CGMS-39 EUM-WP-32
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Prepared by EUMETSAT
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Discussed in WGII

EUM REPORT ON NOWCASTING APPLICATIONS, INCLUDING CLOUD ANALYSIS, FOG DETECTION AND FOREST FIRES

In response to CGMS action WGII 38.33:

CGMS operators to submit to the next CGMS meeting Working Papers on nowcasting applications, including cloud analysis, fog detection and forest fires. Report at CGMS-39.

This paper provides an overview over established nowcasting applications based on Meteosat Second Generation (MSG) observations. These applications range from the use of pure imagery data, mainly based on channel combinations as e.g. channel differences or RGB composites, to more elaborate higher level products. A wealth of nowcasting products is provided through the software of the EUMETSAT Satellite Application Facility in Support to Nowcasting and Short-Range Weather Forecasting (NWC-SAF), but also through products derived centrally at EUMETSAT and made available to users through EUMETCast. The paper also gives examples of recent activities, initiated through collaboration with individual weather services or other science groups.

Recommendation proposed: CGMS-39 WGII to take note

EUM Report on Nowcasting Applications, Including Cloud Analysis, Fog Detection and Forest Fires

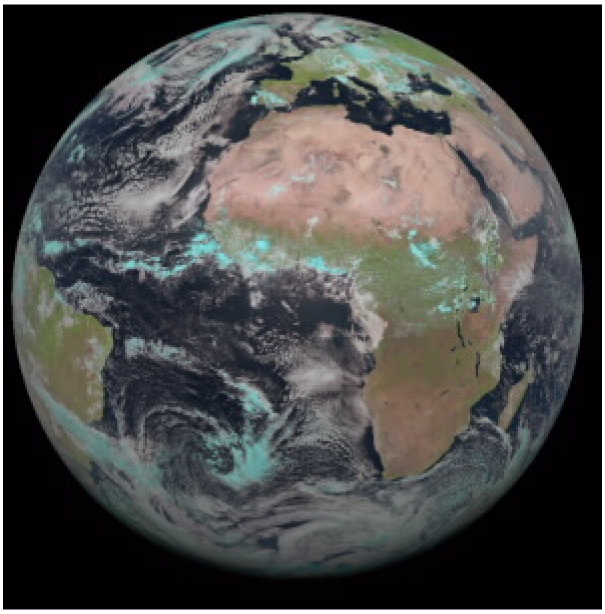
1 INTRODUCTION

Since 2002, EUMETSAT operates the advanced generation of geostationary imagers, the SEVIRI (Spinning Enhanced Visible and Infrared Imager) onboard the Meteosat Second Generation (MSG) satellites. Two MSG satellites have been launched since then and are operated under their operational names Meteosat-8 and Meteosat-9.

Meteosat-9 performs full disc scans with 15 minute repeat cycles from the 0 deg longitude position, while Meteosat-8 performs the so-call Rapid Scan Service, providing scans of the northern third of the full disc every 5 minutes from the 9.5 E longitude position. Figure 1 illustrates the respective viewing geometries.

The MSG SEVIRI channel selection allows for the detection of specific surface, cloud and atmospheric features, e.g. identification of fog, dust storms, fires, air mass properties, cloud microphysics and many more.

Since the launch of MSG, a number of applications have been developed to make use of these new capabilities for nowcasting purposes.



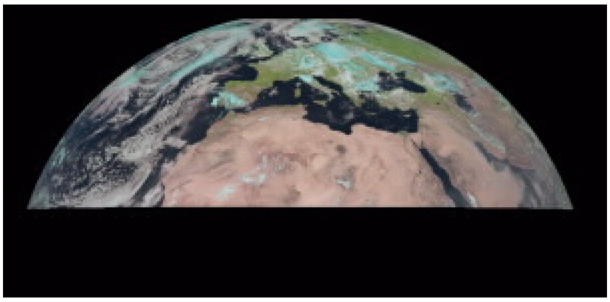


Figure 1: Full disc scan of Meteosat-9 at the 0 deg position (left) and 5-minute scan of Meteosat-8 at 9.5 E longitude (top).

2 MSG SEVIRI NOWCASTING APPLICATIONS

2.1 Image Products

The multi-spectral capabilities of MSG enable the use of colour composites, so-called RGB (red-green-blue) composites, combining the spectral information of several channels and thus highlighting certain features which are less evident on a single channel image. Certain patterns and textures together with continuity in the time domain are well preserved.

Features that can be well observed on MSG RGBs are detailed visualisations of cloud microphysical properties, occurrence of fog, dust storms, volcanic ash, general airmass and surface characteristics.

Usually, the individual single channel images need some pre-processing before they can be used in an RGB combination, e.g. some contrast enhancement that works on a specific image unit (e.g. on brightness temperatures or reflectances). Many RGB "recipes" can be found in the MSG Interpretation Guide on the EUMETSAT web site (http://oiswww.eumetsat.org/WEBOPS/msg_interpretation/index.php). Figure 2 shows an example of such a recipe.

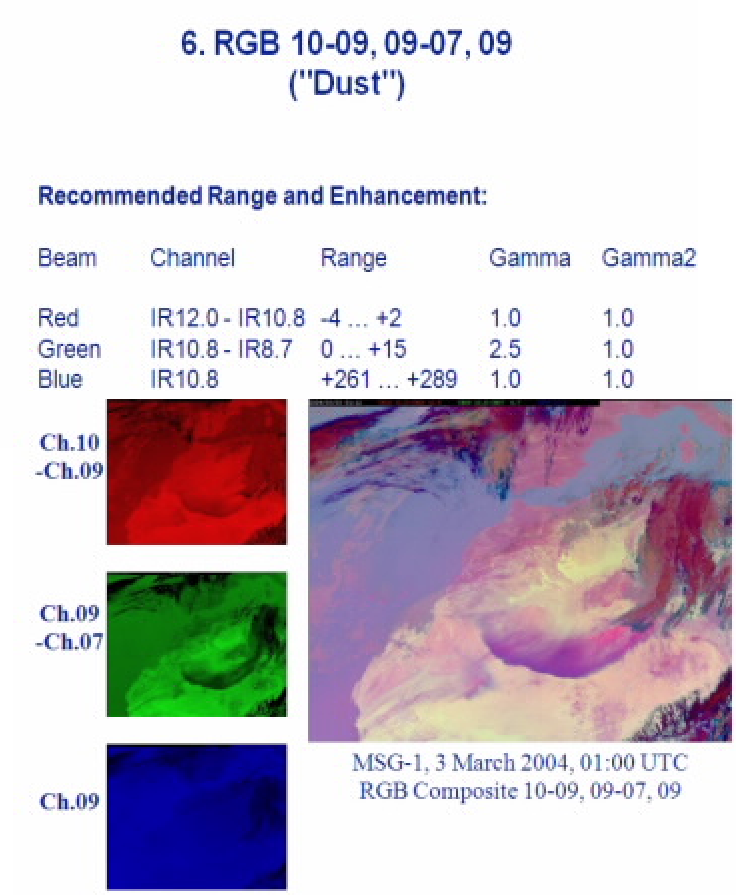


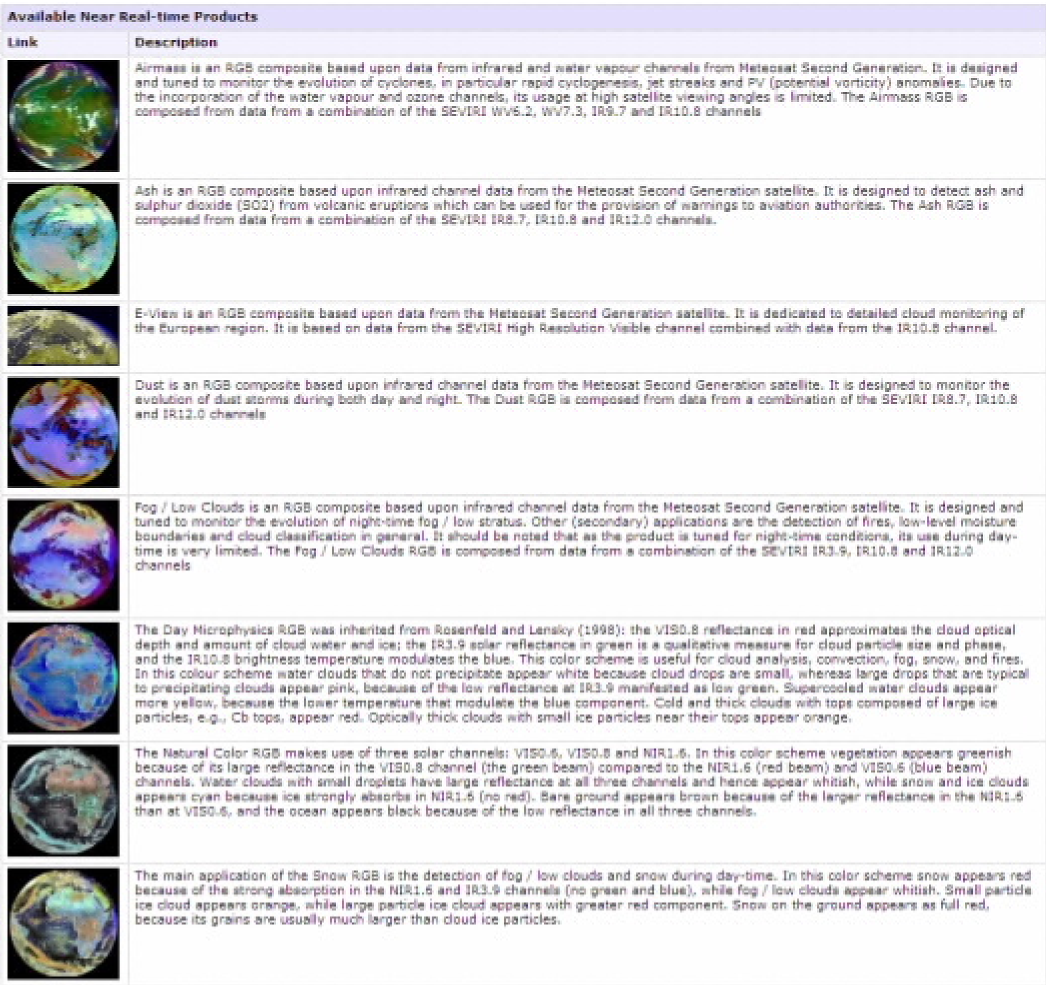
Figure 2: Recipe for the "Dust RGB", taken from the MSG Interpretation Guide for illustration, bottom part of the figure shows an example of the three single channels and the resulting RGB, according to recipe

Soon after the launch of MSG the need for some standardisations in the area of RGBs was recognised, and the Expert Team on Satellite Utilisation and Products (ET-SUP) was tasked to hold a workshop to consider recommendations and guidance for standards. The final report of this workshop is available at http://www.wmo.int/pages/prog/sat/documents/RGB_workshop_final_report_rev1.pdf

Some of the standard RGBs are available as quicklooks for the real-time MSG data on the EUMETSAT web site (airmass, volcanic ash, dust, fog/low clouds, day microphysical, natural colour RGBs), as illustrated in Figure 3.

As RGBs are relatively easy to produce and provide a wealth of information, they are widely used by forecasters. However, one should be aware of certain disadvantages and shortcomings:

(a) RGBs are based on merely 255 greyscales in the single channel image, thus some of the radiometric resolution in the original data is lost
(b) There is no unique relationship between a "colour" and a feature, as second order effects are not considered (e.g. viewing geometry)
(c) Forecasters need considerable knowledge, i.e. training, in order to correctly interpret RGBs – and even then, it is a subjective interpretation
(d) RGBs are not quantitative products!



Available Near Real-time Products

Link	Description
	Airmass is an RGB composite based upon data from infrared and water vapour channels from Meteosat Second Generation. It is designed and tuned to monitor the evolution of cyclones, in particular rapid cyclogenesis, jet streaks and PV (potential vorticity) anomalies. Due to the incorporation of the water vapour and ozone channels, its usage at high satellite viewing angles is limited. The Airmass RGB is composed from data from a combination of the SEVIRI WV6.2, WV7.3, IR9.7 and IR10.8 channels
	Ash is an RGB composite based upon infrared channel data from the Meteosat Second Generation satellite. It is designed to detect ash and sulphur dioxide (SO2) from volcanic eruptions which can be used for the provision of warnings to aviation authorities. The Ash RGB is composed from data from a combination of the SEVIRI IR8.7, IR10.8 and IR12.0 channels.
	E-View is an RGB composite based upon data from the Meteosat Second Generation satellite. It is dedicated to detailed cloud monitoring of the European region. It is based on data from the SEVIRI High Resolution Visible channel combined with data from the IR10.8 channel.
	Dust is an RGB composite based upon infrared channel data from the Meteosat Second Generation satellite. It is designed to monitor the evolution of dust storms during both day and night. The Dust RGB is composed from data from a combination of the SEVIRI IR8.7, IR10.8 and IR12.0 channels
	Fog / Low Clouds is an RGB composite based upon infrared channel data from the Meteosat Second Generation satellite. It is designed and tuned to monitor the evolution of night-time fog / low stratus. Other (secondary) applications are the detection of fires, low-level moisture boundaries and cloud classification in general. It should be noted that as the product is tuned for night-time conditions, its use during day-time is very limited. The Fog / Low Clouds RGB is composed from data from a combination of the SEVIRI IR3.9, IR10.8 and IR12.0 channels
	The Day Microphysics RGB was inherited from Rosenfeld and Lensky (1998): the VIS0.8 reflectance in red approximates the cloud optical depth and amount of cloud water and ice; the IR3.9 solar reflectance in green is a qualitative measure for cloud particle size and phase, and the IR10.8 brightness temperature modulates the blue. This color scheme is useful for cloud analysis, convection, fog, snow, and fires. In this colour scheme water clouds that do not precipitate appear white because cloud drops are small, whereas large drops that are typical to precipitating clouds appear pink, because of the low reflectance at IR3.9 manifested as low green. Supercooled water clouds appear more yellow, because the lower temperature that modulate the blue component. Cold and thick clouds with tops composed of large ice particles, e.g., Cb tops, appear red. Optically thick clouds with small ice particles near their tops appear orange.
	The Natural Color RGB makes use of three solar channels: VIS0.6, VIS0.8 and NIR1.6. In this color scheme vegetation appears greenish because of its large reflectance in the VIS0.8 channel (the green beam) compared to the NIR1.6 (red beam) and VIS0.6 (blue beam) channels. Water clouds with small droplets have large reflectance at all three channels and hence appear whitish, while snow and ice clouds appears cyan because ice strongly absorbs in NIR1.6 (no red). Bare ground appears brown because of the larger reflectance in the NIR1.6 than at VIS0.6, and the ocean appears black because of the low reflectance in all three channels.
	The main application of the Snow RGB is the detection of fog / low clouds and snow during day-time. In this color scheme snow appears red because of the strong absorption in the NIR1.6 and IR3.9 channels (no green and blue), while fog / low clouds appear whitish. Small particle ice cloud appears orange, while large particle ice cloud appears with greater red component. Snow on the ground appears as full red, because its grains are usually much larger than cloud ice particles.

Figure 3: Quicklook RGBs for the MSG real-time data on the EUMETSAT web site (http://oiswww.eumetsat.org/IPPS/html/MSG/RGB/)

2.2 Derived Products

2.2.1 NWC-SAF

The EUMETSAT Satellite Application Facility in Support to Nowcasting and Short-Term Forecasting (NWC-SAF) provides software extracting a number of products from the MSG images, which are relevant for nowcasting and short term prediction purposes. The NWC-SAF software package is intended to be installed at regional forecasting centres, using the locally received MSG data and – if required – local forecast model fields as input.

A full description of the NWC-SAF software package, the underlying algorithms, validation reports, the software package and product demonstrations can be found on the SAF website www.nwcsaf.org.

The list of products include:

(a) pixel based cloud mask
(b) pixel based cloud type information, discriminating 16 different scene types
(c) pixel based cloud top temperature and height information
(d) products covering precipitation and convection issues (convective rainfall raite, precipitating clouds, rapidly developing thunderstorms)
(e) pixel based clear air products (instability indices, precipitable water)
(f) conceptual model and wind products (high resolution wind field, air mass analysis, automatic satellite image interpretation)

2.2.2 EUMETSAT Central Application Facility

Two products, which are relevant for nowcasting applications, are derived centrally at EUMETSAT and are made available to users via EUMETCast: the pixel based fire detection product (FIR) and the Global Instability Indices product (GII).

The FIR product detects wild fires and other fires on a pixel basis from a combination of the measurements taken by the IR3.9 and the IR10.8 channel. The product discriminates "possible fires" and "potential fires". "Possible fires" are detected hotspot where all threshold tests used in the detection algorithm are passed, i.e. a fire in the processed pixel is very likely. In case of "potential fires", some threshold tests are not passed. Figure 2 shows an example. The FIR product is derived for both Meteosat-8 and Meteosat-9.

The FIR product, however, has some limitations:

(a) Small fires remain undetected, due to the relatively large MSG pixel size
(b) False alarms can occur, e.g. under sun glint conditions (small lakes, rivers, flooded surface)
(c) False alarms or missed detections can occur in case of unknown surface emissivity conditions, e.g. over inhomogeneous terrain with spatially variable surface emissivity
(d) False alarms or missed detections at dusk/dawn conditions with rapidly changing IR3.9 radiances
(e) False alarms can be caused by a heterogeneous cloud field, consisting of many small Cu clouds, during daylight hours

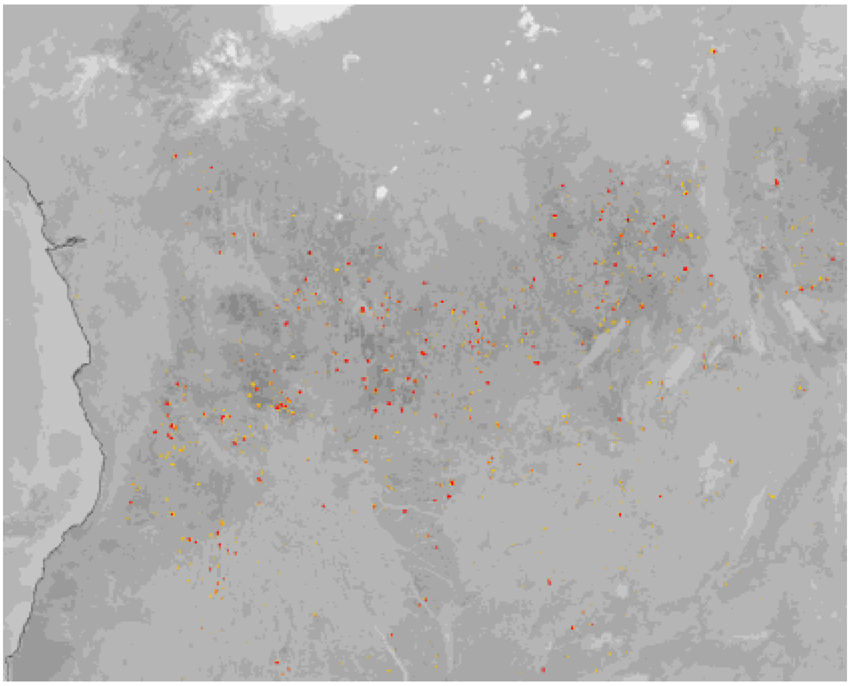


Figure 2: Example of the EUMETSAT FIR Product over Central Africa. "possible" fires are shown in red, "potential" fires in yellow.

The GII product is derived over cloud free scenes and includes a number of instability indices, layer and total precipitable water. The parameters are derived through a physical retrieval, using numerical model forecast profiles together with six MSG infrared channels. The core of the algorithm is very similar to the respective NWC-SAF product.

The product aims at providing forecasters with a first awareness concerning the convection potential of the atmosphere. Its value has been shown in numerous case studies and through detailed presentations given at training sessions. Figure 3 shows a typical example.

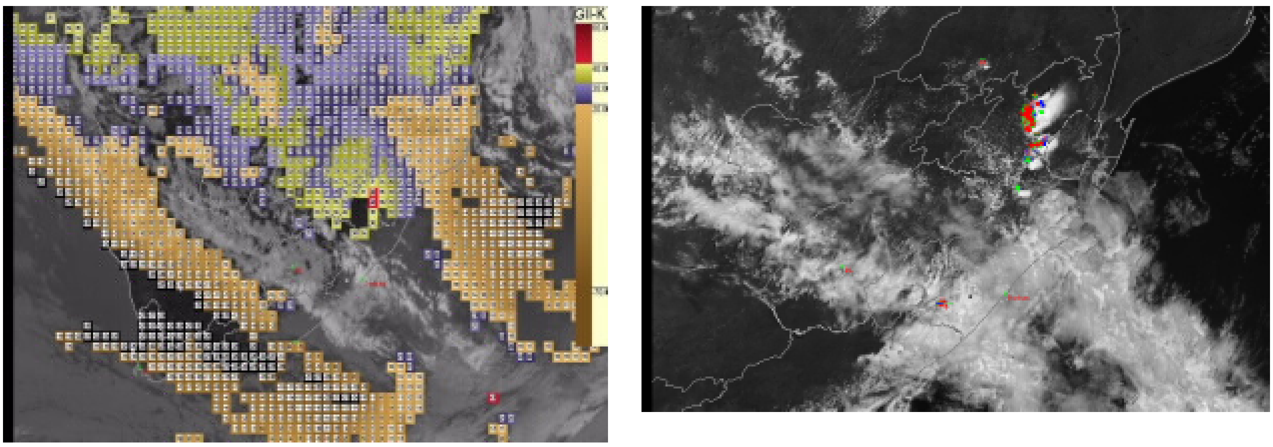


Figure 3: GII K-Index (left) over South Africa, showing high K-Index values (yellow and red) over the Johannesburg/Pretoria region. Right panel shows the IR channel together with lightning data 3 hours later, where the storm has developed in the area of the initially high K-Index values.

The GII product is available for Meteosat-9 as a 3x3 pixel average, for Meteosat-8 on a pixel basis. A full description of the product algorithm and performance can be found in

Koenig, M. and E. de Coning, 2009: The MSG Global Instability Indices Product and Its Use as a Nowcasting Tool. *Weather and Forecasting*, **24**, 272-285, DOI: 10.1175/2008WAF2222141.1

2.3 International Collaboration

A number of activities have been carried out in the past years or are still ongoing regarding the use of MSG data for nowcasting:

Already in 2005, the South African Weather Service (SAWS) expressed great interest in the EUMETSAT GII product. Through a Visiting Scientist collaboration, SAWS installed the GII retrieval software locally. They could thus use their own mesoscale model as input data. Within the SAWS nowcasting research group, the product was developed further, e.g. studies were done with respect to validation with lightning data and further combination of the provided indices to produce probability of lightning maps for the entire Southern Africa region. Figure 4 gives an example. This work was recently published:

de Coning, E., M. Koenig, and J. Olivier., 2010: The Combined Instability Index: A New Very-Short Range Convection Forecasting Technique for Southern Africa. *Meteorological Applications*, DOI 10.1002/met.234, online available http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1469-8080/earlyview

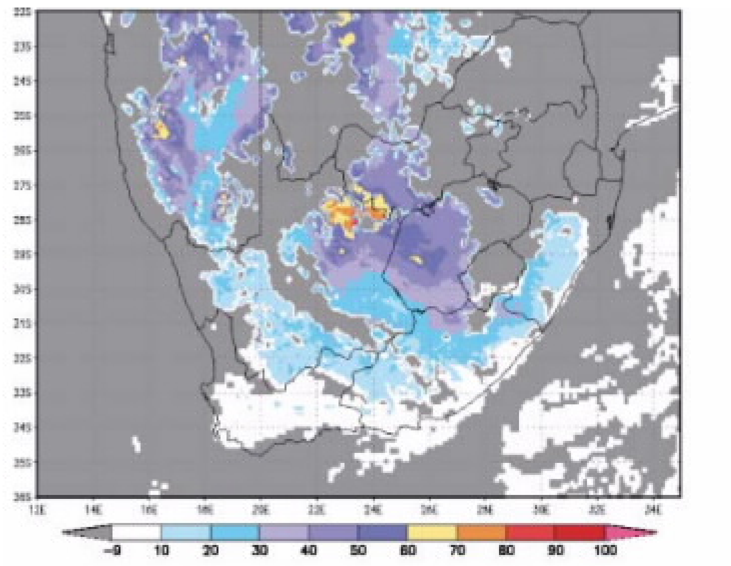


Figure 4: Example of the Convective Instability Index (CII) product, a further development of the EUMETSAT GII product, done at SAWS. CII give a probability of lightning occurrence in the 3-12 hours time range. CII maps are available to SAWS forecasters, and through a website to all Southern African countries. It will soon also be available on EUMETCast.

Regarding the early convection phase, a number of science studies were done regarding the use of MSG data for the detection of the convective initiation. Aim here is to detect a growing cumulus cloud before it appears in radar data, i.e. to provide 30-60 minutes lead time to radar observations. The studies covered the use of both infrared and visible channels and also on the added value of the derived cloud microphysical product. Figure 5 illustrates the concept. Detailed descriptions of this work can be found in:

The work is summarised in the following three publications, and

Mecikalski, J., W. MacKenzie, M. Koenig, and S. Muller, 2010: Cloud-Top Properties of Growing Cumulus prior to Convective Initiation as Measured by Meteosat Second Generation. Part I: Infrared Fields. *Journal of Applied Meteorology and Climatology*, **49**, 521-534, DOI: 10.1175/2009JAMC2344.1

Mecikalski, J., W. MacKenzie, M. Koenig, and S. Muller, 2010: Cloud-Top Properties of Growing Cumulus prior to Convective Initiation as Measured by Meteosat Second Generation. Part II: Use of Visible Reflectance. *Journal of Applied Meteorology and Climatology*, **49**, 2544-2558, DOI: 10.1175/2010JAMC2480.1

Mecikalski, J., P. Watts, and M. Koenig, 2011: Use of Meteosat Second Generation Opticmal Cloud Analysis Fields for Understanding Physical Attributs of Growing Cumulus Clouds. Accepted for publication in *Atmospheric Research.*

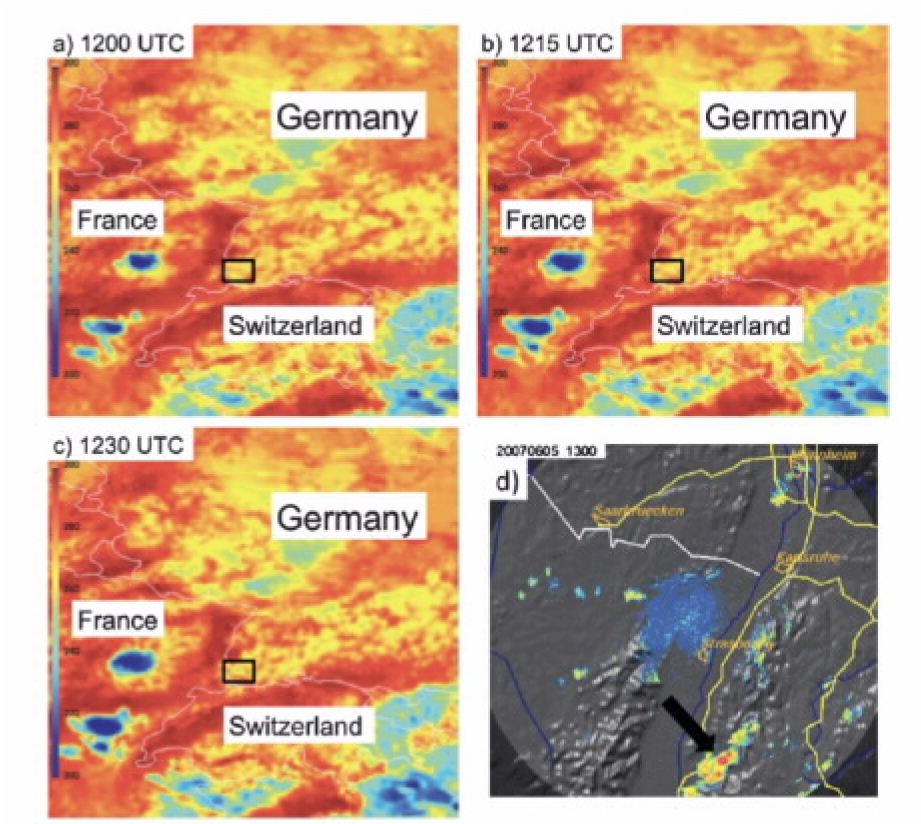


Figure 5: (a)–(c) An example of one CI event shown in the MSG IR10.8 channel on 05 June 2007, with (d) a radar image. The squares in (a)–(c) highlight a small region where cumulus clouds were forming as they moved over a 30-min time frame, from 1200 to 1230 UTC, prior to CI for this sequence. In (d), the 1300 UTC radar image shows the lowest scan reflectivity associated with the developing cumulus clouds in (a)–(c).

Much of the MSG related convection nowcasting work is discussed and coordinated through the Convection Working Group (http://www.convection-wg.org). Members of this group have recently compiled a “Best Practice” document, describing established convection nowcasting methods. This document is seen as a “living document” where Working Group members can add own flavours of the described methods and case studies. The document is available online at http://www.convection-wg.org/doc_meci/best_practise_CWG_v3.pdf .

3 CONCLUSIONS

The multi-spectral capabilities of MSG have opened many new possibilities for nowcasting applications. It can be well expected that these possibilities will be further explored and refined with the advent of the next generation of geostationary satellites as GOES-R and MTG: Better resolution in time and space will allow an even more precise localisation of a relevant event, while the new instruments as the MTG Infrared Sounder and the lightning instruments will provide further information, focussing on the pre-convective environment and on the cloud processes leading to lightning.