J. Relevant utilities

J-1. Setting orography

The first step of the model structure (Job Step 1) is preparing the orography file. The file may be stored in a directory @data/ and named org**.

J-1-1 Format of the orography file

a. Record format

REC. 1	IXTST, IXTEN,JYMST, JYMEN, ZS, SL, FCORI, ROUGHL, FLATIT, FLONGI
REC. 2	NPROJC

b. Contents

Name	Type	Contents	Default	Unit
IXTST	I*4	Start number for x-direction	1	…
IXTEN	I*4	End number for x-direction	NX	…
JYMST	I*4	Start number for y-direction	1	…
JYMEN	I*4	End number for y-direction	NY	…
ZS(NX,NY)	R*4	Orographic height	…	M
SL(NX,NY)	R*4	Land coverage rate	1.0	0.01×%
FCORI(NX,NY)	R*4	Coriolis parameter f_3	…	s^{-1}
ROUGHL(NX,NY)	R*4	Roughness length	0.1	M
FLATIT(NX,NY)	R*4	Latitude	FLAT	degree
FLONGI(NX,NY)	R*4	Longitude	FLON	degree
NPROJC	C*4	Map projection	DES	…

J-1-2 Simple orography for idealized tests

For an ideal test, the orography is given by the following functions. For three-dimensional simulation, the orographic height is given by an isolated mountain as

$$Z_x(x,y) = \frac{h_m}{\{1+(\frac{x-x_0}{a})^2+(\frac{y-y_0}{b})^2\}^{\frac{3}{2}}}, \qquad \text{(J1-2-1)}$$

where h_m is the height of the mountain top and, a and b are the horizontal scale for the x- and y-directions. For two-dimensional simulation, the orography is simply given by

$$Z_x(x) = \frac{h_m}{1+(\frac{x-x_0}{a})^2}, \qquad \text{(J1-2-2)}$$

where a is the half width.

For simple orography, the Descart coordinate is assumed, and 'DES' should be set as NPROJC.

P. G. The above equations are given by the function ZSFN in org*.f in /srcenv. See K-1-2 for details.

J-1-3 Real orography for arbitrary conformal projection

a. GTOPO30 dataset

Real orography is provided by the GTOPO30 dataset, which is global digital elevation data with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer) developed at the US Geological Survey's EROS Data Center. Detailed information on the characteristics of GTOPO30, including the data distribution format, the data sources, production methods, accuracy, and hints for users, is found in the GTOPO30 URL

http://edcdaac.usgs.gov/gtopo30/gtopo30.html

and its README file

http://edcdaac.usgs.gov/gtopo30/README.html.

The original GTOPO30 data is a global data set covering the full extent of latitude from 90 degrees south to 90 degrees north; MRI/NPD-NHM provides limited data of latitude from 10 to 50 degrees north and longitude from 110 to 150 degrees east. See K-2-2 for details.

b. Conversion to conformal projection map

The orography file is transformed into a conformal map projection. The model can accommodate the following three conformal map projections:

1) Polar stereo graphic projection

The horizontal coordinate (x, y) is a projected plane transformed by

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} x_p + ma\cos\varphi\sin\Delta\lambda \\ y_p - ma\cos\varphi\cos\Delta\lambda \end{pmatrix}, \tag{J1-3-1}$$

where (x_p, y_p) is the position of the north pole in the projected map, (φ, λ) the latitude and longitude, $\Delta\lambda$ the deflection of longitude from the standard longitude λ_0, and a the radius of the Earth (Fig. J1-3-1). The map factor, m, is defined by

$$m = \frac{1+\sin\varphi_0}{1+\sin\varphi}, \tag{J1-3-2}$$

where φ_0 is the standard latitude and m is unity at $\varphi = \varphi_0$. For a position (x, y), the inverse transformation of (J1-3-1) is given by

$$\begin{pmatrix} \lambda \\ \varphi \end{pmatrix} = \begin{pmatrix} \lambda_0 + \tan^{-1}\dfrac{x - x_p}{y_p - y} \\ \sin^{-1}\dfrac{A^2 - r^2}{A^2 + r^2} \end{pmatrix}, \tag{J1-3-3}$$

where

$$A = a(1+\sin\varphi_0), \tag{J1-3-4}$$

$$r = \frac{y_p - y}{\cos\Delta\lambda}, \tag{J1-3-5}$$

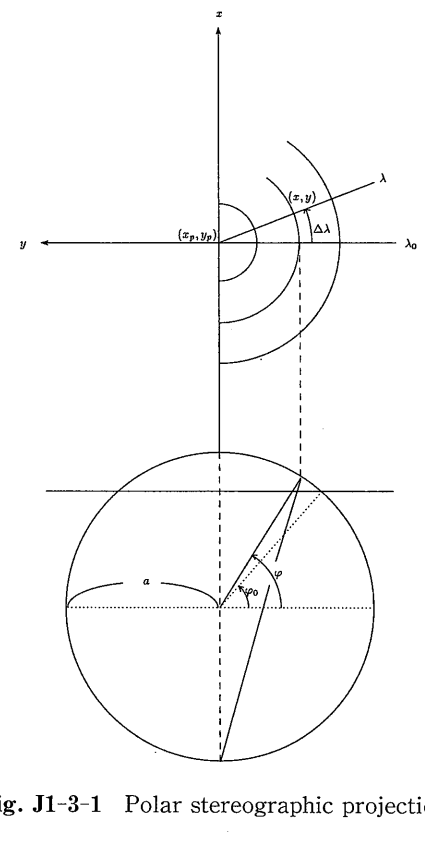

Fig. J1-3-1 Polar stereographic projection.

2) Lambert conformal projection

In a Lambert projection (Fig. J1-3-2), the horizontal coordinate (x, y) is given by

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{bmatrix} x_p + \frac{m}{c} a \cos\varphi \sin c\Delta\lambda \\ y_p - \frac{m}{c} a \cos\varphi \cos c\Delta\lambda \end{bmatrix}, \tag{J1-3-6}$$

where

$$m = \left(\frac{\cos\varphi}{\cos\varphi_1}\right)^{c-1} \left(\frac{1+\sin\varphi_1}{1+sin\varphi}\right)^{c}, \tag{J1-3-7}$$

and

$$c = \ln\left(\frac{\cos\varphi_1}{\cos\varphi_2}\right) / \ln\{\frac{\tan\left(\frac{\pi}{4} - \frac{\varphi_1}{2}\right)}{\tan\left(\frac{\pi}{4} - \frac{\varphi_2}{2}\right)}. \tag{J1-3-8}$$

The map factor m is unity at $\varphi = \varphi_1$ $(\pi/6)$ and $\varphi = \varphi_1$ $(\pi/3)$. c is about 0.72 when $\varphi_1 = \pi/6$ and $\varphi_1 = \pi/3$. The inverse transformation of (J1-3-6) is given by

$$\begin{pmatrix} \lambda \\ \varphi \end{pmatrix} = \begin{bmatrix} \lambda_0 + \frac{1}{c} \tan^{-1} \frac{x - x_p}{y_p - y} \\ \sin^{-1} \frac{B^2 - r^2}{B^2 + r^2} \end{bmatrix}, \tag{J1-3-9}$$

where

$$B = \frac{a(1+\sin\varphi_1)^c}{c(\cos\varphi_1)^{c-1}}, \tag{J1-3-10}$$

$$r = \frac{y_p - y}{\cos\{c(\lambda - \lambda_0)\}}. \tag{J1-3-11}$$

The polar stereographic projection (J1-3-1) to (J1-3-5) is a special case of $c=1$ in (J1-3-6) to (J1-3-11).

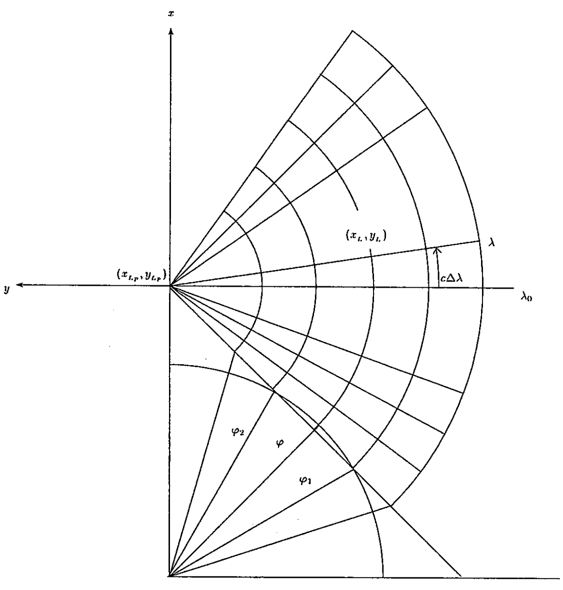

Fig. J1-3-2 Lambert conformal projection.

3) Mercator projection

In a Mercator projection (Fig. J1-3-3), the horizontal coordinate (x, y) is defined by

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} x_o + a\cos\varphi_0 \Delta\lambda \\ y_o + a\cos\varphi_0 \ln\left(\dfrac{1+\sin\varphi}{\cos\varphi}\right) \end{pmatrix}, \qquad \text{(J1-3-12)}$$

where (x_0, y_0) is the position of a point whose latitude and longitude are $(0., \lambda_0)$ in the projected map. The map factor is given by

$$m = \frac{\cos\varphi_0}{\cos\varphi}. \qquad \text{(J1-3-13)}$$

The inverse transformation of (J1-3-12) is given by

$$\begin{pmatrix} \lambda \\ \varphi \end{pmatrix} = \begin{pmatrix} \lambda_0 + \dfrac{x - x_0}{a\cos\varphi_0} \\ \sin^{-1}\dfrac{C-1}{C+1} \end{pmatrix}, \qquad \text{(J1-3-14)}$$

where

$$C = e^{\frac{2(y-y_0)}{a\cos\varphi_0}}. \qquad \text{(J1-3-15)}$$

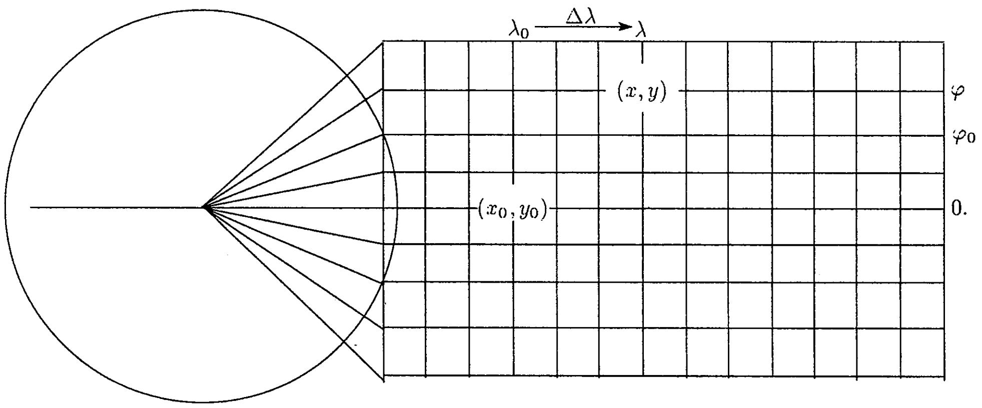

Fig. J1-3-3 Mercator projection.

J-2. File conversion for nesting with RSM

So far, the model has been used for several realistic simulations. The outer models that supply the initial and boundary conditions are the Japan Spectral Model of JMA (JSM) (Saito, 1994, 1997 ; Saito and Kato, 1996 ; Kato, 1996, 1998 ; Seino and Saito, 1999 ; Murata *et al.,* 1999), Regional Spectral Model of JMA (RSM) (Saito, 1996 ; Kato *et al.,* 1998 ; Eito *et al.,* 1999 ; Yoshizaki *et al.,* 2000) and Limited Area Assimilation and Prediction System of BMRC (LAPS) (Saito *et al.,* 2001a). Recently, Saito (2000) has tested nesting the nonhydrostatic model with Global Analysis data of JMA. In this section, we present the nesting utility for RSM as an example.

J-2-1 Input and output files

a. Input file from RSM

The following four files are required from RSM for file conversion for nesting. These files are obtained by running RSM. For details of the files and the 'GVS1' format, see the RSM user's guide (Goda, 1996).

File	Contents	Format	Remarks
RSM.HM	RSM's orography file	GVS1	
RFEB**Z	RSM's eta plane file	GVS1	forecast file
RF2M**Z	RSM's physical monitor	GVS1	forecast file
RASB**Z	RSM's surface file		

b. Temporary file

The following four temporary files are made by running 'readrsm' step. These files (NXO, NYO, NZO) may be smaller than RSM's original size (257,217,36) since they are cut out from RSM's output files according to the nonhydrostatic model domain.

File	Array	Content	Unit	Remarks
@rsm.org	ZS(NXO,NYO), SL(NXO,NYO)	Orography height Land coverage	m 0.01%	Cut out from RSM.HM
@rsm.gpv	RAINO(NXO,NYO), PSEA(NXO,NYO), PAIO(NXO,NYO), UO(NXO,NYO,NZO), VO(NXO,NYO,NZO), TO(NXO,NYO,NZO), QVO(NXO,NYO,NZO)	Accumulated rain Sea-level pressur Surface pressure x-direction wind y-direction wind Temperature Water vapor	mm Pa m/s m/s K Kg/Kg	Cut-out from RFEB**Z
@rsm.sfc	SSTO(NXO,NYO), TINO(NXO,NYO,4)	sea surface temp. ground temperature		cut-out from RASB**Z
@rsm.phy	WETO(NXO,NYO), KINDO(NXO,NYO), ROUGHO(NXO,NYO), TINO(NXO,NYO,4)	wetness land use roughness length ground temperature	0.01% --- m K	cut-out from RF2M**Z

c. Other file

The real orography file for nonhydrostatic model as in J-1-1 is required.

File Name	Array	Content	Unit	Remarks
org**	see J-1-1	see J-1-1	…	…

d. output file

File Name	Array	Content	Unit	Remarks
uvptq**	PSEAM, PTOPM, IDATE(5), U(NX,NY,NZ), V(NX,NY,NZ), W(NX,NY,NZ), PT(NX,NY,NZ) QV(NX,NY,NZ) PTGRD(NX,NY), PTGRDT(NX,NY), PTSEA(NX,NY), PAI(NX,NY), TIN(NX,NY,4)	mean sea level pressure mean model top pressure date x-direction wind y-direction wind z-direction wind potential temperature (θ) water vapor θ at ground (θ_g) time tendency of θ_g θ at sea surface (θ_s) surface pressure ground temperature	Pa Pa … m/s m/s m/s K Kg/Kg K K/s K Pa K	

ptgrd**	IDATE(5), WET(NX,NY), FKTG(NX,NY), ROCTG(NX,NY), ALBED(NX,NY)	date (yy/mm/dd/hh/wk) wetness heat diffusion heat capacity surface albedo	 0.01% m^2/s^4 $J/K/m^3$ 0.01%	
org**.x	see J-1-1	see J-1-1	…	…
sst**	SSTI(NX,NY,4)	sea surface temperature	K	
newfl**.ps	Post Script file	for monitor		

J-2-2 Flowchart of Jobstep 2.

Main program of Jobstep 2 is in srcenv/newflrsm***.f*. The job flow is as follows:

a. Setting parameter

b. Declare arrays, common variables.

c. Set model constants and definition of graphic environments

d. Read RSM orography and surface files (@rsm.org, @rsm.sfc)

e. Set outer model projection

LATLON, REVERSE

g. Define NHM model grids

VRGDIS, SETXRP, SETXRU, SETZRP, SETZRW

f. Read NHM orography file (org**) and setting of NHM model projection

MAPJPN, PRJCT2, RLTLN

g. Interpolate RSM orography and make adjusted NHM orography (org**.x)

NINTR2D, ZSTRNS3

h. Store adjusted NHM orography and surface file (ptgrd**)

NINTR2D, STORTG

do KT=KTST, KTEN

i. Read RSM's forecast file (@rsm.gpv, @rsm.phy)

REVERSE

j. Compute height of eta planes

PHICAL

k. Compute mean pressure at top of NHM

l. horizontal interpolation of RSM's forecast

NINTR2D

m. Adjust ground temperature

n. interpolation of RSM's forecast into NHM grids

INTERJ, NINTRP, NTRANSG

o. Store interpolated value (uvptq**)

STORUV

end do

J-2-3 Subroutine list of Jobstep 2.

Following subroutines are included in each member. Subroutines in the member 'nflutnpd2.f' are developed by the Numerical Prediction Division of JMA.

a. nflutlty2.f :

STORUV : store interpolated values to the file uvptq**

INTERJ : vertical interpolation

NINTRP : three dimensional interpolation

NINTRPT : three dimensional interpolation for θ

INTERZ : vertical interpolation for θ

NINTR2D : horizontal interpolation

VRGDIS : set variable grid distances

SETXRP : set absolute position of scalar points

SETXRU : set absolute position of vector points (U and V)

SETZRP : set height of full level

SETZRW : set height of half level

ZSTRNS3 : adjust NHM orography

REVERSE : change arrays' order in the y-direction

NTRANSG : rotate interpolated model's horizontal wind direction

LOADMT : load grid point values from NHM's output file

STORTG : store ground surface data to ptgrd**

b. nflutplt1.f :

PLTLO2 : plot latitude and longitude lines

PLTLN2 : plot projected lines

PCONTSL : plot contour with coast lines

c. nflutnpd2.f :

LATLON : compute latitude and longitude of each grid of RSM

LLTOIJ : compute RSM grid point from latitude and longitude

RLTLN : compute RSM grid position from latitude and longitude

PHICAL : compute height from pressure and temperature

SPLINX : Spline interpolation

J-3. Plot job

Source program of the plot job is in the directory ../srcplt. Basically the job is similar to that described in Chapter E of Ikawa and Saito (1991), while multi images and shade pattern are supported, and a postscript file is made. For the detail of parameter setting, see Section K.

J-3-1 Model output file (1)

In Job Step 3, STRMTS outputs grid point values of the model integration. The format is as follows. They can be selectively output according to parameter card file KDD (see K-4-3). An economical, compressed file can also be output by STRMTS2.

Record	Output	Contents of GPV
REC.1	ITDT, KD(1), U	x-direction momentum
REC.2	ITDT, KD(2), V	y-direction momentum
REC.3	ITDT, KD(3), W	z-direction momentum
REC.4	ITDT, KD(4), PT, TIN	potential temperature, ground temperature (4 layers)
REC.5	ITDT, KD(5), QV	mixing ratio of water vapor
REC.6	ITDT, KD(6), QC, QM	mixing ratio of cloud water, cloud amount
REC.7	ITDT, KD(7), QR	mixing ratio of rain
REC.8	ITDT, KD(8), ETURB	turbulent kinetic energy
REC.9	ITDT, KD(9), EDDYKM, EDDYKH, DLEN	eddy diffusion coefficients for momentum and heat mixing length
REC.10	ITDT, KD(10), PRS, PSEA, PTOPAV, SMQR, SMQS, SMQH	pressure, sea level pressure, average pressure at model top, accumulated rain, snow and graupel
REC.11	ITDT, KD(11), PQV, PQCW, PPT	production term of water vapor and cloud water, tendency of potential temperature
REC.12	ITDT, KD(12), PQR, PQCI	production term of rain and cloud ice
REC.13	ITDT, KD(13), QCI	mixing ratio of cloud ice
REC.14	ITDT, KD(14), QS	mixing ratio of snow
REC.15	ITDT, KD(15), QH	mixing ratio of graupel
REC.16	ITDT, KD(16), PQS, PQH	production term of snow and graupel
REC.17	ITDT, KD(17), DNSG2, ZS, SL	density*$G^{1/2}$ ground height, land coverage rate
REC.18	ITDT, KD(18), CPHU, CPHV	phase velocity of gravity wave for x- and y- directions
REC.19	ITDT, KD(19), QNCI	number density of cloud ice
REC.20	ITDT, KD(20), QNS	number density of snow

J-3-2 Model output file compressed by using integer*2

The subroutine of STRMTS2 outputs a compressed result file. With this file the plot job illustrated in subsection K-5-2 can be used conveniently. Output kinds can be selected according to the parameter card file KDD (see, K-4-3). The output file produced in the restart run does not make REC.1-REC.10+NZ.

Record	Output	Contents of GPV
REC.1	DT,DX,DY,DZ,PTRF,PRESRF,ZRP,ZRW,ISTRMT, IDATE,KTSTO,STDLAT,N1,C1,N2,C3,C4,C5,CO	Refer to the following remarks
REC.2	(I*4) 0, (C*5) 'ZS', (I*4) 1	Height of terrain
REC.3	(R*4) WMAX,WMIN, (I*2) ZS	
REC.4	(I*4) 0, (C*5) 'SL', (I*4) 1	Sea-land parameter
REC.5	(R*4) WMAX,WMIN, (I*2) SL	
REC.6	(I*4) 0, (C*5) 'FLAT', (I*4) 1	Latitude
REC.7	(R*4) WMAX,WMIN, (I*2) FLAT	
REC.8	(I*4) 0, (C*5) 'FLON', (I*4) 1	Longitude
REC.9	(R*4) WMAX,WMIN, (I*2) FLON	

REC.10	(I*4) 0, (C*5) 'PAIRF', (I*4) NZ	Base of Exner function
REC.11	(R*4) WMAX,WMIN, (I*2) PAIRF(,,1)	
REC.10+NZ	(R*4) WMAX,WMIN, (I*2) PAIRF(,,NZ)	
	(I*4) 1, (C*5) CMSYS, (I*4) NZ	Predicted values of 'F' at 1-th time step
REC.I1	(R*4) FMAX,FMIN, (I*2) F(,,1)	
REC.I1+NZ	(R*4) FMAX,FMIN, (I*2) F(,,NZ)	
	(I*4) 1, (C*5) 'END', (I*4) 0	End of output at 1-th time step
	(I*4) ISTRMT, (C*5) CMSYS, (I*4) NZ	Predicted values of 'F' at *ISTRMT*-th time step
REC.I2	(R*4) FMAX,FMIN, (I*2) F(,,1)	
REC.I2+NZ	(R*4) FMAX,FMIN, (I*2) F(,,NZ)	
	(I*4) ISTRMT, (C*5) 'END', (I*4) 0	End of output at *ISTRMT*-th time step
	(I*4) ISTRMT*J, (C*5) CMSYS, (I*4) NZ	Predicted values of 'F' at *ISTRMT*J*-th time step
REC.I*	(R*4) FMAX,FMIN, (I*2) F(,,1)	
REC.I*+NZ	(R*4) FMAX,FMIN, (I*2) F(,,NZ)	
	(I*4) ISTRMT*J, (C*5) 'END', (I*4) 0	End of output at *ISTRMT*J*-th time step

Here (I*4) denotes integer*4, (I*2) integer*2, (R*4) real*4, and (C*5) character*5. The compressed formula is

```
REAL*4 F4(*),FMAX,FMIN
INTEGER*2 F(*)
WD=(FMAX-FMIN)/64000.0
F(,)=NINT((F4(,)-FMIN)/WD-32000.0).                    (J3-2-1)
```

Remark)

Name	Type	Meaning	Name	Type	Meaning
DT	R*4	Time step interval	DX	R*4	x-direction grid distance
DY	R*4	y-direction grid distance	DZ	R*4	z-direction grid distance
PTRF	R*4	base of potential temperature	PRESRF	R*4	base of pressure for Exner function
ZRP(NZ)	R*4	vertical levels except vertical velocity	ZRW (NZ)	R*4	vertical levels of vertical velocity
ISTRMT	I*4	time step interval of GPV output, date	IDATE (5)	I*4	Date (year, month, day, hour, day of the week)
KTSTO	I*4	Start time of nesting file	STDLAT	R*4	standard latitude
N1	I*4		N2	I*4	
C1(N1)	C*5	Name list of predicted values	C3(N2)	C*5	Name list of predicted values
C4(N2)	C*5	Name list of predicted values	C5(N2)	C*5	Name list of predicted values
CO(N2)	C*5	Name list of predicted values			