

The Intersectoral

Impact Model Intercomparison Project

ISIMIP

**Project Design and
Simulation protocol**

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1 Introduction

This document describes the simulation protocol for the fast-track of the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP). It has been developed by the coordination team at the Potsdam Institute for Climate Impact Research (PIK, info@isimip.org) in close consultation with participating modeling teams from the water, biomes, agriculture, infrastructure and human impacts/health sectors. To ensure that the scientific objectives of the ISI-MIP fast-track are met, unless an explicit arrangement has been made with the ISI-MIP coordination team, the protocol is not open to amendment.

In the agricultural sector there is an ongoing model intercomparison project (AgMIP) through which the agricultural modeling work will be coordinated. Agricultural modeling teams who are not yet part of AgMIP, but are contributing to ISI-MIP, are asked to contact the AgMIP team for coordination (agmip@columbia.edu), but can also base their contribution on the modeling framework outlined in this document. In the water sector, many helpful contributions from WaterMIP, the recently concluded hydrological model intercomparison, are acknowledged.

The principal objective of the ISI-MIP fast-track is to compare projections of climate change impacts from global models, based on consistent climate and socio-economic input. For further information about the scientific objectives of the ISI-MIP fast-track, and instructions on how to join the project, please visit www.isimip.org.

Sections 1-5 of this protocol are relevant to all modeling groups, irrespective of the sector. They describe the timeline of the project, the input data to be provided, and important information about how to set up your experiments and to report your results. Please read these sections carefully before commencing your modeling runs, and refer any questions immediately to info@isimip.org.

In Sections 6-7 you will find sector-specific lists of variables to be provided as output, as well as the scenario runs (more details in section 1.2). In Section 8 a summary of the envisaged scientific products is provided. In the case of groups providing data relating to the agricultural sector, please also refer your questions and comments to the AgMIP coordination team (agmip@columbia.edu).

When publishing results based on the ISI-MIP data set, the project and the participants should be acknowledged and the scenario setting should be referred to as the “ISI-MIP scenario set up”. Modelers contributing data to a multi-model paper written in the fast-track phase of the project should be given the option to become co-authors.

1.1 Research questions

The ISI-MIP fast-track aims to address the following central research questions:

1. What is the difference between a 2 °C, 3°C, and 4°C warmer world and how good are we at telling these difference?

The inter-model spread of impact projections at different levels of global warming will be used a measure of the robustness of the projections (How good are we at telling the difference?).

A highly relevant related question is:

2. Is global mean temperature change a good indicator of the impact? In the case there is a strong scenario dependence of impacts at different levels of global warming, additional indicators such as CO₂ concentration, GDP, or population might be needed to “project” impacts.

The basic sector-specific synthesis papers (minimal outcome, see Section 8.1) will focus on these central research questions. In addition, papers included in the Special Feature (further details in Section 8.1) could focus on these questions, such as:

3. Are there essential deficiencies in our process understanding or the way processes are represented?
4. Are these deficiencies persistent across different impact models?

1.2 Scenario priority list

The ISI-MIP fast-track aims to quantify the uncertainty in the impacts of climate change, both across climate impact models and sectors, and for different levels of global warming. These two objectives are embedded in the set of sector-specific scenarios described in this document (Section 7). The list of chosen scenarios represents a compromise between ensuring harmonization across the sectors and exploring the sector-specific modeling uncertainties. Here we summarize the scientific motivation for the ordering of climate and socio-economic scenarios. The minimal setting corresponds to the minimal set of runs required from each impact model participating in the ISI-MIP fast-track. More details are given in the sector-specific sections.

1.2.1 Minimal setting

The minimal setting spans both the climate model and the climate scenario space to a basic extent. All four RCP concentration scenarios are to be run using data from one global climate model (GCM1). These four runs allow us to compare climate impacts at different levels of global warming (see section 8.1). Additionally, the remaining four priority GCMs (GCM 2-5) are considered together with those RCPs producing the highest and lowest end-of-century forcings (RCP8.5 and RCP2.6 respectively). Where applicable, only the middle-of-the-road socio-economic scenario (SSP2) is used in the minimal setting. Highly relevant sensitivities (e.g. to CO₂ fertilization) are also considered here.

In the cases where climate and human impacts are coupled, the minimal setting includes control runs, which will allow these effects to be disentangled in post-processing.

1.2.2 First Extension

In the first extension, the remaining RCPs (RCP4.5 and RCP6.0) are considered for GCM2-5 (see Appendix 9.3).

1.2.3 Second Extension

For the sectors affected by socio-economic changes, the second extension explores the impact of the different SSPs. For these studies, GCM1 and RCP4.5 are fixed.

1.2.4 Third Extension and beyond

As data for more climate models become available, we will provide the relevant bias-corrected data.

IMPORTANT: Models should run all four RCPs for each model before moving on to the next GCM.

2 Fast-track timeline

The ISI-MIP fast-track aims to provide results in time for consideration for the fifth Assessment Report (AR5) of the IPCC. Adhering to the following timeline makes this ambitious target feasible.

Item	Comments	Date
Dummy input dataset available	Please test it when it is ready, and provide feedback	15 February 2012
Climate input datasets for first GCM available	Data for all GCMs will be added as they become available.	16 March 2012
Climate data for all 5 high-priority GCMs available		1 April 2012
Representative Agricultural Pathways available	For agricultural sector	20 April 2012
Modeling teams upload test output dataset		1 May 2012
Socio-economic dataset available		May 2012 ¹
Deadline for modeling teams to upload full results	Output should be provided as it becomes available; this is the last possible day to provide the data to the coordination team.	1 July 2012
Workshop on results	Location: Walker Institute, Reading, UK	3-6 September 2012
Submission of publications	AR5 WG2 submission deadline; 6-10 papers possibly part of PNAS Special Feature	31 January 2013
Impacts conference	Location: PIK, Germany	April 2013
Acceptance of publications	AR5 WG2 publication acceptance deadline	31 August 2013

3 Data archive

In collaboration with the Climate Service Center (<http://www.climate-service-center.de/>, Hamburg, Germany), a central ISI-MIP data archive will be hosted at the DKRZ (Hamburg, Germany). A link to this will be made available at www.isimip.org. This archive will host both the input and output data.

¹ The SSPs are being developed outside of the ISI-MIP framework and the final public release is uncertain at this point. The ISI-MIP coordination team is in close contact with the SSP development teams and strongly hopes to be able to provide the GDP and population scenarios at an earlier date, hopefully in April.

Please notify the coordination team when submitting a new dataset by emailing isimip-data@pik-potsdam.de with “[data submitted]” in the subject line. For the agricultural sector, please also send notification to agmip@columbia.edu.

For the agricultural sector all output data will be sent to the AgMIP data server. AgMIP will ensure that the data will be sent to the ISI-MIP archive by the July 1 deadline. Data will be flagged as preliminary and not-yet-publishable until the modeling teams have vetted them. In the agricultural sector the vetting is organized by AgMIP. Once finalized, data will be flagged as "vetted".

IMPORTANT: Please note that all data to be included in publications in the planned Special Feature have to be uploaded to the ISI-MIP archive until the July 1 deadline, at least in preliminary form!

4 Input data

The ISI-MIP coordination team will provide bias-corrected climate data from the GCMs participating in the CMIP5. Data will cover the time period from 1950 to 2099, i.e. the historical period², and future projections for all RCPs (RCP 2.6³, RCP 4.5, RCP 6.0, RCP 8.5). For more information on the bias-correction methods applied, see the Appendix 9.1. Socio-economic data (population and GDP) will be provided and will include all Shared Socio-Economic Pathways (SSPs 1-5, developed as part of the ongoing socio-economic scenario development process⁴).

4.1 Climate data

IMPORTANT: Whenever possible, monthly data should only be used for models that run with a monthly time step. Models requiring daily input data should use the daily data provided, rather than downscaling monthly data (i.e. **do not** use built-in weather generators to downscale monthly data to a daily time step unless multiple iterations are required for model processes). Models requiring sub-daily resolution should apply default downscaling methods to the provided daily data.

² If possible – not all GCM data include the period before 1950 – see section 5 for further information.

³ Also called RCP3-PD

⁴ See <http://www.isp.ucar.edu/socio-economic-pathways> for more information.

Variable	Name	Unit (NetCDF format)	Frequency	Bias correction method ⁵
Surface air temperatures T _{avg} T _{min} T _{max} (24 hour values)	tas, tasmin, tasmx	K (K)	daily & monthly	Mean and range matched to WATCH ⁶ data (1960-1999)
Precipitation (snow and rainfall separately)	pr (prsn)	Kg/m ² /s (kg m-2 s-1)	daily & monthly	Statistical distribution matched to WATCH data
Surface radiation (short- and longwave downwelling)	rsds rlds	W/m ² (W m-2)	daily & monthly	Statistical distribution matched to WATCH data
Near-surface wind speed (east- and north-ward)	uas vas	m/s (m s-1)	daily & monthly	Statistical distribution matched to WATCH data
Near-surface wind speed (total)	wind	m/s (m s-1)	daily & monthly	Statistical distribution matched to WATCH data
Surface air pressure	ps	Pa (pa)	daily & monthly	Statistical distribution matched to WATCH data
Near-surface specific humidity	huss	kg/kg (kg kg-1)	daily & monthly	Statistical distribution matched to WATCH data
CO ₂ concentration	co2	ppm (ppm)	annual	None

4.1.1 Format and time periods

- Regular global grid at 0.5°x0.5° resolution; grid information is contained in the meta-data. (Data on a 1.25°x1.85° grid will also be provided for those models unable to complete the necessary runs by the deadline, but should only be used after discussion with the coordination team. Please note that this data may be delayed with respect to the 0.5°x0.5° data.)
- NetCDF (version 4) format. See section 5.2.
- CRU land mask [files include missing-value markers (1.e+20f) over oceans and Antarctica].

⁵ See the Appendix 9.1 for details of the bias-correction method.

⁶Weedon, G. P., et al., 2011, Creation of the WATCH Forcing Data and its use to assess global and regional reference crop evaporation over land during the twentieth century, *J. Hydrometeor.*, 12, 823–848, doi: 10.1175/2011JHM1369.1

4.1.2 Spin-up data

We have prepared a spin-up data set that is to be used if your model requires more than 20 years of spin-up (i.e. equilibration time before the start of the reporting period). The data set has been prepared by de-trending WATCH forcing data for the years 1951-1980, and is normalized to reflect a climate representative of 1950 conditions.

If your model requires between 21 and 50 years of spin-up, please run it first with the spin-up data set provided, and then continue using climate input data from the appropriate GCM, starting in 1951 (thus, at the start of the reporting period in 1971, the model will have had up to 50 years of spin-up).

If your model requires more than 50 years of spin-up, the 30-year spin-up data set can be replicated and assembled back-to-back to obtain longer data sets; in this case, make sure to reverse the order of years in every other copy of the 30-year period, in order to minimize potential discontinuities in low-frequency variability. Then, after running as many instances of the 30-year spin-up data set as required, continue with GCM data in 1951, as explained above.

For CO₂, use 1950 CO₂ concentration while running the 30-year spin-up data set; afterwards, use historical CO₂ concentration, as provided in the input data archive.

4.2 Socio-Economic Data

The parameter space of the Shared Socio-Economic Pathways (SSPs) is spanned by challenges for adaptation and challenges for mitigation. The former essentially means levels of development and the latter can be translated to degree of fossil energy and resource intensity. The five marker scenarios are likely going to be SSP1 (low challenges, sustainability scenario), SSP2 (medium challenges, continuation of current trends), SSP3 (high challenges, fragmentation), SSP4 (high adaptation challenges, inequality), and SSP5 (high mitigation challenges, conventional development). Main characteristics include population, human resources, economic development, human development, technology, lifestyles, environmental and natural resources, policies and institutions.

There is no one-to-one connection of a given SSP with a given RCP. Instead the combination of SSPs with different climate policy and also adaptation assumptions will result in different forcing levels. For each SSP there will be exactly one combination of population and GDP scenario.

More information on the process can be found at <http://www.isp.ucar.edu/socio-economic-pathways>.

The following socio-economic data will be provided based on the SSPs:

Variable	Name	Unit	Frequency
Population	Pop	number of people	5-year time steps ⁷
GDP	Gdp	GDP PPP (can also be written as MER)	5-year time steps

Format and time periods

- Country-scale (alpha-3 country code)
- One historic data-set for 1970-2004
- SSP-specific scenario data for 2005-2100

4.3 Land-Cover and Topographic Data

IMPORTANT: Harmonizing land cover and land-use data is not intended within the ISI-MIP Fast Track. However, if you need data for your model runs and do not have your own set-up you may use the data listed in this section. Land-cover pattern data

Land cover category	Name	Unit
Agricultural land and irrigated area	MIRCA See http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/MIRCA/index.html	% of pixel used for specific crops (rain-fed and irrigated)
Routing network	DDM30 See http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/Global_Water_Modeling/DDM30/index.html for reference. The version provided has been mapped to the CRU land mask, and was also used in WaterMIP.	
Land mask	CRU world map ^{8,9}	1 = land 0 = ocean

⁷ If annual data is required, please interpolate the data.

⁸ New, M., M. Hulme, and P. Jones, 1999: Representing twentieth century space–time climate variability. Part I: Development of a 1961–90 mean monthly terrestrial climatology. *J. Climate*, 12, 829–856.

⁹ New, M., M. Hulme, and P. Jones, 2000: Representing twentieth-century space–time climate variability. Part II: Development of 1901–96 monthly grids of terrestrial surface climate. *J. Climate*, 13, 2217–2238.

5 Reporting model results

5.1 Reporting and reference time periods

Item	Time period	Comments
Reporting time (for transient runs)	1971-2099	Please provide output data for the entire period.
Time slices	present-day ¹⁰ (middle year 1980-2010 2000) (for 2006-2010 data, please use the RCP 4.5 run of each GCM)	<p>Time slices should be provided if your model is too computationally expensive to do the transient runs.</p> <p>If you use an averaged climate for the time slices, please use the socio-economic and CO₂ data corresponding to the middle year of the time-slice period. Otherwise the time-varying information should be used.</p> <p>In the case that not all slices can be run, the near-term is the lowest priority time-slice.</p>
	near-term (middle year 2005-2035 2020)	
	mid-century (middle year 2035-2065 2050)	
	end-of-century (middle year 2069-2099 2085)	
Present-day climate	1980-2010	<p>This period is to be used for constant climate runs (presclim).</p> <p>Derived from GCM runs (NOT from observational data) with one specific present-day climate per GCM.</p> <p>For comparisons with observations the WATCH dataset will be provided in the ISI-MIP archive.</p>
Present-day population/GDP	2000	
Present-day land-use	2000	

¹⁰ This corresponds to the so called satellite-era.

Spin-up	As many years as required before the start of the reporting period (1971)	See section 4.1.2
Reference period	1980-2010	The reference period is defined only for post-processing purposes, to describe future projections relative to present-day conditions. When reporting your output data, always provide absolute values.
Reference year	2000	

5.2 Convention for file names and formats

5.2.1 File names

One variable should be reported per file. The file names should follow this convention:

modelname_GCM_bias-correction_clim-scenario_socio-econ-scenario_sens-scenario_variable_region_timestep_start-year_end-year.nc

e.g. magpie_hadgem2-es_wfd_rcp8p5_ssp2_noco2_default_Xpr-rwhe
_global_decadal_1971_2099.nc

Use **only lowercase** letters in the file names (necessary for some NetCDF viewers).

Codes for variables can be found in the sector-specific output tables (see Section 6).

5.2.2 Scenario naming conventions

The following table lists the specifiers for file names in each sector. Please note that the statement “not applicable” may not hold for models covering more than one sector (e.g. Water and Biomes). (See over page for description of terms.)

Item	Agriculture	Water	Biomes	Health ¹¹
“socio-econ-scenario”	ssp<x>, pressoc - year 2000 population and	ssp<x>, pressoc - year 2000 population	not applicable	ssp<x>_ssp<x> - population and GDP according

¹¹ The health sector is the only sector where population and GDP effects are considered separately (see 2nd extension of run priorities; section 7.4). For the health sector the “socio-econ-scenario” component of the file name has two components separated by an underscore (e.g. ssp2_ssp2 or ssp1_pressoc) where the first component is related to the population scenario and the second one to the GDP scenario.

	GDP (not applicable for biophysical models)	and GDP nosoc - naturalized runs		to SSPx or ssp<x>_pressoc - population according to SSPx; year 2000 GDP
“sens- scenario”	co2 noco2 noirr firr default (refers to default irrigation)	co2 noco2 pico2 leave blank if not applicable to your model	co2 noco2	not applicable
“region”	global	global, [region/basin/sit es]	global	global
“timestep”	monthly, annual, decadal	monthly, daily	annual	daily, monthly, annual
“clim- scenario”	rcp<y>, hist, presclim	rcp<y>, hist, noclim - purely demand-side, no- hydrology run	rcp<y>, hist	rcp<y>, hist, presclim
“bias- correction”	wfd	wfd	wfd	wfd

Explanations:

ssp<x> refers to **ssp1, ssp2, ssp3, ssp4** and **ssp5**

rcp<y> refers to **rcp2p6, rcp4p5, rcp6p0, rcp8p5**

hist refers to historical climate information (to be put for files containing data for decades before 2005)

co2: Transient CO₂ (taken from the RCP and historical data provided via www.isi-mip.org) for CO₂ fertilization effects. If your model does not implement CO₂ fertilization using transient CO₂ concentrations, please use your own implementation and include that in the reporting.

noco2: CO₂ fixed at present-day value, i.e. run with transient historical CO₂ up to the year 2000 and keep CO₂ fixed thereafter. Sensitivity experiment: only applies to models that take CO₂ into account.

pico2: CO₂ fixed at pre-industrial value throughout the entire simulation (i.e. including spin-up)

firr: Full irrigation, i.e. until the soil is saturated.

noirr: No irrigation. Both irrigation variations are required for the agro-economic models.

default: Default irrigation (only valid for agro-economic models).

presclim: Present-day climate (1980-2010) – see section 3.4. For agro-economic models it means averaging biophysical information from the present day period of the biophysical model runs (Note: They differ from GCM to GCM). This run is essential to quantify the pure climate induced changes as the difference between the RCP and the presclim run.

noclim: non-hydrology runs; to compute future non-agricultural water use/ withdrawal/ consumption – only for appropriate models (WaterGAP, H08). Use population and GDP according to SSPs (as provided). For water models only.

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.

nosoc: naturalized runs (no human impact). No population and GDP data prescribed. For water models only.

wfd: denotes that the climate input data were bias corrected using the Watch Forcing Data set.

5.2.3 Format for gridded data

Gridded data should be returned in NetCDF format. It is important that you comply precisely with the formatting specified below, in order to facilitate the analysis of your simulation results in the ISI-MIP framework. Incorrect formatting can seriously delay the analysis. For questions or clarifications, please contact the ISI-MIP project team.

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. If you submit data on a lower resolution than 0.5x0.5 degrees, these numbers will change accordingly (e.g., a 1x1 degree grid would have 180 rows, from -89.5 to 89.5 degrees latitude).

Agricultural sector: 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 – for pixels you did not simulate please put the missing value marker (1.e+20f).

Latitude, longitude and time should be included as individual variables in each file.

5.2.3.1 Naming convention in NetCDF

Dimension	Name	Unit
x	lon	degrees east
y	lat	degrees north
t	time	<time steps> since 1 January, 1901 (where <time steps> is replaced by days, months, etc., according to the time step the data is reported on)
missing value	1.e+20f	

5.2.3.2 Preparing your NetCDF files

To facilitate proper formatting of your output files, shell scripts will be provided on the ISI-MIP website (www.isimip.org) that produce “empty” NetCDF files with the correct format and header information. Please use these scripts to write your output data into NetCDF files. A detailed explanation of how to do this is given here and can also be found on the website .

The NetCDF format should adhere to the settings in the shell (bash) script "output_<time_step>.sh". Scripts are available for the different time steps, namely "daily", "monthly", "annual" or "decadal".

In order to create an empty netcdf file with the correct filename and the required metadata in the header, you must run the script appropriate to the time step of the output data you want to store (e.g. daily data), using the following command:

```
> output_<time_step>.sh x1 x2 x3 x4 x5 x6 x7 x8 x9
```

The arguments are given in the following table.

Arg	Details	example
x1	The first year of data to be stored in the netcdf file (e.g. '1980'). Each file should contain data for one variable only, and for a time interval as specified in sections 5.2.5 and 6 (e.g., monthly data for 1980-1989).	'1980'
x2	Variable name stored in the netcdf file. Please adhere to variable names given in protocol.	'pr'

x3	Long variable name.	'precipitation'
x4	Units of the variable following the CF metadata	'kg m-2 s-1'
x5	Comments on input data versions (please list each input variable in alphabetical order, indicating the version you have used).	'input: huss_v2 pr_v2 ps_v1 tas_v1' '' if empty
x6	Further room for comments (optional).	'includes rain and snowfall' '' if empty
x7	Your institution	
x8	Your email address	
x9	Model name and input data used. Please use all lower case characters. For scenario names, please see Section 3.6.3 of this document.	'impactmodel_climatemodel_clim.scenario_socio.economy.scenario_sens.scenario'

Here is an example how to run the script in a bash shell:

```
> ./output_daily.sh '1980' 'pr' 'precipitation' 'kg m-2 s-1' 'includes rain and snowfall' '' 'PIK' 'isi-mip@pik-potsdam.de' 'im1_hadgem-es_rcp85_ssp2_noco2'
```

Note: The bash shell is standard on most Linux and Mac systems. For Window systems it Cygwin can be used.

Once you have created your NetCDF file, you can check the metadata by running the command "ncdump -h"; and example output is given in the Appendix 9.2 for comparison.

5.2.4 Format for non-gridded data

These should be reported in csv-files, following sector-specific templates that will be made available via the online data portal (www.isimip.org).

5.2.5 Time intervals

Please submit your output data in chunks according to the following table, depending on whether you are reporting a transient experiment or a time-slice experiment, and 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 in section 6).

type of experiment →	transient	time-slice
data time step ↓		
daily	Output files should cover 1 year each	Output files should cover 1 year each

<p>monthly, annual, decadal</p>	<p>Output files should cover 10 years each (e.g. 1971-1980).</p> <p><u>Exceptions:</u> The period 2001-2010 should be reported in two separate files covering 5 years each: 2001-2005 and 2006-2010. The period 2091-2099 should be reported in a file covering 9 years.</p>	<p>Each time slice should be reported in a single file covering 31 years (e.g. 1980-2000, 2069-2099; see section 5.1 for details about the time slices that should be run).</p>
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6 Sector-specific output

IMPORTANT:

1. If your model generates the output variables for more than one sector, please provide them and let us know under info@isimip.org!
2. Variable names are listed here as they should be used in the output file names (see section 5.2).

6.1 Water

Note that variable names are chosen to comply, where possible and sensible, with the ALMA convention¹² 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 5.2).

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:

$$\mathbf{Rainf} + \mathbf{Snowf} = \mathbf{Evap} + \mathbf{Qtot},$$

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

¹² http://www.lmd.jussieu.fr/~polcher/ALMA/convention_output_3.html

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 ¹³
Discharge	Dis	daily* (0.5°x0.5°)	m ³ /s (m ³ s ⁻¹)	*if daily resolution not possible, please provide monthly
Monthly maximum of daily discharge	MaxDis	monthly (0.5°x0.5°)	m ³ /s (m ³ 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.
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, 0-50cm	SoilMoist50	monthly (0.5°x0.5°)	kg/m ² (kg m ⁻²)	upper 50cm. If top layer is deeper than 50cm, please provide top layer soil moisture.

¹³ If storage issues keep you from reporting daily data, please contact the ISI-MIP team to discuss potential solutions.

Soil moisture, root zone	RootMoist	monthly (0.5°x0.5°)	kg/m ² (kg m-2)	Total simulated soil moisture available for evapotranspiration.
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 and intercepted by the canopy.
Rainfall	Rainf	monthly (0.5°x0.5°)	kg/m ² /s (kg m-2 s-1)	These variables are required for test purposes only. Please provide these variables only once, with the first (test) data set you submit, e.g. for the first decade of a single run. Do not include them in any subsequent data submission. NOTE: rainf + snowf = total precipitation
Snowfall	Snowf	monthly (0.5°x0.5°)	kg/m ² /s (kg m-2 s-1)	
<i>Non-hydrological variables</i>				
Land-use pattern dataset		constant (0.5°x0.5°)	fraction	If you apply a land-use data set, please provide the name and source of the data set; do not provide actual data.
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 fresh-water availability and no water losses during

				conveyance and application. While the latter assumption has no implications for crop growth, it helps to make reported irrigation water quantities comparable across models.
Actual irrigation water withdrawal	AlrrWW	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 and no water losses during conveyance and application.
Actual irrigation water consumption	AlrrUse	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	AlrrUseGreen	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 AlrrUseGreen
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/m ² /s (kg m ⁻² s ⁻¹)	if computed
Actual livestock water consumption	ALiveUse	monthly (0.5°x0.5°)	kg/m ² /s (kg m ⁻² s ⁻¹)	if computed

6.2 Biomes

IMPORTANT: As well as the standard 0.5°x0.5°, coarse-grained climate data on a 1.25°x1.85° grid will also be provided. This data is provided to ensure that all modeling

groups will have sufficient time to complete all runs in the 'minimal setting' (see section 5.2). The 0.5°x0.5° remains the default grid resolution, and should be used wherever feasible.

Where applicable, all of the following variables should be uploaded to the ISI-MIP database. If the you cannot provide the data at the temporal or spatial resolution specified, please provide it the highest possible resolution of your model. Please contact the coordination team (info@isimip.org) to for any further clarification, or to discuss the equivalent variable in your model.

Variable	Variable name	Resolution	units (NetCDF format)	Comments
Net primary production	NPP	monthly (0.5°x0.5°)	kg C/m ² /s (kg C m ⁻² s ⁻¹)	
Carbon mass storage in vegetation, soil and litter pools	CVeg, CSoil, CLitter	monthly (0.5°x0.5°)	kg C/m ² (kg C m ⁻²)	
Vegetation type (PFTs)	PFT_x	annual (0.5°x0.5°)	fractional	fractional coverage per PFT Please choose 'x' to be a sensible, lower-case name for each of your PFTs. You should include a full description of these PFTs in a file named '<model>_pft_descr.txt' .
Ecosystem-atmosphere Carbon flux	EcoAtmFlux_C	monthly (0.5°x0.5°)	kg C/m ² /s (kg C m ⁻² s ⁻¹)	respiration - productivity
Ecosystem-atmosphere fluxes for other gases	EcoAtmflux_ <gas>	monthly (0.5°x0.5°)	kg /m ² /s (kg m ⁻² s ⁻¹)	respiration - productivity for all other gases considered in model
Soil moisture	SoilSat	monthly (0.5°x0.5°)	fractional	fractional saturation of entire soil depth
Evaporation from soil	Esoil	monthly (0.5°x0.5°)	kg /m ² /s (kg m ⁻² s ⁻¹)	includes sublimation
Interception	Intercep	monthly (0.5°x0.5°)	kg /m ² /s (kg m ⁻² s ⁻¹)	
Transpiration	Trans	monthly (0.5°x0.5°)	kg /m ² /s (kg m ⁻² s ⁻¹)	

Total runoff	Qtot	monthly (0.5°x0.5°)	kg /m ² /s (kg m-2 s-1)	the total runoff (including "drainage" through the base of the soil model) leaving the land portion of the grid cell
Surface runoff	Qsurf	monthly (0.5°x0.5°)	kg /m ² /s (kg m-2 s-1)	the total surface runoff leaving the land portion of the grid cell
Fire (if applicable)	FireFreq	annual (0.5°x0.5°)	1/yr (yr-1)	frequency
	FireInt	annual (0.5°x0.5°)	kg /m ² /s (kg m-2 s-1)	intensity
	FireFrac	fractional		burnt area fraction single value for each scenario corresponding to year 2100
Leaf Area Index	LAI_<PFT> Please use the same PFT names as provided in your '<model>_pft_desc.txt' file.	monthly (or highest available time resolution) (0.5°x0.5°)	m ² /m ² (m2 m-2)	If applicable. A ratio obtained by dividing the total upper leaf surface area of vegetation from each PFT by the (horizontal) surface area in that grid cell of the land on which that PFT grows. single value for each scenario corresponding to year 2100
Fraction of absorbed Photosynthetic Active Radiation	FPAR_< PFT > Please use the same PFT names as provided in your	monthly (or highest available time resolution)	fractional	The fraction of radiation incident on PFT-specific vegetation, that is available for photosynthesis (0.4 μm <λ<0.7 μm) and is

	'<model>_pft_d escr.txt' file.	(0.5°x0.5°)		actually absorbed by vegetation of that PFT.
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6.3 Agriculture

This section lays out the global output protocol for the agricultural sector’s contribution to ISI-MIP. For further details, please contact AgMIP (agmip@columbia.edu) and us (isi-mip@pik-potsdam.de).

Note that the variable names are chosen to comply with AgMIP conventions, or are harmonized with the conventions used in the water sector (for irrigation water). They are given in lower-case letters only in order to prevent the use of mixed-case names in the file names (see section 3.5.1).

6.3.1 Gridded biophysical models

Each biophysical modeling group has to provide a model reference and document the seeding rates, soils, cultivars, and management of each grid box. If you do not have your own default set-up the IFPRI Impact model configuration may be used as a starting point (contact AgMIP).

Crop Priority list:

1. Wheat¹⁴, maize, soy, rice [whe, mai, soy, ric]
2. Sugarcane, sorghum, millet, rapeseed, sugar beet, barley, rye, oat [sug, sor, mil, rap, sgb, bar, rye, and oat] + managed grass [mgr]¹⁵
3. Others: e.g. field peas [pea], cassava [cas], sunflower [sun], groundnuts [nut], bean [ben], potato [pot], ...

Note that the key diagnostic should only be provided for the minimal setting runs.

Variable	Variable name	Resolution	Unit	Comments
<i>Key model outputs</i>				

¹⁴ In the fast track there will be no distinction between winter and spring wheat.

¹⁵ We have decided to include only managed grassland productivity in the fast-track comparison.

Crop yields	Yield_<crop>	annual (0.5°x0.5°)	dry matter t/ha/yr (t ha-1 yr-1)	Crop-specific
Irrigation water demand (=potential irrigation water Withdrawal)	PIrrWW_<crop>	annual (0.5°x0.5°)	kg/m ² /s (kg m-2 s-1)	Irrigation water withdrawn in case of optimal irrigation (in addition to rainfall), assuming no losses in conveyance and application.
Key diagnostic variables				
Actual growing season evapotranspiration	aet_<crop>	annual (0.5°x0.5°)	kg m-2 s-1	portion of all water (including rain) that is evapo-transpired
Organic Nitrogen application rate (no residues)	ONitr_<crop>	annual (0.5°x0.5°)	t /ha (t ha-1)	
Anorganic Nitrogen application rate	INitr_<crop>	annual (0.5°x0.5°)	t /ha (t ha-1)	
Actual planting dates	plant-day_<crop>	annual (0.5°x0.5°)	Days from January 1st	
Anthesis dates	anth-day_<crop>	annual (0.5°x0.5°)	Days from planting date	
Maturity dates	maty-day_<crop>	annual (0.5°x0.5°)	Days from planting date	
Additional output variables (not necessarily used for the fast track)				
Biomass yields	Biom_<crop>	annual (0.5°x0.5°)	Dry matter t/ha/yr (t ha-1 yr-1)	

6.3.2 Agro-economic models

Crop Priority list:

1. 1 wheat, coarse grains (e.g., maize, millet, sorghum, barley, oats, and rye), rice, oilseeds (e.g., soy, groundnut, rapeseed, palm), sugar, managed grass land
2. others

Other agricultural commodities:

1. ruminant meat, non-ruminant meat
2. Bulk quantities: All crops (arable), pasture (used for “area” only), and agricultural total (crops plus livestock)

Please report the results following the AgMIP standardized set of geographical regions used in the Reference Scenario Comparison as shown in the table, if possible (contact AgMIP for details)!

Code	Region	Notes
WLD	World	
CAN	Canada	
USA	United States of America	
BRA	Brazil	
OSA	Other South and Central America	Incl. Caribbean and Mexico
FSU	Former Soviet Union	
EUR	Europe	Excl. Turkey
MEN	Middle-East and North Africa	Incl. Turkey
SSA	Sub-Saharan Africa	
CHN	China	Incl. Hong-Kong, Macao
IND	India	
SEA	South-East Asia	Incl. Japan, Taiwan
OAS	Other Asia	Other South Asia and other Oceania, Mongolia
ANZ	Australia and New Zealand	
NAM	North America	CAN & USA
OAM	South and Central America	BRA & OSA
AME	Africa and Middle East	MEN & SSA
SAS	Southern and Eastern Asia	CHN & IND & SEA & OAS

Variable	Variable name	Resolution (time, spatial)	Unit (NetCDF format)	Comments
<i>For agro-economic models</i>				

Effective crop yields	Yield_<crop> ¹⁶	time steps (regional)	dry matter t/ha/yr (t ha ⁻¹ yr ⁻¹)	Crop-specific, all crops
Total production	Prod_<crop>	time steps (regional)	kcal/capita (kcal capita ⁻¹)	Crops plus livestock
Applied irrigation water	IrrWW_<cro p>	time steps (regional)	kg/m ² /s (kg m ⁻² s ⁻¹)	Water supplied to the fields
Weighted average producer prices	Xprp_<crop> ¹⁶	time steps (regional)	USD2005/t (2005US\$)	For outputs listed above
Representative price on int'l markets	Xprr_<crop>	time steps (regional)	USD2005/t (2005\$)	For outputs listed above
Weighted average export price	Xprx_<crop>	time steps (regional)	USD2005/t (2005\$)	For outputs listed above
Resource prices for water and land	Xprw, Xprl	time steps (regional)	USD2005/m ³ , USD2005/ha (2005\$)	Or adequate land/water scarcity index
Land use patterns	LUPat_<crop >	time steps (regional)	% (%)	Crop fractions For outputs listed above
Total land use	Area	time steps (regional)	ha (ha)	For outputs listed above, multicropped land should be counted only once
Irrigation pattern	IrrPat	time steps (regional)	% (%)	Fraction of irrigated land
Exogenous rate of	ERYieldIncr	time steps	%/yr	

¹⁶ output codes: whe, mai, ric, soy, mill, sor, sug, rum, nrm, alc, pas, pea, cas, sun, nut, mgr, pst and agt for wheat, maize, rice, soy, sorghum, millet, sugar/sugarcane, ruminant meat, non-ruminant meat, all crops, pasture, peas, cassava, sunflower, groundnuts, managed grass, pasture and agricultural total, respectively.

crop yield increase		(regional)	(% yr-1)	
Effective Nitrogen application	EffNit	annual (regional)	t/ha (t ha-1)	
Total per capita calorie consumption	TotCal	time steps (regional)	kcal/capita /day (kcal cap-1 day-1)	
Animal-based per capita calorie consumption	AniCal	time steps (regional)	kcal/capita/day (kcal cap-1 day-1)	To calculate shares
Total domestic consumption	Cons_<crop>	time steps (regional)	dry matter t/yr (t yr-1)	Crops plus livestock
Food use	Food_<crop>	time steps (regional)	dry matter t/yr (t yr-1)	Crops plus livestock
Feed use (for livestock consumption)	Feed_<crop>	time steps (regional)	dry matter t/yr (t yr-1)	Crops plus livestock
Other use	OthU_<crop>	time steps (regional)	dry matter t/yr (t yr-1)	Crops plus livestock
Net trade	NetT_<crop>	time steps (regional)	dry matter t/yr (t yr-1)	Crop-specific (exports >0, imports <0) Excludes regional intra-trade
Exports	Expo	time steps (regional)	dry matter t/yr (t yr-1)	Excludes regional intra-trade
Imports	Impo	time steps (regional)	dry matter t/yr (t yr-1)	Excludes regional intra-trade

6.4 Health (Malaria)

The vector to be considered is *Plasmodium falciparum*; if not otherwise specified, your default settings are to be used (e.g. current vector distribution map).

IMPORTANT: The minimal output that you should provide consists of time-sliced results for **CS** and **MPop**. Providing data at a higher temporal resolution and adding the variable **LTS** is not mandatory (but highly welcome, of course).

Variable	Name	Unit	Resolution	Comments
<i>Purely climate-related output</i>				
Length of potential transmission season	LTS	days OR months	annual OR time slices (0.5°x0.5°)	Optional
Climatic suitability for malaria transmission	CS	Binary [0, 1]	annual OR time slices (0.5°x0.5°)	Potential transmission season must be > 3 months; precipitation threshold according to default
<i>Climate and socio-economic change combined</i> (for some models this will be done in post-processing)				
Population at risk from malaria	MPop	number of people	5-year steps OR time slices (country-level)	Calculated for all scenario runs (e.g., <i>additional</i> people at risk will be calculated during post-processing based on presclim runs)

7 Sector-specific scenarios and run priorities

IMPORTANT:

1. A priority list of 5 GCMs (in the following referred to as GCM 1-5) will be established and the allocation of GCMs to the GCMs 1-5 in the following tables will be available on the ISI-MIP website (www.isi-mip.org). The philosophy for the selection is further described in the Appendix. However, data availability limits the selection process.
2. Each GCM requires a different spin-up, based on the GCM data from 1951-1970. See section 4.1.2.
3. If computational limitations make it impossible for you to run even the minimal setting completely, please run the **GCM 1** experiments as a priority.
4. Please also note the information given in section 1.2 regarding the scenario priorities.

7.1 Water

	GCMs	RCPs (clim-scenario)	population/GDP (socio-econ-scenario)	Other settings (sens-scenario)	# runs
Minimal setting: GCM1, all RCPs; sensitivity experiments; GCM 2-5, RCP8.5 + 2.6	GCM 1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0) 8.5 (rcp8p5)	nosoc	co2	4
	GCM 1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0) 8.5 (rcp8p5)	pressoc	co2	4
	GCM1	8.5 (rcp8p5)	nosoc	noco2	1
	GCM1	8.5 (rcp8p5)	pressoc	noco2	1
	GCM1	8.5 (rcp8p5)	nosoc	pico2	1
	GCM 2-5	8.5 (rcp8p5) 2.6 (rcp2p6)	nosoc	co2	8
	GCM 2-5	8.5 (rcp8p5) 2.6 (rcp2p6)	pressoc	co2	8
	noclim		ssp2	co2	1
1st extension: GCM 2-5, RCP6.0 + 4.5	GCM 2-5	6.0 (rcp6p0) 4.5 (rcp4p5)	nosoc	co2	8
	GCM 2-5	6.0 (rcp6p0) 4.5 (rcp4p5)	pressoc	co2	8

2nd extension: sensitivity experiments; SSP1,3,4,5	GCM 1	6.0 (rcp6p0) 4.5 (rcp4p5) 2.6 (rcp2p6)	nosoc	noco2	3
	GCM 1	6.0 (rcp6p0) 4.5 (rcp4p5) 2.6 (rcp2p6)	pressoc	noco2	3
	noclim		SSP1 (ssp1) SSP3 (ssp3) SSP4 (ssp4) SSP5 (ssp5)	co2	4
3rd extension	adding more GCMs	adding more RCPs	nosoc	co2	
			pressoc	co2	
Total number of runs (Minimal setting + first two extensions)				40 (+14 sensitivity and noclim runs)	

Explanations:

Grey shading indicates settings that do not apply to all models in this sector.

NOTE: Besides population and GDP, no future scenarios of other non-climate data will be available in time for the ISI-MIP fast track. I.e. in particular no scenarios of irrigated area, electricity consumption, manufacturing gross value added, etc. Therefore, only limited aspects of the future human impact on hydrology will be considered.

NOTE: Models that include vegetation dynamics should run all simulations with **varying natural land cover**.

NOTE: Before beginning with the **3rd extension**, please notify the ISI-MIP team, so that the subsequent order of experiments can be coordinated among modeling teams.

7.2 Biomes

IMPORTANT: For all scenarios in this section, no human land-use is to be assumed.

	GCMs	RCPs (clim-scenario)	Other settings (sens-scenario)	# runs
Minimal setting: GCM1, all RCPs; sensitivity experiment; GCM 2-5, RCP8.5 + 2.6	GCM 1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0) 8.5 (rcp8p5)	co2	4
	GCM 1	8.5 (rcp8p5)	noco2	1
	GCM 2-5	2.6 (rcp2p6) 8.5 (rcp8p5)	co2	8
1st extension: GCM 2-5, RCP6.0 + 4.5	GCM 2-5	4.5 (rcp4p5) 6.0 (rcp6p0)	co2	8
2nd extension: sensitivity experiments	GCM 1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0)	noco2	3
	adding more GCMs	adding more RCPs	noco2 co2	
Total number of runs (Minimal setting + first two extensions)				24

7.3 Agriculture

IMPORTANT: All scenarios use the medium adaptation pathway RAP2 (Representative Agricultural Pathway). The exception are the respective final extensions, where RAPs are varied consistently with RCPs and SSPs.

7.3.1 Biophysical models

IMPORTANT: All runs are pure crop runs.

	GCMs	RCPs (clim-scenario)	Crops	Other settings (sens-scenario)	# of runs
Minimal setting GCM1, all RCPs,	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5)	Pure crop runs - 4 priority-1 crops	co2_noirr	16

CO2 sensitivity experiment GCM2-5, RCP2.6 + 8.5		6.0 (rcp6p0) 8.5 (rcp8p5)			
	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0) 8.5 (rcp8p5)	Pure crop runs - 4 priority-1 crops	co2_firr	16
	GCM1	8.5 (rcp8p5)	Pure crop runs - 4 priority-1 crops	noco2_noirr	4
	GCM1	8.5 (rcp8p5)	Pure crop runs - 4 priority-1 crops	noco2_firr	4
	GCM2-5	2.6 (rcp2p6) 8.5 (rcp8p5)	Pure crop run - 4 priority-1 crops	co2_noirr	32
	GCM2-5	2.6 (rcp2p6) 8.5 (rcp8p5)	Pure crop run - 4 priority-1 crops	co2_firr	32
1st extension GCM2-5, RCPs 4.5 + 6.0	GCM2-5	4.5 (rcp4p5) 6.0 (rcp6p0)	Pure crop run - 4 priority-1 crops	co2_noirr	32
	GCM2-5	4.5 (rcp4p5) 6.0 (rcp6p0)	Pure crop run - 4 priority-1 crops	co2_firr	32
2nd extension GCM1, more RCPs, CO2 sensitivity experiment	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0)	Pure crop runs – 4 priority-1 crops	noco2_noirr	12
	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0)	Pure crop runs – 4 priority-1 crops	noco2_firr	12
3rd extension Priority-2 crops with all GCMs and RCPs, CO2 sensitivity experiment for GCM1 & RCP8.5	GCM1-5	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0) 8.5 (rcp8p5)	Pure crop runs - 9 priority-2 crops	co2_noirr	180
	GCM1-5	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0) 8.5 (rcp8p5)	Pure crop runs – 9 priority-2 crops	co2_firr	180
	GCM1	8.5 (rcp8p5)	Pure crop runs - 9 priority-2 crops	noco2_noirr	9
	GCM1	8.5 (rcp8p5)	Pure crop runs - 9 priority-2 crops	noco2_firr	9
4th extension Priority-2 crops with GCM1, more RCPs, CO2 sensitivity experiment	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0)	Pure crop runs – 9 priority-2 crops	noco2_noirr	27
	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0)	Pure crop runs – 9 priority-2 crops	noco2_firr	27

7.3.2 Agro-economic models

IMPORTANT: All scenarios use the medium adaptation pathway RAP2 (Representative Agricultural Pathway).

Agro-economic models will be run until 2050 drawing from fully irrigated and rainfed simulations performed by their default connected biophysical model (e.g. LPJmL for MAgPIE). The following are consistent storylines that are prioritized. If there is no default connected biophysical model, shifters can be used – please contact AgMIP for specifications on this.

	GCMs	RCPs (clim- scenario)	SSPs (socio-econ- scenario)	Other settings (sens-scenario)	# of runs	
Minimal setting GCM1, all RCPs	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0) 8.5 (rcp8p5)	SSP2 (ssp2)	co2_default	4	
	GCM1	presclim	SSP2 (ssp2)	co2_default	1	
	GCM2-5, RCP2.6 + 8.5 human impact sensitivity experiment	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0) 8.5 (rcp8p5)	pressoc	co2_default	4
		GCM1	8.5 (rcp8p5)	SSP2 (ssp2)	noco2_default	1
		GCM 2-5	2.6 (rcp2p6) 8.5 (rcp8p5)	SSP2 (ssp2)	co2_default	8
		GCM 2-5	presclim	SSP2 (ssp2)	co2_default	4
		1st extension GCM2-5, RCPs 4.5 + 6.0	GCM 2-5	4.5 (rcp4p5) 6.0 (rcp6p0)	SSP2 (ssp2)	co2_default
2nd extension 1) GCM1, RCP4.5, more SSPs 2) GCM1, more RCPs, CO2 sensitivity experiment	GCM1	4.5 (rcp4p5)	SSP1 (ssp1) SSP3 (ssp3) SSP4 (ssp4) SSP5 (ssp5)	co2_default	4	
	GCM1	presclim	SSP1 (ssp1) SSP3 (ssp3) SSP4 (ssp4) SSP5 (ssp5)	co2_default	4	
	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0)	SSP2 (ssp2)	noco2_default	3	

3rd extension	GCM2-5	4.5 (rcp4p5)	SSP1 (ssp1) SSP3 (ssp3) SSP4 (ssp4) SSP5 (ssp5)	co2_default	
	GCM1-5	4.5 (rcp4p5) 8.5 (rcp8p5) 8.5 (rcp8p5)	SSP1 (ssp1) SSP3 (ssp3) SSP3 (ssp3)	co2_default_rap3 co2_default_rap1 co2_default_rap3	
Total number of runs (Minimal settings + first two extensions)					41

7.4 Health (Malaria)

IMPORTANT:

- 1 For malaria models that use climate data only, please run the simulation according to the columns labeled “GCMs” and “RCPs”. Socio-economic data required during *post-processing* should then be chosen as indicated in columns “Population” (and where applicable “GDP”)
- 2 Model groups are expected to provide output up to the 1st extension by July 2012. Output based on the 2nd extension is highly welcome by this date, but can also be provided later.

	GCMs	RCPs (clim-scenario)	Population	GDP	# runs	Comments
Minimal setting: GCM1, all RCPs; sensitivity experiments; GCM 2-5, RCP8.5 + 2.6	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0) 8.5 (rcp8p5)	SSP2 (ssp2)	SSP2 (ssp2)	4	
	GCM1	GCM specific present day climate (presclim)	SSP2 (ssp2)	SSP2 (ssp2)	1	To describe the change in population at risk (not relevant for climate suitability)
	GCM1	2.6 (rcp2p6) 4.5 (rcp4p5) 6.0 (rcp6p0) 8.5 (rcp8p5)	Present day (pressoc)	Present day (pressoc)	4	Added for consistency with other sectors to describe the sole influence of climate change on population at

						risk/climate suitability
	GCM 2-5	2.6 (rcp2p6) 8.5 (rcp8p5)	SSP2 (ssp2)	SSP2 (ssp2)	8	
	GCM 2-5	GCM specific present day climate (presclim)	SSP2 (ssp2)	SSP2 (ssp2)	4	
1st extension: GCM 2-5, RCP6.0 + 4.5	GCM 2-5	4.5 (rcp4p5) 6.0 (rcp6p0)	SSP2 (ssp2)	SSP2 (ssp2)	8	
2nd extension: different SSPs	GCM1	4.5 (rcp4p5)	SSP1 (ssp1) SSP3 (ssp3) SSP4 (ssp4) SSP5 (ssp5)	SSP1 (ssp1) SSP3 (ssp3) SSP4 (ssp4) SSP5 (ssp5)	4	Please do not combine population and GDP from different SSPs.
	GCM1	GCM specific present day climate (presclim)	SSP1 (ssp1) SSP3 (ssp3) SSP4 (ssp4) SSP5 (ssp5)	SSP1 (ssp1) SSP3 (ssp3) SSP4 (ssp4) SSP5 (ssp5)	4	
	GCM1	4.5 (rcp4p5)	SSP1 (ssp1) SSP2 (ssp2) SSP3 (ssp3) SSP4 (ssp4) SSP5 (ssp5)	Present day (pressoc)	5	
Total number of runs					42	

8 Results and publications

All participating teams will have access to the results database for analysis and publications.

8.1 Minimal outcome

The minimal outcome for the project includes:

- 1 One publication per sector providing an overview of the modeling results and focusing on a sound quantification of impacts at different levels of global warming in terms of highly society-relevant indicators. These papers will focus on a figure, like Figure 1 below, with a sector-specific impact metric on the y-axis.

Sector-specific metrics discussed thus far include:

- Agriculture: resource prices, crop yields
- Water: availability per capita (Falkenmark index); availability vs. present-day withdrawal; availability vs. projected withdrawal
- Biomes: Γ -metric of global biome shift (Heyder et al., 2011)¹⁷
- Health: *additional* number of people at risk from malaria due to climate change

2. One publication providing a cross-sectoral synthesis of impacts.

The coordination team will ensure that the overview papers for the water, biomes, and agriculture sector and the cross-sectoral overview are written. Each modeling team providing data input and support will be a co-author on these papers. Impact model simulations must be supplied no later than 1 July, 2012 to become part of the overview papers.

¹⁷ Heyder, U., Schaphoff, S., Gerten, D. and W. Lucht (2011): Risk of severe climate change impact on the terrestrial biosphere. *Environmental Research Letters* 6, 034036.

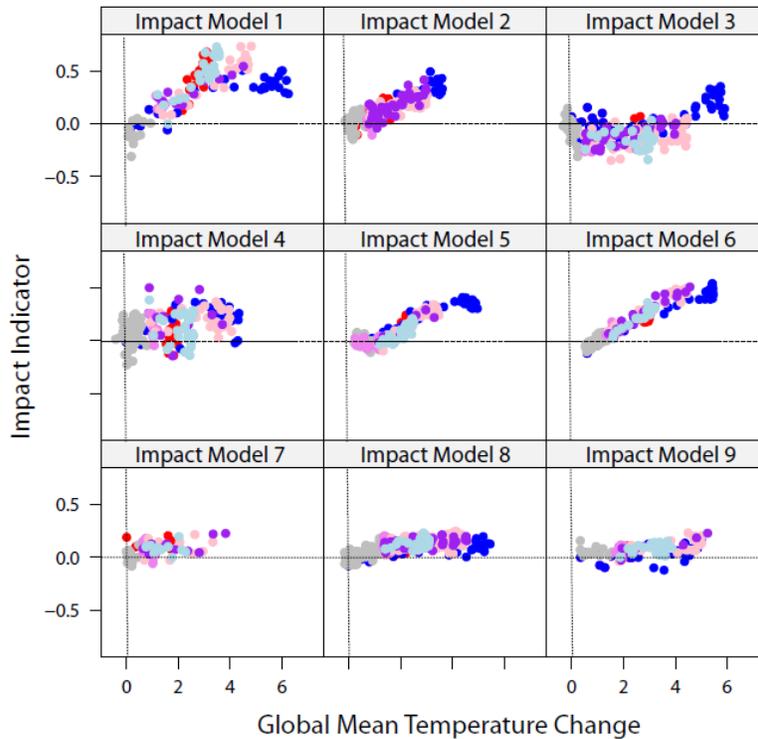


Figure 1. Example plot of changes in impacts as a function of global mean temperature change, assuming a minimal model set-up (one GCM, all RCPs, nine impact models). Each point represents a pair of annual values of global mean temperature change and associated impact indicator. Sub-panels show results for different impact models, and the color indicates different climate scenarios.

8.2 Additional Outcome for Special Feature

The coordination team is in discussion with PNAS to secure a Special Feature for the most pertinent results (6-10 papers) based on the ISI-MIP scenario set-up. This should be submitted in time for the IPCC WG2 paper submission deadline (31 January, 2013). To achieve this, additional high quality papers are required. Beyond this, there is potential for a great many other papers.

In order to identify papers for the Special Feature, as well as for general paper coordination, especially for identifying interesting cross-sectoral analysis topics, we have solicited abstracts for proposed publications from project participants. This is an ongoing process.

9 Appendix

9.1 Bias correction of climate data

The input data sets are corrected based on a statistical bias correction algorithm used in the WaterMIP/WATCH to correct temperature and precipitation values^{18,19}. Monthly correction factors are derived over a construction period of 40 years, where the GCM outputs are compared to the observation-based WATCH forcing data. The GCM data sets are interpolated to the spatial resolution of the WATCH data set and, if required, to the standard calendar. For each month a regression is performed on the ranked data sets. Subsequently, the derived monthly correction factors are interpolated towards daily ones. The correction factors are then applied to projected GCM data.

Additionally, the statistical bias correction algorithm (with adapted cutoff values) is applied to humidity, radiation, pressure, and wind data.

9.2 Example metadata file

Running the command “ncdump -h” on an output file called “impactmodel_hadgem2-es_rcp8p5_ssp2_qtot_monthly_1971_2099.nc” should yield the following statement:

```
netcdf impactmodel_hadgem2-es_rcp8p5_ssp2_qtot_monthly_1971_2099 {
```

```
dimensions:
```

```
    lon = 720 ;
```

```
    lat = 360 ;
```

```
    time = UNLIMITED ; // (3653 currently)
```

```
variables:
```

```
    double lon(lon) ;
```

```
        lon:long_name = "longitude" ;
```

```
        lon:units = "degrees_east" ;
```

¹⁸ Piani, C., G. P. Weedon, M. Best, S. M. Gomes, P. Viterbo, S. Hagemann, and J. O. Haerter, 2010: Statistical bias correction of global simulated daily precipitation and temperature for the application of hydrological models. *J. Hydrol.*, **395**, 199–215.

¹⁹ "Impact of a Statistical Bias Correction on the Projected Hydrological Changes Obtained from Three GCMs and two Hydrology Models", S. Hagemann, C. Chen, J.O. Haerter, J. Heinke, D. Gerten, C. Piani, *Journal of Hydrometeorology* (2011), 12:556-578

```

lon:standard_name = "longitude" ;
lon:axis = "X" ;

double lat(lat) ;

lat:long_name = "latitude" ;
lat:units = "degrees_north" ;
lat:standard_name = "latitude" ;
lat:axis = "Y" ;

double time(time) ;

time:units = "months since 1901-01-01 00:00:00" ;
time:calendar = "standard" ;

float qtot(time, lat, lon) ;

qtot:long_name = "total runoff" ;
qtot:units = "kg m-2 s-1" ;
qtot:_FillValue = 1.e+20f ;
qtot:comment = "total (surface +subsurface) runoff" ;

// global attributes:

:title = "impactmodel output for HadGEM2-ES bias corrected climate 0.5 degree
grid" ;
}

```

9.3 Selection of climate models

Selection of the climate models for the ISI-MIP is intended to aid in quantifying the uncertainty in the impacts of a given level of global mean temperature change. Here we present our model selection philosophy. Unfortunately, however, the actual choice of models is likely to be tightly constrained by data availability.

We assume the simplest possible relationship between changes in temperature [either global mean (ΔT_{GMT}) or land-averaged ($\Delta T_{\text{land-avg}}$)] and precipitation ($\Delta P_{\text{land-avg}}$), and impact indicator ($I_{n,\text{GCM}}$) for a given impact model (n) and climate model (GCM):

$$\Delta I_{n,\text{GCM}} = \alpha_n \Delta T_{\text{GCM}} + \beta_n \Delta P_{\text{land-avg,GCM}}, \quad (1)$$

where α_n and β_n are impact model-specific constants.

Here we need to consider two cases: where Eq. (1) depends on ΔT_{GMT} and $\Delta T_{\text{land-avg}}$ respectively. In the first case, if the impact scales according to Eq. (1), and the different GCMs have the same $\Delta P_{\text{land-avg}}/\Delta T_{\text{GMT}}$, then at a given ΔT_{GMT} , the impacts projected by a single model will be identical across the GCMs, i.e. the four points in Figure 2 below will coincide, since $\Delta P_{\text{land-avg}}$ and ΔT_{GMT} will be the same for all GCMs. Therefore, to get a handle on the full uncertainty in ΔI at a given level of global mean warming, we only need to span the range of $\Delta P_{\text{land-avg}}/\Delta T_{\text{GMT}}$.

Selecting the models according to the $\Delta P_{\text{land-avg}}/\Delta T_{\text{GMT}}$ and ΔT_{GMT} indicators means that the models representing a **warm and wet** and **cold and dry** climate will be included:

- A GCM producing a high $\Delta P_{\text{land-avg}}/\Delta T_{\text{GMT}}$ for a high ΔT_{GMT} corresponds to a **warm and wet** climate.
- Low $\Delta P_{\text{land-avg}}/\Delta T_{\text{GMT}}$ for a low ΔT_{GMT} corresponds to a **cold and dry** climate.

In the second case, in which $\Delta T = \Delta T_{\text{land-avg}}$ in Eq. (1), we need to span the range of $\Delta P_{\text{land-avg}}/\Delta T_{\text{GMT}}$ and $\Delta T_{\text{land-avg}}/\Delta T_{\text{GMT}}$ to comprehensively cover the uncertainty in ΔI at a given global mean temperature.

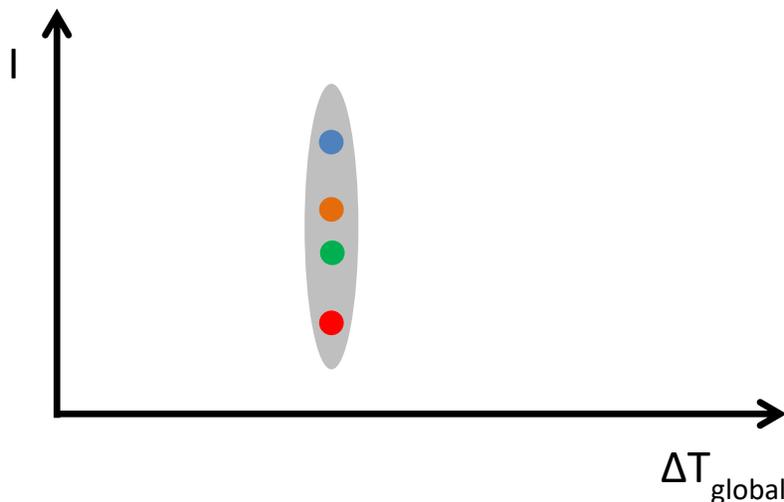


Figure 2 Schematic plot of the climate impacts as projected for 1 impact model, 1 RCP and 4 different GCMs. The points do not correspond to a fixed time, only a fixed ΔT_{GMT} . Only the start and end points of the line are for a common time.

In Figure 3, we characterise 15 AOGCMs that are participating in the CMIP5, according to the changes in temperature and precipitation projected for the end of the century, when

driven by the RCP8.5 (only a few of these models had provided complete data sets at the time of writing). We present this information for two combinations of the temperature-precipitation space: $\Delta P_{\text{land-avg}}/\Delta T_{\text{GMT}}$ vs. ΔT_{GMT} , and $\Delta P_{\text{land-avg}}/\Delta T_{\text{GMT}}$ vs. $\Delta T_{\text{land-avg}}/\Delta T_{\text{GMT}}$, and selection of the models would ideally be optimized to span one of these two spaces as described above. The first selection criterion has the advantage that we ensure coverage of the ΔT_{GMT} range. The “warmest” and the “coldest” models in terms of global mean temperature change might be missed when following the second criterion. Since data availability is a limiting factor in our model selection, we will keep track of where the models that we select sit in the plots below, but cannot guarantee comprehensive coverage. The first two models (GCM1 and GCM2; HadGEM2-ES and IPSL-CM5A-LR respectively) are circled below.

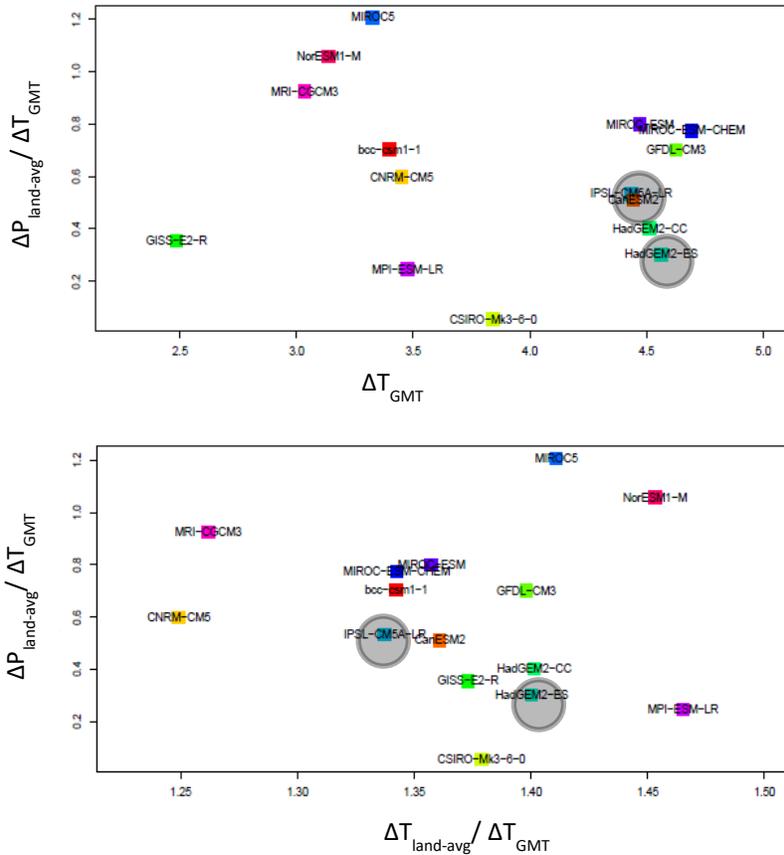


Figure 3 Change in land-averaged precipitation per degree of global warming vs. change in land-averaged temperature (in lower panel, per degree of global warming) for fifteen AOGCMs participating in the CMIP5.