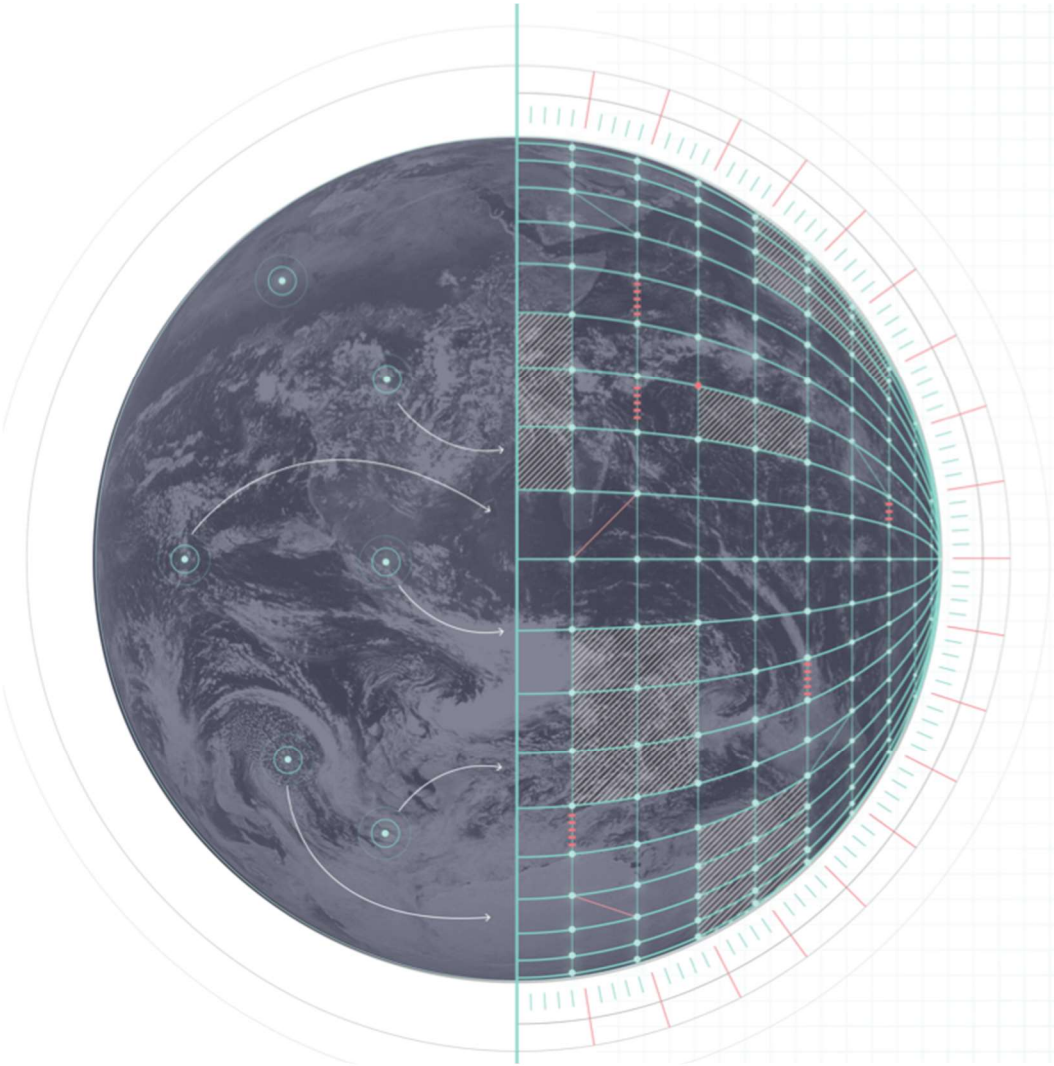


DESTINATION EARTH

Destination Earth On-Demand Extremes Digital Twin

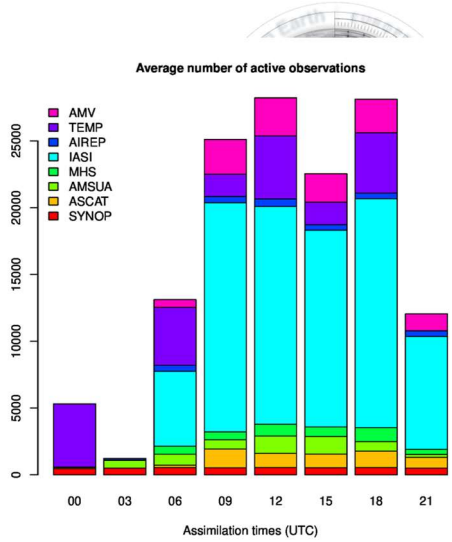
Roger Randriamampianina
&
The On-Demand Extremes Team

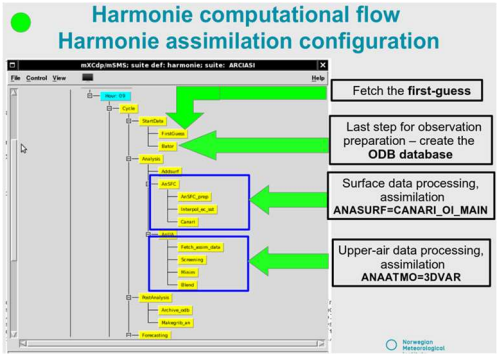
EWGLAM meeting, 25-28 September 2023, Iceland

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

The objectives, among others:

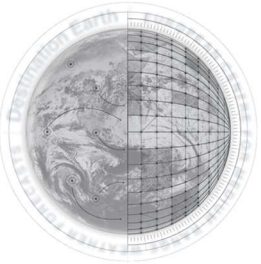
1) Pan-European observation processing for verification, post-processing and data assimilation
2) Configurable, flexible, scalable, and integrated workflows with hectometric resolution NWP and impact models
3) Load on energy efficient HPC platform (EuroHPC)
4) Value demonstration
5) Interfacing with ECMWF DTE, DEDL, DESP as required





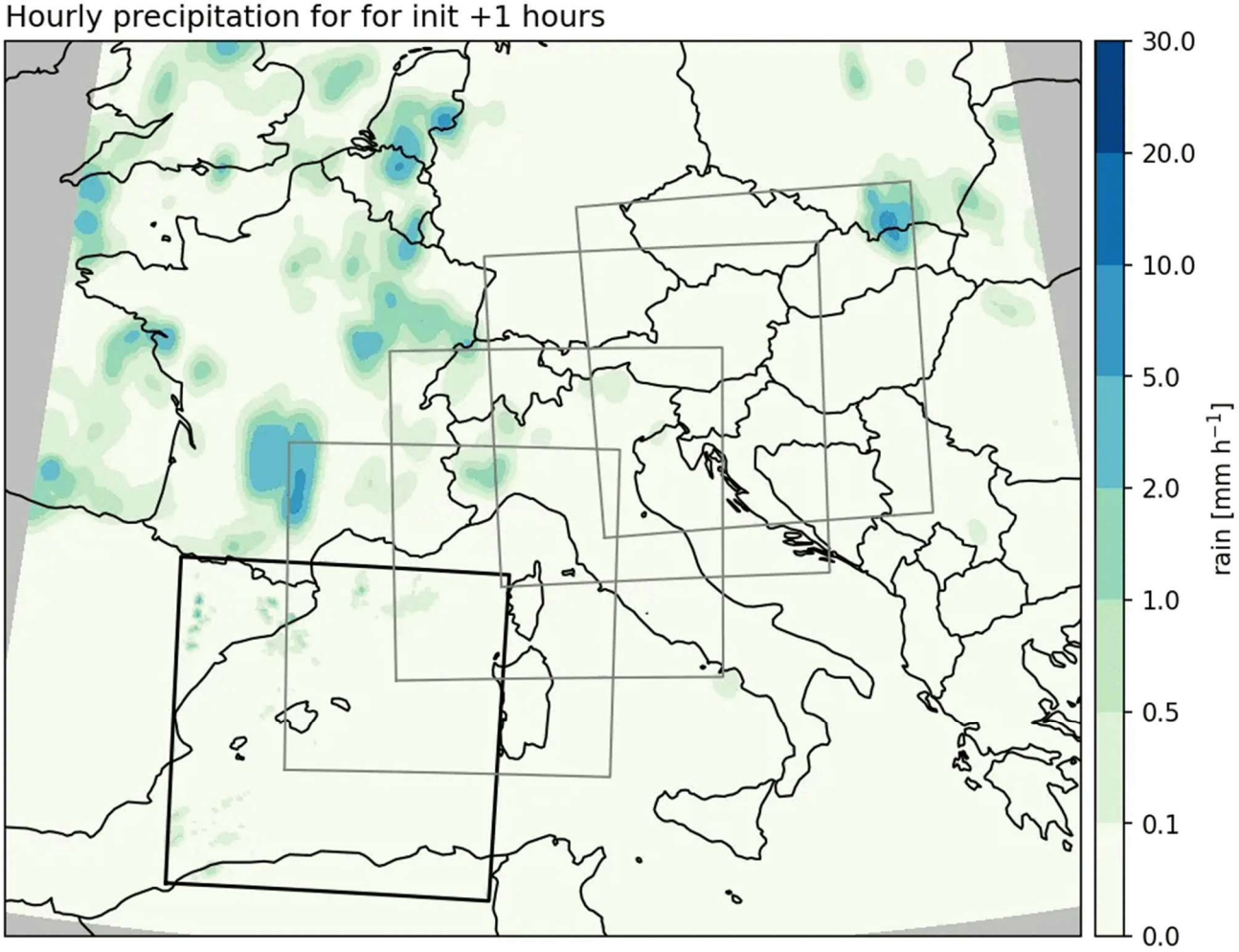
DESTINATION EARTH

On-Demand Extremes DT



Envisage an On-Demand high resolution system (at around 500 m) capable for forecasting/monitoring of a fast moving mesoscale precipitating event around 1-2 days ahead

Note that only one forecast product is shown in this illustration, and by 9 km IFS model



(Phillip Scheffknecht, GeoSphere Austria)

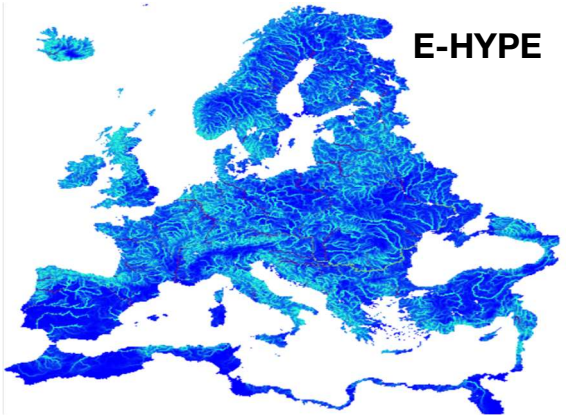
ECMWF

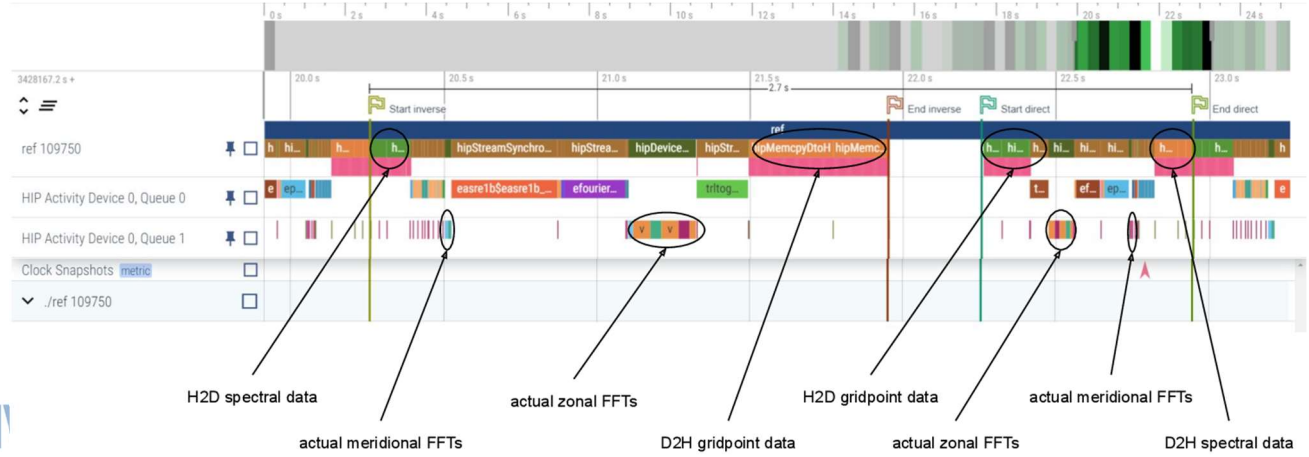
ECMWF

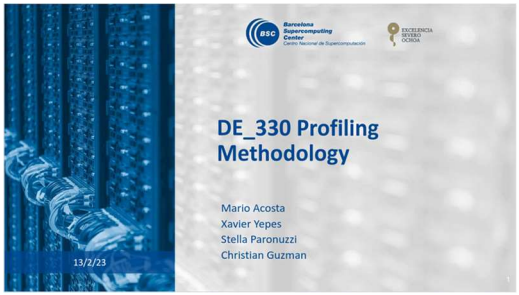
Funded by the European Union

Software support service

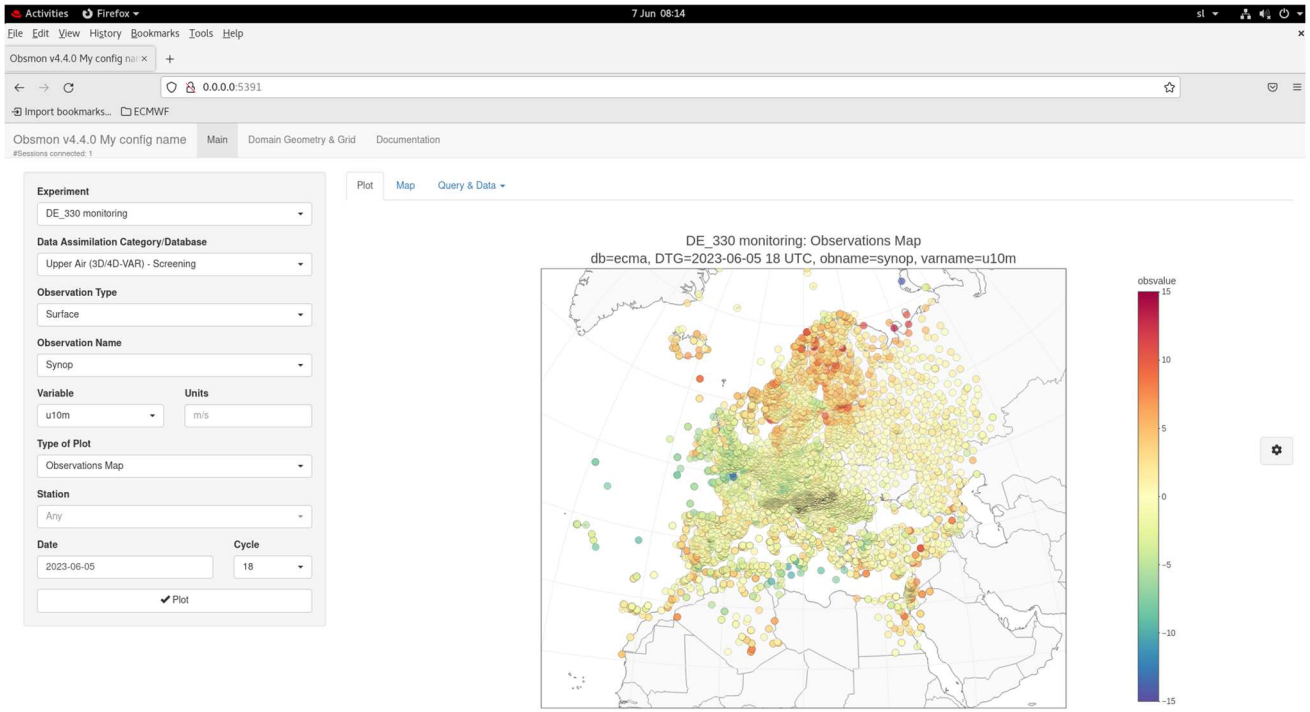
- Support the installation, integration, and porting of the models on various computing platforms, especially EuroHPC pre-exascale systems
  - Access to LUMI offered and training organised
  - Successful installation and testing of model components (AROME & ALARO) both CY46(T/H)1 and CY48T3
- Support the containerization of the pan-European E-HYPE hydrological model
- Support the pre-/post processing for all impact use cases, i.e. WRF-Chem and CMAQ air quality models, 9 national hydrological flood forecasting model systems, …
- Systematic performance analysis of the selected software packages
  - All the tools are installed on LUMI and a presentation to DE_330 partners has been held

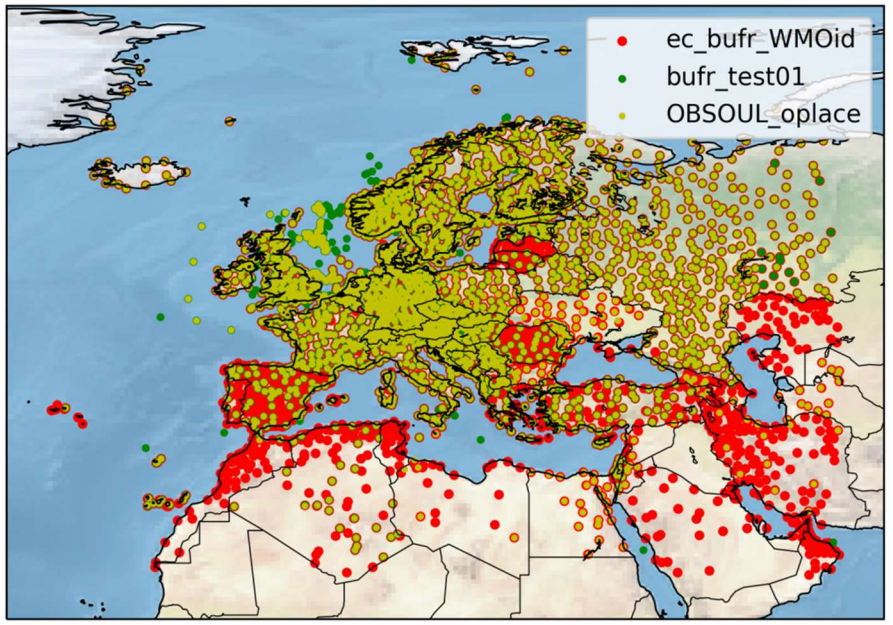






Continuous observation processing and monitoring





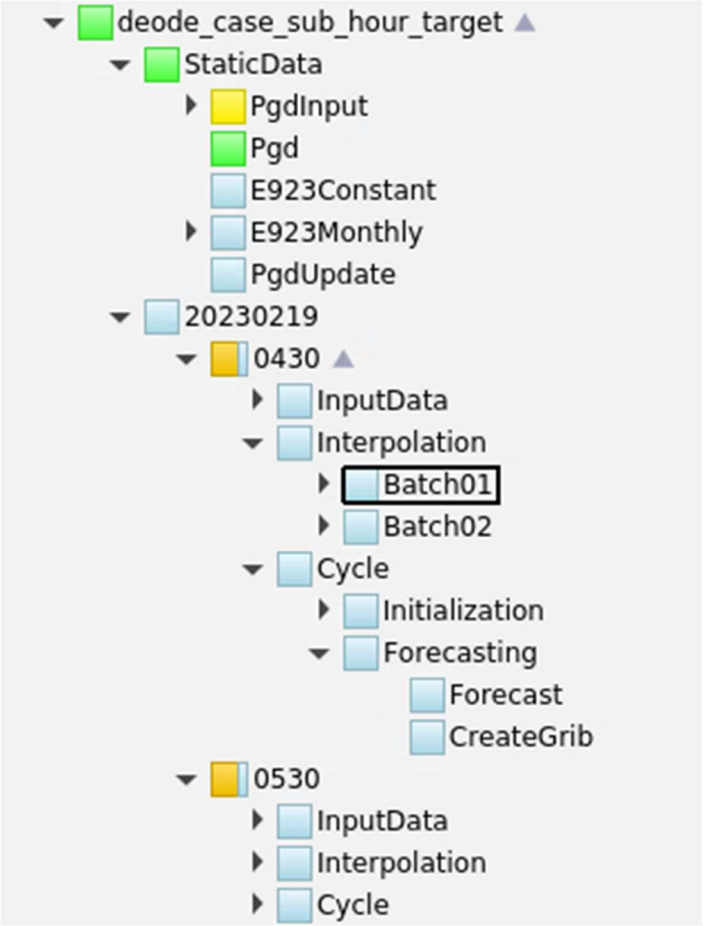
The Obsmon observation monitoring web interactive interface
(Benedikt Strajnar, ARSO)

The on-demand Team welcomes opportunities to collaborate with operational services with open-access, high res obs including crowdsourced data. Presently real time access to LACE, UWC-W and MetCoOP are under exploration

ECMWF

Workflow management

- Workflow management and scripting system:
  - Common baseline on-demand NWP system defined based on ACCORD CY48T3
  - An on-demand DT script is taking shape running entire integrated DT workflow including NWP components
  - The on-demand DT script will facilitate running of the NWP workflow with different ACCORD CSC configurations
  - ecFlow will be the primary tool for the On-Demand DT workflow management



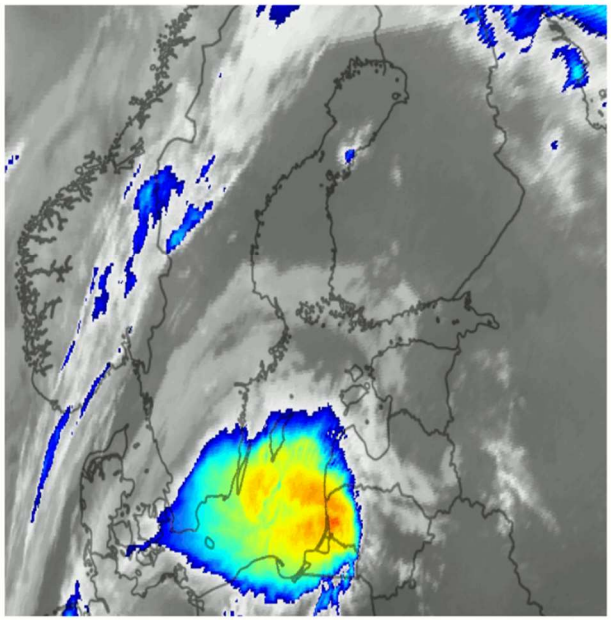
Hyper resolution NWP model runs
The Finland thunderstorm case 2017 Aug 12 is called "Kiira"

MSG SEVIRI CH. 9 (IR)

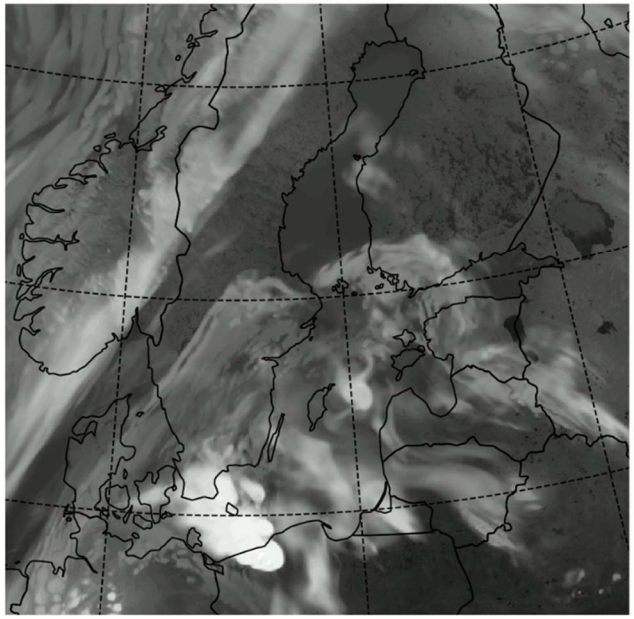
NWP model 2.5 km

NWP model 0.5 km

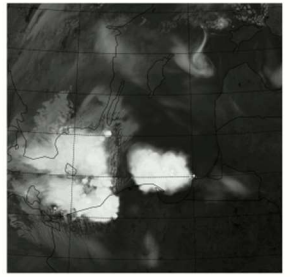
Satellite IR, MSG 10.8 μm
Valid: 12/08/2017 00Z



Model pseudo IR: 2.5 km resolution
Valid: 12/08/2017 00Z
Fc: 12/08/2017 00Z H+00



Model pseudo IR: 500 m resolution
Valid: 12/08/2017 00Z
Fc: 12/08/2017 00Z H+00

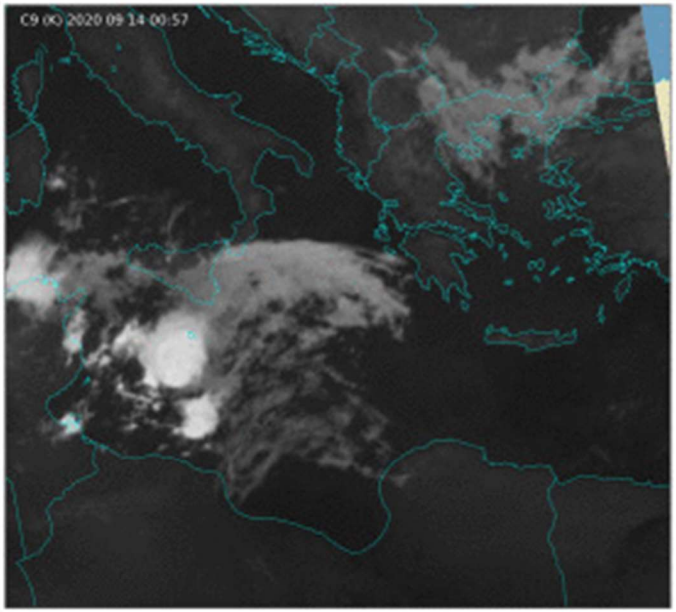


Figures by Erik Gregow, FMI

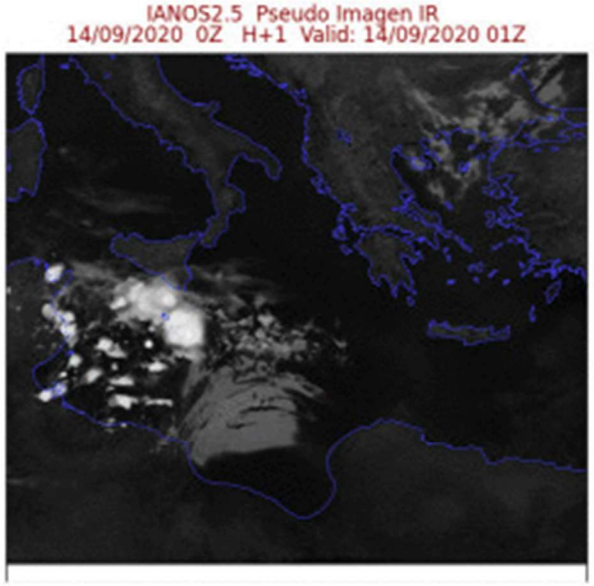
DESTINATION EARTH

Hyper resolution NWP model runs
The Ianos Medicane 2020-09 14-20

MSG SEVIRI CH. 9 (IR)



NWP model 2.5 km



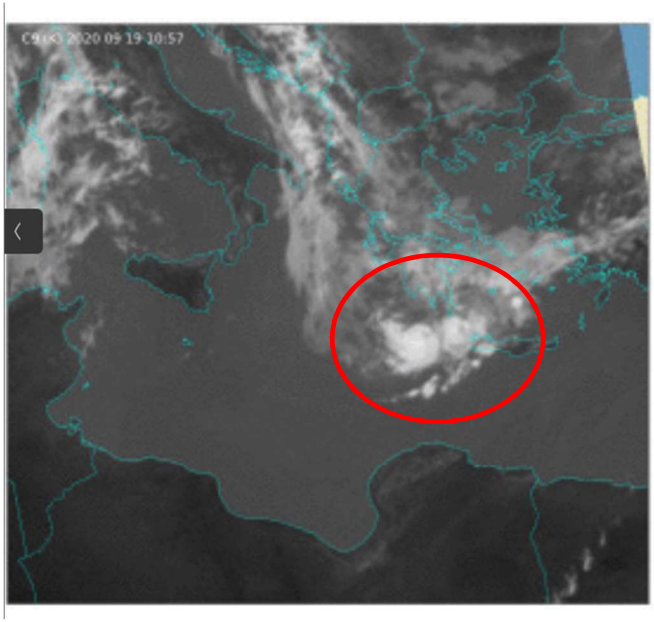
NWP model 0.5 km

ECMWF

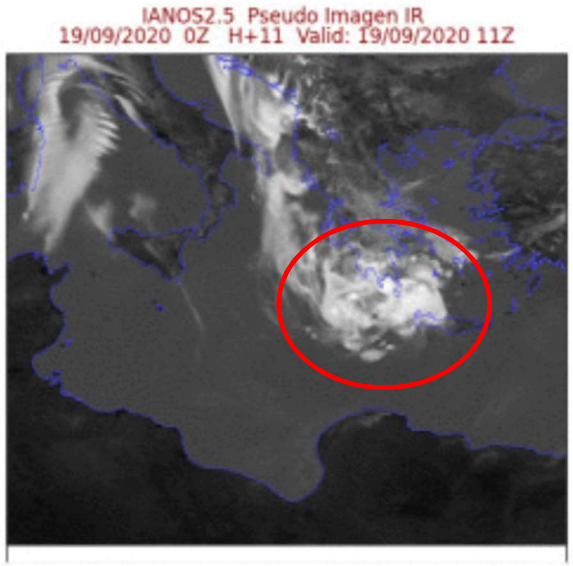
(Javier Calvo, AEMET)

Hyper resolution NWP model runs
The Ianos Medicane 2020-09 14-20

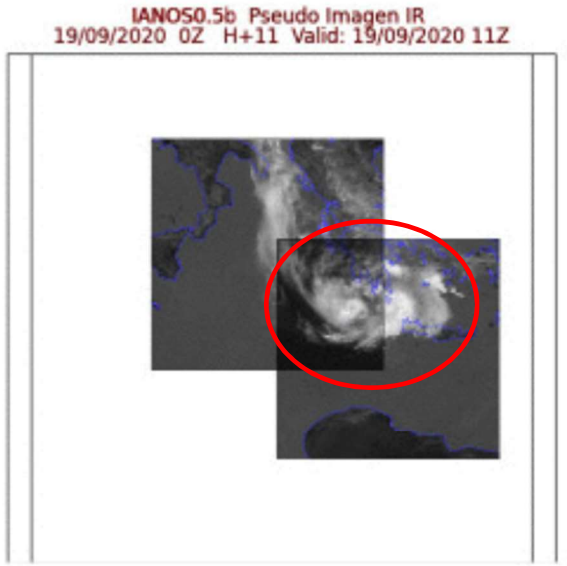
MSG SEVIRI CH. 9 (IR)



NWP model 2.5 km



NWP model 0.5 km

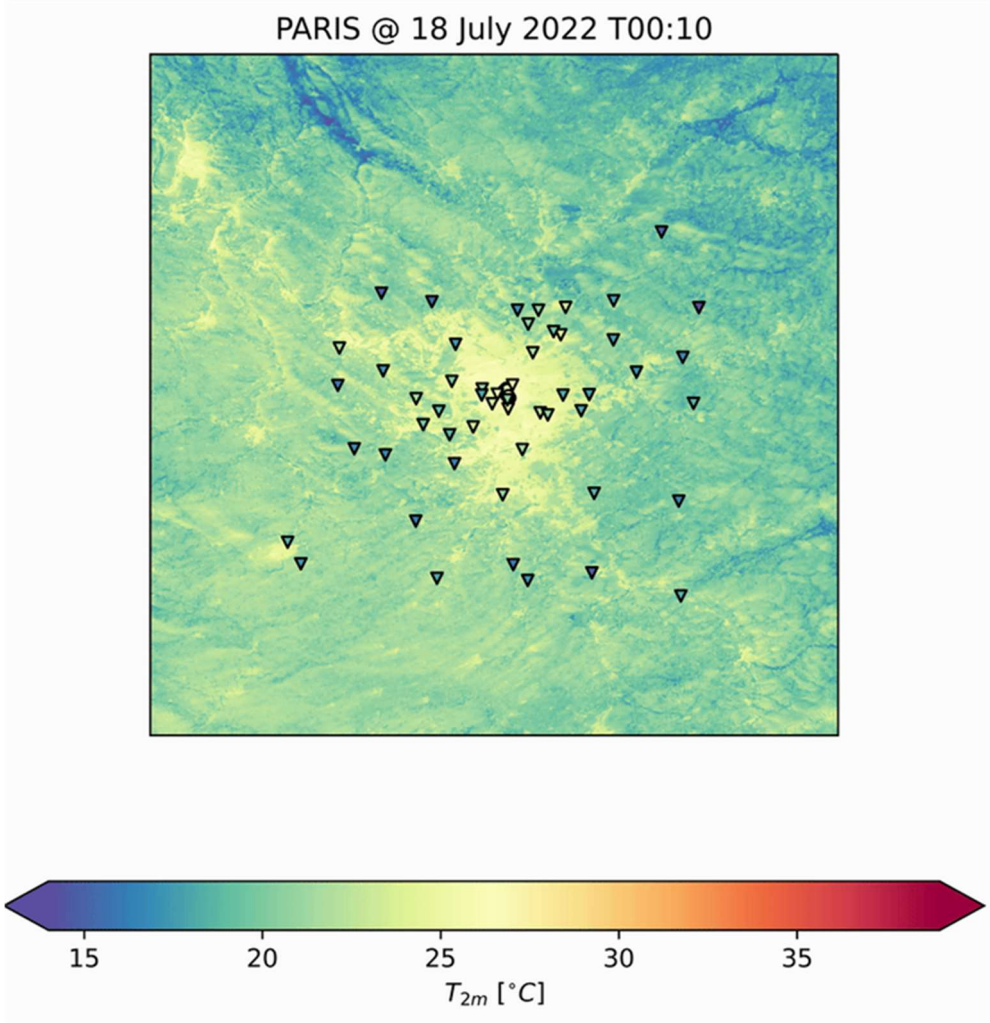


Figures by Javier Calvo, AEMET

Hyper resolution NWP model runs

Paris at 200m

Simulated 2-m temperature with 79 observation sites in and around the centre of Paris
(Jean Wurtz, Météo France and Natalie Theeuwes, KNMI)



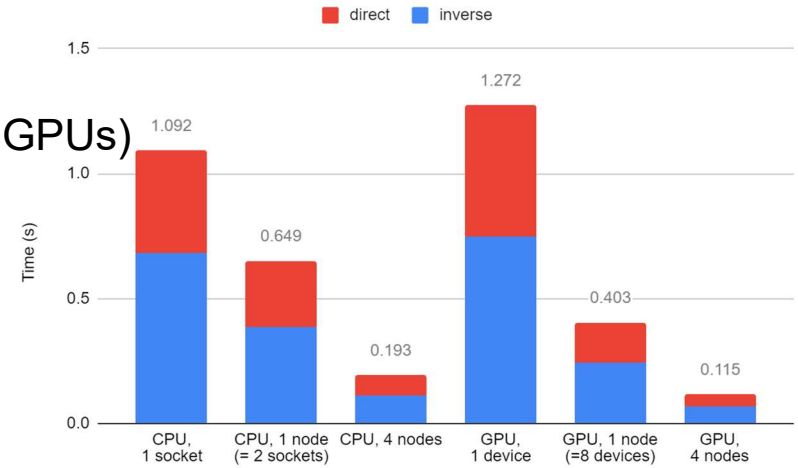
Code adaptation to CPUs and accelerators

- **Code layout of ALARO CSC modified to prepare for GPU porting of physics parameterizations:**
  - Introduction of smart data structures
  - Mechanism to switch between coarse parallel granularity (optimal for CPU) and fine parallel granularity (optimal for GPU)
  - Ready to start porting of individual physics parameterizations to accelerator

- **Apply the source-to-source tools to parts of the codes:**
  - Both LOKI and fxtran are available on LUMI
  - Used to adapt the stand-alone version of ACRANEB2 radiation scheme of the ALARO CSC configuration
  - Participation in LUMI hackathon to perform profiling of different source-to-source recipes

Code adaptation to CPUs and accelerators

- **Porting of limited-area spectral transforms to GPU:**
  - Using combination of HIP and OpenACC
  - Working on LUMI AMD GPUs (in principle also on NVIDIA GPUs)
  - Initial (unoptimized) performance:
    a bit slower than CPU version
    when comparing 1 CPU to 1 GPU



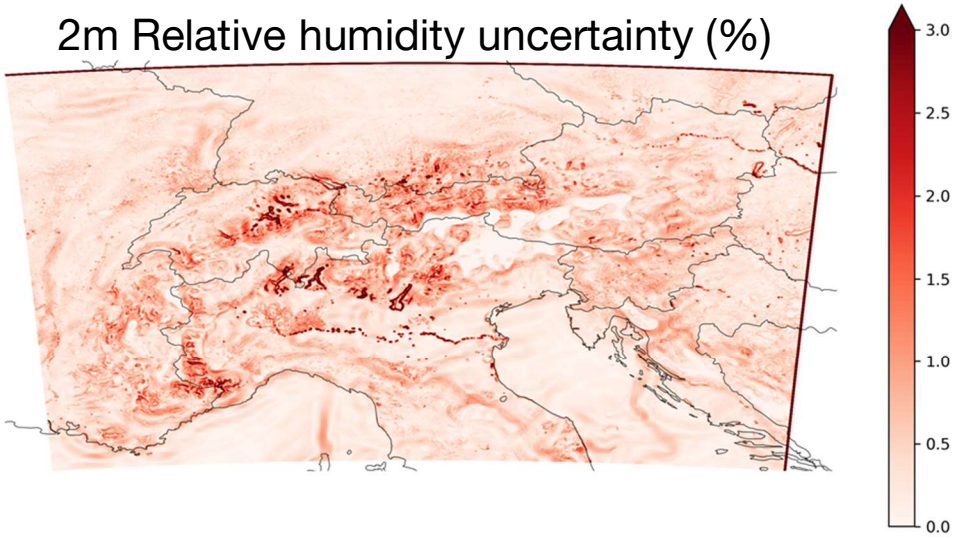
- **Integration of GPU-ported parts in 3D model**
  - Successful integration of ported radiation scheme in 3D ALARO forecast
  - Tested on 4 nodes (32 GPUs)
  - (No performance assessment yet)
  - Next step: integration of GPU-ported spectral transforms

Post-processing framework

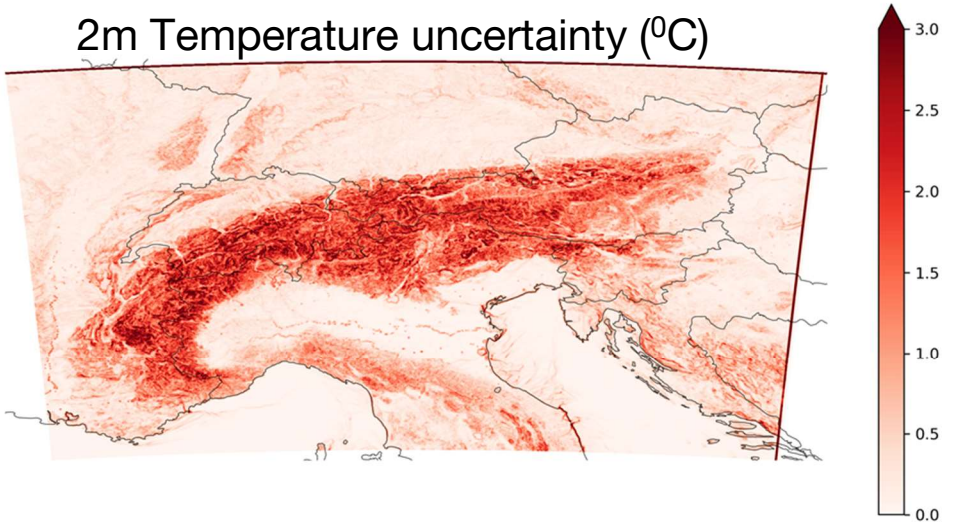
- Implementation of PP framework
  - Get the applications on our GitHub and LUMI, including containerization
  - Coordination about the tools and interfaces to the On-demand DT workflow
- Implementation and demonstration of the first set of post-processing methods
  - Preparing the post-processing methods and codes and assessing relevant data that can be used in phase 1 in benchmarking
  - Special attention on task providing spatio-temporal scenarios for the hydrological applications which is recognised as very challenging wrt to both data and methodology
- Implementation of a first set of algorithms for detection of extreme events
    - Includes Storm surges/tides, heat waves/cold snaps, wildfires and droughts, heavy rainfall/thunderstorms, frost events
    - In the second part of phase 1, methods will be further developed, and additional (more sophisticated) methods will be considered.

Post-processing of hyperresolution model

2m Relative humidity uncertainty (%)

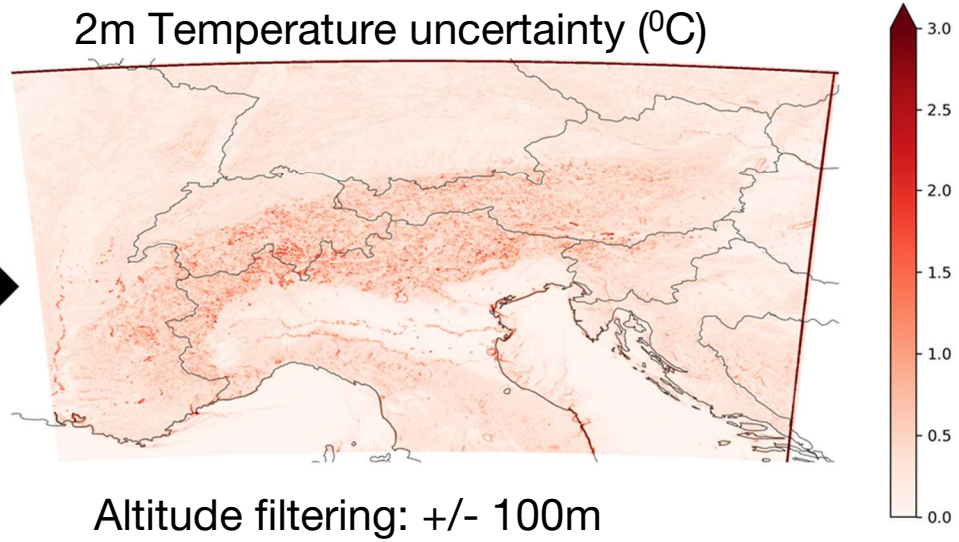


2m Temperature uncertainty (^{0}C)



- Neighborhood (NB) method for deterministic model uncertainty estimation
  - Local NB for each grid-point
- NB shape: square or circle
- Grid-points can be filtered based on their altitude and/or land-sea mask

2m Temperature uncertainty (^{0}C)



Altitude filtering: +/- 100m
-6.5^{0}C/Km temperature correction

Impact modelling - Hydrology (flood events)

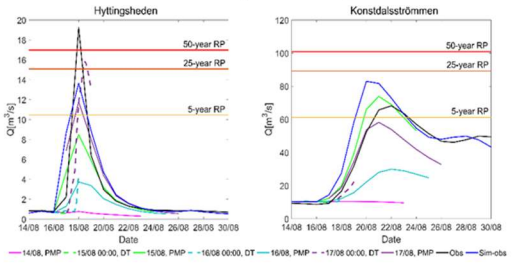
- Demonstrate value and benchmarking for extreme flood use-cases
  - Model sensitivity has been evaluated for:
    - Changes in meteorological input spatial/temporal resolution, initial conditions, discretization, and hydrological model
  - Compare 9 historical extreme flood events using DT high-res. data with reference forecasts
    - All partners have coarse (1.9-2.5 km) and some fine resolution (500-750m) DT data
    - Partner (forcing) data is also collected for simulation with containerised 5 km E-HYPE model

- Co-design actionable response workflows with societal users
  - Onboarding of downstream stakeholders has begun (May-Oct 2023)
  - Drafting of potential actionable response scenarios (Oct-Mar/Apr 2024)

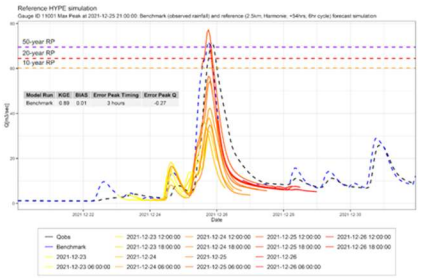
9 hydrological model forecasting chains at various stages in working with DT data

- 9 hydrological forecasting models
- Recent flood events
- Evaluation of DT data in hydrological forecasting
  - change in spatial and temporal resolution
  - change in initial condition
  - change in the discretisation (size of sub catchment, …)
  - different type of hydrological models

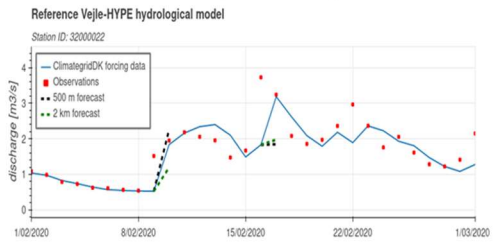
SMHI (Sweden)



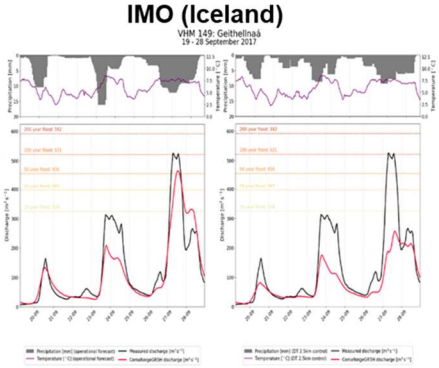
Met EIREANN (Ireland)



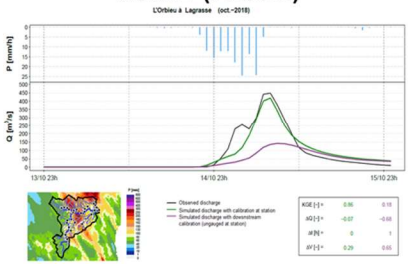
DMI (Denmark)



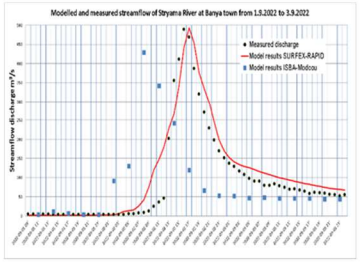
IMO (Iceland)



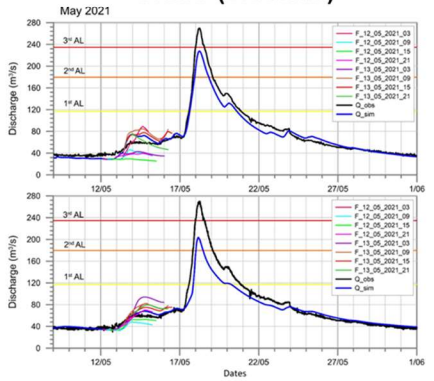
INRAE (France)



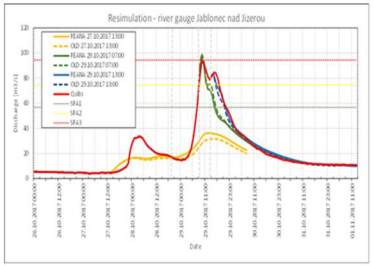
NIMH (Bulgaria)



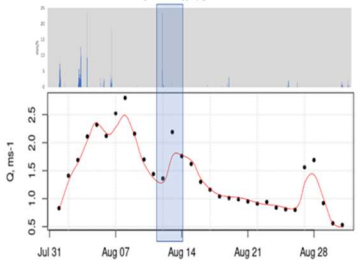
SHMU (Slovakia)



CHMI (Czech Republic)



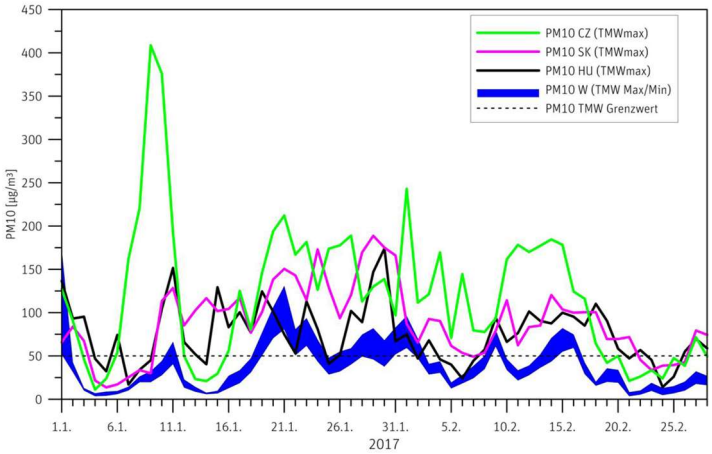
FMI (Finland)



Impact modelling - Air quality overview

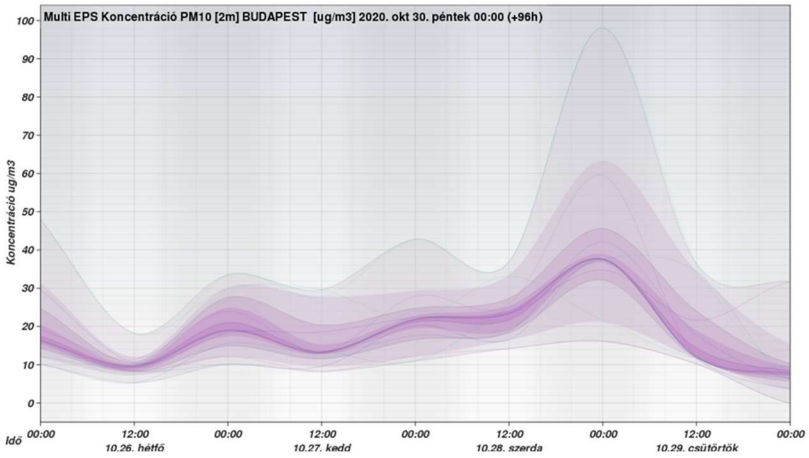
Models preparation:

- Preparation of the individual 6 AQ models to operate on sub 1 km resolution domains
- Harmonisation of input and output data formats amongst AQ models
- Selected AQ-models are prepared to run on LUMI
  - CMAQ, SILAM, WRF-Chem



AQ EPSgram:

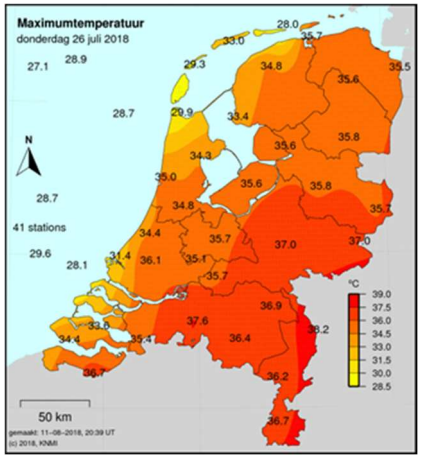
- Providing air quality forecast for different cities/locations
- Visualized values: maximum, median, minimum
- Comparison with observations



This plot shows the CAMS-REG ensemble, as example.
(Zita Ferenczi, OMSZ)

Above: Winter use case for the Carpathian region valleys

Right: Summer use case for Benelux.



ECMWF

Impact modelling - Air quality story

Extreme Digital Twin – Air Quality Impact Model

PLANNING OUTDOOR ACTIVITIES

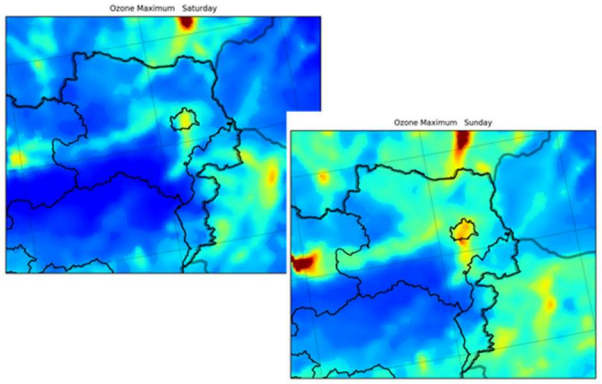
What would be a good location in vicinity of the city avoid air pollution during the weekend?

To which altitude I would have to hike up the next days to escape from the high air pollution in the valley to have a good view and healthy air?

Extreme Digital Twin – Air Quality Impact Model

PLANNING OUTDOOR ACTIVITIES

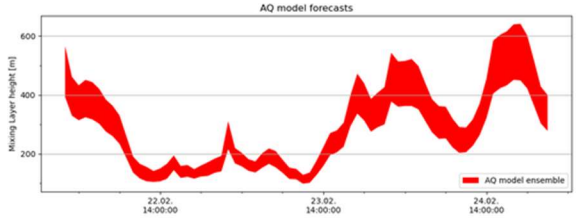
Due to the weather conditions, we expect the maximum of the ozone plume south of the city on Saturday, northern parts have much better air quality on that day, on Sunday the situation is worse in the whole region. We suggest Saturday for outdoor activities.



We advice to climb up altitudes above

- 300 m on the 22nd Feb
- 600 m on the 23rd Feb

to reach “clean air”, which lies over the inversion in the valley.

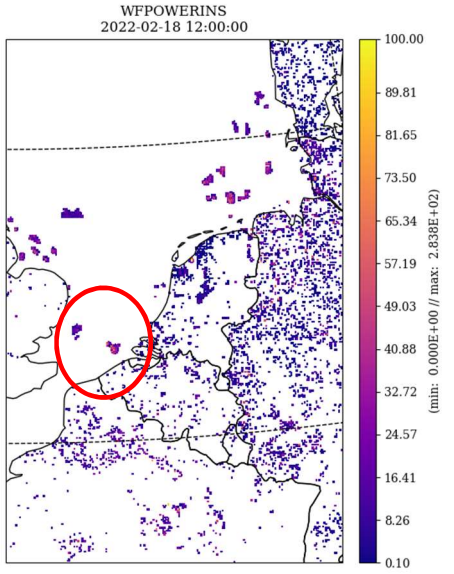


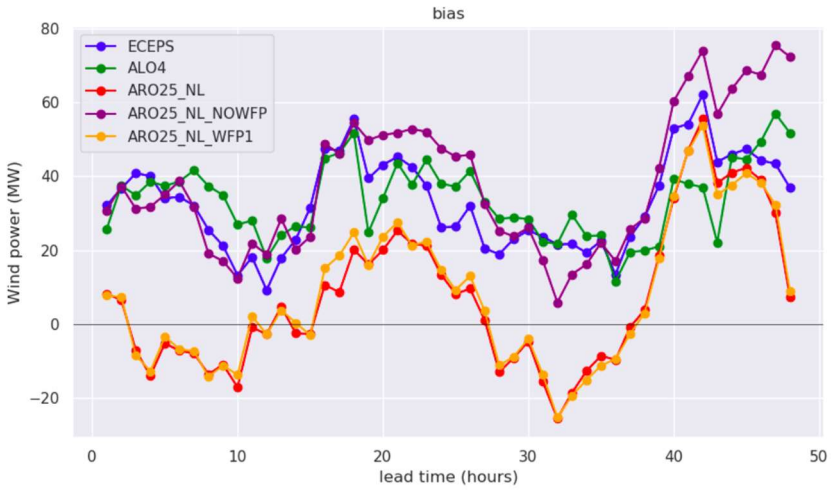
Impact modelling - Renewable energy

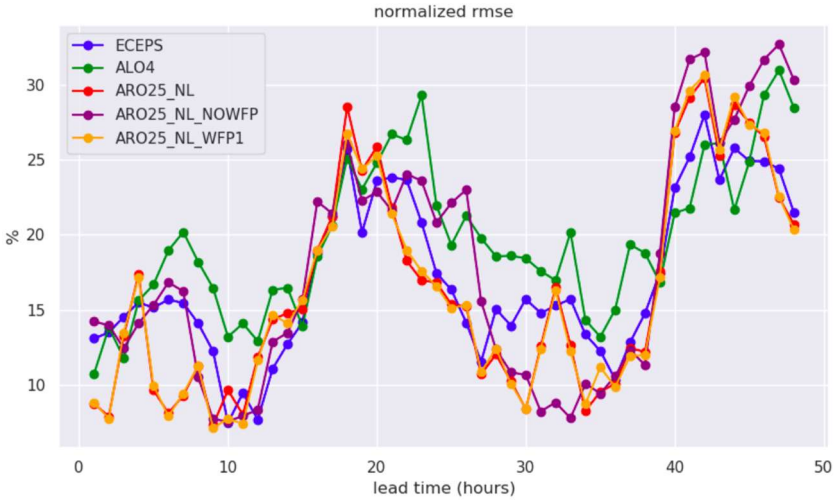
Wind energy: Tests done for Eunice and Derecho cases:

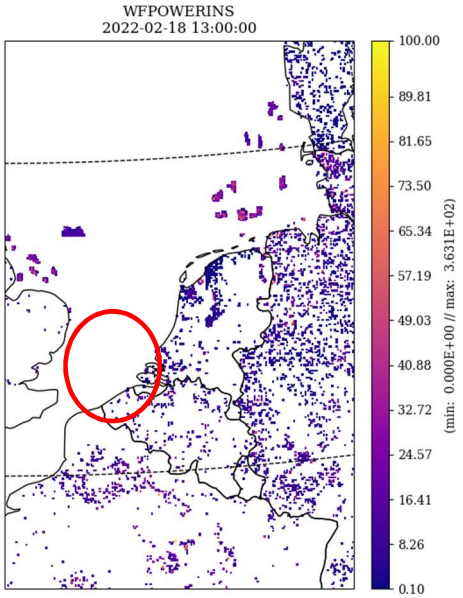
- Testing necessary NWP setup:
  - Wind farm parameterisation on/off
  - This clearly improves the wind power bias
  - Resolutions (2.5 km vs 750 m)
- Generation of synthetic power production data

Figures (right): Storm Eunice (strong wind > 25 m/s) – cut-out event for the Borssele wind farms between 12 and 13 UTC (Natalie Theeuwes, KNMI)



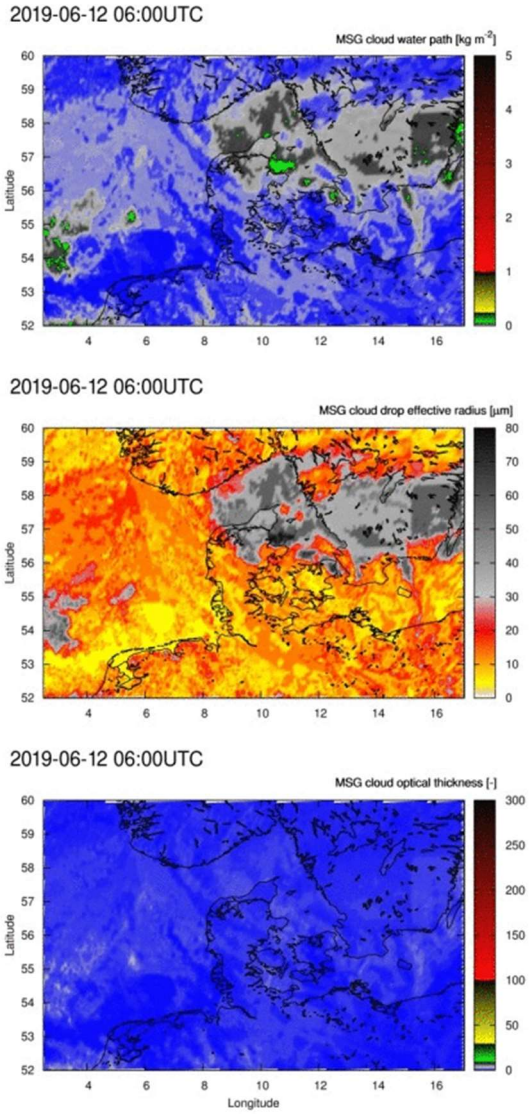






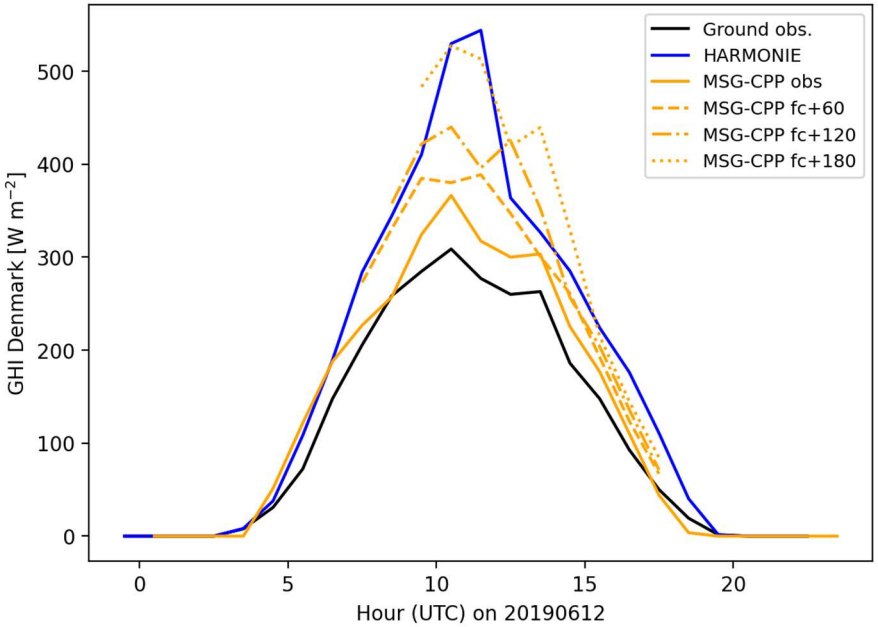
Wind power forecast (07 feb 2022 - 25 feb 2022) (Geert Smet, RMI)

Impact modelling - Renewable energy



Solar energy:

- We have both open data, data that can be shared with permission from owners, and data that cannot be shared
- Test case: Thunderstorms in June 2019 (MSG images shown left; Kristian P. Nielsen, DMI)



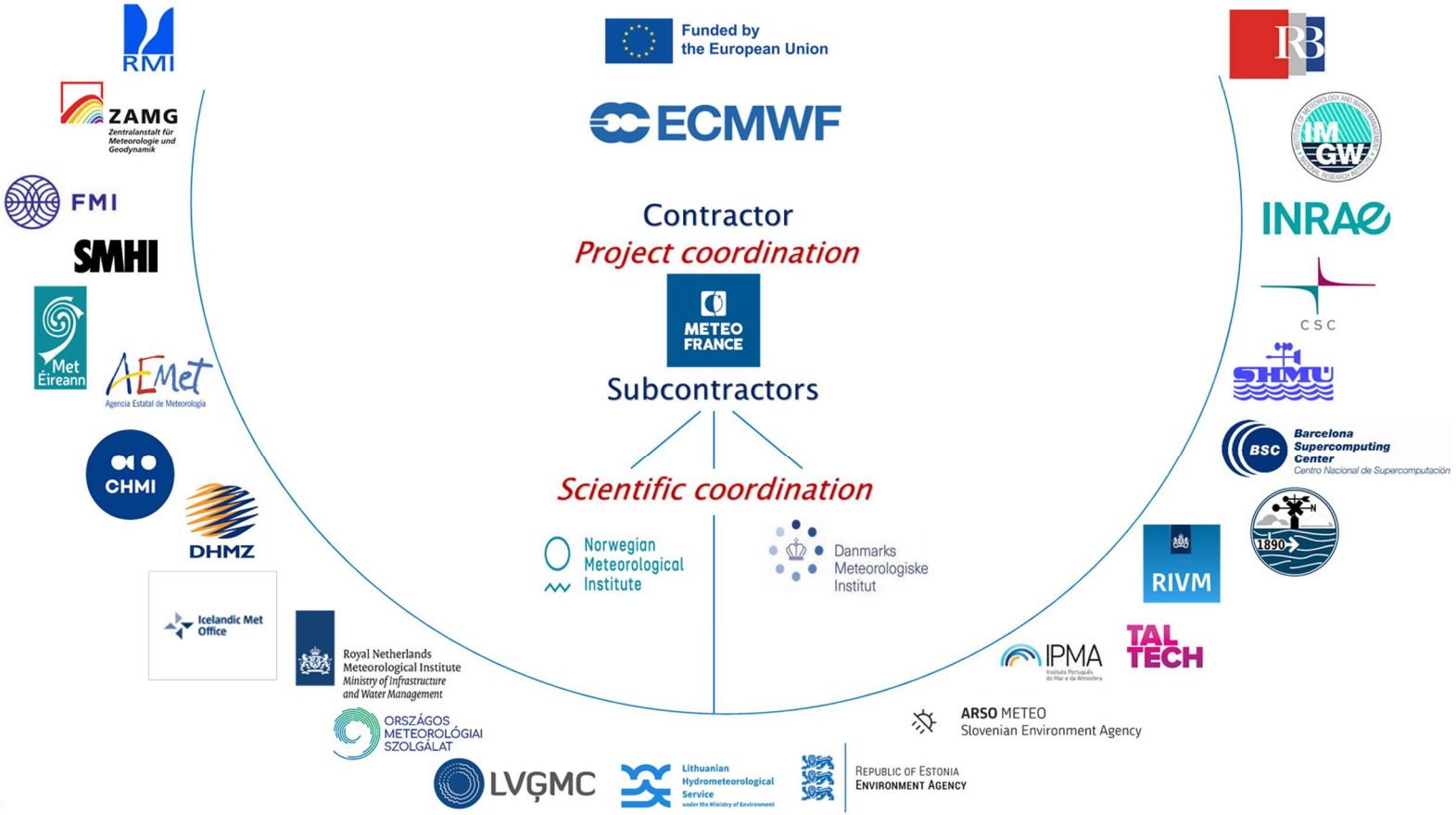
Forecast Global Horizontal Irradiance (GHI) over Denmark for 12 UTC, 12 June 2019 (Jan Fokke Meirink, KNMI)

Concluding remarks

- Continuous software implementation and profiling.
- Two cut-off observation harvesting and monitoring for data assimilation, verification and uncertainty estimation.
- Script system ready for testing at different sub km (200, 500, and 750m) resolution all the forecast components of the NWP.
- 3D ALARO CSC with radiation scheme and spectral transform codes running on GPU.
- Consolidated hydrology workflow adopted. While the sensitivity study of the models to the reference system was performed, that with the sub km datasets has started.
- AQ input and output data content agreed. Simulation with sub km datasets has started.
- A new wind farm parametrization added. This is essential to get the wind power right. Work is also ongoing on PV plants.

On behalf of all the On-Demand Extremes Team, …

Entities involved in DE_330



ECMWF Funded by the European Union

Thank you for you attention

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