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REPRESENTATION OF REGULAR CLIMATE VARIATIONS IN THE EUMETSAT ATMOSPHERIC MOTION VECTOR CLIMATE DATA RECORD

Alessio Lattanzio[1*], M. Doutriaux Boucher*, R. Huckle*,
O. Sus*, L. Medici*, M. Grant*, J. Onderwaater*, R. Borde* and J. Schulz*

*EUMETSAT, Darmstadt, Germany

1. ABSTRACT

EUMETSAT owns a unique archive covering almost 40 years of meteorological satellite data. The imagery acquired by the geostationary Meteosat satellite series goes back to the beginning of the 1980s, while the polar Metop platforms started to deliver data to users in 2007. These data are processed at EUMETSAT to derive Climate Data Records (CDRs) of geophysical parameters. One of these is the Atmospheric Motion Vectors (AMV) product. They can provide important atmospheric indicators to support climate studies. AMVs are derived by tracking the movement of clouds and water vapour features in consecutive satellite images, retrieving speed, direction, and height. Assigning the correct height for the retrieved wind vectors is one of the main sources of uncertainty. A quality indicator (QI) is assessed for each vector, giving an estimation of how good the retrieval was. CDRs of satellite AMVs generated at EUMETSAT are assimilated to produce climate reanalyses at the European Centre for Medium-Range Weather Forecasts (ECMWF) and at the Japan Meteorological Agency (JMA). AMVs can also be used to analyse climate variation patterns such as the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO). The NAO, in connection with the polar vortex, directly steers the direction and strength of the polar jet. A positive NAO aims the jet stream towards northern Europe, while a negative NAO directs the winds southward. The jet is the outer edge of the polar vortex, a permanent feature of atmospheric circulation, present at both poles. The objective of this paper is to present a first attempt at checking if the satellite derived AMVs are suitable to detect known changes in the northern hemisphere jet and to show the potential for further climate change related analyses using AMVs.

2. INTRODUCTION

EUMETSAT is storing geostationary (GEO) satellite measurements from 1981 (see Table 1) and polar orbiting (LEO) platforms since 2007 (see Table 2). Geostationary satellites also cover different sections of the Earth (See Figure 1). Meteosat 2-7 are the Meteosat First Generation (MFG), while Meteosat 8-11 are the Meteosat Second Generation (MSG).

SAT	SSP	Period
MET2-MET7	0E	1981-2006
MET8-MET11	0E	2004-ongoing
MET5	63E	1998-2006
MET7	57E	2006-2017
MET8	41.5E	2017-ongoing

Table 1: Geostationary Satellite, Sub-Satellite point and operational periods.

SAT	Period
METOP-A (M02)	2007-present
METOP-B (M01)	2012-present

Table 2: Polar Satellite and operational periods.

Those data are operationally processed in real time at EUMETSAT to generate different products allowing the monitoring of several geophysical variables. The Atmospheric Motion Vectors (AMV) product is one of those. Winds are important atmospheric indicators able providing support to climate studies. AMVs are derived by tracking the movement of clouds and water vapour features in consecutive satellite images, retrieving speed and direction.

[1] Corresponding author address: Alessio Lattanzio, EUMETSAT, Eumetsat Allee 1, 64295 Darmstadt Germany; e-mail: alessio.lattanzio@eumetsat.int .

Then, the height for each retrieved wind vector is assigned. This step is one of the main sources of uncertainty in the overall processing. A quality indicator (QI) is assessed for each vector (Holmlund, 1998), giving an estimation of how good the retrieval was. CDRs of satellite AMVs generated at EUMETSAT are assimilated to produce climate reanalyses at the European Centre for Medium-Range Weather Forecasts (ECMWF) and at the Japan Meteorological Agency (JMA).

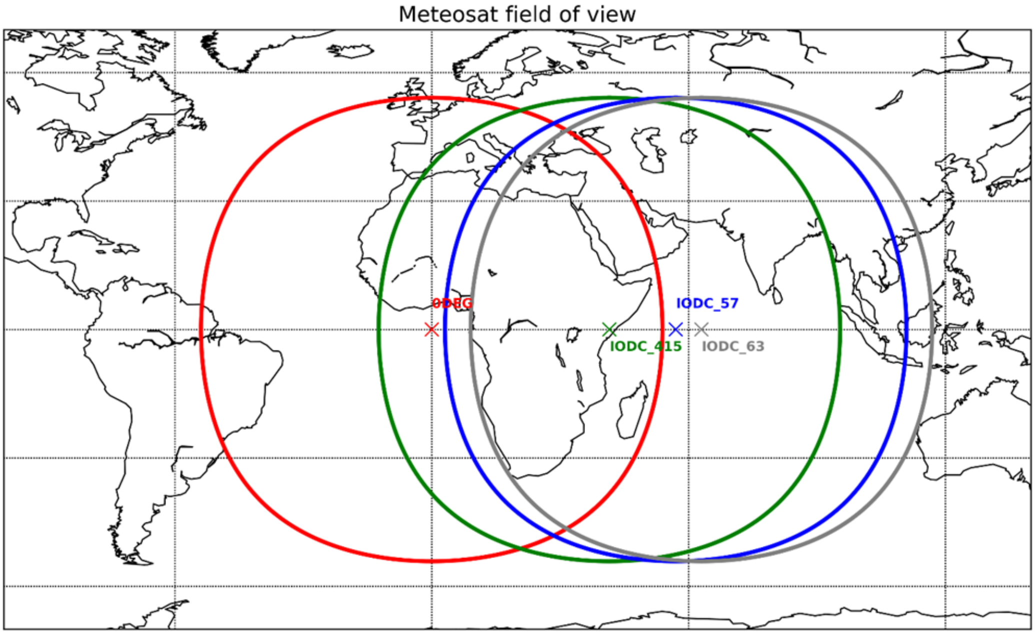

Figure 1: Meteosat field of view according to the different Sub Satellite points: SSP=0° (red), SSP=41.5°E (green), SSP=57°E (blue) and SSP=63°E (gray)

The objective of this paper are: (a) presenting the currently reprocessed AMV both from GEO and LEO platform and (b) to demonstrate that they can be exploited to detect and represent general climate variations indices such as the North Atlantic Oscillation (NAO).

3. AMV REPROCESSING

EUMETSAT generates AMVs operationally in near real time (NRT). The main aim of reprocessing is to obtain a homogenous data record. Reprocessing can be beneficial for several reasons:

a) Extend backwards or fill gaps present in the NRT operational products;
b) New calibration and improvement of input Level 1 data;
c) Improvement in the retrieval algorithm;
d) Improved or corrected auxiliary input data.

Reprocessed AMV can be derived from each geostationary satellite and in two different configurations for polar satellites.

In the latter case, AMV can be detected in:

a) Single Mode: using two consecutive Metop-AVHRR orbits from one satellites; covering from 40 degrees latitude up to the corresponding pole
b) Dual Mode: using consecutive orbits from two different satellites having a global coverage in 1 day.

AMVs are generated from Meteosat according to the method described in Borde et al., 2014. A quality index (QI) is defined for each retrieved wind following the method in Holmlund, 1998. In Figure 2 the number (upper panel) and mean speed (bottom panel) of reprocessed and operational retrieved AMVs are plotted.

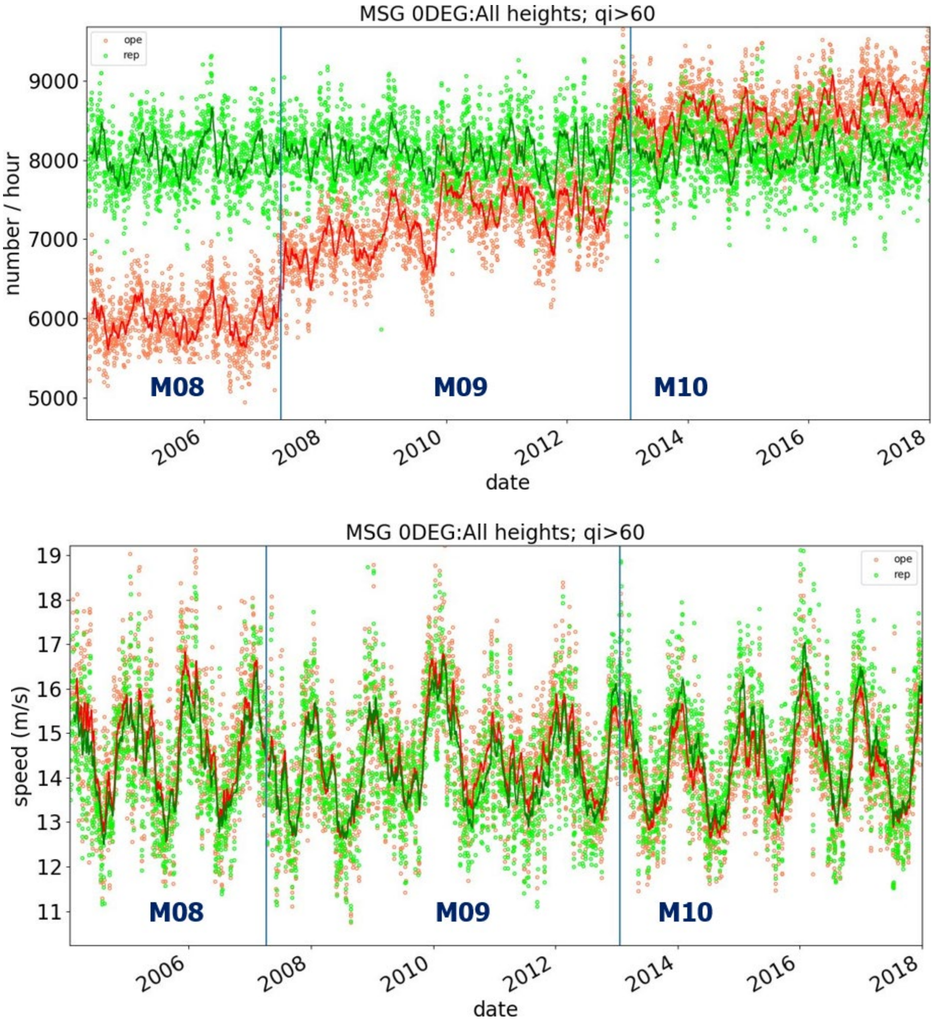

Figure 2: Daily average of the winds retrieved hourly (upper plot) and daily average speed in m/s (bottom plot) for AMVs generated from GEO (MSG-SEVIRI) imagery in the EUMETSAT NRT operational (red) and reprocessing environment (green).

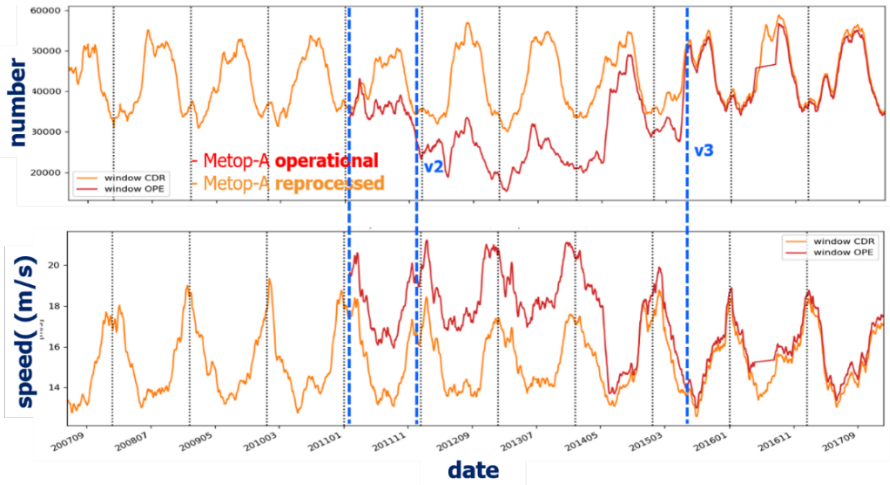

Figure 3: Number of winds retrieved daily (upper plot) and average speed in m/s (bottom plot) for AMVs generated from LEO (Metop-AVHRR) measurements in the operational NRT (red) and reprocessing environment (orange). Plots are shown using a 30-days rolling mean (window).

Reprocessing allowed for an increase in the number of AMVs before 2012 because the NRT setup was different (different QI and maximum latitude threshold for the retrieval, different height assignment method). The lower numbers in the reprocessed AMV after 2013 is due to the usage of only two (IR10.8 and WV6.2) SEVIRI channels for estimating cloud top height. The other infrared channels of the MSG imager (SEVIRI) have not been used in order to have a homogenous retrieval with the first generation of EUMETSAT geostationary satellites (MFG). The speed comparison (Figure 2, bottom panel) shows a good agreement between the reprocessed and the NRT AMVs. The Figure 3 shows a comparison between reprocessed and NRT operational polar AMVs retrieved over the North Pole region (from 40 to 90 degrees North). The reprocessed AMVs have been generated within the Copernicus Climate Change Service (C3S) framework [2]. Reprocessed winds are very stable in number and speed compared to the NRT operational ones. The speed difference between the different versions are due to several updates of operational algorithm, e.g. changes in calculation of the time between two measurements and vector location (centre of the target versus centre of the search box). NRT polar AMVs were only available since 2013; the reprocessing allowed extending the time series back to 2007.

4. NORTH ATLANTIC OSCILLATION AND JET STREAMS

The North Atlantic Oscillation (NAO) is a large-scale atmospheric pressure see-saw driving the weather and climate patterns in the northern hemisphere (Hurrell et al., 2009). It is an index for the difference in sea-level pressure between the Artic and the subtropical Atlantic region. Even if it always expresses the same atmospheric pattern, such an index can have different numerical values, according to used ground stations measurements. In this paper, we refer to the daily NAO index provided by the National Centres for Environmental Prediction (NCEP) Climate Prediction Centre[3]. The NAO daily value as derived by NCEP is plotted for the period 2009-2013 in Figure 4. In the same figure, two winters are highlighted. The winter 2009-2010, which was an extreme one (colder and for a longer time than average) (Cattiaux et al., 2010), characterised by a strong negative NAO index, and the winter 2011-2012 that was characterized by a strong positive NAO index. The NAO variation has a direct impact on the Jet Streams (JS). Jet streams are geostrophic winds; they only depend on the pressure gradient and the Coriolis force. They flow from west to east at a speed higher than 30 m/s and are located in the upper level of the troposphere, between 100 and 400 hPa (Kington and Ley, 1999). The objective of this section is to investigate this connection in the reprocessed AMVs from MSG. Jet streams are expected to become weaker and lower in latitude in case of a negative NAO, and stronger and located at higher latitude for periods of positive NAO. In order to check that such patterns are present in the AMVs generated from the MSG (see Table 1) imagery, first a single day (Figure 5), then a complete winter period (Figure 6) are compared and finally the latitude and the speed anomaly over the period from 2004 to 2017 are estimated (Figure 7). A comparison for the same day (20th of December) in the two periods (2009-2010 and 2011-2012) presented in Figure 5, shows that the median latitude value is 14 degrees lower in case of a negative NAO and that the median speed is 5 m/s slower. Only AMVs with a QI higher than 30 have been considered. The result in the plot behave as expected.

[2] Web link valid in October 2019: https://climate.copernicus.eu/

[3] Web link valid in October 2019: https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml

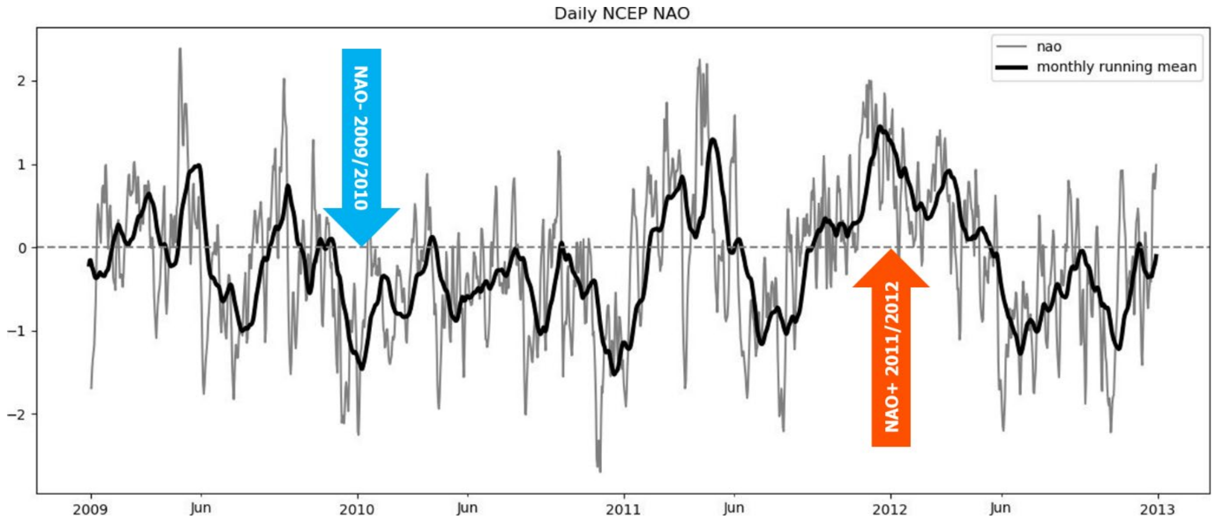

Figure 4: Daily NAO as derived by NCEP. A monthly running average is superimposed to show the variation at larger time scale.

As further analysis step, a full December-January-February (DJF) has been considered (See Figure 6). The JS on average are located lower in latitude in case of Negative NAO (38.6°) compared with the case of positive NAO (46.1°). Even if the maximum latitude are similar, in case of negative NAO the values are mostly above 3σ (Where σ is the standard deviation). In a phase of positive NAO the maximum are mostly inside 3σ.

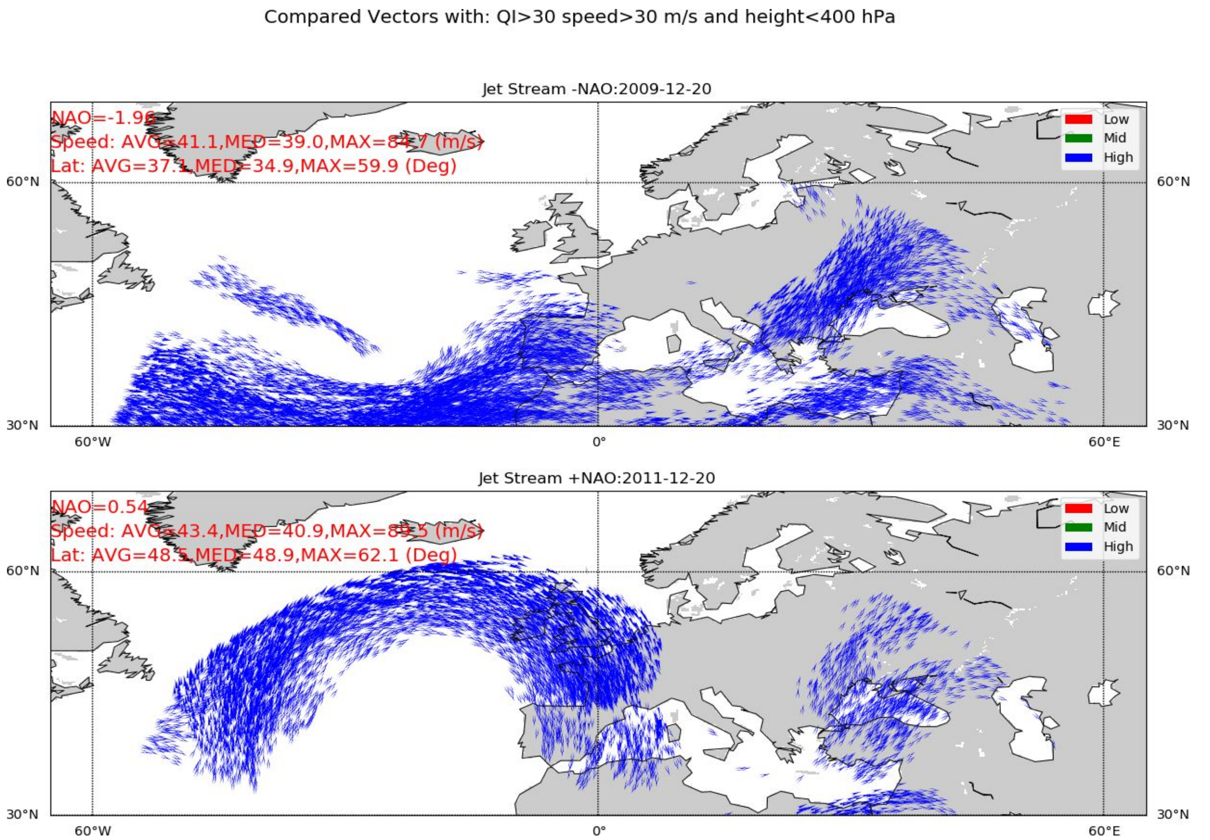

Figure 5: Jet streams retrieved on the same day (20th of December) in 2009 during a strong negative NAO phase (upper plot) and 2011 during a strong positive NAO phase (bottom plot).

The speed appears on average a bit higher in case of positive NAO (42.4 m/s) compared with negative NAO (41.6 m/s) but the difference is not statistically significant. The maximum speed in case of positive NAO appears closer to the 3σ value than in the case of negative NAO. Finally, the yearly latitude and speed anomaly over the full period (2004-2017) has been analysed (see Figure 7).

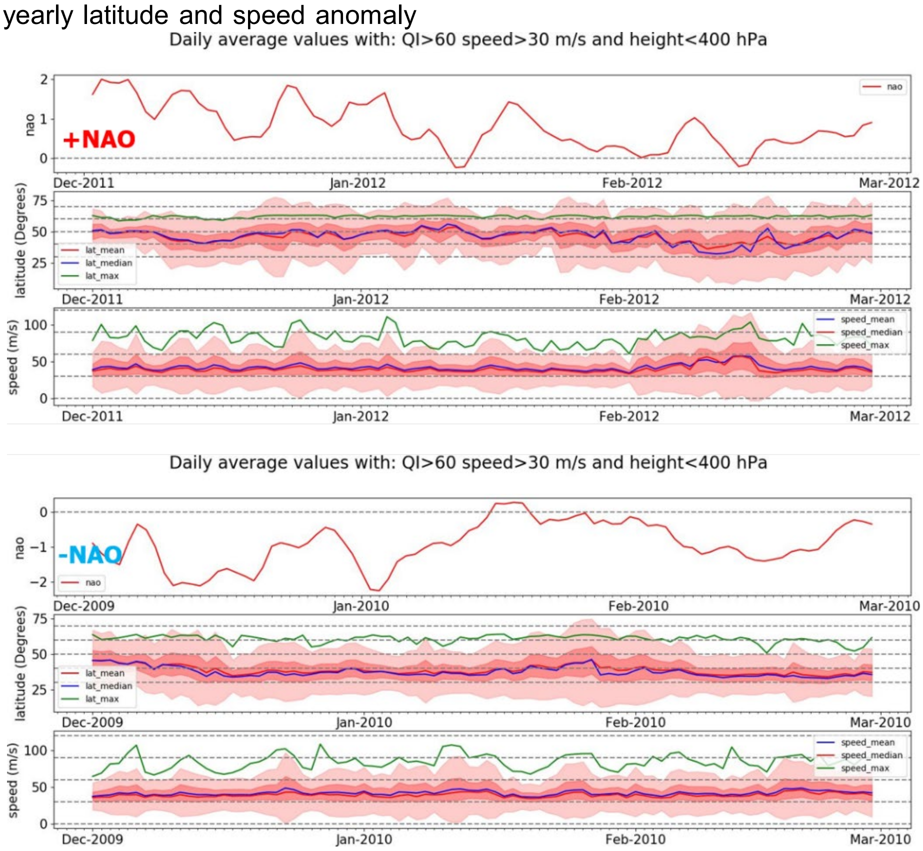

Figure 6: Jet streams daily average of: NAO, latitude and speed retrieved during a strong positive NAO phase (upper plot) and a strong negative NAO phase (bottom plot).

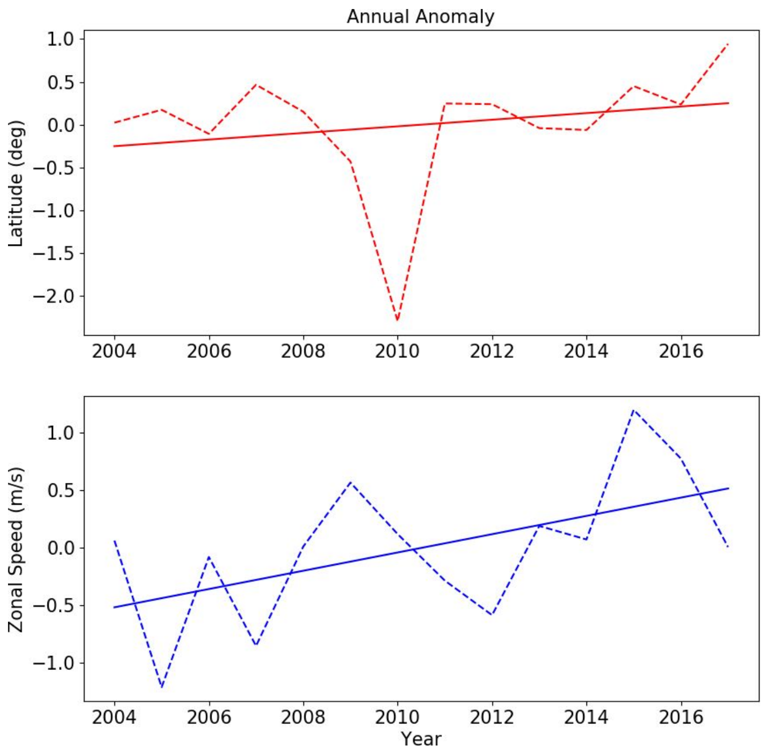

Figure 7: Jet streams anomaly for latitude (upper plot) and zonal speed (bottom plot) calculated along the 2004-2017 period.

In this plot has been considered the "zonal" speed. This is the contribution in the west-east direction of the wind vector. The anomaly is the difference between the yearly mean value and the average over the full period. Latitude anomaly shows a poleward shift and the speed anomaly a positive increase. This is in line with current model predictions (Irvine et al., 2016). The year 2010 is clearly shown as an outlier, due to the extreme winter 2009-2010 (Cattiaux et al., 2010). The time series is too short for any general conclusion on the JS long-term trend. As next step, AMVs derived from MFG will be processed, allowing for a 40-years long data record. This long-term dataset will allow for a more robust long-term analysis.

5. SUMMARY

EUMETSAT owns a data archive covering more than 40 years. It can be exploited to generate several CDR. One important CDR is the Atmospheric Motion Vectors (AMV), derived from instruments on board both LEO and GEO platforms. Metop AVHRR AMVs covering the poles are available from 2007 and global coverage from dual retrieval from 2013. The reprocessed AVHRR winds show an overall good stability compared with the corresponding operational near real time winds. They should be preferred for long-term analysis. METEOSAT AMVs can be derived from 1981. This presentation focused on the period 2004-2017 (MSG period) only. The analysis on the AMV presented in this paper shows an overall good stability and that the quality allows tracking jet stream during time. The jet stream detected from Meteosat imagery follow the NAO variability, as expected and could be further investigated for climate studies. The Meteosat data record will be extended to cover the MFG period, to allow an analysis of the jet streams over the past 40 year.

All data can be requested from EUMETSAT: ops@eumetsat.int

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