SCOPE • CM

Sustained and Coordinated Processing of Environmental Satellite data for Climate Monitoring

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Letter of Intent for SCOPE-CM Phase 2

1. Project title

Inter-calibration of imager **o**bservations from time-series of **geo**stationary satellites (IOGEO)

2. Main applicant

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3. Composition of the project team for this project

EUMETSAT (Darmstadt, Germany)	Rob Roebeling, Tim Hewison
EUMETSAT CM SAF, Deutscher Wetterdienst (DWD)	Marc Schröder
JMA (Tokyo, Japan)	Masaya Takahashi
NOAA's NCDC (Asheville, NC, US)	Kenneth Knapp, Anand Inamdar
NOAA STAR	tbc by Kenneth Knapp

4. Satellite Climate Data Records capabilities

a. Objectives and proposed product

The major objective of this SCOPE-CM project is the generation of a Fundamental Climate Data Record (FCDR) of calibrated and quality-controlled geostationary sensor data. The FCDR will contain the visible, IR window and water vapour absorption channels of geostationary satellites. It is proposed to utilise the inter-satellite methodology developed by GSICS to tie existing time series of satellite data to the best reference available in space. For the thermal infrared spectral range data from the Infrared Atmospheric Sounder Interferometer (IASI), the Atmospheric Infrared Sounder (AIRS) and the High Resolution Infrared Sounder (HIRS) will be used to reference and to link the geostationary IR observations in a traceable approach. In the visible spectral range several techniques developed by GSICS will be tested on their value for the creation of a CDR. The resulting FCDR will be designed to allow the generation of homogeneous geophysical products, either through direct retrieval or data assimilation into reanalysis, that are accurate and stable enough for climate monitoring. The output of this project can be of immediate use for other SCOPE-CM projects, such as those on surface albedo derived from geostationary satellites. The proposed project also offers a feedback mechanism to the applicability of GSICS methodologies for the creation of CDRs.

b. Satellite sensor record

The time series cover, depending on the geostationary satellite concerned, a period of about 30 years, which is roughly the period 1982 – date. The coverage of the water vapour channel is shorter and basically starts in the mid 1990s, with the exception of Meteosat that starts in 1982. The generation of the FCDRs is currently restricted to the visible, infrared and water vapour channels that the geostationary satellites operated by the participating space agencies shared over the entire time-series. The level-1 records of digital counts are archived at the three space agencies participating in this activity, i.e., The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the Japan Meteorological Agency (JMA), and the National Oceanic and Atmospheric Administration (NOAA). The satellites operated by these space agencies are: the Meteosat satellites from EUMETSAT, the Geostationary Meteorological Satellites (GMS) and Multi-Functional Transport Satellite (MTSAT) from JMA, and the Geostationary Orbiting Environmental Satellites (GOES) from NOAA. The generation of the FCDRs derived from level-1 digital counts and/or radiances is the responsibility of each participating space agency. These agencies will perform their processing employing an agreed recalibration approach, and apply it to level-1 native resolution observations of their respective instruments. It is planned to contact further agencies operating geostationary satellites to join this project. Candidates are SCOPE-CM member CMA, as well as INPE and KMA. The mail applicant of this SCOPE-CM project will establish contacts with these agencies, inform them about the project objectives, and invite them to contribute to the project.

5. Justification of the proposed project

a. Historical overview of related activities

The work proposed in this SCOPE-CM project largely relies on the calibration strategies developed within GSICS. GSICS is an international collaborative effort initiated in 2005 by WMO and the CGMS, that has committed to monitor, improve and harmonize the quality of observations from operational weather and environmental satellites of the Global Observing System (GOS). GSICS aims at ensuring consistent accuracy among space-based observations worldwide for climate monitoring, weather forecasting, and environmental applications. This is achieved through a comprehensive calibration strategy which involves: i) monitoring instrument performances, ii) operational inter-calibration of satellite instruments, iii) tying the measurements to absolute references and standards, and iv) recalibration of archived data[1].

The scientific literature describes several studies on the recalibration of infrared and water vapour channels. Picon et al. (2003) [2] anchored the Meteosat-5 water vapour channel to the NOAA-12 HIRS channel 12 and then used ERA-40 reanalysis data to correct biases of the entire series of METEOSAT satellites with respect to the anchor point. Brogniez et al. (2009)[3] were utilising the data set for successfully studying inter-annual variability of upper tropospheric humidity. Knapp et al. (2012)[4] used HIRS observations as recalibration reference for an improved ISCCP B1 radiance product by first deriving a homogenised HIRS record that is then applied to correct the geostationary satellites. Contrary to Brogniez et al. (2009), Knapp et al. (2012) performed an inter-satellite calibration, i.e., they applied their recalibration approach to different geostationary satellites to obtain a FCDR over the area covered by the ring of geostationary satellites. The latter inter-calibration approach can serve as starting point for this SCOPE-CM activity.

Several methods have been developed for the calibration of the visible channels on board passive imaging satellites, such as methods using well understood targets (e.g. deserts, moon, and deep convective clouds) and methods using simultaneous nadir overpasses with other

[1] Goldberg M., G. Ohring, J. Butler, C. Cao, R. Datla, D. Doelling, V. Gartner, T. Hewison, B. Iacovazzi, D. Kim, T. Kurino, J. Lafeuille, P. Minnis, D. Renaut, J. Schmetz, D. Tobin, L. Wang, F. Weng, X. Wu, F. Yu, P. Zhang and T. Zhu., 2011: The Global Space-based Inter-Calibration System (GSICS), Bulletin of the American Meteorology Society, 92, 467475, DOI:10.1175/2010BAMS2967.1.

[2] Picon, L., R. Roca, S. Serrar, J. L. Monge, and M. Desbois, 2003, A new METEOSAT ‚‘water vapor’’ archive for climate studies, J. Geophys. Res., 108(D10), 4301, doi:10.1029/2002JD002640.

[3] Brogniez H., Roca R. and L. Picon 2009 A study of the free tropospheric humidity interannual variability using Meteosat data and an advection-condensation transport model J. Climate 22, 6773-6787.

[4] Knapp Kenneth R., 2012: Intersatellite bias of the high-resolution infrared radiation sounder water vapor channel determined using ISCCP B1 data, Journal of Applied Remote Sensing. 6(1), doi: 10.1117/1.JRS.6.063523.

passive images[5] or spectrometer observations like SCIAMACHY[6]. Till date, the methods presented in these papers have only been applied as recalibration method for observations from a single instrument operated on a series of satellites, and never been applied in an inter-calibration setting. This will be the challenge of this SCOPE-CM activity.

b. Summary of proposed project

A common recalibration approach will be applied by the three project partners. The selection of this approach will be based on the methods assessed within the international collaborative effort “Global Space-based Inter-Calibration System” (GSICS), as well as from previous recalibration studies.

For the inter-calibration of the radiances from the infrared and water vapour channels the approach developed by NOAA serves as baseline (Knapp et al., 2012). Within GSICS further work has been done to minimize the spectral conversion uncertainties between the reference observations from HIRS and the infrared and water vapour observations from the geostationary satellites. Moreover, observations from the IASI instrument have already been used to monitor quality and stability of the HIRS observations on Metop-A. Thus, the IASI instrument can be employed as reference observation. This project will develop a novel inter-calibration approach using double differences between a reference instruments (e.g. IASI) and two monitored instruments (e.g. two GOES satellites) to propagate the calibration back in time. The same approach can be used by replacing the reference instrument with model data (e.g. reanalysis data). Within this SCOPE-CM activity this approach will be further developed and applied to inter-calibrate and validate the level-1 infrared and water vapour radiances of the geostationary imagers of the three space agencies.

Within GSICS an assessment is being made of recalibration and inter-calibration approaches for the visible channels. This SCOPE-CM activity will establish close links with GSICS and take up the recommendations and approaches resulting from this assessment. The selected approach will be adopted and implemented at the space agencies, and applied to inter-calibrate the level-1 visible radiances of their geostationary imagers. Feedback will be provided to GSICS on the performance of the developed approaches.

The major advances that this project makes on top of existing activities are:

- It will make use of best available references in the IR in a consistent way;
- It will use every existing geostationary image and is not restricted to 3 hourly coverage for full Earth scans;
- It will implement novel ways for characterising spectral transfer functions between the instruments extending the classical one-to-one channel clear sky approach;
- It will improve the uncertainty characterisation of the derived FCDR because GSICS methodology involves an assessment of the error budget[7], e.g., containing spectral uncertainties, satellite data collocation noise, temporal stability of the chosen reference, etc.;

[5] Ham, S.-H., and B.J. Sohn, 2010: Assessment of the calibration performance of satellite visible channels using cloud targets: Application to Meteosat-8/9 and MTSAT-1R, Atmos. Chem. Phys., 10, 1-19.

[6] Doelling, D.R., C. Lukashin, P. Minnis, B. Scarino, D. Morstad, 2012: Spectral reflectance corrections for satellite intercalibrations using SCIAMACHY data *Geoscience and Remote Sensing Letters*, **1**, 119-123.

[7] Hewison, T. J., 2013: An Evaluation of the Uncertainty of the GSICS SEVIRI-IASI Inter-Calibration Products", IEEE Trans. Geosci. Remote Sens., vol. 51, no. 3, Mar. 2013, doi:10.1109/TGRS.2012.2236330

- It will make use of newly created observation feedback archives from reanalysis centres for validation purposes. This is directly addressing the needs of the major customers of the FCDR data.

The FCDRs will be provided at native resolution observations of the geostationary instruments. In order to assess the inter-satellite consistency a cross-satellite comparison of the FCDRs will be preformed.

c. Assessment of the feasibility of the proposed project

The data records of the different geostationary satellites, and of most of the proposed reference instruments, are archived at the three participating space agencies. The GSICS project is already advanced in defining and testing different re-calibration approaches for the visible, infrared and water vapour channels. The participating space agencies are capable to process, archive and distribute the recalibrated datasets.

The involved people are all experienced in the topic of inter-satellite calibration and have leading roles in CDR projects and some are directly involved in GSICS.

The planned improvements to today’s records are scientifically challenging and the project needs a certain funding level that determines the speed of progress.

6. Current and targeted Maturity Level

Besides providing above described FCDRs, the project aims to advance the maturity of these FCDRs.

Table 1: Maturity Matrix FCDRs infrared and water vapor channels

	Software Readiness	Meta Data	Documentation	Validation	Public Access	Utility
Current Maturity level	3.0	3.0	4.0	3.0	3.0	3.0
Targeted Maturity level	5.0	5.0	5.0	4.0	5.0	4.0

Table 2: Maturity Matrix FCDRs visible channels

	Software Readiness	Meta Data	Documentation	Validation	Public Access	Utility
Current Maturity level	0.0	0.0	0.0	0.0	0.0	0.0
Targeted Maturity level	3.0	3.0	4.0	2.0	5.0	3.0

7. Results, challenges and potential contributions of the project

The final aim of the project is to provide, for the ring of geostationary satellites, FCDRs of visible, infrared and water vapor radiances spanning the entire period of their operations. It is expected that the FCDRs will be utilized in three ways:

- As basis for the derivation of Thematic Climate Data Records (TCDR) such as surface albedo, clear and all sky radiance products, upper tropospheric humidity, cloud properties, surface irradiation, atmospheric motion vectors, etc.;
- As input to global and regional reanalysis;
- As input to advanced climate model validation activities in the framework of Obs4MIPs.

Scientific challenges involve the general application of GSICS methodology to past instruments, the quantification of the error budget of inter-satellite calibration process, the validation of the overall quality of the FCDR.

Technical challenges are limited as the participating agencies are experienced in handling all involved data.

8. Duration of the project and tentative schedule

Planned length of project: 5 years; proposed starting date: 1 Jan 2014

9. Expected breakdown of the tasks to be performed in this project;

Task	Year	Actors
– Research the potential of using HIRS on Metop, tied to IASI observations, as reference instrument;	2014	EUM, NOAA
– Update the inter-calibration approach for the infrared (IR) and water vapour (WV) channels as used by NOAA, including the useful temporal resolution imagery, double differencing for inter-calibration, and tying the HIRS reference to IASI;		EUM, JMA, NOAA
– Implement the updated IR & WV inter-calibration approach at the three space agencies;		EUM, JMA, NOAA
– Recalibration of the IR & WV radiances for the GEO satellites. The deliverable will either be FCDRs of re-calibrated radiances or the recalibration coefficients to create such an FCDR;		EUM, JMA, NOAA
– Develop a Free Tropospheric Humidity (FTH) geo-ring		DWD

Task	Year	Actors
demonstrator product		
– Inter-compare the IR & WV recalibrated radiances in overlapping regions and compare them against output from observational feedback archive at ECMWF; – Depending on the outcome of the inter-comparison, adapt the inter-calibration approach, reimplementation it, and repeat the IR & WV recalibration effort; – Prepare and provide user documentation for public distribution of the IR & WV FCDRs or their recalibration coefficients; – Technical assessment of visible (VIS) calibration methods in close collaboration with GSICS, including methods using well understood targets (e.g. DCC, desert, or moon targets) and simultaneous nadir overpass radiance comparisons (e.g. against other imagers or spectrometers); – Regenerate the FTH demonstrator product with the WV FCDRs as input and assess the improvement;	2015	EUM, JMA, NOAA EUM, JMA, NOAA EUM, JMA, NOAA EUM DWD
– Define and select of an inter-calibration approach for the VIS channels; – Implement and test the selected VIS inter-calibration approach at the three agencies; – Find beta users for utilisation of the re-calibrated VIS observations in retrieval applications.	2016	EUM, JMA, NOAA EUM, JMA, NOAA EUM, JMA, NOAA
– Recalibration of the VIS radiances for the GEO satellites. The deliverable will either be FCDRs of re-calibrated radiances or the recalibration coefficients to create such an FCDR; – Inter-comparison of the VIS recalibrated radiances; – Gather feedback from beta users; – Depending on the outcome of the inter-comparison and feedback process, adapt the inter-calibration approach, re-implementation it; and repeat the VIS recalibration effort;	2017	EUM, JMA, NOAA EUM, JMA, NOAA EUM ,JMA, NOAA EUM, JMA, NOAA EUM, JMA, NOAA
– Prepare and provide user documentation for public distribution of the VIS reflected radiance FCDRs or its recalibration coefficients; – Arrange distribution of the FCDRs or recalibration coefficients from European, Japanese and US sites.	2018	EUM, JMA, NOAA EUM, JMA, NOAA

A detailed work plan for the activities planned during the year 2014 of this SCOPE-CM activity is presented in Annex-A

10. Indicate the funding situation

Currently, funding is provided by the participating institutions from their basic funding and as part of EUMETSAT's funding of the CM SAF. Since this funding may not cover all activities proposed outlined in this LoI, delays in the planned schedule are likely. Therefore, the participating institutions may need to seek for additional funding from competitive schemes in Europe, the US, or Japan to supplement their contributions to this SCOPE-CM activity. The EUMETSAT Central Facility currently has additional funding for the preparation of data records for reanalysis that may be continued for the years 2014-2016.

11. Required and available processing capacities

Required is a distributed processing system capable of producing radiance records output data with a rate of approximately 1 year of data per week limiting the processing time for the 5 geostationary 30 year record to approximately 30 weeks. In addition, means for exchanging the FCDRs for public distribution need to be established.

Currently available and planned processing environments are/will be capable of fulfilling these needs.

12. Curriculum vitae of the key investigators

EUMETSAT:

Dr. Ir. R.A. (Rob) Roebeling: holds a PhD in Environmental Sciences (2008) from Wageningen University, on Cloud Properties Retrievals from Satellite Observations. He has more than 20 years experience in the field of boundary layer meteorology, crop growth modeling, radiative transfer of the cloud atmosphere and multi-sensor remote sensing. From 2000 till 2011 Dr. Roebeling was employed at KNMI as Senior Scientist, where he was leading a research group on cloud physics and head of the three Observations Sections within the Weather Research Division. In 2011, he started working for EUMETSAT as Climate Product Expert, where he leads projects related to the generation of climate data records, and coordinates international efforts to better serve the climate research community with these records. He is co-chair of the Cloud Retrieval Evaluation Working Group (CRE-WG). He publishes actively, and serves as editor for Meteorology and Atmospheric Physics and as reviewer for several journals.

Dr. Tim Hewison: received the PhD and MSc in Meteorology from University of Reading (UK) in 2006 and 1999, respectively. He is currently the chair of the research working group of the Global Space-based Inter-Calibration System (GSICS), which is an international collaborative effort initiated in 2005 by WMO and the CGMS to monitor and harmonize data quality from operational weather and environmental satellites of the Global Observing System (GOS). Since 2007 he has worked at EUMETSAT, the organization responsible for operating weather satellites for Europe, on the inter-calibration of satellite instruments as part of the GSICS project.

EUMETSAT CM SAF (Deutscher Wetterdienst):

Dr. Marc Schröder: is leading the CM SAF water vapour activities and joined DWD in summer 2007 after a one year visit as visiting scientist at EUMETSAT. He received his PhD from the Free University of Berlin in 2004 and graduated in physics at the University of Oldenburg in 1999. During his studies he visited the University of Wyoming and the University of Wisconsin. He is currently involved in the retrieval of global water vapour and temperature profiles from ATOVS observations, the retrieval of free tropospheric humidity from MVIRI/SEVIRI observations and the retrieval of the Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite data (HOAPS). He is also involved in the development, processing and validation of a SSM/I FCDR. He has published various papers in the fields of satellite and airborne remote sensing as well as radiative transfer. Marc Schröder is co-chairing the GEWEX water vapor assessment, member of the GRUAN task team 5 and PMET.

NOAA:

Dr. Ken Knapp: holds a PhD from Colorado State University (2000) in Atmospheric Science. He has published numerous papers on scientific applications of geostationary data and is presently chief of the Products Branch in the Remote Sensing and Applications Division of NOAA's National Climatic Data Center.

Dr. Anand Inamdar: holds a Ph. D. from Indian Institute of Science, Bangalore (India) in 1991. He worked at Scripps Institution of Oceanography, San Diego (1990-2004) as a Co-I on the NASA-CERES project with Prof. V. Ramanathan. He worked on the evolution of the water vapor greenhouse effect, water vapor feedback and is a primary contributor to the operational surface long wave algorithm from CERES. He has later worked for USDA/ARS on the retrieval of LST from MODIS and GOES satellites over the US southwest. Presently he is working on cross-calibration of the ISCCP B1 visible channel using the PATMOS-x data.

JMA:

Mr. Masaya Takahashi: holds a Master of Science (2005) from Kyushu University in geophysics. He is currently the technical officer of System Engineering Division of the Meteorological Satellite Center, the Japan Meteorological Agency. He is GPRC (GSICS Processing and Research Centre) points of contacts for operational matters, and a member of the GSICS Research Working Group.

ANNEX A. Work plan for year 2014

The work plan presented in Table 1 contains a list of the tasks the team plan to perform and an indication of the schedule. The scheduled periods are given on a quarterly basis (Q1, Q2, Q3, and Q4). Note that some tasks that start in 2014 continue in 2015. In Figure 1 a schematic representation of the planning and milestones is given.

Please note that the proposed contributions of the project partners, EUM, JMA, NOAA, and DWD in this work plan are best effort estimates that may be subject to change.

Table 1: *List of planned activities in SCOPE-CM IOGEO during 2014*

Task	Description	Period	Actors
WP 0 Management			
0.1	Establish contacts with INPE, KMA, and CMA at the upcoming CGMS meeting (CGMS-41 in July 2013)	2013	EUM
0.2	Detail project implementation plan with participating partners. Among others, to include a schematic view of the data flow between the participating space agencies (as requested by the SEP).	2013	ALL
0.3	Define the involved of INPE, KMA, and CMA within this SCOPE-CM-project	Q1	EUM
0.4	Set-up a web application for exchange of project information	Q1	EUM
0.5	Attend quarterly Tele Conferences	Q1 -Q4	ALL
0.6	Contribute to *Progress Report 2014* and *Work Plan 2015*	Q4	ALL
WP 1 R & D inter-calibration methods for the infrared (IR) and water vapour (WV) channels			
1.1	Research the potential of using HIRS on Metop, tied to IASI observations, as reference instrument	Q1	EUM, NOAA
1.2	Contribute to the research on the potential of using HIRS on Metop as reference instrument (WP 1.1)	Q1	JMA
WP 2 Modification of the IR and WV inter-calibration approach			
2.1	Update of the IR and WV inter-calibration approach for the GOES satellites. This activity is performed jointly with JMA and EUMETSAT. The actions are: • to share and discuss inter-calibration methods used within the SCOPE-CM activity on ISCCP reprocessing • to compare inter-calibrated results derived from full resolution data against those derived using sub-sampled ISCCP data • to exchange experiences on settings to be used for selecting simulations overpasses between the monitored and reference instrument, and for applying the double difference approach.	Q2-Q3	NOAA
2.2	Update the IR and WV inter-calibration approach for the METEOSAT satellites in line with the approach proposed by NOAA. This task is performed jointly with JMA and NOAA. The actions are: • to include the useful temporal resolution imagery; • to apply double differencing for inter-calibration; • to tie the HIRS reference to IASI.	Q2-Q3	EUM
2.3	Contribute to the update of the IR and WV inter-calibration approach for the MTSAT satellites in line with the approach proposed by NOAA. This task is performed jointly with NOAA and EUMETSAT.	Q2-Q3	JMA
WP 3 Implementing and testing the IR & WV inter-calibration approach			

3.1	Implement the updated IR & WV inter-calibration approach at the participating space agencies;	Q3	EUM, NOAA, JMA
3.2	Prepare test datasets of observations from the geostationary satellites operated by the participating space agencies; (i.e. METEOSAT, GOES, or MTSAT)	Q3	EUM, NOAA, JMA
3.3	Test the updated IR & WV inter-calibration approach on the test datasets;	Q3-Q4	EUM, NOAA, JMA
WP 4 Generation of inter-calibrated IR & WV radiances for the GEO satellites;			
4.1	Collect data required for the generation of the FCDRs, or the generation of inter-calibration coefficients, for the GEO satellites; (i.e. HIRS and IASI reference data, and geostationary satellite data of the satellites operated by the participating space agencies)	Q3-Q4	EUM, NOAA, JMA
4.2	Generation of FCDRs or inter-calibration coefficients for IR & WV radiances from observations from the METEOSAT, GOES, and MTSAT geostationary satellites;	Q4	EUM, NOAA, JMA
WP 5 Free Tropospheric Humidity demonstrator product			
5.1	Development and computation of a Free Tropospheric Humidity (FTH) geo-ring demonstrator product for July 2009. The items of this activity are: • to define a common reference channel; • to compute spectral calibration coefficients. *Note: this activity starts in 2013.*	Q1-Q2	DWD
5.2	Test the recalibrated WV radiances for the FTH demonstrator product and assess the differences with previously used calibration for the common reference channel.	Q4	DWD