- Identifying from existing marine vocabularies recommended discovery terms (keywords or categories used to tag data sets so they can be found) and markup terms (which identify specific variables in a data set);
- Developing mappings of terms among the recommended vocabularies;
- Developing mappings of terms from other vocabularies to those in recommended vocabularies; and
- Demonstrating the value and utility of the above via a Web service application.

Long-term science goals that will be carried into subsequent efforts include being able to find science data without knowing the precise vocabulary used to label it, merging science data from different data sources, creating reference vocabularies that can be used for new data sets, and ultimately allowing more sophisticated and automated discovery and analyses.

To achieve these goals, the workshop organizers sought to connect data management professionals and ontologists with scientific domain experts in the shared pursuit of a common challenge. If the two sets of experts could unite on specific approaches, these and larger technical and scientific challenges might be addressed. Introductory sessions defined and demonstrated the value of vocabularies and their associated mappings (in finding terms, finding data, and using data) and provided final training in vocabulary and ontology concepts, the procedures of vocabulary mapping, and new applications and Web services that use the mappings. For this exercise, the most common mappings labeled each term as 'same as', 'broader than', or 'narrower than' another term. The properties of these relationships allowed them to be used to infer other mappings automatically. Such automated 'reasoning' illustrates in a simple way the strength of ontologies and associated semantic web concepts.

Workshop leaders sought a balance between providing technical detail and demonstrating progress. The detail was critical to achieving real technical results, but the goal of technical progress kept the meeting from getting hopelessly bogged down in details. Achieving this balance was particularly difficult because the different participant groups had different experiences and skills.

Participants in each of the six domain areas were charged with identifying the common metadata terms used in their domains in the context of existing vocabularies, which the team members primarily identified in advance of the workshop.

Each vocabulary was harmonized with the others prior to the workshop by translating them into the common Ontology Web Language (OWL) for subsequent mapping to other vocabularies. This translation was accomplished using a newly developed tool, Voc2Owl, which converts simple vocabularies (in ASCII format) to OWL. Relationships were then mapped between these OWL-formatted vocabularies using another new tool called Vocabulary Integration Environment (VINE). Both tools were developed for the workshop by Luis Bermudez, of MMI and the Monterey Bay Aquarium Research Institute, and are available from the MMI Web site.

Once the mappings were accomplished, they were then used for data discovery across several existing data systems on the Web already employing these vocabularies.

The success of the workshop can be measured by its productive outcomes, beginning with the 50 vocabularies harmonized to OWL that provided the input to the domain mappings. Over 800 mappings of terms in these harmonized vocabularies were generated directly by the participants, primarily in the domains of chlorophyll, CTD, and currents and waves. This resulted in 2200 automatically generated, or inferred, mappings as described above, for a total of over 3000 mappings. This was a significant accomplishment for a diverse group of participants new to the process and the tools.

As a result of the mappings, the participants were able to experiment with some live Web services, where they could use more specific terms to search more effectively through repositories (e.g., the broad GCMD keyword 'pigments' automatically related to specific pigments such as chlorophyll-*a*, chlorophyll-*b*, and beta-carotene). In addition, based on workshop feedback, the two essential software tools Voc2Owl and VINE have been updated and repackaged.

Although much work remains to be done to effectively find, access, and use scientific data, the results from this workshop are important for improved data discovery and the cost-effective use and interpretation of the discovered data. The environmental science community is still faced with a formidable array of disparate databases and portals across the Internet, as well as the complex infrastructure of ocean observing system repositories. However, the Advancing Domain Vocabularies workshop provided a firm foundation for future related activities, such as follow-on workshops and other activities that will connect the results of this workshop, such as the sensors ontology, to other community efforts.

The workshop, Advancing Domain Vocabularies, was held 9–11 August 2005 at the University Center for Atmospheric Research in Boulder, Colo. All workshop materials, proceedings, reports, activities planning, and the two software tools are available online at http://marinemetadata.org/workshop05/.

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Workshop Highlights Progress in Solar-Heliospheric Physics

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The Solar, Heliospheric, and Interplanetary Environment (SHINE) group is an affiliation of researchers dedicated to promoting an enhanced understanding of the processes by which magnetic fields, plasmas, and energetic particles are produced near the Sun and propagated through the interplanetary medium to Earth and other locations in the heliosphere. The group conducted its annual workshop in July to discuss recent developments in the study of solar variability and its impact on Earth's space environment. One hundred fifty-five scientists, including 27 students, participated in the plenary, working group, and poster sessions.

Student Day activities on 10 July consisted of tutorials given by experienced scientists: solar flares and particle acceleration (Robert Lin, University of California Berkeley), the origin of coronal mass ejections (CMEs) (Spiro Antiochos, Naval Research Laboratory, Washington, D.C.), connecting the Sun and heliosphere (Thomas Zurbuchen, University of Michigan, Ann Arbor), and acceleration and transport of solar energetic particles (SEPs) (Christina Cohen, California Institute of Technology, Pasadena). The tutorials were followed by student presentations on CMEs near the sun and in the interplanetary medium, solar wind, and SEPs.

In presentations designed to serve as an overview of issues that would be discussed later in the working group sessions, the plenary speakers addressed topics of interest to the entire SHINE community: the subsurface magnetic field structure and evolution (George Fisher, UC Berkeley), shocks and particle acceleration (Martin Lee, University of New Hampshire, Durham), particle acceleration near the Sun (Lin), and end-to-end modeling of CMEs and SEPs (Tamas Gombosi, University of Michigan, Ann Arbor). Funding agency representatives [Paul Bellaire, U.S. National Science Foundation (NSF); Madhulika Guhathakurta, NASA; David Byers, Air Force Office of Scientific Research] also made informative plenary talks.

Shine Campaign Events

Each year, the SHINE group focuses its attention on certain well-observed solar eruptive events, called 'campaign events,' that have significant heliospheric consequences. One session covered campaign events (12 May 1997, 1 May 1998, 21 April 2002, 24 August 2002) that were considered in the 2004 workshop. Information on the background corona and the CMEs propagating through it that was obtained from these events proved to be critical inputs to CME models (Richard Frazin, University of Illinois, Urbana-Champaign, and Dusan Odstrcil, University of Colorado, Boulder).

The second campaign event session covered the 'Halloween events' of October and November 2003, which had a serious impact on geospace and the heliosphere [see *Gopalswamy et al.* [2005] for a list of 70 papers published on these events in a three-journal special section (*Journal of Geophysical Research, Geophysical Research Letters,* and *Space Weather*)]. The Halloween events produced two interplanetary shocks that traveled the Sun-Earth distance in less than 20 hours (Nat Gopalswamy, NASA Goddard Space Flight Center, Greenbelt, Md.) and resulted in solar wind speeds close to 2000 kilometers per second (Zurbuchen). The shocks also accelerated SEPs to extreme levels (Richard Mewaldt, California Institute of Technology, Pasadena). The observational inputs, which included parameters such as CME speed, solar wind speed, flare intensity, and SEP intensity, were helpful in establishing standards for the CME models (Ilia Roussev, University of Michigan, Ann Arbor; Jonathan Krall, Naval Research Laboratory, Washington, D.C., and Bernard Jackson, University of California at San Diego, La Jolla).

Working Group Sessions

The Solar working group met in two sessions, the first of which concentrated on the evolution of subsurface magnetic fields. This topic is of special interest to the SHINE group because all the eruptive events have their origin in solar magnetic fields. Current theories, computational models, and helioseismic observations of subsurface magnetic fields and flows were summarized by various presenters (Yu-Hong Fan, High Altitude Observatory, Boulder, Colo.; Ward Manchester, University of Michigan, Ann Arbor; Douglas Braun, Northwest Research Associates, Boulder; Adriaan von Ballegooijen, Harvard-Smithsonian Center for Astrophysics, Cambridge, Mass.). One of the interesting findings reported was the detection of enhanced subsurface flow signatures before the occurrence of a major flare, suggesting that the time-distance helioseismology may reveal energy buildup well before the flare occurrence (Jun-Wei Zhao and Alexander Kosovichev, Stanford University, Calif.).

The second session of the Solar working group was devoted to numerical models of CMEs. The key issues to be addressed by all the CME models are how the energy is stored in solar magnetic structures and how this energy is explosively released in CMEs and flares. Dana Longcope (Montana State University, Bozeman) presented a quantitative model to estimate the free energy storage by tracking the changes in the magnetic field at the photospheric level, and the release of stored energy by a local reconnection process (merging of magnetic field lines directed oppositely).

The Interplanetary working group had a single session, on the relative importance of the background solar wind and CMEs in deciding the heliospheric conditions. Ian Richardson (University of Maryland, College Park) concluded that interplanetary CMEs (ICMEs) may not contribute to the longer-term solar cycle variations in the average values of interplanetary magnetic field, geomagnetic activity level, and cosmic ray intensity. One of the interesting issues addressed in this session was the level of magnetic flux in the heliosphere. Mathew Owens and Nancy Crooker (Boston University) addressed the connection between heliospheric magnetic flux and ICMEs, and they suggested that the models using a circular cross section for the ICME flux rope may be underestimating the magnetic flux content compared with the models using an elliptical cross section. In order to maintain the nominal level of heliospheric magnetic flux, reconnection seems to be required on a timescale shorter than a day (Susan Lepri, University of Michigan, Ann Arbor).

The Energetic Particles working group had three sessions. The first session was on sources of suprathermal ions in the Sun-Earth connected space. These ions, ~2–10 times faster than the solar wind, form the seed population for CME-driven shocks. There seems to be definite evidence that CME-driven shocks near 1 AU accelerate ions out of a solar wind suprathermal tail (George Ho, Johns Hopkins University/Applied Physics Laboratory, Laurel, Md.). Other possible seed particles are pickup ions beyond Earth orbit (Matthew Hill, University of Maryland, College Park) and the superthermal tail due to statistical acceleration/transit-time damping (Nathan Schwadron, Southwest Research Institute, and Len Fisk, University of Michigan, Ann Arbor).

The second session, mechanisms of particle acceleration near the Sun, focused on the physics of SEP acceleration in solar flares and CMEs. CME-driven shocks can accelerate electrons and ions from the solar wind. Particles can also be accelerated at the flare site where magnetic reconnection takes place. Diffusive shock acceleration is the only mechanism that predicts a universal power law spectrum (all energetic particle populations observed in the heliosphere show a monotonic decrease in intensity with increasing energy on a logarithmic scale). This is consistent with a wide variety of energetic particle populations observed in space (Randy Jokipii, University of Arizona, Tucson). A new time-dependent shock-acceleration model (Chee Ng, University of Maryland, College Park) showed that the results are strongly dependent on the injection rate, which is the rate at which particles enter the shock before getting accelerated. An extension of the stochastic acceleration model (thought to be applicable to particle acceleration at the flare site) to ultraheavy ions seems to have limited success (Vahe Petrosian, Stanford University).

The working group's third session was on the effect of the Sun in the outer heliosphere. On the basis of Voyager spacecraft observations taken since 1977, it has become clear that the interstellar medium slows the solar wind and heats it (John Richardson, Massachusetts Institute of Technology, Cambridge). Voyager 1's December 2004 crossing of the heliospheric termination shock marks the direct sampling of astrophysical plasmas. Solar events such as the 2003 Halloween CMEs can reach the termination shock in ~6 months and change its location; they can significantly alter the plasma inside the termination shock (Devrie Intriligator, Carmel Research Center, Santa Monica, Calif.).

Joint sessions

The Interplanetary and SEP working groups had joint sessions focusing on modeling and observation of interplanetary shocks. Most of these shocks are driven by CMEs and are detected in situ by spacecraft such as NASA's Wind (launched in 1994 to measure plasma, magnetic, and energetic-particle properties in the near-Earth solar wind) and the Advanced Composition Explorer (ACE, launched in 1997 to a location 1.5 million kilometers from Earth to provide near-real-time solar wind information). Shocks seen by both Wind and ACE were found to have very similar orientations, Mach numbers, and speeds (Justin Kasper, Massachusetts Institute of Technology).

The reliability of the shock computations is strongly dependent on the strength and type of the interplanetary shock (Adam Szabo, NASA Goddard Space Flight Center). Only forward shocks are typically observed at 1 AU, but reverse shocks are also observed occasionally. Magneto-hydrodynamic (MHD) simulations of CME evolution in the heliosphere indicate that the reverse shock is formed from the interaction between slow and fast solar wind streams deflected by the CME flux rope (Manchester).

The Solar and Interplanetary working groups held a joint session on the origin and evolution of the solar wind. Although solar wind accelerates in the corona and reaches its full speed at tens of solar radii from the Sun, signatures of the chromospheric plasma and its structure can be found linked to the speed and composition of the solar wind measured close to Earth (Scott McIntosh, Southwest Research Institute, Boulder, Colo.).

The Sun's 'open' magnetic field (as opposed to the closed loops) couples the Sun to the heliosphere. Every field line in the heliosphere is rooted on the Sun. Although the details of this coupling depend on the quantitative properties of the magnetic field, the Sun-heliosphere connection can be understood by considering only the topology of the solar open field regions (coronal holes). Two leading ideas on the Sun-heliosphere connection are represented by the interchange reconnection and quasi steady models. The interchange reconnection model requires a complex mixture of open and closed magnetic field lines (Fisk). The steady-state models, on the other hand, involve smooth topologies. It was argued that only the steady-state models are supported by solar observations such as the geometry of coronal holes (Antiochos).

A joint session of the Solar and Energetic Particle working groups was held on the connection between CME-associated radio emissions and particle acceleration. Nonthermal radio emission is a signature of electron acceleration, which may have implications for ion acceleration.

In a session on end-to-end modeling of CMEs and SEPs, which involved all three working groups, discussion focused on how SEPs are accelerated at CME-driven shocks and transported in the interplanetary space, and what needs to be done to improve present models (Janet Luhmann, University of California, Berkeley, and Peter MacNeice, Drexel University, Philadelphia).

One of the issues related to the acceleration of SEPs by CME-driven shocks is the existence of preceding CMEs upstream of the shock. These preceding CMEs and their aftermath can greatly enhance (by a factor of ~10) the turbulence levels upstream of a SEP-producing shock. The enhanced turbulence results in increased maximum SEP energy and higher intensities compared with the case of no preceding CMEs (Gang Li and Gary Zank, University of California, Riverside).

When shocks arrive at the spacecraft, the onboard instruments can directly detect the particles accelerated at the shock and simultaneously measure the shock parameters. These particle events are known as energetic storm particle (ESP) events. The energy spectra of carbon, oxygen, and iron ions in three ESP events measured by ACE were fit nicely by the finite-time shock acceleration model, when the measured shock parameters were used as input (David Ruffolo, Mahidol University, Bangkok, Thailand).

Discussion on Shine Liaison

In the closing session, David Webb (Boston College) led a discussion on the interaction of the SHINE group with the International Heliophysical Year (IHY) and activities of the Geospace Environment Modeling (GEM) program. GEM's new campaign on global interactions would provide an avenue for joint a study of storm intervals with SHINE.

The IHY 2007 program (http://www.ihy2007.org) presents an excellent opportunity for coordinated activities among the SHINE, GEM, and Coupled Energetics and Dynamics of Atmospheric Regions (CEDAR) communities. One of the IHY program's major activities is the U.N. Basic Space Sciences (UNBSS) initiative to deploy small instruments throughout the world to fill gaps in existing networks of interest to the SHINE, GEM, and CEDAR communities. Networks of radio telescopes, neutron monitors, magnetometers, muon telescopes, and global positioning system receivers for ionospheric measurements are being considered for deployment.

One example is the network for measuring the equatorial ionospheric irregularities, which is virtually unavailable in the African region. An IHY/UNBSS effort is under way to set up several Scintillation Network Decision stations within 20 degrees of the geomagnetic equator [*Groves et al.,* 1997] in Africa that will provide measurements on the ionosphere.

SHINE conducted its annual workshop during 11–15 July 2005 in Kona, Hawaii. For further information, visit the Web site http://www.shinegroup.org, where workshop presentations and detailed summaries are available.

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