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GEOSTATIONARY PROJECTION GRIDS FOR THREE GENERATIONS OF METEOSAT

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Abstract

The METEOSAT series of satellites has served the meteorological community for more than 40 years. With the launch of the first MTG satellite in 2021, the third generation of METEOSAT satellites will enter operations. The METEOSAT mission data is rectified (projected and resampled to a defined grid). The grids are not same between METEOSAT satellites of the first, second, and third generation.

For each of the grids, EUMETSAT recommends an algorithm to relate pixel positions to geographic latitude and longitude as well vice versa. This paper provides a comparison of the various grids used and allows the user to choose the correct interpretation of the level 1 image data.

LEVEL 1 DATA GRIDS USED

Geostationary spacecraft are not precisely stationary. They are subject to natural drift, caused by radiation pressure, Sun and Moon gravitational forces etc. Also, the orientation in space is not perfectly stable, and thus, a correction of the raw image data is necessary. The raw METEOSAT radiometer data are processed on ground before they are made available to users. In the processing, the data is rectified to a fixed grid, independently of the small position and attitude variations of the spacecraft. This grid, the normalized geostationary projection, describes the view from a virtual point to an idealized Earth. The view-point is perfectly located in the Equator plane at the given notional longitude, λ (=longitude of the projection centre). The distance between viewpoint and centre of Earth is given by the geostationary radius and the idealized Earth is described by the Earth's reference ellipsoid. This projection defines the line of sight of each pixel as a vector representing the view from a virtual point in geostationary orbit. This vector could be expressed as a function of two angles, elevation and azimuth.

Each pixel of the normalized geostationary projection, describes then the radiance in an elevation and azimuth interval. The angular stepwidth between two adjacent pixels can then be expressed in the corresponding projected distance on Earth at the projection centre: spatial sampling distance, SSD in units of km.

Elevation and azimuth are typically not express in degrees or radians, but in pixel position, following a convention for numbering of the pixels. In order to locate the image data, all these conventions need to be precisely communicated. Unfortunately, during the last decades these conventions changed. In the

following, the conventions used for METEOSAT image data, are recalled together with the parameters needed:

- Size of the grid
- Pixel numbering scheme
- Sampling distance
- Origin of the grid

For the calculation of pixel geographical location, the following information is essential:

- Earth ellipsoid radii
- view-point distance

The view point longitude is more variable, as METEOSAT spacecraft have supported and still support various missions. Some typical longitudes are:

0.0° 0-Degree Full Disk Service
9.5° E Rapid Scan Service
41.5° E Indian Ocean Data Coverage

METEOSAT FIRST GENERATION

In 1977, the first satellite of the METEOSAT series was launched. The METEOSAT first generation (MFG) spacecraft provided images of the full disc of the Earth every half hour from geostationary orbit. In rapid scan configuration, images covering the northern third of the Earth were scanned every five minutes. In 2017, the last satellite of the first generation spacecraft, METEOSAT-7, was decommissioned while the mission has been taken over by the second generation spacecraft.

The instrument of the First Generation METEOSAT spacecraft, MVIRI (Meteosat Visible and Infrared Imager) consists of a 3-band radiometer, providing simultaneous image generation in the thermal infrared region (TIR), in the water vapour absorption bands (WV), and in the visible range (VIS). The visible channels are of higher spatial resolution (2.25 SSD) than the low resolution IR and WV channels (4.5 km SSD – Figure 1).

The following list summarises the characteristics for the two grids for MVIRI rectified products:

- Characteristics
    - High resolution grid 5000 x 5000 pixels, low resolution 2500 x 2500, covering 18.0 deg. wide area
    - High resolution grid (VIS) spacing defined as (18.0 deg. full FOV / 5000 pix) - ca. 2.25 km SSP
    - Low resolution grid (IR & WV) spacing defined as (18.0 deg. full FOV / 2500 pix) - ca. 4.5 km SSP
    - Rectification point on the corner between 4 pixels – high and low resolution grids cover the same space
    - Origin (1,1) in the South East
- Projection
    - Equatorial radius of the Earth = 6378.140 km
    - Polar radius of the Earth = 6356.755 km
    - Earth-centre view-point distance = 42164.0 km

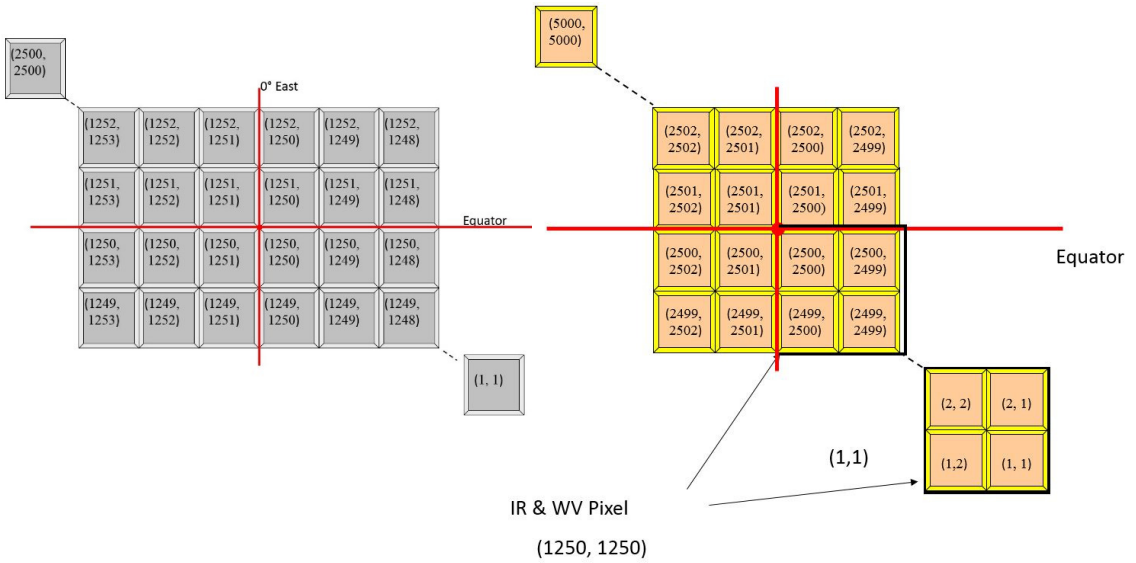

Figure 1: METEOSAT First Generation MVIRI rectified images. Left: low resolution grid for IR and WV images (4.5 km SSD), right: high resolution grid for VIS image (2.25 km SSD).

METEOSAT SECOND GENERATION

The METEOSAT Second Generation (MSG) is the currently operated fleet of geostationary satellites. METEOSAT-11 is the prime operational geostationary satellite, positioned at 0 degrees and providing 0-Degree Full Disk Service every 15 minutes. METEOSAT-10 provides the Rapid Scanning Service, delivering more frequent images every five minutes over parts of Europe, Africa and adjacent seas. METEOSAT-9 provides a backup service to Meteosat-11 Full Earth scanning and a gap filling service to Meteosat-10 Rapid Scanning. METEOSAT-8 operates over the Indian Ocean performing Full Earth scanning. The Spinning Enhanced Visible and InfraRed Imager (SEVIRI) observes the Earth with improved performance compared to the first METEOSAT generation. The design incorporates many new features, including eleven spectral channels ranging from the visible (0.6 µm) to the far infrared part (13.4µm) of the spectrum with a spatial low resolution SSD of 3 km. Moreover, a High Resolution Visible (HRV) channel provides images in the visible spectrum (around 0.75µm) with an SSD of 1 km. Due to the relatively large number of data necessary for HRV, each HRV scan line covers only half of the Earth disk in East-West direction. Which part of the disk is included in HRV is flexible und chosen according to the needs of the mission and the available daylight.

The rectified data is available in the MSG SEVIRI Level 1.5 format. The definition of the grid (Figure 2) is different to the one of MFG. The MSG high and low resolution grids are aligned over the South-East corner pixel, with the centre of the pixel. As a consequence, the areas covered by the two grids are not exactly the same – see Figure 2.

The following list summarises the characteristics for the two grids for MSG SEVIRI Level 1 5 products:

- Characteristics
  - High resolution grid 11136 x 11136 pixels, low resolution 3712x 3712.
  - High resolution grid (HRV) spacing defined as (2^{16} / 2344944937) rad. - 1.00013 km SSP
  - Low resolution grid (non-HRV) spacing defined as (2^{16} / 781648343) rad. - 3.0004 km SSP
  - Rectification point on centre of pixel – High and low resolution grids do NOT cover the same space
  - Origin (1,1) in the South East
- Projection
  - Equatorial radius of the Earth = 6378.1690 km
  - Polar radius of the Earth = 6356.5838 km
  - Earth-centre view-point distance = 42164.000 km

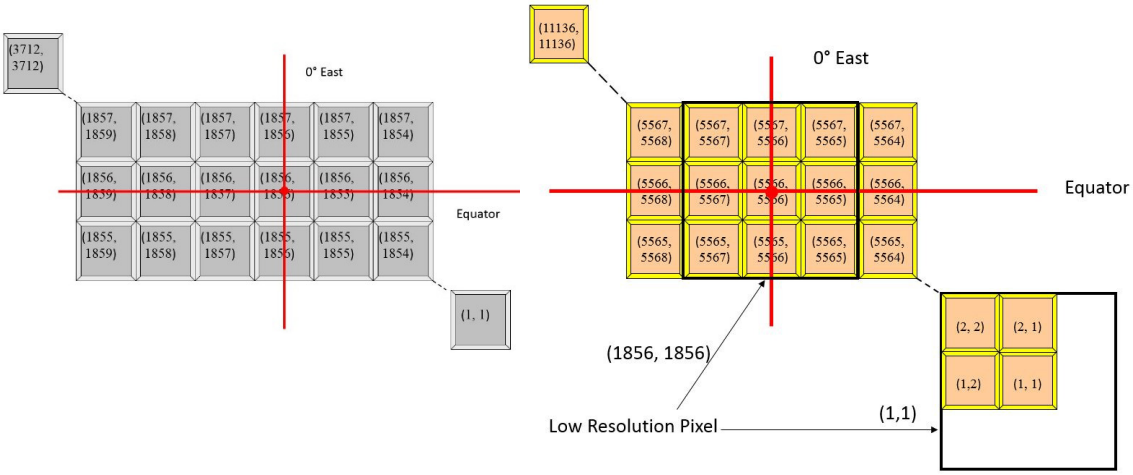

Figure 2: METEOSAT Second Generation SEVIRI level 1.5 images. Left: low resolution grid (3km SSD), right: high resolution grid for HRV images (1km SSD).

METEOSAT THIRD GENERATION

This next generation, following on from METEOSAT Second Generation, will provide an evolution of the imaging service. MTG will see the launch of six new geostationary (imaging and sounding) satellites from 2021 onwards. The satellite series will be based on 3-axis platforms and comprise:

- Four Imaging Satellites (MTG-I) (20 years of operational services expected)
- Two Sounding Satellites (MTG-S) (15.5 years of operational services expected)

Three in-orbit satellites deliver a prime MTG-I full disc service, a second MTG-I satellite for the Rapid Scanning Service, and an MTG-S satellite providing the new sounding services.

The Flexible Combined Imager FCI provides 16 spectral channels of image data, with a basic full disc repeat cycle of 10 minutes, and a European regional rapid scan, which covers quarter of the full disk, with a repeat cycle of 2.5 mins. FCI Level 1C data will provide imaging information in three principal resolutions, 2 km, 1 km and 500 m. Accordingly there are three grids. In contrast to MSG Level 1.5, all these grids are aligned, so that the cover the same area (Figure 3). Similar to the first generation METEOSAT, the view point is on the corner between 4 pixels. However, the origin for counting pixels is the South-West corner of the image, which is different to both, METEOSAT first and second generation products.

The following list summarises the characteristics for the 3 grids for MTG FCI Level 1 C products:

- Characteristics
  - 3 different grids: 22272 x 22272, 11136 x 11136, 5568 x 5568
  - Grid spacing defined as SSD := 0.500 km, 1.000 km, 2.000 km at SSP, resp.
  - Rectification point on the corner between 4 pixels – high and low resolution grids cover the same space
  - Origin (1,1) in the South West (!)
- Projection (WGS 84 ellipsoid)
  - Equatorial radius of the Earth = 6378.137 km
  - Earth flattening f=(r_eq-r_pol)/r_eq = 1 / 298.257223563
  - Altitude of view point = 35786.400 km

  Hence:
  - Polar radius of the Earth = ca. 6356.752 km
  - Earth-centre view-point distance = ca. 42164.537 km

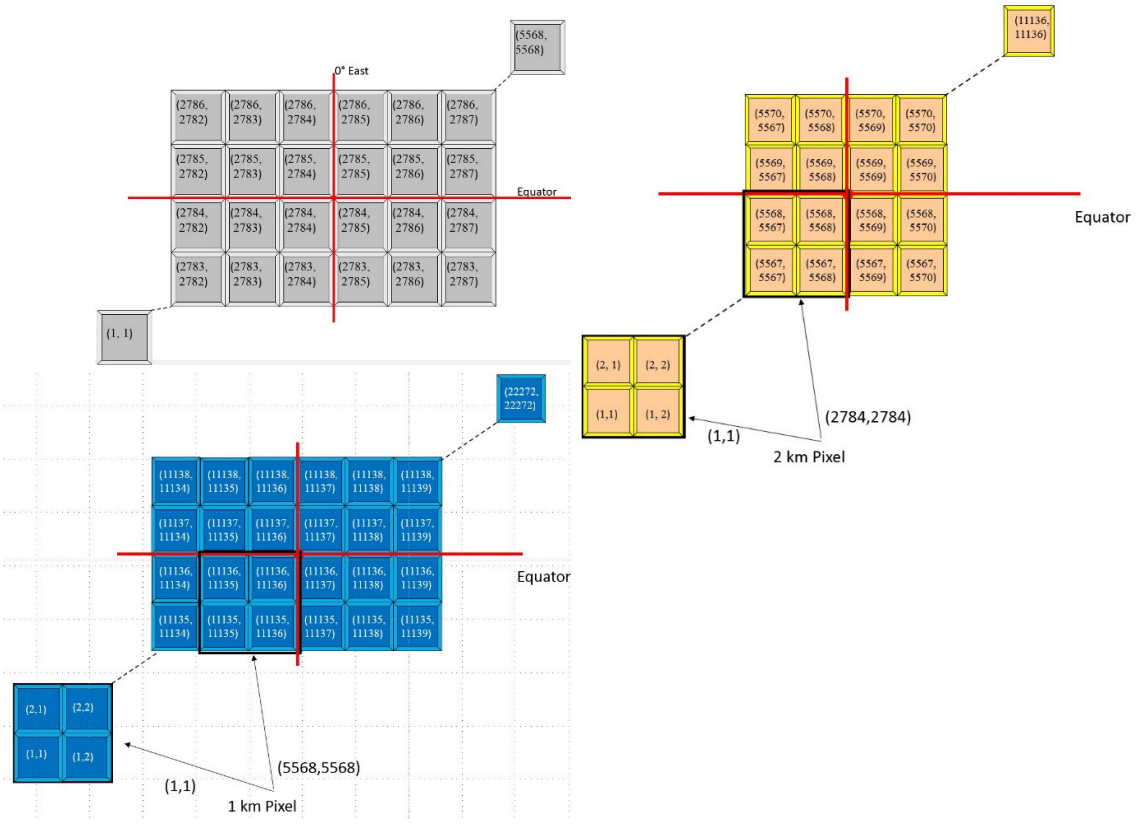

Figure 3: METEOSAT Third Generation FCI level 1c images. Top left: low resolution grid for 2 km SSD, top right: 1 km SSD grid, bottom left: high resolution grid for 0.5 km SSD.

SUMMARY AND CONCLUSION

For the use of data of the different METEOSAT generations, it is important to consider the different grid definitions. For MSG, a long time rectification error resulting in shift of the image of 0.5 low resolution pixel has led to some additional confusion as such an error can lead to misinterpretations of the underlying grid. The problem was corrected for in December 2017. For the three generation METEOSAT level 1 grid definitions, users are advised to refer to the following documents, all available from the EUMETSAT website.

REFERENCES

MFG: “TD06”, METEOSAT First Generation User Handbook, EUM/OPS/USR/10/1537, v1A, 2 May 2011;

MSG: “MSI”, MSG Ground Segment LRIT HRIT Mission Specific Implementation, EUM/MSG/SPE/057,V7, 30 November 2015 “CGMS”, LRIT/HRIT Global Specification, GCMS 03, **Issue 2.6, 9 July 1999;**

MTG: “FCIL1DUG”, FCI L1 Dataset User Guide, EUM/MTG/USR/13/719113; V TBD, date TBD. For MTG, the programme is still in preparation and the documentation is subject to updates. Please refer to the EUMETSAT website.