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Anticipated benefits of improved temporal and spatial resolution

(with focus on deep convective clouds)

EUMeTrain Event Week on MTG-I Satellite, 7 – 11 November 2016

Introduction

The most significant impact of improved spatial resolution and shorter scan interval:

- observations (detection, monitoring, nowcasting, …) and studies of short-lived and small scale features or phenomena

- e.g. fires, valley fog, shallow convection, and tops of deep convective clouds (storms) – namely their overshooting tops

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- e.g. fires, valley fog, shallow convection, and tops of deep convective clouds (storms) – namely their overshooting tops
- geometrical properties and characteristics (visible and near-IR bands), cloud microphysics, cloud-top brightness temperature (BT)

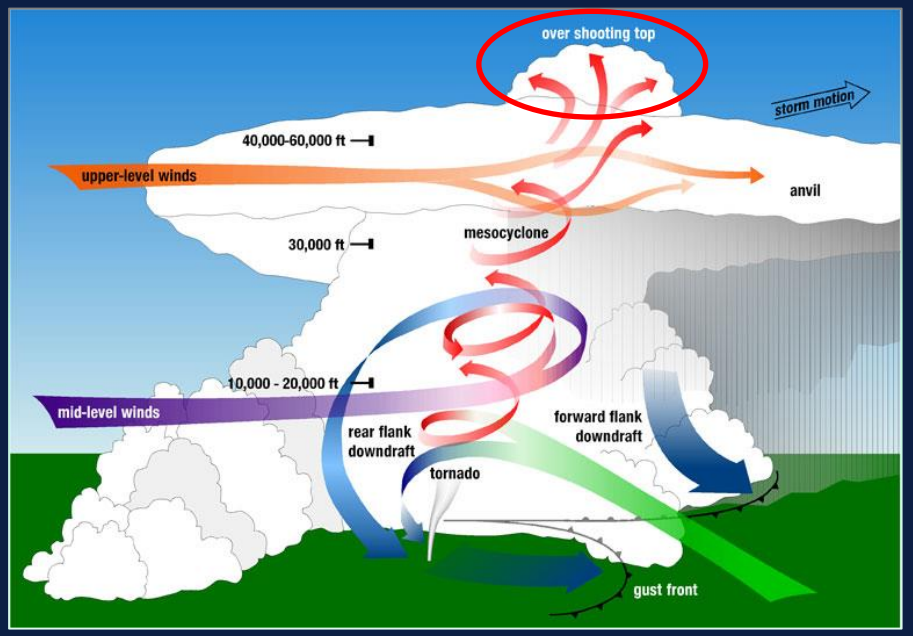
Overshooting tops definition and appearance

OVERSHOOTING TOP
(anvil dome, penetrating top):

A domelike protrusion above a cumulonimbus anvil, representing the intrusion of an updraft through its equilibrium level (level of neutral buoyancy).

It is usually a transient feature because the rising parcel's momentum acquired during its buoyant ascent carries it past the point where it is in equilibrium; the air within it rapidly becomes negatively buoyant and descends. Tall and persistent overshooting tops are frequently observed with strong or severe thunderstorms in which there is a nearly continuous stream of buoyant updrafts.

AMS Glossary of Meteorology,
http://glossary.ametsoc.org/wiki/Overshooting_top



Source: NOAA NSSL (National Severe Storms Laboratory)

Two concepts of the upper parts of an updraft:

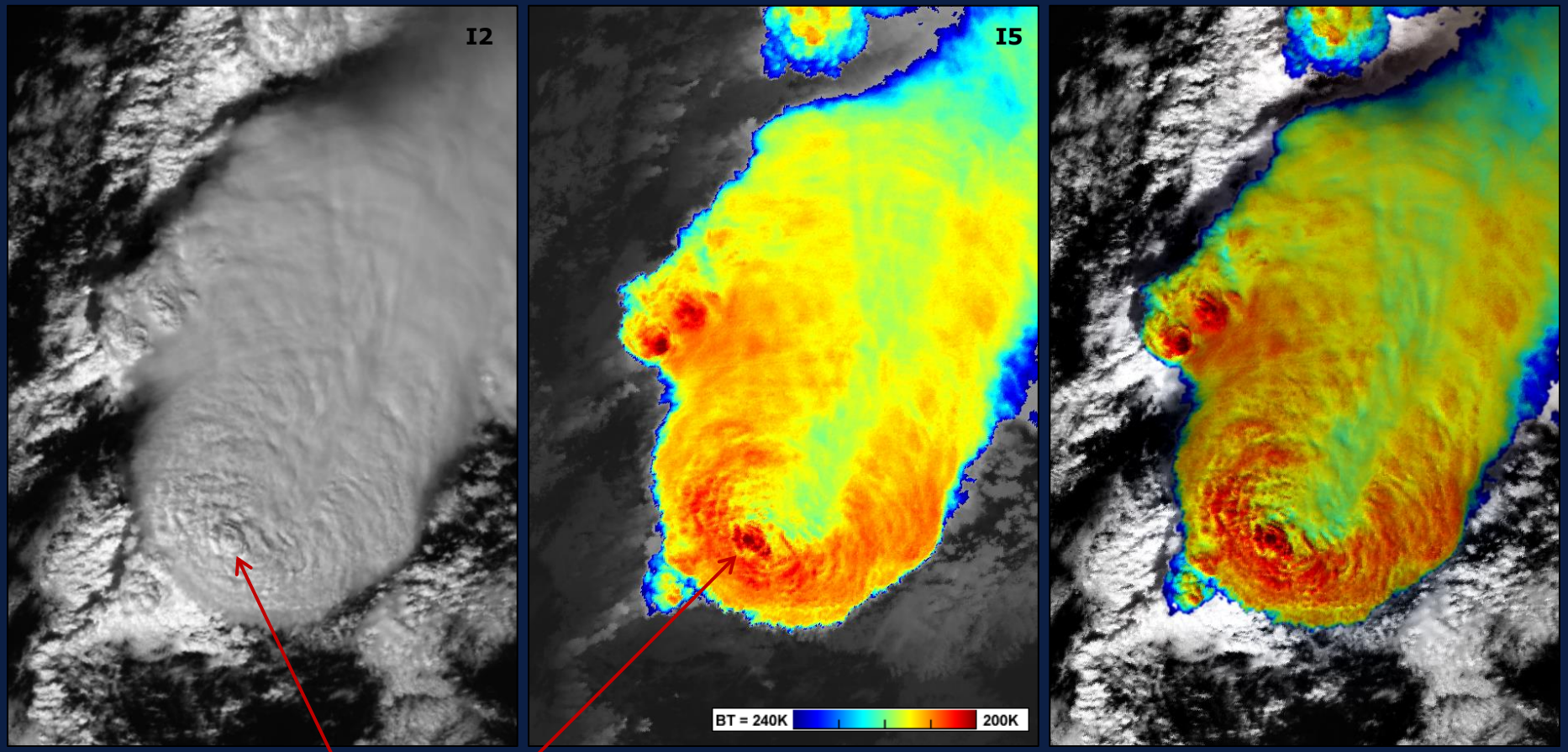
- series of individual "bubbles" (parcels) => short-lived overshooting tops (5 – 15 minutes)
- quasi-steady continuous flow => elevated dome-like structure (large persistent overshooting top) above the updraft area, with a lifetime of tens of minutes, up to ~ 60 – 100 minutes)

Overshooting tops appearance

Example of an overshooting top as seen from anvil level (side view), Bulgaria, Black Sea

Overshooting tops appearance from a satellite

S-NPP VIIRS (I-bands, 375m), 16 September 2016 12:40 UTC, Tyrrhenian Sea



Overshooting top example in visible band (left)
and in color-enhanced thermal IR band (right)

Overshooting tops ...

Overshooting tops are recently being more and more used as one of possible indicators of storm activity, severity …

Certain ambiguities, open questions:

- their typical duration (versus satellite scan periodicity), size and height of OTs
- their appearance/detection in visible and IR bands (cold versus thermally indifferent or even warm OTs) » impact on their detectability by IR methods
- other cloud-top features which may resemble overshooting tops – jumping cirrus, cloud-top waves, plumes, …
- impacts of the satellite spatial resolution (pixel size) – the better the resolution, the easier it is to decide about the nature of the feature (OT discrimination), and more OT's can be revealed

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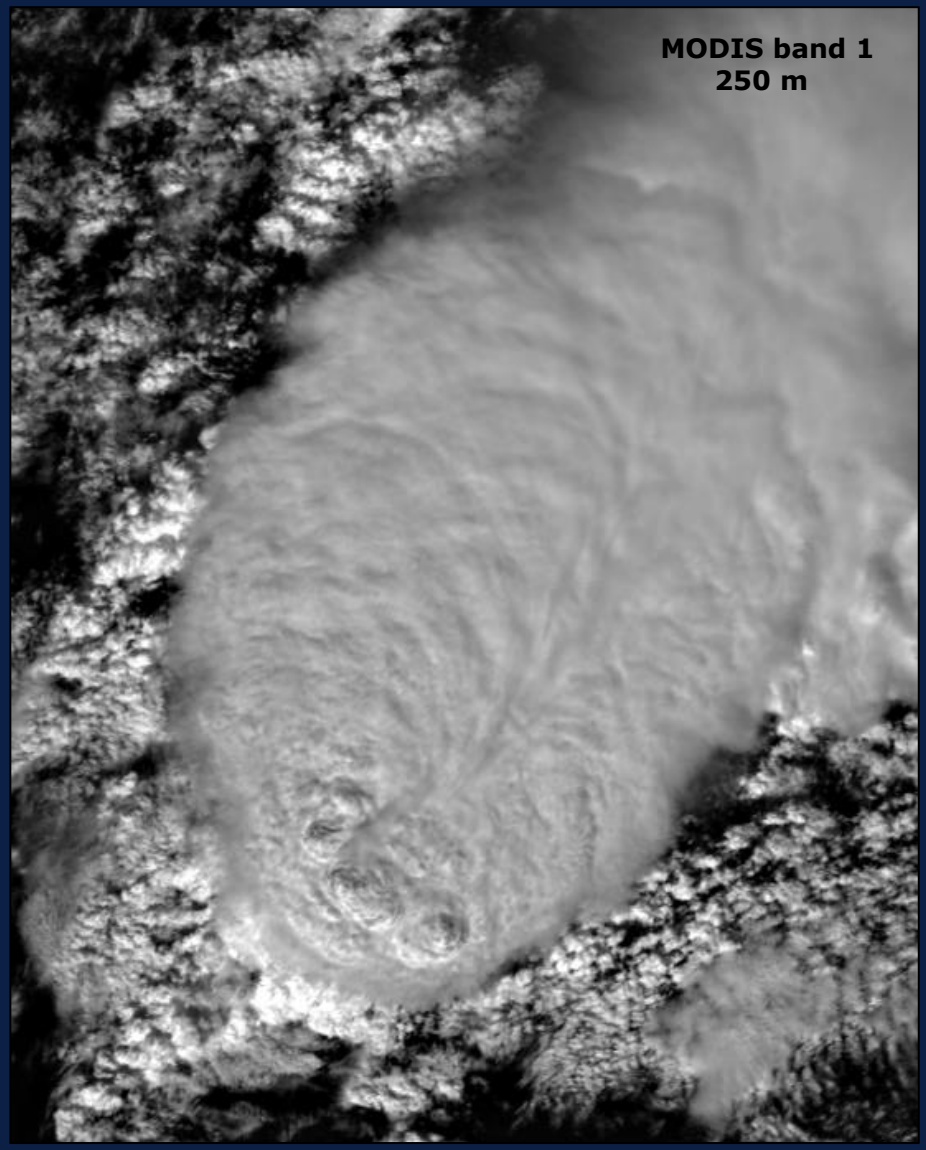
All of this is critically related to satellite spatial resolution (pixel size) as well as temporal resolution (scan frequency)!

SPATIAL RESOLUTION

(PIXEL SIZE)

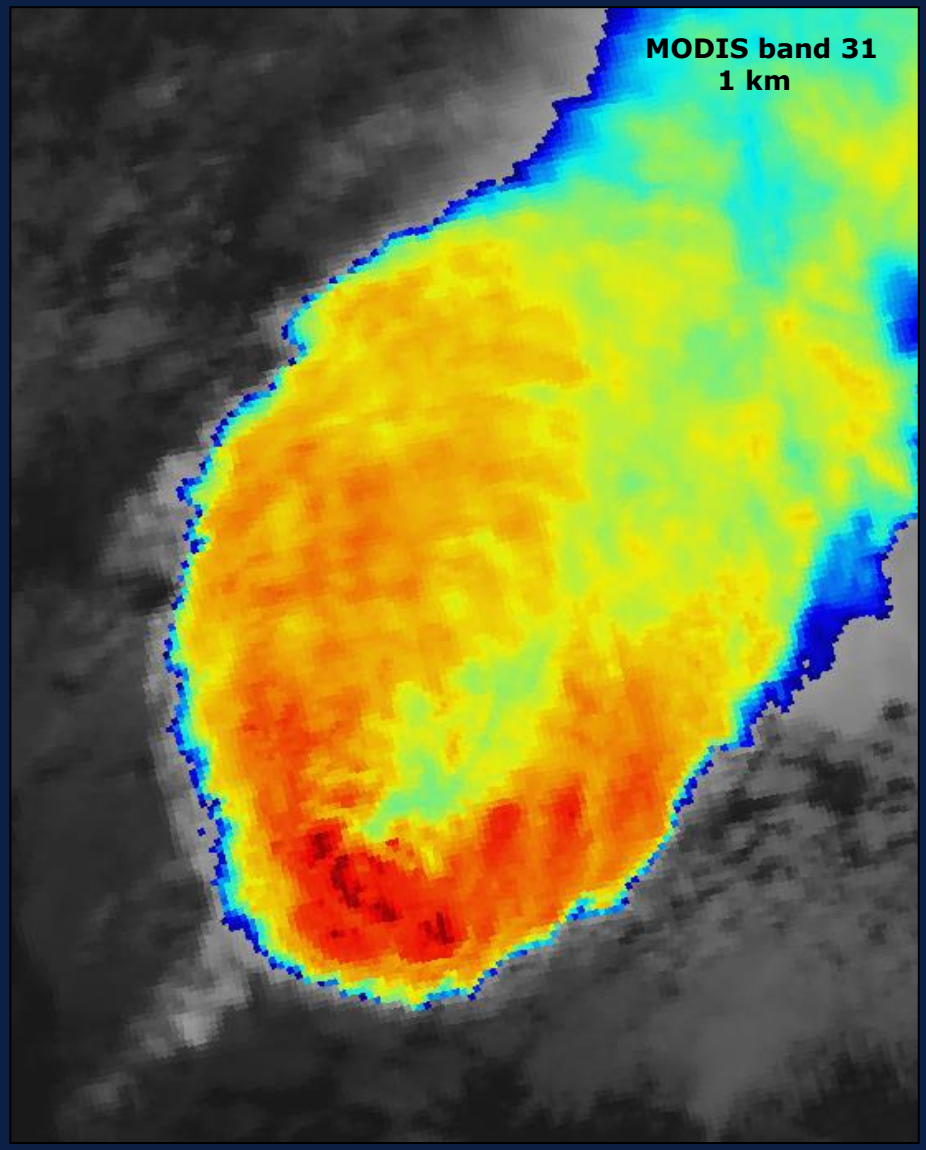
Comparison of MODIS (250m and 1 km) and MSG SEVIRI (~ 1km and ~ 3 km)



MODIS Aqua, 16 September 2016 12:22 UTC

Meteosat-9, 16 September 2016 12:20 UTC

Comparison of MODIS (250m and 1 km) and MSG SEVIRI (~ 1km and ~ 3 km)



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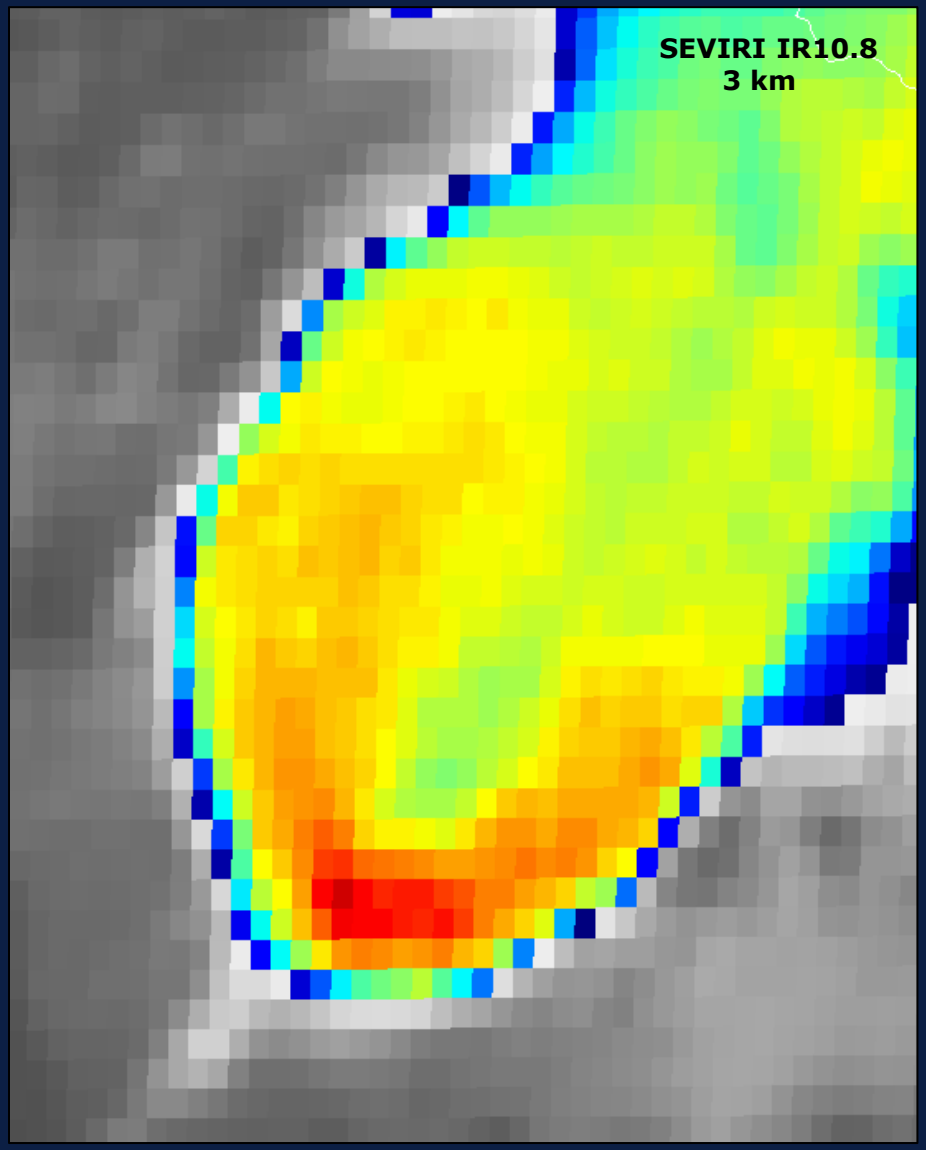

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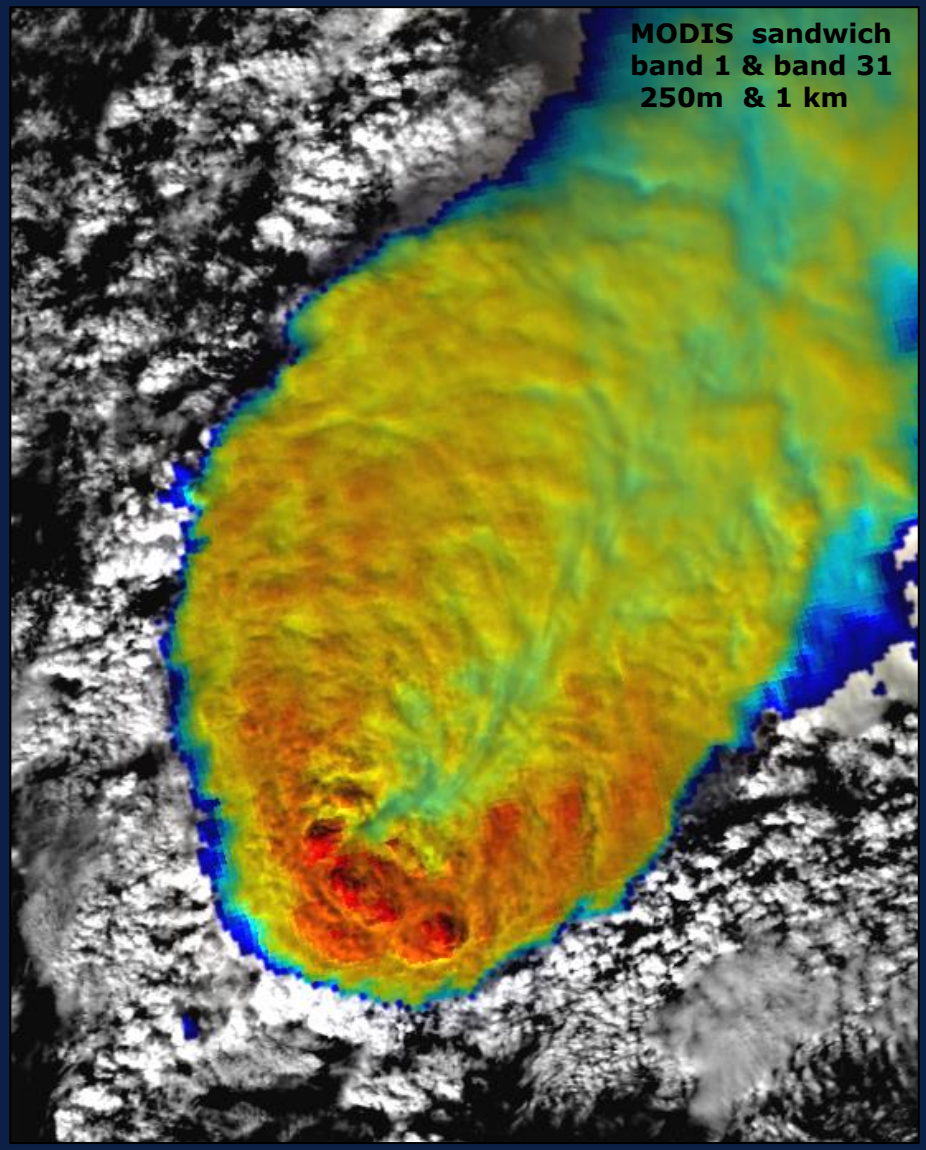

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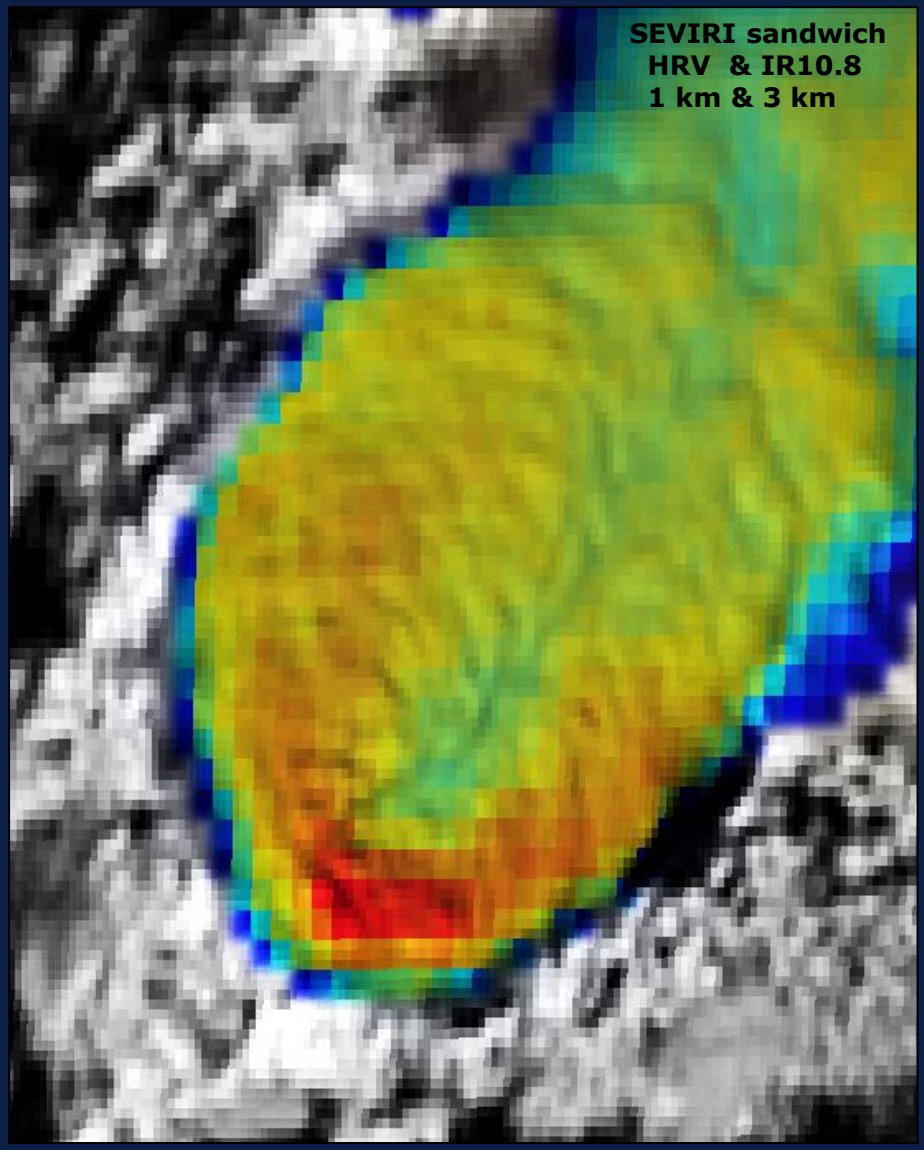


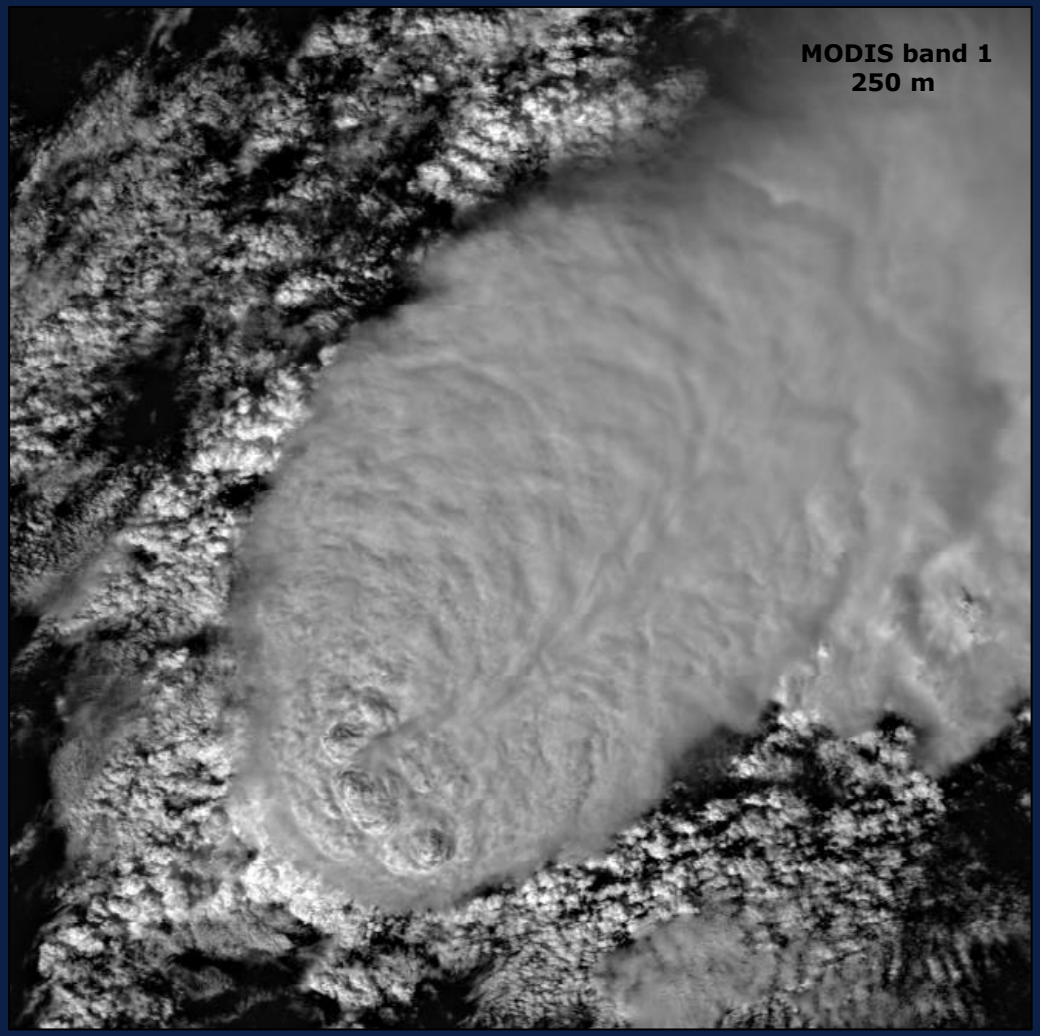
Meteosat-9, 16 September 2016 12:20 UTC

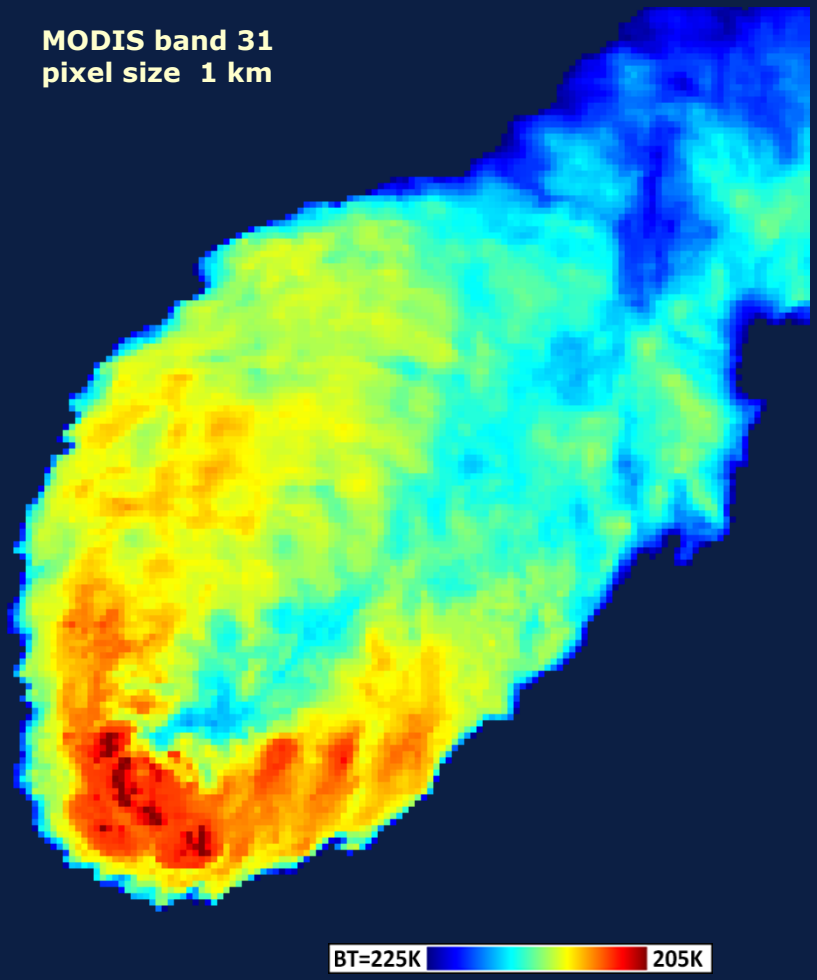
The smaller is the pixel size (the better is the spatial resolution),

- the smaller features can be detected, and more details of various phenomena can be revealed …

Another aspect of the spatial resolution: impact on detection of the lowest cloud top brightness temperature (BT)

Detection of BT minima (coldest spots of storm tops) versus pixel size





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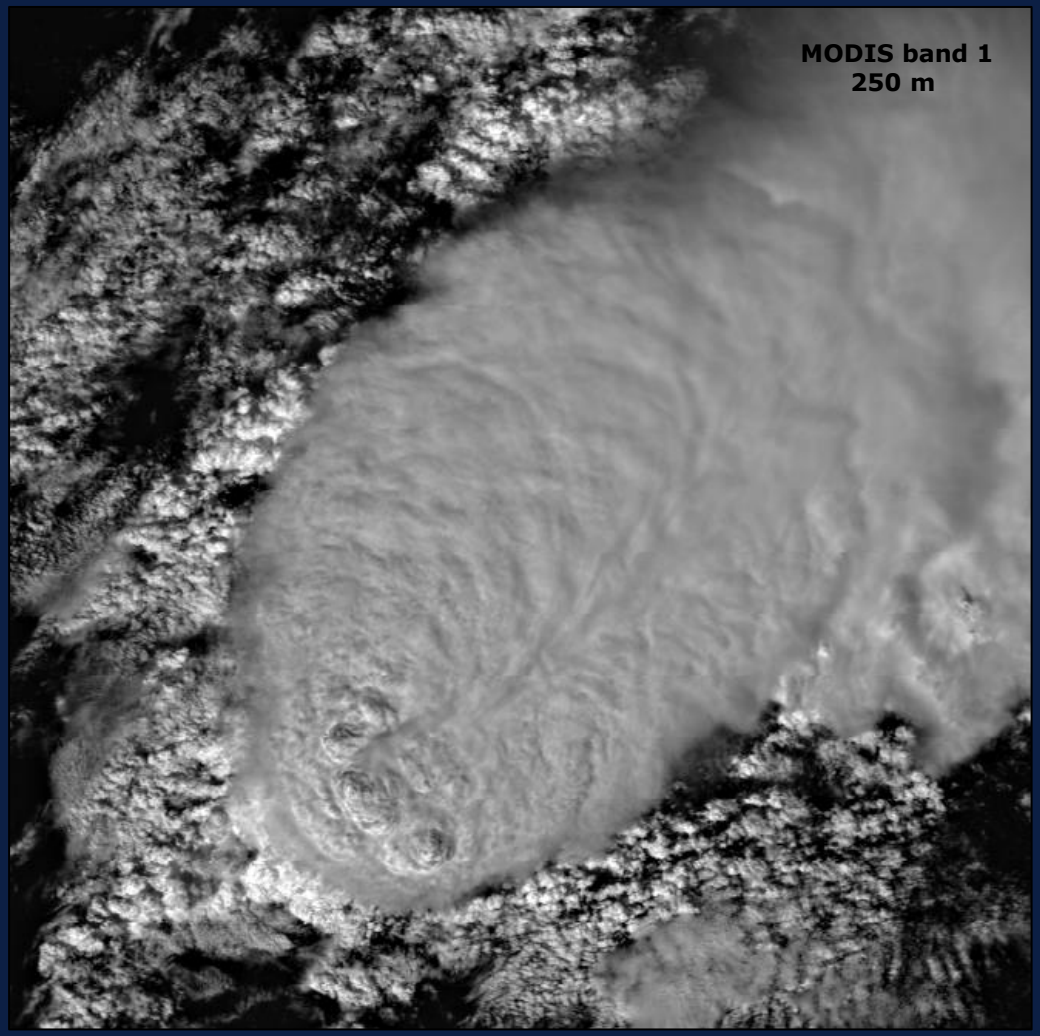

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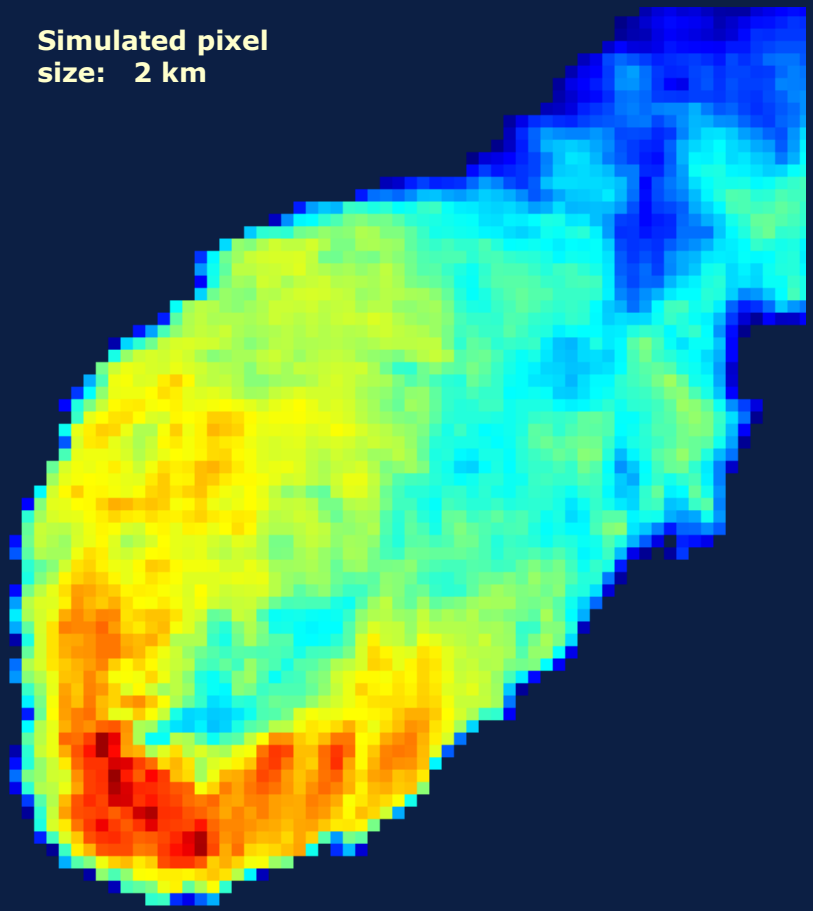

(based on MODIS band 31 data)

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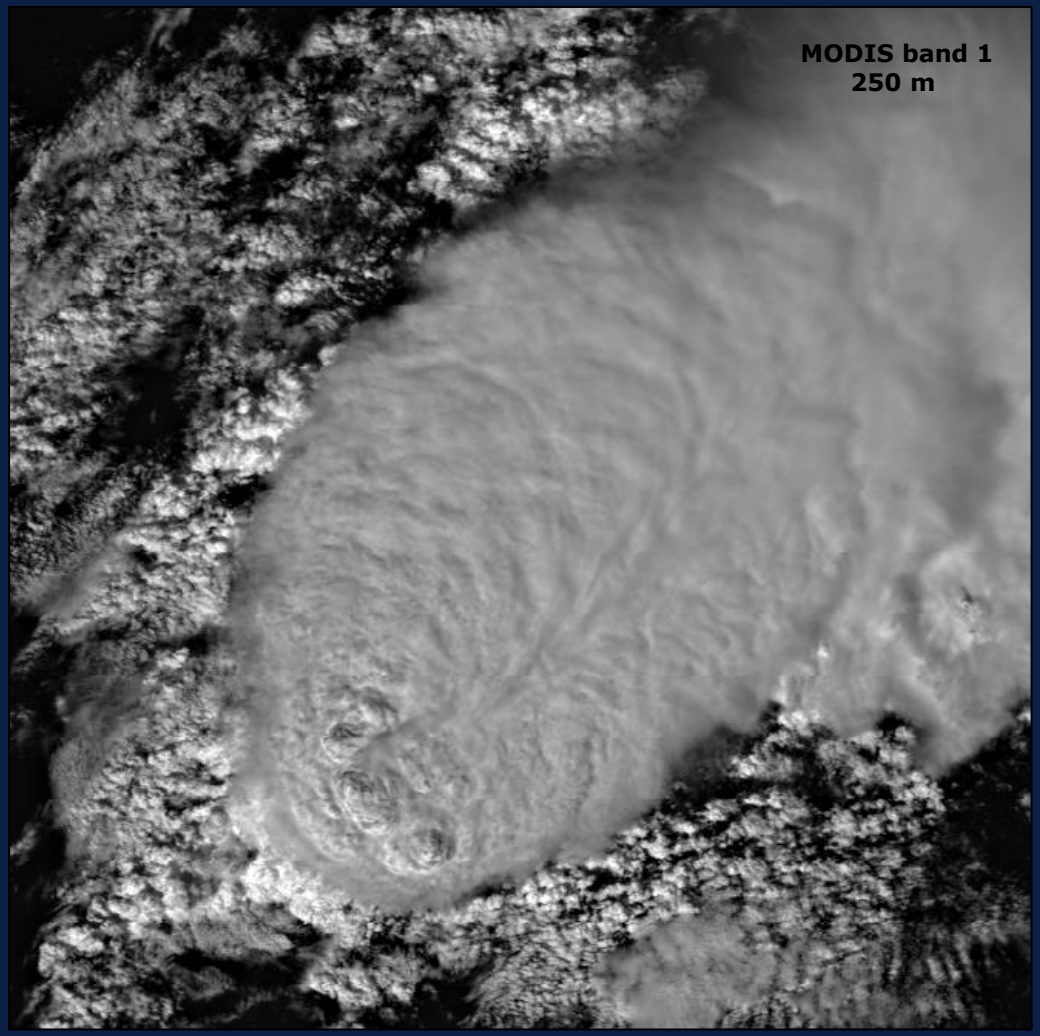

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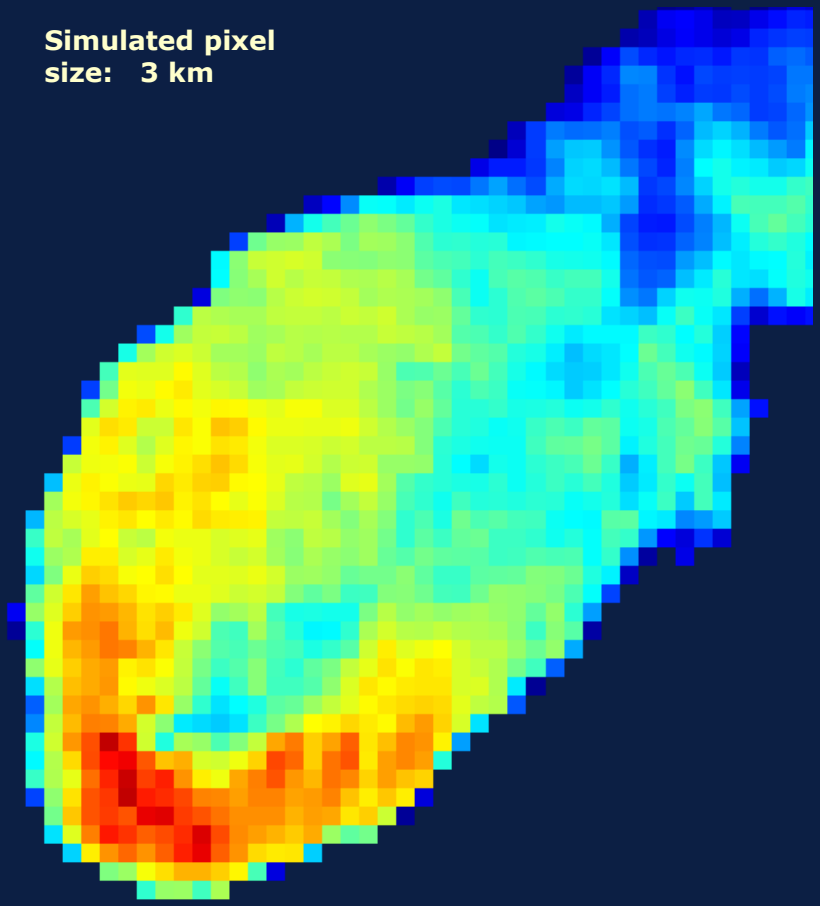

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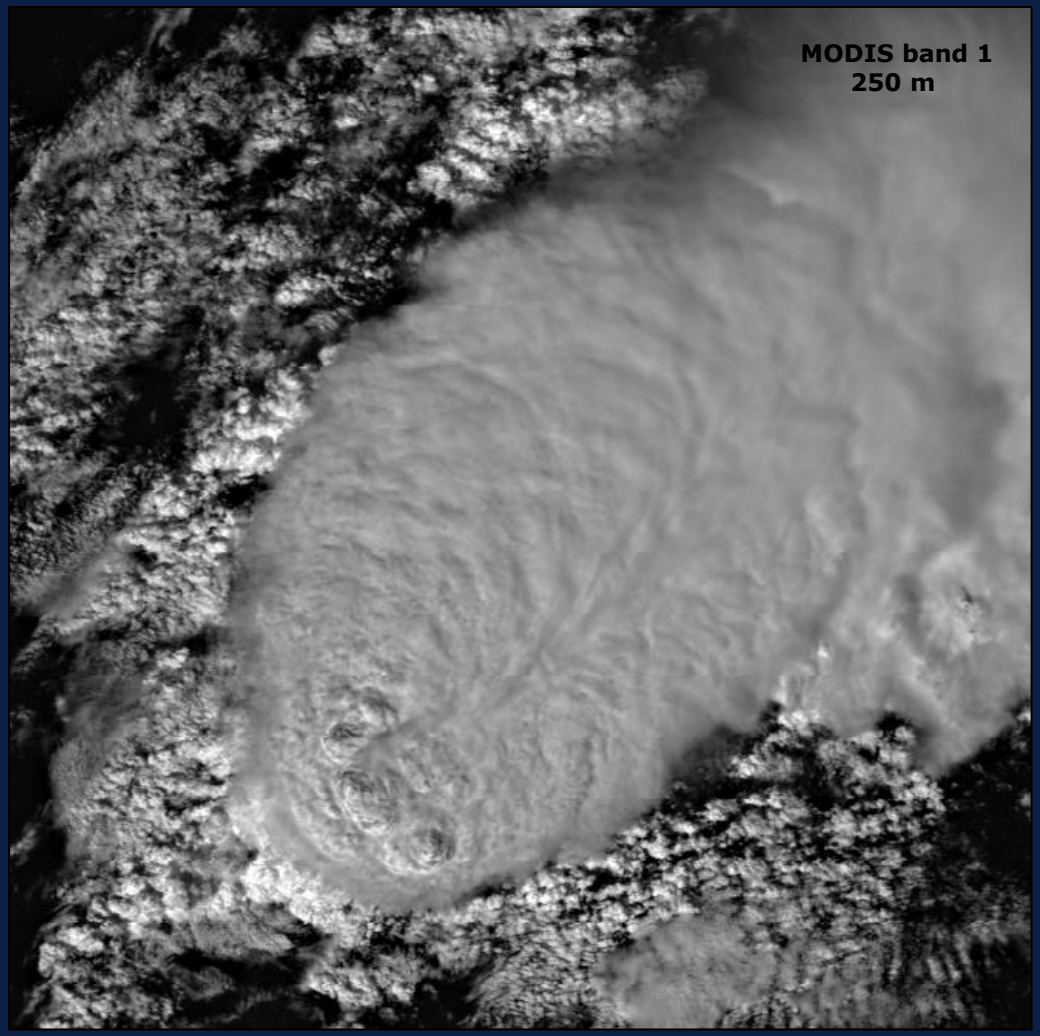

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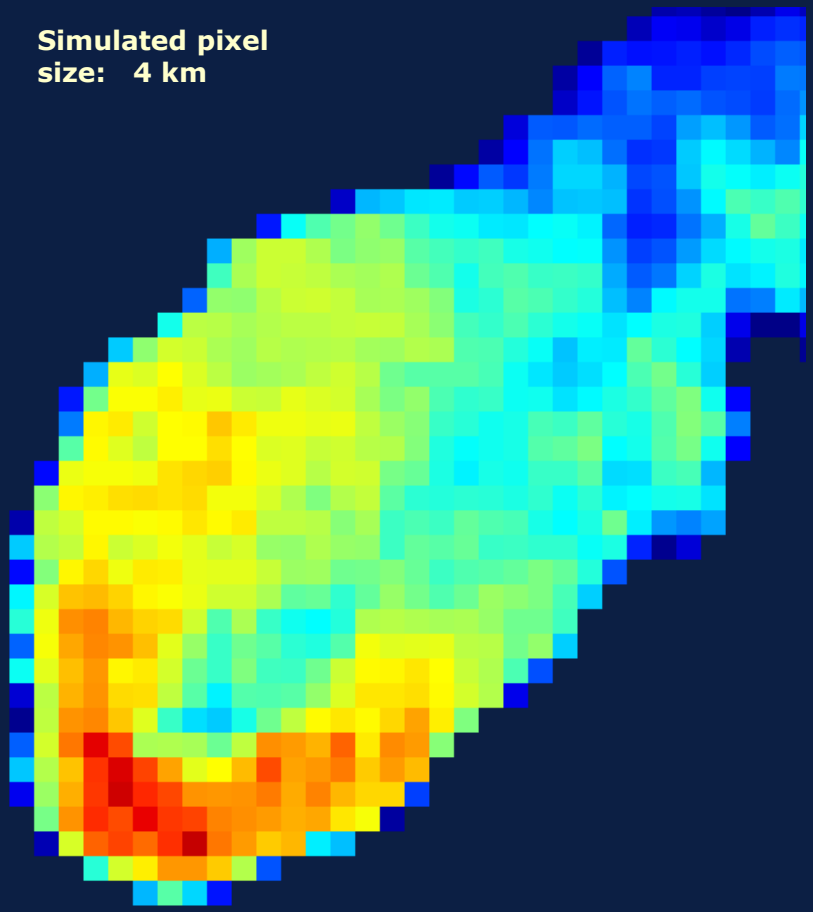
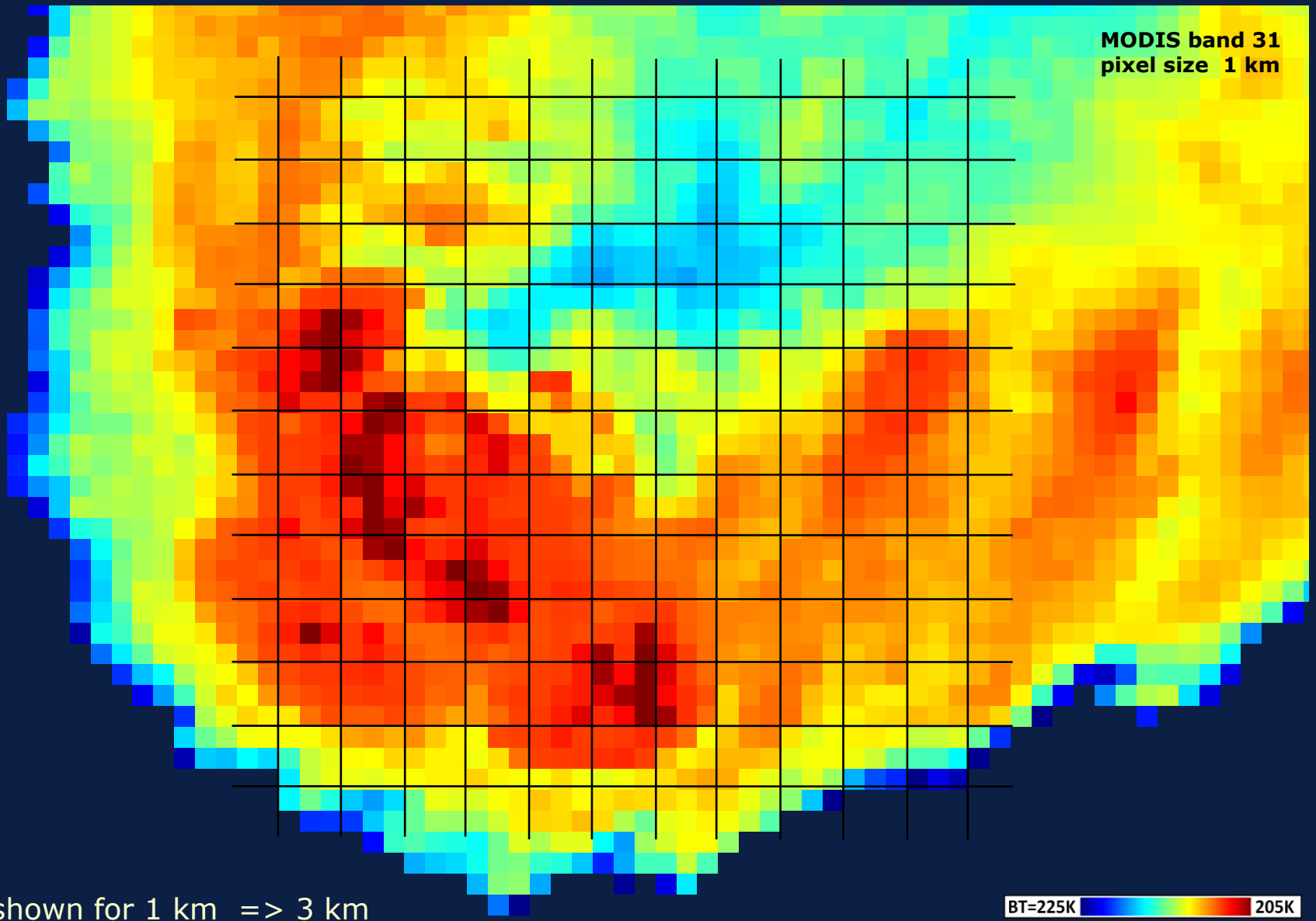


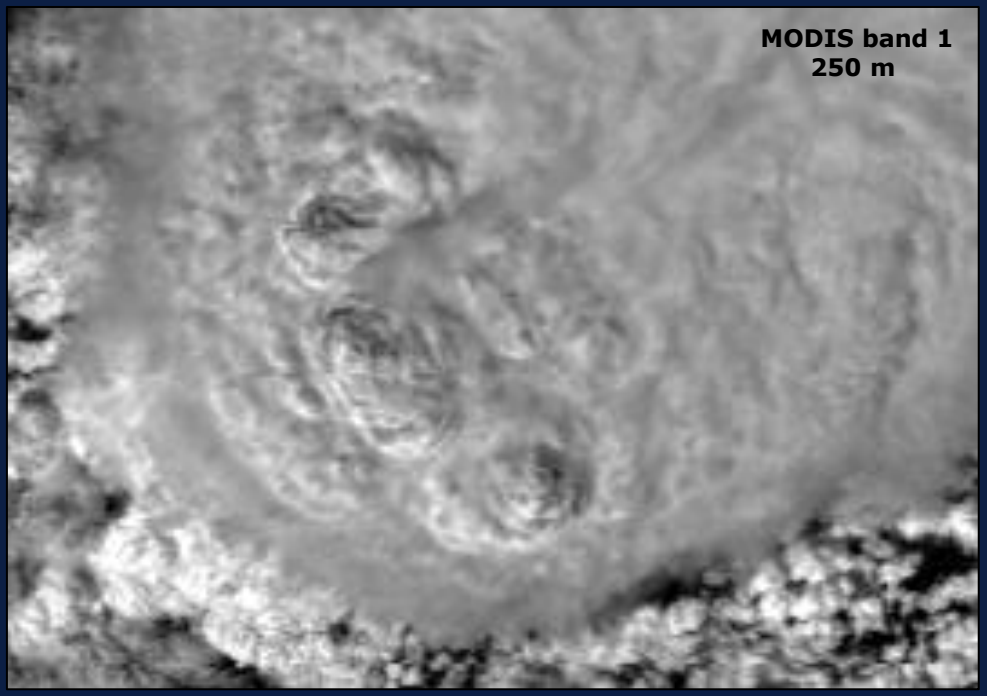
(based on MODIS band 31 data)

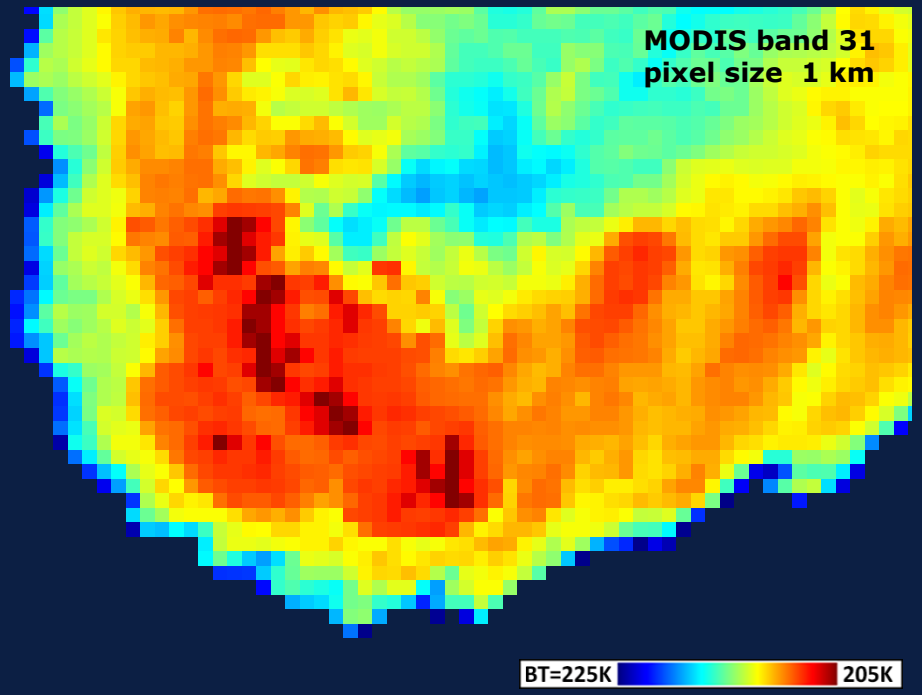
BT minima – depend on averaging of the coldest tops (pixels) with their surroundings



Here shown for 1 km => 3 km

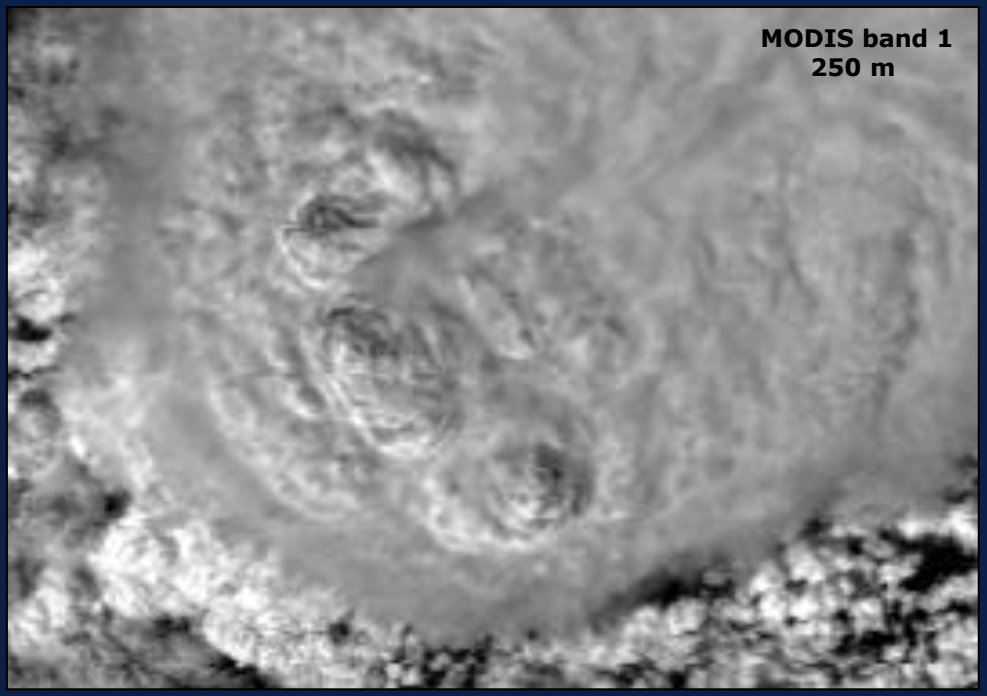
Detection of BT minima (coldest spots of storm tops) versus pixel size

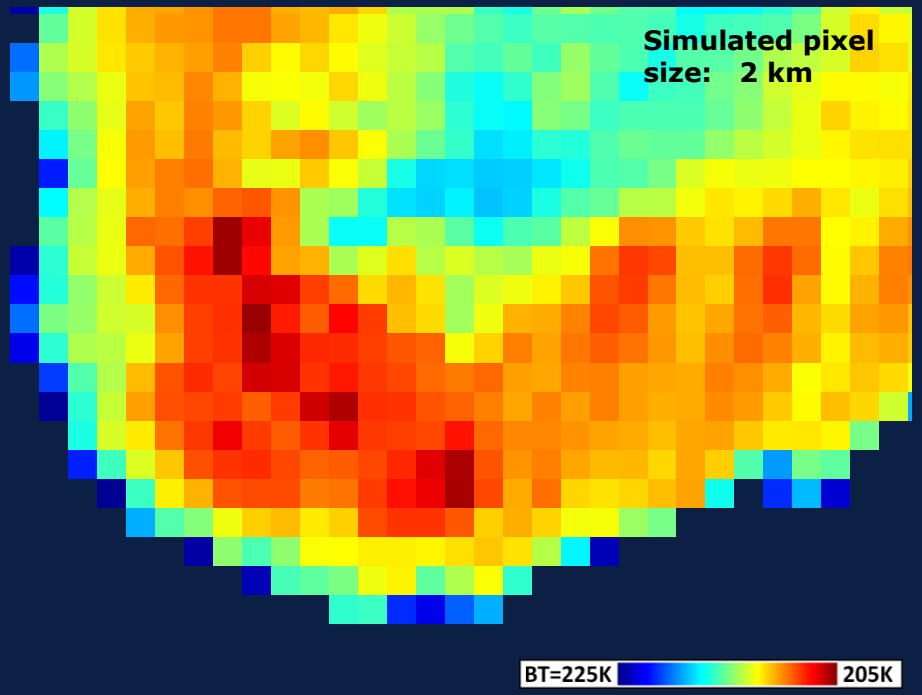




All the dark brown pixels are at 205 K (19 pixels total), including the isolated pixel at south-west part of the anvil

Detection of BT minima (coldest spots of storm tops) versus pixel size



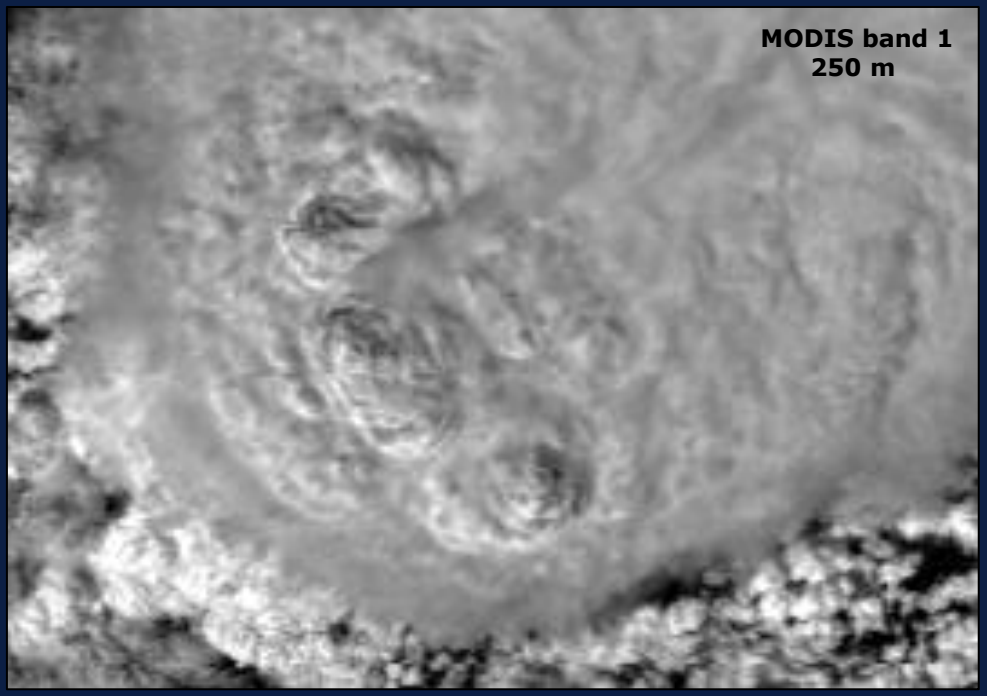


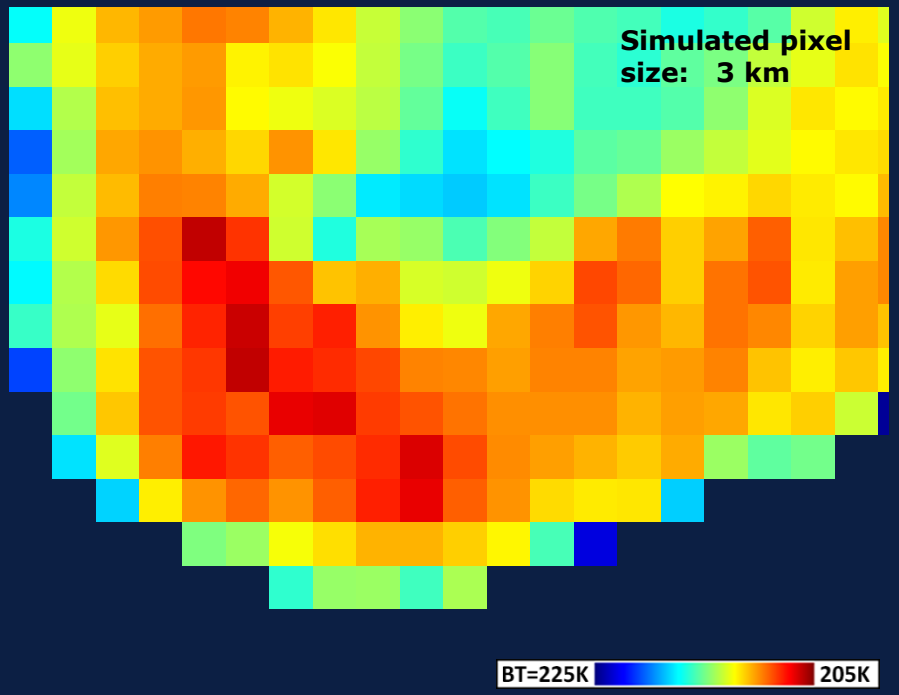
BT(min) has increased slightly, to 205.6 K (1 pixel only)

Total of 6 pixels between 205.6 - 206 K

The isolated pixel is now at 207 K

Detection of BT minima (coldest spots of storm tops) versus pixel size



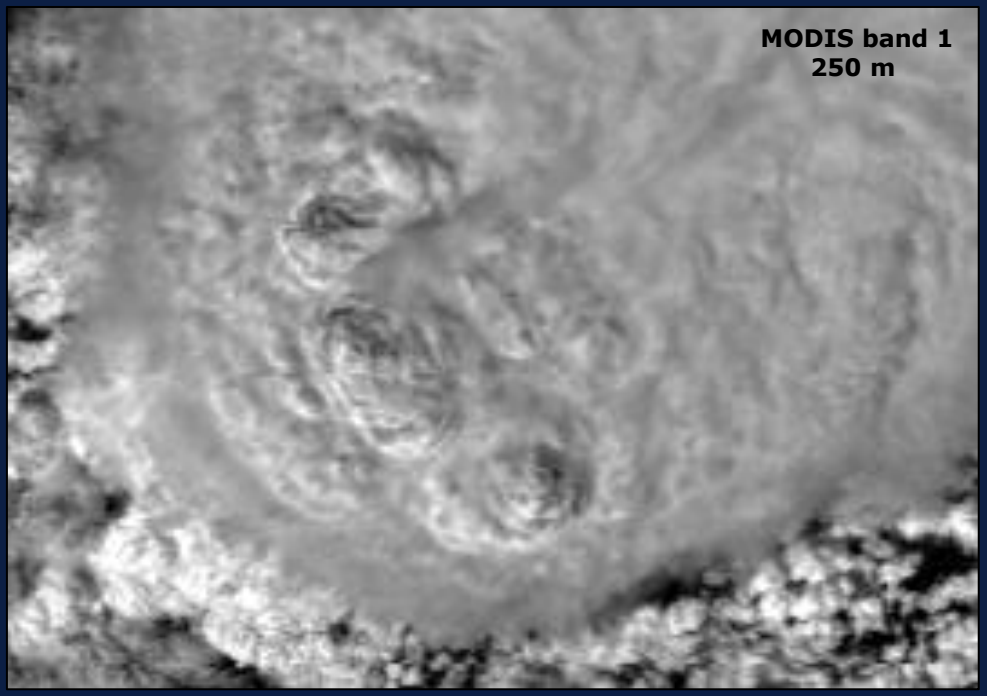


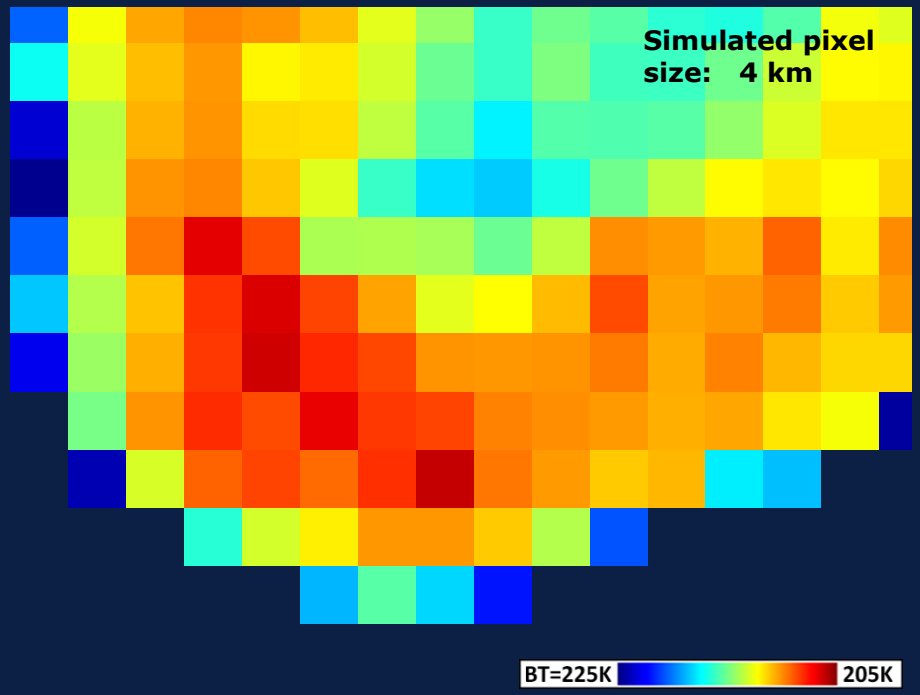
BT(min) has increased to 206.3 K (2 pixels only)

Total of 7 pixels between 206.3 - 207 K

The isolated pixel is now at 208 K

Detection of BT minima (coldest spots of storm tops) versus pixel size





BT(min) has increased to 206.4 K (2 pixels)

Total of 5 pixels between 206.4 - 207 K

The isolated pixel can not be detected anymore

BT lowest values and pixel size

- Biggest impact of averaging (pixel aggregation, lower resolution) on isolated small-scale coldest tops;

- lower effect on larger-scale cold tops (groups of several cold pixels;

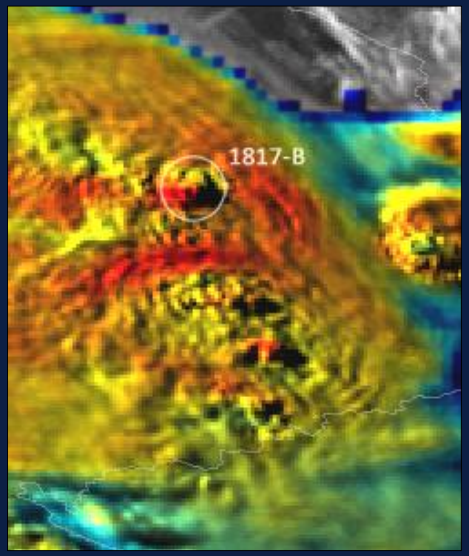
- no effect on large, homogeneous cold areas (such as uniform cirrus layers).

TEMPORAL RESOLUTION

(SCAN FREQUENCY)

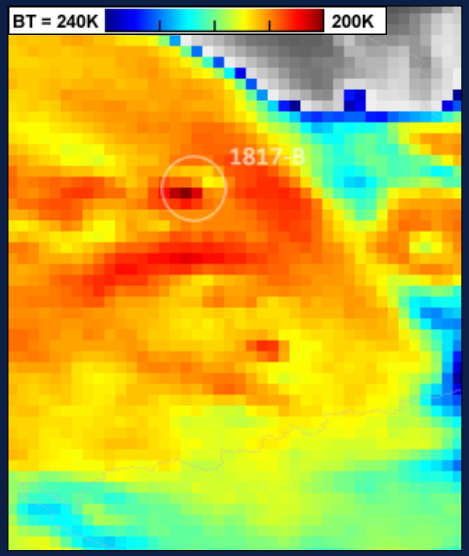
Overshooting tops – appearance examples

Meteosat-8, 20 June 2013 18:17 UTC

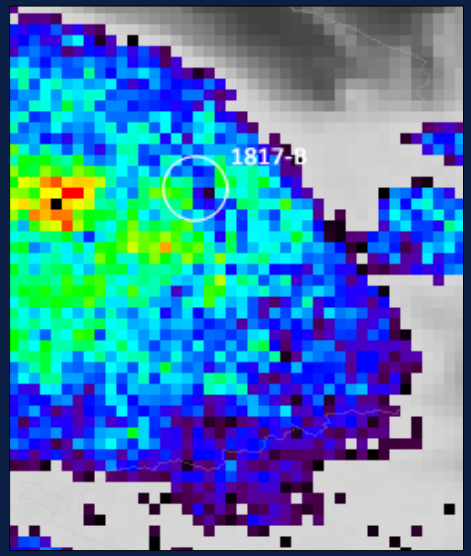


sandwich HRV & IR10.8-BT

HRV



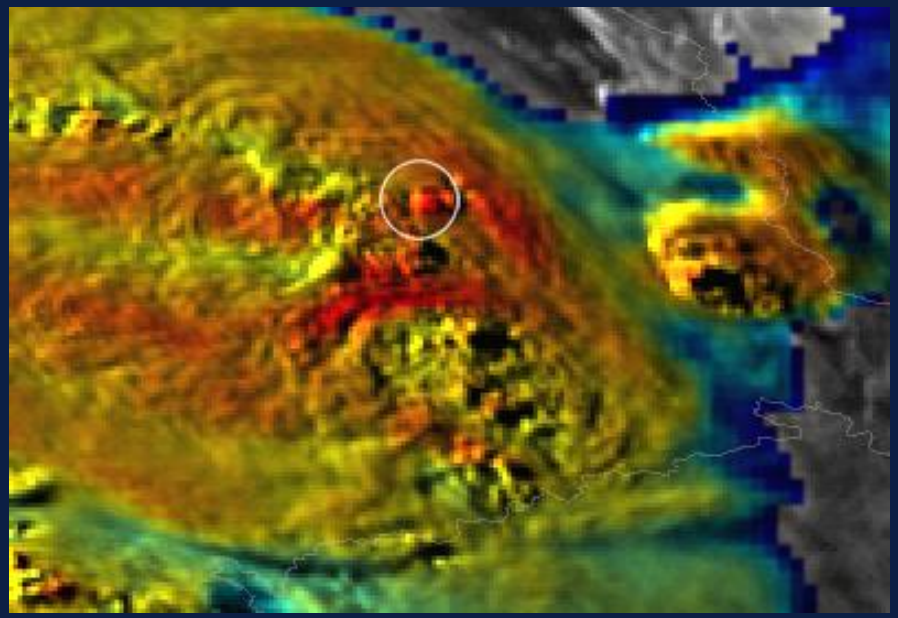
IR10.8-BT (200-240K)

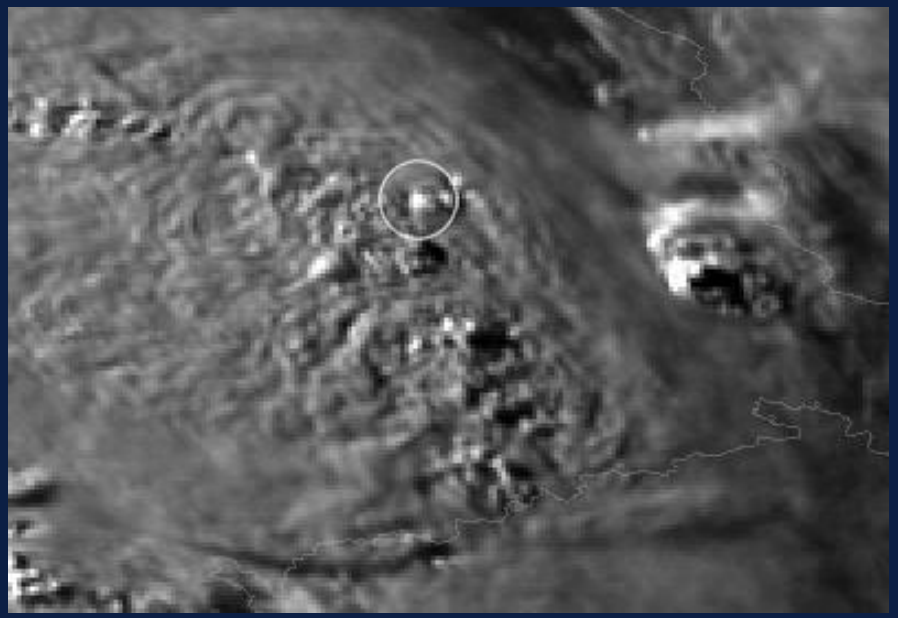


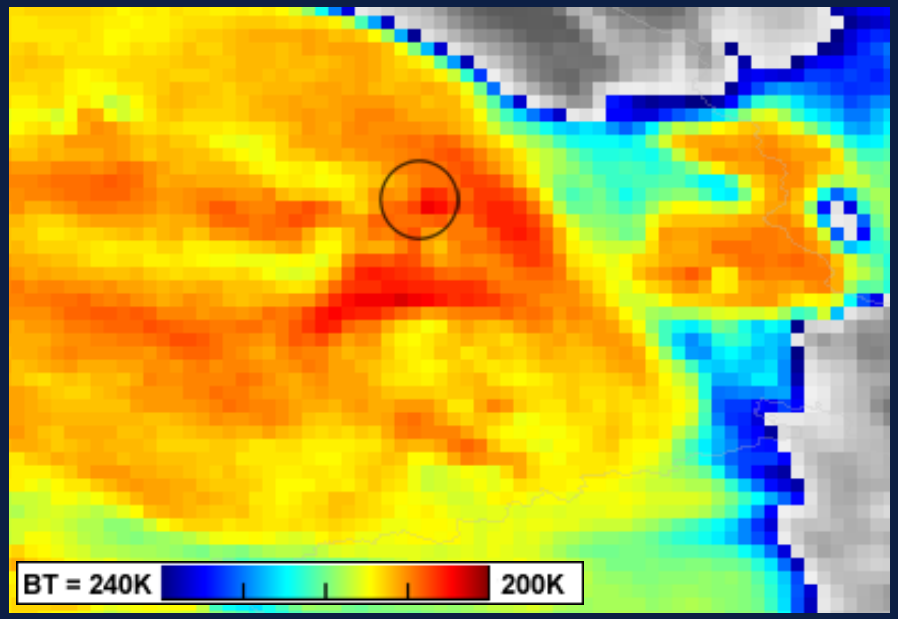
BTD (WV6.2-IR10.8)

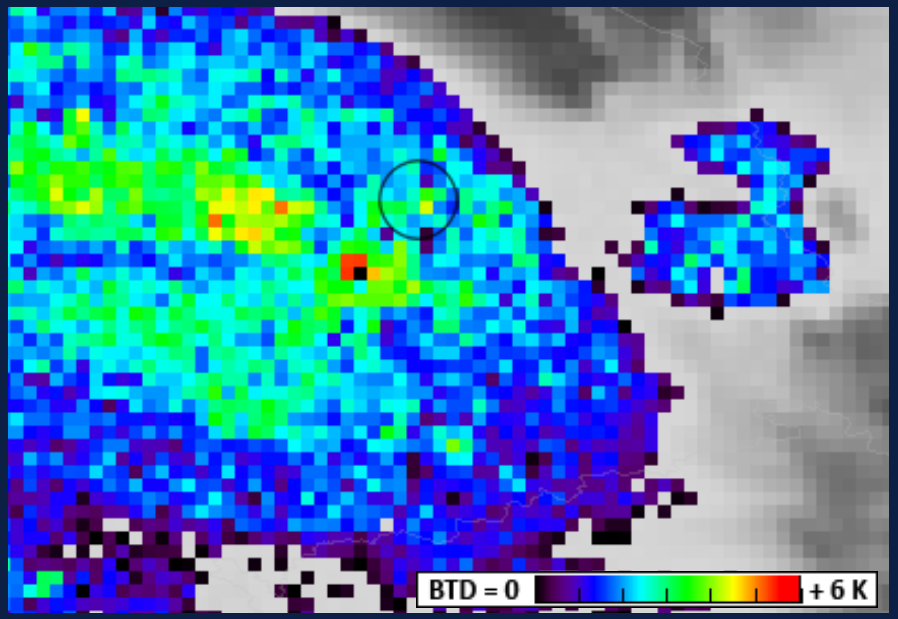
Textbook appearance of the overshooting top – well defined bubble-like shape and casted shadow in HRV, distinct isolated local IR-BT minimum (much colder than its surrounding anvil top); however not associated with any local BTD (WV6.2-IR10.8) maximum

Meteosat-8, 20 June 2013 18:12 UTC









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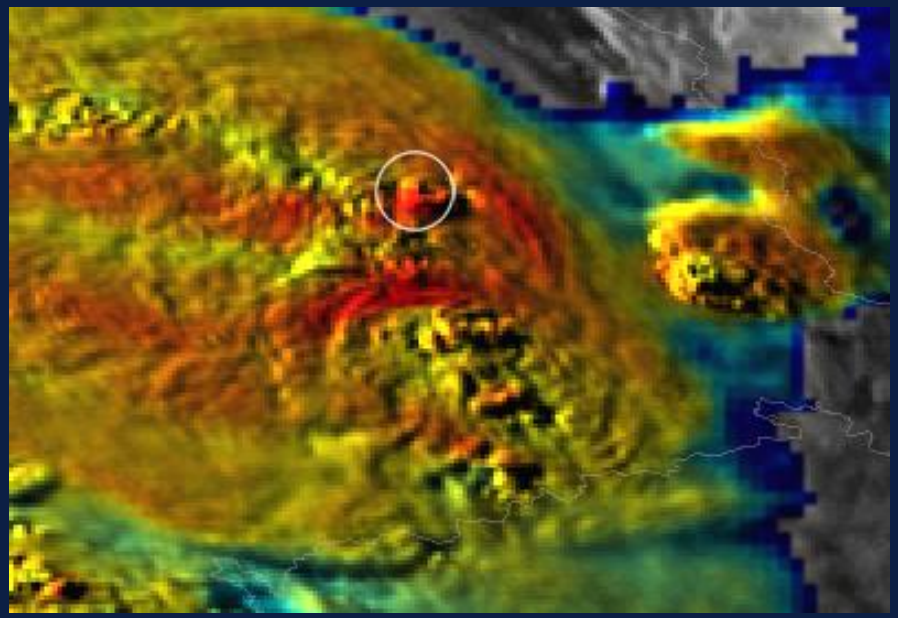

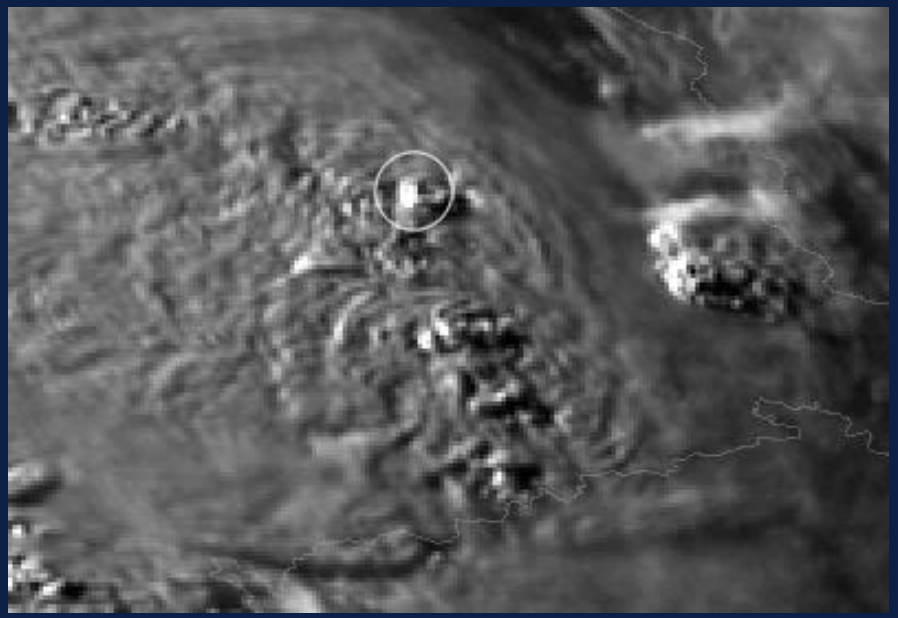

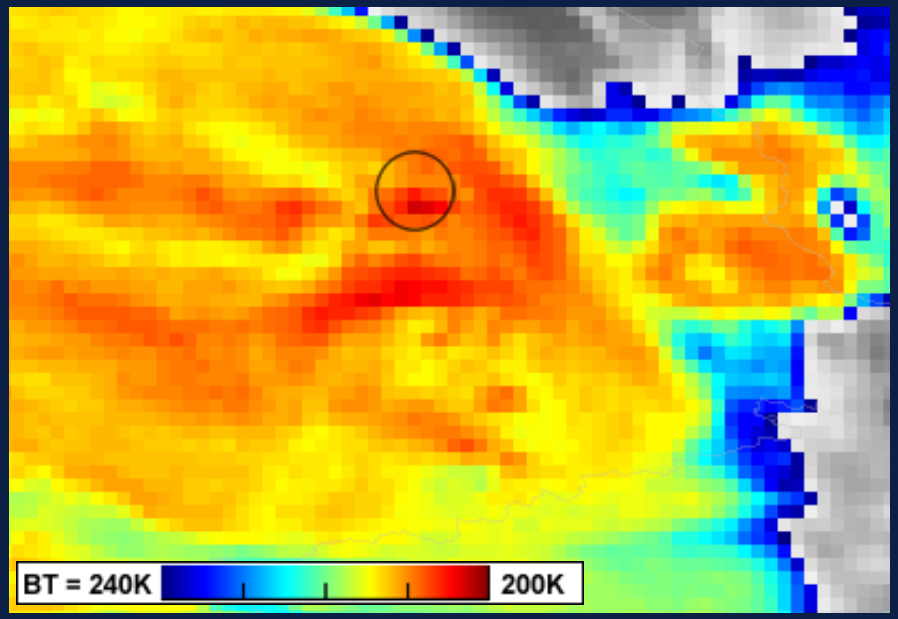

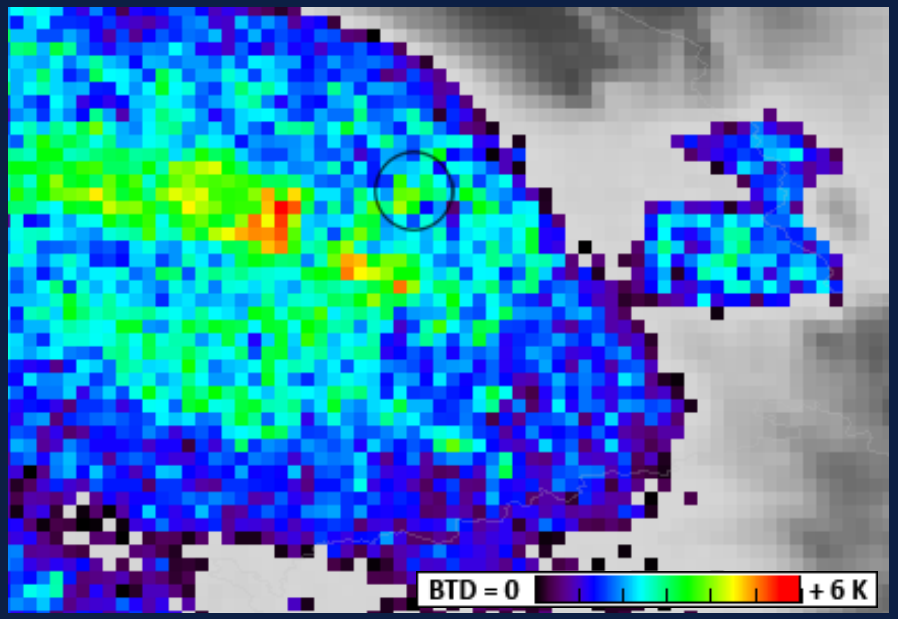

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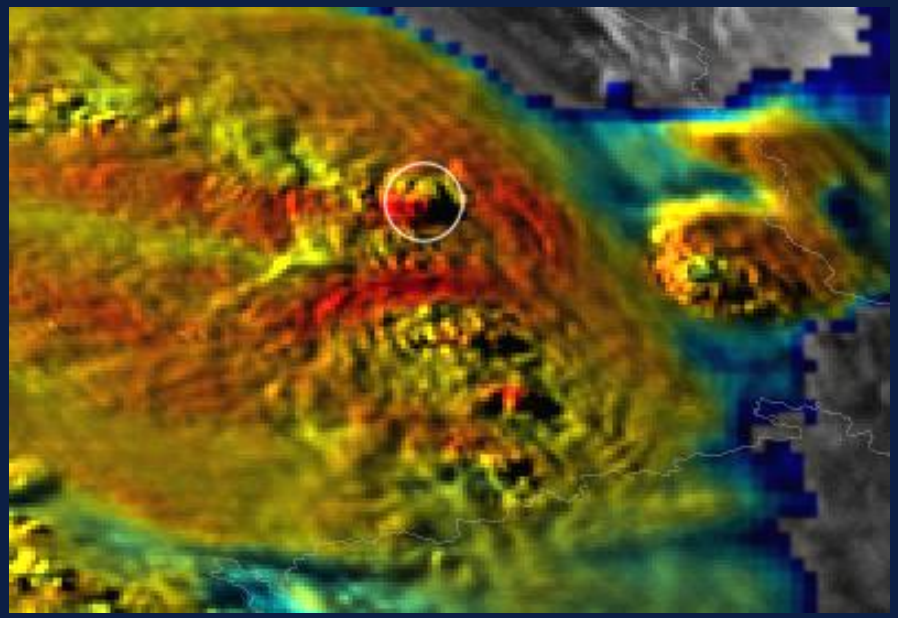

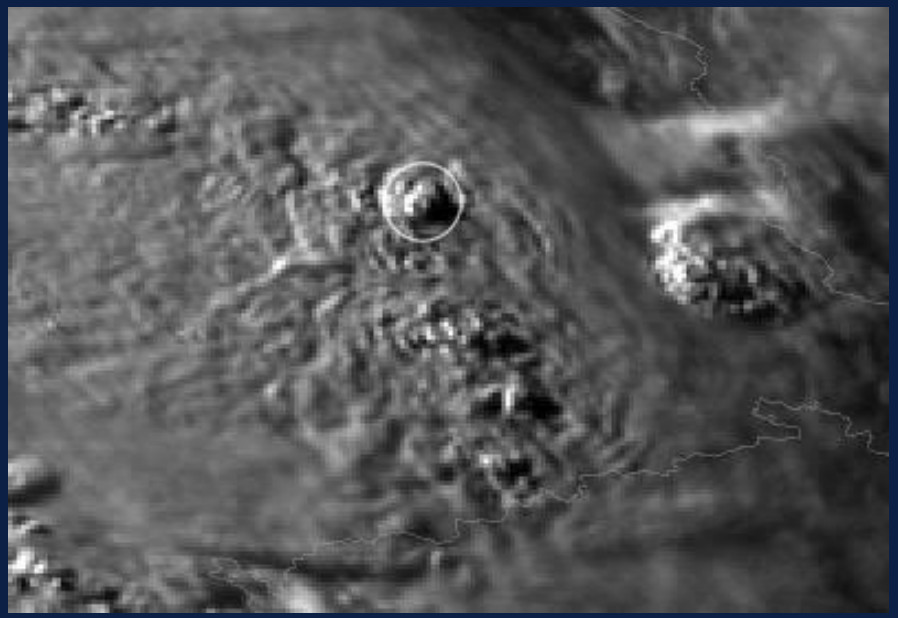

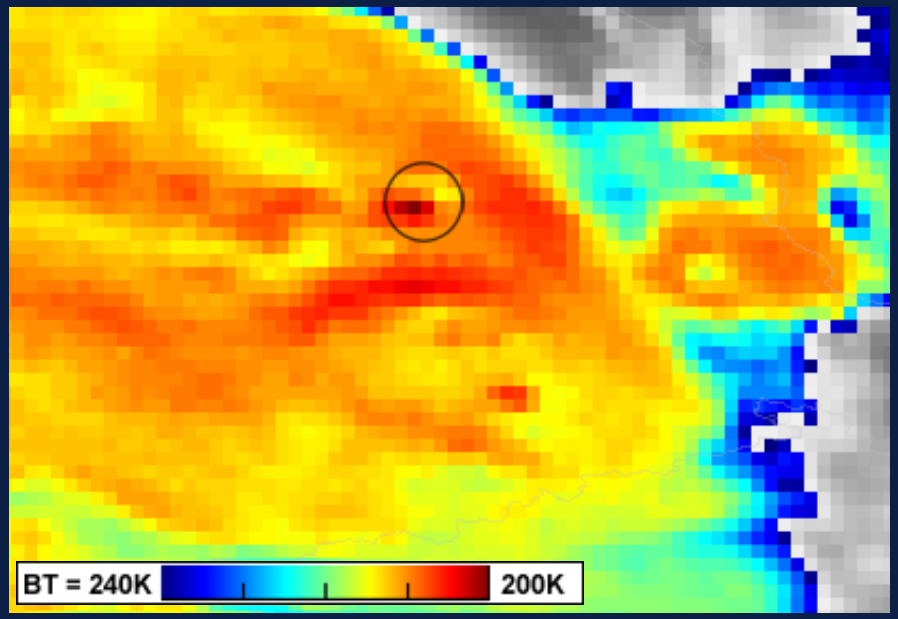

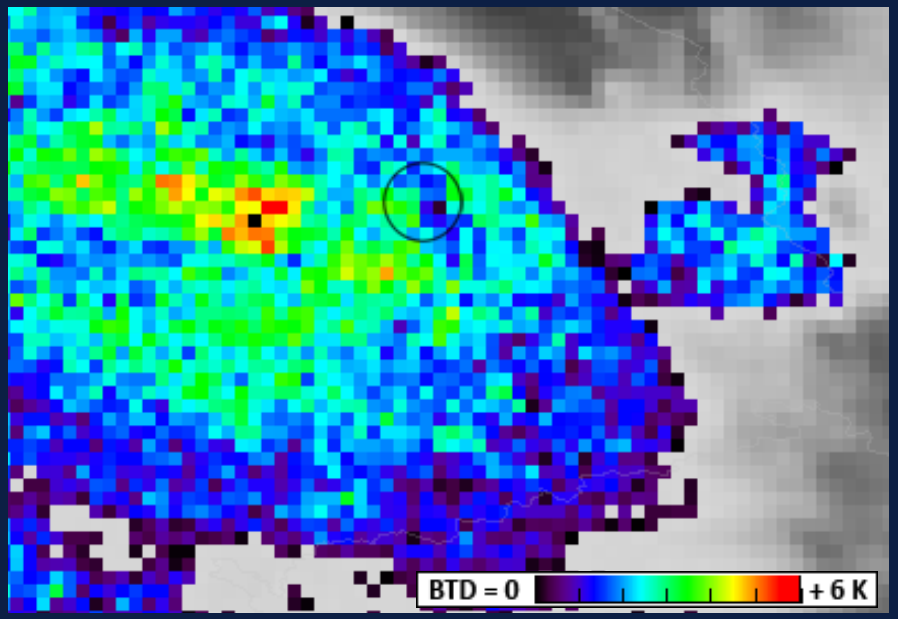

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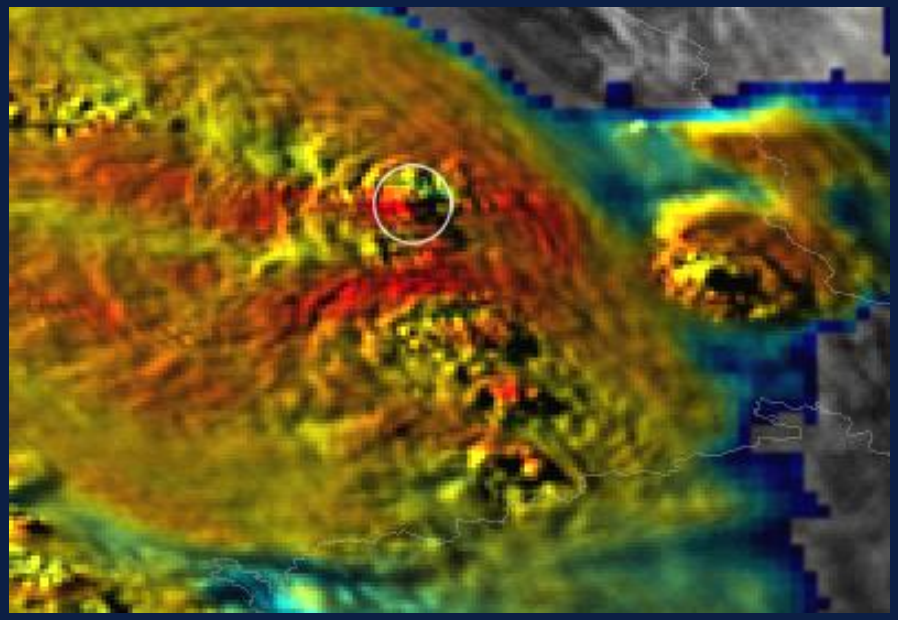

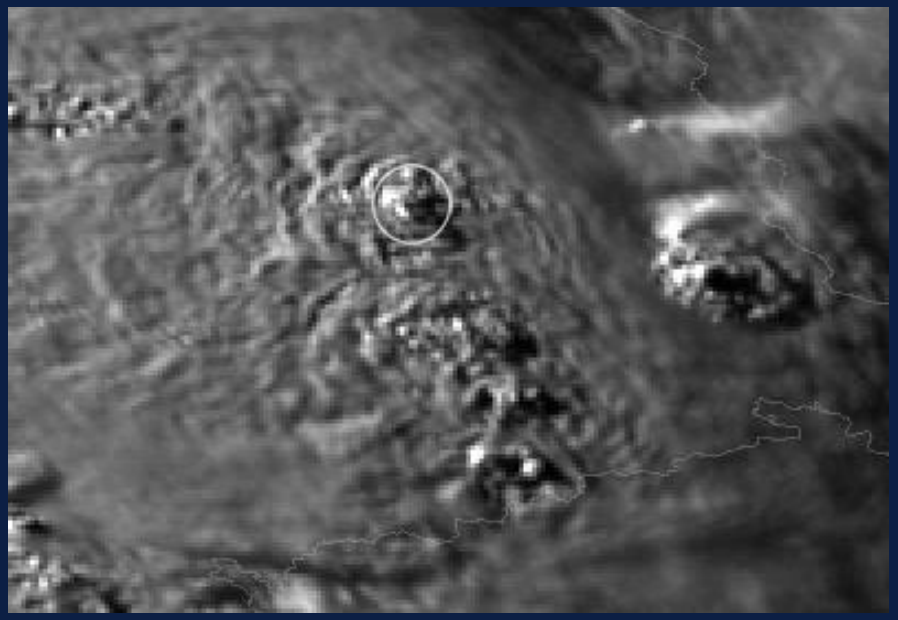

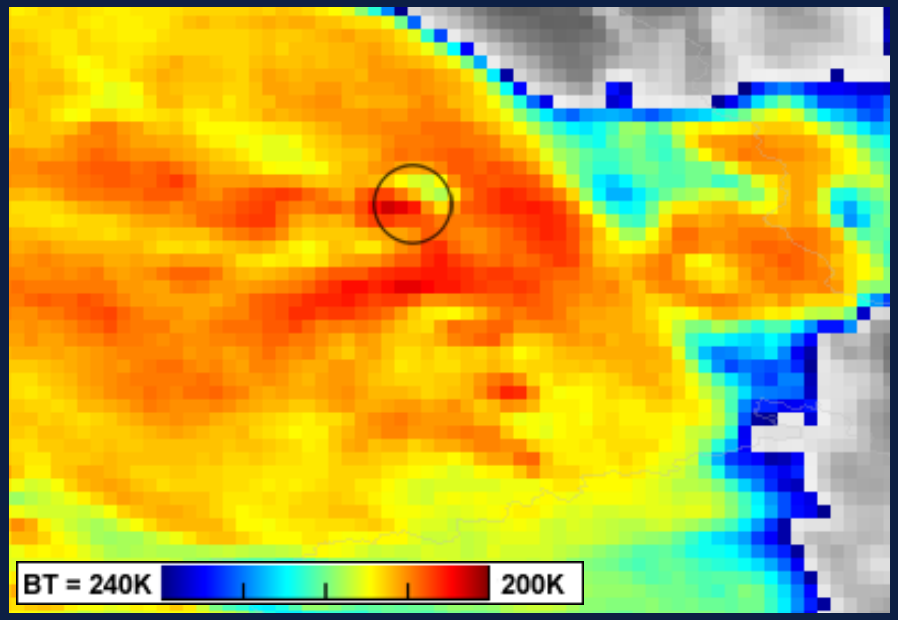

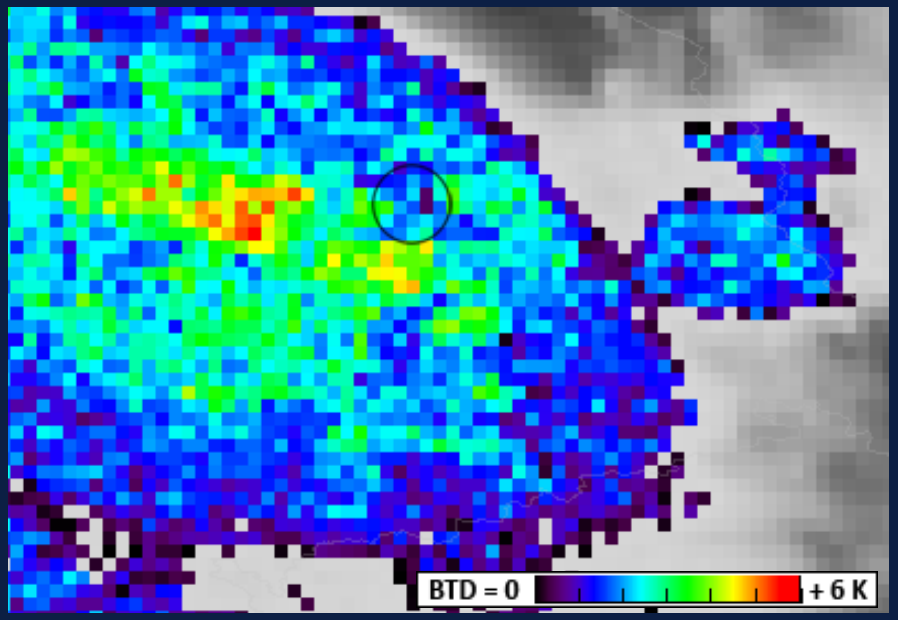

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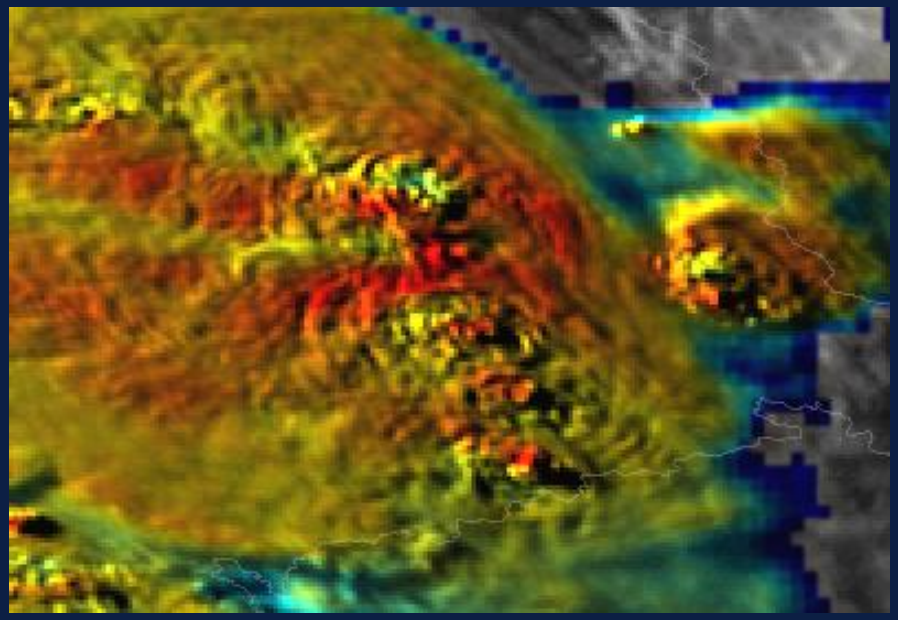
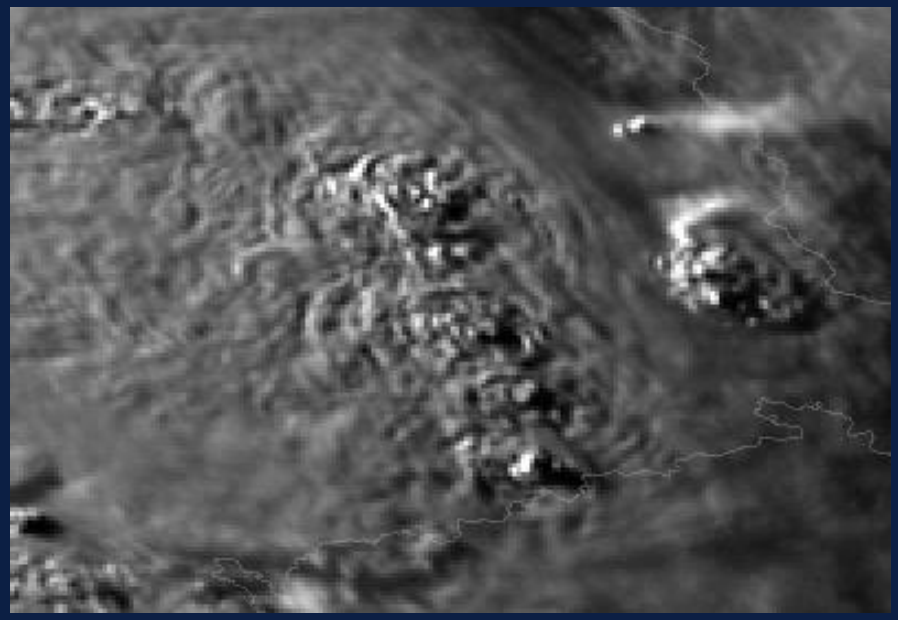
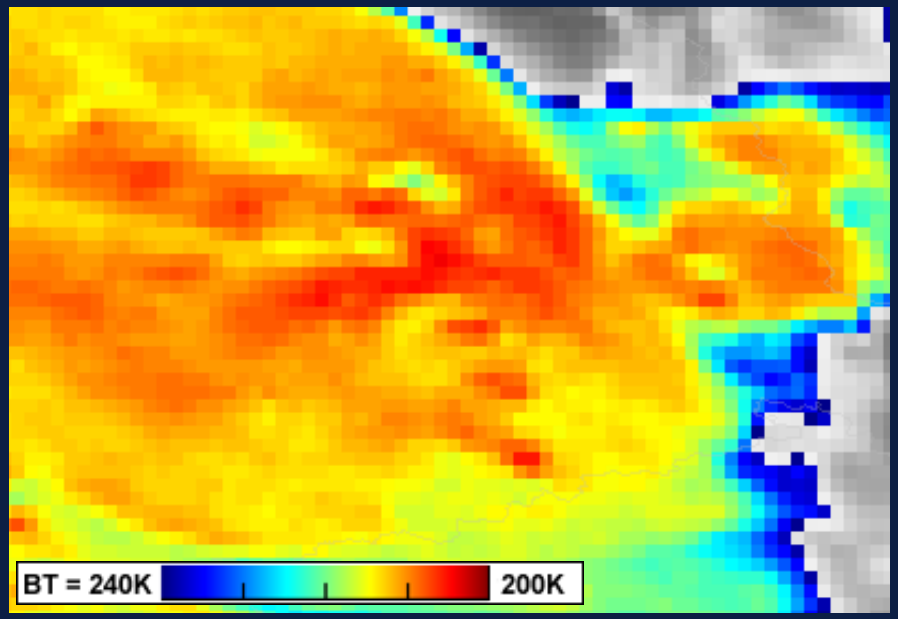
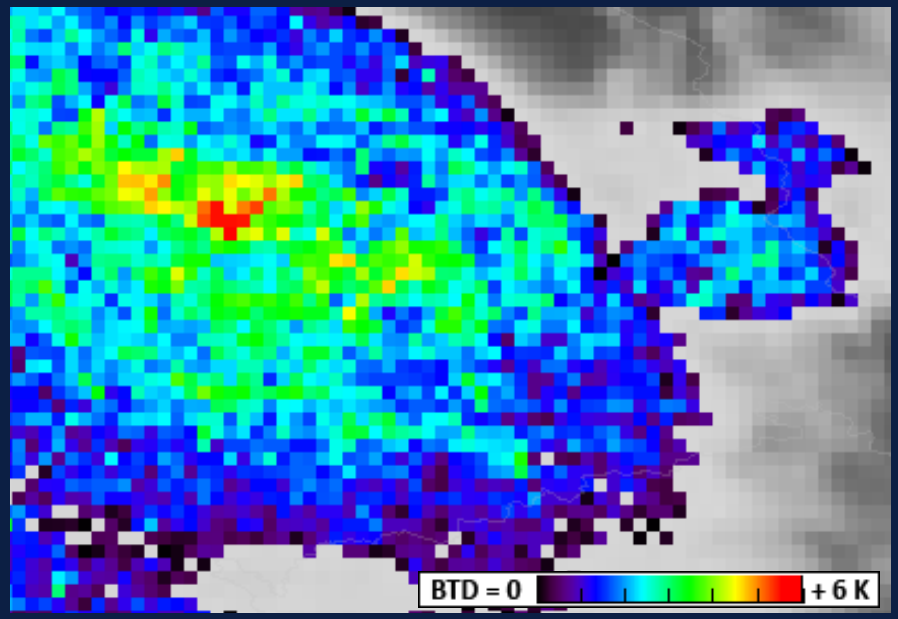


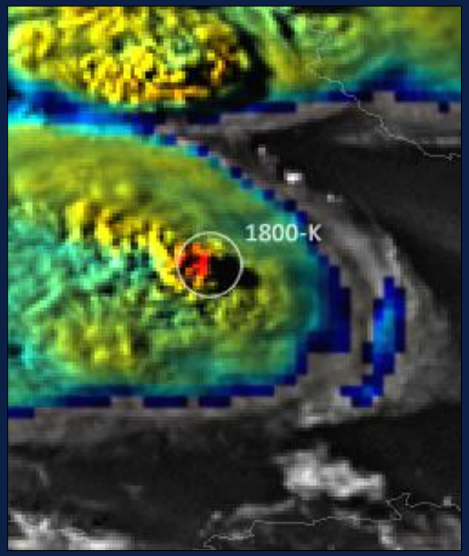




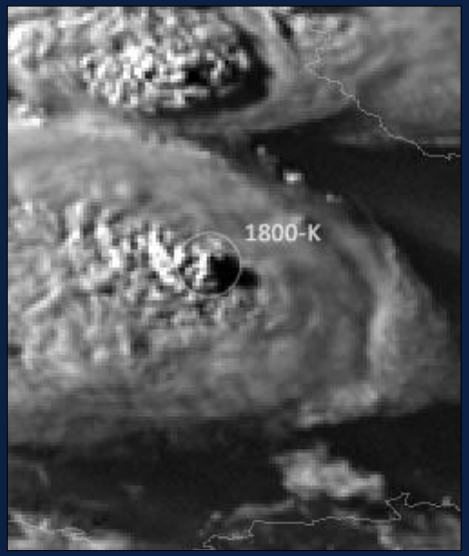


Overshooting tops – appearance examples

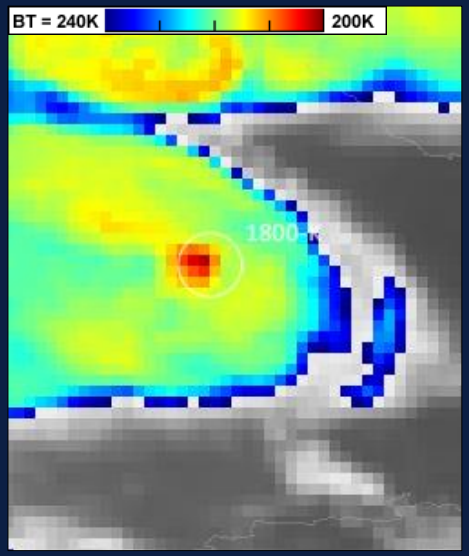
Meteosat-8, 20 June 2013 18:00 UTC



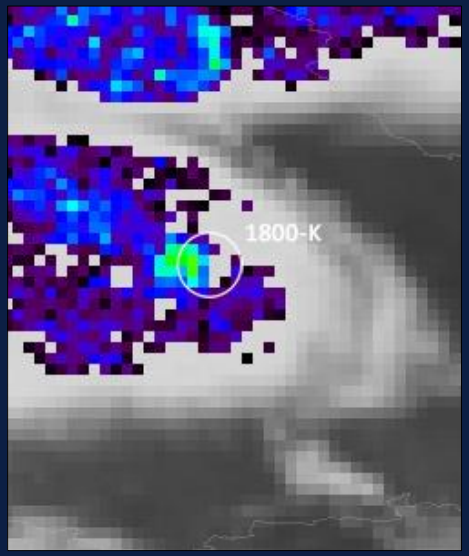
sandwich HRV & IR10.8-BT



HRV



IR10.8-BT (200-240K)

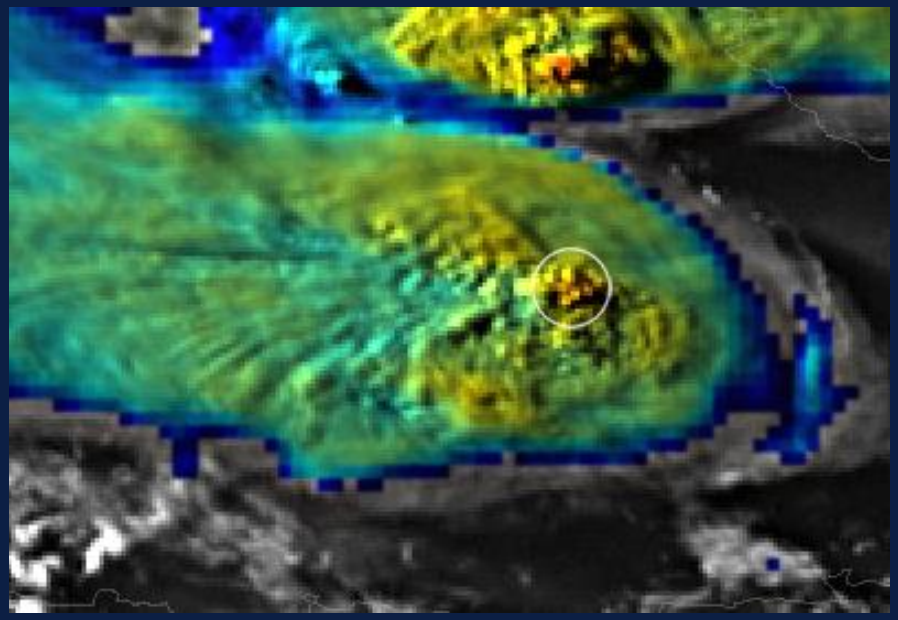


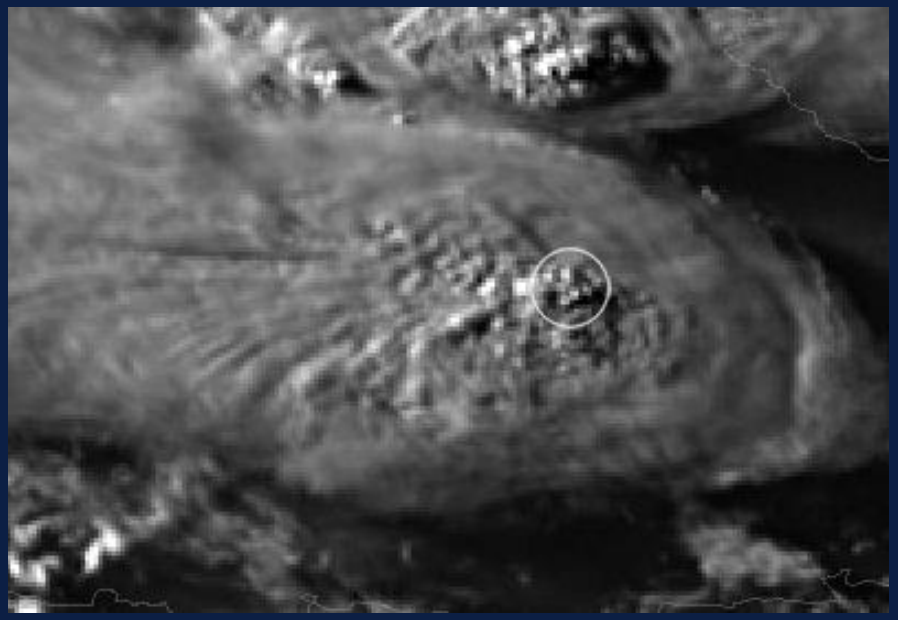
BTD (WV6.2-IR10.8)

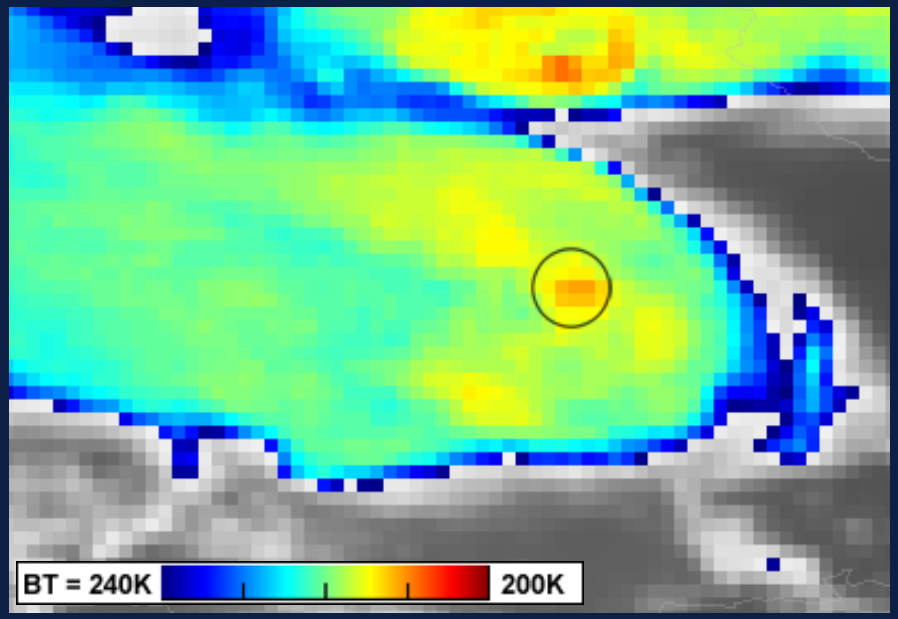
Textbook appearance of the overshooting top – distinct in HRV, with long casted shadow, very strong local IR-BT minimum (much colder than its surrounding anvil cloud top); weak local BTD (WV6.2-IR10.8) maximum shifted downwind of the OT.

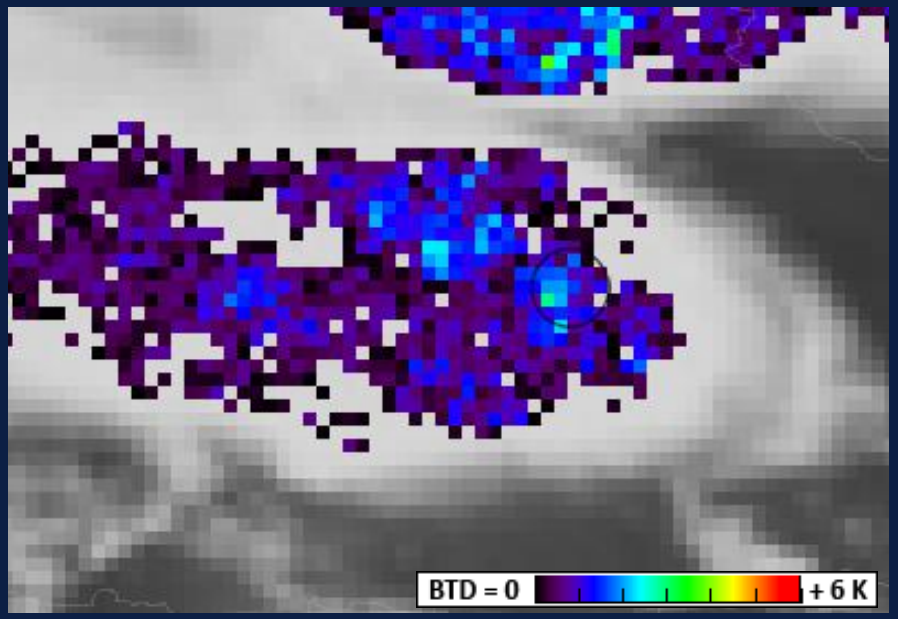
Besides the OT itself, notice also the distinct plume downwind of the OT (westward).

Meteosat-8, 20 June 2013 17:55 UTC

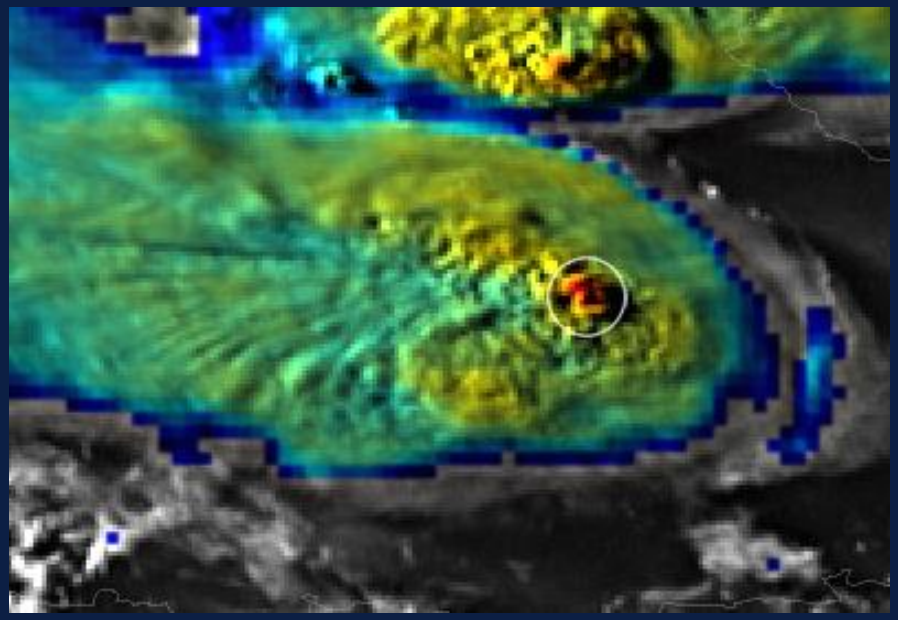


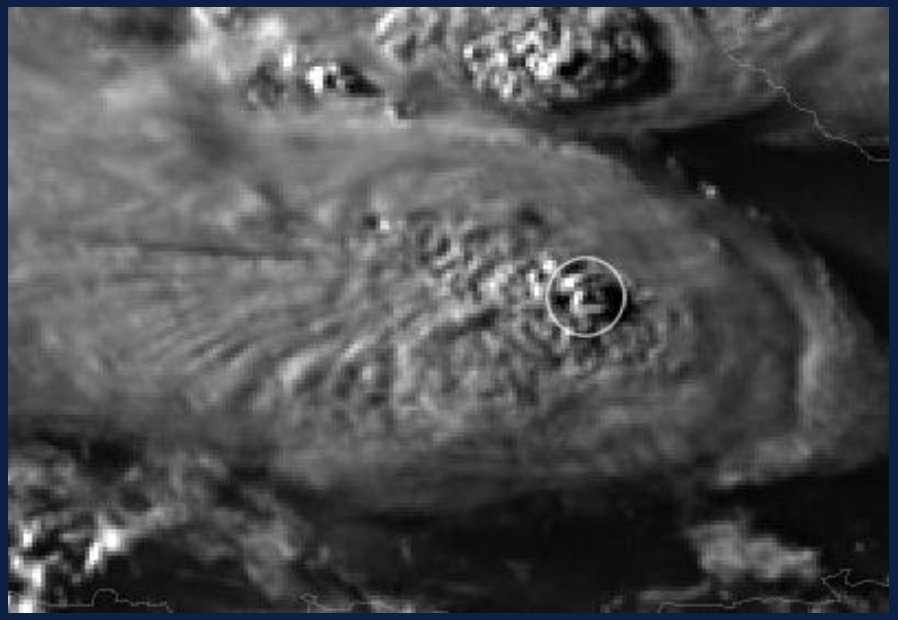


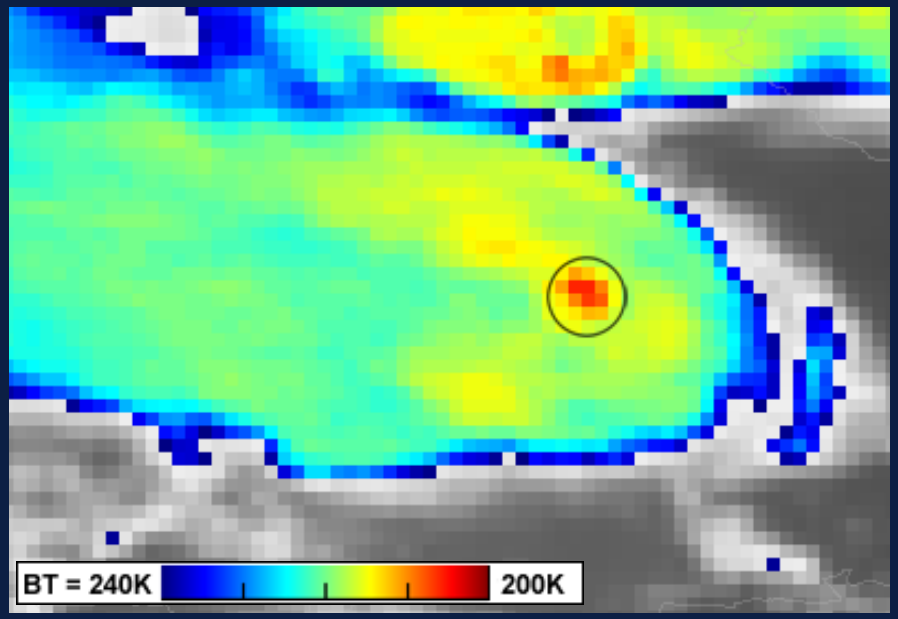


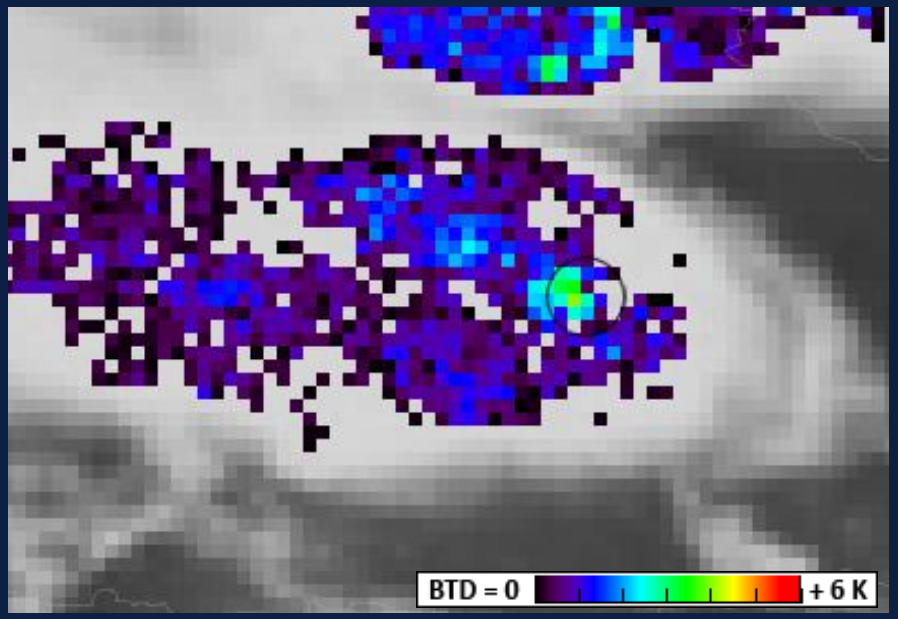


Meteosat-8, 20 June 2013 17:57 UTC

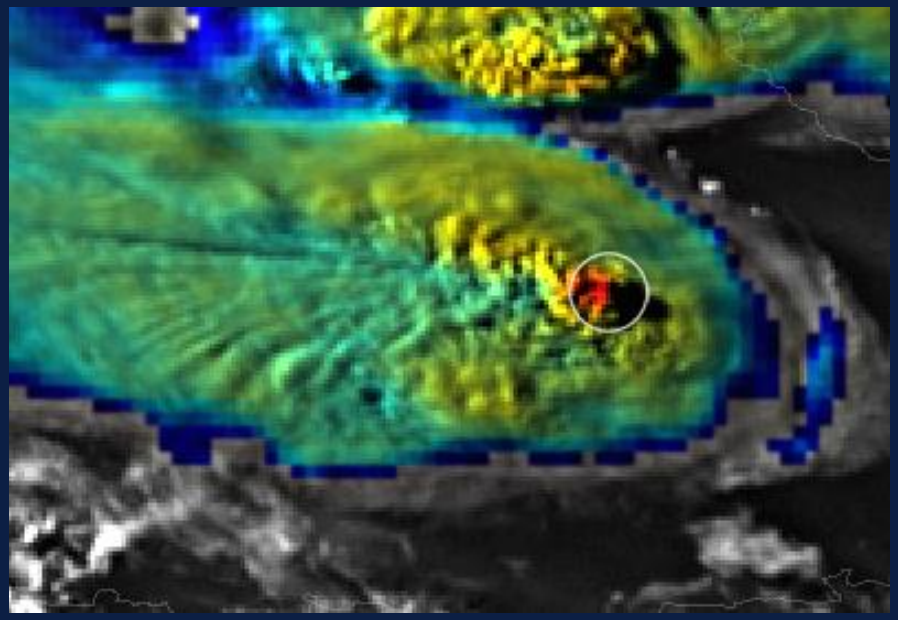


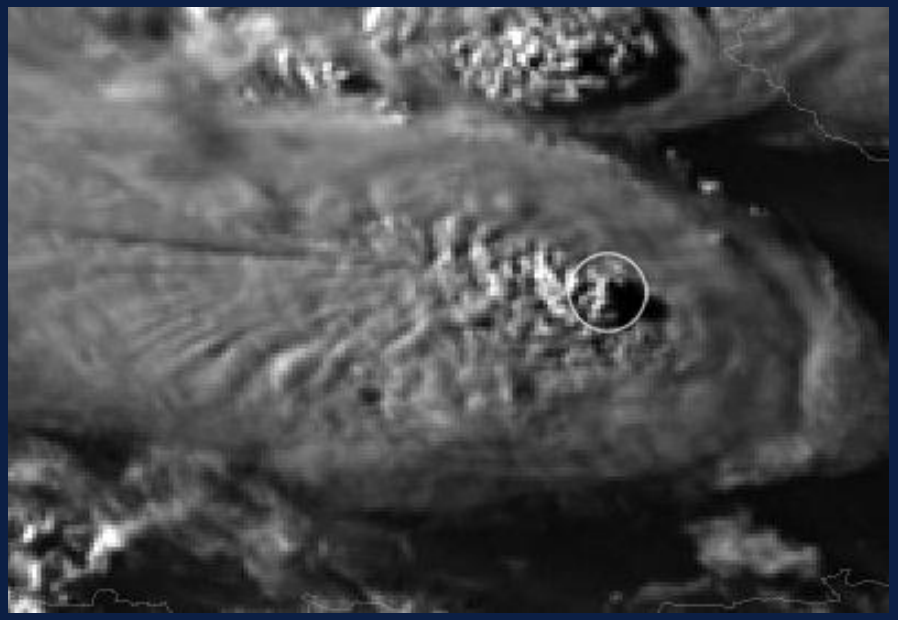


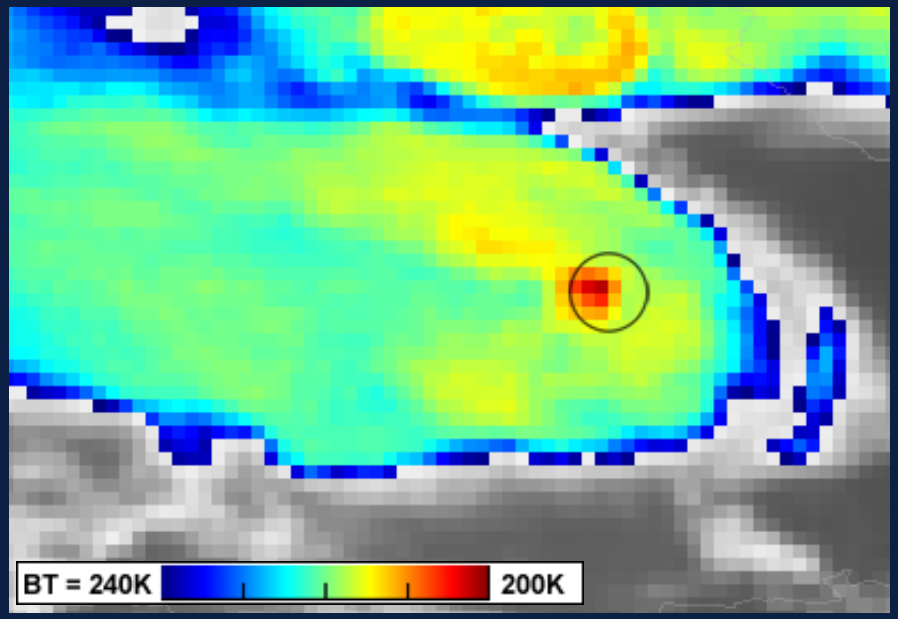


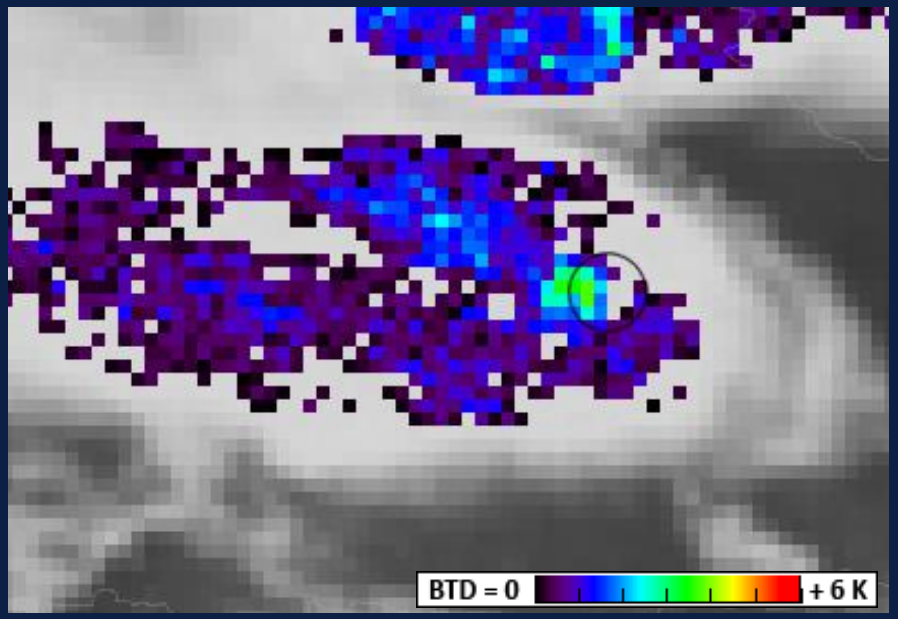


Meteosat-8, 20 June 2013 18:00 UTC

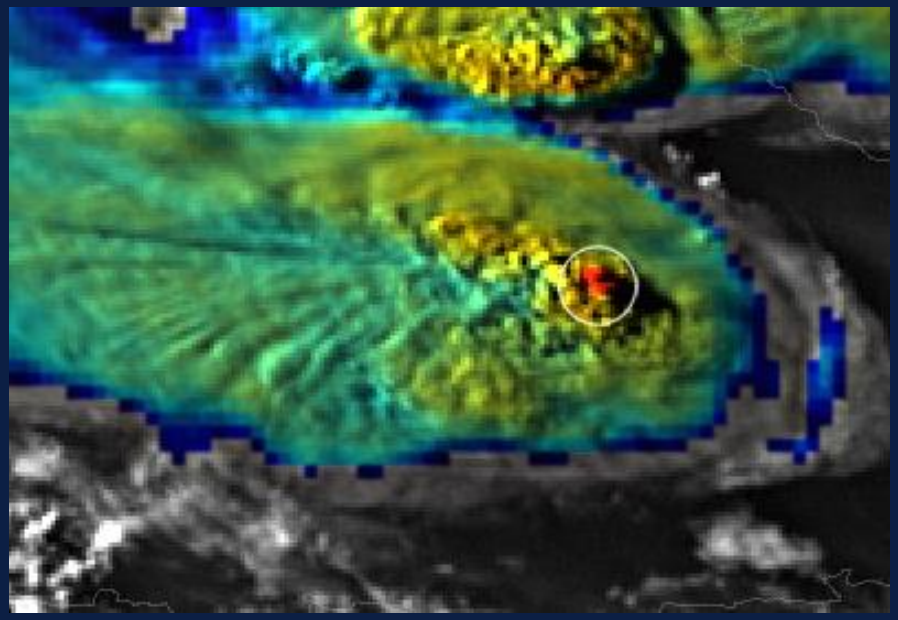


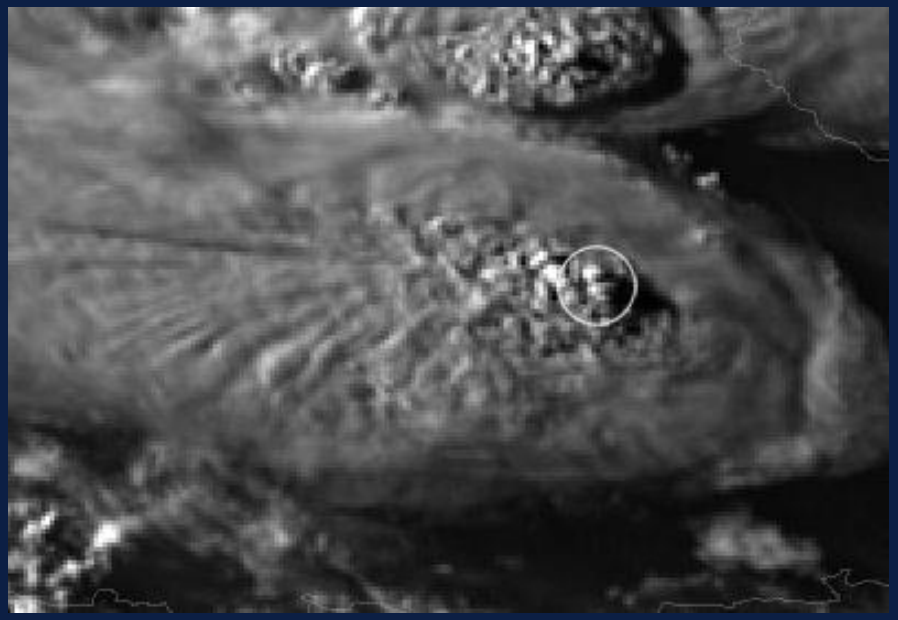


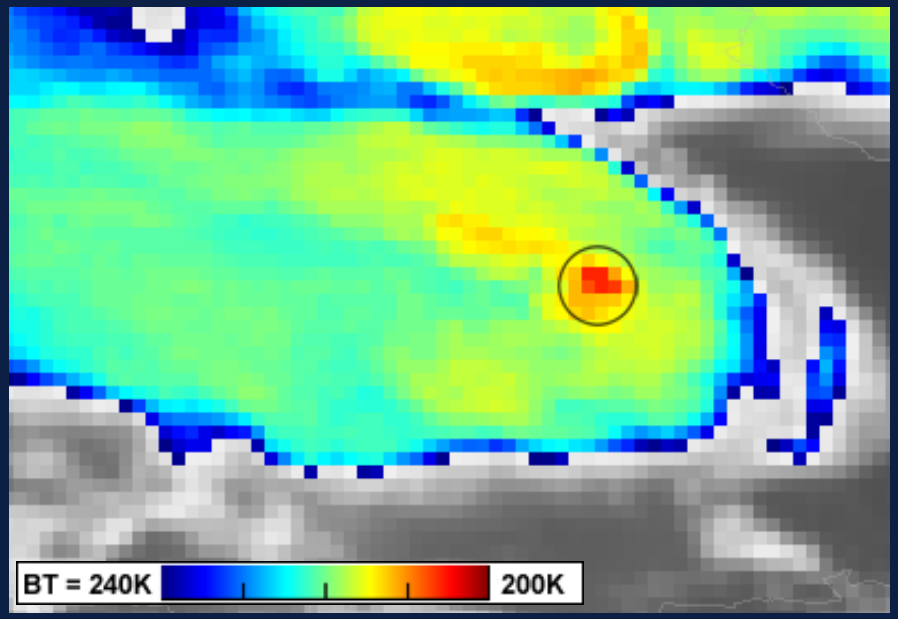


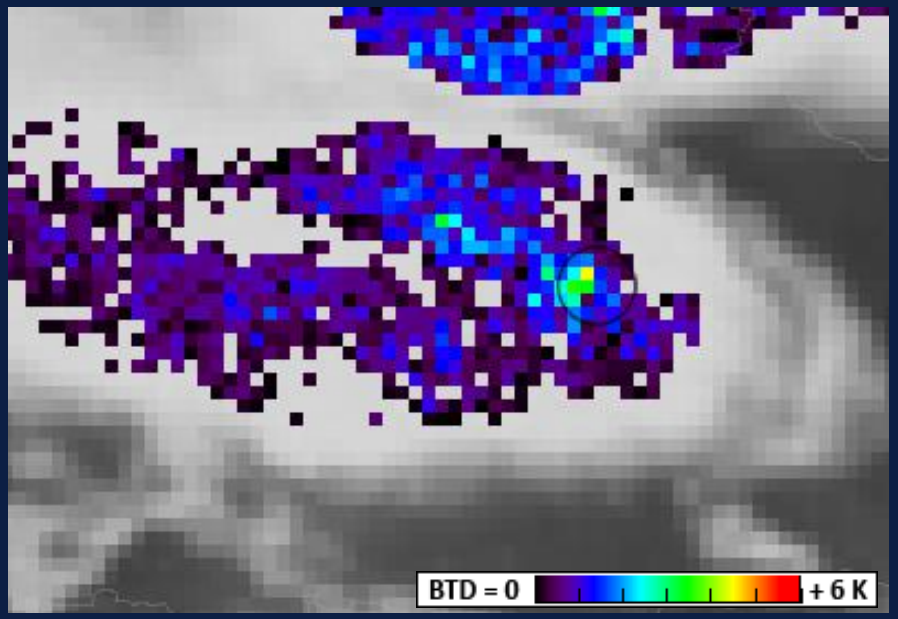


Meteosat-8, 20 June 2013 18:02 UTC

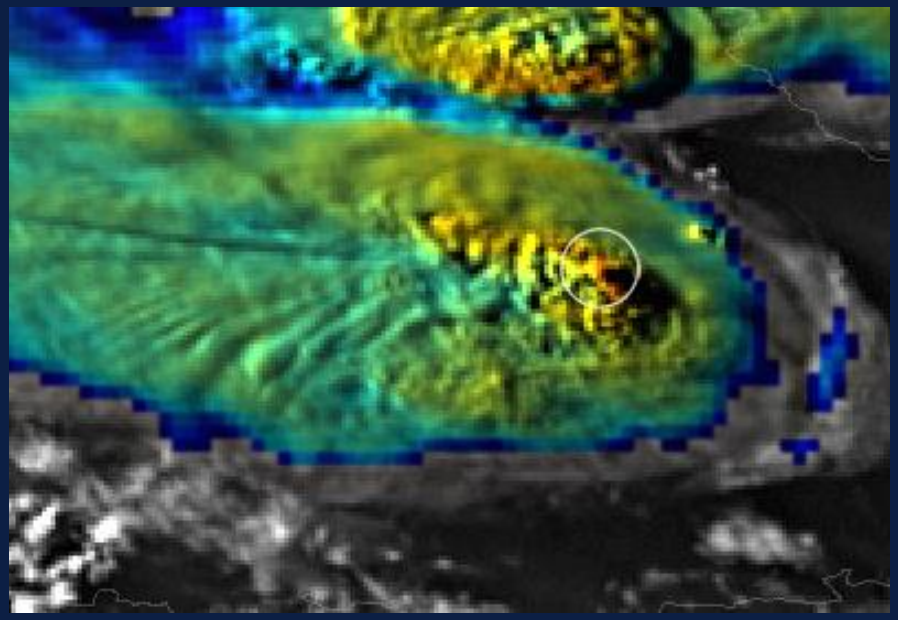


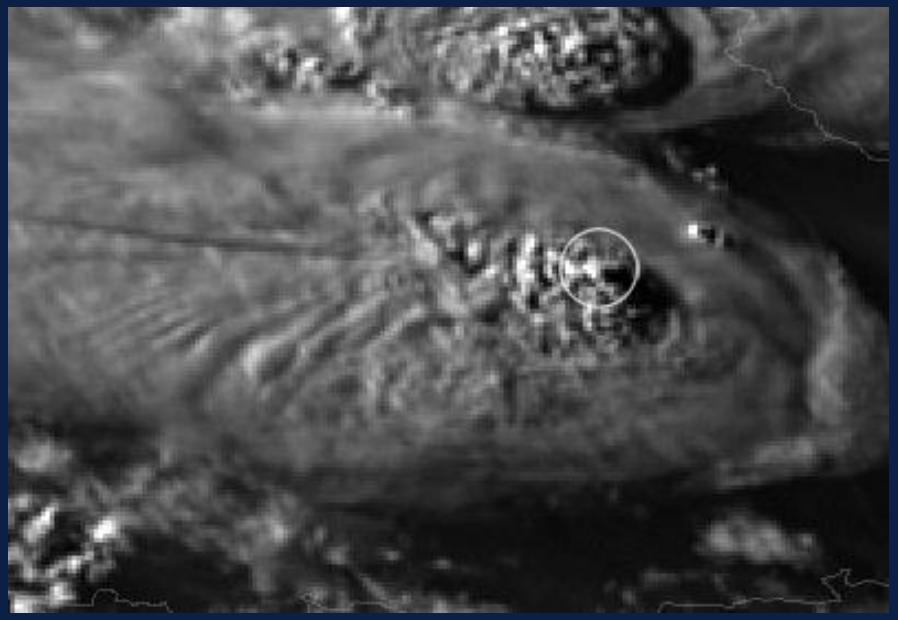


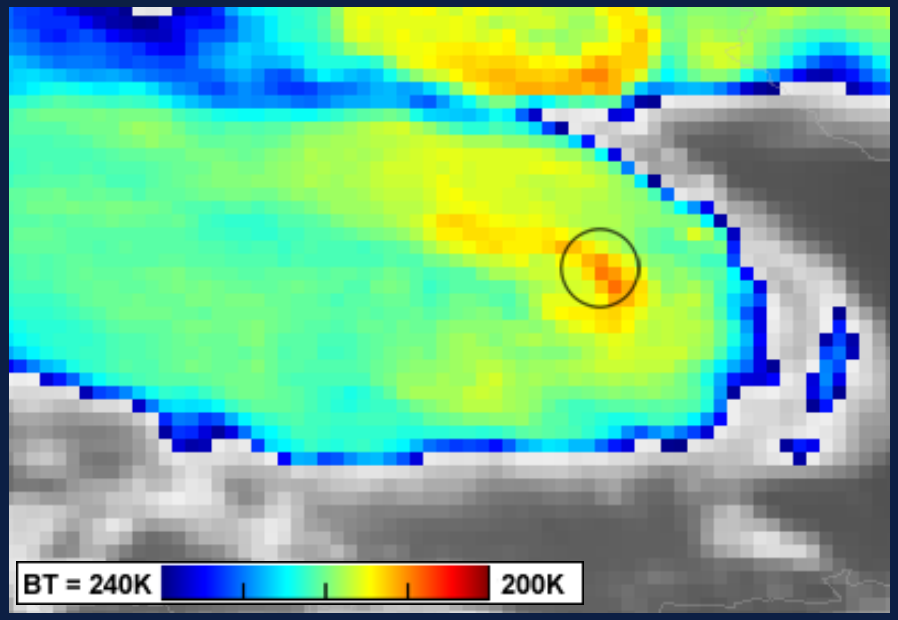


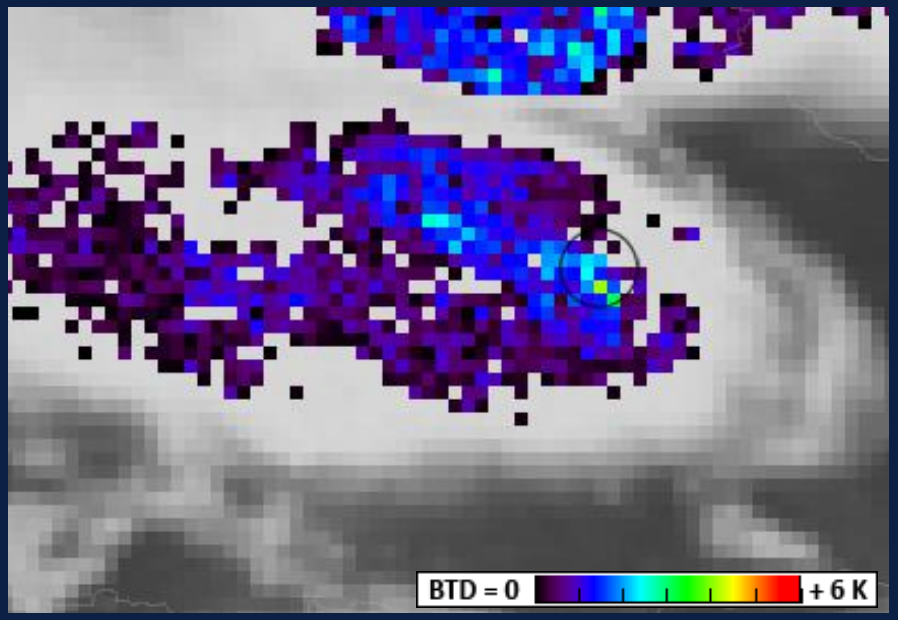


Meteosat-8, 20 June 2013 18:05 UTC







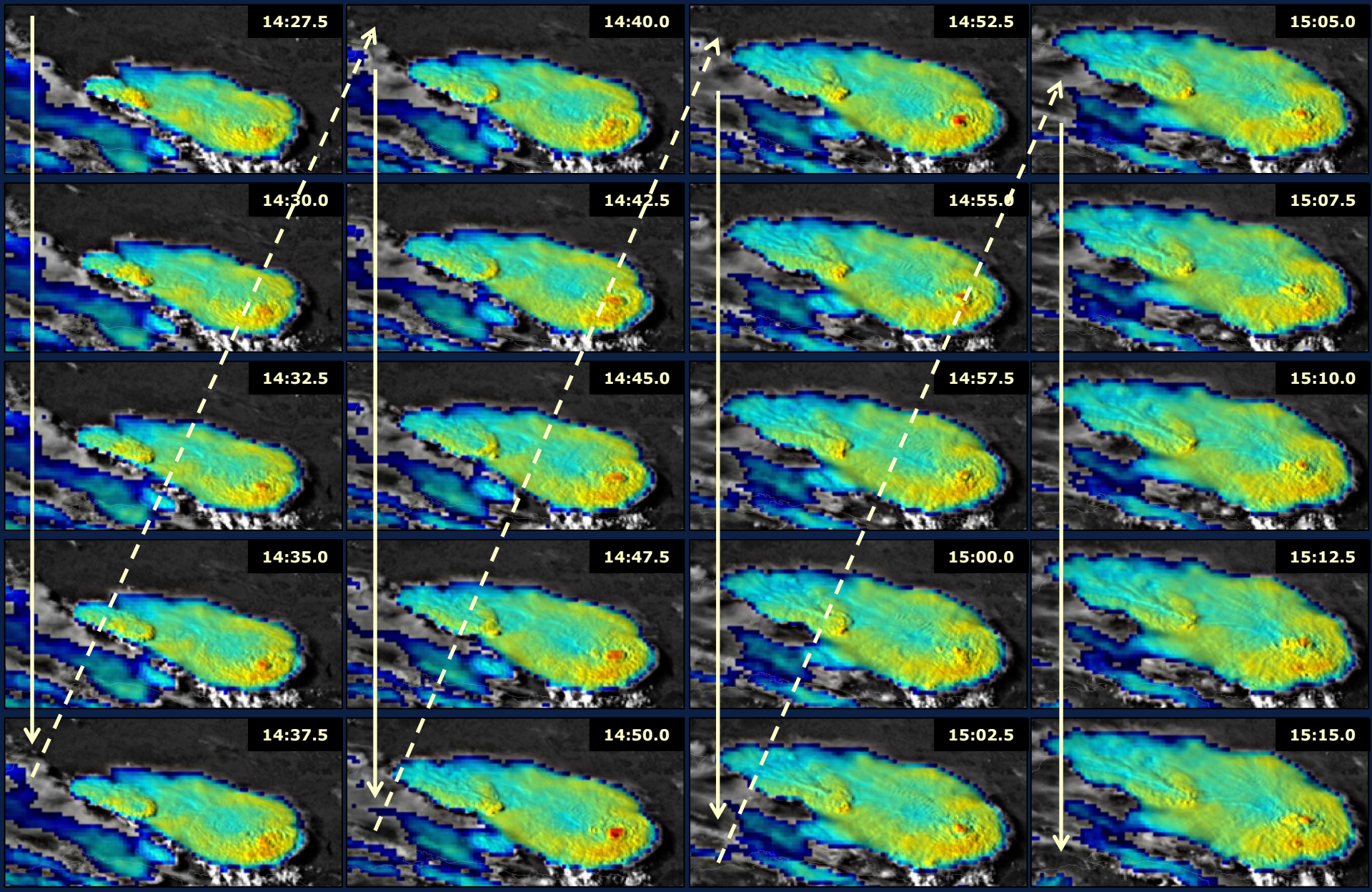


Impact of temporal sampling:

scan interval 2.5, 5, 7.5, 10 and 15 minutes

Scan interval: 2.5 minutes (MSG 2.5-min experiment)

Meteosat-8, 20 June 2013 14:27 - 15:15 UTC

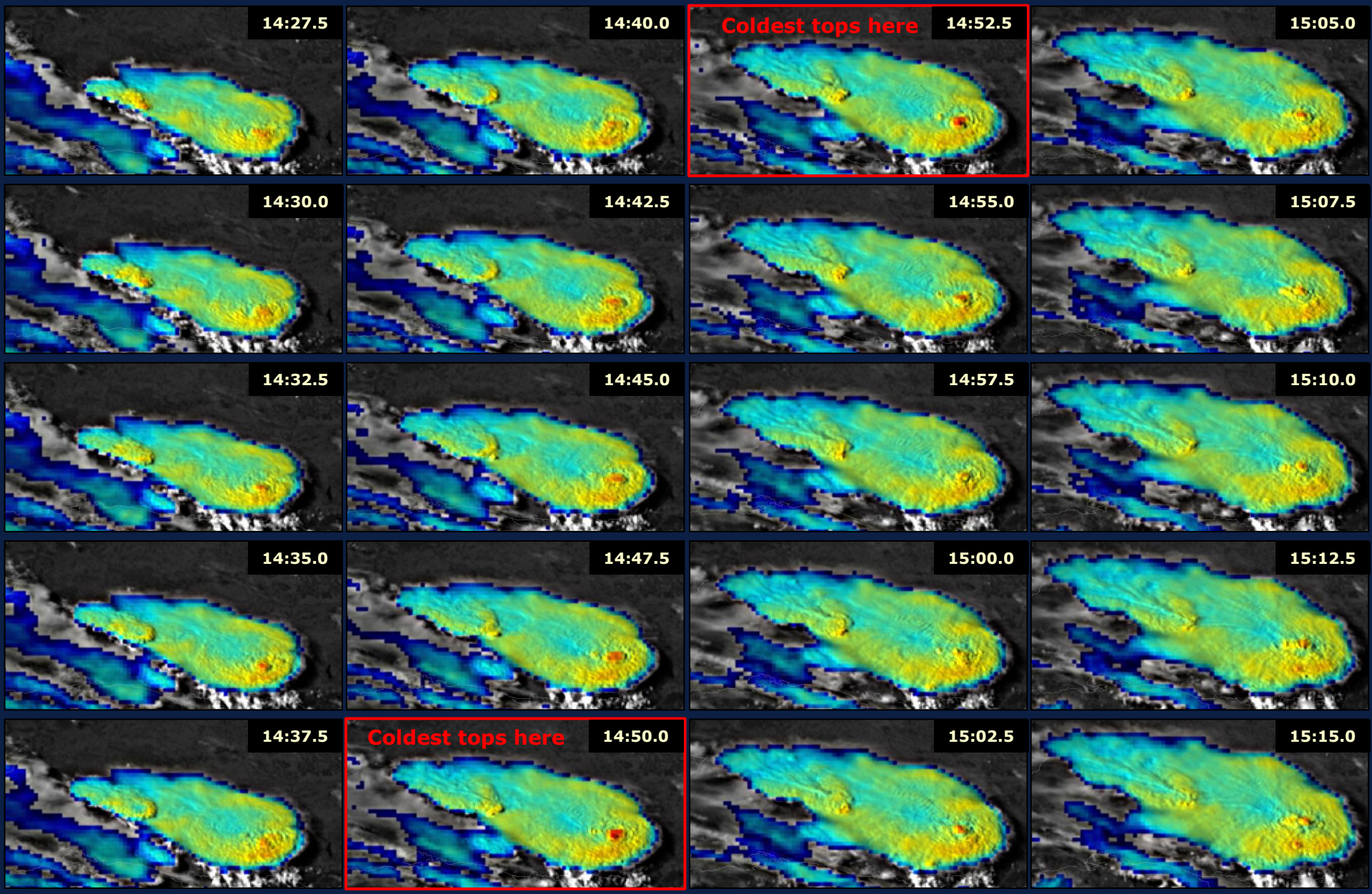


Sandwich product: HRV & IR10.8-BT (200-240K)

Martin Setvák

Scan interval: 2.5 minutes (MSG 2.5-min experiment)

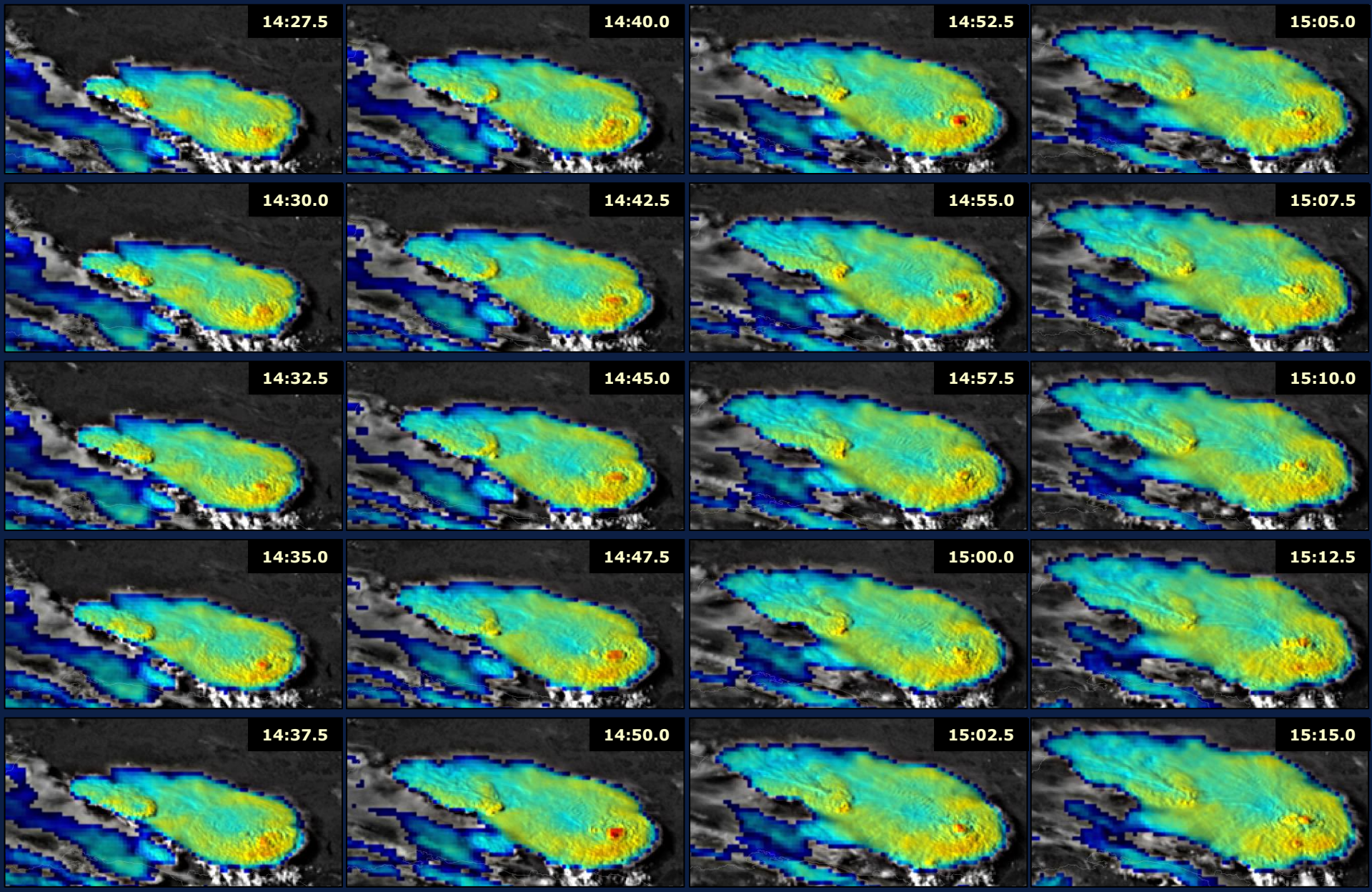
Meteosat-8, 20 June 2013 14:27 - 15:15 UTC



Sandwich product: HRV & IR10.8-BT (200-240K)

Scan interval: 2.5 minutes (MTG-I FCI RSS)

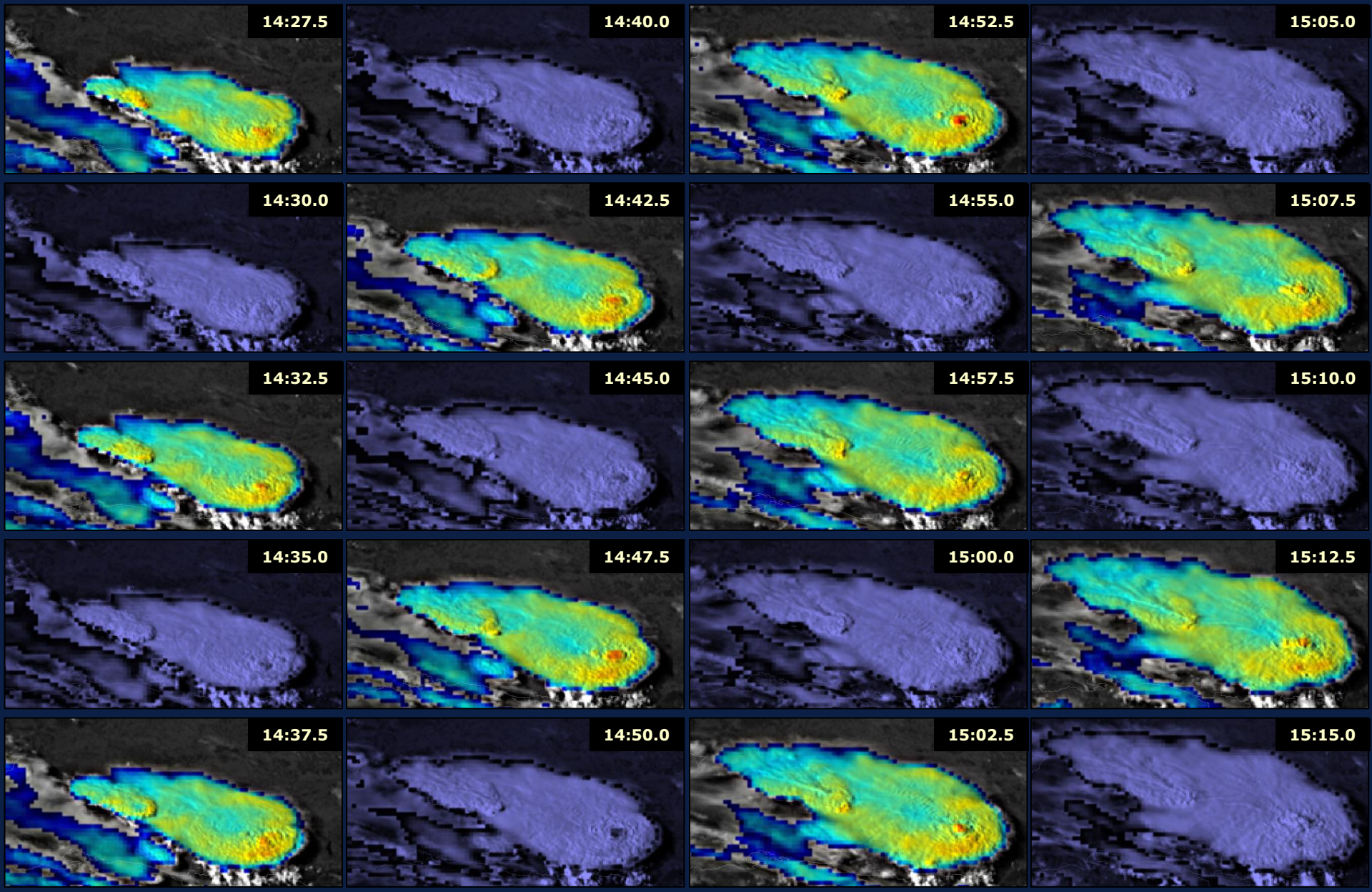
Meteosat-8, 20 June 2013 14:27 - 15:15 UTC



Sandwich product: HRV & IR10.8-BT (200-240K)

Scan interval: 5 minutes (MSG SEVIRI RSS)

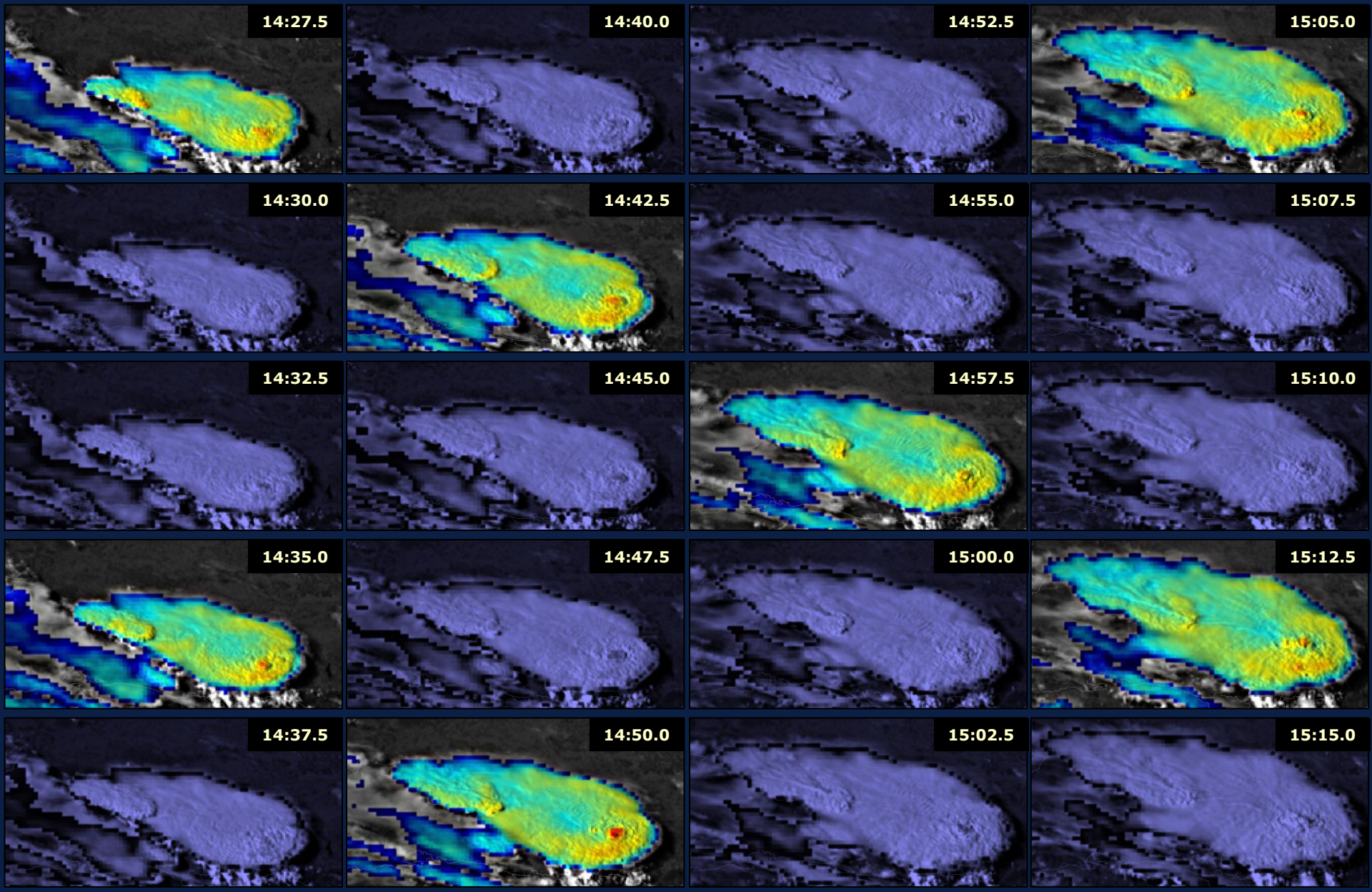
Meteosat-8, 20 June 2013 14:27 - 15:15 UTC



Sandwich product: HRV & IR10.8-BT (200-240K)

Scan interval: 7.5 minutes

Meteosat-8, 20 June 2013 14:27 - 15:15 UTC

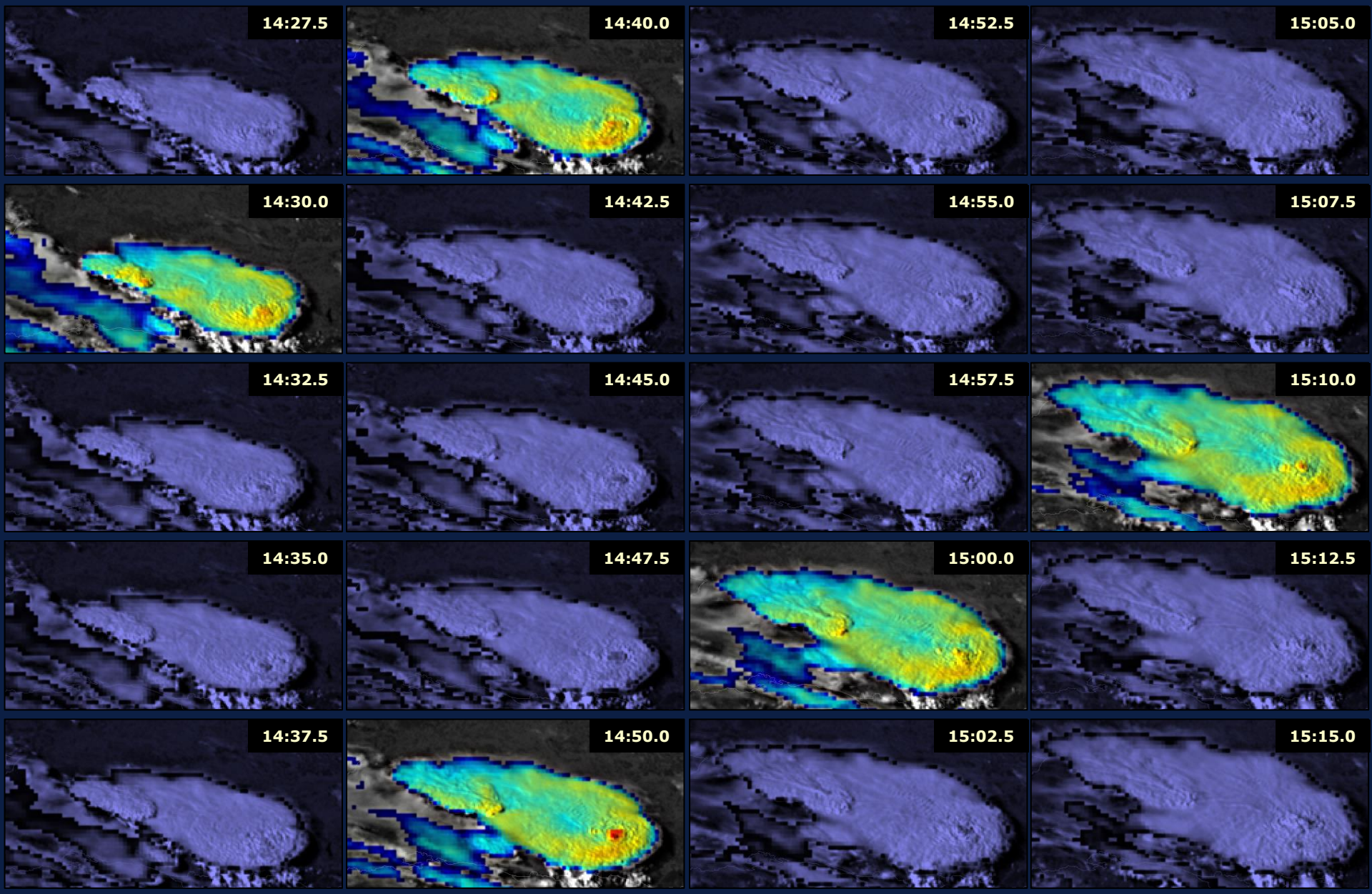


Sandwich product: HRV & IR10.8-BT (200-240K)

Martin Setvák

Scan interval: 10 minutes (MTG-I FCI full disk scan)

Meteosat-8, 20 June 2013 14:27 - 15:15 UTC

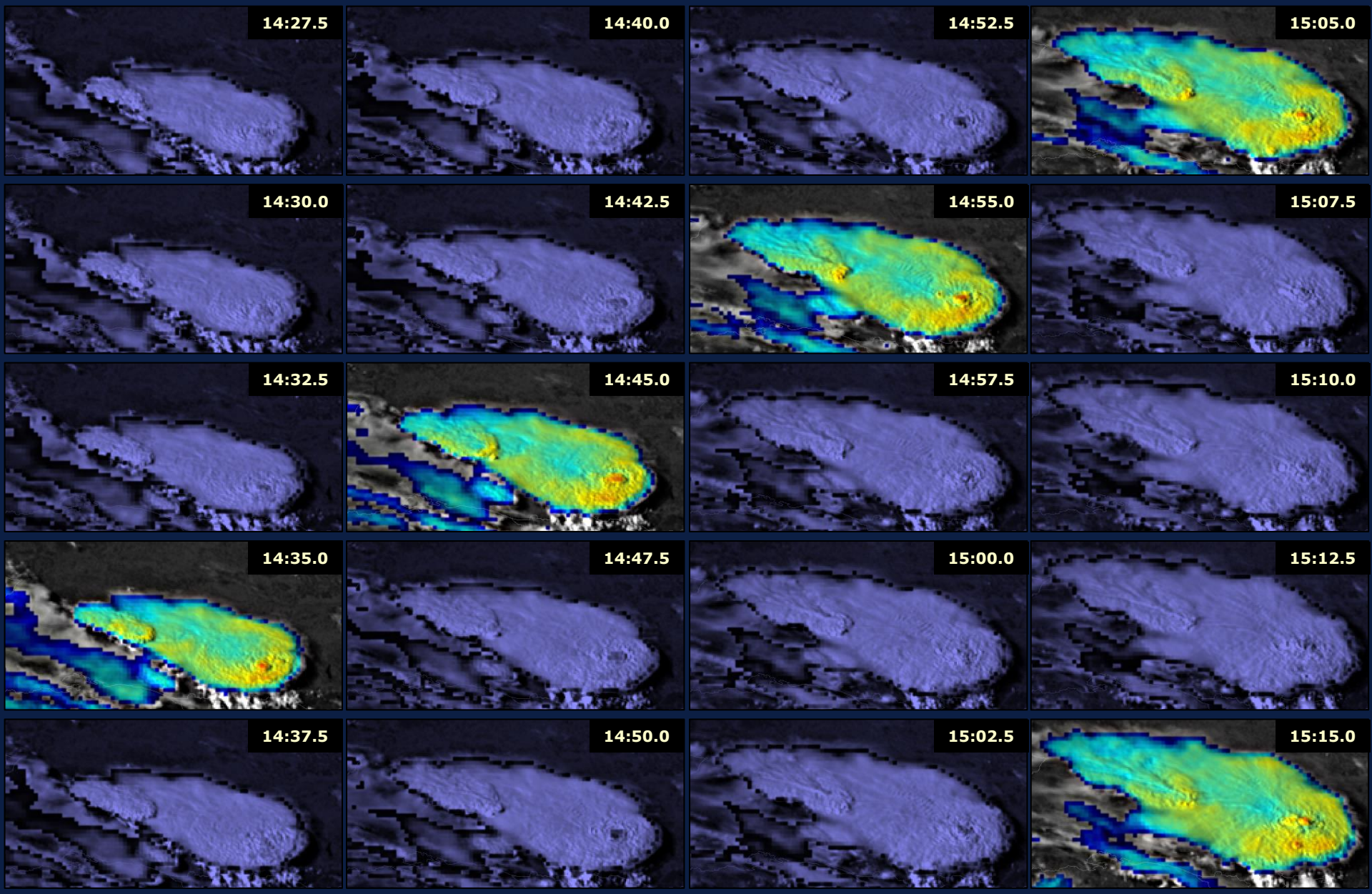


Sandwich product: HRV & IR10.8-BT (200-240K)

Martin Setvák

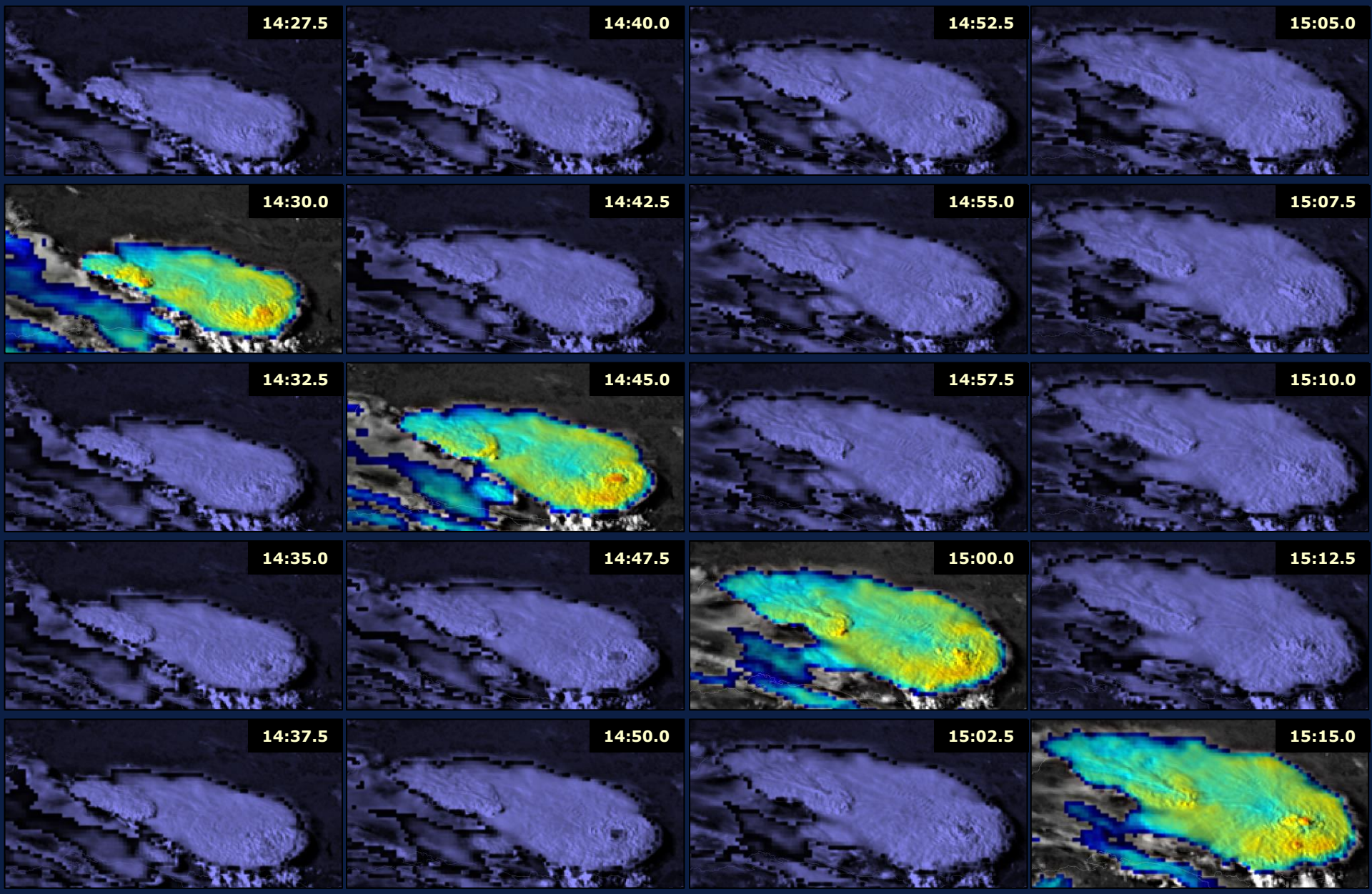
Scan interval: 10 minutes – shifted by 5 minutes

Meteosat-8, 20 June 2013 14:27 - 15:15 UTC



Sandwich product: HRV & IR10.8-BT (200-240K)

Scan interval: 15 minutes (MSG SEVIRI full disk scan) Meteosat-8, 20 June 2013 14:27 - 15:15 UTC



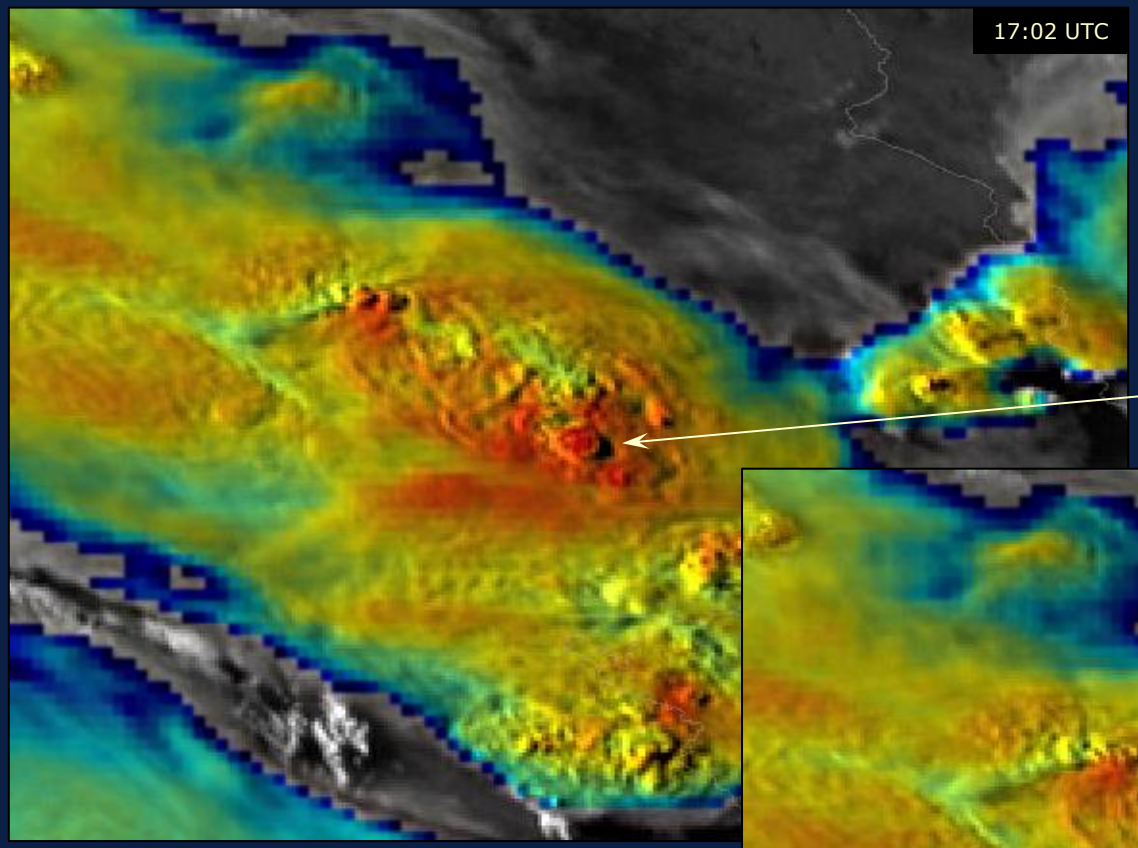
Sandwich product: HRV & IR10.8-BT (200-240K)

Impact of the scan interval (scan frequency) on detection of very short-lived features

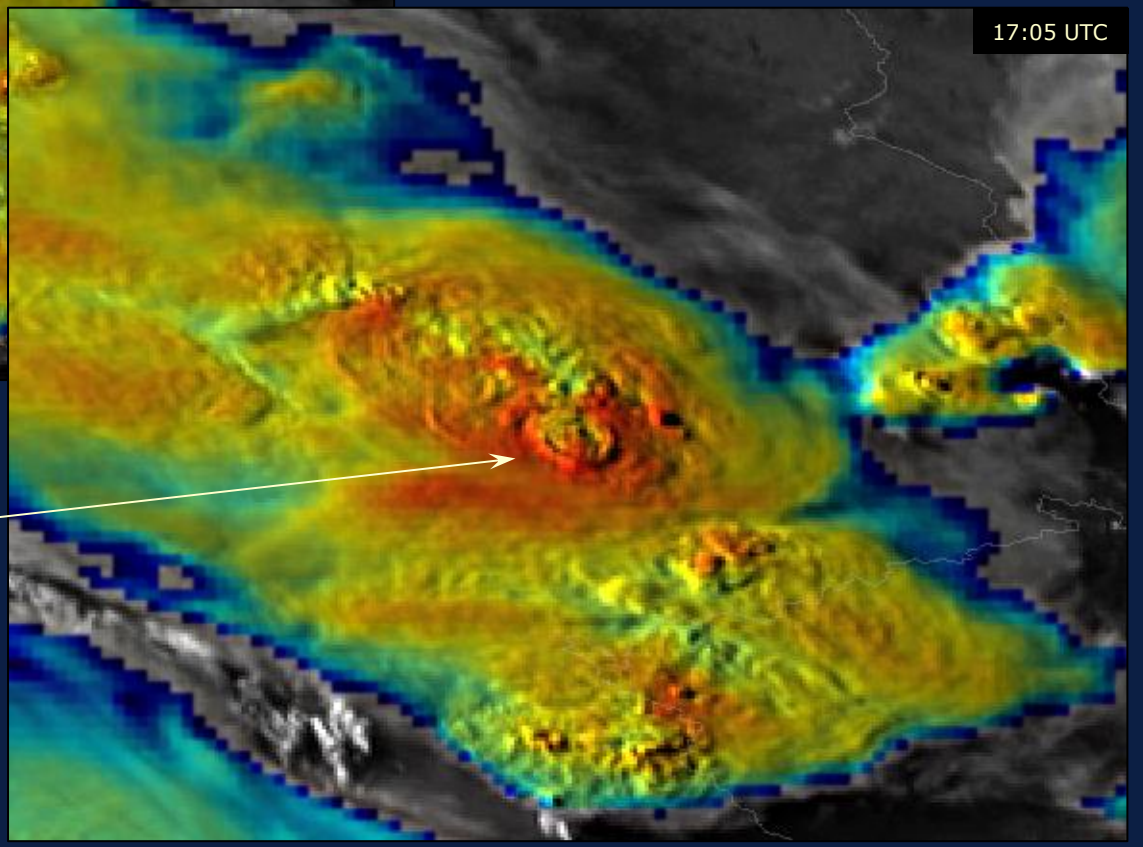
Cold-ring evolution, pancake cloud

20 June 2013 16:55 – 17:22 UTC
Meteosat-8 (MSG-1)

What to look for?



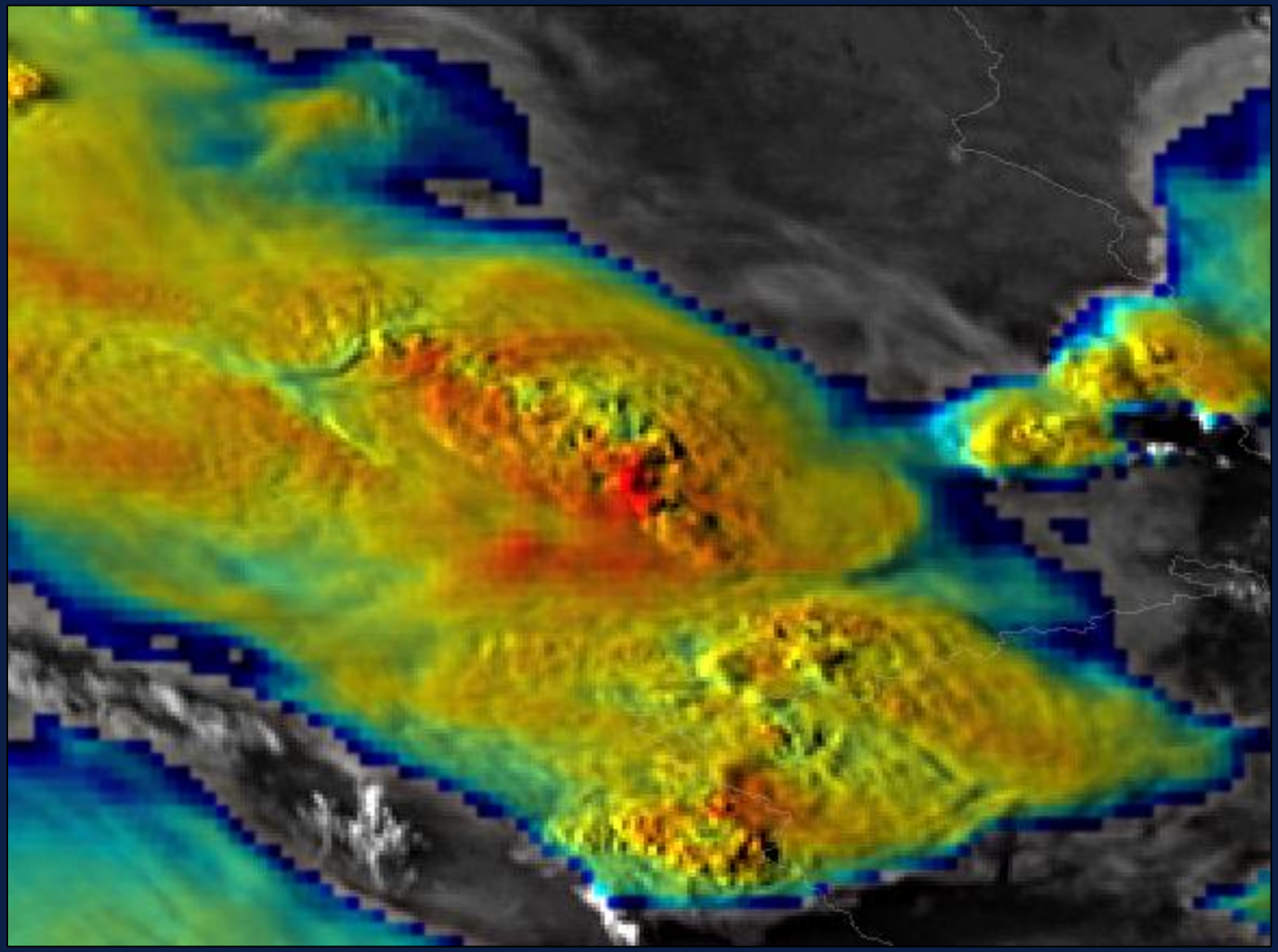
Previous overshooting top activity in this area (16:55 – 17:00 UTC) has formed this feature, resembling an elevated, flat "pancake cloud". This feature was present in this single image only, and also its shadow differs by its shape from those being cast by regular overshooting tops.



Just 2.5 minutes later, the "pancake cloud" is gone, and at its initial location we can see a cold gravity wave spreading outwards, resembling a rim of an impact crater (such as those on the Moon). At its center is a small elevated feature – either a new, transient overshooting top, or a remnant of the "pillar", initially connecting the pancake cloud with the storm top. The elevated rim can be seen also at 17:07, but not anymore afterwards, leaving only the cold ring, spreading further outwards, until dissipating.

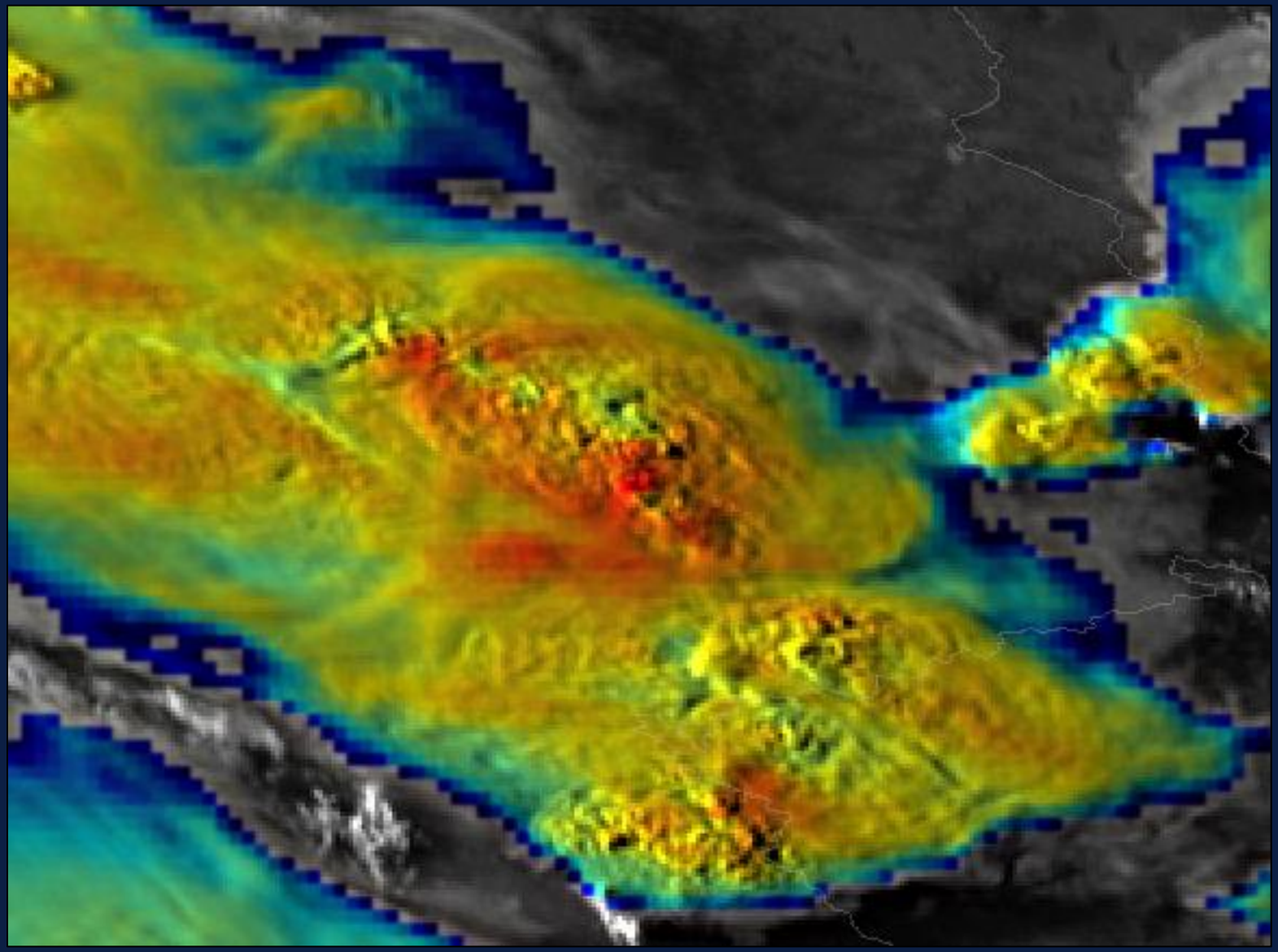
20 June 2013 Meteosat-8 (MSG-1)

16:55 UTC

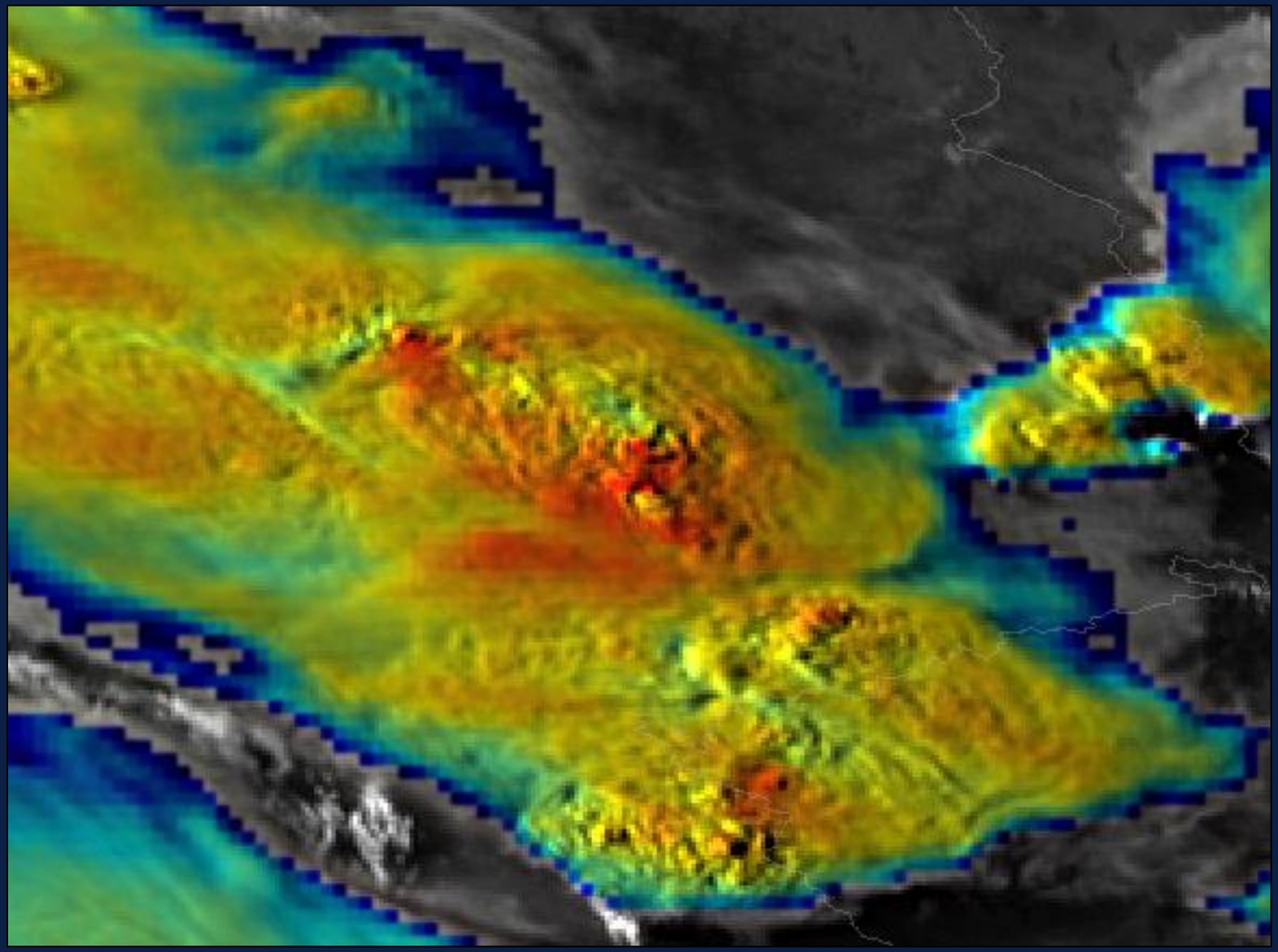


20 June 2013 Meteosat-8 (MSG-1)

16:57 UTC

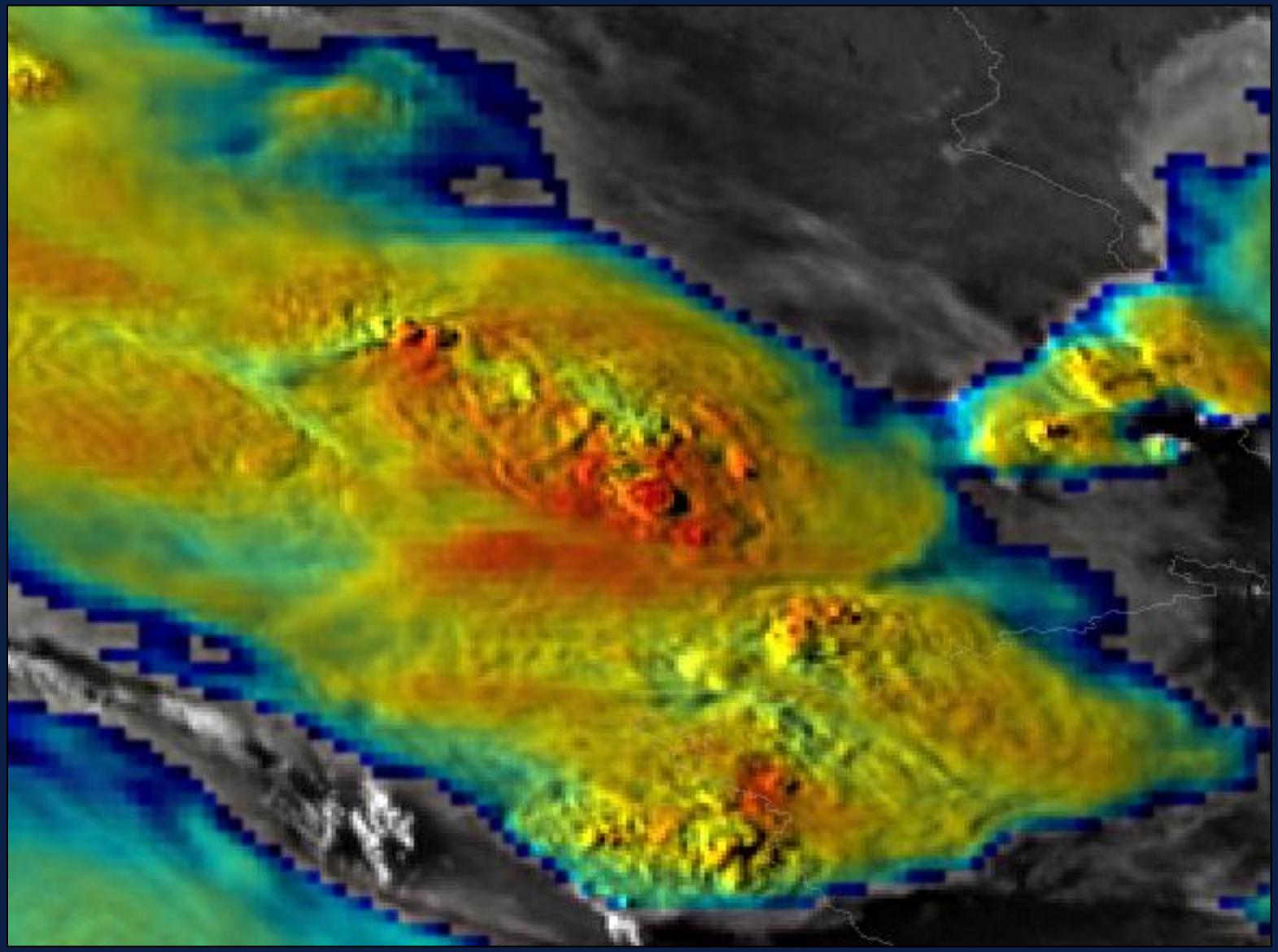


20 June 2013 Meteosat-8 (MSG-1) **17:00 UTC**

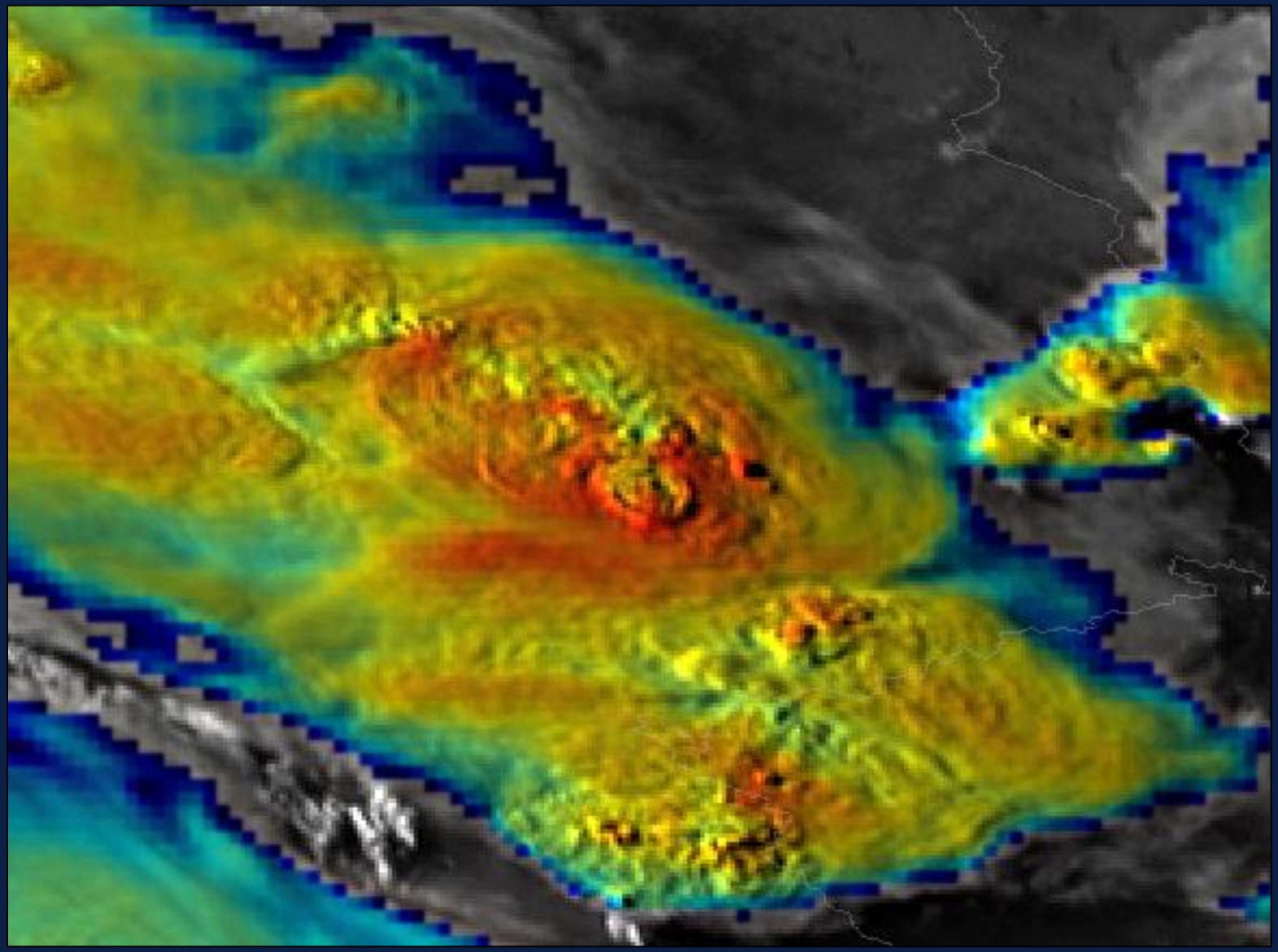


20 June 2013 Meteosat-8 (MSG-1)

17:02 UTC

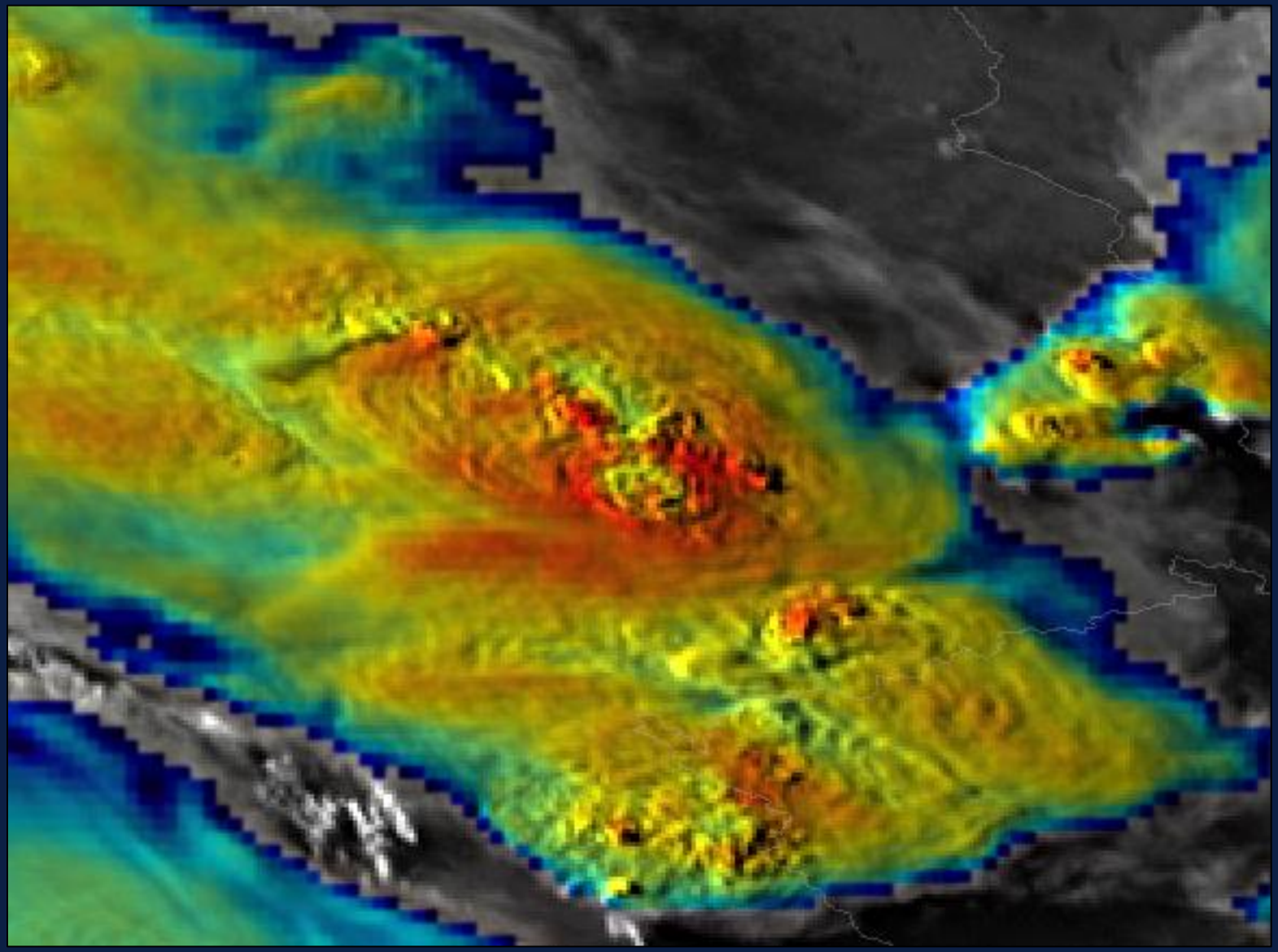


20 June 2013 Meteosat-8 (MSG-1) **17:05 UTC**



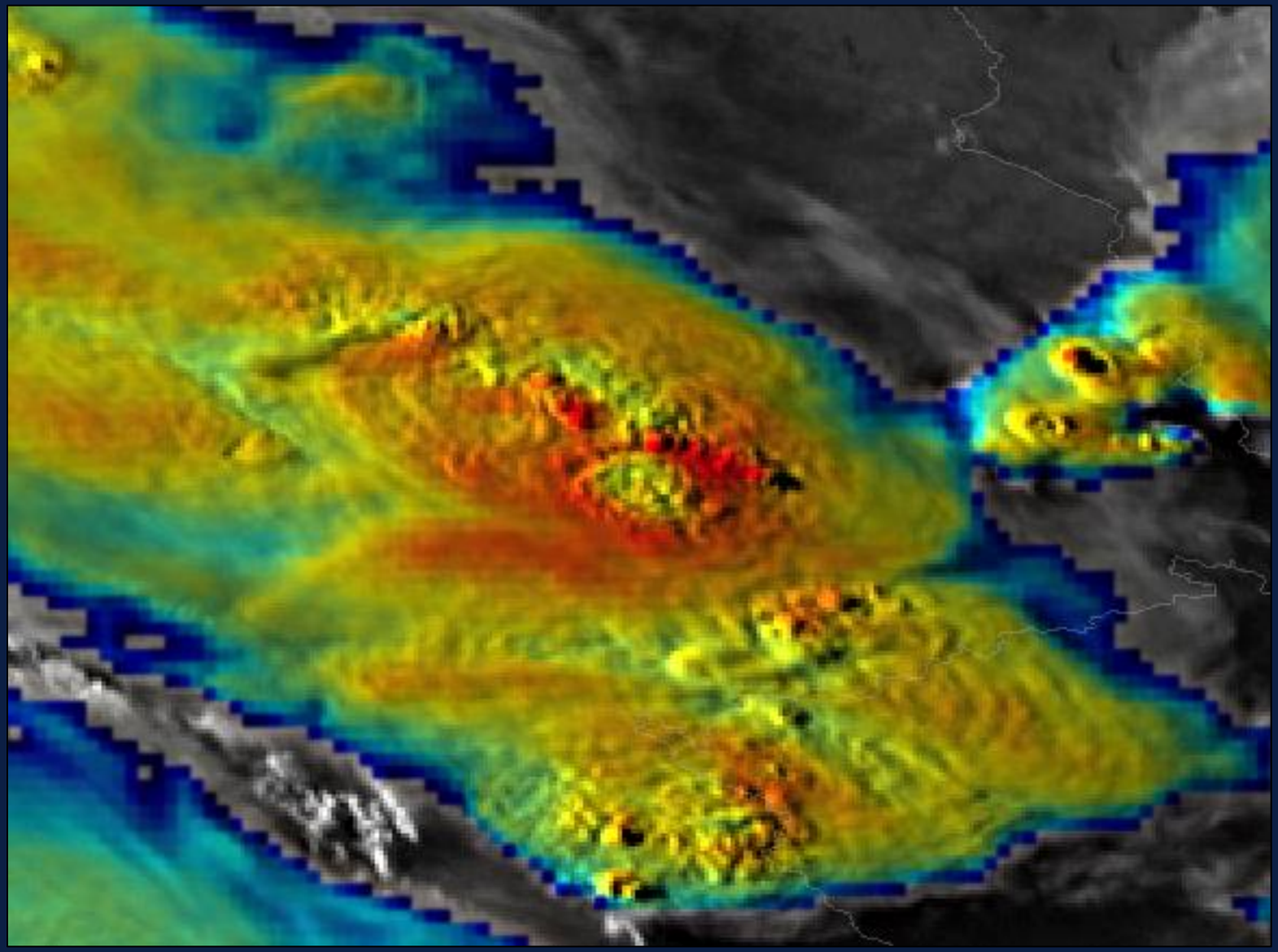
20 June 2013 Meteosat-8 (MSG-1)

17:07 UTC



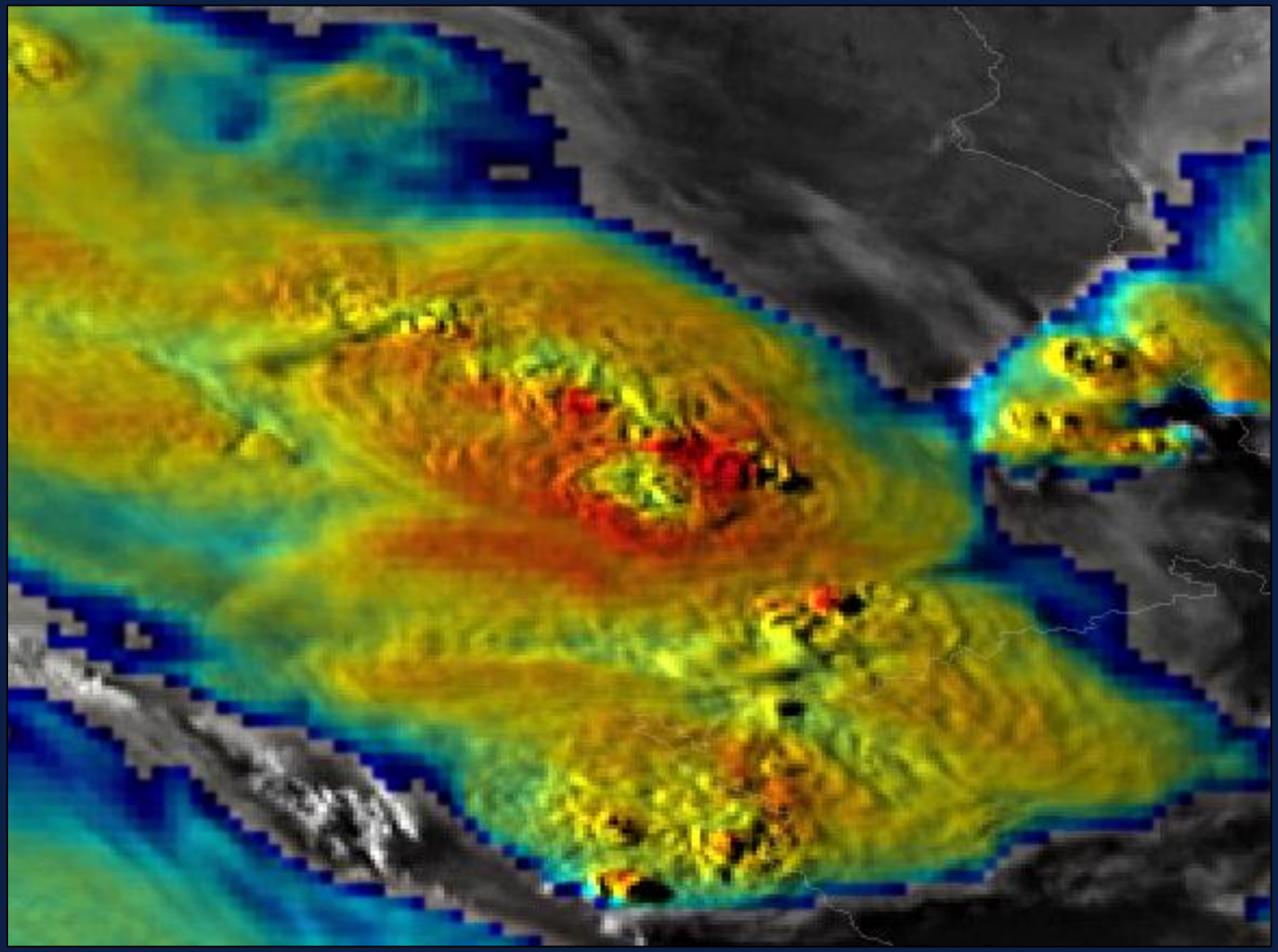
20 June 2013 Meteosat-8 (MSG-1)

17:10 UTC



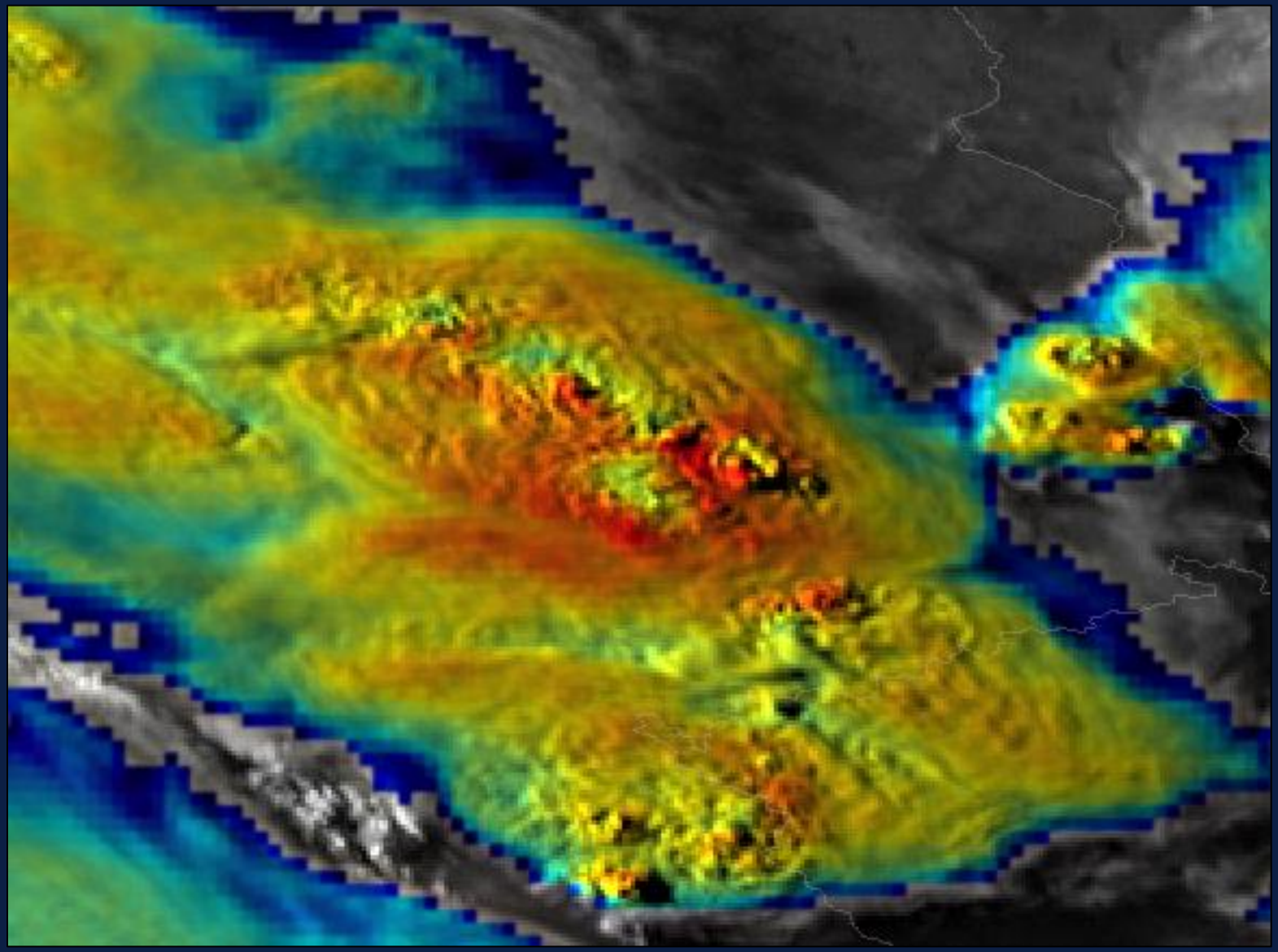
20 June 2013 Meteosat-8 (MSG-1)

17:12 UTC



20 June 2013 Meteosat-8 (MSG-1)

17:15 UTC

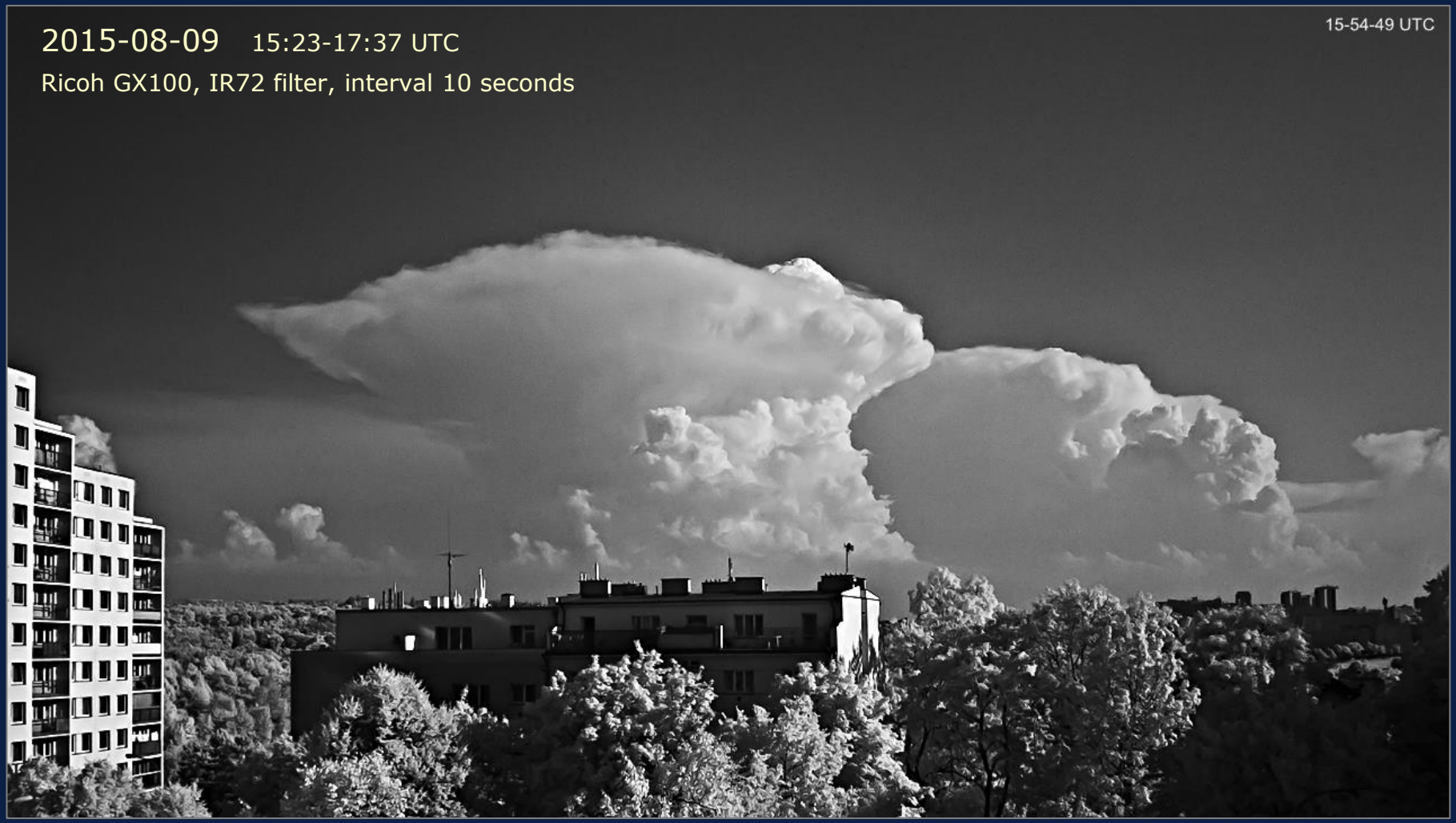


Final comments ...

The biggest impact of spatial resolution (pixel-size) and scan interval (scan frequency) is on smaller-scale and short-lived features, such as overshooting tops of convective storms.

However, to fully benefit of the high spatial resolution and short scan intervals, these need to be applied simultaneously !!!

The role of shooting interval – timelapse photography



TIMELAPSE INTERVAL: 15 min 5 min 2.5 min 1 min 10 sec

(also available at: http://www.setvak.cz/timelapse/2015.html)