Assessing Potential Impact of Air Pollutant Observations from the Geostationary Satellite on Air Quality Prediction through OSSEs

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1. Introduction

The Geostationary Environmental Monitoring Spectrometer (GEMS), a UV-visible scanning spectrometer, is planned to be launched by Korea in 2019. The missions of GEMS are to monitor air quality and provide measurements of air pollutants over Asia. As GEMS is expected to provide high spatiotemporal observations on atmospheric compositions, it is necessary to examine if these observations would be beneficial to the air quality prediction system. In this study, we assess the potential impact of the GEMS observation on air quality prediction through the observing system simulation experiments (OSSEs). In order to estimate the potential impact of radiance observations from GEMS, we conduct the GEMS synthetic radiances assimilation experiments using a hybrid data assimilation method and the Weather Research and Forecasting model with chemistry (WRF-Chem).

2. Methods

The GEMS synthetic radiance observations are generated by the WRF-Chem forecast and the GEMS radiative transfer model (RTM). First, we run the WRF-Chem model with MOZCART chemistry option to produce a nature run (NR), over a high resolution (7.5 km) domain, which is nested by a coarser (30 km) domain (see Fig. 1). Then, NR is transformed by RTM to produce the synthetic GEMS radiances of four wavelengths — 312.2, 318.6, 331.2, and 440 nm. Finally, random error perturbations, corresponding to observational errors, are added to produce realistic synthetic observations.

In order to assimilate the GEMS synthetic radiances, we employed the Maximum Likelihood Ensemble Filter (MLEF; Županski, 2005; Županski et al., 2008), which is a hybrid ensemble/variational data assimilation method. Due to properties of MLEF such as nonlinear capability, high resolution applications, and flow-dependent error covariances (Park et al., 2015), we can describe complexity and transportation of atmospheric chemistry. Control variables include dynamical variables (winds, water vapor mixing ratio, and perturbations of geopotential, potential temperature and dry air mass), and chemical variables (O_3, NO_2, SO_2, and HCHO).

We assimilate the synthetic radiance data and the NCEP conventional observation data. For the synthetic radiance data, we conduct the NR from 0000 UTC 22 to 0600 UTC 23 April 2016,

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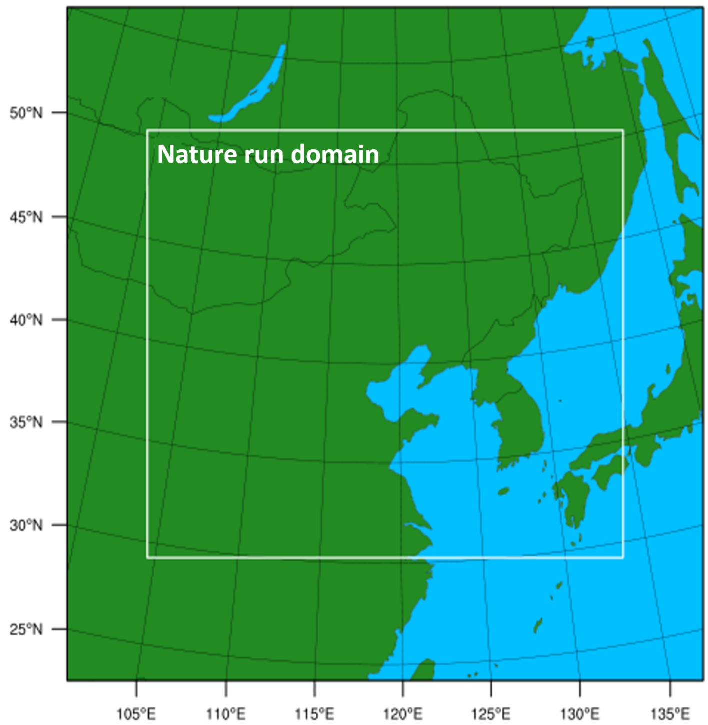

Fig. 1. Computational domains for the DA run (outer domain) and the NR (inner domain) with the horizontal resolutions of 30 km and 7.5 km, respectively.

then transform the output of 0600 UTC 23 April 2016 to the synthetic radiances. The MLEF-WRF-Chem run (hereafter referred to as the "DA run") has a lower resolution than the NR and employs a different chemistry option (CBMZ); thus, resulting in different simulation results. The DA run starts from 0000 UTC 23 April 2016 to generate an ensemble perturbation. After a 6-hour model simulation, the synthetic radiances and the NCEP conventional meteorological observation are assimilated into the MLEF-WRF-Chem system. We perform just one 6-hour data assimilation cycle, and the assimilation is valid on 0600 UTC 23 April 2016.

3. Results

Figure 2 shows the temperature (in °C) and O_3 (in ppmv) fields at 850 hPa from the NR and the DA run (background), respectively. In the DA run, compared to the NR, O_3 is overpredicted over South Korea and nearby sea, and its transport seems slow. As we consider the NR as observation, the difference between the NR and DA run corresponds to the difference between observations and model states. To verify the impact of the radiance observation, we compare the analysis increments of the DA run by assimilating only the NCEP conventional observations and by assimilating both the NCEP conventional observations and the synthetic radiances.

Conventional observations are unrelated to the NR; thus, the analysis increments from the DA run with conventional observations (left panels of Fig. 3) show different result from the NR. The DA run with conventional observations modifies temperature to be higher over the Bohai Sea and lower in the middle of the Mongolia. Due to the role of cross-covariance terms (Park et al., 2015), conventional observations exert impact on chemistry variables. It seems that the increased temperature induces increases in O_3 over the Bohai Sea. The wind fields also affected the behavior

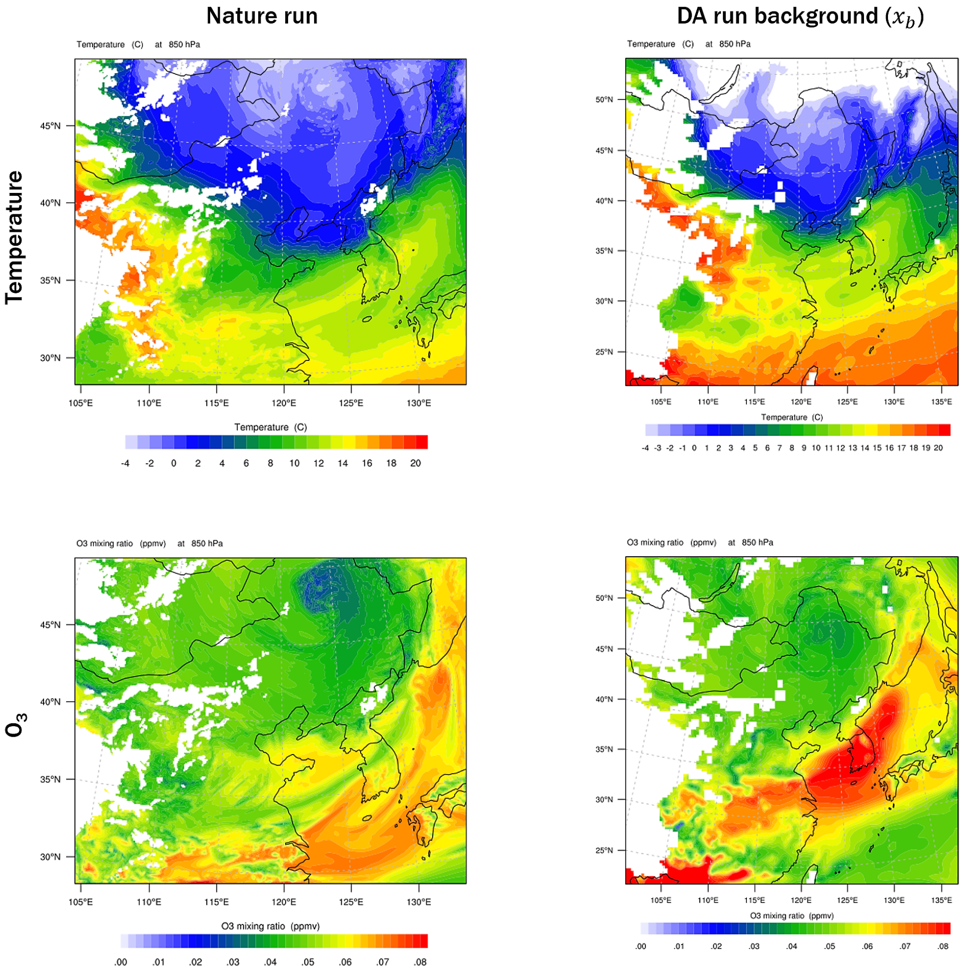

Fig. 2. Simulated temperature (upper panels; in °C) and O_3 (lower panels; in ppmv) at 850 hPa from the NR (left panels) and the DA run background (right panels), valid on 0600 UTC 23 April 2016.

of O_3: increased wind decreases O_3 concentration over Kyushu, whereas decreased wind increases O_3 concentration over the Yellow Sea (not shown). Actually, such modification of O_3 is related to wind direction and concentration amount of O_3. Lee et al. (2017) also reported similar interactions between meteorological variables and dust variables in the process of data assimilation.

Assimilating synthetic radiances incorporates the NR information into the DA run, for synthetic radiances were generated from the NR. When both conventional observations and synthetic radiances are assimilated simultaneously (right panels of Fig. 3), sometimes the impact of each observation may appear to be cancelled out. After assimilation of both observations, the temperature analysis increments depict lower values over the Bohai Sea, and negative values at Mt. Baekdu — due to low temperature in the NR in that area. For O_3, the strong positive increments, appeared in assimilation of conventional data only, has almost disappeared, and negative increments appeared over the eastern Manchuria. It seems that synthetic radiances modify the overpredicted O_3 background.

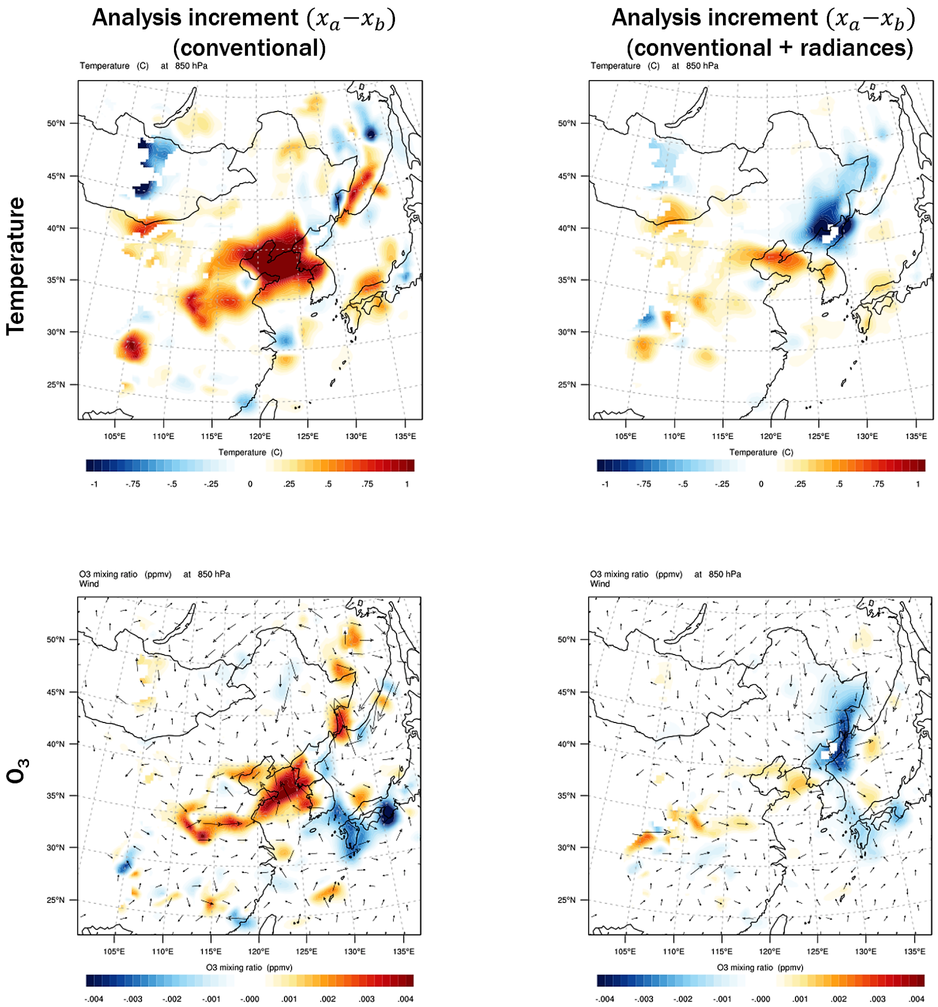

Fig. 3. Same as in Fig. 2 but for the analysis increments from the DA runs which assimilated the NCEP conventional observation only (left panels), and both the NCEP conventional observation and the synthetic radiances (right panels).

4. Conclusions

The potential impact of the GEMS radiance assimilation is assessed with the MLEF-WRF-Chem data assimilation system. Since GEMS radiances are not available yet, we generated synthetic radiances for the assimilation experiments. To assess the potential impact of GEMS radiances on the existing prediction system, we performed two data assimilation experiments: (1) assimilating the NCEP conventional (meteorological) data only; and (2) assimilating both the NCEP conventional data and the GEMS synthetic radiances. The results show assimilating conventional data only can affect chemistry variables through the cross-covariance terms of the MLEF-WRF-Chem data assimilation system. The behavior of O_3 is strongly affected by both temperature and wind. Assimilation of both conventional data and synthetic radiances brings about significant modifications in the analysis increments; sometimes the impact of each observation appear to be offset against each other.

Acknowledgements. This study is supported by the Korea Ministry of Environment (MOE) through the "Public Technology Program based on Environmental Policy (2017000160002)".

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