ATMOSPHERIC MOTION VECTORS IN THE AROME/HARMONIE MESOSCALE MODEL IN AEMET

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Abstract

Atmospheric Motion Vectors (AMV) are widely used by Numerical Weather Prediction (NWP) global assimilation systems, as they can provide information about atmospheric wind in areas not well covered by other observation systems. In regional mesoscale NWP, assimilation cycles are carried out frequently (typically every three hours, but often hourly or even sub-hourly), and the cut-off time for observations is short (typically 1 to 2 hours, but it can be as short as 20 minutes). Therefore, observation sources that combine a high frequency with a short latency are especially valuable. AMVs from the geostationary Meteosat Second Generation (MSG) satellite located at 0 degrees longitude currently represent such a source over Southern Europe.

However, AMVs are not simple point observations of wind, but the result of a complex derivation process. It is well known that AMV errors are large and complex, and that their characteristics vary with e.g. height assignment method or geographical area. In recent years several AMV studies have been carried out to improve the knowledge about error characteristics and vertical representativity, to explore alternative interpretations, or to design suitable height corrections, following different approaches. From the perspective of mesoscale NWP, there is also the issue of the horizontal scale represented by AMVs, partly related to the size of the tracer boxes, and partly to the quality index used to filter AMVs for the assimilation, as this index is essentially a measure of spatial and temporal consistency.

This contribution presents the plans and work in progress in AEMET (Spanish National Meteorological Service) to assimilate AMVs from SEVIRI imagery from the MSG satellite at 0 degrees longitude in the AROME/HARMONIE regional mesoscale NWP model.

1 MOTIVATION AND BACKGROUND

AMVs are widely used by NWP global assimilation systems, as they can provide information about atmospheric wind in areas not well covered by other observation systems. In regional mesoscale NWP, assimilation cycles are carried out frequently (typically every three hours, but often hourly or even sub-hourly), and the cut-off time for observations is short (typically 1 to 2 hours, but it can be as short as 20 minutes). Therefore, observation sources that combine a high frequency with a short latency are especially valuable. AMVs from the geostationary MSG satellite located at 0 degrees longitude currently represent such a source over Southern Europe. However, AMVs are complex retrievals of wind and they present specific challenges.

AEMET is part of HIRLAM (High Resolution Limited Area Model), a consortium of European National Meteorological Services. For its operational short-range NWP, AEMET runs AROME/HARMONIE, a high resolution, non-hydrostatic, convection-permitting model (Seity et al., 2011). The current operational suite uses version 40h1.1, with a horizontal resolution of 2.5 km and 65 vertical levels, over two domains (shown in Figure 1), with an assimilation-forecast cycle of 3 hours, hourly boundary conditions from the ECMWF model, and a 3D-Var system that assimilates conventional observations, AMSU-A and GNSS ZTD. With this context, there is ongoing work, started recently, to explore the assimilation of AMVs and prepare and optimize the assimilation setup.

AMVs from geostationary satellites have been assimilated routinely in global NWP models for decades; however, the situation regarding the assimilation in high resolution limited area models in Europe is quite different. Although there are some recent (Lean et al., 2015) or ongoing studies (Randriamampianina et al., 2016), generally geostationary AMVs are not assimilated in high resolution limited area models in Europe. One of the reasons is that, for several National Meteorological Services (NMS) in Europe, the latitude of a good part of the geographical domain is too high to be well covered by AMVs from a geostationary satellite. Another possible reason is that some NMSs have another good source of wind information for the purpose, such as Mode-S (e.g. Lange and Janjic, 2016). In addition, it is not clear whether AMVs, as generated operationally nowadays, can truly contribute to the model representation of the finer scales, or whether their overall impact on the analysis can be better than neutral.

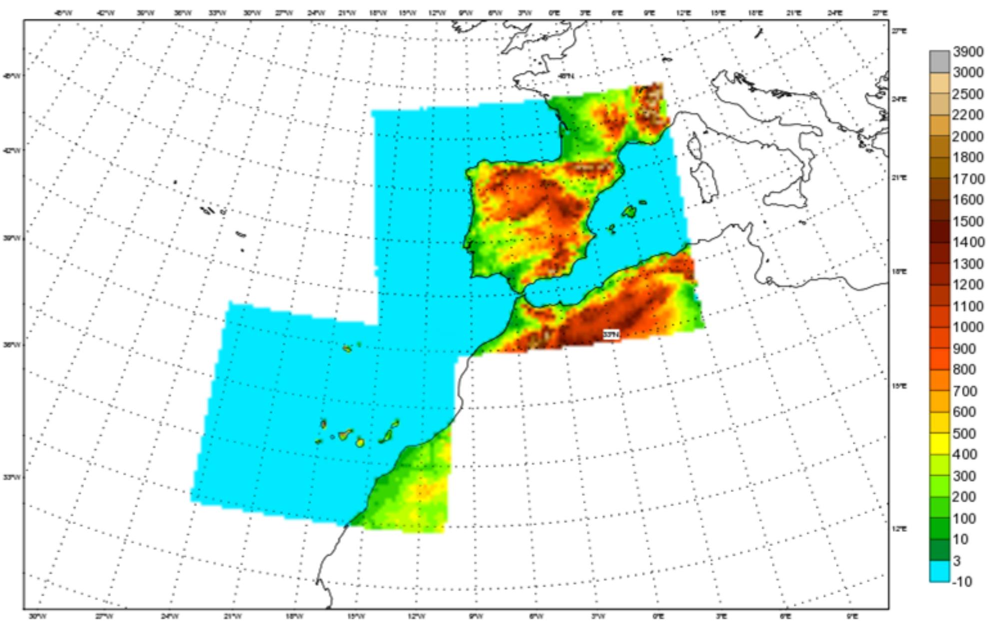

Figure 1: **Operational domains in the AROME/HARMONIE model in AEMET.**

2 MESOSCALE DATA ASSIMILATION AND AMVs

There is a considerable experience in the AMV community regarding the assimilation of AMVs from geostationary satellites, as AMVs have been assimilated in global NWP models for decades. It is well known that their errors are large and complex, and that their characteristics vary with e.g. the height assignment method or geographical area. It is generally accepted that height assignment is currently the origin of a large part of the AMV error, and often the estimate of 70% is given, after Velden and Bedka (2009). In recent years several AMV studies have been carried out to improve the knowledge about error characteristics and vertical representativity, to explore alternative interpretations, or to design suitable height corrections, following different approaches (Velden and Bedka, 2009; Forsythe et al., 2010; Weissmann et al., 2013; Hernandez-Carrascal and Bormann, 2014; Lean et al., 2015; Salonen et al., 2015; Folger and Weissmann, 2016).

In addition, in mesoscale data assimilation some AMV characteristics of relatively low importance in global NWP may become an important issue. If we consider the process of AMV derivation, there are several aspects that prompt the question of whether the horizontal representativity of AMVs might be too coarse for the purpose of mesoscale assimilation. In the operational derivation of AMVs from geostationary imagery, the apparent motion of brightness temperature (or radiance) structures is estimated by using region-matching methods across a sequence of two or more images. The interval between consecutive MSG images is 15 minutes (except for rapid scan imagery), and the size of tracer boxes is 24*x*24 pixels (12*x*12 for the HRVIS channel). Considering that the size of pixels in SEVIRI images at the sub-satellite point is 3 km for all the channels except for HRVIS (1 km), it would be expected that AMVs represent a wind averaged over horizontal neighbourhoods with a diameter around 10 km for the HRVIS channel and of 50 to 100 km for the rest. It seems that only operational AMVs from the HRVIS imagery could actually contribute to the model description of fine scale structures. However, HRVIS AMVs are not available during daytime and their height is in the low-level range. Night time and high levels are covered only by AMVs which in the best case represent the wind averaged over an area much larger than the horizontal resolution of the model. Even if, instead of the nominal horizonal resolution (2.5 km), we think of the effective resolution of the model (10 to 25 km), the horizontal representativity of AMVs is still an issue, at least when finer scale structures are present.

In addition, the Quality Index (QI) typically used in DA to filter AMVs (and retain only those on which there is a high confidence), is essentially a measure of spatial and temporal consistency. By selecting high-QI AMVs we are actually preventing them from contributing to the description of fine scale structures. It has long been pointed out that AMVs produced following the traditional methods may not be suitable for mesoscale applications, and variations of the traditional AMV derivation methods, tailored to mesoscale, have been developed and evaluated (e.g. Bedka and Mecicalski, 2005; Bedka et al., 2009). An obvious approach in mesoscale applications is to lower the QI threshold, i.e. to relax the constraint on consistency. However, this approach opens the door not only to AMVs carrying information on small-scale structures, but also to plainly erroneous estimates of wind. What is needed is an alternative a-priori estimate of AMV quality suitable for the purpose of mesoscale data assimilation.

The time representative of the AMV retrievals is not an issue with global NWP, as most global models use a 4D-Var algorithm. However, in mesoscale assimilation with 3D-Var, it may become an issue. Currently there is a tendency towards hourly assimilation cycles, and it is important that the observations (or retrievals) are representative of the analysis time. In addition, observation-background statistics are be more meaningful if they have the same time. EUMETSAT operational AMVs are produced and distributed hourly, which is suitable for the current needs in high resolution NWP, but have a representative time of 30 minutes past every hour, which does not seem to be appropriate for the purpose.

Another issue is the density of useful observations. In principle it might appear that this is not a problem, particularly with the AMV derivation software from the EUMETSAT Nowcasting SAF (Garcia-Pereda, 2016). However, from the perspective of data assimilation, an increased density of AMVs may not be truly useful unless it is accompanied by a decrease in observation error correlation. In current operational assimilation systems underlies the hypothesis of uncorrelated observations errors, and therefore, in order to ensure that observation error correlation is kept reasonably low, observation thinning is performed previous to the assimilation. Observation error correlation is an issue in assimilation of AMVs. For instance, Bormann et al. (2003) found significant correlations on scales of several hundreds of kilometers. For geostationary AMVs, typically thinning boxes of 200 km by 200 km by 100 hPa are used. Derivation methods that reduce AMV error correlation (e.g. through the development of estimates of quality not based on consistency) would be very valuable in assimilation. However, this aspect does not attract much interest in AMV derivation, while the wind density (sometimes referred to as resolution) is often seen as the key aspect of an AMV derivation system.

It is known that the use of large tracers in the tracking cause an increased smoothing of the wind field, as there is an effective motion averaging over the tracer (possibly at different scales and levels), and alternative tracking methods have been developed to tackle this problem. The nested-tracking method (Bresky et al., 2012) was developed partly with the aim of minimizing the smoothing of the wind field caused by the use of large tracers, while avoiding the tendency of small tracers to lead to false matches during the tracking, i.e. matches not representative of the cloud motion. In this method, tracers are sub-windows (of size e.g. 5*x*5 pixels) nested in traditional-size tracers, and a clustering algorithm separates motion at different scales or heights. Regarding mesoscale data assimilation in Europe, it would be interesting to explore this approach, as it tackles the issue of the excessive averaging of the wind field. The plans of the EUMETSAT Nowcasting SAF to include the nested-tracking method in its AMV derivation software (Garcia-Pereda, 2016) are a step forward in this direction.

3 DIRECTIONS OF WORK

The EUMETSAT Satellite Application Facility on support to Nowcasting (NWC SAF) produces software intended to generate products at the user side on quasi-real time. Two components of the NWC/GEO software are very useful to handle AMVs. First, the High Resolution Winds (HRW) software (Garcia-Pereda, 2016) is a mature and flexible AMV derivation software system, and its flexibility makes it very useful in research. Second, in version v2016 (expected to be available during autumn 2016), the Cloud Products will include, on top of the cloud type, phase and top height, also new microphysics products (optical thickness, liquid/ice water path and effective radius), of special interest for the study of AMVs. The ability of running the HRW and the Cloud Products software on the user side, on quasi-real time, makes them very valuable for research studies, and possibly also in operational assimilation of AMVs.

AMVs seem a potentially useful source of information about atmospheric wind for the initial conditions for the short-range NWP model operational in AEMET. However, AMVs come with their challenges, some specific of mesoscale assimilation and others comon with global models. Considering the AMV issues, the needs for initial conditions and the tools available, we envisage the following directions of work, using the NWC/GEO sofware when appropriate:

- Explore height assignment corrections based on cloud physical properties and/or lidar.
- Explore alternative ways of estimating the confidence in the quality of AMVs, i.e. alternative confidence indices not based on spatial and temporal consistency, e.g. based on the shape of the matching surfaces.
- Explore AMVs from MSG rapid scan imagery.

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