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0.1 Basic Settings

Here we present the basic setup of the model.

0.1.1 Coordinate System

The coordinate system of the atmospheric model consists of longitude λ, latitude φ, and normalized pressure η (definitions are given below), each of which is treated as orthogonal. However, z is used for the vertical coordinate in the ground, which is treated in a land physics component.

Longitude is discretized at equal intervals (`SUBROUTINE: [SETLO]` in asetc.F).

$$\lambda_i = 2\pi \frac{i-1}{I}, \quad i = 1, \dots I. \tag{1}$$

Latitude grids φ_j are derived from the Gauss-Legendre integral formula (`SUBROUTINE: [SETLA]` in asetc.F). This is the zero point of the Legendre polynomial of order J with $\mu = \sin\varphi$ as the argument (`SUBROUTINE: [GAUSS]` in uspst.F). If J is large, we can approximate

$$\varphi_j = \pi \left(\frac{1}{2} - \frac{j-1/2}{J} \right), \quad j = 1, \dots J. \tag{2}$$

Usually, the grid spacing of longitude and latitude is taken to be approximately equal to $J = I/2$, based on the triangular truncation of the spectral method.

Air pressure p is defined at half levels ($p_{k+1/2},\ k = 1, 2, \dots K$) using the following formula using constants $A_{k+1/2},\ B_{k+1/2}$:

$$p_{k+1/2} = A_{k+1/2} + B_{k+1/2}\, p_s, \tag{3}$$

where $A_{1/2} = A_{K+1/2} = 0,\ B_{1/2} = 1,\ B_{K+1/2} = 0$ and thus $p_{1/2} = p_s,\ p_{K+1/2} = 0$. Therefore, the normalized pressure $\sigma \equiv p/p_s$ can be written as below:

$$\sigma_{k+1/2} = \frac{A_{k+1/2}}{p_s} + B_{k+1/2}. \tag{4}$$

Furthermore, a hybrid normalized pressure η is defined as below:

$$\eta_{k+1/2} = \frac{A_{k+1/2}}{p_0} + B_{k+1/2}, \quad p_0 \equiv 1000 \text{ hPa}. \tag{5}$$

Since $A_{k+1/2},\ B_{k+1/2}, p_0$ are constants, $\eta_{k+1/2}$ is also a constant and we use it as the vertical coordinate of the atmopheric model. However, as described in Chapter 2, basic equations are descretized in such a way that $\eta_{k+1/2}$ does not explicitly appear and $\sigma_{k+1/2}$ is used instead to commonize source codes with the σ-coordinate system used in MIROC 5.

Air pressure p_k at full levels ($p_k,\ k = 1, 2, \dots K$) is interpolated from half-level pressure as below:

$$p_k = \left\{ \frac{1}{1+\kappa} \left(\frac{p_{k-1/2}^{\kappa+1} - p_{k+1/2}^{\kappa+1}}{p_{k-1/2} - p_{k+1/2}} \right) \right\}^{1/\kappa}. \tag{6}$$

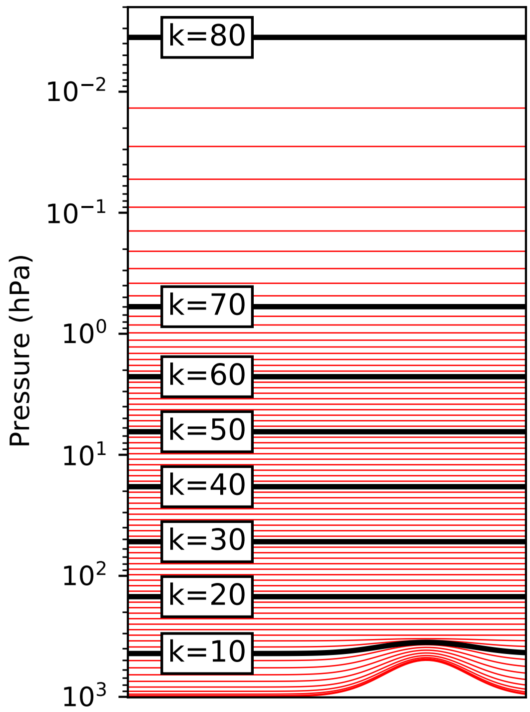

図 1: Default arangement of vertical levels for 80-level simulation.

Full-level pressure in a 80-level configuration is shown in Fig. 1. While lower layers follow the terrain, upper layers are isobaric, and the two are smoothly connected.

All prognostic variables are defined either on a grid of $(\lambda_i, \varphi_j, \eta_k)$ or $(\lambda_i, \varphi_j, z_l)$. (The underground level, z_l, is described in the section on physical processes.)

In the time direction, the forecast equations are discretized at evenly spaced Δt and time integration is performed. However, Δt may change in cases where the stability of the time integration is insufficient.

0.1.2 Physical Constants

The basic physical constants are shown below (`SUBROUTINE [PCONST]` in apcon.F).

Element	Symbol	Unit	Value
Earth radius	a	m	6.37 $\times 10^6$
Gravitational acceleration	g	m s^{-2}	9.8
Atmospheric specific heat at constant pressure	C_p	J kg^{-1} K^{-1}	1004.6
Atmospheric gas constant	R	J kg^{-1} K^{-1}	287.04
Latent heat of water evaporation	L	J kg^{-1}	2.5 $\times 10^6$
Water vapor specific heat at constant pressure	C_v	J kg^{-1} K^{-1}	1810
Gas constant of water	R_v	J kg^{-1} K^{-1}	461
Density of liquid water	d_{H_2O}	kg m^{-3}	1000

Element	Symbol	Unit	Value
Saturated vapor pressure at 0 °C	$e^*(273\text{K})$	Pa	611
Stefan-Bolzman constant	σ_{SB}	W m^{-2} K^{-4}	5.67 $\times 10^{-8}$
Kárman constant	k		0.4
Latent heat of ice melting	L_M	J kg^{-1}	3.4 $\times 10^5$
Freezing point of water	T_M	K	273.15
Constant pressure specific heat of water	C_w	J kg^{-1}	4200
Freezing point of seawater	T_I	K	271.35
Specific heat ratio of ice at constant pressure	$C_I = C_w - L_M/T_M$		2397
Water vapor molecular weight ratio	$\epsilon = R/R_v$		0.622
Coefficient of virtual temperature	$\epsilon_v = \epsilon^{-1} - 1$		0.606
Ratio of specific heat to gas constant	$\kappa = R/C_p$		0.286