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Contribution of Meteosat Second Generation (MSG) to drought early warning

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ABSTRACT: Several low resolution satellite sensors are now available and can provide near real-time monitoring of vegetation cover seasonal changes on a large scale basis. This paper presents a comparison of NDVI derived from SPOT-VEGETATION and MSG-SEVIRI for the whole continent of Africa.

Dekadal NDVI from VEGETATION data are available, obtained from maximum NDVI compositing technique. VEGETATION data from July 1-10, 2004, have been re-sampled at 0.025° spatial resolution (= resolution of MSG-SEVIRI data) for whole Africa. In the case of SEVIRI data, a 2-steps procedure is used: first daily compositing is implemented through analysis of thermal data (maximum surface temperature compositing), followed by dekadal NDVI synthesis.

Results include the observed correlations and discrepancies of NDVI products of the 2 sensors. Results suggest that, due to higher temporal frequency (1 image each 15 mn), MSG-SEVIRI data can be used to obtain improved NDVI products through better removal of cloud-contaminated pixel.

1 INTRODUCTION

Several low resolution satellite sensors are now available and can provide near real-time monitoring of vegetation cover seasonal changes on a large scale basis. In addition to NOAA-AVHRR sensor operated and archived since more than 20 years, new sensors became recently available for continental or global vegetation monitoring, like SPOT-VEGETATION (since 1998), EOS-MODIS (since 2000) or MSG-SEVIRI (since 2004). In this paper, the emphasis will be put on MSG-SEVIRI instrument. The high temporal frequency allows a new approach to temporal compositing inducing an improved removal of cloud-contaminated pixels. The derived NDVI product will be compared to similar product obtained from SPOT-VEGETATION data during the same compositing period (July 1-10, 2004).

2 SATELLITE DATA ACQUISITION AND PROCESSING METHODS

2.1 *MSG Data acquisition*

MSG-1, the first of the Meteosat Second Generation geostationary satellites, has been launched on August 28, 2002. Due to technical problems, it was fully operational only on January 29, 2004 and took the name Meteosat 8.

MSG transmits raw data to the Eumetsat control and processing centre in Darmstadt (Germany), via the primary ground station, for processing. The raw data consists mainly of images generated by the SEVIRI (Spinning Enhanced Visible and Infrared Imager) instrument and the Geostationary Earth Radiation Budget Experiment on board the satellite. Once processed, the data is sent back to the satellite for broadcasting to users.

SEVIRI radiometer is the main instrument on board MSG. It provides images of the Earth disc with 3km resolution at nadir in 11 bands (visible, near infrared, shortwave infrared and thermal infrared). Main features of optical bands are indicated at Table 1.

Channel	Spectral domain	λcen	λmin - λmax
VIS 0.6	Green - Red	0.635	0.56 – 0.71
VIS 0.8	Near Infrared	0.810	0.74 – 0.88
NIR 1.6	Shortwave IR	1.640	1.50 – 1.78

Table 1. *Spectral characteristics of 3 optical bands of SEVIRI instrument*

MSG takes one full resolution image every 15 minutes, thus illustrating the weather in motion. In addition, a panchromatic image is taken with 1km resolution, covering partly the Earth disc, as indicated at **Figure 1**. Image dimensions are 3712 x 3712 pixels in channels 1 to 11, and 5568 x 11136 pixels in channel 12.

Deriving NDVI from MSG data

Temporal compositing of NDVI data is generally based upon the computation of maximum NDVI from a set of multi-temporal data. This technique can not be applied to MSG data taken during a diurnal cycle: due to changes in solar zenithal and azimuthal angles, NDVI exhibit variations which are not related with ground cover. An alternative technique is to follow the diurnal cycle of brightness temperature: the identification of the maximum value during the day is an efficient mean to eliminate pixels contaminated with clouds or cloud-shadows, characterized by low temperatures. Then NDVI is computed for each pixel, using red and near infrared radiances recorded at the time of day of maximum temperature. This procedure has been implemented by the MSG-ATR team (MSG-ATR, 2005). NDVI is multiplied by 1000, and coded as integer value, ranging from -1000 to + 1000. It must be noted that the procedure is applied to raw radiance data (no atmospheric corrections).

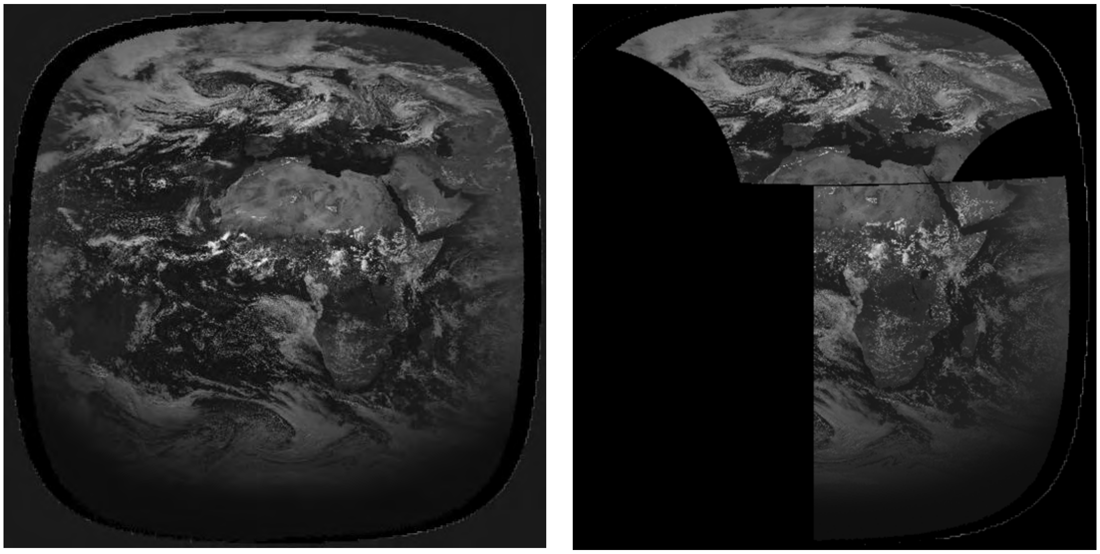

Figure 1. *Example of MSG images at 3km resolution, full disc (left) and 1km resolution (right)*

A sub-image covering the whole continent of Africa has been extracted (38°N to 35°S, 26°W to 60°E); data have been re-sampled at 0.025 degree resolution in Plate-Carrée projection (geographic): the size of resulting image is 3440 x 2920 pixels.

2.2 *SPOT VEGETATION NDVI data*

Dekadal NDVI data are available freely from SPOT VEGETATION distributor (VITO, 2005). NDVI data can be obtained for the whole continent of Africa (38°N to 35°S, 26°W to 60°E) in a geographic projection, with spatial resolution of 0.00892857 degree (~1 km) : the size of image is 9633 x 8177 pixels. Data are available in *hdf* format; one channel "quality of data" is also available, which indicates pixels affected by clouds or cloud-shadows.

NDVI data are given in byte format (Digital counts DC between 0 and 255). NDVI values range between -0.1 (DC = 0) and 0.92 (DC = 255), and the relationship between NDVI and digital counts is given by :

$$NDVI = 0.004*DC - 0.1$$

To compare with MSG data, SPOT VEGETATION NDVI image has been re-sampled at 0.025° resolution, using the nearest neighbour algorithm.

3 RESULTS

3.1 *SPOT-VEGETATION NDVI data*

Re-sampled NDVI image from July 1-10, 2004 is displayed at **Figure 2**. Although resulting from a 10 days synthesis, the image is still affected by cloud contaminated pixels. This is the case in the West Africa tropical region, as indicated at **Figure 3**.

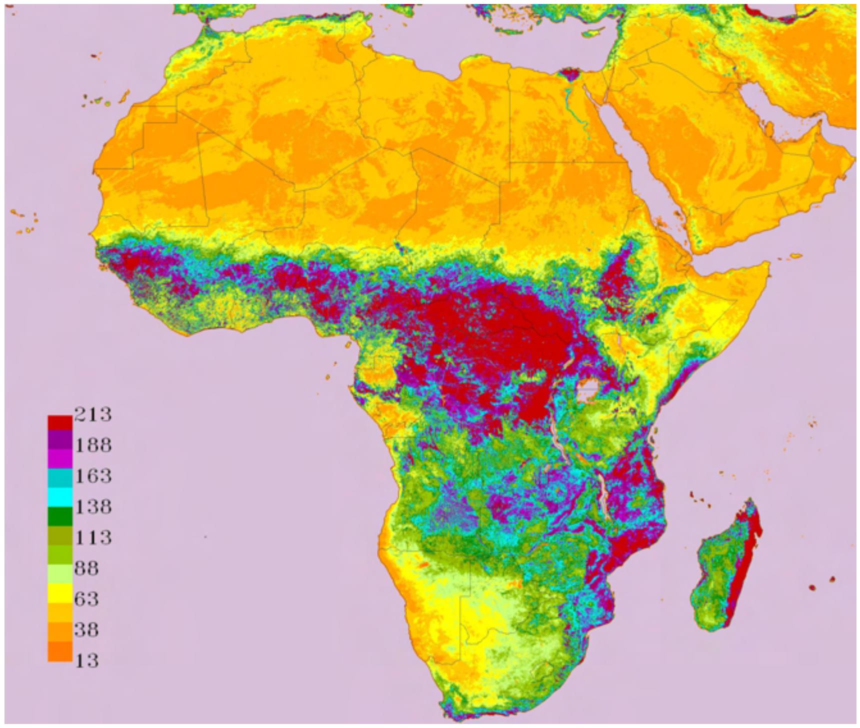

Figure 2. *Dekadal NDVI image derived from SPOT-VEGETATION data (July 1-10, 2004).*

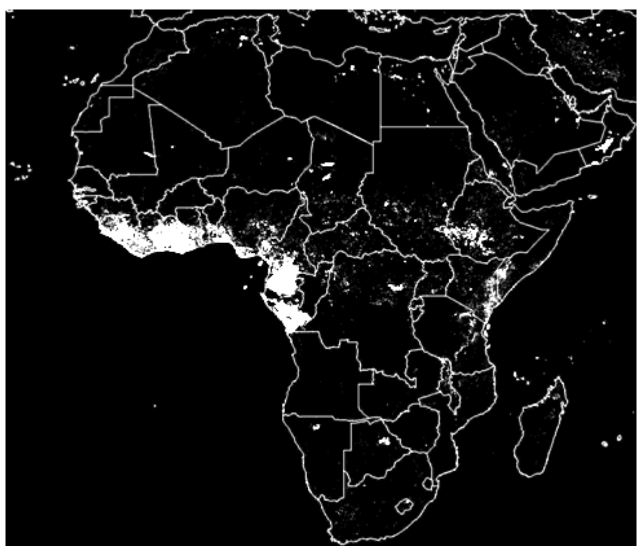

Figure 3. *Cloud-contaminated pixels (white pixels) in SPOT-VEGETATION dekadal image.*

3.2 *MSG SEVIRI data*

MSG SEVIRI data (temporal synthesis, July 1-10, 2004) are depicted at **Figure 4**. The following procedure has been followed, before displaying the results: first, transformation into byte format, using the same scaling procedure as SPOT VEGETATION data: DC = (NDVI + 0.1)/0.004; second, a linear contrast stretch has been applied to the data, as the range of MSG SEVIRI NDVI values is narrower than the range of SPOT- VEGETATION data (see below). The resulting value is defined by:

$$NDVI_{stretched} = 1.73 * NDVI_{byte} - 2.16$$

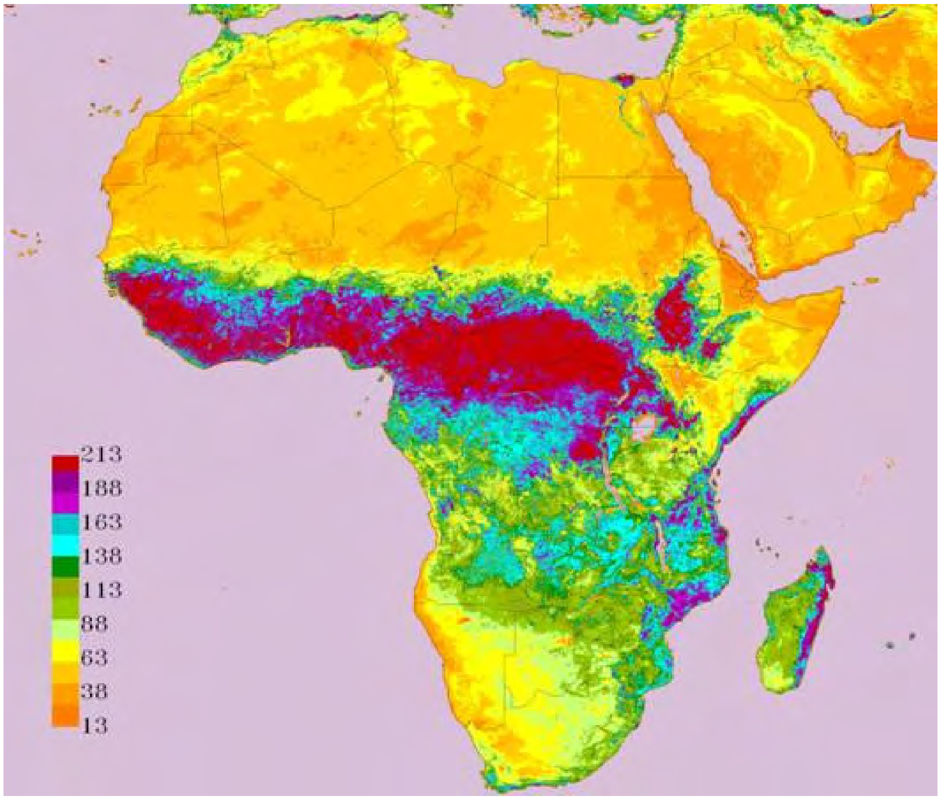

Figure 4. *Dekadal NDVI image derived from MSG-SEVIRI data (July 1-10, 2004).*

3.3 *Correlations between MSG SEVIRI and SPOT data*

Histograms of SPOT-VEGETATION NDVI and MSG SEVIRI NDVI are presented at Figure 5. Only the cloud-free part of the African continent has been considered. One can notice the wider range of values of SPOT VEGETATION data, which can be explained by the fact that atmospheric corrections have been applied, prior to compute NDVI.

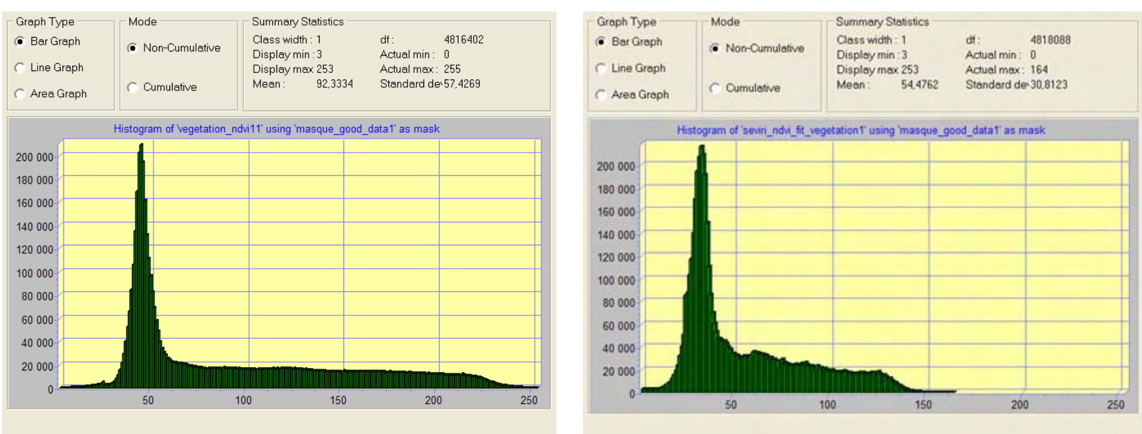

Figure 5. *Histograms of NDVI data : SPOT-VEGETATION (left) and MSG SEVIRI (right)*

Excluding cloud-contaminated pixels, the correlation between SPOT VEGETATION NDVI and MSG SEVIRI NDVI appears rather high (cf. **Figure 6**), with a correlation coefficient $r^2 = 0.87$.

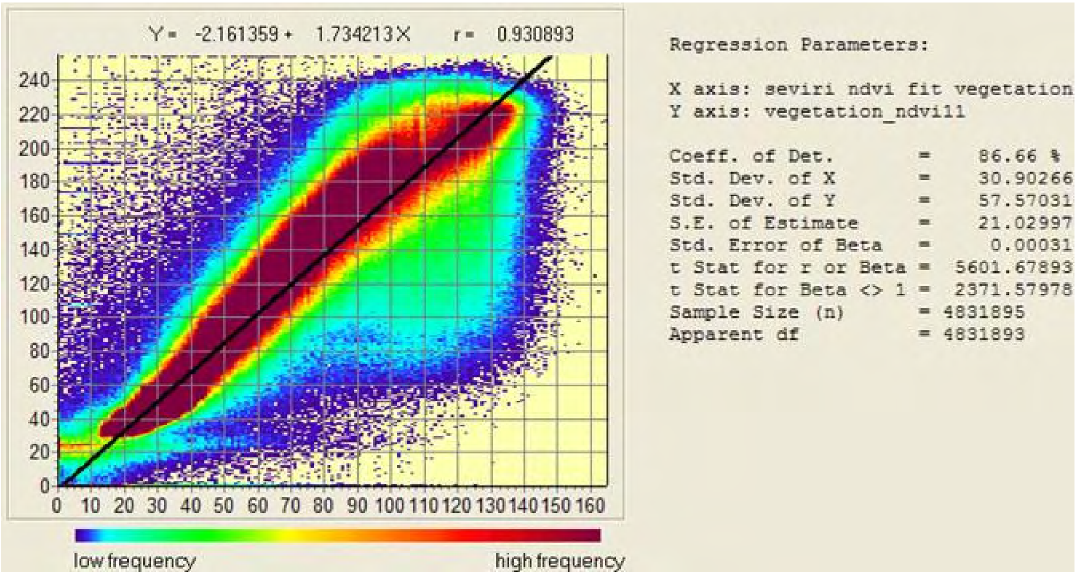

Figure 6. *Scattergram of SPOT VEGETATION NDVI (Y axis) vs MSG SEVIRI NDVI (X axis)*

Even after applying a linear stretch to MSG data, there are still noticeable differences between cloud-free SPOT VEGETATION and MSG SEVIRI derived NDVIs. This is illustrated at **Figure 7**. The main difference is the lower values of SPOT VEGETATION NDVI data in the cloud-contaminated areas (red pixels in Figure 7); but, reversely, in most areas of the Southern hemisphere, SPOT VEGETATION NDVI appears higher than MSG SEVIRI NDVI (blue pixels in Figure 7). Further investigations are needed to explain these differences, and to propose adequate atmospheric corrections of MSG SEVIRI data.

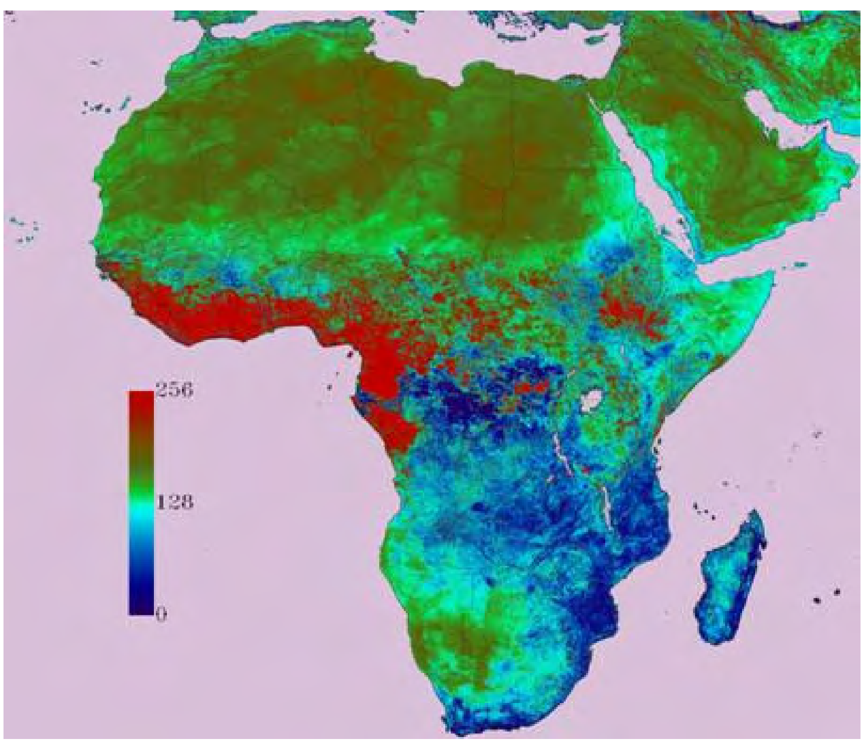

Figure 7. *Image of differences between NDVIs from MSG SEVIRI and SPOT VEGETATION (DC 128 = no difference).*

4 CONCLUSIONS AND PERSPECTIVES

Most monitoring studies and early warning procedures rely on present vegetation condition assessment with reference to some statistical values derived from historical data (KOGAN, 1998 and 2000; DePAUW, 2000). Dekadal NDVI derived from NOAA-AVHRR has been routinely used for drought early warning, in spite of coarse spatial resolution of archived data. SPOT VEGETATION provides since 1998 dekadal NDVI data at 1km resolution (VITO, 2005), and operational systems like Drought Global Watch (HEWS,2005) make use of both data sources, with 10 days or one month compositing periods.

The availability of MSG data can contribute to improve drought early warning systems, because of the following advantages:

- data are easily accessible to users, in real time through low cost receiving systems (free data for research purposes, requiring EUMETSAT agreement);
- many receiving systems have been installed in meteorological offices of developing countries through the E. U.-funded Meteorological Transition in Africa Project(PUMA, 2005), non-meteorological applications are now planned with the launch of the AMESD project : African Monitoring of the Environment for Sustainable Development (AMESD, 2005);
- procedures are now developed, based on open software (Linux) to process data and extract daily parameters like NDVI and surface temperature (MSG-ATR,2005);
- as shown in this study, dekadal syntheses of MSG SEVIRI NDVI are of better quality than those of SPOT-VEGETATION, because of improved removal of cloud-contaminated pixels;
- in most areas, it is suggested than MSG SEVIRI can provide NDVI syntheses of good quality for periods of 5 days or less;
- coarse spatial resolution (3 km) remains a limiting factor, but higher resolution is achievable through data fusion of multispectral bands with panchromatic band at 1 km resolution.

5 REFERENCES

AMESD, 2005 – African Monitoring of the Environment for Sustainable Development; cf Internet site http://www.msgafrica.net/

DePAUW E., 2000 – Drought Early Warning Systems in West Asia and North Africa. In "*Early Warning Systems for Drought Preparedness and Drought Management*"(D. A. Wilhite, M. V. K. Sivakumar & D. A. Wood Eds), Proceedings of an Expert Group Meeting held September 5-7, 2000, Lisbon, Portugal. WMO/Technical Document N° 1037, pp. 65-85. World Meteorological Organization, Geneva, Switzerland. available at Internet site http://www.drought.unl.edu/monitor/EWS/EWS_WMO.html

HEWS, 2005 – Humanitarian Early Warning Service/Drought Global Watch: Internet Site http://www.hewsweb.org/drought/

KOGAN F., 1997 - Global Drought Watch From Space. *Bulletin of the American Meteorological Society*, **78**, 4; 621-636.

KOGAN F., 2000 - Contribution of Remote Sensing to Drought Early Warning of Remote Sensing. In "*Early Warning Systems for Drought Preparedness and Drought Management*"(D. A. Wilhite, M. V. K. Sivakumar & D. A. Wood Eds), Proceedings of an Expert Group Meeting held September 5-7, 2000, Lisbon, Portugal. WMO/Technical Document N° 1037, pp. 86-100. World Meteorological Organization, Geneva, Switzerland. available at Internet site http://www.drought.unl.edu/monitor/EWS/EWS_WMO.html

MSG-ATR, 2005 - *Groupe de Recherches Météosat Seconde Génération-Analyse en Temps Réel*. cf. Internet address http://prodig.univ-paris1.fr/msg/

PUMA, 2005 – Meteorological Transition in Africa (PUMA Task Team Project). See Internet Page: http://www.oosa.unvienna.org/SAP/act2003/austria/doc5a.pdf

VITO, 2005- *Free VEGETATION products.* cf. Internet address http://free.vgt.bito.be/