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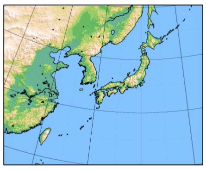
Development of Limited-Area NWP Systems at JMA

Kawano Kohei*, Aranami Kohei, Sawada Masahiro, Matsubayashi Kengo, Kusabiraki Hiroshi, Anzai Taro, Nishimoto Shusuke, Tanoshita Junichi, Okugawa Ryosuke, Kimura Tsubasa, Kawada Hideyuki, Kakehata Takayuki, Hattori Hironori, Matsuba Fumitaka, Anzai Yuri
Numerical Prediction Division, Japan Meteorological Agency, * k_kawano@met.kishou.go.jp

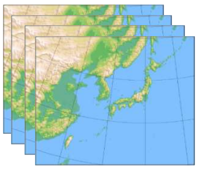
1. Regional operational NWP systems at JMA

Meso-Scale Model (MSM):
Horizontal resolution: 5km
Vertical levels / top: 96 / 37.5km
Forecast hours (initial times):
78 hours (00, 12 UTC)
39 hours (03, 06, 09, 15, 18, 21 UTC)
Initial conditions: Meso-scale analysis (MA) (4D-Var)



Local Forecast Model (LFM):
Horizontal resolution: 2km
Vertical levels / top: 76 / 21.8km
Forecast hours (initial times):
18 hours (00,03,06,09,12,15,18,21 UTC)
10 hours (hourly except for the above)
Initial conditions: Local analysis (LA) (hybrid 3D-Var)

Meso-Scale Ensemble Prediction System (MEPS):
Horizontal resolution: 5km
Vertical levels / top: 96 / 37.5km
Forecast hours (initial times):
39 hours (00, 06, 12, 18 UTC)
Initial conditions: Meso-scale analysis with ensemble perturbations (SV)
Ensemble members: 21 (Control = MSM**)**



2. Update of Local Forecast Model (LFM2403) Mar. 2024

Highlights:
- The forecast range is extended from 10 to 18 hours at 00,03,06,09,12,15,18,21 UTC
- Introducing the Strong Stability Preserving Runge-Kutta scheme (SSP-RK) in the HE-VI and split-explicit short time-step integration
- Improvement on cloud microphysics scheme
- Update of the optical properties for water clouds in long wave

- Introducing SSP-RK (Shu and Osher 1998) in the HE-VI and split-explicit short time-step integration
  - JMA operates regional models using a non-hydrostatic model ASUCA (Ishida et al. 2022).
  - ASUCA employs horizontally explicit vertically implicit (HE-VI) and split-explicit time-integration method to compute the fast modes efficiently.
  - To solve both fast modes and the other terms, ASUCA utilizes the third-order Runge-Kutta scheme proposed by Wicker and Skamarock (2002, WS02).
  - The stability analyses showed SSP-RK provides higher stability than WS02 in the short time-step integration (Kimura et al. 2024).

- Introduction of the cloud microphysics scheme (Ikuta et al. 2021) used in the MSM, with modifications for 2km resolution model (LFM2303).
  - Radar simulator validation shows that the graupel is excessive.
- Revision of the formulation of the conversion process from snow to graupel by riming, based on Connolly et al. (2006).
  - Overestimated reflectivity due to excessive graupel was alleviated.

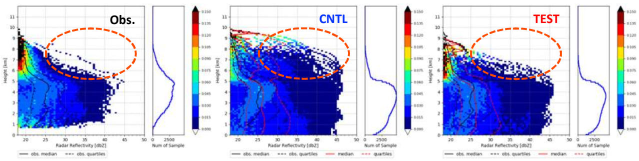


Fig.1 GPM/DPR Reflected Intensity CFAD of the observation (left), original (middle) and LFM2403 (right) configurations.

- Precipitation verification of LFM
  - Three models are verified for summer:2023/6/28-7/12(120 cases) and winter:2023/1/1-1/7, 1/23-1/30 (120 cases).
    - CNTL: LFM extended to 18-hour forecast
    - TEST: LFM extended to 18-hour forecast with model update
    - MSM
  - LFM(CNTL,TEST) shows excessive frequency of heavy rain compared to MSM.
  - Model update mitigates excessive frequency of heavy summer rainfall.
    - Modified snow to graupel conversion process reduced graupel and increased snow.
    - This slowed the condensates fall and reduced localized heavy rainfall.

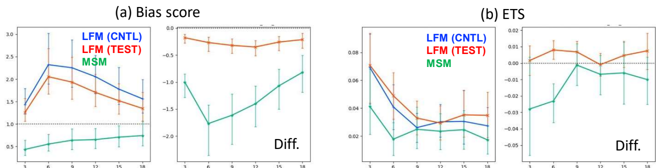


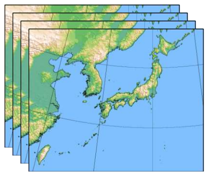
Fig.2 Precipitation (50mm/3h) verification in summer experiment. (a) Bias score and difference from CNTL (b) ETS and difference from CNTL. Horizontal axis is forecast time [hour].

3. Development of LFM-based ensemble prediction system (LEPS)

- A new LFM-based Ensemble Prediction System (LEPS) is under development with a 2 km horizontal grid spacing and 21 members, and is planned to be operational in Mar. 2026.

TBD

Local Ensemble Prediction System (LEPS):
Horizontal resolution: 2km
Vertical levels / top: 76 / 21.8km
Forecast hours (initial times):
18 or 21 hours (4 or 8 times per day)
Initial conditions: Local analysis with ensemble perturbations (derived from MEPS)
Ensemble members: 21 (Control = LFM**)**



- Utilizing perturbations from MEPS forecasts for initial perturbations.
- Due to the higher ability of LFM to represent heavy rain than MSM, LEPS has a higher ability to capture the potential for heavy rain than MEPS, as expected.

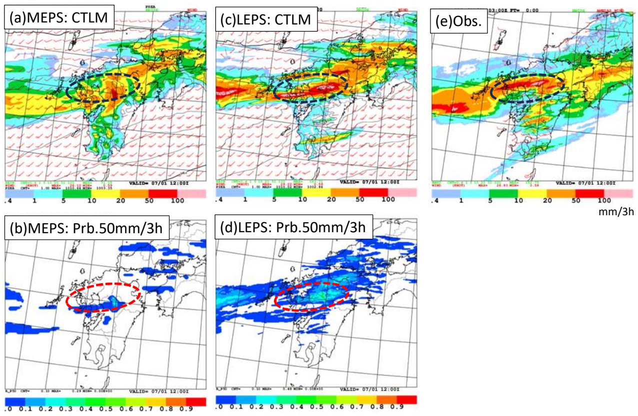


Fig.3 Three-hour accumulated precipitation of forecast from control run (CTLM), probabilistic forecast exceeding 50 mm/3h (Prb.50), and observation (Obs.) for 0300UTC 1 July 2024. (a)MEPS: CTLM, (b)MEPS: Prb.50, (c)LEPS: CTLM, (d)LEPS: Prb.50, (e)Obs. MEPS is at T+15 initialized at 1200 UTC 30 June 2024. LEPS is at T+12 initialized at 1500 UTC 30 June 2024.

- The challenges are:
  - To further clarify the uncertainty in the forecast of mesoscale convective system
  - To further investigate the perturbations needed to capture this
    - Initial perturbation / boundary perturbation / model perturbation

4. Plan to improve horizontal resolution of LFM from 2km to 1km

- Horizontal grid spacing of the LFM is planned to be improved from 2km to 1km in Mar. 2026.
  - Effects of higher resolution seen in ideal experiments.
    - Ideal experiment of cumulus convection proposed by Grabowski et al. (2006), varying horizontal resolution were performed.
    - With 1 km horizontal resolution, the timing of convective initiation and the transition from shallow to deep convection is improved, and excessive deep convection is mitigated.
  - 1 km LFM experiments confirms several real cases of mitigating excessive precipitation compared to 2 km LFM.
    - Further improvement of processes related to vertical transport associated with convection will be key issue while taking advantage of higher resolution.

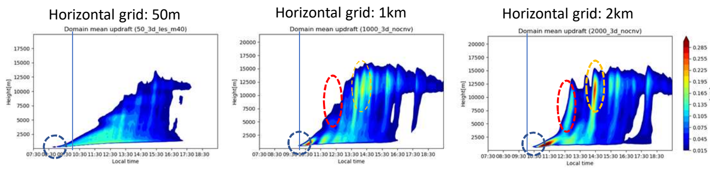


Fig.4 Time-height cross sections of regionally averaged convective updraft from the ideal experiment of cumulus convection proposed by Grabowski et al. (2006).

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