# Potential of Meteosat Second Generation for the monitoring of land surface properties

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The use of meteorological satellites for non-meteorological applications is now well established; notably in the case of the land surface characterisation from AVHRR on NOAA polar orbiters (*e.g.*, Maiden and Greco 1994). This instrument was originally designed for short-term meteorological use and no on-board solar channel calibration was present. In year 2000, EUMETSAT, in collaboration with ESA, will launch a new generation of geostationary satellite, Meteosat Second Generation (MSG). MSG will have enhanced spectral capabilities with respect to the current Meteosat satellite. These enhanced characteristics open new avenues for Earth observations, in particular in relation to the documentation of large-scale diurnal variations of land surface properties. In this context, it is necessary to prepare users to take advantage of the MSG system capabilities, and to stimulate research aimed at establishing the scientific basis for the development of applications. To this end, EUMETSAT and the Joint Research Centre of the European Commission established a working group to investigate the general relevance of MSG for land applications, and research on land surface processes. This MSG Biospheric Applications Working Group (MBWG) is in a unique position to learn from past experiences, and make resulting recommendations to the MSG operators before the first satellite is ever launched. This paper summarises the technical capabilities of MSG that can be potentially exploited for biospheric applications. It also presents some early recommendations of the MBWG in relation to numerical weather prediction (NWP) and seasonal forecasting applications.

| **Channel** | **Band ($\mu$m)** | **Res.** | **# Det.** | **Dyn. Range** | **Noise** |
|---|---|---|---|---|---|
| **HRV** | **0.6 – 0.9** | **1** | **9** | **0–459 $\mathrm{Wm^{-2}sr^{-1}\mu m}$** | **SNR>4.3 @ 1%MDR** |
| **VIS0.6** | **0.56 – 0.71** | **3** | **3** | **0–533 $\mathrm{Wm^{-2}sr^{-1}\mu m}$** | **SNR>10.1 @ 1%MDR** |
| **VIS0.8** | **0.74 – 0.88** | **3** | **3** | **0–357 $\mathrm{Wm^{-2}sr^{-1}\mu m}$** | **SNR>7.28 @ 1%MDR** |
| **IR1.6** | **1.50 – 1.78** | **3** | **3** | **0–75 $\mathrm{Wm^{-2}sr^{-1}\mu m}$** | **SNR>3 @ 1%MDR** |
| **IR3.8** | **3.48 – 4.36** | **3** | **3** | **0–335 K** | **0.35 K@ 300 K** |
| IR6.2 | 5.35 – 7.15 | 3 | 3 | 0–300 K | 0.75 K @ 250 K |
| IR7.3 | 6.85 – 7.85 | 3 | 3 | 0–300 K | 0.75 K @ 250 K |
| **IR8.7** | **8.30 – 9.10** | **3** | **3** | **0–300 K** | **0.28 K @ 300 K** |
| IR9.7 | 9.38 – 9.94 | 3 | 3 | 0–310 K | 1.5 K @ 255 K |
| **IR10.8** | **9.80 – 11.80** | **3** | **3** | **0–335 K** | **0.25 K @ 300 K** |
| **IR12.0** | **11.00 – 13.00** | **3** | **3** | **0–335 K** | **0.37 K @ 300 K** |
| IR13.4 | 12.40 – 14.40 | 3 | 3 | 0–300 K | 1.8 K @ 270 K |

Table 1: The SEVIRI spectral channel characteristics. **Res.** is the sub-satellite sampling distance in km. **# Det.** is the number of detectors per channel. **MDR** is the Maximum Dynamic Range. **SNR** is for Signal to Noise Ratio.

SEVIRI (Spinning Enhanced Visible and Infrared Imager) is the main radiometer on the MSG spacecraft. The 12 SEVIRI channels distributed throughout the short and long wave parts of the electro-magnetic spectrum, and the frequent repeat cycle of 15 minutes will provide the basis for improved and new products that will be used for applications such as in NWP and climate monitoring. The launch of the first MSG satellite is planned in 2000. The sampling resolution at the sub-satellite point is 3×3 km up to 1×1 km for the VIS high resolution band. SEVIRI spectral band characteristics are given in Table (1). Most of biospheric applications will require information at the pixel resolution instead of the synoptic scale. Due to the nature of the scanning mechanism and the curvature of the Earth, the sub-satellite point sampling distance increases as the satellite viewing angles increase (Figure 1).

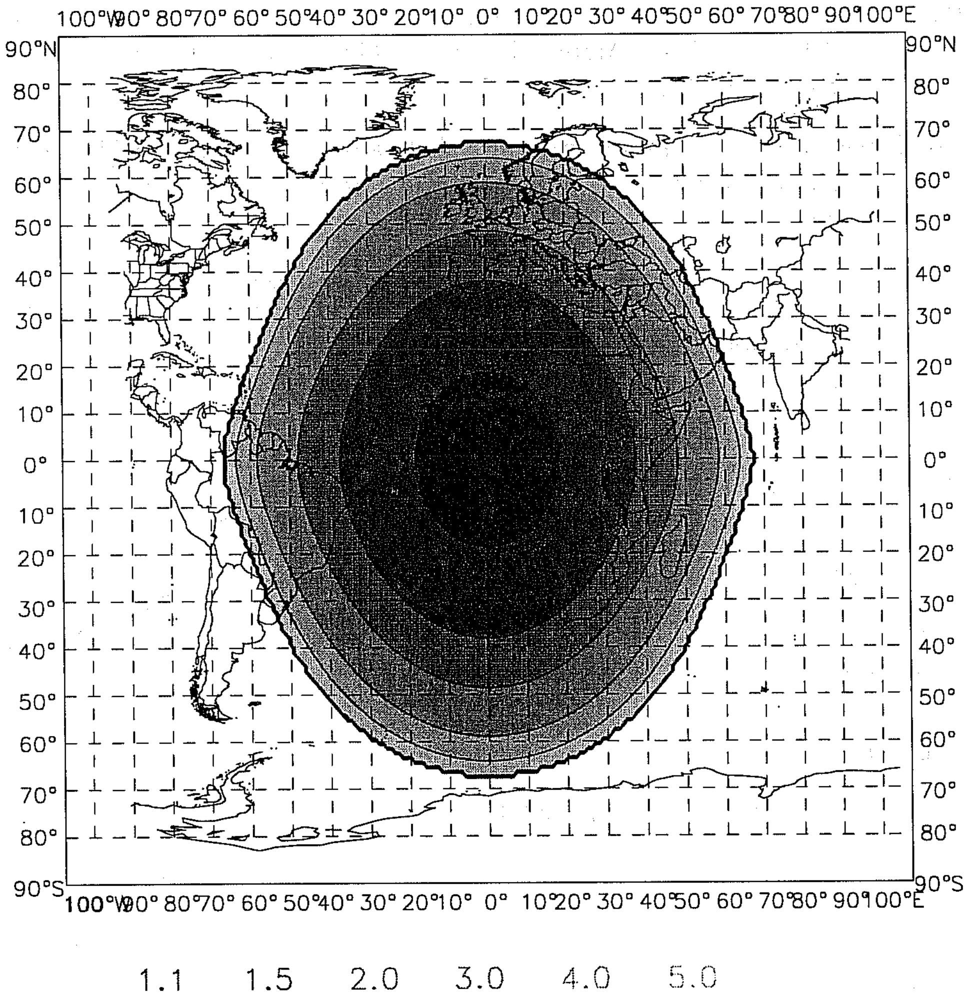

Figure 1: MSG ground resolution. The isolines represent the pixel area normalised by the sub-satellite pixel area. The result is shown in an equidistant cylindrical projection.

The radiometric pre-processing of the images from level 1.0, *i.e.*, raw images, up to level 1.5, *i.e.*, calibrated and geo-located images will be performed by the MSG-IMPF (Image Processing Facility). An on-board black body calibration mechanism coupled with the simulation of the front optics contribution should ensure an absolute calibration of the infrared channels in the order of 1K. The calibration of the solar channels will rely on vicarious methods based on the monitoring of bright desert targets. The relative accuracy of the derived calibration coefficients is expected to be in the range of 5 to 10%. MSG images will be geo-located with an absolute accuracy of 1 pixel and a relative one (from image to image) less than 0.5 pixel RMS. Ground control points will be used to monitor the quality of the geo-location process.

The MSG-MPEF (Meteorological Products Extraction Facility) will generate real-time meteorological products from MSG observations (EUMETSAT 1998). These products will be available at the synoptic scale on a three-hourly basis. The MSG-MPEF is a fully automated processing chain that relies extensively on quality control mechanisms for all the different processing steps. These products will be used for nowcasting and NWP. This facility will also support the calibration of the IR channels with a real-time vicarious calibration method. In addition, MSG-MPEF will derive a cloud mask over land surfaces at the pixel resolution for every image. This mask will contain an indication on the confidence level of cloud detection for cloudy pixels.

The synoptic meteorological products and associated quality control values will be disseminated in near real-time via the WMO GTS (Global Telecommunication System). Level 1.5 images will be available in real-time via the HRIT/LRIT dissemination service. These data can be received with an High Rate or Low Rate User Station. Level 1.5 data and the meteorological products will be archived in the U-MARF (Unified- Meteorological Archiving and Retrieval Facility) and available on request for scientific purposes.

The MBWG recognises a number of variables that can be assessed with MSG for different types of applications. Early conclusions that are of relevant interest for NWP and seasonal forecasts are summarised hereafter.

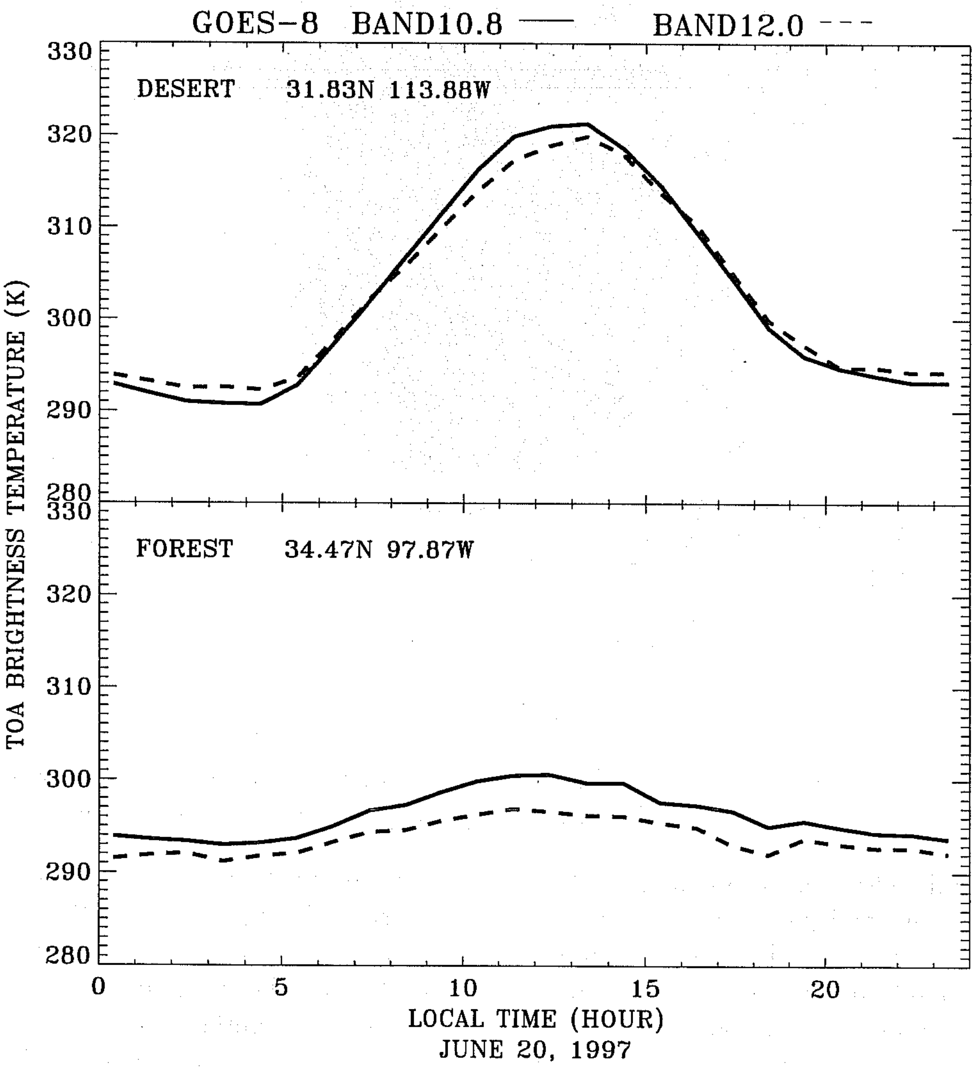

Figure 2: Diurnal variations of the top of atmosphere brightness temperature observed by GOES-8 over desert and forest areas under clear sky condition. The images were taken on June 20, 1997 between 0:15 UTC and 23:15 UTC (*i.e.*, between 18:15 (June 19) and 17:15 (June 20) local time at sub-satellite point).

As already demonstrated with the NOAA-AVHRR instrument, land surface temperature can be derived on an operational basis using a split window approach with an accuracy of 2 to 3 K (*e.g.*, Vogt 1996). The lack of information on the surface emissivity spectral, temporal and spatial variations represent a limitation to this approach. Assimilation of sounding data over land surfaces in NWP models could however benefits from this accuracy range. The frequent image repeat cycle offers indeed a unique opportunity to document diurnal variations in four window, *i.e.*, 3.8, 8.7, 10.8 and 12.0 $\mu$m as a function of space and time. An illustrative example of the MSG capability to monitor diurnal variations in the thermal infrared spectral region is given in Figure (2). It is based on GOES-8 imager clear sky observations over desert and forest areas. In turn, the amplitude of the surface temperature diurnal variations can be exploited to infer qualitative information on the soil moisture. These variations will however be highly affected by the presence of vegetation as can be seen from Figure (2).

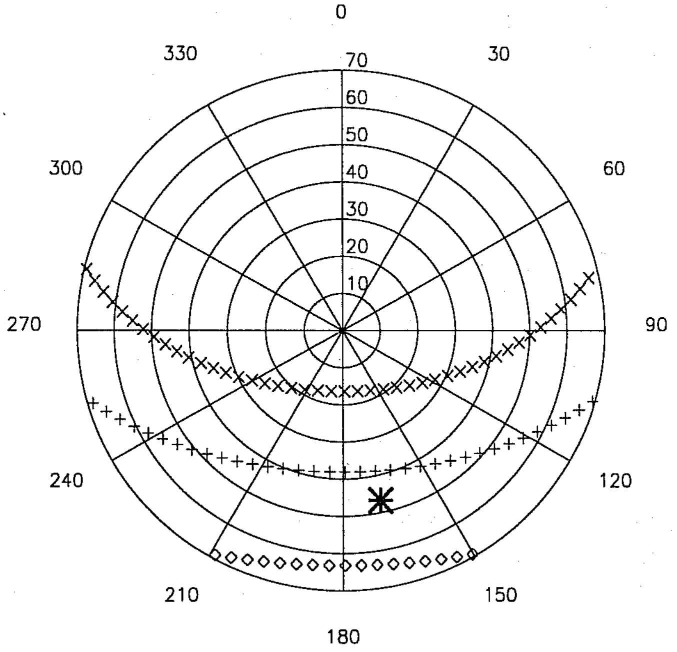

Figure 3: Polar plot of the MSG illumination and viewing geometry for a pixel located in South Europe. The radius and polar angle represent respectively the zenith and azimuth angles. The viewing geometry with respect to the pixel normal is given by the $*$ symbol. Sun zenith angles are given by the $+$ symbol for typical spring observations, $\times$ for summer ones and the $\diamond$ symbol for winter observations.

Thanks to observations in the red and near-infrared spectral regions, MSG will offer the capability to document the amount of vegetation at the same spatial and temporal scale. Indeed, SEVIRI spectral characteristics similar to AVHRR have already prompted scientists to investigate the potential of MSG for large-scale biospheric applications. Most of the AVHRR-based applications rely however on the statistical exploitation of spectral information and data compositing, essentially due to the under-sampling of the illumination and observation angular effects. Conversely, a pixel is always observed with the same viewing angle but different Sun angles with a geostationary orbiting satellite. The MSG capabilities to observe bi-directional reflectances during one day are illustrated on Figure (3). In this example, the geometry of observation and illumination corresponding to a pixel located in South Europe is given for three different illumination conditions: winter, spring and summer. As can be seen, more than 40 observations with different illumination conditions will be available during day time in summer. Consequently, the effects of surface anisotropy on the observed radiances can be properly sampled. Quantitative biospheric applications will therefore require dedicated algorithms that can take advantage of both the frequent observation capabilities and the spectral characteristics of MSG.

New approaches have indeed been developed to exploit directional observations that will be generated by advanced sensors such as MISR on EOS-AM and POLDER on ADEOS. The most promising algorithms will clearly be those that treat the coupled surface-atmosphere problem jointly. Fast surface-atmosphere radiative transfer codes are currently being developed for that purposes. Over dark surfaces, such approaches should also permit the estimation of the aerosol optical thickness. Over bright surfaces, it may be worthwhile to exploit the cooling effect of aerosols in the thermal infrared during day time (*e.g.*, Moulin et al. 1997). The surface bi-directional reflectance and the characterisation of the aerosols can be used in conjunction to a pixel-based cloud information to assess the daily variation of the short-wave downward radiation, a variable that controls the net radiation budget at the surface and therefore the soil moisture and evapotranspiration processes.

When MSG is launched, the number of available land products derived from advanced sensors will be much higher than currently. Hence, the use of MSG for land surface characterisation will have to find an original niche in these new remote sensing missions dedicated to biospheric observations. The original contribution of MSG for NWP and seasonal forecasts results obviously in the frequent image acquisition capabilities over the same area in 8 channels that can "see" the surface.

## References

EUMETSAT (1998). Msg ground segment: Meteorological products extraction facility algorithm specification document. Technical Report EUM/MSG/SPE/022, EUMETSAT.

Maiden, M. E. and S. Greco (1994). NASA's pathfinder data set programme: land surface parameters. *International Journal of Remote Sensing 15*, 1675–1685.

Moulin, C., C. E. Lambert, F. Dulac, and U. Dayan (1997). Control of atmospheric export of dust from North Africa by the North Atlantic Oscillation. *Nature 387*, 691–694.

Vogt, J. V. (1996). Land surface temperature retrieval from noaa avhrr data. In D'Souza, G. and Belward, A. and Malingreau, J.-P. (Ed.), *Advances in the Use of AVHRR Data for land Applications*, pp. 125–151. Dordrecht, Boston, London: Kluwer Academic Publishers.