

# Implementation of the Cylindrical Equidistant Projection for the Non-Hydrostatic Model of the Japan Meteorological Agency

Yosuke Yamazaki<sup>1</sup> and Kazuo Saito<sup>2</sup>

<sup>1</sup>Advanced Earth Science & Technology Organization

<sup>2</sup>Numerical Prediction Division, Japan Meteorological Agency

e-mail: y-yamazaki@naps.kishou.go.jp

The Non-Hydrostatic Model (NHM) is a regional grid-point model which is based on the finite difference scheme and will replace current operational regional hydrostatic spectral model, the Mesoscale Spectral Model (MSM) of the Japan Meteorological Agency (JMA). Recently, the importance of developing non-hydrostatic global model has been increasing with the advance of the computer technology. One of the easiest ways to modify a grid-point model from a regional model to a global one is to implement the latitude-longitude (lat-lon) coordinate. Saito (2001)[1] made a global non-hydrostatic model by implementing the Cylindrical Equidistant (CE) projection for NHM together with a special treatment for the grid points near the poles. A preliminary 24 hours simulation with the horizontal resolution of 1.5 degrees for latitude and longitude was carried out for a global domain using the global analysis (GANAL) of JMA as the initial condition. Although the test run reproduced well the synoptic scale motions of the atmosphere, it would be difficult to perform simulations with higher horizontal resolution because the model was based on a previous version of NHM which was not parallelized. The implementation of the CE projection supported only the semi-implicit scheme (HI-VI scheme), which treats the fast modes (sound waves) implicitly in both horizontal and vertical directions.

The CE projection has been implemented again for the latest version of NHM, which is fully parallelized by using the MPI library and includes many new features such as the Kain-Fritsch cumulus parameterization and higher-order advection schemes[2]. The split-explicit scheme (HE-VI scheme) which treats the fast modes explicitly in the horizontal direction and implicitly in the vertical direction is also supported, together with a newly developed time-splitting scheme for advection terms[3].

NHM is designed to select a type of map projection by its runtime option, and have supported 3 conformal projections; the Polar Stereographic projection, the Lambert conformal projection, and the Mercator projection. The governing equations of NHM are formulated for the arbitrary orthogonal curvilinear coordinate system on the sphere with the horizontal scaling factors of map projection,  $m_i$  defined by

$$ds_i = \frac{dx_i}{m_i} \quad \text{for } i = 1, 2, \quad (1)$$

where  $ds_i$  is the length in the  $i$ -th direction when  $x_i$  varies with  $dx_i$ . Note that  $m_1 = m_2$  in the conformal projections. If we take 1 and 2 in the longitudinal and latitudinal direction respectively, these map factors take the form;

$$(m_1, m_2) = \left( \frac{1}{a \cos \phi}, \frac{1}{a} \right) = \frac{1}{a} \left( \frac{1}{\cos \phi}, 1 \right) \quad (2)$$

for the lat-lon coordinate, and

$$(m_1, m_2) = \left( \frac{\cos \phi_0}{\cos \phi}, 1 \right) \quad (3)$$

for the CE projection, where  $a$  is the radius of the Earth,  $\phi$  the latitude, and  $\phi_0$  the standard latitude. In case of  $\phi_0 = 0$ , the CE projection is equivalent to the lat-lon coordinate except for its coordinate dimension; it is length in the CE projection while angle in the lat-lon coordinate.

To test our implementation of the CE projection, three runs of 18 hours forecast were performed on a HITACHI SR8000 distributed memory parallel supercomputer. The configuration of test runs is summarized in Table 1. Figure 1 shows a result of two runs with same configuration except for their map projection. The CE projection (Fig. 1b) reproduced the reference result with the Lambert conformal projection (Fig. 1a). Another preliminary run for large domain is also performed using GANAL of JMA as the initial and

boundary conditions (Fig. 2). Surface pressure pattern is well simulated, and the difference of domain averaged surface pressure between simulation and GANAL is within 1 hPa in the simulation period (18 hours).

Although the implementation of the CE projection was completed, two steps still remain to run NHM as a global model; re-implementation of the periodic boundary condition, and treatment for the grid points near the poles. Furthermore, from the view-point of computational efficiency, some kind of numerical technique to avoid the pole problem should be implemented; filtering longitudinal high-frequency modes near the poles, or the semi-Lagrangian scheme, and so on.

Table 1: Configuration of the test runs.

Name of the run	LM	CE1	CE2
Projection type	Lambert conformal	Cylindrical equidistant	
Standard latitude(s)	30N, 60N	35.5N	0N
Standard longitude	140.0E	—	
Center of the domain	133E, 35.5N		140E, 0N
Grid number	289 × 231 × 40		121 × 121 × 40
Horizontal resolution	10 km at the standard lat.		1 deg.
Vertical resolution	40 ~ 1180 m (40 levels)		
Initial condition	Meso 4D-Var <sup>a)</sup>		GANAL
Boundary condition	RSM <sup>b)</sup> forecast		GANAL

a) 4 dimensional variational data assimilation system for MSM (10 km mesh)

b) Regional Spectral Model of JMA (20 km mesh)

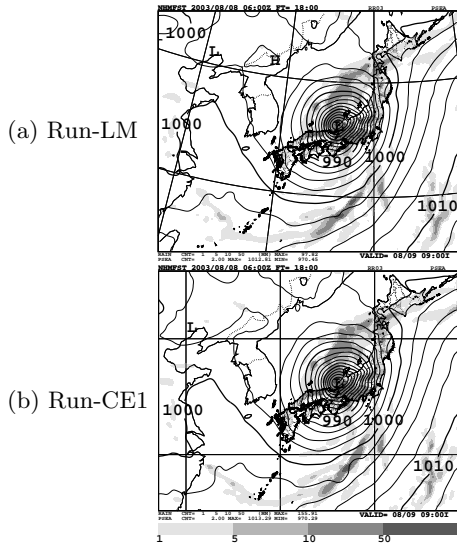


Figure 1: Sea-level pressure [hPa] (contour) and 3 hours precipitation [mm/3hours] (shaded contour) of 18 hours forecast; (a) Lambert conformal projection, and (b) CE projection. Initial time is 06UTC, 8 Aug., 2003.

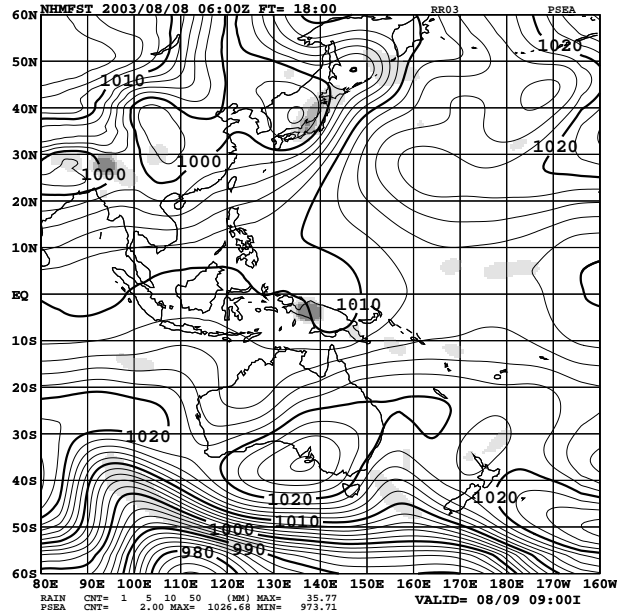


Figure 2: Same as in Fig. 1 but for large domain (Run-CE2).

## References

- [1] Saito, K., 2001: A global version of the Meteorological Research Institute/Numerical Prediction Division Nonhydrostatic Model, *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modeling*, **31**, 6.20-6.21.
- [2] Fujita, T., 2003: Higher order finite difference schemes for advection of NHM, *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modeling*, **33**, 3.9-3.10.
- [3] Saito, K., 2003: Time-splitting of advection in the JMA Nonhydrostatic Model, *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modeling*, **33**, 3.15-3.16.