future.

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The organization of this report is as follows. Chapter B presents an overview of the model. Chapter C gives the governing equations and pressure equations. Chapter D describes their finite discretization form and relevant pressure equation solver. Chapters E and F introduce the initiation procedures and boundary conditions. Chapter G explains newly incorporated physical processes after Ikawa and Saito (1991) and diffusion processes. Chapter H presents examples of numerical simulation. Chapters I and J describe the model code structure and relevant utilities. Chapter K is the user's guide to running the model. In Chapter L, we briefly refer to current and future programs for code parallelization and joint programs of MRI and NPD to develop a regional model of JMA for numerical prediction. A spherical curvilinear orthogonal coordinate version under development to realize a global nonhydrostatic model in the future is also briefly introduced.

Sections C-2-4, C-3-4, D-2-3, G-1-2, G-1-3, G-1-4, G-2-2, G-5-1, H-3, J-3-2 and K-5-2 were mainly written by T. Kato; sections G-5-2 and H-4, by H. Eito; and sections C-3-2 and L-2, by C. Muroi. Section I-2 was written by all authors. Other sections were mainly written by K. Saito.

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B. Overview of the model

The MRI/NPD unified nonhydrostatic model is a multipurpose mesoscale model being developed by the Forecast Research Department of the Meteorological Research Institute and the Numerical Prediction Division of the Japan Meteorological Agency for both research and operational forecasting. Fully compressible equations with conformal mapping or anelastic approximation (AE) can be selected as the basic equations. The fully compressible model doesn't contain approximations, such as the linearlization using the reference atmosphere and/or omitting the diabatic heating term in the pressure equation. In addition to the semi-implicit scheme (HI-VI scheme) employed in MRI-NHM, the split-explicit scheme (HE-VI scheme) developed at NPD has been incorporated into the model for the computational scheme. Accordingly, three dynamic cores (HI-VI, HE-VI and AE) are available and can be selected by a mode switch.

Table B-1 MRI/NPD-NHM Specifications.

Category	Specification	Optional choice
Basic equations	Fully compressible with a map factor (Saito, 1997) Fall-out of precipitable water substances is considered in continuity equation	Anelastic (Ikawa, 1988) Quasi-compressible (Ikawa, 1988) Hydrostatic (Kato and Saito, 1995)
Vertical coordinate	Terrain-following	
Horizontal coordinate	Conformal map projection (Saito, 2000)	Cartesian
Vertical grid structure	Lorenz type	
Horizontal grid structure	Arakawa C	
Advection term	Flux form, second order	Modified centered difference (Kato, 1998)
	Box-Lagrangian scheme for rainfall (Kato, 1995)	Advective form with third/fourth order (Saito, 1998)
Treatment of sound waves	HI-VI (Saito, 1997) HE-VI (Muroi et al., 1999)	Anelastic filtering (AE)
Time differencing	Semi-implicit (for HI-VI) Split-explicit (for HE-VI)	Leap-frog for AE
Turbulent closure	Deardorff level 2.5 (Saito and Ikawa, 1991; Saito, 1993)	
Cloud microphysics	Predict qv, qc, qr, qi, qs, qg (Ikawa *et al.,* 1991)	Predict number density of cloud ice, snow and graupel (Ikawa *et al.,* 1991)
Cumulus parameterization	Moist convective adjustment (Kato and Saito, 1995)	
Atmospheric radiattion	Long- and short-wave radiation specified by relative humidity (Kato, 1999)	Specified by cloud microphysical properties (Eito *et al.,* 1999)
Surface layer (land)	Monin-Obukhov (Sommeria, 1976)	Free slip
(sea)	Kondo (1975)	
Lower boundary	Prognostic ground temperature (Kato, 1996)	Specified ground temperature
Upper boundary	Rigid lid, thermally insulated Rayleigh friction layer	
Lateral Boundary	Radiative nesting boundary condition (Saito, 1994a)	Open (Orlanski, 1976) Cyclic
Initialization	Hydrostatic interpolation from JSM or RSM	Variational calculus for AE scheme (Saito, 1994a)
Numerical diffusion	4-th order linear damping	Nonlinear damping