TWO APPLICATIONS OF IMPROVEMENTS FOR AMVS OF NSMC/CMA

— RE-NAVIGATION BASED ON FULL EARTH DISC IMAGE & CALCULATION OF RADIATION TRANSFER USING NWP DATA

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Abstract

This paper describes two applications of improvements which were added to AMVs system of NSMC/CMA in recent years. The one is re-navigation which is operated in order to reduce or eliminate the error of forecast navigation and calculated using S-VISSR data (including full earth disc image, orbit and attitude data). The other is radiation transfer calculation which uses NWP data as atmosphere profile, simulates the radiation received by satellite from optical cloud assumed at different height and provides data for height assignment of AMVs.

1. RE-NAVIGATION BASED ON FULL EARTH DISC IMAGE

1.1. INTRODUCTION

Image navigation is an essential and fundamental component in atmospheric motion vectors (AMVs) derivation. AMVs derived with a series of images are especially sensitive to image navigation accuracy. Small errors in navigation parameters may cause shifts in image series and bias in AMVs derivation.

An automatic image navigation model for FY2 geosynchronous meteorological satellites has been realized in NSMC. The model uses time series of satellite positions and observation vectors toward earth centre as input, to solve satellite attitude.

Normally, the model works perfect and FY2 image navigation accuracy approaches 1 IR pixel or 2 visible pixels. In some special periods such as the period during satellite eclipse, after orbital and attitude control, etc., the image navigation accuracy is poor and the maximum errors are up to 20 pixels.

In order to reduce or eliminate the image navigation errors in these special periods, a re-navigation method which can effectively improve image navigation accuracy is performed in NSMC.

1.2. IMAGE NAVIGATION MODEL FOR FY2

In NSMC the automatic image navigation model for FY2 geosynchronous meteorological satellites uses time series of satellite positions and observation vectors toward earth centre as input, to solve satellite attitude and sensor misalignments. Normally, FY2 image navigation accuracy approaches 1 IR pixel or 2 visible pixels.

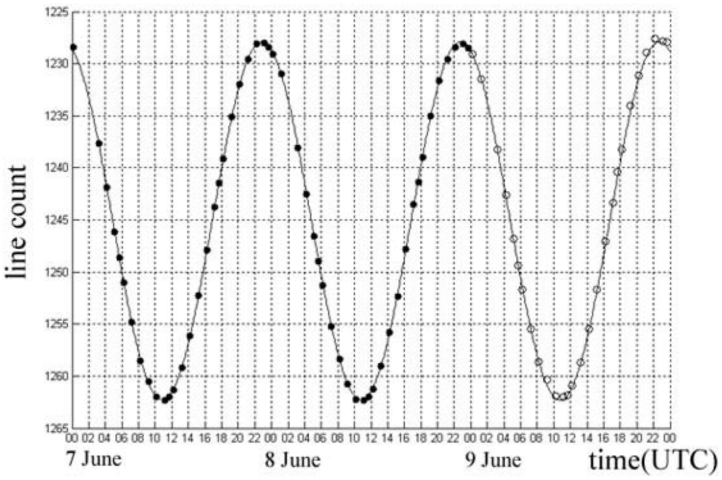

Figure 1: **Time series of earth disk center line count**

Figure 1 shows a sinusoidal function of earth disk center line count time series. The sinusoidal function is simulated with previous data from 7 to 8 June and extended to 9 June. In figure 1, black dots are previous earth disk center line counts for 7 and 8 June with which the simulation and extension are based on; the curve is the simulation and extension of earth disk center line counts; hollow dots are future observations of earth disk center line counts for 9 June which are independent from the extension part of the curve. The good overlap of hollow dots on the extension part of the sinusoidal curve shows that earth disk center line count in future is predictable. So, the automatic image navigation model is depended on the observed earth disk center line counts.

1.3. ERRORS IN SPECIAL PERIODS

In some special periods, the earth disk center line count can't be obtained correctly. It will affect the image navigation accuracy.

1.3.1. DURING SATELLITE ECLIPSE PERIODS

During satellite eclipse periods, two midnight images are not taken every day. The navigation accuracy (around 2 IR pixels) is lower than usual. (Figure 2)

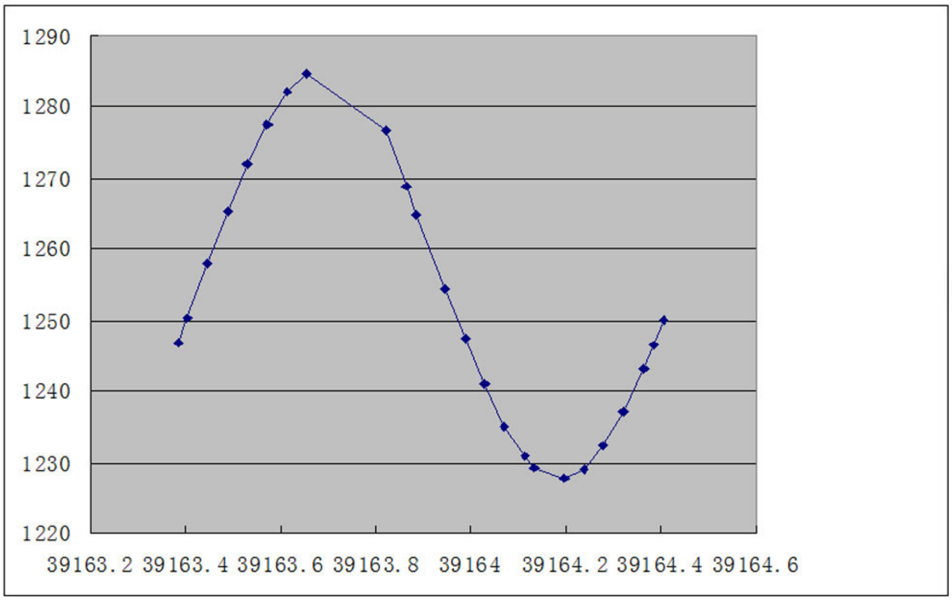

Figure 2: **Time series of earth disk center line count during satellite eclipse periods**

1.3.2. IN 24 HOURS AFTER ORBIT AND ATTITUDE CONTROL

In 24 hours after orbit and attitude control, the image navigation accuracy is poor.

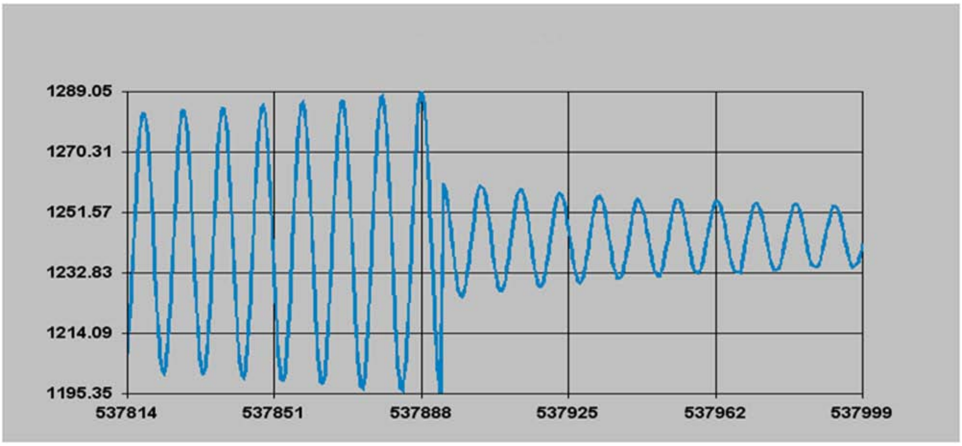

Figure 3: **Time series of earth disk center line count during satellite eclipse periods**

Figure 3 shows that amplitude of sinusoid changed. That reflects that the satellite attitude changed. The line count series of earth disc image are not continuous. The data of past 24 hours can't be used to solve the attitude. Thus, the image navigation accuracy is poor in 24 hours after orbit and attitude control.

1.3.3. INTERFERENCE OF EARTH EDGE DETECTING

Sun or moon entered the view of satellite sensor which will cause a wrong result in earth edge detecting. The image navigation accuracy is affected.

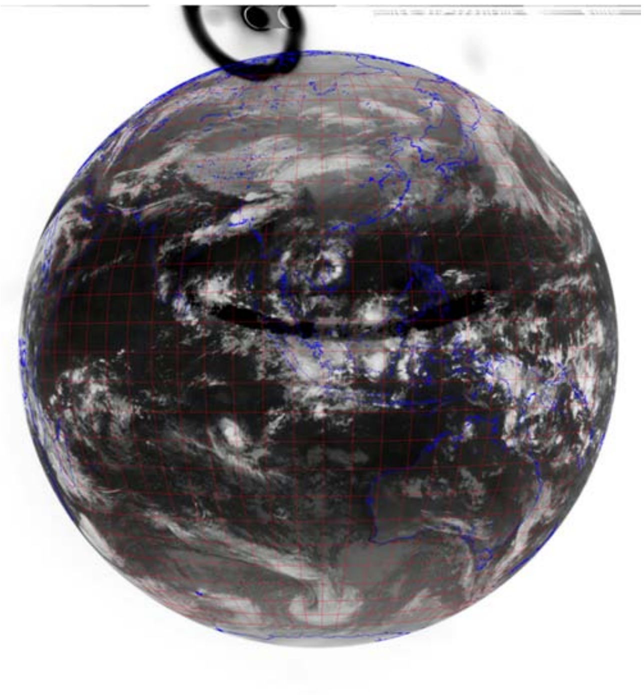

Figure 4: **Sun entered the view of satellite sensor**

1.4. RE-NAVIGATION METHOD

After one observation, the earth disc center in the image can be determined by earth detecting. Using the predicted orbit and altitude parameters, the predicted earth disc center in the image can be calculated. Compared the two center positions, the roll and pitch misalignment can be calculated. Re-navigation method can solve problems above except Sun or moon entered the view of satellite, because it will cause earth edge detecting failed.

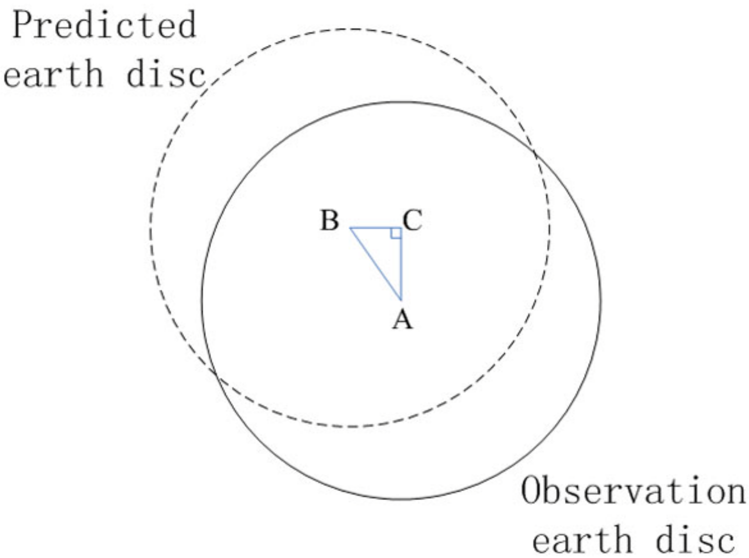

Figure 5: **Sun entered the view of satellite sensor**

In figure 5:

A: the center of observation earth disc (in pixels)

B: the center of predicted earth disc (in pixels)
AC: the bias of roll misalignment (in pixels)
CB: the bias of pitch misalignment (in pixels)
Δ Roll = AC * Stepping-angle
Δ Pitch = CB * Sampling-angle

In figure 6, Yaw misalignment can be determined by the vertical axis of observation earth disc.

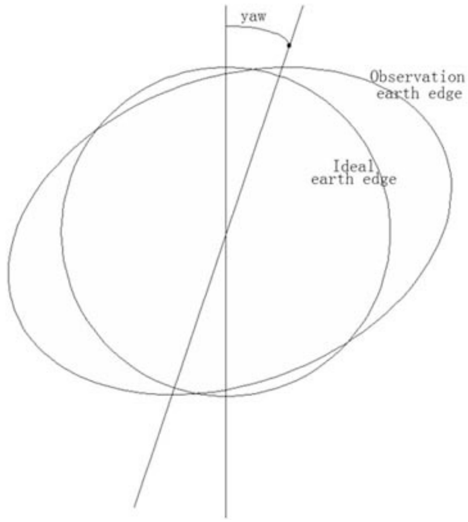

Figure 6: **Sun entered the view of satellite sensor**

Thus, re-navigation misalignments set are shown as below:
Roll = $Roll_{predict} + \Delta Roll$
Pitch = $Pitch_{predict} + \Delta Pitch$
Yaw = yaw

Using these new misalignment parameters and the predicted orbit and attitude parameters, we can obtain accurate navigation result.

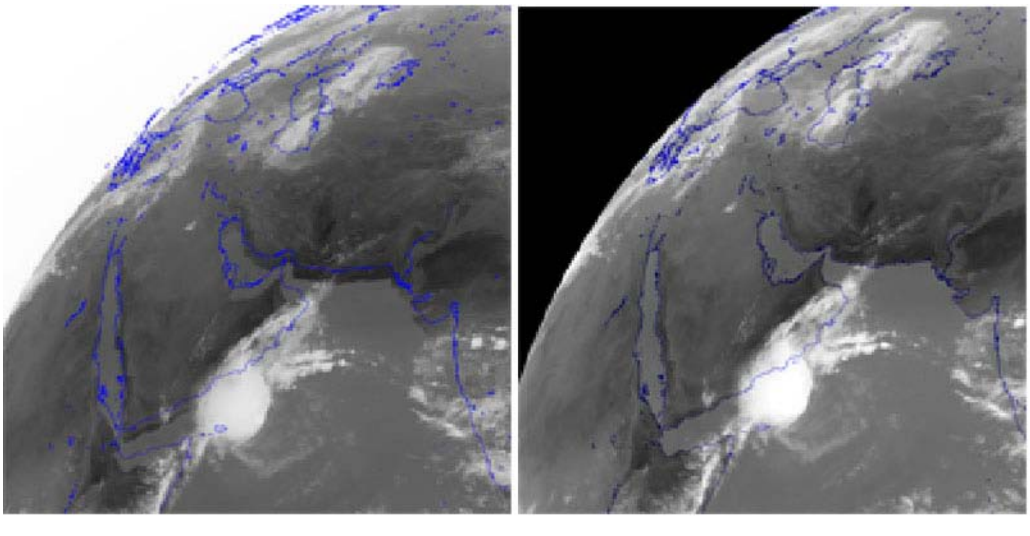

Figure 7: **07:30UTC Nov.1 2007 FY2D first image after satellite control (before and after re-navigation)**

Figure 7 is a comparison of before and after re-navigation. Left image is FY2D first image after satellite control and the navigation bias is up to 20 pixels. On the contrary, right image is re-navigated image and the navigation result is perfect.

2. IMPROVEMENTS ON CALCULATION OF RADIATION TRANSFER USING NWP DATA

The semi-transparency correction tables are used to perform a correction to the IR radiance to take account of semi-transparent cloud or small scale cloud which does not completely fill the field of view. The semi-transparency correction relates the IR radiance to the WV radiance which would occur in the presence of fully opaque cloud at a given level in the atmosphere.

In AMVs operation, the semi-transparency correction tables are used in height assignment. The mission of this application is to improve the accuracy of the curve which shows the theoretical IR/WV relationship for opaque clouds.

2.1. SIX CHANGE IN CALCULATION OF SEMI-TRANSPARENCY CORRECTION TABLES

2.1.1 THE NWP PARAMETER FIELDS ARE IMPROVED

At present, T639 data is used rather than original T213. T639 has the resolution of 0.28125 degree, while T213 has the resolution of 0.5625 degree.

2.1.2 THE VERTICAL EXTENSION OF THE NWP PARAMETER FIELDS

The vertical extension of the NWP parameter fields is expanded from the original surface-100hPa to the present surface-10hPa. By doing so, high level atmospheric status is considered.

2.1.3 USING CLIMATE VALUES OF ATMOSPHERIC COMPOSITIONS

For atmospheric compositions other than water vapor, originally, one set of climate values from American standard atmosphere was used to represent the whole earth disk area. While at present, climate values from 5 regions are used: tropical, mid-latitude summer, mid-latitude winter, high-latitude summer, high-latitude winter. By doing so, radiation contributions from other radiation active gases are better considered.

2.1.4 INCREASE NWP PARAMETER LAYERS

NWP parameter layers are increased. Originally, data from 38 layers are used. At present, data from 120 layers are used. From 10 to 1200 hPa, every 10 hPa interval has a layer.

2.1.5 INCREASE ATMOSPHERE PROFILE RESOLUTION

For temperature profile data resolution, originally the data interval is 10 degree. While at present, the data interval is 5 degree.

For humidity profile data resolution, originally, there are 10 humidity statuses. While at present, there are 20 humidity statuses (0.1, 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90 and 95%).

2.1.6 A SAMPLE OF SEMI-TRANSPARENCY CORRECTION TABLES

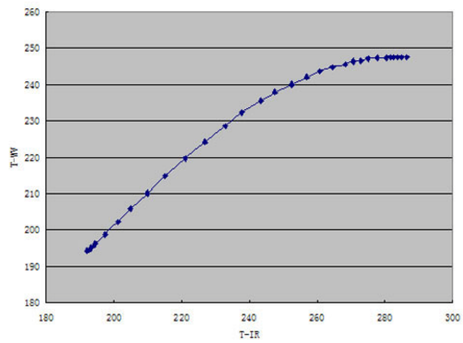

Figure 8: **Opaque cloud IR and WV channel Brightness temperature relationship**

2.2. A NEW IMPROVEMENT IN PROGRESS

At present, T639 has the resolution of 0.28125 degree, while T213 has the resolution of 0.5625 degree. Along with the improvement of NWP resolution, a new problem occurred. In figure 9, calculating semi-transparency correction tables in the path from A to S, the NWP data of C will be the certain height above B rather than A.

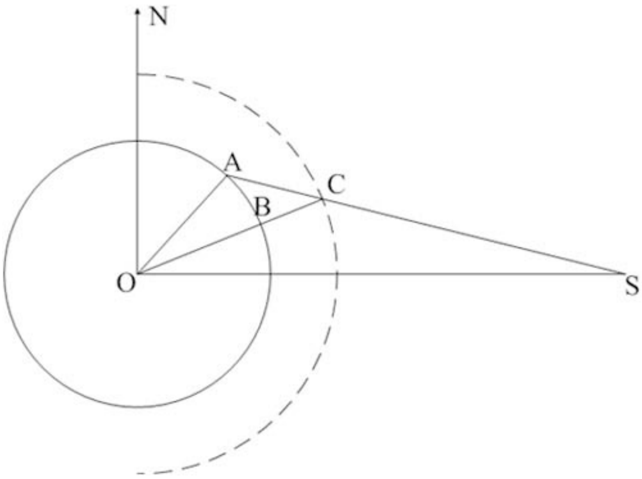

Figure 9: **illustration of profile correction in calculating semi-transparency correction tables**

In figure 9:

O: earth center

S: satellite position

A: one position on earth surface

C: point of intersection that line AS cross a certain NWP layer

B: projection of point C on earth surface

$\angle AOC = \angle AOS - \angle COS$

So a correction occurs when the radiation from A to S is calculated. The correction varies along with height of C and satellite zenith. The correction is $\angle AOC$.

degree / Km	35	40	45	50	55	60	65	70
5	0.03142	0.03765	0.04486	0.05346	0.06405	0.07764	0.09607	0.12295
6	0.0377	0.04517	0.05382	0.06413	0.07683	0.09314	0.11523	0.14743
7	0.04397	0.05269	0.06278	0.0748	0.08961	0.10862	0.13437	0.17187
8	0.05024	0.0602	0.07173	0.08546	0.10238	0.12409	0.15348	0.19628
9	0.05651	0.06771	0.08068	0.09612	0.11514	0.13954	0.17258	0.22065
10	0.06278	0.07522	0.08962	0.10677	0.12789	0.15499	0.19166	0.24499
11	0.06904	0.08272	0.09856	0.11742	0.14063	0.17042	0.21071	0.26929
12	0.0753	0.09022	0.10749	0.12806	0.15337	0.18584	0.22975	0.29355
13	0.08156	0.09772	0.11643	0.13869	0.1661	0.20125	0.24877	0.31778
14	0.08782	0.10522	0.12535	0.14932	0.17882	0.21664	0.26777	0.34198
15	0.09408	0.11271	0.13427	0.15994	0.19153	0.23203	0.28675	0.36613
16	0.10033	0.1202	0.14319	0.17056	0.20424	0.2474	0.30571	0.39026
17	0.10658	0.12768	0.15211	0.18117	0.21693	0.26276	0.32465	0.41435
18	0.11282	0.13516	0.16102	0.19178	0.22962	0.27811	0.34358	0.4384
19	0.11907	0.14264	0.16992	0.20238	0.2423	0.29345	0.36248	0.46242
20	0.12531	0.15012	0.17882	0.21297	0.25497	0.30877	0.38137	0.48641

Table 1: **illustration of profile correction in calculating semi-transparency correction tables**

Table 1 shows that correction value (degree, longitude or latitude) of various height and satellite zenith. When the correction value is greater than half grid of NWP, the position of NWP data at certain height and satellite zenith must be corrected. T213 half grid is 0.28125 degree and T639 half grid is 0.14062 degree. When T213 NWP data is used, the position of NWP data at certain height and satellite zenith (red color in table 1) must be corrected. When T639 NWP data is used, the position of NWP data at certain height and satellite zenith (blue and red color in table 1) must be corrected.

REFERENCES AND FOOTNOTES:

Feng Lu, Xiaohu Zhang, Jianmin Xu, IMAGE NAVIGATION FOR THE FY2 GEOSYNCHRONOUS METEOROLOGICAL SATELLITE, American Meteorological Society, 2008

Zhang Qisong, Xu Jianmin, Zhang Xiaohu, Wang Sujuan , Ma Gong, Hu Xiuqing , Zhang Peng, Zhang Yong, Zhang Hua, Liu Guiqing，STATUS OF OPERATIONAL AMVS FROM FY-2 SATELLITES，Submitted to the 10th International Winds Workshop，Tokyo，Japan，22-26 Feb.，2010