

Coordination meeting on reprocessing of atmospheric motion vectors (AMVs) and ECMWF reanalyses

Key points and Recommendations

1. **30 years of imagery data from the AVHRR instruments have been reprocessed into atmospheric motion vector (AMV) wind products by CIMSS and EUMETSAT.** (This covers 11 satellites, from NOAA-7 in 1982 to NOAA-18 in 2011, as well as MetOp-A in 2007-2012).
2. **EUMETSAT has reprocessed 20 years of Meteosat First Generation AMVs** for the period 1982-2001 and reprocessing Meteosat Second Generation AMV covering 2004-date is ongoing.
3. **CIMSS is about to start reprocessing of NOAA GOES** imagery data since 1995.
4. **AMV reprocessing methods differ** between NOAA NESDIS / CIMSS and EUMETSAT.
5. In order to serve climate users, **the International Winds Working Group (IWWG) could elevate to CGMS level the discussion of a recommendation that all future long missions with AMV products include interim delayed-mode climate-quality AMV reprocessing streams.**
6. A **unified global AMV processing code**, supporting both real-time and historical processing for all satellites, would allow consistency in regional datasets, applying algorithms of choice whenever needed, and possibly realizing synergies and cost savings by consolidating expertise in developments.
7. Reprocessing of additional long-term imagery datasets could be extremely valuable to cover recent satellite missions which do not include AMV processing as a main mission obligation (e.g., **MODIS**), and to **extend backward the start of the “satellite era”** in reanalyses (e.g. **GOES-1 to -7, Nimbus**).
8. **Improved coordination by WCRP Data Advisory Council** is required to better align AMV reprocessing activities with reanalysis needs and schedules.
9. This coordination effort needs to be supported by an **information forum -- collecting reprocessing activities, plans, opportunities, needs, capabilities, as well as reanalysis needs and plans -- with funding to be sought from a large regional climate service** (e.g. future European Climate Services).
10. **A global inventory of reprocessed AMV data holdings**, including dataset maturity is generally missing; such a task should be recommended as **part of an upcoming SCOPE-CM project on AMV reprocessing.**
11. **Feedback processes between reprocessing centers and reanalysis producers** are non-systematic: **ECMWF global reanalysis center is opening up its observation feedback archive** and **IWWG needs to promote winds reprocessing inter-comparisons and communication on AMV reprocessing updates.**
12. As we passed the 50th anniversary of satellite imagery, the coming years may see **loss of original instrument data and essential expertise and such risks need to be identified now, probably at the level of the WCRP Data Advisory Council.**

Goal of the meeting

Assist the **coordination** of the reprocessing efforts of satellite imagery data records from geostationary and polar orbits into climate data records of atmospheric motion vectors for use by reanalyses and accelerate **reprocessed data quality assessment** strategy using reanalyses and observation feedback archive.

Meeting venue and participation

The meeting was held at ECMWF and attended by Dave Santek and Steve Wanzong (CIMSS), Roger Huckle and Marie Doutriaux-Boucher (EUMETSAT), and Carole Peubey, David Tan, Dick Dee, Hans Hersbach, Kirsti Salonen, Niels Bormann, Paul Berrisford, and Paul Poli (ECMWF). After the meeting, Chris Velden (CIMSS) and Jörg Schulz (EUMETSAT) provided further comments on the present document.

ECMWF and EUMETSAT are both partners in the EU FP7 project “Coordination of Earth observation data validation for re-analysis” (Core-Climax) grant agreement no. 313085. Travel for CIMSS and EUMETSAT participants was funded by Core-Climax.

The meeting agenda is given in Annex I.

Context

ECMWF aims to start within a year (around Q2-Q3 2014) a new reanalysis of the recent era, covering the time period since 1979 until the present, with a view to have produced an ERA-Interim replacement within the next 2 years (by Q2-Q3 2015).

This new reanalysis requires procurement of reprocessed observation data, among which Atmospheric Motion Vectors (AMVs) are an important resource.

In Europe, this data procurement process and the feedback processes between the observational reprocessed data providers are still very much ad hoc, and need to be better documented in order to arrive at a sustained, coherent approach as requested by Core-Climax.

Summary of reprocessing efforts for GOES, METEOSAT, and AVHRR, mostly AMVs

	CIMSS	EUMETSAT
Programmatic		
Current data holdings	GOES, SMS-1, -2, MODIS, KALPANA, POES AVHRR, COMS, GMS, METEOSAT-3 onwards, MTSAT, FY-2C/D/E	METEOSAT, METOP and POES AVHRR (starting with NOAA-18)
Already reprocessed	AMV from POES AVHRR (NOAA-7 to -18)	1) AMV and CSR from METEOSAT-2 to -7 up to end of 2000 2) AMV from AVHRR METOP-A up to

EU FP7 Coordination of Earth observation data validation for re-analysis (Core-Climax) Grant agreement no. 313085. Report of the coordination meeting on reprocessing of atmospheric motion vectors and ECMWF reanalyses -- Version 5 Sep 2013 consolidated by Paul Poli (ECMWF)

	CIMSS	EUMETSAT
		end of 2012 (using two algorithms, EUMETSAT operational and CIMSS)
Current production	GOES GVAR -8 to -15 (1995-present): AMV. Expected to be available by 2014. Includes processing of 30-minute images, 15-minute images, and 7-minute rapid scan images (producing possibly 1 wind product every 7 minutes, though limited to extreme weather situations)	AMV, CSR, ASR, THU, CTH, NDVI, CLM, Cloud type, cloud top pressure, cloud top temperature, from METEOSAT-8 and -9. Expected to be available by 2014
Funding for current production	SSEC grant	EU FP7 ERA-CLIM and EUMETSAT own resources
Committed reprocessing		1) AMV, CSR, ASR from Meteosat-7 for years 2001-2004 for zero degree, and for years from 2001 and up to real time for Indian Ocean Data Coverage. Expected to be available by 2014. 2) AMV from AVHRR POES and AVHRR METOP-A and -B reprocessed by 2015. 3) AMV, CSR, ASR from METEOSAT-2 to -9 based on inter-satellite calibrated IR radiances and updated algorithm. Expected to be available by 2016.
Funding for committed reprocessing		EU FP7 ERA-CLIM2 and EUMETSAT own resources
Considered reprocessing	POES AVHRR using updated code and input and more metadata in output MODIS from EOS-Aqua and Terra Repeat current GVAR reprocessing but with latest algorithm (NESDIS GOES-R tracking), and extend reprocessing to older GOES satellites, pre-GVAR.	After ERA-CLIM2 updated codes may arrive from SCOPE-CM and can be used for increasing the consistency of geostationary AMV products. Also planned Meteosat First Generation image reprocessing and inter-satellite calibration lead to new reprocessing of the same data
Of value, but unfunded	<ul style="list-style-type: none"> • KALPANA • GOES-1 to -7 (1978-1995) • SMS-1 and SMS-2 (1979-1981) • ATS (1974) 	<ul style="list-style-type: none"> • Routine METEOSAT-8 and -9 rapid scan images (since May 2008) at 5-minute intervals, producing possibly 1 wind product every 20 minutes, limited to 15N-70N • METEOSAT-8 and -9 high resolution visible channel images
Problems preventing reprocessing of earlier data	GOES-1 to -7 cannot be reprocessed until navigation and calibration have been corrected	<ul style="list-style-type: none"> • Current CCC algorithm cannot be applied to METEOSAT-2 to -7 on the current EUMETSAT

	CIMSS	EUMETSAT
	Upcoming (GOES-R) winds algorithm cannot be applied to reprocessing prior to GOES-8; requires development to cloud analysis	reprocessing system; requires development to cloud analysis product <ul style="list-style-type: none"> For Meteosat First Generation a reprocessing of the Image data including improvements in navigation and image resampling as well as anomaly detection is planned but the resources are tight and time of realisation is uncertain.
Input data preservation	All original tapes transferred to digital (online) at SSEC Data Centre	Funded and committed archive preservation (EUMETSAT Data Centre)
Input data backup (disaster recovery)	1) NOAA NCDC holds the official GOES archive 2) SSEC has additionally processed the original GOES archive and has rescued more data and produced data of higher quality than current NCDC holdings.	1) EUMETSAT Data Centre 2) Third copy back-up off-site
Reprocessing methods, including input and output interfaces		
Input sensor data	GVAR level 1b AVHRR POES level 1b and regridded	METEOSAT level 1.5 MVIRI and SEVIRI AVHRR METOP level 1b (and IASI METOP level 1c)
Input channels	AVHRR: IR 10.8 μm GOES: WV 6.7 μm , IR 10.7 μm , SWIR 3.9 μm , and VIS 0.63 μm	AVHRR: IR 10.8 μm METEOSAT-8 and -9: IR 10.8 μm , WV 6.2 and 7.3 μm , VIS 0.8 μm Note: VIS 0.6 μm not used for AMV METEOSAT-2 to -7: IR [10.5-12.5 μm], WV [5.7-7.1 μm], VIS [0.5-0.9 μm]
Input background	<u>GOES:</u> ERA-Interim reanalysis <u>analyses</u> Pressure levels 1x1 degree ² grid 6-hourly <u>AVHRR:</u> NCEP/NCAR reanalysis <u>analyses</u> Pressure levels 1x1 degree ² grid 6-hourly	ERA-Interim 6-hourly <u>forecasts</u> (+6h and +12h steps) 60 model levels for AVHRR, 31 model levels for METEOSAT-8 and -9, 16 model levels for METEOSAT-2 to -7 0.5x0.5 degree ² grid for AVHRR, 1x1 degree ² grid for METEOSAT-8 and -9, 1.5x1.5 degree ² grid for METEOSAT-2 to -7 6-hourly
Background time interpolation	Linear in time	
Background used for	<ul style="list-style-type: none"> Height assignment for AVHRR and GOES First-guess to tracking 	<ul style="list-style-type: none"> Height assignment for AVHRR and METEOSAT (no best fit applied, EBBT only)

	CIMSS	EUMETSAT
	solution for AVHRR and GOES <ul style="list-style-type: none"> Quality control for GOES and AVHRR in recursive filter editing system 	<ul style="list-style-type: none"> First-guess to tracking solution for AVHRR
Tracking	Compute 2 vectors from 3 consecutive images, spaced by 30 minutes for GOES and 100 minutes for AVHRR, using first-guess tracking solution from background, and then average the two individual vectors to produce final solution Lp norm for GOES Cross-correlation for AVHRR	<u>METEOSAT:</u> Compute 3 vectors from 4 consecutive images, spaced by 30 minutes for METEOSAT-2 to -7, and 15 minutes for METEOSAT-8 and -9 <u>AVHRR:</u> Compute 1 vector from 2 consecutive images spaced by 100 minutes, using first-guess tracking solution from background
Height assignment	<u>GOES:</u> EBBT for VIS, IR, and WV H2O-intercept for IR and cloudy WV, only upper levels CO2-slicing for IR and cloudy WV, only upper levels Cloud base for VIS and IR, only low levels Height assignment based on the above (decision tree) <u>POES AVHRR:</u> Same as above, but no H2O-intercept and CO2-slicing	<u>METEOSAT:</u> EBBT for VIS, IR, and WV and H2O-intercept for IR and WV from METEOSAT-2 to -7, Cloud analysis product's output for METEOSAT-8 and -9 (CCC method) Final assignment for METEOSAT based on 3 intermediate products (average) <u>METOP AVHRR:</u> EBBT (and IASI)
Height assignment future method	1DVAR for GOES and AVHRR	Optimal estimation using the OCA output for METEOSAT-8 and -9
Post-processing	Height reassignment using auto-editor in some cases	Height reassignment using IASI when available, for AVHRR
Quality indicator	EUMETSAT quality indicators (QIs), with and without background (forecast) check RFF quality indicator using height reassignment and potential speed bias adjustment	EUMETSAT quality indicators (QIs), with and without background (forecast) check
Quality control (yes/no)	QI has to exceed 60 Visual inspection of time-series of validation metrics w.r.t RAOB	QI has to exceed 30
Native output format	McIDAS MD format (binary)	METEOSAT-native EPS format for AVHRR
Delivery format	Text (space-separated)	BUFR
Processing system: input data acquisition	Satellite data online	Satellite data retrieved from EUMETSAT Data Centre
Processing system: hardware	Linux cluster, can run ~50 simultaneous streams	Legacy RMPEF (32-bit SUN environment) for METEOSAT

	CIMSS	EUMETSAT
		R-EPS (IBM AIX Power6) for AVHRR Can run 3 simultaneous streams for METEOSAT, and 24 for AVHRR
Hardware resource	In-kind contribution from SSEC	Funded by EUMETSAT
Processing system: main software	For GOES, NOAA/NESDIS operational For AVHRR, CIMSS code	EUMETSAT operational ground segment software, adapted for reprocessing purposes
Reprocessing speed	3900 days/day for AVHRR (using regrided input) Estimated 440 days/day for GOES	50 days/day for AVHRR (including radiance mapping) 9 days/day for METEOSAT
Geographical coverage	AVHRR: latitudes 65 degrees and above GOES: depends on schedule, but usually bounded by: GOES-E: 45S-60N, 30W-112W, GOES-W: 45S-60N, 180W-101W	AVHRR: latitudes above 55 degrees (possibly extend down to 50 degrees) METEOSAT: full circle, up to 65 degrees satellite viewing angle 1 satellite at 0E Since July 1998, 1 satellite at 57E (METEOSAT-5 and then -7)
Temporal resolution	Hourly for GOES Approx. 100 minutes for AVHRR	Hourly for METEOSAT Approx. 100 minutes for AVHRR
Document reference	UW-CIMSS Satellite-Derived Wind Algorithm USER'S GUIDE Prepared by Timothy L. Olander	EUMETSAT Product Navigator MSG MPEF guide AVHRR AMV Generation Specification
Expert knowledge	Software in repository, and user guide	
Validation and uncertainties estimation		
Comparison or validation efforts carried out at reprocessing center	RAOB winds	1) RAOBCORE winds from University of Vienna (L. Haimberger) 2) Algorithm intercomparison for AVHRR
Feedback received	In the form of irregular, unsolicited reports sent by users of AMV reprocessed products	
Desirable feedback process	1. Evaluation by users at early stage of reprocessing within a short time (~month) 2. After reprocessing, report about findings (e.g., strengths, deficiencies, metadata content) from reprocessed dataset, and usefulness of observation (e.g. observation impact), e.g., within a year 3. Quantitative feedback information at the observation level 4. For reanalyses, time-series/maps monitoring during production as routinely done for NWP, separated by reprocessing data provider	
Inter-comparison exercises	1. In 2008, algorithms applied to METEOSAT-8, under IWWG guidance, by CIMSS/NESDIS, EUMETSAT, JMA, KMA, Brazil, documented under https://groups.ssec.wisc.edu/groups/iwwg/activities/amv-intercomparison-studies/amv-intercomparison-study 2. Ongoing (2013), algorithms applied to METEOSAT-9, under IWWG guidance, by CIMSS/NESDIS, EUMETSAT, JMA, KMA, Brazil, CMA, EUMETSAT NWC-SAF 3. Ongoing (2013), algorithms applied to AVHRR METOP-A, by CIMSS and EUMETSAT	

Issues regarding global AMV reprocessing

From the table above and discussions carried out at the meeting between CIMSS, EUMETSAT, and ECMWF representatives, a list of issues was identified regarding global AMV reprocessing. It is hoped that the upcoming SCOPE-CM project on AMV/CSR/ASR historical reprocessing will improve on several of these points, but since this project has not taken shape yet, these issues are listed below, so they can be taken into account inasmuch as possible as the said project plan is being formulated:

1. Incomplete knowledge of reprocessed AMV data holdings between organizations,
2. Differences between AMV reprocessing and real-time processing, because of general inapplicability of latest algorithms (intended for real-time) to reprocessing, without dedicated research and development efforts or enforced requirement for climate research support,
3. Differences between AMV reprocessing techniques applied to similar datasets by different reprocessing centers,
4. Insufficient or untimely feedback of information from users of AMV reprocessed products to reprocessing centres,
5. Unclear expression of requirements from users of AMV reprocessed products in the reanalysis community to data reprocessing centers,
6. Insufficient expression of requirements for background or ancillary data (sometimes in the form of reanalysis fields) from reprocessing data providers,
7. Insufficient coordination of the timing of reprocessing and reanalysis activities, leading sometimes to late exploitation of the data,
8. No global, comprehensive view and coordination of current reprocessing efforts and opportunities,
9. Non-systematic application of the maturity matrix concept to all reprocessing activities (e.g. Bates, J. J. and J. L. Privette, 2012: A maturity model for assessing the completeness of climate data records, Eos Trans. AGU, 93(44), 441),
10. Similar to other satellite environmental records, risks of loss of expertise on historical data, including also media support (cases of loss of original data reported during the meeting, e.g. the first geostationary satellites, though this loss occurred a long time ago), software knowledge, and essential understanding of the satellite instrument.

Implications for global AMV reprocessing efforts

From the above, actions to be undertaken include the following. In parentheses and in bold are indicated who may be assigned those tasks:

1. To draft a simple, but cross-agency, complete, global inventory of existing, and yet to be done, reprocessed data holdings **(to be suggested as a task in SCOPE-CM project on AMV/CSR/ASR reprocessing)**
2. To add a requirement for long missions to commit to funding an interim delayed-mode climate-quality stream and to commit to funding reprocessing at regular intervals with current/near-real-time algorithms **(issue to be escalated by IWWG to CGMS for a future recommendation to its satellite member agencies),**
3. To conduct inter-comparison exercises between reprocessing centers, and promote information exchanges between them **(information to be communicated to WCRP Data Advisory Council)**
4. To facilitate the feedback dialogue between reprocessing data providers and users of reprocessed products, in the form of:
 - reprocessing data evaluation reports, to be issued by users,
 - dedicated sessions about reprocessing, in existing conference cycles, such as reanalysis conferences and community-specific workshops (e.g. IWWG),
 - readily accessible quantitative evaluation monitoring solutions,
 - open and user-friendly access to observation feedback archive at reanalysis centres,
 - participation of all relevant reprocessing centres and reanalysis centres in SCOPE-CM project on AMV/CSR/ASR reprocessing.**(IWWG to regularly collect information on reprocessing and communicate on it at its meetings, global reanalysis centers to open up their observation feedback archive)**
5. To promote a forum to collect reprocessing activities, plans, opportunities, needs, and capabilities, and align them with reanalysis needs and plans, to supplement existing forums under the umbrella of coordinating WMO bodies and endorsed groups: Joint CGMS/CEOS Working Group Climate, CGMS WGs, SCOPE-CM, WCRP-Data Advisory Council **(this missing infrastructure component of a global climate system could be funded by a large regional Climate Service, e.g. European Climate Services),**
6. To define and track the maturity of the reprocessing technology and algorithms **(suggested as a task in the upcoming SCOPE-CM project on AMV/CSR/ASR reprocessing),**
7. To identify reprocessing activities at risk, because of non-resourced data preservation or reprocessing activity, or foreseen loss of expert knowledge with the retirement, in the coming years, of the principal investigators of the first satellite instruments **(suggested as a task to be managed by WCRP Data Advisory Council).**

Annex I: Meeting agenda

Tuesday 9 July 2013, 13.30-17.30: Reprocessing of geostationary satellite data records, 1/2

- Welcome address (ECMWF)
- Scope of the meeting and adoption of agenda (ECMWF)
- Current AMV and radiance datasets holdings at ECMWF (ECMWF)
- Plans for reprocessing GOES data records, with schedules, committed and future, for AMV and radiance (CIMSS)
- Plans for reprocessing Meteosat data records, with schedules, committed and future, for AMV and radiance (EUMETSAT)
- GOES and Meteosat reprocessing issues, with a view to discuss possible convergence between approaches: background information, quality control metrics, height assignment, template image size, number and frequency of consecutive images, ... (CIMSS and EUMETSAT)
- Expected coverage from each dataset (CIMSS, EUMETSAT)

Wednesday 10 July 2013, 9.00-12.00: Reprocessing of geostationary satellite data records, 2/2

- Provision of ancillary input data to reprocessing from ERA-Interim (ECMWF, CIMSS, EUMETSAT)
- Plans for using reprocessed GOES and Meteosat AMV in upcoming reanalyses: ERA-SAT and CERA-SAT (ECMWF)
- Data formats (ECMWF, CIMSS, EUMETSAT)
- ECMWF observation feedback archive: current status, and intended applications serving reanalysis needs and data providers to assess climate datasets quality in reanalysis environment (ECMWF)

Wednesday 10 July 2013, 13.30-17.30: Reprocessing of polar-orbiting AVHRR satellite data records

- Experience with AVHRR AMV at ECMWF (ECMWF)
- Plans for reprocessing NOAA AVHRR data records, with schedules, committed and future (CIMSS)
- Plans for reprocessing MetOp AVHRR data records, with schedules, committed and future (EUMETSAT)
- AVHRR reprocessing issues: quality control metrics, height assignment, number of consecutive overpasses, a priori input ... (CIMSS and EUMETSAT)
- Expected coverage from each dataset (CIMSS, EUMETSAT)
- Provision of ancillary input data to reprocessing from ERA-Interim (ECMWF, CIMSS, EUMETSAT)
- Plans for using reprocessed AVHRR AMV in upcoming reanalyses: ERA-SAT and CERA-SAT (ECMWF)
- Data formats (ECMWF, CIMSS, EUMETSAT)

Thursday 11 July 2013, 9.00 - 12.00: Report drafting. Secretariat is to be provided by ECMWF.