

GEWEX Water Vapour ECV Product Assessment

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Summary and Purpose of Document

This paper introduces the GEWEX water vapour assessment (G-VAP), summarises the current status of G-VAP and outlines the next steps. G-VAP is contributing to the evaluation of water vapour Climate Data Records that includes a comprehensive documentation of the data records, the analysis approaches used and of the assessment results. The need for a comprehensive assessment of all long-term water vapour data records was clearly spelled out by GEWEX in 2011. The assessment will be performed in close contact with the data record PIs assuring a fair process for each participating data record.

Since its beginning the assessment made significant progress in consolidating the assessment plan, in compiling information on data records, in setting up the data basis, in the development of a basic comparison processing tool and in performing first analysis of long-term data records. The large number of available data records, the diversity in parameter definitions and formats is a challenge and requires decisions on priorities related to the analysis performed with the data records. With the consolidation of the assessment plan it is envisaged to define an activity list and associated schedule that can be achieved with available resources.

The first results, further plans and the structure of the G-VAP report will be reported and discussed at the next G-VAP workshop hosted by the Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO, USA on 30 September – 02 October 2013.

ACTION PROPOSED

AOPC-18 is invited to take note.

GEWEX Water Vapour ECV Product Assessment

1 Introduction

The need for quality assessments of Essential Climate Variables (ECVs) Climate Data Records (CDRs) are part of the GCOS guidelines for the generation of data products. The assessment process shall enable users to judge the quality and fitness for purpose of climate datasets and products by informing the users about the strength and weaknesses of existing and readily available data records. Assessments of data sets related to the global energy and water cycles became an integral part of GEWEX activities over the last decade.

Among four of the GEWEX Science Questions, three are concerned with water. Changes in atmospheric water vapour, precipitation, clouds and aerosols affect the energy balance of the Earth and since these processes are intertwined, they are complex and simultaneous. Considerable uncertainty and controversy remain concerning the quantitative impact of these feedback processes. In order to make progress in this difficult area, the GEWEX Data and Assessments Panel (GDAP) seeks to describe the complete water and energy budgets using consistent, long-term, global datasets of radiative fluxes and surface energy exchanges as well as the atmospheric parameters affecting the energy balance. The products currently being coordinated by GDAP consist of cloud properties (ISCCP), precipitation (GPCP), aerosols (GACP), ocean (SeaFlux) and land (LandFlux) surface sensible and latent heat flux as well as Surface and top of atmosphere radiative fluxes (SRB).

GDAP has finalized assessment activities for precipitation as well as cloud and radiation flux products and has ongoing assessment activities for LandFlux and Seaflux and a new assessment activity on tropospheric water vapour (G-VAP) that was initialised by the GEWEX Radiation Panel (GRP, recently renamed to GEWEX Data and Assessments Panel - GDAP) in 2011. This paper is describing the current status of G-VAP after some general remarks on assessments performed in the past and the lessons learnt.

2 General Remarks on Assessments

Recent years have shown that data set diversity can be confusing for users, and without the proper background information and understanding of the limitations of available data, there is a danger that these data may be incorrectly applied or misinterpreted. On the other hand users need to realise that it is often difficult to define a single best climate data source. Data sets are instead most often complementary in nature with varying strengths and weaknesses. It seems common understanding that essential elements that define the usefulness of a data set are certainly its accuracy and error characterization, but data products can be evaluated too favourably by the developers themselves in order to encourage data usage. Experience in GDAP has shown that assessments have benefits for science and applications as well as product providers.

It is the task of the assessments to conduct objective and independent evaluations and inter-comparisons. The basic goal is to point out differences and limitations and, if possible, to provide reasons for them. It helps to involve the scientists that created the data so that sufficient background information on instruments, applied methods, and underlying assumptions and limitations can be more fully understood and conveyed to the user. It has also been observed the involvement of product developers leads often to a tendency to broaden the goal of the assessment from its original intent of informing the user community to one of using the assessment itself as a diagnostic to help investigators improve their respective products. The second objective clearly requires broad participation from the data producers. GDAP has found

that these two objectives are, in fact, compatible with one another but should always be kept distinct in the assessment.

GDAP has found that assessment activities, like the products they assess, should not be viewed as static but rather as dynamic activities that may need to be repeated every 5-10 years depending upon the rate at which products are being added or modified within a given discipline. Even if the validation data, procedures and previously assessed data are archived for interim use by new product developers, comprehensive assessments are critical to move the field forward in a systematic way.

Thus, assessments should include a dedicated, motivated, and respected person to lead the effort, complementary assessment team members with specialized knowledge, regular team meetings – open and closed workshops a centralized data depot for data sets created specifically for the assessment that can be used to facilitate assessments by new products or new versions of existing products and probably most important seed funding for some centralized activities to avoid collapse and/or very long duration. For the G-VAP assessment EUMETSAT is investing resources through its Satellite Application Facility on Climate Monitoring into the centralised activities that helped to set up the assessment and will facilitate work on the comparison of data.

3 Assessment Goals and GCOS ECVs targeted

Water vapour variables in the upper-air and surface are among GCOS specified ECVs that are both currently feasible for global implementation and have a high impact on the United Nations Framework Convention on Climate Change (UNFCCC) requirements. The water vapour ECVs include total column water vapour, tropospheric and lower-stratospheric water vapour profiles and upper tropospheric humidity. As mentioned in the GCOS Implementation Plan's Satellite Supplement (GCOS-154), "satellites now provide a vital means of obtaining observations of the climate system from a global perspective and assessing the behaviour of different parts of the globe. However, "for satellite data to contribute fully and effectively to the determination of long-term records, they must be implemented and operated in an appropriate manner to ensure" adequate stability, homogeneity and accuracy. For the satellite derived ECVs, GCOS specified requirements in two areas: (1) requirements on horizontal, vertical and temporal resolution; and (2) requirements for accuracy and stability. These requirements are also given in GCOS-154.

Beyond the GEWEX need to select a suitable water vapour product an accurate assessment of the sensitivity of atmospheric radiation and clouds to climate change is required for achieving the GEWEX goal of reproducing and predicting, by means of suitable models, the variations of the global hydrological regime, its impact on atmospheric and surface dynamics, and variations in regional hydrological processes and water resources and their response to changes in the environment, such as the increase in greenhouse gases. As water vapour is the primary natural greenhouse gas and intimately linked to cloud formation and precipitation, as well as to the understanding of the global water and energy cycles, its assessment is one of the critical components to lead to model improvements.

The major purpose of G-VAP is to quantify the state of the art in water vapour products being constructed for climate applications, and by this to support the selection process of suitable water vapour products by GDAP for its production of globally consistent water and energy cycle products. G-VAP focuses on overall characteristics of participating satellite water vapour data records and weather prediction model-based reanalysis as determined from comparisons among the data sets and comparisons against other observing systems such as in situ observations and ground-based remote sensing observations.

The assessment of atmospheric profiles (specific humidity preferred) is of highest interest to GDAP as they are the input to the GEWEX products. The usage of products within GDAP activities essentially implies to study long-term data records. The GEWEX needs on satellite based temperature and humidity products are:

- True global coverage, i.e., including all surfaces;
- 3 hourly temporal resolution;
- 10 km spatial resolution;
- Availability from 1979 to present;
- High quality, in particular high temporal stability;

While the requirements on resolution are similar between GCOS-154 and the GEWEX needs, G-VAP will consider the GCOS requirements on accuracy and stability as baseline guidance. Also, G-VAP considers all three GCOS ECVs (total column water vapour, upper tropospheric humidity and tropospheric and lower-stratospheric profiles of water vapour) thereby extending the GEWEX need to the full GCOS requirement. Only the stratosphere will not be considered as this is part of a WCRP SPARC assessment.

Data record specifications will be compiled in data fact sheets (DFS). The DFS encompasses all technical GCOS requirements and the GEWEX needs and is compliant with the WMO core metadata profile. The data records will not be ranked according to quality because individual data records might have been produced for different applications not considering all tested requirements.

4 Assessment Workshops

Two G-VAP workshops have been held, one at ESA/ESRIN, Frascati, Italy in 8-10 March 2011, and another at DWD/CM SAF, Offenbach, Germany in 26-28 September 2012. Both workshops brought together 30-40 producers and users of water vapour and temperature data sets, as well as validation experts, from research institutes, universities, weather services, ground-based and in situ measurement communities, and space agencies.

The outcome of the first workshop can be summarised as follows:

- All three parts of the GCOS Essential Climate Variable (ECV) on water vapour shall be considered: Total Column Water Vapour (TCWV), Upper Tropospheric Humidity (UTH) as well as water vapour profiles and their related temperature profiles (WVT). G-VAP should not include sea-/land-surface temperature or 2m temperature/humidity unless these are integral parts of the water vapour profile;
- The assessment shall consider data records that are provided by assessment participants and data records that are readily available and documented, e.g., global reanalyses;
- The assessment shall focus on overall characteristics of each participating product as determined from inter-comparison and comparisons against in situ observations, against ground-based products as well as analyses of other properties such as the representation of the diurnal cycle and dependence on a priori information;
- In this characterisation process the data records shall not be ranked according to their quality. Rather, the application areas and requirements of the individual data records as well as the GEWEX requirements shall be considered and documented;
- G-VAP shall provide a database that includes collocated products and validation data of sufficient quality and long-term stability to be the main repository for the current assessment and be useful for the development of improved products.

The main outcomes of the second workshop can be summarised as follows:

- The workshop participants decided to start with a couple of data records (provision committed by workshop participants) to set up the technical infrastructure, to develop the tools for comparison and to keep the momentum of the assessment. Further data record and validation data providers will be contacted in due course to broaden the data base of the assessment and to enable the full capability of it;
- For the inclusion of data into data inventories a draft metadata model has been sketched that will be consolidated over the next few months;
- G-VAP considers all data records “long-term” that are longer than ten years. Thus, the assessment will consider data records that may not be used in GEWEX water and energy cycle data sets but which are important to establish a deeper understanding of atmospheric water vapour observations;
- With respect to this definition a preliminary list of instruments relevant to the assessment has been revised and amended;
- The scientific approaches to analyse Level-2 (instantaneous) and Level-3 (spatio-temporally gridded) data records were discussed, and it was agreed that the assessment of long-term Level-3 data records shall focus on stability and homogeneity and when possible their value for trend determination. The Level-2 validation needs to go beyond bias and RMS analysis by considering also PDFs, the representativeness error and averaging kernels whenever available;
- Due to the inherent fundamental differences in the assessment of Level-2 and Level-3 data records, the assessment of long-term Level-3 data records must not build on Level-2 assessment results but shall be started as soon as possible.

The results of both workshops have been published, respectively, in the May 2011 and November 2012 issues of the GEWEX Newsletter.

5 Assessment: First results and plan

By end of 2012 an assessment plan has been drafted. The plan is based on results from the two workshops and from feedback received at the first GDAP meeting in October 2012. The plan recalls the G-VAP scope and states the GEWEX needs on water vapour data records. The main part of the plan comprises of scientific questions which were mainly triggered at the first GDAP meeting and of scientific and technical activities which are needed to answer these questions and to characterise the data records and their utility for the user community. Finally, it assigns responsible persons to each activity and provides a time line and resources as well as tables of candidate data records. Given the current situation on available people the plan needs to be consolidated concerning the distribution of activities discussed at the workshops.

A basic prerequisite for G-VAP is an inventory of adequate data records. It is important to gather technical specifications, application areas, requirements and more information for each data record to have a as much as possible complete description. The first workshop resulted in a candidate data record list and prior to the second workshop a DFS has been drafted and distributed in order to gather the required information. The candidate list and the DFS have been refined following discussions at the second workshop. The final version of the DFS comprises of 48 questions. The DFS largely follows the summary of the WOAP workshop on data set quality assessments held in April 2011 in Frascati, Italy (GCOS-153) and is compliant with the WMO core metadata profile. It is planned to ask the data record PIs to fill the DFS online. The DFS is specific on water vapour data records but the DFS entries does also match most of the questionnaire of the CGMS/CEOS inventory on satellite-derived CDRs facilitating a later addition of data records that are currently not in the CGMS/CEOS inventory.

The candidate data record list encompasses more than 30 satellite data records and more than 30 data records that have potential for evaluation. At present, more than 20 data records have been integrated into the G-VAP data base. The data record formats, the technical specifications

and the product definitions are very diverse. Therefore, a basic processing tool was developed to cope with the different formats and definitions and to provide the capability to encode all data records into NetCDF-3 CF compliant format. The data basis and the capability of the basic tool will be extended in the future.

As mentioned earlier in this paper, scientific questions for the evaluation of the data records have been formulated that determine the metric used in the later analysis. High priority is given to the analysis of homogeneity (breaks) and stability as well as uncertainty on different time/space scales. Typical questions are:

- What is the degree of homogeneity and stability of each satellite data record?
- Are the observed changes and anomalies in line with theoretical expectations?
- Are the differences in observed changes within the uncertainty of the individual trends?

The corresponding technical analysis capabilities which have been set up include:

- Intercomparison of temporal averages on common grid, time series of global monthly averages and Hovmoeller diagrams in absolute and relative space for each data record;
- Analysis of anomaly and variance on common grid relative to the ensemble mean as well as for corresponding globally averaged time series;
- Analysis of long-term changes in water vapour data records following Weatherhead et al. (1998) and Mieruch et al. (2013) by utilising original grid and temporal coverage as well as common grid and common temporal coverage;
- Analysis of observed changes and anomalies relative to expectations from theory using for instance the Clausius Clapeyron equation with an observed SST and an assumption on unchanged relative humidity as well as relevant indices such as JMA SST index on ENSO.

The analysis tools have been set up and applied to the five longest satellite data records of total column water vapour available. Figure 1 shows an example for the common period of 1988-2006.

First analysis results indicate some technical issues with data records causing the need to reload one data record and to re-consider the common time period and to repeat the computation of monthly averages for specific data records to ensure consistent sampling in time and space.

The inter-comparison analysis also aims at the identification of regions and periods with either large and/or systematic differences which should be studied in more detail using Level 2 and potentially Level 1 data as well as ground-based observations to get more insight into the causes of differences. An important aspect of G-VAP is to find physical reasons for observed inconsistencies that later should lead to improvements of the respective products. First results for total column water vapour indicate that some geographical regions such as mountainous regions, tropical forest and desert areas are typically showing inconsistencies among the five data records considered.

Next steps are to refine the analysis tools by extending the analysis of the degree of homogeneity (breakpoint tests etc.) and to assess the stability over time. In addition, the tools will be applied for humidity profiles at specific pressure levels.

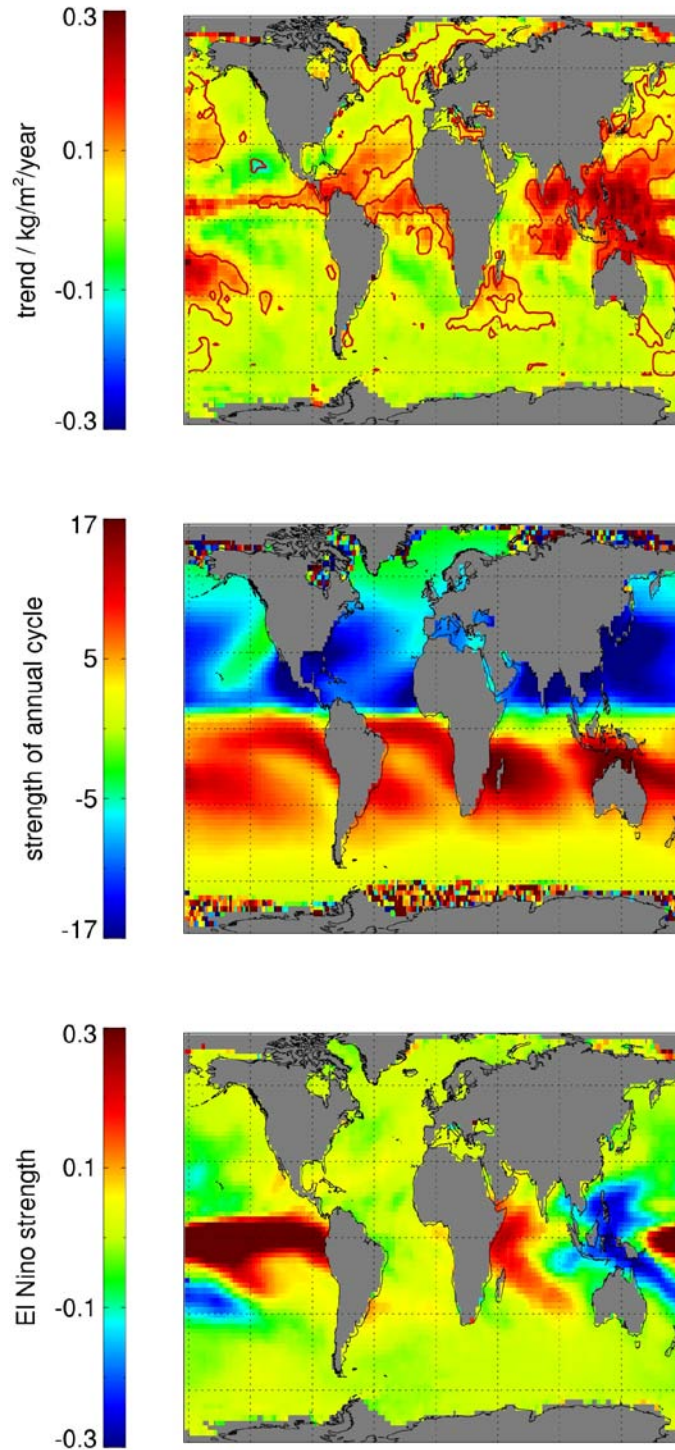


Figure 1: Trend in total column water vapour (in kg/m²/year) including 95% level of confidence contour lines (left panel), strength of annual cycle (middle panel, disregard results at sea ice edge - a maximum sea ice mask was not used) and El Nino strength (right panel). Strength of annual mode and El Nino strength are dimensionless weights assigned to the annual cycle and El Nino modes in the fitting process during trend estimation.

6 Conclusion

G-VAP is contributing to the evaluation of water vapour Climate Data Records that includes a comprehensive documentation of the data records, the analysis approaches used and of the assessment results. The need for a comprehensive assessment of all long-term water vapour data records was clearly spelled out by GEWEX and G-VAP will fill this gap. The assessment will be performed in close contact with the data record PIs assuring a fair process for each participating data record.

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