

A year of hydrological forecast advancements in support of the Copernicus Emergency Management Service

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with contributions from the CEMS-Flood Computational team @ECMWF

3 June 2021

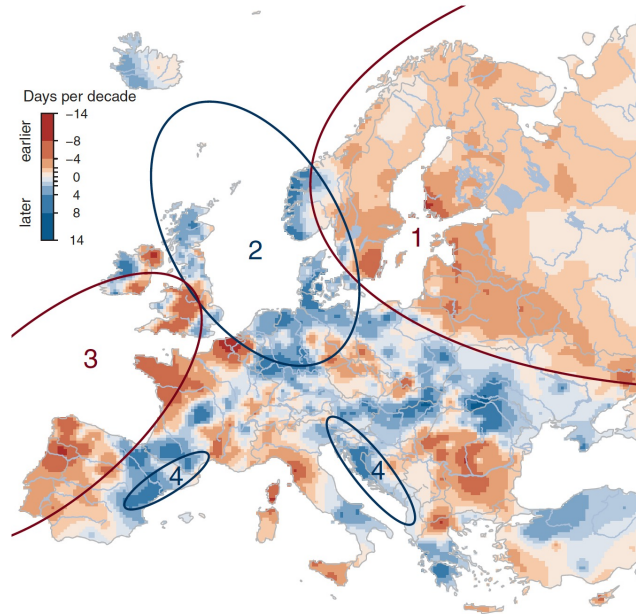




Climate change is modifying flood attributes in complex ways

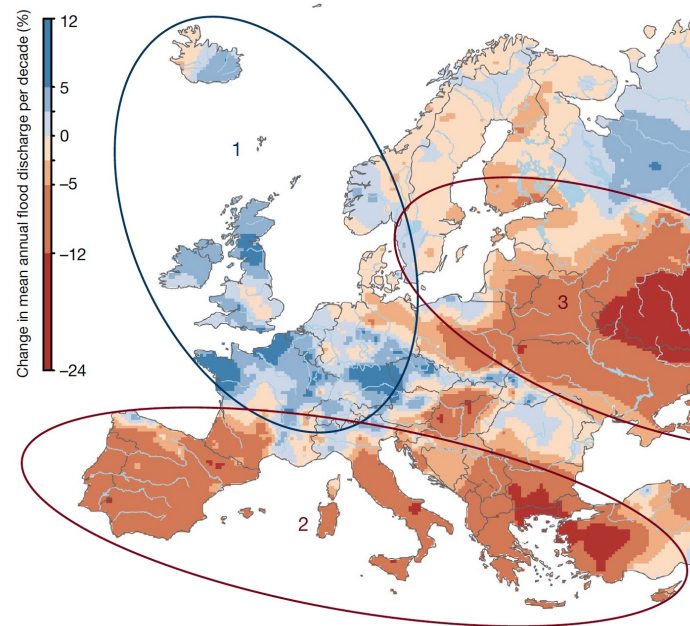
Emergency Management

Flood Timing



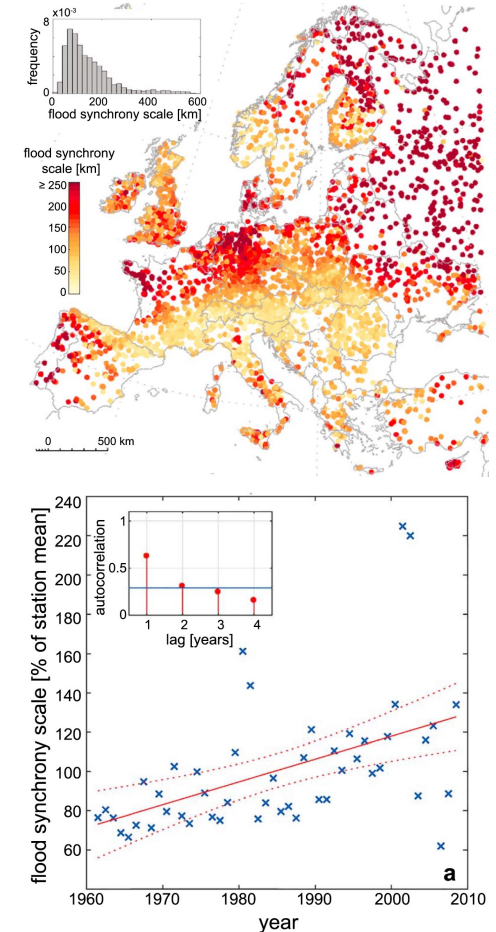
Blöschl et al. (2017) Changing climate shifts timing of European Floods, **Science**

Flood Magnitude



Blöschl et al. (2019) Changing climate both increases and decreases European river floods, **Nature**

Flood Spatial scale



Berghuijs et al. (2019) Growing spatial scales of synchronous river flooding in Europe, **GRL**



CEMS Early Warning & Monitoring



Early Warning & Monitoring

Copernicus EMS Early Warning and Monitoring offers critical geospatial information at European and global level through continuous observations and forecasts for floods, droughts and forest fires.



Floods

The **European Flood Awareness Systems (EFAS)** and **Global Flood Awareness Systems (GloFAS)** provide complementary flood forecast information to relevant stakeholders that support flood risk management at the national, regional and global level.



Fires

The **European Forest Fire Information System (EFFIS)** monitors forest fire activity in near-real time. EFFIS supports wildfire management at the national and regional level for EU member states and across the Middle East and North Africa.



Droughts

The **Drought Observatory (DO)** provides drought-relevant information and early-warnings for **Europe (EDO)** and **globally (GDO)**. The service publishes short analytical reports (Drought News) in anticipation of an imminent drought.





Emergency Management

EFAS & GloFAS consortium



Hydrological data collection (HYDRO)



Mereological data collection (METEO)



Computation (COMP)



- Pre-/post-processing data
- Hydrological modelling chain
- Web & data delivery services
- Operational 24/7
- Products & Evaluation
- Collaborate in Earth System Science R&D

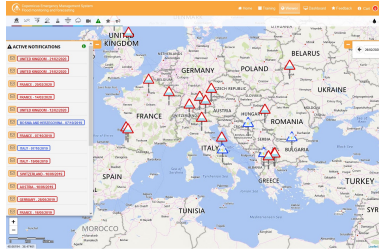
Analytics & Dissemination (DISS)





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Major & minor upgrades to EFAS & GloFAS since 2020

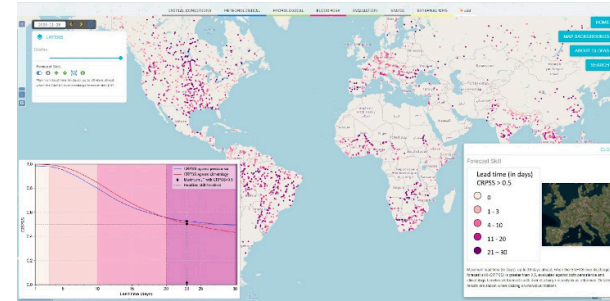
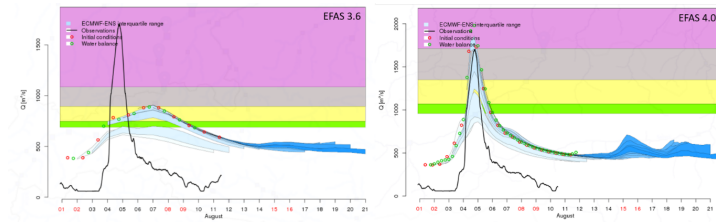


Mar 2020

EFAS v3.5 (minor)
Update static maps
New EFAS climatology
Minor web map viewer improvements

EFAS v4 (major)
From 24hr to 6hr time-step
Major calibration at 1137 stations
New evaluation layers

Oct 2020

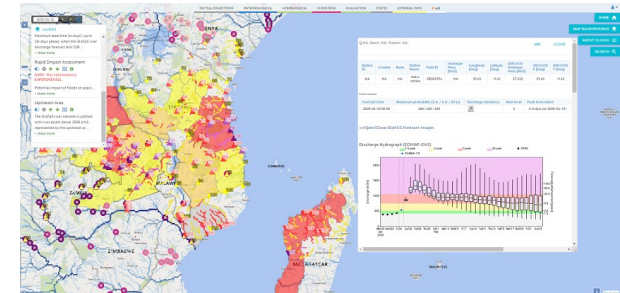


Dec 2020

GloFAS v2.2 (minor)
New GloFAS datasets in MARS/CDS
New web and improved products
New forecast skill layer

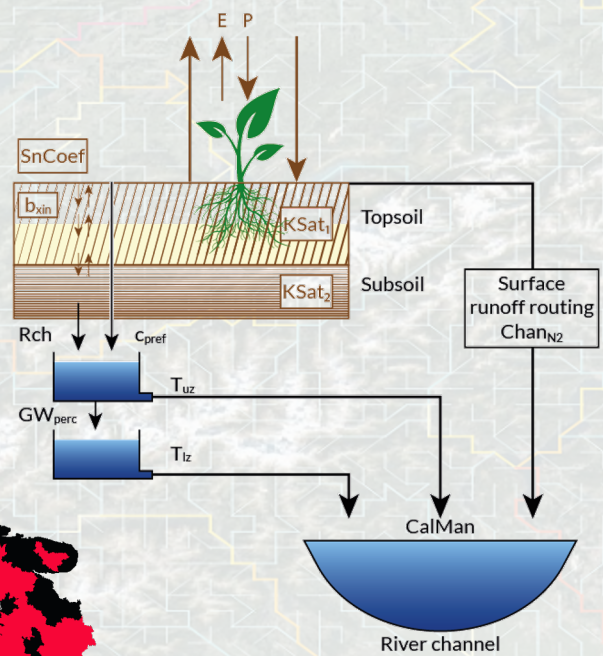
May 2021

GloFAS v3 (major)
New hydrological modelling system & calibration based on full configuration of LISFLOOD
New evaluation layers
Improved rapid flood mapping products





EFAS v4: Changes to hydrological modelling



In EFAS 4:

- 5 x 5 km horizontal resolution
- 6 hr model steps
- Improved location of river gauges on the model river network
- More strict physical ranges for calibration parameters
- 1137 calibration stations
- ~50 % of EFAS domain area belongs to a calibrated catchment (~4 million km² over ~9 million km²)

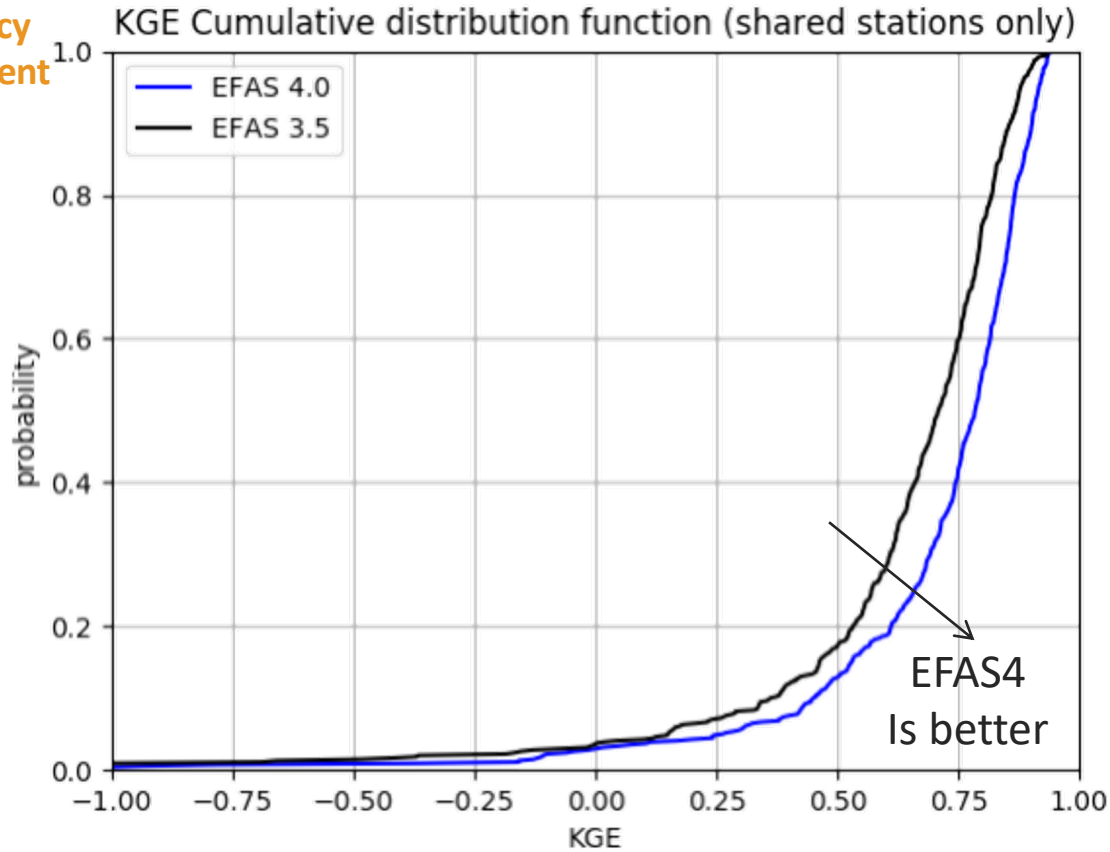


GitHub

<https://ec-jrc.github.io/lisflood/>



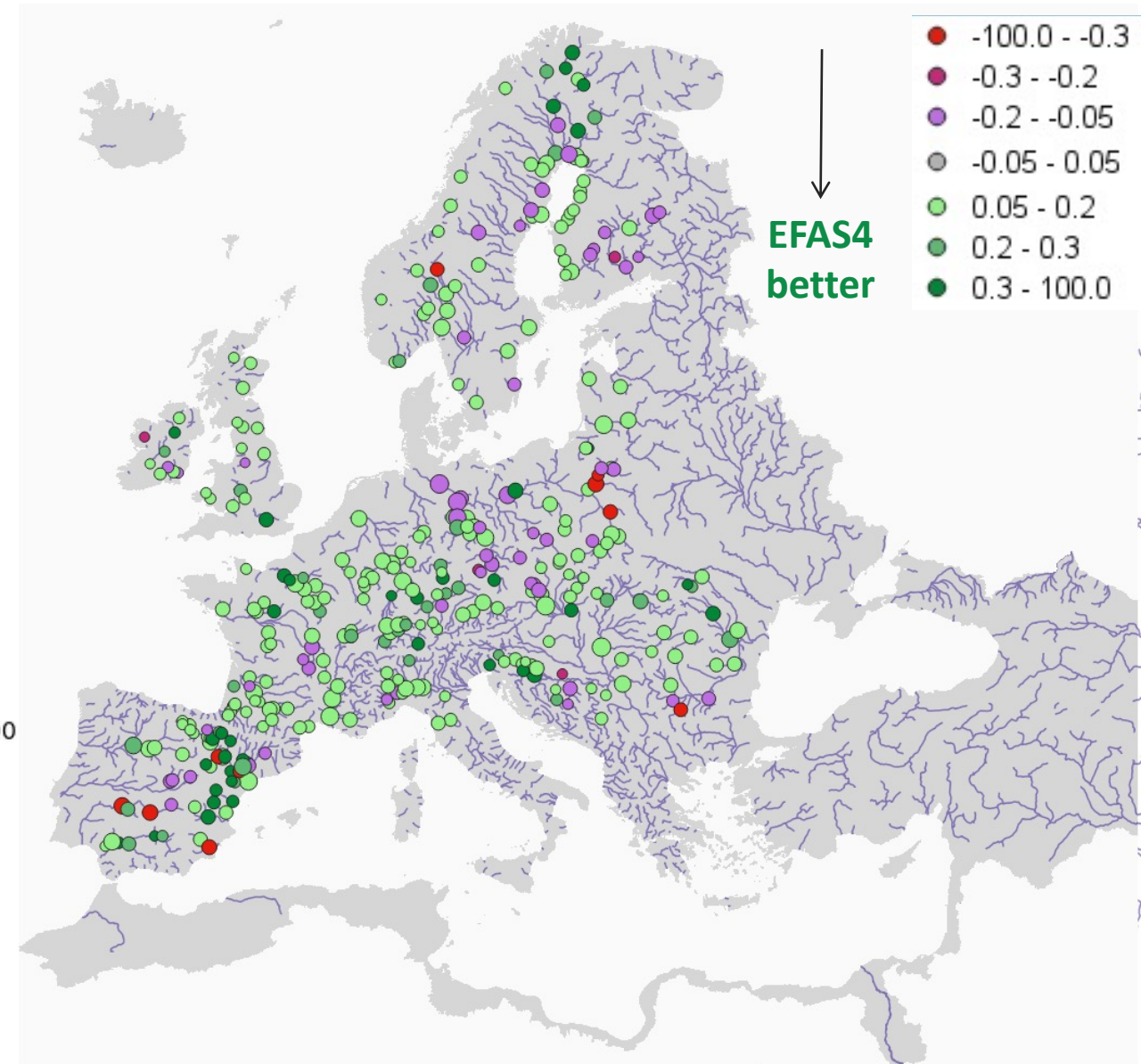
EFAS v4: Hydrological model performance



Modified Kling-Gupta Efficiency:

$$KGE' = 1 - \sqrt{(r - 1)^2 + (\beta - 1)^2 + (\gamma - 1)^2}$$

$$\text{Corr.}, r; \text{ Bias}, \beta = \frac{\mu_s}{\mu_o}; \text{ Var.}, \gamma = \frac{\sigma_s/\mu_s}{\sigma_o/\mu_o}$$

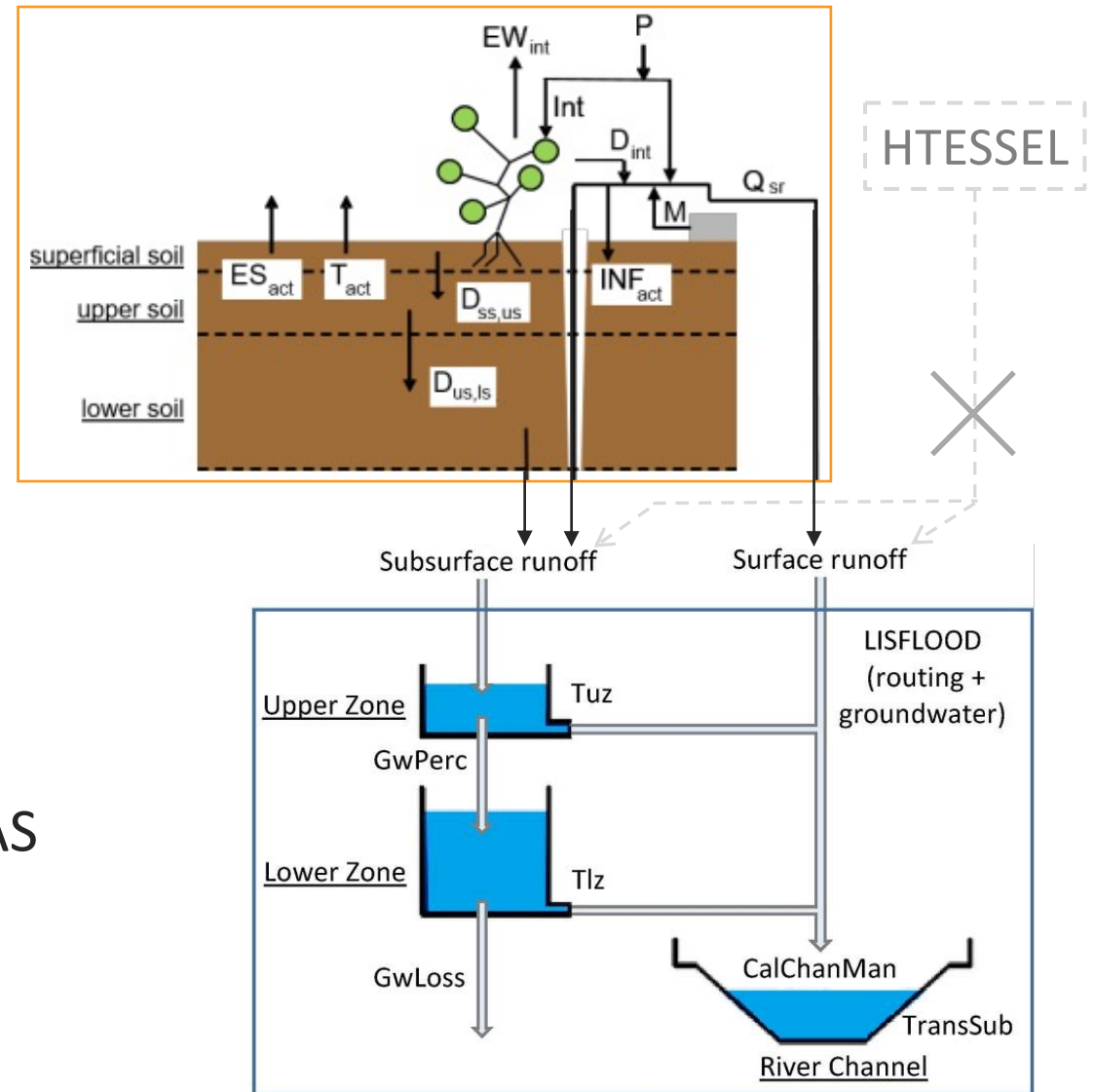


Difference in KGE' between EFAS4 and EFAS3



GloFAS v3: Changes to hydrological modelling

- GloFAS v2.1: **HTESSEL** to compute surface and subsurface runoff; **LISFLOOD** to compute river routing
- GloFAS v3.1: **LISFLOOD** to model all the hydrological processes
- Better control on **all calibration parameters** through the use of only one model
- Same modelling framework for GloFAS and EFAS so that any modelling development benefits both early warning systems

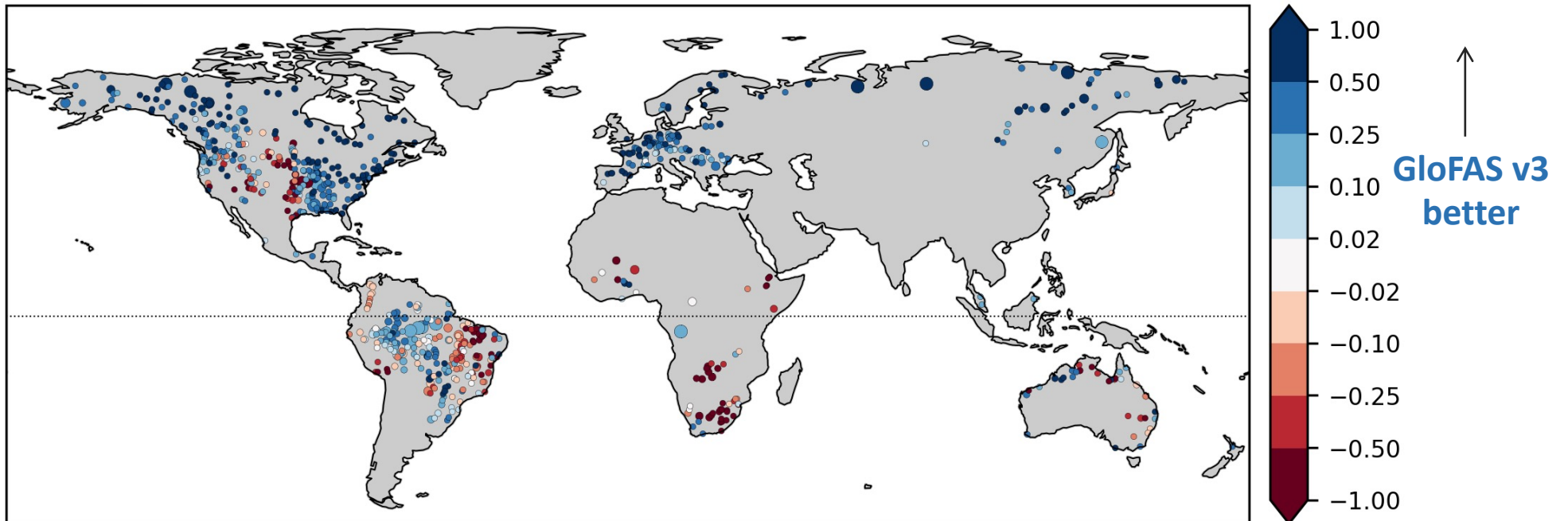




GloFAS v3: Hydrological model performance

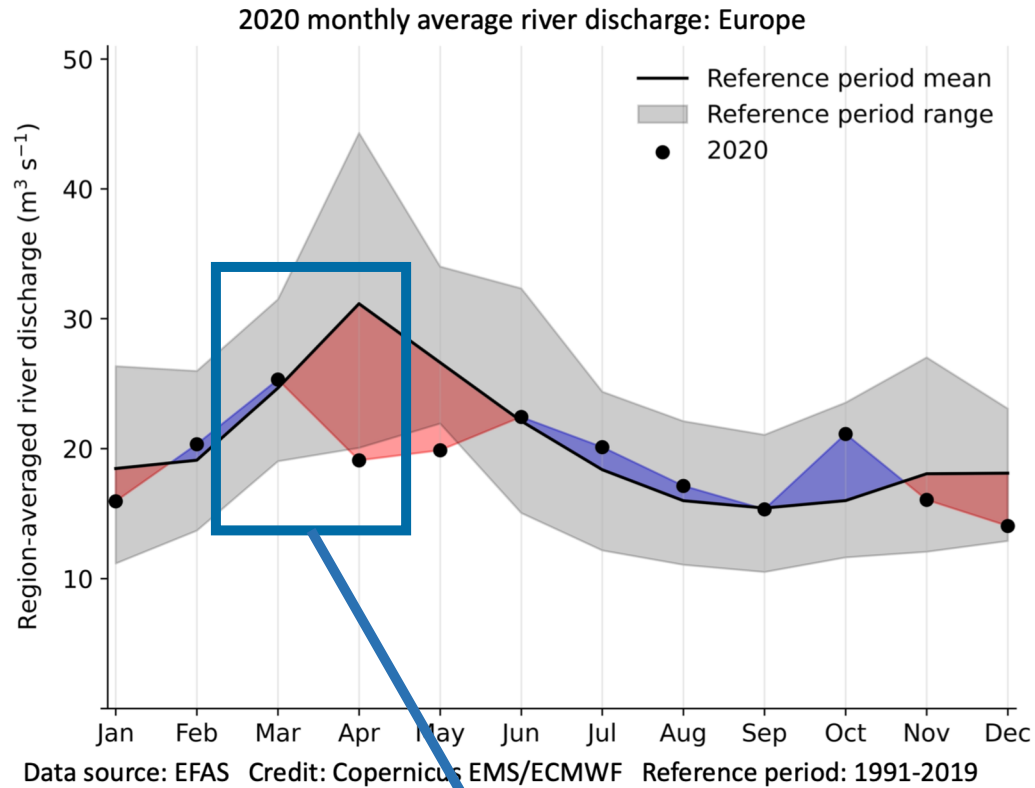
- Full hydrological calibration: overall improvement
- Moderate to high performance in **47%** of catchments in GloFAS v3.1 (compared with **18%** in GloFAS v2.1)
- **Best performance**: middle and higher latitudes of North America, Europe and Asia and areas in South America (where v3.1 is clearly better than v2.1)
- **Worse performance**: much of Africa and other areas mainly in the tropics (where v3.1 is sometimes worse than v2.1)

Difference in KGE' between GloFAS v3 and GloFAS v2

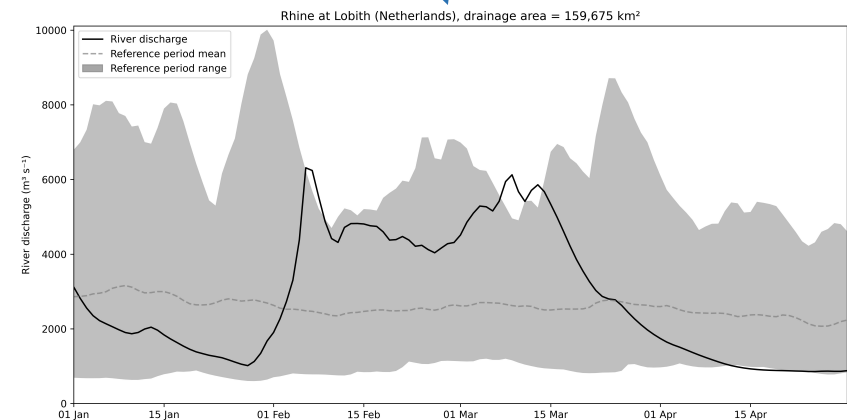
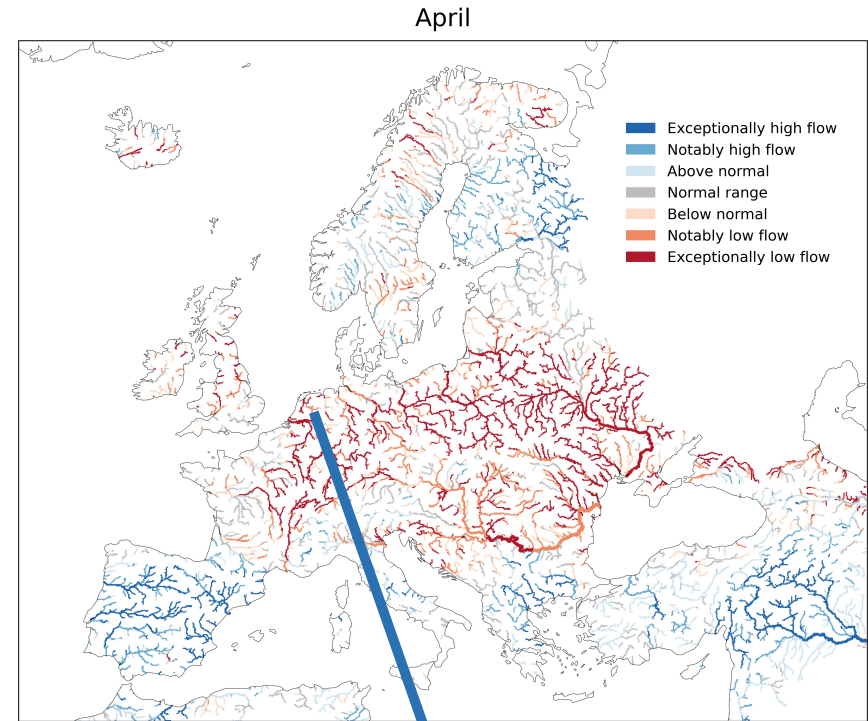




River discharge in the European State of the Climate (ESOTC) 2020



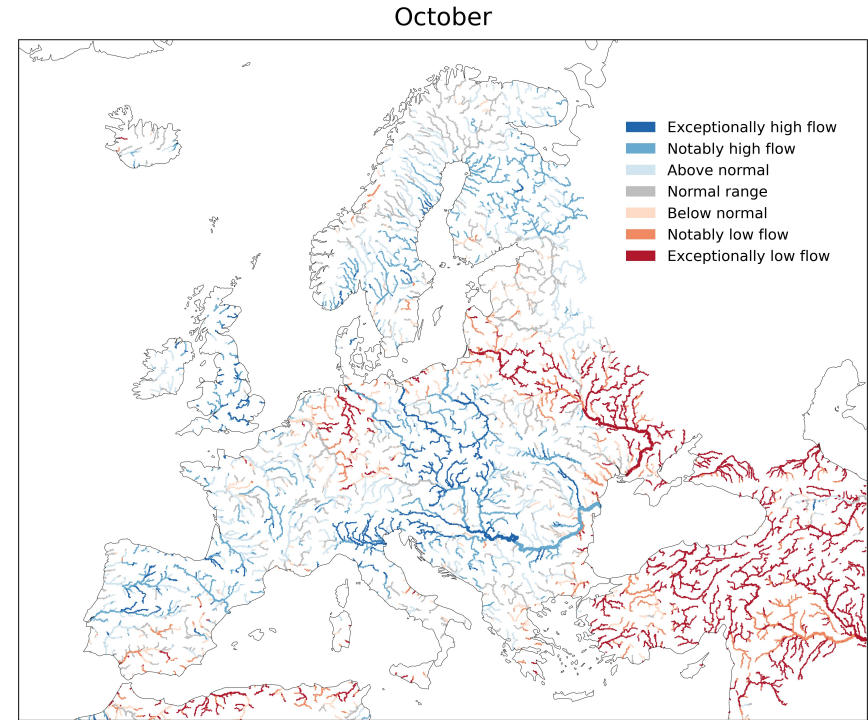
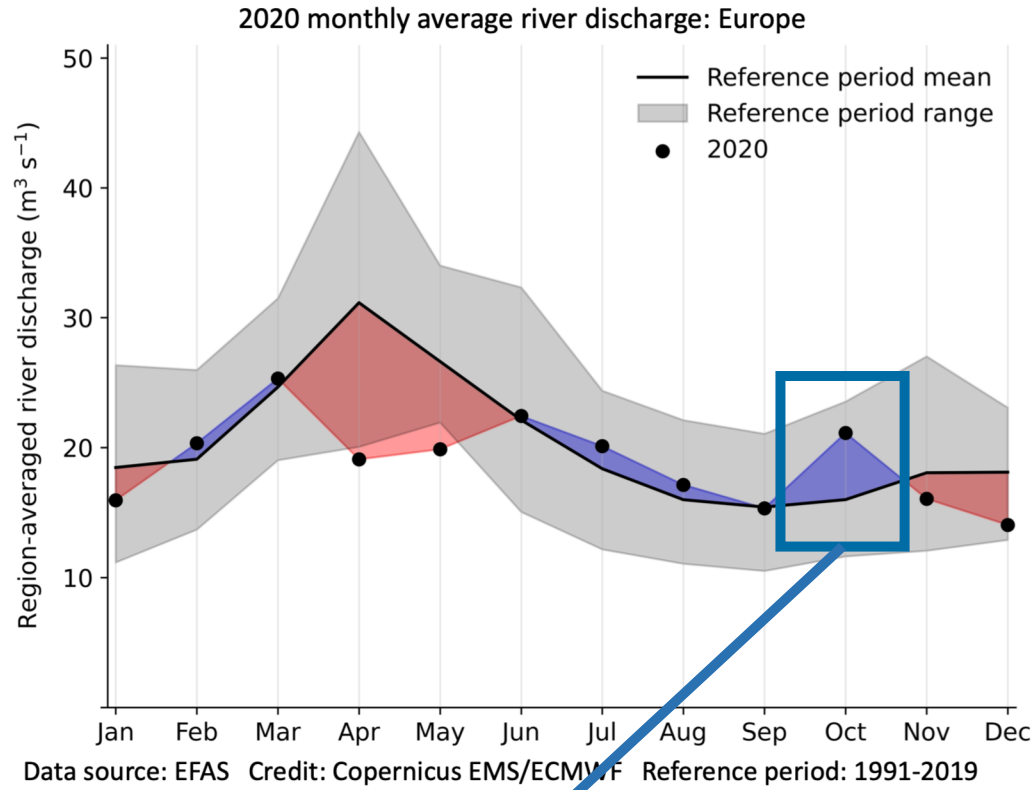
Transition from wet winter to dry Spring



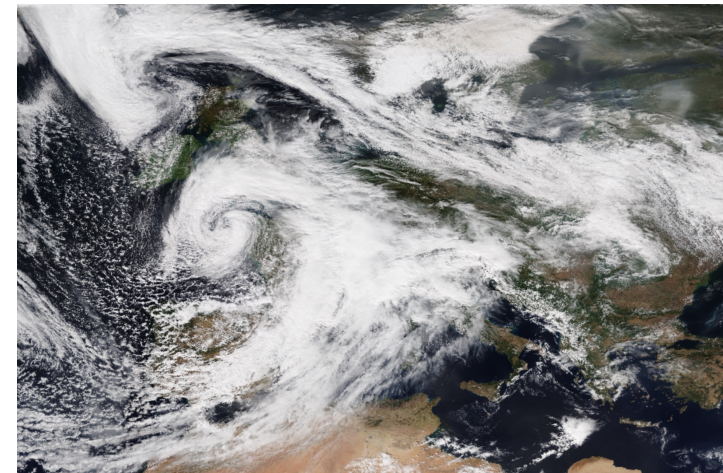


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River discharge in the European State of the Climate (ESOTC) 2020



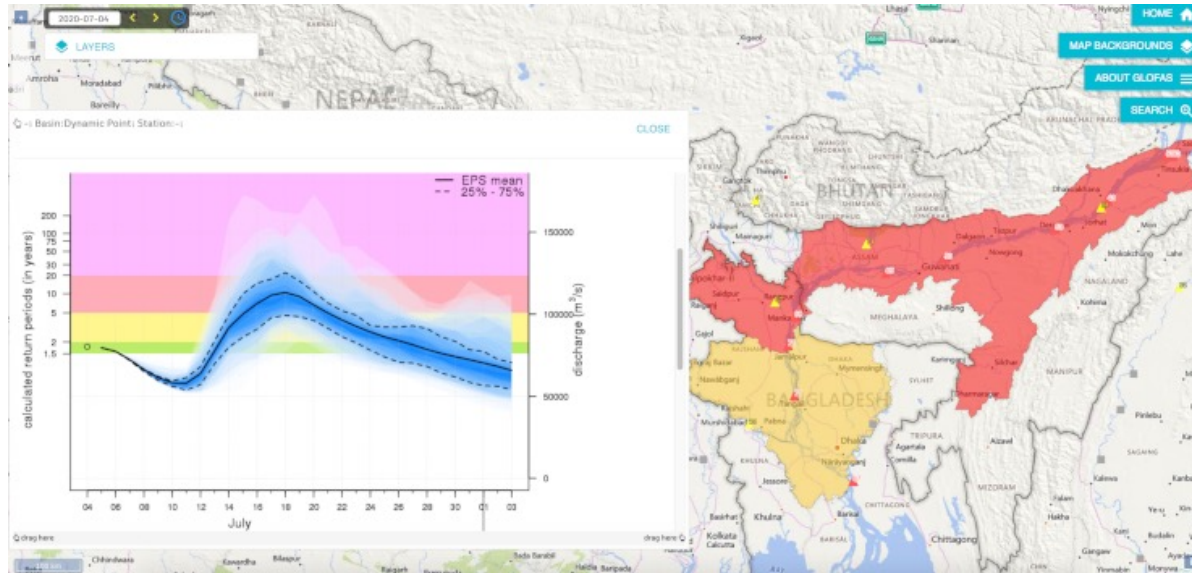
Storm Alex: Over 60% of river network in NW, NE & Danube had above-average river flows



NOAA NESDIS: 2 Oct 2020



July 2020: GloFAS used for forecast-based financing in Bangladesh



The UN released \$5.2 million dollars in humanitarian aid to the people of Bangladesh on 4 July to prepare before a forecast flood peak in mid-July. The finance trigger was based on CEMS GloFAS.



Flood impacts in Brahmaputra (Jamalpur)
Photos: Flood volunteer, Abdul Manna



Nov 2020: Flood bulletins during Hurricane IOTA using GloFAS



Hurricane IOTA - Flood

Event start: 16/17 November 2020 (Hurricane landfall expected ~00-06 UTC)
Forecast issue date: 16 November 2020, 00 UTC (GloFAS river flood forecast); 16 November, 09:00 UTC (coastal surge)
This report issued: 16 November 2020, 1700 UTC **Expected next report:** 17 November 2020, 1700 UTC

Key points

Hurricane Iota is expected to lead to severe impacts across parts of Central America still recovering from the impacts of Hurricane Eta. Further river and flash flooding is expected, along with coastal surge, wind hazards and mudslides. We estimate that ~700,000 people are currently at risk from river flooding, mainly in the municipalities of San Pedro Sula, La Lima, Choloma (Honduras); Morales, Camotán, Los Amantes (Guatemala) and Prinzapolka (Nicaragua)

Meteorological forecast

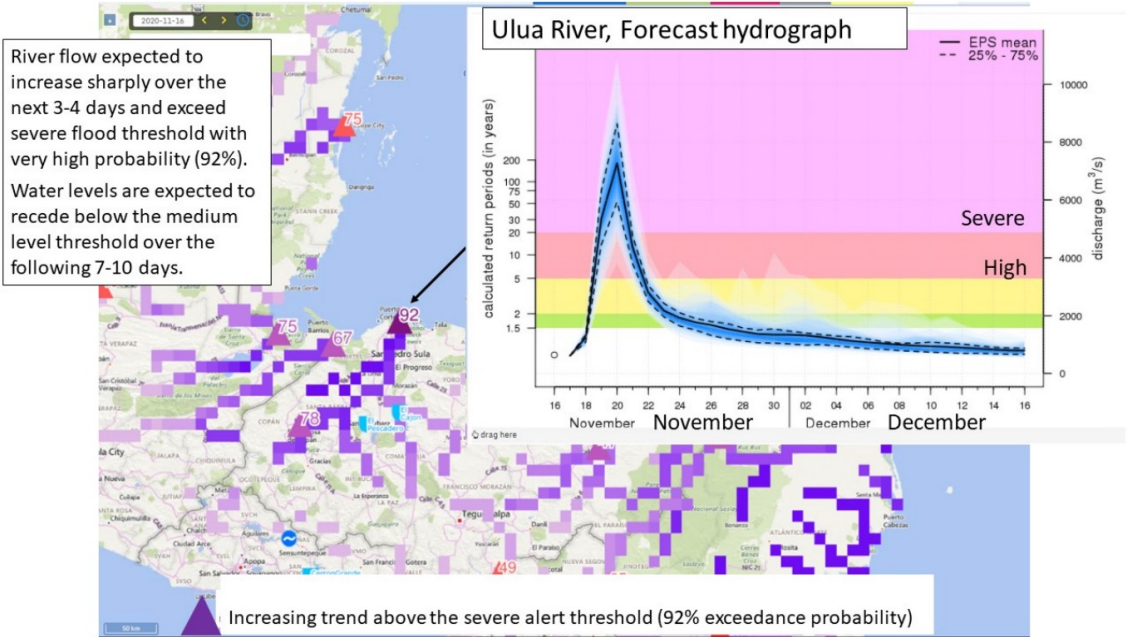
- Landfall of Category 5 hurricane IOTA is expected in northern Nicaragua in the late evening of Monday 16th November 2020, local time.
- Extreme precipitation is likely to be seen across Nicaragua, Honduras, Guatemala, El Salvador and into Belize, some areas will receive >500 mm over the next 5 days

Flood forecast & Impacts

- While forecasted rainfall totals are not anticipated to be as extreme as those from Eta, river catchments are still very wet following Eta which will amplify the likelihood of flooding
- GloFAS indicates that severe flooding is likely across northern and eastern Nicaragua, northern Honduras and eastern Guatemala
- The rivers expected to experience severe flooding over the next 3-5 days are: Ulua and Chamelecon in Honduras, Motagua and Polochic in Guatemala (flooded in Eta), Rio Coco on the Nicaragua / Honduras border and River Prinzapolka in eastern Nicaragua.
- A coastal surge is expected in northern Atlantico Norte (Nicaragua) and eastern Gracias a Dios (Honduras). The maximum surge may be up to 6.0 m between Puerto Cabezas and Cabo Gracias a Dios. Peak surge expected 0200 to 0400 17/11/2020 UTC

Honduras: ~500,000 people at risk. Most at-risk municipalities: San Pedro Sula, La Lima, Choloma.
Guatemala: ~150,000 people at risk. Most at-risk municipalities: Morales, Camotán, Los Amantes.
Nicaragua: ~75,000 people at risk. Most at-risk municipalities: Prinzapolka.

Note: GloFAS is designed to simulate large scale hydrological systems, so predictions for smaller watercourses should be evaluated with caution. GloFAS also does not simulate dam release or dam breaks. Estimates of exposure only account for flooding from rivers (exposed population from coastal surge and windstorm are not included).



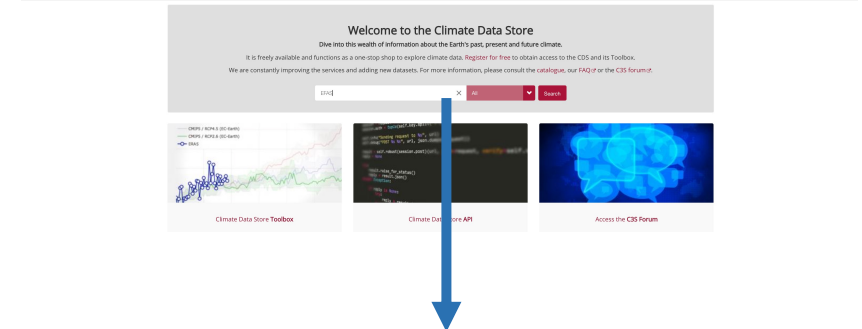
Consortium of University of Reading, University Bristol, HR Wallingford, Fathom global, ECMWF and funded by the UK FCDO





Open data availability on the C3S Climate Data Store (CDS)

Free and open: cds.climate.copernicus.eu



River discharge and related historical data from the European Flood Awareness System

Overview | Download data | Documentation

This dataset provides gridded modelled daily hydrological time series for meteorological observations. The data set is a consistent representation of the most important hydrological variables across the European Flood Awareness System (EFAS) domain. The temporal resolution is up to 30 years modelled time series of:

- River discharge
- Soil moisture for three soil layers
- Snow-water equivalent

It also provides static data on soil depth for the three soil layers. Soil moisture and river discharge data are accompanied by ancillary files for interpretation (see related variables and files in the documentation).

This dataset was produced by forcing the LISFLOOD hydrological model with gridded observational data of precipitation and temperature at a 50-km resolution across the EFAS domain. The most recent version uses a 6-hourly time step, whereas older versions use a 24-hour time step. It is available from 1991-01-01 up until near-real time, with a delay of 30 days. The real-time data is only available to EFAS partners.

Companion datasets, also available through the CDS, are forecasts for users who are looking medium-range forecasts, reforecasts for research, local skill assessment, and post-processing, and seasonal forecasts and reforecasts for users looking for long-term forecasts. For users looking for global hydrological data, we refer to the Global Flood Awareness System (GloFAS) forecasts and historical populations. All these datasets are part of the operational Flood Forecasting within the Copernicus Emergency Management Service (CEMS).

DATA DESCRIPTION

Data type	Gridded. The geographical projection is the WGS84 (EPSG:31466) Lambert Conformal Conic Coordinate Reference System (ETRS-LAEA).
Horizontal coverage	Europe. The domain spans from northern Africa beyond the northern tip of Scandinavia, in the west it ranges far into the Atlantic Ocean and in the east as far as to the Caspian Sea.
Vertical resolution	3 levels for soil moisture, surface level for river discharge and snow depth water equivalent.
Temporal coverage	1 January 1991 to near real-time (30 day delay) for the most recent version.
Temporal resolution	6 hourly from version 4, 24-hourly for previous versions.
File format	GDAL and NetCDF 4.
Versions	Current version: EFAS v4.0 released 2020-10-14. For older versions we refer to the documentation.
Update frequency	New data are added continuously with a minimum of 1 month lag with respect to the actual data for the latest version. Older versions will be discontinued when a new version is released.

MAIN VARIABLES

Name	Units	Description
River discharge in 30-day (24-hour)	m ³ /s	Volume rate of water flow, including sediments, chemical and biological materials, in the river channel averaged over a time step through a cross-section. The value is an average over each 24-hour time step.
River discharge in 6-hour	m ³ /s	Volume rate of water flow, including sediments, chemical and biological materials, in the river channel averaged over a time step through a cross-section. The value is an average over each 6-hour time step.
Snow depth water	kg	The value represent the mass of water per square meter if all the snow in the grid box would be melted. The value is instantaneous meaning that it is valid for the last time step of the ingestion at

Contact
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Licence
CC-BY-NC-ND 4.0 International

Publication date
2019-05-09

References
Citation
DOI: 10.2481/100_e400960-0

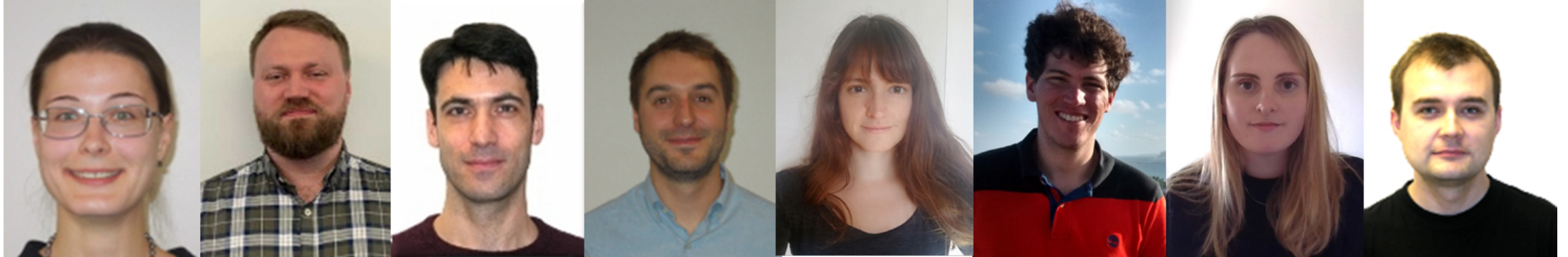
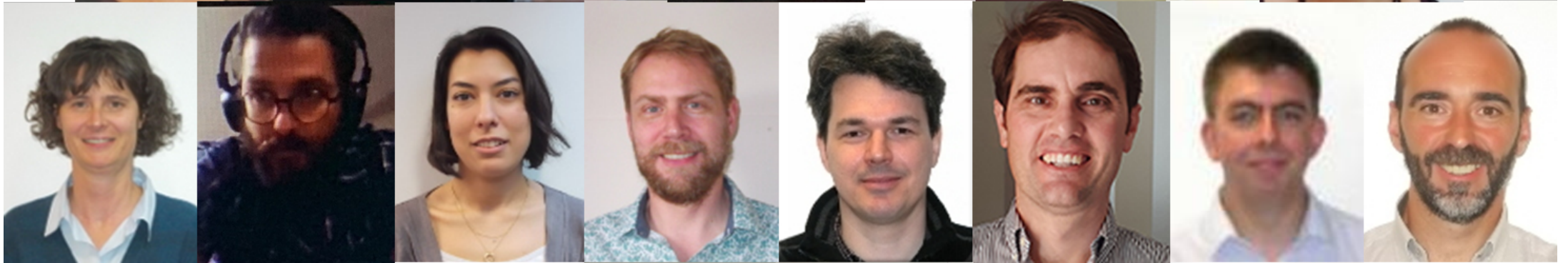
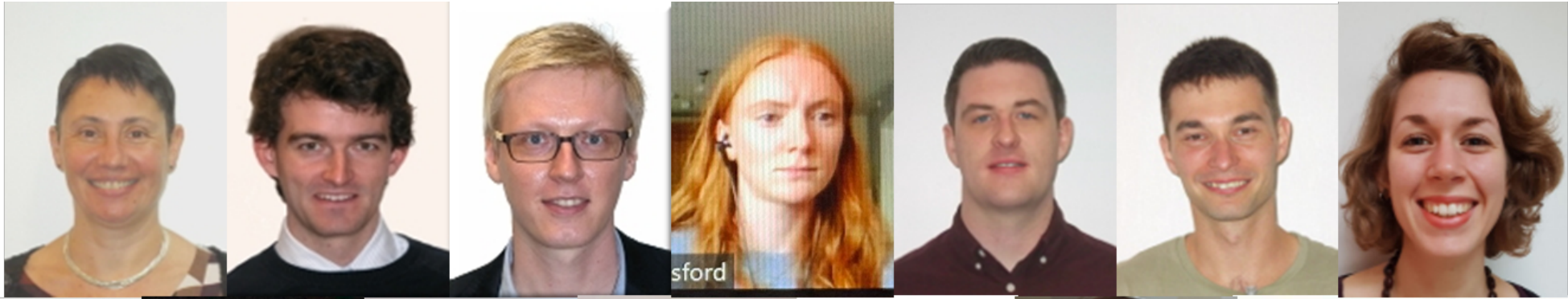
Related data
Reforecasts of river discharge and related data by the European Flood Awareness System
River discharge and related forecasted data by the European Flood Awareness System
Seasonal forecasts of river discharge and related data by the European Flood Awareness System
Seasonal reforecasts of river discharge and related data by the European Flood Awareness System

Dataset	CDS catalogue form
EFAS	
EFAS historical reanalysis	https://cds.climate.copernicus.eu/cdsapp#!/dataset/efas-historical
EFAS forecasts	https://cds.climate.copernicus.eu/cdsapp#!/dataset/efas-forecast
EFAS reforecasts	https://cds.climate.copernicus.eu/cdsapp#!/dataset/efas-reforecast
EFAS seasonal forecasts	https://cds.climate.copernicus.eu/cdsapp#!/dataset/efas-seasonal
EFAS seasonal reforecasts	https://cds.climate.copernicus.eu/cdsapp#!/dataset/efas-seasonal-reforecast
GloFAS	
GloFAS historical reanalysis	https://cds.climate.copernicus.eu/cdsapp#!/dataset/cems-glofas-historical
GloFAS forecasts	https://cds.climate.copernicus.eu/cdsapp#!/dataset/cems-glofas-forecast
GloFAS reforecasts	https://cds.climate.copernicus.eu/cdsapp#!/dataset/cems-glofas-reforecast
GloFAS seasonal forecasts	https://cds.climate.copernicus.eu/cdsapp#!/dataset/cems-glofas-seasonal
GloFAS seasonal reforecasts	https://cds.climate.copernicus.eu/cdsapp#!/dataset/cems-glofas-seasonal-reforecast



Emergency
Management

A year of "extreme" remote working - The CEMS-Flood Team at ECMWF



Thank you!

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EFAS website:
<https://www.efas.eu/>

GloFAS website:
<https://www.globalfloods.eu/>

CEMS-Flood documentation
wiki:
[https://confluence.ecmwf.int/
display/COPSRV/CEMS-Floods](https://confluence.ecmwf.int/display/COPSRV/CEMS-Floods)

CEMS-Flood Data via CDS:
[https://cds.climate.copernicus.
eu/#!/home](https://cds.climate.copernicus.eu/#!/home)