USING MULTIPLE CHANNELS FROM MSG TO IMPROVE ATMOSPHERIC MOTION WIND SELECTION AND QUALITY

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ABSTRACT

In this case study, atmospheric motion winds (AMWs) have been calculated in the tropics (West-Africa and tropical Eastern-Atlantic) from images in the different channels of the first of Meteosat Second Generation satellites, Meteosat-8.

AMW fields of selected channels have been compared and differences between vector fields have been highlighted. The 0.6 µm visible channel (VIS 0.6) and the 10.8 µm infrared channel (IR 10.8) were found to provide the highest number of cloud motion vectors (CMVs) at low levels, and at all levels respectively. These two channels have then been used as reference. In some cases (VIS 0.6 vs VIS 0.8 channels, IR 10.8 vs IR 12. channels), both vector fields are almost identical. Among the tested channels, the water vapour 7.3 µm channel (WV 7.3) provides the highest coverage with new motion vectors, when compared to the AMW fields of the VIS 0.6, WV 6.2 and IR 10.8 channels (which have a close spectral coverage to the channels available on the first generation of Meteosat satellites). Fewer CMVs are extracted in the 3.9 µm IR channel than in the IR 10.8 channel, even during the night.

1. INTRODUCTION

The Meteosat Second Generation (MSG) satellite provides new and improved imagery in comparison to the Meteosat satellites of the first generation (Schmetz et al., 2002) (Meteosat-1 to 7 have been launched between 1979 and 1997). Images in 11 channels with a 3 km resolution at subsatellite point and one high-resolution visible channel (HRV) with a 1 km resolution are retransmitted every 1/4 h from the Meteosat-8 satellite (the first of the MSG satellite series). This potentially enables 68 comparisons between wind fields from two different channels.

A preliminary study has already shown the benefits resulting from the reduction of the time interval between images from 30 min (the nominal time interval for the first Meteosat satellites) to 15 min (for MSG) for low-level winds in the tropics (Szantai and Désalmand, 2003). The current study focuses on differences in cloud and atmospheric structure tracking in the different channels at all levels. The data used in this case study and the atmospheric motion vector (AMV) calculation method are described briefly in the first place. We will then evaluate cloud motion vectors (CMVs) observed in two channels used as reference, the visible 0.63 µm channel (VIS 0.6) and the thermal infrared channel at 10.8 µm (IR 10.8). Comparisons of AMVs (i.e. vectors tracing the motion of clouds and other non-cloudy atmospheric structures such as pure water vapour structures) between these two channels and seven other "new" channels will then be undertaken. A final comparison between AMVs from the two channels in the water vapour absorption band around 6.5 µm (WV 6.2 and WV 7.3) will show the new features tracked in the latter channel.

2. DATA AND METHODOLOGY

AMV calculations have been limited to one case (2 May 2003, at 12:00 UTC). This study focuses on an area over the tropical eastern Atlantic and West-Africa, i.e. between 40°W and 20°E, and from 0° to 18°N approximately. It corresponds to the beginning of the rainy season over this part of the African continent (at latitudes below 10°N), thus convective systems are small and not numerous on that day.

Among the 68 possible comparisons between AMV fields from two channels, we limited this study to 8 cases: two cases involving the visible and near-infrared (at 1.6 μm) channels, 5 cases involving the 6 infrared channels (non "water vapour" channels, with central wavelength above 3 μm) and a comparison between the two water vapour channels. (Vectors from the HRV channels were not examined in this study.) Each AMV field has been calculated according to the following methodology:

- Two AMV fields are calculated from a triplet of images (at 11:45 - 12:00 and 12:15 UTC). Vectors are calculated with the Euclidean distance method.
- Target and search windows used for vector calculation have a size of 12 x 12 pixels (36 x 36 km), and 52 x 52 pixels (156 x 156 km) respectively. These windows cover a smaller area than their counterparts extracted operationally (target windows of 24 x 24 or 16 x 16 pixels are used by EUMETSAT to extract their AMV product from Meteosat-8 images).
- A regular grid with 12 pixels (36 km) between neighbouring gridpoints. As a consequence, target windows do not overlap.
- A series of quality tests extract reliable vectors. These tests remove too small vectors and very large vectors. Temporal and spatial consistency checks are then applied on vector speed and direction.
- No height is determined or assigned to AMVs. As a consequence, the complete extraction and selection procedure of AMVs is less severe than normal procedures used in operational conditions. Nevertheless, a vast majority of AMVs obtained from our methodology forms large groups of consistent vectors.

3. CLOUD MOTION WINDS IN THE VIS 0.6 AND IR 10.8 CHANNELS

The first CMV fields have been extracted from images in the VIS 0.6 and IR 10.8 channels (Fig. 1). These channels have an equivalent (but narrower) spectral band to (than) their VIS and IR counterparts on the first generation of Meteosat satellites. These vectors have been compared to regridded analysed NCEP winds (from a 2.5° x 2.5° original grid and 10 tropospheric pressure levels between 1000 and 200 hPa) and their best-fit pressure level has been determined. On figure 1, vectors are colour-coded as a function of this pressure level.

The VIS 0.6 vector field is dominated by low-level winds (P ≥ 700 hPa) over the ocean, and in areas over land close to the coast (below 10°N). A few medium- or high-level clouds can be observed over land, in particular around (0°E, 12°N). Over the ocean, medium/high-level CMVs are found mainly on or around convective systems, around (5°W - 5°E, 2.5°N) and (18°W, 2.5°N).

The IR 10.8 vector field shows a similar coverage with slightly fewer low-level winds, but with areas with denser medium/high-level winds over the ocean. Over land, a south-westerly flow around (12°W, 15°N) is revealed by numerous vectors apparently associated to relatively thin cirrus clouds. Similarly, a dense group of vectors highlights a south-westerly to north-westerly flow associated to cirrus clouds and complements the group of vectors observed in the VIS 0.6 channel around (0°E, 12°N). The best fit at a medium level observed for the group of vectors over land around (0°E, 6°N) is questionable. At these levels (400 - 500 hPa), NCEP analysed winds are slow and visually these CMVs more likely represent the low-level flow.

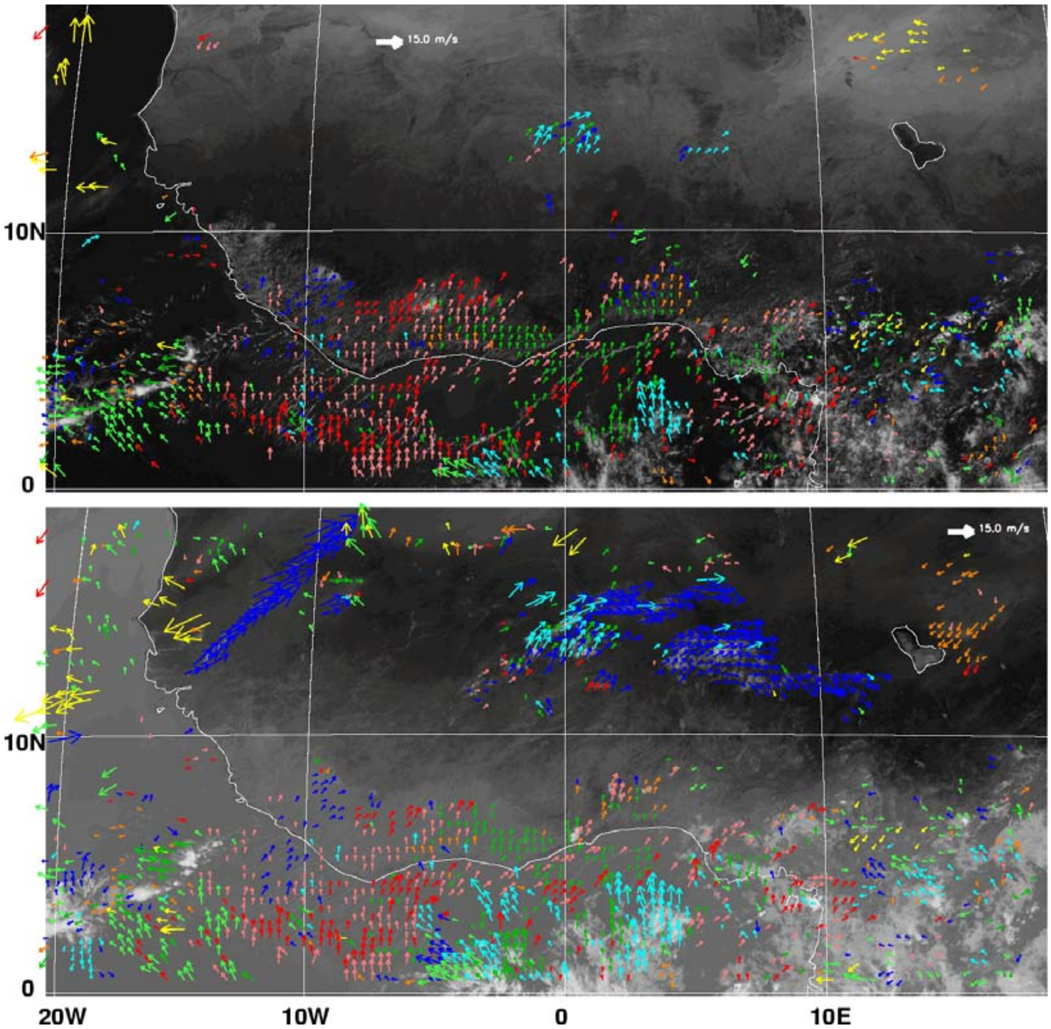

Figure 1: cloud motion winds in the VIS 0.6 (top) and IR 10.8 (bottom) channels at 12:00 UTC. The colour code of the vectors corresponds to the best fit level with NCEP analysed winds : 1000 - 925 - 850 (orange) - 700 (yellow) - 600 - 500 - 400 - 300 - 250 - 200 hPa.

4. COMPARISON OF VISIBLE AND NEAR-INFRARED CLOUD MOTION WIND FIELDS

For each comparison of two vector fields, the first one (generally the VIS 0.6 or the IR 10.8 CMV field) is used as a reference. The following parameters are calculated:

- The percentage of common (collocated) vectors, using the first vector field as a reference.
- The bias, i.e. the average speed difference of common vectors :

$$\mathbf{bias} = \overline{|\mathbf{V}_2|} - \overline{|\mathbf{V}_1|}$$

- The normalised RMS vector difference (NRMSD), i.e. the root mean square vector difference divided by the average speed of the first vector field (for common vectors) :

$$\mathbf{NRMSD} = \frac{\sqrt{\overline{|\vec{\mathbf{V}}_2 - \vec{\mathbf{V}}_1|}}}{\overline{\mathbf{V}}_1}$$

The results of these comparisons are summarised in table 1. Important values of bias and NRMSD as well as low percentages of common vectors indicate different motions of clouds or air masses and / or motions at different levels.

VIS 0.6 vs VIS 0.8 vector fields

These two vector fields are almost similar, with a high percentage (93 %) of common vectors, and the smallest values of bias and NRMSD (table 1). No important group of vectors present in only one channel can be observed.

Channel 1 (reference)	NV1	<V1common> (m/s)	Channel 2	NV2	NVc common vectors	% common vectors	Bias (m/s)	NRMSD (%)
VIS 0.6	2872	7.63	VIS 0.8	2824	2667	92.9	-0.01	7.0
VIS 0.6	2872	7.66	NIR 1.6	2821	2490	86.7	0.03	14.1
IR 10.8	3373	8.08	IR 12.	3247	2944	87.3	0.05	10.4
IR 10.8	3373	8.41	IR 13.4 (CO2)	2475	2130	63.2	0.18	20.0
IR 10.8	3373	7.99	IR 9.7 (O3)	3100	2775	82.3	-0.04	13.2
IR 10.8	3373	8.04	IR 8.7	3263	2916	86.5	-0.05	12.3
IR 10.8	3373	8.81	IR 3.9 (day)	2411	2001	59.3	-0.01	30.2
IR 10.8	3580	8.51	IR 3.9 (night)	3305	2797	78.1	-0.18	26.1
WV 6.2	2945	8.91	WV 7.3	2823	1720	58.4	-0.39	47.1

Table 1. Comparison of pairs of AMV fields (NV1, NV2 and NVc are the number of vectors).

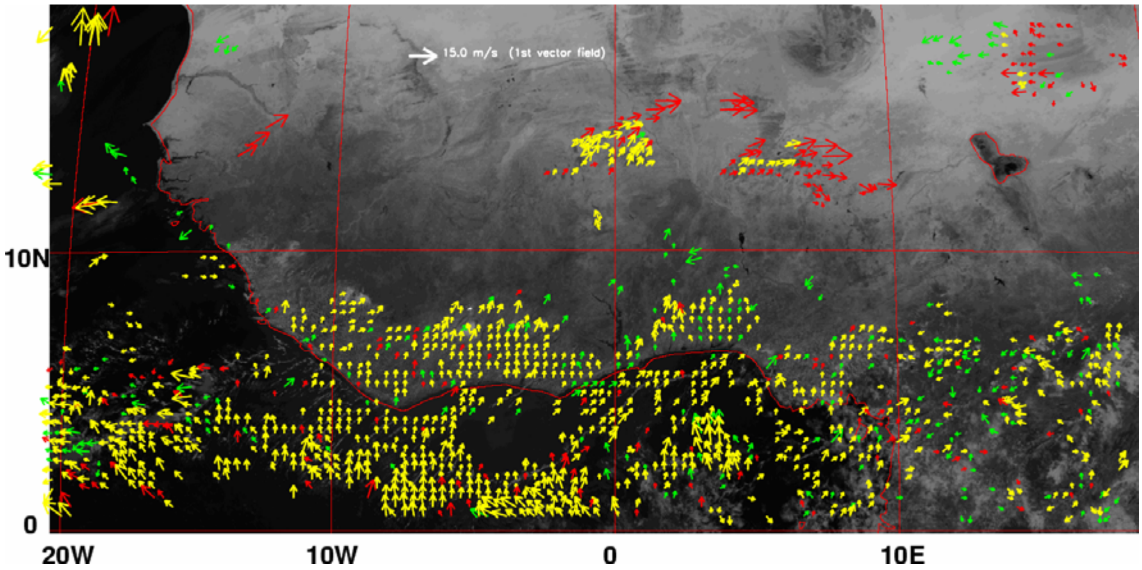

Figure 2: green : VIS 0.6 CMVs only; red : NIR 1.6 CMVs only ; yellow : common vectors. NIR 1.6 image.

VIS 0.6 vs NIR 1.6 vector fields

A large majority of CMVs are common again (yellow vectors on fig. 2), but with larger differences than in the previous comparison (NRMSD of 14 % instead of 7 %). Figure 2 shows that the number of low-level winds (below 10°N) is slightly less important, whereas the number of high-level wind in the group around (0°E, 12°N) is more important than in the VIS 0.6 vector field.

5. COMPARISON OF INFRARED CLOUD MOTION WIND FIELDS

IR 10.8 vs IR 12 vector fields

These two thermal infrared channels centred at 10.8 and 12.0 µm, also called the split-window channels, can help to detect low-level humidity and some types of cirrus clouds. This case leads to similar conclusions to the VIS 0.6 - 0.8 comparisons : both vector fields are very close in number with a high percentage of common vectors (87 %), and minor differences between common vectors (bias < 0.1 m/s and NRMSD ≈ 10 %) (table 1 and fig. 3). Minor regional differences between both vector fields can be observed in ocean areas close to the West-African coast (between (12°W, 8°N) and (16°E, 18°N)).

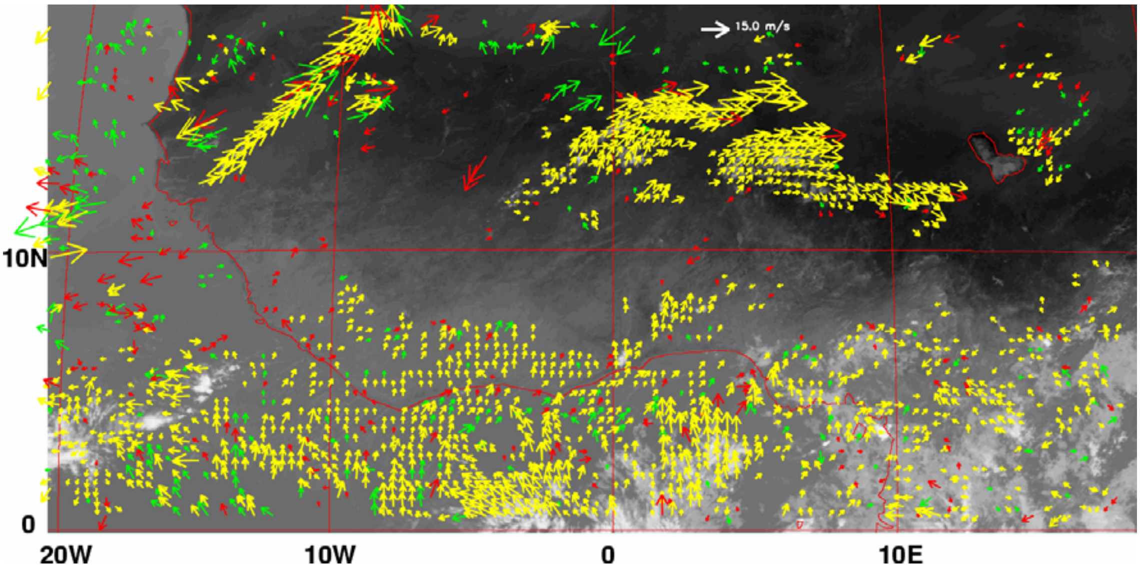

Figure 3: green : IR 10.8 CMVs only ; red : IR 12.0 CMVs only ; yellow : common vectors. IR 12.0 image.

IR 10.8 vs IR 9.7 and IR 8.7 vector fields

The IR channel centred at 9.7 µm is sensitive to absorption by ozone (O_3) in the lower stratosphere. The IR channel centred at 8.7 µm is another window channel, potentially useful for the extraction of thin cirrus clouds and for the ice / water cloud discrimination. In these two channels, vectors are in smaller number than in the IR 10.8 channel. The number of common vectors and the values of bias and NRMSD are intermediate between those of the split-window comparison and those of the IR 10.8 - IR 13.4 vector field comparison (see hereafter). No regional trend can be observed, except a denser group of vectors close to the West-African coast (between (15°W, 8°N) and (18°W, 18°N) approximately) extracted only in the IR 10.8 channel.

IR 10.8 vs IR 13.4 vector fields

The IR channel centred at 13.4 µm is sensitive to absorption by CO_2 in the troposphere. It can be used (with at least one other IR channel) in particular to assign the height of cirrus clouds after the determination of their cloud top temperature with the "CO_2 slicing" method. In this comparison, denser groups of low-level CMVs are detected in the IR 10.8 channel, mainly over sea and over land along the coast (around 5°N), and at the east of Lake Chad (15°E, 15°N) (fig. 4). On the other hand, more high-level winds are extracted in the IR 13.4 channel, mainly around the two groups of vectors tracking cirrus clouds (around 15°N), making these groups thicker. This indicates that the tracking of thin cirrus clouds, located on the edges of thicker cirrus is done more easily in the IR 13.4 (CO_2) channel. Common vectors are less numerous (63 %) and differences between common vectors are more important (bias = 0.18 m/s and NRMSD = 20 %) than in the previous comparisons between IR channels.

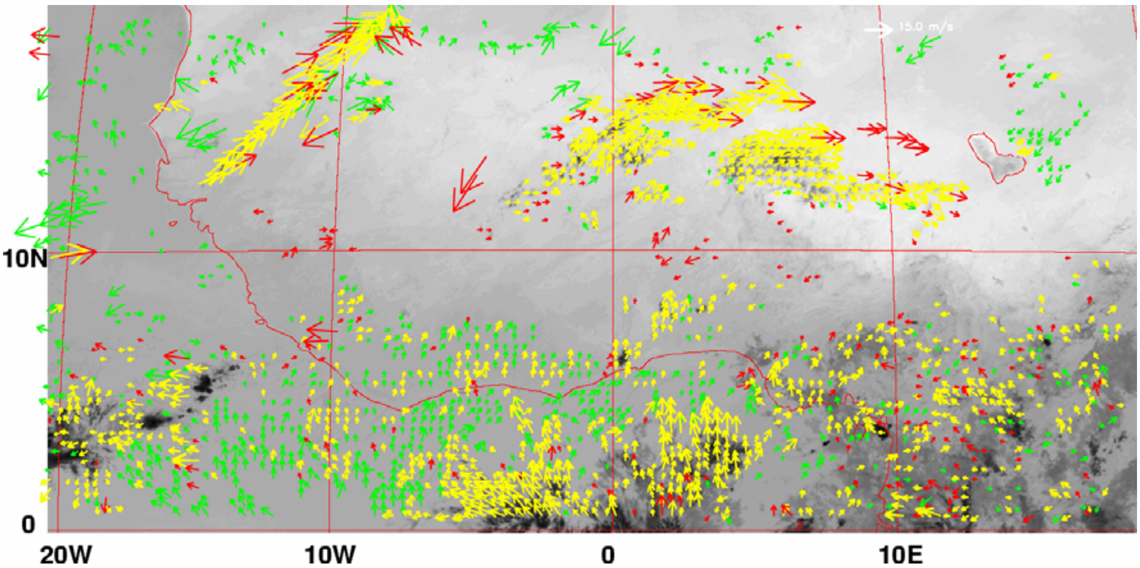

Figure 4: green : IR 10.8 CMVs only ; red : IR 13.4 CMVs only ; yellow : common vectors. IR 13.4 image.

IR 10.8 vs IR 3.9 vector fields

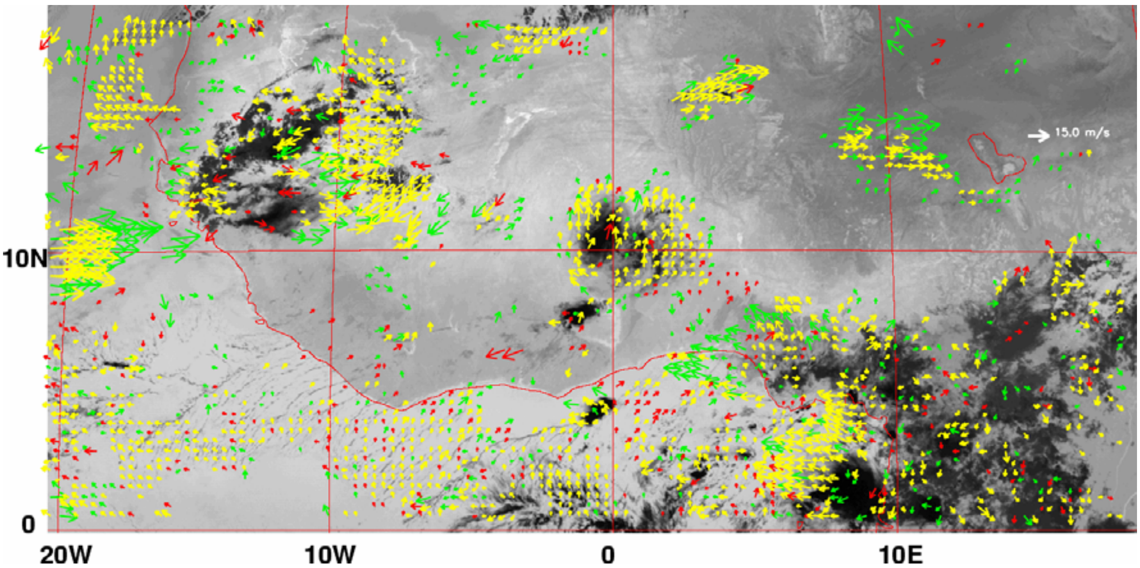

Figure 5: green : IR 10.8 CMVs only ; red : IR 3.9 CMVs only ; yellow : common vectors. IR 3.9 image at night (3 May 2003, 0:00 UTC).

The medium-IR detector, with a band of wavelength centred at 3.9 µm, receives a mixture of solar and terrestrial radiation during daytime, and only terrestrial radiation during the night. It is in this channel that the smallest number of vectors has been extracted. Large groups composed mainly of low-level vectors (below 10°N) and a part of the mainly high-level clouds (above 10°N) present in the IR 10.8 channel are not extracted in the IR 3.9 channel. Relatively important differences between common vectors (representing only 59 % of all IR 10.8 vectors) are indicated by the high value of the NRMSD (30 %).

A second comparison between vector fields calculated during nighttime (on 3 May 2003, 0:00 UTC) was then undertaken (Fig. 5). A higher value in the percentage of common vectors (78 %) and a lower value of the NRMSD (26 %) indicate that differences between the IR 3.9 and 10.8 channels are smaller than in the daytime case, but still important.

6. THE WATER VAPOUR ATMOSPHERIC MOTION WIND FIELDS

The two channels with central wavelengths at 6.2 and 7.3 µm cover parts of an absorption band due to tropospheric water vapour. The WV 6.2 channel has the peak of its contribution function around 350 hPa, whereas the WV 7.3 channel can detect atmospheric structures at lower levels, due to its contribution function peak around 600 hPa.

Fig. 6 shows that the tracking of high-level clouds or pure water vapour structures is more efficient in the WV 6.2 channel than in the WV 7.3 channel. In particular, the two main groups of high-level vectors (located north of 10°N, and also observed in the other IR channels) are broader and denser in the WV 6.2 channel. This likely indicates the tracking of thin cirrus or pure (high-level) water vapour structures, not observable in the WV 7.3 channel. On the other hand, an easterly flow is observed at a low level in a dry area at the north-west of Lake Chad (10°E, 15°N) only in the WV 7.3 channel. No clouds were tracked in this area in the other VIS or IR channels. Mainly medium-level vectors are detected only in this channel and not in the WV 6.2 channel : a southerly flow over the south-east of Nigeria (7°E, 5°N), an easterly flow off the coast of Guinea (15°W, 10°N) and a south-westerly flow east of Lake Chad (15°E, 15°N).

The relatively small proportion of common vectors (58 %) and the high value of the NRMSD (47%) indicate that different structures are more likely to be tracked in the two water vapour channels than in the IR 10.8 + another IR channel. The relatively large value of the bias (|bias| = 0.39 m/s) indicates that the AMVs deduced from the WV 6.2 channel tend to be stronger than those measured in the WV 7.3 channel, due to a location at a higher level for a part of them.

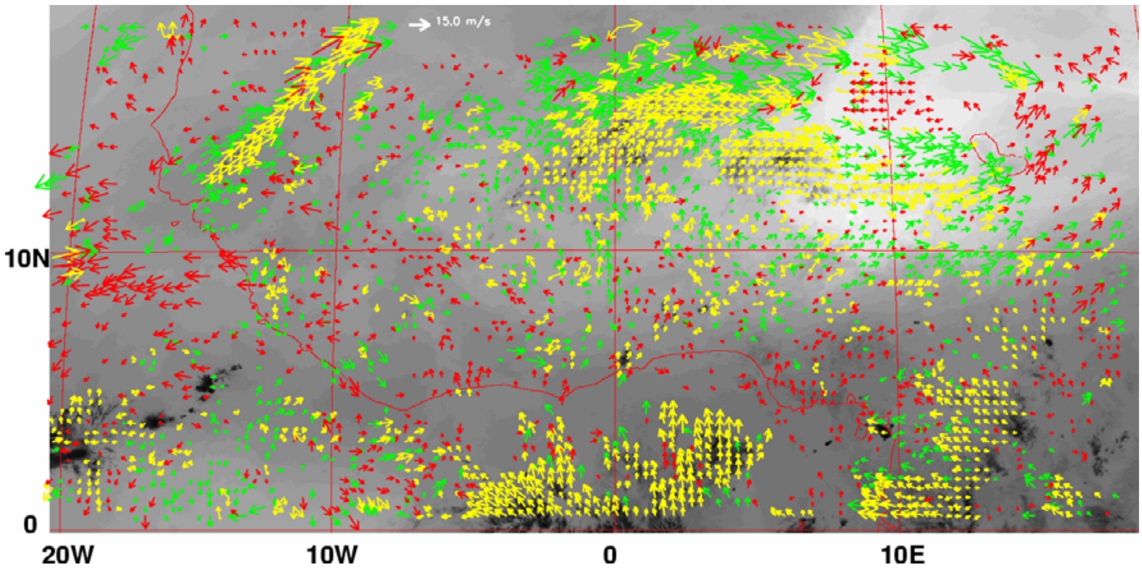

Figure 6: green : WV 6.2 AMVs only ; red : WV 7.3 AMVs only ; yellow : common vectors. WV 7.3 image (areas with lowest midtropospheric humidity are white).

7. CONCLUSIONS

This case study confirms that the tracking of clouds and other atmospheric structures is feasible with all MSG channels in the tropics. The most interesting channels, i.e. which allow the extraction of the densest vector fields at some levels, are the channels equivalent to the three available on the first Meteosat satellites, but with a narrower band of wavelength. The VIS 0.6 and VIS 0.8 channels perform the most efficient extraction of low-level winds (excellent also in the IR 10.8 channel). The IR 10.8 allows the overall best tracking of clouds, in comparison to all the other IR channels (IR 3.9, 8.7, 9.7 (ozone), 12 and 13.4 (CO_2) channels).

Besides the tracking of high-level clouds, the WV 6.2 channel also allows the tracking of upper tropospheric humidity, as the WV channel from the Meteosat of the first generation did. The innovation comes from the "new" WV 7.3 channel, which enables the tracking of pure water vapour structures at low level in dry areas and also at medium level (500 - 600 hPa).

Denser groups of high-level CMVs are extracted in the IR 13.4 (CO_2) channel, in comparison to the IR 10.8 channel. This indicates an improved capacity to track thin cirrus clouds, on the edge of thicker high-level clouds. Whether these new IR 13.4 vectors are different from the vectors extracted in the WV 6.2 channel has still to be checked.

The IR 3.9 channel is disappointing for the tracking of clouds. A better tracking of low-level clouds in particular was expected especially during nighttime, as it has been observed on GOES 3.9 µm images (Dunion and Velden, 2002). The coverage by low-level vectors is close in both MSG IR 10.8 and 3.9 channels, and the tracking of high clouds produces more vectors in the IR 10.8 channels.

In the future, we plan to improve the selection and extraction of AMVs according to their level. The cross-correlation between target windows of different channels, and quality tests between collocated vectors of different channels could help to select vectors at specific (groups of) levels. A more precise height assignment based on usual methods (extraction of brightness temperature of cloud tops, H_2O / IR window and CO_2 slicing methods) and non-satellite data (temperature profiles) may then provide "complete" vectors (including the height parameter).

8. REFERENCES

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