Nonlinear Geophysics

NG11A MCC: Level 1 Monday 0830h

Visualization, Analysis, and Distributed Computing in Nonlinear Geosciences I Posters *(joint with OS, V, AE, DI)*

Presiding: **G Erlebacher,** Florida State University; **D A Yuen,** University of Minnesota

NG11A-0161 0830h POSTER

Amira: Multi-Dimensional Scientific Visualization for the GeoSciences in the 21st Century

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amira (www.amiravis.com) is a general purpose framework for 3D scientific visualization that meets the needs of the non-programmer, the script writer, and the advanced programmer alike. Provided modules may be visually assembled in an interactive manner to create complex visual displays. These modules and their associated user interfaces are controlled either through a mouse, or via an interactive scripting mechanism based on Tcl. We provide interactive demonstrations of the various features of Amira and explain how these may be used to enhance the comprehension of datasets in use in the Earth Sciences community. Its features will be illustrated on scalar and vector fields on grid types ranging from Cartesian to fully unstructured. Specialized extension modules developed by some of our collaborators will be illustrated [1]. These include a module to automatically choose values for salient isosurface identification and extraction, and color maps suitable for volume rendering. During the session, we will present several demonstrations of remote networking, processing of very large spatio-temporal datasets, and various other projects that are underway. In particular, we will demonstrate WEB-IS, a java-applet interface to Amira that allows script editing via the web, and selected data analysis [2]. [1] G. Erlebacher, D. A. Yuen, F. Dubuffet, *"Case Study: Visualization and Analysis of High Rayleigh Number – 3D Convection in the Earth's Mantle"*, Proceedings of Visualization 2002, pp. 529–532. [2] Y. Wang, G. Erlebacher, Z. A. Garbow, D. A. Yuen, *"Web-Based Service of a Visualization Package 'amira' for the Geosciences"*, Visual Geosciences, 2003.

URL: http://www.amiravis.com

NG11A-0162 0830h POSTER

Demonstrating NaradaBrokering as a Middleware Fabric for Grid-based Remote Visualization Services

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Remote Visualization Services (RVS) have tended to rely on approaches based on the client server paradigm. Here we demonstrate our approach - based on a distributed brokering infrastructure, NaradaBrokering [1] - that relies on distributed, asynchronous and loosely coupled interactions to meet the requirements and constraints of RVS. In our approach to RVS, services advertise their capabilities to the broker network that manages these service advertisements. Among the services considered within our system are those that perform graphic transformations, mediate access to specialized datasets and finally those that manage the execution of specified tasks. There could be multiple instances of each of these services and the system ensures that load for a given service is distributed efficiently over these service instances.

We will demonstrate implementation of concepts that we outlined in the oral presentation. This would involve two or more visualization servers interacting asynchronously with multiple clients through NaradaBrokering. The communicating entities may exchange SOAP [2] (Simple Object Access Protocol) messages. SOAP is a lightweight protocol for exchange of information in a decentralized, distributed environment. It is an XML based protocol that consists of three parts: an envelope that describes what is in a message and how to process it, rules for expressing instances of application-defined data types, and a convention for representing remote invocation related operations. Furthermore, we will also demonstrate how clients can retrieve their results after prolonged disconnects or after any failures that might have taken place.

The entities, services and clients alike, are not limited by the geographical distances that separate them. We are planning to test this system in the context of trans-Atlantic links separating interacting entities.

[1] The NaradaBrokering Project: http://www.naradabrokering.org

[2] Newcomer, E., 2002, Understanding web services: XML, WSDL, SOAP, and UDDI, Addison Wesley Professional.

NG11A-0163 0830h POSTER

WEB-IS (Integrated System): An Overall View

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Researchers in the geosciences are being faced with a deluge of large-scale datasets that needs to be analyzed in a fast and efficient manner. We have developed an interactive web-based scheme for data-mining large datasets using three distinct techniques. Collectively WEB-IS (Web-Based Integrated System) is a webservice based on a client-server paradigm which employs the power of a server to provide visualization and data analysis capabilities to multiple clients remotely. WEB-IS1 (http://boy.msi.umn.edu/web-is) extracts multi-resolutional structures in seismic catalogs through cluster analysis. Off-screen rendering is then applied on the server which allows the client to view the results in 3-D. WEB-IS2 (http://boy.msi.umn.edu/amira) exploits the ease of use in the powerful visualization package Amira (www.amiravis.com) through a web-based module which allows for manipulating and analyzing 3-D datasets. WEB-IS3 (http://tomo.msi.umn.edu/ max) is an imaging service which displays selected features from a low resolution environment to one with increased resolution by zooming into the data. Our software uses a combination of programming languages to seamlessly integrate server-side processing with client-side interaction utilities. Fast two-way communication between client and server will be considered for GRID purposes using SOAP (Livingston, D., Advanced SOAP for Web development, Prentice Hall, 2002). Future use of WEB-IS in the GRID computing environment is also being explored using the Narada-Brokering (www.naradabrokering.org) method. Our aim with this software tool is to overcome the hardware limitations of a thin client by harnessing the power of a large visualization server using a simple web interface.

URL: http://boy.msi.umn.edu/web-is

NG11A-0164 0830h POSTER

WEB-IS2: Next Generation Web Services Using Amira Visualization Package

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Amira (www.amiravis.com) is a powerful 3-D visualization package and has been employed recently by the science and engineering communities to gain insight into their data. We present a new web-based interface to Amira, packaged in a Java applet. We have developed a module called WEB-IS/Amira (WEB-IS2), which provides web-based access to Amira. This tool allows earth scientists to manipulate Amira controls remotely and to analyze, render and view large datasets over the internet, without regard for time or location. This could have important ramifications for GRID computing. The design of our implementation will soon allow multiple users to visually collaborate by manipulating a single dataset through a variety of client devices. These clients will only require a browser capable of displaying Java applets. As the deluge of data continues, innovative solutions that maximize ease of use without sacrificing efficiency or flexibility will continue to gain in importance, particularly in the Earth sciences. Major initiatives, such as Earthscope (http://www.earthscope.org), which will generate at least a terabyte of data daily, stand to profit enormously by a system such as WEB-IS/Amira (WEB-IS2). We discuss our use of SOAP (Livingston, D., Advanced SOAP for Web development, Prentice Hall, 2002), a novel 2-way communication protocol, as a means of providing remote commands, and efficient point-to-point transfer of binary image data. We will present our initial experiences with the use of Naradabrokering (www.naradabrokering.org) as a means to decouple clients and servers. Information is submitted to the system as a published item, while it is retrieved through a subscription mechanisms, via what is known as "topics". These topic headers, their contents, and the list of subscribers are automatically tracked by Naradabrokering. This novel approach promises a high degree of fault tolerance, flexibility with respect to client diversity, and language independence for the services (Erlebacher, G., Yuen, D.A., and F. Dubuffet, Current trends and demands in visualization in the geosciences, Electron. Geosciences, 4, 2001).

URL: http://boy.msi.umn.edu/amira

NG11A-0165 0830h POSTER

Visualization of Multi-dimensional MISR Datasets Using Self-Organizing Map

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Many techniques exist for visualization of high dimensional datasets including Parallel Coordinates, Projection Pursuit, and Self-Organizing Map (SOM), but none of these are particularly well suited to satellite data. Remote sensing datasets are typically highly multivariate, but also have spatial structure. In analyzing such data, it is critical to maintain the spatial context within which multivariate relationships exist. Only then can we begin to investigate how those relationships change spatially, and connect observed phenomena to physical processes that may explain them. We present an analysis and visualization system called SOM_VIS that applies an enhanced SOM algorithm proposed by Todd & Kirby [1] to multi-dimensional image datasets in a way that maintains spatial context. We first use SOM to project high-dimensional data into a non-uniform 3D lattice structure. The lattice structure is then mapped to a color space to serve as a colormap for the image. The Voronoi cell refinement algorithm is then used to map the SOM lattice structure to various levels of color resolution. The final result is a false color image with similar colors

representing similar characteristics across all its data dimensions. We demonstrate this system using data from JPL's Multi-angle Imaging Spectro-Radiometer (MISR), which looks at Earth and its atmosphere in 36 channels: all combinations of four spectral bands and nine view angles. The SOM_VIS tool consists of a data control panel for users to select a subset from MISR's Level 1B Radiance data products, and a training control panel for users to choose various parameters for SOM training. These include the size of the SOM lattice, the method used to modify the control vectors towards the input training vector, convergence rate, and number of Voronoi regions. Also, the SOM_VIS system contains a multi-window display system allowing users to view false color SOM images and the corresponding color maps for trained SOM lattices. In addition, SOM_VIS allows users to interactively select an input vector, relate it to its corresponding SOM vector or location in color space, and plot it in 36 dimensions along with its corresponding SOM vector and Euclidean distances between the two. In this presentation, we report results of our exploration of selected MISR datasets using SOM_VIS. Early experience shows that SOM_VIS is not only able to extract features common to channels, but also can identify subtle differences among channels or signals only visible in a few channels. We also present some quantitative performance measures comparing the SOM algorithm to other traditional clustering algorithms. [1] A. Todd & M. Kirby, "Data Visualization via Structured Voronoi Cell Refinement", SIAM Workshop on Mining Scientific Datasets, p.45-52, April 2001

NG11A-0166 0830h POSTER

Visualiztion of Viscous Heating in the Earth's Mantle Induced by Glacial Loading

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We have studied the a possible mechanism of transferring gravitational potential energy into viscous heating in the mantle via glacial loading during the ice ages. Shear heating associated with the transient flow occurring over a short timescale on the order of tens of thousand of years can cause a non-negligible amount of heat production in the mantle. We have applied our initial-value approach to the modelling of viscoelastic relaxation of spherical compressible self-gravitating Earth models with a linear viscoelastic Maxwellian rheology. We have focussed on the magnitude of deformations, stress tensor components and corresponding dissipative heating for ice sheets of the size of the Laurentide ice mass and cyclic loading with a fast unloading phase two orders of magnitude less than that associated with mountain building and vertical tectonics. Much to our surprise , we have found that this kind of internal heating can represent a non-negligible internal energy source with , however, an exogenic origin. The volumetric heating by this fast rate of deformation can be locally higher than the chondritic radiogenic heating during peak events with short timescales. In the presence of an abrupt change in the ice-loading, its time average of the integral over the depth corresponds to equivalent mantle heat flow of the order of magnitude of milliwatts per m^2 below the periphery of ancient glaciers or below their central areas. However, peak heat-flow values in time are almost by about two orders higher. On the other hand, nonlinear rheological models can potentially increase the magnitude of localized viscous heating. To illustrate the spatial distribution of the viscous heating for various Earth and glacier models, we have employed the powerful 3-D visualization system Amira. (www.amiravis.com). With this type of data format we can animate very easily the temporal evolution of the data fields on a moving curvilinear mesh, which spreads over outer and inner mantle boundaries and mantle cross-sections. Amira movies can reveal the complex nature of dissipative heating of the PREM model with a lower-mantle viscosity hill at the end of the recent Pleistocene ice age. This viscoelastic model can be employed in other dynamical situations with fast dynamical timescales, such as the aftermath of a meteoritic impact or other global cryospheric events.

URL: http://www.amiravis.com

NG11A-0167 0830h POSTER

Visualization of Complex Multiscale Phenomena at Subduction Zones

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Increases in the computational power of modern supercomputers have led to a gap between the resolution of digital simulations and the resolution of conventional display devices. This problem is compounded by the increasing size of datasets from simulations and the bandwidth constraints of the Internet. In our simulations, we model a subduction zone using at least 30-50 million markers that track data across many different fields such as temperature, viscosity, density, and chemical composition. We found commercially available software to be insufficient for our visualization needs and so we were driven to develop a new set of tools tailored to high-resolution, multi-aspect, multiscale simulations and adaptable to many other applications in which large datasets are prevalent. In order to address this gap in visualization techniques, we have developed solutions for remote-visualization and for the visualization of locally-stored data. Our remote visualization solution is a web-based, zoomable image service (WEB-IS) that requires minimal bandwidth while allowing the user to explore our data through time, across many properties, and through different spatial scales. For local visualization, we propose the use of bandwidth-intensive, high-resolution display walls with at least 10 million pixels to perform parallel visualization in order to best understand causal and temporal relationships between multiple properties in a simulation.

URL: http://tomo.msi.umn.edu/∼max/web-is/

NG11A-0168 0830h POSTER

Toward the standardization of image analysis from X-ray tomography: Applications to vesicular rocks used for paleoelevation studies

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We have developed a technique for measuring paloelevation through the study of vesicular basalts. It is based on determining size distributions of vesicles from x-ray tomographic data. The data requires further processing to separate partially coalesced or closely adjacent vesicles. We have found that peeling and reconstruction of voxel layers is an effective means of identifying individual entities within a complex structure from tomographic image data. In order to accomplish this, several steps are involved, some of which have traditionally required ad hoc interpretation on the part of the user. These include selection of thresholds between vesicle and rock, criteria for splitting apart partially coalesced vesicles, construction of a binning grid for resulting vesicle size classes, and interpretation of resulting histograms. With a more standardized procedure, it is possible to remove (at least partially) user input in the step by step process, thus increasing portability of the technique. The reduction of the large number of user-defined parameters in the sample analysis will make it possible to further automate the process, thus enabling faster processing and greater sample throughput. It also increases the reproducibility of results between labs or investigators analyzing similar rocks. This will be necessary for any large-scale studies of paleoelevation involving multiple labs and large numbers of sample analyses.

NG11A-0169 0830h POSTER

Data Assimilation for Plume Models

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Numerical forecasting of environmental flows is limited by the degree of accuracy to which the initial conditions are known. Even when initial conditions are reasonably well-known, noise and other effects can also significantly influence the outcome of a simulation. A case in point is weather prediction. Variational data assimilation is a well-proven method in meteorology and oceanography that can decrease the effect of inaccuracies in the initial conditions by integrating observations back into the simulation as it proceeds in time. Here we use a four-dimensional variational data assimilation (4D-VAR) algorithm to observe the growth of 2-D plumes from a point heat source. In order to test the predictability of the 4D-VAR technique for 2-D plumes, we perturb the initial conditions and compare the resulting predictions to the predictions given by a direct numerical simulation (DNS) without any 4D-VAR correction. We have studied plumes in fluids with a Prandtl number characteristic of water and Rayleigh numbers between 10^6 and 10^7, and we find the quality of the prediction to have a definite dependence on the Rayleigh number. As the Rayleigh number is increased, so is the quality of the prediction, due to an increase of the inertial effects in the adjoint equations for momentum and energy. The horizon predictability time, or how far into the future the 4D-VAR method can predict, slightly decreases as Rayleigh number increases, however. We have monitored the 4D-VAR predictions for various Prandtl numbers between 0.1 and 100. We have also studied the 4D-VAR predictions of 2-D thermal convection in fluids with a Prandtl number characteristic of the mantle. These 2-D computations are not computationally intensive and allow us to examine many different physical effects, such as Prandtl and Rayleigh numbers and eventually effects of compressibility.

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NG11A-0170 0830h POSTER

Interactive Visualization of Elastic Wave Velocity Anisotropy in Mantle Minerals

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A graphical user interface (GUI) is developed to visualize the elastic wave velocity anisotropy of minerals in response to pressure and temperature. The scheme involves two steps: First, the Cristoffel wave equation is solved on an adaptive three-dimensional grid of propagation directions. Second, the velocity distribution is rendered using polygon-surface and color-coding techniques. The graphical implementation is done with the standard OpenGL graphics libraries and C. This portable GUI enables interactive, three-dimensional visualization of wave velocity surfaces as a function of P and T. We have used it to analyze the anisotropic behavior of major mantle minerals, including MgO and MgSiO3-perovskite for which the required wave velocities are derived from the elastic constants predicted by first-principles calculations at relevant conditions. A demo will be done during the presentation.

NG11A-0171 0830h POSTER

Application of Mutlidimensional Wavelets to Unveiling Multi-Phase Diagrams and in Situ Rock Physical Properties

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There is a growing recognition of the important role played by multi-component phase transitions on the dynamics of the subducting slab and rising plumes. However, up to now, most of applications are limited by semi-quantitative analysis of relatively simple systems with few phase transformations. On the other hand, recent development of both large internally consistent geologically oriented thermodynamic databases and state of the art Gibbs energy minimization approach allow calculation of equilibrium phase assemblages and prediction of in situ rock physical properties. New challenges emerge when accounting for realistic systems with more than 10-components and complicated nonideal solid solutions closely representing a variety of natural terrestrial and planetary materials. Despite the fact that few examples of combinations of numerical thermomechanical modeling and Gibbs free energy minimization approaches are present in the literature, no uniform automated strategy of compact delineation and visualization of complicated realistic phase diagrams and related in situ physical properties of multicomponent systems has been developed so far. Calculation and visualization of phase diagrams is computationally expensive and difficult to capture visually. Traditionally the phase diagrams are calculated either on an a priori distributed dense set of points in phase space or using bisection algorithms. The former approach is very expensive and impractical for phase diagrams with dimensions higher that three. The latter lacks the robustness and often requires manual tuning. Robust fully adaptive multi-resolution algorithms for calculation of phase diagrams have not yet been explored until now. We will present preliminary results that demonstrate that efficient delineation and visualization of complicated realistic multi-phase diagrams and related in situ rock physical properties can be reached by combining adaptive wavelet based refinement strategy with the recently developed “phase diagram function” based on Gibbs free energy minimization procedure. The examples of automatic construction of P-T phase diagram and related physical properties for the bulk chemical composition of typical high grade metapelite will be presented. The automated adaptive strategy will be presented as well and also the interactive visualization of complex multi-dimensional phase assemblages.

NG11A-0172 0830h POSTER

Adaptive Multilevel Second-Generation Wavelet Collocation Elliptic Solver: A Cure for High Viscosity Contrasts

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An adaptive multilevel wavelet collocation method for solving multi-dimensional elliptic problems with localized structures is developed. The method is based on the general class of multi-dimensional second generation wavelets and is an extension of the dynamically adaptive second generation wavelet collocation method for evolution problems. Wavelet decomposition is used for grid adaptation and interpolation, while O(N) hierarchical finite difference scheme, which takes advantage of wavelet multilevel decomposition, is used for derivative calculations. The multilevel structure of the wavelet approximation provides a natural way to obtain the solution on a near optimal grid. In order to accelerate the convergence of the iterative solver, an iterative procedure analogous to the multigrid algorithm is developed. For the problems with slowly varying viscosity simple diagonal preconditioning works. For problems with large laterally varying viscosity contrasts either direct solver on shared-memory machines or multilevel iterative solver with incomplete LU preconditioner may be used. The method is demonstrated for the solution of a number of two-dimensional elliptic test problems with both constant and spatially varying viscosity with multiscale character.

NG11A-0173 0830h POSTER

The WMTSA Wavelet Toolkit for Data Analysis in the Geosciences

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Whereas Fourier analysis and similar spectral techniques are widely used for data analysis in the geosciences, their application is based on the assumption that the analyzed signal is stationary and well-sampled. However, many phenomena of interest in the natural environment are transitory and non-stationary. Furthermore, limited sampling of observations results in datasets that are incomplete and vary in sampling rates and durations. Wavelet decomposition techniques do not require the assumption of signal stationary. Additionally wavelet analysis methods can accommodate data series of any length, be used for signal filtering and reconstruction, and allow the localization of spectral signatures in time. We present an overview of the WMTSA toolkit, which is an implementation of the wavelet methods for time series analysis presented by Percival and Walden (2000). The WMTSA toolkit is being developed for multiple programming platforms (including Matlab, R, C) and being made available to the greater scientific community to use in their data analysis applications. We will demonstrate an application and results of using the WMTSA toolkit to the study of turbulence in the atmospheric boundary layer. Reference: D. B. Percival and A. T. Walden (2000), Wavelet Methods for Time Series Analysis. Cambridge, England: Cambridge University Press.

NG11A-0174 0830h POSTER

Localization of Oceanic Fronts and Feature Boundaries Using a Variational Technique

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Automatic localization of curvi-linear features (boundaries), including oceanic fronts and contours of rings such as those associated with the free-jet portion of the Gulf Stream, from satellite sea surface temperature (SST) maps is a challenging task, especially in the case of missing observations due to cloud cover. Having this as motivation, we explore whether techniques successfully used for non-oceanographic problems can be beneficial in the realm of oceanography. The goal is to apply a generalized version of the Mumford-Shah functional, a variational technique used in photographic and medical imaging applications, to an oceanographic problem. This method performs optimal smoothing jointly with localization of the feature boundaries. The feature boundary partitions the region into two or more subregions. Minimally, it establishes the location of the front. When there are rings, the boundary also separates the interior and exterior of these rings. As a byproduct of our boundary localization, we estimate the field, which interpolates across areas of missing data, but maintains the discontinuity at the boundary. Optimal interpolation is commonly performed in data analysis and assimilation; however, the technique presented by us is distinctive in the sense that it incorporates information about the feature boundaries into the field estimation process. We start with an objective functional $E(f, \vec{C})$ which we wish to minimize over both the SST field f and the boundary $\vec{C}$, which need not be a single, connected curve. The functional has a data fidelity term, a field smoothness term, and a curve length penalty term. The curve is evolved using level set methods, which can handle changes in the topology of the boundary. This allows us to locate both rings and the front. The boundary is then identified by the discontinuity, or departure from smoothness, in the estimated field. We present experimental results of our technique on various satellite observations of SST data. Preliminary results show reasonable localization of a particular oceanic front and associated rings.

NG11A-0175 0830h POSTER

Climate Data Analysis Tools - (CDAT)

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Climate Data Analysis Tools (CDAT) is a software infrastructure that uses an object-oriented scripting language to link together separate software subsystems and packages thus forming an integrated environment for solving model diagnosis problems. The power of the system comes from Python and its ability to seamlessly interconnect software. Python provides a general purpose and full-featured scripting language with a variety of user interfaces including command-line interaction, stand-alone scripts (applications) and graphical user interfaces (GUI). The CDAT subsystems, implemented as modules, provide access to and management of gridded data (Climate Data Management System or CDMS); large-array numerical operations (Numerical Python); and visualization (Visualization and Control System or VCS). One of the most difficult challenges facing climate researchers today is the cataloging and analysis of massive amounts of multi-dimensional global atmospheric and oceanic model data. To reduce the labor intensive and time-consuming process of data management, retrieval, and analysis, PCMDI and other DOE sites have come together to develop intelligent filing system and data management software for the linking of storage devices located throughout the United States and the international climate research community. This effort, headed by PCMDI, NCAR, and ANL will allow users anywhere to remotely access this distributed multi-petabyte archive and perform analysis. PCMDI's CDAT is an innovative system that supports exploration and visualization of climate scientific datasets. As an "open system", the software sub-systems (i.e., modules) are independent and freely available to the global climate community. CDAT is easily extended to include new modules and as a result of its flexibility, PCMDI has integrated other popular software components, such as: the popular Live Access Server (LAS) and the Distributed Oceanographic Data System (DODS). Together with ANL's Globus middleware software, CDAT's focus is to allow climate researchers the ability to access and analyze multi-dimensional distributed climate datasets.

URL: http://esg.llnl.gov/cdat

NG11A-0176 0830h POSTER

The Extended Concept Of Symmetropy And Its Application To Earthquakes And Acoustic Emissions

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There is the notion of symmetropy that can be considered as a powerful tool to measure quantitatively entropic heterogeneity regarding symmetry of a pattern. It can be regarded as a quantitative measure to extract the feature of asymmetry of a pattern (Yodogawa, 1982; Nanjo et al., 2000, 2001, 2002 in press). In previous studies, symmetropy was estimated for the spatial distributions of acoustic emissions generated before the ultimate whole fracture of a rock specimen in the laboratory experiment and for the spatial distributions of earthquakes in the seismic source model with self-organized criticality (SOC). In each of these estimations, the outline of the region in which symmetropy is estimated for a pattern is determined to be equal to

that of the rock specimen in which acoustic emissions are generated or that of the SOC seismic source model from which earthquakes emerge. When local seismicities like aftershocks, foreshocks and earthquake swarms in the Earth's crust are considered, it is difficult to determine objectively the outline of the region characterizing these local seismicities without the need of subjectiveness. So, the original concept of symmetropy is not appropriate to be directly applied to such local seismicities and the proper modification of the original one is needed. Here, we introduce the notion of symmetropy for the nonlinear geosciences and extend it for the purpose of the application to local seismicities such as aftershocks, foreshocks and earthquake swarms. We employ the extended concept to the spatial distributions of acoustic emissions generated in a previous laboratory experiment where the failure process in a brittle granite sample can be stabilized by controlling axial stress to maintain a constant rate of acoustic emissions and, as a result, detailed view of fracture nucleation and growth was observed. Moreover, it is applied to the temporal variations of spatial distributions of aftershocks and foreshocks of the main shocks, using natural observable data of earthquakes in and around Japan. Our results show the successful applicability of the extended concept of symmetropy to earthquakes and acoustic emissions. Furthermore, it is pointed out that the concept of symmetropy or the extended one of it might be adapted to any pattern recognition in many fields of science, particularly in the nonlinear geosciences and the sciences of complexity. References: Yodogawa, 1982, Percept. Psychophys., v. 32, p. 230-240; Nanjo et al., 2000, Forma, v. 15, p. 95-101; Nanjo et al., 2001, Forma, v. 16, p. 213-224; Nanjo et al., 2002 in press, Symmetry: Art and Science, v. 2.

NG11A-0177 0830h POSTER

SCEC Community Modeling Environment (SCEC/CME) - Data and Metadata Management Issues

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One of the goals of the SCEC Community Modeling Environment is to facilitate the execution of substantial collections of large numerical simulations. Since such simulations are resource-intensive, and can generate extremely large outputs, implementing this concept raises a host of data and metadata management challenges. Due to the high computational cost involved in running these simulations, one must balance the cost of repeating such simulations against the burden of archiving the produced datasets making them accessible for future use such as post processing or visualization, without the need of re-computation. Further, a carefully selected collection of such data sets might be used as benchmarks for assessing accuracy and performance of future simulations, developing post-processing software such as visualization tools, and testing data and metadata management strategies. The problem is rapidly compounded if one contemplates the possibility of computing ensemble averages for simulations of complex nonlinear systems. The definition and organization of a complete set of metadata to describe fully any given simulation is a surprisingly complex task, which we approach from the point of view of developing a community digital library, which provides the means to organize the material, as well as standard metadata attributes. Web-based discovery mechanisms are then used to support browsing and retrieval of data. A key component is the selection of appropriate descriptive metadata. We compare existing metadata standards from the digital library community, federal standards, and discipline specific metadata attributes. The digital library community has developed a standard for organizing metadata, called the Metadata Encoding and Transmission Standard (METS). This schema supports descriptive (provenance), administrative (location), structural (component relationships), and behavioral (display and manipulation applications). The organization can be augmented with discipline specific extension schemata. Candidates include the FGDC spatial data standard, the ISO 19115 schema for geographic data, and the Storage Resource Broker authenticity metadata. Other candidates include various metadata schemata used in observational seismology. We are also considering metadata attributes that are being developed within the SCEC community and are specific to the requirements of that community. A comparison of the metadata attributes will be presented, along with their use in the organization of simulation output from a large-scale anelastic wave prediction simulation, The SDSC Storage Resource Broker (SRB) provides the data handling capabilities to manage the Terabyte scale simulation output, providing support for ingestion, organization, description, preservation and access of datasets. The metadata attributes include, in particular, descriptive information about the simulation run, simulation input parameters, the computational infrastructure, the physical geometry of the problem, and output structure.

NG11A-0178 0830h POSTER

Earth System Grid II (ESG): Turning Climate Model Datasets Into Community Resources

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High-resolution, long-duration simulations performed with advanced DOE SciDAC/NCAR climate models will produce tens of petabytes of output. To be useful, this output must be made available to global change impacts researchers nationwide, both at national laboratories and at universities, other research laboratories, and other institutions. To this end, we propose to create a new Earth System Grid, ESG-II - a virtual collaborative environment that links distributed centers, users, models, and data. ESG-II will provide scientists with virtual proximity to the distributed data and resources that they require to perform their research. The creation of this environment will significantly increase the scientific productivity of U.S. climate researchers by turning climate datasets into community resources. In creating ESG-II, we will integrate and extend a range of Grid and collaboratory technologies, including the DODS remote access protocols for environmental data, Globus Toolkit technologies for authentication, resource discovery, and resource access, and Data Grid technologies developed in other projects. We will develop new technologies for (1) creating and operating "filtering servers" capable of performing sophisticated analyses, and (2) delivering results to users. In so doing, we will simultaneously contribute to climate science and advance the state of the art in collaboratory technology. We expect our results to be useful to numerous other DOE projects. The three-year R&D program will be undertaken by a talented and experienced team of computer scientists at five laboratories (ANL, LBNL, LLNL, NCAR, ORNL) and one university (ISI), working in close collaboration with climate scientists at several sites.

URL: http://www.earthsystemgrid.org

NG11A-0179 0830h POSTER

SCEC Community Modeling Environment (SCEC/CME) - Seismic Hazard Analysis Applications and Infrastructure

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The Southern California Earthquake Center (SCEC) has formed a Geoscience/IT partnership to develop an advanced information infrastructure for system-level earthquake science in Southern California. This SCEC/ITR partnership comprises SCEC, USC's Information Sciences Institute (ISI), the San Diego Supercomputer Center (SDSC), the Incorporated Institutions for Research in Seismology (IRIS), and the U.S. Geological Survey. This collaboration recently completed the second year in a five-year National Science Foundation (NSF) funded ITR project called the SCEC Community Modeling Environment (SCEC/CME). The goal of the SCEC/CME is to develop seismological applications and information technology (IT) infrastructure to support the development of Seismic Hazard Analysis (SHA) programs and other geophysical simulations. The SHA application programs developed by project collaborators include a Probabilistic Seismic Hazard Analysis system called OpenSHA [Field et al., this meeting]. OpenSHA computational elements that are currently available include a collection of attenuation relationships, and several Earthquake Rupture Forecasts (ERF's). Geophysicists in the collaboration have also developed Anelastic Wave Models (AWMs) using both finite-difference and finite-element approaches. Earthquake simulations using these codes have been run for a variety of earthquake sources. A Rupture Dynamic Model (RDM) has also been developed that couples a rupture dynamics simulation into an anelastic wave model. The collaboration has also developed IT software and hardware infrastructure to support the development, execution, and analysis of SHA programs. To support computationally expensive simulations, we have constructed a grid-based system utilizing Globus software [Kesselman et al., this meeting]. Using the SCEC grid, project collaborators can submit computations from the SCEC/CME servers to High Performance Computers at USC, NPACI and Teragrid High Performance Computing Centers. We have developed a SCEC Community Velocity Model server based on Internet standards (XML, SOAP, and WSDL) to provide access to the SCEC Community Velocity Model. We have also continued development of the SCEC Fault Information System (SCEC/FIS) to provide access to the SCEC Community Fault Model and the SCEC Fault Activity Database. Data generated and archived by the SCEC/CME is stored in a digital library system, the Storage Resource Broker (SRB) [Minster et al., this meeting]. This system provides a robust and secure system for maintaining the association between the data sets and their metadata. A browser-based computational pathway assembly web site has been developed [Gupta et al., this meeting]. Users can compose SHA calculations and call SCEC/CME computational programs to process the data and the output. By assembling a series of computational steps, users can develop complex computational pathways the validity of which can be verified with an ontology-based pathway assembly tool. Data visualization software developed by the collaboration to support analysis and validation of data sets includes 4D wave propagation visualization software based on OpenGL [Thiebaux et al., this meeting] and 3D Geowall-based visualization of earthquakes and faults.

URL: http://www.scec.org/cme

NG11A-0180 0830h POSTER

A Geoscience Grid: The SCEC Community Modeling Environment (SCEC/CME)

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The Southern California Earthquake Center (SCEC) is a diverse, distributed scientific community drawn together by the shared vision of understanding the cause and impact of earthquakes. As such, the domain of scientific discourse ranges from understanding the localized causes of fault ruptures to modeling how resulting seismic waves travel through the complex fault structures underlying major population centers, such as Los Angeles. SCEC is an exemplar of a class of collaborations that have come to be known as virtual organizations (VO), distributed, dynamic, multi-institutional

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collaborations that are bound together by a common goal. While existing collaboration tools, such as video conferencing, mailing lists and web servers, can support some of the workflow associated with a VO, many of the Project tasks require a more fundamental sharing of all elements of the IT infrastructure associated with the participants, including data, simulation models, computing and storage resources, visualization resource, etc. During the past eight years, Grid technology has emerged as an infrastructure that supports this type of resource sharing. Building on these advances, SCEC has undertaken activities in which Grids can be used to integrate the various modeling, simulation, and data collection activities of SCEC, with the goal of providing a seamless, integrated computational environment in which all aspects of geophysical elements of earthquakes can be studied, in which important information about earthquakes can be delivered to the community at large, and which promotes education and outreach about geophysics. In this presentation, we will describe the SCEC Community Modeling Environment (SCEC/CME) Grid-based infrastructure that is being built to support the scientific and education mission of SCEC. We will focus on three aspects of the current environment: (1) distributed data management, which is being used to support model validation, (2) knowledge based tools for model description, which are being used to support high-level interfaces to sophisticated modeling tasks, and (3) a distributed visualization facility, which enables remote exploration of large-scale simulation data sets. We will conclude with a description of future directions in which this environment will be taken.

URL: http://www.scec.org/cme

NG11A-0181 0830h POSTER

Earthquake Source Simulations: A Coupled Numerical Method and Large Scale Simulations

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We investigate a scheme for interfacing Finite-Difference (FD) and Finite-Element (FE) models in order to simulate dynamic earthquake rupture. The more powerful but slower FE method allows for (1) unusual geometries (e.g. dipping and curved faults), (2) nonlinear physics, and (3) finite displacements. These capabilities are computationally expensive and limit the useful size of the problem that can be solved. Large efficiencies are gained by employing FE only where necessary in the near source region and coupling this with an efficient FD solution for the surrounding medium. Coupling is achieved through setting up and an overlapping buffer zone between the domains modeled by the two methods. The buffer zone is handled numerically as a set of mutual offset boundary conditions. This scheme eliminates the effect of the artificial boundaries at the interface and allows energy to propagate in both directions across the boundary. In general it is necessary to interpolate variables between the meshes and time discretizations used for each model, and this can create artifacts that must be controlled. A modular approach has been used in which either of the two component codes can be substituted with another code. We have successfully demonstrated coupling for a simulation between a second-order FD rupture dynamics code and fourth-order staggered-grid FD code. To be useful earthquake source models must capture a large range of length and time scales, which is very computationally demanding. This requires that (for current computer technology) codes must utilize parallel processing. Additionally, if larges quantities of output data are to be saved, a high performance data management system is desirable. We show results from a large scale rupture dynamics simulation designed to test these capabilities. We use second-order FD with dimensions of 400 x 800 x 800 nodes, run for 3000 time steps. Data were saved for the entire volume for three components of velocity at every time step and six components of stress at every tenth time step. This generated a 10 terabyte data set that was handled with the SDSC Storage Resource Broker (SRB). Run time was approximately 12 hours on SDSC Blue Horizon machine, and data archival to SRB took approximately 5 days.

NG11A-0182 0830h POSTER

Examples of Linking Codes Within GeoFramework

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Geological processes usually encompass a broad spectrum of length and time scales. Traditionally, a modeling code (solver) is written to solve a problem with specific length and time scales in mind. The utility of the solver beyond the designated purpose is usually limited. Furthermore, two distinct solvers, even if each can solve complementary parts of a new problem, are difficult to link together to solve the problem as a whole. For example, Lagrangian deformation model with visco-elastoplastic crust is used to study deformation near plate boundary. Ideally, the driving force of the deformation should be derived from underlying mantle convection, and it requires linking the Lagrangian deformation model with a Eulerian mantle convection model. As our understanding of geological processes evolves, the need of integrated modeling codes, which should reuse existing codes as much as possible, begins to surface. GeoFramework project addresses this need by developing a suite of reusable and re-combinable tools for the Earth science community. GeoFramework is based on and extends Pyre, a Python-based modeling framework, recently developed to link solid (Lagrangian) and fluid (Eulerian) models, as well as mesh generators, visualization packages, and databases, with one another for engineering applications. Under the framework, a solver is aware of the existence of other solvers and can interact with each other via exchanging information across adjacent boundary. A solver needs to conform a standard interface and provide its own implementation for exchanging boundary information. The framework also provides facilities to control the coordination between interacting solvers. We will show an example of linking two solvers within GeoFramework. CitcomS is a finite element code which solves for thermal convection within a 3D spherical shell. CitcomS can solve for problems either within a full spherical (global) domain or a restricted (regional) domain of a full sphere by using different meshers. We can embed a regional CitcomS solver within a global CitcomS solver. We not that linking instances of the same solver is conceptually equivalent to linking to different solvers. The global solver has a coarser grid and a longer stable time step than the regional solver. Therefore, a global-solver time step consists of several regional-solver time steps. The time-marching scheme is described below. First, the global solver is advanced one global-solver time step. Then, the regional solver is advanced for several regional-solver time steps until it catches up global solver. Within each regional-solver time step, the velocity field of the global solver is interpolated in time and then is imposed to the regional solver as boundary conditions. Finally, the temperature field of the regional solver is extrapolated in space and is fed back to the global. These two solvers are linked and synchronized by the time-marching scheme. An effort to embed a visco-elastoplastic representation of the crust within viscous mantle flow is underway.

URL: http://geoframework.org

NG12A MCC: 2010 Monday 1340h

Nonlinear Processes in Geomorphologic Organization and Natural Hazards I *(joint with B, H, OS, AE)*

Presiding: **E Foufoula,** St. Anthony Falls Laboratory, University of Minnesota**; I Rodriguez-Iturbe,** Princeton University**; C Paola,** St. Anthony Falls Laboratory, University of Minnesota**; S Burroughs,** University of Tampa

NG12A-01 1340h INVITED

Order without a cause

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The pervasiveness of order in landscapes, from striking patterns such as fields of sand dunes to less eye-catching examples such as tussock tundra, motivates efforts to find its cause. However, studying order as an abstract, overarching structure common to many similar systems or as emerging from fundamental physical processes reveals little about the dynamics of specific landscapes, because order is an irreducible property of the dynamics of a system and not a product of causal relations between different aspects of the system. This hypothesis is based on the view that the order of a landscape is the extent to which it is organized into a hierarchy of scale-separated behaviors. With increasing level in the hierarchy, time scale increases and the number of degrees of freedom decreases. The lone relations between adjacent levels connect only the fast-scale variables of the lower level with the slow-scale dynamics of the upper level (through self-organization/slaving). The dynamics at each level is an independent property of the system, not an effect caused by dynamics at any other level. Order is quantified using the number and time scales of levels in the hierarchy. Ice-rich permafrost terrain of the Kitluk drainage basin in Bering Land Bridge National Preserve, Alaska, illustrates a highly developed hierarchical order without a cause. The terrain has numerous levels, ranging from soil particle motion (seconds) to integrated lake drainage networks (10 ka). Using our concept of order, measurements over a range of locations reveal that this seemingly unpatterned landscape contrasts with many patterned systems, such as fields of sorted patterned ground in Western Spitsbergen, where order is less developed. Supported by the Andrew W. Mellon Foundation.

NG12A-02 1355h INVITED

Comparative geomorphologic organization of river and tidal networks

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We address a comparative analysis of certain features observed in river and tidal networks, chiefly to explore the dynamic origin of the extraordinary diversity and yet the deep symmetry that one observes in such particular landforms. It seems of particular interest to compare network structures and a few geomophic features because of the vast diversity (and the relatively high degree of understanding) of the morphologic, hydrologic and ecobiologic processes at work in such eartscapes. River networks are indeed a paradigm of scale-invariant landforms from open, dissipative systems with many degrees of freedom quite ubiquitous in nature, and are described by a noteworthy body of observational and theoretical work, which is briefly reviewed in this context. Tidal networks bear mixed signatures of dynamic processes acting at different scales