Proposal for an IRC working group on the global energy balance

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1. Motivation

The genesis and evolution of Earth's climate is largely regulated by the global energy balance. Anthropogenic climate change is, from a physical point of view, first of all a perturbation of the energy balance of the globe, through human emission of radiatively active greenhouse gases and aerosols, and land use changes. Variations in the global energy balance affect not only the thermal conditions on the planet, but also various other climate elements, such as the components of the hydrological cycle, glaciers, plant productivity and terrestrial carbon uptake (e.g., Ohmura et al. 2007, Wild et al. 2008, Wild 2009, Mercado et al. 2009). Despite the central importance of the global energy balance for the climate system and climate change, large uncertainties still exist in the quantification of the different components of the energy balance and their decadal variations (e.g., Kiehl and Trenberth 1998, Wild et al. 1998, 2005, Loeb et al. 2007a, b, 2009, Trenberth et al. 2009). Knowledge on the energy exchange between Sun, Earth and space has recently been improved through new space-born platforms such as from the Earth's Radiant Energy System (CERES) and Solar Radiation and Climate Experiment (SORCE). These allow the determination of the top of atmosphere radiative fluxes with unprecedented accuracy, even though a realistic closure of the top of atmosphere balance remains a challenge (Loeb et al. 2009). However, uncertainties on the energy distribution *within* the climate system are still considerable. Particularly uncertain are the partitioning of solar energy absorption between the atmosphere and surface, and within the atmosphere between cloudy and cloud-free parts, as well as the determination of the thermal energy exchanges at the surface/atmosphere interface (e.g., Raschke et al. 2005, Wild et al. 2006). Accordingly, the energy balance simulated in global climate models largely differs, particularly in their representation of the surface and atmospheric balances (e.g., Wild 2008 and references therein). These uncertainties translate into large uncertainties in the simulation of other components of the climate system, such as the tightly linked water cycle, and have adverse effects on the coupling of these components in Earth system models.
Improved knowledge and understanding of the magnitude and changes of the global energy balance components are therefore a critical prerequisite for progress in our understanding and prediction of climate change.

2. Aim of working group

The main goals are the assessment of the magnitude and uncertainties of the components of the global energy balance, their decadal changes and underlying causes as well as their significance for other climate system components and climate change.
The working group, comprised of members who produce, disseminate and analyze surface and satellite data products relevant to the study of the Earth's energy balance, will also serve as a forum to discuss to what extent the datasets currently available to the scientific community are

adequate for advancing the state of knowledge on the Earth's energy balance. Where appropriate, the working group will make recommendations highlighting areas where further work is needed (e.g., new datasets, new observations, etc.) Due to the the complexity of the topic and the diverse aspects involved, we intend to address the various issues in a stepwise top-down approach. In a first step, the focus will be on the reassessment of the Earth's global mean energy balance, the temporal and spatial evolution will be addressed in following steps.

In order to achieve these goals, key responsibilities of the working group will be:

- Foster, coordinate and conduct research on the components of the global energy balance and their decadal changes at the TOA, surface and within the atmosphere. Combine surface-based and satellite information to reassess the global mean energy balance, and ultimatively provide a complete picture of the 4 dimensional spatio-temporal evolution of surface, atmospheric and TOA energy balances.
- Foster and coordinate the establishment and dissemination of the necessary space-born and ground-based datasets as an internationally coordinated service to the scientific community.
- Interact with researchers in other domains in need of energy balance data (e.g. climate modelers, hydrologists, glaciologists, carbon cycle modelers, phenologists) to assess their requirements and advise on the data usage.
- Provide better constraints for the energy balance in climate models, particularly in view of the forthcoming IPCC AR5 report.

3. Specific tasks

A number of specific issues will need to be addressed by this working group to advance our understanding of the global energy balance and make optimal usage of the available information on its different components.

Specific issues with respect to the surface energy balance components:

- Collect, centrally store and make available all accessible surface radiation and energy flux data measured worldwide by various projects and institutions (data storage in GEBA, BSRN, WRDC, coordination with Euroflux/Ameriflux/Asiaflux)
- Recover historic radiation data for GEBA
- Assess quality and spatial representativeness of surface observations
- Quantify "urbanization" effect in surface solar radiation data
- Assess satellite derived-products of surface fluxes (close link to Radiative Flux Assessment (RFA) project)
- Merge information from surface observations, satellite-derived products and reanalyses to provide best estimates of temporal and spatial surface flux distributions
- Infer the atmospheric radiation balance by combining collocated surface and TOA estimates, such as from BSRN/GEBA and CERES.
- Use the above products to evaluate surface flux fields in global and regional climate models
- Assess usefulness of hydrological data to constrain surface radiation balance and vice versa
- Establish customized datasets for different research communities (e.g. direct/diffuse solar radiation for carbon cycle modelers)

Specific issues with respect to the TOA balance components:

- Quantify uncertainties in TOA radiation components and uncertainties in associated trends.
- Explore relationship between cloud, aerosol, and TOA radiation changes as a function of changes in atmospheric state for different time and space scales.
- Use observations to evaluate climate model representations of cloud-aerosol-radiation changes as a function of atmospheric state.
- Assess adequacy of existing satellite datasets for advancing our understanding of the TOA radiation balance.
- Explore ways in which future measurement capabilities (e.g., CLARREO, TSIS, CERES) will be used in conjunction with current instruments to advance understanding of the TOA radiation balance.

4. Available data products

A number of data sources with information on the global energy balance components are currently available and need to be critically reviewed with respect to their potential to advance our understanding, in order to identify the major shortcomings in current observation systems.

Direct surface observations:
Global Energy Balance Archive (GEBA) (www.geba.ethz.ch)
Baseline Surface Radiation Network (BSRN) (www.bsrn.awi.de)
World Radiation Data Centre (WRDC) (wrdc.mgo.rssi.ru)
Atmospheric Radiation Measurement (ARM) Program (www.arm.gov)
Surface Radiation Network (SURFRAD) (www.srrb.noaa.gov/surfrad)

Satellite-derived fluxes:
GEWEX Surface Radiation Budget (SRB) (www.gewex.org/srb.html)
ISCCP-FD (isccp.giss.nasa.gov)
CERES (http://eosweb.larc.nasa.gov/project/ceres/table_ceres.html)
University of Maryland Surface Radiation Budget (www.meto.umd.edu/~srb)
European Surface Radiation Budget (ESRB) (esrb.iesl.forth.gr)

Reanalyses:
ECMWF Reanalysis (ERA) (www.ecmwf.int/research/era/)
NCEP reanalysis (www.cdc.noaa.gov/data/reanalysis/reanalysis.shtml)
GEOS reanalysis

4. WG organizational Structure

Co-Chairs:
Martin Wild and Norman Loeb

WG Members:
to be determined.

Members of the working group should be elected so that their unified expertise covers all major aspects of the global energy balance. In that sense the co-chairs ideally complement each other with expertise on the surface radiation balance on one side and TOA radiation balance on the other side.

5. Related IRC Working Groups

Collaboration and interaction with the following existing IRC working groups is foreseen:

GRP - GEWEX Radiation Panel (Rapporteur Chris Kummerow)
BSRN (Rapporteurs Gert Koenig-Langlo and Bruce McArthur)
LASR: Long-term Analysis of Surface Radiation Budget (Chair: Tadahiro Hayasakawa)
CR - Clouds and Radiation (Rapporteur: Thomas Ackerman)

6. Working Groups Meetings

Meetings of the working group on the global energy balance should be held on a regular basis, for practical reasons in conjunction with large conferences where several of the WG members attend anyway, such as with IAMAS, IRS, AGU fall meeting or with the session "Earth radiation budget, radiative forcing and climate change" held regularly at EGU by the WG-chair.

References:

Kiehl, J. T., and K.E. Trenberth, (1997), Earth's annual global mean energy budget, Bulletin of the American Meteorological Association, *78,* 197-208.

Loeb, N.G., B.A. Wielicki, F.G. Rose, and D.R. Doelling (2007a), Variability in global top-of-atmosphere shortwave radiation between 2000 and 2005, *Geophys. Res. Lett., 34,* L03704, doi:10.1029/2006GL028196.

Loeb, N. G., B. A. Wielicki, W. Su, K. Loukachine, W. Sun, T. Wong, K. J. Priestley, G. Matthews, W. F. Miller, and R. Davies (2007b), Multi-instrument comparison of top of the atmosphere reflected solar radiation, *J. Clim., 20,* 575-591.

Loeb, N. and coauthors (2009), Toward optimal closure of the Earth's top-of- atmosphere radiation budget, *J. Climate, 22,* 748-766.

Mercado, L.M., N. Bellouin, S. Sitch, O. Boucher, C. Huntingford, M. Wild, and P.M. Cox (2009), Impact of Changes in Diffuse Radiation on the Global Land Carbon Sink, Nature, *458,* 1014-1018.

Ohmura, A., A. Bauder, H. Mueller, and G. Kappenberger (2007), Long-term change of mass balance and the role of radiation, *Annals of Glaciology, 46,* 367-374.

Raschke, E., Ohmura, A., Rossow, W.B., Carlson, B.E., Zhang, Y.C., Stubenrauch, C., Kottek, M., and Wild, M. (2005) Cloud effects on the radiation budget based on ISCCP data (1991 to 1995). *Int. J. of Climatology, 25,* 1103-1125.

Trenberth, K.E., J.T. Fasullo, and J. Kiehl (2009), Earth's global energy budget, *Bulletin of the American Meteorological Association, 90*, 311–323.

Wild, M., and 9 co-authors (2005), From dimming to brightening: decadal changes in surface solar radiation, *Science, 308*, 847-850.

Wild, M., C. N. Long, and A. Ohmura (2006), Evaluation of clear-sky solar fluxes in GCMs participating in AMIP and IPCC-AR4 from a surface perspective, *J. Geophys. Res.,* 111, D01104, doi:10.1029/2005JD006118

Wild, M., J. Grieser, and C. Schär (2008), Combined surface solar brightening and greenhouse effect support recent intensification of the global land-based hydrological cycle. *Geophys. Res. Lett.*, *35*, L17706, doi:10.1029/2008GL034842.

Wild, M. (2008), Shortwave and longwave surface radiation budgets in GCMs: a review based on the IPCC-AR4/CMIP3 models. *Tellus*, *60,* 932 - 945. doi: 10.1111/j.1600-0870.2008.00342.x.

Wild, M. (2009). Global dimming and brightening: A review. *J. Geophys. Res., 114,* D00D16, doi:10.1029/2008JD011470.