The Gyrokinetic Regime
Geometry
Velocity Space
Linear How-To
Units
Non-Linear Issues
Miscellany

- Primary concerns when setting up nonlinear runs:

  1. Simulation domain size, resolution and aspect ratio

  2. Implicitness parameters

  3. Timing

  4. “Magic” numbers of parallel processes

Simulation Domain Size

- Size of simulation along the field is basically fixed, with $-\pi < \theta < \pi$. I do **not** recommend using `nperiod`>1 for non-linear runs. It is physically acceptable but computationally prohibitive.

- Size of box in perpendicular direction set by either `y0` or `Ly` in the `kt_grids_box_parameters` namelist.

- Size of box in α (or y) direction is $L_y = 2\pi y_0$.

Radial Domain Size

- Size of simulation in radial direction is affected by magnetic shear $\widehat{s}$, L_y and J_{twist}.

- Recall Hammett's talk and discussion of J_{twist} is Mike Beer's PhD thesis, `http://w3.pppl.gov/ mbeer/afs/thesis.html`.

- In a nutshell:

$$\frac{L_x}{L_y} = \frac{J_{\text{twist}}}{2\pi\widehat{s}} \qquad \left(L_x = \frac{y_0 J_{\text{twist}}}{\widehat{s}}\right)$$

- Optimal choice of J_{twist} is not known in general. Recommended choice: jtwist $= 2\pi\widehat{s}$. Corresponds to roughly square simulation domain at outboard midplane.

Boundary Conditions

- Triply-periodic twist&shift boundary conditions In `dist_fn_knobs` namelist, set boundary_option = 'linked'

- Results in different θ_0's (k_ρ's) being linearly coupled together

- In axisymmetric geometry, coupling only occurs among radial wavenumbers with the *same* poloidal wavenumbers.

- To understand which modes are coupled, use

$$k_x \equiv -k_y \widehat{s} \theta_0$$

for modes with finite k_y.

Twisted Domain

- Simple bracket form of nonlinear term valid in general geometry

$$\{\chi, h\} = \frac{\partial \chi}{\partial \rho}\frac{\partial h}{\partial \alpha} - \frac{\partial \chi}{\partial \alpha}\frac{\partial h}{\partial \rho}$$

  can be evaluated with standard de-aliased pseudo-spectral algorithm.

- Derivatives evaluated in transform space, multiplication carried out in real space.

- Requires rectangular domain in (ρ, α) coordinates.

Twisted Domain

- Given L_x and L_y, also require n_x and n_y to fully specify domain.

- Because of FFT's, n_x and n_y (in the `kt_grids_box_parameters` namelist) should have prime factors from the set $\{2, 3, 5\}$ although any value is allowed. Alternative choices just reduce the performance.

- De-aliasing implies a particular relationship between the numbers of k_x and k_y modes in the calculation (Orszag 2/3 rule)

Why Pseudo-Spectral?

1. "Exponentially convergent" derivatives. Compare with finite difference:

$$\frac{\partial f}{\partial x} \sim \frac{f(x+h) - f(x-h)}{2h} + \mathcal{O}(h^2)$$

$$\frac{\partial f}{\partial x} \sim \frac{-f(x+2h) + 8f(x+h) - 8f(x-h) + f(x-2h)}{12h} + \mathcal{O}(h^4)$$

Pseudo-spectral is much better: error in $\frac{\partial f}{\partial x} \sim \mathcal{O}(h^N)$ at fixed h but

$$\text{error} \sim \mathcal{O}\left(\left(\frac{1}{N}\right)^N\right)$$

since h decreases as N increases.

Pseudo-Spectral Advantages

2. At fixed accuracy, pseudo-spectral is memory minimizing.

   - To resolve a function with 1% accuracy, spectral requires $N/2$ (compared to non-spectral scheme with N points)

   - `GS2` is spectral in ρ, α, E, λ, implying $\sim$ factor of 16 savings.

GS2 Perpendicular Grid

- In detail, GS2 uses (with standard Fortran integer arithmetic rules):

$$\texttt{naky} = \frac{n_y - 1}{3} + 1 \qquad\qquad \texttt{ntheta0} = 2\left(\frac{n_x - 1}{3}\right) + 1$$

- The number of k_x modes is equal to **ntheta0**.

- The value of θ_0 for a given mode can be calculated:

$$\theta_0 = \frac{k_x}{\hat{s} k_y}$$

for $k_y \neq 0$. For the $k_y = 0$ modes ($\sim$ the zonal flows), use $\theta_0 = 2\pi/(\hat{s} L_x k_y)$.

Potential Gotchas

- At a given k_y, different k_x modes are coupled by the twist&shift boundary conditions if their θ_0 values differ by integer multiples of 2π. Each connection adds a 2π segment of the eigenfunction.

- If the linear eigenfunctions are extended along the field line, then the nonlinear run should have enough resolution in the x (*i.e.*, ρ) direction to permit sufficient connections to resolve it.

- Operationally, **linear runs with** `grid_option = 'box'` **in the** `kt_grids_knobs` **namelist should give the same results as linear runs with any other grid option**

Recommendations

- Foregoing typically requires $n_x > n_y$. A rule of thumb to use is $n_x \sim 3n_y$. Key is to do linear checks to look for spuriously fast-growing modes. Time-consuming, but better than wasting a nonlinear run.

- For nonlinear runs, in the `dist_fn_species_knobs_i` namelists, recommend setting `fexpr = 0.45` and `bakdif = 0.05`

- Use restart capabilities for nonlinear runs. Need to set `save_for_restart = T` in the `gs2_diagnostics_knobs` namelist and provide a restart file name with `restart_file` in the `init_g_knobs` namelist

Restart Recommendations

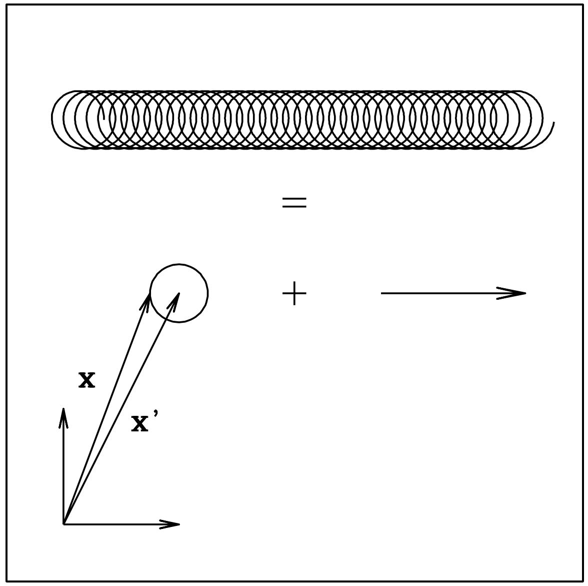
- For restarted runs, use `delt_option = 'check_restart'` in the `knobs` namelist

- Also, set `ginit_option = 'many'` in the `init_g_knobs` namelist

- In general, can use restarts for many purposes. It is wise to save the restart files before re-doing run.

How long is long enough?

- Open question!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