Improving the representation of topographic effects in JMA's regional NWP model

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1. Introduction

JMA’s Local Forecast Model (LFM) is used to provide short-range forecasts for disaster mitigation and aviation safety as part of the Agency's operational regional NWP system operation (JMA 2023). The model’s 2 km horizontal grid spacing is fine enough to resolve most orographic drag, but unresolved drag exerted by sub-grid scale orography still needs to be accounted for. This report details the effects of turbulent orographic form drag (TOFD; Beljaars et al. 2004) parameterization in the LFM and updating of the model surface elevation with a new topographic dataset.

2. Topographic dataset update

The original 30" resolution GTOPO30 dataset (Gesch et al. 1999) for the model mean topography in the LFM was updated to the highly accurate 3" resolution MERIT DEM (digital elevation model) dataset (Yamazaki et al. 2017) developed with elimination of multiple error components from existing spaceborne DEMs. Figure 1 (b) shows the differences in model mean topographic elevation in the LFM between derivation from MERIT DEM and that from GTOPO30. MERIT DEM shows increased model surface elevation in most mountainous areas.

3. TOFD implementation

The TOFD scheme is employed for parameterization of sub-grid scale orographic effects. Here, turbulent form drag is parameterized using the standard deviation of sub-grid terrain elevation to represent the effects of fine topographic variations with horizontal scales shorter than around 5 km. The standard deviation of the filtered sub-grid terrain height is computed from MERIT DEM in the LFM after band-pass filtering of the topographic dataset to determine topographic variations in horizontal scales for TOFD. Beljaars et al. (2004) proposed 2 and 20 km as the upper and lower bounds of the band pass filter (Δ_1 and Δ_2) in the use of GTOPO30. As MERIT DEM represents finer topographic structures, values of Δ_1 = 400 m and Δ_2 = 4 km were determined for the LFM. TOFD scheme parameters dependent on Δ_1 and Δ_2 were also modified from those of Beljaars et al. (2004).

4. Verification

Two series of experiments (CNTL and TEST) were conducted to evaluate improvements relating to topographic effects. CNTL configuration was as per that of the LFM operational suite in place since March 2022, while TEST configuration differed in the incorporation of TOFD and updated model topography. The experimental period was from 2 July to 15 July 2020. Figure 2 (a), showing mean errors of 10 m wind speed against in situ observations, indicates a significantly lower positive bias in TEST. Values for the low-level atmosphere against the wind profiler observations of CNTL were also lower (Figure 2 (b)). The accuracy of precipitation prediction was also improved in TEST. For example, the false alarm ratio was lower for weak to moderate (1 mm/3 h – 30 mm/3 h) rainfall, and the equitable threat score was also improved (not shown).

The case study shown in Figure 3 indicates improved precipitation prediction. In this case, warm moist air is brought by southwesterly winds over the Chubu Mountains and heavy rainfall is observed over the windward side in (d). CNTL shows much higher precipitation prediction downwind (the dashed circle in (a)) than radar/raingauge analysis. In TEST, low-level wind speeds are lower around mountainous areas, and the excessive precipitation prediction downwind is slightly reduced. Topographic effects resulting from TOFD implementation and the new topographic dataset reduced water vapor transport downwind of the mountains, thereby also reducing the incidence of false alarms for precipitation prediction in the area.

References

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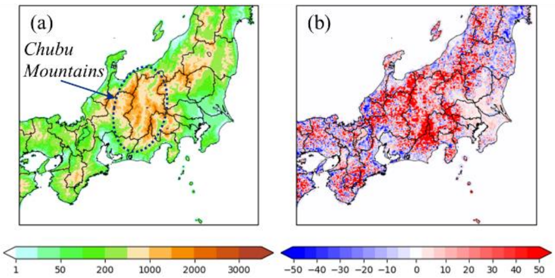

Figure 1: Distribution of model mean topographic elevations [m] in the LFM over eastern Japan. (a) MERIT DEM; (b) difference between MERIT DEM and GTOPO30.

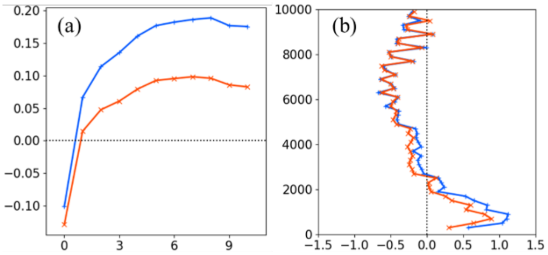

Figure 2: (a) Mean errors of 10 m wind speed against in situ observation [m/s] (horizontal axis: forecast lead time) [h]. (b) Mean error of horizontal wind speed against wind profiler observation [m/s] (vertical axis: height [m]). Blue: CNTL; red: TEST.

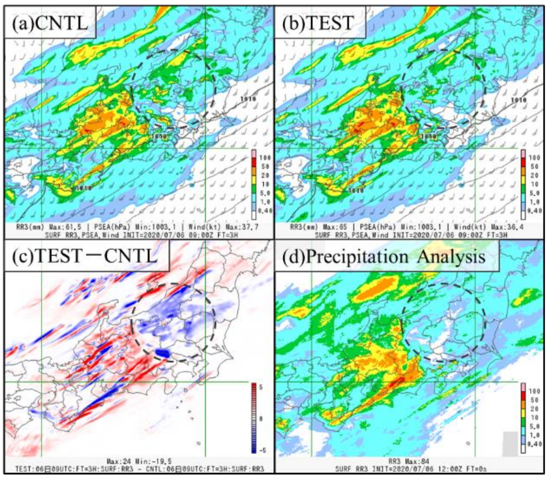

Figure 3: Precipitation for the previous 3 hours [mm] at 12 UTC on 6 July 2020. (a) CNTL, (b) TEST, (c) TEST/CNTL difference, (d) radar/raingauge precipitation analysis. Forecast lead time: 3 hours; contours in (a) and (b): sea level pressure [hPa]; barbs: 10 m winds [kt].