IRC working group Global Energy Balance (GEB)

Annual Report 2011/2012

Martin Wild and Norman Loeb (WG Co-chairs)

I. Current Activities

In the reporting year, a main activity of the IRC "Global Engery Balance" (IRC-GEB) WG chairs has continued to be their involvement in the upcoming 5th IPCC assessment report. Co-Chair Martin Wild is a lead author of Chapter 2 (Observations: Atmosphere and Surface) and therein responsible for the section "changes in radiation budget". Co-Chair Norman Loeb is contributing author for the part on the changes in the Top of Atmosphere Radiation Budget. The first order draft version of IPCC-AR5 has been submitted in the reporting period and has undergone extensive open review. Chapter 2 alone received more than 3000 comments, which had to be addressed during the reporting period. The second order draft addressing all these issues, as well as replies to all review comments will have to be submitted August 10, 2012, coinciding with the IRS2012.

In spring 2012, at the European Geophysical Union (EGU) General Assembly we again organized the session "Earth radiation budget, radiative forcing and climate change", which is closely linked to the aims of this working group. It turned out to be a lively session, with two distinguished invited lectures given by Dr. R. Cahalan and Dr. J. Hansen.

AT ETH Zurich, we could start the project "Towards an improved understanding of the Global Energy Balance: absorption of solar radiation" which we got funded for 3 years by the National Science Foundation. A PhD student (Maria Hakuba) started her PhD on September 1, 2011. The project aims at reducing the uncertainties in the absorption of solar radiation within the climate system, through the use of the information contained in worldwide surface radiation measurements in combination with satellite products.

Further related work is under way at ETH Zurich in an attempt to model the spatio-temporal variations of the Global Energy Balance using a state of the art climate model with particularly sophisticated treatment of aerosol and cloud microphysics (ECHAM-HAM).

In collaboration with working group member Chuck Long, we are continuing to update clear sky solar radiative fluxes at the BSRN sites, based on the Long and Ackermann (2000) clear-sky detection algorithm. These fluxes allow the construction of monthly clear sky estimates at the BSRN sites, which enable the estimation of trends in surface solar radiation under cloud-free conditions as well as the determination of solar absorption in the cloud-free atmospheric column above the sites.

II. Research Results

In a recent study, lead by Co-Chair Martin Wild, and co-authored by Co-Chair Norman Loeb, the radiation budgets as simulated in the latest generation of global climate models for the upcoming IPCC-AR5, have been assessed (CMIP5). A particular emphasis has been placed to provide better constraints on the surface radiative fluxes, which show particularly large uncertainties and discrepancies amongst the models. In addition to satellite observations, we made extensive use of the information contained in the growing number of surface observations to provide observational constraints not only on the top of atmosphere radiation budget, but also on the surface radiative components. We combined these observations with the latest generation of climate models to obtain best estimates for the global mean surface radiative components. These analyses favor a global mean downward solar and thermal radiation at the surface near 185 and 342 Wm^{-2}, respectively, which are most compatible with surface observations. Combined with an estimated surface absorbed solar radiation and thermal emission of 161 Wm-2 and 397 Wm^{-2}, respectively, this leaves 106 Wm^{-2} of surface net radiation available for distribution amongst the non-radiative surface energy balance components. The IPCC AR5 climate models overestimate and underestimate the downward solar and thermal radiation, respectively, thereby simulating nevertheless an adequate surface net radiation by error compensation. This also suggests that, globally, the simulated sensible and latent heat fluxes, around 20 and 85 Wm^{-2} in the multimodel mean, state realistic values. A related energy balance diagram is shown in Figure 1. A paper containing the results of this study has been submitted.

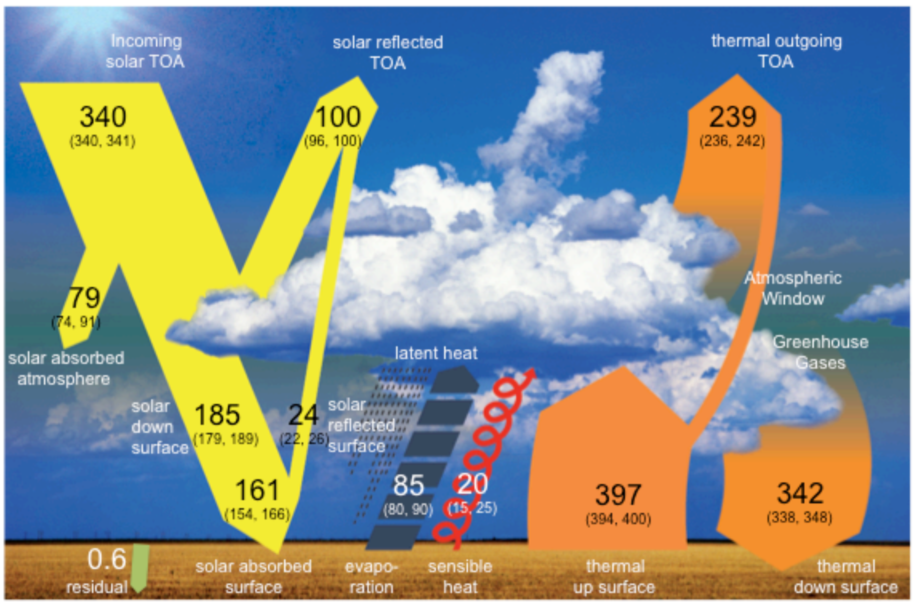

Figure 1:
Best estimates of the global mean energy balance components together with their uncertainty ranges, representing present day climate. Surface estimates based on the analyses presented in this study. TOA estimates from Loeb et al. (2009). Units Wm-2 (From Wild et al., submitted)

Both Co-Chair were also co-authoring the study “An Update on the Earth's energy balance in light of new surface energy flux estimates” currently in press in Nature Geoscience (Stephens et al. 2012). This study, complementary to the abovementioned study, uses new satellite derived estimates of surface radiative fluxes, particularly the longwave downward radiation. The longwave radiation received at the surface is estimated to be significantly larger, by between 10 and 17 Wm^{-2}, than earlier model-based estimates, in line with the results obtained in the study above. Moreover, new satellite observations of global precipitation indicate that the Earth also produces more precipitation than previously thought. This additional precipitation is sustained by more energy leaving the surface in the form of latent heat flux, and thereby offsets much of the increase in longwave flux to the surface. The increased downward longwave radiation is also the subject of another recent paper co-authored by the WG co-chairs (Stephens et al. 2012, J. Climate).

The overall aim of the SNF funded project "Towards an improved understanding of the Global Energy Balance: absorption of solar radiation" is a better understanding of the mean state and spatio-temporal variations of the global energy balance through reducing the uncertainties in one of its components, i. e., the absorption of solar radiation within the climate system. To quantify the solar absorption at the surface and within the atmospheric column, we combine the worldwide surface radiation measurements of the Global Energy Balance Archive (GEBA) and Baseline Surface Radiation Network (BSRN) with collocated satellite-inferred surface albedo and top-of-atmosphere (TOA) radiation data (MODIS, CERES). First results are given in Figure 2, showing the atmospheric column absorption calculated at European BSRN sites (Hakuba et al. 2012, in preparation).

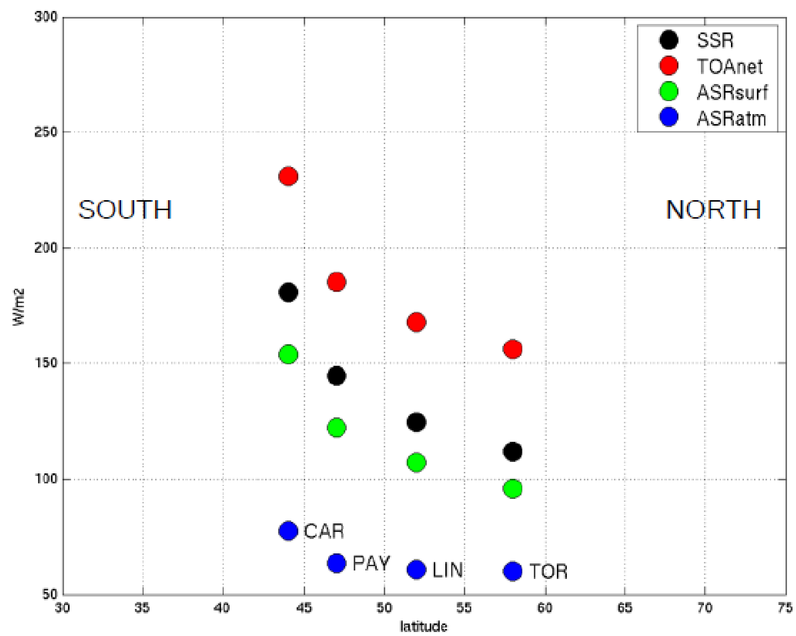

Figure 2:
Absorption of solar radiation at different BSRN sites in Europe as function of latitude: Absorption at the TOA in red (from CERES/EBAF), at the surface in green (from BSRN/MODIS), and within the atmosphere in blue (calculated as residual) (from Hakuba et al., in preparation)

Global Climate modeling efforts at ETH resulted in a paper published in the Journal of Geophysical Research during the reporting period (Folini et al. 2011). The emphasis is on the decadal variations in surface solar radiation (SSR) over Europe. Observational data indicate a decrease of SSR in Europe from about 1950 to the mid-1980s, followed by a renewed increase, with changing aerosol emissions having been suggested as a likely cause for this observed dimming and brightening. To quantify this hypothesis, we performed ensembles of transient sensitivity experiments with the global climate model ECHAM5-HAM, which includes interactive treatment of aerosols. The simulations cover the period 1950–2005. The simulated clear-sky dimming and brightening can be attributed to changing aerosol emissions from fossil fuel combustion. Ensemble means of modeled SSR trends are in agreement with observed values. All-sky conditions show similar trends in the ensemble mean, but the spread among ensemble members is considerable, emphasizing the importance of clouds.

In a recent study published during the reporting period (Loeb et al. 2012) Co-Chair Norman Loeb addresses a seemingly contradictory issue with respect to observed interannual variations in net TOA radiation and ocean heat storage raised by Trenberth and Fasullo (2010). On a global annual scale, interannual variations in net TOA radiation and ocean heat storage should be correlated, since oceans serve as the main reservoir for heat added to the Earth-atmosphere system. Wong et al. (2006) showed that these two data sources are in good agreement for 1992–2003. In the ensuing 5 years, however, Trenberth and Fasullo (2010) note that the two diverge from one another. The new paper by Loeb and co-authors uses improved satellite top-of-atmosphere (TOA) radiation measurements and a new analysis of ocean heat content data to show that while Earth's energy imbalance and ocean heating rate have exhibited variability consistent with El Niño-Southern Oscillation (ENSO), there is no evidence of a decline during the past decade. Satellite observations of top-of-atmosphere (TOA) net radiation constrained by recent in situ ocean heat content data indicate that during the past decade Earth has been accumulating energy at the rate 0.52 ±0.43 Wm–2. These results suggest that although Earth's surface has not warmed significantly during the 2000s, energy is continuing to accumulate in the sub-surface ocean at a rate consistent with anthropogenic radiative forcing.

III. Recommendations

a) Recommendations with respect to the TOA radiation budget components:

- The international community should urge government agencies responsible for building the next generation of Earth Radiation Budget instruments to include onboard calibration equipment that can detect and correct for on-orbit contamination of optics. Lessons learned from over a decade of in-flight experience (e.g., with CERES FM1-FM4 and the SORCE TIM, Kopp et al. 2005) clearly provide evidence that on-orbit contamination of optics does occur and must be detected and corrected for in order to ensure a robust climate record of TOA radiation budget.
- The international community should urge government agencies responsible for building the next generation of Earth Radiation Budget instruments to provide sufficient time for ground calibration activities. Ground calibration is the last major test performed prior to shipment, when there are typically no financial or schedule reserves left. Shortening the length of the ground calibration period due to cost/schedule constraints adds uncertainty to the absolute calibration of the instrument.
- The international community should urge government agencies responsible for building the next generation of Earth Radiation Budget instruments to periodically re-verify the traceability of calibration targets on the ground.
- The international community should urge government agencies responsible for building the next generation of Earth Radiation Budget instruments to establish collaborations with other international agencies specializing in calibration standards (e.g., NIST, NRL).
- The international community should provide guidance on the creation of Earth Radiation Budget climate data records. There is a naive notion in the community that complex climate data records involving a significant level of fusion of multiple data sources at climate accuracy can be transitioned from research to operations. The decades of expertise used to validate, understand, quality control, and continuously fix problems with instrument or ancillary input data sets cannot be bought or transplanted as a set of documents and software. Earth Radiation Budget Climate Data Records capable of accurately characterizing climate at decadal time-scales are inherently more research data products than they are operational data products. Assuming otherwise will likely lead to inferior data products characterized by artifacts that go unnoticed and unresolved in an operational processing environment. While an operational approach works fine for processing weather data, far more rigor and quality assurance is necessary for climate data products, where reprocessing is an integral part of the effort.

b) Recommendations with respect to the surface/atmospheric radiation budget components:

- The prominent picture of the Global Energy Balance in the IPCC report needs substantial revision. Particularly the surface flux estimates need to be revisited, and uncertainty ranges should be added to all components. The recent papers of Stephens et al. and Wild et al. address these issues.
- A continued and expanded operation and maintenance of a well calibrated network of long term surface radiation stations is required to provide direct observations and anchor sites for satellite-derived products and climate model validation, as well as for the detection of important changes in the radiation fields either not detectable by satellites or anticipated by models. The basic measurements include the four primary components (up and down, longwave and shortwave irradiance) with high temporal resolution (minute values) and known accuracy (BSRN accuracy standards).
- These high accuracy observation sites should be expanded to under-represented regions of the globe (such as many low latitude areas) and particularly oceans where alternate or modified observational strategies might be necessary. The use of newly available shortwave radiometers (SPN-1) that are well suited for use in remote deployments such as on buoys and ships, is recommended. These new radiometers comply with low-power systems measuring both diffuse and direct fluxes, which allows for proper correction of tilt from horizontal (Long et. al, 2010).
- Anchor sites should also include direct and/or diffuse shortwave measurements in addition to total incoming shortwave (SW) along with standard surface meteorological measurements. These measurements are useful for the diagnosis of cloud effects on the radiation budget (Zhang et al. 2010), for the evaluation of satellite-derived products and climate models, and for climate impact research (for example biosphere growth and terrestrial carbon uptake, Mercado et al. 2009).
- To improve surface albedo estimates over various surface types and for the assessment of satellite derived albedo products, high accuracy spectral and broadband measurements from towers are desirable at the anchor sites (Roman et al. 2009).
- Atmospheric spectral optical depths should be observed to infer atmospheric column abundance of aerosol, ozone, water vapor and other atmospheric constituents.
- The spatial representativeness of surface anchor sites has to be thoroughly assessed (Dutton et al. 2006, Roman et al. 2009). The possible “urbanization” effect (impact of local air pollution) in surface solar radiation trends needs quantification.
- Clear sky flux products derived from direct observations should be provided for the validation of corresponding fluxes in the models and satellite derived estimates.
- To achieve progress in the accuracy of satellite-derived surface radiation fields, improved and consistent satellite estimates of vertical distributions of cloud and aerosol radiative properties (size, single scattering albedo, asymmetry parameter) and of water vapor are required