Development of a high resolution operational NWP model at JMA

Junichi Ishida, Tabito Hara, Kohei Kawano, Kengo Matsubayashi, Hiroshi Kusabiraki, Haruka Kurahashi, Kenta Ochi, Tadashi Fujita, Yoshihiro Ishikawa, Kensuke Ishii, Yasutaka Ikuta, Kosuke Ono and Hisaki Eito

Numerical Prediction Division, Japan Meteorological Agency (NPD/JMA), 1-3-4 Chiyoda-ku, Tokyo, Japan, 100-8122 e-mail: j-ishida@met.kishou.go.jp

1. Operational high resolution regional model at JMA

- JMA has been operating a regional model with a horizontal resolution of 5km (Meso-Scale Model; MSM) since 2006.
- A higher resolution operational regional model with a 2-km horizontal grid spacing (Local Forecast Model; LFM) was launched in May 2013, covering Japan and its surroundings (Fig. 1).
- The domain coverage is equivalent to covering most part of Europe.

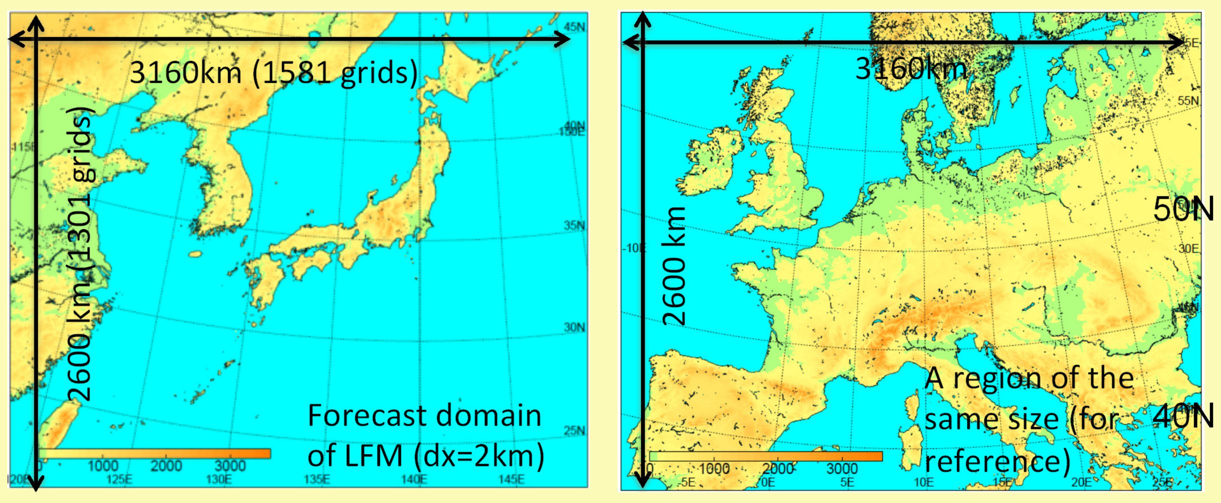

Fig. 1: A forecast domain of LFM (left) and a region with the same size in Europe (LFM covers the significantly large region)

- In order to update forecasts with the latest observations assimilated, **hourly operations** of LFM are conducted.
- No convective parameterizations are employed—it is supposed that grid-mean values can resolve convective transport of momentum, heat and water.
- Initial conditions are provided by a data assimilation system combining 3D-Var and 1-hour forecast by the model.
- Its first guess comes from the MSM (Fig. 2).

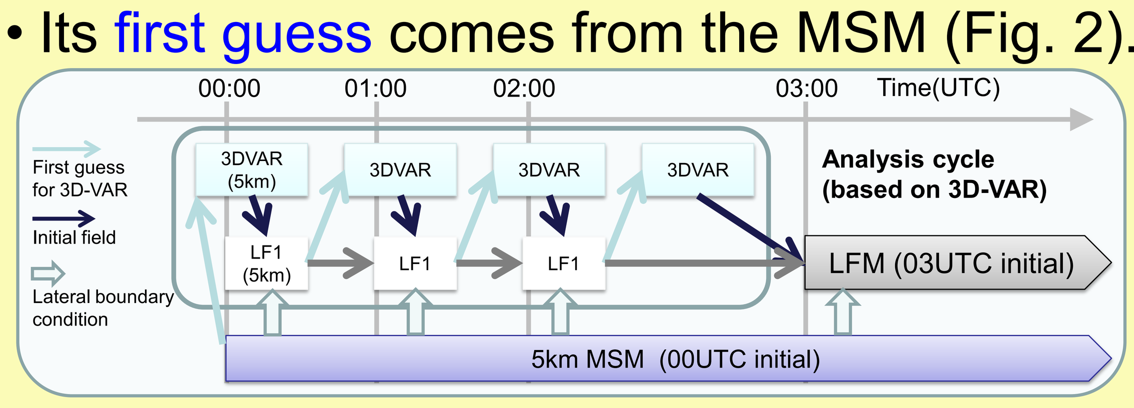

Fig. 2: A schematic diagram of the data assimilation system which provides an initial field for LFM.

2. Advantages of LFM

- LFM can better predict convection initiated by strong forcing (such as convergence at fronts) and resulting heavy precipitation than coarser models such as MSM (dx=5km) (Fig. 3).

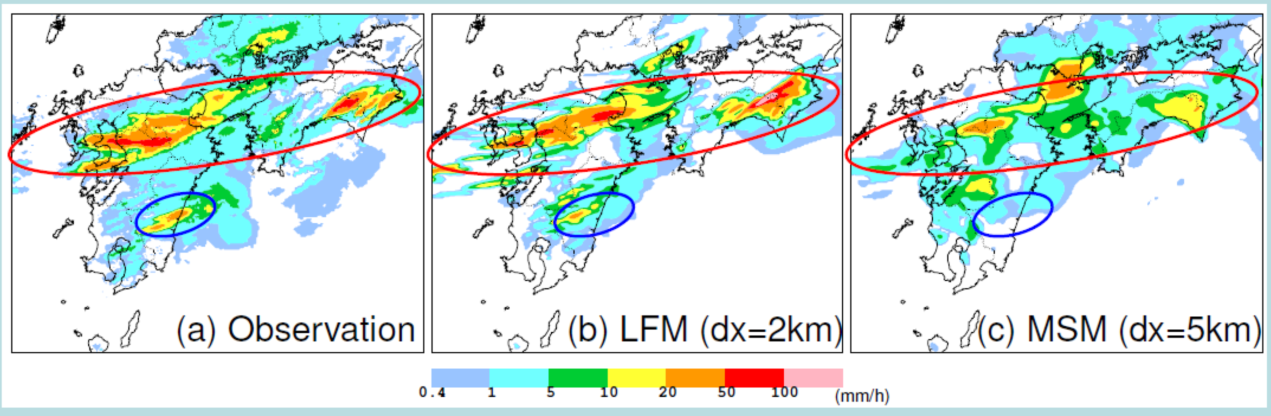

Fig.3: A comparison of 1-hour precipitation forecasts between LFM and MSM. LFM reproduced the line shaped rain band observed along a stationary front better than MSM.

- Due to finer orography in the higher resolution model(Fig. 4), convection initiated by orographically-forced lifting is better represented (Fig. 5).

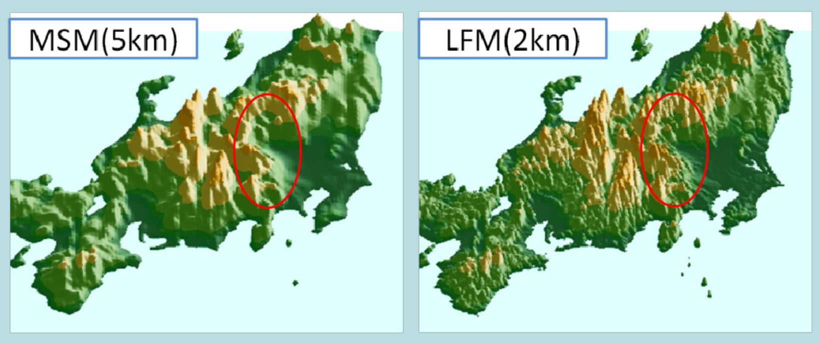

Fig. 4: Topography of the central Japan used in LFM (dx=2km) and MSM (dx=5km). Regions circled by red lines correspond to those circled in Fig.5

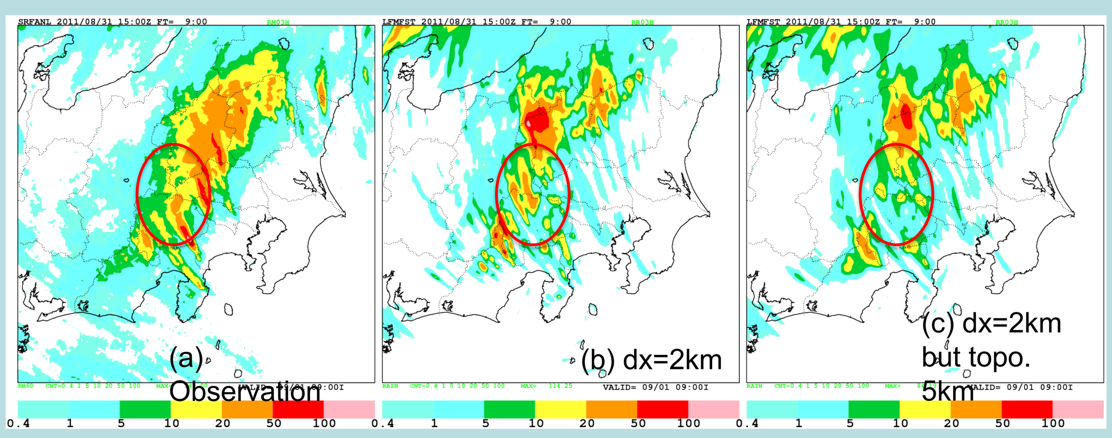

Fig. 5: 3-hr precipitation forecasts by the model with (b) 2km grid spacing and topo., (c) dx=2km but smoothed topo. to 5km one, with (a) corresponding observation.

3. Issues in representing convection (Fig. 6)

- Predicted amounts of precipitation tend to be too much.
- Initiations of convection are often delayed when forcing to lead to the initiation is weak.
  - As a result, too much precipitation is generated in the model by releasing excessively accumulated CAPE.

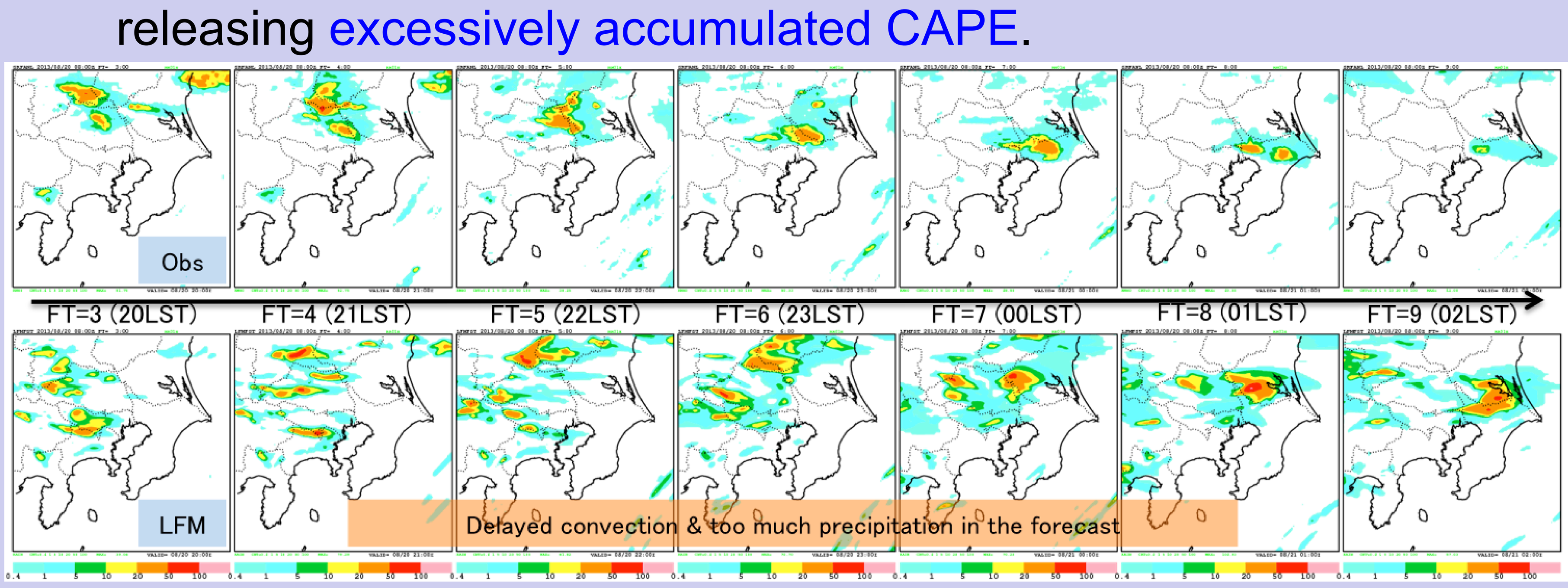

Fig. 6: Time series of 1hr precipitation forecasts and corresponding observation to show a typical convection representation in LFM. (Upper) Observation, (Lower) LFM forecasts

4. Convection in LFM as a cloud permitting model

A cloud "permitting" model cannot treat all phenomena accompanied with convection, though it may resolve a part of them.

Convective parameterizations try to deal with vertical transport, entrainment/detrainment and processes leading to convective initiation (Fig.7).

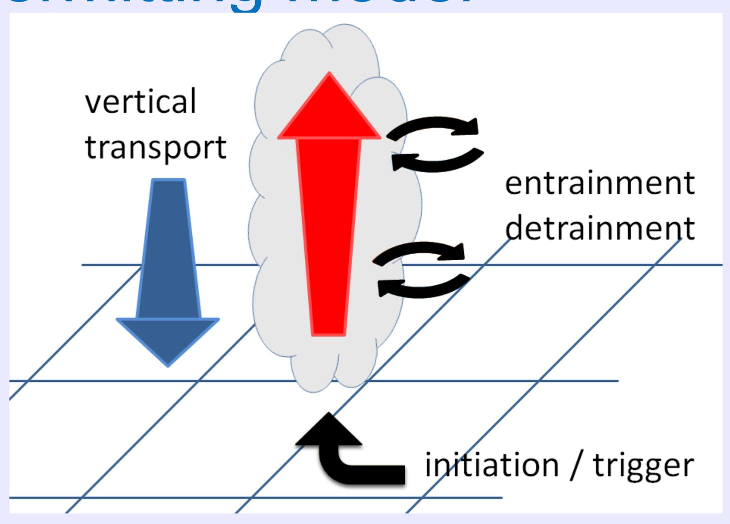

Fig. 7: A schematic model description in convective parameterizations

In a cloud permitting model such as LFM …

- Vertical transport
  - It can be explicitly resolved by grid mean vertical velocity.
- Initiation
  - Part of initiation is controlled by unresolved modes such as finer topography and small convergence.
- Entrainment/detrainment
  - Driven by turbulence near cloud wall and its scale is so small that extremely high resolution (like LES) is required to explicitly resolve it.

→ 2km horizontal resolution is too coarse to explicitly resolve some small scale processes. Parameterizations to treat them are required. For the processes which are treated explicitly, finer dynamics core is also required.

5. Development for a cloud permitting model

JMA started the development of three new frameworks to replace the current forecast model and analysis system.

- New dynamical core "asuca"
  - JMA has been developing a new dynamical core named "asuca" since 2007 (Table 1). The objectives are as follows.
    - Improved computational stability,
    - Higher efficiency on massive parallel scalar multi-core architecture,
    - Exclusion of artificial parameters such as numerical diffusion, etc.
- Physics Library
  - The Physics Library is intending to serve as a repository for various subroutines related to physical processes with unified coding and interface rules, and allows them to be shared among various forecast models. It makes us possible to
    - Develop more efficiently due to the simpler code structures
    - Implement current physics processes into new dynamical core : only a few days were spent to implement full physics.
- Variational data assimilation system based on asuca
  - JMA started a development of 3D-VAR and 4D-VAR system based on asuca in 2011.
    - Close development of Non-linear, Tangent-linear and Adjoint models

What we are developing to treat convection in LFM using new frameworks are …

- Vertical transport
  - The dynamical core with full physics shows good computational stability, but it produces too strong vertical velocity. It may be mainly due to a lack of parameterizations, though there is room for improvement in the core.
- Initiation
  - Consideration of inhomogeneity in each of grids in cloud microphysics? → Under development
  - Adding stochastic forcing to tendencies and surface fluxes → under testing
- Entrainment/detrainment
  - It is a kind of horizontal transport by turbulence.
  - Smagorinsky type horizontal diffusion is under testing as a first step of the parameterization.

We are planning to put the three frameworks into operation for LFM in 2014 and for MSM in 2016.

	ASUCA	JMA-NHM (current model)
Governing equations	Flux form, Fully compressible equations	Quasi flux form, Fully compressible equations
Prognostic variables	ρu, ρv, ρw, $\rho\theta_m$, ρ	ρu, ρv, ρw, θ, p
Spatial discretization	Finite volume method	Finite difference Method
Time integration	Runge-Kutta 3rd (long and short)	Leapflog with time filter (long), Forward backward (short)
Treatment of sound	Conservative Split explicit	Split explicit
Advection	Flux limiter function by Koren (1993)	4th (hor.) and 2nd(ver.) order with advection correction
Numerical diffusion	None	4th order linear and nonlinear diffusion
Treatment of rain-drop	Time-split	Box-Lagrangian
Coordinate	Generalized coordinate or Conformal mapping + Hybrid-Z	Conformal mapping (hor.), Hybrid – Z (ver.)
Grid	Arakawa-C (hor.), Lorentz (ver.)	Arakawa-C (hor.), Lorentz (ver.)

Table 1: Comparison of specifications of asuca and JMA-NHM (current operational model)