8 Water

Table 13 provides an overview of all experiments to be run in the water sector in ISIMIP2a. This table is for your reference only; please read chapters 1-5 and this section carefully before beginning with the experiments.

Table 13 Summary of experiments for water models

	Climate Data	Scenario	Human Impacts	Land use (if applicable)	Other settings (sens-scenario)	# runs
Historical runs	PGMFD v.2 (Princeton)	Hist	nosoc pressoc varsoc	Hyde3 + MIRCA constant (MIRCA2000) Hyde3 + MIRCA	historical CO2 (co2)	3
	GSWP3	Hist	nosoc pressoc varsoc	Hyde3 + MIRCA constant (MIRCA2000) Hyde3 + MIRCA	historical CO2 (co2)	3
	WATCH (WFD)	Hist	nosoc pressoc varsoc	Hyde3 + MIRCA constant (MIRCA2000) Hyde3 + MIRCA	historical CO2 (co2)	3
	WATCH+WFDEI.GPCC	Hist	nosoc pressoc varsoc	Hyde3 + MIRCA Constant (MIRCA2000) Hyde3 + MIRCA	historical CO2 (co2)	3
	Optional run: Princeton	Hist	varsoc	Hyde3 + MIRCA	constant CO2 at 1971 levels (co2const)	1

Future runs	GCM1 (HadGEM2-ES)	hist+ 2.6 (rcp2p6) 6.0 (rcp6p0)	pressoc+ SSP2	Hyde3 + MIRCA Constant from 2000 onwards	historical CO2 + RCP2.6 RCP6.0 (co2)	2
	GCM1 (HadGEM2-ES)	hist+ 6.0 (rcp6p0)	pressoc + SSP2	Hyde3 + MIRCA Constant from 2000 onwards	historical CO2 + fixed CO2 from 2000 onwards (noco2)	1
	GCM1 (HadGEM2-ES)	hist+ 2.6 (rcp2p6) 6.0 (rcp6p0)	pressoc + SSP2	Hyde3 + MIRCA MAgPIE from 2000 onwards	historical CO2 + RCP2.6 RCP6.0 (co2)	2
	GCM2 (IPSL-CM5A-LR)	hist+ 2.6 (rcp2p6) 6.0 (rcp6p0)	pressoc + SSP2	Hyde3 + MIRCA Constant from 2000 onwards	historical CO2 + RCP2.6 RCP6.0 (co2)	2
	GCM2 (IPSL-CM5A-LR)	hist+ 2.6 (rcp2p6) 6.0 (rcp6p0)	pressoc + SSP2	Hyde3 + MIRCA MAgPIE from 2000 onwards	historical CO2 + RCP2.6 RCP6.0 (co2)	2

8.1 Sector-specific input data

In ISIMIP2a – the historical validation exercise – hydrological modelling teams are asked to take into account the historical evolution of irrigated areas, dams and reservoirs, in order to obtain a more realistic estimate of the historical evolution of runoff and discharge. The data sources to be used are listed in

Table 14, along with a soil and vegetation dataset that may be used optionally.

Table 14: Input data to be used for the historical runs (ISIMIP2a), in addition to the common data listed in chapter 4.

Dataset Mandatory (if feasible)	Description	More info	Scale	Variables included; comments
GranD data base, mapped to DDM30 routing network	Dams/Reservoirs	Documentation: http://www.gwsp.org/products/grand-database.html Note: Simple interpolation can result in inconsistencies between the GranD database and the DDM30 routing network (wrong upstream area due to misaligned dam/reservoir location). We provide a file with locations of all larger dams/reservoirs adapted to DDM30 such as to best match reported upstream areas.	global, 0.5°	location, upstream area, capacity, and construction/commissioning year.
DDM30 routing network, mapped to the CRU land mask	flow directions, slope, and basin numbers	Note: The routing network includes large lakes that are not included in the provided land mask. These cells should not be included when results are submitted and there should be no runoff added to the river network from these cells. I.e. these cells are included only for transportation purposes (streamflow).	global, 0.5°	**for global models only**[6]
Optional (does not have to be harmonized):				
HWSD, or GSWP3 (upscaled version of HWSD)	soil map	see http://hydro.iis.u-tokyo.ac.jp/~sujan/research/gswp3/soil-	global, 30 arc sec (HWSD) or 0.5° (GSWP3), fixed	soil type

[6] To allow a direct intercomparison of river flows between global and regional models on a gridded basis, the runoff produced by the global models could be collected and routed through the HydroSHEDS network as a post-processing step, using a single routing model. Volunteers for this task are welcome.

		texture-map.html, upscaling method A. Each model does have the option to use their own soil datasets if they prefer		
GLIMS (Global Land Ice Measurements from Space)	Glacier distribution	http://www.glims.org/About/		
HydroSHEDS	Topography/routing network	Hydrographically corrected SRTM data. Available in 3 resolutions, includes accumulated upstream area. Also HydroSHEDS is not available north of 60 degrees, due to limitations in the SRTM data at high latitudes		**for regional models only**6
CRU elevation data				

8.2 data

Note that variable names are chosen to comply, where feasible, with the ALMA convention[7] and the names used in WATCH/WaterMIP. Although variable names are mixed-case here, make sure to use **only lower-case** letters in the output filenames (see section 6.2).

All variables are to be reported as time-averages with the indicated resolution; do not report instantaneous values ('snapshots'). An exception is **MaxDis**, which is the maximum daily-average discharge in a given month, to be reported on a monthly basis (see below).

Water balance equation in terms of requested output variables:

rainf + snowf = evap + qtot,

where **Evap** is the sum of interception, transpiration, sublimation, and evaporation from the surface. This equation only holds on timescales long enough for changes in water storage (e.g. in soil and groundwater) to average out.

[7] http://www.lmd.jussieu.fr/~polcher/ALMA/convention_output_3.html

*IMPORTANT Some output variables reported for the water sector are also appropriate for use in the permafrost sector described in Section 7.6; these are marked with an *. Some additional variables are also required for the permafrost sector. The full list can be found in* **Table 37**.

Table 15: Output variables to be reported by water sector models. Highlighted variables are requested from both global and regional models, if computed; others only from global models.

Variable	Variable name	Resolution	Unit (NetCDF format)	Comments
Hydrological Variables				
*Runoff	qtot	daily* (0.5°x0.5°)	kg/m^2/s (kg m-2 s-1)	total (surface + subsurface) runoff (Qtot = Qs + Qsb). *if daily resolution not possible, please provide monthly[8]. Please also deliver for the permafrost sector.
Discharge (gridded)	dis	daily* (0.5°x0.5°)	m^3/s (m3 s-1)	*if daily resolution not possible, please provide monthly
Discharge (gauge level)	dis	daily* (at gauge locations specified in **Table 17**)	m^3/s (m3 s-1)	A file will be provided mapping the gauge coordinates to the 0.5x0.5 degree river network. *if daily resolution not possible, please provide monthly
Monthly maximum of daily discharge	maxdis	monthly (0.5°x0.5°)	m^3/s (m3 s-1)	Reporting this variable is not mandatory, but desirable particularly if daily discharge data is unfeasible
Evapotranspiration	evap	monthly (0.5°x0.5°)	kg/m^2/s (kg m-2 s-1)	sum of transpiration, evaporation, interception and sublimation.

8 If storage issues keep you from reporting daily data, please contact the ISIMIP team to discuss potential solutions.

Potential Evapotranspiration	potevap	monthly (0.5°x0.5°)	kg/m^2/s (kg m-2 s-1)	as Evap, but with all resistances set to zero, except the aerodynamic resistance.
*Soil moisture	soilmoist	monthly (0.5°x0.5°)	kg/m^2 (kg m-2)	please provide soil moisture for all depth layers (i.e. 3D-field), and indicate depth in m. Please also deliver for the permafrost sector.
Soil moisture, root zone	rootmoist	monthly (0.5°x0.5°)	kg/m^2 (kg m-2)	Total simulated soil moisture available for evapotranspiration. If simulated by the model. Please indicate the depth of the root zone for each vegetation type in your model
Frozen soil moisture for each layer	soilmoistfroz	monthly (0.5°x0.5°)	kg m-2	Soil_frozen_water_content This variable only for the purposes of the permafrost sector.
*Temperature of Soil	tsl	daily* (0.5°x0.5°)	K	Temperature of each soil layer. Reported as "missing" for grid cells occupied entirely by "sea". THIS IS THE MOST IMPORTANT VARIABLE. Also need depths in meters. Daily would be great, but otherwise monthly would work. This variable only for the purposes of the permafrost sector *if daily resolution not possible, please provide monthly
*Snow depth	snd	monthly (0.5°x0.5°)	m	Grid cell mean depth of snowpack. This variable only for the purposes of the permafrost sector.

*Snow water equivalent	swe	monthly (0.5°x0.5°)	kg/m^2 (kg m-2)	Total water mass of the snowpack (liquid or frozen), averaged over a grid cell. Please also deliver for the permafrost sector.
Annual maximum thaw depth	thawdepth	monthly (0.5°x0.5°)	m	calculated from daily thaw depths
Rainfall	rainf	monthly (0.5°x0.5°)	kg/m^2/s (kg m-2 s-1)	These variables are required for test purposes only. If you need to reduce output data volumes, please provide these variables only once, with the first (test) data set you submit, e.g. for the first decade of each experiment. NOTE: rainf + snowf = total precipitation
Snowfall	snowf	monthly (0.5°x0.5°)	kg/m^2/s (kg m-2 s-1)	
Water management variables (for models that consider water management/human impacts)				
Irrigation water demand (=potential irrigation water Withdrawal)	pirrww	monthly (0.5°x0.5°)	kg/m^2/s (kg m-2 s-1)	Irrigation water withdrawal, assuming unlimited water supply
Actual irrigation water withdrawal	airrww	monthly (0.5°x0.5°)	kg/m^2/s (kg m-2 s-1)	Irrigation water withdrawal, taking water availability into account; please provide if computed
Potential irrigation water consumption	pirruse	monthly (0.5°x0.5°)	kg/m^2/s (kg m-2 s-1)	portion of withdrawal that is evapo-transpired, assuming unlimited water supply

Actual irrigation water consumption	airruse	monthly (0.5°x0.5°)	$kg/m^2/s$ (kg m-2 s-1)	portion of withdrawal that is evapotranspired, taking water availability into account; if computed
Actual green water consumption on irrigated cropland	airrusegreen	monthly (0.5°x0.5°)	$kg/m^2/s$ (kg m-2 s-1)	actual evapotranspiration from rain water over irrigated cropland; if computed
Potential green water consumption on irrigated cropland	pirrusegreen	monthly (0.5°x0.5°)	$kg/m^2/s$ (kg m-2 s-1)	potential evapotranspiration from rain water over irrigated cropland; if computed and different from AIrrUseGreen
Actual green water consumption on rainfed cropland	arainfusegreen	monthly (0.5°x0.5°)	$kg/m^2/s$ (kg m-2 s-1)	actual evapotranspiration from rain water over rainfed cropland; if computed
Actual domestic water withdrawal	adomww	monthly (0.5°x0.5°)	$kg/m^2/s$ (kg m-2 s-1)	if computed
Actual domestic water consumption	adomuse	monthly (0.5°x0.5°)	$kg/m^2/s$ (kg m-2 s-1)	if computed
Actual manufacturing water withdrawal	amanww	monthly (0.5°x0.5°)	$kg/m^2/s$ (kg m-2 s-1)	if computed
Actual Manufacturing water consumption	amanuse	monthly (0.5°x0.5°)	$kg/m^2/s$ (kg m-2 s-1)	if computed
Actual electricity water withdrawal	aelecww	monthly (0.5°x0.5°)	$kg/m^2/s$ (kg m-2 s-1)	if computed

Actual electricity water consumption	aelecuse	monthly (0.5°x0.5°)	$kg/m^2/s$ (kg m-2 s-1)	if computed
Actual livestock water withdrawal	aliveww	monthly (0.5°x0.5°)	kg/m2/s (kg m-2 s-1)	if computed
Actual livestock water consumption	aliveuse	monthly (0.5°x0.5°)	kg/m2/s (kg m-2 s-1)	if computed
Static output (Note: data that cannot be submitted in NetCDF format may be submitted in another suitable format directly via email to Info@isimip.org)				
Vegetation types	Names to be coordinated with biomes/ecosystem sector	static (0.5°x0.5°)	N/A	Map of vegetation / land surface types as used by the model. Please include a description of the parameters and their values associated with these vegetation types (parameter values could be supplied as spatial fields where appropriate). In your description please also provide details of the evapotranspiration scheme used by your model.
Soil types	soil	static (0.5°x0.5°)		Soil types or texture classes as used by your model. Please include a description of each type or class, especially if these are different from the standard HSWD and GSWP3 soil types. Please also include a description of the parameters and values associated with these soil types (parameter values could be submitted as spatial fields where appropriate).
Leaf Area Index	lai (to be	static (0.5°x0.5°) or monthly		if used by, or computed by the model

	coordinated with other sectors)	(0.5°x0.5°) where appropriate		

8.3 Experiments

8.3.1 ISIMIP2a - Calibration of regional hydrological models

The regional hydrological models should be calibrated and validated as usual[9] for river discharge at the gauge stations indicated in Table 20. The calibration should be done in two steps: firstly using observed climate data (if available), and then re-calibrating to WATCH data. The calibration and validation sub-periods of 8-10 years each should be chosen in the period 1971-2010, depending on availability of data. The re-calibration to WATCH climate data is important as the GCM climate scenario data (to be used for climate impact assessment) are bias-corrected to the WATCH dataset. In case the observational climate data is not available, the calibration should be done using WATCH or WATCH+WFDEI.GPCC data. Although all hydrological models use the daily time step, it is suggested to apply criteria of fit: Nash and Sutcliffe efficiency (NSE) and percent bias (PBIAS) to the monthly time series, and compare the monthly and long-term average monthly dynamics. If possible, some intermediate gauges should also be considered in addition to the gauges indicated in Table 20, and comparison of the simulated and observed time series done for them as well. Human influences (dams/reservoirs, water abstraction for irrigation, etc.) should be considered in catchments where their effects are significant. Otherwise, they can be ignored.

Since the focus topic of ISIMIP2 is “Extreme events and variability”, a special attention should be on the variation characteristics (seasonal, interannual), as well as on simulation of high flows and low flows. The latter could be evaluated using the annual high and low percentiles Q10 and Q90. For that, after the usual calibration and validation are done, and satisfactory results are obtained for both periods, representation of annual Q10 and Q90 in the calibration and validation periods should be checked.

[9] I.e. modelling all processes and comparing simulated daily (or monthly) river discharge with the measured one at the predefined gauging station(s). If you have any questions about calibration and validation procedures, please do not hesitate to contact the coordination team.

Following calibration and validation as described above, please run your model for the historical period 1971-2010 for each of the different climate forcing datasets (see Table 5), using the same land use as in the calibration run. No re-calibration is required for the different climate forcing datasets.

8.3.2 ISIMIP2a - Historic runs and validation exercise

Both regional and global hydrological models will be validated for the major river basins in the **ISIMIP2 focus regions** (Figure 1), plus the Blue Nile, Upper Amazon, and Lena basins, for which there are observed discharge and runoff data (see **Table 16** and **Table 17**). The gauging stations for validation (and for calibration of the regional models) are indicated in **Table 17**. In addition, the global models will be validated in additional major river basins, or globally at grid-cell level, where feasible (see below).

If your model accounts for **population and GDP changes** or **technological progress** etc. the available information should be used to prescribe conditions that are as close to the real historical conditions as possible.

Table 16: Observational datasets to be used for validation of the historical runs (ISIMIP2a).

Dataset	Description	More info	Dates	Scale	Variables included	Comment
ISLSCP II UNH-GRDC Composite Monthly Runoff	Observed values of monthly runoff	http://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=994	1986-1995	0.5°x0.5° grid	Qtot	for global models
GRDC Global Runoff	Observed values of daily (or monthly, as available) river discharge across the	GRDC (http://www.bafg.de/GRDC/EN/01_GRDC/13_dtbse/database_node.html)	1900-2012 but years vary by	Catchment gauging station	dis (discharge in m3/s)	for global and regional models

Database	globe		catchment.	The gauges to use for the focus regions are listed in **Table 17**.		
FAOSTAT	Historical irrigation water withdrawal (observations/model combination)	http://www.fao.org/nr/water/aquastat/dbase/index.stm	varies by country, mostly 1990-2010	Country	aIrrww (km^3/a); also other sectoral withdrawals	
USGS	US water withdrawal estimates	http://water.usgs.gov/watuse	every 5 years since 1950	US national, county, watershed	aIrrww (Mgal/a); also other sectoral withdrawals	

Table 17: Catchment gauging stations for the hydrological model calibration/validation and intercomparison.

River Basin	GRDC Station for calibration and validation	GRDC Station Code	GRDC availability (monthly discharge)	GRDC availability (daily discharge)	Area upstream of gauge (km2) according to GRDC or DEM

Rhine	Lobith	6435060	1901-1996	1901-2010	160,800
Tagus (Tejo)	Almourol	6113050	1973–1990	1982-1990	67,490
Niger	Lokoja Dire	1834101 1134700	2007-2012 1924-2012	1970-2006 1924-2003	2,074,171 340,000
Blue Nile	Khartoum	1663100	1900-1982	n.a.	325,000
Ganges	Farakka	2846800	1949-1973	n.a.	835,000
Yellow (Huang He)	Tangnaihai Huayuankou***	n.a. 2180800	n.a.** 1946-1988	n.a.** 2004-2004	121,000 730,036
Yangtze	Pingshan Datong***	n.a. 2181900	n.a.** 1922-1988	n.a.** 2004-2004	446,516 1,705,383
Lena	Stolb Krestovski	2903430 2903427	1978-1994 1936-2002	1951-2002 1936-1999	2,460,000 440,000
Mississippi	Alton Vicksburg***	4119800 4127800	1928-1984 1928-1983	1933-1987 1931-2013	444,185 2,964,255
Amazon	Sao Paulo de Olivenca	3623100	1979-1993	1973-2010	990,781
Murray Darling	Louth Wakool Junction***	5204250 5304140	1954-2000 1929-2001	1954-2008 1929-2001	489,300 n.a.

* calculated in GRASS; ** available from China to some groups; *** only for the global-scale modelling

Hydrological modelling groups (both **global and regional**) should conduct, and submit model outputs for the simulations listed in **Table 18**.

Table 18: Simulation settings for hydrological models

Simulation	Comments
Naturalized (nosoc)	*without* human impacts on river flow Models that can include the effects of land use should use time-varying land use from the "Dynamic MIRCA" dataset (see section 4.1.3), in order to be consistent with other sectors (in particular biomes).
Constant human impacts (pressoc)	present-day (year-2000) dams and water use* Models should include present-day human impacts, in the form of dams and reservoirs as well as any forms of human water use that can be represented in the models (e.g. for irrigation, manufacturing, etc.). Models that can include the effects of land use should use constant (year-2000) land use from MIRCA2000 (year 2000 of the "Dynamic MIRCA" dataset, see section 4.1.3).
Time-varying human impacts (varsoc)	time-varying historical dam construction and water use* As pressoc, except that human imacts should now be time-varying according to the historical data provided. Models that can include the effects of land use should use time-varying land use from the "Dynamic MIRCA" dataset (see section 4.1.3).
Natural vegetation reference run (nat)	A natural vegetation only run without any land-use pattern. This is a reference run to separate fluxes from natural vegetation and agriculture in runs with historic land-use. It is like the nosoc run but without land-use. If your model does not distinguish between natural and managed land, the "nat" run will be identical to the "nosoc" run. It is relevant for those models running biome and water simulations in the same simulation.

*Regional models may ignore human impacts in catchments where human impacts are found to be insignificant. For those catchments, all validation exercises should be conducted with the naturalized simulations.

Two main validation exercises will be conducted with the hydrological models, using the results of these simulations.

8.3.3 Validation Task I: “naturalized” (i.e. without human impacts, nosoc) simulated runoff

The naturalized simulations of runoff, Q_{tot} (= Q_s + Q_{sb}), by **global models** will be validated against the ISLSCP II UNH-GRDC Composite Monthly Runoff dataset (Koster et al. 2006), which is an update of the UNH-GRDC composite runoff fields of *Fekete et al.* (2000), the latter having been used previously to tune and validate global hydrological models (Arnell 1999; Gosling and Arnell 2011; Döll et al. 2003). The original UNH-GRDC data set combined observed river discharge from the GRDC with simulated water balance model (WBM) estimates and consisted of monthly climatologies at 0.5°×0.5° spatial resolution. The ISLSCP II UNH-GRDC dataset was generated by revising the raw WBM monthly means through the application of climate forcing (air temperature, precipitation, vapor pressure, solar radiation, wind speed) from the CRU data set. The revised dataset is advantageous because it includes a gridded (0.5°×0.5°) 10-year time series of monthly runoff for 1986–1995 instead of climatologies only. While the runoff fields are influenced by the accuracy of the WBM, the runoff maps are at least calibrated to gauged streamflow. The ISLSCP II UNH-GRDC Composite Monthly Runoff dataset can be downloaded from here: http://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=994.

Davie et al. (2013) used the ISLSCP II UNH-GRDC dataset to present a preliminary validation of the ISIMIP hydrological models. This validation exercise will extend that analysis by considering the following observed-simulated comparisons because mean annual runoff is only a first indicator of hydrological behavior (Döll and Schmied 2012; Gosling et al. 2011):

1. Catchment-mean monthly and annual runoff climatologies for the ISIMIP2 focus catchments.

2. Catchment-mean timeseries of monthly runoff.

3. Spatial patterns of runoff between simulated and observed.

This validation exercise will be conducted at the global scale by analyzing gridded values and also for the ISIMIP2 focus catchments by analyzing values at gauge locations. Where catchment-mean runoff needs to be computed, this should be calculated by aggregating across all upstream cells (from the gauge) that are included within the catchment boundaries as defined by the DDM30 river network and computing an area-mean (using the DDM30 catchment area). In practice, this means that, similar to the method applied by Haddeland et al. (2011), an area correction factor is applied to the ISLSCP II UNH-GRDC runoff data to account for the fact that the river network, which is at 0.5°x0.5° spatial resolution, may not perfectly overlap with the river basin boundaries. The gauging stations that should be used for selecting upstream cells are displayed in **Table 17**. These stations have been used to ensure consistency in spatial coverage between the two validation exercise (naturalized and human impacts). Comparison of spatial patterns between observed and simulated data should focus only on the cells included within the catchment boundaries and that are upstream of the gauge in **Table 17**.

An important point is that the GRDC streamflow observations that were used to compute the ISLSCP II UNH-GRDC dataset by correcting the WBM simulations, do not span the entire land area of the globe (Koster et al. 2006). Thus, in non-monitored regions, the runoff estimates are derived from uncorrected WBM estimates alone. This means that for some grid cells, the situation may arise where model results are compared to model results (as opposed to comparing model results with observations). To this end, comparisons will need to be limited to catchments where the WBM simulations were predominantly corrected with GRDC observations. The following text explains how this will be achieved. Gridded datasets (0.5x0.5 degree) of the annual correction coefficient that was applied to WBM for each year (i.e. 1986-1995) can be downloaded from here: http://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=994 by using the “Spatial Data Access Tool” (there is one file for each year). These files should be used to create a mask file for each year (e.g. 1=WBM data was corrected and 0=WBM data was not corrected). Then, a final gridded mask file should be created from these 10 annual mask files, which illustrates where at least 5 years of correction coefficients were used (this is similar to the approach adopted by Koster et al. (2006)). This final mask file should then be used to show where the ISLSCP II UNH-GRDC observed runoff data was computed from WBM-corrected data for at least 50% of each respective catchment area displayed in Figure 1. This will minimize the risk of a model-to-model comparison and the validation will only be computed where the above conditions are satisfied. This approach was adopted by Oleson et al. (2008) when validating the land component of the Community Climate System Model (CCSM), Community Land Model version 3 (CLM3).

The naturalized runoff simulated by **regional models** will be validated against the GRDC monthly river discharge data (for gauging stations listed in **Table 17**), see below.

8.3.4 Validation Task II: validation with human impacts (e.g. dams, water-use; pressoc/varsoc).

Simulations of discharge (Dis) with human impacts will be validated against GRDC monthly and daily river discharge time series data.

The catchment gauging stations that should be used for this validation are displayed in **Table 17**; the corresponding data (source: http://www.bafg.de/GRDC/EN/02_srvcs/21_tmsrs/riverdischarge_node.html) will be provided via ISIMIP (subject to agreement of the GRDC). Unlike the naturalized validation exercise discussed previously, the GRDC discharge data is available for differing time periods for the various ISIMIP2 focus catchments (see **Table 17**).

This will facilitate the following analyses, since mean annual runoff is only a first indicator of hydrological behavior (Döll and Schmied 2012; Gosling et al. 2011):

1. Comparisons of mean annual discharge.
2. Comparisons of mean monthly discharge climatology and variability.
3. Comparisons of indicators of high and low flow (e.g. Q5 and Q95, and peak over threshold).
4. Comparisons of flood return period levels (only where there is > 30 years of observed and simulated data, based on extreme value distributions fitted to the data).
5. Calculation of Nash Sutcliffe Efficiency (NSE), Percent Bias (PBIAS) and other error statistics on monthly discharge timeseries.
6. Comparison of simulated water withdrawals with FAOSTAT or USGS observed withdrawals (for models that simulate it).

Validation of the runs with constant human impacts (i.e. with present-day (year-2000) dams and water use) will focus primarily on comparing climatologies and flow statistics over multiple decades. For the runs with time-varying human impacts (i.e. with historical dam construction and water use) the focus will be more on validating the historic inter-annual variability (and possibly trends) in annual and monthly river discharge, as well as high and low flow indicators. By comparing the results of runs with constant and with time-varying human impacts an estimate can be made of the effect of changes in human influence in the past few decades on the hydrological behaviour of catchments.

Furthermore, the availability of daily observed and simulated data for some catchments (see Table W1) presents an opportunity to analyse simulated-observed comparisons for specific flood and drought events in each catchment. At least one drought and one flood case study should be identified (e.g. from Q95 and Q5 data) for each ISIMIP2 focus catchment and graphs of observed-simulated daily discharge plotted.

Where catchment-means needs to be computed (or a conversion from m^3/s to mm), this should be calculated by aggregating across all upstream cells (from the gauge) that are included within the catchment boundaries as defined by the DDM30 river network and computing an area-mean (using the DDM30 catchment area). In practice, this means that, similar to the method applied by Haddeland et al. (2011), an area correction factor is applied to the GRDC discharge data to account for the fact that the river network, which is at 0.5°x0.5° spatial resolution, may not perfectly overlap with the river basin boundaries

8.3.5 ISIMIP2a - Fast track runs for new models

Please consult the fast track protocol Section 7 for those runs and related information. It is available at www.isimip.org/protocol/#isimip-fast-track. In case of any questions please contact info@isimip.org. Please note that aside from harmonized climate and socio-economic input, the default settings of your model should be used. Also note that for output data files the file name (as specified in Section 5.2 of the fast track protocol) is all lower case!