Deutscher Wetterdienst
Wetter und Klima aus einer Hand

The new NWP forecast system of the DWD based on ICON / ICON-EU and COSMO-DE

15th Workshop on Meteorological Operational Systems
ECMWF
28-30th September 2015

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Overview

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

DWD

Changes of the operational environment

Compute server
NWP models

Overview about DWD forecast system

ICON / ICON-EU
COSMO-DE-EPS
“Modell-Uhr”

Actual NWP development at DWD

ICON-EDA
ICON-Ensemble forecast
COSMO-CD2 + EPS
KENDA
ICON-ART
System Issues

Main changes of the operational environment

Compute-Server

- NEC SX-9 → Cray XC40 — 27/05/2014

  + login nodes: Megware Linux cluster
  + compute nodes: mixed system – Ivy Bridge (20 cores) / Haswell (24 cores)

Data handling / Data format

- CSOBANK → SKY — spring 2014

  + with archive access

- GRIB1 → GRIB2 — 24/06/2014

NWP-Model-Suite

- GME + COSMO-EU + COSMO-DE (-EPS) → ICON + ICON-EU + COSMO-DE (-EPS)

  + ICON operational: 20/01/2015
  + ICON-EU operational: 21/07/2015
  + GME: switched off
  + COSMO-EU: still running operational, but frozen
    provides boundary data of COSMO-DE
    postprocessing

DMRZ (Offenbach) - Computing Centre

Computing hall WEST

HPC production

Megware
22 node
480 cores
4352 GiB main memory

Cray XC40
796 nodes
17648 cores
78592 GiB main memory

Global filesystems
Cray Sonexion/
Panasas
1012+120 TiB

Archive system Oracle/IBM-HPSS

Oracle STK SL8500
2 tape silos
20000 storing positions
18 PiB
60 tape drives

IBM X3650
9 nodes
72 cores
216 GiB main memory
480 TiB disk storage

Data server production

5 * SUN x2-4/x2-8
320 cores
4096 GiB main memory
1656 TiB SAN disk storage

Computing hall EAST

HPC research

Megware
28 nodes
616 cores
5120 GiB main memory

Cray XC40
796 nodes
17648 cores
78592 GiB main memory

Global filesystems
Cray Sonexion/
Panasas
2661+170 TiB

Data server research

5 * SUN x2-4/x2-8
320 cores
4096 GiB main memory
1382 TiB SAN disk storage

10 GBit

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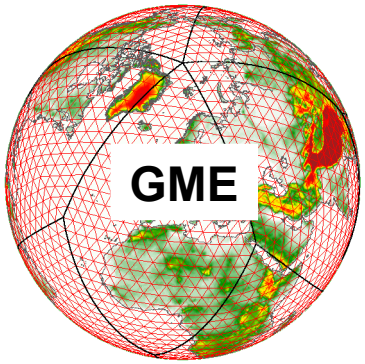
GME → ICON

operational setup



non-hydrostatic	**equation system**	hydrostatic
Hybrid (SLEVE, z-based)	**vertical grid**	Hybrid (p-based)
13 km	**resolution**	20 km
75 km / 90	**model top / levels**	36 km / 60
2.9 Mio.	**grid points/level**	1.5 Mio.
3D Var	**assimilation system**	3D Var
Hybrid MPI-OpenMP	**parallelization**	Flat MPI

Little migration efforts for most GME users

Same output fields as GME with same resolution (0.25° lat/lon) + triangular

NWP models at DWD

Global-Model ICON

Operational since 20/01/2015

Mesh size: 13 km

Vertical levels: 90

Forecast range: 180h / 120h / 30h

00, 03, 06, 09, 12, 15, 18, 21 UTC

Grid area: 173 km^2

ICON-EU nest area Europa

Operational since 21/07/2015

Mesh size: 6.5 km

Vertical levels: 60

Forecast range: 120h / 30h

00, 03, 06, 09, 12, 15, 18, 21 UTC

Grid area: 43 km^2

COSMO-DE (-EPS)

Operational since 2006 (EPS 2010)

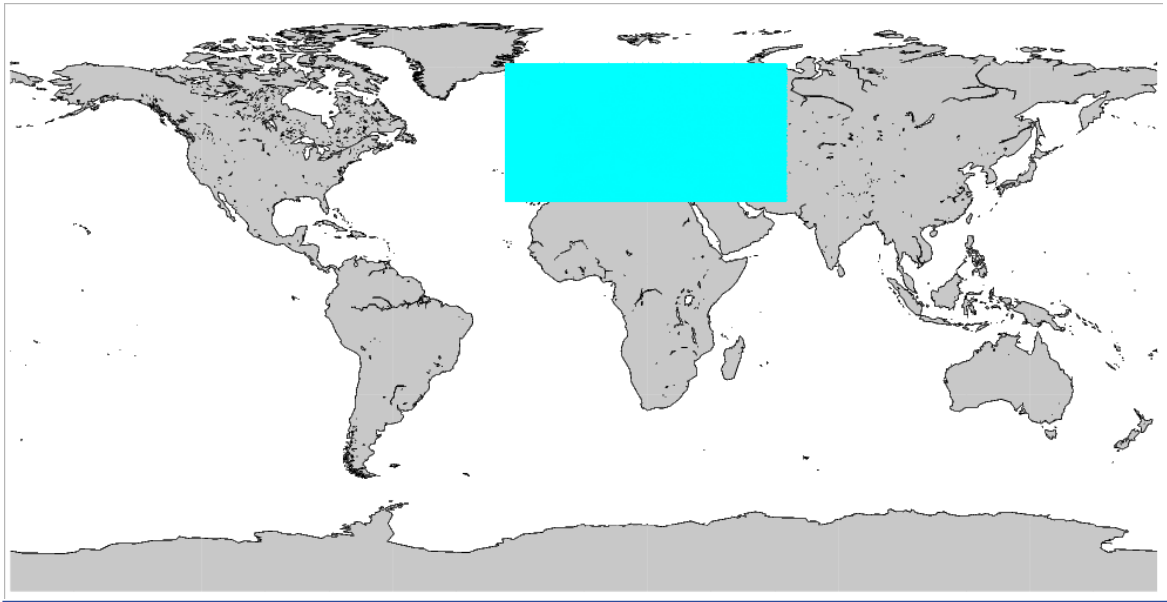
Mesh size: 2.8 km

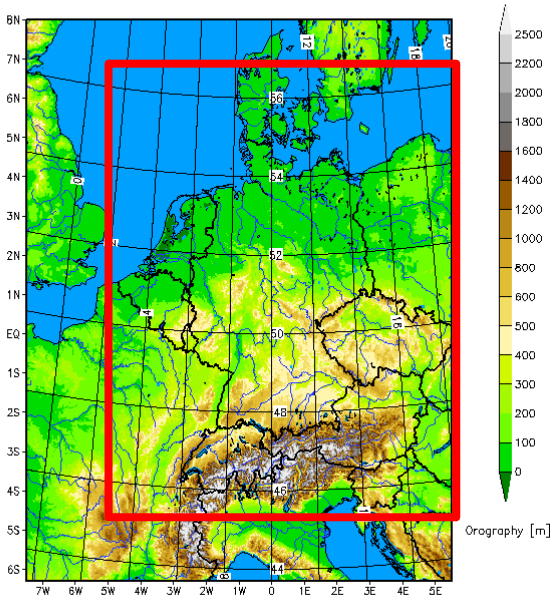
Vertical levels: 50

Forecast range: 27h / 45h

00, 03, 06, 09, 12, 15, 18, 21 UTC

Grid area: 8 km^2





ICOsahedral Nonhydrostatic Model

- Joint development of **DWD** and **MPI-M** (Hamburg) for NWP **and** climate modelling
- 2012, **KIT** (Karlsruhe) joined to implement the chemistry module ART (Aerosols and Reactive Trace Gases).
- About 40 active developers from atmospheric and computational sciences
- ~ 600000 lines of Fortran code

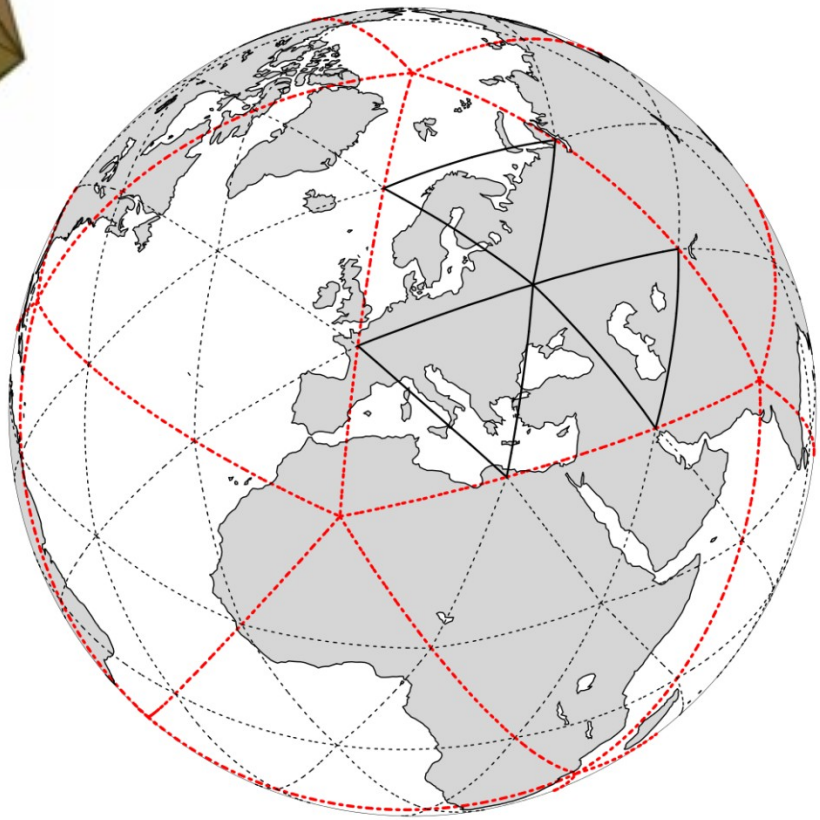
Primary development goals

- Unified modeling system for NWP and climate prediction in order to bundle knowledge and to maximize synergy effects
- Better conservation properties
- Flexible grid nesting in order to replace both GME (global, 20 km) and COSMO-EU (regional, 7 km) in the operational suite of DWD
- Nonhydrostatic dynamical core for capability of seamless prediction
- Scalability and efficiency on O(10^{4+}) cores

Icosahedral grid similar to GME, but unstructured

R2B00

R3B00



Structure of grid nesting

Effective grid spacing (distance between points):

$\Delta x \approx 5050 / (n\ 2^{k})\ [\mathrm{km}]$

Example:

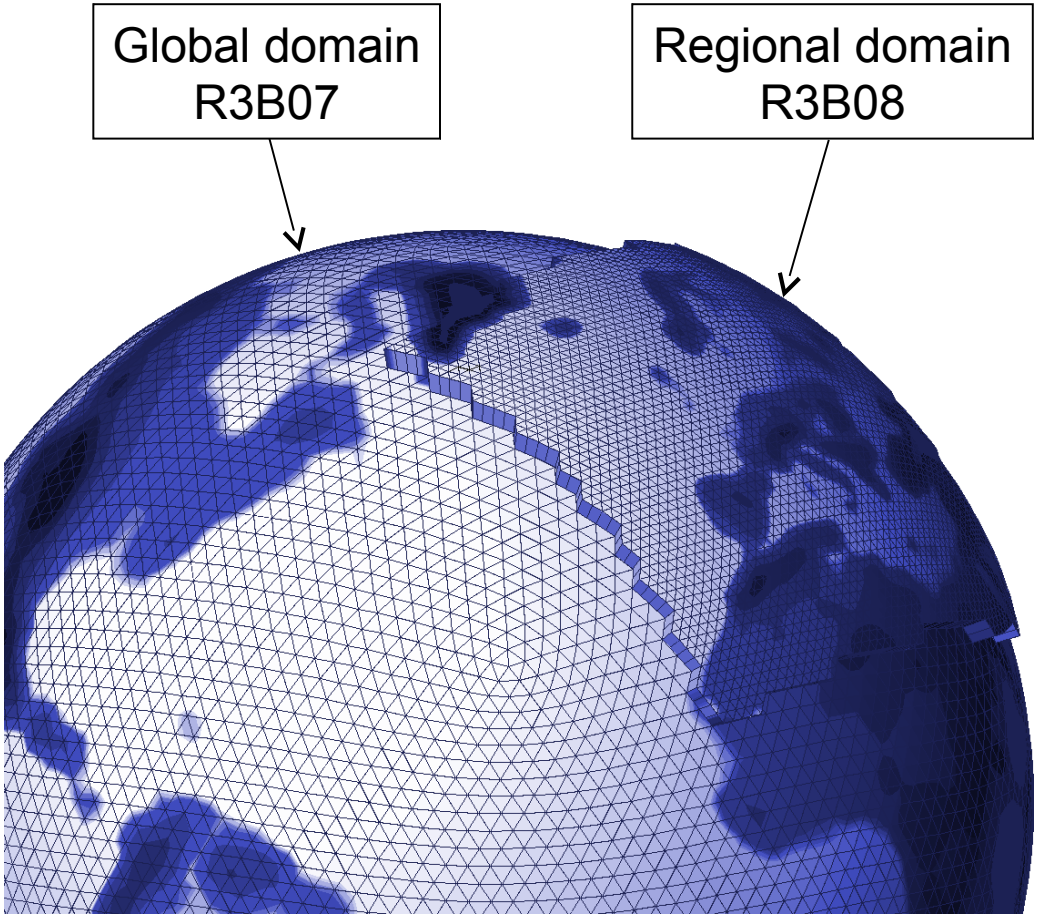
R3B7: n = 3, k = 7

Grid spacing: 13 km

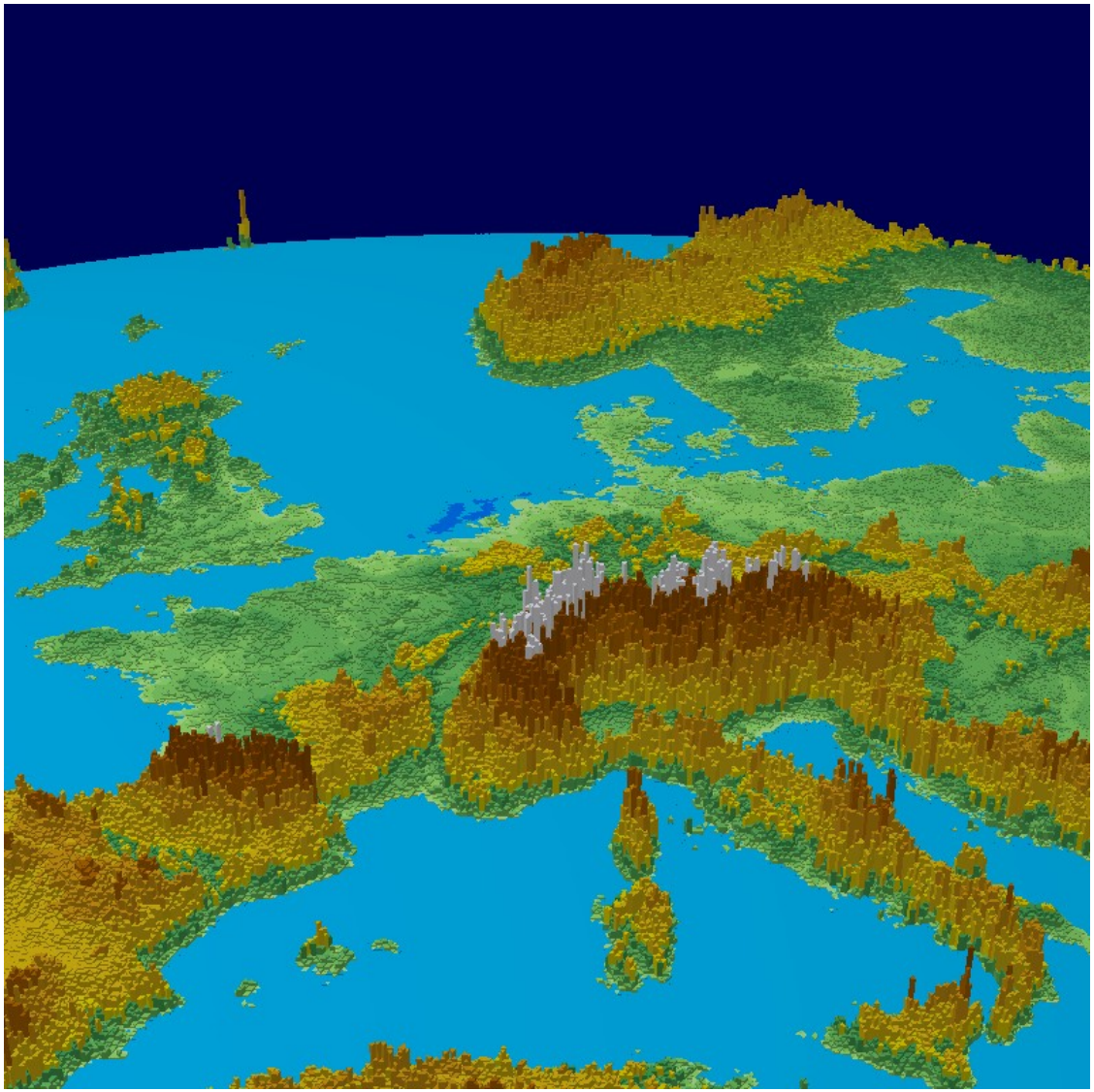
Global grid consists of 2.9 million spherical triangles.

Regional domain with higher horizontal resolution.

Grid spacing: 6.5km



ICON-EU



ICON-Orography for Europe

Grid spacing: 6.5 km

R3B08

Primary development goals

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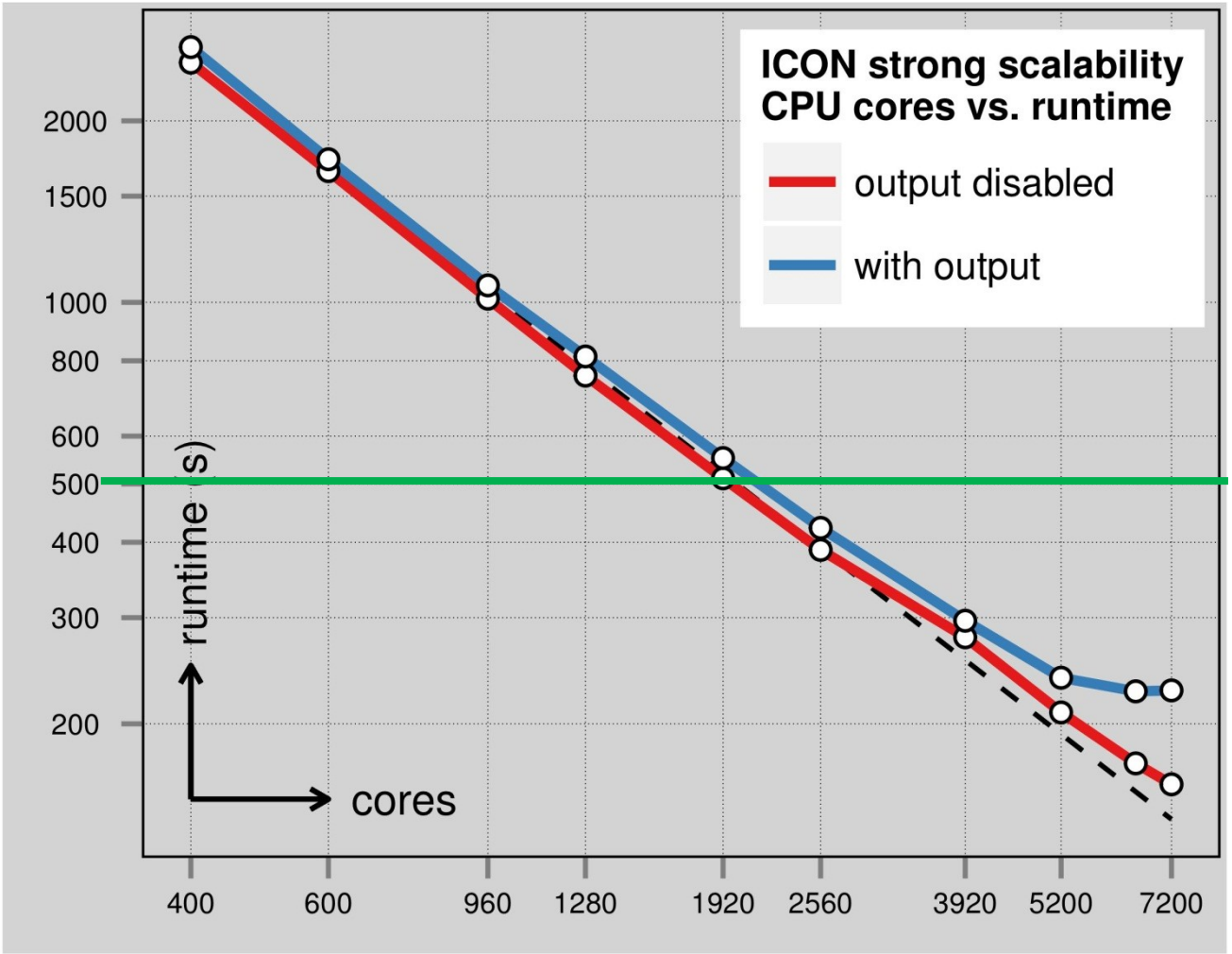
Scaling of ICON 13 km, L90 on Cray XC40 at DWD



Real time (s) for 24-h forecast (di.e. 3600 time steps)

2.9 million grid points / layer; 90 layers

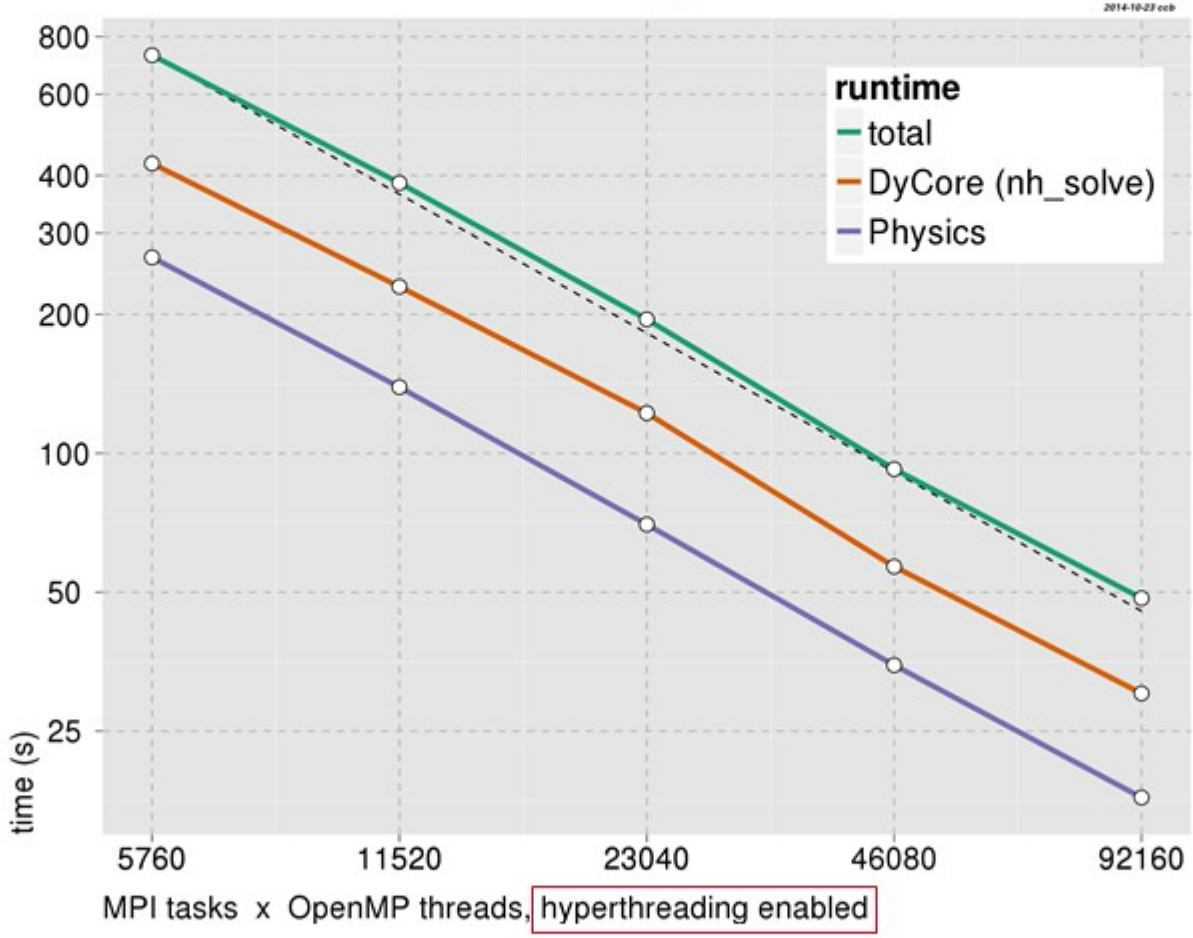
At 7200 MPI-tasks: 400 grid points / task

For operations we need:
24-h forecast in 500 s; i.e. we need about 2000 tasks (cores) on Cray XC40 (Haswell).

Scaling of ICON (5 km grid spacing) on Cray XC30 at ECMWF (Reading)

Static Domain Decomposition

Example: 1100 PEs



COSMO-DE + COSMO-DE-EPS

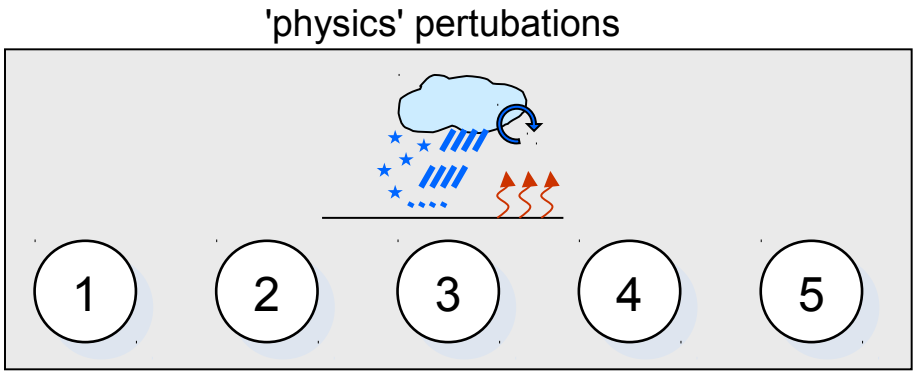
Ensemble forecast system COSMO-DE-EPS with 20 members

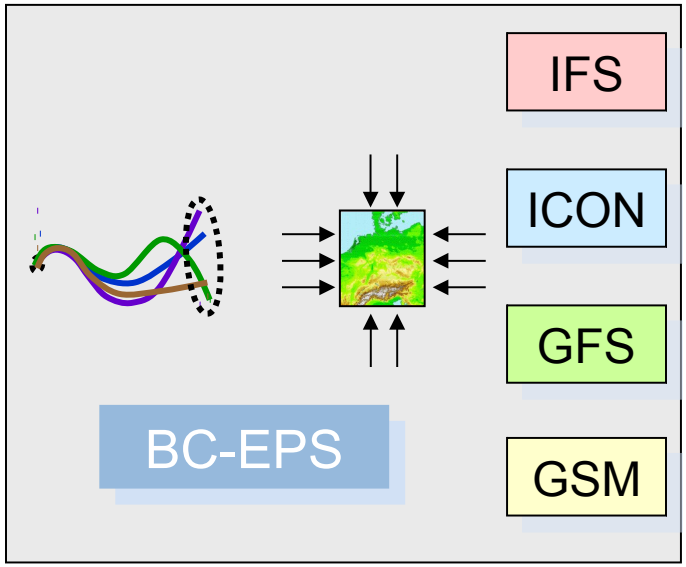
Δx = 2.8 km

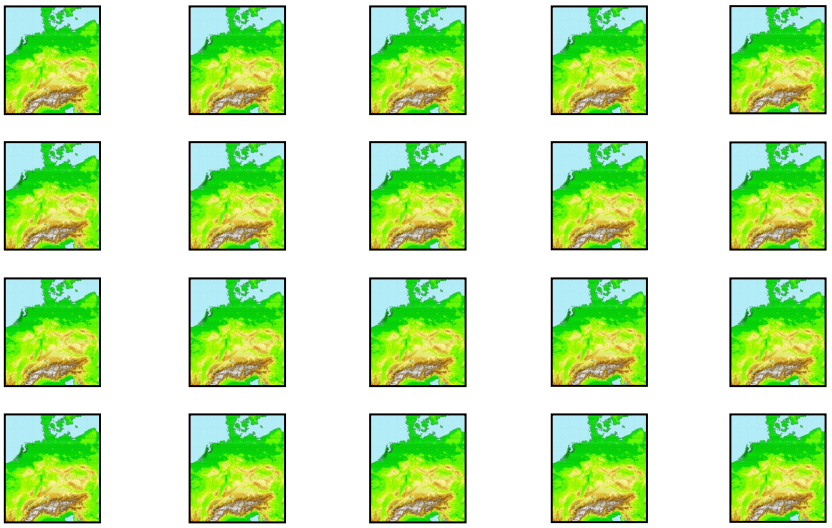
8 times a day

Forecast time: 27h, 03 UTC - 45h

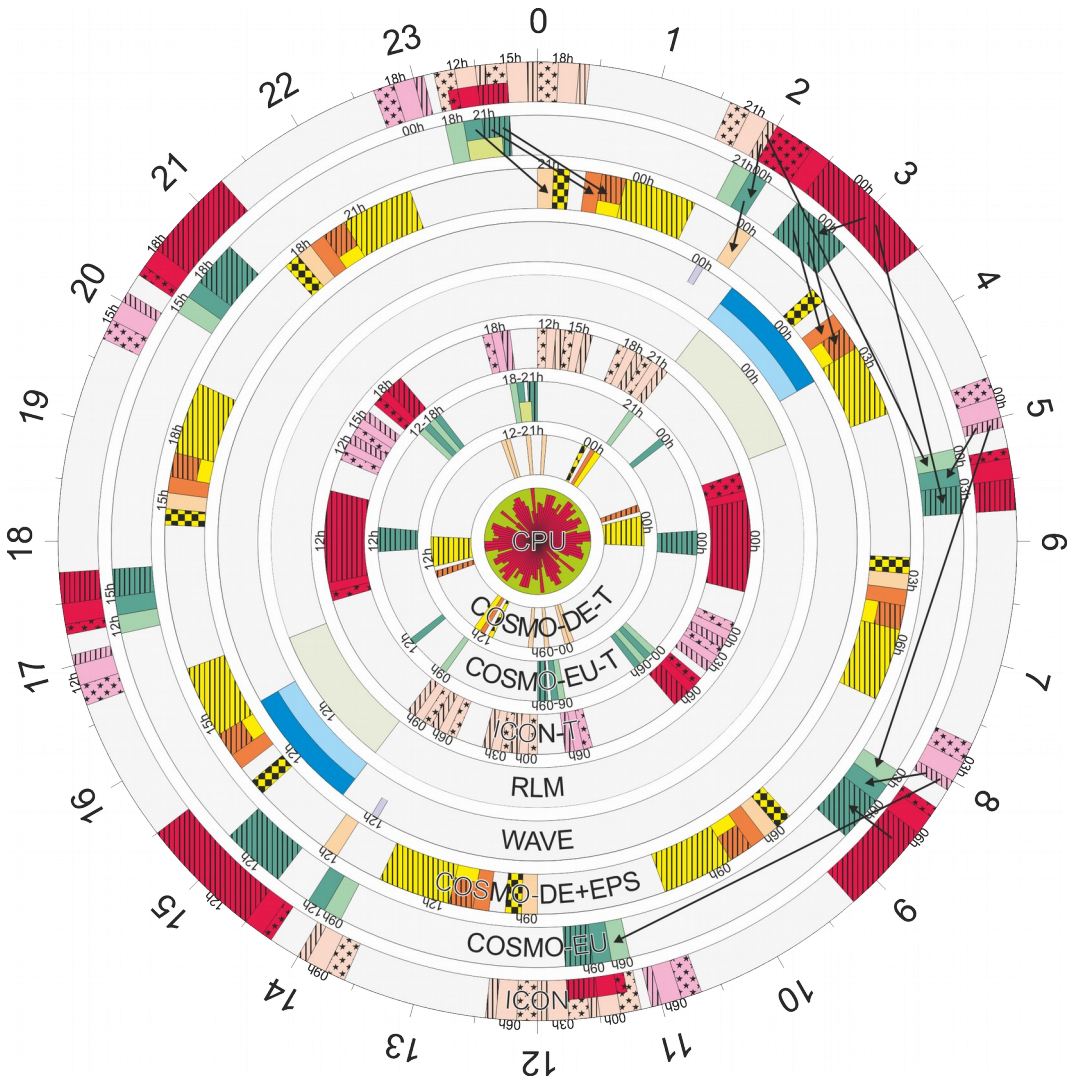
Available: 2 h after observation time







„Modell-Uhr”



Operational timetable of the DWD model suite

ICON, COSMO: Analysis / Nudging
ICON Analysis: serial part
ICON, COSMO: Forecast
COSMO-DE-EPS: Interpolation
WAVE (GWAM, EWAM)
COSMO-EU: Surface moisture analysis

Main run
Pre-Assimilation
Assimilation

00..23 real time [UTC]
00h, 03h, .. model time [UTC]
T Testsuite

Operational Schedule

	type	time [UTC] / interval	forecast time [h]	cut off time X + ??	ready time X + ??
ICON / ICON-EU	main forecast	00, 12 06, 18 03, 09, 15, 21	180 120 30	+ 2:14 + 2:15 + 2:14	+ 3:30 + 3:00 + 2:45
	pre-assimilation	3 hourly	3	+ 4:40	+ 5:05
	assimilation	00, 12 03, 15 06, 18 09, 21	3 3 3 3	+ 11:10 + 8:35 + 6:00 + 4:35	+ 11:35 + 9:00 + 6:25 + 5:00
COSMO-EU	main forecast	00, 12 06, 18 03, 09, 15, 21	78 78 30	+ 2:30 + 2:30 + 2:30	+ 3:05 + 3:05 + 2:45
	assimilation	00, 03, 06, 12, 15, 18 09, 21	3 (cont.)	+ 5:10 (8:10) + 4:50 (7:50)	+ 5:20 + 5:00
COSMO-DE	main forecast	3 hourly	27	+ 0:40	+ 0:55
	assimilation	3 hourly	3 (cont.)	+ 2:10...3:20 (5:10...6:20)	+ 2:20...3:30
COSMO-DE-EPS	main forecast	3 hourly	27	+ 0:55	+ 1:35

New developements 2015 / 2016

- **ICON**
  - Tile approach for TERRA
- **Global Ensemble Data Assimilation (ICON-EDA)**
  - 13 (6.5) km + 40 (20) km
  - pre-operational since 09/09/2015
- **COSMO-D2**
  - 2.2 km, 651x716 grid points, 65 vertical levels
- **Regional Ensemble Data Assimilation COSMO-D2 (KENDA)**
  - 2.2km
  - Data Assimilation Technique: 4d-LETKF, 40 members
- **COSMO-D2-EPS**
  - 2.2km
  - 40 members
- **ICON-Art**
  - Volcanic ash forecast
  - Dispersion of (Saharan) mineral dust

ICON-EDA

Pre-operational since 09/09/2015

- 13 km Deterministic Variational Data Assimilation (3 hourly cycling) with 6.5 km Nest over Europe

  - Initial data for long term forecasts
  - Observation quality control for the LETKF
  - En-Var: Uses flow dependent background from LETKF

- 40 Member 40 km 3 hourly LETKF Data Assimilation Cycle with 20 km Nest over Europe

  - Inital data for ICON EPS

- 40 Member 40 km EPS with 20 km Nest over Europe

  - Additional value of the probabilistic forecast
  - Boundary conditions for the COSMO-DE LETKF
  - Boundary conditions for the COSMO-DE EPS

ICON-EDA (pre-operational since 09. September 2015)

Specifications of LETKF and En-Var

Localisation

l_h	300 km	horizontal localisation scale.
l_s	0.3	vertical localisation scale at surface (1000 hPa)
l_t	0.8	vertical localisation scale at model top (1.5 Pa)

Multiplicative Model Error

ρ_{max}	3.0	upper bound for adaptive covariance ination estimated from Desroziers statistics
rttp	0.75	factor for relaxation to prior perturbation

Additive Model Error

a_b	0.25	amplitude of model error proxy (3D-Var B)
a_{sst}	1K	amplitude for SST perturbations.
l_{sst}	100,1000km	correlation scale for SST perturbations.

En-Var

ß	0.5	weight of Ensemble B matrix

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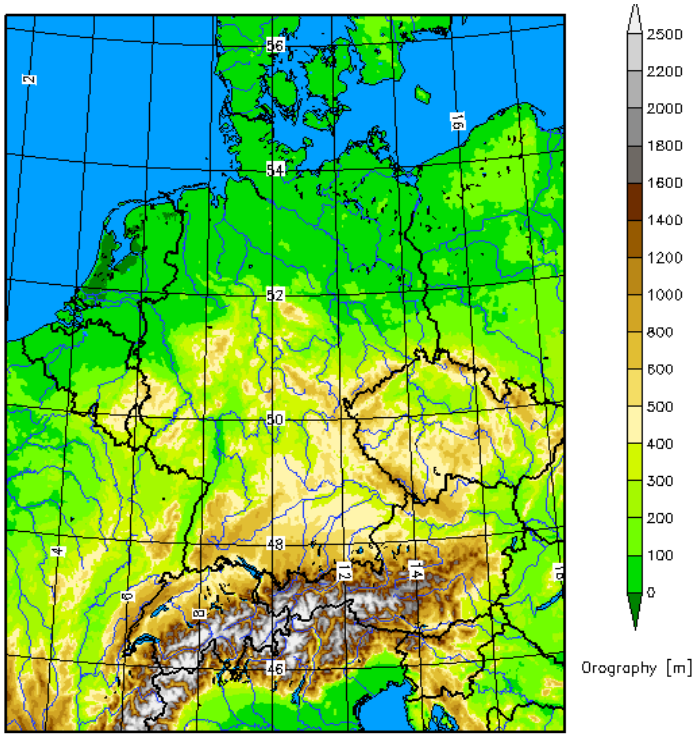
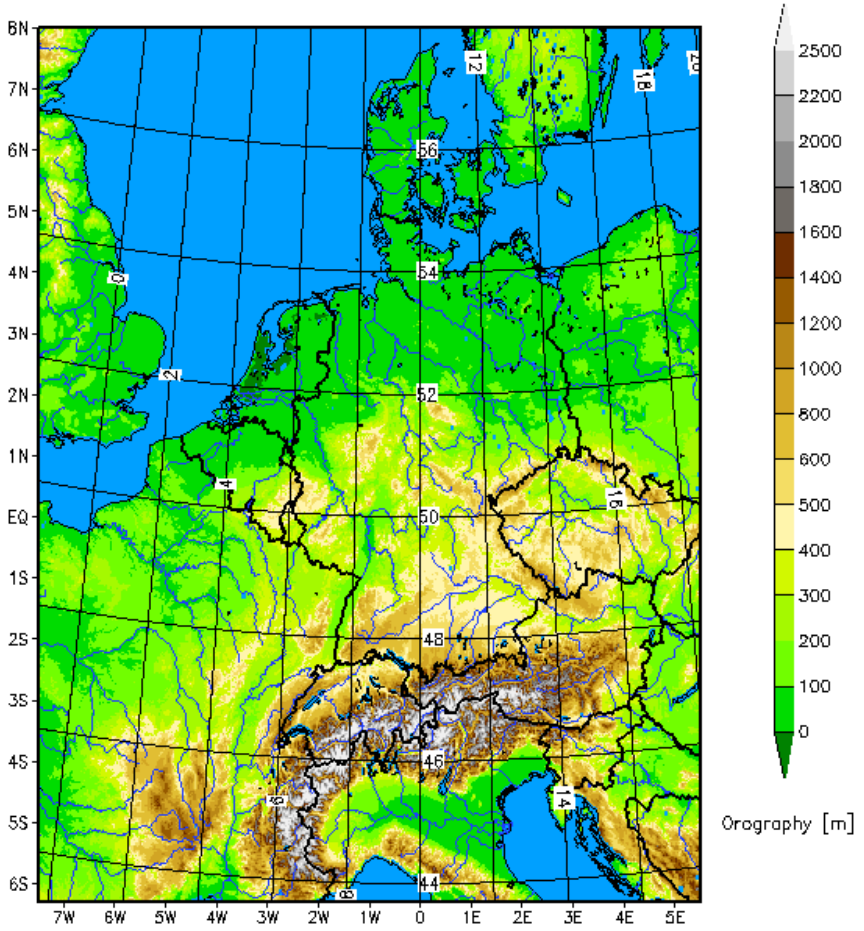
COSMO-D2

Actual: COSMO-DE



421 x 461 x 50, 2.8 km (10.5° * 11.5°)

Future: COSMO-D2



651 x 716 x 65, 2.2 km (13° * 14.3°)

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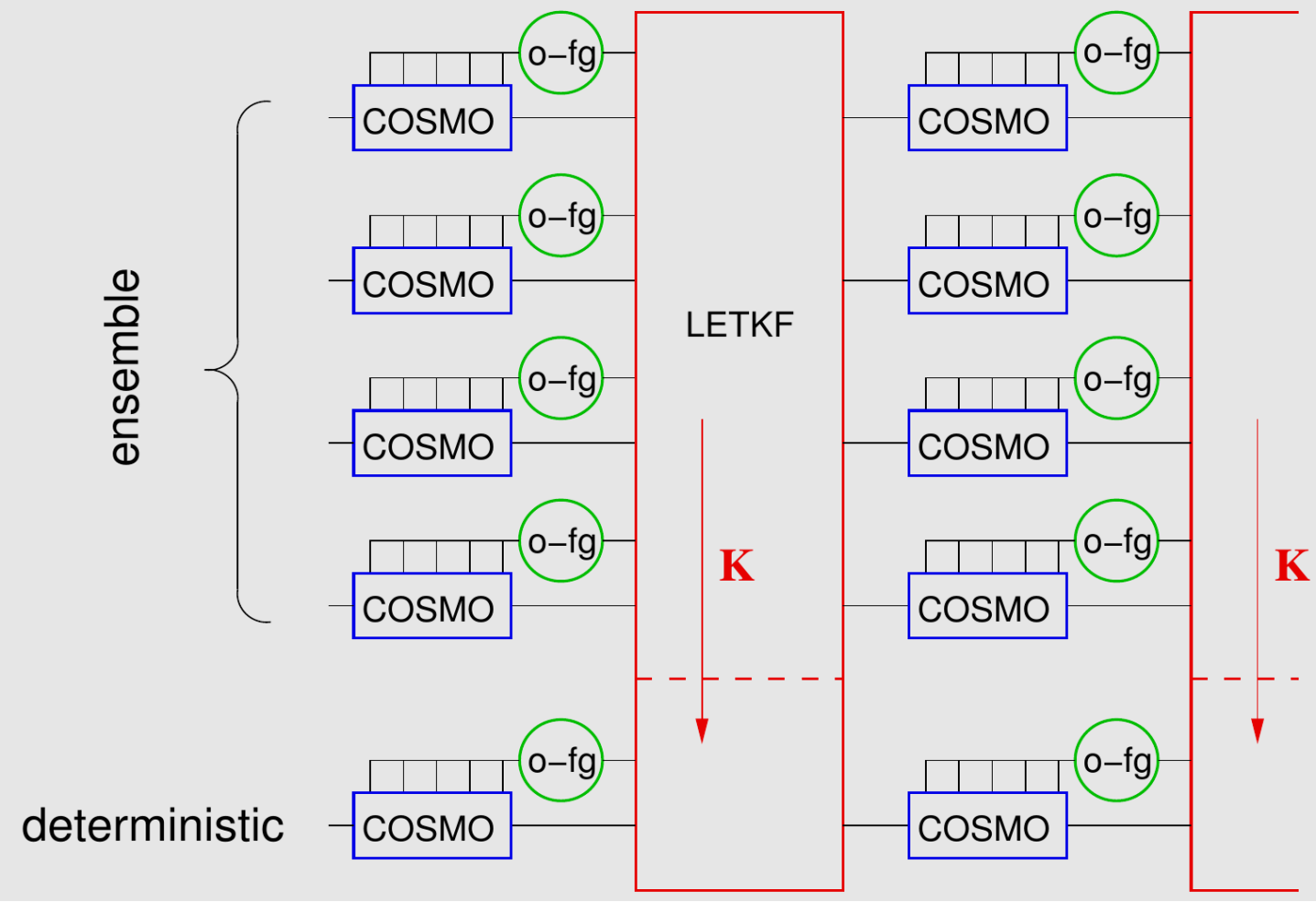
KENDA

Data Assimilation Technique: 4d-LETKF, 40 members



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ICON-ART

"On-Demand" forecast of volcanic ash dispersion for the European airspace (Q4 2016 / Q1 2017)

Global forecasts of volcanic ash dispersion as a new component of the operational NWP system of DWD (planned for 2019)

PerduS: "**Photovoltaikertragsreduktion durch Saharastaub**" (2016-2019)
(Reduction of PV power generation due to Saharan mineral dust)

ICAO MET Panel WG-MISD (Group 1 / RRM)
"Release of Radioactive Material" – Coordinator: Dirk Engelbart (BMVI)
Use ICON-ART as model in addition to LPDM, coordinate work with BfS

ICON-ART in limited area mode as replacement for HEARTS

Some System Issues

Data handling (example: ICON)

- Increase of the produced data and operational I/O bandwidth to the database [one forecast]

- GME	300 GB	86 MB/s
- ICON	900 GB	256 MB/s
- ICON + ICON-EU	1,1 TB	320 MB/s
- ICON + ICON-EU + ICON-EDA with EU-nest	1,9 TB	550 MB/s

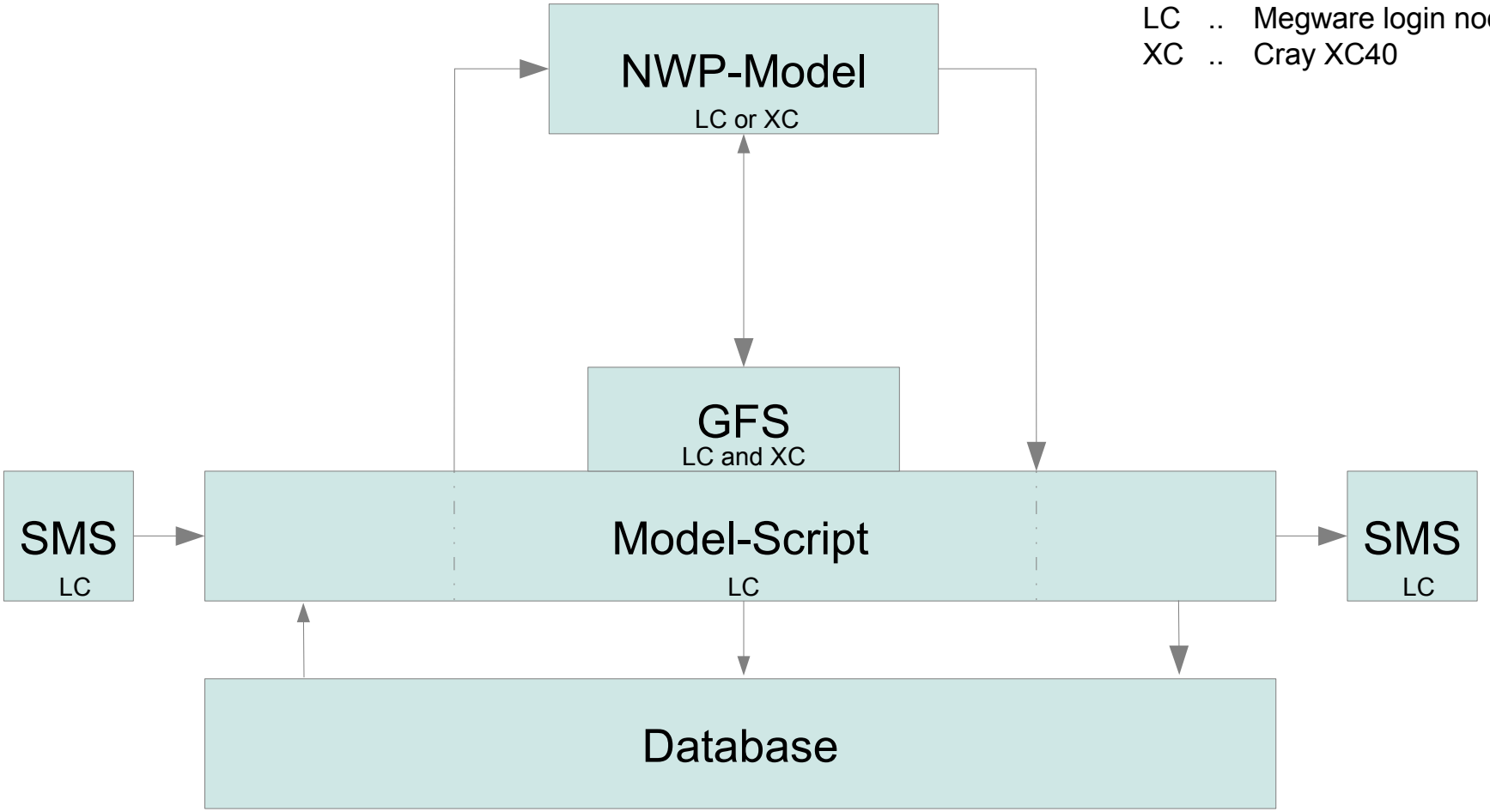
- Amount of data per day: operational and (pre-)operational ICON system
  - 23 TB

- Archive system
  - handle data from
    - Operational NWP runs
    - Pre-Operational NWP runs
    - Experiments

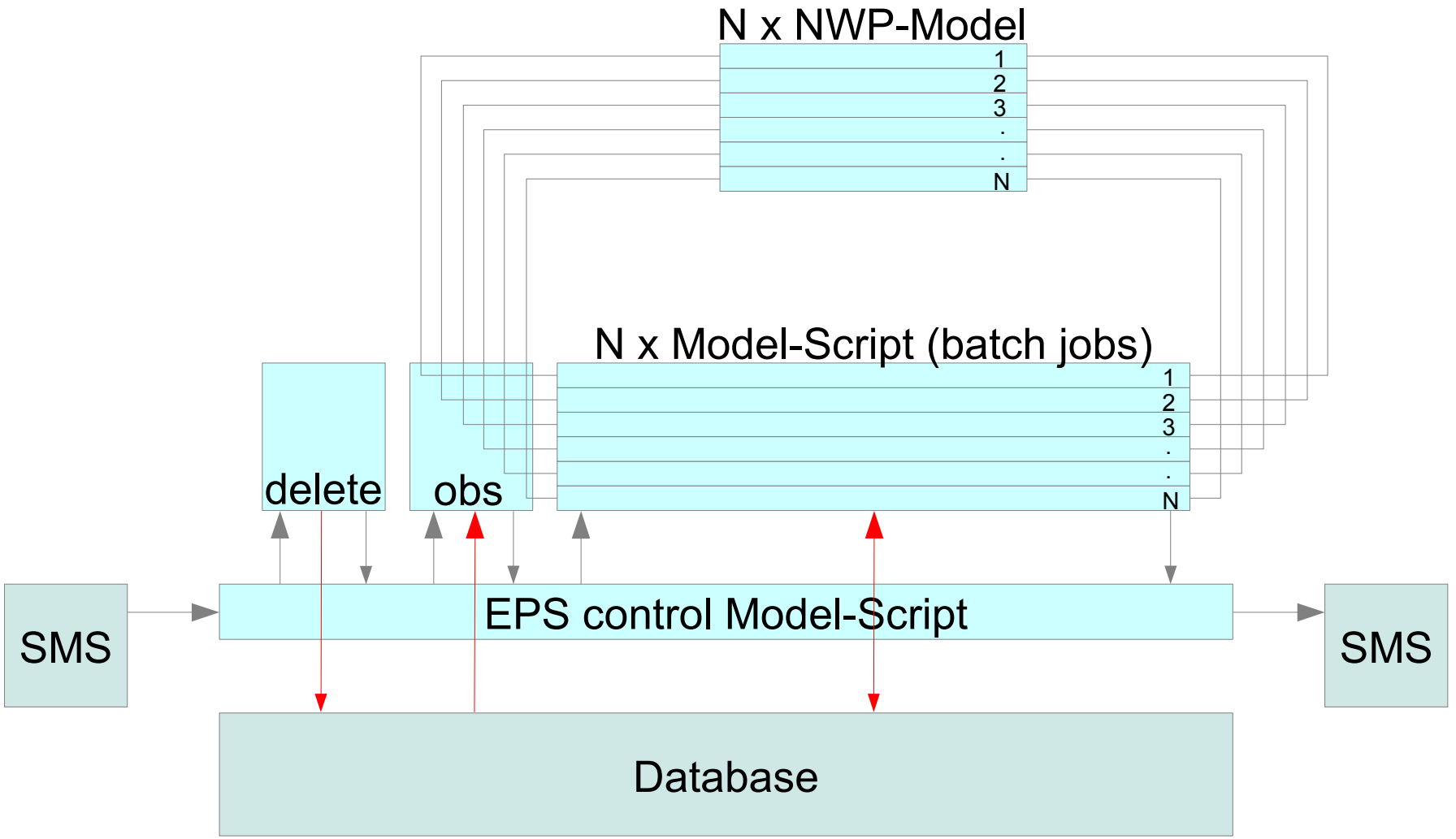
Job control (example: data assimilation run)

- Runtime of a data assimilation forecast run (vv=3h) 240 s
- Batch-System has to start 40+1 forecast runs immediately
  - runtime must not change

Operational Job Control



Operational Job Control - EPS




Thank you for your attention!