MEETING

Meeting Date	20-21 April 2015	**Reference**	ESA-EOPG-LTDP-MIN-0001
Meeting Place	German Remote Sensing Data Center (DLR-DFD)	**Chairperson(s)**	B. Bojkov (ESA), T. Christiensen (DLR-DFD)
Minute's Date	21 July 2015 (draft) 25 September 2015 (final)	**Participants**	*See appendix A*
Subject	AVHRR 1-km (LAC) Expert Meeting	**Copy**	

Minutes of the AVHRR 1-km (LAC) Expert Meeting

The AVHRR 1-km (LAC) Expert Meeting was hosted by the German Remote Sensing Data Center (DLR-DFD) at DLR-Oberpfaffenhoffen, Germany on 20-21 September 2015. Twenty-two experts from Europe and the United States with in-depth knowledge about the AVHRR sensor family, calibration, the retrieval of ECVs, and user communities, participated in the meeting organized by ESA/ESRIN and DLR-DFD. The list of participants is given in Annex A and the final agenda in Appendix B.

Day 1: 20 April 2015

Ms. Tyler Christensen (DLR-DFD, Germany), the local host, gave an overview of the logistics and there was a round table of introductions.

Dr. Bojan Bojkov (ESA/ESRIN, Italy) gave an overview of the objectives of the meeting from ESA's perspective. The outcome of this meeting could form a "pre-" Data Innovation and Science Cluster (DISC, as described in the ESA EO Innovation Europe strategy paper) for AVHRR to demonstrate its feasibility.

Dr. Corinne Frey (DLR-DFD, Germany) presented the TIMELINE project. It only processes 1-km LAC (not GAC) and only DLR data is included with no consolidation of multiple (external) datasets. The processing software used for the L1b generation is based on TerraScan's SeaSpace package and extends the software with additional packages for precise navigation, orthorectification, and quality assessment. For the base L1b product it includes reflectance, brightness temperatures and albedo, in orbit projection, with sensor-harmonization factors available but not applied. The output format is NetCDF CF. Further, water, snow and ice masks will be available. The Atmospheric Correction is provided by TAC Timeline Atmospheric Correction of Brockmann Consult GmbH (unpublished).

Mr. Mirko Albani (ESA/ESRIN, Italy) presented the ESA AVHRR Data Holdings and Ongoing Curation Activities. 3 main stations Maspalomas, Tromsoe, Matera are available plus others will be assessed. Note that **Mr. Albani's** presentation describes the complete holdings know at the time of the meeting.

Dr. Stefan Wunderle (Uni. Bern, Switzerland) presented the University of Bern's 1km archive and its challenges and experiences with calibration, geocoding (incl. ortho-rectification) and retrieval of ECVs (albedo, snow, aerosol optical depth, etc.). The university has been running AVHRR reception 24/7 since 2000 with European coverage for all NOAA's in orbit (e.g. 15, .189) as well as EUMETSATsMetop-1 and -2. The archive contains data since 1984 from own reception and University of Berlin, NOAA-CLASS archive, and DLR, respectively, however, the archive is not built for the long term and maintenance is costly. Climate users for ECV production are key for the future.

Dr. Andrew Heidinger (NOAA/STAR, United States) presented the PATMOS-X experiences in the recalibration of the AVHRR GAC timeseries. It was noted that GAC calibration is the same as for the the LAC. The project covers all sensors, not just some of the NOAA satellites and is linked to MODIS calibration. The calibration activity is based on vicarious calibration sites recommended by CEOS and they added their own sites (all viewed by MODIS and AVHRR). The geolocation correction in PATMOS-X was developed by Fred W. Nagle (1998). Regarding the challenges, there will be a need for an updated calibration method when the MODIS instruments are decommissioned but the CEOS targets will remain the basis to monitor degradation of AVHRR channels in VIS and NIR. Also there are poor AVHRR early years coverage i.e. poor early data calibration and the project could maybe use HRPT LAC data to help fill this gap. The current version of PATMOS-X is C6 and the calibration coefficients are openly available and regularly updated at https://cimss.ssec.wisc.edu/patmosx/documentation.html#references). There will be annual updates available for next 3 years via a contract with US NCDC. There are no plans to go backwards in calibration and future updates will not re-do the baseline, except possibly adding additional calibration targets. It was noted that there is a NOAA LAC archive over Europe, which contains 200 LAC orbits per month.

Dr. Martin Bachmann (DLR-DFD, Germany) presented the DLR approach to AVHRR calibration and geometric corrections. The approach is in line with NOAA and takes also into account the spectral variances between sensors. The radiometric harmonization is based on TerraScan, with calibration from NOAA-OSPO (http://www.ospo.noaa.gov/Products/ppp/notices.html), the following spectral harmonization is based on M.D. Steven *et al.* (2003). As such, the full processing of L0 data uses the NOAA procedures and additional analyses based on the standard CEOS vicarious calibration sites (i.e. Libya 4, Algeria 3, and others).

Dr. Karl-Göran Karlsson (SMHI, Sweden) presented the progress in level 1 work (calibration + navigation AVHHR LAC/GAC) at the Swedish Meteorological and Hydrological Institute. Challenges addressed specifically include Northern-European and Arctic coverage, QC, Calibration and precise navigation. During the Q&A, it was agreed to recommend netCDF, preferably with CF metadata, as the output/distribution data format.

Recommendation 1: AVHRR output/distribution data should be in the netCDF 4 CF format. *Note: AVHRR raw data should be kept in level 1a (or even HRPT, HMF) and only products or AVHRR data after pre-processing including calibration and geocoding, cloud masking etc. should be in netCDF.*

Dr. Jonathan Mittaz (U. reading and NPL, United Kingdom) gave an overview of the AVHRR GAC/LAC Calibration challenges for SST, with a main focus was on Thermal IR. Challenges included: a) poor reference measurements (i.e. prior to the ESA (A)ATSR-series) is available before 1991; and b) early archives have no/little overlap and the calibration transfer from one satellite to the next where no overlap is available. SST is considered a good L2 product (validated against drifting buoy network) and is very sensitive to calibration issues that can be very useful for QC. The work is carried out under the Fidelity and uncertainty in climate data records from Earth Observations - FIDUCEO project (http://www.fiduceo.eu), which aims to create new earth observation datasets which carefully quantify errors and uncertainties.

Mr. Gerhard Gesell (DLR-DFD, Germany) presented the APOLLO Cloud properties algorithm, including the numerous challenges and requirements addressed over 28 years of experience at DLR. Mr. Gesell also gave an overview of the APOLLO evolution, called APOLLO_NG, covering probabilistic cloud detection.

Dr. Karlsson, in his second presentation, gave an overview of the challenges with AVHRR retrievals at high latitudes. Challenges include polar winter conditions, uncertainties, new sensors and better data homogeneity. It was recommended for the future further collaboration and work on uncertainty estimates.

Recommendation 2: Targeted uncertainty estimates for AVHRR should be undertaken.

Dr. Wunderle, in his second presentation, presented his group's work on Snow Extent (SE; binary product with uncertainty measures) and Lake Surface Water Temperature (LSWT) retrievals from AVHRR for a time series from 1989 - 2014. Challenges include a dataset that is calibrated, precise geocoded with good cloud retrieval (including probabilities). The most important recommendation from **Dr. Wunderle** was the need for space agencies to extend the length of the archive, especially the period 1981-1989, and fill in the weekly gaps, so as to directly meet climate research and policy needs.

Recommendation 3: Space Agencies to fill AVHRR 1-km dataset gaps, especially for the period 1981-1989.

Professor Katarzyna Dabrowska-Zielinska (IGIK, Poland) presented her group's AVHRR experiences with land property retrievals in Poland. It was confirmed that there are many uses and applications for AVHRR data in Poland, including crop yield predictions calculated in June which forms a vegetation condition index. For national parks IGIK combines AVHRR with other parameters to derive soil moisture, NDVI, etc. For grasslands they use vegetation indices based on temperature, snow coverage, low temperature and these factors influence grassland yields. For agriculture fields, which are accurate to within a pixel, research has been done on which crops influence the satellite value and this is combined with detailed in situ data on crop covers in each field. Insurance companies want to know about crop freezing and are interested in snow cover / low temperatures, giving an overview of crop damage in the late Winter and Spring and how it influences crop growth development. Regarding ground measurements of LAI these are then compared to satellite measurements for validation. During the Q/A, there was a discussion on ground measurements of land temperature and how this can help show the degradation of satellite sensors—e.g. due to time shift of the satellite.

Dr. Oleg Dubovik (Uni. Lille, France) presented the Generalized Retrieval of Aerosol & Surface Properties (GRASP) and its future applicability to AVHRR 1-km datasets. The algorithm constrains variability in space and/or time to separate the aerosol effects (high temporal, low spatial variability) from the surface effects (high spatial, low temporal variability). The input data needs to be well-calibrated and internally consistent. Aerosol could be used to check for disagreements and instead of waiting for calibrated data, the internal consistency could be used as a constraint for the aerosol calculation. It is a physical way of calibration and could be used to improve the overall consistency. It was noted that ESA (as presented by **Mr. Albani** earlier) has three-years of 1-km data for Australia, Africa for the early 1990's that are unique data and might be interesting for this effort. There was a discussion on how to overcome the problem of retrieving aerosol over bright surfaces when you have only one channel as high reflectance from desert / snow, may overwhelm the aerosol signal and can be missed. **Dr. Dubovik** clarified that the surface brightness does not change much, so temporal variation from day-to-day is probably due to aerosol. Any horizontal variation that does not change much over time is probably due to a bright surface (i.e. if there is no contrast at all, of course, there is nothing you can do).

Ms. Katrin Molch (DLR-DFD) led the open discussion on coherent European AVHRR 1-km Dataset:

Regarding temporal coverage it was agreed that it was application specific such as for example if a user is interested in a time series the temporal coverage should be as long as possible to guarantee a statistical sound procedure to detect changes, or a product may have a daily, weekly or monthly resolution but it should be without gaps. Climate scientists, especially modellers, do not like gaps in their model inputs. Early 1980's data is very interesting.

On spatial coverage, again from an application point of view, a global dataset was preferred, perhaps with a reduced temporal coverage. GAC may well be a solution here.

The priorities for the project must be agreed, including the processing level and data sharing policy. It was agreed that common processors should be adopted.

NetCDF 4 CF was reaffirmed as the preferred output/distribution format, but as with the temporal requirement, this is application/user community specific.

Data distribution policy or conditions of use should be considered. This initiative is potentially unique to other programmes. It was agreed to cross compare the PATMOS-X calibration factors and approach with other models. – cross group experience on calibration would be welcomed. Note that the calibration of the IR channels requires an alternative approach as PATMOS-X does not cover these.

Recommendation 4: PATMOS-X calibration factors should be considered for the visible and near infrared channels.

Day 2: 21 April 2015

Dr. Bojkov introduced the day and underlined that many activities are on-going and it was important to focus on what needs to be done to make good data available to the different user communities.

Dr. Lothar Schüller (EUMETSAT, Germany) presented the AVHRR needs for the EUMETSAT Satellite Application Facilities (SAFs). AVHRR is used in 6 out of 8 SAFs. For the CM-SAF it has AVHRR products from 2004 (cloud parameters, radiation budget (TOA, GRD), atmospheric humidity, creating thematic climate data records. The Hydrology-SAF covers precipitation, soil moisture, snow for use in models. LSA (land surface analysis) covers surface radiation, vegetation and fire. The Nowcasting SAF incorporates software generation and both GEO and EPS satellites. The OSI-SAF (Ocean and Sea Ice) covers sea ice (extent, concentration). The Ozone SAF has a focus: on GOME and uses AVHRR LAC for cloud detection and has a 2007-2012+ timeframe for continuous reprocessed data records. The SAFs are currently in the CDOP-2 phase (2012-2017) and are planning for the CDOP-3 (2017-22) is in progress. CDOP-4 and CDOP-5 foreseen in EPS 2nd generation. EUMETSAT has an AVHRR archive since 2006 starting with NOAA-15 from European Stations, with full coverage of Europe and northern Atlantic. There is a possibly to make available L1c GAC data methodology as contribution and feeds into FIDUCEO (H2020) project as an assessment and to help generate an improved AVHRR FCDR. It was stressed by Dr. Schüller that to ensure consistency in all of these reprocessing efforts, they have a dedicated reprocessing / data record coordination group, to ensure consistency and avoid duplication across 700 different SAF products.

Ms. Christensen presented the results from the recent LTDP AVHRR user needs survey. It was concluded that there is a need for a complete, consistent, central and well calibrated, well documented, time series in NetCDF and CF compliant. Validation was not specifically mentioned by the users but quality flags were specifically asked for, so clearly a consideration. Data preservation for longer than the standard DOI requirement of 10 years was a goal. During the Q&A, **Dr. Bojkov** stressed that we need to understand what the current data holding actually is before we could commit to regular reprocessing and additions to a "master" dataset with newly acquired data. It was questioned if the raw HRPT format should be processed (or not) into NetCDF.

Recommendation 5: Original-format HRPT data resources should be archived when available, but data processed to a consistent L1a or L1b in NetCDF CF format would be delivered to users.

Breakout sessions:

The logistics and end goals for the breakout groups was discussed and agreed. Each group was required to return with 5 prioritised bullets.

Mr. Albani presented the conclusions from the **data consolidation group.** The need of an AVHRR archive for climate users and other stakeholders was stressed during the expert meeting. Some requirements for an archive were determined: accessible for any interested user, free of charge, homogenous (temporal and spatial), and all data shall be stored in one common format. University of Bern has an archive which fulfills almost all the requirements but some data are missing especially in the time frame from 1981 – 1989. **Dr. Wunderle** proposed the following solution: ESA is asked to fill the above mentioned gap with own AVHRR data or from external sources (e.g. Dundee) and deliver the data set to University of Bern. All delivered data will be

checked (readability) and if needed reformatted before they are included in the archive of University of Bern. After harmonization of the archive all AVHRR data stored at University of Bern will be transferred to ESA to make them accessible for all interested users. Furthermore, University of Bern operates an own receiving station for AVHRR data (NOAA and MetOp) and can offer to deliver AVHRR data to ESA until the life time of the sensor (expected 2022). Finally, ESA will host an AVHRR archive covering a climate period from 1981 – 2022 which will be of great interest for science, climate modelers and any other stakeholders.

Recommendation 6: The objective is for ESA and the University of Bern to establish a consistent, 1981-present, L1a dataset out as soon as possible with an initial release by November 2015 and a final release by May 2016. *Note the discoverability and accessibility will be addressed afterwards.*

Recommendation 7: Dr. Wunderle (Uni. Bern) and Dr. Heidinger (NOAA/STAR) to devise initial L1a procedure.

From this 'validated' L1a a L1b can be generated as a FDR. The L0 to L1a process as well as the L1a to L1b processing needs to be documented very clearly. This data set could be a dedicated copy of the data that the individual data holders have, with contributions from different users. It is still to be agreed if the L0 data would be kept & processed to L1a locally or whether the central archive can host L0. It was agreed that the end data set would be free and open. It was agreed that stitching of data was generally not favoured as traceability was lost. There was an informal action placed on **Mr. Albani (ESA)** to discuss with University of Dundee the access to their Level 0 data.

Dr. Heidinger (NOAA/STAR) presented the calibration team recommendations. It was agreed that ortho-rectification was indeed a separate step to the initial geo-location. The method used at the University of Bern seems most appropriate; other geo-location methods are available e.g. TIMELINE (DLR), ANA (SMHI). Ideally there will be a round robin to assess the best algorithm. It will then be possible to process the same data set using different techniques, compare results and see which one performs best.

Recommendation 8: Perform a round-robin for the ortho-rectification/geolocation approach for AVHRR 1-km.

For thermal calibration, the FIDUCEO approach seems most appropriate. The calibration coefficients from FIDUCEO should be available by December 2015 and can be applied to L1a. Improved QC is necessary. The group should participate in existing international cooperation efforts, e.g. CEOS WGCV, solar calibration. A workshop on solar calibration is planned by the CEOS WGCV. GAC calibrations should be fully applicable to LAC, and the LAC could even add a double-check at higher resolution for the European CEOS sites. European calibration techniques exclude many standard techniques, because they require e.g. ice sheets. However, it should be able to be done using the European CEOS-instrumented sites. This is the approach that TIMELINE will use. It was agreed that any inter-calibrated and processed dataset would only stay state-of-the-art for about 5 years. If we want to stay relevant, the processing would have to be re-done with new and improved techniques.

Recommendation 9: Use the FIDUCEO AVHRR GAC thermal channel calibration coefficients for the LAC datasets.

Dr. Fabrizio Nero (ESA/ESRIN, Italy) presented the AVHRR L2 products group discussion. SST, AOT (Aerosol Optical Thickness) and Surface Albedo should initially be considered and possibly add COT (Cloud Optical Thickness) and LST later. It is important to include a cloud mask, e.g. based on CEOS best practices. The GlobTemperature project is investigating cloud retrieval and there is also a two-year CEOS WGCV activity starting, so maybe we could be part of those existing efforts. It was agreed it becomes an FCDR when the climate community finds it useful. It was also agreed to provide uncertainties with the data so people can assess the data quality, and its applicability as an FCDR. How the FCDR is certified / published was discussed.

Recommendation 10: Initial L2 products to consider are Sea Surface temperature (SST), Aerosol Optical Depth (AOD), Surface Albedo, Cloud Optical Depth (COD), and an effective cloud mask.

Next steps and concluding remarks:

- Minutes of this meeting will be circulated for review.
- It was agreed that any future AVHRR 1-km activity should be a compact and targeted activity, at least initially, instead of involved project.
- The consolidation can be a separate activity, providing a complete L1a product. In the meantime, the calibration approach can be pursued.
- There may be a possibility for an ESA ITT by late Summer to address some of the issues raised during this meeting.
- It is essential to connect to other AVHRR activities outside this expert / user group and be in synchronisation with other existing research and data processing efforts and undertake the project as a group effort with openness and transparency.

The organisers thanked everyone for their participation and encouraged everyone to continue to further communicate and collaborate.

Appendix A: List of Attendees

Name	Affiliation, Country
Mr. Mirko Albani	ESA/ESRIN, Italy
Mr. Michael Aspetsberger	Catalysts GmbH, Austria
Dr. Martin Bachmann	DLR, Germany
Dr. Gabi Bippus	Enveo GmbH, Austria
Dr. Bojan Bojkov	ESA/ESRIN, Italy
Ms. Tyler Christensen	DLR, Germany
Prof. Katarzyna Dabrowska-Zielinska	IGIK, Poland
Dr. Oleg Dubovik	University of Lille 1, France
Mr. Sergio Folco	ESA/ESRIN, Italy
Dr. Corrine Frey	DLR, Germany
Mr. Gerhard Gesell	DLR, Germany
Dr.Andrew Heidinger	NOAA/STAR, United States
Dr. Karl-Göran Karlsson	SMHI, Sweden
Dr. Steve Mackin	EOSense, United Kingdom
Dr. Jonathan Mittaz	University of Reading and National Physical Laboratory, United Kingdom
Ms. Katrin Molch	DLR, germany
Dr. Fabrizo Niro	ESA/ESRIN, Italy
Dr. Rene Preusker	Free University of Berlin, Germany
Dr. Lothar Schüller	EUMETSAT, Germany
Mr. John Swinton	Telespazio Vega, United Kingdom
Dr. Andy Walther	University of Wisconsin-Madison, United States
Prof. Stefan Wunderle	University of Bern, Switzerland

Appendix B: Final Agenda

Monday 20 April 2015

13:00-13:10	Welcome/logistics	T. Christensen (DLR)
13:10-13:25	Purpose and objectives	B. Bojkov (ESA)
	Data consolidation	
13:25-13:45	Overview of the DLR TIMELINE project	C. Frey (DLR)
13:45-14:00	Overview of the ESA 1km consolidation Activity at ESA	M. Albani and S. Folco (ESA)
14:00-14:15	The 1km archive at the University of Bern: experiences and challenges	S. Wunderle (U. Bern)
	Break	
	(inter-)Calibration and geometric corrections	
14:25-14:50	PATMOS-X expericences in the recalibration of the AVHRR series	A. Heidinger (NOAA)
14:50-15:05	The DLR approach to AVHRR calibration and geometric corrections	M. Bachmann (DLR)
15:05-15:20	The SMHI approach to AVHRR calibration and geometric corrections	K.-G. Karlsson (SMHI)
15:20-15:35	AVHRR GAC/LAC calibration challenges for SST	J. Mittaz (U. Reading/NPL)
	Break	
	Experiences with AVHRR 1-km data	
15:45-16:00	APOLLO cloud properties - challenges and requirements	G. Gesell (DLR) K.-G. Karlsson (SMHI) / Ø. Godøy (NMI)
16:00-16:15	Challenges with AVHRR retrieval at high-latitudes	S. Wunderle (U. Bern)
16:15-16:30	Snow and lake retrievals with AVHRR	K. Dabrowska-Zielinska (IGIK)
16:30-16:45	AVHRR experiences with land property retrievals in Poland	O. Dubovik (U. Lille 1)
16:45-17:00	GRASP retrieval potential	K. Molch (DLR)
17:00-18:00	*Discussion*	
~18:00	End of Day 1 followed by dinner at Kloster Andechs	

Tuesday 21 April 2015

8:30-8:40	Recap of Day 1	B. Bojkov (ESA)
	User needs	
8:40-9:00	AVHRR needs for the EUMETSAT SAFs	L. Schüller (EUMETSAT)
9:00-9:20	AVHRR user needs survey	T. Christensen (DLR)
	Breakout sessions	
9:20-9:30	Breakout sessions objectives	T. Christensen (DLR)
9:30-10:30	3 breakout sessions: consolidation, calibration, products	

	Break	
10:45-12:00	3 breakout sessions: consolidation, calibration, products	
	Lunch	
13:00-14:00	Breakout session reporting and recommendations	
	Consolidation	M. Albani (ESA)
	Calibration	A. Heidinger (NOAA)
	Products	F. Niro (ESA)
14:00-15:30	Discussion, conclusions, and way forward	B. Bojkov (ESA)
~15:30	End: Day 2	