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Evaluation of the 15 min. NWC SAF High Resolution AMVs

Javier García Pereda

AEMET

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This documentation was developed within the context of the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWP SAF), under the Cooperation Agreement dated 1 December, 2006, between EUMETSAT and the Met Office, UK. The partners in the NWP SAF are the Met Office, ECMWF, KNMI and Météo France.

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Report of the Visiting Scientist Activity at the UK Met Office “Evaluation of the 15 min. NWC SAF High Resolution AMVs”

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**Prepared by
Javier García Pereda (AEMET)**

REPORT SIGNATURE TABLE

Function	Name	Signature	Date
Prepared by	Javier García Pereda (AEMET)		<i>3 January 2012</i>
Reviewed by	Graeme Kelly (Met Office)		<i>9 January 2012</i>
Authorised by	Bryan Conway (Met Office)		<i>10 January 2012</i>

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0 REFERENCES

0.1 NWC SAF Applicable Documents

Ref.	Title	Code	Vers	Date
[AD.1]	Algorithm Theoretical Basis Document for “High Resolution Winds” (HRW – PGE09 v3.1)	SAF/NWC/CDOP/INM/SCI/ATBD/09	3.1	01/04/11
[AD.2]	Product User Manual for “High Resolution Winds” (HRW – PGE09 v3.1)	SAF/NWC/CDOP/INM/SCI/PUM/09	3.1	01/04/11
[AD.3]	Validation Report for “High Resolution Winds” (HRW – PGE09 v3.0)	SAF/NWC/CDOP/INM/SCI/VR/07	1.0	28/12/09
[AD.4]	Validation Report for “High Resolution Winds” (HRW – PGE09 v3.1)	SAF/NWC/CDOP/INM/SCI/VR/09	1.0	01/04/11

Table 1: List of NWC SAF Applicable Documents

0.2 Reference Documents

Ref.	Title
[RD.1]	J.Schmetz, K.Holmlund, J.Hoffman, B.Strauss, B.Mason, V.Gärtner, A.Koch, L. van de Berg, 1993: Operational Cloud-Motion Winds from Meteosat Infrared Images (Journal of Applied Meteorology, Num. 32, pp. 1206-1225).
[RD.2]	S.Nieman, J.Schmetz, W.P.Menzel, 1993: A comparison of several techniques to assign heights to cloud tracers (Journal of Applied Meteorology, Num. 32, pp. 1559-1568).
[RD.3]	C.M.Hayden & R.J.Purser, 1995: Recursive filter objective analysis of meteorological fields, and application to NESDIS operational processing (Journal of Applied Meteorology, Num. 34, pp. 3-15).
[RD.4]	K.Holmlund, 1998: The utilisation of statistical properties of satellite derived Atmospheric Motion Vectors to derive Quality Indicators (Weather and Forecasting, Num. 13, pp. 1093-1104).
[RD.5]	J.M.Fernández, 2003: Enhancement of algorithms for satellite derived winds: the High Resolution and Quality Control aspects. (Proceedings 2003 Meteorological Satellite Conference, EUMETSAT Pub.39, pp.176-182).
[RD.6]	J.García-Pereda & J.M.Fernández, 2006: Description and validation results of the high resolution wind product from HRVIS MSG channel at the EUMETSAT Nowcasting SAF (Proceedings 8 th International Wind Workshop, EUMETSAT Pub.47).
[RD.7]	J.García-Pereda, 2008: Evolution of High Resolution Winds Product (HRW), at the Satellite Application Facility on support to Nowcasting and Very short range forecasting (Proceedings 9 th International Wind Workshop, EUMETSAT Pub.51).
[RD.8]	J.García-Pereda, 2010: New developments in the High Resolution Winds product (HRW), at the Satellite Application Facility on support to Nowcasting and Very short range forecasting (Proceedings 10 th International Wind Workshop, EUMETSAT Pub.56).
[RD.9]	C.M.Hayden & R.T.Merrill, 1988: Recent NESDIS research in wind estimation from geostationary satellite images (ECMWF Seminar Proceedings: Data assimilation and use of satellite data, Vol. II, pp.273-293).
[RD.10]	W.P.Menzel, 1996: Report on the Working Group on verification statistics. (Proceedings 3 rd International Wind Workshop, EUMETSAT Pub.18, pp.17-19).
[RD.11]	J.Schmetz, K.Holmlund, A.Ottenbacher, 1996: Low level winds from high resolution visible imagery. (Proceedings 3 rd international winds workshop, EUMETSAT Pub.18, pp.71-79).
[RD.12]	Xu J. & Zhang Q., 1996: Calculation of Cloud motion wind with GMS-5 images in China. (Proceedings 3 rd international winds workshop, EUMETSAT Pub.18, pp.45-52).
[RD.13]	K.Holmlund & C.S.Velden, 1998: Objective determination of the reliability of satellite derived Atmospheric Motion Vectors (Proceedings 4 th International Wind Workshop, EUMETSAT Pub.24, pp.215-224).
[RD.14]	K.Holmlund, C.S.Velden & M.Rohn, 2000: Improved quality estimates of Atmospheric Motion Vectors utilising the EUMETSAT Quality Indicators and the UW/CIMSS Autoeditor (Proceedings 5 th International Wind Workshop, EUMETSAT Pub.28, pp.72-80).
[RD.15]	R.Borde & R.Oyama, 2008: A direct link between feature tracking and height assignment of operational Atmospheric Motion Vectors (Proceedings 9 th International Wind Workshop, EUMETSAT Pub.51).

Table 2: List of Reference Documents

1 OBJECTIVES OF THIS VISITING SCIENTIST ACTIVITY

A Visiting Scientist Activity has been taken between the NWP SAF (“Satellite application Facility on Numerical Weather Prediction”) and Javier García Pereda (working for AEMET, the Spanish National Weather Service), between the 12 and 16 of December of 2011, at the location of the UK Met Office inside the Meteorology Building at the University of Reading. UK Met Office and University of Reading scientists Graeme Kelly and Peter Lean have attended this meeting. Javier García Pereda has been the main developer of the AMV (Atmospheric Motion Vectors) algorithm inside the NWC SAF (“Satellite application facility on support to Nowcasting and Very short range forecasting”), called “High Resolution Winds”.

At the beginning of the meeting, the first task was the redefinition with Graeme Kelly and Peter Lean of some details of the work plan of the VSA, to be the next ones:

- To have a deep knowledge of all the procedures, functions and characteristics of the “High Resolution Winds algorithm” for its later use and application inside the Met Office (basically inside the NWP models assimilation).
- To define some aspects and characteristics of “High Resolution Winds algorithm”, to have a clear definition of the needed options for an optimal use of “High Resolution Winds algorithm”.
- To make a specific evaluation of the Quality index implemented inside HRW algorithm, for the optimal assimilation of HRW output in the Met Office NWP models.

The second and third aspects relate to tasks one and two defined in the preliminary “Work plan” of the Visiting Scientist Activity, defining basically how to optimally use HRW data to reduce the corresponding “departure statistics”. No specific comparisons with MPEF AMVs have been taken, because they are already available through previous work at the Met Office, and it was considered by Graeme Kelly that this work was not explicitly necessary.

Tasks three and four of the preliminary “Work plan” referred to the evaluation of the HRW departure statistics through the “expected error”. Nevertheless it was agreed with Graeme Kelly and Peter Lean, that it was more useful to them to spend the time of the VSA having a detailed explanation of how HRW algorithm works, the task each one of the function takes and where and how each of the procedures needed for the calculation of the AMVs is taken. Besides, it was considered not to be realistic and determinant to introduce the “expected error” in HRW algorithm in such a small term of time.

A description of these taken tasks is shown next, including the new documents and validation results explicitly elaborated throughout this VSA.

2 DESCRIPTION OF THE TASKS IN THE VISITING SCIENTIST ACTIVITY

2.1 Detailed description of NWCSAF/High Resolution Winds algorithm

As already commented, the Work Plan was redefined at the beginning of the meeting to optimise the possibilities and utility of this Visit. It was agreed that the most helpful option would be a detailed explanation of the algorithm to Graeme Kelly and Peter Lean, for a good understanding and use of HRW algorithm considering their current NWP assimilation needs, and for its application to the calculation of AMVs related to simulated imagery.

Peter Lean described how the Met Office NWP model is now able to calculate now full resolution radiance maps (with a resolution similar to the one given by SEVIRI images), and that after converting these radiance maps to HRIT format they are able to calculate AMVs related to them with HRW algorithm. Comparing the AMVs with the wind fields of the NWP model, an interesting study is going to be possible to discover very well the relationships existing between both types of data: the AMV displacements and the NWP fields. Taking also into account that the NWC SAF Cloud outputs are also going to be calculated with these radiance maps (Cloud mask, cloud type, cloud top temperature and height), an explicit differentiation of results in the comparison of the AMVs and the NWP wind fields is going to be available, related to the cloud type each AMV has been calculated with. Some initial examples of the Cloud and AMVs calculated with NWP simulated imagery were shown by Peter Lean during this meeting.

Two days were needed for this detailed description: a complete explanation of each function inside HRW algorithm, and their dependencies and variables, was taken throughout this time. Part of this time was explicitly used to elaborate a complete diagram tree, where the tasks taken by each HRW function and the corresponding relationship between all of them were defined. With this diagram it is possible with a quick look to know where to go inside HRW algorithm to find a concrete procedure. This diagram tree is shown in next pages, so that it can be available to all other HRW algorithm users.

Throughout this process some suggestions were made by Graeme Kelly and Peter Lean about the HRW code and functions, to facilitate their understanding and usability:

- To change the name of several functions to a more descriptive one of the tasks related.
- To make a description in the function header (a few lines only) of the tasks related to each function, and the corresponding relationships with other functions in HRW code.
- To change the format of the BUFR HRW output file, to be similar to the one used by Eumetsat MPEF AMVs, for a quicker and easier postprocessing of HRW output data (for example, in assimilation in NWP models).

These recommendations will be taken into account for future versions of HRW algorithm (v2013 and afterwards).

Graeme and Peter commented that having a detailed description and explanation of all elements inside HRW code was very useful in understanding HRW algorithm, specially through the clarifications given on some specific issues inside it (like the structure of the AMV data, based basically on two types of data, “tracers” and “tracerwinds with up to three winds per case”, to be updated in parallel).

2.1.1 Diagram Tree of Functions inside NWCSAF/High Resolution Winds algorithm

```

PGE09.c => Main PGE09 function
*** hrw_ReadData => Reads Configuration file
*** hrw_GetAncillaryData => Reads Lat/lon/sat/sun angles
*** hrw_ReadSeviriData => Reads Seviri Data
    *** hrw_Normalization => Verifies SEVIRI image values and Normalizes of VIS image values
*** hrw_ReadClimatProfiles => Reads Climatological profiles
*** hrw_GetAvPressLevels => Defines Possible Pressure Levels
*** hrw_CountAvPressLevels => Counts Available Pressure Levels
*** hrw_AllocLevels => Allocates memory for Pressure Levels
*** hrw_NWPSearch => Reads NWP data
    *** hrw_SetAvPressLevels => Stores Available Pressure Levels in an array
*** hrw_ReadSfcMatrix => Reads Topographic data
*** hrw_Meters2Press => Converts Topographic data to Pressure data
*** hrw_StabilityNorm => Calculates Stability data
*** hrw_ReadTracers => Reads Tracer File from the previous slot
*** hrw_GetWinds => Calculates winds with the tracers from the previous slot
    *** hrw_Alloc_Winds => Allocates memory for variables in GetWinds module
    *** hrw_TracerCharacteristics => Stores "tracer variable" information into corresponding "tracer_wind variable" information
    *** hrw_CloudTypeCalculation => Calculates Cloud type as defined in old Height assignment method
    *** hrw_SetTracerIRArray => Fills tracer area (array) with IR/WV BT or VIS Reflectance data for the old Height assignment
    *** hrw_Get_Cldhgt => Calculates Tracer Cloud Top temperature (for Cloud top pressure)
    *** hrw_Cld_T2P_nwp => Converts Cloud top Temperature to pressure using NWP
    *** hrw_Cld_T2P_std => Converts Cloud top Temperature to pressure using Climate profiles
        *** hrw_Cld_T2P_d => Interpolates Climate profiles to standard atmosphere
        *** hrw_Cld_T2P_0 => Calculates pressure with standard atmosphere
    *** hrw_SetTracerBox => Fills tracer area (matrix) with IR/WV BT or VIS Reflectance data for the old Height assignment
    *** hrw_ChknivCtype => Recalculates tracer mean/sigma temperature with Cloud type information (for Cloud base pressure)
    *** hrw_Cld_T2P_nwp => Converts Cloud base Temperature to pressure using NWP and modified mean/sigma values
    *** hrw_Cld_T2P_std => Converts Cloud base Temperature to pressure using Climate profiles and modified mean/sigma values
        *** hrw_Cld_T2P_d => Interpolates Climate profile to standard atmosphere
        *** hrw_Cld_T2P_0 => Calculates pressure with standard atmosphere
    *** hrw_TracerWindLevel => Defines Tracer pressure level (with cloud top or cloud base) depending on cloud type
    *** hrw_WindGuess => Calculates wind guess
        *** hrw_Mvguv => Interpolates wind guess at the tracer location
        *** hrw_WindModDir => Calculates speed module and direction for the wind guess at the tracer location
    *** hrw_WindDisplace => Calculates wind guess predicted position as initial tracking area centre (when wind guess is used)
    *** hrw_TrackCentre => Calculates wind guess predicted position latitude and longitude increments
    *** hrw_TrackCorrection => Calculates later image tracking true position with euclidean distance or cross correlation methods
        *** hrw_SetTracerArray => Fills tracer area/tracking area arrays with IR-WV BT or VIS Reflectance data for the tracking
        *** hrw_SetTracerCTTPArray => Fills tracking area array with CTHH temperature and pressure for CCC method height assignment
        *** hrw_SetTracerCTTPShortArray => Fills tracking area array with Cloud type for CCC method height assignment
        *** hrw_Track => Computes tracking considering euclidean distance or cross correlation methods
            *** hrw_TrackCorr => Computes a first step tracking considering only pixels separated by a gap for both methods

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*** hrw_TrackLagMin          => Computes euclidean distance minimums/correlation maximums considering only the previous positions
*** hrw_TrackCorrAround     => Computes euclidean distance/correlation values only around prior minimums/maximums
*** hrw_TrackLagCentre      => Defines up to three minimum euclidean distance centres/maximum correlation centres
    *** hrw_TrackLag        => Defines a non integer position of these tracking centres through a quadratic interpolation
*** hrw_GetSegmentSize     => Computes displacement existing between initial tracer centre and later possible tracking centres
*** hrw_CorrSearch         => Calculates the "tracer characteristics" at the final tracking positions
*** hrw_SetTracerBox       => Fills final tracking position (matrix) with IR/WV BT or VIS Reflectances
*** hrw_Frontier_Centile   => Defines BT/reflectance frontiers with the centile thresholds
*** hrw_Centile_Frontier   => Defines centiles considering the BT/Reflectance frontiers
*** hrw_TracerDiffSearch   => Runs the Big pixel brightness variability test in the final tracking positions
    *** hrw_TracerPixelCharacterization => Calculates the Big pixel values
    *** hrw_TracerHorizontalDiff    => Takes the Horizontal direction study in the variability test
    *** hrw_TracerVerticalDiff      => Takes the Vertical direction study in the variability test
    *** hrw_TracerDescDiff          => Takes the Descending direction study in the variability test
    *** hrw_TracerAscDiff           => Takes the Ascending direction study in the variability test
*** hrw_SetArrayValues       => Fills final tracking position (matrix) with IR/WV BT or VIS Reflectance data
*** hrw_Chkniv               => Calculates mean/sigma temperature in the tracking positions
*** hrw_TrackCentreCorrection => Evaluates if principal correlation centre must be changed or not
*** hrw_WindCalculation      => Defines all wind data for each tracking position (including CCC height assignment values)
*** hrw_Cld_T2P_nwp         => Converts Cloud top Temperature to pressure using NWP
*** hrw_Cld_T2P_std        => Converts Cloud top Temperature to pressure using Climate profile
    *** hrw_Cld_T2P_d       => Interpolates Climate profile to standard atmosphere
    *** hrw_Cld_T2P_0       => Calculates pressure with standard atmosphere
    *** hrw_Ymvuv           => Calculates wind components from lat/lon data
    *** hrw_WindModDir      => Calculates speed module and direction
*** hrw_WindGuess           => Recalculates wind guess at CCC method new pressure level for the QI forecast test
*** hrw_Free_Winds         => Deallocates memory for variables in GetWinds module
*** hrw_Qc                  => Calculates Quality Indexes and all related information
*** hrw_QcAlloc_Short / hrw_QcAlloc_Float
/ hrw_QcAlloc_Parameters   |
*** hrw_QcSortLinLat       |> Three functions allocating memory for variables in Qc module
    *** hrw_QcSort          => Sorts wind data considering line and latitude variables
*** hrw_QcPhase1          => Used for the wind data sorting
    *** hrw_QcPhase1_Alloc  => Calculates individual (forecast/temporal/spatial) tests and whole QI value
    *** hrw_QcGetBestPred   => Allocates memory for QcPhase1 module
    *** hrw_QcGetAnt        => Obtains predecessor winds for temporal test
    *** hrw_QcGetBestBuddy  => Defines best predecessor wind for temporal test
    *** hrw_QcMsgAqc        => Defines buddies (near winds) for spatial test
    *** hrw_QcPhase1_Free   => Calculates individual (forecast/temporal/spatial) tests and whole QI value
*** hrw_QcPhase2          => Deallocates memory for QcPhase1 module
*** hrw_IndTopoAssignment => Defines Wind with best quality considering different options
*** hrw_IndTopoReassignment => Calculates Static orographic flag
*** hrw_QcBestWindSelection => Calculates Dynamic orographic flag
*** hrw_FinalControlCheck => Defines Best Wind (from the up to three available cases) and calculates additional Quality flags
*** hrw_QcFree_Short / hrw_QcFree_Float
/ hrw_QcFree_Parameters   |
                          |> Three functions deallocating memory for variables in Qc module

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*** hrw_WritePredWinds => Writes persistent winds in tmp directory
*** hrw_GetTracers => Calculates new tracers at this slot
    *** hrw_Alloc_Tracers => Allocates memory for GetTracers module
    *** hrw_ReadPredWinds => Reads persistent winds
    *** hrw_SearchTracerCharOpt => Searches for a persistent wind position in the search area
    *** hrw_SetTracerInputArray => Fills tracer area (array) with IR-WV BT/VIS Reflectances for tracer search
    *** hrw_SearchTracerLaplacian => Searches for tracers considering the Gradient method
        *** hrw_Hisfron => Computes tracer histogram and frontiers
        *** hrw_Targeb => Calculates tracer position using Gradient method
        *** hrw_SetArrayValues => Fills tracer area (as an array) with IR-WV BT/VIS Reflectances for tracer search
        *** hrw_Chkniv => Calculates mean/sigma temperature in the tracer area
    *** hrw_SearchTracerSharp => Searches for tracers considering the Tracer characteristics method
        *** hrw_SetGridValues => Fills tracer area (matrix) with IR-WV BT/VIS Reflectances for tracer search
        *** hrw_Hisfron => Computes tracer histogram and frontiers
        *** hrw_SetArrayValues => Fills tracer area (array) with IR-WV BT/VIS Reflectances for tracer search
        *** hrw_Chkniv => Calculates mean/sigma temperature in the tracer area
        *** hrw_TracerDiffSearch => Runs the Big pixel brightness variability test
            *** hrw_TracerPixelCharacterization => Calculates the Big pixel values
            *** hrw_TracerHorizontalDiff => Takes the Horizontal direction study in the variability test
            *** hrw_TracerVerticalDiff => Takes the Vertical direction study in the variability test
            *** hrw_TracerDescDiff => Takes the Descending direction study in the variability test
            *** hrw_TracerAscDiff => Takes the Ascending direction study in the variability test
        *** hrw_SetGridValues => Refills tracer area (matrix) with IR-WV BT/VIS Reflectances if the candidate was too near
            *** hrw_TracerDiffSearch => Runs the Big pixel brightness variability test
                *** hrw_TracerPixelCharacterization => Calculates the Big pixel values
                *** hrw_TracerHorizontalDiff => Takes the Horizontal direction study in the variability test
                *** hrw_TracerVerticalDiff => Takes the Vertical direction study in the variability test
                *** hrw_TracerDescDiff => Takes the Descending direction study in the variability test
                *** hrw_TracerAscDiff => Takes the Ascending direction study in the variability test
    *** hrw_TracerDiffSearch => Big pixel brightness variability test, run here only for tracers related to Gradient method
        *** hrw_TracerPixelCharacterization => Calculates the Big pixel values
        *** hrw_TracerHorizontalDiff => Takes the Horizontal direction study in the variability test
        *** hrw_TracerVerticalDiff => Takes the Vertical direction study in the variability test
        *** hrw_TracerDescDiff => Takes the Descending direction study in the variability test
        *** hrw_TracerAscDiff => Takes the Ascending direction study in the variability test
    *** hrw_TracersDetailedDiscrimination => Studies if a Basic tracer can also work as Detailed tracer
        *** hrw_Centile_Frontier => Defines centiles considering the BT/Reflectance frontiers
    *** hrw_Free_Tracers => Deallocates memory for GetTracers module
*** hrw_WriteTracers => Writes tracer file in tmp directory
*** hrw_EncodeBufR => Encodes wind output data for BUFR bulletin writing
    *** hrw_SetReplicatedDesc => Defines specific information for each wind for BUFR bulletin writing
    *** hrw_SetFixedDesc => Defines common information for all winds for BUFR bulletin writing
    *** hrw_WriteBufR => Writes winds in output BUFR file in export/PGE09 directory
*** hrw_Free_Seviri => Deallocates memory for SEVIRI data
*** hrw_Free_TWInd => Deallocates memory for "tracer wind" data
*** hrw_Free_LevelsandGuesses => Deallocates memory for NWP data

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2.2 Optimal use of NWCSAF/High Resolution Winds algorithm

An additional day was used to explain the basic characteristics of HRW algorithm, to define the optimal conditions and filterings defined by Javier García Pereda for the operative use of HRW algorithm. For the moment, at the Met Office use of HRW data was only based on filterings related to the Quality Index (defined as “YT” in the HRW transformed Mcidas MD files).

An additional filtering related to the “Spatial test” (defined as “TESE” in the HRW transformed Mcidas MD files) was also recommended to be used, using only cases with “Spatial test=3” (i.e. cases where the AMV has passed the spatial partial quality index, and the chosen AMV has the best behaviour among the up to three AMVs calculated for each tracer considering the spatial partial quality index). Additionally, a filtering related to the “Orographic flag” (defined as “FLAI” in the HRW transformed Mcidas MD files) with values “Orographic flag=0,4,5” (i.e. cases where the orographic flag was not calculated or no orographic obstacles were found), and to the “Pressure error” (defined as “PERR” in the HRW transformed Mcidas MD files) with values of Pressure error smaller than 150 hPa, were also recommended to be used. This way, HRW outputs would be in line with the optimum conditions defined and validated in “HRW Validation reports”.

Besides, if the HRW AMVs are going to be used in NWP assimilation, it could be preferable to avoid the use of wind guess in the initial definition of the tracking area. The use of the wind guess permits to optimize the running time of HRW algorithm, looking for the tracer position in the later image in a relatively small area around the position defined by the NWP wind guess. But when there are important differences between the wind guess and the true wind observation it is possible that this tracer position in the second image is outside this small area around the position defined by the NWP wind guess. Because of this, the use of the wind guess causes a dependency of the AMVs on the NWP model used, and it should be avoided (specially if the region where NWC SAF products are calculated is small, as in the UK region used at the Met Office, where the running time of HRW algorithm is never going to be too large).

The use of the wind guess is configured as default option in HRW algorithm. To avoid the use of the wind guess next modifications are needed in HRW versions v2011 and later:

- To change a parameter in \$SAFNWC/include/PGE09/hrw_CalculationParameters.h file:
MAX_SEARCH_TRACKSIZE 32400 (only needed in HRW v2011 version).
 - Because it is a hardcoded parameter, it is then necessary to recompile PGE09 executable going to \$SAFNWC/src/PGE09 directory and running “make clean” and “make all” (only needed in HRW v2011 version).
 - To change several parameters in \$SAFNWC/config/safnwc_pge09.cfm configuration file
- | | | |
|------------|-----|---------------------------------------|
| WIND_GUESS | 0 | |
| LLAG_HRV | 180 | |
| ELAG_HRV | 180 | |
| LLAG_OTHER | 60 | (called LLAG_IR in HRW v2011 version) |
| ELAG_OTHER | 60 | (called ELAG_IR in HRW v2011 version) |

These changes permit to calculate AMVs of up to 320 km/h per component in the default “nominal scan configuration”, defining the tracking area around the position of the tracer in the initial image, looking for its true position in the second image in all directions around it.

The effect of not using the wind guess is besides slightly positive in the HRW AMV validation statistics. Considering “nominal scan configuration”, the BIAS and RMSVD (Root mean square vector difference) reduce up to a 10% when the wind guess is not used respect to the case where the wind guess is used. Considering the amount of calculated AMVs, in the IR108 case the amount of validated AMVs increases about a 5%, while in the HRVIS case the amount of AMVs reduces about a 15% (basically related to the larger size of the tracking area used in the HRVIS case). Because of all of this, a recommendation is given to the Met Office to avoid the use of the wind guess in the UK region for the later assimilation of the AMV data.

A comment was made by Graeme Kelly that the comparison of the HRW plotted together with NWP stream lines showed some cases of AMVs related to the low resolution channel (IR108), where the HRW AMVs tend to be completely horizontal/vertical when the corresponding NWP winds and stream lines can show a slightly diagonal shape. After an analysis, it was verified that this is only related to the resolution of the images used for the AMV calculation.

A case of a 20 kts (37 km/h) horizontal AMV was analysed by Javier Garcia Pereda to verify this issue. In the default configuration this AMV defines a displacement of 9 km between two consecutive images in the default configuration (separated by 15 minutes). Considering the nominal resolution of the IR108 images of 3 km (worse when nearing the edge of the planet), a vertical displacement of the AMV smaller than 1.5 km would be undetected (causing the AMV to be in the same row of both initial and later images because of the resolution of the pixel). If the true displacement of the tracer between images has then an angle respect to the horizontal of up to 10°, corresponding with a vertical displacement up to 1.5 km, the corresponding AMV would not be able to detect the vertical displacement because of the resolution of the images. This would explain the slight differences in angle that can appear between the AMV and the corresponding NWP winds and stream lines, related to the resolution of the IR108 image.

It was also experimentally noticed that this problem is not detected with the HRVIS AMVs because of the better resolution of the HRVIS images (which permits less differences between the AMV and the corresponding NWP winds and stream lines, in the example used of only up to 3°, because the maximum vertical displacement that can be unnoticed by the AMV is of only 0.5 km).

It was also concluded that this issue would be smaller if larger time gaps were used between the initial and later images for the calculation of the AMVs (for example 30 minutes).

2.3 Evaluation of NWCSAF/High Resolution Winds algorithm for NWP assimilation

Finally, two additional days were used to make a specific evaluation of the Quality index inside HRW algorithm. Related to this, it was seen that the conditions of use of HRW AMVs can be very different if a perspective related to nowcasting or NWP model assimilation is taken. The Met Office has verified that the default configuration of HRW algorithm is better tuned to a nowcasting perspective, because it provides very detailed fields of winds throughout the whole processing region for their direct use by the forecaster. Nevertheless these fields are too dense for their use in NWP assimilation and additional filterings are to be defined to be effectively used this way.

A description of the modifications implemented at the Met Office to assimilate HRW AMVs in the Met Office regional UK model was shown: they are based on thinning the amount of AMV data by using only AMVs with a higher Quality index threshold (92 for the AMVs related to the HRVIS channel; 97 for the AMVs related to the IR108 channel).

Besides, it had been detected by Graeme Kelly that the behaviour of this QI was not exactly the same than the one used by MPEF AMVs (because in general HRW QI values tend to be higher and higher thresholds were tentatively needed to be used for their NWP assimilation). Nevertheless, this dependence of the QI on the algorithm it is being used has generally been known for the AMVs calculated by different centres, as for example in 2003 paper by J.Le Marshall and A.Rea “Error characterisation of Atmospheric Motion Vectors”.

To illustrate these high HRW QI values, a small presentation was made by Graeme Kelly on the monitoring the Met Office is doing of the NWC SAF High Resolution Winds product. A complete monitoring is being done in Exeter by James Cotton on HRW AMVs together with AMVs coming from other sources, under McIDAS environment. Specific McIDAS tools (like MFLOT to generate data histograms and MDSCAT inside McIDAS-XRD tools to generate scatter plots) are used for this task. The higher density of AMV data in HRW algorithm is remarked, but also the need to define the higher Quality index thresholds shown before to use HRW AMVs in NWP assimilation. Comparing with Eumetsat AMVs, HRW HRVIS AMVs with a Quality index threshold of 92 and HRW IR108 AMVs with a Quality index threshold of 97 have an impact similar to the one shown by Eumetsat AMVs with a Quality index threshold of 80.

It was recognised that the behaviour of this QI not only depends on the weights and parameters used in the corresponding formulas but also on the way the “reference AMVs” used in the spatial and temporal tests are chosen. And for example, two different options are included inside HRW algorithm for this selection of the “reference AMVs”. A specific study has been made to verify that the default option used to select the “reference AMVs” (option PRED_SEARCH_USE 1 in hrw_QcPhase1.c function) is less restrictive and provides a larger amount of AMVs assigning generally larger values in the QI. The other option included in HRW algorithm to choose these “reference AMVs” (option PRED_SEARCH_USE 0 in hrw_QcPhase1.c function) is more restrictive in the selection of “reference AMVs” and provides a smaller amount of AMVs assigning generally smaller values in the QI. It has been verified that this second option might be more in accordance with NWP assimilation needs.

To implement this second option several changes have to be included in HRW code. Option PRED_SEARCH_USE 0 had been deactivated in HRW v2011 and it has to be again activated making next changes:

- To read again in \$SAFNWC/src/PGE09/hrw_ReadData.c function the configurable parameter PRED_SEARCH_USE, reincluding code:

```
/* ----- */
/* Criterion for Quality control reference AMV selection */
/* ----- */
if(IntValue(param_list, 1, "PRED_SEARCH_USE", &val)==-1)
{ Error_E(PGE09, HRW_ERROR_FINDING_PARAM, ": %s parameter",
  "PRED_SEARCH_USE");
  FreeConfList(param_list);
  return ERROR;
}
m->pred_search_use = (S_short)val;
if(m->pred_search_use > 0) m->pred_search_use = 1;
else m->pred_search_use = 0;
```

- To activate again all commented code in \$SAFNWC/src/PGE09/hrw_QcPhase1.c function related to options PRED_SEARCH_USE, inside next “ifs”:

```
if(m->pred_search_use == 0) { . . . }
else if(m->pred_search_use == 1) { . . . }
```

- To change/include again the corresponding parameter in the corresponding configuration file \$SAFNWC/config/safnwc_pge09.cfm with the new option:

```
PRED_SEARCH_USE 0
```

- To recompile PGE09 executable again going to \$SAFNWC/src/PGE09 directory and running “make clean” and “make all”.

A specific validation of the corresponding AMVs has been done to compare the impact of both options in the calculation of the Quality index and the HRW output AMVs.

Two additional options have been tried inside HRW code for an optimum use in NWP assimilation, in both keeping the new option for the selection of the “reference AMVs in the quality tests” (option PRED_SEARCH_USE 0), and eliminating in both the “forecast test” contribution in the QI, as it is normally preferred for the NWP assimilation. A specific study has also been made to verify this change in the HRW output and the validation statistics. The options used are the next ones:

- One in which the Quality index is not using the “forecast test” and the QI values keep on being normalized considering the quality tests that could be run.
- Another one where the Quality index is not using the “forecast test” but the QI values have not been normalized considering the quality tests that could be run.

In the first case, the Quality index keeps in all cases values between 0 and 1, independently of the amount of quality tests run. In the second case, the Quality index keeps values between 0 and 1 only in the cases that all quality tests could be run (i.e. the three temporal tests considering the direction, speed and vector characteristics and the double contribution of the spatial test). When a quality test could not be run the corresponding contribution to the total Quality index is zero and the maximum value of the QI index reduces to smaller values (being the Quality index then only able to have values higher than 83 when all quality tests could be run).

All these modifications are done inside \$SAFNWC/src/PGE09/hrw_QcMsgAqc.c function, which is in charge of defining the individual tests (forecast, temporal, spatial) and the whole QI value. In the first option, variable qc_flag_str->aqc_flag[i] (defining the Quality index for

each of the up to three winds calculated per tracer) has to be made equal to variable `qc_flag_str->et_flag[i]` (defining the Quality index without the forecast contribution) changing next part of the code:

```
/* ----- */
/* Assign data to the final structure */
/* ----- */
for(i=0; i<QC_FLAG_DIMENSION; i++)
{ qc_flag_str->aqc_flag[i] = et_flag[i];
  qc_flag_str->lc_flag[i] = lc_flag[i];
  qc_flag_str->et_flag[i] = et_flag[i]; }
```

In the second option, additionally the definition of the Quality index without the forecast contribution (in local variable `et_flag[i]`) has to be modified so that it is not normalized considering the quality tests that could be run. For this, next modifications are additionally necessary:

```
if(sum_w != W_FC)
    et_flag[i] = (term + w_lc*lc_flag[i])/(w_lc+W_SPD+W_DIR+W_VEC);
```

In both cases, PGE09 executable has to be recompiled again going to \$SAFNWC/src/PGE09 directory and running “make clean” and “make all”.

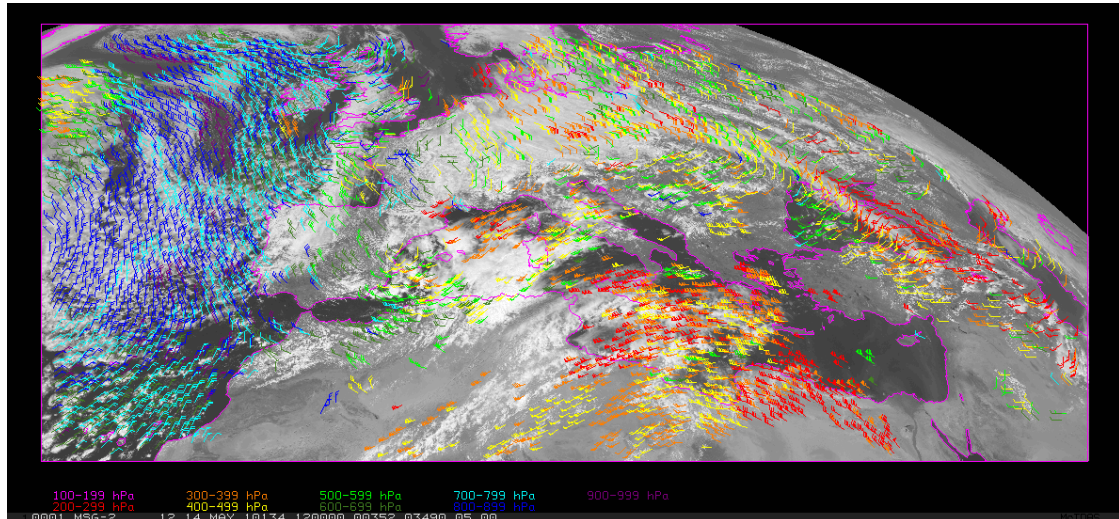
Validation statistics against Radiosounding winds for these four different configurations of HRW algorithm are shown next, for the six months between January and June 2010 in a Region covering Europe and the Mediterranean (a region of 772x1856 low resolution SEVIRI pixels centred in 40.5°N, 11.1°E), and the two MSG/SEVIRI channels with which HRW v2011 is able to calculate AMVs (HRVIS and IR108). The conditions here for the comparison with Radiosounding winds are the ones proposed at the Third International Winds Workshop (Ascona, Switzerland, 1996), and afterwards recommended by the Coordination Group for Meteorological Satellites (CGMS) for the international comparison of satellite winds.

The validation parameters shown in the tables are the next ones: NC (Number of collocations between AMV winds and Radiosounding winds), SPD (Mean speed of the radiosounding winds), NBIAS (Normalized bias), NMVD (Normalized mean vector difference), NRMSVD (Normalized root mean square difference).

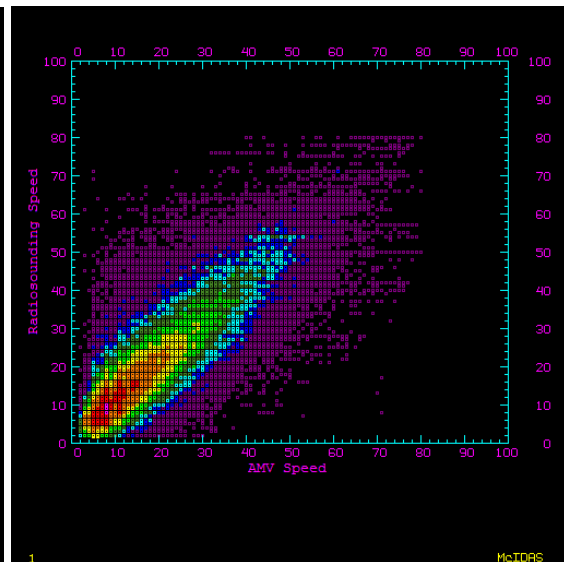
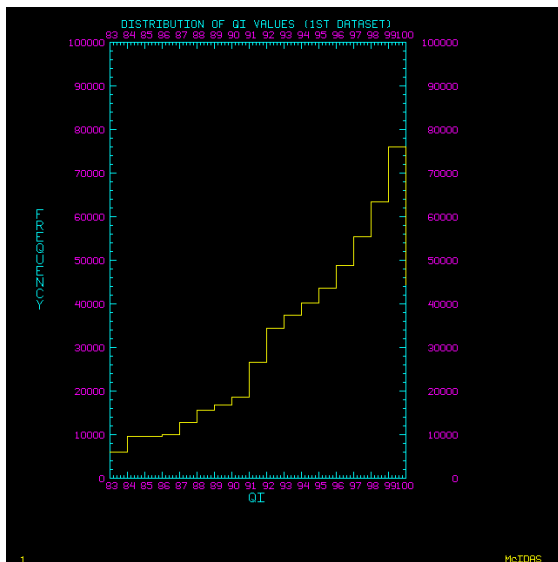
In these experiments, a Quality index threshold of 83 is defined for the AMVs at the High and Medium layer (100-700 hPa), and a Quality index threshold of 85 is defined for the AMVs at the Low layer (700-1000 hPa). The additional filterings related to the Spatial test, the Orographic flag and the Pressure error defined in chapter 2.2 of this document have also been considered.

An example of AMVs for all cases is also shown serving as output comparison, corresponding to the AMVs calculated by HRW algorithm for the date 14th May 2010 at 1200Z. A histogram showing the distribution of the Quality index values in the validated AMVs is also shown, to verify the change this parameter is suffering in the different datasets. Scatter plots of the speeds of the AMVs related to the speeds of the radiosounding winds used in the validation are also shown.

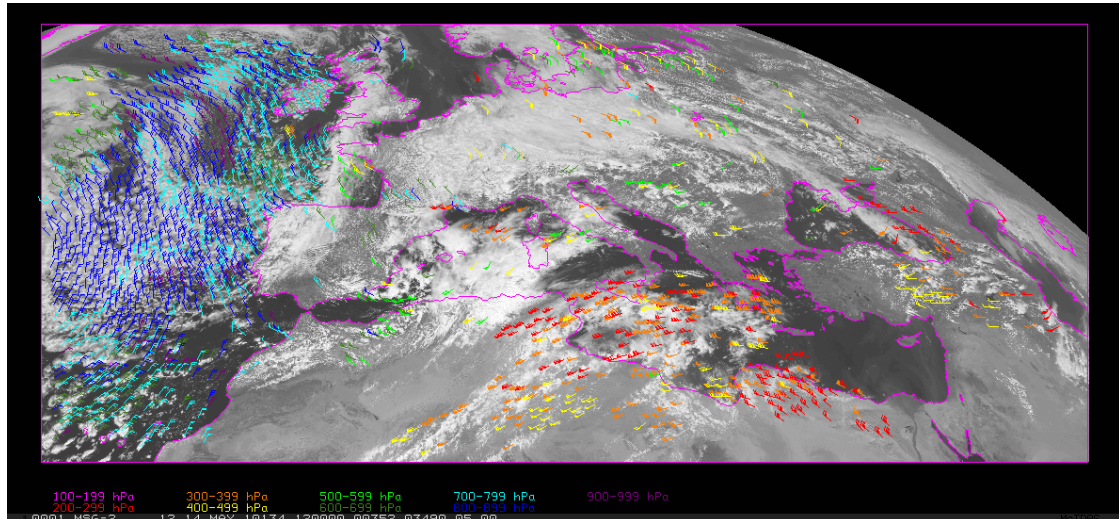
- 1 Considering first as reference statistics the default options in HRW configuration: “Reference AMVs for Quality control using option PRED_SEARCH_USE 1” and “Forecast test included in the Quality index”:



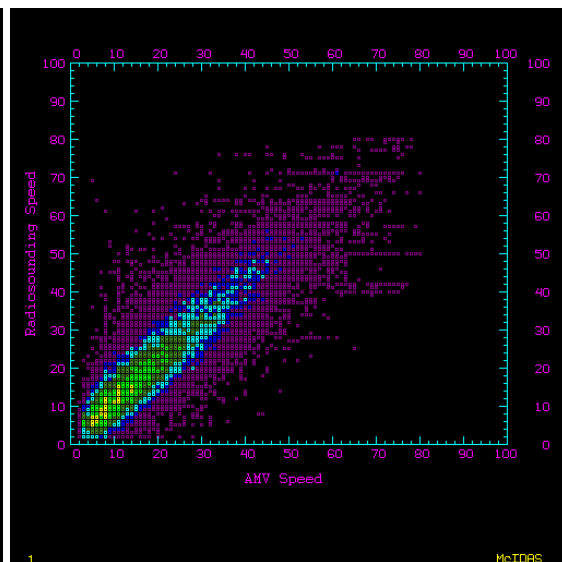
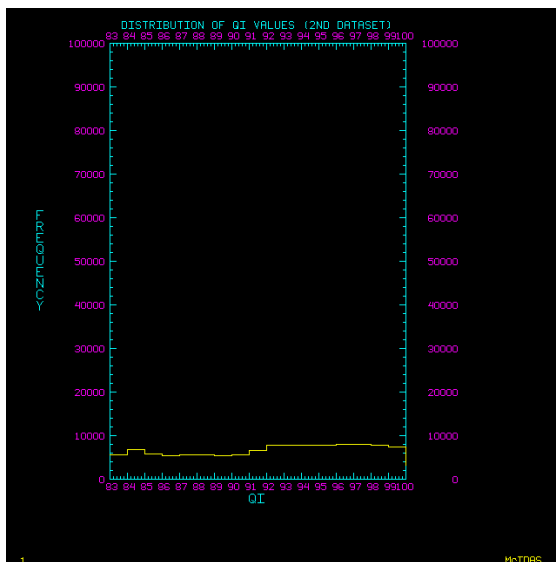
HRW Dataset 1 Jan.-Jun 2010	HRVIS All layers	HRVIS High layer	HRVIS Med. layer	HRVIS Low layer	IR108 All layers	IR108 High layer	IR108 Med. layer	IR108 Low layer
NC	77821	42874	19649	15298	59991	36745	17892	5354
SPD [m/s]	18.16	23.46	13.33	9.50	20.07	24.02	14.69	10.94
NBIAS	-0.11	-0.11	-0.11	-0.09	-0.11	-0.12	-0.08	-0.10
NMVD	0.32	0.28	0.38	0.45	0.32	0.29	0.40	0.42
NRMSVD	0.40	0.36	0.47	0.53	0.40	0.36	0.49	0.49



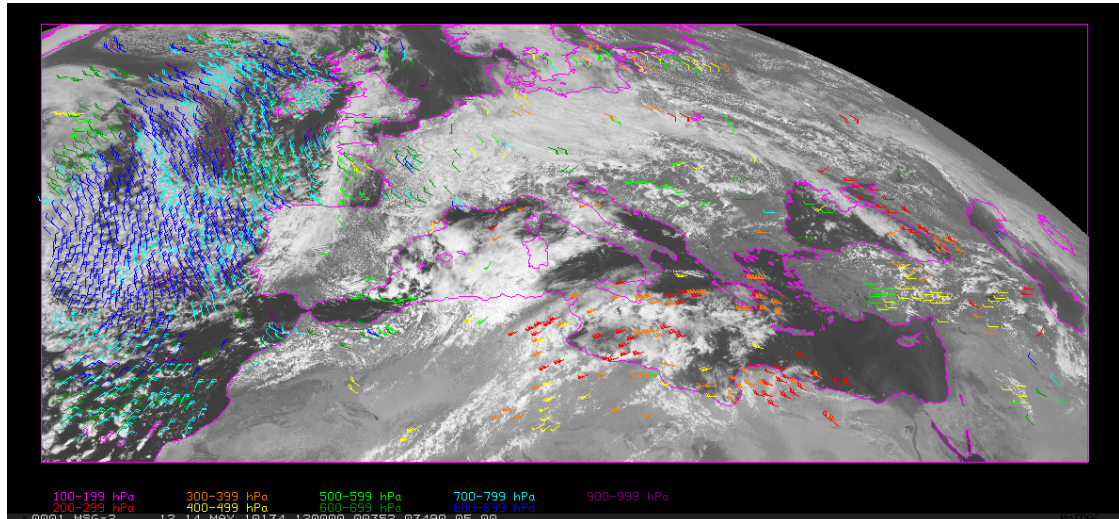
- 2 Considering then the case with “Reference AMVs for Quality control using option PRED_SEARCH_USE 0” and “Forecast test included in the Quality index”:



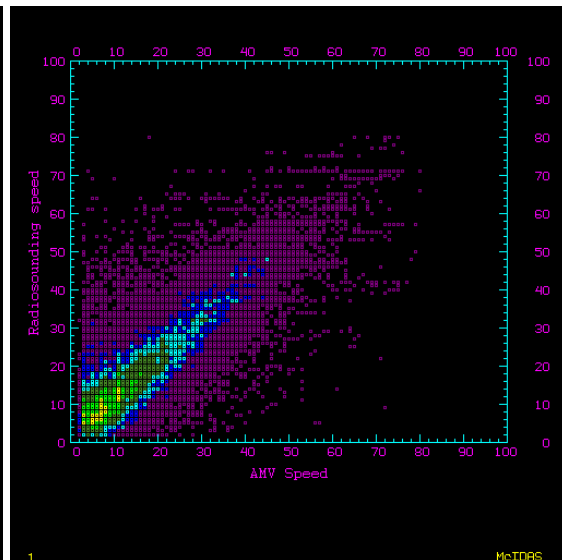
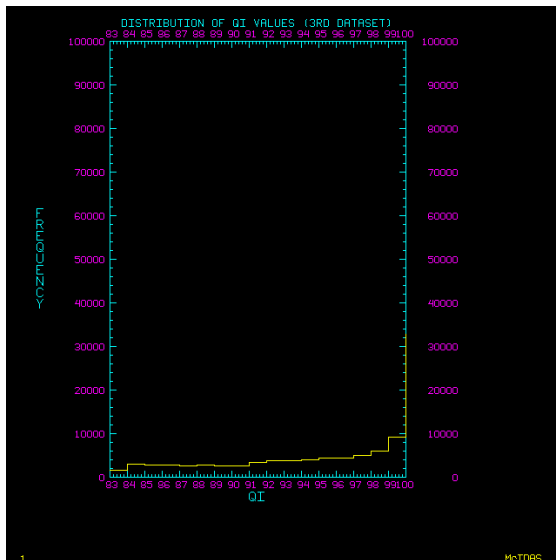
HRW Dataset 2 Jan.-Jun 2010	HRVIS All layers	HRVIS High layer	HRVIS Med. layer	HRVIS Low layer	IR108 All layers	IR108 High layer	IR108 Med. layer	IR108 Low layer
NC	10757	5244	2242	3271	8934	5792	2369	773
SPD [m/s]	19.08	27.13	14.12	9.57	22.83	27.22	15.58	12.17
NBIAS	-0.08	-0.08	-0.11	-0.06	-0.10	-0.10	-0.10	-0.13
NMVD	0.27	0.23	0.34	0.42	0.26	0.24	0.33	0.36
NRMSVD	0.34	0.28	0.41	0.50	0.32	0.29	0.40	0.42



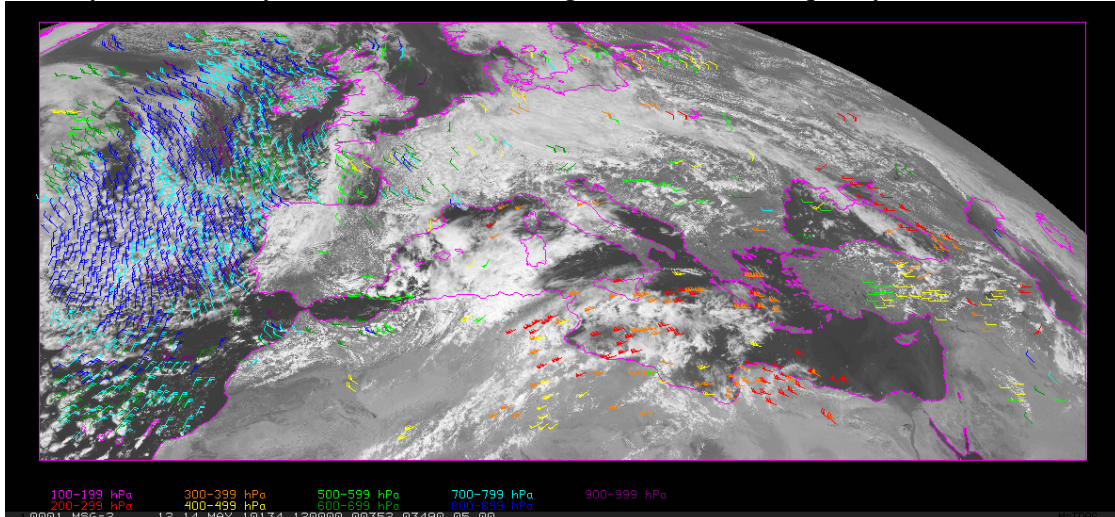
- 3 Considering then the case with “Reference AMVs for Quality control using option PRED_SEARCH_USE 0”, and “Forecast test not included in the Quality index (with Quality index still normalized considering the quality tests that could be run)”:



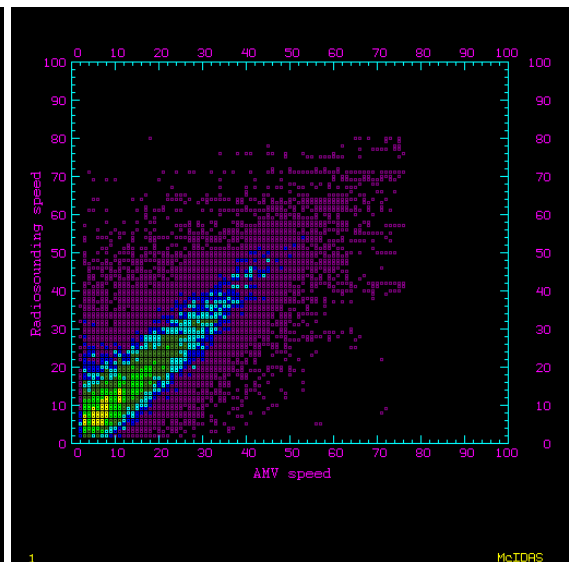
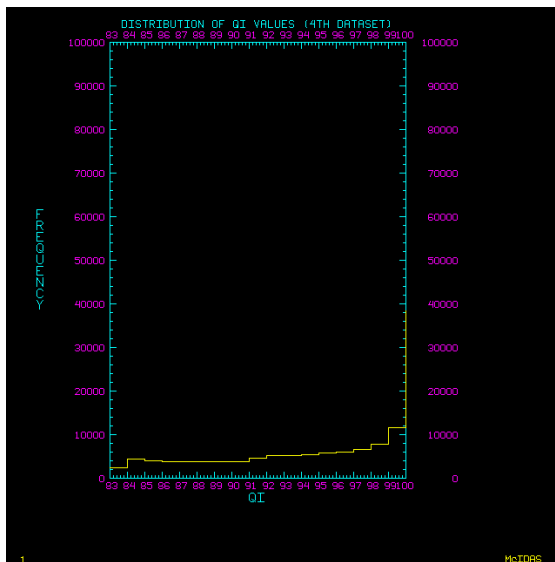
HRW Dataset 3 Jan.-Jun 2010	HRVIS All layers	HRVIS High layer	HRVIS Med. layer	HRVIS Low layer	IR108 All layers	IR108 High layer	IR108 Med. layer	IR108 Low layer
NC	11540	4196	3052	4292	12015	6639	3885	1491
SPD [m/s]	15.33	24.11	12.40	8.83	19.59	24.97	13.88	10.53
NBIAS	-0.14	-0.15	-0.17	-0.08	-0.16	-0.16	-0.16	-0.18
NMVD	0.38	0.30	0.48	0.52	0.36	0.31	0.45	0.54
NRMSVD	0.49	0.39	0.58	0.62	0.46	0.40	0.56	0.66



- 4 Considering then the case with “Reference AMVs for Quality control using option PRED_SEARCH_USE 0”, and “Forecast test not included in the Quality index (with Quality index not normalized considering the quality tests that could be run, so that the Quality index is only able to have values higher than 83 if all quality tests could be run)”:



HRW Dataset 4 Jan.-Jun 2010	HRVIS All layers	HRVIS High layer	HRVIS Med. Layer	HRVIS Low layer	IR108 All layers	IR108 High layer	IR108 Med. layer	IR108 Low layer
NC	11844	4344	3125	4375	12313	6775	3979	1559
SPD [m/s]	15.42	24.20	12.40	8.86	19.59	25.00	13.93	10.53
NBIAS	-0.14	-0.15	-0.17	-0.09	-0.16	-0.16	-0.17	-0.18
NMVD	0.38	0.30	0.48	0.52	0.36	0.31	0.45	0.54
NRMSVD	0.49	0.39	0.58	0.62	0.46	0.41	0.56	0.66



Comparing first datasets 1 and 2, only differentiated by the way the “reference AMVs” have been defined in the Quality tests, the behaviour is very different:

- It is remarkable that the amount of AMVs with the highest Quality index values is very important in the first dataset, and not so in the other ones. With this, it is verified that the comparisons between the AMV and radiosounding winds are less strict in the first dataset and more strict in the other ones.
- The amount of AMVs over the Quality index thresholds is much smaller in the second case (only one out of seven AMVs admitted in dataset 1 is kept in dataset 2), because in general the AMV Quality index values are significantly lower. Because of this, dataset 2 shown an important thinning in the amount of AMVs.
- This thinning has besides a positive effect in the AMV statistics, because the mean NBIAS, NMVD and NRMSVD reduce around an 18% in the second dataset respect to the first one for the AMVs related to both HRVIS and IR108 channel.
- Because of these two reasons (a smaller amount of AMVs and better validation statistics) dataset 2 (with option PRED_SEARCH_USE 0 in hrw_QcPhase1.c function) seems to be more recommendable for NWP assimilation. Dataset 1 (with PRED_SEARCH_USE 1 in hrw_QcPhase1.c function) seems nevertheless to be more recommendable for nowcasting tasks, because it displays better the general flow in all areas with a continuous field of winds everywhere. Under the conditions defined in dataset 2, important holes appear in the field of winds which avoid in many areas the possibility to define the existing flows.

Comparing dataset 2 and 3, differentiated respectively by using or not the “forecast test” inside the Quality index, small differences appear in the amount of AMVs (although in the third dataset it is slightly larger, up to a 20%). At the same time, it is verified that the effect of using the “forecast test” in the Quality index is important to keep the general validation statistics better (in dataset 3, the mean NMVD and NRMSVD are around a 40% worse and the NBIAS more than a 60% worse).

Nevertheless, dataset 2 has an important dependence on NWP data that should be avoided if HRW AMVs are to be assimilated. For example, it was verified with Graeme Kelly in one example around the British Isles with differences between the NWP model and the true situation, that dataset 3 AMVs showed the true displacement of the clouds, while dataset 2 AMVs were not detecting this true displacement of the clouds and were showing a wrong displacement defined by the NWP winds. Because the NWP assimilation has additional control tools to eliminate the wrong AMVs (to compensate the general worse statistics of the AMVs in the third dataset), the conditions defined in dataset 3 it can be preferred in the NWP assimilation to detect cases where the true winds are different to those given by the NWP model. Nevertheless, to be sure about this, an NWP assimilation study might be needed to verify the impact of both configurations (2 and 3) in the NWP forecast.

Finally, comparing datasets 3 and 4 (whose only difference is in the cases where not all the quality tests could be run, being then the Quality index normalized in dataset 3 and not in dataset 4), the differences are very small: the validation statistics are exactly the same and only the amount of AMVs is slightly larger in dataset 4 (although only a 2% larger). Looking of the example maps very few differences can be seen between both cases. For sure, all of this is related to being the amount of AMVs not being able to calculate all quality tests very small. But considering all these elements, the conditions defined in dataset 4 seem to be better to those in dataset 3 because of the security of having run all admitted AMVs all possible quality tests.

3 CONCLUSIONS OF THE VISITING SCIENTIST ACTIVITY

This Visiting Scientist Activity of Javier García Pereda to the Met Office, related to the “Evaluation of NWC SAF High Resolution Winds algorithm”, has defined several important results:

- First of all, a detailed description and explanation of all elements and functions inside HRW algorithm has been given to Graeme Kelly and Peter Lean, so that they understand it much better now and can from now make use of it more effectively for both tasks they are involved in: the assimilation of HRW AMVs in the Met Office regional UK model and the calculation of AMVs from high resolution simulated imagery using this algorithm.
- It has also permitted to define the optimal conditions of use of HRW AMVs, considering additional restrictions apart from the “Quality index threshold”, related to the “Spatial test”, the “Orographic flag” and the “Pressure error”. The way of running HRW algorithm without wind guess for the initial definition of the tracking area (preferable if the HRW AMVs are going to be used for NWP assimilation) has also been explained.
- Finally, an evaluation of HRW algorithm considering different options related to the Quality control (i.e. the use or not of the forecast test in the Quality index, and the way to define the “reference AMVs” to be used in the quality control tests), has been done considering a six month validation period. It has been verified that the two options to select the reference AMVs are respectively better suited for nowcasting and NWP assimilation tasks (being the first one less restrictive with a larger amount of AMVs, defining with detail the wind flow and peculiarities in all areas, and the second one more restrictive, with a visible thinning of the AMV data although with better validation statistics). At the same time, eliminating the quality test against the forecast a relatively similar amount of AMV data with a small degradation in their validation statistics is produced, with a smaller dependence of the NWP forecast (much more if the wind guess is not being used for the definition of the tracking area), what generally is preferred for NWP assimilation tasks.