

Proceedings and Outputs of GEWEX International Symposium on Global Land-surface Evaporation and Climate

13-14 July, Centre for Ecology and Hydrology (CEH), Wallingford, UK

Summary

For humankind to effectively manage adaptation to climate change the uncertainty in predictions of future climate must be reduced. Consequently, there is need to create observation-based benchmarks of GCM performance that can be used to allow selection between GCMs and to guide improvement in model simulation. Because climate change will have important consequences through changes in the Earth's water and energy cycles, providing hydrometeorological benchmarks is a priority. Initiating international activity to define and produce the required hydrometeorological benchmark datasets was the primary purpose of this symposium. Discussion was organized around hydrometeorological benchmarks that could feasibly be produced within 12-18 months, and then within 48-60 months. Because better modelling of evaporation is critical for improving predictions of climate, weather, and water resources, the symposium gave priority to providing a global land-surface evaporation benchmark.

Symposium presentations and posters focussed on assessing the range of estimates of global land-surface evaporation calculated by hydrological models and land surface parameterization schemes and estimated by currently available data products, and also on the potential utility of surface and remotely sensed data for providing an evaporation benchmark (see below for greater detail). There were also extensive discussion sessions and the recommendations emerging from these are as follows.

1. It was recommended that *GEWEX*:
 - (a) lead a discussion among the relevant international scientific community to specify a suite of globally available hydrometeorological benchmark datasets; and
 - (b) foster activity to provide some globally available hydrometeorological benchmark datasets in interim form within 12-18 months, and all in improved form within 48-60 months. To aid broader discussion of the suite of hydrometeorological benchmarks the symposium suggested a "strawman" list of global data products (see below for greater detail)
2. It was further recommended that *GEWEX*, operating through the *Landflux Initiative*, lead:
 - (a) provision of an interim evaporation benchmark within the next 12-18 months which is an appropriate ensemble of the currently available evaporation data products that have observational content; and
 - (b) scientific development that will lead to provision of an improved evaporation benchmark within the next 48-60 months. This may involve using then available remote sensing data products to yield an ensemble of interpolations between available surface observations and should include information on the relative contributions from transpiration, interception, and bare soil (see below for further detail).

1. Introduction

Understanding and predictions fostered by the International Panel on Climate Change (IPCC) are now adequate to guide policy and motivate action to *mitigate* the extent of climate change. However, for humankind to effectively manage *adaptation* to the climate change that is still inevitable, it is essential that uncertainty in the predictions of future climate is reduced. To enable a reduction in uncertainty there is need to create observation-based benchmarks of General Circulation Model (GCM) performance that can be used to narrow the range of predictions by allowing selection of the most realistic GCMs and by stimulating and guiding further improvement in model simulations. Such benchmarks will be measures of the variables that GCMs calculate, or can be made to calculate, including the status within the Earth system of water, energy, and carbon stores and of movements between these stores.

Changes in climate will have wide ranging consequences for human and natural systems. However, arguably their most important effect will be by modifying the Earth's water and energy cycles that influence regional water availability and through this, agricultural and industrial activity, infrastructural needs, and ecosystem services. For this reason, providing benchmarks that can be used to assess the capability of GCMs to simulate *hydrometeorological variables* is a priority. Recognizing this need, scientists from the *UK Joint Centre for Hydro-Meteorological Research* convened a two-day International Symposium on Global Land-surface Evaporation and Climate under the aegis of the *Global Energy and Water-cycle Experiment (GEWEX)*. The 30 participants included invited experts from the international community. The primary purpose of the symposium (which was supported by the *EU WATCH* project and *NOAA*) was to initiate activity among international scientists to first specify and then provide appropriate hydrometeorological benchmark datasets.

Discussion was organized around hydrometeorological benchmarks that could feasibly be produced within 12-18 months to aid the next IPCC review, and those that with further scientific study could be produced in 48-60 months to aid a subsequent IPCC review. Because evaporation provides the primary energy input from land surfaces to the atmosphere and is also the most significant water loss from hydrological catchments, correctly modelling global land-surface evaporation is critical for providing improved climate and weather predictions and for interpreting these in terms of water resources. For this reason, in symposium discussions providing a global land-surface evaporation benchmark was given priority.

2. Symposium Presentations

Presentations focussed on assessing the range of estimates of global land-surface evaporation calculated by hydrological models and land surface parameterization schemes, on assessing the range of currently available remote sensing data products, and on the potential utility of surface and remotely sensed data for providing an evaporation benchmark.

Ludwig presented results from the *WaterMIP* project which demonstrated the wide range of global land surface evaporation estimates (415-590 mm) calculated by a range of global models, and their inconsistency when partitioning evaporation between interception, transpiration, and bare soil evaporation and when calculating regional water balance (worst for tropic forest). Vidale emphasized the importance of radiation and carbon exchange as constraints on evaporation and demonstrated the sensitivity of modelled evaporation to hydraulic and thermal soil parameters. Best discussed use of data-assimilation to inform UKMO models, the challenges encountered when using remotely sensed temperature to constrain surface water and energy balance, and the need to recognize shortcomings in reanalysis data to estimate evaporation.

Sandholt (via web-link) described the “triangle” method for diagnosing evaporation with accuracy better than 50 W m^{-2} in regions with little vegetation cover and sufficient variation in *NDVI* and remotely sensed surface temperature to train the model. De Jeu described a promising global evaporation data product based on a simple evaporation model with assimilation of remotely sensed data whose representation of interception loss met with general approval. Jimenez reported the results of a comparison made under the *LandFlux* initiative of global evaporation estimates for four existing satellite products (Fisher, Princeton, Maryland University, and Paris Observatory), two model calculations (*GSWP*, *JULES*) and two reanalysis products (*MERRA* and *NCEP*). The results showed clustering in both remotely sensed estimates and model-based estimates the origins of which merits further investigation. In discussion it was agreed that the overall consistency of current evaporation products is narrower than for other components of the global water balance (e.g., precipitation) and is already sufficient to recommend providing an evaporation benchmark from available data products in 12-18 months, with subsequent research to allow provision of an improved benchmark in 48-60 months. Jimenez reported the results of a preliminary comparison made under the *LandFlux* initiative of global evaporation estimates for four existing satellite products (University of Oxford, Princeton University, University of Maryland, and Paris Observatory), two model calculations (the *GSWP-2* multi-model ensemble and *JULES* using the *WATCH* forcing data) and two reanalysis products (*MERRA* and *NCEP/NCAR*). The preliminary results showed clustering in both remotely sensed estimates and model-based estimates the origins of which merits further investigation. In discussion it was agreed that the overall consistency of current evaporation products appeared narrower than for other components of the global water balance (e.g., precipitation). If further confirmed, this result is already sufficient to recommend providing an evaporation benchmark from available data products in 12-18 months, with subsequent research to allow provision of an improved benchmark in 48-60 months.

Wood overviewed methods used to estimate components of the global water balance, and evaporation in particular. He emphasized the need to make good use of river flow records in the hydrometeorological benchmarking process and identified closing the global land surface water balance as a “grand challenge”. In discussion it was proposed that using alternative remotely sensed data products as a means for interpolating between available surface observations of evaporation (including, for example, *Fluxnet* data and catchment and atmospheric water balance data) could provide a mechanism

for generating improvement in the ensemble of evaporation data products available for benchmarking models. Reichstein described a novel and promising method for deriving a global evaporation product by merging the landscape scale measurements of evaporation that should be made available from *Fluxnet*. This used a “model tree” with evaporation described by a numerical model with trained dependency on site variables. There was substantial discussion of whether missing *Fluxnet* data during and immediately after rain meant these data are a less valuable measure of the interception component of evaporation than the transpiration component, and of how this might influence the use of *Fluxnet* data in the context of providing a global evaporation benchmark.

Seneviratne reviewed other ways to estimate evaporation including using global soil moisture products and atmospheric water budgets. She emphasized that an evaporation benchmark should not only provide information on total evaporation but also on the relative contribution of transpiration, interception, and soil evaporation components, and that care was needed to check for interdependence between contributing datasets if a benchmark was provided as an ensemble mean. She additionally provided an overview of the LandFlux intercomparison initiative and first analyses performed in this context based on multi-year datasets. Ek gave examples of operational calculations of the water balance in the USA made using the *North American Land Data Assimilation System* and examples of the use Fluxnet data for their verification. He expressed satisfaction with the maturity of the remotely sensed products discussed during the symposium and noted their potential value in an operational context.

Shuttleworth demonstrated that the decrease in pan evaporation rates over several decades does not necessarily mean area-average evaporation has decreased and suggested that pan data might ultimately contribute towards a global evaporation benchmark, but modelling studies are needed to quantify the surface-atmosphere coupling processes that influence pan evaporation. Blyth demonstrated that data from just 10 carefully selected *Fluxnet* sites can successfully be used to assess the performance of the *JULES* land surface model and suggested that some selection between available *Fluxnet* data sources may be valuable when building an improved global evaporation benchmark.

Poster presentations described the impact of soil physical parameterisations on land surface-atmosphere coupling in GCMs (Vidale, Verhoef, Demory and Roberts); weaknesses in representing interception in land surface representations (Demory and Vidale); and a method to allow mechanistic determination of soil heat flux using remotely sensed data; (Verhoef & Murray).

When taken together results presented at the workshop showed that the range of estimates of evaporation from the large-scale hydrological and land surface models was broadly comparable with the range of estimates from currently available data products. This range was greatest in tropical forest regions where both modelled and observed annual evaporation varied between 1000mm and 1400mm. One reason for this might be that, unlike semi arid regions where most precipitation is evaporated or water-saturated regions where most precipitation leaves as river flow, in the tropical regions precipitation

is roughly equally partitioned between evaporation and runoff. This balance is more difficult to model and this could explain why the variance among models is high.

Evaporation of intercepted rainfall makes an important contribution to total evaporation from forests and this may be in part be why there is high variability in tropical forest evaporation estimates. Difficulties in quantifying the interception process at the grid square scale could contribute uncertainty to both modelled and observed evaporation in rainforest biomes: models differ in their calculations of this process, while remotely sensed data are often compromised by cloud cover and the humidity sensors used for surface flux measurements are frequently inoperable in rainy periods.

3. Symposium Discussion

The symposium included extensive discussions after each presentation session and an extended concluding discussion. The recommendations emerging from these discussions are as follows.

1. It was recommended that *GEWEX*:

- (a) lead a discussion among the relevant international scientific community to specify a suite of globally available hydrometeorological benchmark datasets and that can be used to select between the GCMs contributing to the IPCC process in order to foster improvement in the representation of hydrometeorological aspects of GCMs; and
- (b) foster activity to provide this suite of globally available hydrometeorological benchmark datasets
 - I. some in interim form within 12-18 months, to aid the next round of IPCC review
 - II. all in improved form within 48-60 months, to aid a subsequent round of IPCC review

To aid a broader communitywide discussion of the required suite of hydrometeorological benchmark datasets the symposium suggested the following “strawman” list:

- Land surface evaporation (with the diurnal cycle resolved)
- Land surface precipitation (with the diurnal cycle resolved)
- River Flow (for large basins and 100 well distributed small basins)
- Atmospheric water balance
- Snow Water Equivalent
- Radiation (with the diurnal cycle resolved)
- Anthropogenic forcing factors (e.g. water extraction, irrigation, etc)

There was some discussion of the required grid scale for these benchmark datasets but more extensive discussion of this is required.

2. It was further specifically recommended that *GEWEX*, operating through the *Landflux Initiative*, lead:

- (a) provision of an interim land surface evaporation benchmark within the next 12-18 months which is an ensemble of the currently available evaporation data

products that have observational content in the form of remotely sensed variables or surface measurements, but which exclude model calculations from reanalysis data. The ensemble mean and estimated uncertainty in this mean should also be provided after appropriate consideration has been given to possible interdependency between the different products in the ensemble.

- (b) scientific development that will guide provision of an improved land surface evaporation benchmark within the next 48-60 months. This may involve deriving methods to use then-available remote sensing data products to provide an ensemble of interpolations between available surface observations of evaporation including *Fluxnet* data, catchment and atmospheric water balance data, and pan data. It may also involve development of improved statistical methods for defining the ensemble mean of these interpolations.

In addition to estimated total land surface evaporation, the evaporation benchmark should include information on the relative contributions from transpiration, interception, and bare soil in different geographic regions with different land cover and climates. Because the interception process is well understood and proven models of interception loss exist, it may be acceptable to use model-calculated data field to estimate the interception contribution. It is anticipated that new data relevant to soil evaporation will become available over the next 5 years from new arrays of ground based soil moisture measuring networks and satellites systems

The symposium supported the use of *Fluxnet* data in the preparation of the improved evaporation benchmark but cautioned against its indiscriminate use without proper recognition of the impact of energy balance closure issues and the data loss which may result if humidity sensors become inoperable during and immediately after rain.

The issue of data access and openness of data sets was discussed at length at the symposium. It was recommended that efforts to obtain community-wide access to the data needed for an evaporation benchmark should continue, with emphasis on obtaining open access to *Fluxnet* and *FRIEND* data.