DESTINATION EARTH

On-demand Extremes Digital Twin: Progress

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and
Extremes DT Team (see next slide)

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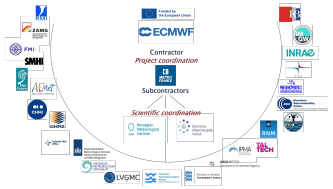
Outline

- A glans at technical and scientific progress
- Daily test runs with special focus on the products
  - Event-driven test cases
  - User-driven test cases
- Conclusions and next step

On-Demand DT



IFSENS

Global DT

Triggering

on-duty team

On-demand

Detection

Configuration

DT-Weather

DT-impact

Post-processing

ECMWF-atos

EuroHPC

FDB

Data Bridge

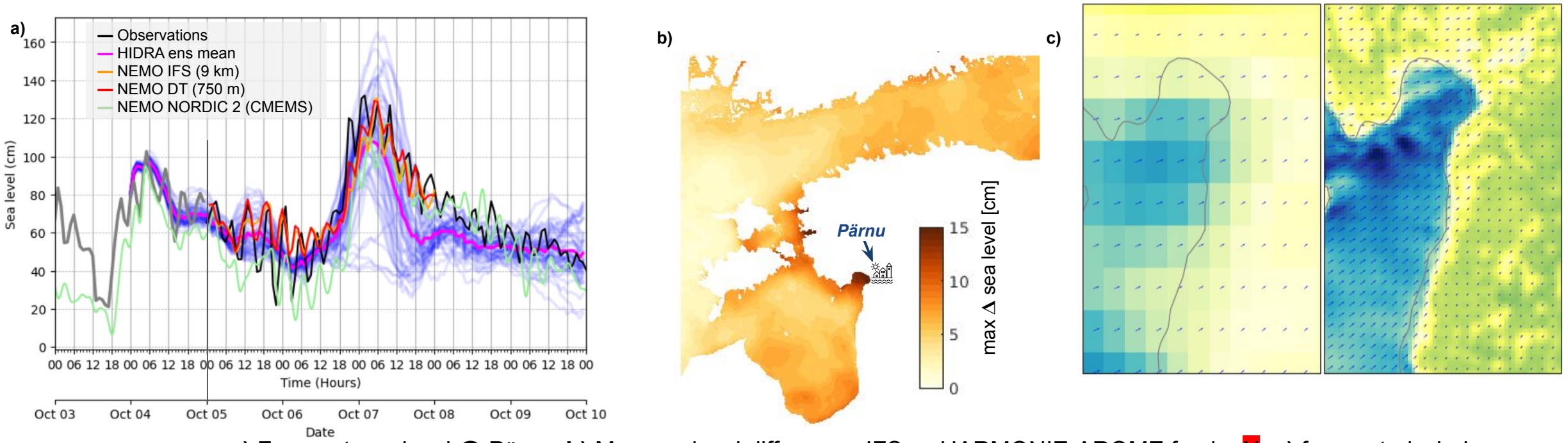
DEDL, DESP

User Interaction

A glans at technical and scientific progress (1)

Detection schemes (EDF), & Triggering (DTF):

- **OPTI-THRED**(precip., CAPE, MUCAPE, Wind gust, Wind10m, Wind100m, Tmin, Tmax) :
  - The code is now reorganised to also process impact-applications-related information
    - Wind ramping, frost, or UTCI (thermal comfort)
- **HIDRA2** (Observation & ECMWF ensemble):
  - Retrained ⇒ detection and prediction of sea level height (Adriatic Sea) and with fixed domain On-demand (HARMONIE-AROME + NEMO_EST05) for Baltic Sea pilot area.

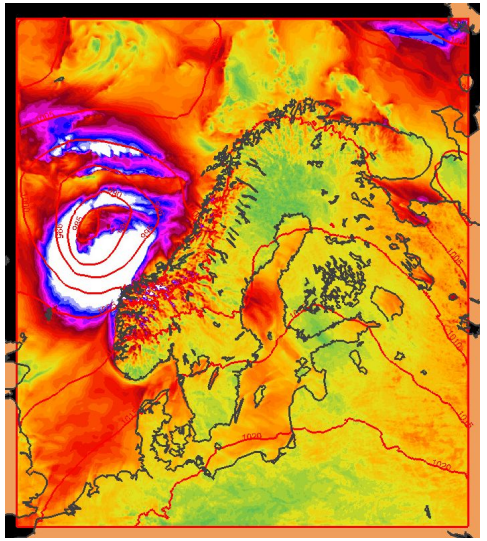


a) Forecast sea level @ Pärnu; **b)** Max sea level difference: IFS vs HARMONIE-AROME forcingN; **c)** forecasted wind

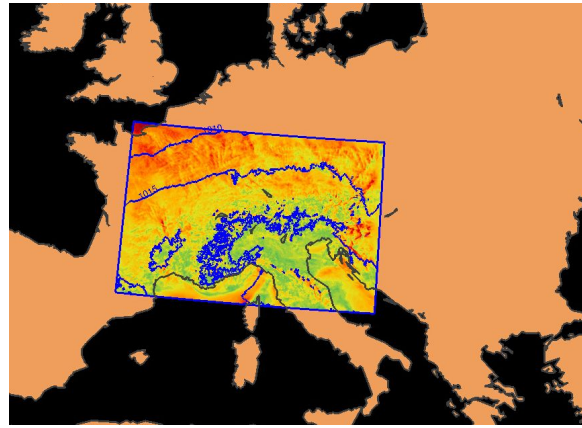
A glans at technical and scientific progress(2)

DT-Weather:

- **Daily operation piloted across Europe: a 18-staff team operation with weekly rotation**
  - Operational on ATOS; Preparation with CY49t2
  - CI/CD produced binaries on ECMWF-ATOS and partly in EuroHPC-LUMI
- **ACCORD system on EuroHPC (LUMI and LEONARDO)**
  - LUMI: Fighting with compiler(s) and versions. Experimenting with ALARO-CY48t3 for daily operation and tests with CY49t2 for all CSCs
  - LEONARDO: Preparation of CY49t2 for all CSC;
  - ACCORD forecast model refactored to run on GPU
- **Pre-operational CY49t2 on ATOS, LUMI and LEONARDO**
  - Single executable with multi-layer, 3 patch SURFEX and ECCOCLIMAP SG for all the 3 CSCs
- **FDB** (Field DataBase):
  - Full data flow communicated via GRIB2-FDB; In preparation for both ECMWF-ATOS and LUMI (in preparation)
- **Verification/Validation**:
  - Real time collection of observation and NRT point verification for operational DTs
- **Coming new components**:
  - Post-processing BQN (precip) and offline SURFEX to be added soon
- **Physical-based EPS model**:
  - Technical testing/development ongoing; incorporated into the Deode-Workflow
  - Ambition to explore NRT runs for selected cases around summer 2025
- **Data-driven models**:
  - Technical testing/development (including creation of ensemble) ongoing; considering to plug into the workflow



data-driven Bris over MetCoOp

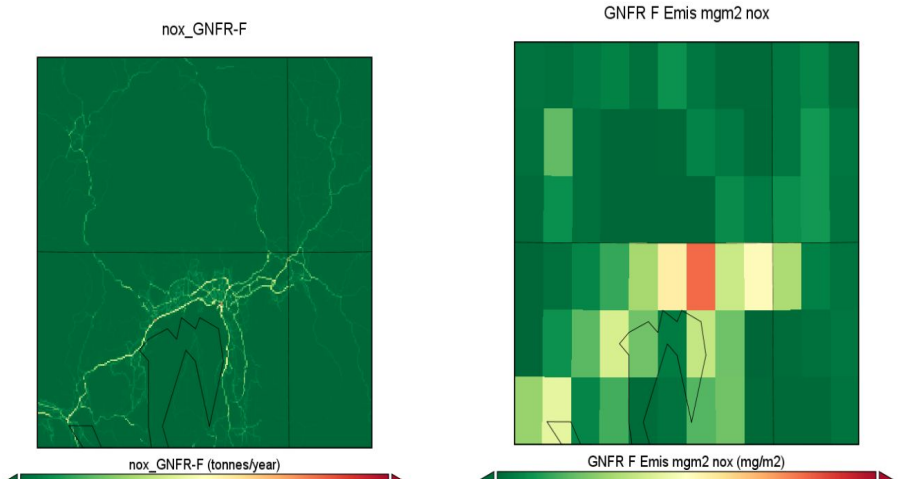


data-driven Bris over Switzerland

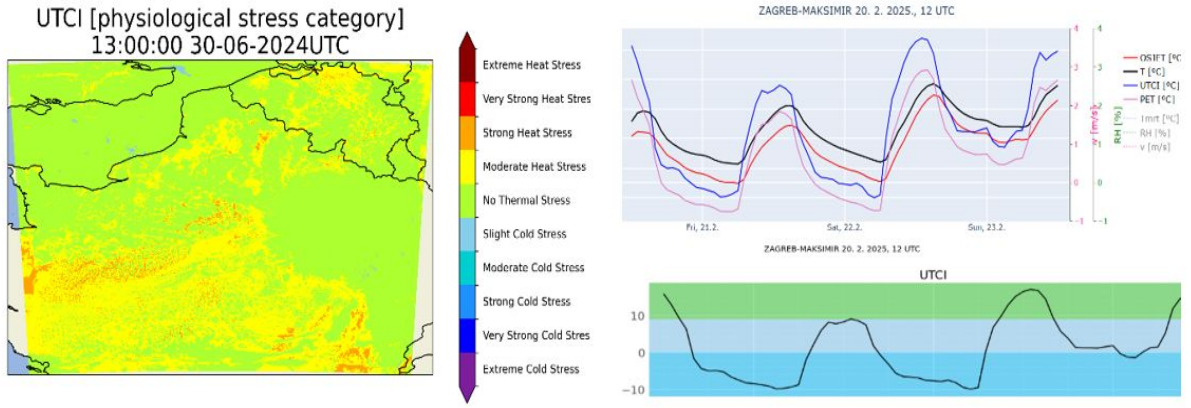
A glans at technical and scientific progress(3)

DT-Impact (effort to make the detection scheme also accounting for impact-based information**)**:

- **Air quality**:
  - 6 (Phase 1); + 1 = 7 (Phase 2)
  - Plugging into Deode-Workflow
  - Started on LUMI (all tested), in development for incorporation into Deode-Workflow
- **Renewable energy**:
  - **Wind**:
    - Getting as many as possible of ***metadata*** to have better wind farm parameterization (WFP) across Europe; WFP works with all 3 CSCs in CY49
  - **Solar**:
    - 2 nowcasting models ⇒ Discussion about getting these into daily runs ongoing
    - Post-processing algorithms
- **WildFire**:
  - Plugging into the workflow ongoing. Reorganisation of the code is needed
- **Thermal comfort**:
  - Plugging into the workflow ongoing.
- **Frost:**
  - Plugging into the workflow ongoing.

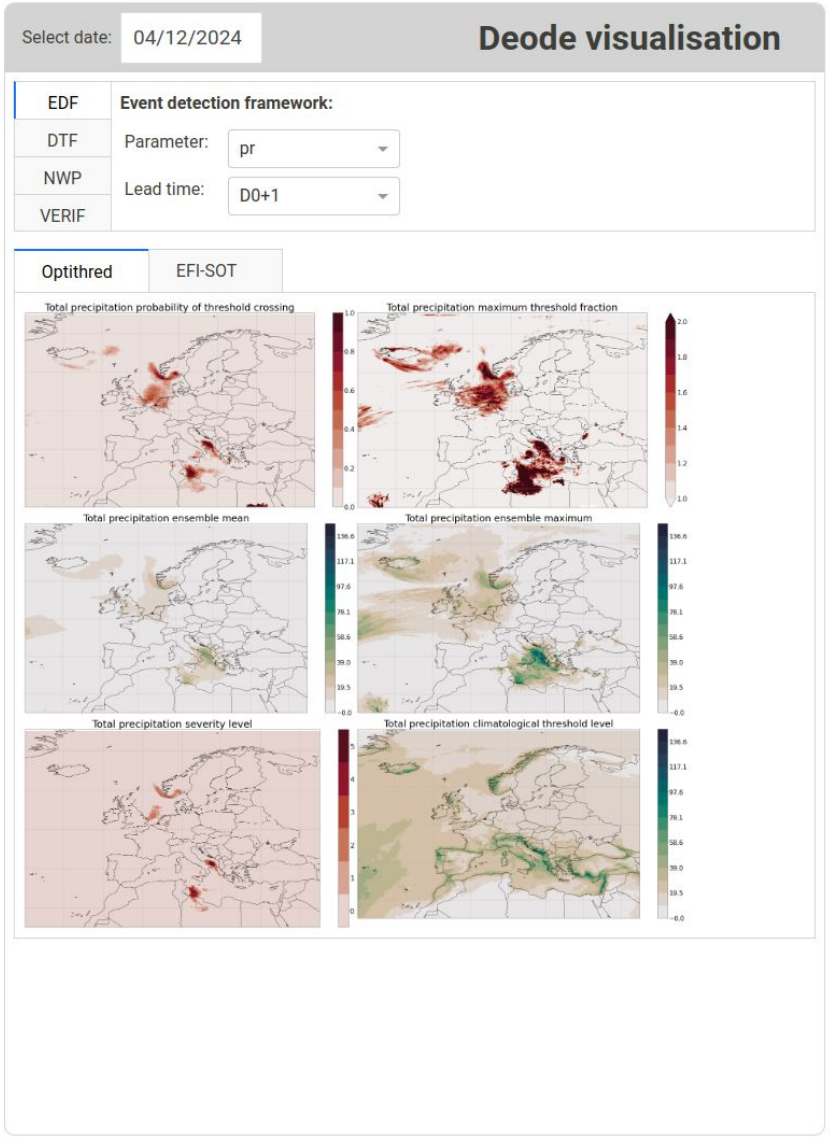


Air quality product at 750m (left) and CAMS (right) product over Oslo

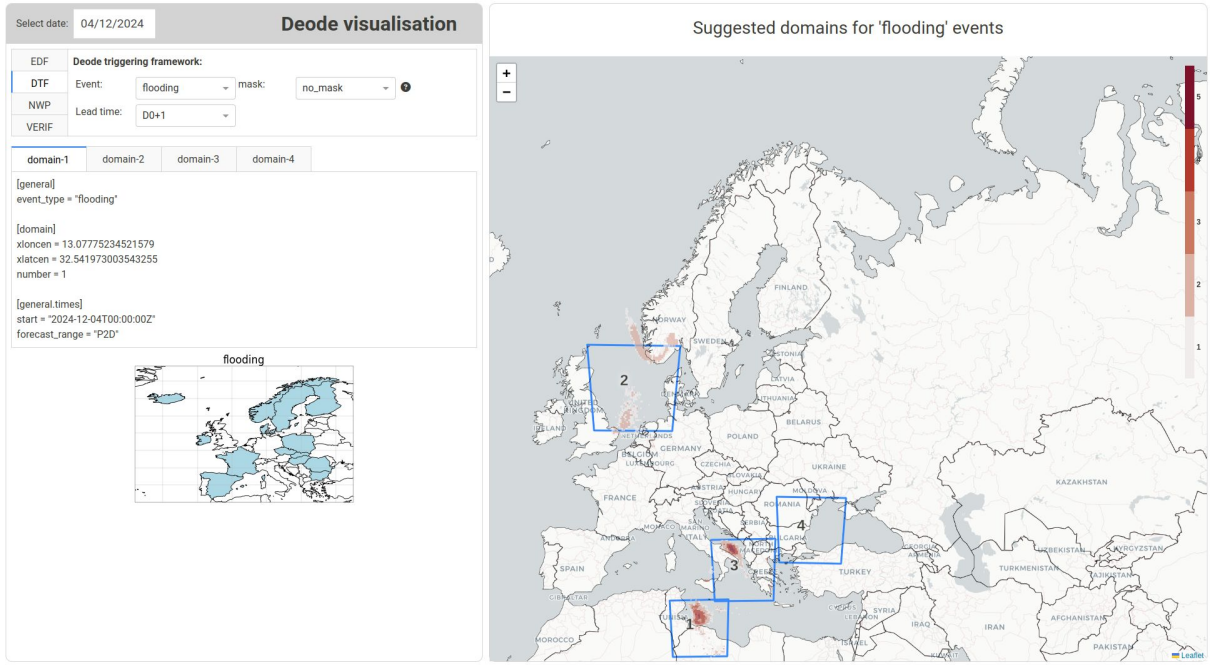


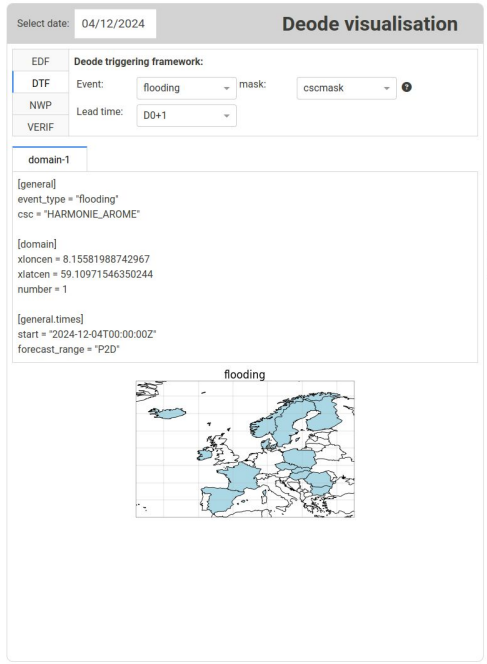
UTCI forecast over France (left) and forecast over location in Croatia (right)

The Event Detection Framework



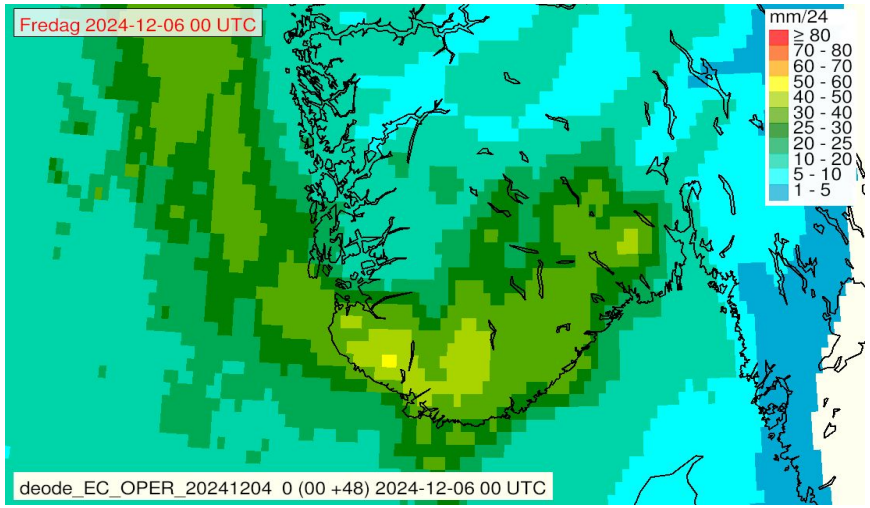
The Deode Triggering Framework to configure On-demand DT

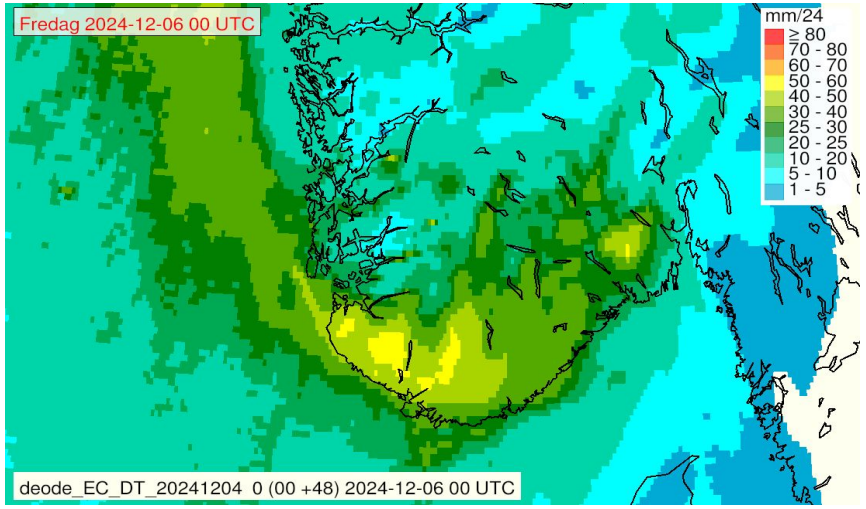


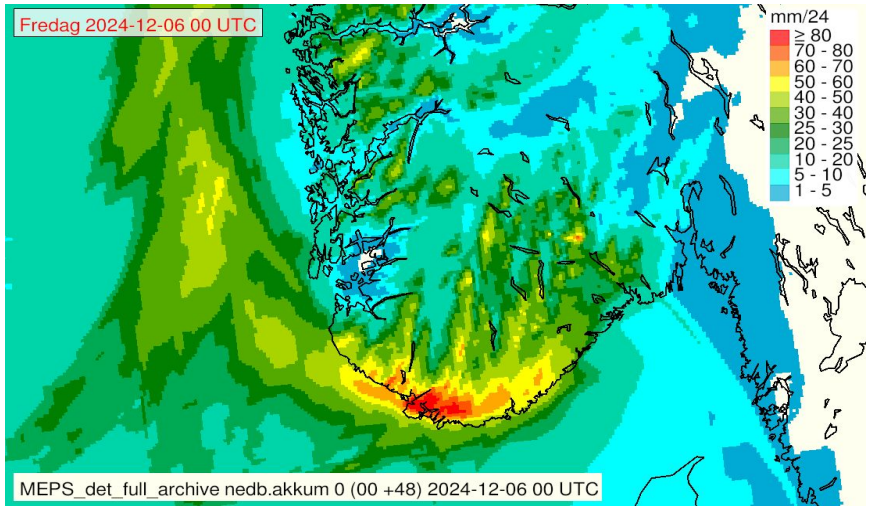


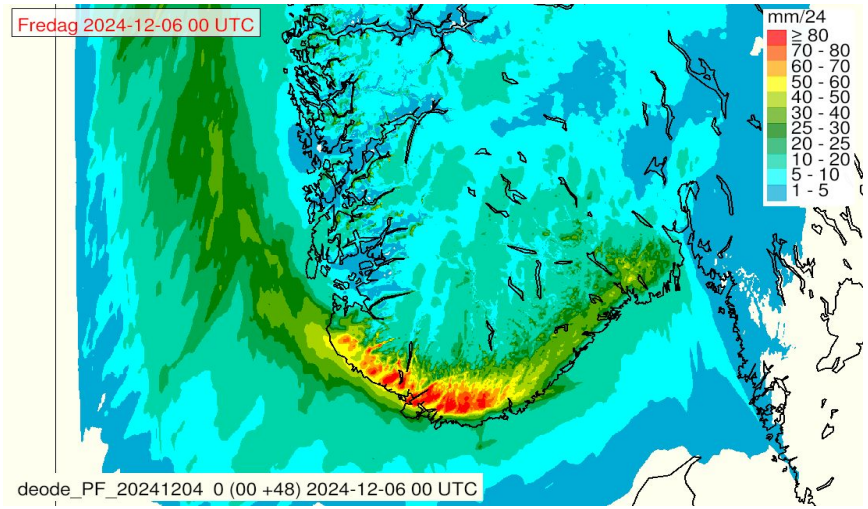
Daily decision about on-demand DT configuration also take into account NWS warning on extreme events; news report (wild fire...)

Precipitation case: from 4 Dec. 2024, 00 UTC; displayed day-2 forecast









We are providing additional information to national services and agencies

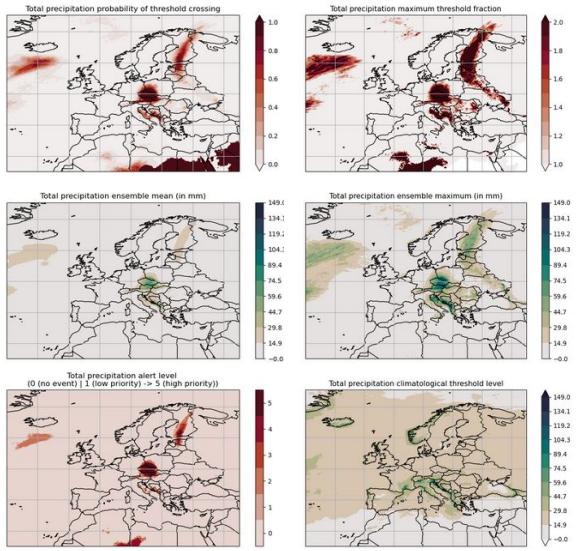
On-Demand DT is now piloted daily over Europe

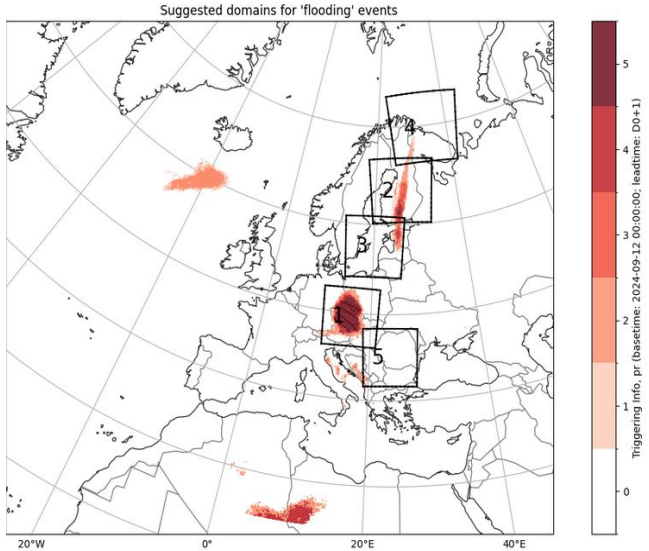
Detection

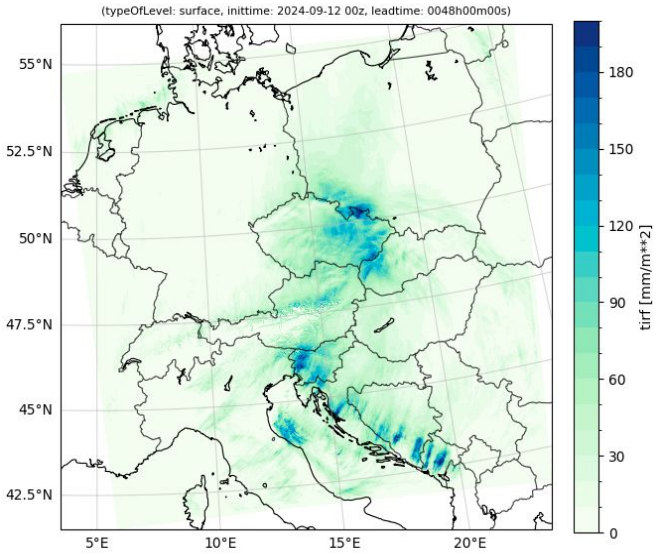
Configuration

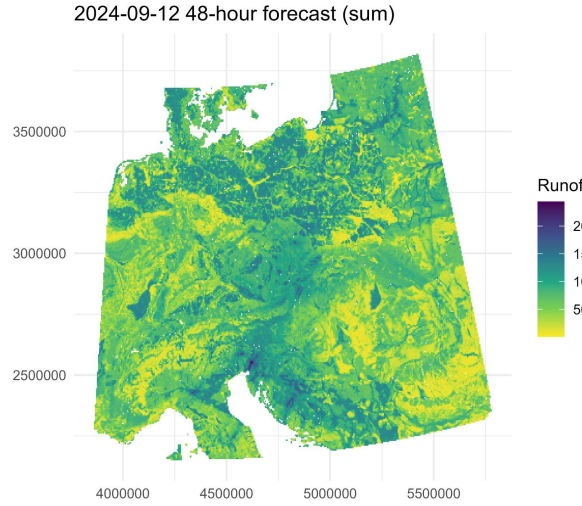
DT-NWP

DT-Impact





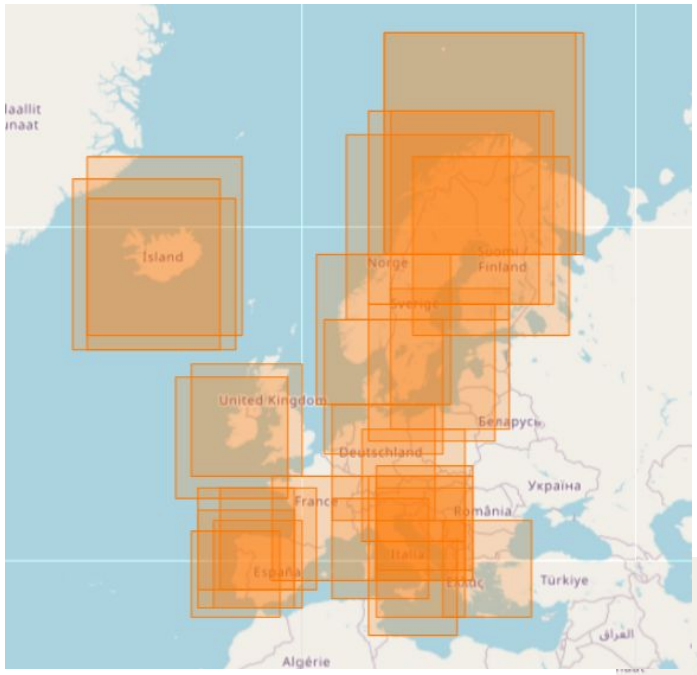




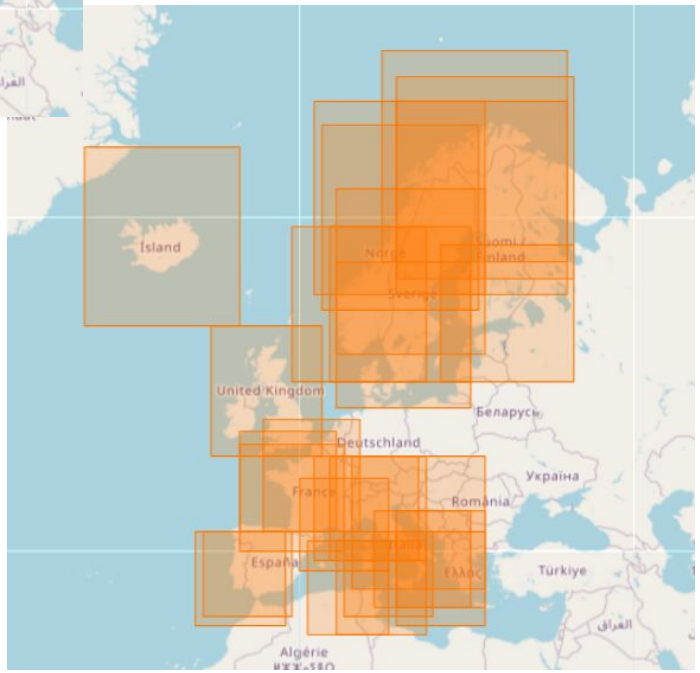
Boris episode. start time on 12 Sept 2024 with 48h forecast

Daily operation: a pan-European coverage with focus on pilot regions

Center points of the event-driven, configurable suites during Oct 2024 -- Feb 2025, typically with 750x750 km domains and 500 m grid-size.



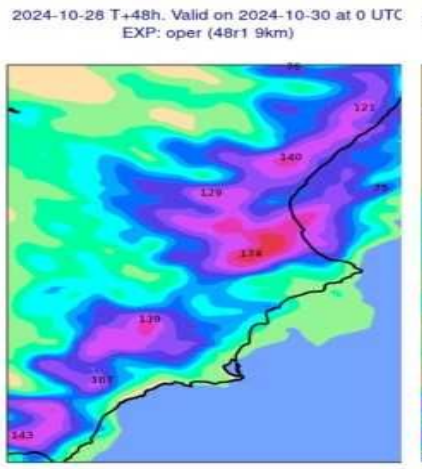
high wind events in Jan/Feb 2025



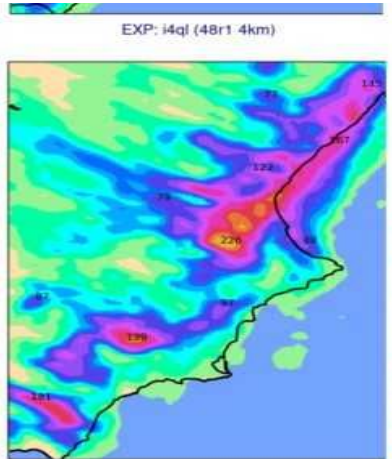
high precip events in Jan/Feb 2025

Capability and added values for major flooding events demonstrated

IFS 9 km

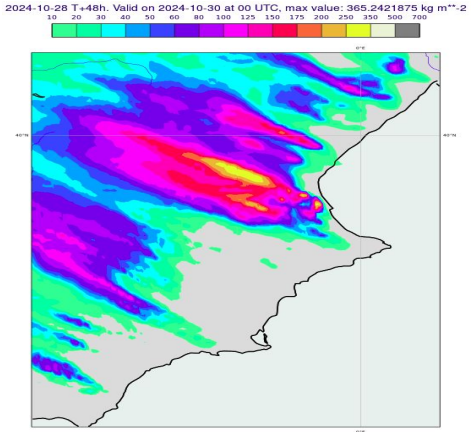


IFS 4.4 km

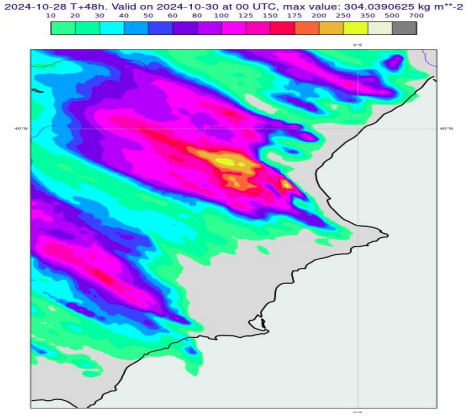


AROME 48T2

500m, max 365 mm

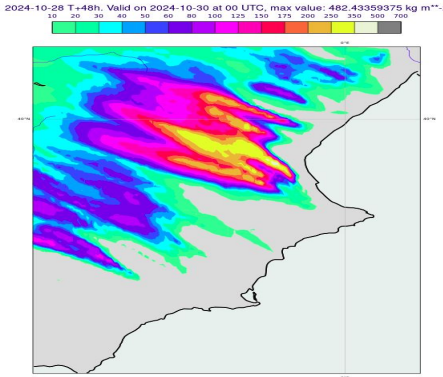


1000m, max 304 mm

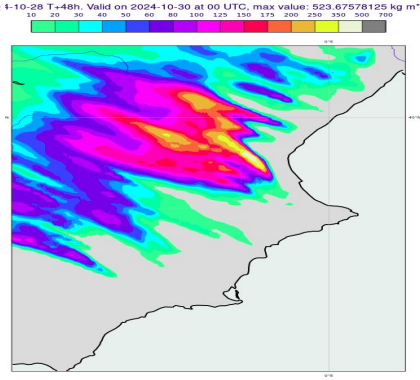


Harmonie AROME 46h1

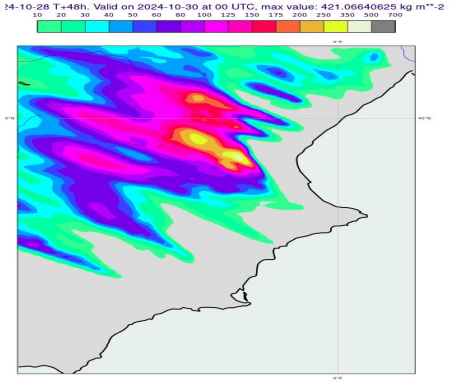
500m, max 482



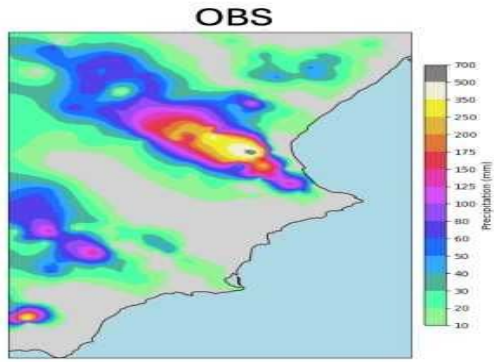
1000m, max 524



2500m, max 421

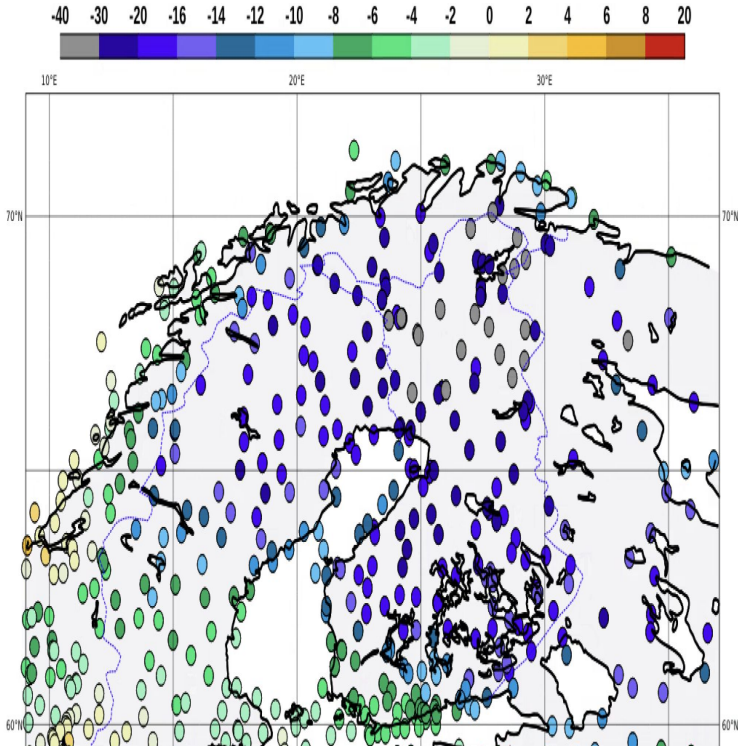


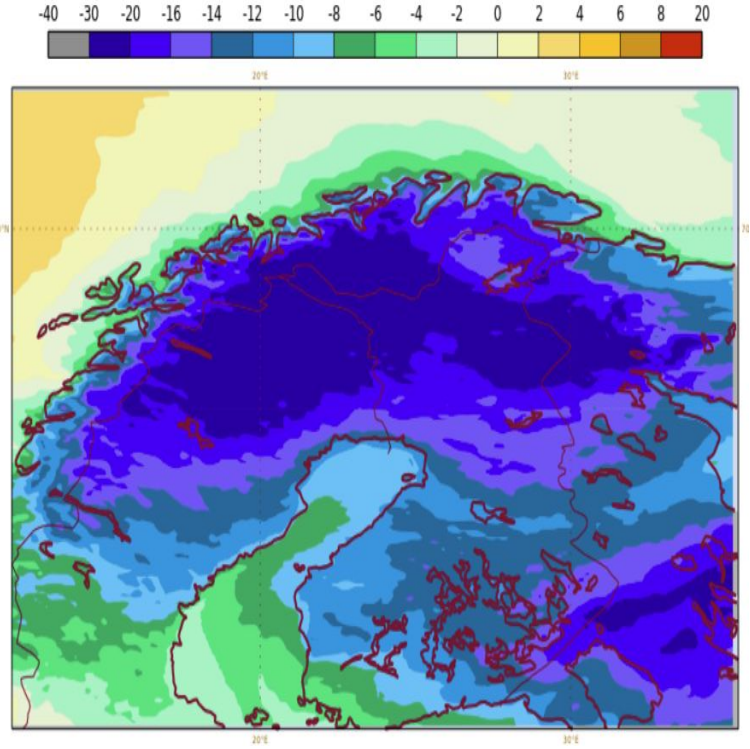
Valencia flooding, 29 Oct 2024

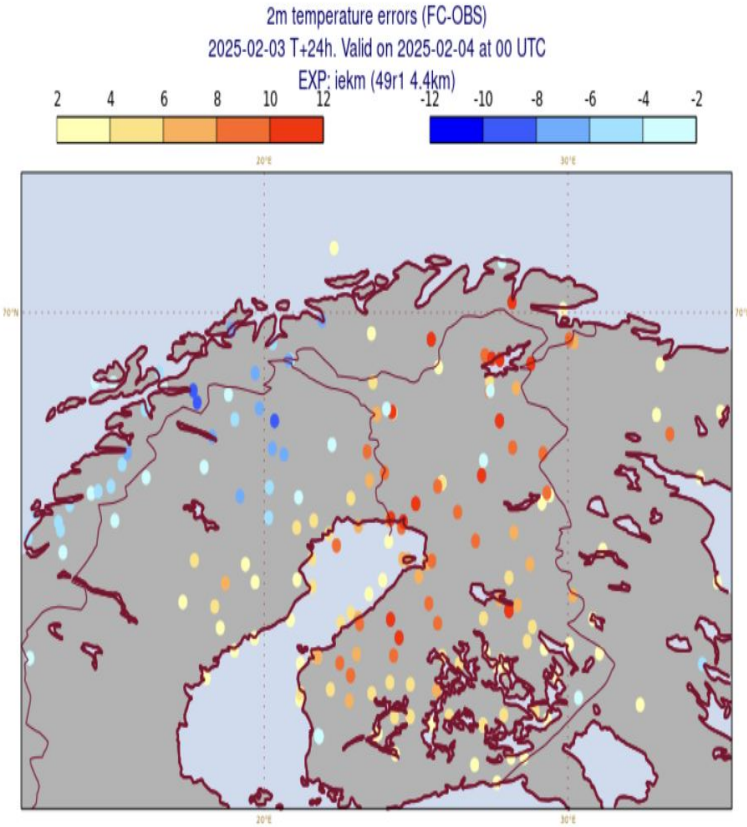


Research collaboration and system convergence in DEODE-fashion

➔ ECMWF global DT expert identified a challenging Nordic cold spell case 4 Feb. 2025





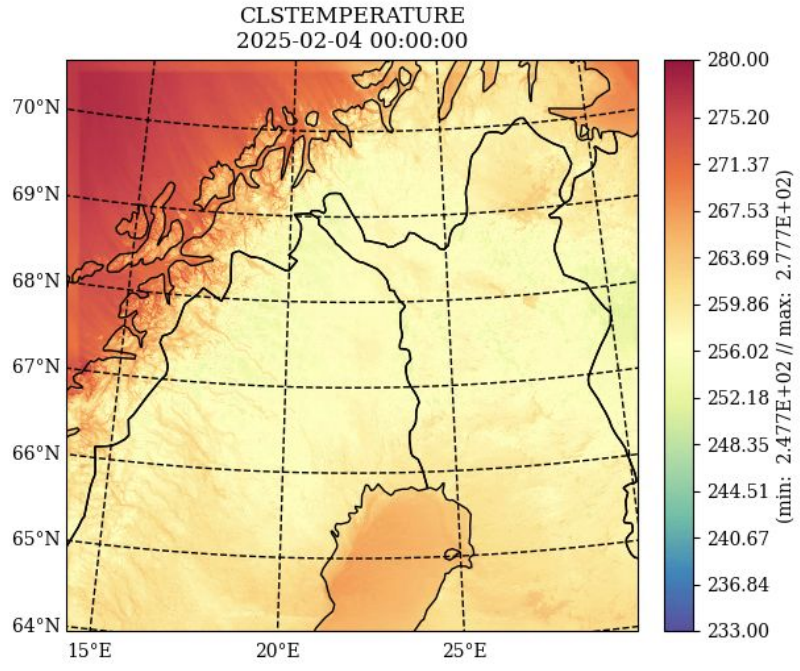


(Courtesy: Estibaliz Gascon)

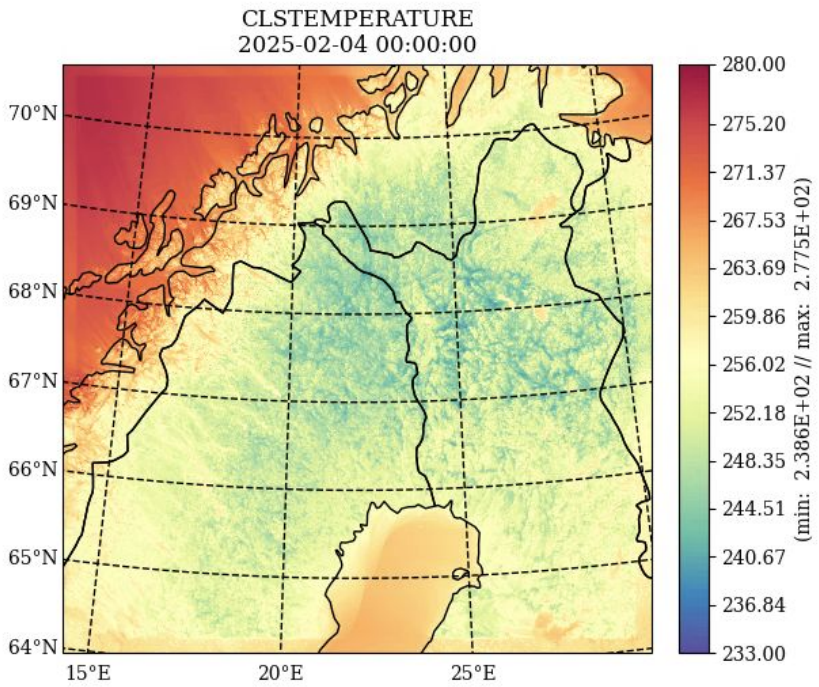
Research collaboration and system convergence in DEODE-fashion

- ECMWF global DT expert identified a challenging Nordic cold spell case (20250204)
- Operation group WP9 examined the case and identified strong sensitivity with different CSC configuration
  - WP9 (operation WP) shares the case in the WP10 meeting (development WP)

AROME



HARMONIE-AROME



(X Yang)

Research collaboration and system convergence in DEODE-fashion

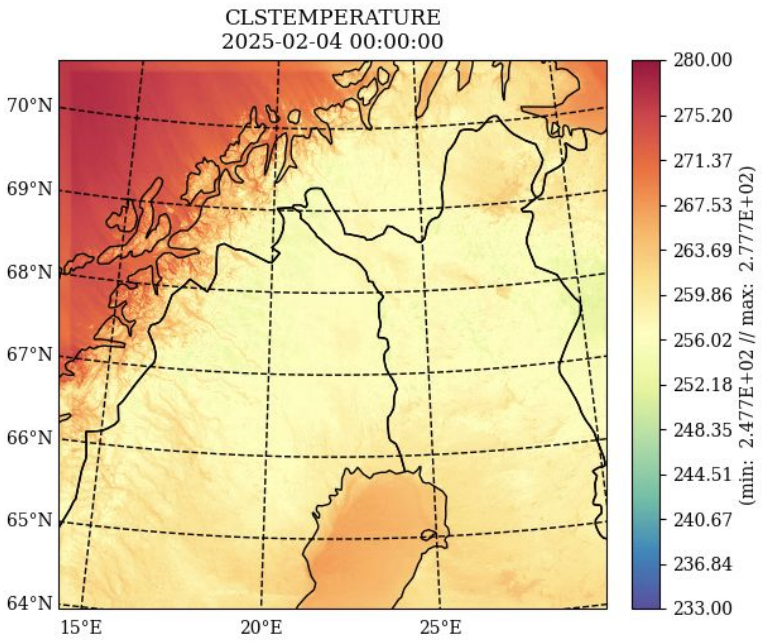
- ECMWF global DT expert identified a challenging Nordic cold spell case (20250204)
- Operation group WP9 examined the case and identified strong sensitivity with different CSC configuration
  - WP9 (operation WP) shares the case in the WP10 meeting (development WP)
- Development group WP10 perform experiments with configuration from WP9
  - Assumption: differences in the default SURFEX settings for different CSCs may be the main cause

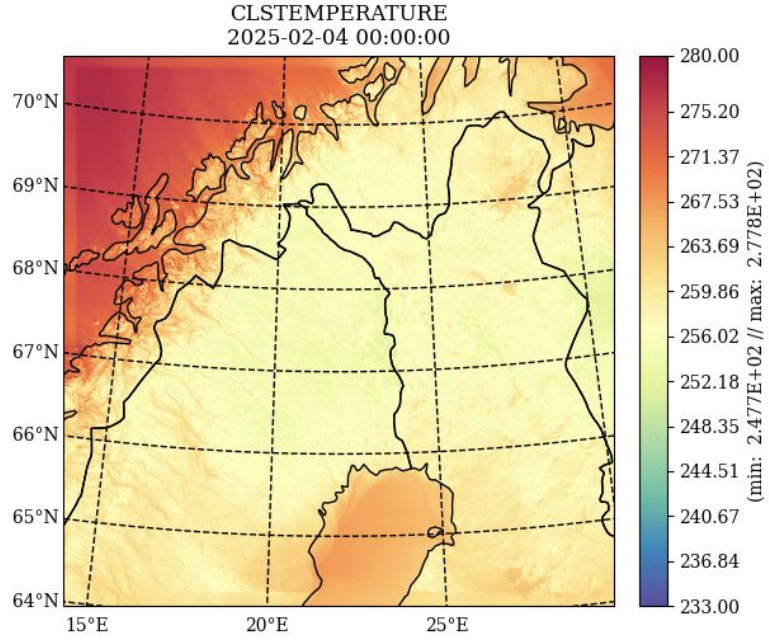
Checking different physics options

AROME atmosphere

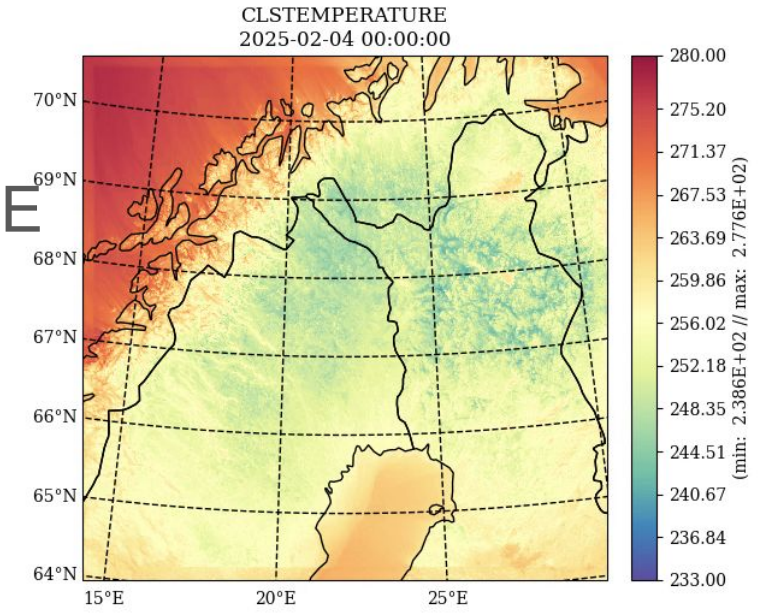
HARMONIE-AROME atmosphere

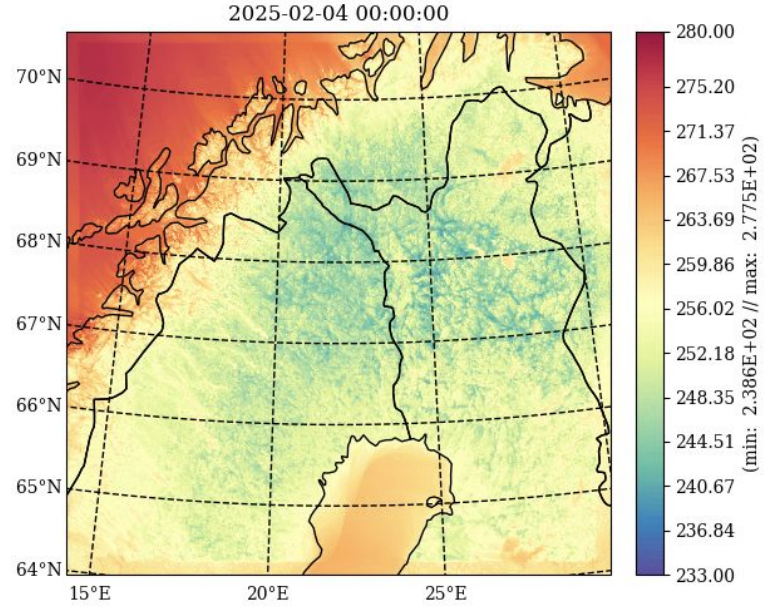
AROME surfex





HARM-AROME surfex





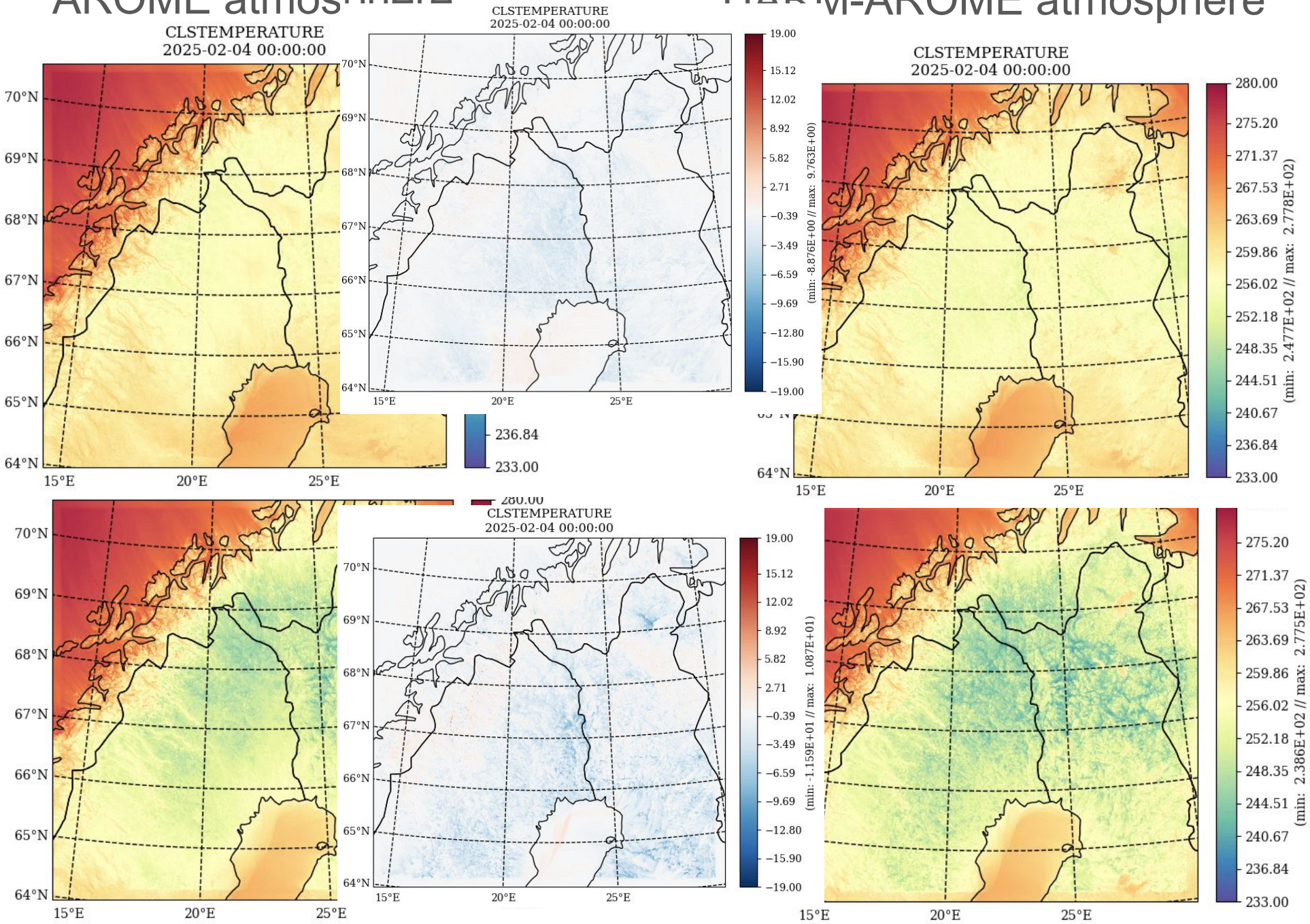
(N Theeuwes)

AROME atmosphere

HARM-AROME atmosphere

AROME surfex

HARM-AROME surfex



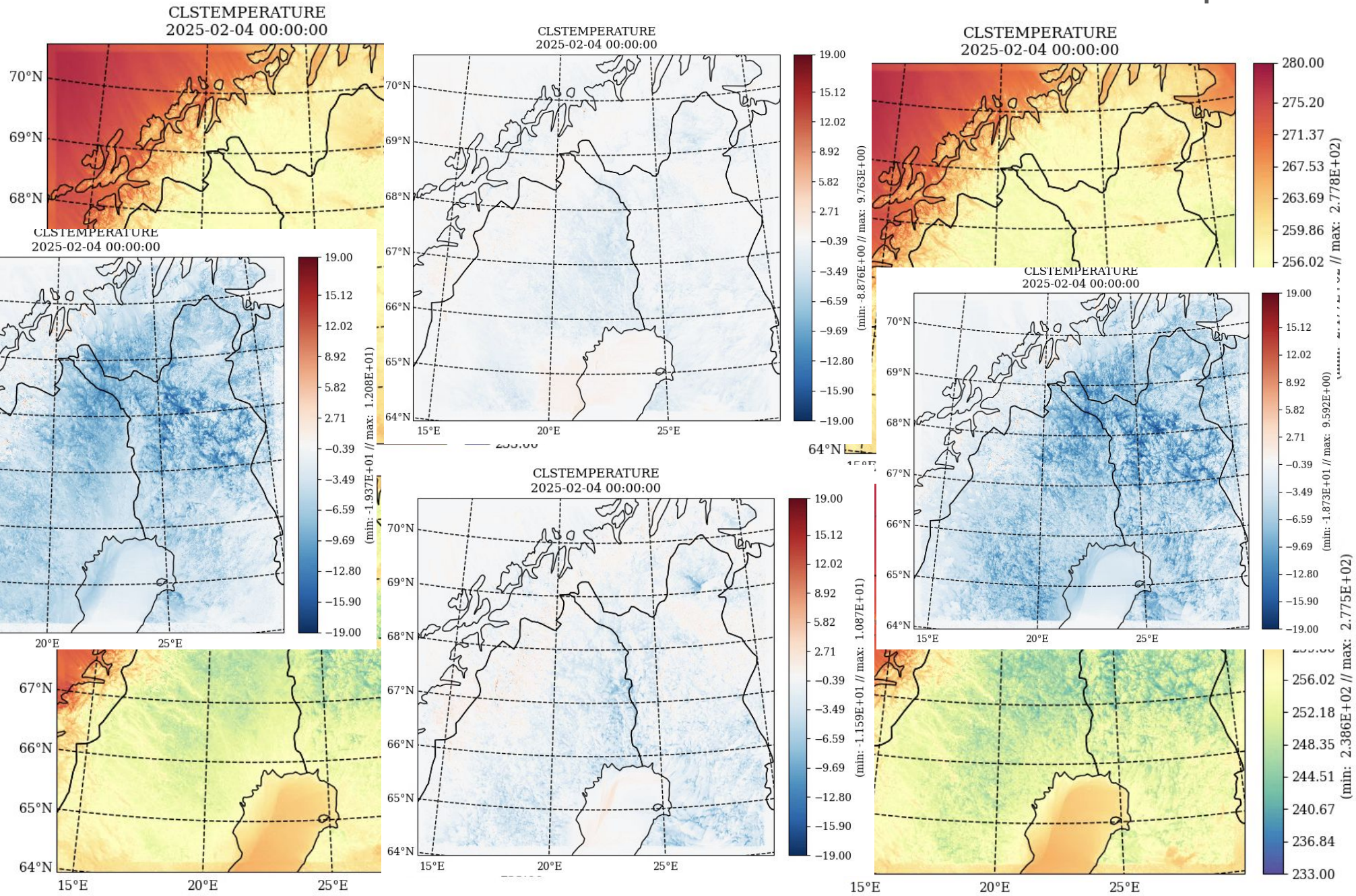
(N Theeuwes)

AROME atmosphere

HARM-AROME atmosphere

AROME surfex

HARM surfex



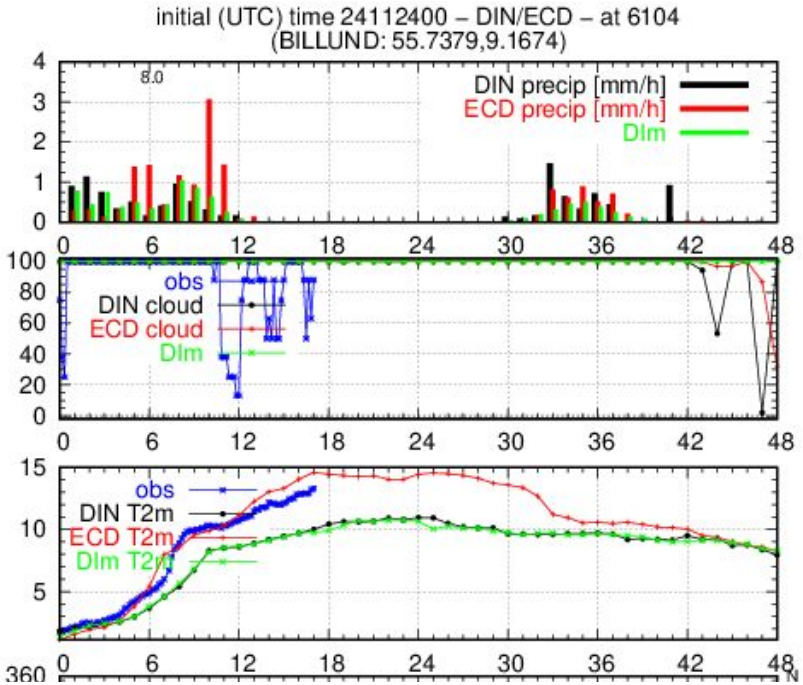
(N Theeuwes)

Research collaboration and system convergence in DEODE-fashion

- ECMWF global DT expert identified a challenging Nordic cold spell case (20250204)
- Operation group WP9 examined the case and identified strong sensitivity with different CSC configuration
  - WP9 (operation WP) shares the case in the WP10 meeting (development WP)
- Development group WP10 perform experiments with configuration from WP9
  - Assumption: differences in the default SURFEX settings for different CSCs may be the main cause
- Findings:
  - defaut SURFEX configuration in the present DEODE-CY49t2 results significant differences
  - it was further discovered (T. Aspelien): DEODE-arome namelist setting with XWSNOW=0.0 appears to be associated with lack of snow cover in larger part of the regions, hence difference of > 10 K

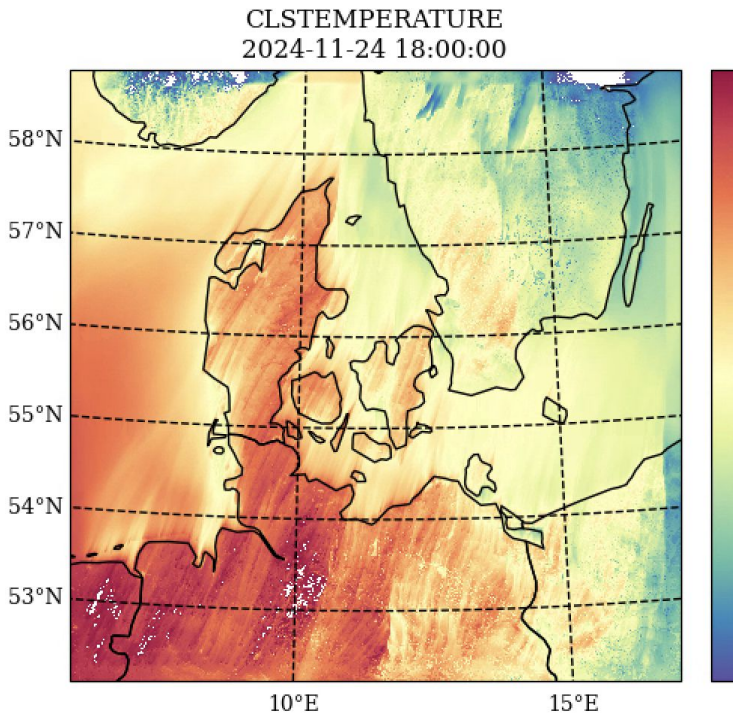
Research collaboration and system convergence in DEODE-fashion

➔ Operation group WP9 identified a rapid temperature rise case in connection with a warm front 24 Nov 2024,
- ◆ Strong sensitivity to CSC configurations

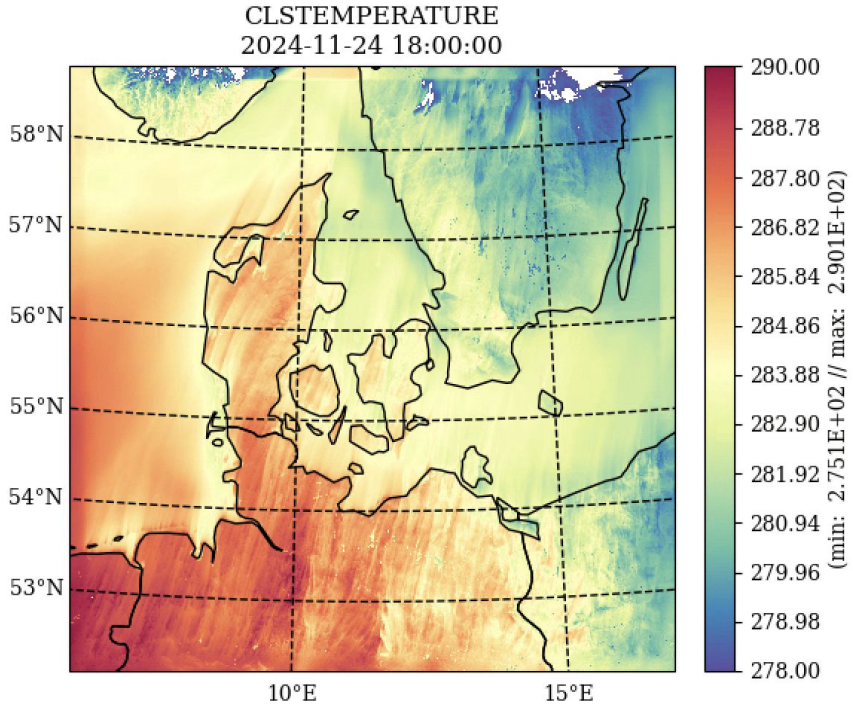


CY49t2
AROME
surfex

CY49t2, AROME



CY49t2, Harmonie-AROME



ECMWF (X Yang)

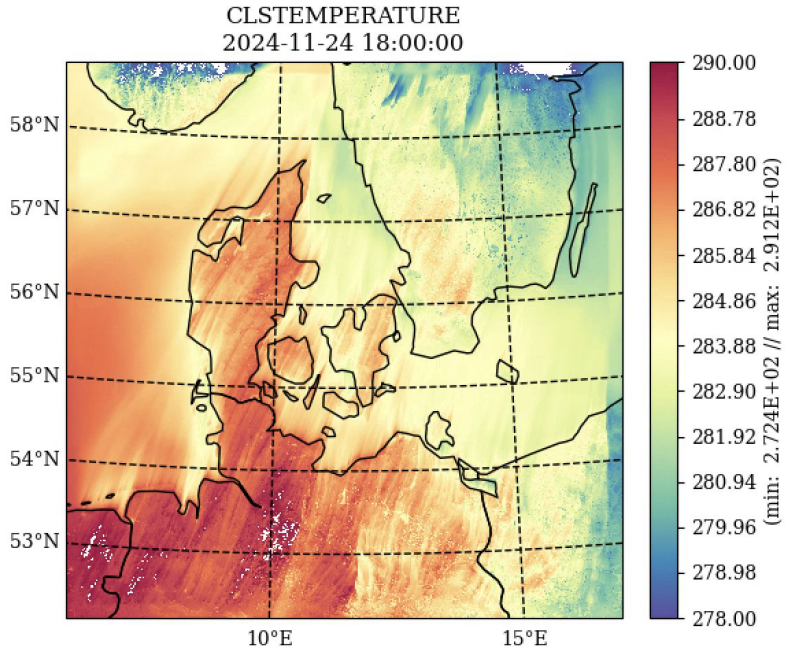
Research collaboration and system convergence in DEODE-fashion

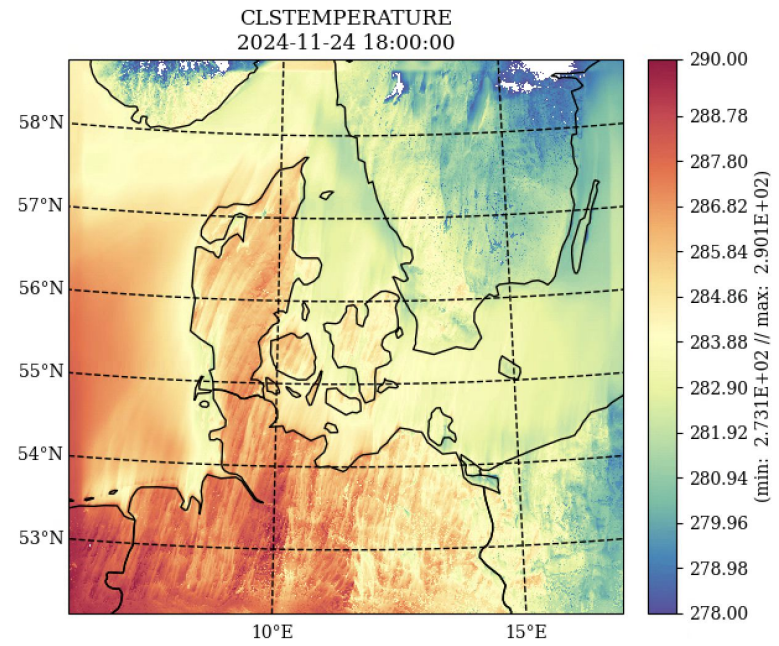
- ➔ Operation group WP9 identified a rapid temperature rise case in connection with a warm front 20241124
  - Strong sensitivity to CSC configurations
- ➔ Development group WP10 suggests to examine sensitivity to configurations about SURFEX and upper air physics

AROME atmosphere

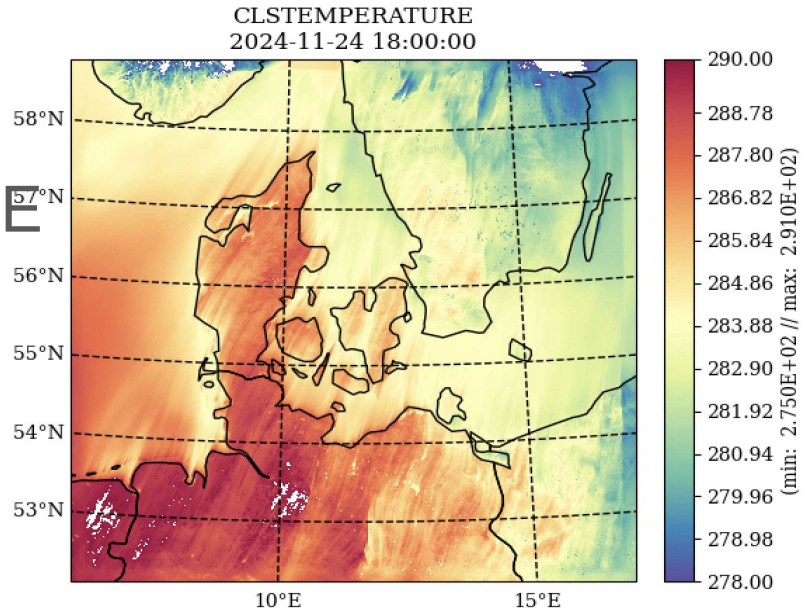
HARM-AROME atmosphere

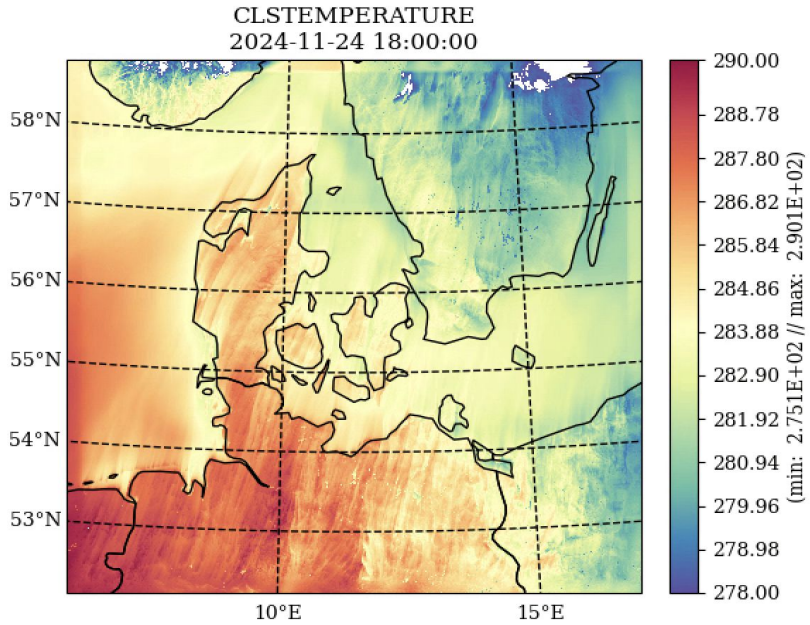
AROME surfex





HARM-AROME surfex





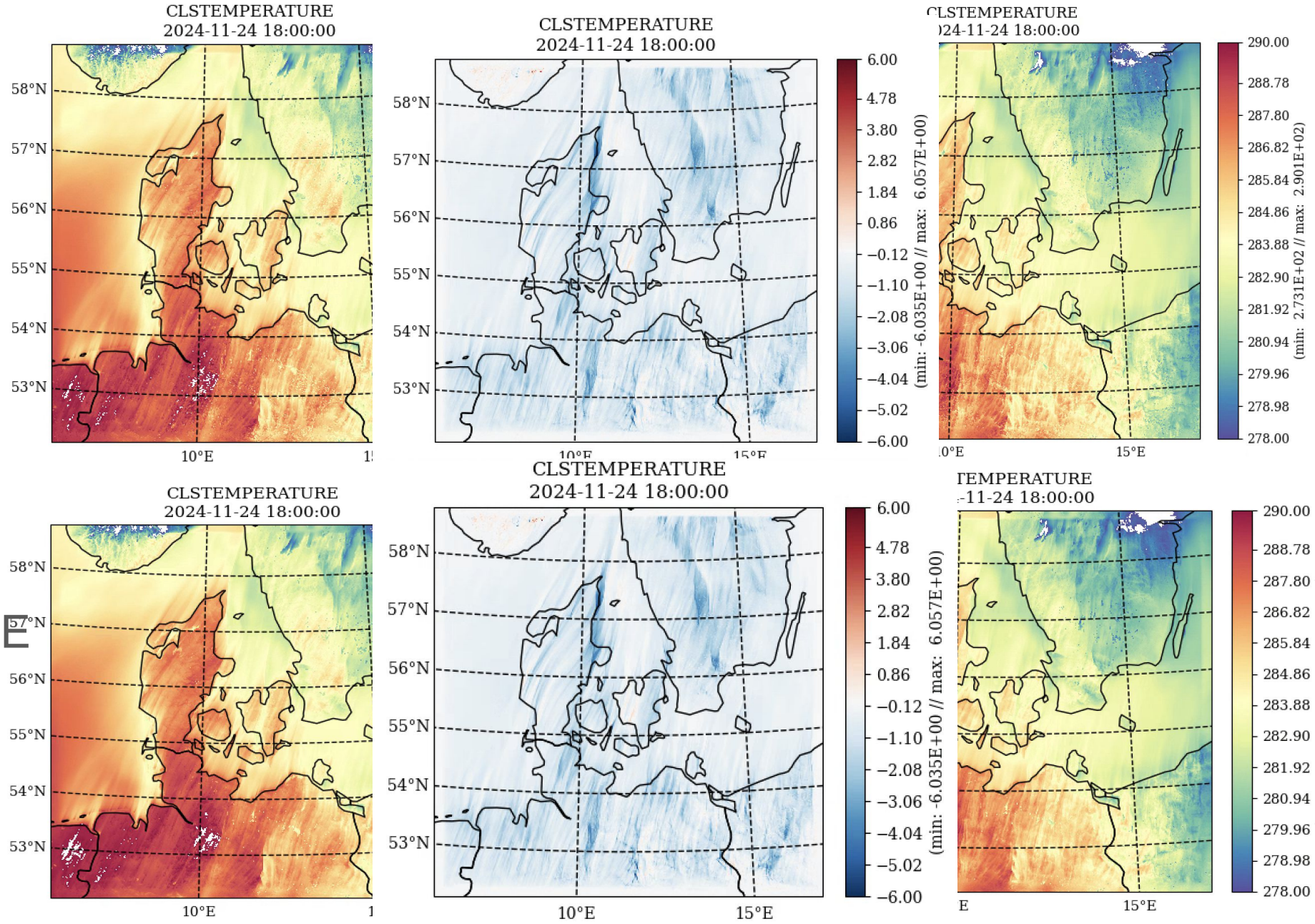
(N Theeuwes)

AROME atmosphere

HARM-AROME atmosphere

AROME surfex

HARM-AROME surfex



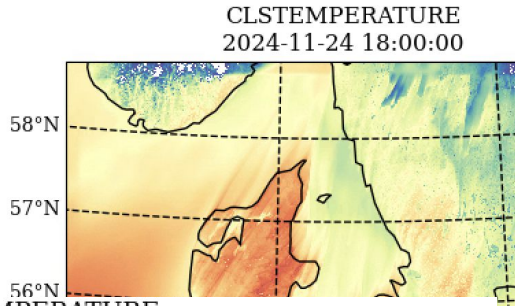
(N Theeuwes)

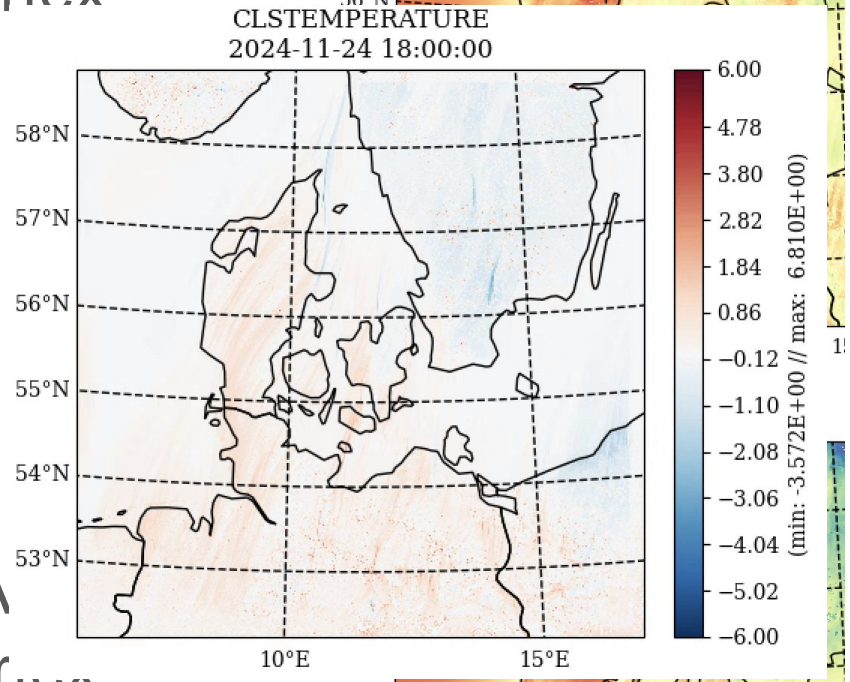
AROME atmosphere

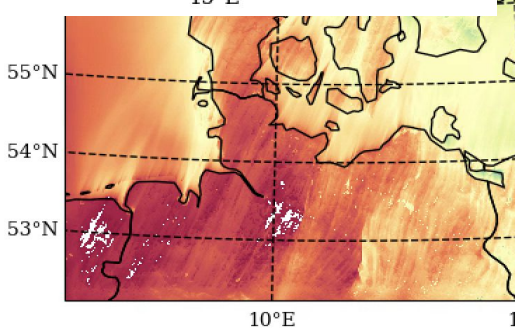
HARM-AROME atmosphere

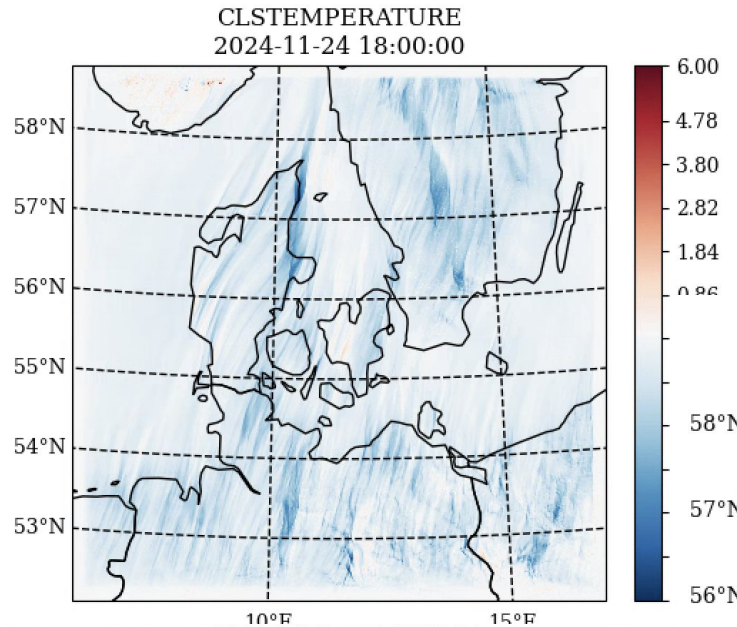
AROME surfex

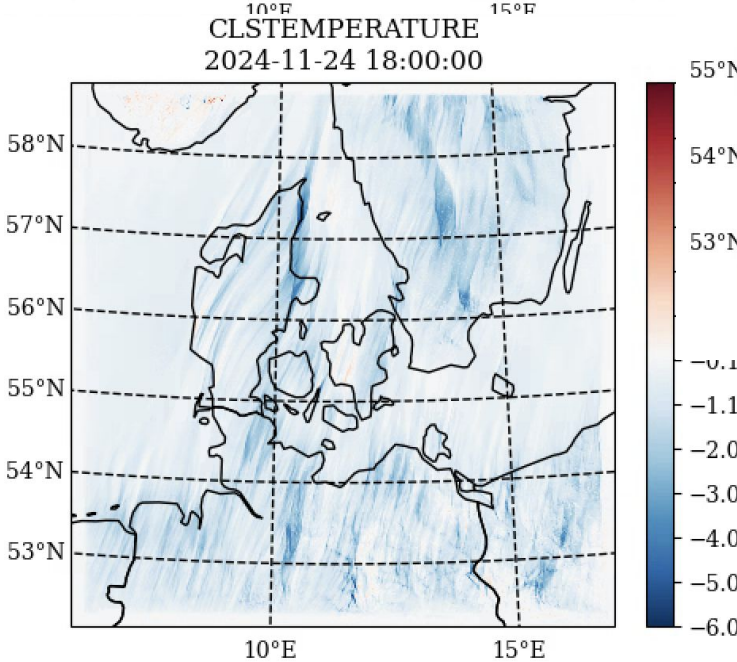
HA surfex

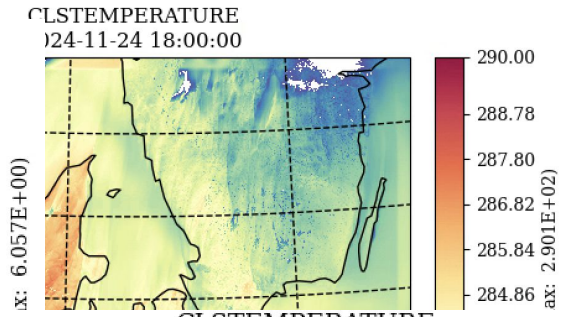


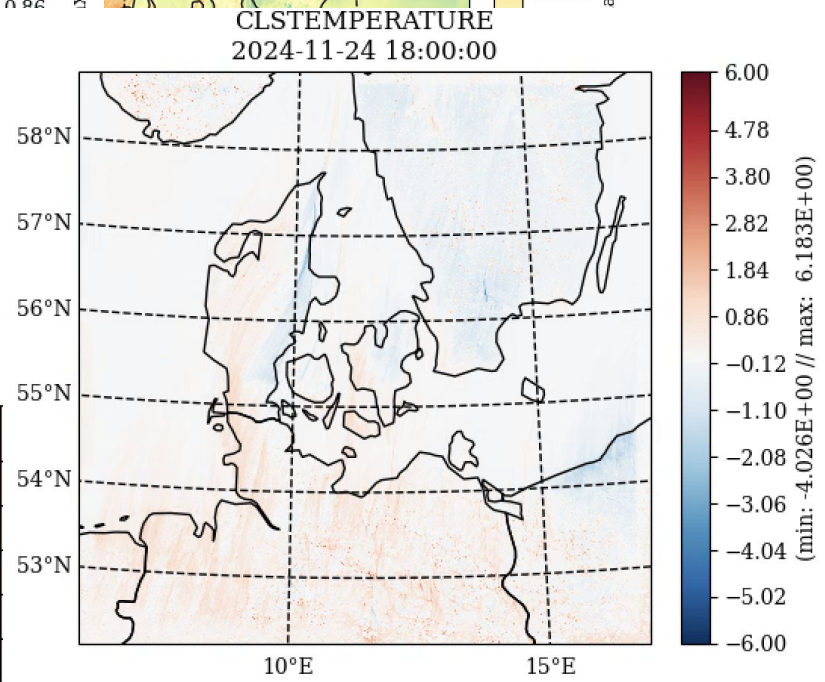


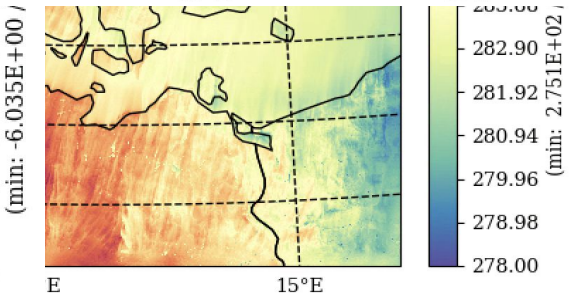










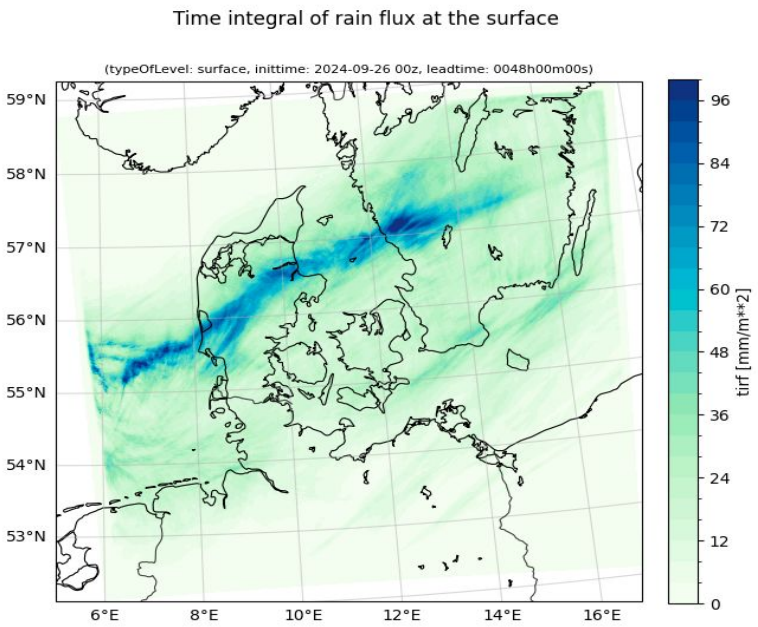


(N Theeuwes)

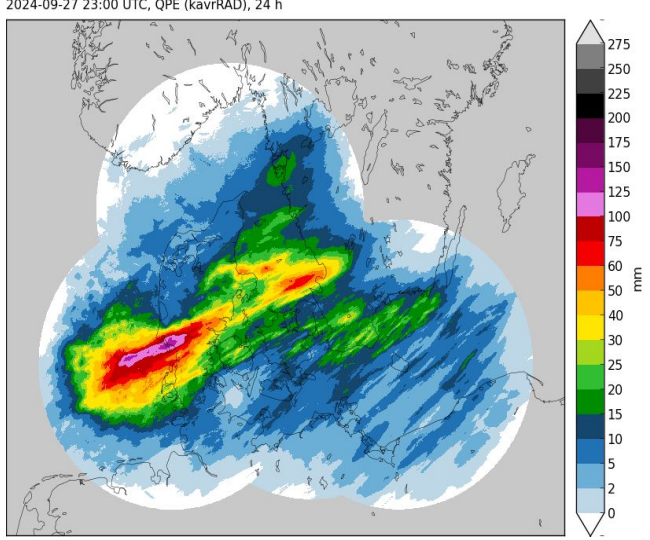
Research collaboration and system convergence in DEODE-fashion

- ➔ Operation group WP9 identified a rapid temperature rise case in connection with a warm front 20241124
  - ◆ Strong sensitivity to CSC configurations
- ➔ Development group WP10 suggests to examine sensitivity to configurations about SURFEX and upper air physics
- ➔ Findings: Main sensitivity associated with upper air physics, less so on configuration of SURFEX
- ➔ Conclusions: Running ACCORD CSC within DEODE framework sometimes exposes unexpectedly large sensitivity with significantly different results. At the end of the day, these contrasts may have been originated from differences in configurations/namelist settings which are not always as intended. The DEODE system, by an unified code and script system, helps to accelerate the harmonisation and convergence that is needed to unlock the potential collaboration in this community.

Danish 100mm flooding event
Sept 27 2024

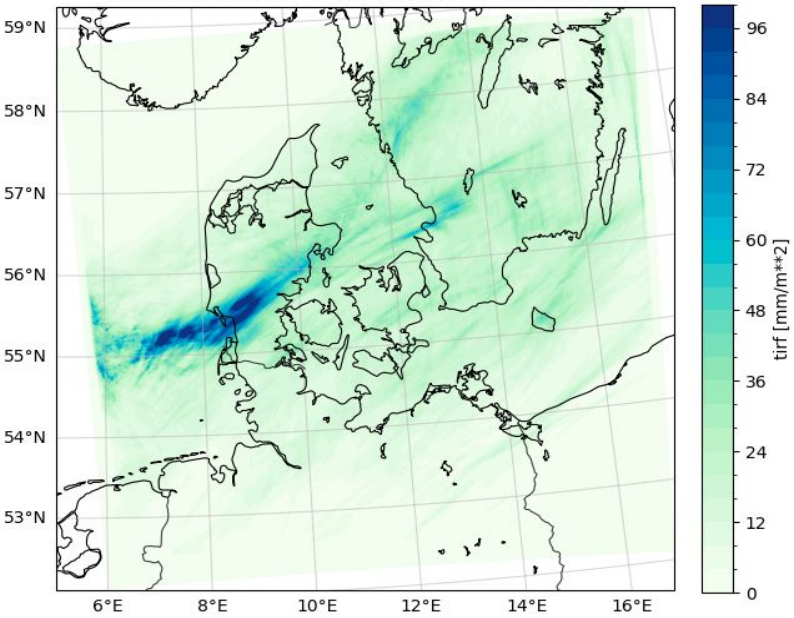


Harmonie 500m
with LBC-from DT-CY48r1

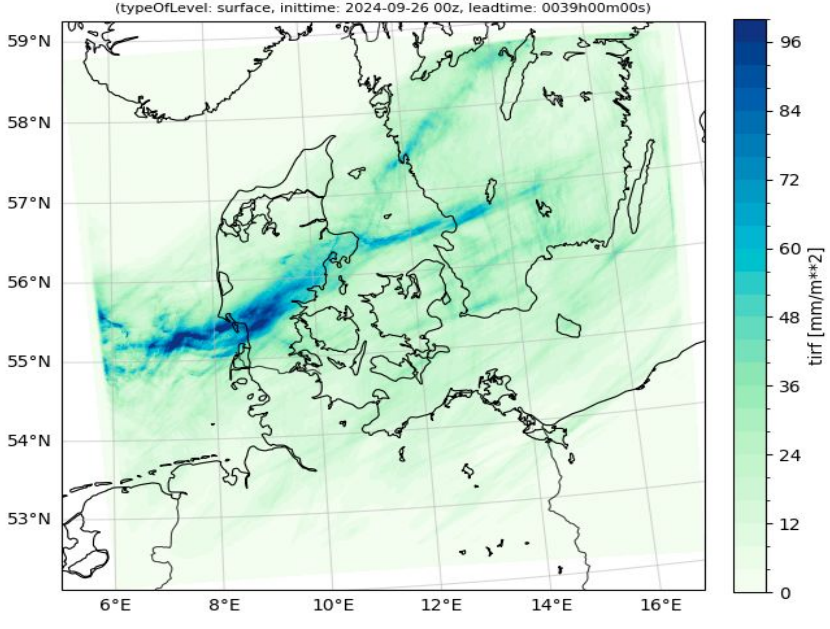


validation_V2, (CY49, CY49r1)

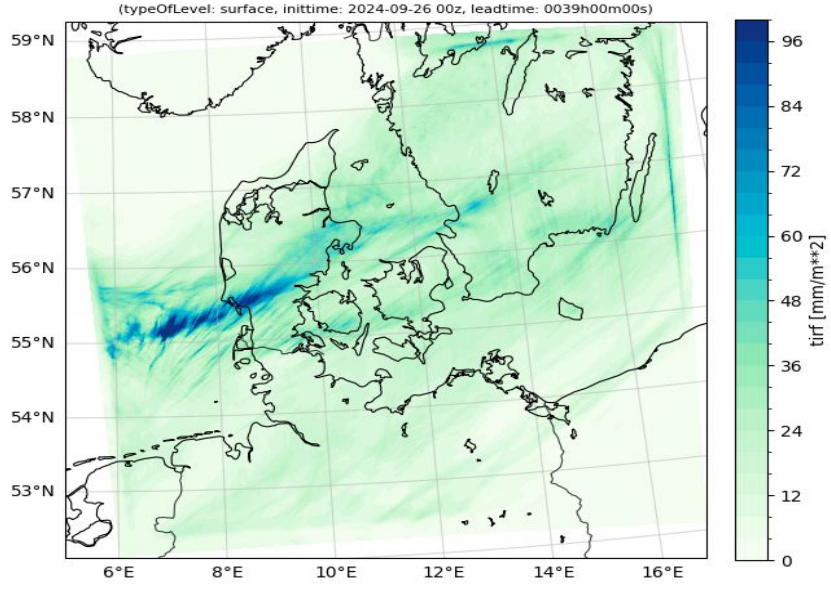
HARMONIE-AROME



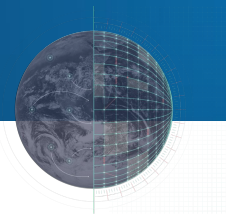
AROME



ALARO



Here the upgrade in the coupling data by global DT-CY49r1 has made differences

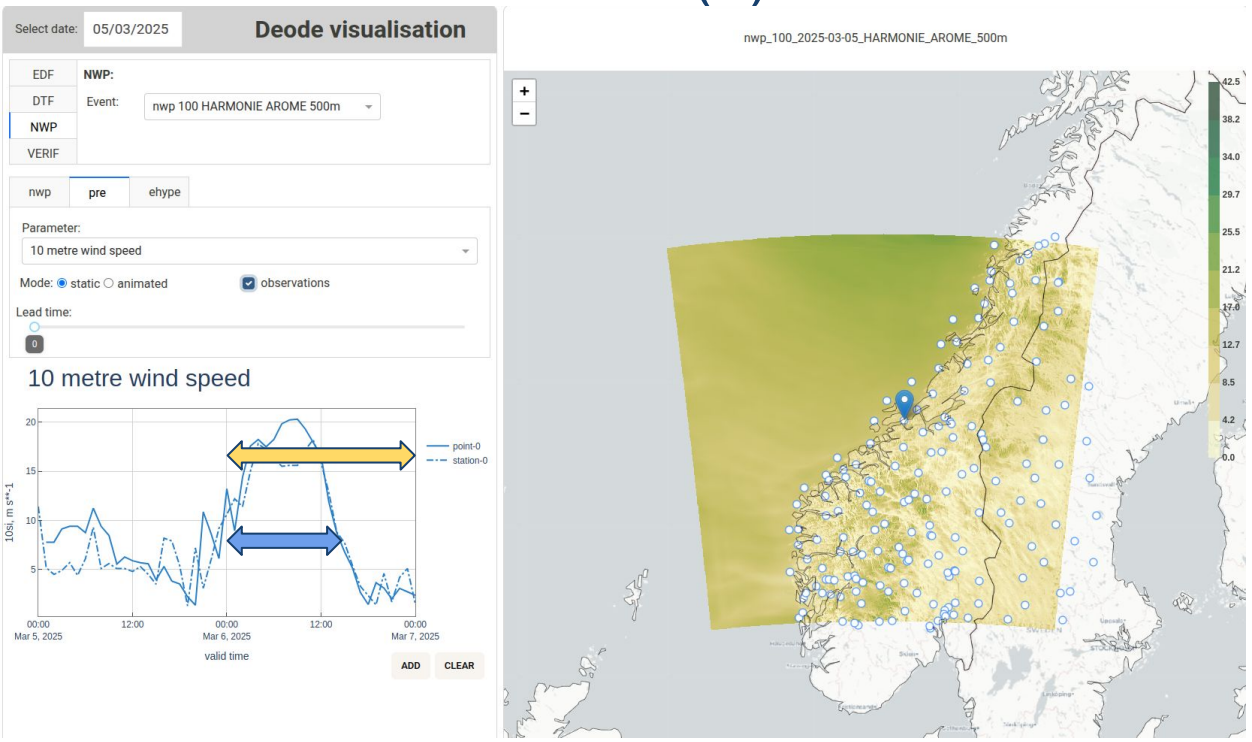


Experience with user-driven cases and call for more feedback

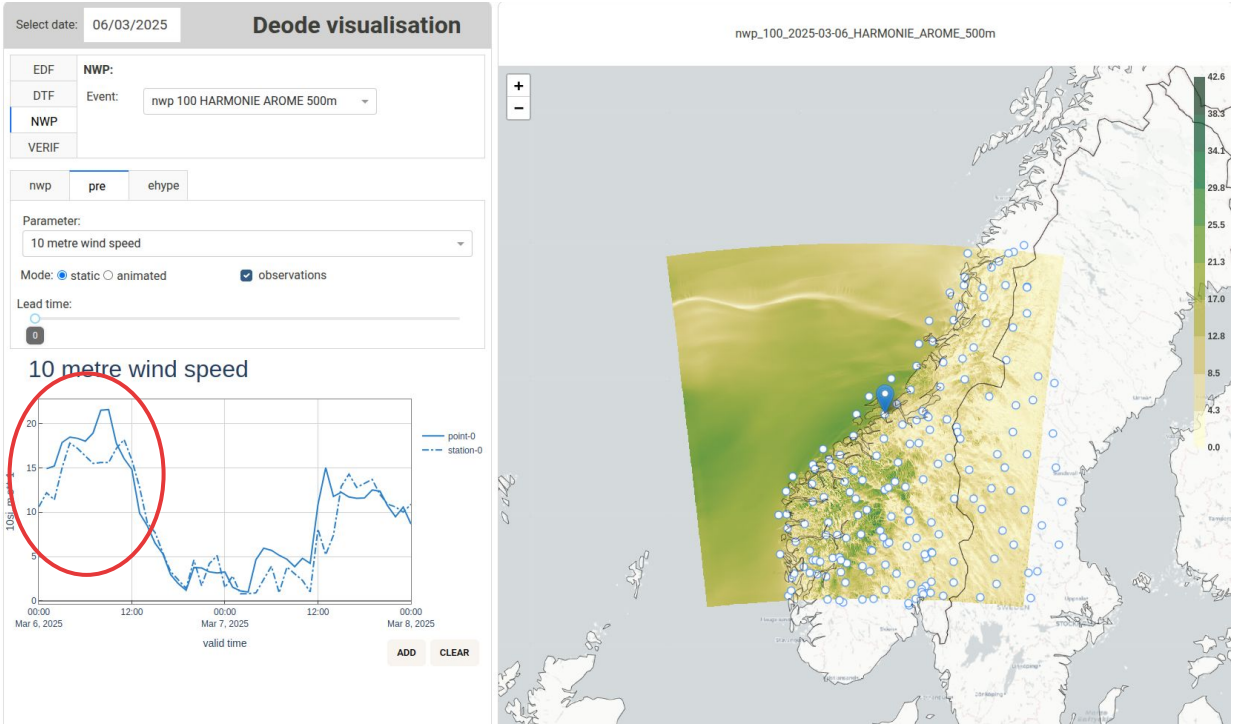
- 200m, 500m and/or 750m tests for Paris RDP, solar eclipse and ski competition events (Austria, Norway and Slovenia)
- Very important during the implementation period
- Thanks to the first feedback, a few improvements appeared on the Deode visualisation
- The Deode operation team is open to explore more of the user-driven applications focusing on hectometric scale modelling and user interaction

Supporting FIS Nordic World Ski Championships - 26 February to 9 March

(a)

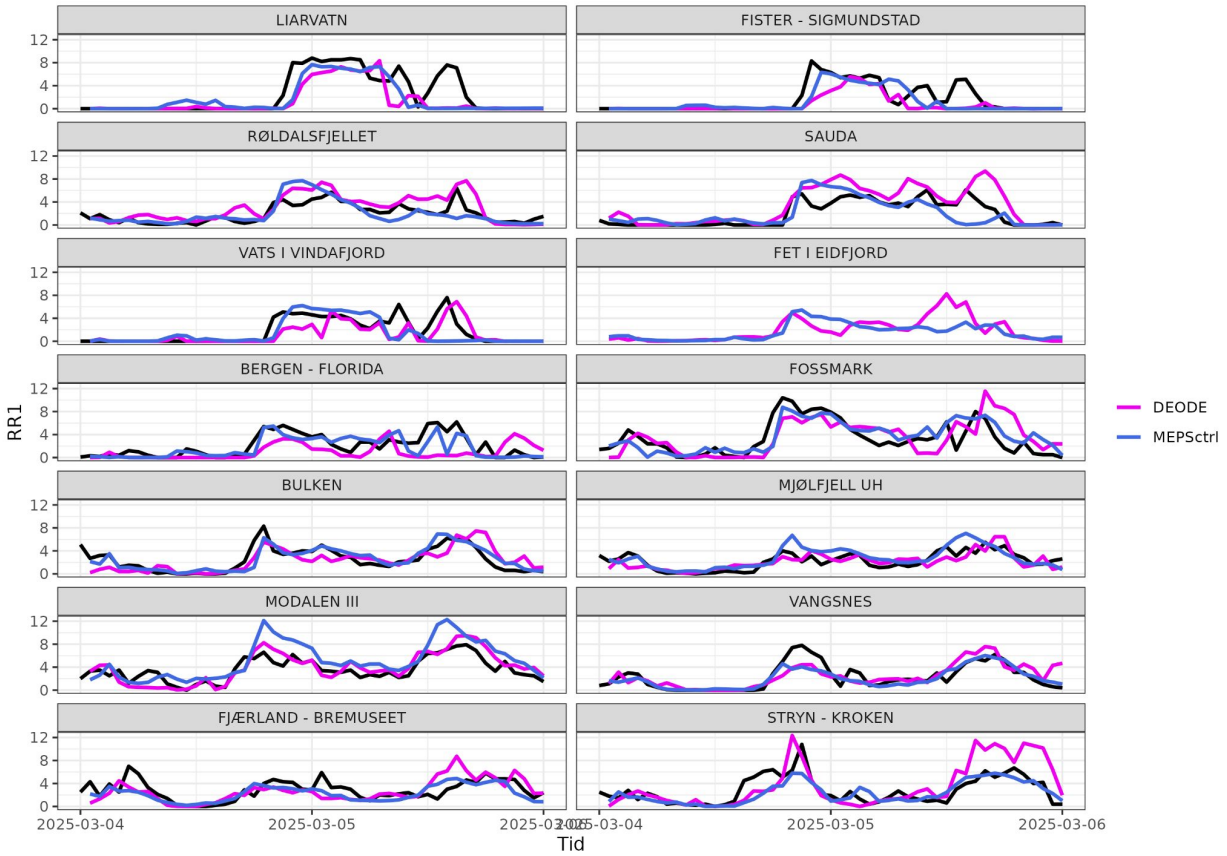


(b)

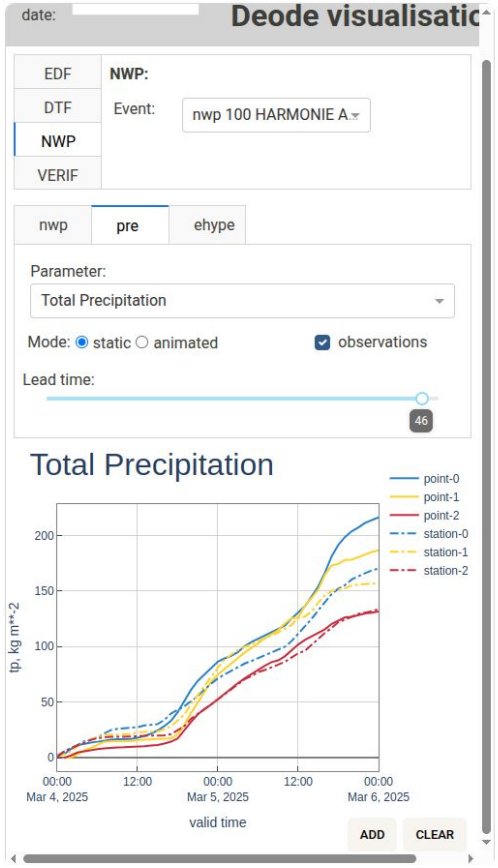


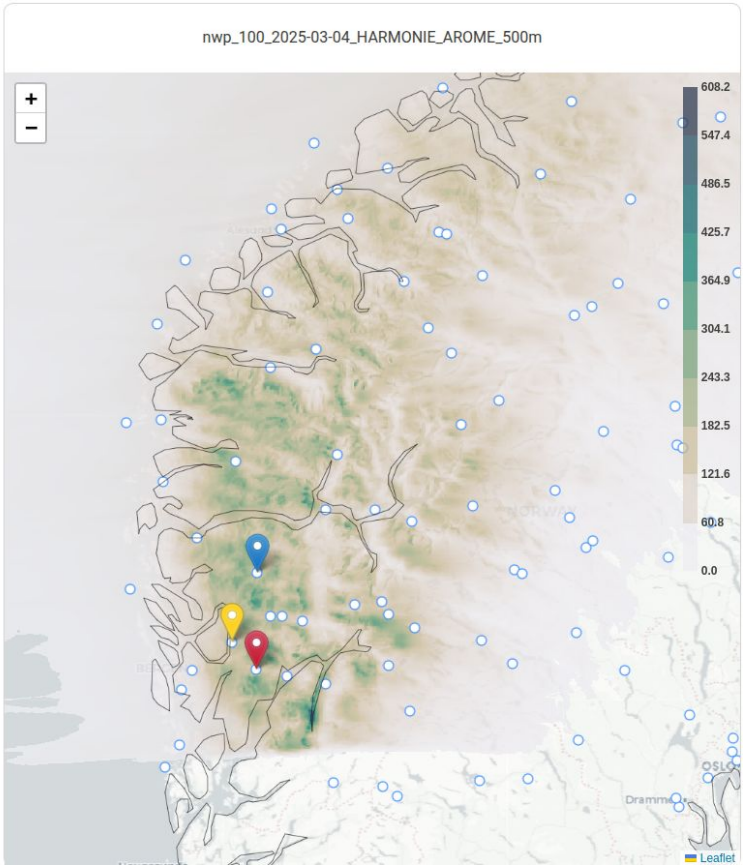
- Forecast of wind speed produced the 5th with the useful forecast in day-2 (6th March – light yellow arrow (a)).
- Few events were postponed during the 6th March until 12:30 (light blue arrow (a))
- The forecast from 5th (strong drop of wind intensity, (a)) could help the local forecasters in taking the good decision. Due to different reasons, this forecast was not used in the decision making, but as general comment, the resolution of the wind was very good and helped them to make different decisions.
- Red circle (b) shows that the forecast was good confirming the decision.
- Note: solid lines are forecasts, dashed lines are observations and the white dots are observations stations.

Extreme precipitation - 4 - 5 March 2025



MEPS 2500m, DEODE 500m; Observations





DEODE (Solid lines) and Observations (dashed lines)

CONCLUSIONS FROM SUCCESS STORIES AND BEYOND…

➔ **Clear added value** observed in certain **extremes** when increasing resolution from IFS 9 km to **4.4 km** for:
- Intensification of Tropical cyclones/medicanes
- Orographic precipitation, other surface variables in complex orographic areas

➔ **Less clear added value** was observed for surface variables and local convection in **flat areas** with the 4.4 km.

➔ ACCORD NWP sub-km added value: resolution increase from **2.5 km to 500 m** shows added value in some extreme cases especially in major flooding events, but needs to be further explored. Benefits from IFS 4.4 km to ACCORD sub-km is observed in various (high impact) events but we continue evaluating common severe events to obtain more clear conclusions**.**

➔ The lack of an **ensemble (UQ)** and specific **data assimilation (better initial condition)** at sub-km scales may partly explain the absence of added values in certain cases. Current efforts to **quantify uncertainty** through ensemble and **statistical post-processing** approaches can help.

➔ DEODE system framework demonstrates values to foster harmonisation and convergence within ACCORD.

CONCLUSIONS FROM SUCCESS STORIES AND BEYOND…

- ➔ We have **elaborated practice** in processing event-driven cases.
- ➔ As expected, **feedbacks from users**(-driven cases) boost the overall system development.
- ➔ Cases can **be requested not later than 3 days** prior to the events.
- ➔ We plan to promote the running system to potential users from ECMWF member state.

ON-DEMAND DT DEPLOYMENT TIMELINE

First configuration available on LUMI
- 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.)

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

Sept 2024 | **Q1 2025** | **Q2 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

Thank you for your attention!

DE330 meeting participants, Sept. 2024, Zagreb, Croatia