Multiple Hydrometeors All-sky Microwave Radiance Assimilation in FV3GFS

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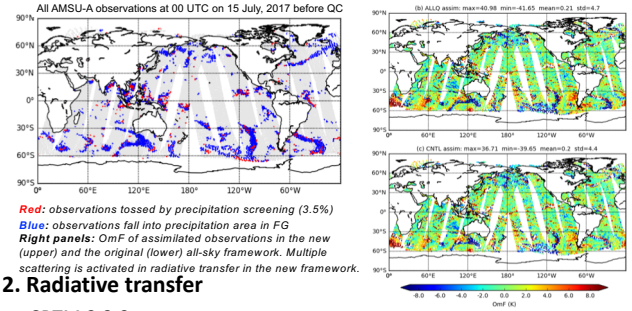
Introduction

In the operational FV3GFS implemented in June 2019, only cloud liquid water and cloud ice are included in the all-sky radiance assimilation framework of Zhu et al. (2016) and Zhu et al. (2019). The GFDL cloud microphysics scheme (Zhou et al. 2019) utilized in the FV3GFS provides not only cloud but also precipitating hydrometeors. In this study, we expanded the all-sky radiance assimilation framework in order to include all the hydrometeors available (cloud liquid water, cloud ice, rain, snow and graupel) in the model. Adding precipitating hydrometeors allows the assimilation of precipitation-affected radiance in addition to cloudy radiance.

Methodology

1. Expanding the all-sky framework

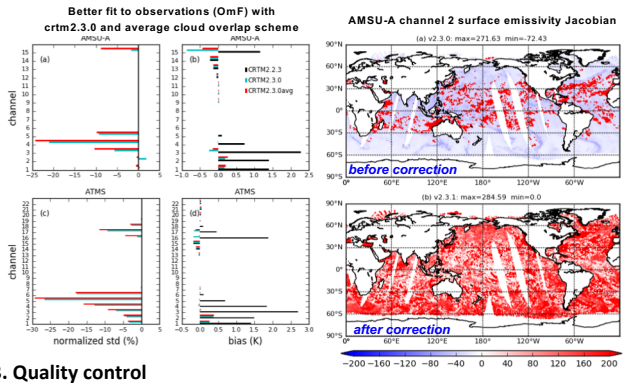
- Augment model state and control variables in the 4DEnVar system
- Interface CRTM with precipitating hydrometeors
- Disable precipitation screening in data thinning and quality control



Red: *observations tossed by precipitation screening (3.5%)*
Blue: *observations fall into precipitation area in FG*
Right panels: *OmF of assimilated observations in the new (upper) and the original (lower) all-sky framework. Multiple scattering is activated in radiative transfer in the new framework.*

2. Radiative transfer

- CRTM 2.3.0
  - Improved modeling of surface reflectivity under scattering condition (Liu et al. 2015)
  - Hydrometeor-weighted average cloud overlap scheme (Geer et al. 2009)
- Correct surface emissivity sensitivity under scattering condition



3. Quality control

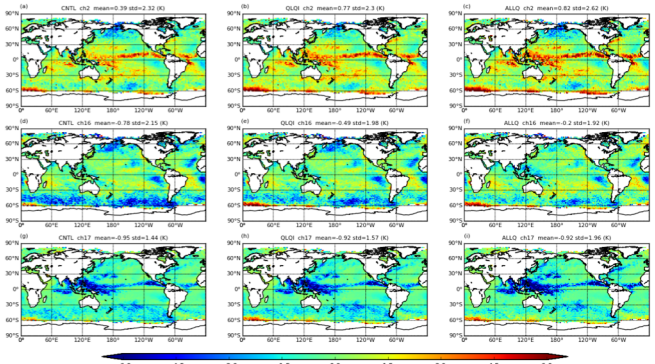
- Exclude observations, where radiative transfer could not handle properly - deep convection areas.

Experiments

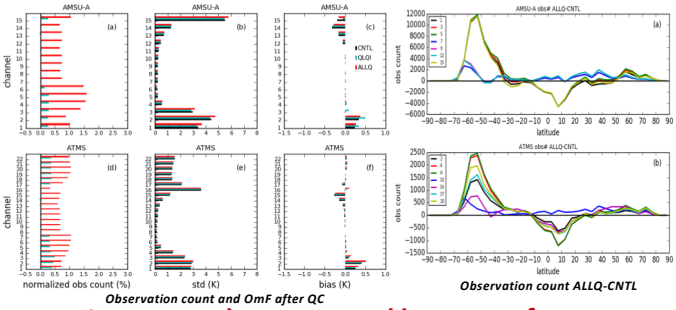
Experiment	Control variable	CRTM	Precipitation screening	Update hydrometeors
CNTL	Cloud water	2.2.3	YES	NO
QLQI	Cloud liquid water and cloud ice	2.2.3	YES	NO
ALLQ	Cloud liquid water, cloud ice, rain, snow and graupel	2.3.0 with average cloud overlap scheme	NO	NO
ALLQ_cycle_hydro	Cloud liquid water, cloud ice, rain, snow and graupel	2.3.0 with average cloud overlap scheme	NO	Yes

⋄ All experiments were run with 4DEnVAR at horizontal resolution of C384 (~25 km) for the control and C192 (~50 km) for the ensemble for two and a half months. AMSU-A and ATMS observations were assimilated in all-sky approach.

First guess departure and data usage

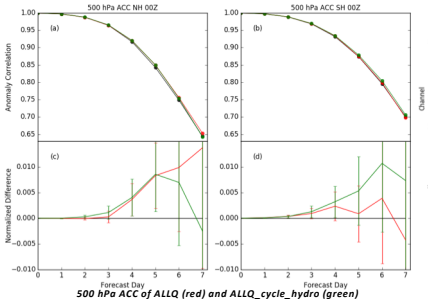


Monthly mean ATMS channel 2, 16 and 17 OmF before QC

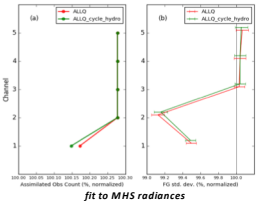


Observation count and OmF after QC ***Observation count ALLQ-CNTL***

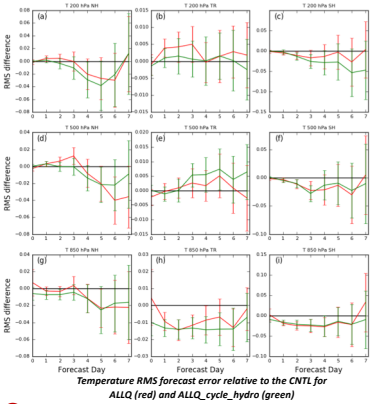
Impact on short-term and long-term forecast



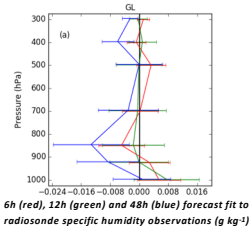
500 hPa ACC of ALLQ (red) and ALLQ_cycle_hydro (green)



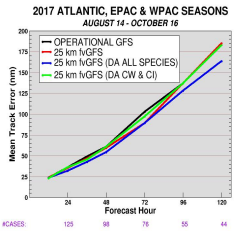
fit to MHS radiances



Temperature RMS forecast error relative to the CNTL for ALLQ (red) and ALLQ_cycle_hydro (green)



6h (red), 12h (green) and 48h (blue) forecast fit to radiosonde specific humidity observations (g kg⁻¹)



Summary

- The capability of initializing the full set of hydrometers in the FV3GFS has been developed
- This expanded all-sky radiance assimilation framework shows neutral to positive impact on overall forecast skill.
- Ongoing efforts include adopting the all-sky framework to the GFDL SHiELD model, including convective cloud (with convective cloud fraction), improving radiative transfer in deep convection region.