A. Preface

The nonhydrostatic model presented in this technical report has been developed by M. Ikawa since 1980 and K. Saito since 1988. This model is intended for a research tool and for providing useful information about the scheme to be adopted by a future operational model which will be used in forecasting regional weather. As a research tool, this model has been used for simulations of convective clouds (Ikawa *et al.*, 1987; Ikawa, 1988) and mountain waves (Ikawa and Nagasawa, 1989; Ikawa, 1990; Saito and Ikawa, 1991).

With the advent of computer facilities, nonhydrostatic models will replace hydrostatic models in short-range weather forecasting for a limited area in the near future. There have been many schemes used in nonhydrostatic models so far developed. In this model, AE (anelastic), E-HI-VI (elastic-horizontally and vertically implicit) and E-HE-VI (elastic-horizontally explicit-vertically implicit) shecmes are implemented, and these three schemes are easily compared with each other under the same numerical environment. Therefore, this model is regarded as an *evaluation kit* of these three schemes. Which is the best scheme among the three still remains to be decided.

This model has to be improved or refined in many points. Further development of the model will be beyond the power of one or two persons. It is hoped that the detailed description of the model and the manual for running the model presented in this technical report will stimulate the cooperative efforts on the further development of this model or provide some useful information for building up a new model.

The points to be revised or improved are as follows:

1. Dynamical framework:
   a) Change of the finite discretization form of the 2-nd order to that of the 4-th order.
   b) 1-way or 2-way nesting.
   c) Change of the grid model to the spectral model by Tatsumi's limited area spectral method (a) is in contradiction to c))
   d) Hybrid vertical coordinates (the lower part of the domain is ξ^*, while the upper part is z).
   e) Radiation condition at the upper boundary (Klemp and Durran, 1983).
2. Physical process:
   a) Refinement of cloud microphysical processes.
   b) Refinement of the parameterization of subgrid-scale turbulence and incorporation of subgrid-scale condensation.
   c) Refinement of the parameterization of surface and air-surface interaction.

d) Incorporation of short- and long-wave radiation. No radiation is incorporated in the present model.

3. Others:

a) Optimization of the program code for the array processor (supercomputer).

b) Debugs of the program code to make the model more reliable.

The organization of this report is as follows. In Chapter B, governing equations, parameterizations of physical processes and their finite discretization are presented. In Chapter C, examples of 3-dimensional simulation are presented, including the model verification by comparing 3-dimensional linear analytic solutions of nonhydrostatic mountain waves with their numerical counterparts. In Chapters D and E, procedures for running the model and plotting model results are presented. In Chapter B, some notes named 'Program Guide' (abbreviated as P.G.) are inserted in order to give useful comments on how field variables are expressed and governing equations are computed in the program code. These notes and Chapters D and E may be skipped by readers who intend to get general information on the model and have no interest in running this model.

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Chapter B except for B-10, C-3, and Chapters D and E were written by M. Ikawa. B-10, C-1, C-2 were written by K. Saito.