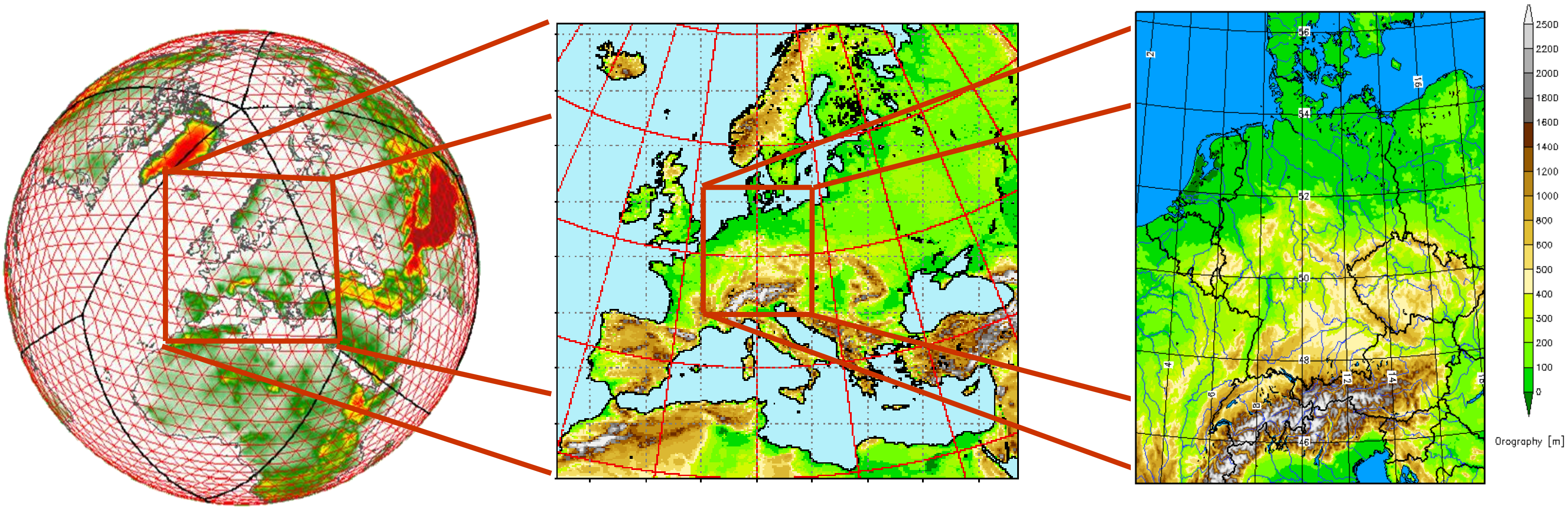
Center report DWD

28th WGNE meeting,
05-09 Nov. 2012, Toulouse

M. Baldauf, H. Frank, G. Zängl, C. Gebhardt, S. Theis (DWD)

The operational Model Chain of DWD: GME, COSMO-EU and -DE

GME | **COSMO-EU** | **COSMO-DE**



GME

hydrostatic
parameterised convection
$\Delta x \approx 20$ km
1482250 * 60 GP
$\Delta t = 66.7$ sec., T = 7 days

COSMO-EU

non-hydrostatic
parameterised convection
$\Delta x = 7$ km
665 * 657 * 40 GP
$\Delta t = 66$ sec., T = 78 h

COSMO-DE

non-hydrostatic
convection-permitting
$\Delta x = 2.8$ km
421 * 461 * 50 GP
$\Delta t = 25$ sec., T = 21 h
(since 16. April 2007)

Changes in GME

- 3DVar: use of 'atmospheric motion vector (AMV)' winds over land
  positive effect on the northern hemisphere and Europe (Dec. 2011)
- 3DVar: use of windprofiler networks (USA, Europe, Japan)
  → derivation of radial wind velocity (Feb. 2012)
- increase of resolution: 30 km → 20 km (‚GME20L60‘)
  advection of rain and snow (March 2012)
- DA: use of scatterometer data from Oceansat-2 (OSCAT) (Juli 2012)
  improvements in regions without other observations (S-hemisphere, tropics)

Plans:

- Replace GME by ICON in Q4/2013 .. Q2/2014

GME20L60

- increase of resolution: 30 km → 20 km (60 levels remaining)
- GME20L60 in production since 01 March 2012
- advection of rain and snow by a Semi-Lagrangian scheme with 2nd order interpolation
- technical changes to improve parallelisation for the 10 'diamonds' of the icosahedral grid (smaller ratio 'halo : inner region' is more important than load balancing) → problems with runtime of GME (and SMA-GME) on NEC SX9 are solved

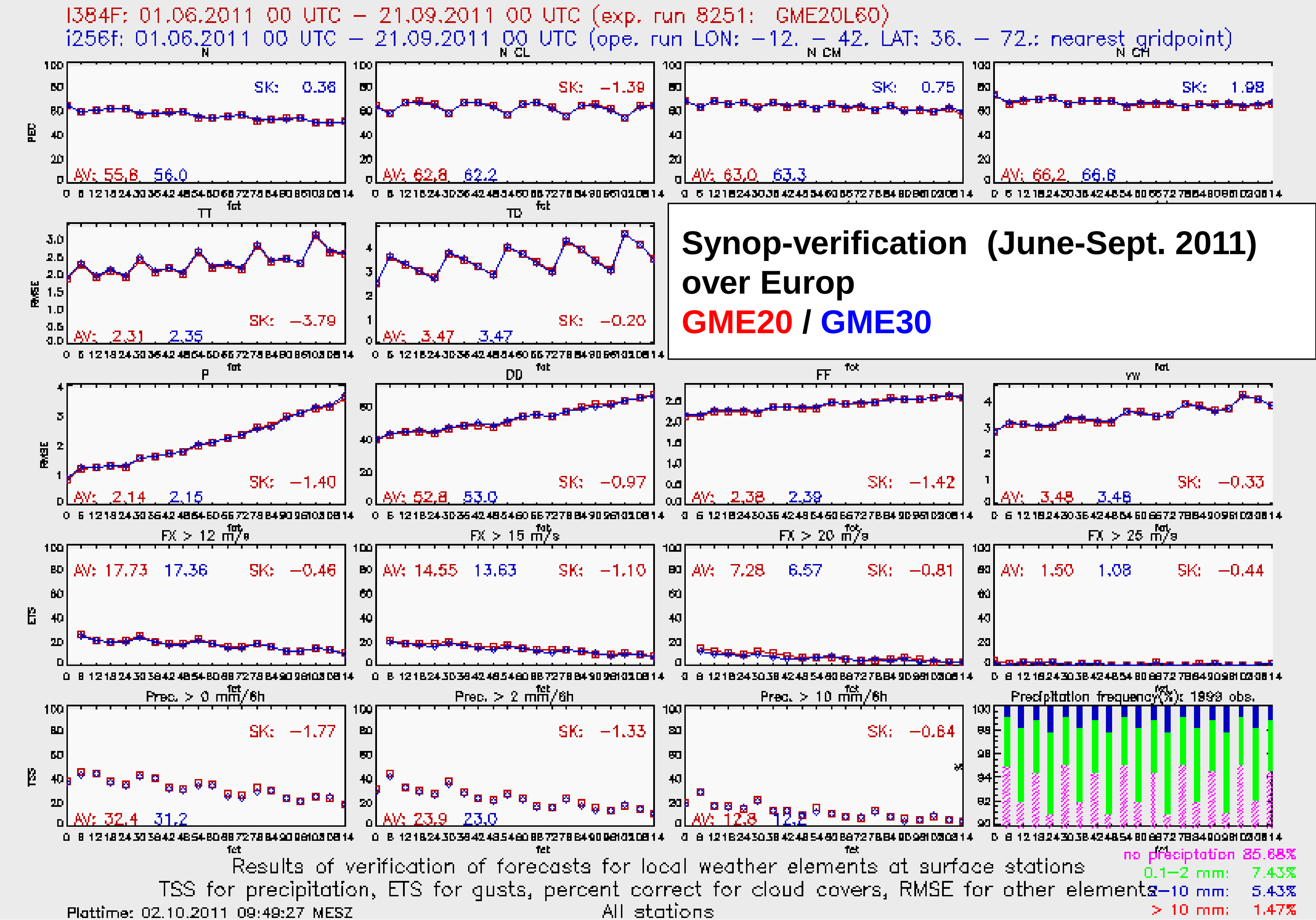
Results:

- GME20L60 slightly better scores than GME30L60 (over hemispheres and for longer forecast times)
- precipitation fields are too smooth (← advection too diffusive)

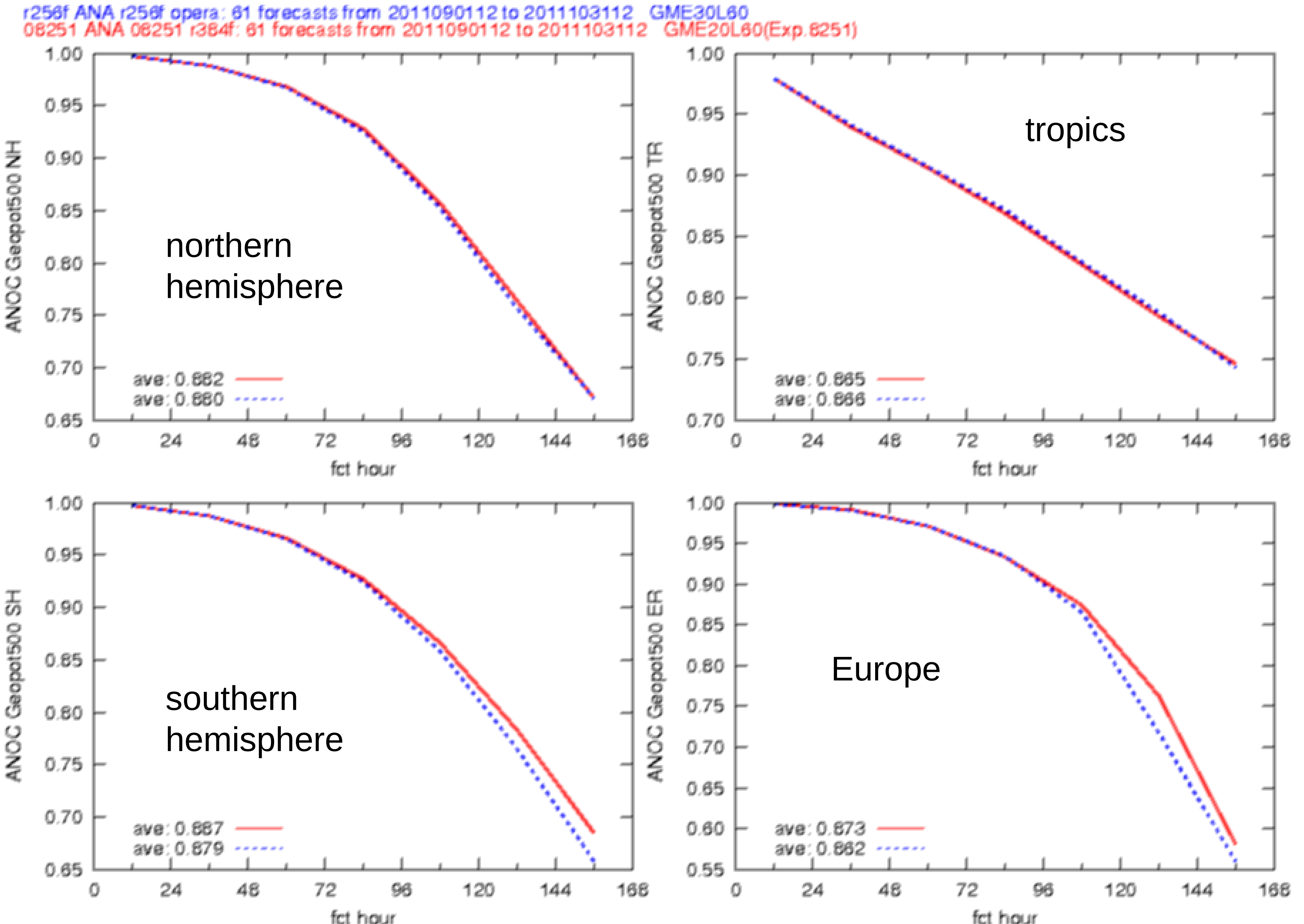
H. Frank

Synop-verification (June-Sept. 2011) over Europ

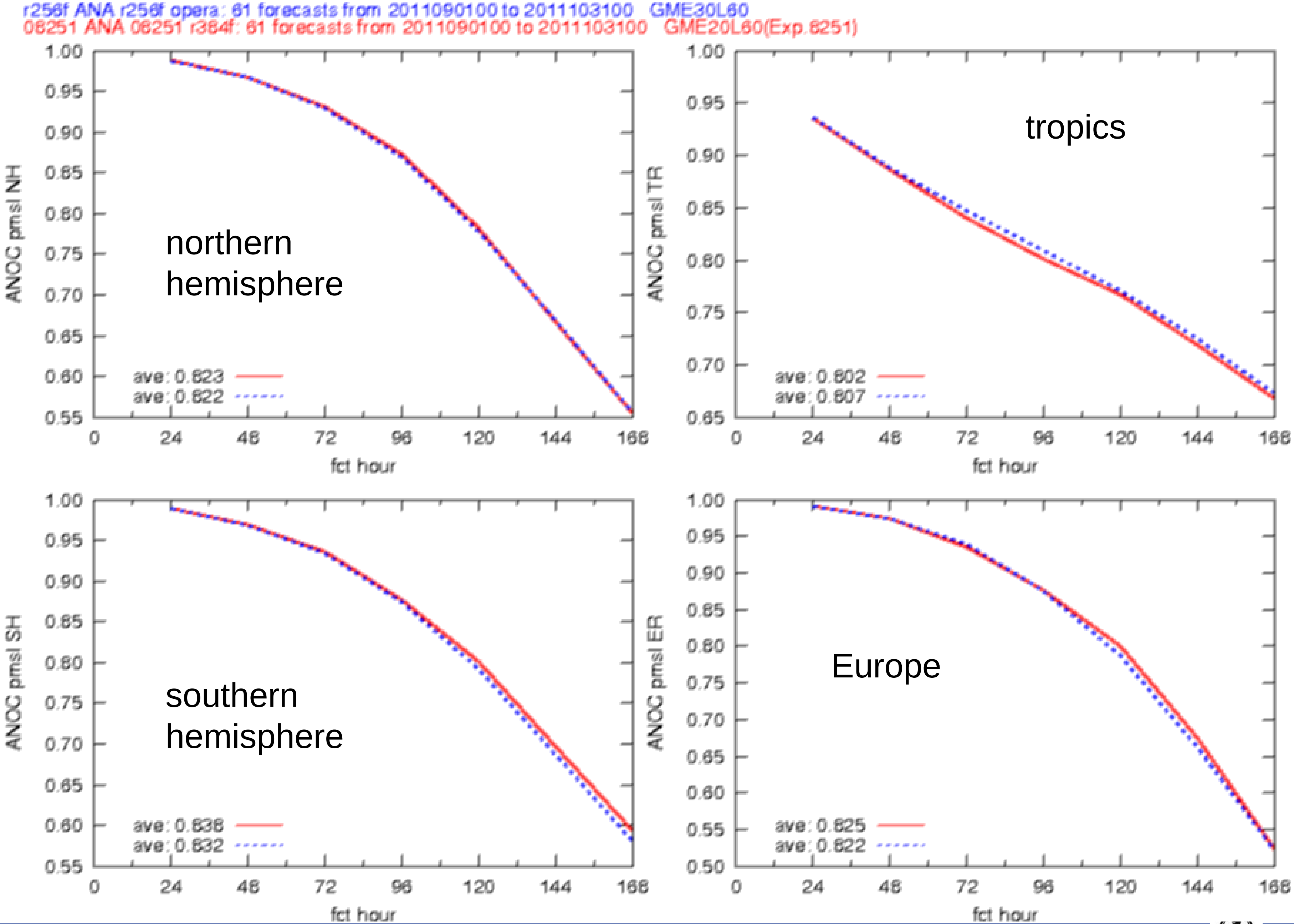
GME20 / GME30



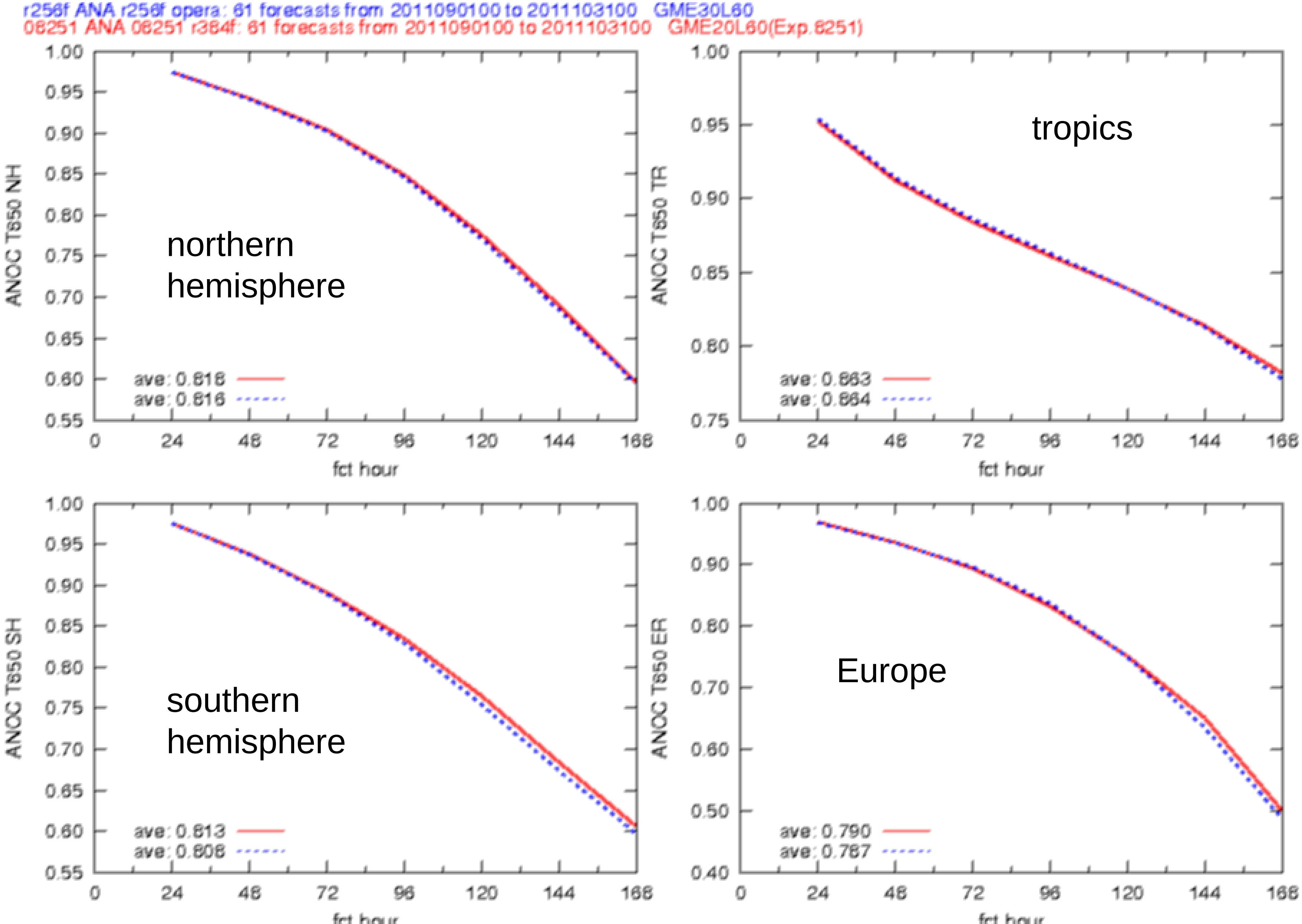
Geopot. 500 hPa anomaly correlation

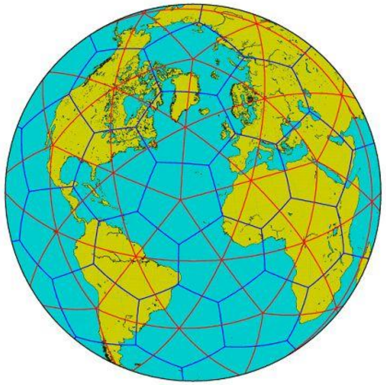


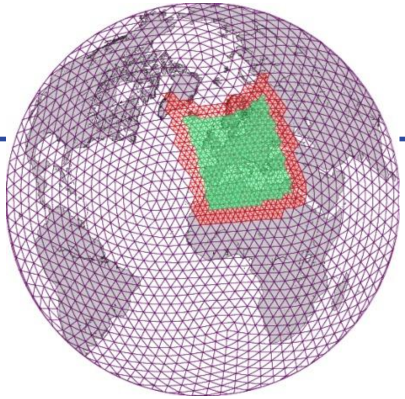
pmsl anomaly correlation



T(850 hPa) anomaly correlation







ICON = ICOsahedral Nonhydrostatic model

G. Zängl

- **Joint development project of DWD and Max-Planck-Institute for Meteorology for the next-generation global NWP and climate modeling system**
- **Nonhydrostatic dynamical core on an icosahedral-triangular C-grid; coupled with (almost) full set of physics parameterizations**
- **Two-way nesting with capability for multiple nests per nesting level; vertical nesting, one-way nesting mode and limited-area mode are also available**

Primary development goals

- Better conservation properties (air mass, mass of trace gases and moisture, consistent transport of tracers)
- Grid nesting in order to replace both GME (global forecast model, mesh size 20 km) and COSMO-EU (regional model, mesh size 7 km) in the operational suite of DWD
- Applicability on a wide range of scales in space and time down to mesh sizes that require a nonhydrostatic dynamical core
- Scalability and efficiency on massively parallel computer architectures with O(10^4+) cores
- At MPI-M: Develop an ocean model based on ICON grid structures and operators; Use limited-area mode of ICON to replace regional climate model REMO.
- Later in this decade: participate in the seasonal prediction project EURO-SIP

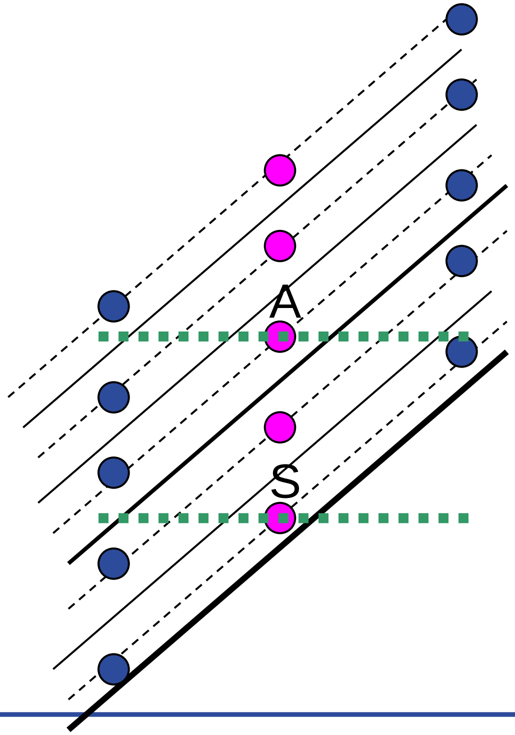
Numerical implementation

- mixed finite-volume (cont. eq.), finite-difference spatial discretization
- two-time-level predictor-corrector time stepping scheme
- HE-VI-scheme: implicit treatment of vertically propagating sound waves, but explicit time-integration in the horizontal (at sound wave time step; not split-explicit);
  larger time step (usually 4x or 5x) for tracer advection / fast physics
- Finite-volume tracer advection scheme (Miura) with 2nd-order and 3rd-order accuracy for horizontal tracer advection; extension for CFL values slightly larger than 1 available
- 2nd-order and 3rd-order (PPM) for vertical advection with extension to CFL values much larger than 1 (partial-flux method)
- Monotonous and positive-definite flux limiters

Special discretization of horizontal pressure gradient

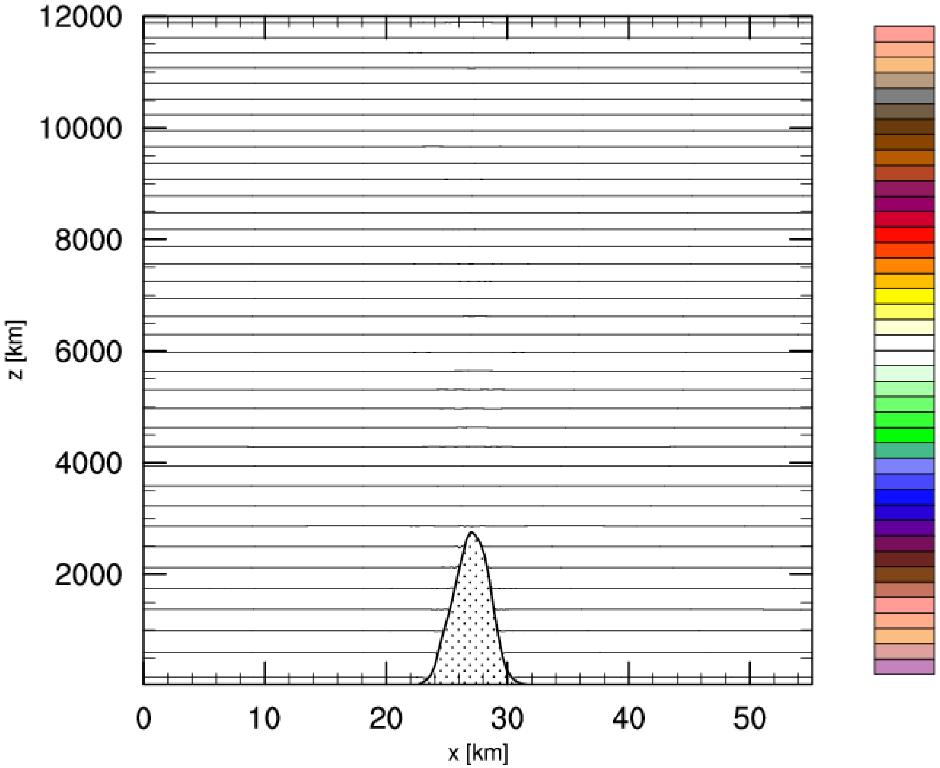
(apart from conventional method; Zängl 2012, MWR)

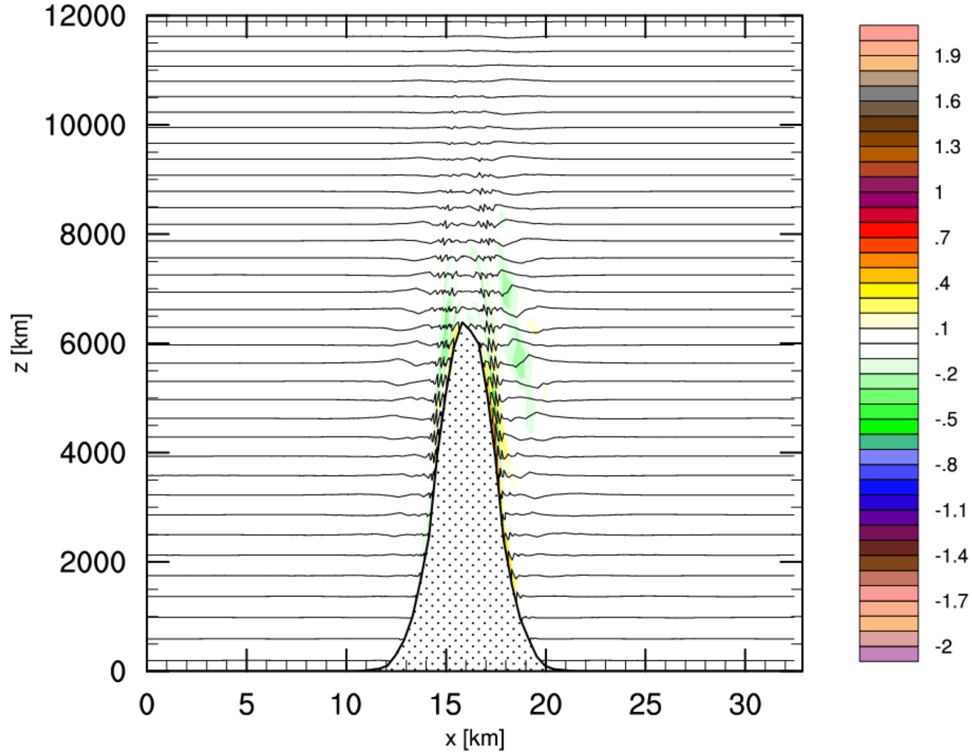
- **Precompute for each edge (velocity) point at level the grid layers into which the edge point would fall in the two adjacent cells**



dashed lines: main levels
pink: edge (velocity) points
blue: cell (mass) points

atmosphere-at-rest test, isothermal atmosphere, results at t = 6h





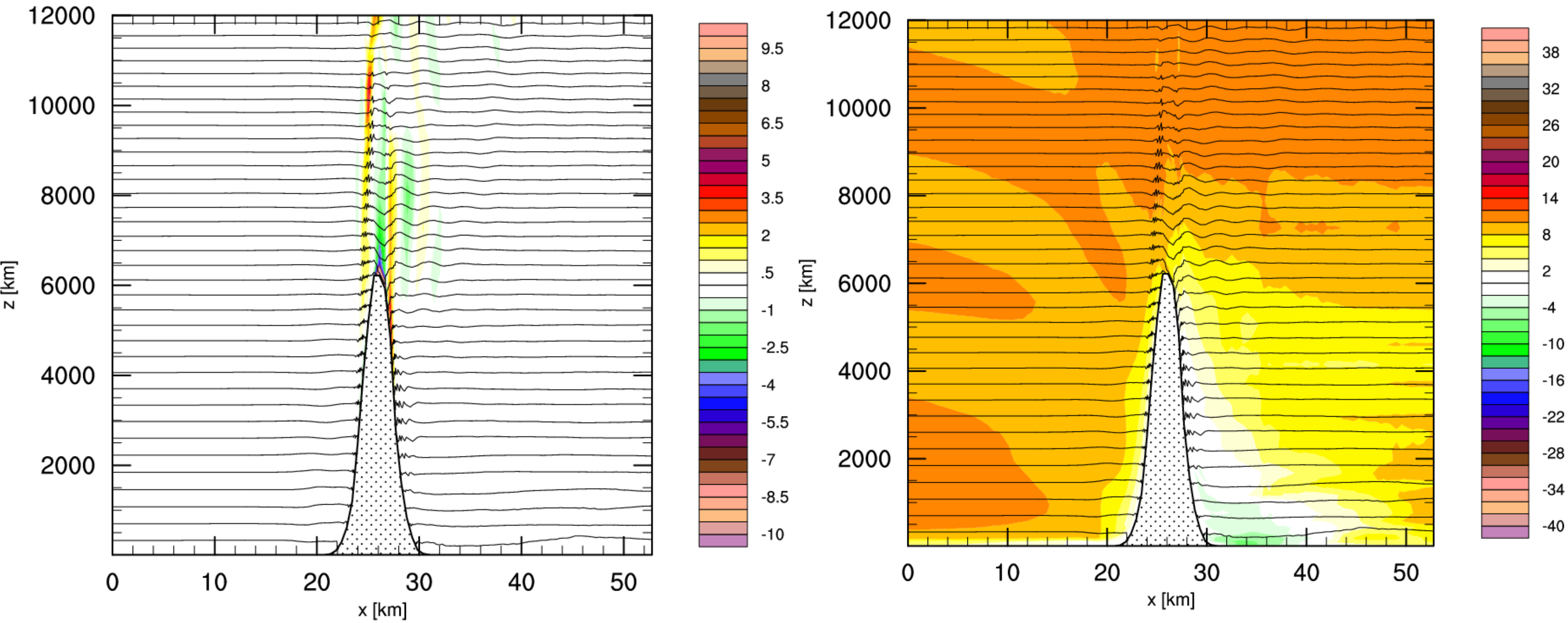
vertical wind speed (m/s), potential temperature (contour interval 4 K)

circular Gaussian mountain, e-folding width 2 km, height: 3.0 km (left), 7.0 km (right)

maximum slope: 1.27 (52°) / 2.97 (71°)

ICON

ambient wind speed 10 m/s, isothermal atmosphere, results at t = 6h

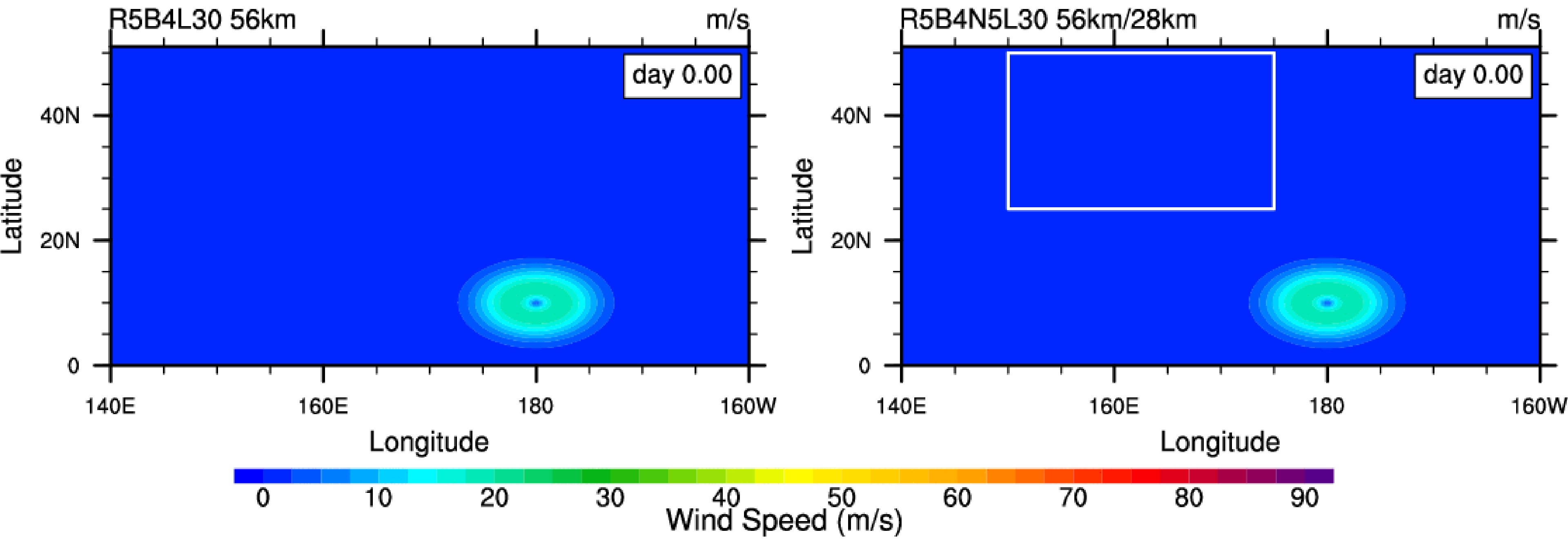


vertical (left) / horizontal (right) wind speed (m/s), potential temperature (contour interval 4 K)

circular Gaussian mountain, e-folding width 2 km, height: 7.0 km

maximum slope: 2.97 (71°)

DCMIP tropical cyclone test with NWP physics schemes, evolution over 12 days



Absolute horizontal wind speed (m/s)

Left: single domain, 56 km; right: two-way nesting, 56 km / 28 km

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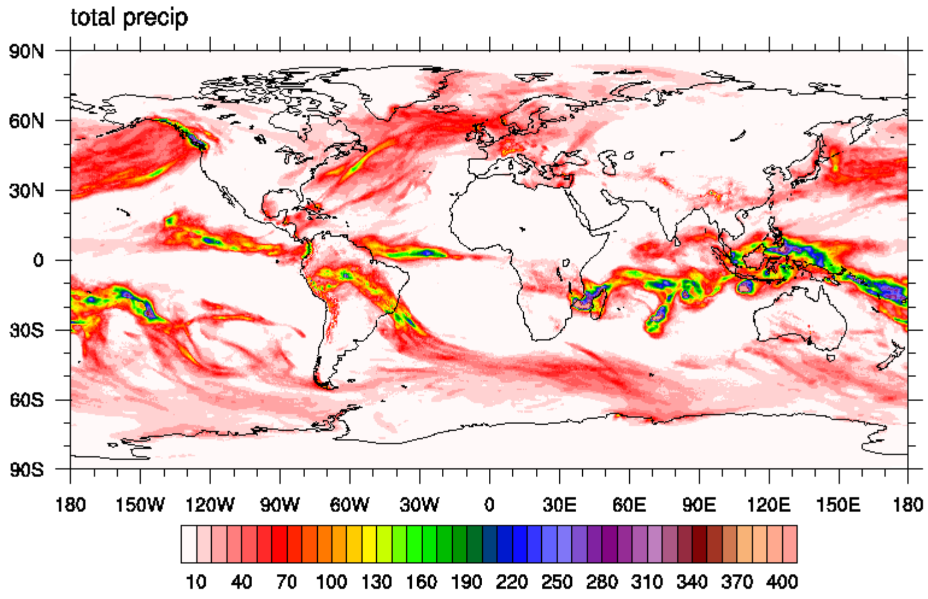
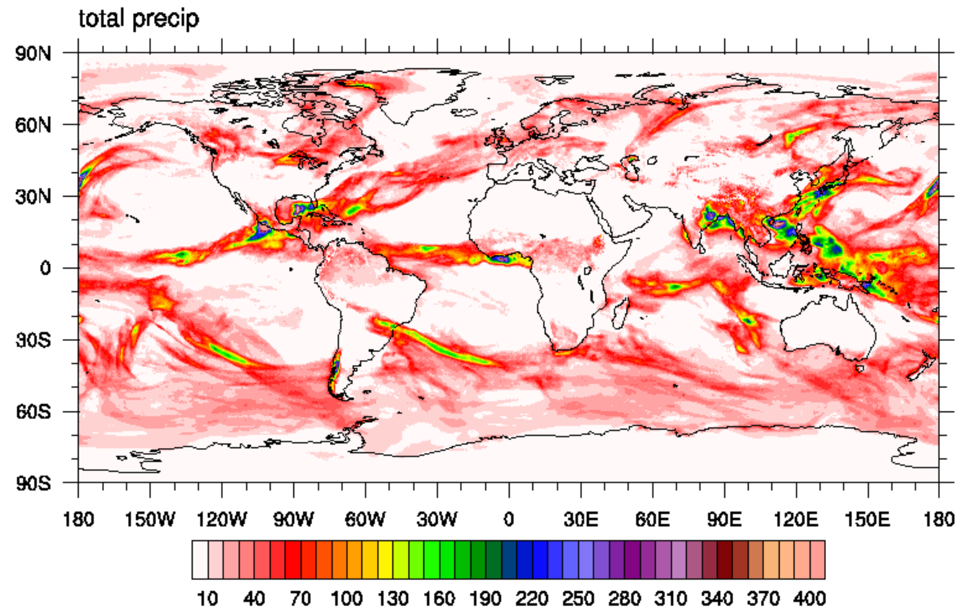
Wetter und Klima aus einer Hand

Real-case forecasts initialized with interpolated IFS analyses:

7-day accumulated precipitation



2 Jan 2012, 00 UTC + 168 h



18 Jun 2012, 00 UTC + 168 h

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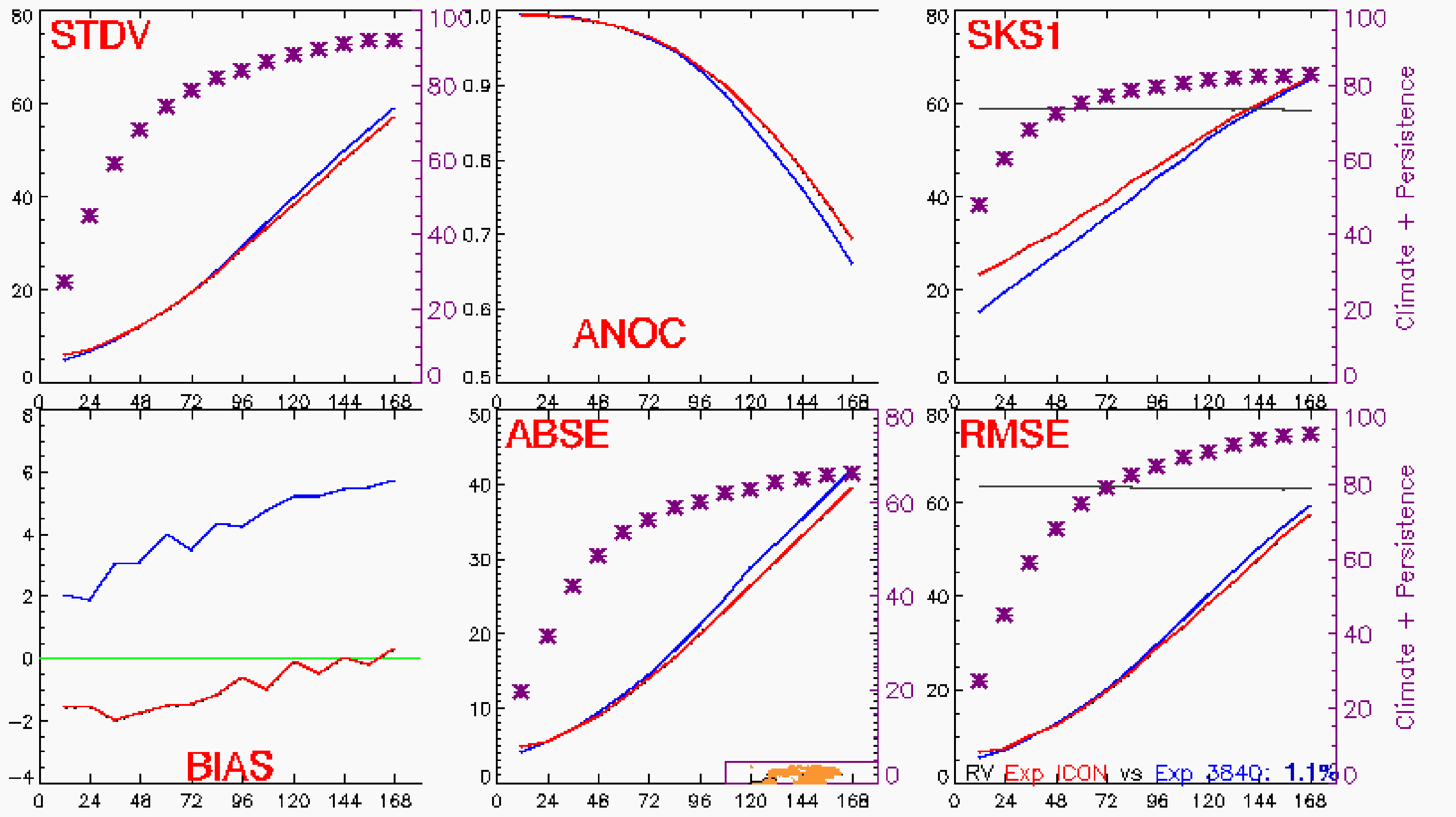
WMO standard verification against IFS analysis: 500 hPa geopotential, NH

blue: GME 40 km with IFS analysis, red: ICON 40 km with IFS analysis



Verifikation der Vorhersagen vom 01.06.2012 00UTC bis 30.06.2012 00UTC Experiment ICON, Experiment 3840, Persistenz, Linien
Parameter: Geopotential, Gebiet: NH , Druckfläche 0500 hPa

ICON

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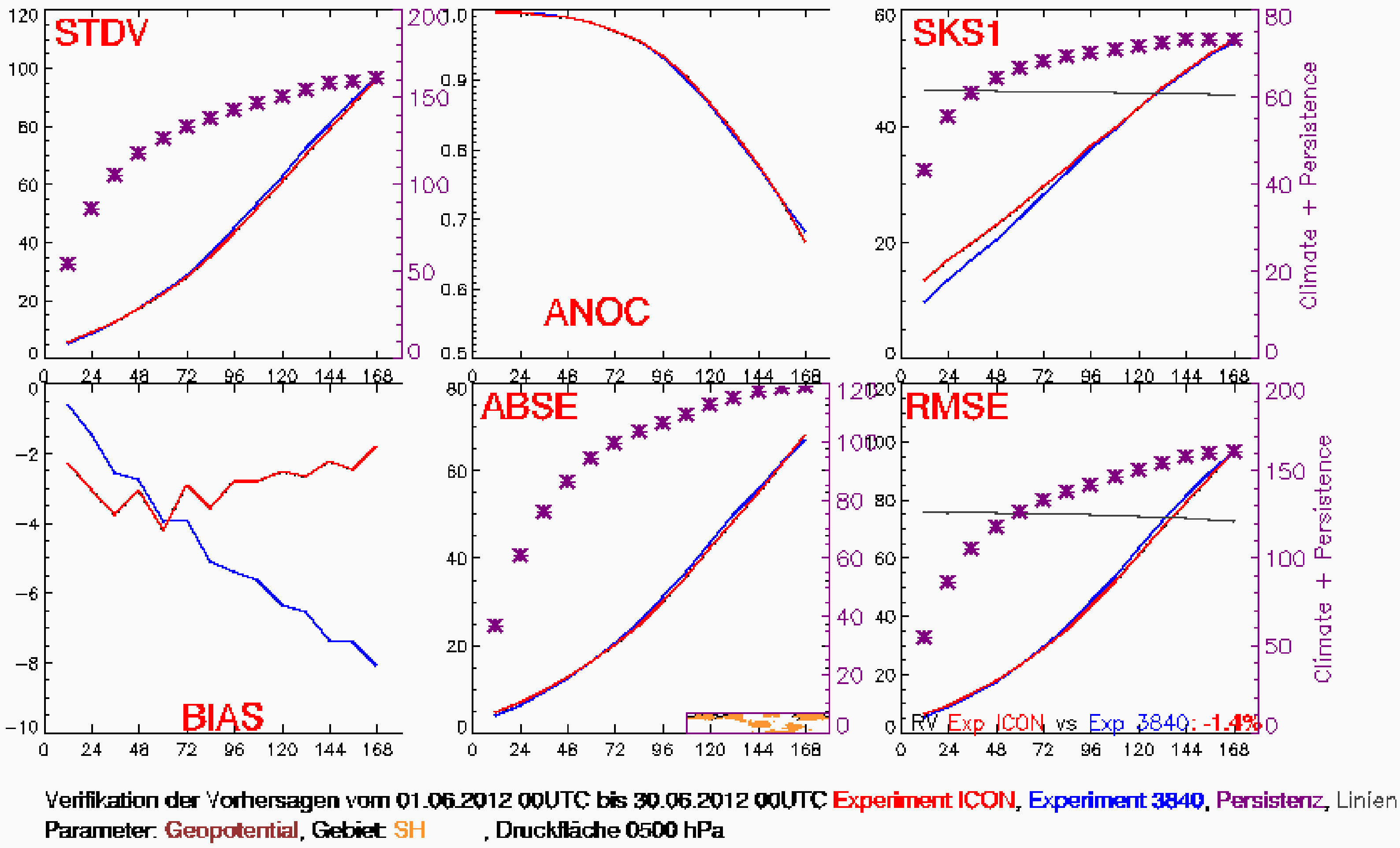
WMO standard verification against IFS analysis: 500 hPa geopotential, SH

blue: GME 40 km with IFS analysis, red: ICON 40 km with IFS analysis



Time plans

- Ongoing: extensive test series with interpolated IFS analysis to optimize forecast quality of ICON
- Q4/2012: Coupling with data assimilation
- Q2/2013: Start of preoperational tests with data assimilation
- Q4/2013-Q2/2014: First step of operational use

Release planning

- Step-by-step strategy, starting with passing the model code to project partners (e.g. HD(CP)²)
- Public releases like for the COSMO model require maturity of the model code and the documentation; this will be based on the experience gained in the collaborative projects
- Resources for user support can only be provided after operational migration to ICON has been completed

Changes in model COSMO-EU (7 km)

- smaller changes/bug fixes in statistical cloud scheme, microphysics evapotranspiration (Dec. 2011)

Changes in the convection-permitting model COSMO-DE (2.8 km)

- horizontal Smagorinsky-diffusion to prevent from shear instabilities (with reduced coefficient c_{smag} ~ 0.03, additionally to a 4^{th} order hyperdiffusion) (Dec. 2011)
  Baldauf, Zängl (2012) COSMO-Newsl.
- introduction of a lake model (FLake) (April 2012)
  Mironov (2010) COSMO Tech. Report No 11
  Mironov et al. (2010) Boreal Env. Res., 15, 218-230.
- usage of the new external parameter set 'GlobCover2009' (ESA, http://ionia1.esrin.esa.int , 300m resolution) instead of GLC2000 → more trees (higher roughness) in northern Germany, less trees in S-Germany and Alps (April 2012)
- operational usage of COSMO-DE-EPS (May 2012)

Plans:

- Increase number of vertical levels L50 → L65 (begin of 2013 ?)
- Increase horizontal resolution 2.8 km → 2 km (2014 ?)

C. Gebhard, S. Theis (DWD)

COSMO-DE-EPS status and plans

- **start of pre-operational mode (9th Dec 2010)** — **2010**

2011

- **undergoing evaluation by forecasters (EPS quality and visualization by NinJo)** — **2012**

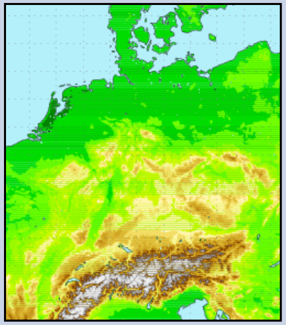
switch to operational mode (22nd May 2012)

- **upgrade to 40 members, redesign**
- **statistical postprocessing**

2013 / 14

operational set-up:

- → 20 members
- → grid size: 2.8 km (COSMO-DE)
  convection-permitting
- → lead time: 0-21 hours,
  8 starts per day (00, 03, 06,... UTC)



model domain

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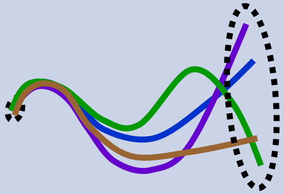
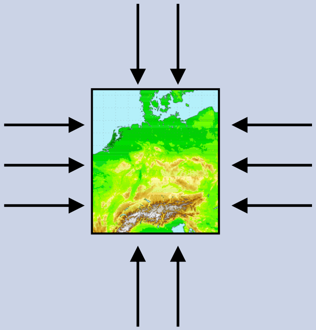
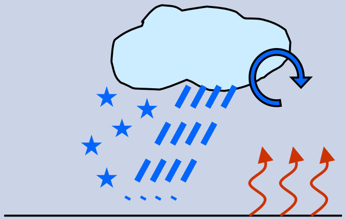
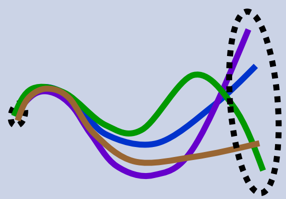
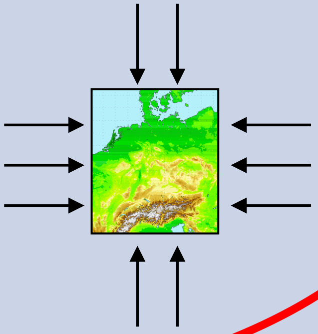
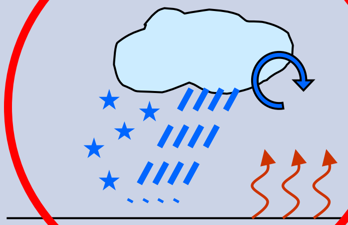
Generation of the 20 EPS members

representing uncertainty in

initial conditions	boundary conditions	model physics
		

Generation of the 20 EPS members

representing uncertainty in

initial conditions	boundary conditions	model physics
		

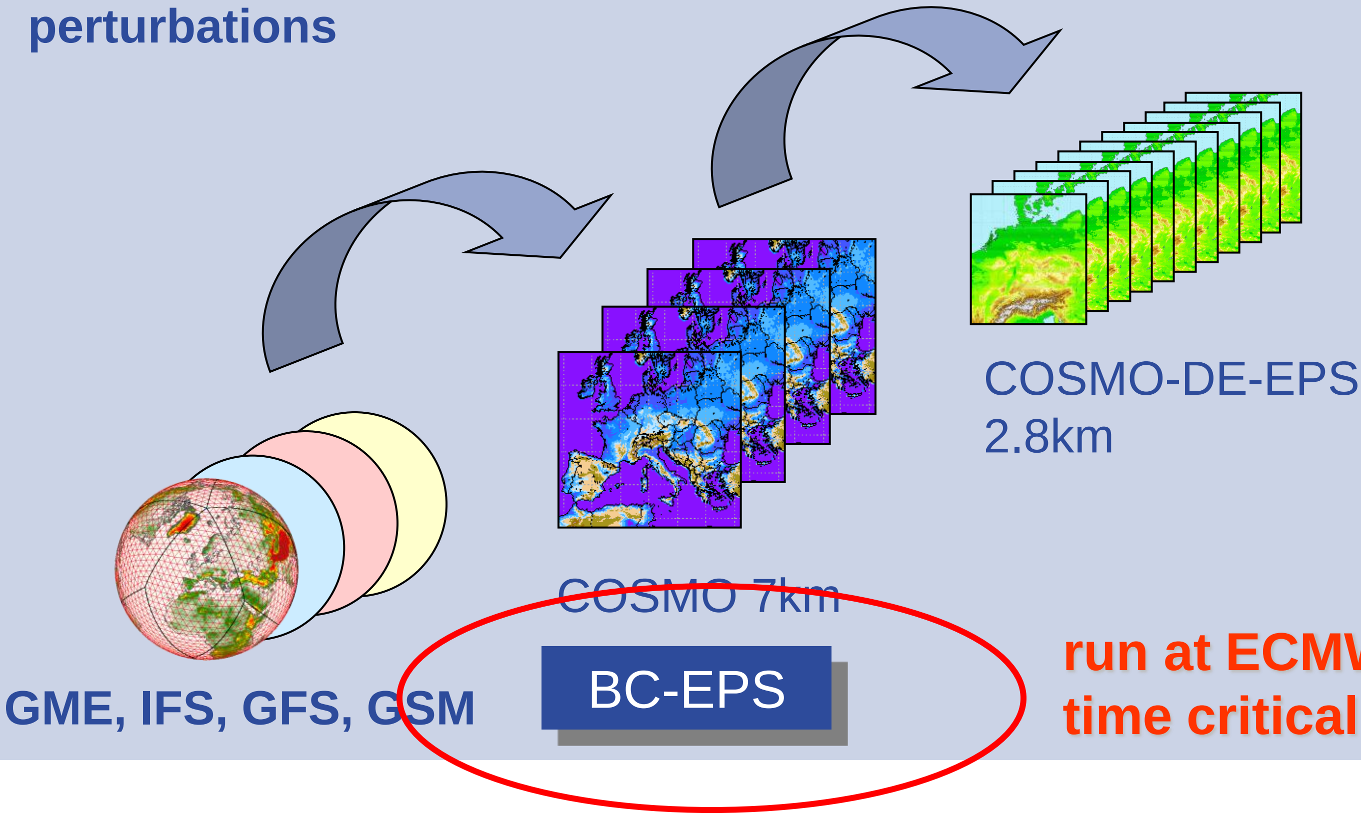
„multi-model“ (4 x)

perturbed parameters

non-stochastic (5 x)

Generation of the 20 EPS members

BC-EPS for boundary and initial perturbations



run at ECMWF as time critical application

Main results from pre-operational phase (20 members)

- ➔ evaluation by forecasters (case studies):
  - ➔ additional benefit for precipitation forecasts
  - ➔ provides early signals for severe weather
  - ➔ most beneficial for convective precipitation in summer
  - ➔ drawback: jumpiness between consecutive runs

- ➔ probabilistic verification (for periods of several months)
  - ➔ probabilities perform better than deterministic “yes/no”
  - ➔ particularly for high precipitation thresholds
  - ➔ particularly for longer lead times
  - ➔ drawback: underdispersiveness (esp. for wind gusts and T_2M)

Rostock severe weather 22.07.2011

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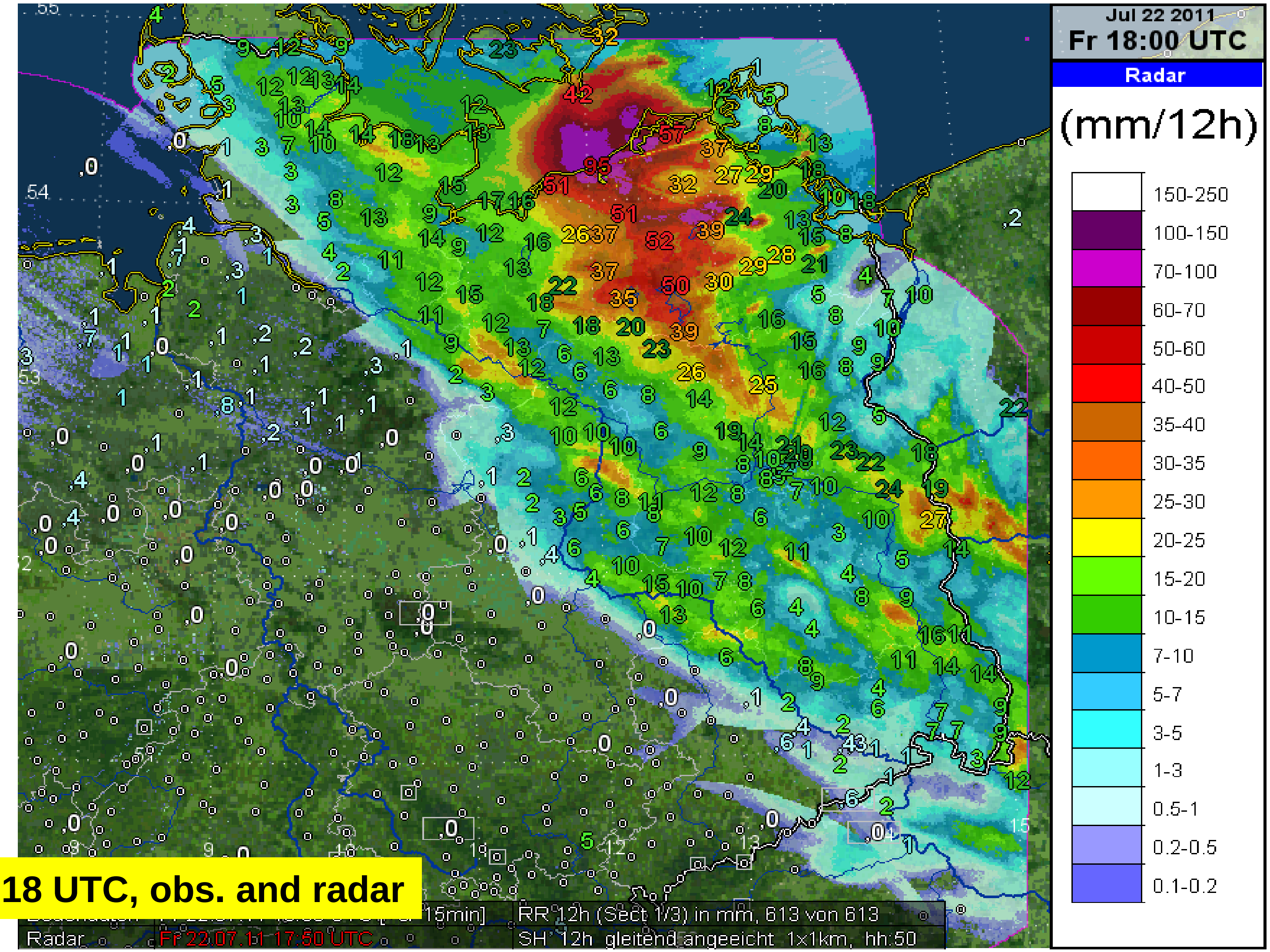

12h-RR, 18 UTC, obs. and radar

Rostock severe weather 22.07.2011

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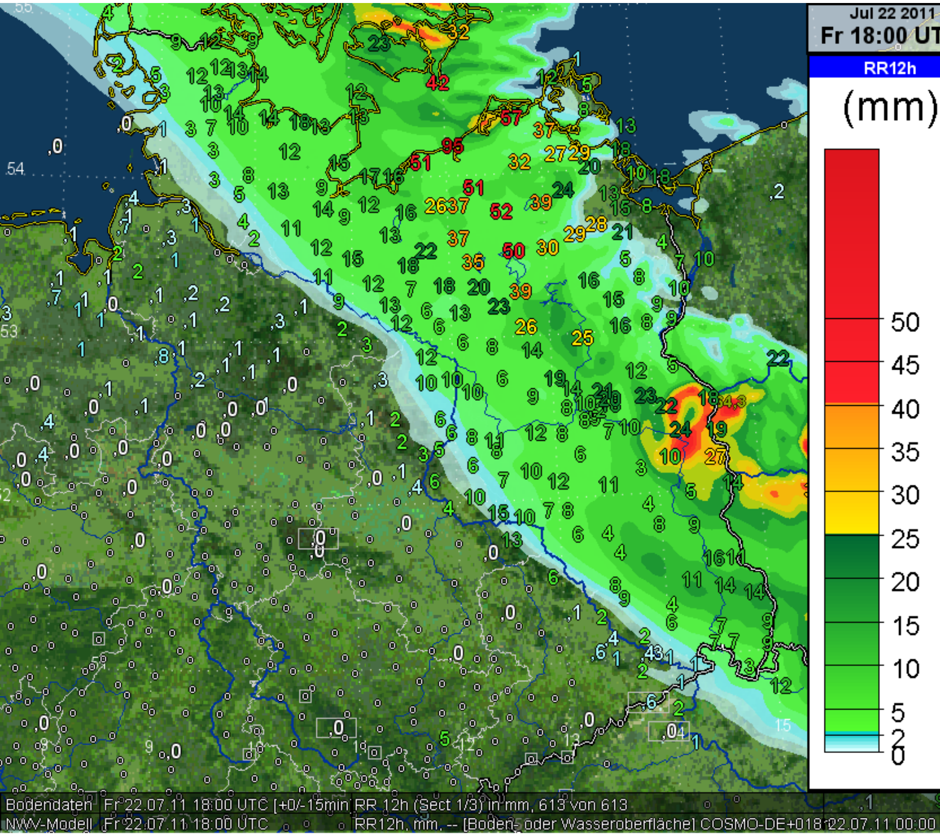
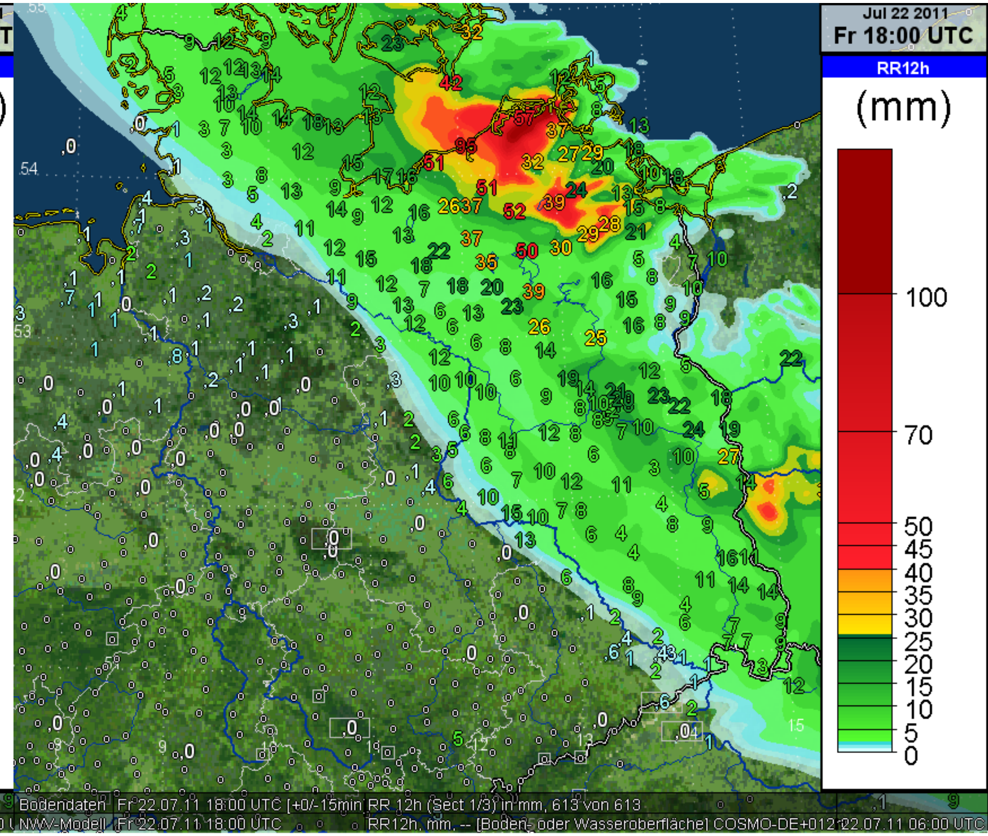




12h-RR, C-DE+18h
00 UTC run

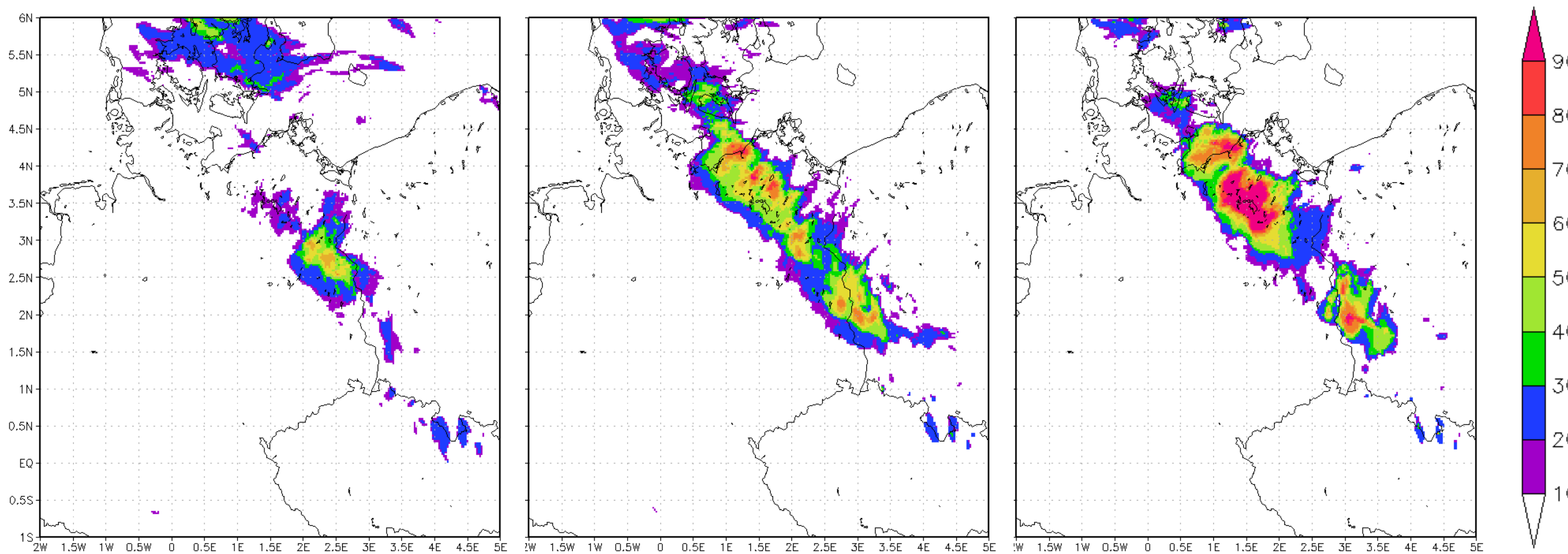
deterministic
COSMO-DE

12h-RR, C-DE+12h
06 UTC run

Rostock severe weather 22.07.2011

COSMO-DE-EPS: Prob ‚RR > 25 mm/12h‘ (06-18 UTC)

21 UTC run (day before)	00 UTC run	03 UTC run
+21h	+18	+15



COSMO-DE-EPS

Rostock severe weather 22.07.2011

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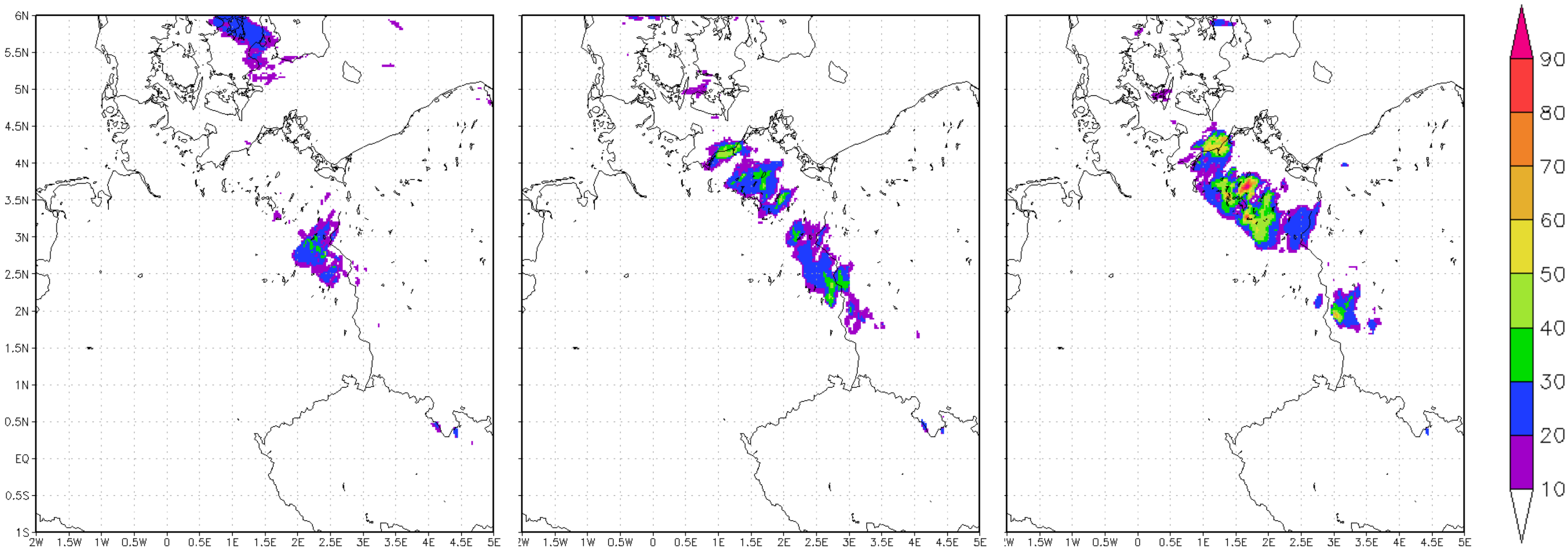
DWD

COSMO-DE-EPS: Prob ‚RR > 40 mm/12h' (06-18 UTC)

21 UTC run (day before)	00 UTC run	03 UTC run
+21h	+18	+15



COSMO-DE-EPS

VERIFICATION OF COSMO-DE-EPS

all results for hourly precipitation

winter 2011/12

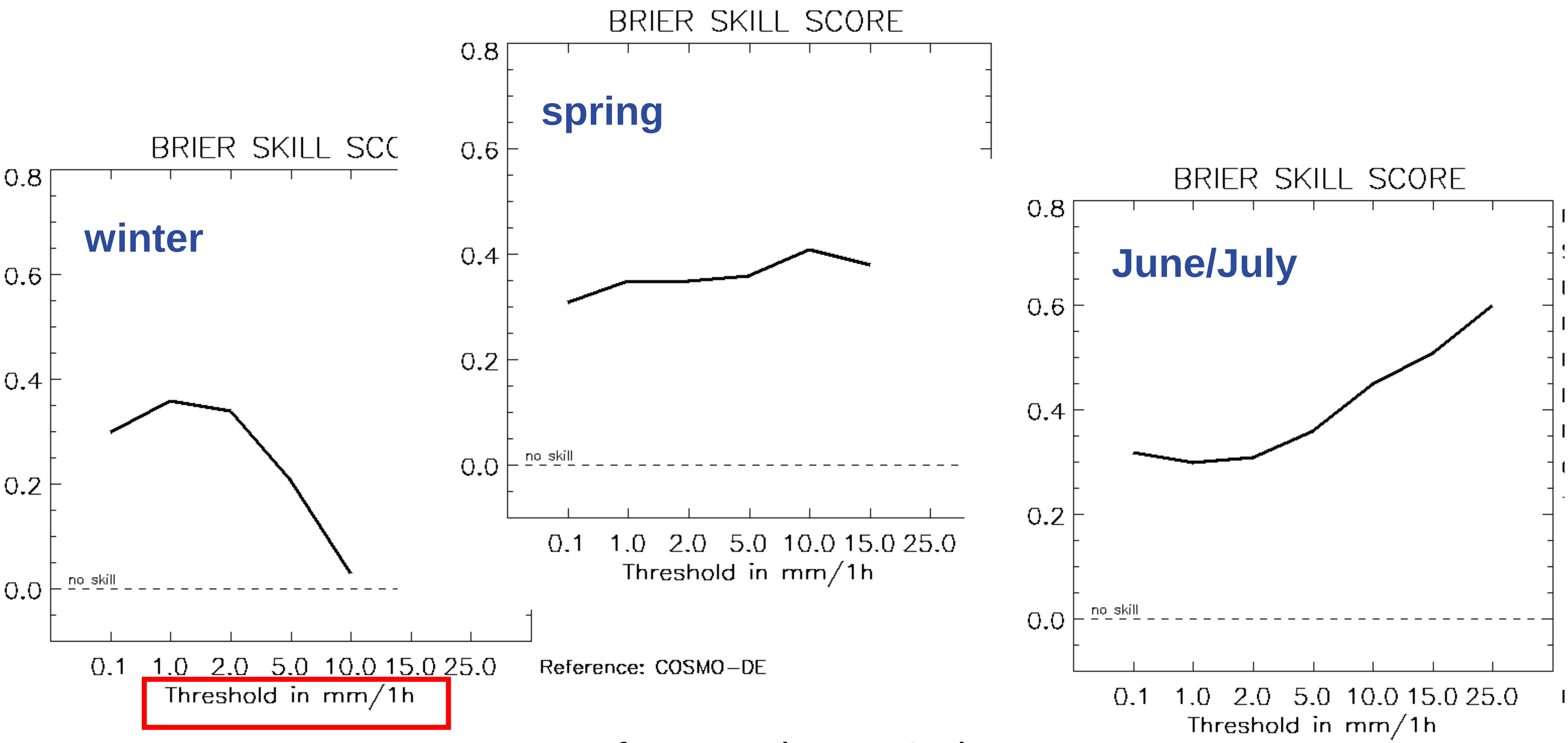
spring 2012

June/July 2012

EPS <u>not</u> calibrated or post-processed

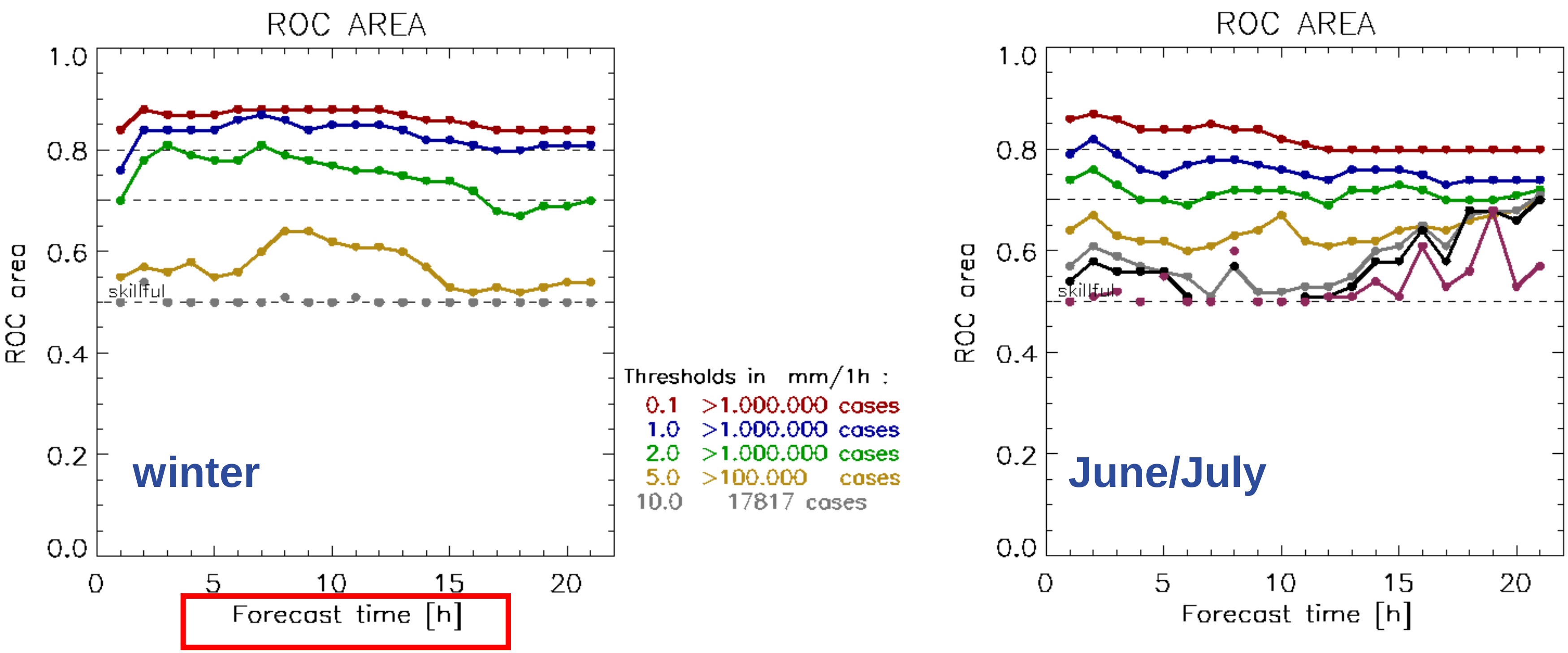
observations: rain-gauge adjusted radar

Brier Skill Score for precipitation (reference: deterministic run of COSMO-DE)

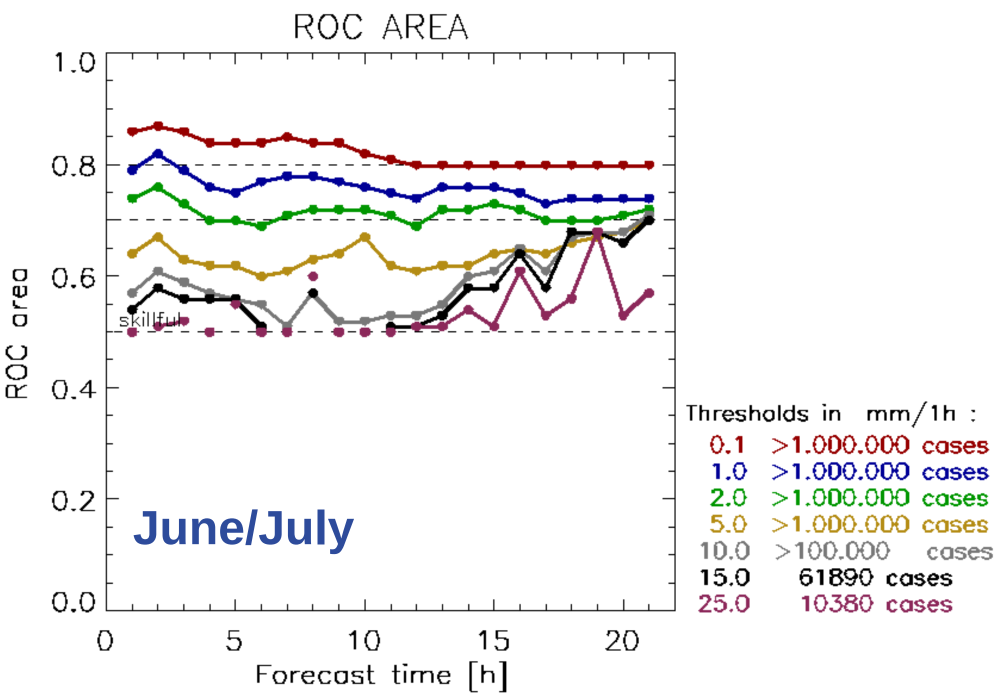


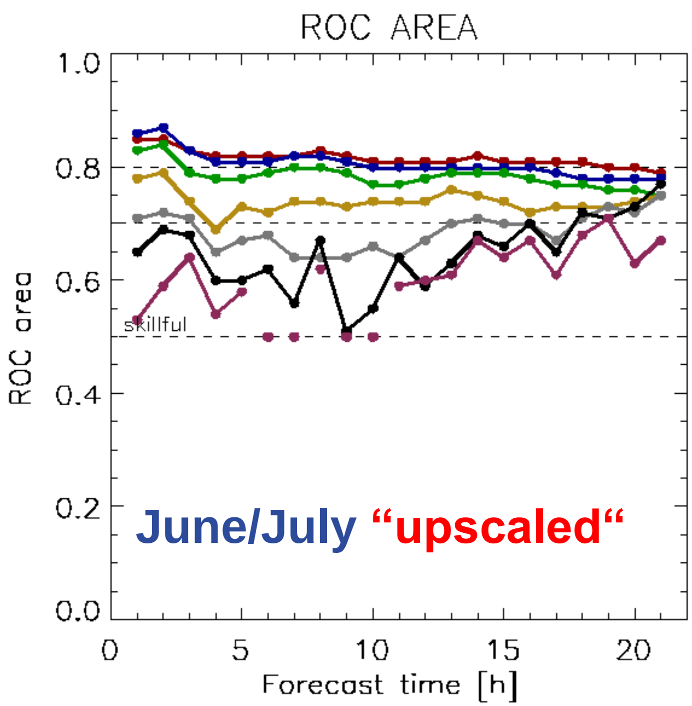
forecast time 1..21 h

ROC area


ROC AREA
1.0
0.8
0.6
0.4
0.2
0.0
ROC area
skillful
winter
0
5
10
15
20
Forecast time [h]
Thresholds in mm/1h :
0.1 >1.000.000 cases
1.0 >1.000.000 cases
2.0 >1.000.000 cases
5.0 >100.000 cases
10.0 17817 cases
ROC AREA
ROC area
skillful
June/July
Forecast time [h]

ROC area

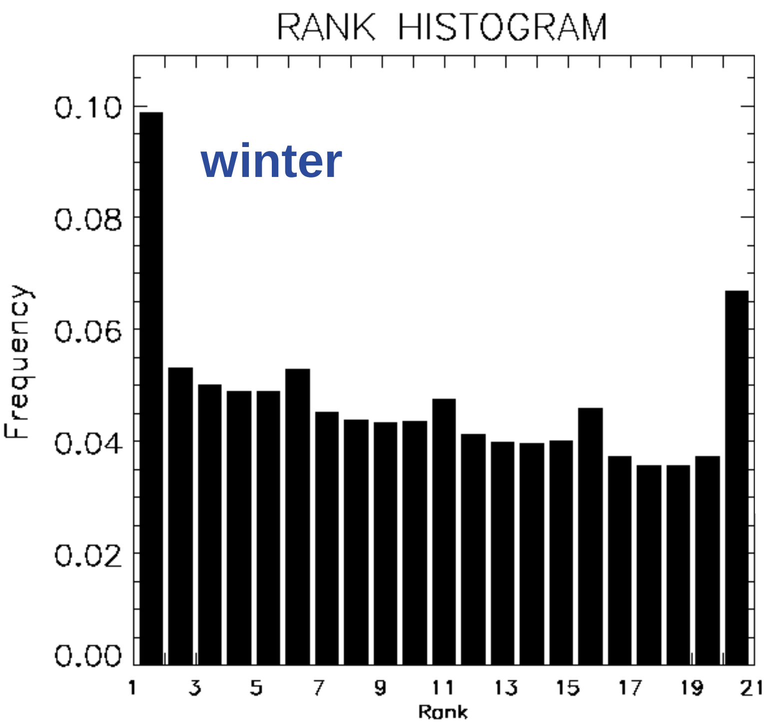


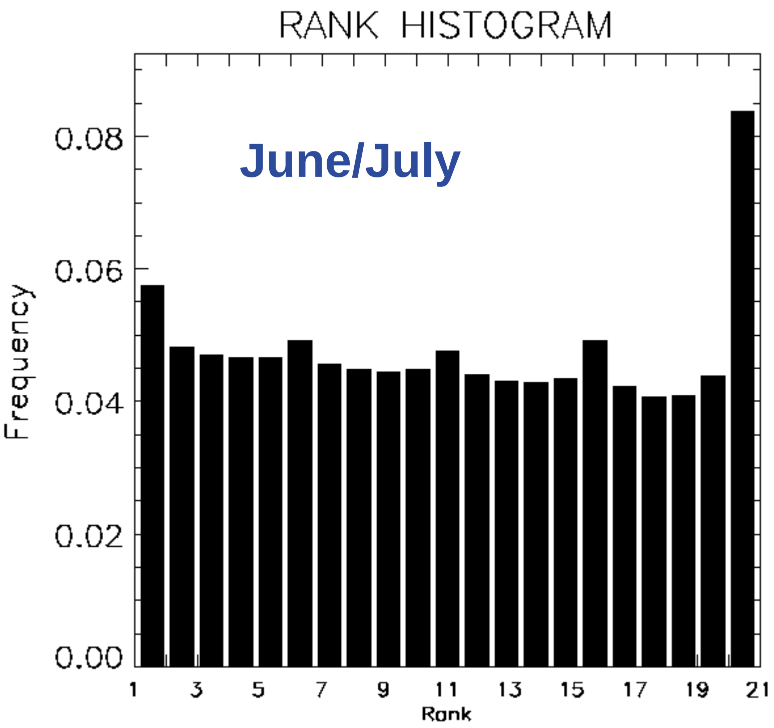


spatially "upscaled" means:

event somewhere within a 10x10 grid points environment

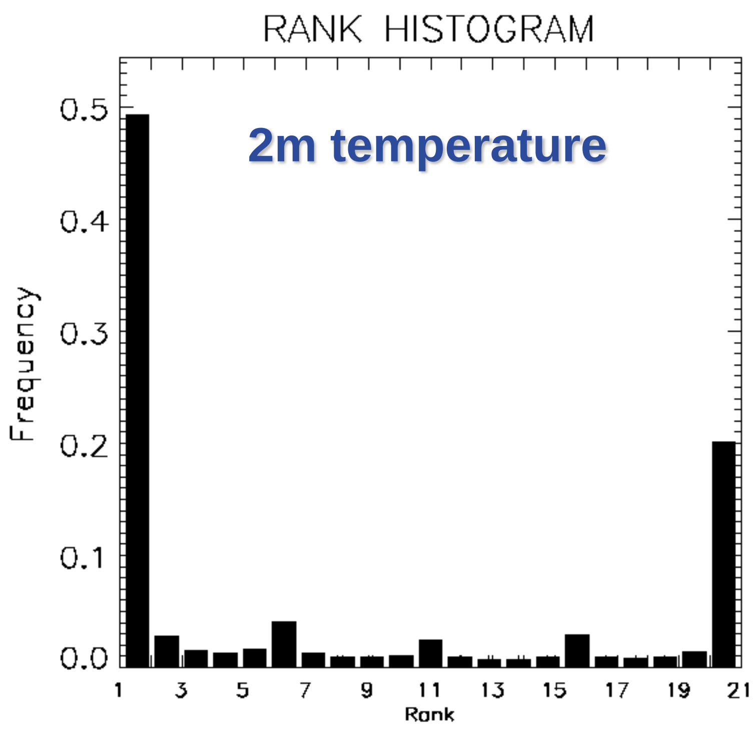
rank histogram

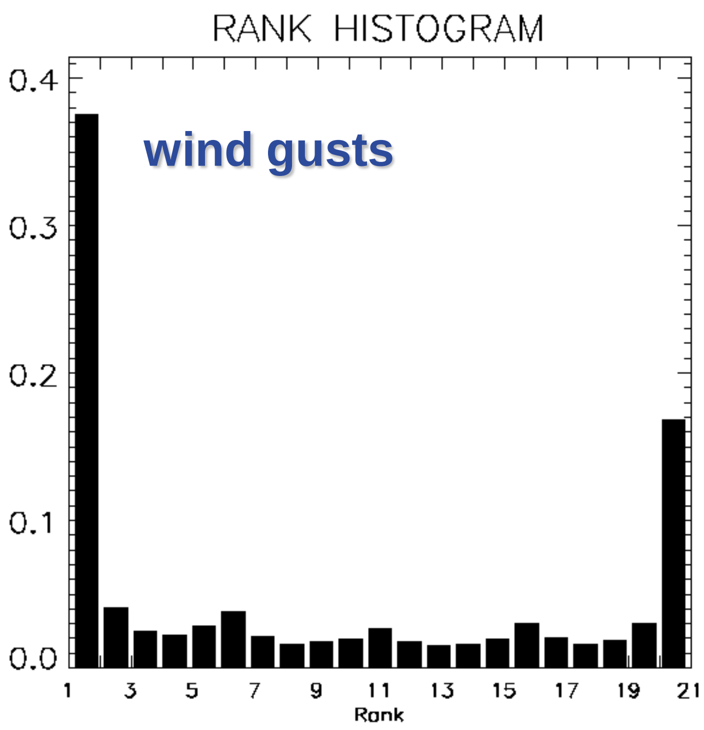




hourly precipitation
EPS <u>not</u> calibrated or post-processed
observations: rain-gauge adjusted radar

rank histogram





June/July 2012

observations: SYNOP

upgrade to 40 members, redesign

➔ use of COSMO-LEPS members as boundary conditions (COSMO-LEPS is driven by IFS EPS of ECMWF)

slight improvements for precip.,
degradation of 2m temperature results

➔ perturbation of soil moisture

better results for 2m temperature, slight improvements for precip.

➔ additional physics perturbations (minimum diffusion, z_0)

better results for 2m temperature,
slight improvement for wind gusts

COSMO-DE-EPS status and plans

2010

- ➔ start of pre-operational mode (9th Dec 2010)

2011

- ➔ undergoing evaluation by forecasters
  (EPS quality and visualization by NinJo)

2012

—— switch to operational mode ——
(22nd May 2012)

2013 / 14

- ➔ upgrade to 40 members, redesign
- ➔ statistical postprocessing
- ➔ lagged average forecast
- ➔ initial conditions by LETKF ("KENDA")
- ➔ lateral boundary conditions by ICON EPS

Contributors are requested to submit an abstract of not more than one page to

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e-mail: **seminar.fe13@dwd.de**

by 15 Feb 2013.

Please note your preference for poster or oral presentation.
Notification of acceptance will be by

15 March 2013.

The first time, the workshop will take place in the Headquarter of DWD, Frankfurter Str. 135 in Offenbach/Main, Germany.

The aim of the workshop is to provide a forum of information concerning all questions related to fine-scale modeling.
Papers on all aspects of *high resolution modelling*, i.e. model resolutions covering about 0.2 to 5 km, in particular the *convective scale*, are welcome, e.g. on

- ***physical parameterizations***
- ***numerical algorithms and their performance***
- ***data assimilation using radar and satellite data***
- ***Predictability***
- ***experience in operational applications including verification issues.***

Presentations on other aspects of nonhydrostatic modelling, such as *global nonhydrostatic modelling* and applications are also welcome.
A special issue of this years meeting with an own session will be

Operationalisation of convection-permitting models

Papers about this topic will be preferentially accepted for oral presentation.
The workshop will be open to *contributors* and *invited participants*.

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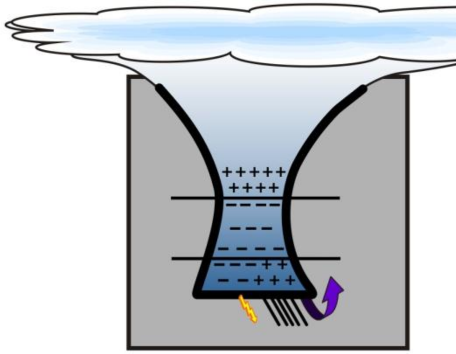
Wetter und Klima aus einer Hand

10th International SRNWP-Worksho on Nonhydrostati Modelling



13.-15. May 2013

Supercomputing environment at DWD (Sept. 2012)

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One production and one research computer **NEC SX-9, each** with:

- 30 nodes with16 CPUs / node = 480 vector processors
- Peak Vector Performance / CPU: 100 GFlops
  Peak Vector Performance total: 48 TFlops
- main memory / node: 512 GByte
  main memory total: 15.4 TByte
- Internode crossbar switch (NEC IXS): 128 GB/s bidirectional

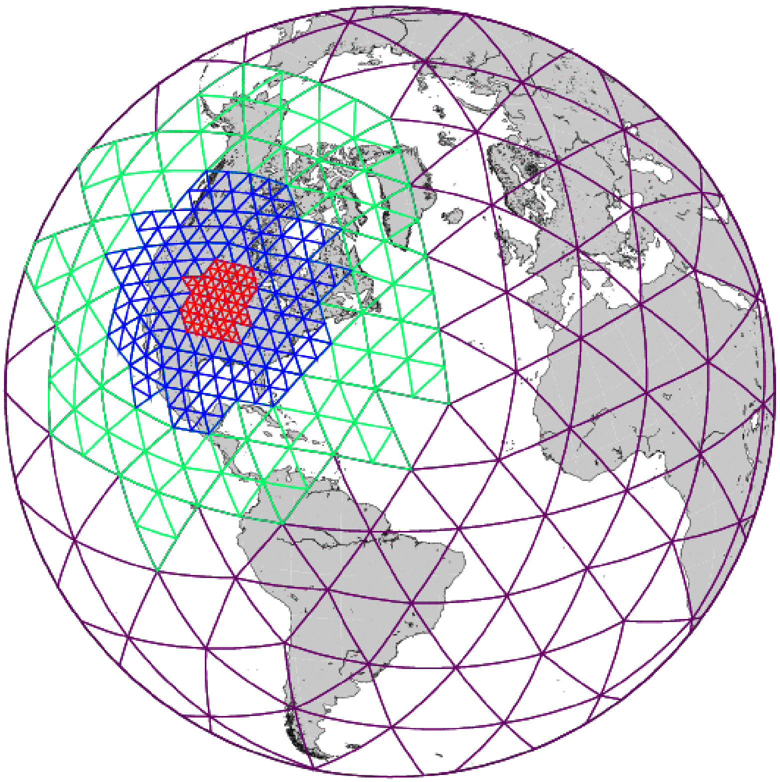
replacement end of 2013, but only with the same computing power

Login nodes: **SUN X4600**

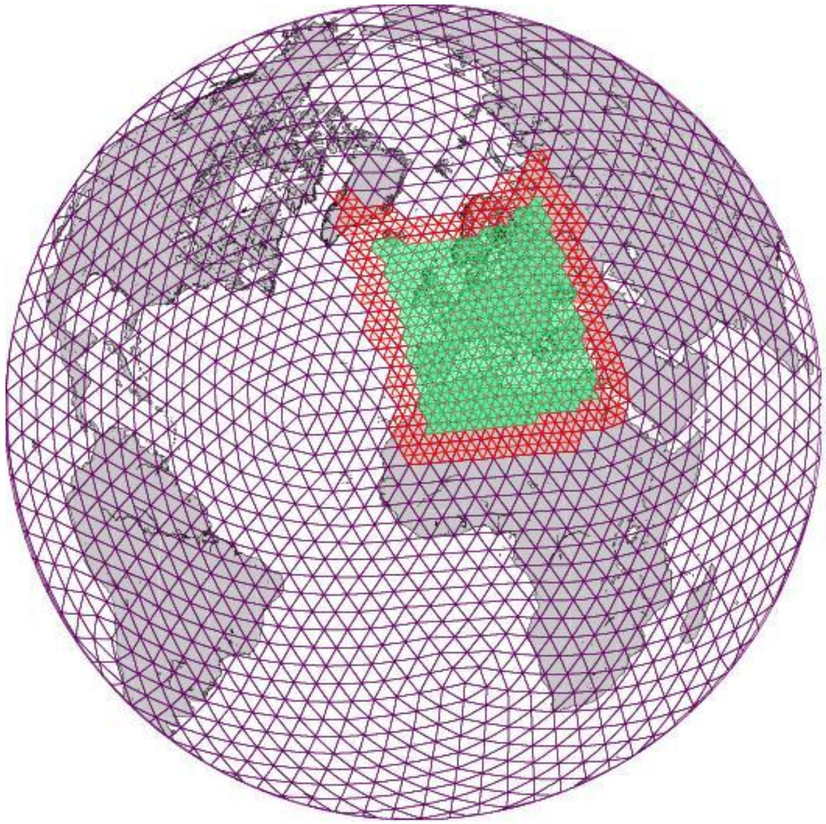
- 15 nodes with 8 processors (AMD Opteron QuadCore)/node = 120 processors (2 nodes for interactive login)
- main memory / node: 128 GB

Database server: two **SGI Altix 4700**

Grid structure with nested domains



circular nests



latitude-longitude nests

Nonhydrostatic equation system (dry adiabatic)

$$\frac{\partial v_n}{\partial t} - (\zeta + f)v_t + \frac{\partial K}{\partial n} + w\frac{\partial v_n}{\partial z} = -c_{pd}\theta_v \frac{\partial \pi}{\partial n}$$

$$\frac{\partial w}{\partial t} + \nabla \cdot (\vec{v}_n w) - w\nabla \cdot \vec{v}_n + w\frac{\partial w}{\partial z} = -c_{pd}\theta_v \frac{\partial \pi}{\partial z} - g$$

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\vec{v}\rho) = 0$$

$$\frac{\partial \rho\theta_v}{\partial t} + \nabla \cdot (\vec{v}\rho\theta_v) = 0$$

v_n,w: normal/vertical velocity component

ρ: density

θ_v: Virtual potential temperature

K: horizontal kinetic energy

ζ: vertical vorticity component

π: Exner function

blue: independent prognostic variables

Physics parameterizations ICON

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Process	Authors	Scheme	Origin
Radiation	Mlawer et al. (1997) Barker et al. (2002)	RRTM (later with McICA & McSI)	ECHAM6/IFS
	Ritter and Geleyn (1992)	δ two-stream	GME/COSMO
Non-orographic gravity wave drag	Scinocca (2003) Orr, Bechtold et al. (2010)	wave dissipation at critical level	IFS
Sub-grid scale orographic drag	Lott and Miller (1997)	blocking, GWD	IFS
Cloud cover	Doms and Schättler (2004)	sub-grid diagnostic	GME/COSMO
	Köhler et al. (new development)	diagnostic (later prognostic) PDF	ICON
Microphysics	Doms and Schättler (2004) Seifert (2010)	prognostic: water vapor, cloud water,cloud ice, rain and snow	GME/COSMO
Convection	Tiedtke (1989) Bechthold et al. (2008)	mass-flux shallow and deep	IFS
Turbulent transfer	Raschendorfer (2001)	prognostic TKE	COSMO
	Brinkop and Roeckner (1995)	prognostic TKE	ECHAM6/IFS
	Neggers, Köhler, Beljaars (2010)	EDMF-DUALM	IFS
Land	Heise and Schrodin (2002), Helmert, Mironov (2008, lake)	tiled TERRA + FLAKE + multi-layer snow	GME/COSMO
	Raddatz, Knorr	JSBACH	ECHAM6

Physics-dynamics coupling

- **Fast-physics processes: incremental update in the sequence: saturation adjustment, turbulence, cloud microphysics, saturation adjustment, surface coupling**
- **Slow-physics processes (convection, cloud cover diagnosis, radiation, orographic blocking, sub-grid-scale gravity waves): tendencies are added to the right-hand side of the velocity and Exner pressure equation**
- **Diabatic heating rates related to phase changes and radiation are consistently treated at constant volume**
- **Option for reduced radiation grid with special domain decomposition to minimize day/night load imbalance**

Generation of Ensemble Members

Perturbation Methods

Peralta, C., Ben Bouallègue, Z., Theis, S.E., Gebhardt, C. and M. Buchhold, 2012: Accounting for **initial condition uncertainties** in COSMO-DE-EPS. Journal of Geophysical Research, VOL. 117, D07108, doi:10.1029/2011JD016581, 2012

Gebhardt, C., Theis, S.E., Paulat, M. and Z. Ben Bouallègue, 2011: Uncertainties in COSMO-DE precipitation forecasts introduced by **model perturbations and variation of lateral boundaries.** Atmospheric Research 100, 168-177. *(contains status of 2009)*

Peralta, C. and M. Buchhold, 2011: **Initial condition perturbations** for the COSMO-DE-EPS, COSMO Newsletter 11, 115–123.