A COMPARISON OF TWO ATMOSPHERIC MOTION VECTOR DERIVATION SCHEMES: THE EUMETSAT MSG PROTOTYPING SCHEME AND THE NSMC SCHEME

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ABSTRACT

In order to examine the effectiveness of the NSMC scheme, a comparison was arranged under the co-operation frame between EUMETSAT and CMA (China Meteorological Administration). Two periods of data from Meteosat-5 including IR and WV channels were processed and compared by both the EUMETSAT and NSMC schemes. The comparison periods were one week long each, and in January and July respectively. The comparison results show that EUMETSAT AMVs with QI above 0.90 have the least difference compare to ECMWF model output and radiosonde reports. But EUMETSAT AMVs with QI above 0.90 holds less data. NSMC AMVs are closer to ECMWF model output and radiosonde reports than EUMETSAT AMVs with QI above 0.6 and 0.75. In case the two schemes giving different height assignment at IR channel or giving different tracking results, NSMC AMVs are closer with ECMWF model output than EUMETSAT AMVs with QI above 0.6 and 0.75. The NSMC scheme supplies high density AMVs with good quality. This is because the NSMC scheme takes procedure to distinguish high and low clouds before height assignment and takes quality control and optimisation at both tracking and horizontal consistency examining components.

1. Introduction

At the third and the fourth International Wind Workshops detailed papers on ”Calculation of Cloud Motion Wind with GMS-5 Images in China” and “Cloud Motion Winds from FY-2 and GMS-5 Meteorological Satellites” were presented by Xu and Zhong (1996, 1998). The second paper proposed a novel approach to height assignment, using the fact that there is a close correlation between IR and WV channels for high clouds. Thus, correlation between IR and WV measurements is used to distinguish high and low clouds before height adjustment. The height adjustments are only performed for tracers classified as high clouds. Other major differences of the NSMC scheme in comparison to other schemes currently in operational use are as follows:

- i) The NSMC scheme does not have a target selection. It makes full use of the targets no matter how small the dynamical range of the target brightness temperature is.
- ii) the target tracking is achieved through an optimised search procedure which avoids computing full correlation surfaces. With this procedure, only about 1/6 points on the matrix need to be calculated for the maximum of correlation to be picked up.
- iii) The maximum and the second peak of maximum at the two successive image pairs are both considered for more continuous tracking.
- iv) Quality control is performed at each component of the NSMC AMV derivation scheme, rather than only at the last step of the scheme.

In order to examine the effectiveness of the NSMC scheme, a comparison was arranged under the co-operation frame between EUMETSAT and CMA (China Meteorological Administration). This paper provides comparison results.

2. Comparison Data and Methods

Two periods of data from Meteosat-5 including IR and WV channels were processed and compared by both the EUMETSAT and NSMC schemes:

- Period 1: from 1200z Jan 1 1999 to 2300z Jan 7 1999, including 14 sets of IR and WV images.
- Period 2: from 1200z July 1 1999 to 2300z July 7 1999, including 14 sets of IR and WV images.

The following comparisons are made:

- Differences between AMVs from the two schemes;
- Differences between ECMWF grid data and AMVs from the two schemes;
- Differences between radiosonde data and AMVs from the two schemes;
- AMVs from the two schemes with large height assignment differences;
- AMVs from the two schemes with large wind speed differences.

ECMWF NWP analysis and forecast data and radiosonde data were used as reference in the comparison. In the NSMC scheme, only AMVs that pass quality control are retained; while in the EUMETSAT scheme, all AMVs derived are kept , however quality indices are assigned to each vector. The NSMC AMVs are compared with the EUMETSAT AMVs with QIs exceeding 0.6, 0.75 and 0.9 , they are written as C, E, G and F respectively.

Comparisons are made for pairs of AMVs in 1-degree latitude/longitude. High level (above 399 hPa), middle level (400-699 hPa) and low level (under 700hPa) AMVs are compared respectively. Interpolations in vertical directions were made for ECMWF and radiosonde data taken part in the comparison. Bias, absolute mean (ABM) and root mean square (RMS) of speed, direction and vector differences are compared for the two comparison periods.

The of the schemes is tested statistically using the F-test. Suppose quantities X and Y are compared. X and Y may be differences of speed, direction or vector speed. Samples of sizes N_X and N_Y are gathered respectively from the two populations X and Y. Suppose RMS_X is larger than RMS_Y . Let $FF=(RMS_X/RMS_Y)^2$. This FF has a F-distribution with (N_X-1, N_Y-1) degree of freedom. In case the value of FF computed from the sample exceeds the critical value at significant level 0.01, with an error probability 0.01 we can say X is larger than Y. By using F-tests, comparison quantities with significant differences are filtered out. The scheme producing AMVs with smaller differences compared with radiosonde or ECMWF grid data are assessed as better.

3. Product Density Associated with Quality Indexes

AMV calculations are performed at different grids in the two schemes. The NSMC scheme calculates winds at every 1-degree latitude/longitude, while the EUMETSAT scheme at every 80-pixels. The grid sizes are different. In the area near sub satellite point, EUMETSAT grid lengths are smaller (Tracers processed are denser); while in the area further from the sub satellite point, NSMC grid lengths are smaller (I.e. more tracers are processed). To make the results comparable, the ratio of the number of AMV products to the total number of tracers processed is adopted as a characteristic quantity . It is named as product ratio. In the EUMETSAT scheme only tracers that meet tracer selection criterion are taken part in the data processing. In the product ratio calculation, tracers not used in data processing are not accounted in total number of tracers processed. For the two comparison periods, product ratios are listed in table 1.

Table 1: Product Ratios for the two omparison periods for NSMC scheme and EUMETSAT scheme with QI 0.6, 0.75 and 0.9, respectively.

Channel, Period	NSMC (C)	EUMETSAT QI 0.6 (E)	EUMETSAT QI 0.75 (G)	EUMETSAT QI 0.9 (F)
IR, Jan.1-7 1999	$\frac{67652}{138334}=48.90\%$	$\frac{42020}{68226}=61.59\%$	$\frac{32878}{68226}=48.19\%$	$\frac{11098}{68226}=16.27\%$
IR, July1-7 1998	$\frac{73141}{138334}=52.87\%$	$\frac{88311}{142628}=61.92\%$	$\frac{66385}{142628}=46.54\%$	$\frac{19472}{142628}=13.65\%$
WV,Jan.1-7 1999	$\frac{74167}{138334}=53.61\%$	$\frac{76885}{141037}=54.51\%$	$\frac{56917}{141037}=40.36\%$	$\frac{22004}{141037}=15.61\%$
WV July1-7 1998	$\frac{76366}{138334}=55.20\%$	$\frac{87899}{155794}=56.42\%$	$\frac{63854}{155794}=44.99\%$	$\frac{18951}{155794}=12.16\%$

From table 1 it is noticed that for IR channel the NSMC scheme and the EUMETSAT scheme with QI 0.75 have a similar product ratio around 50%; for WV channel, NSMC scheme and EUMETSAT scheme with QI 0.6 have similar product ratio around 55%. EUMETSAT scheme with QI 0.9 have much smaller product ratio (around 15%) than NSMC scheme (around 50%). The comparisons between NSMC and EUMETSAT with QI 0.75 for IR channel and between NSMC and EUMETSAT with QI 0.6 for WV channel are considered equal in ability of producing similar density of AMVs.

4. Differences between AMVs derived by the Two Schemes

At first, differences between AMVs derived by the two schemes are compared. Comparison results are as follows:

- AMV speeds from NSMC scheme are smaller than the ones from EUMETSAT scheme. The speed biases of NSMC AMVs minus EUMETSAT AMVs are all negative. This may be due to the tracer size difference;tracer sizes for NSMC and ECMWF are 32*32 and 24*24 pixels respectively.
- All the absolute means of direction differences are less than 10 degrees. Absolute means of speed and vector differences are normally less than 3 m/s, except for WV channel in middle level where the absolute mean speed and vector differences of NSMC AMVs compare with EUMETSAT AMVs with QI above 0.6 and 0.75 reach 4 to 5 m/s.
- Comparison between AMVs derived by the two schemes shows that except for differences of NSMC AMVs compare with EUMETSAT AMVs with QI above 0.6 and 0.75 at WV channel in middle level, all differences are reasonably small. Larger differences of NSMC AMVs compare with EUMETSAT AMVs with QI above 0.6 and 0.75 at WV channel in middle level will be further analysed in section 8.

5. Differences between AMVs and ECMWF Analyses

AMVs derived by both the schemes are compared with the ECMWF grid wind vectors. In the observation area of Meteosat-5, the radiosonde stations are not well distributed. ECMWF model output is the reality examination data with good distribution.
The comparison results above 0.01 statistical significant level at F-tests were shown in table 2.

Table 2: Speed, Direction and Vector Differences of AMVs Versus ECMWF Data above 0.01 Statistical Significant Level at F-tests.

Channel Level	January Speed	January Dir.	January Vector	July Speed	July Dir.	July Vector
IR High Level	F/C C/G C/E	F/C C/G C/E	F/C C/G C/E	F/C C/G C/E	F/C C/G C/E	F/C C/G C/E
IR Middle Level	F/C G/C E/C	F/C C/G C/E	F/C	F/C C/G C/E	F/C C/G C/E	F/C C/G C/E
IR Low Level	C/G C/E	C/G C/E	C/G C/E	F/C C/G C/E	F/C C/E	F/C C/G C/E
WV High Level	F/C C/G C/E	F/C G/C E/C	F/C	F/C C/E	F/C G/C E/C	F/C C/G C/E
WV Middle Level	F/C C/G C/E	F/C G/C E/C	F/C C/G C/E	F/C C/G C/E	F/C	F/C C/G C/E

C is NSMC AMVs. E is EUMETSAT AMVs with QI above 0.6. G is EUMETSAT AMVs with QI above 0.75. F is EUMETSAT AMVs with QI above 0.9. Schemes list as numerators are assessed with significantly smaller difference compare with ECMWF model output.

In each box of table 2, comparisons with statistical significance are shown. The schemes listed as numerators are the ones with significant smaller differences compared with radiosonde data. In case the F-test is not passed, the related box remains empty. From table 2, it is shown clearly that EUMETSAT AMVs with QI above 0.9 have the least differences comparing with ECMWF model output. Considering EUMETSAT AMVs with QI above 0.9 have already simulated into the ECMWF analysis, this is expected. Since the NSMC scheme is independent from NWP output, reasonable larger differences may mean that there is information in the NSMC AMVs. It is also noticed that product ratio of EUMETSAT AMVs with QI above 0.9 is around 15%-- less than one third of the NSMC scheme.

For most comparison items, the NSMC scheme has smaller differences than EUMETSAT AMVs with QI above 0.6 and 0.75. This fact clearly shows ability of the NSMC scheme at producing good quality AMVs with high density. The product ratio of the NSMC scheme is normally above 50%. In low level EUMETSAT IR AMVs with QI above 0.6 and 0.75 have quite large differences compare with ECMWF output. The amount of low level IR AMVs produced by EUMETSAT scheme is also very limited especially in January 1-7 1999. On the other hand, NSMV AMVs are relatively more in number and closer to ECMWF model output. This may be due to the height assignment procedure adopted by the NSMC scheme.

6. Differences between AMVs and radiosonde wind vectors

Differences between AMVs and radiosonde wind vectors are compared. The comparisons with 0.01 significant level of statistics at F-tests were shown in table 3.

Table 3 Speed, Direction and Vector Differences of AMVs Versus Radiosonde Data above 0.01 Statistical Significant Level at F-tests

Channel Level	January Speed	January Dir.	January Vector	July Speed	July Dir.	July Vector
IR High Level	F/C	F/C C/G C/E	F/C C/E	C/F C/G C/E	C/G C/E	C/F C/G C/E
IR Middle Level		C/E C/G		F/C C/G C/E	C/G C/E	F/C C/G C/E
IR Low Level				C/G C/E	C/E	C/G C/E
WV High Level	C/G C/E	F/C C/G C/E	F/C C/G C/E	F/C C/G C/E		F/C
WV Middle Level	C/G C/E	F/C C/E	C/G C/E	C/G C/E	C/G C/E	C/G C/E

In each box of table 3, comparisons with statistical significance are shown. The schemes list as numerators are the ones with less difference compared with radiosonde data. In case the F-test is not passed, the related box remains empty. Table 3 shows that in general EUMETSAT AMVs with QI above 0.9 have the smallest difference compare with radiosonde data. But in July 1-7 1998 in high level, IR AMVs of NSMC have smaller differences compared with radiosonde data than the ones of EUMETSAT with QI above 0.9. In low level, the amount of EUMETSAT AMVs with QI above 0.9 is too small to get significant statistic results. This fact shows the good performance of NSMC scheme at IR channel especially in Northern Hemisphere summer. The good performance of NSMC IR winds at both high and low levels is explained because of the algorithm to distinguish high and low clouds before height assignment. This ability will be further verified in section 6. Table 3 also shows that for the comparison with radiosonde data in all the cases, NSMC AMVs have smaller differences than EUMETSAT AMVs with QI above 0.6 and 0.75. This will be further discussed in section 7.

7. Comparison of AMVs with Large Height Assignment Differences

In the same location (in 1-degree latitude/longitude), in case the height assigned by the two schemes exceed 400 hPa, pairs of data are picked out and compared with ECMWF wind vectors respectively. F-tests were performed at speed, direction and vector differences with ECMWF model output respectively. The comparison results above 0.01 significant level of statistics at F-tests were shown in table 4.

Table 4 Differences between ECMWF Data and IR AMVs Derived from NSMC and EUMETSAT for cases exceeding Height Assignment Differences of 400 hPa tested for a 0.01 Statistical Significant Level with an F-tests

Period	Speed	Direction	Vector
Jan.1-7 1999	C/F C/G C/E	C/F C/G C/E	C/G C/E
July1-7 1998	F/C C/G C/E	C/F C/G C/E	F/C C/G C/E

In each box of table 4, comparisons with statistical significance are shown. The schemes taken as numerators are the ones with less difference compared with ECMWF data. In case F-test not passed, the related box leaves empty. Table 4 shows, for the cases the two schemes give different height assignment for the IR channel, which scheme produces AMVs closer to the ECMWF model output. In both periods for all the comparison items NSMC AMVs are closer to ECMWF model output than EUMETSAT AMVs with QI above 0.6 and 0.75. In January 1-7 1999 NSMC scheme performs even better than EUMETSAT AMVs with QI above 0.9 at speed and direction comparisons. This comparison shows that NSMC scheme has a good ability for IR channel height assignment. This is because the NSMC scheme has a novel procedure to distinguish high and low clouds before height assignment.

8. Comparison of AMVs with Speed Difference

In the same location (in 1-degree latitude/longitude), in case the vectors tracked out by the two schemes exceed 6 m/s, pairs of data are picked out and compared with ECMWF wind vectors respectively. F-tests were performed at speed, direction and vector differences with ECMWF model output respectively. The comparison results above 0.01 significance level for the F-tests are shown in tables 5 and 6. Tables 5 and 6 are for IR and WV AMVs respectively.

Table 5: Differences between ECMWF Data and IR High Level AMVs Derived from NSMC and EUMETSAT with Speed Difference Exceed 6 m/s and above 0.01 Statistical Significant Level at F-tests

Period	Speed	Direction	Vector
Jan.1-7 1999	C/F C/G C/E	C/F C/G C/E	C/G C/E
July1-7 1998	C/G C/E	C/F C/G C/E	C/G C/E

The schemes listed as numerators are the ones with less difference compared with ECMWF data. In case F-test not passed, the related box leaves empty.

Table 6 Differences between ECMWF Data and WV AMVs Derived from NSMC and EUMETSAT with Speed Difference Exceed 6 m/s and above 0.01 Statistical Significant Level at F-tests

Period	Speed	Direction	Vector
Jan.1-7 1999	C/F C/G C/E	C/G C/E	C/G C/E
July1-7 1998	C/F C/G C/E	C/G C/E	C/G C/E

The schemes list as numerators are the ones with less difference compared with ECMWF data. In case F-test not passed, the related box leaves empty.

Tables 5 and 6 show, that in cases the two schemes give different tracking results, which scheme produces AMVs closer to the ECMWF model output. For all comparison items NSMC AMVs are closer with ECMWF model output than EUMETSAT with QI above 0.6 and 0.75. For some comparison items in some periods, NSMC AMVs are even closer with ECMWF model output than EUMETSAT with QI above 0.9.

9. Conclusion and Summary

Major comparison results are as follows:

- For the IR channel the NSMC scheme and EUMETSAT scheme with QI 0.75 have similar product ratio around 50%. For WV channel, NSMC scheme and EUMETSAT scheme with QI 0.6 have similar product ratio around 55%. EUMETSAT scheme with QI 0.9 have much smaller product ratio (around 15%) than NSMC scheme (around 50%).
- Comparison between AMVs of the two schemes shows no major differences. All the ABM direction differences are less than 10 degrees. ABM speed and vector differences are normally less than 3 m/s.

Comparison with ECMWF model output and radiosonde data

- Comparing with ECMWF model output and radiosonde data, EUMETSAT AMVs with QI above 0.9 have the smallest differences, however at the expense of supplying a smaller amount of data. For most comparison items, NSMC AMVs are closer to the ECMWF model output and radiosonde reports than EUMETSAT AMVs with QI above 0.6 and 0.75. This fact clearly shows ability of the NSMC scheme to produce good quality AMVs with high density.

Comparison to IR tracers at same location but being assigned by the two scheme with different heights.

- In case the two schemes give different heights using the IR channel, NSMC AMVs are closer to ECMWF model output than EUMETSAT AMVs with QI above 0.6 and 0.75. In January 1-7 1999 NSMC scheme performs even better than EUMETSAT AMVs with QI above 0.9 at speed and direction comparisons. This comparison shows that NSMC scheme has a good ability for IR channel height assignment. This is because the NSMC scheme distinguishes high and low clouds before height assignment.

Comparison to tracers at same location but being tracked as to have different motion

- In case the two schemes give different tracking results, NSMC AMVs are closer with ECMWF model output than EUMETSAT AMVs with QI above 0.6 and 0.75. For some comparison items in some periods, NSMC AMVs are even closer with ECMWF model output than EUMETSAT with QI above 0.9. This is because the NSMC scheme performs quality control and optimisation at the tracking and the step when horizontal consistency examined. At tracking step, a most consistent pair is chosen from the two largets correlation peaks. For the horizontal consistency examination height assignment results are adjusted by re-selecting results previuosly rejected. Quality control and optimisation at each component of the data processing give contribution to dense data with good quality.

Figure 1 supplies samples of AMV products from the two schemes. In general EUMETSAT AMVs with QI above 0.90 have the smallest difference in comparison to ECMWF model output and radiosonde reports. But EUMETSAT AMVs with QI above 0.90 supply less data. NSMC AMVs are closer to ECMWF model output and radiosonde reports than EUMETSAT AMVs with QI above 0.6 and 0.75.

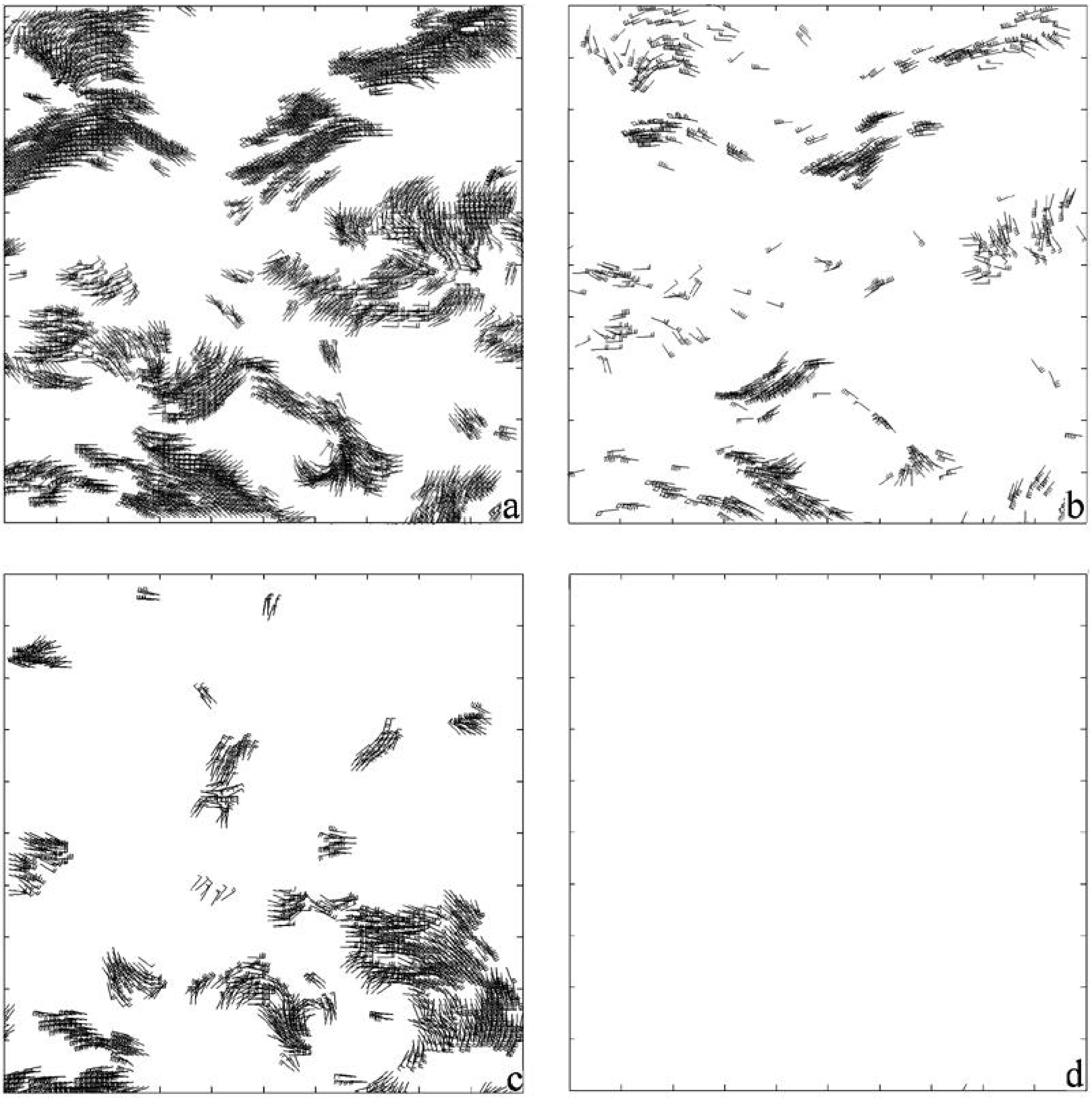

Fig.1 IR AMVs at 1200Z January 3 1999 a) High level AMVs derived by NSMC b) High level AMVs derived by EUMETSAT scheme with QI 0.9 c) Low level AMVs derived by NSMC d) Low level AMVs derived by EUMETSAT scheme with QI 0.9

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