6 Water

6.1 Experiments

Table 10 provides an overview of all experiments to be run in the water sector in ISIMIP2a.

Table 10: Summary of experiments for water models.

Climate Data	Scenario	Human Impacts	Other settings (sens-scenario)	# runs
WATCH-WFDEI	Hist	nosoc pressoc varsoc	historical CO2 (co2)	3
GSWP3-W5E5	Hist	nosoc pressoc varsoc	historical CO2 (co2)	3
GSWP3-EWEMBI	Hist	nosoc pressoc varsoc	historical CO2 (co2)	3
GSWP3	Hist	nosoc pressoc varsoc	historical CO2 (co2)	3
PGMFD v.2 (Princeton)	Hist	nosoc pressoc varsoc	historical CO2 (co2)	3
WATCH (WFD)	Hist	nosoc pressoc varsoc	historical CO2 (co2)	3
Additional sector-specific run: PGMFD v.2 (Princeton)	Hist	varsoc	constant CO2 at 1971 levels (co2const)	1

6.2 Sector-specific input data

In ISIMIP2a, 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** 11, along with a soil and vegetation dataset that may be used optionally.

Table 11: Input data to be used for the historical runs (ISIMIP2a), in addition to the common data listed in Section 4.

Dataset	Description	More info	Scale	Variables included, comments
Mandatory (if feasible)				
Dams/Reservoirs		See **Table** 5 (Other human influences) http://www.gwsp.org/products/grand-database.html		
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**[3]
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-texture-map.html, upscaling method A. Each model does have the option to use their own soil datasets if they prefer.	global, 30 arc sec (HWSD) or 0.5° (GSWP3), fixed	soil type
GLIMS (Global Land Ice Measurements from Space)	Glacier distribution	See http://www.glims.org/About/		
HydroSHEDS	Topography/routing network	Hydrographically corrected SRTM data. Available in 3 resolutions, includes accumulated upstream area. Also,		**for regional models only**[3]

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[3] 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.

		HydroSHEDS is not available north of 60 degrees, due to limitations in the SRTM data at high latitudes.		

6.3 Output data

Note that variable names are chosen to comply, where feasible, with the ALMA convention[4] 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 5.1.1).

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.

> *IMPORTANT: Some output variables reported for the water sector are also appropriate for use in the permafrost sector described in Section* 11*; these are marked with an *. If you plan to submit simulations for the permafrost sector, note that additional variables are also required for the permafrost sector (see* **Table** 28*).*

Table 12: Output variables to be reported by water sector models. Variables highlighted in orange are requested from both global and regional models, if computed; variables highlighted in purple are requested only from regional models; others only from global models.

Variable (long name)	Variable name	Unit (NetCDF format)	Resolution	Comments
Hydrological Variables				
*Runoff	**qtot**	kg m-2 s-1	daily* (0.5°x0.5°)	Total (surface + subsurface) runoff (qtot = qs + qsb). *if

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

				daily resolution not possible, please provide monthly[5]. Please also deliver for the permafrost sector.
Surface runoff	**qs**	kg m-2 s-1	monthly (0.5°x0.5°)	Water that leaves the surface layer (top soil layer) e.g. as overland flow / fast runoff.
Subsurface runoff	**qsb**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of water that flows out from subsurface layer(s) including the groundwater layer (if present). Equals qg in case of a groundwater layer below only one soil layer.
Groundwater recharge	**qr**	kg m-2 s-1	monthly (0.5°x0.5°)	Water that percolates through the soil layer(s) into the groundwater layer. In case seepage is simulated but no groundwater layer is present, report seepage as qr and qg.
Groundwater recharge	**qr**	kg m-2 s-1	monthly (average for basin until gauge location)	Water that percolates through the soil layer(s) into the groundwater layer. In case seepage is simulated but no groundwater layer is present, report seepage as qr and qg.
Groundwater runoff	**qg**	kg m-2 s-1	monthly (0.5°x0.5°)	Water that leaves the groundwater layer. In case seepage is simulated but no groundwater layer is present, report seepage as qr and qg.
Discharge (gridded)	**dis**	m3 s-1	daily* (0.5°x0.5°)	*if daily resolution not possible, please provide monthly.
Discharge (gauge level)	**dis**	m3 s-1	daily* (at gauge locations; see **Table** 13)	*if daily resolution not possible, please provide monthly.
Monthly maximum of daily discharge	**maxdis**	m3 s-1	monthly (0.5°x0.5°)	Optional variable – please report if daily discharge data is not reported.
Monthly minimum of daily discharge	**mindis**	m3 s-1	monthly (0.5°x0.5°)	Optional variable – please report if daily discharge data is not reported.
Evapotranspiration	**evap**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of transpiration, evaporation, interception and sublimation.

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

Evapotranspiration	**evap**	kg m-2 s-1	monthly (average for basin until gauge location)	Sum of transpiration, evaporation, interception losses, and sublimation.
Potential Evapotranspiration	**potevap**	kg m-2 s-1	monthly (0.5°x0.5°)	As evap, but with all resistances set to zero, except the aerodynamic resistance.
Potential Evapotranspiration	**potevap**	kg m-2 s-1	monthly (average for basin until gauge location)	As evap, but with all resistances set to zero, except the aerodynamic resistance.
*Soil moisture	**soilmoist**	kg m-2	monthly (0.5°x0.5°)	Please provide soil moisture for all depth layers (i.e. 3D-field), and indicate depth in m. If depth varies over time or space, see instructions in Section 5.1.5. Please also deliver for the permafrost sector.
Soil moisture	**soilmoist**	kg m-2	monthly (average for basin until gauge location)	Please provide soil moisture for all depth layers (i.e. 3D-field), and indicate depth in m. If depth varies over time or space, see instructions in Section 5.1.5. Please also deliver for the permafrost sector.
Soil moisture, root zone	**rootmoist**	kg m-2	monthly (0.5°x0.5°)	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. If depth varies over time or space, see instructions in Section 5.1.5.
Frozen soil moisture for each layer	**soilmoistfroz**	kg m-2	monthly (0.5°x0.5°)	Soil_frozen_water_content This variable only for the purposes of the permafrost sector.
*Temperature of Soil	**tsl**	K	daily* (0.5°x0.5°)	Temperature of each soil layer. Reported as "missing" for grid cells occupied entirely by "sea". **THIS IS THE MOST IMPORTANT VARIABLE FOR THE PERMAFROST SECTOR.** Also need depths in meters. Daily would be great, but otherwise monthly would work. If depth varies over time or space, see instructions in

				Section 5.1.5. This variable only for the purposes of the permafrost sector. *if daily resolution not possible, please provide monthly.
*Snow depth	**snd**	m	monthly (0.5°x0.5°)	Grid cell mean depth of snowpack. This variable only for the purposes of the permafrost sector.
*Snow water equivalent (= snow water storage)	**swe**	kg m-2	monthly (0.5°x0.5°)	Total water mass of the snowpack (liquid or frozen), averaged over a grid cell. Please also deliver for the permafrost sector.
Total water storage	**tws**	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in all compartments. Please indicate in the netcdf metadata which storage compartments are considered.
Canopy water storage	**canopystor**	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in the canopy.
Glacier storage	**glacierstor**	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in glaciers.
Groundwater storage	**groundwstor**	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in groundwater layer.
Lake storage	**lakestor**	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in lakes (except reservoirs).
Wetland storage	**wetlandstor**	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in wetlands.
Reservoir storage	**reservoirstor**	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in reservoirs.
River storage	**riverstor**	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in rivers.

*Annual maximum thaw depth	**thawdepth**	m	monthly (0.5°x0.5°)	Calculated from daily thaw depths.
River temperature	**triver**	K	monthly (0.5°x0.5°)	Mean monthly water temperature in river (representative of the average temperature across the channel volume).
Rainfall	**rainf**	kg m-2 s-1	monthly (0.5°x0.5°)	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**	kg m-2 s-1	monthly (0.5°x0.5°)	
Water management variables (for models that consider water management/human impacts)				
Irrigation water demand (=potential irrigation water withdrawal)	**pirrww**	kg m-2 s-1	monthly (0.5°x0.5°)	Irrigation water withdrawal, assuming unlimited water supply.
Actual irrigation water withdrawal	**airrww**	kg m-2 s-1	monthly (0.5°x0.5°)	Irrigation water withdrawal, taking water availability into account; please provide if computed.
Potential irrigation water consumption	**pirruse**	kg m-2 s-1	monthly (0.5°x0.5°)	Portion of withdrawal that is evapo-transpired, assuming unlimited water supply.
Actual irrigation water consumption	**airruse**	kg m-2 s-1	monthly (0.5°x0.5°)	Portion of withdrawal that is evapotranspired, taking water availability into account; if computed.
Actual green water consumption on irrigated cropland	**airrusegreen**	kg m-2 s-1	monthly (0.5°x0.5°)	Actual evapotranspiration from rainwater over irrigated cropland; if computed.
Potential green water consumption on irrigated cropland	**pirrusegreen**	kg m-2 s-1	monthly (0.5°x0.5°)	Potential evapotranspiration from rainwater over irrigated cropland; if computed and different from AIrrUseGreen.
Actual green water consumption on rainfed cropland	**arainfusegreen**	kg m-2 s-1	monthly (0.5°x0.5°)	Actual evapotranspiration from rainwater over rainfed cropland; if computed.

Actual domestic water withdrawal	**adomww**	kg m-2 s-1	monthly (0.5°x0.5°)	If computed.
Actual domestic water consumption	**adomuse**	kg m-2 s-1	monthly (0.5°x0.5°)	If computed.
Actual manufacturing water withdrawal	**amanww**	kg m-2 s-1	monthly (0.5°x0.5°)	If computed.
Actual Manufacturing water consumption	**amanuse**	kg m-2 s-1	monthly (0.5°x0.5°)	If computed.
Actual electricity water withdrawal	**aelecww**	kg m-2 s-1	monthly (0.5°x0.5°)	If computed.
Actual electricity water consumption	**aelecuse**	kg m-2 s-1	monthly (0.5°x0.5°)	If computed.
Actual livestock water withdrawal	**aliveww**	kg m-2 s-1	monthly (0.5°x0.5°)	If computed.
Actual livestock water consumption	**aliveuse**	kg m-2 s-1	monthly (0.5°x0.5°)	If computed.
Total (all sectors) actual water consumption	**atotuse**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of actual water consumption from all sectors. Please indicate in metadata which sectors are included.
Total (all sectors) actual water withdrawal	**atotww**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of actual water withdrawal from all sectors. Please indicate in metadata which sectors are included.
Total (all sectors) potential water withdrawal	**ptotww**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of potential (i.e. assuming unlimited water supply) water withdrawal from all sectors. Please indicate in metadata which sectors are included.
Total (all sectors) potential water consumption	**ptotuse**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of potential (i.e. assuming unlimited water supply) water consumption from all sectors. Please indicate in metadata which sectors are included.

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)				
Natural vegetation types	**Names to be coordinated with biomes/ecosystem sector**	N/A	static (0.5°x0.5°)	Map of natural 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 coordinated with other sectors)**		static (0.5°x0.5°) or monthly (0.5°x0.5°) where appropriate	If used by or computed by the model.
Agricultural variables (optional output for all water models that also simulate crop yields)				
Crop yields (dry matter)	**yield-<crop>-<irrigation setting>**	dry matter (t ha-1 per growing season)	per growing season (0.5°x0.5°)	Irrigation setting = “cirr” for “constrained irrigation” or “noirr” for rainfed.
Actual planting dates	**plantday-<crop>-<irrigation setting>**	day of year	per growing season (0.5°x0.5°)	Julian dates.
Actual planting year	**plantyear-<crop>-<irrigation setting>**	year of planting	per growing season (0.5°x0.5°)	This allows for clear identification of planting that is also easy to follow for potential users from outside the project.
Anthesis dates	**anthday-<crop>-<irrigation setting>**	day of year of anthesis	per growing season (0.5°x0.5°)	Together with the year of anthesis added to the list of outputs (see below) it allows for clear identification of anthesis that is also easy to follow for potential users from outside the project.

Year of anthesis	**anthyear-<crop>-<irrigation setting>**	year of anthesis	per growing season (0.5°x0.5°)	It allows for clear identification of anthesis that is also easy to follow for potential users from outside the project.
Maturity dates	**matyday-<crop>-<irrigation setting>**	day of year of maturity	per growing season (0.5°x0.5°)	Together with the year of maturity added to the list of outputs (see below) it allows for clear identification of maturity that is also easy to follow for potential users from outside the project.
Year of maturity	**matyyear-<crop>-<irrigation setting>**	year of maturity	per growing season (0.5°x0.5°)	It allows for clear identification of maturity that is also easy to follow for potential users from outside the project.
Nitrogen application rate	**initr-<crop>-<irrigation setting>**	kg ha-1 per growing season	per growing season (0.5°x0.5°)	Total nitrogen application rate. If organic and inorganic amendments are applied, rate should be reported as inorganic nitrogen equivalent (ignoring residues).
Above-ground biomass (dry matter)	**biom-<crop>-<irrigation setting>**	Dry matter (t ha-1 per growing season)	per growing season (0.5°x0.5°)	The whole plant biomass above ground.
Soil carbon emissions	**sco2-<crop>-<irrigation setting>**	kg C ha-1	per growing season (0.5°x0.5°)	Ideally should be modeled with realistic land-use history and initial carbon pools. Subject to extra study.
Nitrous oxide emissions	**sn2o-<crop>-<irrigation setting>**	kg N2O-N ha-1	per growing season (0.5°x0.5°)	Ideally should be modeled with realistic land-use history and initial carbon pools. Subject to extra study.

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

Comments related to the optional agricultural outputs

The reporting of the crop yield-related outputs differs from the reporting of other variables in the water sector, as it is not done according to calendar years but according to **growing seasons** to resolve potential multiple harvests. See the agriculture section (section 10) for details.
Simulations should be provided for the four major **crops** (wheat, maize, soy, and rice) but output for other crops and also bioenergy crops is highly welcome, too; see Section 10 for crop naming.
Yields simulations provided in the water sector should account for **irrigation water constraints**. For each crop, yields should be reported separately for irrigated land (cirr for “constrained irrigation”) and rainfed land (noirr). This complements the full irrigation (firr) pure crop runs requested in the agriculture part of the protocol (Section 10).

Those models that cannot simulate time varying management/human impacts/fertilizer input should keep these fixed at year 2000 levels throughout the simulations.

6.4 Additional information for regional hydrological models

CALIBRATION: Please use WFDEI (from 1979 to 2016) for calibration, for all simulations.

Table 13**:** Catchment gauging stations for reporting regional hydrological model results.

River Basin (short name for filenames)	Station for calibration and validation (short name for filenames)	Coordinates Lat/Lon	GRDC Station Code	Data availability (monthly discharge)	Data availability (daily discharge)	Area upstream of gauge (km^2) according to GRDC or GIS
Amazon (amazon)	São Paulo de Olivenca (sao-paulo-de-olivenca)	-3.45/-68.75	3623100	1979-1993	1973-2010	990781
Blue Nile (blue-nile)	El-Deim, Sudan Border (el-diem) Khartoum (khartoum)	11/35 15.62/32.55	n.a.* 1663100	1961-2002 1900-1982	n.a. n.a.	160000 325000
Danube (danube)	Wien-Nußdorf (wien-nussdorf)	48.25/16.3	6242500	1828-1899	1900-to date	101700
Ganges (ganges)	Farakka (farakka)	25/87.92	2846800	1949-1973	n.a.	835000
Godavari (godavari)	Tekra (tekra)	19/80	n.a.	1964-2017	1964-2017	119781
Indus	Tarbela Reservoir (tarbela)	72.86/ 34.33	n.a.	2000-2016	2000-2016	173345
Lena (lena)	Krestovski (krestovski) Stolb (stolb)	59.73/113.17 72.37/126.8	2903427 2903430	1936-2002 1978-1994	1936-1999 1951-2002	440000 2460000
Mackenzie (mackenzie)	Artic Red River (artic-red-river)	67.4583/-133.745	4208025	1972-1996	1972-2015	1660000

Mississippi	Alton (alton)	38.885/-90.1809	4119800	1928-1984	1933-1987	444185
Murray Darling (darling)	Louth (louth)	-30.5318/ 145.1144	5204250	1954-2000	1954-2008	489300
Niger (niger)	Dire (dire)	16.2667/-3.3833	1134700	1924-2012	1924-2003	340000
	Koulikoro (koulikoro)	12,8667/-7,55	1134100	1907-2012	1907-2006	120000
	Lokoja (lokoja)	7,8/6,7667	1834101	2007-2012	1970-2006	2074171
	Tossaye (tossaye)	16.9416/ -0.579166	1134850	1954-1992	1954-1992	348000
Pajeú (pajeu)	Floresta (floresta)	-8,6089,-38,5767	n.a. (National system for information on water resources, Brasil)	n.a.	n.a.	12266
Rhine (rhine)	Lobith (lobith)	51.84/6.11	6435060	1901-1996	1901-2010	160800
Tagus (tagus)	Almourol (almourol) Trillo (trillo)	39.47/-8.37 40.7/-2.58	6113050 6213800	1973-1990 1977-1984	1982-1990 1977-1984	61490 3253
Yangtze	Cuntan (cuntan)	29,616667/106,6	n.a.	1987-2006	1987-2006	804859
Yellow, Huang He (yellow)	Tangnaihai (tangnaihai)	35.5/100.15	n.a.	1971-2002	1971-2002	121000

Note: If GRDC station is not available, the data availability is indicated for data from other sources; *GRDC data reported as poor

15 References

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