Assimilation of ground-based GPS STD observations with the MM5 4DVAR

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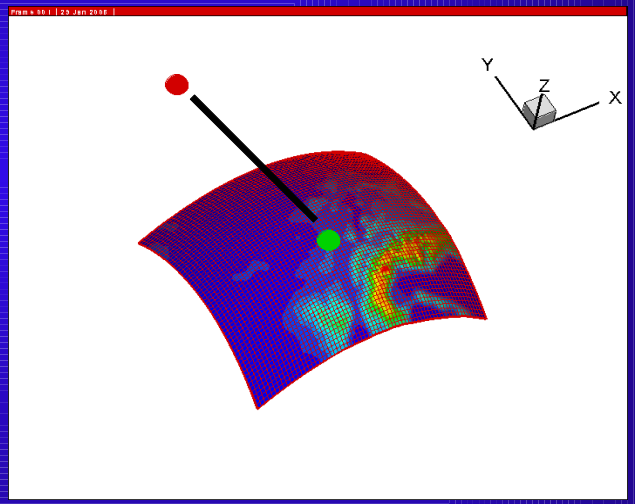
- The use of GPS to study model physics
- Assimilation experiment
- Conclusion & outlook

GPS Slant Total Delay

A STD is an integrated measurement. It is the difference in the optical path length:

$$STD = \int_R^S \left(k_1 \frac{P}{T} + k_2 \frac{e}{T^2} \right) ds$$

The forward model h determines the STD in model grid point space numerically.



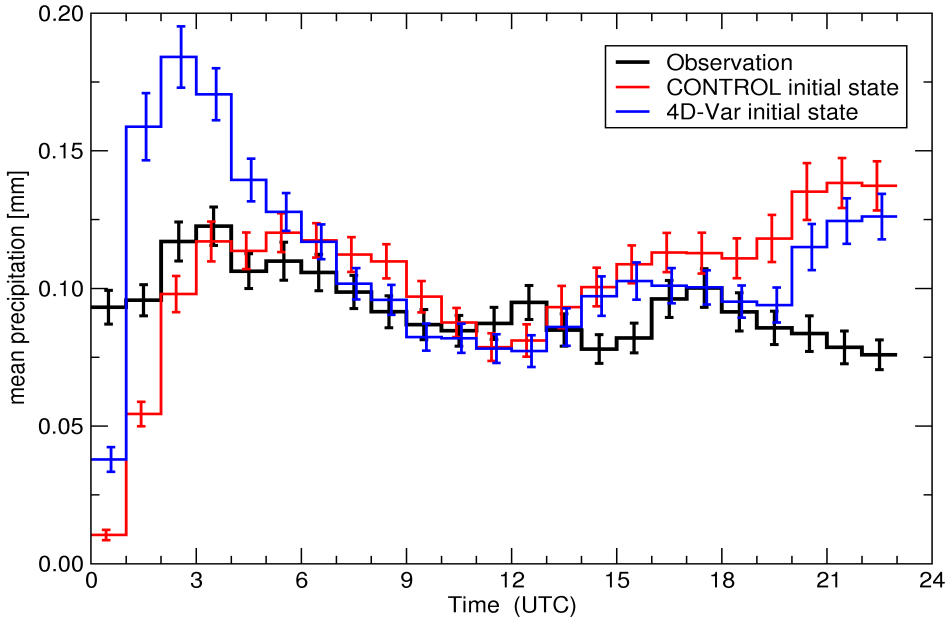
> The overall error is estimated to be of the order of 1 to 10 times cosec(ε) mm.

> Cross validation with M. Bender of GFZ Potsdam was performed.

> h and H^T were implemented into the MPI environment of the MM5 4DVAR system. Speedy STD 4DVAR is routinely possible at UHOH.

Real-time assimilation COPS / D-PHASE

> During the 6-month period June to November 2007 operational 4DVAR of GPS STD & ZTD was performed by UHOH.



Diurnal cycle of precipitation (Aug – Oct 2007).

> More details see poster DAP4 Grzschik et al.

Some Challenges

Optimization of initial field by 4DVAR disregards error in model physics.

During COPS & D-PHASE deficiencies could be identified by screening the model minus observation departure of the high resolution GPS STD data.

> Convection scheme of Anthes - Kuo is only applicable to a grid size > 30km. Tends to produce much convective rainfall (Grell 1995).

> Horizontal diffusion calculated along sigma levels (sigma diffusion) leads to wrong temperature and moisture tendencies in complex terrain (Pielke 1984).

> Sigma diffusion triggers (and or enhances) convection (Zängl 2004).

During COPS and D-PHASE these deficiencies were not eliminated.

Solution

> Development of a (first) improved horizontal diffusion scheme to prevent wrong moister and temperature tendencies in complex terrain. The scheme is similar to the one proposed by Zängl 2002. Implementation of this scheme and the adjoint into the MM5 4DVAR. Done!

> Implementation of the (more sophisticated) Grell cumulus convective scheme and its adjoint into the MM5 4DVAR. Done!

Part 1 : Study Diffusion

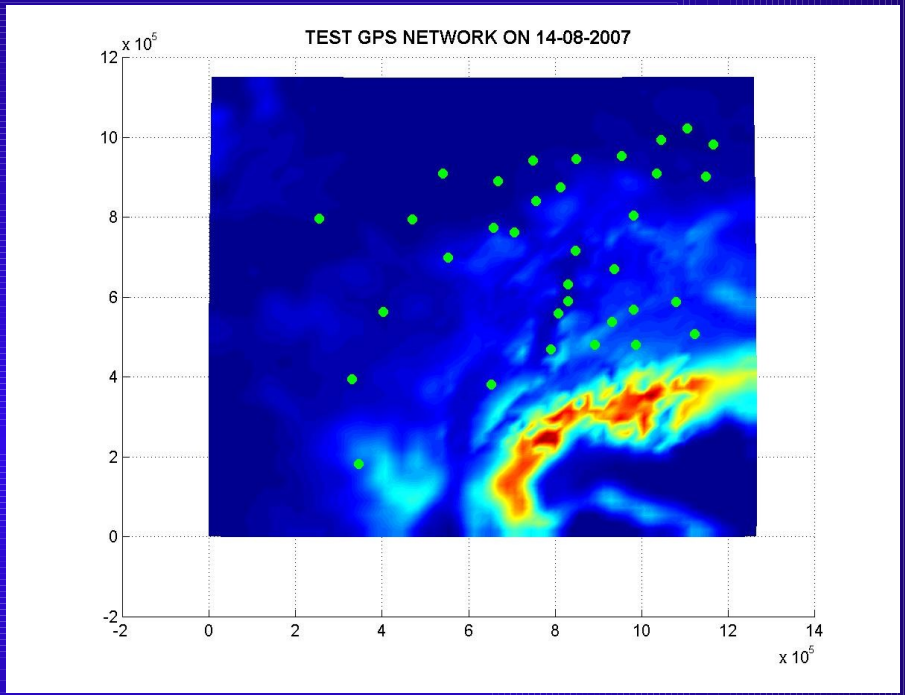
Initial State: The ECMWF analyses at 00UTC on 14-08-2007.

MM5 set up :

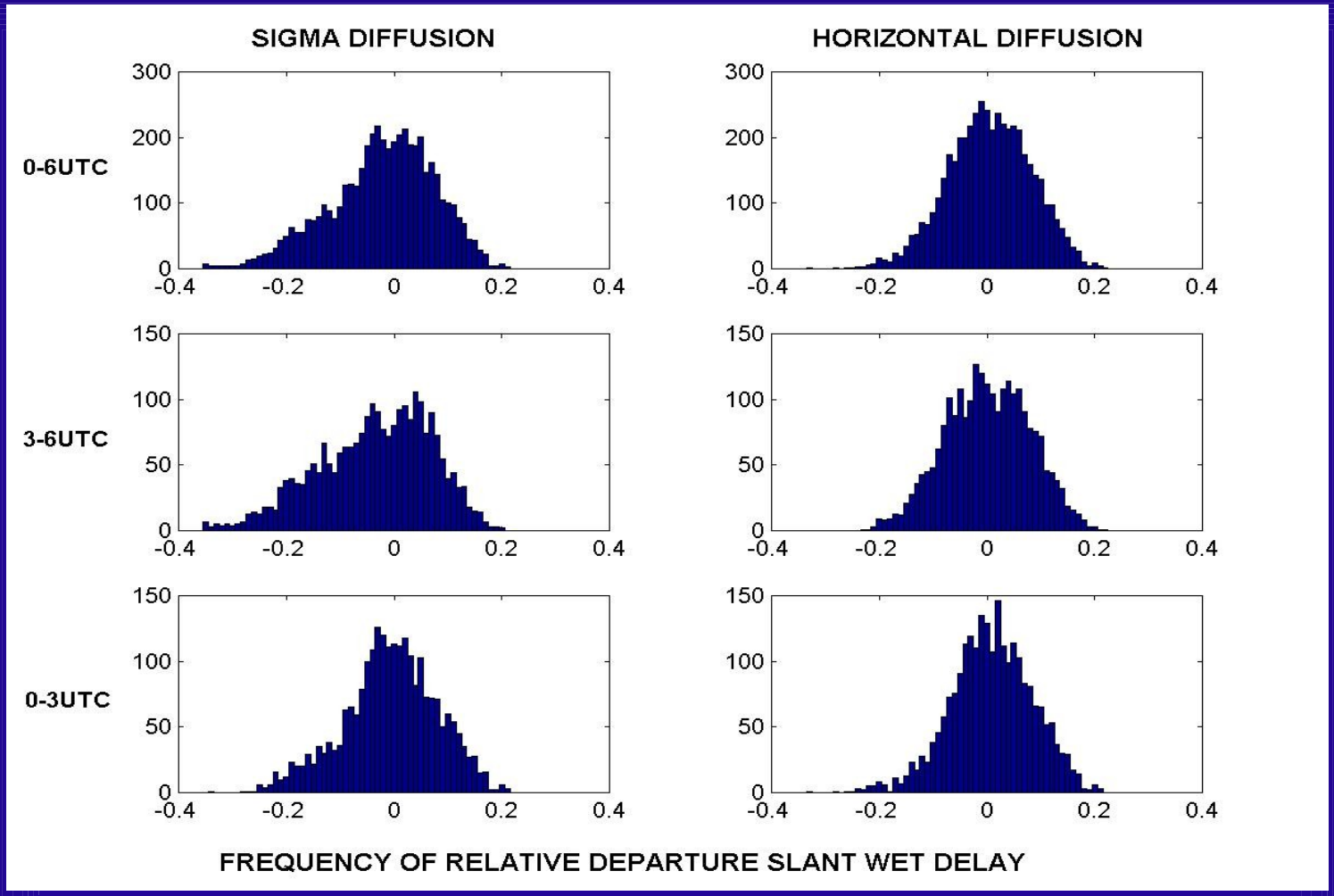
> 18 km horizontal resolution.
> 36 terrain following vertical layer.
> Model top at 100 hPa.
> Horizontal diffusion vers. sigma diffusion with Anthes-Kuo cumulus convective scheme.
> 6 h forecast 00-06UTC

GPS STD set up:

> STD data with a time frequency of 15 minutes. Each STD from a single GPS receiver is considered.
> GPS receivers are randomly chosen.



Statistic



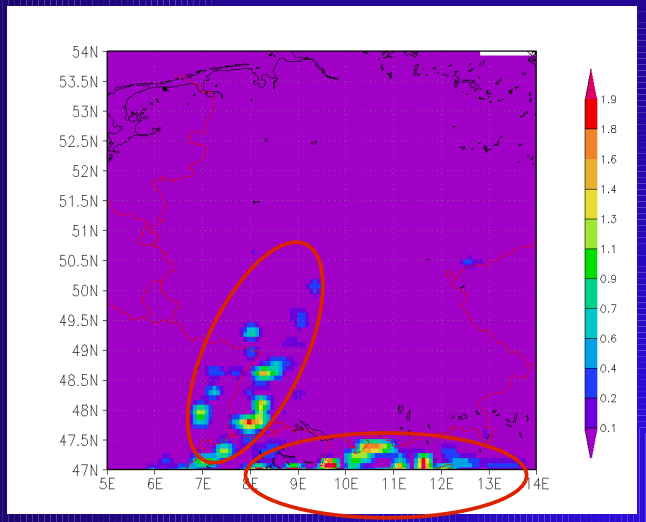
> The distribution is far from being Gaussian with sigma diffusion, the distribution is (close to) Gaussian for horizontal diffusion!

Sigma Diffusion
15 min accumulated Precip. [mm]

Mod. Diffusion
15 min accumulated Precip. [mm]

Radar Composite DWD

00:15-00:30 UTC



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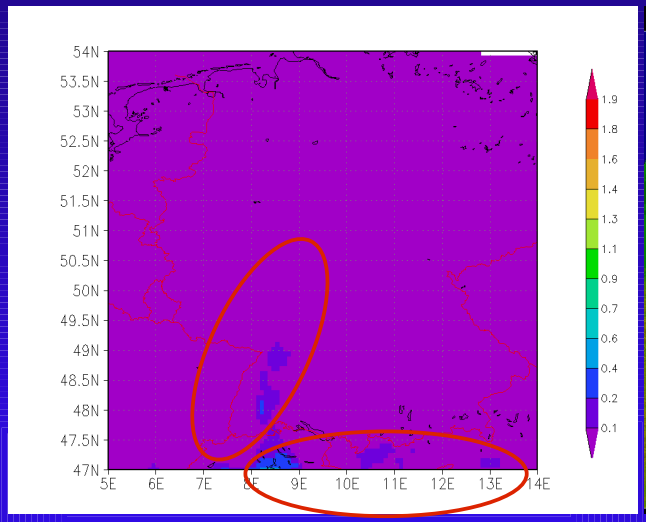

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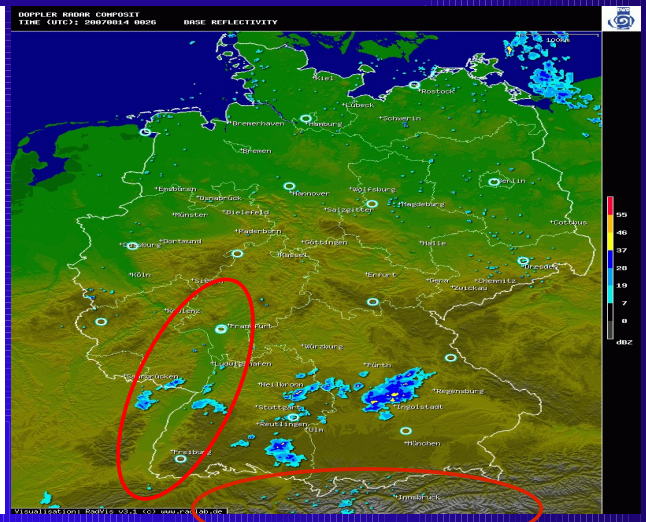

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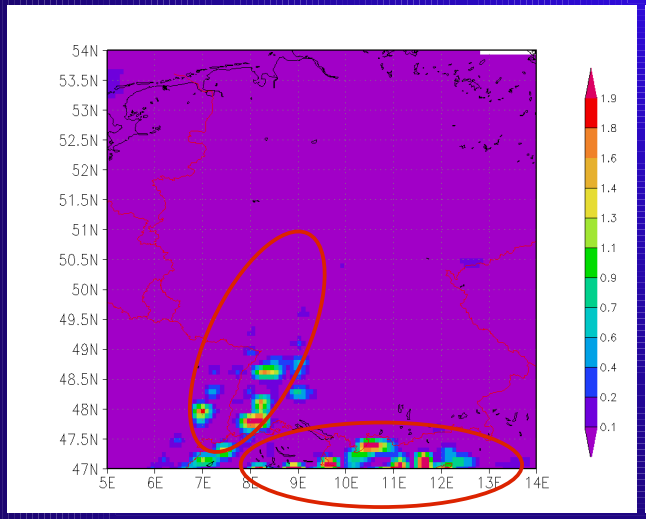

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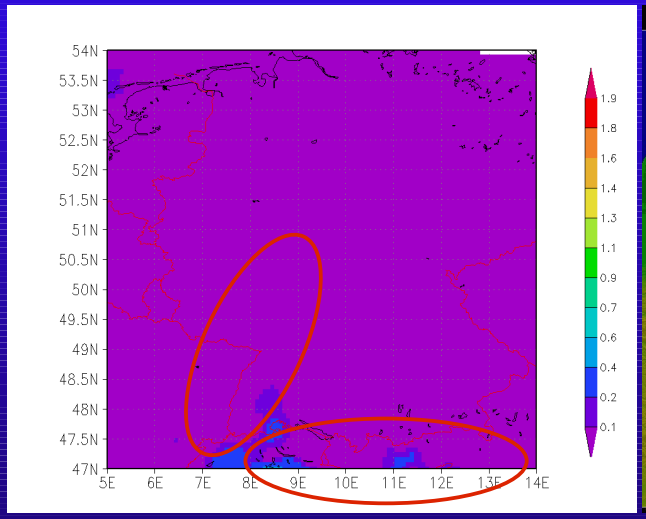
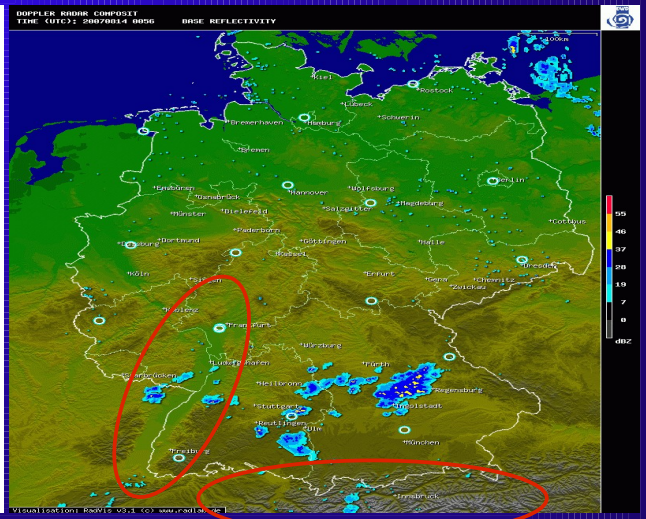
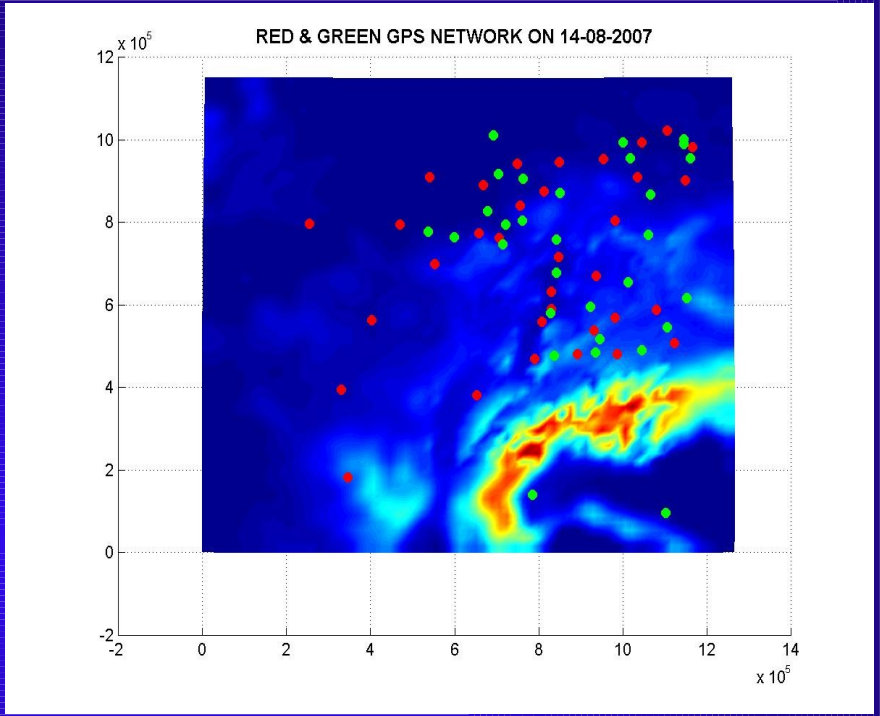


01:00 UTC



Part 2 : Assimilation

Background (first guess):
> The ECMWF analysis at 00 UTC
on 14-08-2007.

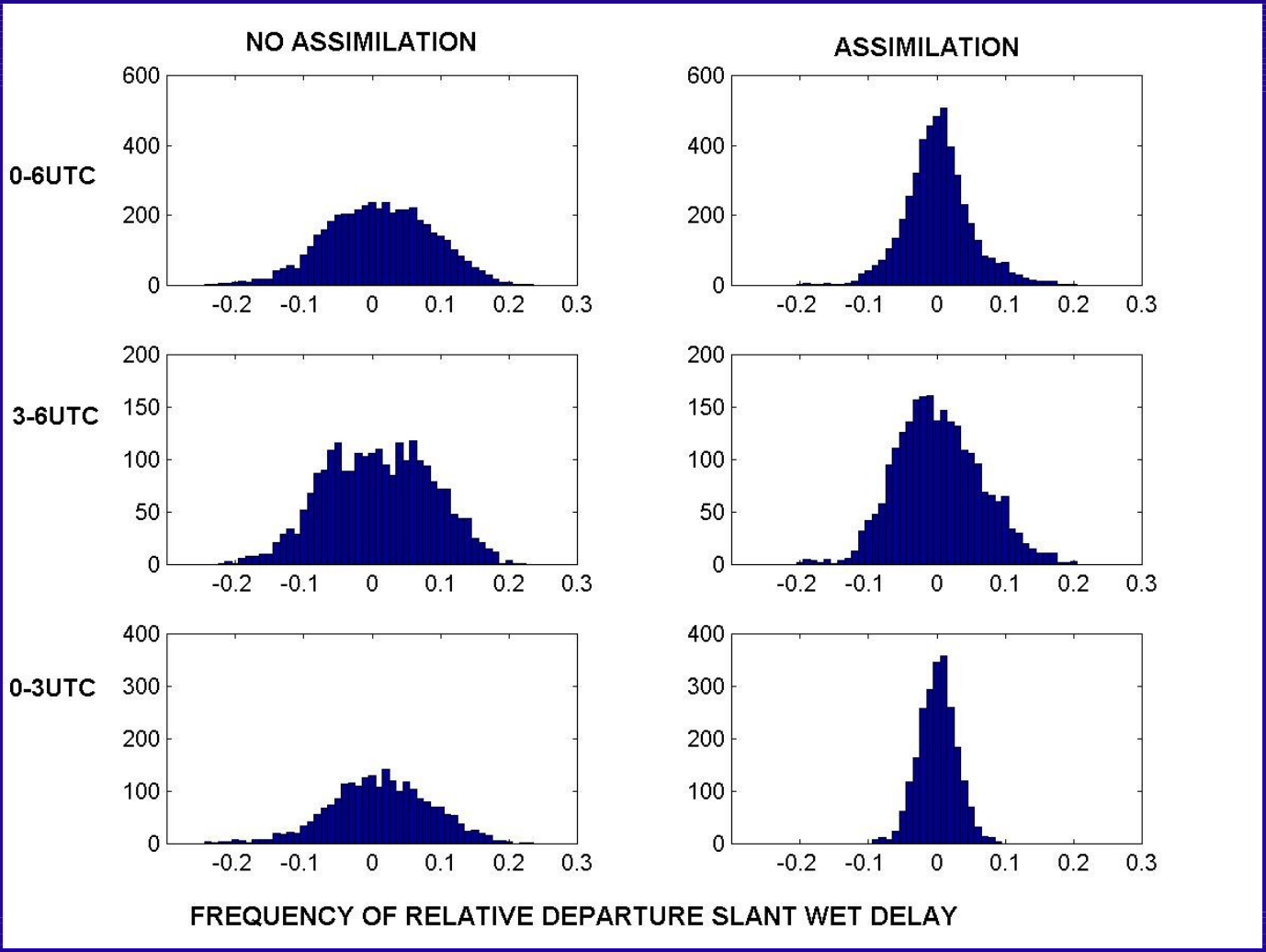


MM5 4DVAR set up :
> 18 km horizontal resolution.
> 36 terrain following vertical layer.
> Model top at 100 hPa.
> Horizontal diffusion with
Grell cumulus convective scheme.
(NLM & ADJ)
> 3 h assimilation window 00-03 UTC
> 6 h forecast 00-06 UTC

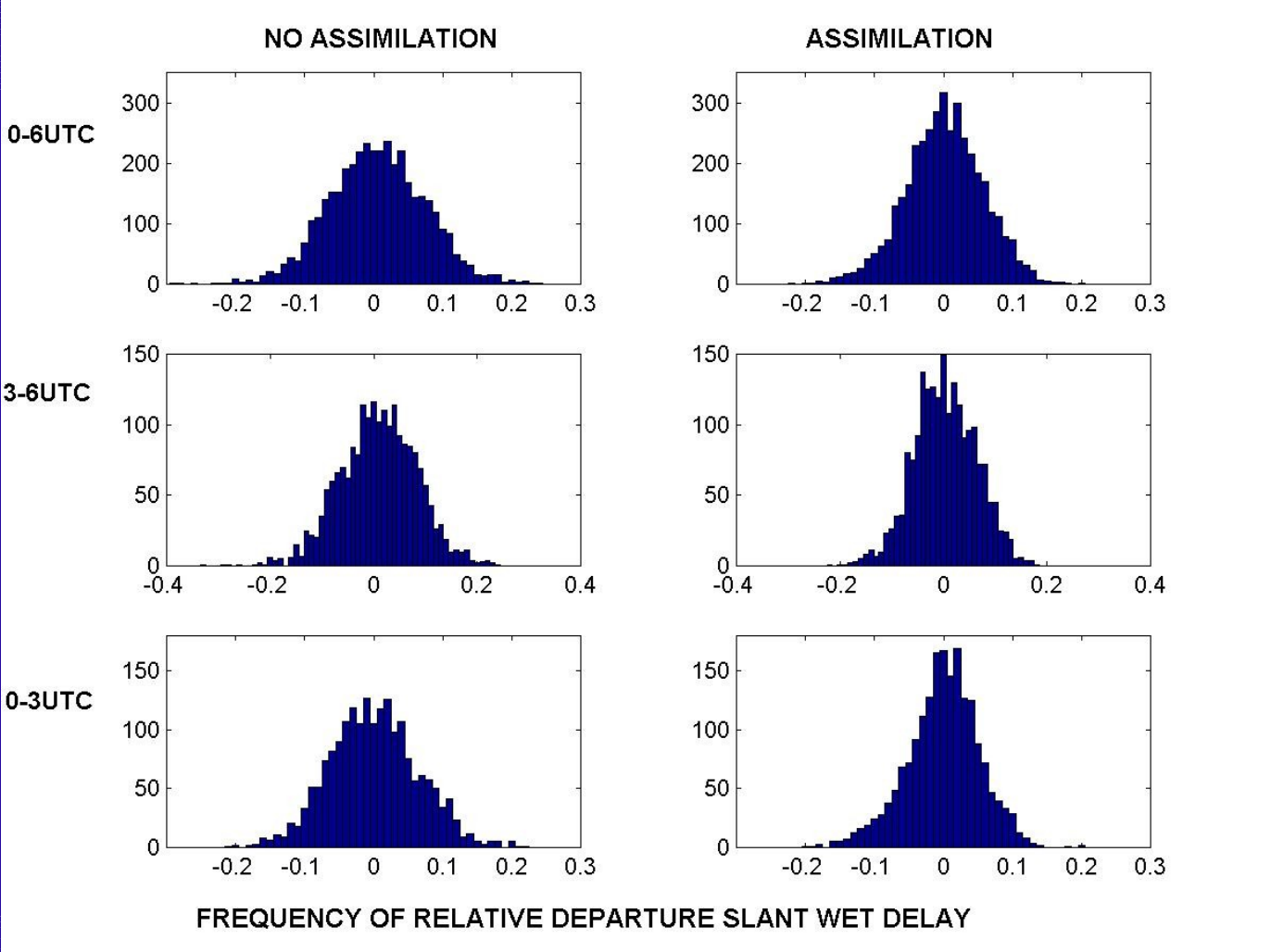
GPS STD set up:
> GPS receivers are randomly chosen.
> Network Red provides STD data for assimilation with a time frequency of 30 minutes.
Each STD from a single GPS receiver is considered.
> Network Green is the observing network. Data provided by this network is not assimilated!

Radiosonde: The MARS archive ECMWF.
Radar: The Doppler Radar Composite DWD.

Assimilation Network RED

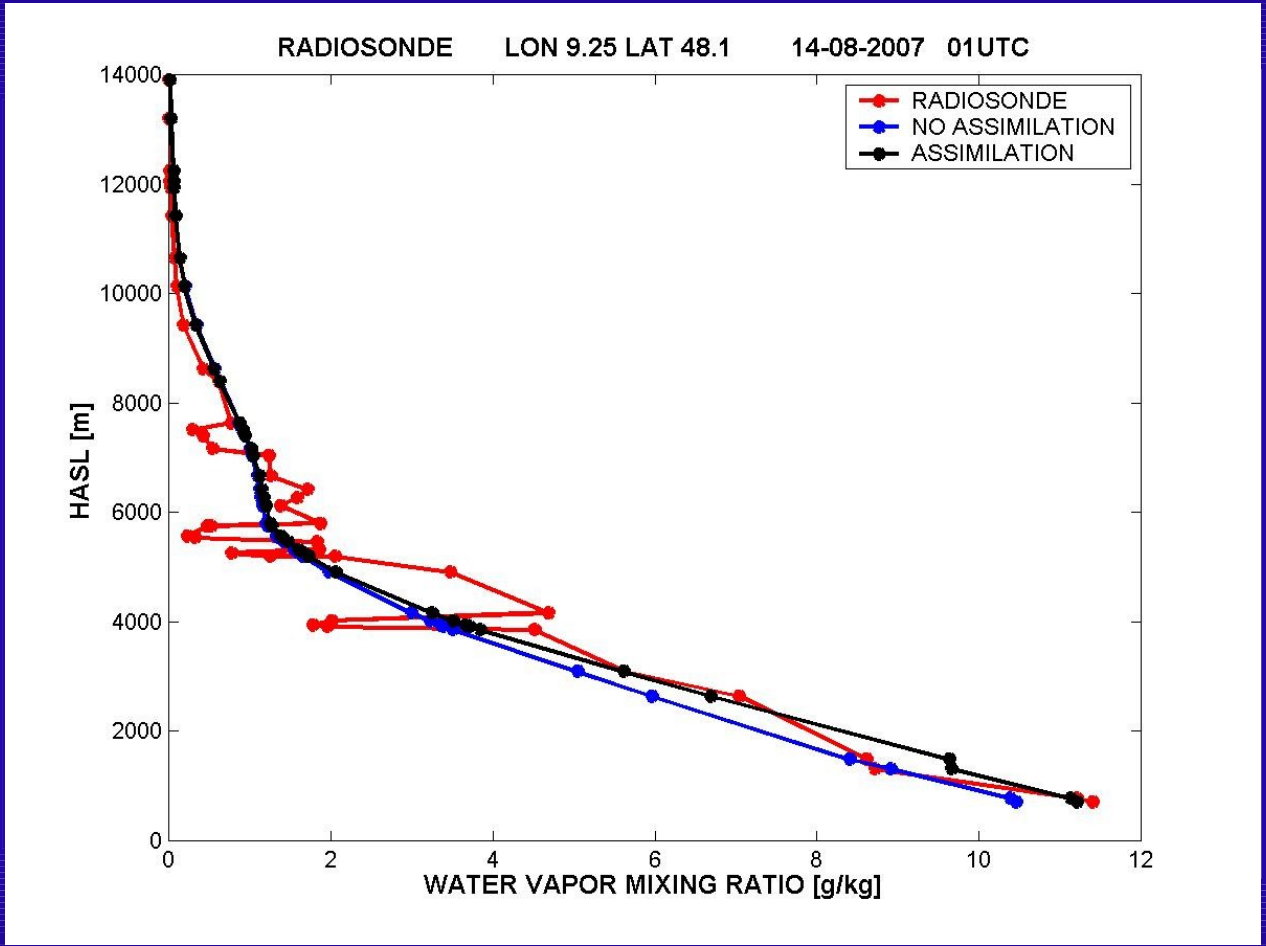


Observing Network GREEN



> … et voila.

Radiosonde

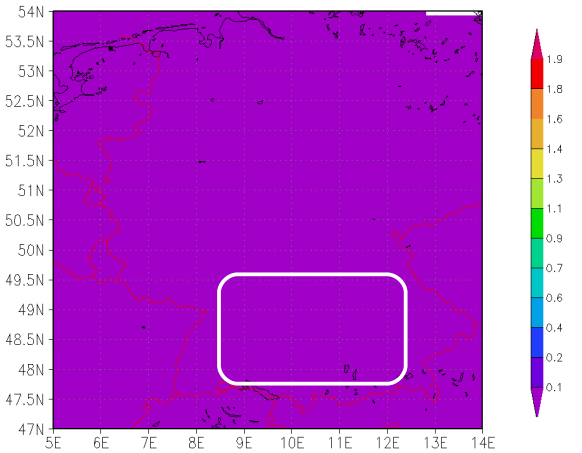

RADIOSONDE LON 9.25 LAT 48.1 14-08-2007 01UTC
RADIOSONDE
NO ASSIMILATION
ASSIMILATION
HASL [m]
WATER VAPOR MIXING RATIO [g/kg]
0
2000
4000
6000
8000
10000
12000
14000
0
2
4
6
8
10
12

No Assimilation
15 min accumulated Precip.[mm]

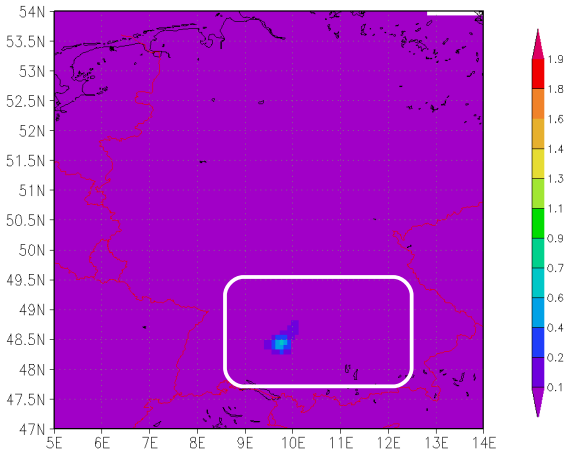
Assimilation
15 min accumulated Precip.[mm]

Radar Composite DWD

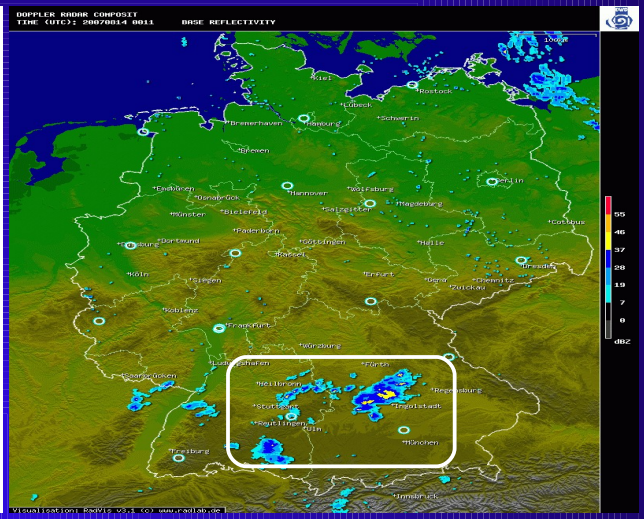
00:15-00:30 UTC



00:15-00:30 UTC



00:30 UTC



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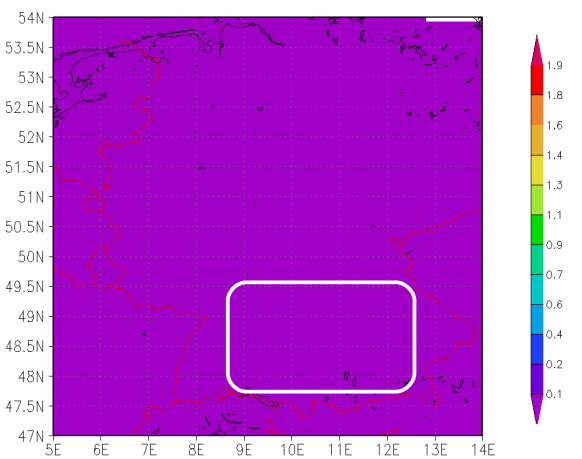

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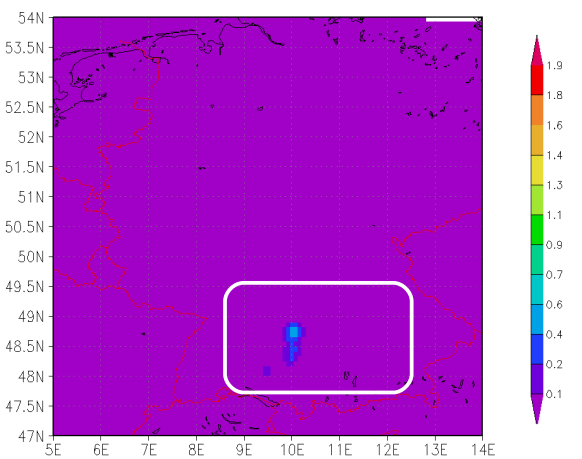

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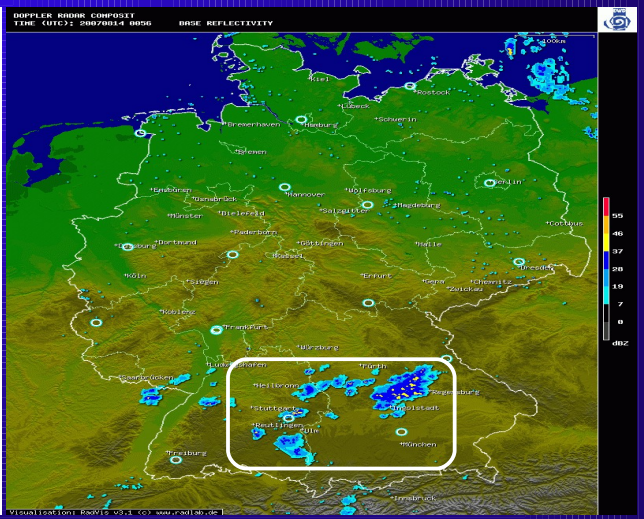
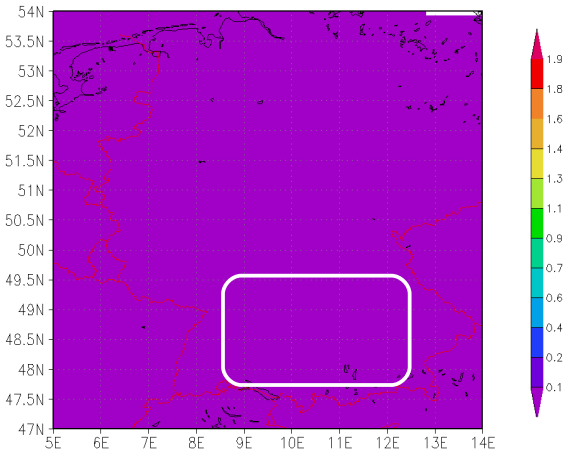


No Assimilation
15 min accumulated Precip.[mm]

Assimilation
15 min accumulated Precip.[mm]

Radar Composite DWD

01:15-01:30 UTC



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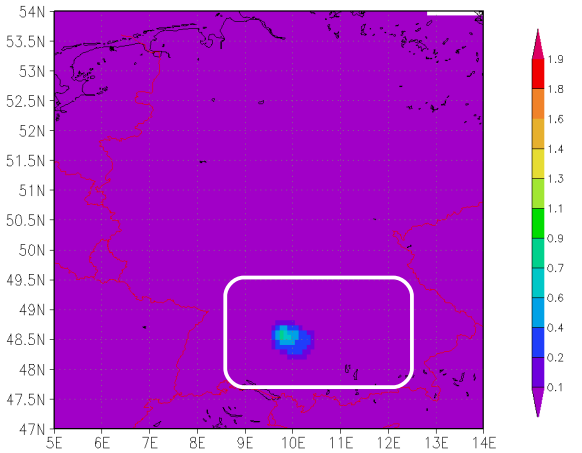

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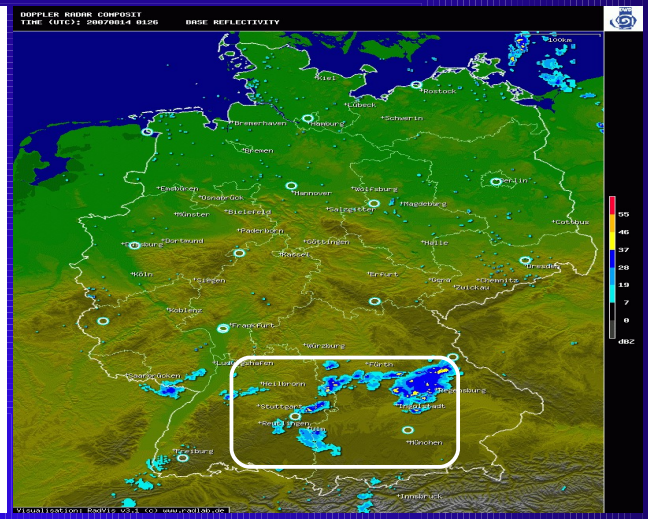
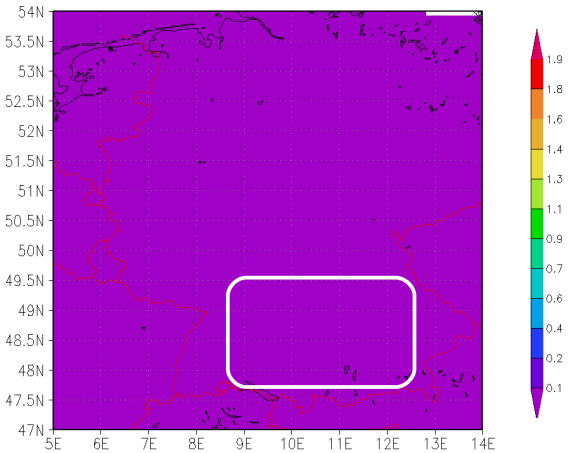


01:45-02:00 UTC



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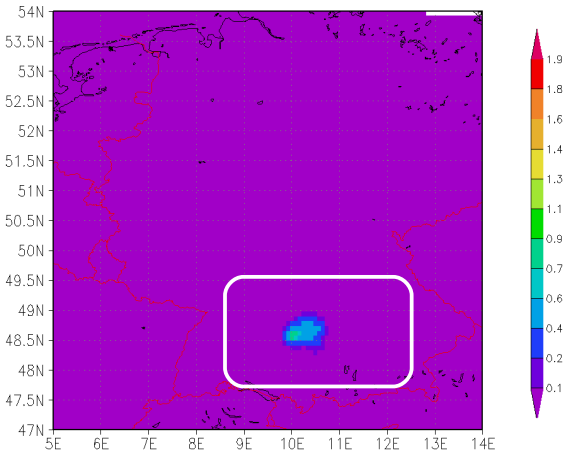
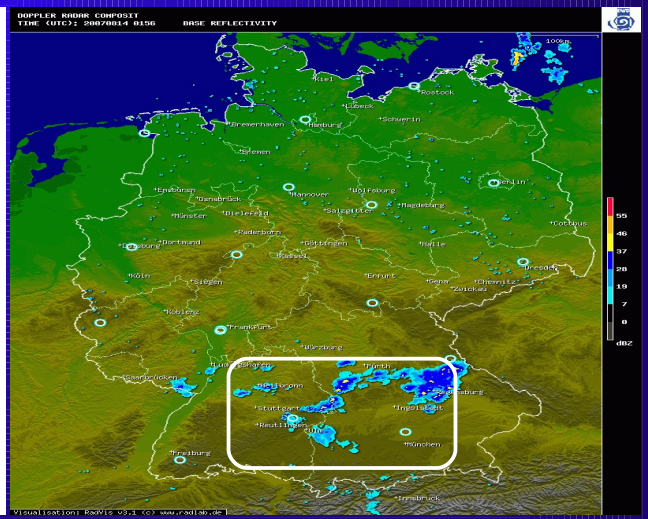


02:00 UTC



Conclusion & Outlook

> As the only institute IPM UHOH successfully assimilated GPS ground-based measurements with 4DVAR during COPS / D-PHASE.

> Thanks to the GPS STD data deficiencies were identified in model physics and were removed. Now GPS STD assimilation seems to work as intended.

Besides model physics:

> Adapt background error statistic from ECMWF.
> Perform a spin up run and implement a digital filter as a weak constraint.

Observing systems:

> Combine different observing systems in assimilation (e.g. radial wind,...).
> Check reliability of observing systems.
> Cross check of different systems and cross check with the ECMWF analyses.

Cooperation with MRI / JMA is discussed.