Dynamic downscaling GPM precipitation observations using 4DVAR data assimilation

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Goal

To produce **downscaled GPM precipitation and SMAP soil moisture products** by assimilating GPM and SMAP observations using a high resolution coupled hydrometeorological model for hydrological applications and to assess the value of such products in hydrologic applications.

	Spatial resolution	Temporal resolution
GPM	25 km	3 hours
SMAP	9 km	3 days
Applications	< 1 km	< 1 hour

Scientific Questions

- How does the assimilation of ONLY precipitation observations (GPM) into the WRF-ptRIBS model improve the predictability of precipitation and soil moisture?

- How does the assimilation of BOTH precipitation (GPM) and soil moisture (SMAP) observations into the WRF-ptRIBS model improve the estimation of both fields.

- What factors influence the skill of the precipitation and soil moisture forecast? What is the hydrologic usefulness of the downscaled precipitation and soil moisture fields obtained by the above mentioned approaches?

Methodology

Dynamic downscaling through data assimilation (DA) using a coupled hydrometeorological model.

	Model	DA Method
Atmospheric	WRF	3/4DVAR
Land Surface	ptRIBS+VEGGIE	EnKF

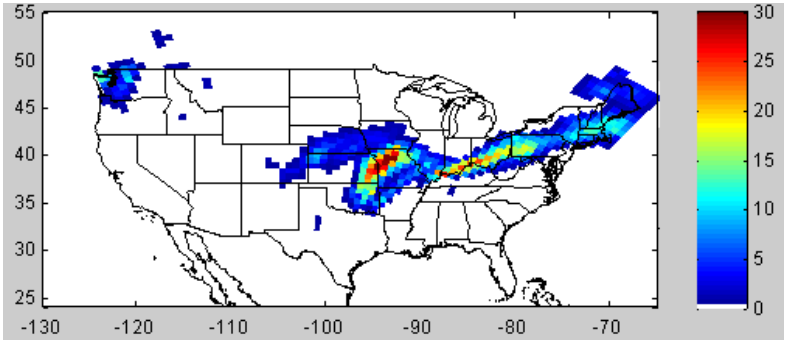
WRF	Weather Research and Forecasting
ptRIBS-VEGGIE	Parallel-triangulated Irregular Network (TIN)-based Real-time Integrated Basin Simulator with VEGetation Generator for Interactive Evolution
4DVAR	Four-Dimensional Variational Data Assimilation
EnKF	Ensemble Kalman Filter

Case Study I

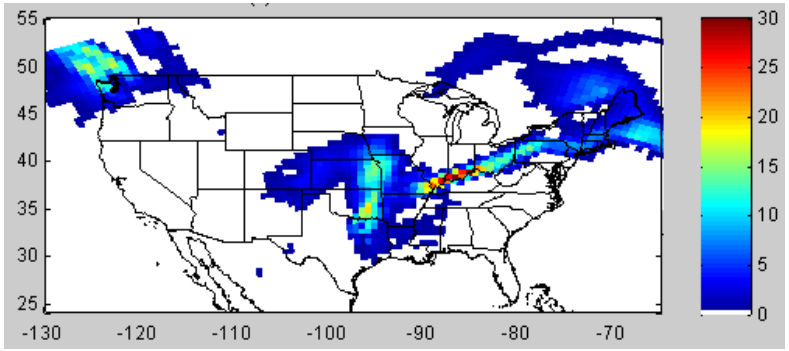
- Question: Should we use 3DVAR or 4DVAR for downscaling precipitation? Should we assimilate radiance or rainfall?

- Method: Test the following scenarios and evaluate six-hour accumulated precipitation with observations from the NCEP Stage IV data.
  - 3DVAR & assimilating AMSU-B radiances (NOAA-15, 16, 17)
  - 4DVAR & assimilating AMSU-B radiances (NOAA-15, 16, 17)
  - 4DVAR & assimilating Stage IV 6-hour precipitation.

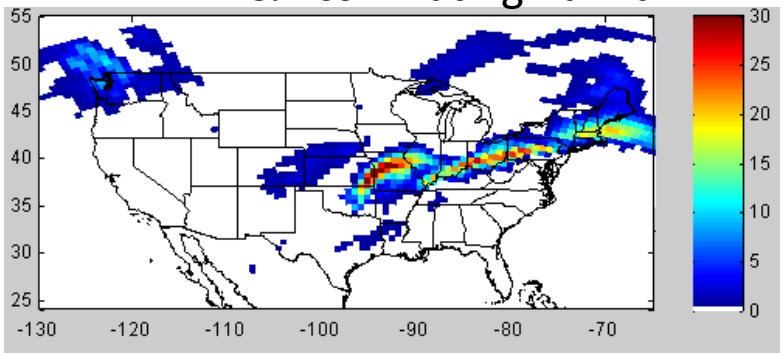
6-hour Precipitation Observation



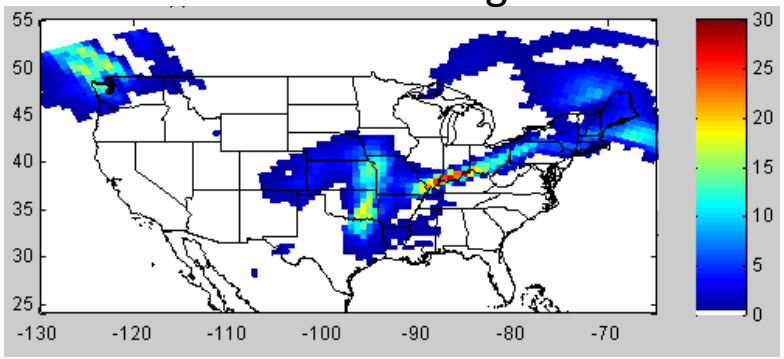
Openloop Run



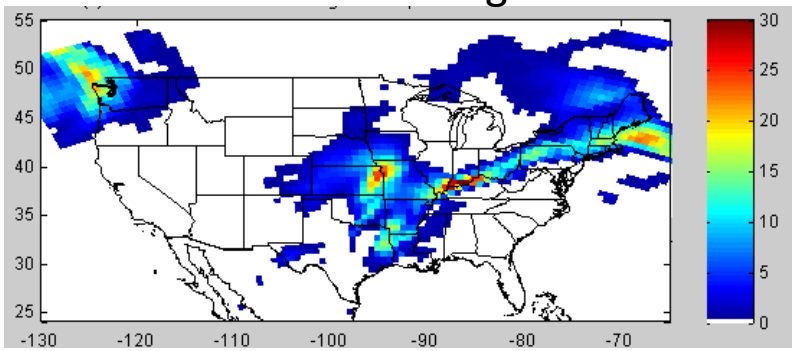
4DVAR & Assimilating Rainfall



3DVAR & Assimilating Radiance



4DVAR & Assimilating Radiance



	Corr.	RMSE
Openloop	0.48	0.69
3DVAR+radiances	0.51	0.68

	Corr.	RMSE
4DVAR+6H Acc. P	0.72	0.54
4DVAR+radiances	0.67	0.58

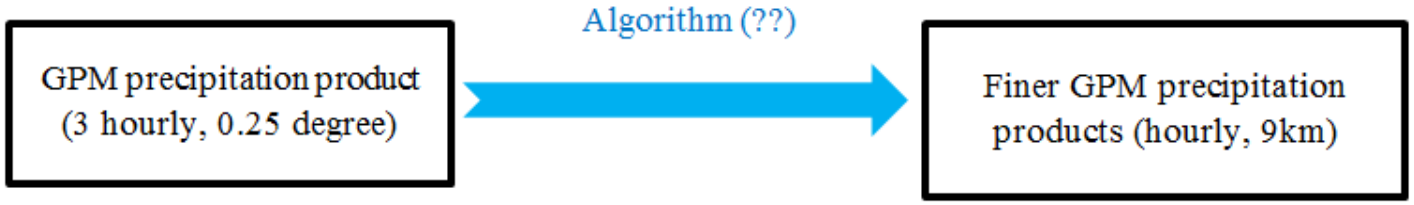
Findings

- 4DVAR DA of radiances produces better downscaled precipitation than 3DVAR does.

- 4DVAR DA of six-hour accumulated precipitation produces better downscaled precipitation than that of radiances.

Case Study II

- Question: How much improvement of downscaling precipitation through assimilating GPM-like precipitation?



Case Study II

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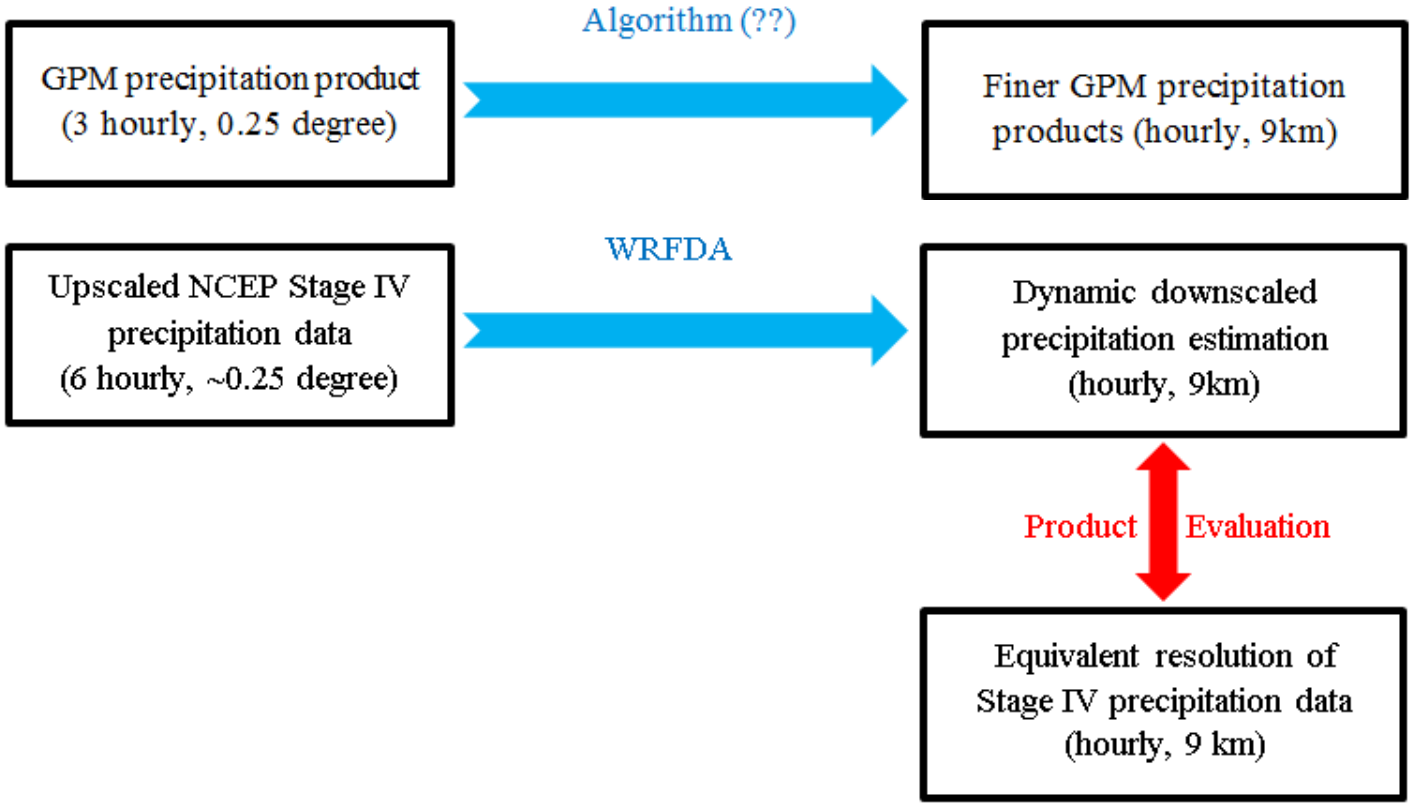
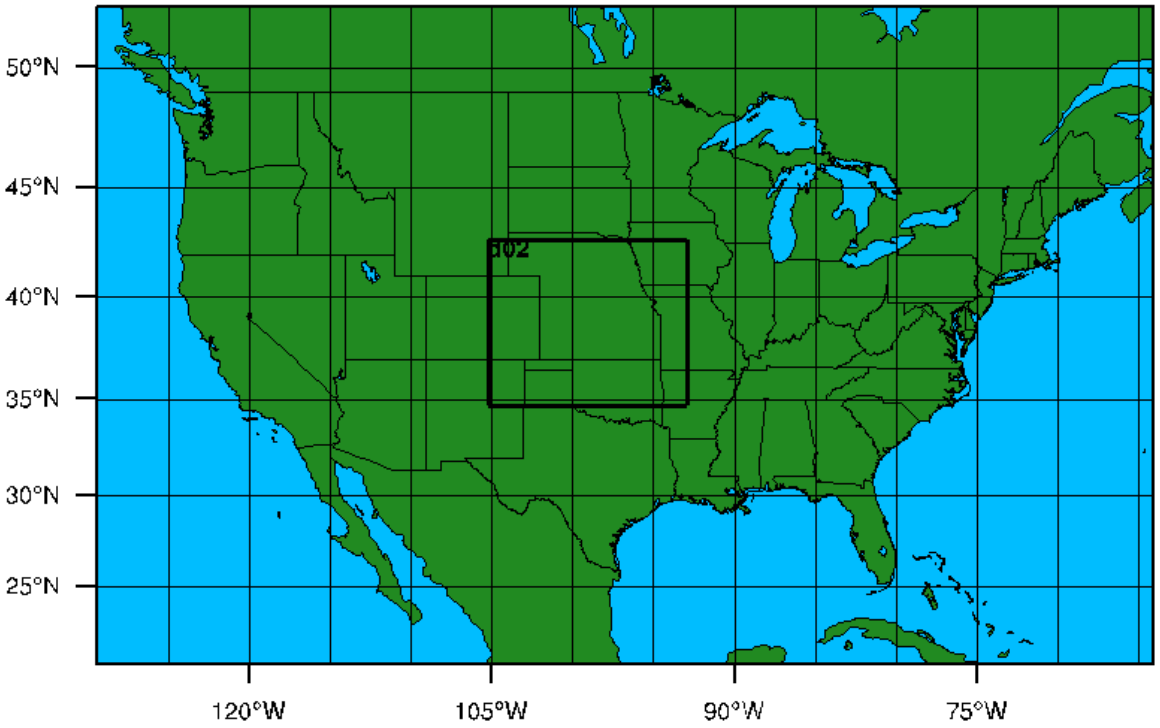
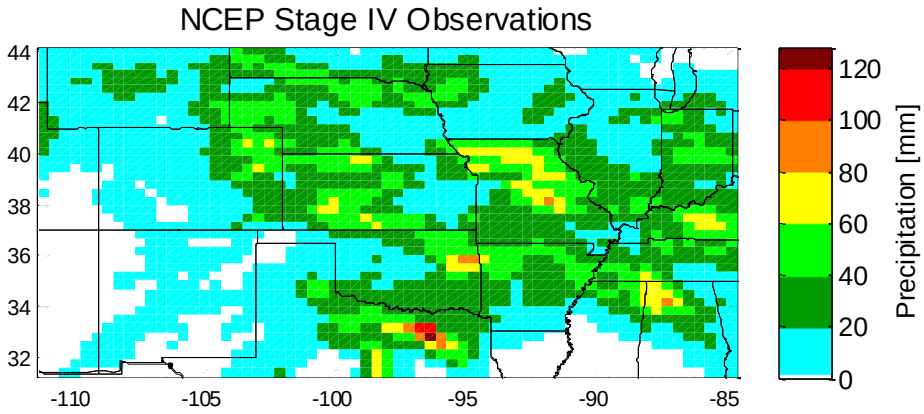


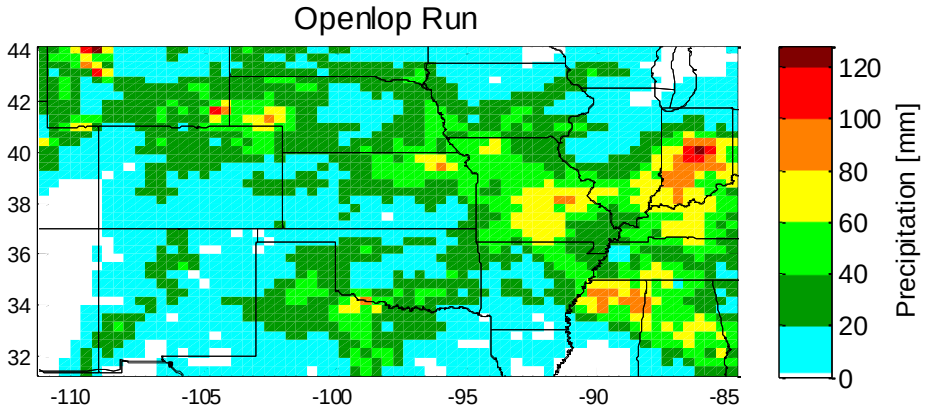
Model Setup

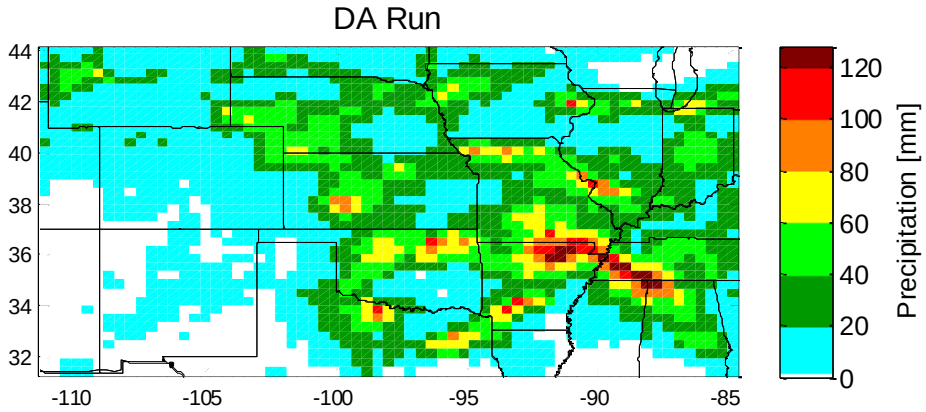
- WRFDA 6-hour cycle 2009.06.10-15 1800 UTC (5 days).
- Parent domain: 160 x 100 with 36 km
- Nested domain: 121 x 101 with 09 km



Five-day Precipitation Accumulation (36-km)

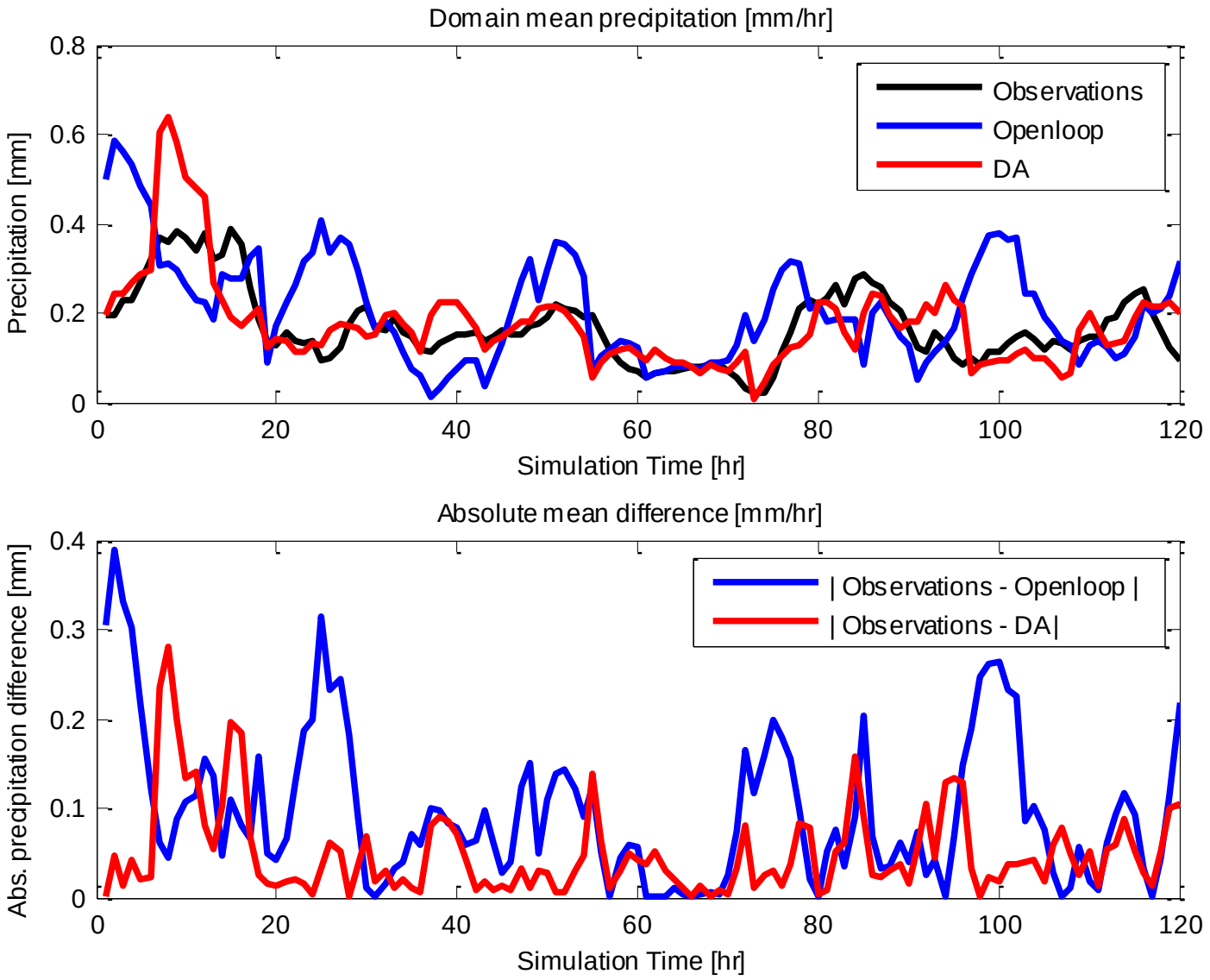






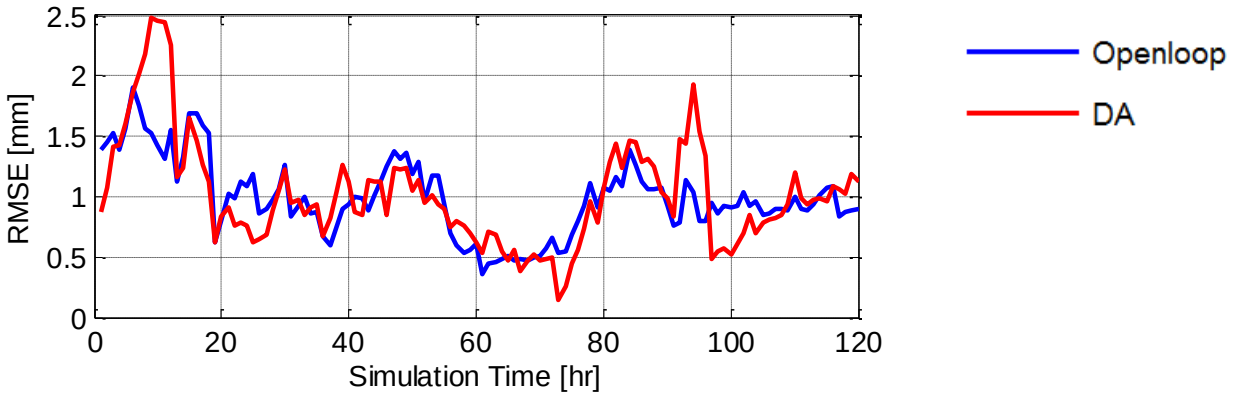
	RMSE [mm]	Abs. Diff. [mm]	Correlation
Openloop Run	20.42	14.35	0.48
DA Run	17.41	10.53	0.63

Hourly Domain Mean Precipitation (36-km)

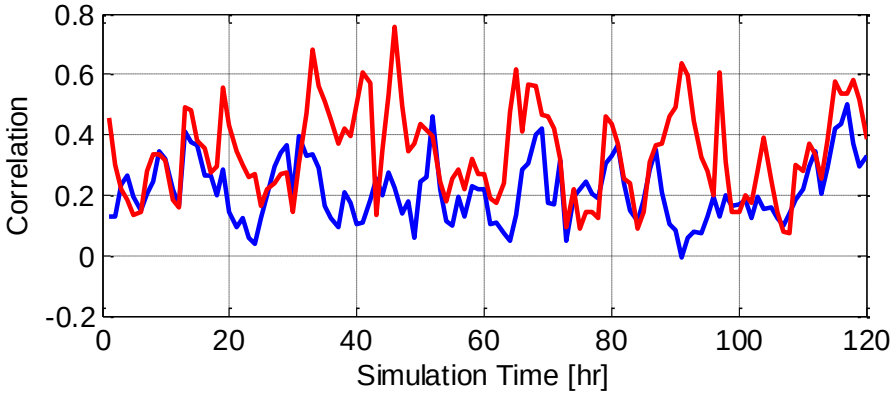


Hourly Precipitation Comparison (36-km)

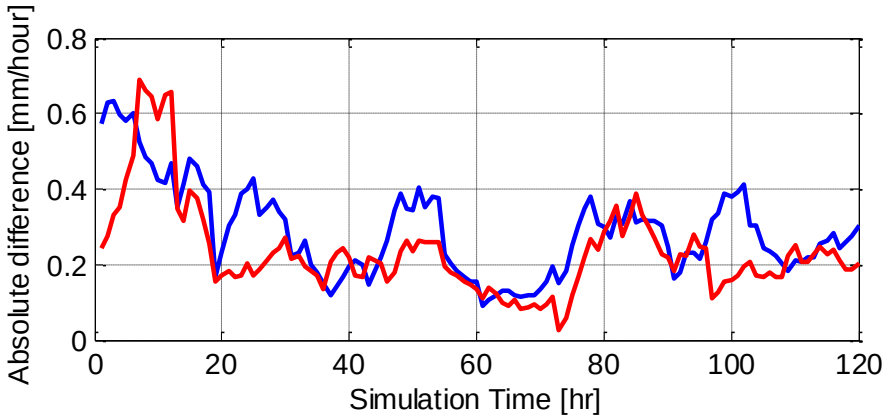
RMSE



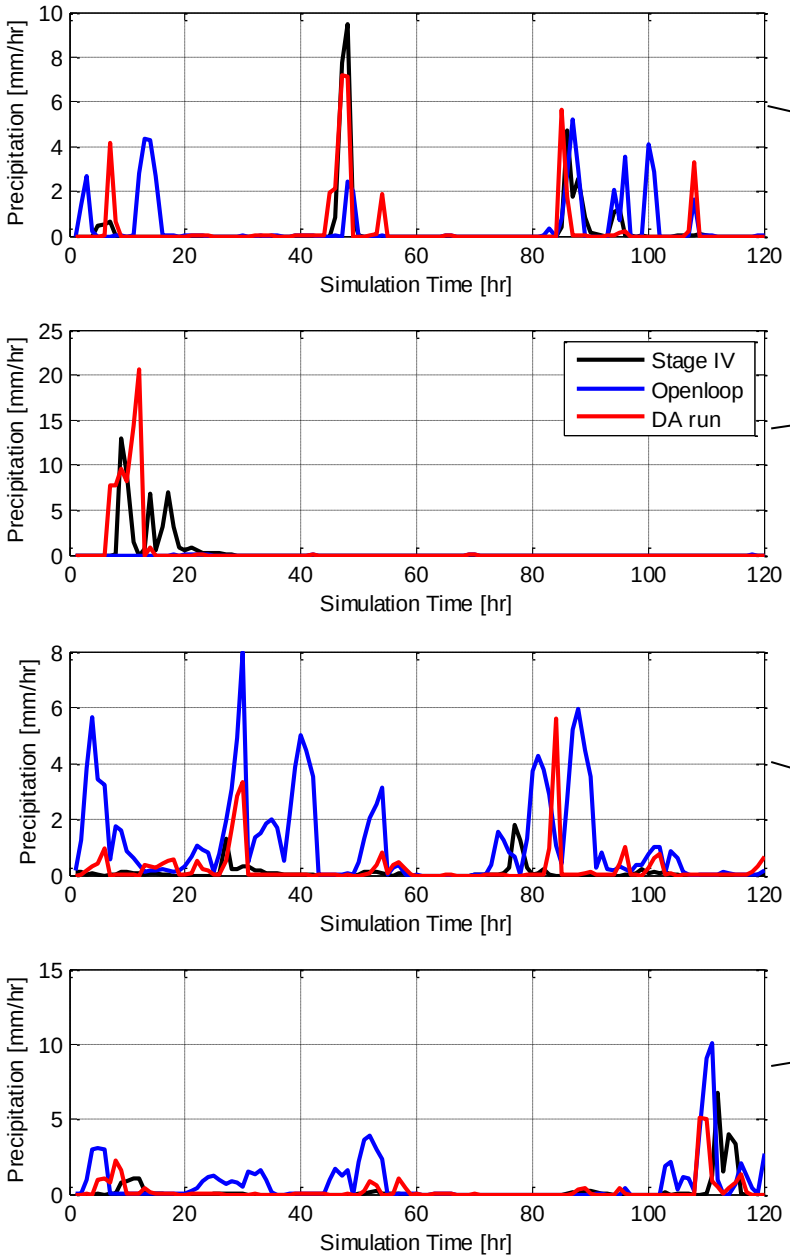
Correlation

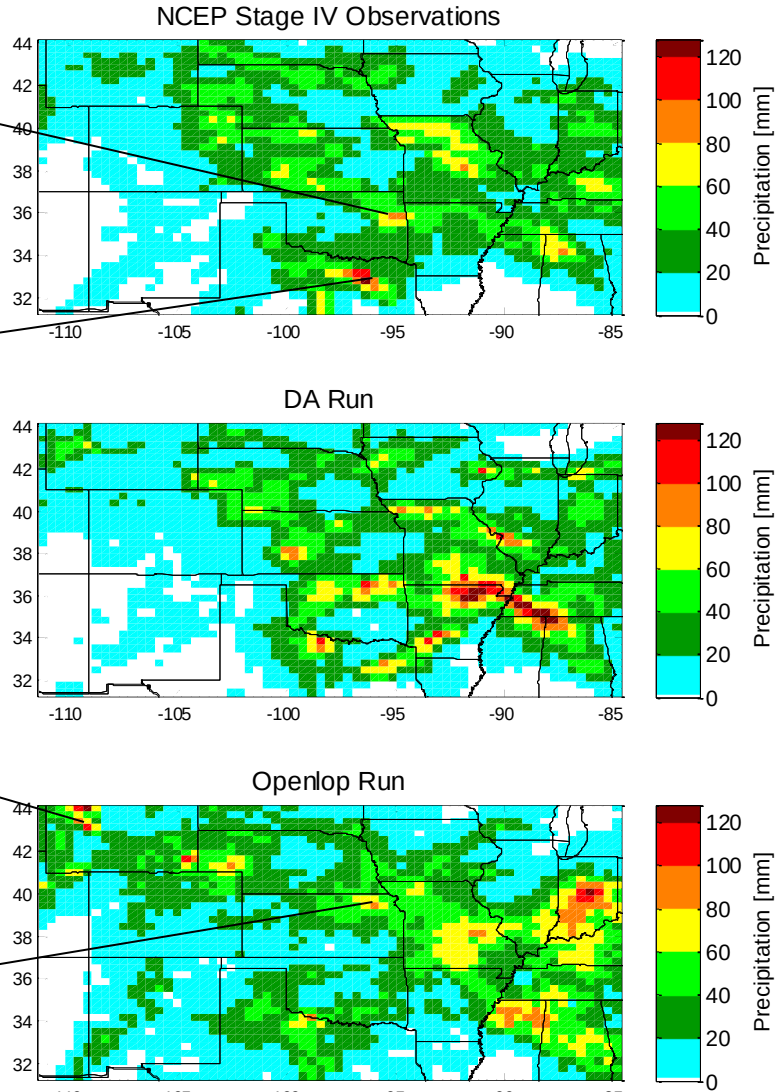


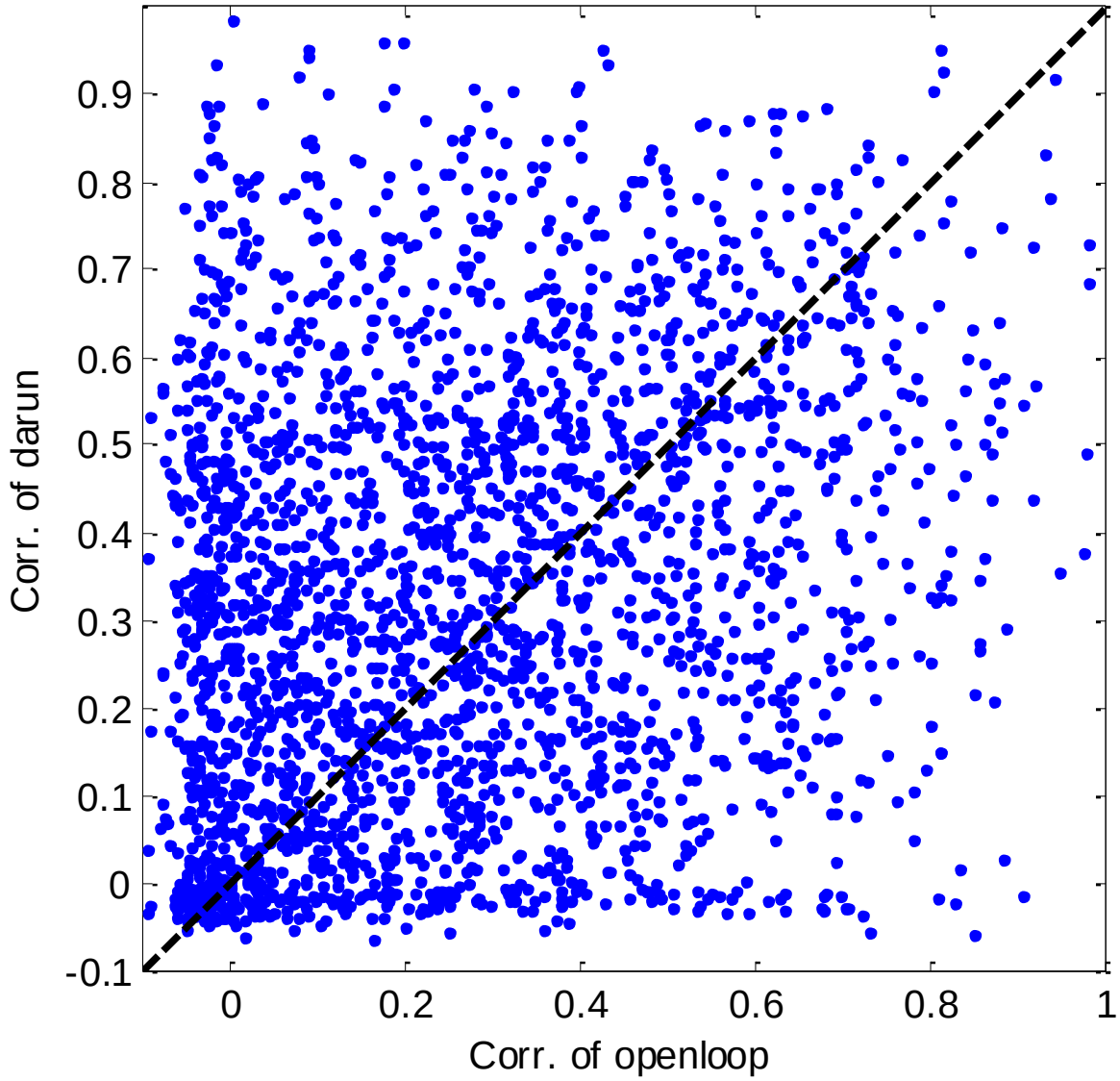
Abs. Difference



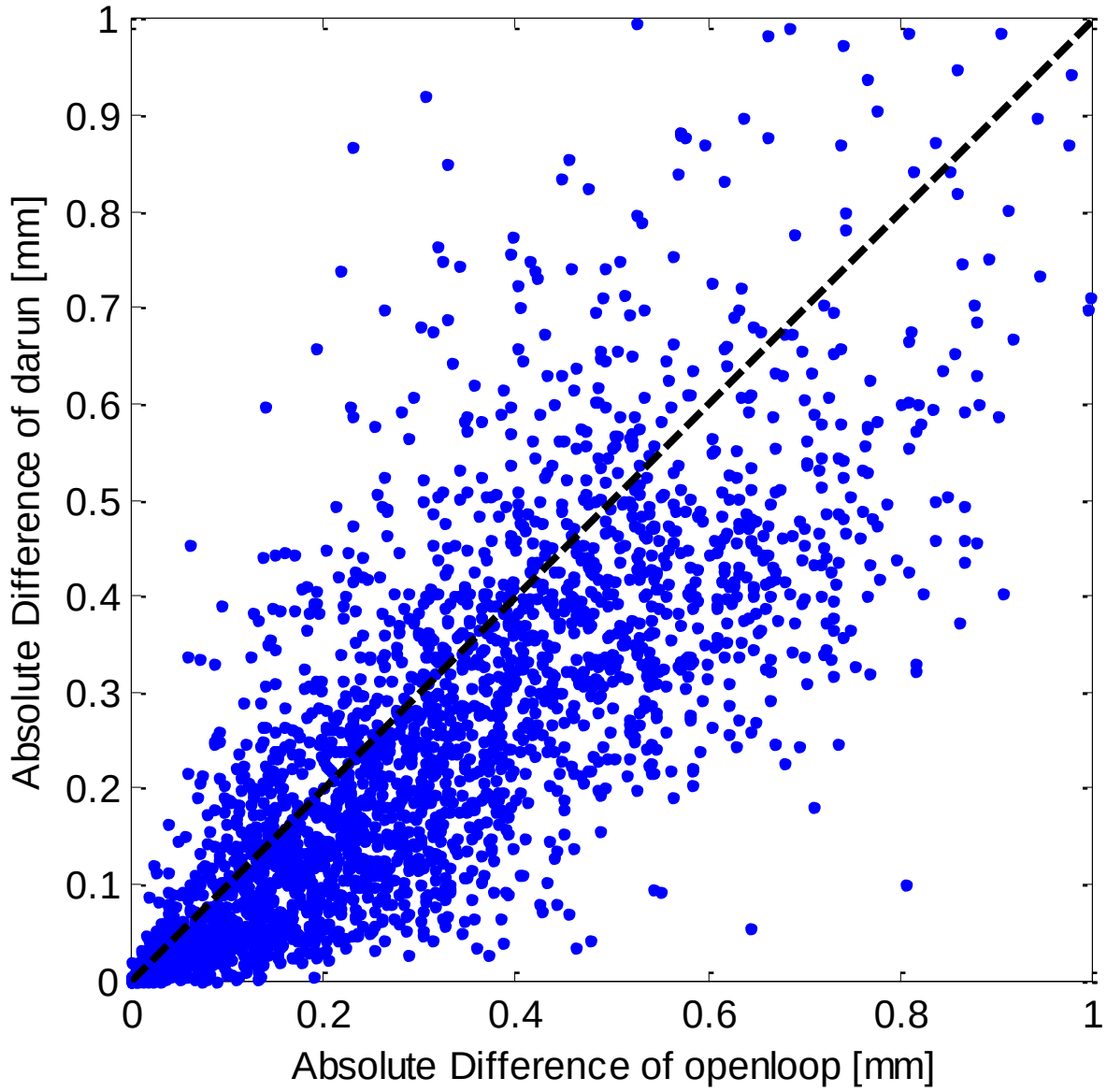
Time Series for Selected Points (36-km)



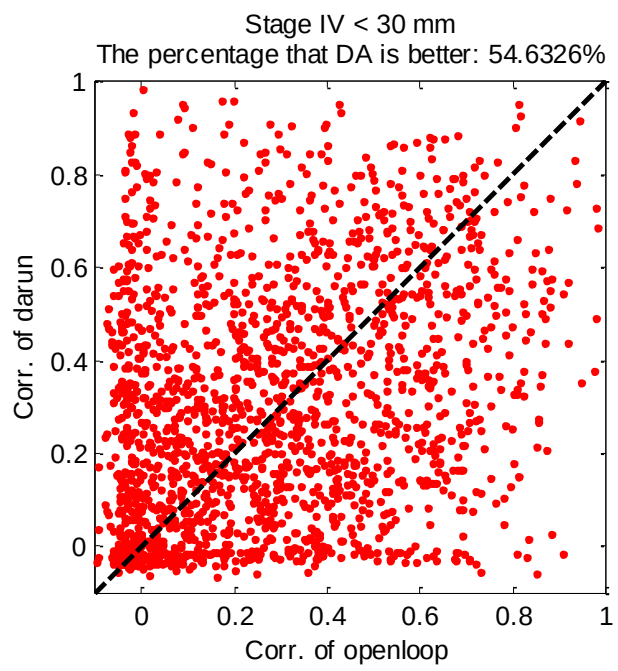


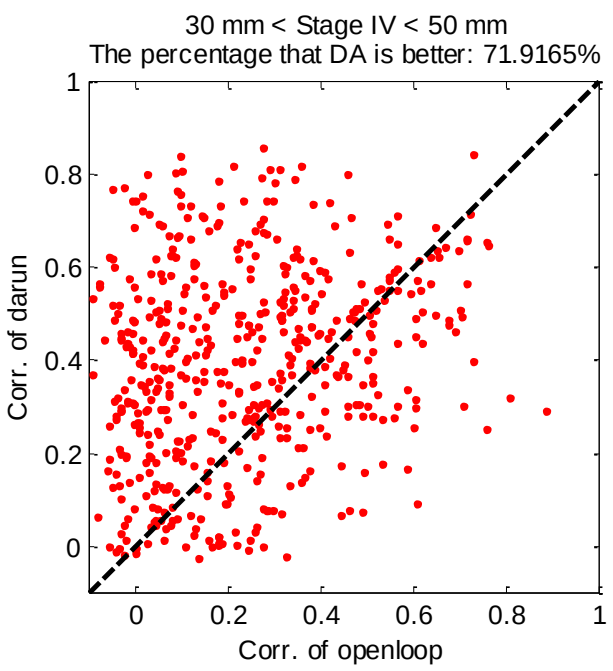


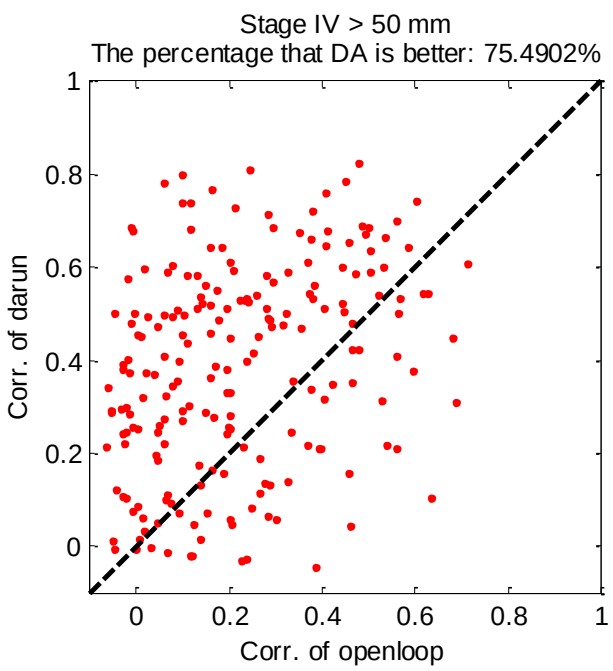
Above 45 degree line: 60% (Improvement rate of DA)

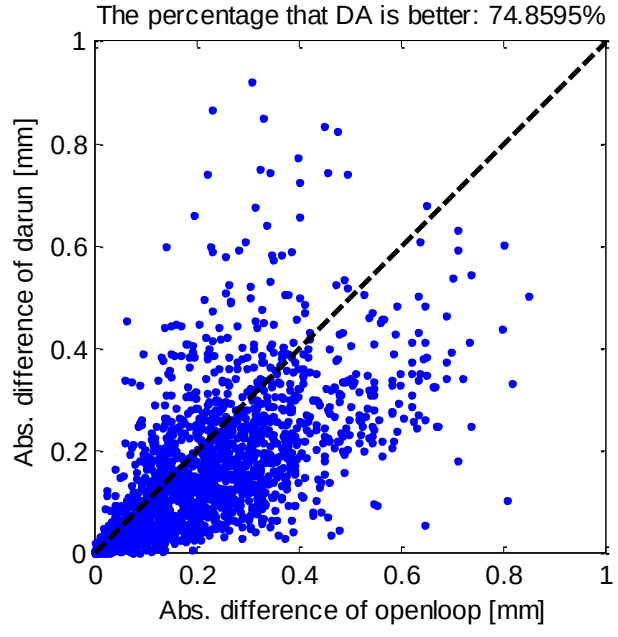


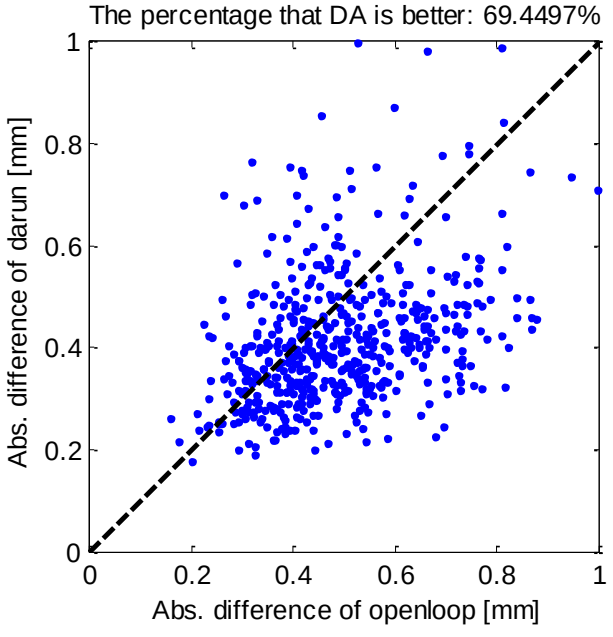
Below 45 degree line: 73% (Improvement rate of DA)

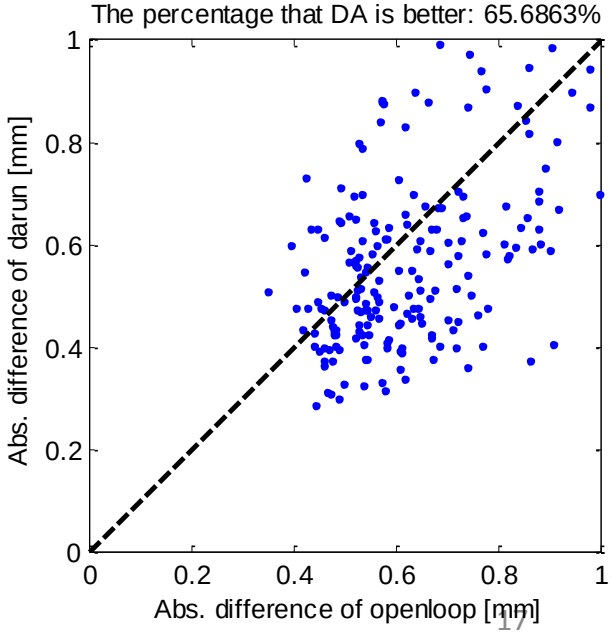

Stage IV < 30 mm
The percentage that DA is better: 54.6326%
Corr. of darun
Corr. of openloop

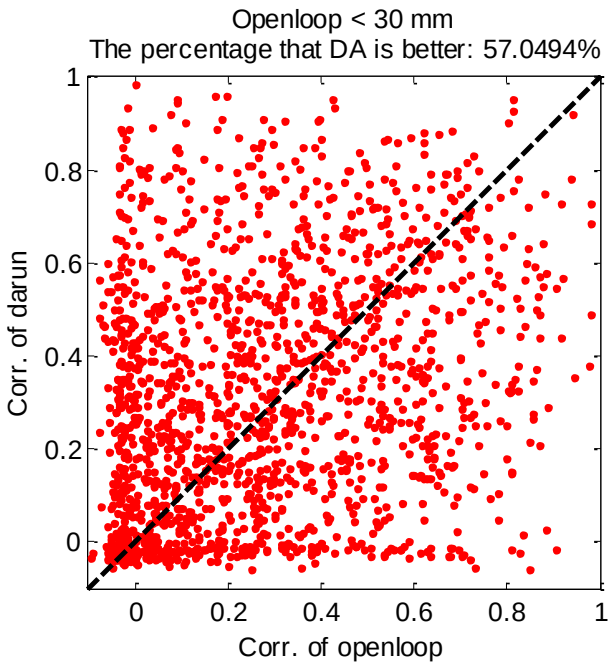

30 mm < Stage IV < 50 mm
The percentage that DA is better: 71.9165%
Corr. of darun
Corr. of openloop

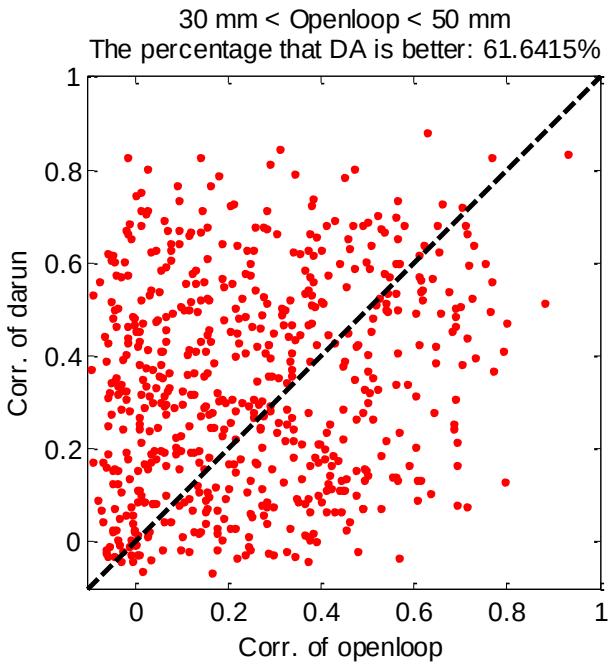

Stage IV > 50 mm
The percentage that DA is better: 75.4902%
Corr. of darun
Corr. of openloop

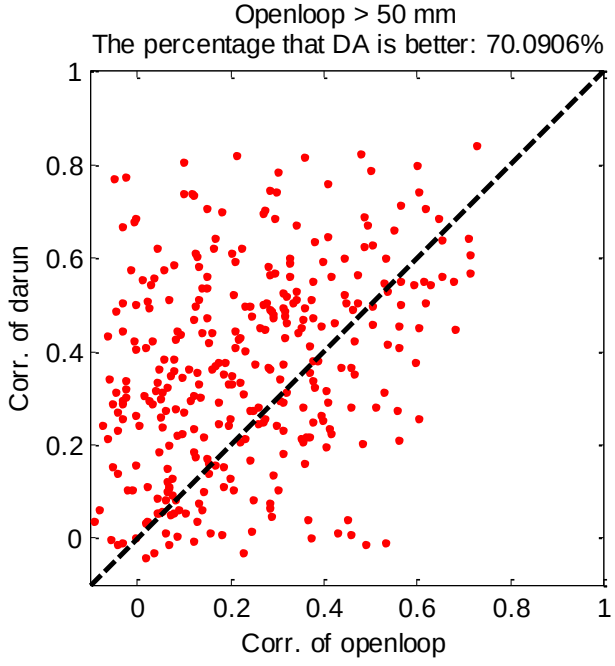

The percentage that DA is better: 74.8595%
Abs. difference of darun [mm]
Abs. difference of openloop [mm]

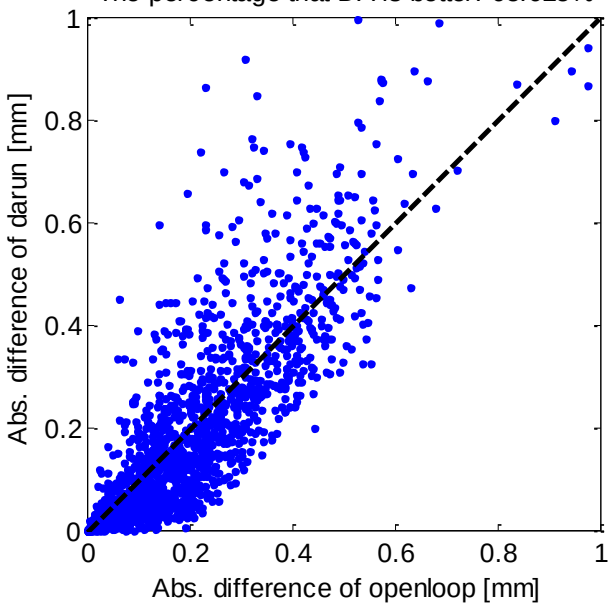

The percentage that DA is better: 69.4497%
Abs. difference of darun [mm]
Abs. difference of openloop [mm]

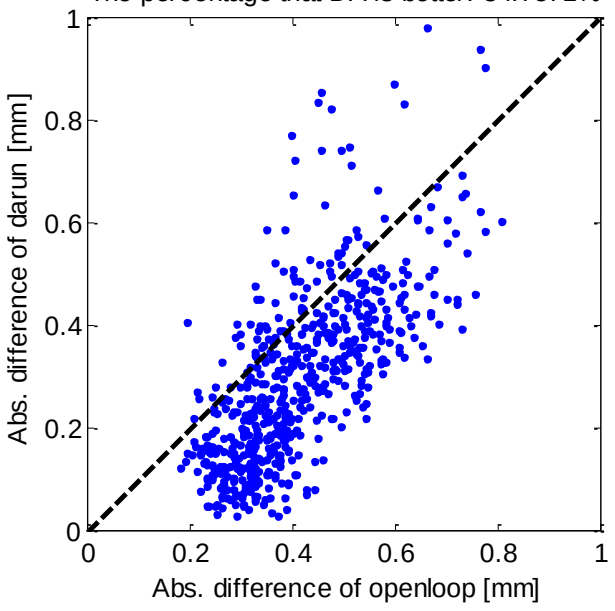

The percentage that DA is better: 65.6863%
Abs. difference of darun [mm]
Abs. difference of openloop [mm]

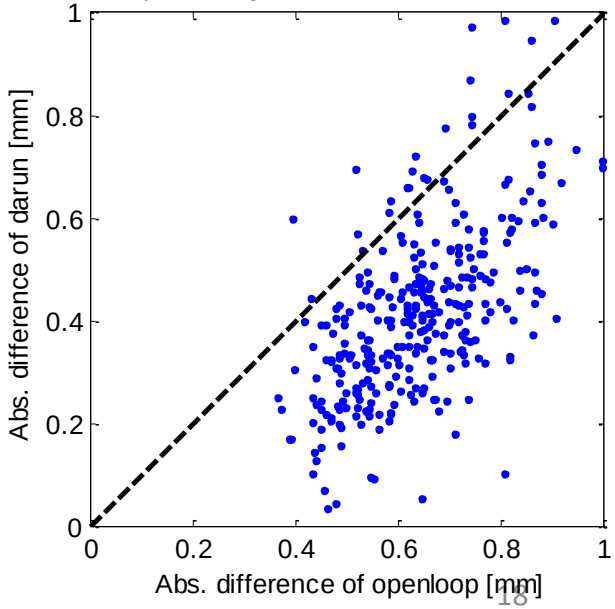

Openloop < 30 mm
The percentage that DA is better: 57.0494%
Corr. of darun
Corr. of openloop


30 mm < Openloop < 50 mm
The percentage that DA is better: 61.6415%
Corr. of darun
Corr. of openloop

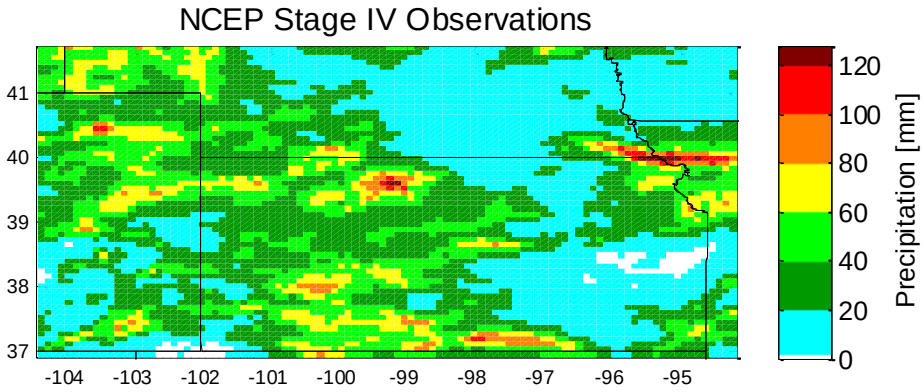

Openloop > 50 mm
The percentage that DA is better: 70.0906%
Corr. of darun
Corr. of openloop

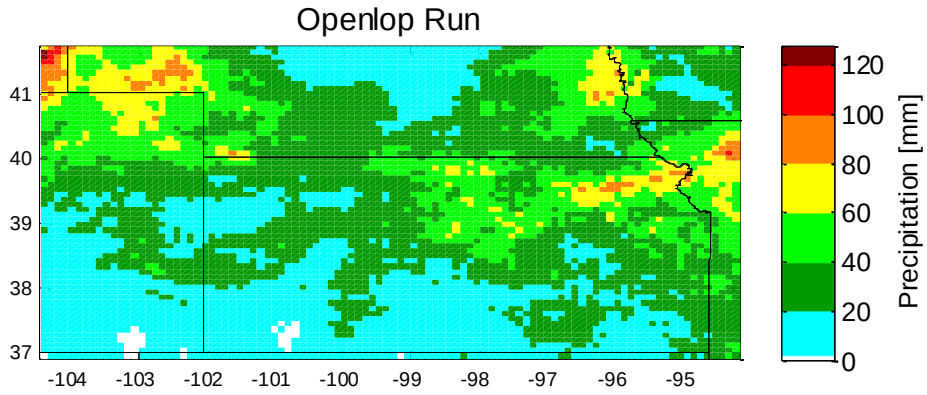

The percentage that DA is better: 65.625%
Abs. difference of darun [mm]
Abs. difference of openloop [mm]

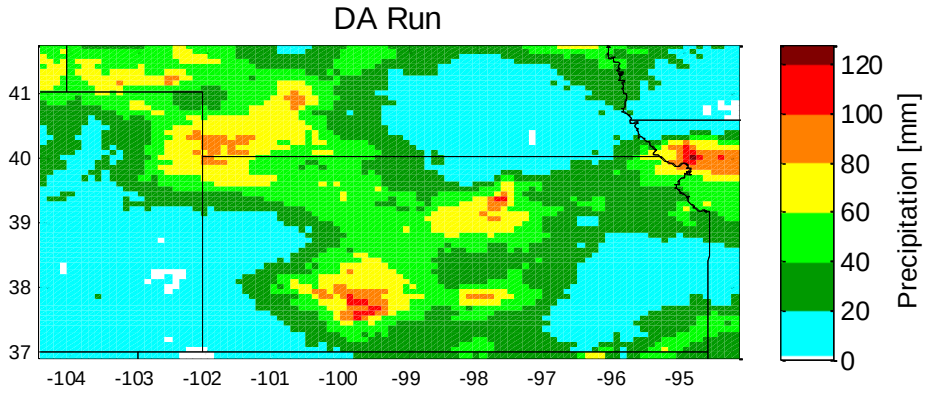

The percentage that DA is better: 84.7571%
Abs. difference of darun [mm]
Abs. difference of openloop [mm]


The percentage that DA is better: 91.8429%
Abs. difference of darun [mm]
Abs. difference of openloop [mm]

Five-day Precipitation Accumulation (9-km)

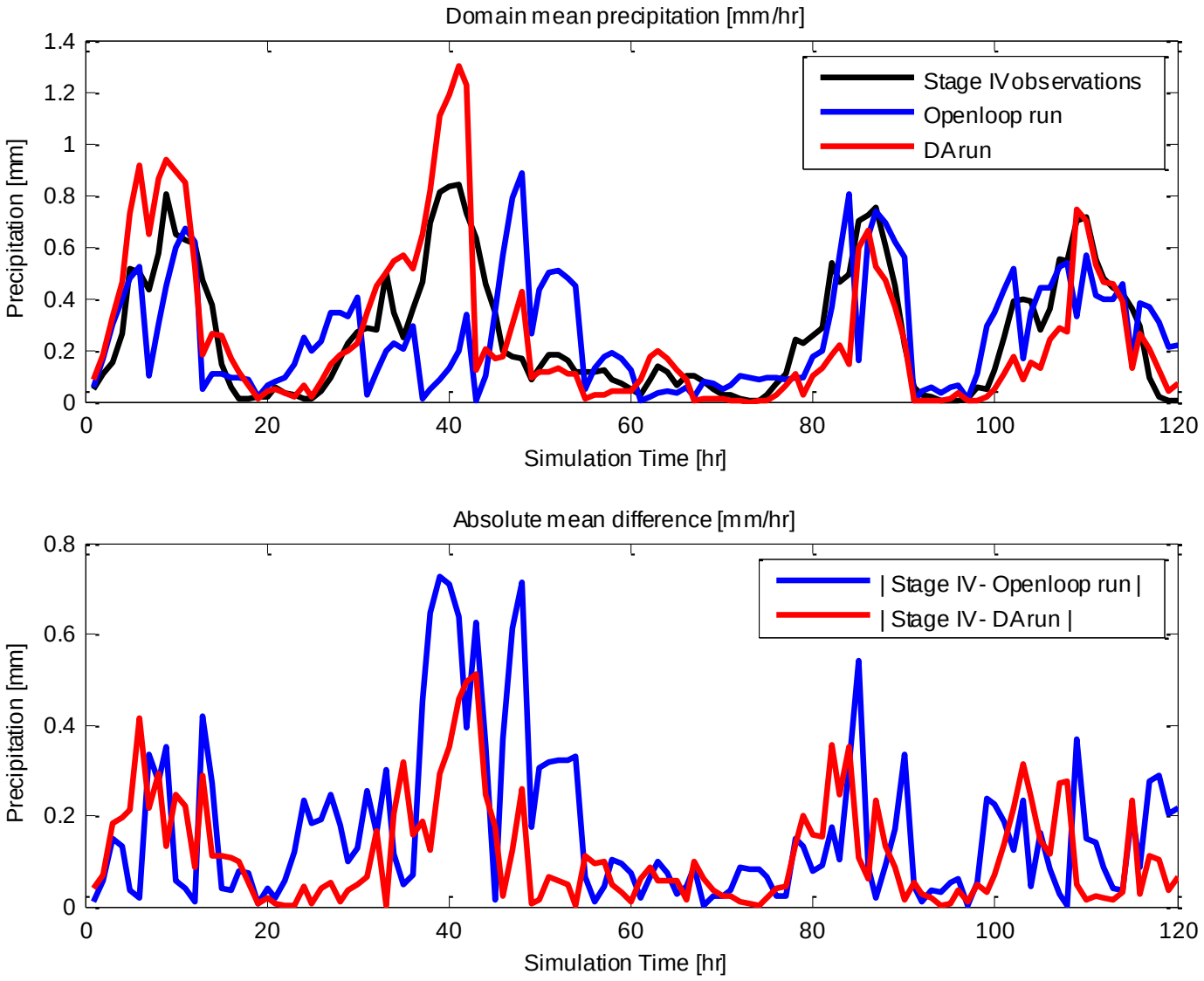






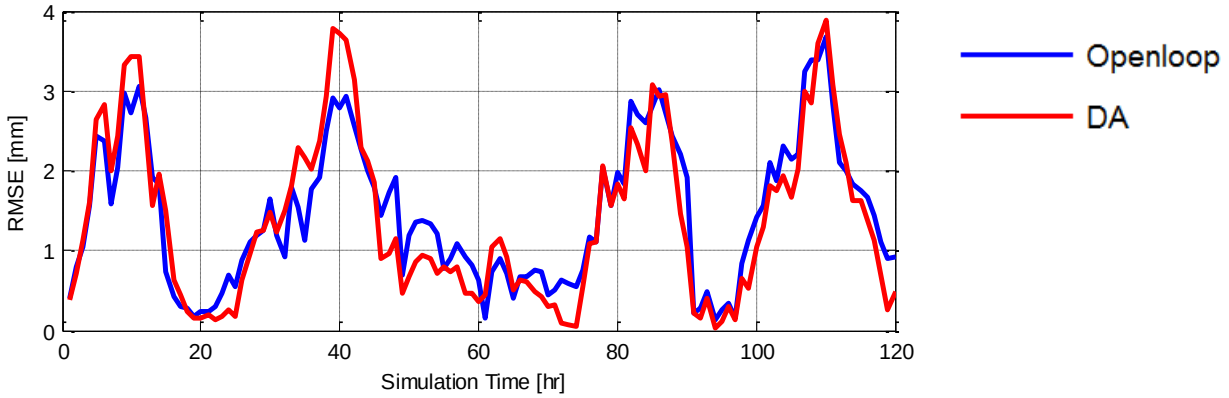
	RMSE [mm]	Abs. Diff. [mm]	Correlation
Openloop Run	25.68	20.06	0.14
DA Run	21.23	15.8	0.49

Hourly Domain Mean Precipitation (9-km)

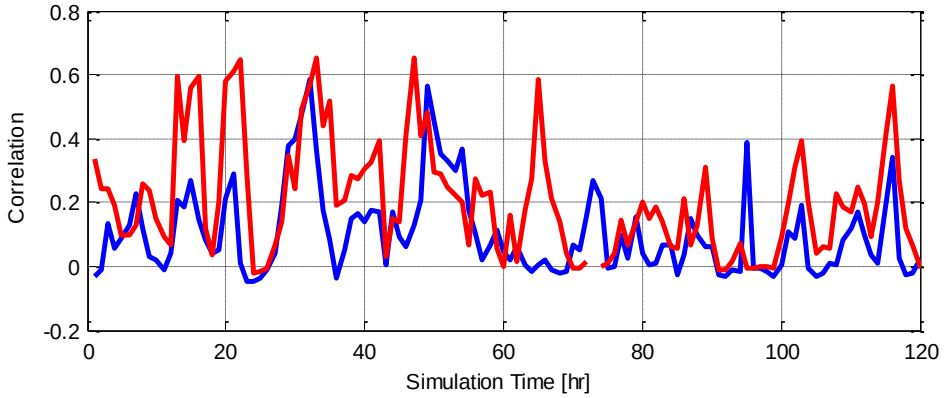


Hourly Precipitation Comparison (9-km)

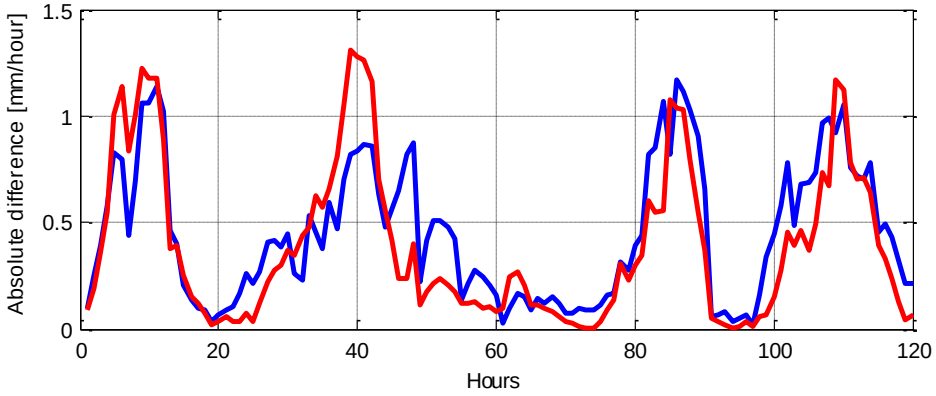
RMSE



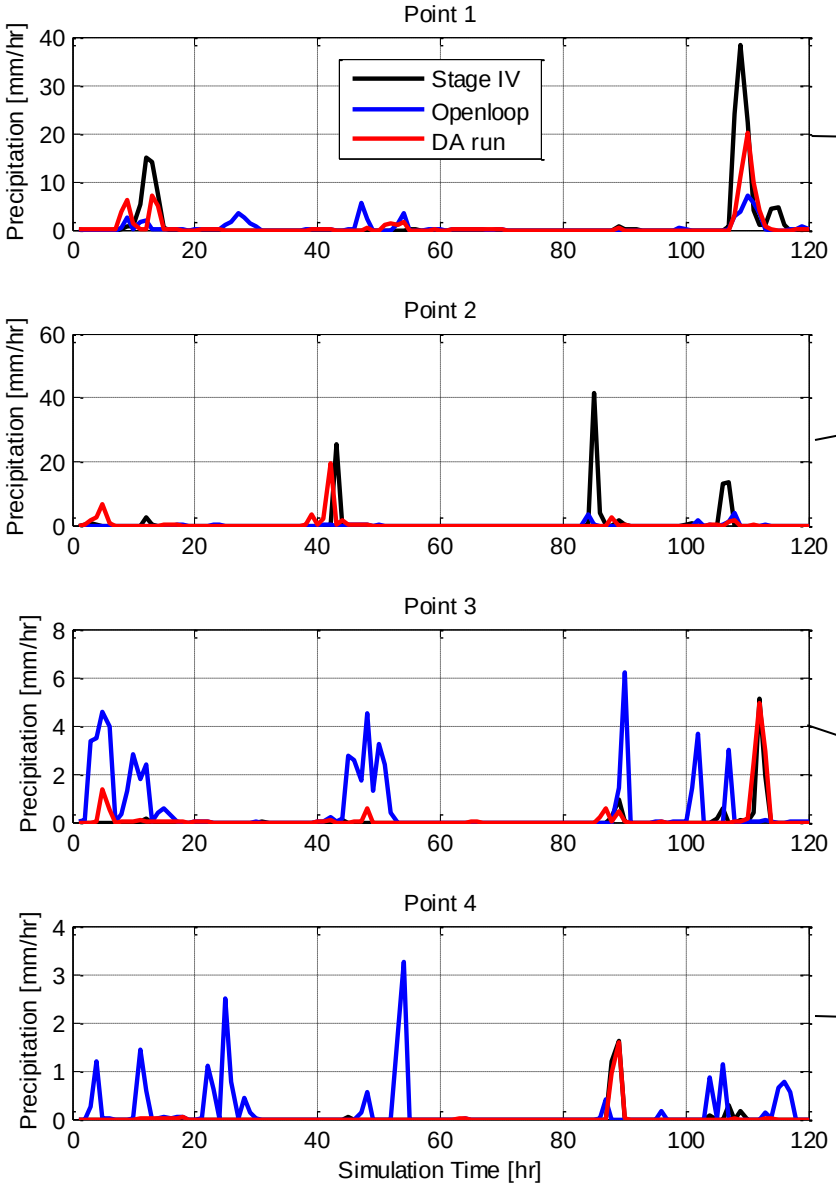
Correlation

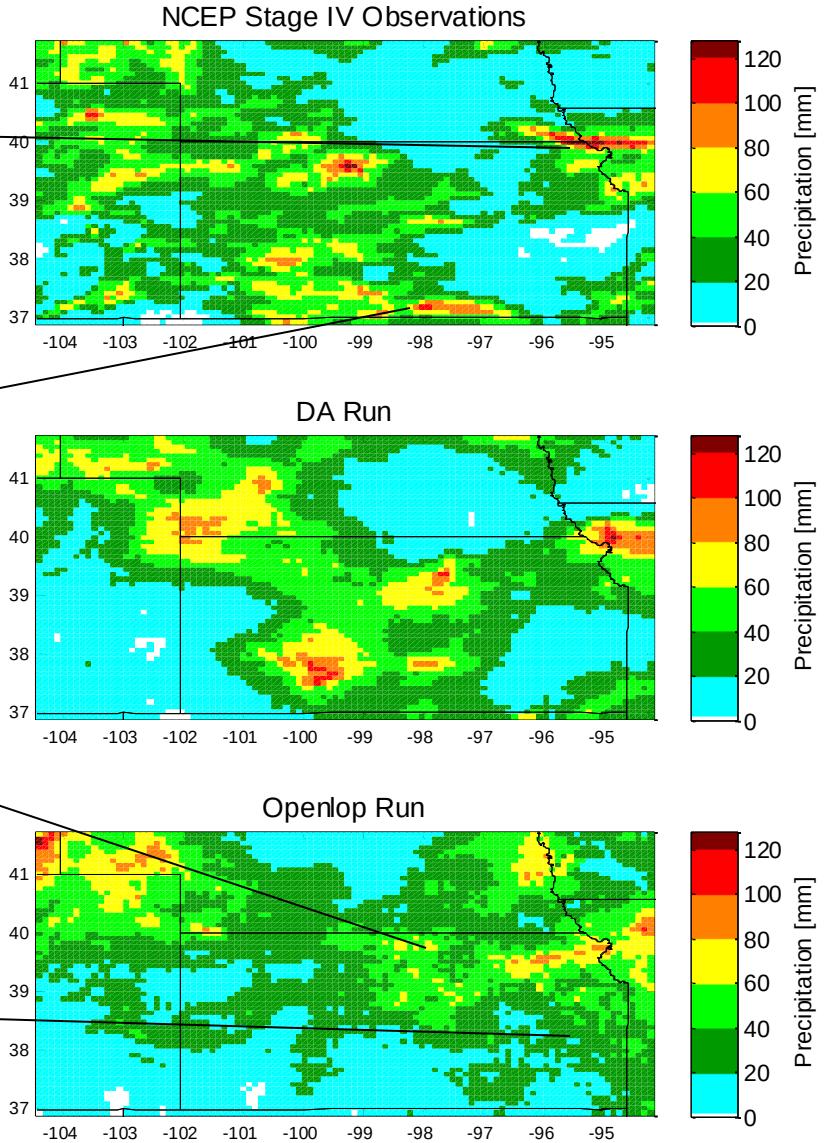


Abs. Difference



Time Series For Selected Points (9 km)





Summary

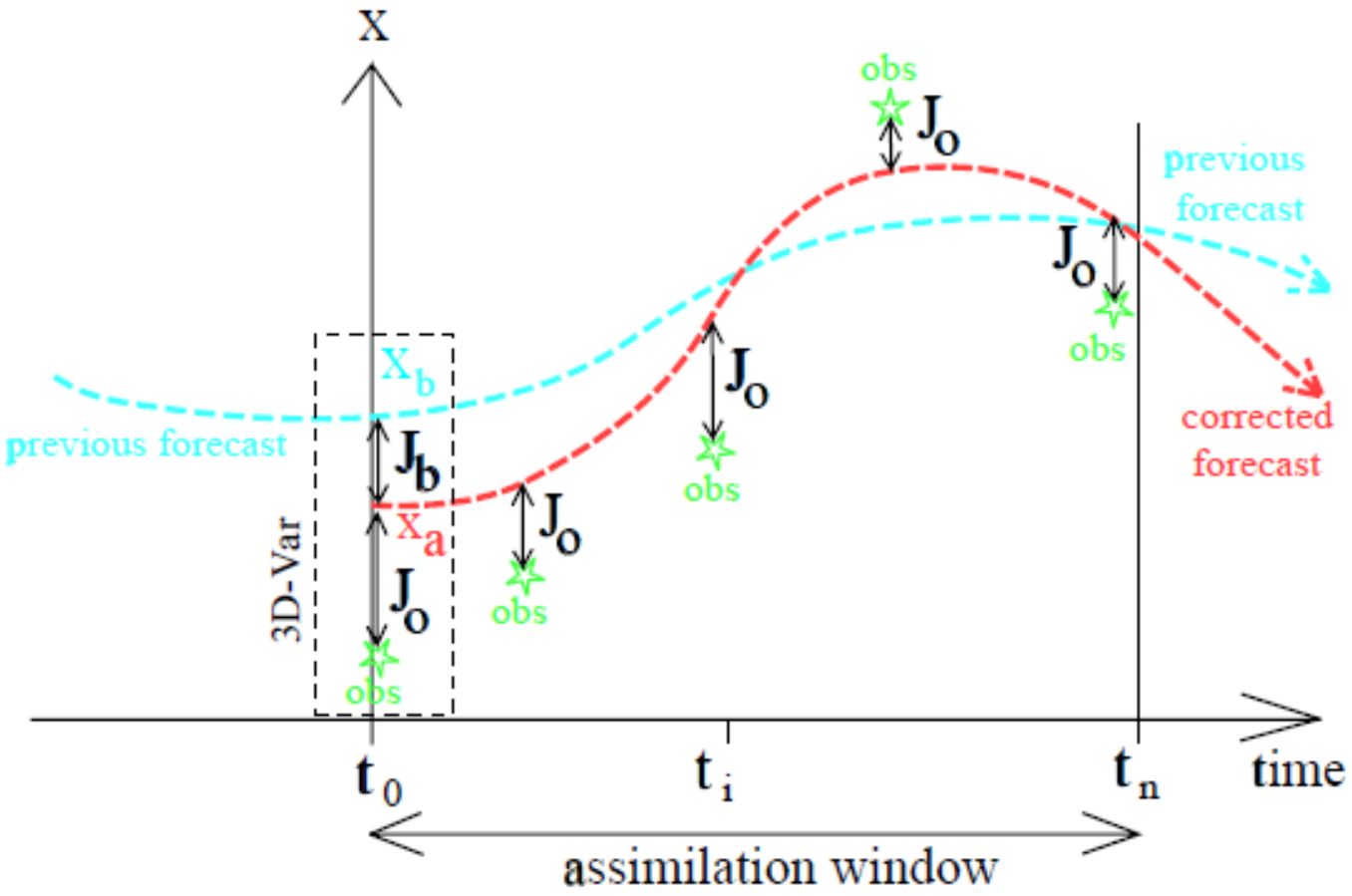
- The coarse-resolution GPM precipitation can be downscaled to finer temporal and spatial resolutions using WRFDA with improved results compared to that using WRF without DA.

- Five-day downscaled precipitation estimation with one-hour and 9-km resolutions is validated and results show that rainfall intensity and spatial distribution is much improved after 4DVAR DA.

- Future work will include the simultaneous DA of GPM precipitation and SMAP soil moisture.

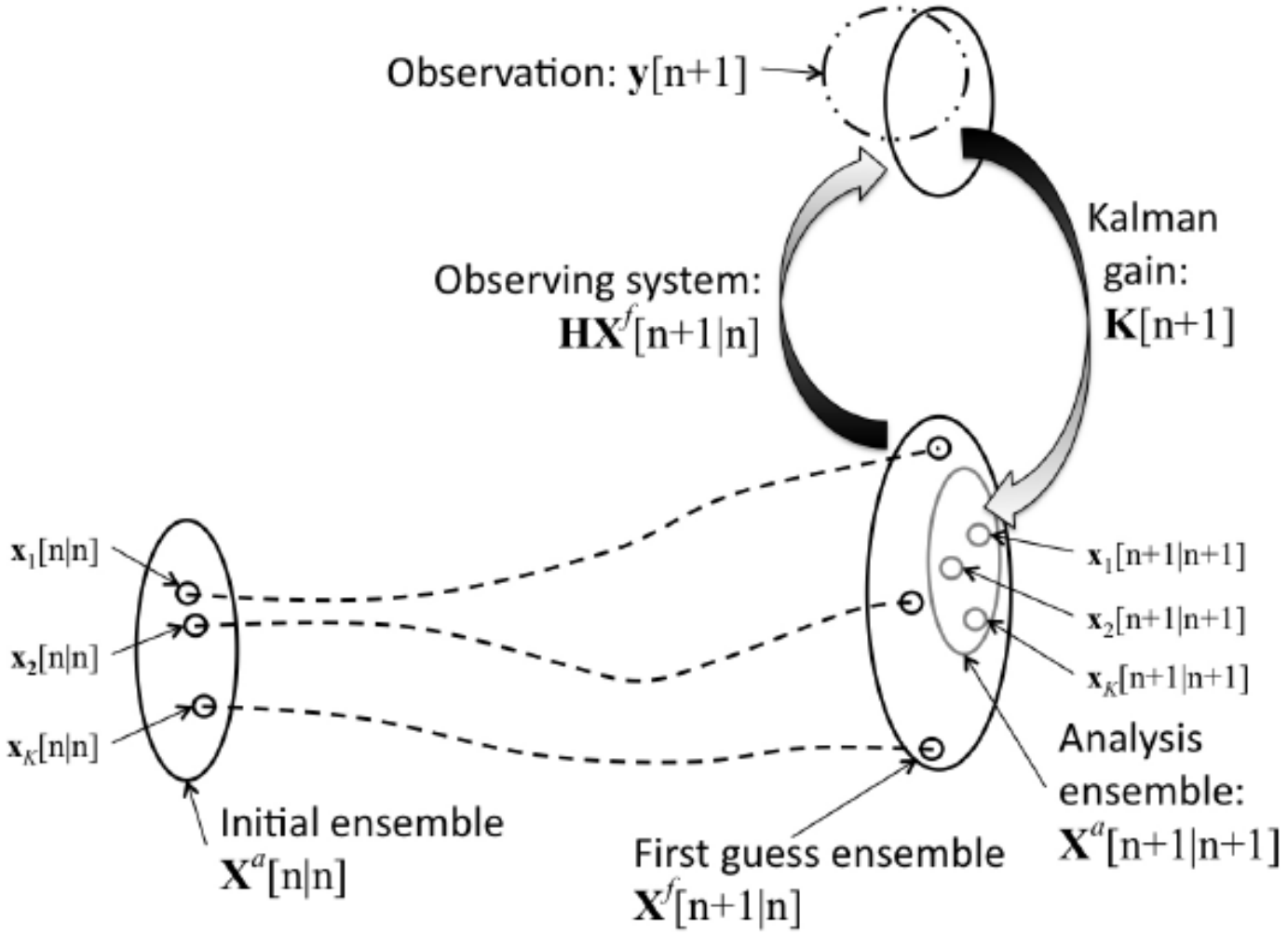
Acknowledgements: This study is sponsored by NASA PMM program through grants NNX11AQ33G and NNX10AG84G. We thank the support of the WRF Help group.

3DVAR & 4DVAR



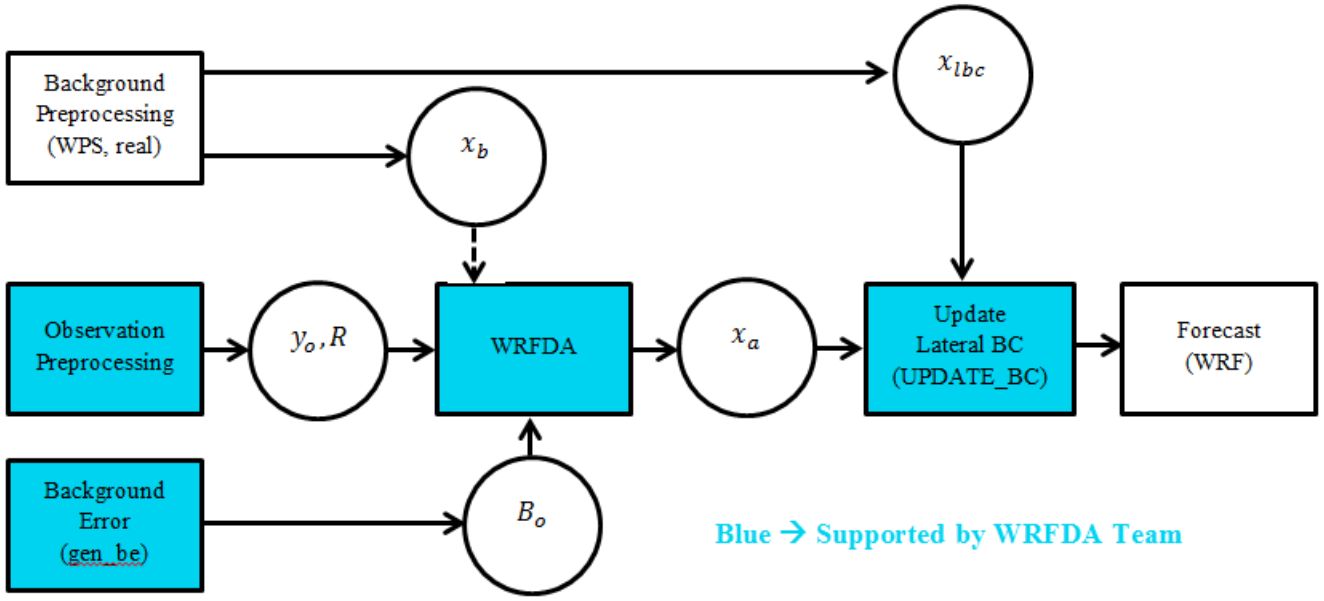
Bouttier and Coutier (1999)

EnKF



(Courtesy of A. Flores)

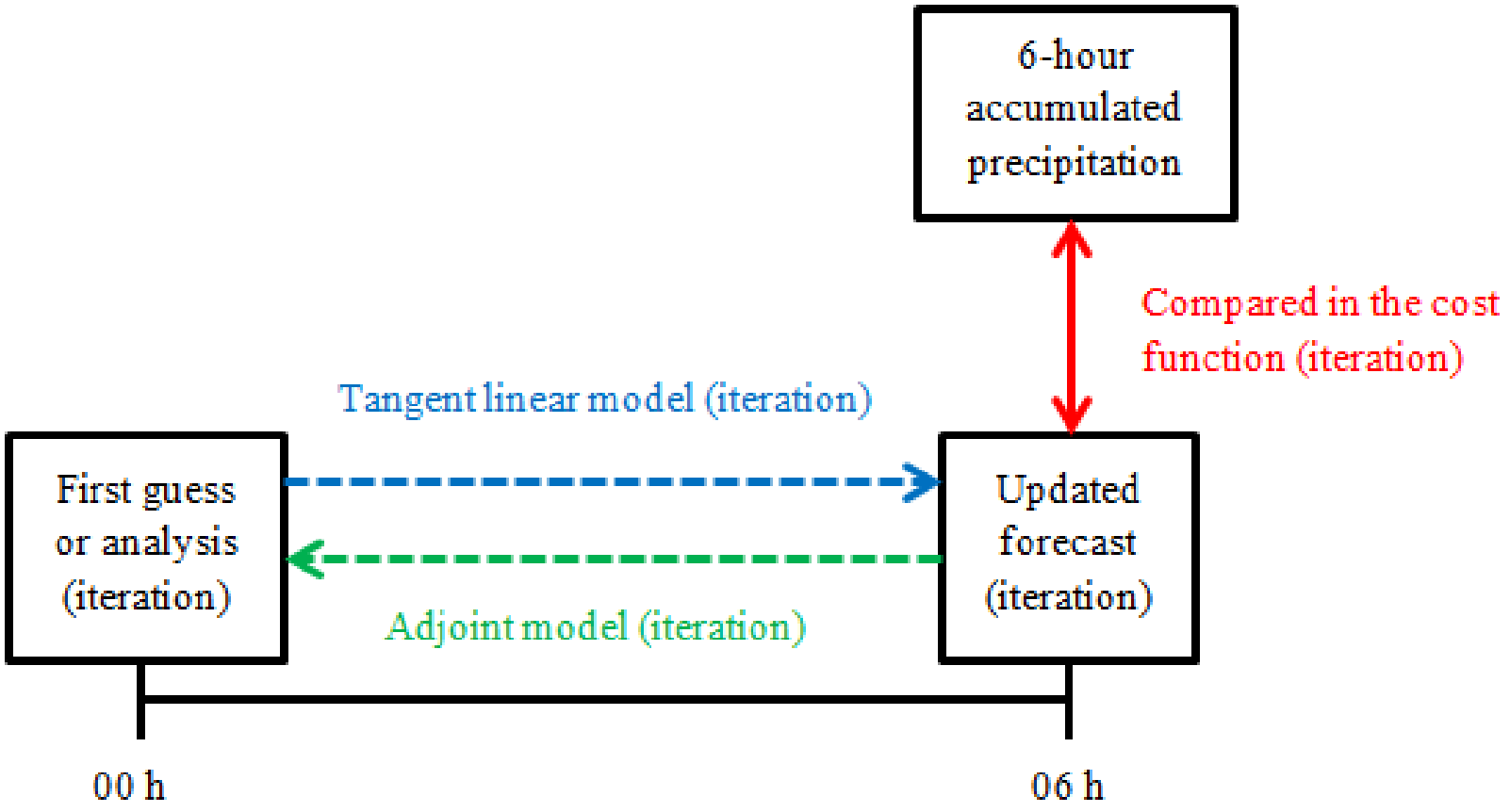
WRFDA



- Newest WRFDA for data assimilation and WRF for forward modeling (version 3.4)
- 3DVAR & 4DVAR
- Background error covariance from the National Meteorological Center (NMC) method. (Parrish and Derber 1992)

First guess of states (e.g. temperature, wind speed, specific humidity)
Lateral boundary condition from WPS/REAL output
Analysis from WRFDA
Observations
Background error covariance
Observational error covariance

Precipitation DA using 4DVAR



- First guess: From GCM forcing.
- The analysis: Updated every iteration through 4DVAR function.