Assimilation of wind information from radiances: AMVs and 4D-Var tracing

Mary Forsythe[1], Carole Peubey[2], Cristina Lupu[2], James Cotton[1]

[1]Met Office, FitzRoy Road, Exeter, EX1 3PB, UK
[2]ECMWF, Shinfield Road, Reading, UK
mary.forsythe@metoffice.gov.uk

ABSTRACT

Wind information can be inferred from the motion of features within sequences of satellite imagery. For numerical weather prediction (NWP) this can be achieved either by deriving atmospheric motion vectors (AMVs) and assimilating these as winds or by direct assimilation of radiances within 4D assimilation systems capable of extracting wind information through tracer advection. Impact experiments and forecast sensitivity to observation (FSO) scores show benefit to forecast accuracy from both approaches. Geostationary clear sky radiance (CSR) assimilation provides complementary information to AMVs, with CSRs providing most benefit at 300–500 hPa and AMVs at 200 hPa and 850 hPa, reflecting the vertical distribution of the two data types. Together they form an important source of tropospheric wind information with good temporal and areal coverage. Challenges exist in further exploiting both datasets. Examples include better blacklisting and representation of the AMV errors, greater use of cloudy radiances and extracting information at higher resolution for convective scale models. Work continues in these areas and should enable continued or improving NWP impact in the future.

1 Introduction

For best results, models require information on the mass field and the wind field. Conventional sources of wind data (radiosondes, aircraft) don't provide uniform global coverage and are particularly sparse over the southern oceans and at high latitudes. Satellite-derived information can help to fill the gaps, providing good areal and temporal coverage. Where does the wind information come from? Winds are not measured directly by satellite instruments, but (for the examples covered in this paper)can instead be inferred from the motion of features within the imagery. To extract this information for NWP, there are currently two approaches (see Figure 1).

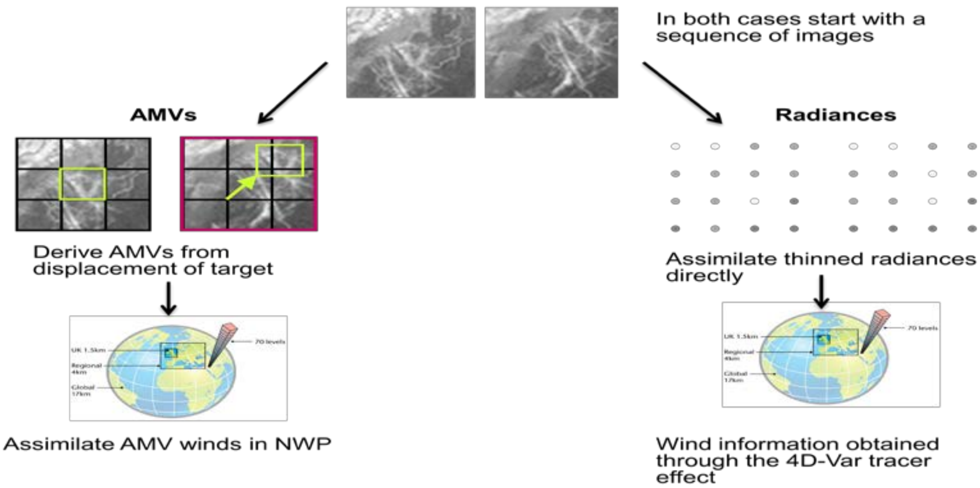


Figure 1: An illustration of the two routes to obtaining wind information in NWP from sequences of satellite imagery.

The first approach, used routinely since the 1970s, is to derive atmospheric motion vectors (AMVs) from the displacement of features within the satellite imagery and to assimilate these vectors as winds within NWP data assimilation. The second approach, made possible by the development of 4D assimilation systems in the 2000s, is to assimilate the thinned radiances directly and obtain wind information through tracer advection (e.g. Peubey and McNally, 2009).

In the following sections we shall discuss first the AMVs and then the direct assimilation of radiances to obtain wind information through the 4D-Var tracer effect. In both cases we will touch on their impact in NWP, some key challenges, ongoing developments and finally a look ahead to the future.

2 AMVS

Atmospheric motion vectors (AMVs) are produced by tracking clouds or areas of water vapour in consecutive satellite images (normally IR channels around 10.8 μm and 3.9μm, visible channels and the water vapour channel around 7 μm). 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 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

The final AMV is an average of two or three component vectors calculated from a sequence of three or four images. An example of the tracking step is shown in Figure 2. For further details of the AMV derivation see Schmetz et al. (1993) and Nieman et al. (1997).

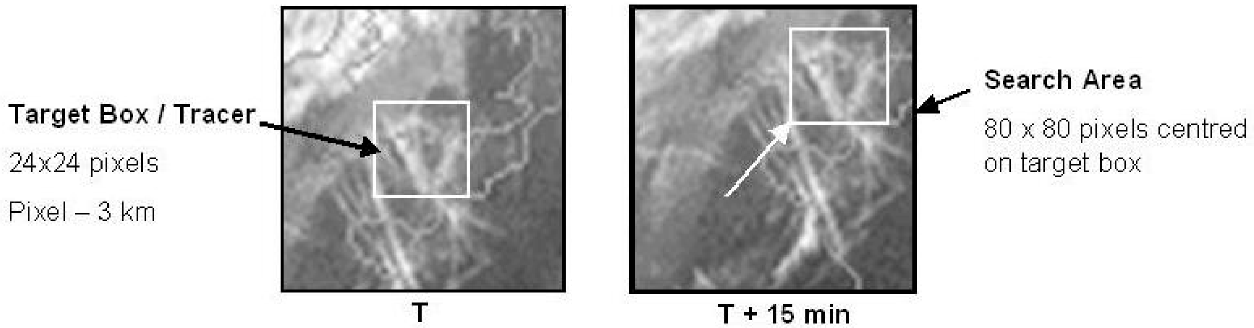


Figure 2: An illustration of the AMV tracking step for Meteosat-9 IR AMVs.The location of the target in the later image is determined by best match of the individual pixel counts of the target with all possible locations of the target in the search area using cross-correlation in the Fourier domain. The wind vector is taken as the displacement between the locations of the target boxes in the two images.

Tetsuya Fujita pioneered the work on remote sensing of atmospheric motion in the 1960s and 70s (for more information see Menzel, 2000). Since this time the quality and quantity of AMV data have increased markedly. This has been partly due to improvements to the satellite imager instruments including an increase in number of channels, shorter time interval between image scans and improved pixel resolution. There have additionally been improvements to the derivation methodology, increases to the spatial and temporal resolution of the data and development of quality indicators (e.g.

Holmlund, 1998; Hayden and Purser, 1995). Work is ongoing to provide further quality information with the AMVs including estimates of height error.

Traditionally geostationary imagery has been used to produce AMVs due to the frequent viewing of the same area of the Earth's atmosphere. Since 2002 AMVs have additionally been produced over the polar regions using consecutive overpasses from polar-orbiting satellites, but this still left a gap in coverage over the meteorologically interesting areas around 50-65 N/S (see Figure 3).

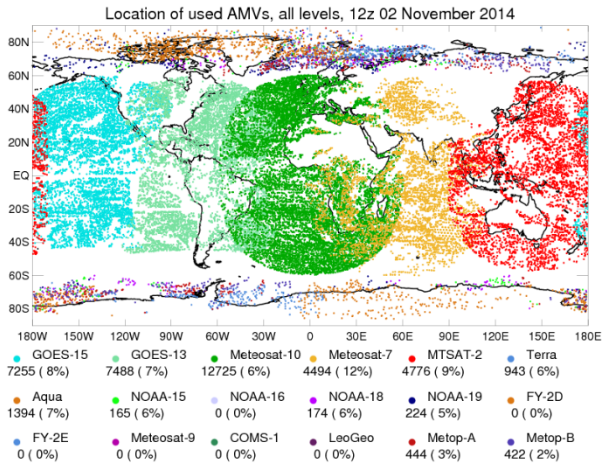


Figure 3: Data coverage plot showing assimilated data for one 6 hour assimilation cycle at 12 UTC on 2November 2014.

In the last few years, new datasets have been developed, or proposed, to help close the gap (see below). Benefit has been seen in assimilation experiments using some of these gap-filling datasets.

- **Polar winds using image pairs** e.g. EUMETSAT Metop
- **Multi-satellite winds** e.g. EUMETSAT dual Metop-A/B winds, CIMSS Leo-Geo winds
- **Increased geostationary coverage** - GOES coverage south of 40S (expect with GOES-R series)
- **Satellites in highly elliptical orbit** e.g. proposed Canadian PCW mission for 2 satellites in highly elliptical orbit (see Garand et al. 2010)
- **Other wind datasets e.g. ADM-Aeolus Doppler wind lidar, MISR**

There are a number of elements to the AMV quality control (QC) and assimilation:

- Blacklisting (QI thresholds, spatial checks, some satellite-channel combinations)
- Thinning (spatial and temporal)
- Background check
- Observation errors
- Observation operator (currently treated as point winds in space and time)

For more information on quality control see Forsythe et al. (2010). The impact of the QC steps on the number of winds assimilated and spread of O-B values is shown in Figure 4. Setting the observation errors more effectively is discussed later.

AMVs are also assimilated in atmospheric reanalyses, mostly using reprocessed data. More impact is seen earlier in the period when the observing system was sparser, highlighting the importance of funding reprocessing of older datasets.

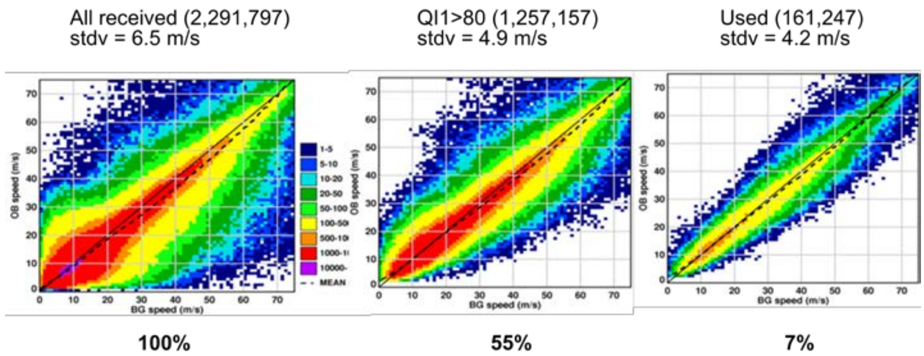


Figure 4: O-B speed bias density plots for Meteosat-9 IR high level (above 400 hPa) NH (20N--90N) winds for August 2014 compared with the Met Office model background. The left plot shows all the data extracted, the middle plot shows the data remaining after a model-independent QI threshold of 80 is applied, the right hand plot shows the used data after further blacklisting, thinning and a background check are applied. Notice the improvement in distribution and standard deviation (stdv) after each step.

To evaluate the impact of AMVs in NWP, a collaborative study was undertaken involving 7 NWP centres (see Payan and Cotton 2012 for details). Two 6-week periods were selected; a set of classical data denial experiments were performed and compared to a reference suite closely matching the operational forecast system. A set of agreed plots were produced to enable comparison between centres and to evaluate the impact of AMVs on analyses and forecasts.

For all centres the main impact on analyses was seen in the tropical belt, typically between 30°S and 30°N, with speed differences of up to 2 m/s. The differences were most prominent in two regions:

1. The eastern half of the Equatorial Pacific Ocean
2. The Indian Ocean, mainly between Eastern Africa and the South of India

There are differences between the two trial periods reflecting the different synoptic flow patterns. Interestingly the impact is not always consistent between centres (e.g. Figure 5). For Period 1 there was a predominantly easterly mean flow in the tropics. The inclusion of the AMVs tended to enhance the strength of this flow at DWD, JMA and NRL, but reduce it at ECMWF and Météo-France.

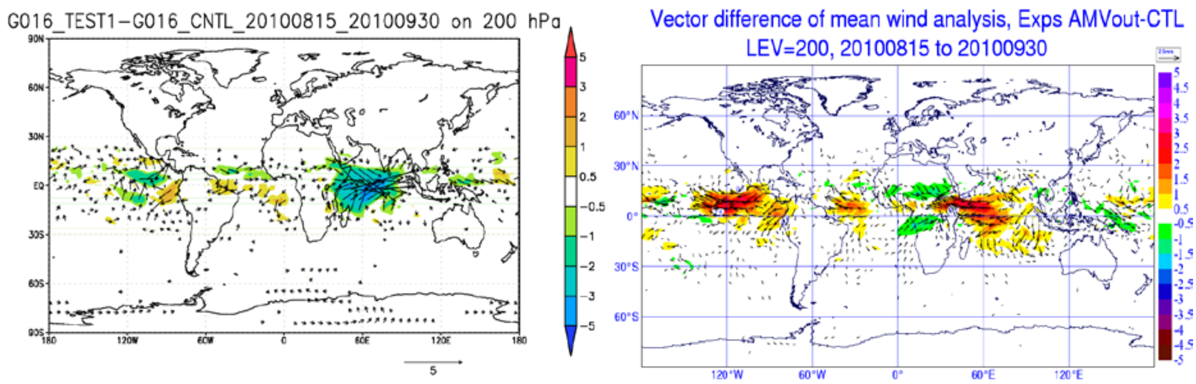


Figure 5: Vector and wind speed analysis differences at 200 hPa (noAMV-reference) for period 1 for JMA (left) and ECMWF (right).

The different impact between centres was investigated further by comparing mean wind analyses from JMA and ECMWF. This showed that differences between the two centres were significantly smaller in the experiments with AMVs than in the denial experiments (Figure 6), suggesting that they were primarily due to differences in the climatology of the forecast models and that the AMVs act to bring the two systems into closer agreement.

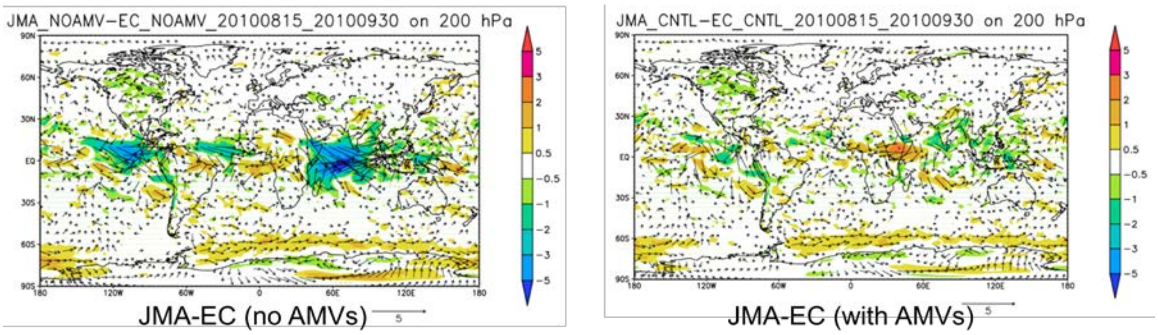


Figure 6: Vector and wind speed analysis differences between the analyses from JMA and ECMWF for period 1 at 200 hPa. AMV denial result (left), and control result with AMV assimilation (right).

Positive forecast impacts were seen at all centres, especially in the upper troposphere, demonstrated by the fit to radiosonde profiles, time series of forecast error, map plots and forecast sensitivity to observation (FSO)diagnostics. Bigger forecast impacts were seen for centres using 3D-Var or making less use of other satellite observations. No geographical regions were identified where the AMVs were performing consistently poorly among several centres suggesting regions of negative impact are mainly system-dependent (QC, thinning, assimilation scheme, forecast model etc.) rather than AMV dependent. FSO results indicate the significant relative importance of AMVs within the global observing system (e.g. Figure 7) and show benefit for all channel-level combinations (plots not shown).

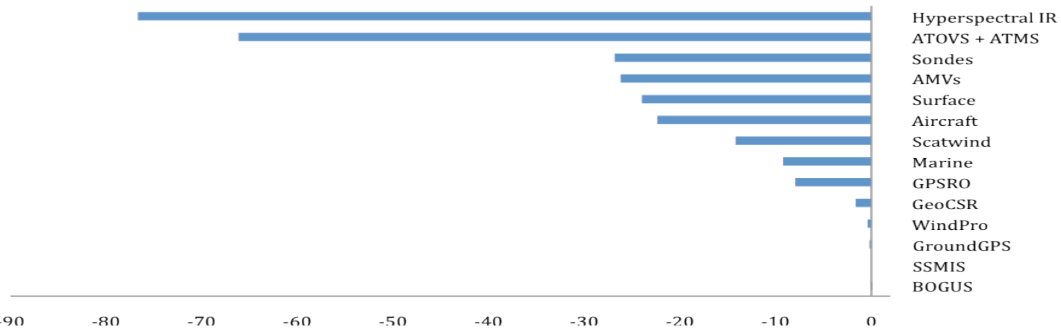


Figure 7: Total impact (J/kg) for the Met Office for June 2014 from different components of the observing system. Negative values indicate a positive influence in terms of forecast error reduction from the observations.

Some of the recent advances and ongoing challenges in AMV research relate to:

1. Understanding the errors
2. Height assignment
3. Observation errors in NWP
4. High resolution winds

Understanding the errors

One of the main difficulties for AMV data is their complicated errors. There are various sources of error in the AMV data that can be introduced in the tracking and height assignment. Sometimes all AMVs in a particular area are affected by the same errors and similar errors can persist to the next derivation cycle. This tendency means that AMV data have temporally and spatially correlated errors (see also Bormann et al., 2003). Another consideration for NWP is how well the final AMV represents the wind field at a specific location, height and time. As Schmetz and Nuret (1989) stated, the AMVs could only give an unbiased estimate of the winds if clouds were conservative tracers randomly distributed within and floating with the airflow. This is not the case; clouds are not randomly arranged, but associated with specific conditions (ascending air masses) and some clouds do not move with the wind. This will remain a limitation even if we can improve the AMV data quality and representation of the errors.

To improve the impact in NWP we need to enhance the AMV data quality and assimilation. To achieve this we need to understand more about the AMV data and sources of error. This is one of the main objectives of the NWP SAF AMV monitoring (see http://nwpsaf.eu/monitoring/amv) and is also a focus of some international activities coordinated through the International Winds Working Group (see http://cimss.ssec.wisc.edu for more information).

NWP SAF AMV analysis reports are produced every 2 years (e.g. Cotton 2014). The core of these reports is a record of features identified in the monthly O-B monitoring plots. By comparing plots against the Met Office and ECMWF backgrounds we can attempt to separate error contributions from the models and from the AMVs. Alongside the standard O-B statistics plots, specific cases are identified for more detailed evaluation, comparing AMV height assignment to model best-fit pressures (e.g. Forsythe et al., 2006) and overlaying AMVs on the satellite imagery. Using this combined approach it has been possible to identify general trends in the AMV quality, some specific cases where the AMV derivation may not be performing optimally and where possible the underlying cause so these can be rectified or handled better in NWP. An example is provided below.

A positive speed bias (AMVs faster than model winds) is seen at ~400 hPa below the sub-tropical jet over the Sahara at 20–30ºN, but this is present only during daytime hours (see Figure 8).

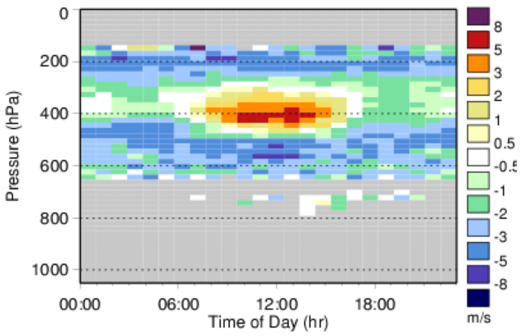


Figure 8: A Hovmoeller plot showing the O-B speed bias for the Meteosat-9 IR 10.8 AMVs against the Met Office background as a function of time of day for February 2009, filtered to only include AMVs with CO_2 slicing height assignment. Notice the marked positive speed bias around 400 hPa during daytime hours.

Comparing AMV assigned heights for one day during February 2009 shows higher assigned heights during night-time (see Figure 9), in better agreement with other cloud top pressure products and model best-fit pressure. It is possible the heights are put too low during the daytime due to inadequate representation of the diurnal temperature range of the desert surface, possibly linked to the interpolation between forecasts 6 hours apart (EUMETSAT use the T+12 and T+18 hr forecasts from ECMWF).Use of 3 hourly or more frequent forecasts is recommended to help reduce the bias.

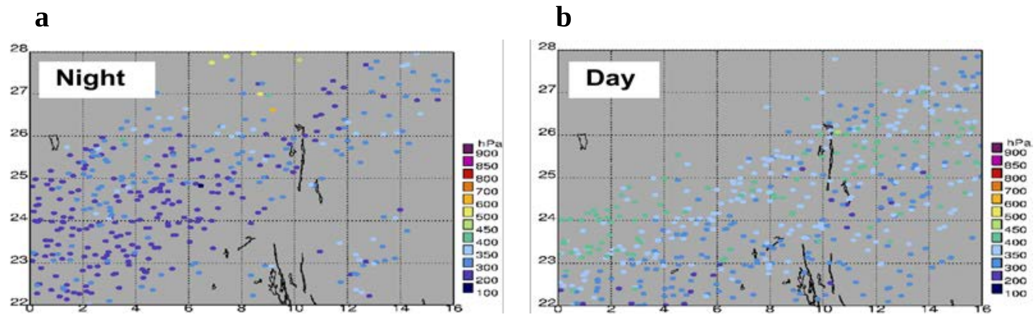
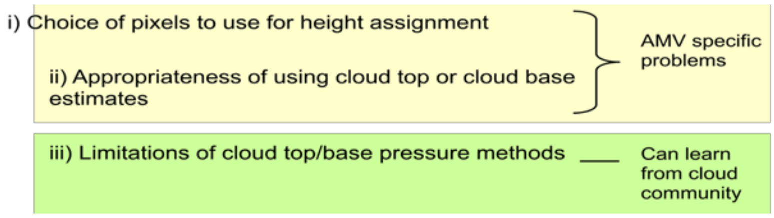


Figure 9: Map plots showing Meteosat-9 IR 10.8 AMV height assignment for (a) 2100–0300 UTC and (b) 0900-1500 UTC on 16 February 2009.

Height assignment

There are several reasons why the height assignment can be problematic:



Progress has been made in all three areas in recent years and these are briefly outlined below.

The target can contain over 100 pixels and these may reflect cloud at different levels in the atmosphere, only some of which may have contributed to the tracking step. EUMETSAT have developed a CCC approach in which the pixel contribution to the cross correlation coefficient is used to select the pixels that contribute most to the tracking and to use these for the height assignment (see Borde et al. 2014). This led to a marked improvement in the quality of particularly the upper level AMVs, although there was some deterioration at low level (thought to be linked to coincident changes to the height assignment approach and not directly to the CCC methodology).

Assumptions are made about which level in the cloud controls the cloud motion. A long-standing idea is to represent the AMVs as layer winds. Several studies have focused on this in recent years (Folger and Weissmann, 2014; Lean et al., 2014; Hernandez-Carrascal and Bormann, 2014; Velden and Bedka, 2009; Forsythe et al., 2010 and Weissmann et al., 2013). This is not an easy question to answer as the issue of which level or layer best represents the motion of the tracked features is often masked by, in some cases, fairly substantial errors in the AMV height assignment. Hernandez-Carrascal and Bormann (2014) aimed to separate these two effects using a simulation framework. AMVs were derived from sequences of images simulated from high-resolution model fields; the AMVs were compared to model winds at different levels/layers with respect to the model cloud (i.e. independent of assigned AMV pressure). They found that the AMVs compared better with model winds at a level within the cloud or with an average over the cloud (capped versions necessary for deeper clouds) than with winds at the cloud top or base. It should be recognised that estimates of cloud top from most existing cloud schemes are anyway somewhere below the true cloud top so may not be that sub-optimal.

A positive step in recent years has been an increasing move towards direct use of pixel-based cloud schemes developed by the cloud community. The AMVs will directly benefit from expertise in this community including new techniques to allow for multi-layer cloud (e.g. Watts et al., 2011) and better handling of heights of cloud edges (e.g. Heidinger, 2014). Many of these schemes also provide estimates of height error and cost which can highlight where height assignment is more problematic and could be used for blacklisting and adjusting observation errors in NWP. An alternative approach to AMV height assignment is to use stereo heights. The best example of this is the MISR AMVs (e.g. Horvath and Davies, 2001; Mueller et al., 2014) produced from multi-angle radiometer imagery. Sentinel-3 may provide another option for AMVs with stereo heights.

Observation errors

In many NWP systems AMV observation errors vary only with pressure. However, we know the errors vary widely dependent on many factors; examples include the navigation, tracking, radiance biases, forecast data, radiative transfer models, passive tracer assumption, validity of treating as a wind at a specific height and the list could go on.

The main source of error is thought to be from the height assignment step. This is likely to be more of a problem in regions of high wind shear, where an error in the height could introduce a large vector error. As an example if a wind is assigned 80 hPa too low or too high in a region of strong shear the resultant vector error could be more than 10 m/s. One option to allow for this is to generate individual observation errors for each wind using information on the quality of the AMV vector and height assignment (Forsythe and Saunders, 2008). If we assume the AMV vector and height errors are independent (reasonable assumption), the total AMV error can be calculated by combining the vector error with the error in vector due to the height error. The latter can be calculated using the model background wind profile and an estimate of the height error. With this approach, the same height error will yield a bigger observation error in regions of high vertical wind shear, allowing us to down-weight winds where a height error would be problematic and to give greater weight where the height assignment is less critical. The inputs required for this approach are estimates of the error in the height assignment and in the u and v wind components. Currently height errors are based on statistics comparing AMV assigned heights to model best-fit pressure (e.g. Salonen et al., 2014), but the plan is to additionally make use of estimates of height error from the derivation when these become available. Figure 10 shows an example of the errors using this approach compared to the traditional pressure-based errors. Benefit has been seen in assimilation experiments at the Met Office and ECMWF.

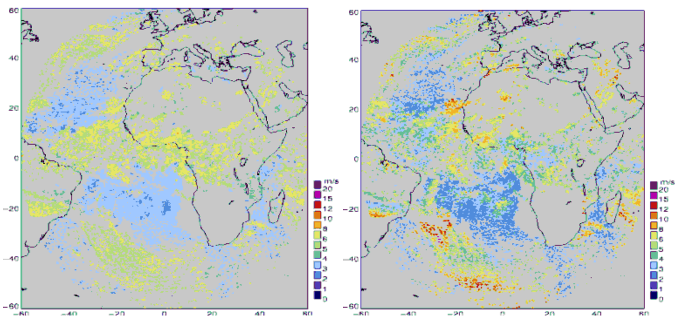


Figure 10: Plots showing the old (left) and new (right) AMV observation errors for Meteosat-9 IR winds for the 00 UTC run on 25 May 2007.

High resolution winds

Current AMV products capture broad-scale to synoptic-scale flow. Looking at movie loops we can see information available on much smaller scales, this is only likely to improve as we move to next generation satellite systems with shorter image intervals and higher pixel resolution (e.g. Himawari-8. GOES-R, Meteosat Third Generation). The question for NWP centres is can we make use of this information to improve our nowcasting and high resolution models, particularly for the forecasting of high impact weather events?

The answer at the moment is we don't know. There are a number of difficulties to overcome with both the AMV derivation and assimilation. In order to produce AMVs representative of smaller scale features of the flow we need to use smaller target boxes (probably 5–10 pixel in dimension) and shorter image intervals (5-10 min). However, the smaller number of pixels in the target makes it harder to find a unique solution and tends to result in a large number of invalid vectors. To address this, we need to focus on filtering out the poorly resolved cases (e.g. using information from the correlation surface) or using a clustering scheme (as applied in the GOES-R nested tracking, Bresky et al., 2012) or finding another way to better constrain the tracking (e.g. Shimoji, 2014). Other considerations for the AMV derivation include: greater sensitivity to registration errors, inability to resolve the slower winds with shorter image intervals and the need to find alternatives to the current QIs, which tend to penalise spatially varying accelerating wind features.

For NWP there are additional considerations. In NWP smaller scales tend to change fast and represent only modest energy conversion. The quantity and coverage of observations required to initialise and evolve these scales is a daunting challenge. Inadequate coverage could compromise the analysis of the larger scales. Also AMVs have correlated errors in space and time. To alleviate problems, data is thinned (or superobbed) and errors are inflated. But if we thin too much, we will lose the mesoscale information of interest. Efforts continue in this area at a number of centres and an IWWG web page has been put together to help foster collaboration.

3 4D-Var tracing

Assimilating radiances directly can impact the analysis wind fields through a number of mechanisms:

1. Background-error correlations and balance relationships – a change to one variable cannot happen in isolation.
2. Through cycling – changes in one analysis time window result in adjustments to other variables when the assimilation system is cycled over many time windows.
3. In 4D-Var where a time-series of model states is fitted to the available observations, linked through model governing equations and physical parameterizations e.g. wind fields can be changed to advect humidity to and from other areas (see Figure 11). Sometimes this is referred to as the 'tracer advection effect'.

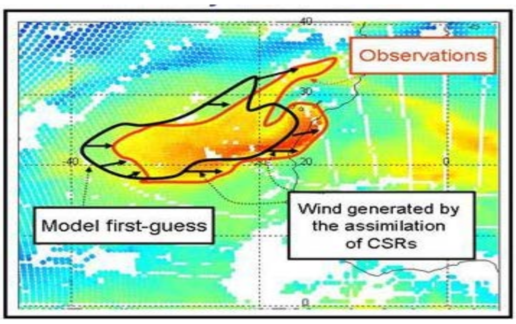


Figure 11:Cartoon illustrating the 4D-Var tracer advection effect.

The third mechanism is of most interest; it is not dissimilar to the traditional AMV derivation, but with the benefit of the assimilation system providing additional constraints. However, there is an important difference of scale. It is worth remembering that CSRs are first area-averaged over cloud-free regions in a 16 pixels by 16 pixels square box (i.e., 48 km by 48 km at sub-satellite point)and then thinned prior to assimilation (e.g. 125 km, 1 hour). So it is probably a bit more like deriving AMVs wearing fuzzy glasses; it will be good to extract broad scale motion, but will not capture the detail. Like the AMVs a number of quality control steps are applied to the radiance data including bias correction, thinning and blacklisting (e.g. above high orography, cloudy scenes, Lupu and McNally, 2014).

Peubey and McNally (2009) (hereafter referred to as *PM09*) investigated the impact of geostationary clear sky radiances on wind analyses, the mechanism of the impact on the winds and the sensitivity to the frequency of assimilated images. Some of the results from this study are highlighted here, but we refer you to the paper for full details.

PM09 ran several assimilation experiments with CSRs assimilated on a reduced baseline (no satellite data); with the aim to identify the dominant mechanism for CSR impact on the wind field:

1. Full 4D-Var
2. no-δT– change in temperature due to CSR assimilation set to zero – only impact on wind increments is through humidity changes
3. no tracer effect– effect of humidity tracer advection is removed by setting to zero the wind increment produced by the humidity changes through the adjoint model
4. no-δT and no tracer effect
5. 3D-Var.

Increments generated by CSRs at 300 hPa at the start of the first 12-hour assimilation window are shown in Figure 12 (i.e. no impact from cycling).

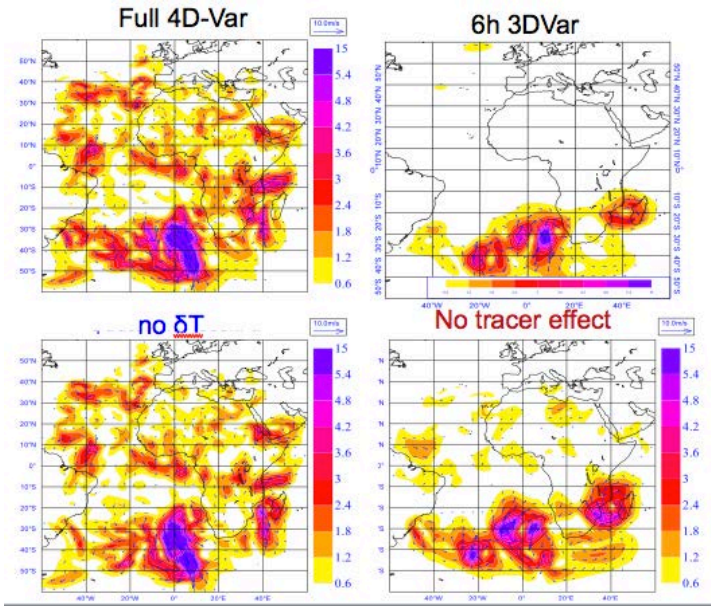


Figure 12: First-cycle 300 hPa wind increment on 3 June 2007 at 2100 UTC produced by the assimilation of CSRs in a set of experiments (full 4D-Var, no δT, no tracer effect and 3D-Var).

The Full 4D-Var and no δT experiments show very similar increment patterns suggesting the main impact on the wind field is via the humidity changes. The no tracer effect experiment shows large changes suggesting this is the dominant process for the impact on the wind increments. The structure of the increments is very similar between the no tracer effect experiment and 3D-Var suggesting that most of the remaining impact is from balance constraints (only way to get 3D-Var wind increments in first cycle).The importance of the humidity tracer effect for CSR impact on the wind field is also demonstrated from wind analysis scores (results not shown – see *PM09*). The wind analysis scores are a measure of how much improvement is seen in the analysis wind field (relative to ECMWF operations) compared to the reduced baseline experiment.

The impact on wind analysis scores of Meteosat-9 CSRs, Meteosat-9 AMVs and all polar radiances (but restricted to the Meteosat-9 disk) are shown in Figure 13, compared to a reduced-baseline experiment with no satellite data.

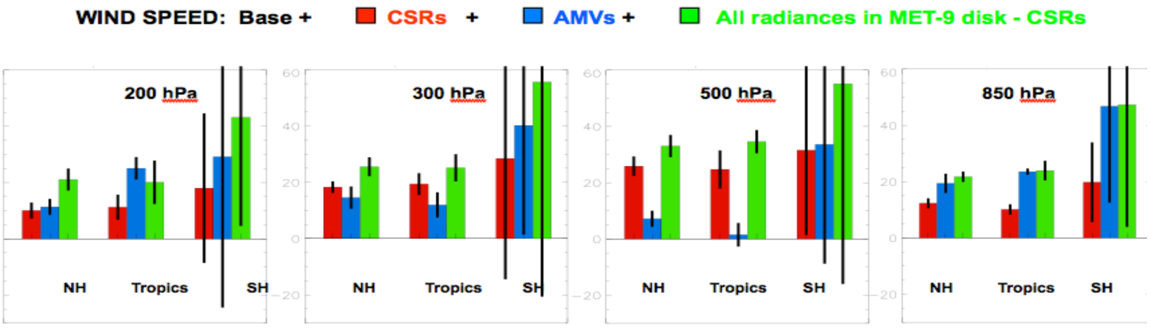


Figure 13: Wind analysis scores for base+CSRs, base+AMVs and base+polar radiances.

Comparing first the Meteosat-9 CSRs and AMVs we can see that CSRs have a larger impact on the wind analysis compared to AMVs at 300 hPa and 500 hPa, but less at 200 hPa and 850 hPa. This can be understood from the vertical distribution of the data with cloud-tracked AMVs mostly located at high and low levels in the troposphere and CSRs at mid level. The two data types are thus very complementary. The polar radiance experiment shows the biggest impact suggesting the importance of improved vertical resolution (e.g. from AIRS). The importance of polar radiance data for constraining the wind field is discussed further in Geer et al (this volume).

PM09 also looked at the importance of observation frequency. They found improved impact with increased frequency and also demonstrated the importance of location within the time window. Assimilating only the last image in the 12 hr time window shows much greater benefit than one at the start as it enables the assimilation process to use humidity as an advected tracer from which information about the flow can be extracted.

Considering the full observing system more impact is seen in FSO scores from the assimilation of geostationary AMVs than geostationary CSR at the Met Office (Figure 7) and ECMWF.

Cloud-affected infrared radiances from geostationary satellites can also be beneficial to improve the forecast quality of NWP systems. Extending to cloudy data is a key focus of current efforts with radiance assimilation, as they are dynamically interesting areas, which should benefit from better observational constraint. But, and it is a big but, this is very challenging for a number of reasons touched on in Section 4. Lupu and McNally (2012) examined the extent to which useful information on humidity can be derived from SEVIRI all-sky radiances (ASR) in the ECMWF 4D-Var system. Initial work with geostationary radiances has focussed on using cloudy data in fully overcast scenes (>0.99), based on a scheme developed at ECMWF for AIRS,IASI, and HIRS (McNally 2009). Overcast scenes over land and ice surfaces, with an unreasonable cloud-top pressure or when the cloud top is determined to be below 900 hPa are not used in the current system. Very few SEVIRI observations pass this test (~8000 in one month).Despite the low numbers, the retained overcast radiances cover the areas where CSR are not available and their local impact may be important. Small positive impact on the wind forecast scores was seen in experiments using the full observing system and the change was implemented operationally at ECMWF in 2012 (Lupu and McNally, 2012).

Work has also been undertaken at ECMWF to investigate the impact of assimilating ozone sensitive radiances from the SEVIRI 9.7 μm channel (Lupu and McNally, 2013). This has the potential to provide very useful wind information in the lower stratosphere, where few other wind observations exist. Experiments were run where the dynamical link between ozone and the rest of the system was enabled. It was demonstrated that by activating the ozone feature tracing, 4D-Var can alter the temperature and wind fields, s well as the ozone field itself in order to improve the fit to observed ozone concentrations. When added to the full observing system, SEVIRI ozone-sensitive radiances slightly improved the fit to other infrared ozone-sensitive radiances, but the wind analysis and forecast impact results did not suggest benefit on improving the ECMWF wind field and as a result the change was not recommended for operational assimilation.

4 A look ahead

NWP models will continue to need information on the wind field to represent the divergent component of the flow properly. This is particularly important in the tropics and for small-scale features of the flow; the latter is likely to get more important as model resolution improves. It is therefore important to continue to provide high quality observations with good horizontal, vertical and temporal coverage. What is the long-term future of AMVs versus direct assimilation of radiances? It is attractive to consider extracting wind information in the assimilation system from direct radiance assimilation, allowing for development and dynamical coupling of features. Assimilation of CSRs already shows improvement to wind analyses and these are largely used instead of clear sky AMVs. However, a number of challenges remain in cloudy regions:

1. Highly non-linear operators with respect to cloud variables
2. Requires adequate representation of model cloud – errors with mismatched cloud locations between models and observations
3. Handling of multi-layer cloud
4. Need more situation-dependent and cloud-specific background error formulations
5. Resolution of analysis in space and time and spatial and temporal density of assimilated radiance data – suggest only extract broad-scale motion.
6. Choice of data assimilation methodology – demonstrated in 4D-Var, but unproven in 4D ensemble approaches.

The question of radiance assimilation versus AMV derivation and assimilation is particularly relevant to future plans for extracting wind information from geostationary hyperspectral IR sounders e.g. MTG-IRS. It is not yet clear which approach will be best. A novel approach to AMV derivation has been developed at CIMSS (Velden et al., 2004) and explored further by Stewart (2013). They use sounder data to derive moisture analyses on different levels and produce wind profiles by applying AMV tracking techniques to these sequences of moisture analyses. The approach has been demonstrated with simulated data, considering both clear and cloudy regions. Whether the wind information comes from this novel twist on AMV derivation or direct radiance assimilation, there is potential to get improved vertical resolution (similar to existing hyperspectral sounders on polar platforms), but at the better temporal resolution possible from a geostationary platform. This may go some way towards meeting the requirement of the Global Observing System for good horizontal, vertical and temporal coverage of the winds, supporting other missions such as Doppler Wind Lidar (e.g. Rennie, this volume).

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