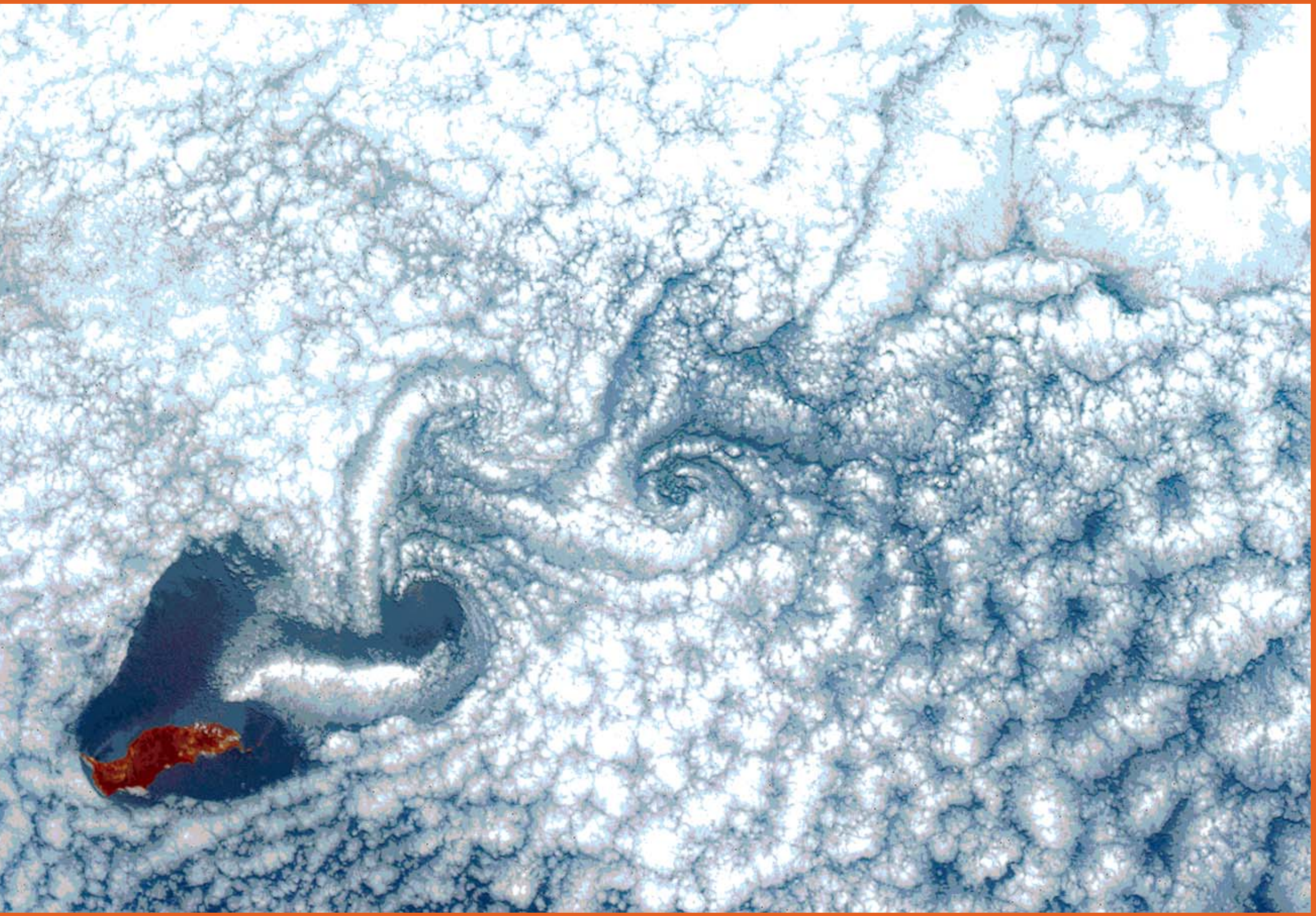
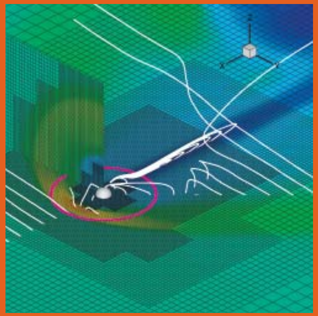
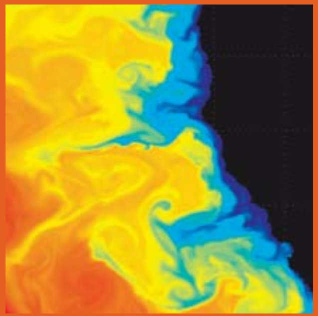
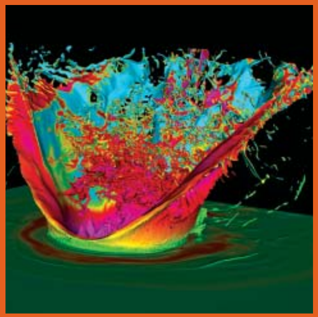
ESTABLISHING A PETASCALE COLLABORATORY FOR THE GEOSCIENCES









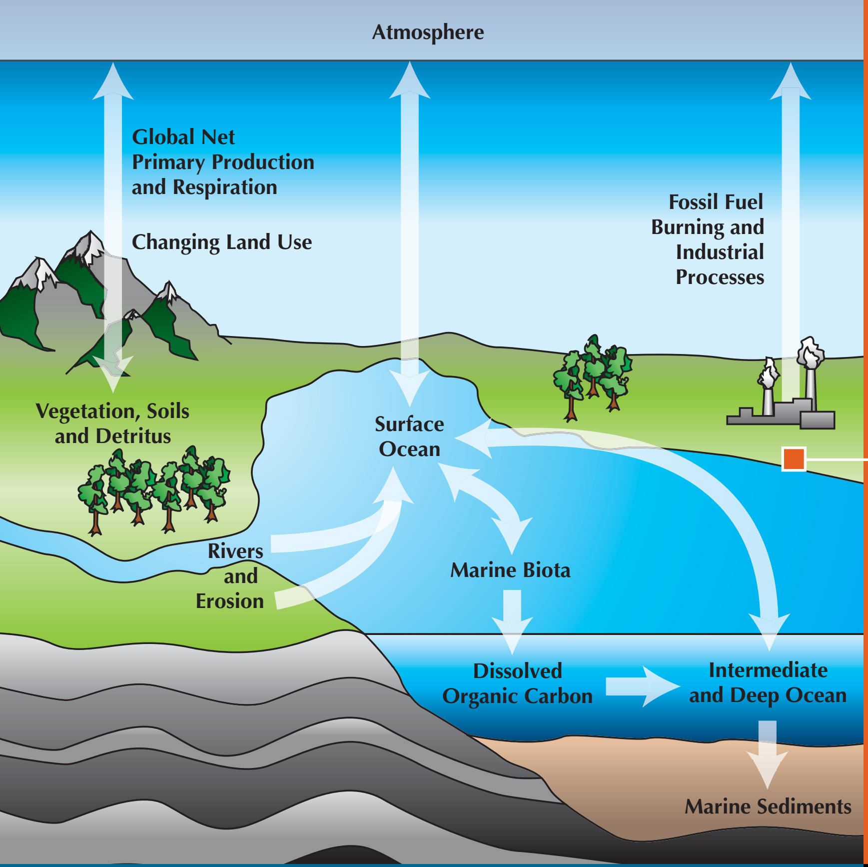
Summary of a Report to the Geosciences Community

WHAT IS A PETASCALE COMPUTER?

The PCG will provide leading edge, high-capability computational resources to address the most demanding problems facing the geosciences. By the end of this decade, these leadership-class systems will attain peak speeds in excess of one petaflop (10^{15} floating-point operations per second) and have memory capacities in excess of one petabyte (10^{15} bytes of information).

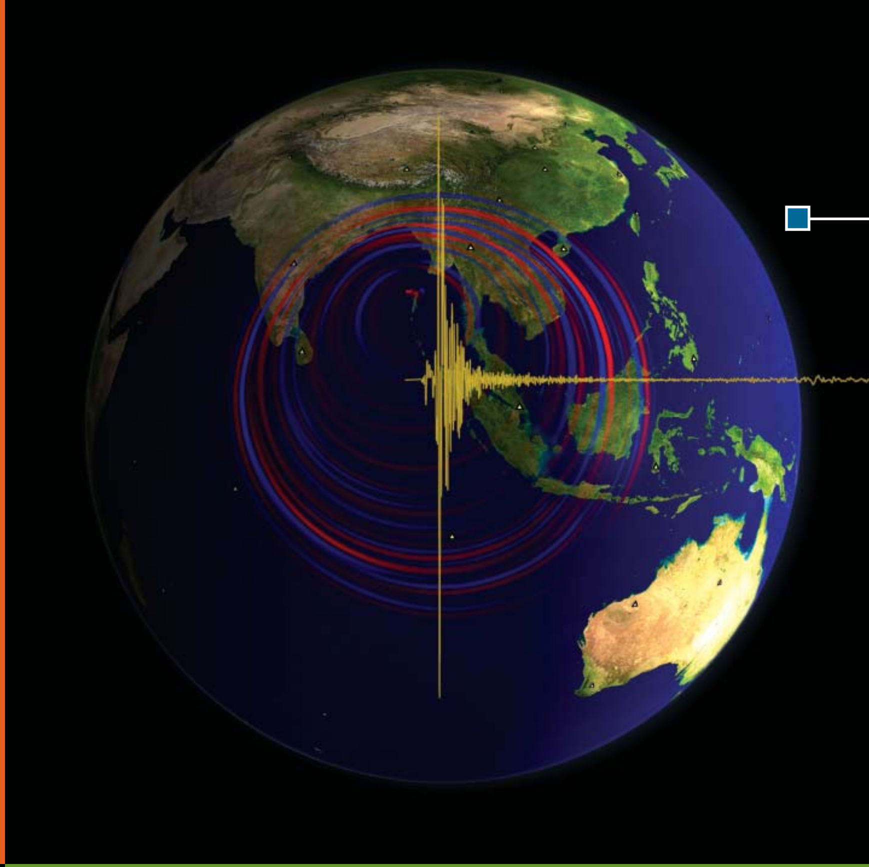
WHAT IS A COLLABORATORY?

A collaboratory refers to a community-specific computational environment for research and education that provides high-performance computing services, data and information services, knowledge management services, human interface and visualization services, and collaboration services, all of which are essential to facilitating high scientific productivity.



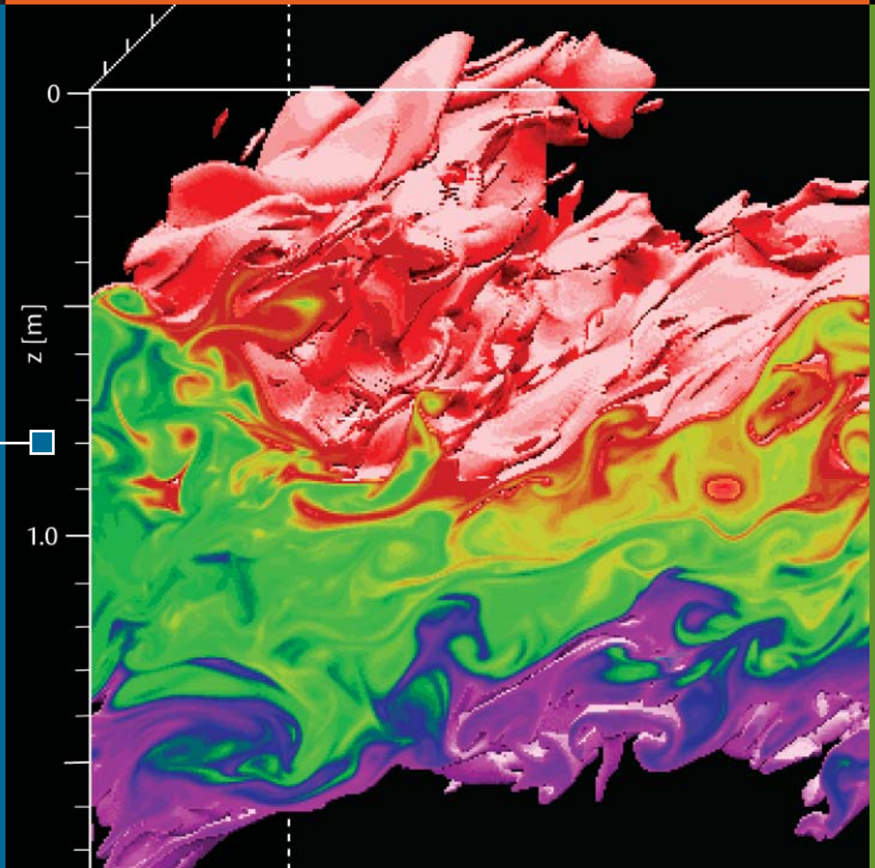
GLOBAL BIOGEOCHEMICAL CYCLES

Understanding the feedbacks among the physical, chemical, and biological components of the Earth system is essential to interpreting past climate variability and to developing a predictive capability for climate evolution. The PCG will facilitate expansion of Earth system models to allow investigations of the coupling and feedbacks between climate and important system elements such as the global nitrogen cycle, mineral dust and other aerosols, tropospheric and stratospheric chemistry, dynamic ecosystems, and surface and subsurface hydrology.



OCEAN TURBULENCE

Turbulent mixing in seawater plays a major role in the global cycling of energy, water, CO_2, and other chemicals. Present-day computing facilities provide valuable insight into mixing physics via extraordinarily detailed simulations of turbulence down to centimeter scales. Until now, however, slowly diffusing variables such as salinity, which are critical to realistic modeling of mixing in the oceans, have been left out of mixing simulations because of the lack of computational power. The PCG will enable exploration of the physics of more complex, but more realistic, turbulent flow regimes.

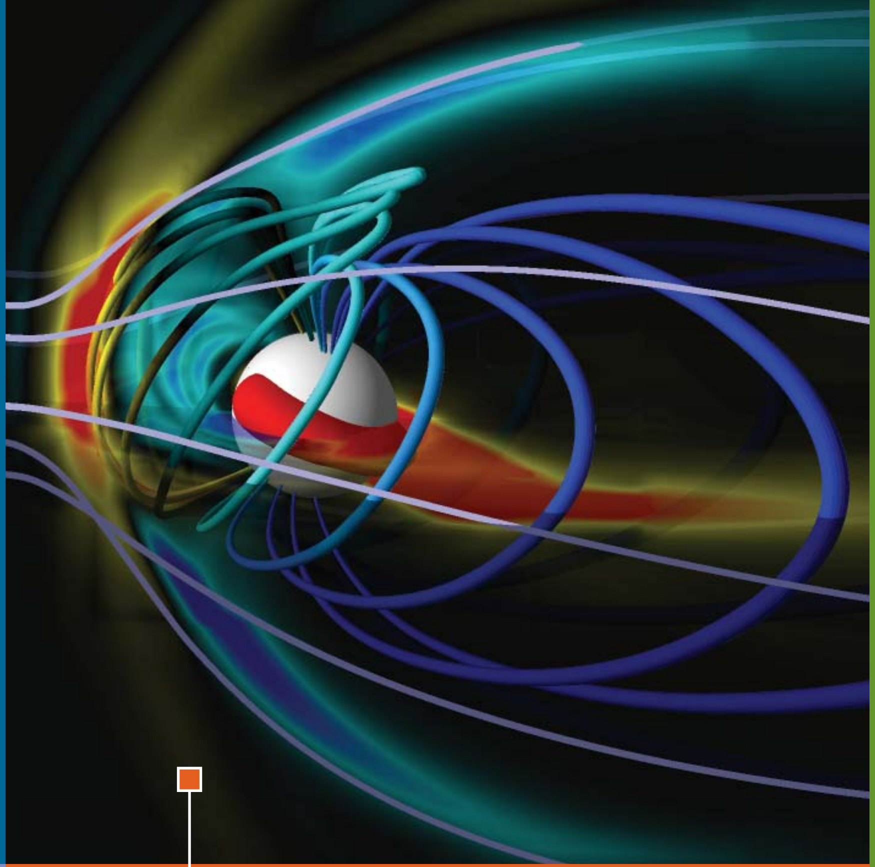


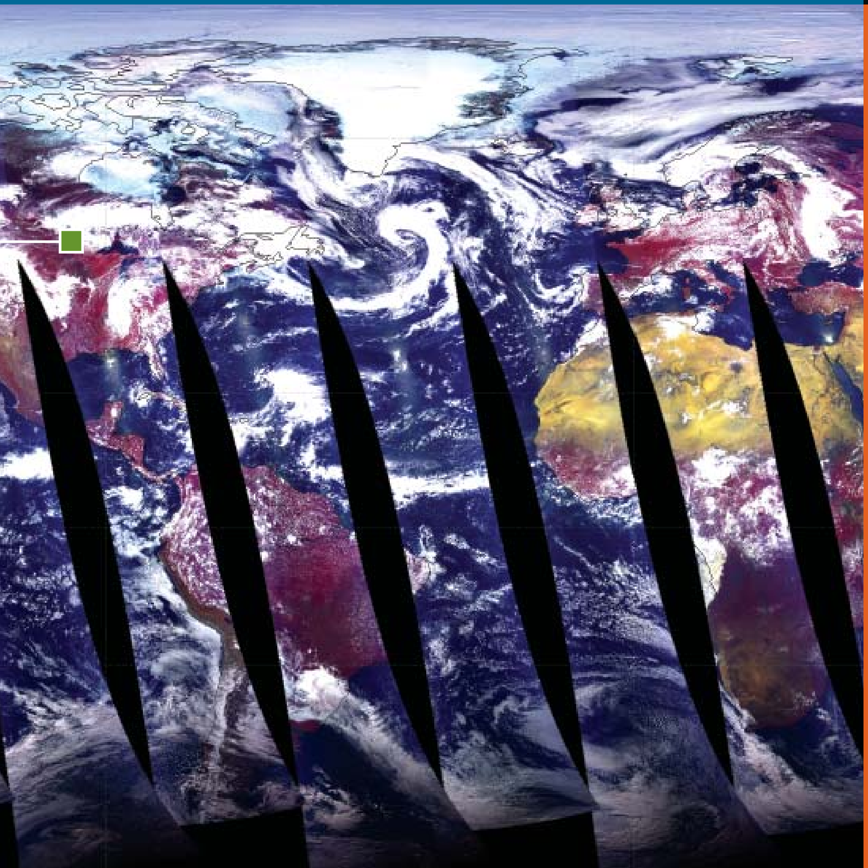
DATA ASSIMILATION

The diversity and volume of Earth system observations are exploding with the advent of newer, more accurate, and more sophisticated sensor systems and observing platforms. The PCG will enable synthesis of the next generation of observing-system data with the next generation of weather, climate, biogeochemical, space physics, and geophysical models, which is essential for realizing the full value of the measurements and for developing a new understanding of the fundamental workings of the Earth system. The PCG will also facilitate the merging of new observations with the historical record and will assist in the design and development of future observing systems.

GLOBAL SEISMOLOGY

Processes operating deep within the Earth drive hazardous events such as earthquakes and volcanic eruptions, but also more subtle, background phenomena such as the Earth's magnetic field. Propagation of seismic waves generated by large earthquakes, such as the one that occurred near Sumatra in December 2004, are one of the only ways to probe the structure and dynamics of deep Earth processes. The PCG will allow scientists to simulate and analyze waves from these large events down to the shortest observable periods, providing insight into structures and regions within the Earth that are inaccessible with current capabilities.





SPACE WEATHER FORECASTS

Powerful solar eruptions can damage satellites, divert airplane routes, threaten space flight, cause power failures, and disrupt long-distance radio communications. Accurate and timely forecasts of space weather are essential to protecting human life and commercial assets. The PCG will allow the development of the next generation of faster and more accurate space weather models that couple new classes of physical processes, data assimilation, and adaptive resolution.

OUTCOMES

SCIENTIFIC DISCOVERY. Recent progress in atmospheric, ocean, solid Earth, and space sciences, and the rapid expansion in our ability to observe our planet, present exciting new opportunities to advance understanding of the Earth as a coupled system. Computational simulation is a cornerstone of geoscience research; access to high-performance computers is key to unlocking Earth's secrets. The PCG will facilitate transformative research in which computational simulations are not only tested by existing observations, but also provide the first glimpses of previously unobserved phenomena and quantitative characterization of complex processes.

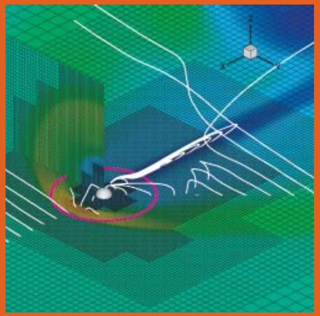
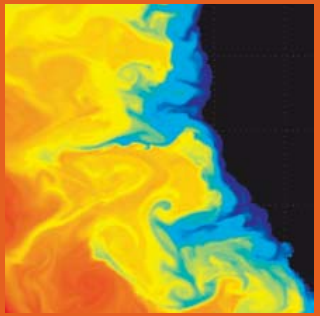
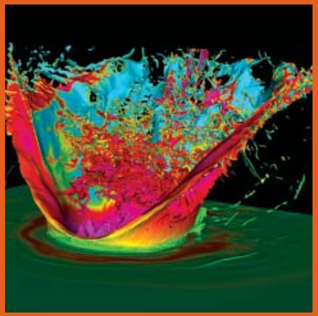
PROGRAMMATIC COORDINATION. The PCG will strengthen existing ties and build new relationships among the geoscience disciplines. It will facilitate the sharing of advances in computational methods, accelerating progress in the development of a comprehensive understanding of the Earth system. Geoscience, among all branches of science, represents a unique balance between the breadth of disciplinary research and commonality of purpose as an interdisciplinary endeavor.

SOCIETAL BENEFITS. Rational planning depends on a comprehensive and predictive understanding of weather, the geospace environment, availability of water or other natural resources, and exposure to natural hazards. New knowledge of Earth system processes acquired using the PCG can be rapidly transferred into operational practice to provide more accurate tools to decision-makers. The benefits conferred by this research will reach every individual and institution in our nation.

ADDITIONAL INFORMATION
For additional information, see Ad Hoc Committee and Technical Working Group for a Petascale Collaboratory for the Geosciences. 2005. *Establishing a Petascale Collaboratory for the Geosciences: Scientific Frontiers.* A Report to the Geosciences Community. UCAR/JOSS. 80 pp.

A PETASCALE COLLABORATORY FOR THE GEOSCIENCES

A Petascale Collaboratory for the Geosciences (PCG) will enable scientists to conduct transformative research on the fundamental processes that determine the structure, dynamics, and metabolism of the Earth system. More powerful models enabled by increased computational resources will allow exploration of new phenomena and will reduce the uncertainty in predictions of variability of the Earth system and its responses to human activity. Using new computational techniques made possible by the PCG, scientists will be able to combine these models with the diverse and ever growing set of measurements delivered by modern observing systems to allow more comprehensive and accurate monitoring of the Earth system.

COVER IMAGES: *Cloud image on front cover.* MISR image from June 11, 2000 (Terra orbit 2569) demonstrates a turbulent atmospheric flow pattern (NASA/GSFC/JPL and the MISR Team). *Above Left.* Three-dimensional view of coronal mass ejection pressure front hitting the magnetosphere (University of Michigan). *Above Middle.* A simulated instantaneous sea-surface temperature field (J. McWilliams, UCLA). *Above Right*. Perspective rendering of 42 seconds after a 10-km diameter granite asteroid strikes the Earth (Gisler et al. 2003. *Science of Tsunami Hazards* 21(2):119-134).

INSIDE IMAGES: *Global Biogeochemical Cycles.* Redrawn after *A U.S. Carbon Cycle Science Plan. A Report of the Carbon and Climate Working Group.* J.L. Sarmiento and S.C. Wofsy, Co-chairs. 1999. http://www.carboncyclescience.gov/planning.html. *Ocean Turbulence*. Temperature field from a direct numerical simulation of turbulence in thermally stratified water. W. Smyth, Oregon State University. *Global Seismology*. Spectral-element simulation of surface ground velocities (red up, blue down) 15.8 minutes after rupture initiation of the great 2004 Sumatra-Andaman earthquake. Reprinted with permission, S. Lombeyda, V. Hjorleifsdottir, J. Tromp, R. Aster. 2005. *Science* 308(5725), cover image. Copyright 2005 AAAS. *Data Assimilation*. AIRS/Aqua RGB-Visible Global Browse image, GES DISC/DAAC, http://daac.gsfc.nasa.gov. *Space Weather Forecasts*. Simulation of the magnetospheric configuration on October 29, 2003 following a large solar eruption. D. De Zeeuw, University of Michigan.

This publication is funded by a subcontract with the University Corporation for Atmospheric Research (UCAR) under the sponsorship of the National Science Foundation. The views herein are those of the authors and not necessarily reflect the views of NSF or UCAR.

Editing and design by Geosciences Professional Services, Inc.

June 2005