Improving scale-awareness of the physics package in Korean Integrated Model

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Recent update history of KIM physics

The increasing resolution of numerical models is crucial for enhancing performance by reducing numerical errors and capturing small scale features. In the second phase of the Korea Institute of Atmospheric Prediction and Systems (KIAPS) project (2020–2026), high-resolution modeling targeting km-scale variable-grid systems is a primary focus. With this motivation, physics development at KIAPS is focusing on enhancing the capability in the high-resolution global model. Initial approaches include addressing the subgrid-scale topographic effect on radiation (Baek and Kim, 2024) and implementing the generalized cloud overlap scheme that accounts for latitude, season, and wind shear effects (Kim, 2024). Scale-awareness in the convective parameterization scheme (CPS), gravitiy wave drag (GWD), and subgrid orography (SSO) are particularly impactful within the horizontal resolution range of most global models. Therefore, we have concentrated on revising these schemes to improve prediction skills, which is a major concern in recent physics development. Table 1 summarizes the configuration of KIM physics and recent updates since the start of the second phase (Lee et al., 2024).

Table 1. KIM physics updates for high resolution modeling

Physics process	Scheme	Update since 2020
Radiation (RAD)	RRTMK	Topographic effect on RAD Revision in cloud overlapping
Subgrid-scale orography (SSO)		Refinement of subgrid-scale orography statistics and turbulent orographic form drag
Gravity wave drag (GWD)	Source-based spectral non-orographic GWD	Modification of frontogenesis threshold
Convection (CPS/SCV)	KSAS	Unified deep and shallow convection Modification of scale-aware updraft convection fraction

Improvements in scale-awareness for CPS and GWD and their performance

Scale-aware parameterization in CPS was originally designed during the first phase of KIAPS (2011–2019; Kwon and Hong, 2017). This method considers two different convective updraft fractions: one as a function of grid size (Δx) and the other as a function of vertical velocity. Recent evaluations revealed that the second parameter does not sufficiently represent scale awareness. To develop more effective scale-aware method, we revised the convective updraft fraction as the ratio of the area occupied by convection within the grid. This adjustment is then used to scale the cloud-base mass flux and triggering according to the horizontal resolution. As a result, the forecast skill for precipitation over the Korea Peninsula has improved at the resolution of NE576 (~8 km) (Figure 1).

The non-orographic GWD scheme in KIM is based on a source-based spectral method that incorporates both convective and frontal GWD components. In this scheme, convective GWD is adjusted to reflect the characteristics of convective clouds, which can vary across different horizontal resolutions. Intensity of frontal gravity waves was originally designed to adopt scale-awareness based on grid size. However, evaluations have indicated that high-resolution simulations overestimate the generation points of gravity waves especially in the low-latitude regions. To address this issue, the frontogenesis threshold has been modified to account for horizontal resolution, ensuring that frontal gravity wave generation regions are diagnosed similarly regardless of resolution. This adjustment reduces wave drag at higher resolutions, leading to a reduction in the mesospheric cooling (warming) effect in the winter (summer) hemisphere due to reduced frontal GWD (Figure 2).

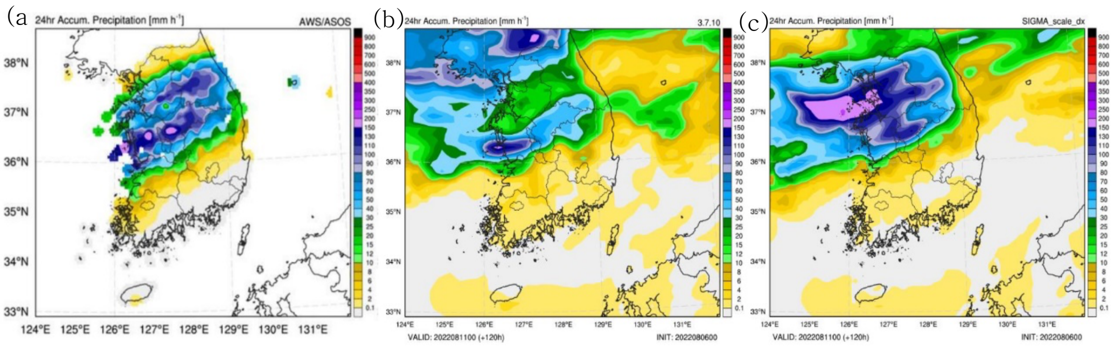

Figure 1. Precipitation for a heavy rainfall event over Korea on 10 August 2022. (a) AWS ASOS, (b) CTL, and (c) modified scale-aware parameterization in CPS

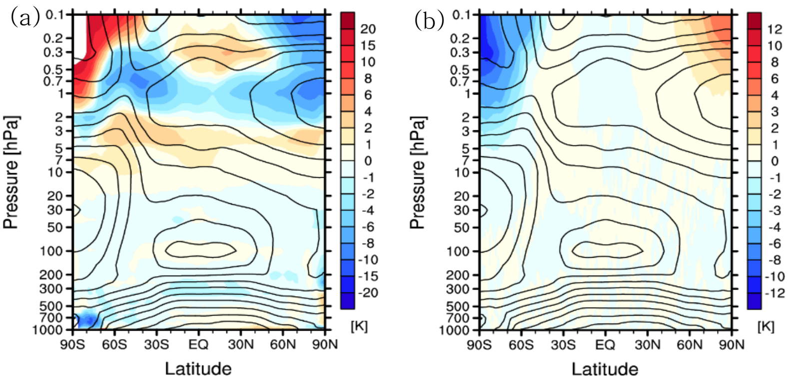

Figure 2. (a) Bias of temperature in CTL experiment against MERRA2 and (b) difference between CTL and modified frontal GWD experiments at +5D forecast from 00UTC 1-5 July 2017 for NE360

Concluding remark

Further evaluations are needed to fully understand scale-aware physics processes for resolution ranges below 8 km. For example, KIM SSO is parameterized to consider mesoscale (Δx–4 km) and turbulent-scale (below 4 km) effects, which should adjust gray-zone features. The scale-awareness of the boundary layer scheme is effective at resolutions less than 1 km. We will further optimize physics schemes for km-scale simulations using our new global variable grid and limited area model at KIAPS.

References

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