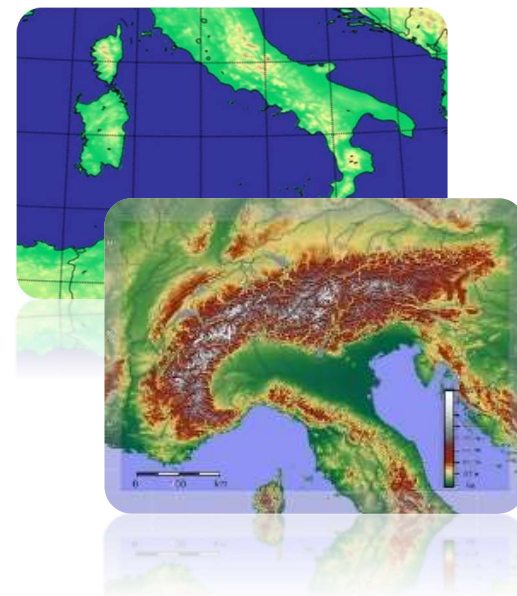




The GLORI project

Chiara Marsigli

Deutscher Wetterdienst
Arpae Emilia-Romagna



Chiara Marsigli, Roland Potthast, Michael Kreyer, Daniela Littmann, Zahra Parsakhoo, Xu Xu, Pier Paolo Alberoni, Harald Anlauf, Christoph Appenzeller, Hartwig Anzt, Marco Arpagaus, Carlo Cacciamani, Terry Cojean, Bas Crezee, Katrin Ehlert, Oliver Fuhrer, Vanessa Fundel, Thomas Gastaldo, Christoph Gebhardt, Fabian Gessler, Dominic Hofer, Stefanie Hollborn, Thomas Hüther, Gholamali Hoshyaripour, Marek Jacob, Jan Keller, Julia Keller, Stefan Kollet, Xavier Lapillonne, David Leutwyler, Alberto del Lozar, Paola Mercogliano, Claire Merker, Carlos Osuna, Virginia Poli, Adriano Raspanti, Daniel Regenass, Pasquale Schiano, Linda Schlemmer, Christoph Schraff, Jan-Peter Schulz, Klaus Stefan, Thorsten Steinert, Arianna Valmassoi, Antonio Vocino, Bernhard Vogel, Claudia Volosciuk, Günther Zängl

GLORI Partners and HPC system



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra



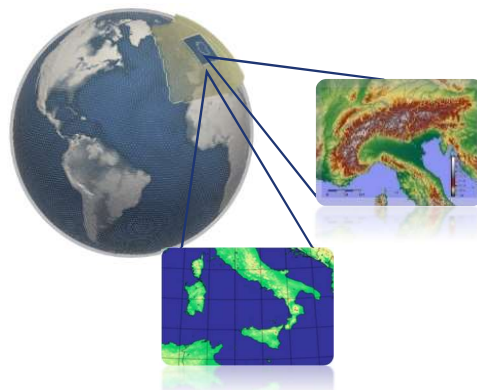
CSCS



Deutscher Wetterdienst
Wetter und Klima aus einer Hand

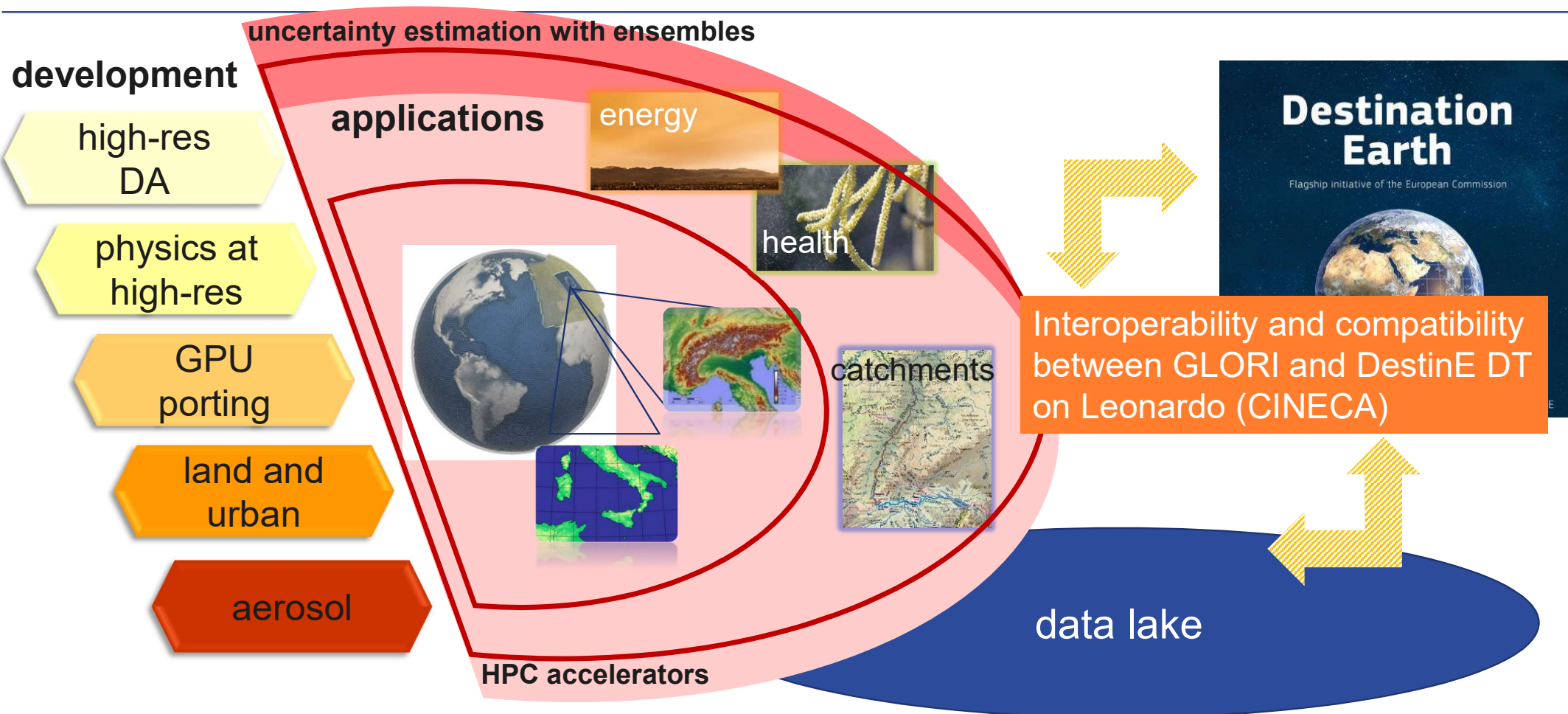


Karlsruhe Institute of Technology



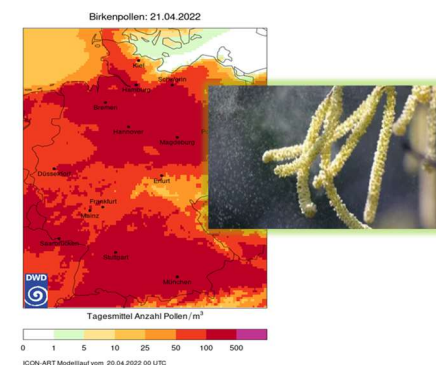
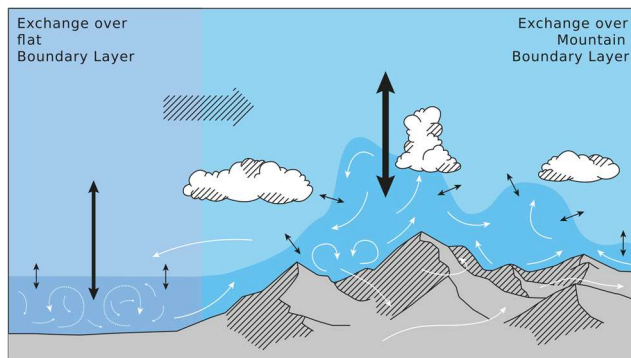
Centro Euro-Mediterraneo
sui Cambiamenti Climatici



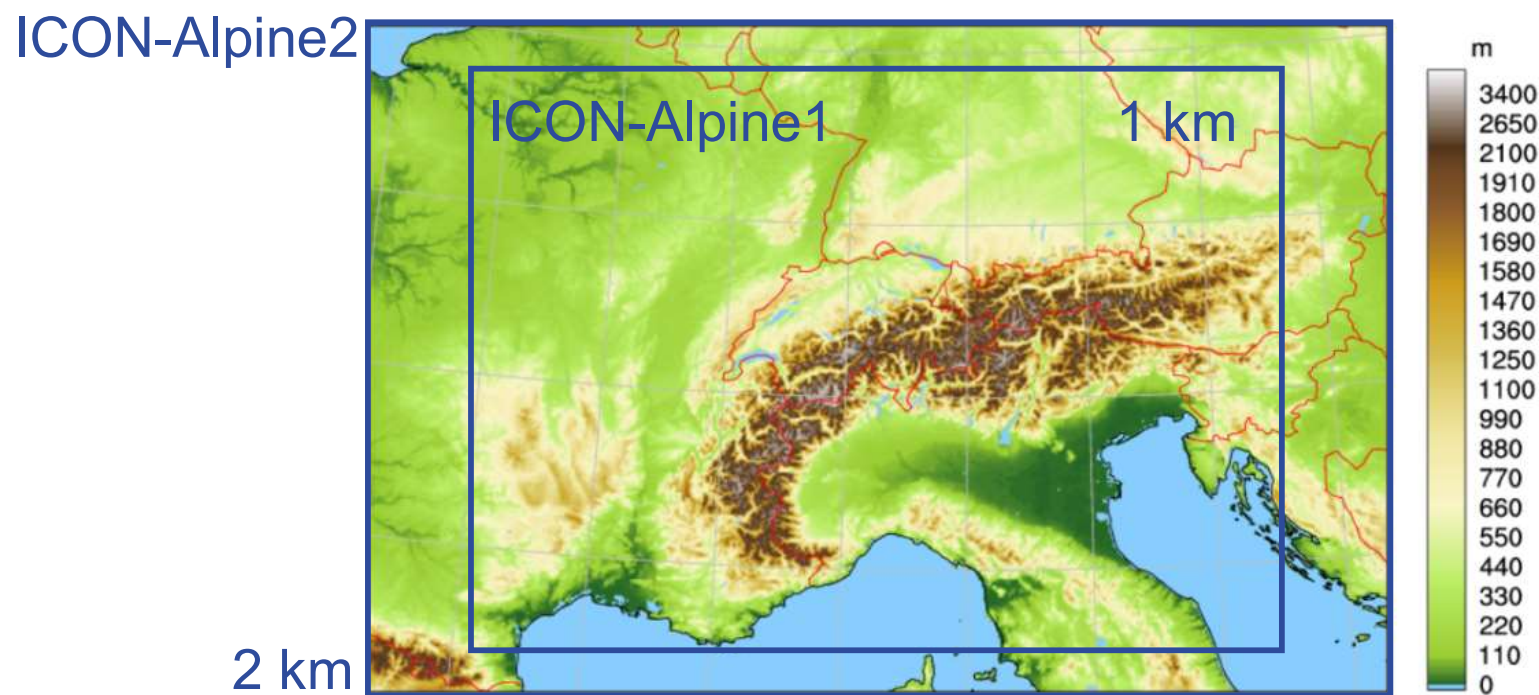


GLORI use cases

- TEAMx: Alpine Twin configuration to provide forecasts for the mission planning of TEAMx
- Floods -> on selected catchments, hydrological models where available at the partners
- Pollen (health) -> thunderstorm asthma (KIT)
- Mineral dust (energy) (KIT)
- Urban Heat Island -> COSMO Priority Project CITTA'
- Urban flooding (CMCC)
- Research (e.g. demonstrate the improved physics)



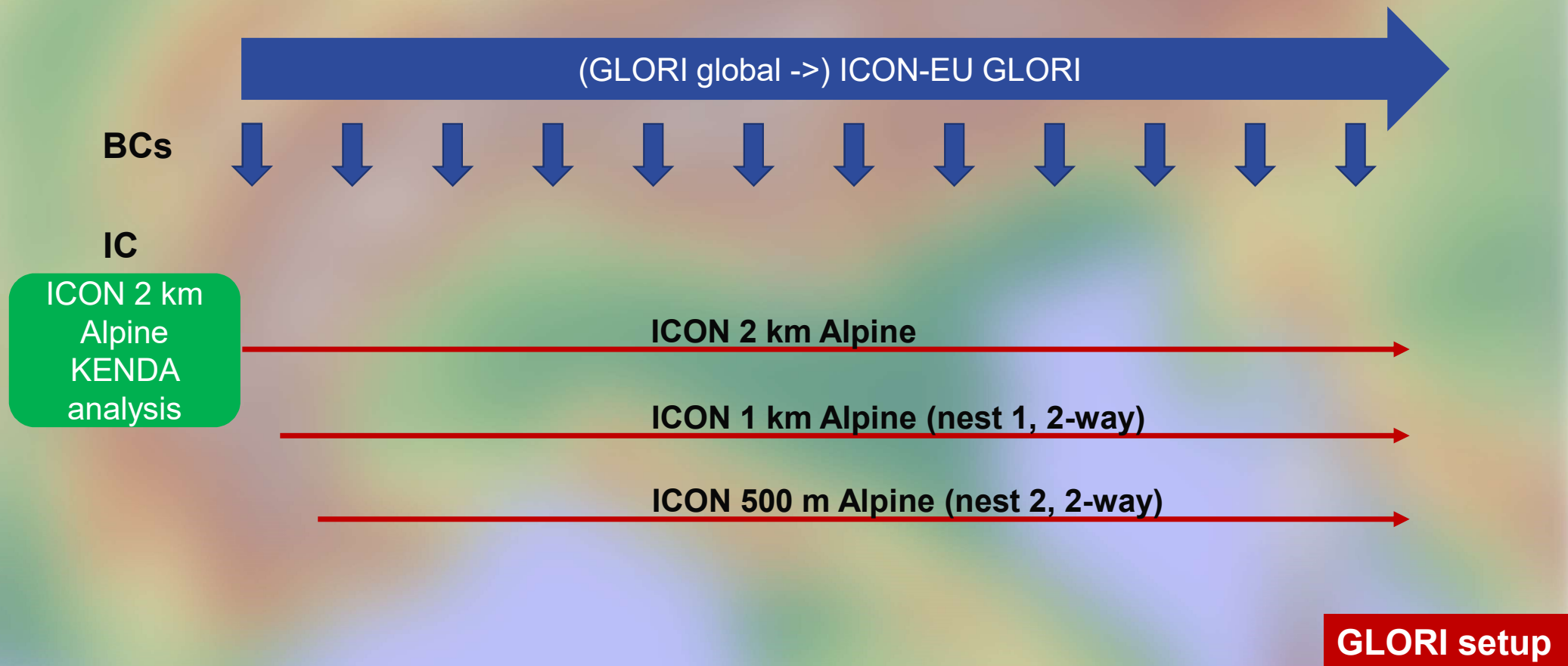
Alpine Twin Setup



Geometric height of the earth surface above msl [m] © MeteoSwiss

Daniela Littmann, DWD

Alpine Twin Setup



GLORI-Alps on HoreKa

- HoreKa is a hybrid CPU-GPU cluster managed by SCC at KIT
- Target machine for global DT and GLORI-Alps

Infrastructure

- Integration will strengthen KIT's contribution to ICON consortium
 - Buildbot implementation providing ART and GPU tests
 - Computing resources for GLORI-DT
- Contributes to sustainable software development

GPU port of ICON-ART

- ICON GPU port does not fully cover GLORI application yet
 - Health application: pollen (port recently completed)
 - Energy application: mineral dust (to be ported within GLORI)
- GPU port is also relevant for GLORI-Med on Leonardo (CPU+GPU) and other heterogeneous target clusters in the future



<https://www.scc.kit.edu/dienste/horeka.php>

Michael Kray, DWD, KIT

Implementation on HoreKa

- **Global-to-Regional ICON – Implementing the Alpine Digital Twin on HoreKa**

- ❖ DWD global operational configuration
- ❖ Test global high resolution
- ❖ LAM: Alpine Domain CH2, nest CH1

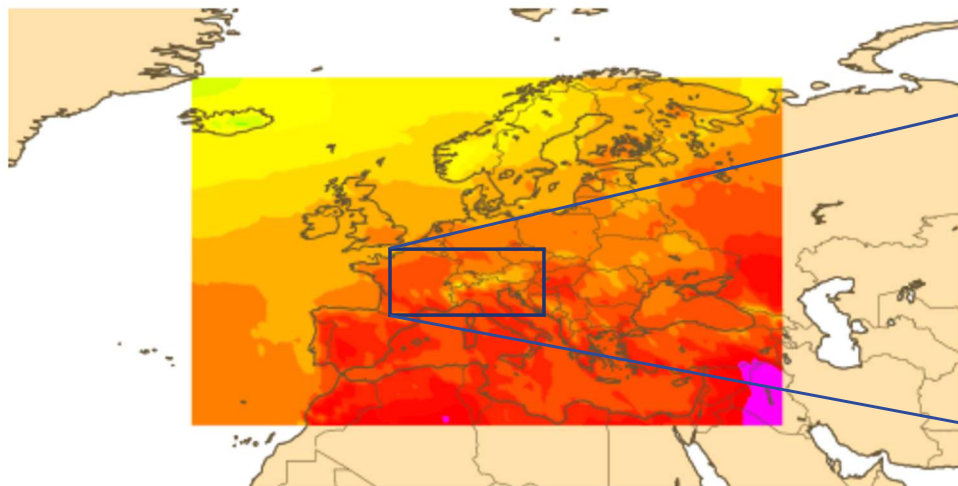
- 13.6 mill CPUh
- 50000 GPUh
- *Operational 1-month ICON ASS & MAIN*
- *3-day high resolution ICON-nwp test*
- *3-day ICON-LAM D2 ASS*
- *3-day ICON-LAM CH2 ASS*

Xu Xu, DWD

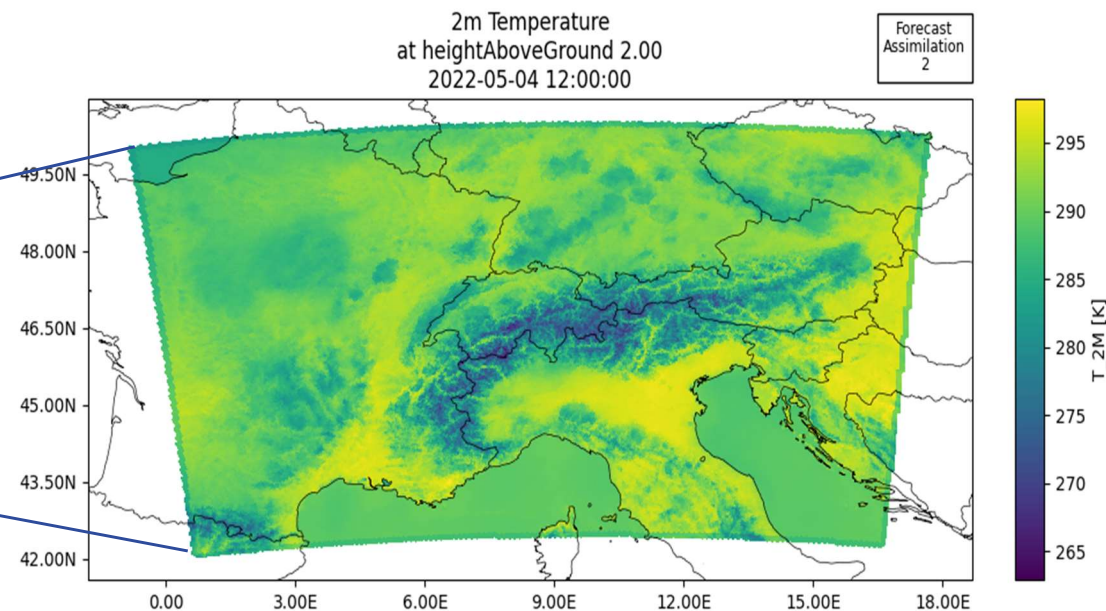


Implementation on HoreKa

Alpine Domain CH2



EU
6.5 km
74 levels



CH2 (1000)
2km / 1km
65 levels

Xu Xu, DWD

Ensemble forecasts with model perturbations

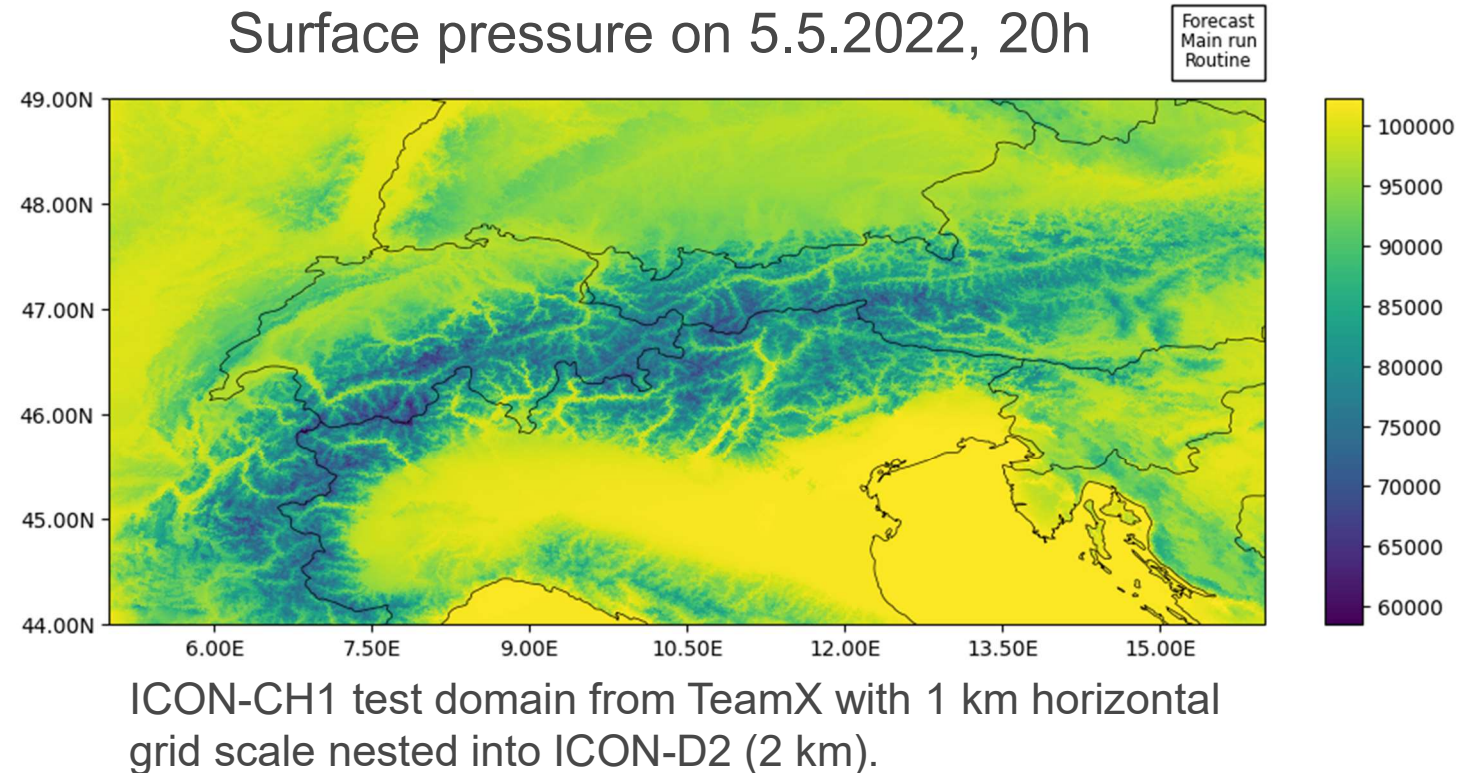
- ➔ High resolution ensemble over Alpine region with the focus on land-surface and atmosphere interaction
- ➔ 24h forecast with 20/10 ensemble members, 2km and 1km
- ➔ Developement of model perturbations
 - Perturbation of surface parameters
 - SPP
- ➔ Improvement of hydrology (sub)processes:
 - ParFlow (offline, and/or coupled)
- ➔ Test the coupling of TERRA and ParFlow

Zahra Parsakhoo, DWD



Model physics experiments - Hindcast

Model top	22 km
Vertical level	65 full (66 half)
Hor. grid scale	2 km, 1 km
LATBC	Analysis (ICON-EU)
2-way-Nesting	
Model version 2.6.6 (currently)	
SGS orographic drag	Lott and Miller scheme (COSMO)
Microphysics	2-momentum
Turbulence	TURBDIFF
Surface Transfer	TURBTRAN
Land	TERRA



Daniela Littmann, DWD

Model physics experiments - Hindcast

Horizontal shear term (TKE source term):

$$q_{sh} = \underbrace{l_h^2 \sqrt{C^3 \alpha_m}} \left[\sqrt{\hat{q}_{ij}^2 + \hat{q}_{ij-}^2 + c_1^2 \hat{q}_{ij+}^2} - c_1 \hat{q}_{ij+} \right]^3$$

$$C = 0.5$$
$$\alpha_m = 16.6$$

$$l_h = \frac{\alpha_{hs} \Delta x}{Ri^{2/3}} f(q^2)$$

$$\hat{q}_{ij} = (\partial_j \hat{u}_i + \partial_i \hat{u}_j)$$

$$\hat{q}_{ij-} = (\partial_i \hat{u}_i - \partial_j \hat{u}_j)$$

$$\hat{q}_{ij+} = (\partial_i \hat{u}_i + \partial_j \hat{u}_j)$$

Symbols:

C Stability factor

α_m Momentum variance factor

α_{hs} Length scale factor for hori. shear

l_h Effective horizontal length scale

Δx Horizontal grid spacing

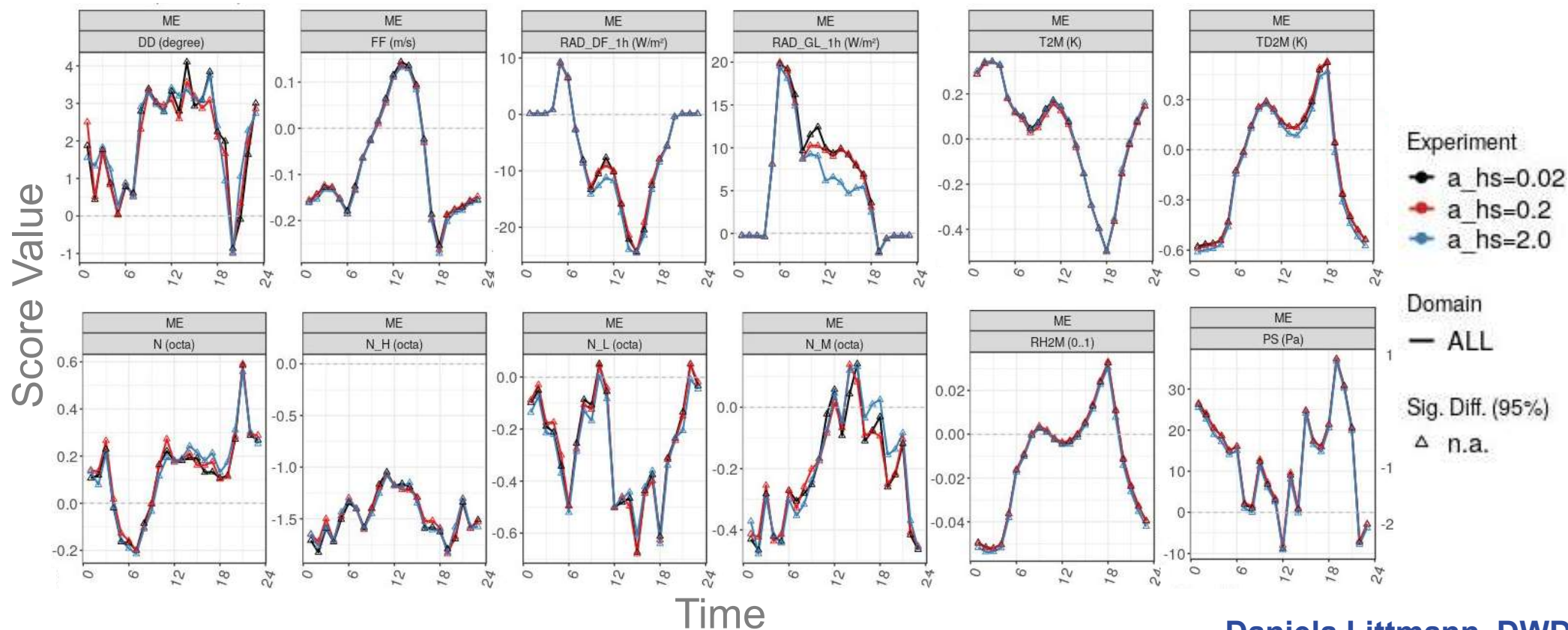
Ri Gradient Richardson number

$f(q^2)$ TKE correction function

Daniela Littmann, DWD

Model physics experiments - Hindcast

May 2022 – ICON-CH1



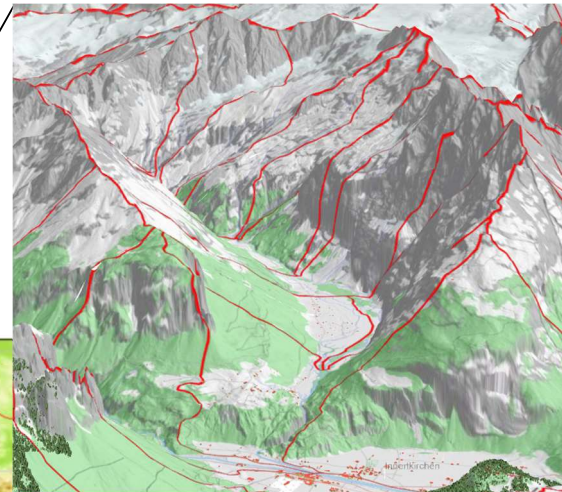
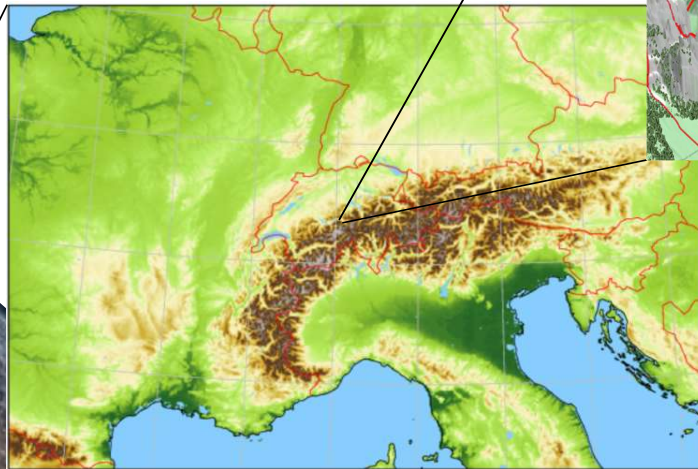
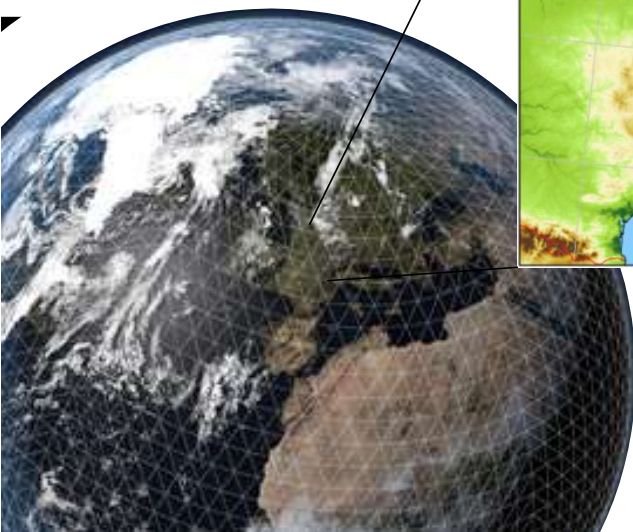
Daniela Littmann, DWD



Global to Regional ICON Alpine Twin

End-to-end pilot applications

- Flood forecasting (e.g., BAFU)
- TEAMx

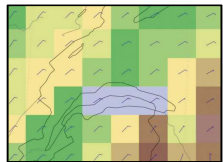


Ürbachtal (SwissTopo)
2 km² catchments (red contours)
ICON-CH1-EPS: $\Delta z=925\text{m}$
SwissTopo terrain: $\Delta z=1900\text{ m}$

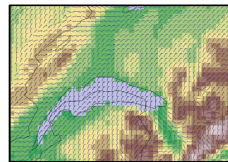




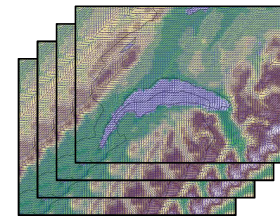
GLORI-A Timeline



Project Start



Technical demonstration
First prototype
 $\Delta x = 0.5 \text{ km}$



Technology Integration
Demonstration with
external application

2022

2023

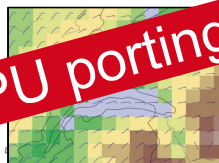
2024

2025

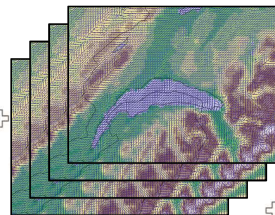
2026

GPU Porting
Setup on Balfrin (A100)
Model ready

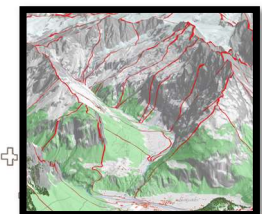
GPU porting done



Improved quality
 $\Delta x = 500 \text{ m}$
TEAMx



End-to-end workflow
for one external user



MeteoSchweiz

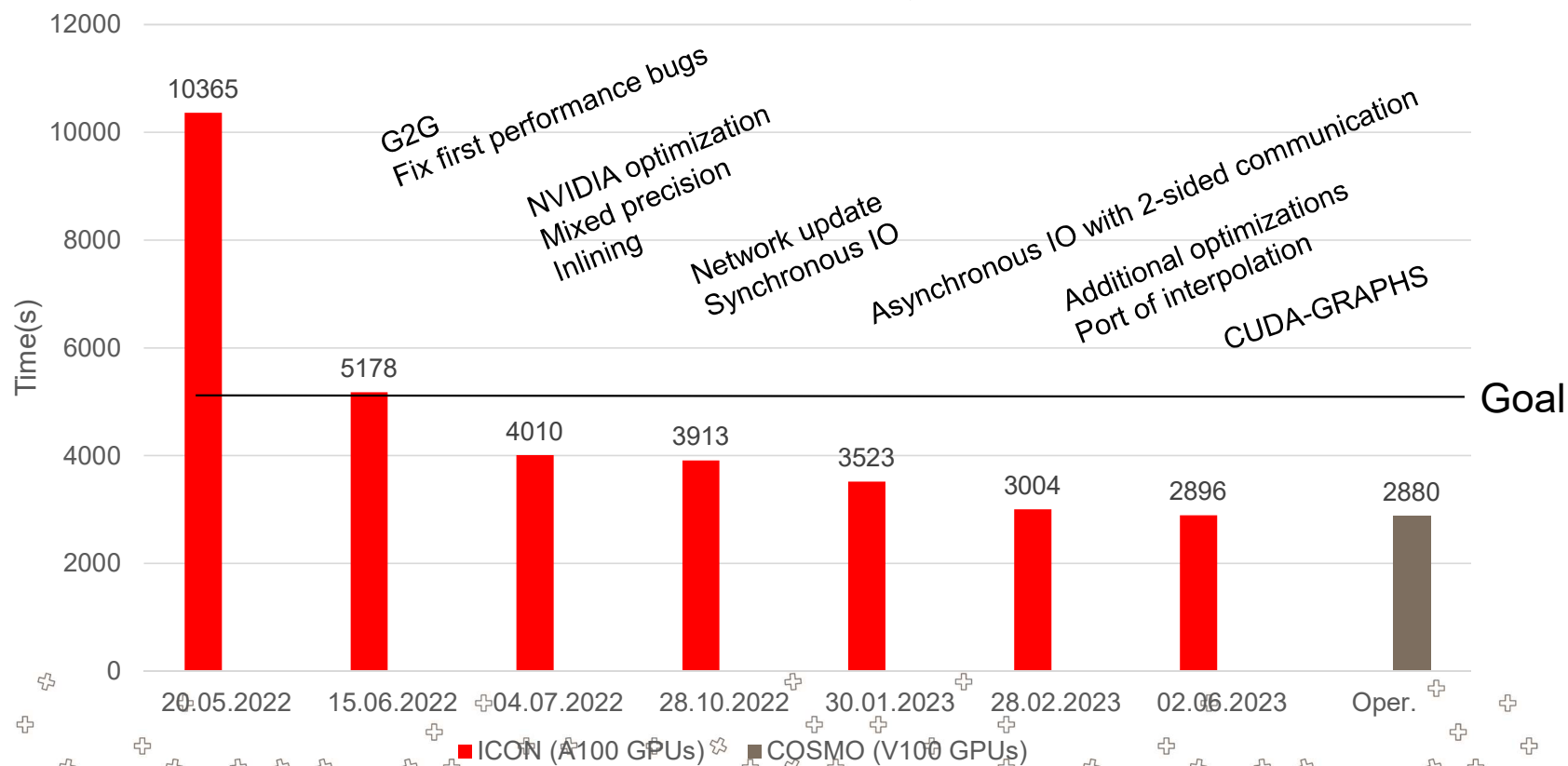
© Ort, Datum Autor/in

15



ICON Performance Improvements

ICON-CH1-EPS on ALPS, +33h with 8 GPUs



1 year of work in collaboration with CSCS & NVIDIA: Factor 3x speedup!



Work in progress: On-demand interface and workflow

Activities Firefox Web Browser Lab-VM Ubuntu 22.04 MCHv5 on ZUelt0221

GLORI-A ImageShack - Deleted ph

file:///home/davide/tmp/DT_interface_website/mockup.html 90% Search

GLORI-A

Initial Date: 09/06/2023 Time: 00:00

Forecast Range: 22h

Spatial Resolution: 500 m nested

Geographical Location: Greater Alpine Region

No. of ensemble members in KENDA (not yet available): 40

No. Ensemble Members of Forecast: 11

Lateral Boundary Conditions: ECMWF

HPC Cluster: Balfrin

Start

Starting forecast on Balfrin cluster...

Data from global simulation available at [s3://www.cscs.ch/data/s3bucket/fwe9z43fswdgarh1e](https://www.cscs.ch/data/s3bucket/fwe9z43fswdgarh1e)

Starting postprocessing...

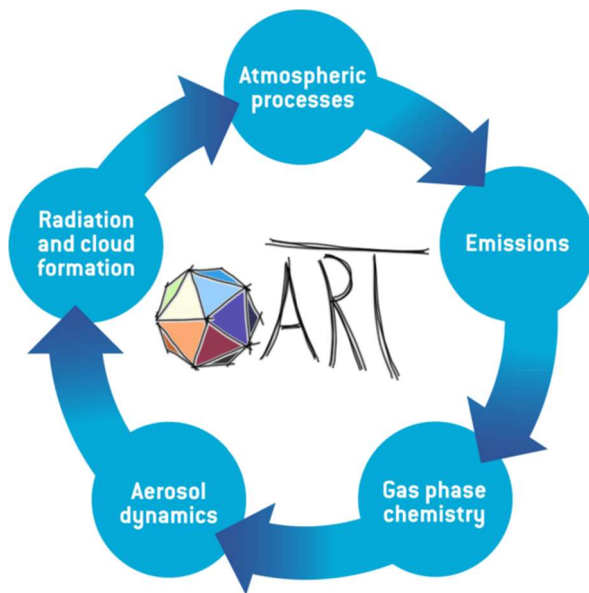
Postprocessed data available at <https://imageshack.com/f/poc47wJp>

GLORI in Italy

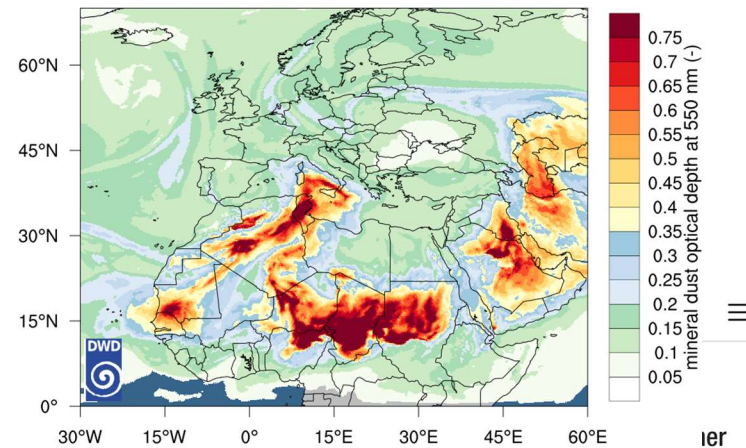
- Data availability and data collection
 - radar reflectivity volumes (Arpae)
- Implementation of GLORI on Leonardo will start soon at Arpae
- Project extension between DestinE and CINECA
 - GLORI Alpine
 - GLORI Med, regional coupled model setup at CMCC
- First flood cases:
 - Emilia-Romagna flood, May 2023, ICON 2km and 1km + hydrological model
 - Flood in Piedmont, 2-3 October 2020
 - Flood in Liguria, 4 October 2021
 - Flood in Marche, 15 September 2022

Dust and pollen forecast for energy and health

ICON-ART



exp_10517, r2b07 Wed., 20220420, 18:00 UTC



Aerosol-Forscher erklärt die neue Saharastaub-Wolke

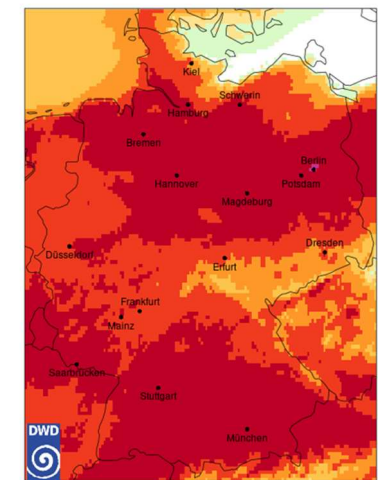
Der Karlsruher Forscher Ali Hoshyaripour kann Saharastaub-Ereignisse vorhersagen. Der Spezialist für natürliche Aerosole erklärt, wo jetzt wieder „Blutregen“ droht – und warum falsche Prognosen die Energiewirtschaft Millionen kosten.



Mit Saharastaub angereicherte Luft aus Nordafrika weht über dem Rheintal, hier Ehrenkirchen im Breisgau, und sorgt für rötlich verfärbtes Tageslicht.

Foto: Philipp von Dittfurth picture alliance/dpa

Birkenpollen: 21.04.2022



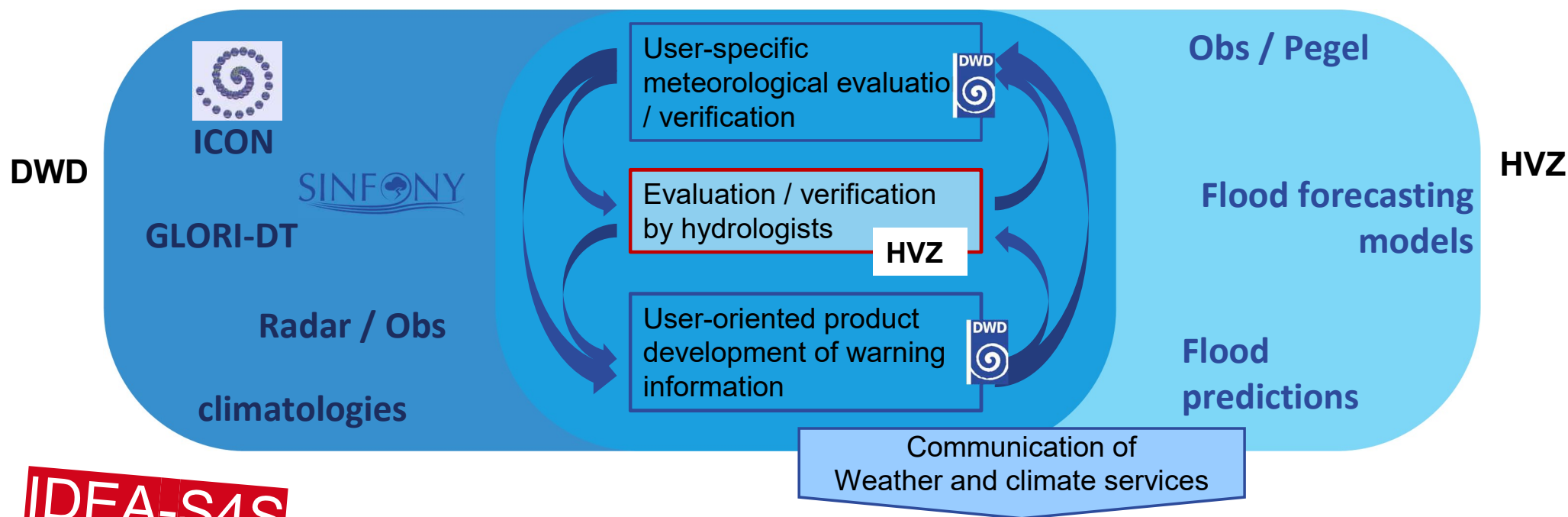
Tagesmittel Anzahl Pollen/m³
0 1 5 10 25 50 100 500

ICON-ART Modelllauf vom 20.04.2022 00 UTC

Ali Hoshyaripour, KIT

Augmenting the hydrometeorological value chain through co-design

Collaboration of DWD with regional flood forecasting centres (HVZ)



IDEA-S4S



**GLORI-Alps basic-
version technically
working**

**Higher-resolution
cases with
improved quality**

2023

2024

2025

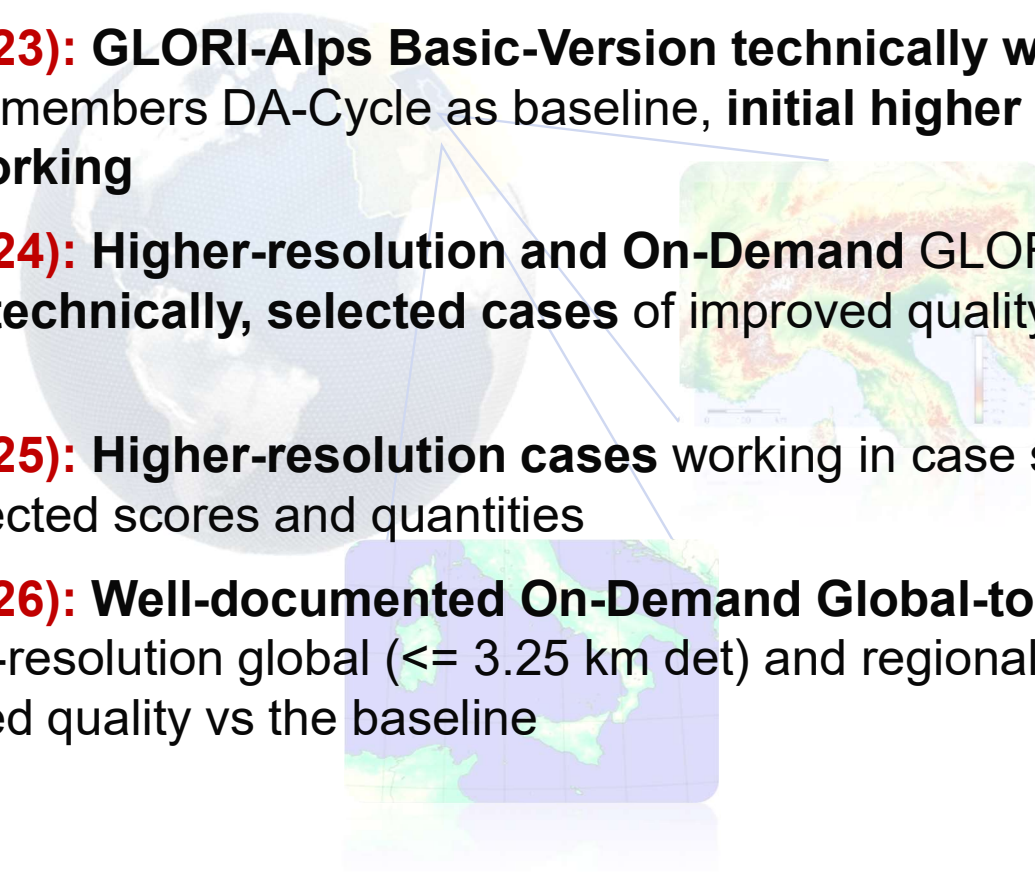
2026

**Higher-resolution
and On-Demand
technically working**

**Well-documented On-
Demand Global-to-
regional Digital Twin**

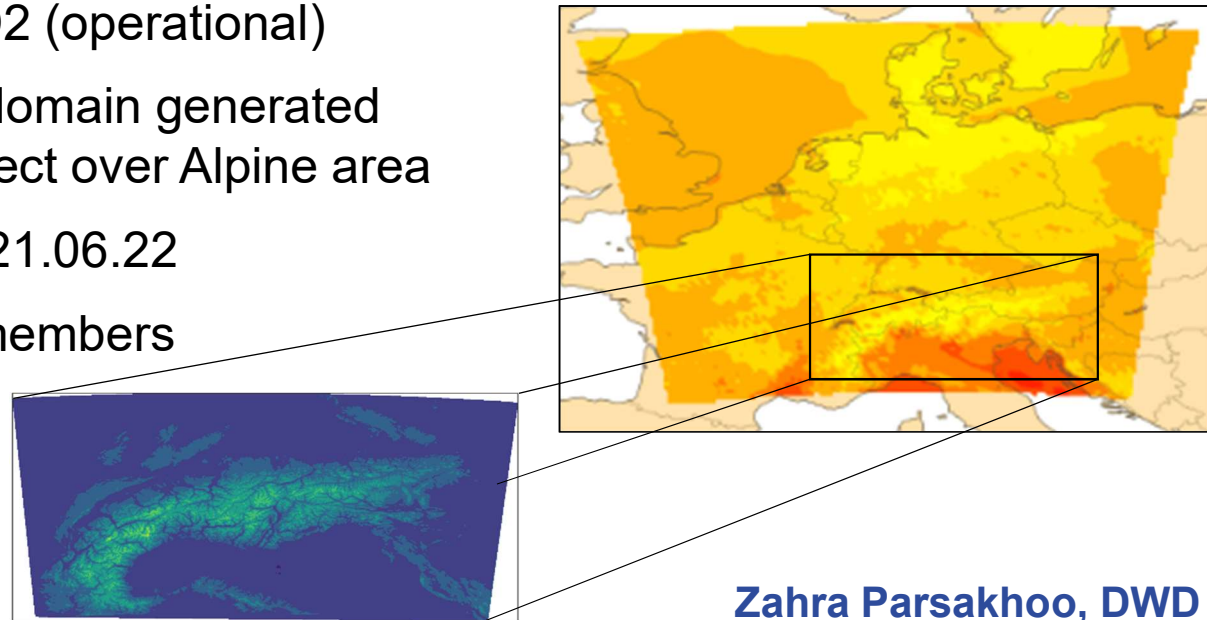


Thank you for your attention!

- 
- **M1 (end of 2023): GLORI-Alps Basic-Version technically working** (13-6.5-1 km resolution), 40 members DA-Cycle as baseline, **initial higher resolution technically working**
 - **M2 (end of 2024): Higher-resolution and On-Demand GLORI-Alps and GLORI-Med working technically, selected cases** of improved quality for selected scores and quantities
 - **M3 (end of 2025): Higher-resolution cases** working in case studies with **improved quality** on selected scores and quantities
 - **M4 (end of 2026): Well-documented On-Demand Global-to-regional Digital Twin** with high-resolution global (≤ 3.25 km det) and regional (500 m) usable with clearly improved quality vs the baseline

Experiments setup

- ➔ GLORI-Alpine domains
- ➔ BACY ensemble forecast run with nesting:
 - 2 model domains:
 - Outer domain: 2km ICON-D2 (operational)
 - Inner domain: 1km nested domain generated by G. Zängl for TEAMx project over Alpine area
 - 2 case studies: 05.05.2022 and 21.06.22
 - 24h forecast with 20 ensemble members



Zahra Parsakhoo, DWD

Experiments setup

ICON-D2 with nest:

- ➔ Test 1: Different parameterisation for shallow convection:
Shallowconv_only | grayzone_deepconv | Two-moment microphysics
- ➔ Test 2: Perturbation OFF for all surface parameters
- ➔ Test 3: Perturbation ON for one or some parameters

ParFlow

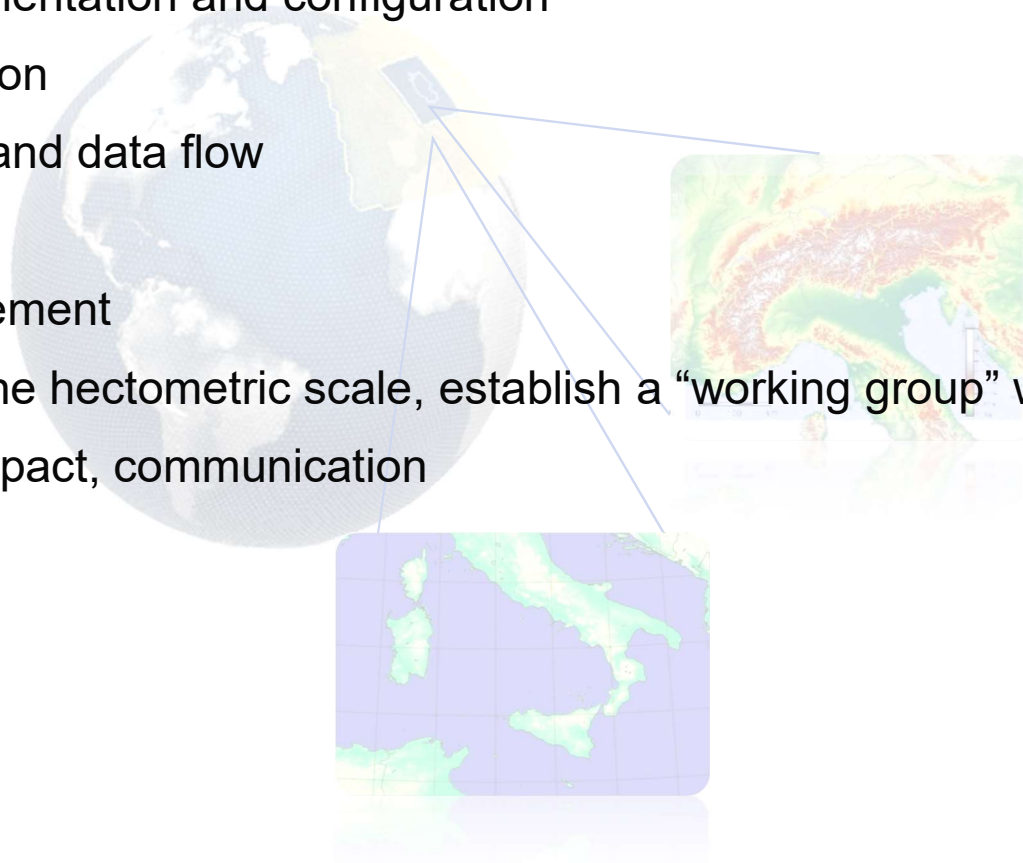
- ➔ Offline run over Germany forced by ICON-D2 atmospheric data

Zahra Parsakhoo, DWD



Working Groups

- WG1 system implementation and configuration
- WG2 data assimilation
- WG3 infrastructure and data flow
- WG4 GPU porting
- WG5 model improvement
 - ICON towards the hectometric scale, establish a “working group” with PP CITTA`
- WG6 verification, impact, communication





News

June 2023: GLORI-A Phase II approved by the Swiss Federal Council: Funding secured for 2024-2026

Ongoing work includes

- Finalization of GPU version with OpenAcc; Consolidation and optimization of the Python Dycore for better performance
- Scoping of
 - On-demand system
 - Use cases: Agile & user-guided development of the DT
 - TEAMx field campaign: First user interview took place
 - Stakeholder analysis for DT data to develop another use case (Flood forecasting / Energy generation / Agricultural applications etc)

MeteoSchweiz

COSMO GM, September 2023, Gdansk