Sustained and Coordinated Processing of Environmental Satellite data for Climate Monitoring

SCM Project Description

SM-07: Liquid Water Path and Rain Water Path Climatologies in the GPM era

1. Composition of the project team for this project

CIMSS & AOS, University of Wisconsin – Madison	Ralf Bennartz
CIRA & ATS Colorado State University	Chris O'Dell
EUMETSAT CM SAF / DWD	Rainer Hollmann, Marc Schröder

2. PI Affiliation details

Principal Investigator: Ralf Bennartz
Applicant/Institution: Space Science & Engineering Center, University of Wisconsin – Madison
Street/Mail Address: 1225 W. Dayton Street, Madison, WI 53706
Phone: 608-265-2249
Email: bennartz@aos.wisc.edu

3. Project Objectives

Cloud liquid water path (LWP) and rain water path (RWP) are key variables for understanding cloud climate interactions. Reasons for this are related to (1) the role of cloud liquid water path in cloud microphysical and radiative properties, (2) the availability of long-term passive microwave observations, and (3) the objective nature of the definition of LWP as compared e.g. to the more subjective nature of the definition of cloud fraction. As a result, LWP and RWP provide excellent diagnostics for Global Climate Model (GCM) validation and evaluation.

In 2010 CM SAF, in cooperation with the Max-Planck-Institute for Meteorology and the University of Hamburg, released the Hamburg Ocean and Atmosphere Parameters and Fluxes from Satellites data (HOAPS). HOAPS includes 15 parameters, among them LWP and RWP (Andersson et al., 2010a,b; Schröder et al., 2013). In 2012, CM SAF had more than 30 registered users for HOAPS (precipitation only).

In 2008 the authors have developed and released the UWisc LWP climatology (O'Dell et al., 2008) based on all conically scanning microwave radiometers available at the time, including SSM/I, AMSR-E, and TMI, and built upon a standard LWP retrieval product. This 20-year climatology has become a de-facto standard for GCM validation with a growing user community of currently more than twenty different research groups, many of which are climate modelers.

Despite the success of this climatology, various open issues concerning the underlying LWP retrieval could not be fully resolved at the time. These issues include the treatment of different absorption models, subscale cloud variability, and rigorous error propagation. Most important to GPM is the issue of separability of rain and cloud water, which is likely not fully possible with passive microwave measurements alone. Research is needed to derive and validate microwave-only LWP/RWP products not only for current instruments, but for GMI and all its constellation instruments (SSM/I, TMI, AMSR-E, AMSR-2, SSMIS, etc). We propose to address these fundamental issues here in order to create the most unbiased possible long-term record of these products that will have continuity into the GPM era. Specifically, we plan to:

- Strongly build on existing expertise within CM SAF (HOAPS) as well as on expertise at CSU and UW-Madison (UWisc climatology).
- Create a new Level-2 retrieval that
    a) is based on strong heritage of previous retrieval algorithms (e. g. ESA DUE GlobVapor as well as Elsasser & Kummerow, 2008),
    b) attempts to combat fundamental deficiencies in current LWP retrievals, such as by retrieving total water path and the fraction of cloud water,
    c) will contain accurate posterior errors through the framework of optimal estimation, and
    d) uses accurately calibrated brightness temperatures;
- Develop and characterize the new retrieval with extensive, accurate simulations of synthetic passive microwave observations;

- Perform an extensive error analysis of the new Level-2 retrieval using additional sensors including the dual-polarization radar on GPM, to understand its errors in relationship to a number of potential sources of error;
- Create an updated Level-3 climatology that a) includes monthly mean LWP/RWP values as well as their diurnal cycles, b) is based on strong algorithm heritage, and c) utilizes all available, suitable passive microwave instruments beginning in 1988 and continuing into the GPM era.

A flow chart of the principal data flow is shown in Figure 1.

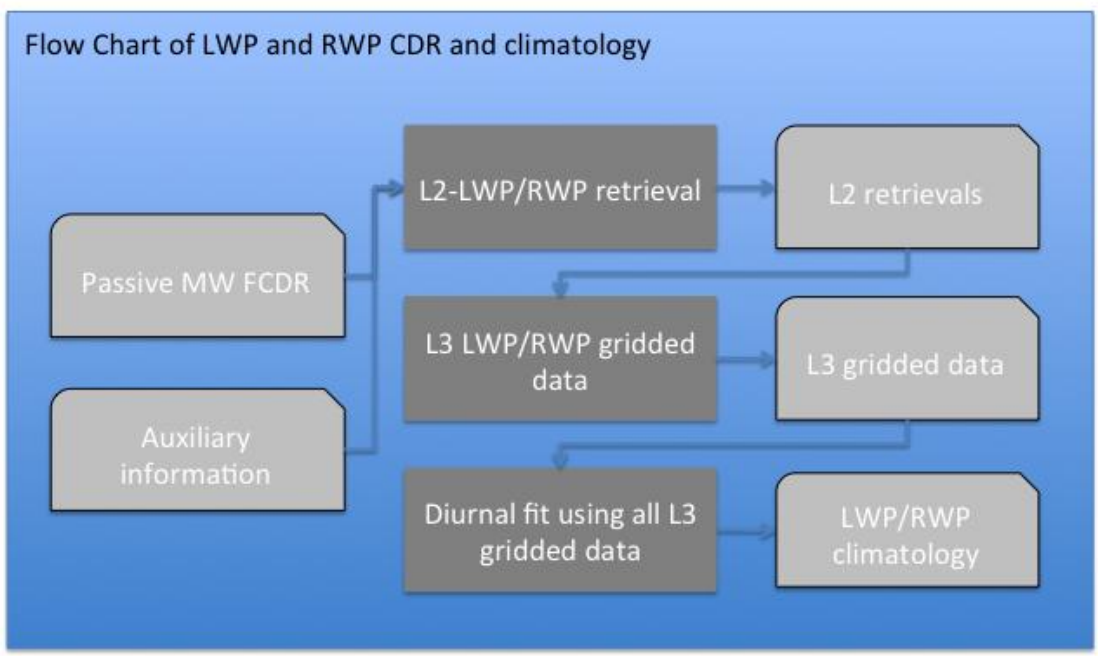

Figure 1: Overview on principal data flow and different stages starting from FCDRs via individual Level-2 (L2) retrieval, Level-3 (L3) gridded data, leading to the final LWP/RWP climatology.

4. Maturity Level and Existing User Communities

4.1. FCDR basis

To address the needs of a long-term, well-calibrated data set of passive microwave radiances, we will use the product of the GPM "XCAL" group, which aims at providing exactly this for GMI on GPM, as well as all its constellation sensors, including the SSM/I and SSMIS sensors. This dataset is partially based upon recent intercalibration for SSM/I done at Colorado State University [*Sapiano et al.*, 2012].

Alternatively the well calibrated and inter-calibrated SSM/I (freely available from www.cmsaf.eu) and SSMIS (to be released in 2014) radiance data record from CM SAF can be utilized. This data record exhibits good stability and shows no systematic artifacts in global maps of inter-satellite biases. Prior to release the data record was well characterized and documented, with ATBD, validation report and product user manual, and has been externally reviewed. The main difference to the X-Cal activity is that the CM SAF data record is inter-calibrated relative to SSM/I observations onboard F11, and not relative to TMI, having advantages in extra tropical areas.

4.2. CDR Code Maturity Level:

Current maturity level: 4 (Bates and Privette (2012) classification).
Target maturity level: 5-6

4.3. Dataset and documentation publicly available here:

https://climatedataguide.ucar.edu/guidance/liquid-water-path-lwp-uwisc-climatology

4.4. Known users

Table 1: Known users of the UWisc LWP climatology *O'Dell et al., [2008]*.

Year	User (PI)	Affiliation	Usage
2011	J. Norris	Scripps	Long-term cloud trends
2011	P. Taylor	Langley	CERES, diurnal cycle of LWP marine Sc
2011	J. Kay	NCAR	CCSM - LWP comp. (climate model eval)
2011	Z-Z Hu	NCEP	CFS comparison/training
2011	A. Gettleman	NCAR	Global climate model validation
2010	S. Bauer	GISS	Global climate model validation
2010	M. Stengel	DWD	Intercomparison of satellite climatologies
2010	J. Cole	CCC (Canada)	IPCC model comparison for AR5
2010	W. Greuell	KNMI	Validation of regional climate model
2010	A. Clement	U. Miami	Satellite cloud trends
2010	B. Madeiros	UCLA	Validation of low clouds in GCMs
2009	A. Sayer	Oxford	Validation of ATSR
2009	A. Horvath	MPIfM	satellite product validation
2009	C.Barber	U. Reading	Marine Sc properties
2009	S. Menon	Berkeley	Climate model evaluation
2009	A. Heidinger	NOAA	Diurnal cycle of stratus clouds
2009	P. Zuidema	U. Miami	Comparison to ship-borne obs
2009	S. Keihm	JPL	Comparison to TOPEX LWP trends
2008	A. Lauer	U. Hawaii	Regional Climate Model Validation
2008	A. Chen	Caltech	Aerosol Indirect effects
2008	U. Lohmann	ETH	IPCC-AR4 validation
2007	R.Wood	U. Washington	Sc properties in Se-Pacific

5. Draft Project Timeline

a) Year 1

- Collect model results for different weather systems and initialize modeling study
- Run slant-path radiative transfer and instrument convolution to generate synthetic TBs
- Perform initial study on rain/liquid separability using model results
- Collocate and assemble MODIS/AMSR/CloudSat data for subscale inhomogeneity study
- Inter-compare CSU and CM SAF SSM/I and SSMIS radiances.
- Improve and process climate data records using microwave imager observations and provide uncertainty estimates on pixel basis.
- Perform initial inhomogeneity study
- Initial publication based on model results

b) Year 2

- Validate and evaluate Level 2 retrieval for LWP/RWP
- Assess and document accuracy of various components of retrieval
- Generate first version of new Level-3 climatology including estimates of systematic and random errors
- Contribute to validation and evaluation of the data records with focus on ship observations.
- Refine generation of climate data record.
- Publication of Level 2 methodology and validation results.

c) Year 3

- Extension of retrieval to additional sensors (e.g. GPM).
- Further refinement of Level 2 and Level 3 algorithms and products
- Continue support to validation and evaluation.
- Enhanced error analysis using newly-available GMI & DPR observations
- Make Level 3 climatology available to broader scientific community
- Final publication on Level 3 results.

d) Detailed time table Year 1:

Months 1-3: Collect model results for different weather systems and initialize modeling study (ongoing CSU)

Months 1-3: Collocate and assemble MODIS/AMSR/CloudSat data for subscale inhomogeneity study (ongoing, UW-Madison)

Months 4-6: Run slant-path radiative transfer and instrument convolution to generate synthetic TBs (CSU/W-Madison)
Months 4-6: Inter-comparison of CSU and CM SAF SSM/I and SSMIS radiance (CM SAF/ DWD)
Months 7-12: Perform initial study on rain/liquid separability using model results (CSU)
Months 7-12: Perform initial inhomogeneity study (UW-Madison)
Months 11-12: Initial publication based on model results (lead CSU)

6. Current Funding

a) EUMETSAT CM SAF / DWD

Part of the planned work is funded in the framework of CM SAF in WP 52121

b) UW-Madison/CSU

Some funding available for reprocessing within newly funded NASA MEaSUREs awarded 2012 (5 yrs project). Algorithm updates and increases in maturity level not fully funded.

c) Expectations to sustain dataset

The PI and Co-PIs fully expect to sustain this dataset beyond SCOPE-CM Phase 2. CM SAF will have a vested interest in sustaining the dataset, in particular with view on EPS-SG MWR.

7. References Cited

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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, doi:10.1029/2012EO440006.

Elsaesser, G. S., and C. D. Kummerow (2008), Toward a fully parametric retrieval of the nonraining parameters over the global oceans. J. Appl. Meteor. Climatol., 47, 1599–1618.

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8. CVs of key partners

Family Name	Given Name	Title	Role in Project	
Bennartz	Ralf	Prof.	PI	

Year of Birth	Country of birth	Nationality/Nationalities
1966	Germany	German

European Community Languages spoken (best first)				
German	English			

Currently working for (organisation)	Since (yr.)	Position
University of Wisconsin/Vanderbilt University	2002	Professor

Curriculum Vitae as well as academic and professional qualifications

Ralf Bennartz is full professor at the Department of Earth and Environmental Sciences at Vanderbilt and at the University of Wisconsin's Space Science and Engineering Center. He received his Ph.D. (1997) from the Free University of Berlin and his M.S. degree in atmospheric physics from the University of Hamburg (1994).

His research interests include satellite remote sensing and atmospheric radiative transfer in the microwave spectral range as well as applications of satellite observations in climate research and data assimilation. He is member of NASA's Precipitation Measurement Mission (PMM) science team, NASA's Orbiting Carbon Observatory (OCO-2) science team, member of the American Meteorological Society's Radiation Commission, IPCC Expert Reviewer, and chair of the U.S. Joint Center for Satellite of Data Assimilation's working group on cloud and precipitation assimilation.

Reference List (Important publications, relevant for this proposal)

Weber, M., Young, B. B., Kulie, M. S. , R. Bennartz, and J. H. Booske, 2012: Atmospheric Attenuation of 400 GHz Radiation due to Water Vapor. IEEE Transactions on Terahertz Science and Technology, doi: 10.1109/TTHZ.2012.2189909

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Family Name	Given	Title	Role in	

	Name		Project	
Hollmann	Rainer	Dr.	EO-Expert	

Year of Birth	Country of birth	Nationality/Nationalities
1968	Germany	German

European Community Languages spoken (best first)				
German	English			

Currently working for (organisation)	Since (yr.)	Position
Deutscher Wetterdienst	2004	Head of Science satellite based climate monitoring

Curriculum Vitae as well as academic and professional qualifications

Dr. Rainer Hollmann is Head of Science of the group satellite based climate monitoring within the department of climat monitoring at DWD. Also he is head of Science of EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) based at Deutscher Wetterdienst, Germany (www.cmsaf.eu) since April 2010. He is a member of the GERB International Science team (GIST) and a member of the EUMETSAT Working group on climate data record generation.

He received his Diploma in Meteorology in 1995 and the PhD in 2000. From 2000-2004 he was Post-Doc at the Institute of Atmospheric Physics at GKSS Research Center in Germany. Since 2004 he is working for DWD in Offenbach within EUMETSAT's CM SAF, in the beginning as expert in the surface radiation group, from 2007-2010 as head of the DWD's cloud remote sensing group of CM SAF focusing on the validation of CM SAF cloud products.

Since 2010 he is the Head of Science satellite based climate monitoring at DWD leading several projects and research activities related to satellite based climate monitoring. His working area is covering short- and longwave radiative transfer simulations, development of algorithms and retrievals of climate-parameters from satellite measurements (e.g. top of the atmosphere radiation budget, cloud properties, and surface radiation budget).

Rainer Hollmann is PI of international projects: ESA cloud CCI, national funded project.

Reference List (Important publications, relevant for this proposal)

Reuter, M., Mieruch, S., Thomas, W. and Hollmann, R., 2010: A method for estimating the sampling error applied to CM SAF monthly mean cloud fractional cover data retrieved from MSG SEVIRI, Trans. Geosci. Remote Sens., 48, in print.

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Family Name	Given Name	Title	Role in Project	
Schröder	Marc	Dr.	EO Expert	

Year of Birth	Country of birth	Nationality/Nationalities
1971	Germany	German

European Community Languages spoken (best first)				
German	English			

Currently working for	Since (yr.)	Position
DWD	2007	Senior Scientist

Curriculum Vitae as well as academic and professional qualifications

Marc Schröder is leading the CM SAF water vapour activities and joined DWD in summer 2007 after a one year visit of 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), which - among others - include precipitation, evaporation and total column water vapour products. Besides development all these activities include code development, processing and in particular validation. He is also involved in the development, processing and validation of a SSM/I FCDR. Independent quality monitoring of radiance observations from satellites (SEVIRI, IASI) is an important issue in climate monitoring and another aspect of his work.

Marc Schröder is co-chairing the GEWEX water vapor assessment, member of the GRUAN task team 5 and PMET.

In previous projects, he carried out the calibration of in-situ radiometers and remote sensing spectrometers and developed associated calibration and data processing software. Furthermore, he achieved substantial competence in 1D and 3D radiative transfer, including development and validation. Recently he was the coordinator of the ESA DUE GlobVapour project and participated in the ESA STSE WACMOS project.

Reference List (Important publications, relevant for this proposal)

Schröder, M., Jonas, M., Lindau, R., Schulz, J., and Fennig, K.: The CM SAF SSM/I-based total column water vapour climate data record: methods and evaluation against re-analyses and satellite, Atmos. Meas. Tech. Discuss., 5, 6423-6453, doi:10.5194/amtd-5-6423-2012, 2012.

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Family Name	**Given Name**	**Title**	**Role in Project**	
O'Dell	Christopher	Prof.	Co-PI	

Year of Birth	**Country of birth**	**Nationality/Nationalities**
1973	United States	U.S.

European Community Languages spoken (best first)				
English	French			

Currently working for (organisation)	**Since (yr.)**	**Position**
Colorado State University	2007	Professor

Curriculum Vitae as well as academic and professional qualifications

Christopher O'Dell is an assistant professor in the Department of Atmospheric Science at Colorado State University, and a principal investigator at CSU's Cooperative Institute for Research in the Atmosphere (CIRA). He received his M.S. (2001) and Ph.D. (2002) degrees from the University of Wisconsin-Madison in astrophysics. He is interested in accurate remote sensing retrievals for clouds and greenhouse gases, including rigorous error characterization within the framework of optimal estimation or equivalent techniques. He is the algorithm design leader for the Orbiting Carbon Observatory (OCO-2) carbon dioxide retrieval algorithm, and also designed the principal cloud-screening algorithm for OCO-2 based on GOSAT measurements in the oxygen-A band. He has also worked extensively on microwave remote sensing over ocean of clouds and water vapor, and on microwave radiance assimilation issues in collaboration with ECMWF.

Reference List (Important publications, relevant for this proposal)

O'Dell, C.W., et al., 2012: The ACOS CO_2 retrieval algorithm, Part I: Description and validation against synthetic observations. *Atmos. Meas. Tech*., 5, 99-121.

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