NWC SAF HIGH RESOLUTION WINDS AS STANDALONE AMV CALCULATION SOFTWARE

Javier García-Pereda [1], Régis Borde [2]

[1] NWC SAF Project Team, Agencia Estatal de Meteorología, Madrid, Spain
[2] European Organisation for the Exploitation of Meteorological Satellites, Darmstadt, Germany

Abstract

The need to have a standalone AMV calculation software, easily usable and available to everybody, has been discussed at 38th and 39th CGMS meetings and also at the 10th International Winds Workshop. One of the main arguments was to provide both AMV and Research communities with a tool facilitating the research, testing and comparison of new AMV developments, which could improve the general quality of extracted AMVs.

High Resolution Winds software (HRW) inside NWC SAF standalone software package for geostationary satellites (SAFNWC/MSG) is easy to obtain from NWC SAF Helpdesk (after signing the corresponding Licence Agreement with EUMETSAT), easy to install, configure and run. It includes all routines and functions needed to process the corresponding MSG/SEVIRI HRIT images and NWP data, to calculate the Cloud products needed by its Height assignment (Cloud type, Cloud top temperature and height), and to calculate the corresponding AMVs.

Its output is available in BUFR format, which with additional tools also available can be easily converted to other formats (like HDF5 or McIDAS MD files). It is currently only adapted to work with MSG data, but during CDOP-2 phase (2012-2017) its adaptation to other geostationary satellites is foreseen.

A test and validation dataset, including MSG/SEVIRI images, ECMWF model data and Radiosounding observations in the European area for the period January-March 2010 would also be available if the corresponding licences could be granted for the external AMV developers. This test and validation dataset could be easily used to verify the impact of any modification in HRW algorithm.

In summary, the NWC SAF/HRW software is modular, well documented and easy to run. Significant changes and improvements can be implemented, tested and validated in a reasonable amount of time. The aim of this paper is to give a general presentation of how to use the existing NWC SAF/HRW software, and discuss its potential to provide a standalone AMV software as requested by the scientific AMV community.

THE SATELLITE APPLICATION FACILITY ON SUPPORT TO NOWCASTING (NWC SAF)

The “Satellite Application Facility on support to Nowcasting and Very short range forecasting (NWC SAF)” is a Consortium established between EUMETSAT and several European National Meteorological Services (Agencia Estatal de Meteorología from Spain, Météo France, Sveriges Meteorologiska och Hydrologiska Institut from Sweden and Zentralamstalt für Meteorologie und Geodynamik from Austria), providing operational services to enhance this area of weather prediction.

To achieve this goal, the NWC SAF develops and maintains two software packages which calculate in real time meteorological products using Geostationary and Polar satellite data, distributes these software packages to its users, and supports them on their usage.

NWC SAF/HIGH RESOLUTION WINDS (HRW)

An Atmospheric Motion Vector (AMV) product is included in the NWC SAF Geostationary software package (SAFNWC/MSG): the "High Resolution Winds" (HRW). Its objective is to provide detailed sets of AMVs for near real time applications. It can be run locally and in near real time by the user, defining its configuration, and the satellite and region to be processed through the corresponding configuration files. Since HRW v3.2 (v2012), released in March 2012, AMVs can be calculated using up to seven MSG/SEVIRI channels: HRVIS, VIS06, VIS08, IR108, IR120, WV062 and WV073, including Cloudy and Clear air water vapour AMVs. The 2012-2017 plan includes additionally its extension to other Geostationary satellites (like the new NOAA/GOES-R or JMA/Himawari-8 series).

All elements for the reading and processing of all needed data (including Satellite, NWP model data and Cloud information for the AMV height assignment using NWC SAF/Cloud Type and Cloud Top Temperature and Height products), for the running of all parts of the algorithm, and for the definition of the AMV output in several formats (BUFR, HDF5 or McIDAS MD files) are included in SAFNWC/MSG software package or at NWC SAF website. The user does not need then any additional elements to calculate and use the AMVs provided by HRW product.

The main steps of "NWC SAF/HRW algorithm" are:

1) *Preprocessing:* the Satellite, NWP model data and Cloud information from NWC SAF/Cloud products to be used are initialized through libraries included within SAFNWC/MSG software.
2) *Tracer calculation:* two methods are used one after the other: "Gradient method" (which searches for well defined cloud edges) and "Tracer characteristics method" (which fills the holes in the coverage).
3) *Tracer tracking and wind calculation:* up to three correlation centres are selected for each tracer using one of two different methods: "Euclidean distance" or "Cross correlation" (default option).
4) *Height assignment:* one of two different methods are used: the old "Brightness temperature interpolation method" (which calculates the cloud top and cloud base pressure, and uses one of them as AMV pressure depending on the cloud type related to the AMV) or ' "CCC method" (Borde and Oyama 2008, [RD.4]) (default option, which defines the AMV pressure considering only the pressure of the pixels contributing most to the image correlation).
5) *Quality Control:* the Quality Indicator Method developed by EUMETSAT and used with MPEF AMVs, is used considering the temporal, spatial and forecast consistency tests.
6) *Orographic test:* tracers affected by land influence are rejected.

More information on NWC SAF/HRW algorithm and procedures can be found in the official documents (the Algorithm Theoretical Basis Document [RD.1], the Product User Manual [RD.2] and the Validation Report [RD.3]) at the NWC SAF Helpdesk.

The input data needed to run SAFNWC/MSG software and its products are:

- Full Resolution unencrypted HRIT MSG/SEVIRI data: received from EUMETCast service.
- NWP model forecast GRIB data for several variables in the working region: many options have already been tried like ECMWF, ARPEGE in France, COSMO in Germany and GDAPS in Korea, but other options can also be used.
- SAFNWC/MSG configuration files: text files where the conditions for the running of the different products are defined by the user, including the satellite configuration file (sat_conf_file), the region configuration file (*.cfg), and the model configuration files (*cfm, defining the options for each product). These options can be changed at any time.

The user only has to worry to locate these data in the corresponding needed directories: $SAFNWC/import/SEVIRI_data, $SAFNWC/import/NWP_data and $SAFNWC/config.

The output data for the different SAFNWC/MSG products can be:

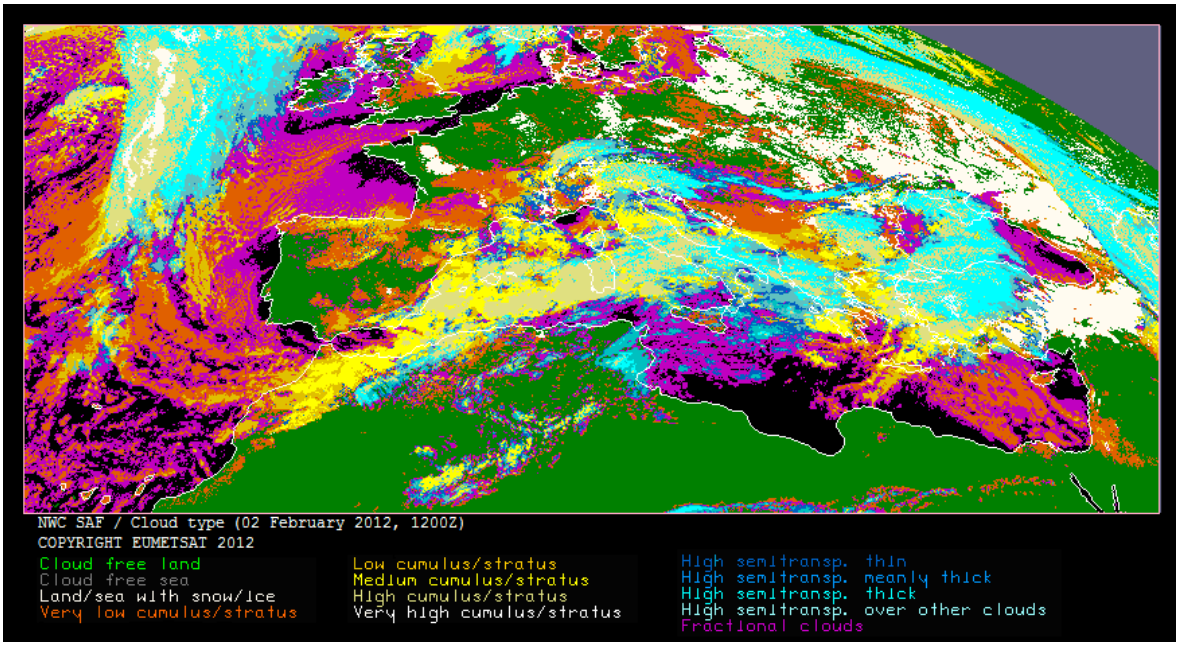
- HDF5 image files, like the ones for the Cloud products later processed by HRW algorithm: Cloud mask, Cloud type, Cloud top pressure, Cloud top temperature, Cloud top height (in the corresponding directories $SAFNWC/export/PGE01, $SAFNWC/export/PGE02 and SAFNWC/export/PGE03).
- BUFR bulletins, like the ones for "High Resolution Winds" product: one or two BUFR bulletins in $SAFNWC/export/PGE09 directory, including the AMVs corresponding to up to two

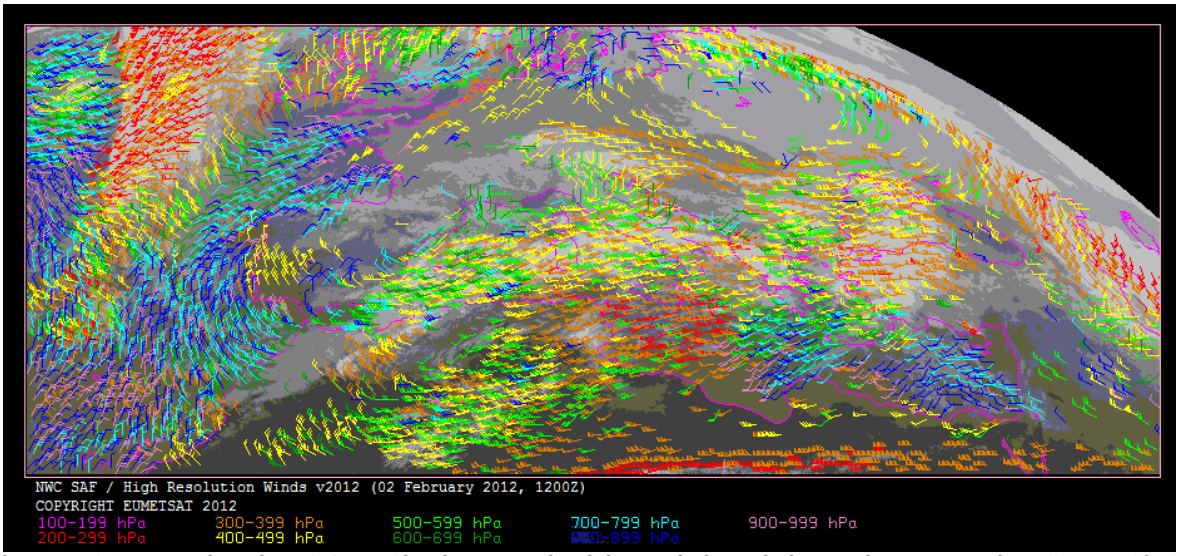
different scales of tracers: “basic winds” (SAFNWC_HRW_***_B.buf, with a default tracer size of 24 pixels) and “detailed winds” (SAFNWC_HRW_***_D.buf, with a default tracer size of 12 pixels).

The output file scan be easily visualized or processed through several options:

- Visualization through applications capable or reading HDF5 format (like HDFview): directly for SAFNWC/MSG products providing this output (like the Cloud products) and also for the products providing BUFR format output, like “High Resolution Winds AMVs”, after conversion to HDF5 with tools also included in the SAFNWC/MSG software package.
- Visualization and later use under McIDAS environment, after conversion of SAFNWC/MSG HDF5 and BUFR outputs to McIDAS AREA and MD files, with tools also freely provided at NWC SAF Helpdesk.
- “High Resolution Winds” AMV BUFR output can besides directly be processed in NWP assimilation (already under way for example in the United Kingdom and Hungary Meteorological Services).

Additional visualization options are going to be developed in NWC SAF next phase (CDOP2, between 2012 and 2017). Figures 1 and 2 show examples of visualization of SAFNWC/MSG Cloud and AMV products under McIDAS environment.





Figures 1 & 2: **Examples of NWC SAF “Cloud type” and “High Resolution Winds” product outputs from SAFNWC/MSG v2012 software package in the “European and Mediterranean Region”, using MSG-2 Satellite data and ECMWF NWP model data (2 February 2012 at 1200Z)**

NWC SAF/HIGH RESOLUTION WINDS PRODUCT VALIDATION

The Validation statistics against Radiosounding winds for the latest version of NWC SAF/High Resolution Winds (v2012), following the criteria defined at the Third International Winds Workshop in Ascona/Switzerland for the comparison of satellite winds with Radiosounding winds (with a maximum distance of 150 km and a maximum pressure difference of 25 hPa between the AMV and the Radiosounding wind), are shown in next Tables.

In Table 1, all atmospheric layers are considered together. In Table 2, validation statistics have been divided for the High (100-400 hPa), Medium (400-700 hPa) and Low (700-1000 hPa) layers. In both tables, the "European and Mediterranean Region" shown in Figures 1 and 2 and the whole year July 2009–June 2010 have been considered.

HRW v3.2 AMV Validation (Jul 2009-Jun 2010)	cloudy HRVIS	cloudy VIS06	cloudy VIS08	cloudy IR108	cloudy IR120	cloudy WV062	cloudy WV073	clear air WV062	clear air WV073	all AMVs
NC	138633	71213	64022	112833	115171	133011	176648	34023	14155	859709
SPD [m/s]	18.03	11.75	11.71	19.68	19.89	23.63	21.96	17.46	13.58	19.08
NBIAS (ALL LAYERS)	-0.11	-0.16	-0.16	-0.11	-0.10	-0.06	-0.08	-0.05	-0.02	-0.08
NMVD (100-1000 hPa)	0.32	0.44	0.44	0.32	0.32	0.29	0.31	0.34	0.39	0.33
NRMSVD	0.40	0.52	0.52	0.41	0.40	0.36	0.39	0.42	0.46	0.41

Table 1: **Validation statistics against Radiosounding winds for NWC SAF/High Resolution Winds v2012 in the "European and Mediterranean Region" shown in Figures 1 and 2 for the whole year July 2009-June 2010, considering all atmospheric layers together (100-1000 hPa). (NC: Number of collocations; SPD: Mean radiosounding speed in m/s; NBIAS: Normalized bias; NMVD: Normalized mean vector difference; NRMSVD: Normalized root mean square vector difference).**

HRW v3.2 AMV Validation (Jul 2009-Jun 2010)	cloudy HRVIS	cloudy VIS06	cloudy VIS08	cloudy IR108	cloudy IR120	cloudy WV062	cloudy WV073	clear air WV062	clear air WV073	all AMVs
NC	74986			69778	73646	126993	141182	34023	1466	522074
SPD [m/s]	23.49			23.12	23.05	23.89	23.35	17.46	14.72	23.02
NBIAS (HIGH LAYER)	-0.10			-0.12	-0.11	-0.06	-0.09	-0.05	+0.04	-0.09
NMVD (100-400 hPa)	0.28			0.30	0.29	0.29	0.30	0.34	0.34	0.30
NRMSVD	0.35			0.37	0.37	0.36	0.37	0.42	0.40	0.37
NC	33356	41595	37728	32724	32364	6018	34416		12689	230890
SPD [m/s]	13.47	13.11	12.97	15.06	15.19	18.18	16.52		13.45	14.37
NBIAS (MEDIUM LAYER)	-0.12	-0.17	-0.17	-0.08	-0.06	+0.00	-0.03		-0.03	-0.10
NMVD (400-700 hPa)	0.38	0.42	0.42	0.39	0.39	0.38	0.39		0.39	0.40
NRMSVD	0.47	0.51	0.51	0.48	0.48	0.48	0.49		0.47	0.49
NC	30291	29618	26294	10331	9161		1050			106745
SPD [m/s]	9.52	9.84	9.89	11.10	11.09		13.13			10.02
NBIAS (LOW LAYER)	-0.09	-0.13	-0.14	-0.09	-0.08		-0.02			-0.11
NMVD (700-1000 hPa)	0.44	0.46	0.46	0.41	0.41		0.40			0.44
NRMSVD	0.52	0.54	0.54	0.49	0.48		0.48			0.52

Table 2: **Validation statistics against Radiosounding winds for NWC SAF/High Resolution Winds v2012 in the "European and Mediterranean Region" shown in Figures 1 and 2, for the whole year July 2009-June 2010, considering three different atmospheric layers: High (100-400 hPa), Medium (400-700 hPa) and Low (700-1000 hPa). (NC: Number of collocations; SPD: Mean radiosounding speed in m/s; NBIAS: Normalized bias; NMVD: Normalized mean vector difference; NRMSVD: Normalized root mean square vector difference).**

Table 3 show performances of NWC SAF HRW software against EUMETSAT/MPEF AMV statistics in the "Northern Extratropical Region" for the same period (kindly provided by Arthur de Smet). it can be verified that the density of NWC SAF/High Resolution Winds with its default configuration is higher (the number of AMVs being at least twice) with a mean NRMSVD around a 17% larger. But if the density of AMVs is slightly reduced (through a higher Quality index threshold) the NRMSVD is very similar to the one of EUMETSAT/MPEF AMVs with a still higher density of AMVs.

Validation comparison (NC & NRMSVD) between NWCSAF/HRW and MPEF AMVs (Northern extra tropical area, Jul 2009-Jun 2010)	NWCSAF/HRW (Default configuration)		NWCSAF/HRW (Smaller AMV density)		EUMETSAT/MPEF (Official statistics)	
ALL LEVELS (100-1000 hPa)	859709	0.41	655350	0.35	363943	0.35
HIGH LEVELS (100-400 hPa)	522074	0.37	423849	0.31	242313	0.29
MEDIUM LEVELS (400-700 hPa)	230890	0.49	164201	0.41	39910	0.43
LOW LEVELS (700-1000 hPa)	106745	0.52	67300	0.46	81720	0.46

Table 3: **Comparison between NWC SAF/High Resolution Winds v2012 and EUMETSAT/MPEF AMV validation statistics in the "Northern extratropical region" for the whole year July 2009-June 2010. (NC: Number of collocations; NRMSVD: Normalized root mean square vector difference).**

NWC SAF SOFTWARE INSTALLATION AND USE

All National Meteorological Services within EUMETSAT Member or Cooperating States are automatically considered as potential users of NWC SAF Software. Any other Organisation may also apply to become user of NWC SAF Software contacting Pilar Fernández, NWC SAF Manager, through the email addresses mafernandeza@aemet.es or asanchezp@aemet.es.

All applicants have become users of NWC SAF Software up to now without restrictions: around 100 institutions from all around the world (Europe, Africa, Americas, Asia), including National meteorological services, Universities, Research institutions, Public service providers, Public and private companies.

The software delivery is authorized to the users according to their Licence Agreement, to be signed by EUMETSAT (represented by Agencia Estatal de Meteorología) and the applicant user. Once the Licence Agreement is signed, access credentials to the NWC SAF Helpdesk Restricted Area are provided, where the NWC SAF software can be downloaded: http://www.nwcsaf.org.

The installation takes only three steps, which can need less than one hour to be ready: to download and decompress the software, to define a few variables in the ".profile file" and activate them, and to run the installation script: "$SAFNWC/src/safnwc_v2012.sh make install".

Nothing else is needed. The whole software with its libraries, products and additional elements to run all SAFNWC/MSG products (including the "High Resolution Winds" AMV software) is installed and ready to run with this short procedure.

Hardware resources needed to run SAFNWC/MSG Software package are besides small and relatively easy to obtain, under several possible environments:

	Sun/Solaris	Intel/Linux
O.S	Solaris 8 or later	Fedora Core 6 RedHat Enterprise 3 RedHat 7.3
Memory	1024 MB	256 MB
Disk Space(1)	10 GB	10 GB
Compilers	Sun WorkShop 6 or Forte Developer 7	gcc 4.1.1 Intel ifort v8.1
CPU	UltraSPARC-III (450MHz)	Pentium 4 (2.4GHz)
Shell	Unix KornShell (ksh)	Unix KornShell (ksh)

Table 4: **Minimum hardware and environment needs to run SAFNWC/MSG v2012 software package**

Other environments, like Linux/Ubuntu, SUSE and Debian are not officially supported, but some NWC SAF users have also tested them successfully.

A “Task Manager tool” is defined inside the Software package to run the needed products in real time or under a programmed schedule. The user simply has to define in the corresponding configuration files the products and tasks to be run, the satellite and region to be considered, and the configuration of each product, and provide the Satellite and NWP model data in the corresponding directories once they have been received.

Then, the Task Manager is started with a simple command: “SAFNWCTM safnwc.cfs”, which starts to run each product for each slot just after the reception of the corresponding Satellite image files.

The products can also be run manually with a few scripts. To run the “High Resolution Winds product” for a defined slot, the user only needs:

- To locate the Satellite and NWP model data in the corresponding directories.
- To prepare NWP model data for their use with: “AllMappingNWP safnwc_region.cfs”.
- To run SAFNWC/MSG Cloud products (Cloud mask, Cloud type, Cloud top temperature and height) with:
  PGE01 $slot safnwc_region.cfs safnwc_pge01.cfm (for the Cloud mask)
  PGE02 $slot safnwc_region.cfs safnwc_pge02.cfm (for the Cloud type)
  PGE03 $slot safnwc_region.cfs safnwc_pge03.cfm (for the Cloud top temp. and height)
- To run SAFNWC/MSG “High Resolution Winds” winds with:
  PGE09 $slot safnwc_region.cfs safnwc_pge09.cfm

After all of this, NWC SAF Cloud HDF5 outputs and AMV BUFR output are available in $SAFNWC/export directory.

Some possible users of NWC SAF/High Resolution Winds as “Standalone AMV Calculation software” could complain on not having an easy access to MSG/SEVIRI data, NWP data or Radiosounding wind data for validation, needed to run and validate HRW AMVs in any study they might be involved in.

Considering this, a three month dataset (for January – March 2010) including: MSG/SEVIRI data in the European area for every day between 1115 and 1200 UTC, ECMWF NWP model forecast data, and Radiosounding data at 1200 UTC for validation tasks has been stored at NWC SAF (occupying around 35 Gigabytes). It could be distributed for research and testing, if the corresponding authorization could be granted from EUMETSAT and ECMWF institutions. With this, any possible user of NWC SAF/High Resolution Winds would have all needed input data to run and test any possible improvement in AMV algorithms.

Additionally, for any improvement in AMV extraction algorithms discovered by the users of NWC SAF/High Resolution Winds algorithm as “Standalone AMV Calculation software”, it could be included in the official release of HRW product if it is considered to be a significant improvement, and the corresponding user could be economically awarded through a “NWC SAF Visiting Scientist Activity”, because of the developments proposed to be integrated in the baseline “High Resolution Winds algorithm”.

NWC SAF HELPDESK

The NWC SAF Consortium keeps a fully dedicated Helpdesk at www.nwcsaf.org, where the Reference Outputs are displayed in real time, and users can login and have access (among other things) to: the NWC SAF Software package, some test datasets, the whole documentation, the catalogue of software changes (SPRs) between versions, and a Mailbox for interaction with the NWC SAF developers.

All questions and doubts by the users can be solved through this Mailbox, related to the installation, use and problems with NWC SAF software and “High Resolution Winds” product.

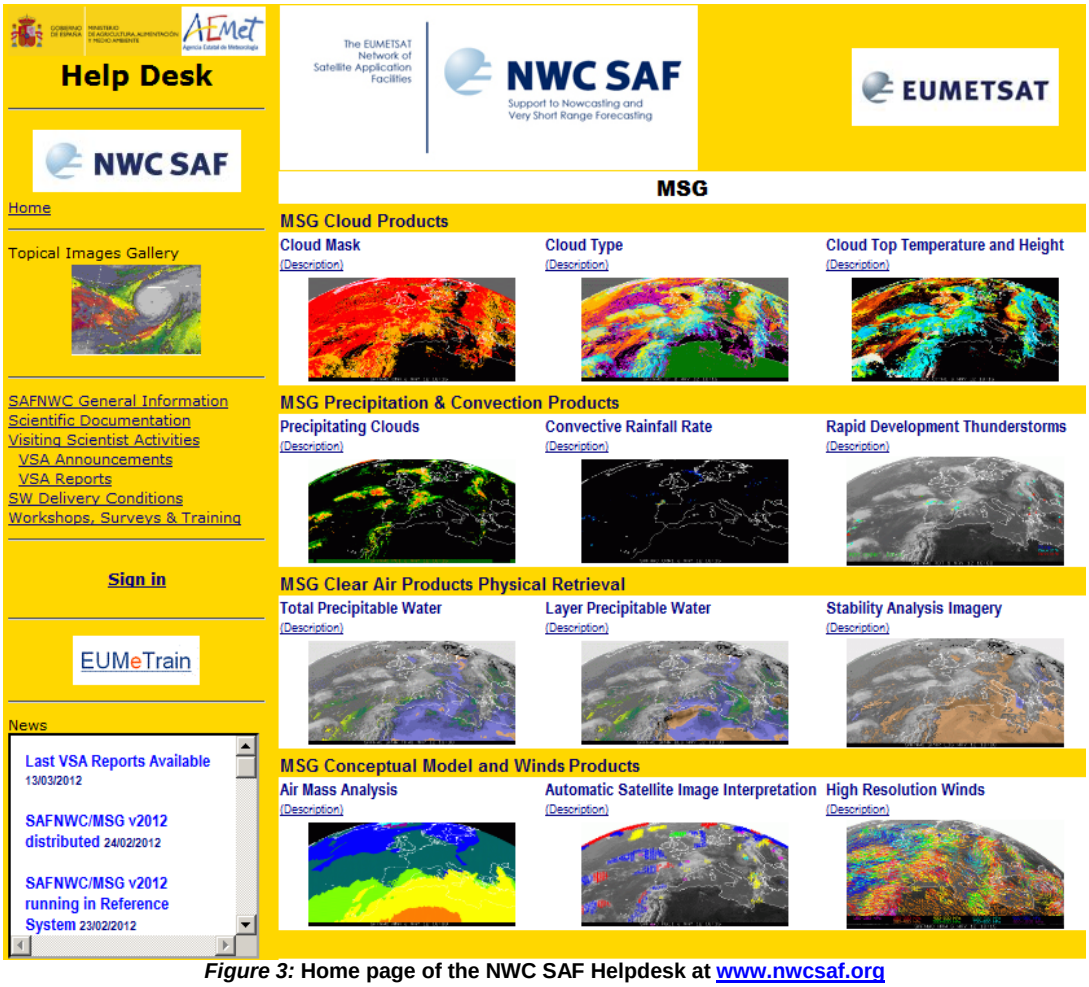


Figure 3: **Home page of the NWC SAF Helpdesk at www.nwcsaf.org**

HIGH RESOLUTION WINDS AS "STANDALONE AMV CALCULATION SOFTWARE"

In summary the "High Resolution Winds product" inside SAFNWC/MSG software package:":

- Satisfies most of the basic requirements identified for a Standalone AMV software:
  - It is very easy to get, install and use.
  - The algorithm code is fairly easy to read (with functions written in C language and a code extensively commented to help its understanding).
  - It is fully portable and standalone (independent from external applications).
  - It can extract AMVs considering visible, infrared and water vapour channel data.
  - For the moment it only works with MSG satellite, but adaptations to other geostationary satellites are foreseen in the next years.
  - It includes all necessary elements and none has to be provided additionally, including: Cloud type and height information extracted with RTTOV Transfer model, a good Height assignment procedure ("CCC method") and Quality control information.
- There is a fully dedicated Helpdesk where NWC SAF users (around 100 already) find support and help on the installation and use of the software.
- There is a periodic release of new official HRW versions, where new developments in the product are implemented. The "Visiting Scientist Activities" open besides the chance of including new procedures developed by the users in the official release and be economically awarded because of them
- There is a possibility of offering a "three month test and validation dataset between January and March 2010" if the necessary permissions by EUMETSAT and ECMWF could be granted. This dataset would give potential users of "High Resolution Winds product" the possibility of running and validating any new AMV development they would be investigating.

The 38th Meeting of the Coordination Group for Meteorological Satellites in 2010 (CGMS-38) concluded on NWC SAF/High Resolution Winds product that:

- It is modular, well documented and well suited as "Standalone AMV calculation software".
- Significant changes can be made in it in a reasonable amount of time.
- It provides a very good, ready-to-go starting point for researchers interested in getting involved in deriving atmospheric winds from satellite measurements.
- It can serve as focal point for sharing and comparing developmental code among different research groups.
- CGMS operators consider NWC SAF/High Resolution Winds as an opportunity to increase the collaboration with AMV experts at other satellite processing centres or universities, which could involve the sharing of pieces of AMV algorithm code and data for: collaborative testing, improved understanding, future algorithm enhancements, further improving the performance of operationally derived AMVs.
- A specific question on the quality of "High Resolution Winds" AMVs was documented through a one year Validation campaign (July 2009 – June 2010), much welcomed by the CGMS.

Several recommendations were additionally defined by the 39th Meeting of the Coordination Group for Meteorological Satellites in 2011 (CGMS-39) on NWC SAF/High Resolution Winds software, but they have already been fulfilled:

- To further test HRW software in NWP data monitoring/assimilation systems:
  - This task is already under way with NWP assimilation experiments in the Hungary and United Kingdom National Meteorological Services.
- To extend it to Clear air water vapour AMVs:
  - This is already implemented in HRW v2012.
- To provide a tested option to allow the running of alternative algorithms to support intercomparison studies:
  - It has been verified that significant changes can be implemented in HRW algorithm in a reasonable amount of time. Additionally, a three month test and validation dataset for the intercomparison of different AMV procedures and methods is available, and could be distributed to the NWC SAF users if the necessary permissions could be granted from EUMETSAT and ECMWF.

REFERENCES

NWC SAF Helpdesk, with general information on the "Satellite Application Facility on support to Nowcasting and Very short range forecasting": www.nwcsaf.org.

Official documentation of "NWC SAF/High Resolution Winds (HRW)" product (available at http://www.nwcsaf.org/indexScientificDocumentation.html)

[RD.1.] García Pereda, J., 2012: Algorithm Theoretical Basis Document for "High Resolution Winds" (HRW-PGE09 v3.2). NWC SAF Document SAF/NWC/CDOP/INM/SCI/ATBD/09.

[RD.2.] García Pereda, J., 2012: Product User Manual for "High Resolution Winds" (HRW-PGE09 v3.2). NWC SAF Document SAF/NWC/CDOP/INM/SCI/PUM/09.

[RD.3.] García Pereda, J., 2012: Validation Report for "High Resolution Winds" (HRW-PGE09 v3.2). NWC SAF Document SAF/NWC/CDOP/INM/SCI/VR/10.

Description of "CCC Height assignment method":

[RD.4.] Borde R., R. Oyama, 2008: "A Direct Link between Feature Tracking and Height Assignment of Operational Atmospheric Motion Vectors', Proceeedings Ninth International Winds Workshop, Annapolis, USA.

Reports of the Coordination Group for Meteorological Satellites (CGMS)

[RD.5.] Report of the 38th Meeting of the CGMS (CGMS-38, 8-12 November 2010, New Delhi, India), available at http://www.cgms-info.org/dl/CGMS-38_Report.pdf.

[RD.6.] Report of the 39th Meeting of the CGMS (CGMS-39, 3-7 October 2011, Saint Petersburg, Russia), available at http://www.cgms-info.org/dl/CGMS-MR-39.pdf.