The impact of a high-accuracy high-resolution digital elevation model on numerical weather predictions

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1 Introduction

In numerical weather prediction (NWP), orography is part of the lower-boundary conditions in solving a set of governing equations to determine future atmospheric states. Accurate weather prediction relies on accurate representation of orography in a model, as well as on a model itself, initial states and other boundary conditions. One obvious way to accurately represent orography in a model is to increase horizontal resolutions. Another way is to use accurate source dataset to create orography for target resolutions. In this context, the upgraded Japan Meteorological Agency (JMA) Global Spectral Model (GSM) has been operated since March 2023 [1]. Orography in the upgraded GSM is more accurately represented by increasing both nominal and effective horizontal resolutions and using highly accurate source datasets. This paper describes the effects of high-accuracy high-resolution datasets on numerical weather predictions.

2 GSM Orography

GSM operation involves the use of 1) model mean orography in resolved dynamics, and 2) statistics for subgrid orography representation in orographic drag parameterizations. Both are provided to the model from ancillary files created using source datasets known as digital elevation models (DEMs).

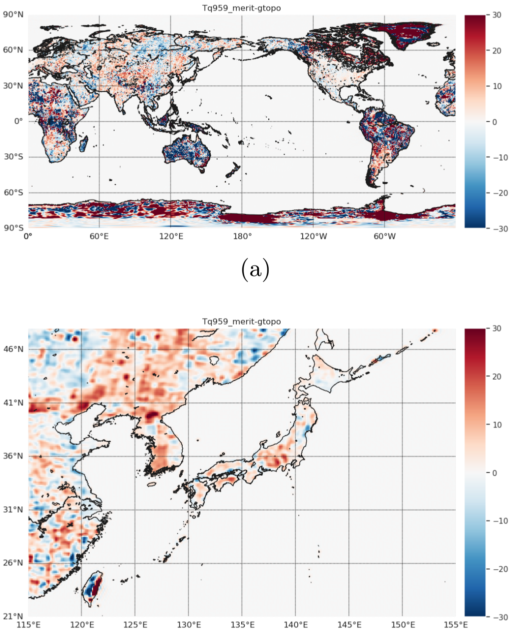
The GSM sources the new MERIT DEM [2] dataset covering the 90°N–60S° region and the new RAMP2 [3] dataset to fill in the 60°S–90°S where MERIT DEM data are unavailable. MERIT DEM is based on Shuttle Radar Topography Mission (SRTM) output [4], representing a quasi-global high-accuracy high-resolution (3 arc-seconds) dataset. Multiple biases in SRTM data are removed in MERIT DEM. In contrast, GTOPO30 [5] was used for the whole globe in the previous version of the GSM [6], which was operated until March 2023.

In the creation of orographic ancillary files, MERIT DEM in 3 arc-seconds is averaged to 30 arc-second grids, which are then combined with RAMP2 data provided in 1-km polar-stereographic form and converted to 30 arc-second lat-lon grids. A model mean orography and statistics for sub-grid orography are created from the resultant global 1-km DEM.

The model mean orography created from the new dataset differs from that of GTOPO30 globally (Figure 1 a). The erroneous mountains in the Guiana Highlands [7] in GTOPO30 are corrected in the new orography. Around Japan, the order of the difference is approximately 10 m. Patchy difference patterns are seen in Figure 1 b, implying that the new model mean orography contains less noise than the previous. This demonstrates that source dataset accuracy influences even coarse-grained fields and a model mean orography, thereby underlining the importance of using a high-accuracy DEM for NWP modeling. Differences are also seen in statistics for subgrid orography between those created from the new and the previous source datasets. The differences in the standard deviation of subgrid orography shown in Figure 2 indicate that those from the new datasets tend to have smoother fields than GTOPO30 data thanks to noise removal (e.g., over Eurasia). However, the standard deviation is larger in new datasets in some regions because the actual resolution in GTOPO30 is coarser than the provided resolution (e.g., over South America).

3 Experiment

The effects of more accurate orography representation and statistics in the GSM were evaluated in data-assimilation experiments for Jan. 2020 and Aug. 2020 against experiments with orography given by GTOPO30. The resolutions were Tq959L128 for 10-day forecasts and 9- and 6-hour forecasts as a first guess, and Tl319L128 for four-dimensional variational assimilation and ensemble forecasts in the data-assimilation cycle.



(a)

(b)

Figure 1: Differences (MERIT DEM+RAMP2 − GTOPO30) in model mean orography [m] at Tq959: (a) global, and (b) around Japan.

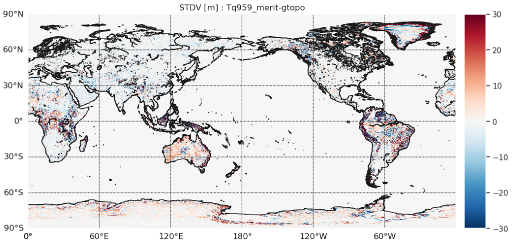


Figure 2: Differences (MERIT DEM+RAMP2 − GTOPO30) in standard deviation of subgrid orography [m] at Tq959.

4 Results

Forecast accuracy was compared in terms of root mean square error (RMSE) against own analysis for geopotential height over the Northern Hemisphere. The RMSE in runs with MERIT DEM+RAMP2 was lower than with GTOPO30 for both winter and summer (Figure 3).

5 Conclusions

Since Mar. 2023, the upgraded JMA GSM has been operated with a model mean orography and statistics for subgrid orography created with the new MERIT DEM and RAMP2 orographic source datasets. The more accurate representation of orography in the GSM contributes to the more accurate analysis and forecasting.

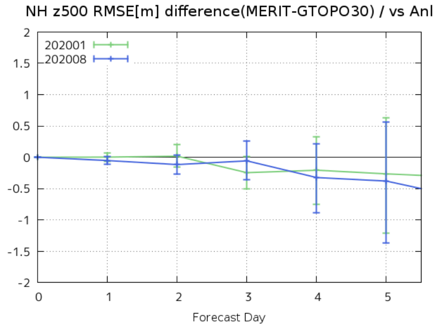


Figure 3: Differences in root mean square error (RMSE) [m] for geopotential height fields over the Northern Hemisphere between experiments with MERIT DEM+RAMP2 and GTOPO30 orography up to 5-day forecasts. Error bars indicate 95% statistical significance estimated using the bootstrap method.

References

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