EUMETSAT NWC SAF

SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING

Scientific and Validation Report for the Wind product processor of the NWC/GEO (MTG-I day-1)

NWC/CDOP4/MTG/AEMET/SCI/VR/Wind, Issue 1 Rev. 0.1

30 May 2025

Applicable to NWC/GEO-HRW-v7.0 (NWC-039)
(NWC/GEO-HRW MTG-I day-1)

Prepared by Agencia Estatal de Meteorología (AEMET)

REPORT SIGNATURE TABLE

Function	Name	Signature	Date
Prepared by	Javier García Pereda, AEMET		*30 May 2025*
Reviewed by	Pilar Rípodas & Llorenç Lliso, AEMET (NWCSAF Project Managers) NWC/GEO MTG-I day-1 ORR-2 Review Board		*30 May 2025*
Endorsed by	NWCSAF Steering Group		*30 May 2025*
Authorised by	Pilar Rípodas & Llorenç Lliso, AEMET (NWCSAF Project Managers)		*30 May 2025*

DOCUMENT CHANGE RECORD

Version	Date	Pages	Changes
1.0.0	*31 March 2025*	55	Version for NWC/GEO-HRW v7.0 in NWC/GEO v2025 (vMTG-I day-1)
1.0.1	*30 May 2025*	55	Reviewed version for NWC/GEO-HRW v7.0 in NWC/GEO v2025 (vMTG-I day-1), after Operational Readiness Review 2 (ORR-2)

TABLE OF CONTENTS

1. INTRODUCTION 10

1.1 SCOPE OF THE DOCUMENT 10
1.2 SOFTWARE VERSION IDENTIFICATION 11
1.3 IMPROVEMENTS FROM PREVIOUS VERSION 11
1.4 REFERENCES 12
1.4.1 Applicable Documents 12
1.4.2 Reference Documents 13

2. DESCRIPTION OF THE VALIDATION PROCEDURE 14

2.1 VALIDATION PROCEDURE 14
2.2 STATISTICAL PARAMETERS 16

3. VALIDATION OF HRW V7.0 AMVS WITH MSG SATELLITES 18

3.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION 18
3.2 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION 20
3.3 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION 22
3.4 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION 24

4. VALIDATION OF HRW V7.0 AMVS WITH MTG-I SATELLITES 26

4.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION 26
4.2 COMPARISON WITH HRW V7.0 AMVS WITH MSG SATELLITES 28
4.3 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION 30
4.4 COMPARISON WITH HRW V7.0 AMVS WITH MSG SATELLITES 32
4.5 MAIN DIFFERENCES IN AMVS FROM MSG AND MTG-I SATELLITES 34

5. VALIDATION OF HRW V7.0 AMVS WITH HIMAWARI-8/9 SATELLITES 37

5.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION 37
5.2 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION 39
5.3 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION 41
5.4 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION 43
5.5 COMPARISON WITH MTG-I SATELLITE SERIES 45

6. VALIDATION OF HRW V7.0 AMVS WITH GOES-R SATELLITES 46

6.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION 46
6.2 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION 48
6.3 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION 50
6.4 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION 52
6.5 COMPARISON WITH MTG-I SATELLITE SERIES 54

7. CONCLUSIONS 55

List of Tables

Table 1. List of Applicable Documents 12

Table 2. List of Reference Documents 13

Table 3. Description of McIDAS WDMR Scheme and Correspondence with NWC/GEO-HRW "NWC" BUFR output 15

Table 4: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Basic AMVs 19

Table 5: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Basic AMVs 19

Table 6: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; CCC height assignment with Microphysics) 21

Table 7: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; CCC height assignment with Microphysics) 21

Table 8: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs 23

Table 9: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs 23

Table 10: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering all layers together against Radiosounding winds (green) and ECMWF NWP analysis winds (blue) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; CCC height assignment with Microphysics) 25

Table 11: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering three separate layers against Radiosounding winds (green) and ECMWF NWP analysis winds (blue) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; CCC height assignment with Microphysics) 25

*Table 12: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (9 Oct 2024-8 Feb 2025 12:00 UTC, Meteosat-12 (MTG-I1) satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Dark green figures show an improvement of at least 50% and light green figures of at least 10%, and dark red figures show a worsening of at least 50% and light red figures of at least 10%, with respect to NWC/GEO-HRW v7.0 Basic AMVs for Meteosat-10 satellite in the same period and region*27

*Table 13: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (9 Oct 2024-8 Feb 2025 12:00 UTC, Meteosat-12 (MTG-I1) satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Dark green figures show an improvement of at least 50% and light green figures of at least 10%, and dark red figures show a worsening of at least 50% and light red figures of at least 10%, with respect to NWC/GEO-HRW v7.0 Basic AMVs for Meteosat-10 satellite in the same period and region*27

Table 14: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-10 satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) 29

Table 15: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-10 satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics).....29

Table 16: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-12 (MTG-I1) satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Dark green figures show an improvement of at least 50% and light green figures of at least 10%, and dark red figures show a worsening of at least 50% and light red figures of at least 10%, with respect to NWC/GEO-HRW v7.0 Detailed AMVs for Meteosat-10 satellite in the same period and region.....31

Table 17: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-12 (MTG-I1 satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Dark green figures show an improvement of at least 50% and light green figures of at least 10%, and dark red figures show a worsening of at least 50% and light red figures of at least 10%, with respect to NWC/GEO-HRW v7.0 Detailed AMVs for Meteosat-10 satellite in the same period and region.....31

Table 18: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-10 satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) 33

Table 19: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-10 satellite; European and

Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) 33

Table 20: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering 100 hPa wide layers, for Meteosat-12 (MTG-I1) satellite (left) and Meteosat-10 satellite (right), against Radiosounding winds (up) and ECMWF NWP analysis winds (down) (9 Oct 2024-8 Feb 2025 12:00 UTC; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Dark green figures show an improvement of at least 50% and light green figures of at least 10%, and dark red figures show a worsening of at least 50% and light red figures of at least 10%, for Meteosat-12 (MTG-I1) AMVs with respect to Meteosat-10 AMVs in the same period and region 36

Table 21: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to equivalent NWC/GEO-HRW v6.2 Basic AMVs 38

Table 22: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to equivalent NWC/GEO-HRW v6.2 Basic AMVs 38

Table 23: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; CCC height assignment with Microphysics) 40

Table 24: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; CCC height assignment with Microphysics) 40

Table 25: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs ... 42

Table 26: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs 42

Table 27: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; CCC height assignment with Microphysics) 44

Table 28: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; CCC height assignment with Microphysics) 44

Table 29: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Basic AMVs 47

Table 30: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Basic AMVs 47

Table 31: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; CCC height assignment with Microphysics) 49

Table 32: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; CCC height assignment with Microphysics).....49

Table 33: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs 51

Table 34: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics). Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs 51

Table 35: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; CCC height assignment with Microphysics) 53

Table 36: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; CCC height assignment with Microphysics).....53

Table 37: Evolution of Validation statistics between NWC/GEO-HRW v6.2 and v7.0 versions related to the Operative thresholds defined in the NWC/GEO-HRW Product Requirement Table 55

List of Figures

Figure 1: NWC/GEO-High Resolution Winds v7.0 Basic AMV output example in the European and Mediterranean region (24 January 2025 12:00 UTC, Meteosat-10 satellite), considering default conditions in `$SAFNWC/config/MSG*/safnwc_HRW.cfm` model configuration file. Colour coding based on the AMV pressure level 18

Figure 2: NWC/GEO-High Resolution Winds v7.0 Detailed AMV output example in the European and Mediterranean region (24 January 2025 12:00 UTC, Meteosat-10 satellite), considering default conditions in `$SAFNWC/config/MSG*/safnwc_HRW.cfm` model configuration file and configurable parameter CDET = 1. Colour coding based on AMV pressure level ... 22

Figure 3: NWC/GEO-High Resolution Winds v7.0 Basic AMV output example in the European and Mediterranean region (24 January 2025 12:00 UTC, Meteosat-12 (MTG-I1) satellite data), considering default conditions in `$SAFNWC/config/MTI*/safnwc_HRW.cfm` model configuration file. Colour coding based on the AMV pressure level 26

Figure 4: NWC/GEO-High Resolution Winds v7.0 Detailed AMV output example in the European and Mediterranean region (24 January 2025 12:00 UTC, Meteosat-12 (MTG-I1) satellite data), considering default conditions in `$SAFNWC/config/MTI*/safnwc_HRW.cfm` model configuration file and configurable parameter CDET = 1. Colour coding based on the AMV pressure level 30

Figure 5: Comparison of NWC/GEO-High Resolution Winds v7.0 Basic AMV output for 24 December 2024 12:00 UTC for Meteosat-10 satellite (left) and Meteosat-12 (MTG-I1) satellite (right) around a low pressure area over the Ionian Sea 35

Figure 6: Comparison of NWC/GEO-High Resolution Winds v7.0 Basic AMV output for 6 December 2024 12:00 UTC for Meteosat-10 satellite (left) and Meteosat-12 (MTG-I1) satellite (right) in the Eastern European region 35

Figure 7: Comparison of NWC/GEO-High Resolution Winds v7.0 Basic AMV output for 31 October 2024 12:00 UTC for Meteosat-10 satellite (left) and Meteosat-12 (MTG-I1) satellite (right) in the region around the Bay of Biscay 35

Figure 8: Comparison of NWC/GEO-High Resolution Winds v7.0 Basic AMV output for 20 December 2024 12:00 UTC for Meteosat-10 satellite (left) and Meteosat-12 (MTG-I1) satellite (right) in Central Europe and Italy 36

Figure 9: NWC/GEO-High Resolution Winds v7.0 Basic AMV output example in the China/Korea/Japan region (6 April 2023 00:00 UTC, Himawari-9 satellite), considering default conditions in `$SAFNWC/config/HIMA*/safnwc_HRW.cfm` model configuration file. Colour coding based on the AMV pressure level 37

Figure 10: NWC/GEO-High Resolution Winds v7.0 Detailed AMV output example in the China/Korea/Japan region (6 April 2023 00:00 UTC, Himawari-9 satellite), considering default conditions in `$SAFNWC/config/HIMA*/safnwc_HRW.cfm` model configuration file and configurable parameter CDET = 1. Colour coding based on the AMV pressure level 41

Figure 11: NWC/GEO-High Resolution Winds v7.0 Basic AMV output example in the Continental United States region (11 June 2019 12:00 UTC, GOES-16 satellite), considering default conditions in `$SAFNWC/config/GOES*/safnwc_HRW.cfm` model configuration file. Colour coding based on the AMV pressure level 46

Figure 12: NWC/GEO-High Resolution Winds v7.0 Detailed AMV output example in the Continental United States region (11 June 2019 12:00 UTC, GOES-16 satellite), considering default conditions in `$SAFNWC/config/GOES*/safnwc_HRW.cfm` model configuration file and configurable parameter CDET = 1. Colour coding based on the AMV pressure level 50

1. INTRODUCTION

The "EUMETSAT Satellite Application Facilities (SAFs)" 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 (NWCSAF)".

The main objective of the NWCSAF 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 NWCSAF webpage, https://nwc-saf.eumetsat.int.

This document is applicable to the adaptation of NWC/GEO software package for geostationary satellites to MTG-I satellite series: NWC/GEO v2025 (vMTG-I day-1).

1.1 SCOPE OF THE DOCUMENT

This document is the "Scientific and Validation Report for the Wind Product Processor of the NWC/GEO vMTG-I day-1" software package, herein called NWC/GEO-HRW - High Resolution Winds, which calculates Atmospheric Motion Vectors and Trajectories considering:

- Up to six channels from MTG-I/FCI imager: four 2 km low resolution water vapour and infrared channels (WV063 6.300 μm, WV073 7.350 μm, IR105 10.500 μm and IR123 12.300 μm), and two 1 km high resolution visible channels (VIS06 0.640 μm and VIS08 0.865 μm).
- Up to seven channels from MSG/SEVIRI imager: six 3 km low resolution visible, water vapour and infrared channels (VIS06 0.635 μm, VIS08 0.810 μm, WV062 6.250 μm, WV073 7.350 μm, IR108 10.800 μm and IR120 12.000 μm), and the 1 km high resolution visible channel (HRVIS 0.750 μm).
- Up to six channels from Himawari-8/9/AHI imager: four 2 km low resolution water vapour and infrared channels (WV062 6.250 μm, WV069 6.950 μm, WV073 7.350 μm and IR112 11.200 μm), one 1 km high resolution visible channel (VIS08 0.860 μm), and the 0.5 km very high resolution visible channel (VIS06 0.645 μm).
- Up to six channels from GOES-R/ABI imager: four 2 km low resolution water vapour and infrared channels (WV062 6.150 μm, WV070 7.000 μm, WV074 7.400 μm and IR112 11.200 μm), one 1 km high resolution visible channel (VIS08 0.860 μm), and the 0.5 km very high resolution visible channel (VIS06 0.640 μm). The adaptation to GOES-R satellite series is available for GOES-16, GOES-17, GOES-18 and GOES-19 satellites, considering Full Disk images in "Mode 6" (images every 10 minutes), for areas in the image where NWC/GEO-Cloud products could be calculated and the quality flag for the satellite channel used for the AMV calculation is zero (optimal) for all pixels implied in the AMV calculation. This way the problems related to the cooling issue in the GOES-17 ABI imager are avoided.

With all this, NWC/GEO-HRW vMTG-I day-1 is able to cover with five different simultaneous geostationary satellites the whole Earth, and AMVs and Trajectories can be calculated simultaneously throughout the whole planet.

NWC/GEO-HRW algorithm adaptation to MSG, Himawari-8/9 and GOES-R was already implemented and validated at previous versions of NWC/GEO up to NWC/GEO v2021. The principal task of NWC/GEO v2025 (vMTG-I day-1) is the adaptation and full validation of NWC/GEO-HRW algorithm to MTG-Imager satellite series.

This Scientific and Validation Report describes the validation results for the four mentioned satellite series for NWC/GEO-HRW v7.0 inside NWC/GEO v2025 (vMTG-I day-1) software package.

As in previous versions of NWC/GEO-HRW, the validation has been based on the comparison of the NWC/GEO-HRW AMVs with winds obtained from Radiosounding bulletins available from the GTS. The statistical indicators established in the "Report from the Working Group on Verification Statistics of the 3rd International Winds Workshop" [RD.12], with some amendments in the "Report from the Working Group on Verification & Quality Indices of the 4th International Winds Workshop" [RD.15]), are calculated to achieve this. These indicators have been thoroughly used throughout the world for the Validation of Satellite winds through the comparison with Radiosounding winds.

Since NWC/GEO-HRW v6.0 in NWC/GEO v2018, AMVs are also validated using ECMWF model analysis winds as additional reference. This permits to evaluate differences in behaviour and scale of NWC/GEO-HRW AMVs with respect to both reference winds.

A comparison with the default configuration of previous version NWC/GEO-HRW v6.2 in NWC/GEO v2021 software package (for AMVs related to MSG, Himawari-8/9 and GOES-R satellite series) is verified to show the improvements of NWC/GEO-HRW product since this version. A specific comparison of the results between MSG and MTG-I in a similar period and region is also shown to check the differences in the AMV output with both satellite series.

1.2 SOFTWARE VERSION IDENTIFICATION

This document describes the algorithm implemented in NWC/GEO-HRW v7.0, Product Id NWC-039, in NWC/GEO v2025 (vMTG-I day-1) software package release.

1.3 IMPROVEMENTS FROM PREVIOUS VERSION

The main changes related to NWC/GEO-HRW v7.0 in NWC/GEO v2025 (vMTG-I day-1) software package with respect to the previous version (NWC/GEO-HRW v6.2 in NWC/GEO v2021 software package) are the following ones.

Specific to NWC/GEO-HRW v7.0:

1. The structure of the NWC/GEO-HRW netCDF outputs changes between these two versions. In NWC/GEO-HRW v7.0, the structure of the netCDF outputs (with two different files for NWC/GEO-HRW AMVs and Trajectories) is "CF compliant" and easier to process (following the recommendations from NWCSAF users).
2. The update from BUFRDC to ECCODES library for the writing of NWC/GEO-HRW BUFR output files (as recommended by ECMWF).
3. NWC/GEO-HRW v7.0 does not provide anymore as output the BUFR bulletin based on the "previous International Winds Working Group (IWWG) format". This format is replaced by the BUFR bulletin based on the "2018 IWWG format". The IWWG gave AMV producers and users the recommendation in its 2018 Workshop to adopt this new AMV BUFR template (through action IWW14 – WG1 – Action 6) within one year after the definition of this new format, and in 2025 all AMV users should already be used to the new format.

Common to all NWC/GEO vMTG day-1 products:

4. The extension of NWC/GEO-HRW processing to the MTG-I (MTG-Imager) satellite series.
5. NWC/GEO-HRW does not support GOES-N satellite series anymore. Processing in the Americas and Eastern Pacific is only provided through GOES-R satellite series.
6. The definition of the Earth ellipsoid changes for the different satellites in NWC/GEO vMTG day-1 software package, being defined as configurable parameters in different configuration files. In NWC/GEO v2021 software package, these parameters were similar for all satellites, so causing some small differences in the satellite navigation.
7. The structure of $SAFNWC/tmp temporal directory changes, defining now different subdirectories for different parameter types.

1.4 REFERENCES

1.4.1 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 referred document applies.

Current documentation can be found at the NWCSAF Helpdesk web: http://nwc-saf.eumetsat.int.

Ref.	*Title*	*Code*	*Ver.*
[AD.1]	Proposal for the Fourth Continuous Development and Operations Phase (CDOP4)	NWC/SAF/AEMET/MGT/CDO4Proposal	1.0
[AD.2]	NWCSAF Project Plan	NWC/CDOP4/SAF/AEMET/MGT/PP	3.0.0
[AD.3]	Configuration Management Plan for the NWCSAF	NWC/CDOP4/SAF/AEMET/MGT/CMP	1.2.0
[AD.4]	NWCSAF Product Requirements Document	NWC/CDOP4/SAF/AEMET/MGT/PRD	3.0.0
[AD.5]	Interface Control Document for Internal and External Interfaces of the NWC/GEO MTG-I day-1	NWC/CDOP2/MTG/AEMET/SW/ICD/1	1.4.0
[AD.6]	Data Output Format for the NWC/GEO MTG-I day-1	NWC/CDOP2/MTG/AEMET/SW/DOF	1.4.0
[AD.7]	Algorithm Theoretical Basis Document for the Wind product processor of the NWC/GEO (vMTG-I day-1)	NWC/CDOP2/MTG/AEMET/SCI/ATBD/Wind	1.1.1
[AD.8]	User Manual for the Wind product processor of the NWC/GEO (vMTG-I day-1): Science Part	NWC/CDOP3/MTG/AEMET/SCI/UM/Wind	1.2.1

Table 1. List of Applicable Documents

1.4.2 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 referred document 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).
[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).
[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).
[RD.8]	J.García-Pereda & J.M.Fernández, 2006: Description and validation results of High Resolution Winds 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).
[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).
[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).
[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).
[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).
[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 "NWCSAF High Resolution Winds" product (Proceedings 11th International Wind Workshop, EUMETSAT Pub.60).
[RD.19]	WMO Common Code Table C-1 (Available as "CCT-2023-11-30/C01.csv" at https://wmoomm.sharepoint.com/:u:/s/wmocpdb/EZquJmm_PHZIln14DDl81PEB-lFNAAE2GEVNAgYxMbyLQA?e=kSj2LK)
[RD.20]	WMO Code Tables and Flag Tables associated with BUFR/CREX table B, version 31 (Available as "BUFR4-41/fromWeb/BUFRCREX_31_0_0/ BUFRCREX_31_0_0_TableB_en.txt" at https://wmoomm.sharepoint.com/:u:/s/wmocpdb/Ee_T4lZfisNJjj-vN5AZmGEBYtW-yZa3oHv4YZXemPussg?e=fANZXz)
[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 NWCSAF/HRW AMVs with AMVs from other producers (available at http://www.nwcsaf.org/aemetRest/downloadAttachment/225)
[RD.25]	D.Santek, R.Dworak, S.Wanzong, K.Winiecki, S.Nebuda, J.García-Pereda, R.Borde & M.Carranza, 2018: 2018 AMV Intercomparison Study Report (available at http://www.nwcsaf.org/aemetRest/downloadAttachment/5092)
[RD.26]	K.Salonen, J.Cotton, N.Bormann & M.Forsythe, 2015: Characterizing AMV height-assignment error by comparing best-fit pressure statistics from the Met Office and ECMWF data assimilation systems (Journal of Applied Meteorology and Climatology, Vol.54, Num.1).

Table 2. List of Reference Documents

2. DESCRIPTION OF THE VALIDATION PROCEDURE

2.1 VALIDATION PROCEDURE

For continuity with previous versions, the validation process for NWC/GEO-HRW vMTG-I day-1 (v7.0) incorporates for each validated AMV both reference winds used in the validation: Radiosounding winds and ECMWF model analysis winds. To do this, relevant data for the validation (AMVs and NWP analysis reference winds from NWC/GEO-HRW AMV "NWC" BUFR output on one side, and the corresponding Radiosounding reference wind for each AMV extracted from Radiosounding wind profiles obtained from the GTS on the other side), are converted into McIDAS MD files following a scheme called WDMR.

The NWP analysis reference winds have been extracted by the autovalidation process included in NWC/GEO-HRW algorithm; the Radiosounding wind profiles are obtained through an intermediate McIDAS process.

The structure of data in this WDMR scheme is shown in the following table. The NWC/GEO-HRW validation process selects AMV data from the WDMR McIDAS MD file, considering the value of some specific parameters, and calculates the corresponding validation statistics. For validation against Radiosounding winds, elements in green in the table are used. For validation against NWP analysis winds, elements in blue in the table are used.

ROW/COLUMN ELEMENT	"NWC" BUFR DESCRIPTOR	PARAMETER MD ID.	WDMR SCHEME DESCRIPTION
Row 01	001007	SS	Satellite Identifier
Column 01	004001/002/003	DAY	Date
Column 02	004004/005	TIME	Time
Column 03	004025	INTT	Temporal interval (tracer to tracking centre)
Column 04	031002	CMAX	Number of NWC/GEO-HRW AMVs per Slot
Column 05	060000	TRAX	Segment size of tracer in X direction in pixels
Column 06	060001	TRAY	Segment size of tracer in Y direction in pixels
Column 07	060100	IDN	AMV sequence number inside the Slot
Column 08	060104	TYPE	Characterization as Basic or Detailed tracer, and Type of Detailed tracer
Column 09	002028	SIZX	Segment size of tracer in X direction in m
Column 10	002029	SIZY	Segment size of tracer in Y direction in m
Column 11	060103	TYPL	Characterization as Cloudy or Clear air wind, and Height assignment method used
Column 12	002164	TYPT	Euclidean Distance or Cross Correlation tracking
Column 13	005001	LAT	Initial latitude
Column 14	006001	LON	Initial longitude
Column 15	005011	DLAT	Latitude increment
Column 16	006011	DLON	Longitude increment
Column 17	012001	T	AMV Temperature
Column 18	007004	P	AMV Pressure
Column 19	011001	DIR	AMV Wind Direction
Column 20	011002	SPD	AMV Wind Speed
Column 21	033007	QI	AMV Quality index using forecast
Column 22	033007	QINF	AMV Quality index not using forecast
Column 23	033007	QIWG	AMV IWWG Common Quality index

ROW/COLUMN ELEMENT	"NWC" BUFR DESCRIPTOR	PARAMETER MD ID.	WDMR SCHEME DESCRIPTION
Column 24		QT	AMV Quality index threshold using forecast
Column 25		QTNF	AMV Quality index threshold not using forecast
Column 26		QTWG	AMV IWWG Common Quality index threshold
Column 27	060202	TES2	Two scale quality test flag
Column 28	060202	TEST	Temporal quality test flag
Column 29	060202	TESE	Spatial quality test flag
Column 30	060202	TESG	Forecast quality test flag
Column 31	060201	TESA	Correlation test flag
Column 32	060203	AVNW	Number of NWP levels used in HRW calculation
Column 33	060204	WPRE	Number of Predecessor AMVs in the trajectory
Column 34	060200	WREP	Number of Computed AMVs for the tracer
Column 35	060101	IDN0	Number of Predecessor AMV in the previous slot
Column 36	060205	FLAI	Orographic flag
Column 37	060202	TESI	Orographic test flag
Column 38	060206	CT	AMV NWC/GEO Cloud type
Column 39	060207	WCH	AMV NWC/GEO Satellite channel
Column 40	060208	CORR	Correlation between tracer and tracking centre
Column 41	060209	PERR	AMV Pressure error
Column 42	060210	PCORR	AMV Pressure correction (by Cloud Microphysics)
Column 43	060211	DIRN	NWP wind direction at AMV level
Column 44	060212	SPDN	NWP wind speed at AMV level
Column 45	060216	DIFN	Difference with NWP wind at AMV level
Column 46	060213	DRNB	NWP wind direction at AMV best fit level
Column 47	060214	SPNB	NWP wind speed at AMV best fit level
Column 48	060217	DFNB	Difference with NWP wind at AMV best fit level
Column 49	060215	PWNB	NWP pressure at AMV best fit level
Column 50		IDR	Radiosounding identifier
Column 51		LATR	Radiosounding latitude
Column 52		LONR	Radiosounding longitude
Column 53		DIRR	Radiosounding wind direction at AMV near level
Column 54		SPDR	Radiosounding wind speed at AMV near level
Column 55		DIFR	Difference with Radiosounding wind
Column 56		PWR	Radiosounding pressure at AMV near level
Column 57		DRRN	Radiosounding wind direction at AMV best fit level
Column 58		SPRB	Radiosounding wind speed at AMV best fit level
Column 59		DFRB	Difference with Radiosounding wind
Column 60		PWRB	Radiosounding pressure at AMV best fit level

Table 3. Description of McIDAS WDMR Scheme and Correspondence with NWC/GEO-HRW "NWC" BUFR output

2.2 STATISTICAL PARAMETERS

The statistical parameters for the validation of NWC/GEO-HRW Atmospheric Motion Vectors (AMVs) are the ones proposed at the Third International Winds Workshop (Ascona, Switzerland, 1996), afterwards recommended by the Coordination Group for Meteorological Satellites (CGMS) for the international comparison of satellite winds.

A description of these statistical parameters is shown here:

1. NC: Number of collocations between the reference wind vectors (Radiosounding winds or NWP analysis winds) [Ur,Vr] and the NWC/GEO-HRW AMV wind vectors [Ui,Vi].
2. SPD: Mean horizontal wind speed in m/s for the reference winds (Radiosounding winds or NWP analysis winds).
3. BIAS: Difference between the mean horizontal wind speed of the reference winds (Radiosounding winds or NWP analysis winds), and the collocated NWC/GEO-HRW AMVs winds:

$$BIAS = \frac{1}{N}\sum_{i=1}^{N}\left(\sqrt{U_i^2 + V_i^2} - \sqrt{U_r^2 + V_r^2}\right)$$

   It shows an estimation of the systematic error related to the calculation of the wind speed modulus (over- or underestimation of the mean AMV wind speed with respect to the mean reference wind speed). The index "i" here denotes each collocation and runs from 1 to the total number of collocations.

4. MVD: Mean vector difference between the reference winds (Radiosounding winds or NWP analysis winds) and the collocated NWC/GEO-HRW AMV wind speeds:

$$MVD = \frac{1}{N}\sum_{i=1}^{N} VD_i$$

   It shows an estimation of the systematic error related to the calculation of vectors, for which:

$$VD_i = \sqrt{(U_i - U_r)^2 + (V_i - V_r)^2}$$

5. RMSVD: Root mean square vector difference:

$$RMSVD = \sqrt{(MVD)^2 + (SD)^2}$$

   It shows an estimation of the systematic and random error related to the calculation of the wind vectors. It is calculated through the Mean vector difference (MVD), and the Standard deviation (SD) of each vector difference with respect to the mean, for which:

$$SD = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(VD_i - MVD)^2}$$

Due to the variable magnitude the defined statistical parameters can have in different samples, the mean horizontal wind speed for the reference winds (SPD, parameter 2) is used for normalization. So, the relative parameters related to the ones before:

3a. NBIAS = BIAS / SPD,

4a. NMVD = MVD / SPD,

5a. NRMSVD = RMSVD / SPD,

which are independent of the magnitude of the winds and can more easily be compared in different samples of data, are going to be used and presented throughout this Validation Report.

Considering the validation against Radiosounding winds, AMVs are compared to the nearest Radiosounding wind, with a maximum distance of 150 km and a maximum pressure difference of 25 hPa (standard limits defined for the comparison of AMVs with Radiosounding winds). This way, only a part of the AMVs can be validated against Radiosounding winds.

Considering the validation against NWP analysis winds, the interpolation of the NWP wind to the AMV location and level is used. This way, formally all AMVs can be validated against NWP analysis winds. Comparing with previous NWC/GEO-HRW validation reports there is here also a change related to the general NWC/GEO default configuration changes, through which ECMWF model data with 25 levels (1000, 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10, 7, 5, 3, 2, 1 hPa) is used instead of the ECMWF model data with 15 levels used in previous versions (1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 10 hPa), which has verified to show better results in the height assignment of NWC/GEO-Cloud products at the highest and lowest levels.

To ease the comparison of the validation of AMVs against both reference datasets (Radiosounding winds and NWP analysis winds), throughout this Validation report only AMVs that could be validated against both reference datasets are considered. Although the size of the AMV sample is so smaller, the number of AMV data validated against both datasets is exactly the same in all cases, and differences in the validation can be better extracted because of using exactly the same AMVs for each case.

3. VALIDATION OF HRW V7.0 AMVS WITH MSG SATELLITES

3.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION

The validation of NWC/GEO-HRW v7.0 algorithm for MSG satellite series is considered first. For continuity with all previous versions and to check corresponding evolution, it is based on the validation of AMVs calculated during 354 days of the yearly period July 2009 – June 2010 at 12:00 UTC, with Meteosat-9 satellite images, in an area covering Europe and the Mediterranean Sea. This area is shown in *Figure 1*.

The default conditions for NWC/GEO-HRW v7.0 for all satellite series, considering "Nominal scan satellite mode", "Basic scale AMVs", "Cross correlation tracking", "CCC height assignment method with Microphysics correction", and a "higher density for tracers related to medium and low level clouds", are considered first. These conditions are specified in the default model configuration files for MSG satellites `$SAFNWC/config/MSG*/safnwc_HRW.cfm`, but with validation of all possible satellite channels. Cloudy AMVs in the layer 100-1000 hPa and clear air AMVs in the layer 100-400 hPa, with a Quality index with forecast ≥ 75%, are considered for the validation.

NWC/GEO-Cloud product outputs (CMA, CT, CTTH and CMIC) in the processing region have to be available so that NWC/GEO-HRW can fully process the conditions defined in the model configuration file. The running of three consecutive slots for all Cloud and HRW products every day during the reference validation period (11:30 UTC, 11:45 UTC and 12:00 UTC), is needed for the validation. An example of NWC/GEO-HRW output with this configuration is shown in *Figure 1*.

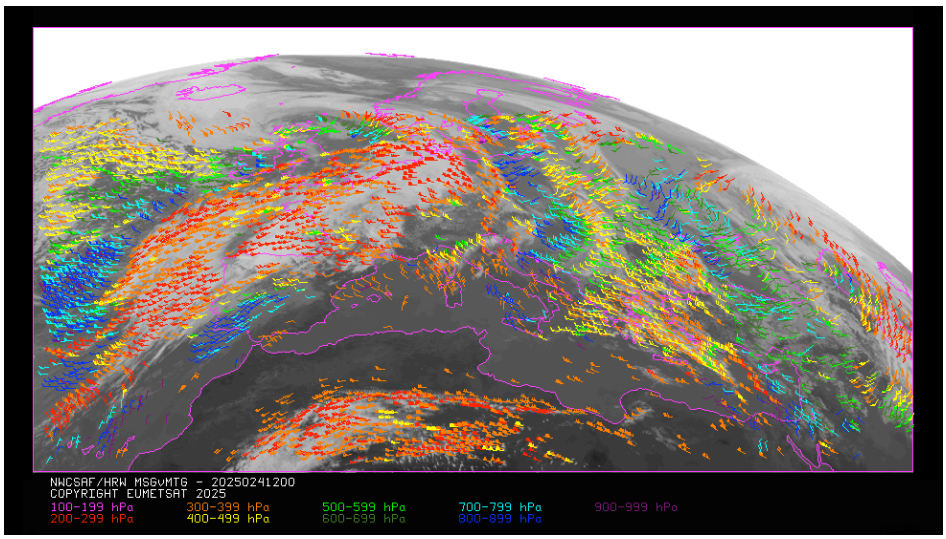

Figure 1: NWC/GEO-High Resolution Winds v7.0 Basic AMV output example in the European and Mediterranean region (24 January 2025 12:00 UTC, Meteosat-10 satellite), considering default conditions in `$SAFNWC/config/MSG*/safnwc_HRW.cfm` model configuration file. Colour coding based on the AMV pressure level

Comparing the statistics against Radiosounding winds and ECMWF NWP analysis in *Table 4* (considering all layers together) and in *Table 5* (considering the three layers separately), the NBIAS, NMVD and NRMSVD parameters are in general smaller (between a 22% and a 100% smaller) against NWP analysis winds. The conclusion can be taken that the general scale and behaviour of AMVs is more similar to the one of NWP analysis winds than to the one of Radiosounding winds.

Considering the different satellite channels, as for previous versions of NWC/GEO-HRW algorithm, the MVD and NRMSVD seem very different considering all layers together, with changes up to a 50% between the best case (Cloudy WV62 AMVs) and the worst case (Cloudy VIS08 AMVs). Nevertheless, this is only caused by the different proportion of AMVs in the different layers for each channel. Inside each one of the layers, differences of NMVD and NRMSVD are much smaller. Considering the different layers, NMVD and NRMSVD parameters are progressively larger for the high, medium and low layer. NWC/GEO-HRW Product Requirement Table new "Target accuracy" for HRW vMTG-I day-1 (with narrower values) is reached in all layers (which requests NRMSVD ≤ 0.36, 0.48, 0.54 respectively for the high, medium and low layer against Radiosounding winds).

NWC/GEO-HRWv7.0 AMVs (Jul 2009-Jun 2010, Meteosat-9)	Cloud HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	86883	152821	138274	220010	221095	104852	207540	18701	1150176
SPD [m/s]	11.06	10.26	10.25	16.13	16.46	22.69	19.10	17.77	15.48
NBIAS (ALL LAYERS)	-0.05	-0.12	-0.13	-0.08	-0.07	-0.01	-0.03	+0.00	-0.07
NMVD (100-1000 hPa)	0.39	0.41	0.42	0.31	0.31	0.27	0.30	0.31	0.33
NRMSVD	0.47	0.49	0.49	0.39	0.38	0.33	0.37	0.38	0.41
NC	86883	152821	138274	220010	221095	104852	207540	18701	1150176
SPD [m/s]	10.83	9.96	9.96	15.84	16.17	22.31	18.78	17.77	15.18
NBIAS (ALL LAYERS)	-0.03	-0.10	-0.10	-0.06	-0.05	-0.00	-0.01	+0.00	-0.05
NMVD (100-1000 hPa)	0.25	0.28	0.28	0.21	0.20	0.16	0.20	0.23	0.22
NRMSVD	0.31	0.34	0.34	0.26	0.26	0.20	0.25	0.29	0.27

Table 4: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Basic AMVs

NWC/GEO-HRWv7.0 AMVs (Jul 2009-Jun 2010, Meteosat-9)	Cloud HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC (35%)	7168			82147	87620	92339	116251	18701	404226
SPD [m/s]	22.54			21.74	21.76	23.36	22.59	17.77	22.18
NBIAS (HIGH LAYER)	-0.03			-0.06	-0.05	-0.02	-0.04	+0.00	-0.03
NMVD (100-400 hPa)	0.24			0.26	0.26	0.26	0.26	0.31	0.26
NRMSVD	0.29			0.32	0.32	0.32	0.32	0.38	0.32
NC (32%)	24042	44197	41713	83781	82525	12513	79617		368388
SPD [m/s]	12.11	11.85	11.78	14.35	14.53	17.73	15.21		13.95
NBIAS (MEDIUM LAYER)	-0.08	-0.14	-0.14	-0.08	-0.07	+0.04	-0.00		-0.07
NMVD (400-700 hPa)	0.37	0.38	0.38	0.35	0.35	0.36	0.38		0.36
NRMSVD	0.44	0.45	0.45	0.43	0.43	0.44	0.46		0.44
NC (33%)	55673	108624	96561	54082	50950		11672		377562
SPD [m/s]	9.12	9.61	9.60	10.36	10.46		11.52		9.81
NBIAS (LOW LAYER)	-0.05	-0.11	-0.12	-0.11	-0.11		-0.00		-0.10
NMVD (700-1000 hPa)	0.46	0.43	0.44	0.39	0.39		0.40		0.42
NRMSVD	0.54	0.51	0.51	0.47	0.46		0.48		0.50
NC (35%)	7168			82147	87620	92339	116251	18701	404226
SPD [m/s]	22.22			21.49	21.51	22.99	22.19	17.77	21.87
NBIAS (HIGH LAYER)	-0.01			-0.05	-0.04	-0.00	-0.03	+0.00	-0.02
NMVD (100-400 hPa)	0.14			0.16	0.16	0.15	0.16	0.23	0.16
NRMSVD	0.17			0.20	0.20	0.19	0.20	0.29	0.20
NC (32%)	24042	44197	41713	83781	82525	12513	79617		368388
SPD [m/s]	11.83	11.48	11.41	14.03	14.23	17.33	14.91		13.63
NBIAS (MEDIUM LAYER)	-0.06	-0.12	-0.12	-0.06	-0.05	+0.06	+0.01		-0.05
NMVD (400-700 hPa)	0.25	0.27	0.27	0.25	0.25	0.25	0.28		0.26
NRMSVD	0.31	0.33	0.33	0.31	0.31	0.31	0.35		0.32
NC (33%)	55673	108624	96561	54082	50950		11672		377562
SPD [m/s]	8.93	9.34	9.34	10.08	10.15		11.21		9.55
NBIAS (LOW LAYER)	-0.03	-0.09	-0.10	-0.09	-0.09		+0.02		-0.08
NMVD (700-1000 hPa)	0.29	0.28	0.29	0.26	0.26		0.31		0.27
NRMSVD	0.35	0.34	0.35	0.32	0.32		0.38		0.33

Table 5: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Basic AMVs

3.2 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION

The comparison of the statistics of NWC/GEO-HRW v7.0 default configuration for MSG satellite series with those for previous version NWC/GEO-HRW v6.2 default configuration in *Tables 6 and 7* is considered here.

In contrast with previous updates of NWC/GEO-HRW algorithm, the changes related to MSG AMVs in this version are very limited (because most of the planned changes for MSG AMVs for this version were already included in the originally unplanned previous version NWC/GEO-HRW v6.2 in NWC/GEO v2021 software package).

Due to this, considering differences between both versions, the number of AMVs is basically the same (with only slight reductions smaller than 3%) and the proportion of AMVs in the three layers (35% in the high layer, 32% in the medium layer and 33% in the low layer) is exactly the same. The good distribution of AMVs in the three layers helps to better characterize the behaviour of the wind in the different levels of the troposphere.

Considering the NMVD and NRMSVD, the values are also the same in the majority of cases or else with slight variations up to a 6%. Considering the NBIAS, only a few cells shown in colours in *Table 5* show variations larger than a 10%, with decreases in green and increases in red.

With all this, the behaviour of NWC/GEO-HRW “Basic AMVs” for MSG satellite series is basically equivalent in the latest two versions (v6.2 and v7.0).

NWC/GEO-HRWv6.2 AMVs (Jul 2009-Jun 2010, Meteosat-9)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	87205	153088	138941	223076	225536	106108	210943	19460	1164357
SPD [m/s]	11.03	10.26	10.28	16.18	16.48	22.77	19.17	18.01	15.54
NBIAS (ALL LAYERS)	-0.05	-0.12	-0.13	-0.08	-0.07	-0.01	-0.03	+0.00	-0.07
NMVD (100-1000 hPa)	0.39	0.41	0.41	0.31	0.31	0.26	0.30	0.30	0.33
NRMSVD	0.46	0.48	0.49	0.38	0.38	0.32	0.37	0.37	0.40
NC	87205	153088	138941	223076	225536	106108	210943	19460	1164357
SPD [m/s]	10.80	9.95	9.99	15.89	16.20	22.40	18.83	17.98	15.24
NBIAS (ALL LAYERS)	-0.03	-0.10	-0.10	-0.06	-0.05	-0.00	-0.01	+0.00	-0.05
NMVD (100-1000 hPa)	0.25	0.28	0.29	0.21	0.21	0.17	0.20	0.23	0.22
NRMSVD	0.31	0.34	0.35	0.26	0.26	0.21	0.25	0.29	0.27

Table 6: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; CCC height assignment with Microphysics)

NWC/GEO-HRWv6.2 AMVs (Jul 2009-Jun 2010, Meteosat-9)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC (35%)	7221			82709	88198	93040	116780	19460	407408
SPD [m/s]	22.17			21.86	21.83	23.48	22.68	18.01	22.28
NBIAS (HIGH LAYER)	-0.02			-0.06	-0.05	-0.02	-0.04	+0.00	-0.04
NMVD (100-400 hPa)	0.23			0.26	0.26	0.25	0.26	0.30	0.26
NRMSVD	0.28			0.31	0.31	0.31	0.32	0.37	0.32
NC (32%)	24251	44481	42496	85498	84967	13068	82282		377043
SPD [m/s]	12.05	11.79	11.73	14.36	14.61	17.73	15.30		13.99
NBIAS (MEDIUM LAYER)	-0.08	-0.14	-0.15	-0.08	-0.07	+0.04	-0.01		-0.07
NMVD (400-700 hPa)	0.37	0.37	0.38	0.35	0.35	0.36	0.37		0.36
NRMSVD	0.44	0.45	0.45	0.43	0.43	0.44	0.45		0.44
NC (33%)	55733	108607	96445	54869	52371		11881		379906
SPD [m/s]	9.14	9.63	9.65	10.43	10.51		11.50		9.86
NBIAS (LOW LAYER)	-0.05	-0.11	-0.12	-0.12	-0.11		-0.00		-0.10
NMVD (700-1000 hPa)	0.46	0.43	0.43	0.39	0.38		0.39		0.42
NRMSVD	0.54	0.50	0.51	0.46	0.46		0.47		0.49
NC (35%)	7221			82709	88198	93040	116780	19460	407408
SPD [m/s]	21.90			21.61	21.58	23.10	22.31	17.98	21.98
NBIAS (HIGH LAYER)	-0.01			-0.05	-0.04	-0.00	-0.03	+0.00	-0.03
NMVD (100-400 hPa)	0.14			0.16	0.16	0.16	0.16	0.23	0.16
NRMSVD	0.17			0.21	0.20	0.19	0.20	0.29	0.20
NC (32%)	24251	44481	42496	85498	84967	13068	82282		377043
SPD [m/s]	11.76	11.40	11.34	14.04	14.30	17.39	14.99		13.66
NBIAS (MEDIUM LAYER)	-0.06	-0.11	-0.12	-0.06	-0.05	+0.06	+0.01		-0.05
NMVD (400-700 hPa)	0.26	0.27	0.27	0.25	0.25	0.25	0.28		0.26
NRMSVD	0.32	0.34	0.33	0.31	0.31	0.31	0.35		0.33
NC (33%)	55733	108607	96445	54869	52371		11881		379906
SPD [m/s]	8.94	9.36	9.39	10.13	10.20		11.21		9.59
NBIAS (LOW LAYER)	-0.03	-0.09	-0.10	-0.09	-0.09		+0.02		-0.08
NMVD (700-1000 hPa)	0.29	0.29	0.29	0.26	0.26		0.31		0.28
NRMSVD	0.35	0.34	0.35	0.32	0.32		0.38		0.34

Table 7: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; CCC height assignment with Microphysics)

3.3 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION

The validation of "Detailed AMVs" (with a default tracer size of 12x12 pixels instead of the 24x24 pixels considered by the "Basic AMVs") for MSG satellite series is considered now. The calculation of "Detailed AMVs" is activated changing configurable parameter CDET = 1 in the default model configuration file. These are provided as an additional dataset of AMVs together with the "Basic AMVs", which are always calculated.

The conditions for the validation of "Detailed AMVs" are exactly equivalent to those shown in chapter 3.1 for the MSG "Basic AMVs". An example of this configuration is shown in *Figure 2*. The validation statistics are presented in *Table 8* considering all layers together, and *Table 9* considering the three layers separately for the same validation period.

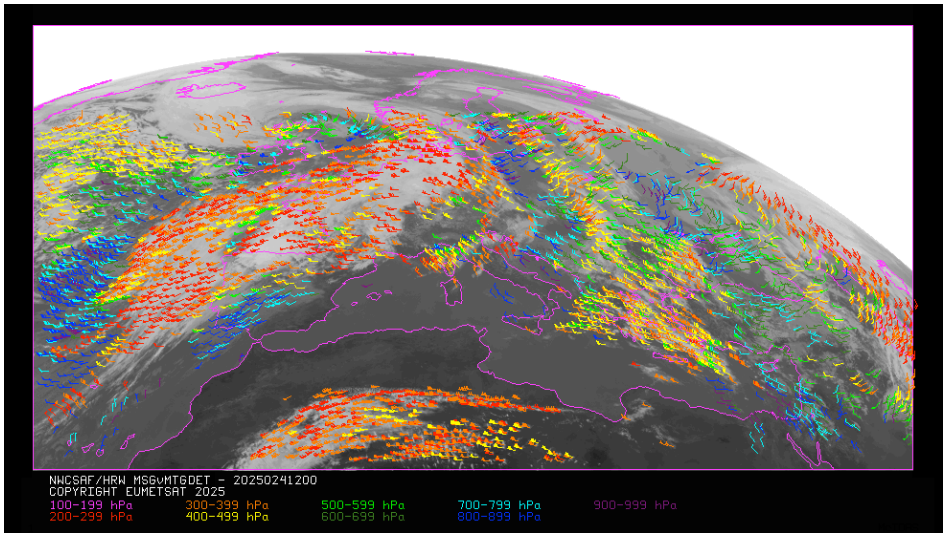

Figure 2: NWC/GEO-High Resolution Winds v7.0 Detailed AMV output example in the European and Mediterranean region (24 January 2025 12:00 UTC, Meteosat-10 satellite), considering default conditions in `$SAFNWC/config/MSG*/safnwc_HRW.cfm` model configuration file and configurable parameter CDET = 1. Colour coding based on the AMV pressure level

Comparing with the "Basic AMVs", a small 10% reduction in the total number of "Detailed AMVs" is seen. This way both datasets can complement each other with similar weights. The distribution of validated AMVs in the different layers has a value of 38%/30%/32% for the high, medium and low layer, which is basically equivalent to the one for "Basic AMVs", so also helping to characterize the behaviour of the wind in the different levels of the troposphere. Considering the validation parameters, the NMVD and NRMSVD are in general slightly better than for the "Basic AMVs", with small reductions up to a 15%, while the NBIAS shows reductions up to a 100% in the "Detailed AMVs" (except for the case of "Clear air AMVs", which has a very small sample). With all this, the behaviour of the "Detailed AMVs" is comparable to the one of the "Basic AMVs", and their use as additional AMV dataset is recommended.

Comparing the statistics against Radiosounding winds and ECMWF NWP analysis winds, all validation parameters are again in general significantly smaller (between a 22% and a 100% smaller) against NWP analysis winds. The conclusion can be taken again that the general scale and behaviour of AMVs is more similar to the one of NWP analysis winds than to the one of Radiosounding winds, and even more for the "Detailed AMVs". Considering the different layers, NWC/GEO-HRW Product Requirement Table new "Target accuracy" for HRW vMTG-I day-1 (with narrower values) is again reached in the three layers (which requests NRMSVD $\leq$ 0.36, 0.48, 0.54 respectively for high, medium and low layer against Radiosounding winds).

In summary, the behaviour of "Detailed AMVs" is very similar to the one of "Basic AMVs" with some improvements but also some degradations, and so both datasets can be used together for the characterization of the wind in the different layers of the troposphere.

NWC/GEO-HRWv7.0 AMVs (Jul 2009-Jun 2010, Meteosat-9)	Cloud HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	52820	180917	175510	201783	200510	54867	171086	1410	1038903
SPD [m/s]	11.47	10.68	10.48	18.20	18.64	24.58	21.84	19.95	16.26
NBIAS (ALL LAYERS)	-0.04	-0.09	-0.09	-0.04	-0.03	-0.02	-0.02	+0.06	-0.05
NMVD (100-1000 hPa)	0.39	0.40	0.41	0.28	0.28	0.26	0.27	0.34	0.32
NRMSVD	0.46	0.47	0.48	0.35	0.35	0.31	0.34	0.44	0.39
NC	52820	180917	175510	201783	200510	54867	171086	1410	1038903
SPD [m/s]	11.22	10.44	10.25	17.92	18.39	24.12	21.50	19.92	15.99
NBIAS (ALL LAYERS)	-0.02	-0.07	-0.07	-0.02	-0.01	-0.00	-0.00	+0.06	-0.03
NMVD (100-1000 hPa)	0.25	0.27	0.27	0.18	0.18	0.15	0.17	0.24	0.21
NRMSVD	0.30	0.32	0.33	0.23	0.22	0.18	0.21	0.30	0.25

Table 8: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs

NWC/GEO-HRWv7.0 AMVs (Jul 2009-Jun 2010, Meteosat-9)	Cloud HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC (38%)	4571			99548	105652	52651	130665	1410	394497
SPD [m/s]	23.19			22.69	22.68	24.83	23.50	19.95	23.24
NBIAS (HIGH LAYER)	-0.02			-0.04	-0.03	-0.02	-0.03	+0.06	-0.03
NMVD (100-400 hPa)	0.24			0.25	0.25	0.25	0.25	0.34	0.25
NRMSVD	0.29			0.31	0.31	0.30	0.31	0.44	0.31
NC (30%)	13110	56092	54190	73312	70978	2216	39012		308910
SPD [m/s]	12.50	11.96	11.82	14.98	15.22	18.75	16.57		14.05
NBIAS (MEDIUM LAYER)	-0.07	-0.10	-0.10	-0.03	-0.02	+0.05	+0.05		-0.04
NMVD (400-700 hPa)	0.37	0.38	0.38	0.33	0.33	0.36	0.37		0.35
NRMSVD	0.44	0.45	0.45	0.41	0.41	0.45	0.45		0.43
NC (32%)	35139	124825	121320	28923	23880		1409		335496
SPD [m/s]	9.56	10.11	9.88	10.86	10.93		13.37		10.10
NBIAS (LOW LAYER)	-0.04	-0.08	-0.08	-0.08	-0.08		+0.05		-0.07
NMVD (700-1000 hPa)	0.44	0.42	0.43	0.36	0.36		0.40		0.41
NRMSVD	0.52	0.49	0.50	0.43	0.43		0.49		0.48
NC (38%)	4571			99548	105652	52651	130665	1410	394497
SPD [m/s]	22.80			22.43	22.44	24.34	23.14	19.92	22.91
NBIAS (HIGH LAYER)	-0.00			-0.02	-0.02	-0.00	-0.02	+0.06	-0.01
NMVD (100-400 hPa)	0.14			0.15	0.15	0.15	0.15	0.24	0.15
NRMSVD	0.18			0.19	0.19	0.18	0.19	0.30	0.18
NC (30%)	13110	56092	54190	73312	70978	2216	39012		308910
SPD [m/s]	12.25	11.63	11.52	14.71	14.94	18.79	16.33		13.77
NBIAS (MEDIUM LAYER)	-0.05	-0.08	-0.08	-0.01	-0.00	+0.05	+0.06		-0.02
NMVD (400-700 hPa)	0.27	0.27	0.27	0.23	0.23	0.24	0.26		0.24
NRMSVD	0.32	0.33	0.33	0.28	0.29	0.29	0.32		0.30
NC (32%)	35139	124825	121320	28923	23880		1409		335496
SPD [m/s]	9.33	9.91	9.68	10.57	10.70		12.91		9.89
NBIAS (LOW LAYER)	-0.02	-0.06	-0.06	-0.06	-0.06		+0.08		-0.05
NMVD (700-1000 hPa)	0.27	0.27	0.28	0.23	0.23		0.31		0.26
NRMSVD	0.33	0.32	0.33	0.28	0.28		0.39		0.31

Table 9: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs

3.4 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION

The comparison of the statistics of NWC/GEO-HRW v7.0 "Detailed AMVs" with those for NWC/GEO-HRW v6.2 in *Tables 10 and 11* is considered here.

As already said for the "Basic AMVs", the changes related to MSG AMVs in this version are very limited (because most of the planned changes for MSG AMVs for this version were already included in the originally unplanned previous version NWC/GEO-HRW v6.2).

Due to this, the number of AMVs is the same (with only slight reductions smaller than 2%, excepting the "Clear air AMVs" for which the reduction is larger, related to their small sample size). The proportion of AMVs in the three layers is exactly the same (38% in the high layer, 30% in the medium layer and 32% in the low layer). The good distribution of "Detailed AMVs" in the different layers helps also to characterize the behaviour of the wind in the different levels of the troposphere.

Considering the NMVD and NRMSVD, the values are also the same in the majority of cases or else with slight variations up to a 7%. Considering the NBIAS, a few cells shown in colours in *Table 8* and *Table 9* show variations larger than a 10%, with decreases in green and increases in red.

With all this, the behaviour of NWC/GEO-HRW "Detailed AMVs" with MSG satellite is basically also equivalent in the latest two versions (v6.2 and v7.0).

NWC/GEO-HRWv6.2 AMVs (Jul 2009-Jun 2010, Meteosat-9)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	53617	180846	176311	204845	203347	55037	172627	1602	1048232
SPD [m/s]	11.44	10.71	10.52	18.29	18.67	24.71	21.90	19.22	16.33
NBIAS (ALL LAYERS)	-0.04	-0.09	-0.09	-0.04	-0.03	-0.02	-0.02	-0.06	-0.05
NMVD (100-1000 hPa)	0.38	0.40	0.40	0.28	0.28	0.25	0.27	0.35	0.32
NRMSVD	0.46	0.47	0.48	0.34	0.34	0.30	0.33	0.45	0.38
NC	53617	180846	176311	204845	203347	55037	172627	1602	1048232
SPD [m/s]	11.16	10.45	10.28	18.00	18.40	24.20	21.55	19.45	16.03
NBIAS (ALL LAYERS)	-0.02	-0.07	-0.07	-0.02	-0.01	-0.00	-0.00	+0.05	-0.03
NMVD (100-1000 hPa)	0.25	0.27	0.27	0.18	0.18	0.15	0.17	0.24	0.21
NRMSVD	0.31	0.33	0.33	0.23	0.23	0.19	0.22	0.31	0.26

Table 10: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering all layers together against Radiosounding winds (green) and ECMWF NWP analysis winds (blue) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; CCC height assignment with Microphysics)

NWC/GEO-HRWv6.2 AMVs (Jul 2009-Jun 2010, Meteosat-9)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC (38%)	4580			100763	106483	52735	131005	1602	397168
SPD [m/s]	23.14			22.83	22.73	24.97	23.61	19.22	23.33
NBIAS (HIGH LAYER)	-0.01			-0.04	-0.03	-0.02	-0.03	-0.06	-0.03
NMVD (100-400 hPa)	0.24			0.24	0.25	0.24	0.25	0.35	0.25
NRMSVD	0.29			0.30	0.30	0.29	0.30	0.45	0.30
NC (30%)	13305	56514	55125	74901	72237	2302	40173		314557
SPD [m/s]	12.63	11.95	11.78	15.07	15.30	18.80	16.63		14.11
NBIAS (MEDIUM LAYER)	-0.07	-0.11	-0.10	-0.03	-0.02	+0.06	+0.05		-0.04
NMVD (400-700 hPa)	0.36	0.37	0.38	0.33	0.33	0.36	0.36		0.35
NRMSVD	0.43	0.44	0.45	0.40	0.41	0.45	0.45		0.43
NC (32%)	35732	124332	121186	29181	24627		1449		336507
SPD [m/s]	9.49	10.14	9.95	10.89	10.98		13.22		10.14
NBIAS (LOW LAYER)	-0.04	-0.08	-0.08	-0.08	-0.07		+0.07		-0.08
NMVD (700-1000 hPa)	0.44	0.41	0.42	0.35	0.35		0.40		0.41
NRMSVD	0.52	0.48	0.49	0.43	0.43		0.48		0.48
NC (38%)	4580			100763	106483	52735	131005	1602	397168
SPD [m/s]	22.81			22.53	22.46	24.43	23.23	19.45	22.99
NBIAS (HIGH LAYER)	-0.00			-0.02	-0.02	-0.00	-0.02	+0.05	-0.01
NMVD (100-400 hPa)	0.15			0.15	0.15	0.15	0.15	0.24	0.15
NRMSVD	0.18			0.19	0.19	0.18	0.19	0.31	0.19
NC (30%)	13305	56514	55125	74901	72237	2302	40173		314557
SPD [m/s]	12.30	11.60	11.45	14.77	15.02	18.81	16.39		13.81
NBIAS (MEDIUM LAYER)	-0.04	-0.08	-0.08	-0.01	-0.00	+0.06	+0.06		-0.02
NMVD (400-700 hPa)	0.26	0.27	0.27	0.23	0.23	0.24	0.26		0.25
NRMSVD	0.32	0.33	0.33	0.28	0.29	0.29	0.32		0.31
NC (32%)	35732	124332	121186	29181	24627		1449		336507
SPD [m/s]	9.24	9.93	9.75	10.62	10.76		13.09		9.93
NBIAS (LOW LAYER)	-0.02	-0.06	-0.07	-0.06	-0.06		+0.08		-0.06
NMVD (700-1000 hPa)	0.27	0.27	0.28	0.24	0.24		0.30		0.27
NRMSVD	0.33	0.32	0.33	0.29	0.29		0.38		0.32

Table 11: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering three separate layers against Radiosounding winds (green) and ECMWF NWP analysis winds (blue) (Jul 2009-Jun 2010 12:00 UTC, Meteosat-9 satellite, Nominal scan, European and Mediterranean region; Cross correlation; CCC height assignment with Microphysics)

4. VALIDATION OF HRW V7.0 AMVS WITH MTG-I SATELLITES

4.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION

The validation of NWC/GEO-HRW v7.0 algorithm for MTG-I satellite series is considered now. It is based on the validation of NWC/GEO-HRW AMVs calculated during 106 days of the period 9 October 2024 – 8 February 2025 at 12:00 UTC, with Meteosat-12 (MTG-I1) satellite images, in the same area covering Europe and the Mediterranean Sea used for MSG satellite series. This area is shown in *Figure 3*.

The default conditions for NWC/GEO-HRW v7.0 for all satellite series, considering "Basic scale AMVs", "Cross correlation tracking", "CCC height assignment method with Microphysics correction", and a "higher density for tracers related to medium and low level clouds", are considered. These conditions are specified in the default model configuration files for MTG-I satellites `$SAFNWC/config/MTI1*/safnwc_HRW.cfm`, but with validation of all possible satellite channels. Cloudy AMVs in the layer 100-1000 hPa and clear air AMVs in the layer 100-400 hPa, with a Quality index with forecast ≥ 75%, are considered for the validation. NWC/GEO-Cloud product outputs (CMA, CT, CTTH and CMIC) in the processing region have to be available so that NWC/GEO-HRW can fully process the conditions defined in the model configuration file. The running of three consecutive slots for all Cloud and HRW products every day during the reference validation period (11:40 UTC, 11:50 UTC and 12:00 UTC), is needed for the validation. An example of NWC/GEO-HRW Meteosat-12 (MTG-I1) AMV output with this configuration is shown in *Figure 3*.

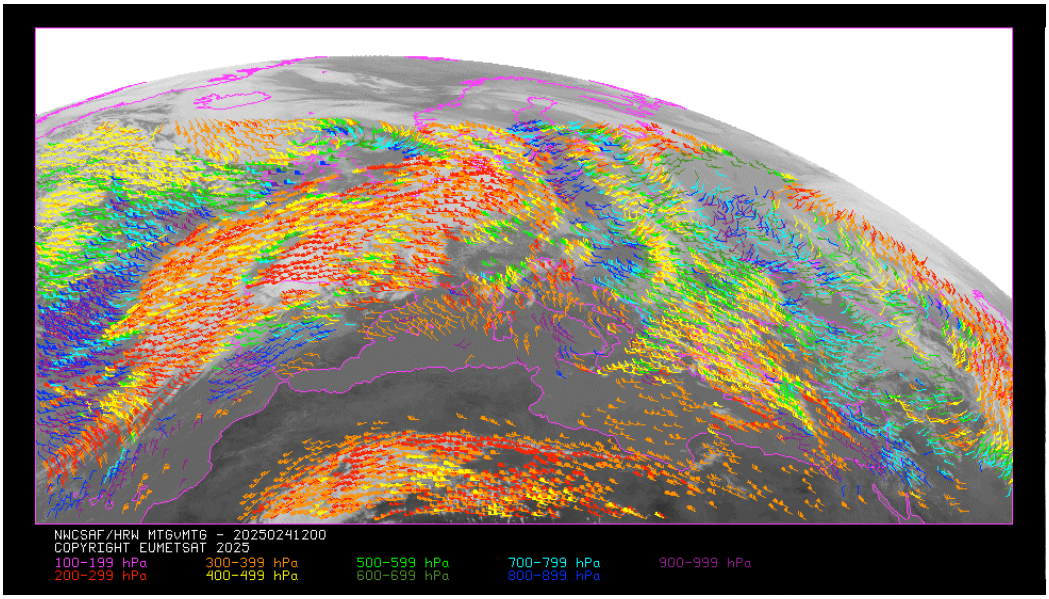

Figure 3: NWC/GEO-High Resolution Winds v7.0 Basic AMV output example in the European and Mediterranean region (24 January 2025 12:00 UTC, Meteosat-12 (MTG-I1) satellite data), considering default conditions in `$SAFNWC/config/MTI*/safnwc_HRW.cfm` model configuration file. Colour coding based on the AMV pressure level

The validation statistics are presented in *Table 12* (considering all layers together) and *Table 13* (considering the three layers separately).

Comparing the validation for the different satellite channels, the main difference is that for clear air AMVs the NBIAS parameter is positive while it is negative for all other channels, and their MVD and NRMSVD parameters are up to a 35% larger. However, their contribution to the characterization of the wind in cloudless areas is important to keep them inside the processing. Visible channels also show higher values of NMVD and NRMSVD parameters. Considering the different layers, as in the MSG case, NMVD and NRMSVD parameters are progressively larger for the high, medium and low layer. NWC/GEO-HRW Product Requirement Table new "Target accuracy" for HRW vMTG-I day-1 is reached in the three layers (which requests NRMSVD ≤ 0.36, 0.48, 0.54 respectively for high, medium and low layer against Radiosounding winds).

NWC/GEO-HRWv7.0 AMVs 9Oct2024-8Feb2025, Meteosat-12	Cloudy VIS06	Cloudy VIS08	Cloudy IR105	Cloudy IR123	Cloudy WV63	Cloudy WV73	Clear Air	All AMVs
NC	93790	76095	234674	240523	176465	231404	37235	1090186
SPD [m/s]	14.39	14.84	18.57	19.18	25.30	22.90	18.46	20.08
NBIAS (ALL LAYERS)	-0.02	-0.02	-0.02	-0.01	-0.00	-0.01	+0.04	-0.01
NMVD (100-1000 hPa)	0.32	0.32	0.29	0.29	0.26	0.28	0.34	0.28
NRMSVD	0.42	0.42	0.38	0.37	0.32	0.35	0.43	0.37
NC	93790	76095	234674	240523	176465	231404	37235	1090186
SPD [m/s]	14.40	14.83	18.74	19.34	25.44	23.04	19.01	20.23
NBIAS (ALL LAYERS)	-0.02	-0.02	-0.03	-0.02	-0.01	-0.02	+0.01	-0.02
NMVD (100-1000 hPa)	0.18	0.18	0.18	0.18	0.15	0.17	0.22	0.17
NRMSVD	0.24	0.24	0.23	0.23	0.19	0.22	0.28	0.22

Table 12: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (9 Oct 2024-8 Feb 2025 12:00 UTC, Meteosat-12 (MTG-I1) satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Dark green figures show an improvement of at least 50% and light green figures of at least 10%, and dark red figures show a worsening of at least 50% and light red figures of at least 10%, with respect to NWC/GEO-HRW v7.0 Basic AMVs for Meteosat-10 satellite in the same period and region

NWC/GEO-HRWv7.0 AMVs 9Oct2024-8Feb2025, Meteosat-12	Cloudy VIS06	Cloudy VIS08	Cloudy IR105	Cloudy IR123	Cloudy WV63	Cloudy WV73	Clear Air	All AMVs
NC (55%)	22722	20084	101210	112540	152236	152138	37235	598165
SPD [m/s]	26.86	27.40	25.14	25.13	26.30	26.10	18.46	25.40
NBIAS (HIGH LAYER)	-0.05	-0.05	-0.03	-0.02	-0.01	-0.04	+0.04	-0.02
NMVD (100-400 hPa)	0.26	0.25	0.26	0.25	0.25	0.25	0.34	0.26
NRMSVD	0.32	0.32	0.33	0.32	0.31	0.32	0.43	0.33
NC (24%)	13743	11073	67054	67572	24229	79266		262937
SPD [m/s]	15.65	15.98	16.82	17.01	19.01	16.75		16.95
NBIAS (MEDIUM LAYER)	+0.03	+0.03	+0.00	+0.01	+0.06	+0.04		+0.02
NMVD (400-700 hPa)	0.31	0.31	0.31	0.32	0.33	0.34		0.32
NRMSVD	0.38	0.38	0.39	0.39	0.41	0.43		0.40
NC (21%)	57325	44938	66410	60411				229084
SPD [m/s]	9.14	8.94	10.32	10.54				9.81
NBIAS (LOW LAYER)	-0.01	-0.00	-0.03	-0.02				-0.02
NMVD (700-1000 hPa)	0.40	0.41	0.38	0.38				0.39
NRMSVD	0.50	0.51	0.52	0.52				0.52
NC (55%)	22722	20084	101210	112540	152236	152138	37235	598165
SPD [m/s]	26.86	27.35	25.44	25.40	26.46	26.28	19.01	25.62
NBIAS (HIGH LAYER)	-0.05	-0.05	-0.05	-0.03	-0.02	-0.04	+0.01	-0.03
NMVD (100-400 hPa)	0.14	0.14	0.15	0.15	0.14	0.15	0.22	0.15
NRMSVD	0.18	0.18	0.19	0.19	0.18	0.19	0.28	0.19
NC (24%)	13743	11073	67054	67572	24229	79266		262937
SPD [m/s]	15.84	16.08	16.99	17.15	19.03	16.81		17.06
NBIAS (MEDIUM LAYER)	+0.02	+0.03	-0.00	+0.00	+0.06	+0.04		+0.02
NMVD (400-700 hPa)	0.19	0.19	0.21	0.21	0.23	0.24		0.22
NRMSVD	0.24	0.25	0.26	0.27	0.29	0.31		0.28
NC (21%)	57325	44938	66410	60411				229084
SPD [m/s]	9.11	8.92	10.30	10.49				9.78
NBIAS (LOW LAYER)	-0.00	-0.00	-0.03	-0.02				-0.01
NMVD (700-1000 hPa)	0.22	0.22	0.24	0.24				0.23
NRMSVD	0.28	0.28	0.30	0.31				0.29

Table 13: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (9 Oct 2024-8 Feb 2025 12:00 UTC, Meteosat-12 (MTG-I1) satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Dark green figures show an improvement of at least 50% and light green figures of at least 10%, and dark red figures show a worsening of at least 50% and light red figures of at least 10%, with respect to NWC/GEO-HRW v7.0 Basic AMVs for Meteosat-10 satellite in the same period and region

4.2 COMPARISON WITH HRW V7.0 AMVS WITH MSG SATELLITES

The statistics of NWC/GEO-HRW v7.0 "Basic AMVs" for MSG satellite series in the same period and region used for MTG-I satellite series (9 October 2024 – 8 February 2025 at 12:00 UTC in the European and Mediterranean region), are shown in *Tables 14 and 15* for comparison with those for MTG-I satellite series. As a visual example, AMVs calculated with Meteosat-10 satellite for the same moment of those calculated with Meteosat-12 (MTG-I1) satellite in *Figure 3* are shown in *Figure 1*.

Comparing the validation of MTG-I AMVs in *Tables 12 and 13* with the one of MSG AMVs in *Tables 14 and 15*, the main element to be taken into account is the much larger population of MTG-I AMVs: the number of AMVs multiplies by a factor of 2.63 considering all AMVs together, 3.63 considering the high layer, 2.46 considering the medium layer and 1.60 considering the low layer, with increments in the population of AMVs at all layers. Due to the different increment factor in the different layers, the distribution of AMVs in the high/medium/low layer becomes a bit different, with a value of 40%/26%/34% for MSG and a value of 55%/24%/21% for MTG-I.

Comparing the validation parameters for MSG and MTG-I AMVs, the NBIAS is in general less negative for all channels and layers for MTG-I, with a mean value of -0.01/-0.02 against Radiosounding/NWP analysis winds for MTG-I AMVs and -0.05 for MSG AMVs. For this improvement, the NBIAS stays negative considering all AMVs together and those in the high and low layer, while for the medium layer it becomes positive.

About the reason why the NBIAS is less negative in general for MTG-I than for MSG, the validation of Himawari-8/9 and GOES-R AMVs in Chapters 5 and 6 of this Validation Report shows similar results than for MTG-I. The smaller resolution of MTG-I/Himawari/GOES-R pixels defines a smaller size in kilometres of the features (tracers) tracked in corresponding AMVs. And smaller features have a smaller NBIAS. This can also be seen comparing for MSG satellites, in Table 4, the NBIAS against Radiosounding winds for HRVIS AMVs (-0.05, with a pixel resolution of 1km) with respect to the one for the rest of VIS and IR channels (between -0.07 and -0.13, with a pixel resolution of 3km).

Considering the NMVD and the NRMSVD, the values for MTG-I are similar or slightly better, with a mean value of the NRMSVD of 0.37/0.22 for MTG-I AMVs and 0.40/0.27 for MSG AMVs against Radiosounding/NWP analysis winds. The improvement is more significant in the validation against NWP analysis at the medium and low layer (over a 25% in several cases).

With all this, a much larger amount of AMVs is calculated with MTG-I satellite, with much better NBIAS values and smaller improvements in the NMVD and NRMSVD values, so justifying a quick adoption of NWC/GEO-HRW v7.0 software with MTG-I satellite series by NWCSAF users.

NWC/GEO-HRWv7.0 AMVs 9Oct2024-8Feb2025, Meteosat-10	Cloud HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	25505	48505	41260	81425	82028	44367	80893	10791	414774
SPD [m/s]	10.73	10.12	9.97	18.01	18.37	24.75	21.07	18.28	17.24
NBIAS (ALL LAYERS)	-0.04	-0.10	-0.10	-0.06	-0.05	-0.02	-0.02	+0.02	-0.05
NMVD (100-1000 hPa)	0.38	0.40	0.41	0.31	0.30	0.26	0.30	0.32	0.31
NRMSVD	0.47	0.48	0.49	0.39	0.39	0.33	0.37	0.43	0.40
NC	25505	48505	41260	81425	82028	44367	80893	10791	414774
SPD [m/s]	10.67	10.13	9.96	18.15	18.53	24.93	21.27	19.02	17.37
NBIAS (ALL LAYERS)	-0.04	-0.10	-0.10	-0.07	-0.06	-0.02	-0.03	-0.01	-0.05
NMVD (100-1000 hPa)	0.25	0.29	0.29	0.21	0.21	0.16	0.20	0.21	0.21
NRMSVD	0.32	0.36	0.36	0.27	0.26	0.20	0.25	0.27	0.27

Table 14: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-10 satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics)

NWC/GEO-HRWv7.0 AMVs 9Oct2024-8Feb2025, Meteosat-10	Cloud HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC (40%)	2072			32527	34551	39040	45664	10791	164645
SPD [m/s]	24.51			24.64	22.64	25.67	25.31	18.28	24.65
NBIAS (HIGH LAYER)	-0.03			-0.07	-0.06	-0.03	-0.05	+0.02	-0.05
NMVD (100-400 hPa)	0.23			0.27	0.26	0.25	0.26	0.32	0.26
NRMSVD	0.28			0.34	0.33	0.32	0.32	0.43	0.33
NC (26%)	3259	7773	6729	27265	27557	5327	28925		106835
SPD [m/s]	14.44	13.95	13.75	16.10	16.10	18.06	16.21		15.87
NBIAS (MEDIUM LAYER)	-0.02	-0.09	-0.08	-0.04	-0.03	+0.07	+0.03		-0.01
NMVD (400-700 hPa)	0.31	0.32	0.33	0.34	0.34	0.36	0.36		0.34
NRMSVD	0.38	0.39	0.40	0.42	0.42	0.43	0.45		0.42
NC (34%)	20174	40732	34531	21633	19920		6304		143294
SPD [m/s]	8.71	9.39	9.23	10.44	10.63		12.69		9.73
NBIAS (LOW LAYER)	-0.05	-0.10	-0.11	-0.09	-0.09		+0.03		-0.09
NMVD (700-1000 hPa)	0.44	0.42	0.43	0.40	0.40		0.44		0.42
NRMSVD	0.55	0.50	0.51	0.52	0.50		0.53		0.52
NC (40%)	2072			32527	34551	39040	45664	10791	164645
SPD [m/s]	24.31			24.93	24.94	25.84	25.56	19.02	24.93
NBIAS (HIGH LAYER)	-0.02			-0.08	-0.07	-0.03	-0.06	-0.01	-0.06
NMVD (100-400 hPa)	0.13			0.17	0.16	0.15	0.16	0.21	0.16
NRMSVD	0.17			0.21	0.21	0.19	0.20	0.27	0.21
NC (26%)	3259	7773	6729	27265	27557	5327	28925		106835
SPD [m/s]	14.66	14.27	13.95	16.22	16.22	18.22	16.35		16.02
NBIAS (MEDIUM LAYER)	-0.03	-0.11	-0.10	-0.05	-0.04	+0.06	+0.02		-0.02
NMVD (400-700 hPa)	0.21	0.24	0.23	0.24	0.24	0.24	0.26		0.24
NRMSVD	0.27	0.29	0.29	0.30	0.30	0.30	0.33		0.31
NC (34%)	20174	40732	34531	21633	19920		6304		143294
SPD [m/s]	8.63	9.34	9.18	10.38	10.61		12.71		9.68
NBIAS (LOW LAYER)	-0.04	-0.10	-0.10	-0.09	-0.09		+0.03		-0.08
NMVD (700-1000 hPa)	0.30	0.30	0.31	0.31	0.30		0.35		0.31
NRMSVD	0.38	0.38	0.38	0.38	0.38		0.43		0.39

Table 15: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-10 satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics)

4.3 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION

The validation of "Detailed AMVs" (with a default tracer size of 12x12 pixels instead of the 24x24 pixels considered by the "Basic AMVs") for Meteosat-12 (MTG-I1) satellite series is considered now. The calculation of "Detailed AMVs" is activated changing configurable parameter CDET = 1 in the default model configuration files. These AMVs are provided as an additional dataset of AMVs together with the "Basic AMVs", which are always calculated.

The conditions for the validation of "Detailed AMVs" are exactly equivalent to those shown in chapter 4.1 for the MTG-I "Basic AMVs". An example of "Detailed AMVs" for the same moment of the "Basic AMVs" in *Figure 3* is shown in *Figure 4*. The validation statistics are presented in *Table 16* (considering all layers together) and *Table 17* (considering the three layers separately) for the same validation period.

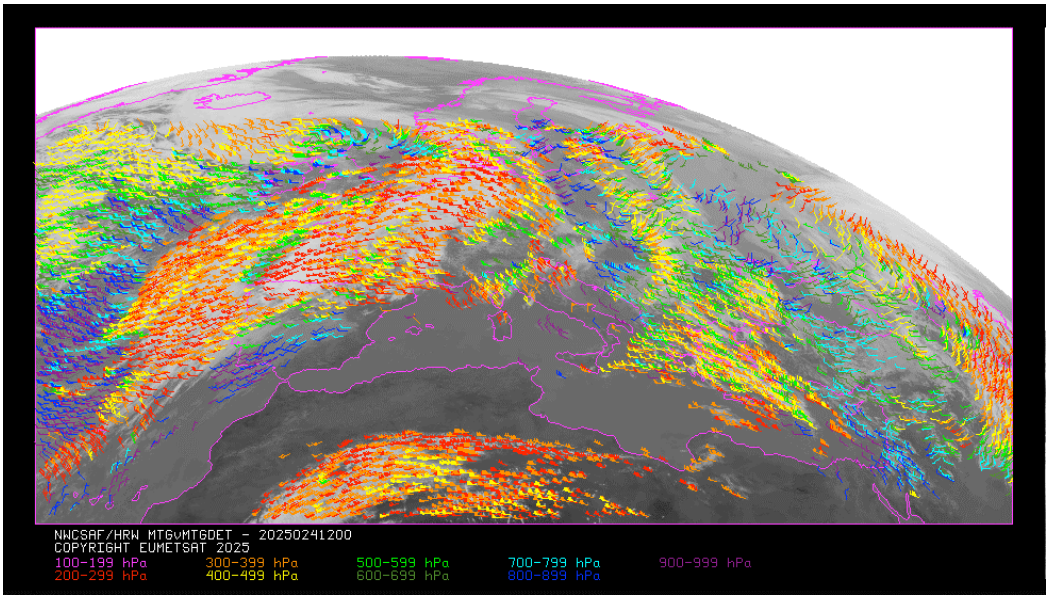

Figure 4: NWC/GEO-High Resolution Winds v7.0 Detailed AMV output example in the European and Mediterranean region (24 January 2025 12:00 UTC, Meteosat-12 (MTG-I1) satellite data), considering default conditions in `$SAFNWC/config/MTI*/safnwc_HRW.cfm` model configuration file and configurable parameter CDET = 1. Colour coding based on the AMV pressure level

Comparing with the "Basic AMVs", a 34% reduction in the number of AMVs is seen for the "Detailed AMVs". This result can be explained through the smaller size of the tracers, the smaller persistence in time of the finer image features and the smaller contrast in the features using smaller tracer sizes. The distribution of validated AMVs in the different layers has a value of 64%/23%/13% for the high/medium/low layer, concentrating the AMVs in the high layer more than for the "Basic scale".

Considering the validation parameters for the whole dataset of "Detailed AMVs", the NMVD and NRMSVD are up to a 10% better than for the "Basic AMVs" while the NBIAS is 0 against both Radiosounding and NWP analysis winds (although here there are compensations of negative values at high levels and positive values at medium levels). The NMVD and NRMSVD parameters are also in general slightly better than for the "Basic AMVs", with small reductions up to a 15%. And NWC/GEO-HRW Product Requirement Table new "Target accuracy" for HRW vMTG-I day-1 is again reached in the three layers (which requests NRMSVD $\leq$ 0.36, 0.48, 0.54 respectively for high, medium and low layer against Radiosounding winds).

In short, the behaviour of "Detailed AMVs" is comparable to the one of "Basic AMVs", with some improvements but also some degradations, and so both datasets can be used together for the characterization of the wind in the different layers of the troposphere.

NWC/GEO-HRWv7.0 AMVs 9Oct2024-8Feb2025, Meteosat-12	Cloudy VIS06	Cloudy VIS08	Cloudy IR105	Cloudy IR123	Cloudy WV63	Cloudy WV73	Clear Air	All AMVs
NC	53514	44178	179923	183990	67523	188135	3161	720424
SPD [m/s]	15.18	15.66	21.83	22.45	27.62	24.95	22.02	22.47
NBIAS (ALL LAYERS)	-0.00	-0.00	+0.00	+0.01	+0.00	-0.00	+0.13	+0.00
NMVD (100-1000 hPa)	0.30	0.30	0.27	0.27	0.25	0.26	0.32	0.27
NRMSVD	0.40	0.39	0.35	0.35	0.33	0.33	0.40	0.35
NC	53514	44178	179923	183990	67523	188135	3161	720424
SPD [m/s]	15.19	15.66	22.18	22.78	27.90	25.14	22.69	22.73
NBIAS (ALL LAYERS)	-0.00	-0.00	-0.01	-0.00	-0.00	-0.01	+0.10	-0.00
NMVD (100-1000 hPa)	0.17	0.17	0.16	0.16	0.13	0.15	0.22	0.16
NRMSVD	0.23	0.22	0.20	0.20	0.17	0.19	0.28	0.20

Table 16: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-12 (MTG-I1) satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Dark green figures show an improvement of at least 50% and light green figures of at least 10%, and dark red figures show a worsening of at least 50% and light red figures of at least 10%, with respect to NWC/GEO-HRW v7.0 Detailed AMVs for Meteosat-10 satellite in the same period and region

NWC/GEO-HRWv7.0 AMVs 9Oct2024-8Feb2025, Meteosat-12	Cloudy VIS06	Cloudy VIS08	Cloudy IR105	Cloudy IR123	Cloudy WV63	Cloudy WV73	Clear Air	All AMVs
NC (64%)	12569	11464	106752	117930	63965	145271	3161	461112
SPD [m/s]	28.40	28.73	25.74	25.62	27.89	26.88	22.02	26.49
NBIAS (HIGH LAYER)	-0.02	-0.02	-0.01	-0.00	-0.00	-0.02	+0.13	-0.01
NMVD (100-400 hPa)	0.24	0.24	0.25	0.25	0.25	0.25	0.32	0.25
NRMSVD	0.31	0.30	0.33	0.33	0.33	0.32	0.40	0.32
NC (23%)	7402	5901	53213	52041	3558	42864		164979
SPD [m/s]	17.00	17.43	17.90	18.12	22.71	18.39		18.14
NBIAS (MEDIUM LAYER)	+0.04	+0.05	+0.04	+0.05	+0.06	+0.08		+0.05
NMVD (400-700 hPa)	0.30	0.30	0.30	0.31	0.30	0.34		0.31
NRMSVD	0.37	0.37	0.37	0.38	0.37	0.42		0.39
NC (13%)	33543	26813	19958	14019				94333
SPD [m/s]	9.83	9.68	11.39	11.83				10.41
NBIAS (LOW LAYER)	-0.00	+0.00	-0.00	+0.01				+0.00
NMVD (700-1000 hPa)	0.37	0.39	0.35	0.34				0.37
NRMSVD	0.46	0.48	0.42	0.42				0.45
NC (64%)	12569	11464	106752	117930	63965	145271	3161	461112
SPD [m/s]	28.37	28.62	26.17	26.00	28.17	27.09	22.69	26.79
NBIAS (HIGH LAYER)	-0.02	-0.02	-0.02	-0.01	-0.01	-0.03	+0.10	-0.02
NMVD (100-400 hPa)	0.13	0.13	0.14	0.14	0.13	0.14	0.22	0.14
NRMSVD	0.17	0.16	0.18	0.18	0.16	0.17	0.28	0.17
NC (23%)	7402	5901	53213	52041	3558	42864		164979
SPD [m/s]	17.15	17.55	18.16	18.39	23.01	18.51		18.36
NBIAS (MEDIUM LAYER)	+0.03	+0.05	+0.02	+0.04	+0.05	+0.07		+0.04
NMVD (400-700 hPa)	0.18	0.18	0.20	0.20	0.20	0.23		0.21
NRMSVD	0.23	0.24	0.25	0.26	0.24	0.29		0.26
NC (13%)	33543	26813	19958	14019				94333
SPD [m/s]	9.82	9.70	11.60	12.00				10.49
NBIAS (LOW LAYER)	+0.00	+0.00	-0.01	-0.00				-0.00
NMVD (700-1000 hPa)	0.21	0.21	0.22	0.22				0.21
NRMSVD	0.26	0.26	0.28	0.28				0.27

Table 17: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-12 (MTG-I1) satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Dark green figures show an improvement of at least 50% and light green figures of at least 10%, and dark red figures show a worsening of at least 50% and light red figures of at least 10%, with respect to NWC/GEO-HRW v7.0 Detailed AMVs for Meteosat-10 satellite in the same period and region

4.4 COMPARISON WITH HRW V7.0 AMVS WITH MSG SATELLITES

The statistics of NWC/GEO-HRW v7.0 "Detailed AMVs" for MSG satellite series in the same period and region used for MTG-I (9 October 2024 – 8 February 2025 at 12:00 UTC in the European and Mediterranean region), are shown in *Tables 18 and 19* for comparison with those for MTG-I satellite series. As an example, AMVs calculated with Meteosat-10 satellite for the same moment of those calculated with Meteosat-12 (MTG-I1) satellite in *Figure 4* are shown in *Figure 2*.

The main element to be taken into account is again the larger population of MTG-I AMVs, although this increment is smaller than for the "Basic AMVs": the number of AMVs multiplies by a factor of 2.22 considering all AMVs together, 3.37 considering the high layer and 2.20 considering the medium layer. There is instead a reduction of 16% in the number if AMVs in the low layer. Due to the different increment factor in the different layers, the distribution of AMVs in the high/medium/low layer is again a bit different, with a value of 42%/23%/35% for MSG against the value of 64%/23%/13% for MTG-I, concentrating the AMVs more in the high layer.

Considering nevertheless both "Basic and Detailed AMVs" datasets together, the number of AMVs multiplies by a factor of 2.45 considering all AMVs together, 3.51 considering the high layer, 2.35 considering the medium layer and 1.26 considering the low layer, so with an increment in all layers.

Comparing the validation parameters for MSG and MTG-I "Detailed AMVs", the NBIAS is better for the MTG-I AMVs, although there are also compensations of negative values at high levels and positive values at medium levels, with a mean value of 0.00 for MTG-I AMVs and -0.02/-0.04 for MSG AMVs against Radiosounding/NWP analysis winds. However there are also some cases for which the NBIAS is better for the MSG "Detailed AMVs": generally in the medium layer and for clear air AMVs.

Considering the NMVD and the NRMSVD, the values for MTG-I are similar or slightly better, with a mean value of the NRMSVD of 0.35/0.20 for MTG-I AMVs and 0.39/0.24 for MSG AMVs against Radiosounding/NWP analysis winds. The improvement is here more significant for the visible AMVs and in the validation against NWP analysis at the low layer (up to around a 40%).

In summary, a larger amount of AMVs is calculated with MTG-I satellite considering both "Basic and Detailed AMVs" together, with better NBIAS values and smaller improvements in NMVD and NRMSVD values, justifying again a quick adoption of NWC/GEO-HRW v7.0 software with MTG-I satellite by NWCSAF users.

NWC/GEO-HRWv7.0 AMVs 9Oct2024-8Feb2025, Meteosat-10	Cloud HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	14874	52768	48499	64697	65795	17903	59260	578	324374
SPD [m/s]	11.68	10.79	10.57	21.08	21.52	27.61	24.40	23.71	18.46
NBIAS (ALL LAYERS)	-0.02	-0.07	-0.07	-0.02	-0.01	-0.00	-0.01	+0.06	-0.02
NMVD (100-1000 hPa)	0.35	0.38	0.39	0.28	0.28	0.26	0.27	0.29	0.30
NRMSVD	0.43	0.47	0.48	0.36	0.36	0.33	0.34	0.35	0.39
NC	14874	52768	48499	64697	65795	17903	59260	578	324374
SPD [m/s]	11.75	10.84	10.60	21.45	21.88	28.09	24.69	24.35	18.71
NBIAS (ALL LAYERS)	-0.02	-0.07	-0.07	-0.04	-0.03	-0.02	-0.02	+0.03	-0.04
NMVD (100-1000 hPa)	0.23	0.27	0.27	0.17	0.17	0.14	0.17	0.18	0.19
NRMSVD	0.29	0.35	0.35	0.22	0.21	0.17	0.21	0.23	0.24

Table 18: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-10 satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics)

NWC/GEO-HRWv7.0 AMVs 9Oct2024-8Feb2025, Meteosat-10	Cloud HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC (42%)	1319			35410	37762	17132	44564	578	136765
SPD [m/s]	24.81			25.54	25.58	27.89	26.68	23.71	26.20
NBIAS (HIGH LAYER)	-0.01			-0.03	-0.02	-0.00	-0.03	+0.06	-0.02
NMVD (100-400 hPa)	0.23			0.26	0.26	0.26	0.25	0.29	0.25
NRMSVD	0.28			0.33	0.33	0.33	0.32	0.35	0.33
NC (23%)	1856	8850	7997	20825	20891	771	13865		75055
SPD [m/s]	15.91	14.11	14.03	16.92	17.16	21.50	17.70		16.51
NBIAS (MEDIUM LAYER)	+0.01	-0.07	-0.07	+0.00	+0.01	+0.02	+0.08		+0.00
NMVD (400-700 hPa)	0.30	0.34	0.34	0.32	0.32	0.28	0.36		0.33
NRMSVD	0.36	0.42	0.41	0.40	0.39	0.34	0.44		0.41
NC (35%)	11699	43918	40502	8462	7142		831		112554
SPD [m/s]	9.53	10.12	9.88	12.65	12.76		14.21		10.36
NBIAS (LOW LAYER)	-0.03	-0.07	-0.07	-0.08	-0.06		+0.13		-0.06
NMVD (700-1000 hPa)	0.40	0.40	0.41	0.35	0.35		0.48		0.39
NRMSVD	0.48	0.48	0.50	0.50	0.50		0.56		0.49
NC (42%)	1319			35410	37762	17132	44564	578	136765
SPD [m/s]	24.82			26.04	26.07	28.35	26.99	24.35	26.63
NBIAS (HIGH LAYER)	-0.01			-0.05	-0.04	-0.02	-0.04	+0.03	-0.04
NMVD (100-400 hPa)	0.13			0.15	0.15	0.14	0.15	0.18	0.15
NRMSVD	0.16			0.19	0.18	0.17	0.18	0.23	0.18
NC (23%)	1856	8850	7997	20825	20891	771	13865		75055
SPD [m/s]	16.46	14.41	14.36	17.21	17.39	22.10	17.91		16.79
NBIAS (MEDIUM LAYER)	-0.02	-0.09	-0.09	-0.01	+0.00	-0.00	+0.07		-0.00
NMVD (400-700 hPa)	0.19	0.25	0.25	0.22	0.22	0.18	0.25		0.23
NRMSVD	0.25	0.32	0.32	0.28	0.28	0.21	0.31		0.29
NC (35%)	11699	43918	40502	8462	7142		831		112554
SPD [m/s]	9.52	10.12	9.86	12.69	12.81		14.35		10.36
NBIAS (LOW LAYER)	-0.02	-0.07	-0.07	-0.08	-0.06		+0.12		-0.06
NMVD (700-1000 hPa)	0.27	0.28	0.28	0.25	0.24		0.38		0.28
NRMSVD	0.34	0.36	0.36	0.33	0.31		0.46		0.35

Table 19: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (9 Oct 2024-8 Feb 2025 12:00 UTC; Meteosat-10 satellite; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics)

4.5 MAIN DIFFERENCES IN AMVS FROM MSG AND MTG-I SATELLITES

Comparing the NWC/GEO-HRW v7.0 output of MSG and MTG-I AMVs, three main elements need to be commented:

1) The better definition in general of the wind flow at all levels in more locations with the larger amount of MTG-I AMVs. This can be seen for example comparing the MSG and MTG-I AMV output:
   - In the whole validation region on 25 January 2025 at 12:00Z in *Figures 1 and 3*.
   - With more detail, around the low pressure area over the Ionian Sea on 24 December 2024 at 12:00Z in *Figure 5*, in which MTG-I AMVs define much better the wind flow from all directions with better AMV densities, and fill much better with AMV observations the holes appearing in the MSG AMV output.
   - Also with more detail, in the Eastern European region on 06 December 2024 at 12:00Z in *Figure 6*, in which MTG-I AMVs define also much better the wind flow in many more locations, and also fill much better with AMV observations the holes appearing in the MSG AMV output.
2) In spite of this, there are some cases in which the MSG AMV output is better, defining better the wind flow. It has been checked this occurs in small portions of a 13% of images inside the MTG-I validation dataset. These cases are related to low levels, as in the example in *Figure 7* for 31 October 2024 at 12:00Z, in which the low level wind flow over the Bay of Biscay is better defined by the MSG AMVs. It has been checked that MTG-I AMVs have not been removed in this area because of quality issues. A more detailed analysis of this will be done in the following version of NWC/GEO-HRW software, to improve these few cases in which the MSG AMV output is better than the MTG-I AMV output.
3) Considering differences existing between the MSG AMVs and the MTG-I AMVs, the only significant one is that low level MTG-I AMVs are frequently at a lower level, as in the example in *Figure 8* for 20 December 2024, in which the MTG-I low level AMVs over Germany, Poland and around the Island of Sardinia can be up to 100 hPa lower. In any case, comparing AMV statistics for MSG and MTG-I in *Table 20* for thinner 100 hPa layers throughout the whole validation period, it can be seen that MTG-I validation statistics are generally better at all layers, with smaller validation parameters (NBIAS, NMVD and NRMSVD), and especially at the low levels. Only the NBIAS at 400-500 hPa is slightly higher for MTG-I AMVs, and all statistics for MTG-I AMVs at 100-200 hPa are also higher, but this last case can be explained by the small amount of AMV data at those highest levels, with less representativeness. The amount of MTG-I AMVs is also higher at all levels except at 700-800 hPa, for which a very small reduction of 6% in the amount of data is seen. With all these results, we can conclude that the AMV pressure level definition for MTG-I AMVs is better, and the difference with the MSG low level AMVs really means an improvement for the MTG-I low level AMVs.

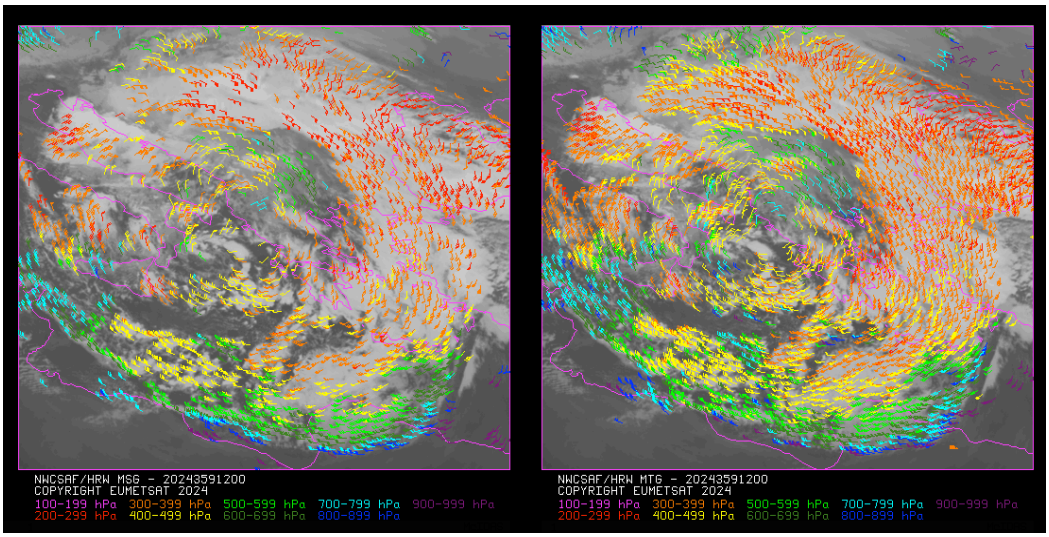

Figure 5: Comparison of NWC/GEO-High Resolution Winds v7.0 Basic AMV output for 24 December 2024 12:00 UTC for Meteosat-10 satellite (left) and Meteosat-12 (MTG-I1) satellite (right) around a low pressure area over the Ionian Sea

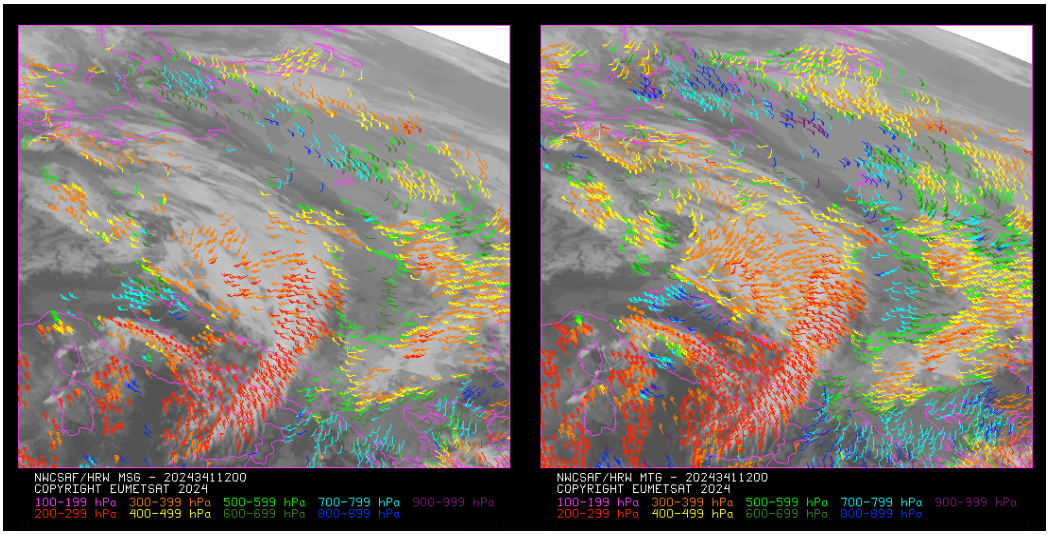

Figure 6: Comparison of NWC/GEO-High Resolution Winds v7.0 Basic AMV output for 6 December 2024 12:00 UTC for Meteosat-10 satellite (left) and Meteosat-12 (MTG-I1) satellite (right) in the Eastern European region

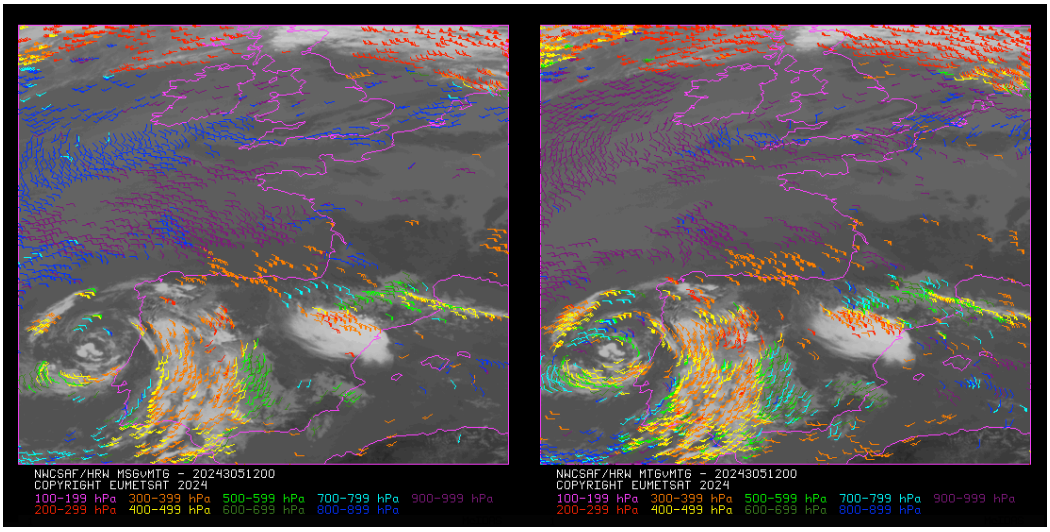

Figure 7: Comparison of NWC/GEO-High Resolution Winds v7.0 Basic AMV output for 31 October 2024 12:00 UTC for Meteosat-10 satellite (left) and Meteosat-12 (MTG-I1) satellite (right) in the region around the Bay of Biscay

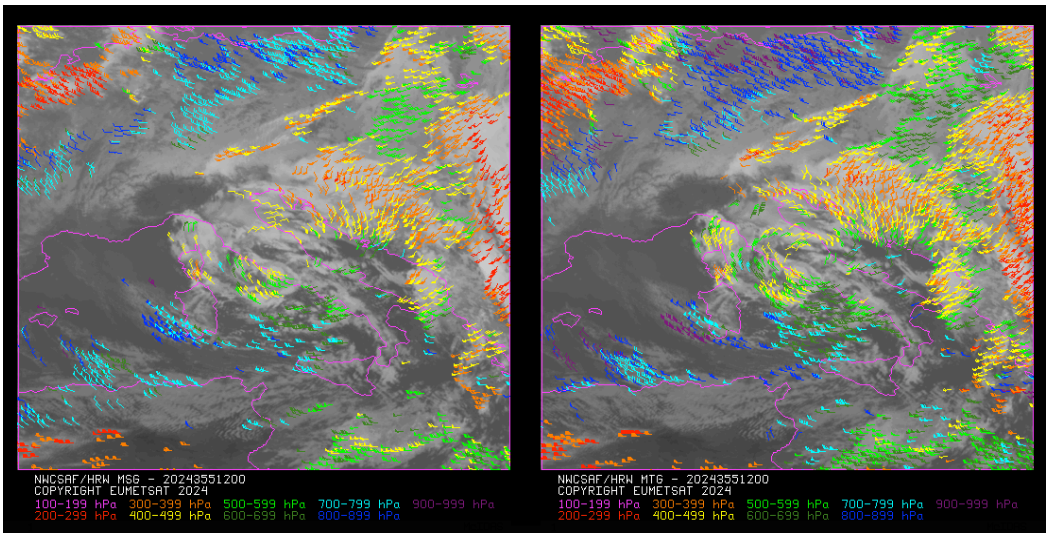

Figure 8: Comparison of NWC/GEO-High Resolution Winds v7.0 Basic AMV output for 20 December 2024 12:00 UTC for Meteosat-10 satellite (left) and Meteosat-12 (MTG-I1) satellite (right) in Central Europe and Italy

NWC/GEO-HRWv7.0 AMVs (9Oct2024-8Feb2025)	Meteosat-12 (MTG-I1) Basic AMVs NC	NBIAS	NMVD	NRMSVD	Meteosat-10 Basic AMVs NC	NBIAS	NMVD	NRMSVD
Reference: Radiosounding winds								
100-200 hPa	726	-0.06	0.23	0.28	87	-0.03	0.19	0.23
200-300 hPa	305169	-0.03	0.25	0.32	82418	-0.05	0.25	0.32
300-400 hPa	292270	-0.01	0.27	0.33	82140	-0.04	0.28	0.34
400-500 hPa	169702	+0.02	0.31	0.38	57528	+0.00	0.32	0.40
500-600 hPa	45036	+0.01	0.34	0.42	23218	-0.03	0.36	0.44
600-700 hPa	48199	+0.03	0.38	0.46	26089	-0.07	0.39	0.49
700-800 hPa	41815	-0.00	0.38	0.45	44558	-0.11	0.40	0.49
800-900 hPa	109404	-0.04	0.37	0.53	74766	-0.08	0.42	0.51
900-1000 hPa	77865	-0.00	0.43	0.53	23970	-0.05	0.50	0.60
Reference: NWP Analysis winds								
100-200 hPa	726	-0.00	0.08	0.11	87	+0.00	0.10	0.11
200-300 hPa	305169	-0.04	0.14	0.18	82418	-0.07	0.15	0.19
300-400 hPa	292270	-0.02	0.17	0.21	82140	-0.04	0.18	0.23
400-500 hPa	169702	+0.02	0.21	0.26	57528	-0.00	0.22	0.28
500-600 hPa	45036	+0.02	0.23	0.30	23218	-0.03	0.25	0.32
600-700 hPa	48199	+0.01	0.26	0.33	26089	-0.09	0.29	0.37
700-800 hPa	41815	-0.01	0.25	0.32	44558	-0.11	0.31	0.39
800-900 hPa	109404	-0.02	0.23	0.28	74766	-0.07	0.30	0.36
900-1000 hPa	77865	-0.00	0.23	0.30	23970	-0.04	0.33	0.41

Table 20: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering 100 hPa wide layers, for Meteosat-12 (MTG-I1) satellite (left) and Meteosat-10 satellite (right), against Radiosounding winds (up) and ECMWF NWP analysis winds (down) (9 Oct 2024-8 Feb 2025 12:00 UTC; European and Mediterranean region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Dark green figures show an improvement of at least 50% and light green figures of at least 10%, and dark red figures show a worsening of at least 50% and light red figures of at least 10%, for Meteosat-12 (MTG-I1) AMVs with respect to Meteosat-10 AMVs in the same period and region

5. VALIDATION OF HRW V7.0 AMVS WITH HIMAWARI-8/9 SATELLITES

5.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION

The validation of NWC/GEO-HRW v7.0 algorithm for Himawari-8/9 satellite series is based on the validation of AMVs calculated during 184 days of the half-yearly period March – August 2023 at 00:00 UTC, with Himawari-9 satellite images, in a region covering China, Korea, Japan and the adjacent parts of the Pacific Ocean. This region is shown in the example in *Figure 9*.

The default conditions for NWC/GEO-HRW v7.0 for Himawari-8/9 satellites, considering "Nominal scan satellite mode", "Basic scale AMVs", "Cross correlation tracking", "CCC height assignment method with Microphysics correction", and a "higher density for tracers related to medium and low level clouds", are considered for the validation. These conditions are specified in the default model configuration files `$SAFNWC/config/HIMA*/safnwc_HRW.cfm`, but with validation of all possible satellite channels. Cloudy AMVs in the layer 100-1000 hPa and water vapour clear air AMVs in the layer 100-400 hPa, with a Quality index with forecast ≥ 75%, are considered for the validation.

NWC/GEO-Cloud product outputs (CMA, CT, CTTH and CMIC) in the processing region have to be available so that NWC/GEO-HRW can fully process the conditions defined in the model configuration file. The running of three consecutive slots for all Cloud and HRW products every day during the reference validation period (23:40 UTC, 23:50 UTC and 00:00 UTC), is needed for the validation.

This configuration is equivalent to the one used for MTG-I, and permits very easily a comparison in the results for both satellite series.

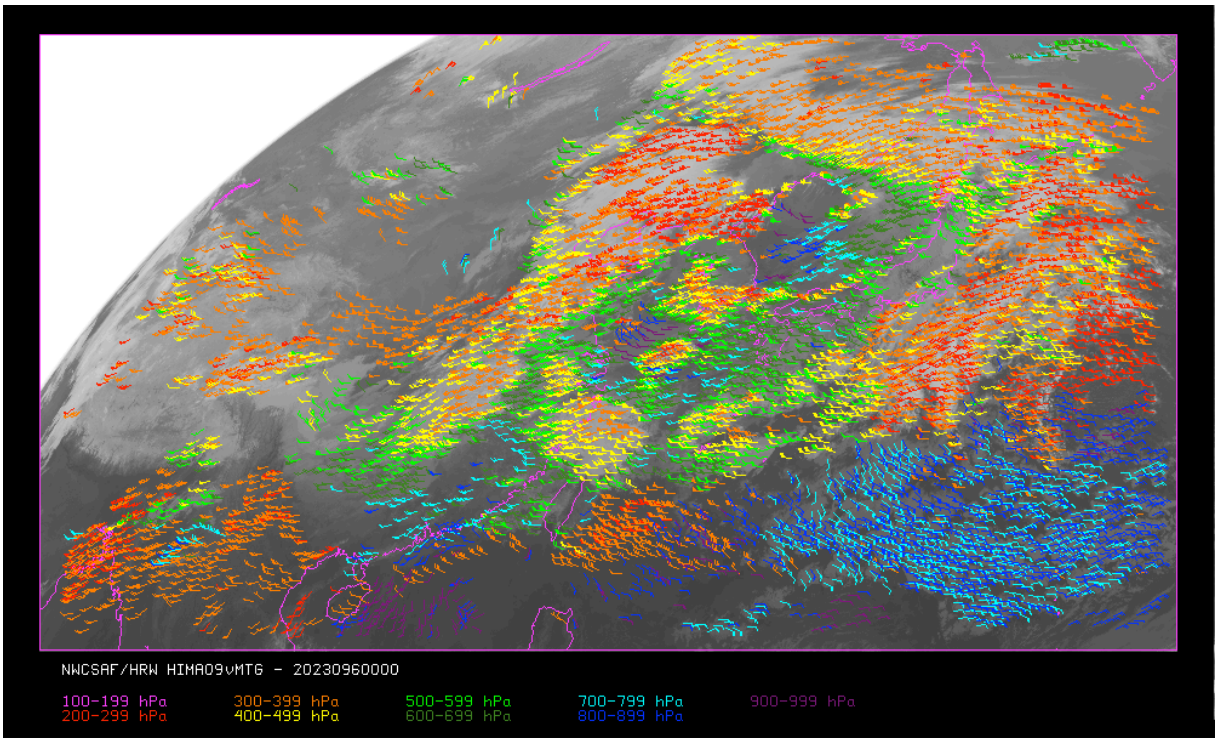

Figure 9: NWC/GEO-High Resolution Winds v7.0 Basic AMV output example in the China/Korea/Japan region (6 April 2023 00:00 UTC, Himawari-9 satellite), considering default conditions in `$SAFNWC/config/HIMA*/safnwc_HRW.cfm` model configuration file. Colour coding based on the AMV pressure level

Comparing the statistics against Radiosounding winds and ECMWF NWP analysis in *Table 21* (considering all layers together) and in *Table 22* (considering the three layers separately), the NBIAS, NMVD and NRMSVD parameters are in general again a 20-30% smaller against NWP analysis winds.

The NWC/GEO-HRW Product Requirement Table new "Target accuracy" for HRW vMTG-I day-1 is again reached in the three layers (which requests NRMSVD ≤ 0.36, 0.48, 0.54 respectively for high, medium and low layer against Radiosounding winds).

NWC/GEO-HRWv7.0 AMVs (Mar-Aug 2023, Himawari-9)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV69	Cloudy WV73	Clear Air	All AMVs
NC	15094	34668	161537	87995	131479	153774	52046	636593
SPD [m/s]	15.67	14.15	19.19	24.29	22.67	21.88	20.72	21.03
NBIAS (ALL LAYERS)	+0.01	+0.01	+0.04	+0.07	+0.07	+0.05	+0.03	+0.04
NMVD (100-1000 hPa)	0.28	0.31	0.28	0.26	0.28	0.28	0.29	0.27
NRMSVD	0.36	0.39	0.35	0.32	0.35	0.34	0.36	0.34
NC	15094	34668	161537	87995	131479	153774	52046	636593
SPD [m/s]	15.88	14.40	19.42	24.49	23.89	22.11	20.84	21.45
NBIAS (ALL LAYERS)	+0.00	+0.00	+0.03	+0.06	+0.06	+0.04	+0.02	+0.03
NMVD (100-1000 hPa)	0.18	0.19	0.20	0.18	0.20	0.20	0.22	0.19
NRMSVD	0.23	0.25	0.25	0.23	0.26	0.25	0.28	0.25

Table 21: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to equivalent NWC/GEO-HRW v6.2 Basic AMVs

NWC/GEO-HRWv7.0 AMVs (Mar-Aug 2023, Himawari-9)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV69	Cloudy WV73	Clear Air	All AMVs
NC (71%)	5146	10328	91153	83415	101643	107702	52046	451433
SPD [m/s]	25.34	23.50	23.36	24.47	24.01	23.87	20.72	23.55
NBIAS (HIGH LAYER)	-0.02	-0.02	+0.03	+0.06	+0.05	+0.03	+0.03	+0.03
NMVD (100-400 hPa)	0.22	0.23	0.25	0.26	0.26	0.25	0.29	0.25
NRMSVD	0.27	0.30	0.31	0.32	0.32	0.31	0.36	0.31
NC (23%)	4854	10895	50624	4580	29836	46072		146861
SPD [m/s]	13.80	13.39	15.96	21.16	18.11	17.22		16.69
NBIAS (MEDIUM LAYER)	+0.06	+0.06	+0.06	+0.14	+0.18	+0.11		+0.10
NMVD (400-700 hPa)	0.31	0.33	0.33	0.36	0.40	0.36		0.35
NRMSVD	0.39	0.41	0.42	0.45	0.50	0.45		0.44
NC (6%)	5094	13445	19760					38299
SPD [m/s]	7.69	7.57	8.22					7.92
NBIAS (LOW LAYER)	+0.07	+0.05	+0.02					+0.03
NMVD (700-1000 hPa)	0.43	0.45	0.44					0.44
NRMSVD	0.54	0.56	0.53					0.54
NC (71%)	5146	10328	91153	83415	101643	107702	52046	451433
SPD [m/s]	25.47	23.53	23.55	24.65	24.21	24.06	20.84	23.73
NBIAS (HIGH LAYER)	-0.02	-0.02	+0.03	+0.05	+0.04	+0.03	+0.02	+0.03
NMVD (100-400 hPa)	0.14	0.15	0.17	0.18	0.18	0.17	0.22	0.17
NRMSVD	0.17	0.19	0.22	0.22	0.22	0.22	0.28	0.22
NC (23%)	4854	10895	50624	4580	29836	46072		146861
SPD [m/s]	13.94	13.76	16.30	21.44	18.41	17.56		17.01
NBIAS (MEDIUM LAYER)	+0.05	+0.03	+0.04	+0.12	+0.16	+0.09		+0.08
NMVD (400-700 hPa)	0.21	0.21	0.23	0.26	0.32	0.27		0.25
NRMSVD	0.26	0.26	0.30	0.33	0.40	0.35		0.33
NC (6%)	4712	12380	17220					38299
SPD [m/s]	8.14	8.00	8.50					8.27
NBIAS (LOW LAYER)	+0.02	+0.01	+0.00					+0.00
NMVD (700-1000 hPa)	0.24	0.25	0.27					0.25
NRMSVD	0.29	0.30	0.34					0.31

Table 22: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to equivalent NWC/GEO-HRW v6.2 Basic AMVs

5.2 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION

The comparison of the statistics of NWC/GEO-HRW v7.0 "Basic AMVs" for Himawari-8/9 satellite series in *Tables 21 and 22*, with those for NWC/GEO-HRW v6.2 in *Tables 23 and 24* is considered here.

As already said previously for MSG satellite series, in contrast with previous updates of NWC/GEO-HRW algorithm, the changes related to Himawari-8/9 AMVs in this version are very limited (because most of the planned changes for Himawari-8/9 AMVs for this version were already included in the originally unplanned previous version NWC/GEO-HRW v6.2).

Due to this, comparing both versions, the number of AMVs in the different layers is very similar (with only slight differences smaller than 2%) and the proportion of AMVs in the three layers is exactly the same (71% in the high layer, 23% in the medium layer and 6% in the low layer). In both versions, the distribution of AMVs in the three layers is less homogeneous than for MSG and MTG-I satellite series for the characterization of the behaviour of the wind in the different levels of the troposphere, but this is related to the China/Korea/Japan region used for the validation, with less maritime areas and large high altitude and desert areas.

Considering the validation parameters, there is however a visible reduction over 10% in the NBIAS in at least a third of the AMV groups in *Tables 21 and 22* (shown in green; although also visible AMVs show an increase over 10% in the high layer NBIAS shown in red). All validation parameters (NBIAS, NMVD, NRMSVD) show also reductions over 10% (in green) at the low layer against NWP model, and also in some cases against Radiosounding winds.

These differences are caused by the use of 25 levels of ECMWF NWP model both in the calculation and validation of AMVs, instead of the 15 levels used in previous versions, which has a positive impact in the vertical location of the AMVs, especially at the low levels. This impact of the use of 25 levels of ECMWF NWP model is much more visible than for the MSG AMVs, very probably related to the larger proportion of high altitude pixels in the China/Korea/Japan region used for the validation of Himawari-8/9 AMVs, whose ground is in the vicinity of some of the additional NWP levels (950, 900, 800 and 600 hPa, related approximately to 500, 1000, 2000 and 4000 m of altitude).

With all this, the behaviour of NWC/GEO-HRW "Basic AMVs" with Himawari-8/9 satellite is better in the latest version v7.0, although this is in general only caused by the use of 25 levels of ECMWF NWP model in the default configuration calculations.

NWC/GEO-HRWv6.2 AMVs (Mar-Aug 2023, Himawari-9)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV69	Cloudy WV73	Clear Air	All AMVs
NC	14923	35125	160474	88831	131950	153625	51383	636311
SPD [m/s]	15.54	14.00	19.23	24.19	22.63	21.84	20.54	20.98
NBIAS (ALL LAYERS)	+0.02	+0.02	+0.04	+0.07	+0.08	+0.06	+0.03	+0.05
NMVD (100-1000 hPa)	0.29	0.31	0.28	0.26	0.28	0.28	0.29	0.27
NRMSVD	0.36	0.40	0.35	0.32	0.35	0.34	0.36	0.34
NC	14923	35125	160474	88831	131950	153625	51383	636311
SPD [m/s]	15.66	14.12	19.43	24.43	22.86	22.09	20.84	21.21
NBIAS (ALL LAYERS)	+0.01	+0.01	+0.03	+0.06	+0.07	+0.05	+0.02	+0.04
NMVD (100-1000 hPa)	0.19	0.21	0.20	0.18	0.20	0.20	0.22	0.19
NRMSVD	0.24	0.26	0.25	0.23	0.26	0.25	0.28	0.25

Table 23: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; CCC height assignment with Microphysics)

NWC/GEO-HRWv6.2 AMVs (Mar-Aug 2023, Himawari-9)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV69	Cloudy WV73	Clear Air	All AMVs
NC (71%)	5091	10426	91069	83965	102110	108211	51383	452255
SPD [m/s]	25.14	23.37	23.27	24.34	23.90	23.70	20.54	23.42
NBIAS (HIGH LAYER)	-0.01	-0.01	+0.04	+0.07	+0.06	+0.04	+0.03	+0.04
NMVD (100-400 hPa)	0.21	0.23	0.25	0.26	0.26	0.25	0.29	0.25
NRMSVD	0.27	0.29	0.31	0.32	0.32	0.31	0.36	0.31
NC (23%)	4579	10509	50095	4866	29840	45414		145303
SPD [m/s]	14.04	13.44	16.11	21.59	18.26	17.39		16.87
NBIAS (MEDIUM LAYER)	+0.06	+0.06	+0.06	+0.14	+0.17	+0.11		+0.10
NMVD (400-700 hPa)	0.31	0.33	0.33	0.35	0.40	0.36		0.35
NRMSVD	0.39	0.41	0.41	0.43	0.49	0.44		0.43
NC (6%)	5253	14190	19310					38753
SPD [m/s]	7.55	7.52	8.26					7.89
NBIAS (LOW LAYER)	+0.07	+0.06	+0.02					+0.04
NMVD (700-1000 hPa)	0.49	0.49	0.45					0.47
NRMSVD	0.60	0.60	0.55					0.57
NC (71%)	5091	10426	91069	83965	102110	108211	51383	452255
SPD [m/s]	25.38	23.48	23.48	24.58	24.16	23.95	20.75	23.66
NBIAS (HIGH LAYER)	-0.01	-0.02	+0.03	+0.06	+0.05	+0.03	+0.02	+0.03
NMVD (100-400 hPa)	0.14	0.15	0.17	0.18	0.18	0.17	0.22	0.17
NRMSVD	0.17	0.19	0.22	0.22	0.22	0.22	0.28	0.22
NC (23%)	4579	10509	50095	4866	29840	45414		145303
SPD [m/s]	14.07	13.63	16.35	21.87	18.43	17.64		17.09
NBIAS (MEDIUM LAYER)	+0.06	+0.05	+0.05	+0.13	+0.16	+0.09		+0.08
NMVD (400-700 hPa)	0.22	0.22	0.24	0.27	0.32	0.28		0.26
NRMSVD	0.28	0.28	0.31	0.34	0.40	0.36		0.34
NC (6%)	5253	14190	19310					38753
SPD [m/s]	7.62	7.59	8.28					7.93
NBIAS (LOW LAYER)	+0.06	+0.05	+0.01					+0.03
NMVD (700-1000 hPa)	0.32	0.32	0.31					0.31
NRMSVD	0.39	0.39	0.39					0.39

Table 24: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; CCC height assignment with Microphysics)

5.3 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION

The validation of "Detailed AMVs" (with a default tracer size of 12x12 pixels instead of the 24x24 pixels considered by the "Basic AMVs") for Himawari-8/9 satellite series is considered now. The calculation of "Detailed AMVs" is activated again changing configurable parameter CDET = 1 in the default model configuration files. These are provided as an additional dataset of AMVs together with the "Basic AMVs", which are always calculated.

The conditions for the validation of "Detailed AMVs" are exactly equivalent to those shown in chapter 5.1 for the Himawari-8/9 "Basic AMVs". An example of this configuration is shown in *Figure 10*. The validation statistics are presented in *Table 25* (considering all layers together) and *Table 26* (considering the three layers separately) for the same validation period.

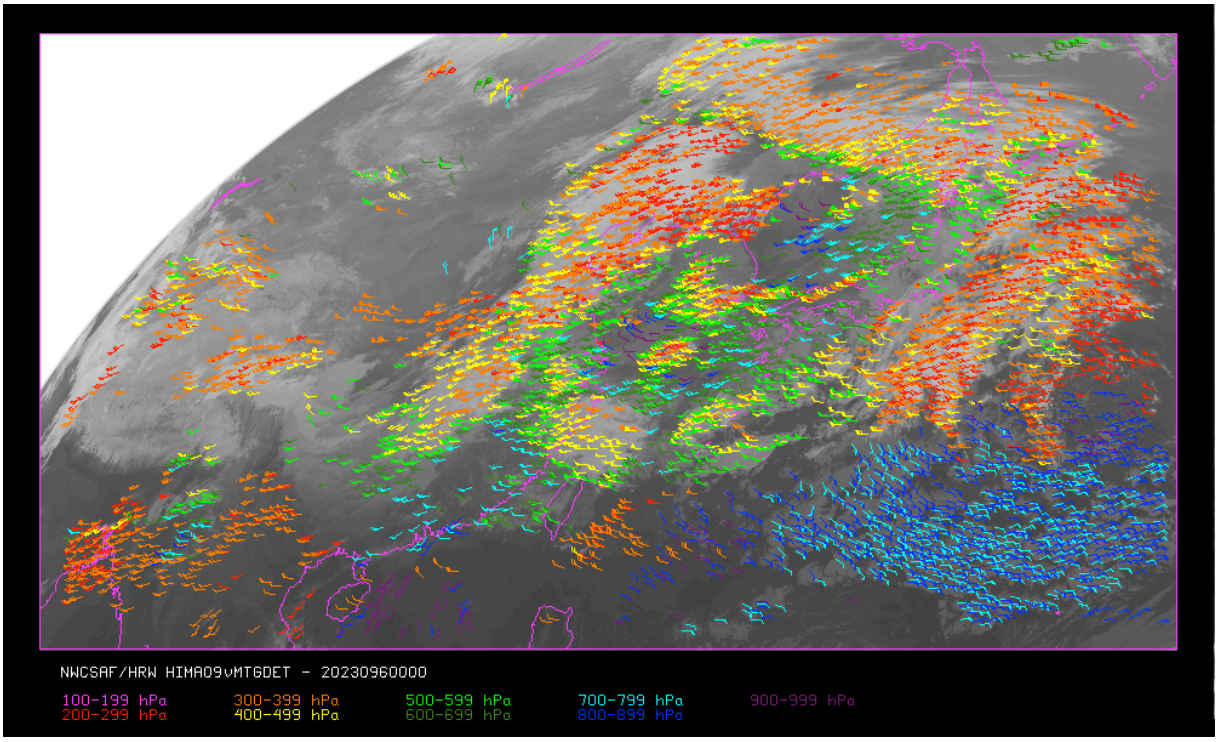

Figure 10: NWC/GEO-High Resolution Winds v7.0 Detailed AMV output example in the China/Korea/Japan region (6 April 2023 00:00 UTC, Himawari-9 satellite), considering default conditions in `$SAFNWC/config/HIMA*/safnwc_HRW.cfm` model configuration file and configurable parameter CDET = 1. Colour coding based on the AMV pressure level

Comparing with "Basic AMVs", a 43% reduction in the number of AMVs is seen for the "Detailed AMVs", in contrast to what happens with MSG satellites, for which the amount of "Detailed AMVs" is more or less equivalent. This can be explained through the smaller persistence due to the smaller size of the Detailed tracers used with Himawari-8/9 satellites, and the smaller contrast in the features using this smaller size; this behaviour is equivalent to the one shown by MTG-I "Detailed AMVs".

The distribution of validated AMVs in the different layers has a value of 74%/22%/4% for the high, medium and low layer, slightly concentrating more the AMVs in the high layer with respect to what was observed with the "Basic AMVs". The smaller number of low level "Detailed AMVs" is also to be taken into account in operational use. Comparing the validation parameters against those for "Basic AMVs", the NBIAS for "Detailed AMVs" is similar or slightly larger while the NMVD and NRMSVD are similar or slightly smaller.

Considering the NWC/GEO-HRW Product Requirement Table, the new "Optimal accuracy" for HRW vMTG-I day-1 is reached in the high layer (which requests NRMSVD $\leq$ 0.30 against Radiosounding winds), and the new "Target accuracy" is reached in the medium and low layer (which requests NRMSVD $\leq$ 0.48, 0.54 respectively against Radiosounding winds).

With all this, the behaviour of "Detailed AMVs" is similar to the one of "Basic AMVs", and both datasets can be used together operationally.

NWC/GEO-HRWv7.0 AMVs (Mar-Aug 2023, Himawari-9)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV69	Cloudy WV73	Clear Air	All AMVs
NC	3449	23177	110610	41816	74778	101486	10321	365637
SPD [m/s]	13.18	15.76	21.54	25.56	24.63	23.79	22.39	22.83
NBIAS (ALL LAYERS)	+0.03	+0.02	+0.06	+0.06	+0.07	+0.06	+0.07	+0.05
NMVD (100-1000 hPa)	0.32	0.28	0.27	0.25	0.27	0.27	0.30	0.26
NRMSVD	0.41	0.37	0.34	0.31	0.33	0.33	0.40	0.33
NC	3449	23177	110610	41816	74778	110486	10321	365637
SPD [m/s]	13.43	15.99	21.76	25.68	24.84	24.02	22.45	23.06
NBIAS (ALL LAYERS)	+0.01	+0.00	+0.05	+0.05	+0.06	+0.05	+0.07	+0.04
NMVD (100-1000 hPa)	0.19	0.18	0.19	0.17	0.18	0.19	0.22	0.18
NRMSVD	0.25	0.23	0.24	0.21	0.23	0.23	0.28	0.23

Table 25: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs

NWC/GEO-HRWv7.0 AMVs (Mar-Aug 2023, Himwari-9)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV69	Cloudy WV73	Clear Air	All AMVs
NC (74%)	516	8308	69942	40738	62778	78078	10321	270681
SPD [m/s]	25.78	24.80	24.66	25.62	25.65	25.35	22.39	25.15
NBIAS (HIGH LAYER)	-0.03	-0.02	+0.05	+0.06	+0.05	+0.04	+0.07	+0.04
NMVD (100-400 hPa)	0.21	0.23	0.24	0.25	0.24	0.24	0.30	0.24
NRMSVD	0.28	0.29	0.30	0.31	0.30	0.30	0.40	0.30
NC (22%)	1354	6562	35598	1078	12000	23408		80000
SPD [m/s]	14.21	14.25	17.10	23.28	19.28	18.58		17.66
NBIAS (MEDIUM LAYER)	+0.05	+0.07	+0.10	+0.14	+0.21	+0.17		+0.13
NMVD (400-700 hPa)	0.31	0.32	0.34	0.35	0.41	0.38		0.36
NRMSVD	0.39	0.40	0.43	0.43	0.50	0.47		0.44
NC (4%)	1579	8307	5070					14956
SPD [m/s]	8.17	7.90	9.70					8.53
NBIAS (LOW LAYER)	+0.08	+0.07	-0.05					+0.06
NMVD (700-1000 hPa)	0.44	0.42	0.41					0.41
NRMSVD	0.53	0.52	0.51					0.51
NC (74%)	516	8308	69942	40738	62778	78078	10321	270681
SPD [m/s]	25.80	24.83	24.85	25.74	25.83	25.53	22.45	25.31
NBIAS (HIGH LAYER)	-0.03	-0.02	+0.04	+0.05	+0.04	+0.03	+0.07	+0.03
NMVD (100-400 hPa)	0.13	0.14	0.16	0.17	0.16	0.16	0.22	0.16
NRMSVD	0.16	0.18	0.21	0.21	0.20	0.20	0.28	0.20
NC (22%)	1354	6562	35598	1078	12000	23408		80000
SPD [m/s]	14.28	14.63	17.38	23.72	19.64	18.97		17.99
NBIAS (MEDIUM LAYER)	+0.05	+0.05	+0.08	+0.11	+0.18	+0.14		+0.11
NMVD (400-700 hPa)	0.20	0.20	0.24	0.25	0.33	0.29		0.26
NRMSVD	0.26	0.26	0.31	0.32	0.40	0.37		0.33
NC (4%)	1579	8307	5070					14956
SPD [m/s]	8.66	8.23	9.94					8.85
NBIAS (LOW LAYER)	+0.02	+0.03	+0.03					+0.02
NMVD (700-1000 hPa)	0.24	0.24	0.26					0.24
NRMSVD	0.29	0.30	0.34					0.31

Table 26: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs

5.4 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION

The comparison of the statistics of NWC/GEO-HRW v7.0 "Detailed AMVs" for Himawari-8/9 satellite series in *Tables 25 and 26*, with those for NWC/GEO-HRW v6.2 in *Tables 27 and 28* is considered here.

As already said previously for the "Basic AMVs", in contrast with previous updates of NWC/GEO-HRW algorithm, the changes related to Himawari-8/9 AMVs in this version are very limited, because most of the planned changes for Himawari-8/9 AMVs for this version were already included in the originally unplanned previous version NWC/GEO-HRW v6.2.

Due to this, comparing both versions, the number of AMVs is very similar in all layers (with only slight differences smaller than 2%) and the proportion of AMVs in the three layers is exactly the same (71% in the high layer, 23% in the medium layer and 6% in the low layer). As for the "Basic AMVs", the distribution of AMVs in the three layers is less homogeneous than for MSG and MTG-I satellite series for the characterization of the behaviour of the wind in the different levels of the troposphere, but this is related to the China/Korea/Japan region used for the validation, with less maritime areas and large high altitude and desert area.

Considering the validation parameters, there is however a visible reduction over 10% in the NBIAS in more than half of the AMV groups in *Tables 25 and 26* (shown in green; although five AMV groups also show an increase over 10%, shown in red). NMVD and NRMSVD parameters also show reductions over 10% (in green) at the low layer in many AMV groups against both Radiosounding winds and NWP analysis winds.

These improvements are again caused by the use of 25 levels of ECMWF NWP model both in the calculation and validation of AMVs, instead of the 15 levels used in previous versions, due to their positive impact in the vertical location of the AMVs. The reasons for this are the same than those expressed for the Himawari-8/9 "Basic AMVs".

With all this, the behaviour of NWC/GEO-HRW "Detailed AMVs" with Himawari-8/9 satellite is better in the latest version v7.0, although as already said this is only caused by the use of 25 levels of ECMWF NWP model in the default configuration calculations.

NWC/GEO-HRWv6.2 AMVs (Mar-Aug 2023, Himawari-9)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV69	Cloudy WV73	Clear Air	All AMVs
NC	3527	23421	110135	42196	75154	101445	10288	366166
SPD [m/s]	12.90	15.48	21.53	25.49	24.52	23.71	22.16	22.75
NBIAS (ALL LAYERS)	+0.06	+0.03	+0.07	+0.07	+0.08	+0.07	+0.08	+0.06
NMVD (100-1000 hPa)	0.33	0.30	0.27	0.25	0.27	0.27	0.30	0.27
NRMSVD	0.42	0.38	0.34	0.31	0.32	0.33	0.39	0.33
NC	3527	23421	110135	42196	75154	101445	10288	366166
SPD [m/s]	13.10	15.58	21.75	25.71	24.74	23.93	22.36	22.96
NBIAS (ALL LAYERS)	+0.04	+0.02	+0.06	+0.06	+0.07	+0.06	+0.07	+0.05
NMVD (100-1000 hPa)	0.22	0.19	0.19	0.17	0.18	0.19	0.23	0.18
NRMSVD	0.27	0.24	0.24	0.21	0.23	0.23	0.28	0.23

Table 27: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; CCC height assignment with Microphysics)

NWC/GEO-HRWv6.2 AMVs (Mar-Aug 2023, Himawari-9)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV69	Cloudy WV73	Clear Air	All AMVs
NC (74%)	526	8311	69634	41038	63026	78109	10288	270932
SPD [m/s]	25.21	24.51	24.56	25.54	25.50	25.23	22.16	25.02
NBIAS (HIGH LAYER)	+0.00	-0.00	+0.06	+0.06	+0.06	+0.05	+0.08	+0.05
NMVD (100-400 hPa)	0.21	0.23	0.24	0.25	0.24	0.24	0.30	0.24
NRMSVD	0.27	0.28	0.30	0.30	0.30	0.29	0.39	0.29
NC (22%)	1363	6362	35631	1158	12128	23336		79978
SPD [m/s]	14.21	14.35	17.23	23.68	19.39	18.64		17.78
NBIAS (MEDIUM LAYER)	+0.07	+0.08	+0.10	+0.15	+0.20	+0.17		+0.13
NMVD (400-700 hPa)	0.32	0.32	0.34	0.35	0.41	0.38		0.36
NRMSVD	0.40	0.40	0.43	0.43	0.50	0.47		0.44
NC (4%)	1638	8748	4870					15256
SPD [m/s]	7.85	7.72	9.83					8.40
NBIAS (LOW LAYER)	+0.10	+0.09	+0.04					+0.07
NMVD (700-1000 hPa)	0.48	0.48	0.42					0.46
NRMSVD	0.57	0.60	0.52					0.57
NC (74%)	526	8311	69634	41038	63026	78109	10288	268904
SPD [m/s]	25.62	24.63	24.80	25.75	25.74	25.45	22.36	25.25
NBIAS (HIGH LAYER)	-0.01	-0.01	+0.05	+0.06	+0.05	+0.04	+0.07	+0.04
NMVD (100-400 hPa)	0.13	0.14	0.17	0.17	0.16	0.16	0.23	0.16
NRMSVD	0.16	0.17	0.21	0.21	0.20	0.20	0.28	0.20
NC (22%)	1363	6362	35631	1158	12128	23336		79978
SPD [m/s]	14.26	14.56	17.41	24.12	19.57	18.86		17.97
NBIAS (MEDIUM LAYER)	+0.07	+0.06	+0.09	+0.13	+0.19	+0.15		+0.12
NMVD (400-700 hPa)	0.22	0.22	0.25	0.25	0.33	0.30		0.27
NRMSVD	0.28	0.28	0.32	0.32	0.40	0.37		0.34
NC (4%)	1638	8751	4870					15259
SPD [m/s]	8.12	7.71	9.98					8.47
NBIAS (LOW LAYER)	+0.06	+0.09	+0.03					+0.06
NMVD (700-1000 hPa)	0.30	0.32	0.28					0.30
NRMSVD	0.36	0.39	0.35					0.37

Table 28: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (Mar-Aug 2023 00:00 UTC, Himawari-9 satellite, China/Korea/Japan region; Cross correlation; CCC height assignment with Microphysics)

5.5 COMPARISON WITH MTG-I SATELLITE SERIES

Comparing the statistics of NWC/GEO-HRW v7.0 default configuration for Himawari-8/9 satellites with those for MTG-I satellites (*Tables 21 and 22* compared with *Tables 12 and 13*), the distribution of AMVs in the different layers has a value for Himawari-8/9 of 71%/23%/6% for the high/medium/low layer, while for MTG-I satellites it has a value of 55%/24%/21%. The larger concentration of AMVs in the high layer for Himawari-8/9 satellites can be caused by two main reasons:

- On one side, the already mentioned China/Korea/Japan region used for the validation with Himawari-8/9, with less maritime areas and large high altitude and desert areas, and so with less frequent low clouds.
- On the other side, the different line-up of satellite channels used in the corresponding AMV processing. For MTG-I there are two visible, two infrared and two water vapour channels, while for Himawari-8/9 there are two visible, one infrared and three water vapour channels. The ones for MTG-I distribute better the AMVs in the high, medium and low layer, while the ones for Himawari-8/9 tend to concentrate more the AMVs in the high layer. An option to improve this could be to use in future versions of Himawari-8/9 algorithm more visible or infrared channels in the AMV processing.

Comparing the validation parameters for both satellites, considering all layers together MTG-I and Himawari-8/9 satellite series show very similar NMVD and NRMSVD values with variations up to a 12% (in some cases better for MTG-I and in other cases better for Himawari-8/9). It is also remarkable that the NBIAS parameter is negative for MTG-I and positive and larger for Himawari-8/9 (-0.01 versus +0.04 against Radiosounding winds).

Considering each layer separately, validation parameters have also small differences up to a 15%, being better for Himawari-8/9 in the high layer and better for MTG-I in the medium and low layer. The most significant difference is the NBIAS for Himawari-8/9 medium level AMVs, with a much larger value of +0.10 (compared to +0.02 in MTG-I AMVs, which can be explained by the larger difficulties to define clouds in the large high altitude areas present in the China/Korea/Japan region).

In spite of the differences (which are inside the normal variability defined by the use of different data for the validation of the same algorithm), the operability of NWC/GEO-HRW algorithm for both satellite series is equivalent. As already said, the “Target accuracy” for HRW vMTG-I day-1 is reached in the three layers for both satellite series.

6. VALIDATION OF HRW V7.0 AMVS WITH GOES-R SATELLITES

6.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION

The validation of NWC/GEO-HRW v7.0 algorithm for GOES-R satellite series is based on the validation of "Basic AMVs" calculated with GOES-16 satellite images, in the region covering the Continental United States shown in *Figure 11*. AMVs calculated during 89 days of the quarterly period May – July 2019, at 00:00 UTC and 12:00 UTC, are considered for this validation. The results are provided in *Tables 29 and 30*.

The default conditions for NWC/GEO-HRW v7.0 for GOES-R satellites, considering "Mode 6 scanning with images every 10 minutes" (operational for GOES-16 since April 2019), "Basic scale AMVs", "Cross correlation tracking", "CCC height assignment method with Microphysics correction", and a "higher density for tracers related to medium and low level clouds", are defined for the validation. These conditions are specified in the default model configuration files `$SAFNWC/config/GOES*/safnwc_HRW.cfm`, but with validation of all possible satellite channels. Cloudy AMVs in the layer 100-1000 hPa and water vapour clear air AMVs in the layer 100-400 hPa, with a Quality index with forecast ≥ 75%, are considered in this validation.

NWC/GEO-Cloud product outputs (CMA, CT, CTTH and CMIC) in the processing region have to be available so that NWC/GEO-HRW can fully process the conditions defined in the model configuration file. The running of three consecutive slots for all Cloud and HRW products for the validation moments (23:40 UTC, 23:50 UTC and 00:00 UTC on one side, and 11:40 UTC, 11:50 UTC and 12:00 UTC on the other side), are needed. This configuration is equivalent to the one used for MTG-I and Himawari-8/9, and permits very easily a comparison in the results for the three satellite series.

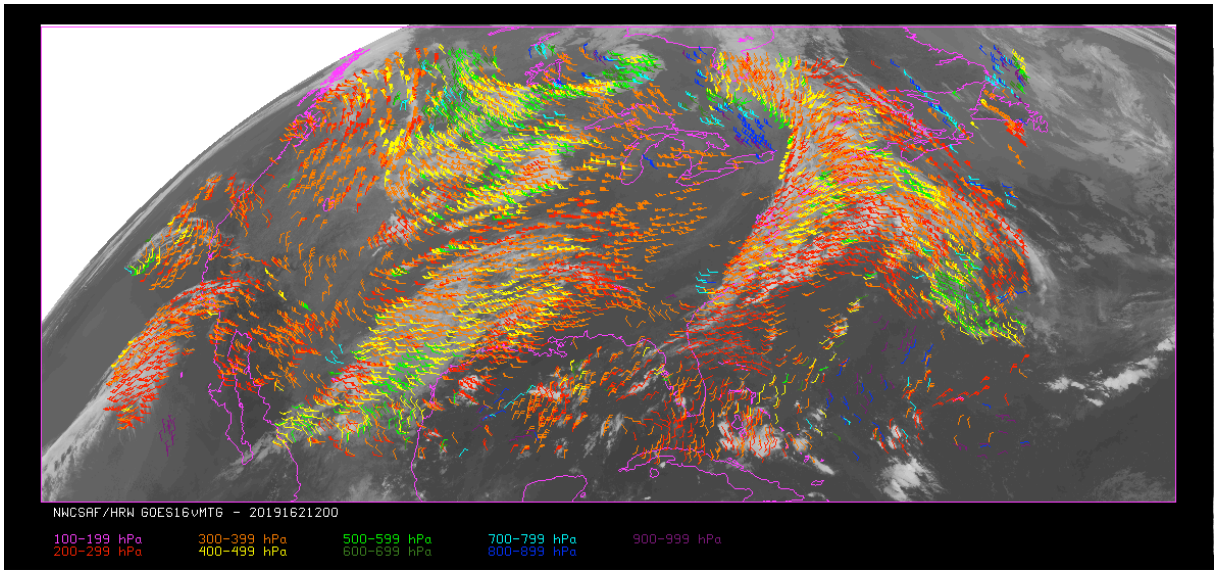

Figure 11: NWC/GEO-High Resolution Winds v7.0 Basic AMV output example in the Continental United States region (11 June 2019 12:00 UTC, GOES-16 satellite), considering default conditions in `$SAFNWC/config/GOES*/safnwc_HRW.cfm` model configuration file. Colour coding based on the AMV pressure level

Comparing the statistics against Radiosounding winds and ECMWF NWP analysis in *Tables 29 and 30*, the NMVD and NRMSVD are once again between a 20% and a 40% smaller against NWP analysis winds. The distribution of AMVs in the high, medium and low layer has a value of 78%/18%/4%, which is relatively similar to the value obtained with Himawari-8/9, although with a bit higher frequency of high level AMVs.

Considering the different layers, as in previous cases, the validation parameters are progressively larger for the high layer, medium layer and low layer. As for all previous satellites series, the NWC/GEO-HRW Product Requirement Table new "Target accuracy" for HRW vMTG-I day-1 is again reached in the three layers (which requests NRMSVD ≤ 0.36, 0.48, 0.54 respectively for high, medium and low layer against Radiosounding winds).

NWC/GEO-HRWv7.0 AMVs (May-Jul 2019, GOES-16 M6)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV74	Clear Air	All AMVs
NC	13417	38579	321719	197879	266905	310119	222056	1370674
SPD [m/s]	17.87	16.61	18.73	23.14	22.05	21.33	17.99	20.41
NBIAS (ALL LAYERS)	+0.04	+0.04	+0.05	+0.07	+0.08	+0.05	+0.05	+0.05
NMVD (100-1000 hPa)	0.27	0.28	0.29	0.27	0.28	0.28	0.31	0.28
NRMSVD	0.33	0.35	0.36	0.33	0.35	0.34	0.39	0.35
NC	13417	38579	321719	197879	266905	310119	222056	1370674
SPD [m/s]	18.15	16.72	18.74	23.05	21.99	21.27	18.11	20.40
NBIAS (ALL LAYERS)	+0.02	+0.03	+0.05	+0.08	+0.08	+0.06	+0.04	+0.05
NMVD (100-1000 hPa)	0.15	0.17	0.21	0.19	0.20	0.19	0.24	0.20
NRMSVD	0.19	0.22	0.26	0.24	0.26	0.25	0.31	0.26

Table 29: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Basic AMVs

NWC/GEO-HRWv7.0 AMVs (May-Jul 2019, GOES-16 M6)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV74	Clear Air	All AMVs
NC (78%)	6909	16455	185451	187564	214576	229348	222056	1062359
SPD [m/s]	24.34	23.50	21.81	23.36	23.06	22.78	17.99	21.78
NBIAS (HIGH LAYER)	+0.01	+0.01	+0.05	+0.07	+0.06	+0.04	+0.05	+0.05
NMVD (100-400 hPa)	0.22	0.23	0.27	0.27	0.26	0.26	0.31	0.27
NRMSVD	0.26	0.27	0.33	0.32	0.32	0.31	0.39	0.33
NC (18%)	2794	10313	95252	10315	52329	80771		251774
SPD [m/s]	15.67	14.86	16.50	19.09	17.89	17.19		17.03
NBIAS (MEDIUM LAYER)	+0.07	+0.06	+0.04	+0.17	+0.18	+0.11		+0.09
NMVD (400-700 hPa)	0.29	0.30	0.32	0.39	0.41	0.36		0.35
NRMSVD	0.35	0.37	0.40	0.50	0.50	0.45		0.43
NC (4%)	3714	11811	41016					56541
SPD [m/s]	7.48	8.52	9.99					9.52
NBIAS (LOW LAYER)	+0.18	+0.11	+0.03					+0.05
NMVD (700-1000 hPa)	0.58	0.45	0.37					0.40
NRMSVD	0.71	0.57	0.45					0.49
NC (78%)	6909	16455	185451	187564	214576	229348	220056	1062359
SPD [m/s]	24.23	23.29	21.76	23.26	22.97	22.67	18.11	21.74
NBIAS (HIGH LAYER)	+0.01	+0.02	+0.05	+0.07	+0.06	+0.05	+0.04	+0.05
NMVD (100-400 hPa)	0.13	0.14	0.19	0.18	0.18	0.17	0.24	0.19
NRMSVD	0.16	0.17	0.24	0.23	0.22	0.21	0.31	0.24
NC (18%)	2794	10313	95252	10315	52329	80771		251774
SPD [m/s]	15.76	14.93	16.56	19.33	17.98	17.28		17.12
NBIAS (MEDIUM LAYER)	+0.06	+0.05	+0.03	+0.16	+0.17	+0.10		+0.08
NMVD (400-700 hPa)	0.20	0.20	0.24	0.31	0.34	0.29		0.27
NRMSVD	0.25	0.26	0.31	0.38	0.42	0.37		0.35
NC (4%)	3714	11811	41016					56541
SPD [m/s]	8.65	9.12	10.12					9.81
NBIAS (LOW LAYER)	+0.02	+0.04	+0.02					+0.02
NMVD (700-1000 hPa)	0.24	0.25	0.25					0.24
NRMSVD	0.30	0.31	0.32					0.31

Table 30: Validation parameters for NWC/GEO-HRW v7.0 Basic AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Basic AMVs

6.2 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION

The comparison of the statistics of NWC/GEO-HRW v7.0 "Basic AMVs" for GOES-16 satellite with those for NWC/GEO-HRW v6.2 in *Tables 31 and 32* is considered here.

As already said previously for MSG and Himawari-8/9 satellite series, in contrast with previous updates of NWC/GEO-HRW algorithm, the changes related to GOES-R AMVs in this version are very limited (because most of the planned changes for GOES-R AMVs for this version were already included in the originally unplanned previous version NWC/GEO-HRW v6.2).

Due to this, comparing both versions, the number of AMVs is basically the same (with slight differences smaller than 2%, except for the low layer which presents a larger reduction in the number of AMVs up to an 11%). The proportion of AMVs in the three layers is similar, although showing the reduction in the amount of low layer AMVs (78% in the high layer, 18% in the medium layer and 4% in the low layer).

As for Himawari-8/9 satellites, the distribution of AMVs in the three layers is less homogeneous than for MSG and MTG-I satellite series for the characterization of the behaviour of the wind in the different levels of the troposphere, but this is also related to the Continental United States region used for the validation, with less maritime areas and large high altitude areas in the Western half of the country.

Considering the validation parameters, there is a reduction over 10% in the NBIAS in a few AMV groups in *Tables 29 and 30* (shown in green; although the NBIAS also increases over 10% in the medium layer infrared AMVs against Radiosounding winds). The NMVD and NRMSVD parameters also show small reductions, up to an 11% in the low layer, against both Radiosounding and NWP analysis winds. As for Himawari-8/9 satellites, these differences are caused by the use of 25 levels of ECMWF NWP model both in the calculation and validation of AMVs instead of the 15 levels used in previous versions, although here for GOES-R satellite series the effect is less visible.

With all this, the behaviour of NWC/GEO-HRW "Basic AMVs" with GOES-R satellites is a bit better in the latest version v7.0, although less clearly than for Himawari-8/9 satellite series.

NWC/GEO-HRWv6.2 AMVs (May-Jul 2019, GOES-16 M6)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV74	Clear Air	All AMVs
NC	13546	39462	323423	194809	263303	305271	220224	1360038
SPD [m/s]	17.68	16.32	18.59	23.22	22.12	21.39	18.00	20.39
NBIAS (ALL LAYERS)	+0.04	+0.04	+0.05	+0.07	+0.08	+0.06	+0.05	+0.06
NMVD (100-1000 hPa)	0.27	0.29	0.29	0.27	0.28	0.28	0.31	0.28
NRMSVD	0.33	0.35	0.36	0.33	0.35	0.34	0.39	0.35
NC	13546	39462	323423	194809	263303	305271	220224	1360038
SPD [m/s]	17.97	16.44	18.60	23.12	22.06	21.34	18.11	20.38
NBIAS (ALL LAYERS)	+0.03	+0.03	+0.05	+0.08	+0.08	+0.06	+0.04	+0.06
NMVD (100-1000 hPa)	0.16	0.18	0.21	0.19	0.20	0.19	0.24	0.20
NRMSVD	0.20	0.23	0.26	0.23	0.26	0.25	0.31	0.26

Table 31: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; CCC height assignment with Microphysics)

NWC/GEO-HRWv6.2 AMVs (May-Jul 2019, GOES-16 M6)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV74	Clear Air	All AMVs
NC (77%)	6772	16221	182577	184458	211167	225262	220224	1046681
SPD [m/s]	24.47	23.63	21.90	23.45	23.16	22.90	18.00	21.86
NBIAS (HIGH LAYER)	+0.01	+0.01	+0.05	+0.07	+0.06	+0.04	+0.05	+0.05
NMVD (100-400 hPa)	0.21	0.23	0.27	0.26	0.26	0.25	0.31	0.26
NRMSVD	0.25	0.27	0.33	0.32	0.32	0.31	0.39	0.33
NC (18%)	2746	10274	94305	10351	52136	80009		249821
SPD [m/s]	15.92	14.78	16.47	19.04	17.92	17.17		17.03
NBIAS (MEDIUM LAYER)	+0.08	+0.06	+0.03	+0.17	+0.18	+0.11		+0.10
NMVD (400-700 hPa)	0.29	0.30	0.32	0.39	0.41	0.36		0.36
NRMSVD	0.36	0.37	0.40	0.50	0.50	0.45		0.44
NC (5%)	4028	12967	46541					63536
SPD [m/s]	7.48	8.42	9.90					9.45
NBIAS (LOW LAYER)	+0.17	+0.11	+0.03					+0.05
NMVD (700-1000 hPa)	0.57	0.47	0.39					0.41
NRMSVD	0.70	0.59	0.48					0.51
NC (77%)	6772	16221	182577	184458	211167	225262	220224	1046681
SPD [m/s]	24.35	23.39	21.87	23.34	23.07	22.80	18.11	21.81
NBIAS (HIGH LAYER)	+0.02	+0.02	+0.05	+0.07	+0.06	+0.05	+0.04	+0.05
NMVD (100-400 hPa)	0.13	0.14	0.19	0.18	0.18	0.17	0.24	0.19
NRMSVD	0.16	0.18	0.24	0.23	0.22	0.21	0.31	0.24
NC (18%)	2746	10274	94305	10351	52136	80009		249821
SPD [m/s]	16.08	14.87	16.53	19.28	18.01	17.26		17.11
NBIAS (MEDIUM LAYER)	+0.07	+0.05	+0.03	+0.16	+0.17	+0.10		+0.09
NMVD (400-700 hPa)	0.19	0.20	0.24	0.31	0.34	0.29		0.28
NRMSVD	0.25	0.26	0.31	0.38	0.42	0.37		0.36
NC (5%)	4028	12967	46541					63536
SPD [m/s]	8.54	9.00	9.99					9.69
NBIAS (LOW LAYER)	+0.02	+0.04	+0.02					+0.02
NMVD (700-1000 hPa)	0.25	0.27	0.27					0.27
NRMSVD	0.32	0.34	0.34					0.34

Table 32: Validation parameters for NWC/GEO-HRW v6.2 Basic AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; CCC height assignment with Microphysics)

6.3 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION

The validation of "Detailed AMVs" (with a default tracer size of 12x12 pixels instead of the 24x24 pixels considered by the "Basic AMVs") for GOES-16 satellite is considered now. The calculation of "Detailed AMVs" is activated again changing configurable parameter CDET = 1 in the default model configuration files. These AMVs are provided as an additional dataset of AMVs together with the "Basic AMVs", which are always calculated. An example of this configuration is shown in *Figure 12*.

The conditions for the validation of "Detailed AMVs" are exactly equivalent to those shown in chapter 6.1 for the GOES-16 "Basic AMVs". The validation statistics are presented in *Table 33* (considering all layers together) and *Table 34* (considering the three layers separately) for the same validation period.

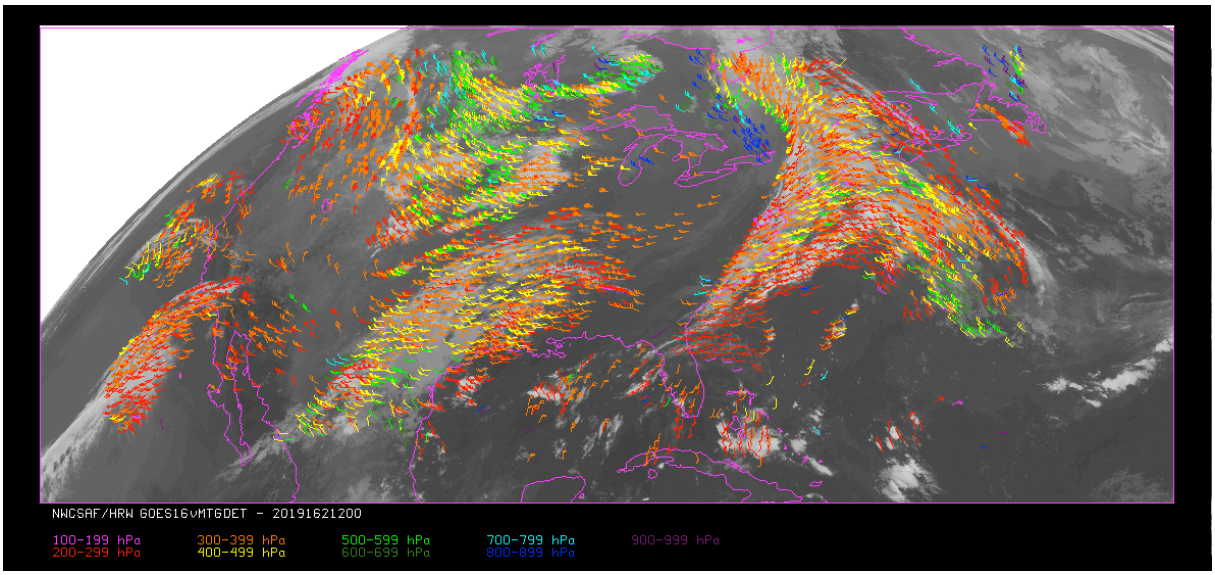

Figure 12: NWC/GEO-High Resolution Winds v7.0 Detailed AMV output example in the Continental United States region (11 June 2019 12:00 UTC, GOES-16 satellite), considering default conditions in `$SAFNWC/config/GOES*/safnwc_HRW.cfm` model configuration file and configurable parameter CDET = 1. Colour coding based on the AMV pressure level

Comparing with the "Basic AMVs", a reduction in the number of AMVs of about a 42% is seen for the "Detailed AMVs". This is similar to the behaviour seen with MTG-I and Himawari-8/9 satellite series. Again, this can be explained through the smaller size and due to that to the smaller persistence of the detailed tracers, and the smaller contrast in the features using smaller tracer sizes.

The distribution of validated AMVs in the different layers has a value of 79%/18%/3% for the high, medium and low layer, slightly concentrating more the AMVs in the High layer with respect to what was observed with the "Basic AMVs". Comparing the validation parameters against those for "Basic AMVs", they are slightly better for the "Detailed AMVs" considering all AMVs together and the high layer, and slightly worse considering the medium and low layer.

The NWC/GEO-HRW Product Requirement Table new "Target accuracy" for HRW vMTG-I day-1 is again reached in the three layers (which requests NRMSVD $\leq$ 0.36, 0.48, 0.54 respectively for high, medium and low layer against Radiosounding winds).

With this, the behaviour of "Detailed AMVs" is very similar to that of "Basic AMVs", and so both datasets can be used together operationally.

NWC/GEO-HRWv7.0 AMVs (May-Jul 2019, GOES-16 M6)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV74	Clear Air	All AMVs
NC	3366	26600	226625	108456	165201	214117	51391	795756
SPD [m/s]	13.15	17.75	20.07	24.23	23.29	22.44	18.93	21.76
NBIAS (ALL LAYERS)	+0.11	+0.04	+0.07	+0.06	+0.07	+0.07	+0.10	+0.06
NMVD (100-1000 hPa)	0.37	0.27	0.28	0.25	0.27	0.27	0.32	0.27
NRMSVD	0.45	0.33	0.35	0.31	0.33	0.33	0.40	0.33
NC	3366	26600	226625	108456	165201	214117	51391	795756
SPD [m/s]	14.24	17.95	20.06	24.10	23.21	22.38	19.15	21.73
NBIAS (ALL LAYERS)	+0.03	+0.03	+0.07	+0.07	+0.08	+0.07	+0.09	+0.07
NMVD (100-1000 hPa)	0.18	0.16	0.20	0.17	0.18	0.19	0.25	0.19
NRMSVD	0.23	0.21	0.25	0.21	0.23	0.24	0.32	0.24

Table 33: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering all layers together against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs

NWC/GEO-HRWv7.0 AMVs (May-Jul 2019, GOES-16 M6)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV74	Clear Air	All AMVs
NC (79%)	741	12096	143357	105914	143705	172013	51391	629217
SPD [m/s]	24.98	24.55	22.53	24.33	23.97	23.55	18.93	23.18
NBIAS (HIGH LAYER)	+0.00	+0.01	+0.07	+0.06	+0.06	+0.05	+0.10	+0.06
NMVD (100-400 hPa)	0.20	0.22	0.26	0.25	0.25	0.25	0.32	0.25
NRMSVD	0.24	0.26	0.32	0.31	0.31	0.30	0.40	0.31
NC (18%)	879	6639	70232	2542	21496	42104		143892
SPD [m/s]	17.64	16.03	16.75	19.86	18.69	17.89		17.40
NBIAS (MEDIUM LAYER)	+0.08	+0.07	+0.07	+0.21	+0.23	+0.17		+0.12
NMVD (400-700 hPa)	0.28	0.29	0.33	0.39	0.43	0.39		0.36
NRMSVD	0.34	0.36	0.42	0.47	0.51	0.48		0.44
NC (3%)	1746	7865	13036					22647
SPD [m/s]	5.86	8.74	10.93					9.77
NBIAS (LOW LAYER)	+0.37	+0.14	+0.04					+0.10
NMVD (700-1000 hPa)	0.82	0.46	0.36					0.43
NRMSVD	0.99	0.59	0.46					0.54
NC (79%)	741	12096	143357	105914	143705	172013	51391	629217
SPD [m/s]	24.84	24.37	22.49	24.19	23.87	23.45	19.15	23.11
NBIAS (HIGH LAYER)	+0.00	+0.01	+0.07	+0.06	+0.06	+0.05	+0.09	+0.06
NMVD (100-400 hPa)	0.12	0.13	0.18	0.16	0.16	0.16	0.25	0.17
NRMSVD	0.15	0.17	0.22	0.21	0.20	0.20	0.32	0.21
NC (18%)	879	6639	70232	2542	21496	42104		143892
SPD [m/s]	18.07	16.23	16.80	20.40	18.86	17.98		17.49
NBIAS (MEDIUM LAYER)	+0.06	+0.05	+0.07	+0.18	+0.22	+0.16		+0.11
NMVD (400-700 hPa)	0.18	0.19	0.25	0.31	0.36	0.32		0.28
NRMSVD	0.23	0.24	0.32	0.38	0.44	0.40		0.35
NC (3%)	1746	7865	13036					22647
SPD [m/s]	7.82	9.54	11.03					10.26
NBIAS (LOW LAYER)	+0.03	+0.04	+0.03					+0.03
NMVD (700-1000 hPa)	0.25	0.23	0.23					0.23
NRMSVD	0.32	0.29	0.28					0.28

Table 34: Validation parameters for NWC/GEO-HRW v7.0 Detailed AMVs considering three separate layers against Radiosounding winds (in white) and ECMWF NWP analysis winds (in yellow) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; Higher density related to medium and low level clouds; CCC height assignment with Microphysics) Green figures show an improvement of at least 10%, and red figures show a worsening of at least 10%, with respect to NWC/GEO-HRW v6.2 Detailed AMVs

6.4 COMPARISON WITH HRW V6.2 DEFAULT CONFIGURATION

The comparison of the statistics of NWC/GEO-HRW v7.0 "Detailed AMVs" for GOES-16 satellite, with those for NWC/GEO-HRW v6.2 in *Tables 35 and 36* is considered here.

As already said previously for the "Basic AMVs", in contrast with previous updates of NWC/GEO-HRW algorithm, the changes related to GOES-R AMVs in this version are very limited (because most of the planned changes for GOES-R AMVs for this version were already included in the originally unplanned previous version NWC/GEO-HRW v6.2).

With this, comparing both versions, the number of AMVs is basically the same (with slight differences smaller than 2% in all cases, except for the low layer which shows as in the Himawari-8/9 case a reduction in the number of AMVs up to a 15%). The proportion of AMVs in the three layers is the same (79% in the high layer, 18% in the medium layer and 3% in the low layer).

As for the "Basic AMVs", the distribution of AMVs in the three layers is less homogeneous than for MSG and MTG-I satellite series for the characterization of the behaviour of the wind in the different levels of the troposphere, but this is related to the Continental United States region used for the validation, with less maritime areas and large high altitude areas in the Western half of the country.

Considering the validation parameters, there is a reduction over 10% in the NBIAS in several AMV groups in *Tables 33 and 34* (shown in green; although the NBIAS also increases over 10% in the low layer VIS06 AMVs against NWP analysis winds). The NMVD and NRMSVD parameters also show small reductions up to a 12% at the low layer against NWP analysis winds. As for Himawari-8/9 satellites, these differences are caused again by the use of 25 levels of ECMWF NWP model both in the calculation and validation of AMVs instead of the 15 levels used in previous versions, although as already said for the GOES-R "Basic AMVs", the effect is here less visible.

With all this, the behaviour of NWC/GEO-HRW "Detailed AMVs" with GOES-R satellites is a bit better in the latest version v7.0, although less clearly than for the Himawari-8/9 satellite series.

NWC/GEO-HRWv6.2 AMVs (May-Jul 2019, GOES-16 M6)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV74	Clear Air	All AMVs
NC	3552	27221	225762	107240	162988	210986	49955	787704
SPD [m/s]	12.50	17.24	20.01	24.28	23.34	22.55	18.83	21.75
NBIAS (ALL LAYERS)	+0.12	+0.05	+0.07	+0.06	+0.08	+0.07	+0.10	+0.07
NMVD (100-1000 hPa)	0.38	0.27	0.28	0.25	0.26	0.27	0.32	0.27
NRMSVD	0.46	0.34	0.35	0.31	0.33	0.33	0.39	0.34
NC	3552	27221	225762	107240	162988	210986	49955	787704
SPD [m/s]	13.66	17.51	20.02	24.19	23.30	22.51	19.05	21.75
NBIAS (ALL LAYERS)	+0.02	+0.03	+0.07	+0.07	+0.08	+0.07	+0.09	+0.07
NMVD (100-1000 hPa)	0.18	0.17	0.20	0.17	0.18	0.19	0.25	0.19
NRMSVD	0.23	0.21	0.25	0.21	0.23	0.24	0.32	0.25

Table 35: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering all layers together against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; CCC height assignment with Microphysics)

NWC/GEO-HRWv6.2 AMVs (May-Jul 2019, GOES-16 M6)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV74	Clear Air	All AMVs
NC (79%)	733	11914	140876	104753	141721	168940	49955	618892
SPD [m/s]	24.81	24.46	22.62	24.38	24.02	23.67	18.83	23.26
NBIAS (HIGH LAYER)	+0.01	+0.01	+0.07	+0.06	+0.06	+0.05	0.10	+0.06
NMVD (100-400 hPa)	0.21	0.22	0.26	0.25	0.25	0.24	0.32	0.25
NRMSVD	0.25	0.27	0.32	0.30	0.30	0.30	0.39	0.31
NC (18%)	859	6520	69111	2487	21267	42046		142290
SPD [m/s]	17.30	15.74	16.81	20.10	18.84	18.06		17.49
NBIAS (MEDIUM LAYER)	+0.09	+0.08	+0.07	+0.20	+0.22	+0.17		+0.13
NMVD (400-700 hPa)	0.29	0.29	0.33	0.39	0.42	0.39		0.36
NRMSVD	0.35	0.36	0.41	0.48	0.51	0.48		0.46
NC (3%)	1960	8787	15775					26522
SPD [m/s]	5.80	8.58	10.72					9.64
NBIAS (LOW LAYER)	+0.35	+0.15	+0.05					+0.10
NMVD (700-1000 hPa)	0.80	0.47	0.38					0.42
NRMSVD	0.95	0.60	0.46					0.52
NC (79%)	733	11914	140876	104753	141721	168940	49955	618892
SPD [m/s]	24.79	24.34	22.61	24.28	23.95	23.61	19.05	23.22
NBIAS (HIGH LAYER)	+0.01	+0.02	+0.07	+0.07	+0.06	+0.05	+0.09	+0.06
NMVD (100-400 hPa)	0.12	0.14	0.18	0.16	0.16	0.16	0.25	0.17
NRMSVD	0.15	0.17	0.22	0.21	0.20	0.20	0.32	0.22
NC (18%)	859	6520	69111	2487	21267	42046		142290
SPD [m/s]	17.74	15.98	16.84	20.53	18.96	18.11		17.57
NBIAS (MEDIUM LAYER)	+0.06	+0.05	+0.07	+0.17	+0.21	+0.16		+0.12
NMVD (400-700 hPa)	0.18	0.19	0.25	0.30	0.36	0.32		0.29
NRMSVD	0.23	0.24	0.32	0.37	0.43	0.40		0.37
NC (3%)	1960	8787	15775					26522
SPD [m/s]	7.71	9.38	10.86					10.14
NBIAS (LOW LAYER)	+0.01	+0.05	+0.04					+0.04
NMVD (700-1000 hPa)	0.25	0.25	0.26					0.25
NRMSVD	0.33	0.32	0.32					0.32

Table 36: Validation parameters for NWC/GEO-HRW v6.2 Detailed AMVs considering three separate layers against Radiosounding winds (in green) and ECMWF NWP analysis winds (in blue) (May-Jul 2019 00:00 & 12:00 UTC; GOES-16 satellite; "Mode 6"; Continental United States region; Cross correlation; CCC height assignment with Microphysics)

6.5 COMPARISON WITH MTG-I SATELLITE SERIES

Comparing the statistics of NWC/GEO-HRW v7.0 default configuration for GOES-R satellites with those for MTG-I satellites (*Tables 29 and 30* compared with *Tables 12 and 13*), the distribution of AMVs in the different layers has a value for GOES-R of 78%/18%/4% for the high/medium/low layer, while for MTG-I satellites it has a value of 55%/24%/21%. The much higher concentration of AMVs in the high layer for GOES-R satellites can be caused by two main reasons:

- On one side, the already mentioned Continental United States region used for the validation with GOES-R, with less maritime areas and large high altitude areas in the Western half of the country, and so with less frequent low clouds.
- On the other side, the different line-up of satellite channels used in the corresponding AMV processing. For MTG-I there are two visible, two infrared and two water vapour channels, while for GOES-R, as for Himawari-8/9, there are two visible, one infrared and three water vapour channels. The ones for MTG-I distribute better the AMVs in the high, medium and low layer, while the ones for GOES-R concentrate more the AMVs in the high layer. An option to improve this could be also to use in future versions of GOES-R algorithm more visible or infrared channels in the AMV processing.

Comparing the validation parameters for both satellites, considering all layers together MTG-I and GOES-R satellite series show similar NMVD and NRMSVD values with variations up to an 18% (in some cases better for MTG-I and in other cases better for GOES-R). It is again also remarkable that the NBIAS parameter is negative for MTG-I and positive and larger for GOES-R (-0.01 versus +0.05 against Radiosounding winds).

Considering each layer separately, validation parameters have also small differences up to 10%, being better for GOES-R in the low layer and better for MTG-I in the medium layer. The most significant difference is, as in the Himawari-8/9 case, the NBIAS for GOES-R medium level AMVs, with a much larger value of +0.09 (compared to +0.02 in MTG-I AMVs), which can be explained by the larger difficulties to define clouds in the large high altitude areas present in the Continental United States region.

In spite of the differences (which are inside the normal variability defined by the use of different data for the validation of the same algorithm), the operability of NWC/GEO-HRW algorithm for both satellite series is again equivalent. And as already said for MTG-I and Himawari-8/9 satellite series, the “Target accuracy” for HRW vMTG-I day-1 is also reached in the three layers for GOES-R satellite series.

7. CONCLUSIONS

NWC/GEO-HRW v7.0 software has been validated against both Radiosounding winds and NWP model analysis winds for all applicable satellite series (MSG, MTG-I, Himawari-8/9, GOES-R). As in previous versions, it has been seen that NBIAS, NMVD and NRMSVD validation parameters are significantly smaller against NWP analysis winds, and the general scale and behaviour of AMV winds is more similar to the one of NWP analysis winds than to the one of Radiosounding winds.

In the comparison with previous version, the validation is very similar for MSG, Himawari-8/9 and GOES-R satellite series, with very similar amounts of AMVs and distribution of AMVs in the three layers (high, medium and low) and very similar validation parameters. The main change for these satellite series is related to the use of 25 levels of ECMWF NWP model both in the calculation and validation of AMVs instead of the 15 levels used in previous versions, which causes especially for Himawari-8/9 satellite series, and less visibly for the other satellite series, reductions of the NBIAS in all layers and small reductions of the NMVD and NRMSVD in the low layer. These changes are enough for users of these satellite series to justify the update to current NWC/GEO-HRW v7.0 version.

For MTG-I satellite series, comparing with MSG satellite series, a much larger amount of AMVs is calculated with MTG-I satellite (2.63 times), with much better NBIAS values and smaller improvements in NMVD and NRMSVD values, so justifying a quick adoption of NWC/GEO-HRW v7.0 software with MTG-I satellite by NWCSAF users in European and African areas.

For all these satellite series, the NWC/GEO-HRW Product Requirement Table "new Target accuracy" for HRW vMTG-I day-1 (with narrower values with respect to those defined in previous NWC/GEO-HRW versions) is reached in all layers (which requests NRMSVD ≤ 0.36/0.48/0.54 respectively for the high/medium/low layer against Radiosounding winds), as shown by *Table 37*. This way, NWC/GEO-HRW v7.0 can be used operationally with equivalent options for the four satellite series: MTG-I, MSG, Himawari-8/9 and GOES-R. Finally, considering the validation for MTG-I, Himawari-8/9 and GOES-R satellite series, there is still some room for improvement trying to increase more the proportion of AMVs in the lower layers.

Evolution of the Validation statistics in NWC/GEO-HRW versions, related to the Operative thresholds defined in the HRW Product Requirement Table (against Radiosounding winds)	High Layer NRMSVD	Medium Layer NRMSVD	Low Layer NRMSVD
NWC/GEO-HRW v6.2 default config, MSG (Jul'09-Jun'10)	0.32	0.44	0.49
NWC/GEO-HRW v7.0 default config, MSG (Jul'09-Jun'10)	0.32	0.44	0.50
NWC/GEO-HRW v7.0 default config, MSG (9 Oct'24-8 Feb'25)	0.33	0.42	0.52
NWC/GEO-HRW v7.0 default config, MTG-I (9 Oct'24-8 Feb'25)	0.33	0.40	0.52
NWC/GEO-HRW v6.2 default config, Himawari-8/9 (Mar-Aug'23)	0.31	0.43	0.57
NWC/GEO-HRW v7.0 default config, Himawari-8/9 (Mar-Aug'23)	0.31	0.44	0.54
NWC/GEO-HRW v6.2 default config, GOES-R (May-Jul'19)	0.33	0.44	0.51
NWC/GEO-HRW v7.0 default config, GOES-R (May-Jul'19)	0.33	0.43	0.49
NWC/GEO-HRW Product Requirement Table Optimal Accuracy	0.30	0.40	0.45
NWC/GEO-HRW Product Requirement Table Target Accuracy	0.36	0.48	0.54
NWC/GEO-HRW Product Requirement Table Threshold Accuracy	0.42	0.56	0.63

Table 37: Evolution of Validation statistics between NWC/GEO-HRW v6.2 and v7.0 versions related to the Operative thresholds defined in the NWC/GEO-HRW Product Requirement Table