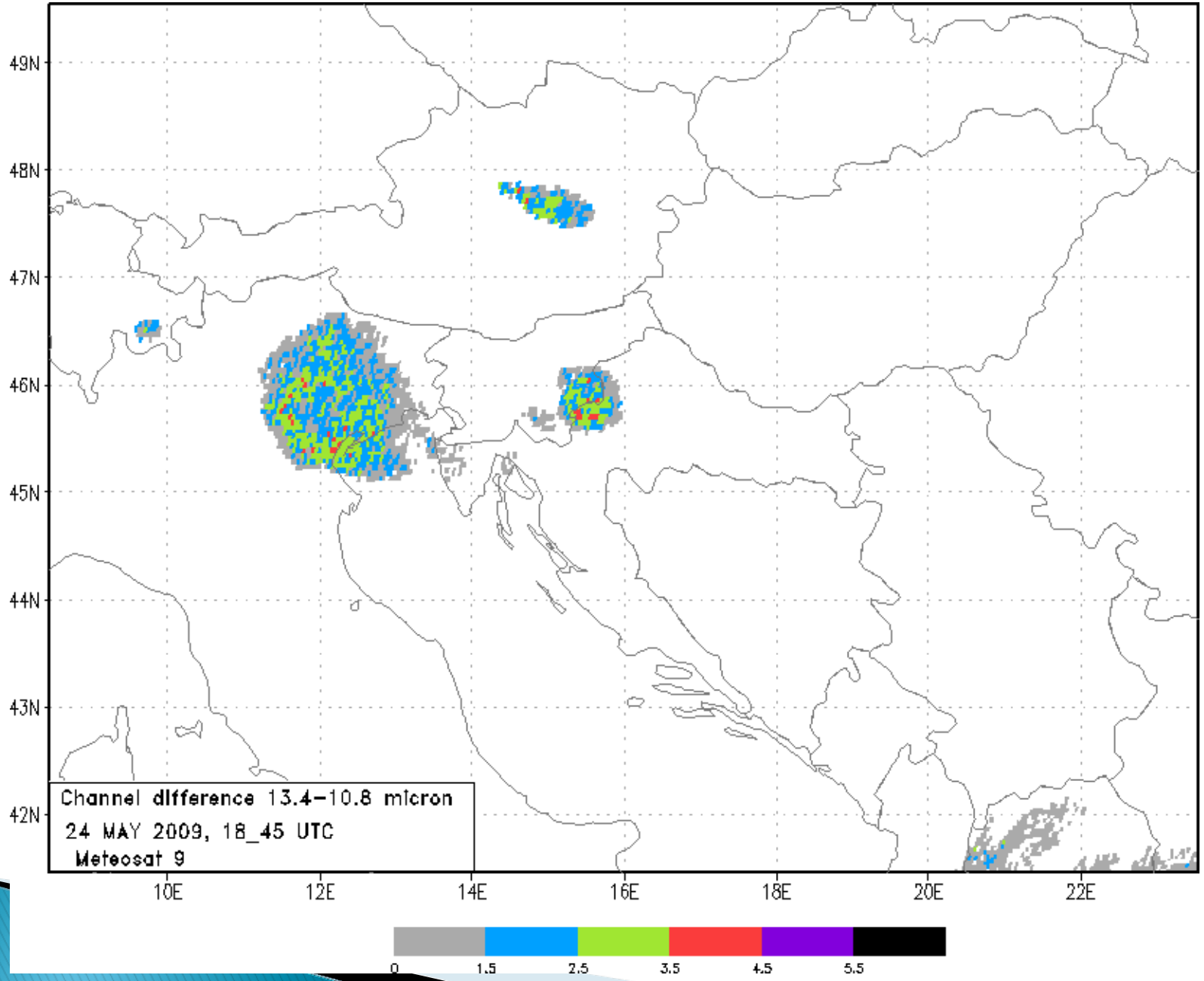
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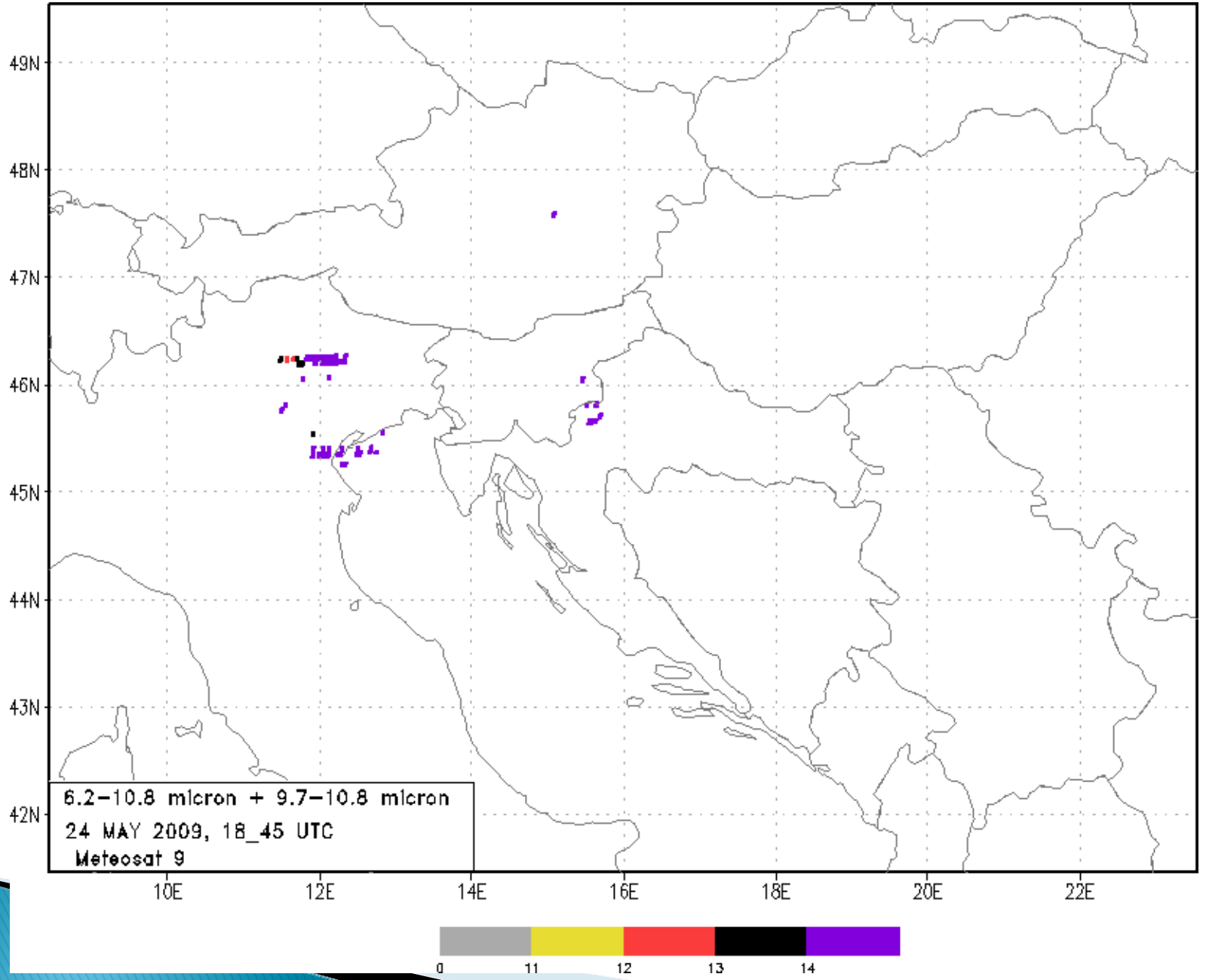
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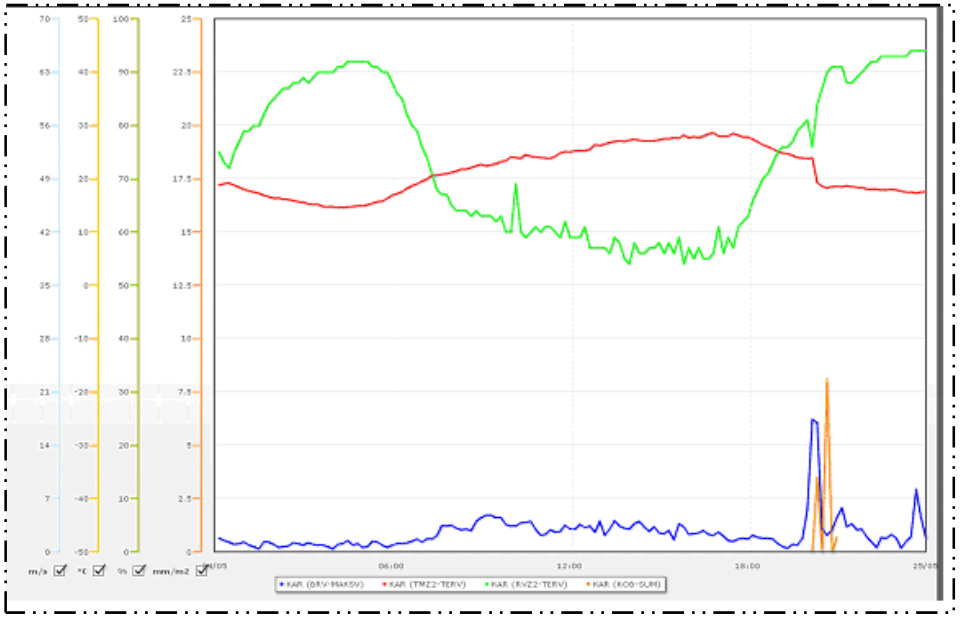
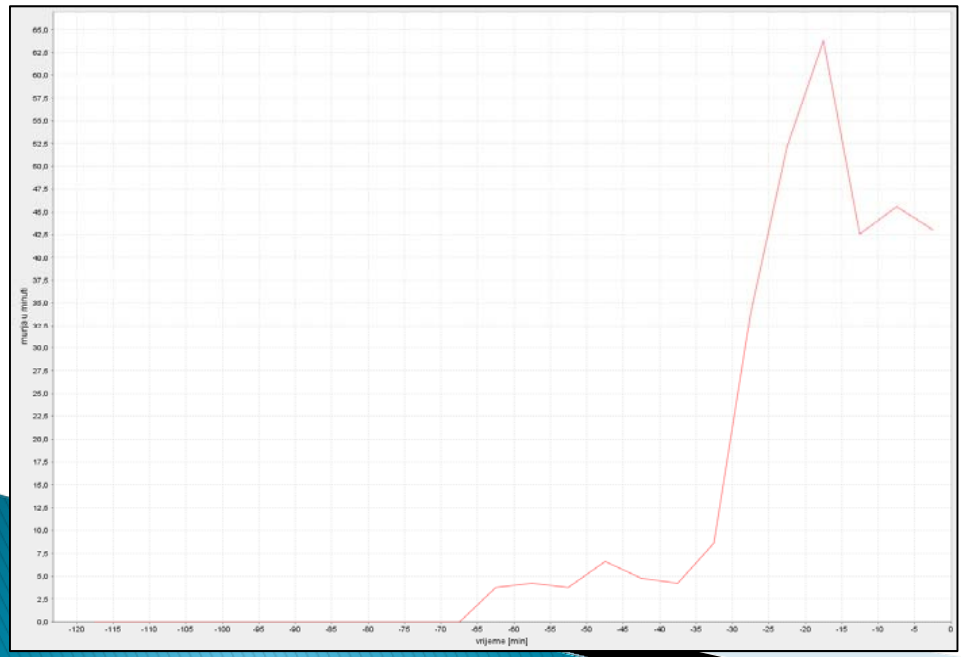




Example: OT vs. Severe weather

Karlovac, 24.05.2009.

OT -18:45 UTC (Bedka, 2010)

Red: temperature:

23.8°C(19 UTC) – 18.6°C(20 UTC)

Green: relative humidity

Orange: precipitation:

12.3 mm during 25 min

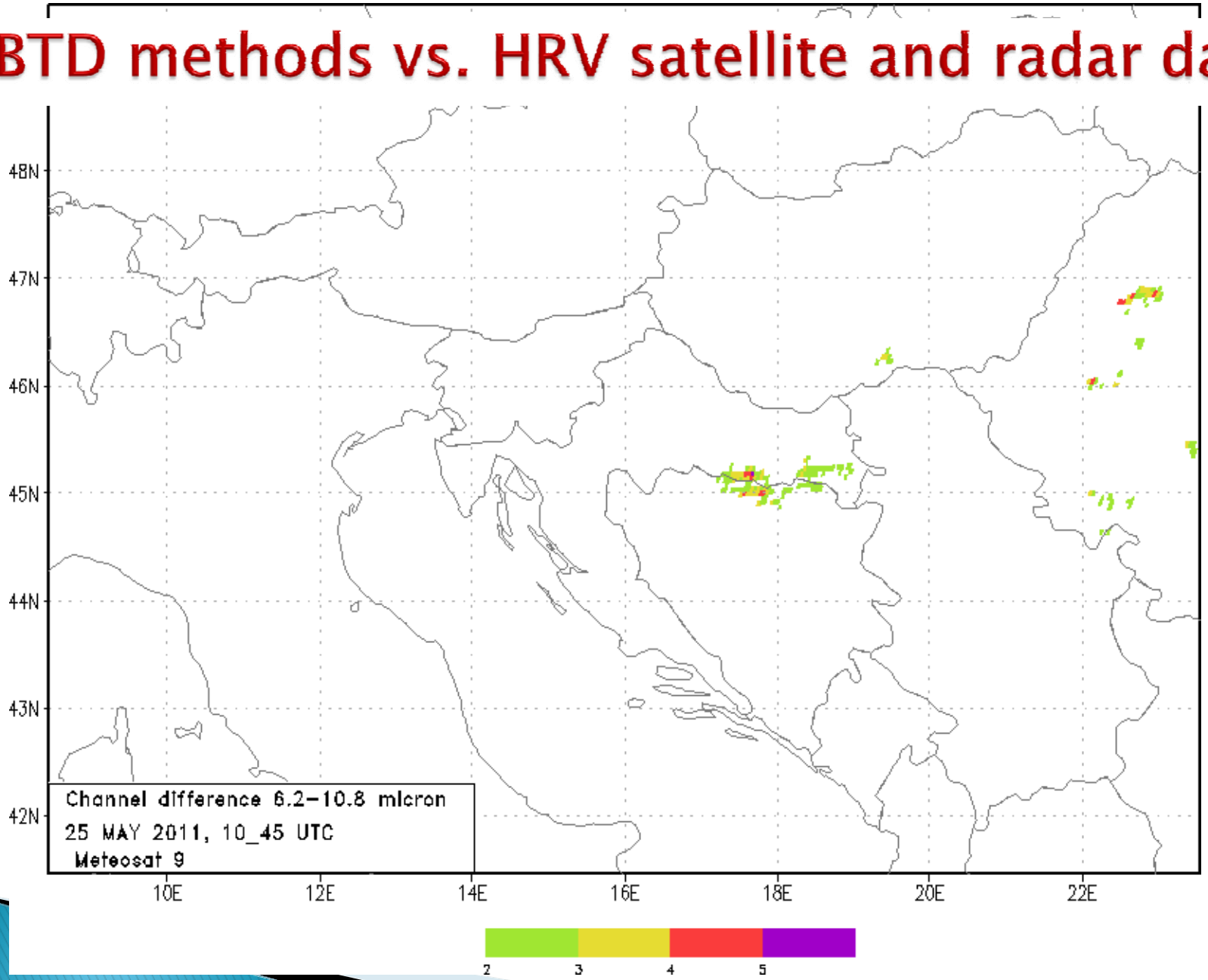
Blue: maximum wind speed:

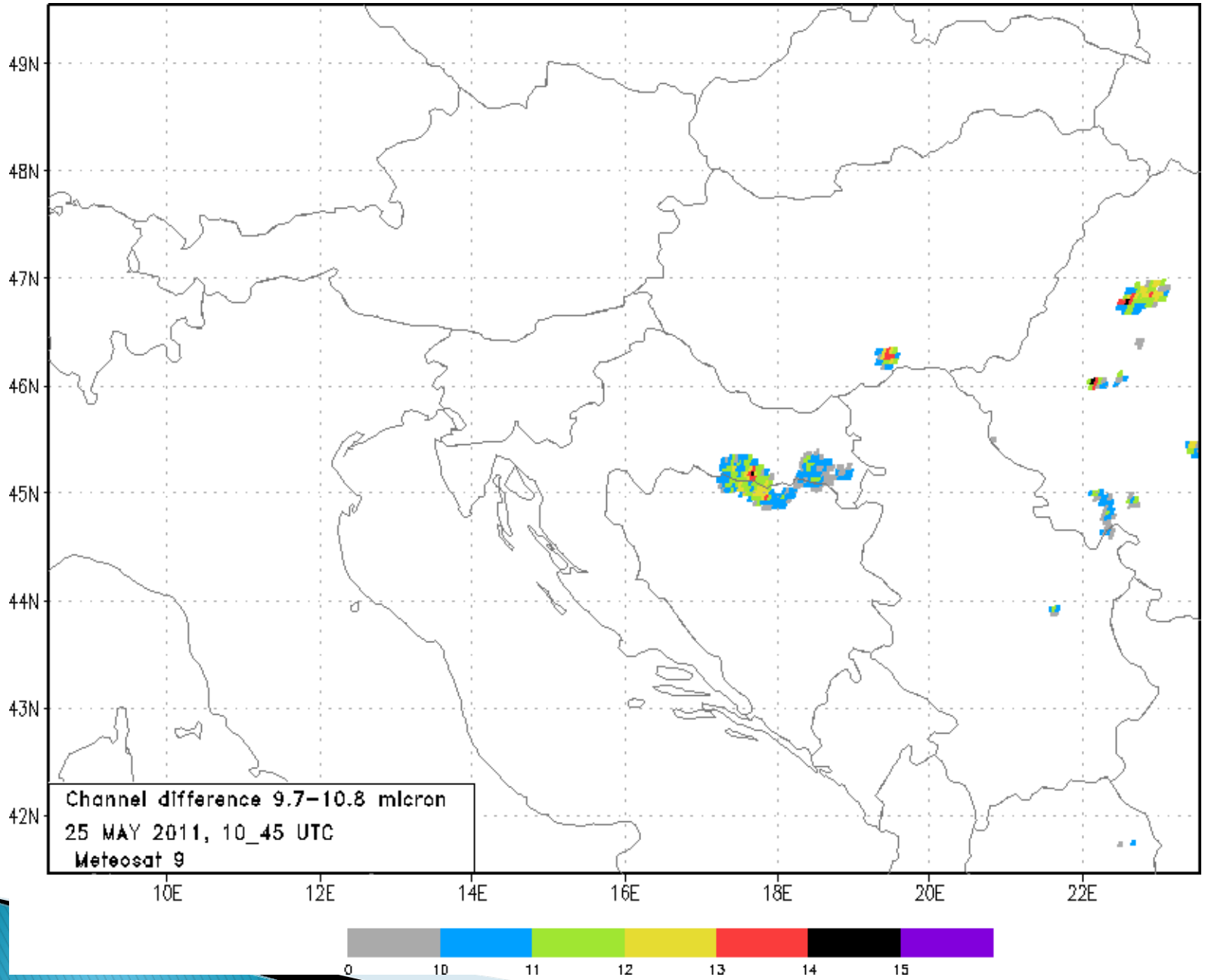
17.4m/s; 19:09 UTC

24.05.2009, 18:00 – 20:00 UTC: Temporal distribution of lightning discharge –

maximum around 19:45 UTC

BTD methods vs. HRV satellite and radar data

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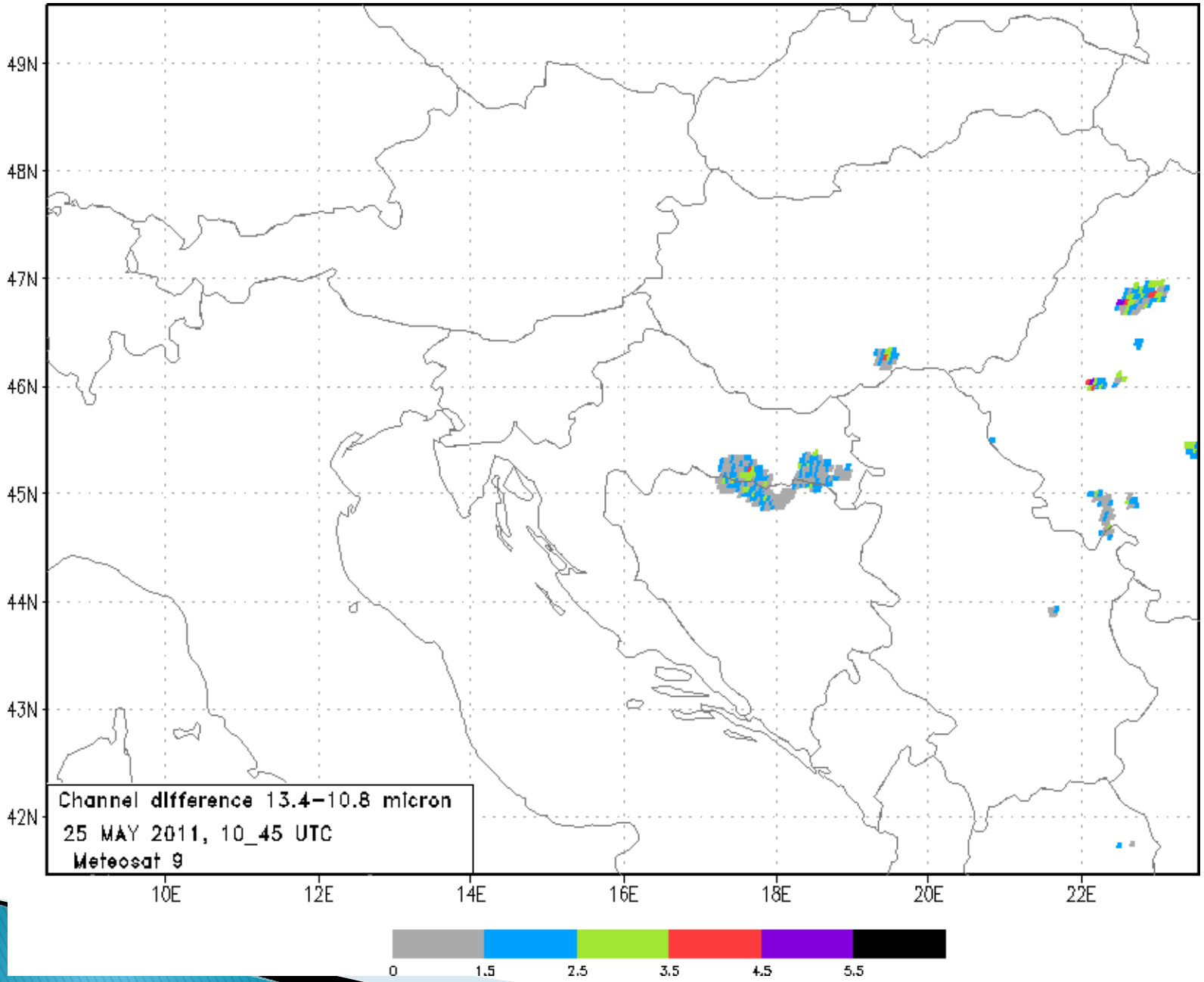
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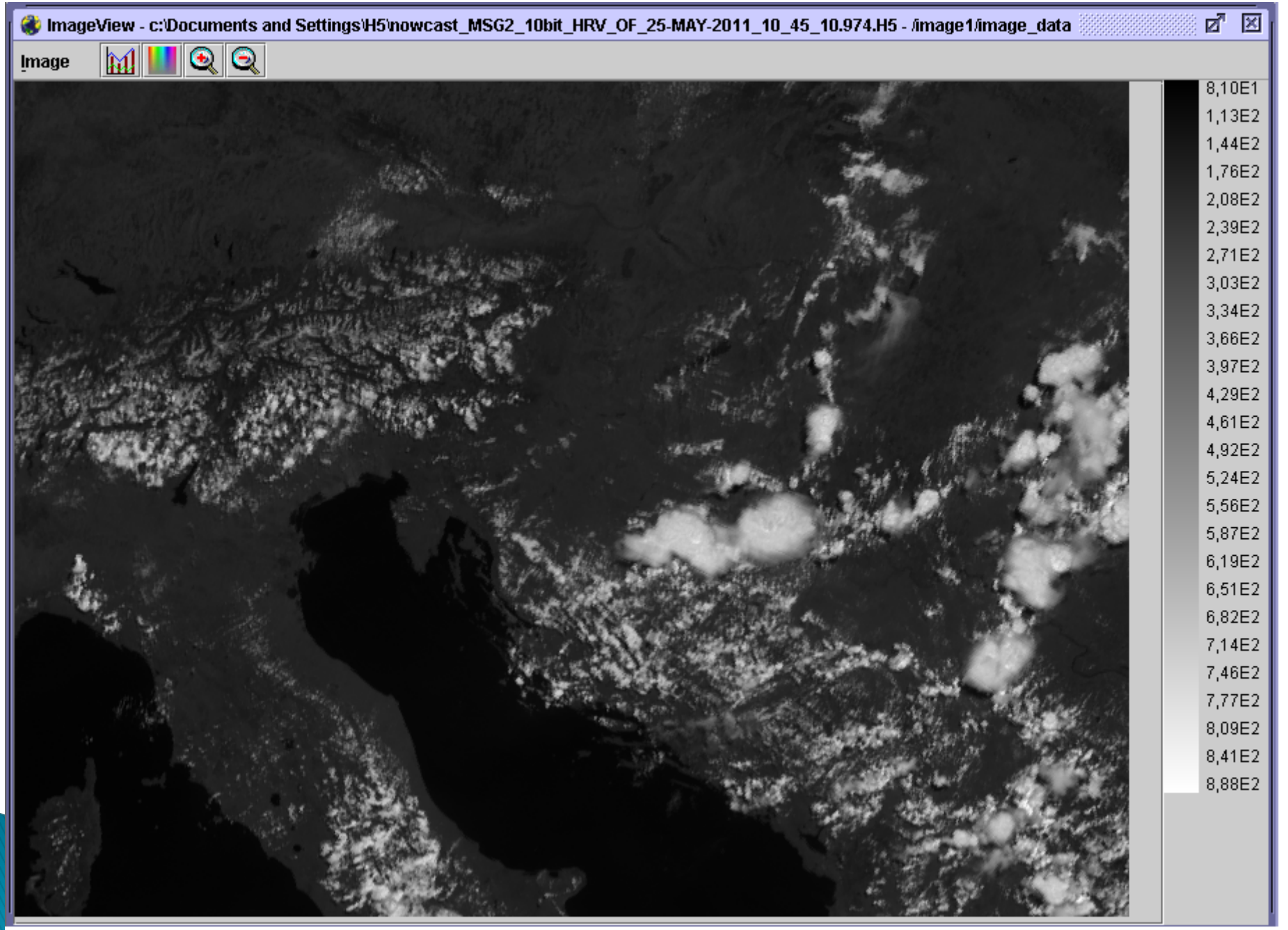
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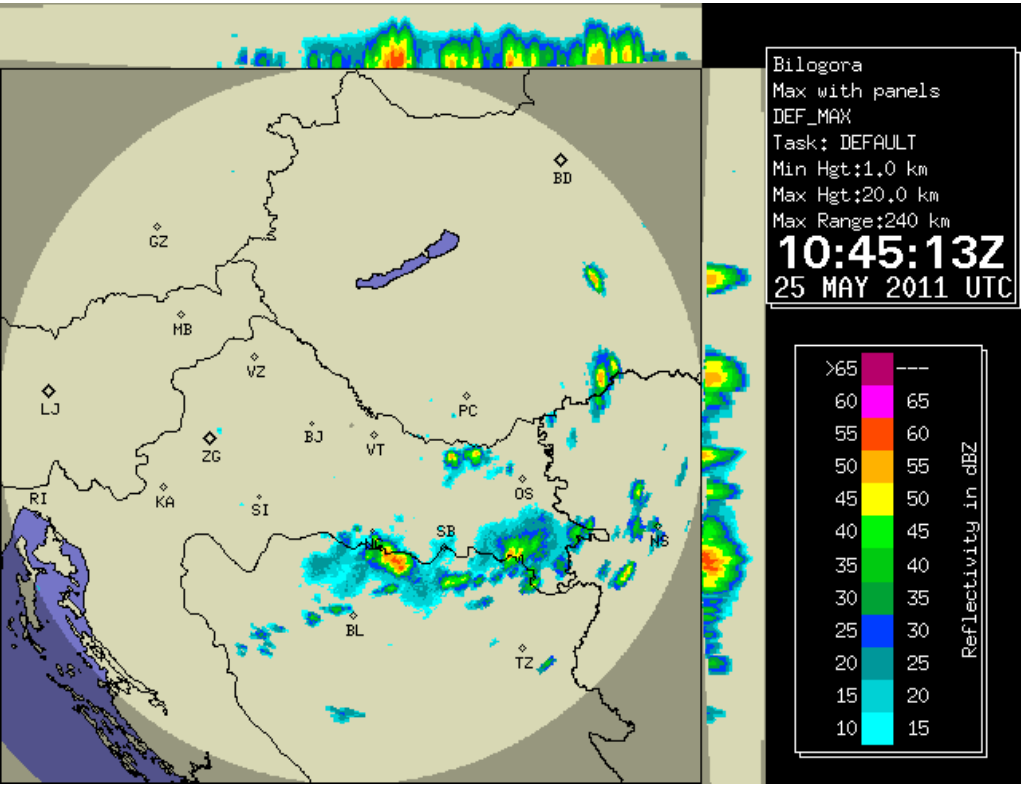
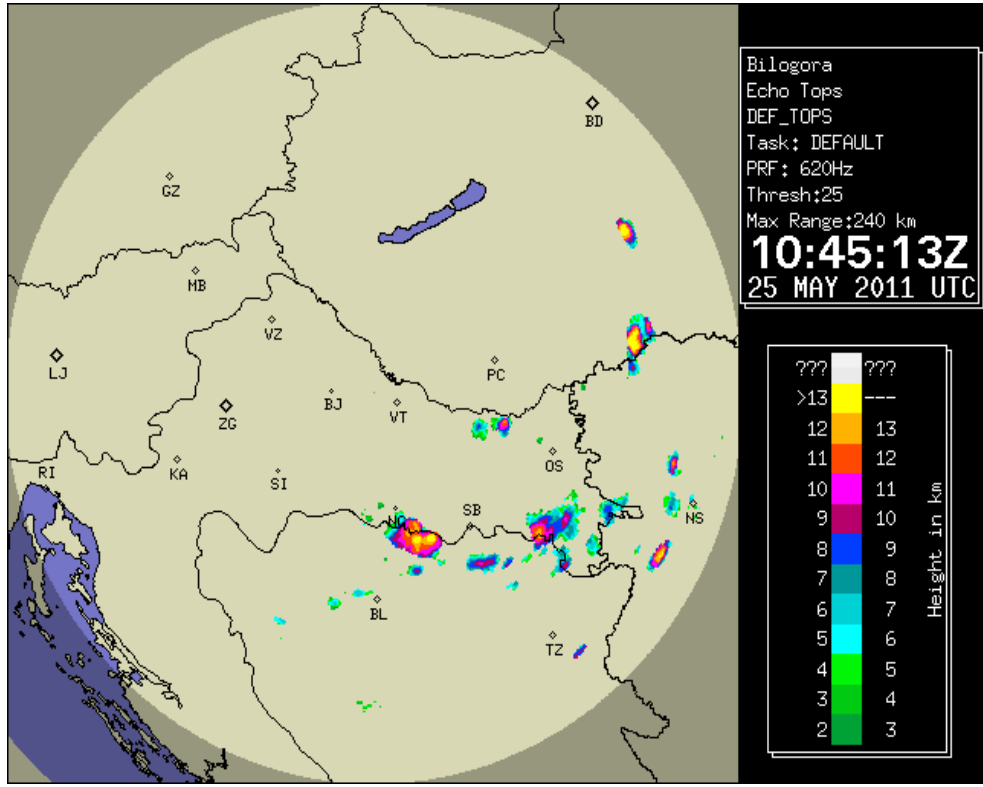
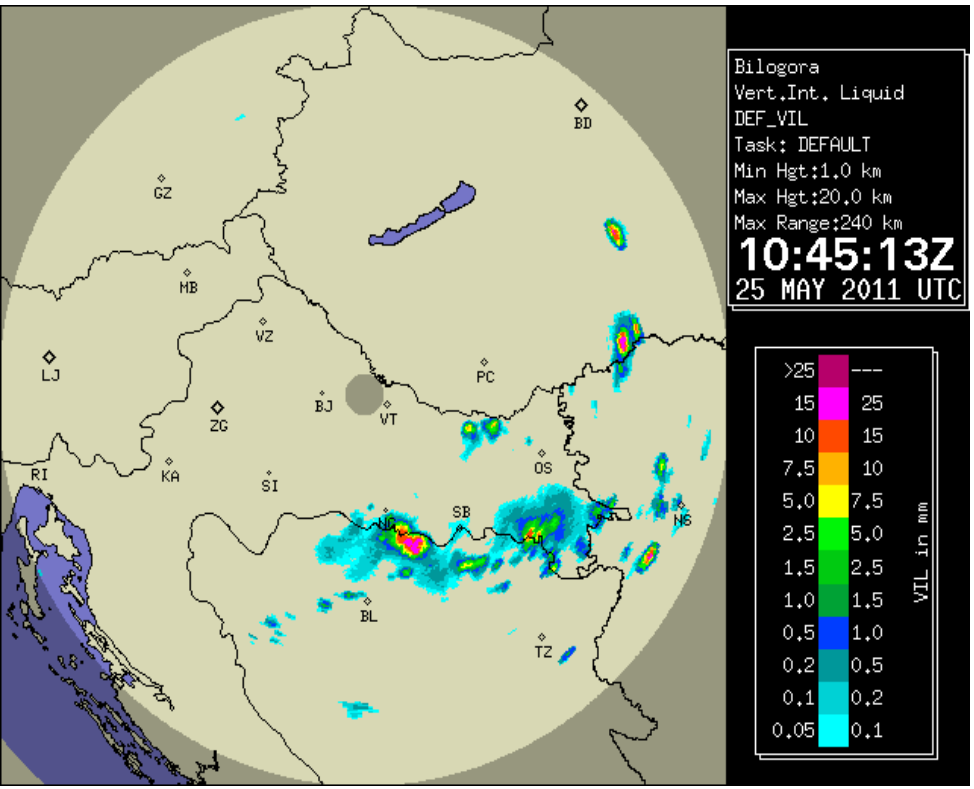
Reflectivity in dBZ



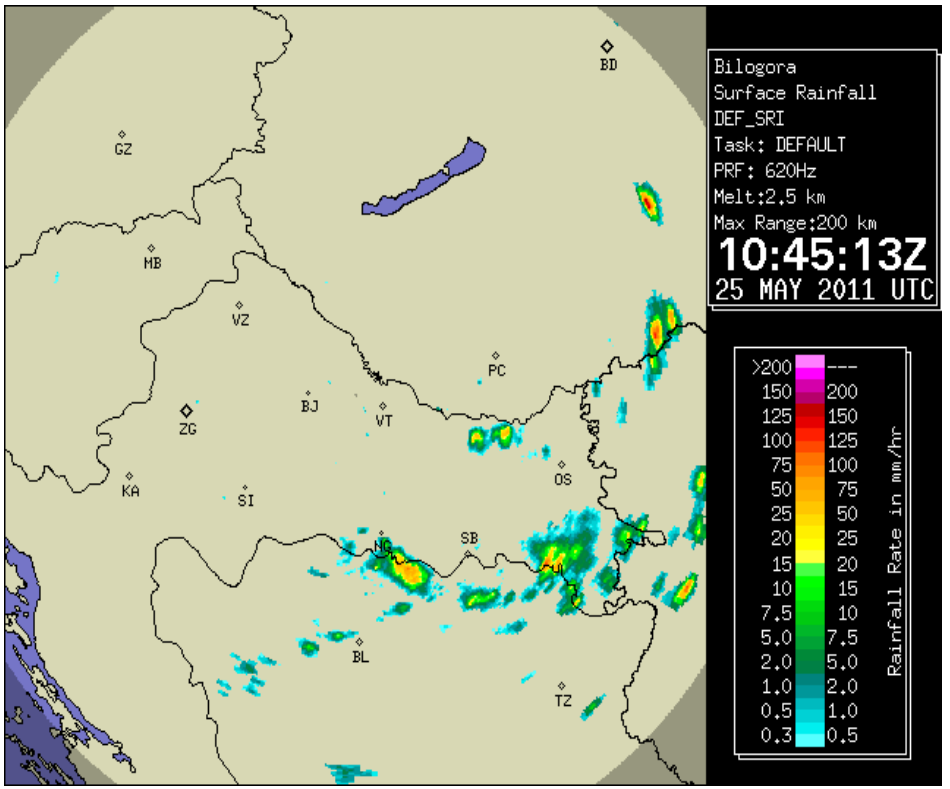
Height in km



Vert. Int. Liquid in mm



Rainfall Rate in mm/hr



- It has been concluded that all investigated methods indicate deep convection (but not necessarily OTs) !

Future work

- Comparison of OT detections by all 4 (5) methods and automatic station data will be made – 2009 and 2010 detections already available!

- OT validation database with OT signatures found in the HRV channel

Thank you for your attention!