Advance Adiabatic Profiles

11/13/05

1) The functionality for the component:

The *adiabatic profiles* are plasma and magnetic field functions that change only due to the presence of transport processes, including sources and sinks, and do not change due to changes in the plasma shape (or equilibrium) only. They are "one dimensional" in the sense that if we define an appropriate magnetic flux coordinate system, these quantities are functions only of the flux coordinate and time. This one-dimensional approximation is exploiting the multiple timescale nature of plasma transport. It is very fast along the field line, and much slower across the field lines. We effectively take the transport to be infinitely fast along the field, and solve for the slower evolution across the magnetic surfaces.

If we have α different ion species, then there are 4 + α different profiles. These are the *differential particle number* for each ion species, a total and an electron *entropy density*, an *angular momentum density*, and a *transform* for the magnetic field. The electron density is determined through quasi-neutrality. We use the toroidal magnetic flux through any surface as the flux coordinate, so that the adiabatic variables are considered to be functions of the toroidal magnetic flux and of time. This routine advances these variables one step in time.

Mathematically, we can define the adiabatic variables as follows: Without loss of generality, we take the axisymmetric magnetic field to be represented as:

$$\vec{B} = \nabla\phi \times \nabla\psi + g(\psi)\nabla\phi . \tag{1}$$

Here ψ is the poloidal magnetic flux per radian and g is the toroidal field function. We define an axisymmetric magnetic flux coordinate system using the toroidal magnetic flux coordinate $\Phi(\psi)$ that is constant along the magnetic field, i.e. satisfying:

$$\vec{B} \bullet \nabla\Phi = 0 . \tag{2}$$

We assume that surfaces of constant Φ form nested toroidal surfaces, and define two angles: θ going the short way around the torus and ϕ going the long way around the torus. We take ϕ to be the usual toroidal angle in a cylindrical coordinate system (R,ϕ, Z) so that $|\nabla\phi|^2 = 1/R^2$ We then define the Jacobian as the reciprocal of the triple product of the gradients of (Φ,θ,ϕ). This allows us to define the differential volume element as:

$$d^3V = \frac{d\Phi d\theta d\phi}{[\nabla\Phi \times \nabla\theta \bullet \nabla\phi]} \equiv J d\Phi d\theta d\phi \ . \tag{3}$$

If V is the volume within a surface containing toroidal flux Φ, we also define the differential volume between flux surfaces , $V' \equiv \dfrac{\partial V}{\partial \Phi}$, which we compute as the following surface integral on a $\Phi = \text{constant}$ surface:

$$V' = \int_0^{2\pi}\int_0^{2\pi} J d\theta d\phi = 2\pi \int_0^{2\pi} J d\theta \tag{4}$$

We also define the flux surface average of a scalar as follows:

$$\langle a \rangle \equiv \int_0^{2\pi} aJd\theta \Big/ \int_0^{2\pi} Jd\theta \tag{5}$$

so that:

$$\int_0^{2\pi} aJd\theta = \frac{1}{2\pi} V' \langle a \rangle \tag{5b}$$

The toroidal and poloidal magnetic fluxes can be defined as follows[1]:

$$\begin{aligned}
\Phi &\equiv \frac{1}{2\pi}\int_0^{\Phi} \mathbf{B}\bullet\nabla\phi d^3V = \int_0^{\Phi} g \int_0^{2\pi} \frac{1}{R^2} J d\theta d\Phi = \frac{1}{2\pi}\int_0^{\Phi} gV' \left\langle 1/R^2 \right\rangle d\Phi \\
\Psi &\equiv \frac{1}{2\pi}\int_0^{\Phi} \mathbf{B}\bullet\nabla\theta d^3V = 2\pi\psi
\end{aligned} \tag{6a,b}$$

Note that (6a) implies: $g = \dfrac{2\pi}{V'\left\langle 1/R^2 \right\rangle}$. Another useful relation is $\dfrac{d}{d\psi} = 2\pi q \dfrac{d}{d\Phi}$ (see below for the definition of q).

Given these definitions, we can define the plasma adiabatic variables as follows:

$$\begin{aligned}
&N_\alpha = n_\alpha V' \quad \text{differential number density of ion species } \alpha \\
&\sigma = pV'^{5/3} \quad \text{total entropy density} \\
&\sigma_e = p_e V'^{5/3} \quad \text{electron entropy density} \\
&\Omega = n\left\langle R^2 \right\rangle V'\omega(\Phi) = nV'\left\langle R^2 \nabla\phi\bullet\vec{V} \right\rangle \quad \text{toroidal angular momentum density} \\
&\iota = \frac{1}{q} = \frac{d\Psi}{d\Phi} \quad \text{magnetic rotational transform}
\end{aligned} \tag{7}$$

Here, n_α is the number density of ion species α, p is the total plasma pressure, p_e is the electron pressure, and n is the total ion density defined by: $n = \sum_\alpha n_\alpha$. The electron density is determined from quasi-neutrality: $n_e = \sum_\alpha Z_\alpha n_\alpha$, where Z_α is the charge state of ion species α. The expression for the toroidal angular momentum density results from taking the bulk fluid velocity to be of the form: $\vec{V} = \vec{V}_\perp + \omega(\Phi) R^2 \nabla\phi$.

The plasma temperatures are defined as the ratios between the pressures and the densities. All ion species are assumed to have temperature T_i and the electrons have temperature T_e. These are expressed in terms of electron volts *(eV)*. Thus, the relation between the densities, pressures, and temperatures are:

$$
\begin{aligned}
p &= k_B(nT_i + n_eT_e) \\
p_e &= k_B n_e T_e
\end{aligned} \tag{8}
$$

where we have introduced the Boltzmann Constant: $k_B = 1.6\times10^{-19}$ *J/eV*.

The adiabatic profiles are time advanced according to the transport equations[2]:

$$
\begin{aligned}
&\frac{\partial}{\partial t} N_\alpha = -\frac{\partial}{\partial \Phi}\left(N_\alpha \Gamma_\alpha\right) + V'S_\alpha \\
&\frac{\partial}{\partial t}\sigma = \tfrac{2}{3}\left(V'\right)^{2/3}\left[V_L \frac{\partial K}{\partial \Phi} - \frac{\partial}{\partial \Phi}\left(Q_i + Q_e\right) + V'\left(S_e + S_i - R_e\right)\right] \\
&\frac{\partial}{\partial t}\sigma_e = \tfrac{2}{3}\left(V'\right)^{2/3}\left[V_L \frac{\partial K}{\partial \Phi} - \frac{\partial}{\partial \Phi}\left(Q_e\right) + V'\left(-\Gamma\frac{\partial p_i}{\partial \Phi} + Q_{\Delta e} + S_e - R_e\right)\right] \\
&\frac{\partial \Omega}{\partial t} = \frac{\partial}{\partial \Phi}\left(V'\left\langle R^2\left|\nabla\Phi\right|^2\right\rangle n\chi_\Omega \frac{\partial \omega}{\partial \Phi}\right) + V'S_\omega \\
&\frac{\partial}{\partial t}\iota = \frac{\partial}{\partial \Phi} V_L
\end{aligned} \tag{9}
$$

Here, we have introduced the toroidal current within a magnetic surface[1]:

$$
\mu_0 K(\Phi) = \frac{\mu_0}{2\pi}\int_0^\Phi \vec{J}\bullet\nabla\phi dV = \oint \frac{d\ell\left|\nabla\psi\right|}{R} = \frac{V'}{\iota}\left\langle \frac{\left|\nabla\psi\right|^2}{R^2}\right\rangle = \frac{V'\iota}{(2\pi)^2}\left\langle \frac{\left|\nabla\Phi\right|^2}{R^2}\right\rangle \tag{10}
$$

where $\mu_0=4\pi\times10^{-7}$ henry/m is the permeability of free space, and we have made use of the relation:

$$
\mu_0 \vec{J} = \nabla \times \vec{B} \tag{11}
$$

We have introduced in (9) the electron-ion equipartition term $Q_{\Delta e}(\Phi)$, the particle flux $\Gamma(\Phi)$, and the loop-voltage and heat fluxes:

$$
\begin{aligned}
V_L(\Phi) &= \frac{2\pi\left\langle \vec{E}\bullet\vec{B}\right\rangle}{\left\langle \vec{B}\bullet\nabla\phi\right\rangle} \\
Q_i(\Phi) &= V'\left(\left\langle \vec{q}_i\bullet\nabla\Phi\right\rangle + \tfrac{5}{2}p_i\Gamma\right) \\
Q_e(\Phi) &= V'\left(\left\langle \vec{q}_e\bullet\nabla\Phi\right\rangle + \tfrac{5}{2}p_e\Gamma\right)
\end{aligned} \tag{12}
$$

Specifying a transport model consists of providing the transport fluxes: $\chi_\Omega, \Gamma, V_L, \left\langle \vec{q}_i\bullet\nabla\Phi\right\rangle, \left\langle \vec{q}_e\bullet\nabla\Phi\right\rangle, Q_{\Delta e}$ as functions of the thermodynamic (or adiabatic) variables and the metric quantities. Also required to solve the equations are the source and sink functions appearing in (9): $S_\alpha, S_e, S_i, S_\omega$, and R_e.

Note that many routines provide ion and electron thermal conductivities (χ_i,χ_e) and particle diffusivities and pinch terms D_α and $V_{p\alpha}$. In terms of these, we have the relations:

$$\begin{aligned}
\Gamma_\alpha &= -\left\langle |\nabla\Phi|^2 \right\rangle \left[\frac{D_\alpha}{n}\frac{\partial n}{\partial\Phi} + V_{p\alpha} \right] \\
\left\langle \vec{q}_i \bullet \nabla\Phi \right\rangle &= -\left\langle |\nabla\Phi|^2 \right\rangle \chi_i n \frac{\partial T_i}{\partial\Phi} \\
\left\langle \vec{q}_e \bullet \nabla\Phi \right\rangle &= -\left\langle |\nabla\Phi|^2 \right\rangle \chi_e n_e \frac{\partial T_e}{\partial\Phi}
\end{aligned} \tag{13}$$

Furthermore, if the thermal conductivities are strong functions of the temperature gradients, as they are for the GLF23 and MMM95 models, we also need the numerical derivatives:

$$\frac{\partial\chi_i}{\partial T_i'}, \frac{\partial\chi_i}{\partial T_e'}, \frac{\partial\chi_e}{\partial T_i'}, \frac{\partial\chi_e}{\partial T_e'} \tag{13a}$$

The equipartition term appearing in (9) is expressible in terms of the electron-ion collision time[2]:

$$Q_{\Delta e} = 3(m_e/m_i)(n_e/\tau_{ei})(T_i - T_e) \tag{13b}$$

The parallel (to the magnetic field $\vec{B}$) electric field is normally determined from an Ohm's law of the form:

$$\left\langle \vec{E} \bullet \vec{B} \right\rangle = \eta_{\parallel} \left\langle (\vec{J} - \vec{J}_{BS} - \vec{J}_{RF} - \vec{J}_{NB}) \bullet \vec{B} \right\rangle \tag{14}$$

Here, $\eta_{\parallel}(\Phi)$ is flux surface averaged parallel resistivity[3], and the first term in the bracket on the right comes from (11). The additional source functions describing current drive due to bootstrap current (BS), wave-particle interaction (RF), and neutral beam injection (NB), $\left\langle \vec{J}_{BS} \bullet \vec{B} \right\rangle, \left\langle \vec{J}_{RF} \bullet \vec{B} \right\rangle, \left\langle \vec{J}_{NB} \bullet \vec{B} \right\rangle$, must be supplied. Because the RF current source is often a strong function of the electric field, we require that the derivative with respect to the electric field also be given[4], i.e.:

$$\left\langle \frac{d\vec{J}_{RF}}{dE_{\parallel}} \bullet \hat{b} \right\rangle . \tag{15}$$

Here, $\hat{b} \equiv \vec{B}/|B|$ is a unit vector in the direction of the magnetic field. This allows us to perform a partial linearization of (14) so that we can evaluate the electric field at the advanced time. Thus, if the parallel electric field at time n is denoted E^n, then we can compute the electric field at time $(n+1)$ as:

$$V_L^{n+1}(\Phi) = \frac{2\pi\left\langle \vec{E}^{n+1}\bullet\vec{B}\right\rangle}{\left\langle \vec{B}\bullet\nabla\phi\right\rangle}$$

$$= \eta_{\|}^{*}\left[\begin{array}{l}\frac{2\pi\left\langle \vec{J}\bullet\vec{B}\right\rangle}{\left\langle \vec{B}\bullet\nabla\phi\right\rangle} - \frac{2\pi\left\langle \vec{J}_{BS}\bullet\vec{B}\right\rangle}{\left\langle \vec{B}\bullet\nabla\phi\right\rangle} - \frac{2\pi\left\langle \vec{J}_{RF}\bullet\vec{B}\right\rangle}{\left\langle \vec{B}\bullet\nabla\phi\right\rangle} \\ +\left\langle \frac{d\vec{J}_{RF}}{dE_{\|}}\bullet\hat{b}\right\rangle V_L^n - \frac{2\pi\left\langle \vec{J}_{NB}\bullet\vec{B}\right\rangle}{\left\langle \vec{B}\bullet\nabla\phi\right\rangle}\end{array}\right] \tag{16}$$

$$\eta_{\|}^{*} \equiv \frac{\eta_{\|}}{1+\eta_{\|}\left\langle \frac{d\vec{J}_{RF}}{dE_{\|}}\bullet\hat{b}\right\rangle}$$

Note that in our notation,

$$\frac{2\pi\mu_0\left\langle \vec{J}\bullet\vec{B}\right\rangle}{\left\langle \vec{B}\bullet\nabla\phi\right\rangle} = \frac{\eta_{\|}}{\left(V'\left\langle \frac{1}{R^2}\right\rangle\right)^2}\frac{\partial}{\partial\Phi}\left([V']^2\left\langle \frac{|\nabla\Phi|^2}{R^2}\right\rangle\left\langle \frac{1}{R^2}\right\rangle \iota\right)$$
$$\left\langle \vec{B}\bullet\nabla\phi\right\rangle = g\left\langle \frac{1}{R^2}\right\rangle = \frac{2\pi}{V'} \tag{17}$$

Initially, the solvers to be used are one extracted from the TSC code[5] based on a block tridiagonal method, and one extracted from the ONETWO code based on the Globally Convergent Newton Method (GCNM)[6].

The TSC solver assumes that the flux quantities are in the form:

$$\Gamma = \Gamma^0 + \Gamma^1\frac{\partial}{\partial\Phi}\left(\frac{N}{V'}\right) + \Gamma^2\frac{\partial}{\partial\Phi}\left(\frac{\sigma}{V'^{5/3}}\right) + \Gamma^3\frac{\partial}{\partial\Phi}\left(\frac{\sigma_e}{V'^{5/3}}\right) + \Gamma^4\frac{\partial}{\partial\Phi}\left(A(\Phi)\iota\right)$$
$$\left\langle \vec{q}_i\bullet\nabla\Phi\right\rangle = Q^{i0} + Q^{i1}\frac{\partial}{\partial\Phi}\left(\frac{N}{V'}\right) + Q^{i2}\frac{\partial}{\partial\Phi}\left(\frac{\sigma}{V'^{5/3}}\right) + Q^{i3}\frac{\partial}{\partial\Phi}\left(\frac{\sigma_e}{V'^{5/3}}\right) + Q^{i4}\frac{\partial}{\partial\Phi}\left(A(\Phi)\iota\right) \tag{18}$$
$$\left\langle \vec{q}_e\bullet\nabla\Phi\right\rangle = Q^{e0} + Q^{e1}\frac{\partial}{\partial\Phi}\left(\frac{N}{V'}\right) + Q^{e2}\frac{\partial}{\partial\Phi}\left(\frac{\sigma}{V'^{5/3}}\right) + Q^{e3}\frac{\partial}{\partial\Phi}\left(\frac{\sigma_e}{V'^{5/3}}\right) + Q^{e4}\frac{\partial}{\partial\Phi}\left(A(\Phi)\iota\right)$$
$$V_L = V^{L0} + V^{L1}\frac{\partial}{\partial\Phi}\left(\frac{N}{V'}\right) + V^{L2}\frac{\partial}{\partial\Phi}\left(\frac{\sigma}{V'^{5/3}}\right) + V^{L3}\frac{\partial}{\partial\Phi}\left(\frac{\sigma_e}{V'^{5/3}}\right) + V^{L4}\frac{\partial}{\partial\Phi}\left(A(\Phi)\iota\right)$$

where

$$A(\Phi) = [V']^2\left\langle \frac{|\nabla\Phi|^2}{R^2}\right\rangle\left\langle \frac{1}{R^2}\right\rangle \tag{19}$$

For the standard model, as given by (16), we have:

$$V^{L4} = \frac{\eta_\parallel^*}{\left(V'\left\langle\frac{1}{R^2}\right\rangle\right)^2}$$

$$V^{L0} = -\eta_\parallel^*\left[\frac{2\pi\left\langle\vec{J}_{BS}\bullet\vec{B}\right\rangle}{\left\langle\vec{B}\bullet\nabla\phi\right\rangle} + \frac{2\pi\left\langle\vec{J}_{RF}\bullet\vec{B}\right\rangle}{\left\langle\vec{B}\bullet\nabla\phi\right\rangle} + \frac{2\pi\left\langle\vec{J}_{NB}\bullet\vec{B}\right\rangle}{\left\langle\vec{B}\bullet\nabla\phi\right\rangle} - \left\langle\frac{d\vec{J}_{RF}}{dE_\parallel}\bullet\hat{b}\right\rangle V_L^n\right]$$

If the transport equations are given by the equivalent of (13), we have:

$$Q^{i0} = \left\langle|\nabla\Phi|^2\right\rangle n\left[\frac{\partial\chi_{\mathrm{i}}}{\partial T_i'}(\frac{\partial T_i^n}{\partial\Phi}) + \frac{\partial\chi_{\mathrm{i}}}{\partial T_e'}(\frac{\partial T_e^n}{\partial\Phi})\right](\frac{\partial T_i^n}{\partial\Phi})$$

$$Q^{i1} = \left\langle|\nabla\Phi|^2\right\rangle\left(\left[\chi_i\text{-}T_e'\frac{\partial\chi_{\mathrm{i}}}{\partial T_e'}\right]\frac{p}{n} + \left[(T_i'+T_e')\frac{\partial\chi_{\mathrm{i}}}{\partial T_e'} - \chi_i\right]\frac{p_e}{n}\right)$$

$$Q^{i2} = -\left\langle|\nabla\Phi|^2\right\rangle(\chi_i\text{-}T_e'\frac{\partial\chi_{\mathrm{i}}}{\partial T_e'})$$

$$Q^{i3} = -\left\langle|\nabla\Phi|^2\right\rangle\left(-\chi_i + (T_i'+T_e')\frac{\partial\chi_{\mathrm{i}}}{\partial T_e'}\right)$$

$$Q^{e0} = \left\langle|\nabla\Phi|^2\right\rangle n_e\left[\frac{\partial\chi_{\mathrm{e}}}{\partial T_e'}(\frac{\partial T_e^n}{\partial\Phi}) + \frac{\partial\chi_{\mathrm{e}}}{\partial T_i'}(\frac{\partial T_i^n}{\partial\Phi})\right](\frac{\partial T_e^n}{\partial\Phi})$$

$$Q^{e1} = \left\langle|\nabla\Phi|^2\right\rangle\left(T_e'\frac{\partial\chi_{\mathrm{e}}}{\partial T_i'}\frac{p}{n} + \left[\chi_e - (T_i'+T_e')\frac{\partial\chi_{\mathrm{e}}}{\partial T_i'}\right]\frac{p_e}{n}\right)$$

$$Q^{e2} = -\left\langle|\nabla\Phi|^2\right\rangle T_e'\frac{\partial\chi_{\mathrm{e}}}{\partial T_i'}$$

$$Q^{e3} = -\left\langle|\nabla\Phi|^2\right\rangle\left(\chi_e - (T_i'+T_e')\frac{\partial\chi_{\mathrm{e}}}{\partial T_i'}\right)$$

$$\Gamma^0 = -\left\langle|\nabla\Phi|^2\right\rangle V_{p\alpha}$$

$$\Gamma^1 = -\left\langle|\nabla\Phi|^2\right\rangle\frac{D_\alpha}{n}$$

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[1] Kruskal, M, and Kulsrud, R, Phys. Fluids **1** 265 (1958)

[2] Hirshman, S, and Jardin, S. "Two-Dimensional Transport of Tokamak Plasmas",S, Phys. Fluids **22** 731 (1979)

[3] Hirshman, Hawryluk, and Birge, Nucl. Fusion **17** 611 (1977)

[4] Ignat D, Valeo, E. and Jardin, S., "Dynamic Modeling of Lower-Hybrid current drive", Nuclear Fusion **34,** 837 (1994)

[5] J. DeLucia, S. Jardin, and A. Todd, "An Iterative Metric Method for solving the

Inverse equilibrium Problem", J. Comp. Phys. **37** 2 (1980)

[6] H. St. John, L. Lao, and M. Murakami, "Methodology and Application of GCNM to Tokamak Transport", Bul l. Am. Phys. Soc., **50** 274 (2005)

2) Determine the minimal interface to provide this functionality.

Generic form of the inputs – What information is required by this component.

INPUT REQUIRED BY THIS ROUTINE FROM THE PLASMA STATE:

- old time values of the profiles: $(N_\alpha^n(\Phi), \alpha = 1, \alpha_{MAX}), \sigma^n(\Phi), \sigma_e^n(\Phi), \Omega^n(\Phi), \iota^n(\Phi)$: these are ($\alpha_{MAX}+4$) real*8 arrays of dimension NPSIT ~ 500, normally on an equally spaced grid in ΔΦ. Boundary conditions can be placed in location NPSIT+1.
- equilibrium metric terms on Φ grid: $V', V'^{5/3}, \left\langle 1/R^2 \right\rangle, \left\langle \left|\nabla \psi\right|^2 / R^2 \right\rangle, \left\langle \left|\nabla \psi\right|^2 \right\rangle$:

  These are 5 real*8 arrays on the same Φ grid.
- Source Terms, Sink Terms, including dJ/dE, etc: On the same Φ grid we need the source terms: $S_\alpha, S_e, S_i, S_\omega, R_e. \left\langle \vec{J}_{BS} \bullet \vec{B} \right\rangle, \left\langle \vec{J}_{RF} \bullet \vec{B} \right\rangle, \left\langle \vec{J}_{NB} \bullet \vec{B} \right\rangle, \left\langle \frac{d\vec{J}_{RF}}{dE_{\|}} \bullet \hat{b} \right\rangle$

OTHER INPUT REQUIRED:

- choice of transport model(s) and coefficients coming from that: We need components to supply on the Φ grid the following real*8 variables corresponding to a particular transport model: $\chi_\Omega, \; Q_{\Delta e}, \eta_{\|}, D, \chi_i, \partial\chi_i / \partial T_i', \partial\chi_i / \partial T_e', \chi_e, \partial\chi_e / \partial T_i', \partial\chi_e / \partial T_e'$
- specification of boundary conditions: for each of the variables being advanced in time, we need an outer boundary condition, and a location of the boundary.
- time step for going from time step *n* to *n+1*: Δt

The generic form of the outputs – What information will this component provide?

OUTPUT PROVIDED TO THE PLASMA STATE:

- new time values of the profiles: $(N_\alpha^{n+1}(\Phi), \alpha = 1, \alpha_{MAX}), \sigma^{n+1}(\Phi), \sigma_e^{n+1}(\Phi), \Omega^{n+1}(\Phi), \iota^{n+1}(\Phi)$: these are ($\alpha_{MAX}+4$) real*8 arrays of dimension ~ 500, normally on an equally spaced grid in ΔΦ.

OTHER OUTPUT:

- MISC quantities needed for plotting and other diagnostics

What interfaces will be required to access the data this component needs from other components, and what interfaces will it provide to other components

- Needs uniform interface to transport model(s) GLF23, MMM95 to provide D, χ_i, χ_e etc
- Needs interfaces to other components to provide χ_Ω, $Q_{\Delta e}, \eta_\|$,
- Needs interfaces with Plasma State to obtain and write information
- Need a way for specifying boundary conditions

3) Identify code specific data

Specific inputs – needs grid size (NPSIT) , time step (Δt), some variables indicating which transport model to use (ITRMOD).

Identify code state data that is required to restart: Just the adiabatic variables at the present time step should be sufficient:
$(N_\alpha^n(\Phi), \alpha = 1, \alpha_{MAX}), \sigma^n(\Phi), \sigma_e^n(\Phi), \Omega^n(\Phi), \iota^n(\Phi)$

Identify other code outputs (that might be useful for diagnostics or visualization for example) that doesn't specifically enter into the simulation: All the transport coefficients, χ_Ω, $Q_{\Delta e}, \eta_\|, D, \chi_i, \chi_e$ should be available for visualization.

4) What expectations or assumptions that the component will have about the data it gets from another component.

Not applicable.

5) Identify possible shared infrastructure components such as global time-keeper, interpolators from one representation to another, flux surface average routines, storage of the component's state for restart.

The flux surface average routines needed by this routine are likely needed by other routines.

6) Identify physics analysis/development needs and identify possible mathematical or algorithmic problems or opportunities for improvement. Identify additional opportunities for parallelism that are not presently realized.

The routine is iterating on a non-linear parabolic equation each time it is called. The present routines are most likely adequate, but could undoubtedly be improved. The most time consuming part of the calculation is the evaluation of the GLF23 function at each grid point, and numerically calculating it's derivatives with respect to the temperature gradients. These routines are not presently parallel, but could easily be made parallel over the flux surfaces in the part of the routine that calculates the transport coefficients using MPI. The block tri-diagonal solve is not presently parallel, but we might want to consider it.

7) Summary of computational needs this component will have when used for the fast MHD campaign. Including computations, memory, amount of time to carry out its designated task in the framework, and kind of parallelism (threaded or distributed memory or both).

The memory requirements are very modest.