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Copernicus Climate Change Service

Product User Guide for the NOAA AVHRR Polar AMV GAC Release 2

D5.4

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Contents

Acronyms

AMV	Atmospheric Motion Vector
AVHRR	Advanced Very High Resolution Radiometer
BUFR	Binary Universal Form for the Representation of meteorological data
C3S	Copernicus Climate Change Service
CCI	Climate Change Initiative
CDR	Climate Data Record
CDS	Climate Data Store
CF	Climate and Forecast
CGS	Core Ground Segment
DOI	Digital Object Identifier
EBBT	Equivalent Black Body Temperature
ECMWF	European Center for Medium Weather Forecast
EUM	EUMETSAT
EUMETSAT	EUropean organisation for the exploitation of METeorological SATellites
ERA	European ReAnalysis
ERA-CLIM2	ERA climate – EU funded project part 2
ERA-Interim	ECMWF interim reanalysis
EPS	EUMETSAT Polar System
ESA	European Space Agency
FCDR	Fundamental Climate Data Record
GAC	Global Area Coverage
GEADR	Global External Auxiliary Data Record
GTS	Global Telecommunication System
HDF5	Hierarchical Data Format version 5
IR	InfraRed
L1B	Level 1B data
LAC	Local Area Coverage
Metop	Meteorological Operational Satellite
MDR	Measurement Data Record
MODIS	Moderate Resolution Imaging Spectroradiometer
MPHR	Main Product Header Record
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
OSCAR	Observing Systems Capability Analysis and Review Tool
PDU	Product Data Unit
PFS	Product Format Specification
PyGAC	A python package to read and calibrate NOAA AVHRR GAC data
QI	Quality Indicator
RAOBCORE	RAdiosonde OBservation COrrection using REanalyses
SPHR	Secondary Product Header Record
TCDR	Thematic Climate Data Record
TIROS	Television Infrared Observation Satellite Program
WMO	World Meteorological Organization

1. Introduction

1.1 Purpose and scope

This document contains the results inherent to Work Package 5 → Task 5.2 → Milestone 10 in [AD1]. The purpose of this guide is to provide users with detailed information about the polar Atmospheric Motion Vectors (AMV) derived from the Advanced Very High Resolution Radiometer (AVHRR) on-board the Meteorological Operational Satellite (Metop) and the National Oceanic and Atmospheric Administration (NOAA) satellites produced within the Copernicus Climate Change Service (C3S) framework. The polar AMVs for this release include wind vectors in the period 1979 – 2019. The AMVs were derived using the algorithm developed by EUMETSAT (EUMETSAT, 2014). The datasets were evaluated and validated as shown in the quality evaluation report (EUMETSAT, 2020).

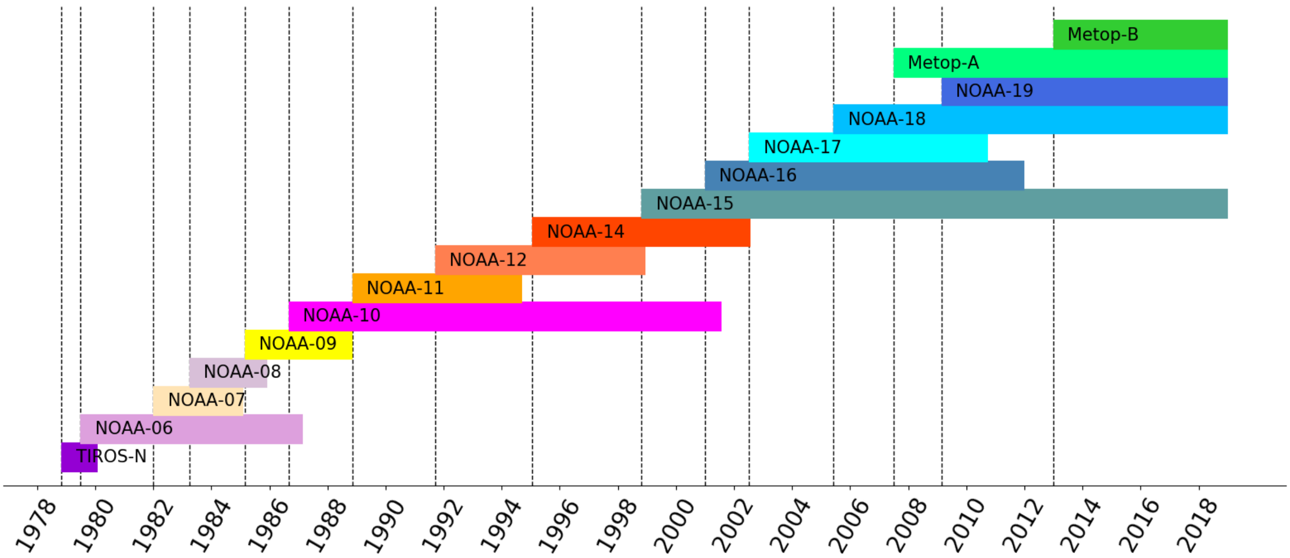

Figure 1: List of satellites flying an AVHRR instrument used as input for the polar GAC AMVs generation. This report includes data for the period 1979 – 2019.

This guide provides:

1. An overview of the specifications of the data record;
2. Scientific and technical details on the generation and definition of the data record;
3. Information on characteristics and limitations of the product;
4. Technical details on the format.

1.2 Structure of this document

Section 1	Introduction (this section)
Section 2	Background
Section 3	Data record definition
Section 3.5.3	Product generation
Section 5	Validation summary
Section 6	Limitations
Section 7	Data access information
Section 8	Product support and feedback
Section 9	Product referencing

1.3 Applicable documents

AD1. C3S_311b_Implementation_Plan_2021_D9.4_v1.

1.4 Reference documents

Borde, R., Doutriaux-Boucher, M., Dew, G. and Carranza, M.: A Direct Link between Feature Tracking and Height Assignment of Operational EUMETSAT Atmospheric Motion Vectors, J. Atmospheric Ocean. Technol., 31(1), 33–46, doi:10.1175/JTECH-D-13-00126.1, 2013.

CF: CF Conventions Home Page, [online] Available from: https://cfconventions.org/ (Accessed 17 December 2020), 2020.

Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., Berg, L. van de, Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J.-J., Park, B.-K., Peubey, C., Rosnay, P. de, Tavolato, C., Thépaut, J.-N. and Vitart, F.: The ERA-Interim reanalysis: configuration and performance of the data assimilation system, Q. J. R. Meteorol. Soc., 137(656), 553–597, doi:10.1002/qj.828, 2011.

Devasthale, A., Raspaud, M., Schlundt, C., Hanschmann, T., Finkensieper, S., Dybbroe, A., Hörnquist, S., Håkansson, N., Stengel, M. and Karlsson, K.-G.: PyGAC: An open-source, community-driven Python interface to preprocess nearly 40-year AVHRR Global Area Coverage (GAC) data record, GSICS Q., 11(summer), 3–5, doi:10.7289/V5R78CFR, 2017.

ESA: RAFCDRv1.0, Technical Report on AVHRR GAC FCDR generation – ESA Cloud_cci, [online] Available from: http://www.esa-cloud-cci.org/?q=documentation, 2017.

EU: ERA-CLIM2 European Union’s Seventh Framework Programme (FP7; Grant Agreement No. 607029 (2014)., [online] Available from: http://cordis.europa.eu/project/rcn/188832, 2014.

EUMETSAT: AVHRR Level 2 Polar Winds Product Generation Specification, [online] Available from: https://www-cdn.eumetsat.int/files/2020-04/pdf_avhrr_l2_pwinds_prod_spec.pdf, 2013.

EUMETSAT: EUMETSAT AVHRR L2 wind product ATBD, 2014.

EUMETSAT: AVHRR Atmospheric Motion Vectors PPF v 3.1 Software Release Notes, 2015.

EUMETSAT: Generic Product Format Specification, [online] Available from: https://www-cdn.eumetsat.int/files/2020-04/pdf_gen_pfs.pdf, 2016.

EUMETSAT: GAC to EPS PFS L1b conversion tool requirements, 2017.

EUMETSAT: ERACLIM2-D3.10 Science Report AVHRR AMV L2 TCDR, 2018.

EUMETSAT: Quality Evaluation Report Extension GAC AVHRR AMV, 2019.

EUMETSAT: Quality Evaluation Report GAC AVHRR AMV R2 D5.4, 2020.

Hersbach, H., Bell, W., Berrisford, P., Horányi, A., J., M.-S., Nicolas, J., Radu, R., Schepers, D., Simmons, A., Soci, C. and Dee, D.: Global reanalysis: goodbye ERA-Interim, hello ERA5, , doi:10.21957/VF291HEHD7, 2019.

Holmlund, K.: The Utilization of Statistical Properties of Satellite-Derived Atmospheric Motion Vectors to Derive Quality Indicators, Weather Forecast., 13(4), 1093–1104, doi:10.1175/1520-0434(1998)013<1093:TUOSPO>2.0.CO;2, 1998.

NOAA: Climate and Forecast (CF) Metadata Conventions | Earthdata, [online] Available from: https://earthdata.nasa.gov/esdis/eso/standards-and-references/climate-and-forecast-cf-metadata-conventions/ (Accessed 17 December 2020), 2019.

WMO: Manual on the Global Telecommunication System, [online] Available from: https://www.wmo.int/pages/prog/www/ois/Operational_Information/Publications/WMO_386/WMO_386_Vol_I_2009_en.pdf, 2009.

2. Background

The Atmospheric Motion Vector (AMV) data records were generated for the Copernicus Climate Change Service [1] (C3S), which is one of the six thematic information services provided by the Copernicus Earth Observation Programme of the European Union [2]. C3S is implemented by the European Centre for Medium-Range Weather Forecasts[3] (ECMWF) on behalf of the European Commission.

The first AVHRR instrument was launched by NOAA in 1978 on-board the TIROS-N satellite. Continuing with NOAA-6 the AVHRR instrument has been on all following NOAA satellites up to NOAA-19 and on the three Metop satellites (A-C). Thus providing a 40-year record. For the NOAA satellites, a global record only exists for the Global Area Coverage (GAC) spatial resolution. For Metop the AVHRR data is available in the original Local Area Coverage (LAC) resolution, which can be converted to the GAC resolution (see section 3 for more details). At EUMETSAT a first period of NOAA and Metop AVHRR-GAC data has been processed within the ERA-CLIM2 project (EU, 2014; EUMETSAT, 2018), spanning the years from 1982 to 2015. An extension until 2018 with a one-year overlap was produced within the C3S project (EUMETSAT, 2019). The current processing now spans the entire data range from 1979 to 2019.

The AMVs are derived by tracking the cloud motion between two consecutive images. This allows retrieving AMVs down to 40° latitude away from the poles. To derive the height of the wind vectors, the EUMETSAT AMV algorithm uses the AVHRR channel 4 (11 µm) images. To perform the height assignment, the algorithm uses the ERA-interim forecast data. For this polar AMV CDR the latest available version of the EUMETSAT algorithm (EUMETSAT, 2014, 2015) (see section 3.1.1) was used.

[1] https://www.copernicus.eu/en/services/climate-change Link valid 02/07/2019
[2] https://www.copernicus.eu/en Link valid 02/07/2019
[3] https://www.ecmwf.int/ Link valid 02/07/2019

This guide provides information applicable to Polar AVHRR-GAC AMV products for the period from 1979 to 2019. AMV data are derived using AVHRR instruments on TIROS-N, NOAA-06 to19 and Metop-A and B.

3. Data record definition

Table 1: CDR fact sheet

General	Data record name	AVHRR-GAC AMV polar release 2
	Data record digital identifier	http://doi.org/10.15770/EUM_SEC_CLM_0056
	Data record short description	Reprocessed level-2 AMVs using images from AVHRR-1/2/3 instrument in GAC resolution from TIROS-N, NOAA and Metop satellites.
	Record type	Thematic Climate Data Record (TCDR)
Instrument	Period covered	TIROS-N: 01 January 1979 – 20 January 1980 NOAA-06: 21 January 1980 – 01 September 1981 NOAA-07: 24 August 1981 – 31 January 1985 NOAA-08: 06 June 1983 – 13 October 1985 NOAA-09: 27 March 1985 – 06 November 1988 NOAA-10: 17 November 1986 – 15 September 1991 NOAA-11: 08 November 1988 – 13 September 1994 NOAA-12: 16 September 1991 – 13 December 1998 NOAA-14: 20 January 1995 – 07 September 2002 NOAA-15: 26 October 1998 – 01 September 2019 NOAA-16: 01 January 2001 – 30 December 2011 NOAA-17: 10 July 2002 – 13 October 2010 NOAA-18: 05 June 2005 – 01 September 2019 NOAA-19: 07 February 2009 – 01 September 2019 Metop-A: 29 June 2007 – 01 September 2019 Metop-B: 01 January 2013 – 01 September 2019
	Content	Polar AMVs level-2 products – single mode
	Generation frequency	Images from 2 orbits are needed, i.e. every 100 minutes.
	Algorithm version	3.1.1
	Instrument name	Advanced Very High Resolution Radiometer (AVHRR)
	Instrument description	The Advanced Very High Resolution Radiometer (AVHRR) is an imaging radiometer in the visible and infrared (IR) portions of the electromagnetic spectrum with channels in the range between 0.58 - 12.5 microns. In total three versions have been in operations. AVHRR/1 has four channels (TIROS-N, NOAA-06, 08 and 10), AVHRR/2 has five channels (NOAA-07, 09, 11 to 14) and AVHRR/3 (from NOAA-15 and Metop) six channels. Channel 4 is the same for all three instrument versions.
Data	Input data	• AVHRR channel 4 (11µm) • ECMWF ERA-interim 6-hourly forecast data
	Output data	AMV (a wind vectors characterised by a speed, a direction, a height and associated quality indicators (QI)) retrieved using the EUMETSAT operational algorithm (v3.1.1)
	Format	The products are provided in EPS-native, BUFR and netCDF format.

Access	Copernicus Climate Change Service (C3S)	C3S website: https://climate.copernicus.eu.
	EUMETSAT Data Centre	The data set is available from EUMETSAT Data Centre (https://eoportal.eumetsat.int/)
	Delivery (EUM)	• ftp pull
Coverage	Spatial	polar region polar wards of 40º
	Temporal	~100 minutes

3.1 AVHRR instrument Characteristics

This section gives an overview of the characteristics of the instruments used to generate the polar winds data record back to 1979 from AVHRR Global Area Coverage (GAC) on-board the TIROS-N, NOAA and Metop satellite series.

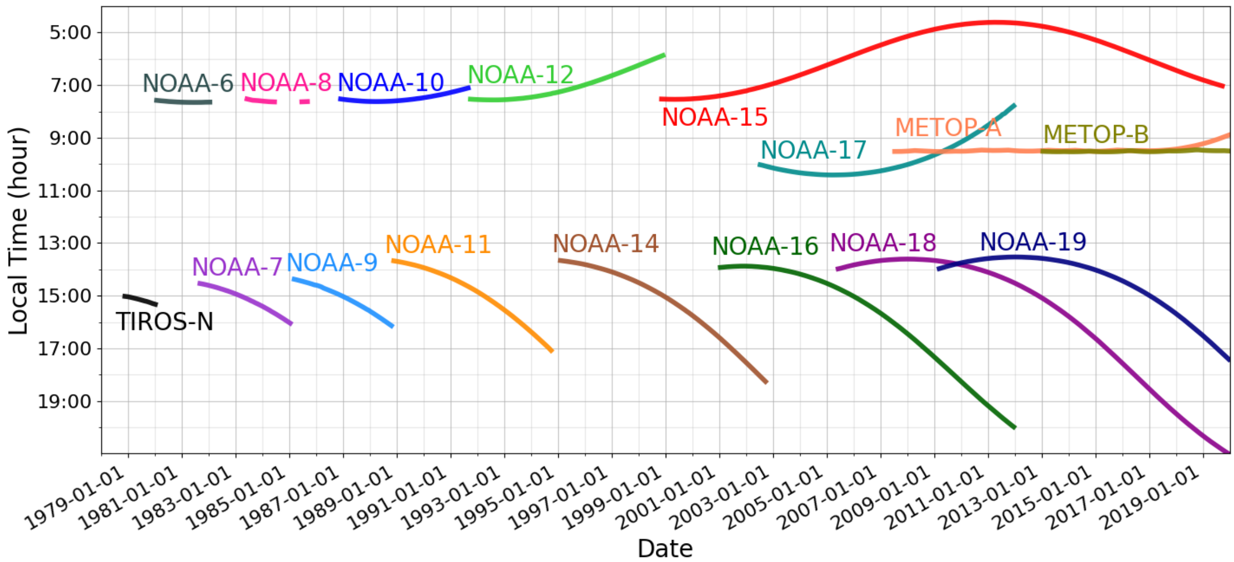

Figure 2: Global view of the local equator crossing time of each NOAA and Metop satellite carrying an AVHRR instruments. Data from all satellites are used for the generation of the AMV data record, plus TIROS-N (not shown here).

NOAA and EUMETSAT operate a series of polar orbiting satellites that carry the AVHRR instrument. The NOAA and EUMETSAT satellites circle the Earth 14 times per day at an altitude of about 833 km. As shown in Figure 2, the equator crossing time changes over time for the NOAA satellites, but not for Metops where the orbit is kept stable. The AVHRR instrument takes 2048 Earth views per scan and per channel, having a swath width of 2893 km and a pixel resolution of about 1.1 km at nadir. The AVHRR passive imager was first a 4-channel radiometer and subsequently improved to 5 and 6 channels at wavelengths between 0.5 and 12.0 µm.

Table 2 summarises the spatial resolution at nadir, the spectral bands and the calibration accuracy for the visible, near-infrared and infrared channels of the AVHRR. The AMVs are derived using only the AVHRR thermal infrared window channel #4.

Table 2: Details about the three versions of the AVHRR instrument. Information from OSCAR WMO websites.

	AVHRR	AVHRR/2	AVHRR/3
Period	Aug. 1979 - 2001	1981 - 2007	1998 → 2025
Satellites	TIROS-N, NOAA-6, -8 and -10	NOAA-7, -9, -11, -12, -13, , and -14	NOAA-15, -16, -17, -18, and -19, Metop-A, -B, -C
Number of channels	4	5	6
Channels central wavelength (μm) and spectral interval (μm)	1- 0.615 (0.55-0.68) 2- 0.912 (0.725-1.1) 3- 3.74 (3.55-3.93) 4- 11.0 (10.5-11.5)	1- 0.615 (0.55-0.68) 2- 0.912 (0.725-1.1) 3- 3.74 (3.55-3.93) 4- 10.80 (10.3-11.3) 5- 12.00 (11.5-12.5)	1- 0.630 (0.58-0.68) 2- 0.862 (0.725-1.00) 3A- 1.61 (1.58-1.64) 3B- 3.74 (3.55-3.93) 4- 10.80 (10.3-11.3) 5- 12.00 (11.5-12.5)
Swath (in pixels)	cross track: 2048 along track: 6	cross track: 2048 along track: 6	cross track: 2048 along track: 6
Resolution at nadir (km)	1.1	1.1	1.1

3.2 AMV Product Content

The Atmospheric Motion Vector (AMV) product provides information on wind speed (m/s), direction (°), and pressure (Pa) of vectors (as shown in Figure 3) which are derived by tracking clouds between two adjacent images in time. For the wind vectors, the meteorological convention is used:

- 0° : Winds blowing from North
- 90° : Winds blowing from East
- 180°: Winds blowing from South
- 270°: Winds blowing from West

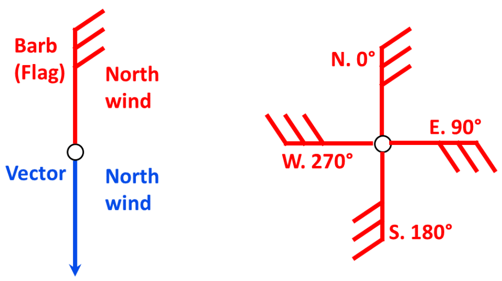

Figure 3: Wind direction measured in degrees in clockwise direction starting from the north. For example, a direction of 225° represents a wind blowing from the southwest. The height of the wind vector is expressed in Pa.

AMVs are retrieved by tracking the motion of clouds or patterns of other atmospheric constituents such as water vapour. Very generally, as a first step a feature is identified in the first image, the second step is to identify this feature again in the second image. If this is successful then wind speed and direction are calculated based on the geographical displacement of the feature and time between images. A height is assigned to each wind vector based on the measured brightness temperature. Finally, a quality index is calculated for each AMV.

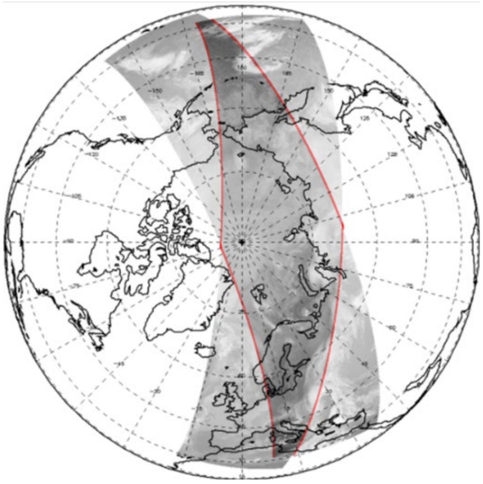

Figure 4: Example of geographical coverage. Using two successive orbit paths of one Metop satellite allowing coverage of north and south poles poleward of 45°. The time difference between two images is ~101 minutes.

Each AMV data sample contains a wind speed (in ms^{-1}), a wind direction (in °), and a wind height information together with geolocation data (latitude and longitude). The height is given as a pressure in Pascal (Pa); the corresponding brightness temperature (in K) is also recorded in the product. The final wind vector height is obtained using the IR EBBT method with the help of the forecast model data (AMV_HA_METHOD=1). It is accompanied by a quality index and other metadata. The quality index amongst others takes into account the temporal and the spatial consistency with the surrounding wind vectors and consistency with the forecast model wind field at the same time and location (Holmlund, 1998).

Tropospheric AMVs are retrieved at all levels below the tropopause, derived from the AVHRR infrared (IR) channel 4 at 11μm (see Table 2).

Figure 5 shows an example of the resulting AMV product. The wind vectors are represented as wind barbs. The colour of each barb gives the retrieved wind vector height. The generated AMVs are grouped into three height classes according to their height as defined in Table 3.

Table 3: AMV height classes.

CLASS	Description
ALL	*All vectors are considered for calculating the statistics*
HIGH	*Only vectors with a CTP < 400 hPa are considered for calculating the statistics*
MID	*Only vectors with 400 ≤ CTP ≤ 700*
LOW	*Only vectors with a CTP > 700 hPa are considered for calculating the statistics*

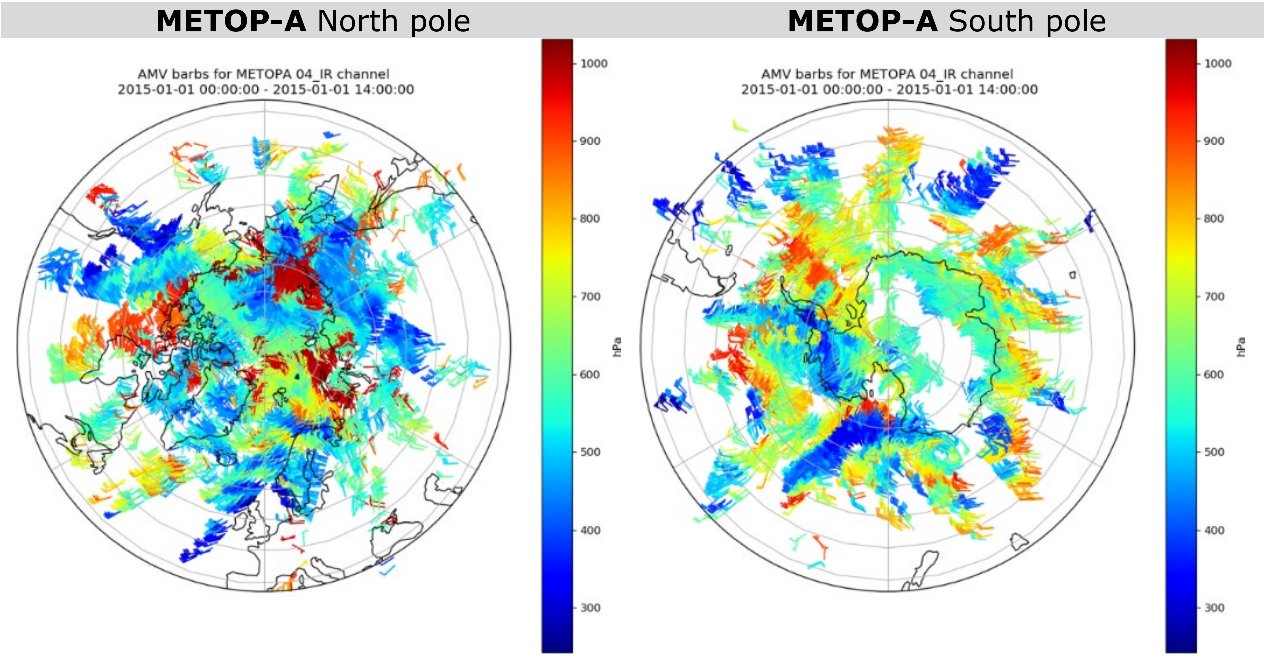

Figure 5: Example of retrieved AMVs from Metop-A for the 1st of January 2015, all AMVs from 00UTC to 14UTC. The colour indicates the height of the wind vector (in hPa) and the size of the arrow its speed (in m/s).

3.3 Temporal Coverage and Completeness

The overall data record temporal coverage is 1979 – 2019, according to the different satellites and products as described in Table 4.

Table 4: Satellite, instrument, spatial and temporal coverage.

Satellite	Instrument	Serial number	Coverage	Reprocessing period
TIROS-N	AVHRR/1	PFM 104	Polar	01/01/1979 – 20/01/1980
NOAA-06	AVHRR/1	FM 103	Polar	21/01/1980 – 01/09/1981
NOAA-07	AVHRR/2	FM 201	Polar	24/08/1981 – 31/01/1985
NOAA-08	AVHRR/1	FM 102	Polar	06/06/1983 – 13/10/1985
NOAA-09	AVHRR/2	FM 202	Polar	27/03/1985 – 06/11/1988
NOAA-10	AVHRR/1	FM 101	Polar	17/11/1986 – 15/09/1991
NOAA-11	AVHRR/2	FM 203	Polar	08/11/1988 – 13/09/1994
NOAA-12	AVHRR/2	FM 205	Polar	16/09/1991 – 13/12/1998
NOAA-14	AVHRR/2	FM 204	Polar	20/01/1995 – 07/09/2002
NOAA-15	AVHRR/3	FM 302	Polar	26/10/1998 – 01/09/2019
NOAA-16	AVHRR/3	FM 303	Polar	01/01/2001 – 30/12/2011
NOAA-17	AVHRR/3	FM 304	Polar	10/07/2002 – 13/10/2010
NOAA-18	AVHRR/3	FM 306	Polar	05/06/2005 – 01/09/2019
NOAA-19	AVHRR/3	FM 308	Polar	07/02/2009 – 01/09/2019
Metop-A	AVHRR/3	FM 305	Polar	29/06/2007 – 01/09/2019
Metop-B	AVHRR/3	FM 307	Polar	01/01/2013 – 01/09/2019

3.4 Spatial coverage

The AMVs are derived over the poles for the single instrument products, with a geographical coverage poleward of 40°N and 40°S respectively (see Figure 5).

3.5 Product format

The data records are available in three formats: the EUMETSAT native EPS format (EUMETSAT, 2013), the BUFR format and the netCDF format.

3.5.1 EUMETSAT native format

The Generic Product Format Specification for the products produced by the Product Generation functions in the EUMETSAT Polar System (EPS) Core Ground Segment (CGS) is described in detail in (EUMETSAT, 2016). The parts of the generic products format more specific to the wind products are described in (EUMETSAT, 2013).

Reprocessed files can be identified by their filenames for which the processing mode is set to ***R***. A reprocessed AVHRR AMV file uses the naming convention described in the Table 5.

Table 5: File names for the reprocessed AVHRR AMV following the EPS naming convention. [mode] is 02. [sat_id] can be TSN for TIRIS-N, Nxx with xx standing for the NOAA satellite number or M01 for Metop-B or M02 for Metop-A. [vvvv] refers to the CDR repreocessed version. For this second release it is 0200.

Filename
AVHR_GAC_[mode]_[sat_id]_[start sensing time]_[stop sensing time]_**R**_O_[processing time]_[vvvv]

For each file, the native EPS EUMETSAT format is made of:

- a Main Product Header Record, **MPHR**, common to all EPS products,
- a Secondary Product Header Record, **SPHR**, informing about quality flag and general product specific information,
- a Global External Auxiliary Data Record, **GEADR**, providing information about processor configuration data
- several Measurement Data Records, **MDR**, detailing each individual AMV

The Appendix A provides an example of the product output for one file and one MDR. The most important fields of the **MDR** are shown in Table 6.

Table 6: Supplementary information to be used with (EUMETSAT, 2013) regarding the AMV product. Note that reprocessed AMV do not include IASI method.

Name	**Description**	**Format**	**Possible value**
AMV_PRESSURE	Final height	Unsigned integer	
AMV_HA_METHOD	Method used	Byte	1= EBBT
HA_PRESSURE HA_PRESSURE_SD HA_TEMPERATURE HA_TEMPERATURE_HD	Values for individual pressure	Unsigned integer [4,3]	| X X X X | ref image | X X X X |previous image | X X X X | X EBBT method X IASI method
INTER_DIRECTION INTER_SPEED	Intermediate components	Unsigned integer [2,1]	First value is from the ref image to the previous one Second value is from the previous image to the reference one

3.5.2 BUFR

The second format the date record is available in is the Binary Universal Form for the Representation of meteorological data (BUFR). BUFR is a binary data format maintained by the World Meteorological Organization (WMO). Details on the AMV BUFR format are given in Appendix C. The details concerning the format of the products generated at EUMETSAT are available under:
http://www.eumetsat.int/website/home/Data/Products/Formats/index.html[5].

The BUFR product's filename provides a unique identifier for each product. The filename follows the WMO Global Telecommunication System (GTS) convention (WMO, 2009). AMV BUFR filenames are described in Table 7.

Table 7: File names description for the reprocessed AVHRR AMV following the BUFR naming convention.

Filename	
Single AVHRR AMV	
W_XX-EUMETSAT-Darmstadt,SOUNDING+SATELLITE,NOAA15+AVHRR_C_EUMP_20150325235503_87515_eps_r_gac_l2_0101.bin	
SATID	satellite id – used for the ref image (first one)
l2	Level 2
r	reprocessed mode
yyymmddhhmmss	start time of the ref PDU image used to derive the AMV product
nnnnn	last orbit number
vvvv	reprocessed release version (0101 = release 1.01)

3.5.3 NetCDF

The third format the AMV data record available, is the Network Common Data Form (NetCDF) format, as a simple conversion from the original native format. The file naming of AMV data in NetCDF4 format follows the standard WMO naming convention applied at EUMETSAT.

Table 8: Description of the NetCDF filename for the CDR.

Filename convention for reprocessed NetCDF filename	
W_XX-EUMETSAT-Darmstadt, <CHANNEL>+ATMOSPHERE+PRODUCT,<SATID>+<INSTRUMENT>_C_<ORIGINATOR>_<STARTDATE>_<ENDDATE>_<FAMILY>_r_<PRODUCT>_l2_<release>.nc	
Example of a filename	
W_XX-EUMETSAT-Darmstadt, IR+ATMOSPHERE+AMV,METOPA+AVHRR_C_EUMP_20071201190000Z_20071201200000Z_polar_r_gac_l2_0200.nc	
Description	
<CHANNEL>	Instrument Channel used → for AVHRR: IR
<SATID>	Satellite name/id
<INSTRUMENT>	AVHRR
<ORIGINATOR>	EUMP
<STARTDATE>	Start sensing time (YYYYMMDDhhmmssZ)
<ENDDATE>	End sensing time (YYYYMMDDhhmmssZ)
<FAMILY>	Satellite family, e.g. leo or geo.
<PRODUCT>	Product type

[4] Link validity tested on 04/07/2019.
[5] Link validity tested on 04/07/2019.

<release>	Version

The PMAp NetCDF variable and meta data naming is following the Climate and Forecast (CF) governance standard applied by EUMETSAT to support product development in the frame of the GSICS Data Management Working Group.

Please refer to Appendix D for a detailed description of the NetCDF files content.

4. Product generation

4.1 Basic retrieval description

Wind vectors are retrieved by tracking the motion of clouds or patterns of other atmospheric constituents such as water vapour. Very generally, as a first step a feature is identified in the first image, the second step is to identify this feature again in the second image. If this is successful then wind speed and direction are calculated based on the geographical displacement and time between images. A height is assigned to each vector based in the case of AVHRR on the brightness temperature. Finally, a quality index is calculated for each AMV.

4.2 Main steps

The operational EUMETSAT AVHRR AMV algorithm is described in detail in (EUMETSAT, 2014) and depicted in Figure 6. In real time at EUMETSAT, AVHRR data are received every three minutes. Each small file received is called Product Data Unit (PDU). The EUMETSAT algorithm has been developed with this concept of PDUs as a base-line input. Therefore, the algorithm used in the reprocessing also uses 3-minute PDUs from AVHRR as input. For each PDU, three PDUs with an overlap from the previous orbit are used to do the feature identification and to allow the full coverage of the reference PDU. Only data from two consecutive orbits are used, which results in AMV retrieved only pole wards of ± 40°. Six hourly ERA-interim forecast data are used as a "first guess" for wind vector speed and direction. Because the time between two images is rather long (100 minutes), the usage of the first guess is needed in order to save computation power and increase the quality of the retrieved winds. ERA-interim temperature profiles are used for the height assignment. The EUMETSAT algorithm is summarised by Figure 6. It uses two AVHRR consecutive orbits, allowing winds to be retrieved up to 40°.

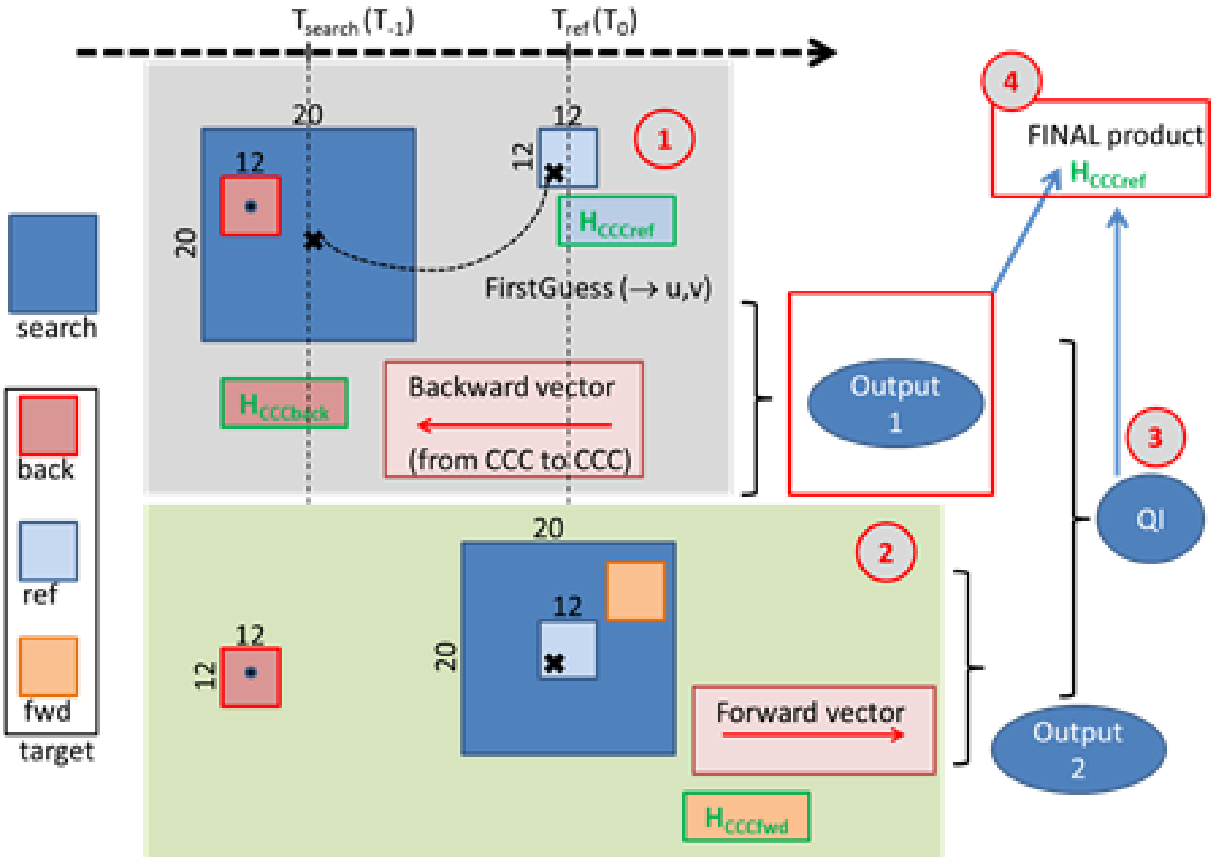

Figure 6: Schematic view of the EUMETSAT AVHRR AMV retrieval. The reference image is observed at time T_{ref} (or T_0), the second image (100 minutes before) is observed at time T_{search} (or T_{-1}). First a reference's target (*ref*) is selected in the image at T_0, the height is computed using the CCC method (Borde et al., 2013). Using this location, the height and the first guess, a location is found to be the center of the search box in the previous image at T_{-1}. In this search box (10 pixels on each side of the center), the *ref* target is tracked and when found it is named backward target (*back*). The speed is derived using the distance between the *ref* and the *back* targets. The height is assumed unchanged and is provided by the height of the *ref* target. As a second step -2- The forward vector is computed by doing a forward tracking, starting from the *back* target and looking for the forward (*fwd*) target in a new search box in the image at T_0. QI are computed comparing backward and forward tracking results. Note that for dual AMVs, Metop-A/B means *ref* is a Metop-A image.

4.3 Input data

This section presents an overview of the input data used for the data record generation: NOAA and Metop AVHRR imagery and ECMWF ERA-interim model forecast data.

4.3.1 AVHRR L1B GAC data

AMV products are derived using AVHRR infrared images (Holmlund, 1998). The main part of the data used is the channel 4 (11µm) brightness temperature, including geolocation. The EUMETSAT algorithm also uses information such as the scan angle and cloud cover. Table 4 lists the flight model and satellite platform used.

The AVHRR data are available in two spatial resolutions. Firstly, the Local Area Coverage (LAC) format, which provides observations at original pixel resolution with 1.1x1.1 km^2 at the sub-satellite point. Secondly, the GAC format, in which four out of every five samples along the scan line are used to compute one average value. The data from only every third scan line are processed, resulting in a spatial resolution of GAC data near sub-satellite point of 1.1x4.4 km^2 with a 2.2 km gap (or 2 pixels) between two scan lines.

For AVHRR instruments on NOAA satellites, data are available globally only in the GAC format. Metop data are available in LAC format and have been reformatted to the GAC format for this CDR. The LAC to GAC resampling principles are illustrated in the Figure 7.

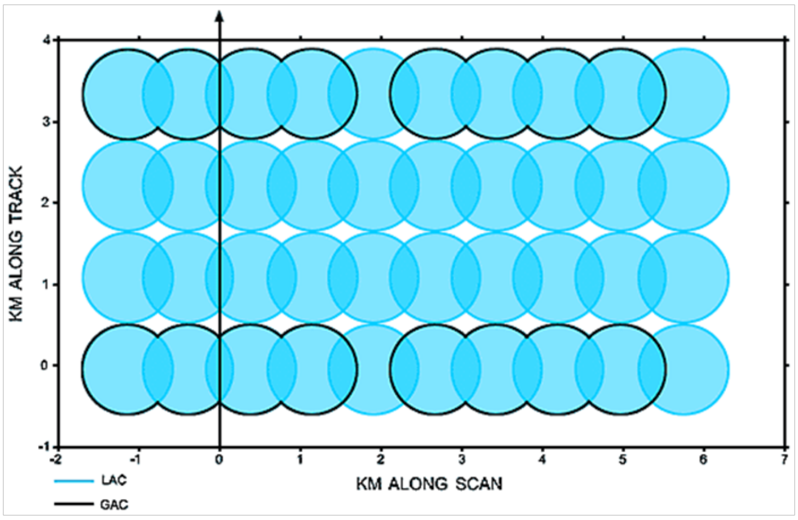

Figure 7: Idealised view of LAC and GAC spatial sampling. GAC format is derived from the LAC format: for each line, 4 pixels are averaged and one pixel is skipped. Only one line every third lines is retained.

The AVHRR level 1B data was generated using the PyGAC software package[6] that contains essential corrections to be applied to the sensor data including best-known calibration. The PyGAC data (ESA, 2017) contains level 1B calibrated reflectance, radiance as well as sun and satellite zenith and azimuth angles and scanline quality information (Devasthale et al., 2017; ESA, 2017). Those data have been converted from the original level 1B GAC data into HDF5 format that contains meta data using the international Climate and Forecast (CF (CF, 2020; NOAA, 2019)) meta data standard. A database containing additional metadata information is also necessary.

The EUMETSAT AMV retrieval algorithm needed to be adapted for the use of PyGAC AVHRR level 1B data in GAC resolution. A converter is used (EUMETSAT, 2017), that transforms the PyGAC dataset and metadata from the HDF5 files into the format required by the EUMETSAT algorithm as described in the Polar System (EPS) Product Format Specification (PFS) (EUMETSAT, 2016). A description of the level 1B data processing chain is presented in Figure 8. The orbit data are also sliced into 3 minute long Processing Data Units (PDU) to be used by the EUMETSAT polar AMV software. One GAC PDU contains 360 AVHRR scan lines and needs to be complete and error free, otherwise the AMV processor does not work. This constraint may have some consequences for older data resulting in data gaps.

[6] https://pygac.readthedocs.io/en/develop

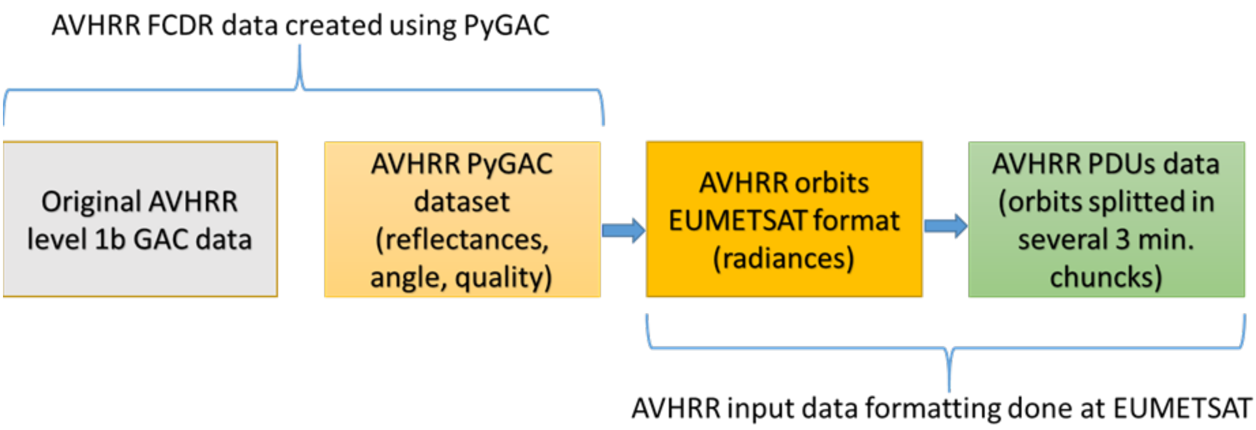

Figure 8: AVHRR level 1 data from their origin to their input in the polar AMV reprocessing algorithm.

4.3.2 Reanalysis data

For the first guess, to compute the height (pressure) of each wind vector and its quality indicator, forecast model outputs from ECMWF ERA-Interim reanalysis (Dee et al., 2011) are used as input for the reprocessing. We use the 6 and 12 hour forecast from the 0 and 12 UTC base times, leading to 4 forecast files per day (0, 6, 12 and 18 UTC). The forecast grid is 0.5°x0.5° with 60 vertical levels. The parameters used for the processing are listed in Table 9. More details on the ERA-Interim re-analysis data can be found on the ECMWF web site[7]. ERA-Interim forecast data is only available until end of August 2019, hence the processing for this CDR ceased at this date. Future processings will need to use other NWP data to go further in time, e.g. the ERA5 release (Hersbach et al., 2019, p.5).

Table 9: ERA-Interim data fields used for AMV processing.

Model Layers (1 - 60)	Surface
Temperature	Geopotential
Wind u-component	Surface pressure
Wind v-component	2m temperature
Specific humidity	2m dew point temperature
	Surface skin temperature

4.4 Output data

The system outputs the Atmospheric Motion Vectors (AMV) in the EPS-native format (EUMETSAT, 2013). A BUFR encoder is applied to generate BUFR formatted files (see section 3.5) from the EPS-native format as well as files in netCDF format. The AVHRR AMVs are generated every 3 minutes. The CDR is provided in files containing AMV aggregation of one day per file. Table 10 to Table 14 summarise the annual sizes of AMV files generated for the whole time series.

[7] Link valid 04/07/2019 https://www.ecmwf.int/en/forecasts/datasets/archive-datasets/reanalysis-datasets/era-interim

Table 10: Data sizes in GB per year and satellite, in the 1970s.

Format		**Year**	
		1978	**1979**
TIROS-N			
Native	Size	0.5	21
BURF	Size	0.01	3.3
NetCDF	Size		1.8

Table 11: Data sizes in GB per year and satellite, in the 1980s.

Format		**Year**									
		1980	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
TIROS-N											
Native	Size	1.1									
BUFR	Size	0.1									
NetCDF	Size	0.01									
NOAA-06											
Native	Size	19	14								
BUFR	Size	2.9	2.1								
NetCDF	Size	1.6	1.2								
NOAA-07											
Native	Size		7.8	21	21	20	2.0				
BUFR	Size		1.3	3.3	3.3	3.2	0.3				
NetCDF	Size		0.7	1.8	1.8	1.7	0.2				
NOAA-08											
Native	Size				5.4	7.7	3.1				
BUFR	Size				0.8	1.3	0.5				
NetCDF	Size				0.5	0.7	0.2				
NOAA-09											
Native	Size						14	18	23	15	
BUFR	Size						2.1	2.9	3.6	2.4	
NetCDF	Size						1.2	1.6	1.9	1.3	
NOAA-10											
Native	Size							3.3	27	26	24
BUFR	Size							0.5	4.4	4.2	3.8
NetCDF	Size							0.3	2.3	2.3	2.1
NOAA-11											
Native	Size									3.1	23
BUFR	Size									0.5	3.5
NetCDF	Size									0.3	1.9

Table 12: Data sizes in GB per year and satellite, in the 1990s.

Format		**Year**									
		1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
NOAA-10											
Native	Size	26	18								
BUFR	Size	4.1	2.9								
NetCDF	Size	2.2	1.5								
NOAA-11											
Native	Size	21	21	21	22	16					
BUFR	Size	3.2	3.1	3.1	3.3	2.4					
NetCDF	Size	1.8	1.7	1.7	1.8	1.3					
NOAA-12											
Native	Size		7.1	24	24	25	27	27	28	27	
BURF	Size		1.2	3.8	3.9	4.0	4.3	4.3	4.4	4.3	
NetCDF	Size		0.6	2.0	2.1	2.1	2.3	2.3	2.4	2.3	
NOAA-14											
Native	Size						25	26	27	27	27
BUFR	Size						3.9	4.1	4.2	4.3	4.2
NetCDF	Size						2.1	2.2	2.3	2.3	2.3
NOAA-15											
Native	Size									5.2	28
BUFR	Size									0.9	4.5
NetCDF	Size									0.5	2.4

Table 13: Data sizes in GB per year and satellite, in the 2000s.

Format		Year									
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NOAA-14											
Native	Size	28	23	16							
BUFR	Size	4.3	3.4	2.2							
NetCDF	Size	2.4	1.9	1.3							
NOAA-15											
Native	Size	17	22	25	29	29	29	29	28	29	29
BUFR	Size	2.6	3.5	4.0	4.6	4.6	4.6	4.6	4.6	4.6	4.6
NetCDF	Size	1.4	1.9	2.2	2.5	2.5	2.6	2.5	2.5	2.5	2.5
NOAA-16											
Native	Size		29	29	29	24	24	29	29	29	29
BUFR	Size		4.6	4.5	4.6	3.8	3.7	4.6	4.5	4.7	4.6
NetCDF	Size		2.6	2.5	2.6	2.1	2.1	2.6	2.5	2.6	2.6
NOAA-17											
Native	Size			14	29	29	29	29	29	29	29
BUFR	Size			2.3	4.6	4.6	4.6	4.6	4.5	4.6	4.6
NetCDF	Size			1.3	2.6	2.5	2.6	2.6	2.5	2.6	2.5
NOAA-18											
Native	Size						17	29	29	29	30
BUFR	Size						2.7	4.6	4.6	4.6	4.7
NetCDF	Size						1.6	2.6	2.6	2.6	2.7
NOAA-19											
Native	Size										26
BUFR	Size										4.0
NetCDF	Size										2.3
Metop-A											
Native	Size								13	27	30
BUFR	Size								2.1	4.5	4.9
NetCDF	Size								1.1	2.4	2.7

Table 14: Data sizes in GB per year and satellite, in the 2010s.

Format		Year									
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NOAA-15											
Native	Size	29	29	28	29	29	28	29	29	27	19
BUFR	Size	4.6	4.6	4.4	4.6	4.6	4.5	4.6	4.6	4.4	2.9
NetCDF	Size	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4	1.6
NOAA-16											
Native	Size	29	29								
BUFR	Size	4.7	4.6								
NetCDF	Size	2.6	2.6								
NOAA-17											
Native	Size	11	1.8								
BUFR	Size	1.4	0.0								
NetCDF	Size	0.8									
NOAA-18											
Native	Size	29	29	29	29	29	29	29	29	30	22
BUFR	Size	4.6	4.6	4.6	4.6	4.6	4.6	4.7	4.7	4.7	3.2
NetCDF	Size	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.7	2.7	1.8
NOAA-19											
Native	Size	30	30	30	30	30	30	30	30	30	22
BUFR	Size	4.8	4.7	4.8	4.7	4.8	4.7	4.8	4.8	4.8	3.2
NetCDF	Size	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	1.8
Metop-A											
Native	Size	30	29	29	29	29	29	29	29	29	21
BUFR	Size	4.9	4.8	4.8	4.8	4.9	4.8	4.8	4.9	4.8	3.2
NetCDF	Size	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	1.7
Metop-B											
Native	Size				26	29	29	30	30	29	22
BUFR	Size				4.1	4.6	4.8	4.8	4.8	4.7	3.3
NetCDF	Size				2.3	2.5	2.6	2.7	2.7	2.6	1.8

5. Summary of the product validation

AVHRR AMVs from TIROS-N, NOAA-06 to 19 and Metop-A and -B have been produced for the period 1979-2019 over the Polar Regions, poleward of 40° latitude, as release 2 of the polar AVHRR GAC CDR (D5.4). AMVs are retrieved using the same EUMETSAT processing chain and algorithm for GAC AVHRR channel 4 input data on-board each satellite. The validation strategy followed the CGMS guidelines for quality evaluation of Atmospheric Motion Vectors (WMO et al., 2011). The AMVs have been compared with independent AMV dataset: ground based reference radiosonde data (RAOBCORE), reanalysis data (ERA-interim), and AMVs derived from MODIS data.

The temporal analysis shows that we have an increase of retrieved AMVs over time, from around 15000 to about 20000 AMVs per day and polar region. This increase is connected to instrument changes and most likely reflects the input data availability and quality. The daily averaged speeds show a significant seasonal cycle but are very stable over time. This first broad analysis indicates that the release 2 of the AVHRR GAC CDR is of a good quality.

Comparison against ERA-Interim forecast data shows that we have mainly positive speed bias of the AMVs. This bias changes over time, depending on the satellite. In later years, the bias becomes smaller and is on average near zero especially for the high level winds. The RSME is constantly between 2 and 3 m/s. When looking at regional distribution of bias and RSME we see a homogeneous distribution with no apparent problematic areas.

The comparison with collocated radio sondes shows a stable comparison over the entire data set. The differences in the high level is higher than for the mid and low level. Expect for a small positive bias in the low level the average speed difference against radio sondes is near zero.

AMVs from NOAA were compared with a completely independent satellite dataset, the CIMSS MODIS AMVs. Numbers in the north are quite similar and differ mainly for the high level winds in the summer months. Over Antarctica we have a significant difference for the number of mid level AMVs, with higher numbers in this CDR. The Average speed in the north shows a fast bias for MODIS at mid and low levels, in the south also the high levels are faster in the MODIS data. Regional distribution and seasonal changes in the wind speed are quite similar in both data records.

A new aspect of this validation was the possibility to compare this release with the previous release of AVHRR GAC AMVs (EUMETSAT, 2019). The promising result from this comparison is that the apparent deficits found in the release 1 for NOAA-15 and the two Metop satellites have been fixed. This of course results in significant differences, mainly in additional AMVs in release 2.

The reprocessed polar AMVs exhibit geographical and seasonal features, in line with well-known atmospheric circulation patterns. The AMVs present a clear seasonal cycle linked with the cloudiness being more pronounced for mid- and high-level clouds. The increase of clouds during the summer months over the Polar Regions can be clearly seen in the number of retrieved AMVs. The wind speed increases with the altitude in all regions.

In conclusion, the comparisons against independent data sources such as in-situ measurements and satellite retrievals demonstrated the suitability of the AVHRR-GAC AMV CDR for data assimilation and climate studies.

6. Known limitations

There is no real limitation for this dataset. Nevertheless, some AMVs can be missing or of degraded quality mainly due to AVHRR input data.

- For the early NOAA satellites up to about NOAA-10 we sometimes see unrealistic high AMV speeds (exceeding 300 m/s). Care needs to be taken when high AMV speeds and slow forecast speeds come together.
- In very limited number of cases, the first forecast speed saved in the AMV product is invalid. The cause is currently unknown. The retrieved AMVs still have a good QI, nevertheless it is recommended not to use these data (180 AMVs only in total).

7. Data access information

The data products are part of the Copernicus Climate Data Store (CDS) and should be available from the Copernicus Climate Change Service (C3S) website: https://climate.copernicus.eu.

The data are also accessible via the EUMETSAT Data Centre. To access the data from EUMETSAT, you need to register with the EUMETSAT Data Centre. When registered, you can order the data through a written request send to EUMETSAT's helpdesk.

7.1 Register with EUMETSAT data center

To register with the EUMETSAT Data Centre:

- Register in the EUMETSAT EO-Portal (https://eoportal.eumetsat.int/) by clicking on the New User – Create New Account tab.
- After finalisation of the registration process, an e-mail is sent to the e-mail address entered in the registration.
- Click the confirmation link in the e-mail to activate your account;
- Login and subscribe to the Data Centre Service by going to the Service Subscription Tab and selecting Data Centre Service.
- Follow instructions issued from the web page to add needed information.

7.2 Order data

The data record described in this product user guide can be ordered via the EUMETSAT User Service Helpdesk in Darmstadt, Germany. Please send a written request to this helpdesk, email *ops@eumetsat.int,* indicating the data record you want to order including its Digital Object Identifier (DOI) number.

If you have more questions or support issues, please contact the User Service Helpdesk directly via e-mail: *ops@eumetsat.int*.

8. Product support and feedback

For enquiries or feedback concerning the product described in this product user guide, the CDS offers Help & Support functionality. Alternatively, the user can contact the EUMETSAT User Service Helpdesk by email: *ops@eumetsat.int.*

9. Product referencing

The data record described in this product user guide has a unique DOI that should be used for referencing. The product’s filename provides a unique identifier for each product. Please note that the DOI is not included in the native-eps nor in the BUFR files.

Appendix A EPS Format Product Record Example

Table 15 shows an example of a dump of a native-eps AMV file named *AVHR_GAC_02_N19_20170612231003Z_20170612231303Z_R_O_20190712011436Z_0101.* The two interesting quality indicators are highlighted, for the first mdr, there are 53 QI including, and 98 QI excluding forecast. More details are found in (EUMETSAT, 2013).

For each mdr, *record_stop_time* refers to the time of the center of the search target (previous image in time) and the *record_start_time* refers to the time of the reference target.

Table 15: Extract of a native-eps file:AVHR_GAC_02_N19_20170612231003Z_20170612231303Z_R_O_20190712011436Z_0101

```
MPHR:
    RECORD_HEADER
        RECORD_CLASS: 1 (MPHR)
        INSTRUMENT_GROUP: 0 (Generic)
        RECORD_SUBCLASS: 0
        RECORD_SUBCLASS_VERSION: 2
        RECORD_SIZE: 3307
        RECORD_START_TIME: 2017/06/12 23:10:03.000
        RECORD_STOP_TIME: 2017/06/12 23:13:03.000
    PRODUCT_NAME: AVHR_AMV_02_N19_20170612231003Z_20170612231303Z_R_O_20190712011436Z
    PARENT_PRODUCT_NAME_1: AVHR_GAC_1B_N19_20170612231003Z_20170612231303Z_R_O_20190709093947Z
    PARENT_PRODUCT_NAME_2: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
    PARENT_PRODUCT_NAME_3: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
    PARENT_PRODUCT_NAME_4: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
    INSTRUMENT_ID: AVHR (AVHRR/3)
    INSTRUMENT_MODEL: 4 ()
    PRODUCT_TYPE: AMV ()
    PROCESSING_LEVEL: 02 (Level 2)
    SPACECRAFT_ID: N19 ()
    SENSING_START: 2017/06/12 23:10:03.000          start time of the PDU
    SENSING_END: 2017/06/12 23:13:03.000            end time of the PDU
    SENSING_START_THEORETICAL: 2017/06/12 23:10:03.000
    SENSING_END_THEORETICAL: 2017/06/12 23:13:03.000
    PROCESSING_CENTRE: TCE1 ()
    PROCESSOR_MAJOR_VERSION: 3
    PROCESSOR_MINOR_VERSION: 1
    FORMAT_MAJOR_VERSION: 11
    FORMAT_MINOR_VERSION: 0
    PROCESSING_TIME_START: 2019/07/12 01:14:28.000
    PROCESSING_TIME_END: 2019/07/12 01:14:36.000
    PROCESSING_MODE: R (Reprocessing)
    DISPOSITION_MODE: O (Operational)
    RECEIVING_GROUND_STATION: RUS ()
    RECEIVE_TIME_START: 2000/01/01 00:00:00.000
    RECEIVE_TIME_END: 2000/01/01 00:00:00.000
    ORBIT_START: 43006
    ORBIT_END: 43007
    ACTUAL_PRODUCT_SIZE: 126970 bytes
    STATE_VECTOR_TIME: 20170612224340396Z UTC
    SEMI_MAJOR_AXIS: 0 mm
    ECCENTRICITY: 0
    INCLINATION: 0 deg
    PERIGEE_ARGUMENT: 0 deg
    RIGHT_ASCENSION: 0 deg
    MEAN_ANOMALY: 0 deg
    X_POSITION: 0 m
    Y_POSITION: 0 m
    Z_POSITION: 0 m
    X_VELOCITY: 0 m/s
    Y_VELOCITY: 0 m/s
    Z_VELOCITY: 0 m/s
    EARTH_SUN_DISTANCE_RATIO: 1.031115
    LOCATION_TOLERANCE_RADIAL: 0 m
    LOCATION_TOLERANCE_CROSSTRACK: 0 m
    LOCATION_TOLERANCE_ALONGTRACK: 0 m
```

```
    YAW_ERROR: 0 deg
    ROLL_ERROR: 0 deg
    PITCH_ERROR: 0 deg
    SUBSAT_LATITUDE_START: 80.457 Deg
    SUBSAT_LONGITUDE_START: 132.856 Deg
    SUBSAT_LATITUDE_END: 73.744 Deg
    SUBSAT_LONGITUDE_END: 94.063 Deg
    LEAP_SECOND: 0
    LEAP_SECOND_UTC: 2000/01/01 00:00:00.000
    TOTAL_RECORDS: 513
    TOTAL_MPHR: 1
    TOTAL_SPHR: 1
    TOTAL_IPR: 2
    TOTAL_GEADR: 1
    TOTAL_GIADR: 0
    TOTAL_VEADR: 0
    TOTAL_VIADR: 0
    TOTAL_MDR: 508        number of AMVs in this file
    COUNT_DEGRADED_INST_MDR: 0
    COUNT_DEGRADED_PROC_MDR: 0
    COUNT_DEGRADED_INST_MDR_BLOCKS: 0
    COUNT_DEGRADED_PROC_MDR_BLOCKS: 0
    DURATION_OF_PRODUCT: 180000 ms
    MILLISECONDS_OF_DATA_PRESENT: 180000 ms
    MILLISECONDS_OF_DATA_MISSING: 0 ms
    SUBSETTED_PRODUCT:  false
SPHR:
    RECORD_HEADER
        RECORD_CLASS: 2 (SPHR)
        INSTRUMENT_GROUP: 4 (AVHRR)
        RECORD_SUBCLASS: 2
        RECORD_SUBCLASS_VERSION: 2
        RECORD_SIZE: 553
        RECORD_START_TIME: 2017/06/12 23:10:03.000
        RECORD_STOP_TIME: 2017/06/12 23:13:03.000
    AMV_TOTAL_NUMBER: 508
    TOTAL_OVERALL_QUALITY: 56 %
    AMV_NUMBER_DISS: 320
    OVERALL_QUALITY: 79 %
    FORECAST_CONSISTENCY: 77 %
    SPATIAL_VECTOR_CONSISTENCY: 79 %
    SPATIAL_HEIGHT_CONSISTENCY: 84 %
    TEMPORAL_HEIGHT_CONSISTENCY: 94 %
    TRACKING_CONSISTENCY: 94 %
    DISSEMINATION_THRESHOLD: 50 %
    SAMPLING_GRID_RESOLUTION: 13200 m
    TARGET_SIZE: 13200 m
    SEARCH_DISTANCE: 22000 m

IPRS[0]:
    RECORD_HEADER
        RECORD_CLASS: 3 (IPR)
        INSTRUMENT_GROUP: 0 (Generic)
        RECORD_SUBCLASS: 0
        RECORD_SUBCLASS_VERSION: 1
        RECORD_SIZE: 27
        RECORD_START_TIME: 2017/06/12 23:10:03.000
        RECORD_STOP_TIME: 2017/06/12 23:13:03.000
    TARGET_RECORD_CLASS: 4 (GEADR)
    TARGET_INSTRUMENT_GROUP: 4 (AVHRR)
    TARGET_RECORD_SUBCLASS: 20
    TARGET_RECORD_OFFSET: 3914

IPRS[1]:
    RECORD_HEADER
        RECORD_CLASS: 3 (IPR)
        INSTRUMENT_GROUP: 0 (Generic)
        RECORD_SUBCLASS: 0
        RECORD_SUBCLASS_VERSION: 1
        RECORD_SIZE: 27
        RECORD_START_TIME: 2017/06/12 23:10:03.000
        RECORD_STOP_TIME: 2017/06/12 23:13:03.000
    TARGET_RECORD_CLASS: 8 (MDR)
    TARGET_INSTRUMENT_GROUP: 4 (AVHRR)
```

```
    TARGET_RECORD_SUBCLASS: 4
    TARGET_RECORD_OFFSET: 4034

GEADR-20:
    RECORD_HEADER
        RECORD_CLASS: 4 (GEADR)
        INSTRUMENT_GROUP: 4 (AVHRR)
        RECORD_SUBCLASS: 20
        RECORD_SUBCLASS_VERSION: 1
        RECORD_SIZE: 120
        RECORD_START_TIME: 2017/06/12 23:10:03.000
        RECORD_STOP_TIME: 2017/06/12 23:13:03.000
    AUX_DATA_POINTER: AVHR_PRC_xx_N19

mdr[0]:    first AMV out of 642
    RECORD_HEADER
        RECORD_CLASS: 8 (MDR)
        INSTRUMENT_GROUP: 4 (AVHRR)
        RECORD_SUBCLASS: 4
        RECORD_SUBCLASS_VERSION: 2
        RECORD_SIZE: 242
        RECORD_START_TIME: 2017/06/12 23:10:09.000
        RECORD_STOP_TIME: 2017/06/12 21:29:22.500
    DEGRADED_INST_MDR:  false
    DEGRADED_PROC_MDR:  false
    AMV_VALIDITY_TIME: 2017/06/12 23:10:03.000
    LATITUDE: 79.464 deg
    LONGITUDE: 132.6369 deg
    SURFACE_TYPE: 3 (undefined)
    CHANNEL_ID:
        AVHRR1 (1 bit) : 0
        AVHRR2 (1 bit) : 0
        AVHRR3a (1 bit) : 0
        AVHRR3b (1 bit) : 0
        AVHRR4 (1 bit) : 1
        AVHRR5 (1 bit) : 0
    WIND_METHOD: 1 (Wind derived from cloud motion observed in the infrared channel)
    MATCHING_METHOD: 2 (Cross-correlation method)
    AMV_DIRECTION: 167.2 deg
    AMV_SPEED: 17 m/s
    AMV_PRESSURE: 98120 Pa
    AMV_TEMPERATURE: 270.4 K
    ALGORITHM_FLAGS:
        IASICOLOCATEDDATA (1 bit) : 0
        INVERSIONHEIGHTASSIGNMENTCORRECTION (1 bit) : 1
        CLOUDBASEASSIGNMENTCORRECTION (1 bit) : 0
        IMAGEENHANCEMENTAPPLIED (1 bit) : 0
        TRIPLETMODE (1 bit) : 0
    AMV_HA_METHOD: 1 (IRW height assignment)
    AMV_PRESSURE_SD: 430 Pa
    AMV_TEMPERATURE_SD: 0.8 K
    QUALITY_VALUES: 95, 98, <invalid>, <invalid>, <invalid>, <invalid>, 82, 97, 100, 100, 100, 85, 100,
<invalid>, <invalid>, <invalid>, 0, 18
    FC_BASETIME: 2017/06/12 12:00:00.000
    FC_STEP: 6, 12 h
    HA_METHODS: 1 (IRW height assignment), 255 (), 255 (), 255 ()
    SENSING_TIME: 20170612212922500Z, 20170612231009000Z, <invalid>
    FC_DIRECTION: 166.5, 166.6, <invalid> deg
    FC_SPEED: 13.6, 12.7, <invalid> m/s
    SAT_ZENITH_ANGLE: 7.62, 5.29, <invalid> m/s
    CLUSTER_SIZE: 14, 14, <invalid>
    HA_PRESSURE
        [0]: 98120, <invalid>, 98120, <invalid> Pa
        [1]: 99240, <invalid>, 99240, <invalid> Pa
        [2]: <invalid>, <invalid>, <invalid>, <invalid> Pa
    HA_PRESSURE_SD
        [0]: 430, <invalid>, <invalid>, <invalid> Pa
        [1]: 5110, <invalid>, <invalid>, <invalid> Pa
        [2]: <invalid>, <invalid>, <invalid>, <invalid> Pa
    HA_TEMPERATURE
        [0]: 270.4, <invalid>, 272, <invalid> K
        [1]: 268.7, <invalid>, 271.8, <invalid> K
        [2]: <invalid>, <invalid>, <invalid>, <invalid> K
    HA_TEMPERATURE_SD
```

```
    [0]: 0.8, <invalid>, <invalid>, <invalid> K
    [1]: 1, <invalid>, <invalid>, <invalid> K
    [2]: <invalid>, <invalid>, <invalid>, <invalid> K
INTER_DIRECTION: 167.2, 167.9 deg
INTER_SPEED: 17, 19.8 m/s
MATCHING_VALUE: 2066, 5639
HA_FC_CONSISTENCY
    [0]: 0, <invalid>, <invalid>, <invalid> %
    [1]: <invalid>, <invalid>, <invalid>, <invalid> %
```

Appendix B Description of AMV BUFR message

This appendix gives an example of one particular BUFR message that can be decoded for an AMV product. Relevant parameters are highlighted in colour in the following table.

Table 16 shows an example of a BUFR message (one AMV). AMVs from all channels are contained in the same BUFR file. Only QI (excluding forecast) higher than 30 are BUFR encoded. Two QI are encoded, corresponding to the QIs with and without forecast.

The BUFR start and end of scan times refer to the time of the search and the reference image, respectively.

Table 16: Example of BUFR message from W_XX-EUMETSAT-Darmstadt,SOUNDING+SATELLITE,NOAA19+AVHRR_C_EUMP_20170612231003_43007_eps_r_gac_l2_0101.bin (first message). The symbol "///" in front of the field means that the field is not populated.

```
  1:    223 = NOAA 19 [Satellite identifier]
  2:    254 = (see Code Table 0'01'031) [Identification of
             originating/generating centre (see Note 10)]
  3:     61 = EUMETSAT Polar System (EPS) [Satellite classification]
  4:  13200 m [Segment size at nadir in X direction]
  5:  13200 m [Segment size at nadir in Y direction]
  6:   2017 Year [Year]
  7:      6 Month [Month]
  8:     12 Day [Day]
  9:     23 Hour [Hour]
 10:     10 Minute [Minute]
 11:      3 Second [Second]
 12: 79.464 Degree [Latitude (high accuracy)]
 13: 132.637 Degree [Longitude (high accuracy)]
 14: 262144 = Bit13 (see Flag Table 0'02'152) [Satellite instrument used in
             data processing(6)]
 15:      1 = Wind derived from cloud motion observed in the infrared channel
             [Satellite derived wind computation method]
 16:  98120 Pa [Pressure]
 17:    167 Degree true [Wind direction]
 18:     17 m s-1 [Wind speed]
 19: 2.7759e+13 Hz [Satellite channel centre frequency]
 20: 2.576e+12 Hz [Satellite channel band width]
 21:  270.4 K [Coldest cluster temperature]
 22:      1 = IRW height assignment [Height assignment method]
 23:      2 = CC - Cross correlation [Tracer correlation method]
 24:    /// = (CodeTable 0'08'012) [Land/sea qualifier]
 25:   7.62 Degree [Satellite zenith angle]
 26:      2 = Medium Range Forecast (MRF) Model [Origin of first guess
             information for GOES-I/M soundings]
 27:     27 = First guess [Time significance]
 28:   2017 Year [Year]
 29:      6 Month [Month]
 30:     12 Day [Day]
 31:     12 Hour [Hour]
 32:     25 = Nominal reporting time [Time significance]
 33:      6 Hour [Time period or displacement]
 34:     28 = Start of scan [Time significance]
 35:     21 Hour [Hour]
 36:     29 Minute [Minute]
 37:     23 Second [Second]
 38:     29 = End of scan [Time significance]          Time
 39:     23 Hour [Hour]
```

```
40:    10 Minute [Minute]
41:     9 Second [Second]
42:   167 Degree true [Wind direction]                first component
43:    17 m s-1 [Wind speed]
44:    28 = Start of scan [Time significance]
45:   /// Hour [Hour]
46:   /// Minute [Minute]
47:   /// Second [Second]
48:    29 = End of scan [Time significance]
49:   /// Hour [Hour]
50:   /// Minute [Minute]
51:   /// Second [Second]
52:   168 Degree true [Wind direction]                second component
53:  19.8 m s-1 [Wind speed]
54:    28 = Start of scan [Time significance]
55:   /// Hour [Hour]
56:   /// Minute [Minute]
57:   /// Second [Second]
58:    29 = End of scan [Time significance]
59:   /// Hour [Hour]
60:   /// Minute [Minute]
61:   /// Second [Second]
62:   /// Degree true [Wind direction]
63:   /// m s-1 [Wind speed]
64:    28 = Start of scan [Time significance]
65:   /// Hour [Hour]
66:   /// Minute [Minute]
67:   /// Second [Second]
68:    29 = End of scan [Time significance]
69:   /// Hour [Hour]
70:   /// Minute [Minute]
71:   /// Second [Second]
72:   /// Degree true [Wind direction]
73:   /// m s-1 [Wind speed]
74:     1 = IRW height assignment [Height assignment method]
75: 98120 Pa [Pressure]                                          height
76: 270.4 K [Temperature/dry-bulb temperature]
77:   /// = (CodeTable 0'02'163) [Height assignment method]
78:   /// Pa [Pressure]
79:   /// K [Temperature/dry-bulb temperature]
80:   /// = (CodeTable 0'02'163) [Height assignment method]
81: 98120 Pa [Pressure]                                          height
82:   272 K [Temperature/dry-bulb temperature]
83:   /// = (CodeTable 0'02'163) [Height assignment method]
84:   /// Pa [Pressure]
85:   /// K [Temperature/dry-bulb temperature]
86:   /// = (CodeTable 0'02'163) [Height assignment method]
87:   /// Pa [Pressure]
88:   /// K [Temperature/dry-bulb temperature]
89:   /// = (CodeTable 0'02'163) [Height assignment method]
90:   /// Pa [Pressure]
91:   /// K [Temperature/dry-bulb temperature]
92:   /// = (CodeTable 0'02'163) [Height assignment method]
93:   /// Pa [Pressure]
94:   /// K [Temperature/dry-bulb temperature]
95:   /// = (CodeTable 0'02'163) [Height assignment method]
96:   /// Pa [Pressure]
97:   /// K [Temperature/dry-bulb temperature]
98:   /// = (CodeTable 0'02'163) [Height assignment method]
99:   /// Pa [Pressure]
100:  /// K [Temperature/dry-bulb temperature]
```

```
101:   /// = (CodeTable 0'02'163) [Height assignment method]
102:   /// Pa [Pressure]
103:   /// K [Temperature/dry-bulb temperature]
104:   103 : ////////// /////+++// +///////// ////////// //////////
         ////////// ////////// ////////// ////////// ////////// /// [Data
         present bit map]
105:   254 = (see Code Table 0'01'031) [Identification of
         originating/generating centre (see Note 10)]
106:     1 = (see Code Table 0'01'032) [Generating application]
107:    95 % [Per cent confidence]                    QI including forecast
108:    95 % [Per cent confidence]
109:    95 % [Per cent confidence]
110:    95 % [Per cent confidence]
111:   254 = (see Code Table 0'01'031) [Identification of
         originating/generating centre (see Note 10)]
112:     1 = (see Code Table 0'01'032) [Generating application]
113:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
114:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
115:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
116:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
117:   254 = (see Code Table 0'01'031) [Identification of
         originating/generating centre (see Note 10)]
118:     1 = (see Code Table 0'01'032) [Generating application]
119:   /// % [Nominal confidence threshold]
120:   /// % [Nominal confidence threshold]
121:   /// % [Nominal confidence threshold]
122:   /// % [Nominal confidence threshold]
123:   254 = (see Code Table 0'01'031) [Identification of
         originating/generating centre (see Note 10)]
124:     2 = (see Code Table 0'01'032) [Generating application]
125:    98 % [Per cent confidence]               QI excluding forecast
126:    98 % [Per cent confidence]
127:    98 % [Per cent confidence]
128:    98 % [Per cent confidence]
129:   254 = (see Code Table 0'01'031) [Identification of
         originating/generating centre (see Note 10)]
130:     2 = (see Code Table 0'01'032) [Generating application]
131:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
132:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
133:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
134:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
135:   254 = (see Code Table 0'01'031) [Identification of
         originating/generating centre (see Note 10)]
136:     2 = (see Code Table 0'01'032) [Generating application]
137:   /// % [Nominal confidence threshold]
138:   /// % [Nominal confidence threshold]
139:   /// % [Nominal confidence threshold]
140:   /// % [Nominal confidence threshold]
141:   254 = (see Code Table 0'01'031) [Identification of
         originating/generating centre (see Note 10)]
142:     3 = (see Code Table 0'01'032) [Generating application]
143:   /// % [Per cent confidence]
144:   /// % [Per cent confidence]
145:   /// % [Per cent confidence]
146:   /// % [Per cent confidence]
147:   254 = (see Code Table 0'01'031) [Identification of
         originating/generating centre (see Note 10)]
148:     3 = (see Code Table 0'01'032) [Generating application]
149:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
150:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
151:   /// = (CodeTable 0'33'035) [Manual/automatic quality control]
```

```
152:    /// = (CodeTable 0'33'035) [Manual/automatic quality control]
153:    254 = (see Code Table 0'01'031) [Identification of
           originating/generating centre (see Note 10)]
154:      3 = (see Code Table 0'01'032) [Generating application]
155:    /// % [Nominal confidence threshold]
156:    /// % [Nominal confidence threshold]
157:    /// % [Nominal confidence threshold]
158:    /// % [Nominal confidence threshold]
```

Appendix C Table description for individual BUFR message

Table 17: as Table 16 but showing the table reference.

BUFR Bufr table
Field :

1: 0'01'007 Satellite identifier [Code Table 0'01'007] (1:1<10><0>)
2: 0'01'031 Identification of originating/generating centre (see Note 10) [Code Table 0'01'031] (3:1<16><0>)
3: 0'02'020 Satellite classification [Code Table 0'02'020] (5:7<9><0>)
4: 0'02'028 Segment size at nadir in X direction [m] (7:6<18><0>)
5: 0'02'029 Segment size at nadir in Y direction [m] (10:6<18><0>)
6: 0'04'001 Year [Year] (13:6<12><0>)
7: 0'04'002 Month [Month] (15:8<4><0>)
8: 0'04'003 Day [Day] (17:2<6><0>)
9: 0'04'004 Hour [Hour] (18:6<5><0>)
10: 0'04'005 Minute [Minute] (20:1<6><0>)
11: 0'04'006 Second [Second] (21:5<6><0>)
12: 0'05'001 Latitude (high accuracy) [Degree] (23:1<25><21>)
13: 0'06'001 Longitude (high accuracy) [Degree] (1360:4<26><24>)
14: 0'02'152 Satellite instrument used in data processing(6) [Flag Table 0'02'152] (2888:4<31><0>)
15: 0'02'023 Satellite derived wind computation method [Code Table 0'02'023] (2893:1<4><0>)
16: 0'07'004 Pressure [Pa] (2894:3<14><13>)
17: 0'11'001 Wind direction [Degree true] (3722:3<9><9>)
18: 0'11'002 Wind speed [m s-1] (4295:6<12><9>)
19: 0'02'153 Satellite channel centre frequency [Hz] (4869:4<26><0>)
20: 0'02'154 Satellite channel band width [Hz] (4873:4<26><0>)
21: 0'12'071 Coldest cluster temperature [K] (4877:4<12><10>)
22: 0'02'163 Height assignment method [Code Table 0'02'163] (5514:6<4><0>)
23: 0'02'164 Tracer correlation method [Code Table 0'02'164] (5515:8<3><0>)
24: 0'08'012 Land/sea qualifier [Code Table 0'08'012] (5517:1<2><0>)
25: 0'07'024 Satellite zenith angle [Degree] (5518:1<15><13>)
26: 0'02'057 Origin of first guess information for GOES-I/M soundings [Code Table 0'02'057] (6346:2<4><0>)
27: 0'08'021 Time significance [Code Table 0'08'021] (6347:4<5><0>)
28: 0'04'001 Year [Year] (6348:7<12><0>)
29: 0'04'002 Month [Month] (6351:1<4><0>)
30: 0'04'003 Day [Day] (6352:3<6><0>)
31: 0'04'004 Hour [Hour] (6353:7<5><0>)
32: 0'08'021 Time significance [Code Table 0'08'021] (6355:2<5><0>)
33: 0'04'024 Time period or displacement [Hour] (6356:5<12><0>)
- 1'10'004 Replication Operator (-)
34: 0'08'021 Time significance [Code Table 0'08'021] (6358:7<5><0>)
35: 0'04'004 Hour [Hour] (6360:2<5><0>)
36: 0'04'005 Minute [Minute] (6361:5<6><3>)
37: 0'04'006 Second [Second] (6553:5<6><6>)
38: 0'08'021 Time significance [Code Table 0'08'021] (6936:1<5><0>)
39: 0'04'004 Hour [Hour] (6937:4<5><0>)
40: 0'04'005 Minute [Minute] (6938:7<6><2>)
41: 0'04'006 Second [Second] (7067:3<6><6>)
42: 0'11'001 Wind direction [Degree true] (7449:7<9><9>)
43: 0'11'002 Wind speed [m s-1] (8023:2<12><9>)
44: 0'08'021 Time significance [Code Table 0'08'021] (8596:8<5><0>)
45: 0'04'004 Hour [Hour] (8598:3<5><0>)
46: 0'04'005 Minute [Minute] (8599:6<6><0>)
47: 0'04'006 Second [Second] (8601:2<6><0>)
48: 0'08'021 Time significance [Code Table 0'08'021] (8602:6<5><0>)
49: 0'04'004 Hour [Hour] (8604:1<5><0>)
50: 0'04'005 Minute [Minute] (8605:4<6><0>)

```
 51:  0'04'006  Second [Second]  (8606:8<6><0>)
 52:  0'11'001  Wind direction [Degree true]  (8608:4<9><9>)
 53:  0'11'002  Wind speed [m s-1]  (9181:7<12><9>)
 54:  0'08'021  Time significance [Code Table 0'08'021]  (9755:5<5><0>)
 55:  0'04'004  Hour [Hour]  (9756:8<5><0>)
 56:  0'04'005  Minute [Minute]  (9758:3<6><0>)
 57:  0'04'006  Second [Second]  (9759:7<6><0>)
 58:  0'08'021  Time significance [Code Table 0'08'021]  (9761:3<5><0>)
 59:  0'04'004  Hour [Hour]  (9762:6<5><0>)
 60:  0'04'005  Minute [Minute]  (9764:1<6><0>)
 61:  0'04'006  Second [Second]  (9765:5<6><0>)
 62:  0'11'001  Wind direction [Degree true]  (9767:1<9><0>)
 63:  0'11'002  Wind speed [m s-1]  (9768:8<12><0>)
 64:  0'08'021  Time significance [Code Table 0'08'021]  (9771:2<5><0>)
 65:  0'04'004  Hour [Hour]  (9772:5<5><0>)
 66:  0'04'005  Minute [Minute]  (9773:8<6><0>)
 67:  0'04'006  Second [Second]  (9775:4<6><0>)
 68:  0'08'021  Time significance [Code Table 0'08'021]  (9776:8<5><0>)
 69:  0'04'004  Hour [Hour]  (9778:3<5><0>)
 70:  0'04'005  Minute [Minute]  (9779:6<6><0>)
 71:  0'04'006  Second [Second]  (9781:2<6><0>)
 72:  0'11'001  Wind direction [Degree true]  (9782:6<9><0>)
 73:  0'11'002  Wind speed [m s-1]  (9784:5<12><0>)
  -  1'03'010  Replication Operator  (-)
 74:  0'02'163  Height assignment method [Code Table 0'02'163]  (9786:7<4><0>)
 75:  0'07'004  Pressure [Pa]  (9788:1<14><13>)
 76:  0'12'001  Temperature/dry-bulb temperature [K]  (10616:1<12><10>)
 77:  0'02'163  Height assignment method [Code Table 0'02'163]
           (11253:3<4><0>)
 78:  0'07'004  Pressure [Pa]  (11254:5<14><0>)
 79:  0'12'001  Temperature/dry-bulb temperature [K]  (11257:1<12><0>)
 80:  0'02'163  Height assignment method [Code Table 0'02'163]
           (11259:3<4><0>)
 81:  0'07'004  Pressure [Pa]  (11260:5<14><13>)
 82:  0'12'001  Temperature/dry-bulb temperature [K]  (12088:5<12><10>)
 83:  0'02'163  Height assignment method [Code Table 0'02'163]
           (12725:7<4><0>)
 84:  0'07'004  Pressure [Pa]  (12727:1<14><0>)
 85:  0'12'001  Temperature/dry-bulb temperature [K]  (12729:5<12><0>)
 86:  0'02'163  Height assignment method [Code Table 0'02'163]
           (12731:7<4><0>)
 87:  0'07'004  Pressure [Pa]  (12733:1<14><0>)
 88:  0'12'001  Temperature/dry-bulb temperature [K]  (12735:5<12><0>)
 89:  0'02'163  Height assignment method [Code Table 0'02'163]
           (12737:7<4><0>)
 90:  0'07'004  Pressure [Pa]  (12739:1<14><0>)
 91:  0'12'001  Temperature/dry-bulb temperature [K]  (12741:5<12><0>)
 92:  0'02'163  Height assignment method [Code Table 0'02'163]
           (12743:7<4><0>)
 93:  0'07'004  Pressure [Pa]  (12745:1<14><0>)
 94:  0'12'001  Temperature/dry-bulb temperature [K]  (12747:5<12><0>)
 95:  0'02'163  Height assignment method [Code Table 0'02'163]
           (12749:7<4><0>)
 96:  0'07'004  Pressure [Pa]  (12751:1<14><0>)
 97:  0'12'001  Temperature/dry-bulb temperature [K]  (12753:5<12><0>)
 98:  0'02'163  Height assignment method [Code Table 0'02'163]
           (12755:7<4><0>)
 99:  0'07'004  Pressure [Pa]  (12757:1<14><0>)
100:  0'12'001  Temperature/dry-bulb temperature [K]  (12759:5<12><0>)
101:  0'02'163  Height assignment method [Code Table 0'02'163]
           (12761:7<4><0>)
```

```
102:  0'07'004  Pressure [Pa]  (12763:1<14><0>)
103:  0'12'001  Temperature/dry-bulb temperature [K]  (12765:5<12><0>)
  -  2'22'000  Quality information follows  (-)
  -  1'01'103  Replication Operator  (-)
104:  0'31'031  Data present bit map  (12767:7<721><0>)
105:  0'01'031  Identification of originating/generating centre (see Note 10)
            [Code Table 0'01'031]  (12857:8<16><0>)
106:  0'01'032  Generating application [Code Table 0'01'032]  (12860:6<8><0>)
  -  1'01'004  Replication Operator  (-)
107:  0'33'007  Per cent confidence [%]  (12862:4<7><7>)
108:  0'33'007  Per cent confidence [%]  (13308:5<7><7>)
109:  0'33'007  Per cent confidence [%]  (13754:6<7><7>)
110:  0'33'007  Per cent confidence [%]  (14200:7<7><7>)
  -  2'22'000  Quality information follows  (-)
111:  0'01'031  Identification of originating/generating centre (see Note 10)
            [Code Table 0'01'031]  (14646:8<16><0>)
112:  0'01'032  Generating application [Code Table 0'01'032]  (14649:6<8><0>)
  -  1'01'004  Replication Operator  (-)
113:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
            (14651:4<4><0>)
114:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
            (14652:6<4><0>)
115:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
            (14653:8<4><0>)
116:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
            (14655:2<4><0>)
  -  2'22'000  Quality information follows  (-)
117:  0'01'031  Identification of originating/generating centre (see Note 10)
            [Code Table 0'01'031]  (14656:4<16><0>)
118:  0'01'032  Generating application [Code Table 0'01'032]  (14659:2<8><0>)
  -  1'01'004  Replication Operator  (-)
119:  0'33'036  Nominal confidence threshold [%]  (14660:8<7><0>)
120:  0'33'036  Nominal confidence threshold [%]  (14662:5<7><0>)
121:  0'33'036  Nominal confidence threshold [%]  (14664:2<7><0>)
122:  0'33'036  Nominal confidence threshold [%]  (14665:7<7><0>)
  -  2'22'000  Quality information follows  (-)
123:  0'01'031  Identification of originating/generating centre (see Note 10)
            [Code Table 0'01'031]  (14667:4<16><0>)
124:  0'01'032  Generating application [Code Table 0'01'032]  (14670:2<8><0>)
  -  1'01'004  Replication Operator  (-)
125:  0'33'007  Per cent confidence [%]  (14671:8<7><7>)
126:  0'33'007  Per cent confidence [%]  (15118:1<7><7>)
127:  0'33'007  Per cent confidence [%]  (15564:2<7><7>)
128:  0'33'007  Per cent confidence [%]  (16010:3<7><7>)
  -  2'22'000  Quality information follows  (-)
129:  0'01'031  Identification of originating/generating centre (see Note 10)
            [Code Table 0'01'031]  (16456:4<16><0>)
130:  0'01'032  Generating application [Code Table 0'01'032]  (16459:2<8><0>)
  -  1'01'004  Replication Operator  (-)
131:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
            (16460:8<4><0>)
132:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
            (16462:2<4><0>)
133:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
            (16463:4<4><0>)
134:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
            (16464:6<4><0>)
  -  2'22'000  Quality information follows  (-)
135:  0'01'031  Identification of originating/generating centre (see Note 10)
            [Code Table 0'01'031]  (16465:8<16><0>)
136:  0'01'032  Generating application [Code Table 0'01'032]  (16468:6<8><0>)
```

```
  -  1'01'004  Replication Operator  (-)
137:  0'33'036  Nominal confidence threshold [%]  (16470:4<7><0>)
138:  0'33'036  Nominal confidence threshold [%]  (16472:1<7><0>)
139:  0'33'036  Nominal confidence threshold [%]  (16473:6<7><0>)
140:  0'33'036  Nominal confidence threshold [%]  (16475:3<7><0>)
  -  2'22'000  Quality information follows  (-)
141:  0'01'031  Identification of originating/generating centre (see Note 10)
              [Code Table 0'01'031]  (16476:8<16><0>)
142:  0'01'032  Generating application [Code Table 0'01'032]  (16479:6<8><0>)
  -  1'01'004  Replication Operator  (-)
143:  0'33'007  Per cent confidence [%]  (16481:4<7><0>)
144:  0'33'007  Per cent confidence [%]  (16483:1<7><0>)
145:  0'33'007  Per cent confidence [%]  (16484:6<7><0>)
146:  0'33'007  Per cent confidence [%]  (16486:3<7><0>)
  -  2'22'000  Quality information follows  (-)
147:  0'01'031  Identification of originating/generating centre (see Note 10)
              [Code Table 0'01'031]  (16487:8<16><0>)
148:  0'01'032  Generating application [Code Table 0'01'032]  (16490:6<8><0>)
  -  1'01'004  Replication Operator  (-)
149:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
              (16492:4<4><0>)
150:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
              (16493:6<4><0>)
151:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
              (16494:8<4><0>)
152:  0'33'035  Manual/automatic quality control [Code Table 0'33'035]
              (16496:2<4><0>)
  -  2'22'000  Quality information follows  (-)
153:  0'01'031  Identification of originating/generating centre (see Note 10)
              [Code Table 0'01'031]  (16497:4<16><0>)
154:  0'01'032  Generating application [Code Table 0'01'032]  (16500:2<8><0>)
  -  1'01'004  Replication Operator  (-)
155:  0'33'036  Nominal confidence threshold [%]  (16501:8<7><0>)
156:  0'33'036  Nominal confidence threshold [%]  (16503:5<7><0>)
157:  0'33'036  Nominal confidence threshold [%]  (16505:2<7><0>)
158:  0'33'036  Nominal confidence threshold [%]  (16506:7<7><0>)
```

Appendix D NetCDF

Variable	Content
cdr_platform_end_time	20070101000000
cdr_platform_start_time	20210101000000
channel_bandwidth	10.3 - 11.3 µm
channel_frequency_center	10.8 µm
channel_id	04
comments	The input to the product are two consecutive images from AVHRR Metop-A and auxiliary ERA-Interim data.
Conventions	CF-1.7
creator_email	ops@eumetsat.int
creator_name	USC Climate Team, EUMETSAT
creation_time	20201004205927
creator_url	https://www.eumetsat.int
data_format_type	NetCDF Classic format
description	Reprocessed Atmospheric Motion Vector (AMV) time series derived from data of the AVHRR instrument on NOAA and EUMETSAT polar o rbiting satellites. AMVs provide wind speed (m/s), wind directi on (degree) and altitude in the atmosphere (hPa). This file con tains infrared window channel AMVs from AVHRR on board Metop-A.
disposition_mode	O
history	20201004205927 - netCDF generated from original data using soft ware version 1.0.
id	10.15770/EUM_SEC_CLM_0056

institution	EUMETSAT
instrument	AVHRR
keywords	AMV, wind, atmospheric motion vector, speed, direction, height, level2, polar, leo, EPS, Metop, AVHRR
licence	EUMETSAT data policy https://www.eumetsat.int/legal-framework/data-policy
metadata_conventions	Unidata Dataset Discovery v1.0
number_of_winds	66075
orbit_eccentricity	0
orbit_end_number	38207
orbit_inclination	0
orbit_semi_major_axis	0
orbit_start_number	38206
parent_file_name	AVHR_GAC_1B_M02_20140301002203Z_20140301233703Z_R_O_20200929151225Z
platform	M02
platform_long_name	Metop-A
processing_centre	TCE1
processing_level	2
processing_mode	R
processing_algorithm_version	3.1
producer_agency	EUMETSAT
product_type	AMV
product_version	Release 2.0
references	10.15770/EUM_SEC_CLM_0056
reference_url	http://doi.org/10.15770/EUM_SEC_CLM_0056
sensing_start_time	20140301002203
sensing_stop_time	20140301233703
sensor_model	305
source	Observational satellite observation: Metop-A AVHRR; Model: ERA-Interim as input
summary	This is the release 2 of the Metop-A AVHRR atmospheric motion vectors and their associated quality parameters. This data record was processed using the near real-time EUMETSAT algorithm v2.2. Each file contains one full Metop orbit (Svalbard to Svalbard) or one day of data.
title	Polar atmospheric motion vectors from Metop-A AVHRR
title_short_name	Metop-A polar AVHRR AMVs

Number	Name	Standard name	Long name	Description	Unit	Valid minimum	Valid Maximum	Type
1	algorithm_flags	status_flag	Algorithm flags	Algorithm flags. 7: IASI co-located data used for height assignment 6: Inversion height assignment correction applied 5: Cloud base assignment correction applied 4: Image enhancement applied 3: Triplet mode 2: [Reserved] 1: [Reserved] 0: [Missing value] All bits: [Missing value]	1	0b	8b	byte
2	cluster_size		number of cloud pixels in cluster	number of cloud pixels in cluster	count	0	32767	Unsinged short integer
3	degraded_inst_mdr	status_flag	instrument degradation	Quality of MDR has been degraded due to an instrument degradation	1	0	1	byte
4	degraded_proc_MDR	status_flag	processing degradation	Quality of MDR has been degraded due to an processing degradation	1	0	1	byte
5	eastward_wind	eastward_wind	u component of the final wind speed	This is the u, or zonal, component of the final AMV speed	m/s	-200	200	float
6	forecast_reference_time	forecast_reference_time	Base/reference time of the forecast	The forecast reference time in NWP is the "data time", the time of the analysis from which the forecast was made. It is not the time for which the forecast is valid.	s	19000000000000	21000000000000	Unsigned integer 64 bit
7	forecast_direction	wind_from_direction	Wind direction of the forecast	Wind direction of the forecast used for the first guess	degree	0	360	float
8	height_assignment_method	status_flag	Individual height assignment methods	Individual height assignment methods. 0: Auto editor; 1: IRW height assignment; 2: WV height assignment; 3: H2O intercept height assignment; 4: CO2 slicing height assignment; 5: Low pixel max gradient; 6: Higher pixel max gradient; 7: Primary height assignment; 8: Layer thickness assignment;	1	0b	15b	byte

				9: Cumulative contribution function -10 percent height; 10: Cumulative contribution function -50 percent height; 11: Cumulative contribution function -90 percent height; 12: Cumulative contribution function – height of maximum gradient; 13: IR / two WV channel rationing method; 14: Composite height assignment; 15/255; [missing value]				
9	height_assignment_pressure	air_pressure	Individual height assignment pressure	Individual height assignment pressure	Pa	0	120000	float
10	height_assignment_pressure_standard_deviation	air_pressure standard_error	Individual height assignment pressure standard deviation	Individual height assignment pressure standard deviation	Pa	0	120000	float
11	height_assignment_temperature	air_temperature	Individual height assignment temperature	Individual height assignment temperature	K	0	400	float
12	height_assignment_temperature_standard_deviation	air_temperature standard_error	Individual height assignment temperature standard deviation	Individual height assignment temperature standard deviation	K	0	100	float
13	latitude	latitude	latitude north positive	Latitude of the vector	degrees_north	-90	90	float
14	longitude	longitude	longitude west negative	Longitude of the vector	degrees_east	-180	180	float
15	matching_method	status_flag	Matching method	Matching method. 0: Norms least square minimum; 1: Euclidean norm with radiance correlation; 2: Cross-correlation method; 3-6: [Reserved]; 7/255: [Missing value]	1	0b	8b	byte
16	matching_value		Matching value	Peak value of correlation method	1	0	255	Unsigned short integer
17	northward_wind	northward_wind	v component of the final wind speed	This is the v, or meridional, component of the final AMV speed	m/s	-200	200	float
18	platform_zenith_angle	platform_zenith_angle	Platform/satellite zenith angle	Platform/Satellite zenith angle	degrees	0	90	float
19	quality_index	aggregate_quality_flag	Overall quality index	Overall wind quality index/flag of the vector including forecast. First entry in quality_flag_values.	percent	0	100	float

20	quality_index_excluding_forecast	quality_flag	Overall wind vector quality index excluding foreca	Overall quality index/flag of the vector excluding forecast. Second entry in quality_flag_value	percent	0	100	float
21	quality_index_values	quality_flag	All wind vector quality indices	All quality indices/flags of the vector. 1: Overall quality; 2: Overall quality excl. forecast; 3: Estimated error; 4 - 6: [reserved]; 7: Forecast consistency; 8: Spatial vector consistency; 9: Spatial height consistency; 10: Temporal height consistency; 11: Tracking vector consistency; 12: Tracking speed consistency; 13: Tracking direction consistency; 14: U-component consistency; 15: V-component consistency; 16 - 18: [Reserved]	percent	0	100	float
22	sensing_time	time	Sensing tim	Time of AMV measurement	s	N/A	N/A	Unsinged integer 64 bit
23	surface_type		Surface/Area type	The Surface type contains a code indicating the type of surface underneath the tracer. 0: Land; 1: Sea; 2: Coastal; 3: [Missing value]	1	0	3	Unsigned short integer
24	wind_brightness_temperature	brightness_temperature	AMV brightness temperature	Brightness temperature of the pixels used for tracking.	K	0	1200	float
25	wind_brightness_temperature_standard_deviation	brightness_temperature standard_error	AMV temperature standard deviation	Standard deviation of the brightness temperature of the pixels used for tracking.	K	0	1200	float
26	wind_from_direction	wind_from_direction	AMV direction	Final AMV direction.	degrees	0	360	float
27	wind_direction_component	wind_from_direction	Directions of the intermediate wind components	Directions of the intermediate wind components	degrees	0	360	float
28	wind_pressure	air_pressure	AMV pressure	Final AMV pressure, i.e. height of the AMV in the atmosphere.	Pa	0	120000	float

29	wind_pressure_standard_deviation	air_pressure standard_error	AMV pressure standard deviation	AMV pressure standard deviation	Pa	0	120000	Float
30	wind_method	status_flag	wind method used for AMV derivation	Method used for AMV derivation. 0: [Reserved]; 1: Wind derived from cloud motion observed in the infrared channel; 2: Wind derived from cloud motion observed in the visible channel; 3: Wind derived from cloud motion observed in the water vapour channel; 4: Wind derived from motion observed in a combination of spectral channels; 5: Wind derived from motion observed in the water vapour channel in clear air; 6: Wind derived from motion observed in the ozone channel; 7: Wind derived from motion observed in the water vapour channel (cloud or clear air not specified); 8 - 12: [Reserved]; 13: Root mean square; 14: [Reserved]; 15/255: [Missing value]	1	0	15	byte
31	wind_speed	wind_speed	AMV speed	This is the final AMV speed.	m/s	0	500	float
32	wind_speed_component	wind_speed	Speed of the intermediate wind components	Speed of the intermediate wind components	m/s	0	360	float

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