Diurnal Variation of COMS MI Image Navigation and Registration Performance

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1. INTRODUCTION

Image Navigation and Registration(INR)

- Distorted image : due to geometrical perturbations such as instrument distortion, thermo-elasticity, AOCS pointing accuracy, LOS instability and etc.
- Navigation error : due to the location of an image does not correspond with the earth-referenced map.

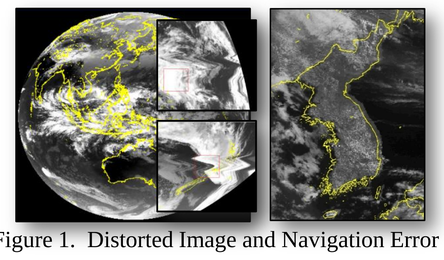


Figure 1. Distorted Image and Navigation Error

- Image navigation : determines the location of a pixel within an image relative to an earth-referenced latitude and longitude.
- Image registration : entails maintaining the location of the pixels within an image and between repeated images to their earth-referenced latitude and longitude.
  a. within frame registration
  b. frame-to-frame registration
  c. channel-to-channel registration

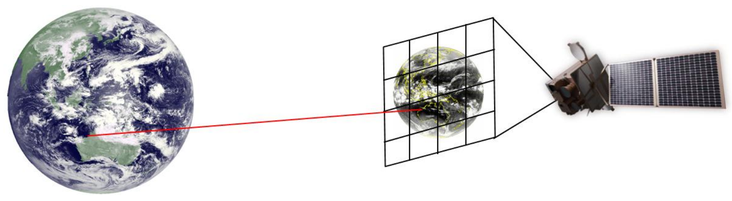
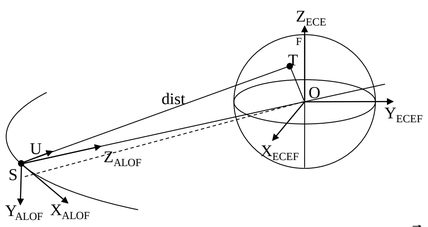


Figure 2. Concept of INR

2. COMS MI INR ALGORITHM

COMS INR for rectification of distorted image is performed by ground processing in National Meteorological Satellite Center (NMSC), using a combination of landmarks, ephemerides and satellite attitude data. The level 1A data is the image which is applied radiometric correction. It is restored to earth-referenced points using the landmarks matching and state vectors refinement. Key technologies of COMS INR are state vector and landmark determination using navigation model and landmark matching algorithm.

The navigation equation relates the location of a pixel in the focal plane, at a certain time to a corresponding sighted earth point. Following navigation equation shows the relationship between a pixel within an image and the corresponding sighted point on ground.



- **SCEF** : Satellite Centered Earth Fixed Frame
- **ECEF** : Earth Centered Earth Fixed Frame
- **ALOF** : AOCS Local Orbital Frame

$$\overrightarrow{OT} = \overrightarrow{OS} + \overrightarrow{ST}$$
$$\overrightarrow{ST} = d \cdot \vec{U}_E$$
$$(x_T, y_T, z_T) = (x_S, y_S, z_S) + d \cdot (x_E, y_E, z_E)$$

$$\vec{U}_E = (x_E, y_E, z_E) \quad \text{in SCEF}$$
$$\overrightarrow{OT} = (x_T, y_T, z_T) \quad \text{in ECEF}$$
$$\overrightarrow{OS} = (x_S, y_S, z_S) \quad \text{in ECEF}$$

$$\vec{T}(t,i)^9 = \vec{S}(t)^8 + dist(t)^7 \cdot R_{xyz}[OrbitoAngles(t)]^6 \bullet R_{xyz}[\pi/2, 0, -\pi/2]^5 \bullet R_{xyz}[CorrAngles(t)]^4 \bullet R_{xyz}[AttAngles(t)]^3 \bullet R_{xyz}[StructAngles(t)]^2 \bullet \vec{U}_{IIRF}[i, instrument(t)]^1$$

Figure 3. Navigation Equation

The landmark matching scheme is based on comparison between image and shoreline database. Figure 4. shows total landmark database in COMS MI INR processing; they are 7,004 landmarks. If the image window is determined predicted position, it performs cloud detection and elimination and shorelines are emphasized in the image window. Finally, the position is retrieved by maximum value of the correlation surface.

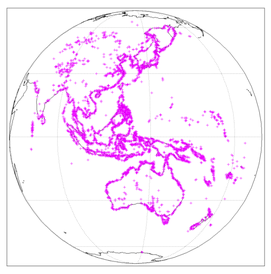


Figure 4. Landmark Database

3. EVALUATION METHODOLOGY

COMS MI level 1B INR performance is based on image geometric quality information and residuals of landmarks including 3σ performance. The residual is the difference between the position of geometric model and landmark. we evaluate the performance with the specification of MI which are determined during the In-Orbit-Test(IOT). The level 1B header include the geometric quality information such as average, standard deviation and quadratic distance of navigation residuals in a image.

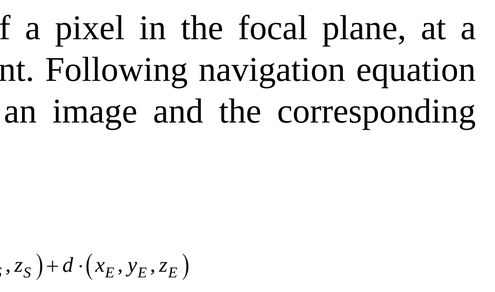


Figure 5. Landmark Residual

- Mean = Average (set of Residuals)
- Sigma = Standard-Deviation (set of Residuals)
- 3σ performance = ABS(Mean) + 3*Sigma (set of Residuals)

4. PERFORMANCE

Statistics of INR Performances

We analyzed the MI level 1B INR performance based on image geometric quality information during two years after COMS MI data official release. As shown following table the 3σ performance is within the specification both channels.

Channel	VIS		IR	
Analysis	**EW (μrad) (Meas./ Spec.)**	**NS (μrad) (Meas./ Spec.)**	**EW (μrad) (Meas./ Spec.)**	**NS (μrad) (Meas./ Spec.)**
Navigation	39.0 / 65.3	36.4 / 65.3	45.3 / 87.5	42.3 / 87.5
Within Frame Registration	46.0 / 63.4	46.0 / 63.4	55.1 /103.9	56.1 / 103.9
Registration between Repeated image (15 min)	20.1 / 55.2	18.1 / 55.2	26.8 / 99.1	25.3 / 99.1
Registration between Repeated image (90 min)	24.4 / 63.4	21.5 / 63.4	30.4 / 103.9	28.5 / 103.9
Total Number of LMKs	4,032,924		15,163,173	

Diurnal Variations

The diurnal variation of COMS MI INR performance shows interesting patterns shown as Figure 6. We find out a sudden increase of the average error values of East-West direction around 9 UTC for April, 2011. The number of valid landmarks used INR processing has unique features between infra-red and visible channels affected by selecting of valid landmark scheme based on solar zenith angle.

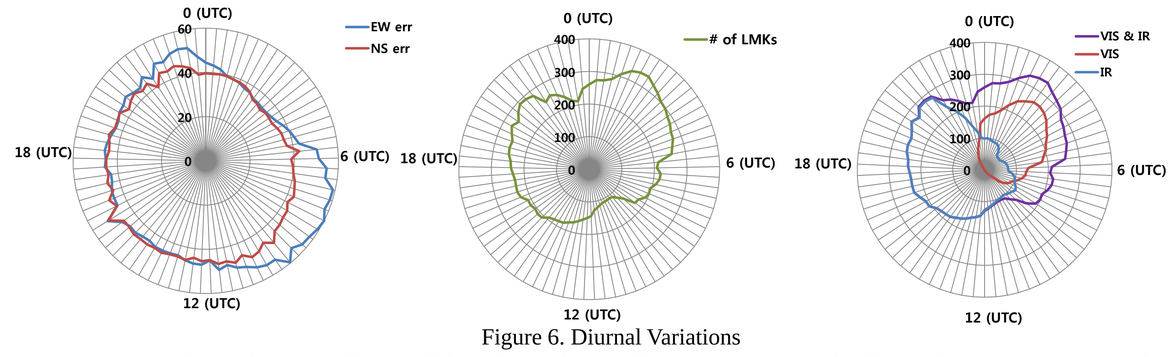


Figure 6. Diurnal Variations

Figure 7. also shows diurnal landmark analysis maps including the position and residuals of used landmarks for each hourly images.

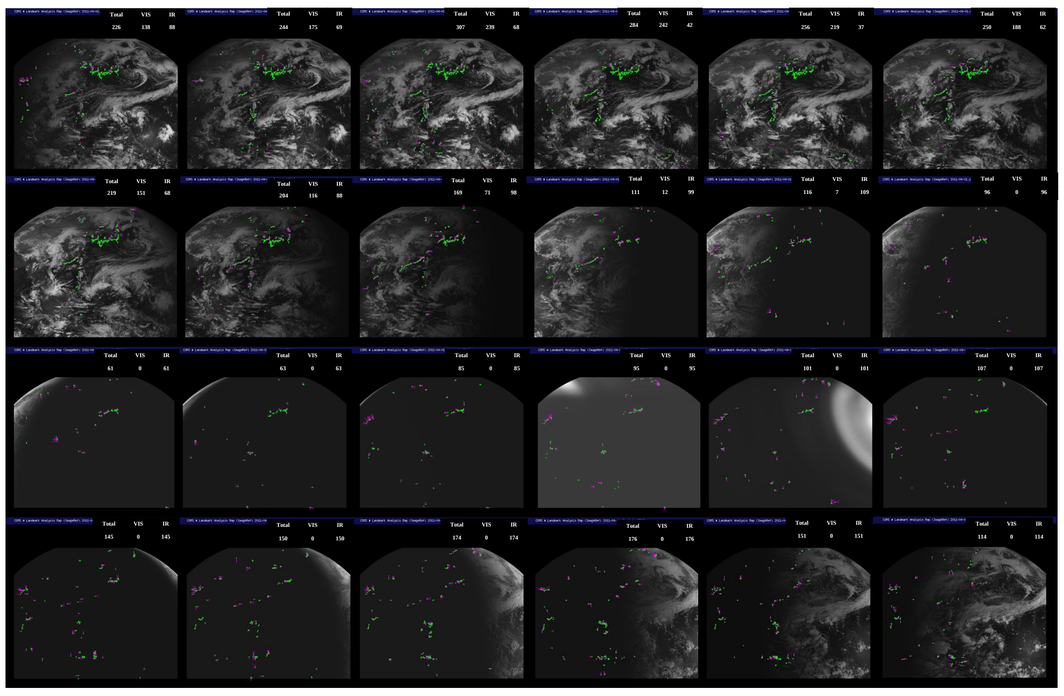


Figure 7. Landmark Analysis Map (00h ~ 23h, 1st Apr., 2011(UTC))

5. CONCLUSIONS

- Analysis of COMS MI INR Performance : 1st Apr. , 2011~ 31th Apr., 2013.
  Navigation Accuracy : VIS 39.4 μrad E-W, 36.4 μrad N-S
  IR 45.3 μrad E-W, 42.4 μrad N-S
- COMS INR performance analysis using landmark residuals error shows that they are within the specification with significant margin.
- Diurnal Variations
  : Negative correlation between the number of landmarks and the navigation accuracy.
  E-W error was suddenly increased around 09 UTC under influence of day/night time channel selection scheme.
  The number of landmarks have unique diurnal patterns between IR and VIS channels.
- For further work, we will investigate the spatio-temporal variability of the used landmarks in INR process.

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