Rayleigh Diagnostic Values

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Contents

1 Overview of Diagnostic Outputs in Rayleigh

The purpose of this document is to describe Rayleigh's internal menu system used for specifying diagnostic outputs. Rayleigh's design includes an onboard diagnostics package that allows a user to output a variety of system quantities as the run evolves. These include system state variables, such as velocity and entropy, as well as derived quantities, such as the vector components of the Lorentz force and the kinetic energy density. Each diagnostic quantity is requested by adding its associated menu number to the *main_input* file. Radial velocity, for instance, has menu code 1, θ-component of velocity has menu code 2, etc.

A few points to keep in mind are

- **This document is intended to describe the diagnostics output menu only.** A complete description of Rayleigh's diagnostic package is provided in Rayleigh/doc/Diagnostic_Plotting.pdf. A more in-depth description of the anelastic and Boussinesq modes available in Rayleigh is provided in Rayleigh/doc/user_guide.pdf.
- A number of *output methods* may be used to output any system diagnostic. No diagnostic is linked to a particular *output method*. The same diagnostic might be output in volume-averaged, azimuthally-averaged, and fully 3-D form, for instance.
- You may notice a good deal of redundancy in the available outputs. For instance, the azimuthal velocity, v_ϕ, and its zonal average, $\overline{v_\phi}$, are both available as outputs. Were the user to output both of these in an azimuthally-averaged format, the result would be the same. 3-D output, however, would not yield the same result. This redundancy has been added to help with post-processing calculations in which it can be useful to have all data products in a similar format.
- Given the degree of redundancy found in the list below, you may be surprised to notice that several values are not available for output at all. Some of these are best added as custom-user diagnostics and may be included in a future release. Many, however, may be obtained by considering either the sum, or difference, of those outputs already available.

2 Definitions and Conventions

2.1 Vector and Tensor Notation

All vector quantities are represented in bold italics. Components of a vector are indicated in non-bold italics, along with a subscript indicating the direction associated with that component. Unit vectors are written in lower-case, bold math font and are indicated by the use of a *hat* character. For example, a vector quantity $\boldsymbol{a}$ would represented as

$$\boldsymbol{a} = a_r\hat{\boldsymbol{a}} + a_\theta\hat{\boldsymbol{\theta}} + a_\phi\hat{\boldsymbol{\phi}}. \tag{1}$$

The symbols ($\hat{\boldsymbol{r}}$, $\hat{\boldsymbol{\theta}}$, $\hat{\boldsymbol{\phi}}$) indicate the unit vectors in the (r,θ,ϕ) directions, and (a_r, a_θ, a_ϕ) indicate the components of $\boldsymbol{a}$ along those directions respectively.

Vectors may be written in lower case, as with the velocity field $\boldsymbol{v}$, or in upper case as with the magnetic field $\boldsymbol{B}$. Tensors are indicated by bold, upper-case, script font, as with the viscous stress tensor $\boldsymbol{\mathcal{D}}$. Tensor components are indicated in non-bold, and with directional subscripts (i.e., $\mathcal{D}_{r\theta}$).

2.2 Reference-State Values

The *hat* notation is also used to indicate reference-state quantities. These quantities are scalar, and they are not written in bold font. They vary only in radius and have no θ-dependence or ϕ-dependence. The reference-state density is indicated by $\hat{\rho}$ and the reference-state temperature by $\hat{T}$, for instance.

2.3 Averaged and Fluctuating Values

Most of the output variables have been decomposed into a zonally-averaged value, and a fluctuation about that average. The average is indicated by an overbar, such that

$$\overline{a} \equiv \frac{1}{2\pi}\int_0^{2\pi} a(r,\theta,\phi)\,\mathrm{d}\phi. \tag{2}$$

Fluctations about that average are indicated by a *prime* superscript, such that

$$a' \equiv a(r,\theta,\phi) - \overline{a}(r,\theta) \tag{3}$$

Finally, some quantities are averaged over the full sphere. These are indicated by a double-zero subscript (i.e. $\ell = 0$, $m = 0$), such that

$$a_{00} \equiv \frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi} a(r,\theta,\phi)\, r\sin\theta \mathrm{d}\theta\mathrm{d}\phi. \tag{4}$$

3 The Equation Sets Solved by Rayleigh

Rayleigh solves the Boussinesq or anelastic MHD equations in spherical geometry. Both the equations that Rayleigh solves and its diagnostics can be formulated either dimensionally or nondimensionally. A nondimensional Boussinesq formulation, as well as dimensional and nondimensional anelastic formulations (based on a polytropic reference state) are provided as part of Rayleigh. The user may employ alternative formulations via the custom Reference-state interface. To do so, they must specify the functions f_i and the constants c_i in equations 5–11 at input time (*in development*).

The general form of the momentum equation solved by Rayleigh is given by

$$\mathrm{f}_1(r)\left[\frac{\partial \boldsymbol{v}}{\partial t} + \boldsymbol{v}\cdot\boldsymbol{\nabla}\boldsymbol{v} + c_1\hat{\boldsymbol{z}}\times\boldsymbol{v}\right] = c_2\,\mathrm{f}_2(r)\Theta\,\hat{\boldsymbol{r}} - c_3\,\mathrm{f}_1(r)\boldsymbol{\nabla}\left(\frac{P}{\mathrm{f}_1(r)}\right) + c_4\left(\boldsymbol{\nabla}\times\boldsymbol{B}\right)\times\boldsymbol{B} + c_5\boldsymbol{\nabla}\cdot\boldsymbol{\mathcal{D}}, \tag{5}$$

where the stress tensor $\mathcal{D}$ is given by

$$\mathcal{D}_{ij} = 2\mathrm{f}_1(r)\,\mathrm{f}_3(r)\left[e_{ij} - \frac{1}{3}\boldsymbol{\nabla}\cdot\boldsymbol{v}\right]. \tag{6}$$

The velocity field is denoted by $\boldsymbol{v}$, the thermal anomoly by Θ, the pressure by P, and the magnetic field by $\boldsymbol{B}$. All four of these quantities are 3-dimensional functions of position, in contrast to the 1-dimensional coefficient functions f_i. The velocity and magnetic fields are subject to the constraints

$$\boldsymbol{\nabla}\cdot\left(\mathrm{f}_1(r)\,\boldsymbol{v}\right) = 0 \tag{7}$$

and

$$\boldsymbol{\nabla}\cdot\boldsymbol{B} = 0 \tag{8}$$

respectively. The evolution of Θ is described

$$\mathrm{f}_1(r)\,\mathrm{f}_4(r)\left[\frac{\partial\Theta}{\partial t} + \boldsymbol{v}\cdot\boldsymbol{\nabla}\Theta\right] = c_6\,\boldsymbol{\nabla}\cdot\left[\mathrm{f}_1(r)\,\mathrm{f}_4(r)\,\mathrm{f}_5(r)\,\boldsymbol{\nabla}\Theta\right] + \mathrm{f}_6(r) + c_8\Phi(r,\theta,\phi) + c_9\mathrm{f}_7(r)\left[\boldsymbol{\nabla}\times\boldsymbol{B}\right]^2, \tag{9}$$

where the viscous heating Φ is given by

$$\Phi(r,\theta,\phi) = 2\,\mathrm{f}_1(r)\mathrm{f}_3(r)\left[e_{ij}e_{ij} - \frac{1}{3}\left(\boldsymbol{\nabla}\cdot\boldsymbol{v}\right)^2\right]. \tag{10}$$

Finally, the evolution of $\boldsymbol{B}$ is described by the induction equation

$$\frac{\partial\boldsymbol{B}}{\partial t} = \boldsymbol{\nabla}\times\left(\,\boldsymbol{v}\times\boldsymbol{B} - c_7\,\mathrm{f}_7(r)\boldsymbol{\nabla}\times\boldsymbol{B}\,\right). \tag{11}$$

Equations 5–11 could have been formulated in other ways. For instance, we could combine f_1 and f_4 into a single function in Equation 10. The form of the equations presented here has been chosen to reflect that actually used in the code, which was originally written dimensionally. We now describe the dimensional anelastic and nondimensional Boussinesq formulations used in the code.

3.1 Dimensional Anelastic Formulation of the MHD Equations

When run in dimensional, anelastic mode (cgs units; **reference_type=2**), the following values are assigned to the functions f_i and the constants c_i:

$$\begin{aligned}
\mathrm{f}_1(r) &\rightarrow \hat{\rho}(r) & c_1 &\rightarrow 2\Omega_0 \\
\mathrm{f}_2(r) &\rightarrow \frac{\hat{\rho(r)}}{c_P} g(r) & c_2 &\rightarrow 1 \\
\mathrm{f}_3(r) &\rightarrow \nu(r) & c_3 &\rightarrow 1 \\
\mathrm{f}_4(r) &\rightarrow \hat{T}(r) & c_4 &\rightarrow \frac{1}{4\pi} \\
\mathrm{f}_5(r) &\rightarrow \kappa(r) & c_5 &\rightarrow 1 \\
\mathrm{f}_6(r) &\rightarrow Q(r) & c_6 &\rightarrow 1 \\
\mathrm{f}_7(r) &\rightarrow \eta(r) & c_7 &\rightarrow 1. \\
c_8 &\rightarrow 1 & c_9 &\rightarrow \frac{1}{4\pi}.
\end{aligned}$$

Here, $\hat{\rho}$ and $\hat{T}$ are the reference-state density and temperature respectively. g is the gravitational acceleration, c_P is the specific heat at constant pressure, and Ω_0 is the frame rotation rate. The viscous, thermal, and magnetic diffusivities are given by ν, κ, and η respectively. Finally, $Q(r)$ is an internal heating function; it might represent radiative heating or heating due to nuclear fusion, for instance. Note that in the anelastic formulation, the thermal variable Θ is interpreted is as entropy s, rather than temperature T. When these substitutions are made, Equations 5–11 transform as follows.

$$\hat{\rho}(r)\left[\frac{\partial \boldsymbol{v}}{\partial t} + \boldsymbol{v}\cdot\boldsymbol{\nabla}\boldsymbol{v} + 2\Omega_0\hat{\boldsymbol{z}}\times\boldsymbol{v}\right] = \frac{\hat{\rho}(r)}{c_P} g(r)\Theta\,\hat{\boldsymbol{r}} + \hat{\rho}(r)\boldsymbol{\nabla}\left(\frac{P}{\hat{\rho}(r)}\right) + \frac{1}{4\pi}\left(\boldsymbol{\nabla}\times\boldsymbol{B}\right)\times\boldsymbol{B} + \boldsymbol{\nabla}\cdot\boldsymbol{\mathcal{D}} \qquad \text{Momentum}$$

$$\hat{\rho}(r)\,\hat{T}(r)\left[\frac{\partial \Theta}{\partial t} + \boldsymbol{v}\cdot\boldsymbol{\nabla}\Theta\right] = \boldsymbol{\nabla}\cdot\left[\hat{\rho}(r)\,\hat{T}(r)\,\kappa(r)\,\boldsymbol{\nabla}\Theta\right] + Q(r) + \Phi(r,\theta,\phi) + \frac{\eta(r)}{4\pi}\left[\boldsymbol{\nabla}\times\boldsymbol{B}\right]^2 \qquad \text{Thermal Energy}$$

$$\frac{\partial \boldsymbol{B}}{\partial t} = \boldsymbol{\nabla}\times\left(\,\boldsymbol{v}\times\boldsymbol{B} - \eta(r)\boldsymbol{\nabla}\times\boldsymbol{B}\,\right) \qquad \text{Induction}$$

$$\mathcal{D}_{ij} = 2\hat{\rho}(r)\,\nu(r)\left[e_{ij} - \frac{1}{3}\boldsymbol{\nabla}\cdot\boldsymbol{v}\right] \qquad \text{Viscous Stress Tensor}$$

$$\Phi(r,\theta,\phi) = 2\,\hat{\rho}(r)\nu(r)\left[e_{ij}e_{ij} - \frac{1}{3}\left(\boldsymbol{\nabla}\cdot\boldsymbol{v}\right)^2\right] \qquad \text{Viscous Heating}$$

$$\boldsymbol{\nabla}\cdot\left(\hat{\rho}(r)\,\boldsymbol{v}\right) = 0 \qquad \text{Solenoidal Mass Flux}$$

$$\boldsymbol{\nabla}\cdot\boldsymbol{B} = 0 \qquad \text{Solenoidal Magnetic Field}$$

3.2 Nondimensional Boussinesq Formulation of the MHD Equations

Rayleigh can also be run using a nondimensional, Boussinesq formulation of the MHD equations (**reference_type=1**). The nondimensionalization employed is as follows:

$$\begin{aligned}
\text{Length} &\rightarrow L & &\text{(Shell Depth)} \\
\text{Time} &\rightarrow \frac{L^2}{\nu} & &\text{(Viscous Timescale)} \\
\text{Temperature} &\rightarrow \Delta T & &\text{(Temperature Contrast Across Shell)} \\
\text{MagneticField} &\rightarrow \sqrt{\rho\mu\eta\Omega_0},
\end{aligned}$$

where Ω_0 is the rotation rate of the grame, ρ is the (constant) density of the fluid, μ is the magnetic permeability, η is the magnetic diffusivity, and ν is the kinematic viscosity. After nondimensionalizing, the following nondimensional numbers appear in our equations:

$$Pr = \frac{\nu}{\kappa} \qquad \text{Prandtl Number}$$
$$Pr = \frac{\nu}{\eta} \qquad \text{Magnetic Prandtl Number}$$
$$E = \frac{\nu}{\Omega_0\, L^2} \qquad \text{Ekman Number}$$
$$Ra = \frac{\alpha g_0 \Delta T\, L^3}{\nu\kappa} \qquad \text{Rayleigh Number,}$$

where α is coefficient of thermal expansion, g_0 is the gravitational acceleration, and κ is the thermal diffusivity. Adopting this nondimensionalization is equivalent to assigning values to f_i and the constants c_i:

$$\begin{aligned}
\mathrm{f}_1(r) &\rightarrow 1 & c_1 &\rightarrow \frac{2}{E} \\
\mathrm{f}_2(r) &\rightarrow \left(\frac{r}{r_o}\right)^n & c_2 &\rightarrow \frac{Ra}{E\,Pr} \\
\mathrm{f}_3(r) &\rightarrow 1 & c_3 &\rightarrow \frac{1}{E} \\
\mathrm{f}_4(r) &\rightarrow 1 & c_4 &\rightarrow \frac{1}{E\,Pm} \\
\mathrm{f}_5(r) &\rightarrow 1 & c_5 &\rightarrow 0 \\
\mathrm{f}_6(r) &\rightarrow 0 & c_6 &\rightarrow \frac{1}{Pr} \\
\mathrm{f}_7(r) &\rightarrow 1 & c_7 &\rightarrow \frac{1}{Pm}. \\
c_8 &\rightarrow 0 & c_9 &\rightarrow 0.
\end{aligned}$$

Note that our choice of $\mathrm{f}_2(r)$ allows gravity to vary with radius based on the value of the exponent n, which has a default value of 0 in the code. Note also that our definition of Ra assumes fixed-temperature boundary conditions. We might choose specify fixed-flux boundary conditions and/or an internal heating through a suitable choice $\mathrm{f}_6(r)$, in which case the meaning of Ra in our equation set changes, with Ra denoting a flux Rayleigh number instead. In addition, ohmic and viscous heating, which do not appear in the Boussinesq formulation, are turned off when this nondimensionalization is specified at runtime. When these substitutions are made, Equations 5–11 transform as follows.

$$\left[\frac{\partial \boldsymbol{v}}{\partial t} + \boldsymbol{v}\cdot\boldsymbol{\nabla}\boldsymbol{v} + \frac{2}{E}\hat{\boldsymbol{z}}\times\boldsymbol{v}\right] = \frac{Ra}{Pr}\left(\frac{r}{r_o}\right)^n \Theta\,\hat{\boldsymbol{r}} - \frac{1}{E}\boldsymbol{\nabla}P + \frac{1}{E\,Pm}\left(\boldsymbol{\nabla}\times\boldsymbol{B}\right)\times\boldsymbol{B} + \boldsymbol{\nabla}^2\boldsymbol{v} \qquad \text{Momentum}$$
$$\left[\frac{\partial \Theta}{\partial t} + \boldsymbol{v}\cdot\boldsymbol{\nabla}\Theta\right] = \frac{1}{Pr}\boldsymbol{\nabla}^2\Theta \qquad \text{Thermal Energy}$$
$$\frac{\partial \boldsymbol{B}}{\partial t} = \boldsymbol{\nabla}\times(\boldsymbol{v}\times\boldsymbol{B}) + \frac{1}{Pm}\boldsymbol{\nabla}^2\boldsymbol{B} \qquad \text{Induction}$$
$$\boldsymbol{\nabla}\cdot\boldsymbol{v} = 0 \qquad \text{Solenoidal Velocity Field}$$
$$\boldsymbol{\nabla}\cdot\boldsymbol{B} = 0 \qquad \text{Solenoidal Magnetic Field}$$

3.3 Nondimensional Anelastic MHD Equations

To run in nondimensional anelastic mode, you must set **reference_type=3** in the Reference_Namelist. The reference state is assumed to be polytropic with a $\frac{1}{r^2}$ profile for gravity. Transport coefficients ν, κ, η are assumed to be constant in radius. When this mode is active, the following nondimensionalization is used (following Heimpel et al., 2016, *Nat. Geo*, 9, 19):

$$
\begin{aligned}
\text{Length} &\rightarrow L && \text{(Shell Depth)}\\
\text{Time} &\rightarrow \frac{1}{\Omega_0} && \text{(Rotational Timescale)}\\
\text{Temperature} &\rightarrow T_o \equiv \hat{T}(r_{\text{max}}) && \text{(Reference} - \text{State Temperature at Upper Boundary)}\\
\text{Density} &\rightarrow \rho_o \equiv \hat{\rho}(r_{\text{max}}) && \text{(Reference} - \text{State Density at Upper Boundary)}\\
\text{Entropy} &\rightarrow \Delta s && \text{(Entropy Constrast Across Shell)}\\
\text{Magnetic Field} &\rightarrow \sqrt{\tilde{\rho}(r_{\text{max}})\mu\eta\Omega_0}.
\end{aligned}
$$

When run in this mode, Rayleigh employs a polytropic background state, with an assumed $\frac{1}{r^2}$ variation in gravity. These choices result in the functions f_i and the constants c_i (tildes indicate nondimensional reference-state variables):

$$
\begin{aligned}
\mathrm{f}_1(r) &\rightarrow \tilde{\rho}(r) & c_1 &\rightarrow 2\\
\mathrm{f}_2(r) &\rightarrow \tilde{\rho(r)}\frac{r^2_{\text{max}}}{r^2} & c_2 &\rightarrow \mathrm{Ra}^*\\
\mathrm{f}_3(r) &\rightarrow 1 & c_3 &\rightarrow 1\\
\mathrm{f}_4(r) &\rightarrow \tilde{T}(r) & c_4 &\rightarrow \frac{\mathrm{E}}{\mathrm{Pm}}\\
\mathrm{f}_5(r) &\rightarrow 1 & c_5 &\rightarrow \mathrm{E}\\
\mathrm{f}_6(r) &\rightarrow Q(r) & c_6 &\rightarrow \frac{\mathrm{E}}{\mathrm{Pr}}\\
\mathrm{f}_7(r) &\rightarrow 1 & c_7 &\rightarrow \frac{\mathrm{E}}{\mathrm{Pm}}\\
c_8 &\rightarrow \frac{\mathrm{E\,Di}}{\mathrm{Ra}^*} & c_9 &\rightarrow \frac{\mathrm{E}^2\,\mathrm{Di}}{\mathrm{Pm}^2\mathrm{Ra}^*}.
\end{aligned}
$$

Two new nondimensional numbers appear in our equations. Di, the dissipation number, is defined by

$$
\mathrm{Di} = \frac{g_o\,\mathrm{L}}{c_\mathrm{P}\,T_o}, \tag{12}
$$

where g_o and T_o are the gravitational acceleration and temperature at the outer boundary respectively. Once more, the thermal anomoly Θ should be interpreted as entropy s. The symbol Ra^* is the modified Rayleigh number, given by

$$
\mathrm{Ra}^* = \frac{g_o}{c_\mathrm{P}\Omega_0^2}\frac{\Delta s}{L} \tag{13}
$$

We arrive at the following nondimensionalized equations:

$$
\begin{aligned}
\frac{\partial \boldsymbol{v}}{\partial t} + \boldsymbol{v}\cdot\boldsymbol{\nabla}\boldsymbol{v} + 2\hat{\boldsymbol{z}}\times\boldsymbol{v} &= \mathrm{Ra}^*\frac{r^2_{\text{max}}}{r^2}\Theta\,\hat{\boldsymbol{r}} + \boldsymbol{\nabla}\left(\frac{P}{\tilde{\rho}(r)}\right) + \frac{\mathrm{E}}{\mathrm{Pm}\,\tilde{\rho}}\left(\boldsymbol{\nabla}\times\boldsymbol{B}\right)\times\boldsymbol{B} + \frac{\mathrm{E}}{\tilde{\rho(r)}}\boldsymbol{\nabla}\cdot\boldsymbol{\mathcal{D}} && \text{Momentum}\\
\tilde{\rho}(r)\,\tilde{T}(r)\left[\frac{\partial\Theta}{\partial t} + \boldsymbol{v}\cdot\boldsymbol{\nabla}\Theta\right] &= \frac{\mathrm{E}}{\mathrm{Pr}}\boldsymbol{\nabla}\cdot\left[\tilde{\rho}(r)\,\tilde{T}(r)\,\boldsymbol{\nabla}\Theta\right] + Q(r) + \frac{\mathrm{E\,Di}}{\mathrm{Ra}^*}\Phi(r,\theta,\phi) + \frac{\mathrm{Di\,E}^2}{\mathrm{Pm}^2\mathrm{Ra}^*}\left[\boldsymbol{\nabla}\times\boldsymbol{B}\right]^2 && \text{Thermal Energy}\\
\frac{\partial \boldsymbol{B}}{\partial t} &= \boldsymbol{\nabla}\times\left(\boldsymbol{v}\times\boldsymbol{B} - \frac{\mathrm{E}}{\mathrm{Pm}}\boldsymbol{\nabla}\times\boldsymbol{B}\right) && \text{Induction}\\
\mathcal{D}_{ij} &= 2\tilde{\rho}(r)\left[e_{ij} - \frac{1}{3}\boldsymbol{\nabla}\cdot\boldsymbol{v}\right] && \text{Viscous Stress Tensor}\\
\Phi(r,\theta,\phi) &= 2\,\tilde{\rho}(r)\left[e_{ij}e_{ij} - \frac{1}{3}\left(\boldsymbol{\nabla}\cdot\boldsymbol{v}\right)^2\right] && \text{Viscous Heating}\\
\boldsymbol{\nabla}\cdot\left(\tilde{\rho}(r)\,\boldsymbol{v}\right) &= 0 && \text{Solenoidal Mass Flux}\\
\boldsymbol{\nabla}\cdot\boldsymbol{B} &= 0. && \text{Solenoidal Magnetic Field}
\end{aligned}
$$

4 Diagnostic Code Tables

The remainder of this document contains tables enumerating the menu codes necessary to specify diagnostic outputs in Rayleigh.

4.1 Velocity Field

Output quantities related to the velocity field, its gradients, and its associated mass flux $\mathrm{f}_1\boldsymbol{v}$ are defined here.

Value	Code	Variable	Value	Code	Variable
v_r	1	v_r	$\frac{\partial v_\phi}{\partial\theta}$	21	dv_phi_dt
v_θ	2	v_theta	$\frac{\partial v'_r}{\partial\theta}$	22	dvp_r_dt
v_ϕ	3	v_phi	$\frac{\partial v'_\theta}{\partial\theta}$	23	dvp_theta_dt
v'_r	4	vp_r	$\frac{\partial v'_\phi}{\partial\theta}$	24	dvp_phi_dt
v'_θ	5	vp_theta	$\frac{\partial \overline{v_r}}{\partial\theta}$	25	dvm_r_dt
v'_ϕ	6	vp_phi	$\frac{\partial \overline{v_\theta}}{\partial\theta}$	26	dvm_theta_dt
$\overline{v_r}$	7	vm_r	$\frac{\partial \overline{v_\phi}}{\partial\theta}$	27	dvm_phi_dt
$\overline{v_\theta}$	8	vm_theta	$\frac{\partial v_r}{\partial\phi}$	28	dv_r_dp
$\overline{v_\phi}$	9	vm_phi	$\frac{\partial v_\theta}{\partial\phi}$	29	dv_theta_dp
$\frac{\partial v_r}{\partial r}$	10	dv_r_dr	$\frac{\partial v_\phi}{\partial\phi}$	30	dv_phi_dp
$\frac{\partial v_\theta}{\partial r}$	11	dv_theta_dr	$\frac{\partial v'_r}{\partial\phi}$	31	dvp_r_dp
$\frac{\partial v_\phi}{\partial r}$	12	dv_phi_dr	$\frac{\partial v'_\theta}{\partial\phi}$	32	dvp_theta_dp
$\frac{\partial v'_r}{\partial r}$	13	dvp_r_dr	$\frac{\partial v'_\phi}{\partial\phi}$	33	dvp_phi_dp
$\frac{\partial v'_\theta}{\partial r}$	14	dvp_theta_dr	$\frac{\partial \overline{v_r}}{\partial\phi}$	34	dvm_r_dp
$\frac{\partial v'_\phi}{\partial r}$	15	dvp_phi_dr	$\frac{\partial \overline{v_\theta}}{\partial\phi}$	35	dvm_theta_dp
$\frac{\partial \overline{v_r}}{\partial r}$	16	dvm_r_dr	$\frac{\partial \overline{v_\phi}}{\partial\phi}$	36	dvm_phi_dp
$\frac{\partial \overline{v_\theta}}{\partial r}$	17	dvm_theta_dr	$\frac{1}{r}\frac{\partial v_r}{\partial\theta}$	37	dv_r_dtr
$\frac{\partial \overline{v_\phi}}{\partial r}$	18	dvm_phi_dr	$\frac{1}{r}\frac{\partial v_\theta}{\partial\theta}$	38	dv_theta_dtr
$\frac{\partial v_r}{\partial\theta}$	19	dv_r_dt	$\frac{1}{r}\frac{\partial v_\phi}{\partial\theta}$	39	dv_phi_dtr
$\frac{\partial v_\theta}{\partial\theta}$	20	dv_theta_dt	$\frac{1}{r}\frac{\partial v'_r}{\partial\theta}$	40	dvp_r_dtr

Value	Code	Variable	Value	Code	Variable
$\frac{1}{r}\frac{\partial v'_r}{\partial\theta}$	41	dvp_theta_dtr	$\frac{\partial^2\overline{v_r}}{\partial r^2}$	61	dvm_r_d2r
$\frac{1}{r}\frac{\partial v'_r}{\partial\theta}$	42	dvp_phi_dtr	$\frac{\partial^2\overline{v_\theta}}{\partial r^2}$	62	dvm_theta_d2r
$\frac{1}{r}\frac{\partial\overline{v_r}}{\partial\theta}$	43	dvm_r_dtr	$\frac{\partial^2\overline{v_\phi}}{\partial r^2}$	63	dvm_phi_d2r
$\frac{1}{r}\frac{\partial\overline{v_\theta}}{\partial\theta}$	44	dvm_theta_dtr	$\frac{\partial^2 v_r}{\partial\theta^2}$	64	dv_r_d2t
$\frac{1}{r}\frac{\partial\overline{v_\phi}}{\partial\theta}$	45	dvm_phi_dtr	$\frac{\partial^2 v_\theta}{\partial\theta^2}$	65	dv_theta_d2t
$\frac{1}{r\sin\theta}\frac{\partial v_r}{\partial\phi}$	46	dv_r_dprs	$\frac{\partial^2 v_\phi}{\partial\theta^2}$	66	dv_phi_d2t
$\frac{1}{r\sin\theta}\frac{\partial v_\theta}{\partial\phi}$	47	dv_theta_dprs	$\frac{\partial^2 v'_r}{\partial\theta^2}$	67	dvp_r_d2t
$\frac{1}{r\sin\theta}\frac{\partial v_\phi}{\partial\phi}$	48	dv_phi_dprs	$\frac{\partial^2 v'_\theta}{\partial\theta^2}$	68	dvp_theta_d2t
$\frac{1}{r\sin\theta}\frac{\partial v'_r}{\partial\phi}$	49	dvp_r_dprs	$\frac{\partial^2 v'_\phi}{\partial\theta^2}$	69	dvp_phi_d2t
$\frac{1}{r\sin\theta}\frac{\partial v'_\theta}{\partial\phi}$	50	dvp_theta_dprs	$\frac{\partial^2\overline{v_r}}{\partial\theta^2}$	70	dvm_r_d2t
$\frac{1}{r\sin\theta}\frac{\partial v'_\phi}{\partial\phi}$	51	dvp_phi_dprs	$\frac{\partial^2\overline{v_\theta}}{\partial\theta^2}$	71	dvm_theta_d2t
$\frac{1}{r\sin\theta}\frac{\partial\overline{v_r}}{\partial\phi}$	52	dvm_r_dprs	$\frac{\partial^2\overline{v_\phi}}{\partial\theta^2}$	72	dvm_phi_d2t
$\frac{1}{r\sin\theta}\frac{\partial\overline{v_\theta}}{\partial\phi}$	53	dvm_theta_dprs	$\frac{\partial^2 v_r}{\partial\phi^2}$	73	dv_r_d2p
$\frac{1}{r\sin\theta}\frac{\partial\overline{v_\phi}}{\partial\phi}$	54	dvm_phi_dprs	$\frac{\partial^2 v_\theta}{\partial\phi^2}$	74	dv_theta_d2p
$\frac{\partial^2 v_r}{\partial r^2}$	55	dv_r_d2r	$\frac{\partial^2 v_\phi}{\partial\phi^2}$	75	dv_phi_d2p
$\frac{\partial^2 v_\theta}{\partial r^2}$	56	dv_theta_d2r	$\frac{\partial^2 v'_r}{\partial\phi^2}$	76	dvp_r_d2p
$\frac{\partial^2 v_\phi}{\partial r^2}$	57	dv_phi_d2r	$\frac{\partial^2 v'_\theta}{\partial\phi^2}$	77	dvp_theta_d2p
$\frac{\partial^2 v'_r}{\partial r^2}$	58	dvp_r_d2r	$\frac{\partial^2 v'_\phi}{\partial\phi^2}$	78	dvp_phi_d2p
$\frac{\partial^2 v'_\theta}{\partial r^2}$	59	dvp_theta_d2r	$\frac{\partial^2\overline{v_r}}{\partial\phi^2}$	79	dvm_r_d2p
$\frac{\partial^2 v'_\phi}{\partial r^2}$	60	dvp_phi_d2r	$\frac{\partial^2\overline{v_\theta}}{\partial\phi^2}$	80	dvm_theta_d2p

Value	Code	Variable	Value	Code	Variable
$\frac{\partial^2 \overline{v_\phi}}{\partial \phi^2}$	81	dvm_phi_d2p	$\frac{\partial^2 v_\theta}{\partial \theta \partial \phi}$	101	dv_theta_d2tp
$\frac{\partial^2 v_r}{\partial r \partial \theta}$	82	dv_r_d2rt	$\frac{\partial^2 v_\phi}{\partial \theta \partial \phi}$	102	dv_phi_d2tp
$\frac{\partial^2 v_\theta}{\partial r \partial \theta}$	83	dv_theta_d2rt	$\frac{\partial^2 v'_r}{\partial \theta \partial \phi}$	103	dvp_r_d2tp
$\frac{\partial^2 v_\phi}{\partial r \partial \theta}$	84	dv_phi_d2rt	$\frac{\partial^2 v'_\theta}{\partial \theta \partial \phi}$	104	dvp_theta_d2tp
$\frac{\partial^2 v'_r}{\partial r \partial \theta}$	85	dvp_r_d2rt	$\frac{\partial^2 v'_\phi}{\partial \theta \partial \phi}$	105	dvp_phi_d2tp
$\frac{\partial^2 v'_\theta}{\partial r \partial \theta}$	86	dvp_theta_d2rt	$\frac{\partial^2 \overline{v_r}}{\partial \theta \partial \phi}$	106	dvm_r_d2tp
$\frac{\partial^2 v'_\phi}{\partial r \partial \theta}$	87	dvp_phi_d2rt	$\frac{\partial^2 \overline{v_\theta}}{\partial \theta \partial \phi}$	107	dvm_theta_d2tp
$\frac{\partial^2 \overline{v_r}}{\partial r \partial \theta}$	88	dvm_r_d2rt	$\frac{\partial^2 \overline{v_\phi}}{\partial \theta \partial \phi}$	108	dvm_phi_d2tp
$\frac{\partial^2 \overline{v_\theta}}{\partial r \partial \theta}$	89	dvm_theta_d2rt			
$\frac{\partial^2 \overline{v_\phi}}{\partial r \partial \theta}$	90	dvm_phi_d2rt			
$\frac{\partial^2 v_r}{\partial r \partial \phi}$	91	dv_r_d2rp			
$\frac{\partial^2 v_\theta}{\partial r \partial \phi}$	92	dv_theta_d2rp			
$\frac{\partial^2 v_\phi}{\partial r \partial \phi}$	93	dv_phi_d2rp			
$\frac{\partial^2 v'_r}{\partial r \partial \phi}$	94	dvp_r_d2rp			
$\frac{\partial^2 v'_\theta}{\partial r \partial \phi}$	95	dvp_theta_d2rp			
$\frac{\partial^2 v'_\phi}{\partial r \partial \phi}$	96	dvp_phi_d2rp			
$\frac{\partial^2 \overline{v_r}}{\partial r \partial \phi}$	97	dvm_r_d2rp			
$\frac{\partial^2 \overline{v_\theta}}{\partial r \partial \phi}$	98	dvm_theta_d2rp			
$\frac{\partial^2 \overline{v_\phi}}{\partial r \partial \phi}$	99	dvm_phi_d2rp			
$\frac{\partial^2 v_r}{\partial \theta \partial \phi}$	100	dv_r_d2tp			

Value	Code	Variable	Value	Code	Variable
$\mathrm{f}_1 v_r$	201	rhov_r	$\mathrm{f}_1 v'_\phi$	206	rhovp_phi
$\mathrm{f}_1 v_\theta$	202	rhov_theta	$\mathrm{f}_1 \overline{v_r}$	207	rhovm_r
$\mathrm{f}_1 v_\phi$	203	rhov_phi	$\mathrm{f}_1 \overline{v_\theta}$	208	rhovm_theta
$\mathrm{f}_1 v'_r$	204	rhovp_r	$\mathrm{f}_1 \overline{v_\phi}$	209	rhovm_phi
$\mathrm{f}_1 v'_\theta$	205	rhovp_theta			

Value	Code	Variable	Value	Code	Variable
ω_r	301	vort_r	$\boldsymbol{\omega}' \cdot \boldsymbol{\omega}'$	313	enstrophy_pp
ω_θ	302	vort_theta	ω_r^2	314	vort_r_sq
ω_ϕ	303	vort_phi	ω_θ^2	315	vort_theta_sq
ω'_r	304	vortp_r	ω_ϕ^2	316	vort_phi_sq
ω'_θ	305	vortp_theta	$\omega_r'^2$	317	vortp_r_sq
ω'_ϕ	306	vortp_phi	$\omega_\theta'^2$	318	vortp_theta_sq
$\overline{\omega_r}$	307	vortm_r	$\omega_\phi'^2$	319	vortp_phi_sq
$\overline{\omega_\theta}$	308	vortm_theta	$\overline{\omega_r}^2$	320	vortm_r_sq
$\overline{\omega_\phi}$	309	vortm_phi	$\overline{\omega_\theta}^2$	321	vortm_theta_sq
$\boldsymbol{\omega} \cdot \boldsymbol{\omega}$	310	enstrophy	$\overline{\omega_\phi}^2$	322	vortm_phi_sq
$\boldsymbol{\omega}' \cdot \overline{\boldsymbol{\omega}}$	311	enstrophy_pm	Z	323	zstream
$\overline{\boldsymbol{\omega}} \cdot \overline{\boldsymbol{\omega}}$	312	enstrophy_mm			

4.2 Vorticity

Codes associated with the vorticity field $\boldsymbol{\omega}$ are defined here. The vorticity field $\boldsymbol{\omega}$ is given by

$$\boldsymbol{\omega} = \boldsymbol{\nabla} \times \boldsymbol{v}. \tag{14}$$

Value	Code	Variable	Value	Code	Variable
$\frac{1}{2}\mathrm{f}_1\boldsymbol{v}^2$	401	kinetic_energy	$\boldsymbol{v}^2$	413	vsq
$\frac{1}{2}\mathrm{f}_1 v_r^2$	402	radial_ke	${v_r}^2$	414	radial_vsq
$\frac{1}{2}\mathrm{f}_1 v_\theta^2$	403	theta_ke	${v_\theta}^2$	415	theta_vsq
$\frac{1}{2}\mathrm{f}_1 v_\phi^2$	404	phi_ke	${v_\phi}^2$	416	phi_vsq
$\frac{1}{2}\mathrm{f}_1\overline{\boldsymbol{v}}^2$	405	mkinetic_energy	$\overline{\boldsymbol{v}}^2$	417	mvsq
$\frac{1}{2}\mathrm{f}_1\overline{v_r}^2$	406	radial_mke	$\overline{v_r}^2$	418	radial_mvsq
$\frac{1}{2}\mathrm{f}_1\overline{v_\theta}^2$	407	theta_mke	$\overline{v_\theta}^2$	419	theta_mvsq
$\frac{1}{2}\mathrm{f}_1\overline{v_\phi}^2$	408	phi_mke	$\overline{v_\phi}^2$	420	phi_mvsq
$\frac{1}{2}\mathrm{f}_1\boldsymbol{v}'^2$	409	pkinetic_energy	$\boldsymbol{v}'^2$	421	pvsq
$\frac{1}{2}\mathrm{f}_1{v_r'}^2$	410	radial_pke	${v_r'}^2$	422	radial_pvsq
$\frac{1}{2}\mathrm{f}_1{v_\theta'}^2$	411	theta_pke	${v_\theta'}^2$	423	theta_pvsq
$\frac{1}{2}\mathrm{f}_1{v_\phi'}^2$	412	phi_pke	${v_\phi'}^2$	424	phi_pvsq

4.3 Kinetic Energy

Codes associated with the generalized kinetic energy density, $\frac{1}{2}\mathrm{f}_1(r)\boldsymbol{v}^2$, are defined here.

4.4 Thermal Variables

Codes associated with the thermal variables Θ and P, and their gradients, are defined here.

Value	Code	Variable	Value	Code	Variable
Θ	501	entropy	$\frac{\partial\Theta'}{\partial\phi}$	521	entropy_p_dphi
P	502	pressure	$\frac{\partial P'}{\partial\phi}$	522	pressure_p_dphi
Θ'	503	entropy_p	$\frac{\partial\overline{\Theta}}{\partial\phi}$	523	entropy_m_dphi
P'	504	pressure_p	$\frac{\partial\overline{P}}{\partial\phi}$	524	pressure_m_dphi
$\overline{\Theta}$	505	entropy_m	$\frac{1}{r}\frac{\partial\Theta}{\partial\theta}$	525	entropy_dtr
$\overline{P}$	506	pressure_m	$\frac{1}{r}\frac{\partial P}{\partial\theta}$	526	pressure_dtr
$\frac{\partial\Theta}{\partial r}$	507	entropy_dr	$\frac{1}{r}\frac{\partial\Theta'}{\partial\theta}$	527	entropy_p_dtr
$\frac{\partial P}{\partial r}$	508	pressure_dr	$\frac{1}{r}\frac{\partial P'}{\partial\theta}$	528	pressure_p_dtr
$\frac{\partial\Theta'}{\partial r}$	509	entropy_p_dr	$\frac{1}{r}\frac{\partial\overline{\Theta}}{\partial\theta}$	529	entropy_m_dtr
$\frac{\partial P'}{\partial r}$	510	pressure_p_dr	$\frac{1}{r}\frac{\partial\overline{P}}{\partial\theta}$	530	pressure_m_dtr
$\frac{\partial\overline{\Theta}}{\partial r}$	511	entropy_m_dr	$\frac{1}{r\sin\theta}\frac{\partial\Theta}{\partial\phi}$	531	entropy_dprs
$\frac{\partial\overline{P}}{\partial r}$	512	pressure_m_dr	$\frac{1}{r\sin\theta}\frac{\partial P}{\partial\phi}$	532	pressure_dprs
$\frac{\partial\Theta}{\partial\theta}$	513	entropy_dtheta	$\frac{1}{r\sin\theta}\frac{\partial\Theta'}{\partial\phi}$	533	entropy_p_dprs
$\frac{\partial P}{\partial\theta}$	514	pressure_dtheta	$\frac{1}{r\sin\theta}\frac{\partial P'}{\partial\phi}$	534	pressure_p_dprs
$\frac{\partial\Theta'}{\partial\theta}$	515	entropy_p_dtheta	$\frac{1}{r\sin\theta}\frac{\partial\overline{\Theta}}{\partial\phi}$	535	entropy_m_dprs
$\frac{\partial P'}{\partial\theta}$	516	pressure_p_dtheta	$\frac{1}{r\sin\theta}\frac{\partial\overline{P}}{\partial\phi}$	536	pressure_m_dprs
$\frac{\partial\overline{\Theta}}{\partial\theta}$	517	entropy_m_dtheta	$\frac{\partial^2\Theta}{\partial r^2}$	537	entropy_d2r
$\frac{\partial\overline{P}}{\partial\theta}$	518	pressure_m_dtheta	$\frac{\partial^2 P}{\partial r^2}$	538	pressure_d2r
$\frac{\partial\Theta}{\partial\phi}$	519	entropy_dphi	$\frac{\partial^2\Theta'}{\partial r^2}$	539	entropy_p_d2r
$\frac{\partial P}{\partial\phi}$	520	pressure_dphi	$\frac{\partial^2 P'}{\partial r^2}$	540	pressure_p_d2r

Value	Code	Variable	Value	Code	Variable
$\frac{\partial^2\overline{\Theta}}{\partial r^2}$	541	entropy_m_d2r	$\frac{\partial^2\Theta}{\partial r\partial\phi}$	561	entropy_d2rp
$\frac{\partial^2\overline{P}}{\partial r^2}$	542	pressure_m_d2r	$\frac{\partial^2 P}{\partial r\partial\phi}$	562	pressure_d2rp
$\frac{\partial^2\Theta}{\partial\theta^2}$	543	entropy_d2t	$\frac{\partial^2\Theta'}{\partial r\partial\phi}$	563	entropy_p_d2rp
$\frac{\partial^2 P}{\partial\theta^2}$	544	pressure_d2t	$\frac{\partial^2 P'}{\partial r\partial\phi}$	564	pressure_p_d2rp
$\frac{\partial^2\Theta'}{\partial\theta^2}$	545	entropy_p_d2t	$\frac{\partial^2\overline{\Theta}}{\partial r\partial\phi}$	565	entropy_m_d2rp
$\frac{\partial^2 P'}{\partial\theta^2}$	546	pressure_p_d2t	$\frac{\partial^2\overline{P}}{\partial r\partial\phi}$	566	pressure_m_d2rp
$\frac{\partial^2\overline{\Theta}}{\partial\theta^2}$	547	entropy_m_d2t	$\frac{\partial^2\Theta}{\partial\theta\partial\phi}$	567	entropy_d2tp
$\frac{\partial^2\overline{P}}{\partial\theta^2}$	548	pressure_m_d2t	$\frac{\partial^2 P}{\partial\theta\partial\phi}$	568	pressure_d2tp
$\frac{\partial^2\Theta}{\partial\phi^2}$	549	entropy_d2p	$\frac{\partial^2\Theta'}{\partial\theta\partial\phi}$	569	entropy_p_d2tp
$\frac{\partial^2 P}{\partial\phi^2}$	550	pressure_d2p	$\frac{\partial^2 P'}{\partial\theta\partial\phi}$	570	pressure_p_d2tp
$\frac{\partial^2\Theta'}{\partial\phi^2}$	551	entropy_p_d2p	$\frac{\partial^2\overline{\Theta}}{\partial\theta\partial\phi}$	571	entropy_m_d2tp
$\frac{\partial^2 P'}{\partial\phi^2}$	552	pressure_p_d2p	$\frac{\partial^2\overline{P}}{\partial\theta\partial\phi}$	572	pressure_m_d2tp
$\frac{\partial^2\overline{\Theta}}{\partial\phi^2}$	553	entropy_m_d2p	$\frac{\partial}{\partial r}\left(\frac{P}{\hat{\rho}}\right)$	573	rhopressure_dr
$\frac{\partial^2\overline{P}}{\partial\phi^2}$	554	pressure_m_d2p	$\frac{\partial}{\partial r}\left(\frac{P'}{\hat{\rho}}\right)$	574	rhopressurep_dr
$\frac{\partial^2\Theta}{\partial r\partial\theta}$	555	entropy_d2rt	$\frac{\partial}{\partial r}\left(\frac{\overline{P}}{\hat{\rho}}\right)$	575	rhopressurem_dr
$\frac{\partial^2 P}{\partial r\partial\theta}$	556	pressure_d2rt			
$\frac{\partial^2\Theta'}{\partial r\partial\theta}$	557	entropy_p_d2rt			
$\frac{\partial^2 P'}{\partial r\partial\theta}$	558	pressure_p_d2rt			
$\frac{\partial^2\overline{\Theta}}{\partial r\partial\theta}$	559	entropy_m_d2rt			
$\frac{\partial^2\overline{P}}{\partial r\partial\theta}$	560	pressure_m_d2rt			

Value	Code	Variable	Value	Code	Variable
$\mathrm{f}_1\mathrm{f}_4\Theta$	701	thermal_energy_full	$(\mathrm{f}_1\mathrm{f}_4\Theta)^2$	707	thermal_energy_sq
$\mathrm{f}_1\mathrm{f}_4\Theta$	702	thermal_energy_p	$(\mathrm{f}_1\mathrm{f}_4\Theta)^2$	708	thermal_energyp_sq
$\mathrm{f}_1\mathrm{f}_4\overline{\Theta}$	703	thermal_energy_m	$\left(\mathrm{f}_1\mathrm{f}_4\overline{\Theta}\right)^2$	709	thermal_energym_sq
$c_P\hat{\rho}T$	704	enthalpy_full	$(c_P\hat{\rho}T)^2$	710	enthalpy_sq
$c_P\hat{\rho}T'$	705	enthalpy_p	$(c_P\hat{\rho}T')^2$	711	enthalpyp_sq
$c_P\hat{\rho}\overline{T}$	706	enthalpy_m	$\left(c_P\hat{\rho}\overline{T}\right)^2$	712	enthalpym_sq

4.5 thermal energy

Codes associated with the thermal energy density and the enthalpy are defined here.

4.6 Magnetic Field

Codes associated with the magnetic field $\boldsymbol{B}$ and its gradients appear here.

Value	Code	Variable	Value	Code	Variable
B_r	801	b_r	$\frac{\partial B_\phi}{\partial \theta}$	821	db_phi_dt
B_θ	802	b_theta	$\frac{\partial B'_r}{\partial \theta}$	822	dbp_r_dt
B_ϕ	803	b_phi	$\frac{\partial B'_\theta}{\partial \theta}$	823	dbp_theta_dt
B'_r	804	bp_r	$\frac{\partial B'_\phi}{\partial \theta}$	824	dbp_phi_dt
B'_θ	805	bp_theta	$\frac{\partial \overline{B_r}}{\partial \theta}$	825	dbm_r_dt
B'_ϕ	806	bp_phi	$\frac{\partial \overline{B_\theta}}{\partial \theta}$	826	dbm_theta_dt
$\overline{B_r}$	807	bm_r	$\frac{\partial \overline{B_\phi}}{\partial \theta}$	827	dbm_phi_dt
$\overline{B_\theta}$	808	bm_theta	$\frac{\partial B_r}{\partial \phi}$	828	db_r_dp
$\overline{B_\phi}$	809	bm_phi	$\frac{\partial B_\theta}{\partial \phi}$	829	db_theta_dp
$\frac{\partial B_r}{\partial r}$	810	db_r_dr	$\frac{\partial B_\phi}{\partial \phi}$	830	db_phi_dp
$\frac{\partial B_\theta}{\partial r}$	811	db_theta_dr	$\frac{\partial B'_r}{\partial \phi}$	831	dbp_r_dp
$\frac{\partial B_\phi}{\partial r}$	812	db_phi_dr	$\frac{\partial B'_\theta}{\partial \phi}$	832	dbp_theta_dp
$\frac{\partial B'_r}{\partial r}$	813	dbp_r_dr	$\frac{\partial B'_\phi}{\partial \phi}$	833	dbp_phi_dp
$\frac{\partial B'_\theta}{\partial r}$	814	dbp_theta_dr	$\frac{\partial \overline{B_r}}{\partial \phi}$	834	dbm_r_dp
$\frac{\partial B'_\phi}{\partial r}$	815	dbp_phi_dr	$\frac{\partial \overline{B_\theta}}{\partial \phi}$	835	dbm_theta_dp
$\frac{\partial \overline{B_r}}{\partial r}$	816	dbm_r_dr	$\frac{\partial \overline{B_\phi}}{\partial \phi}$	836	dbm_phi_dp
$\frac{\partial \overline{B_\theta}}{\partial r}$	817	dbm_theta_dr	$\frac{1}{r}\frac{\partial B_r}{\partial \theta}$	837	db_r_dtr
$\frac{\partial \overline{B_\phi}}{\partial r}$	818	dbm_phi_dr	$\frac{1}{r}\frac{\partial B_\theta}{\partial \theta}$	838	db_theta_dtr
$\frac{\partial B_r}{\partial \theta}$	819	db_r_dt	$\frac{1}{r}\frac{\partial B_\phi}{\partial \theta}$	839	db_phi_dtr
$\frac{\partial B_\theta}{\partial \theta}$	820	db_theta_dt	$\frac{1}{r}\frac{\partial B'_r}{\partial \theta}$	840	dbp_r_dtr

Value	Code	Variable	Value	Code	Variable
$\frac{1}{r}\frac{\partial B_r'}{\partial\theta}$	841	dbp_theta_dtr	$\frac{\partial^2\overline{B_r}}{\partial r^2}$	861	dbm_r_d2r
$\frac{1}{r}\frac{\partial B_r'}{\partial\theta}$	842	dbp_phi_dtr	$\frac{\partial^2\overline{B_\theta}}{\partial r^2}$	862	dbm_theta_d2r
$\frac{1}{r}\frac{\partial\overline{B_r}}{\partial\theta}$	843	dbm_r_dtr	$\frac{\partial^2\overline{B_\phi}}{\partial r^2}$	863	dbm_phi_d2r
$\frac{1}{r}\frac{\partial\overline{B_\theta}}{\partial\theta}$	844	dbm_theta_dtr	$\frac{\partial^2 B_r}{\partial\theta^2}$	864	db_r_d2t
$\frac{1}{r}\frac{\partial\overline{B_\phi}}{\partial\theta}$	845	dbm_phi_dtr	$\frac{\partial^2 B_\theta}{\partial\theta^2}$	865	db_theta_d2t
$\frac{1}{r\sin\theta}\frac{\partial B_r}{\partial\phi}$	846	db_r_dprs	$\frac{\partial^2 B_\phi}{\partial\theta^2}$	866	db_phi_d2t
$\frac{1}{r\sin\theta}\frac{\partial B_\theta}{\partial\phi}$	847	db_theta_dprs	$\frac{\partial^2 B_r'}{\partial\theta^2}$	867	dbp_r_d2t
$\frac{1}{r\sin\theta}\frac{\partial B_\phi}{\partial\phi}$	848	db_phi_dprs	$\frac{\partial^2 B_\theta'}{\partial\theta^2}$	868	dbp_theta_d2t
$\frac{1}{r\sin\theta}\frac{\partial B_r'}{\partial\phi}$	849	dbp_r_dprs	$\frac{\partial^2 B_\phi'}{\partial\theta^2}$	869	dbp_phi_d2t
$\frac{1}{r\sin\theta}\frac{\partial B_\theta'}{\partial\phi}$	850	dbp_theta_dprs	$\frac{\partial^2\overline{B_r}}{\partial\theta^2}$	870	dbm_r_d2t
$\frac{1}{r\sin\theta}\frac{\partial B_\phi'}{\partial\phi}$	851	dbp_phi_dprs	$\frac{\partial^2\overline{B_\theta}}{\partial\theta^2}$	871	dbm_theta_d2t
$\frac{1}{r\sin\theta}\frac{\partial\overline{B_r}}{\partial\phi}$	852	dbm_r_dprs	$\frac{\partial^2\overline{B_\phi}}{\partial\theta^2}$	872	dbm_phi_d2t
$\frac{1}{r\sin\theta}\frac{\partial\overline{B_\theta}}{\partial\phi}$	853	dbm_theta_dprs	$\frac{\partial^2 B_r}{\partial\phi^2}$	873	db_r_d2p
$\frac{1}{r\sin\theta}\frac{\partial\overline{B_\phi}}{\partial\phi}$	854	dbm_phi_dprs	$\frac{\partial^2 B_\theta}{\partial\phi^2}$	874	db_theta_d2p
$\frac{\partial^2 B_r}{\partial r^2}$	855	db_r_d2r	$\frac{\partial^2 B_\phi}{\partial\phi^2}$	875	db_phi_d2p
$\frac{\partial^2 B_\theta}{\partial r^2}$	856	db_theta_d2r	$\frac{\partial^2 B_r'}{\partial\phi^2}$	876	dbp_r_d2p
$\frac{\partial^2 B_\phi}{\partial r^2}$	857	db_phi_d2r	$\frac{\partial^2 B_\theta'}{\partial\phi^2}$	877	dbp_theta_d2p
$\frac{\partial^2 B_r'}{\partial r^2}$	858	dbp_r_d2r	$\frac{\partial^2 B_\phi'}{\partial\phi^2}$	878	dbp_phi_d2p
$\frac{\partial^2 B_\theta'}{\partial r^2}$	859	dbp_theta_d2r	$\frac{\partial^2\overline{B_r}}{\partial\phi^2}$	879	dbm_r_d2p
$\frac{\partial^2 B_\phi'}{\partial r^2}$	860	dbp_phi_d2r	$\frac{\partial^2\overline{B_\theta}}{\partial\phi^2}$	880	dbm_theta_d2p

Value	Code	Variable
$\frac{\partial^2 \overline{B_\phi}}{\partial \phi^2}$	881	dbm_phi_d2p
$\frac{\partial^2 B_r}{\partial r \partial \theta}$	882	db_r_d2rt
$\frac{\partial^2 B_\theta}{\partial r \partial \theta}$	883	db_theta_d2rt
$\frac{\partial^2 B_\phi}{\partial r \partial \theta}$	884	db_phi_d2rt
$\frac{\partial^2 B'_r}{\partial r \partial \theta}$	885	dbp_r_d2rt
$\frac{\partial^2 B'_\theta}{\partial r \partial \theta}$	886	dbp_theta_d2rt
$\frac{\partial^2 B'_\phi}{\partial r \partial \theta}$	887	dbp_phi_d2rt
$\frac{\partial^2 \overline{B_r}}{\partial r \partial \theta}$	888	dbm_r_d2rt
$\frac{\partial^2 \overline{B_\theta}}{\partial r \partial \theta}$	889	dbm_theta_d2rt
$\frac{\partial^2 \overline{B_\phi}}{\partial r \partial \theta}$	890	dbm_phi_d2rt
$\frac{\partial^2 B_r}{\partial r \partial \phi}$	891	db_r_d2rp
$\frac{\partial^2 B_\theta}{\partial r \partial \phi}$	892	db_theta_d2rp
$\frac{\partial^2 B_\phi}{\partial r \partial \phi}$	893	db_phi_d2rp
$\frac{\partial^2 B'_r}{\partial r \partial \phi}$	894	dbp_r_d2rp
$\frac{\partial^2 B'_\theta}{\partial r \partial \phi}$	895	dbp_theta_d2rp
$\frac{\partial^2 B'_\phi}{\partial r \partial \phi}$	896	dbp_phi_d2rp
$\frac{\partial^2 \overline{B_r}}{\partial r \partial \phi}$	897	dbm_r_d2rp
$\frac{\partial^2 \overline{B_\theta}}{\partial r \partial \phi}$	898	dbm_theta_d2rp
$\frac{\partial^2 \overline{B_\phi}}{\partial r \partial \phi}$	899	dbm_phi_d2rp
$\frac{\partial^2 B_r}{\partial \theta \partial \phi}$	900	db_r_d2tp
$\frac{\partial^2 B_\theta}{\partial \theta \partial \phi}$	901	db_theta_d2tp
$\frac{\partial^2 B_\phi}{\partial \theta \partial \phi}$	902	db_phi_d2tp
$\frac{\partial^2 B'_r}{\partial \theta \partial \phi}$	903	dbp_r_d2tp
$\frac{\partial^2 B'_\theta}{\partial \theta \partial \phi}$	904	dbp_theta_d2tp
$\frac{\partial^2 B'_\phi}{\partial \theta \partial \phi}$	905	dbp_phi_d2tp
$\frac{\partial^2 \overline{B_r}}{\partial \theta \partial \phi}$	906	dbm_r_d2tp
$\frac{\partial^2 \overline{B_\theta}}{\partial \theta \partial \phi}$	907	dbm_theta_d2tp
$\frac{\partial^2 \overline{B_\phi}}{\partial \theta \partial \phi}$	908	dbm_phi_d2tp

Value	Code	Variable	Value	Code	Variable
$\mathcal{J}_r$	1001	j_r	$\overline{\boldsymbol{\mathcal{J}}} \cdot \overline{\boldsymbol{\mathcal{J}}}$	1012	jm_sq
$\mathcal{J}'_r$	1002	jp_r	$\overline{\boldsymbol{\mathcal{J}}} \cdot \boldsymbol{\mathcal{J}'}$	1013	jpm_sq
$\overline{\mathcal{J}}_r$	1003	jm_r	$(\mathcal{J}_r)^2$	1014	j_r_sq
$\mathcal{J}_\theta$	1004	j_theta	$(\mathcal{J}'_r)^2$	1015	jp_r_sq
$\mathcal{J}'_\theta$	1005	jp_theta	$(\overline{\mathcal{J}}_r)^2$	1016	jm_r_sq
$\overline{\mathcal{J}}_\theta$	1006	jm_theta	$(\mathcal{J}_\theta)^2$	1017	j_theta_sq
$\mathcal{J}_\phi$	1007	j_phi	$(\mathcal{J}'_\theta)^2$	1018	jp_theta_sq
$\mathcal{J}'_\phi$	1008	jp_phi	$(\overline{\mathcal{J}}_\theta)^2$	1019	jm_theta_sq
$\overline{\mathcal{J}}_\phi$	1009	jm_phi	$(\mathcal{J}_\phi)^2$	1020	j_phi_sq
$\boldsymbol{\mathcal{J}} \cdot \boldsymbol{\mathcal{J}}$	1010	j_sq	$\left(\mathcal{J}'_\phi\right)^2$	1021	jp_phi_sq
$\boldsymbol{\mathcal{J}'} \cdot \boldsymbol{\mathcal{J}'}$	1011	jp_sq	$(\overline{\mathcal{J}}_\phi)^2$	1022	jm_phi_sq

We use the shorthand $\boldsymbol{\mathcal{J}}$ to denote the curl of $\boldsymbol{B}$, namely

$$\boldsymbol{\mathcal{J}} \equiv \boldsymbol{\nabla} \times \boldsymbol{B}. \tag{15}$$

4.7 $\boldsymbol{\nabla} \times \boldsymbol{B}$

Value	Code	Variable	Value	Code	Variable
$\frac{1}{2}c_4\boldsymbol{B}^2$	1101	magnetic_energy	$\frac{1}{2}c_4\overline{B_\theta}^2$	1107	theta_mme
$\frac{1}{2}c_4B_r^2$	1102	radial_me	$\frac{1}{2}c_4\overline{B_\phi}^2$	1108	phi_mme
$\frac{1}{2}c_4B_\theta^2$	1103	theta_me	$\frac{1}{2}c_4\boldsymbol{B'}^2$	1109	pmagnetic_energy
$\frac{1}{2}c_4B_\phi^2$	1104	phi_me	$\frac{1}{2}c_4{B'_r}^2$	1110	radial_pme
$\frac{1}{2}c_4\overline{\boldsymbol{B}}^2$	1105	mmagnetic_energy	$\frac{1}{2}c_4{B'_\theta}^2$	1111	theta_pme
$\frac{1}{2}c_4\overline{B_r}^2$	1106	radial_mme	$\frac{1}{2}c_4{B'_\phi}^2$	1112	phi_pme

4.8 Magnetic Energy Density

Output codes related to the generalized magnetic energy density, $\frac{1}{2}c_4\boldsymbol{B}^2$, are defined here.

Value	Code	Variable	Value	Code	Variable
$\mathrm{f}_1 \left[\boldsymbol{v} \cdot \boldsymbol{\nabla} \boldsymbol{v}\right]_r$	1201	v_grad_v_r	$-c_1\mathrm{f}_1 \left[\hat{\boldsymbol{z}} \times \boldsymbol{v}\right]_\phi$	1221	Coriolis_Force_phi
$\mathrm{f}_1 \left[\boldsymbol{v} \cdot \boldsymbol{\nabla} \boldsymbol{v}\right]_\theta$	1202	v_grad_v_theta	$-c_1\mathrm{f}_1 \left[\hat{\boldsymbol{z}} \times \boldsymbol{v}'\right]_r$	1222	Coriolis_pForce_r
$\mathrm{f}_1 \left[\boldsymbol{v} \cdot \boldsymbol{\nabla} \boldsymbol{v}\right]_\phi$	1203	v_grad_v_phi	$-c_1\mathrm{f}_1 \left[\hat{\boldsymbol{z}} \times \boldsymbol{v}'\right]_\theta$	1223	Coriolis_pForce_theta
$\mathrm{f}_1 \left[\boldsymbol{v}' \cdot \boldsymbol{\nabla} \overline{\boldsymbol{v}}\right]_r$	1204	vp_grad_vm_r	$-c_1\mathrm{f}_1 \left[\hat{\boldsymbol{z}} \times \boldsymbol{v}'\right]_\phi$	1224	Coriolis_pForce_phi
$\mathrm{f}_1 \left[\boldsymbol{v}' \cdot \boldsymbol{\nabla} \overline{\boldsymbol{v}}\right]_\theta$	1205	vp_grad_vm_theta	$-c_1\mathrm{f}_1 \left[\hat{\boldsymbol{z}} \times \overline{\boldsymbol{v}}\right]_r$	1225	Coriolis_mForce_r
$\mathrm{f}_1 \left[\boldsymbol{v}' \cdot \boldsymbol{\nabla} \overline{\boldsymbol{v}}\right]_\phi$	1206	vp_grad_vm_phi	$-c_1\mathrm{f}_1 \left[\hat{\boldsymbol{z}} \times \overline{\boldsymbol{v}}\right]_\theta$	1226	Coriolis_mForce_theta
$\mathrm{f}_1 \left[\overline{\boldsymbol{v}} \cdot \boldsymbol{\nabla} \boldsymbol{v}'\right]_r$	1207	vm_grad_vp_r	$-c_1\mathrm{f}_1 \left[\hat{\boldsymbol{z}} \times \overline{\boldsymbol{v}}\right]_\phi$	1227	Coriolis_mForce_phi
$\mathrm{f}_1 \left[\overline{\boldsymbol{v}} \cdot \boldsymbol{\nabla} \boldsymbol{v}'\right]_\theta$	1208	vm_grad_vp_theta	$c_5 \left[\boldsymbol{\nabla} \cdot \boldsymbol{\mathcal{D}}\right]_r$	1228	viscous_Force_r
$\mathrm{f}_1 \left[\overline{\boldsymbol{v}} \cdot \boldsymbol{\nabla} \boldsymbol{v}'\right]_\phi$	1209	vm_grad_vp_phi	$c_5 \left[\boldsymbol{\nabla} \cdot \boldsymbol{\mathcal{D}}\right]_\theta$	1229	viscous_Force_theta
$\mathrm{f}_1 \left[\boldsymbol{v}' \cdot \boldsymbol{\nabla} \boldsymbol{v}'\right]_r$	1210	vp_grad_vp_r	$c_5 \left[\boldsymbol{\nabla} \cdot \boldsymbol{\mathcal{D}}\right]_\phi$	1230	viscous_Force_phi
$\mathrm{f}_1 \left[\boldsymbol{v}' \cdot \boldsymbol{\nabla} \boldsymbol{v}'\right]_\theta$	1211	vp_grad_vp_theta	$c_5 \left[\boldsymbol{\nabla} \cdot \boldsymbol{\mathcal{D}}'\right]_r$	1231	viscous_pForce_r
$\mathrm{f}_1 \left[\boldsymbol{v}' \cdot \boldsymbol{\nabla} \boldsymbol{v}'\right]_\phi$	1212	vp_grad_vp_phi	$c_5 \left[\boldsymbol{\nabla} \cdot \boldsymbol{\mathcal{D}}'\right]_\theta$	1232	viscous_pForce_theta
$\mathrm{f}_1 \left[\overline{\boldsymbol{v}} \cdot \boldsymbol{\nabla} \overline{\boldsymbol{v}}\right]_r$	1213	vm_grad_vm_r	$c_5 \left[\boldsymbol{\nabla} \cdot \boldsymbol{\mathcal{D}}'\right]_\phi$	1233	viscous_pForce_phi
$\mathrm{f}_1 \left[\overline{\boldsymbol{v}} \cdot \boldsymbol{\nabla} \overline{\boldsymbol{v}}\right]_\theta$	1214	vm_grad_vm_theta	$c_5 \left[\boldsymbol{\nabla} \cdot \overline{\boldsymbol{\mathcal{D}}}\right]_r$	1234	viscous_mForce_r
$\mathrm{f}_1 \left[\overline{\boldsymbol{v}} \cdot \boldsymbol{\nabla} \overline{\boldsymbol{v}}\right]_\phi$	1215	vm_grad_vm_phi	$c_5 \left[\boldsymbol{\nabla} \cdot \overline{\boldsymbol{\mathcal{D}}}\right]_\theta$	1235	viscous_mForce_theta
$c_2\mathrm{f}_2\Theta$	1216	buoyancy_force	$c_5 \left[\boldsymbol{\nabla} \cdot \overline{\boldsymbol{\mathcal{D}}}\right]_\phi$	1236	viscous_mForce_phi
$c_2\mathrm{f}_2\Theta'$	1217	buoyancy_pforce	$-c_3\mathrm{f}_1\frac{\partial}{\partial r}\left(\frac{P}{\mathrm{f}_1}\right)$	1237	pressure_Force_r
$c_2\mathrm{f}_2\overline{\Theta}$	1218	buoyancy_mforce	$-c_3\frac{1}{r}\frac{\partial P}{\partial \theta}$	1238	pressure_Force_theta
$-c_1\mathrm{f}_1 \left[\hat{\boldsymbol{z}} \times \boldsymbol{v}\right]_r$	1219	Coriolis_Force_r	$-c_3\frac{1}{r\sin\theta}\frac{\partial P}{\partial \phi}$	1239	pressure_Force_phi
$-c_1\mathrm{f}_1 \left[\hat{\boldsymbol{z}} \times \boldsymbol{v}\right]_\theta$	1220	Coriolis_Force_theta	$-c_3\mathrm{f}_1\frac{\partial}{\partial r}\left(\frac{P'}{\mathrm{f}_1}\right)$	1240	pressure_pForce_r

4.9 momentum equation

All terms from the momentum equation, and their Reynolds decomposition, are defined here.

Value	Code	Variable
$-c_3 \frac{1}{r} \frac{\partial P'}{\partial \theta}$	1241	pressure_pForce_theta
$-c_3 \frac{1}{r\mathrm{sin}\theta} \frac{\partial P'}{\partial \phi}$	1242	pressure_pForce_phi
$-c_3 \mathrm{f}_1 \frac{\partial}{\partial r} \left(\frac{\overline{P}}{\mathrm{f}_1} \right)$	1243	pressure_mForce_r
$-c_3 \frac{1}{r} \frac{\partial \overline{P}}{\partial \theta}$	1244	pressure_mForce_theta
$-c_3 \frac{1}{r\mathrm{sin}\theta} \frac{\partial \overline{P}}{\partial \phi}$	1245	pressure_mForce_phi
$c_2 \mathrm{f}_2 \Theta_{00}$	1246	buoyancy_force_ell0
$-c_3 \mathrm{f}_1 \frac{\partial}{\partial r} \left(\frac{P_{00}}{\mathrm{f}_1} \right)$	1247	pressure_force_ell0_r
$c_4 \left[(\boldsymbol{\nabla} \times \boldsymbol{B}) \times \boldsymbol{B} \right]_r$	1248	j_cross_b_r
$c_4 \left[(\boldsymbol{\nabla} \times \boldsymbol{B}) \times \boldsymbol{B} \right]_\theta$	1249	j_cross_b_theta
$c_4 \left[(\boldsymbol{\nabla} \times \boldsymbol{B}) \times \boldsymbol{B} \right]_\phi$	1250	j_cross_b_phi
$c_4 \left[(\boldsymbol{\nabla} \times \boldsymbol{B'}) \times \overline{\boldsymbol{B}} \right]_r$	1251	jp_cross_bm_r
$c_4 \left[(\boldsymbol{\nabla} \times \boldsymbol{B'}) \times \overline{\boldsymbol{B}} \right]_\theta$	1252	jp_cross_bm_theta
$c_4 \left[(\boldsymbol{\nabla} \times \boldsymbol{B'}) \times \overline{\boldsymbol{B}} \right]_\phi$	1253	jp_cross_bm_phi
$c_4 \left[\left(\boldsymbol{\nabla} \times \overline{\boldsymbol{B}}\right) \times \boldsymbol{B'} \right]_r$	1254	jm_cross_bp_r
$c_4 \left[\left(\boldsymbol{\nabla} \times \overline{\boldsymbol{B}}\right) \times \boldsymbol{B'} \right]_\theta$	1255	jm_cross_bp_theta
$c_4 \left[\left(\boldsymbol{\nabla} \times \overline{\boldsymbol{B}}\right) \times \boldsymbol{B'} \right]_\phi$	1256	jm_cross_bp_phi
$c_4 \left[\left(\boldsymbol{\nabla} \times \overline{\boldsymbol{B}}\right) \times \overline{\boldsymbol{B}} \right]_r$	1257	jm_cross_bm_r
$c_4 \left[\left(\boldsymbol{\nabla} \times \overline{\boldsymbol{B}}\right) \times \overline{\boldsymbol{B}} \right]_\theta$	1258	jm_cross_bm_theta
$c_4 \left[\left(\boldsymbol{\nabla} \times \overline{\boldsymbol{B}}\right) \times \overline{\boldsymbol{B}} \right]_\phi$	1259	jm_cross_bm_phi
$c_4 \left[(\boldsymbol{\nabla} \times \boldsymbol{B'}) \times \boldsymbol{B'} \right]_r$	1260	jp_cross_bp_r
$c_4 \left[(\boldsymbol{\nabla} \times \boldsymbol{B'}) \times \boldsymbol{B'} \right]_\theta$	1261	jp_cross_bp_theta
$c_4 \left[(\boldsymbol{\nabla} \times \boldsymbol{B'}) \times \boldsymbol{B'} \right]_\phi$	1262	jp_cross_bp_phi

4.10 thermal energy equation

Terms from the thermal energy equation, and their Reynolds decomposition, are defined here.

Value	Code	Variable	Value	Code	Variable
$\mathrm{f}_1\mathrm{f}_4\boldsymbol{v}\cdot\boldsymbol{\nabla}\Theta$	1401	rhotv_grad_s	$-c_6\boldsymbol{\nabla}\cdot\boldsymbol{F}_{cond}$	1421	s_diff
$\mathrm{f}_1\mathrm{f}_4\boldsymbol{v'}\cdot\boldsymbol{\nabla}\Theta'$	1402	rhotvp_grad_sp	$-c_6\boldsymbol{\nabla}\cdot\boldsymbol{F'}_{cond}$	1422	sp_diff
$\mathrm{f}_1\mathrm{f}_4\boldsymbol{v'}\cdot\boldsymbol{\nabla}\overline{\Theta}$	1403	rhotvp_grad_sm	$-c_6\boldsymbol{\nabla}\cdot\overline{\boldsymbol{F}}_{cond}$	1423	sm_diff
$\mathrm{f}_1\mathrm{f}_4\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\overline{\Theta}$	1404	rhotvm_grad_sm	$c_6\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5\left(\frac{\partial^2\Theta}{\partial r^2}+\frac{\partial\Theta}{\partial r}\left[\frac{2}{r}+\frac{\mathrm{d}}{\mathrm{dr}}\ln\left\{\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5\right\}\right]\right)$	1424	s_diff_r
$\mathrm{f}_1\mathrm{f}_4\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\Theta'$	1405	rhotvm_grad_sp	$c_6\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5\left(\frac{\partial^2\Theta'}{\partial r^2}+\frac{\partial\Theta'}{\partial r}\left[\frac{2}{r}+\frac{\mathrm{d}}{\mathrm{dr}}\ln\left\{\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5\right\}\right]\right)$	1425	sp_diff_r
$\mathrm{f}_1\mathrm{f}_4 v_r\frac{\partial s}{\partial r}$	1406	rhotvr_grad_s	$c_6\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5\left(\frac{\partial^2\overline{\Theta}}{\partial r^2}+\frac{\partial\overline{\Theta}}{\partial r}\left[\frac{2}{r}+\frac{\mathrm{d}}{\mathrm{dr}}\ln\left\{\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5\right\}\right]\right)$	1426	sm_diff_r
$\mathrm{f}_1\mathrm{f}_4 v'_r\frac{\partial\Theta'}{\partial r}$	1407	rhotvpr_grad_sp	$c_6\frac{\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5}{r^2}\left(\frac{\partial^2\Theta}{\partial\theta^2}+\cot\theta\frac{\partial s}{\partial\theta}\right)$	1427	s_diff_theta
$\mathrm{f}_1\mathrm{f}_4 v'_r\frac{\partial\overline{\Theta}}{\partial r}$	1408	rhotvpr_grad_sm	$c_6\frac{\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5}{r^2}\left(\frac{\partial^2\Theta'}{\partial\theta^2}+\cot\theta\frac{\partial\Theta'}{\partial\theta}\right)$	1428	sp_diff_theta
$\mathrm{f}_1\mathrm{f}_4\overline{v_r}\frac{\partial\overline{\Theta}}{\partial r}$	1409	rhotvmr_grad_sm	$c_6\frac{\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5}{r^2}\left(\frac{\partial^2\overline{\Theta}}{\partial\theta^2}+\cot\theta\frac{\partial\overline{\Theta}}{\partial\theta}\right)$	1429	sm_diff_theta
$\mathrm{f}_1\mathrm{f}_4\overline{v_r}\frac{\partial\Theta'}{\partial r}$	1410	rhotvmr_grad_sp	$c_6\frac{\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5}{r^2\sin^2\theta}\frac{\partial^2\Theta}{\partial\phi^2}$	1430	s_diff_phi
$\mathrm{f}_1\mathrm{f}_4\frac{v_\theta}{r}\frac{\partial\Theta}{\partial\theta}$	1411	rhotvt_grad_s	$c_6\frac{\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5}{r^2\sin^2\theta}\frac{\partial^2\Theta'}{\partial\phi^2}$	1431	sp_diff_phi
$\mathrm{f}_1\mathrm{f}_4\frac{v'_\theta}{r}\frac{\partial\Theta'}{\partial\theta}$	1412	rhotvpt_grad_sp	$c_6\frac{\mathrm{f}_1\mathrm{f}_4\mathrm{f}_5}{r^2\sin^2\theta}\frac{\partial^2\overline{\Theta}}{\partial\phi^2}$	1432	sm_diff_phi
$\mathrm{f}_1\mathrm{f}_4\frac{v'_\theta}{r}\frac{\partial\overline{\Theta}}{\partial\theta}$	1413	rhotvpt_grad_sm	$F_Q(r)$	1433	vol_heat_flux
$\mathrm{f}_1\mathrm{f}_4\frac{\overline{v_\theta}}{r}\frac{\partial\overline{\Theta}}{\partial\theta}$	1414	rhotvmt_grad_sm	$\mathrm{f}_6(r)$	1434	vol_heating
$\mathrm{f}_1\mathrm{f}_4\frac{\overline{v_\theta}}{r}\frac{\partial\Theta'}{\partial\theta}$	1415	rhotvmt_grad_sp	$c_5\Phi(r,\theta,\phi)$	1435	visc_heating
$\mathrm{f}_1\mathrm{f}_4\frac{v_\phi}{r\sin\theta}\frac{\partial\Theta}{\partial\phi}$	1416	rhotvp_grad_s	$\mathrm{f}_7 c_4\left(\boldsymbol{\mathcal{J}'}\cdot\boldsymbol{\mathcal{J}'}\right)$	1436	ohmic_heat
$\mathrm{f}_1\mathrm{f}_4\frac{v'_\phi}{r\sin\theta}\frac{\partial\Theta'}{\partial\phi}$	1417	rhotvpp_grad_sp	$\mathrm{f}_7 c_4\left(\boldsymbol{\mathcal{J}'}\cdot\boldsymbol{\mathcal{J}'}\right)$	1437	ohmic_heat_pp
$\mathrm{f}_1\mathrm{f}_4\frac{v'_\phi}{r\sin\theta}\frac{\partial\overline{\Theta}}{\partial\phi}$	1418	rhotvpp_grad_sm	$\mathrm{f}_7 c_4\left(\overline{\boldsymbol{\mathcal{J}}}\cdot\overline{\boldsymbol{\mathcal{J}}}\right)$	1438	ohmic_heat_pm
$\mathrm{f}_1\mathrm{f}_4\frac{\overline{v_\phi}}{r\sin\theta}\frac{\partial\overline{\Theta}}{\partial\phi}$	1419	rhotvmp_grad_sm	$\mathrm{f}_7 c_4\left(\overline{\boldsymbol{\mathcal{J}}}\cdot\boldsymbol{\mathcal{J}'}\right)$	1439	ohmic_heat_mm
$\mathrm{f}_1\mathrm{f}_4\frac{\overline{v_\phi}}{r\sin\theta}\frac{\partial\Theta'}{\partial\phi}$	1420	rhotvmp_grad_sp	$\mathrm{f}_1\mathrm{f}_4 v_r\Theta$	1440	rhot_vr_s

Value	Code	Variable	Value	Code	Variable
$\mathrm{f}_1\mathrm{f}_4 v'_r \Theta'$	1441	rhot_vrp_sp	$c_P \mathrm{f}_1 v'_r \,\overline{T}$	1461	enth_flux_rpm
$\mathrm{f}_1\mathrm{f}_4 v'_r \overline{\Theta}$	1442	rhot_vrp_sm	$c_P \mathrm{f}_1 v'_\theta \,\overline{T}$	1462	enth_flux_thetapm
$\mathrm{f}_1\mathrm{f}_4 \,\overline{v_r} \Theta'$	1443	rhot_vrm_sp	$c_P \mathrm{f}_1 v'_\phi \,\overline{T}$	1463	enth_flux_phipm
$\mathrm{f}_1\mathrm{f}_4 \,\overline{v_r}\, \overline{\Theta}$	1444	rhot_vrm_sm	$c_P \mathrm{f}_1 \,\overline{v_r}\, T'$	1464	enth_flux_rmp
$\mathrm{f}_1\mathrm{f}_4 v_\theta \Theta$	1445	rhot_vt_s	$c_P \mathrm{f}_1 \,\overline{v_\theta}\, T'$	1465	enth_flux_thetamp
$\mathrm{f}_1\mathrm{f}_4 v'_\theta \Theta'$	1446	rhot_vtp_sp	$c_P \mathrm{f}_1 \,\overline{v_\phi}\, T'$	1466	enth_flux_phimp
$\mathrm{f}_1\mathrm{f}_4 v'_\theta \overline{\Theta}$	1447	rhot_vtp_sm	$c_P \mathrm{f}_1 \,\overline{v_r}\, \overline{T}$	1467	enth_flux_rmm
$\mathrm{f}_1\mathrm{f}_4 \,\overline{v_\theta} \Theta'$	1448	rhot_vtm_sp	$c_P \mathrm{f}_1 \,\overline{v_\theta}\, \overline{T}$	1468	enth_flux_thetamm
$\mathrm{f}_1\mathrm{f}_4 \,\overline{v_\theta}\, \overline{\Theta}$	1449	rhot_vtm_sm	$c_P \mathrm{f}_1 \,\overline{v_\phi}\, \overline{T}$	1469	enth_flux_phimm
$\mathrm{f}_1\mathrm{f}_4 v_\phi \Theta$	1450	rhot_vp_s	$-c_6 \mathrm{f}_1\mathrm{f}_4\mathrm{f}_5 \frac{\partial\Theta}{\partial r}$	1470	cond_flux_r
$\mathrm{f}_1\mathrm{f}_4 v'_\phi \Theta'$	1451	rhot_vpp_sp	$-c_6 \mathrm{f}_1\mathrm{f}_4\mathrm{f}_5 \frac{1}{r} \frac{\partial\Theta}{\partial\theta}$	1471	cond_flux_theta
$\mathrm{f}_1\mathrm{f}_4 v'_\phi \overline{\Theta}$	1452	rhot_vpp_sm	$-c_6 \mathrm{f}_1\mathrm{f}_4\mathrm{f}_5 \frac{1}{r\sin\theta} \frac{\partial\Theta}{\partial\phi}$	1472	cond_flux_phi
$\mathrm{f}_1\mathrm{f}_4 \,\overline{v_\phi} \Theta'$	1453	rhot_vpm_sp	$-c_6 \mathrm{f}_1\mathrm{f}_4\mathrm{f}_5 \frac{\partial\Theta'}{\partial r}$	1473	cond_fluxp_r
$\mathrm{f}_1\mathrm{f}_4 \,\overline{v_\phi}\, \overline{\Theta}$	1454	rhot_vpm_sm	$-c_6 \mathrm{f}_1\mathrm{f}_4\mathrm{f}_5 \frac{1}{r} \frac{\partial\Theta'}{\partial\theta}$	1474	cond_fluxp_theta
$c_P \mathrm{f}_1 v_r T$	1455	enth_flux_r	$-c_6 \mathrm{f}_1\mathrm{f}_4\mathrm{f}_5 \frac{1}{r\sin\theta} \frac{\partial\Theta'}{\partial\phi}$	1475	cond_fluxp_phi
$c_P \mathrm{f}_1 v_\theta T$	1456	enth_flux_theta	$-c_6 \mathrm{f}_1\mathrm{f}_4\mathrm{f}_5 \frac{\partial\overline{\Theta}}{\partial r}$	1476	cond_fluxm_r
$c_P \mathrm{f}_1 v_\phi T$	1457	enth_flux_phi	$-c_6 \mathrm{f}_1\mathrm{f}_4\mathrm{f}_5 \frac{1}{r} \frac{\partial\overline{\Theta}}{\partial\theta}$	1477	cond_fluxm_theta
$c_P \mathrm{f}_1 v'_r T'$	1458	enth_flux_rpp	$-c_6 \mathrm{f}_1\mathrm{f}_4\mathrm{f}_5 \frac{1}{r\sin\theta} \frac{\partial\overline{\Theta}}{\partial\phi}$	1478	cond_fluxm_phi
$c_P \mathrm{f}_1 v'_\theta T'$	1459	enth_flux_thetapp			
$c_P \mathrm{f}_1 v'_\phi T'$	1460	enth_flux_phipp			

Value	Code	Variable	Value	Code	Variable
$[\boldsymbol{B}\cdot\boldsymbol{\nabla}\boldsymbol{v}]_r$	1601	induct_shear_r	$\left[\overline{\boldsymbol{B}}\cdot\boldsymbol{\nabla}\overline{\boldsymbol{v}}\right]_\theta$	1621	induct_shear_vmbm_theta
$-\left(\boldsymbol{\nabla}\cdot\boldsymbol{v}\right)B_r$	1602	induct_comp_r	$-\left(\overline{\boldsymbol{\nabla}}\cdot\overline{\boldsymbol{v}}\right)\overline{B_\theta}$	1622	induct_comp_vmbm_theta
$-[\boldsymbol{v}\cdot\boldsymbol{\nabla}\boldsymbol{B}]_r$	1603	induct_advec_r	$-\left[\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\overline{\boldsymbol{B}}\right]_\theta$	1623	induct_advec_vmbm_theta
$[\boldsymbol{\nabla}\times(\boldsymbol{v}\times\boldsymbol{B})]_r$	1604	induct_r	$\left[\boldsymbol{\nabla}\times\left(\overline{\boldsymbol{v}}\times\overline{\boldsymbol{B}}\right)\right]_\theta$	1624	induct_vmbm_theta
$-c_7\left[\boldsymbol{\nabla}\times(\mathrm{f}_7\boldsymbol{\nabla}\times\boldsymbol{B})\right]_r$	1605	induct_diff_r	$-c_7\left[\boldsymbol{\nabla}\times\left(\mathrm{f}_7\boldsymbol{\nabla}\times\overline{\boldsymbol{B}}\right)\right]_\theta$	1625	induct_diff_bm_theta
$[\boldsymbol{B}\cdot\boldsymbol{\nabla}\boldsymbol{v}]_\theta$	1606	induct_shear_theta	$\left[\overline{\boldsymbol{B}}\cdot\boldsymbol{\nabla}\overline{\boldsymbol{v}}\right]_\phi$	1626	induct_shear_vmbm_phi
$-\left(\boldsymbol{\nabla}\cdot\boldsymbol{v}\right)B_\theta$	1607	induct_comp_theta	$-\left(\overline{\boldsymbol{\nabla}}\cdot\overline{\boldsymbol{v}}\right)\overline{B_\phi}$	1627	induct_comp_vmbm_phi
$-[\boldsymbol{v}\cdot\boldsymbol{\nabla}\boldsymbol{B}]_\theta$	1608	induct_advec_theta	$-\left[\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\overline{\boldsymbol{B}}\right]_\phi$	1628	induct_advec_vmbm_phi
$[\boldsymbol{\nabla}\times(\boldsymbol{v}\times\boldsymbol{B})]_\theta$	1609	induct_theta	$\left[\boldsymbol{\nabla}\times\left(\overline{\boldsymbol{v}}\times\overline{\boldsymbol{B}}\right)\right]_\phi$	1629	induct_vmbm_phi
$-c_7\left[\boldsymbol{\nabla}\times(\mathrm{f}_7\boldsymbol{\nabla}\times\boldsymbol{B})\right]_\theta$	1610	induct_diff_theta	$-c_7\left[\boldsymbol{\nabla}\times\left(\mathrm{f}_7\boldsymbol{\nabla}\times\overline{\boldsymbol{B}}\right)\right]_\phi$	1630	induct_diff_bm_phi
$[\boldsymbol{B}\cdot\boldsymbol{\nabla}\boldsymbol{v}]_\phi$	1611	induct_shear_phi	$[\boldsymbol{B}'\cdot\boldsymbol{\nabla}\overline{\boldsymbol{v}}]_r$	1631	induct_shear_vmbp_r
$-\left(\boldsymbol{\nabla}\cdot\boldsymbol{v}\right)B_\phi$	1612	induct_comp_phi	$-\left(\overline{\boldsymbol{\nabla}}\cdot\overline{\boldsymbol{v}}\right)B'_r$	1632	induct_comp_vmbp_r
$-[\boldsymbol{v}\cdot\boldsymbol{\nabla}\boldsymbol{B}]_\phi$	1613	induct_advec_phi	$-[\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\boldsymbol{B}']_r$	1633	induct_advec_vmbp_r
$[\boldsymbol{\nabla}\times(\boldsymbol{v}\times\boldsymbol{B})]_\phi$	1614	induct_phi	$[\boldsymbol{\nabla}\times(\overline{\boldsymbol{v}}\times\boldsymbol{B}')]_r$	1634	induct_vmbp_r
$-c_7\left[\boldsymbol{\nabla}\times(\mathrm{f}_7\boldsymbol{\nabla}\times\boldsymbol{B})\right]_\phi$	1615	induct_diff_phi	$-c_7\left[\boldsymbol{\nabla}\times(\mathrm{f}_7\boldsymbol{\nabla}\times\boldsymbol{B}')\right]_r$	1635	induct_diff_bp_r
$\left[\overline{\boldsymbol{B}}\cdot\boldsymbol{\nabla}\overline{\boldsymbol{v}}\right]_r$	1616	induct_shear_vmbm_r	$[\boldsymbol{B}'\cdot\boldsymbol{\nabla}\overline{\boldsymbol{v}}]_\theta$	1636	induct_shear_vmbp_theta
$-\left(\overline{\boldsymbol{\nabla}}\cdot\overline{\boldsymbol{v}}\right)\overline{B_r}$	1617	induct_comp_vmbm_r	$-\left(\overline{\boldsymbol{\nabla}}\cdot\overline{\boldsymbol{v}}\right)B'_\theta$	1637	induct_comp_vmbp_theta
$-\left[\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\overline{\boldsymbol{B}}\right]_r$	1618	induct_advec_vmbm_r	$-[\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\boldsymbol{B}']_\theta$	1638	induct_advec_vmbp_theta
$\left[\boldsymbol{\nabla}\times\left(\overline{\boldsymbol{v}}\times\overline{\boldsymbol{B}}\right)\right]_r$	1619	induct_vmbm_r	$[\boldsymbol{\nabla}\times(\overline{\boldsymbol{v}}\times\boldsymbol{B}')]_\theta$	1639	induct_vmbp_theta
$-c_7\left[\boldsymbol{\nabla}\times\left(\mathrm{f}_7\boldsymbol{\nabla}\times\overline{\boldsymbol{B}}\right)\right]_r$	1620	induct_diff_bm_r	$-c_7\left[\boldsymbol{\nabla}\times(\mathrm{f}_7\boldsymbol{\nabla}\times\boldsymbol{B}')\right]_\theta$	1640	induct_diff_bp_theta

4.11 Induction Equation

Terms from the induction equation, and their Reynolds decomposition, are described here.

Value	Code	Variable
$[\boldsymbol{B'} \cdot \boldsymbol{\nabla}\overline{\boldsymbol{v}}]_\phi$	1641	induct_shear_vmbp_phi
$-\left(\overline{\boldsymbol{\nabla}} \cdot \overline{\boldsymbol{v}}\right) B'_\phi$	1642	induct_comp_vmbp_phi
$-[\overline{\boldsymbol{v}} \cdot \boldsymbol{\nabla}\boldsymbol{B'}]_\phi$	1643	induct_advec_vmbp_phi
$[\boldsymbol{\nabla} \times (\overline{\boldsymbol{v}} \times \boldsymbol{B'})]_\phi$	1644	induct_vmbp_phi
$-c_7\,[\boldsymbol{\nabla} \times (\mathrm{f}_7\boldsymbol{\nabla} \times \boldsymbol{B'})]_\phi$	1645	induct_diff_bp_phi
$\left[\overline{\boldsymbol{B}} \cdot \boldsymbol{\nabla}\boldsymbol{v'}\right]_r$	1646	induct_shear_vpbm_r
$-\left(\overline{\boldsymbol{\nabla}} \cdot \boldsymbol{v'}\right) \overline{B_r}$	1647	induct_comp_vpbm_r
$-\left[\boldsymbol{v'} \cdot \boldsymbol{\nabla}\overline{\boldsymbol{B}}\right]_r$	1648	induct_advec_vpbm_r
$\left[\boldsymbol{\nabla} \times \left(\boldsymbol{v'} \times \overline{\boldsymbol{B}}\right)\right]_r$	1649	induct_vpbm_r
$\left[\overline{\boldsymbol{B}} \cdot \boldsymbol{\nabla}\boldsymbol{v'}\right]_\theta$	1650	induct_shear_vpbm_theta
$-\left(\overline{\boldsymbol{\nabla}} \cdot \boldsymbol{v'}\right) \overline{B_\theta}$	1651	induct_comp_vpbm_theta
$-\left[\boldsymbol{v'} \cdot \boldsymbol{\nabla}\overline{\boldsymbol{B}}\right]_\theta$	1652	induct_advec_vpbm_theta
$\left[\boldsymbol{\nabla} \times \left(\boldsymbol{v'} \times \overline{\boldsymbol{B}}\right)\right]_\theta$	1653	induct_vpbm_theta
$\left[\overline{\boldsymbol{B}} \cdot \boldsymbol{\nabla}\boldsymbol{v'}\right]_\phi$	1654	induct_shear_vpbm_phi
$-\left(\overline{\boldsymbol{\nabla}} \cdot \boldsymbol{v'}\right) \overline{B_\phi}$	1655	induct_comp_vpbm_phi
$-\left[\boldsymbol{v'} \cdot \boldsymbol{\nabla}\overline{\boldsymbol{B}}\right]_\phi$	1656	induct_advec_vpbm_phi
$\left[\boldsymbol{\nabla} \times \left(\boldsymbol{v'} \times \overline{\boldsymbol{B}}\right)\right]_\phi$	1657	induct_vpbm_phi
$[\boldsymbol{B'} \cdot \boldsymbol{\nabla}\boldsymbol{v'}]_r$	1658	induct_shear_vpbp_r
$-(\boldsymbol{\nabla} \cdot \boldsymbol{v'})\, B'_r$	1659	induct_comp_vpbp_r
$-[\boldsymbol{v'} \cdot \boldsymbol{\nabla}\boldsymbol{B'}]_r$	1660	induct_advec_vpbp_r
$[\boldsymbol{\nabla} \times (\boldsymbol{v} \times \boldsymbol{B'})]_r$	1661	induct_vpbp_r
$[\boldsymbol{B'} \cdot \boldsymbol{\nabla}\boldsymbol{v'}]_\theta$	1662	induct_shear_vpbp_theta
$-(\boldsymbol{\nabla} \cdot \boldsymbol{v'})\, B'_\theta$	1663	induct_comp_vpbp_theta
$-[\boldsymbol{v'} \cdot \boldsymbol{\nabla}\boldsymbol{B'}]_\theta$	1664	induct_advec_vpbp_theta
$[\boldsymbol{\nabla} \times (\boldsymbol{v} \times \boldsymbol{B'})]_\theta$	1665	induct_vpbp_theta
$[\boldsymbol{B'} \cdot \boldsymbol{\nabla}\boldsymbol{v'}]_\phi$	1666	induct_shear_vpbp_phi
$-(\boldsymbol{\nabla} \cdot \boldsymbol{v'})\, B'_\phi$	1667	induct_comp_vpbp_phi
$-[\boldsymbol{v'} \cdot \boldsymbol{\nabla}\boldsymbol{B'}]_\phi$	1668	induct_advec_vpbp_phi
$[\boldsymbol{\nabla} \times (\boldsymbol{v} \times \boldsymbol{B'})]_\phi$	1669	induct_vpbp_phi

Value	Code	Variable	Value	Code	Variable
$r\,\sin\theta \mathrm{f}_1\left[\boldsymbol{v'}\cdot\boldsymbol{\nabla}\boldsymbol{v'}\right]_\phi$	1801	samom_advec_pp	$\mathrm{f}_1 r \sin\theta\,\overline{v_\theta}\;\overline{v_\phi}$	1810	famom_dr_theta
$r\,\sin\theta \mathrm{f}_1\left[\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\overline{\boldsymbol{v}}\right]_\phi$	1802	samom_advec_mm	$\frac{c_1}{2}\mathrm{f}_1 r^2 \sin^2\theta\,\overline{v_r}$	1811	famom_mean_r
$-c_1 \mathrm{f}_1 r \sin\theta\left(\cos\theta\, v_\theta + \sin\theta\, v_r\right)$	1803	samom_coriolis	$\frac{c_1}{2}\mathrm{f}_1 r^2 \sin^2\theta\,\overline{v_\theta}$	1812	famom_mean_theta
$r\,\sin\theta\left[\boldsymbol{\nabla}\cdot\overline{\boldsymbol{\mathcal{D}}}\right]_\phi$	1804	samom_diffusion	$\mathrm{f}_1 \nu \sin\theta\left(v_\phi - r\frac{\partial\,\overline{v_\phi}}{\partial r}\right)$	1813	famom_diff_r
$r\,\sin\theta c_4\left[\left(\boldsymbol{\nabla}\times\overline{\boldsymbol{B}}\right)\times\overline{\boldsymbol{B}}\right]_\phi$	1805	samom_lorentz_mm	$\mathrm{f}_1 \nu\left(\cos\theta\,\overline{v_\phi} - \sin\theta\frac{\partial\,\overline{v_\phi}}{\partial\theta}\right)$	1814	famom_diff_theta
$r\,\sin\theta c_4\left[\left(\boldsymbol{\nabla}\times\boldsymbol{B'}\right)\times\boldsymbol{B'}\right]_\phi$	1806	samom_lorentz_pp	$-r\sin\theta c_4\, B'_r\, B'_\phi$	1815	famom_maxstr_r
$\mathrm{f}_1 r \sin\theta v'_r v'_\phi$	1807	famom_fluct_r	$-r\sin\theta c_4\, B'_\theta\, B'_\phi$	1816	famom_maxstr_theta
$\mathrm{f}_1 r \sin\theta v'_\theta v'_\phi$	1808	famom_fluct_theta	$-r\sin\theta c_4\,\overline{B_r}\,\overline{B_\phi}$	1817	famom_magtor_r
$\mathrm{f}_1 r \sin\theta\,\overline{v_r}\;\overline{v_\phi}$	1809	famom_dr_r	$-r\sin\theta c_4\,\overline{B_\theta}\,\overline{B_\phi}$	1818	famom_magtor_theta

4.12 Angular Momentum

Terms from the angular momentum equation and their associated fluxes are defined here. Only those terms contributing to the axisymmetric mean are calculated. Terms of form $a'\,\overline{a}$, which do not contribute to the mean, are omitted.

Value	Code	Variable	Value	Code	Variable
$-c_3\mathrm{f}_1\boldsymbol{v}\cdot\boldsymbol{\nabla}\left(\frac{P}{\mathrm{f}_1}\right)$	1901	press_work	$c_4\overline{\boldsymbol{v}}\cdot\left[\left(\boldsymbol{\nabla}\times\overline{\boldsymbol{B}}\right)\times\overline{\boldsymbol{B}}\right]$	1922	mag_work_mmm
$-c_3\mathrm{f}_1\boldsymbol{v'}\cdot\boldsymbol{\nabla}\left(\frac{P'}{\mathrm{f}_1}\right)$	1902	press_work_pp	$\frac{1}{2}\mathrm{f}_1 v_r\, v^2$	1923	ke_flux_radial
$-c_3\mathrm{f}_1\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\left(\frac{\overline{P}}{\mathrm{f}_1}\right)$	1903	press_work_mm	$\frac{1}{2}\mathrm{f}_1 v_\theta\, v^2$	1924	ke_flux_theta
$c_2 v_r \mathrm{f}_2\Theta$	1904	buoy_work	$\frac{1}{2}\mathrm{f}_1 v_\phi\, v^2$	1925	ke_flux_phi
$c_2 v'_r \mathrm{f}_2\Theta'$	1905	buoy_work_pp	$\frac{1}{2}\mathrm{f}_1\, \overline{v_r}\, \overline{v}^2$	1926	mke_mflux_radial
$c_2\overline{v_r}\mathrm{f}_2\overline{\Theta}$	1906	buoy_work_mm	$\frac{1}{2}\mathrm{f}_1\, \overline{v_\theta}\, \overline{v}^2$	1927	mke_mflux_theta
$c_5\boldsymbol{v}\cdot[\boldsymbol{\nabla}\cdot\boldsymbol{\mathcal{D}}]$	1907	visc_work	$\frac{1}{2}\mathrm{f}_1\, \overline{v_\phi}\, \overline{v}^2$	1928	mke_mflux_phi
$c_5\boldsymbol{v'}\cdot[\boldsymbol{\nabla}\cdot\boldsymbol{\mathcal{D}'}]$	1908	visc_work_pp	$\frac{1}{2}\mathrm{f}_1\, \overline{v_r}\, {v'}^2$	1929	pke_mflux_radial
$c_5\overline{\boldsymbol{v}}\cdot\left[\boldsymbol{\nabla}\cdot\overline{\boldsymbol{\mathcal{D}}}\right]$	1909	visc_work_mm	$\frac{1}{2}\mathrm{f}_1\, \overline{v_\theta}\, {v'}^2$	1930	pke_mflux_theta
$\mathrm{f}_1\boldsymbol{v}\cdot[\boldsymbol{v}\cdot\boldsymbol{\nabla}\boldsymbol{v}]$	1910	advec_work	$\frac{1}{2}\mathrm{f}_1\, \overline{v_\phi}\, {v'}^2$	1931	pke_mflux_phi
$\mathrm{f}_1\boldsymbol{v'}\cdot[\boldsymbol{v'}\cdot\boldsymbol{\nabla}\boldsymbol{v'}]$	1911	advec_work_ppp	$\frac{1}{2}\mathrm{f}_1\, v'_r\, {v'}^2$	1932	pke_pflux_radial
$\mathrm{f}_1\overline{\boldsymbol{v}}\cdot[\boldsymbol{v'}\cdot\boldsymbol{\nabla}\boldsymbol{v'}]$	1912	advec_work_mpp	$\frac{1}{2}\mathrm{f}_1\, v'_\theta\, {v'}^2$	1933	pke_pflux_theta
$\mathrm{f}_1\boldsymbol{v'}\cdot[\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\boldsymbol{v'}]$	1913	advec_work_pmp	$\frac{1}{2}\mathrm{f}_1\, v'_\phi\, {v'}^2$	1934	pke_pflux_phi
$\mathrm{f}_1\boldsymbol{v'}\cdot[\boldsymbol{v'}\cdot\boldsymbol{\nabla}\overline{\boldsymbol{v}}]$	1914	advec_work_ppm	$c_5\,[\boldsymbol{v}\cdot\boldsymbol{\mathcal{D}}]_r$	1935	visc_flux_r
$\mathrm{f}_1\overline{\boldsymbol{v}}\cdot[\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\overline{\boldsymbol{v}}]$	1915	advec_work_mmm	$c_5\,[\boldsymbol{v}\cdot\boldsymbol{\mathcal{D}}]_\theta$	1936	visc_flux_theta
$c_4\boldsymbol{v}\cdot[(\boldsymbol{\nabla}\times\boldsymbol{B})\times\boldsymbol{B}]$	1916	mag_work	$c_5\,[\boldsymbol{v}\cdot\boldsymbol{\mathcal{D}}]_\phi$	1937	visc_flux_phi
$c_4\boldsymbol{v'}\cdot[(\boldsymbol{\nabla}\times\boldsymbol{B'})\times\boldsymbol{B'}]$	1918	mag_work_ppp	$c_5\,[\boldsymbol{v'}\cdot\boldsymbol{\mathcal{D}'}]_r$	1938	visc_fluxpp_r
$c_4\overline{\boldsymbol{v}}\cdot[(\boldsymbol{\nabla}\times\boldsymbol{B'})\times\boldsymbol{B'}]$	1919	mag_work_mpp	$c_5\,[\boldsymbol{v'}\cdot\boldsymbol{\mathcal{D}'}]_\theta$	1939	visc_fluxpp_theta
$c_4\boldsymbol{v'}\cdot\left[\left(\boldsymbol{\nabla}\times\overline{\boldsymbol{B}}\right)\times\boldsymbol{B'}\right]$	1920	mag_work_pmp	$c_5\,[\boldsymbol{v'}\cdot\boldsymbol{\mathcal{D}'}]_\phi$	1940	visc_fluxpp_phi
$c_4\boldsymbol{v'}\cdot\left[(\boldsymbol{\nabla}\times\boldsymbol{B'})\times\overline{\boldsymbol{B}}\right]$	1921	mag_work_ppm	$c_5\,\left[\overline{\boldsymbol{v}}\cdot\overline{\boldsymbol{\mathcal{D}}}\right]_r$	1941	visc_fluxmm_r

4.13 Kinetic Energy Equation

Terms appearing in the kinetic energy equation ($\boldsymbol{v}\cdot\frac{\partial\hat{\rho}\boldsymbol{v}}{\partial t}$) are described here.

Value	Code	Variable	Value	Code	Variable
$c_5 \left[\overline{\boldsymbol{v}} \cdot \overline{\boldsymbol{\mathcal{D}}}\right]_\theta$	1942	visc_fluxmm_theta			
$c_5 \left[\overline{\boldsymbol{v}} \cdot \overline{\boldsymbol{\mathcal{D}}}\right]_\phi$	1943	visc_fluxmm_phi			
$-c_3 v_r P$	1944	press_flux_r			
$-c_3 v_\theta P$	1945	press_flux_theta			
$-c_3 v_\phi P$	1946	press_flux_phi			
$-c_3 v'_r P'$	1947	press_fluxpp_r			
$-c_3 v'_\theta P'$	1948	press_fluxpp_theta			
$-c_3 v'_\phi P'$	1949	press_fluxpp_phi			
$-c_3 \overline{v_r}\, \overline{P}$	1950	press_fluxmm_r			
$-c_3 \overline{v_\theta}\, \overline{P}$	1951	press_fluxmm_theta			
$-c_3 \overline{v_\phi}\, \overline{P}$	1952	press_fluxmm_phi			
$--$	1953	production_shear_ke			
$--$	1954	production_shear_pke			
$--$	1955	production_shear_mke			

4.14 Magnetic Energy Equation

Terms appearing in the Magnetic energy equation ($\boldsymbol{B} \cdot \frac{\partial \boldsymbol{B}}{\partial t}$) are described here.

Value	Code	Variable	Value	Code	Variable
$[(\boldsymbol{v}\times\boldsymbol{B}-\eta\boldsymbol{\mathcal{J}})\times\boldsymbol{B}]_r$	2001	ecrossb_r	$\boldsymbol{B}'\cdot\left[\boldsymbol{\nabla}\times\left(\boldsymbol{v}'\times\overline{\boldsymbol{B}}\right)\right]$	2021	induct_work_ppm
$[(\boldsymbol{v}\times\boldsymbol{B}-\eta\boldsymbol{\mathcal{J}})\times\boldsymbol{B}]_\theta$	2002	ecrossb_theta	$\boldsymbol{B}'\cdot[\boldsymbol{\nabla}\times(\overline{\boldsymbol{v}}\times\boldsymbol{B}')]$	2022	induct_work_pmp
$[(\boldsymbol{v}\times\boldsymbol{B}-\eta\boldsymbol{\mathcal{J}})\times\boldsymbol{B}]_\phi$	2003	ecrossb_phi	$\overline{\boldsymbol{B}}\cdot[\boldsymbol{\nabla}\times(\boldsymbol{v}'\times\boldsymbol{B}')]$	2023	induct_work_mpp
$[(\boldsymbol{v}'\times\boldsymbol{B}'-\eta\boldsymbol{\mathcal{J}}')\times\boldsymbol{B}']_r$	2004	ecrossb_ppp_r	$\overline{\boldsymbol{B}}\cdot\left[\boldsymbol{\nabla}\times\left(\overline{\boldsymbol{v}}\times\overline{\boldsymbol{B}}\right)\right]$	2024	induct_work_mmm
$[(\boldsymbol{v}'\times\boldsymbol{B}'-\eta\boldsymbol{\mathcal{J}}')\times\boldsymbol{B}']_\theta$	2005	ecrossb_ppp_theta	$\boldsymbol{B}\cdot[\boldsymbol{B}\cdot\boldsymbol{\nabla}\boldsymbol{v}]$	2025	ishear_work
$[(\boldsymbol{v}'\times\boldsymbol{B}'-\eta\boldsymbol{\mathcal{J}}')\times\boldsymbol{B}']_\phi$	2006	ecrossb_ppp_phi	$-\boldsymbol{B}\cdot[\boldsymbol{v}\cdot\boldsymbol{\nabla}\boldsymbol{B}]$	2026	iadvec_work
$\left[\left(\overline{\boldsymbol{v}}\times\overline{\boldsymbol{B}}-\eta\overline{\boldsymbol{\mathcal{J}}}\right)\times\overline{\boldsymbol{B}}\right]_r$	2007	ecrossb_mmm_r	$-\boldsymbol{B}\cdot(\boldsymbol{\nabla}\cdot\boldsymbol{v})\,\boldsymbol{B}$	2027	icomp_work
$\left[\left(\overline{\boldsymbol{v}}\times\overline{\boldsymbol{B}}-\eta\overline{\boldsymbol{\mathcal{J}}}\right)\times\overline{\boldsymbol{B}}\right]_\theta$	2008	ecrossb_mmm_theta	$\boldsymbol{B}'\cdot\left[\overline{\boldsymbol{B}}\cdot\boldsymbol{\nabla}\boldsymbol{v}'\right]$	2028	ishear_work_pmp
$\left[\left(\overline{\boldsymbol{v}}\times\overline{\boldsymbol{B}}-\eta\overline{\boldsymbol{\mathcal{J}}}\right)\times\overline{\boldsymbol{B}}\right]_\phi$	2009	ecrossb_mmm_phi	$-\boldsymbol{B}'\cdot[\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\boldsymbol{B}']$	2029	iadvec_work_pmp
$\left[(\boldsymbol{v}'\times\boldsymbol{B}')\times\overline{\boldsymbol{B}}\right]_r$	2010	ecrossb_ppm_r	$-\boldsymbol{B}'\cdot(\boldsymbol{\nabla}\cdot\overline{\boldsymbol{v}})\,\boldsymbol{B}'$	2030	icomp_work_pmp
$\left[(\boldsymbol{v}'\times\boldsymbol{B}')\times\overline{\boldsymbol{B}}\right]_\theta$	2011	ecrossb_ppm_theta	$\boldsymbol{B}'\cdot[\boldsymbol{B}'\cdot\boldsymbol{\nabla}\overline{\boldsymbol{v}}]$	2031	ishear_work_ppm
$\left[(\boldsymbol{v}'\times\boldsymbol{B}')\times\overline{\boldsymbol{B}}\right]_\phi$	2012	ecrossb_ppm_phi	$-\boldsymbol{B}'\cdot\left[\boldsymbol{v}'\cdot\boldsymbol{\nabla}\overline{\boldsymbol{B}}\right]$	2032	iadvec_work_ppm
$\left[\left(\boldsymbol{v}'\times\overline{\boldsymbol{B}}\right)\times\boldsymbol{B}'\right]_r$	2013	ecrossb_pmp_r	$-\boldsymbol{B}'\cdot(\boldsymbol{\nabla}\cdot\boldsymbol{v}')\,\overline{\boldsymbol{B}}$	2033	icomp_work_ppm
$\left[\left(\boldsymbol{v}'\times\overline{\boldsymbol{B}}\right)\times\boldsymbol{B}'\right]_\theta$	2014	ecrossb_pmp_theta	$\overline{\boldsymbol{B}}\cdot\left[\overline{\boldsymbol{B}}\cdot\boldsymbol{\nabla}\,\overline{\boldsymbol{v}}\right]$	2034	ishear_work_mmm
$\left[\left(\boldsymbol{v}'\times\overline{\boldsymbol{B}}\right)\times\boldsymbol{B}'\right]_\phi$	2015	ecrossb_pmp_phi	$-\overline{\boldsymbol{B}}\cdot\left[\overline{\boldsymbol{v}}\cdot\boldsymbol{\nabla}\overline{\boldsymbol{B}}\right]$	2035	iadvec_work_mmm
$[(\overline{\boldsymbol{v}}\times\boldsymbol{B}')\times\boldsymbol{B}']_r$	2016	ecrossb_mpp_r	$-\overline{\boldsymbol{B}}\cdot(\boldsymbol{\nabla}\cdot\overline{\boldsymbol{v}})\,\overline{\boldsymbol{B}}$	2036	icomp_work_mmm
$[(\overline{\boldsymbol{v}}\times\boldsymbol{B}')\times\boldsymbol{B}']_\theta$	2017	ecrossb_mpp_theta	$\overline{\boldsymbol{B}}\cdot[\boldsymbol{B}'\cdot\boldsymbol{\nabla}\boldsymbol{v}']$	2037	ishear_work_mpp
$[(\overline{\boldsymbol{v}}\times\boldsymbol{B}')\times\boldsymbol{B}']_\phi$	2018	ecrossb_mpp_phi	$-\overline{\boldsymbol{B}}\cdot[\boldsymbol{v}'\cdot\boldsymbol{\nabla}\boldsymbol{B}']$	2038	iadvec_work_mpp
$\boldsymbol{B}\cdot[\boldsymbol{\nabla}\times(\boldsymbol{v}\times\boldsymbol{B})]$	2019	induct_work	$-\overline{\boldsymbol{B}}\cdot(\boldsymbol{\nabla}\cdot\boldsymbol{v}')\,\boldsymbol{B}'$	2039	icomp_work_mpp
$\boldsymbol{B}'\cdot[\boldsymbol{\nabla}\times(\boldsymbol{v}'\times\boldsymbol{B}')]$	2020	induct_work_ppp	$\boldsymbol{B}'\cdot[\boldsymbol{B}'\cdot\boldsymbol{\nabla}\boldsymbol{v}']$	2040	ishear_work_ppp

Value	Code	Variable	Value	Code	Variable
$-\boldsymbol{B}'\cdot[\boldsymbol{v}'\cdot\boldsymbol{\nabla}\boldsymbol{B}']$	2041	iadvec_work_ppp			
$-\boldsymbol{B}'\cdot(\boldsymbol{\nabla}\cdot\boldsymbol{v}')\,\boldsymbol{B}'$	2042	icomp_work_ppp			
$-c_7\boldsymbol{B}\cdot[\boldsymbol{\nabla}\times(\mathrm{f}_7\boldsymbol{\nabla}\times\boldsymbol{B})]$	2043	idiff_work			
$-c_7\boldsymbol{B}'\cdot[\boldsymbol{\nabla}\times(\mathrm{f}_7\boldsymbol{\nabla}\times\boldsymbol{B}')]$	2044	idiff_work_pp			
$-c_7\overline{\boldsymbol{B}}\cdot\left[\boldsymbol{\nabla}\times\left(\mathrm{f}_7\boldsymbol{\nabla}\times\overline{\boldsymbol{B}}\right)\right]$	2045	idiff_work_mm			