USE OF MSG/SEVIRI IN THE WMO SAND AND DUST STORM WARNING ADVISORY AND ASSESSMENT SYSTEM (SDS WAS) FOR EUROPE, NORTH AFRICA AND MIDDLE EAST

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Abstract
Sand and dust storms represent serious natural hazards, causing numerous negative impacts on aviation safety, health, ground transport, agriculture and climate. Therefore, the World Meteorological Organization (WMO) has established the Sand and Dust Storm Warning Advisory and Assessment System (SDS WAS) to improve the capabilities for more reliable sand and dust storm forecasts and monitoring. The main objective of this project is to establish a WMO-coordinated global network of SDS forecasting Centres, which will deliver useful products to a wide range of users in order to reduce the impacts of SDS. Spain is implementing the WMO SDS WAS Regional Centre for Europe, North Africa and Middle East. This Regional Centre will deal with both operational and scientific aspects related to atmospheric dust monitoring and forecasting. SEVIRI (Spinning Enhanced Visible and Infrared Imager), on board Meteosat Second Generation (MSG), provides 15-minute loop images that allow to identify dust source regions by means of subtle changes from one image to the next. Even though, SEVIRI (with only three narrow bands in the solar spectrum placed at 0.63, 0.81 and 1.64 mm, in addition to the wide HRV band) is not as optimal for the viewing of dust as other multi-spectral sensors, such as SEAWIFS or MODIS. Moreover, SEVIRI images present the same problems detected in other satellites when the information provided is used to detect dust. The main ones are the confusion of dust with water/ice clouds and that the reflectivity on visible wavelengths is hampered by the fact that land surfaces are characterized by a wide range of albedos. Over Africa, SEVIRI solar bands contain the information related to the presence of the dust mixed up with the ground information. In order to detect the presence of dust in SEVIRI visible images, it is necessary to detach the information of the background introduced by the textures of the desert, and to enhance the information concerning the dust. Two different steps have been established to tackle the problem: first of all, to normalize the visible channels radiance and later, to build the monthly cloudless normalized radiance masks for each channel.

INTRODUCTION
This paper is embedded in the activities for the development of the SDS WAS for Europe, Africa and Middle East Regional Centre. The area of this Regional Centre is shown in Figure 1, being mostly inside the Meteosat satellites coverage.

The first part of the paper is devoted to the implementation of the RGB images recommended by EUMETSAT for monitoring desert dust with MSG. Later, some early developments made at the AEMET to enhance the analysis of dust information contained in the SEVIRI VIS channels will be presented.

Figure 1: Region covered by SDS WAS for Europe, Africa and Middle East Regional Centre.
SEVIRI PRODUCTS BACKGROUND

Continuous monitoring of desert dust using EUMETSAT RGB images

EUMETSAT recommends the use of some RGB images for dust monitoring in the “MSG interpretation guide” which is available on its web page. The Dust RGB is an RGB composition based upon infrared channel data from SEVIRI. It is designed to monitor the evolution of dust storms over deserts during both day and night.

| Dust (night & day) |
|-------------------|-----------------|-----------------|-----------------|-----------------|
| RGB colour plane  | Channel (difference) | MIN  | MAX    | GAMMA | Prominent features |
| R                 | 12.0 - 10.8          | -4 K  | +2 K    | 1.0   | Dust(over land)  |
| G                 | 10.8 - 8.7           | 0 K   | +15 K   | 2.5   | Thin Ci          |
| B                 | 10.8                | 261 K | 289 K   | 1.0   | Contrails        |

One of the strongest sand storms over land, which took place in February 2007, has been selected as an example of the use of these RGB images. The intensity of the storm over land can be appreciated in the Dust RGB images shown in figure 3. Dust concentration is indicated by the gradation of pink colours, which characterize this kind of dust RGB images. Loops of dust RGB images for this event are available on [http://salam.upc.es](http://salam.upc.es) -> “Agenda”).

The Natural RGB compositions are based upon visible channels data from SEVIRI. It is recommended for the tracking of dust across the oceans during daytime.

| Natural Colours |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| RGB colour plane | Channel | MIN  | MAX    | GAMMA | Prominent features |
| R               | 1.6          | 0 %   | 100 %   | 1.0   | Ice/water clouds, fog,snow |
| G               | 0.8          | 0 %   | 100 %   | 1.0   | Dust(over ocean),smoke |
| B               | 0.6          | 0 %   | 100 %   | 1.0   | (Green) vegetation |

**Dust related products**

EUMETSAT is developing two MPEF day-2 aerosols related products, within its Meteorological Product Extraction Facility (MPEF). On the other hand, EUMETSAT Satellite Application Facilities for Nowcasting and Very Short Range Forecasting (NWC SAF) software package provides a dust product. This product is included in the Cloud Mask product as a flag that indicates the presence of dust. As the rest of NWC SAF products, it is obtained in near real time, at full resolution (3km x 3km at nadir) every cycle of 15 minutes for the region selected by the user. More information about this can be obtained in the NWC SAF web page ([http://nwcsaf.inm.es](http://nwcsaf.inm.es)).

![Figure 2: PGE01 Cloud Mask (CMa) Dust flag NWC SAF from MSG of 21st February 2007 at 12 UTC. Pixels in green indicate dust.](image)
Figure 3: Dust RGB images of 21st, 22nd and 23rd February 2007 at 12 UTC.
EARLY AEMET DEVELOPMENTS

Normalized natural RGB

Due to the fact that the incoming radiance is different depending on the position of the earth throughout the year, and also depending on the moment the satellite makes the observation, it will be convenient to normalize in a certain manner the radiance values obtained by the radiometer in order to compare situations that can last several days and that can appear at any time during the year.

The Bidirectional Reflectance Factor (BRF) allows to manage the radiances taking into account the solar zenith angle (SZA), the Sun Earth distance (SE), the channel bandwidth (BW) and the Sun Irradiance (SI).

\[
BRF = \frac{\pi \cdot RAD \cdot BW \cdot SE^2}{SI \cdot \cos(SZA)} \tag{1}
\]

The BRF variable factors can be grouped in one term, called normalized Radiance in this paper (equation 2):

\[
RADn = \frac{RAD \cdot SE^2}{\cos(SZA)} \tag{2}
\]

The normalized radiance for the 0.6, 0.8 and 1.6 micron SEVIRI channels is routinely calculated using a McIDAS command developed at the AEMET. The Natural RGB command is applied to the normalized radiances and the obtained RGB images are called normalized Natural RGB images. The normalized Natural RGB image shows a better dust monitoring to simple sight over ocean. It also allows observing dust events during more hours, solving the problems introduced by sunrise or sunset. Moreover, the normalization makes it possible to compare normalized Natural RGB images of different situations throughout the year.

Dust monitoring over land pixels using SEVIRI visible channels

Detection of dust over bright land such as deserts is more difficult than over ocean, and it requires IR information to separate the dust signal from the other components of the scene. Over land pixels, visible channels are not so efficient in the dust monitoring. The 21st-23rd February 2007 sand storm event has been selected to investigate the information contained in the visible channels over land. The normalized Natural RGB images for this event are shown in figure 4, where the dust is represented as a blurred region in the image. On the visible channels over the region of interest (blue circle), it can be seen how the presence of dust is mixed with the ground information.

The objective is to detect the presence of dust in visible SEVIRI images. Thus, it is necessary to detach the information of the background introduced by the textures of the desert, and to enhance the information coming from the dust.
Figure 4: Normalized radiance Natural RGBs images of 21st, 22nd and 23rd February 2007 at 12 UTC.
This task has been performed developing a McIDAS command that operationally calculates cloudless radiance masks for each channel (0.6, 0.8, 1.6 micron) with the previous 30 days images at 12 UTC. The used criteria to construct this operational “30-day mask” for each channel are different for land and sea pixels. Over every land pixel, the array containing the radiances for the previous 30 days is sorted (in ascending order). Later on, the day with the highest NDVI is searched among the third part of the data with lower values (excluding the minimum value). In the case of sea pixels, the data for the 30 days are managed together and the value with the maximum frequency of the histogram for the 30 days is selected. All the sea pixels are set to this fixed value.

When a Natural RGB image is built with the masks of the previous 30 days, it can be obtained an RGB image where only ground information is retained. As an example, in figure 5 it is shown the mask built using the information contained in the previous 30 days to the 21st February 2007 dust event.

As the differences between the image and the mask are small, the use of the square root of the differences is more adequate to enhance the presence of dust. In figure 6, it is shown an RGB composition with the square root of the differences between each normalized radiance and its normalized radiance of the mask (following the same Natural RGB channel order). It can be seen how the textures of the desert have disappeared and how the regions affected by the presence of dust have been clearly enhanced together with clouds.

Further developments to combine the dust information from IR channel and the dust information from the difference between the VIS channels and the 30 days mask are needed. This kind of processing is very fast and cheap and can be used as complement to dust models and in situ measurements to allow a better monitoring of dust events. In particular, the comparison with dust numerical model outputs of DREAM, which is running on Barcelona Supercomputer Center (BSC), is on going inside the SDS WAS project.
Figure 6: Normalized radiance Natural RGBs images of 21st, 22nd and 23rd February 2007 at 12 UTC.
CONCLUSIONS

The SEVIRI spectral range, its spatial resolution (3 km in the IR bands at nadir), and its 15 minutes cycle allow to better monitor desert dust events. The RGB images constitute an easy and fast approach for dust monitoring. The use of visible normalized radiances improves the dust monitoring when the Natural RGB is applied. An operational environment system for dust monitoring based on web pages is being developed at the AEMET. However, further work is needed to improve the quality of the dust estimation using visible channels over land pixels and to combine with IR information.

Preliminary results (as the example shown in this work) suggest that differences between the normalized radiances and the desert masks could be used in the development of algorithms to obtain quantitative estimations of column Aerosol Optical Thickness (AOT) which will be validated against PHOTONS/AERONET data.

REFERENCES

