Hydro-JULES hydrological MIP protocol, version 1.1

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Introduction

Hydro-JULES is a NERC funded research programme bringing together a wide community of modellers to inform a new generation of hydrological models. As part of the Hydro-JULES cross-cutting benchmarking and model intercomparison theme, we have been consulting the community about running a hydrological Model Intercomparison Project (MIP). Following a series of meetings with stakeholders and further community consultation, we are now ready to circulate our community-agreed MIP protocol. We would be very pleased to have more models included in the MIP; if you run a hydrological model and would like to be included, please read the protocol and contact us at hydrojules@ceh.ac.uk.

The purpose of the MIP is to gather together modelled river flow outputs spanning a historical 30-year period in order to help explore and summarise the current strengths of hydrological models used by the UK community. The MIP will include a range of types of hydrological models; crucially all of the models will use consistent driving data to generate outputs for a large number of GB catchments. This will allow us to explore the relative strengths of different approaches to hydrological modelling, enhancing our understanding of hydrological process representation in models. We aim to answer questions about the importance of different methods of process representation across flow regimes and catchment types. We also wish to investigate the relative strengths of taking a multi-model ensemble approach to hydrological modelling. We anticipate that this work will lead to at least one publication, the author list for which will include all MIP participants. We will also make all model outputs open and accessible to the hydrological community, enabling further research and analysis beyond the scope of the hydro-JULES project.

About this protocol

In this protocol we describe the experiments, input datasets, and output variables which will be included in the MIP. We also outline how to provide model results and some of the metrics that will be used to analyse them. This is the protocol for phase 1 of the MIP; future phases may have a different or wider scope, including different driving data, output variables, and/or spatial and temporal extents. Please also see our future roadmap for more details on future plans.

1. Experiments

a. **Spatial extent.** This MIP will compare modelled river flow for 673 catchments across the UK. This will comprise the 671 catchments covered by the CAMELS-GB dataset(https://doi.org/10.5194/essd-12-2459-2020) as well as the Tweed at Kingledores (https://nrfa.ceh.ac.uk/data/station/info/21014) and the Severn at Abermule (https://nrfa.ceh.ac.uk/data/station/info/54014) (data for these catchments to be provided by Gemma Coxon).

b. **Temporal extent.** We will analyse daily river flow outputs for the years 1990 to 2019 inclusive for models which produce this output. We will also perform analyses for the years 2010 – 2019 inclusive (this shorter time span allows for machine learning methods to have sufficient training years).

c. **Calibration/Training.** For inclusion in the full comparison of hydrographs, modellers who require calibration/training periods should use (any) years between 1961 and 1989 for this purpose. For inclusion in this shorter analysis period, modellers can use years between 1961 and 2009 for calibration/training. If recalibration is not possible for your model, please contact the MIP team (hydrojules@ceh.ac.uk).

d. **Spin-up**. Models requiring a spin-up should use data from any years between 1961 and 1989. We have no restrictions on how model stores are initialised or the length of spin-up period.

e. **Model setup.** Spatial resolution, parameter values and ancillary datasets may be chosen by the user to suit their model. We will seek to document differences between models.

2. Driving data

This MIP requires common meteorological driving data for all physical models. Gridded meteorological drivers from, or based on, the CHESS-met dataset should be used, apart from precipitation, which should be from the HadUK-Grid dataset. See Table 1 for a summary of required input datasets and where these can be accessed. For models requiring catchment-average inputs, these will be available as part of CAMELS-GB version 2. Please email Gemma Coxon (gemma.coxon@bristol.ac.uk) for early access to these data. CAMELS-GB v2 does not include catchment average data for all CHESS-met variables, please email the MIP team if these are required by your catchment model. Modelers may otherwise aggregate or disaggregate the gridded driving data in time or space to suit their model (e.g. to create subdaily meteorological forcing) but we ask that details of any such procedures are provided along with output data.

Table 1. Summary of hydrometeorological input variables to be used within the MIP and where they can be accessed.

Variable	Data to use for the MIP	Data access	
		For models requiring catchment-average inputs	For models requiring gridded inputs
Precipitation	HadUK-Grid precipitation	Available as part of CAMELS-GB v2, email Gemma Coxon for early access (gemma.coxon@bristol.ac.uk)	Download from CEDA archive: https://dx.doi.org/10.5285/b963ead70580451aa7455782224479d5 or access on JASMIN: /badc/ukmo-hadobs/data/insitu/MOHC/HadOBS/HadUK-Grid/v1.3.0.ceda/
Potential evapotranspiration (with or without interception)	CHESS-PE Optional extra runs: Hydro-PE HadUK-Grid		Download from EIDC: https://doi.org/10.5285/8651771d-aa6d-4d0f-8bcd-b3be1f733852 or access on JASMIN: /gws/nopw/j04/hydro_jules/data/uk/driving_data/chess/chess-pe/

			(available to all registered users) For optional extra runs, Hydro-PE HadUK Grid can be downloaded from: https://doi.org/10.5285/beb62085-ba81-480c-9ed0-2d31c27ff196
Air temperature	CHESS-met		Download from EIDC: https://doi.org/10.5285/835a50df-e74f-4bfb-b593-804fd61d5eab or access on JASMIN: /gws/nopw/j04/hydro_jules/data/uk/driving_data/chess/chess-met/ (available to all registered users)
Specific humidity		-	
Downward shortwave radiation			
Downward longwave radiation			
Surface air pressure			
Wind speed			
Daily temperature range			

CHESS-met comprises meteorological data for the period 1961-2019 at a daily timestep, 1km resolution at a measurement height of 1.2m. The variables available are: air temperature at 1.2m (K), specific humidity at 1.2m (kg kg-1), downward shortwave radiation (W m-2), downward longwave radiation (W m-2), surface air pressure (Pa), wind speed at 10m (m s-1), daily temperature range (K). The CHESS-met dataset also contains precipitation. However, in this MIP we will use precipitation from the HadUK-Grid dataset.

For models that require PE as an input, we require modellers to use CHESS-PE. This is the PE product most consistent with the CHESS-met drivers and the JULES model and comprises two related datasets; modellers can select either the PETI option which includes a correction for interception, or the PET version which has no correction for interception. We recognise that a limitation of the CHESS-PE product is that it only extends until 2019, and therefore runs cannot include the 2021/2022 drought. We invite any modellers submitting flows to the main MIP to also consider producing a second set of flows using Hydro-PE HadUK-Grid as the PE input. Details of these optional extra runs are given in section 7.

While we require consistent meteorological driving data, there will be no constraints on other inputs. We want to encourage as many modellers to contribute to the MIP as possible, and recognise that it would not be practical to request that everyone uses the same ancillary datasets. We also understand that there are vast differences in data requirements between models. For models requiring catchment characteristic data, this is available from the CAMELS-GB dataset: [Catchment attributes and hydro-meteorological timeseries for 671 catchments across Great Britain (CAMELS-GB) - EIDC]().

3. Output variables

Please provide daily timeseries of river flow in m^3s^{-1} for the 673 catchments specified above, for the years 1990 – 2019 inclusive, or for the years 2010-2019 inclusive. River flow outputs can be supplied either in a netcdf format or as a .csv file with 17 header lines containing all the all the required model run information. Please format the filename in lowercase as: [model]_[start-date]_[end-date]_[PE input]_[any additional required run identifier]. For example g2g_1990_2019_chesspeti.csv. Table 2 details information that should be supplied as global attributes (if supplying flows in netcdf format) or header lines (if supplying flows as a csv).

Please supply model outputs as an array of river flows. Columns should be the year, month and day followed by flows for each of the MIP catchments (preferably with gauging station numbers in ascending order). Please supply any missing values as -1, with an explanation for why these could not be simulated given in the model_MIP_notes section.

Template model output files have been provided on JASMIN (/gws/nopw/j04/hydro_jules/data/uk_hydro_mip), with an example of what this looks like in Figure 1.

Table 2. Information that should be supplied as global attributes / as a header alongside simulated flows.

csv line no.	Name	Description	Example
1	title	Short title describing model runs	Grid-to-Grid (G2G) daily mean flows (m3 s-1) covering 1990-2019, generated for the Hydro-JULES MIP
2	creator_name	Name of person carrying out the model runs	Rosanna Lane
3	creator_institution	Primary institution of person carrying out the model runs	UK Centre for Ecology and Hydrology (UKCEH)
4	creator_email	Email address of person carrying out the model runs	roslan@ceh.ac.uk
5	date_created	dd/mm/yyyy	01/04/2025
6	input_PE	CHESS-PETI or CHESS-PET	CHESS-PETI

		(Hydro-PE HadUK-Grid for optional extra runs)	
7	input_precip	This should be HadUK-Grid	HadUK-Grid
8	input_temperature	This should be CHESS-MET or None	CHESS-met
9	time_period_start	Start date of model outputs, given as DD/MM/YYYY	01/01/1990
10	time_period_end	End date of model outputs, given as DD/MM/YYYY	31/12/2019
11	model_name	Full name of model	Grid-to-Grid (G2G)
12	model_reference	Reference to use when discussing model	Bell et al. (2009) Use of soil data in a grid-based hydrological model to estimate spatial variation in changing flood risk across the UK. JoH, 377(3-4), 335-350.
13	model_spatial_resolution	Resolution (specify if catchment, HRU-based or gridded model)	1km grid
14	model_timestep_minutes	Model time step in minutes (i.e. 1440 if run at a daily resolution)	15
15	model_calibration	details of model calibration	uncalibrated. G2G is mainly parameterised using spatial datasets of landscape properties (e.g. HOST soil types) rather than via catchment calibration.
16	model_setup	details of model setup	Here, the model has been run for each 1km grid square across Great Britain, and flows have been extracted for grid squares which best relate to the locations of gauging stations.
17	model_MIP_notes	Any model specific notes that are relevant for the MIP	G2G simulates naturalised flows on a 1km grid and is therefore not expected to match observations for catchments with heavily modified flow regimes or small areas.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	title: Grid-to-Grid (G2G) daily mean flows generated for the Hydro-JULES MIP																			
2	creator_name: Rosanna Lane																			
3	creator_institution: UK Centre for Ecology and Hydrology (UKCEH)																			
4	creator_email: roslan@ceh.ac.uk																			
5	date_created: 01/04/2025																			
6	input_PE: CHESS-PETI																			
7	input_precip: HadUK-Grid																			
8	input_temperature: CHESS-met																			
9	time_period_start: 01/01/1990																			
10	time_period_end: 31/12/2019																			
11	model_name: Grid-to-Grid (G2G)																			
12	model_reference: Bell et al. (2009) Use of soil data in a grid-based hydrological model to estimate spatial variation in changing flood risk across the UK. JoH																			
13	model_spatial_resolution: 1km grid																			
14	model_timestep_minutes: 15																			
15	model_calibration: uncalibrated. G2G is mainly parameterised using spatial datasets of landscape properties (e.g. HOST soil types) rather than via catchment calibration.																			
16	model_setup: the model has been run for each 1km grid square across Great Britain, and flows have been extracted for grid squares which best relate to the locations of gauging stations.																			
17	model_MIP_notes: G2G simulates naturalised flows on a 1km grid and is therefore not expected to match observations for catchments with heavily modified flow regimes or small areas.																			
18	YYYY	MM	DD	1001	2001	2002	3003	4001	4003	4005	4006	5003	6007	6008	7001	7002	7003	7005	7006	8004
19	1990	1	1	0.912	8.194	6.024	6.262	24.08	4.786	3.383	2.894	15.311	49.611	1.967	6.127	11.343	1.162	1.233	4.998	4.998
20	1990	1	2	0.897	7.6	5.51	5.938	22.912	4.876	3.37	2.748	15.05	44.97	1.817	5.987	9.578	1.107	1.131	4.725	4.725
21	1990	1	3	0.815	7.224	5.197	5.733	21.926	4.44	3.169	2.604	14.682	41.929	1.712	5.704	8.942	1.054	1.056	4.748	4.748
22	1990	1	4	0.72	6.941	4.885	5.364	20.639	3.892	2.928	2.45	13.79	40.061	1.616	5.096	8.66	1.021	1.033	5.212	5.212
23	1990	1	5	0.654	6.704	4.746	5.205	19.666	4.166	3.097	2.429	13.429	38.31	1.558	4.688	8.113	1.007	1.027	5.97	5.97
24	1990	1	6	0.605	6.463	4.625	5.67	20.4	4.855	4.301	2.964	15.279	37.34	1.754	5.262	7.404	0.993	0.977	6.038	6.038
25	1990	1	7	0.562	6.338	4.562	7.25	25.126	5.051	5.286	4.182	21.686	42.531	2.216	6.19	7.298	0.956	0.903	5.9	5.9
26	1990	1	8	0.588	7.123	5.414	8.742	29.659	5.082	5.123	4.438	25.752	59.114	2.561	6.893	8.027	0.903	0.873	5.284	5.284
27	1990	1	9	0.781	9.055	7.5	11.109	36.994	7.22	8.409	7	36.422	80.528	4.463	11.712	8.951	0.854	1.045	5.101	5.101
28	1990	1	10	0.946	11.206	9.225	16.567	59.573	10.151	11.228	10.296	50.461	123.847	5.346	17.066	14.164	0.828	1.459	7.054	7.054
29	1990	1	11	0.84	10.926	8.83	20.172	68.419	9.027	9.427	9.327	44.678	158.13	4.351	13.201	20.87	0.817	1.34	7.582	7.582
30	1990	1	12	0.7	10.012	7.894	16.957	60.934	7.944	7.581	7.634	35.899	134.471	3.762	10.524	16.474	0.814	1.039	6.669	6.669
31	1990	1	13	0.666	9.554	7.636	15.297	51.939	7.672	6.53	6.59	29.658	121.003	3.41	9.976	13.356	0.784	0.859	5.994	5.994
32	1990	1	14	0.823	9.874	7.976	18.481	49.265	8.302	10.134	12.076	35.422	108.778	5.226	9.307	12.238	0.729	0.765	4.912	4.912
33	1990	1	15	2.208	15.612	17.137	39.027	108.066	17.717	20.003	27.68	88.829	189.178	10.377	19.267	11.613	0.685	0.867	4.431	4.431

Figure 1. Example of a model output file in .csv format.

4. Where to put results and how they will be analysed

JASMIN storage for model outputs is available, for the main runs at: /gws/nopw/j04/hydro_jules/data/uk_hydro_mip/main/ and for the optional extra runs at /gws/nopw/j04/hydro_jules/data/uk_hydro_mip/optional_extra/. To access this space users will need to be members of the Hydro-JULES group workspace. JASMIN users can apply to join if necessary (follow the guidance here: https://help.jasmin.ac.uk/docs/short-term-project-storage/apply-for-access-to-a-gws/, and please mention the MIP). If participants are not JASMIN users, please contact the team to make alternative arrangements for uploading model outputs (hydrojules@ceh.ac.uk).

We will run analysis against NRFA daily flow data and make the analysis and analysis tools available to all MIP contributors.

We will evaluate flows using a range of metrics and hydrological signatures, over both the 30-year and 10-year simulation periods. These will include summary metrics such as the Kling Gupta efficiency and Nash-Sutcliffe efficiency, alongside analysis of annual/seasonal bias, flow variance, correlation, flow quantiles, peak flow timing and magnitude.

5. Getting involved

This MIP will pull together river flow outputs from a wide range of UK hydrological models, generating a valuable dataset. Our analysis of these outputs will help to inform understanding of hydrological process representation in models across flow regimes and catchment types. We will gather model outputs from participants through 2025 and begin analysis in 2026. If you have a model which is suitable for inclusion in the MIP, or any other queries, please contact us on hydrojules@ceh.ac.uk.

6. Guidelines

Participants involved in the MIP are committing to the following guidelines:

- To understand and follow the modelling protocol, including the guidance on submitting model data and meta-data (see section 0).
- To ensure the suitability of their model and to conduct required internal quality checks before submission.
- To submit model output according to the prescribed timelines.
- All submitted data will be made openly available (with the expectation of appropriate citation in the MIP outputs and any future use).
- To be available to provide additional information on their model and setup as required for the MIP output publication.

7. Optional extras: alternative PE

A key component of the Hydro-JULES MIP is that we require all models to be run with the same driving data. This will allow us to explore the relative strengths of different modelling approaches, focusing on how differences in process representation and model resolution impact modelled flows. We have selected CHESS-PE as the potential evapotranspiration (PE) product to be used in the MIP, as it is accompanied by the CHESS-met dataset which contains the variables required to run the JULES model.

However, we recognise that the choice of driving data will impact flows and other models may have been calibrated based on other PE products. The impact of driving data on modelled flows is also an interesting question. We therefore invite modellers who have submitted outputs following the main MIP protocol to submit a second set of runs using Hydro-PE. The protocol for this second set of model outputs is outlined below.

Temporal extent: The Hydro-PE HadUK-Grid product is available until 2022. We therefore propose running models from 1990 to 2022 inclusive when using Hydro-PE HadUK Grid. This extended period will still allow comparison with the main MIP over 1990-2019, while also covering the 2021/2022 drought.

Spatial extent, calibration and model setup: the model should be run over the same catchments and following the same guidelines for model setup as outlined in the main MIP protocol.