Assimilation of Radar Reflectivity in the LMK

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Radar Data

Latent Heat Nudging

Case Study: Summer Period July 2004

Conclusions and Outlook

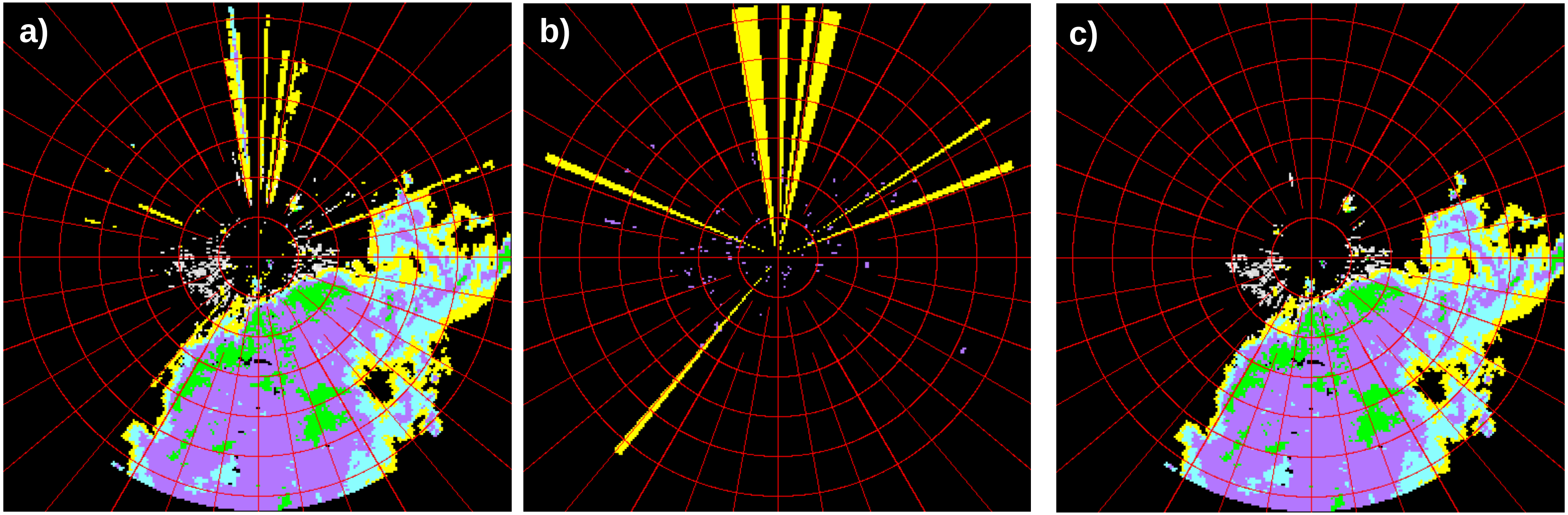
Radar Data

- Reflectivity from „precipitation scan“ (DX-product, or nowadays RZ-product):
  - lowest elevation angel varies between 0.5° and 1.8°
  - spatial resolution: 1 km x 1°, max. range 120 km
  - temporal resolution: 5 minutes (linear interpolation in between)
- Data processing:
  - correction of ground clutter by doppler filter
  - correction of orographic attenuation
  - use of a variable Z-R-relation to get precipitation rate
  - compositing of the 16 German doppler radar (no international composite available yet)

Radar Data (next generation, coming soon)

- Quality control product of the „precipitation scan“ (DXQ-product, or nowadays RY-product):
  - same specifications as DX
- Detection of non-rain echoes (work by K. Helmert and B. Hassler):
  - spokes of positive or negative attenuation
  - circular arcs of positive or negative attenuation
  - echos of small extension (smaller than 9 pixels) caused by wind energy plants etc.
  - special case of anomalous propagation („German Pancake“)
- **Compositing of the 16 German doppler radar in consideration of the quality product**

Berlin, 21 June 2005 22:10 UTC



Effect of implemented radar quality control for Berlin, 21 June 2005 22:10 UTC :

a) Original observations

b) detected non-rain echoes as quality flags

c) observation without non-rain echoes

Latent Heat Nudging

- **Observation:** radar reflectivities

- **Problem:** "indirect" observation
  nudging schemes (LM) require information on
  prognostic variables: T, q, u, ...

- **Required:** relation: precipitation rate $\leftrightarrow$ model variables

- **Approach:** concepts based on processes/conditions usually present with precipitation
  - precipitation $\leftrightarrow$ condensation $\leftrightarrow$ release of latent heat $\leftrightarrow$ T, q

    $\rightarrow$ adjustment of latent heat release in the model

    $\rightarrow$ Latent Heat Nudging

Latent Heat Nudging

- **Realisation:** adding the nudging increment to the temperature tendency

$$\frac{\partial T}{\partial t} = F(T) + \frac{\partial T_{Nudging}}{\partial t} + \frac{\partial T_{LHN}}{\partial t}$$

- **Method:** modification of diabatic (latent) heating rates, in order to simulate the observed precipitation rates

$$\Delta T_{LHN} = (\alpha - 1) \cdot \Delta T_{LH_{mod}} \qquad with \qquad \alpha = \frac{RR_{obs}}{RR_{mod}}$$

- **Assumption:** vertical integrated latent heat release in one column $\propto$ precipitation rate at the ground

“Prognostic” Precipitation

diagnostic

- just a diagnostic expression for the precipitation flux P_x :

$$-\frac{1}{\rho}\frac{\partial P_x}{\partial z} = S_x$$

- Precipitation falls immediately and in the same column, in which it has been formed.

$\Delta t = 0$; $\Delta xy = 0$

prognostic

- full prognostic equation for the mass fraction q^x :

$$\frac{\partial q_x}{\partial t} + \vec{v} \cdot \vec{\nabla} q_x - \frac{1}{\rho}\frac{\partial P_x}{\partial z} = S_x$$

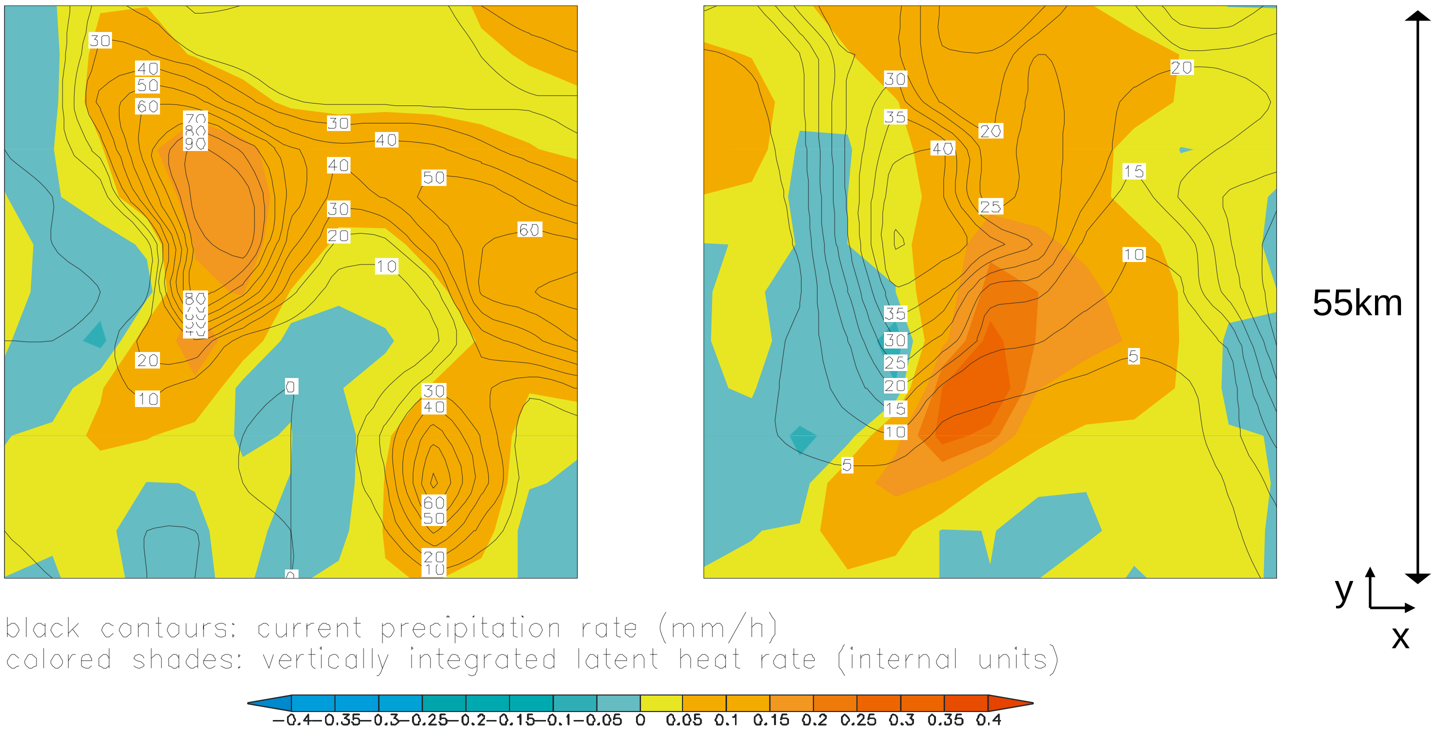
- Precipitation falls with a certain sedimentation velocity through the model space and could be advected horizontally , too.

$\Delta t > 0$; $\Delta xy \neq 0$

LHN-Assumption: vertical integrated latent heat release $\propto$ precipitation rate

diagnostic precipitation

prognostic precipitation



The correlation between the vertically integrated rate of latent heat release and the surface precipitation rate is significantly smaller in the simulation with prognostic precipitation

With respect to LHN it seems to be more effectiv to reduce the temporal delay than to solve the effect of spatial displacement.

→ an immediate reference information, on how much precipitation the LHN-increments have initialised already, is required within each time step

use of a **'reference precipitation'** ***RR**$_{ref}$*:

$$\alpha = \frac{RR_{obs}}{RR_{mod}} \quad \rightarrow \quad \alpha = \frac{RR_{obs}}{RR_{ref}}$$

- **diagnostically calculated precipitation rate**
  (by additional call of diagnostic precipitation scheme without any feedback on other model variables)

- **vertically averaged precipitation flux**
  (more consistent, however it does not eliminate the temporal delay completely)

Recommendations when using LHN together with prognostic precipitation:

- use of a reference precipitation
- adjustment of specific humidity in order to maintain relative humidity
- apply LHN-increments only where latent heat rates are positive
- search for nearby grid points, if model precipitation rate is too low but to use a moderate forcing of precipitation at these points
- vertical filtering of profiles of LHN-increments
- impose absolute limits to LHN-increments
- horizontal filtering of incoming variables (of small extend)

Searching for nearby grid points

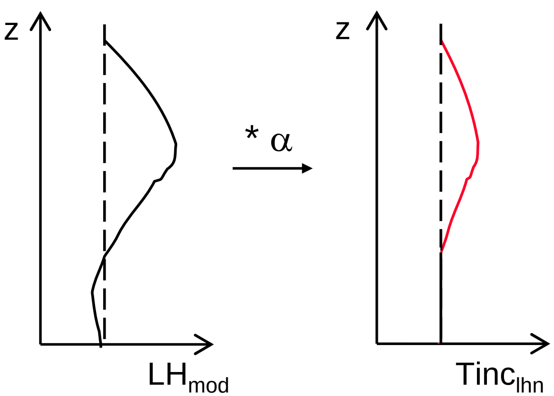
Example:

RR_{obs} = 3.1 mm/h

RR_{ref} = 0.1 mm/h

RR_{search} = 2.1 mm/h

0	0	0	0	0
1	0	0	0	0
1.7	0	0.1	0.3	0
2.1	0.2	0.1	0.2	0
1.5	0.8	0	0	0



But, how much should be the scaling factor α?

$$\alpha : \begin{cases} \in (1.0, 2.0) & \rightarrow \quad \text{weak forcing} \\ > 2.0 & \rightarrow \quad \text{strong forcing} \end{cases}$$

$$RR_{max} = f(RR_{ref}, RR_{obs})$$

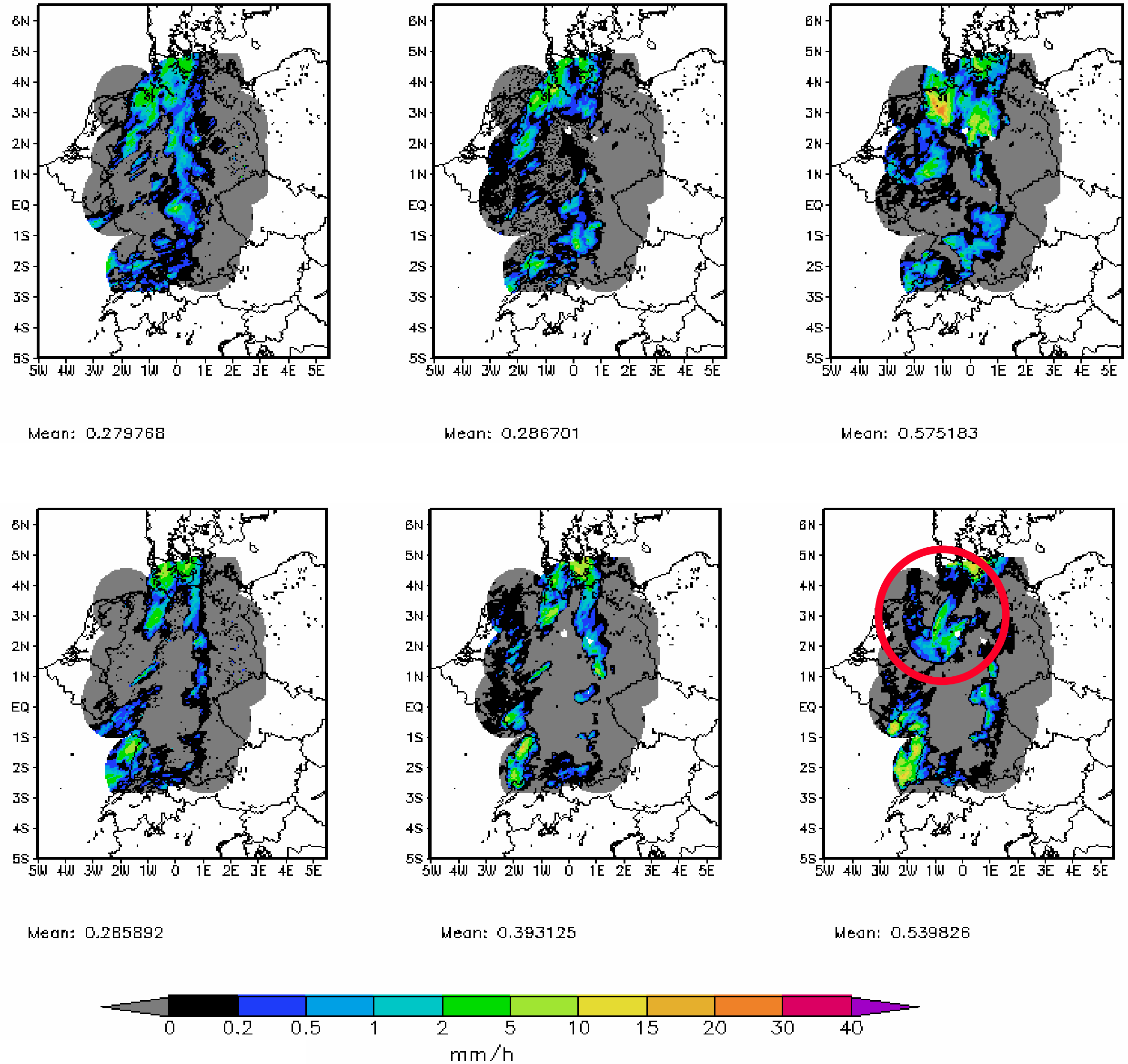
Assimilation run at 21.05.2005

Hourly Precipitation:

above: 4 UTC
below: 6 UTC

left: radar observation
middle: LHN run with weak forcing
right: LHN run with strong forcing

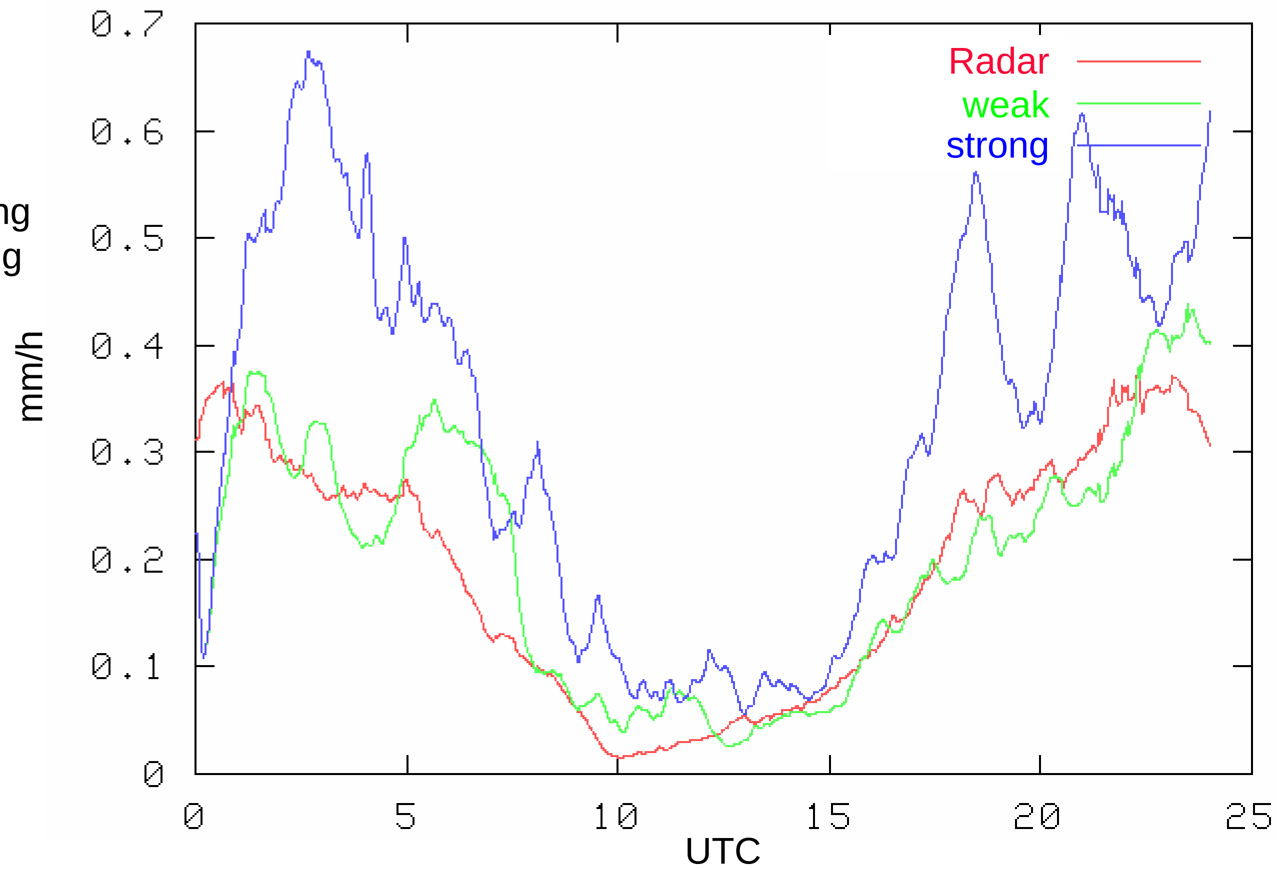
Radar | weak forcing | strong forcing



Assimilation run at 21.05.2005

spatial average of
actual precipitation rate:

red: radar observation
green: LHN run with weak forcing
blue: LHN run with strong forcing



Case Study: Summer Period 08.07. - 20.07.2004

control run: LMK run without LHN

(exp 713) (LMK version not up to date)

exp 5263: LMK run with LHN

(LMK version not up to date and **strong** forcing in LHN)

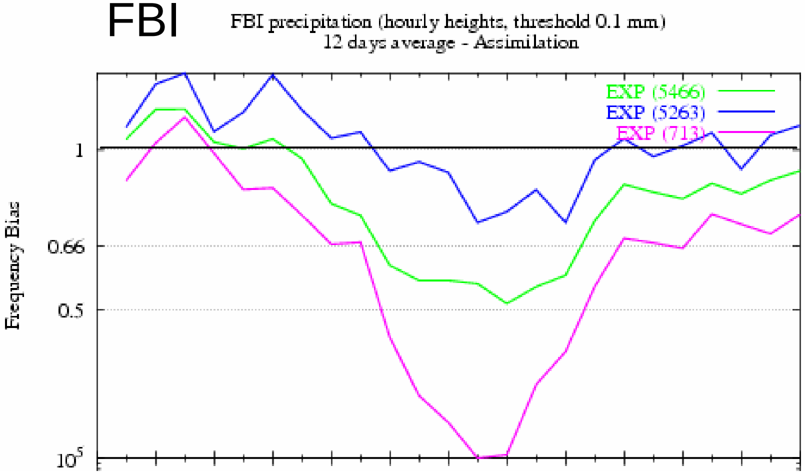
exp 5466: LMK run with LHN

(LMK version up to date and **weak** forcing in LHN)

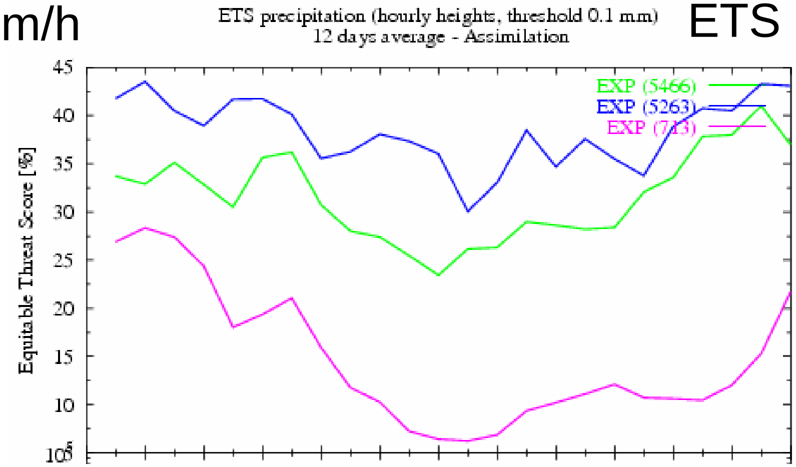
Assimilation

FBI

0.1 mm/h

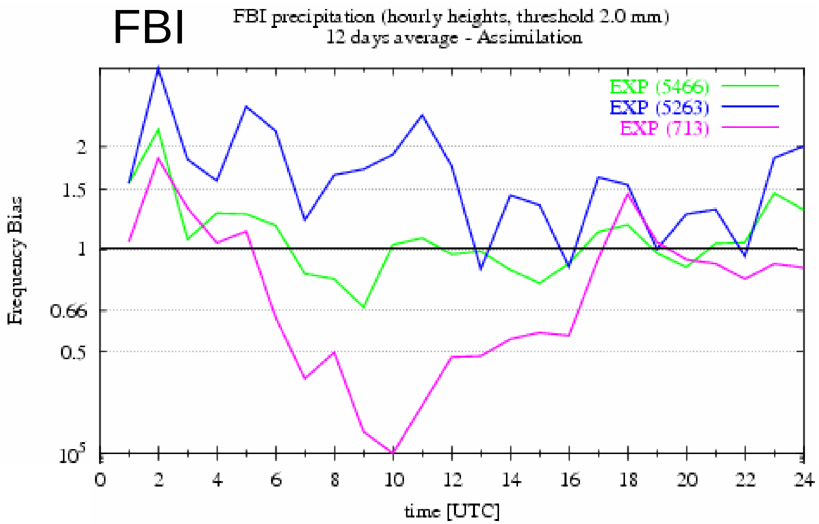


ETS



FBI

2.0 mm/h



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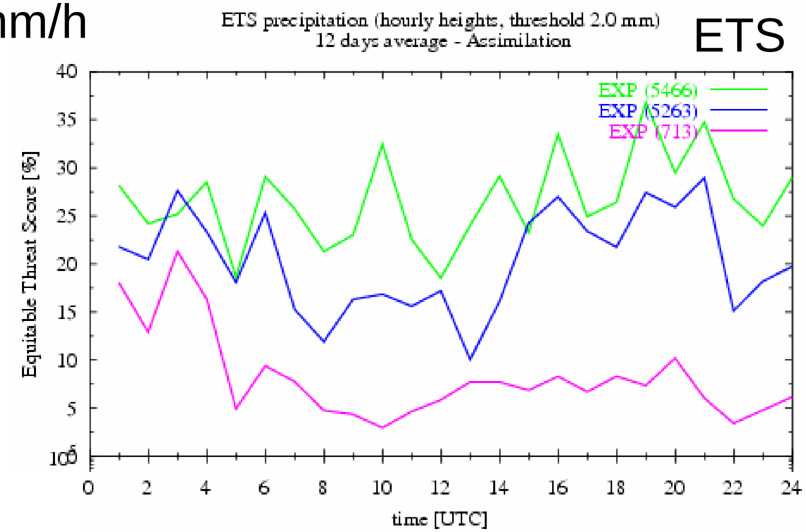
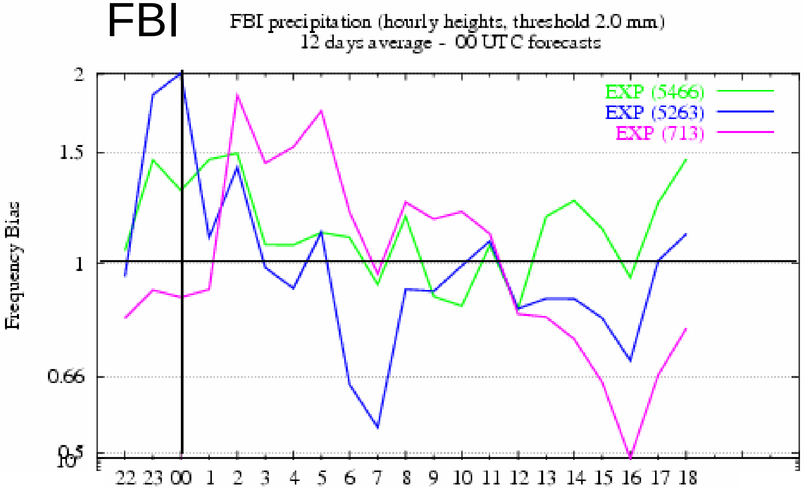


Free Forecast

Threshold= 2.0 mm/h

00 UTC

FBI



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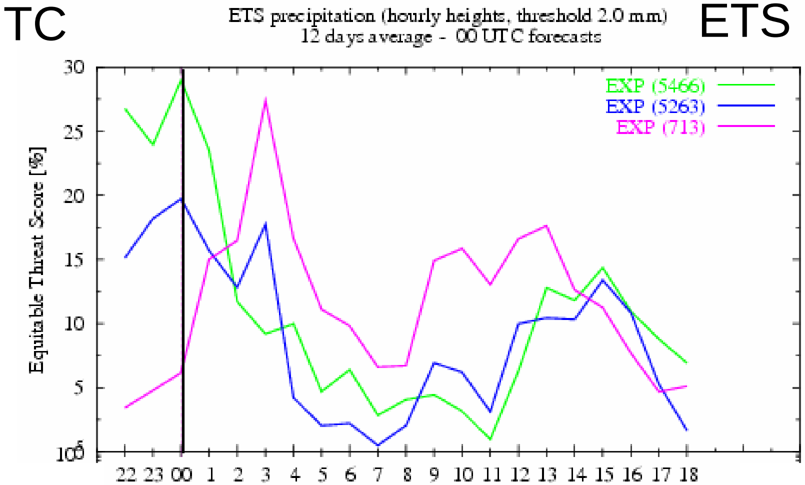
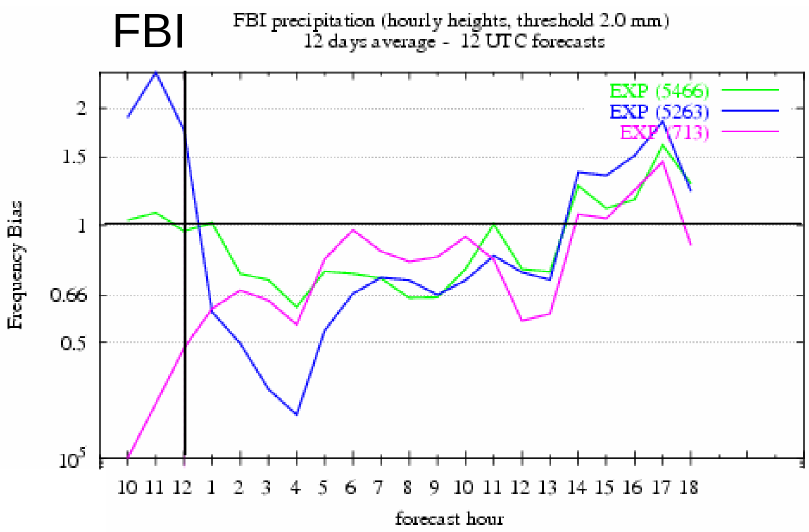


12 UTC

FBI



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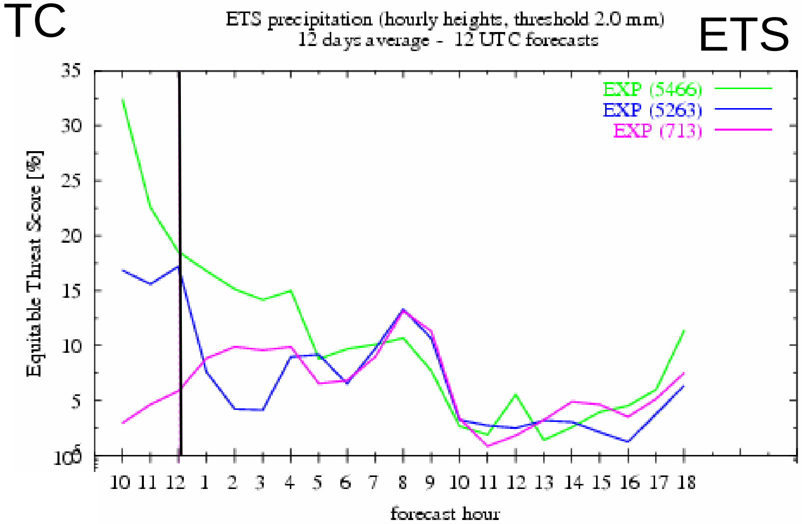


Conclusions and Outlook

- use of prognostic precipitation weakens the basic assumption of LHN
- use of a reference precipitation can fix the problem
- together with other adaptations (not mentioned here) a good performance of LHN during the assimilation is established
- the positive effect of LHN lasted up to 6 hours, but we have still problems within 00 UTC forecast
- a correct forcing within the grid point search has a significant impact on the results

Conclusions and Outlook (2)

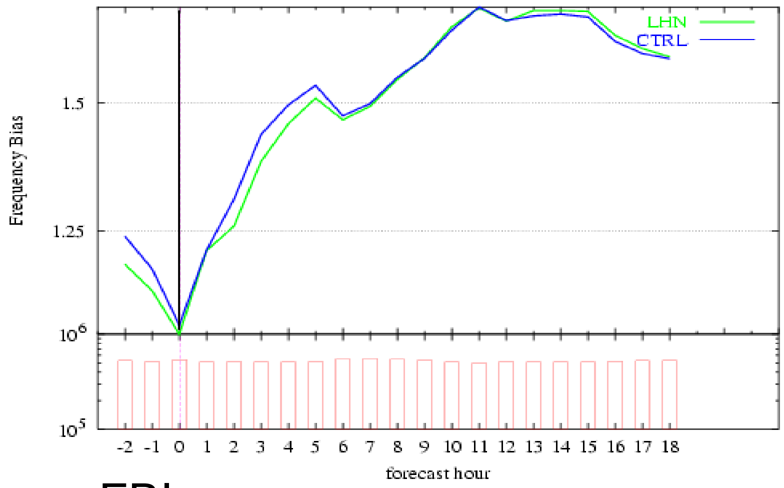
- We would like to understand more precisely what does trigger the convection in LMK most. Could we use this knowledge to optimise the LHN-algorithm?
- We are still looking for an answer why the influence of the LHN during the free forecast is decaying so fast, especially in 00 UTC forecasts.
- Does a vertical redistribution of the LHN-increments change the results significantly?
- Start a long term test suite for Spring and Summer last year - hopefully at the end of this week.

Additional Slides ...

Free Forecast – 124 forecasts average (31 days: 0, 6, 12, 18 UTC)

0.2 mm/h

FBI



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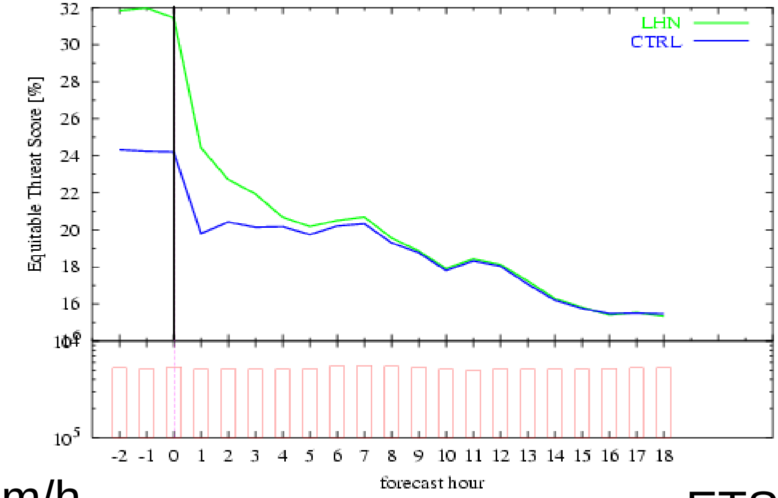
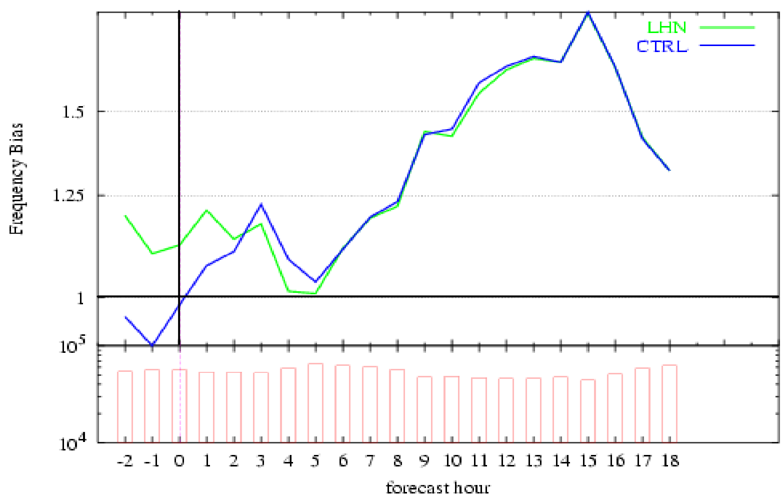


2.0 mm/h

FBI



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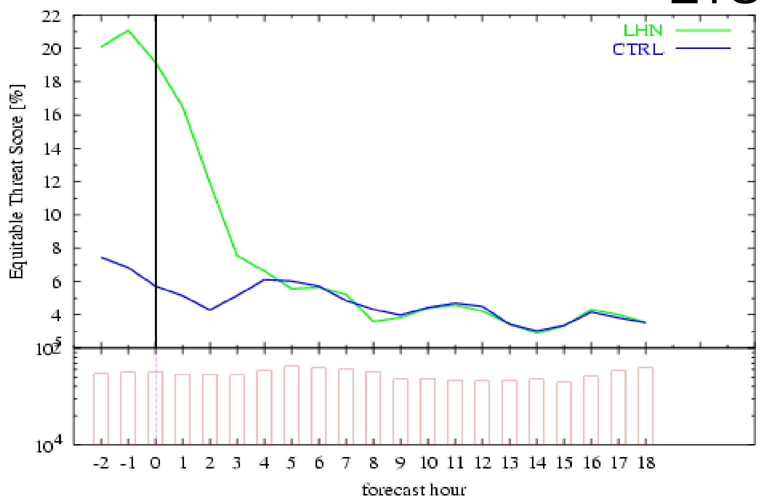

Radar Data

Merging of DX data with international composit (PI product) in areas without DX data

PI specifications:

- radar reflectivity at the ground
  (int. Composite: Germany and surrounding countries)
- spatial resolution: 4km × 4km
- temporal resolution: 15 minutes (data from volume scan)
- using simple Z-R-relation
- problems: non rain echoes, only 7 reflectivity classes
- **crucial point: What does „0“ means?**
  missing values are defined as „0“ as well as no precipitation!

A technical announcement

- On time verification tool to verify modelled precipitation rates against radar observation.
- Possible at any model run (esp. In runs with LHN),
- You need:
  - Radar obserservation as GRIB in a coorect format
  - NUDGING namelist: llhnverif llhnverif_start, llhnverif_end, lhn_diag
- You get:
  - spatial mean of observed and modelled precipitation rates
  - tables of contingence and several scores for 6 thresholds (0.1 ... 10 mm/h)
- all output in new file : YULHN
- awk-scripcts are available

By the way of YU-files (LM-output files)

- We designed tools for visualisation of the YU-files:
  - YUCHKDAT (contained all GRIBOUT variables as mean, max, or min values in output frequency)
  - YUPRMEAN (contained means of several variable
  - YULHN (contained data of verification tool or LHN)
- You need:
  - any YU-file
- You get on gnuplot screen :
  - time series of the a chosen variable within YUCHKDAT; YUPRMEAN or YULHN
  - time loop of a chosen variable within YUCHKDAT
- Some features
  - comparison of up to 5 model runs are possible
  - print option to create png or ps plots
- Interested: jochen.foerstner@dwd.de or klaus.stephan@dwd.de