# STATUS OF ATMOSPHERIC MOTION VECTORS AT ECMWF

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**ABSTRACT**

An update on the status of the monitoring and use of AMVs at ECMWF is presented, with a particular focus on Meteosat 8 AMVs, which have been assimilated operationally at ECMWF since June 2005. Other monitoring and assimilation activities have included the transition from GOES 9 to JMA's MTSAT-1R and the arrival of a new product from CMA's FY-2C.

The impact of the transition from Met-7 to Met-8 on the ECMWF forecast was found to be overall relatively neutral. Met-8 provides us with an extra water vapour channel (7.3µm) and a considerable increase in AMVs as a result of higher temporal and spatial resolution. Monitoring of Met-8 winds has suggested using a more severe QI than for Met-7. The increased number of channels compared to previous Meteosat satellites enables changes to be made to the height assignment techniques. A limited study was carried out to assess the impact of a modification made to the $CO_2$ slicing height assignment technique used operationally by EUMETSAT in the production of Met-8 AMVs.

JMA switched the production of AMVs from GOES-9 to MTSAT-1R mid-July 2005. We present some monitoring and impact trials against ECMWF's model background, using the recommended QI ≥ 85. Some preliminary statistics are also shown for the newly available CMA's FY-2C AMVs. Finally, a brief mention is given to the reprocessing of Meteosat AMVs in ECMWF's interim reanalysis.

## I. INTRODUCTION

Since the 7th International Winds Workshop, several changes have taken place at ECMWF including the assimilation of AQUA MODIS winds, the transition from using Meteosat-7 to Meteosat-8, the arrival of MTSAT winds and termination of GOES-9 AMV usage over the west pacific region and the very recent new acquisition of FY-2C winds.

## II. METEOSAT-8

The first satellite of EUMETSAT's Meteosat Second Generation satellites, Meteosat-8, became operational on the 29th January 2004. By mid-February, AMVs derived from Meteosat-8 were included into ECMWF's data assimilation system in passive mode. Operational monitoring began on the 9th March 2004 and on the 28th June 2005, ECMWF began to assimilate Meteosat-8 AMVs operationally instead of Meteosat-7 winds which remained as backup. Meteosat-8 provides us with a larger number of AMVs than its predecessor as a result of higher temporal and spatial resolution. AMVs are produced hourly, derived from cloudy and clear-sky targets in the WV (6.2 µm and 7.3 µm), and cloud winds in the IR (10.8 µm) and VIS (0.8 µm) from 15 minute imagery.

### 2.1 Impact and use of Met-8 winds AT ECMWF

The arrival of the new Met-8 winds required a revision of the quality control and blacklists to take into account the new data characteristics, additional channels, and the larger amount of winds being processed. Comparisons of wind statistics against QI between Met-7 and Met-8 winds were found to have relatively small differences (von Bremen, 2005). A monitoring study of Met-8 AMVs (von Bremen, 2005) nevertheless suggested using a higher QI threshold (85) than for Met-7. In spite of this, the Met-8 winds still outnumbered those of Met-7. The same thinning process was chosen as for Met-7, one wind selected per thinning box (200kmx200km) and timeslot. The wind is selected according to its QI and to the closeness between the observation time and the model background time.

An impact trial was set up to analyse the forecast impact of assimilating Met-8 AMVs instead of Met-7 AMVs. The experiment used ECMWF's 4DVAR data assimilation system with model resolution T511 and 60 levels in the vertical and an incremental analysis resolution of T159. The experiment was conducted for a period of 89 days (2 Dec 2004 - 28 Feb 2005). 10 day forecasts were computed from every 12Z analysis and were verified against the operational analysis. The control for this experiment was the operational suite (IFS cycle 28r4) which still assimilated Met-7 AMVs.

The exact selection characteristics for the experiment are listed in the following blacklist:

**QI ≥ 85 for all winds**
**IR**: no winds between 700 and 460hPa
**VIS**: no winds above 700hPa level
**WV cloud 6.2**: no winds below 400hPa level
**WV cloud 7.3**: no winds below 600hPa level
**WV cloud and IR**: no winds below 250hPa level in the Tropics (25S-25N)

Figure 1 shows the zonal mean of OBS-FG bias for Met-8 IR channel for a period of 3 days. (a) shows the wind biases for the winds with a QI>60 (a relaxed threshold, closer to that attributed to Met-7 winds) while (b) shows the "used" AMVs in the impact experiment. Note that the "used" winds will also have been subject to the first guess check. This figure clearly illustrates the restrictions imposed by the new blacklist which successfully excludes the areas of large biases.

## Forecast Impact

Forecast impact results from an 89 day experiment are presented here. The new Met-8 winds perform slightly better than the control in the Northern Hemisphere (NH), slightly worse in the Southern Hemisphere (SH) and are relatively neutral in the Tropics (e.g. Fig. 2). The root mean square errors for the 200hPa winds in the Tropics are minimal. The 500 hPa geopotential height anomaly correlation forecast scores show the score differences to be significantly positive on day 4 in the NH and significantly negative for the first 4 days for the SH.

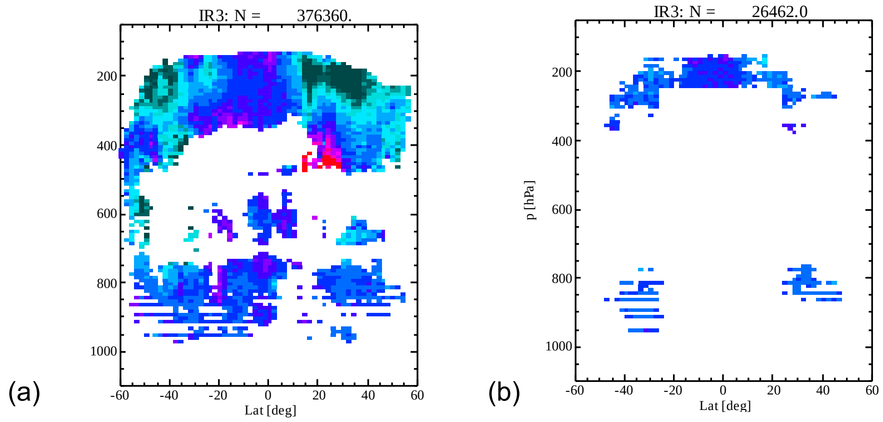



**Figure 1: Zonal mean of OBS-FG bias (m/s) for Met-8 IR for the period 2 Dec 00 UTC - 4 Dec 18 UTC 2004. (a) shows all the winds with QI > 60 (b) the "used" AMVs in the experiment.**

It was concluded that it was safe to introduce Met-8 AMVs operationally. The fact that the forecast impact was not as impressive as might have been expected suggests that more needs to be done in order to make maximum use of the Met-8 products. The thinning strategy is one aspect to consider in the future, for example. Bormann *et al*. (2003) have shown the potential problems of not considering

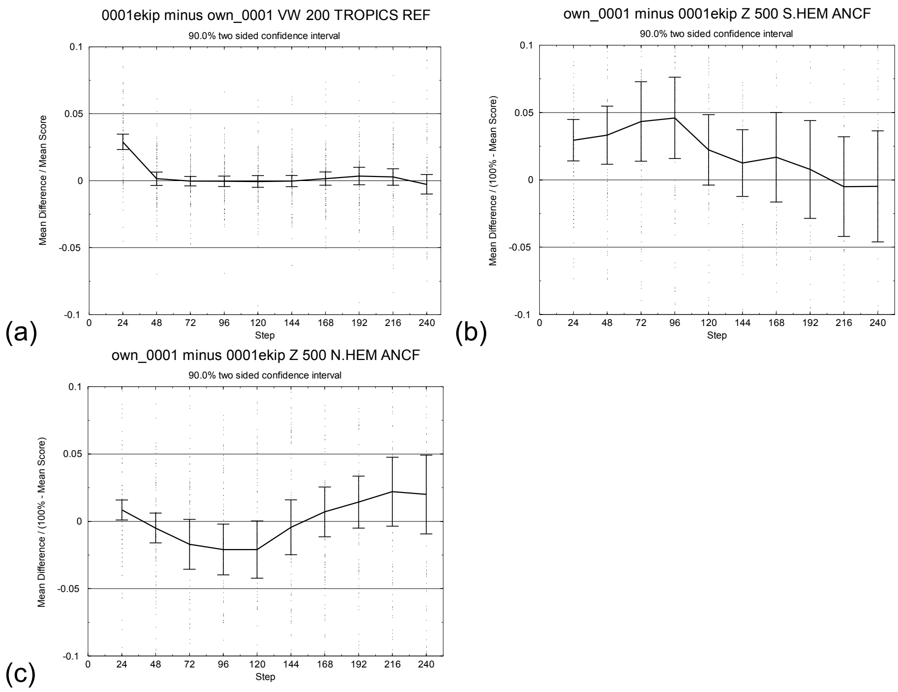



**Figure 2: (a) Differences in wind root mean square forecast error scores for between the control (own_0001) and experiment (0001ekip) for up to forecast day 10 for the Tropics at 200 hPa. Differences in geopotential height anomaly correlation forecast scores for the (b) SH and (c) NH at 500 hPa. The differences are normalised by (100% - mean score), where the mean score is calculated with the data from both experiment and control. The error bars show the confidence interval (90%) of the mean difference computed from 89 cases.**

horizontal error correlations in the system, a problem which could now be exacerbated by the increased number of winds in the system. EUMETSAT are also continuing to work on height assignment issues and further quality improvement.

## 2.2 Height assignment change

Several height assignments have been investigated by EUMETSAT, making use of the additional channels available from Met-8 (Borde and Arriaga, 2004 and de Smet, 2004). The current operational set up uses only a subset of the available height assignment methods. One of the two used operationally, the $CO_2$ slicing technique, makes use of a channel centred in the $CO_2$ absorption band at 13.4 µm on the SEVIRI instrument. The method (Niemann *et al*. 1993) requires the emissivities and cloud fractions of two channels to be close in value. The 13.4 µm channel is therefore used in combination with another IR channels also available on Met-8: 10.8 or 12.0µm. Borde and Arriaga (2004) showed a good correlation between the different combinations of channels and found that the heights produced could be close to within 20hPa of each other. Until the 1st Dec 2005 the 10.8/13.4µm combination was implemented operationally. However the method tended to assign winds too high (personal comm. Jörgen Gustafsson) and this prompted EUMETSAT to review the choice of channels. The 12.0/13.4µm combination, with the closest cloud emissivities, was expected to produce better results. This was confirmed by height assignment studies based on the collocation of several satellites (Preusker *et al*. (2005)), and the collocation of radiosondes and satellite (personal comm. Jörgen Gustafsson).

Monitoring and impact trials were carried out at ECMWF in order to test the forecast impact of changing these channels. BUFR Met-8 winds with heights calculated from the EBBT and the new 12.0/13.4 µm $CO_2$ slicing method, were made available by EUMETSAT for a period of 14 days: 3-16 May 2005. We note that a study of such a short period was inadequate for a thorough impact assessment. The control for the experiment was the operational Met-8 winds which used the original operational height assignments (EBBT and 10.8/13.4 µm $CO_2$ slicing method).

**Monitoring experiment**

A monitoring experiment was first carried out with ECMWF's 29r1 IFS cycle (T511 L60) for the 14 days during which the winds were included in the ECMWF's data assimilation system in passive mode. As the $CO_2$ slicing method is predominantly applied to winds above 253K, high level winds were expected to be affected. The monitoring experiment showed this to be the case, with changes observed in both the 7.3WV (Figure 3) and 10.8IR (not shown) at level 400-0hPa. The NH and SH show a better agreement with the first guess as the negative bias is reduced. The Tropics, a region where the fast and slow biases compensate each other subsequently revealed a small positive bias. In all cases, the standard deviations of the speed departures remain very close to those before the height assignment change. The reduction in the slow speed bias over the Extra-tropics is consistent with the finding that the change in the $CO_2$ slicing method lowers the high level winds.

Looking more specifically at the results, the mean vertical profile of the u-component of the wind bias (not shown) was found to show an increase in the number of Met-8 AMVs at mid levels, accompanied by a decrease at high levels. This further supports the expected lowering of upper level winds.

The change in height assignment also led to more symmetric distributions of observation vs first guess wind speed at high levels over Extratropics (not shown). The implication of this is that the asymmetric first guess check may need to be revised as penalising the slow negative bias winds is no longer appropriate.

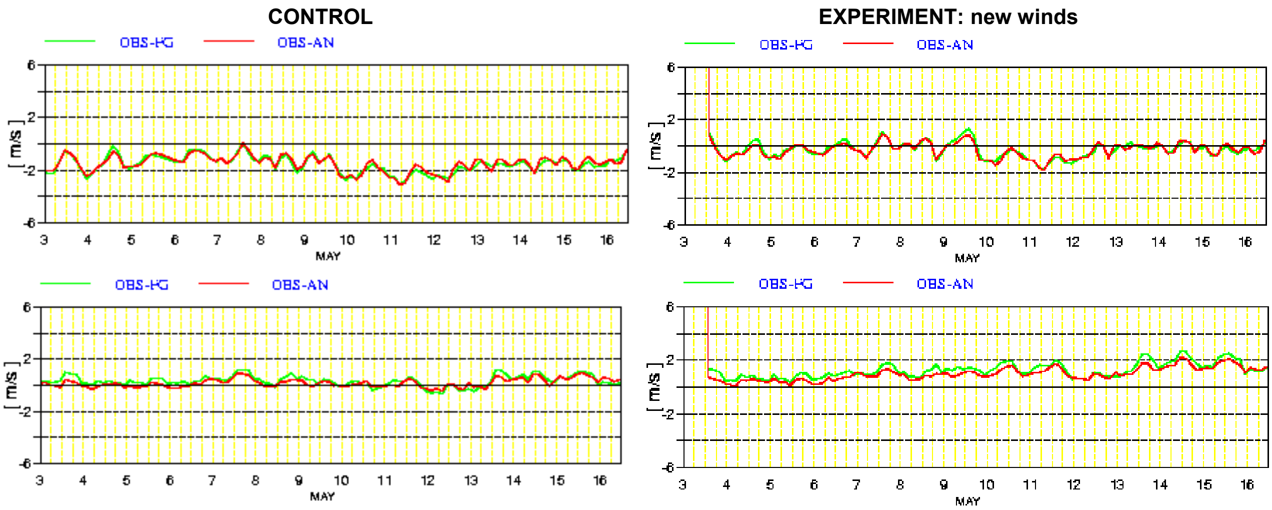



**Figure 3: Timeseries of 7.3µm water vapour AMV departures and standard deviations for NH (top) and Tropics (bottom). A QI>80 has been applied. The left hand column corresponds to the control (operational Met-8 winds) and the right hand column to the new Met-8 winds.**

**Forecast impact experiment**

The next step was to carry out an impact study to assess the $CO_2$ slicing method change on ECMWF's forecast. The experiment was set up using ECMWF's 4DVAR data assimilation system and run using IFS cycle 29r2 (T511 L60). 10 day forecasts were computed every 12Z and compared to ECMWF's operational analysis. The control was the operational suite (IFS cycle 29r2) that assimilated the original Met-8 winds. No further changes were made to the set up.

For the 14 day trial, the overall forecast impact of the new winds was found to be neutral. Differences in geopotential height anomaly correlation and wind vector RMS error forecast scores (not shown here) showed no significance at the 90% level, emphasising the problem of using a short dataset.

## III. MTSAT

On 28$^{th}$ June 2005, the Japanese Meteorological Agency (JMA) switched MTSAT-1R (140$^{0}$E) into operation. Its predecessor, GMS-5, had been discontinued on the 22$^{nd}$ May 2003 and replaced by

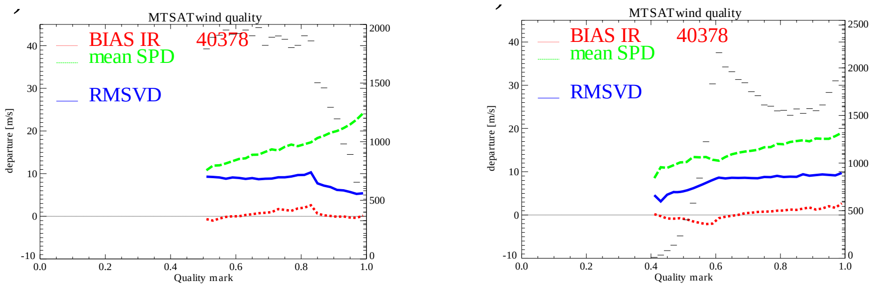
NOAA's GOES-9 (155$^0$E) satellite in the interim period. Dissemination of MTSAT-1R AMVs began on the 15$^{th}$ July 2005 but JMA encountered some navigational problems which impacted on the number of AMVs disseminated. Statistical comparisons conducted by JMA against rawinsondes supported the use of a stringent first guess dependent QI threshold of ≥ 85 for MTSAT.

JMA make available wind vectors with both model first guess dependent and independent QIs as a quality measure. These are based on the EUMETSAT QI scheme (Holmlund, 1998, and Holmlund *et al.*, 2001). ECMWF aims to use first guess independent QIs for all of its satellite AMV usage to minimise model dependency.

ECMWF are currently running without winds over the West Pacific while the analysis of MTSAT AMVs is underway. Results of monitoring and assimilation trials for periods over the NH summer are shown in this section, with a particular focus on comparing the performance of selecting winds using the first guess dependent (fg-QI) and independent QIs. The NH winter will be analysed at a later date.

**Monitoring**

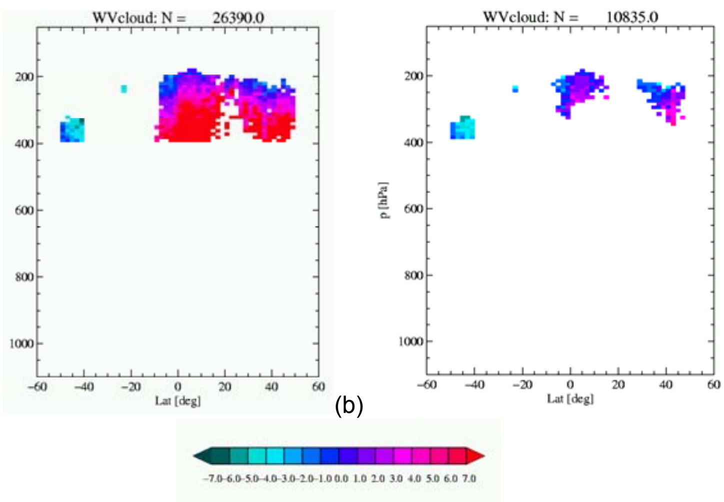
MTSAT winds were monitored passively in order to view their quality prior to running an assimilation trial. The experiment ran from the 20 July - 3 Aug 2005 and used ECMWF's model cycle 29R2 (T511, L60). The wind statistics against fg-QI for the NH IR winds (Figure 4(a)) show the root mean square vector difference (RMSVD) dropping significantly at the 80/85 QI mark. A similar trend is found for the cloudy WV winds and for the Tropical regions. The SH statistics and all regions in the VIS show less sensitivity with a smoother decline in the RMSVD with a fg-QI. The statistics support JMA's recommendation of using an overall QI ≥ 85. However, we note that there is also a sharp decrease in the number of winds with fg-QI > 80 and so the number of winds available for assimilation would be very small. AMVs selected using the fg-independent QI, in contrast are more numerous with QI above 85 (Figure 4 (b)). However, the fg-independent QI appears to give little information on wind quality (in




(a) (b)

**Figure 4: Wind statistics against (a) first guess dependent QI and (b) first guess independent QI for MTSAT NH IR high level winds (<400 hPa). Plots show the mean observed wind speed (green), the RMS of vector difference (blue), the obs-fg bias (red) and the distribution of QI values (black dashes). The period covered is 22-28$^{th}$ July 2005.**

(a)




(b)

**Figure 5: Zonal mean obs-fg (m/s) for MTSAT WV AMVs for the period 22-28th July 2005, using a first guess independent QI (a) and first guess dependent QI (b).**

contrast to what is usually observed for Meteosat winds). The RMSVD for such winds stays level or slowly increases with QI notably for AMVs at lower height levels (not shown here). This is not favourable.

Despite the high QI threshold, large biases prevail, as shown in the zonal mean plots in Figure 5. The strong positive biases in the fg-independent QI winds in (a) are removed by the fg-QI winds in (b) but the number of winds is also approximately halved. The negative bias in the SH does not appear to be as sensitive to the choice of QI.

## Assimilation Trial

The impact of MTSAT was tested for a month: 1 - 31 August 2005 with ECMWF's cycle 29r2 (model resolution T511, L60, incremental analysis resolution T159 - 4DVAR assimilation system). 10 day forecasts for each 12Z analysis were generated. The control was the corresponding operational setup which had no AMVs over the region covered by MTSAT. The same blacklist was chosen as for its predecessor, GOES-9, but with a QI ≥ 85 applied globally. The experiment was set up for both fg-QI and fg-independent QIs. The asymmetric first guess check and thinning remained unchanged.

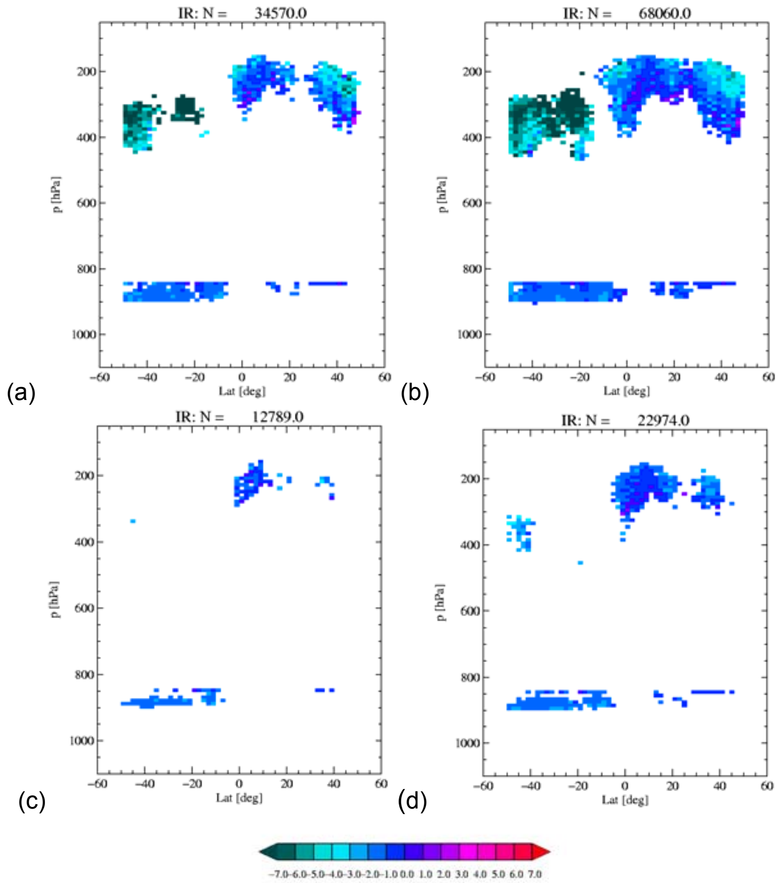
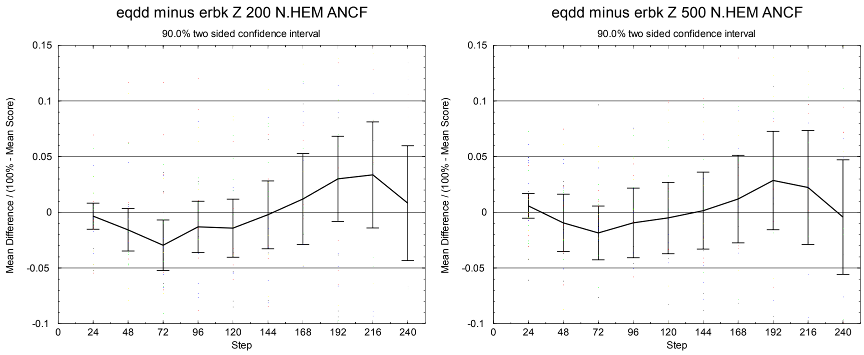



**Figure 6: Zonal mean of obs-fg (m/s) for MTSAT IR winds for the period 4-14th Aug 2005. (a) and (b) correspond to winds selected by QI > 85 and (c) and (d) to "used" winds (i.e. those assimilated into the model). The left hand plots correspond to fg-QI winds and the right hand plots to fg-independent QI winds.**

Figure 6 shows the zonal mean biases for MTSAT IR AMVs. Left and right plots show winds selected by fg-QI and fg-independent QI, respectively, while the top and bottom show winds selected with QI>85 and "used" winds, respectively. "used" winds is defined here as those assimilated into the model, having been subject to the quality control and thinning. The biases still present in (a) and (b) are removed by the quality control and thinning (in (c) and (d), but at a severe cost in terms of the

number of winds subsequently available for assimilation. This is particularly notable for the SH, where the quality control removes almost all winds in this region. The number of fg- QI “used” winds in (c) is particularly discouraging.
The introduction of MTSAT winds, subject to quality control and thinning into ECMWF’s assimilation model produced neutral results in terms of 10 day forecasts (Figure 7). This is perhaps not too surprising considering the low number of winds available for the assimilation. The overall results suggest that the fg-QI performs slightly better than the fg-independent QI against the control. However nearly all the forecast scores are statistically insignificant.




(a) (b)

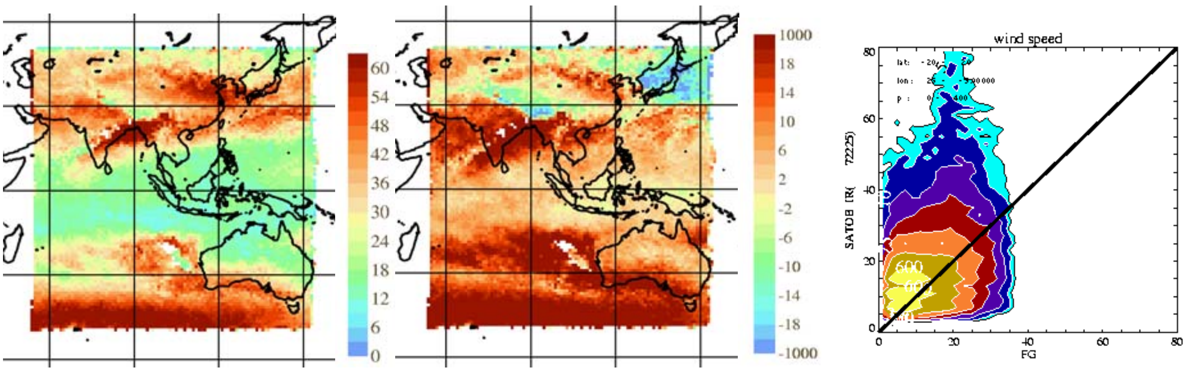
**Figure 7: Differences in the (a) 200 and (b) 500 hPa geopotential height anomaly correlation forecast scores for up to day 10, between the control (eqdd) and the experiment (erbk) for the NH. Experiment erbk contains forecast dependent QI AMVs. The error bars show the confidence interval (90%) of the mean difference computed from 31 cases. (a) contains the only statistically significant positive result, at day 3.**

## Summary

A fg-dependent QI may be a “safe” option for the time being, but a revision of the quality control (i.e. the asymmetric first guess check) and better quality control from the AMV providers may still enable us to use the fg-independent QI at some point in the near future. A second assimilation experiment will be conducted shortly for the NH winter period.

## IV FY-2C

The Chinese Meteorological Administration (CMA) has recently begun producing IR and WV AMVs from Fengyun-2C (FY-2C), a Chinese geostationary satellite operating at 105$^{0}$E with a 5-channel imager. Some data has been made available for monitoring although currently no QI information is provided. At this stage no selection can be made. Some preliminary statistics are presented below in view of a more thorough investigation when QIs are made available from CMA. Figure 8 (a) and (b) are examples of mean AMV speed and mean departures from the ECMWF model, respectively, for high level IR FY-2C winds. The greatest differences between the observations and the model correspond to the areas of greatest speed. Some of the disagreements correspond to areas of cloudy activity (inspection of IR MTSAT imagery). However, the band of winds with strong positive biases below 40$^{o}$S cannot be explained this way. Speed density plots of observations against ECMWF’s first



(a) (b) (c)

**Figure 8: (a) Mean speed (m/s) and (b) mean first guess departure (m/s) of FY-2C IR AMVs against ECMWF's model for the period 02/02/2006 - 28/02/2006. (c) Density plots of FY-2C wind speed versus first guess for high level tropical winds.**

guess also show that the observations contain some considerable biases (e.g. Figure 8(c)). As the observations from FY-2C contain *all* winds, with no quality selection, it is difficult to draw too many conclusions. Further inspection of the FY-2C winds nonetheless shows some agreement with the ECMWF wind field although we see some indications that the heights may not be correctly assigned. This could provide some explanation as to why there are such strong biases in the winds.

## V. ERA40 and future re-analyses.

Monitoring studies are planned for the Meteosat reprocessed winds provided by EUMETSAT for the Interim Reanalysis which aims to run from 1989 to real time. Reprocessed Met-3, Met-4 and Met-7 AMVs are to be tested against ECMWF's model. Two datasets are available: Extended Low-Resolution winds (IR, WV and VIS) and High-Resolution Visible winds. The ERA40 specific configuration of ECMWF's IFS model will be used. Experiments will make use of a 4DVAR assimilation and IFS cycle 30r1 with 60 vertical levels and $T_L$ 159.

## VI. CONCLUSIONS/SUMMARY

The transition from assimilating Met-7 to Met-8 AMVs at ECMWF was smooth and had a relatively neutral impact on the forecast. The large increase in the number of winds disseminated and in the number of channels available has opened up possibilities for improvements notably in the height assignment methods, an example of which we saw here regarding the $CO_2$ slicing method.

JMA's MTSAT has replaced GOES 9, disseminating AMVs over the West Pacific region since July 2005. ECMWF is currently running with no AMVs over that area while some final trials are being conducted. CMA's FY-2C winds have recently been made available however we are still waiting for QI information in order to begin some monitoring trials.

Finally, reanalyses are ongoing projects at ECMWF. The current interim reanalysis project involves collaborating with EUMETSAT for the reprocessing of satellite data from 1989 to the present day.

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