Toward Assimilating Satellite Cloud and Precipitation Observations in NOAA HWRF System

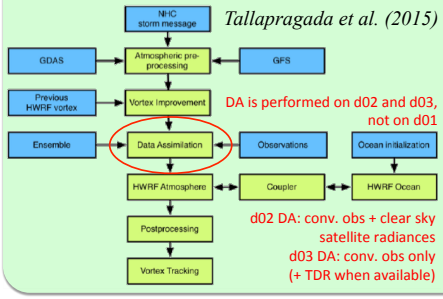
Ting-Chi Wu[1], Milija Zupanski[1], Lewis D. Grasso[1], Paula J. Brown[2], and Christian D. Kummerow[1,2], and John A. Knaff[3]

1. Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, Colorado, U.S.A.
2. Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, U.S.A.
3. NOAA/Center for Satellite Applications and Research, Fort Collins, Colorado, U.S.A.

1. Introduction

The NOAA HWRF system currently only considers satellite radiances at cloud-clear and/or non-precipitating scenes (clear-sky radiance) in the hybrid GSI data assimilation. In addition, satellite retrieved hydrometeor information is not included in the operational practice. This study examines the GSI capability to assimilate all-sky satellite radiances and hydrometeor retrievals in the HWRF system.

2. HWRF Overview (2015 Implementation)

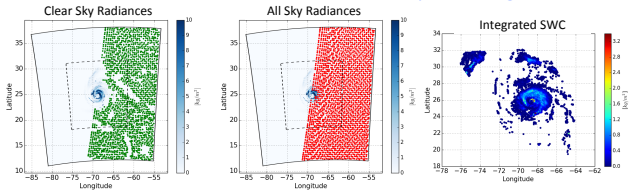


Tallapragada et al. (2015)

- d01/d02/d03 Δx = 18/6/2 km; nlev =75
- Hybrid GSI: 20% GFS static + 80% GFS 80-mem ensemble (Δx ~ 30 km)
- FGAT : - 3, 0, +3h
- Community Radiative Transfer model (CRTM) v2.1.3 is employed

3. Satellite Cloud and Precipitation Observations

- Advanced Technology Microwave Sounder (ATMS) radiances (left and middle): will focus on Ch 18-22 (humidity soundings)



- Hurricane GPROF *(Brown et al. 2016)* retrieved hydrometeors based on TMI/GMI database (right): integrated solid-water contents (SWC) and Integrated liquid-water contents (LWC).

4. Background and Methodology

- HWRF (2015) employs Ferrier-Aligo microphysics scheme, which predicts the combined sum of hydrometeor species, the total cloud condensate (CWM), instead of individual hydrometeor species.
- However, in the operational HWRF (2015) configuration
  - Hybrid GSI does not consider CWM update
  - CWM initialization is missing during the HWRF vortex initialization, leaving backgrounds in clear-sky condition

➢ In this study, we modifies the operational HWRF to
- ➢ Initialize background fields of CWM and hydrometeor parameters using HWRF forecasts from previous cycle
- ➢ Add CWM as control variable in hybrid GSI
- ➢ Partition CWM into individual hydrometeor species

$$q_l = (1 - F\_RAIN)\cdot(1 - F\_ICE)\cdot CWM \quad \text{Liquid water}$$
$$q_r = F\_RAIN\cdot(1 - F\_ICE)\cdot CWM \quad \text{Rain water}$$

F_RAIN: fraction of rain, F_ICE: fraction of ice, and F_RIMEF: riming rate

$$q_i = w\cdot F\_ICE\cdot CWM \quad where \quad w = \begin{cases} 0.05\cdot\dfrac{T-233.15}{10} + 0.1\cdot\dfrac{T-243.15}{(-10)} & if \quad T \le 243.15K \\ 0.05 & if \quad T > 243.15K \end{cases}$$

Ice

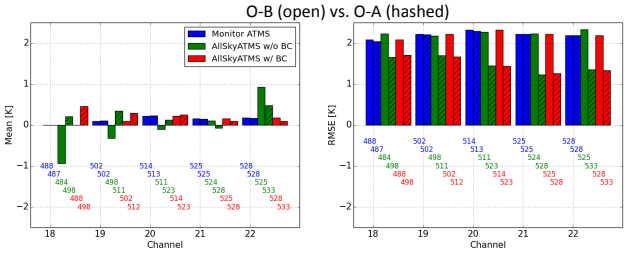
$$precip\_ice = (1-w)\cdot F\_ICE\cdot CWM = \begin{cases} q_s & if \quad 1 \le F\_RIMEF \le 5 \quad \text{Snow} \\ q_g & if \quad 5 < F\_RIMEF \le 5 \quad \text{Graupel} \\ q_h & if \quad F\_RIMEF > 20 \quad \text{Hail} \end{cases}$$

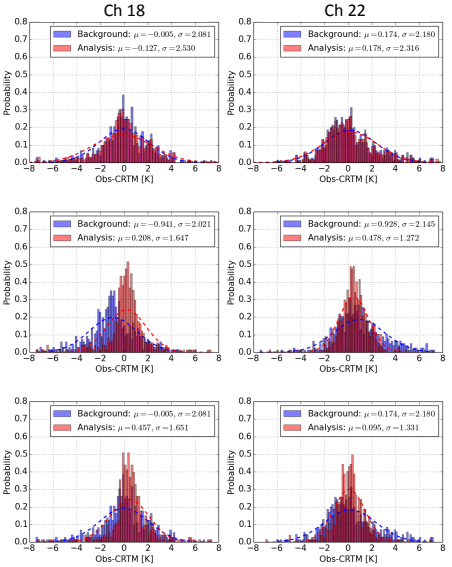
- Then, the individual hydrometeor species are used
  - ➢ by CRTM to compute ATMS all-sky radiance
  - ➢ by new observation operators developed to assimilate integrated SWC and integrated LWC (more details will be presented on poster #49 on Wednesday)

5. Analysis Results

➢ **ATMS Radiances (Ch 18-22)**

O-B (open) vs. O-A (hashed)





------ normal fit to O-B or O-A histogram

Monitor ATMS

No assimilation of ATMS is performed in GSI. Only evaluate ATMS radiances in background and analysis states.

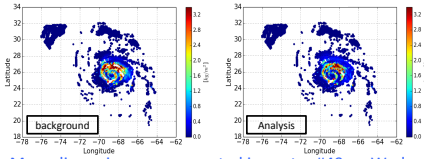
AllSky ATMS w/o Bias Correction*

* Bias Correction in GSI is based on the clear sky radiances.

AllSky ATMS w/ Bias Correction*

➢ **Integrated SWC and Integrated LWC**

In general, integrated SWC is over-estimated in the background. This is likely due to the discrepancy between the HWRF grid (2km) and the relatively low resolution Hurricane GPROF retrievals (~ 5-10 km). More discussions are presented in poster #49 on Wed.



6. Future Work

- Additional efforts are required to investigate and implement bias correction specific to all sky radiances.
- The assimilation impacts on HWRF forecast are yet be examined.

Reference

- Brown, P., C. Kummerow, and D. Randel, 2016: Hurricane GPROF: An optimized ocean microwave rainfall retrieval for Tropical. *J. Atmos. Ocean. Technol.*, (Early Online Releases).
- Tallapragada, V., S. Gopalakrishnan, Q. Liu, and T. Marchok, 2015: Hurricane Weather Research and Forecasting (HWRF) model: 2015 scientific documentation. *Dev. Testbed Cent.*, 1–113.

Acknowledgement: NOAA Sandy Supplemental Grant # NA14OAR4830122. and JCSDA S4 Supercomputer.