GEWEX Data and Assessment Panel (GDAP) – Annual Report
Reporting Period: January 2015 – December 2015

URL: http://gewex.org/GDAP.html

Chair(s) and term dates:

Chair: Jörg Schulz, EUMETSAT, July 2014 – March 2017

Vice Chair: Matthew McCabe, King Abdullah University, Saudi Arabia, January 2015 – March 2017

1 Panel Activities and 4. Science Highlights

1.1 GEWEX Data Sets including the integrated product

1.1.1 ISCCP and ancillary data for the integrated product

The neural network HIRS (nnHIRS) product, which is a retrieval of temperature and humidity profiles, is essential to provide temperature and humidity profiles as well as several surface parameters for the integrated product. The product has been completed for 1980-2014 and is available to the processing of other GEWEX products. Issues were detected when using earlier versions of the nnHIRS product to compute longwave radiative fluxes, so the last version has been adjusted to improve agreement with surface station temperatures and humidities. This version has not been used so far but will be very soon by SRB. All other ancillary products needed for the provision of an integrated product are all finished for the whole time period (currently 1980-2014) and online.

The full re-processing to generate ISCCP V2 has not started yet (although we have a prototype data set for 2007-2009). The processing was transferred to NOAA NCEI with the consequence that quality control and quality improvement of the input data became major work lasting one full year. Once the processing begins (maybe in February 2016) NCEI should be able to process about 10 yr per month. A "final" version of ISCCP products for 2007-2009, referring to the cloud products, should be available very soon now.

1.1.2 SRB

GEWEX SRB team continued to assess new nnHIRS and ISCCP HX data sets, make algorithm improvements, and analysis test cases in preparation for production of the integrated data product. During the year, two different versions of nnHIRS and ISCCP HX were received. These were assessed by comparisons to other data sets and by running various cases through the SRB production system. nnHIRS data sets were compared with ERA-I, MERRA, MERRA2 and NVAP-M data sets. Near surface data parameters are compared against NOAA NCEI global surface weather station data sets. ISCCP HX, HGG and HGM data products were compared to ISCCP DX, D1 and D2. In addition, there were several other input and algorithm changes implemented as well. Included in these were the implementation of the Max Planck Aerosol Climatology (MAC v1) and new ISCCP ancillary data sets including ice/snow, ozone and surface types. Adjustments to various stages in the SRB production system were required to incorporate these changes. One additional input quantity is surface skin temperatures for the year 2007. SRB is testing the use of the land surface temperature product from LANDFlux and the diurnal ocean surface skin temperature from the SeaFlux project. Thus, SRB derives a 3-hourly blended global surface skin temperature input using these and the ISCCP HX skin temperature retrievals. This represents the next stage in energy flux integration. Several case studies were performed to evaluate the effect of these inputs on the SRB outputs. The resulting fluxes were compared to fluxes from the Baseline Surface Radiation Network sites (BSRN) and fluxes now released by the CERES Mission for both TOA and Surface fluxes. Although, other comparisons are ongoing, the results of these tests will be included as part of our uncertainty analysis for the latest SRB version. In general, the SW data products showed improvements relative to the previous version. However, the LW TOA and surface radiative flux data products have significantly larger differences relative to the surface measurements and CERES. Thus, SRB is still evaluating the new various cloud and ancillary data products and algorithm changes for issues. After completion of this assessment and further testing, SRB will be able to deliver both the SW

and LW fluxes from the current nnHIRS and ISCCP HX data product versions. This should be completed in the next 1-2 months.

1.1.3 GPCP

The new Version 2.3 of GPCP is in final testing. This new version fixes a few problems with cross-calibrations among satellites that had caused artificial shifts. It also uses new GPCC Full analysis. Plan is to release this new version in early 2016 to replace Version 2.2.

GPCP Monthly Interim Climate Data Record (ICDR) is produced within 10 days of end of month for climate diagnostics work. [I'll send you slides for Dec. In early Jan. in case you want to use at SSG; will also take a first look at all of 2015 to look at annual pattern for warmest year on record and with El Nino].

1.1.4 SEAFLUX

SeaFlux has produced a Climate Data Record covering 1988 – 2007 which is similar to the SEAFLUX 1.0 product delivered for the integrated product. It contains extensions towards real time working with the SSMIS instruments. Major differences are the use of neural net derived winds, rather than CCMP (which has reduced trend in global wind speed). In order to pre-1998, used a ship-of-opportunity-based reference data set. Not as high-quality as the SeaFlux research vessel only data set, higher noisiness.

Comparison activities show that both latent heat and sensible heat fluxes show inter-product differences of 5-10 Wm^{-2} globally and 10-20 Wm^{-2} over the Southern Ocean. Several of the products show a moderate trend from the early 1990's, in contrast to OAFlux and some reanalysis products. At the global scale, both humidity/temperature differences and wind speed differences appear to be important, and offsetting in some cases. Wind speed is in better overall agreement than humidity and temperature differences.

Further study shows that the structure in the retrieval atmospheric humidity (Qa) biases appear to be co-aligned with patterns of cloud weather states as defined using ISCCP cloud-top histograms. The largest biases in several of the Qa retrievals are aligned best with Global WS 7 (Mostly clear, with thin boundary layer cloud). New ways for retrieval are being tried by using cloud information derived from the microwave instruments to distinguish between weather regimes.

1.1.5 LANDFLUX

The Landflux project has made good progress towards completion of Version 1 global land surface heat fluxes. Simulations covering the period 1984-2007 have been completed using four different methodologies, with latent heat (LE) fluxes produced at 3 hourly, 1 degree resolution for this period. Work is continuing on the development of a global sensible heat flux product (H), with the aim for this to be completed by mid-2016.

A validation study of the Landflux product against 45 globally distributed flux-towers was recently undertaken (see McCabe et al. 2015), providing a first comprehensive evaluation of the Landflux datasets. In a parallel effort, findings from the ESA funded WACMOS-ET project have also been published, supporting the research being undertaken by investigators within Landflux (see Michel et al. 2015, Miralles et al. 2015). An overview paper on global flux estimation is in the planning stages.

1.1.6 Soil Moisture

An ISSI Workshop was held in November in Bern with representations from across satellite soil moisture user community (NWP, climate, hydrology). Goal of this meeting was to establish a common requirement baseline for satellite soil moisture products and to identify the evaluation metrics and approaches that are needed to verify if products comply with these standards. The results of the meeting have been summarised and are currently worked out in more detail in a draft white book for satellite soil moisture validation. The draft white book will be discussed with a larger user community (~20 users) in a dedicated workshop to be held at ESA ESTEC on April 28-29, 2016.

Specific achievements:

a. All Radiometer Data Products From SMAP Mission Now Available at the National Snow and Ice Data Center.
b. New release of ESA CCI multi-satellite soil moisture dataset (period 1978-2014, including SMMR, SSM/I, TMI, AMSR-E, WindSat, AMSR2, ERS 1/2-AMIand MetOp-A ASCAT)

c. Signal-to-noise ratio (based on triple collocation) has been introduced as new evaluation metric for soil moisture product evaluation and intercomparison (see point 7)
d. Issuing of a Special Issue in JAG on the retrieval and validation of satellite soil moisture (with GDAP panel member W. Dorigo as guest editor): http://www.sciencedirect.com/science/journal/03032434/45/part/PB)

1.1.7 Integrated Product

Work on the integrated product has been continued but more realism is applied. Two different types of integration are aimed at:

a. Integration of GEWEX products as they are presenting all parts in one collection to allow download from one place rather than collecting from different places;
b. Integration by using the same ancillary files for all data sets and by using outputs from one product as input to another as it was done by using ISCCP to construct SRB. The strategy here has changed from using only those parts which can be proven to bring improvements to the individual products.

Performing b. actually has proven to be very difficult, in particular using derived temperature and humidity profiles from HIRS as inputs to SRB and the SEAFLUX and LANDFLUX schemes.

SRB has used the HIRS products together with Sea/LandFlux surface values along with the latest ISCCP and MAC-v1 aerosols to compute fluxes. It was found that shortwave fluxes look actually quite good and ready for distribution but long wave fluxes are biased positive (too large downwelling) 7 W/m^{-2} over oceans for a net $5W/m^2$ bias globally. The HIRS products cannot be very good in the lower atmosphere and close to the surface as no HIRS channel is very sensitive to it and water vapor is estimated basically form differential absorption in window channel differences. Disucssion is ongoing to use reanalysis instead but MERRA stopped end of 2015 and MERRA 2 needs to be better understood as some biases to BSRN station data have increased. Maybe the use of ECMWF reanalysis can help here.

Given the fact that the HIRS temperature and humidity retrievals have been tuned with surface stations, e.g., from SEAFLUX consensus is reached that SeaFlux and LandFlux use their own near surface estimates as before.

Ancillary information such as ice edge are also critical in an integration process but maybe not the exactly same should be used as different products have different sensitivity to it. The current ice edge definition used is less conservative than the sea ice product used by the ocean community. This can have a large impact on air-sea (up to changes of the global mean) and also radiation fluxes. So it might be better to use existing proved flagging from the individual products.

Basically all products are ready to go to produce data from 1998 onwards only with SRB waiting for the ISCCP products to be finalized and the need to take a decision for the use of temperature and humidity profiles for the LW fluxes.

1.2 GEWEX Data Quality Assessments

1.2.1 Water Vapor Assessment

The 5th G-VAP workshop was hosted by the Space Science and Engineering Center (SSEC), University of Wisconsin, Madison, WI, USA and took place at the University of Wisconsin's Lowell Center in Madison on 04 and 05 November 2015. Approximately 25 participants from research institutes, universities and SME (Small and Medium-sized Enterprises, Colorado State U, FU Berlin, SSE, U. Lille, Vanderbilt U., U. Wisconsin), from weather services (AEMET, DMI, DWD, NOAA), from the ground-based and in-situ measurement communities (NOAA) as well as from space agencies (ESA, EUMETSAT) attended the workshop.

The main objectives of the 5th meeting were to

- Present and discuss results achieved thus far,
- Decide on next steps of G-VAP in order to finalise remaining open activities,
- Further discuss the draft of the WCRP report on G-VAP, feedback from GDAP and the finalisation of the WCRP report,
- Formulate recommendations for future analysis, e.g., in GDAP context and for the attention of agencies,
- Continuation as, e.g., a "science group on atmospheric water vapour".

The main outcomes of the 5th workshop are summarized as follows:

- The updated planning for drafting the WCRP report on G-VAP, the freezing of the data archive and the time line to finalise G-VAP have been confirmed by the workshop. Among others: sectional reports finalised until March 2016, preliminary draft to GDAP in April 2016, and final draft to GDAP in August 2016;
- The release of collocated data and data on common grid by G-VAP was endorsed;
- It is envisaged to include the U. of Wisconsin's HIRS data record as it covers more than 30 years and it contains profile information. The data is expected to be available by the end of 2015;
- The proposal to continue G-VAP beyond the acceptance of the WCRP report on GVAP was well received and the participants are willing to support G-VAP in the future.

From this it is expected that the water vapour assessment will be finished at the time of the 2016 GDAP meeting. GDAP will discuss with G-VAPs proposal for continued work which should result in a biennial reporting of water vapour scientific findings relevant to GEWEX.

1.2.2 Aerosol Assessment

The aerosol assessment has presented the report "A Critical Review of the Efficacy of Commonly Used Aerosol Optical Thickness Retrievals: Literature Assessment" at the occasion of the 2015 GDAP meeting. However, the report could not be published because it has no clearance from the main author for distribution. We will continue to clear this report and this will mark the end of the aerosol assessment unless aerosol product users, e.g., from the modeling community request more activity from GDAP.

Meanwhile the AeroCom forum for aerosol global modeling and communications with providers of data for needed input (emissions) and for model evaluation has been formed and reports also to GDAP through Stefan Kinne. Aerocoms main goals are to understand complexities in aerosol component global modeling (emission to forcing), to use available aerosol data to constrain models which leads to close interactions and collaborations with the remote sensing communities and to define harmonized model experiments to investigate and understand model behavior.

As a by-product the MAC climatology has been developed and has continuously improved all spectral properties needed for radiative transfer including seasonality and decadal anthropologic change. The climatology gives access to climate impacts without detailed modeling. MACv2 was released and can be downloaded at ftp-projects.zmaw.de/aerocom/climatology/MACv2_2015.

1.2.3 Precipitation Assessment

We have discussed and identified key questions to address in different assessment phases. High priority is placed on the evaluation of GPCP climatology in comparison with other selected precipitation products for the first interim report. The datasets participating at this stage include GSMaP, CMORPH, and CMAP, but more data sets, including re-analysis results may be identified during 2016. The GPM radar, ground radar networks, and gauge analyses may be also helpful, if carefully analyzed with individual strengths and weaknesses in mind, for assessing uncertainties from multiple angles. Meanwhile, we continue to identify the key problems to deal with for the subsequent assessment cycles. Extreme precipitation is among the top priorities after the climatology.

Understanding and quantifying the potential uncertainties in the GPCP climatology is of urgent importance to address the budget closure issues of the integrated products.

The prioritized foci for the precipitation assessment remain as:

- *Global and Regional Climatology (long-term mean and trend)* - with focus on the regionally dependent sources of uncertainty.
- *Time series analysis in the context of different modes of climate variability* - Diurnal, intra-seasonal, seasonal, inter-annual, etc.
- *Extremes* – which could benefit of new activity on ground-based radar data reprocessing
- *Frozen precipitation* - Snow and mixed-phase precipitation
- *Structural Errors* - Errors that are not eliminated by temporal/spatial averaging.

The data sets considered in the assessment may not only contain classical precipitation data sets but also measurements to constrain precipitation such as GRACE in polar areas, surface salinity for long term freshwater budget, soil moisture as potential rain gauge, and moisture transport derived from re-analysis.

Suggestion have been made to shorten own analysis and take benefit from literature but comparisons have been done in an inhomogeneous way. The GEWEX assessment can connect to CLIVAR through the use of climate model metrics to be applied to satellite data record. The topic frozen precipitation shall be linked with CliC.

GDAP annual meeting 2015 has endorsed the precipitation assessment planning but requested the formulation of more specific science questions. A first workshop to define the questions around the first topic is planned for autumn 2016 possibly in combination with the next GDAP meeting. In addition, Chris Kummerow will establish needed connect with the GHP Mounterrain project on rugged terrain precipitation.

1.2.4 Soil Moisture Assessment

The above mentioned white book on the identification of the evaluation metrics and approaches that are needed to verify if products comply with these standards will serve as baseline for a soil moisture assessment. A review of the white book my GDAP may happen this year. While the interest and need for an assessment of the various products from satellite, re-analysis and models is there, the progress is hampered by the community taking a long time to find agreements on how to do evaluation. In addition, the discussion was hampered during 2015 by the fact that Wouter Dorigo could not participate in the GDAP 2015 meeting.

1.3 Ground based observational networks

1.3.1 BSRN

BSRN has a new project manager, Chuck Long (NOAA) who was jointly adopted by GEWEX and GCOS. BSRN objectives remain to be:

- Monitor the surface shortwave and longwave radiative components and their changes with the best methods and instrumentation currently available (*Detailed observations*)
    - Spatially and climatologically diverse sampling
- Provide accurate data for the calibration of satellite-based estimates of the surface radiative fluxes (*Global coverage*)
- Produce high quality observational data for validating the theoretical computations of radiative fluxes by models (*Climate prediction*)
- Improve fundamental measurement capabilities with the goal to provide the highest possible quality data from continuously-operated field sites
- BSRN has developed practices for instrumentation, calibration, and operation that fulfill highest specifications.

BSRN is a volunteer organization, with stations sponsored by host organizations and governments.

BSrn has 6 working groups:

- Infrared Working Group
- Long-Term Data Sets Working Group
- Archive Working Group
- Cold Climate Issues Working Group participates in polar prediction project
- Oceanic Working Group
- Uncertainties Working Group

In 2014 59 Stations have provided data to the BSRN Archive, 5 additional stations are planned, 4 proposed, and 6 have been closed. The BSRN archive contains now ~700 years station data. The data are heavily used and cited almost 1500 times without self-citations in almost 1200 peer reviewed articles.

1.3.2 International Soil Moisture Network (ISMN)

The International Soil mOisture Network integrates 49 networks containing ~ 2050 Stations (1600 last year) that have put ~ 8000 soil moisture datasets (6500 last year) into the archive. Historical datasets reach back to 1952. Operational datasets are being updated in near-real time.

ISMN still rapidly growing, several new networks and datasets will be integrated in near future: (e.g. China (Wuhan University), Korea, Romania). Still large grow potential, e.g., Chinese meteorological service operates 100s of SM stations. If they would share them through the ISMN, this would have an enormous scientific impact (most registered ISMN users come from China). Chinese representatives at the GDAP annual meeting in Xiamen gave positive signals on this topic.

The ISMN is a success story, serving a large international scientific community and having large implications well beyond science, e.g. through improvement of weather and climate models (ESMs), improvement of remote sensing products, and support to agriculture applications. ISMN has good-value for money (costs ~50-100kEUR/y) but financial support for 2009-June 2016 has come from ESA EOP SMOS. A new funding source is still to be found.

1.3.3 Global Precipitation Climatology Centre (GPCC)

GPCC has delivered a detailed report to GHP which is not repeated here. GPCC remains an important part for the construction of GPCP.

2 New projects in place

None

3 New projects and activities being planned, including timeline

3.1 Ground-based radar data records

Obviously activities in radar data reprocessing are by far less mature than what is in place meanwhile on satellite data, but 30 years ago we have been in a similar state with regard to satellite data, when it was understood that satellite data can be used for more than weather forecasting or other real-time application.

GDAP plans to work towards a similar extension of the usage of radar data by coordinating and synthesizing activities. A first step should be, that even if we cannot solve right now the problem of global radar data exchange (see Fig. 1 for available radar systems), (there's no Global Radar Data Centre yet in place), all operators of radar data should be approached to take care that radar data is at least stored in a manner, that someone can pick it up 15yrs later and still can utilize it. As this is cost intensive we need to show that a much bigger spectrum of potential usages for radar data compared to the current status quo encountered world-wide really does exist.

NOAA has completed a reprocessing for the period covering from 2001 to 2012. The reanalysed data are available at 1-km and 5-minute resolution. An important step in the process of generating the best possible precipitation estimates is to assess the bias in the radar-only product and to implement techniques for merging in situ data providing the best bias-adjusted estimates. Deutscher Wetterdienst (DWD) has completed reprocessing of DWD radar data since 2001 (for Germany) including statistical evaluation with focus on extreme precipitation and the development of user-specific products for application in, e.g., hydrology, civil protection and agriculture.

Although this has attempted earlier with not much success we will try to start a new project that brings together scientists working on radar reprocessing considering aspects of archiving, reprocessing, and exchanging radar data and the development of consistent radar precipitation databases for use in hydroclimatological studies. Potential leaders of such a project could be Andreas Becker, DWD and Brian Nelson (NOAA). A first workshop should be planned for 2017.

The existing reprocessed data holdings should be used by the Extreme GC and feedback should be provided to the project within GDAP.

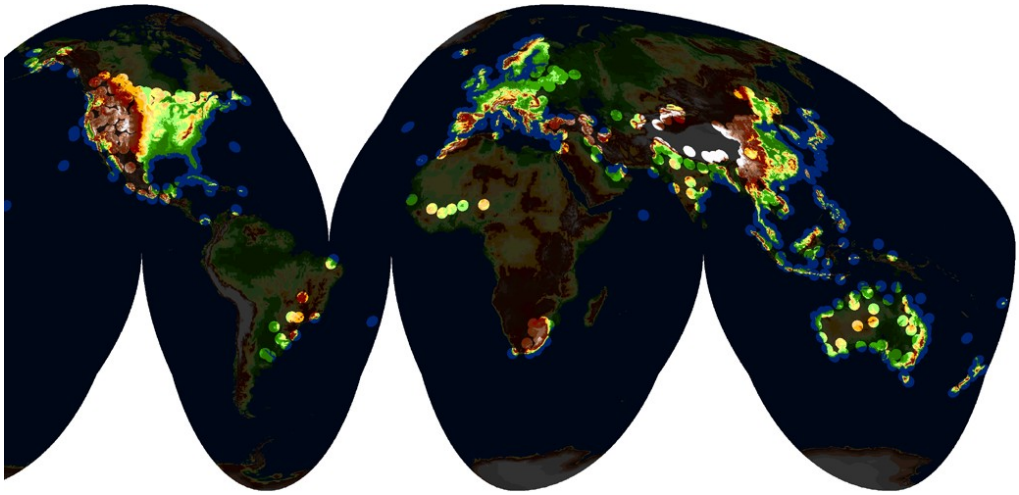

Fig. 1. Current weather radar coverage provided by national weather services (in Goode Homolosine projection). For computing the area illuminated by terrestrial weather radars, we assumed a maximum range of 200 km per radar device. The underlying database was established based on a web search of national weather services' web pages, web documents, and the WMO radar database http://wwr.dmi.gov.tr (which is quite incomplete, though, in comparison to the results shown in this figure). The sources of information are listed in the Supplement Sect. 1. The figure shows that almost complete coverage is achieved for North and Central America, as well as Western and Central Europe. Good coverage is also available for the Middle East, South, Southeast and East Asia, and Australia. Large parts of Africa and South America remain uncovered, yet, as well as vast parts of Russia (although a new network with about 140 Doppler radars is planned to be established in Russia by 2018).
(Source: Heistermann et al., 2013: Technical Note: An open source library for processing weather radar data (wradlib). Hydrol. Earth Syst. Sci., 17, 863–871, 2013, www.hydrol-earth-syst-sci.net/17/863/2013/, doi:10.5194/hess-17-863-2013.

3.2 GEWEX UTCC PROES - Process Evaluation Study on Upper Tropospheric Clouds and Convection

The goal of the GEWEX PROES activities is to provide observational based metrics for a better understanding of climate related physical processes.

One of the WCRP grand challenges is to determine the role of convection on cloud feedbacks. Therefore the GEWEX UTCC PROES working group aims to gain a better understanding of the interconnection between the convection and the heating induced by the outflowing anvils. By widening the focus on the role of all cirrus clouds (link to SPARC) another key question arises: how large are the relative cirrus contributions, in occurrence and in radiative heating, originating from convection and from in situ freezing driven by large-scale forcing?

At present the working group includes about 30 scientists. The first workshop was held on 16 Nov 2015 in Paris. 20 participants presented and discussed feedback hypotheses and the resources to tackle the scientific questions: 1) cloud systems and atmospheric environment from observations, 2) Lagrangian transport to determine cirrus origin and life cycle, 3) process modelling and large-scale parameterizations and 4) radiative transfer.

The analysis of large-scale convective cloud systems shows that the size of these systems is strongly linked to their convective strength.

In a first step, we intend to build a synergetic data base of high-altitude cloud systems to be used by the participants. In addition, a simulator of high-altitude cloud systems is being built for the evaluation of different formation schemes in climate models. Informal meetings will be held whenever the coordinators have the occasion (during conferences or visits); and a second official workshop is planned in fall 2016 in New York (travel support request sent after GDAP meeting 2015).

3.3 Uncertainty analysis

Uncertainty analysis is a very important aspect that needs to be addressed to make GEWEX related products useful for answering the science questions. Within Europe two distinct projects addressing the uncertainty characterisation of satellite data records (FIDUCEO) and addressing the uncertainty of

surface based reference observations and their use to characterise satellite measurements (GAIA-CLIM) have started. In addition, GEWEX data set producers and assessments have further addressed how uncertainty might be quantified in products and through comparisons with other data.

A good example for such work was the recent workshop on uncertainties in water vapor measurement at 183GHz. The workshop discussed biases observed between measurements at 183 GHz and calculations using different radiative transfer models and using either radiosondes (RAOBS) or short range forecasts from Numerical Weather Prediction (NWP) systems. There were three main objectives of the workshop: firstly to describe the biases, trying to separate those biases which were common to all approaches from those which may have been a result of a particular methodology; secondly to identify and, where possible, quantify uncertainty in every component of the comparison; and lastly, where possible to begin the process of attribution of the biases, which could in due course lead to their elimination. In order to address these ambitious goals, experts in many different aspects were assembled. This included specialists in RAOBS calibration, NWP models and data assimilation, instrument biases and radiative transfer models, both the models themselves and the underlying spectroscopy. Comparisons were also undertaken with other techniques for sensing humidity information such as Global Navigation Satellite Systems (GNSS), Differential Absorption Lidar (DIAL), Raman lidar and infrared (IR) radiances.

GDAP will continue to support such activities to achieve better overall uncertainty characterization of satellite derived data sets. ESA and EUMETSAT will conduct a workshop on uncertainty characterisation for satellite data sets in 2017.

4 Science issues

4.1 Ground-based radar data reprocessing

A necessary condition for global climatological approaches based on radar data is:

- Archiving of raw and processed radar data by institutions that operate radar networks, needs to be elevated to a similar level of commitment as obtained for (operational) satellite data. The ESGF success is a probable model for a distributed solution of such observation databases. However, the problem was somehow easier to address with a set of models, where most dimensions are complete, than with observations which present many dimensions (temporal frequency, type of variable, vertical sampling, technique of measurement, etc...). Defining a minimum set of standards for observations, without duplicating the years of work in this area, would help create observations to be discoverable and searchable by everyone. This needs to include digital object identifiers or other unique data set identifiers. GEWEX may help to implement this through WMO bodies and in direct consultation with radar operators.
- Consistent reprocessing in terms of methodology of various types of radars starting with common precipitation radars (C, S-band radars) should be achieved. This requires an initial workshop that considers the existing approaches and initializes a process that may lead to a baseline similar to what is achieved for satellite data. It is expected that nomenclature from the satellite world could be transferred to the radar data reprocessing activities.
- Data and software exchange can be key for success and the initial workshop may provide a basis for agreements on this. Currently, radar data reprocessing or climatological evaluation of radar data is performed or under consideration by different weather services or institutes, e.g. DWD, Météo France, FMI, KNMI, KMI, Meteo Swiss, and NOAA. Within Europe some approaches to combine and unify radar data on an international scale by OPERA and BALTRAD are existing but concentrate mostly on real time applications.

It is evident that this topic is a long term activity as many conditions necessary for a successful generation of radar data climatologies do not exist today. However, the example of the evolution for satellite data shows that at a scale of 10 years very useful data sets may be developed.

4.2 LANDFLUX

Developing a global sensible heat flux product is proving challenging, given the reliance on accurate and representative surface temperature data. The project requires the development of consistent surface temperature and radiation data to move forward with the integrated product. Identifying a robust and simple model for snow evaporation is also required for polar and related regions. Other science issues are highlighted in the referenced papers, but include consistency

in forcing, model parameterizations and variable model performance with biome and land-cover type.

4.3 Soil Moisture

- SMAP radar was officially given up and NASA now focuses on Sentinel-1 as replacement for SMAP radar
- Funding of International Soil Moisture Network, a satellite validation platform coordinated by GEWEX, secured only until June 2016.

5 List contributions to the GEWEX Science Questions and plans to include these

The general contribution of GDAP data products to GEWEX science questions has been evaluated to be:

GEWEX Science Questions		GDAP Projects and Products										
		GPCP/GPCC Assessment	ISCCP	GVAP	GACP AEROCOM	SRB	EBAF	Landflux	Seaflux	Soil Moisture	Groundwater Storage	Integrated Product
Observation and Prediction of Precipitation	How well can precipitation be described	y	y	y	y	n	n	n	y	y	y	y
	How do changes in climate affect the characteristics	y	c	c	c	c	n	c	c	y	y	y
	How much confidence do we have in predictions	y	c	c	c	n	n	n	n	y	y	y
Global Water Resources	How do changes in the land surface and hydrology influence water resources?	n	n	n	n	c	n	c	n	c	c	c
	How does climate change impact water resource systems?	n	n	n	n	n	n	n	n	n	n	n
	How can new observations lead to improvement in management?	p	n	n	n	n	n	n	n	p	n	p
Climate Extremes	Observing system requirements?	y	y	y	y	y	y	y	y	y	y	y
	Modelling capabilities?	u	u	u	u	u	u	u	u	u	u	u
	Modelling processes involved in extremes?	y	y	y	n	n	n	n	n	n	n	n
	Improved early warning systems?	y	c	y	u	y	n	n	n	n	n	n
Energy and water Cycles	Can we balance the budget at TOA?	n	c	c	c	c	y	n	c	n	n	c
	Can we balance the budget at surface?	y	y	y	y	y	y	y	y	y	y	y
	Can we track the changes over time?	y	y	y	y	y	y	y	y	y	y	y
	Can we relate changes and processes?	p	y	y	p	p	p	p	p	p	p	y
	Cloud-aerosol-precipitation feedback	y	y	y	y	y	y	n	n	n	n	n

Figure 1: Potential contribution of GDAP activities to GEWEX science questions; y = yes, n=no, c=contribute, u=unknown, p=potential.

5.1 Observations and Predictions of Precipitation

- GPCP and other data sets provide the baseline for addressing questions related to precipitation. The planned precipitation assessment will address some basic questions around the existing data sets. GPM provides a new observational basis for tailored data sets addressing questions associated to the PROES activities.
- GPCC's precipitation analysis products based on in-situ observed data in near real-time, as well as non real-time, contribute by improving the observational precipitation data sets (Becker et al., 2013). A combination of GPCC's daily analysis with the satellite-based HOAPS data set for 1988-2008 is done, and is in work for the Full Data Daily Analysis (V.1) for 1988-2013. In future an update of the combined data set on a yearly basis is planned.
- The envisaged activities on radar precipitation will further strengthen the ability to address question associated with the extremes GC.

5.2 Global Water Resource Systems

GDAP products do not contribute very much to this complex. However, soil moisture data sets may be used to address the question on how changes in land surface and hydrology influence water resources.

5.3 Changes in Extremes

Documenting changes in extremes requires high temporal resolution data sets. The collection of GEWEX data sets should be analysed in that respect. Surface radar could be a new source for analyzing precipitation extremes but the work needed to bring the data into a state for analysis should not be underestimated (see above). Surface temperature extremes may be easier to address as new data records on surface temperature are being made employing also geostationary satellite instruments that provide better space time sampling.

On the in situ side GPCC's new daily precipitation analyses (First Guess Daily, Full Data Daily) and the underlying daily precipitation data will help to investigate changes in precipitation extremes (Schamm et al., 2014).

5.4 Water and energy cycles

All GDAP product contribute to all questions related to the analysis of the water and energy cycles. The question of tracking changes over time or better computing trends in cycle components still represent a major challenge. This is not only because of the limited length of most satellite data time series but also due to the fact that many existing GEWEX data sets and also some new products use sub-optimal inputs of measured satellite radiances. Activities in creating so called Fundamental Climate Data Records, currently mostly pushed by international global re-analysis activities, need to be strengthened to make substantial progress.

The non real-time products Global Precipitation Climatology and Full Data Reanalysis help to determine the average precipitation over land for the period 1951-2000 (Schneider et al., 2014). Based on the continuously enlarged and improved GPCC data base new and improved versions of the non real-time products will be released in future.

6 Other key science questions that you anticipate your community would want to tackle in the next 5-10 years within the context of a land-atmosphere project (1-3 suggestions)

- What role GEWEX data sets may play in the initialization of decadal predictions. This would in particular be interesting if this becomes a Grand Challenge.

7 Briefly list any specific areas of your panel's activities that you think would contribute to the WCRP Grand Challenges as identified by the JSC (not covered under 9).

7.1 Provision of skillful future climate information on regional scales (includes decadal and polar predictability)

- Most GDAP products are 1^{o}, 3 hourly resolution and may not be suitable for many regional studies. Things like a radar precipitation climate data record would change that picture but it is a challenge. To create useful data sets for regional scale applications a better set of requirements is needed, e.g., what variables are needed and at what resolution and accuracy.
- BSRN is directly participating in the polar prediction project (http://www.polarprediction.net/yopp.html). Several BSRN stations are part of the International Arctic Systems for Observing the Atmosphere (IASOA) Radiation Working Group

7.2 Regional Sea-Level Rise

- GDAP is developing the link with CLIVAR GSOP in the Ocean Heat Concept activities to bring together TOA radiation and Ocean Heat Content estimates.

7.3 Cryosphere response to climate change (including ice sheets, water resources, permafrost and carbon)

- Not much today but CliC PROES on ice mass balance may create the need for new tailored datasets that GDAP would care for.

7.4 Improved understanding of the interactions of clouds, aerosols, precipitation, and radiation and their contributions to climate sensitivity

- Improved understanding of the interactions of clouds, aerosols, precipitation, and radiation and their contributions to climate sensitivity is supported by the GDAP Integrated Product. The data sets are made specifically to test co-variance and climate sensitivity
- ISCCP was engaged in CFMIP and continues to be, saw also usage of atmospheric motion vectors in analysis of storm tracks. Interactions of clouds, aerosols, precipitation, and radiation and their contributions to climate sensitivity was part of GDAP studying onset of precipitation and the impact of aerosols on this question. Progress is slow while global datasets are still being developed.
- As this GC has no observational component yet GDAP is very interested to interact with this GC and to support with the prediction and analysis of tailored data sets.

7.5 Past and future changes in water availability (with connections to water security and hydrological cycle)

- GDAP shall contribute to all activities related to fostering understanding of processes and model evaluation using the existing data sets but also to create problem specific data sets and in particular utilize the GPM mission.

7.6 Science underpinning the prediction and attribution of extreme events

- Addressed extremes in precipitation data sets, e.g., Lockhoff et al. (2014). Would be interesting to perform similar analysis with individual and integrated product. Need to have more intense discussion with GC on data needs to elaborate on encouraging tailored data sets for the extremes GC. The activity on radar based precipitation is clearly addressing the needs of this GC.

8 Cooperation with other WCRP projects (CLIVAR, CliC, SPARC), outside bodies (e.g. IGBP) and links to applications

8.1 WCRP Data Advisory Council

a. Surface Flux Team

SRB is participating in the new WDAC Surface Fluxes Task Team led by Carol-Anne Clayson and Brian Ward. This group shall cover land, ocean, ice, biogeochemical, heat, moisture, momentum, turbulent, radiative fluxes utilizing in situ and remote sensing observations.

Terms of References were proposed to WCRP but needed more focus and will be reiterated at next WDAC meeting in April 2016. In addition, the proposed membership needs change towards a more balanced approach (currently only European and US members).

b. Quality assessment best practises

GDAP has proposed “Data Set Quality Assessments: Needs, Benefits, Best Practices and Governance” paper (see Annex I) to WDAC which has been reviewed across WCRP programs. This paper shall provide guidance towards a more homogeneous approach towards assessments of data set quality. It is expected that it will be endorsed at next WDAC in April 2016.

8.2 Joint workshop with CLIVAR on air-sea energy exchange

Key questions addressed by the workshop:

- What are the magnitude and the uncertainties of our estimates of Earth's energy imbalance (EEI), and how does it vary over time?
- How can we improve validation requirements for and from climate models and reanalysis systems to improve estimates of EEI?
- How can we better constrain the surface energy fluxes and their spatio-temporal variations at regional scale?
- How are TOA net radiation and ocean heating rate distributed in space and time?

Key elements for GDAP:

- Complement GSOP inventory of surface flux products “assessment”-type **information regarding strengths and weaknesses** of the various flux products, in an effort analogous to the “Climate Data Guide” (NCAR/UCAR, USA)

- **Quantify different types of uncertainties** of surface fluxes, their correlation structure, sensitivity to uncertain parameters and satellite retrieval schemes to improve the usefulness of global flux products.
- **Develop an innovative ensemble approach** to generate multiple realizations of flux surface products, combining the individual strengths of existing data sets, the latest knowledge in bulk formulations and associated input data, and the most recent efforts in re-processing flux data sets of climate quality (e.g. ESA CCI)
- **Exploit integral constraints** along with statistical approaches using reconstruction of probability density functions for surface fluxes to check consistency of Net Heat Flux product components on a series of regional "Cages" (ESA-OHF)
- **Develop a community-led flux platform** to share, access and inter-compare easily 6 different sets of flux climatologies, and their input data (e.g. different SSM/I data streams), thereby fostering close collaboration between different communities, as well as new ways of combining in situ measurements and flux data

8.3 Evolving connect to obs4mips

GDAP chair continues active membership in WDAC obs4mips task team and supports open data call. Currently, only GPCP is available via the ESGF and ISCCP via the CFMIP activity including a data set simulator. The data call remains open until 31 March 2016 and all GEWEX data set projects are encouraged to submit data to obs4mips. LANDFLUX has indicated a submission already but for some groups there are still issues with the reformatting of data towards the obs4mips grid and format that may present a challenge to data producers. In addition to the GEWEX data set, some products participating in GEWEX cloud and water vapour assessments are already present or indicated for obs4mips. One issue is that although the CMIP experiments are defined the data needs for some of them remain not well known. More communication between CMIP and obs4mips is initiated via the CMIP panel chair (Veronika Eyring) to create more contacts of individual MIP leaders and data set providers.

8.4 Connect to WMO SCOPE-CM activities on ISCCP, geostationary surface albedo

The WMO Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring initiative continues to host ISCCP data processing at NOAA NCEI which is supported by several data centers (mostly space agencies) delivering the needed input data for ISCCP. Other links between GEWEX data sets and SCOPE-CM could not be fostered during 2015. However, SCOPE-CM will discuss in 2016 which new projects requiring international collaboration should start. A hot candidate is certainly precipitation because GPCP needs a similar set of inputs as ISCCP and within Europe new initiatives towards global precipitation climate data records will be funded by EUMETSAT from 2017 onwards.

8.5 Reporting to International Radiation Commission

GDAP and BSRN reported to the International Radiation Commission (URC) in 2015 as part of the IUGG conference in Prague. However, not much feedback was received on GDAP from the presentation. IRC continues to think about the reporting style with no decision taken for 2016.

9 Workshops/meetings held

a. Joint workshop on uncertainties at 183GHz 29 - 30 June 2015, Paris, France
b. GDAP Annual meeting, 29 Sep – 1 Oct 2015, Xiamen, China;
c. Workshop CONCEPT-HEAT, 28 Sep – 1 Oct 2015, Exeter, UK
d. 5th GEWEX Water Vapor Assessment Workshop, 4-5 November 2015, University of Wisconsin, Madison, USA
e. ISSI Workshop on soil moisture, November 2015, Bern, Switzerland;
f. 1st GEWEX UTCC PROES Workshop 16 Nov 2015 in Paris, France.

10 Workshops / meetings planned. Include travel support needs anticipated (for WCRP). Include tentative meetings planned up to 2 years (for IGPO planning purposes)

a. Participation in 6th session of WDAC, 7 and 8 April 2016, NOAA NCEI, Asheville, USA, no support needed.

b. 14th BSRN Science and Review Workshop, 26-29 April, 2016, Bureau of Meteorology, Canberra, Australia, sponsoring through GEWEX and GCOS has been agreed;
c. ESA CCI soil moisture user workshop, 28-29 April 2016 at ESA ESTEC, no travel support needed;
d. 2nd GEWEX UTCC PROES Workshop, planned for fall 2016,New York, USA, travel support request was sent to GEWEX office after GDAP meeting 2015;
e. GDAP Annual meeting, GEWEX Office, Washington D.C, October/November 2016, travel support for some membership candidates needed
f. Kickoff workshop for precipitation assessment, combination with GDAP meeting in DC area, October/November 2016, travel support for some participants might be needed;
g. A first workshop bringing together experts in the field of radar reprocessing is anticipated for 2017, time is still open, location will be Europe or USA, travel support will certainly be needed;
h. ESA-EUMETSAT workshop on uncertainty characterisation in satellite data records, 2017, Europe, travel support for some participants from Asia and USA.

11 Other meetings that were attended on behalf of GEWEX or your Panel

Project results have been presented at a number of international meetings including EGU, IUGG, ESA Earth Observation for Water Cycle Science conference, MODSIM and AGU.

12 Issues for the SSG

12.1 Maintanance of the BSRN Archive at the World Radiation Monitoring Center

The current Director of the World Radiation Monitoring Center (WRMC, http://bsrn.awi.de/), Dr. Gert König-Langlo is retiring as of May, 2017.The WMRC is the central archive of the Baseline Surface Radiation Network (BSRN) data. WRMC and BSRN Archive have been hosted at the Alfred Wegener Institute following the endorsement of an agreement of (and attendant funding from) the AWI Director, Dr. Peter Lemke in 2007. Gert König reported to GDAP that so far he has not received any promise from the current AWI Director, Prof. Dr. Karin Lochte, to provide the required post-doc position, etc. after his retirement to continue the WRMC/BSRN Archive. A well-trained and excellent person ready to take over is available: Dr. Amelie Driemel who is already working for the WRMC/BSRN as data curator. Thus Gert König is asking for a letter of support to convince the director of AWI Prof. Dr. H.C. Karin Lochte (http://www.awi.de/en/aboutus/organisation/management.html) to host the World Radiation Monitoring Center of the Baseline Surface Radiation Network (http://www.bsrn.awi.de/) beyond his retirement in May 2017.

Gert König suggests that the more letters of support sent from WMO persons of import such as the BSRN Project Manager), the GDAP chair (as BSRN Science Chair), Carolin Richter (as the Director of the GCOS Secretariat), Stefan Rösner (as the German GCOS coordinator), Peter van Oevelen (as Director of the GEWEX Project Office), Dawn Erlich (as assistant to the GEWEX director), and as many others of note as we can muster to convince Dr. Lochte and AWI that their continued hosting of the BSRN Archive is very much appreciated and needed.

GDAP thinks that we may write one support letter from GEWEX signed by the GEWEX chairs, GEWEX Office Director, GDAP chair and BSRN Project Manager. In addition, we should try to muster support letters from the users of BSRN data, e.g., producer of the SRB data set and similar.

If AWI decides not to continue we will have to find some other organization to host it, and in the process would possibly lose all the wonderful progress that Gert König and his crew have accomplished since 2007, including the Pangea data base distribution system, BSRN Toolbox software for data quality assessment and data extraction, and the wonderful Web site they have built and maintain. If we cannot get an endorsement and agreement from AWI in place before, then we will have to look for an alternate host during the upcoming BSRN Workshop in Canberra 26-29 April 2016 just in case a renewed endorsement from AWI does not happen prior to Gert König's retirement.

13 List of key publications (*where appropriate*)

1. Gruber, A., Su, C.-H., Zwieback, S., Crow, W., Dorigo, W., Wagner, W. (2016). Recent advances in (soil moisture) triple collocation analysis. International Journal of Applied Earth Observation and Geoinformation, 45, part B, pp 200-211, doi:10.1016/j.jag.2015.09.002

2. McCabe, MF, Ershadi A, Jimenez C, Miralles DG, Michel D and Wood EF (2015). "The GEWEX LandFlux project: evaluation of model evaporation using tower-based and globally-gridded forcing data." Geosci. Model Dev. Discuss. 8(8): 6809-6866.
3. Michel, D, Jiménez C, Miralles DG, Jung M, Hirschi M, Ershadi A, Martens B, McCabe MF, Fisher JB, Mu Q, Seneviratne SI, Wood EF and Fernández-Prieto D (2015). "The WACMOS-ET project – Part 1: Tower-scale evaluation of four remote sensing-based evapotranspiration algorithms." Hydrol. Earth Syst. Sci. Discuss. 12(10): 10739-10787.
4. Miralles, DG, Jiménez C, Jung M, Michel D, Ershadi A, McCabe MF, Hirschi M, Martens B, Dolman AJ, Fisher JB, Mu Q, Seneviratne SI, Wood EF and Fernaìndez-Prieto D (2015). "The WACMOS-ET project – Part 2: Evaluation of global terrestrial evaporation data sets." Hydrol. Earth Syst. Sci. Discuss. 12(10): 10651-10700.Raschke, E., S. Kinne, W. B. Rossow, P.W. Stackhouse, Jr., and M. Wild et al., 2015: Comparison of radiative energy flow in observationl datasets and climate modeling [accepted to JClim]
5. Stackhouse, P.W., Jr., A.J. Soja, J.C. Mikovitz, T. Zhang, A. Tsvetkov and D.J. Westberg, 2015: Long-term radiation budget variability in Northern Eurasia: potential for assessing variability during the fire season (submitted ERL, Sept. 2015).

This list may not be comprehensive.

14 List of members and their term dates (including changes) where appropriate:

Joerg Schulz	2010 – 2017 (Chair)
Matthew McCabe	2008 – 2017 (Vice-Chair)
Wouter Dorigo	2013 – 2017
Carlos Jimenez	2010 – 2017
Christian Kummerow	2014 – 2017
Felix Landerer	2013 – 2015
Norman G. Loeb	2005 – 2015
Hirohiko Masunaga	2010 – 2017
Axel Schweiger	2008 – 2015
Sonia Seneviratne	2008 – 2015
B.J. Sohn	2007 – 2015
Claudia Stubenrauch	2007 – 2016
Susan Van den Heever	2008 – 2015
Tianjun Zhou	2011 – 2017
Andrew Heidinger	2012 – 2016

Newly proposed candidates for 2016-2019

Ali Behrangi (NASA JPL), precipitation, link to extremes GC

Myoung Hwan Ahn (Ehwa University, Korea) remote sensing expert

Shinya Kobayashi (JMA, Japan) reanalysis, data assimilation

Diego Miralles (University Gent, Belgium) land surface fluxes, GLEAM model

Rémy Roca (LEGOS, France) energy and water cycle science

Mathew Rodell (NASA GSFC) water budget, water storage

Philip Stier (Univ. Oxford, UK) global modeling, radiative transfer, data

Nick Schutgens (Univ. Oxford, UK) data assimilation, data, modeling, radiative transfer

Christopher Taylor (Centre for Ecology & Hydrology, UK) land surface modeller with increasing interest in observations

The proposed candidates will rejuvenate GDAP, but it is evident that a couple of candidates from USA need to be added to this list. The SSG is invited to make proposals.

Annex I

Data Set Quality Assessments: Needs, Benefits, Best Practices and Governance

Jörg Schulz, EUMETSAT, Chair GEWEX Data and Assessment Panel

Peter Gleckler, Lawrence Livermore National Laboratory

and many WCRP contributors hereby deeply acknowledged

1. Introduction

This document addresses the need for systematic assessments of the quality of data sets used in various applications such as climate services as well as climate science, including their use in the evaluation of climate model performance. The purpose of this document is to initiate a discussion within WCRP as to how the core projects, working groups and WCRP Grand Challenges can initiate data set quality assessments in a more coherent way, ensuring that the outcomes of assessments are beneficial for their own activities and also for activities across WCRP.

The scope of this discussion paper is limited to a description of the general benefits, high level practices, and potential governance structures for data set quality assessments. Detailed best practices are not included as part of this document because they depend too much on the actual physical system and data sets that are being assessed. The document is entirely based on experience garnered from conducting data set quality assessments for more than two decades within several WCRP core projects.

The document provides a brief description of the background from which the need arises and a short, but not exhaustive history of data set assessments as they were performed in GEWEX, CLIVAR, SPARC and elsewhere. It then lists the currently known types of assessments and the benefits that were drawn from them. The last set of sections proposes high-level best practices and addresses funding needs and governance issues.

2. Background

Climate variability and long-term changes in climate pose significant challenges to societies. The availability and communication of climate information through climate services significantly supports prevention of economic setbacks and humanitarian disasters. In addition, climate services play a critical role in national development planning, managing development opportunities and risks, and in mitigating and/or adapting to changes in climate. To provide authoritative information to all of these areas it is necessary to develop the best possible understanding of the quality of climate observations and derived products. Formalized, impartial, data set quality assessments are one way to analyse the fitness-for-purpose of climate data sets and can play a crucial role in the acceptance process of climate data products for climate services.

Comprehensive assessments of the physical science basis of climate change conducted by the Intergovernmental Panel on Climate Change (IPCC) refers to detailed scientific assessments of observations of various aspects of the climate system, with dedicated consideration of specific areas such sea level change, biogeochemical cycles, clouds and aerosols, and regional climate phenomena. Measurements are used to assess the status of the climate and to evaluate climate model simulations for the past to build confidence in model projections for the future. The use of measurements throughout the IPCC report is based on peer-reviewed publications about the individual climate data records (CDRs) and sometimes on comparison of CDRs. The IPCC Working Wroup I report (IPCC, 2013), in particular chapter 2, provides comparison of a limited number of data records whereby the selection of particular CDRs depends on the expert knowledge of the authors. Only in one case does the IPCC refer to a publication related to a WCRP GEWEX assessment which is the cloud data set assessment (Stubenrauch et al., 2013). IPCC assessments reveal important geographical and temporal gaps in

observations, understanding of system processes, and confidence in observations and projections themselves. However, IPCC assessments could, and should, make much more extensive use of community-wide assessments of the quality of existing CDRs, which could be provided under the leadership of WCRP, in particular the WCRP Data Advisory Council (WDAC).

A specific activity to facilitate the comparison of satellite observations with climate model data is the Observations for Model Intercomparisons (Obs4MIPS) initiative that makes observational data products more accessible for comparisons (Teixera et al., 2014). Obs4MIPS has organised a collection of well-established and documented data sets that have been organized according to the 5th Coupled Model Intercomparison Project (CMIP5) model output requirements and made available through the Earth System Grid Federation (ESGF). The technical alignment of data sets and model output fields is a key element that facilitates the comparison of model data and observations. In addition, Obs4MIPS has created a standardised documentation that is of particular relevance for model evaluation.

The Obs4MIPS activity was initiated by NASA but there are opportunities for contributions from a broader community. The broadening of the community is organised under the umbrella of WDAC by the establishment of a specific Obs4MIPS task team. Ferraro et al. (2015) have summarised the status of the evolution of Obs4MIPs in support of CMIP6. One particular challenge that arises from extending this activity is the management of many more data sets, including multiple data sets for the same model output field and their quality assurance. This calls for a process that allows the provision of information about the quality of data sets included in the Obs4MIPS portfolio. Data set quality assessments, if performed efficiently, could be an attractive activity that provides this information in a systematic way for the full Earth system. Thus, it is important to consolidate standards and high-level practices across WCRP for CDR assessments.

Alongside WCRP activities, space agencies have started a collaborative effort to formulate a so-called architecture for climate monitoring from space (Dowell et al., 2013). This should facilitate the development of an end-to-end system capable of delivering the necessary space-based observations for climate monitoring from space. One of the initial steps was to establish an inventory of CDRs of Essential Climate Variables (ECVs) as defined by the Global Climate Observing System (GCOS). Such an inventory can be used to analyse gaps in this value chain, starting from satellite measurements and ranging to the information provided to decision/policy makers as outlined in the architecture (Dowell et al., 2012). This includes the production and evaluation of CDRs which require a careful assessment of the scientific quality so as not to provide wrong or misleading information downstream. The joint CEOS-CGMS Working Group Climate has started to consider how such quality assessments may be conducted and who could contribute to them. It is obvious that a multitude of differently organised research structures may be able contribute but leadership of WCRP through WDAC may be envisaged for this undertaking.

Comprehensive data set quality assessments are critical to move science forward in a systematic way. Trenberth et al. (2014) stated that: "*Originally the task was getting a single time series of an ECV. Now there is a proliferation of multiple datasets purporting to be "the correct one". Many are created for specific purposes but all differ, often substantially, and the strengths and weaknesses or assumptions may not be well understood or well stated. Consequently, assessments are required to evaluate these aspects and to help improve the datasets.*"

In a cycle of quality assessment and reprocessing of data sets, the analysis of data products in direct comparison to reference data, with respect to their consistency with other data sets, e.g., in representing a part of the energy or water cycle, and/or in comparison with model output data always reveals differences that point to particular weaknesses in certain data sets. More importantly, this can also point to limitations in our capability to perform measurements with the required accuracy and/or sampling. In addition, assessments reveal limitations in our understanding of the measurement process in general, that is, the assignment of traceable uncertainties and our understanding of physical processes that are essential to convert measurements into derived data products. This is particularly true for satellite data sets.

Assessment activities often bring together a critical mass of research groups that analyse deficits and work on improvements of methodology to analyse measurements and the improvement of these measurements, e.g., by defining new satellite missions that address specific deficits in our knowledge.

The following outline for data quality assessments is based partly on experiences gained from the GEWEX Data and Assessments Panel (GDAP; formerly the GEWEX Radiation Panel), described in Kummerow et al. (2012), and from similar SPARC and CLIVAR activities.

3. History of Quality Assessments

GEWEX promotes the assessment of existing data products to adequately characterise each product and its strengths and limitations for various uses. GDAP conducted several data assessments that were related to the establishment of an observations-based estimate of the energy and water cycle over the last decade.

Three quality assessments were finalised: precipitation (Gruber and Levizzani, 2008), radiation fluxes (Raschke et al., 2012), and cloud properties (Stubenrauch et al., 2012, Stubenrauch et al., 2013). Several others are ongoing: aerosol properties, turbulent fluxes over the oceans (SEAFLUX) and land surfaces (LANDFLUX), as well as water vapour. The motivation for these assessments has developed from studying the limits of applicability of a GEWEX data record (precipitation) to real multi-data record comparison exercises (e.g. on radiation, clouds, water vapour, and heat fluxes). All quality assessments were done to determine which data product is best suited to a particular purpose or how a data product could be developed to become applicable in energy and water cycle studies at different space and time scales. Most of the GEWEX assessments concentrate on satellite-derived data records with the exception of the precipitation assessments that also consider rain gauge data because they are used to calibrate satellite precipitation data records.

Prior to the GEWEX activities, an assessment was performed by SPARC, focusing on upper troposphere/lower stratosphere (UTLS) water vapour (Kley et al., 2000) with the goal of analysing and assessing long-term changes in UTLS water vapour, with an emphasis on the observed increase of water in the stratosphere. SPARC is currently working on an update of this assessment using the improved knowledge and observations from the past 10 years.

The assessment activities of GEWEX and SPARC cover only a small fraction of CDRs needed to fully characterise changes in the Earth system but may function as a nucleus for more extensive systematic assessment activities in other domains. In addition to GEWEX and SPARC, assessment activities have also started in other areas, in particular the oceanic research community. For instance, the International Ocean Colour Coordination Group (IOCCG) sponsored by the Scientific Committee on Oceanic Research (SCOR) and the Global High Resolution Sea Surface Temperature (GHRSST) Climate Data Record Technical Advisory Group, with their associated CEOS so called virtual constellations on Ocean Colour Radiometry and Sea Surface Temperature, have started to develop coordination structures in which data record assessments can be performed.

The Climate and Ocean: Variability, Predictability and Change (CLIVAR), in particular through the Global Synthesis and Observations Panel (GSOP), has long been promoting and coordinating assessments of various data sets including for example:

- In-situ data sets of sub-surface ocean temperature through the efforts of the International Quality Controlled Ocean Database (IQuOD) [www.iquod.org]. New data sets of sub-surface salinity and oxygen are foreseen,
- Satellite products used for climate studies, such as ocean surface wind, air-sea fluxes (Josey, 2006, Yu et al., 2012, www.oceanheatflux.org)
- Ocean synthesis products, including inter-comparison efforts through the Ocean Reanalysis Intercomparison project (ORA-IP) Joint intercomparison of ocean synthesis & forward model simulation and the EU COST project Evaluating Ocean Syntheses [www.eos-cost.eu].

Members of the CLIVAR community have been actively involved in quality and consistency assessments of ocean vector wind measurements as coordinated by the International Ocean Vector Wind Science Team for ocean surface wind stress measurements from different satellite platforms (Ku-, C-, and L-band scatterometers), and in assessments of satellite measurements of sea surface salinity by the salinity remote sensing community (SMOS, Aquarius, SMAP).

CLIVAR has routinely used these data sets to advance our understanding of the ocean-atmosphere interactions and in particular the role of the ocean. More recently, CLIVAR has established a new research focus on “Consistency between planetary energy balance and ocean heat storage (CONCEPT-HEAT)” aiming to better close the Earth’s energy budget. In particular, the CONCEPT-HEAT initiative aims to reconcile different and independent estimates of energy flows derived from independent observing systems, including Argo buoys, in-situ networks, models and satellites, with different sampling

capability and accuracy. This innovative initiative will provide new insight into diverse independent data sets related to energy flows, thereby providing scientists with a unique holistic insight.

Discussions among representatives from different communities facilitated by the CEOS-CGMS Working Group Climate revealed many commonalities in current activities, e.g., emerging similar practices of providing estimates of uncertainty, but also important differences, in particular in the specific aims of assessment activities.

4. Assessment Types and Potential Benefits

Data record 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 used or misinterpreted. On the other hand, users need to realise that it is often difficult to define a single best CDR. CDRs are instead most often complementary in nature with varying strengths and weaknesses depending on the nature of the application and depending on the observing system used to construct the CDR. For instance, the retrieval of basic cloud properties depends on the sensor channel wavelengths as demonstrated in the cloud assessment of Stubenrauch et al., 2013.

The primary goal of a quality assessment is to highlight differences and limitations of CDRs and, if possible, to justify all aspects of the assessment. Such assessments should become part of the peer-reviewed literature (open access journals preferably) and be distributed as widely as possible, e.g., in ECV inventories, commentary meta-data tools, web portals, etc.

Panels such as GDAP currently consider two types of assessments that are valuable to user communities:

1. **Development of review articles on CDRs considering specific science aspects extending from process understanding to trend analysis, specific geophysical variables (e.g., GCOS ECVs), or topics of importance for IPCC climate assessments. Such review articles could be written by a group of selected experts and reviewed by the panel members not involved in writing the article and journal reviewers. The results can be of immediate use, for instance to IPCC report authors. This also avoids the restrictive approaches on data selection for IPCC reports and provides balanced and peer-reviewed judgement of existing knowledge;**
2. **Dedicated CDR quality assessment projects that perform a scientific analysis of existing CDRs and publish the results in peer-reviewed literature.**

Type 1 assessments may follow cycles of IPCC assessments and can also point to the need for a type 2 assessment, e.g., if the available information for a review article is insufficient and/or incomplete.

Type 2 assessments should not be viewed as static but rather as dynamic activities that are ongoing and provide outputs at regular intervals, e.g., every 2 years. The reporting should contain updates resulting from updated and/or new CDRs, as well as consideration of specific topics, e.g., precipitation in mountainous regions that is hard to observe.

CDR quality assessments are beneficial to science, applications, as well as CDR providers. For the science and user communities, assessments:

- **provide independent and transparent quality assurance of CDRs;**
- **endorse the use and credibility of CDRs for a broader community;**
- **identify key limitations in CDRs to stimulate improvements;**
- **allow objective selections of appropriate CDRs,**

and for the data record providers the assessments:

- **provide background information on available CDRs;**
- **provide easy access to data in a common user-friendly format;**
- **establish reference data test-beds and tools for external evaluations that can be reused.**

In addition, as many CDRs source data from multiple satellite programmes, the data quality assessments also contribute to an assessment of the strengths and weaknesses of the current observing system. This provides useful guidance on development needs of the future observing system, which is, for example, part of the CEOS-CGMS WG Climate tasks.

5. High Level Best Practices

15 Generalisation of assessment best practices is sometimes impractical and may not be useful. However, converging on common practices in some areas can ensure a similar level of evaluation of the quality of CDRs. These records may cover various aspects of the Earth climate system and may include many types of measurements (ground-based, satellite-based, in-situ and derived products that may combine measurements from multiple sources) as well as data from reanalyses. To make assessments comparable it is important to agree on some high level principles:

1. **While assessments should include the creators of the CDRs being assessed, the assessment team needs to extend well beyond that group so as to avoid data products being evaluated favourably by the developers to encourage data use;**
2. **Assessments need to target well-developed expectations of CDRs such as those documented in GCOS-143 or those encapsulated in the GCOS Climate Monitoring Principles. By ensuring that each assessment targets these key requirements on CDRs, each assessment will have a similar structure and the user community will develop clear expectations of what assessments will encompass. However, the structure should not be so restrictive as to prevent the publication of results unique to the assessment. Every assessment must, at the very least, document the scientific utility of the CDR being assessed as well as the characterisation of uncertainties in the CDR;**
3. **A lexicon of best practices to create CDRs also including practices on data comparisons and nomenclature used for characterising uncertainties;**
4. **Metrics to assess how far best practices have been followed.**

These four principles should be adhered to any group performing an assessment.

1. **Under general procedures, it is understood that each assessment should be hosted by a scientific body to whom the group performing the assessment reports, and who would be responsible for the assessment report. As mentioned above, the assessment is tasked to conduct objective and independent evaluations and inter-comparisons. It is advantageous to involve the scientists that created the CDRs so that sufficient background information on the instruments providing the measurements, applied methods, and underlying assumptions and limitations can be captured in detail and conveyed to the user. However, to ensure independence, independent experts need to be included in the assessment team to prevent biases in the reporting of results for specific CDRs, e.g., by selection of a particular comparison metric, reference data, or physical range of parameters. Although this is not easy, various groups have achieved such level of independence through various processes, such as reporting to a governing panel/project or via external review.**

   Another aspect of involving product developers in an assessment is the 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 data products. Although this is a clear benefit for the data producers and may ensure their participation, it has been found that while these two objectives are compatible, they should always be kept distinct in the assessment so as to keep the assessment manageable. Thus, in general, a data quality assessment should concentrate on providing information to the science and user community first, and then move to updates of the various data sets considered outside of the assessment.

2. **As a general structure, an assessment of climate data records should always cover the following elements:**
   - **A survey of available CDRs with their related background information;**
   - **A quantitative intercomparison against reference data (especially if data of higher accuracy and/or maturity are available), if available, to elucidate the strengths and weaknesses of the CDRs being assessed;**
   - **Comparisons of different CDRs at different temporal and spatial scales. GDAP has found that including model and reanalyses data sets in the comparisons is often useful in that it immediately incorporates the needs of an eventual user community;**
   - **Recommendations for intended CDR uses and identification of areas for which data should not be applied;**

- **Open, full, and easy access to the assessment report and all examined CDRs[1] and methods.**

With regard to the last item, it has been found that even if the validation data, procedures, and previously assessed data are archived for interim use, comprehensive assessments are critical to move the field forward in a systematic way.

Furthermore assessments should include:

- **A dedicated, motivated, and respected expert or group of experts to lead the effort;**
- **Assessment team members with individual, but complementary, specialized knowledge;**
- **Regular team meetings – open and closed workshops;**
- **A centralized data repository created specifically for the assessment (e.g., validation data or common gridded products) that can be used to facilitate assessments with new products or new versions of existing products.**

3. **A charter of best practices to ensure coherent use of nomenclature should be developed and hosted by a sub-group of WDAC. Such a lexicon would need to be coordinated with other bodies such as GCOS and the CEOS-CGMS Working Group Climate. Such a development could benefit from on-going initiatives such as QA4EO and related projects such as the European QA4ECV project.**
4. **A procedure to assess the extent to which best practices have been followed in generating the CDRs is useful in the survey of available CDRs and also helps to keep the assessment activity manageable by concentrating on CDRs of a certain maturity. Progress on such metrics, for example based on the work published by Bates and Privette (2012), has been made in projects such as the European Union project CORE-CLIMAX (CORE-CLIMAX, 2015).**

In addition to the described best practices, each assessment needs to have a strategy for the dissemination of its results and how to make an impact on the scientific community. The classical way of peer-reviewed publications and a WCRP report remains important because it ensures a proper review. However, the WCRP core project web appearance should put stronger emphasis on assessment activities and results. Data catalogues from data providers could be enhanced with tools providing commentary meta-data for a data set, e.g., those developed in the EU CHARMe project. These can point to assessment results and also databases used in the assessment. In addition, the Obs4MIPS platform can also serve as a good means to disseminate the results, at least for those data sets of potential use in climate model evaluation. Finally, other suitable online platforms such as the NCAR Climate Data Guide can be used for better dissemination to the community.

6. Needs for Funding

Past and current assessment activities usually relied on pure voluntary efforts, and thus can take considerable time to finish and can even collapse without strong leadership. Within GDAP several assessments took a very long time (>10 years), a timespan far too long to address the needs of such assessments. Full funding of assessment activities is out of the scope of most funding agencies, however, ideally some seed funding for centralized activities, e.g., on a centralised data depot and initial workshops should be provided to establish the assessment. A good recent example is the setup of the GEWEX water vapour assessment, for which ESA sponsored an initial workshop and EUMETSAT is funding central activities for about two years through its Climate Monitoring Satellite Application Facility (CM SAF). This allows the assessment to advance and keeps the participants together and active.

It is recognised that funding practices strongly differ across the globe but the membership of WDAC, including the CEOS-CGMS WG Climate (representing space agencies), can certainly help to improve the situation if convincing cases for assessments are brought forward. Such cases could be taken up by existing national and international programs, such as the NOAA Climate Data Record Programme, NASA Measures, ESA Climate Change Initiative, EUMETSAT SAFs, and other initiatives.

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[1] Some data will not be hosted in one place because of high data volumes. Thus, easy access is fulfilled if the data are readily accessible via internet without needing special permission.

7. Governance Aspects

A couple of relevant questions related to the governance of assessments are:

- **Who should initiate an assessment?**
- **Who should organise it?**
- **Who should undertake the assessment?**
- **Who should evaluate quality assessments?**

Currently, there is no overall coordination of data record quality assessments related to GCOS ECVs; energy, water, and matter cycles; or other topics of importance to the IPCC. Assessments are often initiated and performed by specific scientific or other organisational bodies that represent both users and developers. The aims of these assessments range from providing objective information to the scientific community about the status of data records to more ambitious goals such as making trend estimates and using the data record comparison as a means to find or create the best data record for a specific purpose. Data record assessments are much more common in communities and bodies that work with satellite data compared to those related to in situ data records.

It is suggested to initiate data record quality assessments by any scientific or organisational body that identifies a need for such an assessment. However, the assessment then needs a 'harbour in which to anchor', to ensure support and an independent review.

Within WCRP the Core Projects may task relevant panels or groups of experts to act as initiator, organiser, and reviewer of data record quality assessments following the model set out here For assessments requested from outside, e.g. from the CEOS-CGMS Working Group Climate, WCRP should play a critical role in performing them; WDAC could become the known receiver of such requests and can help to channel it within WCRP. WDAC could also play an important role for developing a prioritisation of assessment needs to guide funding agencies in their support of assessments.

The organisation of an assessment is best placed at the level of panels or activities within WCRP core projects, because this is the place where scientific knowledge is concentrated and lead scientists for assessments can most easily be identified.

Scientific groups undertaking assessments should be formed in an open way to assure broad participation, however, attention should be paid to the selection of data records so as not to end up with only once-off activities that are of limited value to users. The scientists leading the assessment need to report to the group overseeing the particular activity/panel at regular intervals, e.g., annually. This group, for example a core project's Scientific Steering Group (SSG) would then report to the WCRP Joint Steering Committee (JSC).

Organisation of assessments will not be restricted to WCRP since other domain/topic-specific bodies (e.g., CGMS working groups as ITWG, IPWG, CEOS Virtual Constellations) exist that may organise their own assessments.

The role of WDAC should be to oversee assessments performed within and outside of WCRP, in particular pointing out where assessments potentially lack in critical areas for science, the IPCC, and climate services. The WDAC membership is ideally positioned to do this in coordination with GCOS and the space sector. WDAC could establish an inventory of assessments that could be provided to various bodies such as the WCRP JSC.

By identifying area where assessments are lacking, WDAC can also act as the initiator of data quality assessments, which may, at a later stage, be performed by WCRP core projects. WDAC should also be active in supporting the funding of data quality assessments since this is vital to ensure the success of these assessments. In addition, WDAC could organise the collection and publication of best practices for climate data record generation.

8. Conclusion

This document provides an outline for data quality assessments explaining the needs, benefits, high level best practices, and a potential light governance structure. It is mostly based on experiences from the GEWEX Data and Assessments Panel, but also refers to more recent discussions among space agencies on the architecture for climate monitoring from space where quality assurance is a very important topic.

WDAC is invited to take note, discuss, provide feedback, and lay out a way forward.

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10. Glossary

CEOS	Committee on Earth Observation Satellites
CGMS	Coordination Group of Meteorological Satellites
CHARMe	European Union Framework 7 Project on commentary metadata and tools

	(charme.org.uk)
CLIVAR	Climate and Ocean: Variability, Predictability and Change (core project of WCRP)
CMIP	Coupled Model Intercomparison Project
CM SAF	EUMETSAT Satellite Application Facility on Climate Monitoring
CORE-CLIMAX	European Union Framework 7 Project in the context of Climate Services (www.coreclimax.eu)
ECV	Essential Climate Variable (defined by GCOS)
ESA	European Space Agency
ESGF	Earth System Grid Federation
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GCOS	Global Climate Observing System
GDAP	GEWEX Data and Assessment Panel (former GEWEX Radiation Panel)
GEWEX	Global Energy and Water Cycle Exchanges (core project of WCRP)
GHRSST	Global High Resolution Seas Surface Temperature (international open group for SST data producers, users, and scientists)
GSOP	Global Synthesis and Observations Panel (CLIVAR panel)
IOCCG	International Ocean Colour Coordination Group (affiliated programme of SCOR)
IPWG	CGMS International Precipitation Working Group
IPCC	Intergovernmental Panel on Climate Change
ITWG	CGMS International TOVS (TIROS Operational Vertical Sounder) Working Group
JSC	Joint Scientific Committee (highest scientific body of WCRP)
LANDFLUX	GDAP project on turbulent heat fluxes over land surfaces
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
Obs4MIPS	Observations for Model Intercomparisons
QA4EO	Quality assurance framework for earth observation (QA4EO has been endorsed by CEOS as a contribution to facilitate the GEO vision for a Global Earth Observation System of Systems (GEOSS).
QA4ECV	European Union Framework 7 Research project on establishing a Quality Assurance Framework for Climate Data Records (www.qa4ecv.eu)
SCOR	Scientific Committee on Oceanic Research
SEAFLUX	GDAP project for turbulent heat fluxes over ocean
SPARC	Stratospheric-tropospheric Processes and their Role in Climate (core project of WCRP)
SSG	Scientific Steering Group (sub body of WCRP core projects that reports to the WCRP JSC)
UTLS	Upper Troposphere Lower Stratosphere
WCRP	World Climate Research Programme
WDAC	WCRP Data Advisory Council