GEWEX Data and Assessments Panel (GDAP) Meeting

Boulder, Colorado, USA
9–12 October 2017

Rémy Roca[1] and Tristan L'Ecuyer[2]
[1]Laboratoire d'Etudes en Geophysique et Oceanographie Spatiales, LEGOS, Toulouse, France; [2]University of Wisconsin-Madison, Madison, Wisconsin, USA

The annual meeting of GDAP was hosted by Kevin Trenberth at the Mesa Laboratory of the National Center for Atmospheric Research. The meeting began with a special one-day workshop to coordinate the GEWEX and Climate and Ocean Variability, Predictability and Change (CLIVAR) research focus on planetary heat balance and ocean heat storage (CONCEPT-HEAT) activities centered upon documenting the Earth's energy imbalance. The main goals of the GDAP meeting were to: (1) obtain updates on all GDAP-sponsored ground sites [e.g., Global Precipitation Climatology Centre (GPCC) and Baseline Surface Radiation Network (BSRN)] and data sets [e.g., Surface Radiation Budget (SRB), Global Precipitation Climatology Project (GPCP), SeaFlux and LandFlux]; (2) establish plans for completing the currently open aerosol and cloud assessments; (3) re-scope the precipitation assessment; (4) discuss progress toward the GEWEX integrated data product (5) initiate a new paradigm of integrated budget closure assessments; and (6) establish GDAP's role in supporting crosscutting GEWEX activities like the Process Evaluation Study (PROES). Discussions focused on defining additional goals and directions for GDAP under the new leadership of its co-chairs, Rémy Roca and Tristan L'Ecuyer.

CONCEPT-HEAT Meeting

The joint meeting between GDAP and CLIVAR's CONCEPT-HEAT working group led to a better understanding of the different perspectives of these two WCRP communities regarding the important topic of quantifying the Earth's energy imbalance (EEI), which is the most fundamental driver of climate change. Quantifying global EEI and its regional and temporal variations requires a coordinated effort to integrate the best available observational data sets using modern methodologies. CONCEPT-HEAT, GDAP and the sea level community have all made progress toward this goal. Kevin Trenberth, Graeme Stephens and Detlef Stammer provided updates on each group's activities. CONCEPT-HEAT efforts have centered on establishing best estimates of changes in global ocean heat content (OHC), establishing consistency between OHC and top-of-atmosphere (TOA) radiation measurements and mapping air-sea fluxes as a residual using atmospheric and oceanic reanalyses. GEWEX integrative EEI activities have advanced primarily through GDAP, and specifically, the new Integrated Product. For more than three decades, GDAP (formerly the GEWEX Radiation Panel, GRP) has supported atmospheric and surface flux data sets and assessed their accuracy, and these activities are transitioning into fully integrated energy and water cycle assessments. The CLIVAR-sponsored sea-level budget initiative is addressing the specific problem of improved estimation of changes in OHC through analogous budget approaches. Benoit Meyssignac and Steve Nerem presented encouraging results from an effort to combine surface altimetry (e.g., Jason), terrestrial water storage (e.g., Gravity Recovery and Climate Experiment, GRACE) and in situ observations (e.g., Argo) to derive an integrated picture of the linkages between sea level change and EEI. Meyssignac emphasized the the associated uncertainties (see figure on next page).

Results presented by Carol Anne Clayson, Mathias Hauser, and Isabel Trigo reflect the progress toward establishing global estimates of land and ocean heat and moisture fluxes, and also highlighted the need to reduce structural uncertainties in these data sets. New variational methodologies that blend gridded flux observations with transport constraints show promise for advancing estimates of ocean basin-scale energy imbalances with associated uncertainty estimates. However, some key open questions remain that are particularly germane to GDAP objectives: *how do we move beyond using spreads between products as measures of uncertainty? What accuracy should the new integrated EEI activities be striving for? And what spatial and temporal analysis scales are realistically supported by current data sets?* These questions are, in part, motivated by the target audience for new EEI estimates. Andrew Gettelman pointed out the value of EEI and ocean-atmosphere heat exchange constraints, noting that many climate models still exhibit imbalances in TOA radiation of 2 Wm^{-2} or more. Bill Frey provided additional motivation for quantifying regional EEI and ocean-atmosphere exchanges by observing that models suggest that ocean heat uptake at mid-latitudes may exert a strong buffer reducing the influence of cloud feedbacks on climate sensitivity. Accurate estimates of EEI on regional scales may enable decadal-scale prediction. Steve Yeager suggested that the Community Earth System Model (CESM) has significant skill in hindcasts of variations of upper ocean heat content.

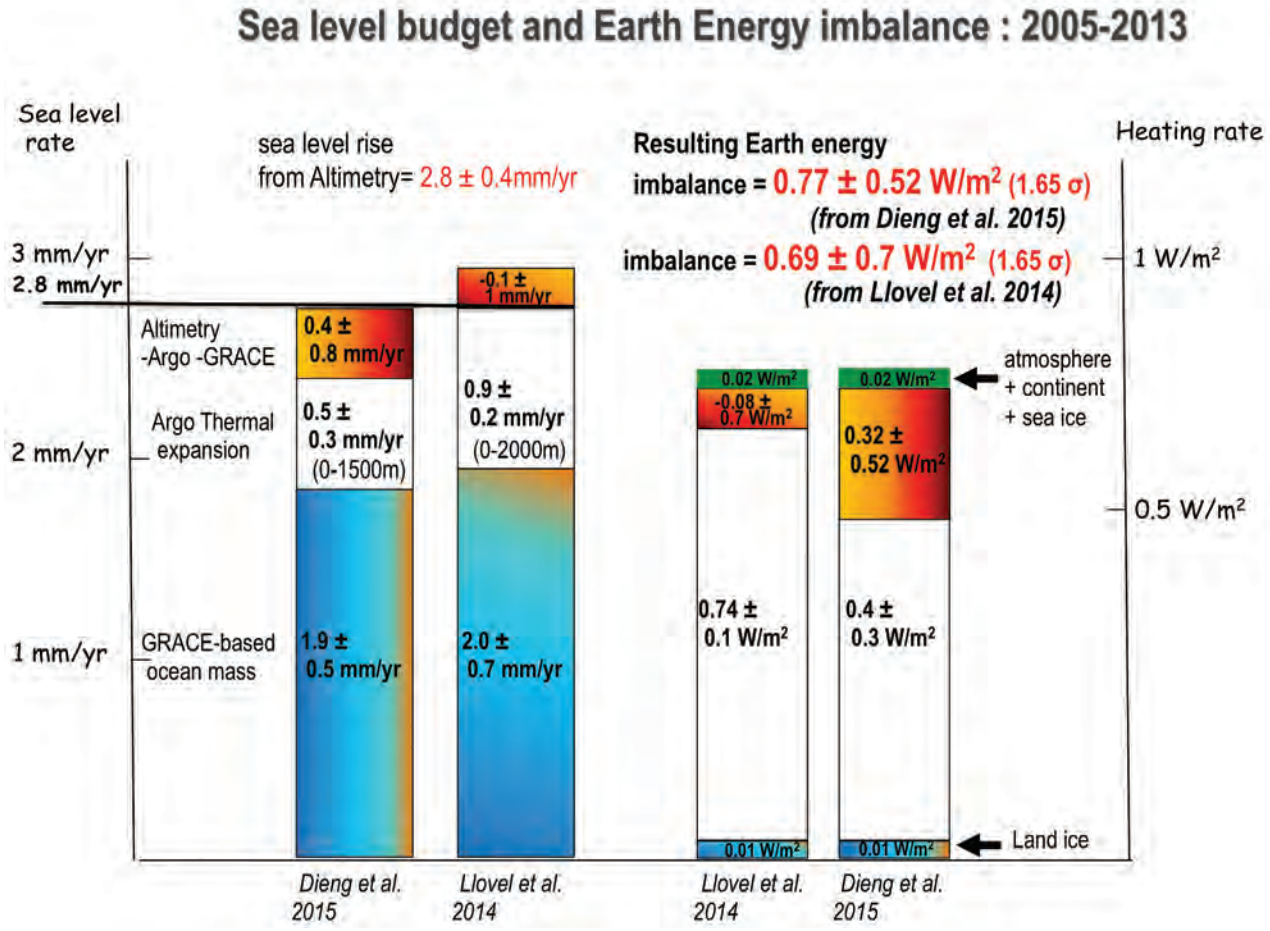
In addition to articulating support for focused EEI activities centering on integrating satellite and in situ observations, a key outcome of this one-day workshop was the need for a comprehensive assessment, or intercomparison, of methods for inferring EEI. A targeted effort to build upon recent approaches for objectively integrating distinct estimates of TOA radiation, atmospheric and oceanic mass and heat transports, air-sea fluxes, direct and indirect ocean heat content analyses and estimates of surface ice mass, heat content and water storage was also recommended. The consensus was to have a joint CLIVAR-GEWEX EEI workshop and it was suggested that this workshop be held in Toulouse, France, in late 2018. The goal of this open 3.5-day workshop would be to foster collaboration between the communities in WCRP to work toward an integrated view of EEI. The workshop would include invited keynote speakers and a lot of time for discussion. Four session topics were proposed: (1) coordinated assessment of global EEI and its components, (2) Regional EEI and transports, (3) Observational needs and prediction and (4) Cross-WCRP interactions on EEI. A steering committee

will be identified shortly composed of individuals representing CONCEPT-HEAT, CLIVAR and GEWEX along with additional representation from the Climate and Cryosphere (CliC) Project and the ocean reanalysis/modeling community.

Main GDAP Meeting

Rémy Roca opened the GDAP meeting on Tuesday by noting that GDAP leadership officially transitioned from outgoing co-chairs Jörg Schultz and Matthew McCabe to Rémy Roca and Tristan L'Ecuyer last December. In the nine months that followed, progress has been made toward each of GDAP's core activities, including: (1) sponsoring production and analysis of several key energy and water cycle data sets from satellites [e.g., International Satellite Cloud Climatology Project (ISCCP), GPCP, SeaFlux, SRB]; (2) sponsoring and overseeing assessments of these and other community data sets to improve uncertainty estimates; (3) sponsoring ground-based networks including BSRN and GPCC; (4) facilitating data access by scientific user communities; (5) acting as an interface between GEWEX activities and data sets [e.g., PROES, the GEWEX Aerosol and Precipitation (GAP) assessment, GASS]; (6) representing GEWEX at WCRP, WMO and other meetings and (7) reporting and responding to the GEWEX Scientific Steering Group (SSG).

Rémy Roca reported on GDAP activities to the GEWEX SSG in February 2017. The water vapor assessment report was well received but there was discussion of expanding the scope of the precipitation assessment. This is now underway and the International Precipitation Working Group (IPWG) and NASA Precipitation Measurement Missions (PMM) communities have been engaged. The SSG also suggested including land



Results from two different studies (Llovel et al., 2014 and Dieng et al., 2015) are shown where the Earth energy imbalance (EEI) was measured from space with the sea level budget approach for 2005–2013. Satellite altimetry provides estimates of the global mean sea level rise (GMSL), which is due to ocean thermal expansion and ocean mass change. The GRACE mission provides estimates of the global ocean mass (GOM) change that is primarily a result of land ice melt. GRACE data indicate a GOM change of about 2 mm/yr which corresponds to a heat gain by the cryosphere of about 0.01 Wm^{-2} over 2005–2013. The residual (GMSL−GOM) provides estimates of the thermal expansion of the ocean and is directly related to change in the ocean heat content (OHC). For 2005–2013, the residual from satellite altimetry minus GRACE indicates a total thermal expansion of about 0.8 mm/yr which corresponds to an OHC of about 0.7 Wm^{-2}. When added to the heat gain by the atmosphere, the continent and the sea ice, it gives a ***total Earth energy imbalance of 0.73±0.55 Wm^{-2} at the 90% confidence level*** *(1.65 sigma assuming a gaussian distribution). This estimate of OHC (and the associated EEI) has the advantage of covering the entire ocean from -82°S to +82°S. It is also consistent with the Argo-based estimate of OHC of the top 2000 m of the ocean (within the uncertainty).*

Participants at the GDAP Meeting.

surface temperature (LST) and possibly fluorescence as GDAP variables. Tristan L'Ecuyer represented GDAP at the 2nd GAP workshop, which was held in Oxford, UK. A primary outcome of that meeting was the need for metrics to evaluate aerosol influences on precipitation in global models and that GDAP should play an advisory role in establishing these. L'Ecuyer also participated in the Upper Tropospheric Cloud-Convection (UTCC) PROES meeting in New York, where GEWEX cloud, radiation and precipitation data sets are being used to study convection. Both Tristan and Rémy participated in the joint GEWEX/CONCEPT-HEAT Workshop prior to this GDAP meeting. GDAP will continue to maintain close connections to the WCRP Data Advisory Council (WDAC) and Observations for Model Intercomparisons Project (Obs4MIP) groups in an advisory capacity.

Global energy and water cycle data sets continue to be refined. New versions of several (e.g., SRB Release-4.0 and SeaFlux V2.0) have either been released or are in final stages of evaluation. The water vapor assessment report has been submitted and is under review. The next GEWEX water Vapor Assessment (G-VAP) meeting will take place at the University of Leicester, UK on 25-26 October 2017. An initial assessment of precipitation climatologies and seasonal cycles separated into land and ocean regions has also been completed by Hiro Masunaga. A more comprehensive assessment that includes sampling errors, examines regime-dependent differences and addresses high latitude and orographic precipitation and the needs of specific applications is now being scoped with inputs from the IPWG and PMM communities. Alexander Gruber presented an update on the soil moisture assessment and Claudia Stubenrauch outlined a timeline for the updated cloud assessment. The deadline for submitting new data sets to the updated cloud assessment is March 2018 and the analysis will be completed by the end of summer. This work complements ongoing activities within the International Cloud Working Group (led by Mike Foster and Martin Stengel). The aerosol assessment needs to be resurrected although there has been some progress in this by Stefan Kinne under the AeroCom Project and a new Max Planck Institute Aerosol Climatology (MACv2.0) data set is available.

Good progress has been made on the **GEWEX Integrated data set**. One year of the complete 1-degree, 3-hourly product (January-December 2017) is available for download at: *ftp://rain.atmos.colostate.edu/ftp/pub/GEWEX_IP/pbrown/GEWEX_IP/2007/*. This data set is being used to examine water cycle closure at the ocean basin scale, consistent with the concept of closure-based assessments envisioned for GDAP by former chair, Chris Kummerow. Such closure studies are part of a broader reshaping of GDAP objectives and activities to reflect the new directions in satellite and climate science. While assessment of individual parameters will continue, *some focus is shifting toward integrated assessments of global data projects that apply energy and water cycle closure constraints as an integrated measure of systematic errors in data sets*. This effort, coupled with a renewed focus on defining application-centric uncertainties appropriate to specific time and space scales, will help GDAP better serve the science community. Prior assessments, new objective optimization approaches and the GEWEX Global Integrated Product that bring together the separate parameter centric products at the highest feasible space-time resolution for global process studies will play a key role in this activity. New global data products should continue to be focused on improving the long-time-record quality of the products so that they can be used more confidently for climate monitoring studies. This activity should now make plans for the long-term stewardship of these products, including continuing to lead efforts to convert research analyses to climate operations.

The final day of the meeting focused on reassessing GDAP's core mission, discussing open business and setting new directions. A consensus regarding GDAP assessment activities is evolving along having more integrated themes that seek tests of water cycle and energy balance closure and aim to establish consistency between data sets (e.g., between surface radiative fluxes and the aerosols, land surface temperature and cloud fields used to generate them). This is viewed as a positive step toward meeting the evolving needs of the community and has triggered the suggestion that GDAP undergo a small name change to the **GEWEX Data and Analysis Panel**. GDAP will continue to support the ongoing set of assessment activities to their logical conclusion (submission of a formal report) and

would also initiate several new integrated assessments leading to a more complete description of the weather-to-climate scale variations of the global energy and water cycle. GDAP is planning to have an active role in organizing related sessions at the upcoming GEWEX Science Conference in May 2018 and will continue to support ground-based networks like BSRN and GPCC. BSRN continues to serve as the reference for surface radiation budget estimates. Stability is very good but establishing absolute calibration of fluxes is still an ongoing activity. The next BRSN scientific review and workshop will take place in Boulder, Colorado on 20-26 July 2018.

The top priorities for completing ongoing assessments in the coming year include: completing the cloud assessment update, expanding the scope of the precipitation assessment, resurrecting and completing the aerosol assessment and initiating a new radiative heating rate profile assessment. GDAP may also recommend a formal soil moisture assessment or endorse creating an official GEWEX global soil moisture product. With these continuing activities as a foundation, future emphasis will be focused on integrated assessments to constrain atmosphere and oceanic transports of energy and water. It is envisioned that future reprocessing of current global products will benefit from such information by increasing the physical consistency of the products and reducing spurious variations in the long-term record. GDAP will also leverage the results of these integrated assessments to engage space agencies and other international stakeholders to refine global climate observing systems and associated climate data records.

To stimulate these integrated assessments, three initial activities are being discussed. The first involves applying merged data sets like the GEWEX Integrated Product (which will be released to the community in the coming months and expanded to include more years) to test energy and water budget closure on regional and global scales. It is anticipated that this effort will provide independent evidence for regime-dependent structural errors in flux products that may ultimately lead to their improvement. This activity necessarily requires more deliberate interaction with general circulation modeling groups. To that end, future membership of GDAP will include representatives from the modeling communities.

Through the integrated assessment effort, GDAP will also directly contribute to complementary CONCEPT-HEAT studies that are directed toward quantifying global and regional EEI and establishing consistency between TOA fluxes and ocean heat content. To foster this activity, a representative from the ocean heat content or ocean reanalysis community may be added to GDAP. A third application of integrated assessments may center on re-scoping the LandFlux activity to include a more comprehensive assessment of land surface fluxes in the context of land surface temperature and ground water storage. GDAP may seek to incorporate global LST into its product suite as part of this activity. GDAP may also pursue adding a member with broad experience in land surface processes/flux in the future. To foster closer ties with the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Program community in future assessments, GDAP may also consider basing a land surface closure assessment around the ARM Southern Great Plains site.

The new vision of GDAP supporting global energy and water-related scientific investigations through integrated assessments warrants two additional activities. First, Roca and L'Ecuyer will initiate a revamping of the GDAP web pages to more accurately reflect its role in supporting other GDAP panels, PROES and broader scientific collaborations. This will include organizing people involved with GDAP into three groups: (1) core members, (2) project and assessment leads (PALS) and (3) science and analysis leads (SALS). The second activity will be an effort to engage all of these groups in compiling a set of "General Guidelines for Scientific Assessments" that will summarize GDAP's vision of best practices for conducting assessments that maximize value to the scientific community. This report will integrate existing best practice documents from other WCRP groups but will cover a much broader focus that includes initial scoping meetings, methods for framing assessments around science questions, identifying reviewers, disseminating reports and engaging stakeholders including space agencies and government groups.

A number of additional programmatic recommendations were raised at the meeting. GDAP strongly endorses the proposed creation of an ISCCP-NG product to utilize new geostationary and polar orbiting cloud information and coordinate efforts to inter-calibrate sensors. GDAP emphasizes the need for supporting comprehensive assessments of individual fluxes and integrated assessments of energy and water cycle closure on global to regional scales. GDAP recommends a review of current methods for transferring global data products to operational centers and the development of explicit succession plans for maintaining required expertise. The complete report of the GDAP meeting will be available at: *https://www.gewex.org/panels/gewex-data-and-assessments-panel/meetings-and-reports/*.

New member Isabel Trigo will host the next GDAP meeting in Portugal the last week of November 2018. GDAP will have a significant presence at the upcoming 8th GEWEX Science Conference in Canmore, Alberta, Canada in May 2018. Session 9, Energy Budget and Water Cycle Closure and Assessment, will focus on contributions that synthesize multiple energy and water variables derived from observations (in situ, satellite), reanalyses or climate models to examine energy and water cycle closure on regional through global scales. To submit an abstract and register, please visit the conference website at: *https://www.gewexevents.org/events/2018conference/*.

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