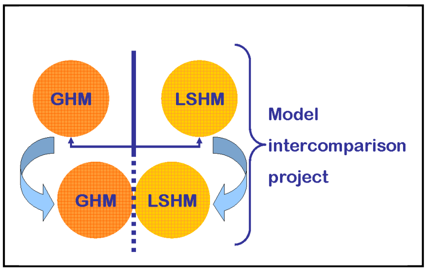
Technical Report No.1

FIRST RESULTS FROM INTERCOMPARISON OF SURFACE WATER AVAILABILITY MODULES



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1. Introduction

There are many uncertainties in our understanding of the current water cycle and how it will develop in the future. A number of studies have sought to assess the global-scale implications of climate change for water resources, their availability and water resources stresses. Since the mid-1990s a small set of global hydrology and water resource models have been developed that are capable of computing the basic dimensions of the world water balance. These models have been used to address a wide range of global-scale questions including the impact of climate change on global water resources, the location of future areas of critical change in the global water system, and the magnitude of changes in ecosystem services provided by the global freshwater system.

While all these models have been piling up published results, related studies differ in their simulation of resource availability, through the use of different input data sets, and in their interpretation of the socio-economic implications of changes in resource availability, through the use of different indicators of impact and representations of demands for water. Their estimates about the global water system have never been systematically compared to each other. But such a comparison would be very useful scientifically because it would indicate the magnitude of uncertainty in estimating the world water balance.

To advance research on the global water balance, and to begin a comparison of model-based estimates of the global water system, the Global Water System Project (GWSP, www.gwsp.org) in April 2007 brought together members of the scientific community concerned with global-scale modelling of the water cycle, followed by an intercomparison of model simulation results of the global water cycle. Representatives from six global modelling groups came together for the first time to exchange information and plan common activities. This paper presents the first results of an intercomparison of these approaches to estimate water resources and their stresses across the global domain, focusing on the *hydrological* component of global-scale water resources assessments. The specific aim of this intercomparison exercise was:

- How do different water balance models simulate the water balance over the global domain?
- How do different water balance models simulate future changes in the water balance due to climate change?

2 Concept of the intercomparison

In most cases differences between simulations of the water balance depend on (i) model formulation and (ii) the input data used to drive the models. In order to achieve harmonized estimates from several models concerning total annual water availability under current and future climate or other key parameters of the global water system, it is essential to adopt a tight protocol for a rigorous model intercomparison. In this intercomparison we seek to reduce the effect of differences in input data, by running each model with the same driving forces. In summary the following standardizations were undertaken:

- definition of regions for intercomparison;
- definition of selected time periods for intercomparison (baseline run and future scenarios);
- standardization of hydro-meteorological input data;
- standardization of other input data;
- indicators for model intercomparison.

Definition of regions

On the basis of different spatial scales the main indicators for the water balance had to be aggregated on global / continental / eco-regional / catchment scale. For final modelling purposes the definitions of these different regions was provided for each modelling group by sending out a gridded map showing the separation of each of the defined regions.

The global / continental scale is defined by (abbreviations in brackets):

  - North America (NA)
  - South America (SA)
  - Europe (EU)
  - Asia (AS)
  - Africa (AF)
  - Australia/Oceania (AU)
  - Polar (without Antarctica; PO)

On eco-regional scale the different regions were based on the Koeppen climate map (see Leemans and Cramer 1991). In this case the focus was on the five regions listed below:

  - A: Tropical
  - B: Dry
  - C: Temperate
  - D: Cold
  - E: Polar

For a detailed analysis on river basin scale the following catchments were selected:

  - Europe: Danube;
  - South America: Amazon;
  - North America: MacKenzie, Mississippi;
  - Africa: Orange, Nile;
  - Australia: Murray – D.;
  - Asia: Yangtze, Lena, Yellow, Ganges – Brahmaputra.

Definition of time periods

Two time slices were defined for the intercomparison exercise. The current state of water balance indicators was calculated for a 30 years period covering the years from 1961 to 1990. This is referred to later in this document as the baseline run. The scenario runs were set in contrast and span the period from 2071 till 2100. From the wide variety of climate scenarios, two contrasting IPCC-SRES scenarios, A1B and B1, were chosen.

Hydro-meteorological input data

Climatic input parameters which had to be standardized and provided for all modeling groups were: P (precipitation), T (temperature), radiation (incident net radiation or sunshine duration), ws (wind speed), e (vapour pressure), n (number of raindays within a month) (for all the parameters see table 1). The data was interpolated on a 0.5°x0.5° grid and distributed in the NetCDF and ASCII data format.

The provided data had a monthly time resolution, so that every group had to compute its own daily or sub-daily time series. The delivered data was not corrected in any form (e.g. no correction of precipitation data).

The climate input data for current climate conditions used in this study consists of the CRU data set (version 2.1; Mitchell & Jones 2005). Air temperature and precipitation for both future scenarios were calculated from two different transient atmospheric General Circulation Models (GCM) to account for the spatial variability of climate patterns in GCMs. The first GCM projection applied here was calculated by the Hadley Center Coupled Model (HadCM3, Gordon et al. 2000), whereas the second data set results from the MPI model ECHAM5 (Roeckner et al. 2006).

Table 1: Standardized hydro-meteorological input data for the different periods based on monthly time series.

parameter	current data	scenario
P	x	x
T	x	x
radiation	x	x (no change)
ws	x	x (no change)
e	x[1]	x (no change[2])
n	x	x (no change)

x available
1 calculated from rel. humidity
2 calculated as a function of temperature (scenario) and rel. humidity (not changed) => f(Δt, rel. humidity)

To create the scenario forcing data the ‚Delta change approach' was applied: the projected 30 years monthly GCM changes were calculated, i.e. scenario run minus control run, and then changes were added to the CRU data.

Altogether one baseline run (current climate conditions) and four scenario runs (two times A1B and two times B1) were performed. Multiplied with the number of participating models (see chapter 3) there is a number of 7 simulations for the baseline run and 28 simulation runs for future projections respectively.

Other input data

A standardization of time independent data, like the land-see-mask or a global soil map, was not taken into account. Also a common land cover map was not provided. Other model specific input data was not harmonized or manipulated, although this reveals a kind of uncertainty in the different modelling approaches and hence a spread in model results.

Indicators for model intercomparison

The agreed-upon standardized inputs were used to compute various aspects of the world water balance including (abbreviations in brackets):

- precipitation (prec),
- temperature (temp),
- cell runoff (defined as maximum water availability for each grid-cell; runoff),
- soil water content (mean monthly values, total soil water content and percentage of max capacity; soil moisture),

- evapotranspiration (cell total potential evapotranspiration (pet) and cell total actual evapotranspiration (aet) including sublimation, canopy ETP, ETP from waterbodies),
- average snow water equivalent (swe as monthly mean value),
- snow melt.

All indicators for the water balance intercomparison were calculated in a mean monthly time series (averaged over the specific 30 years time period for the baseline run and the four scenario runs respectively) and aggregated to the region in concern.

3 Overview of the different modelling approaches

In total results from seven different global hydrological models (GHMs) were available to give a preliminary estimate of global hydrological quantities. The following models were included in these assessments (in parentheses institution where it is mainly developed and some reference papers):

1. WaterGAP (University of Kassel, University of Frankfurt; Alcamo et al. 2003; Döll et al. 2003)
2. MATSIRO (University of Tokyo, National Institute for Environment Studies (Japan); Hanasaki et al. 2007a),
3. HO7 (University of Tokyo, National Institute for Environment Studies (Japan); Hanasaki et al. 2007b),
4. MacPDM (University of Reading; Arnell, 2003)
5. SL scheme/HD model [MPI-HM] (Max Planck Institute for Meteorology MPI-M; Hagemann & Dmenil Gates 2003, Hagemann & Dmenil 1998)
6. WBMplus (University of New Hampshire; Vorsmarty et al. 2000)
7. VIC (VIC community; Nijssen et al. 2001),

The following sections will give a short description for each of the model and table 2 summarizes the most important details. The results presented in chapter 5 and 6 refer to the number each model is assigned to in table 2 (see column 1 table 2). For more model details see literature cited.

WaterGAP

WaterGAP comprises two main components, a Global Hydrology Model and a Global Water Use Model. The Global Hydrology Model simulates the macroscale behaviour of the terrestrial water cycle to estimate water resources, while the Global Water Use Model computes water use for the domestic, industrial, irrigation and livestock sectors. Both water availability and water use computations cover the entire land surface of the globe (except the Antarctic) and are performed for cells on a 0.5° by 0.5° spatial resolution.
The WaterGAP-Global Hydrology Model calculates a daily vertical water balance for both land area and open water bodies in each 0.5-cell. The sum of runoff produced within a cell plus the upstream discharge into a cell is transported through groundwater, lakes, reservoirs and wetlands to rivers. Finally, the river discharge is routed to the next downstream cell according to a global drainage direction map (Döll & Lehner 2002). The calculated total discharge has been calibrated against measured values (from GRDC, 2000) for 724 drainage basins worldwide. The calibration procedure is implemented via tuning of a model parameter describing the land surface runoff to achieve a sufficient match to observed long-term average annual discharge. For drainage basins without measured discharge data, runoff factors are regionalized by applying a multiple regression approach (Döll et al., 2003).

MATSIRO

HO7

The land surface hydrology module of the H07 model calculates the energy and water budget, including snow, on the land surface from the forcing data. This module is based on a bucket model, but differs from the original formulation in the following two aspects. First, soil temperature is calculated using the force restore method. Second, a simple subsurface runoff parameterization is added to the model.

MacPDM

MacPDM simulates streamflow at a spatial resolution of 0.5x0.5o, treating each cell as an independent catchment, and calculates the evolution of the components of the water balance at a daily time step. Precipitation is intercepted by vegetation. Potential evaporation is calculated using the Penman-

Monteith formula, with stomatal and aerodynamic resistances and leaf area dependent on vegetation type. Each cell is divided into two land cover classes - grass and "not grass" - with the relative proportions of the two varying with the "not grass" vegetation type. Each part of the cell has the same inputs and soil properties, and the output of the two parts is summed to give total cell response. Water that reaches the ground becomes "quickflow" if the soil is saturated and infiltrates if the soil is unsaturated. Soil moisture is depleted by evaporation and drainage to a deep store. Drainage occurs when soil moisture storage is above field capacity. Water from this deep store drains to the stream as "slowflow". Soil moisture storage capacity varies statistically across the cell, which means that the proportion of the cell that is saturated varies over time. It is assumed that the entire cell has the same soil texture, and the absolute magnitude of soil moisture storage capacity is a function of the soil texture and rooting depth of the vegetation. The variability in soil moisture storage capacity around the cell average value is defined by a shape parameter. Actual evaporation is a linear function of potential evaporation and average cell soil moisture content, and falls below the potential rate once soil moisture storage falls below field capacity. Model parameters are not calibrated from site data.

SL scheme/HD model
The MPI-HM (Max Planck Institute for Meteorology Hydrological Model) comprises of the simplified land surface (SL) scheme (Hagemann and Dümenil Gates, 2003) and the hydrological discharge (HD) model (Hagemann and Dümenil Gates, 2001). The SL scheme is representing vertical soil water fluxes. It incorporates the main components of the hydrological cycle at the land surface and primarily uses relations that are functions of temperature and precipitation. The HD model globally simulates the lateral freshwater fluxes at the land surface at 0.5° resolution. It is a state of the art discharge model that is applied and validated on the global scale, and it is also part of the coupled atmosphere-ocean GCM ECHAM5/MPI-OM (Latif et al., 2003).

WBMplus

VIC
The Variable Infiltration Capacity (VIC) macroscale hydrology model (Liang et al., 1994) is a grid-based model that usually is implemented at spatial scales from one-eighth to one degree latitude by longitude, and at hourly to daily temporal resolution. Each grid cell is partitioned into multiple vegetation types, and the soil column is divided into multiple (typically three) soil layers. Evapotranspiration is calculated using the Penman-Monteith equation. The saturation excess mechanism, which produces surface runoff, is parameterized through the Xinanjiang variable infiltration curve (Zhao et al., 1980). Release of baseflow from the lowest soil layer is controlled through the non-linear Arno recession curve (Todini, 1996). Surface runoff and baseflow for each cell are routed to the basin outlet through a channel network as described by Lohmann et al. (1998). The model can be run in two modes: energy or water balance. In both water and energy balance modes, snow accumulation and ablation processes are solved via an energy balance approach (following Wigmosta et al. 1994) that operates at a subdaily time step, regardless of whether the time step is daily during snow-free periods. In this project, the VIC model was run in the computationally efficient water balance mode.

Table 2: Main features for participating GHMs in first round of model intercomparison.

no	model name	spatial resolution	temporal resolution		basic structure and procedures								calibra-tion
			met. data	model runs	inter-ception	evapo-ration	snow	soil	ground-water	runoff	dams	routing	
1	WaterGAP	0.5	monthly	daily	x	x	x	x	x	x	x	x	x
2	MATSIRO	1	6hourly	daily	x	x	x	x	-	x	-	(x)	-
3	UT/NIES	1	3hourly	daily	?	x	x	x	-	x	x	(x)	-
4	MacPDM	0.5	monthly	daily	x	x	x	x	(x)	x	-	-	-
5	MPI	0.5	mon./daily	daily	-	x	x	x	-	x	-	x	-
6	WBMPlus	0.5	monthly	daily	(-)	x	x	x	x	x	x	x	-
7	VIC	0.5	daily	daily	x	x	x	x	-	x	x	x	-

5 Comparison of baseline water balance simulations

In this report we will concentrate on the global and continental results due to missing data for the other regions or river basins for some of the models.
The areal extent of all predefined continents within each model is given in table 3. When comparing the biggest differences in terms of percent change from minimum to maximum areal extent it is obvious that beside the polar region (5.6% difference) the highest differences are obtained for Europe (4.3%), North America (3.6%), and Australia (3.5%). This is a very important aspect, because this will of course lead to differences in model results which have nothing to do with model physics, but just resulting from different land-see-masks (see chapter 2).

Table 3: Areal extent of predefined continents and biggest difference (in terms of % change from minimum to maximum value) between the different models.

	Area [10^6 km^2] by model							difference
Region	1	2	3	4	5	6	7	[%]
Polar (PO)	2.2	2.2	2.2	2.2	2.1	2.2	2.1	5.6
North America (NA)	22.1	21.5	21.5	22.3	21.5	22.4	22.1	3.6
Europe (EU)	10.1	9.8	9.8	10.0	10.0	9.8	9.7	4.3
Asia (AS)	44.9	44.2	44.2	45.2	44.2	45.0	44.6	2.2
Africa (AF)	29.8	29.7	29.7	30.0	29.8	30.1	29.9	1.1
South America (SA)	17.8	17.7	17.7	17.9	17.7	17.9	17.8	1.6
Australia (AU)	7.9	7.8	7.8	8.1	7.8	8.1	8.0	3.5
Global (GL)	134.9	133.0	133.0	135.7	133.1	135.4	134.1	2.0

Mean annual water balance indicators on global scale (baseline run)
The modelled global estimates for the main water balance indicators are shown in figure 1. The long term mean annual values for precipitation, temperature, actual evapotranspiration, cell runoff, snow water equivalent, and soil moisture are presented for the baseline run (values are based on the climate normal period 1961-1990).
Although precipitation and temperature should be the same for each model, there are some differences in total amount of global values. Global mean annual temperature varies from 12.9 °C to 13.2°C and precipitation is between 103,102 km^3/a and 107,271 km^3/a. Beneath the above mentioned differences in the continental extents, this is due to the fact that model 2 and model 3 uses a slightly different input data set for these variables published by Ngo-Duc et al. 2005.
Mean annual total runoff on global scale for all seven models is of about 37,980 km^3/a. The spread ranges from 31,383 km^3/a for model 5 to 42,755 km^3/a for model 4. This results in a coefficient of variation (CV) of about 0.09 (see also table 4) which means that the variation is comparative small. This is also true for the actual evapotranspiration. The global mean annual aet is of about 66,169 km^3/a whereas the span goes from 63,382 km^3/a to 68,805 km^3/a (CV: 0.03).

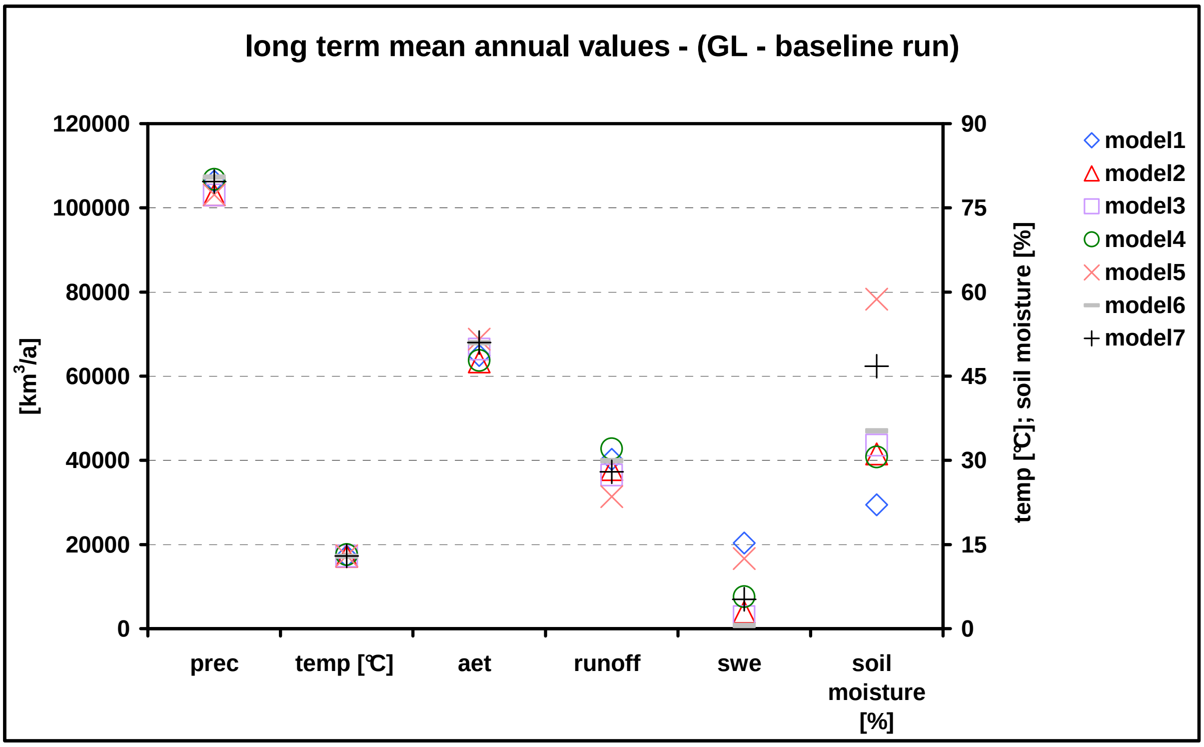

Figure 1: Long term mean annual values for main water balance indicators on global scale for the baseline run (precipitation=prec, temperature=temp, actual evapotranspiration=aet, cell runoff=runoff, snow water equivalent=swe, soil water content (in percentage from maximum storage)=soil moisture).

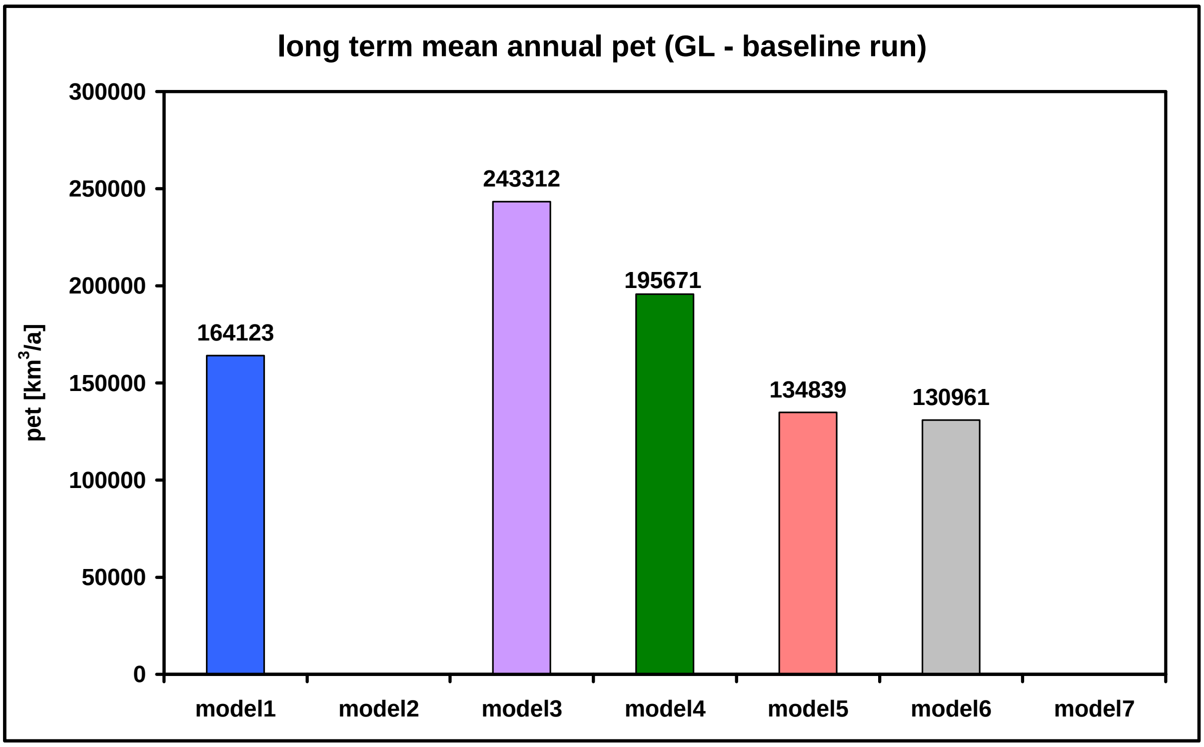

Figure 2: Long term mean annual potential evapotranspiration (pet) for the baseline run on global scale. There was no data available for model2 and model7.

Table 4: Coefficient of variation for the baseline run for main water balance indicators on global/continental scale.

	region							
indicator	PO	NA	EU	AS	AF	SA	AU	GL
prec	0.54	0.02	0.02	0.03	0.01	0.01	0.05	0.02
temp	0.34	0.01	0.05	0.02	0.00	0.00	0.00	0.01
pet	0.56	0.30	0.18	0.28	0.27	0.18	0.40	0.27
aet	1.25	0.05	0.09	0.07	0.05	0.05	0.04	0.03
runoff	1.00	0.08	0.14	0.13	0.17	0.08	0.41	0.09
swe	1.20	0.95	1.10	0.97	2.37	1.36	1.56	0.87
soil moisture	0.60	0.34	0.24	0.36	0.46	0.28	0.57	0.33

This homogeneity can not be found for other water balance indicators like potential evapotranspiration, snow water equivalent and soil moisture. The values for global mean annual pet are shown in figure 2. Two models did not provide any values at all, but lowest values are provided by model 6 (130,961 km^3/a) whereas highest amount of pet is delivered by model 3 (243,312 km^3/a). Altogether this results in a CV of 0.27 which indicates a high range of variability. Even higher are the coefficients of variation for swe and soil moisture (in terms of percentage of max capacity). The domain for swe lies between 749 and 20,382 km^3/a (annual mean: 8467 km^3/a;CV 0.87), the domain for soil moisture between 22% and 59% (annual mean 37%; CV 0.33).
This can not only be explained by different formulations in model physics, e.g. different formulas for pet (like Priestly-Taylor, Penman, etc.), this must be cause due to completely different model structures. It has to be clarified how many soil layers each model consists of, how they are treated and how they are linked to the groundwater. Also the definition of swe has to be checked and whether or not it can accumulate over the years or not.

Mean monthly water balance indicators on global scale (baseline run)
Another aspect of model agreements or disagreements is shown in figure 3a. In this graph the mean monthly variability for runoff on the global scale and the climate normal period is described exemplarily based on the seven simulations for the baseline run. Herein the whole width for cell runoff from minimum to maximum is presented as well as the mean the median and the 15% to 85% quantiles. The closest agreements are attained for the period November till March, the biggest disagreements are obtained for the months April till October. This is identically for the parameters aet and pet but not for the others (prec, temp, swe, soil moisture). Prec and temp show a continuous conformance all over the year in contrast to swe and soil moisture where the wide spread can be observed all over the year.

Mean annual water balance indicators on continental scale (baseline run)
A closer look at the different continents suggests the highest variability for the Polar region (PO, without Antarctica) and the dry regions (Australia and Africa, see table 4) considering the overall water balance. All the parameters in PO, AU and AF indicate that model behaviour in these regions is very heterogeneous so that further investigations have to be done to explain theses differences.
The parameter with the highest uncertainty in model results is swe (CV ranges from 0.95 – 2.37), but also the values for pet and soil moisture are very uncertain all over the globe. Nonetheless the results for the integrated parameter cell runoff is of medium variability underpinning the assumption that on higher spatial resolutions most physical processes are weighted out and water availability on continental scale can be achieved with acceptable confidence (see also figure 4a).
All these findings can also be observed for the Koeppen regions. The results will not be discussed in detail but the key findings are more or less the same (see table 5): the highest uncertainty in model results can be found in the dry climate zones (B) and the parameters with highest variability are swe, pet and soil moisture. The other zones imply nearly the same level of agreement.

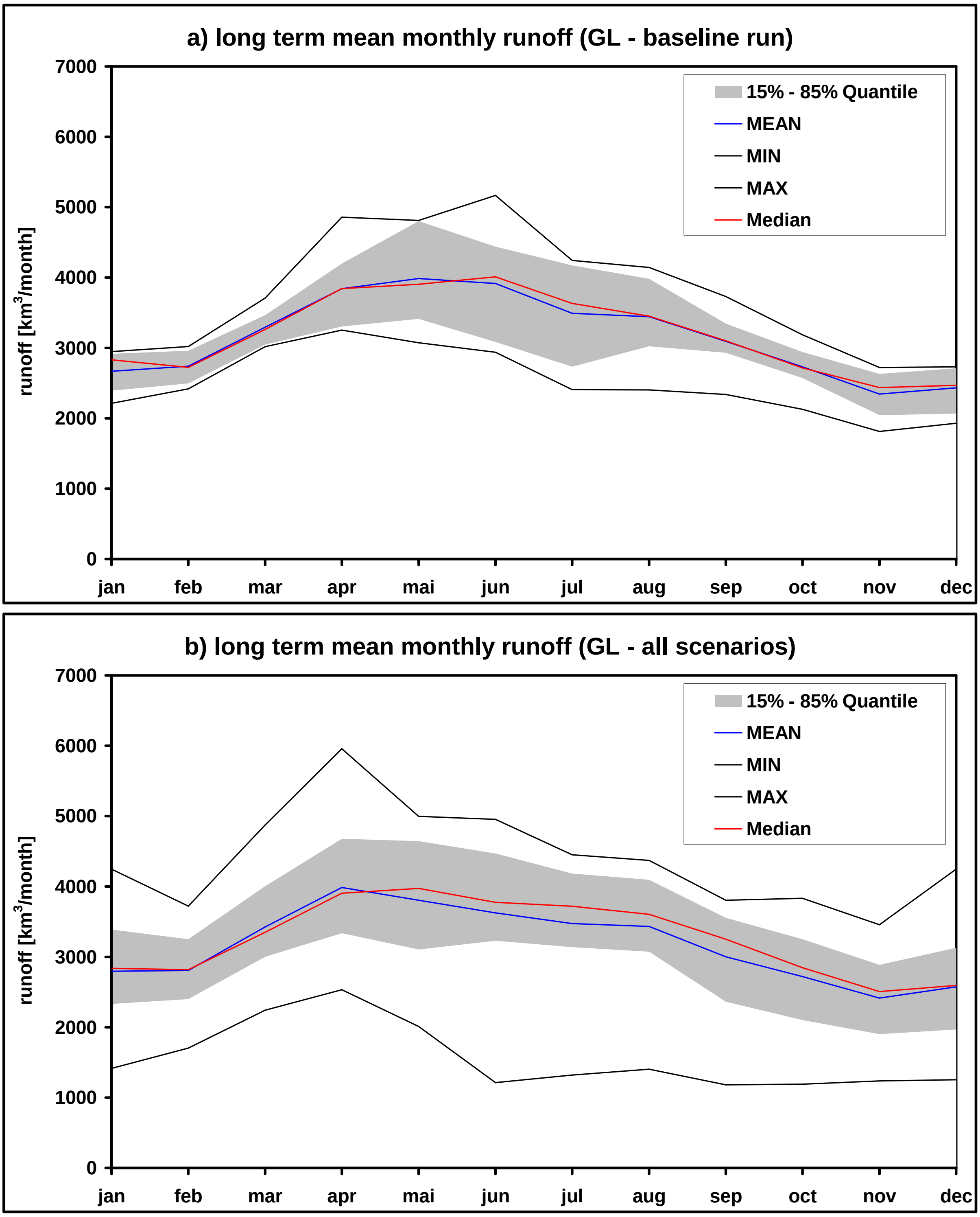

Figure 3: Monthly variability for long term mean monthly runoff simulations on global scale expressed as minimum (MIN), maximum (MAX), mean (MEAN), median (Median) and the 15% and 85% quantile respectively. a) long term mean monthly runoff for baseline run (in total 7 simulations), b) long term mean monthly runoff for all scenarios (in total 28 simulations).

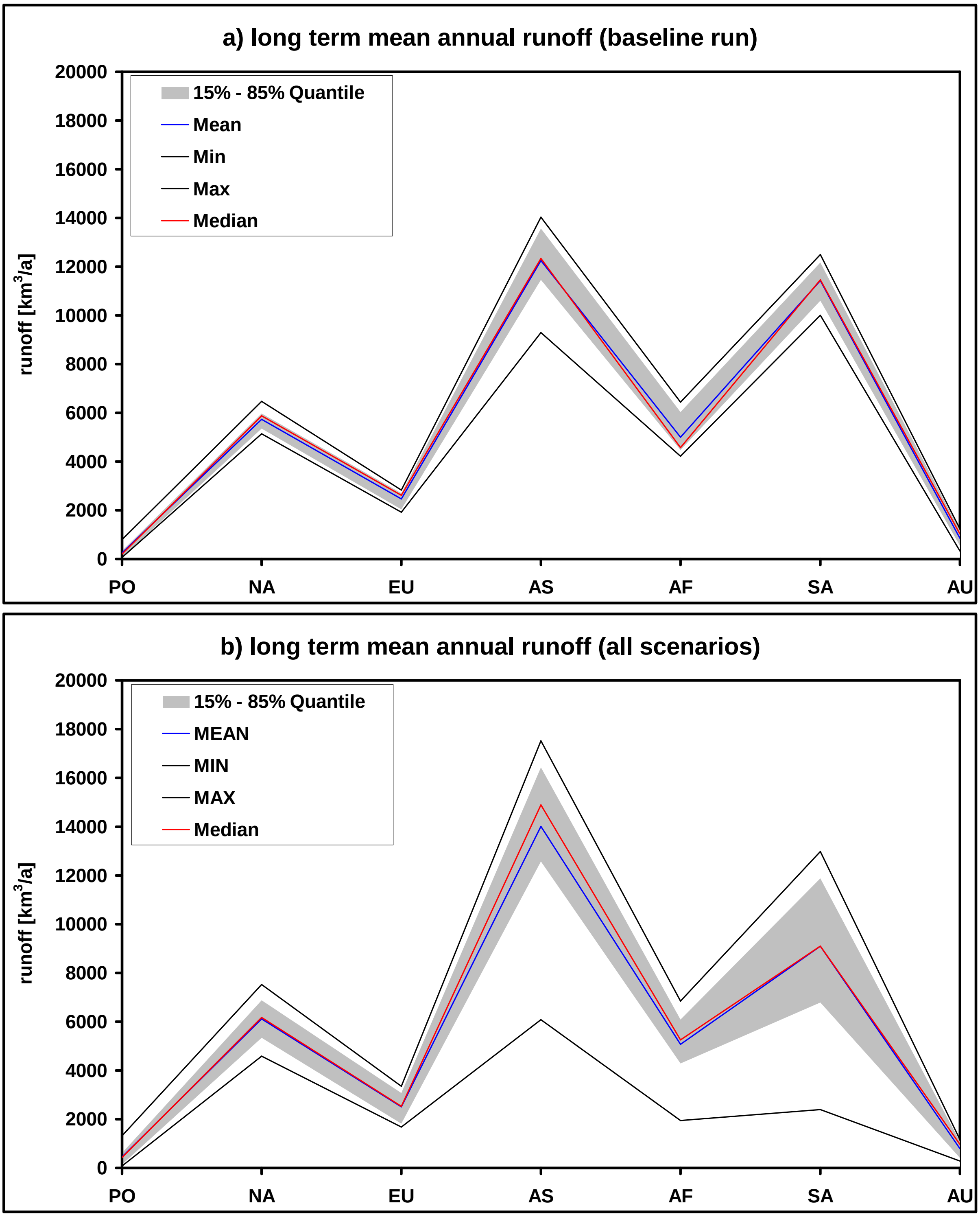

Figure 4: Long term mean annual runoff simulations on continental scale expressed as minimum (MIN), maximum (MAX), mean (MEAN), median (Median) and the 15% and 85% quantile respectively. a) long term mean annual runoff for baseline run (in total 7 simulations), b) long term mean annual runoff for all scenarios (in total 28 simulations).

Table 5: Coefficient of variation for the baseline run for main water balance indicators in the Koeppen regions.

indicator	region A	B	C	D	E	GL
prec	0.05	0.02	0.03	0.01	0.11	0.02
temp	0.00	0.01	0.02	-1.09	-0.06	0.00
pet	0.17	0.39	0.31	0.30	0.49	0.31
aet	0.06	0.06	0.06	0.09	0.08	0.03
runoff	0.09	0.67	0.10	0.14	0.10	0.09
swe	2.27	0.68	0.84	0.55	1.01	0.93
soil moisture	0.31	0.62	0.33	0.38	0.32	0.35

6 Comparison of future water balance simulations

The comparison of present and future key parameters of the global water system can exemplarily be discussed for the integrated parameter runoff. In figure 5 the results on global scale for the two IPCC-SRES scenarios A1B (figure 5a) and B1 (figure 5b) are set in contrast to the baseline run and compared for the two different GCMs (total cases 28 = 7 GHMs x 2 emission scenarios x 2 GCMs). Summed up an increase for future global water runoff is obtained in 13 cases whereas a decrease can be observed in 15 cases (see also table 5) with a high range of variability reaching from -40% up to +30% relative to the current situation. The results show an agreement of an increasing trend for runoff in Asia, North America, and the Polar region, in South America, and Australia however a decreasing trend is more likely. The future direction of runoff change for Europe, and Africa is indifferent. Here we have an equal number of simulations for a positive or negative direction respectively. It's obvious from this point of view that it depends more on the model than on the climate scenario in which direction global hydrological components tends to evolve.
A significant change in dynamics of the mean monthly curves regarding the global runoff can not be assessed (see figure 3b), although the predictions are less certain all over the year. This is also true for the continental values like figure 4b indicates. In total a slight trend to higher values of runoff is suggested, but again the impacts of climate change lead to a broader span in predictions.
All these findings highlight the assumption that differences between hydrologic models are much more important than differences between emission scenarios or climate models.

Table 5: Ensemble results for climate change impact on global and continental runoff.

Continent	Number of models with increase*	Maximum increase [%]	Number of models with decrease*	Maximum decrease [%]
PO	28	187.0	0	-
NA	20	33.4	8	-11.4
EU	12	27.1	16	-17.4
AS	24	43.3	4	-34.6
AF	14	47.3	14	-54.0
SA	5	15.2	23	-76.1
AU	7	14.0	21	-28.6
GL	13	29.6	15	-39.9

* total cases 28 = 7 GHMs x 2 emission scenarios x 2 GCMs

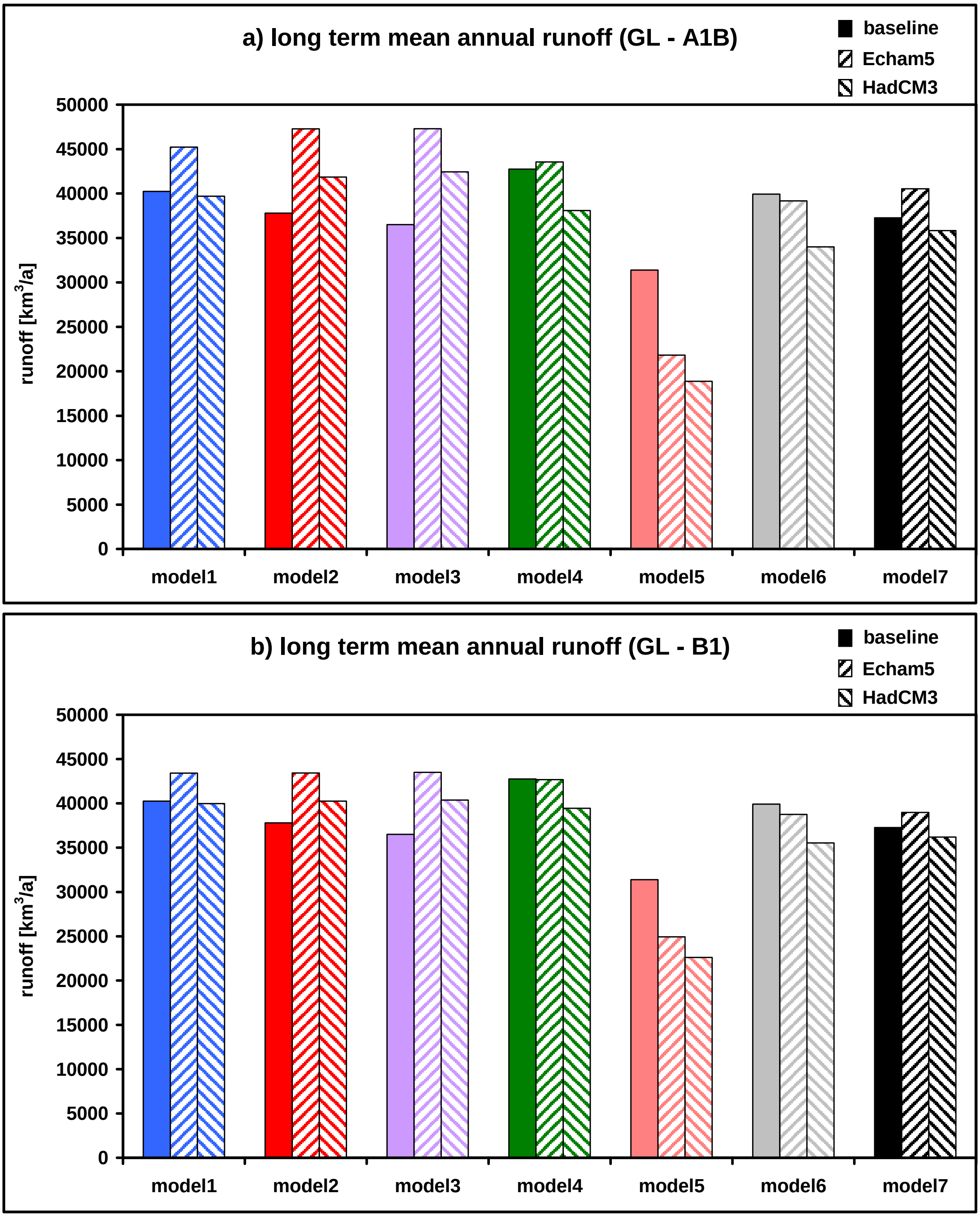

Figure 5: Long term mean annual runoff on global scale for baseline run in contrast to the long term mean annual runoff for two different GCMs (Echam5 and HadCM3). a) long term mean annual runoff based on the emission scenario A1B, b) long term mean annual runoff based on emission scenario B1.

7 Conclusions and outlook

In this study the first results of an intercomparison of different modelling approaches to estimate the global water resources and their hydrological components are presented. The specific aim of this paper was to answer the question of how different various global hydrological models simulate the water balance over the global domain, and how certain or uncertain future changes in the water balance due to climate change can be predicted.

For the global perspective indicators like total cell runoff and actual evapotranspiration are within the same magnitude for all of the different models. Dimensions of current global runoff are within a range of 37,900 km^3/a. But the question arises how do model structure differ for each of the GHMs, because other parameters like the potential evapotranspiration, the snow water equivalent, and the soil moisture comprise a wide range of simulation results.

Although main driving forces like precipitation and temperature were supported for each of the modelling groups, differences on global and continental scale occurred. The main reason for this discrepancy is due to the fact, that not every model accounts for the same land-see-mask. Also other basic input data such as a global soil map or a global land use map etc. were not harmonized and therefore contribute to a certain extent to diversity in model results.

The closest agreements for mean monthly runoff (and also for aet and pet) on global scale are attained for the period November till March, the biggest disagreements are obtained for the months April till October. Precipitation and temperature differ in total amount as stated above but there is no specific period within the year in which higher deviations could be identified. In contrast the wide spread for snow water equivalent and soil moisture can be observed all over the year. These parameters together with the potential evapotranspiration showed the highest uncertainty in model results.

A closer look at the different continents suggests the highest variability for the Polar region (PO, without Antarctica) and the dry regions (Australia and Africa). All the water balance parameters indicate that model behaviour in these regions is very heterogeneous so that further investigations have to be done to explain theses differences.

The aim of this model application was not only to asses the current water resources situation and its computability, but also to predict future changes due to climate change and its predictability. Future global runoff (2071-2100) relative to the current situation will vary between a range of -40% to +30%, but tends to be slightly higher than today (38,000 km^3/a in future). The application of the different modelling approaches is not consistent in regard to future directions of water availability. Low agreement on direction of runoff change is obtained for Europe and Africa and even on global scale half of the models show an increase whilst the other half project a decrease. A significant change in dynamics of the mean monthly values can not be assessed, although the predictions become less certain all over the year.

Summarizing, the impacts of climate change lead to a broader span in the predictions and differences between hydrologic models are much more important than differences between emission scenarios or climate models.

Next steps

The '*First GWSP International Workshop on Computing the World Water Balance'* held in April 2007 at Kassel University and organized in cooperation with the Global Water System Project (GWSP) was meant to be the first in a series, which has engaged an international community of global modelling experts. As the efforts move forward, this community is now seeking the advice of a broader body of experts, who can provide insight in past and future water availability and water use. To open the forum will mean, to be able to include not only the Global Hydrological Models (GHMs) but also the Land Surface Hydrology Models (LSHMs) within the Global Climate Models for an enhanced analysis and improvement of modelling the global water balance.

Therefore the WATCH consortium has launched a joint GWSP - WATCH effort for a global water balance intercomparison study. As a result the '*Second International Workshop on Computing the World Water Balance'* was held in April 2008 at Wageningen University. In addition to the first meeting, the focus of this ongoing effort will be on building interfaces between water resources, hydrological and climate models, attempting a maximum possible consistency in spatial and time scales involved, and in related process descriptions, which is one of the main innovative components of WATCH.
Through integrated model intercomparisons and evaluations, participating models will improve the parameterization of physical processes. Besides this, we will also look at global consumptive water use in different sectors not only for irrigation but also for domestic, manufacturing and livestock farming purposes.
The protocol and other details for the next round of this intercomparison project are also available on the internet (see http://www.eu-watch.org/modelintercomparison).

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