Transitioning AMPS to the CCMC

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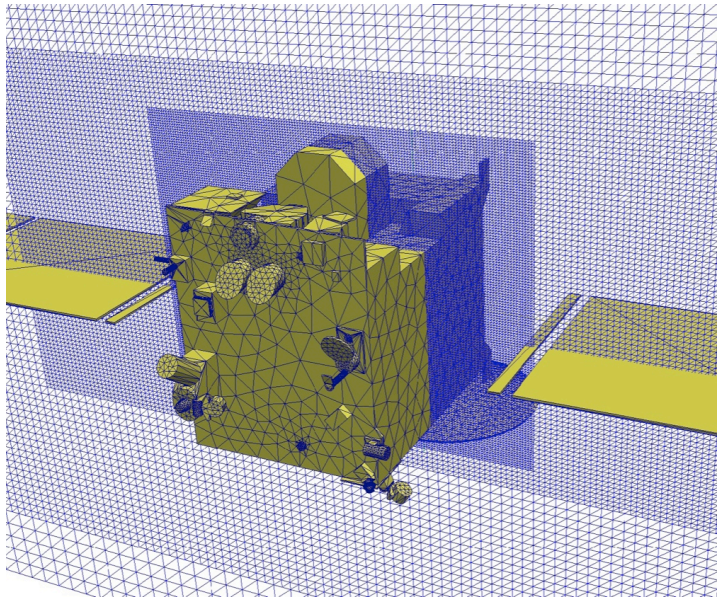
Adaptive Mesh Particle Simulator (AMPS)

- Adaptive Mesh Particle Simulator (AMPS)
  - Fully three dimensional
  - Numerical Scheme: Direct Simulation Monte Carlo (DSMC)
  - Modeling of the neutral and charged species, neutral and charged dust
- Kinetic description
  - Boltzmann equation
  - The evolution of the system is modeled by tracing the model particles
- Two phase flow modeling
- Included processes
  - Electron impact, charge exchange, photolytic reactions
  - Charting of the dust grains

Adaptive Mesh Particle Simulator (AMPS)

- Applications
  - Comets, planetary satellites and exospheres
  - Tracking of the ions and charged dust
- Integrated with SPICE and SWMF
- Optimizations
  - Local time step and particle weight
  - Individual particle weight correction
- Domain discretization
  - Adaptive Mesh Refinement (AMR) with cut-cells
- Parallel implementation
  - Domain decomposition
  - Static (volume, cell number) and dynamic load balancing (particle number, execution time)
  - Hybrid implementation: MPI (between nodes) + OpenMP (within each node)



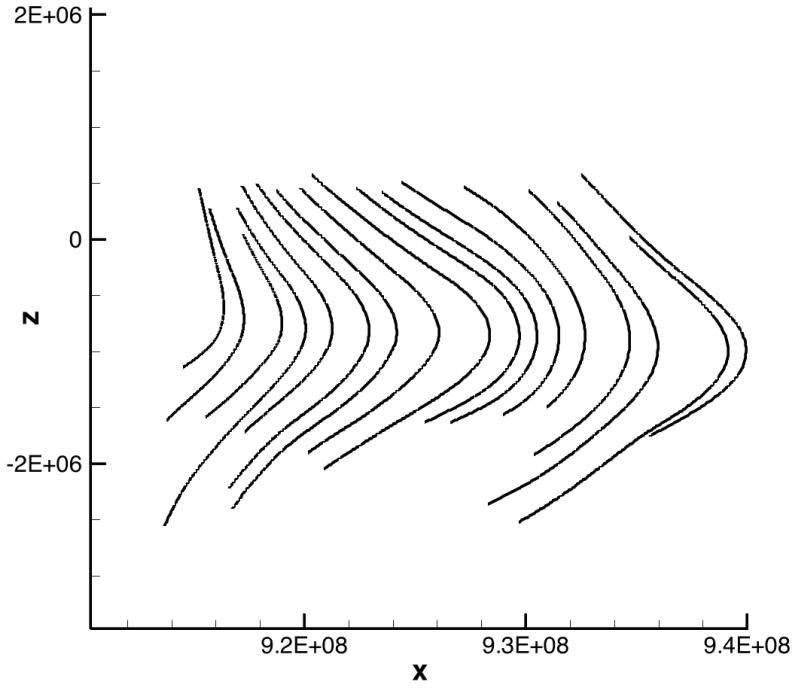
AMPS in CCMC

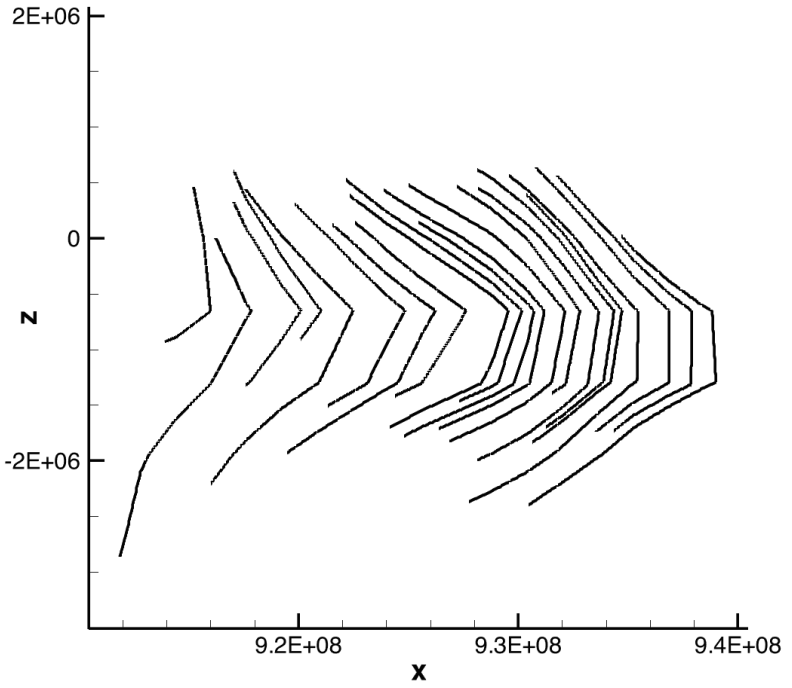
- Analyze charged particle trajectories moving in plasma
  - Post processing tool: use pre-calculated plasma and magnetic field
- Import of the plasma flow simulations into AMPS
  - Time-dependent results of the plasma modeling is saved in files
  - Kameleon is used for interpolating of the plasma model into AMPS' mesh
- Results provided by AMPS
  - Individual particle trajectories
  - Samples of the distribution functions
- Particle trajectory integration in AMPS
  - Boris
  - Guiding center
  - Particle tracking along a magnetic field line

AMPS in CCMC

- Electric and magnetic fields are interpolated onto a particle location
  - 2nd order interpolation (Borovikov et al., 2015)

- Example of particle trajectories calculated with 2nd order and a piecewise constant interpolations of the electric and magnetic fields:

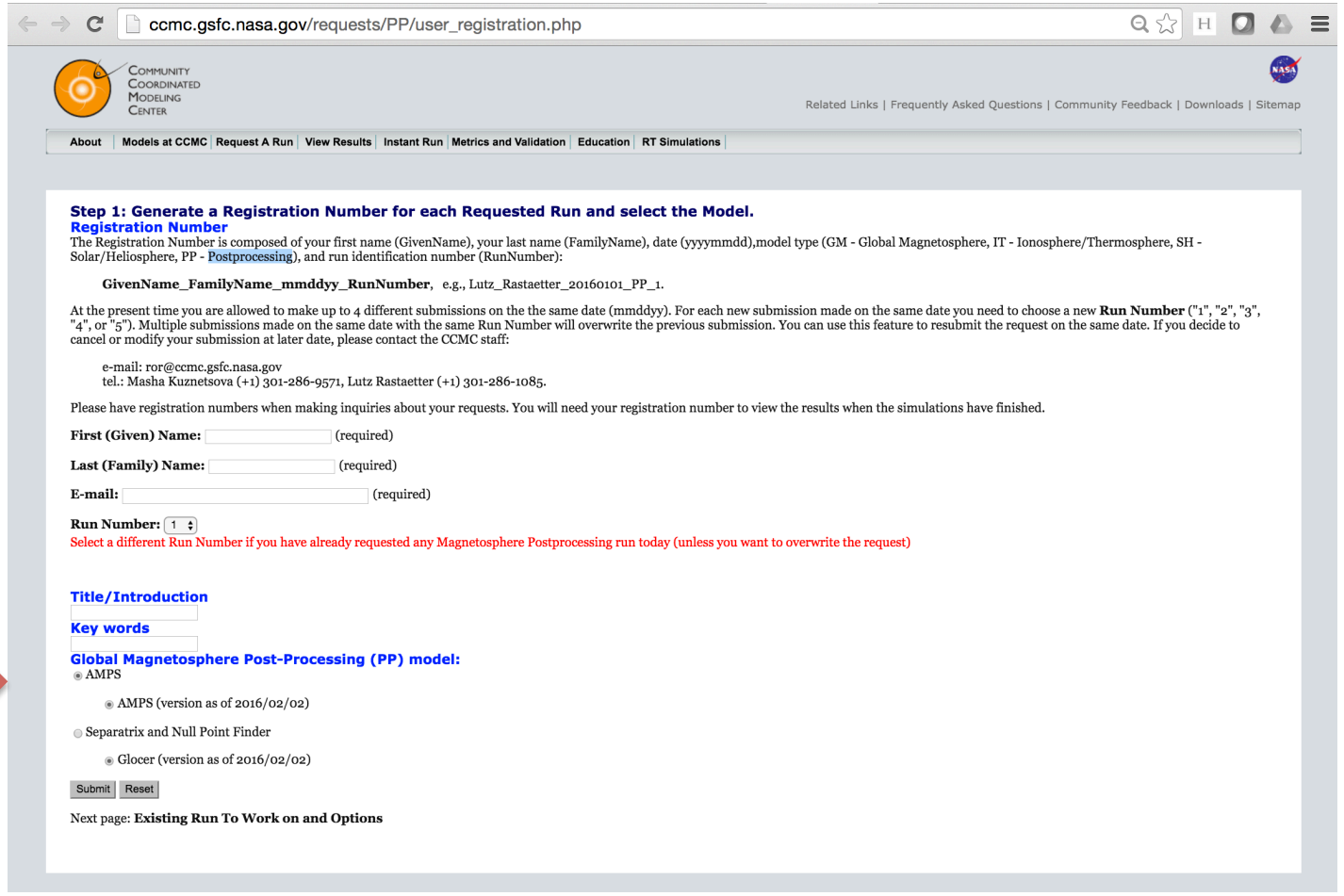




User Interface

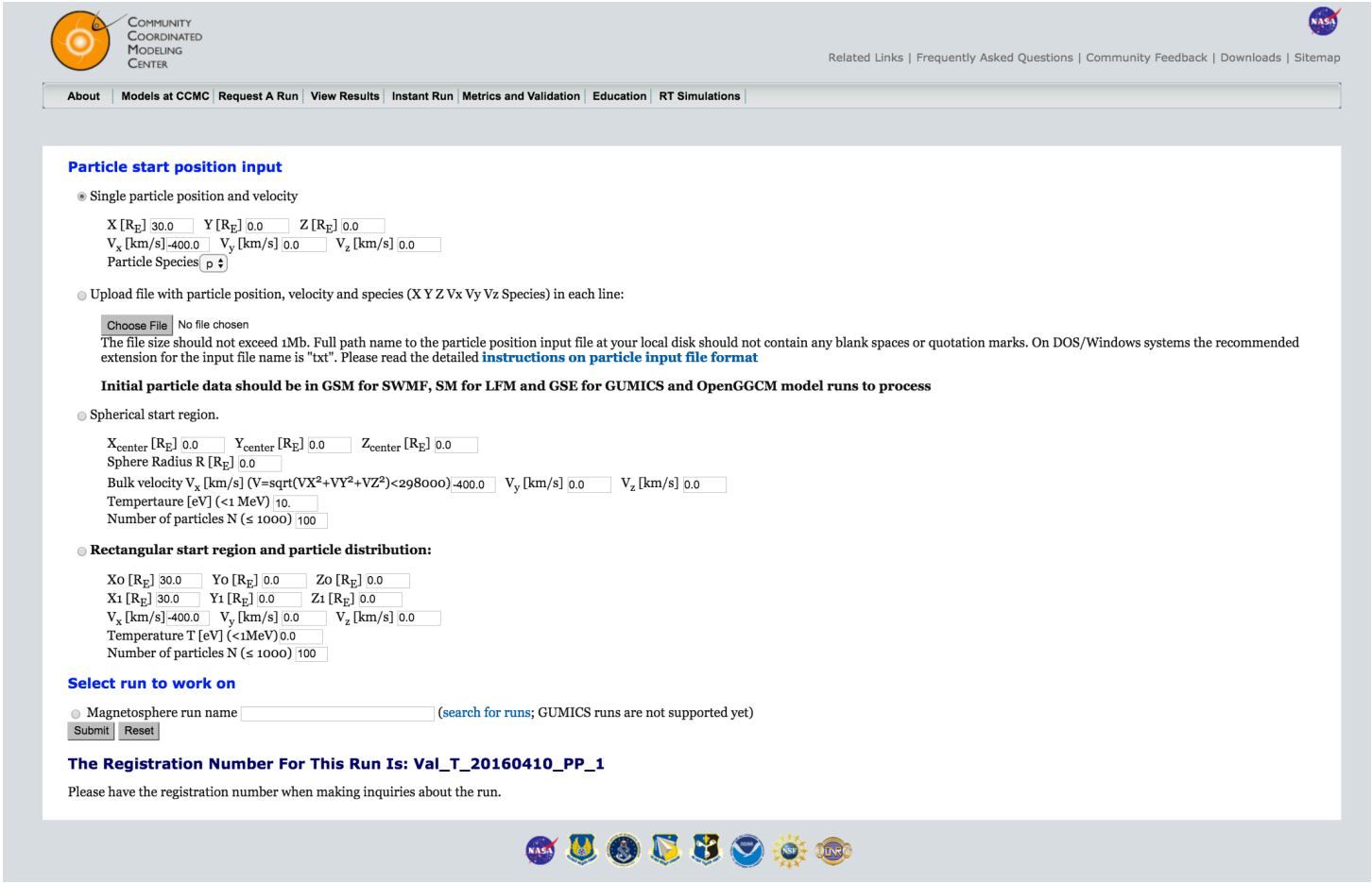
- A prototype of the web based user interface is under testing

AMPS



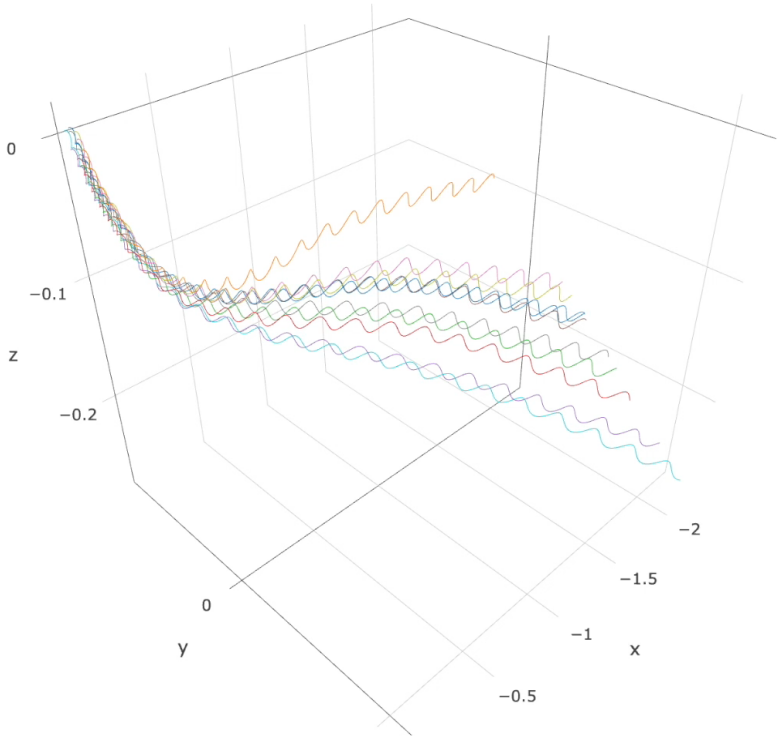
User Interface

- Initial parameters of the simulated trajectories



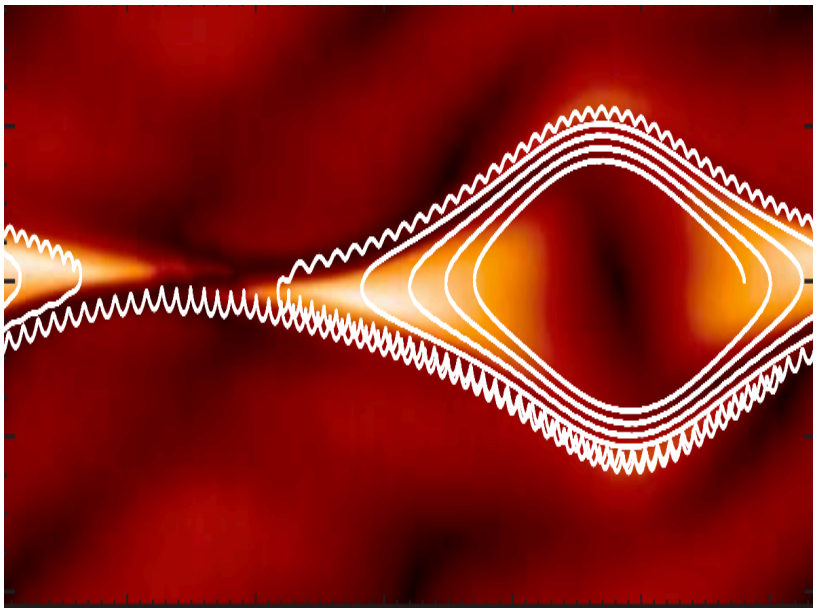
Visualization of the calculated trajectories

- Both desktop and browser viewers
- Visualization of the background model data
  - Cut-planes
  - Field line
- Visualization of the particle trajectories
  - Time slider
  - Particle trails
  - Annotated color bars



Example: Electron Acceleration

- Electron acceleration at magnetic islands during a reconnection (Drake, 2006)
- Background MHD simulation (Guidoni, DeVore and others, GSFC)
  - Plasma dynamics during a solar flare
    - Electron trajectories along closed field lines
      - Particles are attached to the field line
      - Guiding center motion
      - Field lines extracted from MHD data (magnetic flux function)
      - Time (linear) and space (2^{nd} order) interpolation
    - Results
      - Energy gain ≈2-3



Configuration of a magnetic island (Drake, 2006)

Conclusion

- Adaptive Mesh Particle Simulator
  - Self-sufficient Direct Simulation Monte Carlo model
  - A component of SWMF
  - A particle tracking tool in CCMC

- Application
  - Tracking of the charged particle trajectories, and sampling of distribution functions
  - Kinetic modeling of the charge particle dynamics moving in ambient plasma

- User interface and visualization components under testing
- More to come….