WG1 Overview

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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current DA method: nudging

PP KENDA for km-scale EPS: LETKF

LETKF for HRM (final setup)

radar reflectivity (precip):
- latent heat nudging
- 1DVar (comparison)

radar radial wind:
- VAD (at DWD: no benefit)
- nudg. V_r (offline monitoring)

GPS (GNSS):
- IWV (new modif., tests)
- (tomography profiles)

screen-level:
- scatterometer wind (tests)
- (improved use of Synops)

Satellite radiances, 1DVAR:
- AMSU-A, SEVIRI, IASI (new tests)
- spatial AMSU-A obs errors statistics

study of influenc of biases on convection :
- Vaisala RS-92 humidity obs dry bias
- model warm bias (daytime, low levels)

surface (snow …)
→ PP COLOBOC

Recent experiments with the nudging-type assimilation at DWD

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- latent heat nudging (LHN)
  - use of extended radar composite
  - influence of spatial scale on scores

  (*Klaus Stephan*)

- assimilation of ground-based GPS-derived integrated water vapour (IWV)

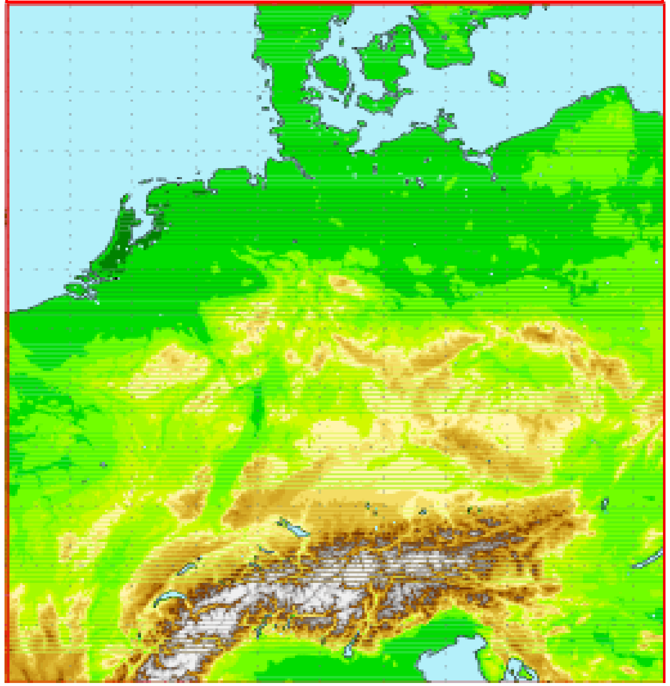
  (*Karolin Eichler, Klaus Stephan, Christoph Schraff*)

- the deficit of convective precip in 12-UTC runs: an issue of biases in the data assimilation
  - radiosonde humidity observation bias
  - temperature / pressure model bias

  (*Klaus Stephan, Christoph Schraff*)

COSMO-DE: $\Delta x = 2.8$ km
(deep convection explicit,
shallow convection param.)

domain size : ~ 1250 x 1150 km



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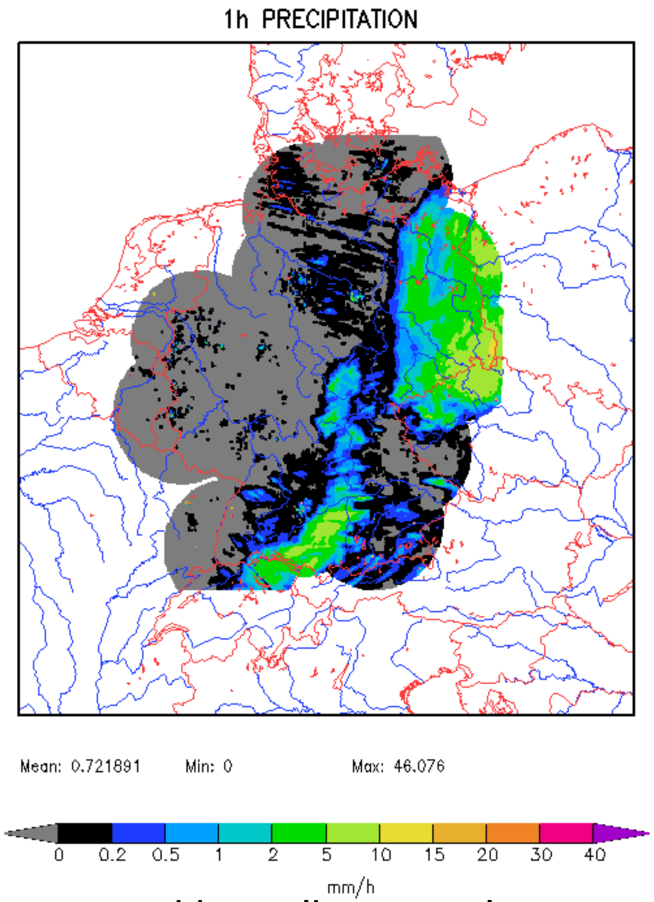
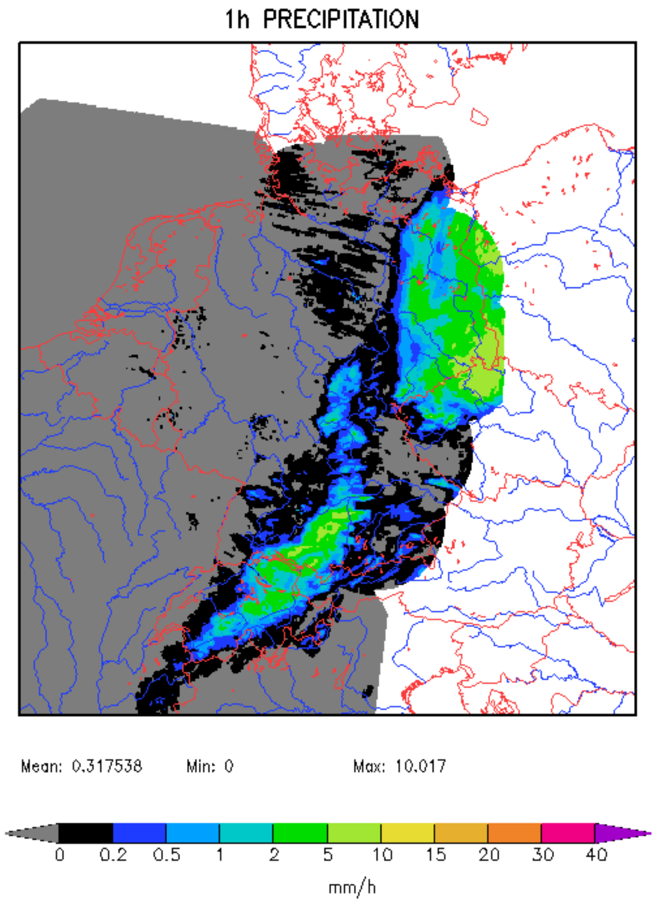
Use of extended composite of radar-derived surface precipitation in LHN

all experiments & plots by Klaus Stephan



with quality control
on single-radar data



+ NL composite (3 Sta.)
+ B composite (2 Sta.)
+ 10 French stations
+ 3 Swiss stations

limited quality control:

+ filtering of clutter
+ gross error detection (anomalous histogram)
+ blacklist (by comparison to satellite cloud)
– no radar beam height map for bright band detection

LHN in COSMO-DE:
use of extended radar composite

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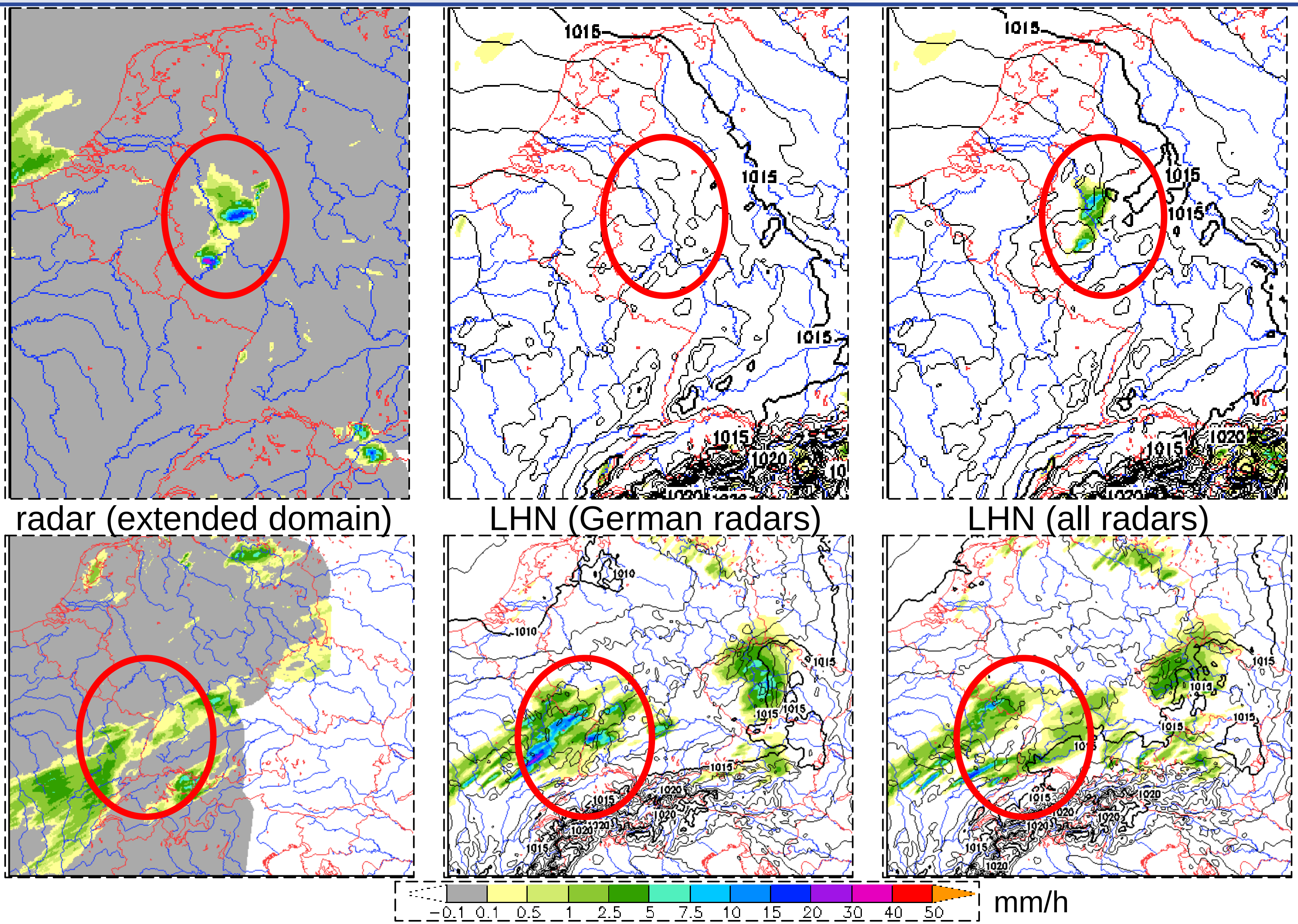

25 May 09,
12 UTC
+ 5 h

14 July 09,
0 UTC
+ 7 h

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LHN in COSMO-DE: use of extended radar composite

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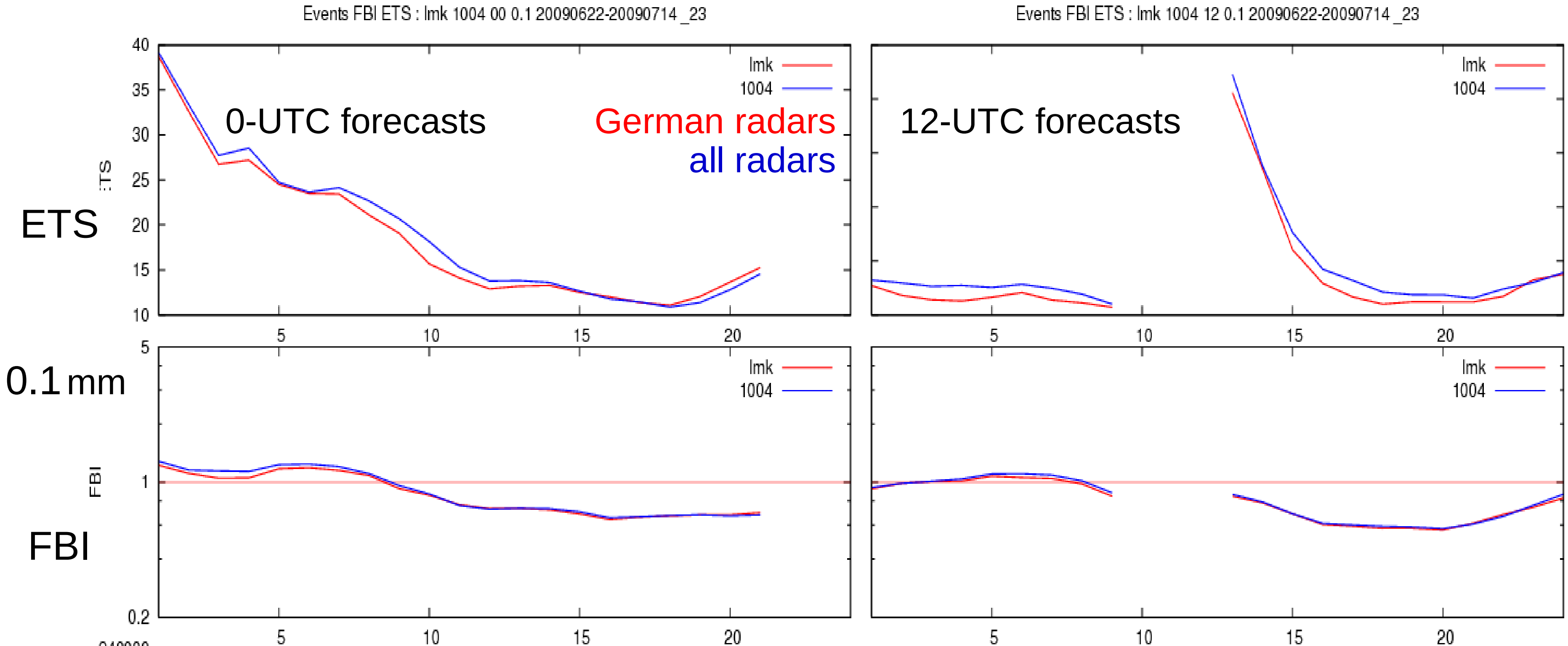
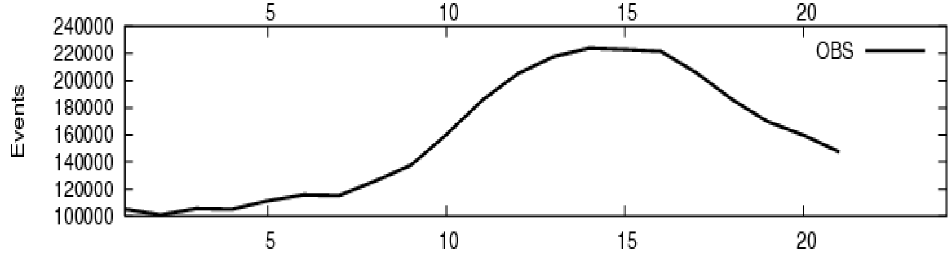
skill scores 22 June – 14 July 2009





- slight improvement in scores
- large improvement in single cases
- operational in spring 2010

Daniel Leuenberger (Meteo-Swiss) : re-introduction of spatial quality function w

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LHN in COSMO-DE:
influence of spatial scale on scores

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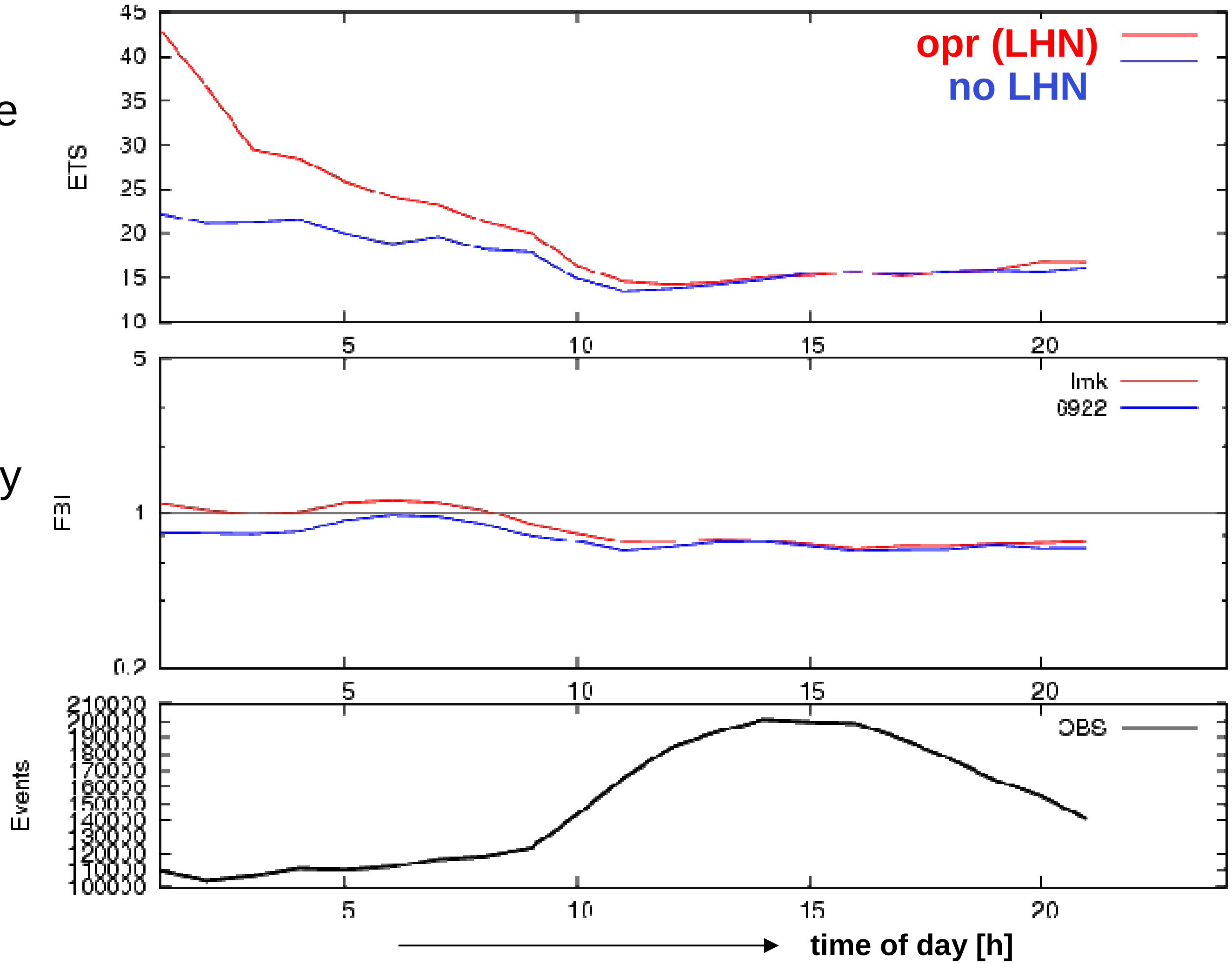
15 June – 15 July 2009 , 0-UTC COSMO-DE forecast runs, threshold = 0.1 mm/h

Equitable Threat Score

Frequency Bias



use of German radar network only

LHN in COSMO-DE: influence of spatial scale on scores

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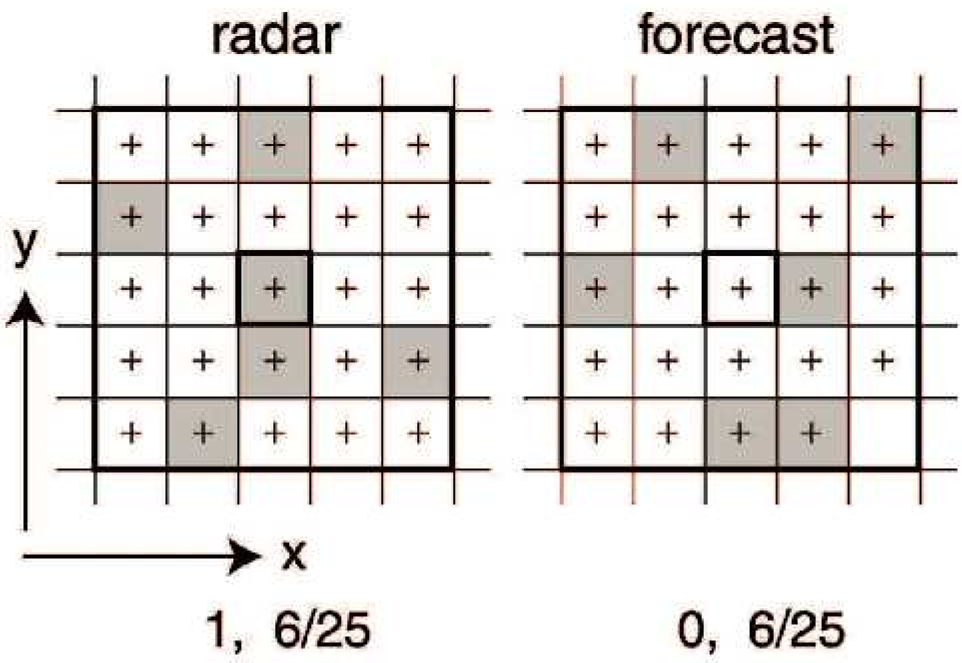
Fractions Skill Score

(*Roberts and Lean, 2008, MWR*)



O resp. F :

number of grid points
with value > threshold
in the neighbourhood

$$FFS = 1 - \frac{MSE}{MSE_{ref}}$$

$$MSE = \overline{(O-F)^2}^{\,domain}$$

$$MSE_{ref} = \overline{O^2 + F^2}^{\,domain}$$

(MSE_{ref} : largest possible *MSE*)

LHN in COSMO-DE: influence of spatial scale on scores

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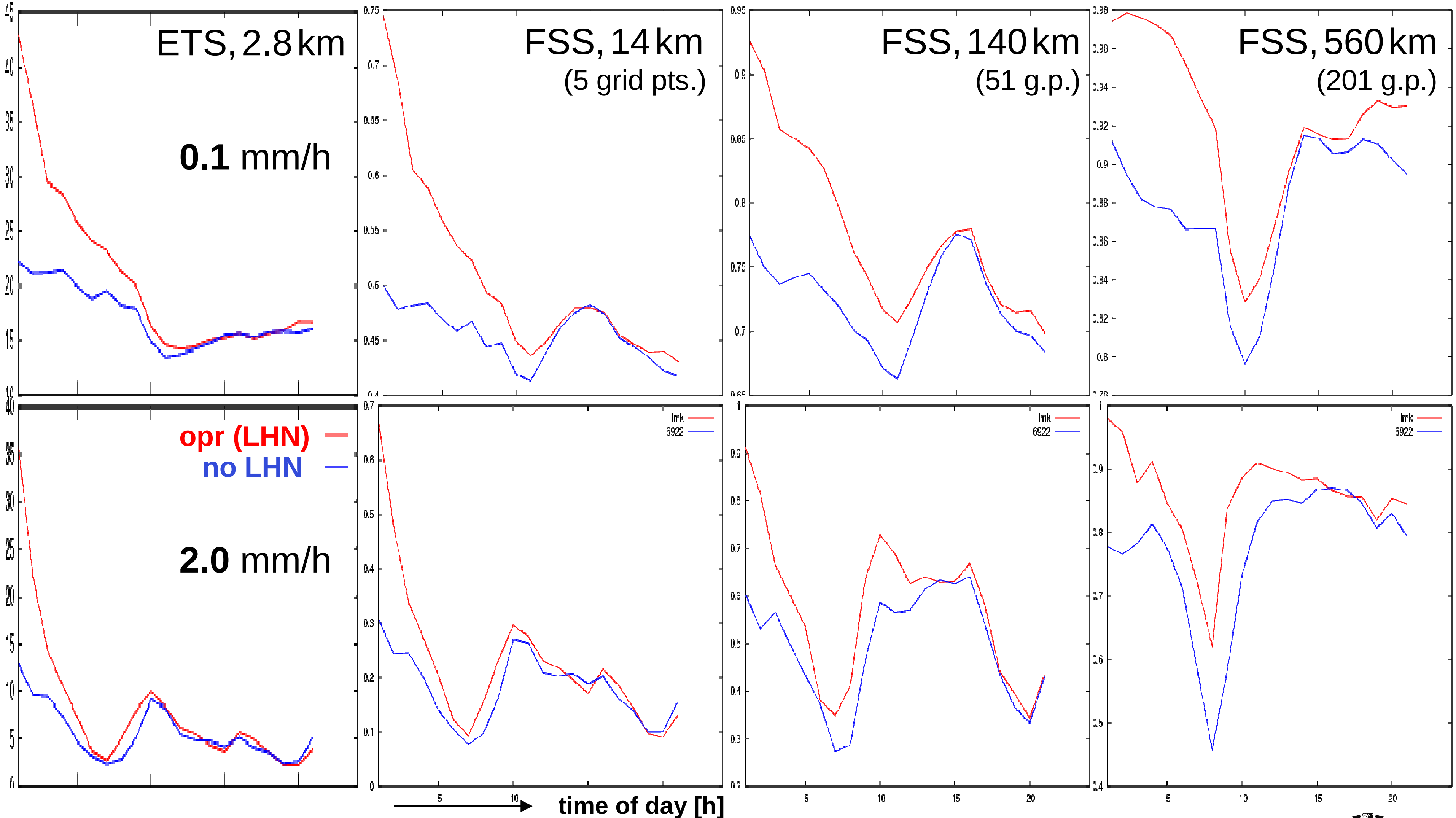
15 June – 15 July 2009 , **0**-UTC COSMO-DE forecast runs



LHN in COSMO-DE:
influence of spatial scale on scores

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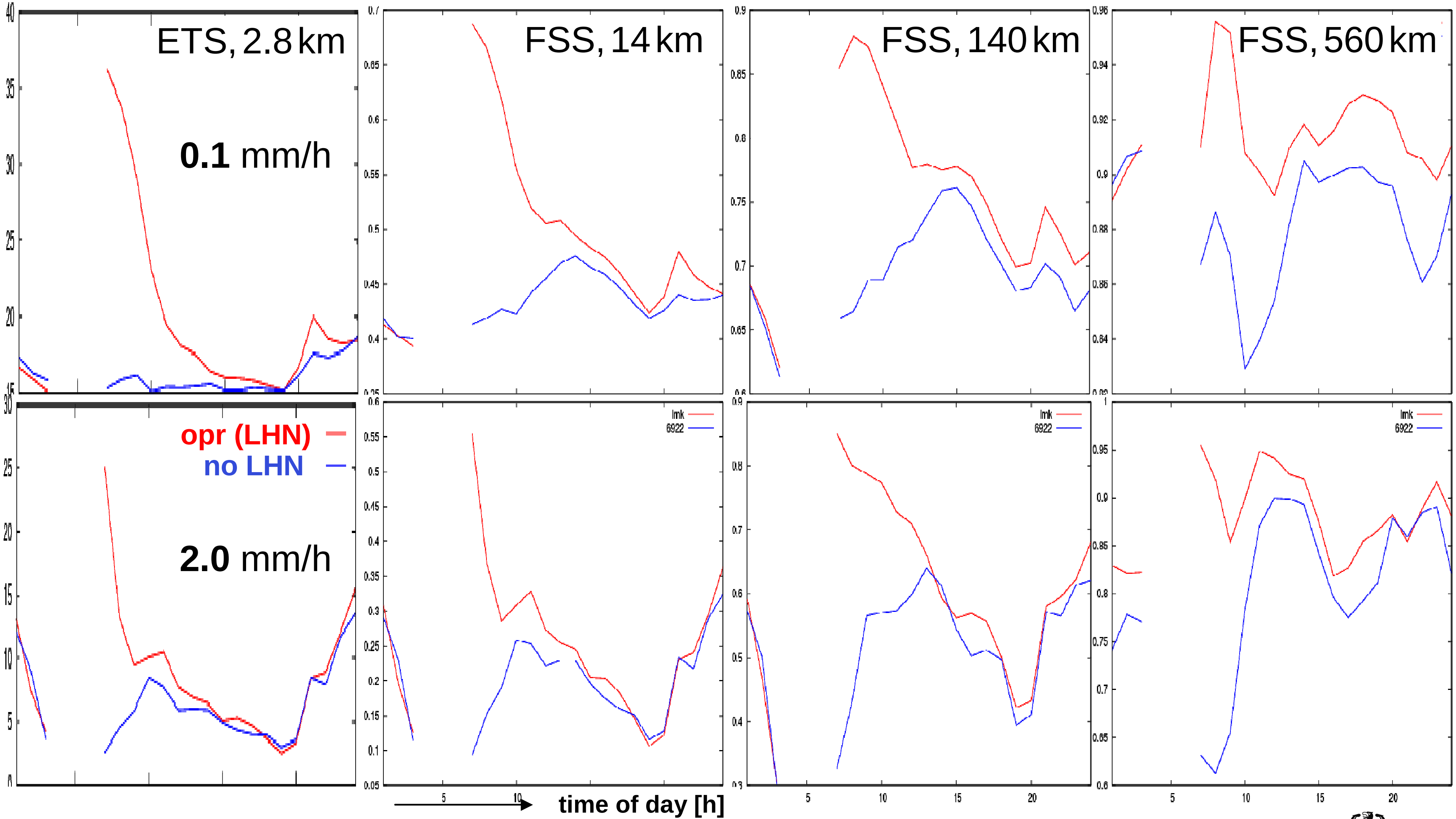
15 June – 15 July 2009 , **6**-UTC COSMO-DE forecast runs



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LHN in COSMO-DE:
influence of spatial scale on scores

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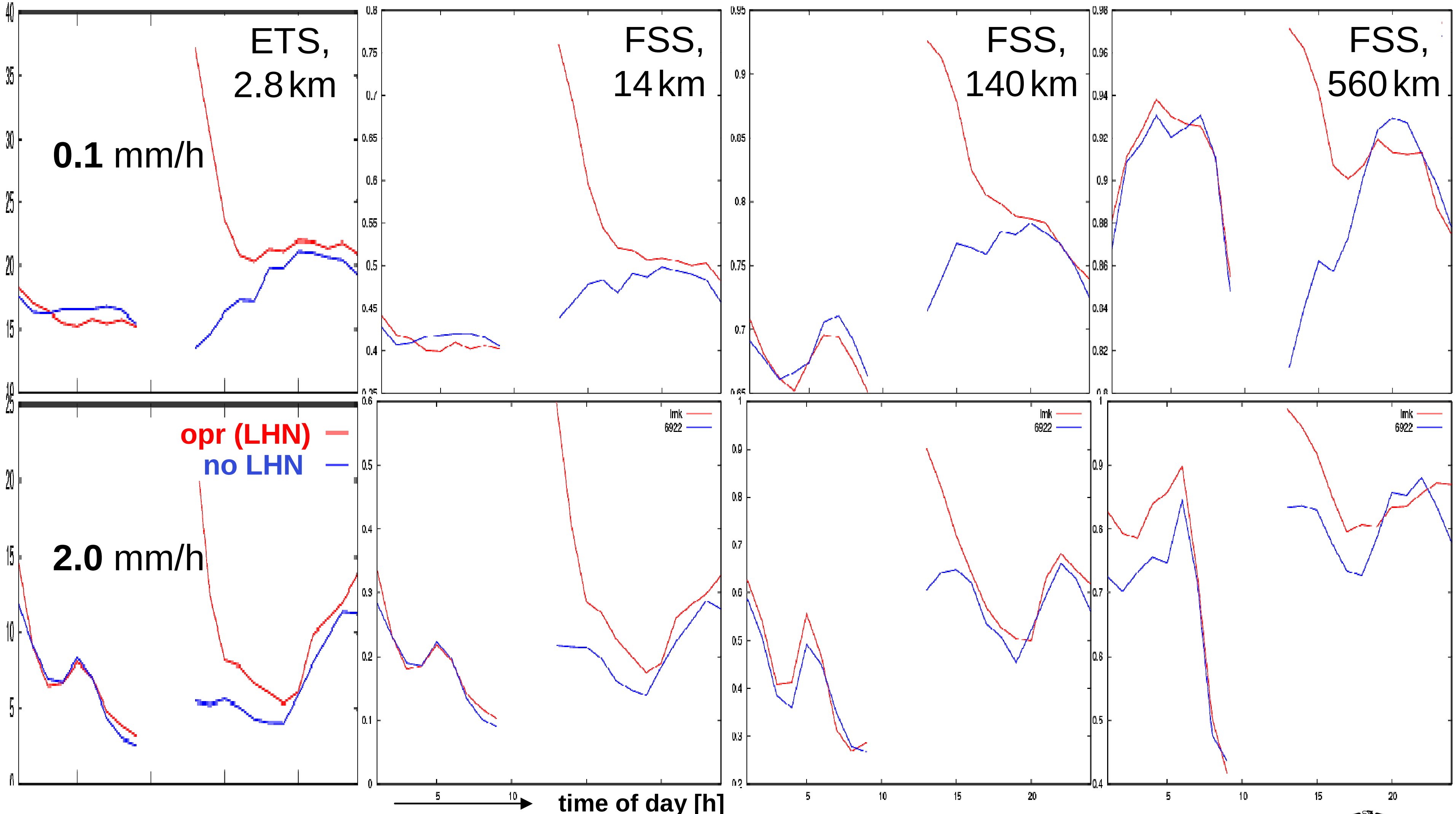
15 June – 15 July 2009 , **12**-UTC COSMO-DE forecast runs



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LHN in COSMO-DE:
influence of spatial scale on scores

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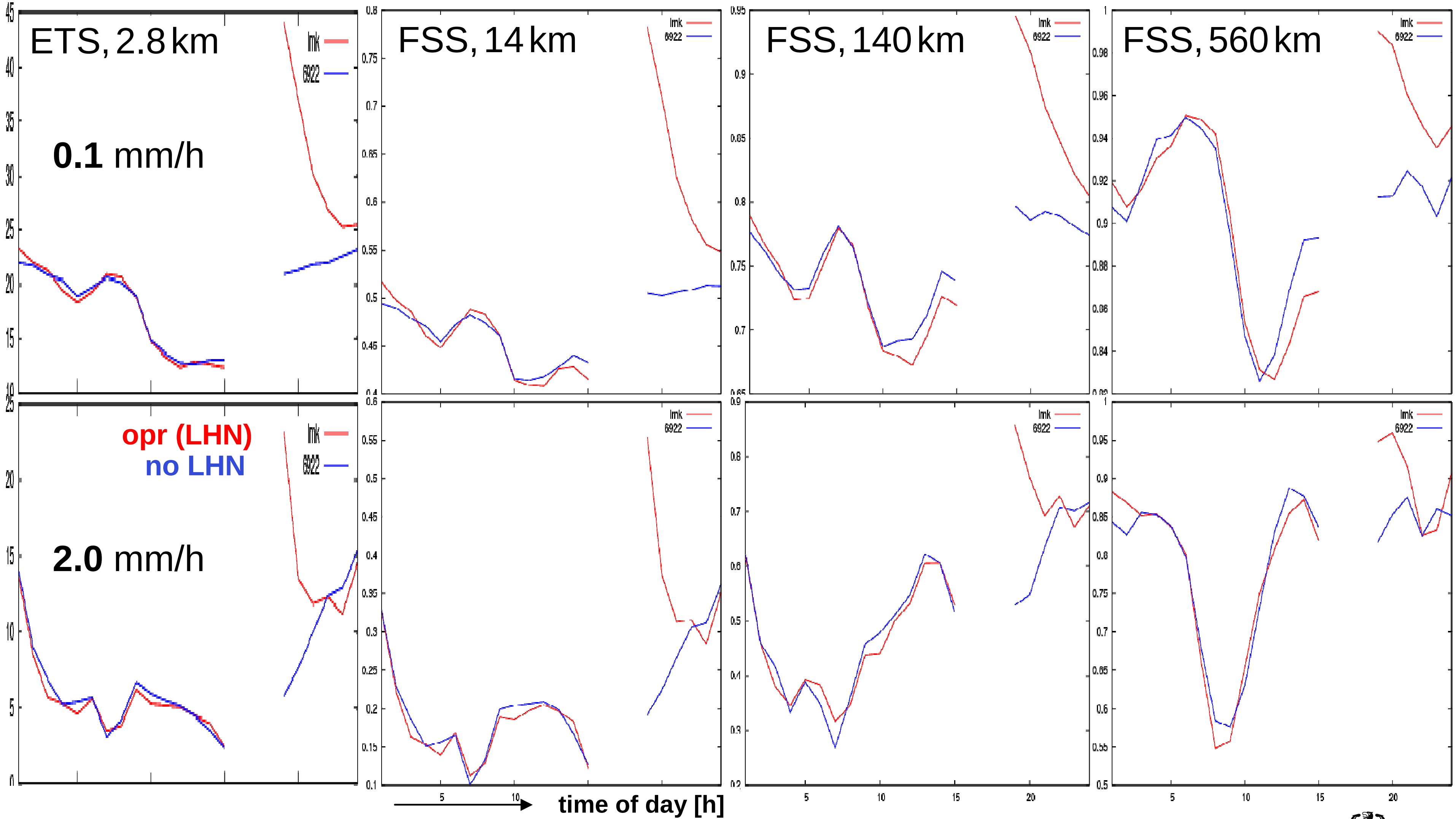
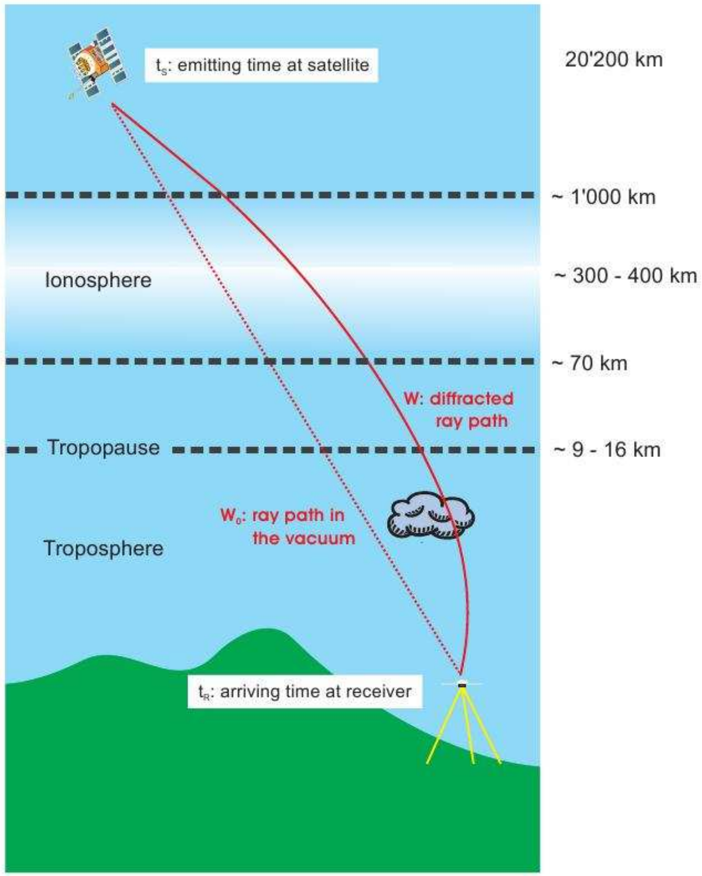
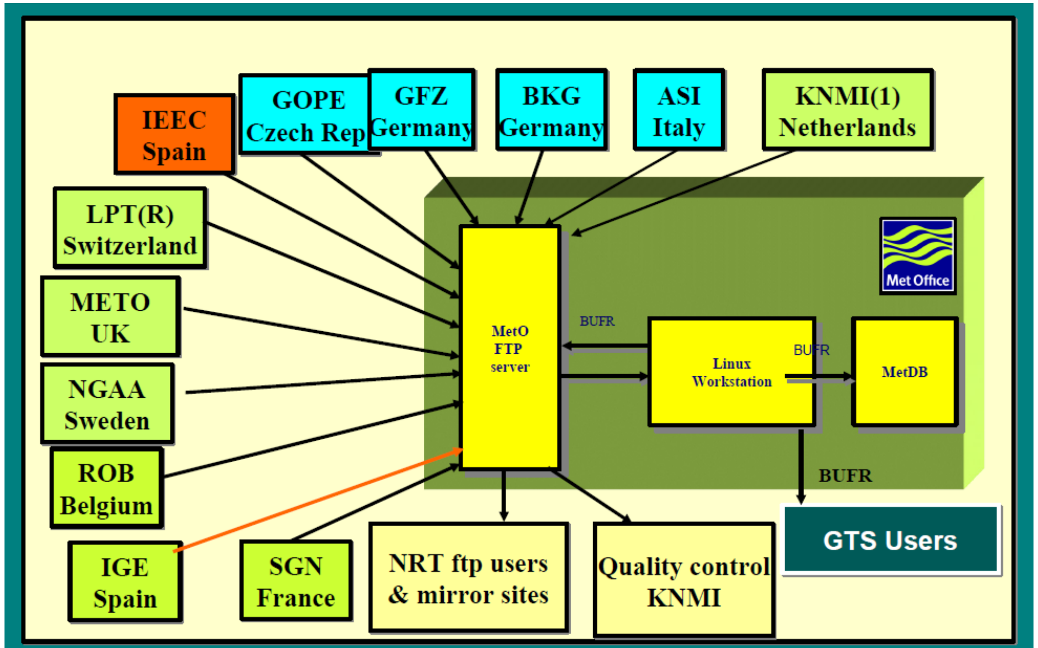
15 June – 15 July 2009 , **18**-UTC COSMO-DE forecast runs



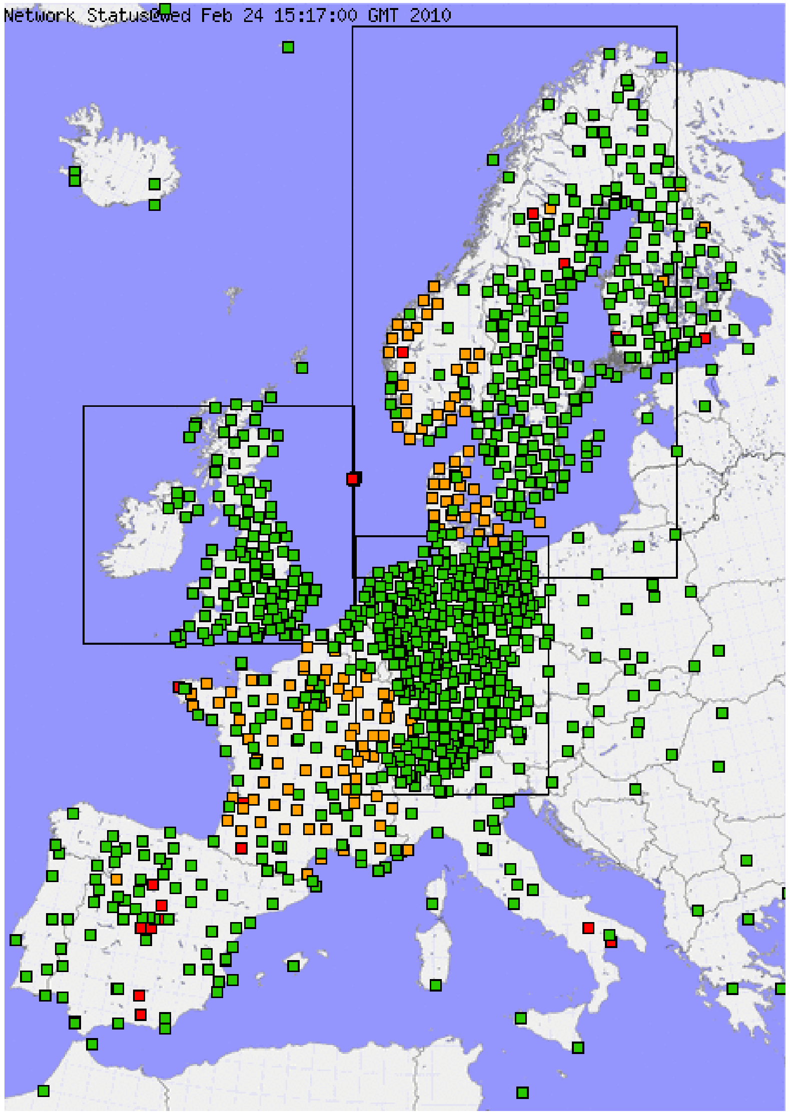
- GNSS = Global Navigation Satellite System
  - GPS (USA)
  - GLONASS (Russia)
  - GALILEO (EU)
  - ...
- delay of a signal due to atmospheric refractivity
- Slant Total Delay (STD, integrated value) : 'measured' by calculating the time difference between sending and receiving the signal
- Zenith Total Delay (ZTD) : by mapping TSD
- Zenith Wet Delay (ZWD) = ZTD – ZDD, where Zenith Dry Delay computed using model pressure and temperature
- Integrated Water Vapour proportional to ZWD



Troller, M.R. (2004): 'GPS based Determination of the Integrated and Spatially Distributed Water Vapor in the Troposphere.'



Green = nation member of E-GVAP. Blue = nation not member of E-GVAP.
Orange = no updates to processing.



http://egvap.dmi.dk/

assimilation of ground-based GNSS-IWV: processing in the nudging

- certain processing centres are preferred over others in the redundancy check
- reject observed IWV < 2 kg/m²
- first guess check for IWV, threshold = 0.15 $IWV_{saturat.}$; spatial consistency check
- conversion of IWV into humidity:
  scale model specific humidity profile
  to obtain retrieved specific humidity profile :

$$q_{v_{obs}} = q_{v_{mo}} \cdot \frac{IWV_{obs}^{(corr)}}{IWV_{mo}}$$

- if retrieved profile exceeds saturation at some levels, correct it iteratively
- determine quality weights at each model layer

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assimilation of ground-based GNSS-IWV: the problem of late data availability

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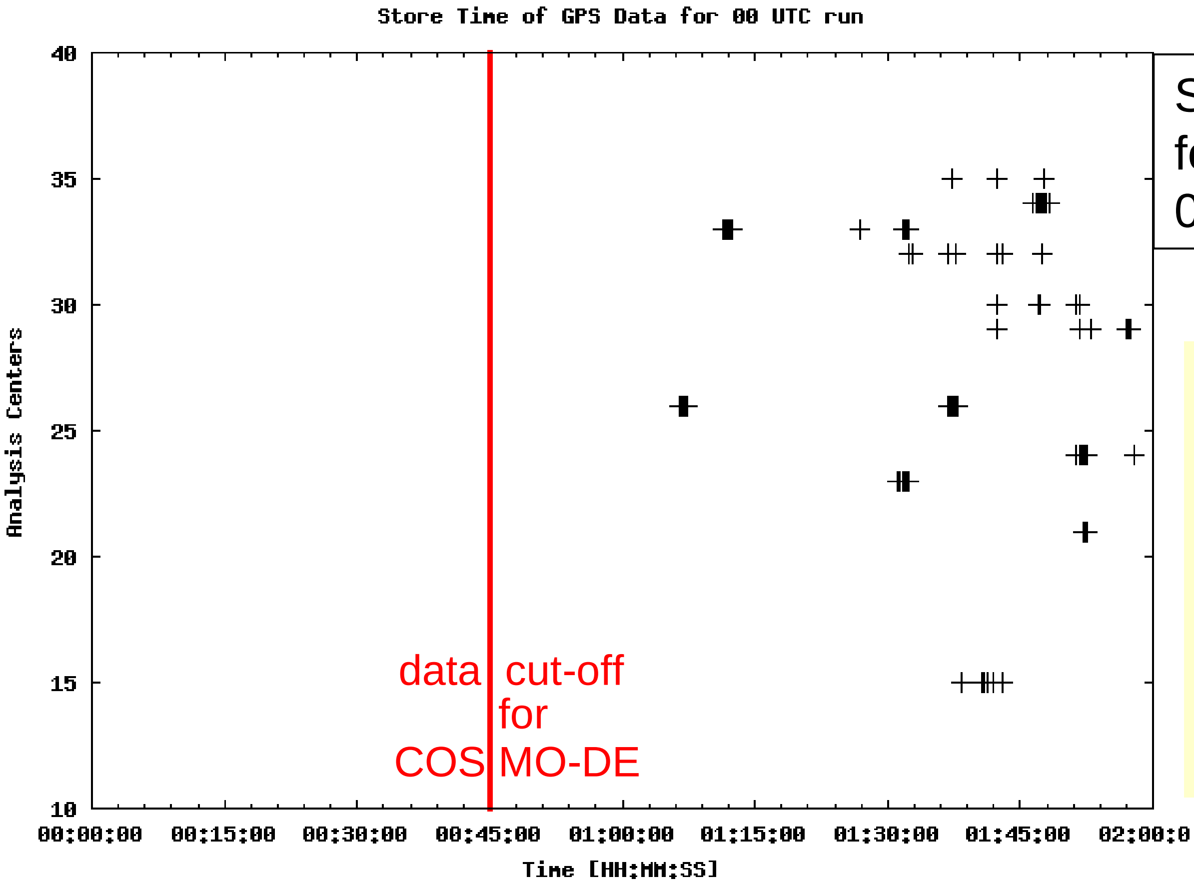

Store time of GNSS data for reference time 00:00:00 - 00:45:00 UTC

data availability for

- forecast : < 1 %
- time critical analysis: ~ 50 % (mainly from $t < t_{ana} - 1$h)
- assimilation : ~ 90 %

(of what is available after days)

nearly no GNSS data used from last hour before analysis time and during 'nudgcast'

$\rightarrow$ forecast impact larger, if more data were used ?

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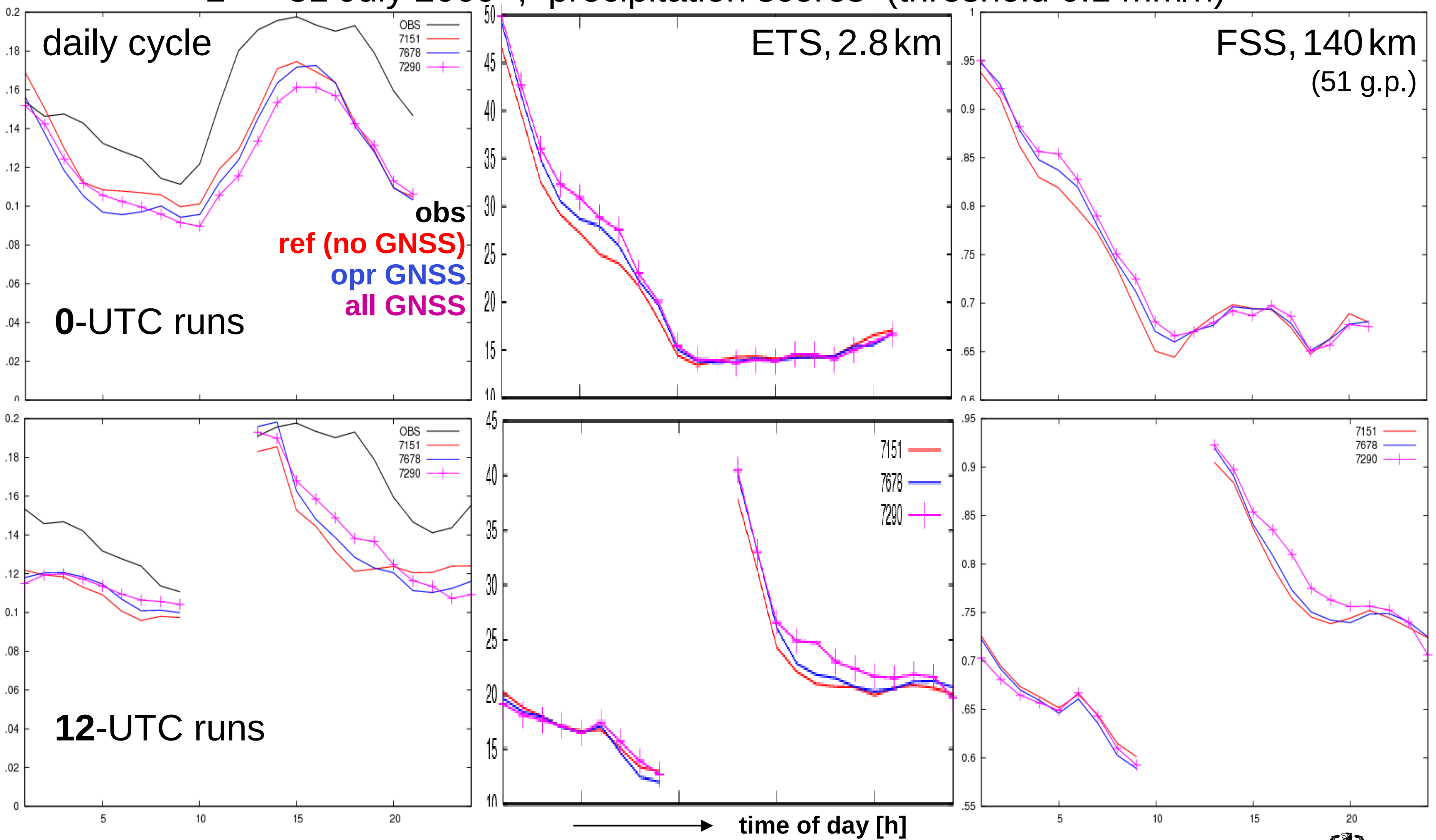
2 – 31 July 2009 , precipitation scores (threshold 0.1 mm/h)



assimilation of ground-based GNSS-IWV:
results for summer period

GNSS experiment

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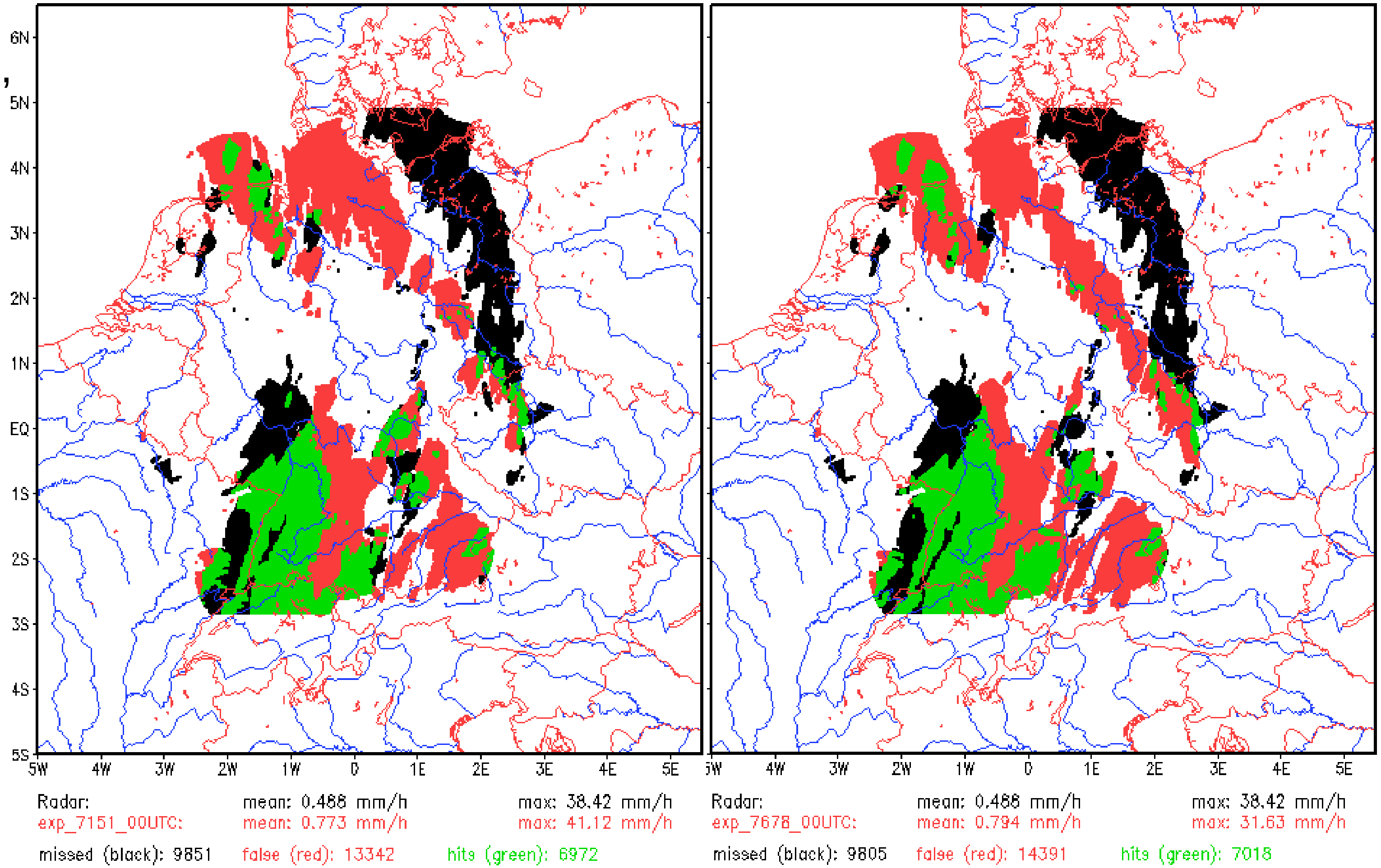
location of precip
(> 0.1 mm/h)
on 17 July 2009,
16 UTC

hits (precip)
missed events
false alarms

reference (no GNSS) GNSS experiment



phase lag of squall line: increased (only) very (!) slightly by GNSS

assimilation of ground-based GNSS-IWV: results for summer period

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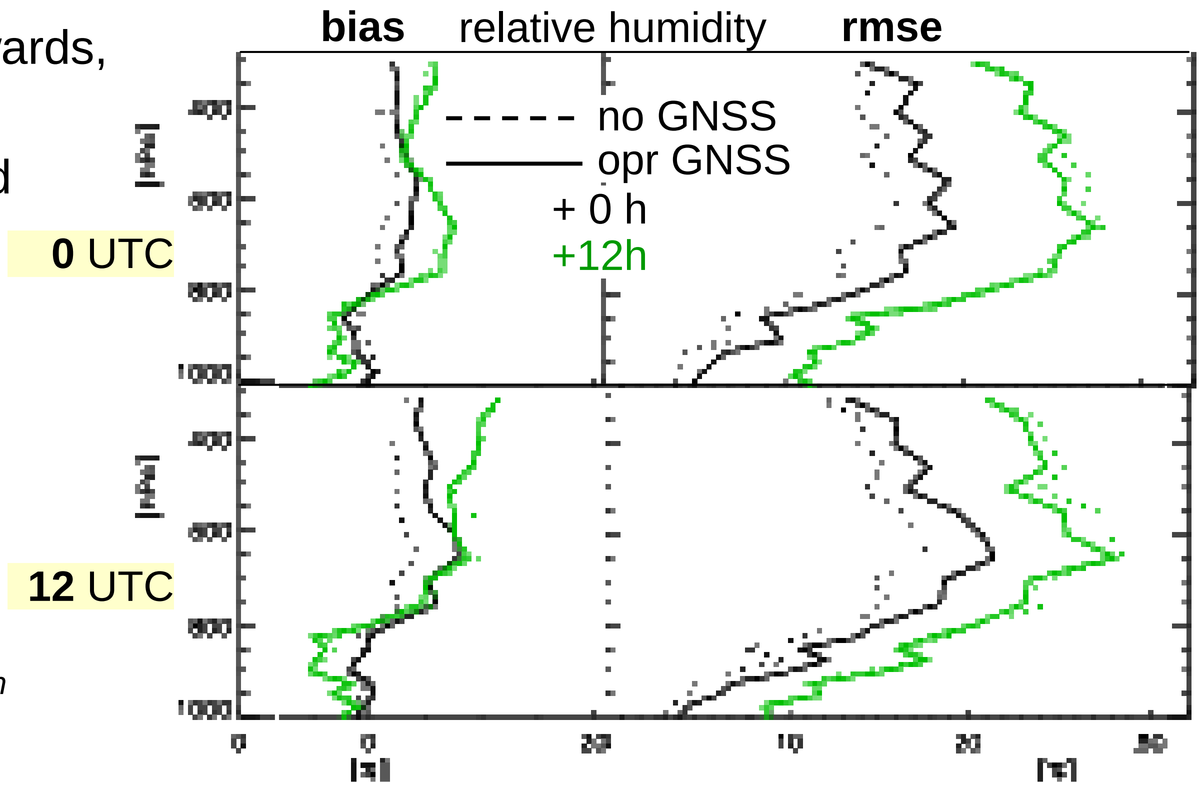
- upper-air verification:
  - humidity conveyed upwards, moistening at 12 UTC
  - humidity rmse improved at + 12 h
  - neutral impact for wind + temperature



- Synop verification:
  - no negative impacts
  - bias slightly reduced for p_s, T_{2m}, $T_{d,\,2m}$, dd_{10m}
- precipitation:
  - scores strongly improved during assimilation
  - scores moderately improved in forecast, could be significantly enhanced if GNSS data were available closer to real time
  - phase errors (lag) of fronts / convergence lines (only) very slightly increased

assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

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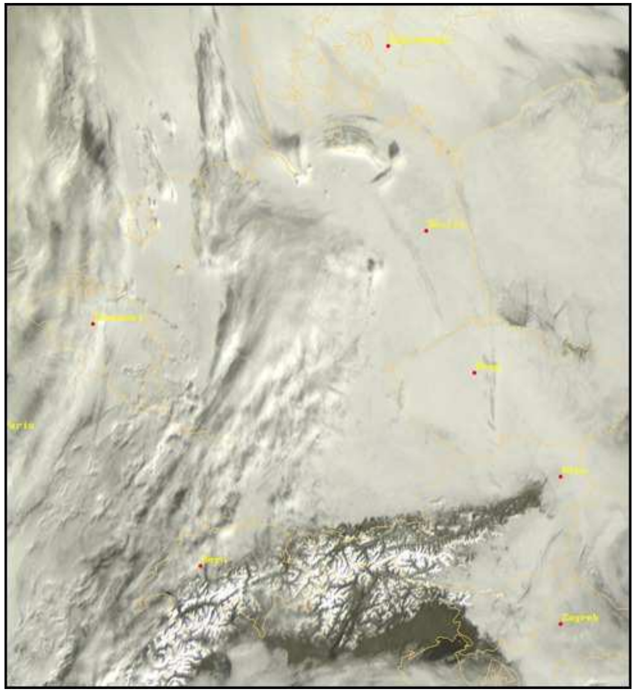
winter period: 2 – 24 Jan. 2010, with ~ 10 days with low stratus

expected: problems with IWV-nudging in cases of strong vertical humidity gradients

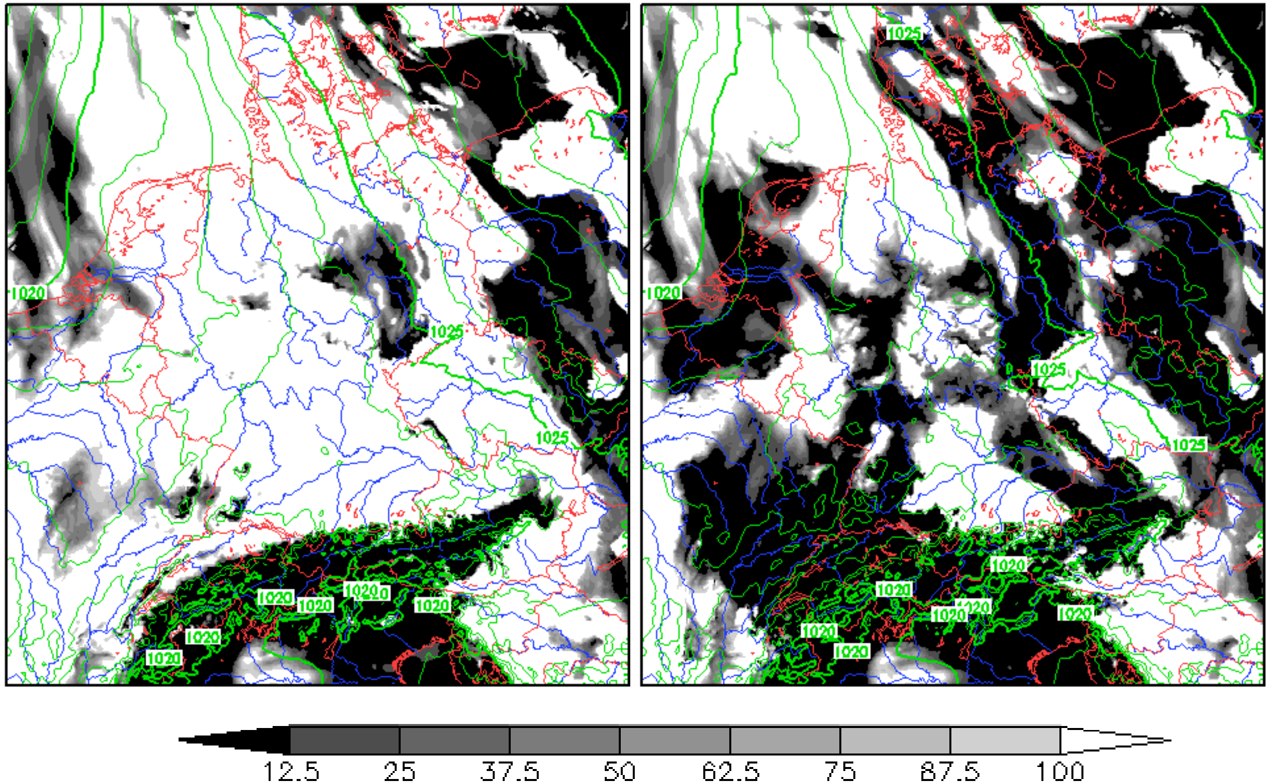
→ examples

15 Jan 2010, 10 UTC



COSMO-DE analyses

reference (no GNSS) GNSS experiment



low cloud cover [%]

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assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

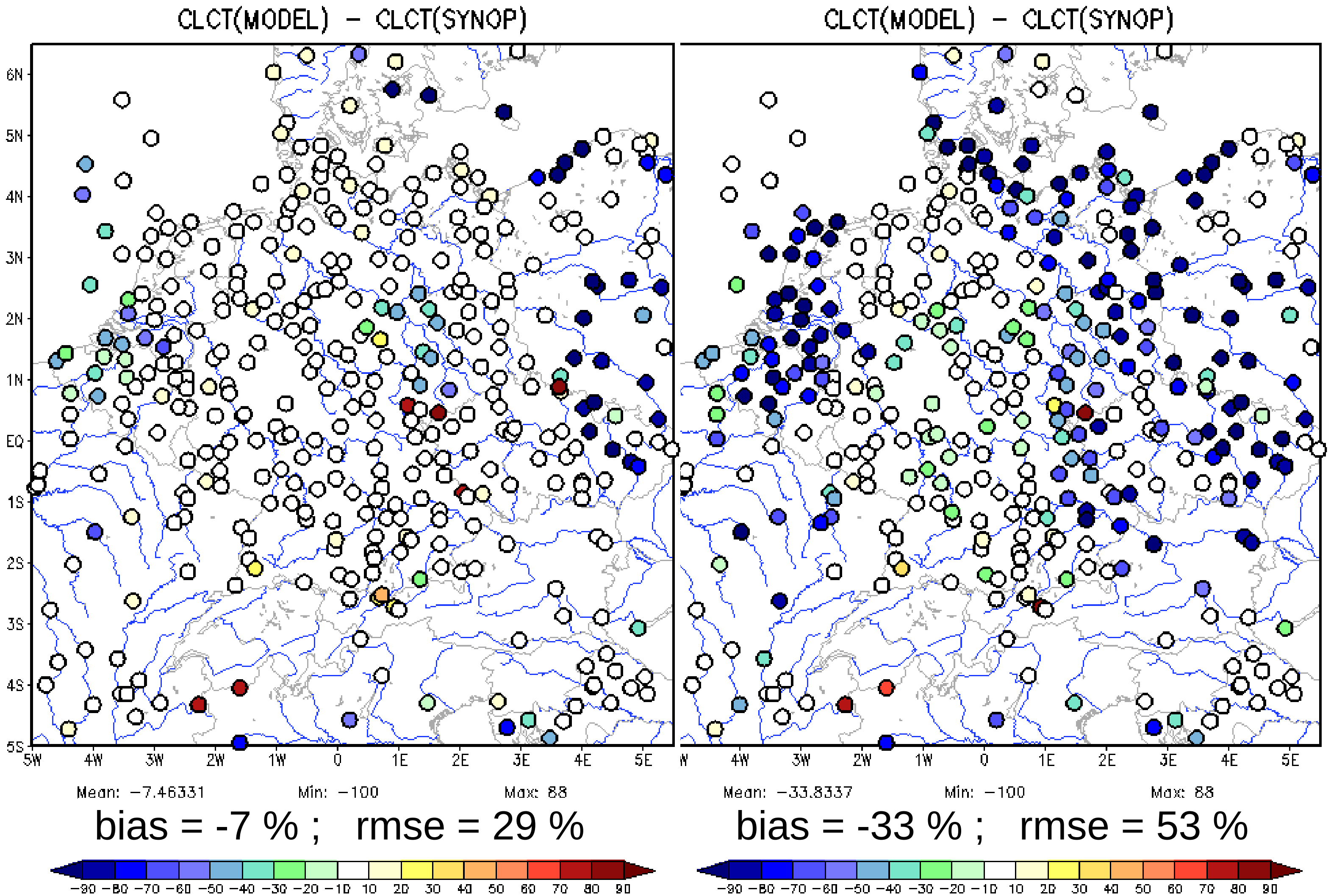
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

COSMO-DE analysis minus Synop obs., 15 Jan, 10 UTC

total cloud cover

reference (no GNSS)

GNSS experiment



bias = -7 % ; rmse = 29 %

bias = -33 % ; rmse = 53 %

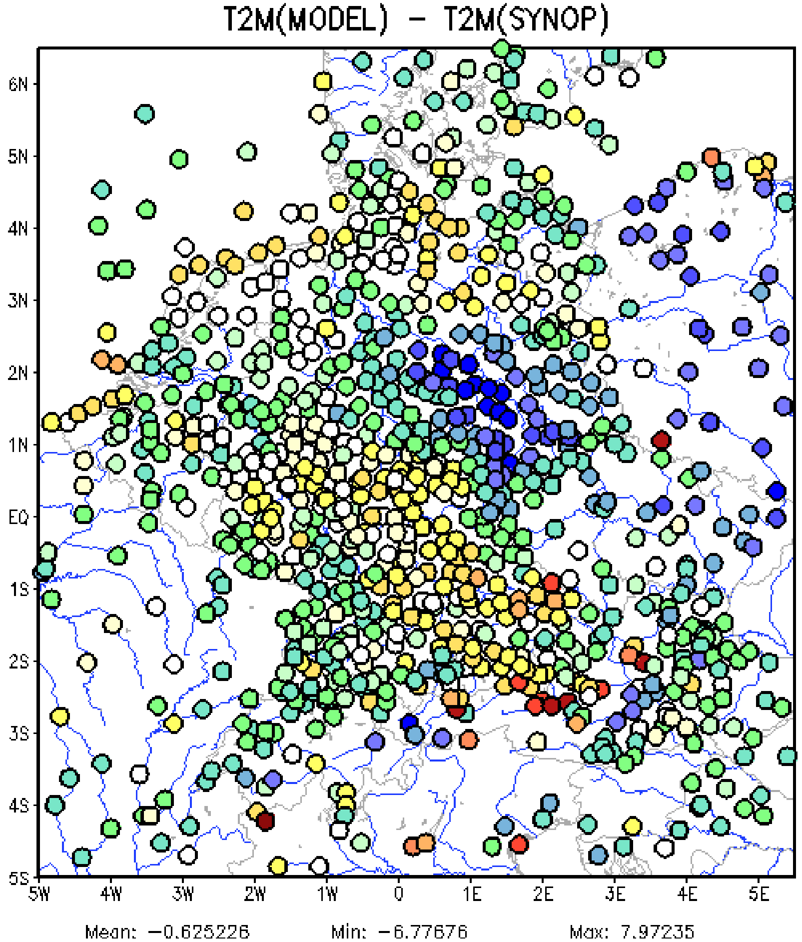
assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

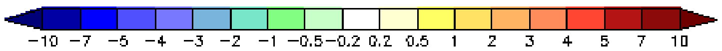
COSMO-DE analysis minus Synop obs., 15 Jan, 10 UTC

2-m temperature

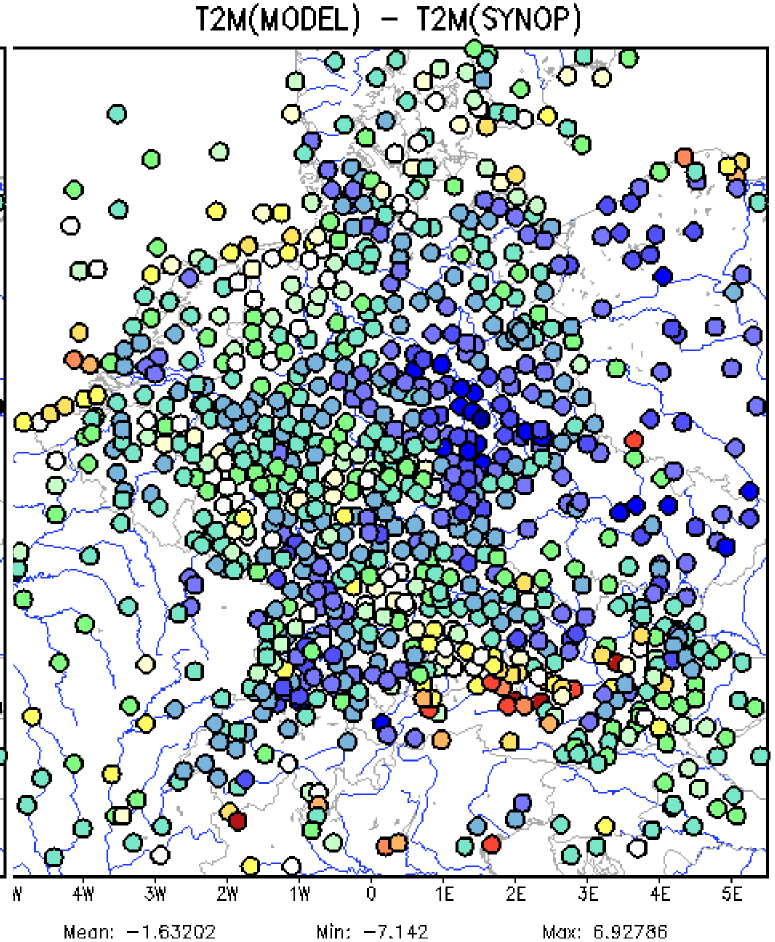
reference (no GNSS)



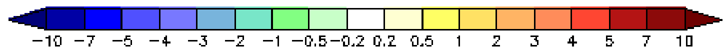
bias = -0.63 K ; rmse = 1.7 K



GNSS experiment



bias = -1.63 K ; rmse = 2.4 K



assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

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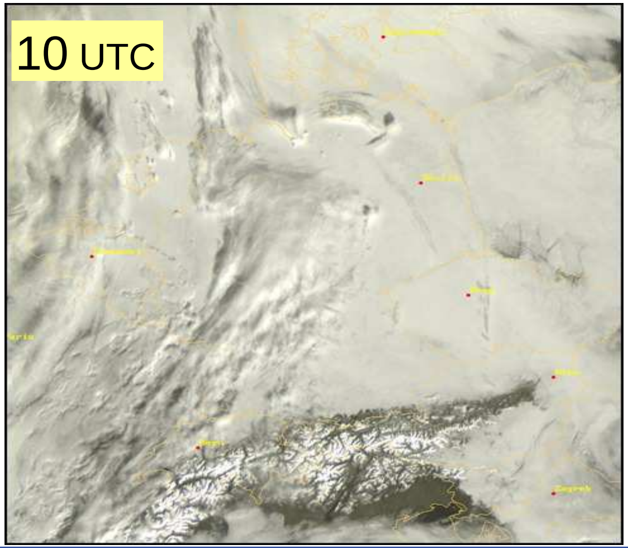
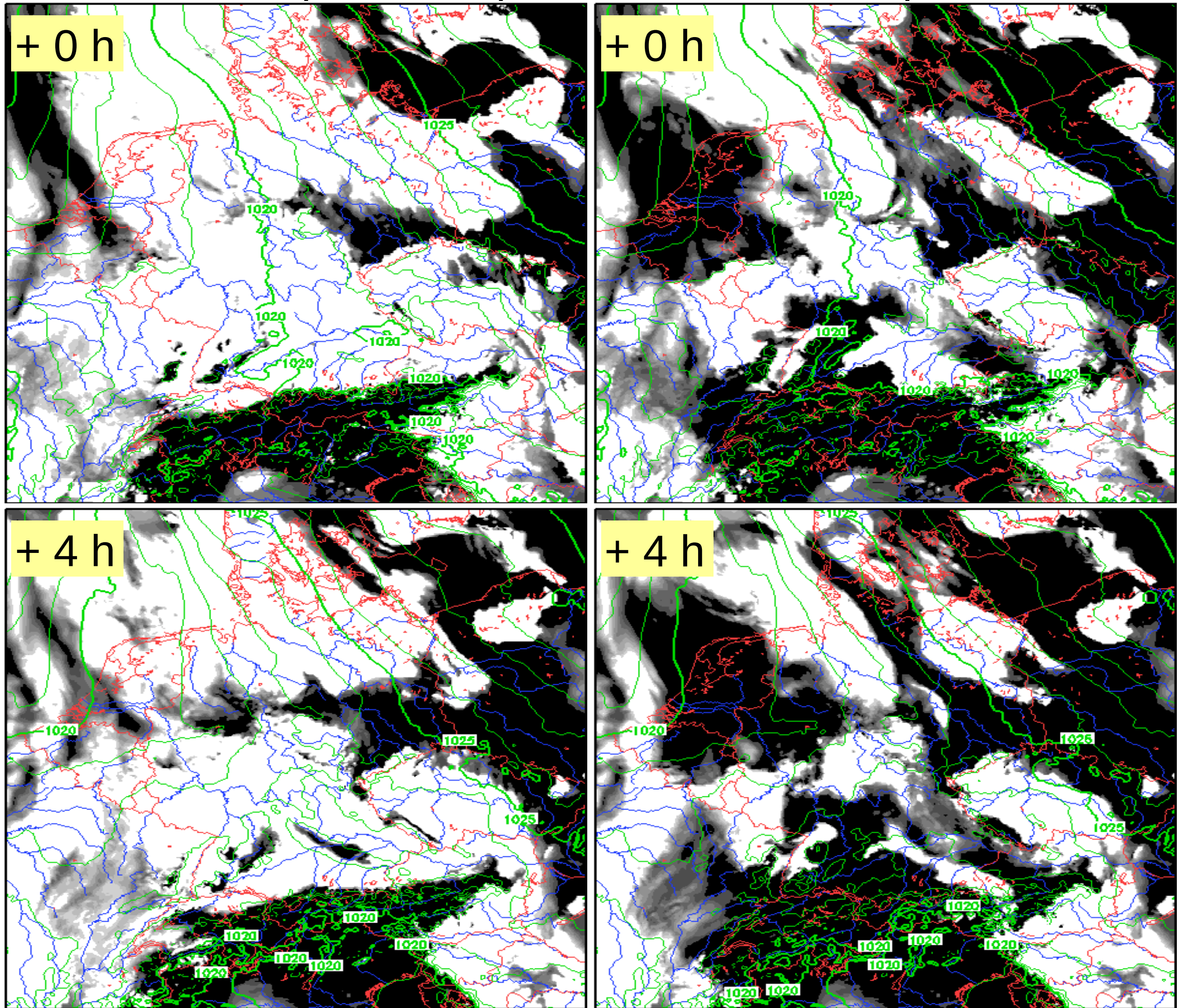
Wetter und Klima aus einer Hand

COSMO-DE forecasts starting from 15 Jan 2010, 6 UTC

low cloud cover [%]



reference (no GNSS) | GNSS experiment



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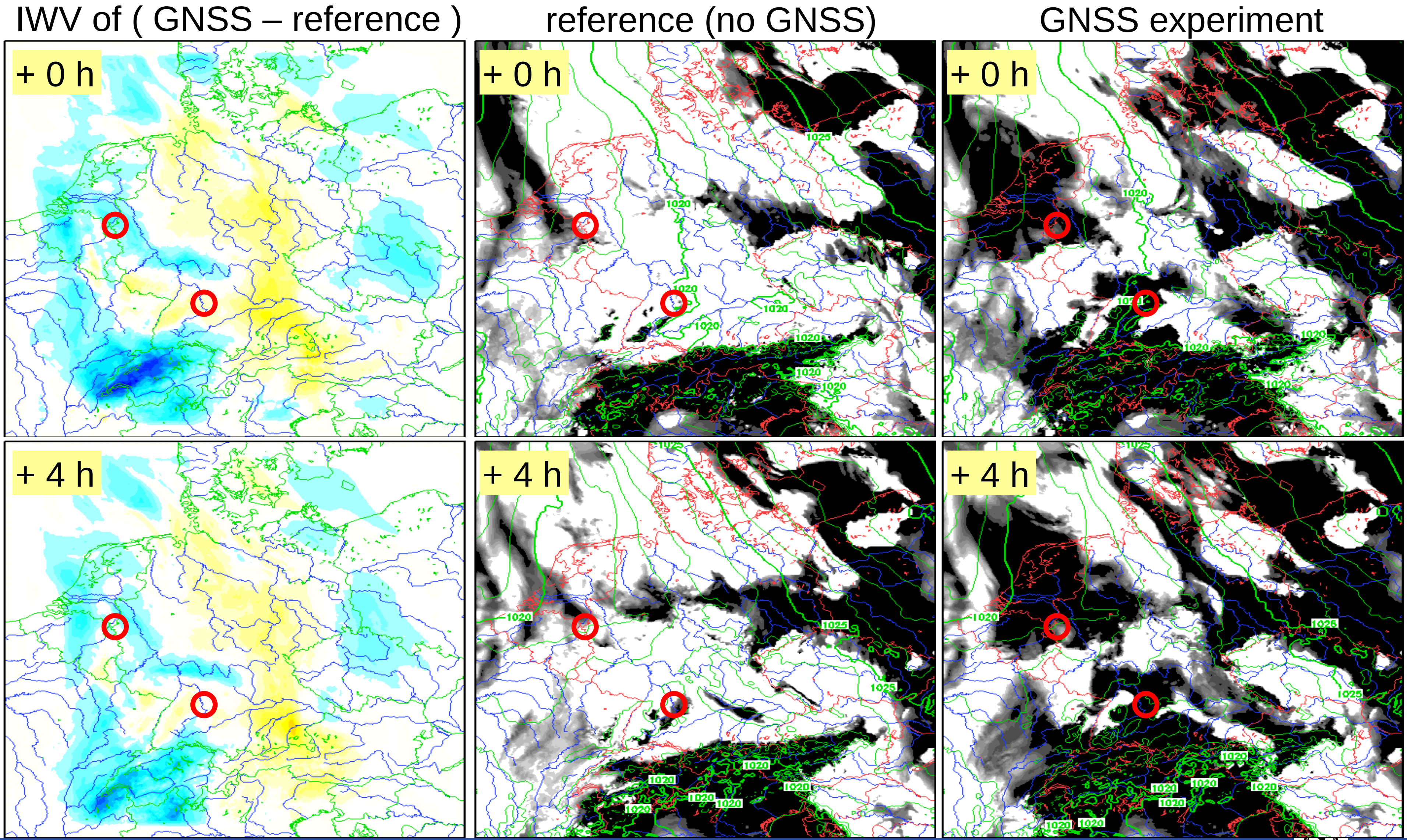
assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



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assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

vertical profiles
Aachen

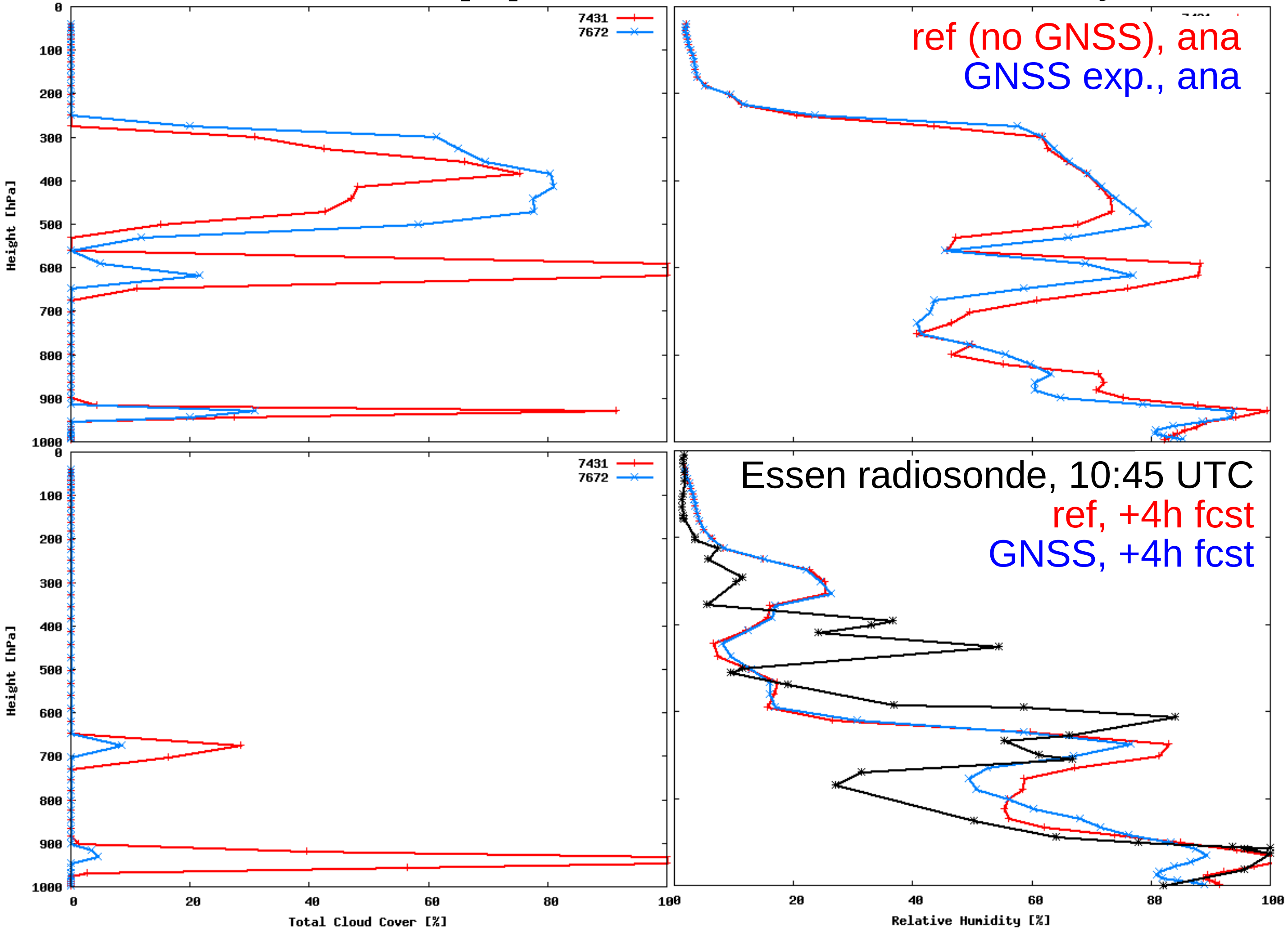
6 UTC

10 UTC

low cloud removed,
reason:
use of GNSS
reduces IWV

cloud cover [%]

relative humidity



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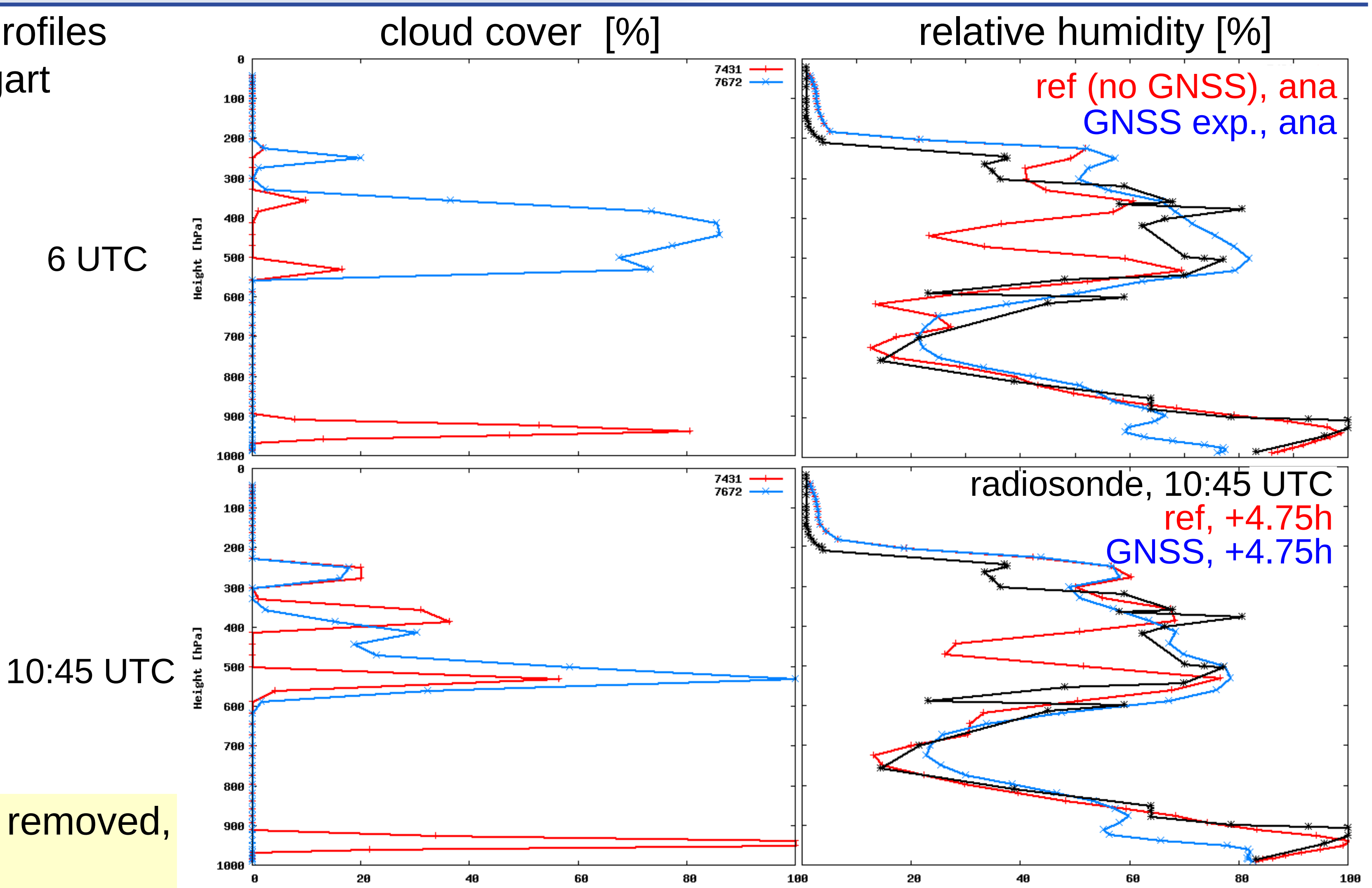
assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

vertical profiles
Stuttgart



low cloud removed,
reason:
use of GNSS conveys humidity from low troposphere upwards (without reducing IWV)

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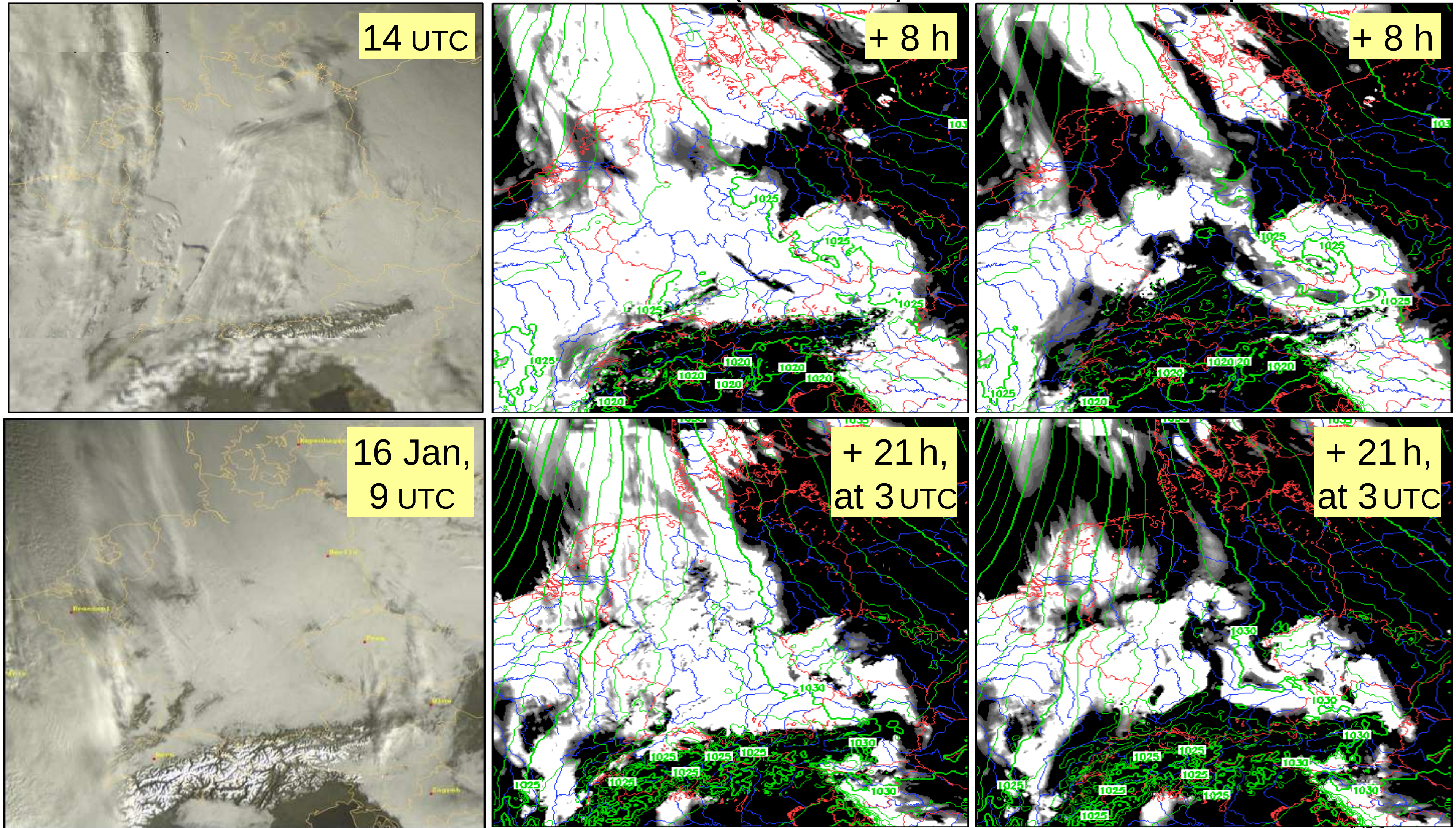
assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

forecasts from 15 Jan, 6 UTC | reference (no GNSS) | GNSS experiment



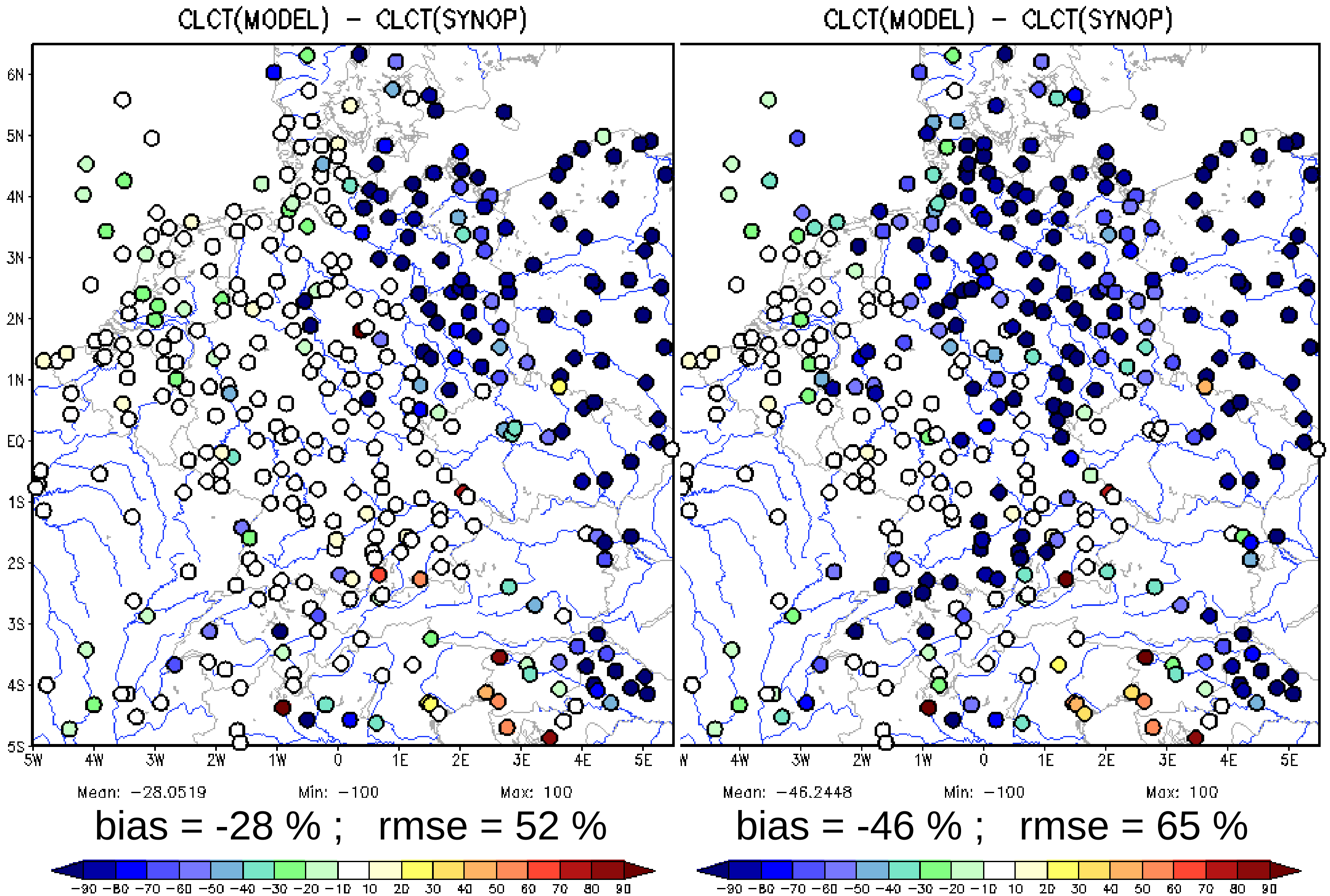
assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

21-hour forecasts starting from 15 Jan, 6 UTC

total cloud cover

reference (no GNSS) | GNSS experiment



bias = -28 % ; rmse = 52 %

bias = -46 % ; rmse = 65 %

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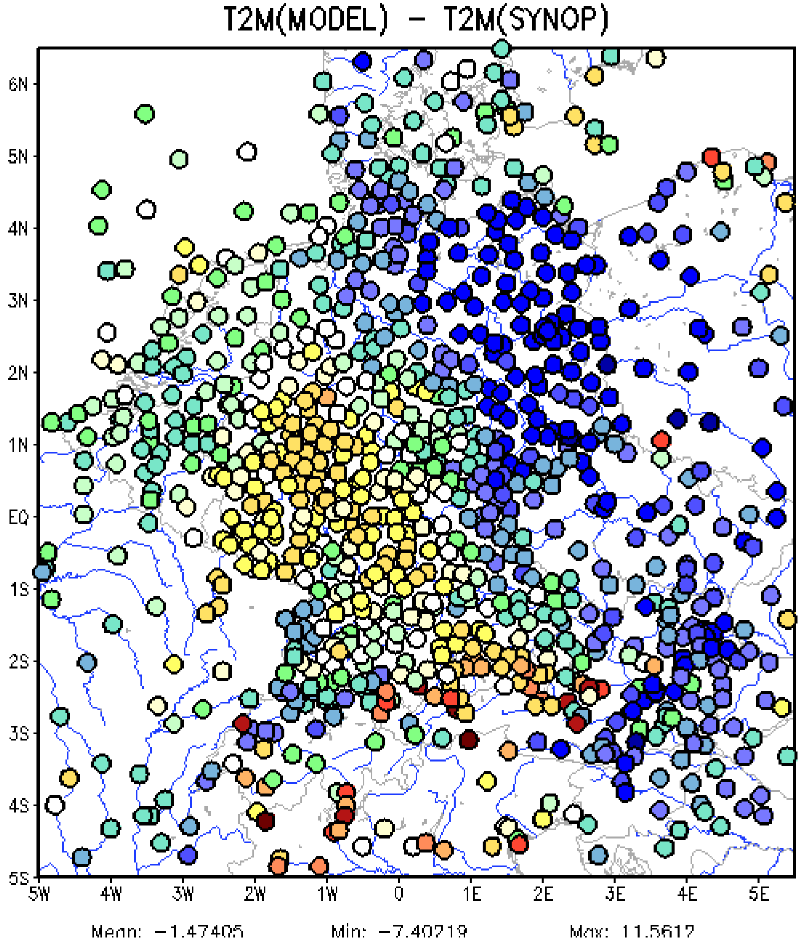
assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

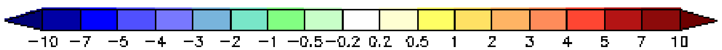
21-hour forecasts starting from 15 Jan, 6 UTC

2-m temperature

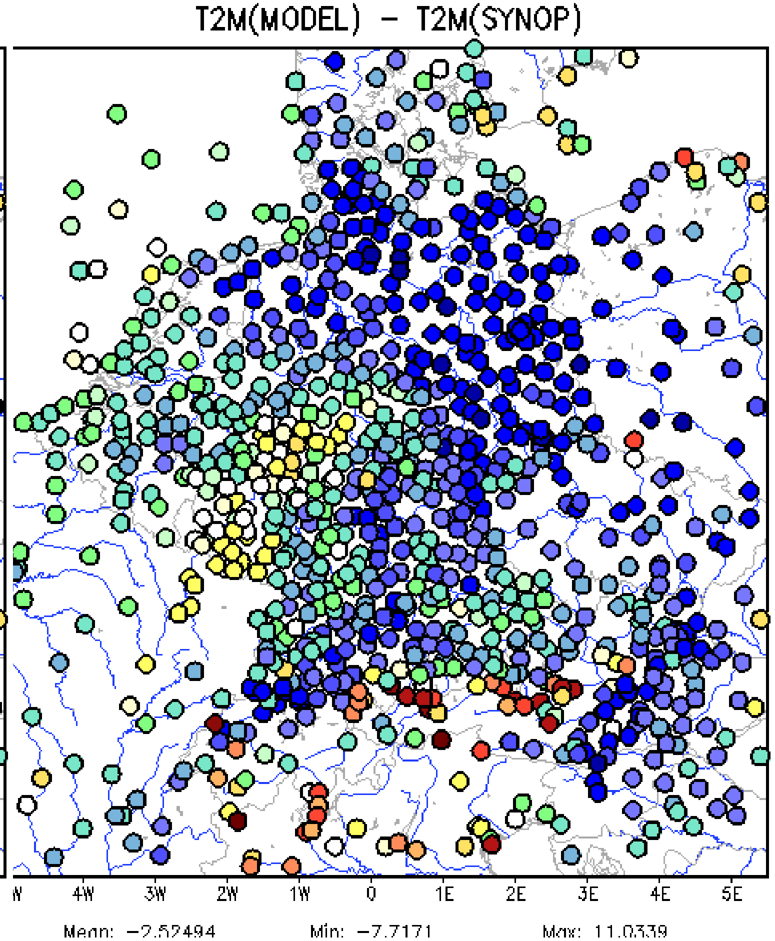
reference (no GNSS)



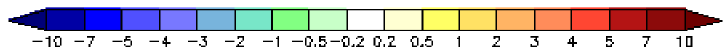
bias = -1.47 K ; rmse = 3.0 K



GNSS experiment



bias = -2.52 K ; rmse = 3.7 K



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assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

Deutscher Wetterdienst
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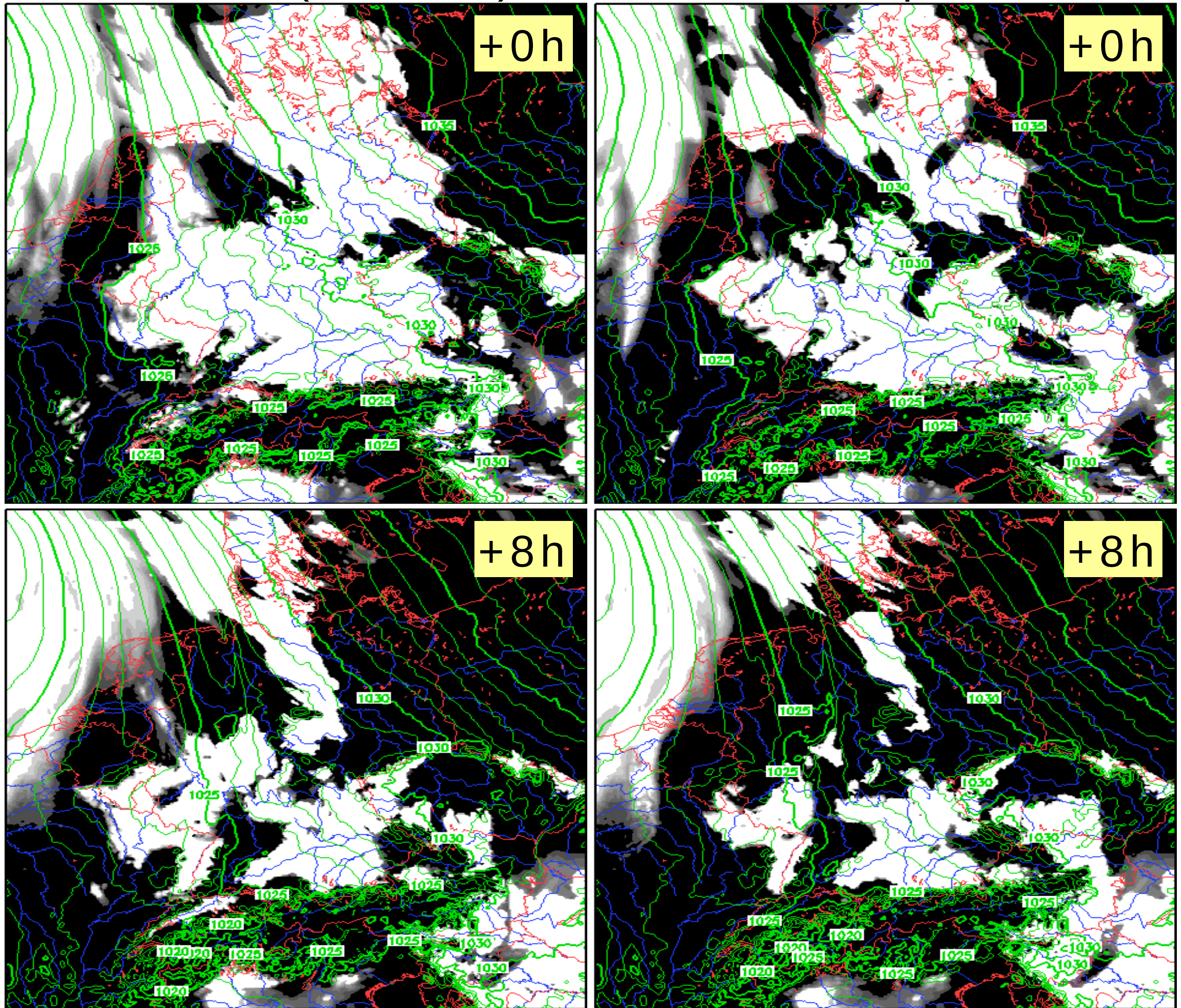
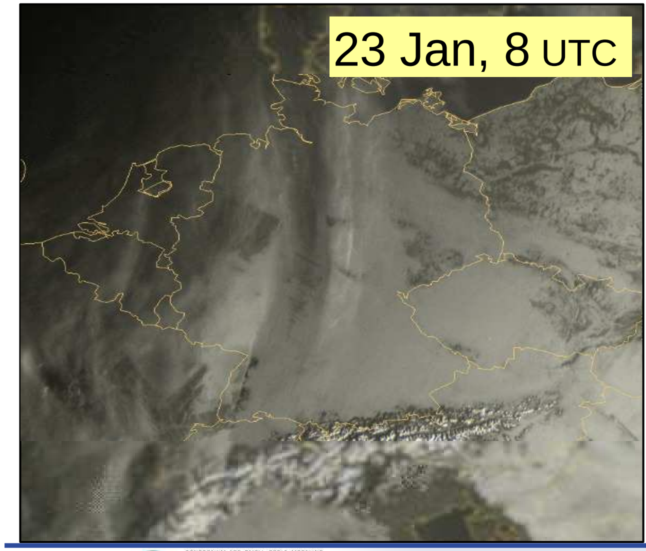
forecasts from 23 Jan, 0 UTC

reference (no GNSS)

GNSS experiment





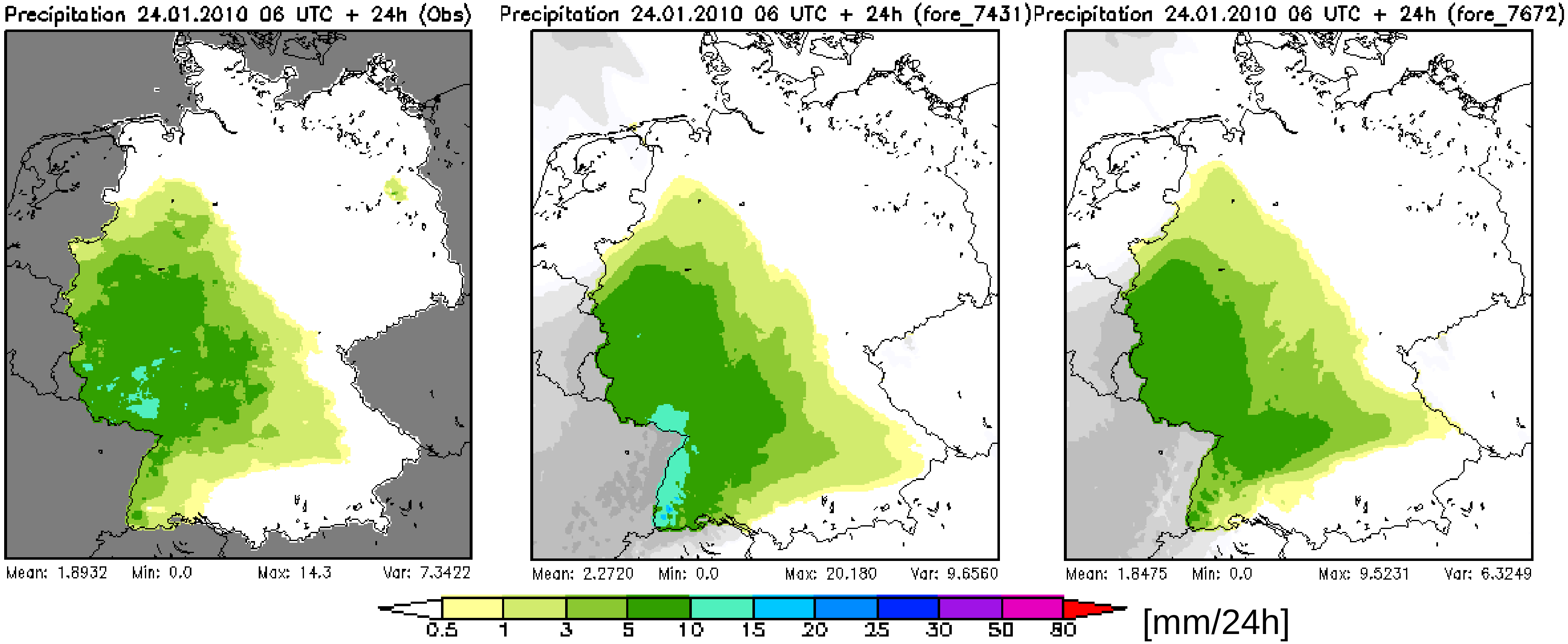
assimilation of ground-based GNSS-IWV: impact on wintertime precipitation

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

24-hour precipitation sum for 25 Jan. 2010, 6 UTC

sum of 2 COSMO-DE 6 – 18 hour forecasts

radar obs | reference (no GNSS) | GNSS experiment



[mm/24h]

→ positive impact in southern Germany

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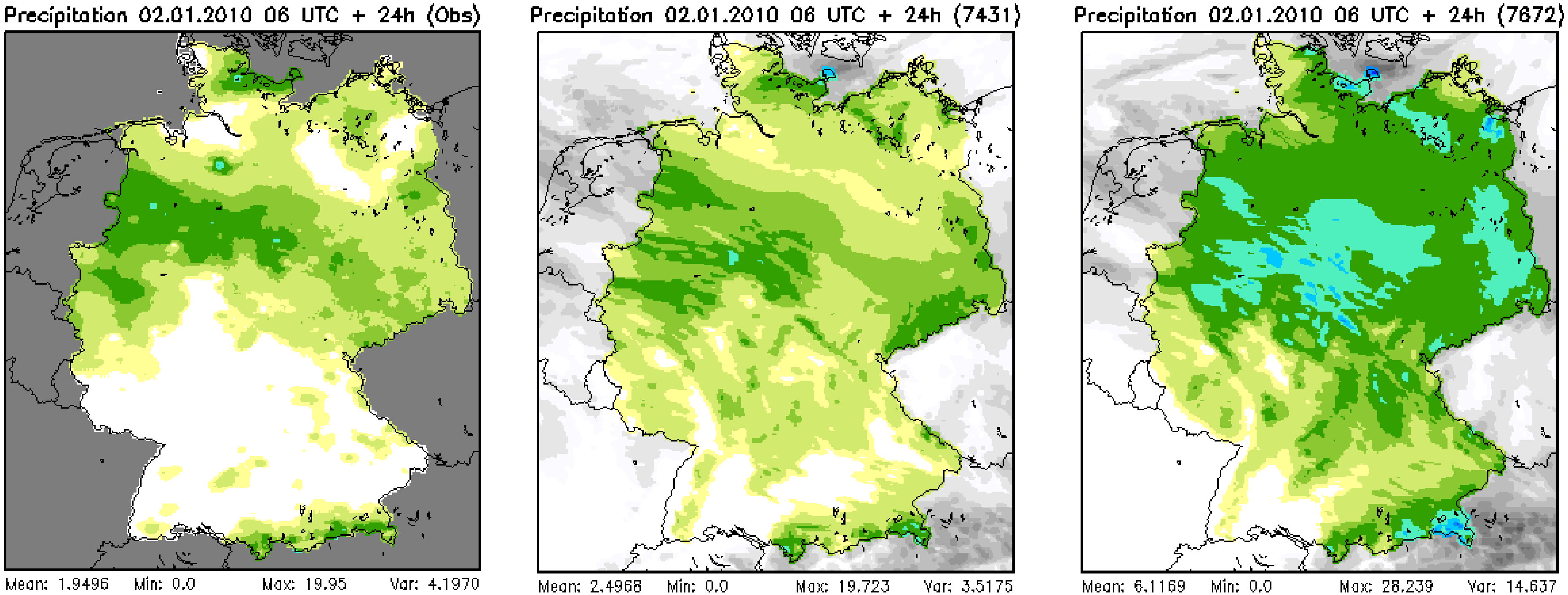
assimilation of ground-based GNSS-IWV: impact on wintertime precipitation

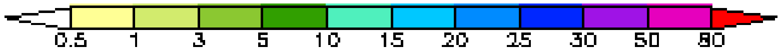
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

24-hour precipitation sum for 3 Jan. 2010, 6 UTC

COSMO-DE assimilation

radar obs | reference (no GNSS) | GNSS experiment



[mm/24h] 

→ excessive increase of snowfall !

→ reason: GNSS can increase humidity in (sub-saturated) levels with cloud ice, where the model can get rid of the added water vapour by producing ice + snow

→ no net change of humidity, but continous production of snowfall

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assimilation of ground-based GNSS-IWV:
impact on wintertime precipitation

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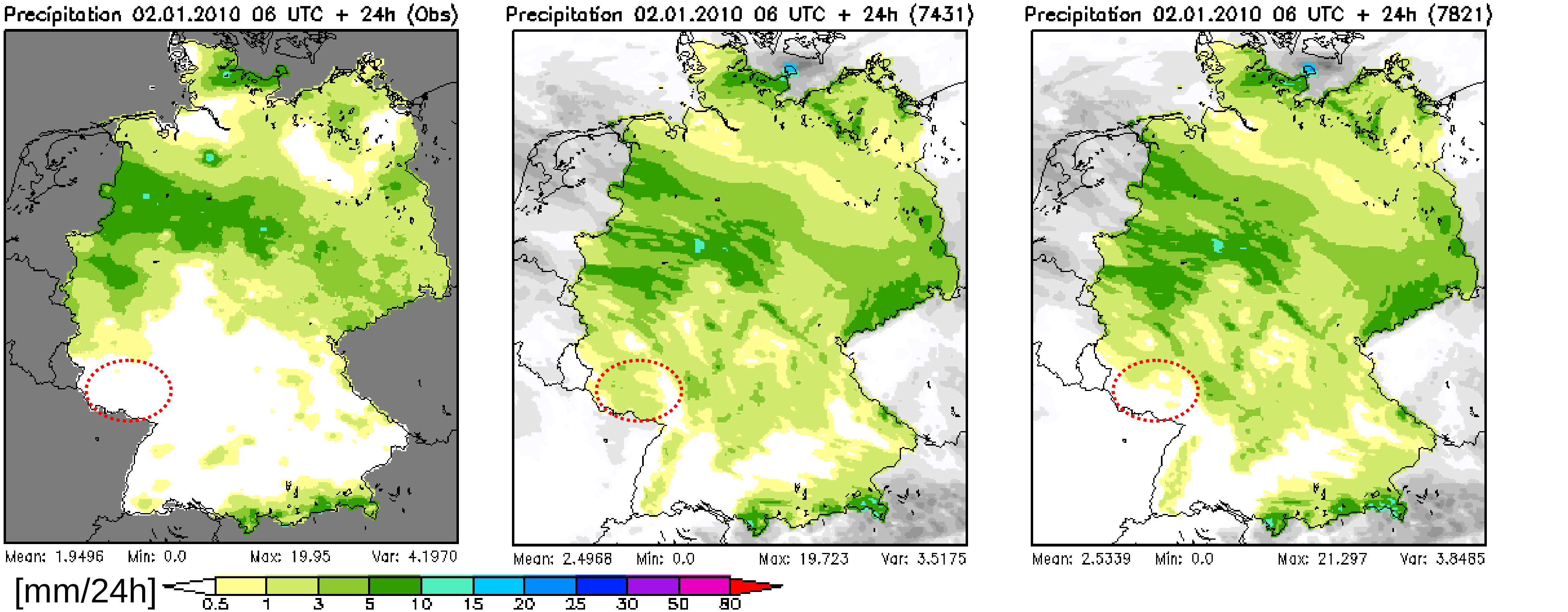
→ refinement: no use of GNSS obs increments in levels with cloud ice

COSMO-DE assimilation

radar obs | reference (no GNSS) | GNSS experiment

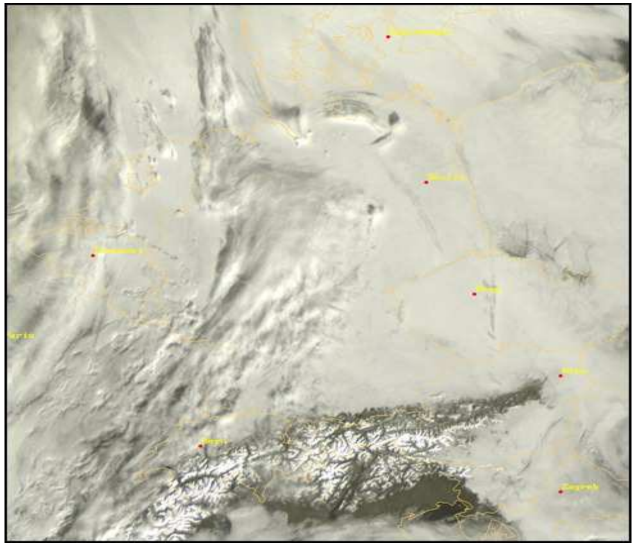


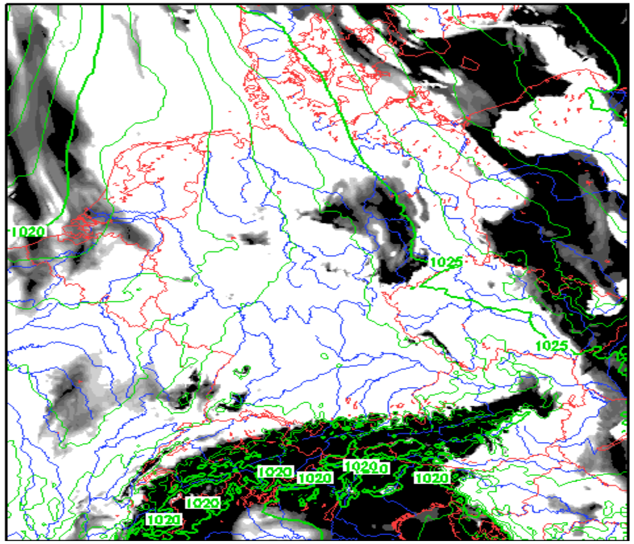
→ **no** excessive increase of snowfall !

assimilation of ground-based GNSS-IWV: impact on wintertime low stratus

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

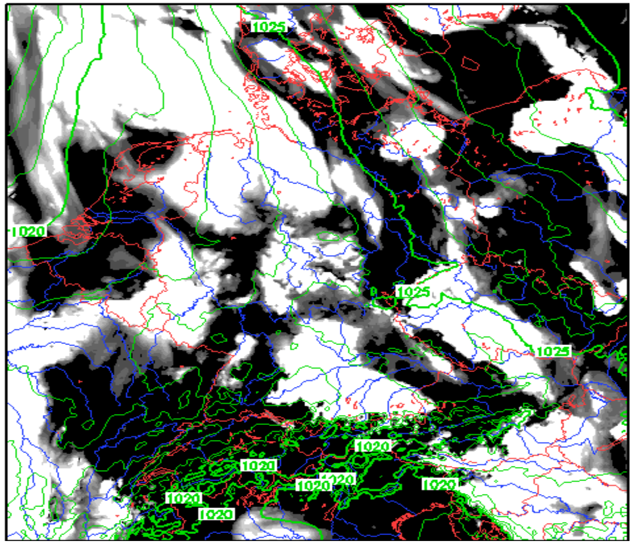
15 Jan, 10 UTC

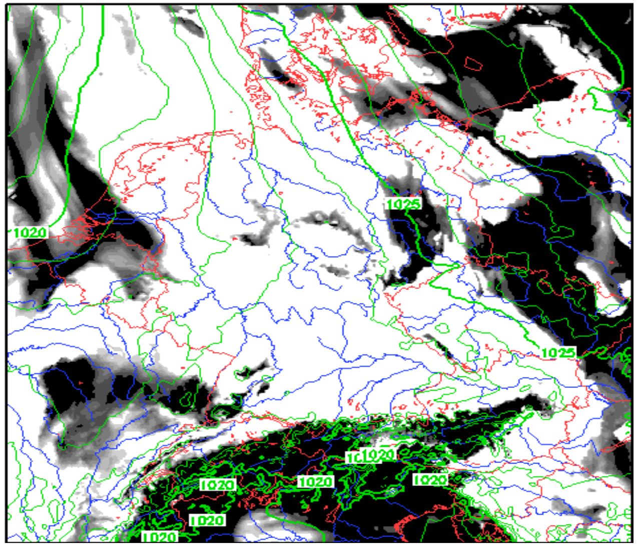




reference analysis (no GNSS)

original GNSS analysis





revised GNSS analysis

assimilation of ground-based GNSS-IWV: summary

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Wetter und Klima aus einer Hand

- summer: neutral to positive impact (humidity, precip),
  precip could be more improved if GNSS data were available sooner

- winter:
  - upper-air verification: neutral impact
  - Synop verification: slightly negative for total & low cloud, T_{2m}
  - negative impact on low stratus / excessive snowfall with original version

    → revision: neglect GNSS obs increments in presence of cloud ice
    (→ reduced upward transport of humidity due to GNSS)
  - neutral impact on snowfall (and low stratus ?) with revised version

→ further steps:
  - re-compute full winter and summer (!) test periods with revised version
  - probably need define appropriate criteria related to strong vertical gradients of humidity (temperature) where influence of GNSS is reduced / eliminated
  - try to get GNSS data closer to real time
  - monitoring / quality control issues (blacklisting)

influence of biases on COSMO-DE: status at last GM

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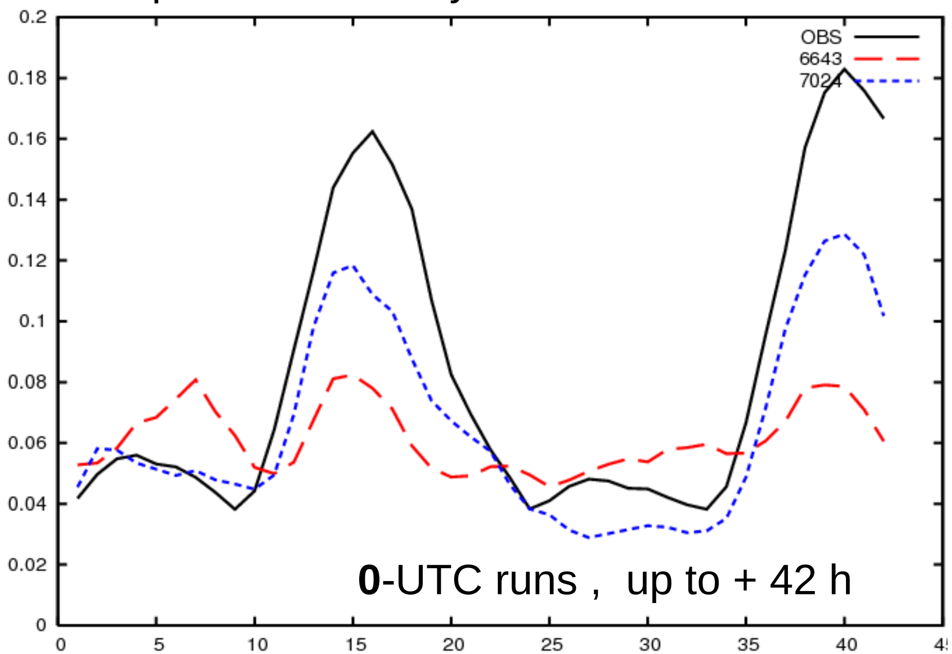
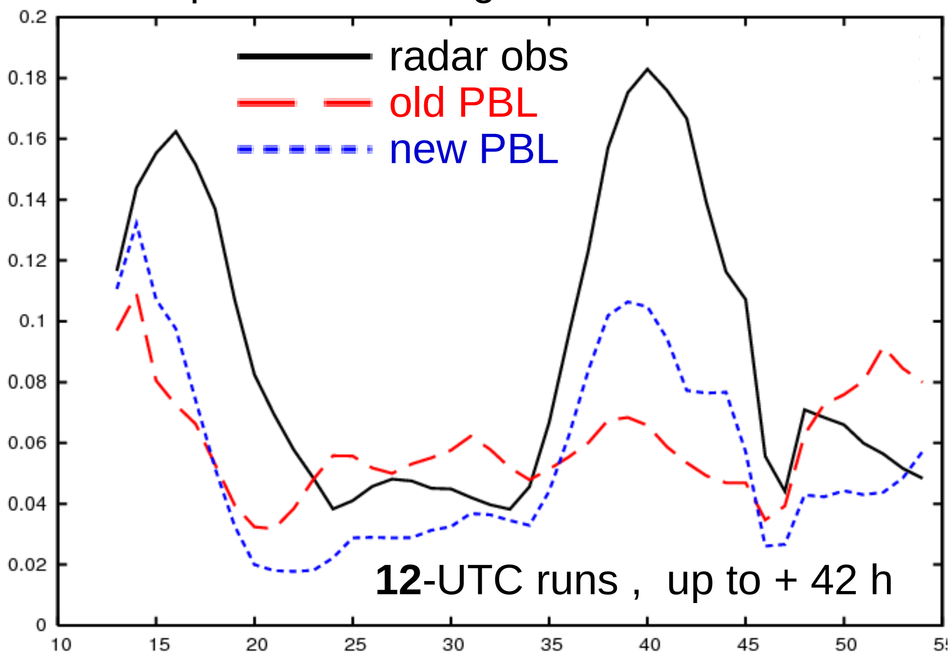
Wetter und Klima aus einer Hand

Starting point: convection-permitting COSMO version as operational in summer 2007 strongly underestimated diurnal cycle of precipitation in convective conditions

→ 'new PBL' (COSMO V4_8) : reduced turbulent mixing (opr. summer 09):
  - reduced max. turbulent length scale (Blackadar length : 200 m → 60 m)
  - reduced subgrid cloud fraction in moist turbulence

test period : 31 May – 13 June 2007: warm, rather frequent and strong air-mass convection





42-hour forecasts: 'new PBL' greatly improves diurnal cycle of precip, except for first 12 hours (incl. peak in afternoon) of 12-UTC runs

influence of biases on COSMO-DE: status at last GM

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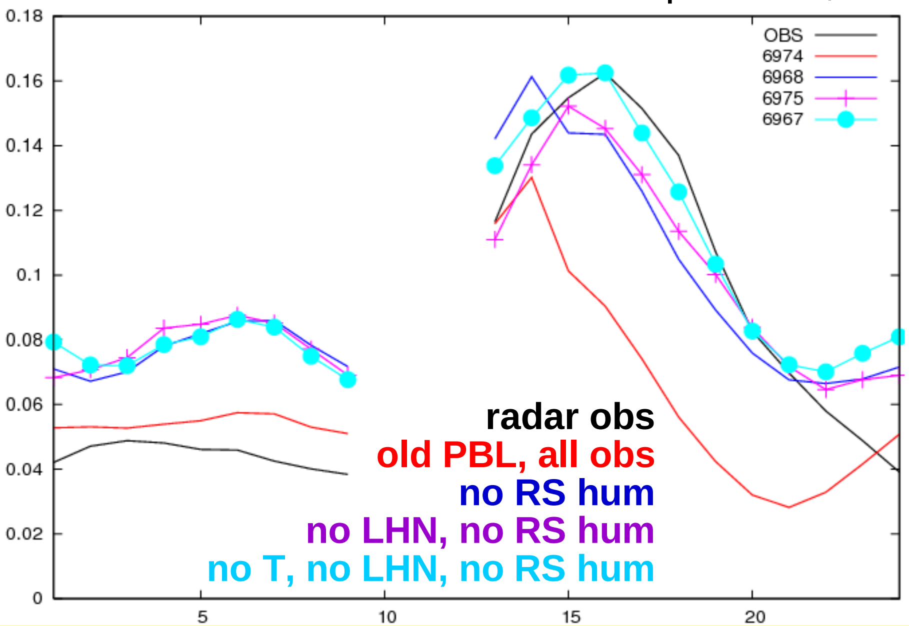
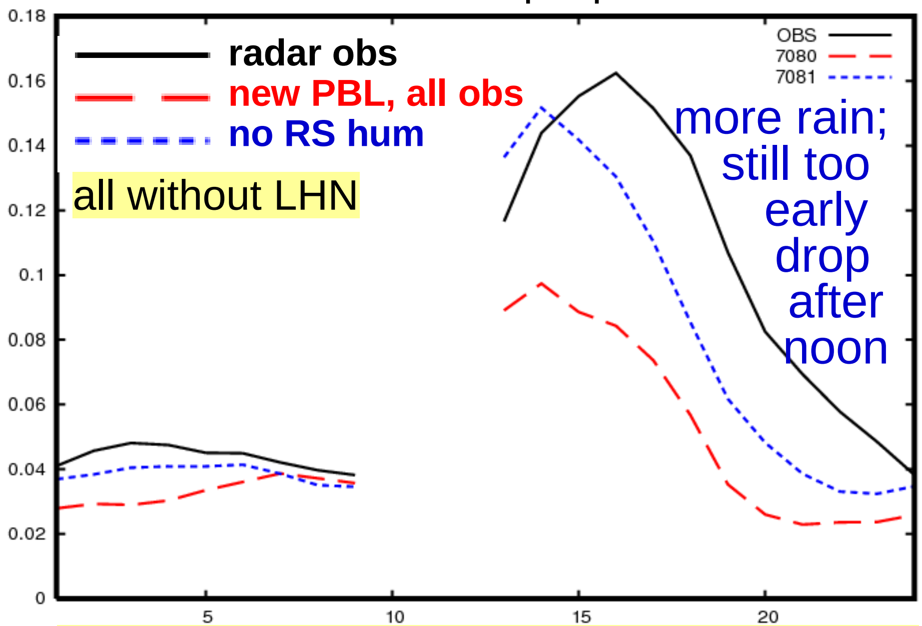
Why do biases in the diurnal cycle of precipitation depend on the initial time of forecasts ?

Possible reasons for problems with 12-UTC runs:

- Latent Heat Nudging ? → small impact on bias (except first ~ 3 hours)
- radiosonde humidity: daytime RS92 dry bias ?
- radiosonde / aircraft temperature, due to warm bias in model low troposphere ?





old PBL, no radiosonde humidity:
afternoon much better, too much at night
no upper-air *T*: even better, worse scores

new PBL, no radiosonde humidity:
increases precip (at noon),
but does not mitigate afternoon drop

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influence of biases on COSMO-DE: new results: neglect of T, p_s obs

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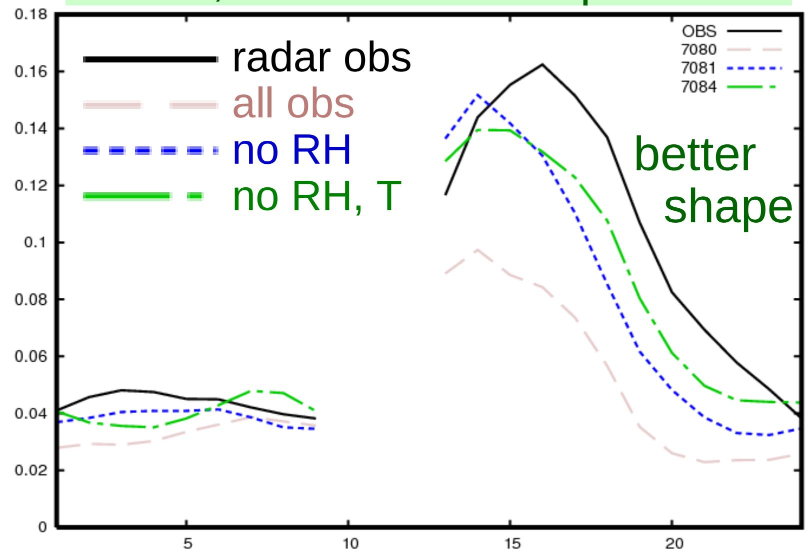
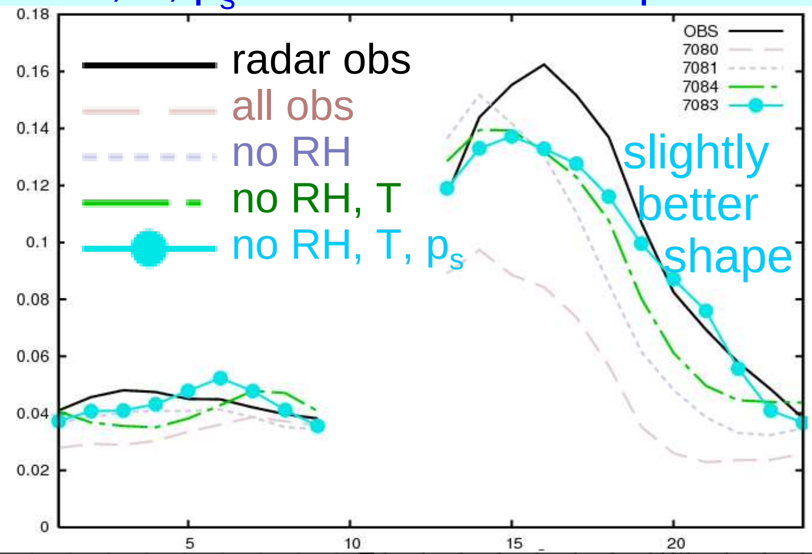
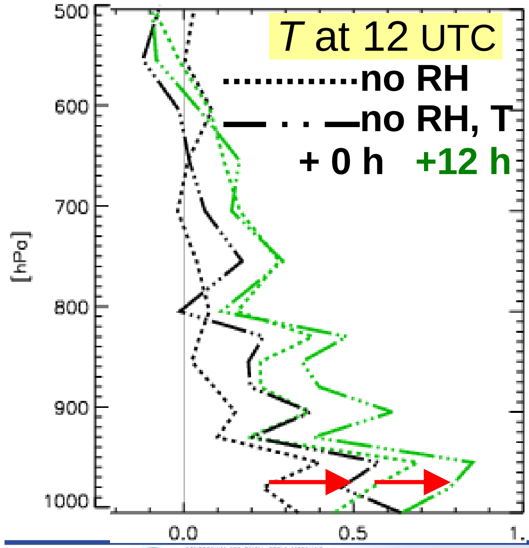
‘no RH, T’: also no temperature

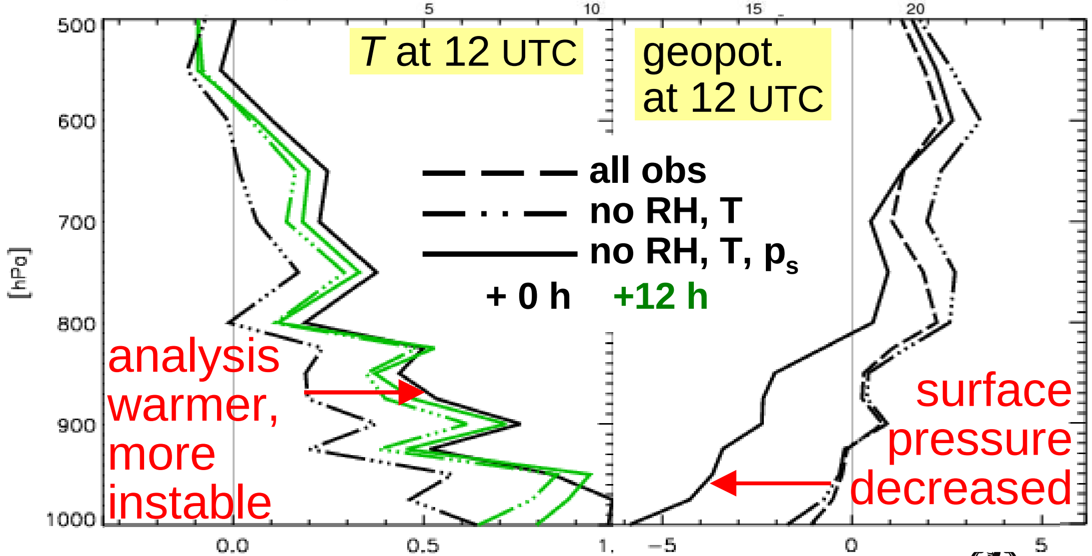


no RH, T, p_s’: also no surface pressure





analysis + forecast warmer, more instable



influence of biases on COSMO-DE:
bias correction of radiosonde humidity

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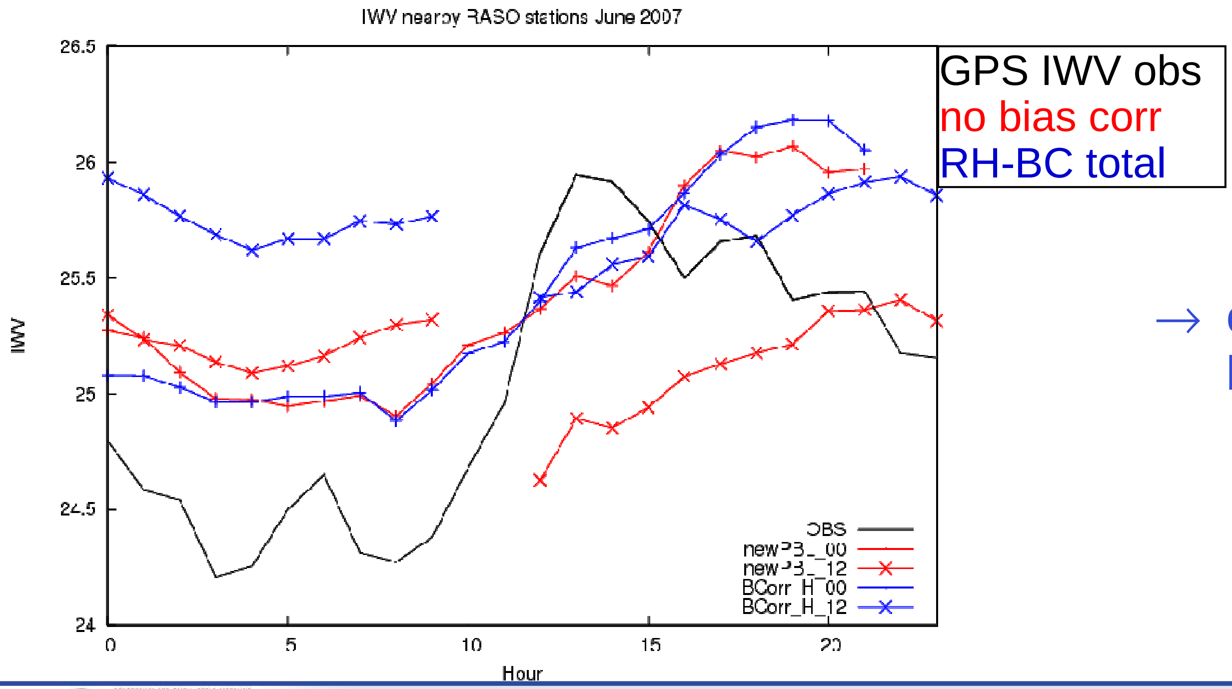
Dry bias of Vaisala RS92 radiosonde: Neglect of humidity is not desirable

→ bias correction, according to Miloshevich et al., 2009 (*J. Geophys. Res.*) :

– 'RH-BC solar': correct solar radiation error (dep. on solar elevation, p, RH_{obs})
(~ 7 – 10 % of RH_{obs} below 500 hPa, >>10 % above)

– 'RH-BC total': correct total error (dep. on pressure level p , RH_{obs})
(night: ~ –3 % of RH_{obs} below 500 hPa, > 0 % above)



→ corrects humidity bias at 12 UTC

influence of biases on COSMO-DE: bias correction of radiosonde humidity

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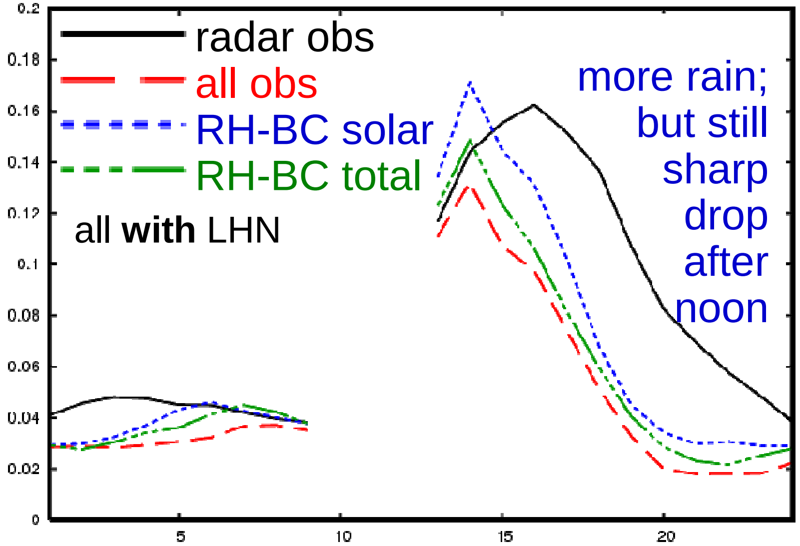
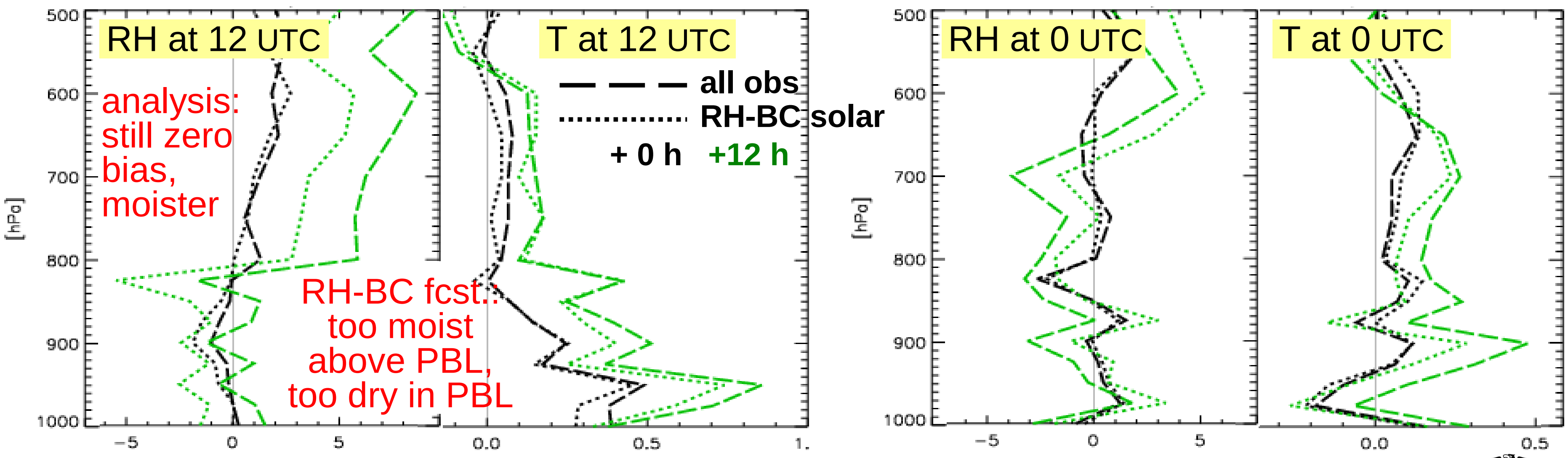
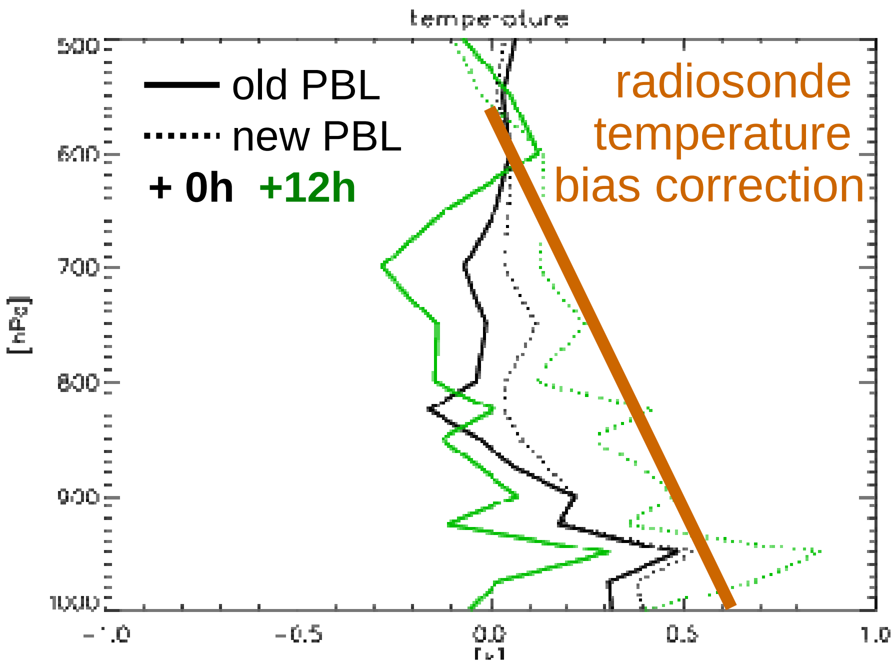




influence of biases on COSMO-DE:
bias correction: adjust to T, p_s model bias

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

'new PBL' leads to significant warm bias (of forecasts) in low troposphere at noon
i.e. COSMO-DE needs excessive instability on a large scale
to produce sufficient convective precip on its own



→ add bias to temperature / pressure obs to match model bias,

dep. on solar zenith angle
(max. at noon, although max. observed pressure bias is in afternoon):

- temperature profile: radiosonde: linearly increasing to 0.8 K below 500 hPa
  aircraft: ~ constant 0.2 K below 500 hPa
- surface pressure: up to -0.8 hPa

influence of biases on COSMO-DE:
bias correction: adjust to T, p_s model bias

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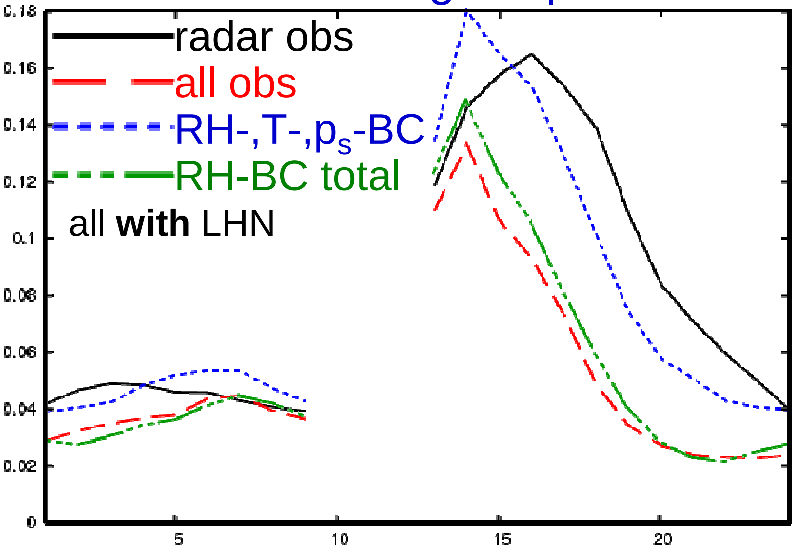
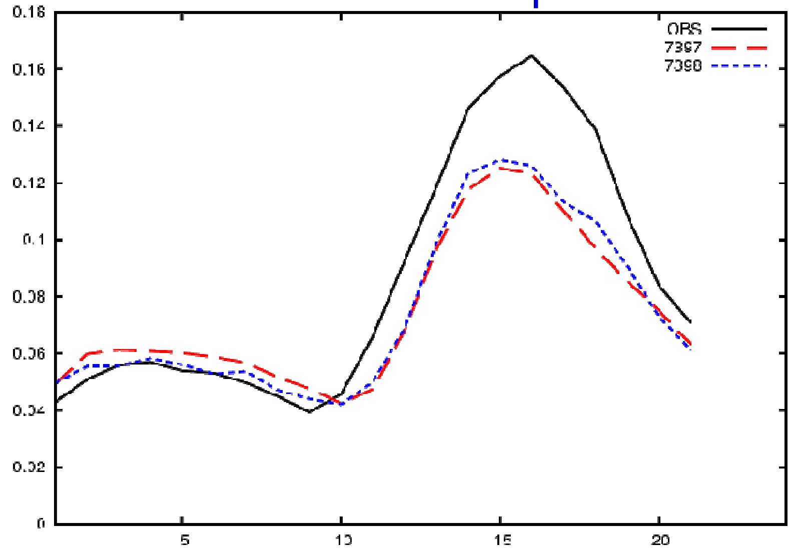
12-UTC runs: large improvement



0-UTC runs: small improvement



influence of biases on COSMO-DE: consequences

should bias corrections be applied operationally ?

– humidity: desirable: - corrects observation bias, slightly improves forecasts
  - less compensating errors for tuning of model (physics)

  → option will be introduced in V4_X (autumn)

– temperature, surface pressure: not desirable, model improvement needed

  → (accidental) experiment with 80 vertical levels and 'old PBL' has shown improved convective precipitation without introducing temperature bias

  → comprehensive testing of new set-up 'L65' with 65 vertical levels and possible additional model modifications:

    – re-increased max. turbulent length scale
    – 2-moment scheme for rain (better treatment of evaporation of falling precip)
    – mass conserving saturation adjustment
    – reduced min. diffusion coefficient
    – 3rd order vertical diffusion
    – (explicit humidity correction in turbulence)
    – new reference atmosphere, veget.-dep. albedo, aerosol climatology