13.3

DEVELOPMENT OF A NONHYDROSTATIC MODEL FOR VERY SHORT-RANGE FORECASTING AT JMA

Tsukasa Fujita*, K. Saito, Y. Yamada, J. Ishida, M. Narita, S. Goto
Japan Meteorological Agency, Chiyoda-ku, Tokyo, Japan

C. Muroi, T. Kato, and H. Eito
Meteorological Research Institute, Tsukuba, Ibaraki, Japan

1. INTRODUCTION

A nonhydrostatic model (hereafter NHM) for operational weather forecasting has been developed by the Numerical Prediction Division / Japan Meteorological Agency (JMA) collaborating with the Meteorological Research Institute. The model is based on its former edition (Saito et al. 2001, Ikawa and Saito 1991), and further improved in its dynamics and physics for computational stability and efficiency in addition to incorporation of parallel operation. After modifications and optimizations are made, the model successfully runs with fairly long timesteps of 30-40 seconds at horizontal resolution of 10 km. NHM replaces the operational hydrostatic spectral model (MSM) to provide very short-range forecast for severe meteorology.

2. NUMERICAL IMPLEMENTATION

2.1 *Model Formulation*

Fully-compressible governing equations are employed for the model. A split-explicit time integration scheme (HE-VI scheme, Muroi et al. 2000) is implemented, and terms responsible for the acoustic waves are split and integrated explicitly in the horizontal, implicitly in the vertical. The advection terms are treated in the second order scheme with a flux correction scheme (Kato 1998).

A bulk cloud microphysics (three ice scheme) is used in NHM. The raindrop and graupel falling is treated in a Lagrangian manner to avoid the timestep restriction due to the large terminal velocity (Kato 1995). Also, certain parameterization schemes, such as a moist convective adjustment scheme, are adopted as optional treatments.

Table 1 shows some of the features of the model implementation. Development of other features such as higher order advection schemes and convective parameterization schemes is under way for not only operational use but research activities.

2.2 *Parallel Implementation*

The entire domain of the model is divided into more than one subdomains to incorporate parallel computation. The partitioning is performed in the north-south direction with each subdomain kept intact in the west-east direction for efficiency in vector computation. The node-to-node communication is executed using MPI.

Table 1　Specifications of NHM

Dynamical Frame	Eulerian, flux form, nonhydrostatic fully compressible equations
Horizontal Grid	Arakawa C
Projection	Lambert
Vertical Coord.	Z*, Lorenz type
Advection Term	Flux form, second order scheme with flux correction
Dynamical Core	HE-VI
Turbulent Closure	Deardorff level 2.5
Numerical Diffusion	Fourth order linear damping, nonlinear damping
Moist Process	Bulk cloud microphysics (qv, qc, qr, qi, qs, qg) / Moist convective adjustment
Surface Layer	Monin-Obukhov
Upper Boundary	Rigid lid, Rayleigh friction layer
Lower Boundary	4-level prognostic ground temperature

3. COMPARISON WITH A HYDROSTATIC MODEL

Comparison of NHM with MSM is conducted to investigate the performance of NHM. The initial fields are made through the operational 3D OI (4D VAR using MSM for the outer loop and its adjoint for the inner loop, after Mar. 2002) system.

The results show that NHM prediction presents smaller areas for weak to moderate rain, and larger ones for strong rain than MSM does. This feature is considered to result from the cloud microphysics, and seems favorable for prediction of disastrous rain events.

Bias scores of the two models for 3-hour precipitation are represented in Fig.1. The forecasts are for June 2001, and the maximum rainfall data in 40 km x 40 km areas are verified against the corresponding observational data based on radar observation corrected by raingauges. The

---

[*] *Corresponding author address*: Tsukasa Fujita, Numerical Prediction Division, Japan Meteorological Agency, Chiyoda-ku, Tokyo 100-8122, Japan; e-mail: fujita@npd.kishou.go.jp

characteristics of the NHM prediction mentioned above is seen in the higher bias scores for the large rain rate. The spin-up problem manifests itself exaggeratedly, since the initial conditions of the model does not contain appropriate fields of the water substances.

Threat scores shown in Fig.2 reflect the characteristics seen in the bias scores: for stronger rain, NHM provides better information than MSM does, and the result is reversed for weak rain.

4. OPERATIONAL SPECIFICATIONS

NHM is planned to be integrated up to 18 hours with 361x289 grid points of 10 km uniform spacing to provide quantitative precipitation forecast over the entire Japanese territory. The model is also intended to run for airport operation at higher resolution with boundary conditions given by the 10 km run. Aspects of the operation are shown in Table 2.

Choice of options and certain optimizations are made considering the performance and efficiency. For example, the HE-VI scheme is favored for its computational efficiency for the distributed memory parallel computer while a 3D implicit scheme (HI-VI) is available as an alternative method, and the cloud microphysics is simplified with sufficient accuracy. Also, the gravity wave (buoyancy) term is split in the HE-VI scheme for stable runs with longer timestep, and the moist convective adjustment scheme is used together with the cloud microphysics to suppress excessive updrafts. Preliminary experiments revealed errors in the advective processes impairs the model stability, however, the flux correction successfully eliminates the defect. The latest edition (as of May 2002) provides 18-hour forecast in about 30 minutes using 40 nodes of HITACHI SR8000.

Table 2 Operational Specifications of NHM

Purpose	Very short-range forecasting	Airport operation (plan)
Horizontal Resolution	10 km	2 km
Horizontal Grid	361x289	150x150
Timestep	30 sec	5 sec
Lateral Boundary	JMA Regional Spectral Model	Double nest with 10 km NHM
In operation	Early 2004	Late 2004

REFERENCES

Ikawa, M., 1988: Comparison of some schemes for nonhydrostatic models with orography. *J. Meteor. Soc. Japan*, **66**, 753-776

Ikawa M., and K. Saito, 1991: Description of a nonhydrostatic model developed at the Forecast Research Department of the MRI. *Tec. Rep. MRI*, **28**, 238 pp.

Ishida J., K. Saito, Y. Yamada, T. Fujita, M. Narita, S. Goto, C. Muroi, T. Kato and H. Eito, 2002: Development of JMA nonhydrostatic model for operational forecasting, *Prep, Spring Conf. MSJ.*, **81**, B306 (in Japanese).

Kato T., 1995: Box-Lagrangian rain-drop scheme. *J. Meteor. Soc. Japan*, **73**, 241-245

Kato T., 1998: Numerical simulation of a band-shaped torrential rain observed over southern Kyushu, Japan on 1 August 1993. *J. Meteor. Soc. Japan*, **76**, 97-128

Muroi C., K. Saito, T. Kato and H. Eito, 1999: Development of JMA nonhydrostatic mesoscale model and its computational efficiency, *Prep, Spring Conf. MSJ.*, **77**, P124 (in Japanese).

Saito K., T. Kato, H. Eito and C. Muroi, 2001: Documentation of the Meteorological Research Institute / Numerical Prediction Division Unified Nonhydrostatic Model. *Tec. Rep. MRI*, **42**, 133 pp.

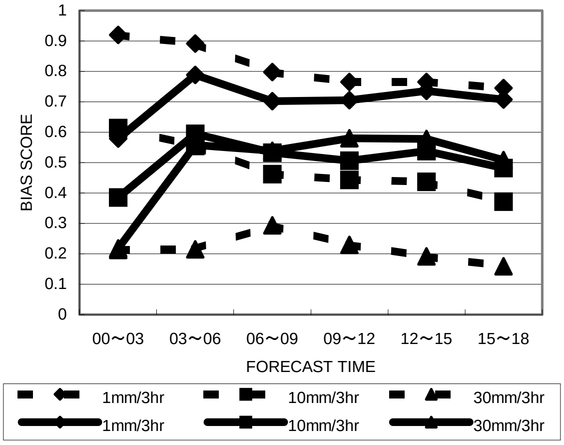

Fig. 1 Bias scores of NHM (solid) and MSM (dashed). After Ishida et al. (2002).

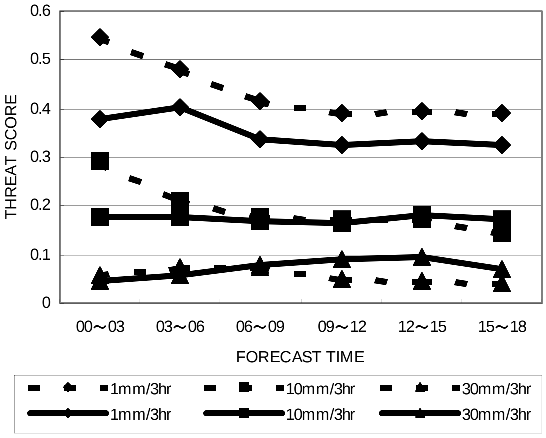

Fig. 2 Same as Fig.1 but for threat scores.