The new DWD forecast system

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Outline

IT - infrastructure

NWP models
- GME
- COSMO-EU
- COSMO-DE

Operational schedule
- “Modelluhr”

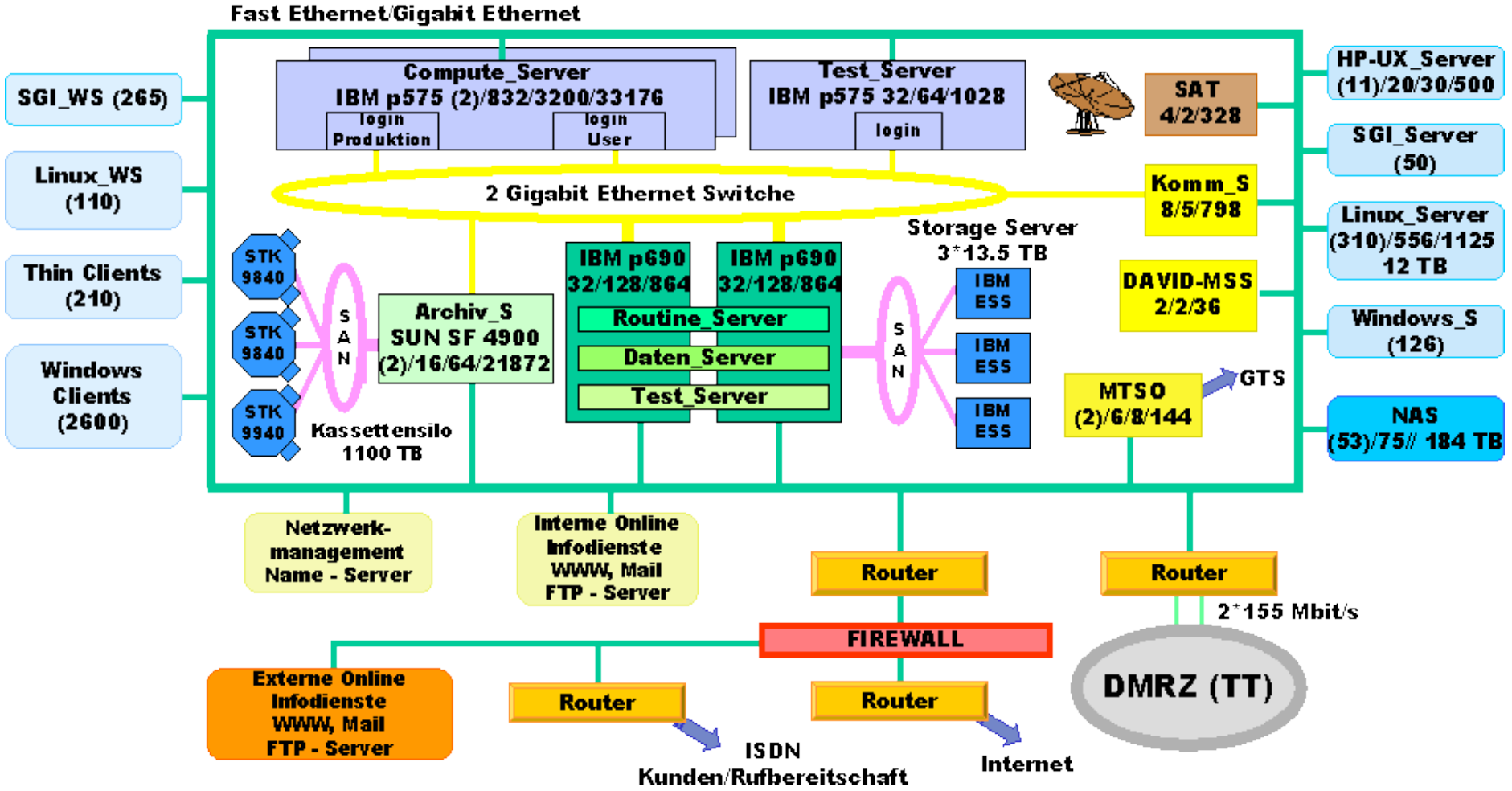
Databases / Data handling
- Databases
- Archive
- Data flow
- Data distribution

Outlook

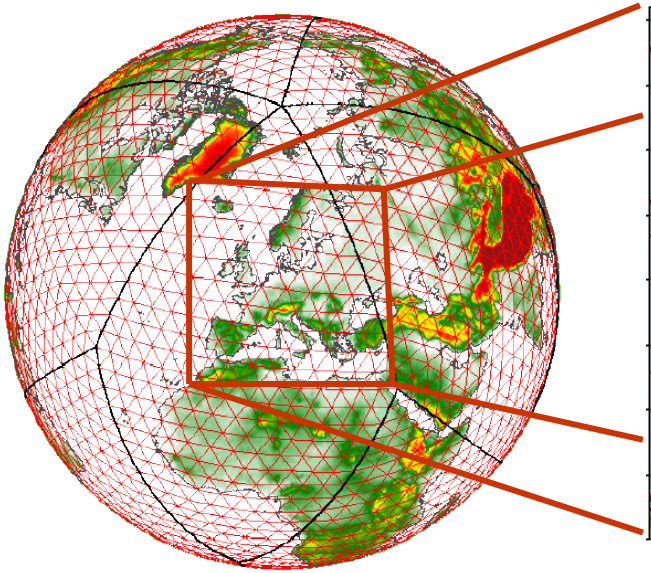
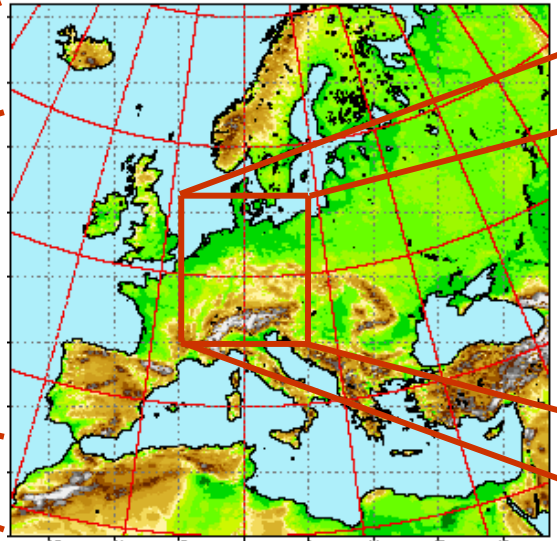
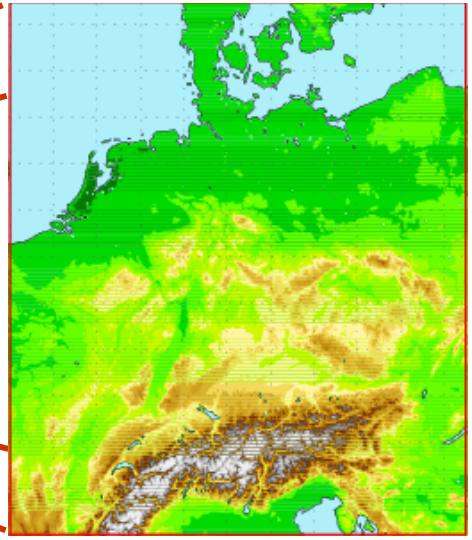
IT - Infrastructure

IT-Struktur des DWD - Konfiguration 2006

Stand: September 2006 Kenngrößen: (Anzahl Systeme)/Anzahl Prozessoren/Arbeitsspeicher in GB/Plattenplatz in GB



The operation Model Chain of DWD: GME, COSMO-EU, COSMO-DE (since 16. April 2007)

GME	COSMO-EU (LME)	COSMO-DE (LMK)
		
hydrostatic parameterised convection $\Delta x \approx 40$ km 368642 * 40 GP $\Delta t = 133$ sec., T = 7 days	non-hydrostatic parameterised convection $\Delta x = 7$ km 665 * 657 * 40 GP $\Delta t = 40$ sec., T= 78 h	non-hydrostatic resolved convection $\Delta x = 2.8$ km 421 * 461 * 50 GP $\Delta t = 25$ sec., T = 18 h

Global Model GME

40 km version (NI=192): Operational since 27.09.2004

Model properties

- triangular grid
- horizontal resolution: 40 km
- vertical levels: 40
- grid cell area: 1384 km²

- hydrostatic
- 7-layer soil model including freezing/melting of soil water
- sea ice model
- seasonal variation of plant cover based on NDVI data

Global Model GME

Data assimilation

- 8 times a day: analysis + 3 h forecast of GME

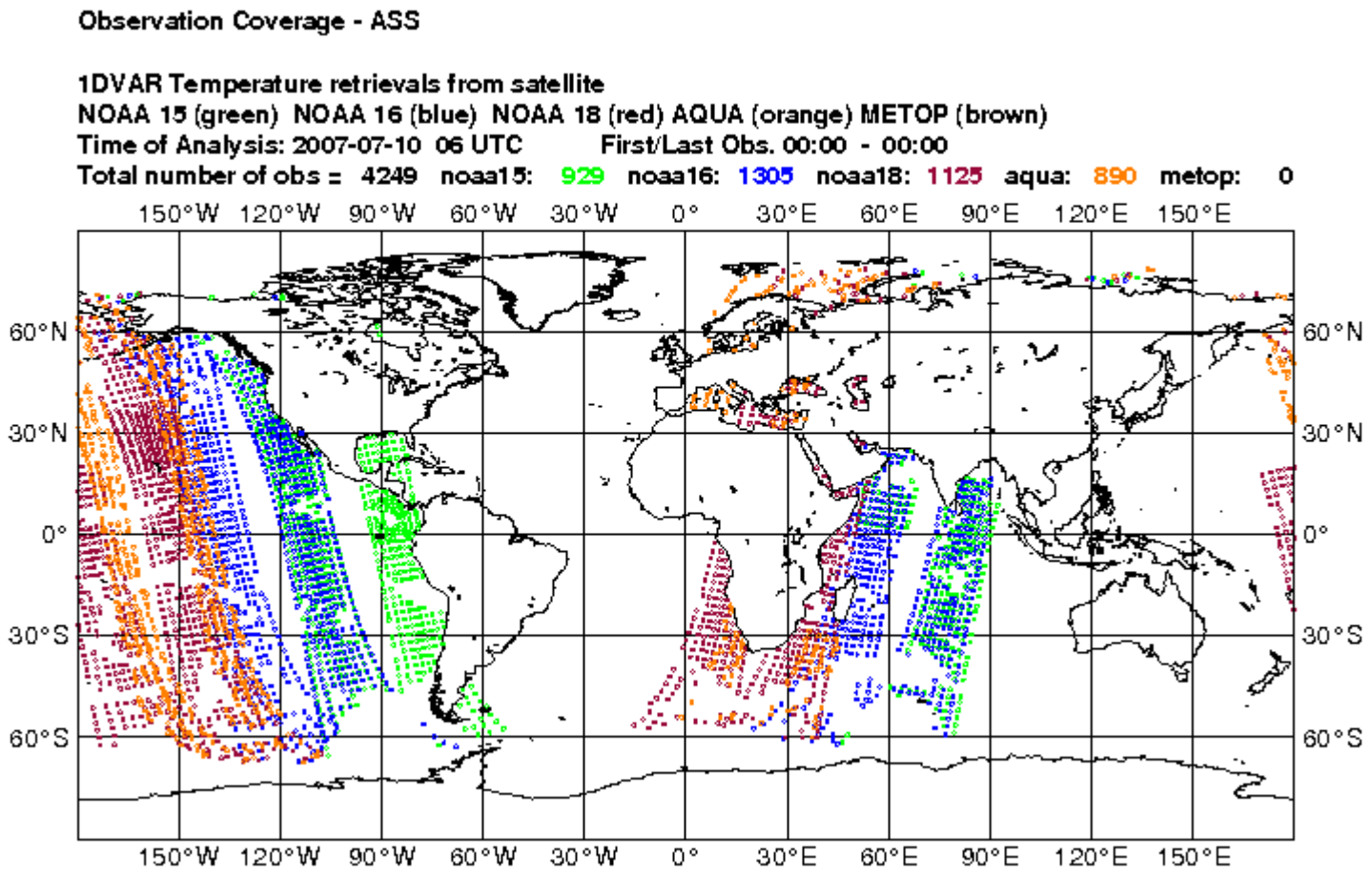
- analysis of atmospheric fields: Optimal Interpolation
- separate analysis of sea surface temperature at 00 UTC
- separate analysis of snow (density/depth/temperature)

- use of “pseudo temps” at 00 UTC derived from ECMWF 00 analysis above sea and Antarctica (minimal distance between points: 180km)

- 1D-Var of ATOVS data (AMSU-A)

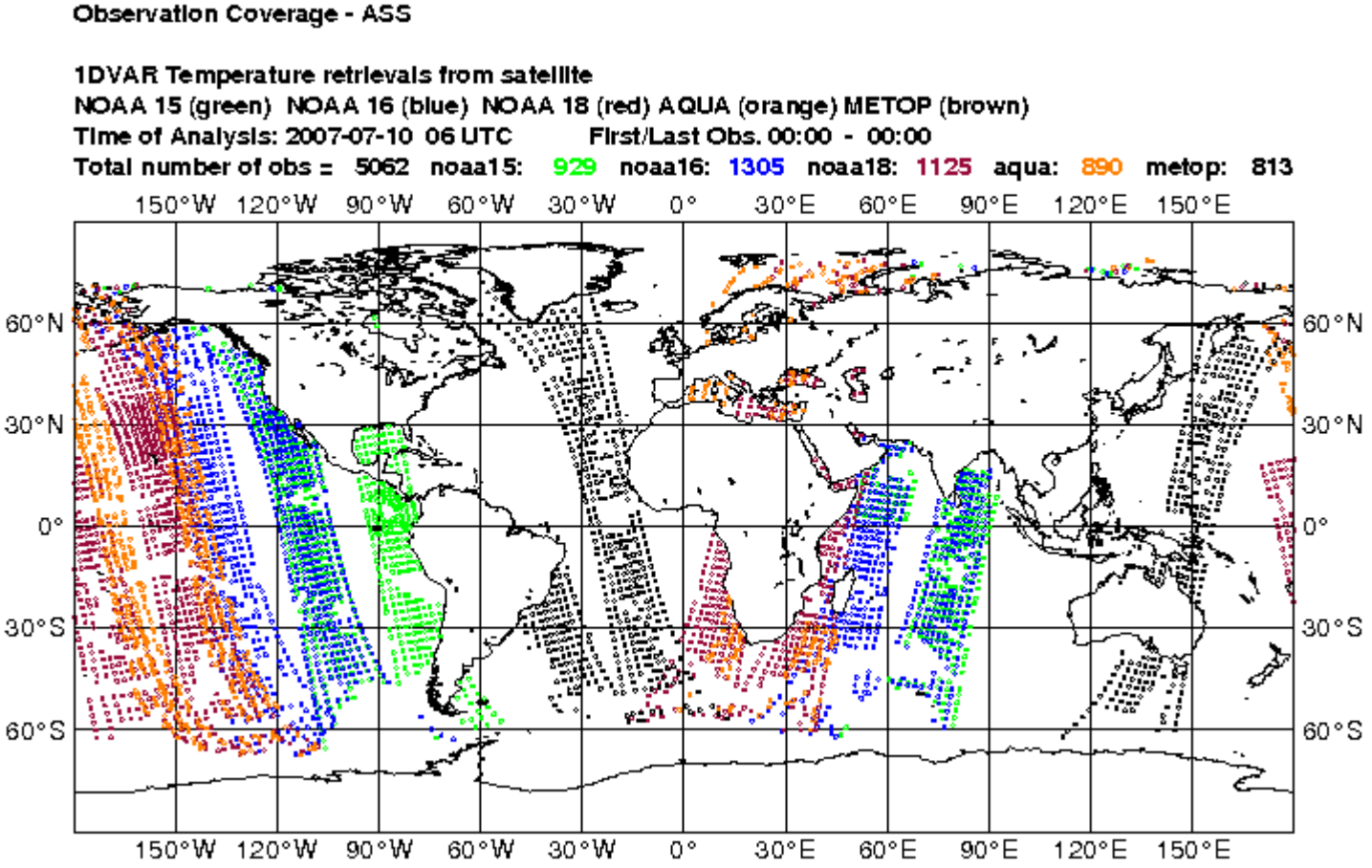
Global Model GME

Usage of AMSU-A on NOAA-15, -16, -18 and AQUA



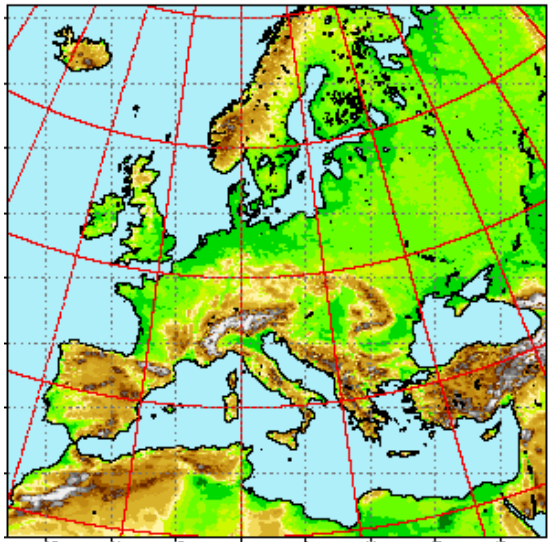
Global Model GME

Usage of AMSU-A on NOAA-15, -16, -18, AQUA and METOP-A (planed)



COSMO-EU

Operational since 28.09.2005



Model properties

- horizontal resolution: 7 km
- vertical levels: 40
- grid cell area: 49 km²
- forecast area: Europe

- non-hydrostatic
- 7-layer soil model including freezing/melting of soil water
- parametrized convection
- prognostic variables: p, u, v, w, T, q_v, q_c, q_i, q_r, q_s, TKE
- boundary data from GME hourly

Data assimilation

- 8 times a day

- continuous data assimilation (nudging scheme, 8 x 3h)
- surface moisture analysis at 00 UTC
- separate analysis of sea surface temperature at 00 UTC
- separate analysis of snow (density/depth/temperature) at 00, 06, 12, 18 UTC

COSMO-DE

Goals

Development of a model-based NWP system for very short range ('*Kürzestfrist*') forecasts 18h (21h) of severe weather events on the meso-γ scale, especially those related to

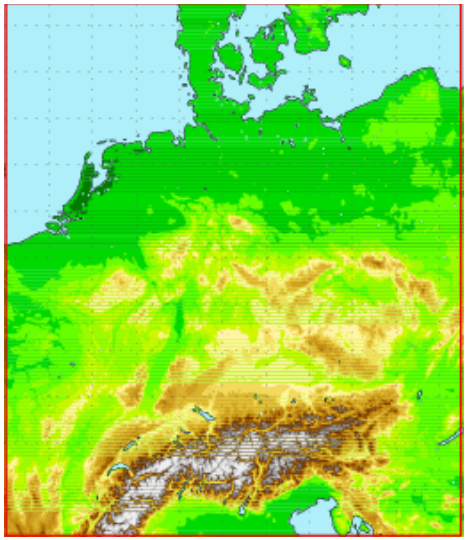
- deep moist convection
  (super- and multi-cell thunderstorms, squall-lines, MCCs, rainbands,...)
- interactions with fine-scale topography
  (severe downslope winds, Föhn-storms, flash floodings, fog, ...)

Operational since 16.04.2007

COSMO-DE and forecaster → talk of Thomas Schumann

COSMO-DE

Model properties



- horizontal resolution: 2,8 km
- vertical levels: 50
- grid cell area: 7,84 km²
- forecast area: Germany

- non-hydrostatic
- resolved convection
- 7-layer soil model including freezing/melting of soil water
- prognostic variables: p, u, v, w, T, q_v, q_c, q_i, q_r, q_s, $\mathbf{q_g}$, TKE
- boundary data from COSMO-EU hourly

COSMO-DE

Operational properties

- rapid update cycle: 8 times a day 18h forecast
  use as LAF - ensemble
- short observation cut off: X+40min
- forecast available within database: X+1h
- model output frequency: 15min
- use of radar data: 2 dimensional composite every 5 minutes
  (better precipitation forecast until vv=4..5h)

Data assimilation

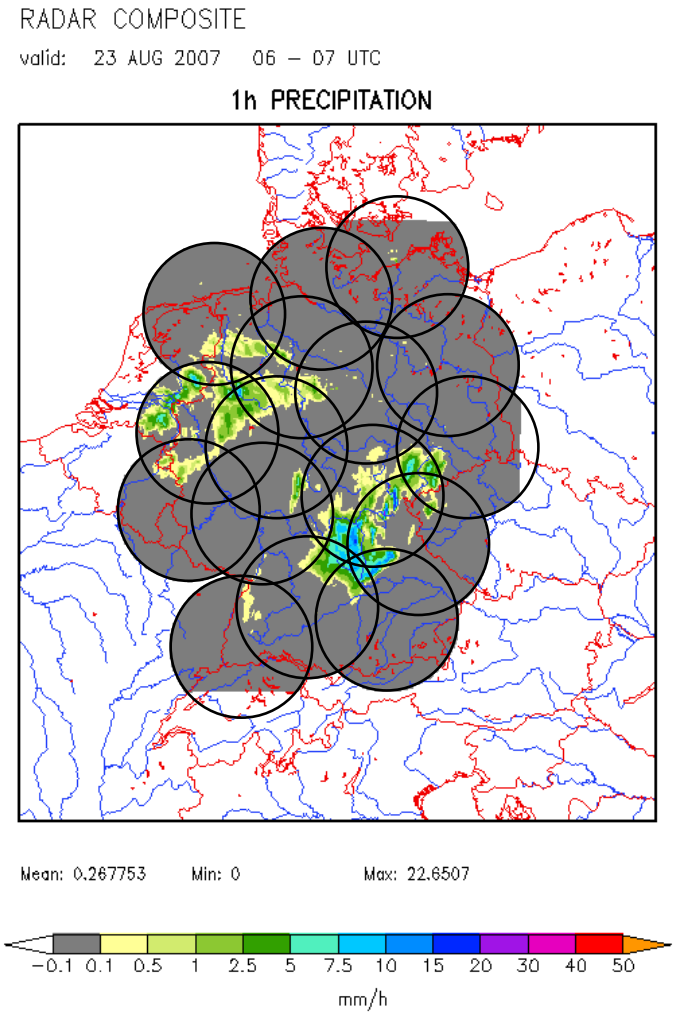
- 8 times a day: analysis + 3h nudging run

- continuous data assimilation (nudging scheme, 8 x 3h)
- separate analysis of sea surface temperature at 00 UTC
- separate analysis of snow (density/depth/temperature) at 00, 06, 12, 18 UTC
- assimilation of radar data with Latent Heat Nudging

Radar Data

Composite of 16 stations (reflectivity)

- terrain following scan, elevations: 0.5°-1.8°
- spatial resolution: 1km x 1km
- timeliness: 5 minutes
- quality check of spurious data (clutter, AnaProp, …)
- variable Z-R relation to derive rain rates



COSMO-DE - LHN

Latent Heat Nudging

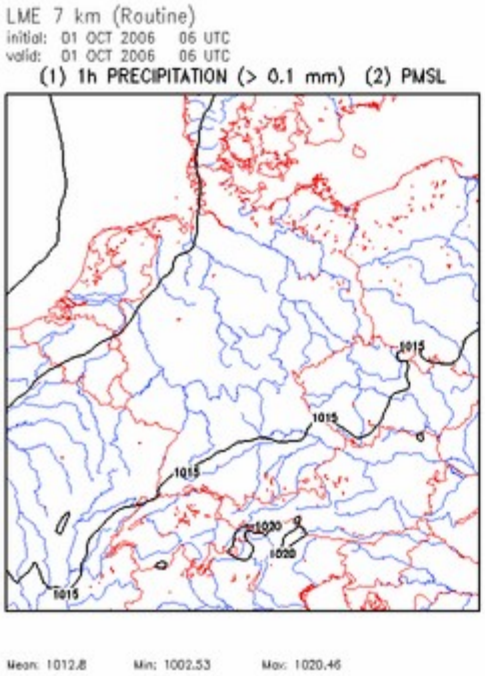
- Special nudging technique to assimilated radar derived precipitation
- Goal: Trigger the model's dynamic that it is able to produce the observed precipitation by its own
- Precipitation will have only little influence of thermodynamic
- Therefore temperature is used as it is strongly connected with precipitation formation

COSMO-DE

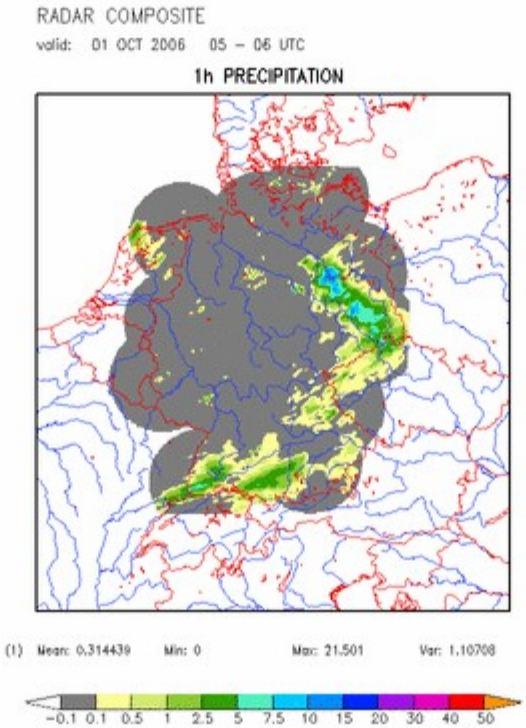
Convectively enhanced frontal precipitation, 1.10.2006, 18 UTC

Obs.: up to 20 mm/12 h

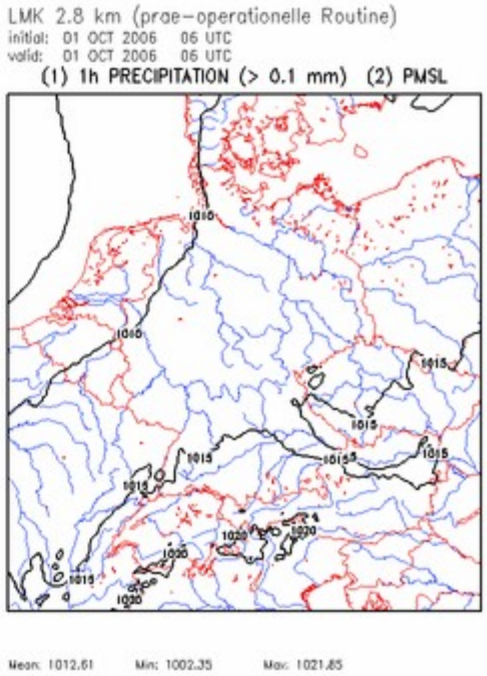
COSMO-EU (Δx=7 km)



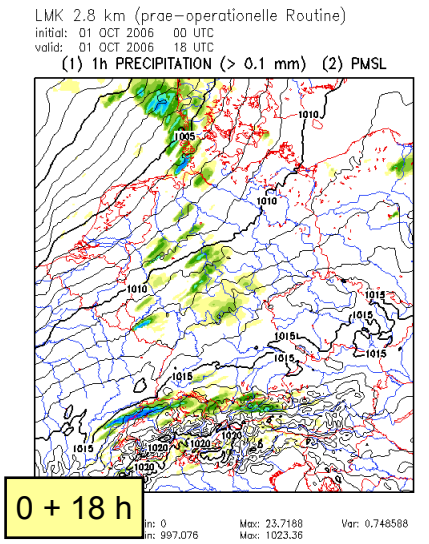
Radar observation

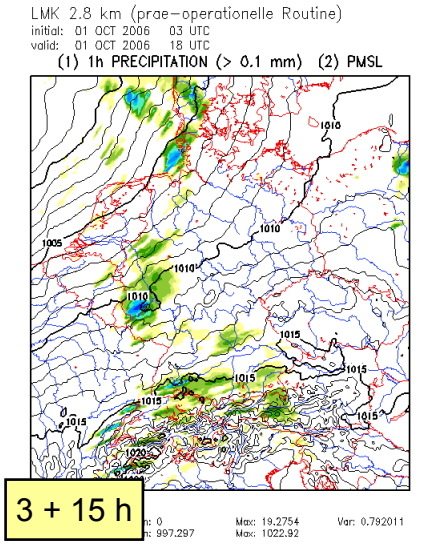


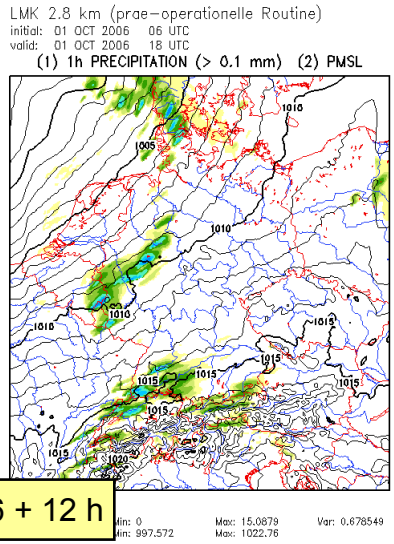
COSMO-DE (Δx=2.8 km)

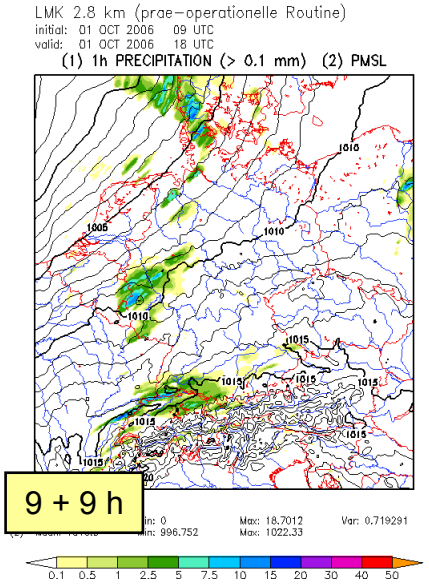


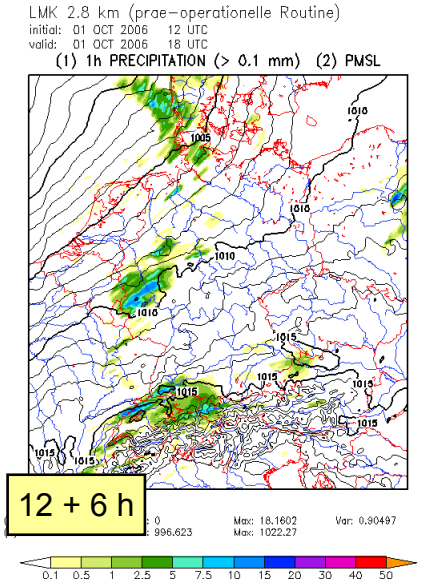
COSMO-DE

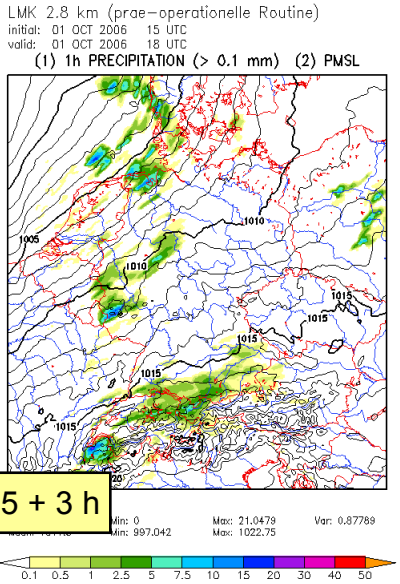












LAF-ensemble

- 1h-precipitation sum
- target time: 01.10.2006 18UTC

Physical parametrisation

Moist convection

no cumulus convection parametrization

→ explicit simulation of deep moist convection with its life cycle

→ no distinction between convective and stratiform precipitation

Shallow convection

especially needed to transport moisture out of the PBL

Turbulence

→ prognostic TKE (*Mellor-Yamada (1974)* level 2.5)

→ 1D vertical

→ subgrid-scale condensation

→ moist turbulence (buoyancy production of TKE altered by condensation process)

→ optional: 3D calc. of fluxes with full coordinate transformations
(*Herzog et. al., 2002, Baldauf, 2005, 2006*)

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Operational schedule
- “Modelluhr”

Databases / Data handling
- Databases
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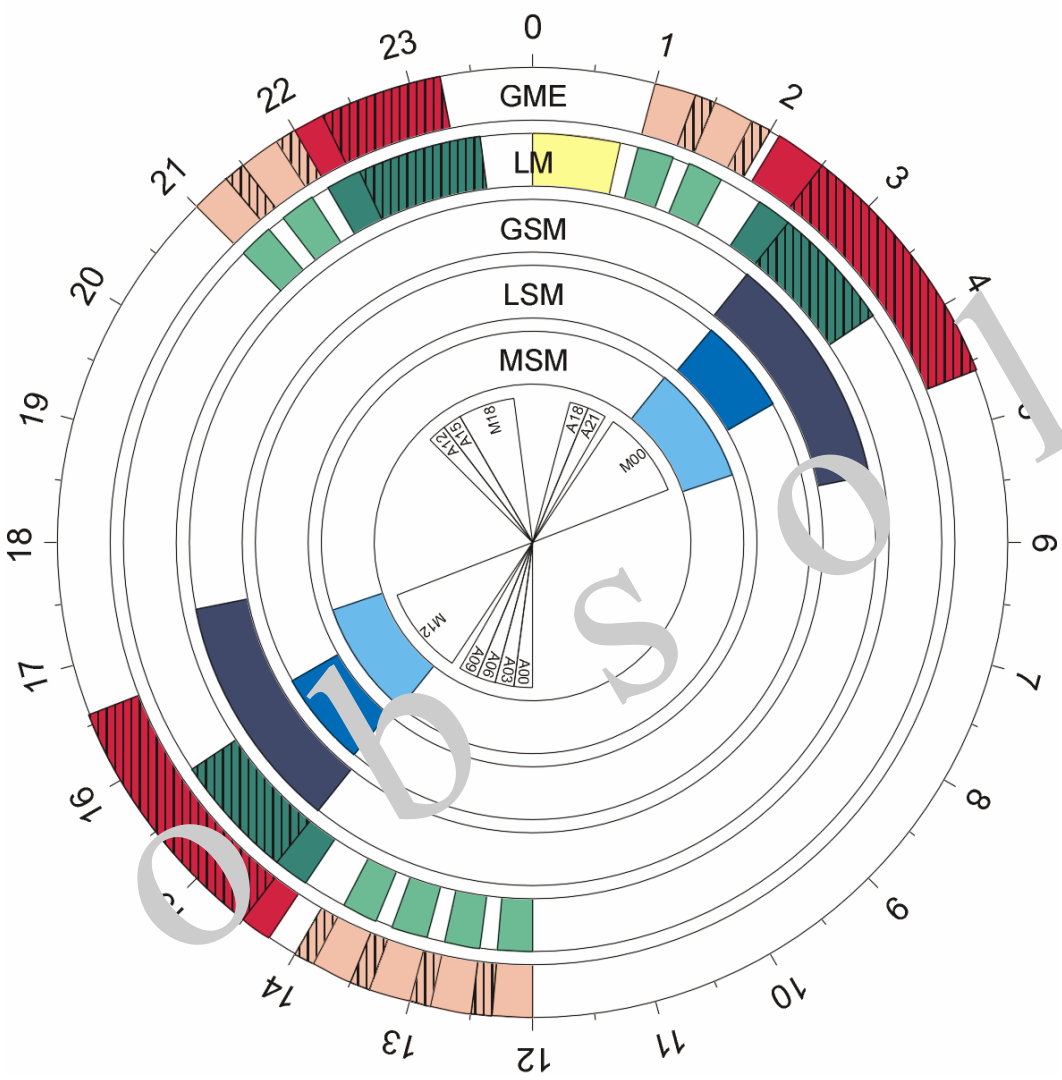
Outlook

Operational schedule (old)



Operational timetable of the DWD
forecast models
GME, LME, GSM, LSM, MSM

GME, LM: Analysis

GME, LM: Forecast

GSM, LSM, MSM

LM: surface moisture analysis

A ... Assimilation

M ... Forecast

Operational schedule

Requirements due to COSMO-DE

Meteorological

- rapid update cycle (8 x daily)
- forecast available at X+1h within database
- own data assimilation
- no decrease of the forecast quality of GME and COSMO-EU

Technical

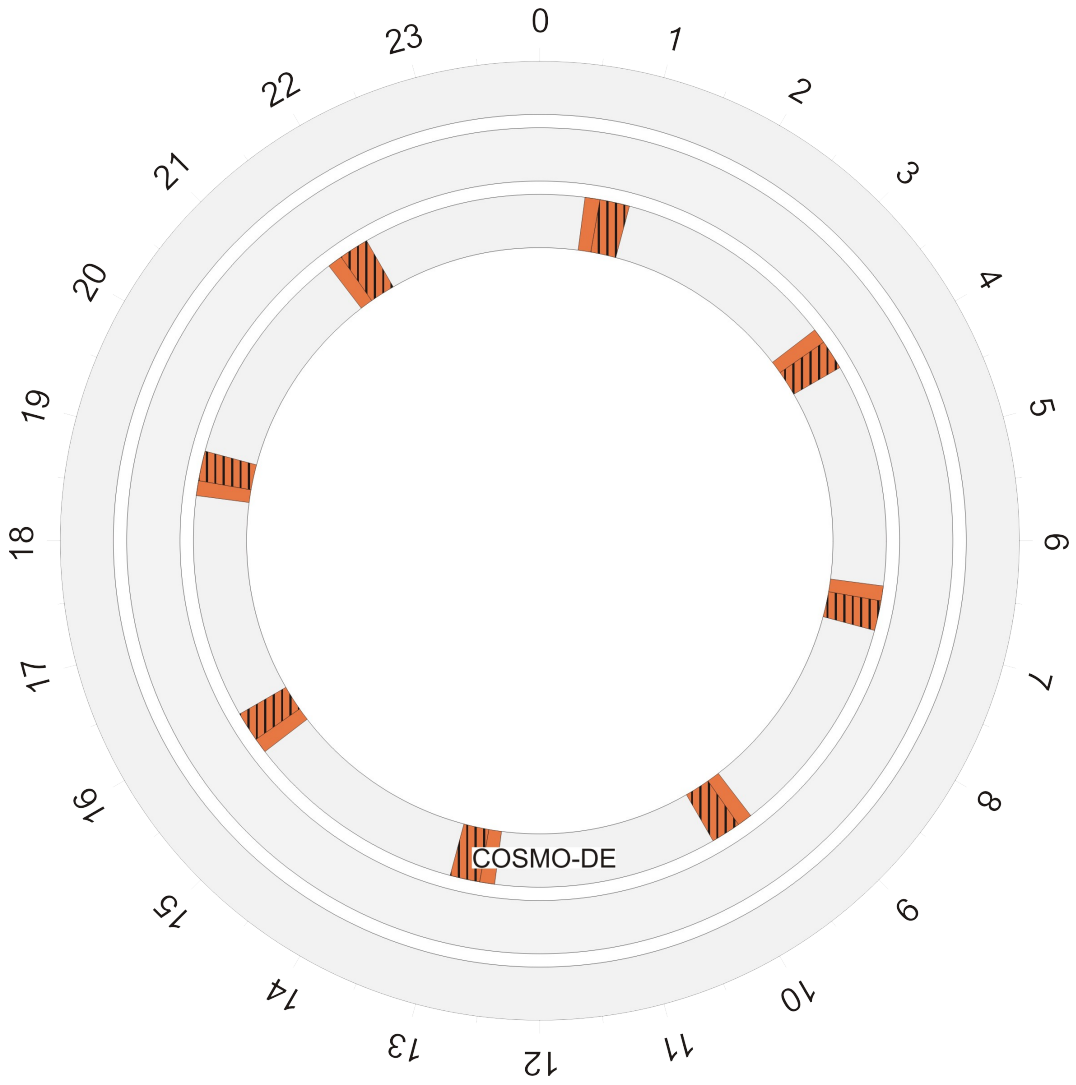
- compute server: maximum number of nodes to use is 42 (COSMO-EU and COSMO-DE cannot run at the same time)

Operational schedule

Node usage on compute-server (compute nodes)

• available nodes	42 = 52 – 4 (login) – 4 (GPFS) – 2 (spare)	
• GME	7	2 hours
• COSMO-EU	33	1 hour
• COSMO-DE	32	20 minutes
• interpolation GME→COSMO-EU	1	1 hour
• interpolation COSMO-EU→DE	1	20 minutes
• WAVE	1	2 hours

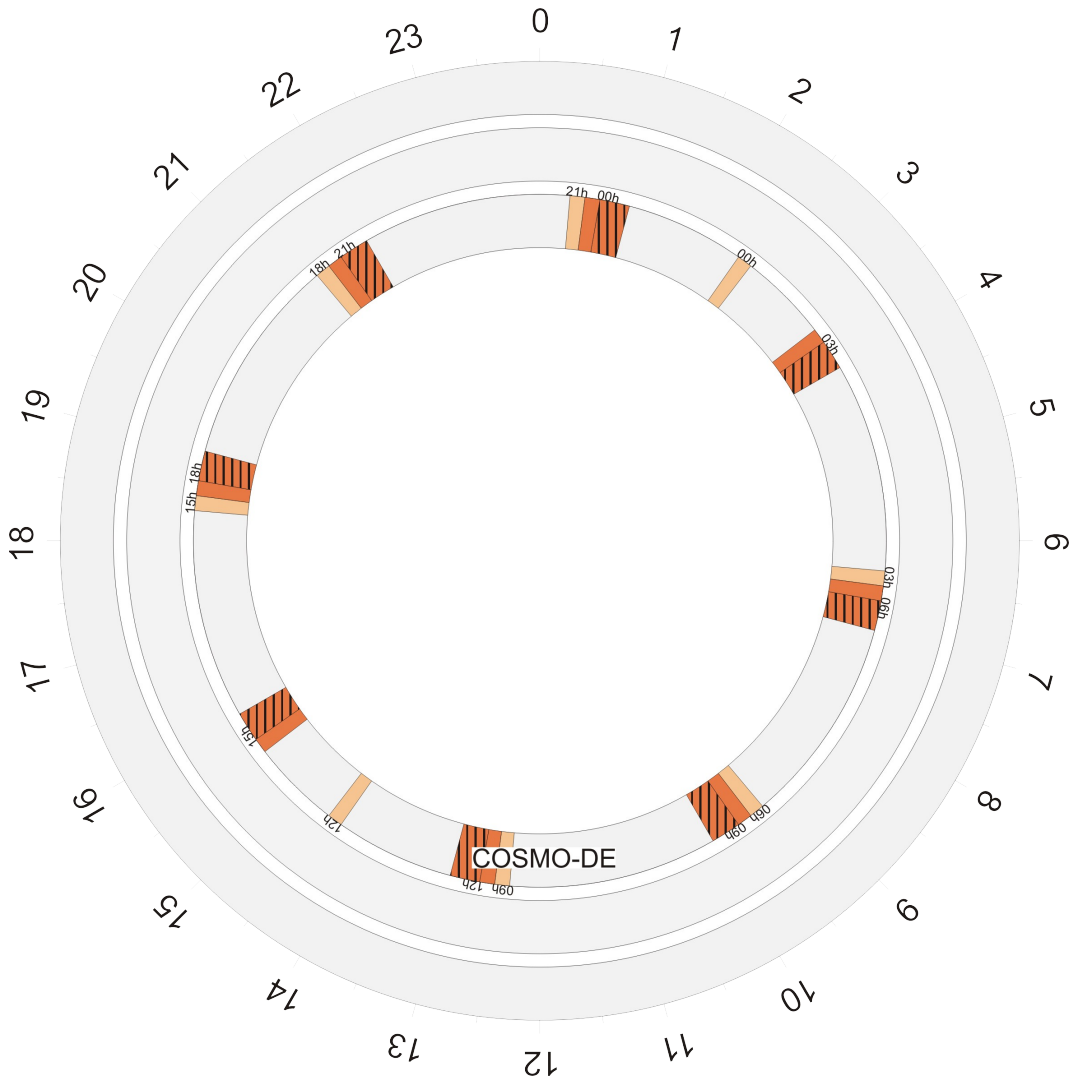
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE (main)	8 x daily

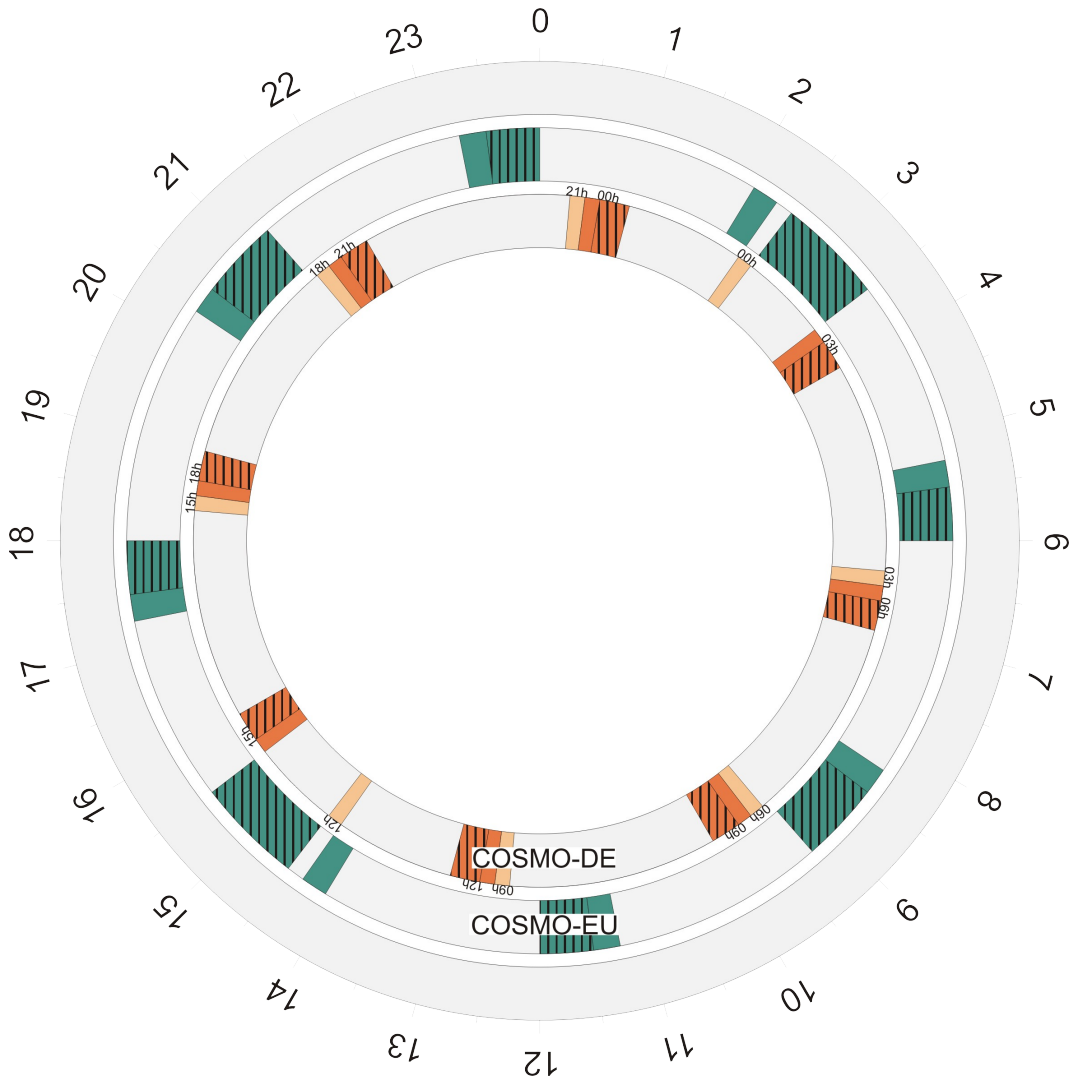
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE (main)	8 x daily
COSMO-DE (main+ass)	

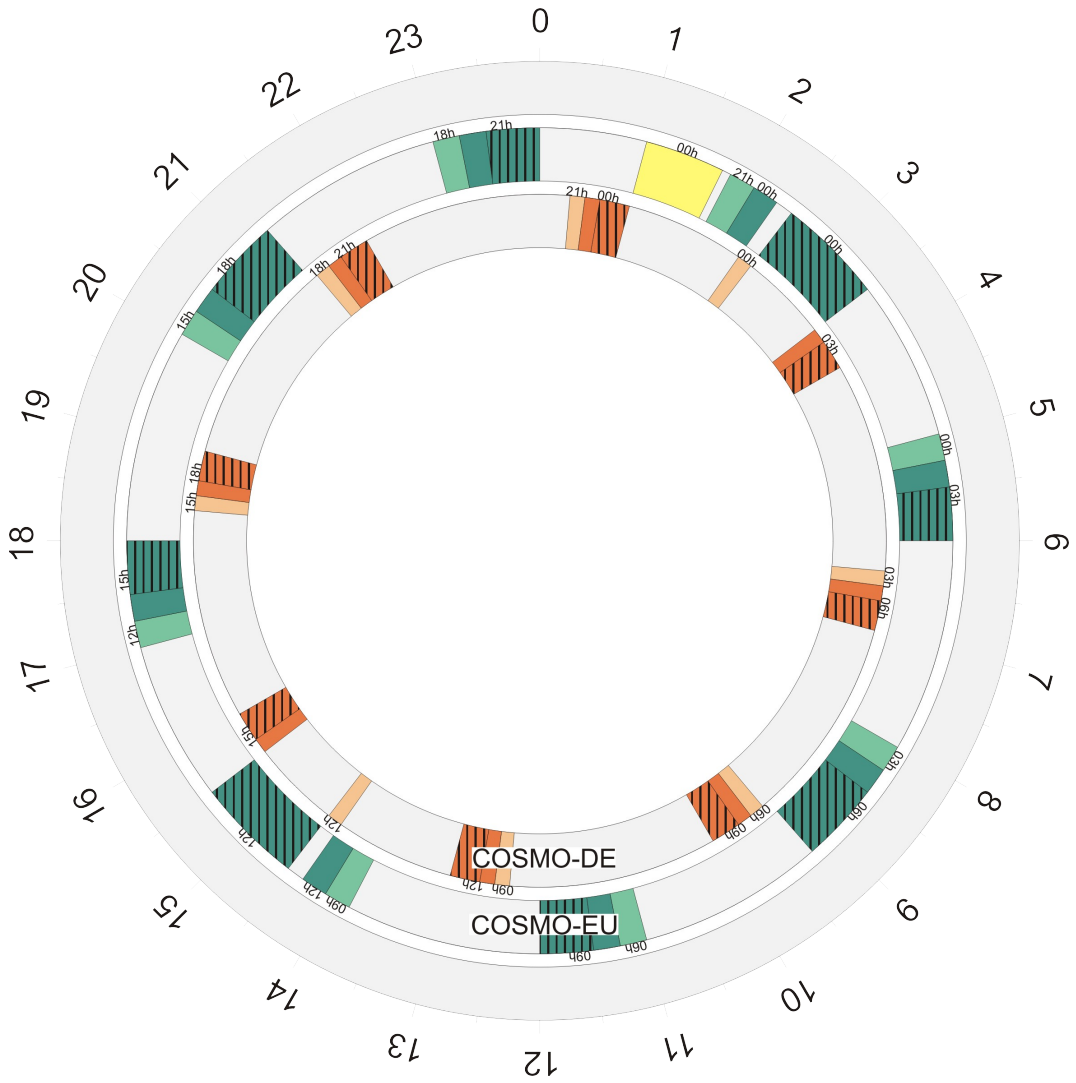
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE	8 x daily
COSMO-EU (main)	8 x daily

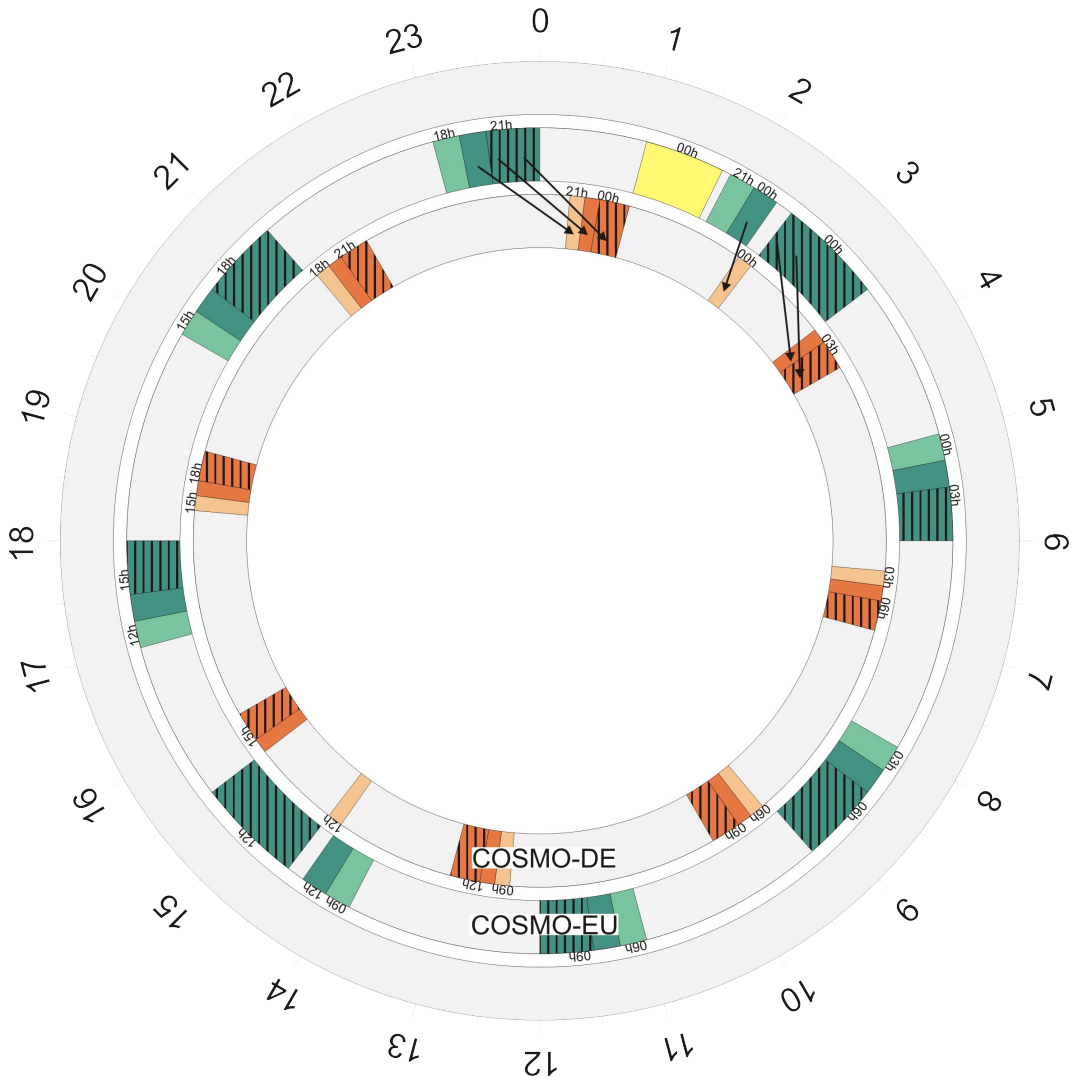
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE	8 x daily
COSMO-EU (main+ass)	8 x daily

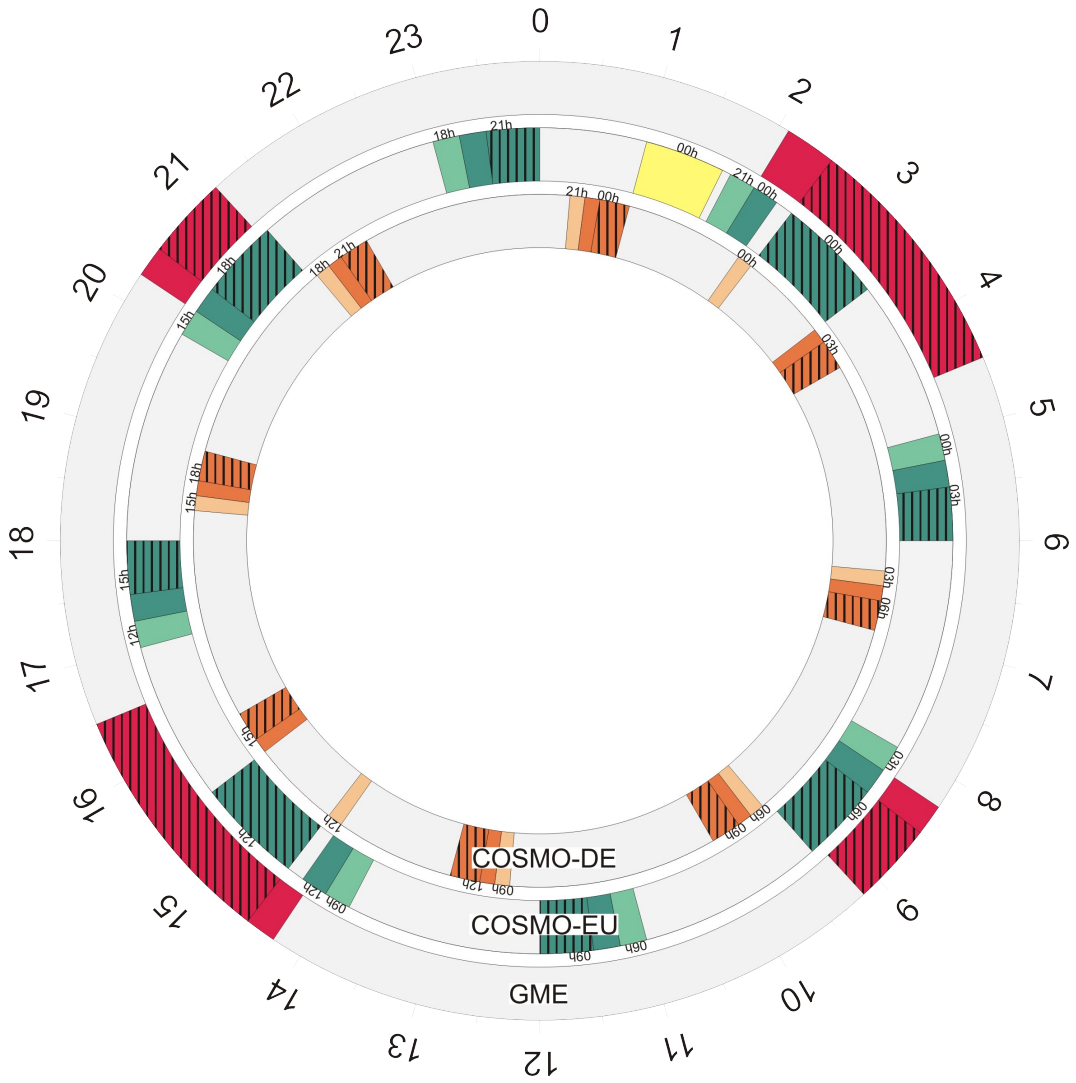
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE	8 x daily
COSMO-EU	8 x daily

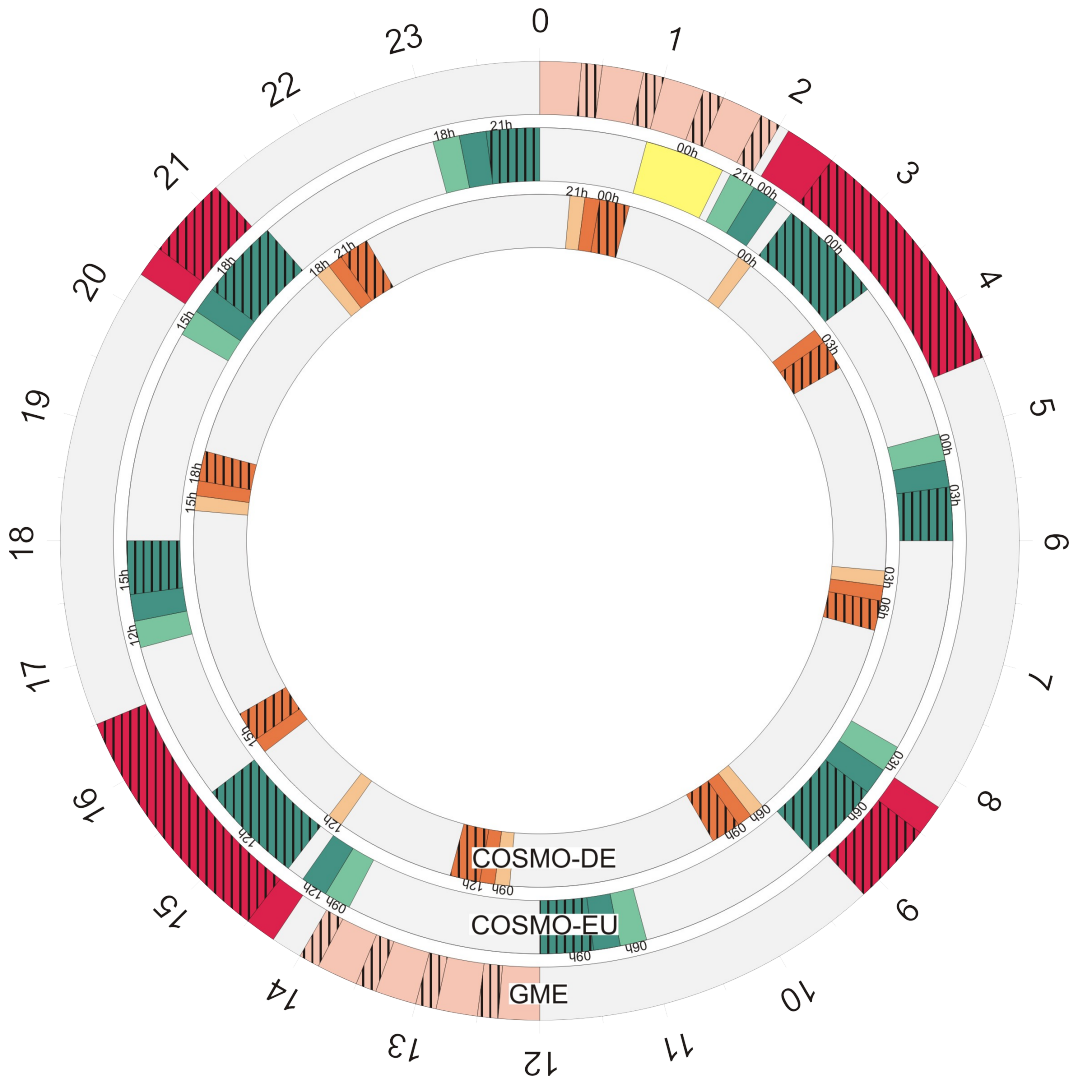
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE	8 x daily
COSMO-EU	8 x daily
GME (main)	4 x daily

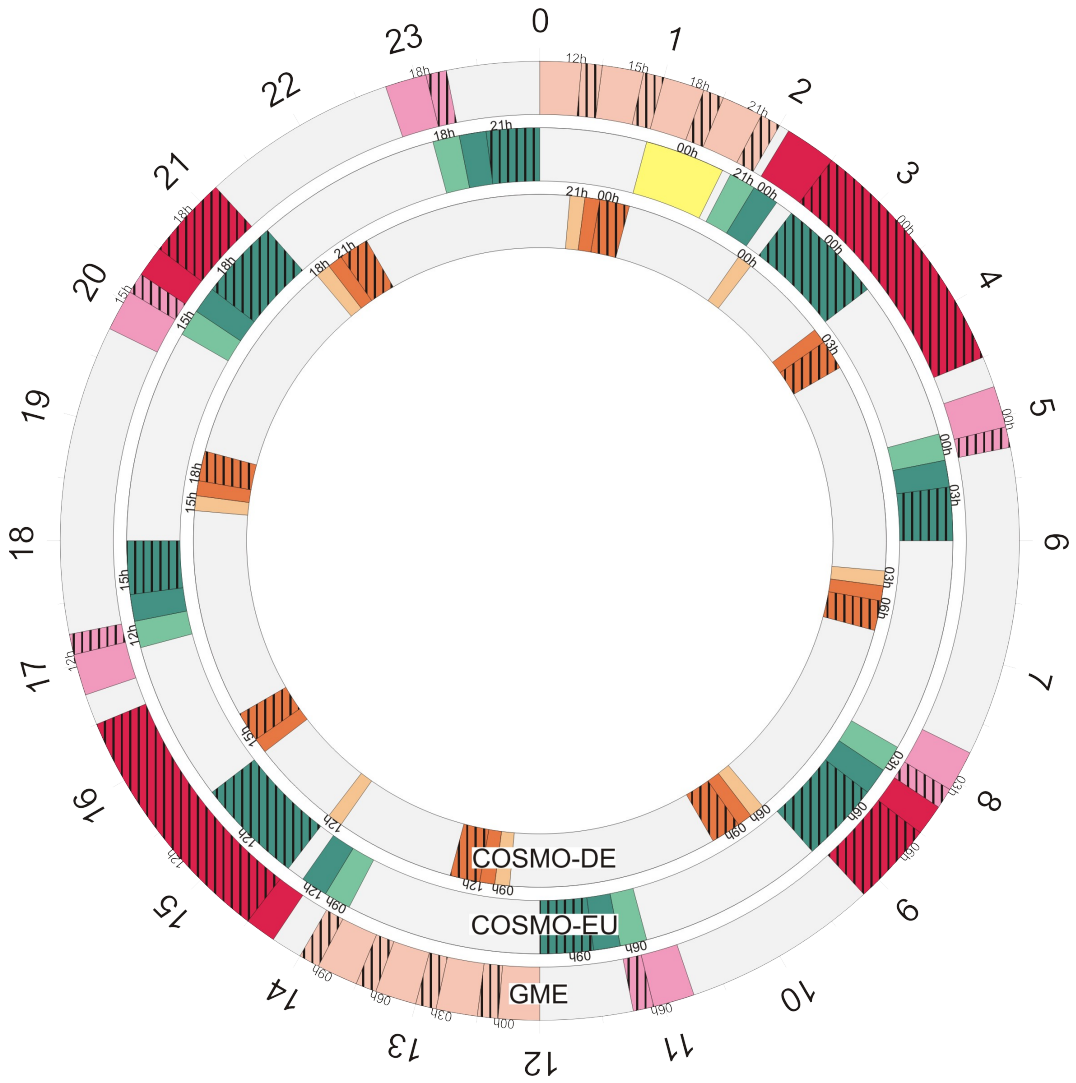
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE	8 x daily
COSMO-EU	8 x daily
GME (main)	4 x daily
GME (main+ass)	

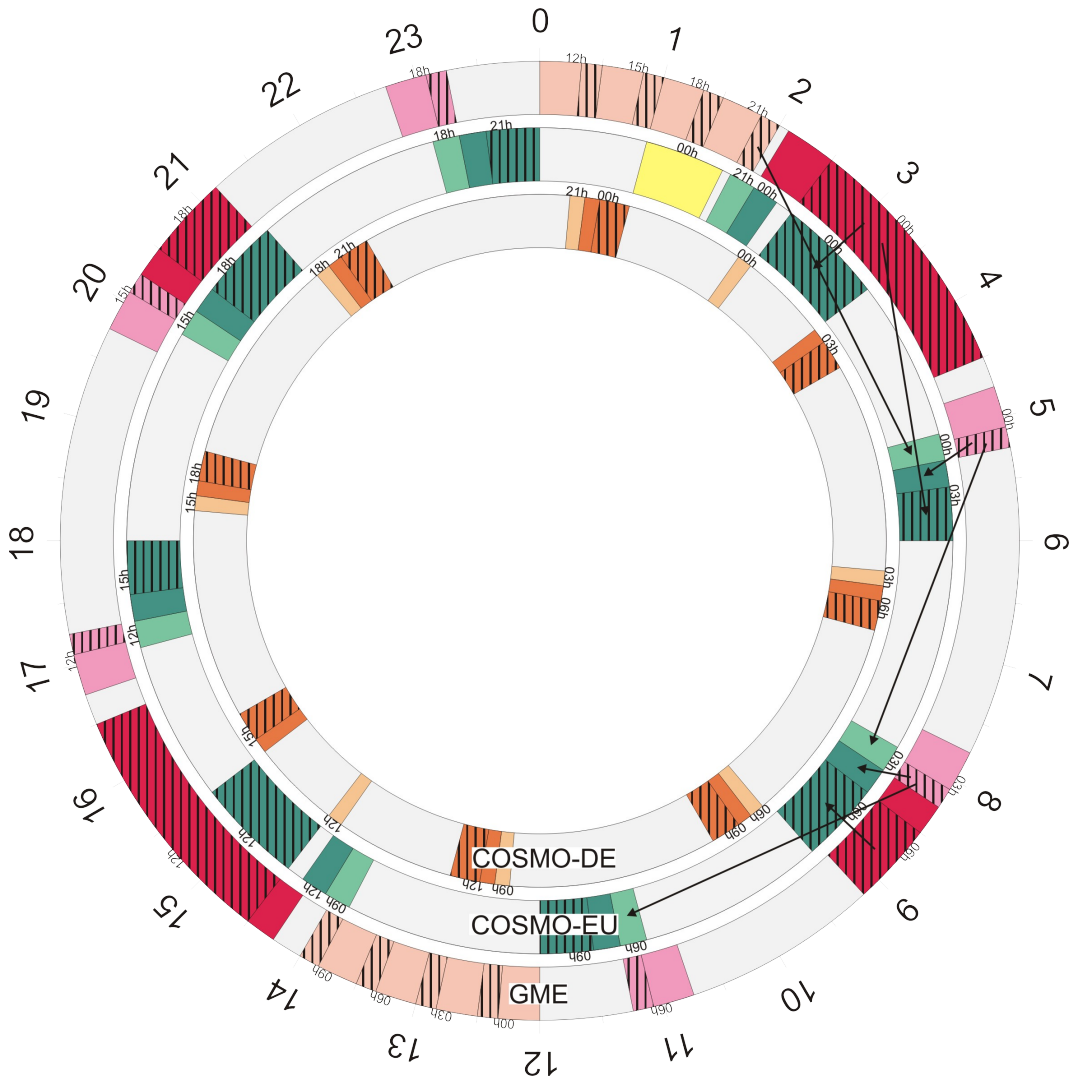
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE	8 x daily
COSMO-EU	8 x daily
GME (main)	4 x daily
GME (main+ass)	
GME (main+ass+pre)	

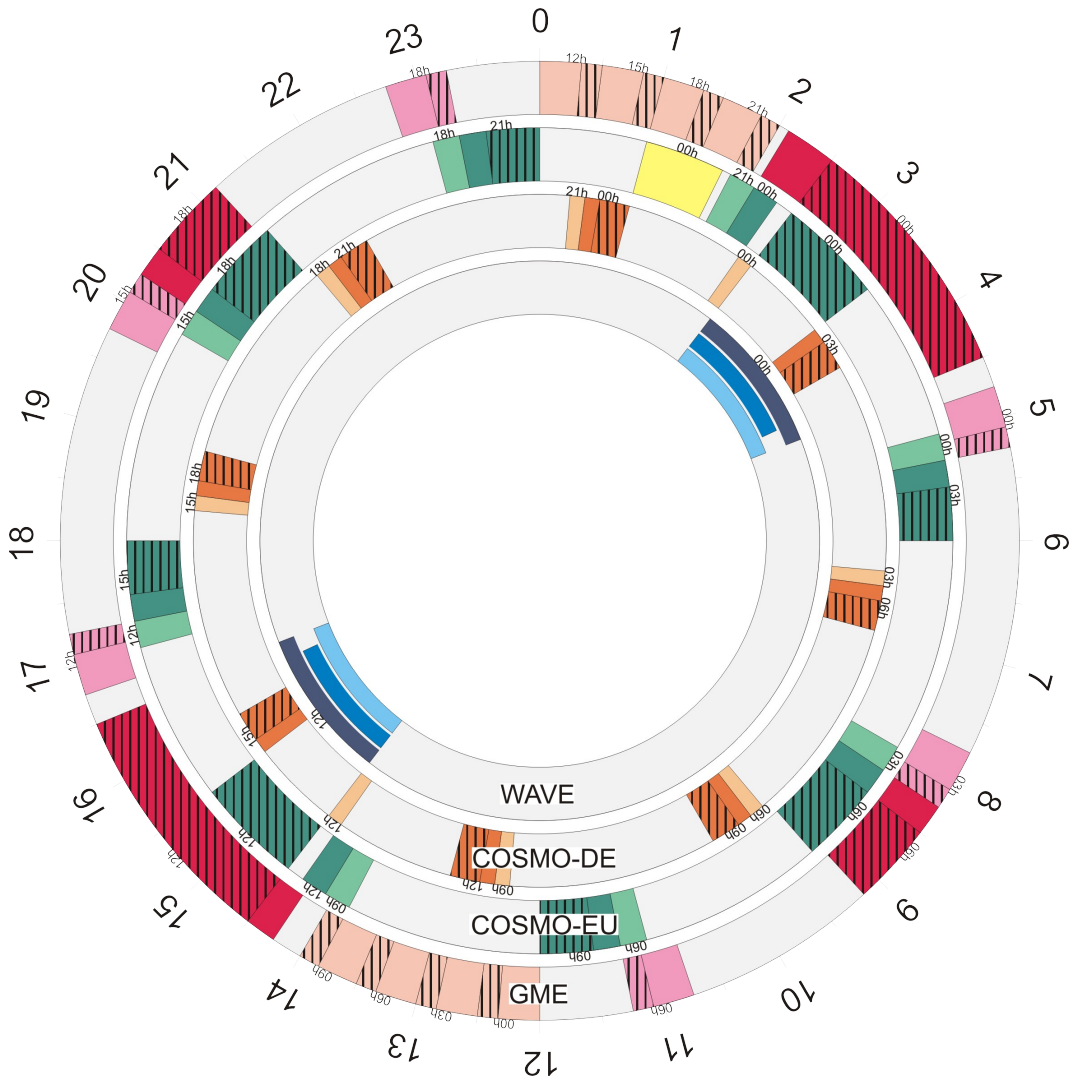
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE	8 x daily
COSMO-EU	8 x daily
GME	4 x daily

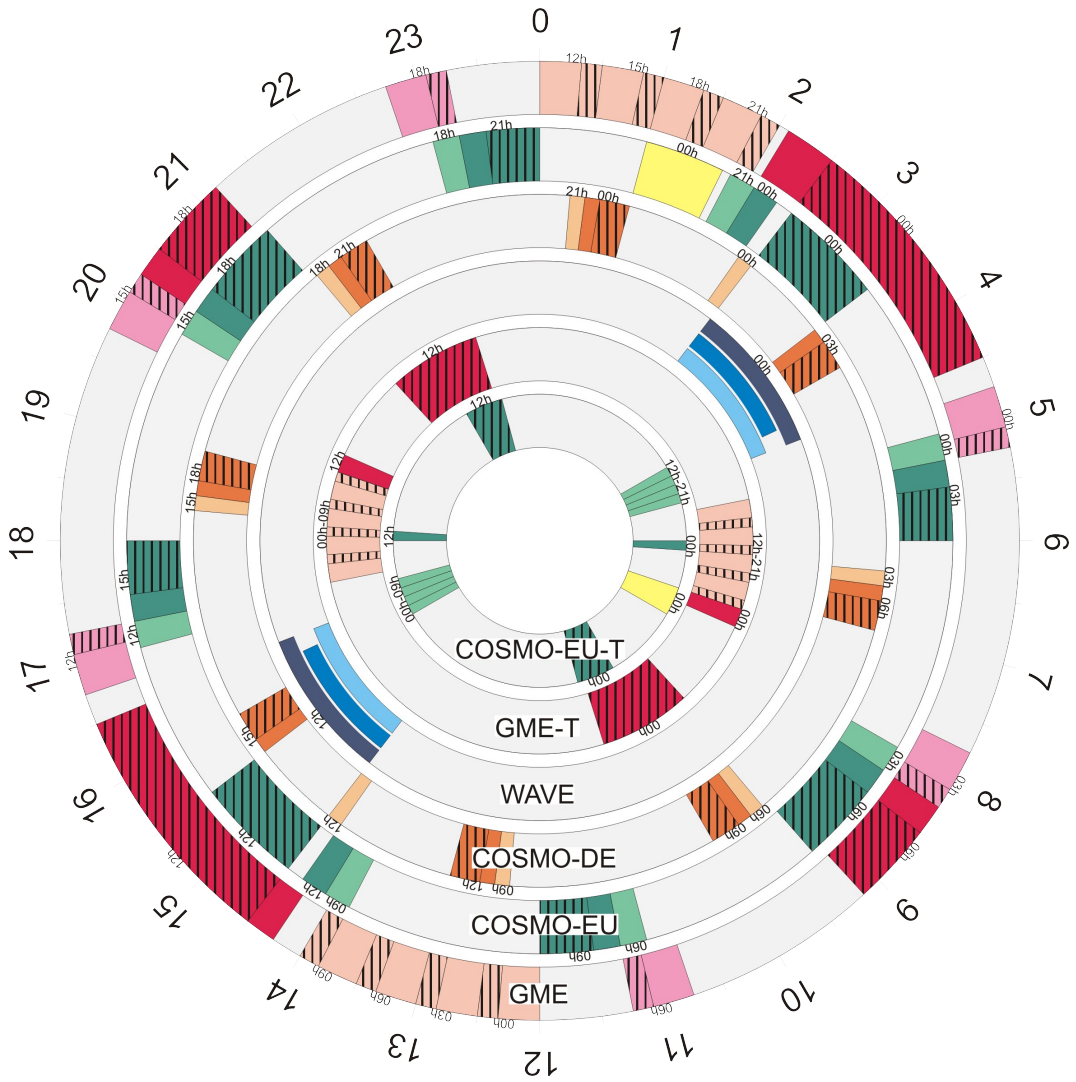
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE	8 x daily
COSMO-EU	8 x daily
GME	4 x daily
WAVE	2 x daily

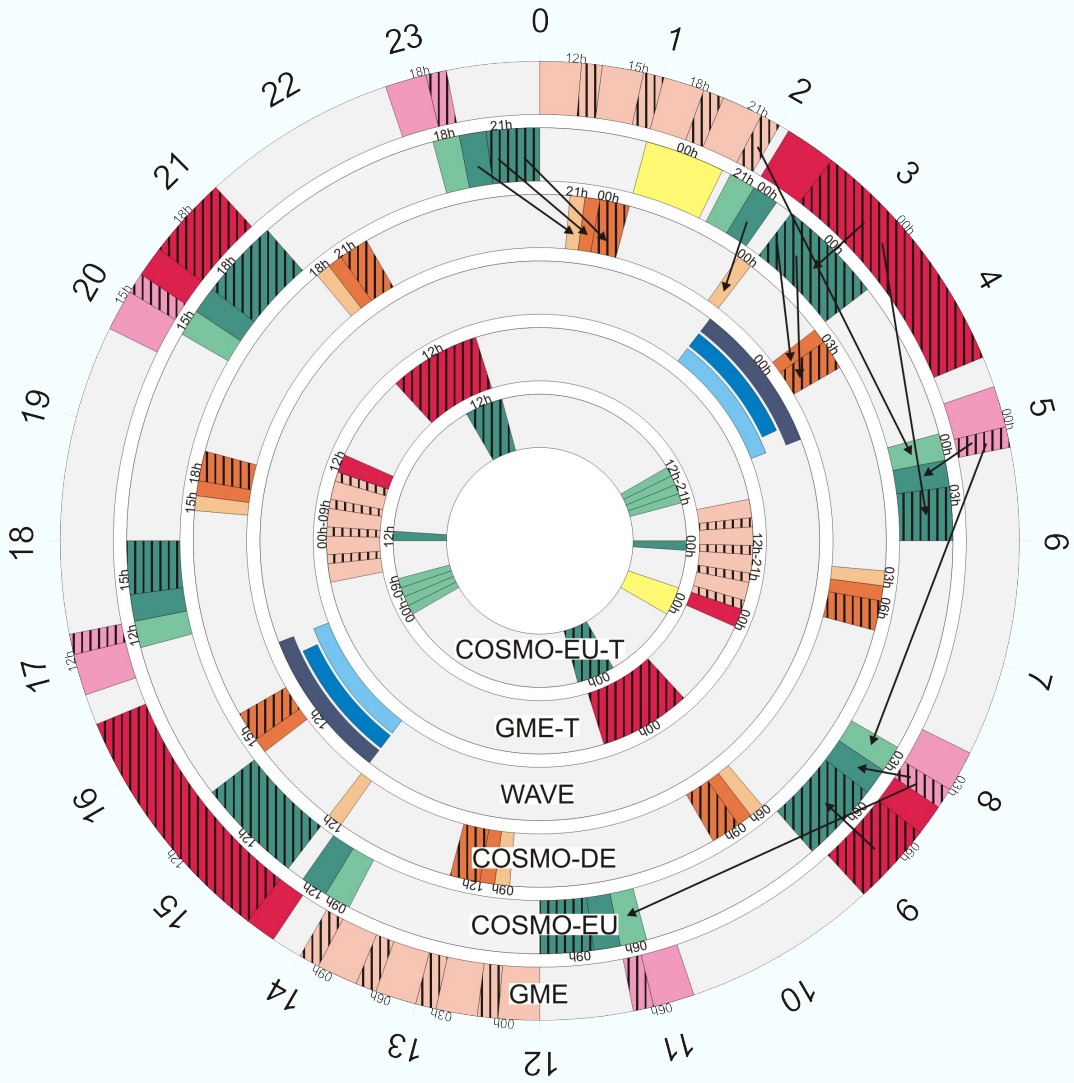
Operational schedule



"Modell-Uhr"
GME / COSMO-EU / COSMO-DE

COSMO-DE	8 x daily
COSMO-EU	8 x daily
GME	4 x daily
WAVE	2 x daily
GME (test suite)	2 x daily
COSMO-EU (test suite)	2 x daily

Operational schedule



Operational timetable of the DWD model suite GME, COSMO-EU, COSMO-DE and WAVE

	GME, COSMO: Analysis / Nudging
‖	GME, COSMO: Forecast
	WAVE (GSM, LSM, MSM)
	COSMO-EU: Surface moisture analysis
T	Testsuite
	Main run
	Pre-Assimilation
	Assimilation
00..23	real time [UTC]
00h, 03h, ..	model time

Operational schedule

main run

model	time [UTC]	forecast time	cut off [UTC]	ready [UTC]
GME	00, 12 06, 18	174 78	02:14 / 14:14 08:15 / 20:15	04:30 / 16:30 09:00 / 21:00
COSMO-EU	00, 12 06, 18 03, 09, 15, 21	78 48 24	02:14 / 14:14 08:15 / 20:15 05:15 / 11:15 / 17:15 / 23:15	03:30 / 15:30 09:15 / 21:15 06:00 / 12:00 / 18:00 / 24:00
COSMO-DE	00, 03, 06, 09 .. 21	18 (21)	00:30 / 03:30 / 06:30 .. 21:30	01:00 / 04:00 / 07:00 .. 22:00

Operational schedule

pre-assimilation run

model	time [UTC]	forecast time	cut off [UTC]
GME	00, 03, 06, 12, 15, 18	3	04:44 / 07:44 / 10:44 / 16:44 / 19:44 / 22:44

assimilation run

model	time [UTC]	forecast time	cut off [UTC]
GME	00, 12 03, 15 06, 18 09, 21	3 3 3 3	12:03 / 00:03 12:33 / 00:33 13:03 / 01:03 13:33 / 01:33
COSMO-EU	00, 03, 06, 12, 15, 18 09, 21	3 3	05:00 / 08:00 / 11:00 / 17:00 / 20:00 / 23:00 13:50 / 01:50
COSMO-DE	00, 12 03, 06, 09, 15, 18, 21	3 3	02:20 / 14:20 06:20 / 09:20 / 12:20 / 18:20 / 21:20 / 00:20

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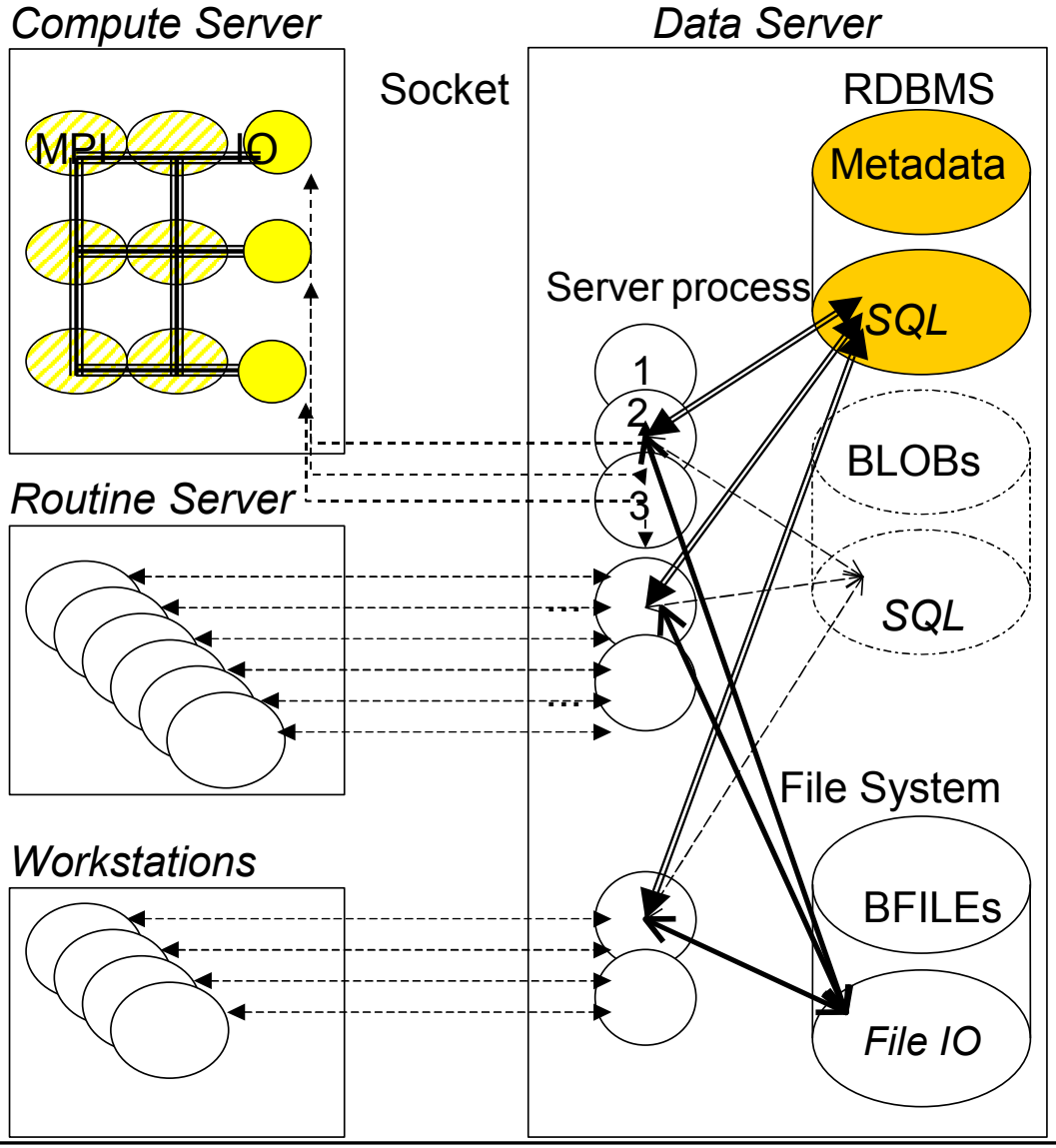
Outlook

Database



Database configuration

with respect

to handling binary data

Database

based on a commercial RDBMS (ORACLE)

access from clients is performed by socket communication

- user interface 'csobank' (DWD software, multiple platforms)
- SQLNET via 'obank' (with restrictions) if available

data format

- GRIB
- BUFR
- pure binary (ascii, compressed files , ...)

internal store of binary data

- BLOB (possible but not widely used)
- BFILE (only metadata within ORACLE, data within filesystem, access via pointer)

Archive

- archive handling is included into “oserver”-software
  - many special features to handle data of NUMEX within private databases (create, explicit archiving, explicit unarchiving, aload, testing, ...)
- users don't have to know, whether data are already archived or not

	all	forever	expire	NUMEX
size [TB]	**1600**	**300**	**300**	**875**
files	**7.900.000**	**950.000**	**1.650.000**	**3.950.000**
tapes	**12750**	**3825**	**1785**	**4845**

Tape I/O [TB]: 1010 read 1592 write

october 2007

- NUMEX: use the archive as a **large disk cache** of some Petabyte (depends on tape size)

Archive

Problem: new NWP models produce new data → but every archive is limited

one solution: gribzip

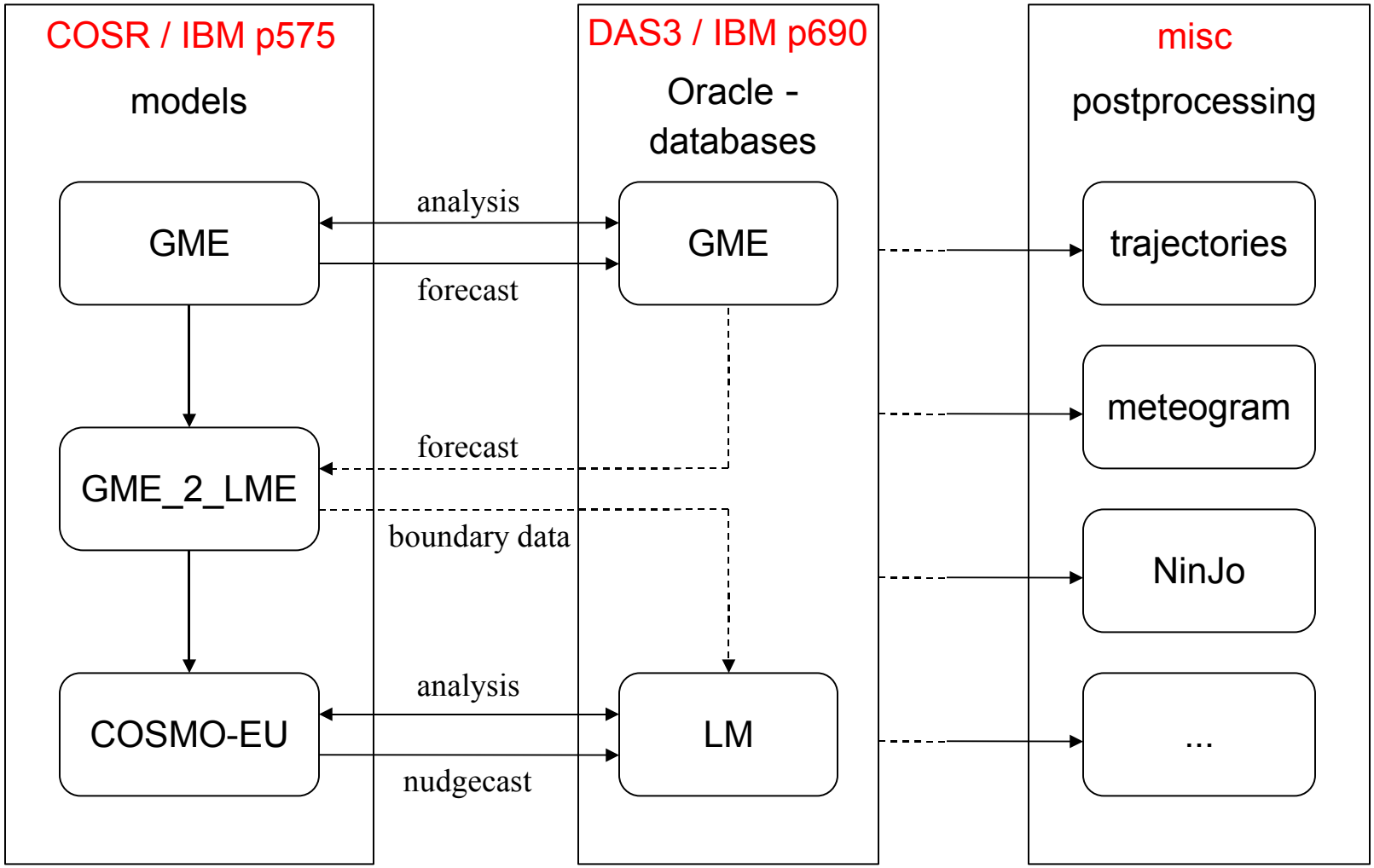
developer: Institute for Algorithms and Scientific Computing – SCAI
Fraunhofer ICT Group

compression / decompression of GRIB1 data produced by the COMSO-model

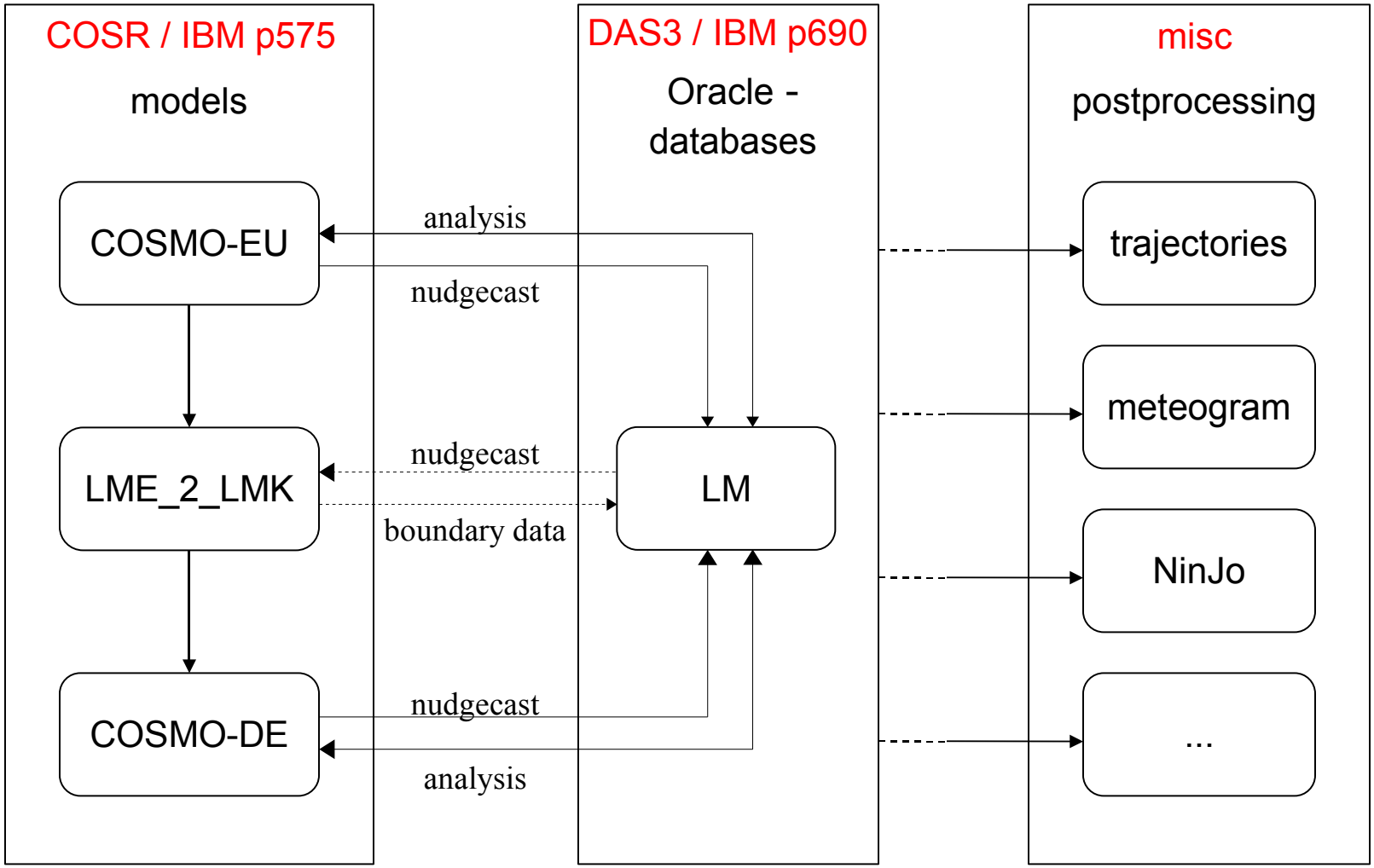
achieved compression factor:	ca. 2,5 to 2,8
throughput on IBM Power 4:	5,5 MB/s (including file I/O)
introduced at DWD since 2007-11-06:	compress COSMO-model data produced by NUMEX

Link: http://www.scai.fraunhofer.de/nuso.0.html?L=1
http://www.ercim.org/publication/Ercim_News/enw61/lorentz.html

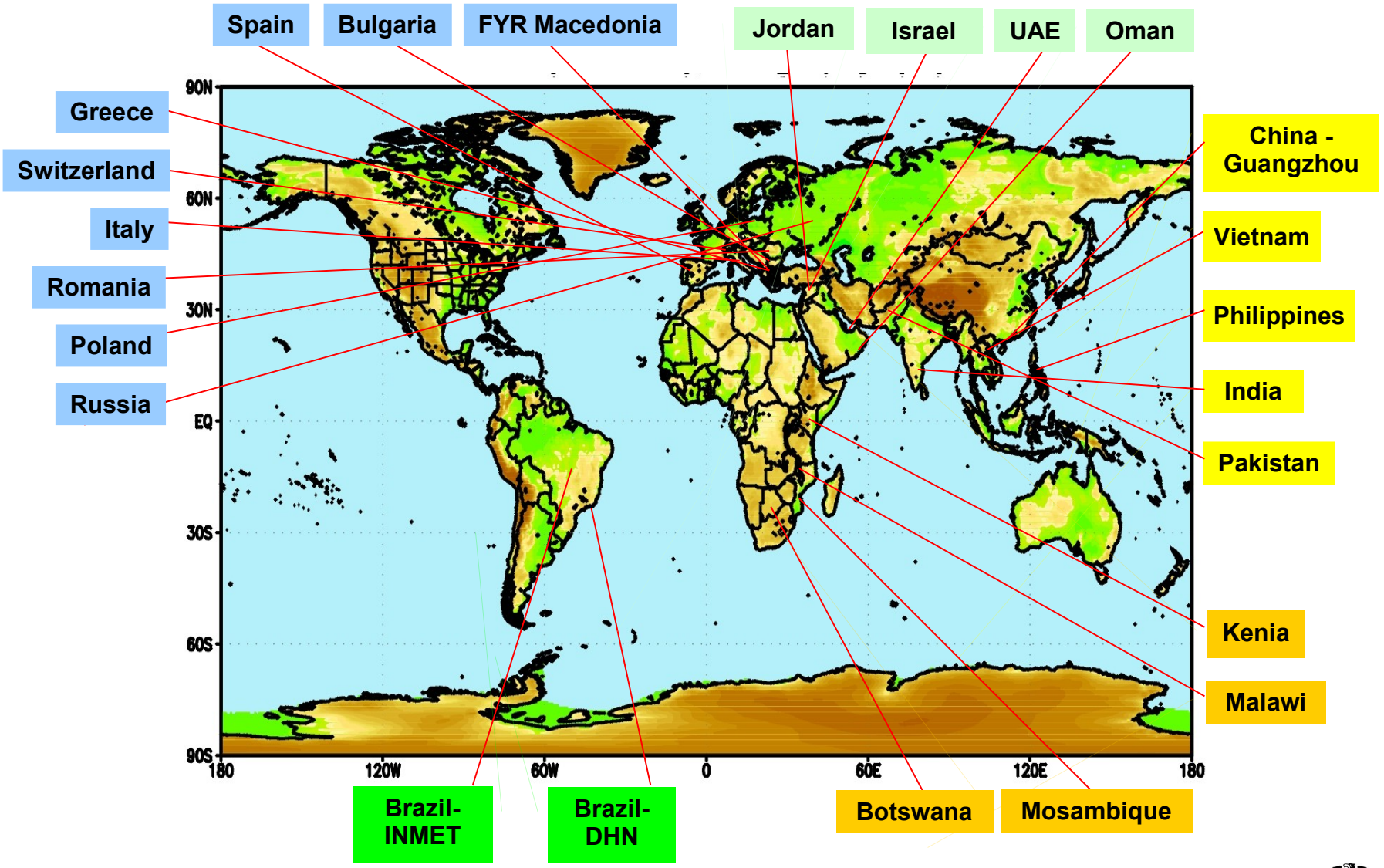
Data flow GME → COSMO-EU



Data flow COSMO-EU → COSMO-DE



GME – boundary data to COSMO and HRM



HRM

- Operational NWP Model at 20 services worldwide
- Hydrostatic, (rotated) latitude/longitude grid
- Operators of second order accuracy
- 7 to 28 km mesh size, various domain sizes
- 30 to 40 layers (hybrid, sigma/pressure)
- Prognostic variables: p_s, u, v, T, q_v, q_c, q_i
- Same physics package as GME
- Programming: Fortran90, OpenMP/MPI for parallelization
- From 00 and 12 UTC: Forecasts up to 78 hours
- Lat. bound. cond. from GME at 3-hourly intervals

BACK

Data Distribution

Commercial users

- by law: DWD has to take money from commercial users getting GRIB or BUFR data

- data requests → data service section
- data distribution → TI – section (mostly)
  → sometime needs a while :-(

- automatic interfaces in development
- long time process ..

Data Distribution

Research users

→ no fee for the data

- universities and research institutes in Germany use the COSMO model for research purposes → advantage of DWD :-)
- QPF project SPP1167 of DFG
- CLIMA-LM community
- ..

great demand for an automatic data delivery system to get analysis and boundary grib data for their model runs

Data Distribution - SPP1167

SPP – Web-Interface

- free use for SPP community and other research institutes
- own user administration (no need to have an internal DWD user ID)
- no direct access to DWD internal infrastructure (avoid security problems)
- definition of detailed data requests via web-interface

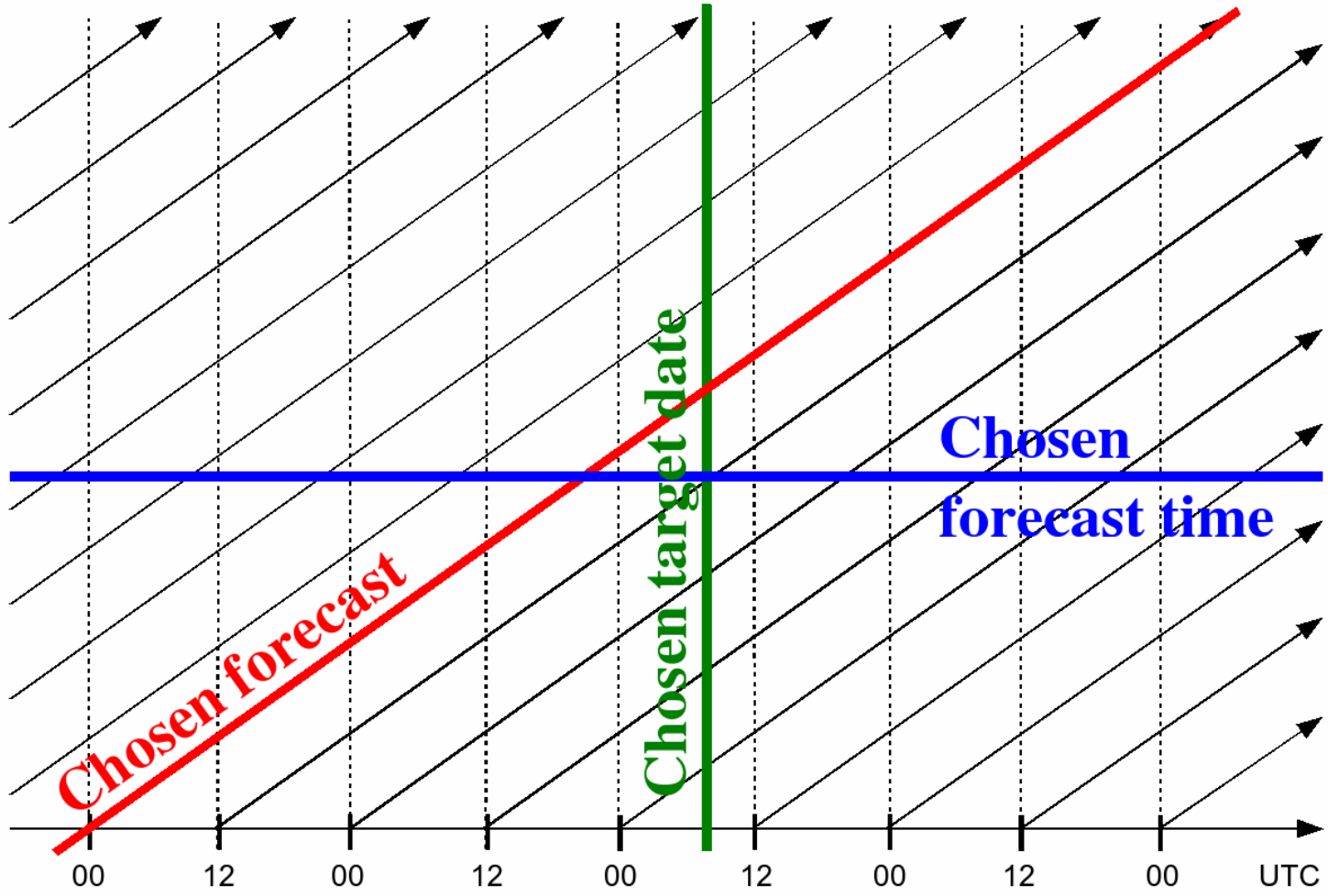
- execution via NUMEX infrastructure
- data are provided on an special FTP-server (7 days available)
  → no problems with external network administrators (universities, ..)
- technical problems during execution are solved by DWD staff
  (external user will not notice them)

- limitations: no observational data
  only model data older than 2 days

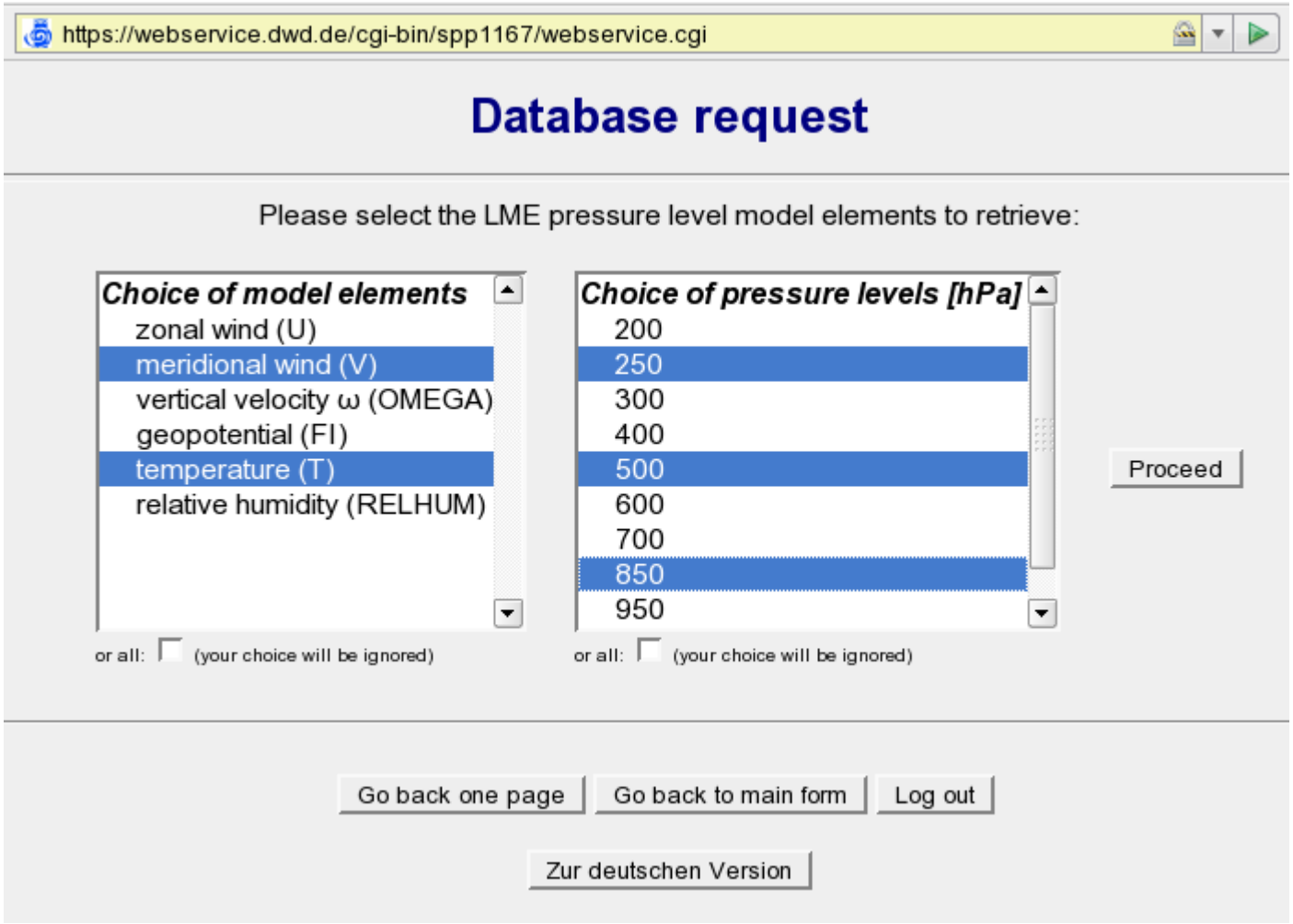
- use of the web-interface for internal purposes of DWD too !!!

Data Distribution - SPP1167

Access modes to data within database and archive



Data Distribution - SPP1167



Outline

IT - infrastructure

NWP models
- GME
- COSMO-EU
- COSMO-DE

Operational schedule
- “Modelluhr”

Databases / Data handling
- Databases
- Archive
- Data flow
- Data distribution

Outlook

Outlook - DMRZ_E

Compute server: 2 x NEC SX-9

2008 8 Nodes with 16 Cores 13 TFlop/s (5 TFlop/s)
2010 factor 3

login nodes: 3 TFlop/s peak
200 TB disc space (I/O: 4GB/s)
availability 99.9% / month

Data server: SGI Altix with 2 partitions

ORACLE
290 TB disc space BFILEs, 30 TB metatdata (I/O: 2GB/s read/write)
availability 99.9% / month

Outlook - GME / COSMO

GME

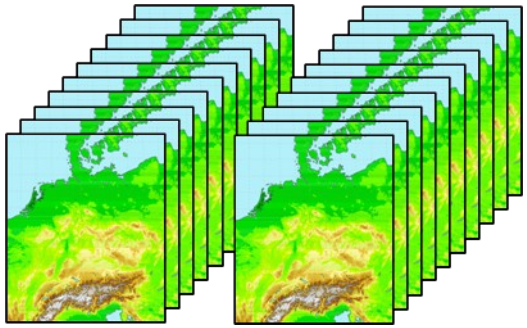
- 2008 3Dvar for satellite data
- 2008 surface moisture analysis
- 2009 GME 20km (NI=384) 60 level

COSMO-EU

- 2008 Lake model

COSMO-DE

- 2009 EPS 20 members pre-operational
- 2011 EPS 40 members operational

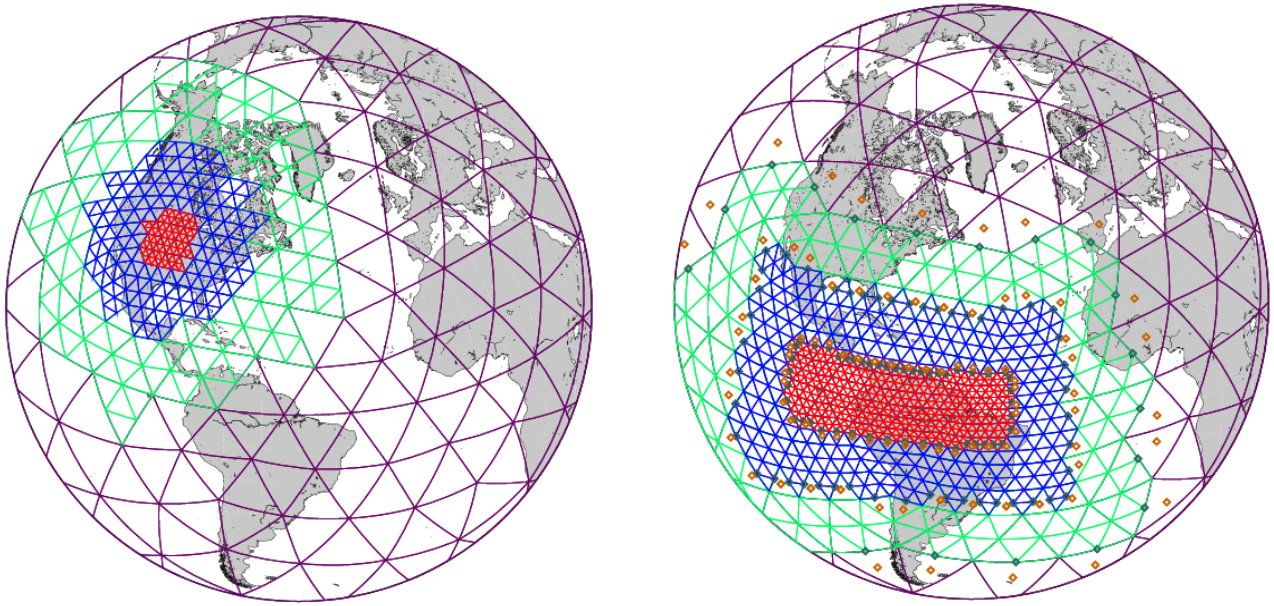


Outlook - ICON

ICOsahedral **N**onhydrostatic Global Circulation Model (2011)

A joint model development of DWD and Max-Planck-Institute for Meteorology

Develop a new global *weather forecast* and *climate simulation* model on the i*cosahedral-hexagonal grid* and solving the fully compressible *nonhydrostatic* equations with a *local zooming option*



Thank You