New Coupled Models of Emerging Magnetic Flux in Active Regions

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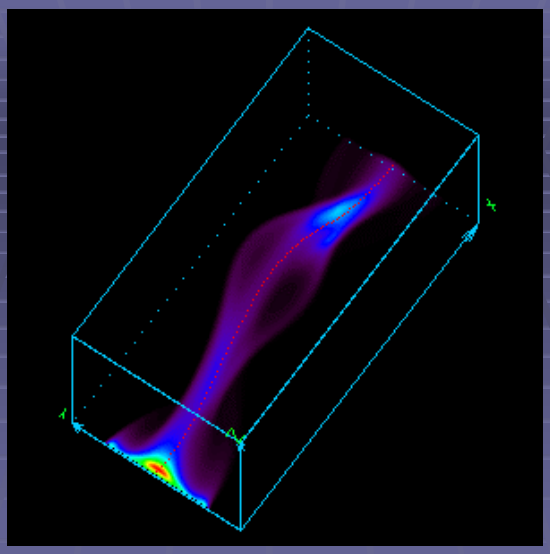
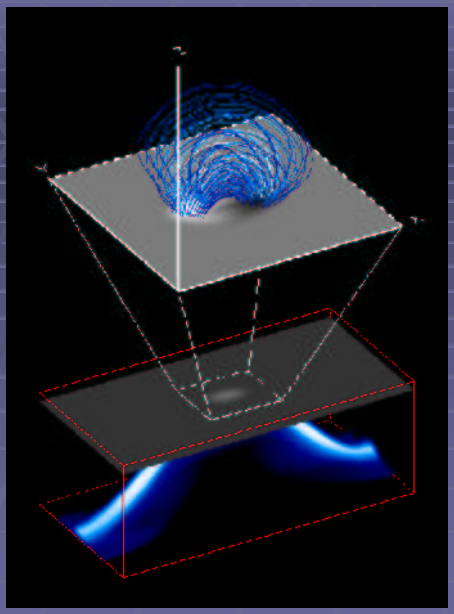
- We report on our progress in coupling the adaptive mesh refinement and domain decomposition framework PARAMESH (MacNeice et al. 2000) with an updated version of the 3-D ideal MHD code ZEUS-3D (Stone & Norman 1992).
- To illustrate the ability of this new combined code (which we have dubbed ZeusAMR) to model phenomena of widely differing spatial scales, we simulate the emergence of magnetic flux into the solar corona by driving the lower photospheric boundary of ZeusAMR with a sub-photospheric simulation of a buoyant Omega-loop performed by the 3-D anelastic MHD code, ANMHD (Abbett et al.2001, Fan et al. 1999).

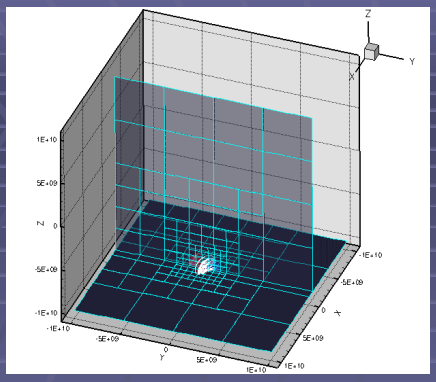


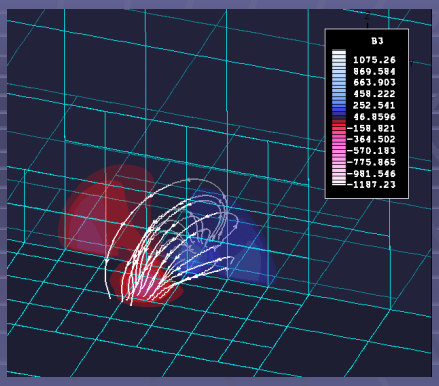
The above figure shows a volume rendering of |B| in the ANMHD domain, which spans roughly 5 pressure scale heights.



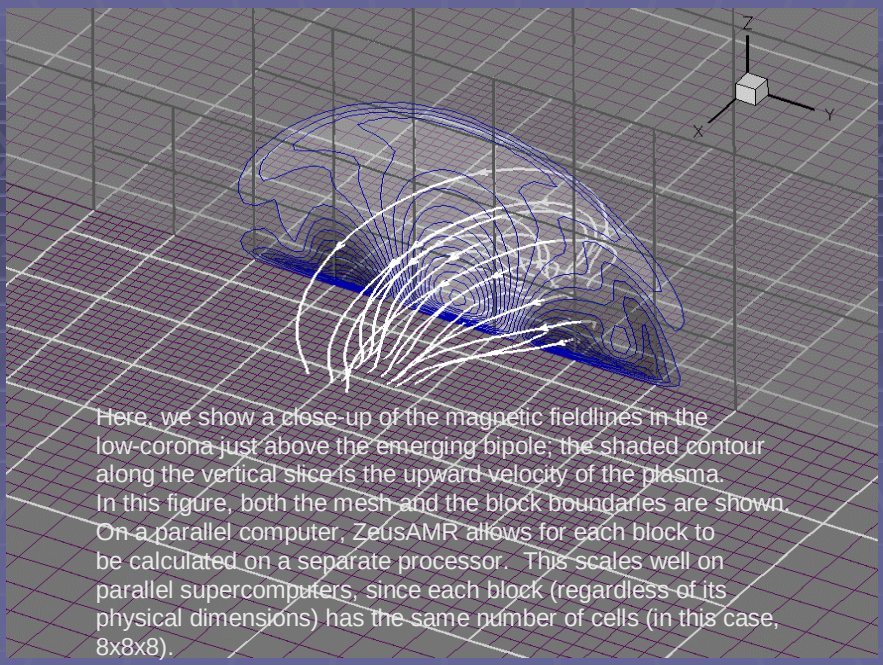
A snapshot of a Zeus3D corona being driven by the emerging Omega loop of the previous slide. Magnetic fieldlines are traced in blue, and the vertical component of the magnetic field along the Zeus-3D lower boundary is shown as a greyscale image: the light areas represent regions of positive polarity, and dark areas represent negative polarity.

Here, no adaptive mesh is used, and as a result, only a small fraction of the emerging flux can be modeled.

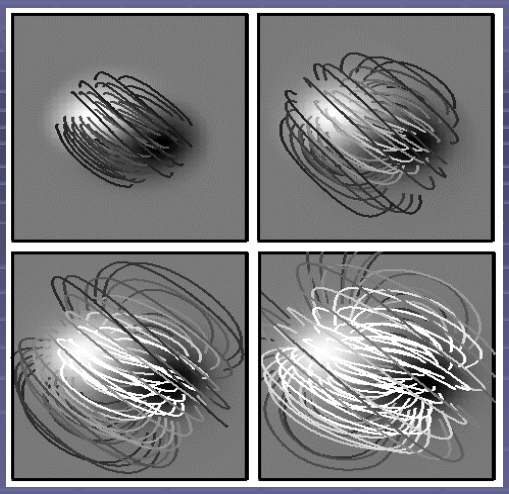




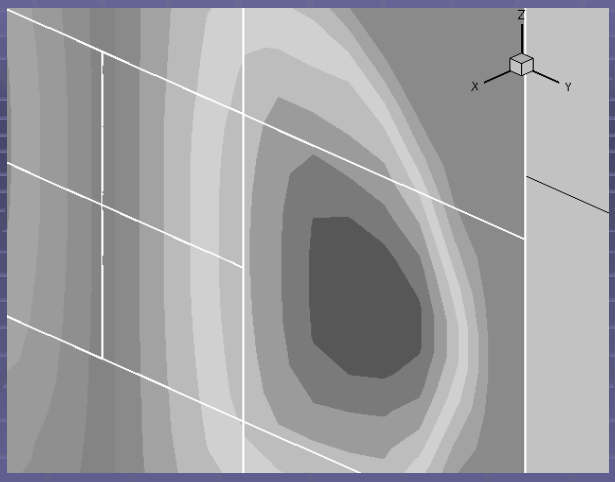
The figures above show a snapshot in time (from different vantage points) of the initially field-free ZeusAMR corona responding to this emerging Omega-loop. Note that the mesh has refined in the neighborhood of the active region and has de-refined elsewhere in response to a refinement criterion based on a normalized second derivative of the field strength.



Here, we show a close-up of the magnetic fieldlines in the low-corona just above the emerging bipole; the shaded contour along the vertical slice is the upward velocity of the plasma. In this figure, both the mesh and the block boundaries are shown. On a parallel computer, ZeusAMR allows for each block to be calculated on a separate processor. This scales well on parallel supercomputers, since each block (regardless of its physical dimensions) has the same number of cells (in this case, 8x8x8).



For comparison, we show similar simulations of emerging flux (with the same photospheric boundary) using ZeusAMR without the adaptive mesh. In this case, we can only model the area close to the active region since we lack the dynamic range afforded to us with AMR enabled.



It is important to ensure the conservation of quantities such as momentum and mass flux across blocks of different resolution, otherwise the act of refining and de-refining the mesh may introduce unphysical forces into the computation. ZeusAMR uses the PARAMESH framework to enforce this conservation. The above figure illustrates how well the horizontal flow-field matches between blocks of different resolution during the initial stages of a hydrodynamic blast test.

Summary

- We have completed a major portion of the code development necessary to construct a user-friendly, easy-to-update, portable, parallel version of Zeus-3D with adaptive mesh refinement.
- Our early results give us confidence that we will be able to provide the solar and space physics communities with a well-tested, beta-version of ZeusAMR in the near future.