INLINE
Integrated pan-European rainfall and floods impact forecasts for cooperation in emergency management

Co-funded by the European Union

INLINE project

Integrated pan-European rainfall and floods impact forecasts for cooperation in emergency management (UCPM-KAPP)

Marc Berenguer, Shinju Park, Xinyu Li, Calum Baugh, Karen O'Regan, Nikos Mastrantonas, Oisin Morrison, Seppo Pulkkinen, Heikki Millikovsky, F. Javier Rodríguez, Sara Gómez, Violeta Matos, Tomás Gutiérrez, Nuno Moreira, Bárbara Gomes, Antonio Santiago, Ana M. Durán, Rosa M. Torres, Carmen Montero Bruno Borges, Abel Gomes

EFAS AM, Bratislava, SK - 01 Oct 2026

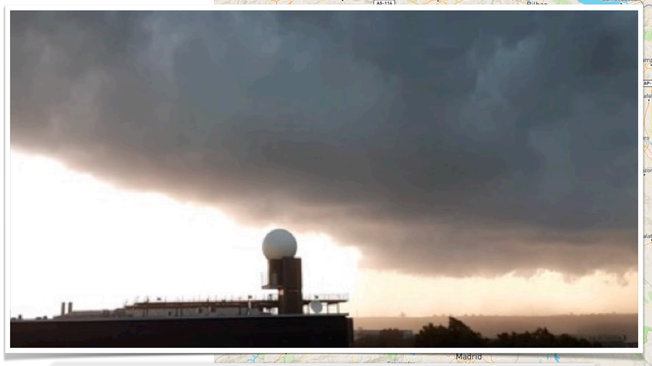
CRAHI UPC Centre de Recerca Aplicada en Hidrometeorologia UNIVERSITAT POLITÈCNICA DE CATALUNYA
ECMWF
ILMATIETEEN LAITOS METEOROLOGISKA INSTITUTET FINNISH METEOROLOGICAL INSTITUTE
aemet Agencia Estatal de Meteorología
IPMA Instituto Português do Mar e da Atmosfera
EMA Agencia de Emergencias de Andalucía Junta de Andalucía
GOBIERNO DE ESPAÑA MINISTERIO DEL INTERIOR DIRECCIÓN GENERAL DE PROTECCIÓN CIVIL Y EMERGENCIAS
EMERGÊNCIA E PROTEÇÃO CIVIL AUTORIDADE NACIONAL

Main objective

Advance on the capabilities of EWS with tools to anticipate the impacts caused by storms, heavy rain and floods, to support the decision-making workflows of various levels of Civil Protection Agencies (CPAs), including their coordination and cooperation.

Impact forecasts for storms, heavy rainfall and flash floods

Storm impact nowcasting (0-3h)



Heavy rainfall, hail, lightning

Based on radar nowcasting & ML

European-wide exposure

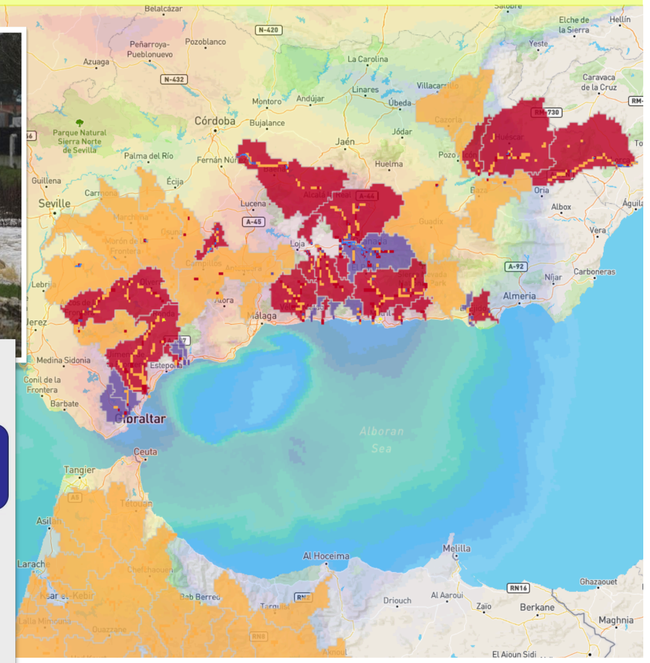
Flash flood impacts (0-120 h)



Flash floods (catchments 10 - 2000 km²)

Resolution: 1 h, 1 km - Frequency: 1 h

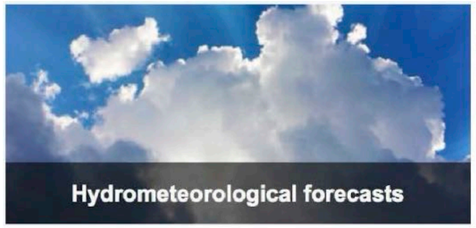
Blended precipitation forecasts	Flash flood hazard	Flash flood impacts
• Using probabilistic nowcasting & NWP • Seamless blending in the first 6 hours.	• Basin-aggregated precipitation on the river network. • Hazard assessment by comparison with climatological thresholds	• By combining hazard with exposure.



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Real-time impact forecasting for CPAs

Combining hazard and impact forecasts, official warnings and exposure and vulnerability datasets for compound impact forecasting to support coordination and cooperation of CPAs.



- Official NHMs warnings (Meteoalarm).
- Gauge-adjusted OPERA QPE.
- Probabilistic rainfall forecasts (0-120h).



- Storm hazard nowcasts (0-3h).
  - Hail.
  - Wind gusts.
  - Heavy rain.
  - Lightning.
- Storm impact nowcasts (0-3 h).





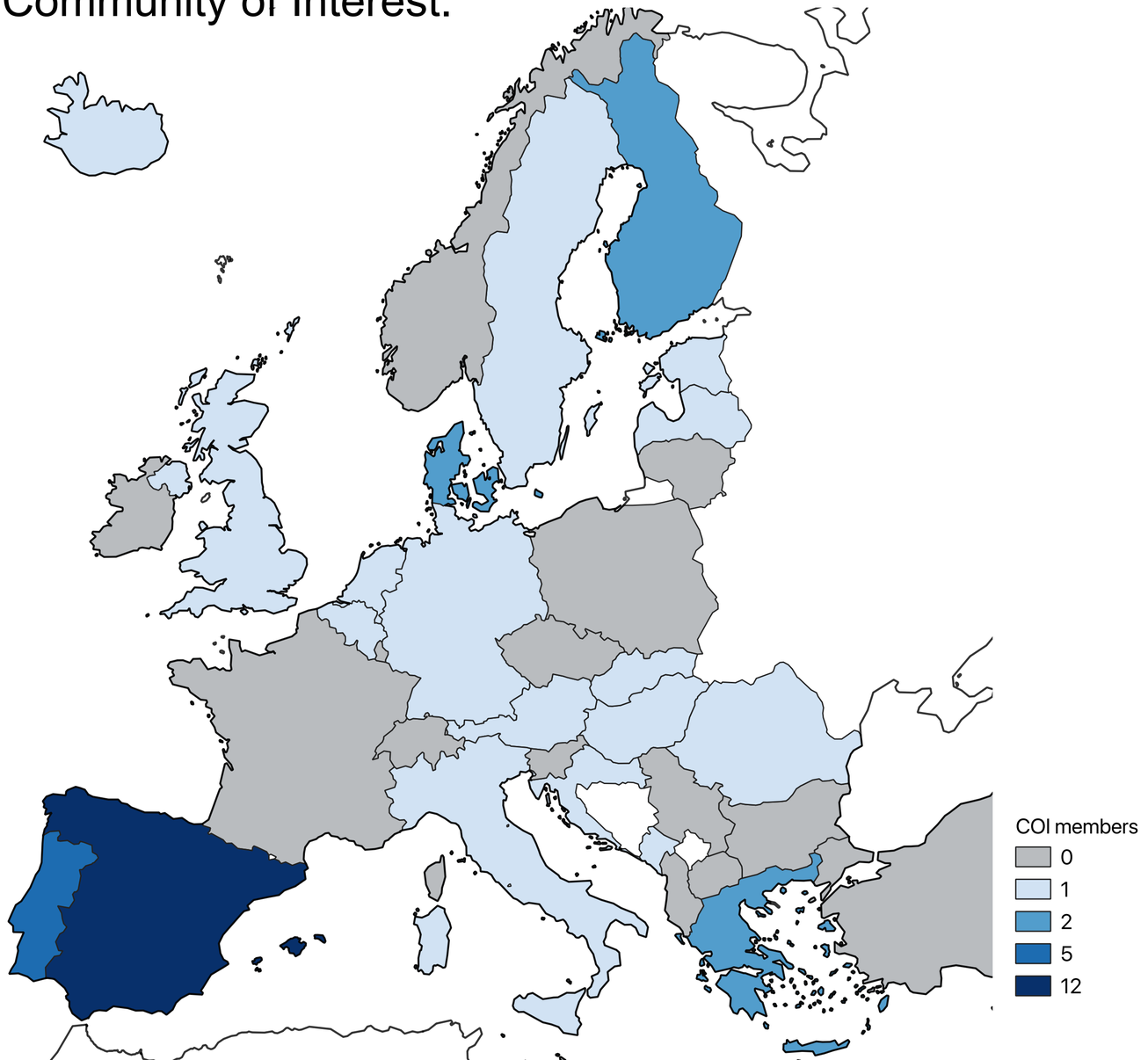
- Combined exposure map (1 arcmin):
  - Population density.
  - Transportation networks.
  - Energy, health, education infrastructures.
- Flood hazard maps (Floods Directive)
- Critical points in flood areas
- Other critical points.

Integrated through user-specific notifications

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INLINE demonstration

- In real time (September 2025 – November 2026).
- With the participation of an INLINE Community of Interest.



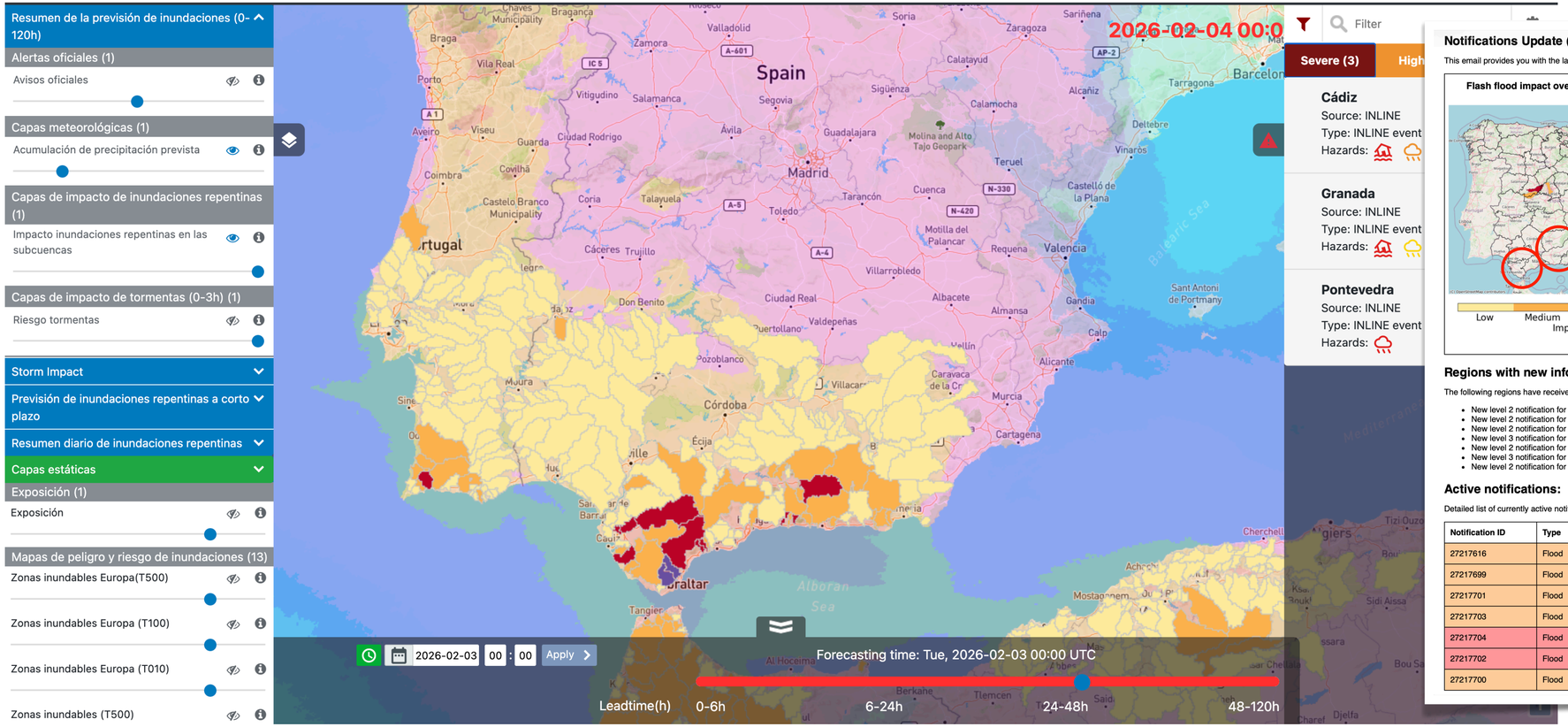
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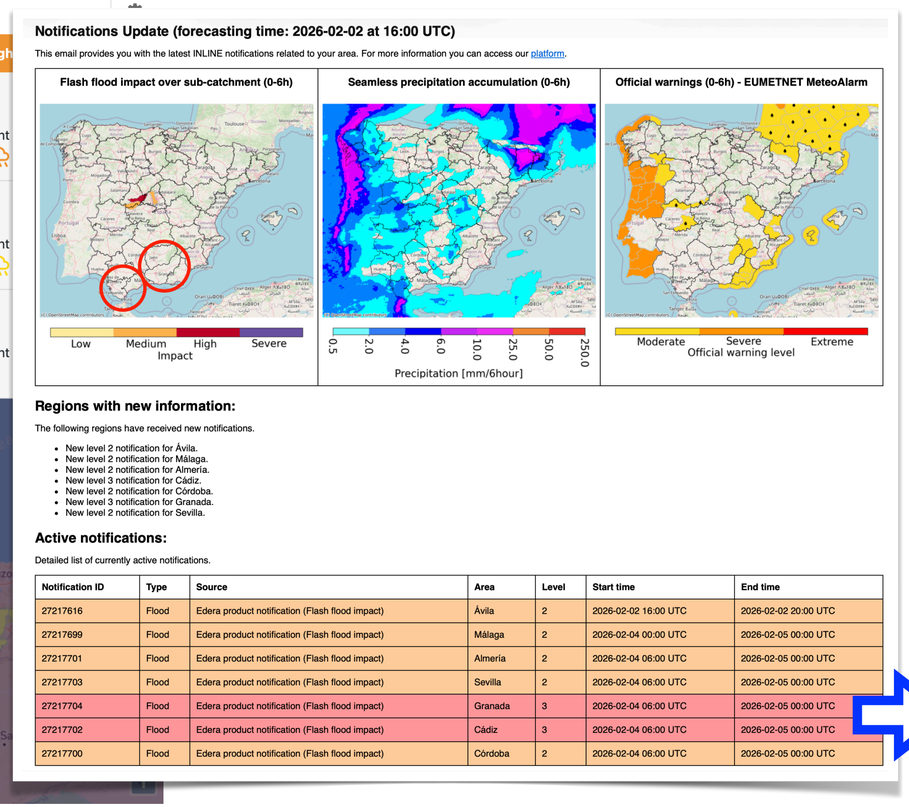
INLINE demonstration

- In real time (September 2025 – November 2026).
- With the participation of an INLINE Community of Interest.
- Access to the products in real time through
  - WMS/API
  - INLINE web-based platform
- Trigger of user-specific automatic messages:
  - Regional domain and sub-division
  - Products
  - Thresholds
  - Frequency
- Integration of *local* products/information (exposure, vulnerability, observations…)
- Active participation of end users in the evaluation.

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the European Union

Andalusia, ES: 03-07 February 2026





Notification ID	Type	Source	Area	Level	Start time	End time
27217616	Flood	Edera product notification (Flash flood impact)	Ávila	2	2026-02-02 16:00 UTC	2026-02-02 20:00 UTC
27217699	Flood	Edera product notification (Flash flood impact)	Málaga	2	2026-02-04 00:00 UTC	2026-02-05 00:00 UTC
27217701	Flood	Edera product notification (Flash flood impact)	Almería	2	2026-02-04 06:00 UTC	2026-02-05 00:00 UTC
27217703	Flood	Edera product notification (Flash flood impact)	Sevilla	2	2026-02-04 06:00 UTC	2026-02-05 00:00 UTC
27217704	Flood	Edera product notification (Flash flood impact)	Granada	3	2026-02-04 06:00 UTC	2026-02-05 00:00 UTC
27217702	Flood	Edera product notification (Flash flood impact)	Cádiz	3	2026-02-04 06:00 UTC	2026-02-05 00:00 UTC
27217700	Flood	Edera product notification (Flash flood impact)	Córdoba	2	2026-02-04 06:00 UTC	2026-02-05 00:00 UTC

EMA Agencia de Emergencias de Andalucía · Junta de Andalucía
DIRECCIÓN GENERAL DE PROTECCIÓN CIVIL Y EMERGENCIAS

3000 people evacuated (CA, JA)



03 Feb





04-05 Feb

Several PMA deployed & coordination comitee



Córdoba



Jerez



ArcosFra-ElPuerto



GRAZALEMA!!!





Emergency Plan (Sit-2)





Closure of schools & other public centers



Specialized army unit (Sit-2)



Impacts due to rain, overflows & wind



10-12 critical points across the region

- Almost 12.000 incidents in total (112 incidents)
- Over 11.000 people evacuated
- More than 150 roads blocked
- 1 casualty

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INLINE Multi-Criteria Evaluation Framework

- Real-time demonstration with end users (access to products and notifications).
- Extended to the INLINE CoI (40+ organisations in 21 countries).

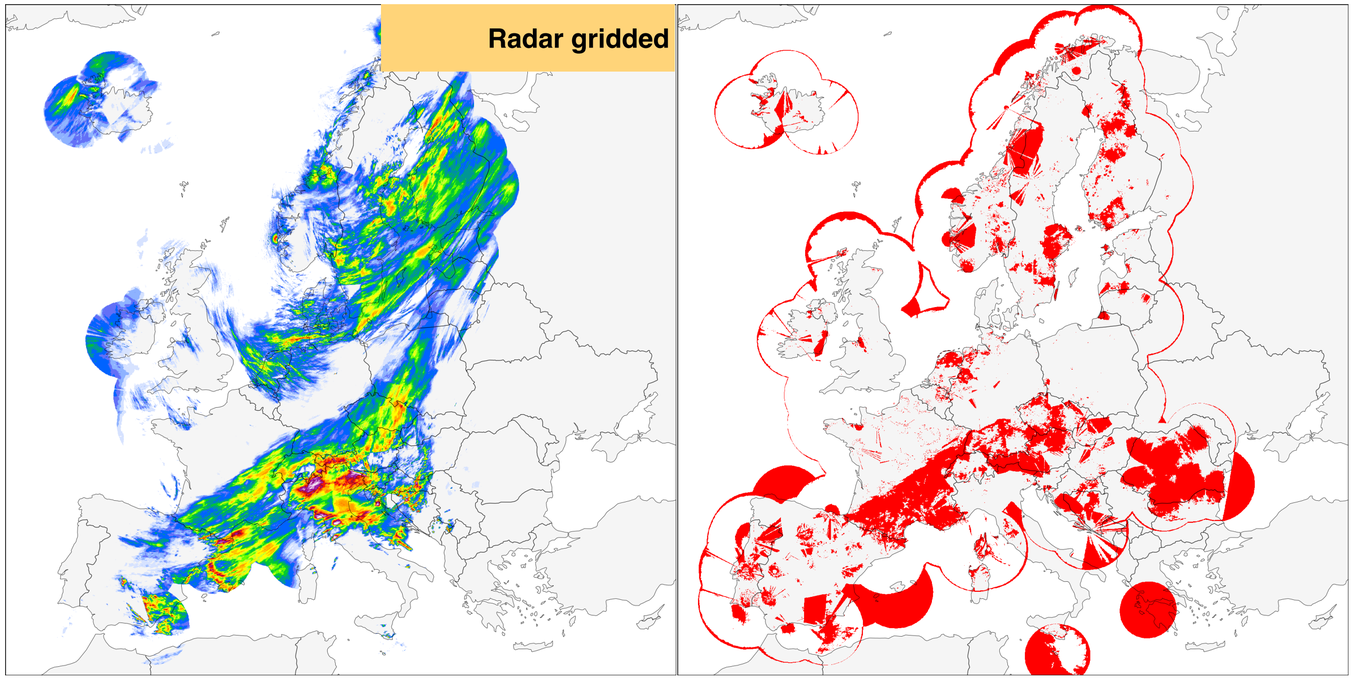
Hydrometeorological forecasts
• Precipitation estimation • Impact on LISFLOOD initialization • Storm hazard nowcasts • Flash flood hazard forecasts

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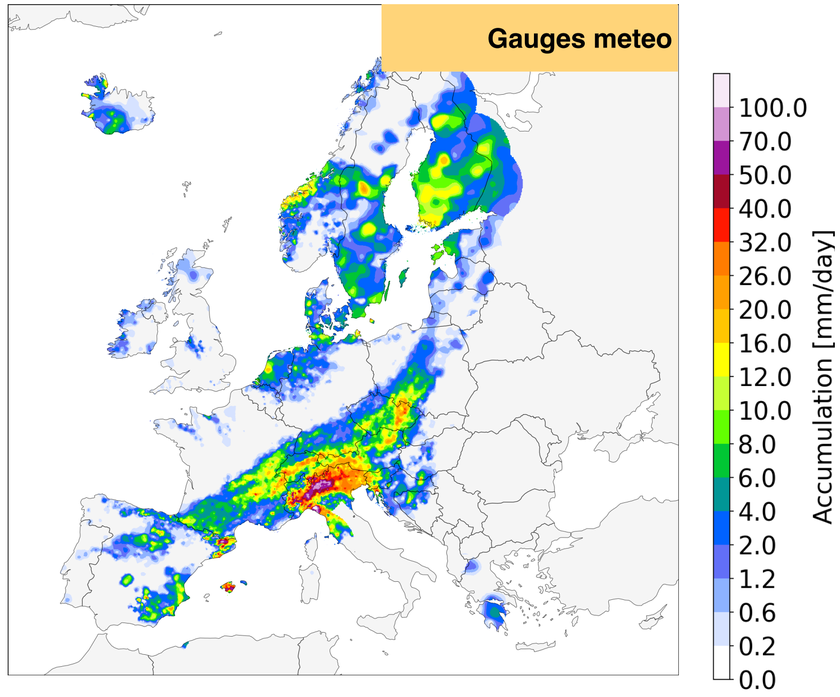
Precipitation inputs for hydrological forecasting

- Based on the radar-based composite produced by EUMETNET OPERA.
- Bias-adjusted with past EFAS rain-gauge observations.
- Improved identification of artifacts.

09 Sep 2026



09 Sep 2026



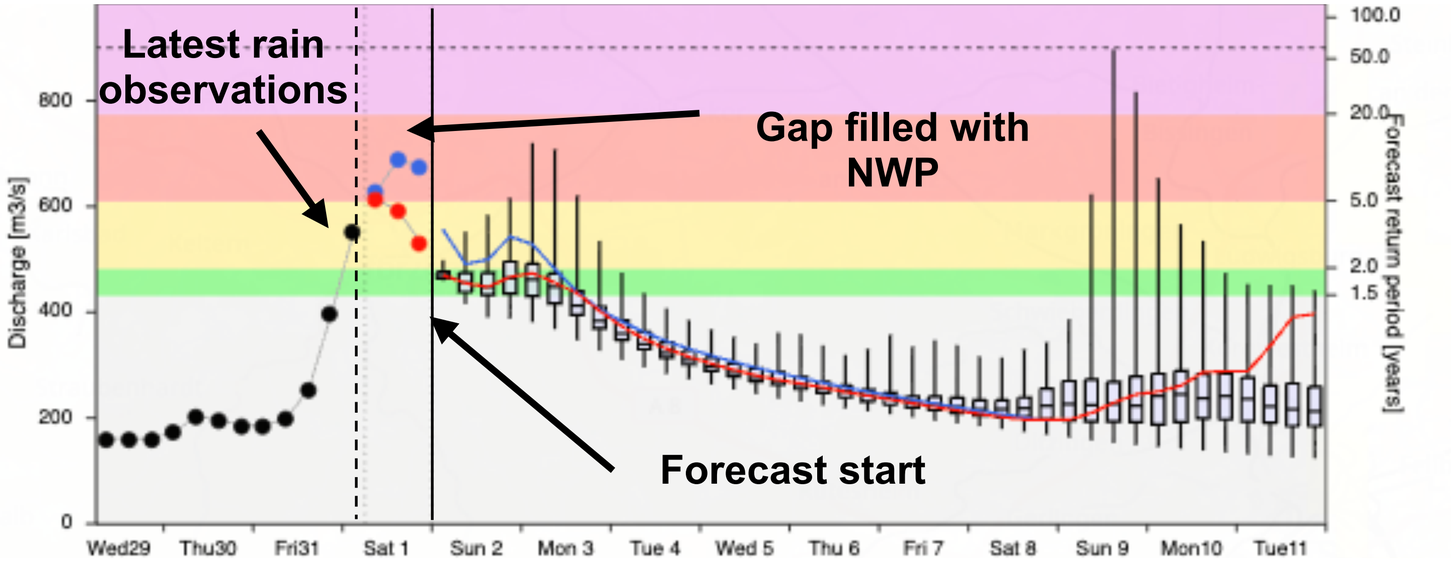
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Precipitation inputs for hydrological forecasting

Does using **radar-based precipitation observations** for the fill-up period of EFAS improve the discharge simulations?

Currently,

- ~18-30-hour delay in receiving gauge observations.
- The observation gap is filled using ECMWF IFS control member.



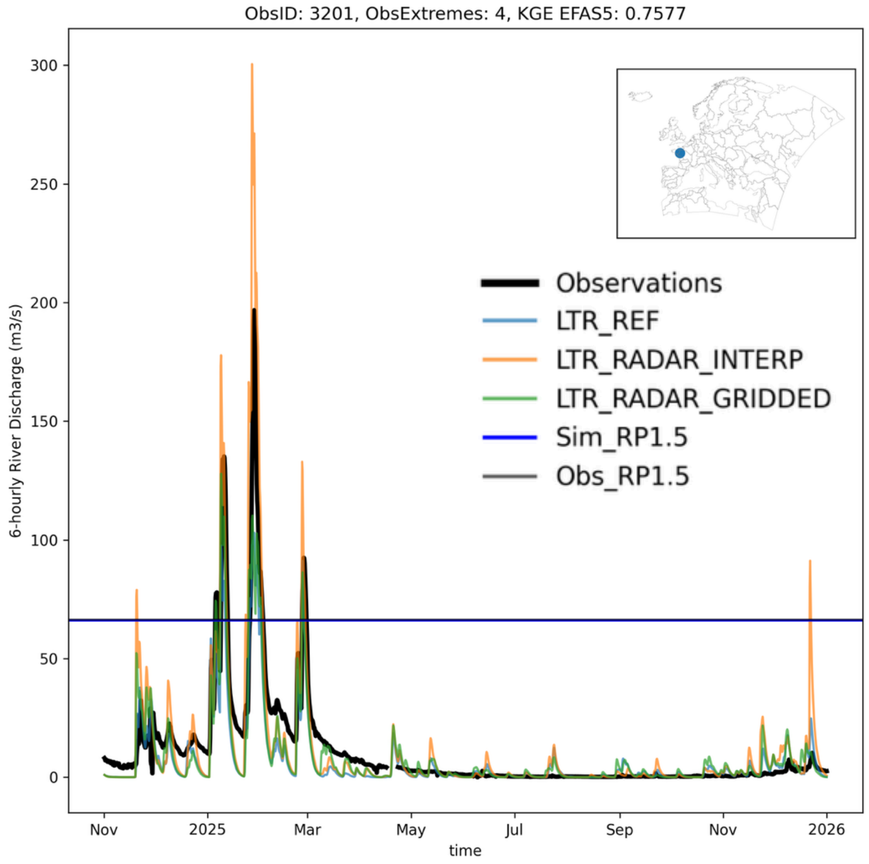
Two experiments (15 months):

- Long-term run: full simulation.
  → *vs. gauge-based*
- Fill-up run: filling the observation gap.
  → *vs. NWP-based*

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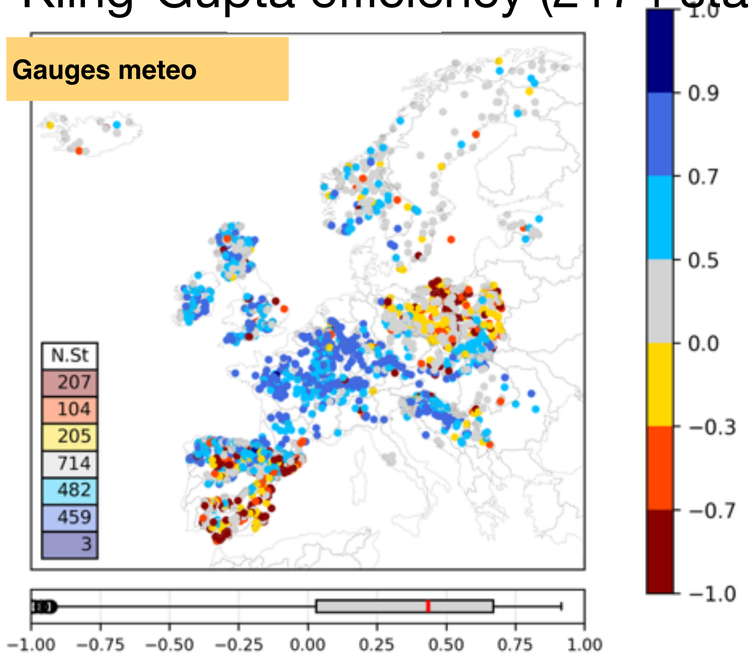
Long-Term Run

Example station:

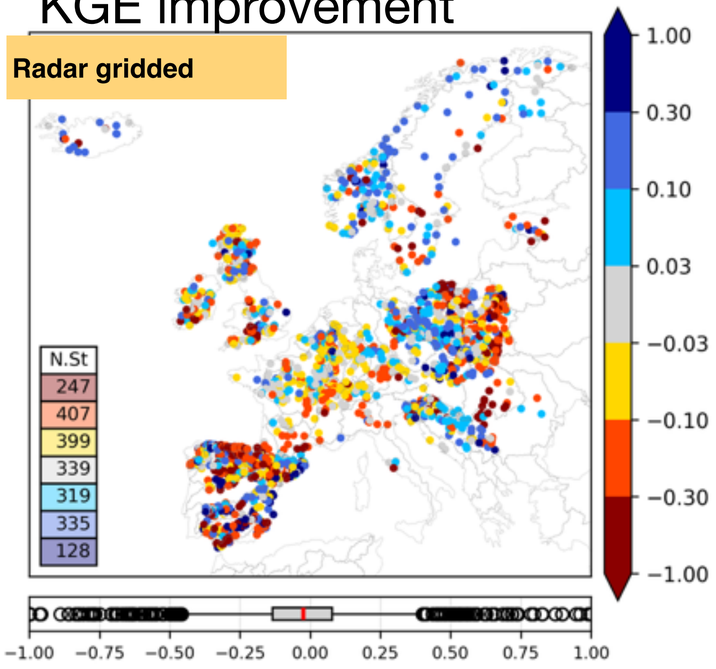


	KGE	KGE_r	KGE_y	KGE_B	hits	misses	false_alarms
LTR_REF	0.64	0.92	1.04	0.66	3	1	0
LTR_RADAR_INTERP	0.72	0.9	1.24	1.12	3	1	3
LTR_RADAR_GRIDDED	0.75	0.89	1.01	0.77	4	0	0

Kling-Gupta efficiency (2174 stations):



KGE improvement



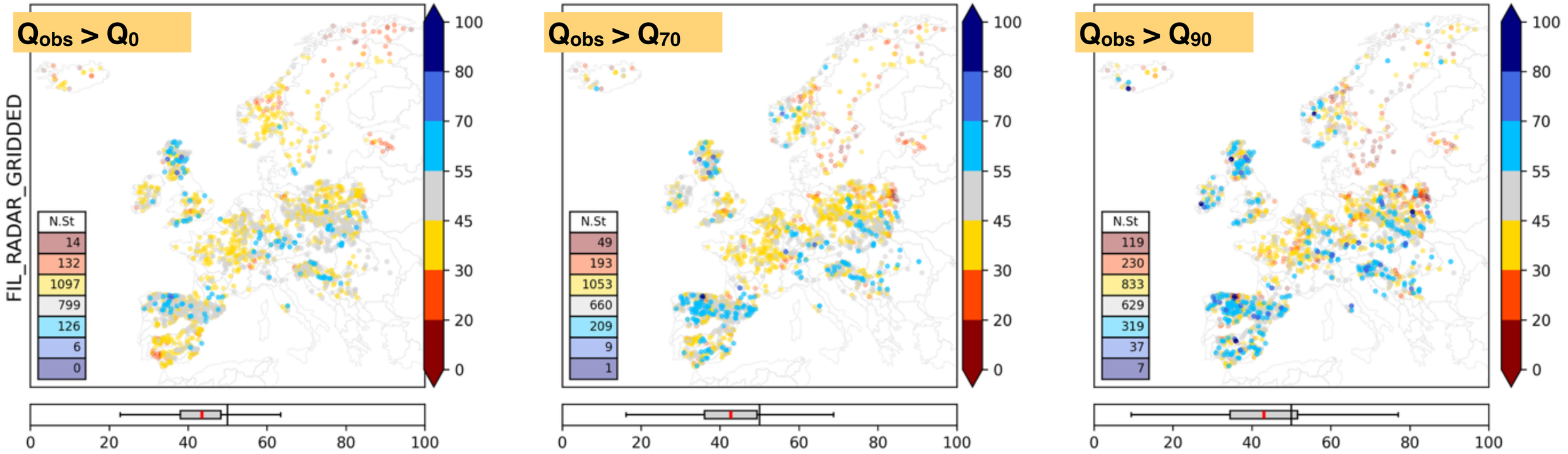
Mastrantonas et al. (2026)

Co-funded by the European Union

Fill-up run

Percentage of runs where the radar product is closer to observations than the current operational product.

Only checking last time step of each Fill-Up Run.



Mastrantonas et al. (2026)

Co-funded by the European Union

Precipitation inputs for hydrological forecasting

Forcing EFAS with radar precipitation products:

- Improvement mainly in northern and eastern Europe
- Usefulness increases for high quantile flows
- Positive impact of high-res monitoring of precipitation variability.
- Less skill in locations with dense gauge network (e.g., Germany)
- Lower skill for locations with poor radar QPE (e.g., France)

❖ Short period of analyses prevents generalizations

❖ LTR model is positively biased to the Reference forcing due to calibration

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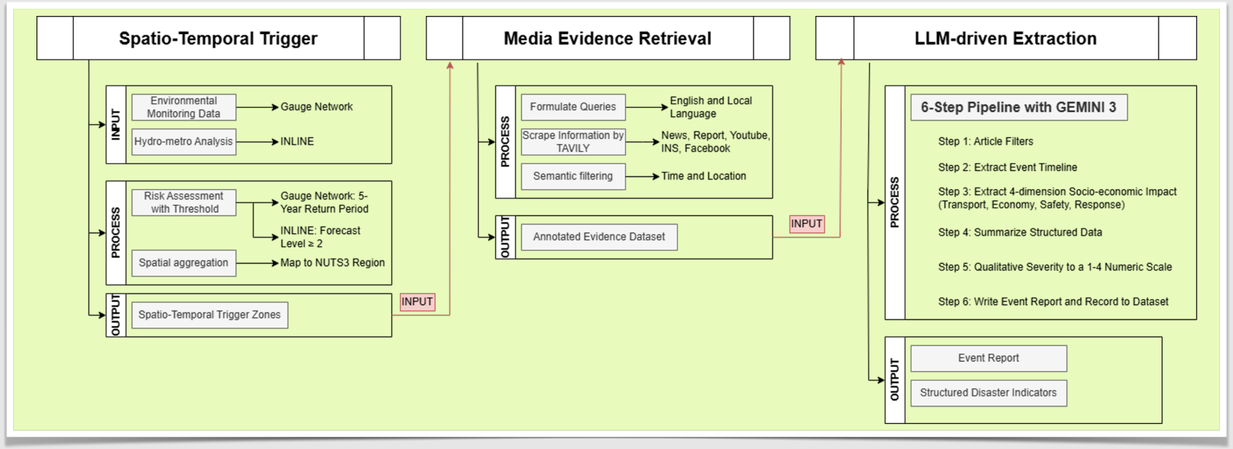
INLINE Multi-Criteria Evaluation Framework

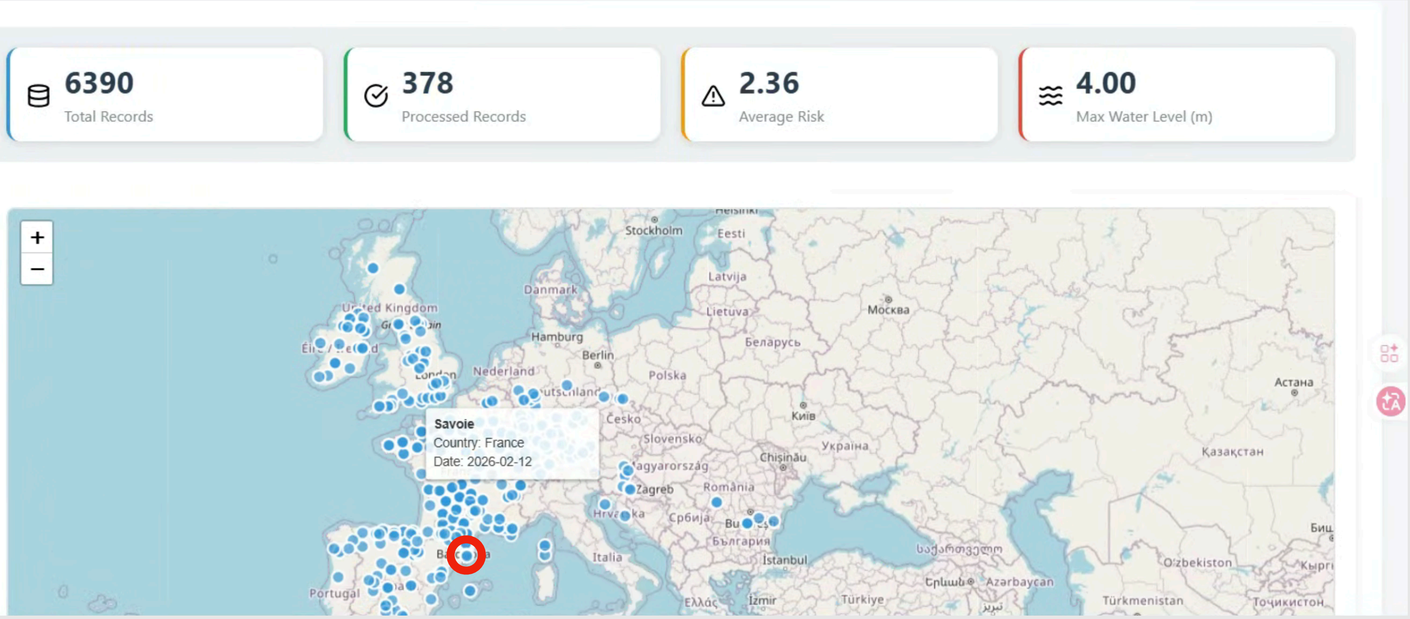
- Real-time demonstration with end users (access to products and notifications).
- Extended to the INLINE CoI (40+ organisations in 21 countries).

Hydrometeorological forecasts	Impact forecasts
• Precipitation estimation • Impact on LISFLOOD initialization • Storm hazard nowcasts • Flash flood hazard forecasts	• CPA reports on selected events • At the European scale with a systematic impact database

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Systematic evaluation against the FloodEcho impact database





Overall Impact Level

3

Medium (3 Level)

Transport impacts 4

- BP-1121: Closed due to landslides [1]
- C-58: Closed between Terrassa and Manresa [3]
- B-122: Closed in Terrassa [3]
- AP-7: 12km traffic retentions [3]
- El Prat Airport: Temporary suspension of landings and takeoffs [4]
- Rail Network: Six lines (R2-sur, R-14, R-15, R-16, R-17, R-11) affected by infrastructure

Economic impacts 3

- Massive flight cancellations and rebookings at El Prat [4]
- Logistics delays due to 12km jams on AP-7 artery [3]
- Tourism impact in Montserrat National Park due to blocked access [1]

Impacts on safety 2

- 14 people evacuated from Sant Benet [1]
- 9 people sheltered in Santa Cova [1]
- 5 people sheltered in El Bruc [1]
- Vehicle trapped in Vilanova del Camí [4]

Emergency response 3

- 200 calls to 112 emergency line [1]
- Rescue teams deployed ropes and harnesses for mountain evacuations [1]
- Airport adjusted operational systems for safety [4]
- Civil Protection issued warnings to avoid outdoor activities [1]

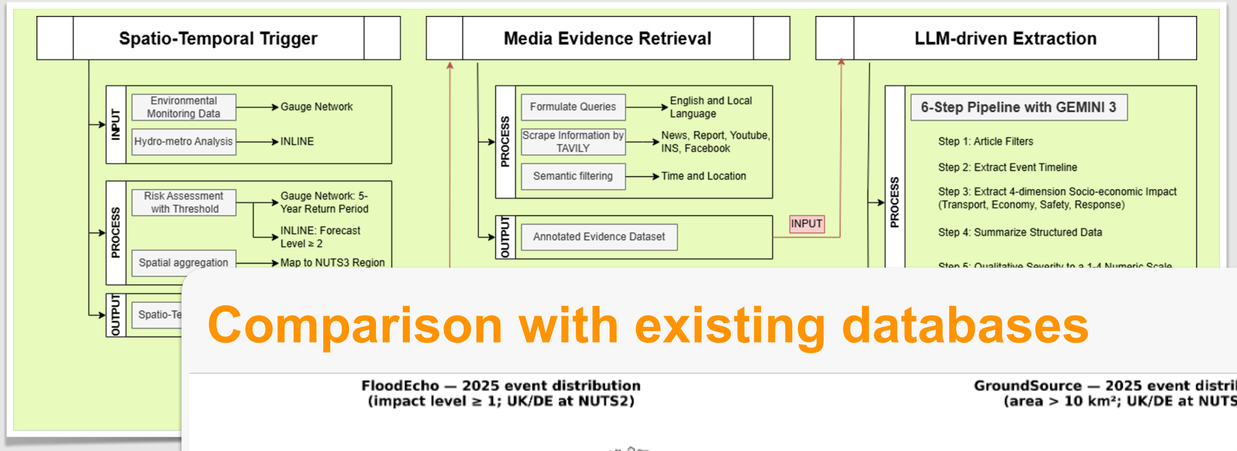
Global summary 3

- Temporary collapse of major transport hubs including El Prat airport and AP-7 [3,4]
- Specialized mountain rescues required for stranded hikers [1]
- Systemic rail delays across six regional lines [3]

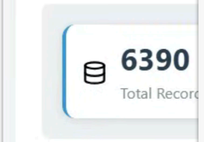
Li et al. (2026)

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Systematic evaluation against the FloodEcho impact database

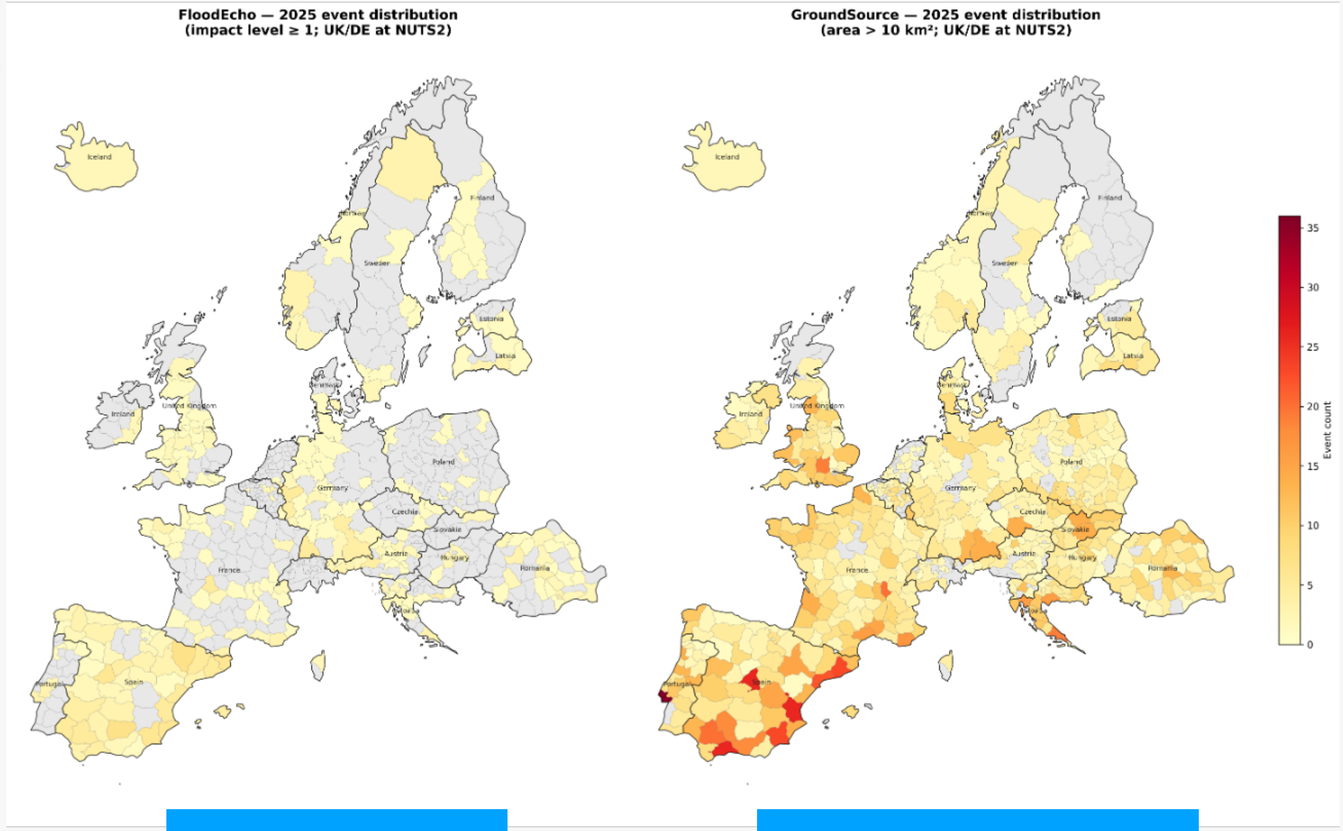








Comparison with existing databases



FloodEcho

GroundSource

Evaluation of INLINE FF impact

Impact data

INLINE forecasts

Inline \ Actual	L0 None	L1 Low	L2 Medium	L3 High	L4 Severe
None/LV1	961	13	74	94	6
LV2	399	4	23	39	2
LV3	1110	6	71	75	—
LV4	270	3	16	21	3

Li et al. (2026)

INLINE Multi-Criteria Evaluation Framework

- Real-time demonstration with end users (access to products and notifications).
- Integration of end users into the INLINE CoI (40+ organisations in 21 countries).

Hydrometeorological forecasts	Impact forecasts	Added value for emergency management
• Precipitation estimation • Impact on LISFLOOD initialization • Storm hazard nowcasts • Flash flood hazard forecasts	• CPA reports on selected events	• Survey strategy

Initial survey

Dear Participant, Thank you for taking the time to contribute to this survey on key features of flood and storm i
your insights regarding the development and evaluation of the INLINE project. While we encourage you to com
view, please feel free to answer as many or as few questions as you like—every piece of feedback is incredibly v
to quantify users' understanding of INLINE products and to evaluate the overall success of the project. Estimate

Section 1: Background Information

1.1 Please enter your Email address.

1.2 Which organization/company/institution are you affiliated with?

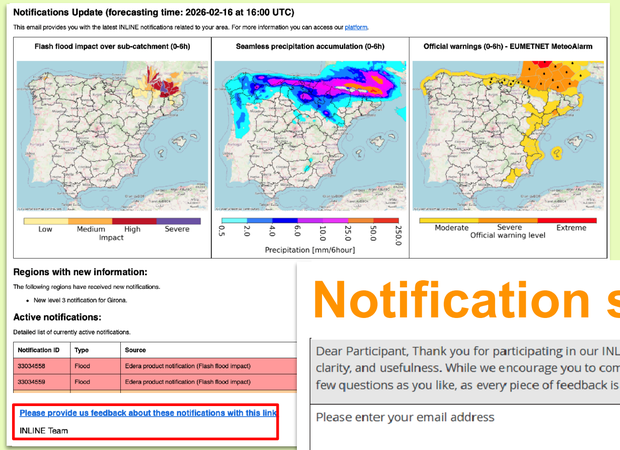
Final survey (Dec 2026)

Dear Participant, Thank you for participating in the final comprehensive evaluation of the INLINE project. This q
the final outcomes of the INLINE project systematically. We aim to thoroughly measure its actual performance i
support, added value, and the effectiveness of cross-border cooperation, and to gather valuable feedback for f
crucial for objectively measuring the project's achievements. All collected data will remain anonymous and be k
completion time: 25–30 minutes.

Section 1: Background Information and Overall Satisfaction

1.1 What is your role in the INLINE project?

- ◯ Scientist or Researcher
- ◯ Project developer: IT, management, etc
- ◯ Stakeholders: National hydro-meteorological institutes, etc
- ◯ End-user: CPA (civil protection agencies), etc



Notification survey

Dear Participant, Thank you for participating in our INLINE notification performance feedback survey to help us
clarity, and usefulness. While we encourage you to complete the questionnaire for a comprehensive view, please
few questions as you like, as every piece of feedback is incredibly valuable to us. Estimated time: 5–10 minutes.

Please enter your email address

What type of feedback would you like to provide today?

- ◯ I want to evaluate the performance of a received notification
- ◯ I want to report an event that was not forecasted by the INLINE system (Missed event)
- ◯ I haven't subscribed to notifications but accessed the INLINE platform during the event.

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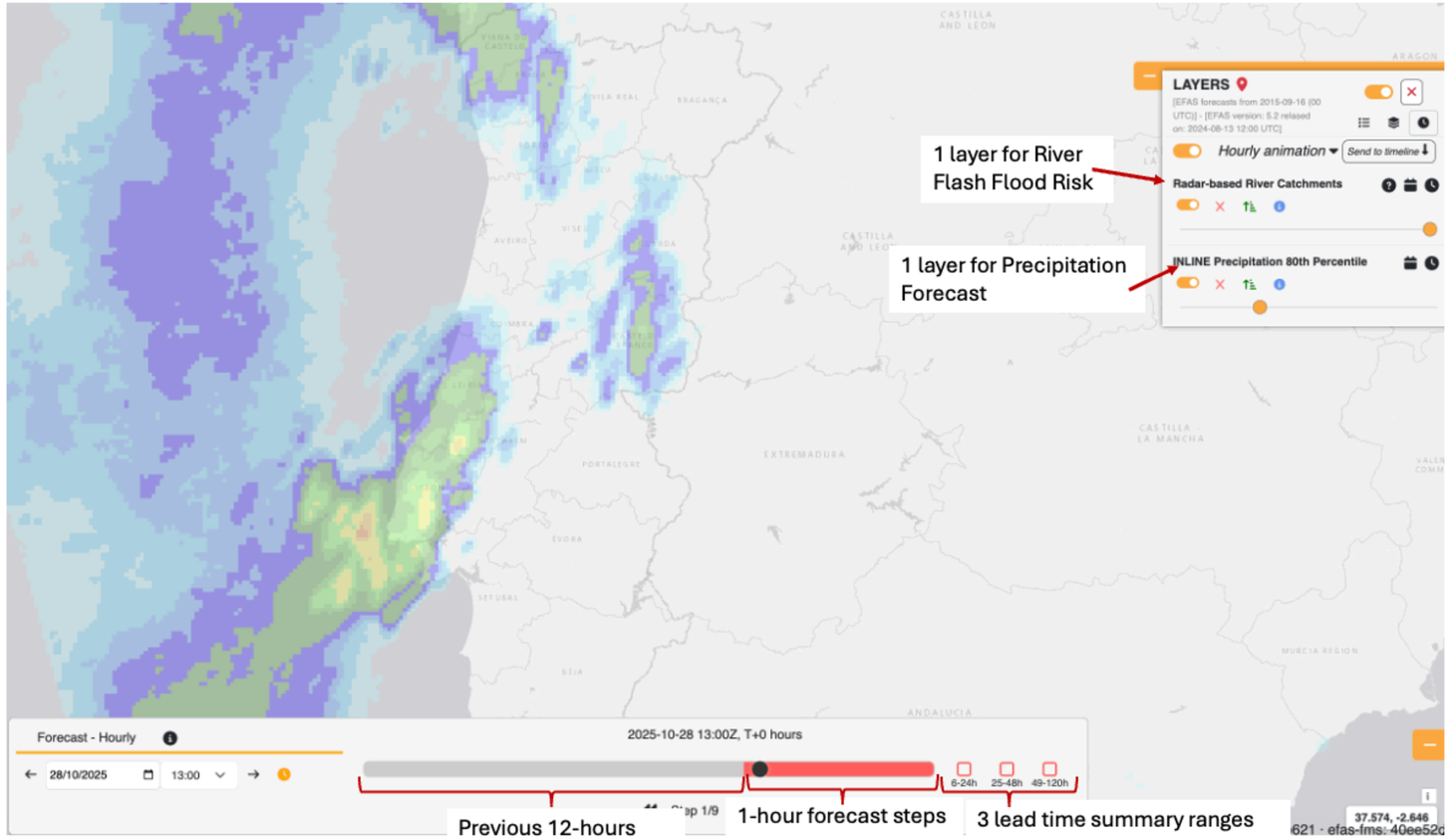
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Integration in EFAS

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ECMWF
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE
aemet Agencia Estatal de Meteorología
IPMA Instituto Português do Mar e da Atmosfera
EMA
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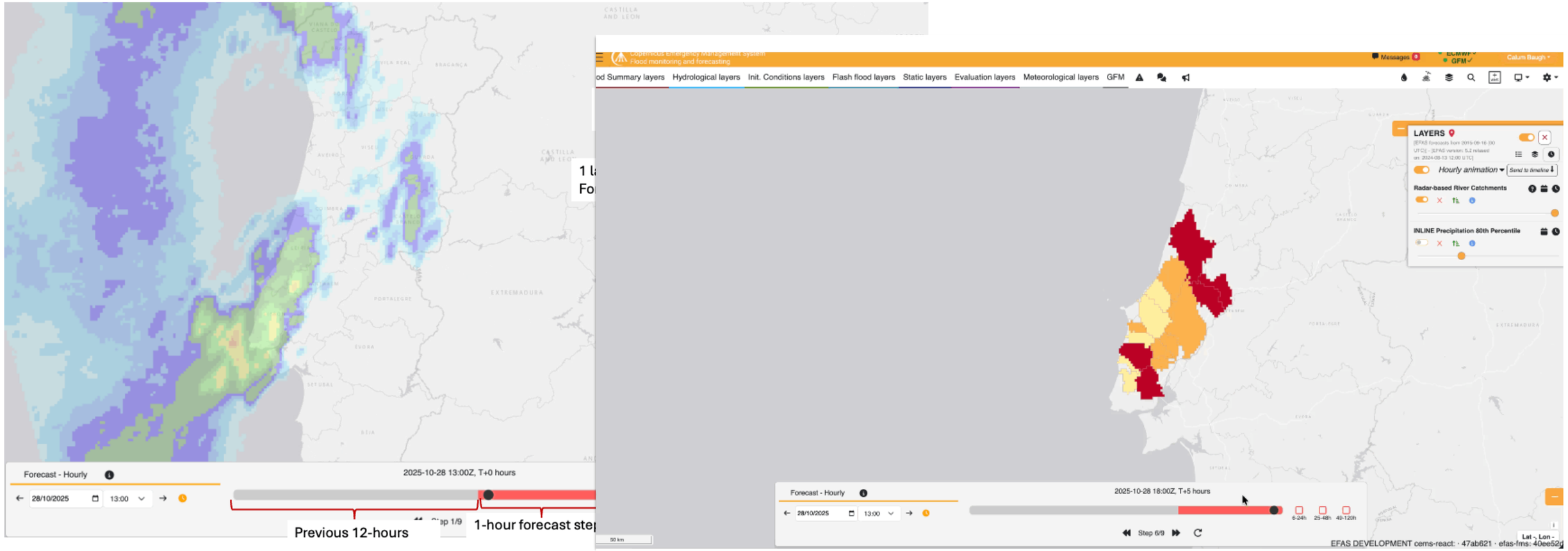
Improvements to EFAS Radar Flash Flood Products



- 1 product for flash flood impact across all lead times.
- Animated products load much faster.
- Forecast rainfall colour scheme consistent with other EFAS products.
- Available beyond 5 days in the past.

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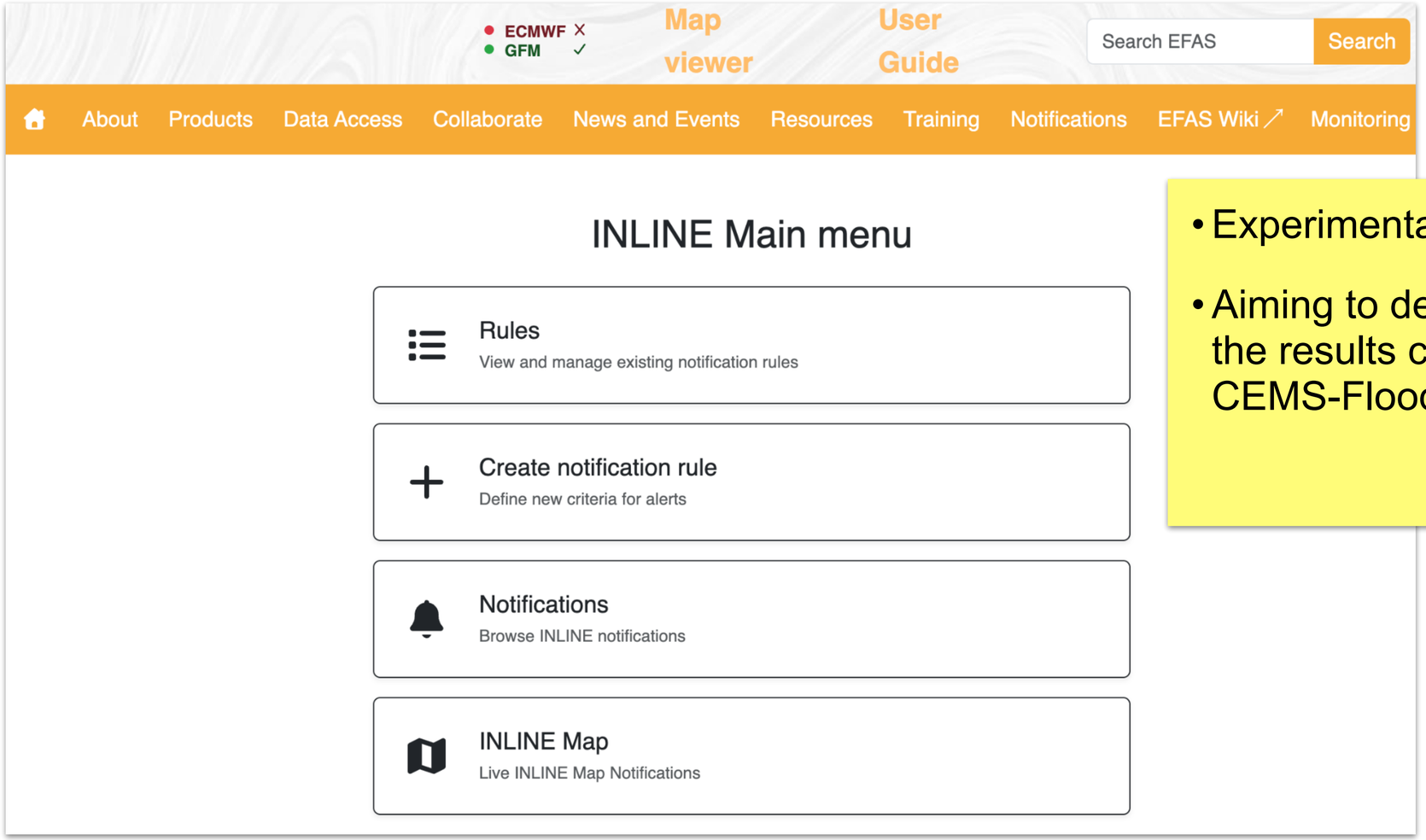
Improvements to EFAS Radar Flash Flood Products



- 1 product for flash flood impact across all lead times.
- Animated products load much faster.
- Forecast rainfall colour scheme consistent with other EFAS products.
- Available beyond 5 days in the past.
- Improved visualization: River catchments + river network displayed when zoomed in for more detail.

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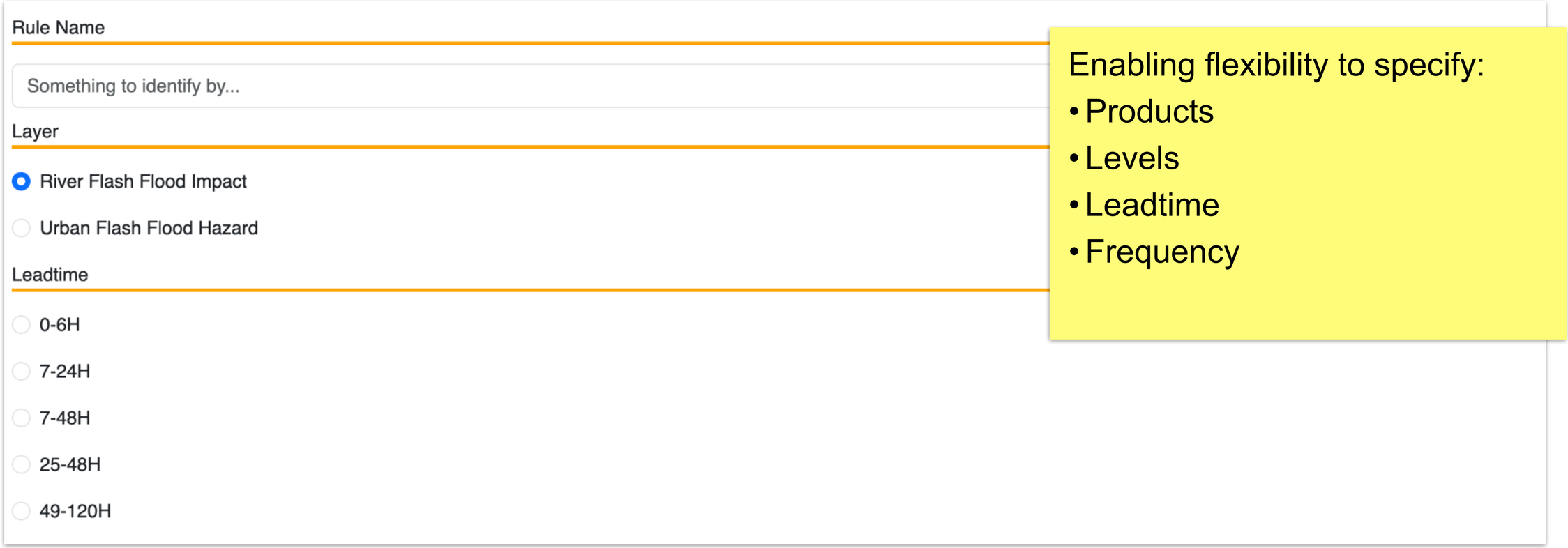
User-adapted automatic notification functionality



- Experimental service.
- Aiming to demonstrate how the results could work in CEMS-Floods.

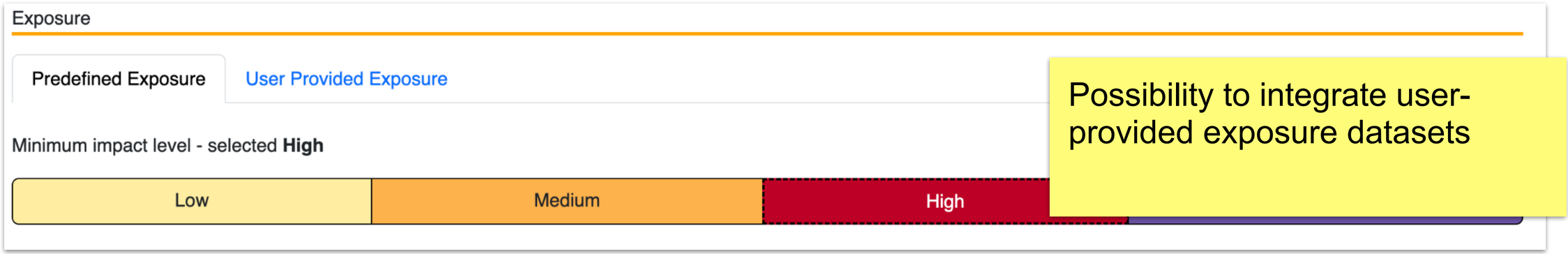
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User-adapted automatic notification functionality



Enabling flexibility to specify:

- Products
- Levels
- Leadtime
- Frequency



Possibility to integrate user-provided exposure datasets

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Join the INLINE CoI:

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