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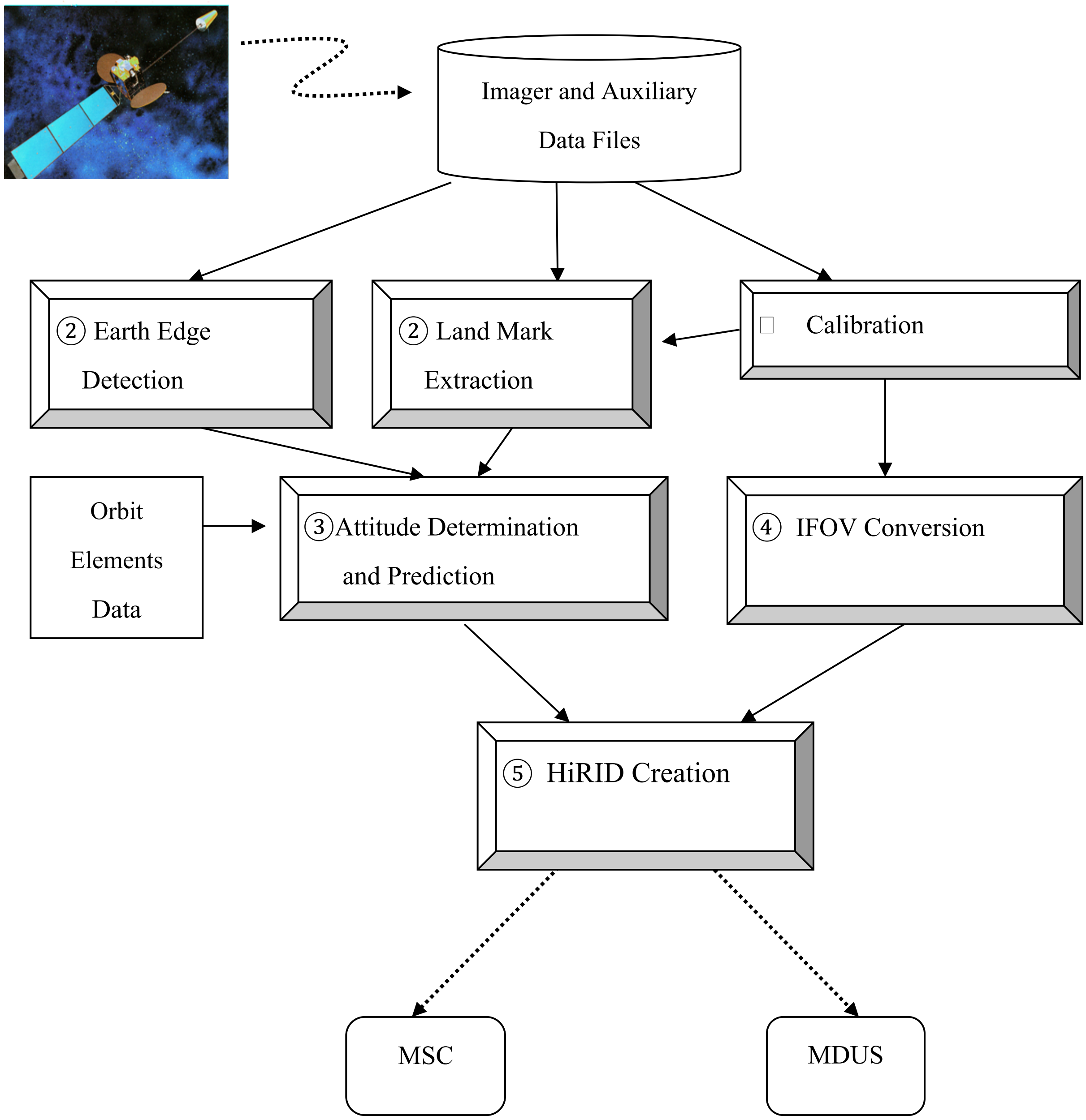
IMAGE PROCESSING METHOD FOR MTSAT IMAGER DATA

This document explains the image processing method to produce HiRID (High Resolution Image Data) from the imager observation data of MTSAT. It contains the description of each processing of the navigation, calibration and IFOV (Instantaneous Field of View) conversion.

1.Introduction

Digital image data for Medium-scale Data Utilization Stations (MDUS) from MTSAT are named High Resolution Image Data (HiRID) and will be disseminated in place of Stretched Visible and Infrared Spin Scan Radiometer (S-VISSR) data of GMS-5. The HiRID is also transmitted to Meteorological Satellite Center (MSC) from the Command and Data Acquisition Station (CDAS) via the microwave line, and used for the analysis, extraction and productions of meteorological products.

The following block diagram shows the outline of the processes to produce HiRID from imager observation data of MTSAT.



2. Characteristics of HiRID

The HiRID format is designed to be upper-compatible with S-VISSR format. Therefore, ground resolutions of HiRID infrared and visible images at the sub-satellite point will be reduced to 5.0 km and 1.25 km, which are originally 4.0 km and 1.0 km respectively. In addition, the brightness levels of the visible data of HiRID remain to be 6 bits or 64 levels while those of the original imager observation data of MTSAT are 10 bits or 1024 levels. The quantization levels of all infrared channels (IR 1-4) of HiRID will be increased to 10 bits or 1024 levels from 8 bits or 256 levels in the case of S-VISSR data.

Calibration tables for IR data of S-VISSR are updated at every observation. On the other hand, fixed calibration tables are used in HiRID. Imager observations with MTSAT are performed using two detectors of each IR channel and eight detectors of VIS channel. In order to correct the difference of characteristics in detectors, calibration is performed for every channel data as described below.

At first, brightness levels of observed data are converted into physical values using conversion coefficients which take the difference in detectors into consideration. The derived physical value is assigned again to a brightness level using the fixed conversion table (temperature level in IR and albedo level in VIS).

HiRID is different from S-VISSR data in the fact that the fixed calibration table is used, and that the relation between the latitude/longitude and line/ pixel is fixed except for the fluctuation of the satellite attitude.

3. Generation of HiRID data

HiRID is produced by the following steps. (Fig.1)

3.1Calibration

(i). Infrared channel

Infrared brightness count are calibrated with (formula 1) in order to eliminate the effect of variation in scan mirror emissivity. The calibration coefficients m and b in formula 1 are determined an each line. (Formula 2) (Formula 3)

$$R=\frac{q\cdot C^2+m\cdot C+b-\varepsilon(\theta)\cdot R_m}{1-\varepsilon(\theta)} \qquad (1)$$

$$m=\sum^{6} C_n\cdot T^n \qquad (2)$$

$$b=-m\cdot C_{sp}-q\cdot C_{sp}{}^2+\varepsilon(sp)\cdot R_{msp} \qquad (3)$$

Where

R: Radiance

C: brightness digital count

C_{sp}: brightness digital count of space data calculated by time interpolation with linear formula using post-clamp data (space data after scan reverse with space clamp operation) and pre-clamp data (space data before scan reverse with space clamp operation).

q: coefficient measured in the ground test (fixed data)

R_m: radiance from the scan mirror calculated by scan mirror temperature telemetry

R_{msp}: radiance from the scan mirror during space look calculated by scan mirror temperature telemetry

$\varepsilon(\theta)$: Scan mirror emissivity ($=a_0+a_1\theta+a_2\theta^2$)

(a_0,a_1,a_2 are coefficients determined in the orbit test, θ is east-west scan angle)

C_n: slope coefficient determined by the non-real time calibration procedure

T: Modified primary mirror temperature calculated by some telemetry data in the latest 100 lines

(ii). Visible channel

The following formula is used for the visible calibration.

$$R= q\cdot C^2+m\cdot C+b \qquad (4)$$

$$m=\frac{R_{sun}-q\cdot(C_{sun}^2-C_{sp}^2)}{C_{sun}-C_{sp}} \qquad (5)$$

$$b=-m\cdot C_{sp}-q\cdot C_{sp}^2 \qquad (6)$$

R_{sun}: reference sunlight albedo

C_{sun}: brightness digital count of sun light data

3.2 Landmark extraction and Earth Edge Detection

The Landmark extraction is performed using both the visible image and the temperature difference image between the IR-1 and IR-2 before the instantaneous filed of view (IFOV) conversion. The results are used in the procedure 3.3.

The earth Edge detection is performed using the infrared 1 and 2 images before the IFOV conversion. The attitude parameters (Observation starting time, right ascension and celestial declination of the spin axis direction and β angle) in the documentation of HiRID used in the procedure 3.5 are updated by the earth edge data and results of the landmark extraction.

3.3 Attitude Determination and Prediction

The attitude of the satellite and misalignment of detectors are estimated from the landmark extraction data and the orbit prediction data (non-real time procedure) at every observation.

3.4 IFOV conversion (Image data generation)

(i). The digital count is converted to radiance using formula (1) and (4).

(ii). The following digital filter designated for each channel is applied to make the IFOV conversion to the calibrated radiance data.

$$R(I,J)=\sum^{15}\sum^{15}[NS(i)EW(j)\cdot Raw(I+i, J+j)] \qquad (7)$$

I: position in north-south direction

J: position in east-west direction

R: radiance after IFOV conversion

Raw : radiance before IFOV conversion

NS(i): north-south IFOV conversion filter

EW(j):east-west IFOV conversion filter

(iii). The Whittaker-Shannon sampling theorem is applied to the conversion of image to HiRID on the fixed latitude/longitude coordinate system.

$$H(x,y)= \Sigma\Sigma R(n,m)\mathrm{sinc}[(x-n\Delta x)/\Delta x]\cdot \mathrm{sinc}[(y-m\Delta y)/\Delta y] \qquad (8)$$

H:HiRID image(x:HiRID pixel y:HiRID line)

R(n,m): image after IFOV conversion

$\Delta x,\Delta y$: sampling distances after IFOV conversion

$\mathrm{sinc}(x)\equiv\sin(\pi x)/(\pi x)$

(iv). The radiance is converted to digital count using the fixed HiRID calibration table.

3.5 HiRID creation

This process combines image data made in the preceding procedures and non-image such as attitude parameters, and creates HiRID output data. Attitude parameters are updated during the observation in order to compensate image distortion.

3.6 Non-real time procedure

The following non-real time procedures are executed.

Orbit Prediction

The orbit prediction is performed twice a day or more, when the new orbit elements are inputted. Trilateration range and range rate (TRRR) for determination of the orbit is performed usually four times a day.

Calibration quality control

The purpose of this step is to check and determine several calibration parameters. The slope coefficients C_n are determined by blackbody calibration data using regression analysis. Blackbody observation is performed before each image observation. The following formula is used for blackbody calibration.

$$m_{bb}= \frac{r_{bb}+q\cdot(C_{bb}^2+b-C_{sp}^2)}{} \qquad (9)$$

$C_{bb}-C_{sp}$

$r_{bb}=[1-\varepsilon(45°)]\cdot R_{bb}+[\varepsilon(45°)-\varepsilon(sp)]\cdot R_{mbb}$ (10)

C_{bb}: brightness digital count of the black body

R_{bb}: radiance from the black body calculated by the black body temperature telemetry

R_{mbb}: radiance from the scan mirror during the black body observation

Navigation quality control

The purpose of this step is to check and determine several navigation parameters.

References

Weinreb, M., and others "Operation calibration of the Imager and Sounder on the GOES-8 and -9 Satellites" NOAA Technical Memorandum NESDIS 44, Feb.1997

Jonson,R.X., and Weinreb,M.,"GOES-8 imager midnight effects and slope correction" Proceeding SPIE vol.2812 596-608, Aug.1996

Seiichiro Kigawa "Image Pre-processing Algorithm for MTSAT" Meteorological Satellite Center Technical Note 37.1999