Inplementation

evolving quantities					
ne	Lambda	Ppar	Pperp		
$\hat{n}_e$	$\hat{\Lambda}$	$\hat{p}_\parallel$	$\hat{p}_\perp$		
derived quantities					
phi	Vpar	Psi	Tperp	Jpar	gyrophi
$\hat{\phi}_c$	$\hat{u}_{\parallel e}$	$\hat{\psi}$	$\hat{T}_\perp$	$\hat{J}_{\parallel c}$	$\hat{\Phi}_c$
gyrophi_a	gyrophi_b	gyroPsi	gyroPsi_a	gyrone	
$\hat{\Phi}_c^a$	$\hat{\Phi}_c^b$	$\hat{\Psi}$	$\hat{\Psi}^a$	$\hat{\bar{n}}_e$	
intermediate quantities					
ns	Ts	Ts1	gyroVpar	gyrophi_as	gyrophi_ai
$\hat{n}_s$	$\hat{T}_s$	$\hat{T}_{s1}$	$\hat{\bar{u}}_{\parallel e}$	Φ_s^a	$2\hat{\phi}_c - \hat{\Phi}_s^a$
gyrophi_bs	gyrophi_bs1	gyrophi_bs2	Psi_sour	gyroPsi_as	gyroPsi_ai
$\hat{\Phi}_s^b$	$\hat{\Phi}_{s1}^b$	$\hat{\Phi}_{s2}^b$	$-\frac{\bar{v}_{th}\bar{\Omega}_e\bar{L}}{\hat{B}V_{Ae}^2}\hat{n}_{0e}\hat{\bar{u}}_{\parallel e}$	$\hat{\Psi}_s^a$	$2\hat{\psi} - \hat{\Psi}_s^a$
gyroPsi_a	Jpar	phi_sour	phi_i	Grad2_ne	
$\hat{\Psi}_s^a$	$\hat{J}_{\parallel c}$	$-\frac{\tau^2}{\tau+1}\frac{\bar{\rho}_e\hat{T}_{e0}}{\bar{L}\hat{n}_{e0}}\hat{\bar{n}}_e$	$\frac{\tau}{\tau+1}\frac{\bar{\rho}_e\hat{T}_{e0}}{\bar{L}\hat{n}_{e0}}\hat{\bar{n}}_e + \hat{\phi}$	$\partial_\parallel^2 n_e$	
equilibrium and geometry					
rhoe	omegae	n0	P0	T0	
$\hat{\rho}_e$	$\hat{\Omega}_e$	$\hat{n}_{e0}$	$\hat{p}_0$	$\hat{T}_0$	
Other parameters					
tau	etae	Zion	omegae_bar	rhoe_bar	V_alfven
$\tau = T_{i0}/T_{e0}$	$\hat{\eta}_e = L_n/L_T$	Z	$\bar{\Omega}_e = e\bar{B}/m_e$	$\bar{\rho}_e = m_e\bar{v}_{th}/\bar{B}e$	$V_{Ae} = \bar{B}^2/\mu_0 m_e \bar{N}$
inversion parameters					
gyroa	gyrob	gyroc	gyrod	gyroe	
1.0	$-\rho_e^2/2\bar{L}^2$	2.0	$-\rho_e^2/\bar{L}^2$	$-(\tau+1)\rho_e^2/\bar{L}^2$	

Inversion function

$$d\nabla_\perp^2 x + \frac{1}{c}\nabla_\perp c \cdot \nabla_\perp x + ax = b$$
$$x = invert\_laplace(\&b,\ flags,\ \&a,\ \&c,\ \&d)$$

Operators

$$\mathbf{b} \times \hat{\nabla} A \cdot \hat{\nabla} B = b0xGrad\_dot\_Grad(A, B)$$
$$\hat{\partial}_\parallel A = Grad\_parP(A)$$
$$\frac{\mathbf{b} \times \nabla A}{B} \cdot \nabla B = bracket(A, B, flags)$$

For ρ_e, use equilibrium temperature.

- Grids
  - cbm18_dens6_nx128ny1024_etg.grid.nc
    psi: 0.776~0.913, nx132, ny1024, x at 60
    flat density
  - cbm18_dens6_nx1028ny512_etg.grid.nc
    psi: 0.4~1.1, nx1028, ny516, x at 654

3. Te proportional to density, Te=1000eV
option 1

- Resolution
  - In BOUT++, x is radial direction, y is parallel direction, z is bynormal direction. Electron gyroradius is about 0.05mm (B=2T, T0=1.6KeV), radial resolution is 0.
  - $k_\perp \rho_e \sim 0.7$, $k_\perp \sim nq/a$, $a = 1.2m$, $\rho_e \sim 0.05mm$, $\Rightarrow n \sim 16.8/q \times 10^3$
- Cyclone case parameters
  Radial extension $5mm$, nx=132, ny=256
  $R_0 = 4.0m$, $a = 0.72m$, $R_0/L_T = 6.9$, $R_0/L_n = 2.2$, so we have $R_0/L_p = 9.1 \Rightarrow L_p = 0.4396$.
  $q = 1.4$, $s = 0.1$
  normalized domain $x \sim (0.4948, 0.5052)$
- q profile

$$q(r) = q_0 + q_1 r^\alpha$$
$$s(r) = \frac{r}{q}\frac{dq}{dr} = \frac{\alpha q_1}{q} r^\alpha$$

Assume α is fixed, at the simulation postion $r_0 = 0.5 * 0.48 = 0.24$, we have $q(r_0) = q_A$, $s(r_0) = s_A$, then we get

$$q_0 = q_A - q_1 r_0^\alpha$$
$$q_1 = \frac{s_A q_A}{\alpha r_0^\alpha}$$

In ETG Cyclone case, $q_A = 1.4$, $s_A = 0.1$, we set $\alpha = 2$, so we get

$$q_0 = 1.33$$
$$q_1 = 1.2153$$

Transfer to normalized coordinate $r = 0.48x$

$$q(x) = q_0 + 0.48^2 q_1 x^2$$
$$= 1.319 + 0.273x^2$$

- Pressure profile
  Length scale

$$\frac{1}{L_n} = \frac{d \ln n_0}{dr}$$
$$\frac{1}{L_T} = \frac{d \ln T_0}{dr} = \frac{d \ln p_0/n_0}{dr} = \frac{1}{L_p} - \frac{1}{L_n}$$
$$\Rightarrow L_p = \frac{L_T L_n}{L_T + L_n}$$

In ETG Cyclone case, In normalized unit, the length scale is $L_{pn} = L_p/a1$

$$p = \frac{1}{2}(1 - \tanh(\frac{x - x_0}{\mu_0}))(1 - \gamma) + \gamma$$
$$\frac{1}{L_{pn}} = |\frac{d \log p(x)}{dx}|$$

$\gamma = 0.1$, $x_0 = 0.5$, so we get $\mu_0 = 0.4995$.