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Development of Limited-Area NWP Systems at JMA

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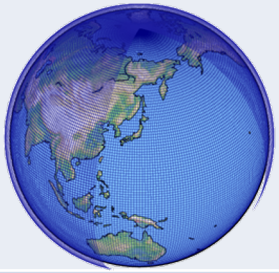
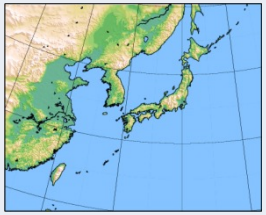
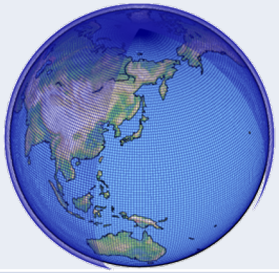
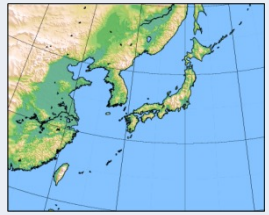
Operational suites of NWP systems at JMA

	Global Spectral Model (GSM)	Meso-Scale Model (MSM)	Local Forecast Model (LFM)	Global Ensemble Prediction System (GEPS)[1]	Meso-Scale Ensemble Prediction System (MEPS)
Objectives	Short- and medium-range forecasts	Disaster reduction, aviation forecasts, short-range forecasts	Aviation forecasts, disaster reduction	Typhoon forecasts, one-week forecasts	Disaster reduction, aviation forecasts
Forecast domain	Global 	Japan and its surroundings 	Japan and its surroundings 	Global 	Japan and its surroundings 
Horizontal resolution	TL959 (≈ 20 km)	5 km	2 km	TL479 (≈ 40 km)	5 km
Vertical levels / top	128 / 0.01 hPa	76 / 21.8 km	76 / 21.8 km	128 / 0.01 hPa	76 / 21.8 km
Forecast hours (initial times)	264 hours (12 UTC), 132 hours (00, 06, 18 UTC)	51 hours (00, 12 UTC), 39 hours (03, 06, 09, 15, 18, 21 UTC)	10 hours (00–23 UTC hourly)	264 hours (00, 12 UTC), 132 hours (06, 18 UTC)[2]	39 hours (00, 06, 12, 18 UTC)
Initial conditions	Global analysis (4D-Var)	Meso-scale analysis (4D-Var)	Local analysis (3D-Var)	Global analysis (4D-Var) with ensemble perturbations (SV, LETKF)	Meso-scale analysis with ensemble perturbations (SV)
Ensemble members	—	—	—	51	21 (Control = MSM)

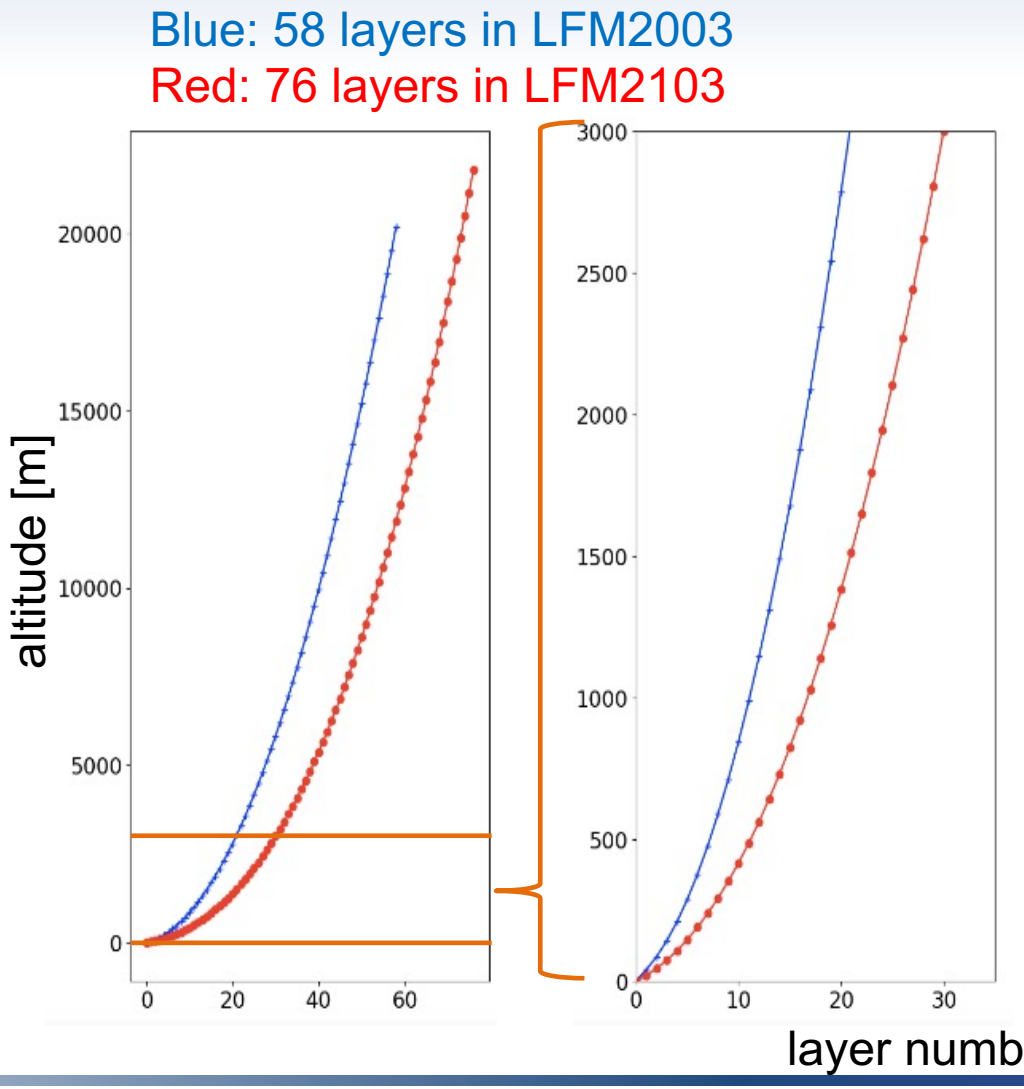
1 Only the specifications of typhoon forecasts and one-week forecasts
2 Only when a TC of TS intensity or higher is present or expected in the RSMC Tokyo–Typhoon Center's area of responsibility (0°–60°N, 100°E–180°)

Recent Activities

- Local Forecast Model (LFM)
  - Enhancing vertical layers from 58 to 76 and improving physics schemes in March 2021 (LFM2103) (Kusabiraki et al. 2021)
- Meso-Scale Ensemble Prediction System (MEPS)
  - Operation since June 2019 (MEPS1906, Ono et al. 2021)
  - Improved initial and lateral boundary perturbations in September 2020 (MEPS2009) (reported at 42nd EWGLAM meeting)

Enhancing vertical layers in LFM2103

- The number of vertical layers is increased from 58 to 76.
- The vertical resolution is enhanced. 30 layers are allocated from the ground to 3000 m.
- The lowest height in the full level is 10 m.



Introducing the Leonard Term

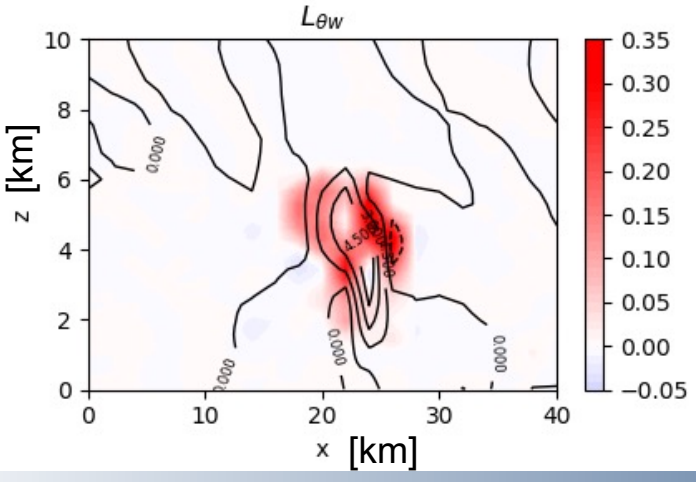
- The vertical subfilter flux is parameterized following Moeng et al. (2010) and Verrelle et al. (2017):

$$\tau_{wc} = \frac{K_L}{12}\left(\Delta x^2 \frac{\partial w}{\partial x}\frac{\partial c}{\partial x} + \Delta y^2 \frac{\partial w}{\partial y}\frac{\partial c}{\partial y}\right) + \tau_{wc,Kgrad}$$

the Leonard term

the Reynolds term as parameterized by a traditional vertical column model

It depends on the horizontal gradient (different from a vertical column model).



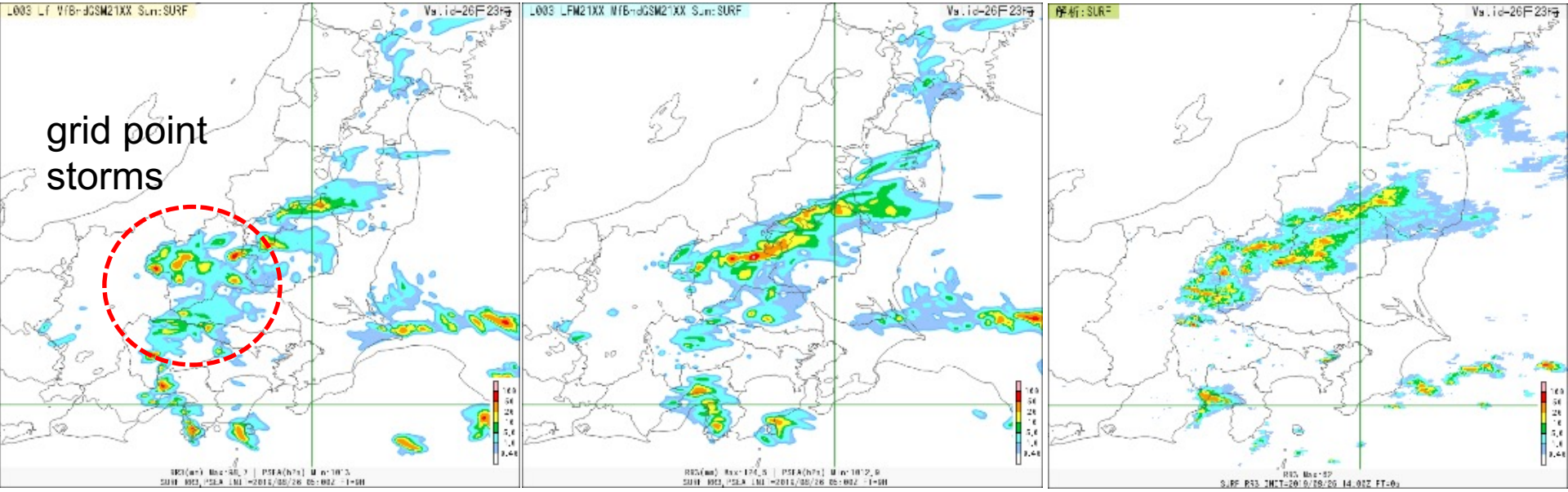
Contour: vertical velocity
Shade: vertical heat flux by the Leonard term

3-hour accumulated precipitation

LFM2003

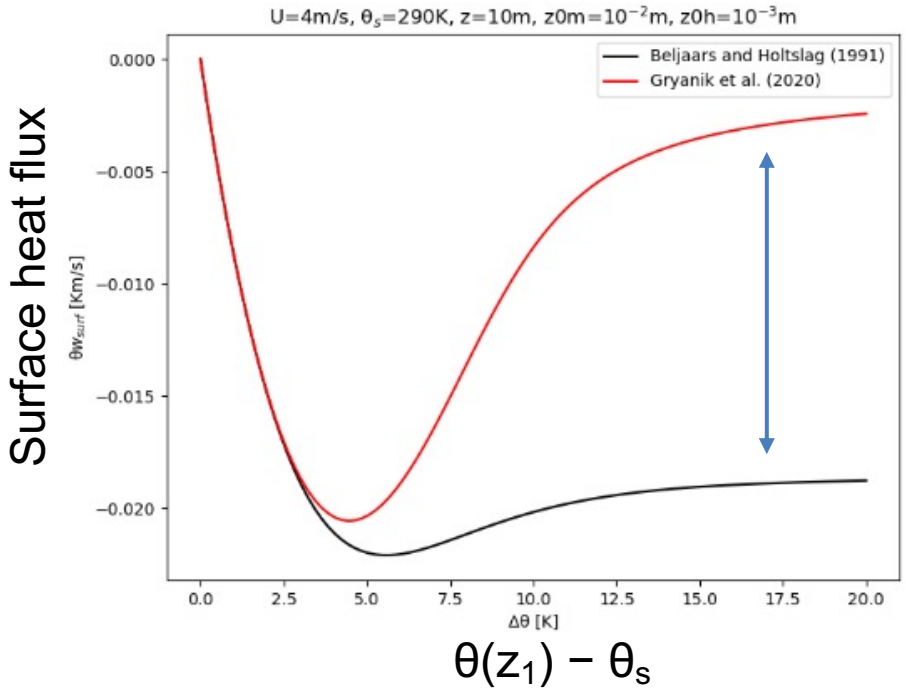
LFM2103

Radar/Raingauge-Analyzed Precipitation



- The heat and vapor fluxes due to the Leonard term contribute to reduce artificial grid point storms.

Modification of surface flux

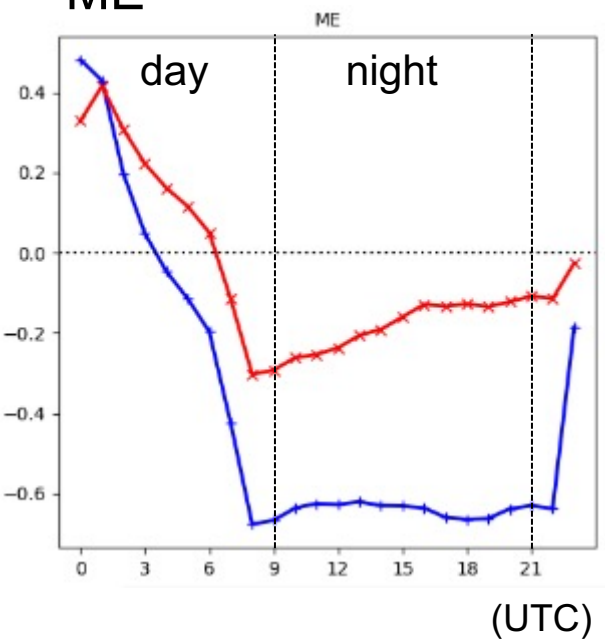


Black: Beljaars and Holtslag (1991)
Red: Gryanik et al. (2020)

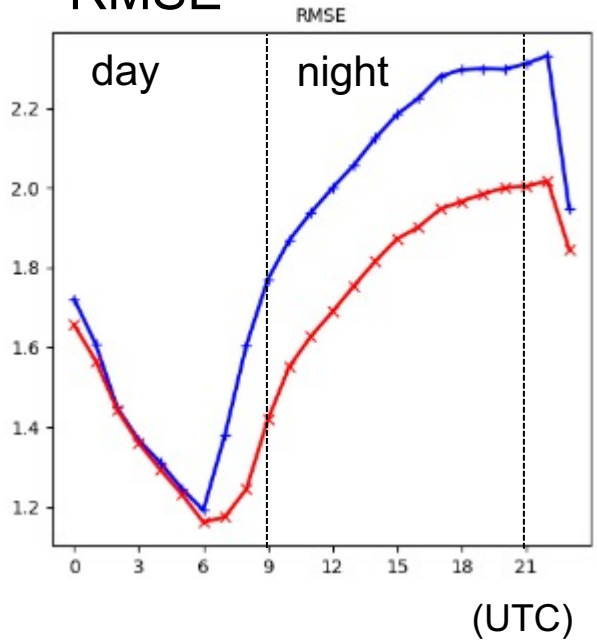
- The surface flux is evaluated using the Monin-Obukhov similarity theory.
- The stability function by Beljaars and Holtslag (1991) was used in the previous LFM.
- The stability function by Gryanik et al. (2020) is applied for a stable boundary layer.
- The surface heat flux is weakened in strongly stable conditions.

ME and RMSE of 1.5 m air temperature against ground observations

ME



RMSE



Verification period:
2020.1.11-2020.1.21
(winter)

Blue: LFM2003
Red: LFM2103

- Negative temperature bias seen in the nighttime is significantly reduced in the current LFM.

Future plans

- Meso-Scale Model (MSM)
  - increasing vertical layers from 76 to 96
  - extension of forecast hours
  - introducing a 1D ocean mixed layer model
  - will be in operation from 2022
- Local Forecast Model (LFM)
  - introducing a Hybrid-3DVar system using MEPS
  - will be in operation from 2022

References

- Kusabiraki, H., Kitamura, Y. , Sawada, M., Matsubayashi, K., Nishimoto, S., 2021: Increasing Vertical Resolution and Updating Physical Processes in JMA's Regional NWP System, CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modelling, Sec. 5 7-8.
- Ono, K., Kunii, M., Honda, Y., 2021: The regional model-based Mesoscale Ensemble Prediction System, MEPS, at the Japan Meteorological Agency. *Quart. J. Roy. Meteor. Soc.*, **147**(734), 465-484.
- Ishida, J., Aranami, K., Kawano, K., Matsubayashi, K., Kitamura, Y., Muroi, C., 2021: ASUCA: JMA operational non-hydrostatic model, *J. Meteor. Soc. Japan, submitted*.