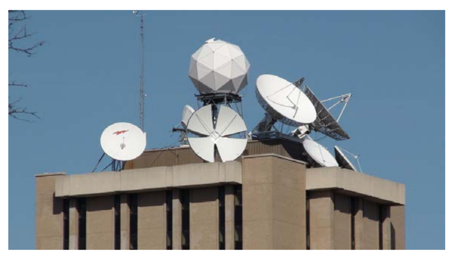
15p.06



Value-added Impact from Geostationary Hyperspectral Infrared Sounder on high impact weather forecasting – demonstration with a quick regional OSSE

Pei Wang[1], Zhenglong Li[1], Jun Li[1], Agnes Lim[1], Timothy J. Schmit[2], Robert Atlas[3]

[1]Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin-Madison

[2]Center for Satellite Applications and Research, NESDIS/NOAA

[3]Atlantic Oceanographic and Meteorological Laboratory, NOAA, Miami, Florida

Email: zhenglong.li@ssec.wisc.edu

1. Introduction

a. LEO hyperspectral IR sounder
- AIRS/IASI/CrIS
- Great success in global forecast

b. GEO hyperspectral IR sounder
- EUMETSAT: IRS/MTG (2020)
- China: FY4A launched in 2016
- USA: GOES-R HES withdrawn
- Advantage: high temporal/vertical/spatial resolution
- Great spatial coverage for regional NWP

c. Observing System Simulation Experiment (OSSE)
- Study the value added impacts compared to existing instruments
- Simulate observations for existing and future instruments
- Validate the simulations
  - -- Synthetic observations
  - -- Nature run (NR)
- Quick regional OSSE (r-OSSE) on a local severe storm (LSS)
- Are high temporal hyperspectral IR measurements worthy?

2. High resolution NR (HRNR) for LSS

The high resolution LSS NR is generated, and domain shown in Figure 1.
- WRF-NMM 3.6.1
- Initialization and boundary from 6-hourly GFS analysis from global OSSE (Lim et al. 2017)
- 54 hours from 5/25 2006 18 UTC to 5/28 00 UTC
- Output every 30 minutes
- Storm 00 – 12 UTC on 5/27
- 1600x1320 grid points, 2 km resolution, 51 vertical layers, top at 10 hPa
- Eta (Ferrier) microphysics scheme, the GFDL longwave and shortwave schemes, the Eta similarity surface layer scheme, the Noah land surface model, the MYJ planetary boundary layer scheme, and no cumulus parameterization

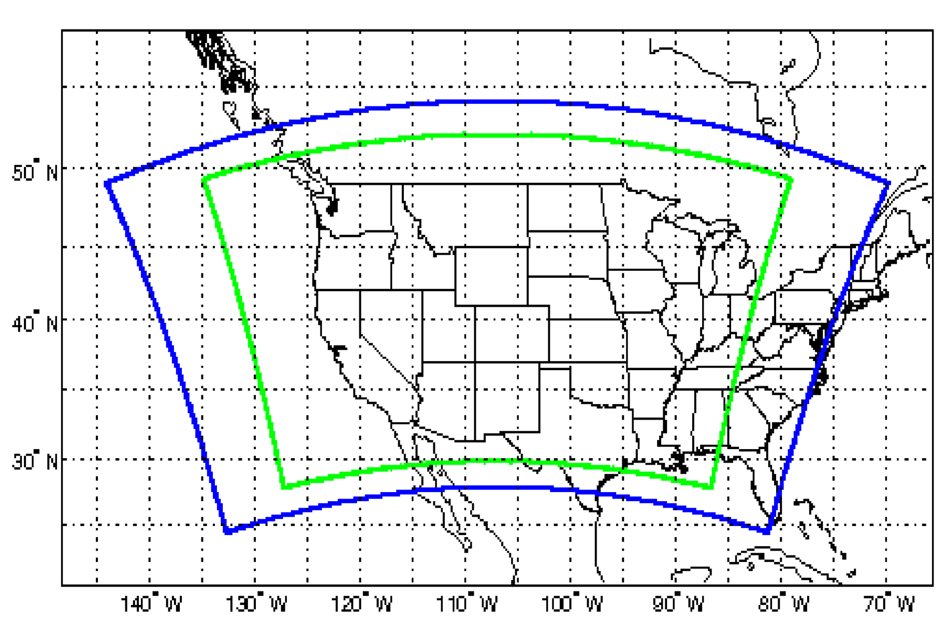


Figure 1. The model domain for the Nature Run (outside, blue), and the experiments (inside, green)

3. Synthetic observation simulation

3.1 LEO orbit simulator

A LEO orbit simulator is develop to simulate orbits for all existing and future LEO sensors. The following 11 sensors are simulated to represent the existing capability from LEO satellites:
- AIRS, IASI on Metop-a/b, CrIS (validation in Figure 2)
- ATMS, AMSU-A from NOAA satellites, Aqua, and Metop-a/b

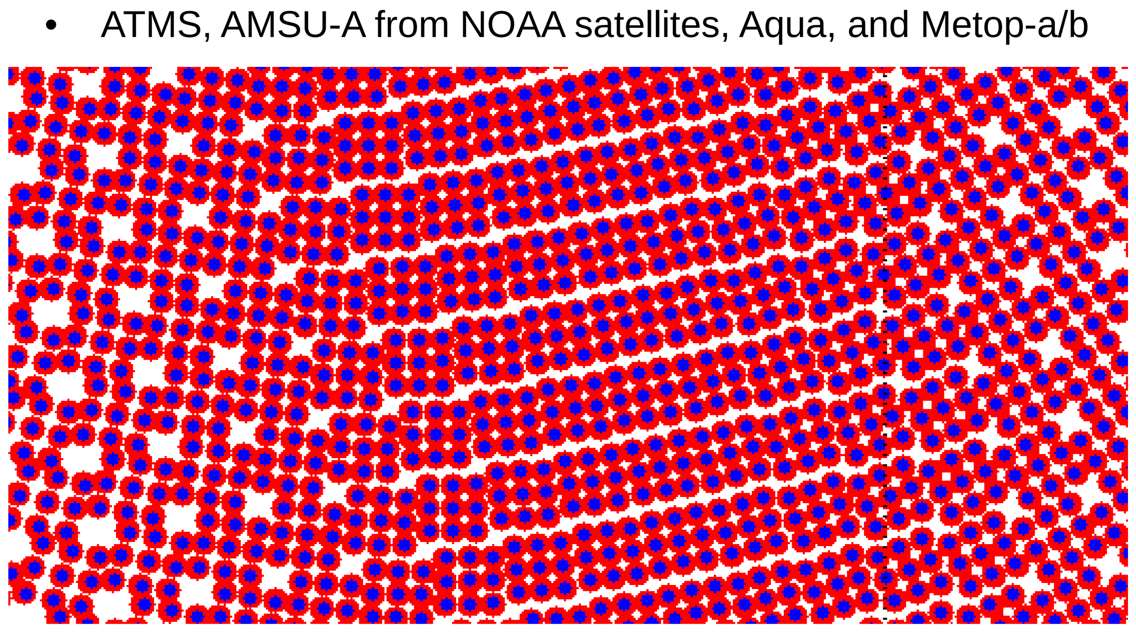


Figure 2. Validation of simulated CrIS orbit using observations. The red dots represent the simulated location of CrIS FOVs, and blue dots represent observations. The time of the granule is 23:54:10 UTC on September 23, 2014.

3.2 Radiative transfer model

An efficient hyperspectral IR radiative transfer model (HIRTM, Li et al. 2017) is used to simulate hyperspectral IR sounder radiances:
- Clear from SARTA
- Cloudy from Wei et al. 2004
- Capable of AIRS, IASI, and CrIS

All other sounder radiances are simulated using CRTM V 2.1.3 with ODAS.

3.3 GEO radiance validation

An IASI is put on GOES-16 located at -89.5 degree in longitude with a spatial resolution of 4 km and temporal resolution of 1 hour. The validation of the GEO IASI radiances is difficult because the NR has nothing to do with the reality. So there are no real observations that can be used for direct validation. An indirect validation is carried out to focus on whether the temporal variation of the simulated radiances is similar to reality. If the temporal variation of the NR is not realistic, or if the simulated radiances are not realistic, it is unlikely the temporal variation of the simulated radiances will be in a similar pattern as the real observations. Figure 3 shows the comparison with GOES-12 Imager.

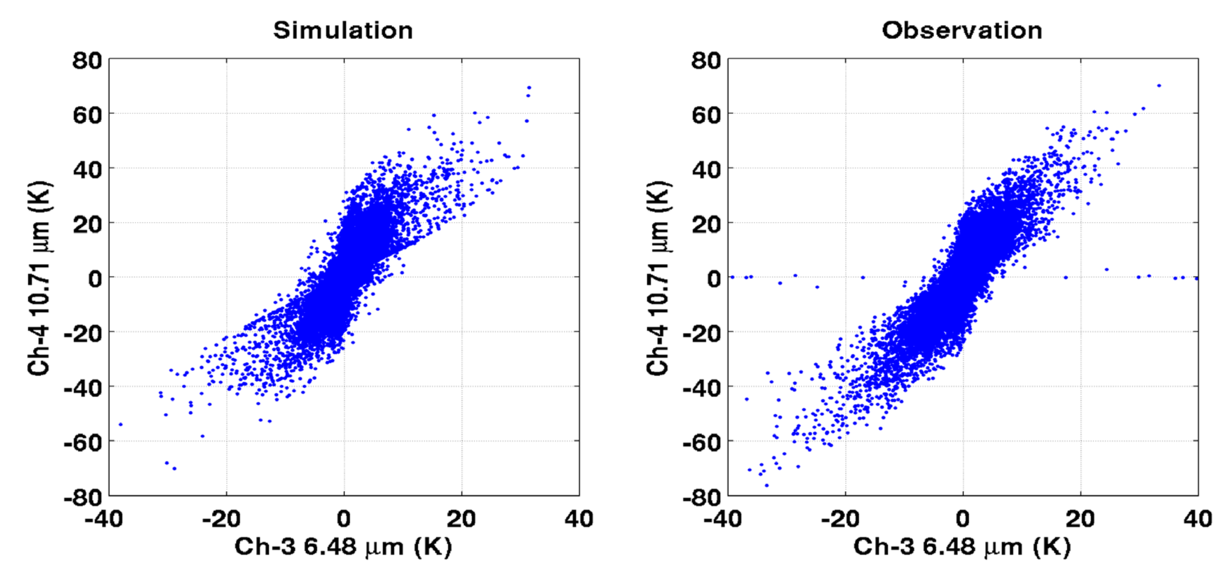


Figure 3. The temporal variation of GOES-12 Imager bands 3 and 4 from the simulation (left) and the observations (right).

All LEO radiances are converted to BUFR. Synthetic atmospheric sounding retrievals are generated for GEO IASI Radiance, and converted to PREPBUFR format.

4. Assimilation experiments and impact study

4.1 Experiment design

- Forecast model: WRF-ARW V3.6.1
- Assimilation system: GSI V3.3
- Initialization and boundary from 6-hourly GFS analysis from global OSSE (Lim et al. 2017)
- 450x280 grid points, 9 km resolution, smaller coverage (Figure 1), 51 vertical layers, top at 10 hPa
- New Thompson scheme for microphysics, RRTMG for longwave radiation scheme, RRTMG for shortwave radiation scheme, Yonsei University scheme for planetary boundary layer, and Kain-Fritsch scheme for cumulus parameterization
- Spatial thinning for GEO IASI: 60 km

Figure 4 shows the flow chart of the experiment design.

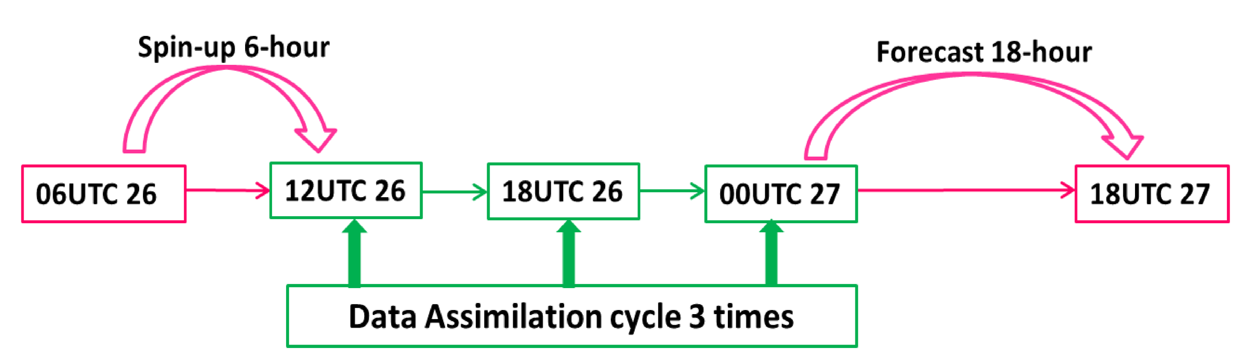


Figure 4. Flow chart of the experiment design

Two experiments are carried out:
- Control Run (CNTRL) assimilates simulated radiosonde observations (temperature, moisture, and u/v winds) and simulated LEO satellite radiance observations, representing the existing capability.
- GEO experiment (GEO) assimilates GEO IASI soundings as additional observations, representing future capability from geostationary hyperspectral IR sounder.

4.2 Impact on analysis temperature field

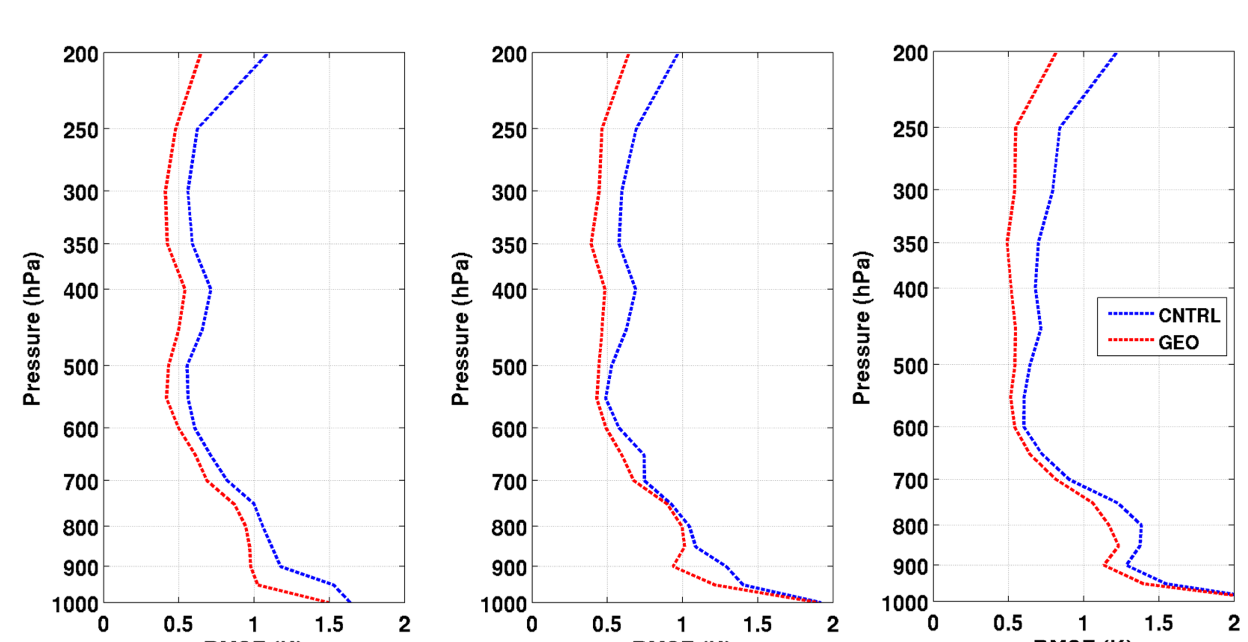


Figure 5. The temperature RMSE between HRNR and CNTRL (blue), and between Nature Run and GEO (red) from 200 hPa to 1000 hPa at 1200 UTC May 26 (left), 1800 UTC May 26 (mid) and 0000 UTC May 27 (right).

4.3 Overall evaluation

A single normalized RMSE is used to evaluate the overall performance of the analysis and forecast, which combines different parameters with different weights:
- Thermodynamic parameters (T/Q/U/V, 250/500/700/850 hPa), 50 %
- CAPE, 10%
- CIN, 10%
- Helicity, 10%
- Precipitation 1 - ETS, 20%

For each parameter, RMSE is calculated by comparing with HRNR for four time steps (final analysis at 00 UTC on May 27, plus 3 forecast times: 06, 12 and 18 UTC on May 27). All RMSE is normalized before combined.

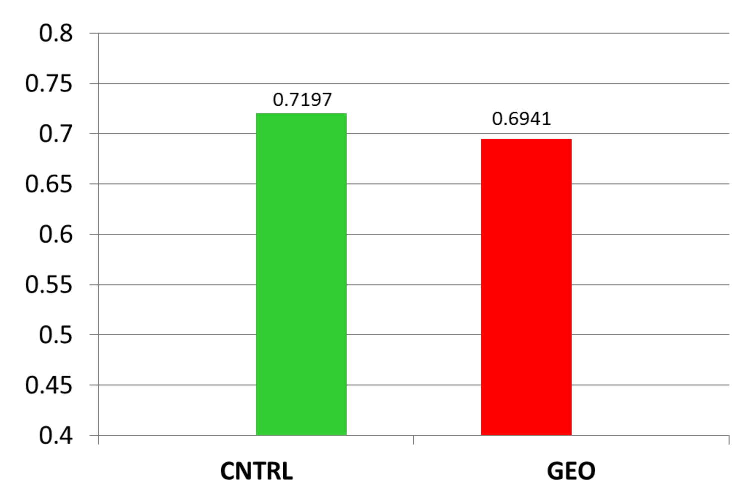


Figure 6. The final normalized RMSE of the two experiments, CNTRL (green) and GEO (red). Over reduction of RMSE by 3.56 %.

4.4 Impact of assimilation frequency and thinning distance

Different experiments with different thinning distance and assimilation frequency are carried out:
- 15, 30, 60, and 120 km
- 3 and 6 hours

The improvement in percentage of different experiments over control run is shown in Table 1. Results show that:
- all experiments show positive impact from assimilation of GEO IASI soundings
- With every 6 hour assimilation, smaller thinning distance leads to better analysis/forecast results.
- With every 3 hour assimilation, smaller thinning distance helps until 30 km. Beyond that, the positive impact is reduced.
- The optimal improvement appears with 30 km thinning and 3 hour cycle, with an overall reduction of the analysis and forecast error by 4.60 % from the GEO IASI soundings.

	15 km	30 km	60 km	120 km
3 hours	3.87	4.60	4.22	3.44
6 hours	4.41	3.83	3.56	3.20

Table 1. Improvement in percentage (%) of different experiments (thinning distance and refresh rate) compared to control run.

5. Summary

- A quick regional OSSE frame has been developed
  - ➢ nature run generation
  - ➢ orbit simulator
  - ➢ synthetic observation simulation and validation
  - ➢ impact study.
- The application to a case study of a local severe storm using GEO IASI observations is carried out.
  - ➢ the GEO IASI may add substantial positive values on the analysis and forecast of thermodynamic parameters of T/Q/U/V, and the overall error reduction in analysis and forecast is 3.56 %.
  - ➢ more frequent assimilation and shorter thinning distance may further improve the positive impact from GEO IASI with the current GSI/WRF-ARW system.
  - ➢ The peak improvement with an error reduction of 4.60 % is found with a thinning distance of 30 km and a cycle of 3 hours.

6. Acknowledgement

This work is partly supported by NOAA Office of Projects, Planning and Analysis (OPPA). The views, opinions, and findings contained in this report are those of the authors and should not be construed as an official National Oceanic and Atmospheric Administration or U.S. government position, policy, or decision.