	<p>User Manual for the Wind product processors of the NWC/GEO: Science Part</p>	<p>Code: NWC/CDOP2/GEO/AEMET/SCI/UM/Wind Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-AEMET-SCI-UM-Wind_v1.0.doc Page: 1/56</p>
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User Manual for the Wind product processors of the NWC/GEO: Science Part

NWC/CDOP2/GEO/AEMET/SCI/UM/Wind, Issue 1, Rev. 0


15 October 2016

Applicable to GEO-HRW v5.0 (NWC-037)

Prepared by Agencia Estatal de Meteorología (AEMET)

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DOCUMENT CHANGE RECORD

Version	Date	Pages	Changes
1.0	15 October 2016	56	<p>Initial version; Content derived from Document “Product User Manual for High Resolution Winds (HRW - PGE09 v4.0)”, SAF/NWC/CDOP/INM/SCI/PUM/09</p> <p>Updated after NWC/GEO v2016 STRR & DRR including:</p> <ul style="list-style-type: none"> • Changes proposed at NWC/GEO v2016 STRR/DRR • An updated list of “Model configuration files” • An updated validation with the latest changes since November 2015 in NWC/GEO libraries, Cloud and HRW algorithms • A table with the list of possible errors caused by GEO-HRW-v5.0 algorithm

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1. INTRODUCTION

The EUMETSAT Satellite Application Facilities (SAF) are dedicated centres of excellence for the processing of satellite data, and form an integral part of the distributed EUMETSAT Application Ground Segment.

This documentation is provided by the SAF on support to Nowcasting and Very short range forecasting (NWC SAF). The main objective of the NWC SAF is to provide, develop and maintain software packages to be used with operational meteorological satellite data for Nowcasting applications. More information about the project can be found at the NWC SAF webpage, <http://www.nwcsaf.org>.

This document is applicable to the NWC SAF processing package for geostationary Meteorological satellites, NWC/GEO.

1.1 SCOPE OF THE DOCUMENT

This document is the User Manual (UM) for the Wind Product Processor of the NWC/GEO software package (GEO-HRW, High Resolution Winds), which calculates Atmospheric Motion Vectors and Trajectories considering:

- Up to seven channels from MSG series SEVIRI imager: the 3 km Low Resolution Visible channels (VIS06 0.6 μm and VIS08 0.8 μm), Water Vapour channels (WV062 6.2 μm and WV073 7.3 μm), Infrared channels (IR108 10.8 μm and IR120 12.0 μm), and the 1 km High Resolution Visible channel (HRVIS 0.7 μm).
- Up to three channels from GOES-N series Imager: the 4 km Low Resolution Water Vapour channel (WV065, 6.5 μm) and Infrared channel (IR107, 10.7 μm), and the 1 km High Resolution Visible channel (VIS07, 0.7 μm).

This User Manual describes the goal and implementation of GEO-HRW algorithm, and a basic description of its algorithm. It also provides information on the needed input data and the resulting output data.


1.2 SOFTWARE VERSION IDENTIFICATION

This document describes the algorithm implemented in the GEO-HRW-v5.0 (Product id NWC-037) of the NWC/GEO v2016 software package release.

1.3 IMPROVEMENTS FROM PREVIOUS VERSIONS

The main improvements related to GEO-HRW v5.0 algorithm are the next ones:

1. The redefinition of the whole GEO-HRW algorithm considering the new NWCLIB library inside NWC/GEO software, which simplifies the way of processing additional geostationary satellites, and provides a series of common tools to be used by all NWC/GEO products.
2. The provision for the first time of a detailed documentation of all GEO-HRW code, through a specific file in html format with the support of Doxygen tool, and through comments inside the C/Fortran code explaining every single step of the algorithm.
3. The inclusion in “CCC height assignment method” of a pressure level correction physically based on the cloud depth, considering new parameters provided by NWC/GEO Cloud Microphysics (CMIC) product (the liquid water path for liquid clouds and the ice water path for ice clouds).
4. The extension of GEO-HRW algorithm processing to the GOES-N satellite series (GOES-13, GOES-14 and GOES-15), considering the calculation of AMVs with up to three channels from the corresponding GOES Imager: the 4 km Low Resolution Water Vapour channel (6.5 μm) and Infrared channel (10.7 μm), and the 1 km High Resolution Visible channel (0.7 μm).

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1.4 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

1.4.1 Definitions

Basic dataset	Winds for the algorithm wide tracer scale
Cloud type	Cloud type defined for each tracer with NWC/GEO CT output data, used for example to define which of the two calculated height levels (cloud top, cloud base) is used in the “Brightness temperature interpolation height assignment process”.
Consistency	Wind difference compared to some expected wind, quantified in probabilistic terms for the Quality Index calculation
Detailed dataset	Winds for the algorithm narrow tracer scale
Exclusion array	Places of the image which cannot be tracer locations because of the failing closeness threshold
First (tracking) candidate	Preferred tracking candidate for a tracer after the definition of the correlation centres, before the Quality Index calculation
Ind_topo	Value of the Algorithm Orographic flag parameter, calculated to detect land influence in the Atmospheric Motion Vectors
Interscale test (QI test)	Consistency of the detailed winds respect to the basic scale related winds
LAT_C, LON_C	Coordinates at correlation centre (POS_REAL)
LAT_T, LON_T	Coordinates at tracer centre
Neighbour wind	Close enough wind to a given one
Not closed adjustment centre	Adjustment centre at the border of the tracking area
Orographic flag (dynamic)	Flag to show possible land influence in the previous positions of the tracer. It is calculated after the static orographic flag procedure, and indicated through parameter Ind_topo (Values: 1,2,3,4,5,6)
Orographic flag (static)	Flag to show possible land influence in the tracer position. Indicated through parameter Ind_topo (Values 1,2,3,6)
Overall QI	Final QI, weighted sum of QI of individual tests except two scale test
Persistent tracers	Tracers related to AMVs calculated in the previous cycle, specific to the tracer continuity option
Predecessor wind	The one for which the final tracer location is the starting location of a new tracer in the tracer continuity option
Prior wind	Close enough AMVs from the previous image to the current tracer location and level, used in the Quality temporal correlation test
Quality indicator (or QI)	Consistency method to flag the quality of the generated Atmospheric motion vectors
Segment of the image	A set of contiguous pixels defined by its size and location

Single scale procedure	Tracer selection procedure with only wide (basic) scale tracers
Starting location (in the initial image)	Each a priori tracer location throughout the search region. In principle uniformly covering the defined region of the image.
TESO indicator	Orographic test parameter, detailing if the orographic flag could be calculated and the relative results in winds for the same tracer, to be added to the Quality TEST indicators after Quality Control
TEST indicator	Values of flags after the quality control processing steps, detailing which tests were applied and the relative results for winds of the same tracer
Tracer	Square segment of the image of fixed size (tracer size), identified by the location of its centre, and considered valid candidate for the AMV calculation by any of the two tracer calculation methods
Tracer candidate	Square segment in the image of fixed size, where conditions for tracer search using “Tracer characteristics method” are evaluated
Tracer continuity	Processing option where part of the set of tracers is defined through the final position of the AMVs in the previous cycle
Tracer location	Tracer image coordinates (line, element) of its centre
Tracer selection procedure	Strategy to get a complete set of tracers throughout the desired region of the image. It consists of 2 iterations (2 methods) for the single scale procedure; 4 iterations (2 methods, 2 scales) for the two scale procedure
Tracer side/size	Line or element dimension of the tracer
Tracking	Determination of the best pixel adjustment inside the search area of a later image to a given tracer in a prior image
Tracking area	Square segment in the final image containing the search area for a given tracer, and where all tracking candidates are located
Tracking candidate	Each square segment in the final image that has to be evaluated for the tracking of a given tracer, and its centre
Two scale procedure	Tracer selection for tracers of two different tracer sizes (basic and detailed, being the size of the second one half of the first)

Table 1: List of Definitions

1.4.2 Acronyms and Abbreviations.

AMV	Atmospheric Motion Vector
BUFR	Binary Universal Form for the Representation of meteorological data
CDOP	NWC SAF Continuous Development and Operations Phase
CDOP2	NWC SAF Second Continuous Development and Operations Phase
CIMSS	NOAA & UW's Cooperative Institute for Meteorological Satellite Studies
EBBT	Equivalent Black Body Temperature
ECMWF	European Centre for Medium Range Weather Forecasts
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
GEO-HRW	NWC SAF Product Generation Element for the High Resolution Winds
GOES	NOAA's Geostationary Operational Environmental Satellite
HRVIS/VIS07	MSG HRVIS/GOES-N 0.7µm High Resolution Visible channel
HRW	NWC/GEO High Resolution Winds
IOP	NWC SAF Initial Operations Phase
IR108/IR107, IR120	MSG 10.8µm/GOES-N 10.7µm and MSG 12.0µm Infrared channels
MPEF	EUMETSAT's Meteorological Product Extraction Facility
MSG	EUMETSAT's Meteosat Second Generation Satellite
NOAA	United States' National Oceanic and Atmospheric Administration
NWC/GEO	NWC SAF Software Package for Geostationary satellites
NWCLIB	NWC/GEO Common Software Library
NWC SAF	EUMETSAT's Satellite Application Facility on support to Nowcasting and Very short range forecasting
NWP	Numerical Weather Prediction Model
PGE	NWC SAF Product Generation Element
RID	Review Item Discrepancy
SCI	NWC SAF Scientific Report
SMR	NWC SAF Software Modification Report
SPR	NWC SAF Software Problem Report
SW	Software
TM	NWC/GEO Task Manager
UW	University of Wisconsin/Madison
VIS06, VIS08	MSG 0.6µm and 0.8µm Low Resolution Visible channels
WMO	World Meteorological Organization
WV62/WV65, WV73	MSG 6.2µm/GOES-N 6.5µm and MSG 7.3µm Water vapour channels

Table 2: List of Acronyms and Abbreviations

1.5 REFERENCES

1.5.1 Applicable Documents

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X]

For versioned references, subsequent amendments to, or revisions of, any of these publications do not apply. For unversioned references, the current edition of the document referred applies.

Current documentation can be found at the NWC SAF Helpdesk web: <http://www.nwcsaf.org>.

<i>Ref.</i>	<i>Title</i>	<i>Code</i>	<i>Version</i>
[AD.1]	Proposal for the Second Continuous Development and Operations Phase (CDOP2)	NWC/CDOP2/MGT/AEMET/PRO	1.0
[AD.2]	NWC SAF CDOP-2 Project Plan	NWC/CDOP2/SAGF/AEMET/MGT/PP	1.9
[AD.3]	Configuration Management Plan for NWC SAF	NWC/CDOP2/SAF/AEMET/MGT/CMP	1.4
[AD.4]	NWC SAF Product Requirements Document	NWC/CDOP2/SAF/AEMET/MGT/PRD	1.9
[AD.5]	Interface Control Document for Internal and External Interfaces of the NWC/GEO	NWC/CDOP2/AEMET/SW/ICD/1	1.1
[AD.6]	Data Output Format for the NWC/GEO	NWC/CDOP2/AEMET/SW/DOF	1.1
[AD.7]	System Version Document for the NWC/GEO	NWC/CDOP2/AEMET/SW/SCVD	1.1
[AD.8]	Estimation of computer environment needs to run NWC SAF products operatively in 'Rapid scan mode'	NWC/CDOP/INM/SW/RP/01	1.0
[AD.9]	Validation Report for "High Resolution Winds" (HRW – PGE09 v2.2)	NWC/CDOP/INM/SCI/VR/05	1.0
[AD.10]	Validation Report for "High Resolution Winds" (HRW – PGE09 v3.0)	NWC/CDOP/INM/SCI/VR/07	1.0
[AD.11]	Validation Report for "High Resolution Winds" (HRW – PGE09 v3.1)	NWC/CDOP/INM/SCI/VR/09	1.0
[AD.12]	Validation Report for "High Resolution Winds" (HRW – PGE09 v3.2)	NWC/CDOP/INM/SCI/VR/10	1.0
[AD.13]	Validation Report for "High Resolution Winds" (HRW – PGE09 v4.0)	NWC/CDOP2/INM/SCI/VR/13	1.0
[AD.14]	Algorithm Theoretical Basis Document for the Wind product processors of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SCI/ATBD/Wind	1.1
[AD.15]	Scientific and Validation Report for the Wind product processors of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SCI/VR/Wind	1.0
[AD.16]	User Manual of the GOES2NC tool	NWC/CDOP2/GEO/AEMET/SW/UM/GOES2NC	1.0

Table 3: List of Applicable Documents

1.5.2 Reference Documents

The reference documents contain useful information related to the subject of the project. These reference documents complement the applicable ones, and can be looked up to enhance the information included in this document if it is desired. They are referenced in this document in the form [RD.X]

For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the current edition of the document referred applies.

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, 1998: A future product on HRVIS Winds from the Meteosat Second Generation for nowcasting and other applications. (Proceedings 4th International Wind Workshop, EUMETSAT Pub.24, pp.281-288).
[RD.6]	J.M.Fernández, 2000: Developments for a High Resolution Wind product from the HRVIS channel of the Meteosat Second Generation. (Proceedings 5th International Wind Workshop, EUMETSAT Pub.28, pp.209-214).
[RD.7]	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.8]	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 8th International Wind Workshop, EUMETSAT Pub.47).
[RD.9]	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 9th International Wind Workshop, EUMETSAT Pub.51).
[RD.10]	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 10th International Wind Workshop, EUMETSAT Pub.56).
[RD.11]	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.12]	W.P.Menzel, 1996: Report on the Working Group on verification statistics. (Proceedings 3rd International Wind Workshop, EUMETSAT Pub.18, pp.17-19).
[RD.13]	J.Schmetz, K.Holmlund, A.Ottenbacher, 1996: Low level winds from high resolution visible imagery. (Proceedings 3rd international winds workshop, EUMETSAT Pub.18, pp.71-79).
[RD.14]	Xu J. & Zhang Q., 1996: Calculation of Cloud motion wind with GMS-5 images in China. (Proceedings 3rd international winds workshop, EUMETSAT Pub.18, pp.45-52).
[RD.15]	K.Holmlund & C.S.Velden, 1998: Objective determination of the reliability of satellite derived Atmospheric Motion Vectors (Proceedings 4th International Wind Workshop, EUMETSAT Pub.24, pp.215-224).
[RD.16]	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 5th International Wind Workshop, EUMETSAT Pub.28, pp.72-80).
[RD.17]	R.Borde & R.Oyama, 2008: A direct link between feature tracking and height assignment of operational Atmospheric Motion Vectors (Proceedings 9th International Wind Workshop, EUMETSAT Pub.51).
[RD.18]	J.García-Pereda, R.Borde & R.Randriamampianina, 2012: Latest developments in "NWC SAF High Resolution Winds" product (Proceedings 11th International Wind Workshop, EUMETSAT Pub.60).
[RD.19]	WMO Common Code Table C-1 (WMO Publication, available at http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_v12/LatestVERSION/WMO306_v12_CommonTable_en.pdf)
[RD.20]	M.Dragosavac, 2007: BUFR Reference Manual (ECMWF Operations Department Publication, available at https://www.wmo.int/pages/prog/gcos/documents/gruanmanuals/ECMWF/bufr_reference_manual.pdf)
[RD.21]	P.Lean, G.Kelly & S.Migliorini, 2014: Characterizing AMV height assignment errors in a simulation study (Proceedings 12th International Wind Workshop, EUMETSAT Pub.63).
[RD.22]	Á.Hernández-Carrascal & N.Bormann, 2014: Cloud top, Cloud centre, Cloud layer – Where to place AMVs? (Proceedings 12th International Wind Workshop, EUMETSAT Pub.63).
[RD.23]	K.Salonen & N.Bormann, 2014: Investigations of alternative interpretations of AMVs (Proceedings 12th International Wind Workshop, EUMETSAT Pub.63).
[RD.24]	D.Santek, J.García-Pereda, C.Velden, I.Genkova, S.Wanzong, D.Stettner & M.Mindock, 2014: 2014 AMV Intercomparison Study Report - Comparison of NWC SAF/HRW AMVs with AMVs from other producers (NWC SAF Visiting Scientist Report, available at http://www.nwcsaf.org/HD/files/vsdoc/CIMSS_AMV_Comparison_FinalReport_04July2014.pdf)
[RD.25]	D.J.Seidel, B.Sun, M.Petty & A.Reale, 2011: Global radiosonde balloon drift statistics (Journal of Geophysical Research, Num. 116).

Table 4: List of Reference Documents

2. HIGH RESOLUTION WINDS (GEO-HRW) DESCRIPTION

2.1 GOAL OF HIGH RESOLUTION WINDS (GEO-HRW) PRODUCT

The High Resolution Winds product aims to provide, for near real time meteorological applications, detailed sets of Atmospheric Motion Vectors (AMVs) and Trajectories from EUMETSAT's Meteosat Second Generation (MSG series) and NOAA's Geostationary Operational Environmental Satellite (GOES-N series) geostationary satellites, considering up to seven MSG/SEVIRI channel data (High resolution visible and Low resolution 0.6 μ m/0.8 μ m visible, 10.8 μ m/12.0 μ m Infrared and 6.2 μ m/7.3 μ m Water vapour channels: HRVIS, VIS06, VIS08, IR108, IR120, WV62, WV73) and up to three GOES-N channel data (High resolution 0.7 μ m visible and Low resolution 10.7 μ m Infrared and 6.5 μ m Water vapour channels: VIS07, IR107, WV65) throughout all hours of the day, as a dynamic information in the NWC/GEO package.

The product includes pressure level information, and a quality control flagging giving some indication of its error in probabilistic terms, with auxiliary indicators about how the product was determined. GEO-HRW provides trajectories considering the successive tracking of the same tracer in consecutive images.

It has been developed by AEMET in the framework of the EUMETSAT Satellite Application Facility on support to Nowcasting and Very short range forecasting (NWC SAF). This product is useful in Nowcasting applications, used in synergy with other data available to the forecaster. For example, in the watch and warning of dangerous wind situations, in the monitoring of the general flow, of low level convergence (when and where cumulus start to develop), of divergence at the top of developed systems, or other cases of small scale circulation or wind singularities. It can also be used in form of objectively derived fields, and assimilated in Numerical Weather Prediction Models (together with many other data), as an input to Analysis, Nowcasting and Very short range forecasting applications. The quality flags should be very useful for these cases.

High Resolution Winds output is similar to other products calculating Atmospheric Motion Vectors: the winds, trajectories and all parameters related to them are calculated at a level 2 of processing. No level 3 of processing (as a grid interpolation or a meteorological analysis based in GEO-HRW output) is included.

2.2 OUTLINE OF THE ALGORITHM

As a whole, High Resolution Winds algorithm is designed in a modular way, so that it can be easy to handle and modify. The whole process includes the next steps:

1. Preprocessing:

- The initialization of data: calculation of latitude/longitude/solar zenith angle/satellite zenith angle matrices; reading of NWP data; Brightness temperature data for the MSG or GOES-N infrared and water vapour channels to be used, and Normalized reflectance data for the MSG or GOES-N visible channels to be used. Outputs from several NWC/GEO products are also to be read if so configured: CT (Cloud Type), CTTH (Cloud Top Temperature and Pressure), and CMIC (Cloud phase, Liquid water path and Ice water path).

2. Processing:

- First, tracers are calculated in an initial image with two consecutive methods: Gradient, Tracer characteristics.
- Later, these tracers are tracked in a later image through one of two different methods (Euclidean distance, Cross correlation), with the selection of up to three correlation centres.
- Atmospheric Motion Vectors (AMVs, winds) and Trajectories are calculated, considering the displacement between the position of each tracer and the corresponding correlation centres in consecutive images.
- The pressure level of the AMVs and Trajectories is defined through one of two different methods:
 - “Brightness temperature interpolation method”, which calculates the ‘Top pressure’ and ‘Base pressure’ related to the AMV, interpolating the Brightness temperature of the corresponding channel (using infrared 12.0 μ m in the MSG case and 10.7 μ m in the GOES-N case for the visible channels) to the NWP vertical temperature profile, and defining the pressure level with one of these two possible levels. NWC/GEO CT Cloud type output related to the AMV can be used in the procedure if it is available and it has so been configured.
 - “Cross Correlation Contribution method (CCC method)” (for Cross correlation tracking if NWC/GEO CT Cloud type and CTTH Cloud top temperature and pressure outputs are available), which defines the AMV pressure considering only the pressure of the pixels contributing most to the image correlation. A pressure correction related to the cloud depth can also be considered for Cloudy AMVs, if NWC/GEO CMIC Cloud phase, Liquid water path and Ice water path have also been calculated.

3. Postprocessing:

- A Quality control with “EUMETSAT Quality Indicator” method is implemented, with the choice of the “Best AMV” considering the several AMVs calculated for each tracer, and a Final control check to eliminate wrong winds very different to those in their vicinity.
- An “orographic flag” can also be calculated if so configured, which incorporating topographic data detects those AMVs affected by land influence.

The code was progressively developed with GOES, MFG and MSG data. Examples with MSG and GOES-N data are presented throughout the description of the algorithm to illustrate the process. The different options and coefficients are also presented. Many of them are configurable: in such a case, this circumstance is specifically indicated. The channels for which AMVs are to be extracted are for example defined by configurable parameter ‘WIND_CHANNEL’ (with value ‘HRVIS,VIS06,VIS08,IR108,IR120,WV62,WV73’ when AMVs from all possible MSG/SEVIRI channels are extracted; value ‘VIS07,IR107,WV65’ when AMVs from all possible GOES-N channels are extracted).

The AMVs can be calculated considering different image repetition cycles (defined by configurable parameter SLOT_GAP). For example, when MSG satellites are considered, consecutive images (15 minutes apart, defined by SLOT_GAP=1) are recommended to be considered for the initial tracer calculation and their later tracking under ‘Nominal scan mode’ configuration. Under ‘Rapid scan mode’ configuration, alternate images (10 minutes apart, defined by SLOT_GAP=2) are recommended to be considered for the initial tracer calculation and their later tracking to maximize the amount of calculated winds with the best possible validation statistics.

When GOES-N satellites are considered, two default configurations are provided for the calculation of AMVs: every 15 minutes (for example, for the “Continental United States region” with GOES-East satellite) and every 30 minutes (for example, for the “North America region” with GOES-East satellite). In this cases, SLOT_GAP=1 is also defined.

2.2.1 Preprocessing

During the initialization process, next parameters are extracted for the selected region:

- Normalized reflectances for any MSG/SEVIRI or GOES-N visible channel to be used, brightness temperatures for any MSG/SEVIRI or GOES-N infrared or water vapour channel to be used.
- NWP temperature profiles. NWP wind component profiles can also be extracted for the Forecast consistency quality test and for the definition of the tracking area in the later image. NWP geopotential profiles can also be extracted to calculate the ‘Orographic flag’.
- NWC/GEO CT Cloud Type output for the previous slot and selected region, in case the ‘AMV Cloud type’ is calculated in the ‘Brightness temperature interpolation height assignment method’. NWC/GEO CT Cloud Type and CTTH Cloud Top Temperature and Pressure outputs for the current slot and selected region, in case ‘CCC height assignment method’ is used. NWC/GEO CMIC Cloud Phase, Liquid Water Path and Ice Water Path outputs for the current slot and selected region, in case the Microphysics correction is to be used inside ‘CCC height assignment method’.
- Latitude, longitude, solar and satellite zenith angle matrices (calculated by NWC/GEO library with the provided data).

Only satellite data for the requested channels and the NWP temperature profiles are strictly needed for the calculation of AMVs and Trajectories. In any case, the more additional data used contribute to a higher number and better quality of the AMV and Trajectory outputs.

2.2.2 Tracer calculation

Two tracer computation methods are applied: Gradient; Tracer characteristics. They are used one after the other in two different tracer selection strategies throughout the region: the ‘single scale procedure’ (when one scale of tracers is calculated), and the ‘two scale procedure’ (when two different scales of tracers are calculated: “basic” and “detailed”, being the line and element size of the detailed tracers half the size of basic tracers). Both methods calculate a tracer optimising its location around one of the ‘starting locations’ in the image. The starting locations are at fixed uniform distances of lines and elements throughout the image.

A resolution (‘tracer size’) of 24 pixels is proposed as baseline for the ‘single scale procedure’ (used when configurable parameter CDET is empty) for all types of tracers. Nevertheless, different values can be defined for the ‘tracer size’ for the High resolution visible channel (MSG/HRVIS or GOES/VIS07) through configurable parameters LSIZ_HRV and ESIZ_HRV, and for the Low resolution channels (all the rest) through configurable parameters LSIZ_OTHER and ESIZ_OTHER.

A resolution of 24 pixels for the ‘basic tracers’ and 12 pixels for the ‘detailed tracers’ is proposed for the two scale procedure (when configurable parameter CDET is ALL). A smaller processing subregion can be introduced as option for the detailed scale (the basic AMVs and Trajectories will always be computed in the whole selected region). This is done when configurable parameter CDET is RANGE, defining the starting position and the size of the detailed region with LIN_D, ELE_D, NUML_D and NUME_D configurable parameters.

A new option since GEO-HRW-v4.0 (with configurable parameter CALCULATE_TRAJECTORIES = 1, which is the default option), defines new tracer centres starting at the integer final line/column position of AMVs calculated previously at the same slot. So, a set of ‘persistent tracers’ is successively tracked in consecutive images defining trajectories with the progressive positions of the tracer throughout the time.

In these trajectories, tracer locations are only defined considering final locations of good quality ‘predecessor winds’ (i.e. AMVs included in the output file for the same slot, with a QI value over the QI threshold, and with all additional criteria for the valid AMV filtering). It is additionally necessary for these tracer locations to be considered as valid, that they fulfill again all conditions defined by the “tracer determination method” used for the corresponding ‘predecessor wind’.

2.2.3 Tracer tracking

The tracking method seeks for the best ‘adjustment centre’ of a tracer computed in a previous image, over a larger portion on the following image (tracking area), performing a pixel by pixel comparison inside a segment of the same size (tracking candidate), repeatedly moving this segment over the tracking area until the best candidates are found. For this, one of next algorithms is used:

- Euclidean distance (configured with TRACKING = LP), where the sum $LP_{ij} = \sum \sum (T-S)^2$ is calculated considering the visible normalized reflectances/infrared or water vapour brightness temperatures of all tracer (T) and tracking candidate (S) pixels at correlative locations. The best locations are defined through the minimum values of the sum LP_{ij} .
- Cross correlation (configured with TRACKING=CC, default value), that computes the correlation $CC_{ij} = \text{Cov}_{TS} / (\sigma_T \cdot \sigma_S)$ where ‘ σ ’ is the standard deviation or root of the variance and ‘Cov’ is the covariance between the tracer and tracking candidate. The best locations are defined through the maximum values of the correlation CC_{ij} .

To increase the speed of GEO-HRW algorithm, the tracking area centre can be located at the position of the tracer which is forecast for the later image by the NWP wind components, interpolated to the tracer location and level, if so defined with configurable parameter WIND_GUESS = 1. Nevertheless, since GEO-HRW v4.0 the algorithm has been optimized not to use the wind guess as default option, so reducing the dependence of the algorithm and the calculated AMVs from the NWP model used. Although the running time of GEO-HRW algorithm can still be around two to three times longer than using the wind guess, because of the previous reasons it is recommended to the users to keep operationally the configuration without use of the wind guess (with configurable parameter WIND_GUESS = 0).

The ‘tracking area size’ is defined through configurable parameters LLAG_HRV and ELAG_HRV (for the High resolution HRVIS channel) and LLAG_OTHER and ELAG_OTHER (for the Low resolution channels); different default values are defined for both types of resolutions. Up to 3 tracking centres (defined by parameter MAX_NUM_WINDS) are retained for both tracking methods: the absolute and 2 local best positions. The line/column and latitude/longitude location of the ‘adjustment centres’ in the later image can additionally be refined with second order interpolation if configurable parameter USE_SUBPIXELTRACKING = 1 is used (which is the default option).

2.2.4 Height assignment with ‘Brightness temperature interpolation method’

This method has been used by GEO-HRW algorithm in all versions up to now. Operatively, this method runs before the tracer tracking. Since GEO-HRW-v4.0 it is only used when specifically defined with configurable parameter `DEFINewithCONTRIBUTIONS = 0`, or when the wind guess is used to define the tracking area in the later image with configurable parameter `WIND_GUESS = 1`. It is also only available if a NWP temperature forecast has been provided, with a minimum number of NWP levels defined with configurable parameter `MIN_NWP_FOR_CALCULATION` (with a default value of 4). If this NWP temperature forecast is not provided, the running of GEO-HRW algorithm stops, calculating no AMVs or Trajectories.

The input for the height assignment is the corresponding brightness temperature for each one of the infrared and water vapour channels, MSG/IR120 brightness temperature for each one of the MSG visible channels (HRVIS, VIS06, VIS08), and GOES/IR107 for the GOES-N visible channel (VIS07). A ‘base temperature’ and a ‘top temperature’ are calculated with the corresponding brightness temperatures. A temperature to pressure conversion is then inferred with these two values and the NWP temperature forecast.

After this, with configurable parameter `USE_CLOUDTYPE = 1`, the output of NWC/GEO CT Cloud Type product is read for the selected region and prior slot (when the tracers were calculated), to define which of the two calculated pressure values (‘base pressure’ or ‘top pressure’) represents better the displacement defined by the Atmospheric Motion Vector. Operatively, for this it is necessary to run NWC/GEO CMA and CT products before GEO-HRW product.

The ‘Tracer cloud type’ is calculated as the most common value of the CT Cloud Type inside the tracer, if its presence is at least $\frac{3}{2}$ times that of the second most common. If this condition is not fulfilled the values `Cloud_type = 21` (multiple cloud types), `= 22` (multiple clear air types), or `= 23` (mixed cloudy/clear air types) are defined, when respectively the two most common cloud types inside the tracer are both cloudy types, both clear air types, or none of these two cases.

With all of this, some tracers are eliminated depending on the ‘tracer cloud type’ and the satellite channel they have been calculated with. These cases are identified inside a dark cell in the next table and are related to cloud free tracers in the visible and infrared channels (not in the water vapour channels), fractional clouds in all cases (which in general show significantly worse validation statistics), and some cloud types for which the Root mean square vector difference (RMSVD) is at least a 25% worse than for the channel with the best statistics for that cloud type.

Considering the rest of cases, the height assignment is defined through the ‘top pressure’ in the Water vapour clear air tracers, in the tracers related to “High semitransparent thin clouds” and “High semitransparent meanly thick clouds”, and in the tracers related to “High semitransparent clouds above other clouds or above snow/ice” in the infrared channels. All these cases are identified with ‘Top’ in the next table.

In all other cases the height assignment is defined through the ‘base pressure’. These specific cases are identified with ‘Base’ in the next table. If `USE_CLOUDTYPE = 0` or NWC/GEO CT Cloud Type output is not available, the value `Cloud_type = 0` (cloud type not processed) is given. Because most of the cloud types fit better with the cloud base, in this case the cloud base is considered for all tracers.

MSG channels	HRVIS	VIS06	VIS08	WV062	WV073	IR108	IR120
GOES-N channels	VIS07			WV065		IR107	
1 Cloud free land				Top	Top		
2 Cloud free sea				Top	Top		
3 Land contaminated by snow/ice				Top	Top		
4 Sea contaminated by ice				Top	Top		
5 Very low cumulus/stratus	Base	Base	Base		Base	Base	Base
6 Low cumulus/stratus	Base	Base	Base		Base	Base	Base
7 Medium cumulus/stratus	Base	Base	Base		Base	Base	Base
8 High opaque cumulus/stratus	Base			Base	Base		
9 Very high opaque cumulus/stratus	Base			Base	Base		
10 Fractional clouds							
11 High semitransp. thin clouds				Top	Top	Top	Top
12 High semitransp. meanly thick clouds	Top			Top	Top	Top	Top
13 High semitransp. thick clouds	Base			Base	Base	Base	Base
14 High semitransp. above other clouds				Base	Base	Top	Top
15 High semitransp. above snow/ice				Base	Base	Top	Top
21 Multiple cloud types	Base			Base	Base	Base	Base
22 Multiple clear air types				Top	Top		
23 Mixed cloudy/clear air types	Base			Base	Base	Base	Base

Table 5: AMV filtering related to the ‘AMV cloud type’ and each channel, and consideration of the ‘top pressure’ or ‘base pressure’ in the Brightness temperature interpolation height assignment method for the valid cases

2.2.5 Height assignment with ‘CCC method’

This method (“Cross Correlation Contribution method”) is available since GEO-HRW v3.1 algorithm. It was developed by Régis Borde and Ryo Oyama, and is fully documented in the 2008 Paper “A direct link between feature tracking and height assignment of operational AMVs” [RD.17]. It requires the use of “Cross correlation” as Tracking method, and the calculation of NWC/GEO CT Cloud type and CTTH Cloud Top Temperature and Pressure for the selected region and slot before the running of GEO-HRW product.

The method defines the wind pressure level considering only the pressure of the pixels contributing most to the image correlation. It has also the advantage of including in the height assignment all procedures included in NWC/GEO CTTH product for the Cloud pressure calculation, including:

- Opaque cloud top pressure retrieval from Window 10.8 μm and 12.0 μm brightness temperatures, with simulation of radiances with RTTOV, and ability of thermal inversion processing,
- Semitransparent cloud top pressure retrieval with Radiance ratioing technique and H20/IRW intercept method, considering 6.2 μm , 7.3 μm and 13.4 μm channels,

which are common methods used by other AMV producers. The implementation of ‘CCC method’ is defined through the configurable parameters TRACKING = CC and DEFINECONTRIBUTIONS = 1 (which is the default option for both MSG and GOES-N satellite series), and operatively is run after the tracer tracking. If DEFINECONTRIBUTIONS = 0, ‘CCC method’ is skipped by GEO-HRW algorithm.

A modification of ‘CCC method’ was defined in GEO-HRW-v3.2 for a separate treatment of ‘Cloudy AMVs’ and ‘Water vapour clear air AMVs’, these ones defined as those AMVs calculated with MSG/WV062, MSG/WV073 or GOES-N/WV065 channels for which the ‘Correlation contribution sum’ is larger for the group of Clear air pixels (Cloud type 1 to 4) than for the group of Cloudy pixels (Cloud type 5 to 9 and 11 to 15), considering all pixels inside the tracer for which the Pixel correlation contribution is positive:

- In the ‘Cloudy AMVs’, a pressure value is calculated for each ‘adjustment centre’ considering the partial contribution to the correlation (CC_{ij}) and the NWC/GEO CTTH Cloud top pressure (CTP_{ij}) with formula $P_{CCC} = \Sigma(CC_{ij} \cdot CTP_{ij}) / \Sigma CC_{ij}$. For the calculation, only pixels with a valid CTP_{ij} value (corresponding to a cloudy, non fractional cloud type), and with CC_{ij} over a threshold (the mean correlation contribution or else zero) are considered.

A similar calculation is done for the temperature of each ‘adjustment centre’ with NWC/GEO CTTH Cloud top temperature (CTT_{ij}). The cloud type of the ‘adjustment centre’ is calculated as the one with the highest ‘Correlation contribution sum’. A pressure error is also calculated for each ‘adjustment centre’ with the formula $\Delta P_{CCC} = \sqrt{(\Sigma(CC_{ij} \cdot CTP_{ij}^2) / \Sigma CC_{ij} - P_{CCC}^2)}$, useful as a new Quality control parameter for the output AMVs. A maximum pressure error can be defined with the configurable parameter MAXPRESSUREERROR (default value 150 hPa).

In all these calculations, for AMVs extracted with visible images, only pixels whose reflectance is higher than the mean are considered (i.e., they are in the “bright branch” of the Reflectance(Pixel correlation contribution) graph). For AMVs extracted from infrared or water vapour channels, only pixels whose brightness temperature is colder than the mean are considered (i.e., they are in the “cold branch” of the Brightness temperature(Pixel correlation contribution) graph).

This last procedure has changed respect to the one used in previous GEO-HRW versions, coming back to the original options defined in [RD.17] document.

It is clear that ‘CCC method’ offers a direct correspondence between the pressure levels given for GEO-HRW Cloudy AMVs and Trajectories, and those given to the Cloud tops by NWC/GEO CTTH product. It also defines a clear correspondence between the elements considered for the pressure level calculations, and the real cloud features observed in the satellite images.

Nevertheless, several studies in 2014 (Peter Lean et al. [RD.21], Á.Hernández-Carrascal & N.Bormann [RD.22], K.Salonen & N.Bormann [RD.23]), suggest that AMVs would better be related to a pressure level lower than the Cloud top. An empirical relationship has been found to exist between the “difference between the AMV pressure level calculated with CCC method and the AMV best fit pressure level”, and the “CCC Liquid/Ice water path value” for the AMV, so that a correction for the “AMV pressure level” related to the Cloud depth can be defined. This “CCC Liquid/Ice water path value” is obtained considering the new NWC/GEO CMIC Cloud phase, Liquid Water path and Ice water path output. ‘CCC Cloud phase’ is defined in a similar way to the one used for the ‘CCC Cloud type’, and the ‘CCC Liquid/Ice water path values’ are then calculated for Liquid/Ice phase AMVs, considering the similar formulae:

$$LWP_{CCC} = \Sigma(CC_{ij} \cdot LWP_{ij}) / \Sigma CC_{ij} \quad IWP_{CCC} = \Sigma(CC_{ij} \cdot IWP_{ij}) / \Sigma CC_{ij}$$

Corrections in the AMV pressure value have been obtained as functions of LWP_{CCC} and IWP_{CCC} parameters, considering a yearly tuning period between July 2010 and June 2011 in the European and Mediterranean region, with MSG2 data and Radiosounding winds as reference for the best fit level. The corrections, such as defined in Table 6, are in general positive, so lowering the pressure level of the AMV. They cause an improvement in all Validation parameters, and are implemented as default option with MSG satellites with configurable parameter `USE_MICROPHYSICS = 2` (not with GOES-N satellite series because of the lack of NWC/CMIC product occurring with this satellite series).

The user has necessarily to run all NWC-GEO Cloud products (CMA, CT, CTTH, CMIC) so that all this process can be activated. If NWC-GEO CMIC product output is not available but the other ones are, GEO-HRW runs “CCC method height assignment without Microphysics correction”.

Correction for the AMV pressure level [in hPa] based on the Cloud microphysics	
VISIBLE LIQUID PHASE CLOUDY AMVs MIC.CORR[hPa] = 12 without LWP MIC.CORR[hPa] = $-30 + 316 \cdot LWP [kg/m^2]$ if $LWP < 0.2594 kg/m^2$ MIC.CORR[hPa] = 52 if $LWP > 0.2594 kg/m^2$	VISIBLE ICE PHASE CLOUDY AMVs MIC.CORR[hPa] = 29 without IWP MIC.CORR[hPa] = $-26 + 295 \cdot IWP [kg/m^2]$ if $IWP < 0.2271 kg/m^2$ MIC.CORR[hPa] = 41 if $IWP > 0.2271 kg/m^2$
INFRARED LIQUID PHASE CLOUDY AMVs MIC.CORR[hPa] = 17 without LWP MIC.CORR[hPa] = $-8 + 261 \cdot LWP [kg/m^2]$ if $LWP < 0.1685 kg/m^2$ MIC.CORR[hPa] = 36 if $LWP > 0.1685 kg/m^2$	INFRARED ICE PHASE CLOUDY AMVs MIC.CORR[hPa] = 16 without IWP MIC.CORR[hPa] = $-5 + 45 \cdot IWP [kg/m^2]$ if $IWP < 3.0444 kg/m^2$ MIC.CORR[hPa] = 132 if $IWP > 3.0444 kg/m^2$
WATER VAPOUR LIQUID PHASE AMVs MIC.CORR[hPa] = -31 without LWP MIC.CORR[hPa] = $-63 + 245 \cdot LWP [kg/m^2]$ if $LWP < 0.2571 kg/m^2$ MIC.CORR[hPa] = 0 if $LWP > 0.2571 kg/m^2$	WATER VAPOUR ICE PHASE AMVs MIC.CORR[hPa] = -6 without IWP MIC.CORR[hPa] = $-22 + 45 \cdot IWP [kg/m^2]$ if $IWP < 2.7555 kg/m^2$ MIC.CORR[hPa] = 102 if $IWP > 2.7555 kg/m^2$

Table 6: Correction for the AMV pressure level [in hPa], based on the Cloud microphysics

- In the ‘Water vapour clear air AMVs’, no CTP_{ij} pressure values exist logically from NWC/GEO CTTH output for the clear air pixels. Because of this, the Brightness temperature from the corresponding channel (BT_{ij}) is used instead, considering only the pixels whose brightness temperature is colder than the threshold (i.e., they are in the “cold branch” of the Brightness temperature (Pixel correlation contribution) graph). A ‘CCC temperature value error, ΔT_{CCC} ’ is now also calculated considering a formula similar to the one used in the previous chapter for the pressure error: $\Delta T_{CCC} = \sqrt{(\Sigma(CC_{ij} \cdot BT_{ij}^2) / \Sigma CC_{ij} - T_{CCC}^2)}$.

With these data, three different temperature values are defined by next formulas: $T_{CCC} + \Delta T_{CCC}$, T_{CCC} , $T_{CCC} - \Delta T_{CCC}$. For each one of these values, a temperature to pressure conversion is obtained through interpolation to the NWP temperature forecast, giving three pressure values: $P_{CCC_{MAX}}$ (related to $T_{CCC} + \Delta T_{CCC}$), P_{CCC} (related to T_{CCC}) and $P_{CCC_{MIN}}$ (related to $T_{CCC} - \Delta T_{CCC}$). P_{CCC} is defined as the ‘CCC Pressure value’ for the clear air AMVs. $\Delta P_{CCC} = |P_{CCC_{MAX}} - P_{CCC_{MIN}}|/2$ is

defined as the ‘CCC Pressure error value’ for the clear air AMVs (only in cases for which a vertical reduction or increase of temperature is found). In the cases where the ‘CCC Pressure value’ or the ‘CCC Pressure error value’ cannot be calculated, the AMVs are discarded.

Since GEO-HRW-v4.0 with configurable parameter DEFPOSWITHCONTRIBUTIONS = 1 (which is the default option), the location of the AMV inside the tracer in both initial and final images is also defined not as the tracer/tracking centre but as the weighted position displacement defined with the similar formulae (where X_{ij} and Y_{ij} correspond to the line and column position of each pixel):

$$X_{ccc} = \frac{\sum(CC_{ij} \cdot X_{ij})}{\sum CC_{ij}} \quad Y_{ccc} = \frac{\sum(CC_{ij} \cdot Y_{ij})}{\sum CC_{ij}}$$

With this relocation of the AMV, its position is related to the part of the tracer with largest correlation contribution. When trajectories are defined (as already told with configurable parameter CALCULATE_TRAJECTORIES = 1), tracking consecutively during several slots the same tracer, this relocation of the AMV position is only calculated for the first AMV in the trajectory and keeps the same value during all the time the trajectory is alive, to avoid discontinuities in its positioning.

2.2.6 Wind calculation

Once the latitude and longitude corresponding to the initial tracer location and the up to three ‘adjustment centres’ are defined, the rectangular coordinates of the corresponding winds (in m/s) are calculated. Although the difference with the calculation procedure used in previous versions is completely negligible, since GEO-HRW-v50 the calculation of the speed components considering the displacement along the corresponding ‘great circle’ with the ‘haversine formula’, and the bearing angle related to this ‘great circle’, is used.

More information about all this procedure is available in the “Algorithm Theoretical Basis Document for the Wind product processors of the NWC/GEO” [AD.14].

Since GEO-HRW-v50, for the calculation of speed, the real time difference between the scanning time for the lines defining the tracer location in the initial image and the adjustment centre location in the later tracking image, is also used. For MSG satellite series, this procedure takes into account the real time the image scanning began for the given slot and the time needed to scan each image line. For GOES-N satellite series the procedure is easier, taking simply into account the scanning time for each pixel provided in the satellite input data files.

The definition of the position of the tracking area centre in the later image when the wind guess is used with WIND_GUESS = 1, through displacement of the tracer position in the initial image with the rectangular NWP wind components, uses also since GEO-HRW-v50 an equivalent procedure with a displacement along the corresponding ‘great circle’.

2.2.7 Postprocessing: Quality control and Choice of the best wind

Basically, the Quality Indicator method developed by EUMETSAT and implemented for the MPEF Atmospheric Motion Vectors (K.Holmlund, 1998), is used here.

This method assigns a quantitative flag (QI, ranging from 0% to 100%) to any Atmospheric Motion Vector. It is based on normalised functions fit to statistical properties in the behaviour of the AMVs. These properties are related to the expected change of the AMVs considering: temporal consistency (comparison to winds in the previous slot at the same location and level), spatial consistency (comparison to neighbour winds in the same slot at the same location and level) and consistency relative to a background (NWP wind forecast interpolated to the same slot, in the same location and level).

5 tests are applied (direction, speed and vector temporal consistency tests, vector spatial and forecast consistency tests) giving 5 individual QI; their weighted sum provides the overall QI (after two corrections which affect respectively winds with very low speed, and low winds with a high correlation between infrared and water vapour channels in the location of the wind).

The weights for the QI tests are defined in \$SAFNWC/include/HRW/hrw_QualitySchema.h file, and in case of need the user can evaluate the impact of the different tests in the output results changing their corresponding values. For the two scale procedure, an additional 'interscale test' is computed for detailed AMVs derived from a basic scale tracer (compared to the corresponding basic scale AMVs).

Only one wind per tracer is selected for the GEO-HRW output, through two different criteria. The suggested option (parameter BEST_WIND_SELECTION = 1) is to choose the best at most of next criteria: interscale spatial quality test, temporal quality test, spatial quality test, forecast quality test, correlation. If this is not definitive the best wind for the forecast quality test; if this is also not definitive the wind with the best correlation.

TEST output parameter will reflect, apart from the number of quality tests that each wind has passed, whether the wind is the best (value = 3), slightly worse (value = 2), or fairly worse (value = 1) than other winds calculated for the same tracer for each available criterion. If any of the quality tests could not be passed, this is identified with the value = 0 (it is frequent that a test could not be calculated, when no AMV was found for the comparison).

For the temporal consistency of consecutive winds related to a same trajectory, some limits are defined in speed difference (MEANVEC_SPEED_DIF = 10 m/s), direction difference (MEANVEC_DIR_DIF = 20°) and pressure level difference (MEANVEC_PRESSURE_DIR = 50 hPa). These limits must be obeyed so that additional sectors can be added to the trajectory.

Additionally, with winds related to a predecessor wind inside a trajectory, if configurable parameter USE_MEANWIND = 1 is used, a correction of the GEO-HRW wind output for the current slot is done with the corresponding 'predecessor wind' for the same trajectory when it exists, in which the mean value of speed, direction, correlation, quality, temperature, pressure and pressure error considering both winds is used in the GEO-HRW wind output. Nevertheless, this option is not used as the default one.

Despite the Quality control, it is detected sometimes that an AMV has a direction or speed completely different to the ones in its immediate vicinity, without a clear justification for such big changes in direction or speed. To eliminate these AMVs, which can be considered as errors, a function to calculate the speed and direction histograms with all valid AMVs in relatively small areas inside the working region can be run: the Final Control Check (activated with configurable parameter FINALCONTROLCHECK = 1, which is the default option). When any of the columns of the speed or direction histograms has only one element, it is excluded: the lack in the same area of another AMV with relatively similar velocities or directions is enough to consider it as an error.

2.2.8 Postprocessing: Orographic flag calculation

Topographic information is finally incorporated to the algorithm, which in combination with NWP data, calculates an ‘Orographic flag’ to detect and reject those Atmospheric Motion Vectors affected by land influence. The reasons for this land influence can be: AMVs associated to land features incorrectly detected as cloud tracers; tracers blocked or whose flow is affected by mountain ranges; tracers associated to lee wave clouds, with atmospheric stability near mountain ranges.

The procedure reads two topographic matrices with representative “Minimum and Maximum Heights” (S_NWC_SFCMIN* and S_NWC_SFCMAX*, located in \$SAFNWC/import/Aux_data/Common directory), which are then converted to the “Surface pressure levels corresponding to these Minimum and Maximum Heights”, considering NWP geopotential data. With these P_sfcmin/P_sfcmax values, the “Static orographic flag” is calculated at the position of each tracer. Its possible values are:

- Ind_topo=0: The “Orographic flag” could not be calculated.
- Ind_topo=1: AMV wrongly located below the lowest representative pressure level (mainly due to Microphysics corrections in the AMV pressure).
- Ind_topo=2: Very important orographic influence found in the current AMV position.
- Ind_topo=3: Important orographic influence found in the current AMV position.
- Ind_topo=6: No orographic influence found in the current AMV position.

The “Dynamic orographic flag” is then calculated: values of Ind_topo are modified to verify the possibility of a previous in time orographic influence. This part only happens if Ind_topo = 6 and the tracer is related to predecessor AMVs in previous slots. The value of Ind_topo = 6 is then modified considering the next conditions:

- Ind_topo = 0: The “Orographic flag” could not be calculated.
- Ind_topo = 4: Very important orographic influence found at a previous position of the AMV.
- Ind_topo = 5: Important orographic influence found at a previous position of the AMV.
- Ind_topo = 6: No orographic influence is found in any current/previous position of the AMV.

The comparison test TESO is also calculated, similar to the ones in section 2.2.7 and with the same values, to compare the different AMVs for the same tracer related to orography.

With option USE_TOPO = 1, the Orographic flag is calculated and incorporated to the output file. With USE_TOPO = 2 (which is the default option), all AMVs with any Orographic influence (i.e. with Ind_topo = 1 to 5) are eliminated from the output files.

2.3 DESCRIPTION OF HIGH RESOLUTION WINDS (GEO-HRW) OUTPUTS

Two different types of AMV outputs are possible for NWC/GEO High Resolution Winds.

On the one hand, BUFR output format, already used by SAFNWC/MSG v2013 software package and the previous ones, has been requested by the users working since long with this format, especially those related to the assimilation of the GEO-HRW Atmospheric Motion Vectors in NWP models.

On the other hand, netCDF output format has also been requested as an improvement during the “2010 Madrid Users' Workshop” and the “Consolidated Report on 2010 User Survey and Users' Workshop” document (SAF/NWC/IOP/INM/MGT/2010-US+WS) for the NWC/GEO software package, and has been approved by the EUM Format Advisory Group (See EUM/STG-OPSWG/30/11/VWG/15 presentation) for products delivered by the EUMETSAT Data Centre.

2.3.1 AMV/Wind BUFR bulletins

One file for the single AMV scale, or two different files for two different AMV scales (related each one of them to ‘Basic winds’ and ‘Detailed winds’, when so configured with configurable parameter CDET = ALL or RANGE), in form of BUFR bulletins, are produced for each processed region for every running slot. If winds have been calculated for several channels, they are all included in the same BUFR bulletin. The BUFR bulletin can have two different formats, depending on the value of configurable parameter OUTPUT_FORMAT.

2.3.1.1 AMV/Wind BUFR bulletins with NWC SAF specific format

When OUTPUT_FORMAT = NWC, an AMV BUFR bulletin equivalent to those defined in all previous version of GEO-HRW product is written in \$SAFNWC/export/HRW directory under the name S_NWC_HRW-WIND_<satid>_<regionid>-BS_YYYYMMDDThhmmssZ.bufr (for the ‘single or basic AMV scale’), or the name S_NWC_HRW-WIND_<satid>_<regionid>-DS_YYYYMMDDThhmmssZ.bufr (for the ‘detailed AMV scale’), where “satid” is the identifier of the satellite used, “regionid” is the identifier of the region used, and “YYYYMMDDThhmmssZ” is the date and time of the processed slot for which the AMVs have been calculated.

To correctly define the BUFR bulletins, the user has additionally to define the Originating Centre of the Information through configurable parameter BUFR_CENTRE_OR (with a default value of 214, which is valid for NWC SAF Headquarters in Madrid; the numeric codes for other locations are available at the WMO Common Code Table C-1 [RD.19]).

The BUFR table used for the writing of the AMVs in the BUFR output file considering this format (identified as \$SAFNWC/import/Aux_data/PGE09/B0000000000214012094.TXT) is the next one:

001007	SATELLITE IDENTIFIER	CODE TABLE 001007	0	0	10
001031	IDENTIFICATION OF ORIGINATING/GENERATING CENTRE	CODE TABLE 001031	0	0	16
001032	GENERATING APPLICATION (CODE TABLE 001032)	CODE TABLE 001032	0	0	8
002023	SATELLITE DERIVED WIND COMPUTATION METHOD	CODE TABLE 002023	0	0	4
002057	ORIGIN OF FIRST GUESS INFORMATION	CODE TABLE 002057	0	0	4
002152	SATELLITE INSTRUMENT USED IN DATA PROCESSING	CODE TABLE 002152	0	0	31
002153	SATELLITE CHANNEL CENTRE FREQUENCY	Hz	-8	0	26
002154	SATELLITE CHANNEL BAND WIDTH	Hz	-8	0	26
004001	YEAR	YEAR	0	0	12
004002	MONTH	MONTH	0	0	4
004003	DAY	DAY	0	0	6
004004	HOURL	HOURL	0	0	5
004005	MINUTE	MINUTE	0	0	6
004025	TIME PERIOD OR DISPLACEMENT	MINUTE	0	-2048	12
005044	SATELLITE CYCLE NUMBER	NUMERIC	0	0	11
033035	MANUAL/AUTOMATIC QUALITY CONTROL	CODE TABLE 033035	0	0	4
060000	SEGMENT SIZE AT NADIR IN X DIRECTION (PIXELS)	PIX	0	0	7
060001	SEGMENT SIZE AT NADIR IN Y DIRECTION (PIXELS)	PIX	0	0	7
127000	REPLICATION OPERATOR	-	0	0	0
031002	EXTENDED DELAYED DESCRIPTOR REPLICATION FACTOR:WINDS	NUMERIC	0	0	16
060100	WIND SEQUENCE NUMBER	NUMERIC	0	0	24
060101	PRIOR WIND SEQUENCE NUMBER	NUMERIC	0	0	24
002028	SEGMENT SIZE AT NADIR IN X DIRECTION	M	-1	0	18
002029	SEGMENT SIZE AT NADIR IN Y DIRECTION	M	-1	0	18
002164	TRACER CORRELATION METHOD	CODE TABLE 002164	0	0	3
005001	LATITUDE (HIGH ACCURACY)	DEGREE	5	-9000000	25
006001	LONGITUDE (HIGH ACCURACY)	DEGREE	5	-18000000	26
005011	LATITUDE INCREMENT (HIGH ACCURACY)	DEGREE	5	-9000000	25
006011	LONGITUDE INCREMENT (HIGH ACCURACY)	DEGREE	5	-18000000	26
007004	PRESSURE	PA	-1	0	14
011001	WIND DIRECTION	DEGREE TRUE	0	0	9
011002	WIND SPEED	M/S	1	0	12
012001	TEMPERATURE	K	1	0	12
033007	PER CENT CONFIDENCE (WITH FORECAST TEST)	%	0	0	7
033007	PER CENT CONFIDENCE (WITHOUT FORECAST TEST)	%	0	0	7
060102	TRACER TYPE (CODE TABLE 060102)	CODE TABLE 060102	0	0	2
060103	HEIGHT ASSIGNMENT METHOD (CODE TABLE 060103)	CODE TABLE 060103	0	0	4
060200	NUMBER OF WINDS COMPUTED FOR THE TRACER	NUMERIC	0	0	3
060201	CORRELATION TEST (CODE TABLE 060201)	CODE TABLE 060201	0	0	3
060202	APPLIED QUALITY TESTS (CODE TABLE 060202)	CODE TABLE 060202	0	0	11
060203	NUMBER OF AVAILABLE NWP WIND GUESS LEVELS	NUMERIC	0	0	7
060204	NUMBER OF PREDECESSOR WINDS	NUMERIC	0	0	7
060205	OROGRAPHIC INDEX (CODE TABLE 060205)	CODE TABLE 060205	0	0	3
060206	CLOUD TYPE (SAFNWC/MSG) (CODE TABLE 060206)	CODE TABLE 060206	0	0	5
060207	WIND CHANNEL (SEVIRI CHANNEL ID) (CODE TABLE 060207)	CODE TABLE 060207	0	0	5
060208	CORRELATION	%	0	0	7
060209	PRESSURE ERROR OR CORRECTION	PA	-1	-8000	14

Table 7: BUFR table for AMV BUFR output files with NWC SAF specific BUFR format

These BUFR bulletins are based on BUFR Master Table number 0, Version number 12. For all parameters in Table 7, the first column shows the “Parameter identification code”, the second column shows the “Parameter description”, the third column shows the “Unit used for the codification of the parameter (in some cases identified through a Code Table)”, the fourth column shows the “Number of decimals used in the codification of the parameter (where a value of 1 is used for a precision of one decimal place and a value of -1 is used for a precision only up to the tens)”, the fifth column shows the “Default value of the parameter” and the sixth column shows the “Number of bits used for the parameter codification and so the maximum value the parameter can have (for example, for parameter 060203/Number of available wind guess levels, the maximum value of the parameter is $2^{7-1} = 127$).

The Code Tables used for all parameters in this table except those characterized as 060xxx (which are specific parameters for NWC SAF BUFR output bulletins) are described in the BUFR Reference Manual [RD.20]. The Code Tables for the NWC SAF specific parameters are explained next:

- Code Table 060102, Tracer type:

- 0 for 'Basic tracer'
- 1 for 'Detailed tracer related to a Narrow basic tracer'
- 2 for 'Detailed tracer related to a Wide basic tracer'
- 3 for 'Detailed tracer unrelated to a Basic tracer'.

- Code Table 060103, Height assignment method:

Values 0 to 3 are related to 'Brightness temperature interpolation height assignment method' and values 4 to 15 are related to 'CCC height assignment method'. Due to the actual implementation of GEO-HRW algorithm, value 2 is never used.

- 0: NWP interpolation using Top pressure in Clear air AMV
- 1: NWP interpolation using Top pressure in Cloudy AMV
- 3: NWP interpolation using Base pressure in Cloudy AMV
- 4: CCC method using low threshold and cold branch in Clear air AMV
- 5: CCC method using high threshold and cold branch in Clear air AMV
- 6: CCC method using low threshold and cold/bright branch in Cloudy AMV with undefined phase
- 7: CCC method using high threshold and cold/bright branch in Cloudy AMV with undefined phase
- 8: CCC method using low threshold and cold/bright branch in Cloudy AMV with liquid phase
- 9: CCC method using high threshold and cold/bright branch in Cloudy AMV with liquid phase
- 10: CCC method with microphysics correction using low threshold and cold/bright branch in Cloudy AMV with liquid phase
- 11: CCC method with microphysics correction using high threshold and cold/bright branch in Cloudy AMV with liquid phase
- 12: CCC method with low threshold and cold/bright branch in Cloudy AMV with ice phase
- 13: CCC method with high threshold and cold/bright branch in Cloudy AMV with ice phase
- 14: CCC method with microphysics correction using low threshold and cold/bright branch in Cloudy AMV with ice phase
- 15: CCC method with microphysics correction using high threshold and cold/bright branch in Cloudy AMV with ice phase.

- Code Table 060201, Correlation test:

- 0 for 'Wind not selected as the Best wind for a tracer not having the Best correlation value'
- 1 for 'Wind not selected as the Best wind for a tracer having the Best correlation value'
- 2 for 'Wind selected as the Best wind for a tracer not having the Best correlation value'
- 3 for 'Wind selected as the Best wind for a tracer having the Best correlation value'.

- Code Table 060202, Applied Quality tests:

For each one the next Quality flags: Orographic flag, Forecast quality flag, Spatial quality flag, Temporal quality flag, Interscale quality flag:

0 for ‘Wind for which the corresponding quality test could not be calculated’

1 for ‘Wind whose corresponding quality test is at least a 21% worse than for the wind calculated for the same tracer with the best quality test (in the orographic test, the orographic flag value is at least two units lower than for the wind calculated for the same tracer with the best orographic flag)’

2 for ‘Wind whose corresponding quality test is up to a 20% worse than for the wind calculated for the same tracer with the best quality test (in the orographic test, the orographic flag value is one unit lower than for the wind calculated for the same tracer with the best orographic flag)’

3 for ‘Wind with the best corresponding quality test among the winds calculated for a tracer’.

- Code Table 060205, Orographic flag:

The values of this parameter are between 0 and 6, corresponding to those defined for ‘IND_TOPO’ parameter in Chapter 2.2.8 of this document.

- Code Table 060205, Cloud type:


The values of this parameter are between 0 and 23, corresponding to those defined in *Table 5* in Chapter 2.2.4 of this document.

- Code Table 060207, Wind channel (satellite channel used for the AMV/Trajectory calculation):

MSG series values: 5 for ‘HRVIS’ 2 for ‘VIS06’ 3 for ‘VIS08’ 10 for ‘WV62’
12 for ‘WV73’ 16 for ‘IR108’ 17 for ‘IR120’.

GOES-N series values: 2 for ‘VIS07’ 10 for ‘WV65’ 16 for ‘IR107’.

Formally, several different BUFR messages with AMVs calculated for an only MSG/SEVIRI channel, in each case with an only Subset of up to 1000 AMVs (winds), are included in this AMV BUFR output file.

	User Manual for the Wind product processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/AEMET/SCI/UM/Wind Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-AEMET-SCI-UM-Wind_v1.0.doc Page: 28/56
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2.3.1.2 AMV/Wind BUFR bulletins with Eumetsat/MPEF format

When OUTPUT_FORMAT = EUM, an AMV BUFR bulletin equivalent to those defined for the AMV extraction at the Meteosat Product Extraction Facility in Eumetsat is written under the name S_NWC_HRW-WINDEUM_<satid>_<regionid>-BS_YYYYMMDDThhmmssZ.bufr (for the ‘single or basic AMV scale’), or the name S_NWC_HRW-WINDEUM_<satid>_<regionid>-DS_YYYYMMDDThhmmssZ.bufr (for the ‘detailed AMV scale’) in \$SAFNWC/export/HRW directory, where “satid” is the identifier of satellite used, “regionid” is the identifier of the region used and “YYYYMMDDThhmmssZ” is the date and time for which the AMVs have been calculated.

To correctly define the BUFR bulletins, the user has additionally to define the Originating Centre of the Information through configurable parameter BUFR_CENTRE_OR (with a default value of 214, which is valid for NWC SAF Headquarters in Madrid; the numeric codes for other locations are available at the WMO Common Code Table C-1 [RD.19]).

The BUFR template used for the writing of the AMVs in the BUFR output file considering this format (which is similar to the ones described for the MPEF AMVs at Eumetsat website at <http://www.eumetsat.int/website/home/Data/Products/Formats/index.html>), and which corresponds to BUFR Master Table number 0, Version number 12 (identified by GEO-HRW algorithm as \$SAFNWC/import/Aux_data/HRW/B00000000000000012000.TXT), is shown next, with some explanation underlined and in italics of the content of the different parameters when used by GEO-HRW algorithm.

Formally, the EUMETSAT/MPEF AMV BUFR format is a kind a blend of the NWC SAF AMV and Trajectory BUFR specific formats, because of including at the same time information related to the reference AMV to be used (which depending on the value of USE_MEANWIND configurable parameter, can be related to the latest AMV in any GEO-HRW trajectory, or to the mean value of the latest two AMVs in the GEO-HRW trajectory), and information related to the up to four latest AMVs in any GEO-HRW trajectory (which is the information provided in the Trajectory BUFR files with the NWC SAF specific BUFR format, later explained later in Chapter 2.3.2). Considering this, when configurable parameter OUTPUT_FORMAT = EUM is defined, only the AMV BUFR bulletin with the EUMETSAT/MPEF format is provided, and no Trajectory BUFR bulletins are provided.

In any case, it is only recommended to use the option to write GEO-HRW output with the EUMETSAT/MPEF format, when the main interest of the GEO-HRW AMV calculation is the assimilation of the AMVs in NWP models or other applications (possibly together with the EUMETSAT/MPEF AMVs). The main reason for this is that part of the information calculated with the AMVs cannot be included using this format because there is no place for it (like the “cloud type”, the “orographic flag” or the “correlation value”), and because of this, this additional information cannot be used operationally when this kind of AMV BUFR output is used. Moreover, the size of the AMV BUFR bulletins with the EUMETSAT/MPEF format is much larger, and can cause more important storage problems.

Formally, several different BUFR messages with up to 100 subsets with an only AMV, all of them related to the same MSG/SEVIRI channel, are included in this AMV BUFR output file.

001007 SATELLITE IDENTIFIER
001031 IDENTIFICATION OF ORIGINATING/GENERATING CENTRE
002020 SATELLITE CLASSIFICATION
002028 SEGMENT SIZE AT NADIR IN X DIRECTION *(Not used)*
002029 SEGMENT SIZE AT NADIR IN Y DIRECTION *(Not used)*
004001 YEAR *(For the reference AMV to be used)*
004002 MONTH *(For the reference AMV to be used)*
004003 DAY *(For the reference AMV to be used)*
004004 HOUR *(For the reference AMV to be used)*
004005 MINUTE *(For the reference AMV to be used)*
004006 SECOND *(For the reference AMV to be used)*
005001 LATITUDE/HIGH ACCURACY *(For the reference AMV to be used)*
006001 LONGITUDE/HIGH ACCURACY *(For the reference AMV to be used)*
002152 SATELLITE INSTRUMENT DATA USED IN PROCESSING
002023 SATELLITE DERIVED WIND COMPUTATION METHOD
007004 PRESSURE *(For the reference AMV to be used)*
011001 WIND DIRECTION *(For the reference AMV to be used)*
011002 WIND SPEED *(For the reference AMV to be used)*
002153 SATELLITE CHANNEL CENTRE FREQUENCY
002154 SATELLITE CHANNEL BAND WIDTH
012071 COLDEST CLUSTER TEMPERATURE *(Not used)*
002163 HEIGHT ASSIGNMENT METHOD *(For the reference AMV to be used)*
002164 TRACER CORRELATION METHOD *(For the reference AMV to be used)*
008012 LAND/SEA QUALIFIER *(Not used)*
007024 SATELLITE ZENITH ANGLE *(For the reference AMV to be used)*
002057 ORIGIN OF FIRST GUESS INFORMATION

008021 TIME SIGNIFICANCE *(Not used)*
004001 YEAR *(Not used)*
004002 MONTH *(Not used)*
004003 DAY *(Not used)*
004004 HOUR *(Not used)*
008021 TIME SIGNIFICANCE *(Time series)*
004024 TIME PERIOD OR DISPLACEMENT *(Between slots, in minutes)*
008021 TIME SIGNIFICANCE *(Starting time for the latest AMV in the trajectory)*
004004 HOUR
004005 MINUTE
004006 SECOND
008021 TIME SIGNIFICANCE *(Ending time for the latest AMV in the trajectory)*
004004 HOUR
004005 MINUTE
004006 SECOND
011001 WIND DIRECTION *(For the latest AMV in the trajectory)*
011002 WIND SPEED *(For the latest AMV in the trajectory)*
008021 TIME SIGNIFICANCE *(Starting time for the second latest AMV in the trajectory)*
004004 HOUR
004005 MINUTE
004006 SECOND
008021 TIME SIGNIFICANCE *(Ending time for the second latest AMV in the trajectory)*
004004 HOUR
004005 MINUTE
004006 SECOND
011001 WIND DIRECTION *(For the second latest AMV in the trajectory, when available)*
011002 WIND SPEED *(For the second latest AMV in the trajectory, when available)*
008021 TIME SIGNIFICANCE *(Starting time for the third latest AMV in the trajectory)*
004004 HOUR
004005 MINUTE
004006 SECOND
008021 TIME SIGNIFICANCE *(Ending time for the third latest AMV in the trajectory)*
004004 HOUR
004005 MINUTE
004006 SECOND

011001 WIND DIRECTION (*For the third latest AMV in the trajectory, when available*)
011002 WIND SPEED (*For the third latest AMV in the trajectory, when available*)
008021 TIME SIGNIFICANCE (*Starting time for the fourth latest AMV in the trajectory*)
004004 HOUR
004005 MINUTE
004006 SECOND
008021 TIME SIGNIFICANCE (*Ending time for the fourth latest AMV in the trajectory*)
004004 HOUR
004005 MINUTE
004006 SECOND
011001 WIND DIRECTION (*For the fourth latest AMV in the trajectory, when available*)
011002 WIND SPEED (*For the fourth latest AMV in the trajectory, when available*)

002163 HEIGHT ASSIGNMENT METHOD (*Not used*)
007004 PRESSURE (*Not used*)
012001 TEMPERATURE/DRY BULB TEMPERATURE (*Not used*)
002163 HEIGHT ASSIGNMENT METHOD (*Not used*)
007004 PRESSURE (*Not used*)
012001 TEMPERATURE/DRY BULB TEMPERATURE (*Not used*)
002163 HEIGHT ASSIGNMENT METHOD (*Not used*)
007004 PRESSURE (*Not used*)
012001 TEMPERATURE/DRY BULB TEMPERATURE (*Not used*)
002163 HEIGHT ASSIGNMENT METHOD (*Not used*)
007004 PRESSURE (*For the latest AMV in the trajectory*)
012001 TEMPERATURE *For the latest AMV in the trajectory*
002163 HEIGHT ASSIGNMENT METHOD (*Not used*)
007004 PRESSURE (*Not used*)
012001 TEMPERATURE/DRY BULB TEMPERATURE (*Not used*)
002163 HEIGHT ASSIGNMENT METHOD (*Not used*)
007004 PRESSURE (*For the second latest AMV in the trajectory, when available*)
012001 TEMPERATURE *For the second latest AMV in the trajectory, when available*
002163 HEIGHT ASSIGNMENT METHOD (*Not used*)
007004 PRESSURE (*Not used*)
012001 TEMPERATURE/DRY BULB TEMPERATURE (*Not used*)
002163 HEIGHT ASSIGNMENT METHOD (*Not used*)
007004 PRESSURE (*For the third latest AMV in the trajectory, when available*)
012001 TEMPERATURE *For the third latest AMV in the trajectory, when available*
002163 HEIGHT ASSIGNMENT METHOD (*Not used*)
007004 PRESSURE (*Not used*)
012001 TEMPERATURE/DRY BULB TEMPERATURE (*Not used*)
002163 HEIGHT ASSIGNMENT METHOD (*Not used*)
007004 PRESSURE (*For the fourth latest AMV in the trajectory, when available*)
012001 TEMPERATURE *For the fourth latest AMV in the trajectory, when available*

222000 QUALITY INFORMATION FOLLOWS
236000 DEFINE BIT-MAP
031031 DATA PRESENT INDICATOR (*Descriptor repeated 103 times, not used*)

001031 IDENTIFICATION OF ORIGINATING/GENERATING CENTRE
001032 GENERATING APPLICATION (*Quality Control using forecast*)
033007 % CONFIDENCE (*For the latest AMV in the trajectory*)
033007 % CONFIDENCE (*For the second latest AMV in the trajectory, when available*)
033007 % CONFIDENCE (*For the third latest AMV in the trajectory, when available*)
033007 % CONFIDENCE (*For the fourth latest AMV in the trajectory, when available*)
222000 QUALITY INFORMATION FOLLOWS
237000 REUSE PREVIOUSLY DEFINED BIT-MAP
001031 IDENTIFICATION OF ORIGINATING/GENERATING CENTRE
001032 GENERATING APPLICATION (*Quality Control using forecast*)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (*For the latest AMV in the trajectory*)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (*For the second latest AMV in the trajectory*)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (*For the third latest AMV in the trajectory*)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (*For the fourth latest AMV in the trajectory*)
222000 QUALITY INFORMATION FOLLOWS


```

237000 REUSE PREVIOUSLY DEFINED BIT-MAP
001031 IDENTIFICATION OF ORIGINATING/GENERATING CENTRE
001032 GENERATING APPLICATION (Quality Control using forecast)
033036 NOMINAL CONFIDENCE THRESHOLD (For the latest AMV in the trajectory)
033036 NOMINAL CONFIDENCE THRESHOLD (For the second latest AMV in the trajectory)
033036 NOMINAL CONFIDENCE THRESHOLD (For the third latest AMV in the trajectory)
033036 NOMINAL CONFIDENCE THRESHOLD (For the fourth latest AMV in the trajectory)
222000 QUALITY INFORMATION FOLLOWS
237000 REUSE PREVIOUSLY DEFINED BIT-MAP
001031 IDENTIFICATION OF ORIGINATING/GENERATING CENTRE
001032 GENERATING APPLICATION (Quality Control not using forecast)
033007 % CONFIDENCE (For the latest AMV in the trajectory)
033007 % CONFIDENCE (For the second latest AMV in the trajectory, when available)
033007 % CONFIDENCE (For the third latest AMV in the trajectory, when available)
033007 % CONFIDENCE (For the fourth latest AMV in the trajectory, when available)
222000 QUALITY INFORMATION FOLLOWS
237000 REUSE PREVIOUSLY DEFINED BIT-MAP
001031 IDENTIFICATION OF ORIGINATING/GENERATING CENTRE
001032 GENERATING APPLICATION (Quality Control not using forecast)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (For the latest AMV in the trajectory)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (For the second latest AMV in the trajectory)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (For the third latest AMV in the trajectory)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (For the fourth latest AMV in the trajectory)
222000 QUALITY INFORMATION FOLLOWS
237000 REUSE PREVIOUSLY DEFINED BIT-MAP
001031 IDENTIFICATION OF ORIGINATING/GENERATING CENTRE
001032 GENERATING APPLICATION (Quality Control not using forecast)
033036 NOMINAL CONFIDENCE THRESHOLD (For the latest AMV in the trajectory)
033036 NOMINAL CONFIDENCE THRESHOLD (For the second latest AMV in the trajectory)
033036 NOMINAL CONFIDENCE THRESHOLD (For the third latest AMV in the trajectory)
033036 NOMINAL CONFIDENCE THRESHOLD (For the fourth latest AMV in the trajectory)
222000 QUALITY INFORMATION FOLLOWS
237000 REUSE PREVIOUSLY DEFINED BIT-MAP
001031 IDENTIFICATION OF ORIGINATING/GENERATING CENTRE
001032 GENERATING APPLICATION (Quality Control only using forecast)
033007 % CONFIDENCE (For the latest AMV in the trajectory)
033007 % CONFIDENCE (For the second latest AMV in the trajectory, when available)
033007 % CONFIDENCE (For the third latest AMV in the trajectory, when available)
033007 % CONFIDENCE (For the fourth latest AMV in the trajectory, when available)
222000 QUALITY INFORMATION FOLLOWS
237000 REUSE PREVIOUSLY DEFINED BIT-MAP
001031 IDENTIFICATION OF ORIGINATING/GENERATING CENTRE
001032 GENERATING APPLICATION (Quality Control only using forecast)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (For the latest AMV in the trajectory)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (For the second latest AMV in the trajectory)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (For the third latest AMV in the trajectory)
033035 MANUAL-AUTOMATIC QUALITY CONTROL (For the fourth latest AMV in the trajectory)
222000 QUALITY INFORMATION FOLLOWS
237000 REUSE PREVIOUSLY DEFINED BIT-MAP
001031 IDENTIFICATION OF ORIGINATING/GENERATING CENTRE
001032 GENERATING APPLICATION (Quality Control only using forecast)
033036 NOMINAL CONFIDENCE THRESHOLD (For the latest AMV in the trajectory)
033036 NOMINAL CONFIDENCE THRESHOLD (For the second latest AMV in the trajectory)
033036 NOMINAL CONFIDENCE THRESHOLD (For the third latest AMV in the trajectory)
033036 NOMINAL CONFIDENCE THRESHOLD (For the fourth latest AMV in the trajectory)

```

Table 8: BUFR table for AMV BUFR output files with EUMETSAT/MPEF BUFR format

2.3.2 Trajectory BUFR bulletin

If the calculation and writing of trajectories is activated for GEO-HRW algorithm with configurable parameters `CALCULATE_TRAJECTORIES = 1` and `OUTPUT_FORMAT = NWC` (which is the default option), one file for the trajectories related to the single AMV scale, or two different BUFR files for the trajectories related to the two different AMV scales ('Basic winds' and 'Detailed winds', when so configured with configurable parameter `CDET = ALL` or `RANGE`), are produced. If trajectories have been calculated for several channels, they are all included in the same BUFR bulletin. It is important here to remember that no Trajectory BUFR output file is produced if the EUMETSAT BUFR format is selected with configurable parameter `OUTPUT_FORMAT = EUM`.

The Trajectory BUFR bulletin is written in `$SAFNWC/export/HRW` directory under the name `S_NWC_HRW-TRAJ-<satid>_<regionid>-BS_YYYYMMDDThhmmssZ.bufr` for the basic scale. `S_NWC_HRW-TRAJ-<satid>_<regionid>-DS_YYYYMMDDThhmmssZ.bufr` is used for the detailed scale. Again, "satid" is the identifier of the satellite used, "regionid" is the identifier of the region used, and "YYYYMMDDYhhmmssZ" is the date and time of the slot for which the trajectories have been calculated.

As previously also seen, to correctly define the BUFR bulletins, the user has to define the Originating Centre of the Information through configurable parameter `BUFR_CENTRE_OR` (with a default value of 214, which is valid for NWC SAF Headquarters in Madrid; the numeric codes for other locations are available at the WMO Common Code Table C-1 [RD.19]).

The BUFR specific table used for the writing of the Trajectories in the BUFR output file (identified as `$SAFNWC/import/Aux_data/HRW/B0000000000214012098.TXT`), and which is rather similar to the one used for the writing of the AMVs, is shown as *Table 9*. It is based on BUFR Master Table number 0, Version number 12, although with some specific parameters for the NWC SAF BUFR output bulletins identified as 060xxx.

It behaves similarly as explained in Chapter 2.3.1.1 for the AMV BUFR bulletins using the NWC SAF specific format. The Code Tables used for the NWC SAF specific BUFR output parameters (also characterized as 060xxx), are exactly the same ones used in Chapter 2.3.1.1. All other Code Tables are similarly described in the BUFR Reference Manual [RD.20].

Different BUFR messages with an only Subset with one Trajectory each (with up to 24 AMVs in the trajectory), are included in this Trajectory BUFR output file.

001007	SATELLITE IDENTIFIER	CODE TABLE 001007	0	0	10
001031	IDENTIFICATION OF ORIGINATING/GENERATING CENTRE	CODE TABLE 001031	0	0	16
001032	GENERATING APPLICATION (CODE TABLE 001032)	CODE TABLE 001032	0	0	8
002023	SATELLITE DERIVED WIND COMPUTATION METHOD	CODE TABLE 002023	0	0	4
002057	ORIGIN OF FIRST GUESS INFORMATION	CODE TABLE 002057	0	0	4
002152	SATELLITE INSTRUMENT USED IN DATA PROCESSING	CODE TABLE 002152	0	0	31
002153	SATELLITE CHANNEL CENTRE FREQUENCY	Hz	-8	0	26
002154	SATELLITE CHANNEL BAND WIDTH	Hz	-8	0	26
004001	YEAR	YEAR	0	0	12
004002	MONTH	MONTH	0	0	4
004003	DAY	DAY	0	0	6
004004	HOURL	HOURL	0	0	5
004005	MINUTE	MINUTE	0	0	6
004025	TIME PERIOD OR DISPLACEMENT	MINUTE	0	-2048	12
005044	SATELLITE CYCLE NUMBER	NUMERIC	0	0	11
033035	MANUAL/AUTOMATIC QUALITY CONTROL	CODE TABLE 033035	0	0	4
060000	SEGMENT SIZE AT NADIR IN X DIRECTION (PIXELS)	PIX	0	0	7
060001	SEGMENT SIZE AT NADIR IN Y DIRECTION (PIXELS)	PIX	0	0	7
060104	TRAJECTORY SEQUENCE NUMBER	NUMERIC	0	0	24
117000	REPLICATION OPERATOR	-	0	0	0
031002	EXTENDED DELAYED DESCRIPTOR REPLICATION FACTOR:WINDS	NUMERIC	0	0	16
002164	TRACER CORRELATION METHOD	CODE TABLE 002164	0	0	3
005001	LATITUDE (HIGH ACCURACY)	DEGREE	5	-9000000	25
006001	LONGITUDE (HIGH ACCURACY)	DEGREE	5	-18000000	26
005011	LATITUDE INCREMENT (HIGH ACCURACY)	DEGREE	5	-9000000	25
006011	LONGITUDE INCREMENT (HIGH ACCURACY)	DEGREE	5	-18000000	26
007004	PRESSURE	PA	-1	0	14
011001	WIND DIRECTION	DEGREE TRUE	0	0	9
011002	WIND SPEED	M/S	1	0	12
012001	TEMPERATURE	K	1	0	12
033007	PER CENT CONFIDENCE (WITH FORECAST TEST)	%	0	0	7
033007	PER CENT CONFIDENCE (WITHOUT FORECAST TEST)	%	0	0	7
060103	HEIGHT ASSIGNMENT METHOD (CODE TABLE 060103)	CODE TABLE 060103	0	0	4
060205	OROGRAPHIC INDEX (CODE TABLE 060205)	CODE TABLE 060205	0	0	3
060206	CLOUD TYPE (SAFNWC/MSG) (CODE TABLE 060206)	CODE TABLE 060206	0	0	5
060207	WIND CHANNEL (SEVIRI CHANNEL ID) (CODE TABLE 060207)	CODE TABLE 060207	0	0	5
060208	CORRELATION	%	0	0	7
060209	PRESSURE ERROR OR CORRECTION	PA	-1	-8000	14

Table 9: BUFR table for the Trajectory output file

2.3.3 netCDF output files

One file for the single AMV scale, or two different files for two different AMV scales (related each one of them to ‘Basic winds’ and ‘Detailed winds’, when so configured with configurable parameter CDET = ALL or RANGE), in form of netCDF output files, are produced for each processed region for every running slot if configurable parameter OUTPUT_PARAMETER = NET. If the AMVs have been calculated for several satellite channels, they are all included in the same file.

The netCDF file is written for the basic scale in \$SAFNWC/export/HRW directory under the name S_NWC_HRW-WIND_<satid>_<regionid>-BS_YYYYMMDDThhmmssZ.nc. For the detailed scale the name S_NWC_HRW-WIND_<satid>_<regionid>-DS_YYYYMMDDThhmmssZ.nc is used. “satid” is the identifier of the satellite used, “regionid” is the identifier of the region used, and “YYYYMMDDThhmmssZ” is the date and time of the processed slot for which the AMVs have been calculated.

The High level structure of the netCDF output for the NWC/GEO High Resolution Winds is shown in Table 10. It will contain ‘n’ groups; each one containing the AMVs/Trajectories derived using a specific satellite channel (HRVIS, VIS06, VIS08, WV62, WV73, IR108, IR120 for MSG series and VIS07, WV65, IR107 for GOES-N series). Each one of these groups will contain ‘nb_winds’ groups, each one containing the information related to a specific Atmospheric Motion Vector/Trajectory.

If additionally configurable parameter CALCULATE_TRAJECTORIES = 1, the trajectories related to the ‘Basic winds scale’ and the ‘Detailed winds scale’ are also included in the corresponding netCDF output file. If trajectories have been calculated for several satellite channels, they are included in the same file. Each trajectory will finally contain ‘nb_sect’ groups, containing the corresponding number of Trajectory sectors.

	Content
Dimensions:	
n	Number of Satellite channels used for AMV calculation
nb_winds	Number of AMVs for each Satellite channel
Types:	
compound Segment	// Structure to contain 1 Segment data
Segment(*) Trajectory	// Structure to contain nb_sect Segment data (1 Trajectory)
compound Wind	// Structure to contain 1 Wind Data (including Trajectory)
Variables	
Wind wind(nb_winds)	// Wind data
Attributes	

Table 10: High Level specification of the GEO-HRW netCDF output

The detailed structure of the netCDF output for the NWC/GEO High Resolution Winds Trajectories is shown in Table 11. The “BUFR Code Tables” defined in Table 11 are described in the BUFR Reference Manual [RD.20], except table except those characterized as 060xxx, which are explained in Chapter 2.3.1.1 of this document. The list of common attributes described in Section 4.3 of the “Data Output Format for the NWC/GEO” document [AD.6] is also to be taken here into account.

Dimensions:	Content
n	Number of Satellite channels used for AMV calculation
nb_winds	Number of AMVs for each Satellite channel
Types:	
compound Segment	// Structure to contain 1 Trajectory Segment
int tracer_corr	// Tracer Correlation method (BUFR code table 002164)
float lat	// Latitude (degrees)
float lon	// Longitude (degrees)
float lat_inc	// Latitude increment (degrees)
float lon_inc	// Longitude increment (degrees)
float pressure	// Pressure (Pa)
float pressure_err	// Pressure Error or Correction (Pa)
float wind_speed	// Wind Speed (m/s)
float wind_direction	// Wind Direction (degree)
float temperature	// Temperature (K)
unsigned byte confidence_fore	// Per cent confidence with forecast test
unsigned byte confidence_no_fore	// Per cent confidence without forecast test
unsigned byte height_method	// Height Assignment Method (BUFR code table 060103)
unsigned byte orography	// Orographic index (BUFR code table 06205)
unsigned byte cloud_type	// NWC/GEO Cloud Type (BUFR code table 06206)
unsigned byte correlation	// Correlation (% , [0,100])
Segment(*) Trajectory	// Trajectory defined as a variable-length array of Segment structures
compound Wind	// Structure to contain Wind Data (1 data, including trajectory)
unsigned int wind_id	// Wind sequence Number
unsigned int wind_prev_id	// Prior wind sequence number
unsigned int segment_x	// Segment size at nadir in X direction (meters)
unsigned int segment_y	// Segment size at nadir in Y direction (meters)
unsigned int segment_x_pix	// Segment size at nadir in X direction (pixels)
unsigned int segment_y_pix	// Segment size at nadir in Y direction (pixels)
int tracer_corr	// Tracer Correlation method (BUFR code table 002164)
float lat	// Latitude (degrees)
float lon	// Longitude (degrees)
float lat_inc	// Latitude increment (degrees)
float lon_inc	// Longitude increment (degrees)
float pressure	// Pressure (Pa)
float pressure_err	// Pressure Error or Correction (Pa)
float wind_speed	// Wind Speed (m/s)
float wind_direction	// Wind Direction (degree)
float temperature	// Temperature (K)
unsigned byte confidence_fore	// Per cent confidence with forecast test
unsigned byte confidence_no_fore	// Per cent confidence without forecast test
unsigned byte tracer_type	// Tracer Type (BUFR code table 060102)
unsigned byte height_method	// Height Assignment Method (BUFR code table 060103)
unsigned byte n_winds	// Number of winds computed for the tracer
unsigned byte correlation_test	// Correlation test (BUFR code table 06201)
unsigned short quality_test	// Applied Quality tests (BUFR code table 06202)
unsigned byte nwp_wind_levels	// Number of available NWP wind guess levels
unsigned byte n_pred_winds	// Number of predecessor winds
unsigned byte orography	// Orographic index (BUFR code table 06205)
unsigned byte cloud_type	// NWC/GEO Cloud Type (BUFR code table 06206)
unsigned byte correlation	// Correlation (% , [0,100])
Trajectory trajectory	// Wind Trajectory (with variable number of Points)
Variables:	
Wind wind(nb_winds)	// Wind data
Attributes	
standard_name	horizontal_wind_vector
long_name	"NWC GEO High Resolution Winds"
wind_computation_method	// Satellite derived wind computation method (BUFR code table 002023)
first_guess	// Origin of the first guess (BUFR code table 025202)
channel_id	// Satellite channel id
channel_centre_frequency	// Satellite channel centre frequency (Hz)
channel_centre_width	// Satellite channel band width (Hz)
cycle	// Satellite cycle number
qi_control	// Manual/automatic quality control (BUFR code table 033035)
time_period	// Time period or displacement (minutes)

Table 11: Detailed specification of the GEO-HRW netCDF output

2.3.4 Output data filterings

Several output data filterings are included during GEO-HRW algorithm running, which sometimes depend on the value of several configurable parameters in the GEO-HRW model configuration file. These parameters are:

- WIND_CHANNEL (default value HRVIS,VIS08,IR120,WV62,WV73 for MSG/SEVIRI satellite series; VIS07,IR107,WV62 for GOES-N satellite series), which defines the channels for which AMVs (and trajectories) are generated.
- QI_THRESHOLD: defines the Quality index threshold for the AMVs in the output files. Depending on the value of QI_THRESHOLD_USEFORECAST (default value 1), the “Quality index with forecast” or the “Quality index without forecast” are respectively used for the AMV filtering.
- CLEARAIRWINDS: defines if the Clear air water vapour AMVs are to be included in the output files (default value 1, meaning yes).
- MAXPRESSUREERROR: defines the maximum pressure error (in hPa) permitted in the output AMVs, when “CCC height assignment method” has been used.
- MIN_CORRELATION: defines the minimum correlation (as a %) in the output AMVs, when the “Cross Correlation tracking” has been used.
- FINALFILTERING: defines several filterings in the output AMVs, depending on its value.
 - With FINALFILTERING > 0, the AMV pressure level filtering defined in *Table 12* is implemented (where blue layers for the different channels are eliminated; light blue layers are eliminated only for ‘Clear air AMVs’ and very dark blue layers are only eliminated if configurable parameter VERYLOWINFRAREDAMVS = 0). These cases with elimination of data correspond to AMVs with NRMSVD values at least one sixth higher than for the satellite channel with a minimum NRMSVD.
 - With FINALFILTERING > 1 (which is the default option), the Cloud type filtering defined in *Table 5* is implemented for the different satellite channels.
 - With FINALFILTERING > 2, AMVs with a “Spatial quality flag” = 1,2 are also eliminated.
 - Finally, with FINALFILTERING = 4, AMVs with a “Spatial quality flag” = 0 are also eliminated.

MSG sat.	HRVIS	VIS06	VIS08	IR108	IR120	WV62	WV73
GOES-N sat.	VIS07			IR107		WV65	
100-199 hPa							
200-299 hPa							
300-399 hPa							
400-499 hPa							
500-599 hPa							
600-699 hPa							
700-799 hPa							
800-899 hPa							
900-999 hPa							

Table 12: AMV filtering related to the Height level and each satellite channel

3. IMPLEMENTATION OF GEO-HRW PRODUCT

Two main steps are identified. The user manually interacts with the NWC/GEO software package during the installation step, and the GEO-HRW execution step is automatically monitored by the Task Manager (if real time environment is selected).

3.1 NWC/GEO SOFTWARE PACKAGE INSTALLATION AND PREPARATION

The right to use, copy or modify this software is in accordance with EUMETSAT policy for the NWC/GEO software package.

Once the user has obtained the necessary permissions to download the software package, the software installation procedure does not require any special resources. It is limited to decompress the distribution file (a gzip compressed tar file) which successfully builds the executable (GEO-HRW-v50 executable file), to be stored into the \$SAFNWC/bin directory. The installation steps for NWC/GEO must follow the document “System Version Document for the NWC/GEO” [AD.7].

3.2 GEO-HRW EXECUTION STEP

The execution step is the processing of images with GEO-HRW-v50 algorithm in the region defined by the user. The running time scheduling relies on the Programmed Task Definition File. This process consists in the running of the command \$SAFNWC/bin/GEO-HRW-v50 along with the required parameters (slot, region file and model configuration file) by the Task manager. *Figures 1 to 3* in next pages summarise how the tasks to generate GEO-HRW-v50 output are performed by this executable.

The operational use of GEO-HRW-v50 executable requires the definition of the Region Configuration File \$SAFNWC/config/safnwc_region.cfg (document [AD.5] must be verified about how the region can be defined).

The user has also to define the Model Configuration File to be used. Four different files are provided as default options with the software: \$SAFNWC/config/safnwc_HRW.cfm.MSG15MIN and \$SAFNWC/config/safnwc_HRW.cfm.MSG05MIN, for use every 15 minutes in ‘Nominal scan mode’ and every 5 minutes in ‘Rapid Scan mode’ with MSG series data, and for use with GOES-N series data every 15 and 30 minutes \$SAFNWC/config/safnwc_HRW.cfm.GOES15MIN and \$SAFNWC/config/safnwc_HRW.cfm.GOES30MIN.

The implementation of the running mode depends on the satellite configuration and the corresponding \$SAFNWC/config/sat_conf_file used. Each configuration file is an ASCII file, so further modifications can be easily performed with a text editor. The GEO-HRW model configuration file manages all variables in the executable file that are useful for the user.

To have NWC/GEO Cloud Type, Cloud Top Temperature and Pressure and/or Cloud Microphysics available for their use by GEO-HRW algorithm, it is needed to run GEO-CMA-v40, GEO-CT-v30, GEO-CTTH-v30 and GEO-CMIC-v10 executables before GEO-HRW-v50 for the same slot and region.

The ‘Rapid Scan mode’ in MSG data processing is only recommended to be used in relatively small areas (“National areas”), if all NWC/GEO products have to run together and a relatively small environment has been used for the installation of NWC/GEO software. With the five minute running constraint imposed by the MSG/SEVIRI ‘Rapid scan mode’, these circumstances permit the repeating of the process with all available satellite slots. In a “Continental area” it is generally not possible to run all NWC/GEO products operatively in ‘Rapid scan mode’ unless a powerful environment is used. [AD.8] document should be verified for more information on this.

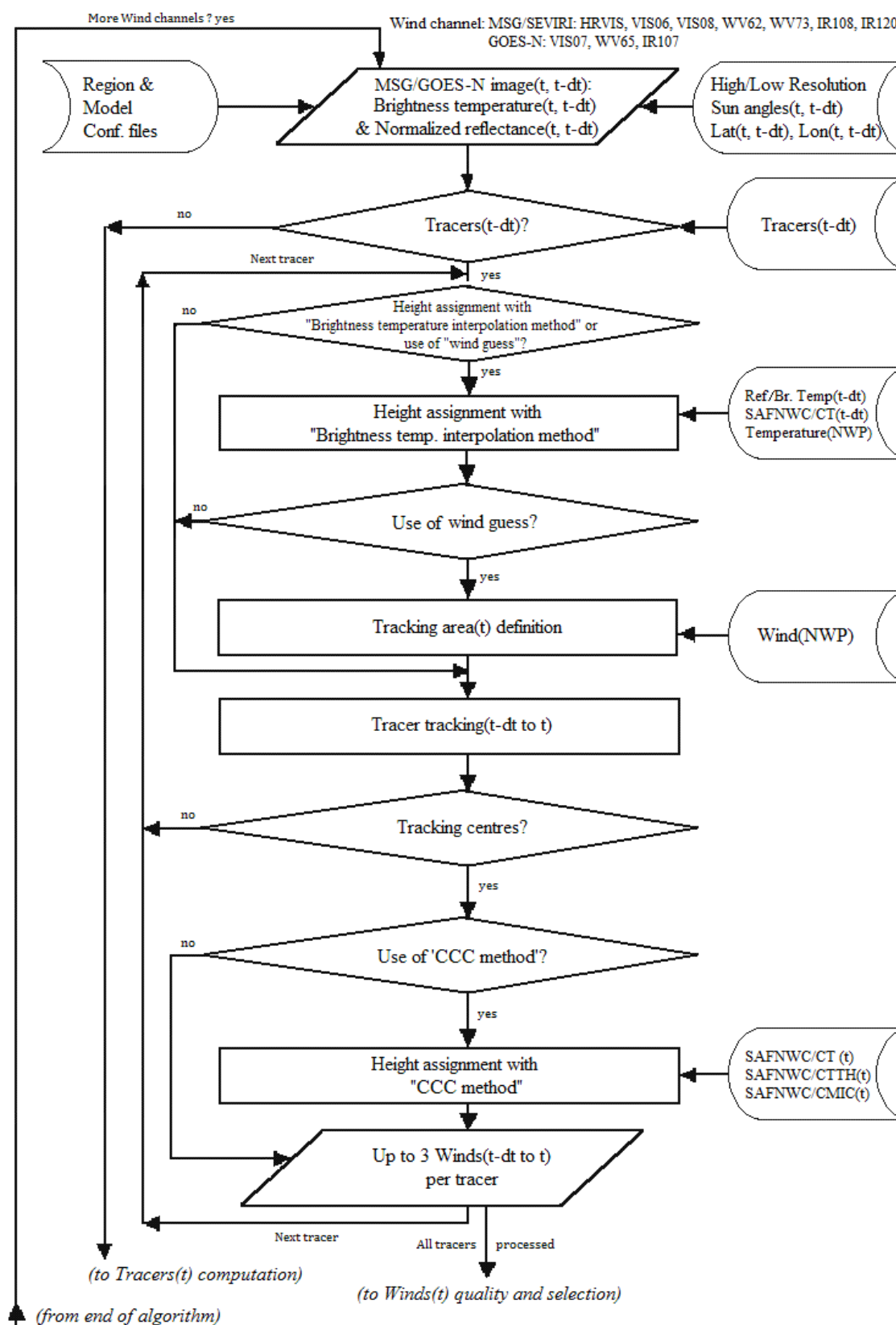


Figure 1: GEO-HRW implementation: Part 1, Preprocessing and AMV computation

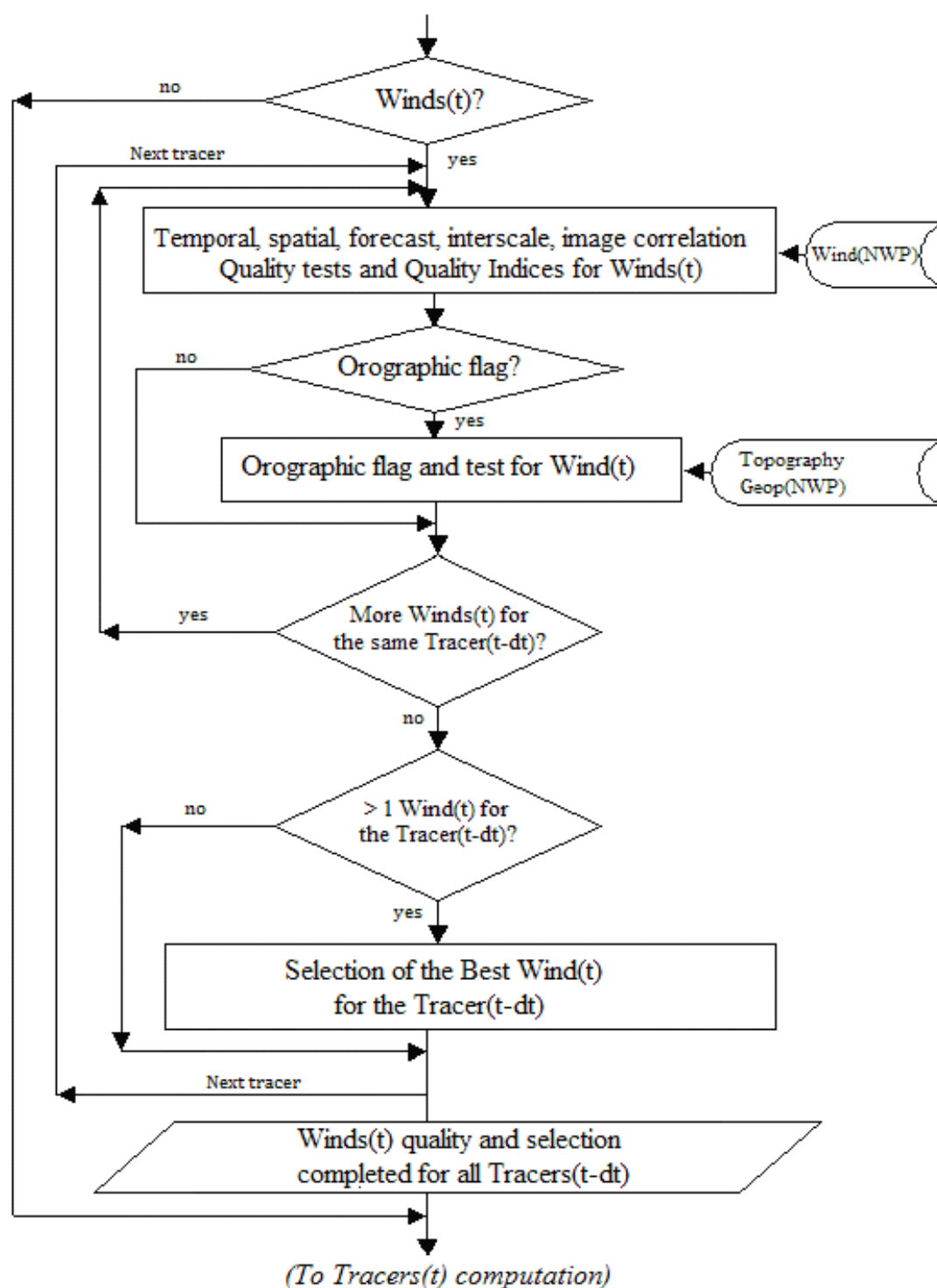


Figure 2: GEO-HRW implementation: Part 2, AMV quality and selection

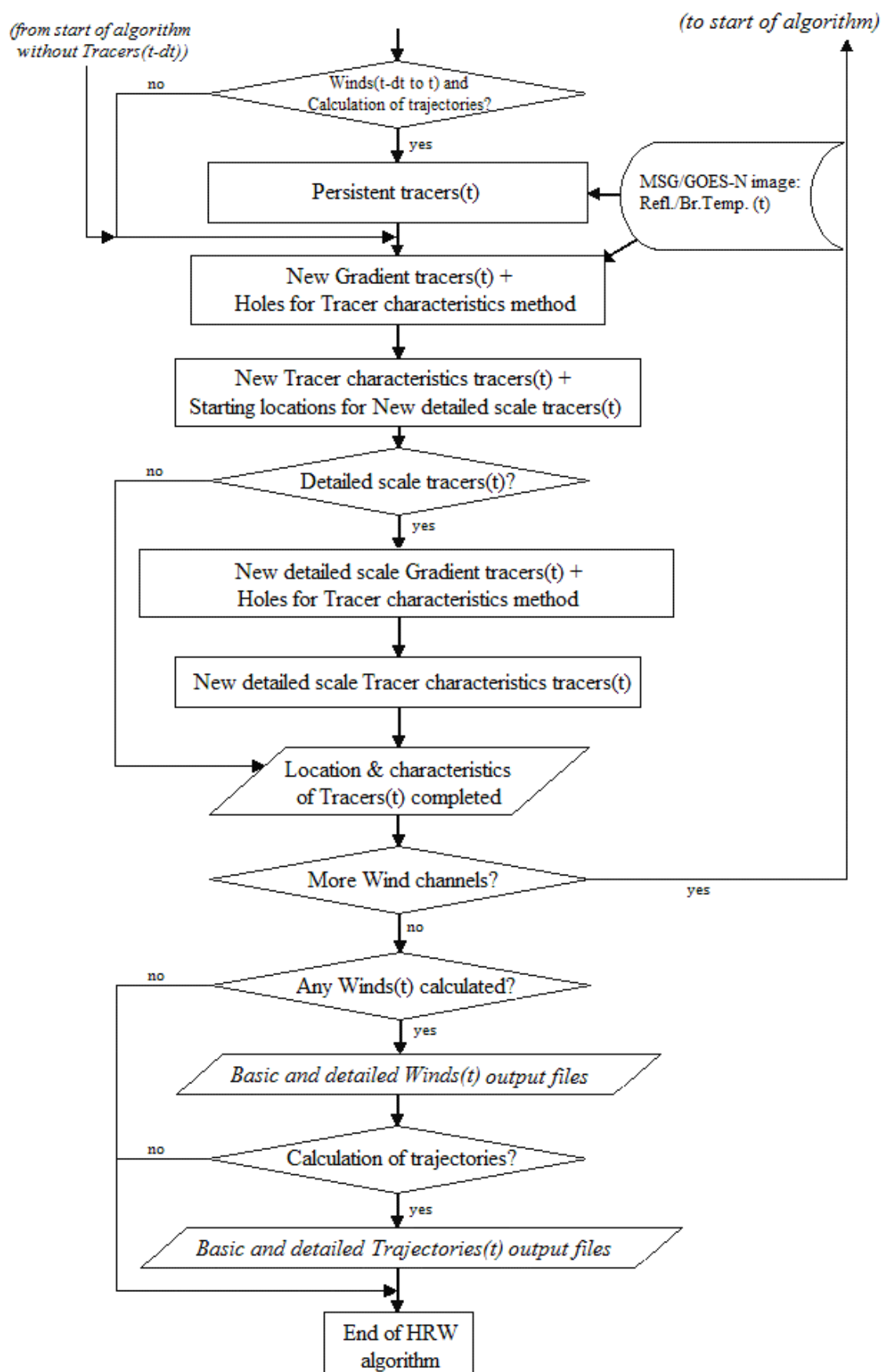


Figure 3: GEO-HRW implementation: Part 3, Tracer computation and writing of output files

3.3 GEO-HRW DOCUMENTATION

Since NWC/GEO v2016 software package, a detailed description of all algorithms, of the involved interfaces and data types, is provided in html format with the support of Doxygen tool, from comments included within the code of the products. Documentation for GEO-HRW-v50 algorithm is in the file:

NWC-CDOP2-GEO-AEMET-SW-ACDD-Wind_html_v1.0.zip.

To navigate throughout this documentation, decompress it and open following file in a web browser:

NWC-CDOP2-GEO-AEMET-SW-ACDD-Wind_html_v1.1d/HRW_html/index.html

Additionally, every single step in the algorithm has been commented in detail throughout all functions of GEO-HRW-v50 code, so that all any AMV developer can very easily know all the process of the algorithm having a look to the corresponding C/Fortran functions.

For a quicker reference, a Diagram tree of all functions of GEO-HRW-v5.0 algorithm is also provided in the “Algorithm Theoretical Basis Document for the Wind product processors of the NWC/GEO” document [AD.14]. This Diagram tree allows NWC/GEO users and developers to quickly know at a glance how it works.

3.4 GEO-HRW RUNNING ERRORS

The following table shows the whole list of errors and warnings that can appear during the running of GEO-HRW product, the reasons causing these errors and warnings, and the way the NWC SAF user can try to solve them. In any case, if the errors or warnings persist, NWC SAF Helpdesk should be contacted.

Error (E) or Warning (W) Code	Message	Reason	Recovery action
E - 151	"Usage of HRW executable: GEO-HRW-v50 <slot> <region_conf_file> <model_conf_file>"	Input parameters are incorrect	Check instructions to start the run of NWC/GEO-HRW product
E - 152	"Error allocating memory for tracers related to the previous slot"	Unable to allocate required memory for "tracer" struct	There are memory problems to run NWC/GEO-HRW product in the defined region with the defined configuration and computer. Use a larger computer or a smaller region.
E - 153	"Error allocating memory for tracer_wind struct, relating tracers and AMVs"	Unable to allocate required memory for "tracer_wind" struct	
E - 154	"Error allocating memory for structs related to a wind_channel_info struct"	Unable to allocate required memory for "wind_channel_info" struct	
E - 155	"Error allocating memory for the NWP grids for each variable"	Unable to allocate required memory for NWP grids	
E - 156	"Satellite data for current slot are not valid"	Satellite data are not valid	Verify if there is any problem with the satellite data used by NWC/GEO-HRW product
E - 161	"Error reading Parameters from Satellite configuration file"	Error after NwcCFReadSat function	Verify that the \$SAFNWC/config/sat_conf_file used for running NWC/GEO-HRW product is correct
E - 162	"Error in date format (%s). Required (YYYY-MM-DDThh:mm:ssZ)"	Error after NwcTimeSetStr function	Verify that the date format used for running NWC/GEO-HRW product is correct
E - 163	"Error setting Processing region"	Error after NwcRegionSet function	Verify that the \$SAFNWC/config/region_conf_file used for running NWC/GEO-HRW product is correct
E - 164	"Error reading Pressure levels from the Model configuration file"	Error after NwcNwpReadPLevel function	Verify that the \$SAFNWC/config/nwp_conf_file used for running NWC/GEO-HRW product is correct
E - 165	"Unable to initialize the NWP Temperature / Wind / Geopotential NWP profile"	Error after NwcNwpInitProfile function	Verify that the \$SAFNWC/config/nwp_conf_file & \$SAFNWC/config/model_conf_file used for running NWC/GEO-HRW product are correct
E - 166	"Error allocating memory for wind_channel_info struct"	Error after NwcSatInit function	There are memory problems to run NWC/GEO-HRW product in the defined region with the defined configuration and computer. Use a larger computer or a smaller region.

Error (E) or Warning (W) Code	Message	Reason	Recovery action
E - 171	"Error reading Parameters from the HRW configuration file"	Error after hrw_ReadData function	Verify that the \$SAFNWC/config/model_conf_file used for running NWC/GEO-HRW product is correct
E - 172	"Error getting latitude / longitude / sun angles for the High resolution region"	Error after hrw_GetAncillaryData function	<p>All these errors are caused by the running of NWC/GEO-HRW product, and cannot be solved by the NWCSAF user.</p> <p>Nevertheless, as a whole, they should occur in less than a 0.5% of the cases.</p> <p>If the frequency is higher than that, please contact NWCSAF Helpdesk.</p>
E - 173	"Error reading satellite data for current slot"	Error after hrw_ReadSatelliteData function	
E - 174	"Error reading tracers from previous slot"	Error after hrw_ReadTracers function	
E - 175	"Error reading Trajectories for the previous slot"	Error after hrw_ReadTrajectories function	
E - 176	"Error during the AMV Tracking process"	Error after hrw_GetWinds function	
E - 177	"Error during the AMV Quality Control"	Error after hrw_Qc function	
E - 178	"Error writing Predecessor winds in SAFNWC/tmp directory"	Error after hrw_WritePredWinds function	
E - 179	"Error writing Trajectories in SAFNWC/tmp directory"	Error after hrw_WriteTrajectories function	
E - 180	"Error calculating tracers for current slot"	Error after hrw_GetTracers function	
E - 181	"Error writing tracers in SAFNWC/tmp directory"	Error after hrw_WriteTracers function	
E - 182	"Error writing the AMVs in the netCDF output file"	Error after hrw_EncodeNetCDF function	
E - 191	"NWP temperature data are not available; Winds cannot be calculated"	AMVs cannot be calculated because NWP data could not be read	Verify that NWP temperature data for at least MIN_NWP_FOR_CALCULATION levels (with a default value of 4) have been provided for the running of NWC/GEO-HRW product in \$SAFNWC/import/NWP_data directory

Table 13: List of errors for GEO-HRW-v50 algorithm

4. INPUTS AND CONFIGURABLE PARAMETERS

4.1 LIST OF INPUTS FOR HIGH RESOLUTION WINDS

A region configuration file (`file.cfg`), and a GEO-HRW model configuration file (`file.cfm`), with the parameters and options defined by the user for calculation, are needed in `$SAFNWC/config` directory for the running of GEO-HRW-v50 executable.

- Two model configuration files are suggested for MSG: `safnwc_HRW.cfm.MSG15MIN` and `safnwc_HRW.cfm.MSG05MIN` (respectively for ‘Nominal scan mode’ and ‘Rapid scan mode’, with calculation of AMVs respectively every 15 and 5 minutes).
- Two model configuration files are suggested for GOES-N: `safnwc_HRW.cfm.GOES15MIN` and `safnwc_HRW.cfm.GOES30MIN`. The first one can be used for example for calculation of AMVs every 15 minutes in the “Continental United States” region. The second one can be used for example for calculation of AMVs every 30 minutes in the “North America” region.

The complete list of configurable parameters included in these files, with their description and their corresponding default values, is available in Section 4.2 of this document. Some output examples of the running of GEO-HRW-v50 with these Model Configuration Files are shown in Section 6.

Besides, for every running slot, next input data are to be supplied. Of all these data, only MSG HRIT or GOES-N GVAR satellite data for the running slot and NWP temperature data for the running region are strictly needed for the running of GEO-HRW algorithm:

- Considering MSG satellite series: full resolution uncompressed HRIT data for the selected region, for the running slot and the previous slot, for all MSG/SEVIRI channels to be used for the AMV calculation in `$SAFNWC/import/Sat_data` directory. IR120 channel is additionally needed for the visible channel processing when the old “Brightness temperature interpolation height assignment” is to be used. IR108 and WV62 channels are additionally needed if the default configuration of the Quality control is kept (including the “Image correlation test”).
- Considering GOES-N satellite series: full resolution uncompressed GVAR data for the selected region, for the running slot and the previous slot. GOES-N GVAR data have first to be converted to NWC/GEO netCDF satellite input data format with the provided GOES2NC java tool (more information about this can be extracted from the document “User Manual of the GOES2NC tool” [AD.16]), and included in `$SAFNWC/import/Sat_data` directory. IR107 channel is in any case needed for the visible channel processing when the old “Brightness temperature interpolation height assignment” is to be used. IR107 and WV65 channels are in any case needed if the default configuration of the Quality control is kept (including the “Image correlation test”).
- List of tracers, predecessor winds and trajectories calculated at the previous slot, if existing.
- NWP data: Fields of NWP for at least the selected region, with an horizontal resolution of 0.5° and a NWP time step of at most 6 hours, for a minimum of four and as a recommendation as many as possible of following levels: 1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 10 hPa, in `$SAFNWC/import/NWP_data` directory. NWP components of the wind (u,v) are also needed for the ‘Quality control forecast test’ or if the NWP wind guess is used for the definition of the ‘tracking area’. NWP geopotential is also needed if the “Orographic flag” is calculated.
- NWC/GEO CT and CTTH output for the running region and slot in `$SAFNWC/export/CT` and `$SAFNWC/export/CTTH` directories, if “CCC height assignment method” is used. NWC/GEO CMIC output in `$SAFNWC/export/CMIC` directory also, if the Microphysics correction is used inside “CCC height assignment method”.
- NWC/GEO CT output for the running region and the previous slot in `$SAFNWC/export/CT` directory, if the NWP wind guess has to be used for the definition of the ‘tracking area centre’, or the “Brightness temperature interpolation height assignment with Cloud products” is used.

4.2 LIST OF HIGH RESOLUTION WINDS CONFIGURABLE PARAMETERS

The High Resolution Winds model configuration file holds the configurable parameters needed for the running of GEO-HRW-v50 executable. It must be located within \$SAFNWC/config directory. Four different reference Model Configuration Files have been included for the running of NWC/GEO-HRW-v5.0: two for their operational use with MSG/SEVIRI data every 15 minutes (safnwc_HRW.cfm.MSG15MIN) and every 5 minutes (safnwc_HRW.cfm.MESG05MIN); two for their operational use with GOES-N data every 15 minutes (safnwc_HRW.cfm.GOES15MIN) and every 30 minutes (safnwc_HRW.cfm.GOES30MIN). A brief description of the configurable parameters included in these files is shown in the next table.

Keyword	Description	Type	Default Value(s)
Identification parameters			
PGE_ID	PGE identification. This keyword is optional, but should not be changed by the user.	Chain of characters	GEO-HRW
SAT_BANDS	Satellite bands that can be used to run the PGE. This keyword is optional, but should not be changed. It defines the maximum value of bands for which AMVs can be calculated.	Chain of characters	HRVIS, VIS06, VIS08, WV62, WV73, IR108, IR120 (MSG)
WIND_CHANNEL	Satellite bands really used for AMV calculation. As possible values, it can include any of the bands shown by the previous parameter separated by commas (not by spaces).	Chain of characters	VIS07, WV65, IR107 (GOESN) HRVIS, VIS08, WV62, WV73, IR120 (MSG)
SLOT_GAP	Ordering number of the previous satellite slot, for which tracers are to be considered for the AMV processing. Possible values: 1: Nominal mode for MSG and GOES-N (15 min., previous slot) 2: Rapid scan mode for MSG (10 min, second previous slot)	Integer	1 (MSG 15 min. mode) 2 (MSG 05 min. mode) 1 (GOESN)
Output parameters			
BUFR_CENTRE_OR	Originating/generating centre of the BUFR file, as defined in WMO Common Code Table C-1. It is to be modified with the code related to the corresponding centre (e.g. 214 for Madrid).	Integer	214
OUTPUT_FORMAT	Output file format. Possible values: - NWC: AMV & Trajectories BUFR files, with the specific NWC SAF format. - EUM: AMV BUFR files, with the EUMETSAT/MPEF BUFR format. - NET: AMV netCDF files - ALL: All previous files together	Chain of characters	NWC
QI_THRESHOLD	Quality Index threshold for the AMVs	Integer	70
QI_THRESHOLD_USEFORECAST	Option to show if the Quality index threshold used in the wind output filtering includes the Quality forecast test	Integer	1
QI_BEST_WIND_SELECTION	Criterion for Best wind selection (Values: 0/1), as defined in the ATBD document.	Integer	1
CLEARAIRWINDS	Flag to decide if Clear air AMVs calculated	Integer	1
CALCULATE_TRAJECTORIES	Flag to decide if Trajectories calculated	Integer	1
FINALFILTERING	Flag for a final filtering of the AMVs based on: - Their Height level (when > 0), - Their Cloud type (when > 1), - Their Quality spatial test (1,2 as invalid values when > 2; 0,1,2 as invalid values when > 3).	Integer	2
USE_TOPO	Flag for calculation of the Orographic flag (when > 0), and for its AMV filtering (when 2)	Integer	2
USE_MEANWIND	Flag showing if the mean value of the latitude increment, longitude increment, speed, direction, temperature, pressure, pressure error and correlation related to an AMV and its predecessor (in case it exists) are used (when positive).	Integer	0
MAXPRESSUREERROR	Maximum pressure error in the AMVs (hPa), when 'CCC height assignment method' used.	Integer	150
VERYLOWINFRAREDAMVS	Flag showing if very low infrared AMVs (below 900 hPa) are admitted in the AMV output file	Integer	0
FINALCONTROLCHECK	Flag to indicate if "Final Control Check" is used	Integer	1

Keyword	Description	Type	Default Value(s)
Working area description parameters			
LAT_MIN	Latitude and longitude borders (in degrees) for the processing region (Basic AMVs)	Real	-75.0
LAT_MAX		Real	75.0
LON_MIN		Real	-179.0
LON_MAX		Real	179.0
LAT_MIN_DET	Latitude and longitude borders (in degrees) for the processing region (Detailed AMVs)	Real	-75.0
LAT_MAX_DET		Real	75.0
LON_MIN_DET		Real	-179.0
LON_MAX_DET		Real	179.0
FRAC_DAY_SCENE	Minimum fraction of area illuminated by the sun needed to calculate the visible AMVs (HRVIS, VIS06, VIS08 channels)	Integer	8
ZEN_THRES	Sun zenith angle threshold (degrees)	Double	87.0
MSG_ZEN_THRES	Satellite zenith angle threshold (degrees)	Double	80.0
Tracer parameters			
MAX_TRACERS	Maximum number of tracers	Integer	120000
LSIZ_HRV	Basic tracer line/column dimension	Integer	24
ESIZ_HRV	(with MSG/HRVIS or GOES-N/VIS07 AMVs)	Integer	24
LSIZ_OTHER	Basic tracer line/column dimension	Integer	24
ESIZ_OTHER	(with all other AMVs)	Integer	24
MIN_BRIGHTNESS_VIS	Minimum acceptable 1 byte reflectance value in the search for targets (with visible AMVs)	Double	120.0
MIN_BRIGHTNESS_OTHER	Minimum acceptable 1 byte brightness temperature value in the search for targets (with infrared and water vapour AMVs).	Double	60.0
GVAL_VIS	Minimum acceptable 1 byte reflectance contrast in the pixels of a tracer (with visible AMVs)	Double	60.0
GVAL_OTHER	Minimum acceptable 1 byte brightness temperature contrast in the pixels of a tracer (with infrared and water vapour AMVs)	Double	48.0
TRACER_SEARCH_STEP_HRV	Minimum separation (in pixels) between tracers (for MSG/HRVIS or GOES-N/VIS07 AMVs)	Integer	24
TRACER_SEARCH_STEP_OTHER	Minimum separation (in pixels) between tracers (for all other AMVs)	Integer	6
Tracking parameters			
TRACKING	Tracking method. Possible values: LP: Euclidean difference CC: Cross correlation	Chain of characters	CC
DEFINECONTRIBUTIONS	Flag to decide if "CCC height assignment" is to be used (requires also TRACKING=CC)	Integer	1
DEFPOSCONTRIBUTIONS	Flag to decide if the position of the AMV in the target is relocated to the position of maximum correlation contribution defined by "CCC height assignment" (requires also TRACKING=CC and DEFINECONTRIBUTIONS=1)	Integer	1
USE_CLOUDTYPE	Flag to decide if the Tracer cloud type is used by the old "Brightness temperature interpolation height assignment method" (when positive).	Integer	2
USE_MICROPHYSICS	Flag to decide if the Microphysics correction is to be calculated to "CCC height assignment" (when > 0), and if this Microphysics corrections is applied to the final AMV pressure (when > 1) (requires also TRACKING=CC and DEFINECONTRIBUTIONS=1)	Integer	2 (MSG) 0 (GOESN)
WIND_GUESS	Flag to decide if the Wind guess is used for the definition of the Tracking area	Integer	0
MIN_CORRELATION	Minimum correlation in the Tracking process (if Cross correlation method used)	Double	80.0 (MSG) 50.0 (GOESN)
LLAG_HRV	Tracking line/column increment (with MSG/HRVIS or GOES-N/VIS07 AMVs)	Integer	272 (30 min. mode) 136 (15 min. mode)
ELAG_HRV	(this value is dependent of the time distance between satellite slots)	Integer	92 (05 min. mode) 272 (30 min. mode) 136 (15 min. mode) 92 (05 min. mode) 68 (30 min. mode)
LLAG_OTHER	Tracking line/column increment (with all other AMVs)	Integer	46 (MSG 15 min. mode) 34 (GOESN 15 min. mode) 32 (05 min. mode) 68 (30 min. mode)
ELAG_OTHER	(this value is dependent of the time distance between satellite slots)	Integer	46 (MSG 15 min. mode) 34 (GOESN 15 min. mode) 32 (05 min. mode)
USE_SUBPIXELTRACKING	Flag to decide if Subpixel tracking is to be used	Integer	1

Keyword	Description	Type	Default Value(s)
Detailed tracer parameters			
CDET	It defines if a detailed set of tracers is required. The range can be equal to the initial scale or only a subset of the initial region. When the range is smaller, the keywords LIN_D, NUML_D, ELE_D and NUME_D cannot be empty. Possible values: ALL: The range for the search of detailed tracers is the same as the basic scale. RANGE: Processes only a regional subset. <empty>: Detailed tracer search is not required.	Chain of characters	<empty>
LIN_D	Initial line/column of the region subset considered for detailed tracers. Possible values: - <empty> when CDET = ALL / empty	Integer	<empty>
ELE_D	- <A line/column number included in processing region> when CDET = RANGE	Integer	<empty>
NUML_D	Number of lines/columns of the region subset considered for detailed tracers. Possible values: - <empty> when CDET = ALL / empty	Integer	<empty>
NUME_D	- <A number of lines/columns included in processing region> when CDET = RANGE	Integer	<empty>
NWP parameters			
MIN_NWP_FOR_CALCULATION	Minimum number of NWP levels needed to calculate AMVs	Integer	4
NWP_PARAM	NWP parameters requested by GEO-HRW algorithm: * NWP_PT: Temperature at several levels (K)	Chain of characters	NWP_PT, 1, NEIGHBOUR
NWP_PARAM	* NWP_UW: Wind velocity at several levels, u component (m/s)	Chain of characters	NWP_UW, 1, NEIGHBOUR
NWP_PARAM	* NWP_VW: Wind velocity at several levels, v component (m/s)	Chain of characters	NWP_VW, 1, NEIGHBOUR
NWP_PARAM	* NWP_GEOP: Geopotential height at several levels (m)	Chain of characters	NWP_GEOP, 1, NEIGHBOUR
	Sampling rate used: 1		
	Interpolation method used: NEIGHBOUR		

Table 14: GEO-HRW Model Configuration File Description

If the user has the need to reduce GEO-HRW running time, especially when working with a different slower platform, it is recommended to reduce the amount of channels for which AMVs should be calculated.

This issue applies specially when processing MSG data because of the larger amount of channels. Although it can be very useful to keep the calculation of AMV data with the seven different MSG/SEVIRI channels that are available (HRVIS, VIS06, VIS08, WV62, WV73, IR108, IR120, as seen in some examples in the “Validation report for GEO-HRW v3.2” [AD.12]), because of the general similarity that exists between AMVs extracted from IR108 and IR120 channel on one side, and VIS06 and VIS08 channel on the other side, the first recommendation to reduce GEO-HRW running time would be to keep five MSG/SEVIRI channels for the AMV calculation through WIND_CHANNEL = HRVIS, VIS08, WV62, WV73, IR120 (which is the default configuration for GEO-HRW product). If further reductions in the amount of processed channels are needed, it would be recommended at least to keep next four channels: WIND_CHANNEL = HRVIS, WV62, WV73, IR120 (as also seen in the “Validation report for GEO-HRW v3.2” [AD.12]).

In general, when using GOES-N satellite data it should always be possible to keep the AMV calculation for the three suggested channels: WIND_CHANNEL = VIS07, WV65, IR107.

5. HIGH RESOLUTION WINDS PRODUCT VALIDATION

The main GEO-HRW-v50 Validation statistics against Radiosounding winds for GEO-HRW-v50 Basic AMVs, following the criteria defined at the Third International Winds Workshop (Ascona, Switzerland, 1996) for the comparison of satellite winds, are shown next. Additional Validation statistics can be obtained in the “Validation report for GEO-HRW v5.0”, document [AD.15].

5.1 HIGH RESOLUTION WINDS VALIDATION FOR MSG SATELLITE SERIES

For MSG satellite series, the main Validation statistics correspond to the reference period used since some years ago for GEO-HRW algorithm: July 2009–June 2010 at 12:00 UTC, with MSG2 satellite data, in an area covering Europe and the Mediterranean Sea, such as shown in *Figure 4*.

Two different configurations are shown in the validation: the first one considering the conditions defined in the default \$SAFNWC/config/safnwc_HRW.cfm.MSG15MIN configuration file, in which “CCC height assignment with Microphysics correction” is considered, and for which NWC/GEO Cloud product outputs (CMA, CT, CTTH, CMIC) have to be available. The other one considers the running of GEO-HRW-v50 with the same configuration file, but without the provision of NWC/GEO Cloud product outputs, so considering “Brightness temperature interpolation height assignment without cloud products”.

In both cases, cloudy AMVs in the layer 100-1000 hPa and clear air AMVs in the layer 100-425 hPa, with a Quality index with forecast ≥ 70 for the High and Medium layer and a Quality index with forecast ≥ 75 for the Low layer, are considered.

The validation parameters shown are: NC (Number of collocations between GEO-HRW AMVs and Radiosounding data), SPD (Mean speed of Radiosounding data), NBIAS (Normalized bias), NMVD (Normalized mean vector difference), and NRMSVD (Normalized root mean square vector difference”).

The statistics for both height assignment methods are supplied, to show that when NWC/GEO Cloud product outputs are not available and “Brightness temperature interpolation height assignment without Cloud products” has to be used, the AMV quality is similar: NMVD and NRMSVD parameters are less than a 10% larger, although with a reduction of about a 25% in the amount of AMV data.

Comparing the statistics for the different satellite channels, the MVD and NRMSVD seems very different considering all layers together, with changes larger than the 50% between the best case (Cloudy WV062 AMVs) and the worst case (Cloudy VIS08). Nevertheless, this is only caused by the different proportion of AMVs in the different layers for each channel. Inside each one of them, differences of NMVD and NRMSVD for the different channels are much smaller.

Doing the comparison with GEO-HRW-v40 AMV Validation (available for example in the Validation report for GEO-HRW v5.0, document [AD.15]), it can be seen that with the default circumstances for both algorithms (Basic AMVs; Cross correlation tracking; CCC height assignment; Microphysics correction implemented in GEO-HRW-v50 procedure), the Validation results for GEO-HRW-v50 algorithm improves for all Validation parameters, with:

- An increase in the amount of compared AMVs of about a 17% (from 1239492 to 1483511),
- A reduction in the NBIAS of about a 20% (from -0.10 to -0.08),
- Smaller reductions in the NMVD (from 0.31 to 0.30) and NRMSVD (from 0.38 to 0.36).

So, the evolution of GEO-HRW-v50 respect to previous versions of the algorithm is positive, providing more AMV data with a better quality. Considering the different layers, the GEO-HRW Product Requirement Table Optimal accuracy (with a value of 0.35) is reached in the High layer, and the GEO-HRW Product Requirement Table Target accuracy (with values respectively of 0.50 and 0.56) is reached in the Medium and Low layer, both using and not using NWC/GEO Cloud products as input data.

The results of the 2014 AMV Intercomparison Study Report (Comparison of NWC SAF/HRW AMVs with AMVs from other producers [RD.24]) are also important to be taken into account for the validation of NWC/GEO-HRW algorithm. In this study, the AMVs calculated with NWC/GEO-HRW were compared to the AMVs calculated by six other institutions (EUMETSAT/MPEF, NOAA, Japan Meteorological Agency - JMA, China Meteorological Administration - CMA, Korea Meteorological Administration - KMA and the Weather Forecast and Climatic Studies Centre from the Brazilian National Spatial Research Institute – CPTEC/INPE) using the same MSG satellite and ECMWF NWP model data.

The report shows that NWC/GEO-HRW AMVs together with the EUMETSAT/MPEF AMVs have the two best validation statistics in the AMV intercomparison, using “CCC method” for the AMV height assignment.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV62	Cloudy WV73	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	31630	97221	87177	256951	331831	313072	317120	48509	1483511
SPD [m/s]	16.64	10.51	10.48	22.78	20.80	18.53	18.67	16.64	18.70
NBIAS (ALL LAYERS)	-0.04	-0.14	-0.15	-0.04	-0.07	-0.09	-0.08	-0.00	-0.08
NMVD (100–1000 hPa)	0.29	0.41	0.42	0.26	0.28	0.29	0.29	0.32	0.30
NRMSVD	0.35	0.49	0.49	0.32	0.35	0.35	0.35	0.39	0.36
NC	14748			235550	238459	186143	193173	41261	909334
SPD [m/s]	21.77			23.31	23.15	22.16	22.11	17.19	22.48
NBIAS (HIGH LAYER)	-0.03			-0.04	-0.08	-0.08	-0.07	-0.01	-0.07
NMVD (100–400 hPa)	0.24			0.26	0.26	0.26	0.26	0.31	0.26
NRMSVD	0.29			0.31	0.32	0.32	0.31	0.38	0.32
NC	8532	37419	34188	21401	84678	86936	86010	7248	366412
SPD [m/s]	14.64	12.08	11.94	16.90	15.10	14.61	14.69	13.51	14.35
NBIAS (MEDIUM LAYER)	-0.05	-0.18	-0.18	+0.02	-0.05	-0.12	-0.11	+0.09	-0.10
NMVD (400–700 hPa)	0.31	0.38	0.38	0.37	0.37	0.35	0.35	0.40	0.36
NRMSVD	0.48	0.46	0.45	0.46	0.45	0.43	0.43	0.47	0.44
NC	8350	59802	52989		8694	39993	37937		207765
SPD [m/s]	9.64	9.52	9.54		12.09	10.14	10.18		9.88
NBIAS (LOW LAYER)	-0.02	-0.12	-0.12		-0.09	-0.12	-0.12		-0.11
NMVD (700–1000 hPa)	0.44	0.44	0.44		0.38	0.41	0.40		0.43
NRMSVD	0.52	0.51	0.52		0.46	0.48	0.48		0.50

*Table 15: Validation parameters for GEO-HRW-v50
(Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean area;
Basic AMVs; Cross correlation tracking;
CCC height assignment with Microphysics parameters)*

GEO-HRW-v50 AMVs								All
(Jul 2009-Jun 2010)	HRVIS	VIS06	VIS08	WV62	WV73	IR108	IR120	AMVs
NC	23855	74554	69975	317904	321140	149190	162831	1119449
SPD [m/s]	16.08	11.59	11.63	22.11	18.04	16.84	16.78	17.98
NBIAS (ALL LAYERS)	-0.01	-0.06	-0.06	-0.04	+0.02	+0.02	+0.02	-0.00
NMVD (100-1000 hPa)	0.31	0.38	0.38	0.27	0.34	0.31	0.32	0.32
NRMSVD	0.38	0.46	0.45	0.33	0.42	0.38	0.39	0.39
NC	8417			310650	132497	40419	45913	537896
SPD [m/s]	22.48			22.19	21.24	24.78	24.57	22.36
NBIAS (HIGH LAYER)	-0.02			-0.03	+0.02	-0.00	-0.00	-0.01
NMVD (100-400 hPa)	0.24			0.27	0.29	0.25	0.25	0.27
NRMSVD	0.29			0.33	0.34	0.30	0.30	0.33
NC	9037	30312	29333	7254	191643	65549	70573	403701
SPD [m/s]	14.35	14.65	14.62	18.80	15.83	16.22	15.96	15.76
NBIAS (MEDIUM LAYER)	-0.00	-0.07	-0.07	-0.19	+0.02	+0.06	+0.07	+0.02
NMVD (400-700 hPa)	0.35	0.34	0.34	0.43	0.40	0.34	0.35	0.37
NRMSVD	0.43	0.41	0.40	0.53	0.49	0.42	0.43	0.45
NC	6401	44242	40642			43222	46345	180852
SPD [m/s]	10.11	9.49	9.47			10.35	10.31	9.92
NBIAS (LOW LAYER)	-0.00	-0.04	-0.05			-0.03	-0.04	-0.04
NMVD (700-1000 hPa)	0.43	0.42	0.42			0.38	0.38	0.40
NRMSVD	0.51	0.50	0.50			0.45	0.45	0.48

*Table 16: Validation parameters for GEO-HRW-v50
(Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean area;
Basic AMVs; Cross correlation tracking;
Brightness temperature interpolation height assignment without Cloud products;
No distinction between Cloudy and Clear air Water vapour AMVs due to the lack of Cloud products)*

5.2 HIGH RESOLUTION WINDS VALIDATION FOR GOES-N SATELLITE SERIES

For GOES-N satellites, Validation statistics correspond to a yearly period July 2010–June 2011 with GOES-13 satellite data, in an area covering the Continental United States such as shown in *Figure 6*.

Two different configurations are shown in the validation: the first one considering the conditions defined in the default \$SAFNWC/config/safnwc_HRW.cfm.GOES15MIN configuration file, in which “CCC height assignment without Microphysics correction” is considered, and for which NWC/GEO CMA, CT and CTHH product outputs have to be available. The other one considers the running of GEO-HRW-v50 with the same configuration file, but without the provision of NWC/GEO Cloud product outputs, so considering “Brightness temperature interpolation height assignment without cloud products”.

Radiosoundings for all main synoptic hours (00:00, 06:00, 12:00 and 18:00 UTC) are used for the statistics to increase the amount of comparisons. In any case, dawn or dusk occurs at the main synoptic hours 00:00 and 12:00 with a largest number of Radiosounding observations, because of which the number of visible AMVs is much smaller in the comparisons. AMVs at 23:45, 05:45, 11:45 and 17:45 are used for the comparisons, because no GOES-13 images are available at the main synoptic hours.

Comparing with the equivalent statistics for MSG (shown in *Table 15* and *Table 16*), all statistics for GOES-N AMVs (NBIAS, NMVD, NRMSVD) are very similar, and in some cases even slightly better. Considering the different channels (VIS07, WV065, IR107) there are no remarkable differences with the equivalent MSG channels.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	Cloudy VIS07	Cloudy WV65	Cloudy IR107	Clear Air	All AMVs
NC	5849	205757	208726	47253	467585
SPD [m/s]	22.34	24.46	22.98	15.31	23.00
NBIAS (ALL LAYERS)	+0.00	-0.03	-0.08	-0.00	-0.05
NMVD (100–1000 hPa)	0.25	0.27	0.29	0.35	0.28
NRMSVD	0.31	0.33	0.36	0.48	0.36
NC	4694	191878	173848	47253	417673
SPD [m/s]	24.71	24.68	24.33	15.31	23.47
NBIAS (HIGH LAYER)	+0.00	-0.03	-0.09	-0.00	-0.05
NMVD (100–400 hPa)	0.24	0.27	0.28	0.35	0.28
NRMSVD	0.29	0.33	0.35	0.47	0.36
NC	460	13879	25067		39406
SPD [m/s]	18.10	21.43	18.60		19.59
NBIAS (MEDIUM LAYER)	-0.03	-0.00	-0.06		-0.04
NMVD (400–700 hPa)	0.28	0.29	0.32		0.31
NRMSVD	0.36	0.36	0.40		0.38
NC	695		9811		10506
SPD [m/s]	9.17		10.24		10.17
NBIAS (LOW LAYER)	-0.06		-0.10		-0.10
NMVD (700–1000 hPa)	0.35		0.39		0.38
NRMSVD	0.43		0.48		0.48

*Table 17: Validation parameters for GEO-HRW-v50
(Jul 2010-Jun 2011, GOES13 satellite, 00/06/12/18:00 UTC, Continental United States area;
Basic AMVs; Cross correlation tracking; CCC height assignment without Microphysics correction)*

GEO-HRW-v50 AMVs				All
(Jul 2009-Jun 2010)	VIS07	WV65	IR107	AMVs
NC	8176	281224	77701	367101
SPD [m/s]	18.61	21.91	21.87	21.83
NBIAS (ALL LAYERS)	+0.05	-0.00	+0.02	+0.00
NMVD (100-1000 hPa)	0.30	0.29	0.29	0.29
NRMSVD	0.38	0.36	0.35	0.36
NC	3834	252275	36889	292998
SPD [m/s]	23.37	22.05	26.92	22.68
NBIAS (HIGH LAYER)	+0.06	+0.00	+0.00	+0.00
NMVD (100-400 hPa)	0.28	0.28	0.26	0.28
NRMSVD	0.35	0.35	0.32	0.35
NC	2530	28949	28624	60103
SPD [m/s]	17.94	20.65	19.91	20.18
NBIAS (MEDIUM LAYER)	+0.07	-0.07	+0.06	-0.00
NMVD (400-700 hPa)	0.32	0.32	0.32	0.32
NRMSVD	0.40	0.41	0.39	0.40
NC	1812		12188	14000
SPD [m/s]	9.49		11.19	10.97
NBIAS (LOW LAYER)	-0.02		-0.03	-0.03
NMVD (700-1000 hPa)	0.35		0.35	0.35
NRMSVD	0.44		0.42	0.42

*Table 18: Validation parameters for GEO-HRW-v50
(Jul 2010-Jun 2011, GOES13 satellite, 00/06/12/18:00 UTC, Continental United States area;
Basic AMVs; Cross correlation tracking;
Brightness temperature interpolation height assignment without Cloud products;
No distinction between Cloudy and Clear air Water vapour AMVs due to the lack of Cloud products)*

These result mean that NWC/GEO-HRW algorithm can perfectly be used operatively with GOES-N satellite series, proving the validity of exporting GEO-HRW algorithm to other geostationary satellite series.

Considering the different layers, the GEO-HRW Product Requirement Table Optimal accuracies (respectively 0.35, 0.40 and 0.45 for High, Medium and Low layer) are reached for all layers with GOES-N satellite series when “Brightness temperature interpolation height assignment without Cloud products” is used.

Very slightly higher values of the NRMSVD parameter cause that using “CCC height assignment without Microphysics correction” the Product Requirement Table Optimal accuracy is not reached by a small margin at the High and Low layer (showing the fact that the Cloud products had to be calculated with only five channels for GOES-N satellites instead of the twelve channels used for MSG satellites). In spite of this, and considering the specific study done on which assignment method is better for GOES-N satellite series in the “Validation report for GEO-HRW v5.0” (document [AD.15]), “CCC height assignment without Microphysics correction” is preferred as default option for the running of GEO-HRW algorithm with GOES-N satellite series.

As a final comment, it is necessary to remark that the Target accuracy is widely reached in all conditions for both MSG and GOES-N satellite series.

5.3 HIGH RESOLUTION WINDS PRODUCT ASSUMPTIONS AND LIMITATIONS

The main circumstance that has to be taken into account when using NWC/GEO High Resolution Winds product, is the variability with time of the amount of available AMV and Trajectory data. This is related to the evolution with time in the working region of cloudy areas (or cloudless areas with humidity patterns in the water vapour images, if Clear air Water vapour Atmospheric Motion Vectors are considered).

Nevertheless, the situation has improved since version GEO-HRW-v3.2. Previously, the applicability of GEO-HRW algorithm was limited to cloudy areas because of considering HRVIS and IR108 channels only. The new AMVs at GEO-HRW-v3.2 related to humidity patterns in the water vapour channels (WV062, WV073) show for the first time wind vectors in clear air areas. Besides, the possibility to calculate AMVs with up to seven different channels with MSG/SEVIRI satellite (or up to three different visible, infrared and water vapour channels with GOES-N satellite), increases significantly the density of AMV data.

With all of this, the presence of geographical areas inside the working region where GEO-HRW algorithm does not find any wind vector is now smaller. Nevertheless, because the presence of humidity patterns in the clear air areas where tracers can adequately be defined and tracked is not guaranteed, and because in general clear air AMVs have worse validation statistics (causing the filtering of valid clear air AMVs to be more demanding than the filtering of cloudy AMVs), the presence of areas inside the working region where no AMVs are available and no information can be extracted is still possible. The users should evaluate, which implications this might have when using GEO-HRW algorithm.

About the calculated Atmospheric Motion Vectors, the main source of errors is related to inconsistencies between the NWP model used and the true atmosphere. This is especially important:

- In the definition of the ‘tracking area’ and in the Quality control, related to inconsistencies in the vertical wind profile. On the one hand, tracers may not be found in areas where the displacement is different to the one defined by the forecast. On the other hand, the errors in the forecast winds can cause the AMVs to have a worse forecast QI than the one they should, and because of this some good winds might be rejected.

The first problem is solved not using the wind guess (with WIND_GUESS = 0), which despite the increases in the running time of GEO-HRW algorithm it implies (because of using larger ‘tracking areas’), the optimizations included since GEO-HRW-v4.0 make this configuration fully operative as the default option for GEO-HRW algorithm. Users should keep this configuration, so reducing the dependence of the AMVs on the NWP model.

The second problem is solved using the “Quality index without forecast” in the operation of GEO-HRW algorithm (implemented with QI_THRESHOLD_USEFORECAST = 0 since GEO-HRW-v4.0), which avoids the influence of the NWP model in the Quality of the AMVs. Nevertheless, this option has not been considered as the default one because the impact of the NWP model in the Quality of the AMVs is considered to be generally more positive than negative.

- In the height assignment (in general the main remaining challenge that scientists are currently facing with AMV extraction), if the ‘Brightness temperature interpolation height assignment’ is used, small errors in the temperature profile can cause important errors in the heights assigned to the tracers. Besides, in this case the assumption is taken that the temperature is supposed to diminish constantly with higher levels throughout the atmosphere. Due to this, problems in the level assignment appear when a temperature inversion is present. (This problem is solved since GEO-HRW-v3.1 using the ‘CCC height assignment method’, where the ‘thermal inversion problem’ is solved using GEO-CTTH product output data).
- Considering all this, the use of the NWP model is nevertheless considered to be mandatory for the AMV height assignment (directly through the ‘Brightness temperature interpolation height assignment, or indirectly through the ‘CCC height assignment method’ related to

NWC/GEO CTTH Cloud top pressure output). The quality of the height assignment inferred in previous versions of GEO-HRW algorithm without use of NWP data is considered not to be good enough to be used anymore, and so the option to calculate AMVs without NWP data has been skipped in GEO-HRW-v50 algorithm.

With all of this, the important improvements in the latest GEO-HRW versions (since v2.2 to v5.0) have reduced the limitations this algorithm previous had.

First of all, the use of NWC/GEO CT output helps to eliminate wrong ground tracers identified as clouds in the visible and infrared channels (related to “cloud free land or sea” or “land or sea contaminated with ice or snow”), and to verify the different behaviours of the AMVs considering the Cloud type they are related to. Secondly, the use of NWC/GEO CTTH output with ‘CCC method’ in the height assignment includes several new procedures (like the Radiance ratioing technique and the H2O/IRW intercept method for the definition of the AMV height related to semitransparent clouds), which have improved the statistics of the AMVs related to the semitransparent cloud types respect to the previous versions of the algorithm. Finally, the inclusion of Microphysics data in GEO-HRW-v50 permit to take into account the Cloud depth for an improved AMV height assignment.

The adaptation of GEO-HRW algorithm to infrared and water vapour channels also helped to extend the AMV calculation to all hours of the day, and to both cloudy and clear air areas, following the necessities and suggestions of NWC SAF users. This eliminates the temporal limitation to daytime which GEO-HRW algorithm previously had. The extension to calculate winds in the ‘Rapid scan mode’ with MSG/SEVIRI satellite permits also to obtain new winds even every five minutes with every new slot, increasing the amount of available AMVs in a 15 minute time lapse by a factor of around 3 respect to the ‘Nominal scan mode’.

The default configuration not using the ‘wind guess’ in the definition of the ‘tracking area’ and the introduction of the ‘Quality index without forecast’ (reducing the influence of the NWP model in the calculation and definition of the quality of the AMVs) also contribute to improve the general quality of GEO-HRW AMVs.

Considering finally the calculation of trajectories through the successive tracking of the same tracer in consecutive slots, the most important limitation is the persistence in time of the tracers for the definition of the trajectories. To keep the quality of the corresponding AMVs, it has been considered necessary that the tracers should keep their characteristics (such as defined by ‘Gradient method’ or ‘Tracer characteristics method’) throughout the entire trajectory.

Because of the temporal evolution of the tracers, under these requirements after one hour only between 30% and 50% of the tracers persist; after three hours only between the 5% and 15% of the tracers persist. Additionally, the persistence is smaller due the smaller size of the tracers in the ‘Detailed scale’. Considering this, users of GEO-HRW product should be aware about the utility the trajectories provided to them under these conditions.

Additionally, the persistence of the tracers is different considering different meteorological situations, in which the temporal change of the atmospheric structures is quicker or slower. Considering this, the density of trajectories can be very different in different parts of a same region. This is an issue that users should also have into account when using the trajectories calculated by GEO-HRW algorithm.

6. VISUALISATION EXAMPLES OF HIGH RESOLUTION WINDS

Real time graphic displays of the NWC/GEO High Resolution Winds product, generated at the NWC/GEO Reference System, are to be available without any restriction in the website of the NWC SAF Help Desk (<http://www.nwcsaf.org>).

Next figures show typical displays of GEO-HRW product for AMVs and Trajectories considering the default configuration. First, with MSG2 satellite data in the European and Mediterranean region used for GEO-HRW-v50 validation (Figures 4 and 5). Later, with GOES13 satellite data in the Continental United States region also used for GEO-HRW-v50 validation (Figures 6 and 7). A colour coding based on the AMV and Trajectory pressure level has been used.

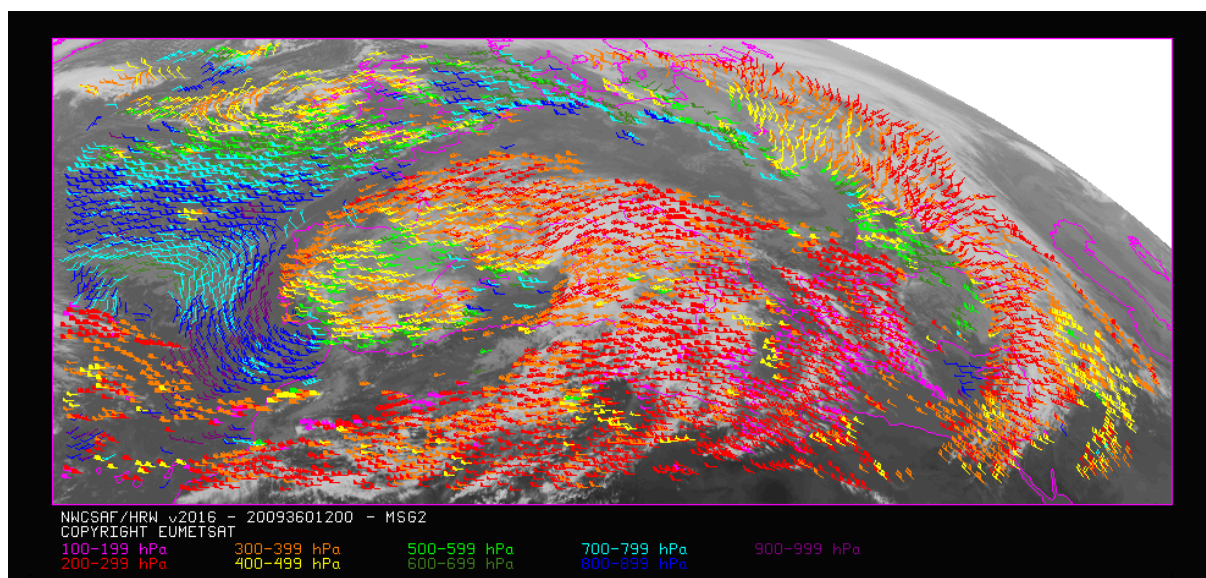


Figure 4: NWC/GEO High Resolution Winds v2016 AMV output example in the European and Mediterranean region (26 December 2009 1200Z, Nominal scan mode, MSG2 satellite), considering the default conditions defined in \$SAFNWC/config/safnwc_HRW.cfm.MSG15MIN model configuration file. Colour coding based on the AMV pressure level

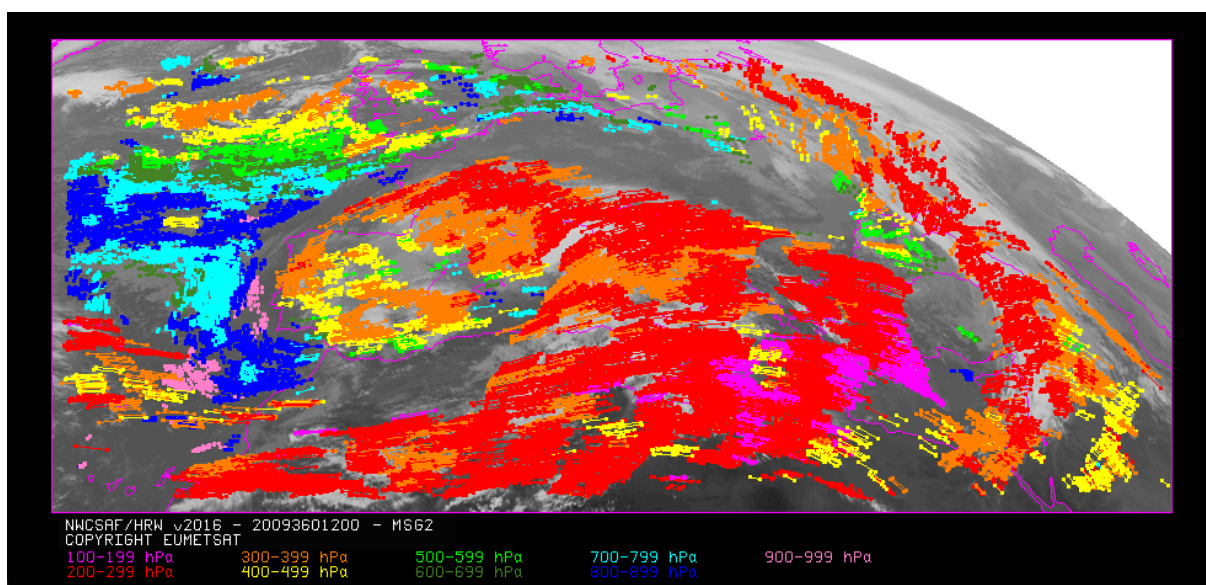


Figure 5: NWC/GEO High Resolution Winds v2016 Trajectory output example in the European and Mediterranean region (for trajectories lasting at least one hour, for 26 December 2009 1200Z, Nominal scan mode, MSG2 satellite), considering the default conditions defined in \$SAFNWC/config/safnwc_HRW.cfm.MSG15MIN model configuration file. Colour coding based on the AMV pressure level

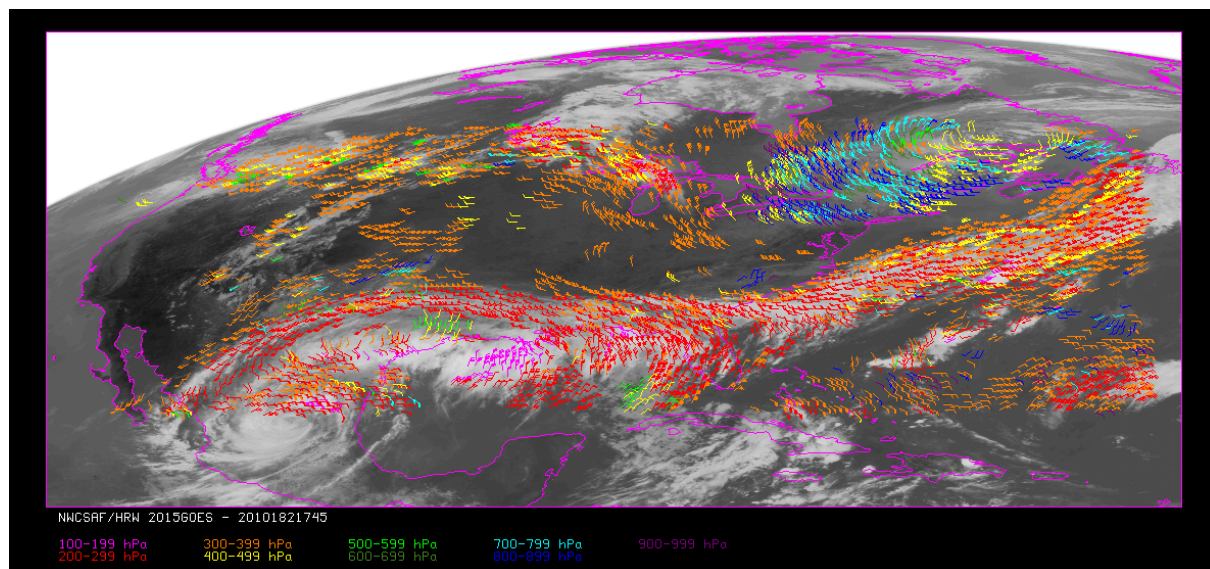


Figure 6: NWC/GEO High Resolution Winds v2016 AMV output example in the Continental United States region (1 July 2010 1745Z, GOES13 satellite), considering the default conditions defined in \$SAFNWC/config/safnwc_HRW.cfm.GOES15MIN model configuration file. Colour coding based on the AMV pressure level

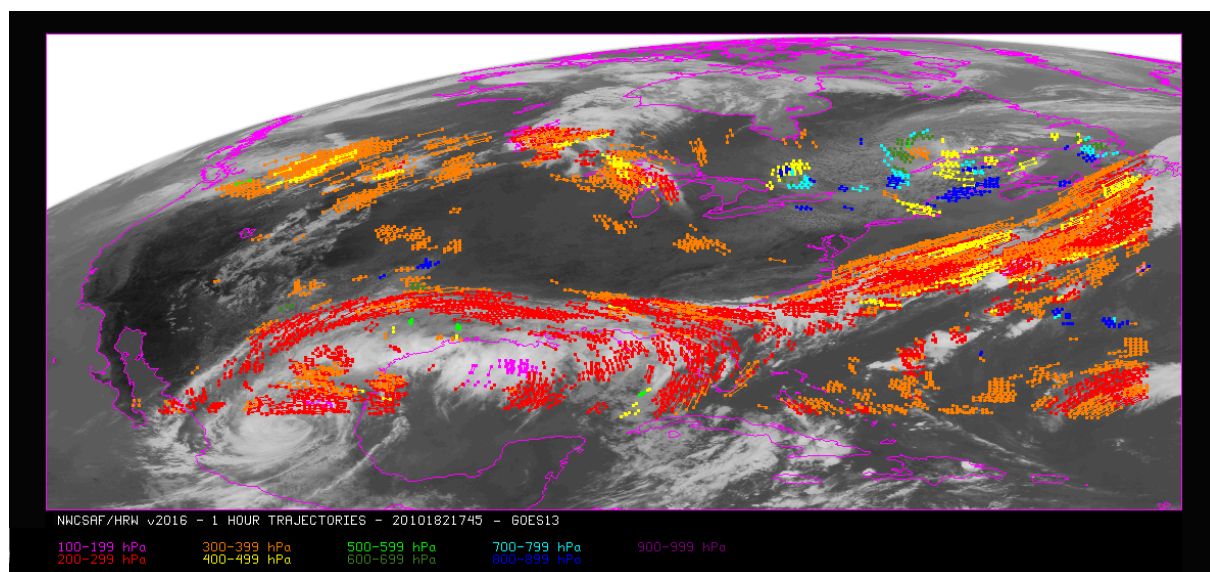


Figure 7: NWC/GEO High Resolution Winds v2016 Trajectory output example in the Continental United States region (for trajectories lasting at least one hour, for 1 July 2010 1745Z, GOES 13 satellite), considering the default conditions defined in \$SAFNWC/config/safnwc_HRW.cfm.GOES15MIN model configuration file. Colour coding based on the AMV pressure level