The Assimilation of Layer Precipitable Water and the Impacts on Weather Forecasting in a Regional NWP Model

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Motivation

The forecast of local storms and tropical cyclones is very sensitive to the initial conditions (or the analysis atmospheric fields). Both the observed moisture information and the background fields directly affect the initial conditions through data assimilation, and then further affect the precipitation forecast. The Advanced Baseline Imager (ABI) from GOES-R can provide atmospheric water vapor with three water vapor absorption spectral bands during both day and night. The advanced Himawari-8 Imager (AHI) on Himawari-8 used operationally has almost the same features (spectral, spatial and temporal) as ABI in infrared bands. With high temporal and spatial resolution, humidity information from ABI and AHI can improve regional/storm scale data assimilation. The impacts of layer precipitable water (LPW) from ABI and AHI are assessed using WRF-ARW / GSI systems on CONUS storm and Typhoon Soudelor (2015).

Our study focused on the following questions:

- How to use the LPW data in the assimilation system and NWP model?
- What is the impact of the LPW data in regional NWP model, especially for the precipitation forecast?
- What is the impact of the LPW for Typhoon Soudelor (2015) track and intensity forecast?

Data and Experiment Design

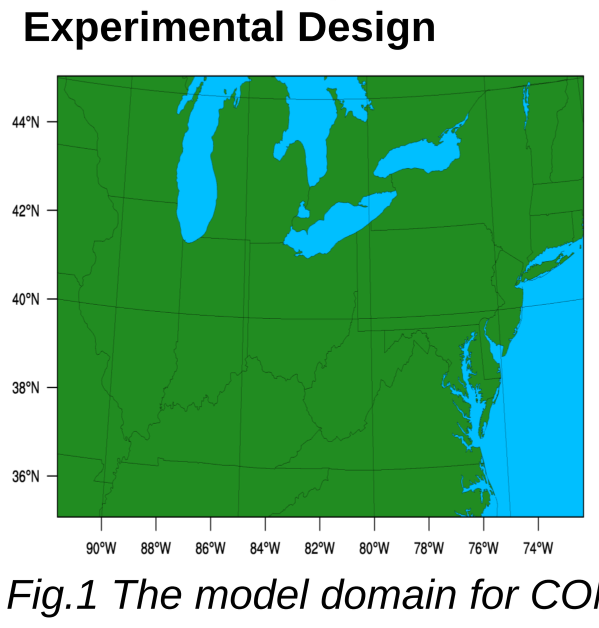
Data

- Conventional Data (GTS)
- Layer Precipitable Water (LPW) based on the GOES-R Advanced Baseline Imager (ABI) LAP algorithm.
- LPW based on the Himawari-8 Imager (AHI) LAP algorithm.
- Three layers of LPW: sigma level values (0.3-0.7, 0.7-0.9, and 0.9-1)
- Background data from NCEP FNL
- AMV from Himawari-8 AHI IR bands

Models

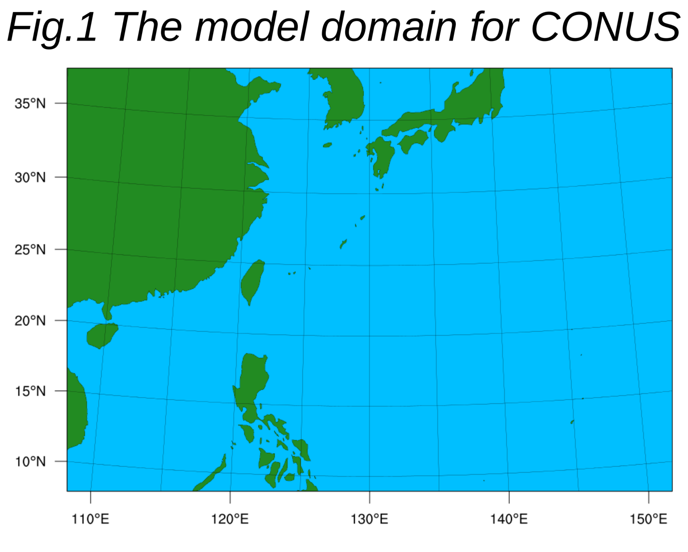
- Data Assimilation: DTC- GSI V3.3.
- A foreword operator for LPW and the related module has been implemented in GSI V3.3 system.
- Regional Forecast Model: WRF (ARW) V3.6.1
- 4 km horizontal resolution for CONUS case
- 12 km horizontal resolution for Typhoon Soudelor
- 51 vertical layers from surface to 10 hPa

Experimental Design



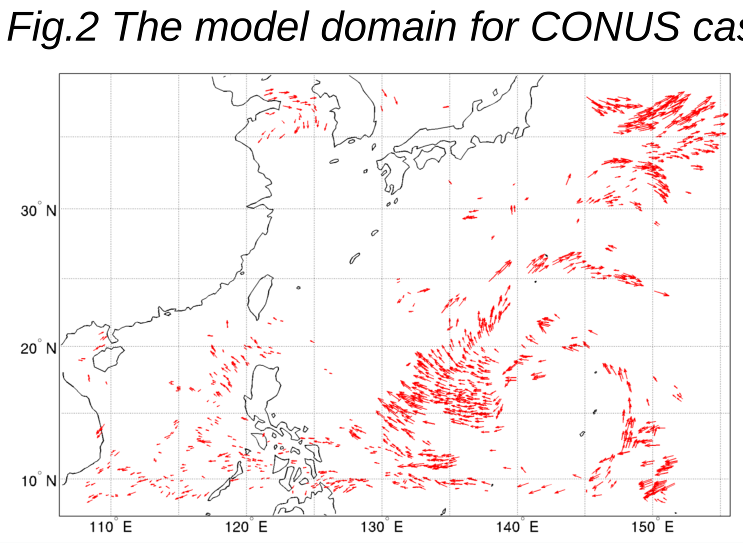
Spin-up: 2012-6-29 06z to 12z
Assimilation: 2012-6-29 12z
Forecast: 2012-6-29 12z to 2012-6-30 12z

Fig.1 The model domain for CONUS case



Assimilation: 2015-8-3 00z to 2015-8-5 00z
Forecast: 2015-8-3 00z to 2015-8-8 00z

Fig.2 The model domain for CONUS case



AHI AMV observations (coverage) After GSI QC

Forecast Verification Scores

Table I: Contingency table used in verification statistics for dichotomous (et. Yes/No) forecasts and observations.

Forecast	Observation: Yes	Observation: No	
Yes	Hits (YY)	False Alarms (YN)	YY + YN
No	Misses (NY)	Correct rejections (NN)	NY + NN
	YY + NY	YN + NN	**Total = YY + YN + NY + NN**

- **Equitable Threat Score (ETS)**
  ETS = (YY – Hits random) / (YY + NY +YN – Hits random)
  Hits random = (YY + YN) (YY + NY) / Total

Part I: Results of CONUS Case Study

6-hour forecast precipitation 2012-06-29 18z to 30 00z

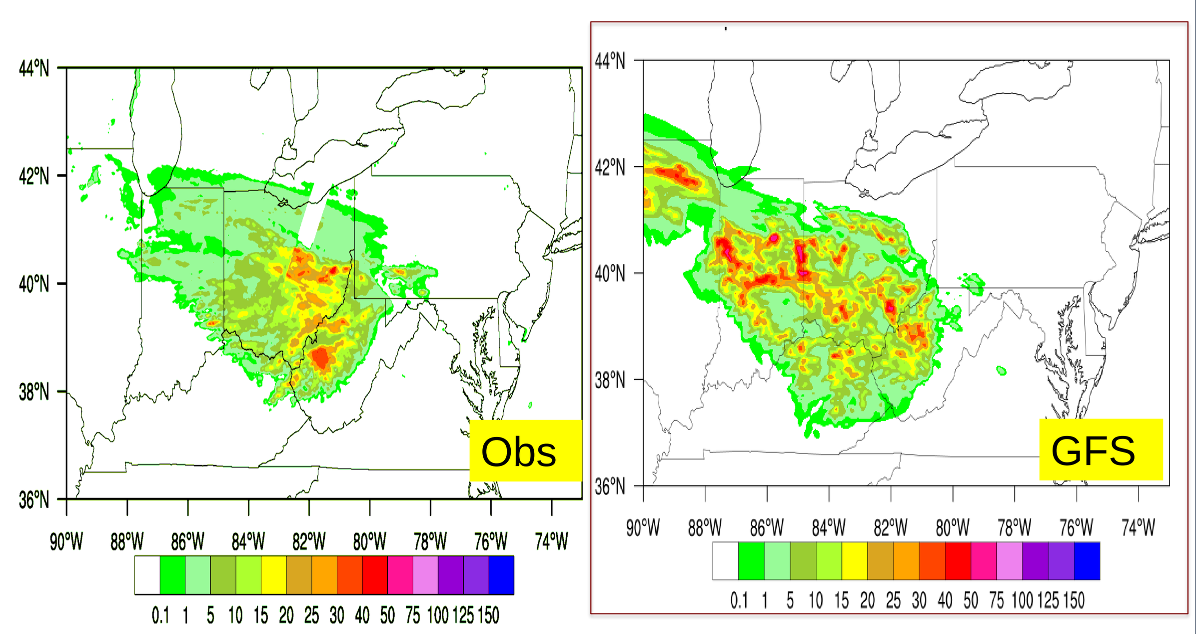


Fig 3. The 6-h accumulated precipitation of observations (Obs), NCEP GFS analysis as background from 2012-06-29 18z to 30 00z

Assimilation of LPW data

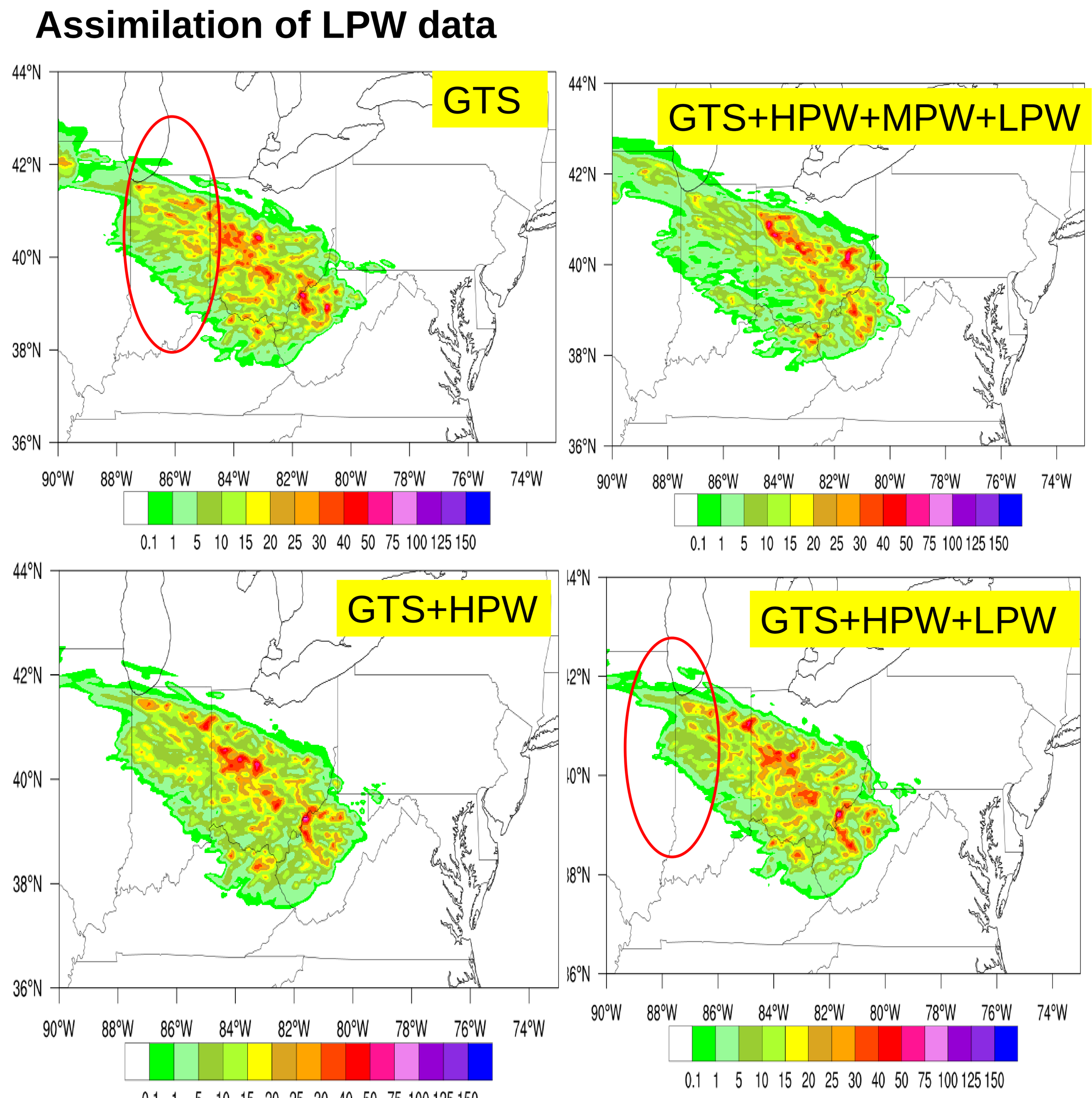
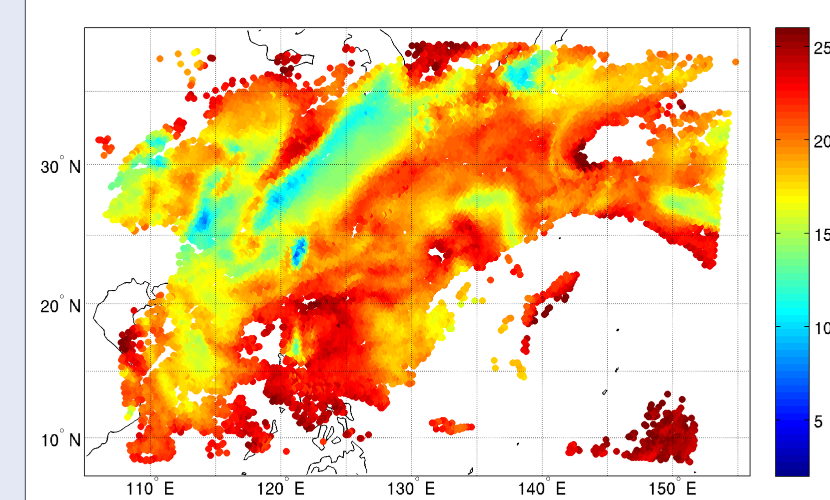


Fig 4. The 6-h accumulated precipitation of assimilation of GTS, GTS+HighPW+MidPW+LowPW, GTS+HighPW and GTS+HighPW+LowPW from 2012-06-29 18z to 30 00z

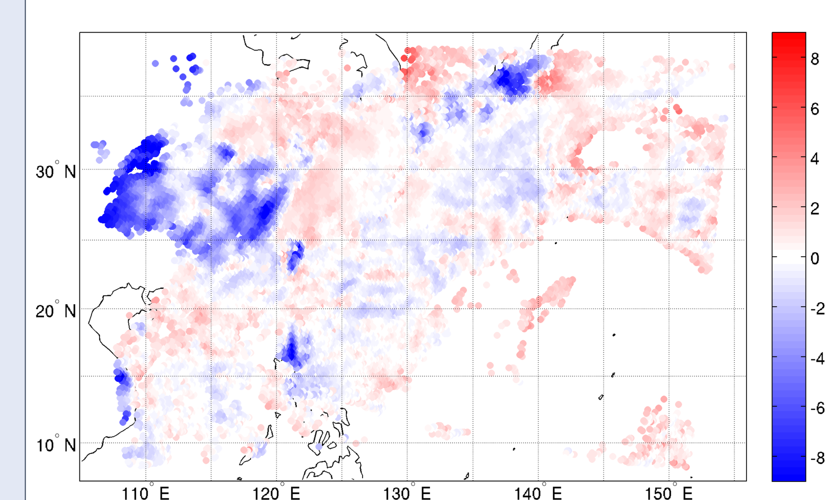
2012-6-29 18z to 30 00z				
ETS scores	0.1 mm	1 mm	5 mm	10 mm
GTS	**0.5393**	**0.4978**	**0.4243**	**0.2330**
GTS+LPW(H)	0.5639	0.5403	0.4447	0.2315
GTS+LPW(M)	0.4881	0.4137	0.3066	0.1770
GTS+LPW(L)	0.5446	0.5093	0.4312	0.2364
GTS+LPW(HM)	0.5578	0.5386	0.4486	**0.2412**
GTS+LPW(ML)	0.5335	0.4925	0.4274	0.2309
GTS+LPW(HL)	**0.5800**	**0.5644**	**0.4510**	0.2302
GTS+LPW(HML)	0.5434	0.4854	0.4171	0.2958

Table II: The ETS scores for precipitation.

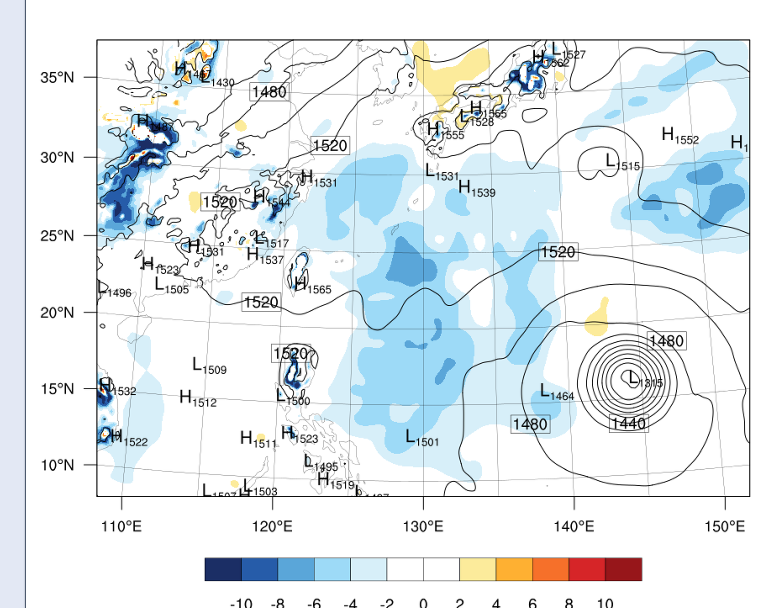
Part II: Results of Typhoon Soudelor (2015)



AHI Layer PW observations (sigma level 0.7-0.9) (unit: mm)

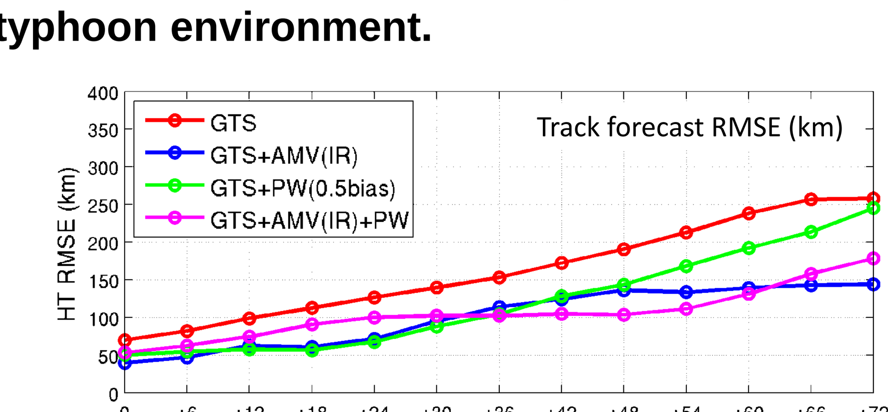


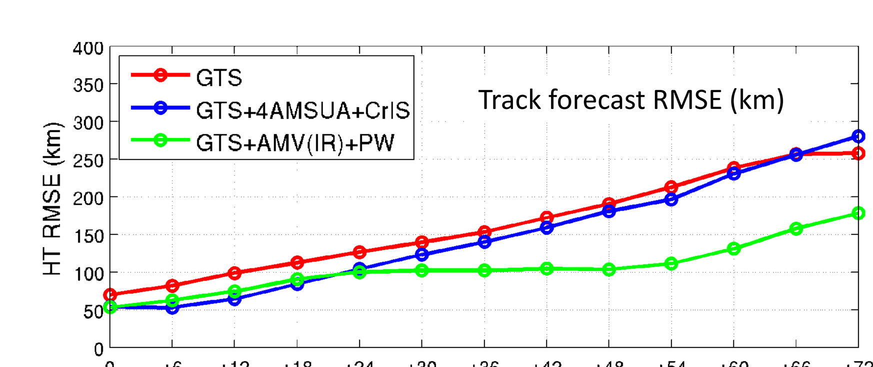
Lower PW Innovation (O-B) (unit: mm)



850 hPa specific humidity (g/g) analysis difference between assimilating GTS plus three layer PW and assimilating GTS only at 00z 03 August, 2015.

Compared with AHI three LPW observations in the environment, the NWP model background is drier in the upper troposphere and wetter in the boundary layer for Typhoon Soudelor case. After assimilation of AHI three LPW observations, 850 hPa analysis is less humidity in the typhoon environment.





- Compared with assimilating conventional data only, adding AMVs or PW (from 3 layers) improves the analysis fields.
- Both AMVs and PW improve track forecasts.
- PW improves intensity forecast after 12 hours, AMVs improves intensity forecasts after 54 hours.

Summary and Future work

- The LPW from GOES Sounder data could be assimilated in GSI V3.3 successfully. The three layers PW data (High PW, Mid PW and Low PW) can be assimilated separately.
- For CONUS case, the ETS scores showed that the combination of high PW and low PW together could provide best precipitation forecasts.
- For Typhoon Soudelor (2015), the assimilation of PW (from 3 layers) and AMVs can improve typhoon track forecasts. The combination of AMVs and PW together can further improve track forecasts after 30 hours. The results of assimilation of LEO and GEO satellites are comparable.
- More case studies will be done in the future, including tropical cyclones and storms.

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