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A STUDY OF THE AMV CORRELATION SURFACE

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Abstract

There are many sources of error in the atmospheric motion vector (AMV) data. Recent effort has focused on errors in the AMV height assignment, which is thought to be the major contributor in many cases. However, there is increasing interest in errors from the tracking step, particularly with the smaller target box sizes used to generate high resolution AMVs or where longer image intervals are used for polar AMV products.

Visualising the AMV correlation surfaces from the tracking can be useful to identify whether the tracking is well constrained or not. Some examples show tightly constrained maxima, whereas others show broad maxima or multiple maxima. This information could be exploited in NWP through improvements to the AMV filtering and observation errors.

INTRODUCTION

AMVs are produced by tracking cloud or areas of water vapour in consecutive satellite images. The main derivation steps are:

1. Correct and rectify the raw data
2. Locate a suitable tracer within the image
3. Perform a cross-correlation or sum of square differences to locate the same feature in an earlier or later image
4. Calculate the vector from the displacement in tracer location
5. Assign a height to the vector
6. Perform quality control

An example of the tracking step is shown in Figure 1. For further details of the AMV derivation see Schmetz et al. (1993) and Nieman et al. (1997).

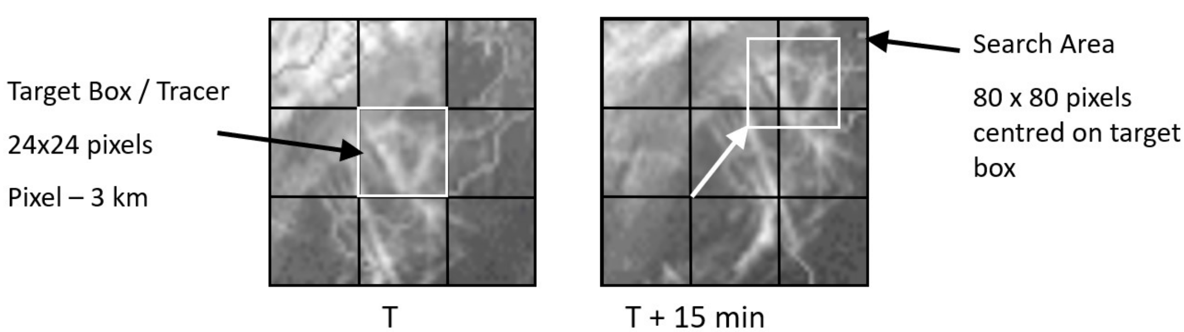

Figure 1: *An illustration of the AMV tracking step for EUMETSAT Meteosat-9 IR AMVs. The location of the target in the later image is determined by best match of the individual pixel counts of the target with all possible locations of the target in the search area using cross-correlation. The wind vector is taken as the displacement between the locations of the target boxes in the two images.*

The purpose of this study is to use code provided from the NWC SAF (a modified version of HRW v2016) to plot examples of the AMV correlation surface. Work elsewhere (e.g. Shimoji 2014) has shown that using smaller target boxes results in more noisy wind fields and investigation of the correlation surfaces often shows there are multiple maxima. Can we identify cases where poor agreement of the AMV and model background wind vectors (O-B) are associated with correlation surfaces containing multiple maxima or broad maxima suggesting the tracking is poorly constrained?

In the following sections we discuss the motivation for this study and show examples of low level and high level AMV correlation surfaces for winds derived using 24x24 pixel targets with the NWC SAF/HRW software. We then consider how this information could be used to develop additional AMV filtering and to provide constraint of the observation errors for use in NWP.

MOTIVATION

For traditional AMV production from geostationary satellites, height assignment is thought to be the dominant source of error and there has been less focus given to the tracking step. In recent years it has become more apparent that there are also circumstances in which the tracking step can be problematic.

At IWW10 Greg Dew (2010) showed an example of AMVs derived for polar images with an interval of ~100 min (Figure 2a). Using the standard AMV derivation approach without a first guess check the derived vector field was very noisy and inconsistent. He found it was necessary to include the use of a model first guess to constrain the tracking. However, it is generally preferred to avoid this approach (e.g. Borde and García-Pereda 2014), as it introduces an undesirable dependence of the AMVs on the model wind field.

At IWW12 Kazuki Shimoji (2014) shared an example of a correlation surface for an AMV derived using a smaller 5x5 target box (Figure 2b). The aim of using smaller target boxes is to derive AMVs more representative of the local flow, targeting high resolution NWP models and nowcasting applications. With the smaller box sizes, however, the tracking becomes much more challenging. There are many cases where correlation surfaces show multiple maxima. Are there still examples where the tracking is well constrained? Can we use the correlation surfaces to help screen out the poorly constrained cases?

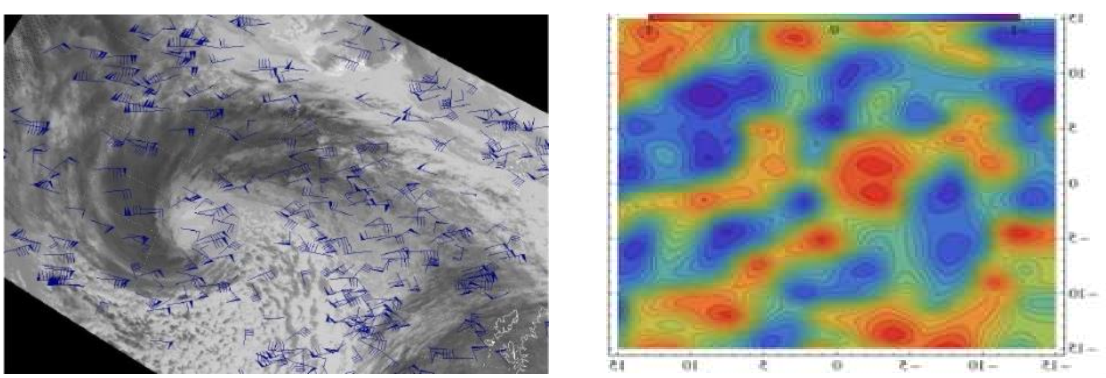

Figure 2: **Examples where the tracking step has been more problematic. (left) showing inconsistent wind field derived using ~100 min interval tracking for polar AMVs (example from Greg Dew's IWW10 talk, 2010) and (right) correlation surface showing multiple maxima for an example of 5x5 pixel target tracking to derive high resolution AMVs (example from Kazuki Shimoji's IWW12 talk, 2014).**

For the standard global geostationary AMVs it is likely the height assignment errors still dominate. However, an earlier NWP SAF investigation (Cotton and Forsythe 2010) highlighted an issue in the jet regions where clouds with a smoother appearance in the satellite imagery were sometimes associated with a negative O-B bias. In these cases would we expect to see correlation surfaces with broad, elongate maxima due to the lack of cloud texture to constrain the motion in both dimensions?

SOME EXAMPLES

Low level:

At low level many of the correlation surfaces are well constrained as illustrated by examples A and B in Figure 3. There are, however, examples where this is not the case e.g. example C in Figure 3.

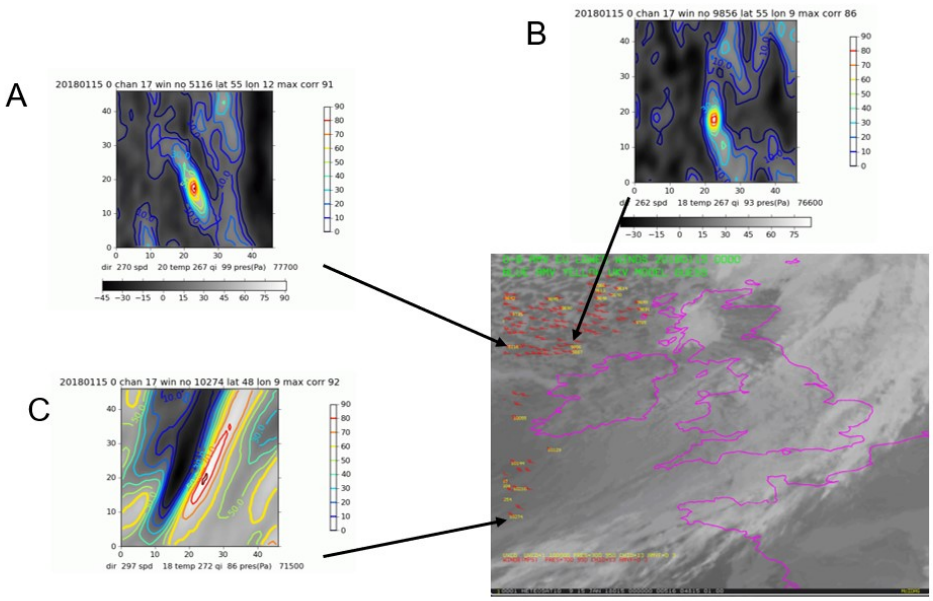

Figure 3: **Examples of low level (below 700 hPa) AMV correlation surfaces. The satellite image showing the location of these AMVs is also shown.**

High level:

At high level the correlation surfaces are often less well defined. Some examples show a clear maxima (e.g. Example D in Figure 4). Frequently the surfaces show elongated maxima (e.g. Examples A and B), presumably due to the clouds lacking sufficient texture to constrain the motion well in both dimensions. In some cases there are multiple maxima or very broad maxima (e.g. Examples A and C).

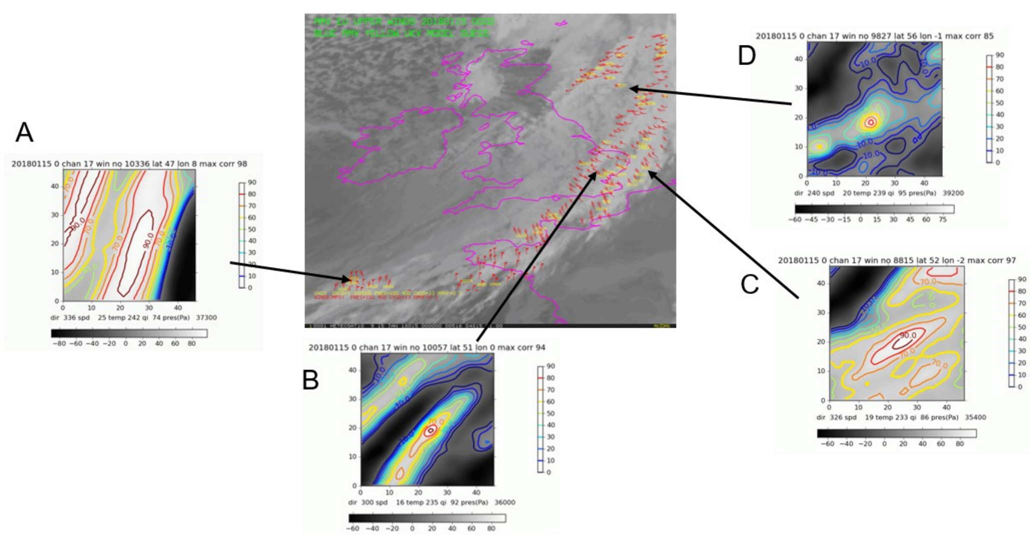

Figure 4: **Examples of high level (above 400 hPa) AMV correlation surfaces. The satellite image showing the location of these AMVs is also shown**

Looking at the correlation surfaces it is not unreasonable to wonder how we end up with such a consistent set of vectors overall. It seems probable that this is linked to the various quality control steps applied during the derivation. This has yet to be confirmed.

HOW CAN WE USE THIS INFORMATION?

Can we develop a method to flag the poorly constrained cases so we can remove them from the assimilation?

One approach would be to adapt the method used to exclude AMVs with poorly constrained best-fit pressures (Salonen et al. 2015), but in 2 dimensions. This involves first locating the maxima within the correlation surface and then checking if there is a value greater than a certain threshold percentage of this maxima beyond a set distance (e.g. outside the yellow circle shown in Figure 5). This should help to flag cases with broad maxima or multiple maxima (Figure 5b illustrates both).

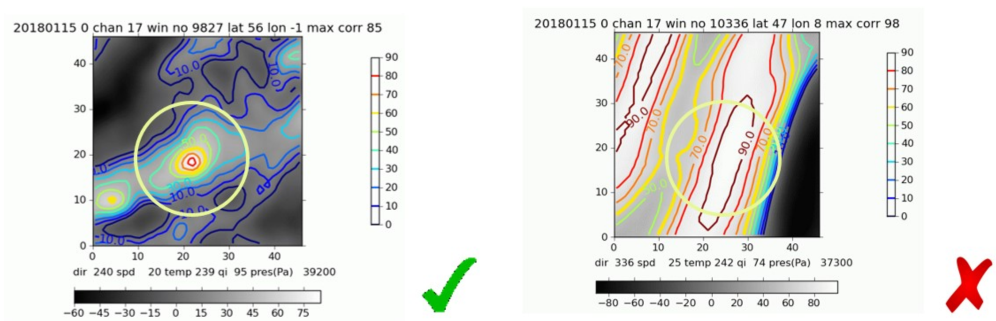

Figure 5: **Illustration of possible approach to identify well-constrained correlation surfaces. (left) example of well constrained correlation surface, (right) example of a poorly constrained correlation surface.**

Can we go a step further and extract information that could be used to set observation errors for use in NWP? Several NWP centres use an individual observation error scheme described in Forsythe & Saunders (2008). This assumes the AMV vector and height assignment errors are independent (reasonable assumption). An estimate of the AMV error is calculated by combining an estimate of the vector error from the tracking with an estimate of the error in vector due to an error from the height assignment. So far most focus has been on the height assignment error. Estimates of the height error are calculated statitistically based on observed minus best-fit pressure statistics. Within the observation error scheme the same height error will lead to bigger observation errors in regions of high vertical wind shear, allowing us to down-weight winds where a height error could be problematic. Could we also take advantage of information from the correlation surface to better constrain the estimate of error in vector from the tracking step?

Figure 6 demonstrates how the shape of the correlation surface maxima provides information on how well constrained the motion is in different directions. It might be possible to fit an elipse to this surface to provide estimates of error along the major and minor axes.

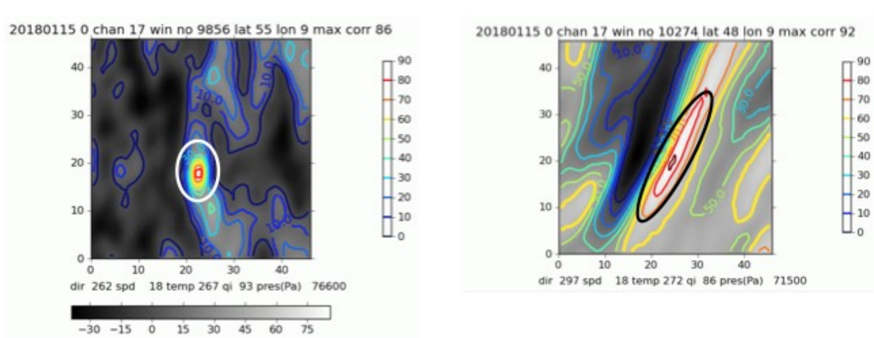

Figure 6: **Illustration of possible approach to extract information on the error in the tracking step.**

CONCLUSIONS AND FUTURE WORK

For many global AMVs, height assignment remains the main source of error. For polar AMVs and high resolution AMVs, the tracking step has proved more challenging due to the use of longer image intervals (polar imagery) or smaller target sizes (designed to extract higher resolution information). There may also be cases where traditional AMVs struggle due to smoother cloud features. In these cases motion is sometimes well constrained in one dimension, but poorly constrained in the other. With very smooth low cloud features, the motion can sometimes be poorly constrained in all directions. From an initial analysis it is clear there is information in the correlation surfaces that might be helpful to filter out poorly constrained cases or to provide estimates of error in the tracking step. These errors can be used within current AMV observation schemes.

The results presented here are from a preliminary investigation. A key target of this work is to use the knowledge gained to develop quality indicators, flags or estimates of the error from the tracking that can be used by NWP to filter out the poorly constrained cases or down-weight them in the assimilation.

Another, more specific, goal relates to the derivation of AMVs more representative of the local flow, targeting high resolution NWP models and nowcasting applications. Work elsewhere has shown that using smaller target boxes results in more noisy wind fields and investigation of the correlation surfaces often shows there are multiple maxima. Can we use the correlation surfaces to help screen out the poorly constrained cases, enabling use of slightly smaller target boxes than could otherwise be achieved?

Another area it would be interesting to investigate further is the jet wind regions where an earlier NWP SAF investigation highlighted that clouds with a smoother appearance in the satellite imagery were sometimes associated with a negative O-B bias. Do we see correlation surfaces with broad, elongate maxima in these cases?

REFERENCES

Borde, R. and J. García-Pereda, 2014. Impact of Wind Guess on the Tracking of Atmospheric Motion Vectors. *Journal of Atmospheric and Oceanic Technology*, **31**, 458-467

Cotton, J. and M. Forsythe, 2010. 4th analysis of the data displaying on the NWP SAF AMV monitoring website (AR4), *NWPSAF-MO-TR-024, available from https://www.nwpsaf.eu*

Dew, G. AVHRR polar winds derivation at EUMETSAT: Current status and future developments. *Proceedings of the 10th International Winds Workshop, Tokyo, Japan, available from http://cimss.ssec.wisc.edu/iwwg/iwwg_meetings.html*

Forsythe, M. and R. Saunders, 2008. AMV errors: a new approach in NWP. *Proceedings of the 9th International Winds Workshop, Annapolis, available from http://cimss.ssec.wisc.edu/iwwg/iwwg_meetings.html*

Nieman, S.J., W.P. Menzel, C.M. Hayden, D. Gray, S.T. Wanzong, C.S. Velden and J. Daniels, 1997. Fully automated cloud drift winds in NESDIS operations. *Bulletin of the American Meteorological Society*, **78**, 1121-1133.

Salonen, K., J. Cotton, N. Bormann and M. Forsythe, 2015. Characterizing AMV Height-Assignment Error by Comparing Best-Fit PressureStatistics from the Met Office and ECMWF Data Assimilation Systems. *Journal of Applied Meteorology and Climatology*, **54**, 225-242.

Schmetz, J., K. Holmlund, J. Hoffman, B. Stauss, B. Mason, V. Gaertner, A. Koch and L. Van der Berg, 1993. Operational cloud-motion winds from Meteosat infrared images. *Journal of Applied Meteorology*, **32**, 1206-1225.

Shimoji, K., 2014. Motion tracking and cloud height assignment methods for Himawari-8 AMVs. *Proceedings of the 12th International Winds Workshop, Copenhagen, (will be) available from http://cimss.ssec.wisc.edu/iwwg/iwwg_meetings.html*.