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# NWCSAF/HIGH RESOLUTION WINDS AMV SOFTWARE VERSION 2018

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**Abstract**

The “High Resolution Winds product (HRW)”, developed inside the “Satellite Application Facility on support to Nowcasting and very short range forecasting (NWCSAF)” standalone NWC/GEO software package, provides a detailed calculation of Atmospheric Motion Vectors and Trajectories locally and in real time by its users.

Last operational version was released to users in November 2016 inside NWC/GEO v2016 software package. A new version of “High Resolution Winds product (HRW)”, is now being prepared and expected for release in the autumn 2018 inside NWC/GEO v2018 software package.

Its main new features include: the calculation of AMVs and Trajectories with Himawari-8/9 satellite series, the auto-validation of the calculated AMVs during the running of the product against NWP forecast or analysis winds, the option to calculate larger densities of AMVs at low levels, and the option to mix several time frames for the AMV calculation (considering short time frames for the tracer tracking and large time frames for the displacement calculation).

The common Quality Index and the new BUFR format for the AMV output files, such as defined by the International Winds Working Group, are also included for homogenization with other AMV products. A parallelization process is also to be included, to ease the processing of the product in larger regions.

## NWCSAF/GEO SOFTWARE PACKAGE

Eumetsat's "Satellite Application Facility on support to Nowcasting and Very short range forecasting (NWCSAF)" develops and distributes to Meteorological Services and Researchers "NWC/GEO Software Package".
This software package provides its users the calculation locally and in near real time of a total of 15 meteorological products, related to clouds, precipitation, convection, humidity and stability, conceptual models and winds.

Among them, "High Resolution Winds (HRW)" product provides high density sets of Atmospheric Motion Vectors (AMVs) and Trajectories for every satellite slot.
Current operational version of "High Resolution Winds" is v2016, released in November 2016 and shown in the previous International Winds Workshop.

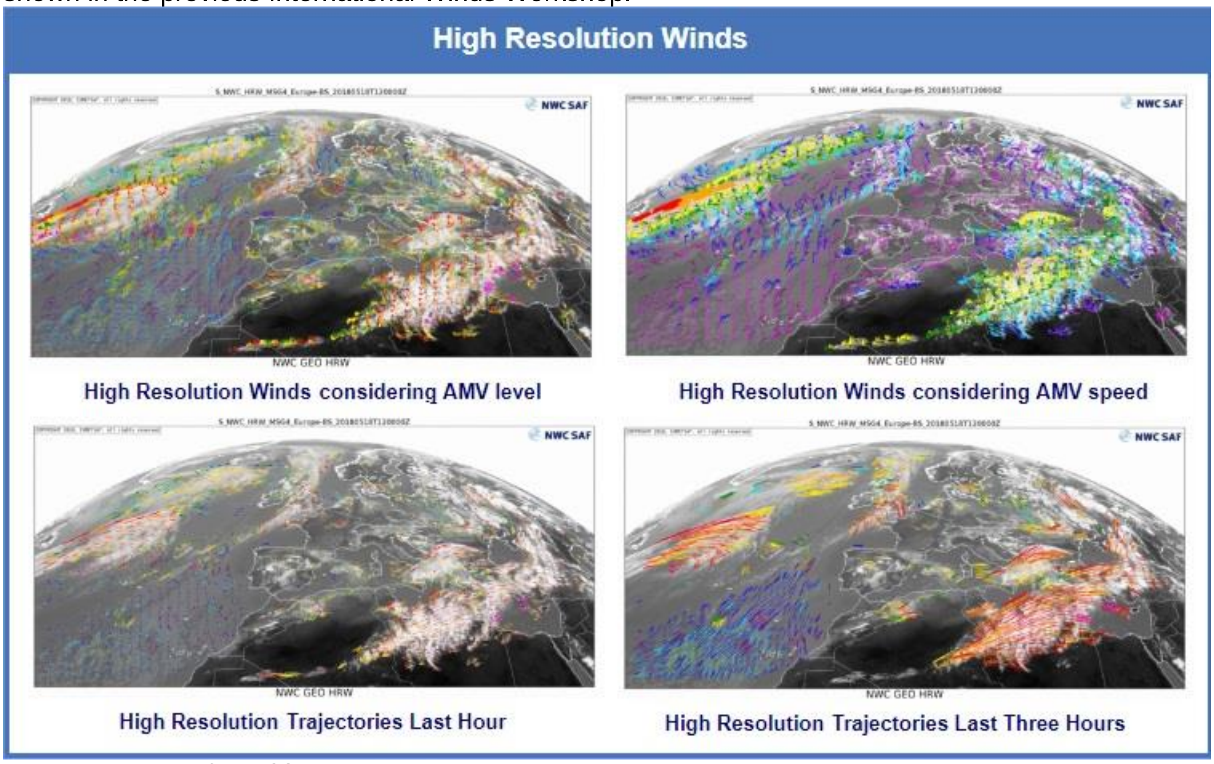
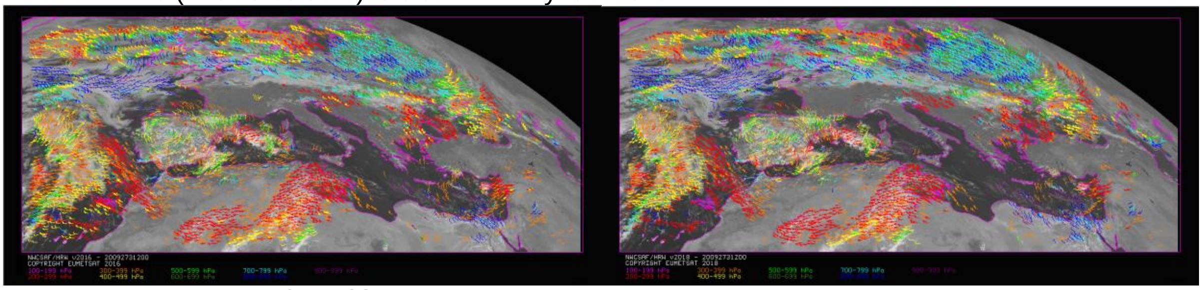



***Figure 1:*** **Example of "NWCSAF/HRW v2016" outputs, such as displayed in near real time at www.nwcsaf.org webpage, for 18th May 2018 at 13:00Z, for MSG-2 satellite in the European and Mediterranean region.**

## NWCSAF/HIGH RESOLUTION WINDS v2018

"High Resolution Winds v2018" is now being prepared for release in the autumn 2018. The main improvements for this version are:

1. The calculation of more AMVs at low levels. This change was defined from a requirement from the users, and is obtained reducing to a half the separation of tracers related to very low and low clouds. Comparing this example of HRW v2016 (left) and v2018 (right), the higher density of low level AMVs (in blue colours) is clear in many locations:



***Figures 2 and 3:*** **Examples of "NWCSAF/HRW v2016 (left) and v2018 (right)" outputs for 30th September 2009 at 12:00Z, for MSG-2 satellite in the European and Mediterranean region.**

Comparing in Figures 4 and 5 the AMV statistics against radiosounding winds for HRW v2016 and v2018 (for MSG-2 satellite AMVs in the European and Mediterranean region in the period July 2009 to June 2010):

- There is an absolute increase of low level AMVs, and a relative increase of low level AMVs (from a 14% to a 23%).
- The process is a bit slower, with the total number of AMVs reducing a bit (a 24%).
- Considering the validation statistics, they are basically the same for the three layers, with a slight reduction in the Normalized bias (NBIAS).

| HRW v2016 | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Clear | High | Medium | Low |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MSG | HRVIS | VIS06 | VIS08 | WV062 | WV073 | IR108 | IR120 | air | Layer | Layer | Layer |
| NC | 31630 | 97221 | 87177 | 256951 | 331831 | 313072 | 317120 | 48509 | 909334 | 366412 | 207765 |
| SPD [m/s] | 16.65 | 10.51 | 10.49 | 22.79 | 20.81 | 18.53 | 18.68 | 16.64 | 22.48 | 14.35 | 9.88 |
| NBIAS | -0.04 | -0.15 | -0.15 | -0.05 | -0.08 | -0.10 | -0.09 | 0.00 | -0.07 | -0.10 | -0.12 |
| NMVD | 0.29 | 0.42 | 0.42 | 0.27 | 0.29 | 0.29 | 0.29 | 0.33 | 0.27 | 0.37 | 0.43 |
| NRMSVD | 0.35 | 0.49 | 0.50 | 0.33 | 0.35 | 0.36 | 0.36 | 0.40 | 0.32 | 0.45 | 0.50 |

| HRW v2018 | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Clear | High | Medium | Low |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MSG | HRVIS | VIS06 | VIS08 | WV062 | WV073 | IR108 | IR120 | air | Layer | Layer | Layer |
| NC | 68289 | 100053 | 90999 | 142240 | 232897 | 231234 | 233810 | 20710 | 581415 | 282704 | 256113 |
| SPD [m/s] | 12.91 | 10.30 | 10.27 | 22.87 | 20.24 | 17.60 | 17.82 | 17.48 | 22.28 | 13.96 | 9.81 |
| NBIAS | -0.03 | -0.13 | -0.14 | -0.03 | -0.06 | -0.09 | -0.08 | 0.02 | -0.06 | -0.09 | -0.10 |
| NMVD | 0.35 | 0.42 | 0.42 | 0.27 | 0.29 | 0.30 | 0.30 | 0.30 | 0.27 | 0.37 | 0.43 |
| NRMSVD | 0.42 | 0.49 | 0.50 | 0.33 | 0.36 | 0.37 | 0.37 | 0.37 | 0.33 | 0.45 | 0.50 |

***Figures 4 and 5:*** **Validation statistics against radiosounding winds for NWCSAF/HRW v2016 (up) and v2018 (below). Basic scale AMVs for MSG-2 satellite in the European and Mediterranean region, for the period July 2009-June 2010, are considered. Statistics for the different satellite channels shown in black, and for the three atmospheric layers shown in red: high layer (100-400 hPa), medium layer (400-700 hPa), and low layer (700-1000 hPa). (NC: Number of collocations; SPD: Mean radiosounding wind speed in m/s; NBIAS: Normalized bias; NMVD: Normalized mean vector difference; NRMSVD: Normalized root mean square vector difference).**

2. The adaptation of HRW algorithm to Himawari-8/9 satellite series, with AMVs extracted from 0.6 μm visible channel (with 0.5 km resolution), 0.8 μm visible channel (with 1.0 km resolution), 11.2 μm infrared channel (with 2.0 km resolution), and 6.2 μm, 6.9 μm, 7.3 μm water vapour channels (with 2.0 km resolution).
   All processes for AMV extraction are equivalent to those for MSG, using "CCC method with Microphysics correction" as height assignment. A retuning of the microphysics correction has been done for Himawari, due to differences in the NWCSAF/Cloud products for MSG and Himawari.

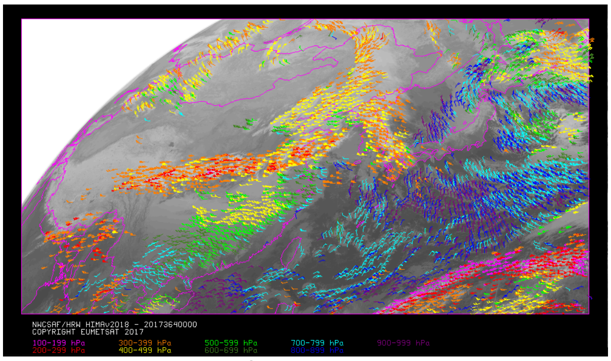


***Figure 6:*** **Example of "NWCSAF/HRW v2018" output for 30th December 2017 at 00:00Z, for Himawari-8 satellite in the China-Korea-Japan region.**

Considering in Figure 7 the statistics against radiosounding winds for Himawari-8 AMVs (in the China-Korea-Japan region for the period November 2017 to February 2018), and comparing them with the statistics for MSG-2 AMVs in Figure 5:

> There is a significant improvement of all validation parameters at the high and medium layers, with the NBIAS reducing to zero and the Normalized mean vector difference (NMVD) and Normalized root mean square vector difference (NRMSVD) reducing a 15%-30%.

> There is a slight worsening of all validation parameters at the low layer, with the NBIAS increasing a 30% and the NMVD and NRMSVD increasing a 5%.

With these values, HRW AMVs are considered fully operational for Himawari satellites, inside the "Optimal accuracy" for high and medium layers, and inside the "Target accuracy" for the low layer.

| HRW v2018 Himawari | Cloudy VIS06 | Cloudy VIS08 | Cloudy WV062 | Cloudy WV069 | Cloudy WV073 | Cloudy IR112 | Clear Air | High Layer | Medium Layer | Low Layer |
|---|---|---|---|---|---|---|---|---|---|---|
| NC | 6029 | 13504 | 51000 | 87276 | 116298 | 122598 | 27756 | 219119 | 152062 | 53280 |
| SPD [m/s] | 32.77 | 25.91 | 39.94 | 35.02 | 32.13 | 27.22 | 38.28 | 41.43 | 26.56 | 12.39 |
| NBIAS | 0.01 | 0.01 | 0.02 | 0.02 | -0.02 | -0.02 | -0.02 | 0.00 | 0.01 | -0.13 |
| NMVD | 0.19 | 0.23 | 0.20 | 0.23 | 0.24 | 0.27 | 0.23 | 0.19 | 0.31 | 0.44 |
| NRMSVD | 0.24 | 0.28 | 0.25 | 0.28 | 0.30 | 0.34 | 0.29 | 0.24 | 0.39 | 0.53 |

***Figure 7:*** **Validation statistics against radiosounding winds for NWCSAF/HRW v2018. Basic scale AMVs for Himawari-8 satellite in the China-Korea-Japan region, for the period November 2017-February 2018, are considered. Statistics for the different satellite channels shown in black, and for the three atmospheric layers shown in red: high layer (100-400 hPa), medium layer (400-700 hPa), and low layer (700-1000 hPa). (NC: Number of collocations; SPD: Mean radiosounding wind speed in m/s; NBIAS: Normalized bias; NMVD: Normalized mean vector difference; NRMSVD: Normalized root mean square vector difference).**

3. <u>The option for a "Mixed scanning processing"</u>, considering at the same time short and long time intervals (for example, with Rapid scan and Nominal scan processes). Small intervals of time between the initial and final image increase the amount of AMVs and the quality of the tracking process, due to the smaller changes in the tracers. But this way, problems occur with the calculation of the displacement, due to the spatial resolution of the images (where often displacements can be smaller than a pixel).

The situation is much better verifying the tracking process with short time intervals (for example 5 minutes for MSG, and 2.5 minutes for Himawari), and calculating the displacement of the AMVs with long time intervals (for example 15 minutes for MSG, and 10 minutes for Himawari).

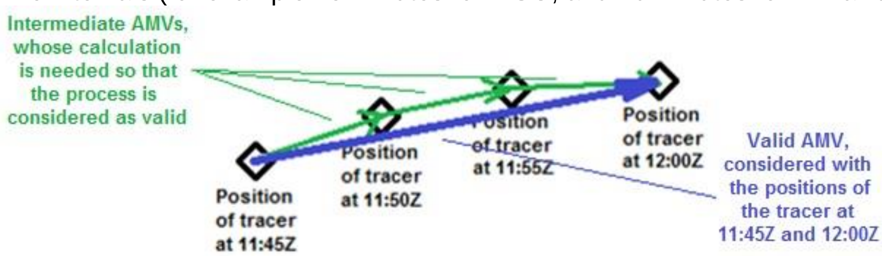



***Figure 8:*** **Schema for the AMV calculation, using the "mixed scanning processing", with Rapid scan and Nominal scan with MSG satellites. The tracking process of the tracer is verified every 5 minutes, while the AMV is calculated considering the positions of the tracer every 15 minutes.**

<u>4. The inclusion of the "IWWG Common Quality Control module"</u>, as additional parameter in the HRW outputs, for homogenization with the rest of AMV products.
Three "Quality indices" are so provided for each AMV: the "HRW Quality index with forecast", the "HRW Quality index without forecast", and the "IWWG Common Quality index without forecast".
The "AMV Intercomparison" done for this International Winds Workshop shows that this parameter has a real skill to increase the homogeneity between AMVs from different centres. However, it has to be used with care, because its value distribution has shown to be very limited.

<u>5. The auto-validation of the calculated AMVs during the running of HRW algorithm</u>, using NWP model forecast or analysis winds at the AMV level and best fit level as references. Here, it is to be taken into account that in general NWP analysis winds will not be available for real time tasks.
This information can be very useful for the processing of HRW data. Statistics are provided for the whole AMV dataset, the different layers and the different satellite channels (as configured by the user) and the corresponding information on the "NWP wind at the AMV level" and the "NWP wind at the best fit level" are stored with the AMV outputs for further processing of the AMV statistics.

```
HRWDATE:20171102T000000Z NWPCONF:ANA *** AMV:BAS       CHA:TOTAL LAY:ALL *** NC: 20052 SPD[M/S]:22.290 NBIAS:+0.066 NMVD:0.198 NRMSVD:0.250
HRWDATE:20171102T000000Z NWPCONF:ANA *** AMV:BASCLEAR CHA:TOTAL LAY:ALL *** NC:  1952 SPD[M/S]:23.901 NBIAS:-0.042 NMVD:0.220 NRMSVD:0.267
HRWDATE:20171102T000000Z NWPCONF:ANA *** AMV:BASCLOUD CHA:VIS06 LAY:ALL *** NC:   483 SPD[M/S]:23.689 NBIAS:+0.053 NMVD:0.164 NRMSVD:0.203
HRWDATE:20171102T000000Z NWPCONF:ANA *** AMV:BASCLOUD CHA:VIS08 LAY:ALL *** NC:  1285 SPD[M/S]:16.443 NBIAS:+0.096 NMVD:0.211 NRMSVD:0.268
HRWDATE:20171102T000000Z NWPCONF:ANA *** AMV:BASCLOUD CHA:IR112 LAY:ALL *** NC:  5490 SPD[M/S]:18.687 NBIAS:+0.074 NMVD:0.211 NRMSVD:0.267
HRWDATE:20171102T000000Z NWPCONF:ANA *** AMV:BASCLOUD CHA:WV062 LAY:ALL *** NC:  2241 SPD[M/S]:27.804 NBIAS:+0.077 NMVD:0.169 NRMSVD:0.214
HRWDATE:20171102T000000Z NWPCONF:ANA *** AMV:BASCLOUD CHA:WV069 LAY:ALL *** NC:  3648 SPD[M/S]:24.710 NBIAS:+0.087 NMVD:0.195 NRMSVD:0.248
HRWDATE:20171102T000000Z NWPCONF:ANA *** AMV:BASCLOUD CHA:WV073 LAY:ALL *** NC:  4953 SPD[M/S]:22.750 NBIAS:+0.078 NMVD:0.196 NRMSVD:0.245
```

***Figure 9:*** **Example of AMV statistics shown in the HRW log file for each running of HRW v2018 product (for Himawari satellite AMVs, against NWP analysis winds).**

<u>6. The parallax correction in the position and displacement of the AMVs</u>. With this, there is a general reduction of the speed of the AMVs, but the consequences are more formal than real: the reduction is smaller than a 3% always, and smaller than a 1% in the 99% of cases.

<u>7. The simplification of the HRW algorithm running files and configuration parameters</u>, reducing the number of default HRW configuration files to one per satellite series only.

<u>8. The implementation of the new "IWWG AMV BUFR output"</u>, for homogenization with the rest of AMV products.
The HRW output to be provided, is to be configured by the NWCSAF user: up to four output options can be defined in parallel for the same running of HRW algorithm. This way, the user of HRW v2018 will decide very easily when to change its HRW output to the new "IWWG AMV BUFR" output.

<u>9. The parallelization of HRW code</u>. The processing times of HRW algorithm increase visibly with the new satellite series, and especially with the new "very high resolution satellite channels". The parallelization will allow to reduce the processing times, if the user has the corresponding computer resources.
The process will be done considering the largest reductions in the processing times with the least changes in HRW code.

To be developed later, for release in the first half of 2019:
<u>10. The adaptation of HRW algorithm to GOES-R/S satellite series</u>.
The adaptation is to be very similar to the one for Himawari, using equivalent satellite channels (VIS06, VIS08, WV062, WV070, WV074, IR112). It will be released after full AMV validation.
This way, NWCSAF/HRW product will be able in 2019 to run operationally for the first time all around the planet Earth, with 5 geostationary satellites: 2 MSGs over Europe/Africa and West Asia, Himawari over East Asia, and GOES-R and -S over the Americas.

## NWCSAF/HIGH RESOLUTION WINDS LATER UP TO 2022

For the period 2019-2022, next activity will be the main objective:
<u>The version “day 1” of NWCSAF/HRW, for MTG-Imager satellite series (in 2021-2022).</u>

The experience of HRW algorithm with Himawari and GOES-R/S satellites series will be very helpful for this adaptation. Currently, the main difficulties are expected to be related to the optimal use for the AMV extraction of the high resolution visible channels (trying to optimize the AMV densities and the processing times), and to the improvement of the AMVs at the low layer (trying to make their statistics more similar to those of high and medium layers).

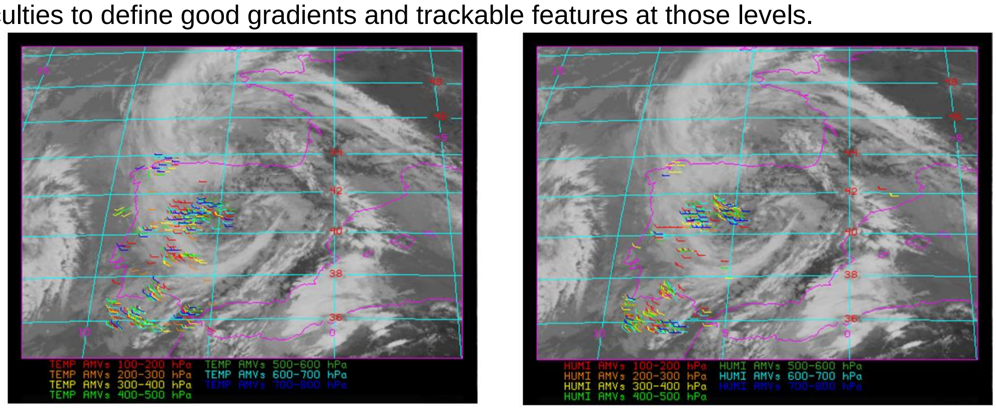
About the extension of HRW algorithm to other options with GEO satellites (the extension to other GEO satellite series or the integration of other methods developed for other AMV algorithms), specific resources are at this moment not allocated for that up to 2022. A suggestion of collaboration with other institutions is being made here to integrate these options inside HRW algorithm. The financing of these tasks is even possible through the NWCSAF Visiting Scientist Activities.

Several suggestions have also been received for the extension of HRW algorithm to run with polar satellites (inside the parallel NWCSAF/PPS software package). The cause for this is that user requirements evolve for a quick calculation of polar AMVs in hourly cyclings.
This adaptation would be reasonable: both HRW-GEO and HRW-PPS would be based on NWCSAF/Clouds, with similar outputs. For maintenance reasons, it would be important that there would be an only HRW code, integrated in both software packages.
This is now not in NWCSAF plan, although an analysis of this is currently done inside the NWCSAF Project Team. The plan can be changed through the interest shown by the IWWG for this adaptation of HRW product to polar satellites, such as expressed by the “Working Group 2” of this International Winds Workshop in their meeting.

## RETRIEVAL OF AMVS WITH MTG-S/IRS SOUNDER INSTRUMENT

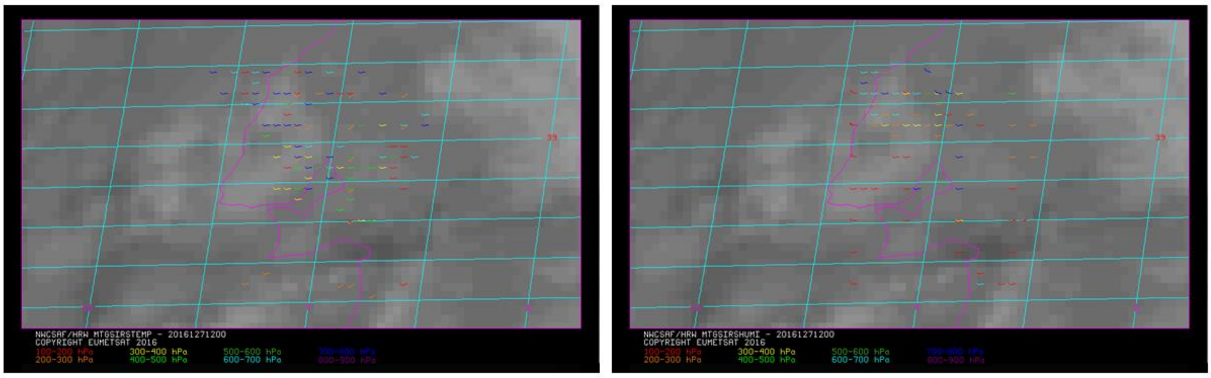
NWCSAF will also develop a specific NWCSAF/GEO-S software package, for the processing of the “Infrared Sounder Instrument (IRS)” on board MTG-S sounder satellites (operational in 2023 or later).
The work will be based on contributions by Miguel Ángel Martínez, Xavier Calbet and Javier García-Pereda. NWCSAF/GEO-S software package will include the retrieval of winds in a version for “day 2”.

A study was done in 2017 for AMV extraction from proxy data from IASI for MTG-S L2 vertical temperature and moisture profiles. The conclusions of the study were: it is possible to extract AMVs from these temperature and moisture fields at medium and low levels (400-1000 hPa), but it is much more difficult to obtain representative AMVs at high levels due to the low values of specific humidity, and difficulties to define good gradients and trackable features at those levels.




***Figures 10 and 11:*** **Example of AMVs extracted from constant level temperature fields (left) and constant level humidity fields (right), defined as proxy data for MTG-S/IRS sounder profiles, in the area around the Iberian peninsula, for 6th May 2016 at 12:00Z.**

There is besides a real option to obtain AMV profiles in some locations (i.e., AMVs at all high, medium and low layers), giving the option to calculate wind shear in these locations. But the horizontal density of AMV profiles is clearly not homogeneous, which is a general property of all AMV datasets used up to now which never denied their usability.




***Figures 12 and 13:*** **Example of the corresponding AMV profiles, extracted from the constant level temperature fields (left) and constant level humidity fields (right) defined in Figures 10 and 11, in the vicinity of Lisbon (Portugal), for 6th May 2016 at 12:00Z.**

These data would provide additional meteorological information, useful for analysis and forecasting, beyond the one provided by AMVs calculated with satellite images. But they would be complementary information, and would not substitute AMVs calculated with satellite images (or wind data and profiles obtained with other schemes like “Optical flow” by Olivier Hautecoeur at EUMETSAT or Miguel Ángel Martínez at NWCSAF).

## HIGH RESOLUTION WINDS AS “STAND ALONE AMV CALCULATION SOFTWARE”

Due to its characteristics and its ease to be obtained, understood and run locally, NWCSAF/High Resolution Winds product was proposed in previous International Winds Workshops as “Stand alone AMV calculation software”, available to all AMV researchers and users.

Its good validation results by independent studies (the 2014 AMV Intercomparison with MSG, and the current AMV Intercomparison with Himawari), should be enough to convince any researchers about the use of NWCSAF/HRW product.

In case of interest on using NWCSAF software packages and its products, all National Meteorological Services within Eumetsat Member or Cooperating States are automatically considered as potential users. Any other organisation may also apply to become user of it.

Up to now all applicants have become users of NWCSAF software without any restrictions: national meteorological services, universities, research institutions, public service providers, public and private companies, and individual users from all around the world (Europe, Americas, Africa, Asia).

To become a user of NWCSAF software package, and for any further questions or suggestions on NWCSAF/HRW algorithm, please contact the NWCSAF Helpdesk webpage (http://www.nwcsaf.org) or the NWCSAF/High Resolution Winds developer Javier García-Pereda (jgarciap@aemet.es).

## REFERENCES

The NWCSAF Helpdesk, with general information on the "Satellite Application Facility on support to Nowcasting and Very short range forecasting", its software packages and products: www.nwcsaf.org.


***Figure 11:*** **Home page of the NWCSAF Helpdesk at www.nwcsaf.org**

Documentation of "NWCSAF/High Resolution Winds (HRW) v2018" software, available at the NWCSAF Helpdesk www.nwcsaf.org (at Science > Scientific Documentation) once it becomes official:

1. García-Pereda, J., 2018a: Algorithm Theoretical Basis Document for the Wind product processors of the NWC/GEO. NWC SAF Document NWC/CDOP3/GEO/AEMET/SCI/ATBD/Wind
2. García-Pereda, J., 2018b: User Manual for the Wind product processors of the NWC/GEO: Science part. NWC SAF Document NWC/CDOP3/GEO/AEMET/SCI/UM/Wind.
3. García-Pereda, J., 2018c: Scientific and Validation Report for the Wind product processors of the NWC/GEO. NWC SAF Document NWC/CDOP3/GEO/AEMET/SCI/VR/Wind.

Other presentations at the International Winds Workshops with relevant information:

4. García-Pereda, J. and R. Borde, 2012: NWC SAF High Resolution Winds (HRW) as Stand alone AMV calculation software. Proceedings, *11th International Winds Workshop, Auckland, New Zealand.*
5. Santek, D., J. García-Pereda, C. Velden, I. Genkova, D. Stettner, S. Wanzong, S. Nebuda and M. Mindock, 2014: A New Atmospheric Motion Vector Intercomparison Study. Proceedings, *12th International Winds Workshop, Copenhagen, Denmark.*
6. Santek, D., R. Dworak, S. Wanzong, K. Winiecki, S. Nebuda, J. García-Pereda, R. Borde and M. Carranza, 2018: Third Atmospheric Motion Vector Intercomparison Study. Proceedings, *14th International Winds Workshop, Jeju, Korea.*