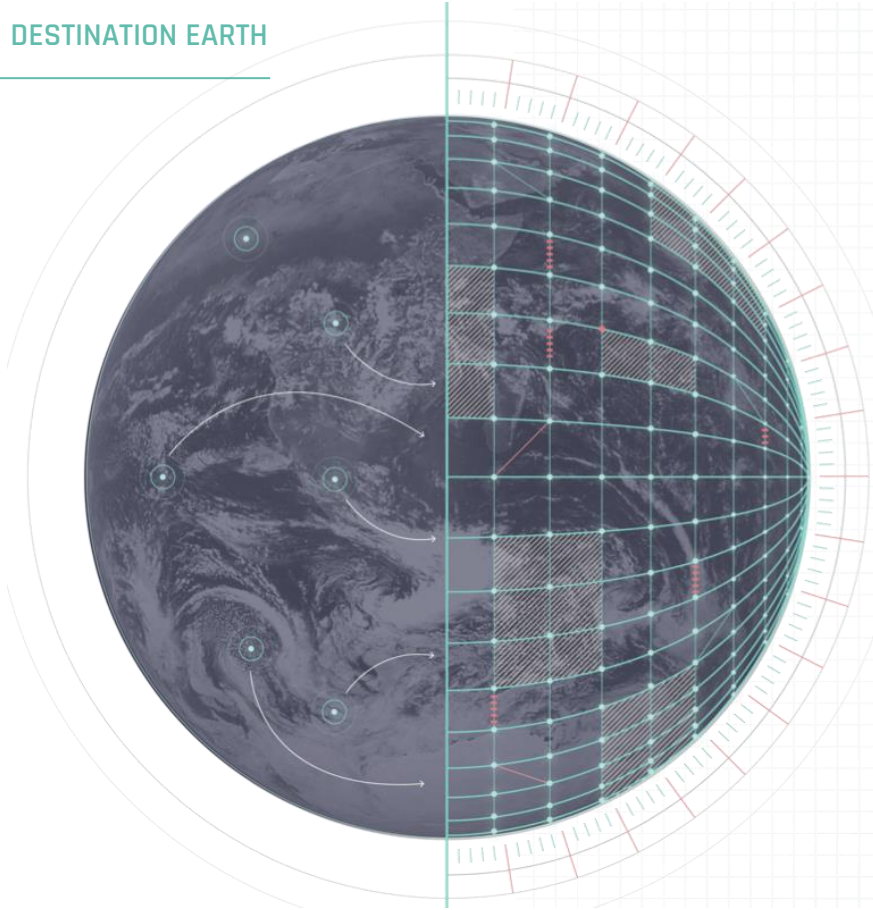


DESTINATION EARTH

Destination Earth On-Demand Extremes: Towards other extreme weather impacts

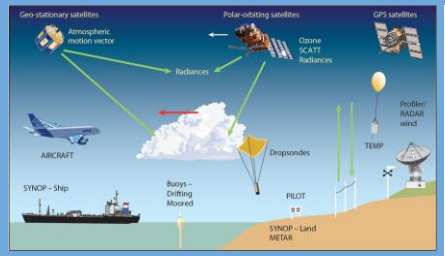
Kristian Horvath, DHMZ, Alexander Kann, Geosphere
&
The On-Demand Extremes Task 33044 Team

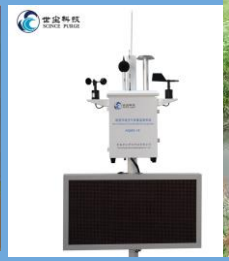
2nd Destination Earth User eXchange, 13 - 14 November 2023

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

Funded by the European Union

On-Demand Extremes workflow





Environmental observation processing and monitoring

Trigger: Statist. or AI-based extreme

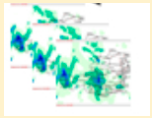
event detection

Quality control; machine learning; data assimilation

Global DT
Regional NWP

Triggered on-demand Hectometric-resolution digital twin

Analyses
Nowcasts
Forecasts



Post-processing:
Global DT
Regional NWP

Linear statistics
AI methods
Uncertainty estimation

EuroHPC

Key users

Hydrology
Air quality
Renewable energy

Civil protection
Marine/Road safety
Social impact

Other impacts:
Forest fire
Agriculture

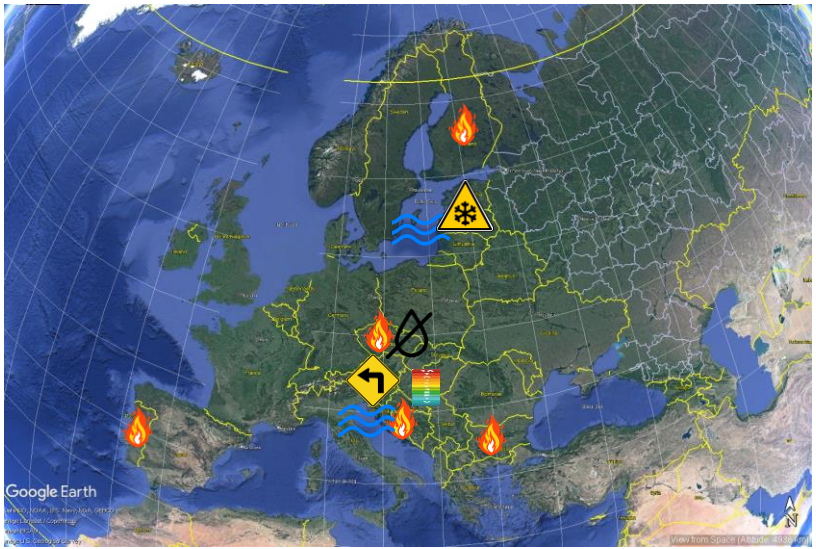
Test cases

Goal: develop user-oriented products (applications) & demonstrate capability and the added value of hyper-resolution NWP

Diversity of applications (8) and test cases, EU-wide

Applications initially set up in local computing environments and ECMWF HPC

Data preparation & demonstrations in progress (TRL)



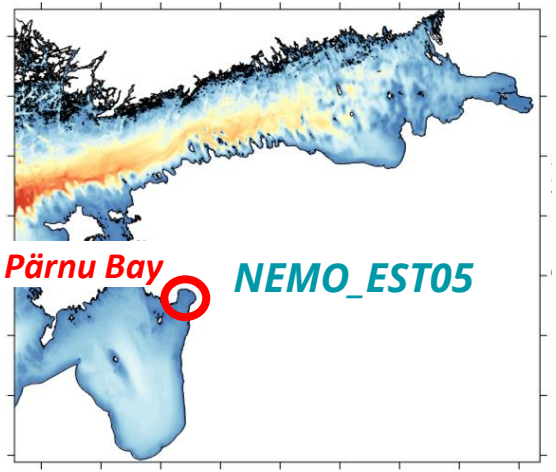
Type of event/application	Region	Test case period
Storm surge	Baltic Sea	10-25 October 2021
	Adriatic	June 2019 to December 2020
Waves	Baltic Sea	1 - 31 October 2021
	Adriatic	7 -20 November 2019, 1-31 December 2019
Road weather	Austria	9-10 March 2023
Wildfire	Portugal	14-17 October 2017
	Czech Republic	24 - 31 July 2022
	Bulgaria	3-4 August 2021
	Croatia	16-25 July 2017
	Finland+Global	mid-August 2023
Drought	Czech Republic	April to August 2018
Frost	Czech Republic	20 Mar - 31 May 2020
	Bulgaria	21-25 April 2017
Thermal stress	Croatia	21-23 July 2022
Freezing rain	Estonia	19-25 Feb 2021

Capability Demonstration: storm surge

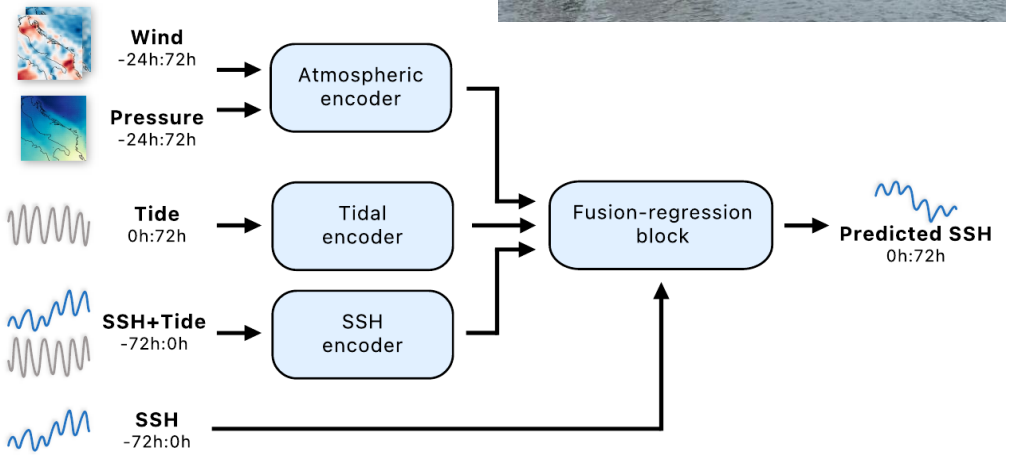
Joint test case in semi-enclosed Pärnu bay, Baltic, susceptible to storm surges

Focuses on the surge event that occurred during Oct 2021 and Oct 2023 raising water levels for up to 1.5 m:

- NEMO 4.0 hydrodynamical model
- HIDRA2 deep learning architecture



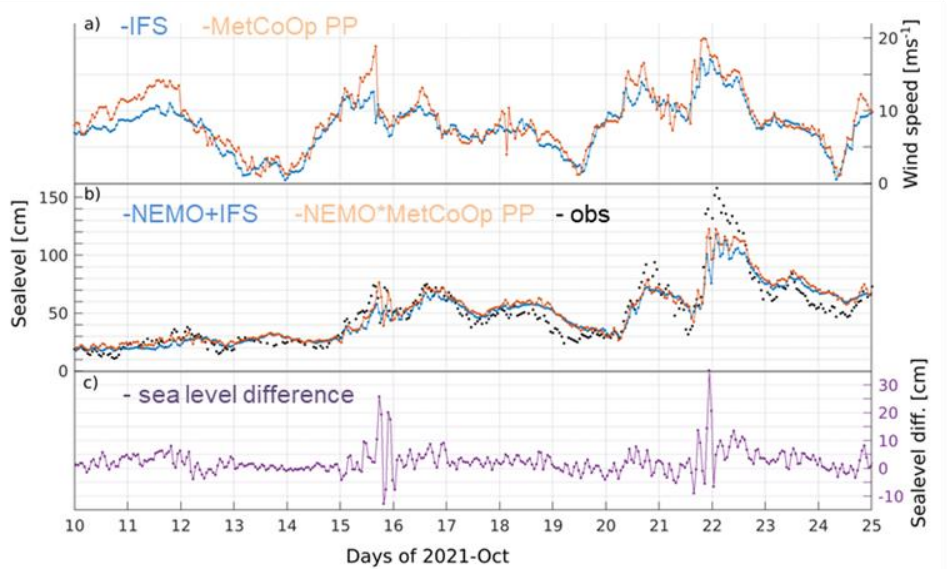
Regional downscaling of CMEMS BALMFC NRT
resolution: dx: ~1 km, 110 layers (dz~1m)
open boundary: BALMFC, NemoNordic2 (2 km)
meteorology: ECMWF IFS



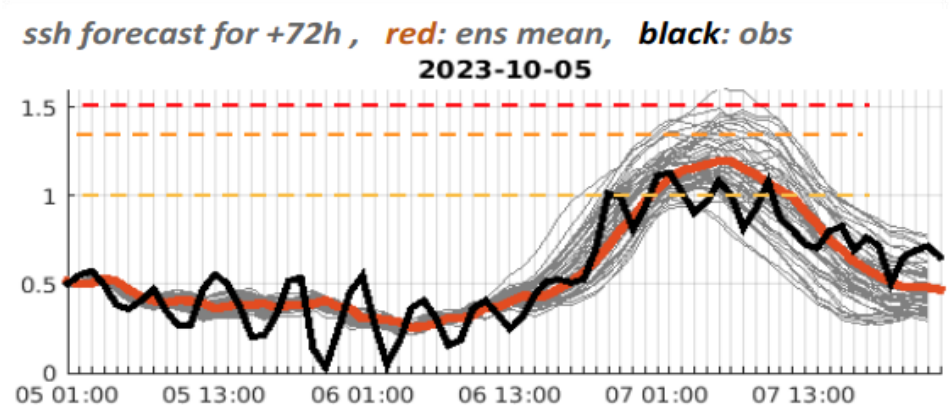
Spatial encoders are based on 2D and 1D convolutional layers.
Temporal encoders are based on 1D convolutional layers.
Details in GMD paper: https://gmd.copernicus.org/articles/16/271/2023/

Capability Demonstration: storm surge

Pärnu bay, Baltic (similar analysis exists for Adriatic)



	Overall				Storm surge events SSH > 100 cm			
	MAE (cm)	RMSE (cm)	Bias (cm)	Acc (%)	MAE (cm)	RMSE (cm)	Bias (cm)	Acc (%)
HIDRA2	3.5	4.8	0.2	95.3	9.5	11.7	-6.9	62.0



Notable difference up to 30 cm in experiments using NEMO with IFS and MetCoOP post-processed data

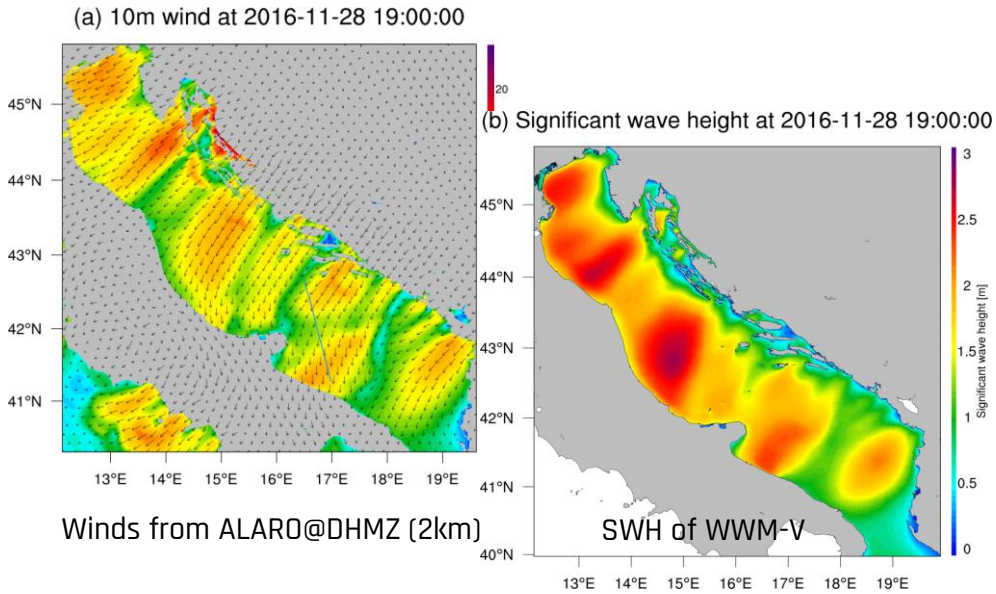
Very promising results of ML (neural network) approach with RMSE on the order of 10 cm for storm surge over 100 cm

Capability Demonstration: waves

Wave test case in the Adriatic Sea

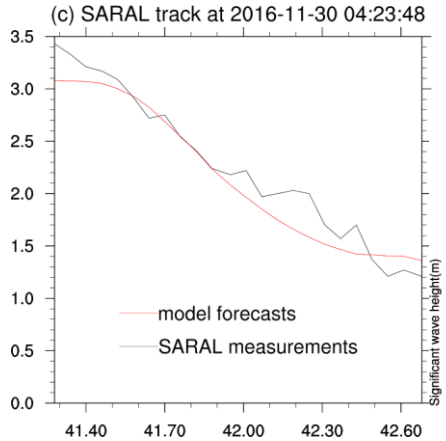
Major waves arise from strong cross-mountain downslope hurricane scale windstorms and along basin sirocco winds

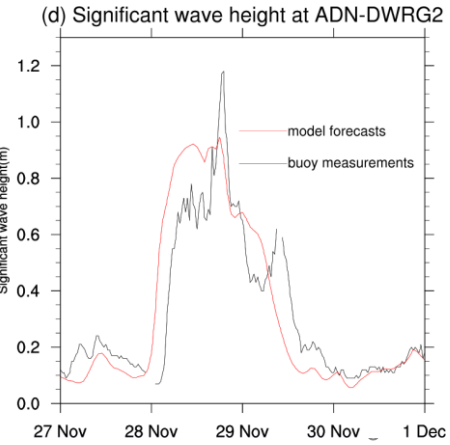
WWM-V unstructured wave model (being extended to Wave Watch III)



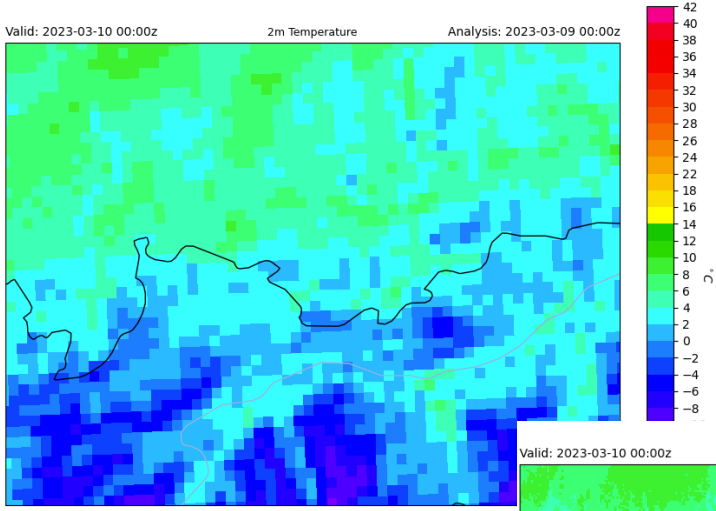
Winds from ALARO@DHMZ (2km)

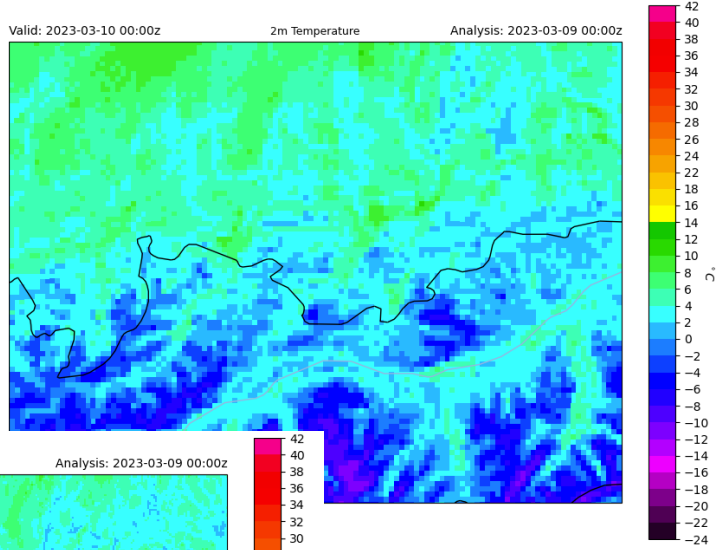
SWH of WWM-V

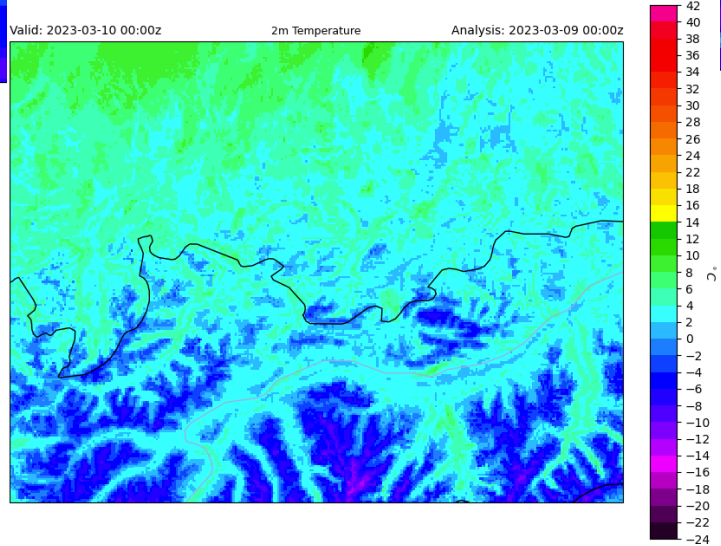




Capability Demonstration: road weather





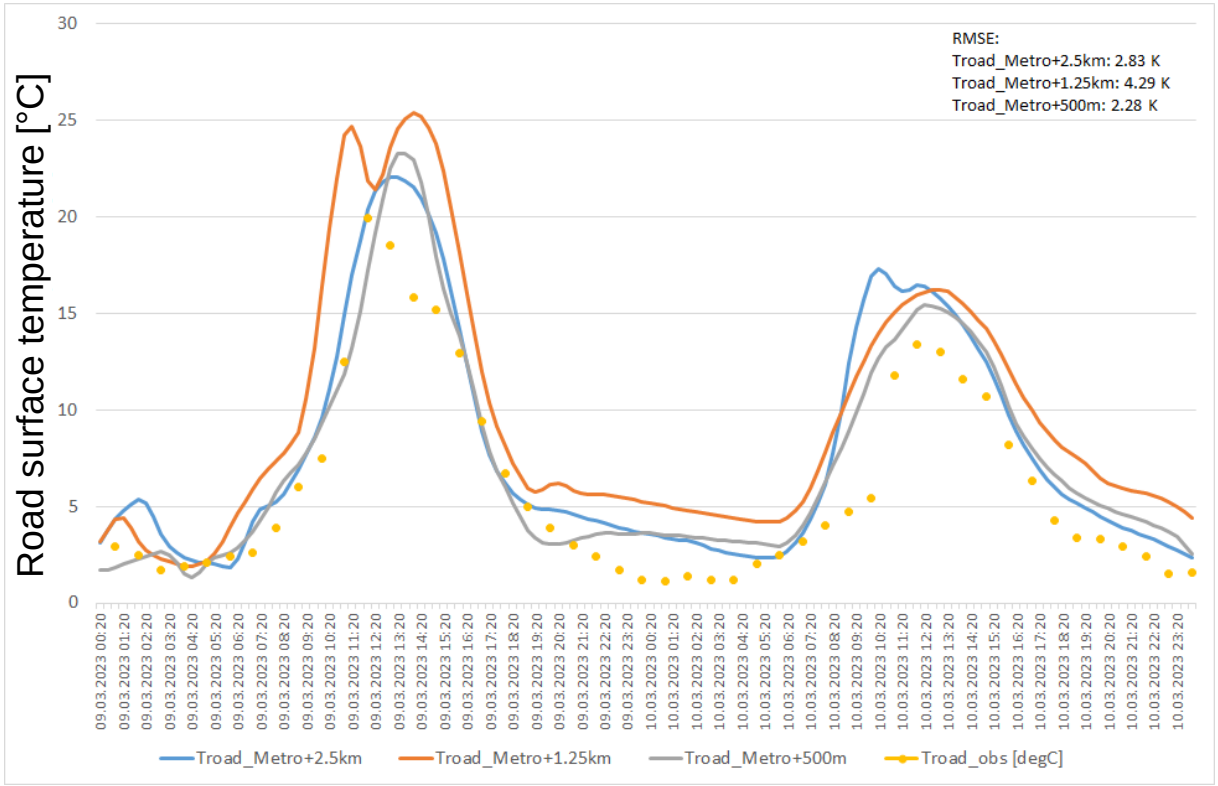


Road weather test case
9./10.3.2023 Inn Valley, Austria

- METRo road weather forecast software (road conditions)
- Requires road structure and condition, the atmospheric forcing and observation data at the respective location

AROME configs on 2.5km vs 1.25km vs 500m, zoomed over Inn Valley

Capability Demonstration: road weather



Model	RMSE T_{road}
AROME 2.5 km	2.83 K
AROME 500 m	2.28 K (20% lower)

METRo road surface temperature forecast, initialized at 9.3.2023, 0000 UTC, with atmospheric forcing from the 3 different AROME configurations. Yellow dots denote observed values.

Capability Demonstration: fire weather

Test cases: Portugal, Croatia, Bulgaria, Czech Republic, Finland

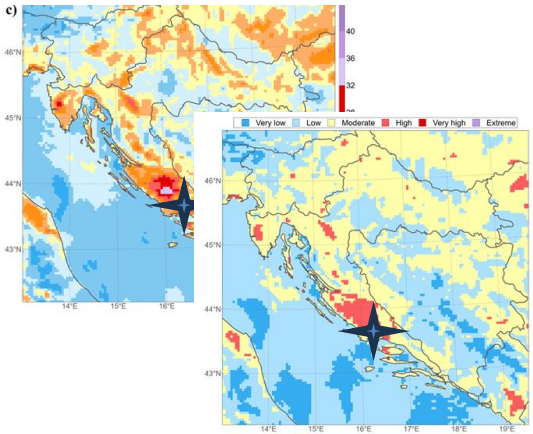
Analysis includes a series of indexes: FWI, FFMC, ISI, HDW, CHI, HI, API30 – selection in on-demand context, importance of droughts and instabilities - assessment of fire intensity/danger, but also management (combat) of forest fires incl. fire plume dispersion

Portugal: 15 October 2017, extreme weather, droughts, burned 300 kha including urban areas

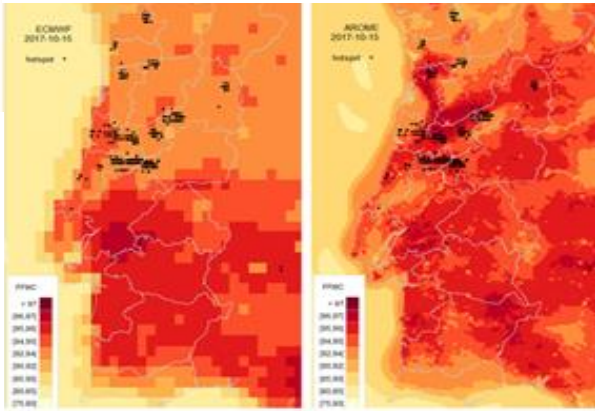
Czech Republic: 24 July 2022, large fire in the norther part of the country

Croatia: 9 days lasting fire reached 4 km from the centre of Split, 2nd largest city

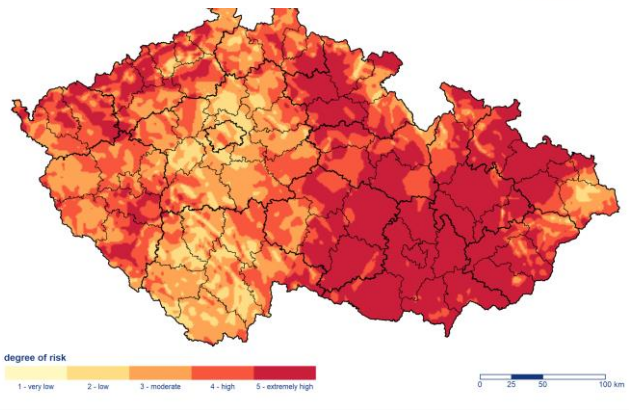
FWI, fire danger class (ALARO4km)



FFMC ECMWF 0.125 AROME 2.5 km



Fire risk ALARO1km



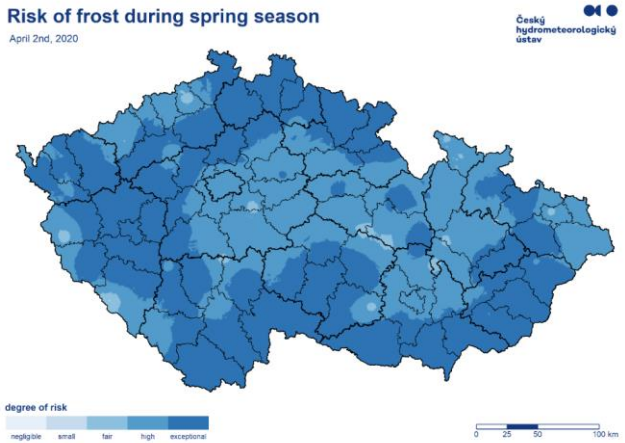
The black points are geolocalization of FRP (Fire Radiative Power, from LSA SAF) from 11 to 14 UTC of the same day

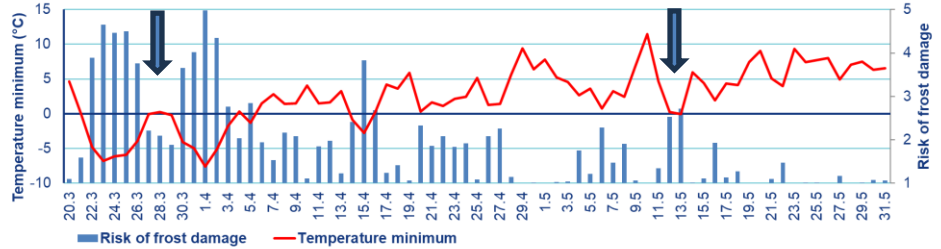
Capability Demonstration: frost

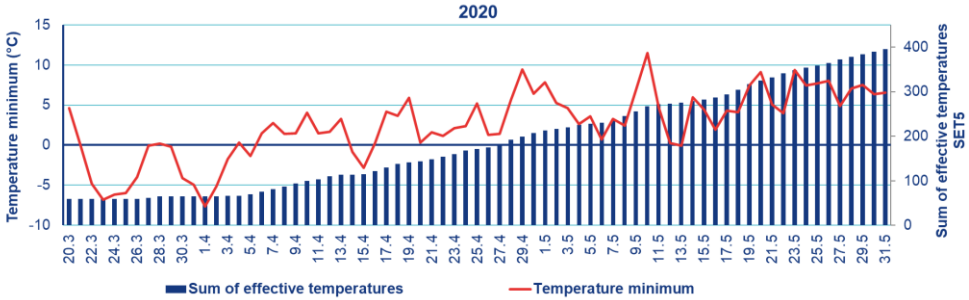
Spring frost test cases: Czech Republic, Bulgaria

Czech Republic, spring frost 2020

- 5-degree scale of frost index
- Inputs: max/min temperature, sum of effective temperature > 5°C, its deviation from the long-term normal (1991-2020), day of the year number (measures of the degree of development of the growing season)





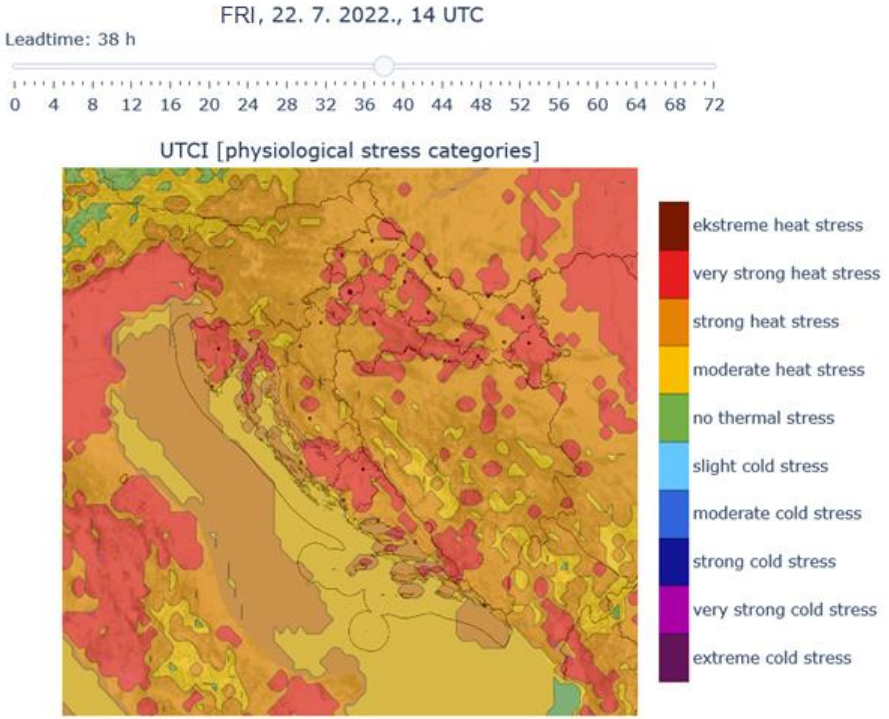


- A more accurate expression of the risk of frost to the vegetation as compared to the simple monitoring of the Tmin
- E.g. the frost risk on 13/05/2020 is higher than on 28/03/2020 due to the more advanced stage of the growing season
- Comparison with other methods and damage databases in progress

Capability Demonstration: thermal comfort/health

Thermal comfort/health test case in Croatia in July 2022

- Universal Thermal Climate Index (UTCI) to evaluate thermal stress of human body in given meteorological environment
- In context of extremes, useful information during heat waves, cold waves and strong wind events
- UTCI values in °C, interpreted in categories of physiological stress
- Appropriate for all assessments of the outdoor thermal conditions: daily forecasts, warnings of extreme weather bioclimatic mapping, urban and regional planning, environmental epidemiology, climate impact
- Compared with PET and TCI
- Largest importance in cities - will be tested on urban (Paris) use case with hyperresolution NWP data



T, RH, wind, radiation from ALARO@DHMZ (4km)

Outlooks and next steps

- A range of applications is being demonstrated using numerical models and various methods, including deep learning, and tested with differing sources of NWP data, including IFS, national LAM products, METCOOP ensembles and hyperresolution grid spacing NWP
- Continue enhancing applications and demonstrating the impact & added-value of hyperresolution NWP model data, including postprocessing and uncertainty estimates
- Demonstrate EU-wide applicability, intensify integration of work per each application (common test area, comparison of methods, working out on-demand strategies etc.)
- Strenghten co-development and feedback from end-users and others involved in full-value chain to make these applications more suitable for decision-making
- Integrate into DT workflow

ECMWF

Funded by
the European Union

Thanks for your attention

Post-processing framework & other extreme weather impacts

Postprocessing framework (WP4)

Task 1: Framework for probabilistic, seamless forecasts (incl. optimization of NWP direct model output, seamless, probabilistic, on hyper-resolution, for various high impact parameters).

Task 2: Statistical / AI-based post-processing methods with special emphasize on uncertainty estimation, for various parameters).

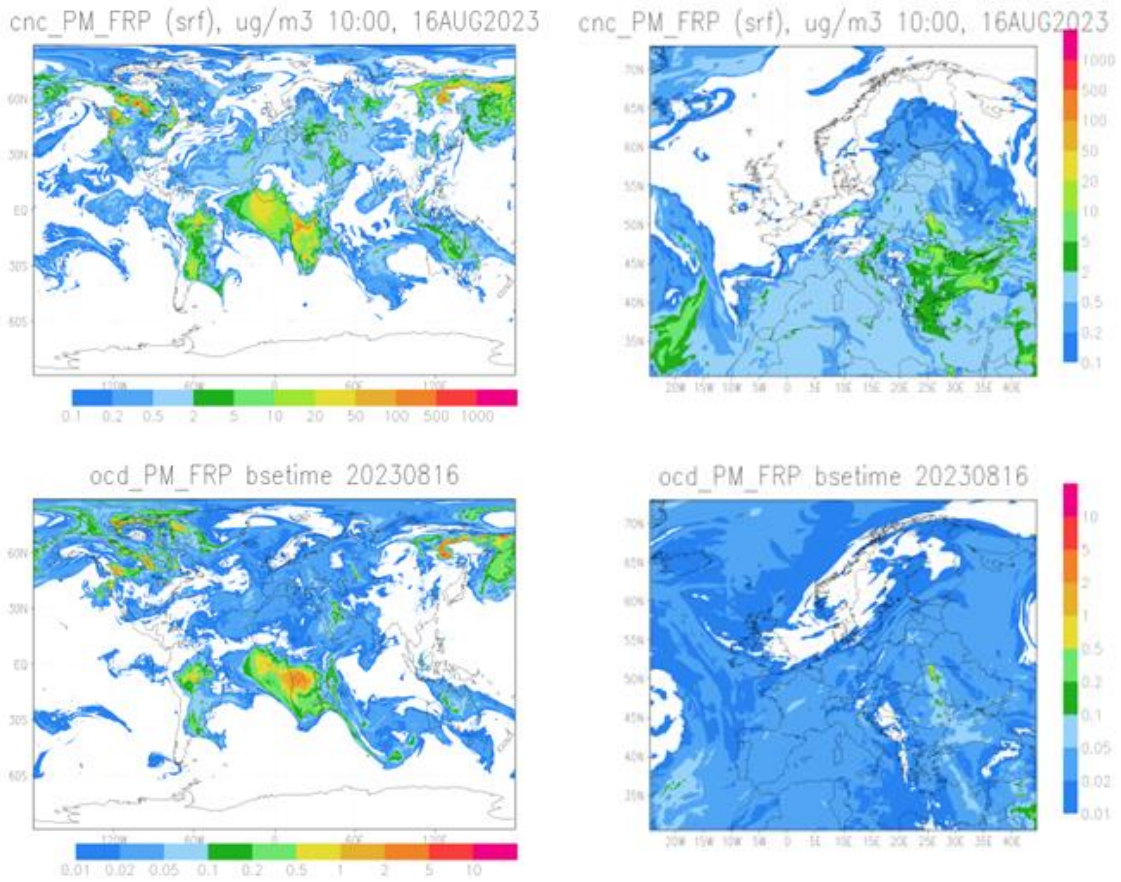
Task 3: Extreme event detection (automatic, AI-based detection to trigger on-demand system).

Task 4: Exploitation of Post-Processing framework for key users / applications (Civil Protection, Marine Safety, additional demo applications)

- ➢ Development & Demonstration of end-user applications
  - User-tailored products: storm surge, wave, road weather, forest fire, frost, droughts, thermal comfort, freezing rain
  - Exploring and evaluating the added value of hyper-resolution DT on behalf of extreme events

Capability Demonstration: fire weather

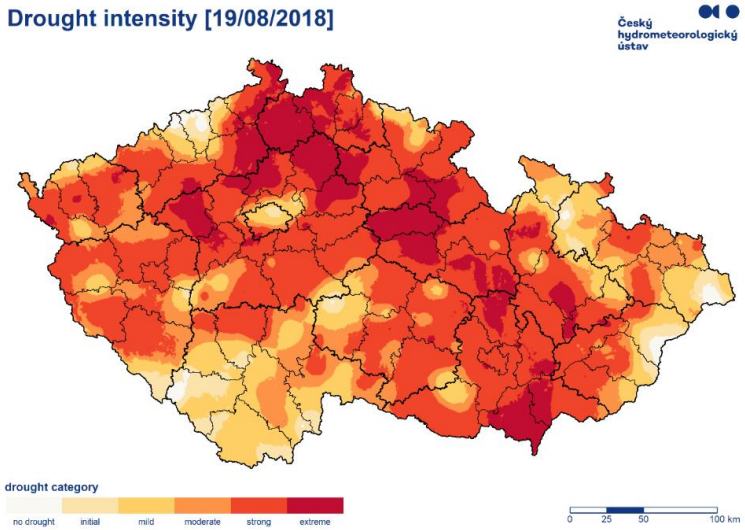
- Fire smoke dispersion evaluated globally for mid-Aug 2023, strong fires worldwide
- SILAM-IS4FIRES model for fire smoke distribution, calculates optical depth and surface concentrations
- Input data for the forecast comes from the MODIS Fire Radiative Power near-real-time observations &ECMWF IFS
- The distribution patterns of fires and fire smoke are highly inhomogeneous, with the smoke plumes travelling over large distances still staying comparatively narrow → need for VHR inputs



Capability Demonstration: drought

Drought test case in Czech Republic in 2018

- 6-degree scale of drought index
- A more accurate expression of the drought distribution compared to sole usage of precipitation deficits
- Drought/wetness factor determined using API30 along with current seven-day air temperature data
- Comparison with soil moisture and other methods and damage databases in progress



Based on observations

Capability Demonstration: freezing rain

Freezing rain test case in Estonia in July 2022

- Slipery roads resulted in a large number of accidents and significant damage
- Common with snow falling into an elevated layer of air that is warmer than 0˚C with a sub-freezing layer below

Modelling experiments:

- METCOOP25D 2.5 km grid spacing
- EST_HR1 AROME configuration 500 m grid spacing

Subtle but important differences include depth and spatial coverage of the warm layer, which is being investigated further