Supplement of:
HERA: a high-resolution pan-European hydrological reanalysis (1950-2020)

Tilloy et al. (2024)

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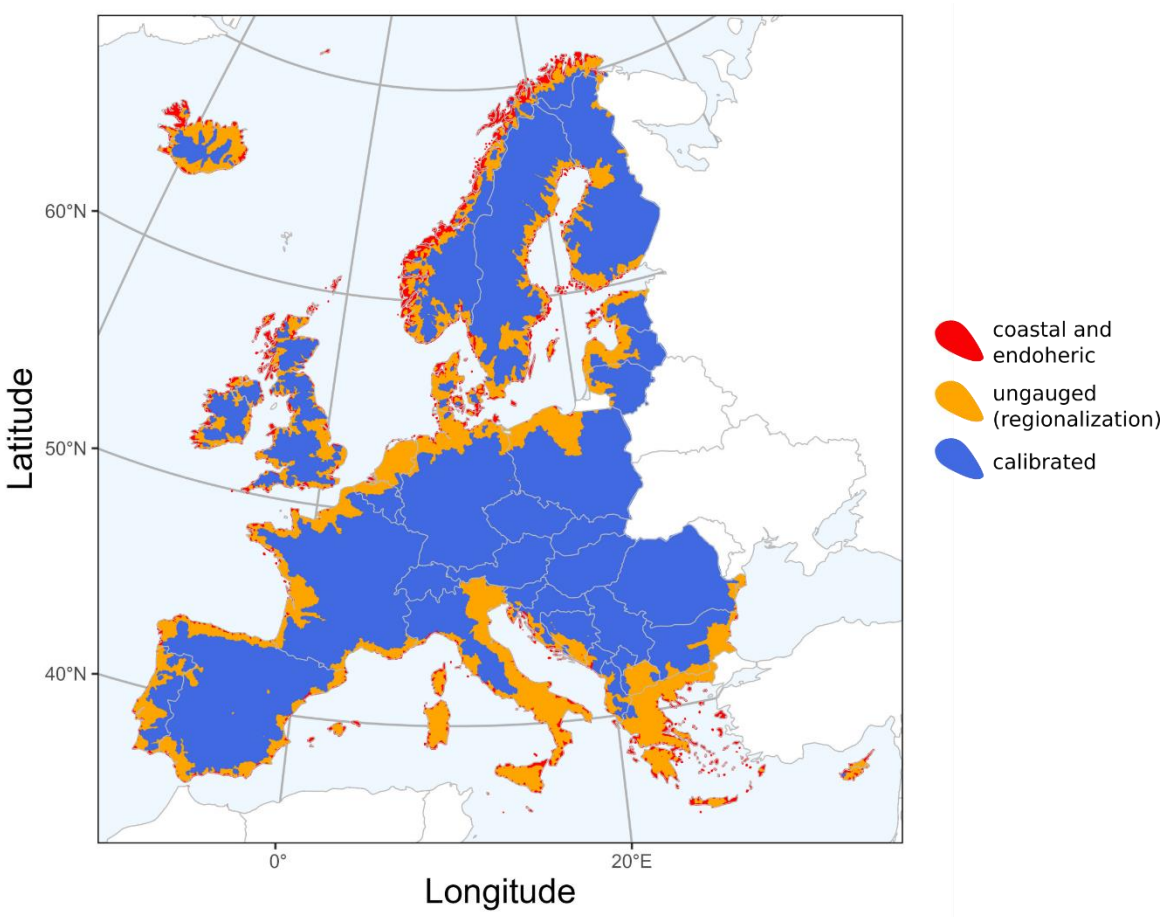

Figure S1: HERA domain with spatial distribution of catchments with calibrated (blue, 69.6% or domain area), regionalized (orange, 23.9% of domain area) and default (red, 6.5% of domain area) parameters.

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]
UpperZoneTimeConstant	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]
LowerZoneTimeConstant	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]
ReservoirRnormqMult	Multiplier to adjust normal reservoir outflow [−]	1	[0.25 – 2]
LakeMultiplier	Multiplier to adjust lake outflow [−]	1	[0.5 – 2]

Table S2: Surface fields maps used as input to the LISFLOOD model 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 source 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	CGLS-LC100,	LF-EU maps

	evaporation rate of irrigated crops (averaged by time and ecosystem type)	SPAM, FAO	
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, SPAM, FAO	LF-EU maps
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	RiceAtlas	LF-EU maps

	first time		
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	Ease with which water moves through pore spaces of the surface soil for other	SoilGrids	LF-EU maps

1 other			
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,	HERA/water_demand

		MSWX	
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 fields inputs for LISFLOOD model. For more information on the generation of surface fields, the author can refer to 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,*	https://www.globaldamwatch.org/directory

	geographically explicit and reliable database for the scientific community.	
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

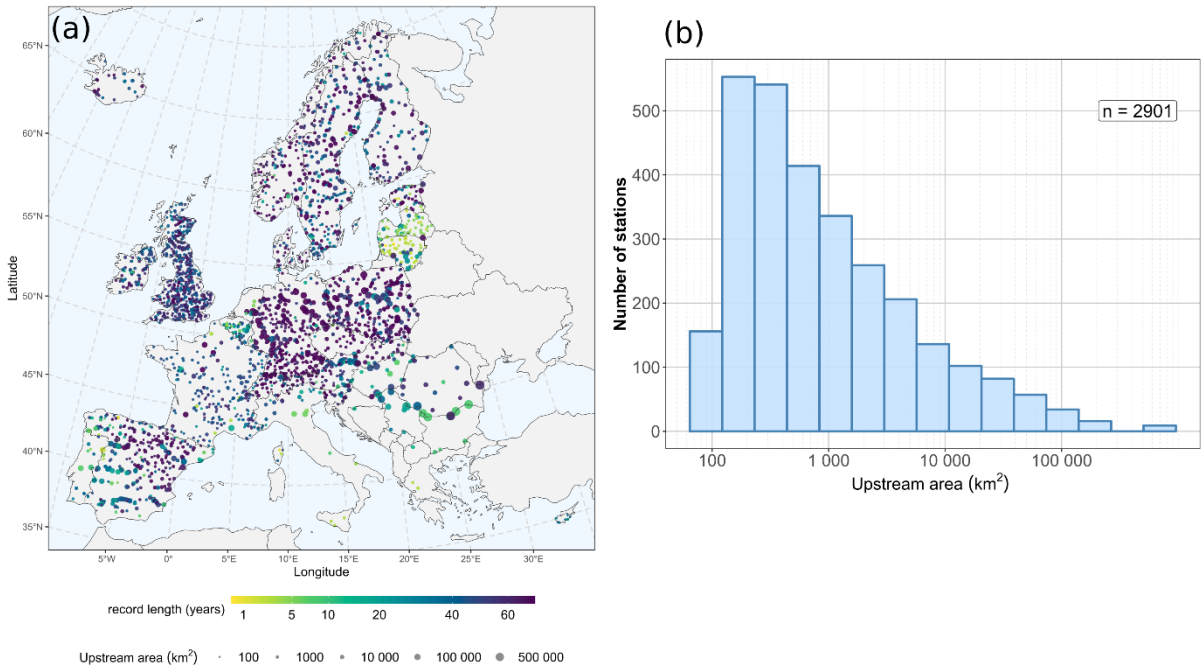

Figure S2: Metadata of the 2901 river gauging stations used in the validation of HERA. It shows (a) the location, upstream area and record length associated to each stations and (b) the distribution of upstream area of the selected river gauging stations.

References

LISFLOOD static and parameter maps for Europe: http://data.europa.eu/89h/f572c443-7466-4adf-87aa-c0847a169f23, last access: 11 January 2024.

CEMS-Flood online documentation: https://confluence.ecmwf.int/display/CEMS/CEMS-Flood, last access: 14 December 2023.