EVALUATION OF TWO AMV POLAR WINDS RETRIEVAL ALGORITHMS USING FIVE YEARS OF REPROCESSED DATA

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Abstract

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) participates in the European Re-Analysis of global CLIMate observations (ERA-CLIM) project (Dee 2011). This European Union project aims to prepare input data and assimilation systems for a new global atmospheric reanalysis of the 20th century. Among other activities this requires the generation of consistent climate data records (CDR) from satellite data. One of EUMETSAT's contributions to the ERA-CLIM project is the generation of polar Atmospheric Motion Vectors (AMVs) from METOP-A AVHRR data back to the year 2007.

For this purpose EUMETSAT has two algorithms available: the EUMETSAT operational algorithm and an algorithm developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS). Both algorithms utilise the Infrared (IR) window channel (11 μm) from the AVHRR. But the algorithms differ with respect to the number of satellite orbits used, tracking of clouds, the use of weather forecast model data and the quality analysis of resulting wind vectors. The different numbers of orbits used leads to a different spatial coverage, the EUMETSAT algorithm can retrieve winds up to 55° away from the poles, the CIMSS algorithm only up to 65°. Thus, the generation of two AMV records enables the systematic analysis of the differences between the two algorithms and versus independent in-situ measurements.

Comparison against radiosondes and ERA-Interim reanalysis data show that the EUMETSAT algorithm produces on average faster winds with a slightly higher standard deviation than the CIMSS algorithm. A triple collocation between the two AMV data records and radiosondes show in general a very good agreement between the three. The comparison between the EUMETSAT algorithm and reprocessed AMVs derived from Meteosat measurements also show good agreement in the overlap region between 55°and 65°.

ALGORITHMS AND INPUT DATA

For the generation of the METOP-AVHRR AMV data record two algorithms were available to EUMETSAT. These are the operational EUMETSAT AVHRR-AMV algorithm and the algorithm provided by CIMSS. The main specifications of the two algorithms are listed in Table 1.

AVHRR L1b data were taken as prime input data for both algorithms. As auxiliary data Numerical Weather Prediction (NWP) forecast data from ERA-Interim (Dee et al., 2011) were used. AMVs from both algorithms were processed for the period from March 2007 to December 2012. For more details see Table 1. Both algorithm give a quality indicator (QI) associated to each wind vector. It is based on a temporal, spatial consistency and forecast consistency (Holmlund et al., 2001). The biggest source of uncertainty for the AMV generation is the correct height assignment of the retrieved winds. The EBBT method uses the temperature profile of the NWP data and the Brightness Temperature form the AVHRR data and assigns the AMV to the corresponding temperature in the NWP profile. Further development in the optimal height assignment is necessary to reduce this error.

EUMETSAT algorithm

The EUMETSAT AVHRR-AMV algorithm used for this CDR generation was version 2.1.2 of EUMETSATs operational EPS ground segment (Dew et al. 2012). This algorithm performs a one-step AMV retrieval for which two consecutive orbits from AVHRR channel 4 (11 μm) data form the basis. The algorithm is based on the one used at EUMETSAT to derive winds from the series of Meteosat Second Generation geostationary satellites (MSG) (Borde et al., 2013). NWP forecasts are used for the first guess and for height assignment (EBBT method). Due to the use of only two overlapping orbits the retrieval of data is possible up to ±55° latitude from the pole.

CIMSS algorithm

The CIMMS algorithm used is an adapted version from the CIMSS algorithm described by Olander (2001). The retrieval is divided in two steps. Firstly the AVHRR L1B data (BT from channel 4) are remapped to a polar stereographic grid (so called AREA files). Secondly, the AMV retrieval algorithm is applied on the remapped data. The algorithm uses three consecutive orbits to retrieve AMVs. As a consequence, the wind vectors are derived only from ±65° latitude to the poles.

	EUMETSAT	CIMSS
Forecast data –ERA-interim		
Variables	T, u, v	T, u, v, specific humidity
Vertical levels	60 levels (model)	10 levels (pressure)
Resolution	0.5°x0.5°	1°x1°
AMV derivation		
Processing area	±55° latitude to the poles	±65° latitude to the poles
Number of orbits used	two	three
Height assignment		
	NWP temperature profile IASI height if available	NWP temperature profile + best fit adjustment to wind field. IASI height if available

Table 1: **Main specification of the EUMETSAT and CIMSS algorithms.**

Radiosonde data

For the validation of the two data records radiosonde data from the RAOBCORE (Haimberger et al. 2012) data record generated at the University of Vienna, covering the period 2007 to end 2010, was used. For the Antarctic only seven radiosonde stations were available, therefore most statistics presented here are for the Arctic, were up to 100 stations were available.

RESULTS

The two AMV data records were validated against in-situ (radiosondes) and compared against numerical weather prediction analysis (ERA-Interim, not shown) and, for the EUMETSAT algorithm only, against corresponding AMV retrievals from reprocessed MSG. Analysis was done by collocating data or using a common grid.

Comparison of EUMETSAT and CIMSS AMVs

A first ‘sanity check’ between the two data records was performed by comparing the retrieved wind fields. In Figure 1, an example of the wind fields for one orbit over the South Pole are shown. The wind features over central Antarctica are detected by both algorithms. In both figures low level winds (yellow) occur only over the ocean; this is in agreement with regard to the topography of the Antarctic continent. The EUMETSAT algorithm is the only one able to retrieve cloud features north of 65° south.

A second 'sanity check' was done on averaged wind speed and direction distributions. For this purpose so called wind roses in Figure 2 show us aggregated data for June 2009. Only data for the same geographical region (i.e. north of 65°) are used in the two plots. The distribution of wind speed and direction is very similar for both data records. This suggests that no major errors occur in the two data records.

The wind speed comparison between the collocated AMVs from the EUMETSAT and the CIMSS algorithm (Figure 3) shows that overall the EUMETSAT AMVs are approx. 2 m/s faster than the CIMSS AMVs. However there is a general good agreement for the majority of the AMVs between EUMETSAT and CIMSS algorithms. Some outliers remain giving quite a standard deviation of about 5.5 m/s.

Time collocated winds from EUMETSAT and CIMSS algorithm have been gridded on a 0.5x0.5° regular latitude-longitude grid to be easily compared. The gridded statistics of the speed differences presented in Figure 3 (left panel) reveal no regional variation concerning the speed bias. Using the same grid for the vector differences between the two datasets (Figure 3 (right)) we observe that the best agreement is over the sea with 3 to 4 m/s, while over the land (especially Greenland) the vector differences reach up to 10 m/s. The results over Greenland are statistically not significant due to the very small number of collocations. However it is likely that the target selection and feature tracking with 3 orbits gives different wind vectors compared to the usage of 2 orbits.

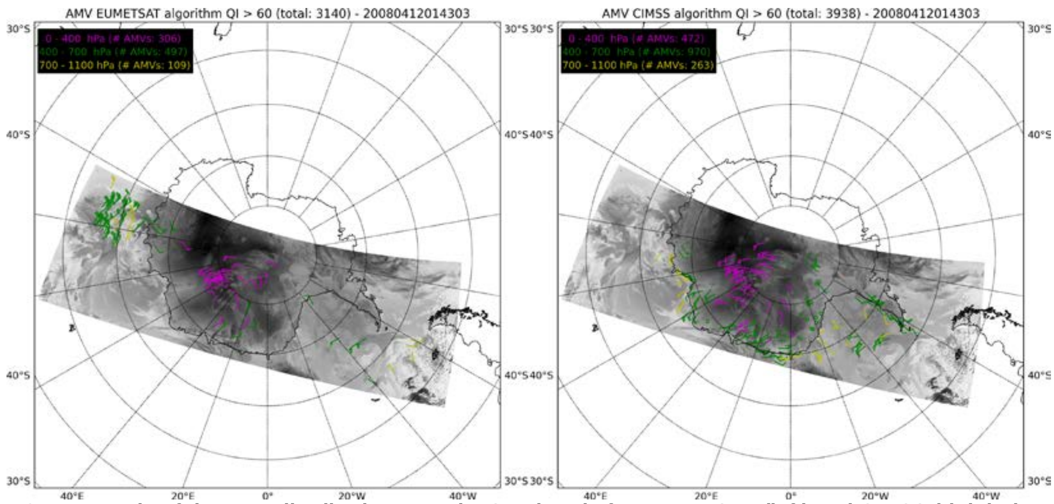

Figure 1: One example of the **AMV distribution over the South Pole for EUMETSAT (left) and CIMSS (right) algorithm for the 12th April 2008. Note, that not every AMV is plotted, but rather a random selection of about 10%. The colours represent the height of the vector: yellow, green and purple representing low, mid and high level vectors, respectively.**

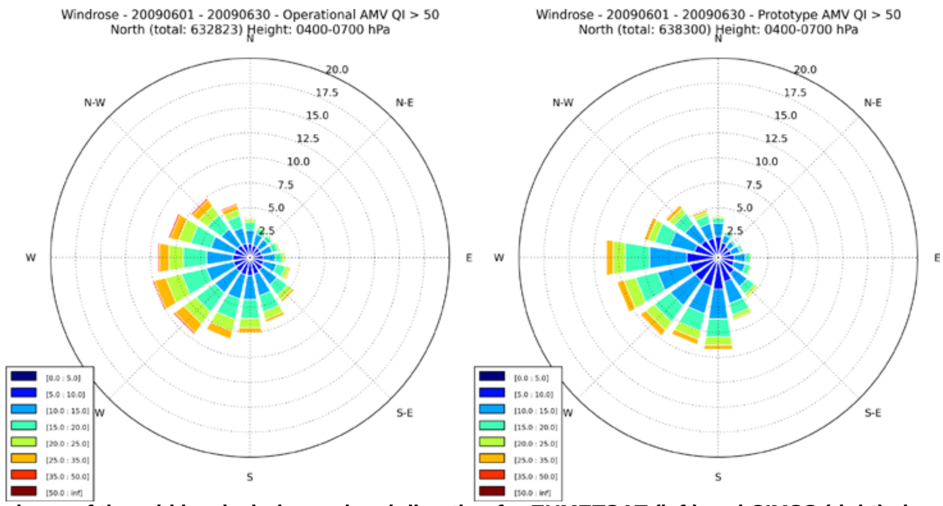

Figure 2: **Windrose of the mid level wind speed and direction for EUMETSAT (left) and CIMSS (right) algorithm for the month of June 2009.**

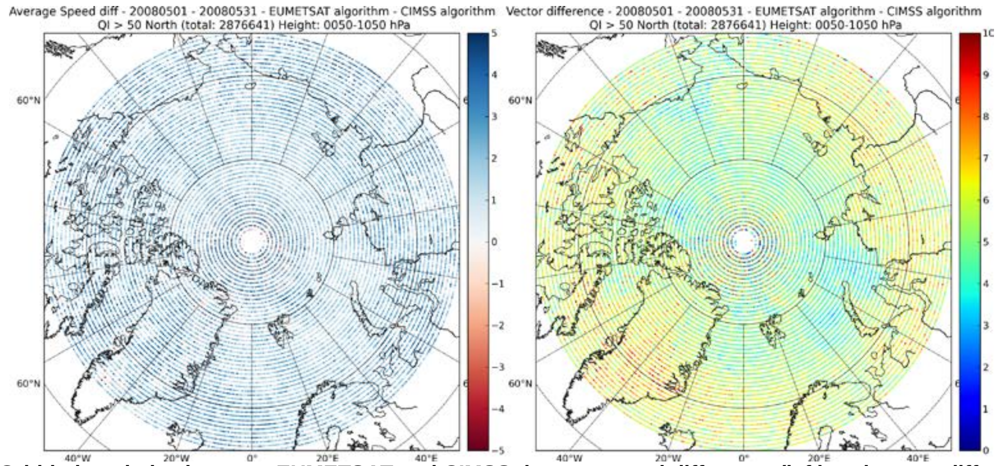

Figure 3: **Gridded statistics between EUMETSAT and CIMSS dataset, speed difference (left) and vector difference (right) for the month of May 2008.**

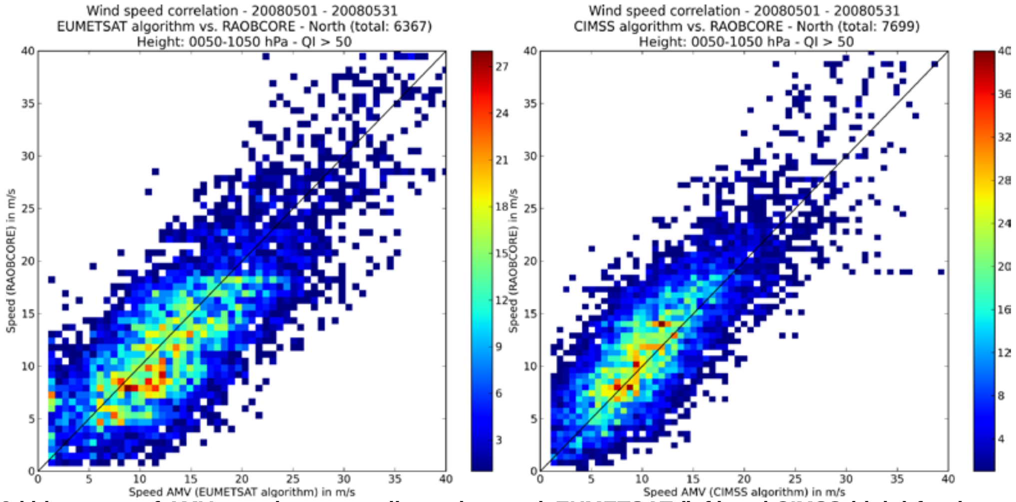

Figure 4: **2d histogram of AMV speed versus radiosonde speed, EUMETSAT (left) and CIMSS (right) for the month of May 2008. Note that only AMV within ±65° are considered.**

Validation of AMVs against radiosondes

The AMVs from the two data records were collocated against radiosondes from the RAOBCORE data record using a 100 km and 100 minute collocation criterion, in addition only AMVs with a Quality Indicator (QI) larger than 50 were used. To ensure comparability between the statistics, only data from 65° to the poles, were considered. The results are shown in a 2d-histogram in Figure 4. We observe a positive speed bias for the AMVs from the EUMETSAT algorithm and slight negative bias for the AMVs of the CIMSS algorithm. Moreover, the spread of the EUMETSAT against the radiosonde data is slightly larger than for the comparison between the CIMSS and the radiosonde data. One explanation is that within the CIMSS algorithm a height adjustment using a best fit method to the NWP wind field data is performed.

In this paper we used triple collocation to analyse the consistency between the EUMETSAT, CIMSS and RAOBCORE datasets. Triple collocation is a powerful tool to quantify error structures in large-scale data records is triple collocation that can be applied to three independent datasets of a specific physical parameter that represents the same spatial and temporal scales and are subject to mean random errors with a Gaussian nature (Stoffelen 1998). The main idea is that none of the three datasets is the absolute ‘truth’ so that every dataset has its own errors. We used triple collocation to quantify the residual errors of the three data records for the temporal variations in wind speeds during the period June 2007 till November 2011. It needs to be noted that our datasets are not fully independent and more investigation is needed to fully understand the results.

Figure 5 shows several statistics between the three data records, average speed difference, standard deviation, vector difference and relative difference. We see a positive speed bias over the entire time series for the EUMETSAT AMVs against the CIMSS AMVs and only a very small bias compared with the radiosonde data. The CIMSS data has a very clear negative speed bias compared to the radiosonde data. The standard deviation and vector difference are similar for all comparisons, only the CIMSS versus radiosonde data seems slightly better from 2009 onwards, why this is the case is not clear yet. The relative difference is largest for the collocated AMVs from EUMETSAT and CIMSS and similar but with different sign for the comparison against the radiosondes. Figure 6 shows the errors and the linear regression values towards the EUMETSAT data record. In the upper plot the residual error for each data record is shown. The lower this value in comparison to the other datasets, the 'better' this dataset is. In our case there is no dataset that is distinctively different from the others. This means no data record is particularly good or bad. The middle and lower part of this figure show the values for the linear regression of the RAOBCORE and the CIMSS dataset towards the EUMETSAT dataset. Only in 2007 there are some small variations in slope and intercept, for the rest of the time series the slope is close to one and the intercept near zero, again indicating a good overall agreement between the datasets.

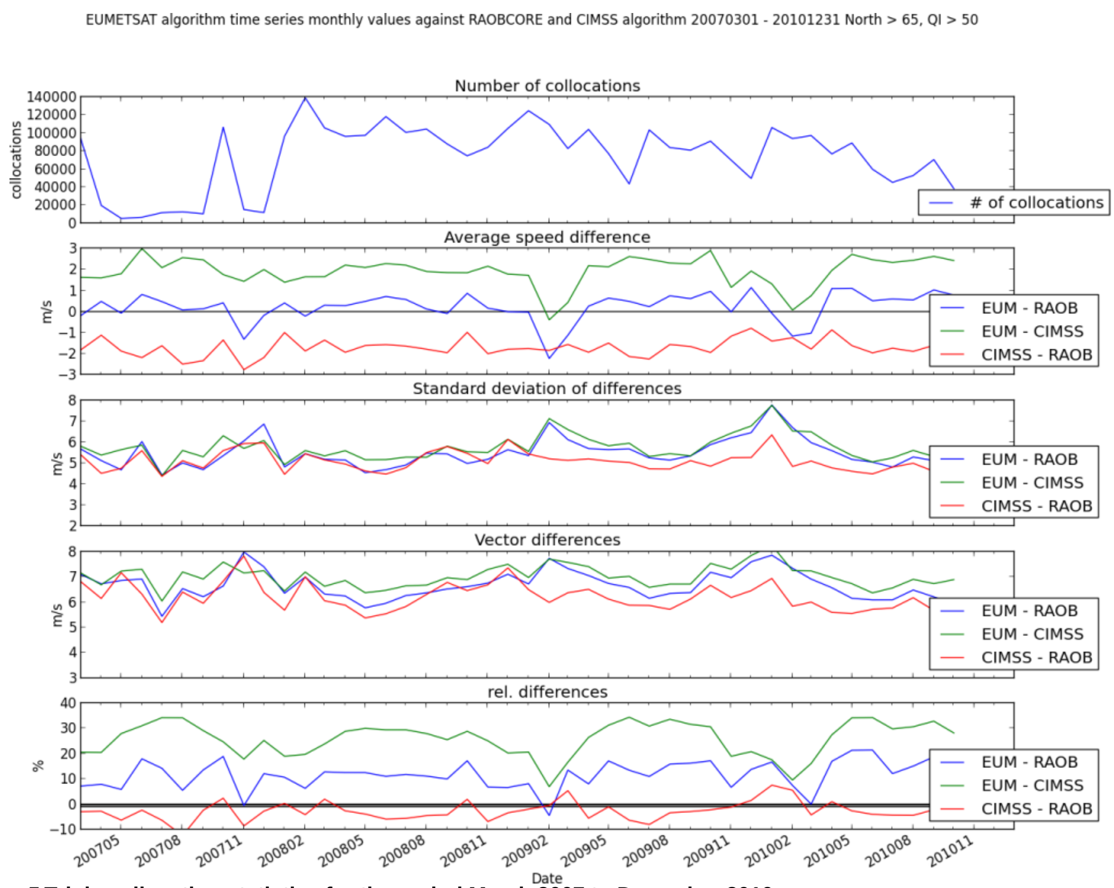

Figure 5 **Triple collocation statistics for the period March 2007 to December 2010**

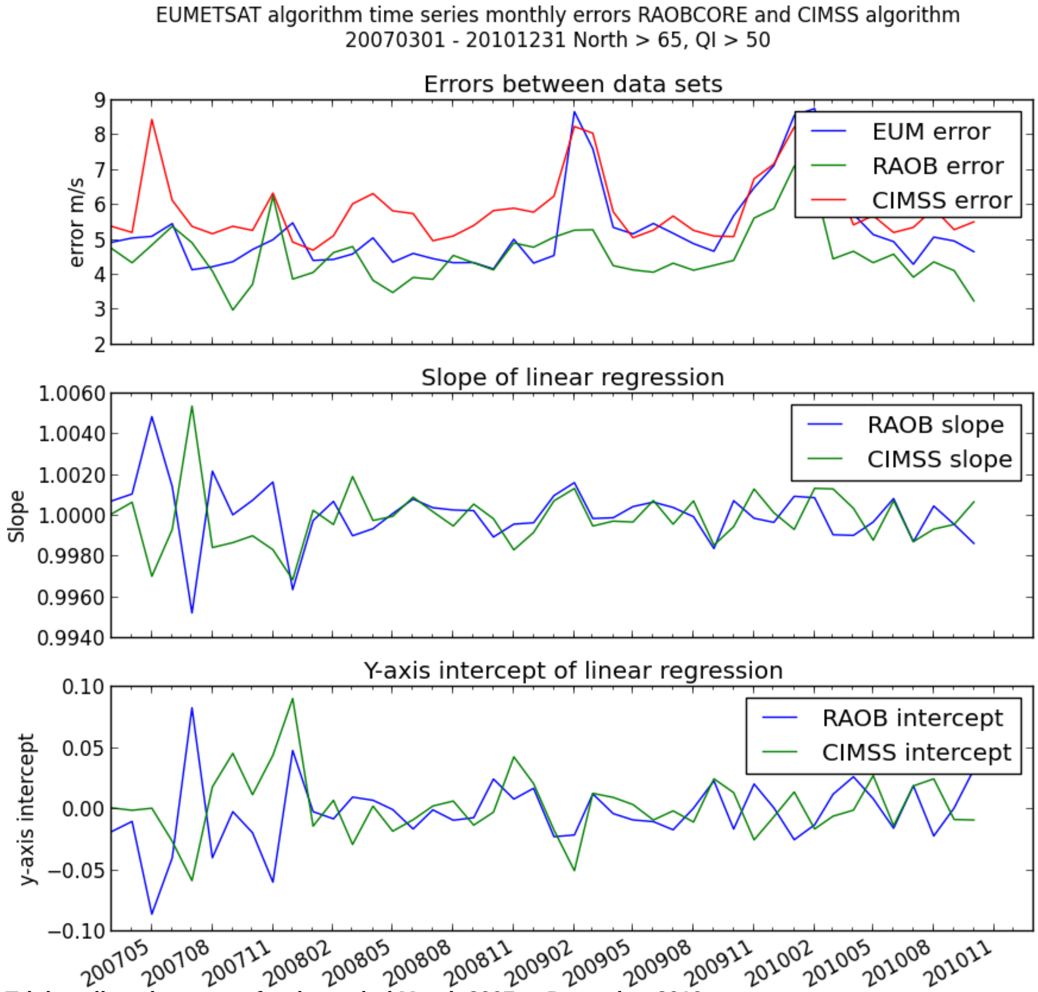

Figure 6 **Triple collocation errors for the period March 2007 to December 2010**

Comparison of AVHRR and MSG AMVs

For the region where the retrievals from the EUMETSAT AVHRR AMV algorithm and the EUMETSAT MSG AMV algorithm overlap some statistics for the first half of 2008 were produced. As the EUMETSAT AVHRR algorithm only uses two orbits the areal coverage reaches further away from the poles in this case down to 55°. As the AMVs for MSG are retrieved up to 65° some comparisons can be performed in this region (55-65). In Figure 7 the speed correlation between the two data records is shown, again displaying a slight positive speed bias of the AVHRR AMVs relative to the MSG AMVs. In general, the agreement is good, the speed bias and the standard deviation are in the same order as compared to the other datasets used in this paper. This indicates that the AMVs retrieved with the EUMETSAT AVHRR algorithm present a valuable data record that also covers the area between 55° and 65°, where not many measurements exist at the moment, but which is important for the characterisation of European weather.

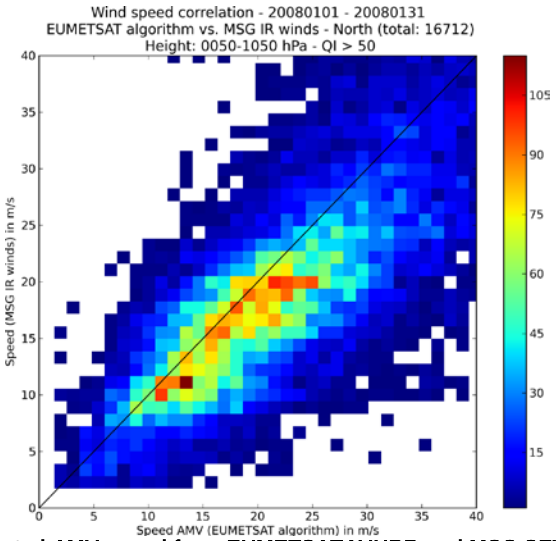

Figure 7: **2d histogram of collocated AMV speed from EUMETSATAVHRR and MSG SEVIRI (IR channel) data.**

CONCLUSION

In this study two METOP-AVHRR AMV data records covering 2007 to 2012 using METOP-A data were introduced, compared against each other and against reprocessed MSG AMVs, as well as validated against radiosonde observations. The data records were created with two different algorithms using the same data sources as input. The first algorithm was the operational EUMETSAT METOP-AVHRR AMV algorithm also used in the EUMETSAT EPS ground segment. The second algorithm was the adapted CIMMS algorithm.

The two data records show good agreement between each other, both algorithms detecting similar wind patterns, whereby the EUMETSAT algorithm has a further geographical extend away from the poles due to the use of only two orbits. The AMVs from the EUMETSAT data record have a positive speed bias relative to the collocated AMVs from the CIMSS data record. Although there is no distinct geographical features in the comparison, the agreement is better over oceanic areas than over land.

In comparison with radiosonde data, the agreement for both datasets is good, with the CIMSS algorithm showing a slow bias and the EUMETSAT algorithm showing a small fast bias. In some cases the standard deviation of the difference for the CIMSS dataset is smaller than for the EUMETSAT dataset. The biggest source of uncertainty and error for the AMVs remains the height assignment. The EBBT method based on NWP temperature profiles was used for this analysis and is the recommended method when using these datasets.

The triple collocation of the two AMV data records and the ROBCORE data showed a good and consistent agreement. None of the data records seems to have significant performance issues.

The comparison between the EUMETSAT AVHRR AMVs and MSG AMVs shows also a very good agreement, with only a small fast bias for AVHRR AMVs. Therefore the AVHRR AMVs can play an important role of providing AMV data in the gap between the traditional triplet polar AMVs, such as provided by the CIMMS algorithm, and the AMVs from geostationary satellites.

We can conclude that two very consistent and useful datasets were produced. Each of which has their own strength and weaknesses but give valuable and consistent information on the atmospheric flow in the North and South Polar regions over nearly six years.

An extension of the existing data records with data from 2013 including further validation and also the reprocessing of the entire data record with the latest EUMETSAT algorithm is planned as some significant improvements have been made in recent months.

REFERENCES

Borde, R., M. Doutriaux-Boucher, M. Carranza, and G. Dew, (2013), A Direct Link between Feature Tracking and Height Assignment of Operational EUMETSAT Atmospheric Motion Vectors, to be published in J. Atmos. Oceanic Technol.

Dee, D., (2011), ERA-CLIM: European Reanalysis of Global Climate Observations, GMES Climate Change Conference, Helsinki.

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., van de Berg, L., 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., de Rosnay, P., Tavolato, C., Thépaut, J.-N. and Vitart, F., (2011), The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Q.J.R. Meteorol. Soc., **137**: 553–597. doi: 10.1002/qj.828.

Dew G., R. Borde, M. Carranza and M. Doutriaux-Boucher, (2012), AVHRR polar winds derivation at EUMETSAT: current status and future developments, Proceeding of the 11th International wind workshop (IWW) in Auckland, New Zealand, EUMETSAT.

Holmlund K., C. S. Velden, M. Rohn, (2001), Enhenced automated quality control applied to high-density satellite-derived winds, Mon. Wea. Rev., **129**, 517-529.

Haimberger, L., C. Tavolato, and S. Sperka, (2012), Homogenization of the global radiosonde temperature dataset through combined comparison with reanalysis background series and neighboring Stations, *J. Climate*, **25**, 8108-8131.

Olander, T.L., (2001), UW-CIMSS Satellite-derived wind algorithm, User guide, CIMSS.

Stoffelen, A., (1998), Towards the True Near-Surface Wind Speed: Error Modelling and calibration Using Triple Collocation, J. Geophys. Res., **103**, 7755-7766.