The Inter-Sectoral Impact Model Intercomparison Project

ISIMIP2a Simulation protocol (extended version)

Last updated on 15 September 2020

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1 Introduction

1.1 ISIMIP: General concept

ISIMIP provides a framework for the collation of a consistent set of climate impact data across sectors and scales. This framework will serve as a basis for model evaluation and improvement, allowing for improved estimates of the biophysical and socio-economic impacts of climate change at different levels of global warming. It also provides a unique opportunity for considering interactions between climate change impacts across sectors through consistent scenarios.

ISIMIP is intended to be structured in successive rounds, each having its own focus topics and focus regions that inform the scenario design. The main components of the ISIMIP framework are:

- A common set of climate and other input data which will be distributed via a central database;
- A common modelling protocol to ensure consistency across sectors and scales in terms of data, format and scenario set-up;
- A central archive where the output data will be collected and made available to the scientific community.

1.2 General remark regarding adaptation

As in the ISIMIP Fast Track, simulations should not be designed to describe the effects of different adaptation measures. In contrast, it is the aim to describe the impacts of climate change on different sectors under “present-day” management assumptions. There are individual exceptions to this general rule (such as “naturalized” runs within the water sector). These exceptions are clearly specified in the sector-specific scenario set-up of the simulations. Wherever such an exception is not mentioned please choose the “present day” option regarding management.
In particular, the historical validation runs should be “as close to the real historic conditions as possible” (i.e. to the extent to which this can be achieved without major model improvement).

2 General Design of ISIMIP2a – Focus topic

"Extreme events and variability" was chosen as the focus topic of ISIMIP2a, reflecting the interest of the community as well as stakeholders in investigating and improving the representation of variability and extreme events, in particular in impact models and along the entire modelling chain. Therefore, the model evaluation and validation task specified in this protocol is explicitly designed to evaluate the models' ability to reproduce observed historical variability, responses to extreme climatic events such as heat waves, droughts, floods, heavy rains and storms, and representation of extreme impact events. Based on these evaluation exercises, modelling teams will have the opportunity to adjust model parameters and implement necessary model improvements. Moreover, the ISIMIP2a simulations serve to validate the impact models that are used for future projections in ISIMIP2b.

Note that the emphasis on this focus topic does not exclude some other work not directly related to extreme events and variability. For example, in particular for regional models and in new sectors, it may be important to first calibrate and investigate performance for average condition.

3 Motivation of experiment design

This chapter provides a short description of the scientific rationale behind the design of each of the experiments in ISIMIP2a. The details of the experiments are further described in the remainder of the protocol.

The overarching objective of the historical validation experiment is to gain insight into the ability of current impact models to reproduce observed features of simulated variables, with an emphasis on (but not limited to) variability and extreme events. Simulations are designed such as to match historical conditions as closely as possible, within the limitations of e.g. availability of historical forcing data, variety of model formulations, and model development resources. In addition, ISIMIP2a serves to evaluate the models used for future projections in ISIMIP2b. Therefore, it is **important to apply the same model version for ISIMIP2a and ISIMIP2b**.

Four different observations-based historical climate datasets will be used to force impact models, to allow for a comparison of the different historical simulations. Each data set has its own strengths and weaknesses (e.g. regarding temporal extent, quality of specific variables, previous application within the modeling community) and generally represents a plausible reconstruction of the terrestrial climate of the past ~100 years. The different historical simulations will allow a systematic quantification of the effect of the choice of forcing data on impact model results; allow comparison to previous studies using either of these datasets; and provide an extensive data base for model evaluation and impact assessment, in particular with regard to the focus topic (e.g. a certain climatic extreme event could be better reproduced in one data set than in the other).

Addendum August, 2019: ISIMIP2a now includes a fifth and sixth observations-based climate dataset (GSWP3-W5E5 and GSWP3-EWEMBI). The W5E5 and EWEMBI data contained in these datasets span the period 1979-2016, and were backward-extended to 1901 using GSWP3, hence the names. See details below.

4 Common input data and settings for all sectors

This chapter describes climate forcing data and other input data that should be used by modelling groups in all sectors. Note that several different experiments with differences in input data and other settings are requested; see the sectoral chapters for a list of the requested experiments. In this chapter, we only describe the common input data sets.
If you require additional input data that is not specified in this chapter, please use your default data source. In case anything remains unclear please contact the coordination team or sectoral coordinators.

4.1 Atmospheric data

Please use the historical climate data listed in **Table** 1 for the historical calibration and validation runs. The runs should start in 1901, or earlier if spin-up is needed (see below and Section 5.1). All data will be available through the ISIMIP website, www.isimip.org. Separate historical simulations should be conducted with each of four different datasets, **in the order indicated** in the last column of **Table** 1. This is because each of the datasets has its own advantages and shortcomings, and thus by using several of them, it will be possible to assess the influence of the choice of forcing data on the overall results. Moreover, this procedure serves the needs of the different participating sectors (e.g. data over ocean is needed for the fisheries sector) and facilitates consistency with other model intercomparison exercises (e.g. ISIMIP Fast Track; GSWP3). Modelling groups that cannot run all datasets before the submission deadline should nonetheless begin in the order indicated and inform the ISIMIP coordination team.

Table 1: Historical (atmospheric) climate data sets to be used in calibration and validation runs. All data sets contain the variables near-surface air temperature (tas), precipitation (pr), near-surface relative humidity (rhs), surface downwelling longwave radiation (rlds), surface downwelling shortwave radiation (rsds), surface pressure (ps), near-surface wind speed (wind), and partly also daily minimum and maximum near-surface air temperature (tasmin and tasmax, resp.). Note that simulations should be conducted with each of these datasets.

Dataset	Reanalysis	Years	Resolution, coverage	Bias target	Priority; comments
WATCH-WFDEI (WATCH a.k.a. WFD: Weedon, et al., 2011; WFDEI: Weedon et al., 2014)	ERA-40, ERA-Interim	1901- 2016	0.5° Land	CRU, GPCC	1 Combined forcing file (WFD 1901-1978, WFDEI 1979-2016) will be provided by ISIMIP. WFDEI precipitation and snowfall data are those corrected with GPCC. **NOTE** a discontinuity in the data exists at the transition from WATCH to WFDEI, and results must be interpreted with caution.
GSWP3-W5E5 (GSWP3: Dirmeyer et al., 2006; W5E5: Lange S. , 2019a; Cucchi et al., 2020)	ERA5	1901-2016	0.5° Land + Ocean	CRU, GPCC, GPCP	2 Combined forcing file (homogenized GSWP3 1901-1978, W5E5 1979-2016) will be provided by ISIMIP. To minimize discontinuities at the 1978/1979 transition, GSWP3 data were homogenized with W5E5 data using the ISIMIP3BASD v2.4.1 bias adjustment method (Lange, 2019c; Lange, 2020).
GSWP3-EWEMBI (GSWP3: Dirmeyer et al., 2006; EWEMBI: Lange S., 2019b)	ERA-Interim	1901-2016	0.5° Land + Ocean	GPCC, GPCP, CRU, SRB	3 Combined forcing file (homogenized GSWP3 1901-1978, EWEMBI 1979-2016) will be provided by ISIMIP. To minimize discontinuities at the 1978/1979 transition, GSWP3 data were homogenized with EWEMBI data using the ISIMIP3BASD v2.4.1 bias adjustment method (Lange, 2019c; Lange, 2020).

GSWP3 (Dirmeyer et al., 2006)	20CR	1901-2010	0.5° Land + Ocean	GPCC, GPCP, CPC-Unified, CRU, SRB	4 Based on dynamical downscaling. Further details on the global dynamical downscaling method are given in (Yoshimura & Kanamitsu, 2008) (Yoshimura & Kanamitsu, 2013).
PGMFD v2.1 (Princeton) (Sheffield et al., 2006)	NCEP/NCAR Reanalysis 1	1901-2012	0.5° Land + Ocean	CRU, SRB, TRMM, GPCP, WMO validated against GSWP2	5
WATCH (WFD) (Weedon, et al., 2011)	ERA-40	1901-2001	0.5° Land	CRU, GPCC	6

Historical **CO2 concentrations** are also provided in the input data archive (/ISIMIP/ISIMIP2a/InputData/climate_co2/co2 /historical_CO2_annual_1765_2018.txt). They are based on time series of global atmospheric CO2-concentrations from (Meinshausen, Raper, & Wigley, 2011) for 1765-2005 and (Dlugokencky & Tans, 2019) from 2006-2018.

Note that simulation results only need to be submitted for the reporting periods specified in Section 5.1. The parts of the climate forcing data prior to the reporting period may be used for spin-up purposes and/or to facilitate further analyses. Simulation results for years outside the reporting period may still be submitted to the ISIMIP repository on a voluntary basis.

4.2 Oceanic data

See Section 12.

4.3 Land-use/land-cover

We provide a time-varying historical land-use (LU) data set that should be used for the historical validation runs. The time series starts in 1861 and ends in 2018 (files under /ISIMIP/ISIMIP2a/InputData/landuse_humaninfluences/landuse/ and /ISIMIP/ISIMIP2a/InputData /landuse_humaninfluences/n-fertilizer/[1]) and should be applied for the spin-up as well as for the historical runs, as described above. This landuse data is ultimately based on the HYDE 3.2 data set (Klein Goldewijk, 2016). This data was in turn harmonized by the land use group of George Hurtt at the University of Maryland College Park, which provides the "Land-Use Harmonization" (LUH2 v2h) data set (Hurtt, Chini, Sahajpal, Frolking, & et al, In prep.) [see also https://luh.umd.edu/]. This data set provides land use categories, pastures and rangeland, 5 crop types (C3 annual, C3 perennial, C4 annual, C4 perennial and C3 nitrogen fixing crops). Furthermore, the LUH2 v2h data set gives information on management, i.e. it provides information of irrigated vs rainfed areas and on fertilization rates. We interpolated this data set onto the ISIMIP standard grid in order to generate the "landuse-totals", the "landuse-pastures", the "landuse-urbanareas" and the "n-fertilizer-5crops" ISIMIP input files. In order to downscale the 5 crop files to the 15 crops (maize, groundnut, rapeseed, soybeans, sunflower, rice, sugarcane, pulses, temperate cereals [incl. wheat], temperate roots, tropical cereals, tropical roots, others annual, others perennial, and others N-fixing), the Monfreda data set (Monfreda, Ramankutty, & Foley, 2008) has been used. In this step the 5 crop types are split into 15 crop types according to the ratios given by the Monfreda data. Models that simulate their own natural vegetation should report that. All these grid cell shares don't necessarily add up to 1, since we ignore some landuse categories such as natural vegetation, ponds, highways and so on. If you need this (in previous protocol versions called "others"), please calculate 1-all other categories.

1 Previous versions of these data in 'deprecated' folders within these same locations.

Table 2: Land-cover and soil data to be used in historical validation runs.

Dataset	Description	More info	Scale	Variables included
Mandatory				
Historical land use patterns	Combination of HYDE3.2/LUH2h v2h and Monfreda land use data. **Note:** Data covers from 1861 to 2018.	HYDE 3.2: (Klein Goldewijk, 2016) LUH v2h: (Hurtt, Chini, Sahajpal, Frolking, & et al, In prep.) Monfreda: (Monfreda, Ramankutty, & Foley, 2008)	Global 0.5°Annual	Irrigated and rainfed crop areas for the following crop classes: c3per, c4per, maize, oil_crops_groundnut, oil_crops_rapeseed, oil_crops_soybean, oil_crops_sunflower, others_c3ann, others_c3nfx, pulses, rice, temperate_cereals, temperate_roots, tropical_cereals, tropical_roots Furthermore, there are pastures, rangeland, managed_pastures and urbanareas,
Historical area covered by natural vegetation	Derived from "HYDE3/ MIRCA" as 1-(all agricultural area). Note that forestry is counted as natural vegetation because of lack of historical forestry data.		See above	Fraction of grid cell covered by natural vegetation.
Optional				
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 has the option to use their own soil datasets if preferred.	Global 30 arc sec (HWSD) *or* 0.5° (GSWP3) Fixed	Soil types: Sand, Loamy Sand, Sandy Loam, Loam, Silt Loam, Silt, Sandy Clay Loam, Clay Loam, Silty Clay Loam, Sandy Clay, Silty Clay, Clay, Ice.

Table 3: Agricultural land-use categories.

Land-use type	Historical reconstruction	Disaggregation into functional crop types (LUH2)	Individual crops or crop groups
Irrigated crops	LUH2	Total cropland disaggregated into: C_3 annual, C_3 nitrogen-fixing, C_3 perennial, C_4 annual, C_4 perennial (contains only sugarcane)	C_3 annual disaggregated into: rapeseed, rice, temperate cereals, temperate roots, tropical roots, sunflower, others C_3 annual C_3 perennial: (no further disaggregation) C_3 nitrogen-fixing disaggregated into: groundnut, pulses, soybean, others C_3 nitrogen-fixing C_4 annual disaggregated into: maize, tropical cereals C_4 perennial: sugarcane
Rainfed crops	LUH2	Total cropland disaggregated into: C_3 annual, C_3 nitrogen-fixing, C_3 perennial, C_4 annual, C_4 perennial (contains only sugarcane)	C_3 annual disaggregated into: rapeseed, rice, temperate cereals, temperate roots, tropical roots, sunflower, others C_3 annual C_3 perennial: (no further disaggregation) C_3 nitrogen-fixing disaggregated into: groundnut, pulses, soybean, others C_3 nitrogen-fixing C_4 annual disaggregated into: maize, tropical cereals C_4 perennial: sugarcane
Pastures	LUH2	Total pastures are provided.	In addition, pastures are split into managed pastures and (natural) rangelands
Bioenergy production (rainfed grass)	-		e.g., miscanthus (if you use a different bioenergy crop, please indicate this in the model description)
Bioenergy production (rainfed trees)	-		e.g., poplar (temperate), eucalyptus (tropical) (if you use a different bioenergy crop, please indicate this in the model description)
Urban	LUH2		Variable is called urban areas

4.4 Socio-economic input

Table 4: Socio-economic data provided for ISIMIP2a.

Variable	Name	Unit	Time coverage, frequency	Comments
Population, country level and 0.5°x0.5° grid level[2]	pop	number of people	1860-2017, annual time steps	National and gridded historic population data are taken from the History Database of the Global Environment (HYDE) version 3.2.1 (http://themasites.pbl.nl/tridion/en/themasites/hyde/download/index-2.html). Estimates for total as well as urban and rural population counts are available. This does not only extend previously provided population data but might also outdate previous data to a series of bug fixes since HYDE version 3.2.000.
Gross Domestic Product (GDP), country level and 0.5°x0.5° grid level	gdp	GDP PPP 2005 USD	1861-2016, annual time steps	Historic country-level GDP data are an extension of the data provided by Geiger, 2018 (https://www.earth-syst-sci-data.net/10/847/2018/essd-10-847-2018.html), and are derived mainly from the Maddison Project database. Gridded GDP data is based on the downscaling algorithm developed by Murakami & Yamagata, 2019 (https://www.mdpi.com/2071-1050/11/7/2106, http://dataservices.gfz-potsdam.de/pik/showshort.php?id=escidoc:2740907). The years 2000-2016 have been rescaled to provide a better match to the updated national GDP time series. All datasets are also available via the ISIMIP website, www.isimip.org.

[2] Various other resolutions (0.1° x 0.1°, 0.125° x 0.125°, 0.0833° x 0.0833° (5arcmin), 0.0416° x 0.4166° (2.5arcmin)) are also available.

4.5 Other human influences

For all these input variables, we describe reconstructions to be used for the historical (**hist**) simulations (see **Table** 5).

Table 5: Data sets representing "other human influences" for the historical simulations (**hist**).

Driver	Historical reconstruction
Reservoirs & dams (1800-2025) • **location** • **upstream area** • **capacity** • **construction/commissioning year**	Global data on 0.5° grid, mapped to the DDm30 routing network. Including some dams with planned completion in the future. Sources: - 6862 dams of capacity > 100 mcm (0.1 km^3) from GranD database (http://wp.geog.mcgill.ca/hydrolab/grand/). - 50 dams of capacity > 1000 mcm (1 Gt) with construction/commissioning year after 2010 from Kansas State University (KSU, Dr. Jida Wang). A file is provided with information on dams/reservoirs from both sources, with locations adapted to DDM30 to best match reported upstream areas. **Note on mapping**: Dam locations are originally given as point-information and simple mapping to the nearest grid cell center in the DDM30 stream network can lead to inconsistencies. For dams from GRanD, the comparison of GRanD upstream area and DDM30 upstream area was used as criterion to check the agreement of the location. A correction was applied to all dams with an upstream area in the GRanD data bigger than 10000 km^2 (844 dams, making up 94% of the total upstream area) and more than 50% deviation from the upstream area reported in GranD: They were shifted to the 8 possible neighboring cell centers and the dam was moved to the grid cell centre resulting in the smallest deviation in the upstream area. In total, 144 dams have been moved. For dams from KSU, no upstream area was provided and thus no comparison was possible; dams locations were mapped to DDM30 manually. **Note on usage**: Because the data from KSU is yet unpublished, modeling teams using it are asked to offer co-authorship to the team at KSU on any resulting publications. Please contact info@isimip.org in case of questions.
N fertilizer use (kg per ha of cropland)	Annual crop-specific input per ha of crop land for C_3 and C_4 annual, C_3 and C_4 perennial and C_3 Nitrogen fixing. This data set is part of the LUH2 dataset developed for CMIP6 (Hurtt, Chini, Sahajpal, Frolking, & et al, In prep.) based on HYDE3.2. The 2016 value is assumed to be identical to the 2015 value.
Nitrogen (NH_X and NO_Y) deposition	Monthly, 0.5°gridded data for global nitrogen deposition (1860-2016) NH_X and NO_Y deposition (g N m-2 yr-1) from the NCAR Chemistry-Climate Model Initiative (CCMI). Nitrogen deposition data was interpolated to 0.5° by 0.5° by the nearest grid. Data in 2015 and 2016 is assumed to be same as that in 2014. More information is

	available in (Tian, et al., 2018).
Fishing intensity	Depending on model construction, one of: Fishing effort from the Sea Around Us Project (SAUP); catch data from the Regional Fisheries Management Organizations (RFMOs) local fisheries agencies; exponential fishing technology increase and SAUP economic reconstructions. This data can currently not be hosted on ISIMIP servers; modelers are asked to contact the sectoral coordinators of the marine ecosystems and fisheries sector to gain access to this data.
Forest management	Based on observed stem numbers.
Water abstraction for domestic and industrial uses	For modelling groups that do not have their own representation, we provide files containing the multi-model mean domestic and industrial water withdrawal and consumption generated from ISIMIP2a varsoc runs of WaterGAP, PCR-GLOBWB, and H08. This data is available in the ISIMIP2b archive, from 1901 until 2005 (ISIMIP2b/InputData/water_abstraction/histsoc). Remaining years after 2005 should be filled in with the analogous data from RCP6.0 (ISIMIP2b/InputData/water_abstraction/rcp60soc/), which is based on multi-model projections from the Water Futures and Solutions project (Wada et al., 2016, http://www.geosci-model-dev.net/9/175/2016/).

4.6 Focus regions

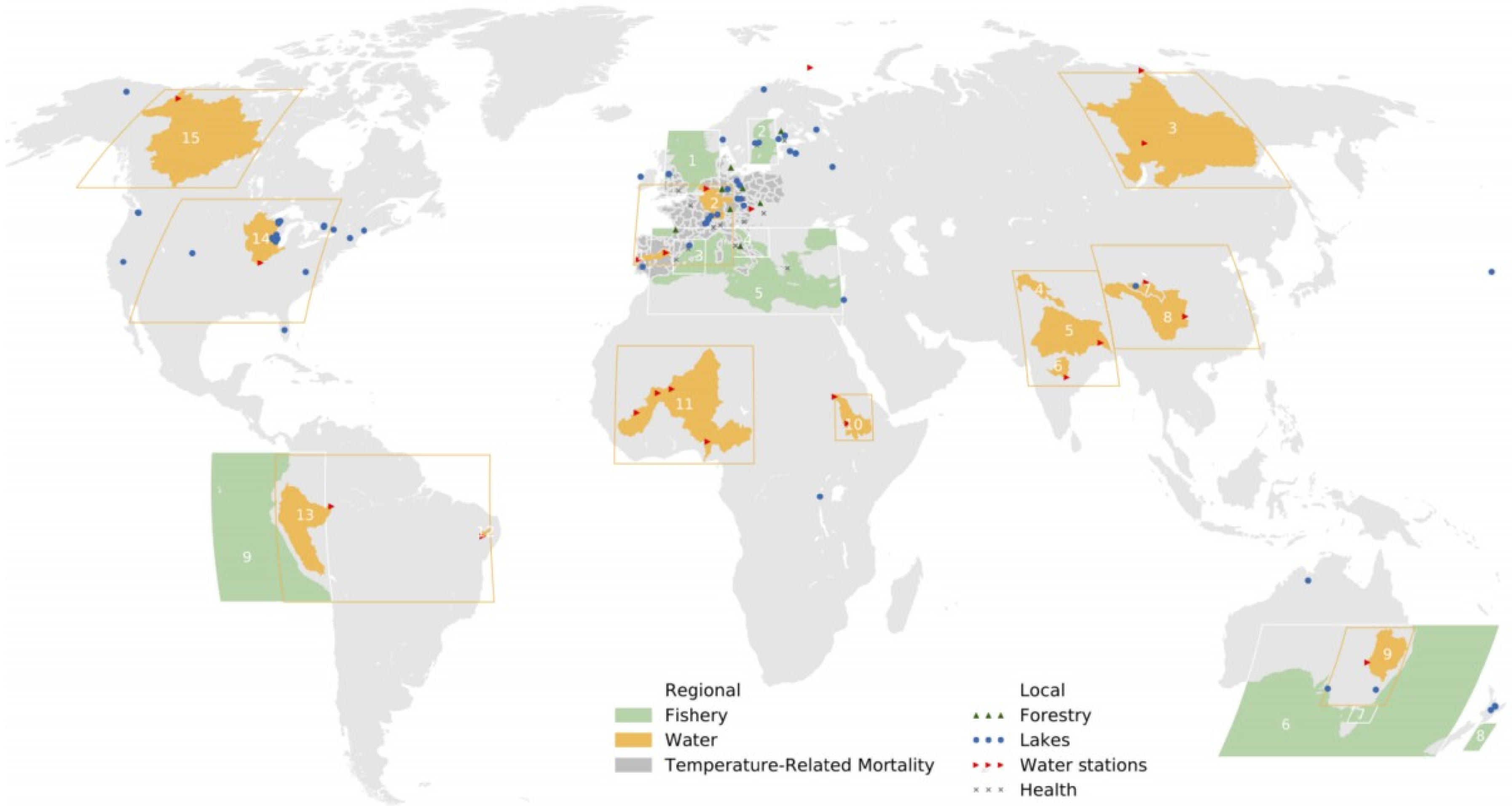

Figure 1**:** ISIMIP2a extended focus regions. See **Section** 6-14 for sector-specific details.

4.7 Scenario design

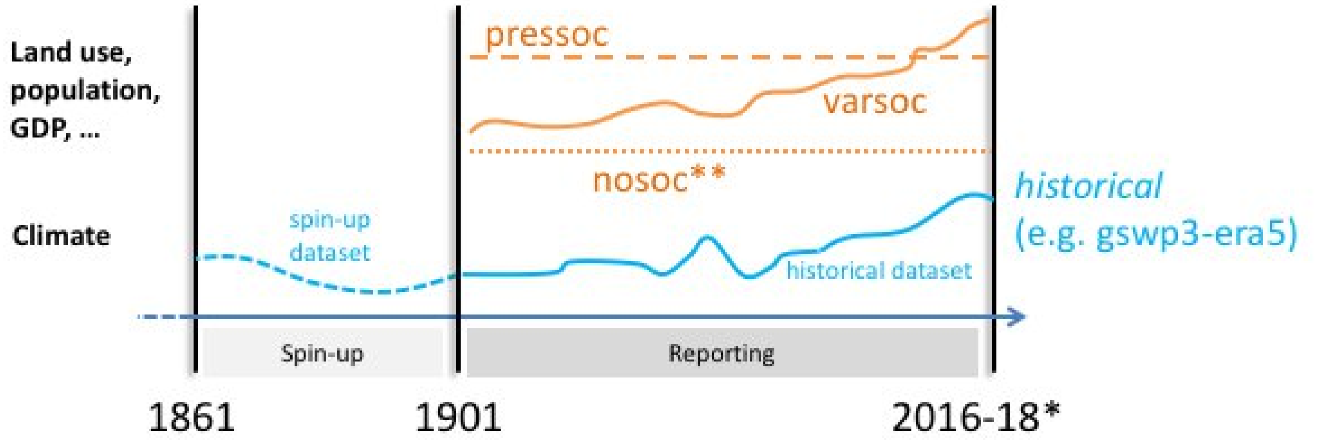

Figure 2: Schematic representation of the scenario design for ISIMIP2a. In addition to land use, population, and GDP, other non-climatic anthropogenic forcing factors and management (such as irrigation, fertilizer input, selection of crop varieties, flood protection levels, dams and reservoirs, water abstraction for human use, fishing effort, atmospheric nitrogen deposition, etc.) should follow the same scenario. *End year is different for each dataset. **no human influences except year-2000 land-use.

Table 6: General definition of socio-economic, CO_2 sensitivity, and agricultural management scenarios. See sector-specific sections for further specifications.

	Scenario name	Description
Socio-economic scenarios	nosoc	No human influences except for year-2000 constant land-use patterns. No anthropogenic water abstraction (e.g. irrigation), no reservoirs/dams. No population and GDP data prescribed. For forest models, this means running the model without any management (but nitrogen deposition should be included). If your model includes natural regeneration, please only regeneration those species previously present on the plot.
	pressoc	Present-day human impact runs: only climate varies; keep all other settings (population, GDP, land-use, technological progress, etc.) constant at year 2000 values. This run will be used to quantify adaptation pressure under current socio-economic conditions. For water models, pressoc includes present-day irrigation and other water uses / reservoirs. See further details for health models in **Section** 14.
	varsoc	Not only climate but also population, GDP, land-use, technological progress, etc. varies over the historical period. For forest simulations, this means: Manage forests according to historical management guidelines without species change. See further details for health models in **Section** 14.
	nat	A natural vegetation only run without any land-use pattern (optional for biomes models). 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.
CO_2 sensitivity scenarios	co2	Transient CO2 concentration (taken historical data) for CO2 fertilization effects. If your model does not implement CO2 fertilization using transient CO2 concentrations at all, please use your own implementation and include that in the reporting. For simulations without any CO2 implementation also use the “co2” tag to indicate that this driver is given implicitly in the driving climate forcing.

	noco2	Sensitivity experiment: only applies to models that take CO2 into account. CO2 concentration fixed at present-day value, i.e. run with transient historical CO2 up to the year 2000 and keep CO2 fixed at 369ppm thereafter.
	co2const	Keep CO2 concentration constant at 1971 level. For spin-up, use time-varying, historical CO2 concentration until 1970.
Agricultural management scenarios	firr (for crop models)	Full irrigation, i.e. until the soil is saturated.
	noirr (for crop models and hydrological models)	No irrigation. Both firr and noirr are required for the agro-economic models.
	cirr (for hydrological models)	Constrained irrigation.
	harmnon (for crop models)	Full fertilizer run, i.e. ensuring no N constraints, harmonized sowing and harvesting dates.
	fullharm (for crop models)	Full harmonization with regard to fertilizer application rates, sowing, and harvesting dates.
	default (for crop models)	“Best guess” representation of historical conditions regarding fertilizer application rates, sowing and variety settings that best reproduce given harvesting dates.

4.8 Spin-up

Simulation results should be reported from 1901 onwards. For models requiring spin-up, we provide 120 years of data produced by first removing a linear trend from the 1901-1930 portion of each forcing dataset, and then resampling these years at random (files <variable>_<climate_forcing>_1781_1900_spinup.nc4 in detrended/ subfolders). If more than 120 years of spin-up are needed, these data can be repeated as often as needed. For combined datasets (e.g. GSWP3-W5E5) use the spin-up dataset corresponding to the *first* part of the dataset.

After running the necessary length of spin-up data, continue with the respective climate forcing data set, starting in 1901. See Section 4.1 for more information on the historical climate forcing data sets.

Use historical CO_2 concentration, as provided in the input data archive (filename: /ISIMIP/ISIMIP2a/InputData/climate_co2/co2/historical_CO2_annual_1765_2018.txt), for the part of the spin-up directly preceding the reporting period. When using a longer spin-up period that (nominally) extends back further than 1765, please keep CO_2 concentration constant at 1765 level until reaching the year corresponding to 1765.

5 Reporting model results

5.1 Formatting, naming conventions and publication process

5.1.1 File names

Any model output files submitted to ISIMIP should follow the naming convention below. This naming convention is designed to be applicable across all sectors in ISIMIP. The file name is supposed to reflect the input data and scenario choices that went into the simulation; NOT to reflect specificities of individual models (these should be documented in the model database on the ISIMIP website). Please keep this in mind when preparing your files, and feel free to ask the coordination team in case of doubt.

File names consist of a series of identifiers, separated by underscores; see examples below. Things to note:

- Report **one** variable per file
- In filenames, use **lowercase** letters only
- Use underscore ("_") to separate identifiers
- Variable names consist of a single word without hyphens or underscores
- Use hyphens ("-") to separate strings within an identifier, e.g. in a model name
- NetCDF file extension is .nc4

In case of any questions, please contact the coordination team (info@isimip.org) before submitting files.
The file names should follow this convention for the **historical calibration and validation runs**:

<model-name>_<obs>_<bias-correction>_<clim-scenario>_<socio-econ-scenario>_<sens-scenarios>_<variable>_<region>_<timestep>_<start-year>_<end-year>.nc4

where the parts in brackets should be replaced with the appropriate identifier as in **Table** 7, and the order of identifiers should be respected. Identifiers may be dependent on the sector. The associated sectors are given in brackets in **Table** 7.
For example:

swim_watch_nobc_hist_nosoc_co2_dis_blue-nile-khartoum_daily_1971_2001.nc4 for the regional water sector and

lpjml_gswp3_nobc_hist_2005soc_co2_yield-mai-firr-default_global_annual_1971_2012.nc4 for a maize crop model run.

Table 7: File name specifiers for output data.

Item	Possible specifiers (use lowercase letters only!)	Explanation
<model-name>	*(your model name as registered with ISIMIP)*	Name of the impacts model. **IMPORTANT:** If you previously submitted data to ISIMIP2a and your model has been modified in the meantime, then • either run any new ISIMIP2a-extended simulations using the **same model version** as for the initial ISIMIP2a simulations, • or **assign a new name** to your updated model. E.g. if your model was called BESTModel1, you may call it BESTModel1b for the new uploads
<obs>	gswp3, princeton, watch, wfdei, gswp3-ewembi, gswp3-w5e5 (all sectors) localclim (Forests)	Name of the observations-based dataset providing the climate forcing data. For locally observed weather data from a weather station or similar which is in direct proximity of the forest stand and has been used for detailed model evaluation runs.
<bias-correction>	nobc	Indicates that no bias correction was performed on the climate data (e.g. observational data or ocean data).
<clim-scenario>	hist	Historical climate information.
<socio-econ-scenario>	nosoc pressoc varsoc nat	See **Table 6** in Section 4.7

<sens-scenario>	co2 noco2 co2const	See **Table 6** in Section 4.7
<variable>	*(variable names listed in the sector specific output tables)*	Output variable of the impact model. The identifier can also be used for information about the plant functional type (pft) in the biomes and permafrost sectors; the pft/species naming is model-specific and hence has to be reported in the impact-model database (www.isimip.org/impactmodels). In the forest sector, the identifier might contain information about the tree species; the species names codes are listed in Table 23. In the health sector, the identifier might contain information about the realization (se Section 14.2); the naming is model-specific and hence has to be reported in the impact model database (www.isimip.org/impactmodels).
	Plus a combination of the following settings for crop models (separated by dashes):	
	firr (for crop models) noirr (for crop models)	See **Table 6** in Section 4.7
	harmnon (for crop models) fullharm (for crop models) default (for crop models)	See **Table 6** in Section 4.7
<region>	global common name of river basin and gauge station as listed in Table 13. **Table** 13 forest site name as defined in Table 20**.** city/country/region name	For global simulations. For simulations covering one of several basins or a single location within a focus region (in the form "[river basin]-[station name]", e.g., "rhine-lobith"). For simulations of the regional forest models. For Health/Temperature-related mortality
<timestep>	daily, monthly, annual, decadal	
<start-year>_<end-year>		For the forest simulations, the full simulation period can be covered in one file; e.g. 1952-2012.

5.1.2 Format for gridded data

Gridded data should be returned in NetCDF4 format with a compression level of at least 5. It is important that you comply precisely with the formatting specified below, in order to facilitate the analysis of your simulation results in the ISIMIP framework. Incorrect formatting can seriously delay the analysis or lead to errors. For questions or clarifications, please contact the ISIMIP coordination team. Further information and instructions follow in this section and at the ISIMIP website (https://www.isimip.org/protocol/preparing-simulation-files/).

Global data are to be submitted for the ranges **-89.75** to **89.75** degrees latitude, and **-179.75** to **179.75** degrees longitude, i.e. 360 rows and 720 columns, or 259200 grid cells total. Please report the output data row-wise starting at 89.75 and -179.75, and ending at -89.75 and 179.75. The standard horizontal resolution is 0.5x0.5 degrees, corresponding to the resolution of the climate input data; with reporting intervals of 0.5 degrees_east for longitude, and of -0.5 degrees_north for latitude. Submitting data at lower resolution than 0.5x0.5 degrees is only encouraged in exceptional cases; in those cases, the above numbers will change accordingly (e.g., a 1x1 degree grid would have 180 rows, from 89.5 to -89.5 degrees latitude).

Antarctica and Greenland do not have to be simulated. If you are limited by data (e.g. soil data) you can also reduce the latitude range of your simulations, however, the **minimal latitude range** to be simulated is -60 to + 67 degrees. **Important:** When *reporting* results the whole grid as specified above should be reported – pixels you did not simulate should be filled with the missing value marker (1.e+20f).

Regional model teams should interpolate their output data to the same, common 0.5x0.5 degree grid as described above, and submit in the same NetCDF file format. Each file should **cover the entire globe** (even though the filename should contain the name of the region), with any grid cells outside the simulated region to be filled with missing values (1.e+20f). This will not lead to significantly larger files as long as NetCDF compression is used. **Exception:** Single (one-point) timeseries do not have to be embedded into the 0.5x0.5 degree grid, but should be reported as NetCDF4 files with the coordinates of the point included in the header information (e.g., lon : 172.84 degrees_east; lat : 47.08 degrees_north).

Note that submitting results in this format is important to facilitate comparison among different models and between global and regional scale. The **ISIMIP coordination team will be glad to assist** with the preparation of these files if necessary. **In addition** to the global file, regional model teams may submit a second file containing the output data in their default format. This may be e.g. on a finer resolution than 0.5°, on a non-regular grid, etc.

Please note the corresponding file naming conventions in Section 5.1.1.

5.1.3 NetCDF files: general conventions

Latitude, longitude and time should be included as individual variables in each file, following the conventions of **Table** 8. When defining the variable in a file, time should be the first dimension; e.g., albedo(time,lat,lon).

Table 8: Naming and format conventions for NetCDF files.

Dimension	Name	Unit
X	Lon	degrees east
Y	Lat	degrees north
T	Time	<time steps> since 1901-01-01 00:00:00 (where <time steps> is replaced by days, months, etc., according to the time step the data is reported on) Note: crop models use a different time step; see Section 10.3.
missing value	1.e+20f	
fill value	1.e+20f	

Once you have created your NetCDF file, you can check the metadata by running the command ncdump -h; an example output is given on the ISIMIP website, www.isimip.org (Protocol -> Important information about preparing your simulation files).

5.1.4 Format for non-gridded data

Data that is not defined on a grid, such as point-based data (e.g. for particular gauges or data for world regions), should nonetheless be reported in NetCDF format (e.g. as a separate file for each gauge or region), each file containing a single time series. The ISIMIP coordination team will assist with the preparation of these files where necessary. **It is important that all ISIMIP results exist in NetCDF format**, in order to be compatible with the structure and functionalities of the ESGF repository.

5.1.5 Variables with layers

For variables that can be simulated on multiple **fixed layers** (e.g. variables with DBH classes in Forest Models, or with fixed depth layers in the Lakes sector), we require the following:

- The level dimension has a specific name per sector; i.e. 'levlak' for the lakes sector, 'lev' for the water sector or 'dbh_class' for forest models
- For variables where a level cover a range, like soil depth or dbh class, specify the lower and upper boundaries of every layer, with data corresponding to the midpoint of each layer (e.g. dbh class or depth layer)
  - The boundaries of the top/bottom layers will end up in a variable called 'depth_bnds', and the midpoint will be in 'depth'
  - 'depth' and 'depth_bnds' are double

- For variables where a level has the function of an index, it is not necessary to indicate boundaries
- For variables where it is possible to have layers or not (e.g. variable "harv" in Forest Models), add global attribute 'dbhclass_profile' and use label 'true' if the file contains layers (e.g. multiple dbh classes) or 'false' depending on the case

For variables simulated on **depth layers varying** over time and/or over space (e.g. soil moisture on layers that can get deeper or shallower over time, or have different depths at different locations), we distinguish between variables where the levels vary per grid cell, and variables where the levels vary over time. For such variables, we additionally require the following:

- For variables where depth of layers varies over time, add global attribute 'time_varying_soil_layer_depth' and use label 'true' or 'false' depending on the case
- For variables where depth of layers varies per grid cell, add global attribute 'location_varying_soil_layer_depth' and use label 'true' or 'false' depending on the case

More information and example outputs are available on the ISIMIP website, www.isimip.org (Protocol -> Important information about preparing your simulation files).

5.1.6 Time intervals

Please submit your output data in chunks according to the **Table** 9 depending on the time step of the output variable you are reporting (the requested time step for each variable is listed in the sector-specific tables).

Table 9: Definition of time intervals

Daily time step	For files holding *global* daily data, files should cover 10 years starting in the second year of a decade and end in the first year of the next decade (e.g. 1991-2000). If the time period starts after the second year of the decade or ends before the first year of the new decade, the start or end year of the time period should be used as the start or end year of the file respectively. *Non-global* daily data should be submitted for the entire simulation period in single files per variable.
monthly, annual, or decadal time step	Output should be reported in one single time series file per experiment.
30-year averages (biodiversity	Output should be reported in one single file per period.

only)	
5-year period (health)	Output should be reported in one single file per period.
growing-season (agriculture)	Output should be reported in one single file per period. Time dimension is replaced by a unitless coordinate variable with integer values, or counter, named ‘growing-season’, indicating the number of growing season since starting year of the period.

5.1.7 Submission of simulations

Data should be submitted to a dedicated file system on a central server located at DKRZ Hamburg. More information on how to access this server and on formatting of your files is available on the ISIMIP website at https://www.isimip.org/protocol/preparing-simulation-files/. The ISIMIP coordination team will gladly provide assistance upon request.

5.1.8 Format checks

The **ISIMIP data management team will check** the formatting of the files submitted to the server at DKRZ Hamburg. File naming, variable and dimensions definitions and units, grid formatting, time axis, coverage of simulation period and global metadata are reviewed and corrected when possible. Files with severe errors will be reported and a following submission will be requested. Files passing the checks will be published in the OutputArea of DKRZ. Further information on the checks performed can be found at https://www.isimip.org/protocol/preparing-simulation-files/#quality-check-of-your-simulation-data.

5.2 Documentation of models and experiments

In addition to adhering to the common settings described in this protocol, it is essential to keep track of further details regarding the configuration of each individual model. This ensures that the simulation results can appropriately be interpreted by authors of multi-model studies, and that these can remain transparent and usable for a long time into the future. For this purpose, the ISIMIP coordination team provides a questionnaire that all modelling teams are asked to answer. The questionnaire is accessible online through the ISIMIP website; for assistance please write to Info@isimip.org.

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