The Weather-Induced Extremes Digital Twin

ECMWF and DEODE (DE330)

Funded by the European Union
Destination Earth implemented by ECMWF esa EUMETSAT

WHY DO WE NEED A NOVEL INFORMATION SYSTEM?

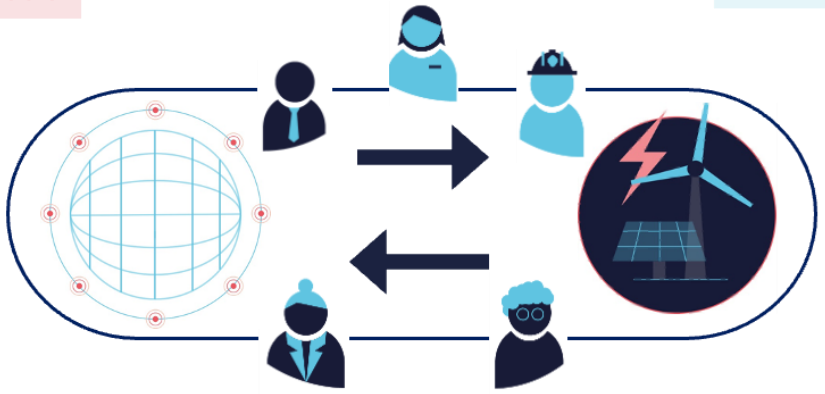
OPERATION

Simulating the scale at which impacts occur

QUALITY

IMPACTS

Configuring flexible domains targeting impacts



Combining solutions from physical ensembles to AI

UNCERTAINTY QUANTIFICATION

INTERACTIVITY

Building workflows to stream high-frequency NWP data

WHO IS BUILDING THE EXTREMES DT?

From daily worldwide detection of extremes…

ECMWF

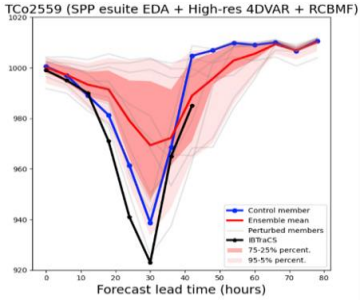
Global DT

- IFS-NEMO
- 4.4km (¼ deg ocean)
- Hourly outputs
- Initialized at 00Z daily
- Impact sectors :
  - CaMa-Flood
  - Flexible aerosols

… to on-demand refinement over Europe

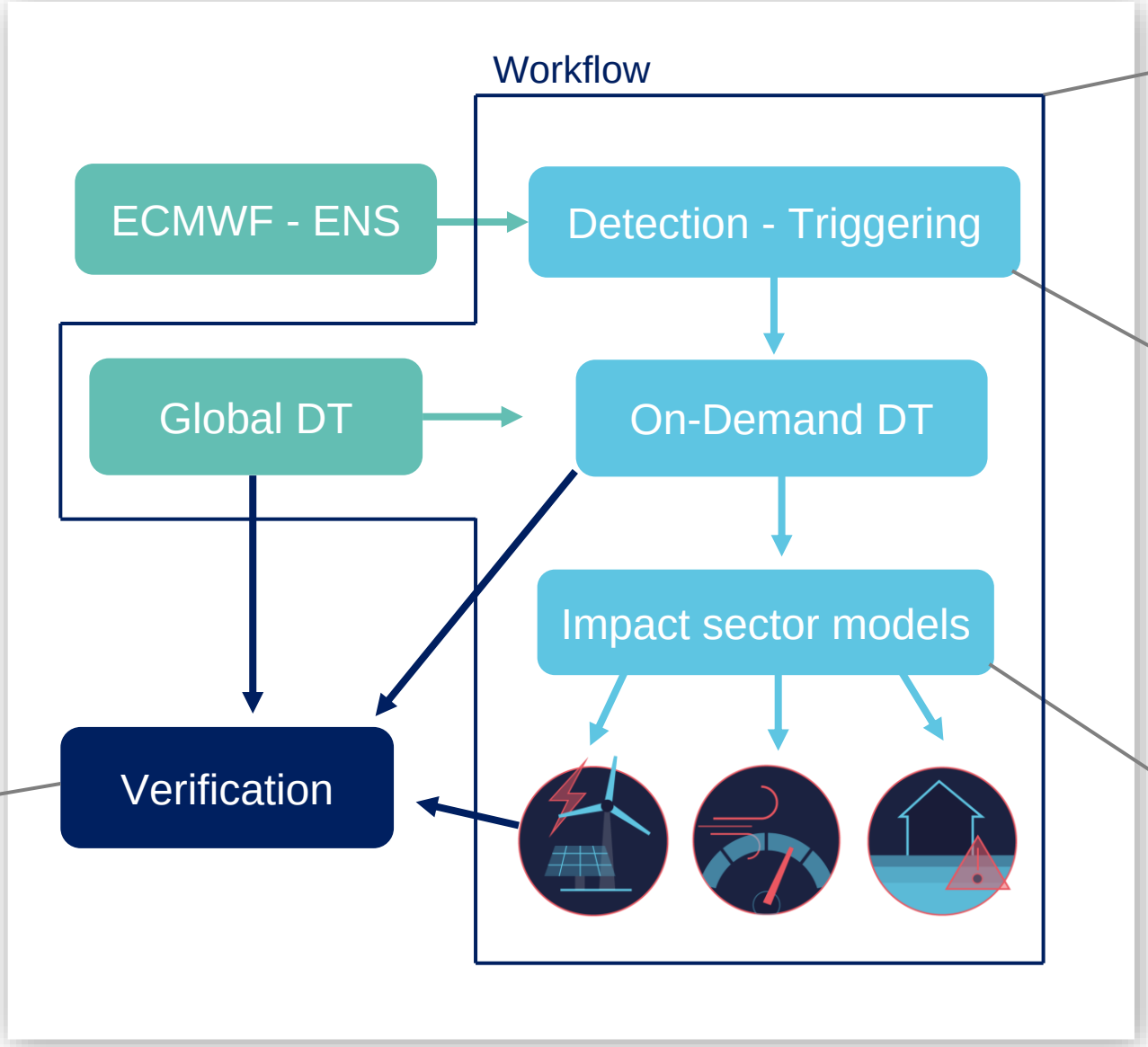
On-Demand DT

- Arome, Harmonie-Arome, Alaro
- 750 to 500m
- Sub-hourly outputs
- Initialized on-demand
- Impact sectors :
  - Hydrology (9+1 models), Storm surge
  - Air-quality (7 models)
  - Renewable energy (wind, solar)
  - Thermal comfort, Wildfire, Frost



3. Towards uncertainty quantification in the EDT

Aristofanis Tsiringakis (ECMWF)



1. On-Demand Extreme DT workflow

Xiaohua Yang (DMI)

4. Detection of extremes and triggering of the On-Demand DT

Jonathan Demaeyer (RMIB)

5. Use Case Success Stories: from forecasts to impacts

Estíbaliz Gascón (ECMWF)

2. Integration of impact sector models in the EDT

Roger Randriamampianina (MET Norway)

The On-Demand DT workflow

Xiaohua Yang

Funded by the European Union
Destination Earth
implemented by
ECMWF
esa
EUMETSAT

Toward an user- or event-driven on-demand DT

Impact / extreme type / extension / evolution / speed

Resolution (domain extension & position): 200m / 500m / 750m

Physics (CSC): Arome / Harmonie-Arome / Alaro

Best initial condition & LBC Forecast

Uncertainty quantification and decision-ready information

Impact modelling

DEDL

ECMWF

Example: Pollution - stationary large; flooding - varying extension, different speed;

Example: Pollution, air quality - 750m; flooding depending on the extension (200m / 500m / 750m) (possible few connected domains), wind energy (500m); urban meteorology (200m)

Example: North or south Europe- Harmonie-Arome western, central, eastern Europe - Arome / Alaro

Initialisation: using the global continuous DT

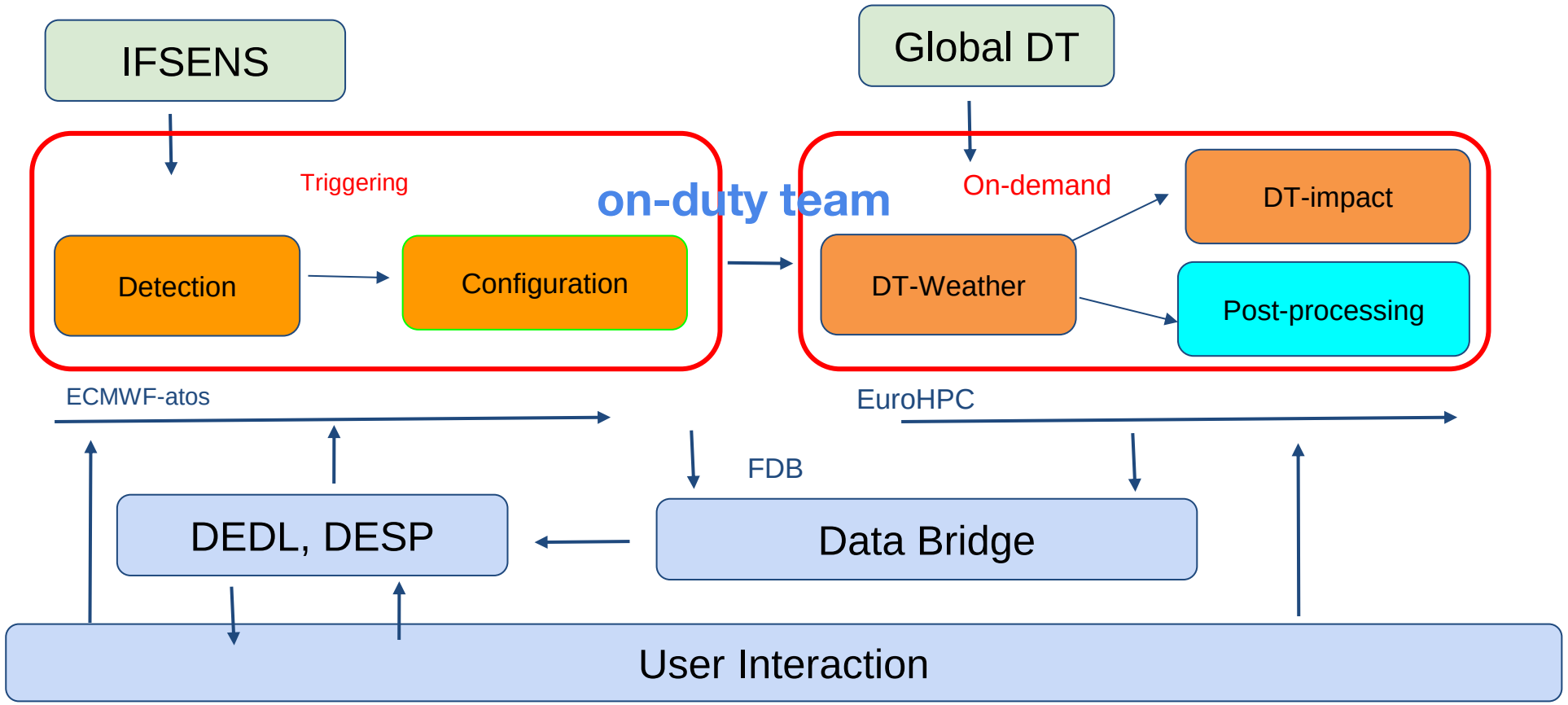
Using: Machine learning and physical base methods

Example: flooding; air quality; energy meteorology; agriculture; frost, coastal & urban flooding

ECMWF Funded by the European Union

From detection of extreme to on-demand production of hectometric scale DT integrating weather, impact sectors and end users

On-Demand DT



DT Weather consists of workflows around DT-NWP (deterministic), DT-UQ based on NWP-EPS and/or-data driven weather forecasting EPS

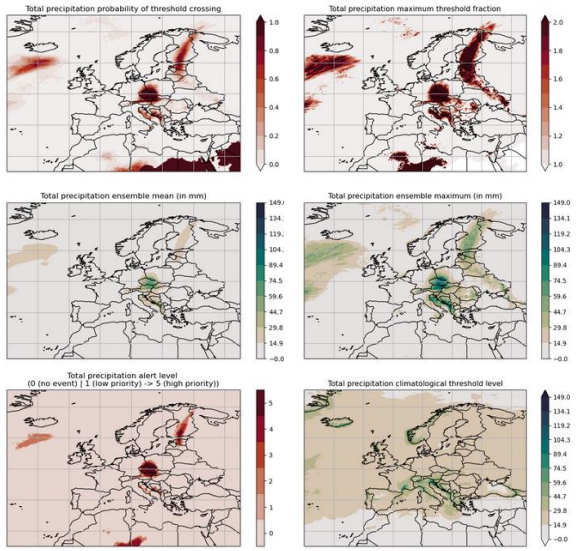
On-Demand DT is now piloted daily over Europe

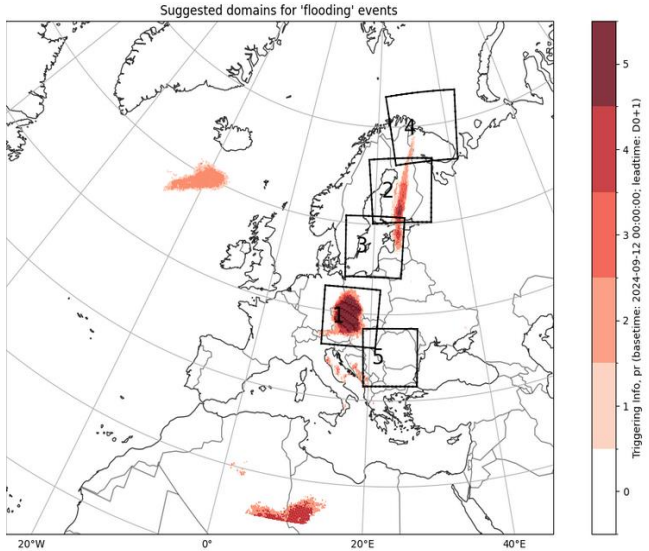
Detection

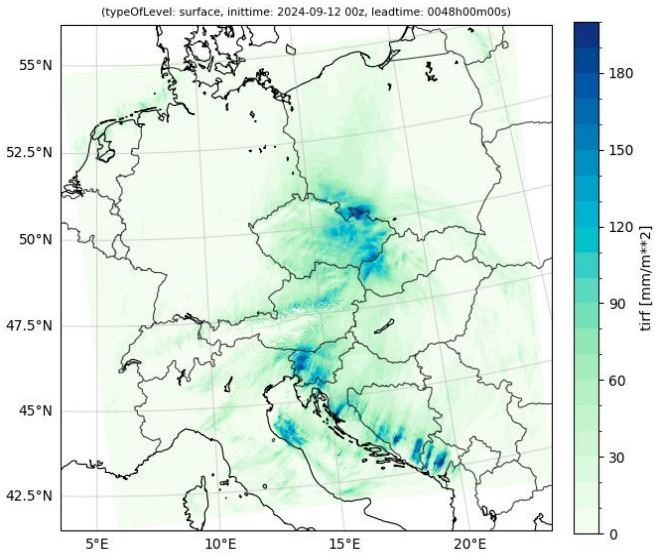
Configuration

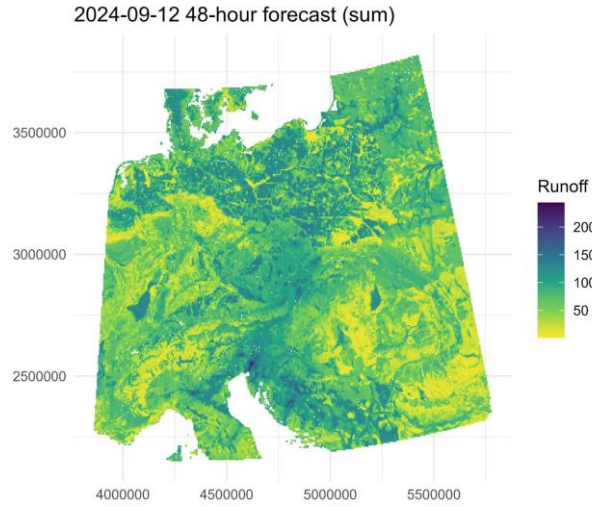
DT-NWP

DT-Impact









Boris episode. start time on 12 Sept 2024 with 48h forecast

ECMWF

Work is ongoing with workflows around uncertainty quantification...

Why, What, Which and How… to trigger? --> lookup table

Flooding
Stormsurge
Heatwaves
Air Pollution
Storm
Frost
Wildfire

Hectometric scale with added values?

LAM model infrastructure?

Predictability?

Affordability?

Hydrology (Flood, Surge)
Air Quality and Health
Renewable energy

NMS
Emergency service
Warning authority
Energy sectors
Agriculture
Healthcare

Impactful

Cost-efficient

Impact sector

End users

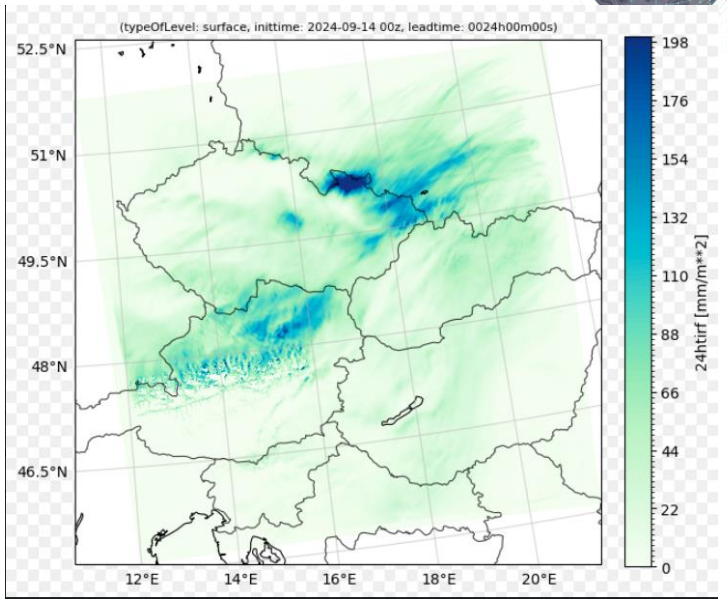
DEODE Triggering Framework

Piloting the on-demand extremes DT close to real time

Operational team with weekly rotating took shape starting July 2024

1) explore organisation of operational activity and 2nd line support
2) implement system infrastructures around available real time workflow
3) daily operation, maintenance and troubleshooting
4) daily touchbase involving decisions, distribution and review of on-demand runs

- Maintain and monitor daily real-time components (Paris RDP, On-demand NWP runs)
- ~120+ sub-km on-demand runs performed in the first 2 months
- Monitoring with charting and evaluation
- Involvement of duty forecaster representatives



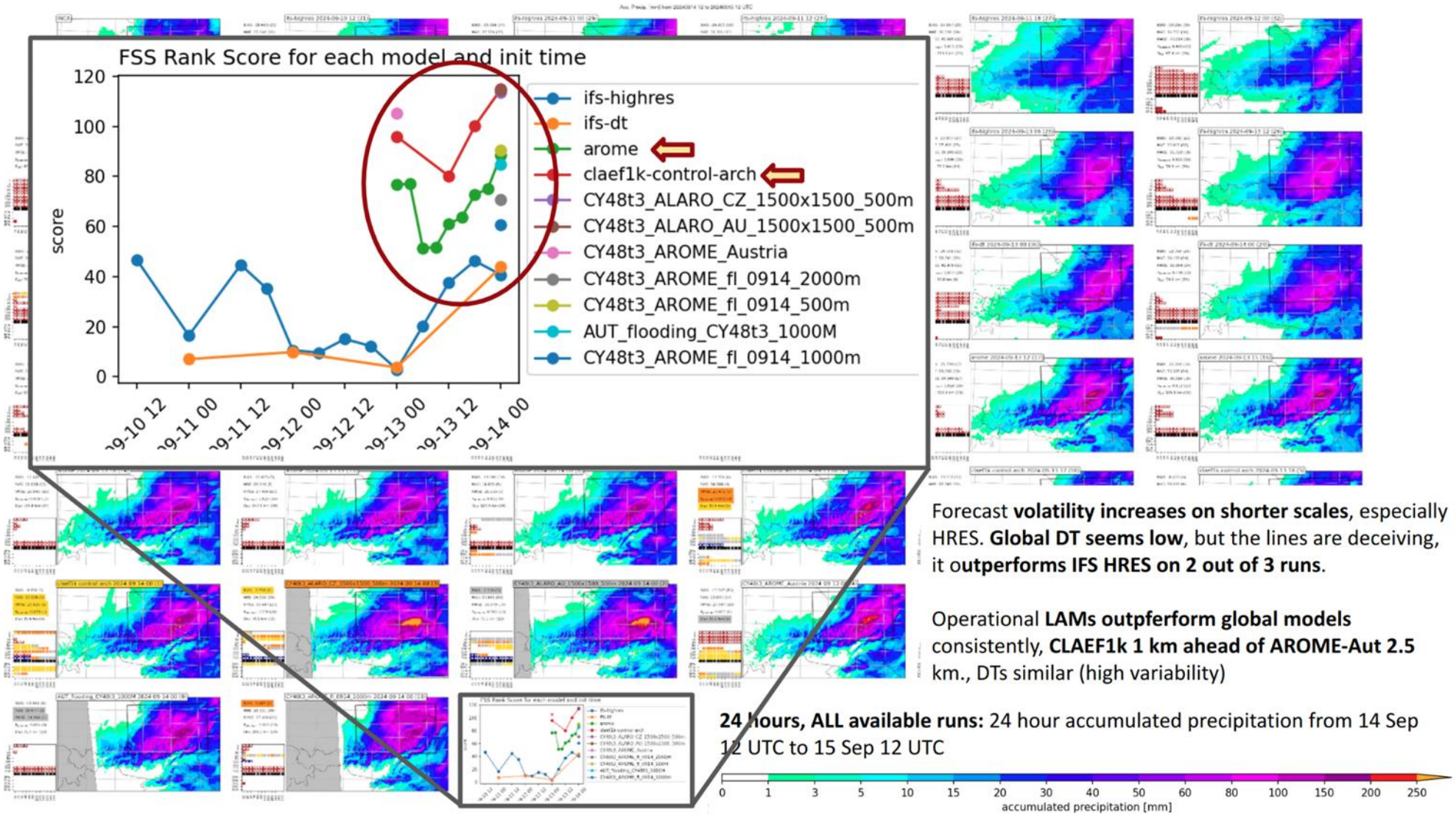
24h accumulated rain on 14 Sep by Arome@500m

Storm Boris

Week nr	30	31	32	33	34	35	36	37	38	39
Nr of runs	4	8	0	9	14	10	10	16	35	14

- Most cases on flooding, convection and storms, some on heatwaves and wildfire, covering most European areas
- Most with grid resolution of 500m, some with 750m and 1000m
- Combination of automatic and manual triggering

Quality assessment against other available data



Forecast **volatility increases on shorter scales**, especially HRES. **Global DT seems low**, but the lines are deceiving, it **outperforms IFS HRES on 2 out of 3 runs**.

Operational **LAMs outpferform global models** consistently, **CLAEF1k 1 km ahead of AROME-Aut 2.5** km., DTs similar (high variability)

24 hours, ALL available runs: 24 hour accumulated precipitation from 14 Sep 12 UTC to 15 Sep 12 UTC

(Phillip Scheffknecht; Geosphere Austria)

On-Demand DT deployment timeline

First configuration available on LUMI
Real time data on bridge for :
- Wind energy over Europe (few metadata)
- Solar energy: Post-processing power prod. (DK & AU)
- NWC-base solar energy (BeNeLux)
- Air Quality (AQ) over (BeNeLux & Central EU)
- Storm surge detection (Baltic & Adriatic Seas)
- Storm surge: High-res. sea level prediction (Baltic S.)

REST-API triggering prototype available for selected users

Uncertainty quantification:
- Forest-based method for wind & temperature

Sept 2024 | **Q1 2025** | **Q2 2025** | **Oct 2025** | **Jan 2026** | **Mar 2026** | **Apr 2026**

Hydrology :
– E-HYPE
– 9 pilot areas over Europe

On-Demand workflow on LEONARDO
Post-processing (BQN)
– Quantiles or probabilities for precip.

Activation of automatic domain

AQ models and On-Demand over Europe