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WORKSHOP ON REMOTE SENSING TECHNIQUES WITH APPLICATIONS TO AGRICULTURE, WATER AND WEATHER RESOURCES

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EVALUATION OF THE GEOSTATIONARY SATELLITE IMAGES GROUND RESOLUTION

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ABSTRACT

A computing method which allows the evaluation of the ground resolution behaviour in the images transmitted by the METEOSAT-2 geostationary satellite is described.
The image ground resolution, which decreases from subsatellite point as a function of the satellite-observed point angular distance, is determined taking into account the Earth's flattening factor.
Ground resolution quantitative data concerning a location-Points geographical grid, obtained by using the described procedure superimposed on a METEOSAT-2 typical image, are reported.
Moreover a nomogram obtained by assuming a spherical Earth, which allows rapid determination of the ground resolution, is reported.

Keywords: Remote Sensing, Geostationary Satellite, Image, Ground Resolution.

1. INTRODUCTION

In this paper a method is presented to compute the ground resolution as a function of the geographical observed points in the METEOSAT-2 satellite images (Ref. 1).
As it is well known, the main mission of the Meteosat-2 satellite is to provide multispectral images of the full earth's disk, visible from the geostationary orbit (Ref. 2).
The obtained images of the Earth can be subdivided in two classes, according to their ground resolution:
--High Resolution: (VIS) 5000 lines by 5000 pixels per line, with a spatial resolution of 2.5 km. at the subsatellite point.
--Low Resolution: (IR-WV) 2500 lines by 2500 pixels per line, with a spatial resolution of 5 km.
The images remotely obtained by the on-board radiometer are transmitted to ground, after a processing (which takes into account both attitude and satellite motion), are disseminated by using the satellite itself as a relay.
Satellite images represent the earth curved surface in a plane, hence they are map projections.
In computing the ground resolution as a function of the geographical coordinates of the observed point, the curved reference surface assumed for the Earth is an ellipsoid or a sphere.
The tranformation from the reference surface to the projection surface is defined by a set of mathematical equations describing the relationship between Latitude (ϕ) and Longitude (λ) in the reference surface and the coordinates (x,y) in the projection plane.
Any projection of a curved surface onto a plane involves distortions of distances and areas.
The contact point where the plane of projection is tangent to the reference surface (subsatellite point $Ss(\lambda_S,\phi_S)$), is the center of an area of minimum distortion; on the contrary at the edges of image the distortion is maximum.
If we consider the line of image that lies on the equator, at the subsatellite point, the field of view of a pixel is a square area, on the earth surface, 2.5 km of side (for visible channel); at the edge of considered line the pixel field of view is a trapezoidal area about 80 time longer.

2. GROUND RESOLUTION

In computing the ground resolution we assume the ellipsoid as reference surface for the Earth; in Fig. 1 the satellite-earth geometry is outlined.
From the triangle $A\Theta\alpha$:

$$\tan A = (R_e+h)\sin\Theta \;/\; (R(\phi)-(R_e+h)\cos\Theta) \qquad (1)$$

where: R_e = 6378.140 km Earth's equatorial radius;
h = 35786.032 km satellite height;
Θ = central angle.

The Earth's radius as a function of geodetic(geographical) latitude is given by:

$$R(\phi) = R_e\left(1-\frac{f}{2}+\frac{f}{2}\cos 2\phi\right)+h_o \qquad (2)$$

where: f = 1/298.257 Earth's flattening;
h_o = altitude in km of the observed point (λ,ϕ) with respect to the ellipsoid.

The relationship between geodetic latitude Φ and geocentric latitude ϕ' (spherical) is given by:

$$\tan\phi' = (1-f)^2\tan\phi \qquad (3)$$

From Fig. 1 it is also:

$$A = 90^o + e \qquad (4)$$

$$\theta+\alpha + e = 90^{o} \quad (5)$$

where: "e" is the satellite elevation angle above the local horizon and α is the nadir angle.

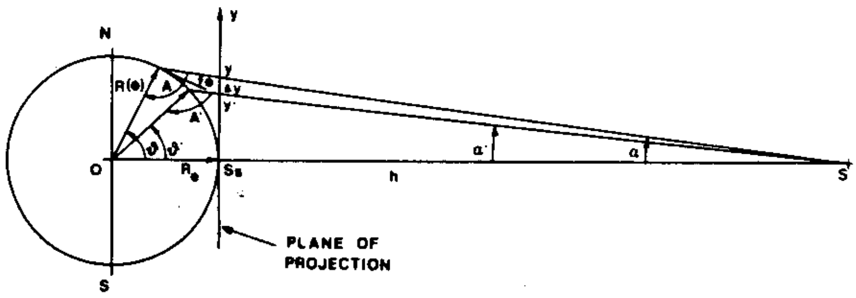

Fig. 1 Satellite-Earth geometry; cross-section on the satellite longitude-meridian.

The maximum angular distance θ that can be observed from geostationary orbit on the satellite longitude meridian (North and South satellite horizon bounds) results to be:

$$\theta = 81.328^{o}$$

corresponding to $\phi = 81.385^{o}$

with $e = 0^{o}$ and $\alpha = 8.672^{o}$

On the equator (West and East satellite horizon bounds) θ results (Ref. 3):

$$\theta = 81.300^{o} = \Delta\lambda$$

with:

$$\Delta\lambda = |\lambda - \lambda_s|$$

$$e = 0^{o} \ ; \ \alpha = 8.700^{o}$$

From the equation (3) it results that, if in computing the ground resolution the reference surface assumed for the Earth is a sphere, the error in the pixel location determination results to be maximum for pixels placed at middle latitude and it is of the order of ~ 0.2 degrees in the central angle θ (corresponding to a distance of 22 km on the Earth surface or about 6 pixels in the high resolution images).
As above reported the high resolution image consists of 5000 lines with 5000 pixels per line. The observable full Earth disk from the geostationary height (North-South direction), corresponds to an angle of:

$$2\alpha_{max} = 17.344^{o}$$

while the scanning in the South-North direction of the radiometer on-board the satellite is:

$$1.25 \cdot 10^{-4} \text{ rad.}$$

for each satellite rotation; so the number of informative lines for the full earth disk image is:

$$(2\alpha_{max} / 1.25 \cdot 10^{-4} \text{ rad.}) = 2422 \text{ lines per channel}$$

which corresponds to 4844 lines for the two visible channels. Likewise the maximum number of informative pixels which are contained in one line (equatorial line) is:

$$(2\alpha_{max} / 1.25 \cdot 10^{-4} \text{ rad.}) = 2430 \text{ pixels}$$

where:

$$2\alpha_{max} = 17.4^{o}$$

with reference to the geometry of Fig. 1, we can now determine the pixel size onto the projection plane:

$$\Delta y = \overline{Ss\ y} / 2422 = 2.253 \text{ km} \quad (6)$$

with:

$$\overline{Ss\ y} = h \tan \alpha_{max} \quad (7)$$

The ground spatial resolution as a function of the latitude along the meridian of the subsatellite point, is obtained by computing $\overline{Ss\ y}$ segment lenght corresponding to one latitude value and $\overline{Ss\ y'}$ lenght relative to the first line below:

$$\overline{Ss\ y'} = \overline{Ss\ y} - \Delta y \quad (8)$$

It follows:

$$\tan \alpha' = \overline{Ss\ y'} / h \quad (9)$$

$$\sin A' = (R_e+h) \sin \alpha' / R(\phi) \quad (10)$$

$$\theta' = 180^{o} - (\alpha' + A') \quad (11)$$

Consequently, the earth resolution at the considered latitude is:

$$(\theta - \theta') = (\widehat{\theta - \theta'}) \frac{\pi}{180^{o}} R(\phi) \text{ (km)} \quad (12)$$

and represents the lenght of the trapezoidal area onto the earth surface corresponding to the fiels of view of each pixel.
The same ground resolution evaluation method can be used for all points (λ,ϕ) of the Earth surface

within the satellite horizon area; i.e. those points with an angular distance Θ with respect to the subsatellite point Ss lower than 81.328°. The angular distance between the subsatellite point $Ss(\lambda_s, \phi_s)$ and the observed point (λ, ϕ), is given by:

$$\cos \Theta = (\cos \Delta\lambda \cos \Delta\phi') \qquad (13)$$

where:

$$\Delta\lambda = | \lambda - \lambda_s | \leq 81.328°$$

$$\Delta\phi' = | \phi' - \phi_s | \leq 81.328°$$

In the hypothesis of spherical shape of the Earth, the ground resolution behaviour is the same along all the great circle arcs crossing the subsatellite point (where it has the best value of 2.5 km for the high resolution images).
Fig. 2 shows the variation of the ground resolution along the great circle arc (spherical Earth) in the high resolution images.
In particular the instantaneous field of view variability of pixels on the equatorial scan-line is reported.
As it can be seen in Fig. 2, the spatial resolution at the subsatellite point is 2.25 km, which agrees with the 2.5 km characteristic value of the high resolution images and with the sensor angle of view on board the satellite, which is 2.326 km in the visible band (Ref. 1).
The table 1 gives a complete description of the ground resolution variability within a quadrant of the Earth disk image.
Fig. 3, at last, shows both the ground resolution computed values and a geographical grid reference superimposed on a METEOSAT-2 satellite visible band image.

3. CONCLUSIONS

The proposed method and the results reported

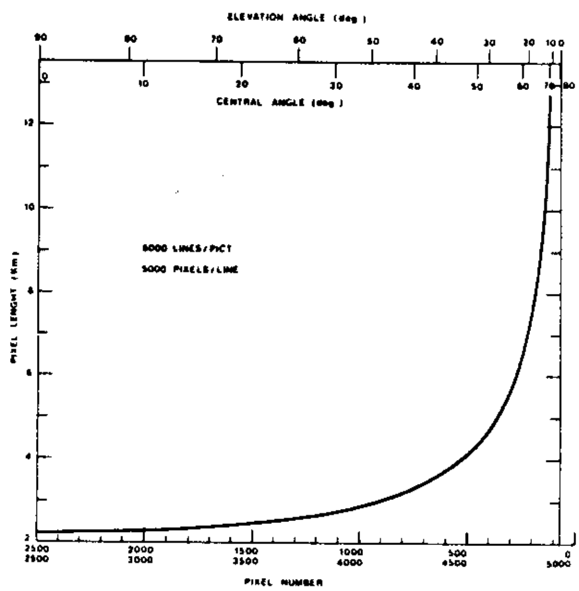

Fig. 2 Instantaneous field of view variability of pixels on equator scanline (or great circle arc for spherical Earth).

enable the user to know accurately the real ground spatial resolution of each pixel within a Meteosat image or, in general, within any image from geostationary satellite, when each pixel has been correlated with ground geographical coordinate.
This evaluation is very important in all those cases in which it is useful to compare and correlate the information of images transmitted from different satellites to produce final user "integrated thematic maps".

Table 1

Ground resolution variability

METEOSAT GROUND RESOLUTION (KM)

LATITUDE \ LONGITUDE (DEG.)	0.0	8.0	16.0	24.0	32.0	40.0	48.0	56.0	64.0	72.0	80.0
80.0	82.64	86.63	100.5	131.8							
72.0	14.96	15.26	16.22	18.07	21.38	27.57	41.22	84.86			
64.0	7.97	8.10	8.51	9.28	10.57	12.74	16.68	25.23	53.76		
56.0	5.41	5.49	5.75	6.23	7.02	8.29	10.46	14.66	25.29	85.74	
48.0	4.12	4.18	4.37	4.72	5.30	6.21	7.72	10.48	16.75	41.66	
40.0	3.36	3.41	3.57	3.85	4.31	5.04	6.22	8.32	12.81	27.89	
32.0	2.89	2.93	3.06	3.31	3.78	4.32	5.31	7.05	10.65	21.65	
24.0	2.58	2.62	2.74	2.96	3.31	3.86	4.74	6.27	9.36	18.32	137.8
16.0	2.39	2.43	2.54	2.74	3.07	3.58	4.39	5.79	8.59	16.45	105.3
8.0	2.29	2.32	2.43	2.63	2.94	3.42	4.20	5.53	8.18	15.48	90.67
0.0	2.26	2.29	2.39	2.59	2.90	3.38	4.14	5.45	8.05	15.18	86.48
	0.0	8.0	16.0	24.0	32.0	40.0	48.0	56.0	64.0	72.0	80.0

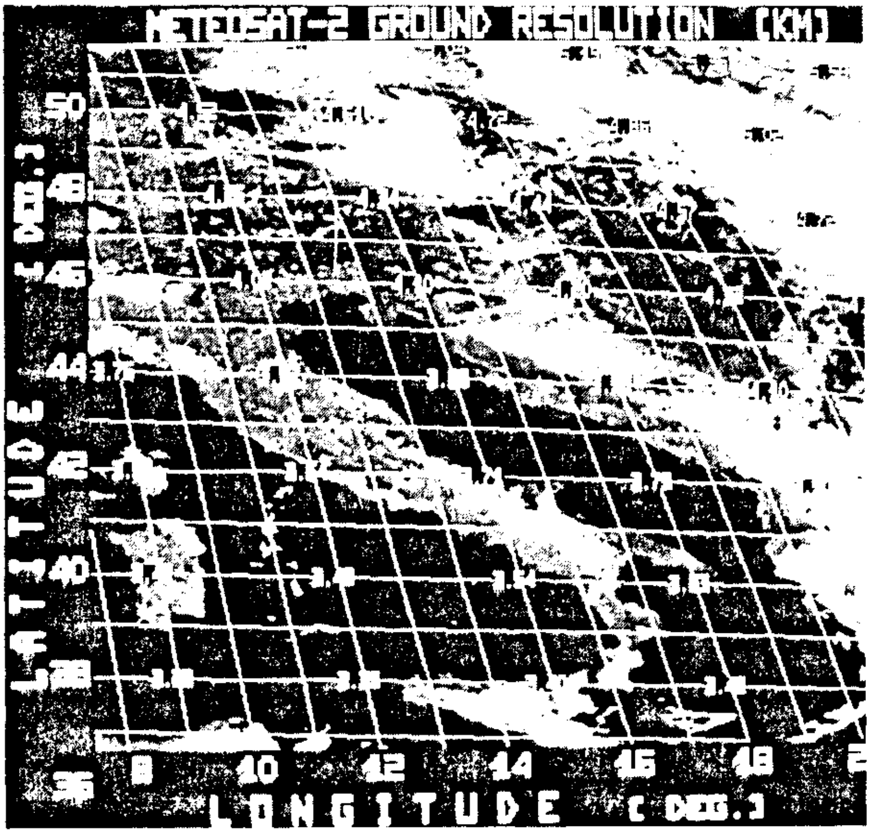

Fig. 3 Example of ground resolution values superimposed on a METEOSAT-2 satellite image.

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