Prepared by JMA
Agenda Item: 5
Discussed in Plenary

HIMAWARI-8/9 FOLLOW-ON SATELLITE PROGRAM AND NWP IMPACTS ASSESSMENT OF HYPERSPECTRAL IR SOUNDER

In response to CGMS Action Plenary/A48.02

The Japan Meteorological Agency (JMA) has been considering the Himawari-8/9 follow-on program since JFY2018, keeping in mind the CGMS baseline and the Vision for WIGOS in 2040, including in particular the deployment of hyperspectral infrared sounder (HSS) across the full GEO ring.

In 2018, Meteorological Operation Focusing on Science and Technology Toward 2030 was recommended by the Meteorological Subcommittee under the Council of Transport Policy implemented by Japan’s Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The direction was taken into account in the JMA’s NWP Strategic Plan Toward 2030, which was also established in 2018 to promote strong and steady technical development in the area of numerical weather prediction (NWP) as part of social information infrastructure in disaster prevention and related fields. HSS on a geostationary satellite (GeoHSS) is expected to play an important role to meet the goals in the strategy.

To consolidate the potential impacts of GeoHSS on the NWPs which were derived in the previous study, reanalysis-based OSSEs were conducted for the typhoon and heavy rainfall events using GDAS ad RDAS. GeoHSS data with high frequency over wide area improved both synoptic and meso scale atmospheric state, and this leads to significant improvements of typhoon track and heavy rainfall location forecasts with a long lead time. Even though the demonstrated results in this study have yet to reach the goals of the JMA’s NWP Strategic Plan Toward 2030, we think a full utilization of real GeoHSS observation data with higher spatial resolution in the upgraded future NWP models will play a critical role for achieving them.

Action/Recommendation proposed: none

1 Introduction

The Japan Meteorological Agency (JMA) has been considering the Himawari-8/9 follow-on program since 2018, keeping in mind the CGMS baseline and the Vision for WIGOS in 2040, including in particular the deployment of hyperspectral infrared sounder (HSS) across the full GEO ring. The program is stated in the Implementation Plan of the Basic Plan on Space Policy, which is decided/revised by the Strategic Headquarters for National Space Policy, Cabinet Office, Government of Japan: "By JFY2023 Japan will start manufacturing the Geostationary Meteorological Satellite that will be the successor to Himawari-8 and -9, aiming to put it into operation in around JFY2029".

In 2018, Meteorological Operation Focusing on Science and Technology Toward 2030 was recommended by the Meteorological Subcommittee under the Council of Transport Policy implemented by Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The direction was taken into account in the JMA's NWP Strategic Plan Toward 2030, which was also established in 2018 to promote strong and steady technical development in the area of numerical weather prediction (NWP) as part of social information infrastructure in disaster prevention and related fields (JMA, 2018). HSS on a geostationary satellite (GeoHSS) is expected to play an important role to meet the following goals in the strategy.

- Improve the accuracy of 3-day typhoon forecast up to the same level with the current position error of 1-day forecast (100 km)
- Provide information on the risk of disasters associated with the heavy rainfall from half a day before

Our study based on an observing system simulation experiment (OSSE) using JMA's global and regional data assimilation (DA) systems (JMA, 2020 and Okamoto et al., 2020) clearly demonstrated the value of the GeoHSS to improve the NWP. To further assess the potential impacts of GeoHSS in the Himawari-8/9 follow-on program, the additional OSSE were carried out for typhoon and extreme weather events in Japan.

2 Method

The assessment was carried out by the same approach as that was adopted in the previous study. The specifications of the GeoHSS were based on the Infrared Sounder (IRS) on board the Meteosat Third Generation (MTG) satellite. The follow-on satellite is assumed to be at 140.7°E, where Himawari-8/9 are located. Hypothetical GeoHSS observations were simulated using the fifth generation of European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis (ERA5; Hersbach et al.

2020) data as pseudo-truth atmospheric profiles. The hypothetical brightness temperature (BT) were created using Radiative Transfer for TOVS (RTTOV) version 12.2 (Saunders et al., 2018) for global DA, and ERA5 grid values for temperature and humidity profiles were bilinearly interpolated for regional DA. The spatial and temporal distances of the hypothetical GeoHSS were 30 km and 1 h, respectively, as defined in relation to ERA5 products.

In this study, JMA's operational global and regional DA systems (GDAS and RDAS) as of 2018 were used. GDAS involves the use of an incremental four-dimensional variational (4D-Var) scheme with a horizontal resolution of up to 20 km for the outer model and 55 km for the linearized inner model, and a six-hour assimilation window divided into six time slots. Clear-sky GeoHSS radiances from 36 temperature-sensitive channels and 25 water vapor (WV)-sensitive channels were assimilated. RDAS adopts nonhydrostatic 4D-Var scheme, which carries out analysis every three hours by ingesting observations every hour within a 3-h DA window. The horizontal resolutions are 5 km for the outer loop and 15 km for the inner loop, and the vertical resolutions are 48 and 38, respectively, up to 22 km. In this regional DA experiment, temperature and relative humidity (RH) profiles were horizontally thinned to 45-km spacing, and thirteen vertical layers (1,000 to 50 hPa) for temperature and seven layers at and below 300 hPa for the RH were chosen. Data below the highest cloud-affected layer were rejected based on the cloud fraction of ERA5.

In order to assess the potential contribution of GeoHSS to the above-mentioned targets described in JMA's NWP Strategic Plan Toward 2030, four typhoons landfalling in Japan on 2018 (Jongdari (T1812), Cimaron (T1820), Jebi (T1821) and Trami (T1824)) were as a case study for the global DA cycle experiments. One forecast whose initial times was 3 days (72 hours) before landing in Japan was chosen for each typhoon and the positional errors of these four cases were averaged. Typhoon Leepi (T1815) also landed in Japan, but it was excluded due to its short lifetime. The regional DA experiment was conducted on the case of heavy rainfall in western Japan in July last year to confirm the improvement of precipitation predicted for 12 hours.

3 Results

In this section, the experiment with and without GeoHSS are called EXP and CNT, respectively.

Figure 1 shows averaged errors of track forecasts for the four typhoons making landfall in Japan, 2018. The positional errors of 3-day (72-hour) forecasts were 176.28 km in EXP and 317.33 km in CNT. The error of EXP was 141.05 km less than that of

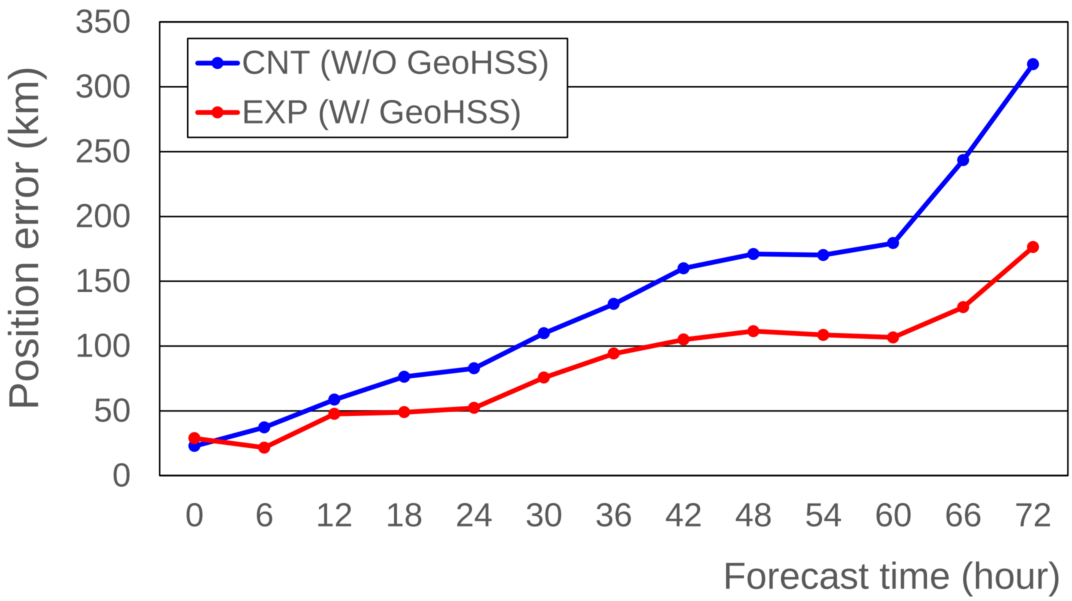

Fig. 1. Averaged errors of track forecasts for four typhoons (Jongdari (T1812), Cimaron (T1820), Jebi (T1821) and Trami (T1824)) making landfall in Japan in 2018.

CNT. It is easily understood that EXP shows significantly improved track forecasts. This result implies that GeoHSS has a potential to contribute to large-scale disaster prevention measures such as wide area evacuation, which requires long lead time.

Figures 2b and 2c show the 3-hour accumulated rainfall forecast at 12 h initialized at 2100 UTC on 3 July 2020. Both experiments predicted heavy rainfall in western Japan well overall, but CNT failed to predict the location of the heaviest rain area that caused devastating flood. Meanwhile, EXP better predicted the location. Accurate prediction of mesoscale convective systems with enough lead time (e.g., 12 hours) is very important to avoid nighttime evacuation, but it is a challenging task for regional NWP. This result suggests that high spatiotemporal-resolution GeoHSS would provide a vital information to improve such weather forecasts.

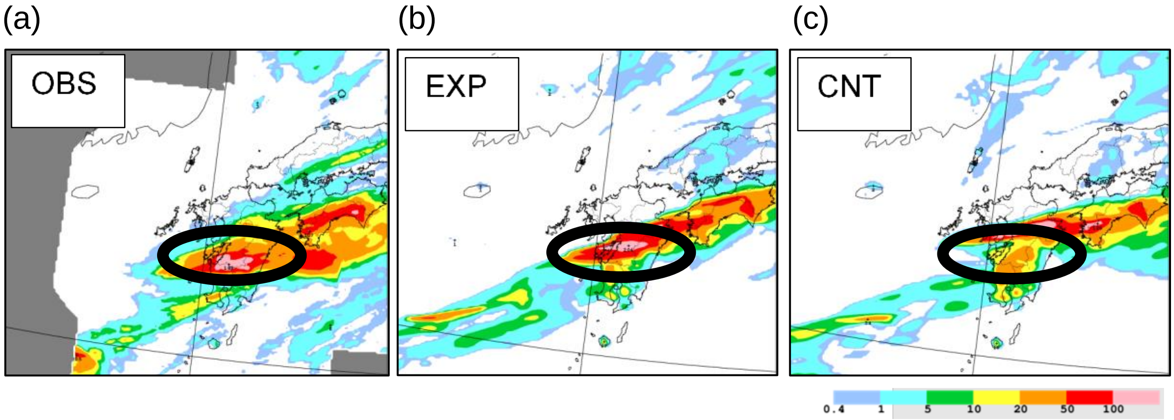

Fig. 2. Three-hour accumulated rainfall (mm) valid at 0900 UTC 04 July 2020 from (a) the radar/rain-gauge observations and the forecasts at 12 h in (b) EXP, (c) CNT. Rainfall in the Kyushu region is marked with black circles.

4 Conclusion

To consolidate the potential impacts of GeoHSS on the NWPs which were derived in the previous study, reanalysis-based OSSEs were conducted for the typhoon and heavy rainfall events using GDAS ad RDAS. GeoHSS data with high frequency over wide area improved both synoptic and meso scale atmospheric state, and this leads to significant improvements of typhoon track and heavy rainfall location forecasts with a long lead time. Even though the demonstrated results in this study have yet to reach the goals of the JMA's NWP Strategic Plan Toward 2030, we think a full utilization of real GeoHSS observation data with higher spatial resolution in the upgraded future NWP models will play a critical role for achieving them.

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