Progress in the assimilation of ground-based GPS observations using the MM5 4DVAR system

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- Slant total delay (STD) operator development
- Progress of the IPM MM5 4DVAR system
- 1-31 August 2007 and IOP8b
- Conclusion

STD operator development

$$STD = \int N\, ds + \int ds - \int dg$$

Option A LOS: The bending of the ray trajectory is not taken into account.

> Non-linear, tangent linear, and adjoint models (NLM, TLM and ADJ) implemented and tested for correctness.

> 'online' in the MM5 4DVAR MPI environment.

Option B Ray-tracing: Solve the Euler Lagrange equation to determine ray trajectory:

$$y'' = (\partial_y n - \partial_x n\, y')(1 + y'^2 + z'^2)/n$$
$$z'' = (\partial_z n - \partial_x n\, z')(1 + y'^2 + z'^2)/n$$

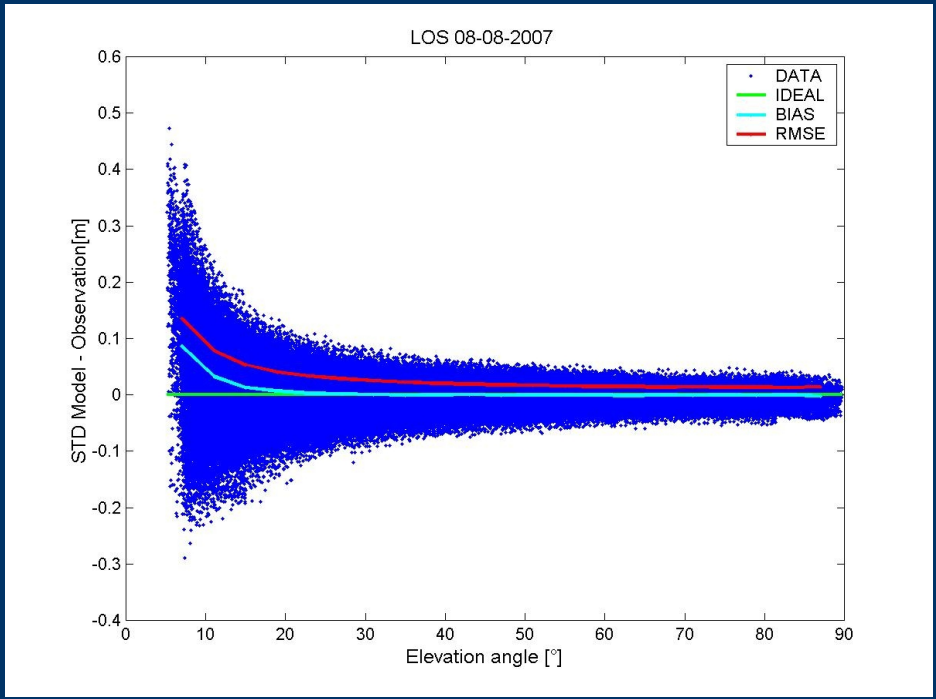
> Non-linear two-point boundary value problem solved by collocation method.

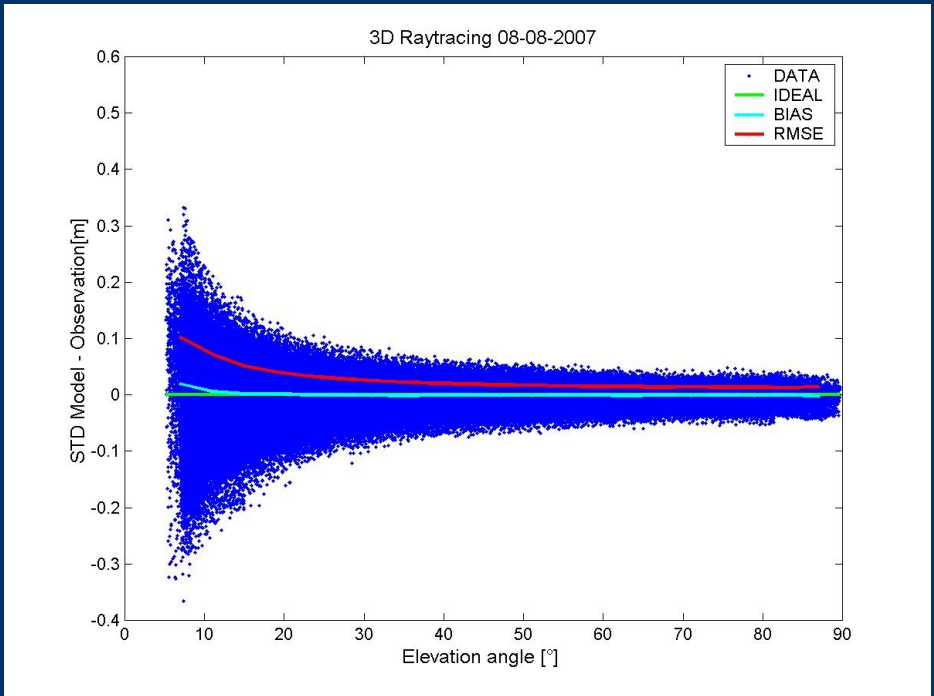
> Can be readily applied for GPS radio occultation simulation.

> NLM, TLM and ADJ implemented and tested for correctness.

> 'offline' yet.

Simulated STD relative to STD data processed by GFZ Potsdam:

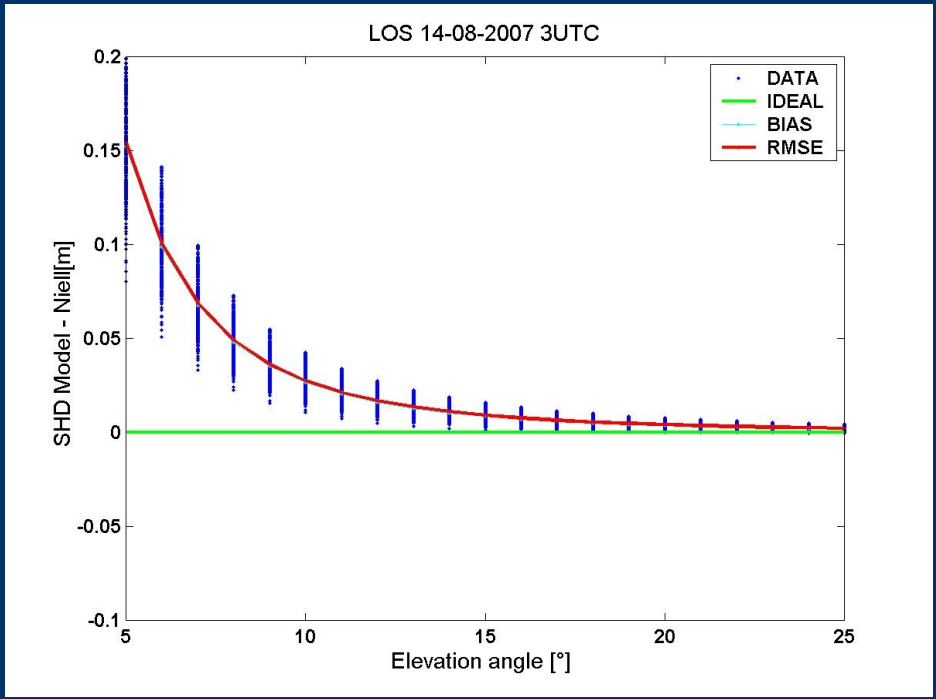


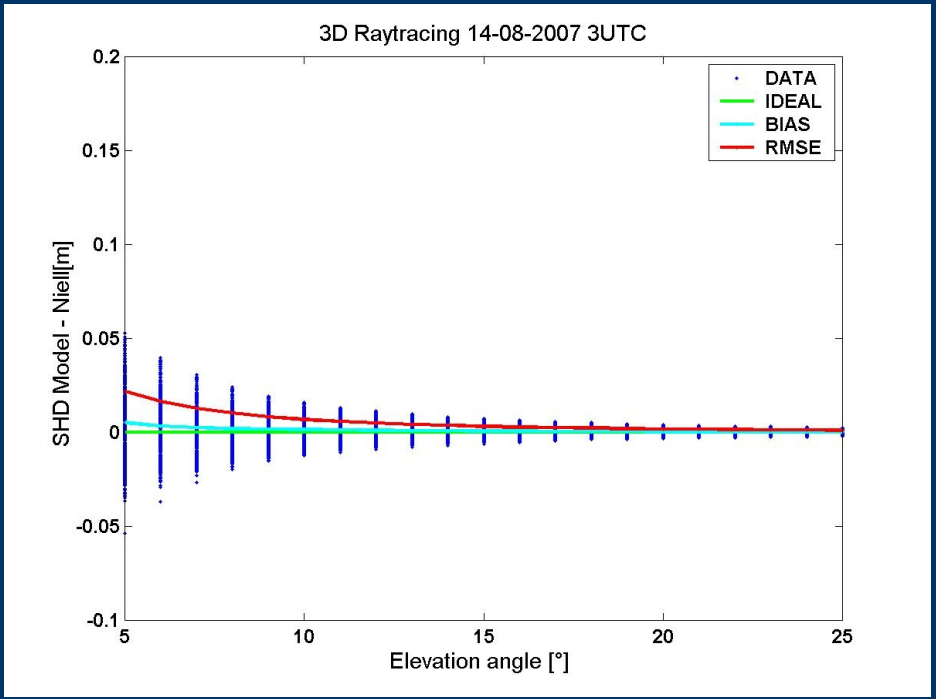


> LOS solution is only applicable for elevation angels above 30°.
Ray-tracing solution is applicable over the entire elevation range.

> The sensitive region in data assimilation will be increased considerably.

Simulated SHD relative to the Niell dry mapping:





> The agreement between the ray-tracing solution and Niell is very good.

> The remaining offset can be attributed to the presence of asymmetries in the atmosphere which can not be captured by the solution of Niell.

Progress of the IPM MM5 4DVAR

A Development of an improved horizontal diffusion scheme to prevent wrong moister and temperature tendencies in complex terrain (based on Li and Atkinson, Bound.-Layer Meteor. 1999).

B Implementation of the Grell cumulus convective scheme.

C Modified linearized vertical diffusion to prevent unstable modes in the PBL scheme (see e.g. Mahfouf, Tellus 1999). The perturbation of the diffusion coefficient K' is neglected:

$$\partial_t \psi' = \partial_z K \partial_z \psi'$$

> A and B is a necessity in terms of accuracy. C makes the 4DVAR very robust.

Further details: Zus et al. Meteorol. Z., QPF Special Issue, in press, 2008.

Configuration in this experiment

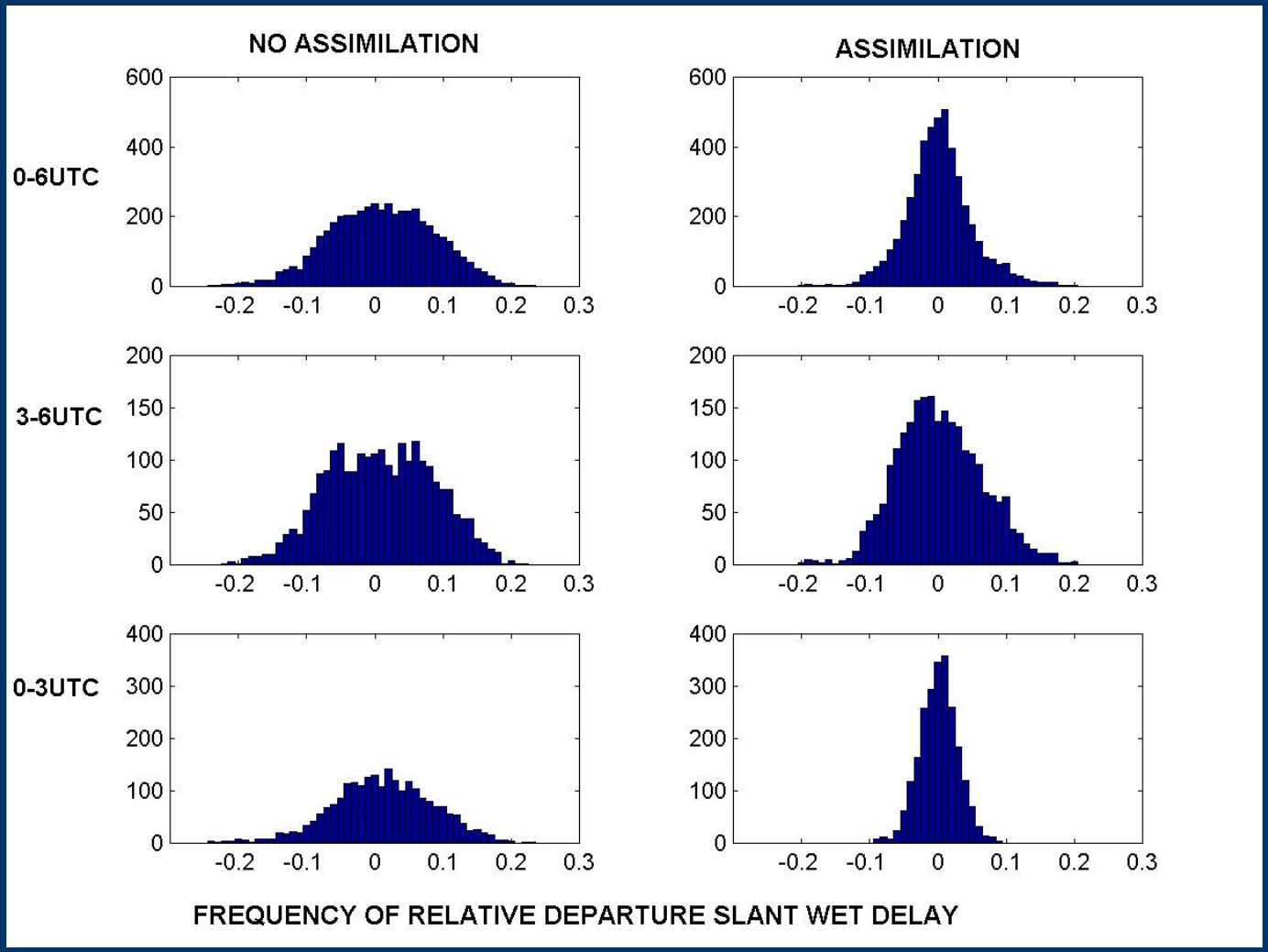
Domain: 18 km horizontal resolution, 36 vertical layer, model top at 100 hPa.

MM5 (v3.4) 4DVAR (0-3UTC):
Grell convection
Horizontal diffusion (Zus)
MRF vertical diffusion
Large scale precipitation
No heat and moister fluxes
Ground temperature not predicted
Simple radiation scheme
...

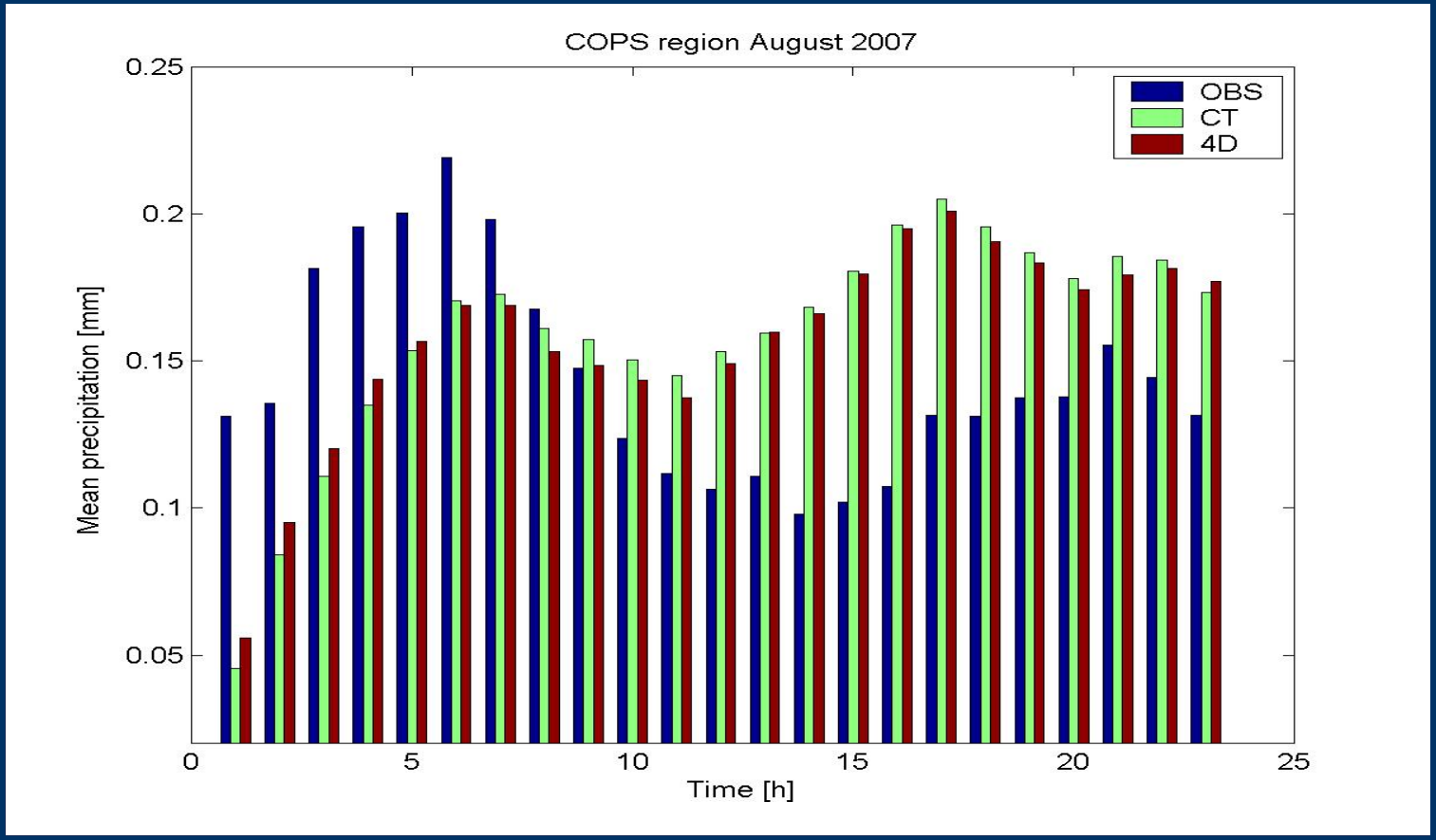
MM5 (v3.7) Forecast (0-24UTC):
Kain Fritsch 2 convection
Horizontal diffusion (Zängl, MWR 2002)
MRF vertical diffusion
Reisner 2 cloud physics
Heat and moister fluxes switched on
Ground temperature predicted
RRTM
...

GPS data:
STD data provided by GFZ Potsdam
50 GPS receivers randomly chosen
30 minutes assimilation frequency
Elevation cut off at 30° (LOS)

Initial State:
The ECMWF analyses, i.e. a synergy of various observing systems and a previous forecast (4DVAR) .


NO ASSIMILATION
ASSIMILATION
0-6UTC
3-6UTC
0-3UTC
FREQUENCY OF RELATIVE DEPARTURE SLANT WET DELAY

Diurnal cycle of precipitation, August 2007 COPS region

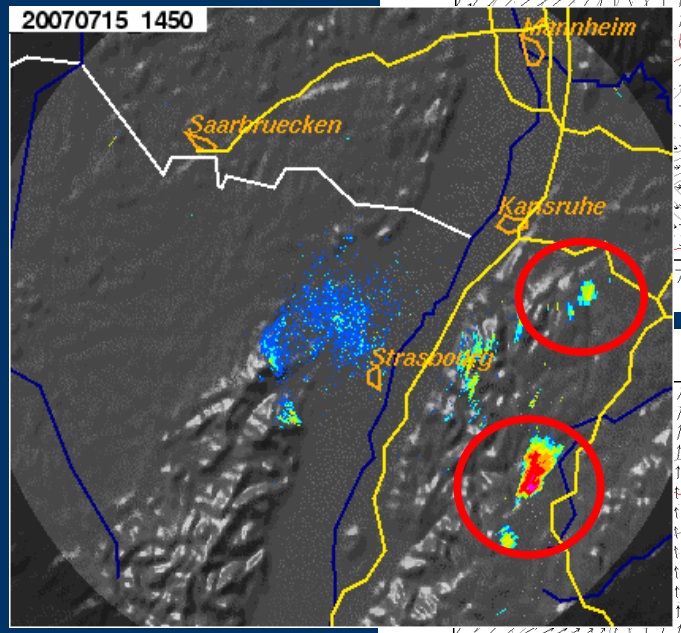


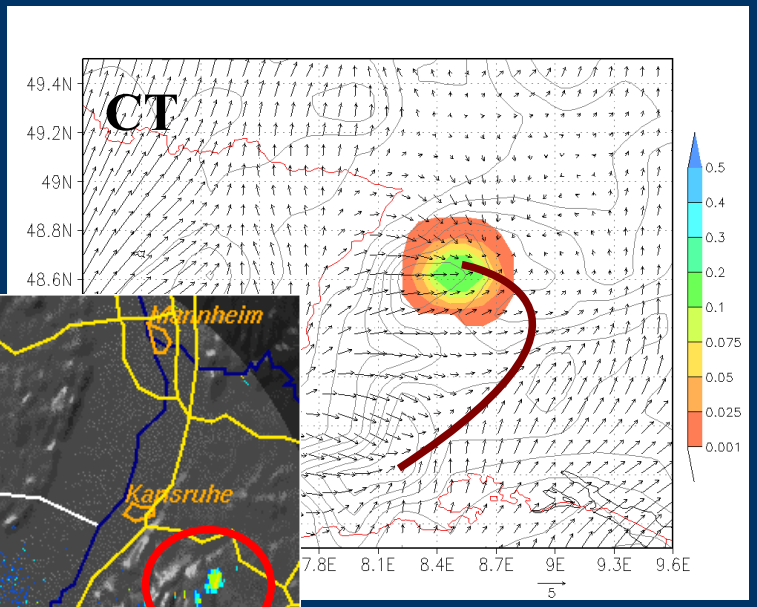
> Evaluation of the precipitation pattern in the COPS area:

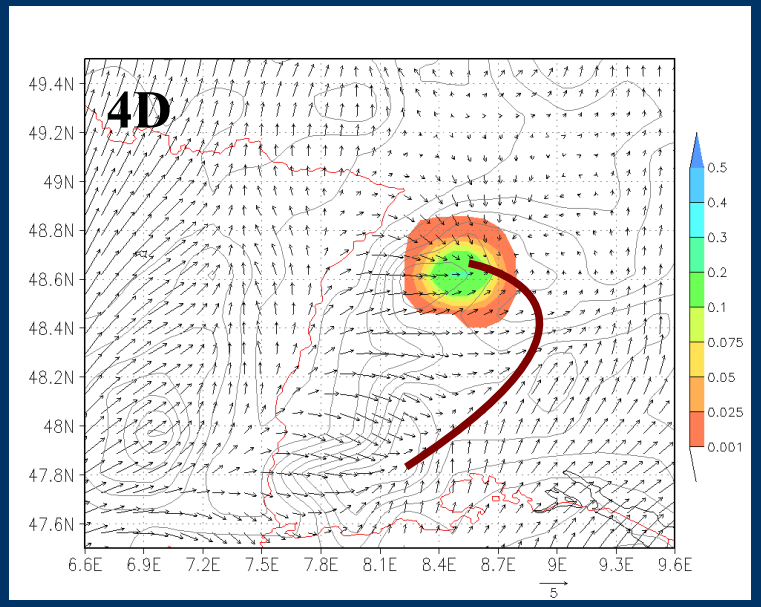
	CT	4D	Rel. Diff. [%]
BIAS	6.45	5.87	- 8.9
RMSE	36.29	34.71	- 4.4
PMCC	0.562	0.594	+ 5.7

15 July 2007, IOP8b a qualitative inter-comparison (Δx=18km !)

15:30UTC







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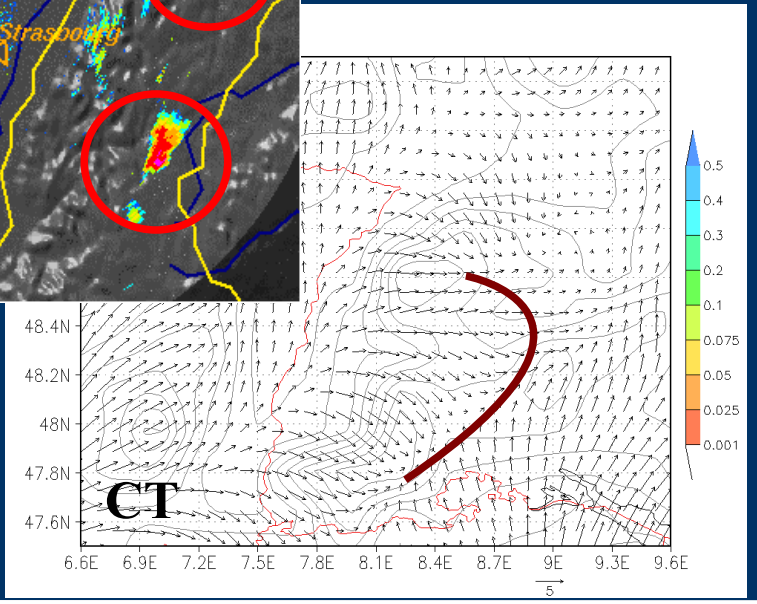
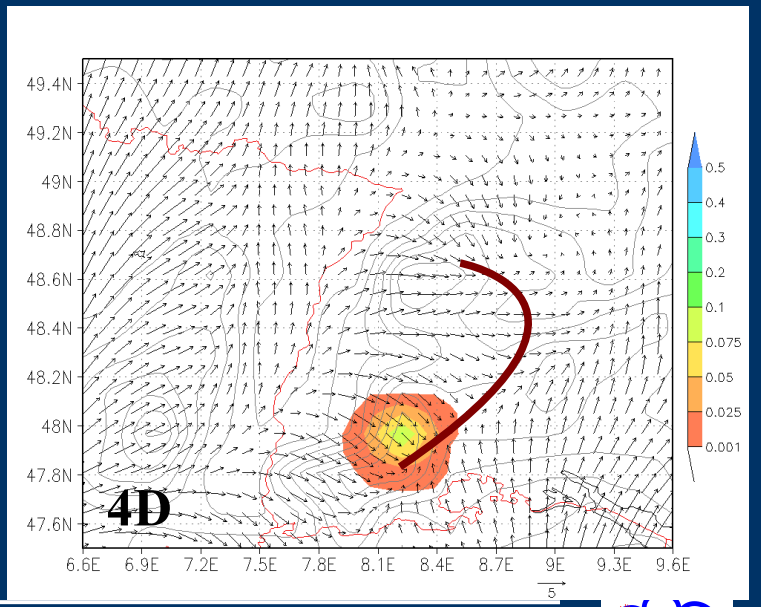




Conclusions

> Ray-tracing allows one to use the full information content of the STD data.

> Major changes in the MM5 4DVAR model physics implemented by IPM increased a.) the accuracy and b.) the stability of the system.

> STD data can be assimilated and YES it does have a slight positive impact on the precipitation forecast in the COPS region. GPS 'butterflies' are always good for a small surprise.

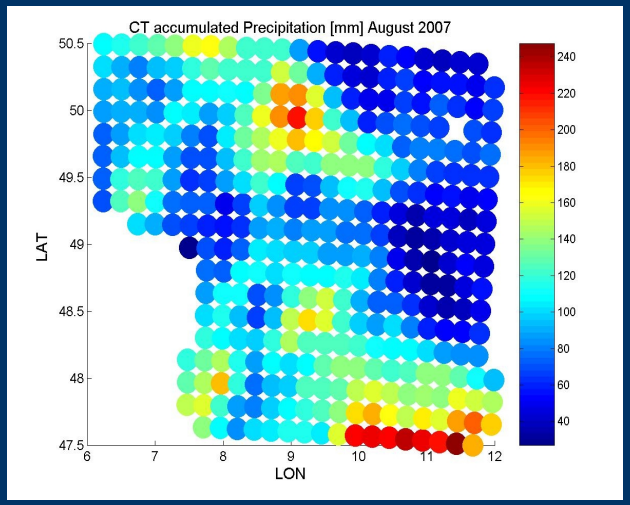
> Outlook: Focus on a series of medium to heavy rainfall days. Access impact of model physics, model resolution, background/observation errors.

> Assimilation of different observing systems, particularly radar radial velocity and GPS data on different scales, move to the convection-permitting scale with WRF.

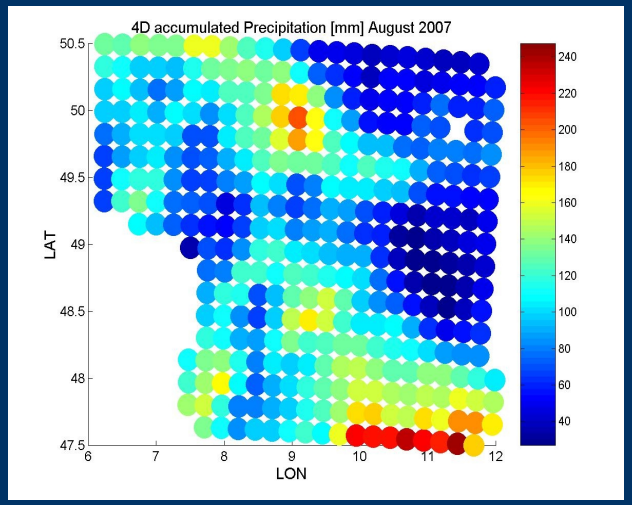
> Compare high-resolution 4DVAR with EnKF in connection with WWRP COPS/D-PHASE mesoscale research environment.

Precipitation pattern COPS area, August 2007 (31 days 0-24UTC)

CT



4D



Observation