Use of Meteosat Second Generation Data for Convection Nowcasting

Extended Abstract

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1. Introduction

The high spectral, spatial and temporal resolution data of EUMETSAT's geostationary Meteosat Second Generation (MSG) satellites support a large range of nowcasting applications, as e.g. detection of fog, desert dust and volcanic ash, general air mass characteristics., It specifically allows the detailed monitoring of the various stages of convection, starting with the pre-convective environment, followed by the onset of convective initiation, ultimately leading to mature storms with overshooting tops and cold ring or V-shape structures.

MSG carries the instrument SEVIRI (Spinning Enhanced Visible and Infrared Instrument), which takes full disc scans in a total of 12 spectral channels, covering the visible, near-infrared and infrared part of the spectrum between 0.6 µm and 13.4 µm wavelength. Figure 1 shows thumbnails of these 12 spectral channels

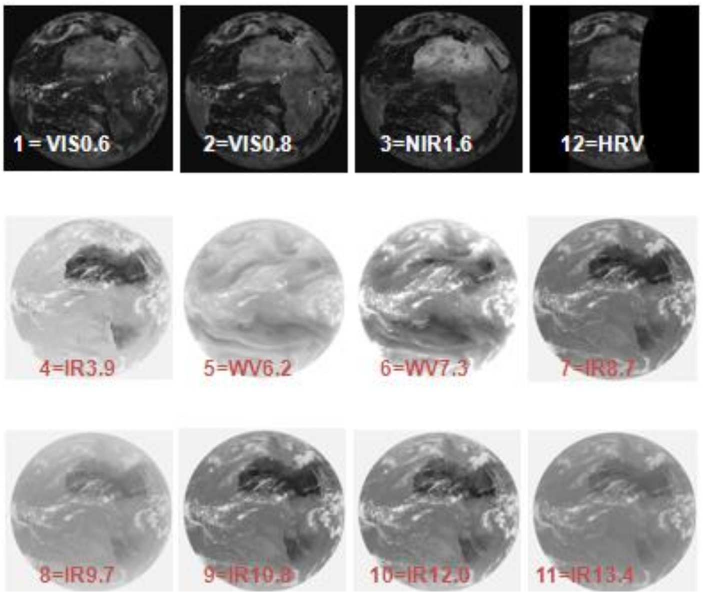

Figure 1: Quick view of the 12 SEVIRI channels. Channel numbers and acronyms are given, providing the channel centre wavelength.

Channel 12 is a broadband visible channel, providing information on a 1 km resolution, opposed to the nominal 3 km resolution of all other 11 channels (resolution given at the subsatellite point).

Two MSG satellites are currently in orbit, Meteosat-9 providing the full disc scans every 15 minutes at the 0 deg longitude position, Meteosat-8 providing 5 minute scans of the northern third of the full disc (Europe and Northern parts of Africa), from its position at 9.5 E.

The use of colour composites (or RGB = Red-Green-Blue composites) provides forecasters with an easy way to embark on the multi-spectral capabilities of MSG: Combining several channels, either as single channels or as already predefined channel combinations like channel differences, in one colour image keeps the unique spectral signature of each channel, thus providing information on a number of parameters. Several “standard” RGB composites are used, e.g. for a general air mass analysis, dust and volcanic ash monitoring, or identifying the severest part of convective storms. Figure 2 shows examples.

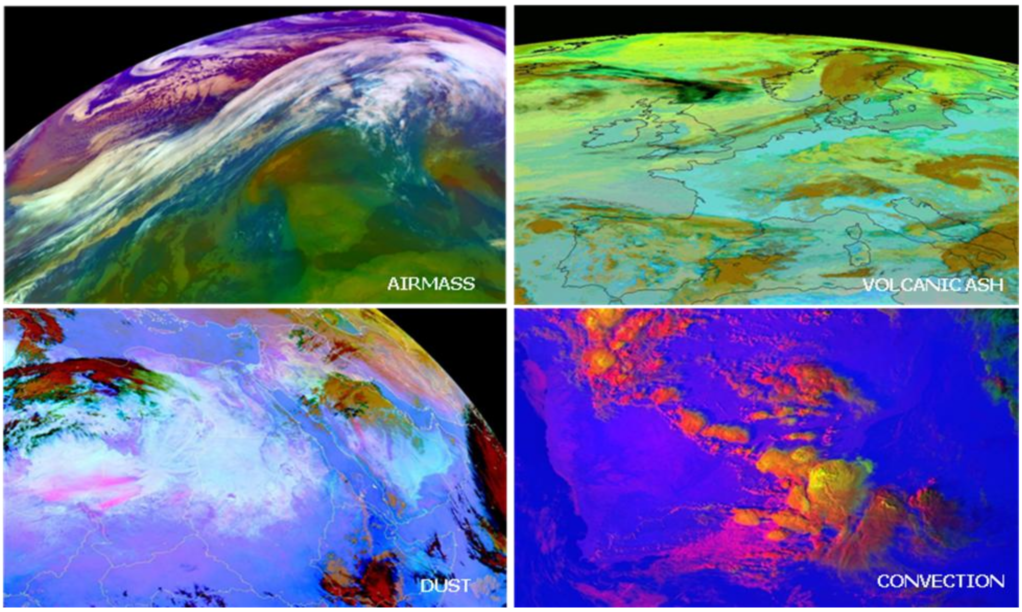

Figure 2: Examples of RGBs, each highlighting a certain atmospheric feature or process.

The geostationary orbit provides the unique opportunity to capture rapid changes in atmospheric conditions, i.e. the time component adds another important dimension to the spectral information when these images are seen in animations.

MSG data can support the convection nowcasting in three aspects:

(a) Analysis of the pre-convective environment, especially giving information on the air mass (in-)stability
(b) Analysis of the convective initiation process of still small Cu clouds
(c) Analysis of the storm top structures of mature convective storms

Much of this work is coordinated through and discussed in the EUMETSAT Convection Working Group, http://www.convection-wg.org.

2. The Pre-Convective Environment

The MSG observations, when used in combination with short-range atmospheric temperature and humidity profiles, allow the derivation of instability indices, which are one of the EUMETSAT MSG meteorological products. Instability indices like the Lifted Index or the K-Index comprise the information on the atmospheric stability in a single number; the atmosphere is statically stable or unstable if that number is below/above a certain threshold. These indices can only be derived from clear sky satellite observations and should be regarded as a general first alert as to the convective potential of the atmosphere. Figure 3 shows an example over South Africa: The left panel shows the K-Index, as computed from

MSG observations of 0800 UTC on 26 October 2006. Each coloured block describes a successfully retrieved index, where colours from blue to yellow and red show increasing instability, while brow delineates a stable atmosphere. The grey shades illustrate the presence of clouds, where no index could be retrieved. A very high K-Index, exceeding 40°C, was found east of Johannesburg (shown in red). The same area encountered a very severe storm 3 hours later, as shown in the IR image on the right panel, with ground based lightning observations overlaid.

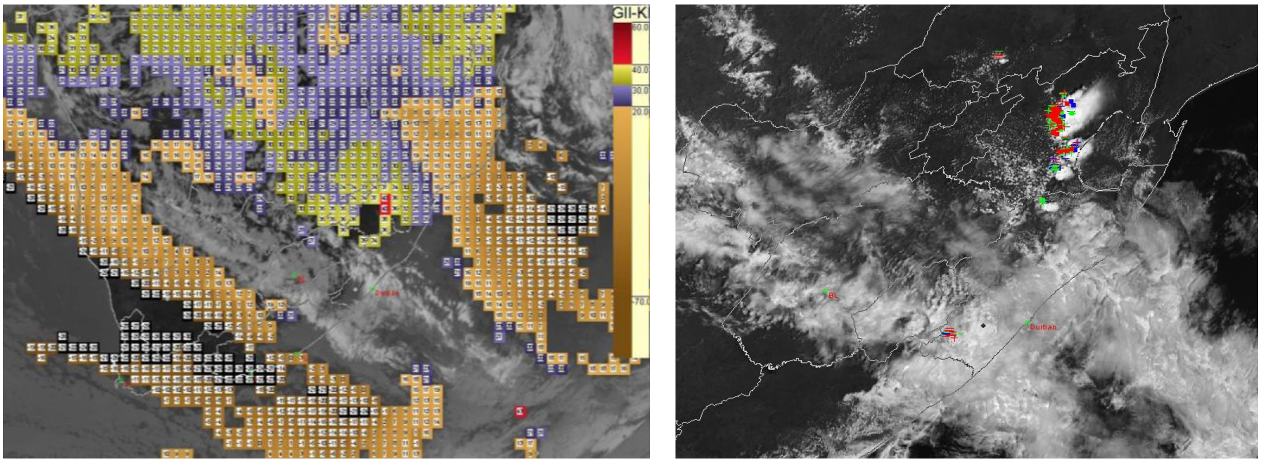

Figure 3: Example of a warning case of initially high K-Index (left, 0800 UTC 26 October 2006), leading to severe storms 3 hours later (right: IR image and lightning observations for 1100 UTC), see text for more details. Figures courtesy Estelle de Coning, South African Weather Service.

Case studies can show that the satellite derived instability information actually provide additional information over the short-range forecast, as e.g. instability gradients and extreme values are changed and thus give a better situational awareness for the forecasters.

3. Convective Initiation (CI)

MSG observations can help in identifying those Cu clouds which have convectively initiated and will likely grow to a mature convective storm. Aim of this analysis is to select Cu clouds at a very early development stage, i.e. before the clouds appear on weather radar, thus providing some more warning lead time. The Convective Initiation product applies so-called Interest Fields, which are single channel brightness temperatures, channel temperature differences and 15- and 30-minute time trends of these values. The Interest Fields are tested against some pre-defined thresholds. In case most of the Interest Fields meet or exceed their threshold, the cloud is marked as a CI event. Table 1 lists the MSG interest fields, together with some associated physical processes.

MSG IR Interest Fields per Physical Process

Cloud Depth	Glaciation	Updraft Strength
• 6.2-10.8 µm difference	• 15-min Trend Tri-spectral	• 30-min 6.2-7.3 µm Trend
• 6.2-7.3 µm difference	• Tri-spectral	• 15-min 10.8 µm Trend
• 10.8 µm T_B	• 30-min Trend Tri-spectral	• 30-min 10.8 µm Trend
• 7.3-13.4 µm	• 15-min 8.7-10.8 µm	• 15-min 6.2-7.3 µm Trend
• 6.2-9.7 µm difference	• 15-min 12.0-10.8 µm Trend	• 30-min 9.7-13.4 µm Trend
• 8.7-12.0 µm difference	• 15-min 3.9-10.8 µm Trend	• 30-min 6.2-10.8 µm Trend
	• 12.0-10.8 µm difference	• 15-min 6.2-12.0 µm Trend
		• 15-min 7.3-9.7 µm Trend

Channels related to the following were found to contain redundant information as they were highly correlated:

8.7-13.4 µm, 8.7-10.8 µm, 7.3-10.8 µm, 13.4-10.8 µm, 8.7-12.0 µm, and Time Trends of these fields.

Table 1: CI Interest Fields for MSG

Figure 4 shows an example for a CI event over Hungary, 21 May 2011. Many case studies have shown a lead time of the CI product compared to radar of up to one hour.

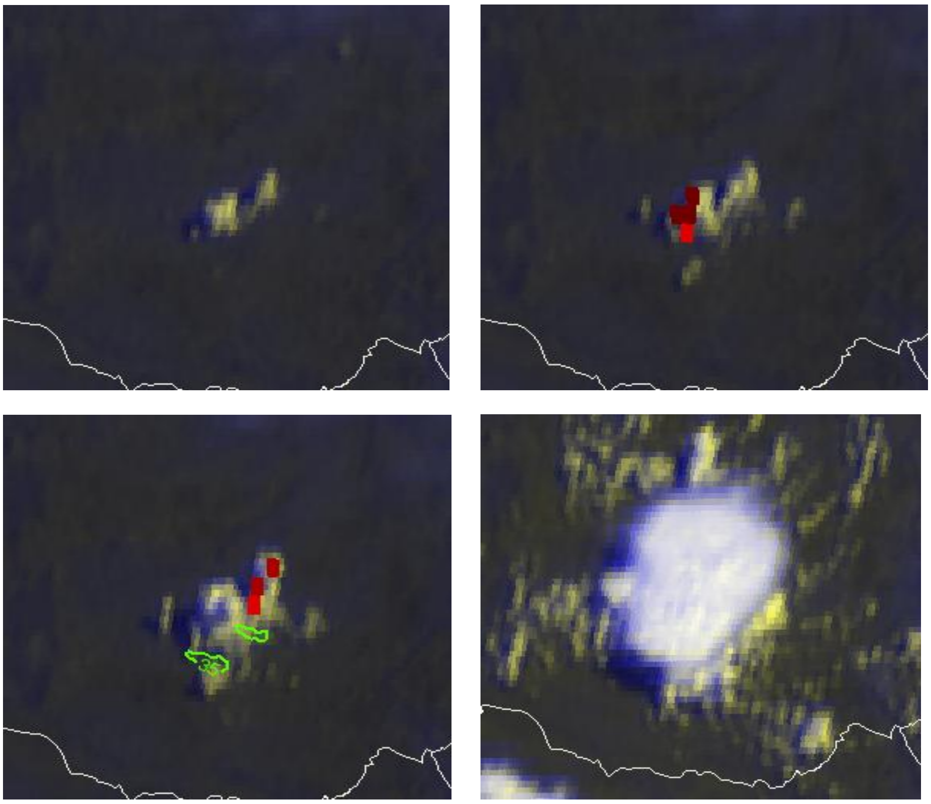

Figure 4: Example of a CI analysis.
Top left: Individual Cu cloud, observed on 0800 UTC on 21 May 2006 over Hungary
Top right: Observation on 0815 UTC, red colour indicates a positive CI identification
Bottom left: Same cloud on 0830 UTC, green contours show 35 dBz radar signal
Bottom right:Satellite impression of fully developed storm at 0925 UTC

4. Mature Convective Clouds

Satellite images of convective cloud tops reveal cloud top structures which are important indicators for the storm life cycle and its severity. Especially overshooting tops are often associated with severe weather at the ground (hail, wind gusts, lightning), and are frequently not well observed by weather radars, i.e. satellite images are an important nowcasting tool in this field.

Thermal IR images can well show the cloud top temperatures, while images taken in the reflected solar band depict the top texture. MSG's high resolution visible channel with its 1 km resolution is especially useful here. The so-called "Sandwich Product" visually combines the 1 km texture information with the cloud top temperatures of the IR10.8 channel; Figure 5 shows an example.

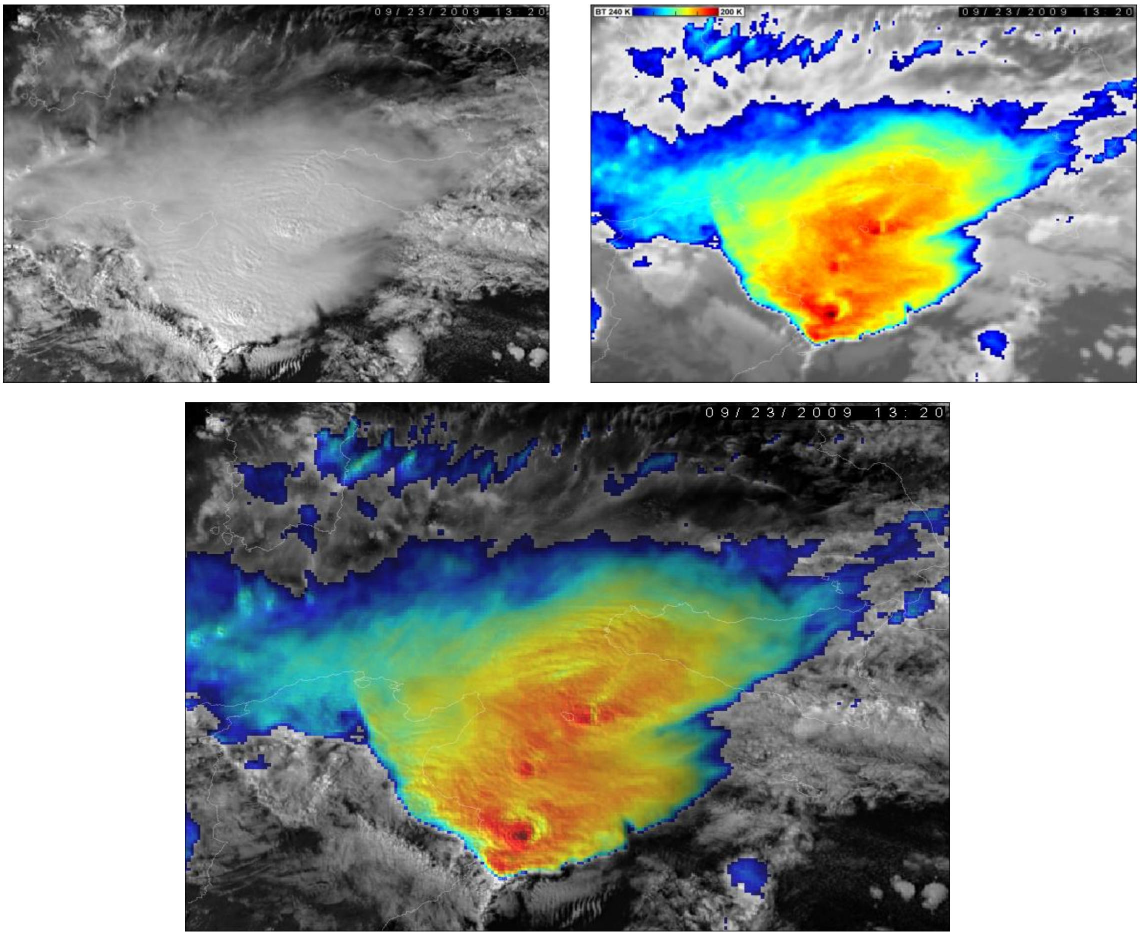

Figure 5: Concept of the Sandwich Product: The 1 km high resolution visible image (top left) is combined with the temperature information of channel IR10.8 (top right, colour coded such that red delineates the lowest temperature values). The combined image (bottom) contains the 1km texture information and the cloud top temperature, thus providing good visual information on the location of overshooting tops, cold ring or V-shaped structures and gravity waves. Courtesy Martin Setvák, Czech Hydrometeorological Institute.

An objective analysis of the overshooting top locations, when compared with recordings of automatic weather stations, show a significant correlation. Figure 6 shows an example.

It should be noted, however, that the satellite observations need to be corrected for the parallax error, which for high clouds can easily amount to 20-30 km in Europe.

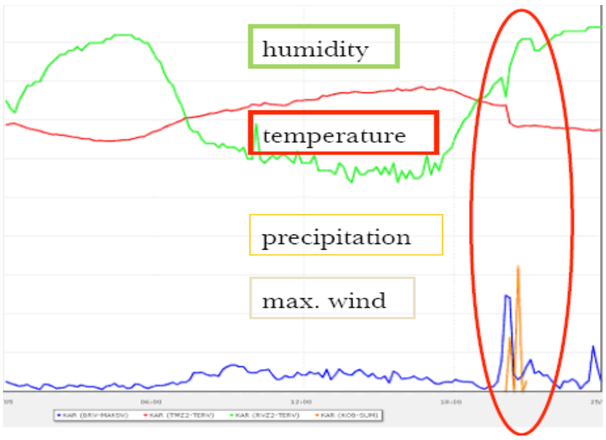

Figure 6: Sharp gradients in meteorological parameters are frequently observed below overshooting tops. The figure shows the automatic recordings of the station Karlovac in Croatia, the red circle marks a detected overshoot at the station location. Courtesy Petra Mikus, Croatian Meteorological service.

The near-infrared bands allow the analysis of cloud phase and particle size at the cloud top: Water clouds show a higher reflectivity than ice clouds, and smaller particles reflect more sunlight than larger particles, as schematically shown in Figure 7.

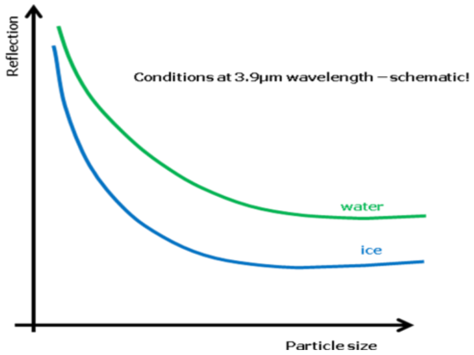

Figure 7: Schematic of water and ice reflectivity, depending on particle size, for channel at 3.9 µm wavelength.

These physical properties are utilised in the special "Convection RGB" (Figure 8): This RGB focuses on high cloud tops. Very cold tops with small ice particles are shown in bright yellow colour. Small ice particles at such heights are the result of strong updrafts, i.e. the yellow areas show the most intense part of the storms. Such a simple RGB, however, can be somewhat deceiving, as the yellow colour can also be the result of an extremely cold cloud top, so that such an RGB should be always used in combination with other information. Quantitative retrievals of cloud top microphysical properties exist in support to the more qualitative RGB.

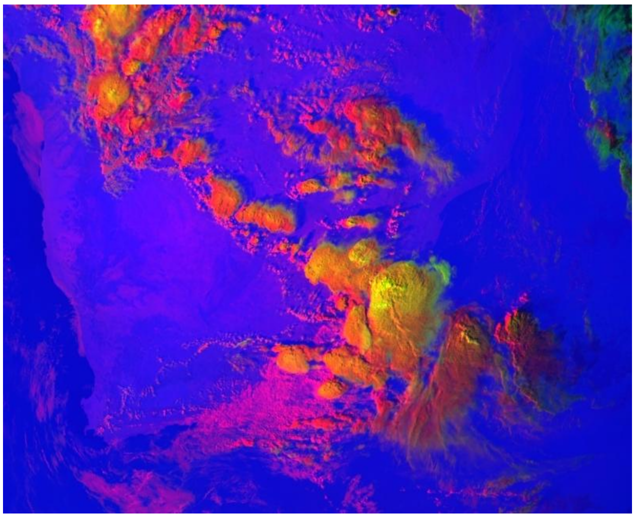

Figure 9: Convection RGB, here shown for a scene over the southern part of Africa. Red: VIS0l8, Green: IR3.9 – IR10.8, Blue: IR10.8 channels.

5. Outlook: Meteosat Third Generation

The future Meteosat Third Generation system (MTG, first launch planned for 2017) will equip forecasters with even better tools for convection nowcasting:

Full disc images will be taken in 16 spectral bands, every 10 minutes, with a subsatellite resolution between 1 and 2 km; regional scans will be provided every 2.5 minutes with an even better spatial resolution. Additional channels in the solar band will allow a more precise quantitative retrieval of cloud microphysical properties. The high time and space resolution will support the early detection of Cu clouds and their convective initiation. MTG will also carry an infrared hyper-spectral sounder, which has a high potential in characterising the pre-convective atmosphere. The Lightning Imager, another new instrument onboard MTG, will detect in-cloud and cloud-to-ground lightning strokes, thus characterising the development, i.e. intensity and movement of convective storms.

6. References

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