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Supplement of

HERA: a high-resolution pan-European hydrological reanalysis (1951–2020)

Aloïs Tilloy et al.

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Model calibration

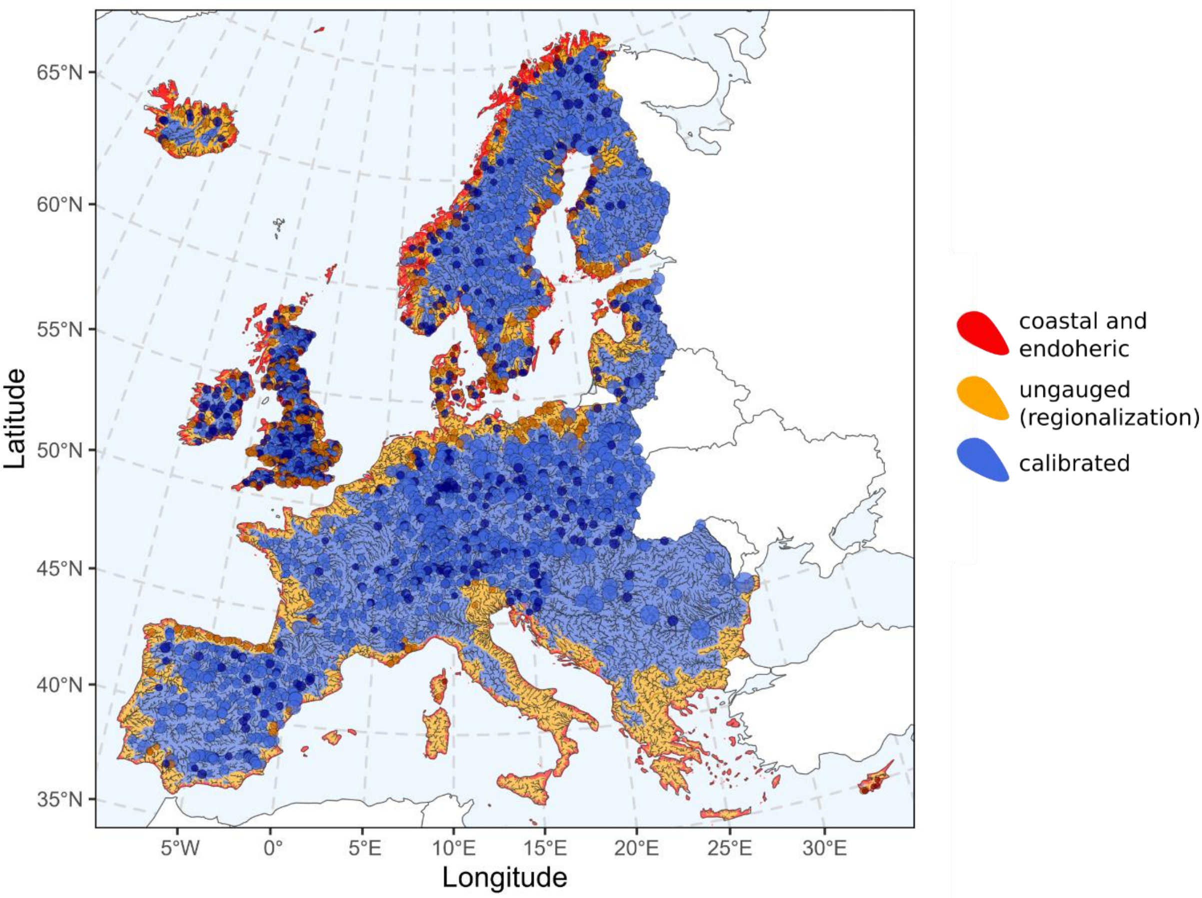

Figure S1: HERA domain with spatial distribution of catchments with calibrated (blue, 69.6% or domain area), regionalized (orange, 23.9% of domain area) and default (red, 6.5% of domain area) parameters. Dots represent the 2448 stations used for the validation of HERA. Dots are coloured according to their calibration status: red (default), orange (regionalized), light blue (calibrated domain), dark blue (stations used for the calibration).

Table S1: LISFLOOD calibration parameter for EFAS-5 (for more details, refer to CEMS-Flood online documentation, 2023)

Parameter name	**Description**	**Default value**	**Parameter range**
SnowMeltCoef	Snow melt rate in degree day model equation [mm/(C day)]	4	[2.5 – 6.5]
b_Xinanjiang	Exponent in Xinanjiang equation for infiltration capacity of the soil [-]	0.5	[0.01 – 5]
PowerPrefFlow	Exponent in the empirical function describing the preferential flow (i.e. flow that bypasses the soil matrix and drains directly to the groundwater) [-]	4	[0.5 – 8]
UpperZoneTime Constant	Time constant for upper groundwater zone [days]	10	[0.01 – 40]
GwPercValue	Maximum percolation rate from upper to lower groundwater zone [mm/day]	0.8	[0.01 – 2]
LowerZoneTime Constant	Time constant for lower groundwater zone [days]	100	[40 – 500]
LZThreshold	Threshold to stop outflow from lower groundwater zone to the channel [mm]	10	[0 – 30]
GwLoss	Maximum loss rate out of lower groundwater zone expressed as a fraction of lower zone outflow [−]	0	[0 – 1]
QSplitMult	Multiplier to adjust discharge triggering floodplains flow [-]	2	[0 – 20]
CalChanMan1	Multiplier for channel Manning's coefficient n for riverbed [−]	1	[0.5 – 2]
CalChanMan2	Multiplier for channel Manning's coefficient n for floodplains [−]	1	[0.5 – 5]
adjust_Normal_ Flood	Multiplier to adjust reservoir normal filling (balance between lower and upper limit of reservoir filling). [-]	0.8	[0.01 – 0.99]
ReservoirRnorm qMult	Multiplier to adjust normal reservoir outflow [−]	1	[0.25 – 2]
LakeMultiplier	Multiplier to adjust lake outflow [−]	1	[0.5 – 2]

Model inputs

Table S2: Surface field maps used as input to OS LISFLOOD to general the hydrological reanalysis. HERA refers to the HERA dataset while LF-EU maps refers to the LISFLOOD static and parameter maps for Europe (2024) dataset. More information on main data sources is provided in Table S3.

Surface field name	Description	Main data source	Data location
	Morphology and river network		
Mask area	Boolean map defining model boundaries		HERA
Local drainage direction (LDD)	Connects every grid-cell forming a river network from springs to mouth	CaMa-Flood	LF-EU maps
Grid-cell area (pixArea)	Area of every grid cell	CaMa-Flood	LF-EU maps
Grid-cell length	Length of every grid cell	Grid-cell area	LF-EU maps
Upstream area (upArea)	Accumulated area of all connected grid-cells of the LDD from springs to mouth	LDD, pixArea	LF-EU maps
Standard deviation of elevation	Amount of elevation variation within a grid-cell	MERID DEM	LF-EU maps
Gradient	Elevation gradient between two connected grid-cells	MERIT DEM, LDD	LF-EU maps
Channel bottom width	Width of the bottom of the channel	CaMa-Flood	LF-EU maps
Channel length	Length of river channel in each grid-cell	CaMa-Flood	LF-EU maps
Channel gradient	Gradient (slope) of river channel inside a grid-cell	MERIT DEM, CaMa-Flood, LDD	LF-EU maps
Manning's roughness coefficient for channels	Manning's roughness coefficient of river channel for each grid-cell	MERIT DEM,upArea	LF-EU maps
Channel mask	Channel presence in the grid-cell indicator	Mask	HERA
Side slope	Slope of river banks		LF-EU maps
Bankful channel depth	Channel depth	upArea	LF-EU maps
	Vegetation types and properties		
Crop coefficient for forest	Ratio between the potential (reference) evapotranspiration rate, in mm/day, and the potential evaporation rate of forest (averaged by time and ecosystem type)	CGLS-LC100, SPAM, FAO	LF-EU maps
Crop coefficient for irrigated crops	Ratio between the potential (reference) evapotranspiration rate, in mm/day, and the potential evaporation rate of irrigated crops (averaged by time and ecosystem type)	CGLS-LC100, SPAM, FAO	LF-EU maps
Crop coefficient for other cover type	Ratio between the potential (reference) evapotranspiration rate, in mm/day, and the potential evaporation rate of other cover type (averaged by time and ecosystem type)	CGLS-LC100, SPAM, FAO	LF-EU maps
Crop group number for forest	Represents a vegetation type and is an indicator of its adaptation to dry climate (forest)	CGLS-LC100,	LF-EU maps

		SPAM, FAO	
Crop group number for irrigated crops	Represents a vegetation type and is an indicator of its adaptation to dry climate (irrigated crops)	CGLS-LC100, SPAM, FAO	LF-EU maps
Crop group number for other cover type	Represents a vegetation type and is an indicator of its adaptation to dry climate (other)	CGLS-LC100, SPAM, FAO	LF-EU maps
Manning's surface roughness coefficient for forest	Roughness or friction applied to the flow by the surface on which water is flowing (forest)	CGLS-LC100, SPAM, FAO	LF-EU maps
Manning's surface roughness coefficient for irrigated crop	Roughness or friction applied to the flow by the surface on which water is flowing (irrigated crops)	CGLS-LC100, SPAM, FAO	LF-EU maps
Manning's surface roughness coefficient for other cover types	Roughness or friction applied to the flow by the surface on which water is flowing (other)	CGLS-LC100, SPAM, FAO	LF-EU maps
Leaf area index for forest	Defined as half the total area of green elements of the canopy per unit horizontal ground area m2/m2 (10-day average; 36 fields in total)	CGLS-LAI	LF-EU maps
Leaf area index for irrigated crop	Defined as half the total area of green elements of the canopy per unit horizontal ground area m2/m2 (10-day average; 36 fields in total)	CGLS-LAI	LF-EU maps
Leaf area index for other cover types	Defined as half the total area of green elements of the canopy per unit horizontal ground area m2/m2 (10-day average; 36 fields in total)	CGLS-LAI	LF-EU maps
Rice planting day 1	Most probable day of the year when rice is planted for the first time	RiceAtlas	LF-EU maps
Rice planting day 2	Most probable day of the year when rice is planted for the second time	RiceAtlas	LF-EU maps
Rice planting day 3	Most probable day of the year when rice is planted for the third time	RiceAtlas	LF-EU maps
Rice harvesting day 1	Most probable day of the year when rice is harvested after planting for the first time	RiceAtlas	LF-EU maps
Rice harvesting day 2	Most probable day of the year when rice is harvested after planting for the second time	RiceAtlas	LF-EU maps
Rice harvesting day 3	Most probable day of the year when rice is harvested after planting for the third time	RiceAtlas	LF-EU maps
Soil properties			
Soil depth layer 1 for forest	Forest soil depth for surface soil [layer 1]	SoilGrids	LF-EU maps
Soil depth layer 1 for other	Other soil depth for surface soil [layer 1]	SoilGrids	LF-EU maps
Soil depth layer 2 for forest	Forest soil depths for middle soil [layer 2]	SoilGrids	LF-EU maps
Soil depth layer 2 for other	Other soil depths for middle soil [layer 2]	SoilGrids	LF-EU maps
Soil depth layer 3 for forest	Forest soil depths for subsoil [layer 3]	SoilGrids	LF-EU maps

Soil depth layer 3 for other	Other soil depths for subsoil [layer 3]	SoilGrids	LF-EU maps
Saturated volumetric soil moisture content layers 1 for forest	Maximum water content in surface soil for forest	SoilGrids	LF-EU maps
Saturated volumetric soil moisture content layers 1 for other	Maximum water content in surface soil for other	SoilGrids	LF-EU maps
Saturated volumetric soil moisture content layers 2 for forest	Maximum water content in middle soil for forest	SoilGrids	LF-EU maps
Saturated volumetric soil moisture content layers 2 for other	Maximum water content in middle soil for other	SoilGrids	LF-EU maps
Saturated volumetric soil moisture content layers 3	Maximum water content in subsoil	SoilGrids	LF-EU maps
Residual volumetric soil moisture content layer 1	Minimum water content in the surface soil	SoilGrids	LF-EU maps
Residual volumetric soil moisture content layer 2	Minimum water content in the middle soil	SoilGrids	LF-EU maps
Residual volumetric soil moisture content layer 3	Minimum water content in the subsoil	SoilGrids	LF-EU maps
Pore size index layer 1 for forest	pore size index of the surface soil for forest	SoilGrids	LF-EU maps
Pore size index layer 1 for other	Van Genuchten parameter λ representing the pore size index of the surface soil for other	SoilGrids	LF-EU maps
Pore size index layer 2 for forest	Van Genuchten parameter λ representing the pore size index of the middle soil for forest	SoilGrids	LF-EU maps
Pore size index layer 2 for other	Van Genuchten parameter λ representing the pore size index of the middle soil for other	SoilGrids	LF-EU maps
Pore size index layer 3	Van Genuchten parameter λ representing the pore size index of the subsoil	SoilGrids	LF-EU maps
Van Genuchten equation parameter layer 1 for forest	Van Genuchten parameter α of the surface soil for forest	SoilGrids	LF-EU maps
Van Genuchten equation parameter layer 1 for other	Van Genuchten parameter α of the surface soil for other	SoilGrids	LF-EU maps
Van Genuchten equation parameter layer 2 for forest	Van Genuchten parameter α of the middle soil for forest	SoilGrids	LF-EU maps
Van Genuchten equation parameter layer 2 for other	Van Genuchten parameter α of the middle soil for othert	SoilGrids	LF-EU maps
Van Genuchten equation parameter layer 3	Van Genuchten parameter α of the subsoil	SoilGrids	LF-EU maps
Saturated soil conductivity for layer 1 forest	Ease with which water moves through pore spaces of the surface soil for forest	SoilGrids	LF-EU maps

Saturated soil conductivity for layer 1 other	Ease with which water moves through pore spaces of the surface soil for other	SoilGrids	LF-EU maps
Saturated soil conductivity for layer 2 forest	Ease with which water moves through pore spaces of the middle soil for forest	SoilGrids	LF-EU maps
Saturated soil conductivity for layer 2 other	Ease with which water moves through pore spaces of the middle soil for other	SoilGrids	LF-EU maps
Saturated soil conductivity for layer 3	Ease with which water moves through pore spaces of the subsoil	SoilGrids	LF-EU maps
Land use			
Forest surface fraction	Evergreen and deciduous needle leaf and broad leaf tree areas	CGLS-LC100, HANZE,	HERA/socioeconomic_maps
Sealed surface fraction	Urban areas, characterizing the human impact on the environment	CGLS-LC100, HANZE,	HERA/socioeconomic_maps
Irrigated surface fraction	Irrigated areas of all possible crops excluding rice	CLC2018, HANZE	HERA/socioeconomic_maps
Inland water fraction	Rivers, freshwater and saline lakes, ponds and other permanent water bodies over the continents	CGLS-LC100, HANZE	HERA/socioeconomic_maps
Irrigated rice fraction	Irrigated areas of rice	CLC2018, SPAM, HANZE	HERA/socioeconomic_maps
Other land cover fraction	Agricultural areas, non-forested natural area, pervious surface of urban areas		HERA/socioeconomic_maps
Water demand			
Water demand for domestic use	Daily supply of water volume for indoor and outdoor household purposes and for all the uses that are connected to the municipal system (e.g., water used by shops, schools, and public buildings)	GHS-POP, AQUASTAT, MSWX	HERA/water_demand
Water demand for industrial use	Daily supply of water volume for fabricating, processing, washing and sanitation, cooling or transporting a product, incorporating water into a product	GHS-POP, AQUASTAT, GCAM	HERA/water_demand
Water demand for thermoelectric use	Daily supply of water volume for the cooling of thermoelectric and nuclear power plant	GHS-POP, AQUASTAT, GCAM, MSWX	HERA/water_demand
Water demand for livestock use	Daily supply of water volume for domestic animal need	AQUASTAT, GCAM, GLW3	HERA/water_demand
Lakes and reservoirs			
Lake mask	Area covered by lakes only (binary representation)	GLWD	LF-EU maps
Reservoir map	Location and identifier of each reservoir	EFAS, HANZE, GranD	HERA/reservoirs

Table S3: Main datasets used in the creation of surface field inputs for LISFLOOD model. More information on the generation of these surface fields can be found in Choulga et al. (2023).

Dataset name	Description	Data source
AQUASTAT	*FAO's global information system on water resources and agricultural water management.*	https://www.fao.org/land-water/databases-and-software/aquastat/en/
CaMa-Flood	*The Catchment-based Macro-scale Floodplain (CaMa-Flood) Global River Hydrodynamics Model v4.0 265 maps (CaMa-Flood) is a global hydrography dataset.*	http://hydro.iis.u-tokyo.ac.jp/~yamadai/cama-flood/
CGLS-LAI	*The Copernicus Global Land Service (CGLS) Leaf Area Index (LAI) 1km Version 2 collection (CGLS-LAI) is a set of global maps data describing vegetation dynamics – the annual evolution of LAI at 10-day intervals over the period of 1999-2020.*	https://land.copernicus.eu/global/products/lai
CGLS-LC100	*The Copernicus Global Land ServiceLand Cover (LC) 100m map (CGLS-LC100) 283 is a global land cover map of the year 2015.*	https://land.copernicus.eu/global/products/lc
CLC2018	*The Coordination of Information on the Environment (CORINE) Land Cover (CLC) inventory for 2018 (CLC2018) is a set of maps describing the land cover/ land use status of 2018 covering 39 countries in Europe.*	https://land.copernicus.eu/en/products/corine-land-cover/clc2018
FAO	*The FAO Irrigation and Drainage Paper No. 56 (FAO) is a publication covering geographically referenced statistics for crop development stages, crop coefficients, crop height, rooting depth, and soil water depletion fraction for common crops found across the world.*	https://www.fao.org/land-water/databases-and-software/crop-information/en/
GCAM	*Global Change Analysis Model (GCAM) is an integrated, multi-sector model developed by the Joint Global Change Research Institute (JGCRI) to explore the overall behaviour of human and physical systems dynamics and interactions.*	https://github.com/JGCRI/gcam-core
GHS-POP	*The Global Human Settlement Population Grid multitemporal version R2019A (GHS POP) is a spatial raster dataset that depicts the distribution of population, expressed as the number of people per grid-cell.*	https://ghsl.jrc.ec.europa.eu/ghs_pop2019.php
GLWD	*The Global Lakes and Wetlands Database (GLWD) is a global database of water bodies.*	https://www.worldwildlife.org/pages/global-lakes-and-wetlands-database
GRanD	*The Global Reservoir and Dam Database (GRanD) is a product of the Global Water System Project. It collates existing dam and reservoir datasets with the aim of providing a single, geographically explicit and reliable database for the scientific community.*	https://www.globaldamwatch.org/directory
HANZE	*The Historical Analysis of Natural Hazards in Europe (HANZE) is a pan-European database of exposure to natural hazards and damaging historical floods since 1870.*	https://data.4tu.nl/collections/_/5065346/1
MERIT DEM	*Multi-Error-Removed Improved-Terrain Digital Elevation Model v.1.0.3 (MERIT DEM) is a high accuracy global DEM at 3 arc second resolution (~90 m at the Equator).*	http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/
MSWX	*Multi-Source Weather (MSWX) is a high-resolution (3-hourly, 0.1°), bias-corrected meteorological product with global coverage from 1979 to present.*	https://www.gloh2o.org/mswx/

RiceAtlas	*The RiceAtlas v3 (RiceAtlas) is a spatial database of global rice calendars and production.*	https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/JE6R2R
SPAM	*The Spatial Production Allocation Model (SPAM) – Global Spatially-Disaggregated Crop Production Statistics Data for 2010 v2.0 (SPAM2010) is a global dataset which redistributes crop production information from country and sub-national provinces level to a finer grid-cell level.*	https://mapspam.info/data/
SoilGrids	*The International Soil Reference and Information Centre (ISRIC) SoilGrids250m global gridded soil information release 2017 (fSoilGrids) is as a set of global soil property and class maps at 250 m resolution.*	https://www.isric.org/explore/soilgrids/faq-soilgrids-2017

Table S4: Water demand in km^3.y^{-1} by sector used for the HERA simulation (1951-2020) over the EFAS domain. Values correspond to Figure 4.c.

year	Domestic	Energy	Industrial	Livestock	Total
1951	34.04	46.21	38.98	6.28	125.51
1952	35.02	48.27	40.70	6.28	130.26
1953	36.00	50.12	42.49	6.28	134.88
1954	36.99	52.07	44.21	6.28	139.55
1955	37.95	54.04	46.03	6.28	144.29
1956	39.04	56.24	47.93	6.28	149.49
1957	40.16	58.19	49.88	6.28	154.50
1958	41.27	60.26	51.79	6.28	159.60
1959	42.40	62.32	53.68	6.28	164.69
1960	40.18	55.42	49.73	6.28	151.62
1961	41.32	56.99	51.00	6.28	155.58
1962	42.54	59.07	52.45	6.28	160.34
1963	43.94	60.87	53.61	6.28	164.69
1964	45.46	63.84	55.79	6.28	171.36
1965	46.88	65.34	57.42	6.28	175.92
1966	48.37	67.04	59.04	6.28	180.74
1967	49.83	69.15	60.83	6.28	186.09
1968	51.51	71.59	62.80	6.28	192.18
1969	53.36	74.52	65.20	6.28	199.36
1970	55.17	78.01	67.72	6.28	207.19
1971	56.96	80.57	69.76	6.28	213.56
1972	59.20	84.29	72.66	6.28	222.42
1973	62.22	88.49	76.70	6.28	233.69
1974	64.59	90.82	79.59	6.28	241.27
1975	66.15	91.74	80.68	6.28	244.84
1976	68.41	95.47	84.04	6.28	254.20
1977	70.58	96.43	85.53	6.28	258.82
1978	72.94	99.59	88.32	6.28	267.13
1979	76.85	103.98	92.79	6.28	279.90
1980	77.37	104.31	93.41	6.28	281.36
1981	78.25	104.52	93.77	6.28	282.82
1982	78.95	104.83	94.20	6.28	284.26
1983	79.51	105.67	94.69	6.28	286.14
1984	79.88	106.26	95.24	6.28	287.66
1985	80.64	107.08	95.74	6.28	289.74
1986	81.19	107.59	96.18	6.28	291.24
1987	81.82	108.12	96.75	6.28	292.96
1988	82.61	108.52	97.52	6.28	294.93
1989	83.88	109.09	98.39	6.28	297.64
1990	84.95	109.56	99.38	6.28	300.17
1991	85.69	109.19	97.89	6.17	298.93
1992	86.29	107.96	96.55	6.07	296.88
1993	86.61	104.48	94.70	5.99	291.78
1994	86.76	103.76	94.12	5.91	290.54
1995	86.95	102.17	93.16	5.85	288.13
1996	86.83	100.36	92.13	5.79	285.11
1997	87.21	100.46	91.82	5.75	285.25
1998	88.42	100.09	90.90	5.73	285.14
1999	89.59	99.32	89.87	5.72	284.50
2000	90.58	99.01	89.04	5.73	284.36
2001	91.94	98.60	87.98	5.74	284.26
2002	93.13	98.19	86.90	5.77	283.98
2003	92.65	96.80	83.46	5.79	278.70
2004	92.03	95.50	80.06	5.82	273.41
2005	91.84	94.20	76.67	5.86	268.56

2006	91.45	92.96	73.11	6.09	263.62
2007	91.05	91.83	69.58	6.35	258.81
2008	90.49	90.36	67.06	6.62	254.53
2009	90.39	88.44	64.42	6.90	250.16
2010	90.07	86.91	61.94	7.21	246.13
2011	89.72	84.60	60.29	7.61	242.22
2012	89.15	82.25	58.61	8.00	238.00
2013	90.44	81.74	58.39	8.37	238.94
2014	91.49	81.21	58.16	8.74	239.61
2015	92.52	80.71	57.92	9.10	240.25
2016	93.36	79.86	57.99	9.30	240.51
2017	94.63	79.08	58.09	9.49	241.29
2018	95.24	80.43	60.19	9.68	245.54
2019	95.89	80.53	61.30	9.88	247.60
2020	96.26	75.57	58.59	10.07	240.49

Model validation

Gauging stations used in validation

Table S 5 Stations manually checked for the validatation of HERA

Longitude	Latitude	upa	StationID	csource	obs_qa	sim_qa	station	river_name	KGE'	removal	comment	trueUpA	Tlong	Tlat	dist
-6.942	37.975	144	2004160	SpatialQMatch	0.3	1.1	AROCHE	NA	-1.36	NO	Arid catchment				0.7
-0.775	40.175	666	6227620	GRDCUpA	0.8	1.0	EL TERDE	RIO MIJARES	-0.47	NO	Arid catchment				1.6
-1.625	38.408	1541	2007043	EFAS	0.4	2.3	MINATEDA	ARROYO DE TOBARRA	-3.65	NO	Arid catchment				1.2
-2.525	40.258	249	2003173	SpatialQMatch	0.2	1.1	PERALEJA, LA	NA	-2.58	NO	Arid catchment				1.9
14.792	37.658	700	6353500	EFAS	3.3	9.5	PONTE MACCARRONE	FIUME SIMETO	-1.17	NO	Arid catchment				0.9
-3.208	37.875	7019	6217500	EFAS	17.2	7.5	POSITO	RIO GUADIANA MENOR	-0.52	NO	Arid catchment				0.8
-2.275	38.242	368	2007102	SpatialQMatch	1.6	0.3	TAIBILLA	NA	-12.68	NO	Arid catchment + reservoirs not in HERA				1.1
-0.692	40.958	650	2009127	SpatialQMatch	0.9	0.3	ALCAINE	NA	-0.53	NO	Downstream a reservoir				0.8
-6.142	37.675	1025	2005077	EFAS	3.5	8.0	CENTRAL DE CALA	NA	-0.55	NO	Downstream a reservoir				1.0
13.942	37.175	1958	6353400	EFAS	4.2	16.6	DRASI	SALSO	-2.08	NO	Downstream a reservoir				0.6
-2.975	37.542	4073	2005019	SpatialQMatch	6.7	2.6	NEGRATIN	NA	-1.74	NO	Downstream a reservoir				2.9
-4.842	42.842	322	2002035	SpatialQMatch	1.4	4.8	OTERO DE GUARDO	NA	-1.66	NO	Downstream a reservoir				1.4
18.575	66.992	2200	3001969	SpatialQMatch	61.9	26.8	SEITEVARE KRV	NA	-0.48	NO	Downstream a reservoir				1.7
-5.475	38.925	7672	6216630	EFAS	9.7	25.8	ZUJAR	RIO ZUJAR	-0.93	NO	Downstream a reservoir				2.3
-3.592	39.192	11966	6216520	EFAS	0.8	2.7	VILLARRUBIA	RIO GUADIANA	-1.54	NO	Downstream a reservoir				0.7
11.842	47.875	220	6343110	GRDCUpA	1.8	7.8	ERB	LEITZACH	-2.55	YES	Dubious observations				1.7
3.375	44.192	165	6125300	EFAS	1.3	4.7	HERMET	CHAPOUROUX	-1.60	YES	Dubious observations				1.2
4.625	48.742	2143	6122120	EFAS	3.6	21.7	VITRY-EN-PERTHOIS	SAULX	-3.96	YES	Dubious observations				0.4
-0.175	51.408	131	4039003	SpatialQMatch	1.9	1.9	SOUTH WIMBLEDON	NA	-0.57	NO	Heavily influenced river (Wandle in London)				1.3
13.342	58.358	714	3002371	SpatialQMatch	5.6	4.6	ATTORP	NA	-0.52	NO	Influenced by reservoir not in HERA				0.7
23.142	54.075	495	990163	SpatialQMatch	3.8	1.6	CZERWONY FOLWARK	NA	-1.99	NO	Influenced by reservoir not in HERA				1.7
19.242	50.142	2094	910490	SpatialQMatch	18.1	12.3	JELEN	NA	-1.60	NO	Influenced by reservoir not in HERA				1.2
9.492	56.575	555	6934170	GRDCUpA	4.6	3.3	LOEVEL BRO	SKALS A	-0.53	NO	Influenced by reservoir not in HERA				0.2
13.658	37.475	1299	6353300	EFAS	2.4	12.4	PASSOFONDUTO	PLATANI	-3.39	NO	Influenced by reservoir not in HERA				1.2
24.658	54.692	218	6574108	GRDCUpA	2.0	0.9	SEMELISKES	STREVA	-1.96	NO	Influenced by reservoir not in HERA				2.8
22.992	54.075	184	6474107	GRDCUpA	1.3	0.8	SOBOLEWO	CZARNA HANCZA	-0.98	NO	Influenced by reservoir not in HERA				0.8
19.175	50.242	896	990138	SpatialQMatch	7.3	4.5	NIWKA	NA	-2.01	NO	Influenced river				0.8
19.125	50.258	521	990136	SpatialQMatch	4.9	4.8	SZABELNIA	NA	-0.95	NO	Influenced river				0.8
32.475	34.742	239	6196040	EFAS	0.4	1.1	AKHELIA	POTAMOS TIS EZOUSAS	-1.03	NO	Aride catchment				1.1
-0.042	51.592	1353	4038023	SpatialQMatch	2.4	8.0	Low Hall	NA	-1.42	YES	LONDON channel				1.9
-1.025	38.058	186	2007064	SpatialQMatch	4.3	1.0	BENIEL	NA	-0.81	NO	Matched wrong river pixel	14230	-1.00833	38.04167	2.0
-0.692	40.975	653	2009118	EFAS	1.1	0.3	OLIETE	NA	-0.58	NO	Matched wrong river pixel	811	-0.675	40.99167	1.9
-2.675	40.158	358	2003172	SpatialQMatch	0.6	1.2	HUETE	NA	-0.94	NO	Matched wrong river pixel	476	-2.6917	40.2083	2.9
6.825	50.742	298	6335040	GRDCUpA	0.8	3.0	WEILERSWIST	SWISTBACH	-2.50	NO	Matched wrong river pixel	300	6.8583	50.7583	3.1
-2.592	55.508	695	4021025	SpatialQMatch	2.9	15.1	Ancrum	NA	-3.25	NO	Matched wrong river pixel	183	-2.60823	55.52474	0.8
9.408	48.658	191	6335700	GRDCUpA	1.2	2.8	OBERENSINGEN	AICH	-0.46	NO	Matched wrong river pixel	169	9.2917	48.64167	1.9
13.125	56.125	1177	3001635	SpatialQMatch	3.1	8.7	KLIPPAN 2	NA	-0.93	NO	Matched wrong river pixel	150	13.1583	56.1417	2.3
-3.058	57.058	851	4012005	SpatialQMatch	3.8	16.5	Invermuick	NA	-2.34	NO	Matched wrong river pixel	102	-3.075	57.025	2.2
-0.025	51.442	123	4039056	SpatialQMatch	0.4	1.7	Catford Hill	NA	-2.66	NO	Influenced river				0.1
0.458	52.342	367	4033023	SpatialQMatch	0.2	1.2	Beck Bridge	NA	-2.99	YES	river with UpA<100km2				1.7
4.092	44.308	234	6139070	GRDCUpA	1.6	7.5	GAGNIERES (BANNES)	GANIERE	-2.65	YES	river with UpA<100km2				2.8
-1.558	51.425	322	4039028	SpatialQMatch	0.7	2.5	Hungerford	DUN	-1.66	YES	river with UpA<100km2				1.7
-6.358	54.225	212	4206002	SpatialQMatch	0.7	3.2	Jerretspass	NA	-2.58	YES	river with UpA<100km2				1.4
5.092	51.142	125	6220345	GRDCUpA	0.1	0.3	MEERHOUT	KLEINBROEKBEEK	-3.66	YES	river with UpA<100km2				2.4

-0.442	51.642	578	4039088	SpatialQMatch	0.5	2.8	Rickmansworth	NA	-3.41	YES	river with UpA<100km2				1.4
0.542	52.558	356	4033029	SpatialQMatch	0.5	1.2	Whitebridge	STRINGSIDE	-0.50	YES	river with UpA<100km2				2.1
16.458	48.125	126	6242715	GRDCUpA	0.7	2.8	SCHWECHAT (RATHAUSPARK)	KALTER GANG	-2.20	YES	river with UpA<100km3				2.3
17.108	59.275	226	6233411	GRDCUpA	1.3	0.6	AKERS KRUTBRUK	RACKSTA A	-0.54	NO	Influenced by reservoir not in HERA				1.3
2.342	48.675	956	6122130	GRDCUpA	3.8	3.8	MORSANG-SUR-ORGE	ORGE	-0.43	NO	strong bias reduces KGE				0.9
5.275	46.175	100	6139640	EFAS	0.5	1.9	MONTAGNAT	REYSSOUZE	-1.58	YES	Upwaters of a karstic river				1.2
-1.725	52.492	132	4028066	SpatialQMatch	1.0	2.5	Coleshill	COLE	-0.67	NO	Influenced river				1.1
0.158	51.442	118	4040016	SpatialQMatch	0.5	1.2	Crayford	CRAY	-0.44	NO	Influenced river				1.3
-20.358	63.858	585	6401150	GRDCUpA	44.7	22.7	ARBAEJARFOSS	YTRI-RANGA	-1.98	NO					1.0
-0.008	41.242	3807	6226550	GRDCUpA	1.6	3.2	CASPE	RIO GUADALOPE	-0.44	NO					0.9
15.708	48.275	839	6242515	GRDCUpA	4.7	13.0	HERZOGENBURG (STRASSENBRUECKE)	TRAISEN	-0.95	NO					1.0
26.342	56.358	616	6373226	GRDCUpA	3.0	6.6	KULENIEKI	USA	-0.44	NO					2.0
19.675	53.442	792	990159	SpatialQMatch	5.0	3.3	KULIGI	NA	-0.42	NO					1.7
-1.775	51.092	164	4043004	SpatialQMatch	0.8	1.8	Laverstock	NA	-0.44	NO					2.1
20.475	53.775	580	990072	SpatialQMatch	3.7	2.6	OLSZTYN-KORTOWO	NA	-0.87	NO					2.1
-0.975	38.075	14456	2007028	SpatialQMatch	6.0	15.6	ORIHUELA	NA	-0.81	NO					2.6
24.292	54.125	4294	6574721	GRDCUpA	32.4	16.8	PUVOCIAI	MERKYS	-0.51	NO					1.1
19.375	50.275	471	990137	SpatialQMatch	3.9	2.2	SLAWKÓW	NA	-2.11	NO					3.3
17.192	54.675	815	990132	SpatialQMatch	8.3	7.2	SMOLDZINO	NA	-0.46	NO					2.0
17.508	53.875	1659	990090	SpatialQMatch	10.2	8.0	SWORNEGACIE	NA	-1.19	NO					1.8
17.908	53.592	2477	6458560	GRDCUpA	19.4	11.6	TUCHOLA	BRDA	-1.09	NO					2.1
25.125	54.442	445	6574723	GRDCUpA	4.0	2.2	VOKE-ZAGARINE	MERKYS	-1.13	NO					1.3

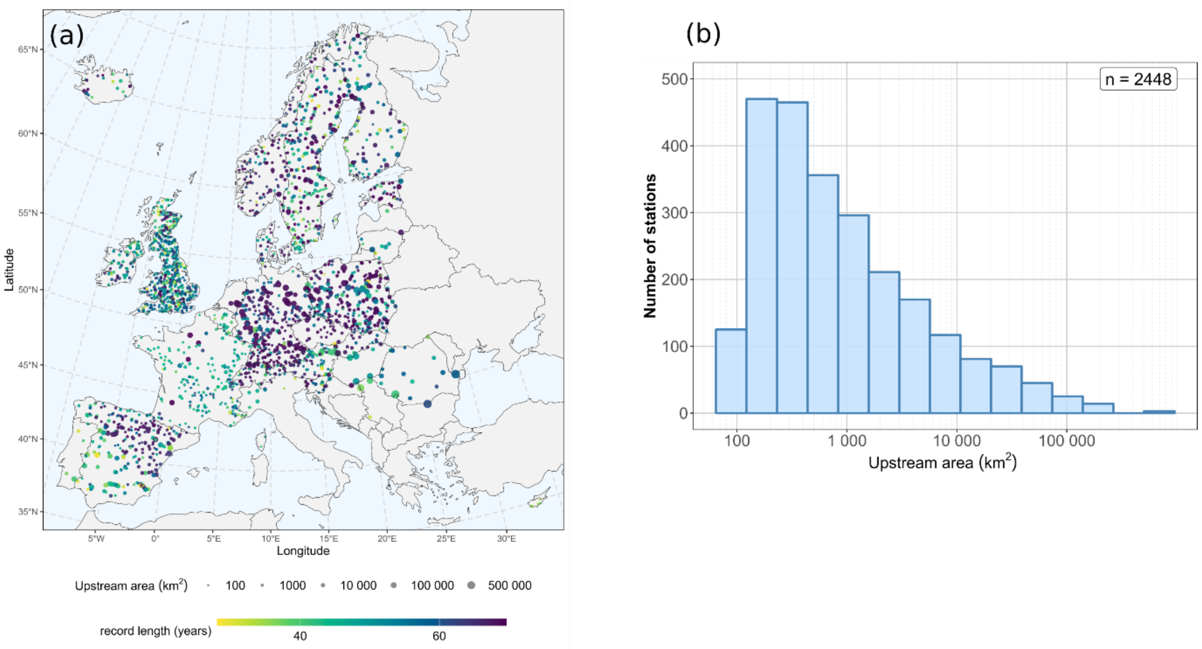

Figure S2: Metadata of the 2448 river gauging stations used in the validation of HERA. It shows (a) the location, upstream area and record length associated to each stations and (b) the distribution of upstream area of the selected river gauging stations.

Comparison with other hydrological datasets

Reported performances

In **Table S6**, we provide a summary of the main characteristics of HERA and three other recent hydrological reanalysis mentioned in the article: GLOFAS-ERA5 (Harringan et al., 2020), GRFR (Yang et al., 2021) and a simulation from the mHM model (Samaniego et al., 2019), hereafter referred as EUmHM. We can appreciate from **Table S6** the difference between each dataset and their validation. HERA seems to outperform the two global reanalysis in terms of KGE', which is not surprising due to the better data coverage in Europe, and to the increased diversity of landscapes and climates at global scale.

Table S 6: Characteristics and reported performances of HERA and three recent hydrological reanalysis

Dataset	HERA	GLOFAS-ERA5	EUmHM	GRFR
Reference	Tilloy et al. (2024)	Harringan et al. (2020)	Samaniego et al. (2019)	Yang et al. (2021)
Spatial coverage	Europe	Global	Europe	Global
Temporal coverage	1951-2020	1979-Present	1960-2010	1980-2019
Spatial resolution	0.0167º	0.25 º	5km (≈0.05 º)	0.05º
validation catchments (N)	2848	1801	357	14698
Median validation catchment area (km^2)	583 (27% < 250 km2)	30 046	1 700	Not provided (29% < 250 kn2)
KGE' (median)	0.55 (58% >0.5)	0.33	0.6	Not provided (27% > 0.5)
Pearson r (median)	0.73	0.61	0.8	Not provided
Bias ratio (±20%)	50	28	50	44
Variability ratio (%<1)	83	61	65	Not provided

The reported performances of HERA and EUmHM are very similar. A deeper comparison between HERA and EUmHM is provided below.

Comparison with the EUmHM hydrological run over 515 European catchments

Here we compare HERA with the EUmHM run generated with the mHM model (Kumar et al., 2013; Samaniego et al., 2010). This hydrological simulation was recently used to assess flood-generating mechanisms in Europe (Tarasova et al., 2023). HERA and EUmHM use a different model, different meteorological input (bias-adjusted downscaled ERA5-land vs downscaled E-OBS) and different resolution (1' and 6-hourly vs 5km and daily). We were provided daily discharge data by Larisa Tarasova for a set of 1444 European catchments (mean upstream area=2602 km^2) over the period 1960-2010. We performed a spatial matching similar to the one presented in **Section 3** of the main article, using upstream area as a matching parameter and averaged discharge as a filtering measure (same rules as in **Section 3**). Over the 2448 catchments used in the validation of HERA (**Section 3**), a total 515 common catchments between HERA and the provided EUmHM points were identified (**Figure S3**).

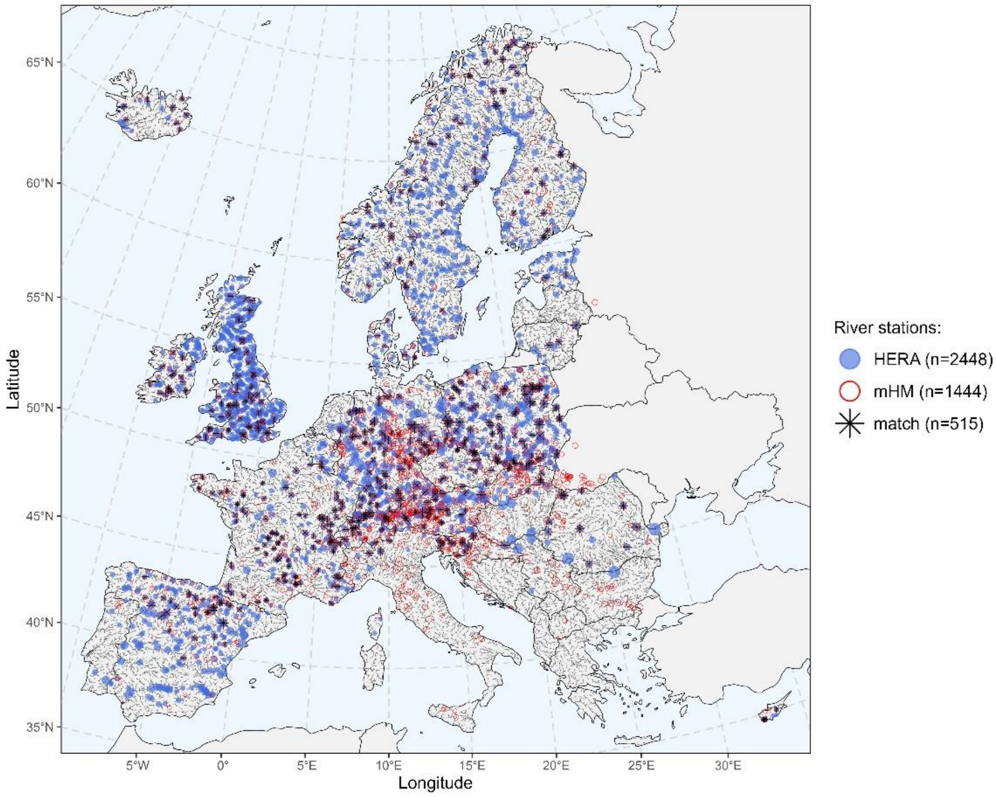

Figure S3: Location of the catchments used in the HERA validation (blue dots), EUmHM catchments (red circles) and common catchments obtained from the matching procedure.

As displayed in **Figure S4** and **Figure S5**, HERA outperforms EUmHM over the common catchments in terms of KGE' ($KGE'_{med(HERA)}$ = 0.57 and $KGE'_{med(EUmHM)}$ = 0.52). **Figure S4.a** display the differences in performance spatially while Figure S4.b shows the ordered difference in KGE'. From **Figure 4.b**, we can see that HERA outperforms EUmHM in 54% (280) of the catchments. EUmHM seems to be penalized by a very low KGE' in some catchments. The lower performance in mHM is driven by a higher bias (**Figure S6.b**), despite better correlations compared to HERA (**Figure S6.a**).

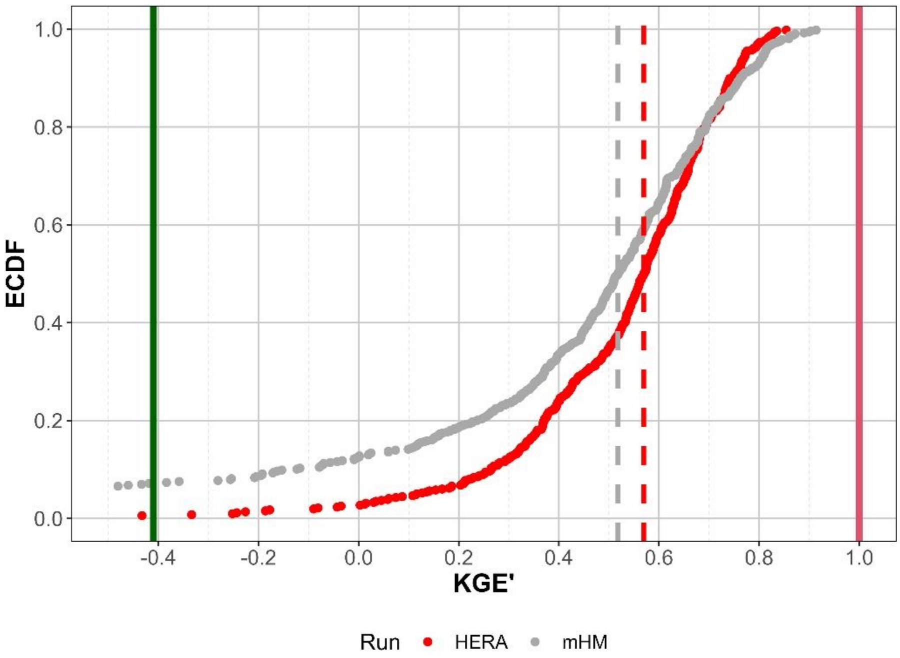

Figure S4: Cumulative probability distribution of KGE' for HERA (red) and EUmHM (grey) for the 515 common catchments. The green line represents the benchmark KGE' value (-0.41), the red line is the optimal value (1) and the two dashed vertical line show the median KGE' for both simulations.

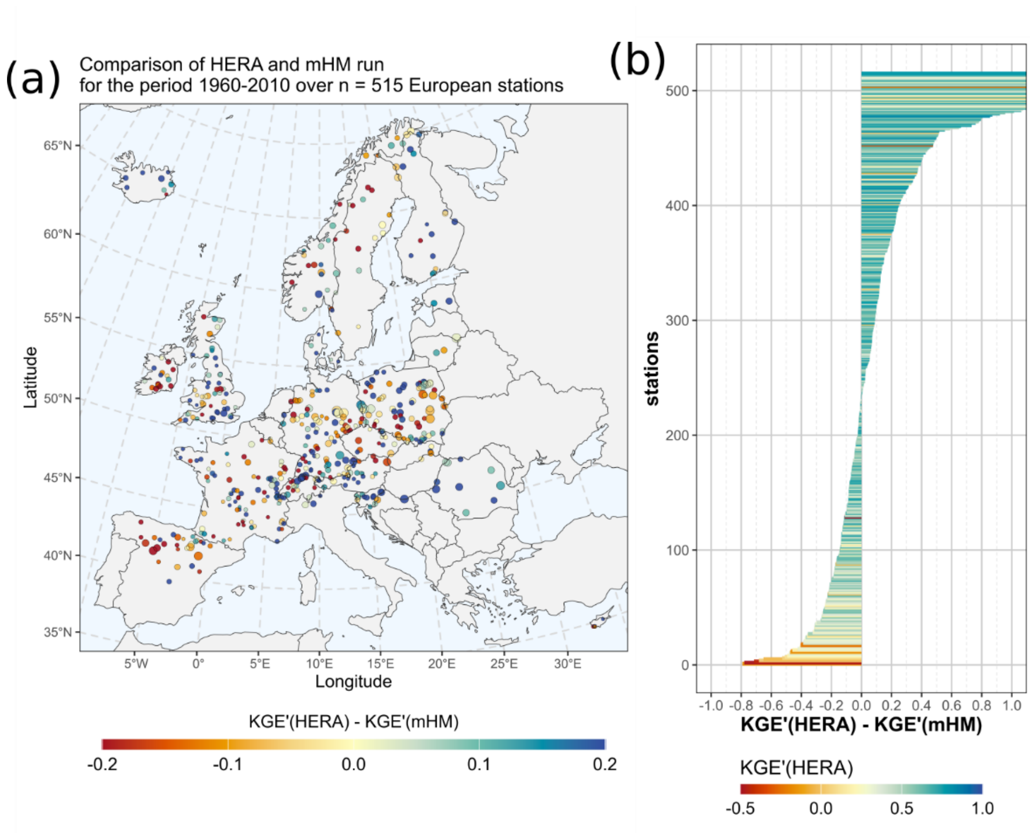

Figure S5: Performance comparison between HERA and EUmHM in terms of KGE', (a) difference in KGE' at each location and (b) ordered difference from lowest (EUmHM performs better) to highest (HERA performs better).

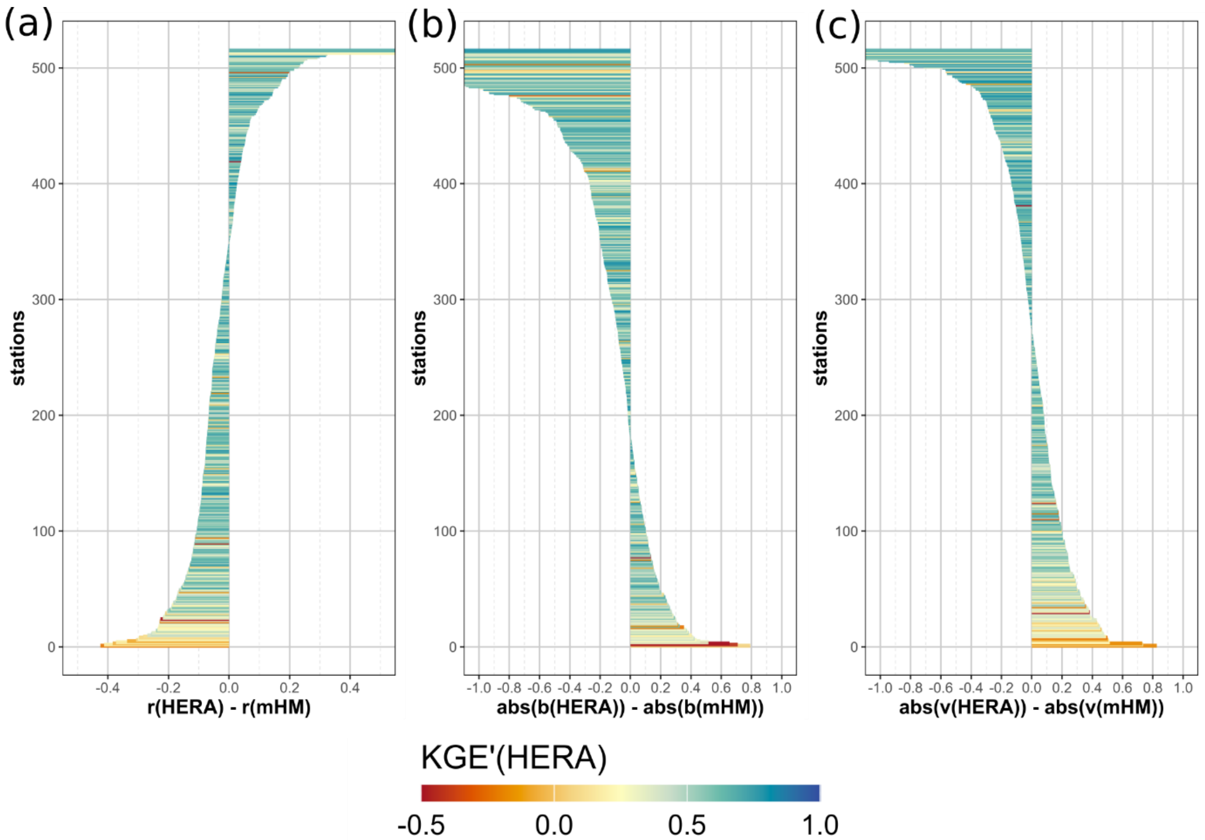

Figure S 6: Ordered difference in the three components of KGE': (a) correlation (HERA<EUmHM for negative values), (b) absolute (1-β), with 0 being no bias (HERA>EUmHM for negative values), and (c) absolute (1-γ) with zero meaning that the variability is perfectly reproduced (HERA>EUmHM for negative values).

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