Bill Abbett reports the completion of our initial effort to couple a 3-D MHD model corona with a 3-D subsurface simulation; the results of these experiments will be summarized in Abbett and Fisher, “A Coupled Model for the Emergence of Magnetic Flux into the Solar Corona” (in press). This paper highlights the importance of the flow-field on the evolution and structure of the coronal field, and points out a fundamental requirement for modelers who wish to drive MHD model coronae with photospheric vector magnetograms: A fully self-consistent photospheric velocity field--one that at least satisfies the vertical component of the induction equation at the interface--is necessary to properly describe the time-dependent magnetic topology of the corona above an active region. We have begun work incorporating data from AR8210 (the MURI case study) into our local 3D model corona. We begin with a non-linear force-free initial state provided by Stephane Regnier, and are using a subsequent magnetogram in an attempt to evolve the corona. Initial results of this calculation have been given to Loraine Lundquist for incorporation into her model that generates synthetic X-ray emission which can then be compared to observations of the corona directly above the active region being modeled.

Janet Luhmann was invited to give a keynote presentation on CME initiation at the 2002 SHINE meeting in Banff. That paper: "CME Initiation- A Zoo, Not an Animal", was further developed into a research article, submitted for publication to Solar Physics (Coronal Magnetic Field Context of Simple CMEs Inferred from Global Potential Field Models, by Luhmann, Lee, Zhao and Yashiro). She has been charged with coleading a SHINE "Challenge" on the subject of reconnection in the corona resulting from relative motion of the photosphere and corona- sometimes called interchange reconnection. This involves organizing several working groups on solar and interplanetary observations, and theory and modeling, to see if progress can be made on the subject by next SHINE workshop. The working group leaders are in the process of being recruited. She has started working with MURI student Loraine Lundquist on her planned use of potential field source surface models for studying coronal emissions and the related coronal temperature and density structure, and is co-author of a related AGU abstract by Paulett Liewer which compares coronal holes in SOHO EIT, Yohkoh, and He10830 images with potential field source surface model open field regions.

Luhmann is also helping Michigan MURI member Joseph Kota organize a MURI small workshop on Solar Energetic Particles models in Tucson in March ’03. That workshop will include about 15 MURI and outside participants. The goal is to build strategies for utilizing numerical simulations to better understand and model SEP acceleration and transport. The Center for Integrated Space weather Modeling (CISM) NSF Science and Technology Center has now started operating, with its solar science headquarters at SSL. Luhmann is working with Fisher to organize some overlapping discussions on modeling
CMEs at the upcoming December workshop. Luhmann has been asked to serve on the CCMC Science Working Group, to help advise the CCMC on community model choices and priorities.

Dr. Brian Welsch continued his collaboration with the Solar Theory group at the Naval Research Lab, running simulations using the Adaptively-Refined Magnetohydrodynamic Solver (ARMS) code provided by the NRL group on high performance computing (HPC) facilities the Army's Engineer Resource Development Center. By imposing a shear flow to force initially distinct flux systems to collide, these simulations can illuminate the role magnetic reconnection in forming pre-eruptive

![Figure 1 - field lines from an initially unsheared arcade](image-url)
structures.

Figure 2 - field lines after the arcade has been sheared

He also worked on improving a suite of codes developed by the MURI team to investigate methods of deriving velocities consistent with sequences of magnetograms, for use in driving coronal MHD codes with observational data.

Dr. Welsch resubmitted a paper to the Astrophysical Journal (ApJ) entitled, “Magnetic Helicity Injection by Horizontal Flows in the Quiet Sun: I. Mutual Helicity Flux,” and it was accepted for publication this May. He also attended the AGU meeting, where he presented a poster titled “Magnetic Helicity Injection by Horizontal Flows in the Quiet Sun: II. Self Helicity Flux,” and made substantial progress on the manuscript of this work for submission to ApJ.

In addition, at the MURI team meeting at UC Berkeley, Dr. Welsch gave a talk summarizing the Berkeley-based group's work in developing techniques to drive coronal MHD simulations with vector magnetogram data.

George Fisher gave a brief invited talk at the SHINE meeting describing the results of the MURI vector magnetogram workshop and the MURI CME numerical experiments workshop, and stressed the importance of velocity information in MHD models of CME initiation. He then asked Dana Longcope preview his SHINE poster describing his proposed solution to this problem.
Report from BBSO/NJIT: Sent by Yong-Jae Moon

1. WWW page of Latest Digital Vector Magnetogram Data:

BBSO latest image web site (http://www.bboj.njit.edu/cgi-bin/LatestImages) provides latest digital vector magnetograms available. The transverse fields are overlaid with corresponding longitudinal magnetograms or intensity images.

2. CME-flare relationship in homologous events:

We have studied the relationship between coronal mass ejections and flares, investigating four homologous CME-flare events that occurred in NOAA Active Region 9236 on November 24-25, 2000. Our study takes the following two approaches. First, we examine the relationship between CME kinematics and flare strength for four homologous CME-flare events. The homology of the events relieves us from the obscurity that is otherwise involved in statistical studies due to various random effects. Second, we directly estimate the initial eruption speed of a filament associated with the X1.8 flare among the four homologous events, using two sequences of 1-min cadence H-alpha images(high-resolution blue wing and full-disk centerline). The kinematic evolution of the erupting filament is then compared with the evolution of the GOES X-ray flux and the hard X-ray emission observed by Yohkoh.

In these investigations, we have found that:

1. there is a conspicuous correlation between the ejection speeds of CMEs in LASCO C2/C3 field of view and the peak fluxes of the associated flares,
2. the start of the filament eruption is timed about 10 min before the onset of the associated X1.8 flare,
3. the eruption speed increases exponentially in its initial eruption stage, and
4. the simple extrapolation of the eruption speed profile is directly linked to a LASCO CME seen at 22:06 UT on November 24 with a very good temporal and spatial proximity. Our results indicate that in this case, the flare cannot be a cause of the CME despite the good kinematic correlation (Moon et al., in preparation).

3. Publications:

Cho et al., "Initial results of Ichon radio spectrograph", accepted for Solar Physics.

Moon et al., "Impulsive variation of magnetic helicity change rate associated with eruptive flares" accepted for ApJ.

Moon et al., "A statistical study of two classes of coronal mass ejections" accepted for ApJ.
Report from Colorado/CIRES: sent by Dusan Odstrcil

We have initiated development of the interface between the coronal and heliospheric codes. This interface will be based on the new Paramesh package that was implemented during the two-week stay at the UCB/SSL with significant help from Bill Abbott and Steve Ledvina. Further, we have initiated development of the graphical user interface (ENKI) to the ENLIL code. This interface will simplify the preparation of input data, code compilation with different parameters, execution of jobs, and preview of the results. Rob Markel, the part-time programmer, is developing a web interface to provide uniform access to the local and remote computer systems.

We have re-computed some of our previous simulations of interplanetary disturbances and interacting magnetic flux ropes using finer numerical resolution. These results were presented at the SHINE Workshop in two invited talks.

Presentations:
Odstrcil D., Interactions of CMEs with background solar wind and other CMEs, SHINE workshop, Banff, Canada, August 18-22, 2002, (invited talk).
Odstrcil D., Interacting CMEs, SHINE workshop, Banff, Canada, August 18-22, 2002, (invited talk).

Report from Drexel University: Sent by Peter MacNeice

Drexel University personnel: Dr.Peter MacNeice, Dr. Andrew Phillips, Mr. Jimin Gao

In summary, we continued development work on our existing CME 'breakout' model code, continued development work on a High Order Godunov version, and fixed some minor bugs in version 3.0 of the Paramesh AMR package.

We have implemented a scheme within our Godunov code, based on an approach by LeVeque, which enables accurate balancing of source terms with fluxes, in the context of a Godunov type solver. This is necessary if our code is to maintain an initial force-free hydrostatic atmosphere in its stationary state. We are testing whether this modification produces a stable equilibrium. We have verified this with a HLLE approximate Riemann solver, for both low order and MUSCL, with or without Collela's corner-transport feature. We are currently repeating these tests for the Roe solver and for the exact Riemann solver.

We have developed a set of initial conditions for the FCT code which break the equatorial symmetry in all our previous model calculations. We have also been reviewing and reworking the basic FCT modules to enable easier use and modification, particularly with respect to adjustment of the levels of numerical diffusion. We hope this will lead to a resolution of the cavitation problem which has plagued our higher resolution runs.
We have identified and fixed some minor bugs in the MPI messaging of Paramesh V3.0. We are currently awaiting NASA permission to release this through SourceForge.

**Report from Hawaii: Sent by Jeff Kuhn**

Mees continues to observe with the IVM, Stokes polarimeter, MCCD, H-Alpha Coronagraph, and white light telescope.

We are co-observing with the Max Millennium effort.

Mickey has completed the installation of a filter wheel in the narrow-band path of the Imaging Vector Magnetograph (IVM). The filter wheel permits rapid switching between observed spectral lines, without requiring disassembly of the instrument. Filters currently installed are for H-alpha, Fe I 630.25 and Na D1.

New narrow-band blocking filters for the same three lines have been received and are being evaluated. The new filters are expected to provide more uniform transmission over their passband and better rejection of adjacent Fabry-Perot orders.

The IVM optical configuration was also changed slightly to place the blocking filters in a telecentric configuration. This should improve the uniformity of the filter bandpass over the field of view.

Also, one of the liquid-crystal variable retarders was replaced. With all these changes, we have a little tuning and calibration to do, but the instrument appears to behave pretty much as planned.

The SOLARC telescope has been outfitted with a 4 micron PbSe detector to measure the sky and telescope noise background. An optical chopper and lock-in system allow low level flux observations. The measured sky background is about 1 millionth of the solar disk intensity at 1.5 arcmin from the limb and about 8 millionths near the limb. These backgrounds may even be reduced with a cleaner primary mirror but meet our expectations from telescope and sky models and will allow sensitive coronal spectroscopic observations.

The 1-5 micron IR array camera has been completed. It is now working in the lab on Oahu and will shortly be shipped to Haleakala. A lab spectrograph for coronal observations has also been assembled in the Oahu lab. Using flourite fibers we have put together a working Ebert-Fastie configuration that uses the new HgCdTe array camera.

Dutch students Frans Snik and Jeroen Rietjens are working in the Oahu lab on a 3 month research internship. Their work to check the spectrograph design, finish the IR camera, and test the performance of IR flourite fibers ends next quarter.
TOWARD SIMULATING AR8210

The MSU MURI team made several important advances in the MURI objective of a numerical simulation of the activity in the active region 8210 (AR8210). In a teleconference between Canfield, Regnier and Longcope (MSU) and Fisher and Abbett (SSL/UCB) plans were laid for a preliminary simulation of the 45 minute interval beginning at 1998-05-01T19:40.

The preliminary steps identified were:
1. to complete the reduction of IVM magnetograms
2. produce a force-free equilibrium to serve as initial condition, and
3. develop a photospheric velocity field to serve as a lower boundary condition.

Almost all of these planned steps have been completed. Stephane Regnier (SR) worked on the reduction of IVM vector magnetograms for AR8210. This involved resolving the 180-ambiguity on the transverse component of the magnetic field for a time series of 80 magnetograms. SR built 15 min averaged magnetograms used for velocity field measurements. From the time series, SR derived some relevant magnetic parameters as the net flux, the total flux, the best alpha, the current helicity, etc. Finally, SR carried out a study of measurements uncertainties.

Dana Longcope and SR used two of the 15-min averaged magnetograms (19:40 and 19:56) to infer the photospheric velocity. The inferred velocity will provide the lower boundary condition of the simulation.

The MEF velocity inversion algorithm had been developed (and continues to be refined) by Longcope with collaboration of several MURI team members. Its basic formulation and its application to a simple test case was presented by Longcope at the SHINE meeting (Banff AL, Aug 18-22, 2002). The interval from AR8210 marked its first application to real data. The results of this first test are quite encouraging, showing a general flow-field consistent with the movies.

See http://solarmuri.ssl.berkeley.edu/~dana/public/images/ar8210/vel.jpg

Much of this analysis is summarized on the Web page produced by SR this quarter. This web page includes the analysis of the photospheric and coronal magnetic field of AR8210 from both line-of-sight and vector magnetic field.

http://solar.physics.montana.edu/regnier/MURI/muri_pro.html

Canfield worked with MSU physics senior Trish Jibben and American Indian Research Opportunities sophomore Kendall Harwood to produce pre-eruption movies of region AR 8210 on May 1. The data are H-alpha imaging spectra from the Mees Solar Observatory
MCCD Imaging Spectrograph, and were used to produce line-center spectroheliogram and velocity movies before and during the eruption. The movies show many velocity events, indicative of frequent reconnection episodes, but have yet to be studied in detail.

Canfield participated in the SHINE meeting in Banff. Discussions included a session on models of solar eruptions. Work on AR8210 by Moore and Sterling, which bears on the debate between the "breakout" model and the "sheared core tether cutting" model, was discussed. The Hawaii MCCD observations proved to be critical in demonstrating that the latter model could not account for the early stages of the May 1 eruption, lending support to the "breakout" interpretation for this event.

E. Priest and SR discussed the determination of topological elements from real data and the implications of electric currents on the topology of active regions. SR worked on the characterization of topological elements (null points, separatrix, spine, fans) for AR8210. Longcope made an independent determination of the topological structure of AR8210.

http://solarmuri.ssl.berkeley.edu/~dana/team/images/ar8210mdi.jpg
http://solarmuri.ssl.berkeley.edu/~dana/team/images/ar8210mdi_fp.jpg
(Both analyses are works in progress.)

OTHER MSU PROGRESS

Piet Martens (PM) worked on a paper entitled "Measurements of Flux Cancellation During Filament Formation", with Paul Wood (a grad student from St. Andrews, supervisor Eric Priest.) Paul was a 2000 REU student at MSU, and returned this summer to complete our work. The paper will be submitted to Solar Physics some time this Fall.

PM also worked on an on-line catalog of Sigmoid and Filaments. This project is carried out in collaboration with Alex Pevtsov of Sac Peak and local High School teacher Ivy Merriot, and co-funded (for the teacher's time and expenses) under the "Partners in Science Program" of the Murdock Foundation. The goal is to collect H-alpha patrol data for the times and locations of the 100 or so sigmoids observed over its lifetime by Yohkoh-SXT, digitize, catalog, and co-align these images, analyze them, and publish the data on-line.

A preliminary analysis by Alex Pevtsov has already shown that the relation between sigmoids and filaments is much more complex than one would intuitively expect. Ivy went to Sac Peak twice this Summer to collect and digitize the data, the second time she was accompanied by four high school students who made this their annual science project.

During the summer, Sam Coradetti (another REU Student), Canfield and SR worked on the magnetic evolution of active region and the relation between the dipolarization degree and the occurrence of flares. Results are shown at the following web address:
http://solar.physics.montana.edu/coradett

PUBLICATIONS:

Report From Stanford University: Sent by Yang Liu

In the period from July 2002 to September 2002, we continued to collect and analyze solar magnetic field data; we continued to produce and distribute daily synoptic charts using both WSO and MDI data; we continued to produce a variety of synoptic frames used in others' analyses and produced daily updates of synoptic charts using MDI data from longitudes other than central meridian. We also finished a work on tilt angle of bipolar regions.

We have developed an algorithm to remove ‘offset’ in SOHO/MDI magnetograms, which is now routinely used in data processing. This methodology is detailed described in our paper, which will be submitted to Solar Physics. In this paper, we also show that mean field and synoptic frame from corrected magnetograms have been significantly improved. The systematic error in MDI 5-minute magnetograms can also be corrected using this method; and therefore it can improve the synoptic charts due to correction of this error and/or decrease of noise. This demonstrates that this correction is effective and necessary. This method may also be used to remove systematic error in magnetograms induced by instruments and/or data processing, so that to calibrate data taken by different instruments.

In a paper submitted to Solar Physics (Tian, Liu, and Wang, 2002), we analyzed 517 bipolar active regions, which have well-defined bipolar magnetic configurations, in order to study tilt angle of the active regions in dependence with latitude and magnetic flux. From those samples, we found that tilt angle is a function of the latitude and magnetic flux, which supports the scaling law model (Fan, et al. 1994), the magnetic polarity separation is correlated to the magnetic flux, in agreement of results of Wang and Sheeley (1989), and magnetic flux is in balance in most regions.

In the coming months, we plan to test reliability and effectiveness of our module that corrects the effect of east-west inclination of large-scale photospheric magnetic fields in order to get the "real" radial component has been developed; and to develop algorithms to fill in polar field in magnetic synoptic charts.

PUBLICATIONS:

During this report period, we began to demonstrate use of the UCSD time-dependent tomography on our Web site and these analyses have begun working in a regular way to map CMEs in real time using interplanetary scintillation data. Although we still do not know the extent to which each CME observed in LASCO coronagraph observations is observed in our analyses, we note that at least many of the major CMEs are observed, and their 3D shapes can be measured. These have been used to map, for instance, the approximate three-dimensional locations and to determine the approximate Earth-arrival of halo CME’s observed initially by the Solar and Heliospheric Observatory (SOHO) coronagraphs. These analyses are presented on our Web page found from http://casswww.ucsd.edu/solar/. Many CMEs (including halo CMEs) have been observed in the data in real time since this site began operation. Figure 1 is an example of the LASCO data and a remote-observer view of the IPS disturbance associated with a halo CME observed on our Web site prior to its Earth-passage. The CME erupted from the Sun on July 26, 2002, and its disturbance was observed to pass primarily south of Earth from July 29 – August 1, 2002. Following passage of the major portion of this disturbance, a geomagnetic storm occurred at Earth (on August 1-2, 2002). More information about this event and a video of it can be found at UCSD Web site: http://casswww.ucsd.edu/solar/news.html

The numbers of images including those used by the animated gif movies shown on our Web site have become enormous, and we have had to upgrade our Web server (from funds other than those of this MURI contract) to accommodate this larger number of data products.

In addition to graduate students Tamsen Dunn and Susan Rappoport, two additional students hired during the summer months have made progress is several different areas of research and data visualization. An undergraduate student (Austin Duncan) is jointly
hired by UCSD and SAIC’s Mickic, Linker and Riley to work on projects of mutual interest and eventually, the interface between the UCSD tomography program and the SAIC 3D-MHD programs. During the summer, in addition to helping with upgrades of our server system, he began revising some of the bash scripts that may eventually be used on our Web page, and he made some of the UCSD visualization programs available to the SAIC group. Another of our students, graduate student Cindy Wang (who worked as an undergraduate student this summer in our group) has helped graduate student Tamsen Dunn in the real-time access and analysis of magnetic field data and its presentation. Cindy became a graduate student in the UCSD Computer Science and Engineering Department this September, and we have hired her using MURI funds in this capacity to help visualize our 3-D heliospheric plasma analyses, and to access and help analyze SMEI data. The SMEI launch has been advanced in time, and we now expect a launch from Vandenburg during the next MURI report period on December 15 this year!

Presentations (Jackson et al., 2002 (invited); Dunn et al., 2002) at the SPIE meeting in Hawaii in August were successful. An invited presentation at the URSI meeting in The Netherlands (Hick et al., 2002) was also successful. All three of these presentations are associated with conference proceeding papers. Following these presentations T. Dunn proceeded on to Japan (funded by an NSF international travel grant to UCSD) to collaborate with our colleagues at STELab. At STELab in coordination with XuePu Zhao, Tamsen presented her results at a STELab colloquium and installed the Zhao-Hoeksema CSSS magnetic model (Zhao and Hoeksema, 1995) on STELab computers. In addition, Tamsen provided the STELab group access and the where-with-all to use NOAA magnetic field maps provided in real time by N. Arge of NOAA, Boulder, Colorado.

References:


Report from UNH: Sent by Terry Forbes

CME Initiation Mechanisms

Figure 4. Magnetic field sources for the flux rope model of Lin et al. (2002). The sources consists of a circular, force-free flux rope with its two ends anchored in the photosphere and a current sheet disk below. The flux rope is prevented from erupting outwards by an overlying magnetic arcade (not shown) which is produced by two spot-like magnetic source regions of opposite polarity lying on the photosphere.
During the 3rd quarter the group at UNH has completed detailed analyses of two promising models in collaboration with Jun Lin and Aad van Ballegooijen at the Harvard-Smithsonian Center for Astrophysics (CfA), and Joachim Birn at the Los Alamos National (LANL). The collaborations with CfA and LANL are both centered on models which contain a magnetic flux rope in the corona prior to the onset of the CME. The CfA work uses a model derived from the three-dimensional model of Titov and Démoulin (1999) which is based on the earlier two-dimensional models of Forbes and Priest (1995) and van Ballegooijen and Martens (1989). Figure 1 shows the latest configuration developed by Lin et al. (2002). It contains, not only a flux rope, but also a current sheet, underneath it. The configuration has no equilibrium when the photospheric field decays below a critical value. The model is highly idealized because the flux rope is assumed to be very thin, and it requires the photosphere to evolve in such a way as to maintain the circular shape of the flux rope. Nevertheless, despite these highly idealized aspects, the model demonstrates that it is possible, at least in principle, for a flux-rope which has its ends anchored (i.e. line-tied) in the photosphere to undergo a loss of equilibrium. A question which has been of considerable debate in the past (see Antiochos et al. 1999, or Forbes 2000).

In collaboration with Joachim Birn at LANL, we have developed a general technique for finding magnetohydrostatic equilibria containing both a current sheet and a flux rope. The technique allows both the inclusion of gravitational and pressure forces, but it assumes that variation of the magnetic field in the direction perpendicular to gravity is stronger than in the other two directions. Two examples of configurations obtained using this technique are shown in Figure 2. Either example could serve as an initial state for a CME simulation, but the equilibrium properties of the configurations has not yet been sufficiently explored to make detailed predictions about the photospheric evolution required to trigger an eruption.
Some proposed CME models (for example, the one shown in Figure 1) assume that current sheets can exist in lower the corona prior to the eruption of the field, but other models assume the exact opposite (e.g. Lin et al. 2001). Whether such sheets can exist or not depends on the relative rates of formation and decay. The slow evolution of the photospheric magnetic field tends to form sheets at locations in the corona such as null points and their associated separatrices, but magnetic reconnection tends to dissipate the sheets. Thus, extensive current sheets will form if the time scale for reconnection is long compared to the time scale for the evolution of the photosphere.

To estimate the reconnection rate prior to CME onset, UNH has begun a collaboration with Piet Martens at Montana State University (MSU). The study has two goals. One is to reconsider the effect of current sheet formation on the CME model published by Forbes and Isenberg (1991), and the other is to X-ray observations (from Yohkoh and TRACE) of pre-eruptive configurations that appear to evolve by a process of slow reconnection. The Forbes and Isenberg model (1991) contains a current sheet prior to onset, and it does not produce an eruption at all unless the radius of the flux rope is unreasonably small ($< 1$ km). However, there is now good reason to think that the failure of this model is entirely due to the presence of the current sheet in the pre-eruptive configuration, and that if this sheet is absent, then the model will produce an eruption for reasonable parameter values.

**Figure 5:** Perspective views of the flux rope configurations of Birn et al. (2002). The top panel shows the shear-free configuration ($B_\phi$, the field component running parallel to the flux rope, $= 0$) while the bottom panel shows the force free configuration ($j$, the current density, $= 0$). The red curve lying in the horizontal plane of the bottom panel is the polarity inversion line, where the normal component of the photospheric field is zero.
In collaboration with UNH, Ilia Roussev of Michigan State University has carried out a series of simulation runs in Cartesian coordinates which are based on the 3D flux rope configuration of Titov and Démoulin (1999). Figure 3 shows the most promising result to date. Starting with flux rope parameters that are predicted to be unstable by Titov and Démoulin, the simulations show what appears to be the rapid development of a kink instability which initially causes an upward motion of the flux rope.

**References**


![Figure 6](Image)

**Figure 6.** Evolution of the magnetic field in a fully three-dimensional numerical simulation based on a modified version of the pre-eruptive configuration proposed by Titov and Démoulin (1999). The lines are determined from only the $B_x$ and $B_z$ vector field components at the midplane, $y = 0$, perpendicular to the axis of the flux rope (i.e., they correspond to the intersection of magnetic flux surfaces with the midplane). The color scale shows the vertical component of the velocity, with zero being cyan. The configuration is shown after the eruption is well developed when supermagnetosonic reconnection jets have formed in both the upward and downward directions (I. Roussev, private communication 2002).


