RECENT WORKS AIMED AT OPERATIONAL FY2C AMVS

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ABSTRACT

Recent works aimed at operational FY2 AMVs are described. The following works are performed:

1) Image Navigation of FY2 is improved. An automatic image navigation algorism is realized. Navigation accuracy for FY2 images reaches pixel level.
2) Calibration of FY2 is improved. Inter calibrations between FY2 and NOAA observations are performed. Infrared and water vapour channel calibrations are improved and compatible with NOAA observations.
3) Cloud cluster analysis of FY2 is made.
4) Height assignment procedure is improved. Opaque cloud radiation is calculated with NWP data by using radiation model. Original assumption on same IR and WV brightness temperature for opaque cloud is removed.
5) EUMETSAT Quality indexes are calculated with CMA’s numerical prediction model output.
6) BURF coding is under producing.
7) The major characteristics of the previous scheme are reserved. Those include the followings:
8) A stepwise search procedure is adopted. Search area does not rely on NWP results.
9) The absolute maximum and secondary peaks (if present) at two successive image pairs are used to identify potential displacement vectors.
10) Sub-pixel optimization is made in search procedure.
11) In height assignment component, distinction between high and low clouds is made before height adjustment by correlation between the IR and WV matching templates.
12) Quality control is an integral part of the processing. Time consistency examination is performed immediately after tracer tracking; horizontal consistency examination and height adjustment are performed immediately after height assignment. Tracers failed in the examinations are eliminated.

1. INTRODUCTION

NSMC developed its own AMV scheme. This total automatic scheme had been performed in operation with GMS5 data from January 1997 to April 2003. In the process of calculating AMVs with FY2 data, it is noticed that high quality pre-processing is essential. A big effort is then made at improving fundamental data pre-processing quality. At the same time, the scheme itself is also improved. This paper introduces recent works performed in NSMC aimed at operational AMV product. Sections 2-4 introduce pre-processing, scheme improvement and cloud analysis respectively. Section 5 describes test run results.

2. IMPROVEMENTS IN FY2 DATA PREPROCESSING

An automatic image navigation algorism is realized operationally. The algorithm has been issued at the 6 IWWS (Xu J, Lu F, Zhang Q S, 2002). Navigation accuracy for FY2B image reaches pixel level.

Inter calibration with NOAA16 (17), is realized operationally. AVHRR and HIRS data is downloaded from NOAA GAC data set. AVHRR channel 4 and 5 are used to calibrate FY2B IR channel, HIRS channel 12 is used to calibrate FY2B WV channel. The inter calibration procedure includes time match, location match, view angle match and spectrum match. NOAA and FY2 data with observation time difference less than 15 minutes is consider time matched. Both NOAA and FY2 data are remapped to Lon/Lat projection with geographic location matched with each other. Image pixels of the two satellites with satellite zenith angles less than 20 degrees are matched with each other, the pixels with cosine differences less than 0.1 are chosen. Spectrum matches are performed with 13 tropical radiosonde profiles with and without thin cirrus. In different atmospheric conditions, incident radiation energy ratios between NOAA and FY2 instruments are calculated. Inter calibration of IR and WV channels between NOAA and FY2B satellites are performed weekly. In case sloop of calibration has significant change, after manual selection, the new calibration table may replace the old one. Schmetz etc. (1998) showed sensitivity of the height assignment to satellite calibration errors.

3. SCHEME IMPROVEMENTS

In the original NSMC AMV derivation scheme, an assumption was made at height assignment. It is assumed that the opaque high cloud top has the same IR and WV brightness temperature. With this assumption and the IR-WV statistical relationship in the image segment, environment temperature of the cloud is gain (Szejwach G, 1982). The NSMC AMVs produced with GMS5 data from January 1997 to April 2003 was compared with radiosonde data. The comparison results showed that the NSMC AMVs are slower than radiosonde winds. The inappropriate height assignment assumption is considered a major factor responsible to speed error. Thus, the above mentioned height assignment assumption is removed. Opaque cloud radiation is calculated with NWP data by using atmospheric radiation correction look up table.

MODTRAN is used to create atmospheric radiation correction look up tables. The atmosphere is divided into 53 layers. In each layer, atmospheric conditions are constructed by the combination of 11 temperature and 11 humidity measurements. In each layer with each atmospheric status, the atmospheric optical depths in the layers are gained by integration with MODTRAN. In the integration, the atmospheric optical depths are consists of three major parts: water vapour line absorption/emit, water vapour continuous absorption/emit and absorption/emit by other atmospheric compositions. The spectrum resolution in the integration is wave number with unit cm-1. The integration spectrum scope is from 700 to 1200 for FY2B IR channel and from 1300 to 1600 for FY2B WV channel.

In operation, atmospheric radiation correction is gained by using look up tables. A set of atmospheric profiles in 17 layers is received from T213 Numerical Weather Prediction Model (NWP) of National Meteorological Center (NMC) China Meteorological Administration (CMA). Those data are inserted to 53 layers. By using look up table, atmospheric radiation corrections from each layer to the top of the atmosphere for IR and WV channels and then the IR and WV channel Brightness temperature for opaque clouds at different layers are gained. Opaque cloud IR and WV channel Brightness temperature relationship is combined with IR-WV statistical relationship in the image segment to get semi transparent cloud correction. Atmospheric reduction correction is also made.

To improve tracking, two measures were adopted: 1) Tracking scope is expanded from 64x64 pixels to 96x96 pixels. This improves AMVs at the high speed end. The original tracking scope is unable at covering the movement of high speed tracers. 2) In dark areas on water vapour image, cross correlation is often failed at tracing. For those areas in water vapour images, Euclidean distance is used at tracing (Dew G, Holmlund H, Logica, 2000).

EUMETSAT Quality indexes are calculated with CMA numerical prediction model output (Holmlund K, Velden C S, Rohn M, 2001). BURF coding is under producing.

The major characteristics of the previous scheme are reserved. Those include the followings:

A stepwise search procedure is adopted. Search area does not rely on NWP results. The absolute maximum and secondary peaks (if present) at two successive image pairs are used to identify potential displacement vectors. Sub-pixel optimization is made in search procedure.

In height assignment component, distinction between high and low clouds is made before height adjustment by correlation between the IR and WV matching templates. Quality control is an integral part of the processing. Time consistency examination is performed immediately after tracer tracking; horizontal consistency examination and height adjustment are performed immediately after height assignment. Tracers failed in the examinations are eliminated.

4. CLOUD AND TOPOGRAPHY FILTERING

Cloud filtering is an important part at AMV derivation scheme. This is especially true for FY2 AMV derivation. Tibetan Plateau is in the observation area of FY2. Surface altitude of Tibetan Plateau is higher than low cloud in Eastern China. In Northern Hemisphere winter, topography of Tibetan Plateau is clearly shown in water vapour channel images. With mixed layer clouds and even topography in the images, object tracking quality is reduced. Thus, cloud and topography filtering should be performed as a part of data pre-processing in the AMV scheme.

Cloud filtering mainly performs two jobs: to separate cloud from surface named as total cloud detection and to separate high cloud from low cloud and surface named as high cloud detection. In both the cloud detection schemes, an individual pixel is catalogued into one of the two groups: either clear or cloudy.

High cloud detection is performed on the pixel bases with infrared and water vapour channels. Atmospheric corrections are made for the two channel measurements. Correlation between the two channel measurements is calculated for each pixel in a 9 pixel area around it. Pixels with low infrared and water vapour bright temperatures and high correlation are catalogued as high level cloud. This procedure runs well except in Tibetan Plateau where some ground features are shown in winter water vapour images and are catalogued as high cloud. Thus in Tibetan Plateau, high cloud pixels should pass cloud detection procedure as well.

Cloud detection is performed with dynamical threshold method on the segment bases. Segment size is 32x32 pixels. Infrared and visible channels are basic data; water vapour channel is also used. Cloud detection procedure includes histogram analysis, threshold determination and deviation analysis. Dynamic thresholds for each segment are created through three steps: At first, individual image at a specific time of a day is carefully analysed to find dynamical thresholds at different channels for the day and the segment. Secondly, historical data for that time in the past 15 days is summarized to find dynamical thresholds for the segment. Thirdly, diurnal variation of the dynamical thresholds in a day for the segment is harmonized to remove and revise inappropriate values. With dynamic thresholds at visible and infrared channels, cloud masks are created automatically for each pixel on any single image.

For each segment, histogram analysis is performed to get dynamical threshold. At the histogram of an image segment that contains both clear and cloud pixels, a peak would appear at low grey level end (high temperature or low reflectance). It is possible that this peak represents clear surface. The detail procedure to get dynamical threshold follows Vittorio A V D,etc.(2002). Figure 1 is a diagram that shows Vittorio's definition for cloud detection threshold. Vittorio's threshold is at the point with max slope variation (maximum scaled second derivate of histogram), rather than at the bottom of the histogram itself. Based on Vittorio's definition, only pure surface pixels are catalogued as surface, mixed pixels are catalogued as cloud. In our testing, Vittorio's definition can get relative stable value of dynamic threshold. Thus, we adopt Vittorio's definition and procedure at cloud detection for individual image.

Visible channel is very useful in cloud detection. Dynamic cloud detection threshold is much easier to be found in visible channel than in infrared channel. In the most cases, distinct contract in reflectance is between clear and cloudy pixels. But when sun zenith angle exceeds 65 degrees, visible channel data are not used.

In threshold extracting process, surface types and elevation are thought about carefully. In the area of a segment, if there are more than two kinds of surface type or the Digital Elevation Model (DEM) shows more than 1000 m difference, the segment is divided into sub areas. In infrared image processing, adiabatic lapse rate correction for topography is also made. The surface classification data and DEM data are from Geographic Information System (GIS). They are useful ancillary data to cloud detection.

In case the maximum scaled second derivate was not found. That means pixels in the analysed segment have the similar properties. Other four areas are analysed. Those four areas are in the same 32x32 pixel size, but moved 16 pixels to the east, west and north, south respectively. Of the thresholds from the above mentioned five analysis areas, the one at low grey level end (high temperature or low reflectance) is chosen as dynamical threshold.

Deviation in 9 pixels around the pixel helps in broken cloud detection at sea. Sea surface has relative uniformity properties. If sea pixels are contaminated by small and broken cloud, the deviations of the related pixels become larger. In this case, 15-day composite clear data and numerical weather forecasting data are used as ancillary data to help cloud detection.

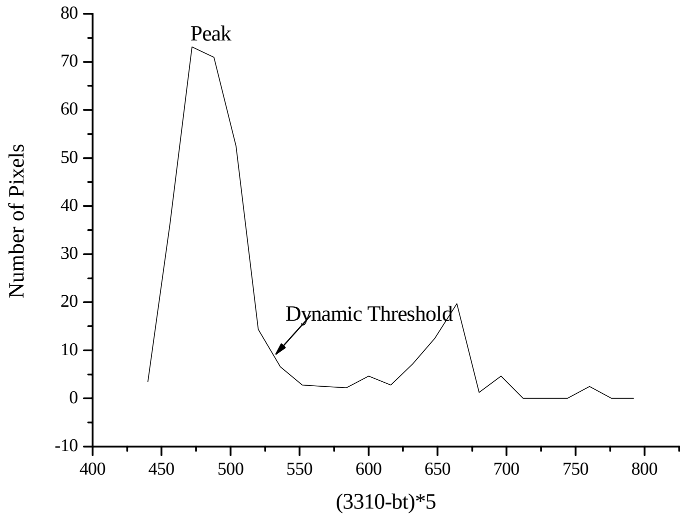

Figure 1. Histogram processing for selecting dynamic threshold at the maximum of the scaled second derivate.

Besides dynamic threshold method, some simple but very useful methods are also adopted at cloud detection. For example, brightness temperature difference between infrared and water vapour channel is used to detect high cloud (small value associate with high cloud). In most cases, brightness temperature at infrared channel is higher than water vapour channel. If brightness temperature difference between infrared and water vapour channel appears as negative, the pixel was covered by deep convective cloud.

The Algorithm is tested with FY2B data. Figure 2 is original infrared and visible of FY-2B images at 0300Z 16 Jan 2004. In Figure 3, cloudy pixels are shown as grey in different levels, while sea pixels are shown as blue and land pixels green or yellow. Figure 3 shows cloud classification result. In the image, cloud is classified into high cloud (white colour) and middle–low cloud (grey colour). From Figure 3, it is seen that the algorithm performs well for most area. But in high latitude regions, the cloud detecting methods failed sometimes due to strong surface temperature inversions. Some surface conditions may make this approach inappropriate, most notably over snow and ice condition. In addition, some cloud types such as thin cirrus, low stratus at night, and small cumulus are difficult to detect because of insufficient contrast with the surface radiance.

FY2B has only three channels (visible, infrared and water vapour). With five channels (split window and 3.6µm channels added), cloud detection will be improved, especially in snow and ice area. Cloud filtering will be performed when the cloud detection scheme become stable in operation.

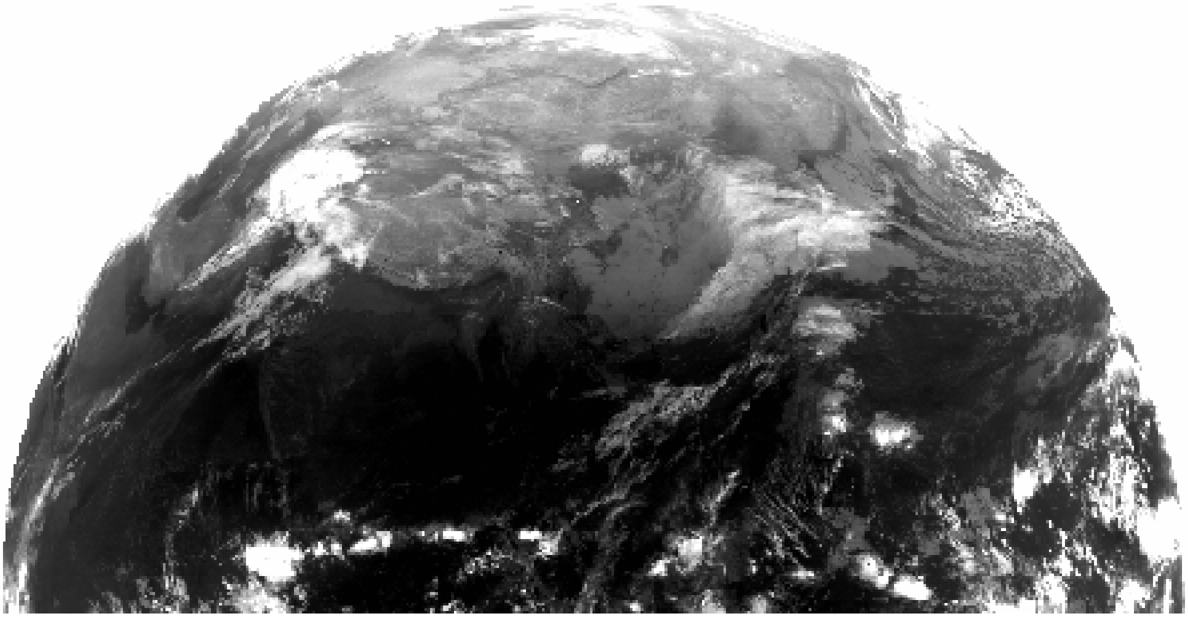

Figure 2a. Infrared image of FY2B 03Z 16 Jan 2004.

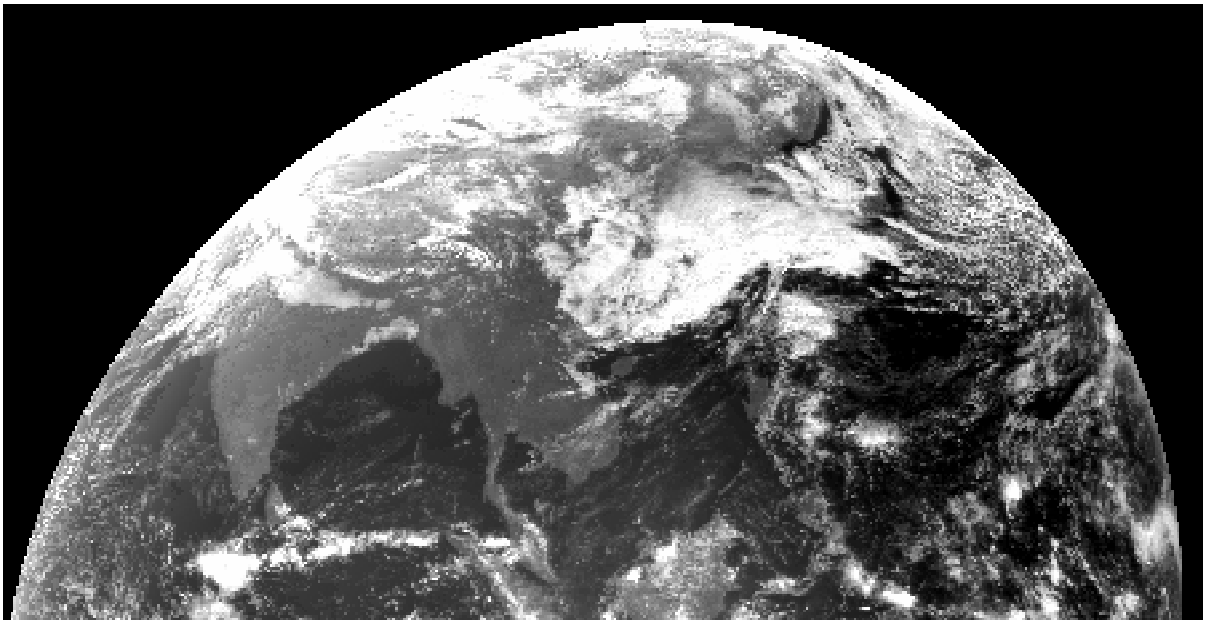

Figure 2b. Visible image of FY2B 03Z 16 Jan 2004.

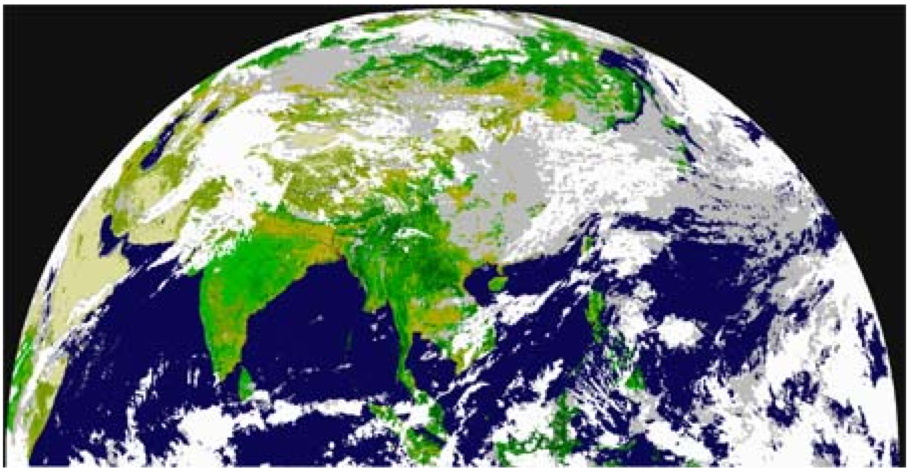

Figure 3. Cloud classification result 03Z 16 Jan 2004 (White is high cloud grey is middle and low cloud)

5. TEST RUN RESULTS WITH FY2B DATA

Test operation is undertaken with FY2B data. Figure 4 shows AMVs from FY2B at 20Z 23 Feb 2004. The performance of FY2BAMVs is under estimation.

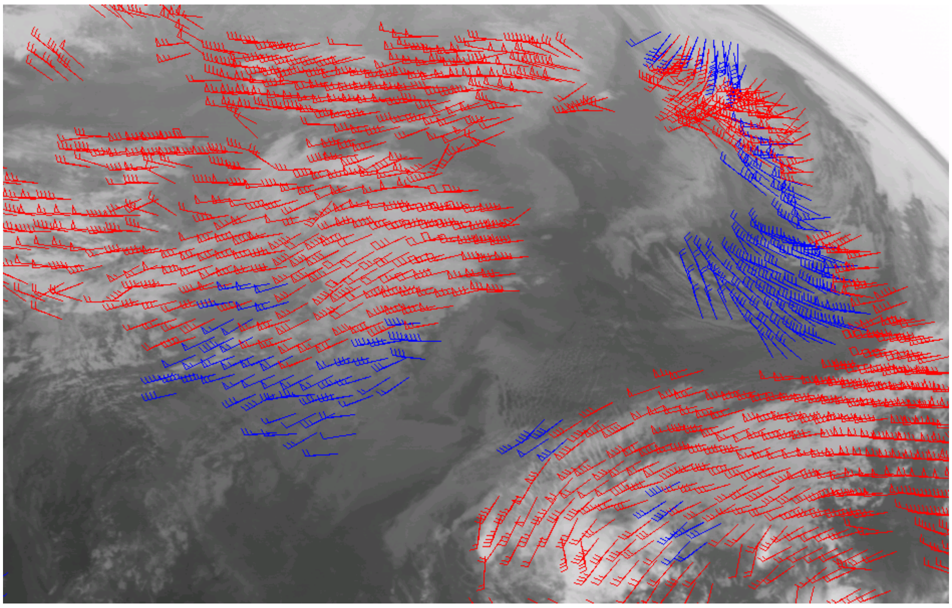

Figure 4. AMVs from FY2B at 20Z 23 Feb 2004.

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