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The Impact of Assimilating GPS-PW data using WRF-3DVAR on a Simulation of a Squall Line Observed during IHOP

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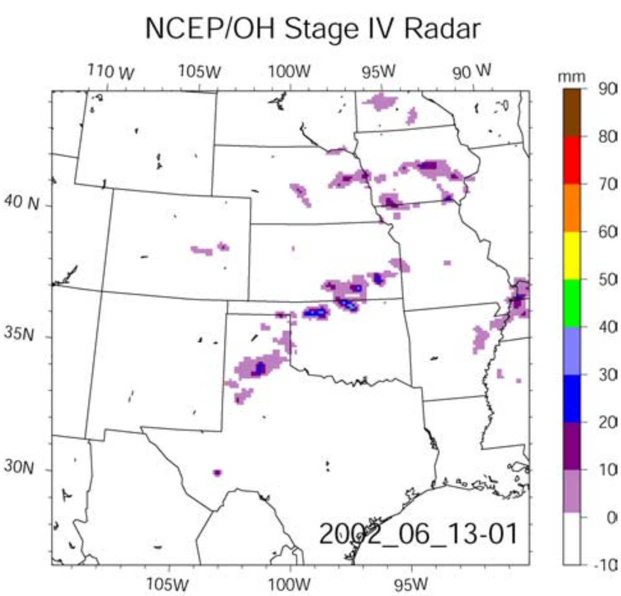
1. INTRODUCTION

Analysis and prediction of a local weather using NWP models and observations from ground-based GPS and Doppler radar are required to protect electric power facilities, reduce risks and save money. Recently, the Weather Research and Forecasting (WRF) model and a new three-dimensional variational data assimilation system (WRF-3DVAR) have been developed. In the present study, we investigate the impact of assimilation of ground-based GPS using the WRF-3DVAR system on a simulation of squall line observed over the Southern Great Plains on June 12th – 13th 2002. This squall line occurred during the International H_2O Project (IHOP). Figure 1 shows the hourly precipitation amount on June 13th 00 and 06 UTC based on NCEP/OH Stage IV data. At 00 UTC the squall line was well-developed from southeast Kansas to the Texas Panhandle. The squall line propagated to the southeast over the next six hours. This is the phenomenon we are focusing on.



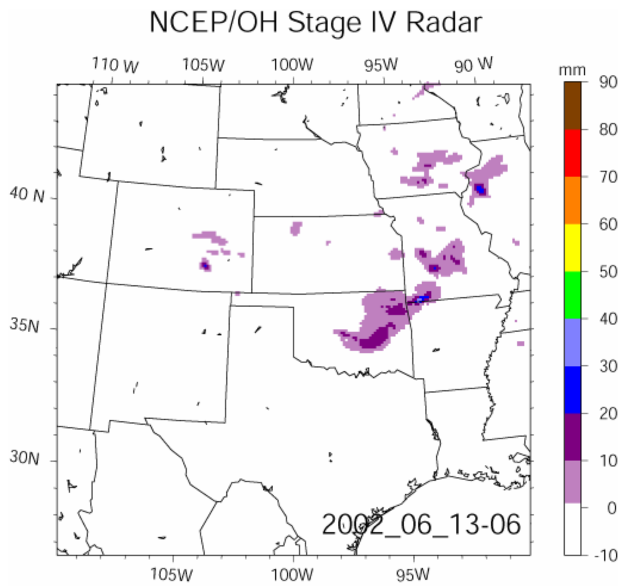


Fig. 1: Hourly precipitation amount on June 13th 00 UTC and 06 UTC based on NCEP/OH Stage IV data.

2. RESULTS FROM THE WRF MODEL

The WRF model has been developed by NCAR and its collaborating centers (NCEP, AFWA and NOAA/FSL). This model is a non-hydrostatic, compressible, NWP model with mass coordinate system. The basic equations consist of the equations of motion, heat, and moisture, and the continuity equation. The WRF model has several schemes for each physical process. Schemes used in the present simulation are summarized in Table 1. Simulations are conducted over the IHOP area for the squall line phenomenon. For the initial and boundary conditions, the ETA analysis and forecast data with 40km horizontal resolution are used for the present simulations, respectively (Table 2). We have run the WRF model with 10 km resolution for all simulations. However, it is known that the 5-10km resolution range is a difficult range to determine use of a cumulus parameterization scheme or not. Therefore, as a preliminary study, we investigated the sensitivity of the WRF model to cumulus parameterization

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schemes for squall line simulation. The sensitivity experiments showed that cumulus parameterization had a negative impact for the present squall line case (Fig. 2 vs Fig. 3). Thus, the cumulus parameterization is not used in the present study.

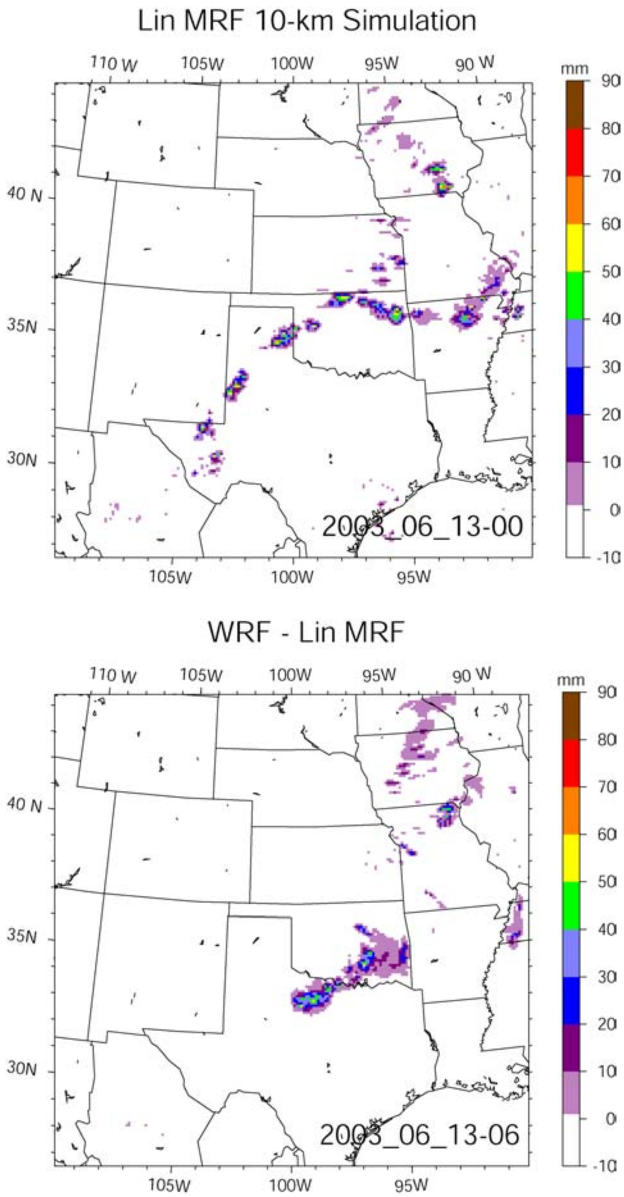

Fig. 2: Hourly precipitation amount on June 13th 00 and 06 UTC from the WRF without the Kain-Fritch cumulus parameterization.

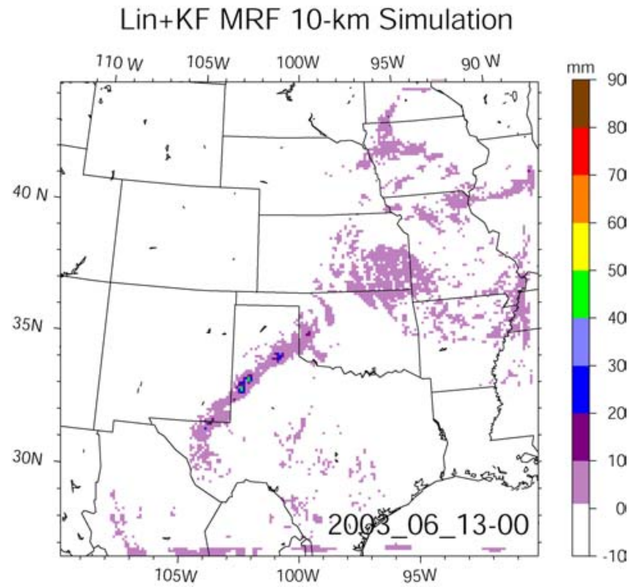

Fig. 3: Hourly precipitation amount on June 13th 00 UTC from the WRF with the Kain-Fritch cumulus parameterization.

Table 1: Schemes used in the present simulation

Process	Schemes
PBL	MRF non-local closure model
SFL	Monin-Obkhov similarity theory
Land Surface	Slab model with 5-layer heat equation for the soil layer
Radiation	RRTM line by line model
Microphysics	Lin 6-elements cloud model

Table 2: Simulation cases

Case	Data used in the initial time
Control	ETA analysis
Preliminary	ETA analysis
3DVAR	ETA analysis + GPSPW

3. IMPACTS OF GPS ASSIMILATION USING WRF-3DVAR SYSTEM

A new WRF-3DVAR system has been developed based on the MM5-3DVAR system developed at NCAR (e.g., Barker et al., 2003). The basic goal of the WRF-3DVAR system is to produce an optimal estimate of the true atmospheric state at analysis time through iterative solution of a prescribed cost function. In this system, a quasi-Newton minimization technique is used. The background error covariance matrix is approximated via the 'NMC-method' of averaging forecast differences. Quality Control Check is performed by the observation preprocessor prior to the 3DVAR system.

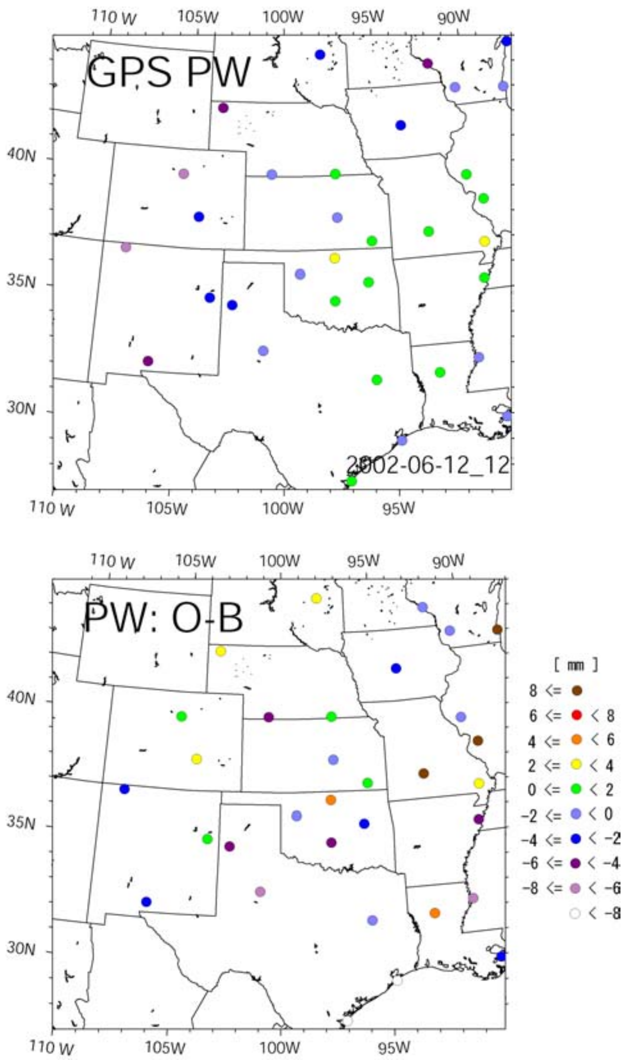

Figure 4: PW estimated from ground-base GPS and the background error of PW (PW from GPS - first guess from ETA analysis) on June 12th 12 UTC.

To investigate the impact of assimilation of GPS-PW by the WRF-3DVAR, we conduct the 3DVAR GPS-PW cold start simulation, i.e., 3DVAR is performed using ground-based GPS-PW data at only the initial time (Fig. 4). RMS error over the whole domain reduces over 2 mm by the assimilation, and CAPE increases from 720 to 1126 at the site of 36.5 latitude and -97.0 longitude (Table 3). Figure 5 shows simulated hourly precipitation on 00 and 06 June 13th for the 3DVAR GPS-PW case. For this case, the location of the squall line seems to be good and the overestimation around the northeast part of Kansas on 13th 00 UTC from the control run is decreased. The movement of the squall line is also slower than that without assimilation and in better agreement with observations.

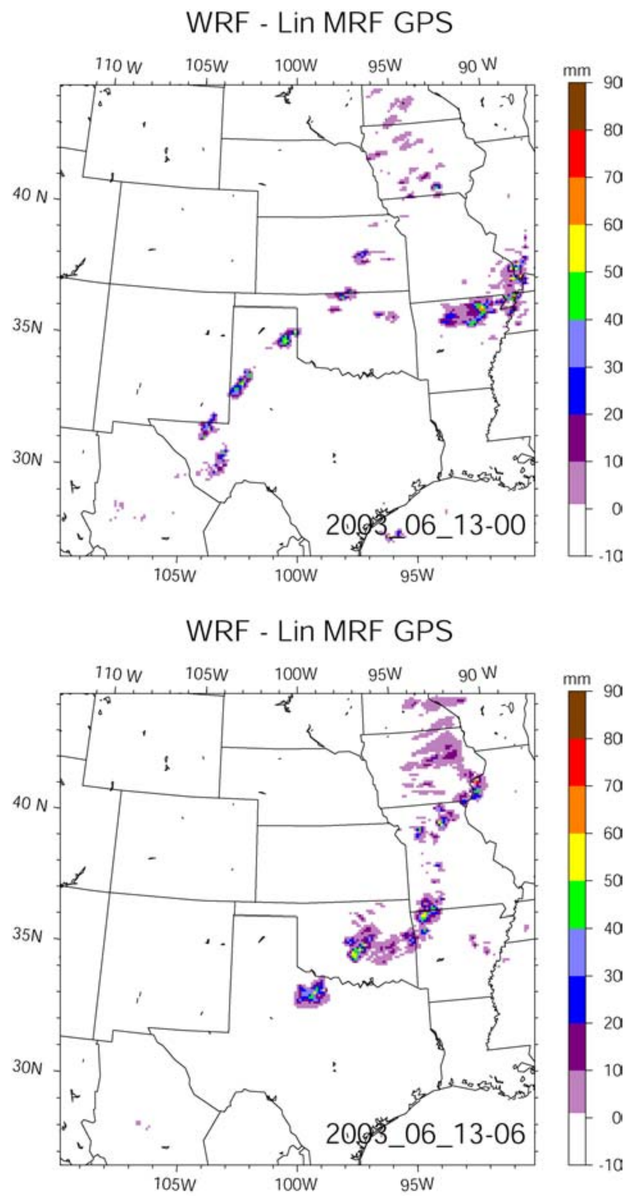

Fig. 5: Same as Fig. 2, but for the results using WRF-3DVAR system.

Figure 6 shows RMS error of PW from the control and 3DVAR GPS-PW runs. RMS error from the 3DVAR GPS-PW run is smaller than that from the control run during the simulation period as well as initial time.

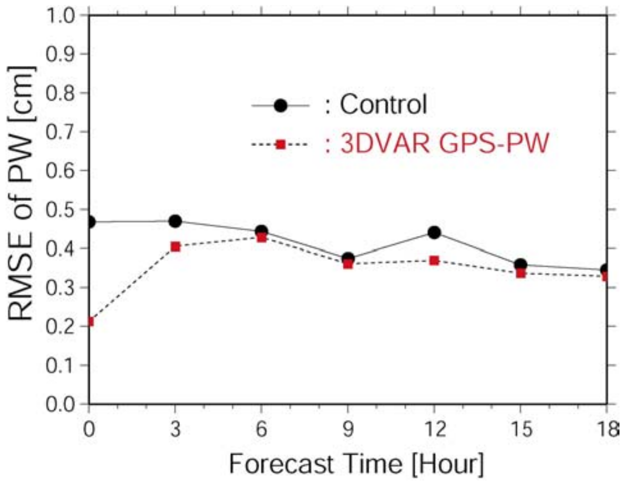

Fig. 6: RMS error of PW from the control and 3DVAR GPS-PW runs.

Table 3: Parcel Information of Control and 3DVAR GPS-PW cases at latitude = 36.50, longitude = -97.

Info \ Case	Control	3DVAR GPS-PW
PW	4.74	5.05
SW index	-4.9	-6.0
K index	39	41
CAPE	720	1126
CIN	-174	-112
LCL	884	896
LFC	679	712

4. SUMMARY AND FUTURE PLAN

Data assimilation of PW using the WRF-3DVAR system reduces the overestimation of hourly precipitation of heavy rain in the present case. Improvement of initial PW could overcome the error using advanced data assimilation. We are currently running an experiment with GPS-PW assimilation by WRF-3DVAR cycling.

ACKNOWLEDGEMENT

We would like to thank Mr. Wei Huang and Mr. Dave Gill of NCAR for their help.

REFERENCES

Barker, D., W. Huang, Y.-R. Guo, and A. Bourgeois, 2003: A Three-Dimensional Variational (3DVAR) Data Assimilation System For Use With MM5. NCAR/TN-453+STR, 68pp.