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

Co-funded by the European Union

INLINE Storm Impact Products

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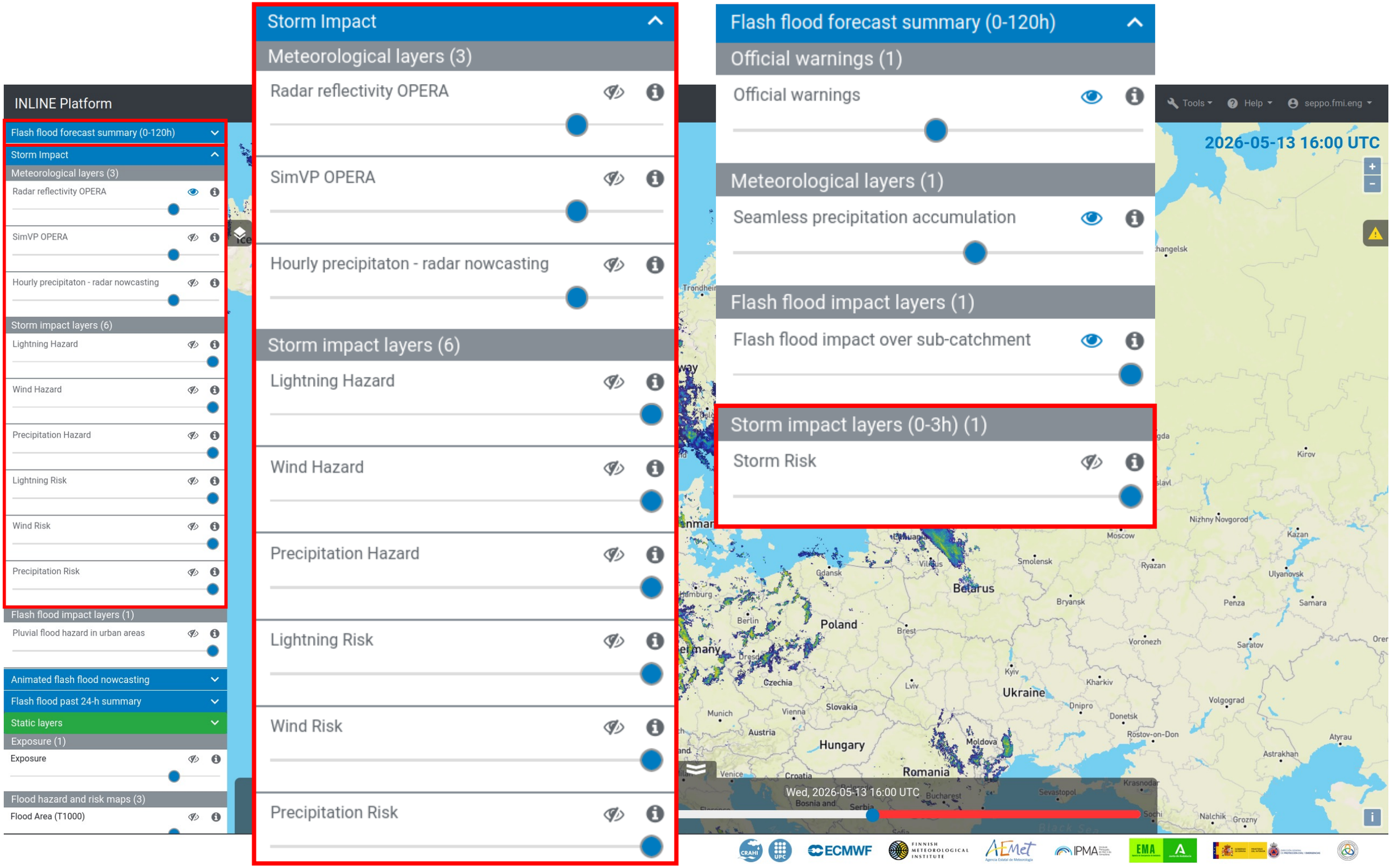
Finnish Meteorological Institute
26 May 2026

Overview



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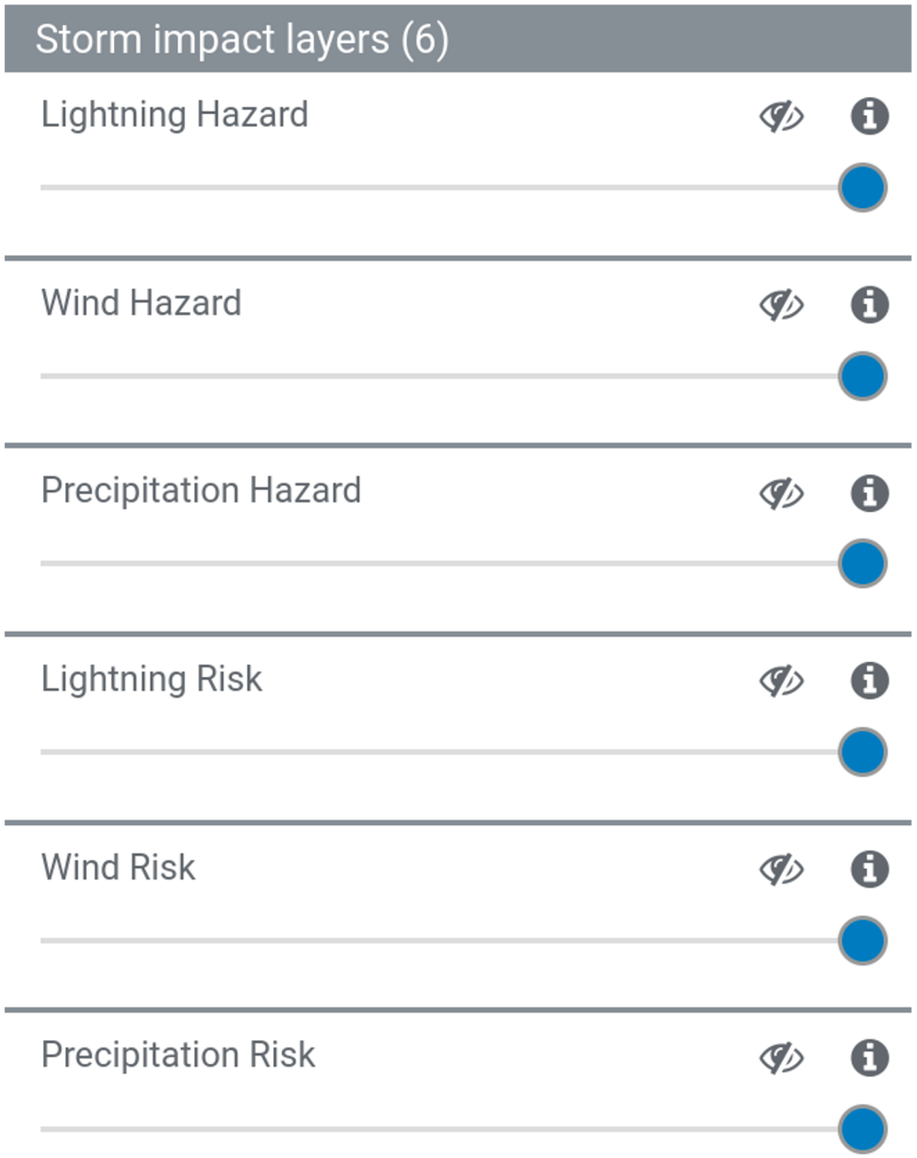
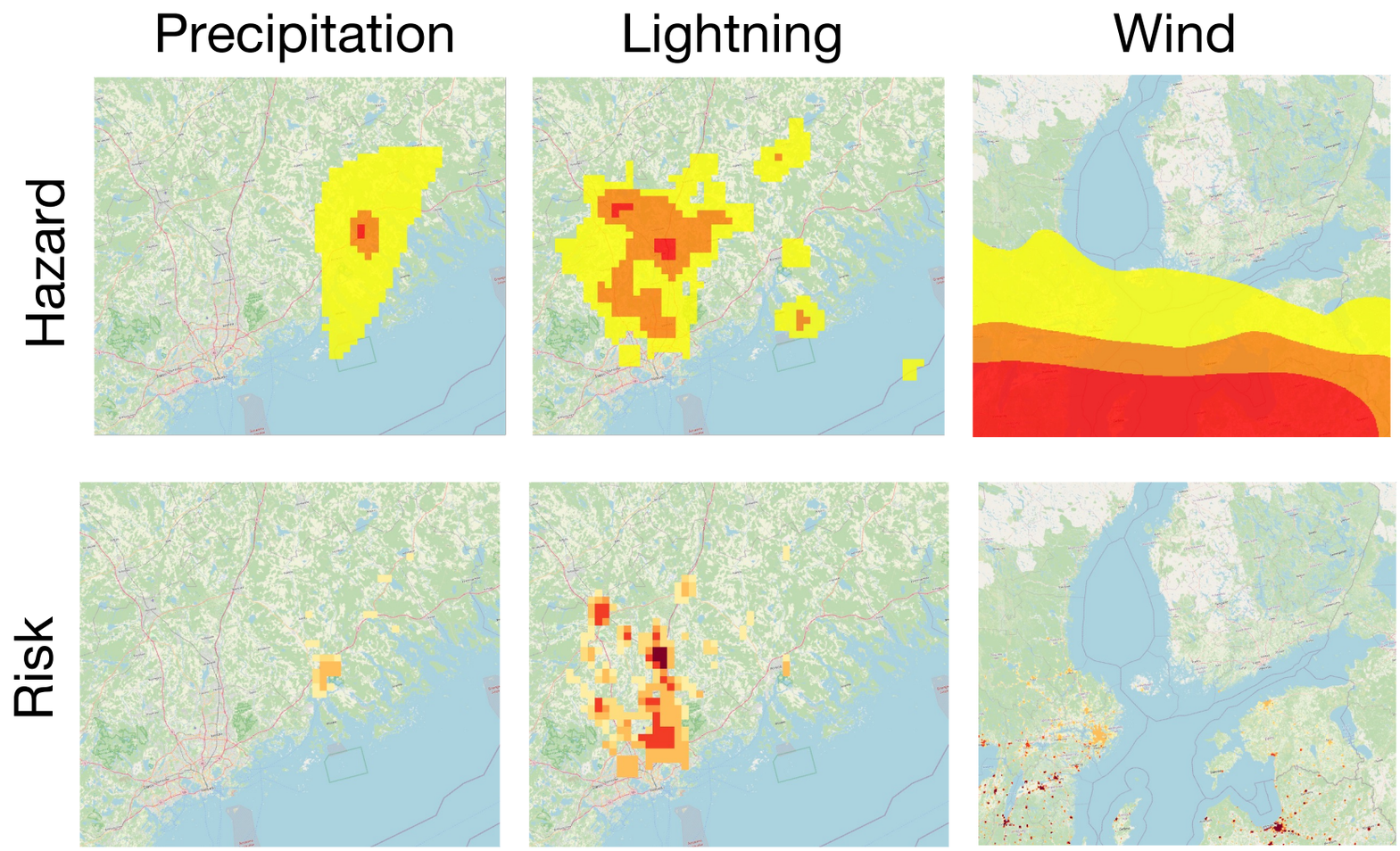
Storm hazard and risk nowcasts





- Meteorological forecasts translated into color-coded warnings
- 3-hour time range
- 2 km spatial resolution and 15-minute time step
- Updated every 15 minutes
- Products available on INLINE platform since beginning of December 2025

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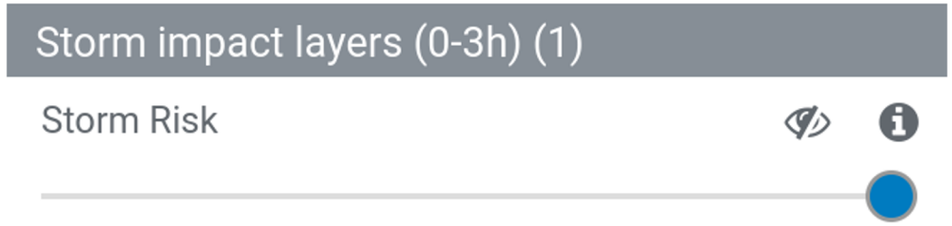
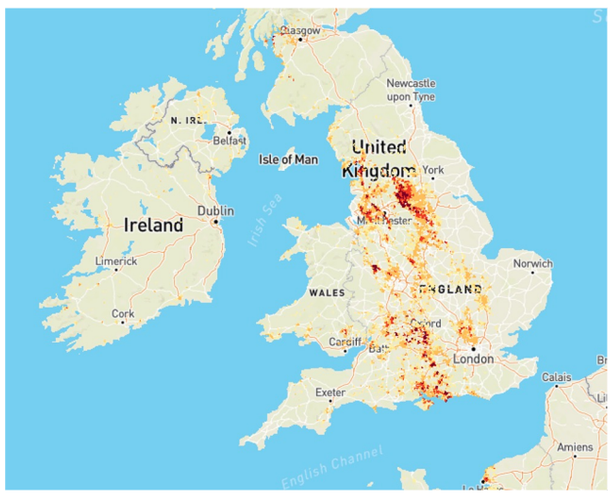
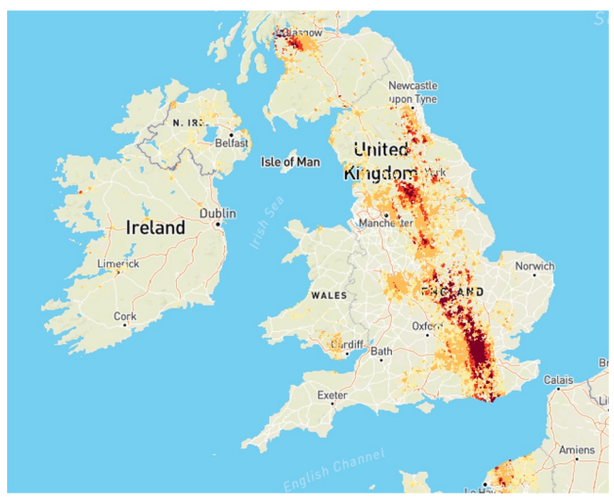
Summary layers
2025-12-05



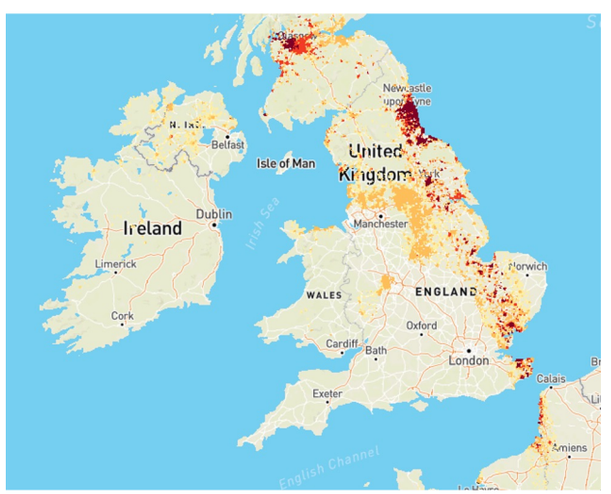
17:00 UTC



+1 hour

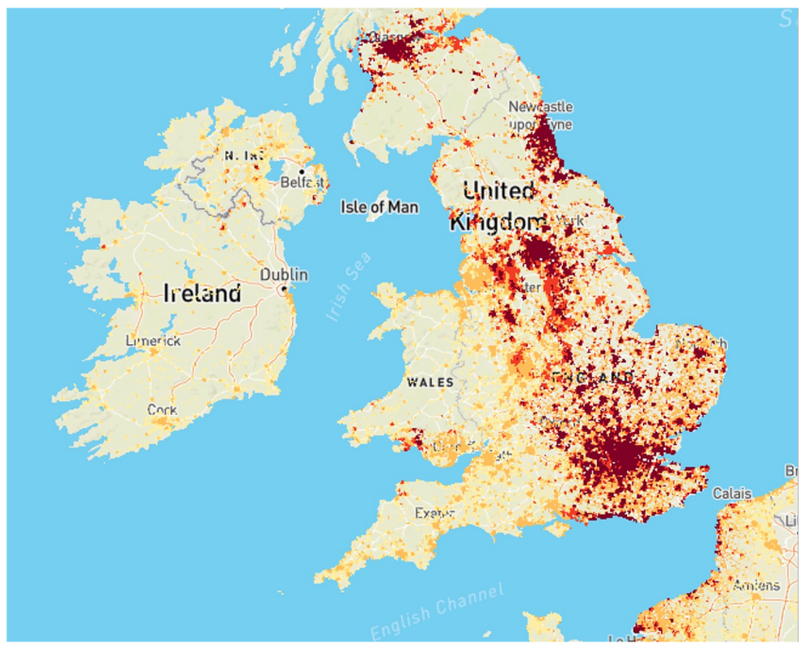


+2 hours



+3 hours

Summary



Maximum precipitation risk level from nowcasts to the next 3 hours

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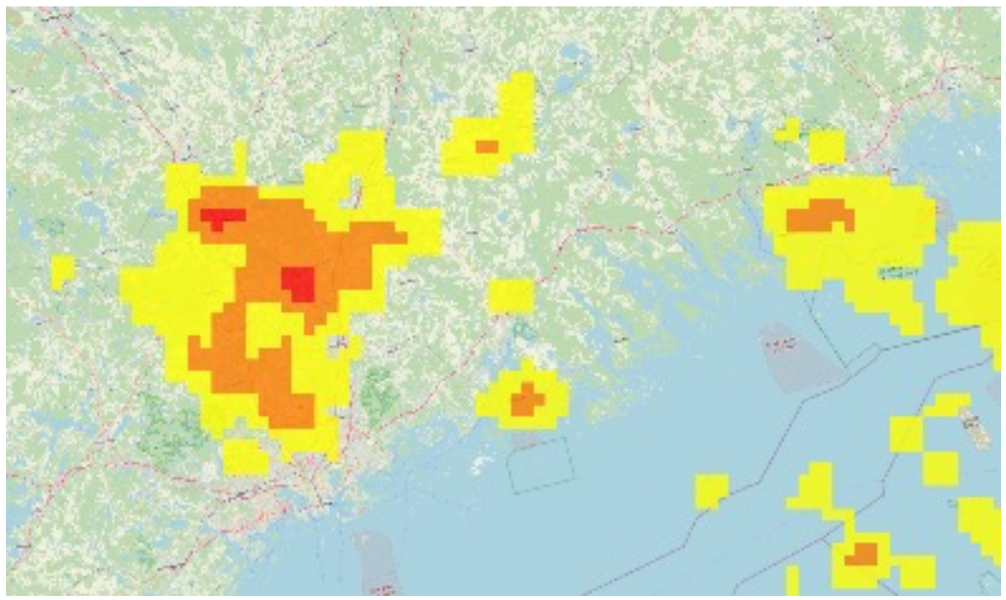
Multi-hazard / risk

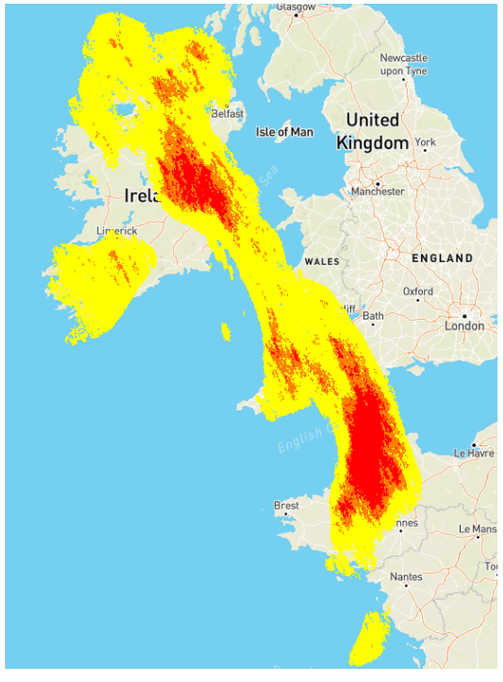
Hazard / risk type	Data source / forecast model
Precipitation	OPERA radar composites / neural network
Wind speed	ECMWF IFS forecast model
Flash density	NORDLIS lightning observation network (Nordic countries only) / extrapolation

Lightning hazard



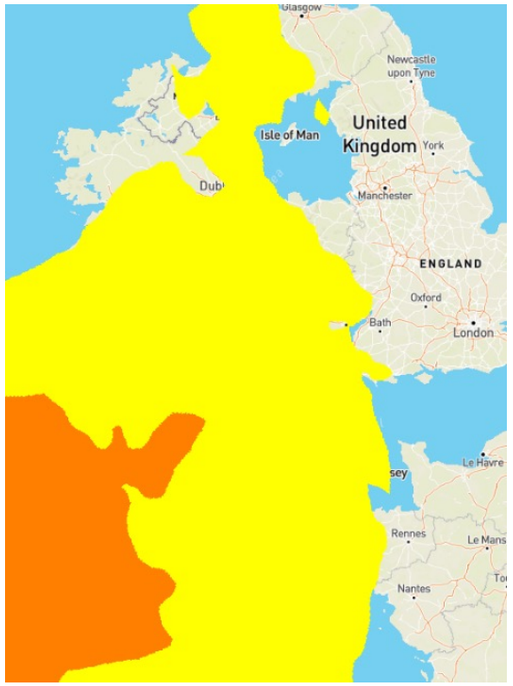
Finland 29th June 2025 08:15 UTC + 30 minutes

Precipitation hazard



Precipitation

Wind hazard



Wind risk

5th December 2025 11:00

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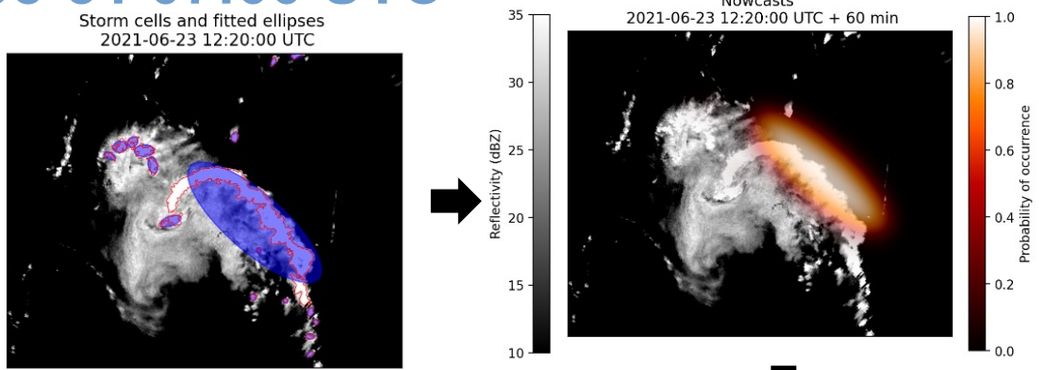
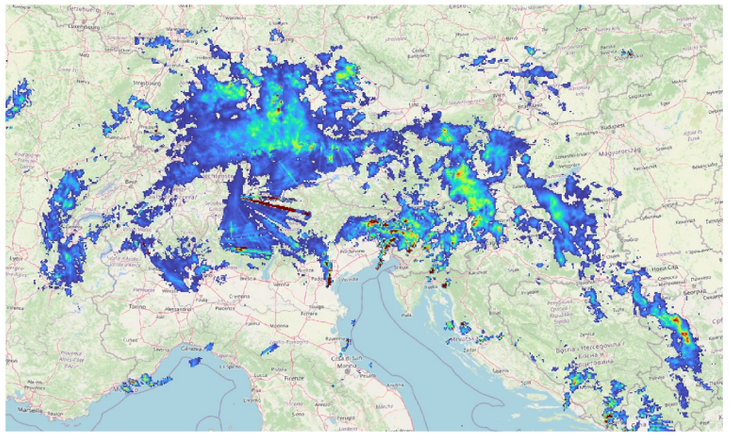
Comparison between storm impact products

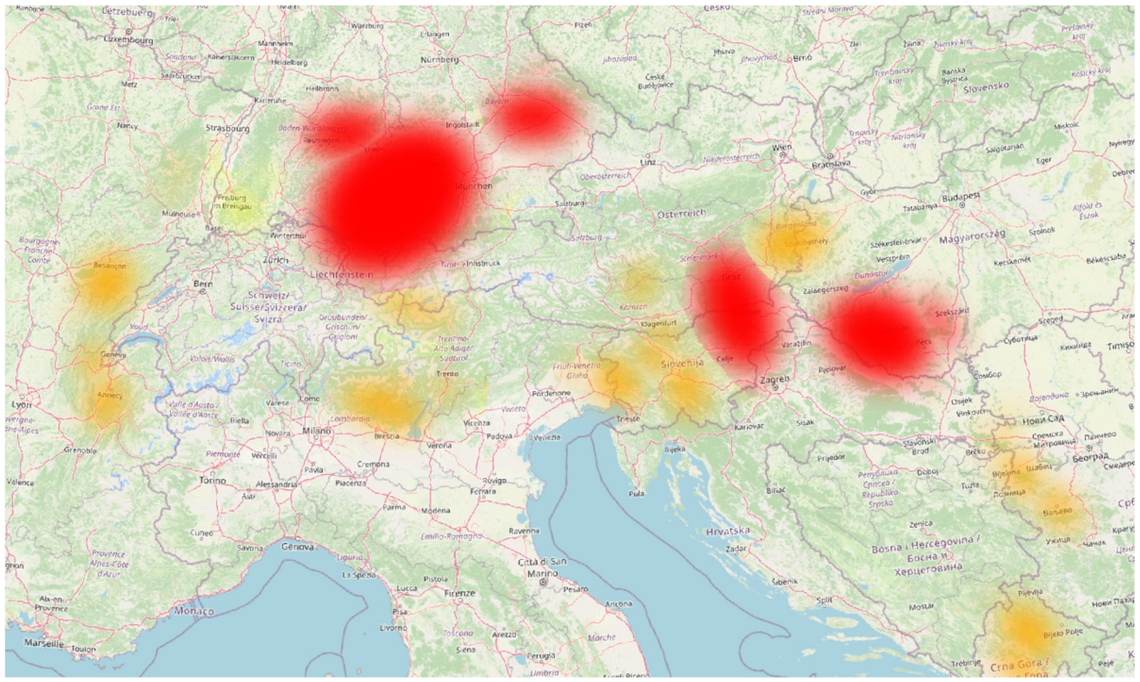
2025-05-31 07:00 UTC



OPERA rain rate at 08:00 UTC



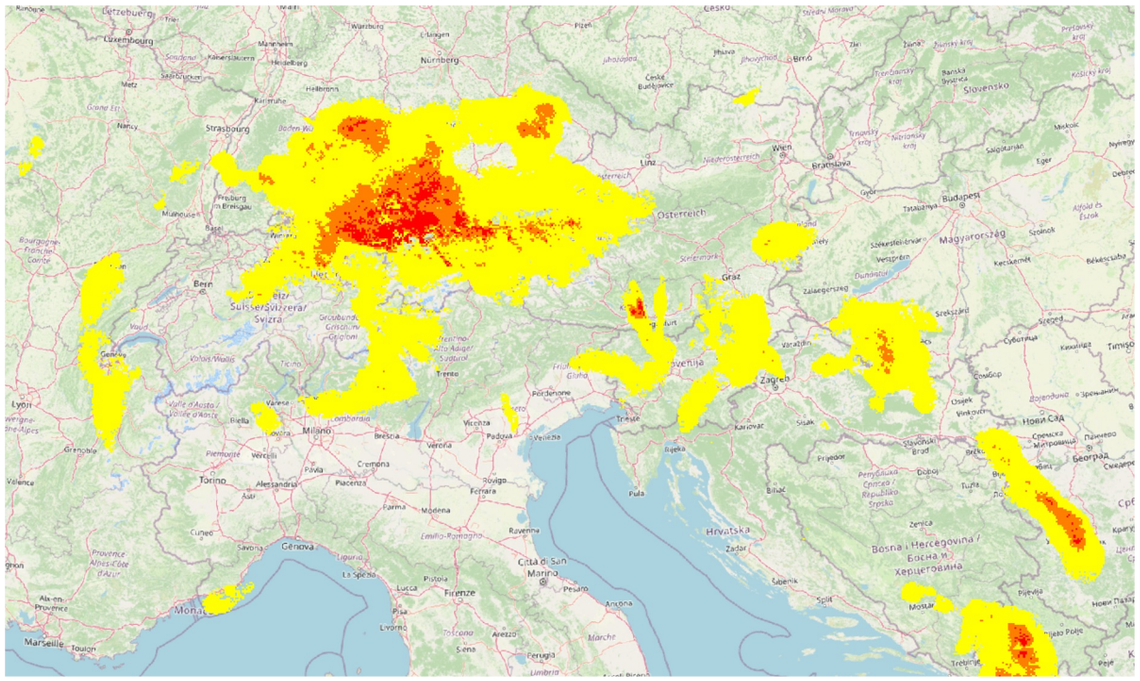
EDERA



Storm tracking + AI

- Storm cells approximated with ellipses
- Only linear motion of ellipses predicted
- Ellipses become more spread and transparent with increasing forecast length

INLINE



Fully AI-based forecast

- Can predict changes in intensity
- No transparency: probability information not shown
- Less blurring with increasing forecast length

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Precipitation hazard and risk

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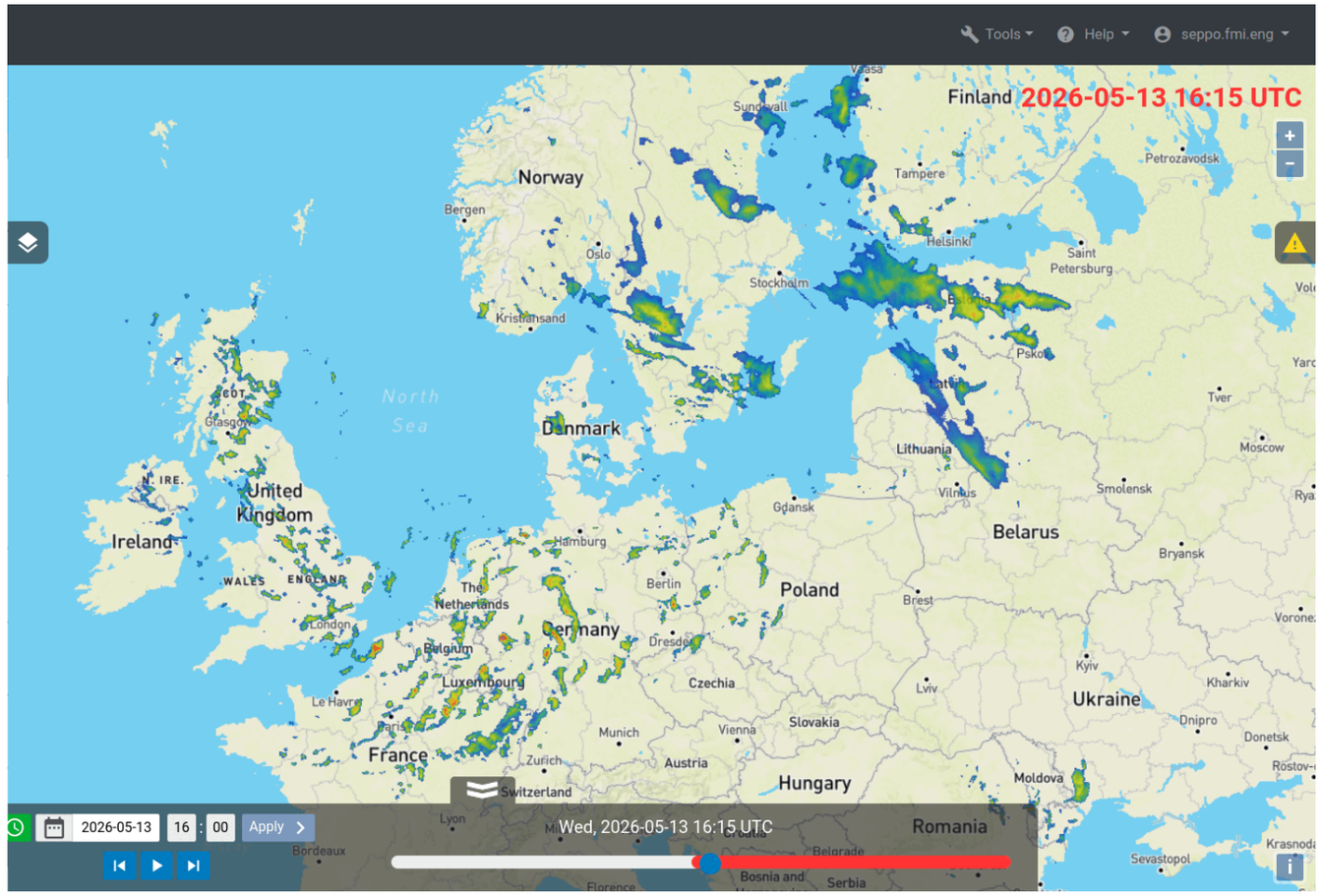
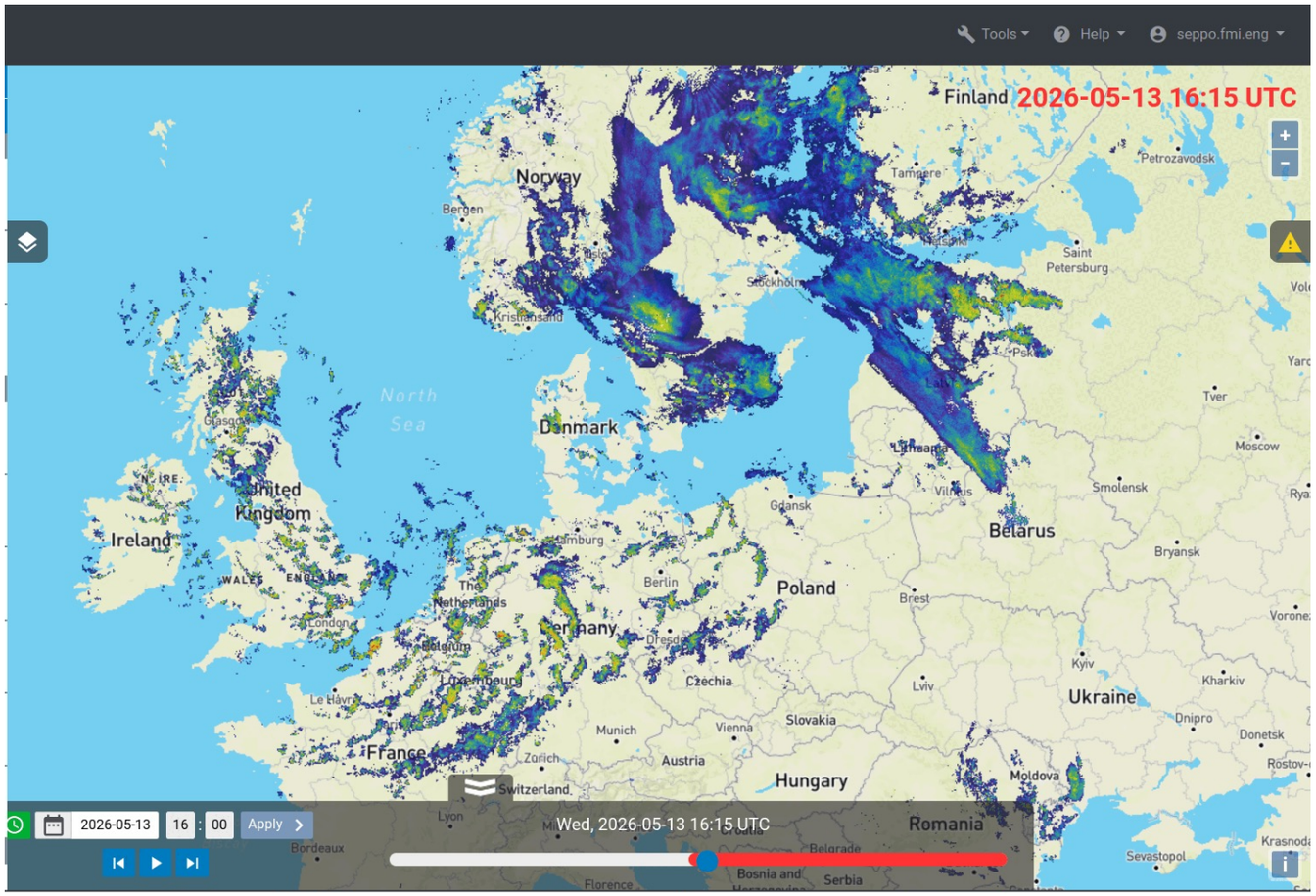
Precipitation nowcasts

SimVP OPERA layer
Neural network

Main advantage:
Improved forecast skill



Radar reflectivity OPERA layer
Extrapolation / SBMCast



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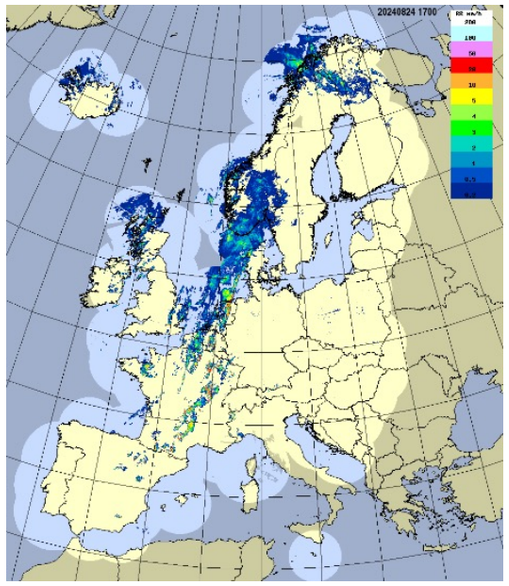
Methodology

Convolutional neural network (SimVP) + post-processing

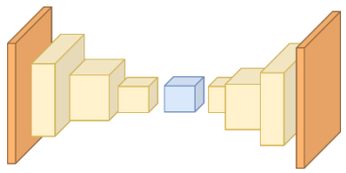
4 time steps

OPERA rain rate composites



©EUMETNET

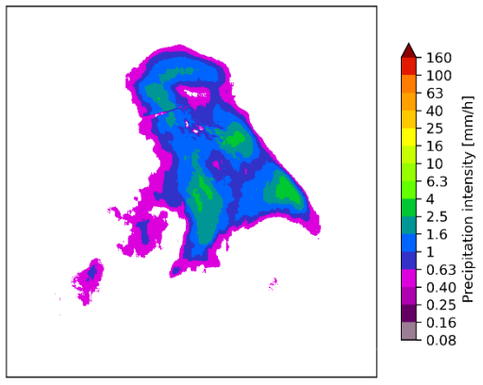
SimVP

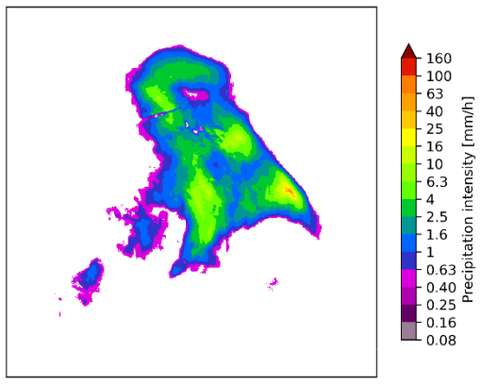


4 time steps (1 hour)

3 hours

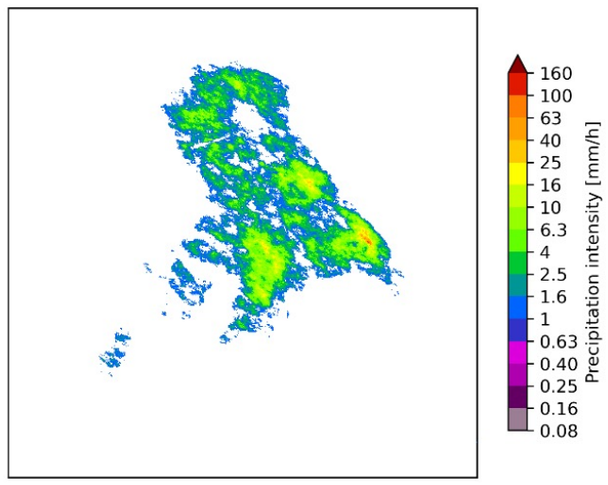
Bias correction

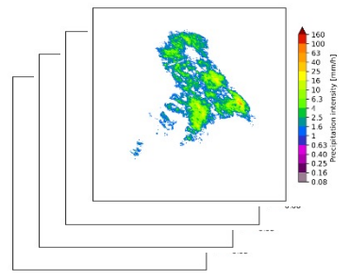




Ensemble generator

Ensemble nowcast





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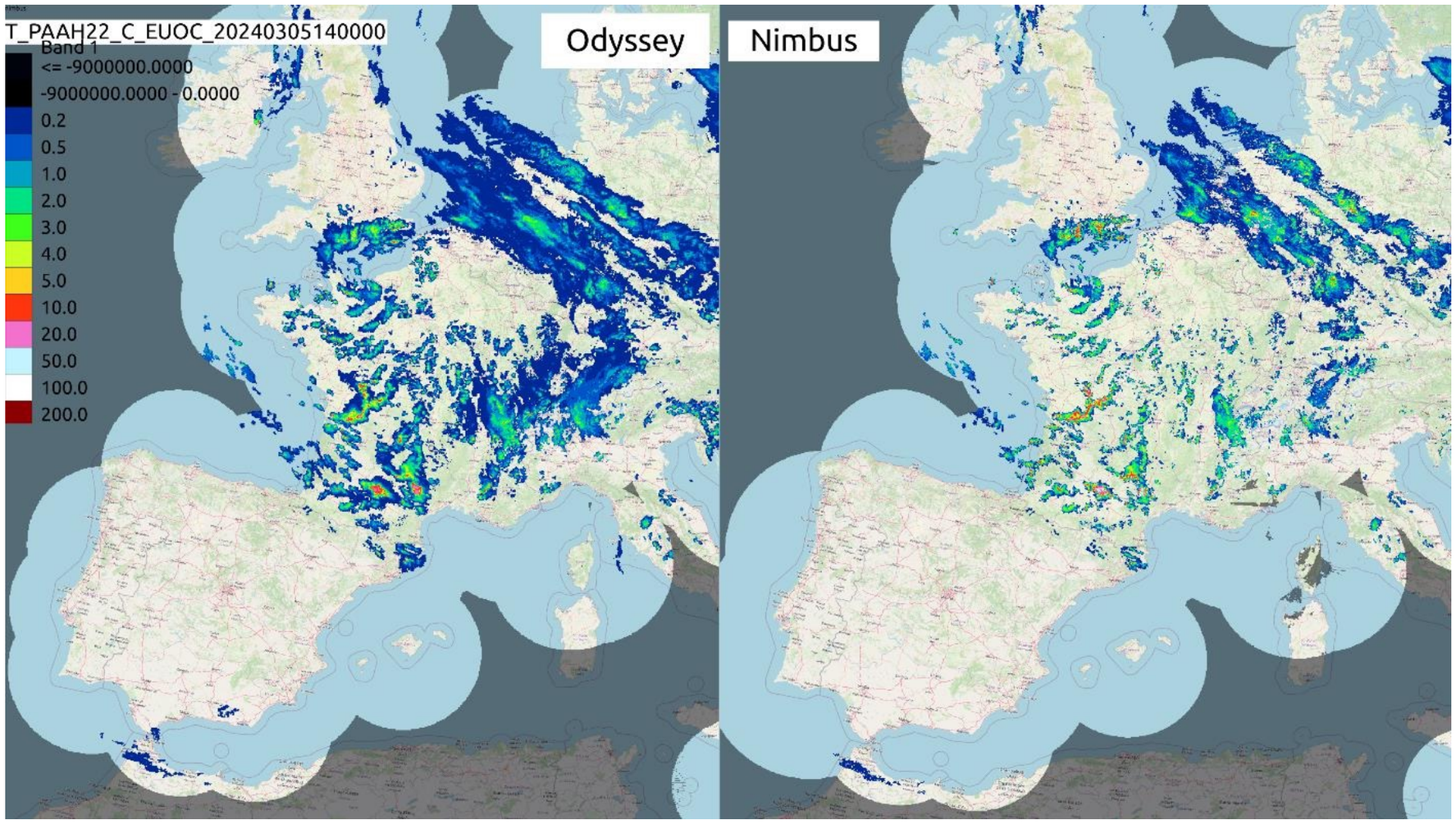
OPERA radar composites

Training dataset:
May-September 2020-2024



Best for high-resolution prediction of severe weather (e.g. lightning or hail) →

Best for predicting rainfall →

Product line	Subproducts	Spatial resolution	Update interval
CIRRUS	**Max. reflectivity**	**1 km**	**5 minutes**
NIMBUS	• **Rainfall rate** • **Hourly rainfall accumulation**	**2 km**	**15 minutes**

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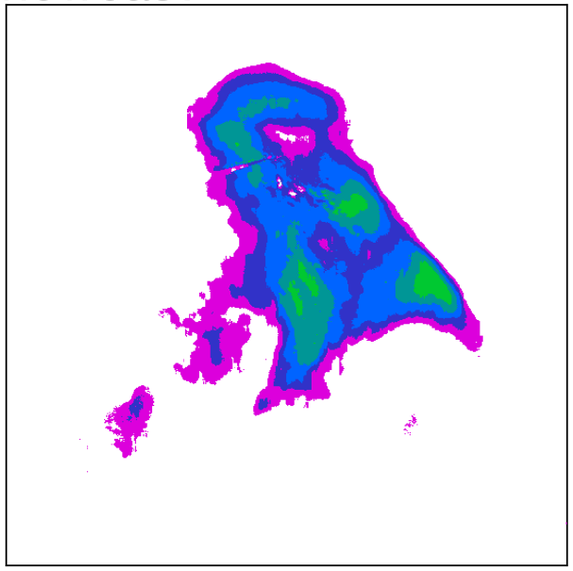
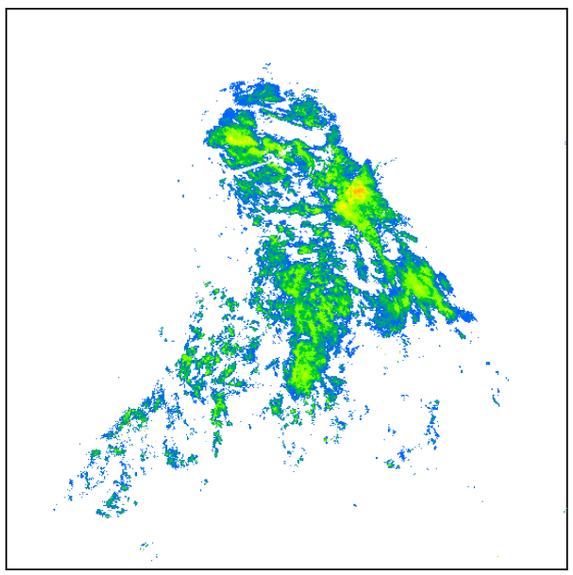
Post-processing

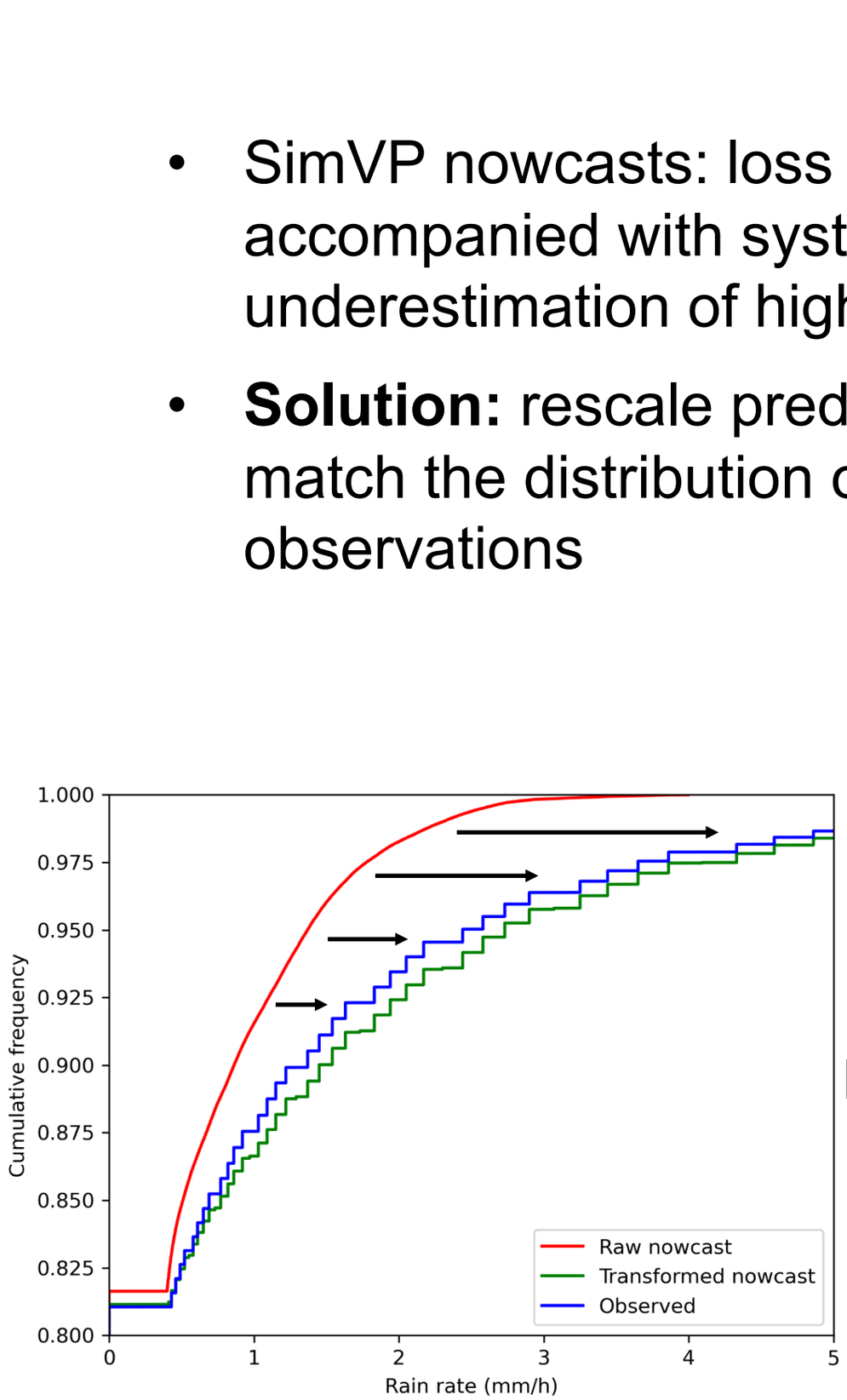
- SimVP nowcasts: loss of spatial detail accompanied with systematic underestimation of high rain rates
- **Solution:** rescale predicted values to match the distribution of latest available observations

Unprocessed SimVP nowcast

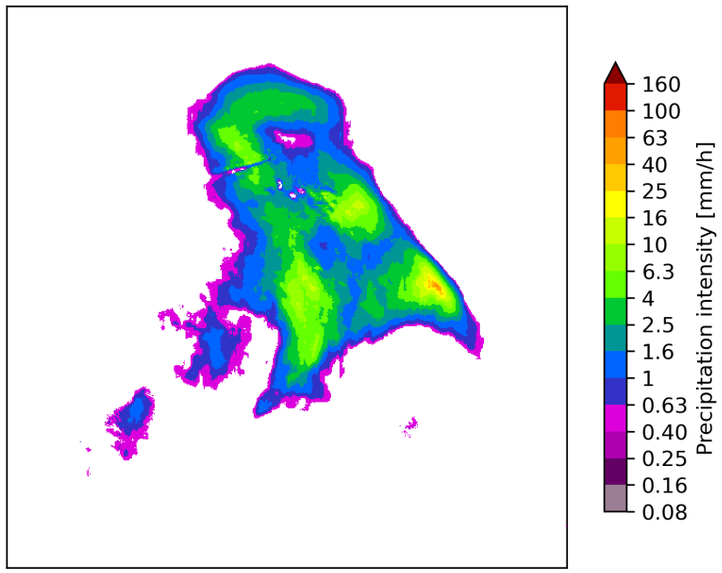


Observed





Transformed SimVP nowcast



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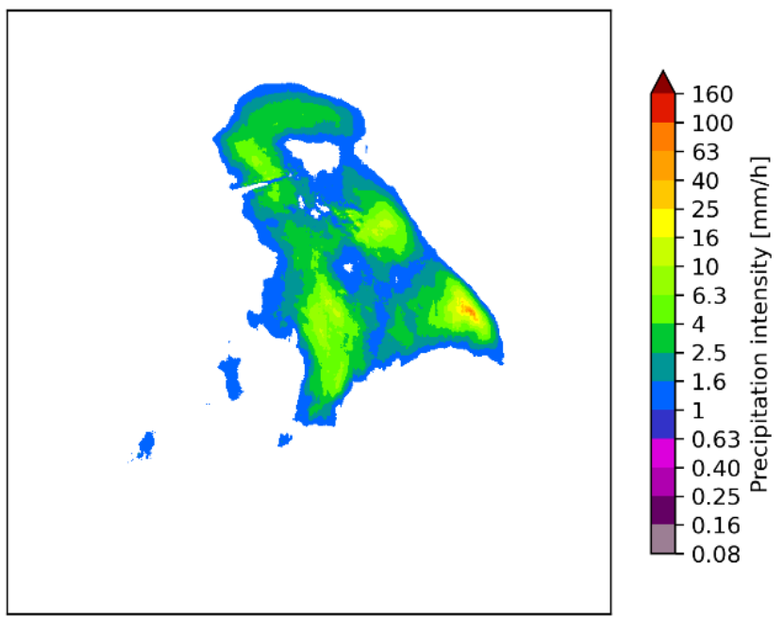
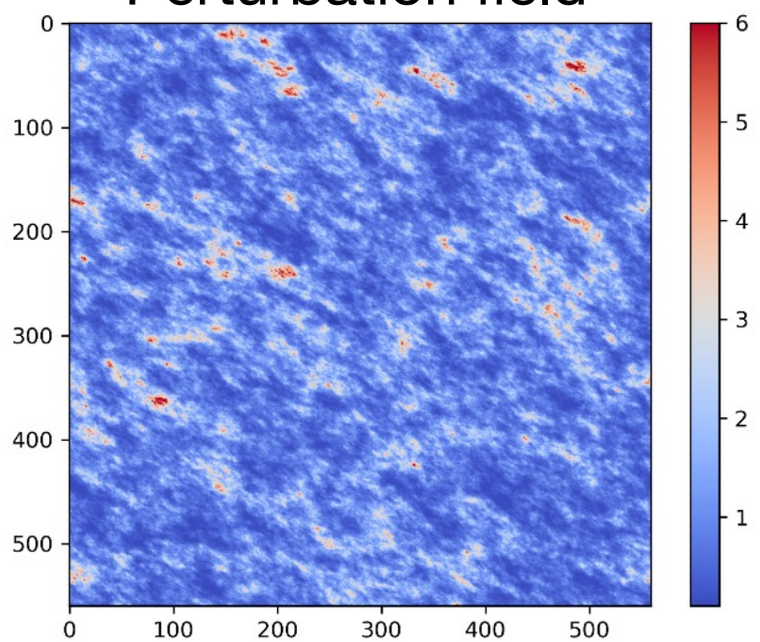
Ensemble and probabilistic nowcasts

Nowcast from neural network



*

Perturbation field



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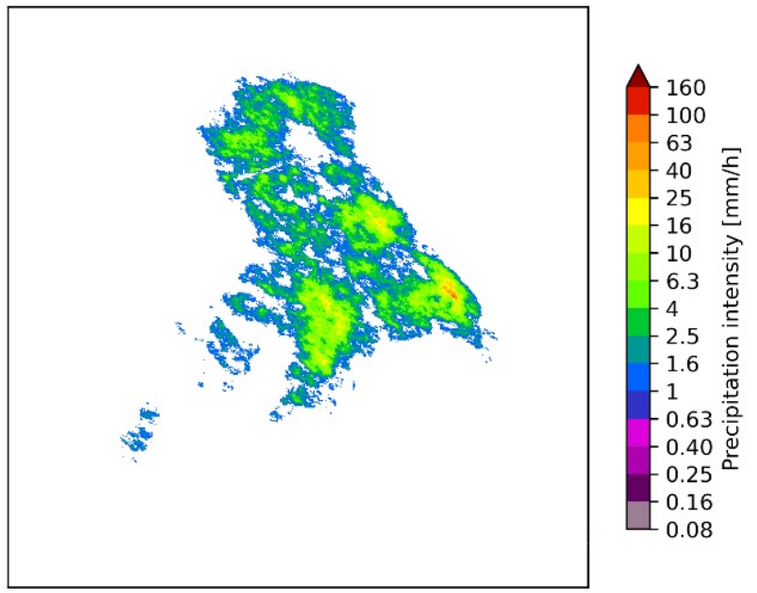
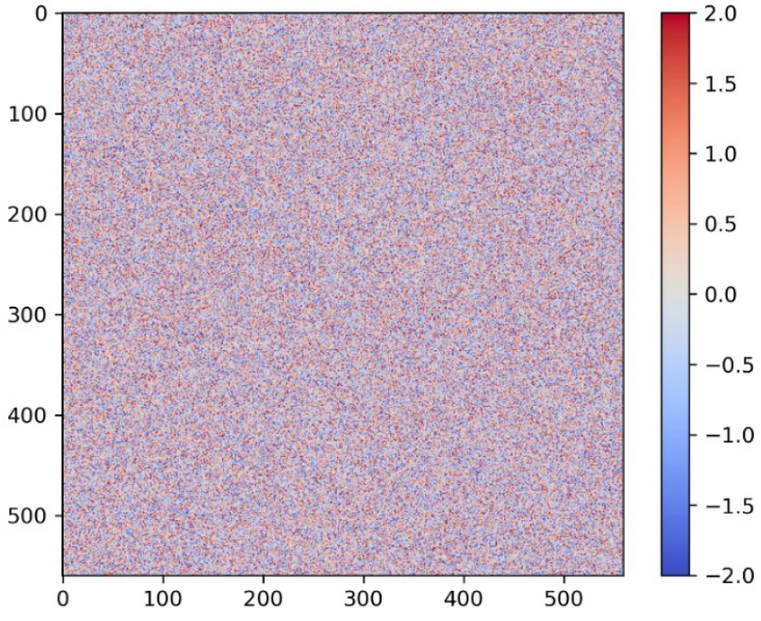
Perturbed nowcasts



Filtering

White noise



Repeat n times

Ensemble

Exceedance probabilities

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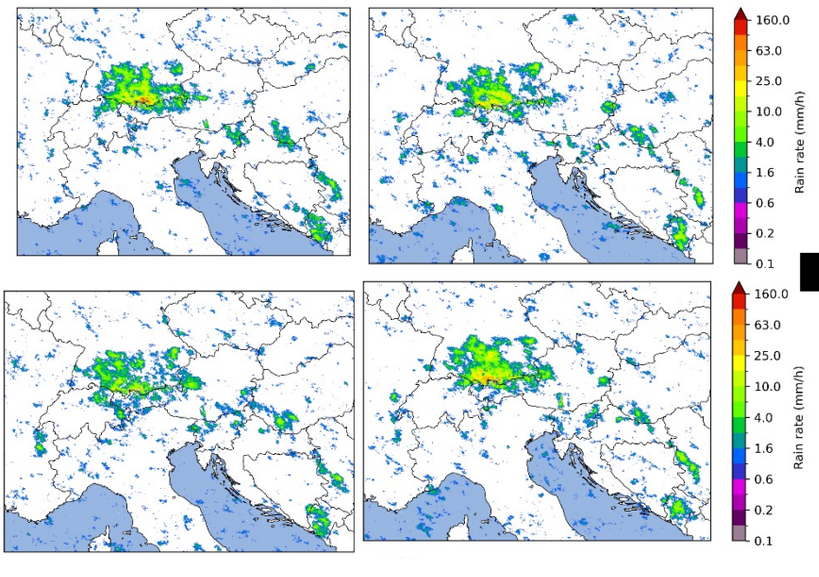
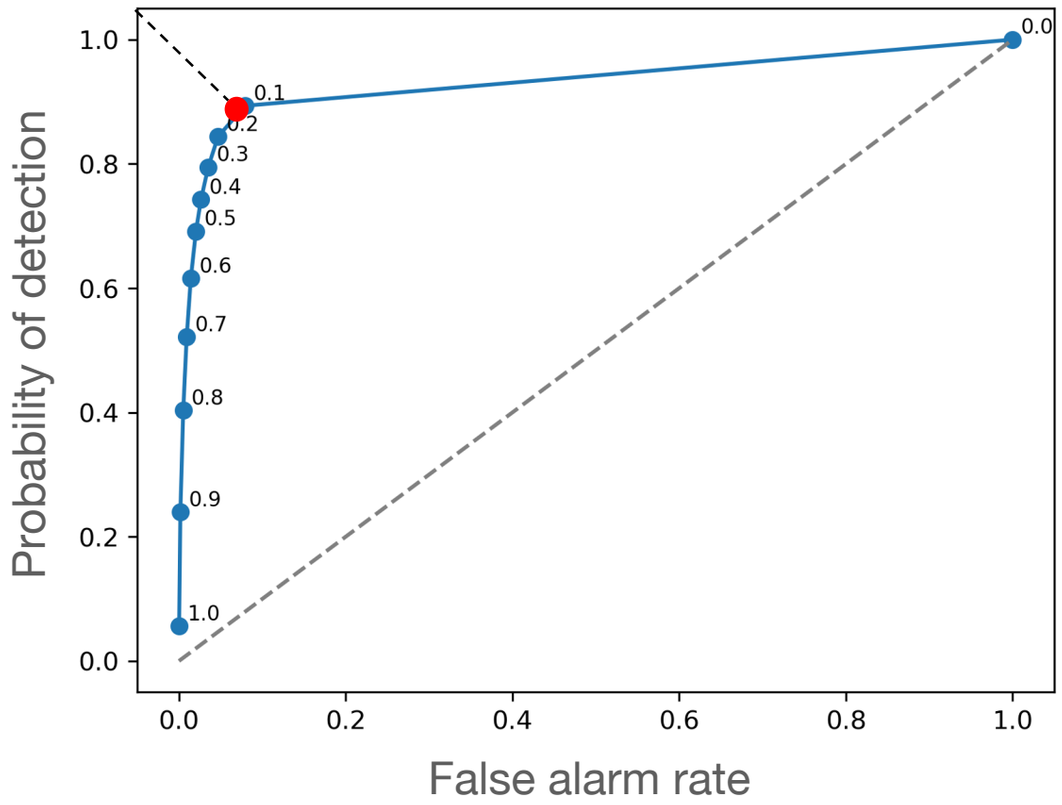
Precipitation hazard

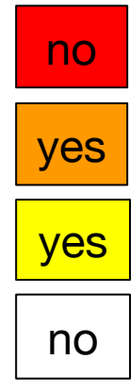
Ensemble of
forecast rain rates



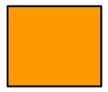
Optimal probability thresholds from ROC curves



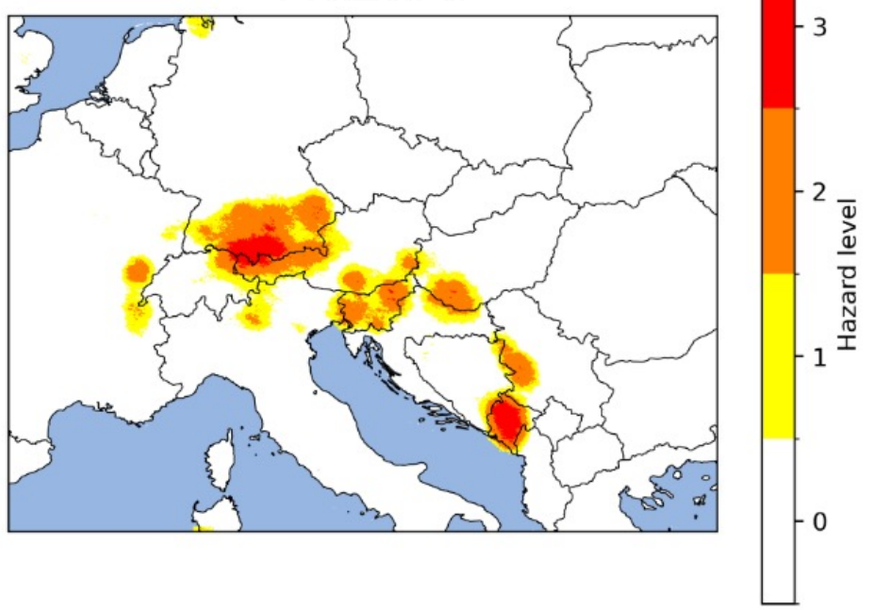
Threshold
exceeded



Maximum level
with “yes”



Hazard



Hazard classes
rain rate (mm/h)

- < 1
- 1-5
- 5-10
- > 10

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Question

Would users like to see probability information and how?

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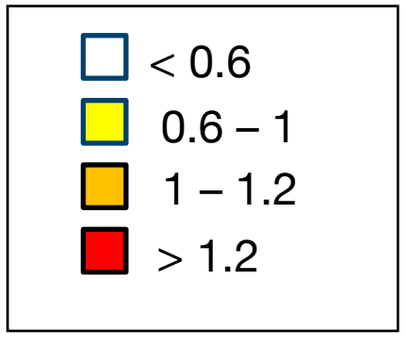
Precipitation risk

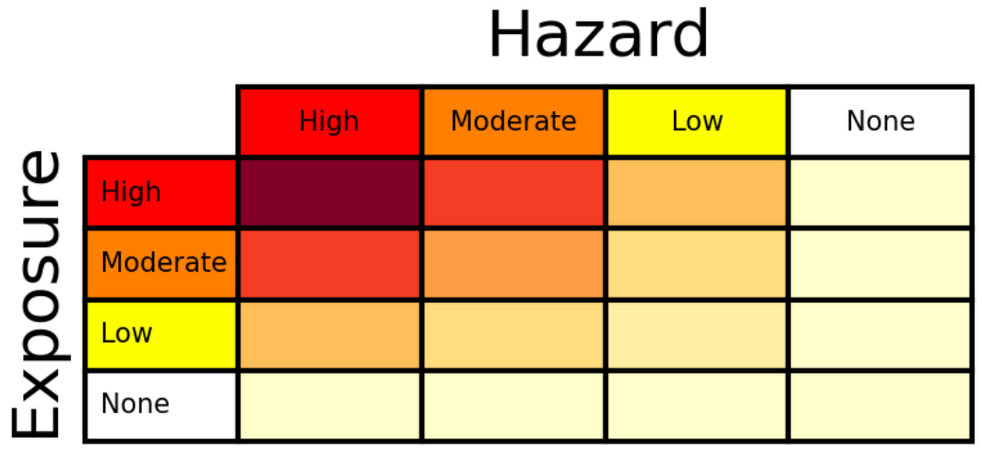
Combined exposure by ECMWF

- Normalized exposure rasters from Global Human Settlement Layer, JRC and HARCI-EU datasets
- Sectors: population, health, education, transport and energy

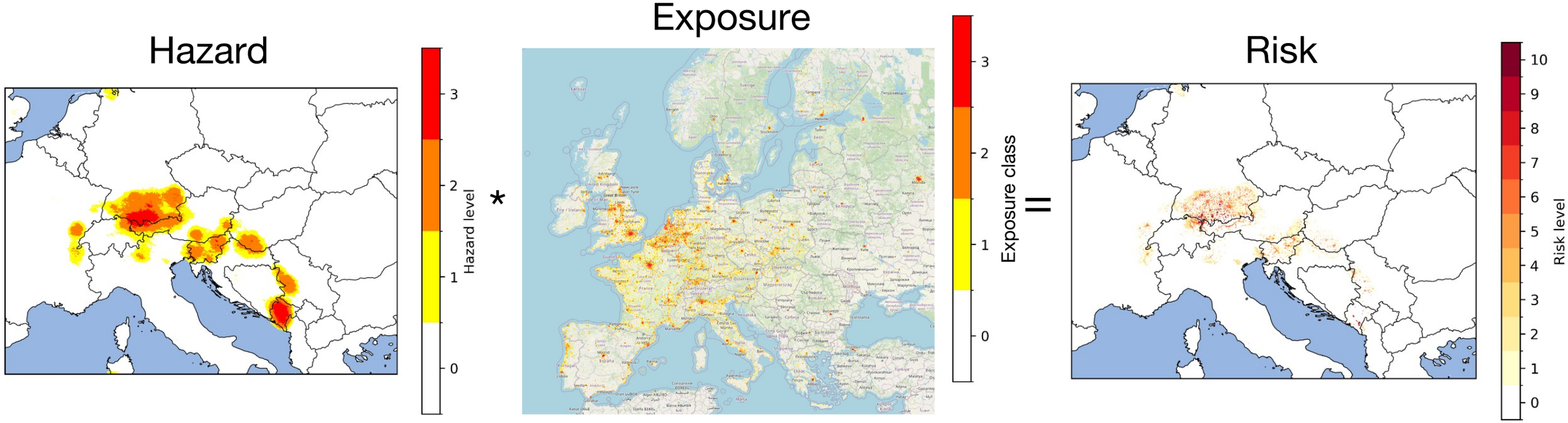
Exposure classes



How to select these thresholds?



Possible combinations



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Questions

1. How to select hazard and exposure thresholds?
2. Should we use only one exposure layer (e.g. population) at a time without combining them into one?

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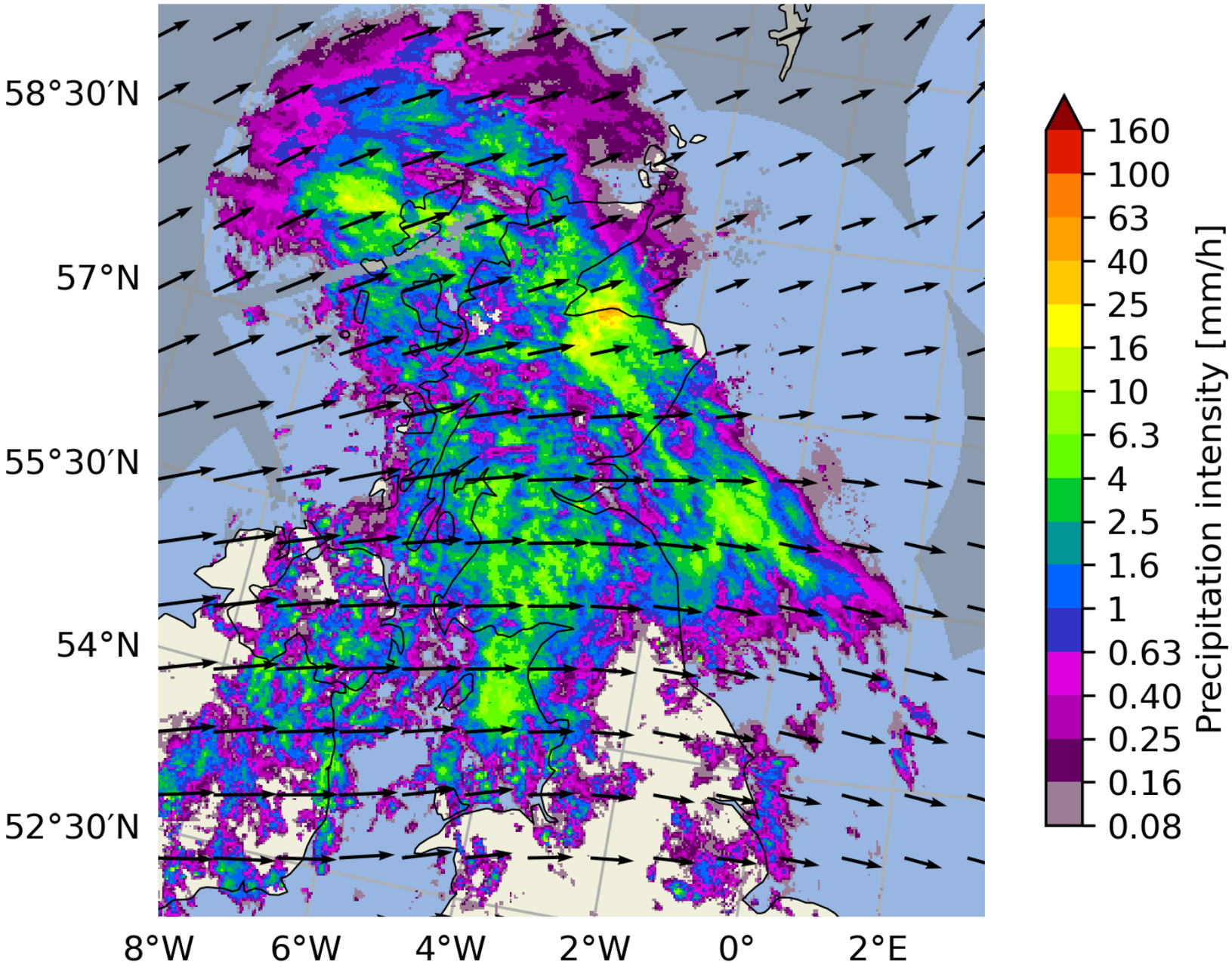
Precipitation nowcasting by extrapolation



- Used in the Radar reflectivity OPERA and Hourly precipitation – radar nowcasting layers for future predictions
- Method: SBMCast (Berenguer et al. 2011)
- Only motion
- No intensity changes
- Keeps the visual appearance of precipitation

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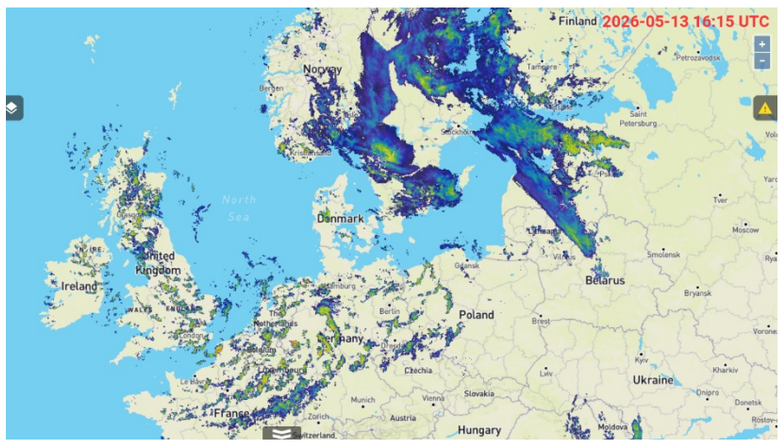
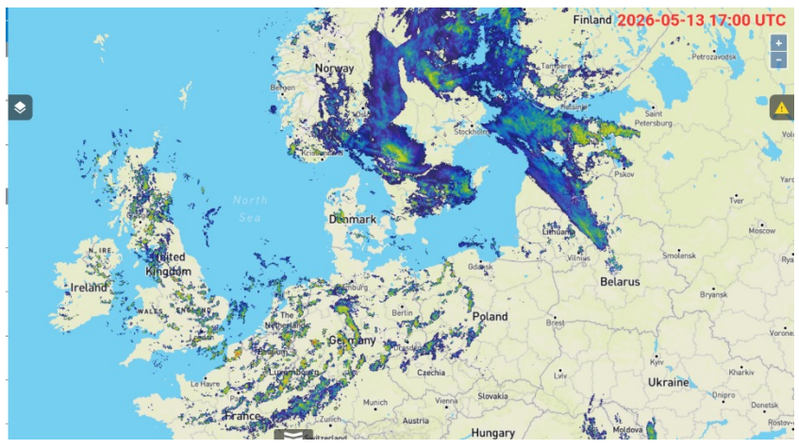
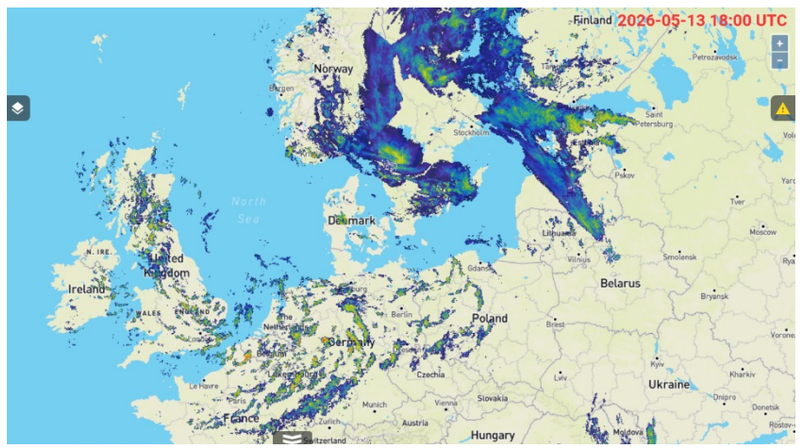
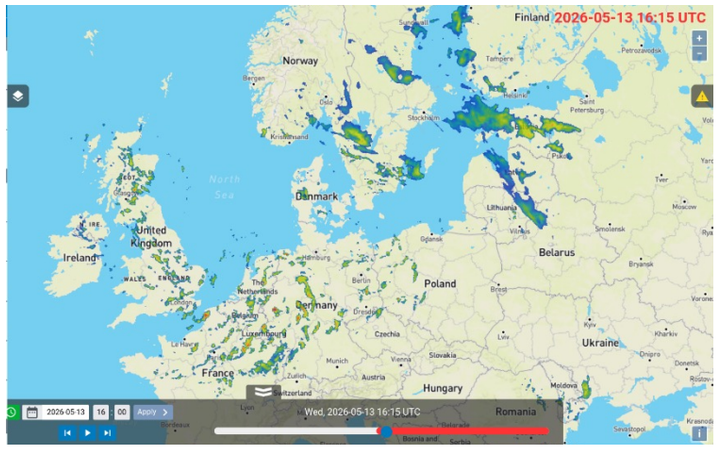
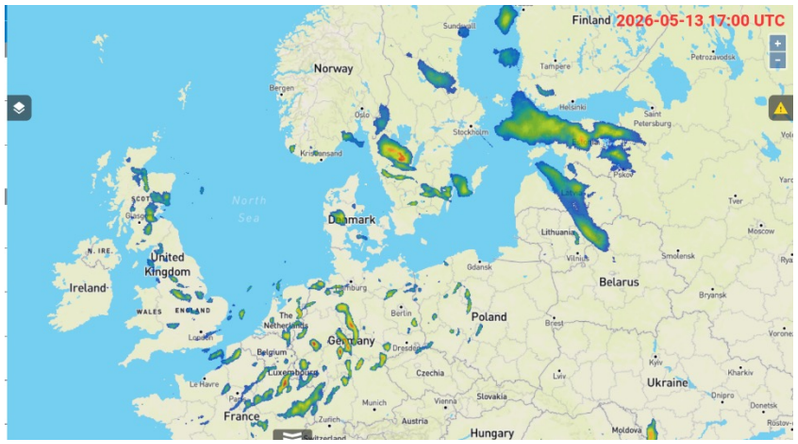
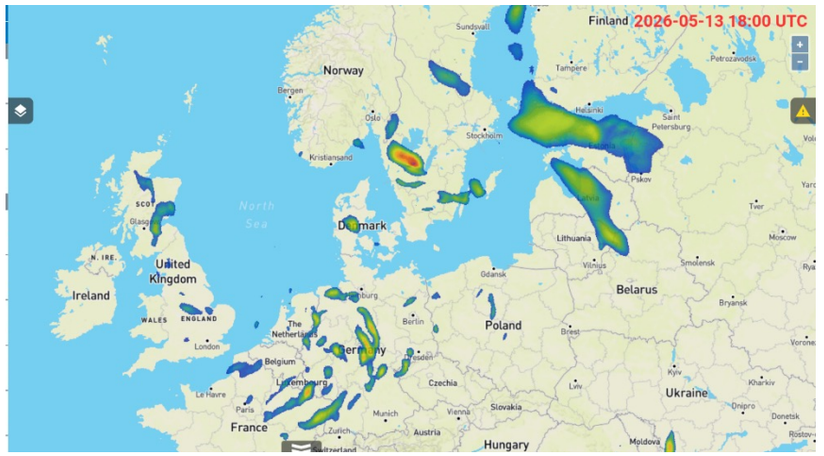
Nowcast are produced in a 2 km grid, but …

	15 minutes	1 hour	2 hours
Extrapolation			
	~ 2 km	~ 2 km	~ 2 km
Neural network			
	~ 5 km	~ 10 km	~ 20 km

Effective spatial resolution

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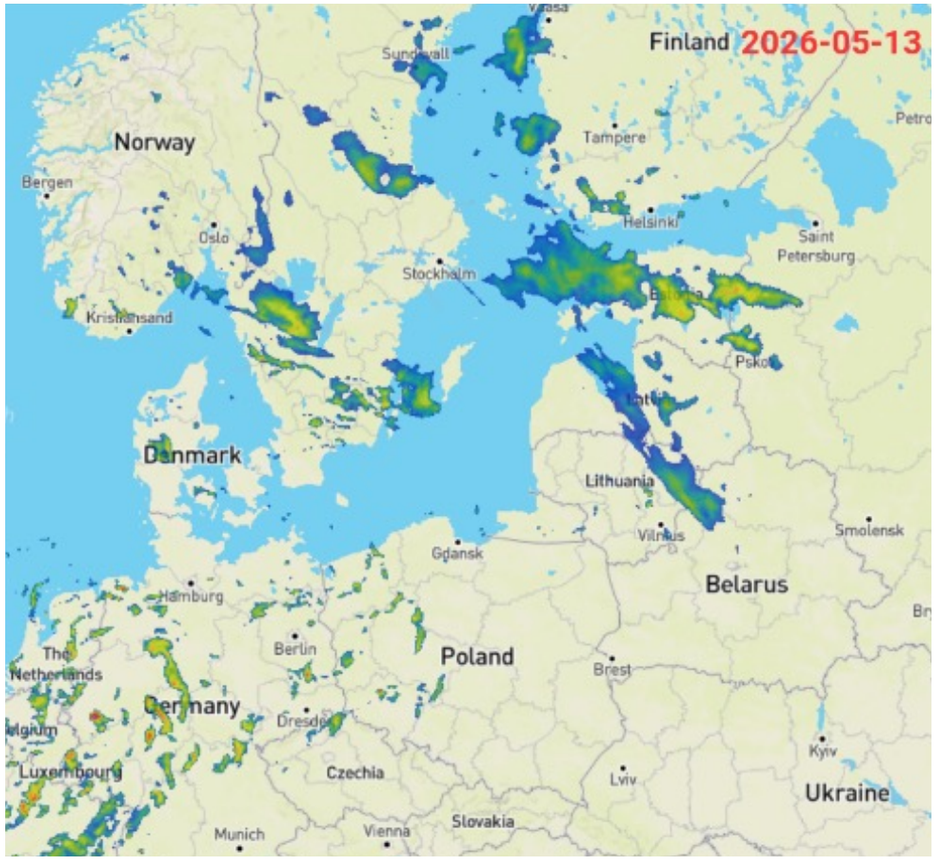
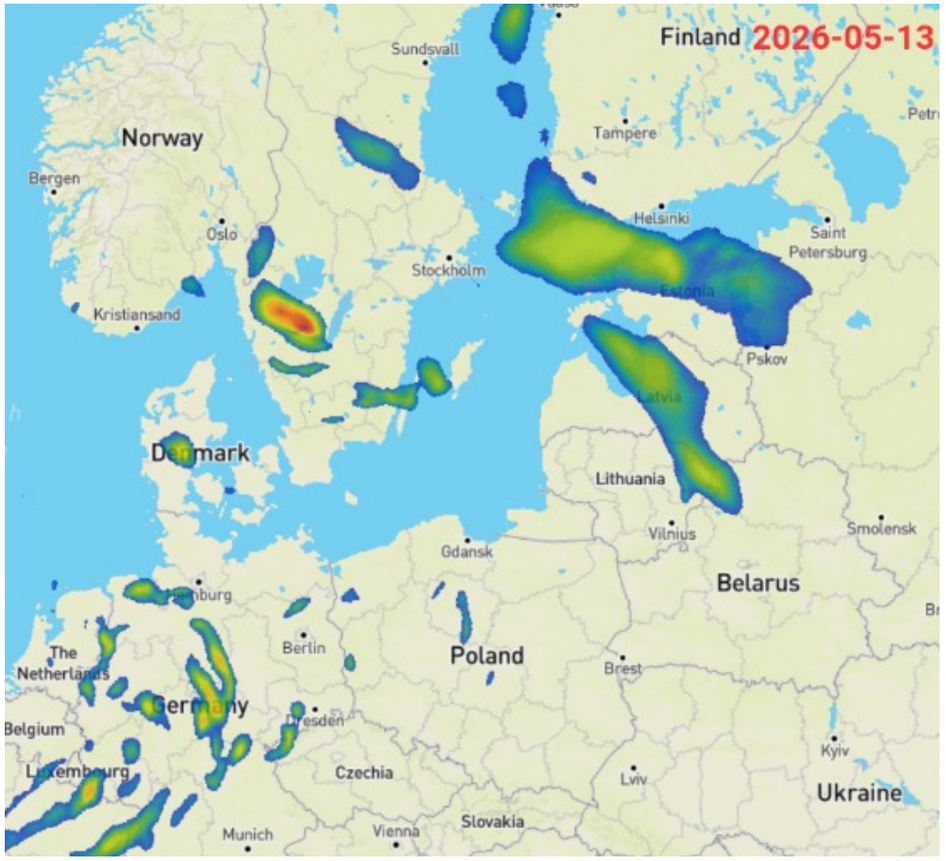
Interpretation

Blurring is due to uncertainty

15 minutes



2 hours



- Increasing uncertainty with increasing forecast length
- Large-scale precipitation is easy to forecast
- Forecasting small-scale precipitation is very difficult
- Not predicting small-scale precipitation features is the safe choice for the neural network

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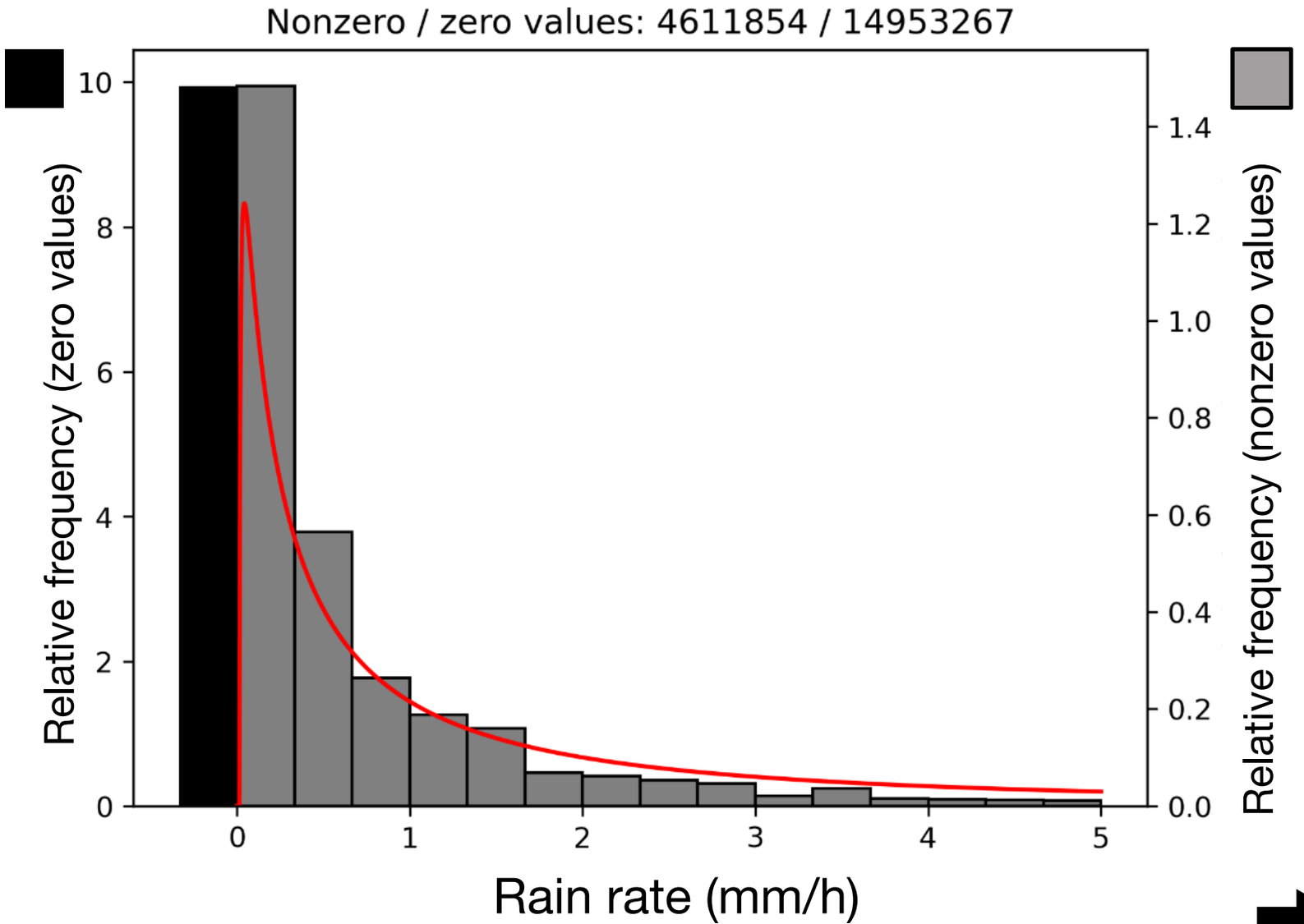
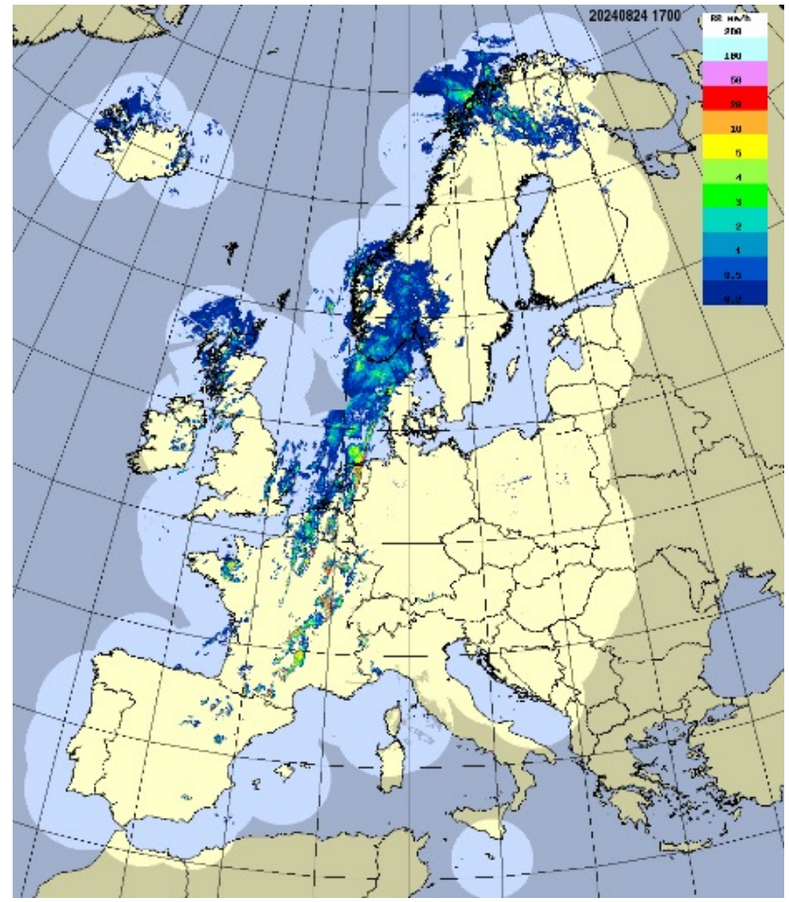
Machine learning methods have difficulties to predict heavy precipitation





- Heavy precipitation is rare
- Machine learning models are inclined towards mean value (zero and weak precipitation)

➡ Post-processing needed

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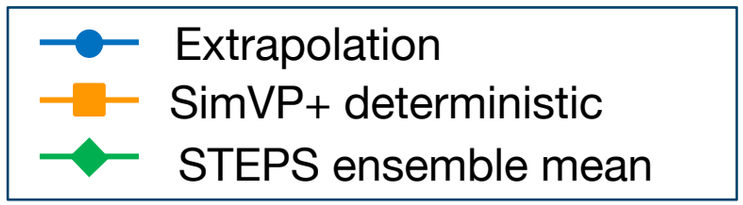
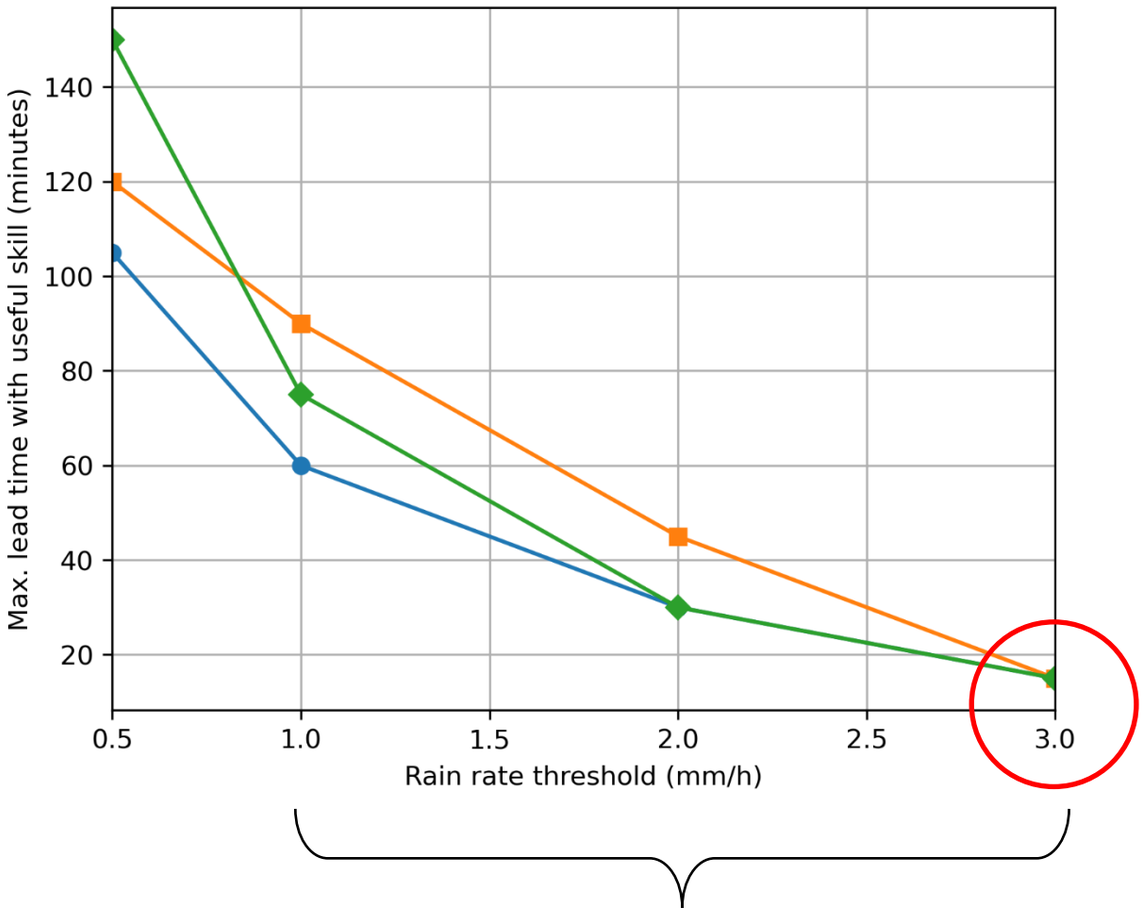
Limits of useful skill: 2 km spatial resolution

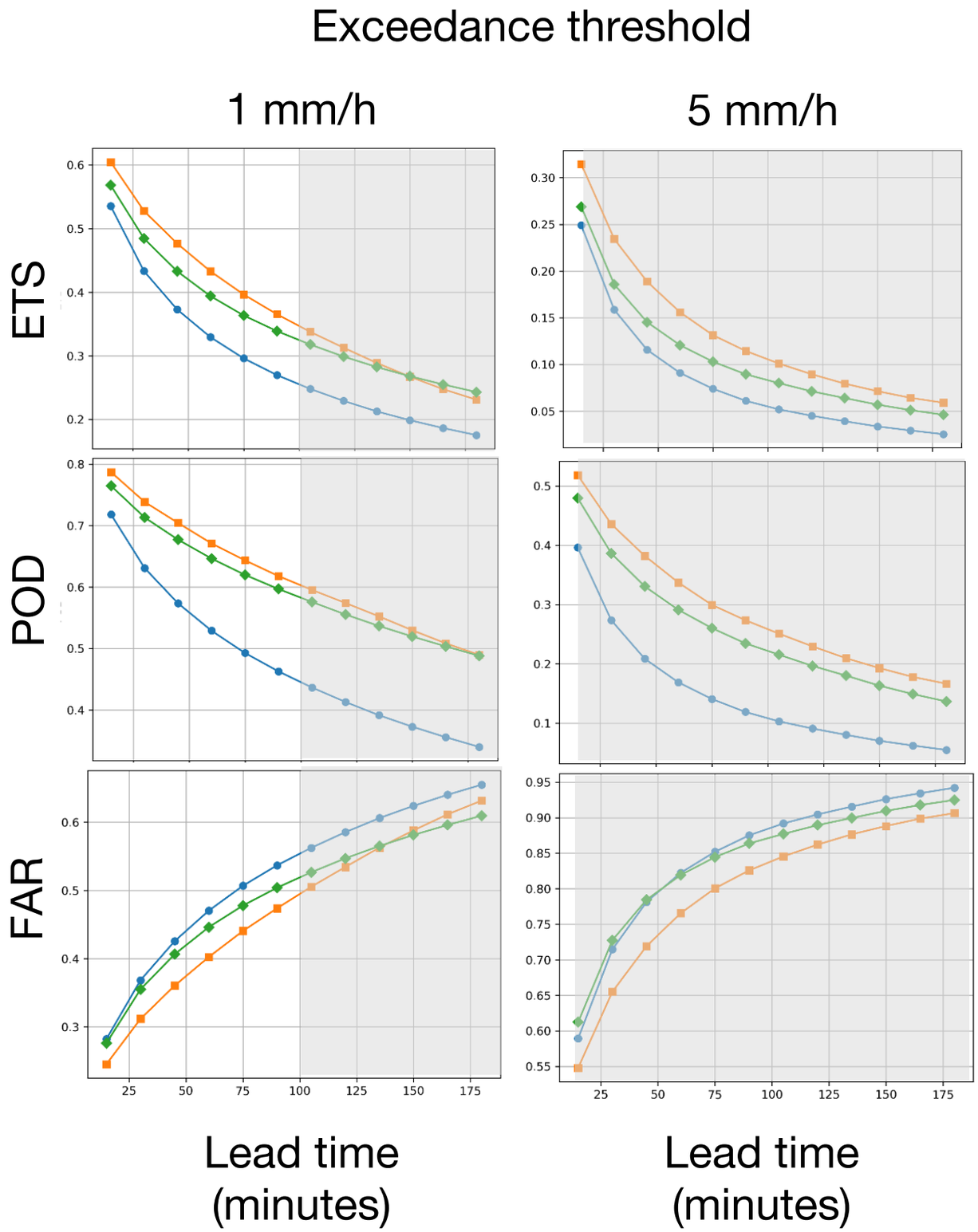


Criteria for a useful forecast:

- POD > 0.5
- FAR < 0.5



Yellow hazard level



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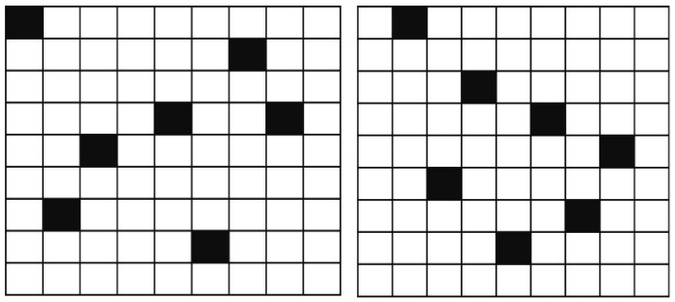
Fractions skill scores

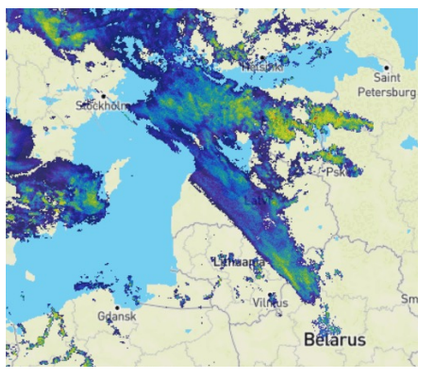
% of exceedance predictions correct in a spatial window



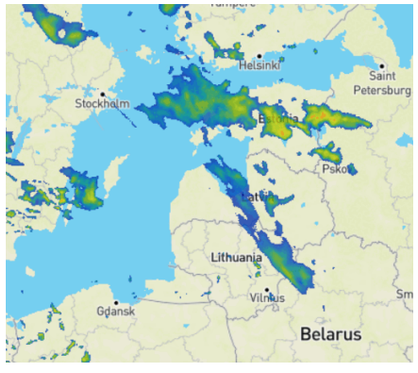
Criterion of useful skill: FSS > 0.5

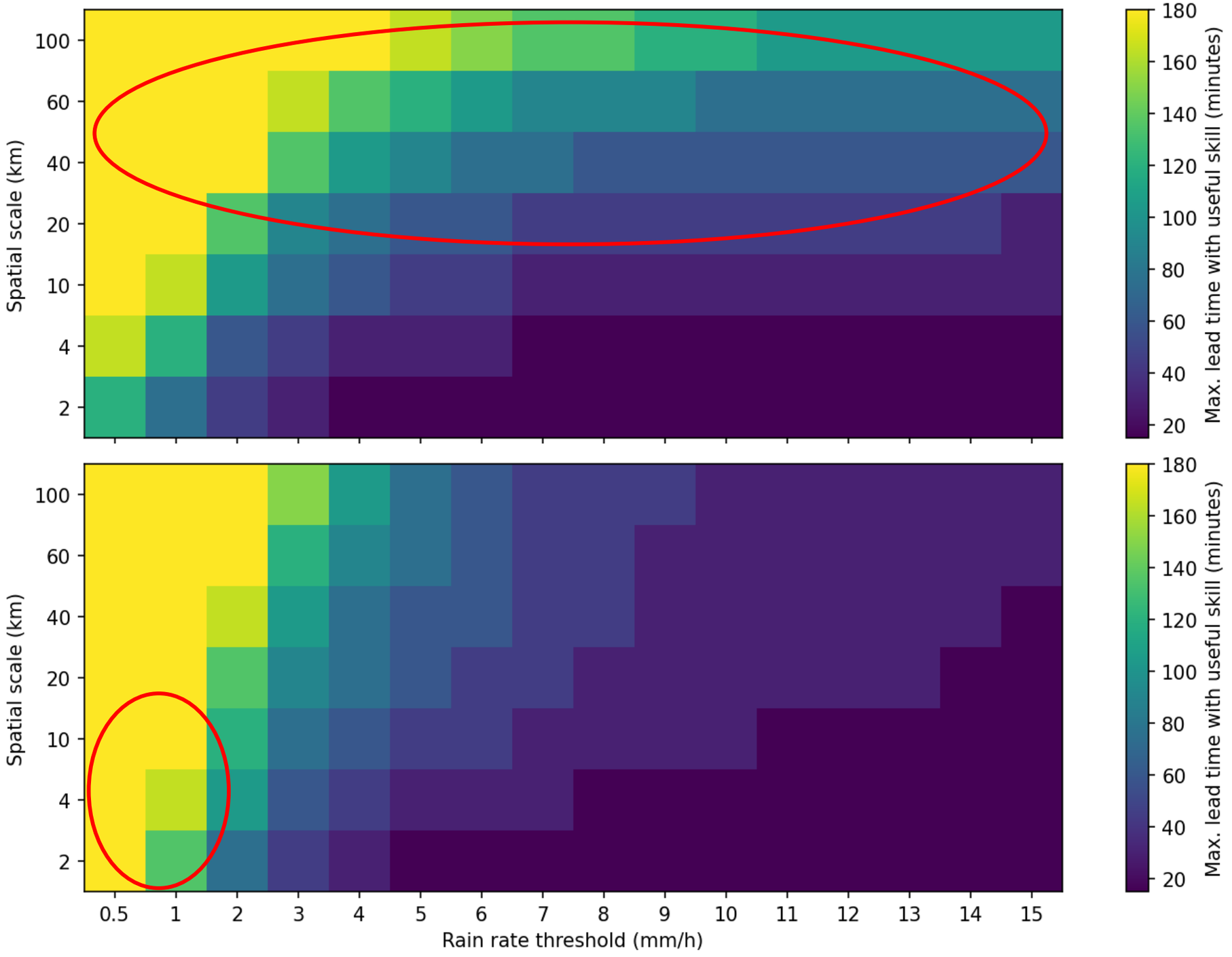
Answers to: What would the forecast skill be if location errors were allowed?

Extrapolation



Neural





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Time ranges of useful forecast skill

Hazard classes
rain rate (mm/h)

- < 1
- 1-5
- 5-10
- > 10

2 km scale, no location error allowed

- Yes / no precipitation (0.5 mm/h): 2 hours
- 1 mm/h: 1.5 hours
- 5 mm/h: 15 minutes
- 10 mm/h: not useful

Use neural network

Location errors of up to 20 km allowed

- 1 mm/h: 3 hours
- 5 mm/h: 1.5 hours
- 10 mm/h: 1 hour

Use extrapolation instead
Also: looks like precipitation without blurring

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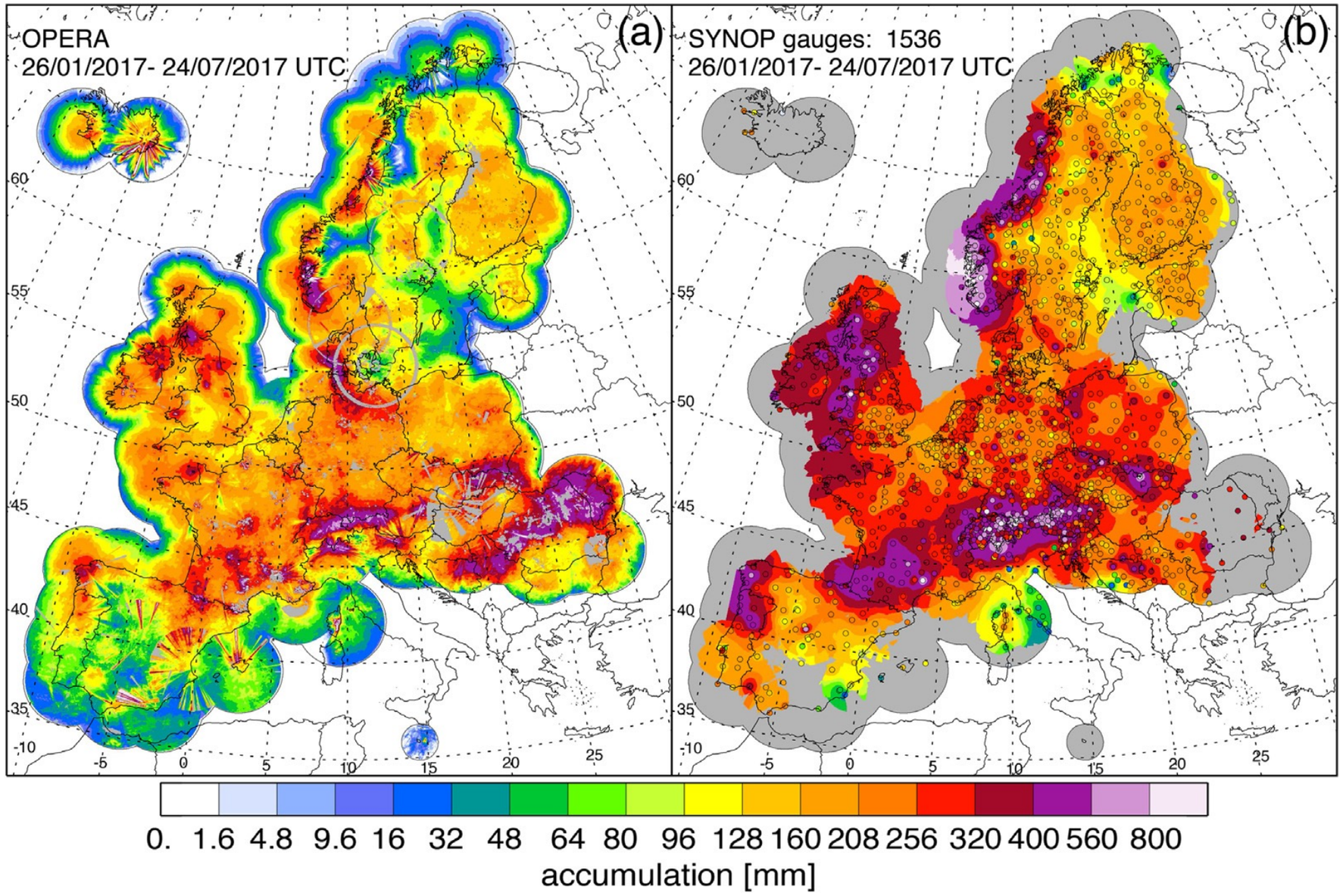
Quality of OPERA composites

Park et al. 2019



- The storm impact products use raw OPERA composites without rain gauge correction
- Gauge observations not available in sub-hourly time scales needed for the storm products
- OPERA underestimates true rain rate and accumulated rainfall **(up to 2-3 times smaller)**

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Other hazard types

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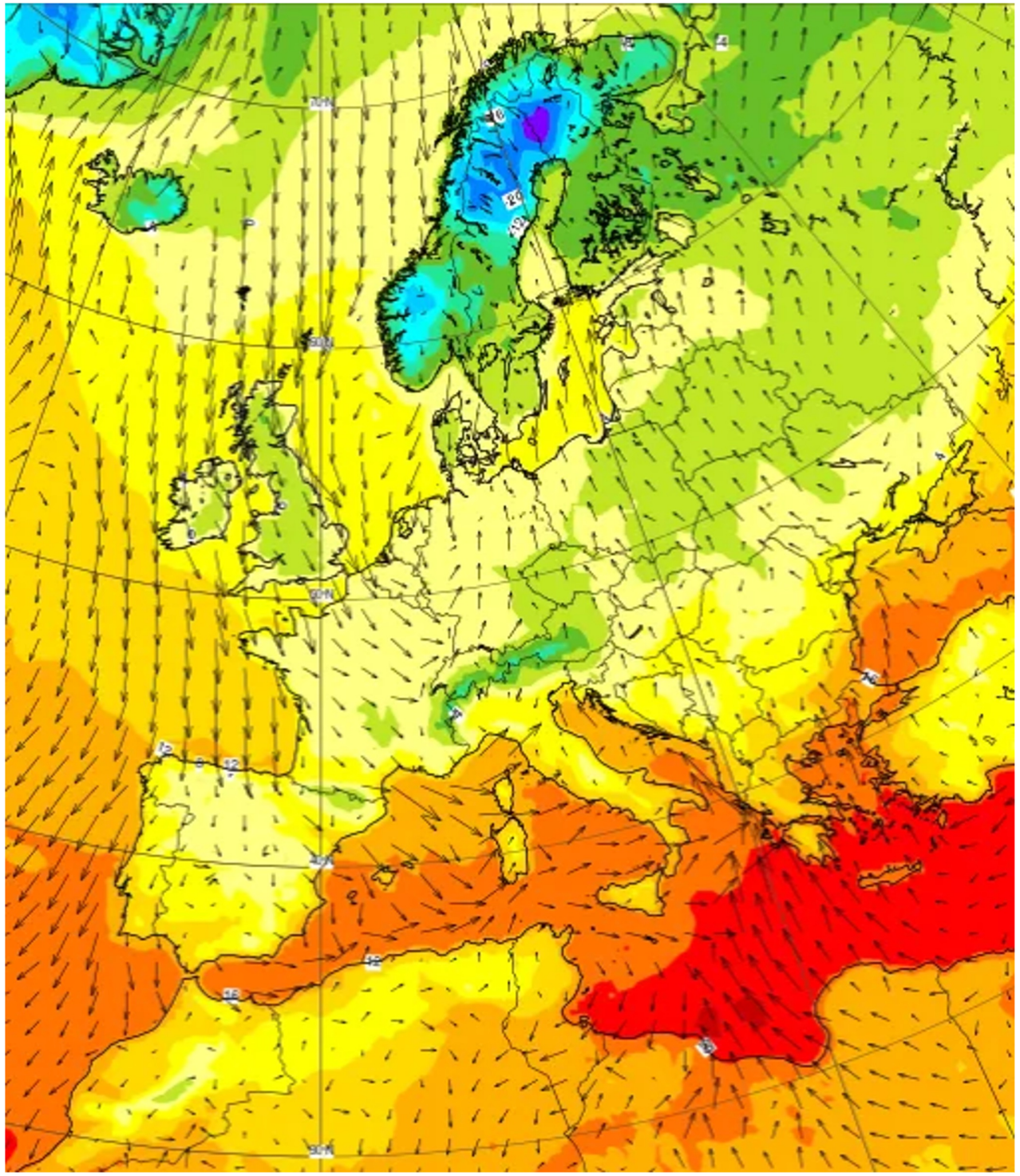
Wind products



ECMWF / IFS wind forecasts

10 m wind: u- and v- components → wind speed →

Hazard classes

- < 20
- 20 - 30
- 30 - 40
- > 40

m/s

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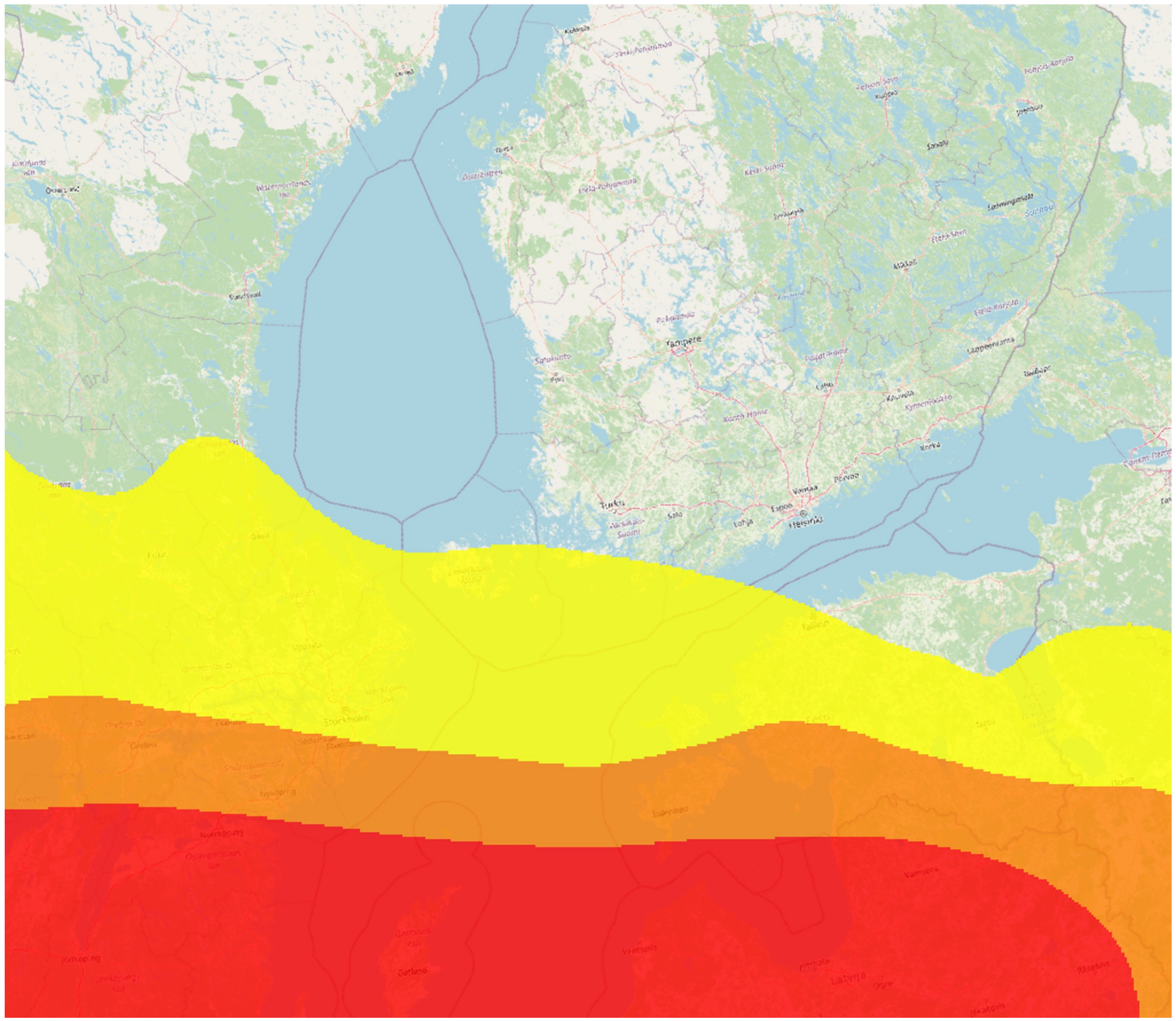
Wind products

- Model forecasts have very coarse scale
- Added value compared to already existing wind forecasts?
- Other model fields: wind gusts?



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Question

Is there need for high-resolution wind gust products?

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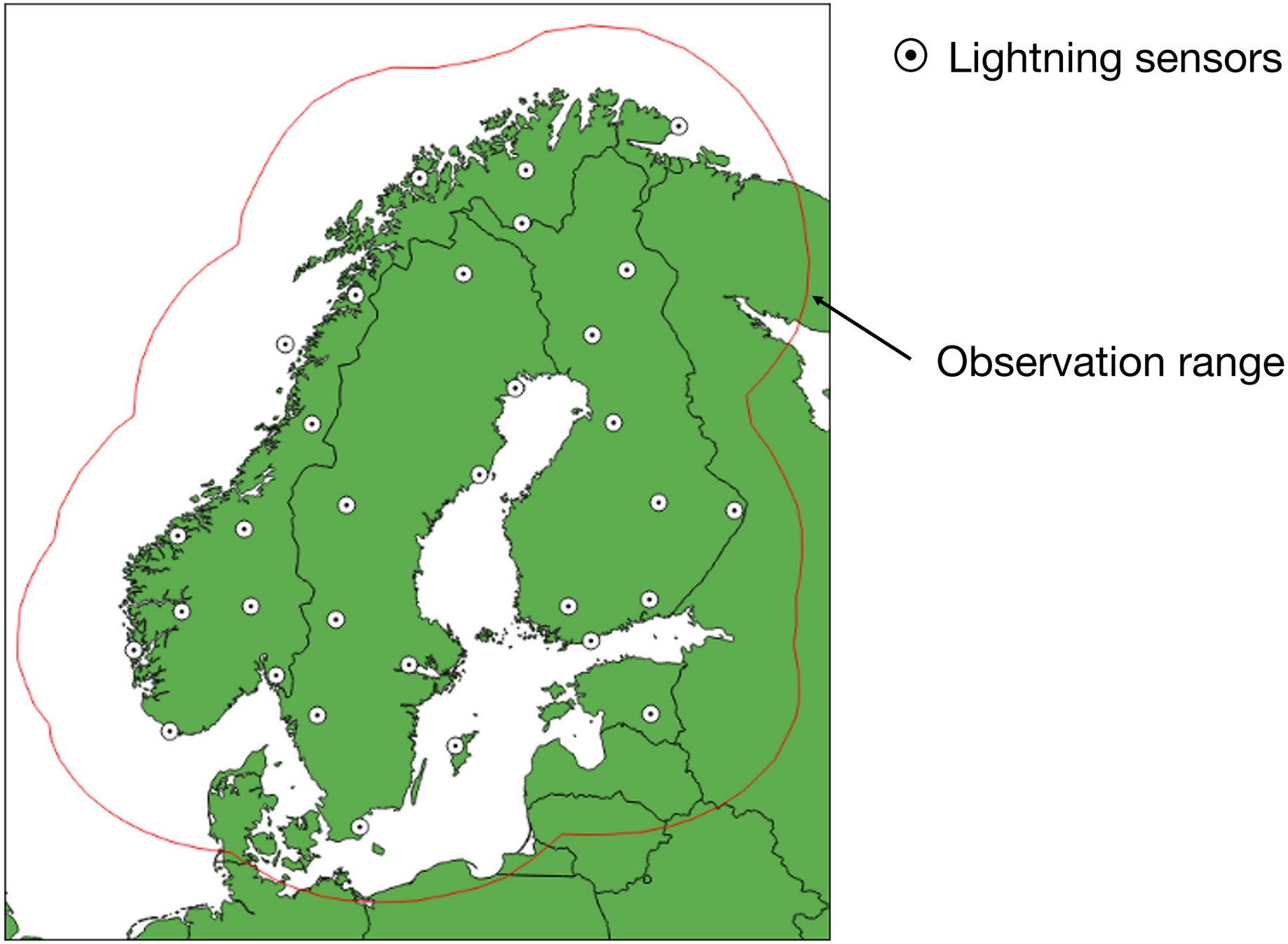
Lightning products



Location and time of lightning flashes from NORDLIS (limited to Northern Europe)

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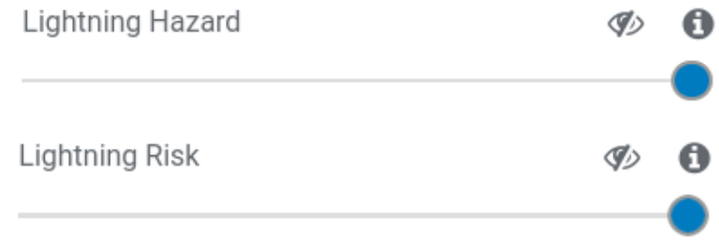
Lightning products



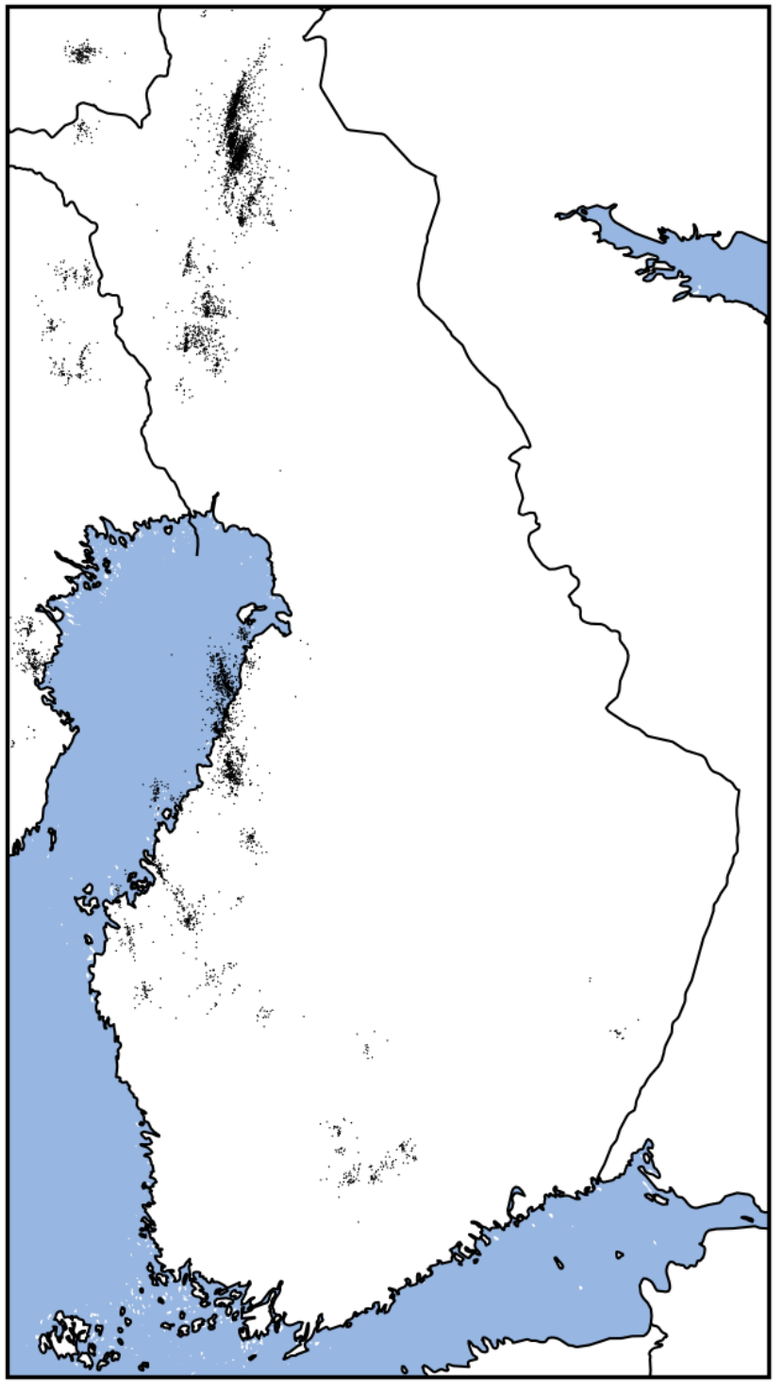
Hazard classes

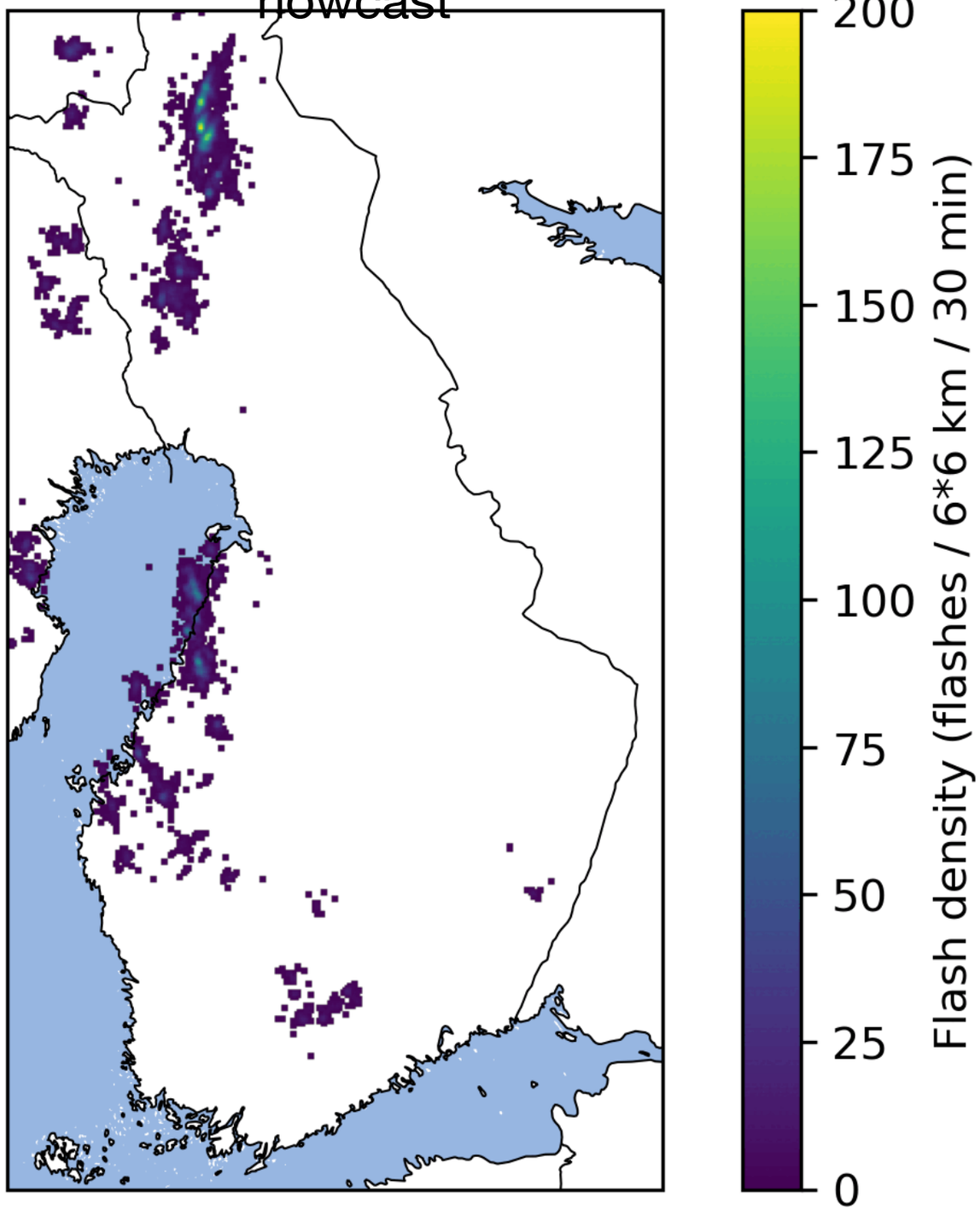
- < 1
- 1 - 10
- 10 - 50
- > 50

flashes / 6*6 km / 30 min

Advection nowcast

Flash locations





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Question

Is there need for pan-European lightning products?

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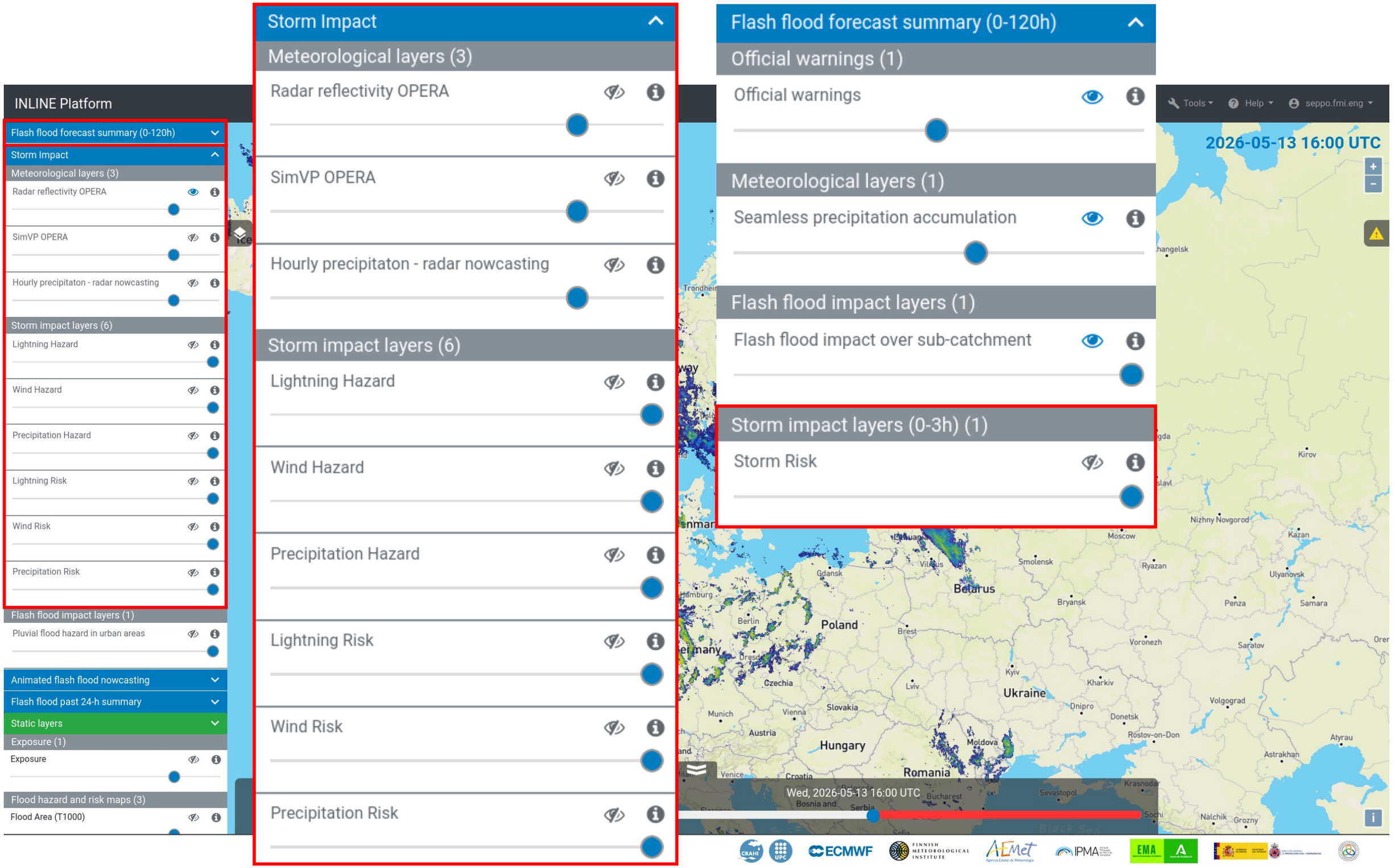
Overview



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