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 forward 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 to 2012-6-30 12z

Forecast Verification Scores

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

<table>
<thead>
<tr>
<th>Forecast</th>
<th>Observation</th>
<th>Hits</th>
<th>False Alarms</th>
<th>Misses</th>
<th>Correct Rejections</th>
<th>ETS Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>YY</td>
<td>0</td>
<td>YY</td>
<td>YY + NY</td>
<td>YY + NY</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>YN</td>
<td>0</td>
<td>NY</td>
<td>NY + NN</td>
<td>NY + NN</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>YN</td>
<td>0</td>
<td>YY</td>
<td>YY + NY</td>
<td>YY + NY</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

ETS = (YY + YN) / (YY + NY + YN + NN)

Table II: The ETS scores for precipitation.

<table>
<thead>
<tr>
<th>ETS scores</th>
<th>0.1 mm</th>
<th>1 mm</th>
<th>5 mm</th>
<th>10 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTS</td>
<td>0.5393</td>
<td>0.4978</td>
<td>0.4243</td>
<td>0.2330</td>
</tr>
<tr>
<td>GTS+LPW(H)</td>
<td>0.5639</td>
<td>0.5403</td>
<td>0.4447</td>
<td>0.2315</td>
</tr>
<tr>
<td>GTS+LPW(M)</td>
<td>0.4881</td>
<td>0.4137</td>
<td>0.3066</td>
<td>0.1770</td>
</tr>
<tr>
<td>GTS+LPW(L)</td>
<td>0.5446</td>
<td>0.5093</td>
<td>0.4312</td>
<td>0.2364</td>
</tr>
<tr>
<td>GTS+LPW(HM)</td>
<td>0.5578</td>
<td>0.5386</td>
<td>0.4486</td>
<td>0.2412</td>
</tr>
<tr>
<td>GTS+LPW(ML)</td>
<td>0.5335</td>
<td>0.4925</td>
<td>0.4274</td>
<td>0.2309</td>
</tr>
<tr>
<td>GTS+LPW(ML)</td>
<td>0.5800</td>
<td>0.5644</td>
<td>0.4510</td>
<td>0.2302</td>
</tr>
<tr>
<td>GTS+LPW(ML)</td>
<td>0.5434</td>
<td>0.4854</td>
<td>0.4171</td>
<td>0.2958</td>
</tr>
</tbody>
</table>

Part II: Results of Typhoon Soudelor (2015)

Assimilation of LPW data

Fig. 3 The 6-h accumulated precipitation of observations (Obs), NCEP GFS analysis as background from 2012-06-29 12z to 30 00z

Fig. 4 The 6-h accumulated precipitation of assimilation of GTS, GTS+LPW(H), GTS+LPW(M), GTS+LPW(L). The combination of AMVs and PW together can improve track forecasts.

Summary and Future work

• The LPW from GOES Sounder data can 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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