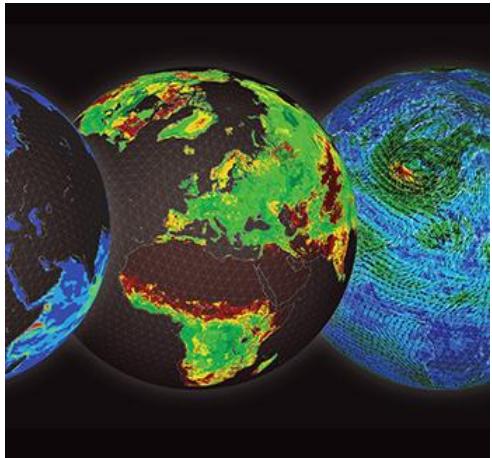


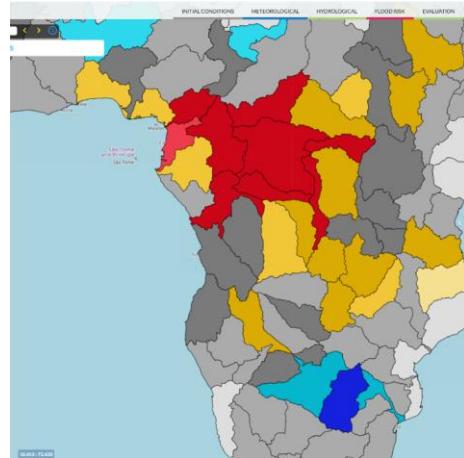
Operational global hydrological sub-seasonal and seasonal forecasting

Prepared for WMO Online Workshop on Global Tools for
Flood and Drought Prediction
Christel Prudhomme, Ervin Zsoter, Mohamed Azhar, Shaun Harrigan

The training pillars



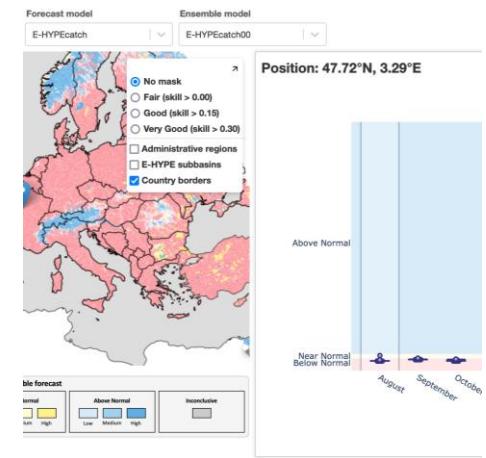
Context of sub-seasonal and seasonal hydrological forecasting



Hydrological outlook products



Data access and analysis



The C3S Water service

Who are we?



**Christel
Prudhomme**
Lead of the hydrological
monitoring and
forecasting team



Ervin Zsoter
Hydrometeorological
forecasting expert



**Mohamed
Azhar**
Hydrologist specialised
in GIS and data
management

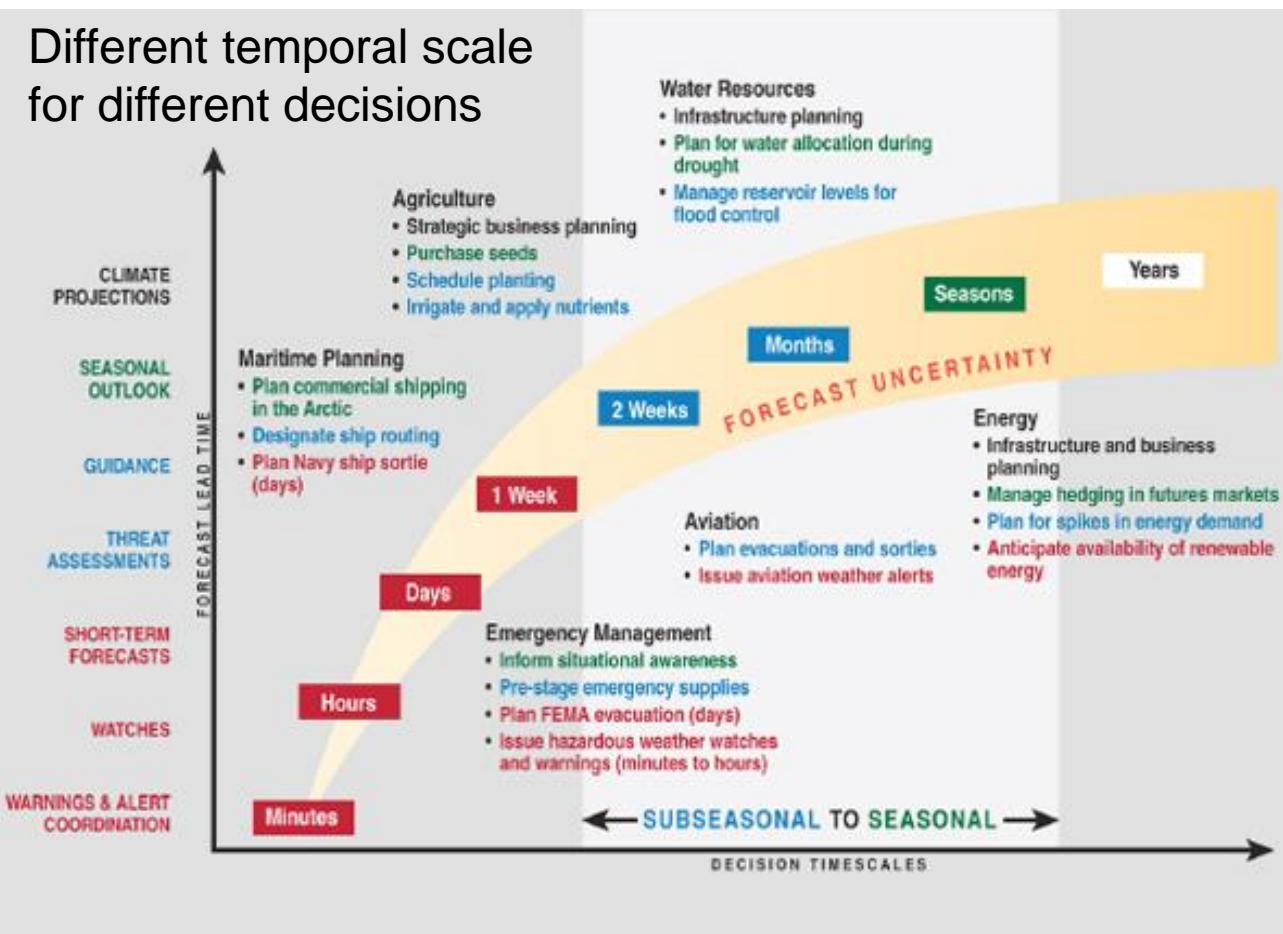


**Shaun
Harrigan**
Scientist in
Hydroclimatology

Sub-seasonal and seasonal forecasting

Why do we want outlooks several weeks/ months ahead?

Different temporal scale for different decisions

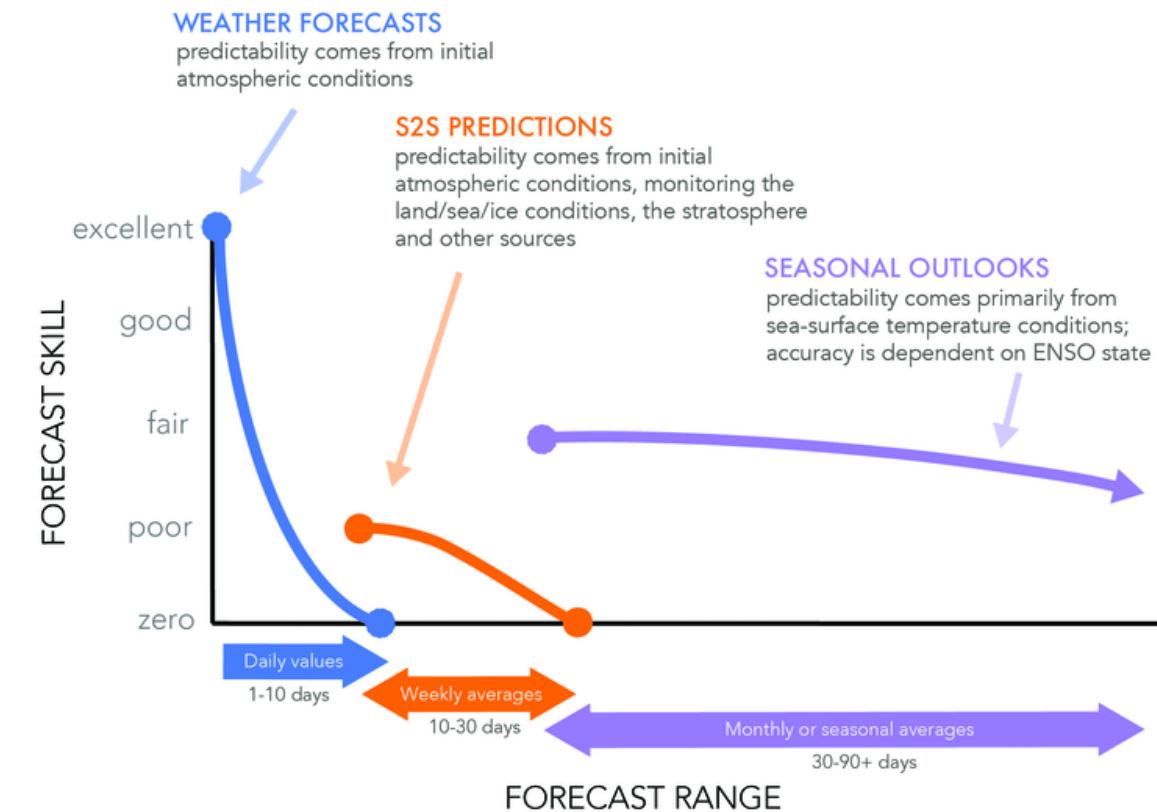


Source: <https://www.nap.edu/read/21873/chapter/5#44>



EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Trade-off between decision making and skill



Source: IRI, adapted by E. Gawthrop from figure by T. Barnston

Where does predictability come from? And what can be expected?

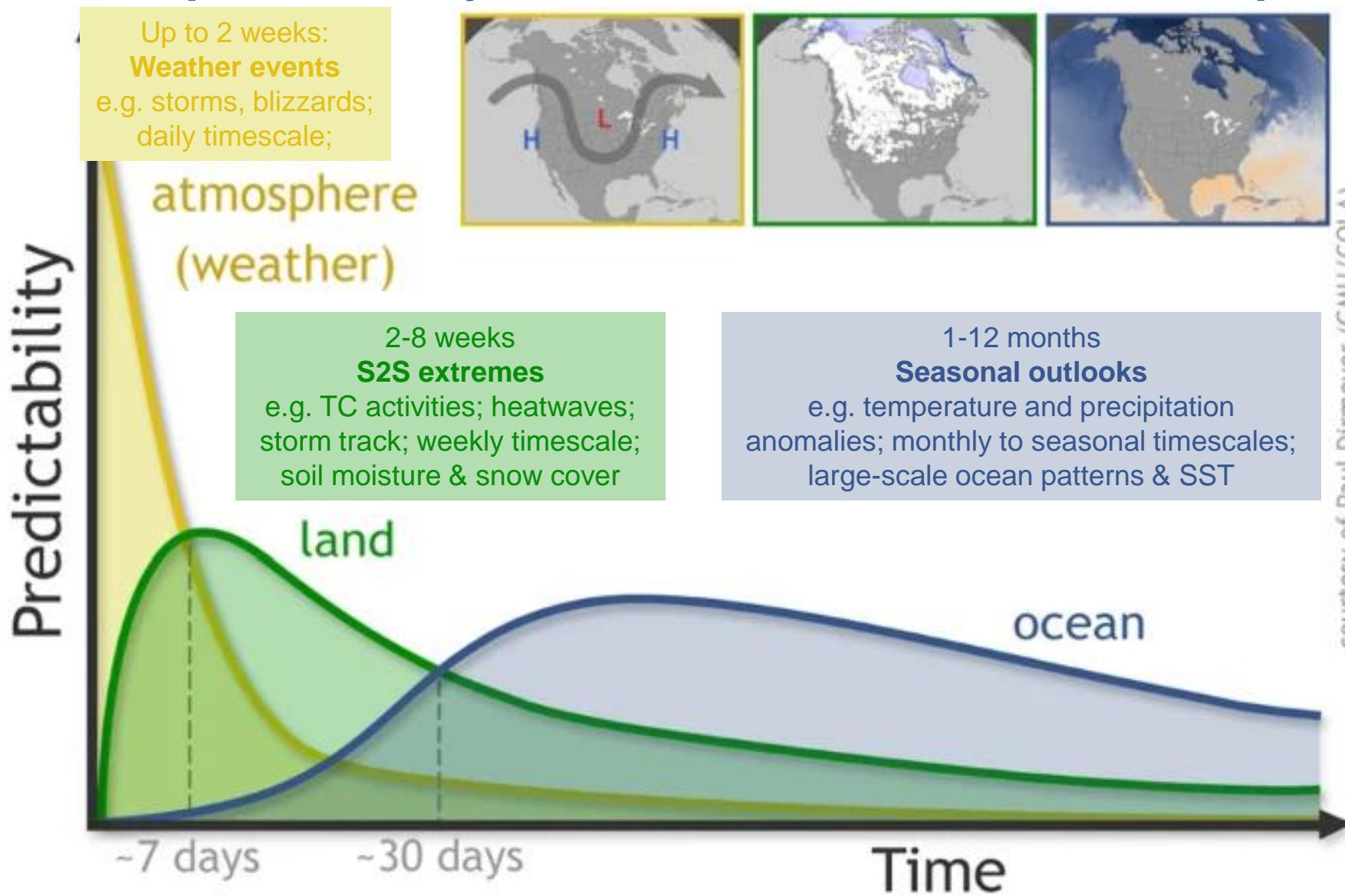
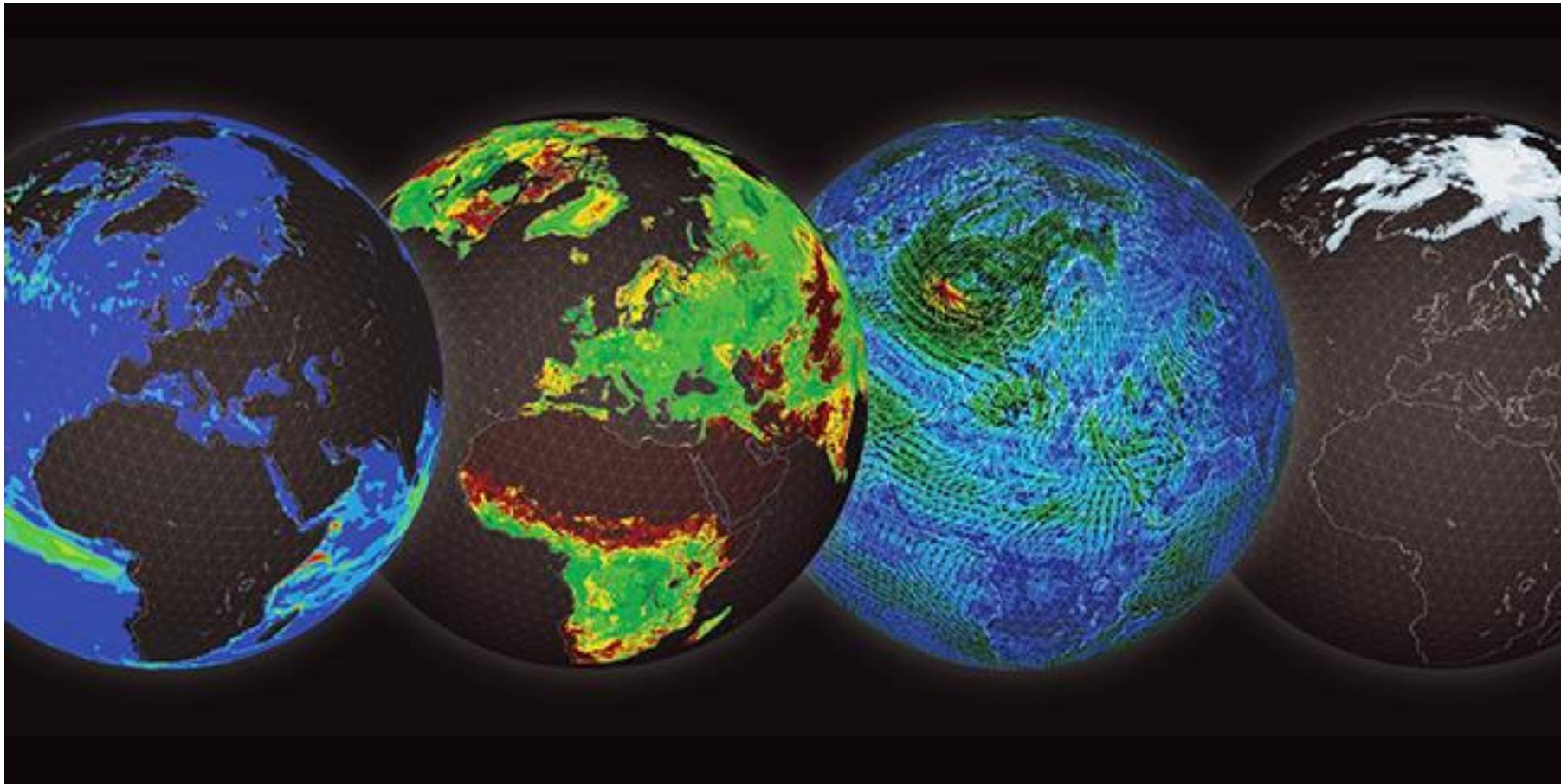


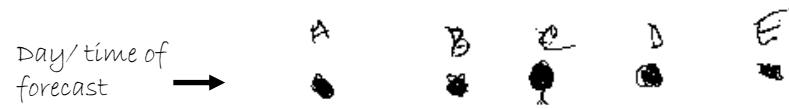
Diagram adapted from original by Paul Dirmeyer, GMU/COLA,

ECMWF forecasts: an earth-system approach



Coupled Ocean, Land and Atmosphere modelling

Uncertainty in weather forecasting: the pinball analogy



The evolution of the weather with time is **chaotic**

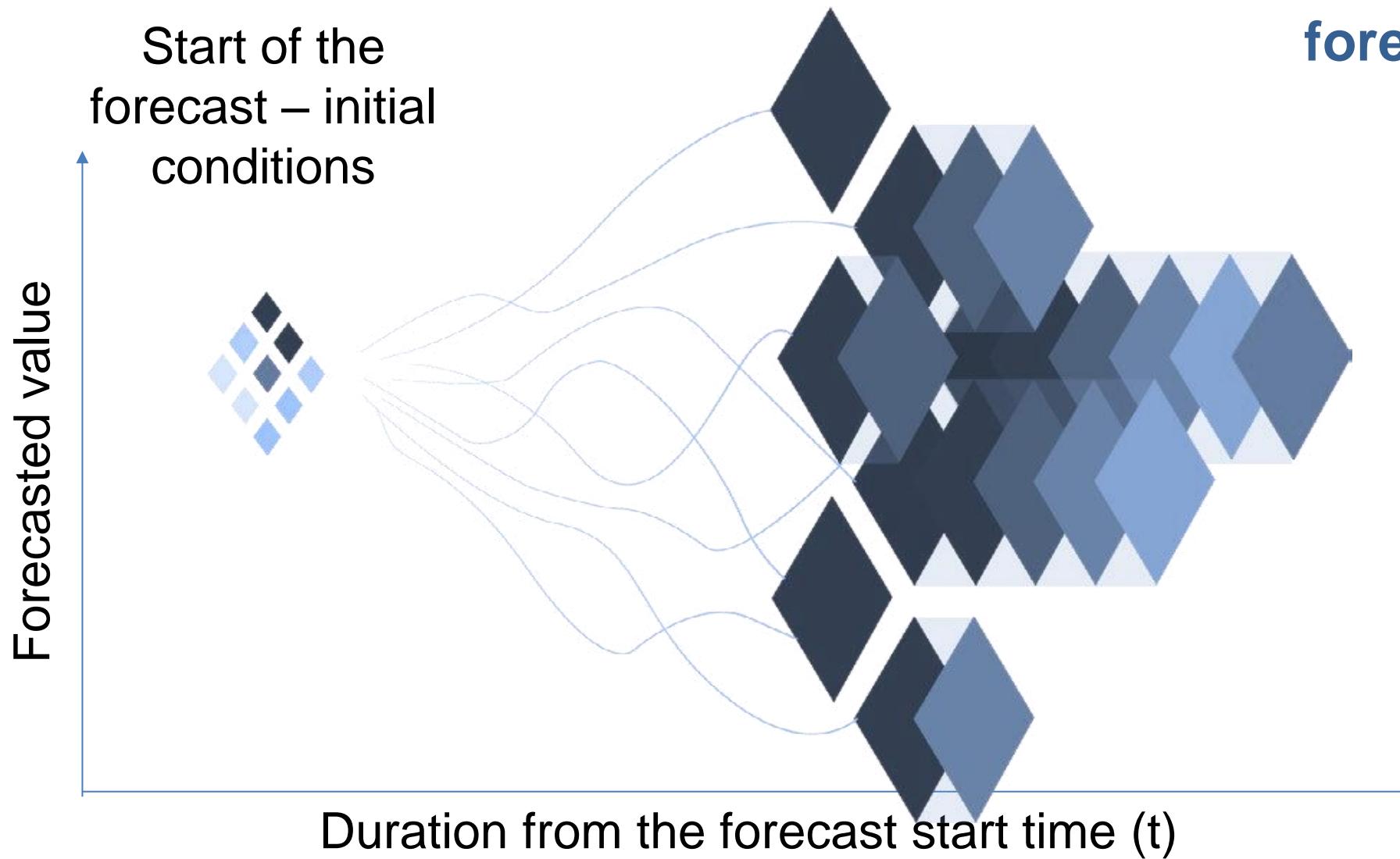
A small change in the **initial conditions** may lead to a large difference in the weather trajectory

The aim of a useful forecast is to:

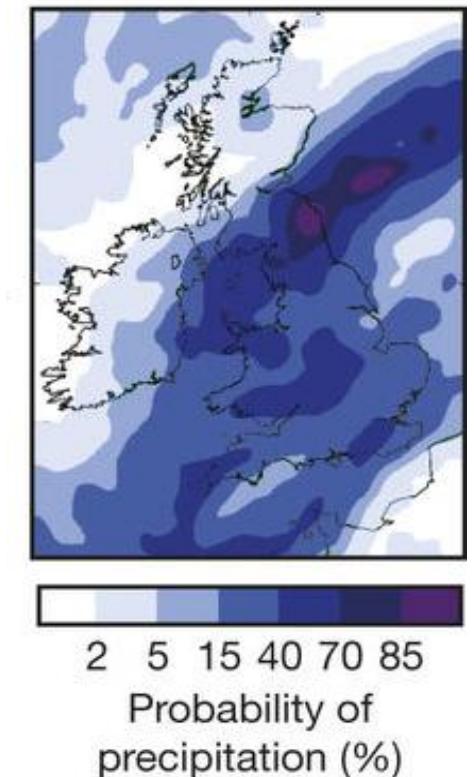
- Identify the **range of possible outcomes** (uncertainty)
- If possible with their **associated likelihood** (probability distribution)
- Including the **most extreme scenarios**

Source: <http://www.meteor.iastate.edu/gccourse>

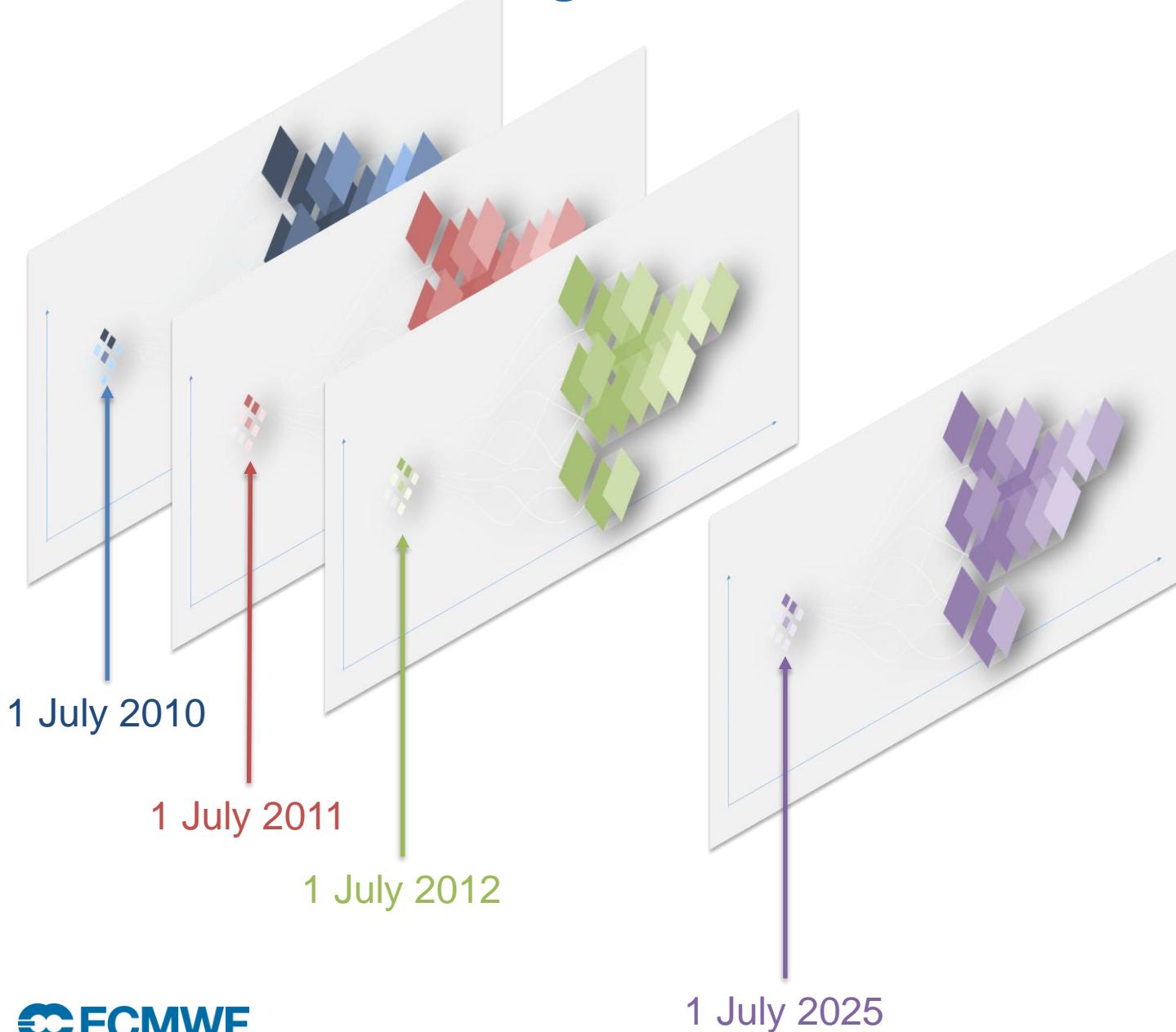
Capturing forecast uncertainty



Ensemble forecasting



Reforecasts: forecasts generated for initial conditions of past dates



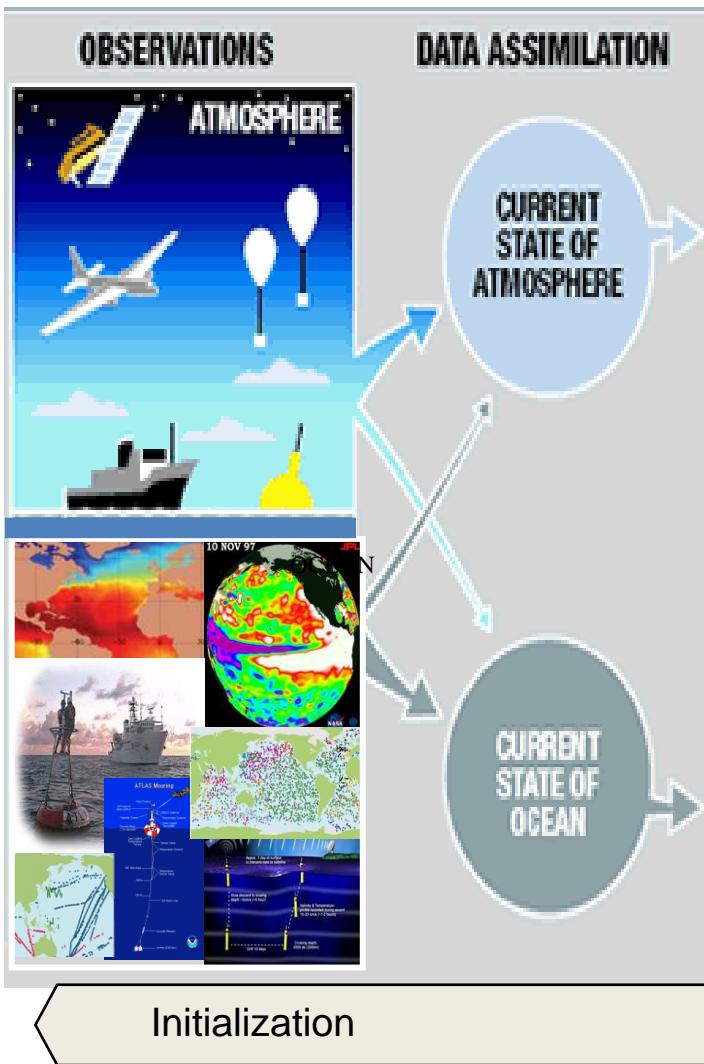
What are they?

- **Historical data**: reforecasts created by running the NWP on historical dates
- **Consistent model**: use same NWP model and configuration as real-time operational forecast
- **Reanalysis data**: typically used as initial conditions

What can they be used for?

- **Climatological context**: multiple realisations of weather to provide model-related climatology or thresholds
- **Forecast skill** : long dataset useful to assess the skill of the model over different periods
- **Diagnostic**: understanding when and why a model makes certain errors to guide future model development

The ECMWF Integrated Forecasting System



Hydrological prediction

Source of predictability

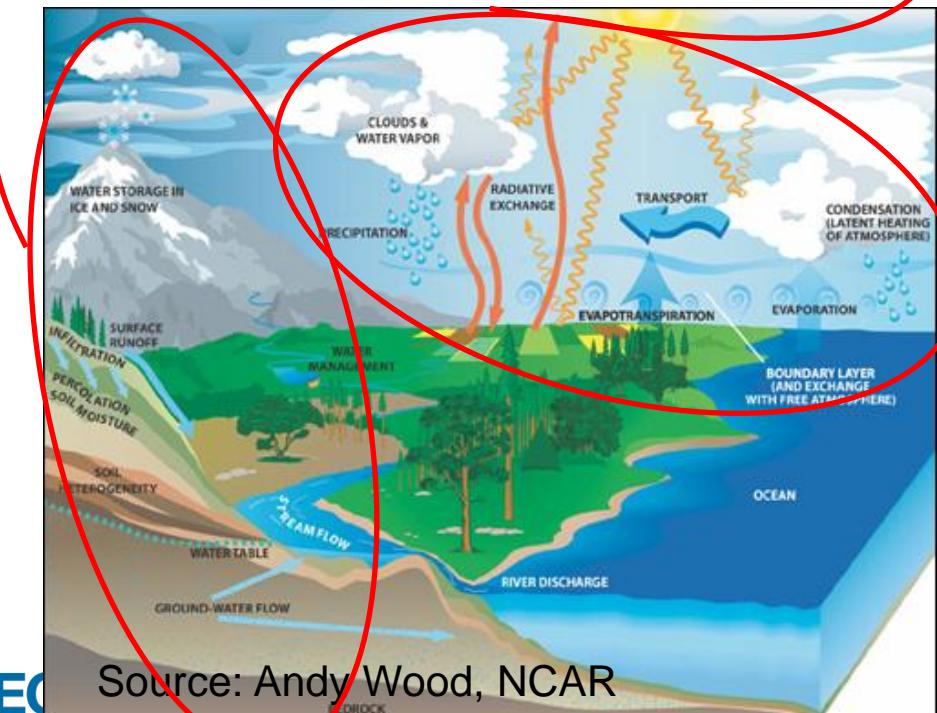
Atmospheric: (Skilful) seasonal forecasts:

SSTs/MSLP → Precipitation, Temperature

Provided through NWP forecasts

Initial Hydrologic Conditions (IHCs):

Soil moisture, groundwater, snow accum./melt

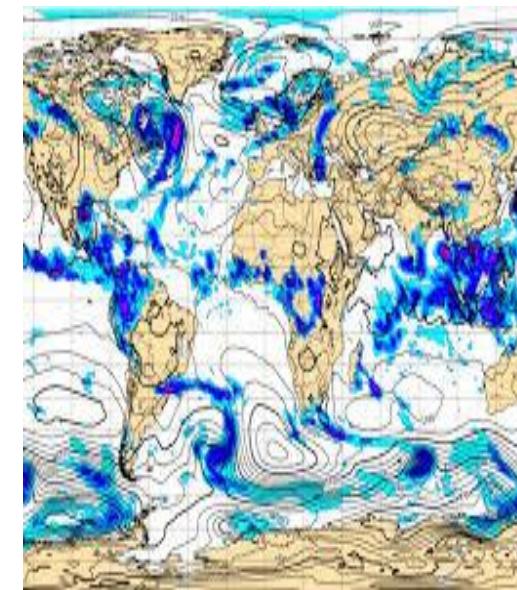


Provided through NRT-update of land water status

Interpolated observations when possible
Reanalysis in NRT good

Weather analysis

best guess of atmospheric conditions



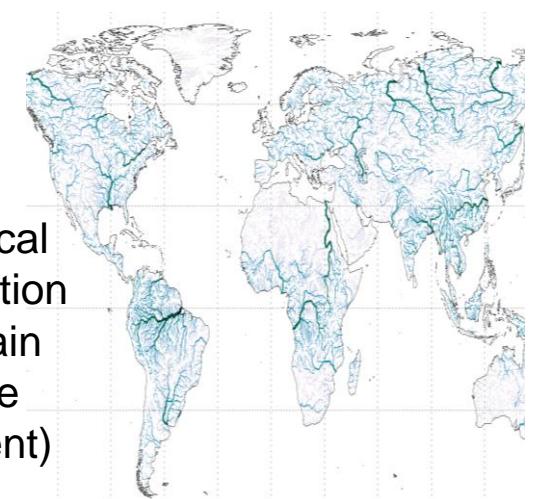
e.g. precipitation, temperature, evaporation

Hydrological analysis

best guess of land water conditions or IHCs



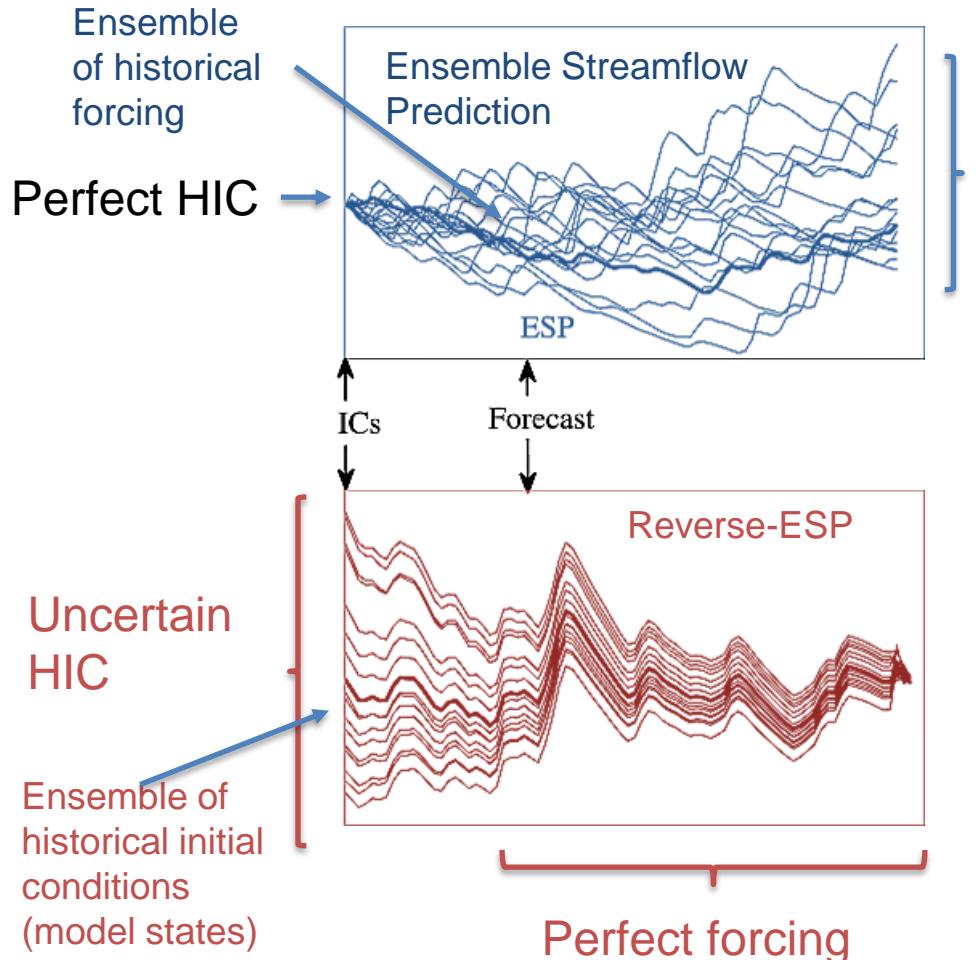
Hydrological transformation
(full domain coverage requirement)



e.g. river discharge, soil moisture, snow water equivalent

Initial conditions vs forecast uncertainty

Ensemble experiments to test skill sensitivity



Li et al., 2009, JGR, DOI:
(10.1029/2008JD010969)



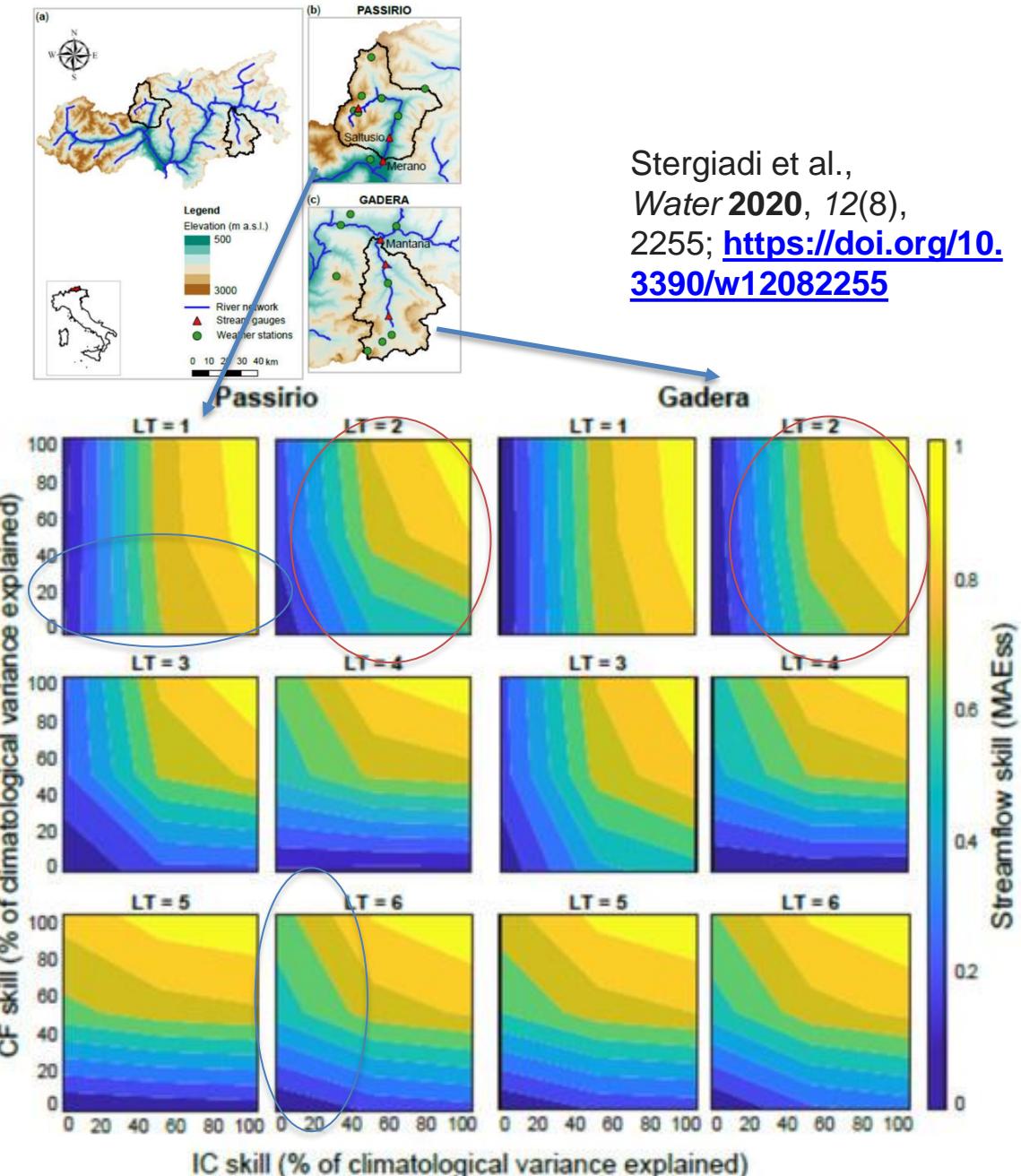
EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Forecast
Uncertainty

Calculate the
skill of each
forecasts by
comparing
with
observations

Importance HIC vs FC varies:

- with leadtime
- with catchment /season



Stergiadi et al.,
Water 2020, 12(8),
2255; <https://doi.org/10.3390/w12082255>

Forecast generation strategies

Statistical



Observed historical streamflow

Streamflow to streamflow
Statistical analyses
Low compute cost



Seasonality

ESP



Observed historical + NRT weather

Weather to streamflow
Physics/ data driven models
Medium compute cost



Initial Hydrological Conditions

Hybrid



Observed historical + modelled future weather
Observed NRT streamflow

Streamflow & weather to streamflow
Statistical analyses (analogues)
Low compute cost



Initial Hydrological Conditions
Future weather patterns

Dynamical prediction



Observed NRT + future modelled weather data



Weather to streamflow
Physics/ data driven models
High compute cost



Initial atmosphere, land, ocean and hydrological conditions
Future weather timeseries

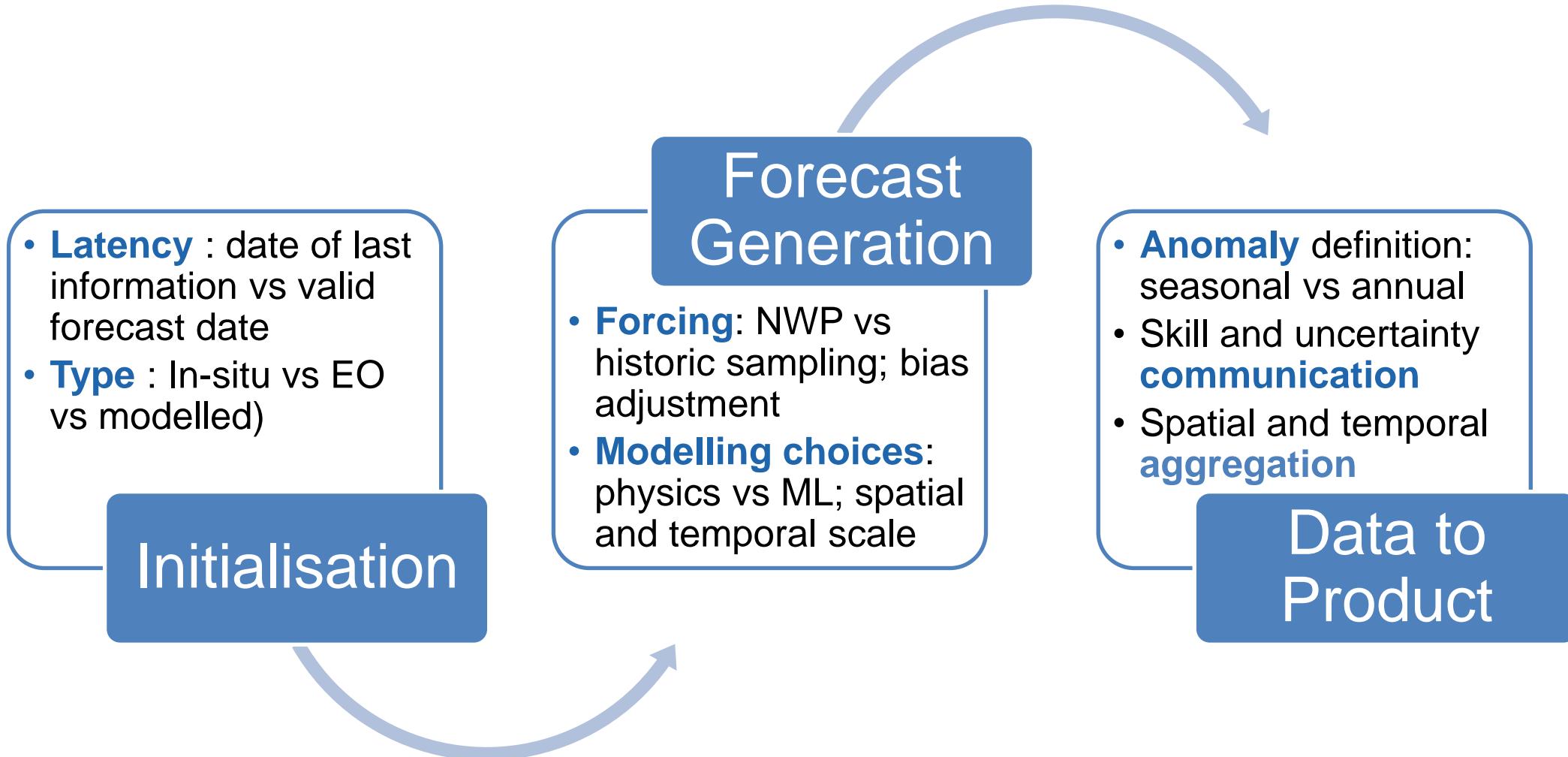
Data

Method

Predictability

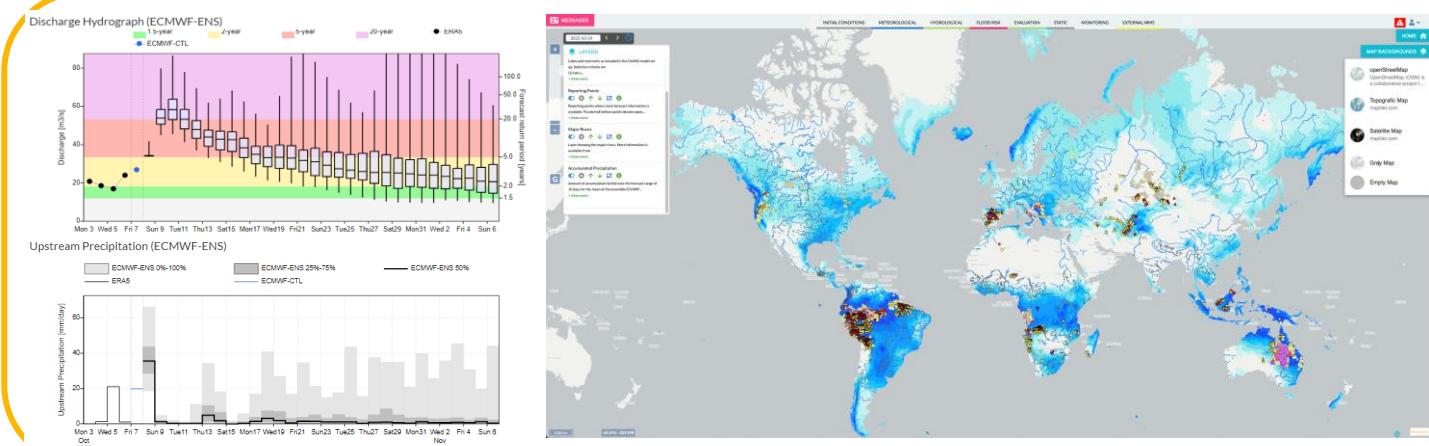
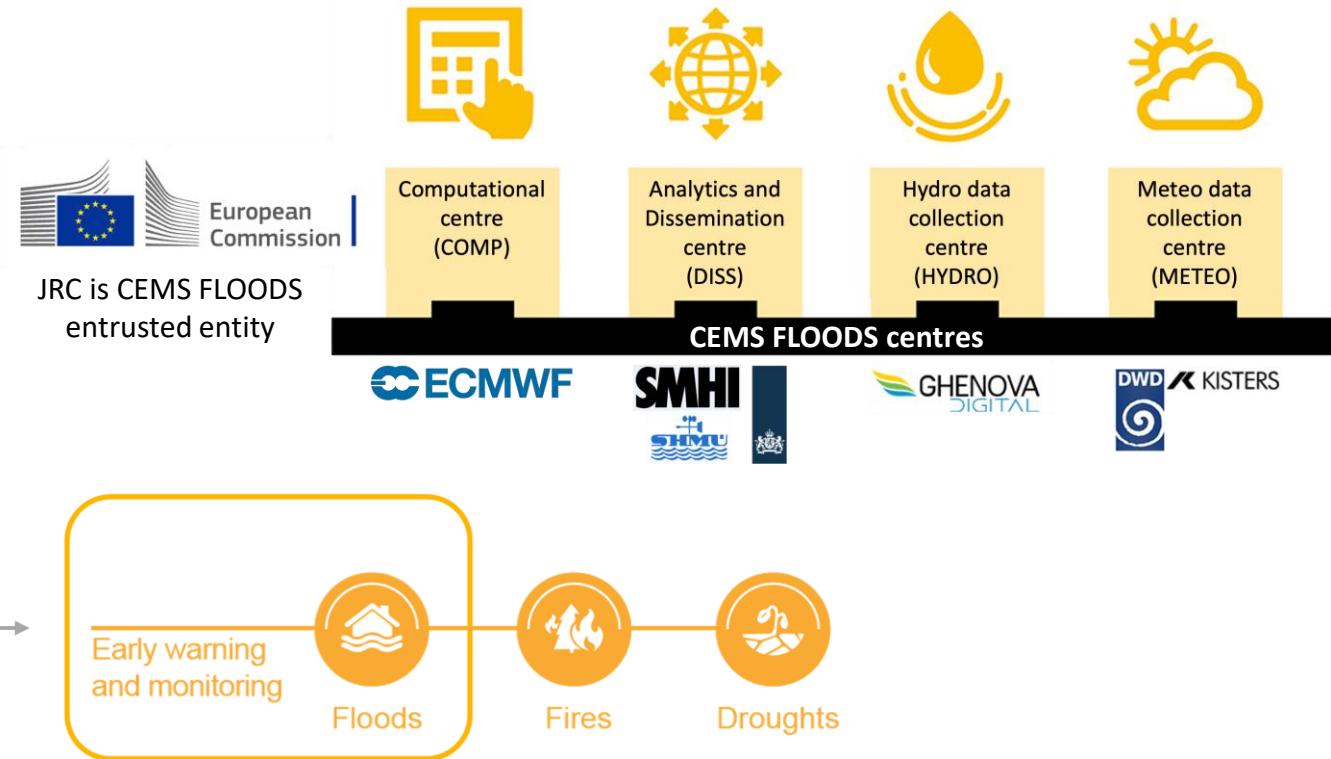
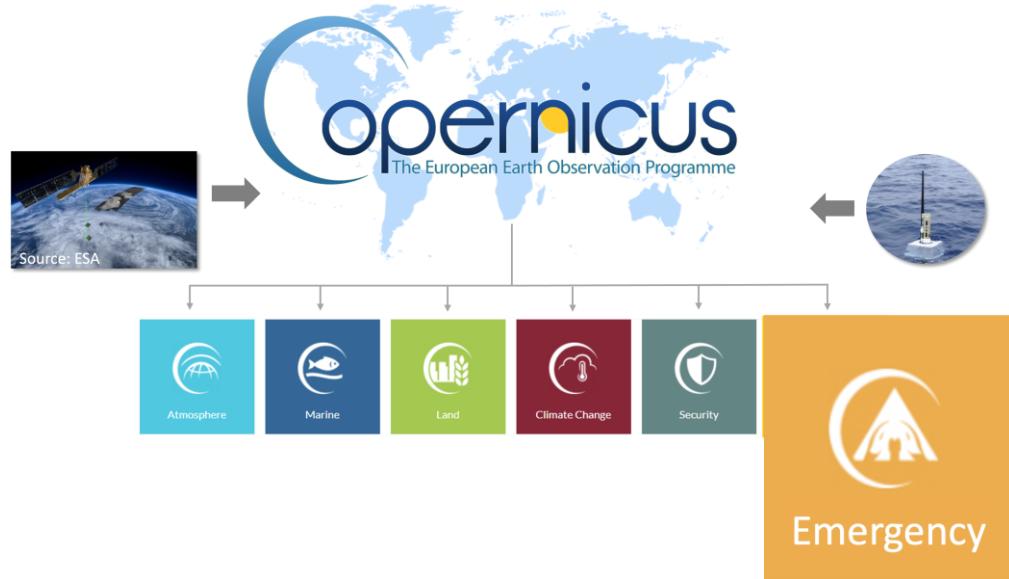
Assumptions

Beyond the modelling chain: data and products for actionable forecasts



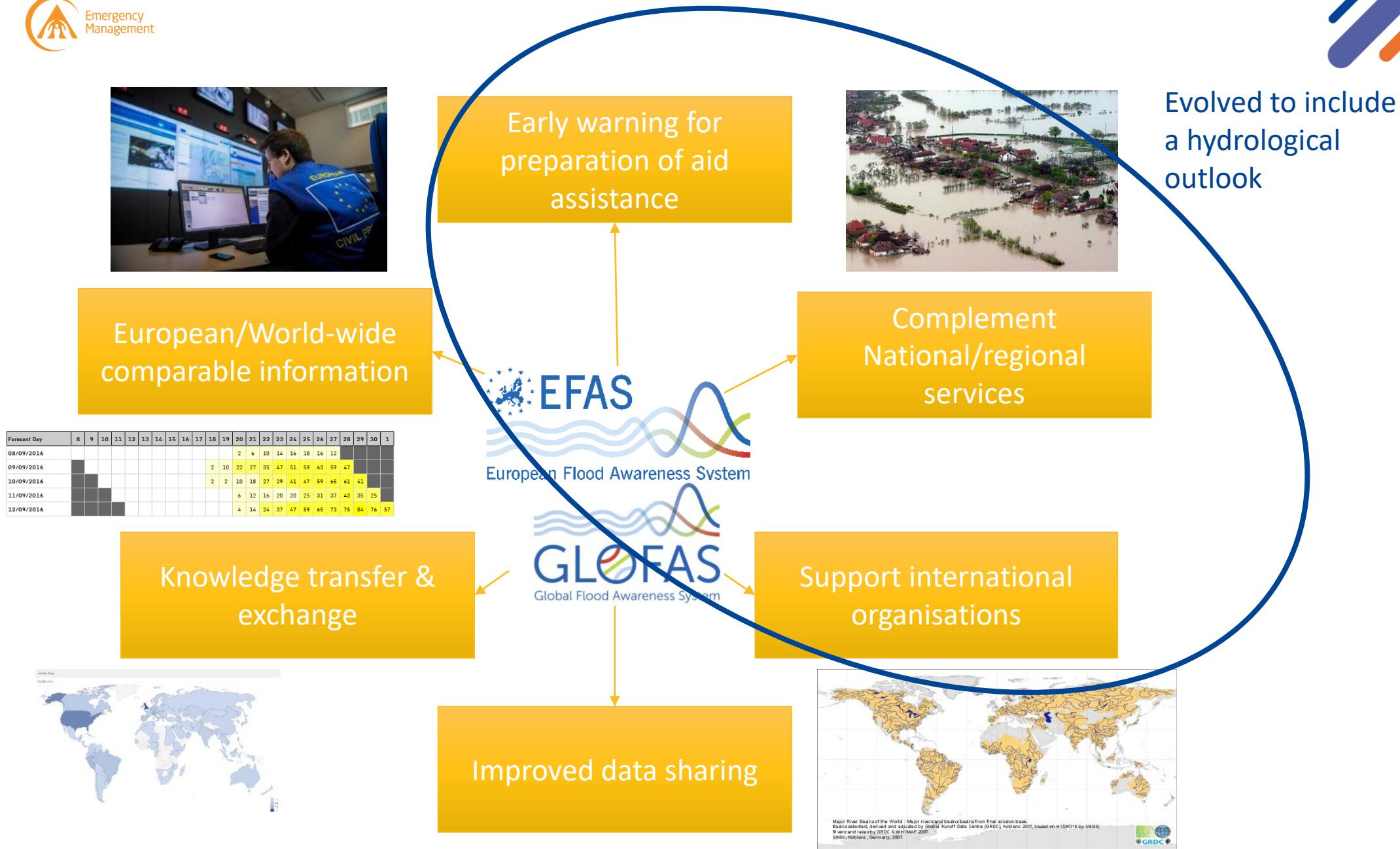
The GloFAS sub- seasonal and seasonal hydrological outlook system

CEMS-Flood context



The **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. They support **ERCC activities**.

GloFAS products are freely accessible to all, and highlights **flood signal** over next 30 days and **hydrological outlooks** over next 7 months

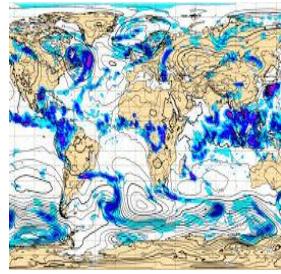




#EUSpace



The CEMS Flood processing chain



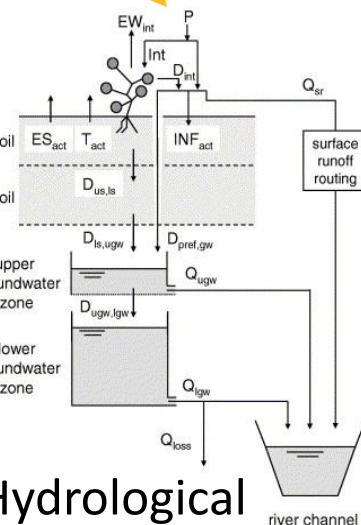
Weather
ERA5T to
forecast date



Weather
forecasts up
to 7 months

ECMWF ENS / SEAS5

Time-invariant data
Geo-spatial maps, parameters



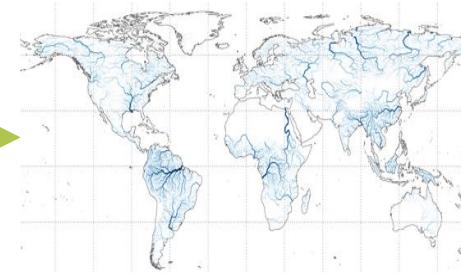
Hydrological
Model
LISVAP, LISFLOOD

Surface fields at 5km resolution
Calibrated ~2000 catchments
Covering Global domain

Initialisation

Forecast Generation

Data to product



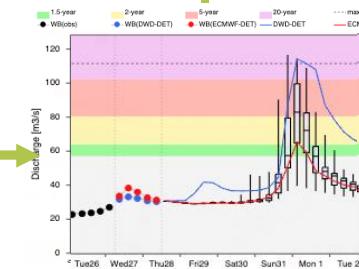
Hydrological status
update
*River discharge, Soil
moisture, etc...*



Ensemble hydrological
forecast datasets
*River discharge, soil moisture,
etc..*



Climatology
Flood thresholds

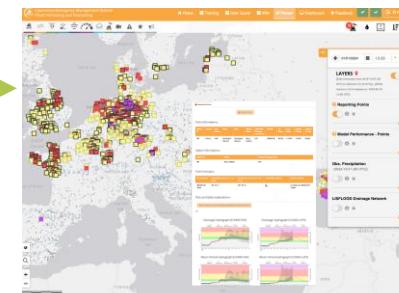


Hydrological forecast
product generation
*Flood hydrographs, seasonal
outlooks, etc...*



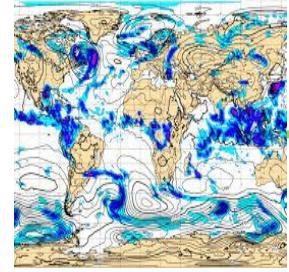
Data Service
EWDS

Reanalysis, forecasts,
reforecast, seasonal
forecasts and
seasonal reforecasts



Web Service
CEMS GLOFAS

The CEMS Flood processing chain



Weather
ERA5T to
forecast date

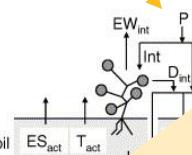


Weather
forecast
to 7 months

24h-15d
daily



Time-invariant data
*Geo-spatial maps,
parameters*

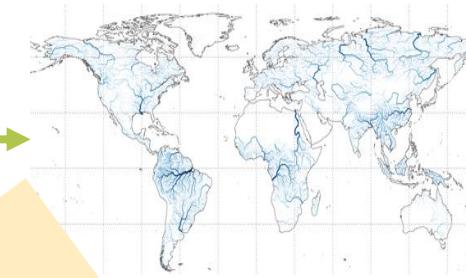


Medium-range
Ensemble NWP (ECMWF IFS-ENS)
Daily discharge + hydro variables from LISFLOOD

Hydrological
Model
LISVAP, LISFLOOD

Surface fields at 5km resolution

1-6w
daily



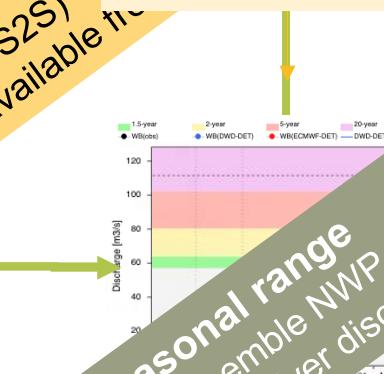
Hydrological status
update
*River discharge, Soil
moisture, etc...*

Sub-seasonal range
Ensemble NWP (blended IFS-ENS+S2S)
Daily discharge from LISFLOOD (available from 1-6w)

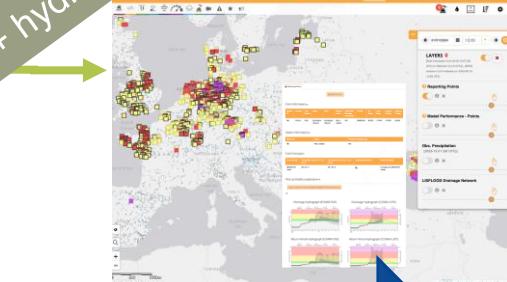
Ensemble
hydrological

monthly

Products (maps, graphs and metadata information) accessible from GloFAS-IS - [Ervin](#)
Data (river discharge, soil wetness index, snow water equivalent time series outputs) accessible from EWDS for downstream applications - [Mohamed](#)



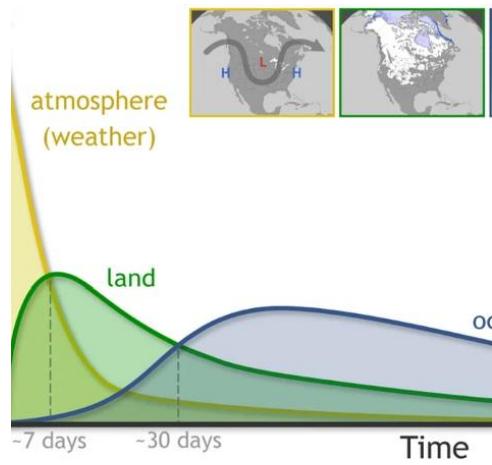
Seasonal range
Ensemble NWP (SEAS5)
Daily river discharge + hydro variables from LISFLOOD (available from 1-7m)



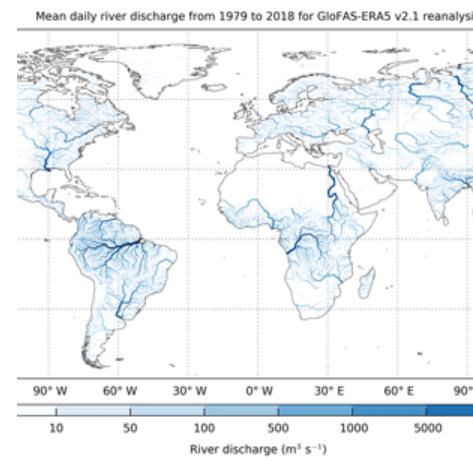
Lead time
1-7m

Update frequency

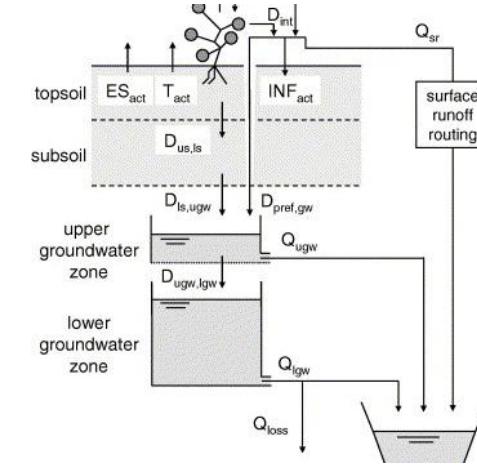
Recap of hydrological long-range forecasting



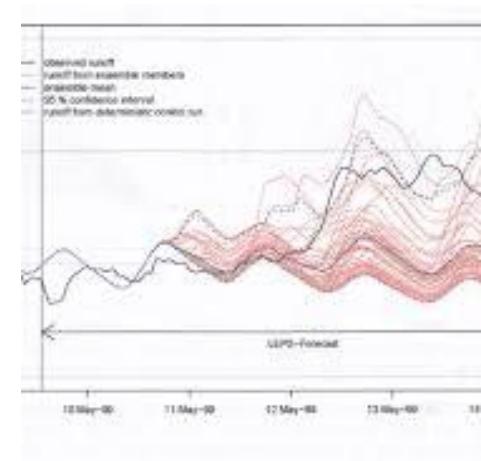
Role of **land and ocean** in the predictability of weather forecasts for weeks to months



Hydrological Initial Condition influences river discharge predictability



Different **forecast generation chains** with different data needs and complexity



Ensemble forecasting and **reforecasts** to capture uncertainty and skill

Sub-seasonal/seasonal hydrological outlook forecast products

Do we need weekly and monthly averaging?

Skill drops to near 0 on the daily scale beyond 15-20 days

Sub-seasonal SSW index CRPSS

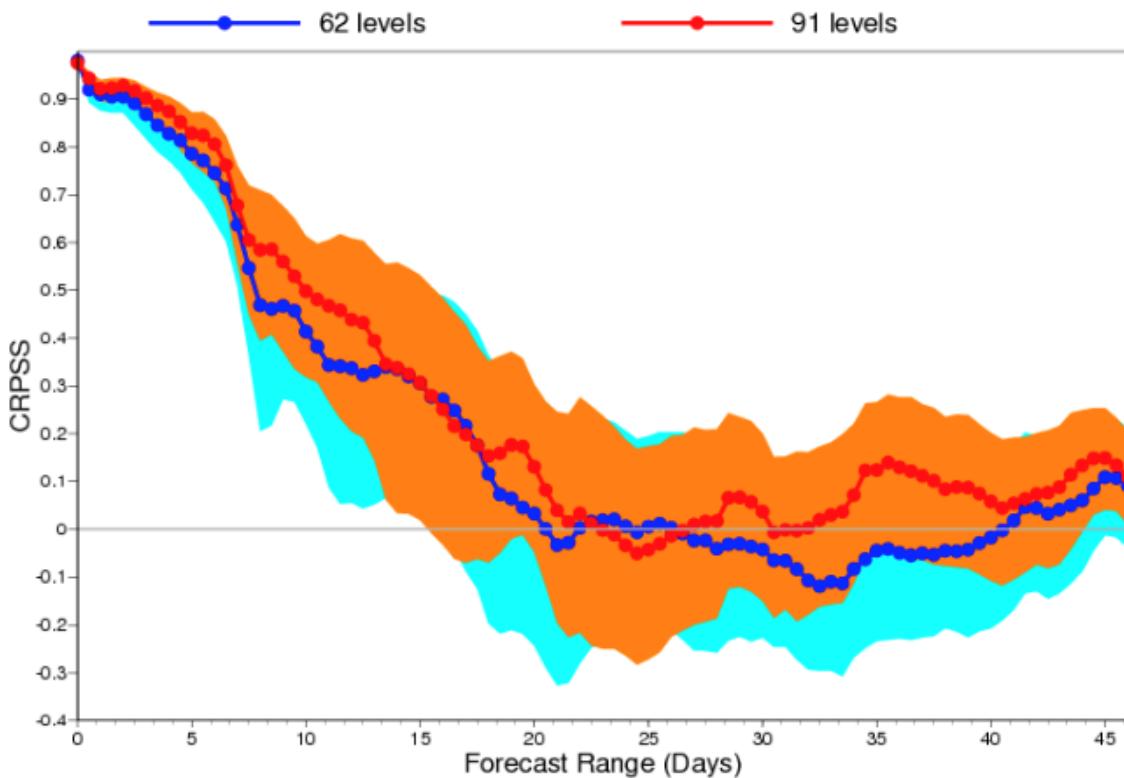
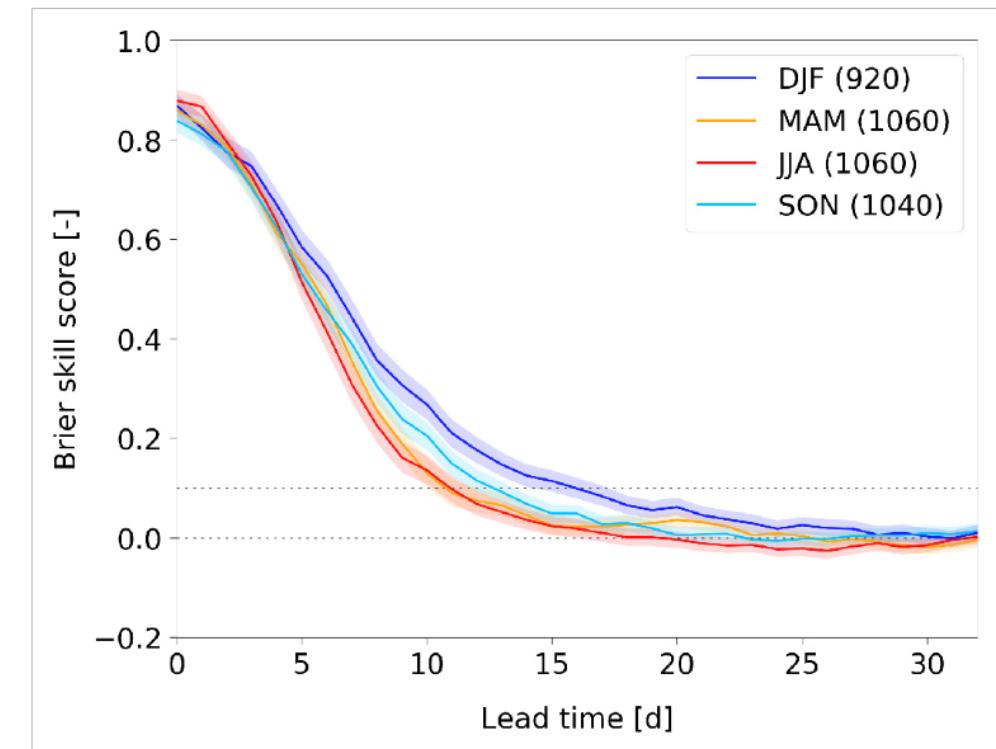


Figure 11: Ranked probability skill scores of the SSW index computed from 80 15-member 45-day reforecasts starting the 1st February, May, August and November 1989 to 2008 using IFS cycle 36r4. The red curve shows the RPSS scores obtained when using 91 vertical levels and the blue curve shows the RPSS skill scores obtained with the 62 vertical levels control experiment.

<https://doi.org/10.1002/qj.2256>

Sub-seasonal weather regime Brier Skill Score



Seasonal multicategory BSS for all weather regimes (life cycle; including the "no regime" category) as a function of lead time. The numbers in the legend show the number of forecasts in the respective season. The stratification is done according to whether the forecast initial date is in the corresponding season [Colour figure can be viewed at wileyonlinelibrary.com]

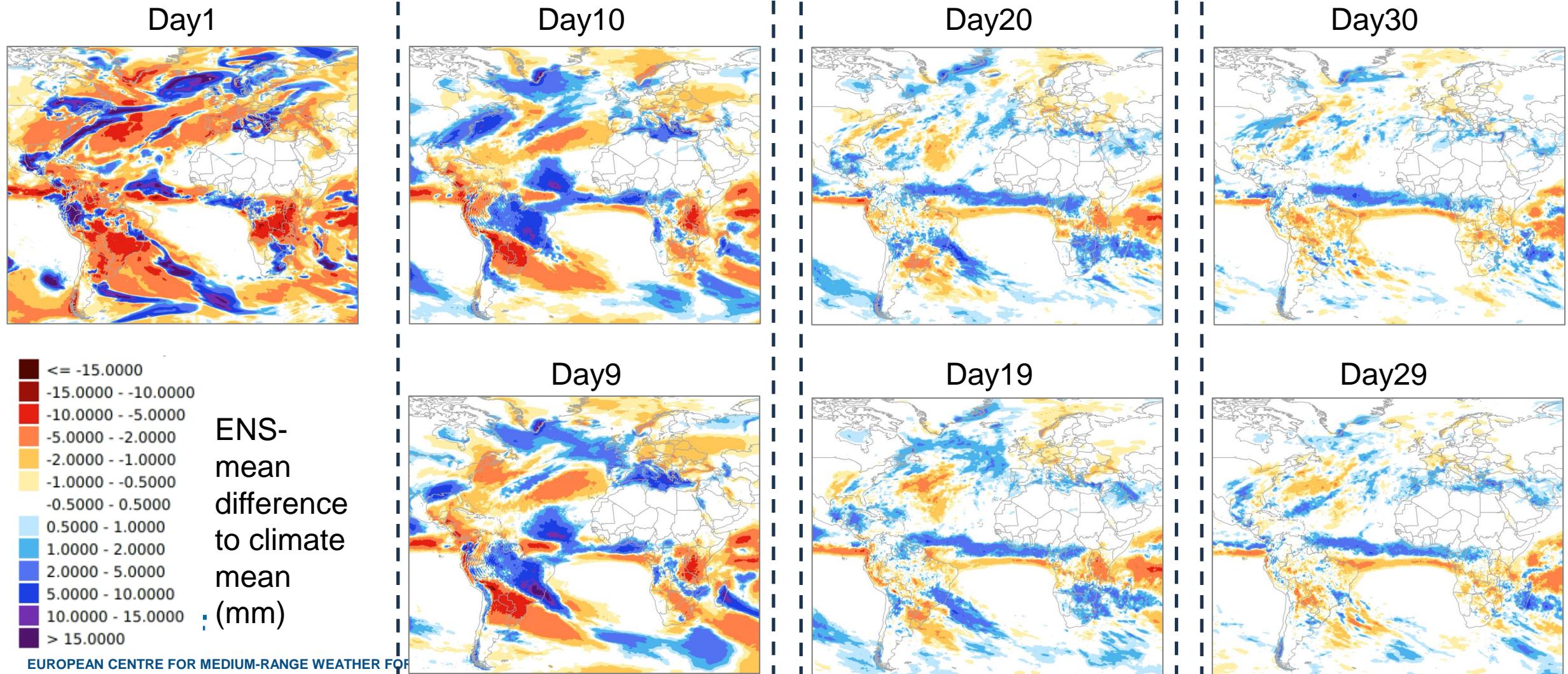
<https://doi.org/10.1002/qj.4178>

Weekly/monthly averaging – Precipitation anomalies

Day-to-day variability in forecast signal much reduced beyond 15 days

FC: 2025-11-27

Strongest anomalies remain, with 'random'/small-scale variability to be smoothed by weekly/monthly averaging

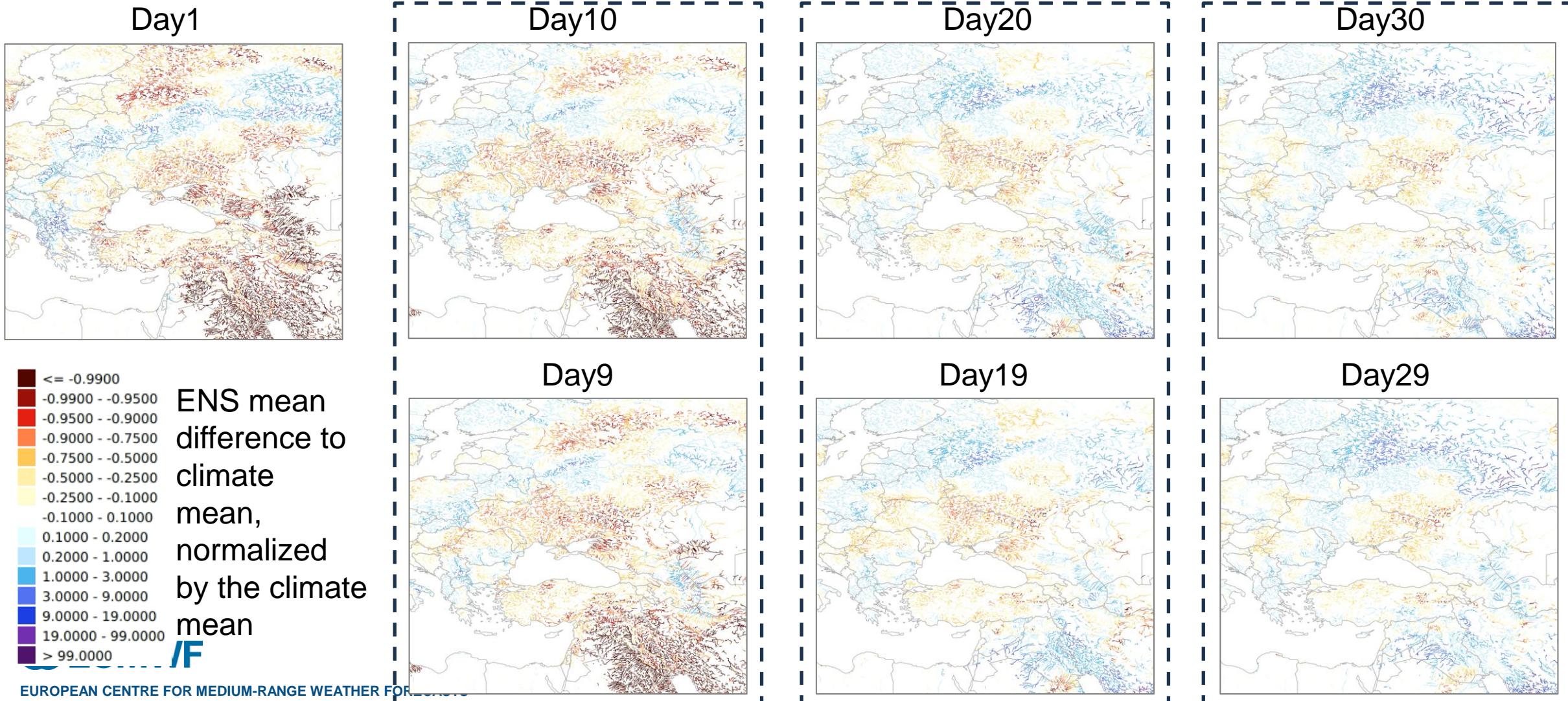


Weekly/monthly averaging – River discharge anomalies

Stronger, more persistent anomalies in river discharge thanks to the 'memory' of land-surface

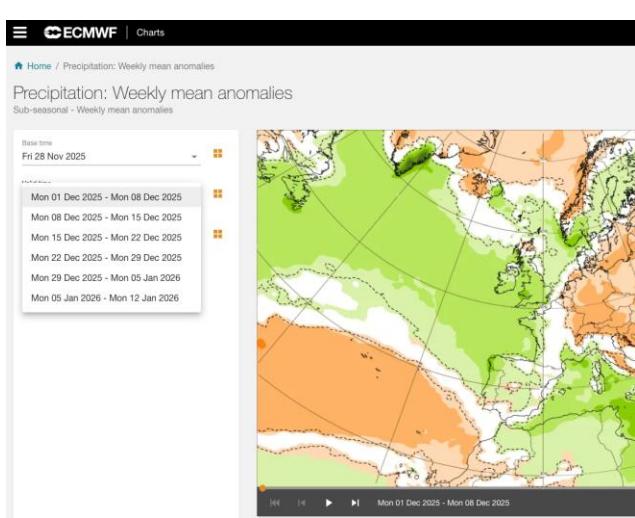
Weekly/monthly averaging still necessary to remove 'random'/small-scale variabilities

FC: 2025-11-27



Examples for hydrological sub-seasonal/seasonal products

ECMWF weekly (sub-seasonal) and monthly (seasonal) precip anomalies



The GloFAS sub- seasonal/seasonal outlook products

Sub-seasonal/seasonal forecast implementation in CEMS-flood

Real time forecasts

Real-time sub-seasonal / seasonal river discharge forecasts

Averaged to calendar weeks / months

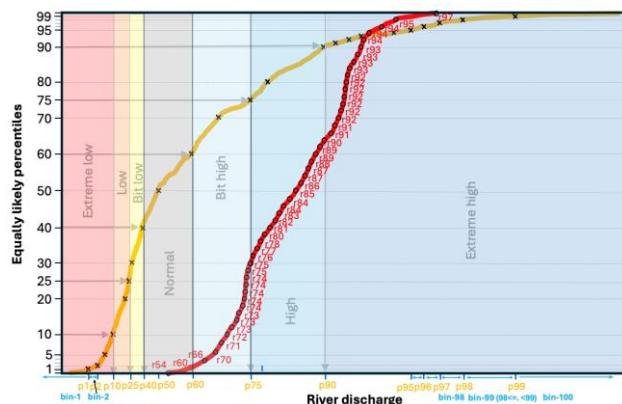
Model climatologies

Sub-seasonal / seasonal 99-value climatological distribution

Generated from 20-year of river discharge reforecasts

Averaged to calendar weeks / months

Ensemble forecast extremity (rank) computation



- Sub-seasonal products updated daily (for 00 UTC) at around 14 UTC
- Seasonal products updated once a month (for 1st of the month) at around 6th of the month

Forecast anomaly and uncertainty computation

Real-time sub-seasonal / seasonal river discharge forecast anomaly and uncertainty

For calendar weeks / months

Based on the 51 ensemble member ranks (computed against reforecast-based model climatology)

Probabilities for 7 (5+2) **anomaly categories**

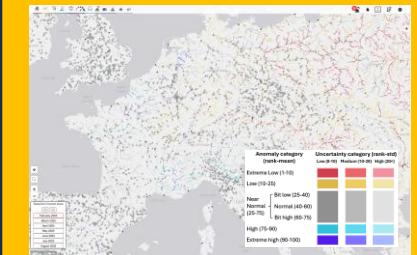
Expected anomaly category (one of 7) defined by the rank mean

Uncertainty category (one of 3) defined by the rank standard deviation

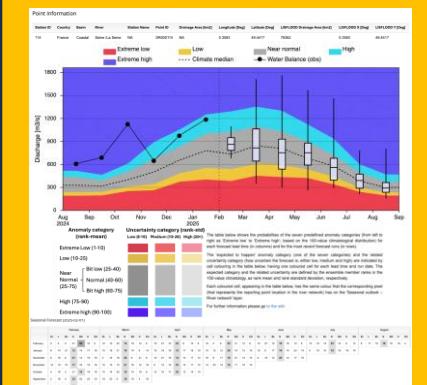
Forecast products

Same product design for sub-seasonal/seasonal

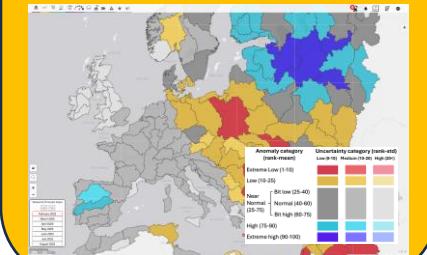
River network map



Reporting point product

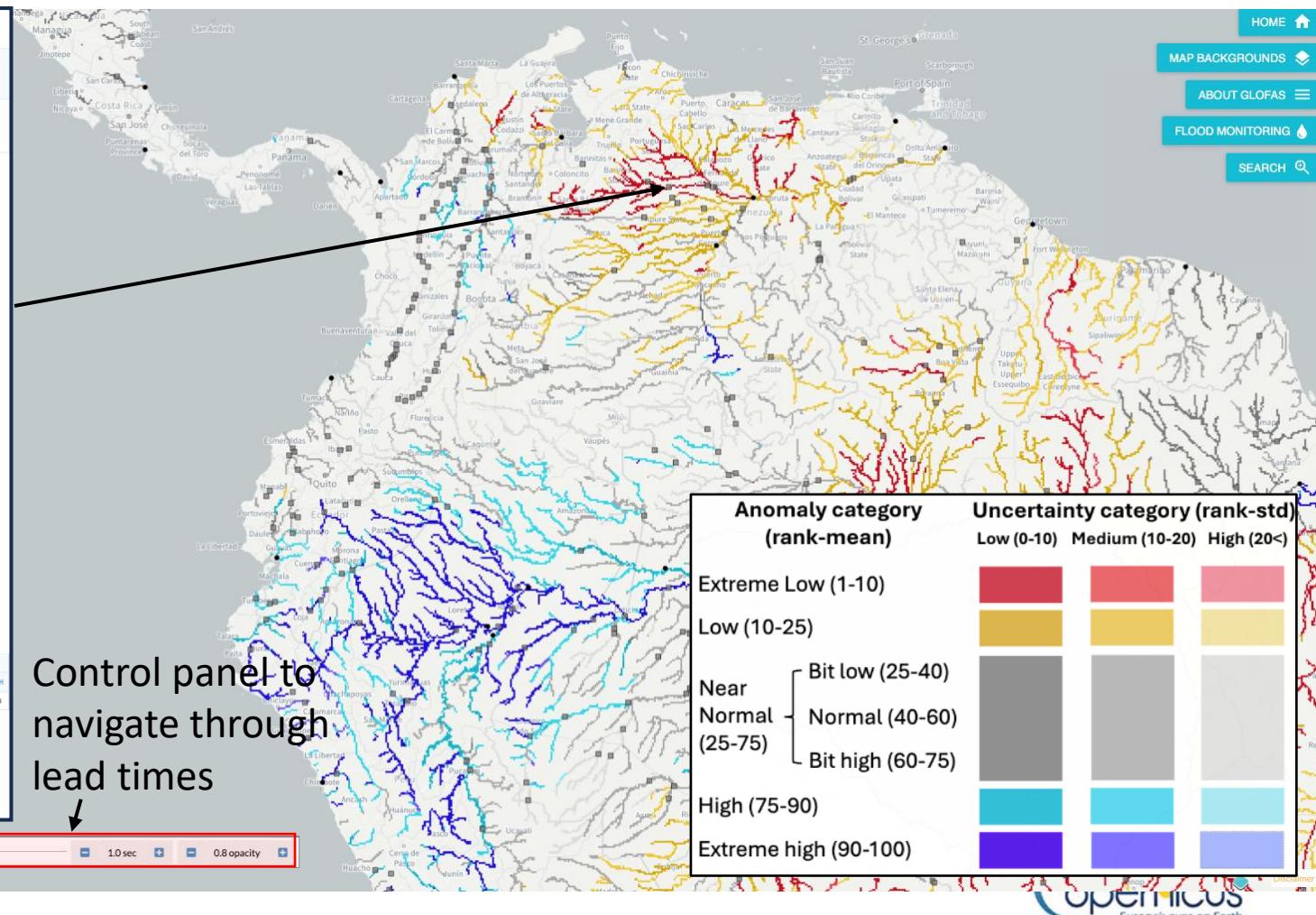
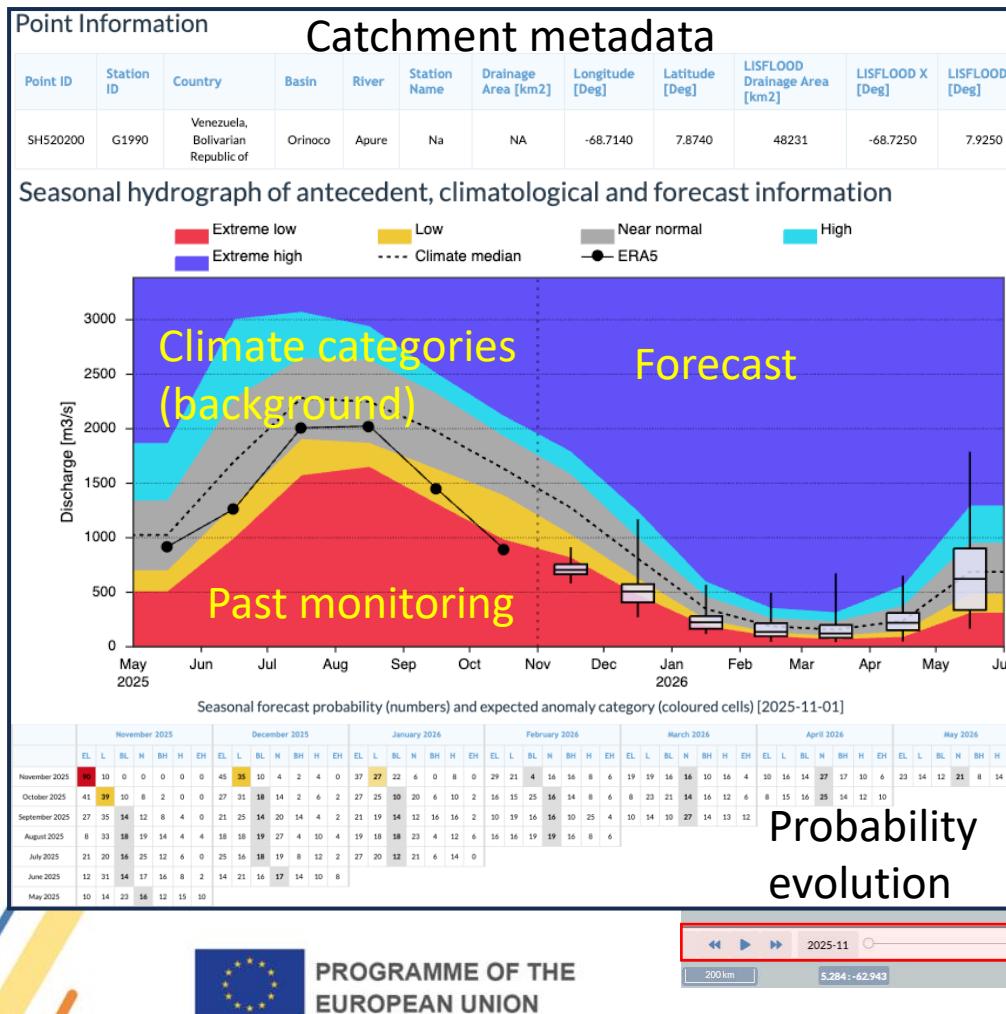


Basin summary map



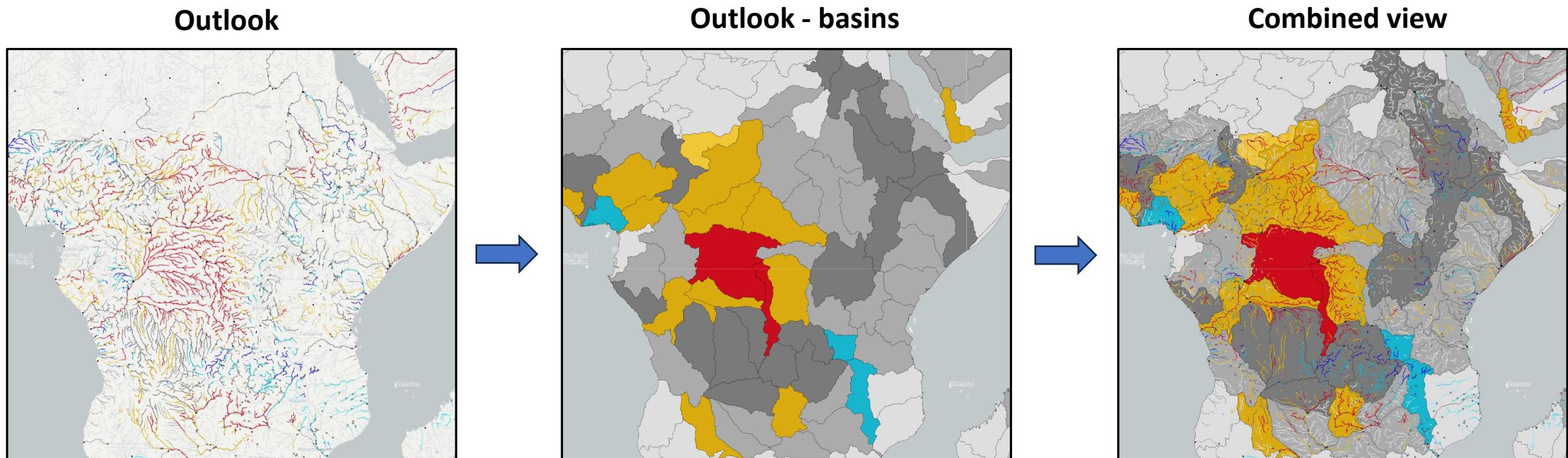
GloFAS sub-seasonal/seasonal web layers – ‘Outlook’

- ‘Outlook’ layer: Forecast signal on river pixels + reporting points (popup window with hydrograph and probability evolution)
- 5*3 categories/colours used (5 anomaly and 3 uncertainty categories)
- Maps are scrollable, separate maps for all lead times

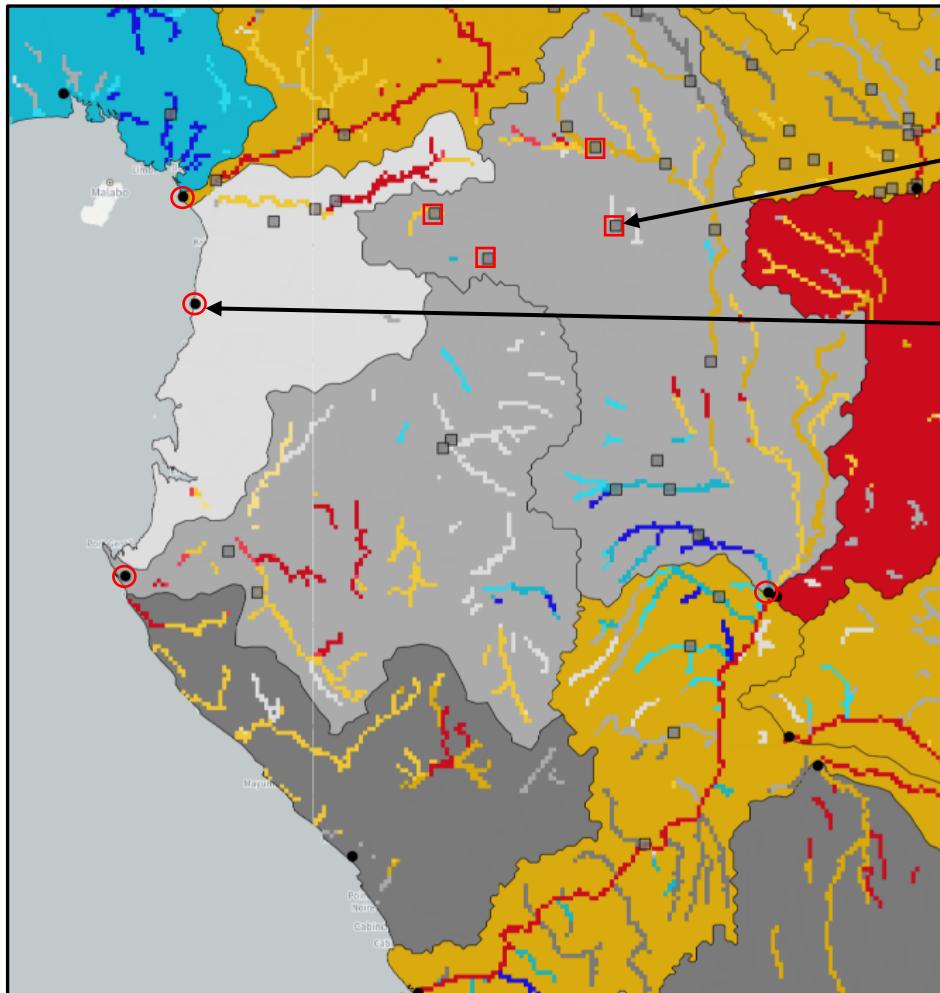


GloFAS sub-seasonal/seasonal web layers – ‘Outlook basins’

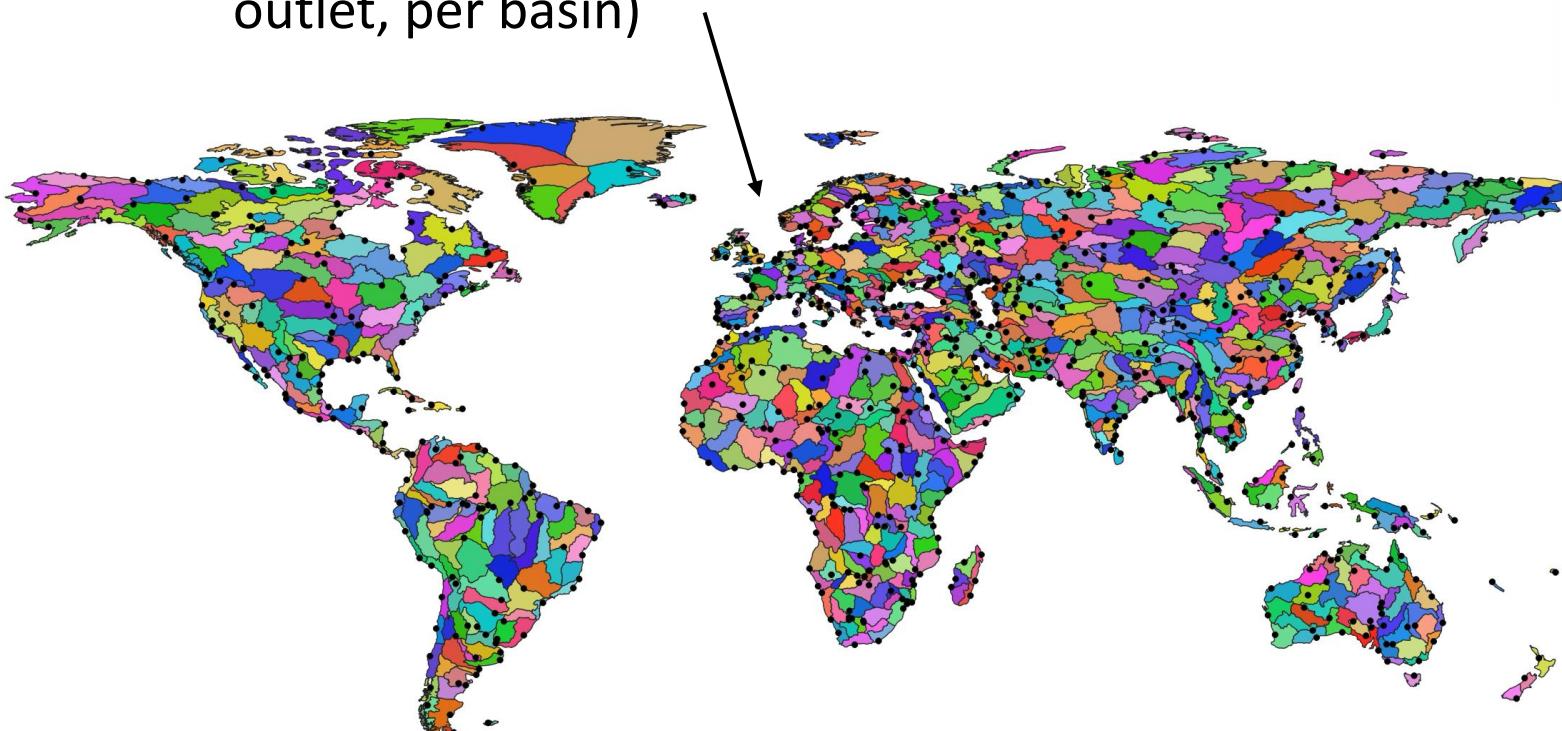
- ‘Outlook - Basins’ layer: Forecast signal at river pixels aggregated over predefined basins
- Aggregation helps users to see large-scale signal by reducing the usually large spatial heterogeneity (coming from the land-surface characteristics)
- Same 5*3 categories/colours used



Sub-seasonal/seasonal reporting points



- Regular reporting points (as used in the medium-range GloFAS products)
- Basin-representative points (one point, usually outlet, per basin)



PROGRAMME OF THE
EUROPEAN UNION

Sub-seasonal forecast probability example

Forecast evolution table for the forecast run of 17 March 2025

Sub-seasonal forecast probability (numbers) and expected anomaly category (coloured cells) [2025-03-17]

	Mar, Mon 17						Mar, Mon 24						Mar, Mon 31						Apr, Mon 07						Apr, Mon 14						Apr, Mon 21												
	EL	L	BL	N	BH	H	EL	L	BL	N	BH	H	EL	L	BL	N	BH	H	EL	L	BL	N	BH	H	EL	L	BL	N	BH	H	EL	L	BL	N	BH	H							
Mar, Mon 17	0	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	22	78	0	0	0	2	20	35	43	0	0	2	14	20	31	33	0	2	12	10	12	37	27		
Mar, Sun 16	0	0	0	0	0	0	100	0	0	0	0	0	37	63	0	0	0	2	8	29	61	0	0	0	16	24	23	37	0	2	8	12	22	23	33	0	6	8	16	12	14	33	23
Mar, Sat 15	0	0	0	0	0	0	100	0	0	0	0	0	25	75	0	0	0	2	8	29	61	0	0	0	2	16	25	22	35	0	2	8	20	16	25	29	0	2	14	14	21	22	27
Mar, Fri 14	0	0	0	0	0	0	100	0	0	0	0	14	23	63	0	0	0	2	8	37	53	0	0	0	2	20	26	27	25	0	4	10	22	21	25	18	0	4	16	25	16	23	16
Mar, Thu 13	0	0	0	0	0	31	69	0	0	0	8	22	35	35	0	0	2	22	22	23	31	0	0	10	18	23	22	27	0	2	8	20	29	20	21	0	2	14	21	20	23	20	
Mar, Wed 12	0	0	0	0	0	14	86	0	0	0	4	20	37	39	0	0	6	14	18	25	37	0	0	10	12	29	31	18	0	8	14	23	16	19	20								
Mar, Tue 11	0	0	0	0	0	35	65	0	0	0	8	35	26	31	0	0	0	16	29	31	24	0	0	2	16	26	31	25	0	4	8	24	12	25	27								
Mar, Mon 10	0	0	0	0	4	29	67	0	0	8	14	20	33	25	0	4	12	25	18	18	23	0	4	21	33	8	16	18	0	8	18	25	18	12	19								
Mar, Sun 09	0	0	0	0	2	33	65	0	0	6	18	23	31	22	0	2	2	27	22	18	29	0	2	20	20	8	25	25	0	14	12	12	21	23	18								
Mar, Sat 08	0	0	0	2	4	23	71	0	0	10	29	20	20	21	0	4	12	18	27	27	12	0	4	10	29	25	16	16	0	8	10	23	18	21	20								
Mar, Fri 07	0	0	0	2	4	43	51	0	0	6	31	26	25	12	0	6	12	45	10	17	10	0	12	12	18	8	29	21	0	2	16	25	20	12	25								
Mar, Thu 06	0	2	2	8	8	33	47	0	6	8	21	23	22	20	0	10	19	18	29	12	12	0	10	10	25	29	22	4															
Mar, Wed 05	0	0	2	12	16	31	39	0	4	12	31	12	20	21	0	16	21	16	21	12	14	0	18	10	31	12	21	8															
Mar, Tue 04	0	0	14	16	12	27	31	0	8	21	25	18	16	12	4	12	19	16	18	19	12	0	18	14	23	21	16	8															
Mar, Mon 03	0	8	14	23	14	29	12	0	23	10	25	14	12	16	2	19	23	8	20	12	16	2	8	25	19	16	12	18															
Mar, Sun 02	0	0	14	35	24	23	4	0	23	25	12	18	14	8	2	16	21	27	14	10	10	2	18	21	21	12	18	8															
Mar, Sat 01	2	12	23	33	10	16	4	2	29	25	22	4	16	2	4	31	21	20	8	10	6	6	25	22	33	6	6	2															
Feb, Fri 28	4	27	20	23	6	12	8	17	33	18	16	2	10	4	6	29	12	31	12	6	4	10	21	19	14	16	16	4															
Feb, Thu 27	8	27	16	17	14	16	2	10	21	19	20	16	8	6	4	25	16	23	6	10	16	4	23	12	23	8	18	12															
Feb, Wed 26	0	16	35	27	8	12	2	8	25	20	27	6	12	2	12	15	21	16	16	16	4	10	21	14	25	10	14	6															
Feb, Tue 25	2	19	21	16	12	14	16	10	21	19	14	16	16	4	10	21	14	25	10	14	6																						

Forecast lead times (calendar week or month)

Forecast run dates

Anomaly categories (all 7) from 'EL' (Extreme low) to 'EH' (Extreme high)

- Highlighted colour is the same as the corresponding river pixel on the Outlook product

Expected anomaly/uncertainty category highlighted by coloured cell + bold number



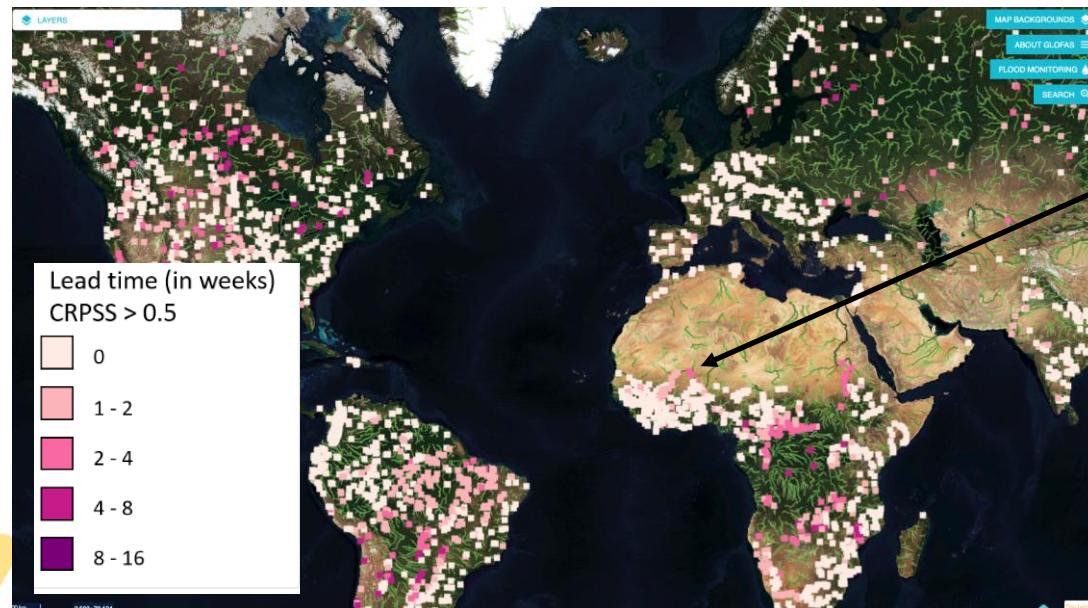
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Then some further rows below this...

Copernicus
Europe's eyes on Earth

GloFAS seasonal forecast performance analysis

- Seasonal skill assessment based on reforecasts
- Verified by CRPSS, using climatology as reference
- Showing lead time when CRPSS decreases below 0.5
- Currently based on 16-week forecast horizon
- Against simulated truth (ERA5-forced river discharge reanalysis)

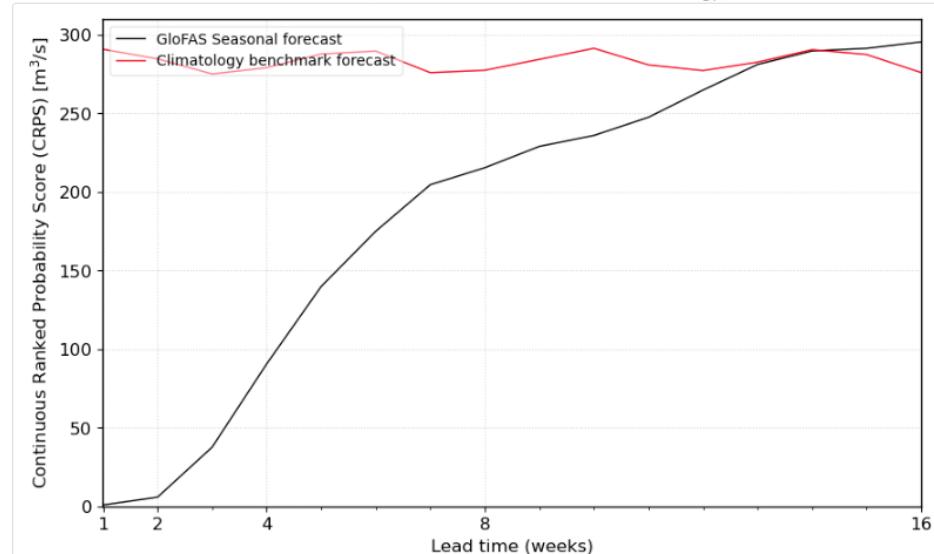
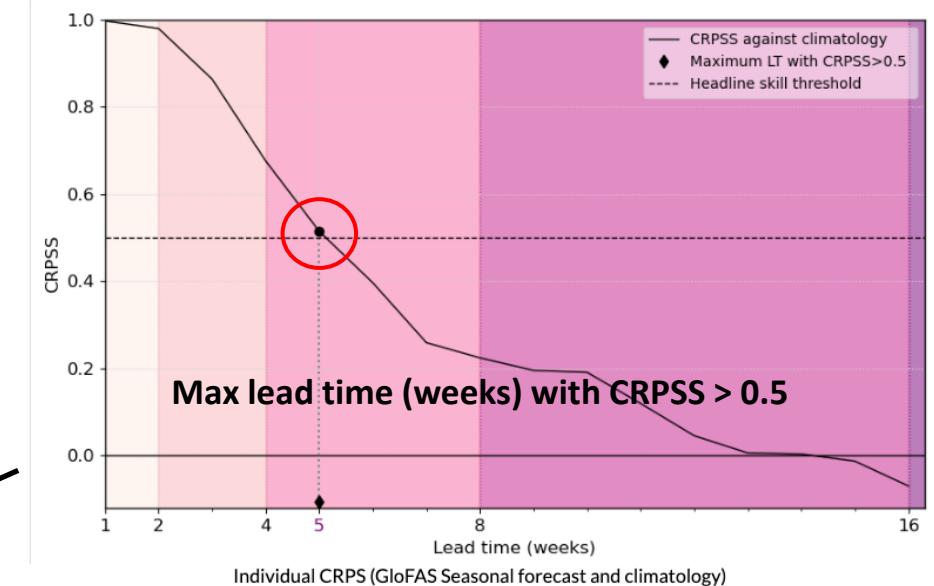


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Seasonal Forecast Skill

Station ID	Country	River	Station Name	Drainage Area [km ²]	LISFLOOD X [Deg]	LISFLOOD Y [Deg]	Lead time (in weeks) CRPSS > 0.5
G1785	Mali	Niger	Niger River At Tossaye	376110	-0.575	16.925	5

Seasonal forecast skill against climatology benchmark w.r.t. reanalysis



Where to see the GloFAS sub-seasonal/seasonal products?

The image shows a screenshot of the GloFAS web interface. At the top, there is a navigation bar with tabs: MESSAGES, INITIAL CONDITIONS, METEOROLOGICAL, HYDROLOGICAL, FLOOD RISK, EVALUATION, STATIC, MONITORING, EXTERNAL WMS, and georss. Below the navigation bar is a map of Europe and Africa. A yellow box on the left side of the map contains the text: "New-style sub-seasonal and seasonal layers (from June 2025)". A red box highlights the "HYDROLOGICAL" section of the sidebar, which lists various forecast products. A yellow box on the right side of the map contains the text: "Seasonal (and sub-seasonal) forecasts are available on global-flood.emergency.copernicus.eu/". A red box highlights the "Legacy seasonal layer (until May 2025)" on the map. A red box highlights the "Legacy Seasonal Outlook" section of the sidebar, which lists reporting points, basin overviews, and river networks. A white box on the right side of the map contains the text: "For documentation of the method and products please go on the GloFAS wiki:" followed by two URLs: <https://confluence.ecmwf.int/display/CEMS/GloFAS+sub-seasonal+and+seasonal+forecast+products> and <https://confluence.ecmwf.int/display/CEMS/CEMS-flood+sub-seasonal+and+seasonal+forecast+product+generation+methodology>.

New-style sub-seasonal and seasonal layers (from June 2025)

Legacy seasonal layer (until May 2025)

HYDROLOGICAL

- NEW! AIFS Single
- Flood summary for days 1-15
- Reporting Points
- Seasonal Outlook
- Seasonal Outlook - Basins
- Sub-seasonal Outlook
- Sub-seasonal Outlook - Basins
- 5 Year Return Period Exceedance
- 20 Year Return Period Exceedance
- Flood summary for days 1-3
- Flood summary for days 4-10
- Flood summary for days 11-15
- Legacy Seasonal Outlook - Reporting Points
- Legacy Seasonal Outlook - Basin Overview
- Legacy Seasonal Outlook - River Network

Seasonal (and sub-seasonal) forecasts are available on global-flood.emergency.copernicus.eu/

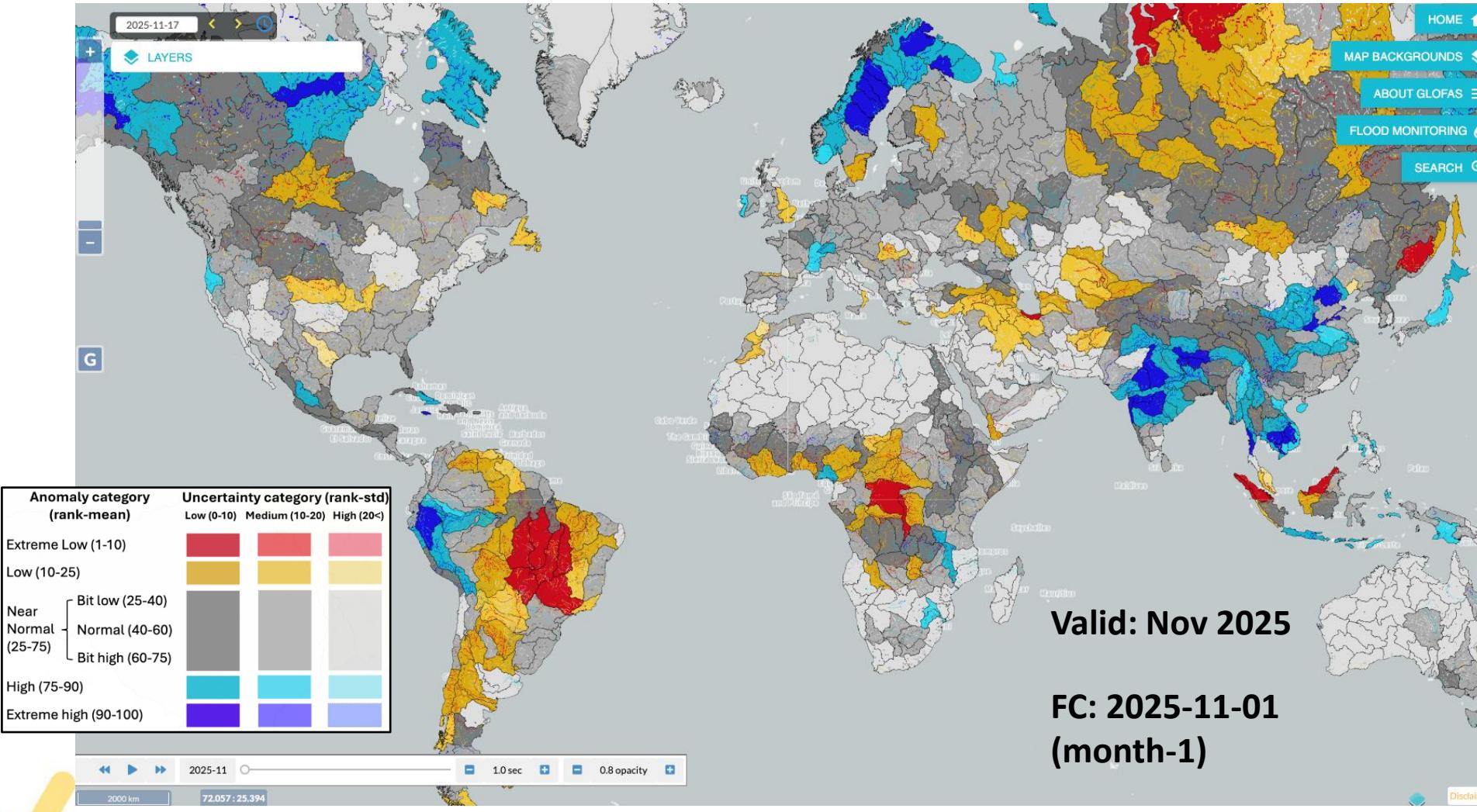
For documentation of the method and products please go on the GloFAS wiki:

<https://confluence.ecmwf.int/display/CEMS/GloFAS+sub-seasonal+and+seasonal+forecast+products>

<https://confluence.ecmwf.int/display/CEMS/CEMS-flood+sub-seasonal+and+seasonal+forecast+product+generation+methodology>

Navigating the GloFAS hydrological outlook products

Seasonal forecast example – Month-1



Valid: Nov 2025

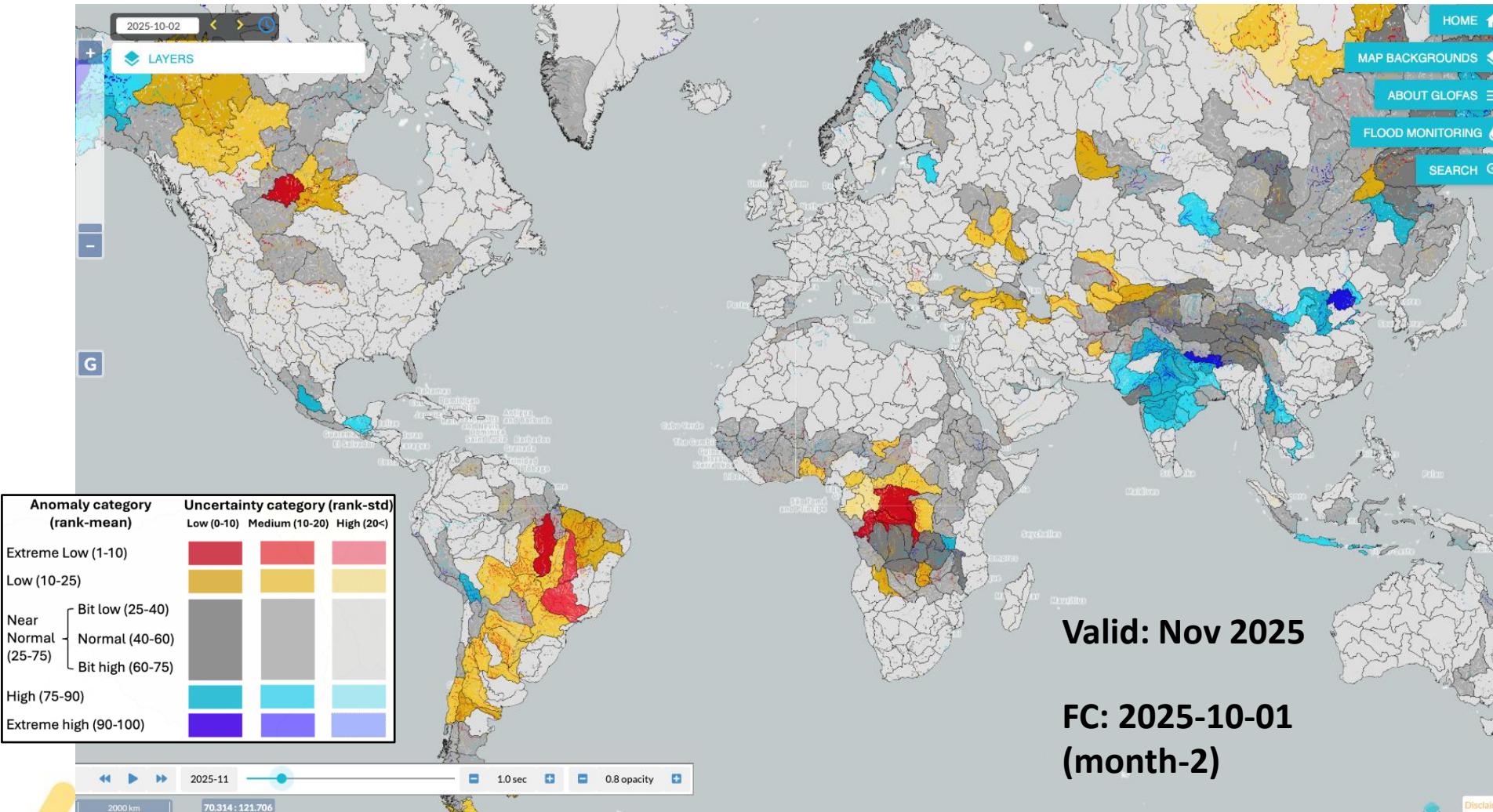
FC: 2025-11-01
(month-1)

- Forecast signal converges to 'uncertain near normal' with increasing the lead time (lightest grey)
- Very dry areas also tend to appear as 'uncertain near normal' (lightest grey)



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Seasonal forecast examples – Month-2



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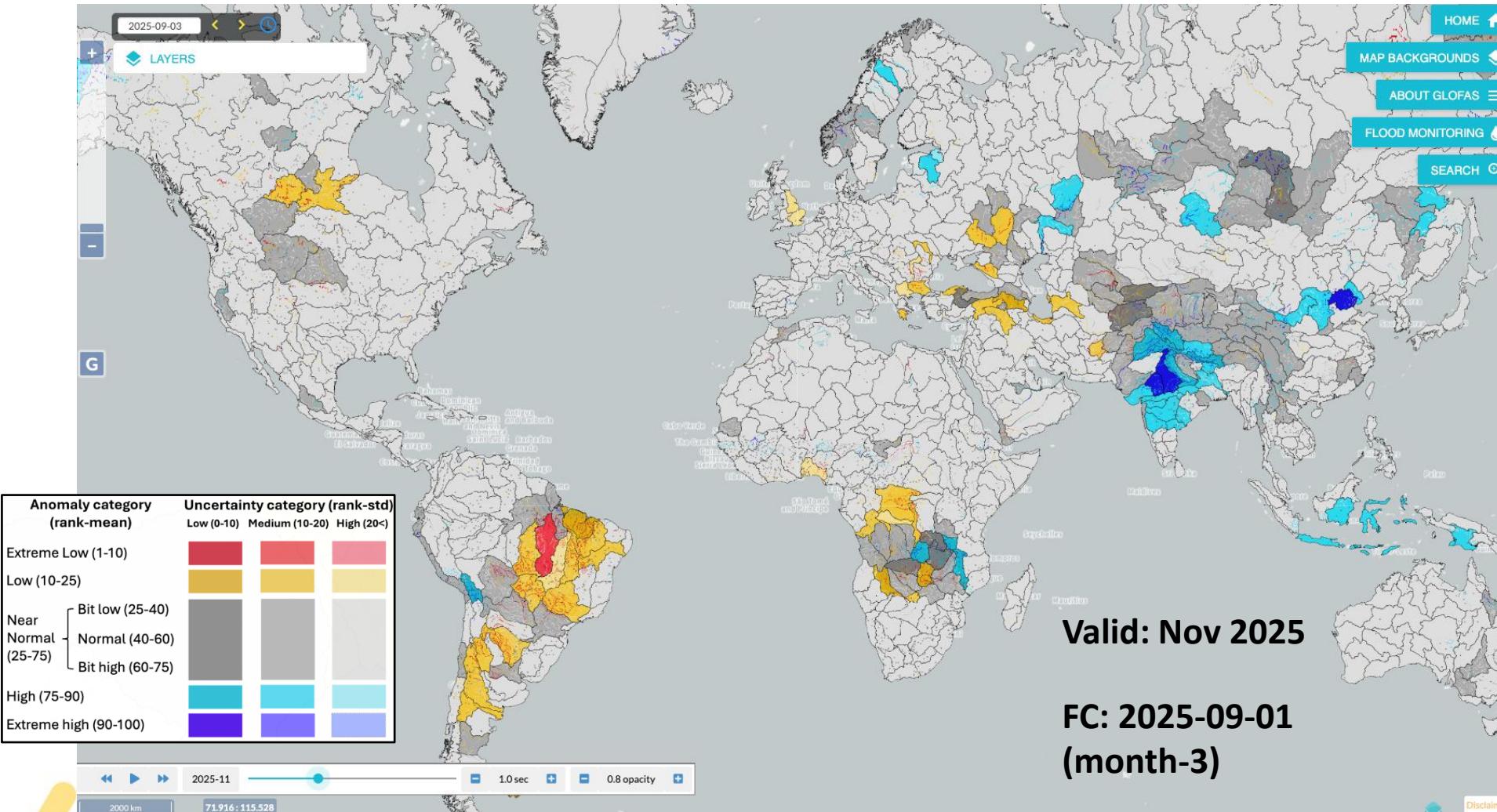


Valid: Nov 2025

FC: 2025-10-01
(month-2)

- Forecast signal converges to 'uncertain near normal' with increasing the lead time (lightest grey)
- Very dry areas also tend to appear as 'uncertain near normal' (lightest grey)

Seasonal forecast examples – Month-3



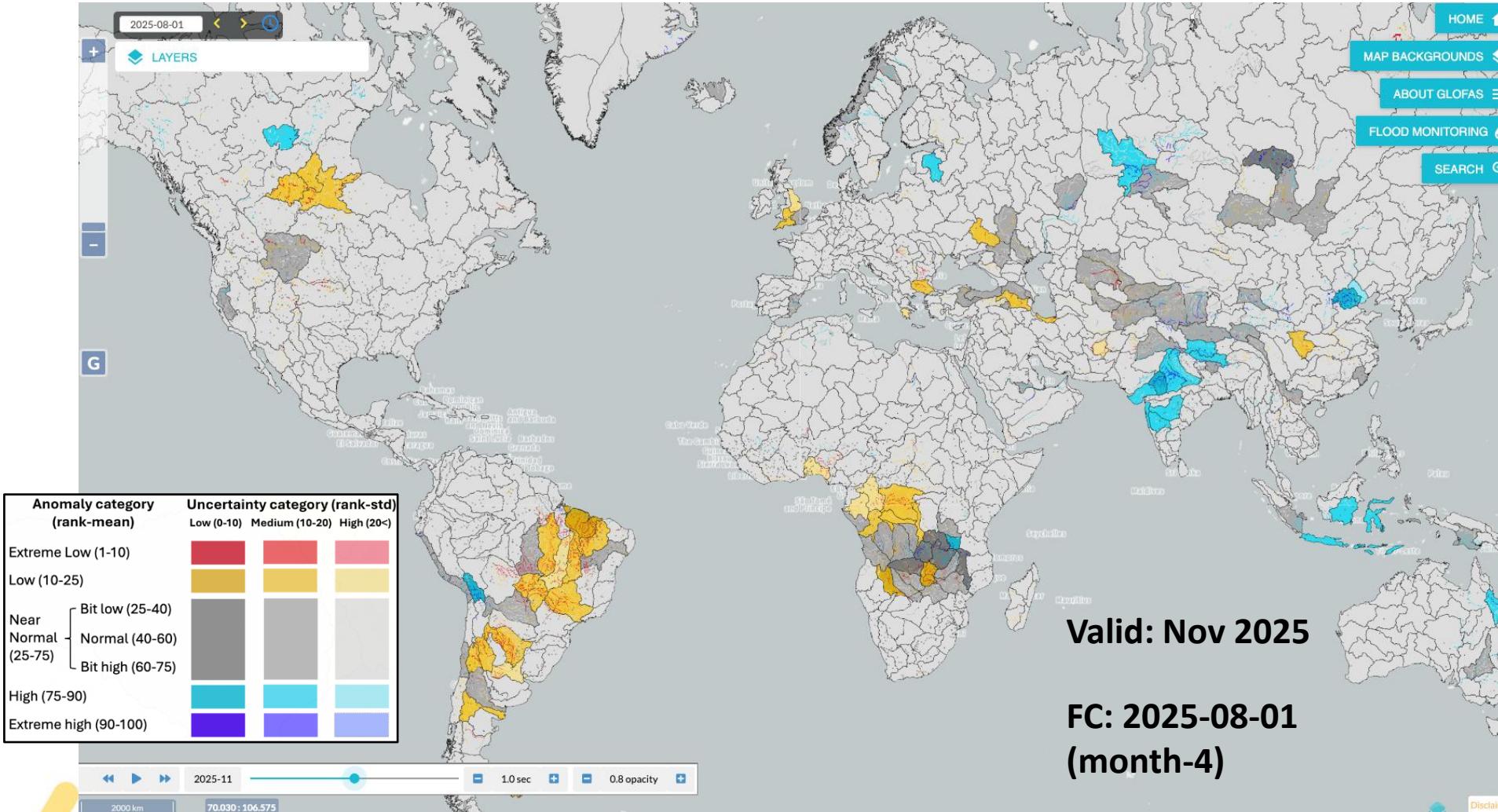
PROGRAMME OF THE
EUROPEAN UNION



- Forecast signal converges to 'uncertain near normal' with increasing the lead time (lightest grey)

- Very dry areas also tend to appear as 'uncertain near normal' (lightest grey)

Seasonal forecast examples – Month-4



Valid: Nov 2025

FC: 2025-08-01
(month-4)

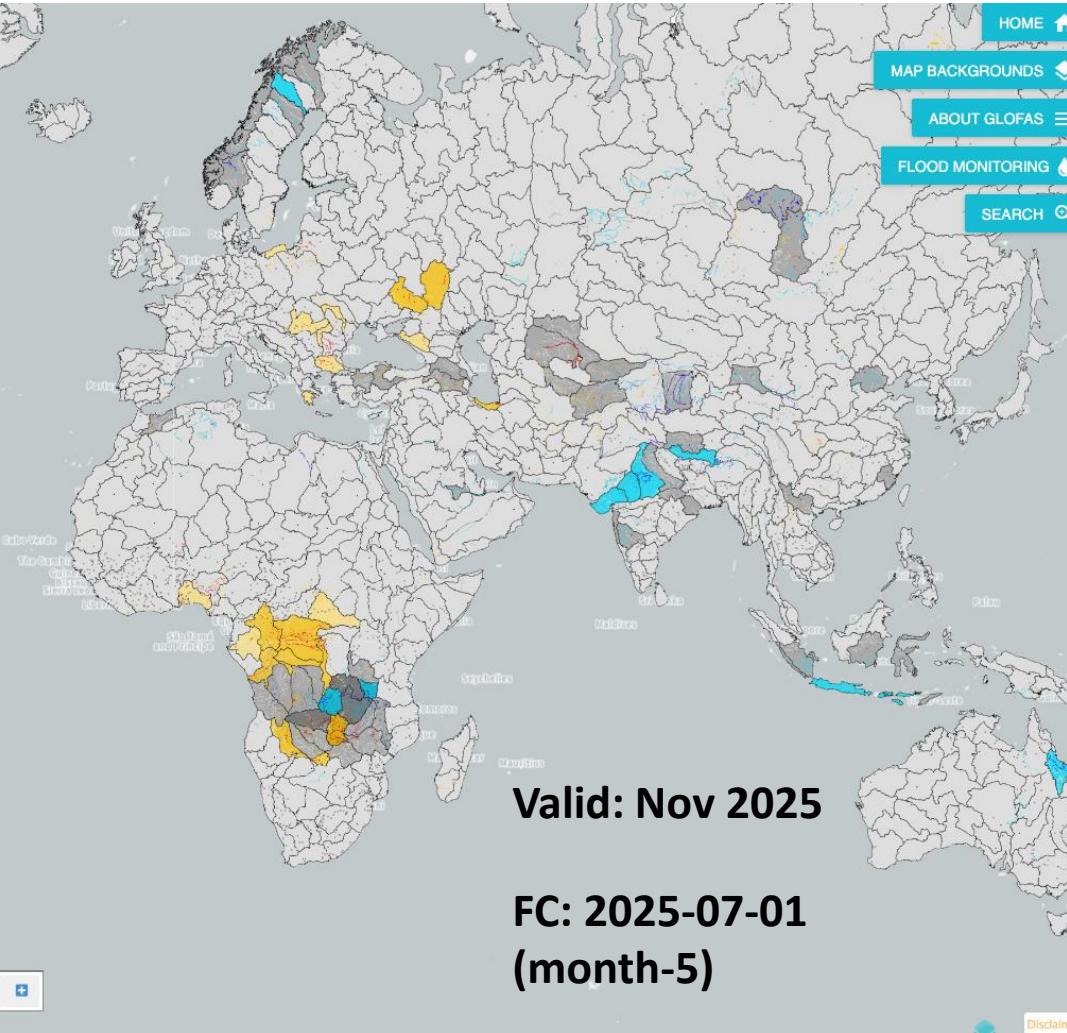
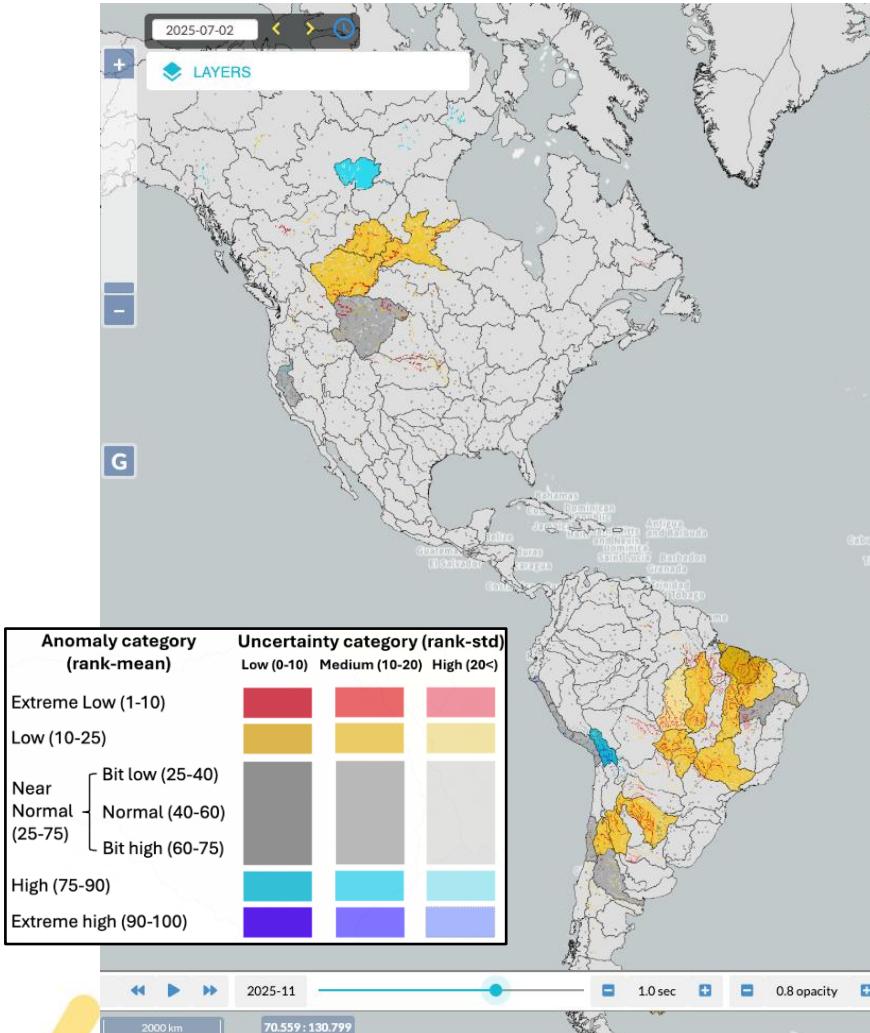
- Forecast signal converges to 'uncertain near normal' with increasing the lead time (lightest grey)
- Very dry areas also tend to appear as 'uncertain near normal' (lightest grey)



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Seasonal forecast examples – Month-5



Valid: Nov 2025

**FC: 2025-07-01
(month-5)**

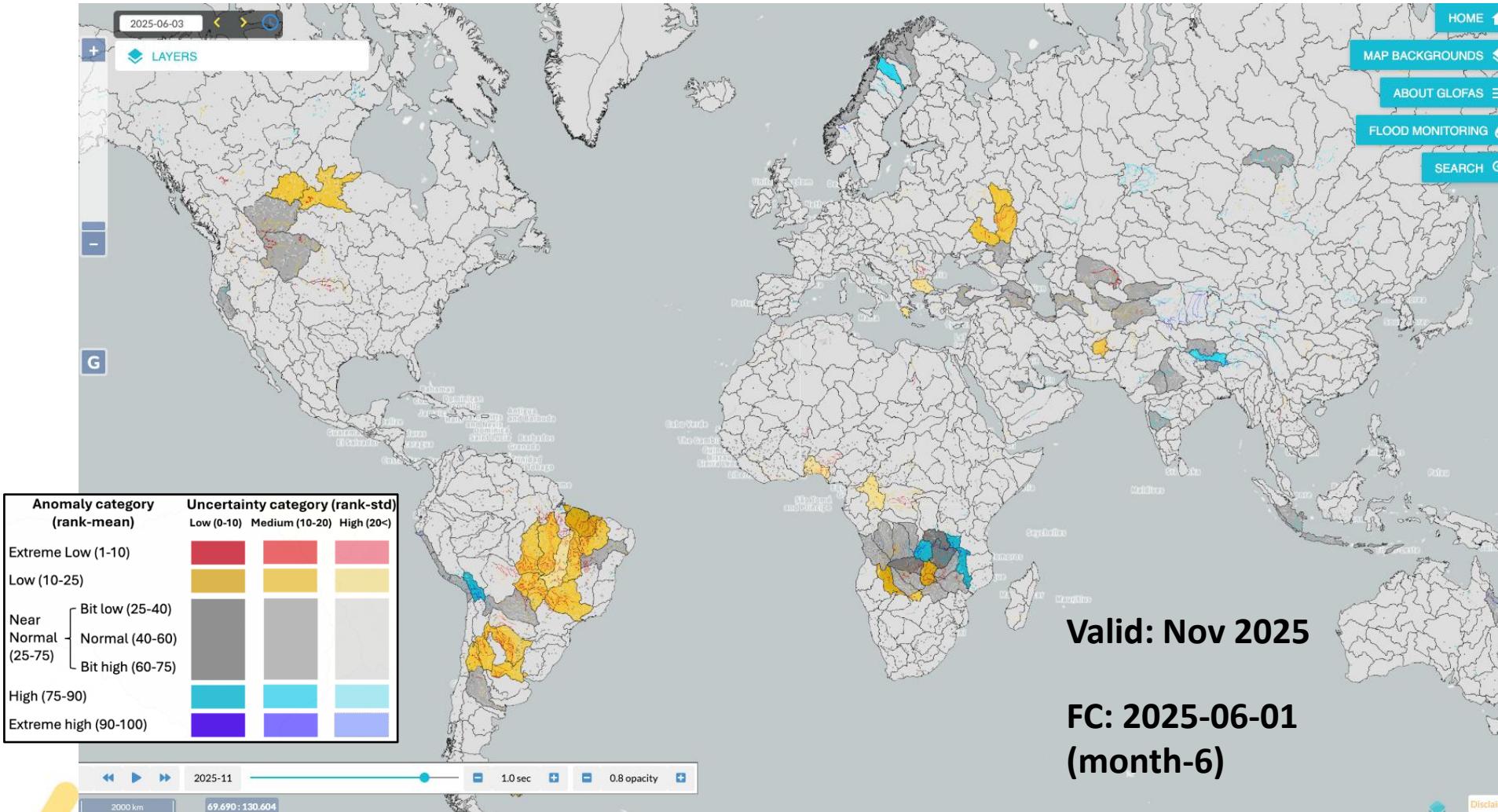
- Forecast signal converges to 'uncertain near normal' with increasing the lead time (lightest grey)
- Very dry areas also tend to appear as 'uncertain near normal' (lightest grey)



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Seasonal forecast examples – Month-6



Valid: Nov 2025

**FC: 2025-06-01
(month-6)**

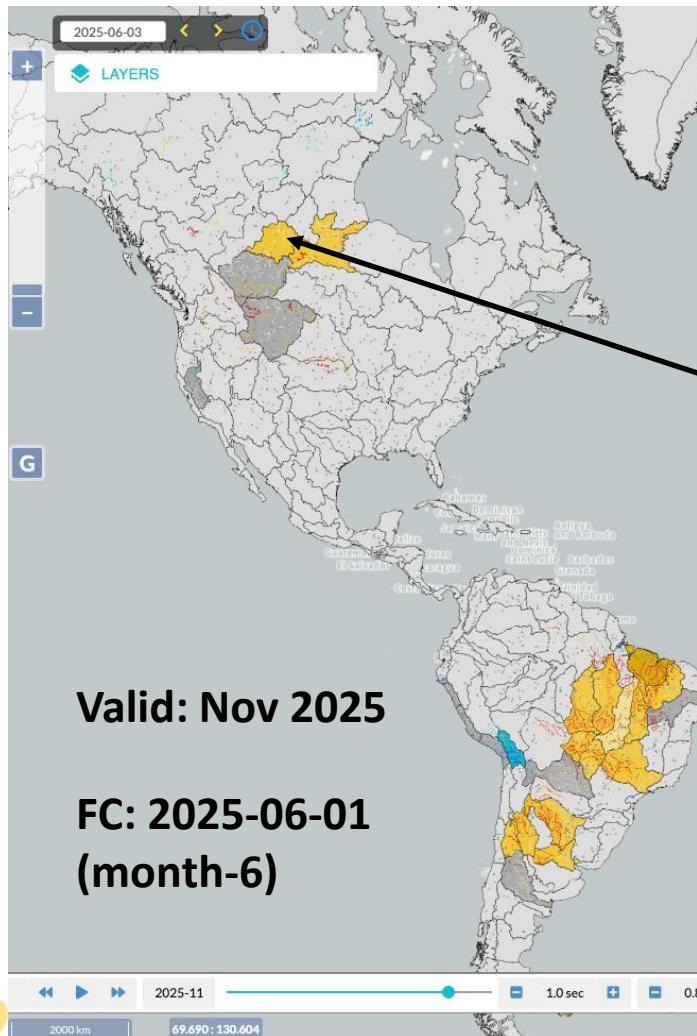
- Forecast signal converges to 'uncertain near normal' with increasing the lead time (lightest grey)
- Very dry areas also tend to appear as 'uncertain near normal' (lightest grey)



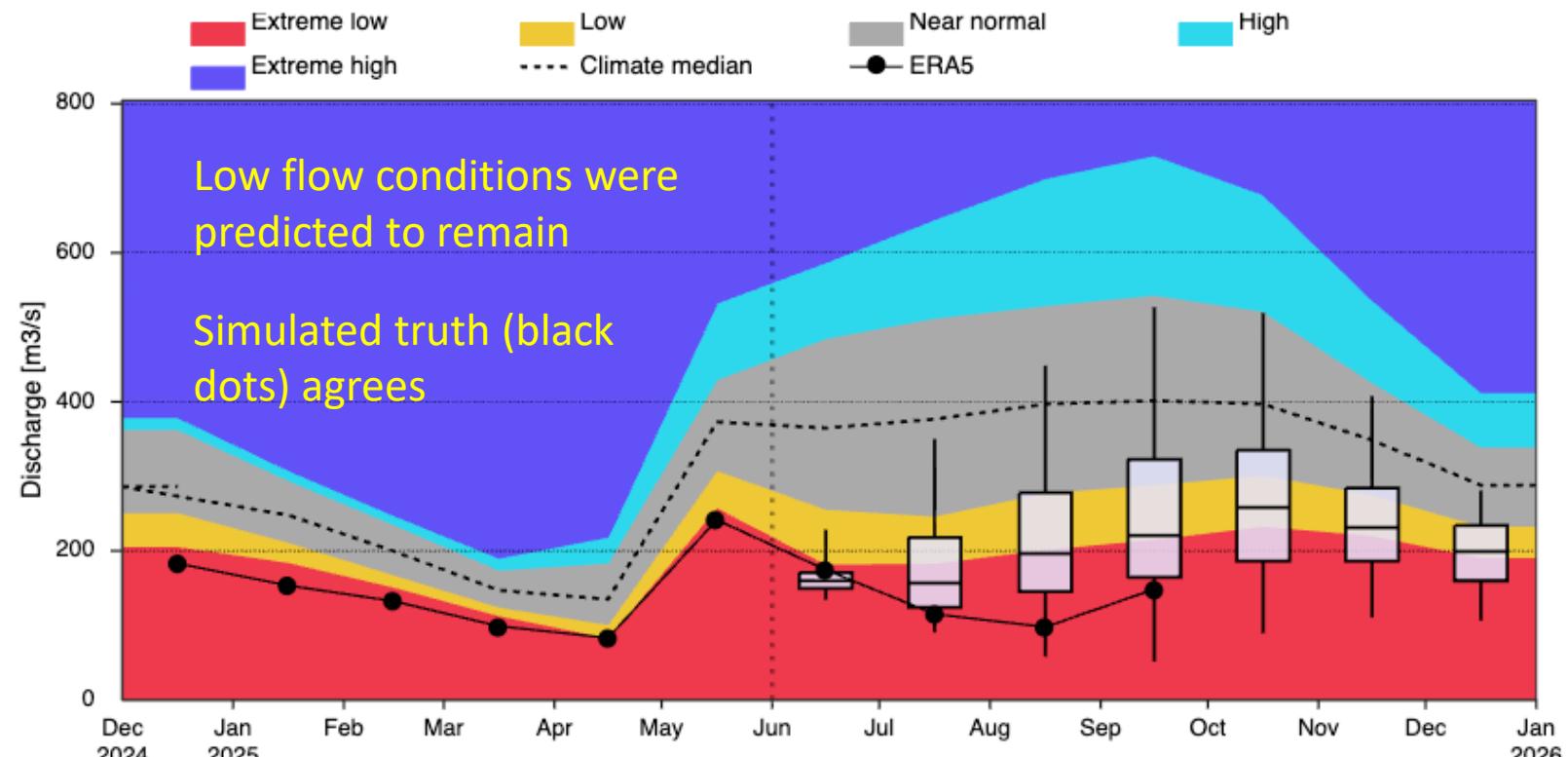
PROGRAMME OF THE
EUROPEAN UNION



Seasonal forecast examples



Seasonal hydrograph of antecedent, climatological and forecast information

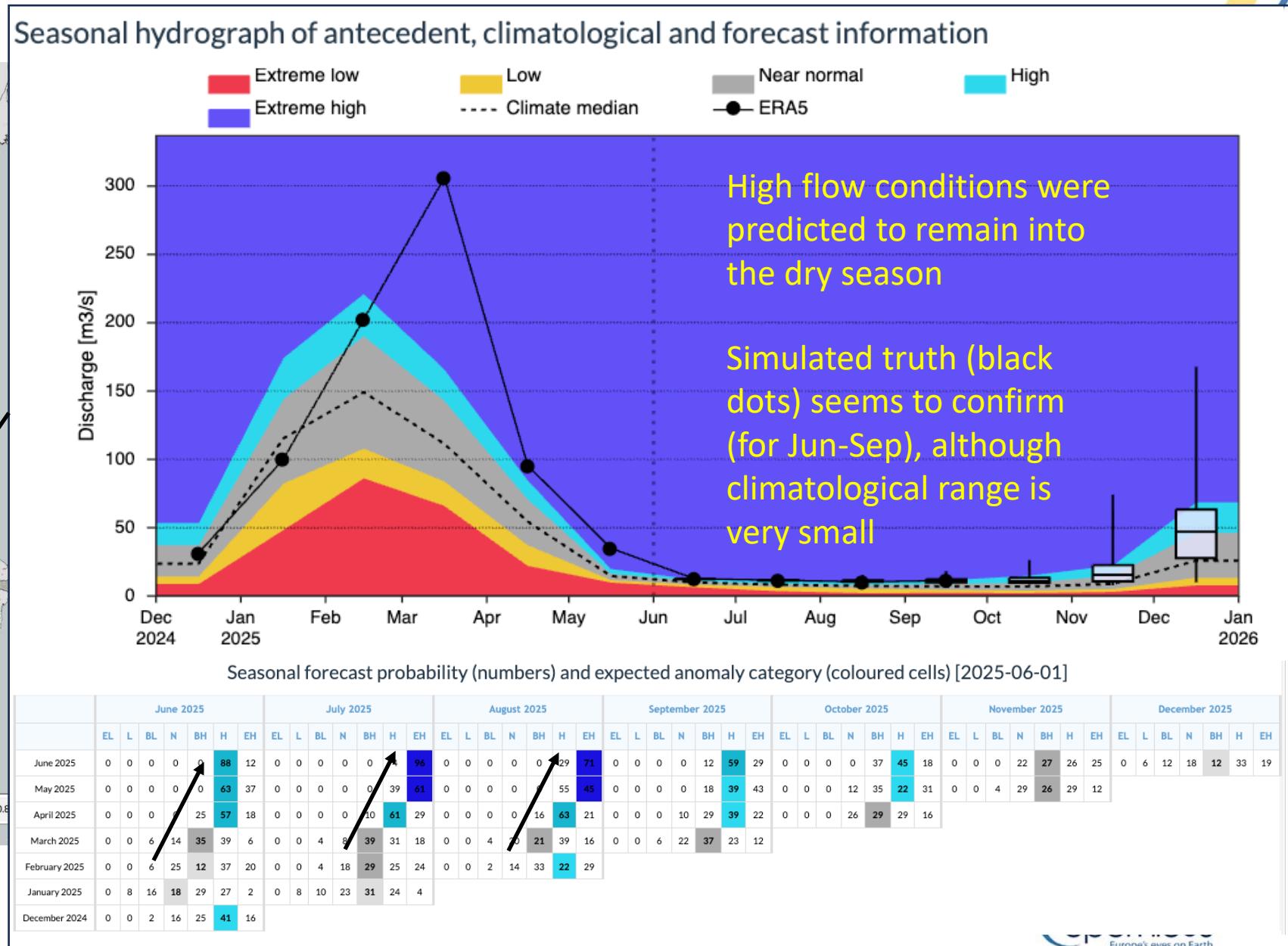
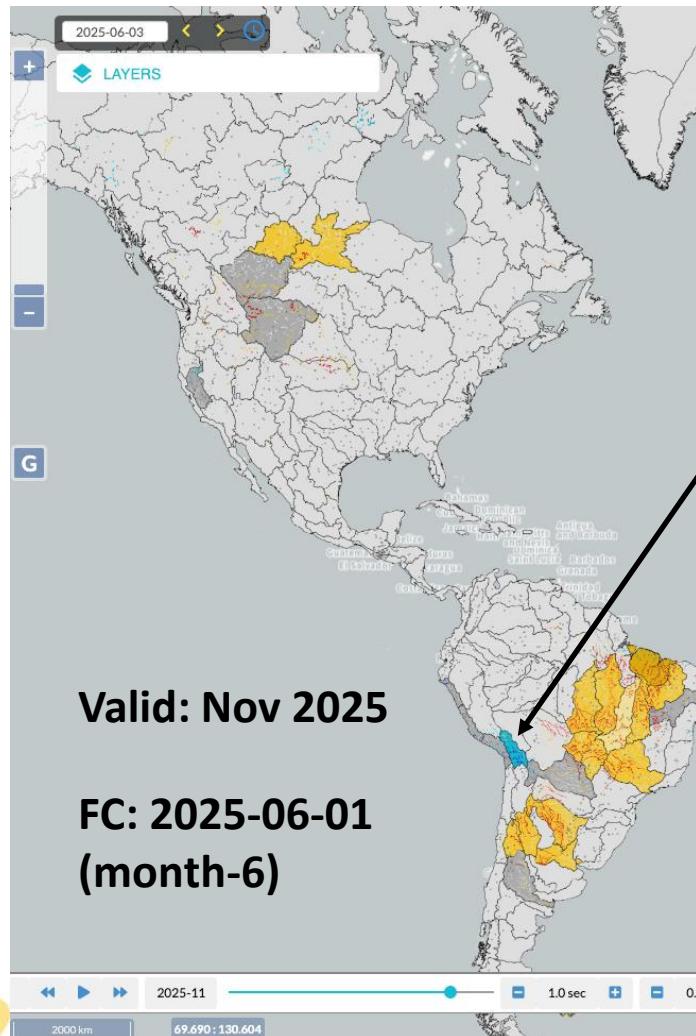


Seasonal forecast probability (numbers) and expected anomaly category (coloured cells) [2025-06-01]

² The signal gradually developed (especially for June/July)

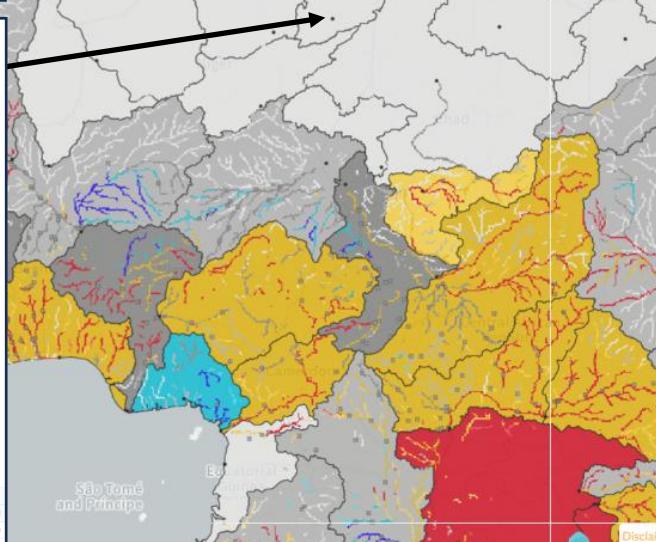
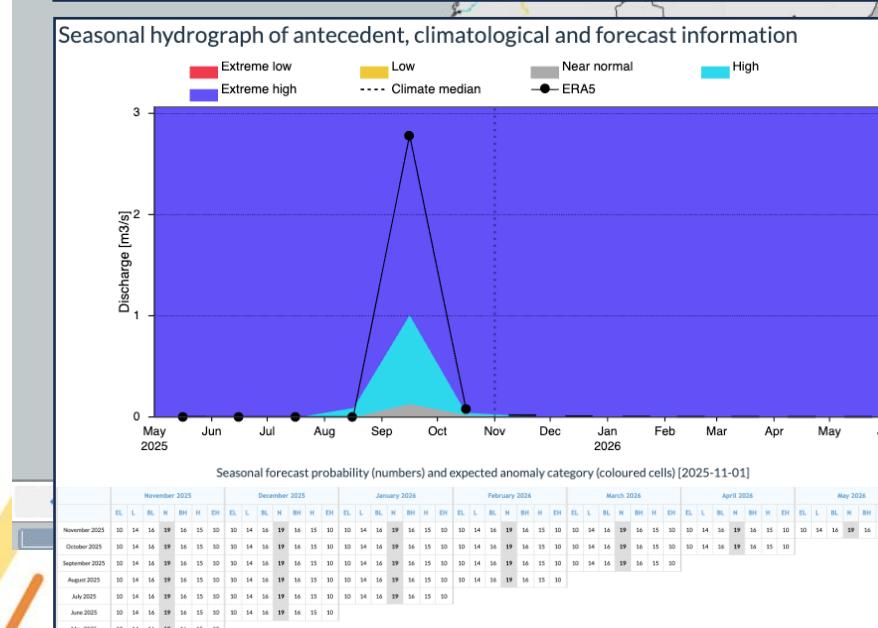
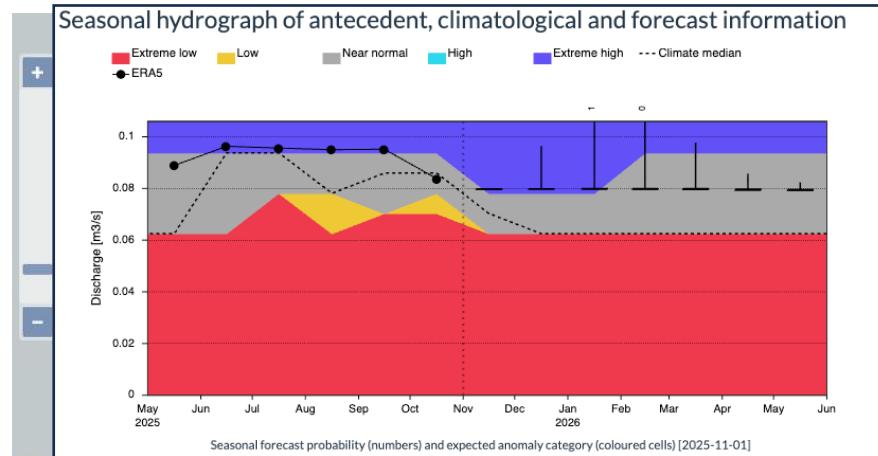


Seasonal forecast examples



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EUROPEAN UNION

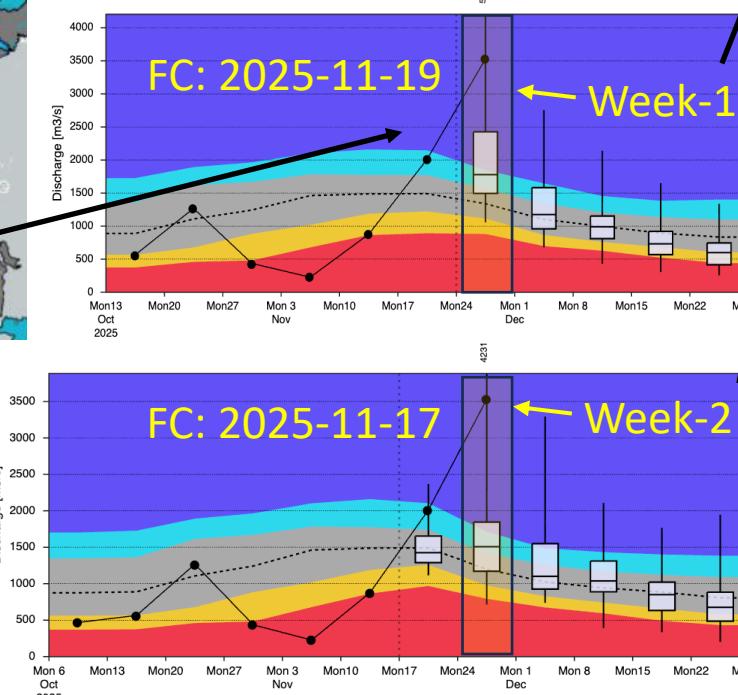
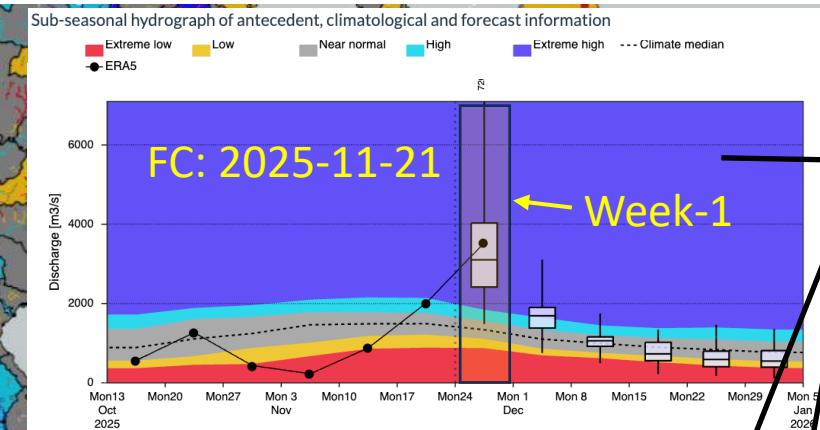
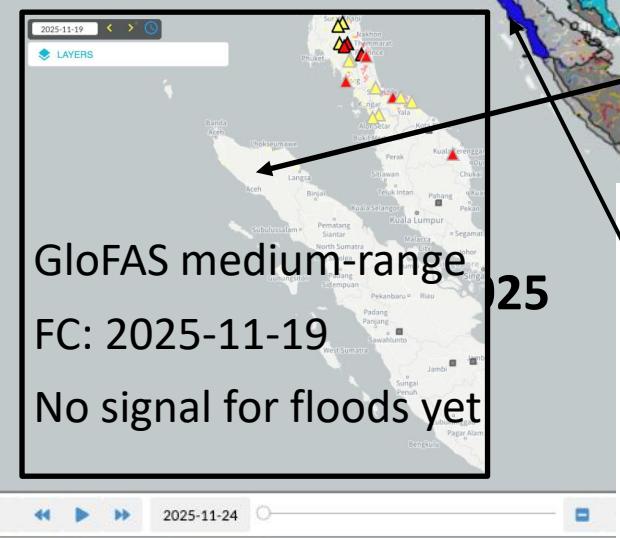
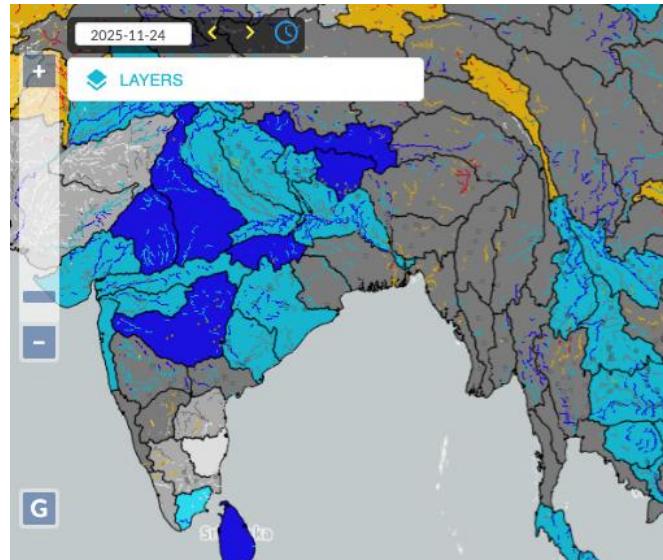
Sub-seasonal/seasonal product limitations



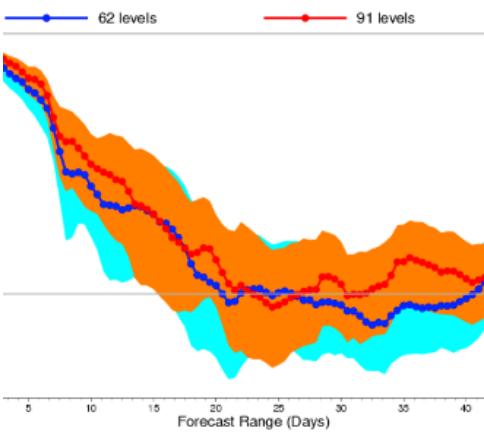
- Small catchments are not expected to be represented well
- Short-lived events might not be represented well either (i.e. a single flood; not a longer wet period)
- Very dry areas difficult to represent
 - Anomalies can not really be defined in super dry areas
 - Forecast signal collapses into undefined, with uniform probability distribution and uncertain /near-normal category (lightest grey)
 - The hydrographs can sometimes show near 0 values and/or strange looking climate ranges

Sri Lanka / Indonesia floods – Nov 2025

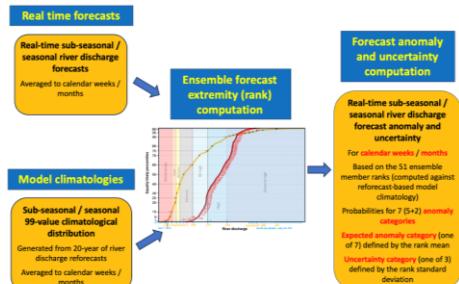
- Early indication of very high weekly mean flow with very low probability on 2025-11-17
- Gradually strengthening signal, with right realistic discharge forecast from 2025-11-21



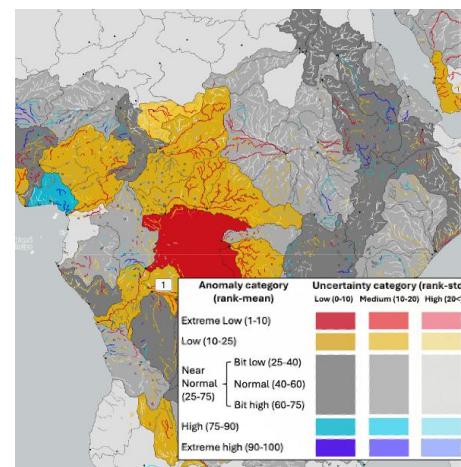
Recap of sub-seasonal/seasonal outlook products



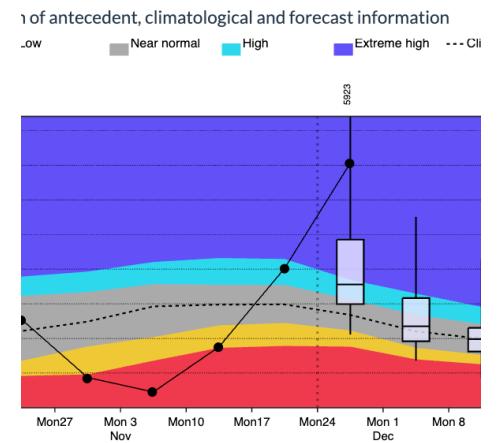
Weekly and **monthly** averaging helps highlighting the remaining lower predictability at these longer ranges



A **common methodology** is implemented in CEMS-flood to design sub-seasonal and seasonal products



Web **products** are designed to **capture** all main aspects of the hydrological **forecast signal**



Sub-seasonal products can **help highlighting risk** for potential floods earlier than dedicated medium-range flood forecasts

Data discovery and access: the Data Stores



Climate Change

The CDS (ADS and EWDS) history

What are the CDS, ADS (and now the EWDS)?

The CDS, ADS and EWDS are single points of access to the wide range of quality-assured datasets produced by or in collaboration with the Copernicus Climate Change Service (C3S), the Copernicus Atmospheric Monitoring Service (CAMS), respectively. The Early Warning Data Store host some of the data of the Copernicus Emergency Management Service (CEMS).

Objectives of the CDS and other DS

-  Make data discovery simple and relevant
-  Provide easy-to-use applications to explore data
-  Provide online capabilities to process the data
-  Enable reproducible and traceable research
-  Users spend less time handling data

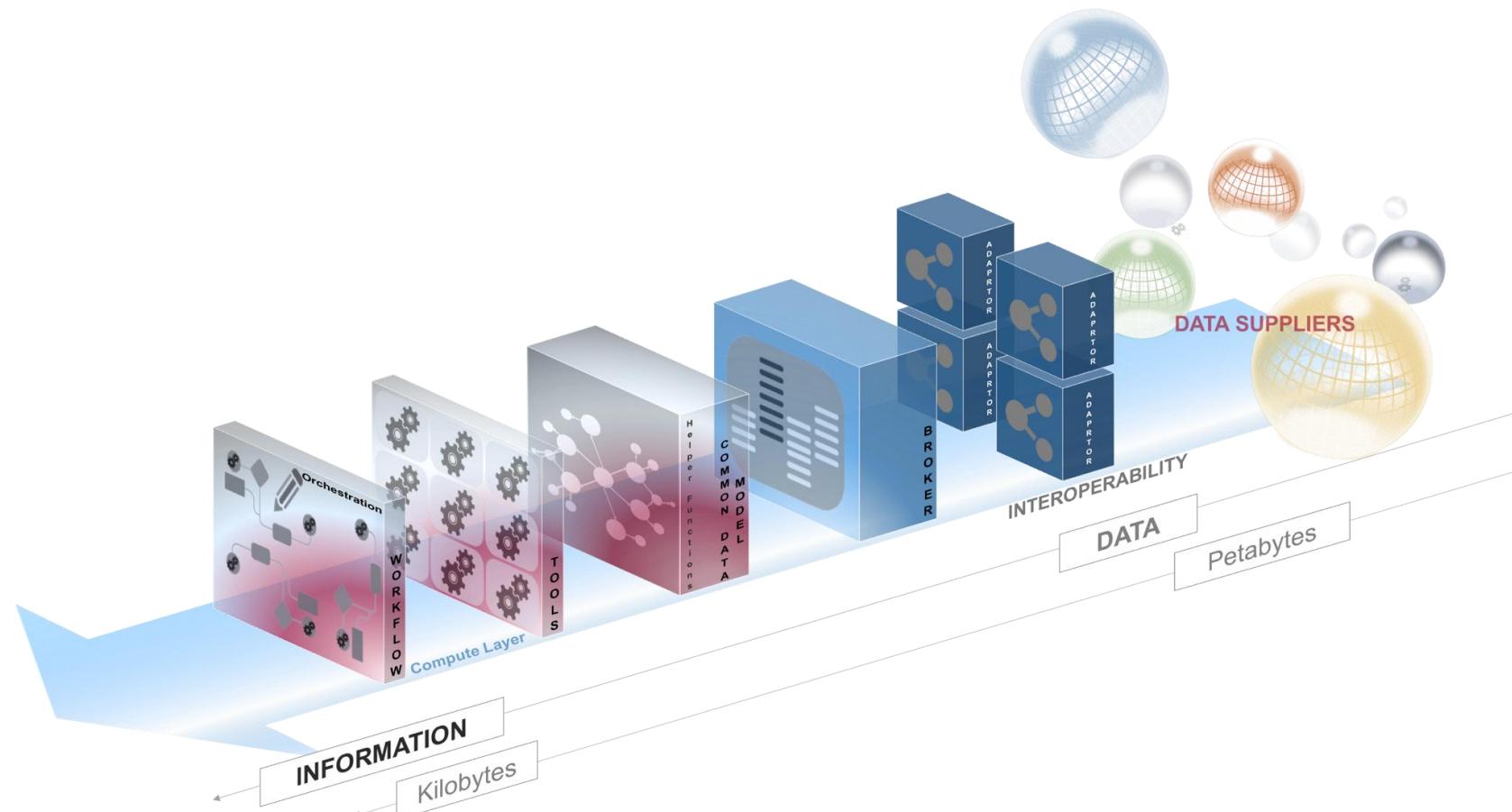




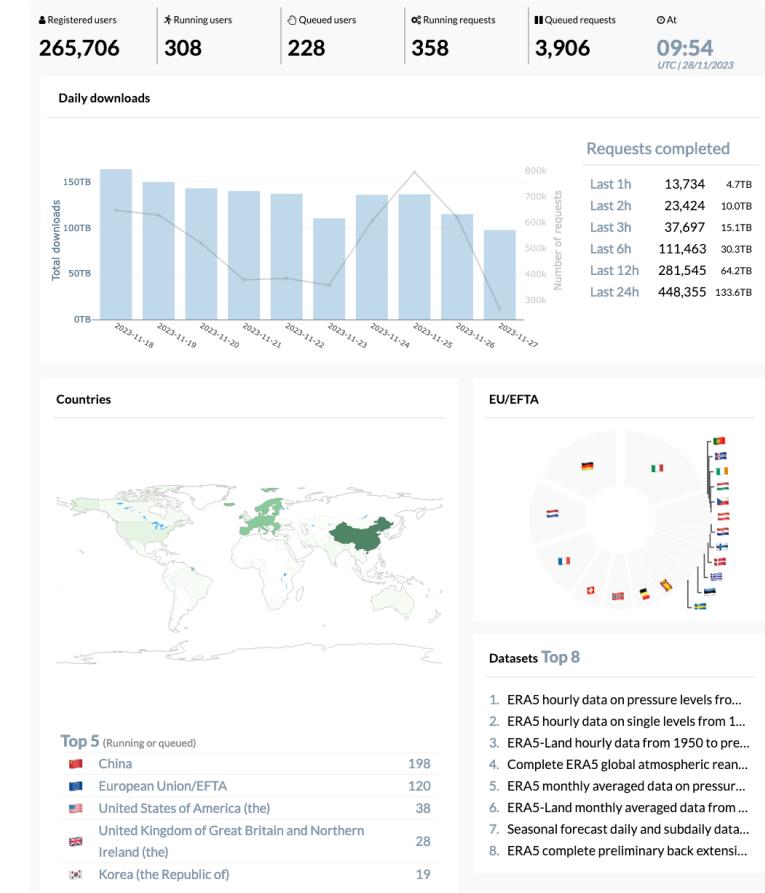
Climate Change

The CDS (and other DS) history

The CDS is a **distributed system**, providing access to existing datasets through a unified web interfaces



Typical performance





Behind the system

Flexible deployment

The Kubernetes deployment means that the system can be easily redeployed on other infrastructure for other projects.

The system is highly scalable and the object store approach downloads provides the fidelity required to serve the growing user base.

JupyterHub and earthkit for online processing

Jupyter notebooks have become a popular development environment for python users and there are a range of training resources available.

earthkit ensures synergy in public facing software developments of C3S and other ECMWF activities.



A FAIR Catalogue

Following the FAIR principles and adopting standardised webAPIs will increase uptake of the catalogue(s) and be compatible with machine learning methods



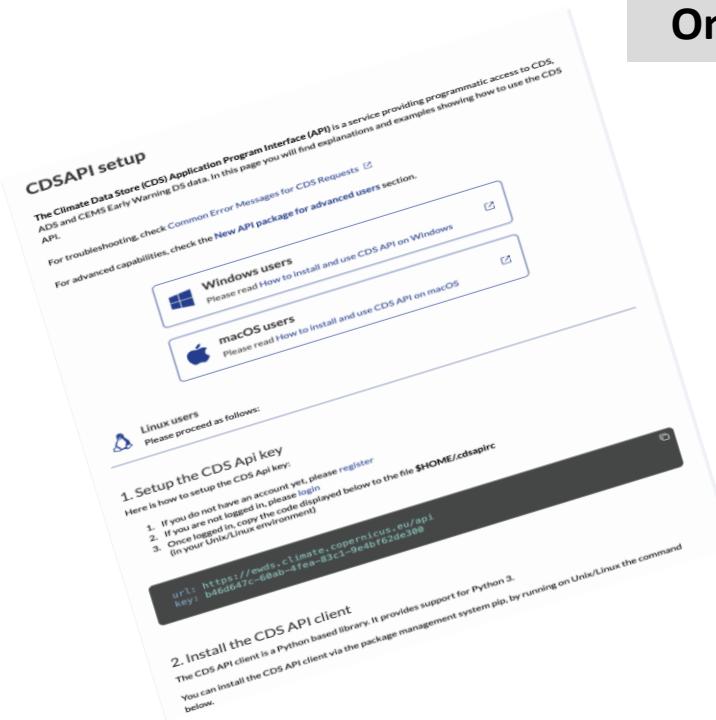
The API



The Data Stores also provide programmatic access via the Python API [[cdsapi Python package](#)]



The Climate Data Store (CDS) Application Program Interface (API) is a service providing programmatic access to CDS, ADS and CEMS Early Warning DS .



One API to download data from all the datastores

CEMS Early Warning Data Store

Datasets

Documentation

Live *

About CEMS

CEMS-FLOODS datasets licence

✓ Accepted

API request

Please go to the [documentation page](#) for information as to how to use the CDS API.

`curl https://cds.climate.copernicus.eu/api/v2/` Hide API request code

```
import cdsapi

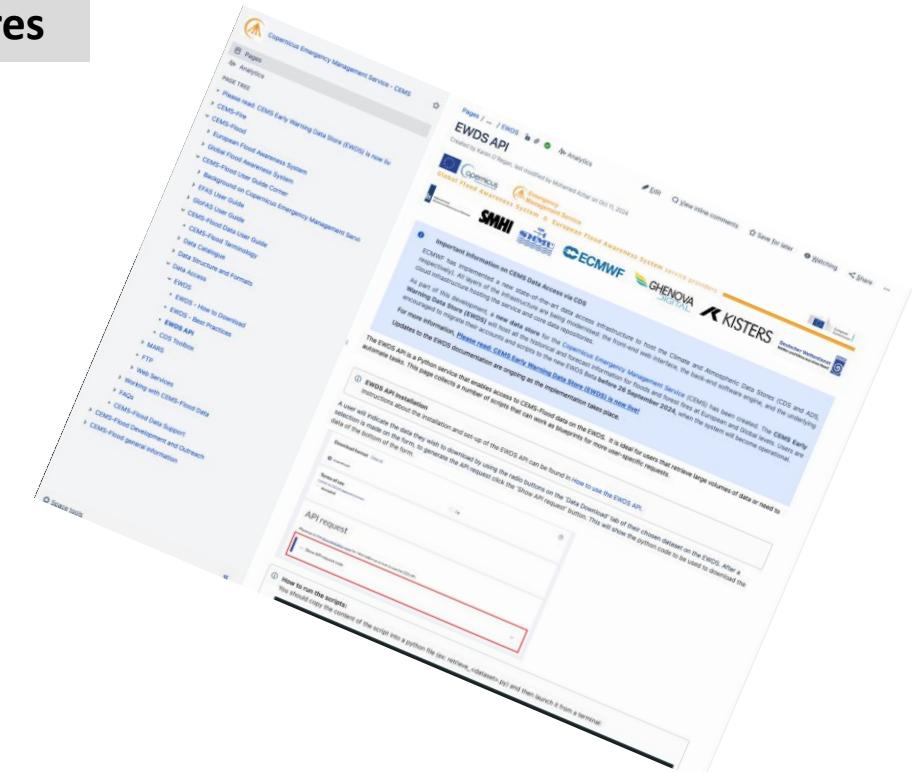
dataset = "cemsglofas-seasonal"
request = {
    "system_version": ["operational"],
    "hydrological_model": ["lisflood"],
    "variable": ["river_discharge_in_the_last_24_hours"],
    "year": ["2025"],
    "month": ["10"],
    "leadtime_hour": [
        "0",
        "48",
        "72",
        "96",
        "120",
        "144"
    ],
    "data_format": "grib2",
    "download_format": "unarchived"
}

client = cdsapi.Client()
client.retrieve(dataset, request).download()
```

Copy

Submit form

Clear all fields





Climate Change

earthkit



Earthkit is the namespace for ECMWF open-source python code

Objectives of earthkit



Lower the barrier to entry



Make common tasks simple and efficient



Provide quality assurance to computation



Interoperable with data and tools from many sources



Embrace open-source approach for traceability and collaboration.

<https://earthkit.ecmwf.int/>



The screenshot displays the earthkit ecosystem. At the top, the earthkit website is shown with a dark background, featuring the earthkit logo, a globe image, and text about streamlining earth science workflows. Below this, a section titled 'The earthkit ecosystem' lists various components: earthkit-data, earthkit-meteo, earthkit-geod, earthkit-climate, earthkit-time, earthkit-transforms, and earthkit-hydro. At the bottom, the earthkit-plots documentation is shown, featuring the earthkit-plots logo, a red globe icon, and a code snippet for generating a line chart from ERA5 data. The code includes imports for earthkit and ek, a data source definition, chart styling, and metadata detection.

```
import earthkit as ek

ds = ek.data.from_source("sample", "era5-timeseries-nh-summer-2025.nc")

chart = ek.plots.TimeSeries()
chart.line(ds, units="celsius", color="red")

# Metadata detection and formatting
chart.title("ERA5 hourly (variable_name) at (latitude:%Lt) (longitude:%Ln)")
chart.ylabel("(variable_name) (units)")

# Shortcuts for common time series formatting
chart.xticks(frequency="1h", format="%H", period=True)
```



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Climate Change

earthkit



Operations on river networks.



Manipulation of dates and time for weather forecasting.

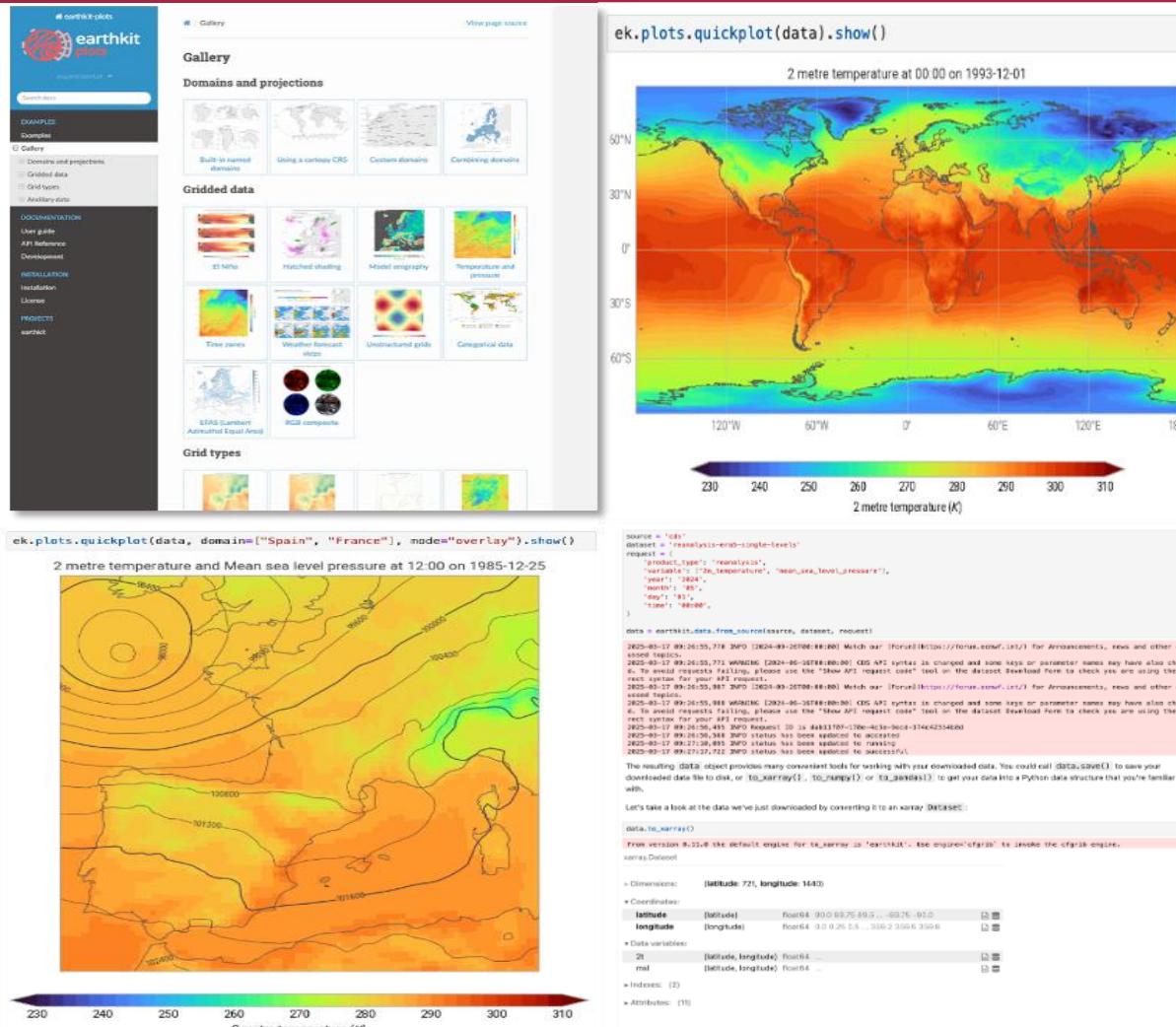


Aggregation and transformation of geospatial data.



Meteorological computations.

<https://earthkit.readthedocs.io>



Regridding of geospatial data.



Format-agnostic Python interface for geospatial data with a focus on meteorology and climate science.



Geospatial computations.



Visualisation tools and templates



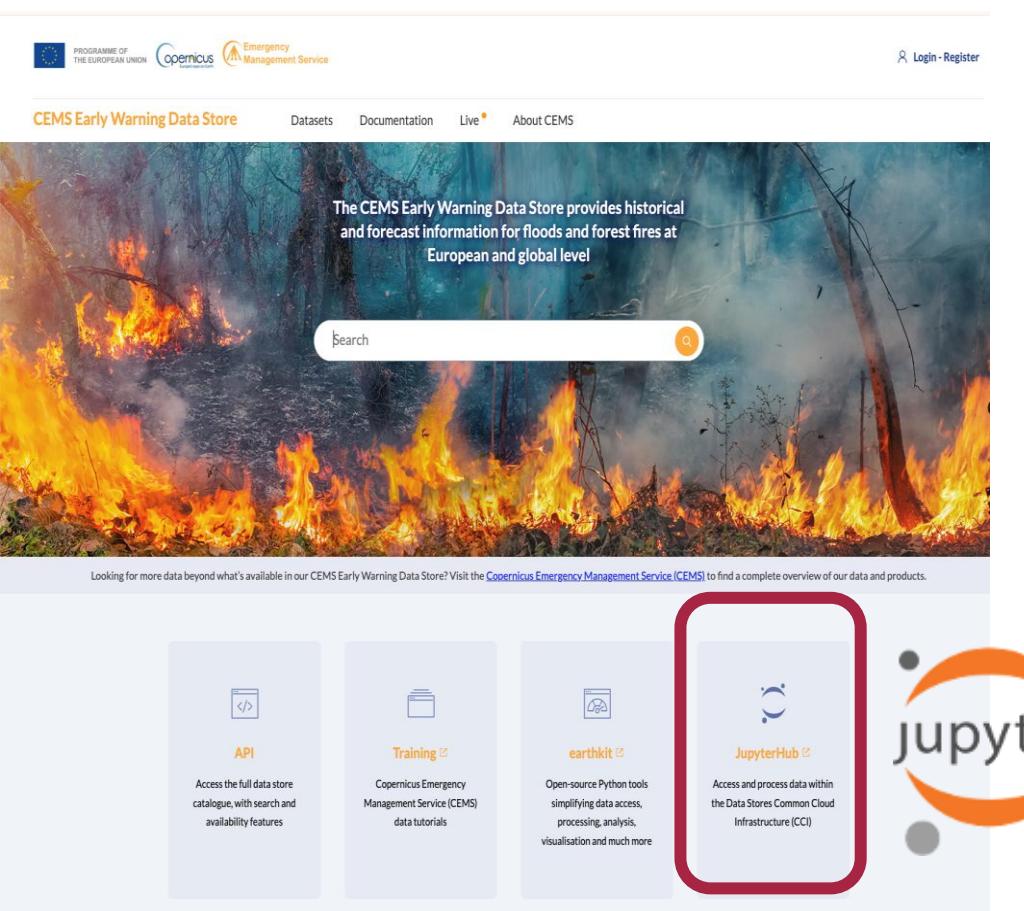
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ECMWF



Climate Change

JupyterHub for DSS

The data store services offer the **DSS JupyterHub Service** as an online computing environment, and earthkit as the supported post-processing and visualisation software.

The CEMS Early Warning Data Store provides historical and forecast information for floods and forest fires at European and global level. The page features a large image of a forest fire, a search bar, and a sidebar with links to API, Training, earthkit, and JupyterHub.

The CEMS Early Warning Data Store provides historical and forecast information for floods and forest fires at European and global level.

Search

CEMS Early Warning Data Store Datasets Documentation Live About CEMS

The CEMS Early Warning Data Store provides historical and forecast information for floods and forest fires at European and global level.

Looking for more data beyond what's available in our CEMS Early Warning Data Store? Visit the [Copernicus Emergency Management Service \(CEMS\)](#) to find a complete overview of our data and products.

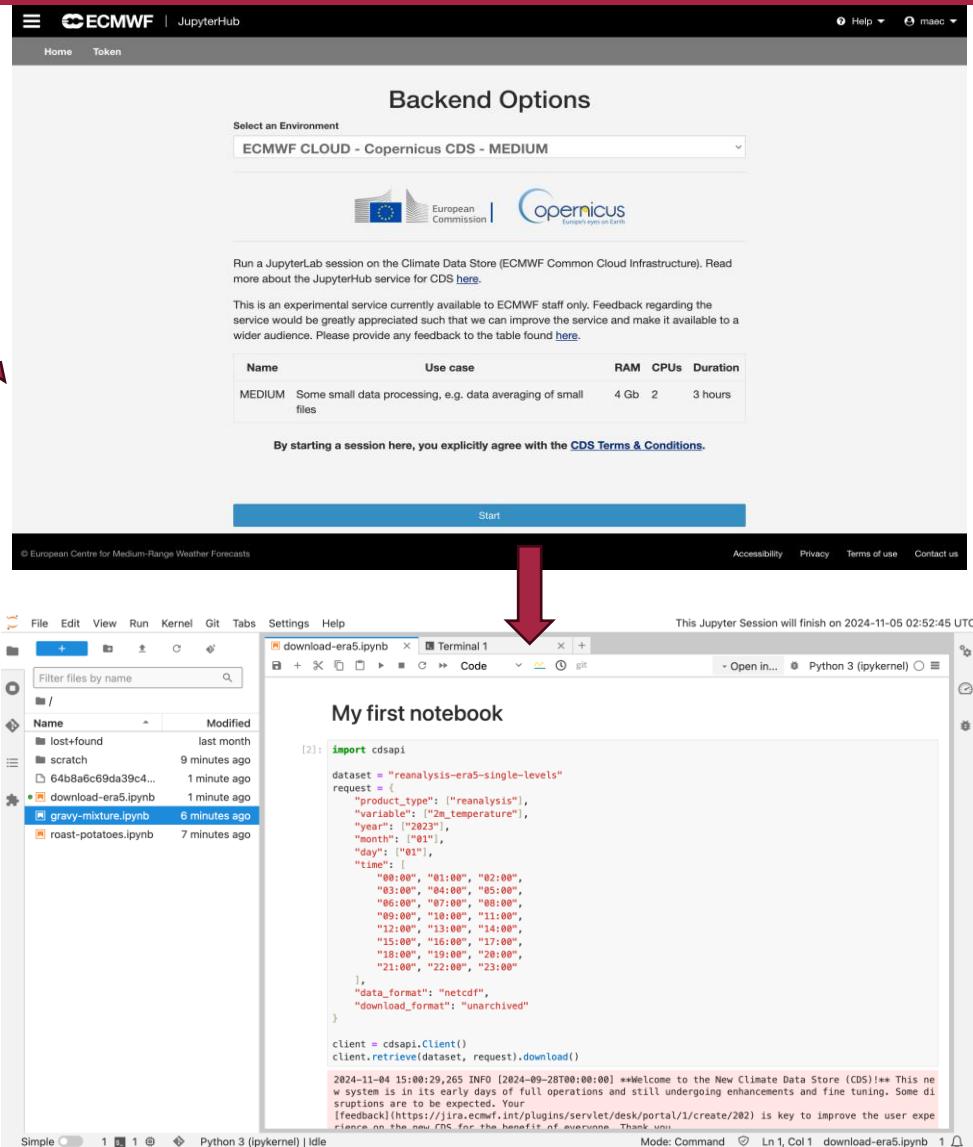
API
Access the full data store catalogue, with search and availability features

Training
Copernicus Emergency Management Service (CEMS) data tutorials

earthkit
Open-source Python tools simplifying data access, processing, analysis, visualisation and much more

JupyterHub
Access and process data within the Data Stores Common Cloud Infrastructure (CCI)



The ECMWF JupyterHub interface shows the Backend Options page for the ECMWF CLOUD - Copernicus CDS - MEDIUM environment. It includes the European Commission and Copernicus logos, a table of session details, and a Jupyter notebook interface with a red arrow pointing to it.

ECMWF | JupyterHub

Home Token

Backend Options

Select an Environment
ECMWF CLOUD - Copernicus CDS - MEDIUM

European Commission | Copernicus

Run a JupyterLab session on the Climate Data Store (ECMWF Common Cloud Infrastructure). Read more about the JupyterHub service for CDS [here](#).

This is an experimental service currently available to ECMWF staff only. Feedback regarding the service would be greatly appreciated such that we can improve the service and make it available to a wider audience. Please provide any feedback to the table found [here](#).

Name	Use case	RAM	CPUs	Duration
MEDIUM	Some small data processing, e.g. data averaging of small files	4 Gb	2	3 hours

By starting a session [here](#), you explicitly agree with the [CDS Terms & Conditions](#).

Start

European Centre for Medium-Range Weather Forecasts

File Edit View Run Kernel Git Tabs Settings Help

download-era5.ipynb Terminal 1

My first notebook

```
import cdsapi
dataset = "reanalysis-era5-single-levels"
request = {
    "product_type": ["reanalysis"],
    "variable": ["2m_temperature"],
    "year": "2022",
    "month": "01",
    "day": "01",
    "time": [
        "00:00", "01:00", "02:00",
        "03:00", "04:00", "05:00",
        "06:00", "07:00", "08:00",
        "09:00", "10:00", "11:00",
        "12:00", "13:00", "14:00",
        "15:00", "16:00", "17:00",
        "18:00", "19:00", "20:00",
        "21:00", "22:00", "23:00"
    ],
    "data_format": "netcdf",
    "download_format": "unarchived"
}
client = cdsapi.Client()
client.retrieve(dataset, request).download()
```

2024-11-04 15:00:29,265 INFO [2024-09-28T00:00:00] **Welcome to the New Climate Data Store (CDS)!** This new system is in its early days of full operations and still undergoing enhancements and fine tuning. Some disruptions are to be expected. Your [feedback] (<https://jira.ecmwf.int/plugins/servlet/desk/portal/1/create/282>) is key to improve the user experience on the new CDS for the benefit of everyone. Thank you!

Simple 1 2 3 Python 3 (ipykernel) | Idle Mode: Command L 1, Col 1 download-era5.ipynb 1



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Climate Change

Documentation, Notebooks and Training Material



Demonstrate how to access and use C3S, CAMS and CEMS data effectively



Highlight the important features and applications of data products



Document public facing software packages with in-context examples



Provide traceability for published reports and documents

The screenshot shows the 'Copernicus Climate Change Service (C3S) Data Tutorials' page. It features a sidebar with links to various climate services and a main content area with a list of tutorials. Each tutorial card includes a thumbnail, a title, and a brief description. The tutorials cover topics such as 'How to access and handle data of the past, present and future climate?', 'Atmospheric Monitoring Service (CAMS) Tutorials', and 'Sketchbook Earth: Illustrated Climate Chronicles'.

The screenshot shows the 'Sketchbook Earth: Illustrated Climate Chronicles' page. It features a central image of a sketchbook with various climate-related illustrations. Below the image, there is a brief introduction and a list of notebooks. Each notebook entry includes a thumbnail, a title, and a brief description. The notebooks cover topics such as '1| Greenhouse Gases - The Prime Suspect', '2| Journey to the Frozen Sea', and '3| It's Panta Rei... (Everything)'.

The screenshot shows the 'earthkit-climate' documentation page. It features a sidebar with 'CONTENTS' and a main content area with code examples. The examples demonstrate how to use the 'earthkit-climate' library to perform tasks like 'Load some test data' and 'Calculate the monthly climatologies of the ERA5 data'. Below the examples, there is a section for 'Easily embed PDFs in your web app' with a screenshot of a PDF viewer.

The screenshot shows the 'Copernicus Emergency Management Service - CEMS Home' page. It features a sidebar with 'Pages' and a main content area with a 'PAGE TREE'. The tree structure includes 'CEMS-Flood' and 'CEMS-Flood User Guide Corner'. The main content area also includes a 'CEMS-Flood' section with a brief introduction and a 'CEMS-Flood User Guide' section. On the right side, there is a search bar and a logo for 'Emergency Management'.



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Climate Change

Contact/Support



Through the **EWDS Help section**, you can access the official **ECMWF Support Portal**, where you'll find detailed guidance and can directly contact support.



Response times are fast, and the team is very responsive



The **Support Portal** is the main entry point for all queries related to ECMWF data, including EFAS and GloFAS products.



Support covers everything from **data access and interpretation**, to **technical questions and service reliability**.



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Hydrological outlook data at your fingertips: the Early Warning Data Store

What is EWDS ?

CEMS

Early Warning Data Store
Copernicus Emergency Management Service (CEMS)



The EWDS is a single point of access to the wide range of quality-assured floods datasets produced by or in collaboration with the Copernicus Emergency Management Service. It is developed and maintained by ECMWF



The EWDS is an easy-access archive for all historical and forecast information for floods and forest fires at European and global scales.



It is available openly to the general public upon registration with an ECMWF account.



The EWDS is the recommended and easiest way to access EFAS/GLOFAS data and all relevant metadata information;



Users can select the type of data and dates of the time series they want to download. All archived EFAS/GLOFAS data is in the form of raw hydrological time series outputs, and accessible to all. All versions of EFAS/GLOFAS are available for download. The data is primarily available in GRIB2 format but is also made available in NetCDF4 (experimental) format.



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Europe's eyes on Earth

Datasets

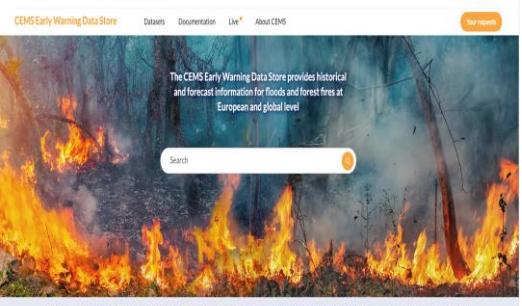


CEMS Early Warning Data Store

Datasets Documentation Live About CEMS

Variables

- River discharge
- Runoff water equivalent
- Snow depth water equivalent
- Soil wetness index



Variables

- Elevation
- Upstream area
- Field capacity
- Wilting point
- Soil depth



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Datasets

Domain	Type	Dataset
European	Forecast	Efas forecasts
	Reforecasts	Efas seasonal forecasts
	Historical run forced with observations	Efas reforecasts
Global	Forecast	Efas seasonal reforecasts
	Reforecasts	Efas historical simulations
	Historical run forced with reanalysis	Glofas forecasts
	Forecast	Glofas seasonal forecasts
	Reforecasts	Efas reforecasts
	Historical run forced with reanalysis	Efas seasonal reforecasts
	Forecast	Glofas historical simulations



Documentation/Training



Direct Access to Official CEMS-Flood Wiki



The wiki is structured into three key branches:



EFAS Documentation - Detailed product specs and operational guidance for the European system.



GloFAS Documentation - Information tailored for the Global system's datasets and forecasts.



User Guide Corner - General data access support

- How to download and work with EFAS/GloFAS data
- Data availability and formats
- Step-by-step usage help



The EWDS offers **step-by-step tutorials** through the CEMS-Flood wiki, along with **well-structured Jupyter Notebooks** designed to guide users through practical data access and analysis workflows.



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Tutorial materials

Part 1 : Accessing and downloading GloFAS data from CEMS Early Warning Data Store

Part 2 : Best practices to download GloFAS Seasonal forecasts from CEMS Early Warning Data Store

Part 3 : Download and plot seasonal forecast using earthkit



All scripts are written in python

Link to the jupyter book

<https://simow-az.github.io/2025-wmo-workshop-training-glofas-seasonal-V1/Welcome.html>

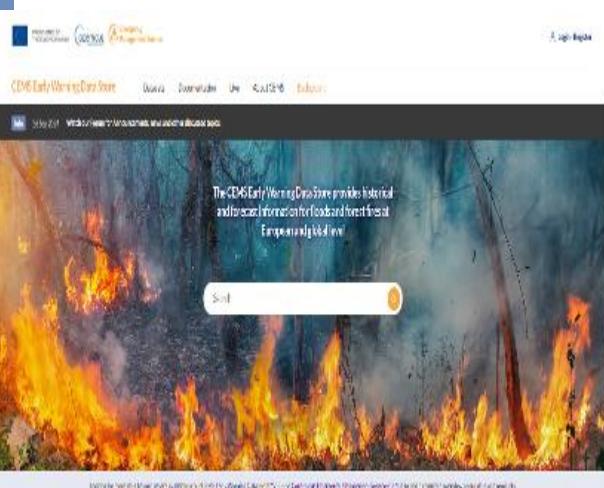
Scan the QR code to go to the jupyter book



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Recap of data access and analysis



Explore the datasets available through the **EWDS**

<https://ewds.climate.cernicus.eu/datasets>

Create an **ECMWF account** and **set-up the api**

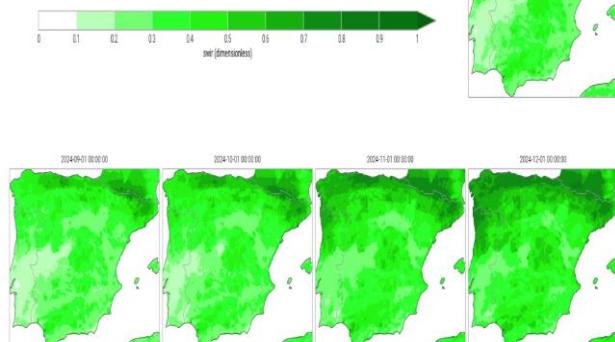
EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Download and explore the seasonal forecast files

```
[1]: import earthkit as ekh

[1]: DATASET = 'cemsglofas-seasonal'
LEADTIMES = ['%d' % l for l in range(24, 2976, 24)]
REQUEST = {
    'system_version': ['operational'],
    'hydrological_model': ["liflood"],
    'variable': 'river_discharge_in_the_last_24_hours',
    'year': ["2024"],
    'month': ["08"],
    'leadtime_hour': LEADTIMES,
    'area': [43.79, -9.30, 36.00, 3.33],
    'data_format': 'grib2', # Or netcdf
    'download_format': 'unarchived'
}
data=ekh.data.from_source('cds',DATASET,REQUEST)
```

Glofas seasonal run: 2024-08-01 00:00 UTC,
monthly ensemble mean of Soil Wetness Index



Download the data for your area of interest

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Start analysing the data using **earthkit/python**

The C3S Water Service: an operational multi-model seasonal hydrological forecast framework



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The C3S Water Service

1.) Operational hydrological monitoring

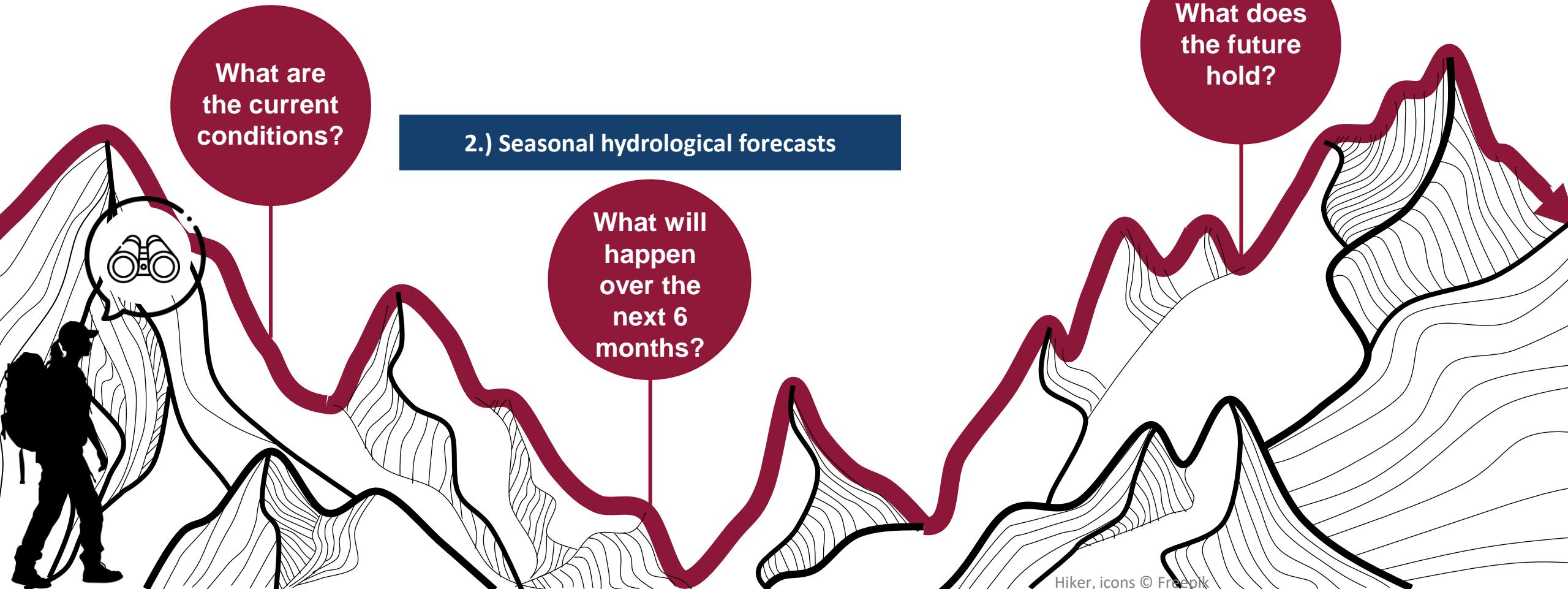
What are
the current
conditions?

2.) Seasonal hydrological forecasts

What will
happen
over the
next 6
months?

3.) Hydrological climate change projections

What does
the future
hold?

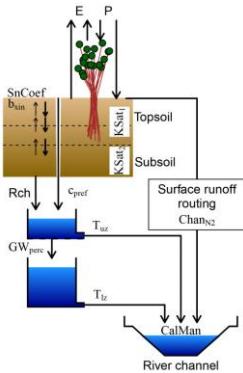




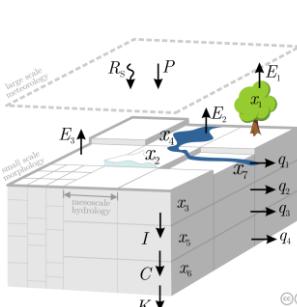
What types of global hydrological models are available operationally?

1.) Global Hydrological Models (GHMs)

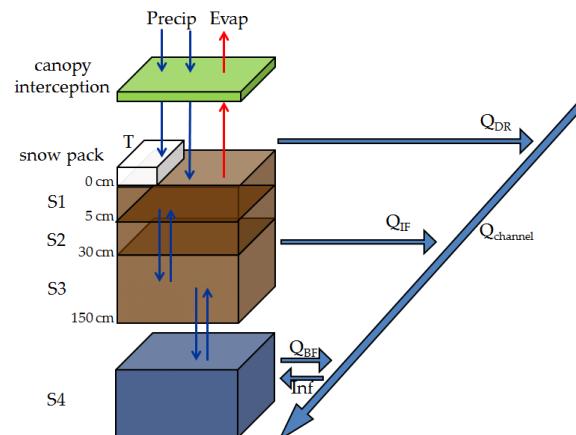
LISFLOOD (CEMS)



mHM (UFZ)

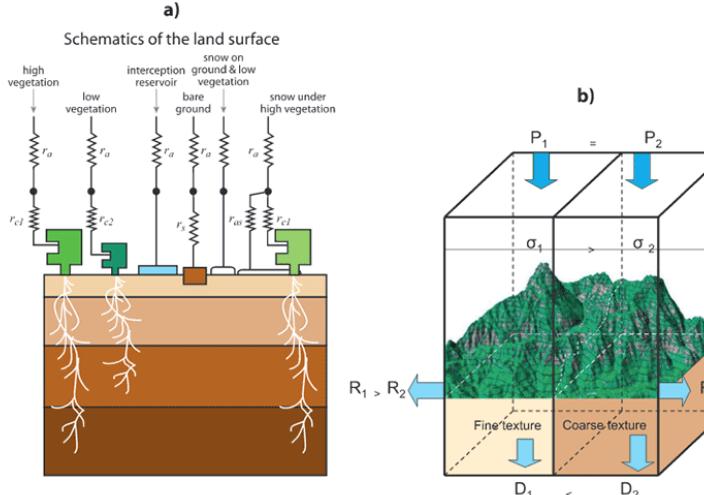


PCRGLOB_WB (Utrecht)

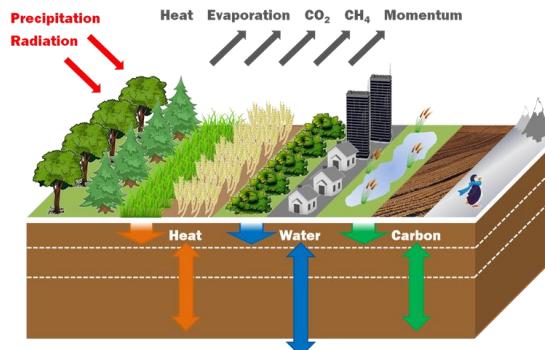


2.) Land surface models

ecLand (ECMWF)

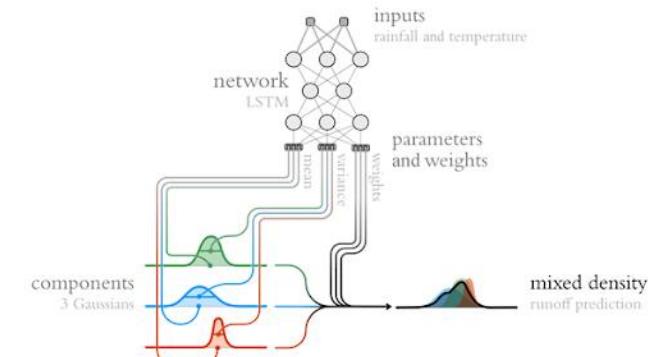


JULES (UKCEH)



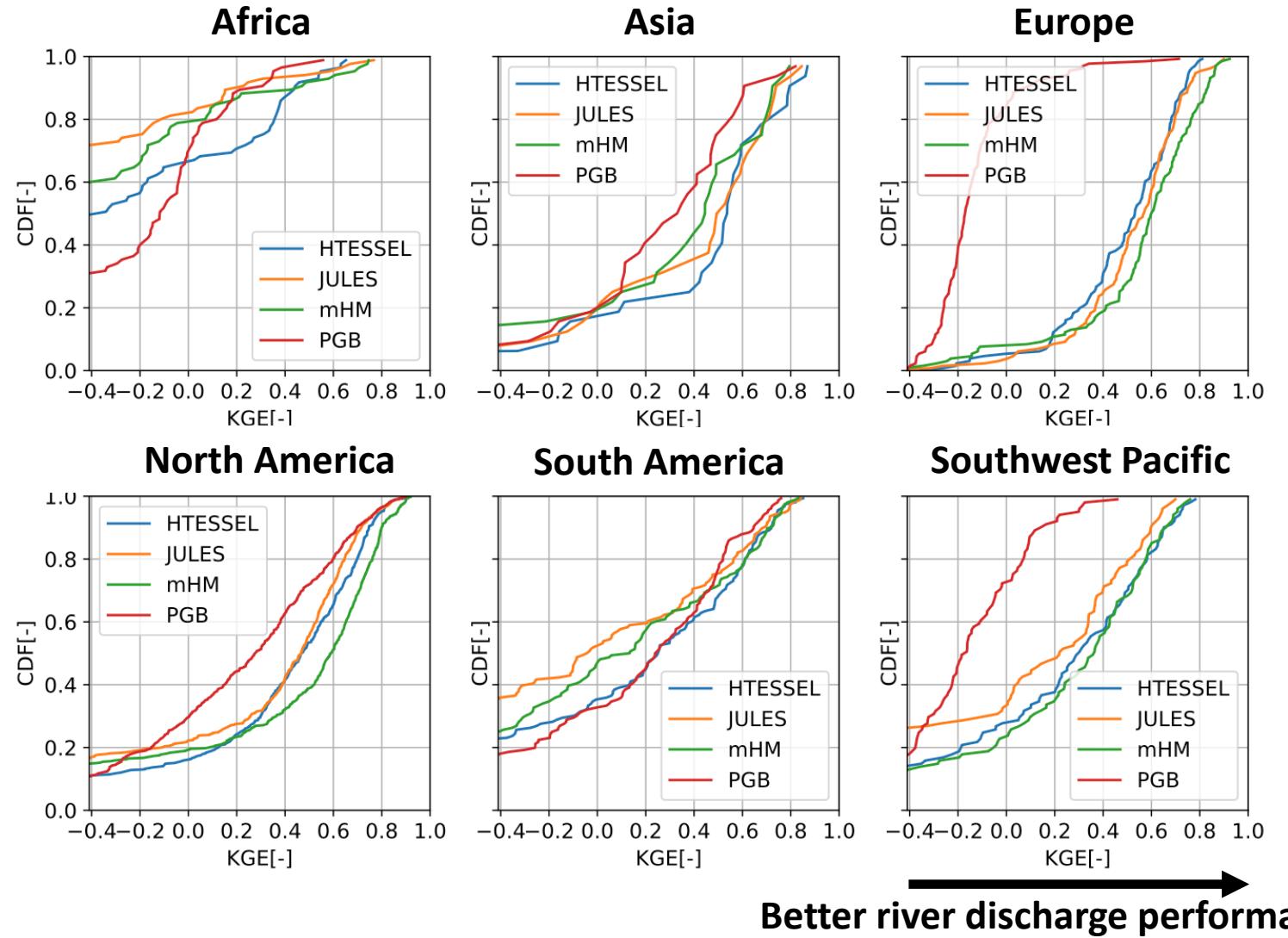
3.) AI-based hydrological models

e.g. Flood Hub (Google)

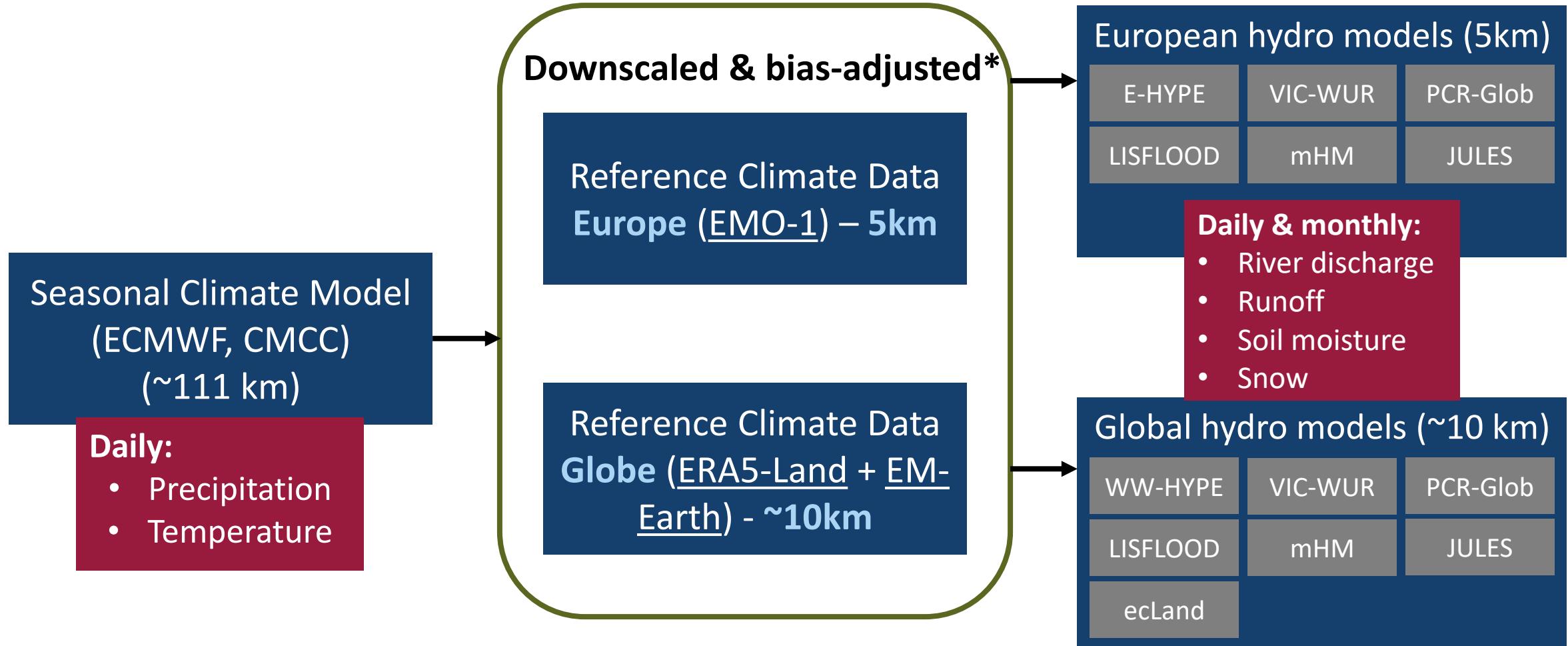


There's no best hydrological model everywhere!

Thober et al. 2023, C3S
Water Service Quality
Assurance Report,
D410.3.2.1 – model v
obs. river discharge.



Multi-model seasonal hydrological forecast chain



*Multi-scale bias AdjuStment (MIDAS, [Berg et al. 2024](#)) - a robust quantile-mapping method for consistent, bias-corrected climate data across extremes.

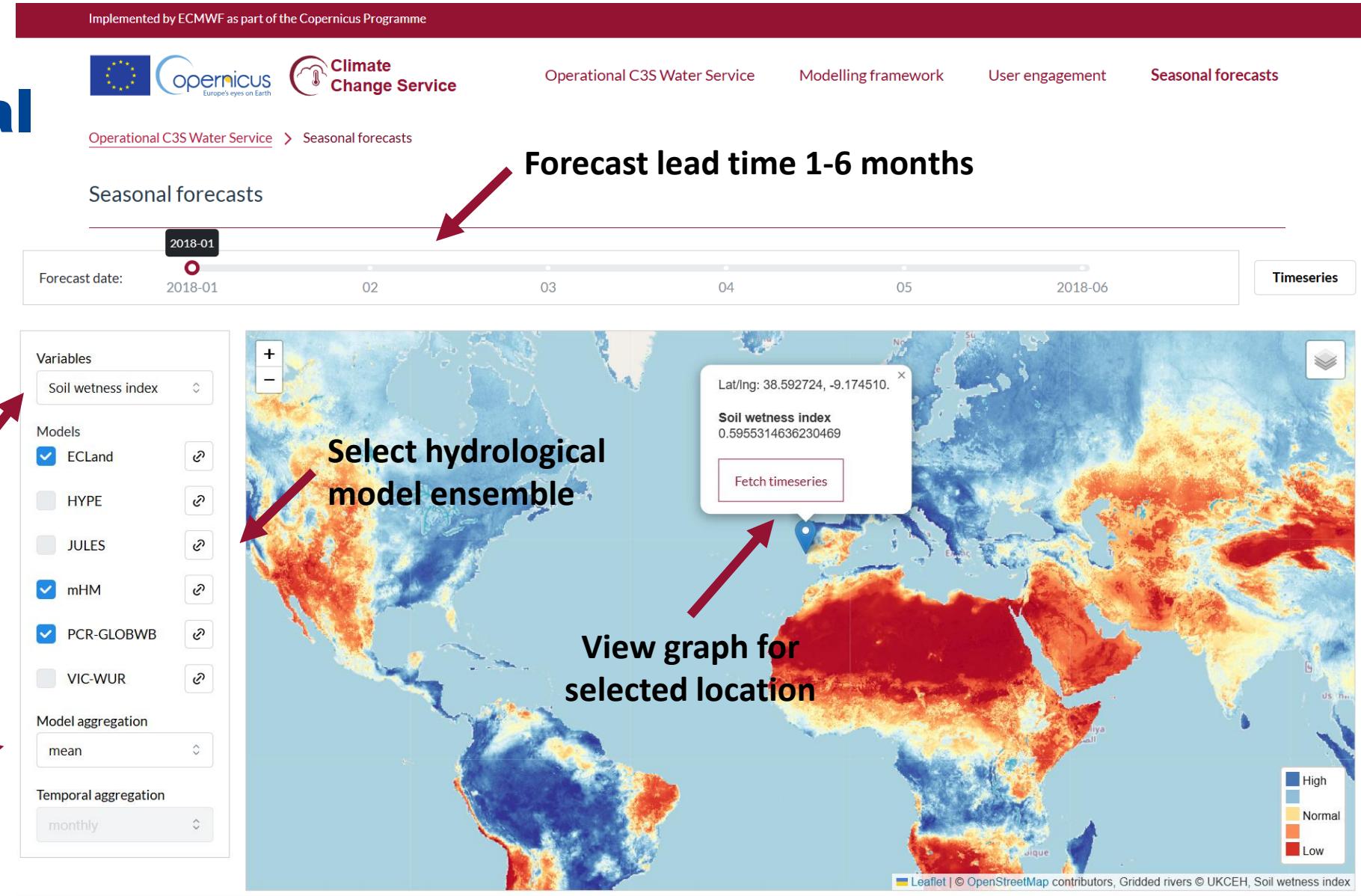


V1 of seasonal forecast app

(not yet publicly available)

Select forecast variable

Select ensemble aggregation / blending approach





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How to stay up-to-date with the C3S Water Service?

- **Timeline:** C3S Water Service contract **Feb 2025** to **Jan 2028**
- **Website** (more to follow soon!):
- <https://c3swaterservice.climate.copernicus.eu/>

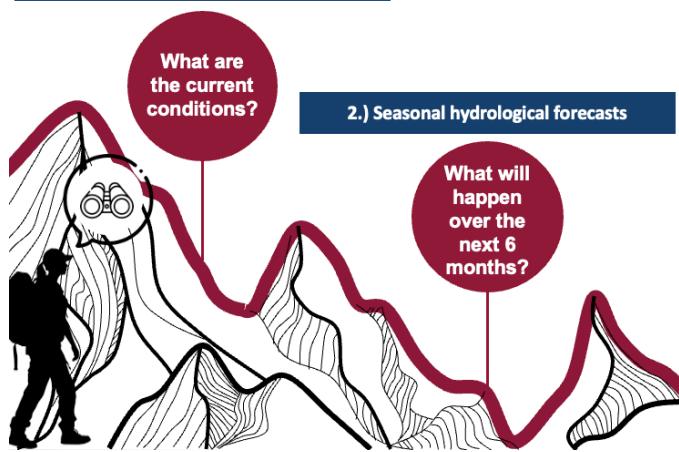


- Links to **data** (on the CDS), **Apps**, **Demonstrations**, and **User Surveys** to help shape the service!

Recap of the C3S Water Service?

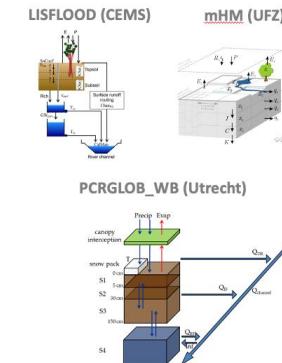
The C3S Water Service

1.) Operational hydrological monitoring

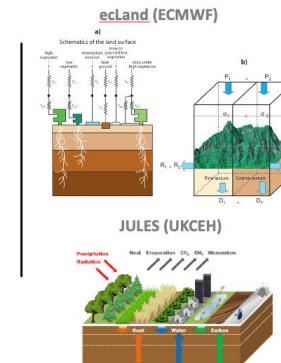


A seasonal hydrological service provides current **hydrological status** and an **outlook** over the next month to several seasons ahead

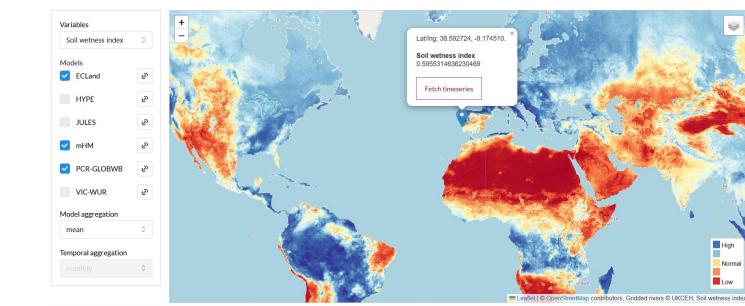
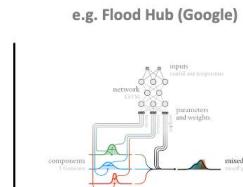
1.) Global Hydrological Models (GHMs)



2.) Land surface models



3.) AI-based hydrological models



There is no single best seasonal climate or hydrological model everywhere – multi-model framework needed to capture **model structure uncertainty**

User co-design of applications with **open data** imperative to drive downstream uptake of seasonal hydrological forecasts

Quiz time

Thank you

Pillar 1: hydrological sub-seasonal and seasonal forecasting

- 1.) What is the major factor in atmosphere predictability over 3 months?
 - Choices: atmosphere; land; [ocean](#)
- 2.) How important are hydrological initial conditions in hydrological sub-seasonal forecasting?
 - Choices: not important at all; the only fact that matters; [importance depends on catchment water storage](#)
- 3.) What hydrological forecast strategy can best handle climate change?
 - Choices: Statistical, ESP, [Dynamical](#)

Pillar 2: Hydrological outlook products

- 4.) How frequently are ECMWF and GloFAS sub-seasonal forecasts updated?
 - Choice: [every day](#); twice per week; every week
- 5.) How many forecast anomaly categories are used in GloFAS seasonal forecast products:
 - Choices: 2, [5](#), 10
- 6.) What is the recommended time-aggregation of sub-seasonal hydrological outlooks:
 - Choices: daily, [weekly](#), monthly

Pillar 3: Data access and analysis

- 7.) How many variables are available through the EWDS for the seasonal forecast?
 - Only discharge, [Land hydrology variables](#), Discharge and precipitation
- 8.) How frequently are the seasonal forecasts made available on the EWDS?
 - Monthly at the beginning of each month, [Monthly on the 10th of each month](#), weekly at the beginning of each week.
- 9.) What is the main benefit of using Earthkit package ?
 - Faster data download than cdsapi, Fast data download and processing, [Fast data processing](#).

Pillar 4: climate services

- 10.) What is the benefit of including multiple climate and/or hydrological models in a seasonal forecast?
 - Choices: Speeds up forecast generation, reduces need for model calibration, [captures model structure uncertainty](#)
- 11.) What is a reforecast or hindcast in seasonal hydrological forecasting:
 - Choices: A real-time forecast for the previous month, [A retrospective forecast used to assess model skill](#), A deterministic simulation used to initialise forecasts
- 12.) What does ensemble spread show:
 - Choices: Model resolution, Gauge availability, [Forecast uncertainty](#)
- 13.) Seasonal forecasts typically provide information over what time range?
 - Choices: 1–3 days, [1–7 months](#), 5–10 years

Thank you & Further information!

www.efas.eu EFAS website

www.globalfloods.eu GloFAS website

<https://ewds.climate.copernicus.eu/> CEMS-Flood data on the Early Warning Data Store

<https://confluence.ecmwf.int/display/CEMS/CEMS-Flood> CEMS-Flood Documentation



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