Simulating Jupiter's weather layer: Accompanying data for Parts I and II

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4 December 2018 v1.0

1 Overview

This dataset contains instantaneous model states from two simulations of Jupiter's atmosphere, to accompany the following papers by the authors in *Icarus*:

- **Simulating Jupiter's weather layer. Part I: Jet spin-up in a dry atmosphere**

- **Simulating Jupiter's weather layer. Part II: Passive ammonia and water cycles**

The data were generated by a version of the MIT General Circulation Model (MITgcm) modified to simulate Jupiter's upper troposphere and lower stratosphere. The MITgcm is available from `http://mitgcm.org`, and its documentation can be found at `https://mitgcm.readthedocs.io/en/latest/`. A complete description of our Jupiter model can be found in Part I, except for the cloud scheme, which is described in Part II.

The model simulates Jupiter's weather layer between $18\,\mathrm{bar}$ and $0.01\,\mathrm{bar}$ on a global longitude-latitude Arakawa-C grid with $\sim 0.7°$ grid spacing (512 by 256 grid points). There are 33 levels equally spaced in $\log(\mathrm{pressure})$. The dynamical core is a finite volume model that solves the primitive equations for an incompressible fluid on a rotating sphere, using the vector-invariant form of the momentum equations, centred second order advection-diffusion of potential temperature, and a second order flux limiter for tracer advection. The model includes parametrizations of radiative forcing with a realistic annual-mean distribution of solar forcing in latitude and an optional infrared heat flux into the bottom of the domain, vertical diffusion, dry convection, a sponge layer damping eddies at the top, and weak drag to rest at the model bottom. There is a Shapiro filter and a polar zonal filter. The cloud scheme transports solid and gaseous ammonia, gaseous hydrogen sulphide, solid ammonium hydrosulphide, and solid, liquid, and gaseous water. Ammonia and water change phase depending on their temperature, hydrogen sulphide and gaseous ammonia react to produce ammonium hydrosulphide, and all condensate species sediment.

2 Model grid

The model grid is a global longitude-latitude-pressure Arakawa-C grid. For full details the user is referred to the MITgcm documentation, Chapters 2.11.4 ("Horizontal grid") and 2.11.5 ("Vertical grid"). In the horizontal, all quantities except the zonal and meridional velocities are defined at the middle of each grid cell:

$$\begin{pmatrix} \tilde{\lambda}_i \\ \tilde{\phi}_j \end{pmatrix} = \begin{pmatrix} \Delta\lambda\left(i - \tfrac{1}{2}\right) & i = 1 \ldots N_\lambda \\ -90 + \Delta\phi\left(j - \tfrac{1}{2}\right) & j = 1 \ldots N_\phi \end{pmatrix}$$

where λ is east longitude, ϕ is latitude, $N_\lambda = 512$, $N_\phi = 256$, $\Delta\lambda = 360/N_\lambda$, and $\Delta\phi = 180/N_\phi$. $\Delta\lambda$ and $\Delta\phi$ are both (exactly) $0.703\,125°$. The zonal velocity is held at the longitudinal faces of the cell:

$$\begin{pmatrix} \lambda_i \\ \tilde{\phi}_j \end{pmatrix} = \begin{pmatrix} \Delta\lambda.i & i = 0 \ldots N_\lambda \\ -90 + \Delta\phi\left(j - \tfrac{1}{2}\right) & j = 1 \ldots N_\phi \end{pmatrix}$$

The meridional velocity is held at the latitudinal faces of the cell:

$$\begin{pmatrix} \tilde{\lambda}_i \\ \phi_j \end{pmatrix} = \begin{pmatrix} \Delta\lambda \left(i - \frac{1}{2} \right) & i = 1 \dots N_\lambda \\ -90 + \Delta\phi.j & j = 0 \dots N_\phi \end{pmatrix}$$

In the vertical, all quantities are at cell centres except vertical velocity, which is at the top and bottom cell faces. Section 2.11.5 of the MITgcm documentation describes the vertical grid.

3 Dataset contents

The data are instantaneous snapshots of the flow fields from two simulations, covering a period of 100 d with snapshots every 20 d.

- **RunA** has no heat flux into the bottom of the domain.
  It contains snapshots after 154 760, 154 780, 154 800, 154 820, 154 840, and 154 860 simulated days.

- **RunB** has 5.7 W m^{-2} heat flux into the bottom of the domain.
  It contains snapshots after 132 900, 132 920, 132 940, 132 960, 132 980, and 133 000 simulated days.

The dataset contains two zipped and compressed files **RunA.tgz** and **RunB.tgz**. When decompressed, each .tgz file expands into a folder containing several netCDF files output by the simulation.

The netCDF files are standard output files from the MITgcm (MITgcm documentation, Chapter 9.3, "NetCDF I/O: pkg/mnc"). They have been post-processed to combine the individual tiles (one for each processor the simulations were run on) into one file, and to change the filename to use the timestamp (in seconds since the beginning of the simulation) rather than the model iteration number.

Compressed / zipped file	**RunA.tgz**	**RunB.tgz**
Expanded folder	**RunA/**	**RunB/**
Main model variables	**state.13371264000.glob.nc**	**state.11482560000.glob.nc**
	state.13372992000.glob.nc	**state.11484288000.glob.nc**
	state.13374720000.glob.nc	**state.11486016000.glob.nc**
	state.13376448000.glob.nc	**state.11487744000.glob.nc**
	state.13378176000.glob.nc	**state.11489472000.glob.nc**
	state.13379904000.glob.nc	**state.11491200000.glob.nc**
Tracer concentrations	**ptracers.13371264000.glob.nc**	**ptracers.11482560000.glob.nc**
	ptracers.13372992000.glob.nc	**ptracers.11484288000.glob.nc**
	ptracers.13374720000.glob.nc	**ptracers.11486016000.glob.nc**
	ptracers.13376448000.glob.nc	**ptracers.11487744000.glob.nc**
	ptracers.13378176000.glob.nc	**ptracers.11489472000.glob.nc**
	ptracers.13379904000.glob.nc	**ptracers.11491200000.glob.nc**
Grid arrays	**grid.glob.nc**	**grid.glob.nc**

3.1 Common quantities

Some quantities are included in more than one netCDF file.

Dimensions:

- **X** = 512: Number of longitude grid cells.

- **Xp1** = 513: Number of longitude cell faces.

- **Y** = 256: Number of latitude grid cells.

- **Yp1** = 257: Number of latitude cell faces.

- **Z** = 33: Number of vertical grid cells.

- **Zp1** $= 34$: Number of vertical grid cell faces.

- **Zu** $= 33$: Number of vertical grid cell upper faces.

- **Zl** $= 33$: Number of vertical grid cell lower faces.

- **T** $= 1$: Number of model times stored.

Variables:

- **X**: Longitude of cell centre (degrees east).

- **Xp1**: Longitude of cell corner (degrees east).

- **Y**: Latitude of cell centre (degrees north).

- **Yp1**: Latitude of cell corner (degrees north).

- **Z**: Vertical coordinate of cell centre (Pa).

- **Zl**: Vertical coordinate of lower cell face (Pa).

- **T**: Model time (s).

- **iter(T)**: Iteration count.

Each of these is 1D with length given by the dimension of the same name above, except where indicated.

The following global attributes define how the horizontal domain is split up to run on multiple processors. Details can be found in MITgcm documentation Chapter 3.7.1 ("Model Array Dimensions"): **sNx** $= 128$, **sNy** $= 8$, **OLx** $= 2$, **OLy** $= 2$, **nSx** $= 1$, **nSy** $= 1$, **nPx** $= 4$, **nPy** $= 32$, **Nx** $= 512$, **Ny** $= 256$, **Nr** $= 33$.

3.2 "state" files

The netCDF file contains the following quantities:

- **U(T,Z,Y,Xp1)**: Zonal (eastward) velocity ($\mathrm{m\,s^{-1}}$).

- **V(T,Z,Yp1,X)**: Meridional (northward) velocity ($\mathrm{m\,s^{-1}}$).

- **W(T,Zl,Y,X)***: Vertical velocity $\omega = Dp/Dt$ in pressure coordinates (> 0 is downwards) ($\mathrm{Pa\,s^{-1}}$).

- **Temp(T,Z,Y,X)***: Potential temperature (K).

- **S(T,Z,Y,X)**: Salinity. Not used. Array full of zeroes.

- **Eta(T,Y,X)***: Surface pressure anomaly (Pa). The pressure at the "surface" is $p_s = 18\,\mathrm{bar} + $ **Eta**. Note that the model's vertical levels (**rF**, **rC**, etc.) are at fixed pressures.

For quantities marked *, the units in the file are incorrect (they are for the ocean version of the model), but we can't change them.

3.3 "ptracers" files

The netCDF file contains the following quantities:

- **NH3_g(T,Z,Y,X)**: Ammonia (NH_3) gas mass mixing ratio ($\mathrm{kg\,kg^{-1}}$).

- **NH3_s(T,Z,Y,X)**: Ammonia (NH_3) solid mass mixing ratio ($\mathrm{kg\,kg^{-1}}$).

- **H2S_g(T,Z,Y,X)** Hydrogen sulphide (H_2S) gas mass mixing ratio ($\mathrm{kg\,kg^{-1}}$).

- **NH4SH_s(T,Z,Y,X)**: Ammonium hydrosulphide (NH_4SH) solid mass mixing ratio ($\mathrm{kg\,kg^{-1}}$).

- **H2O_g(T,Z,Y,X)**: Water (H_2O) gas mass mixing ratio ($\mathrm{kg\,kg^{-1}}$).

- **H2O_l(T,Z,Y,X)**: Water (H_2O) liquid mass mixing ratio. This array is full of zeroes ($\mathrm{kg\,kg^{-1}}$).

- **H2O_s(T,Z,Y,X)**: Water (H_2O) solid mass mixing ratio ($\mathrm{kg\,kg^{-1}}$).

3.4 "grid" files

These files contain the complete set of grid variables used by the model. In addition to the variables listed in Sect. 3.1, the following are defined (reference chapter in the MITgcm documentation in brackets):

- Horizontal area of each cell (m^2) [2.11.4, "Horizontal grid"]:
  rA(Y,X), **rAw(Y,Xp1)**, **rAs(Yp1,X)**, **rAz(Yp1,Xp1)**.

- E Longitude / Latitude positions of θ points (degrees) [2.11.4, "Horizontal grid"]:
  XC(Y,X), **YC(Y,X)**.

- E Longitude / Latitude positions of vorticity points (degrees) [2.11.4, "Horizontal grid"]:
  XG(Yp1,Xp1), **YG(Yp1,Xp1)**.

- Cell centre, face, and corner separation in longitude (m) [2.11.4, "Horizontal grid"]:
  dxC(Y,Xp1), **dxF(Y,X)**, **dxG(Yp1,X)**, **dxV(Yp1,Xp1)**.

- Cell centre, face, and corner separation in latitude (m) [2.11.4, "Horizontal grid"]:
  dyC(Yp1,X), **dyF(Y,X)**, **dyG(Y,Xp1)**, **dyU(Yp1,Xp1)**.

- Vertical grid positions (Pa) [2.11.5, "Vertical grid"]:
  RC(Z)*, **RF(Zp1)***, **Zp1(Zp1)**, **Zu(Zu)**, **Zl(Zl)**, **RU(Zu)***, **RL(Zl)***.

- Vertical grid spacing (Pa) [2.11.5, "Vertical grid"]: **drC(Zp1)**, **drF(Z)**.

- Coriolis parameter f at cell centre and corner (rad s^{-1}) [2.15.3, "Vector invariant momentum equations: Coriolis terms"]: **fCori(Y,X)**, **fCoriG(Yp1,Xp1)**.

- Pressure at top of atmosphere (Pa) [2.11.5, "Vertical grid"]: **R_low(Y,X)**.

- Bottom surface at rest (18 bar everywhere) [2.11.5, "Vertical grid"]: **Ro_surf(Y,X)**.

- Fluid thickness at rest (18 bar everywhere) [2.11.5, "Vertical grid"]: **Depth(Y,X)**.

- Filling fraction of partially-filled cells (1 everywhere) [2.11.6, "Topography: partially filled cells"]:
  HFacC(Z,Y,X), **HFacS(Z,Yp1,X)**, **HFacW(Z,Y,Xp1)**.

For quantities marked *, the units in the file are incorrect (they are for the ocean version of the model), but we can't change them.

Acknowledgments