DESTINATION EARTH

On-Demand Extremes Digital Twin: Extreme Floods Application

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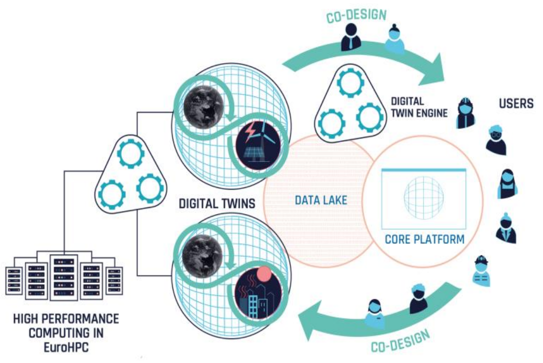
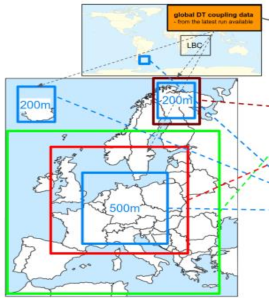
and many others, SMHI

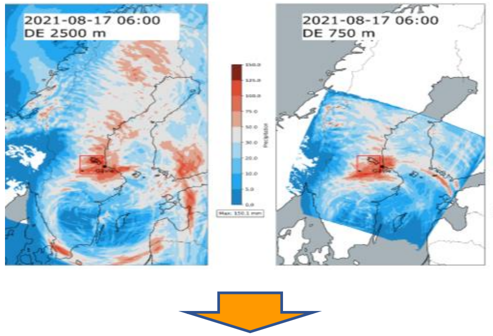
Funded by the European Union Destination Earth implemented by ECMWF esa EUMETSAT

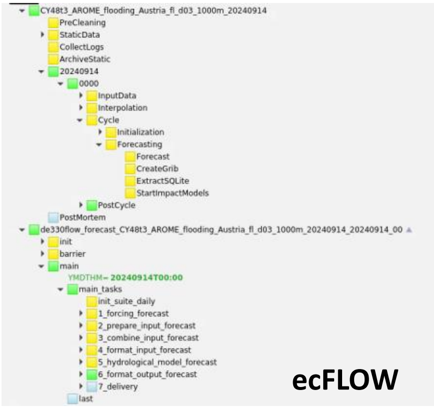
Project objectives

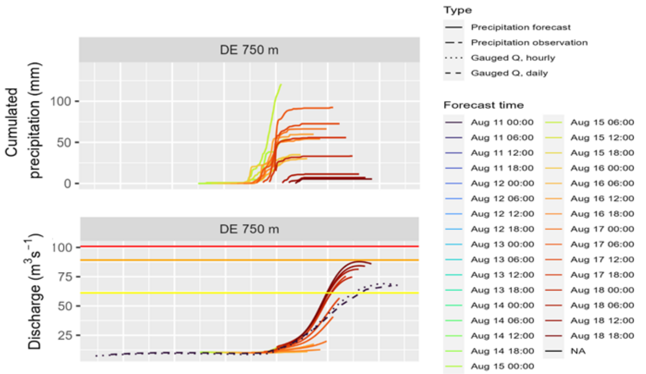
1) Pan-European application/*service* combining weather and impact-specific (e.g. hydrology) observation and simulation capabilities
2) Configurable, flexible and scalable **workflows** with hectometric resolution NWP data fed into impact models **on-demand**
3) **Value demonstration** for various impact areas (e.g. hydrology/floods)
4) Reliable load on high-performance computing (EuroHPC)
5) Interfacing with ECMWF DTE, DEDL, DESP as required











Co-create a daily on-Demand DT operation

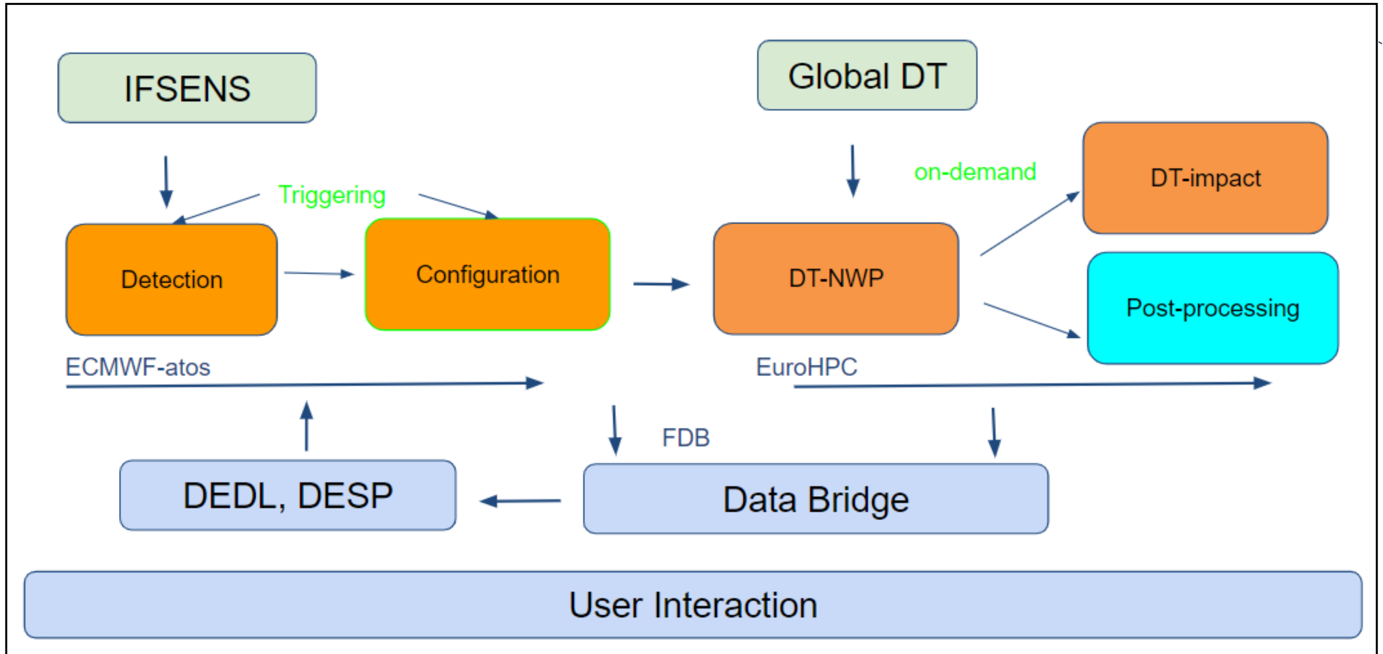
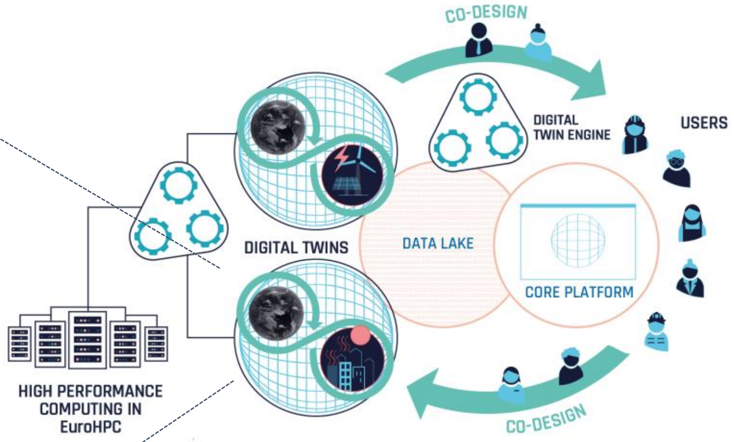


Fig. credit: X. Yang, DMI



- **Piloting the on-demand extremes** daily production of forecasts on EuroHPC, gradually introduced starting July 2024, with fully functional hydrological workflow expected in Oct. 2024

DE_330-MF / DE33013
Flooding and Agriculture

Co-developing the **on-demand extremes DT Floods** application

Hydrology – Extreme floods

Motivation

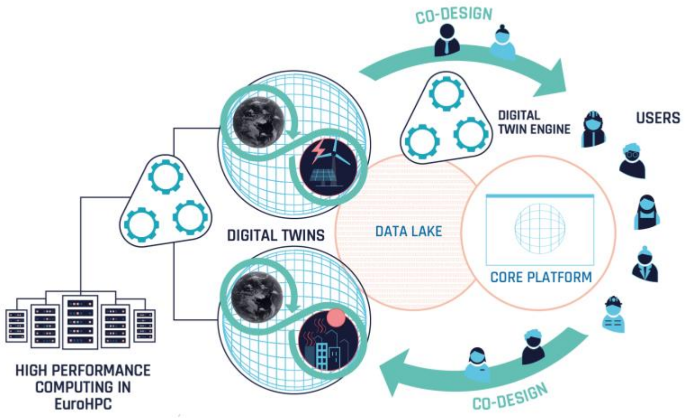
– Facilitate societal preparedness and enhance capacity to prepare for extreme floods

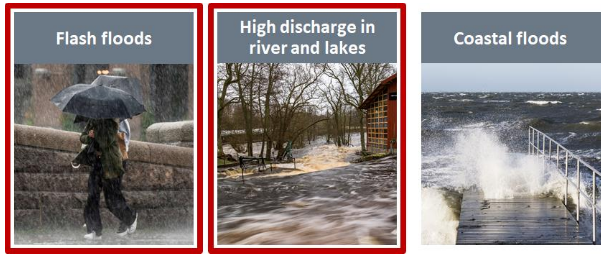
Objectives

– Co-develop on-demand extremes DT *pilot service* for prediction of floods
  - **Create** (pre-)operational workflows**,** with focus on triggering/activation routines (phase 2)
  - **Generate** decision-ready outputs, considering initial visualization needs (phase 2)
– Co-define and demonstrate added value of *pilot service*, within existing services
  - **Feed sub-km scale NWP DT data** into diversity of locally-driven operational hydrological prediction systems to configure/pilot on-demand extremes DT Floods application
  - **Evaluate** near-real time pilot events

Work with USERS (direct; indirect)

– Operational flood forecasters (hydrologists); hydrologists with interest in hectometric NWP data
– Local/regional authorities; emergency services; …

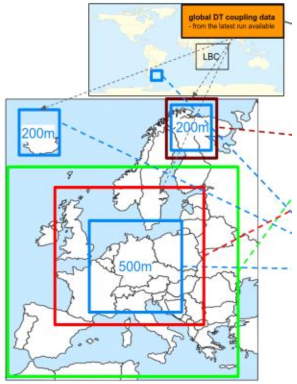





Storm Boris, Sept. 2024

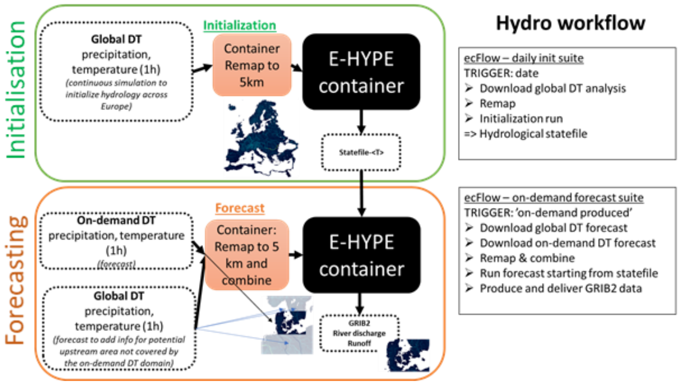
SMHI INRAE Danmarks Meteorologiske Institut FMI Met Éireann SHMU Icelandic Met Office CHMI

2 development paths adopted



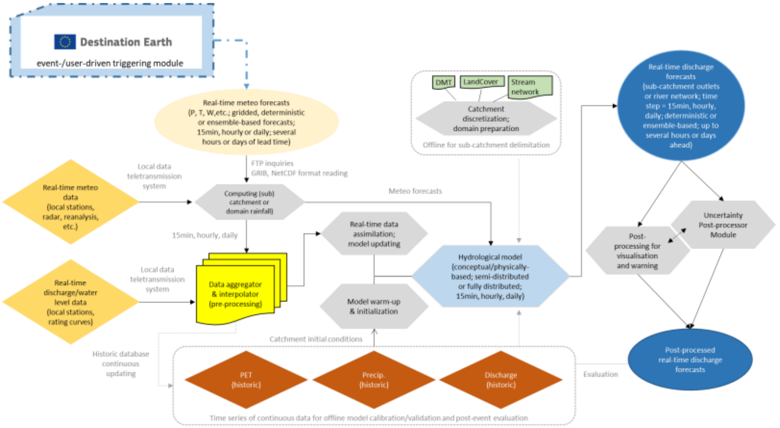
On-demand hectometric NWP data

Path 1: Generate integrated NWP-hydrological model workflow



E-HYPE domain (5k EFAS grid)

Path 2: Prepare national hydrological model workflows for coupling to DT data



Path 1: SMHI

– **Phase 1:**

- ➢ **Incorporate** pan-European hydrological (E-HYPE) model within DT Extremes workspace
- ➢ Why E-HYPE?
  - Enable hydrological forecasts across Europe
  - Explore potential to enrich the DT workflow internally

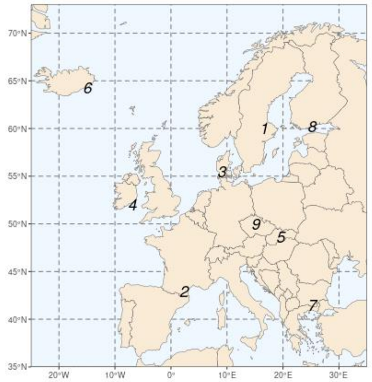
Path 2: 9 EU partners working with flood forecasting

– **Phase 1:**

- ➢ **Establish** technical hydrological model workflows for ingesting DT data
- ➢ **Conduct** sensitivity/uncertainty analyses
- ➢ **Co-design** actionable response workflows with downstream users of flood forecasting data

Phase 1: Reconstructed historical extreme flood events

➢ Evaluate added value of DT data



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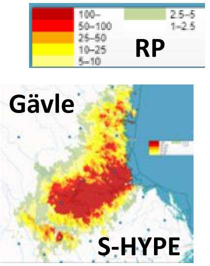
Benchmarking: Phase 1

- Some initial indications of improvements in flood forecasts, capturing precipitation fields exhibiting strong spatial variabilities in intensities and amounts
  - Notably for floods originating from convective precipitation events, in flashier catchments (rapid response)
- Identification of misalignments in DT forecasts can help further evolve the pilot service
  - Misplacement of highest intensity rainfall;
  - Timing displacement;
  - Under/overestimation of precipitation amounts
- Only one historical event analyzed per partner!
  - Many events already well-constrained/characterized by local flood forecasting services
  - May give indication which types of extreme events would give most added value to existing services



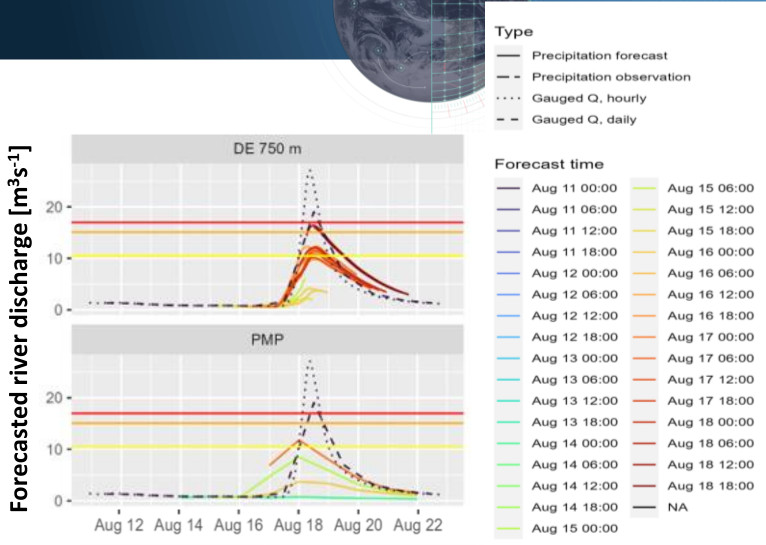
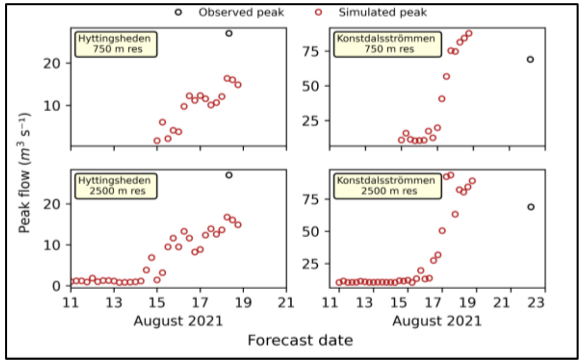


Fig. credit: R. Capell



DT forecast analysis: peak magnitude (Q_{riv}) based on forecast day for Gävle, Sweden extreme flood event. Fig. credit: Y. Hundecha

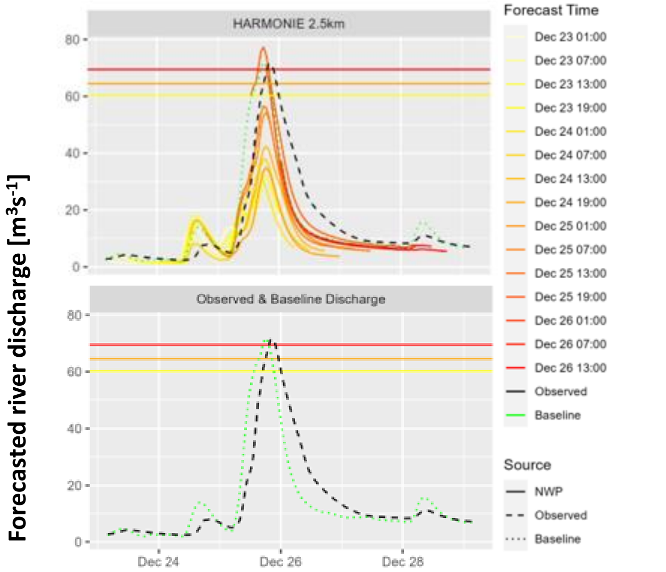
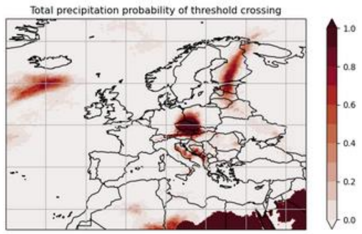


Fig. credit: C. Broderick, Met Éireann

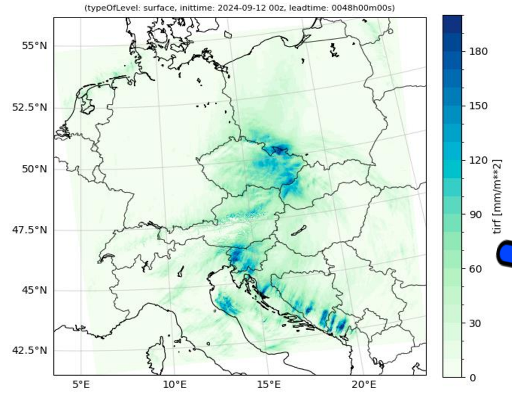
Phase 2: Evolving the *pilot service*



Figures: X. Yang, DMI

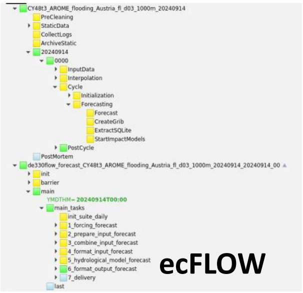
Detection

Time integral of rain at the surface

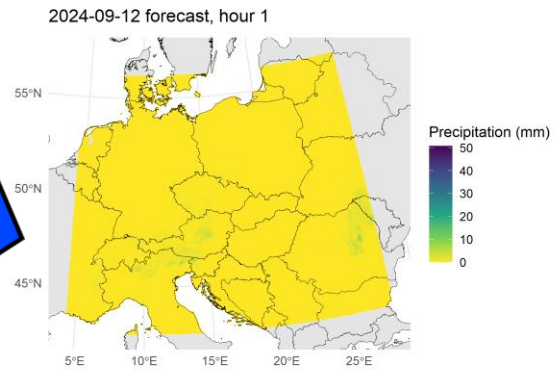


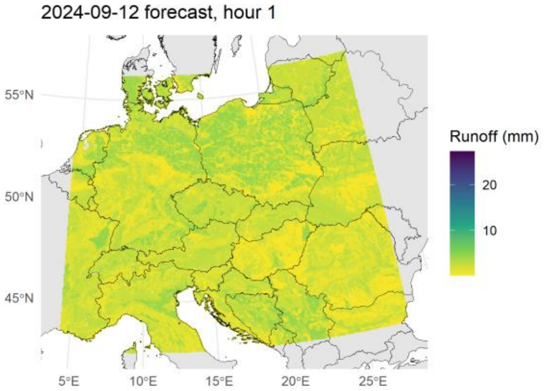
E-HYPE domain + river basins (5km EFAS grid)

Triggering



Total precipitation: E-HYPEgrid sub-domain





Total local surface runoff

Animation: R. Capell

Hydrological impact analysis

Path 1: Internal DT workflow coupling

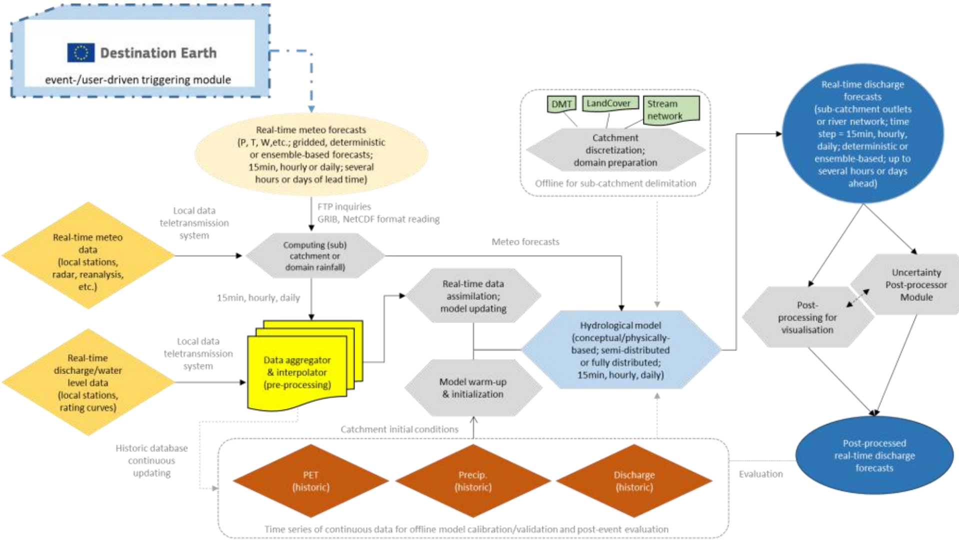
– **Phase 2:**

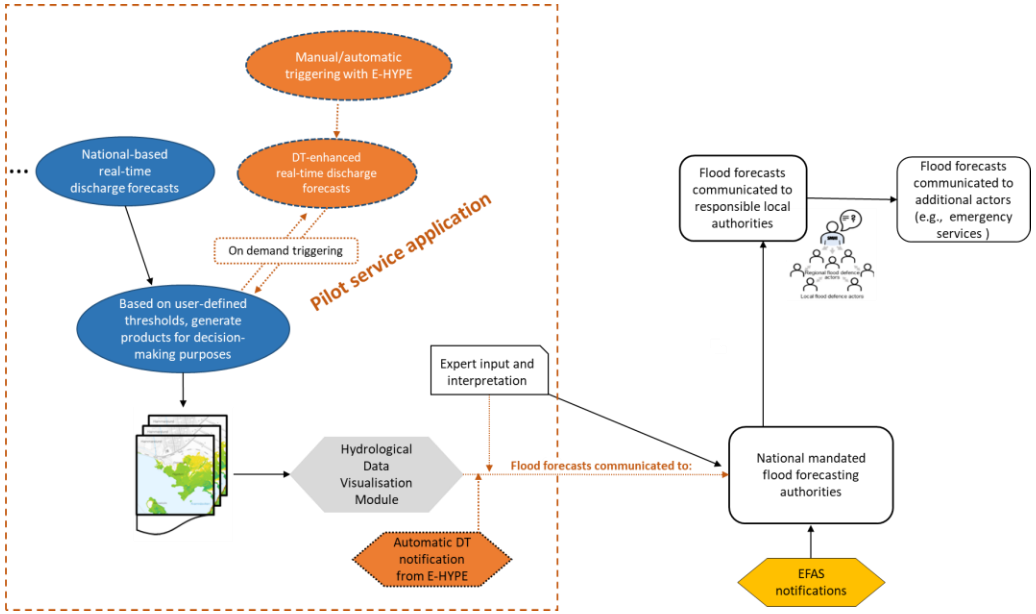
- **Develop** fully automatic end-to-end DT Extremes workflow (detection to impact modeling)
  - Utilizing Storm Boris to finalize workflow
  - **Ready to work with potential users** of E-HYPE data on e.g. outputs, visualization needs, etc.
    - Compare to select observation data – request pending
- **Add** probabilistic initializations to E-HYPE workflow
- **Evaluate** added value of probabilistic NWP 6-member forecast ensemble (750 m)

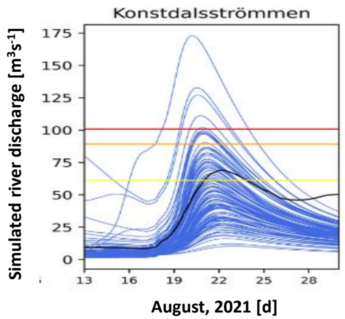
Storm Boris, Sept. 2024

Photo credit: BBC

Phase 2: Evolving the *pilot service*





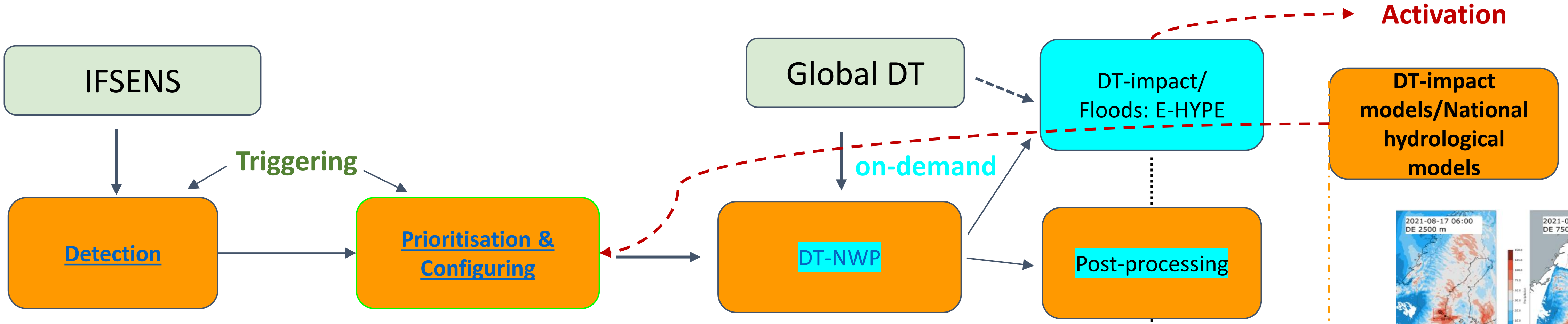


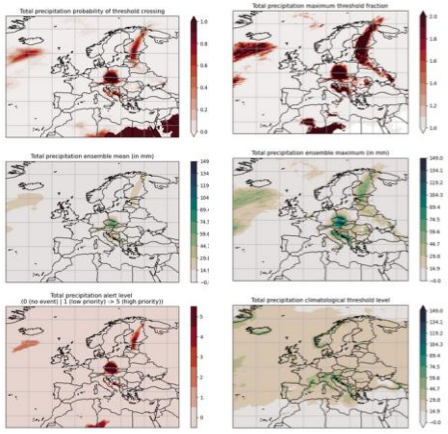
Path 2: External workflow coupling

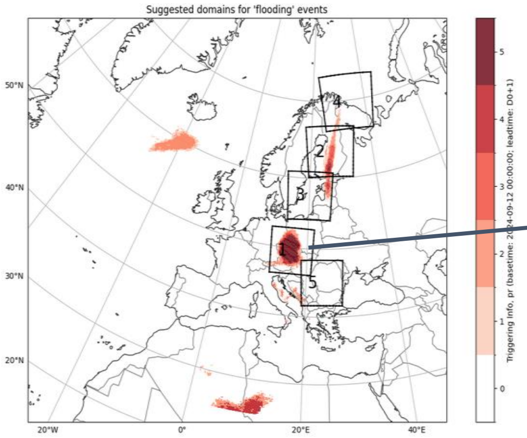
– **Phase 2:**

- **Co-develop** technical end-to-end workflows
  - **Progress** *service* towards (pre-)operational-level readiness state
- **Generate** initial condition hydrological ensembles
- **Evaluate** DT’s ability to improve placement of short-lived (4-6 hr) events
  - **Simulate** near-real time event
- **Consider** visualization of decision-ready information, including uncertainty
- **Explore & promote** usefulness and added value of DT forecasts
- **Envision** a *pilot service,* together with & supporting various user groups of flood forecasting data

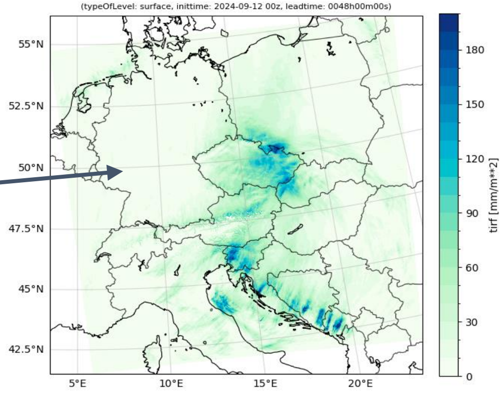
Co-create NWP-HYD workflow: internal/external coupling

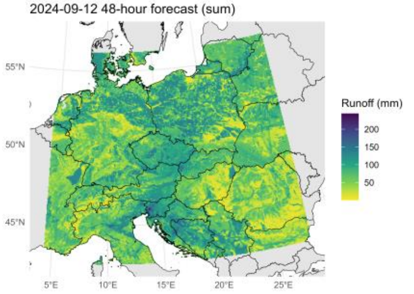


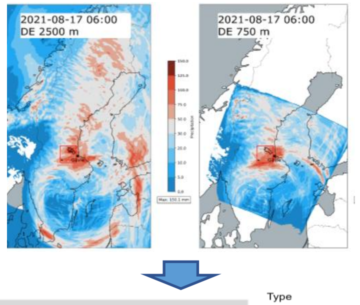


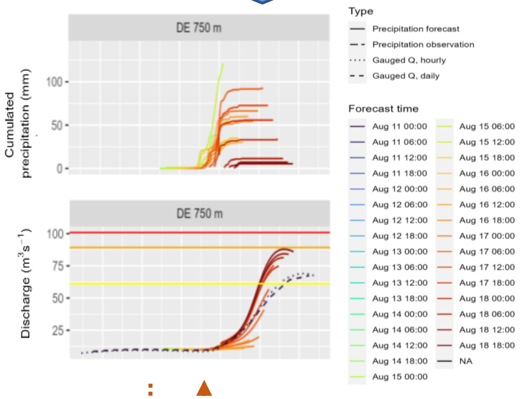


Figures: X. Yang, DMI









Figures: R. Capell

Requires Interactions with Users!

Outlook

- **Phase 2**
  - **Explore** uncertainty quantification, perturbing of initial state in hydrological model (→ long memory)
  - NWP high-resolution ensemble processing (?) → evaluate added value

- **Next phase(s)**
  - **Evolve/co-design** service with existing and new user groups
  - **Explore** further where value can be added
    - **Improve** existing hydrological forecast services
    - **Unlock** new niche/application potential, not currently well covered

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Thank you!

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