Third workshop on the GEWEX water vapor assessment

Workshop summary

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1 Overview

The third workshop of the GEWEX water vapor assessment (G-VAP) was hosted by the Cooperative Institute for Research in the Atmosphere (CIRA) in Fort Collins, CO, USA on 30 September – 02 October 2013. More than 20 participants from research institutes, universities and SME (CREST, CSU, FUB, Moog, UCAR, U. Colorado, U. Leicester, U. Wisconsin, Vanderbilt U.), from weather services (DWD; NOAA), from the ground-based and in-situ measurement communities (ARM (PNNL), U. Albany) as well as from space agencies (EUMETSAT) attended the workshop. A list of participants, their affiliations and email addresses are given in Appendix C. The presentations of the third G-VAP workshop are available at http://gewex-vap.org/?page_id=529.

The main objectives of the 3rd meeting were to

- Provide status on activities and present and discuss results achieved thus far,
- Decide on way forwarad: Refine and potentially extend on-going activities with the main objective to find explanations for observed discrepancies and limitations in long-term satellite data records,
- Discuss structure of G-VAP report.

Prior to the workshop three discussion letters have been distributed to registered workshop participants in order to prepare the workshop. Each discussion letter contained a series of questions and first answers to these questions. The content of these discussion papers are reflected in the following dedicated topics for group discussion:

- Assessing homogeneity and stability (moderator: R. Bennartz, rapporteur: R. Lindstrot), • Identification of reasons for observed inconsistencies (moderator: M Schröder (for A. Gambacorta), rapporteur: M. Lockhoff),
- Cooperation with SPARC (moderator: Karen Rosenlof, rapporteur: M. Schröder).

The workshop started with overview presentations on GDAP. After presentations from PIs to provide an update on candidate satellite data records and data records for comparison, interim results from the GEWEX water vapor assessment and related activities were presented. Finally an update on the SPARC water vapor II activity was given. The workshop agenda can be found in Appendix B.

The presentations triggered intense and valuable discussions. These discussions addressed and answered all aspects and questions of the discussion letters and group discussions.

The main outcomes of the third workshop are summarised as follows:

- Finalise intercomparison, comparison to ground-based and in-situ observations, homogeneity, trend and stability analysis using gridded data and identify strengths and reasons for inconsistencies and include refinements as described in Table 1.
- Analyse the temporal change of regional PDFs.
- Cooperation between SPARC and G-VAP on analysis of UTH and UTLS data records.
- Summarize recommendations and needs as input to a GEWEX letter to agencies.

These recommendations and needs are:

- ***Develop and provide PDF based climatology of satellite-based radio-occultation data.***
- ***Analyse differences between observations under all-sky as well as cloudy and clear sky conditions.***
- ***Need for continental high quality satellite data records.***
- ***Need for inter-calibrated radiance/brightness temperature data records and homogeneously reprocessed instantaneous satellite data records.***

2 Background

This year's 3rd G-VAP workshop builds upon two previous workshops held in 2011 and 2012. The 1st workshop was hosted by the European Space Agency's European Space Research Institute (ESA-ESRIN) with support from the ESA DUE GlobVapour project in March 2011. This workshop set the general framework for the assessment by agreeing on variables, data records and general procedures to be considered. The workshop summary was published in the GEWEX Newsletter[1]. The 2nd workshop, hosted by Deutscher Wetterdienst and EUMETSAT's Satellite Application Facility on Climate Monitoring (CM SAF) in September 2012 aimed at the consolidation of the G-VAP strategy and the technical implementation. The results of the 2nd GVAP workshop were presented to the first GDAP meeting in Paris, October 2012, where further recommendation were received. The major outcomes of the 2nd workshop and feedback from the first GDAP meeting have also been summarized in the GEWEX Newsletter[2]. Based on decisions and recommendations a list of actions was compiled, which can be found in Appendix A of this document, including their current status.

Results from the previous G-VAP workshops and feedback from GDAP were used for setting up the G-VAP assessment plan. This plan summarizes scope and goals of the assessment, introduces science questions and provides details on the planned technical and scientific activities. Prior to publication on www.gewex-vap.org the plan has been send to the community to allow for feedback and for consolidation. The G-VAP assessment plan is now in consolidated and final form.

3 Major Results of 3rd Workshop

During their talks and the follow-up discussions, C. Kummerow and W. Rossow emphasised the need for a timely accomplishment of assessments. Long durations of assessments are typically accompanied by an increasing number of updated data records. If a publication of outdated results needs to be avoided this would lead to further delays. It was noted that first assessments take longer for setting up the data base and the analysis system. Later assessments may adopt a scope which is less broad, may strongly benefit from the availability of a common data base and may thus be accomplished in shorter time. The completion of G-VAP in fall 2015 is consensus. W. Rossow further stated that it is important to look at homogeneity, stability and changes over time but also, that it is generally needed to closer analyse the link between processes and their impact on climate. He also introduced the ISCCP-nnHIRS data record which relies on the HIRS product provided by NOAA. The ISCCP-nnHIRS product is currently in the process of being produced and provided as common input data to GEWEX product projects.

[1] http://www.gewex.org/gewex-content/files_mf/1432209506May2011.pdf
[2] http://www.gewex.org/gewex-content/files_mf/1432211736Nov2012.pdf

R. Newsome and J. Wang presented latest efforts and results related to ground-based and in-situ observations. The ARM programme operates AERI, MWR, MWRP and lidar systems that allow high temporal resolution observations of atmospheric water vapour during day and night. Depending on the instrument the temporal and vertical resolution are as high as 1 minute and 75 m, respectively. Five permanent ARM stations are in operation and the longest record goes back to 1993. The data is freely available from the ARM webpage. GNSS observations have high accuracy and theoretical stability. The data from NCAR comprises of ~1000 stations. All station data have been processed consistently, and the data is available with a temporal resolution of 2 hours. Comparisons to the homogenised IGRA data and TCWV from SSM/I (Remote Sensing Systems, RSS) revealed that the radiosonde data seem to have degraded quality after 2009 and that the satellite data are in closer agreement with GNSS data when second closest, not closest neighbour to GNSS stations are considered. Within G-VAP, ARM/GRUAN data will serve as reference for the analysis of instantaneous satellite profile data. GNSS was agreed to be a valuable reference for assessing diurnal sampling issues of satellite.

Updates on candidate satellite data records were given by J. Forsythe (NVAP-M), R. Lindstrot (MERIS), R. Bennartz (ESA-MWR), T. August (IASI Version 6), and R. Kursinski (GPS-RO). R. Lindstrot introduced the MERIS TCWV product which is available over land with high spatial resolution (0.05°). This product was developed in the ESA DUE GlobVapour project. FUB recently extended the temporal coverage of the product to March 2012. Also, ESA started a project to reprocess MWR (on-board ERS-1, ERS-2, ENVISAT) observations. The project will provide a MWR TCWV data record for the period 1991-2011 in 2014 to G-VAP. This ESAMWR project was introduced by R. Bennartz. The new EUMETSAT water vapour product (version 6) combines IASI, MHS and AMSU-A data and is thus available in clear and cloudy sky conditions. Input to an optimal estimation retrieval scheme is a first guess which is determined from statistical retrieval schemes, and averaging kernels are provided together with the profile products. 1.5 years of data can be provided in near future. The NVAP-M climate version was introduced by J. Forsythe and includes SSM/I, HIRS, AIRS and radiosonde data. A time series of the number of samples was provided. In order to reach consistent sampling in time a resampling activity is planned. R. Kursinski gave a short introduction to retrieval methods for water vapor from GPS-RO data and characteristics of the COSMIC data set. As true all-sky observations with high vertical resolution and stability GPS-RO data are a valuable reference data set. This was demonstrated by comparison results in which AIRS products and weather and climate model output do not well represent the wet and dry end of the distribution, thereby underlining the importance of studying PDFs and not only means. In the follow-up discussions it was recommended to use the GPS-RO data within G-VAP for the assessment of sampling effects (clear-sky, all-sky, clear-cloudy sky) and as a reference.

Additional evaluation activities were presented by J. Roman, A. Reale, and T. Trent. J. Roman showed results of a study analysing potential changes in the water vapor distribution using GCMs. In particular the changes at the high end of the distribution, that is, the extremes, received large interest at the workshop. It was consensus that G-VAP will analyse changes in the PDF for data records with a temporal coverage of 25 years and more. A. Reale presented the NOAA Product Validation System (NPROVS) and its update, the NRPOVS+. NPROVS+ now utilises reference and dedicated radiosonde data as well as GPS-RO data. Using reference radiosondes a new approach to evaluate satellite data was introduced. It was consensus that NPROVS+ will be the basic system for the evaluation of a subset of instantaneous satellite data in G-VAP. The practical realization of such efforts are currently under discussion. T. Trent carefully reprocessed GTS radiosonde data up to a height 18 km and uses the data for comparison to IASI and AIRS data. The improved radiosonde data and the collocated data can be provided to G-VAP. He further emphasised the need to

demonstrate the information content of satellite observations, the value of averaging kernels in the comparison process and made a cautionary note on the quality of available reference data.
G-VAP results were presented by M. Lockhoff, L. Shi and M. Schröder. M. Lockhoff presented results from the intercomparison and homogeneity activities (covering scientific activities 1-3 defined in the GEWEX assessment plan) based on 6 long-term data records, namely HOAPS, SSM/I-RSS, NVAP-M, ERA-Interim, MERRA and NCEP-CFSR. Regionally largest discrepancies between the data sets were found over land, especially over the Andes, dry areas, Arctic, Antarctic as well as over eastern and western parts of the North American continent. Also global and regional time series revealed inhomogeneities. It turned out that most of these inhomogeneities (break points) and other artefacts can be attributed to changes in the observing system (changes of satelllites, observation frequency, etc).

L. Shi intercompared UTH data from MHS, HIRS and METEOSAT and observed that UTH from HIRS exhibits largest scatter while UTH from METEOSAT is significantly drier than the UTH from HIRS and AMSU-B. The work is mainly done by Q. Yang with funding from CM SAF. Together with Carl Schreck she further analysed the correlation of UTH from HIRS and METEOSAT to major climate indices (Nino 3.4, PDO, NAO). Differences in correlation are potentially caused by data gaps and biases between the data.

An analysis of trends in UTH from METEOSAT was presented by M Schröder. Also, the frequency of occurrence of UTH being smaller than 10% (UTHp10) was introduced and analysed. The spatial patterns of UTH and UTHp10 exhibit maximum changes in dry areas. However, these changes are statistically not significant in most regions. He further showed trend intercomparison results for six of the longest term data records. The focus was on TCWV but first results were also presented for trends in profiles. Trends in TCWV exhibit significant differences among the data records in terms of absolute values and in specific regions like central South America, central Africa, Sahara and Arabian Peninsula and the Arctic and Antarctic. An analysis of regional anomalies shows that regions of distinct trends usually coincide with breakpoints in the time series. These breakpoints are not evident on global scale but become evident on regional scale. It was consensus that the data record ensemble will not be considered as reference. Instead single records need to be used, e.g., those which exhibit largest degree of homogeneity.

The results from the intercomparison of trends received large interest and triggered intense discussions. General consensus was that observed insignificant trends are valuable information which need to be provided together with confidence probability and uncertainty. It was discussed that the analysis can be improved by consideration of number of valid observations as function of time and long-term calibration uncertainties. Also the analysis of the regression between TCWV and SST will receive lower priority due to the various assumptions that enter this theoretical consistency analysis. It was decided to finalise the analysis for data records of more than 25 years temporal coverage and to clearly state the assumptions behind this analysis.
K. Rosenlof introduced the SPARC water vapour II activity and provided information on metric, data records and approaches. Within this activity the quality of satellite data records is typically not analysed below 125 hPa. SPARC decided to first publish the results and then to prepare the final report in order to avoid originality conflicts. Contacting the editor prior to submission is recommended.

It was then discussed that the joint analysis of full period cloud, precipitation and water vapour data records is needed to better understand the physical processes that link UT and LS. SPARC and G-VAP will keep this in mind when cooperating on the analysis of UTH (G-VAP) and UTLS data

records (SPARC) and potentially provide recommendations with the aim to foster intense analysis of processes that link UT and LS. Contact persons are B. Read and L. Shi as well as M. Schröder. SPARC and G-VAP will set-up a joint overview table of UTH and UTLS data records. In general the discussions brought up very valuable input regarding the refinement of the analysis carried out so far and the way forward. Also, the first answers to the questions raised with respect to the discussion letters were well received, with exceptions mentioned in this summary. Finally, the presentation on the report structure was well received. It was agreed to also include a dedicated section on recommendations and cautionary notes as well as to include short summaries on pros and cons per observing methodology.

In view of the tight timelime (finalisation of the report in fall 2015) there is a need for assigning priorities to both activities and data records. It was consensus to assign highest priority to finish the works on intercomparison, comparison, homogeneity, stability and trends for long-term data records using gridded data and to the PDF-analysis.

It was recalled that the deadline for latest data upload is fall 2014. This was considered to be critical because new versions of data records which have been analysed already might be released in the meantime. It was again emphasised that G-VAP is not an iterative process and that data records are to be considered only once. Finally, it was recalled that G-VAP needs scientists to take over responsibility and carry out scientific activities.

The workshop decided on the activities listed in Table 1.

Table 1: List of activities.

Activity	**Responsible**	**Until**
Compare breakpoint positions to changes in observing system and gradients in major climate indices, relate breakpoint strength to variance before and after breakpoint time and inform PIs	Maarit Lockhoff	Continuous
Analyse trend as function of temporal coverage for exemplary data record (e.g., HOAPS)	Marc Schröder	December 2013
Set-up password protected ftp server	Maarit Lockhoff, Marc Schröder	As soon as possible
Contact PIs to get information on long-term calibration uncertainty and number of valid observations per month for full record length	Marc Schröder	Fall 2014
Analyse consistency between temperature and absolute humidity as well as relative humidity using satellite data records of more than 10 years temporal coverage	Lei Shi	Next workshop
Draft summary report on information content description, value averaging kernels and collocation uncertainty	Thomas August, Tim Trent	February 2014
Analyse differences in climatologies per weather type (clear, cloudy, all-sky)	Maarit Lockhoff	Next workshop
Intercompare differences between PDFs from different orbits using multi-platform data records (subset from long-	Maarit Lockhoff	Next workshop

Activity	Responsible	Until
term candidate satellite data records)		
Address diurnal sampling issues using GNSS data	Maarit Lockhoff	Next workshop
Consolidate details of profile evaluation	Marc Schröder, Tony Reale, A. Gambacorta	As soon as possible
Exchange information on metrics, data records and general approaches and include B. Read (L. Shi and M. Schröder) in activity on UTH analysis (UTLS analysis) – joint SPARC and G-VAP activity	Lei Shi, Marc Schröder	November 2013
Summarize recommendations and needs as input to a GEWEX letter to agencies	Chris Kummerow, Marc Schröder	Early 2014

4 Conclusion

In order to avoid the release of an outdated final report in view of the emergence of new data record versions the final report will be submitted to GDAP for review in late 2015. During this and previous workshops a wide variety of ideas were proposed to analyse the data records with the aim to increase our knowledge about their strengths and weaknesses. In addition, the number of satellite data records, reanalysis as well as ground-based and in-situ observations is enormous. With the aim to finalise the report by 2015 it became again evident that priorities need to be assigned to data records and activities. It was decided that the highest priority should be given to finalise the work on the data inventory as well as the inter-comparison, comparison to ground based and in-situ data, homogeneity and stability analysis and the analysis of differences in trends using gridded data. Inconsistencies that have been observed will be explained to the maximum extend possible. This will be done first for data records of more than 25 years and then, for a subset of activities, for data records of more than 10 years and will include the refinements given in the previous section. This analysis will be extended by an analysis of changes in the PDF over time for data records of 25 years and more. The results from these efforts form the core part of the report, in a consensus form.
Beyond this it was decided that qualitative analysis and case studies form the annex of the report. These studies may consider a subset of candidate data records as well as may have a focus on specific regions and periods.

The G-VAP workshop recommends the following:

- Develop and provide PDF based climatology of satellite-based radio-occultation data,
- Analyse differences between observations under all-sky, cloudy and clear sky conditions.

The presentations further clearly revealed the

- Need for continental high quality satellite data records,
- Need for inter-calibrated radiance/brightness temperature data records and homogeneously reprocessed instantaneous satellite data records.

These recommendations and needs will be included in a GEWEX letter to the agencies and will be communicated to national representatives in WMO.
The workshop tentatively decided to conduct the next workshop at the Institute for Space Sciences, Free University Berlin, Berlin, Germany in the week 06-10 October 2014.

Appendix A List of activities from 2nd Workshop

Table 2: List of activities from 2nd workshop.

Activity	Responsible	Comments	Status
Draft assessment plan	Co-chairs	Available online	closed
Clarify framework of potential cooperation with ICARE	Co-chairs		open
Establish formal communication link to SPARC	Co-chairs	See this summary	closed
Establish group to initiate technical implementation	Co-chairs	IDL-based G-VAP tool was set up by A. Walter and R. Bennartz	closed
Establish group on assessing Level-2 water vapour profiles and decide on collocation criteria	A. Gambacorta, T. August, B. Ho, M. Lockhoff	New activity inTable 1	closed
Prioritise data records	Co-chairs	See assessment plan and these minutes	closed
Decide on satellite based profile pilots and contact pilot data providers	M. Lockhoff, A. Gambacorta	New activity inTable 1	closed
Update data fact sheets according to workshop discussions	F. Fell with support from cochairs	Updated	closed
Set-up G-VAP webpage	Co-chairs	www.gewex-vap.org	closed

Table 3: List of activities to be addressed by March 2013.

Activity	Responsible	Comments	Status
Establish group to advise longterm analysis	M. Schröder, R. Bennartz	Covered by discussion letters in future	closed
Draft data policy	M. Schröder, R. Bennartz	See assessment plan	closed
Contact data providers to join effort (continuous activity)	Co-chairs		ongoing

Appendix B Workshop Agenda

G-VAP – Workshop

30 September - 02 October 2013

Agenda

Venue:

Cooperative Institute for Research in the Atmosphere (CIRA)
Colorado State University
Fort Collins, USA

Version 1.0
26 August 2013

Monday, 30th Sep 2013

09:00 – 09:15	Welcome *Kummerow*
09:15 – 09:30	Aims of meeting and logistics *Schröder, Shi, Divico*
09:30 – 10:30 (15 min. each)	Continuous water vapour observations at ARM sites *Newsom*
	The ESA DUE SSM/I+MERIS product *Lindstrot*
	IASI retrieval and evaluation activities at EUMETSAT *August*
	NASA Water Vapor Project-MEaSUREs (NVAP-M) global water vapour dataset: Early results for climate studies *Vonder Haar, Forsythe*
10:30 – 11:00	Coffee break
11:00 – 11:15	Trend comparison between GNSS and satellite microwave observations *Wang*
11:15 – 11:30	Regional trends in precipitable water vapour *Roman*
11:30 – 11:45	ESA's MWR project *Bennartz*
11:45 – 12:15	An introduction to the GEWEX products *Kummerow*
12:30 – 14:00	Lunch break
14:00 – 14:30	GEWEX water vapour and temperature profiles *Rossow*
14:30 – 15:00	G-VAP plan, web and data fact sheet *Schroeder*
15:00 – 15:30	Water vapour and profile validation using NPROVS/GPROVS *Reale, Gambacorta*
15:30 – 16:00	IASI/AIRS validation using radiosondes *Trent*
15:30 – 16:00	Coffee break
16:00 – 17:30 (15 min. each)	First results from inter-comparison *Lockhoff*
	Assessing homogeneity *Lockhoff*
	Trends in TCWV and theoretical expectation *Schröder*

	First Level2 evaluation *Lockhoff*
17:30	Adjourn

Tuesday, 1st Oct 2013

09:00 – 10:30 (15 min. each)	UTH inter-comparison *Shi, Yang*
	Correlation of UTH data records to climate indices *Shi, John*
	Trends in UTH *Schröder*
	Latest results from GPS-RO *Kursinski*
10:30 – 11:00	Coffee break
11:00 – 12:30	Introduction to discussion on how to assess homogeneity and stability (Group discussion) *Moderator: Bennartz; Rapporteur: Lindstrot*
12:30 – 14:00	Lunch break
14:00 – 14:30	Summary of group discussion *Moderator*
14:30 – 15:30	Introduction to discussion on how to find reasons for distinct differences in space and time (Group discussion) *Moderator: Schröder; Rapporteur: Lockhoff*
16:00 – 17:00	Group discussion continued
17:00	Adjourn

Wednesday, 2st Oct 2013

08:30 – 09:00	Summary of group discussion *Moderator*
09:00 – 09:30	An introduction to SPARC water vapour II *Rosenlof*
09:30 – 10:30	Introduction to discussion on SPARC/G-VAP cooperation (Group discussion) *Moderator: Rosenlof; Rapporteur: Schröder*
10:30 – 11:00	Coffee break

11:00 – 11:30	Summary of group discussion *Moderator*
11:30 – 12:00	Wrap-up, next meeting
12:00 – 12.30	AoB
12:30	Expected end

List of participants

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* Monday only
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