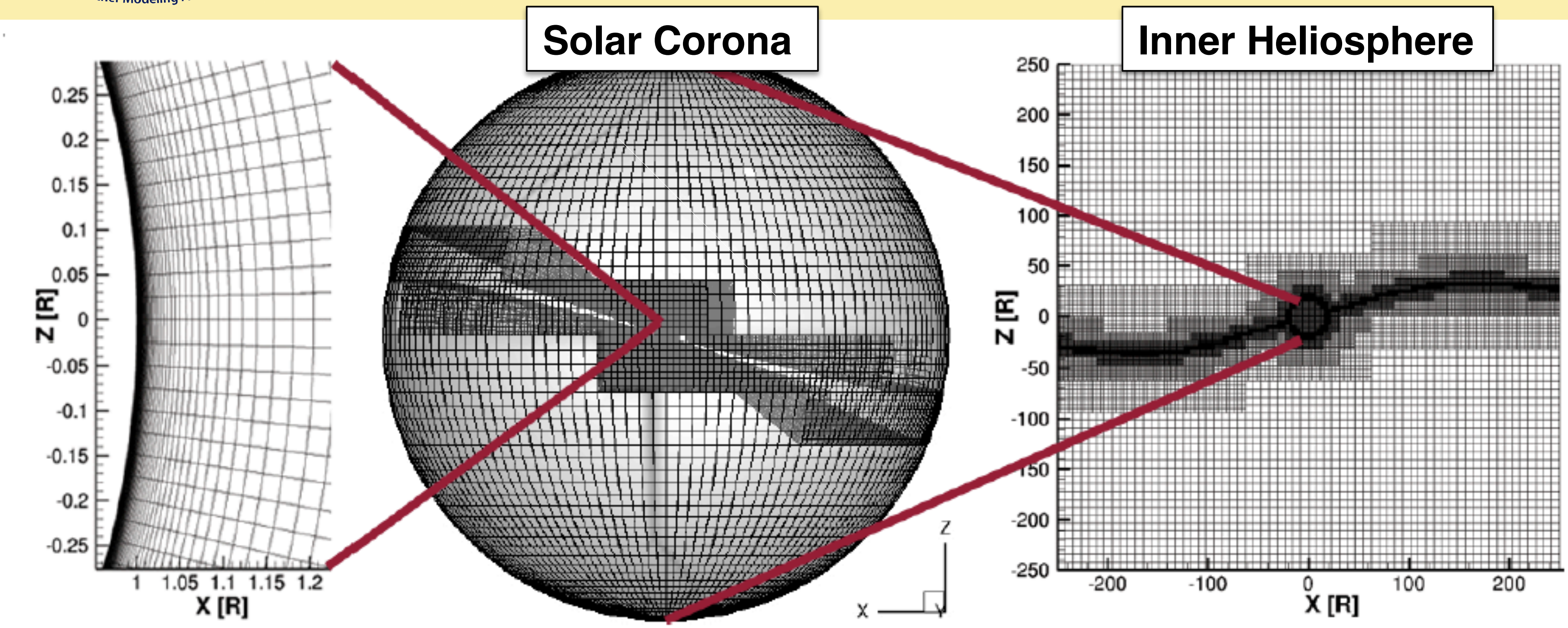
Solar Energetic Particles (SEPs) Model with Field-Line-Threads

- **The SEP acceleration and transport and the wave excitation can be modeled using one dimensional equations for a Field-Line-Thread.**
  - In the course of transport, focusing, pitch angle scattering etc as well as self-consistent wave excitation the particle stays at the same magnetic field line (Thread) advected with a highly conducting plasma;
  - The waves excited by the particles at the given Thread, then propagate along the same Thread, so that wave-SEP transport and wave-SEP coupling may be described within the Threaded model.
- **The use of multiple threads (MultiFLAMPA) allows us to separate the contributions from different factors to the SEP flux time variation.**
  - Variation may be caused by the dynamic process at the given magnetic field line (such the shock wave development)
  - Variation may occur because the Threads are advected, so that at different time instants the observer position is crossed by the Threads with different conditions for the SEP acceleration and transport.

Computational Grids



- Significant grid stretching to grid resolve the upper chromosphere and transition region in addition to artificial transition region broadening (Lionello et al. 2009, sokolov et al. 2013)

Interpolation on a 3D AMR Grid: SEP Diffuse-Shock-Acceleration

- **An important technological problem of smooth interpolation on 3D AMR block adaptive grid arises, for the case of multiple Threads.**
  - While solving numerically the SEP acceleration and transport, we trace numerically the points, of which the Thread consists of, using the plasma velocities ***interpolated*** from the MHD model (FLAMPA, 2004).
  - The coefficients in the kinetic equation are calculated from the MHD data velocities ***interpolated*** from the MHD model to the thread
  - Diffuse-Shock-Acceleration model requires to find the position of the shock wave at a given Thread. A shock wave is a jump in the ***interpolated*** density distribution along the Thread, ***assuming that*** the interpolation procedure is jump-free (***continuous***).
  - We use block-adaptive grids. Within the block interior, the grid is Cartesian uniform and 2(3)-linear interpolation is continuous.
  - Near the resolution changes the uniform bocks at different resolution meet. The grid is locally not Cartesian. The interpolation procedure is not continuous and should be revised (D. Borovikov, UofM)

Interpolation on 3D AMR Grid: Corners

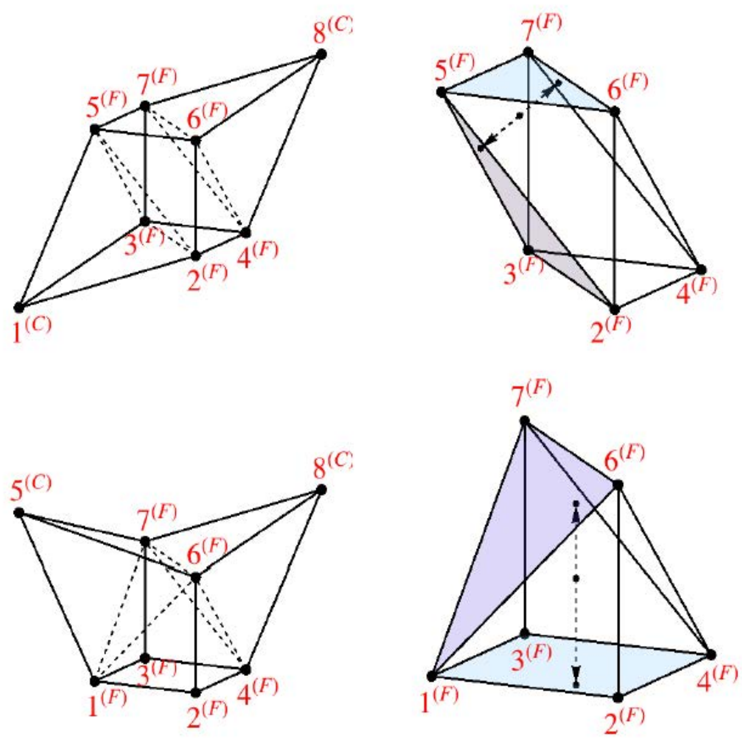


Figure 7: Resolution corner for two Coarse points

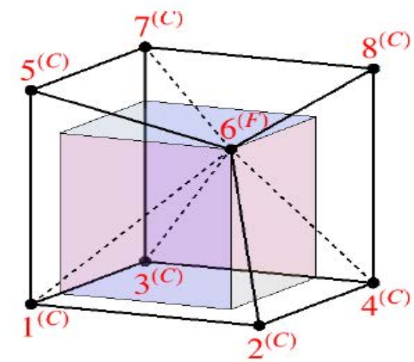


Figure 12: Resolution corners for 7 Coarse points.

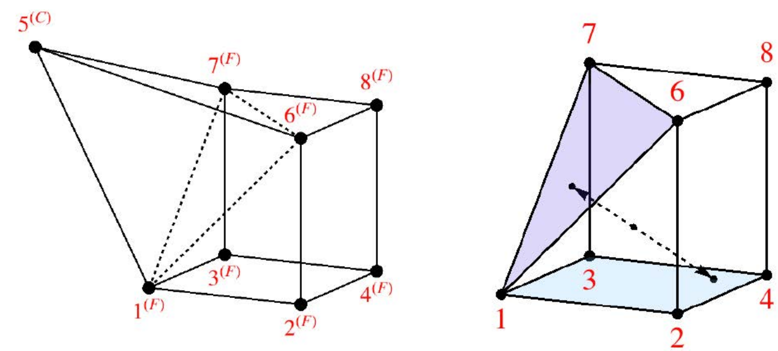
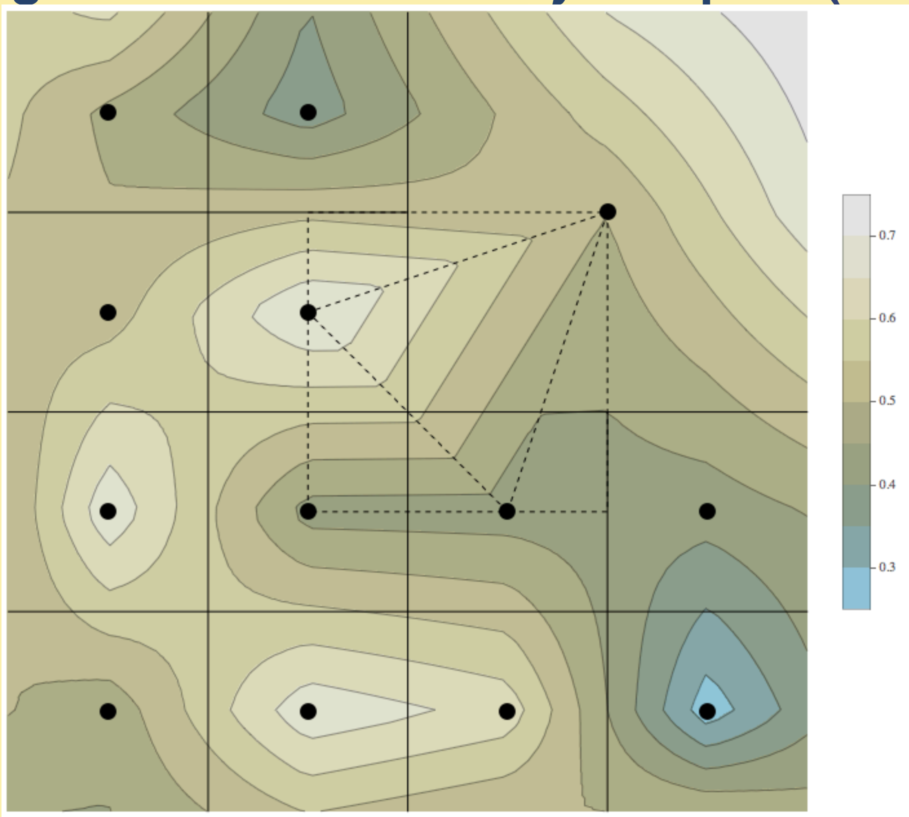


Figure 6: Interpolation on one Coarse, seven fine points corner.

- **There are hundreds of different combinations of coarser (C) and finer (F) cell centers to be involved into interpolation**

Interpolation on 3D AMR Grid: We Made it Smooth

- 2D AMR grid data are *randomly* sampled (not smooth at all)



- A continuity of the level contours (no jumps) witnesses a continuity of the interpolation procedure
- For smoothly interpolated data along a smooth thread the maximal gradients occur on the shock wave and they are not compromised by the interpolation artifacts.