

GEON Cyberinfrastructure Developments in the Earth Sciences

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Unidata Seminar, 1 October 2004

Outline of Talk

EarthScope IT systems and some future needs

Developing Cyberinfrastructure Resources
(e.g GEON NSF Information Technology Research Project)

Education and Outreach
(Map Tools for EarthScope Science and Education)

With thanks to many contributors to this talk, both direct and indirect via the web!

EarthScope: Exploring the Structure and Evolution of the North American Continent

How do we achieve this?

Instrumentation

Information Technology

Community Research

Education and Outreach

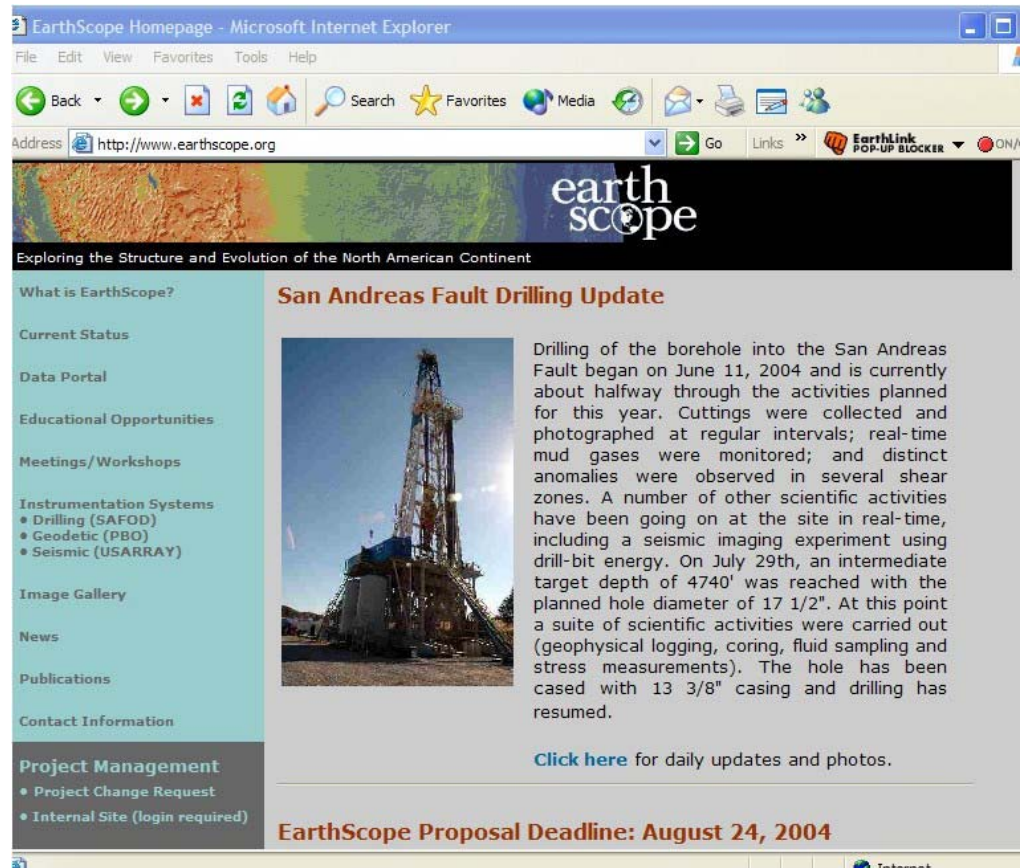
Emerging

Cyberinfrastructure

...all contributing to an

Integrated EarthScope

Project



The screenshot shows the EarthScope Homepage in a Microsoft Internet Explorer browser window. The address bar displays <http://www.earthscope.org>. The page features a header with the EarthScope logo and the tagline "Exploring the Structure and Evolution of the North American Continent". A left sidebar contains a navigation menu with links to "What is EarthScope?", "Current Status", "Data Portal", "Educational Opportunities", "Meetings/Workshops", "Instrumentation Systems" (including Drilling (SAFOD), Geodetic (PBO), and Seismic (USARRAY)), "Image Gallery", "News", "Publications", and "Contact Information". The main content area highlights a "San Andreas Fault Drilling Update" with a photograph of a drilling rig and a detailed text update. At the bottom, it states the "EarthScope Proposal Deadline: August 24, 2004".

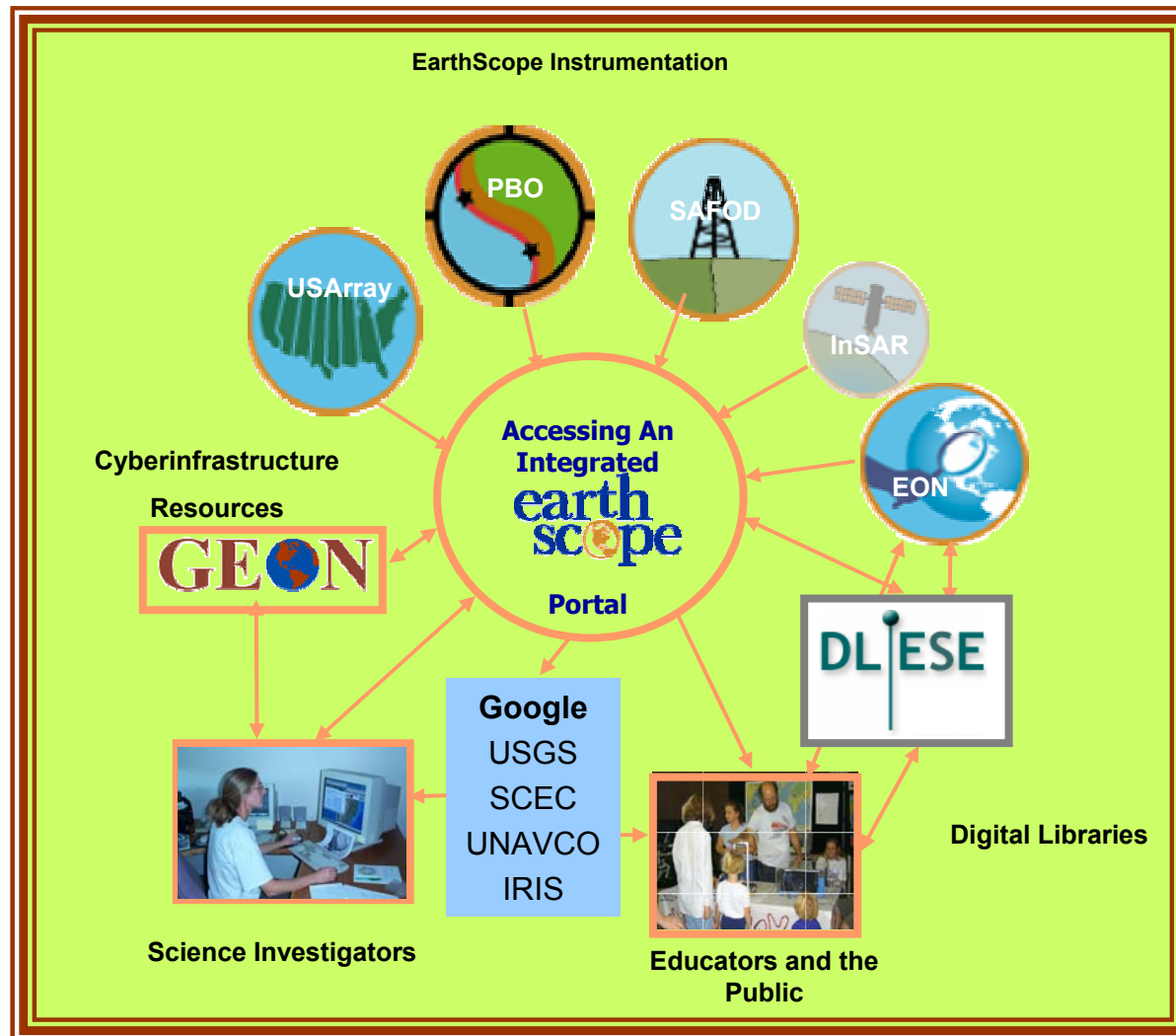
San Andreas Fault Drilling Update

Drilling of the borehole into the San Andreas Fault began on June 11, 2004 and is currently about halfway through the activities planned for this year. Cuttings were collected and photographed at regular intervals; real-time mud gases were monitored; and distinct anomalies were observed in several shear zones. A number of other scientific activities have been going on at the site in real-time, including a seismic imaging experiment using drill-bit energy. On July 29th, an intermediate target depth of 4740' was reached with the planned hole diameter of 17 1/2". At this point a suite of scientific activities were carried out (geophysical logging, coring, fluid sampling and stress measurements). The hole has been cased with 13 3/8" casing and drilling has resumed.

[Click here](#) for daily updates and photos.

EarthScope Proposal Deadline: August 24, 2004

An Integrated EarthScope ... leading to new scientific discoveries!

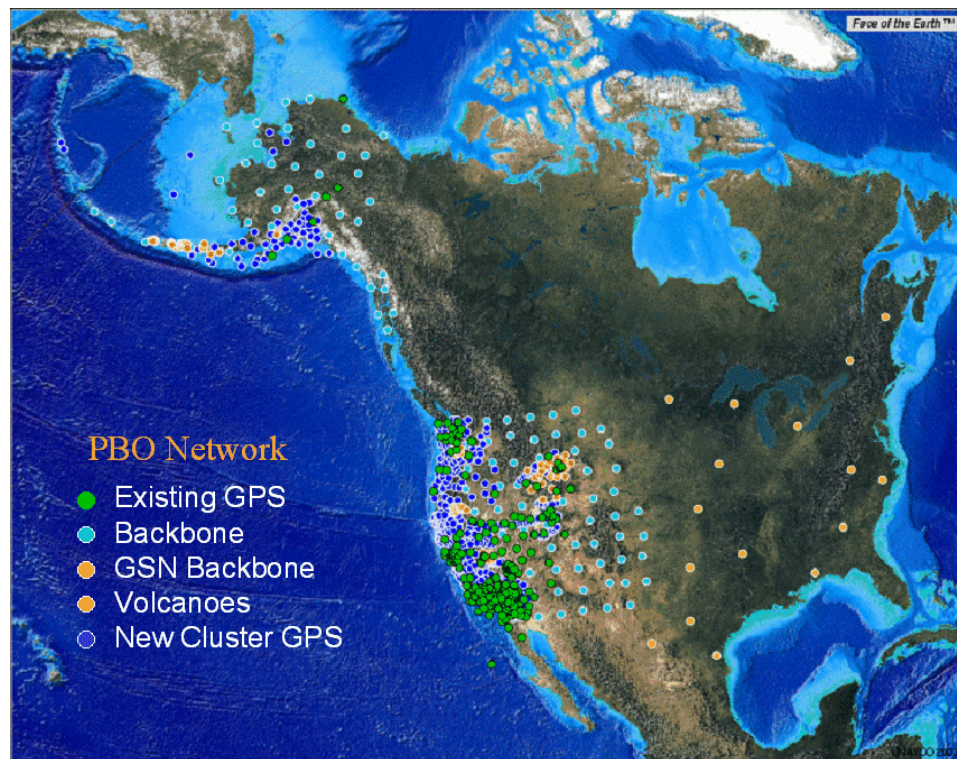


EarthScope Instrumentation



EarthScope GPS and Strainmeter Instrumentation

891 new CGPS stations
226 existing CGPS stations
100 SGPS receivers
143 BSM stations
5 LSM stations

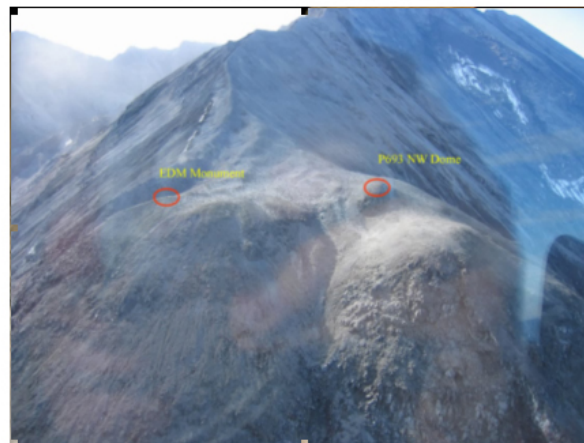


EarthScope Mt. St. Hellens Emergency Response

5 New continuous GPS Stations are being installed in October.



UNAVCO, INC.
PLATE BOUNDARY OBSERVATORY



Site Name: P693 NW Dome, Mt. St. Helens, Washington
Recon Number: P693

Submitted By: **Peter Gray**

Organization: **UNAVCO, PBO – PNW Region**

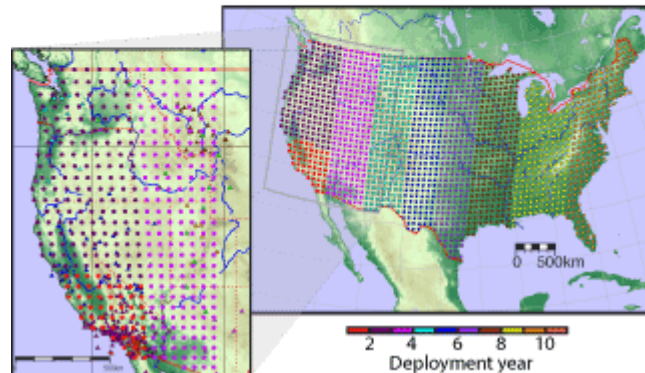
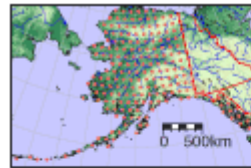
Date of Reconnaissance: **Aug. 5, 2004**

10/1/20041

Reconnaissance Form v1.1

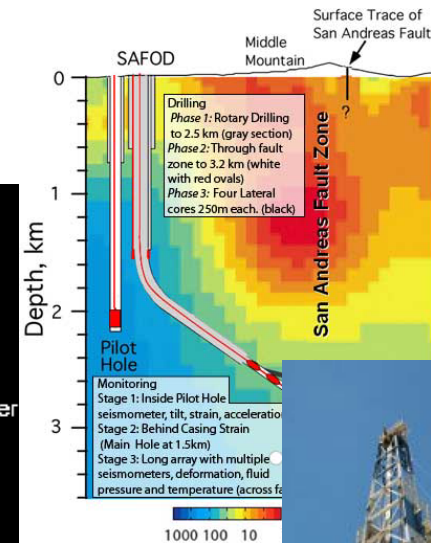
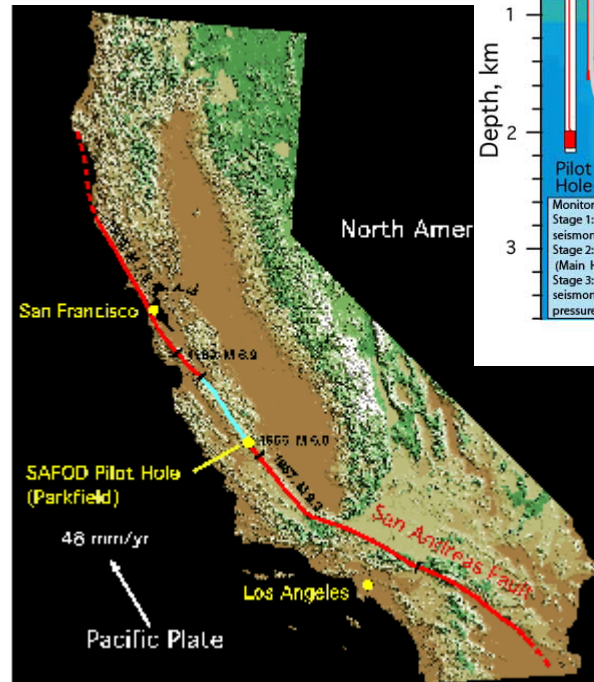
EarthScope Transportable and Fixed Seismic Instrumentation

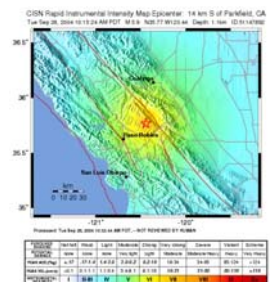
- 400 Instrument Broadband Transportable Array (~2000 locations)
- 39 permanent stations (16 with GPS)
- Instrument Flexible array (200 Broadband, 200 short-period, 2000 high-frequency)
- Magneto-telluric field systems (40)



EarthScope San Andreas Fault Observatory at Depth (SAFOD)

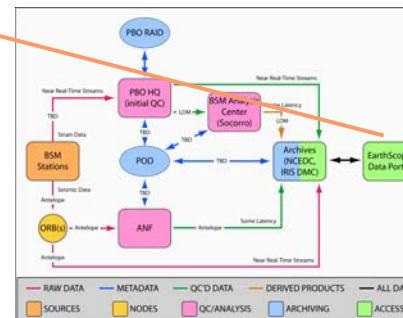
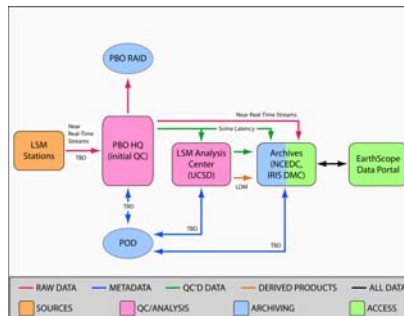
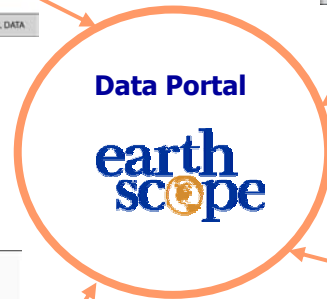
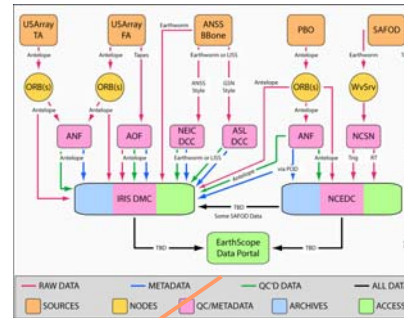
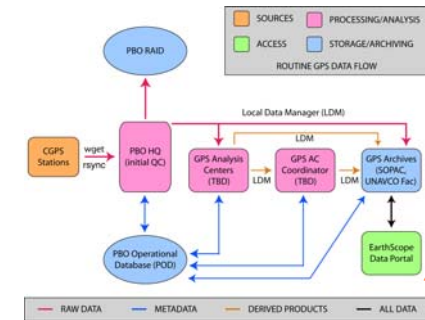
- seismic (bore hole and near field)
- down bore hole pressure, temperature, stress and strain
- directly sampled fault zone materials (rock and fluids)





EarthScope Data Portal

system for data, metadata, and derived products



Figures from Greg Anderson, see EarthScope data plans for details

EarthScope Information Technology – A critical component needed to make EarthScope accessible to scientists, educators and the public

Providing:

- Reliable and open access to data and products
- Rapid data access
- Handle and store large volumes of data
- Complex 4-D datasets
- Long-term security
- Integration into analysis, modeling and visualization

“EarthScope Data Products for Science and Education”

- Raw data
- Derived products
- Interpretive products
- Knowledge products
- Educational products

Sample EarthScope PBO Data and Products

GPS

Raw data and metadata

- Permanent Station and Campaign Raw Data
- Station Metadata

Derived Products

- Velocity Vectors
- Coordinate Time Series
- Co-seismic Offsets

Borehole and Laser Strain

Raw data and metadata

- Strain and Seismic Waveforms

Geologic Data

- Geochronology
- Aerial Imagery (ALSM, Photos)

Knowledge Products

- GPS-Derived Strain Rates
- Deformation Models spanning seismic to Geologic time scales

Sample EarthScope USArray Data and Products

Seismic Data

- Traveling Array and Flexible Array Station Waveform Data
- Station, Event Metadata

Derived Products

- Earthquake locations, arrival times, focal mechanisms, source time functions, cross-correlated phases, shear-wave splitting measurements, and normal modes

Knowledge Products

- 3 and 4-dimensional models of the Earth's interior including tomographic images of P and S velocity, Poisson Ratio, attenuation and anisotropy

EarthScope - the instrument facility - is about the data

Cumulative Data from the Plate Boundary Observatory

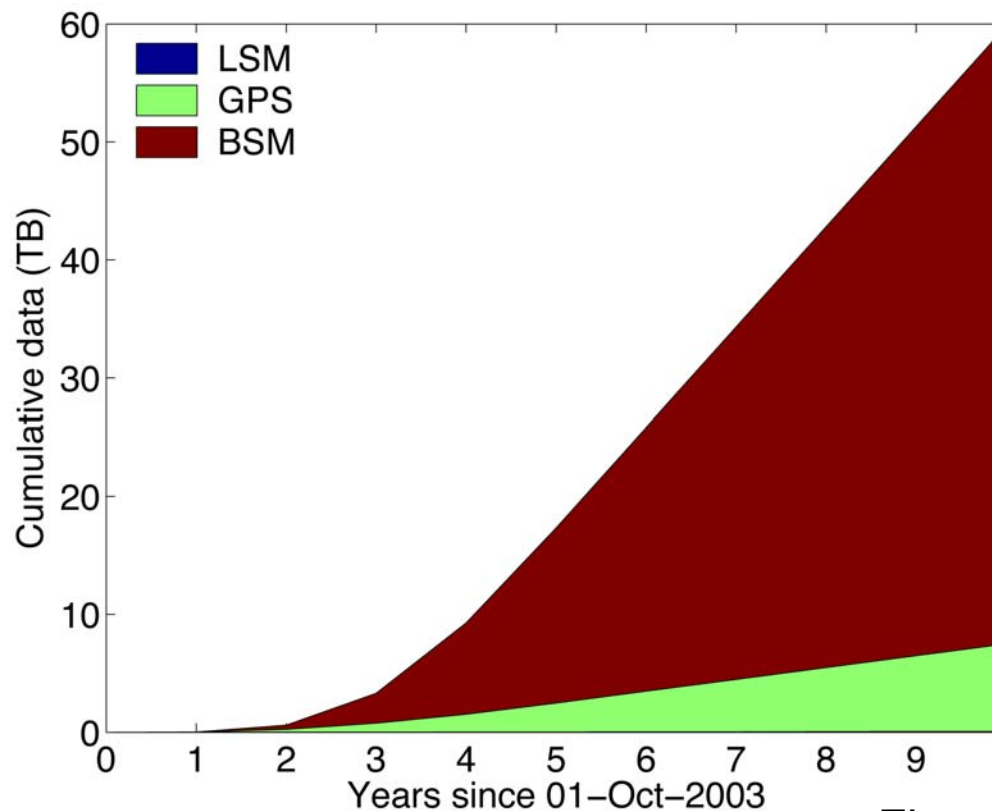
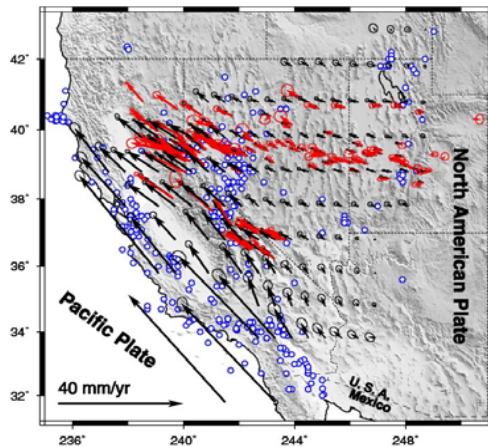
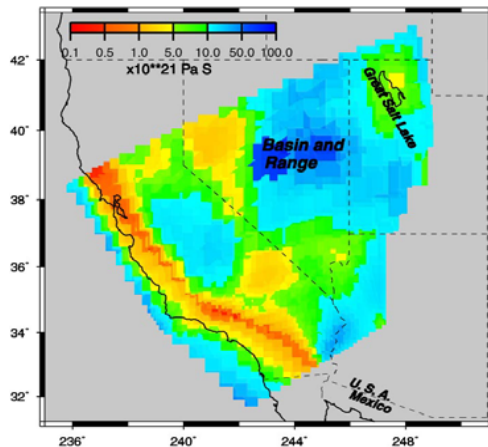
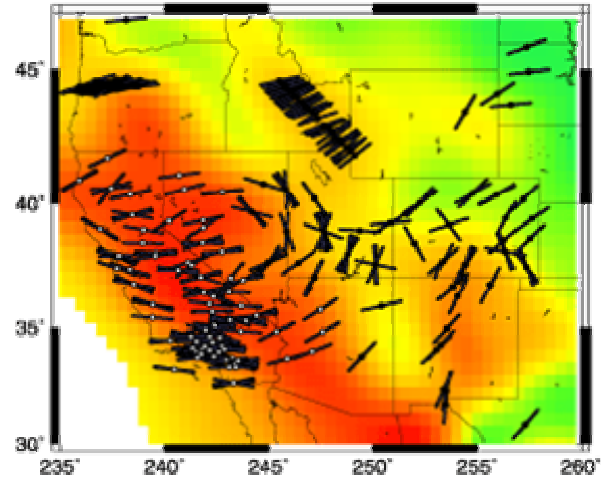


Figure from Greg Anderson

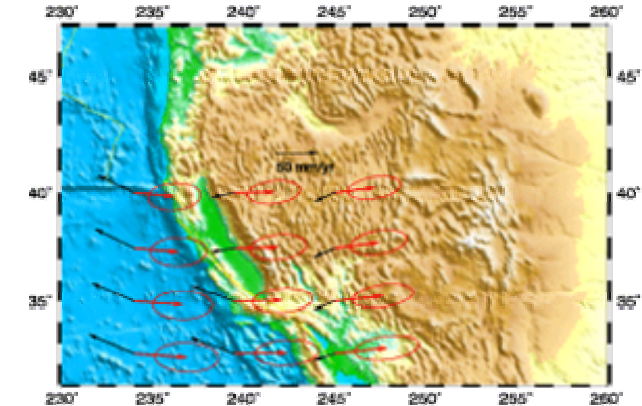
Earthscope - the project - is about putting it together to make new scientific discoveries!



Left: Inverting for lithospheric viscosity through a force-balance model of surface deformation



Right: Inverting for mantle flow velocity by adding mantle deformation from seismic anisotropy.



(Flesch et al., 2000)

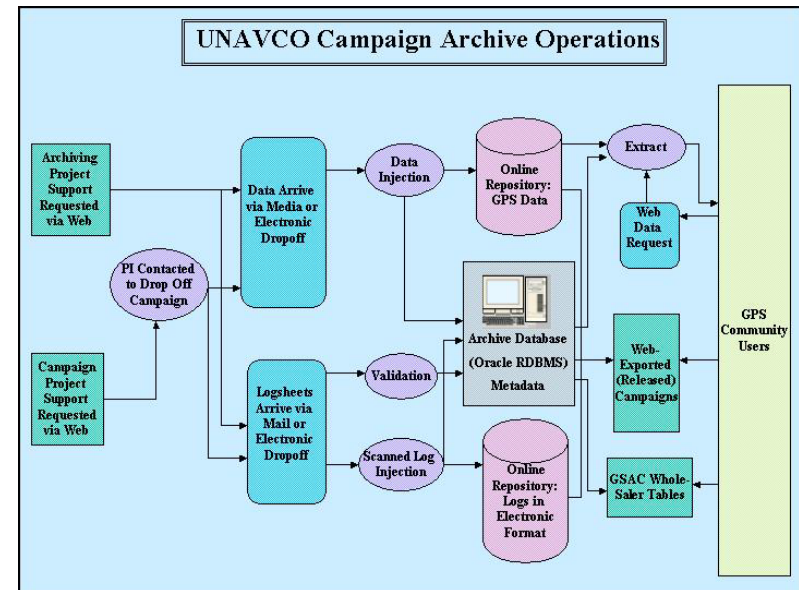
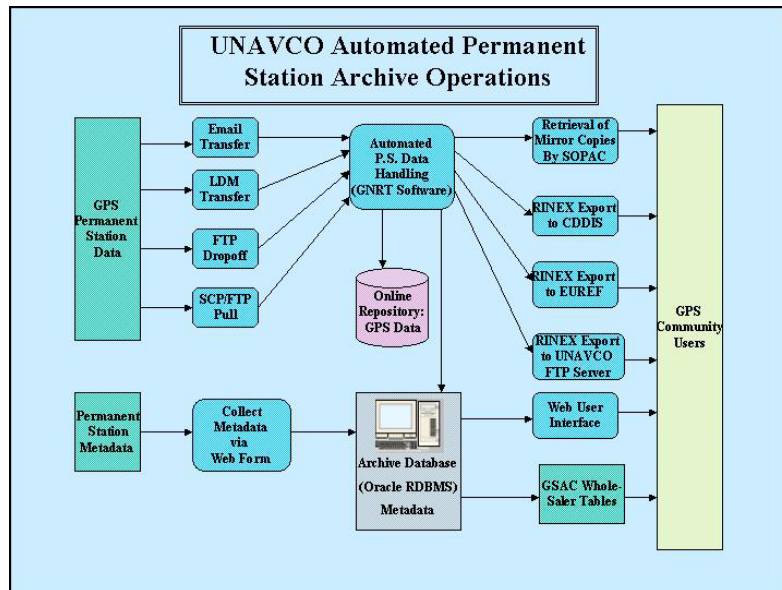
(Silver and Holt, 2001)

Academic Research Geophysical Data Access

**e.g. UNAVCO and GPS Seamless Archives
IRIS
and**

**Numerous other geological and geophysical
databases from academic consortia and
individual investigators**

UNAVCO Archive



Automated data delivery systems or web access from the UNAVCO website. More recently the GPS Seamless Archive Centers (GSAC) for raw GPS data discovery and retrieval beyond the confines of the website. Separate access to GPS velocity and strain archives via web pages and map tools. The IT challenge is to integrate these data and derived products into a broader cyberinfrastructure such as GEON and EarthScope.

GPS Seamless Archive (GSAC)

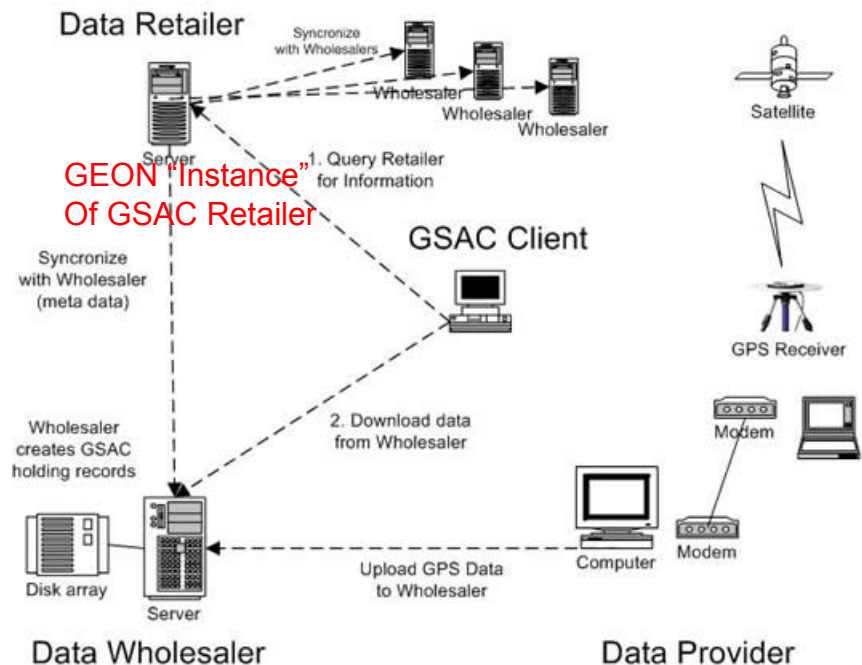
The GSAC helps you locate GPS data files which are archived at different GPS Data Archive Centers from a single user interface.

GSAC Clients:

1. The GSAC Wizard is a web-based client.
2. The GSAC command-line client.

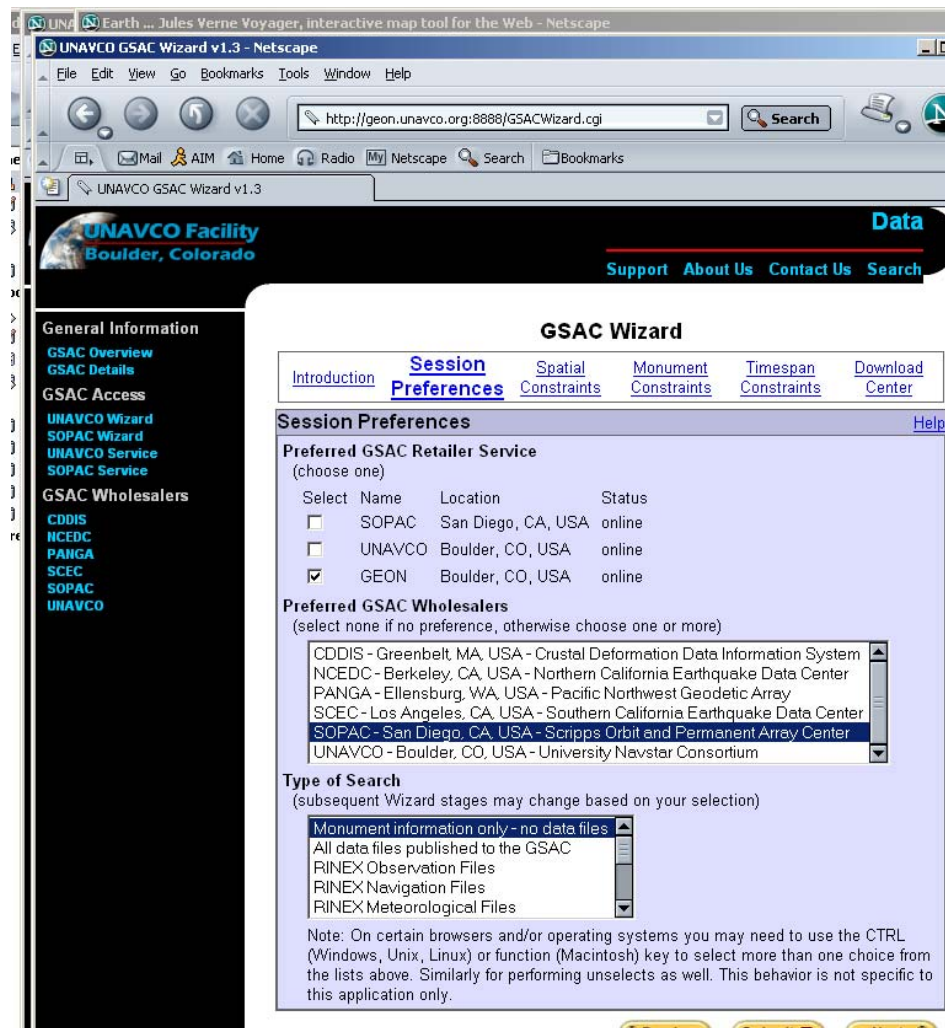
GSAC Retailer:

1. Gathers metadata and file locations from wholesalers
2. Organizes data into a POSTSQL relational database (same as GEON)
3. Provides services to GSAC Clients
The GSAC will be the primary means of GPS raw data and data product discovery and access for **EarthScope**



GSAC developed by Scripps and UNAVCO

GSAC Retailer “Wizard”



UNAVCO GSAC Wizard v1.3 - Netscape

http://geon.unavco.org:8888/GSACWizard.cgi

UNAVCO Facility
Boulder, Colorado

Data
Support About Us Contact Us Search

GSAC Wizard

Introduction **Session Preferences** Spatial Constraints Monument Constraints Timespan Constraints Download Center

Session Preferences

Preferred GSAC Retailer Service
(choose one)

Select	Name	Location	Status
<input type="checkbox"/>	SOPAC	San Diego, CA, USA	online
<input type="checkbox"/>	UNAVCO	Boulder, CO, USA	online
<input checked="" type="checkbox"/>	GEON	Boulder, CO, USA	online

Preferred GSAC Wholesalers
(select none if no preference, otherwise choose one or more)

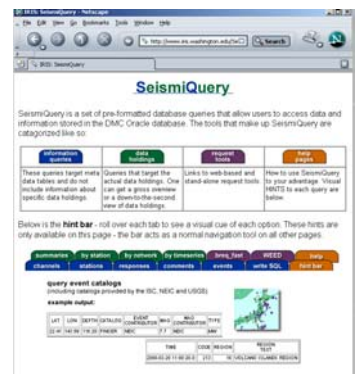
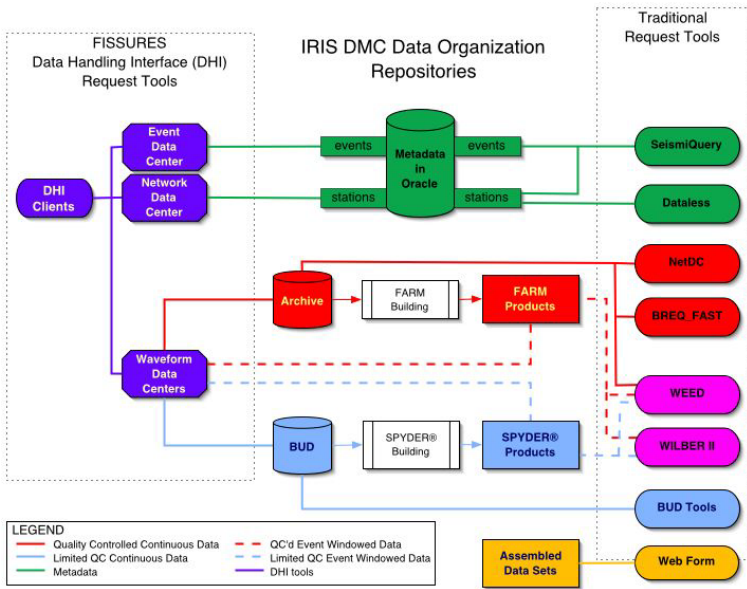
- CDDIS - Greenbelt, MA, USA - Crustal Deformation Data Information System
- NCEDC - Berkeley, CA, USA - Northern California Earthquake Data Center
- PANGA - Ellensburg, WA, USA - Pacific Northwest Geodetic Array
- SCEC - Los Angeles, CA, USA - Southern California Earthquake Data Center
- SOPAC - San Diego, CA, USA - Scripps Orbit and Permanent Array Center
- UNAVCO - Boulder, CO, USA - University Navstar Consortium

Type of Search
(subsequent Wizard stages may change based on your selection)

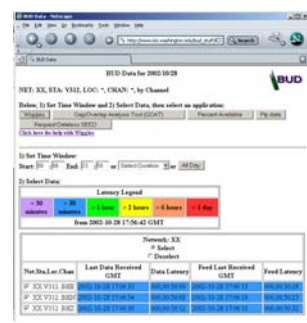
- Monument information only - no data files
- All data files published to the GSAC
- RINEX Observation Files
- RINEX Navigation Files
- RINEX Meteorological Files

Note: On certain browsers and/or operating systems you may need to use the CTRL (Windows, Unix, Linux) or function (Macintosh) key to select more than one choice from the lists above. Similarly for performing unselects as well. This behavior is not specific to this application only.

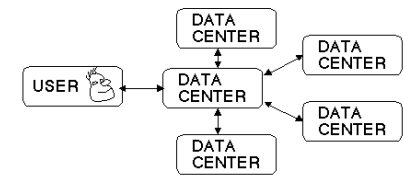
IRIS Seismic and Strain Data Retrieval



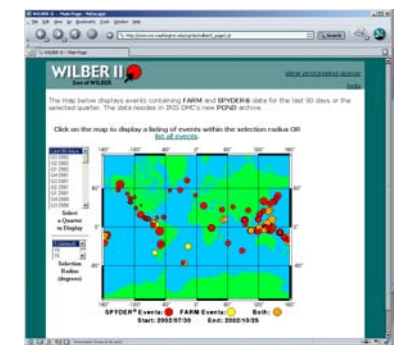
SeismiQuery Interface: Meta-data queries



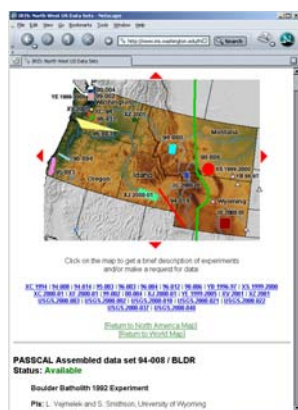
BUD Interface: IRIS Near-real-time system



Networked Data Centers: Email and Ftp



WILBER II Interface: Quality-Checked, Near-real-time and historic waveform data retrieval

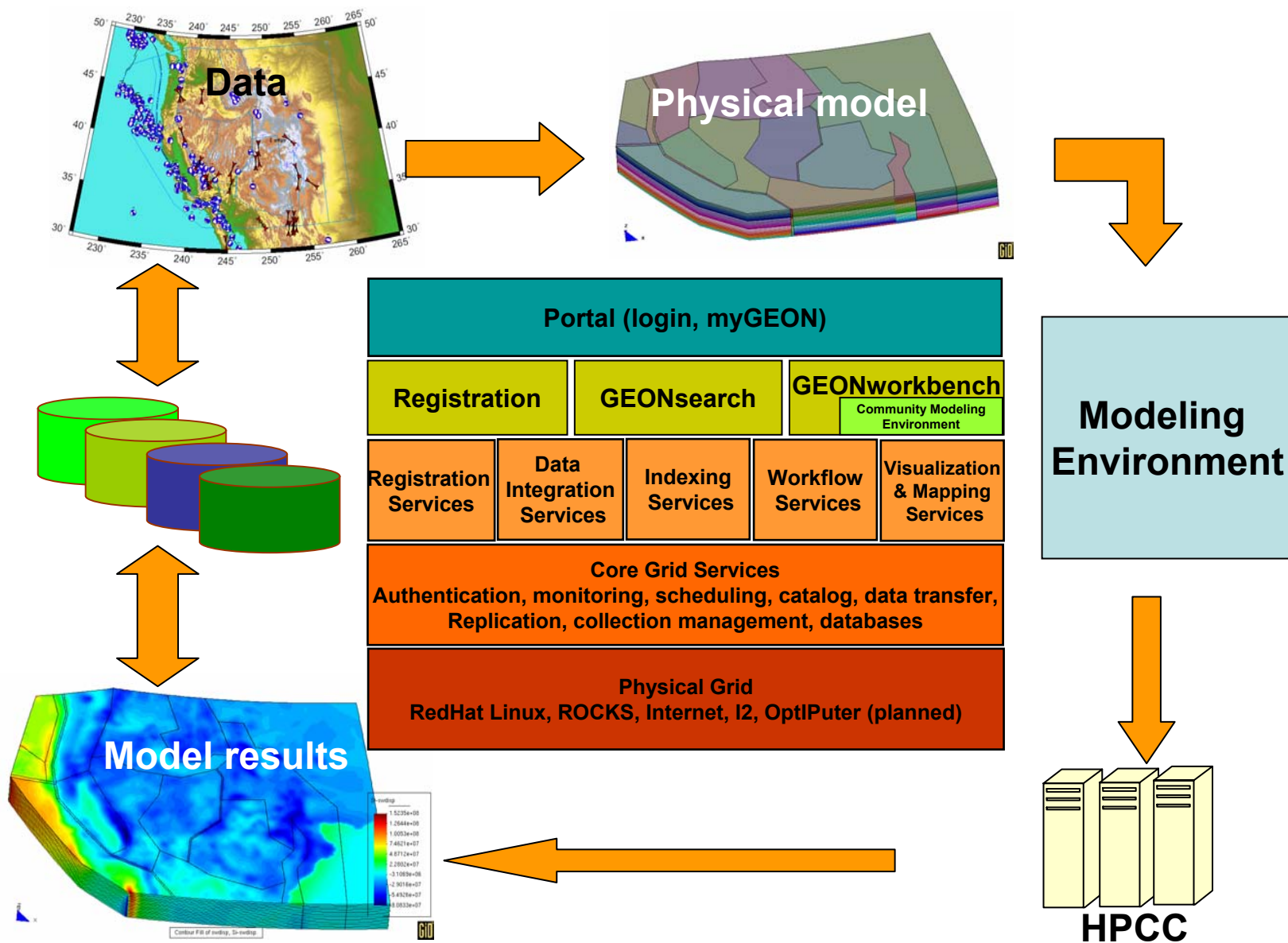


Requests for Assembled Data From the Flexible array

GEON Information Technology Research Project

**A cyberinfrastructure project
to combine IT with
Geoscience knowledge**

GEON: GEOsciences Network



GEON: GEOsciences Network

EarthScope provides the connectivity of knowledge from surface geology, through the lithosphere into the deeper mantle Krishna Sinha, GEON PI

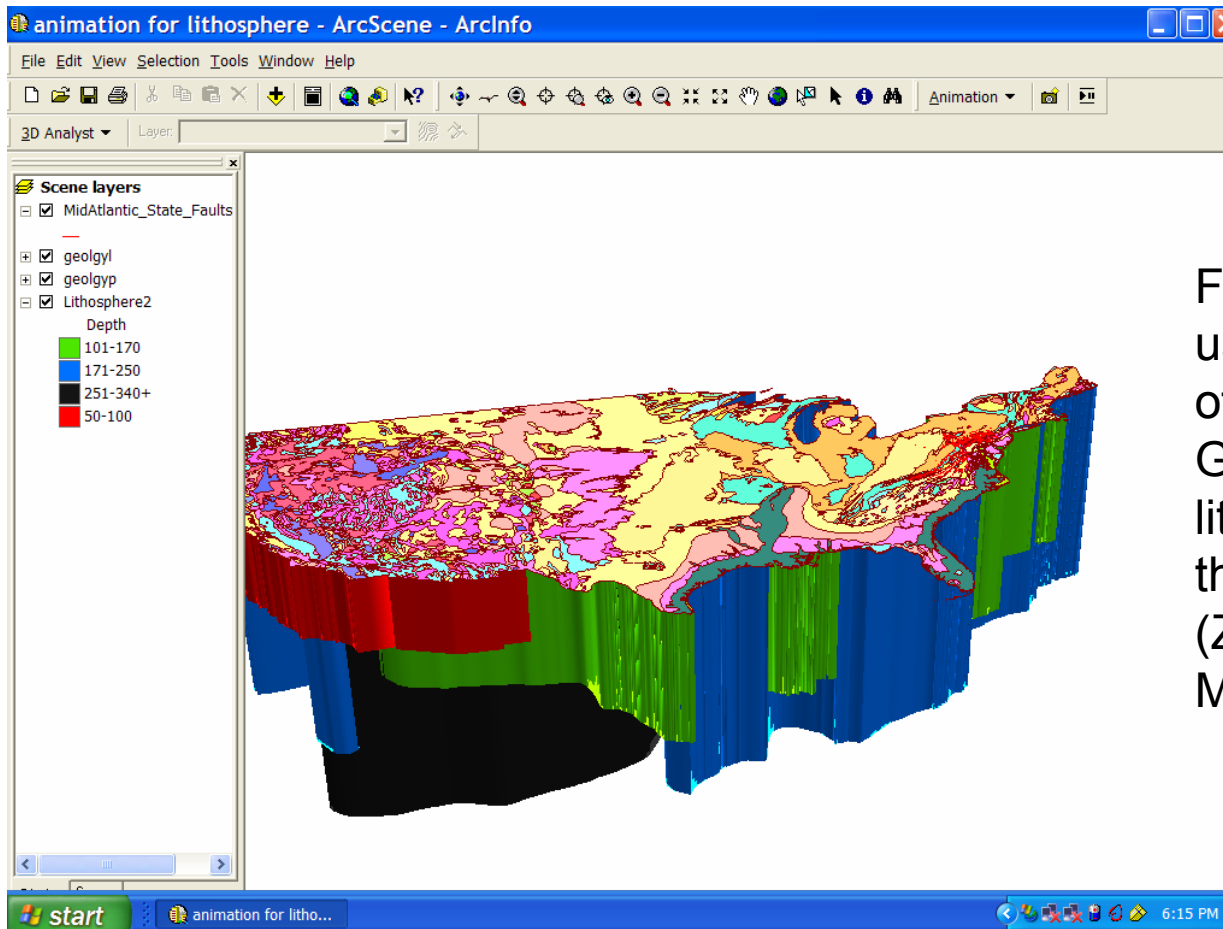


Figure made
using ArcScene
of USGS
Geologic map,
lithosphere
thicknesses
(Zoback and
Moony, 2003)

GEON Project Scope

- Develop a distributed, services-based system that enables geoscientists to publish, share, integrate, analyze, and visualize their data, ontologies, tools, workflows, applications, and models
- Conduct integrated scientific studies on targets of opportunities in the test beds, in concert with geosciences community

GEON Project Activities

- GEON will
 - develop services for data integration and model integration, and associated model execution and visualization
 - Mid-Atlantic test bed will focus on tectonothermal, paleogeographic, and biotic history from the late-Proterozoic to mid-Paleozoic
 - Rockies test bed will focus on integration of data with dynamic models, to better understand deformation history
 - develop the most comprehensive regional datasets in test bed areas

Current GEON participant institutions

NSF Supported

- Arizona State University
- Bryn Mawr College
- Penn State University
- Rice University
- San Diego State University
- San Diego Supercomputer Center / University of California, San Diego
- University of Arizona
- University of Idaho
- University of Missouri, Columbia
- University of Texas at El Paso
- University of Utah
- Virginia Tech
- UNAVCO, Inc.
- Digital Library for Earth System Education (DLESE)

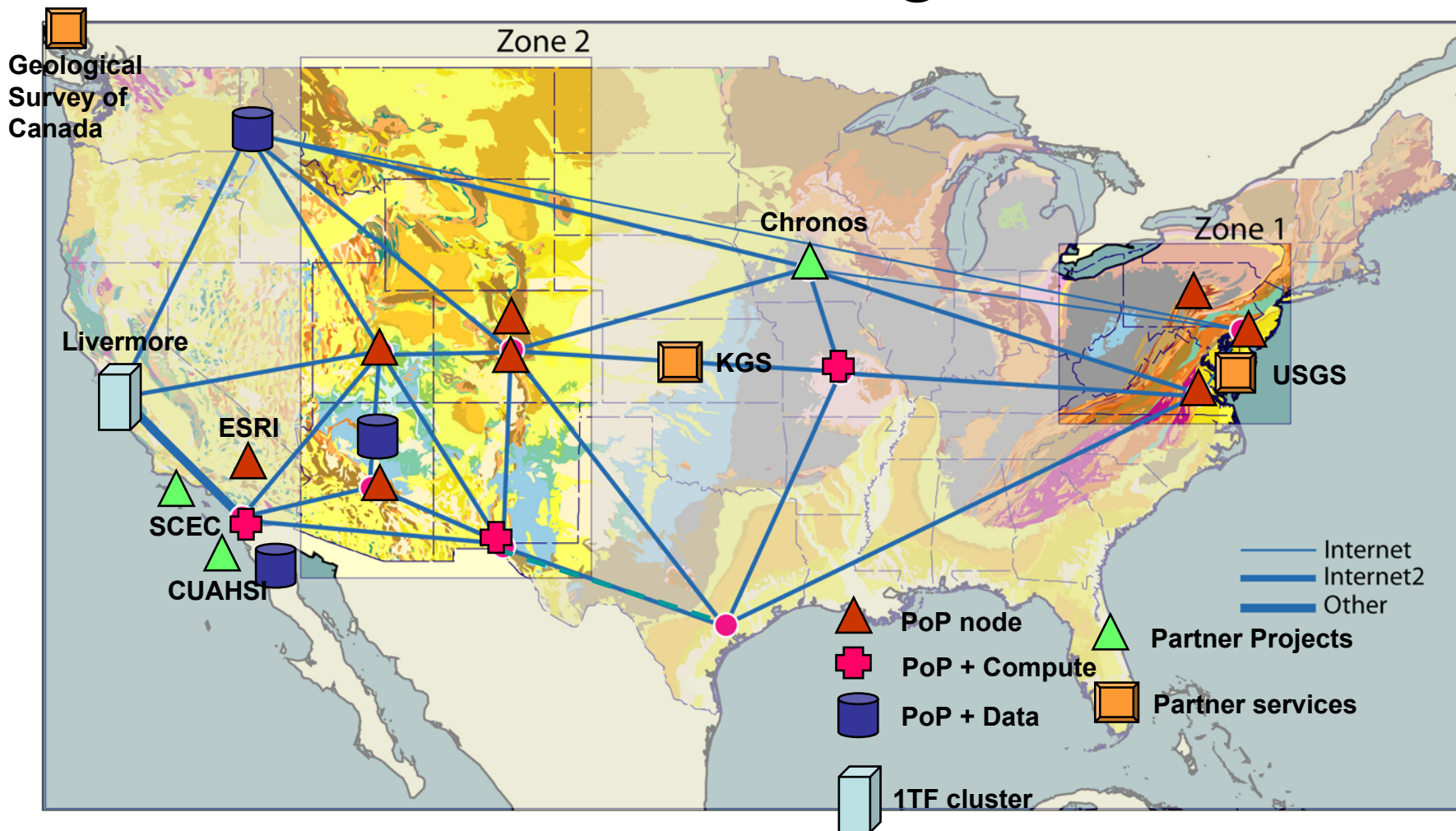
Partners

- California Institute for Telecommunications and Information Technology (Cal-(IT)²)
- Chronos
- CUAHSI
- ESRI
- Geological Survey of Canada
- Georeference Online
- IBM
- Kansas Geological Survey
- Lawrence Livermore National Laboratory
- U.S. Geological Survey (USGS)
- HP
- Other Affiliates
- Southern California Earthquake Center (SCEC), EarthScope, IRIS, NASA

IT Approach

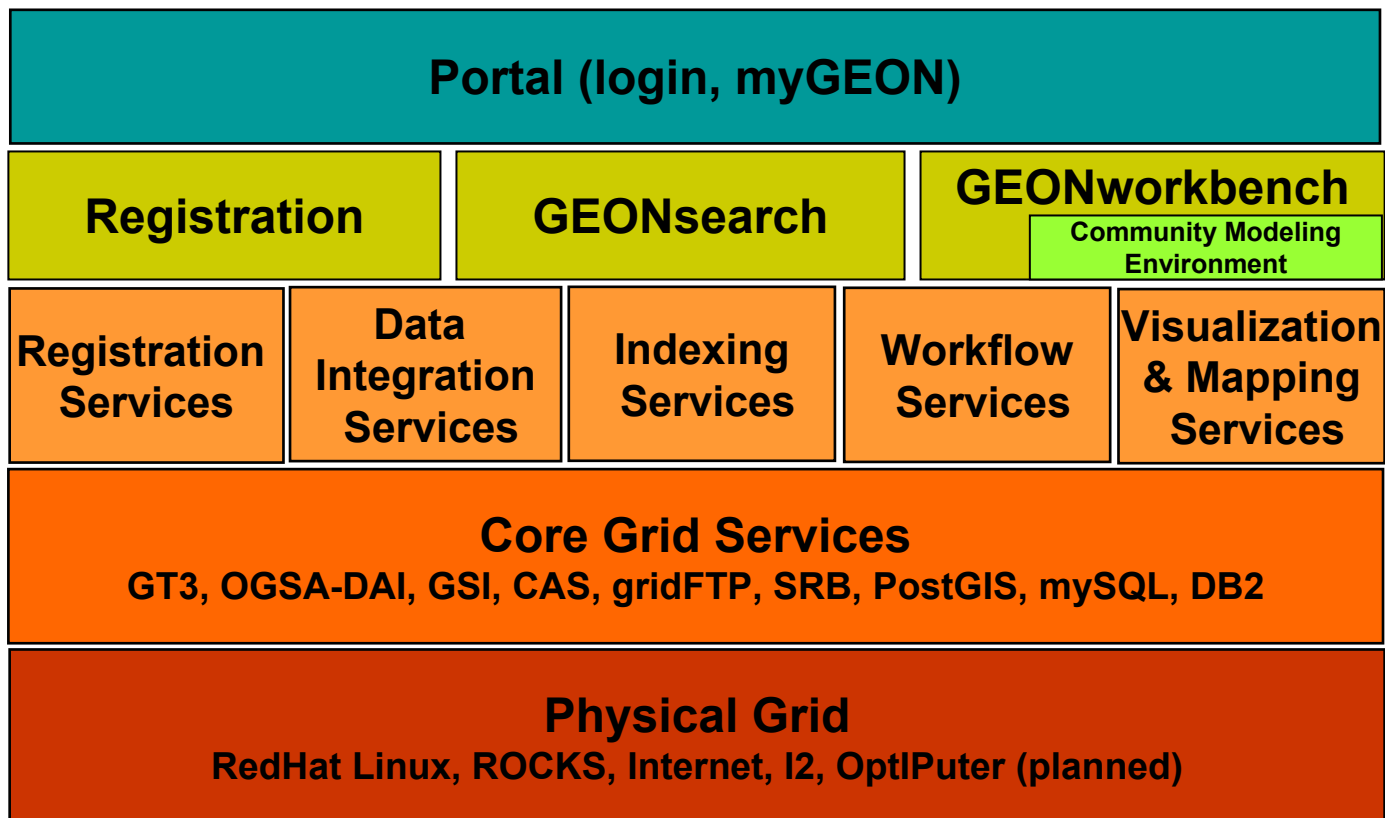
- Develop *cyberinfrastructure* to support the “day-to-day” conduct of science (*e-science*)
 - Based on a Web/Grid services-based distributed environment
- Work closely with geoscientists to help create data sharing frameworks, best practices, and useful and usable capabilities and tools
- The “two-tier” approach
 - Use best practices, including commercial tools,
 - while developing advanced technology in open source, and doing CS research
- Leverage from other intersecting projects

The GEONgrid



- Grid Systems and Portal – Dr. Karan Bhatia, SDSC

GEONgrid Software Layers



GEON Database Projects

GEON PIs:

- Geologic maps (Mid-Atlantic, multiple scales; detailed)
- Geochemical analyses of igneous rocks
- Map of all faults in the mid-Atlantic testbed
- Geologic maps with metamorphic information (Mid-Atlantic)
- Data sets of P-T time
- Sedimentary and Paleontological databases (Global)
- ASTER webservices
- USGS (DEM, 30m, 1/3, 1/9), direct access; equivalent hydrologically-corrected versions, imagery (W. US)
- Physical properties of rocks (General)
- Gravity data (Continental US)
- Magnetic data (Continental US)
- Lithospheric structure models (W. US)
- Regional-scale (1:1,000,000) geology and geophysical data sets from Cornell
- Reconciled geologic maps of a portion of the Northern Rocky Mountains
- Tectonic map of the same region, also DEM, gravity, magnetic, etc.)
- GPS data products, global strain rate
- Updated seismicity data for Colorado region
- Extensive Yellowstone Geologic and geophysical database
- Reference model of the western U. S. (preliminary)
- CRONOS_chronostratigraphic database

Partners:

- NATCARB webservice link
- CA Baja
 - geochronological database
 - Reconcile CA and Baja geologic maps
 - SRTM data
- NASA Goddard link
 - paleomagnetic data set, archeomagnetic data set, magnetic field models, imagery
 - New DEMs from ICESAT (LIDAR) (Global Scale), SRTM, LIDAR
- Geological Survey of Canada
 - Geologic Data
- ESRI
 - Grid service wrappers for ArcWeb Services
 - Ability to publish GEON “products” using ArcWeb Services
- CUAHSI
 - Hydrological Data
- Purdue
 - Realtime – remote sensing data, national soil database
- IRIS
 - Wave forms via Synseis, event data

GEON Cyberinfrastructure ...

**More than just about the data,
GEON is about going from
simple Queries to complex
Questions**

(a peek under the hood)

A query example: Use SQL to ask a database to show you all white wines from California with a vintage 2003.

A question: "Tell me what wines I should buy to serve with each course of the following menu. And, by the way, I don't like Sauternes." ... from W3C

This requires two databases (e.g. food and wine) and prescribed relationships between them that are defined for computers as Ontologies

Ontology

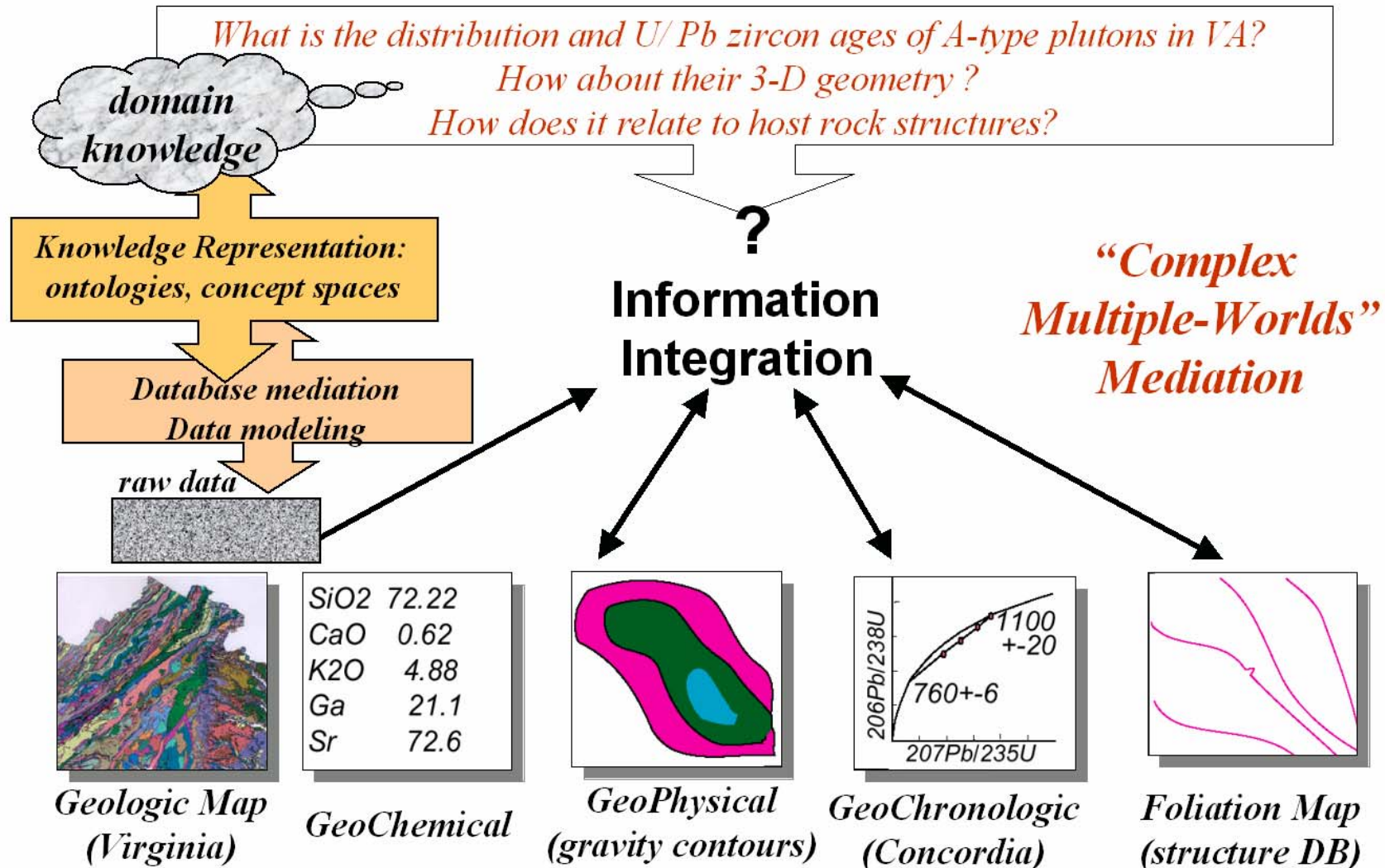
- **Q. What is an ontology? (from W3C)**
- A. Although the concept of ontology has been around for a very long time in philosophy, in recent years it has become identified with computers as a machine readable vocabulary that is specified with enough precision to allow differing terms to be precisely related.
- More precisely, from the [OWL Requirements Document](#):
- An ontology defines the terms used to describe and represent an area of knowledge. Ontologies are used by people, databases, and applications that need to share domain information (a domain is just a specific subject area or area of knowledge, like medicine, tool manufacturing, real estate, automobile repair, financial management, *food, wine* etc.). Ontologies include computer-usable definitions of basic concepts in the domain and the relationships among them [...]. They encode knowledge in a domain and also knowledge that spans domains. In this way, they make that knowledge reusable.

- GEON uses OWL the Web Ontology Language (w3C)
- OWL is designed for use by applications that need to process the content of information instead of just presenting information to humans. OWL facilitates greater machine interpretability of Web content than is supported by XML, RDF, by providing additional vocabulary along with a formal semantics.
- Code looks like:
 - `rdfs:Class rdf:ID="WINE`
 - `<rdfs:subClassOf rdf:resource="#POTABLE-LIQUID"/>`
 - `<rdfs:subClassOf> <daml:Restriction> <daml:onProperty`
`rdf:resource="#MAKER"/> <daml:minCardinality> 1 </daml:minCardinality>`
`</daml:Restriction> </rdfs:subClassOf>`
 - `rdfs:Class rdf:ID="MEAL-COURSE
rdf:resource="#CONSUMABLE-THING"/> <rdfs:subClassOf>
<daml:Restriction> <daml:onProperty rdf:resource="#FOOD"/>`

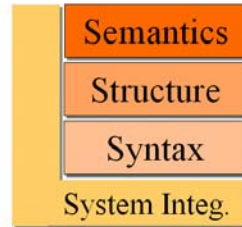
Current GEON Ontology Efforts

- Formal ontology of plutons
 - Taxonomy for textures and shapes of plutons
 - Informal ontology for processes as they effect igneous rocks
 - Metamorphic ontology
 - Preliminary ontology for structural geology
-
- Ontologies are being developed through a series of workshops. There will also be resources at the GEON Portal to allow for submission of new ontologies and toolkits to help develop them.

The Problem: Scientific Data Integration or: ... from Questions to Queries ...



Information Integration Challenges: *S⁴ Heterogeneities*



- **Systems Integration**

- platforms, devices, data & service distribution, APIs, protocols, ...
- ➔ **Grid middleware technologies**
- + e.g. single sign-on, platform independence, transparent use of remote resources, ...

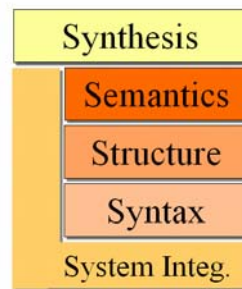
- **Syntax & Structure**

- heterogeneous data formats (*one for each tool ...*)
- heterogeneous data models (*RDBs, ORDBs, OODBs, XMLDBs, flat files, ...*)
- heterogeneous schemas (*one for each DB ...*)
- ➔ **Database mediation technologies**
- + XML-based data exchange, integrated views, transparent query rewriting, ...

- **Semantics**

- fuzzy metadata, terminology, “hidden” semantics, implicit assumptions, ...
- ➔ **Knowledge representation & semantic mediation technologies**
- + “smart” data discovery & integration
- + e.g. ask about **X** (**‘mafic’**); find data about **Y** (**‘diorite’**); be happy anyways!

Information Integration Challenges: *S⁵ Heterogeneities*



- **Synthesis** of analysis pipelines, integrated apps & data products, ...
 - How to make use of these wonderful things & put them together to solve a scientist's problem?

→ Scientific Problem Solving Environments

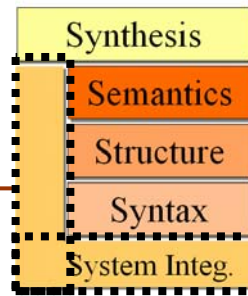
→ GEON Portal and Workbench (“scientist’s view”)

- + ontology-enhanced data registration, discovery, manipulation
- + creation and registration of new data products from existing ones, ...

→ GEON Scientific Workflow System (“engineer’s view”)

- + for designing, re-engineering, deploying analysis pipelines and scientific workflows; ***a tool to make new tools ...***
- + e.g., creation of new datasets from existing ones, dataset registration,...

A Prerequisite: Resource Registration



- **(1) Register ontologies**
 - geologic age; rock classifications (GSC, BGS), seismology; ...
- **(2) Register Dataset (myShapeFiles.zip)**
- **(3) Perform Item-level dataset registration (1 ⇔ 2)**
 - ADN metadata; other controlled vocabularies & ontologies (e.g. geologic age timescale (USGS), SWEET (NASA), ...)
- **Use ontology-based query UI / application at GEON Portal**
 - e.g. query by **geologic age** and **chemical composition**

Dataset to Ontology Registration (Item-level)

The image shows a screenshot of the GEON grid portal in a Microsoft Internet Explorer browser window. The page is titled "Registering Datasets to Ontologies Item Level". The registration process is divided into two main sections: "New Resource Registration" and "Mapping Resource to Ontology".

Annotations:

- A cloud labeled "Domain Knowledge Ontologies" is connected by a dashed line to a cylinder labeled "Arizona".
- A red circle highlights the "New Resource Registration" section, which includes a dropdown menu for "Choose a dataset type:" set to "Shapefile" and a "GO" button.
- A red circle highlights the "Mapping Resource to Ontology" section, which includes fields for "Dataset ID:" (GEON-25dfb3db-e710-11d8) and "Ontology ID:" (GEON-01bfac9a-e7c2-11d8), and radio buttons for "item-level" (selected) and "item-detail".
- A red circle highlights the "Selected Ontology" section, which includes "Ontology Name: Basic Numerics", "Data Format: OWL", and a description: "This defines numeric related concepts and properties.".
- A red circle highlights the "Selected Dataset" section, which includes "Title: Arizona Geology Map", "Format: shapefile", "Spatial Coverage: North: 37 East: -109.04 South: 31.33 West: -114.82", "Temporal Coverage: from 0.0 ma to 0.0ma", and "Description: This is a geology map of Arizona in USA.".
- A dashed line connects the "Selected Ontology" section to the "Selected Dataset" section.
- A dashed line connects the "Selected Dataset" section to a dropdown menu in the "This dataset" field, which is set to "has instances of" and "the selected class".

Domain Knowledge Ontologies (Left Panel):

- age: Carboniferous
- age: Permian
- age: Ufimian
- epoch: Rotliegendes
- age: Kingurian
- age: Artinskian
- age: Sakmarian
- age: Asselian
- period: Carboniferous
- sub-period: Pennsylvanian
- epoch: Gzelian
- age: Noginskian
- age: Klazminskian
- epoch: Kasimovian
- age: Dorogomilovskian
- age: Chamovnicheskian
- age: Krevyakinskian
- epoch: Moscovian
- age: Myachkovskian
- age: Podolskian
- age: Kashirskian
- age: Vereiskian
- epoch: Bashkirian
- age: Melekesskian
- age: Gzhel
- age: Gzhel
- age: Gzhel
- age: Gzhel
- age: Gzhel
- sub-period: Mississippian
- epoch: Serpukhovian
- age: Alportian
- age: Chokierian

GEON Search: Concept-based Querying

GEONgrid Portal - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address <http://geon01.sdsc.edu:8181/gridsphere/gridsphere?cid=Geon+Search&JavaScript=en&> Go Google

Welcome Administration **GEONsearch** GEONworkbench GeoScience GEON EOT GEON Systems GEONdocs GEONforums UserProfile

Home **Geon Search** GEON Ontology Geon Data Registration

GEON Search

1 Metadata Related:

Choose resource type:
<All Resource Types>


Choose subjects:
<All Subjects>

Optional keywords:

2 Spatial Coverage:

Type a place name:
 GO

or select an area on the map:



3 Temporal Coverage:

☒ any ☐ present ☐ geologic time

4 Ontology Related: [reset]

Choose an ontology:

Choose a concept:

Choose a relation:

Select a Subject to Show Resources

Biological oceanography	Chemical oceanography	Cryology
Ecology	Environmental science	Forestry
Geochemistry	Geologic time	Geology
Geophysics	Human geography	Hydrology
Mineralogy or petrology	Natural hazards	Paleontology
Physical geography	Physical oceanography	Soil science
Structural geology	Technology	

Resources in Geology 1-2 of 2 files

Title: Arizona Geology Map
Format: shapefile
Dataset Id: GEON-25dfb3db-e710-11d8-b226-ab22ed7681c0
Spatial Coverage: North: 37 East: -109.04 South: 31.33 West: -114.82
Temporal Coverage: any
Description: This is a geology map of Arizona in USA.
Relations: This dataset
has instances of ComplexUnit;
has instances of Rectangle;

[View All Metadata](#) [View Map](#) [Download](#)

Title: Utah Geology Map
Format: shapefile
Dataset Id: GEON-a23f4596-e713-11d8-98eb-5dc7f8d37f79
Spatial Coverage: North: 42 East: -109.04 South: 37 West: -114.05
Temporal Coverage: any
Description: This is a geology map of Utah in USA.

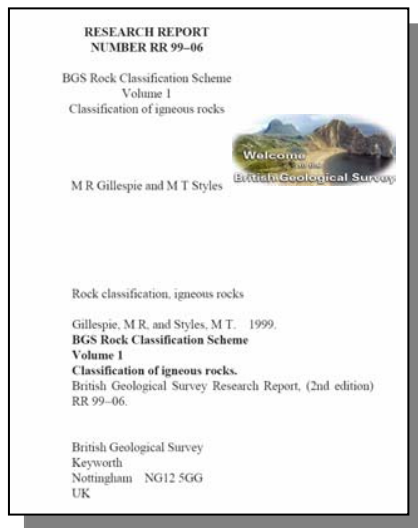
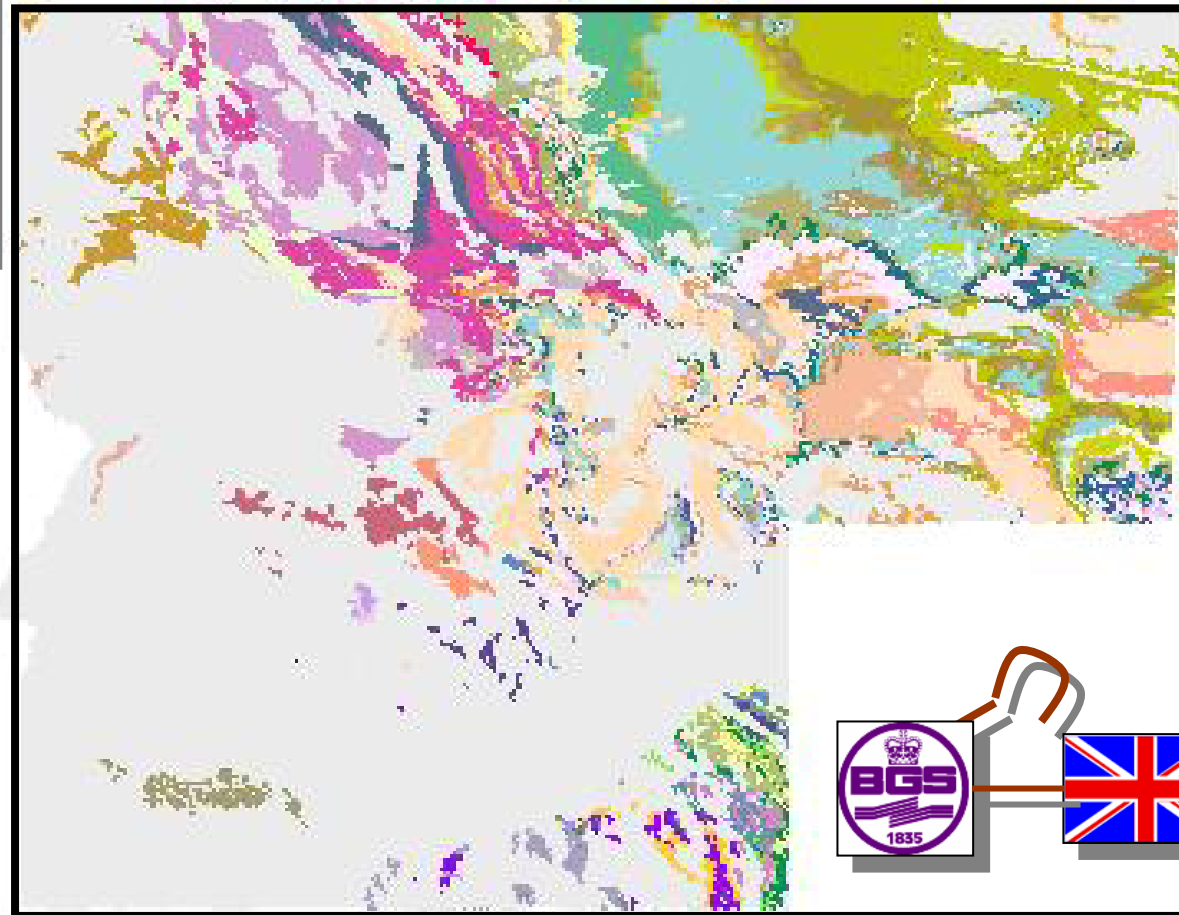
[View All Metadata](#) [View Map](#) [Download](#)

Sedimentary Rocks: BGS Ontology

GeologicAge:
Any

RockAndSediment:
-SedimentAndSedimentaryRock

Query



Sedimentary Rocks: GSC Ontology

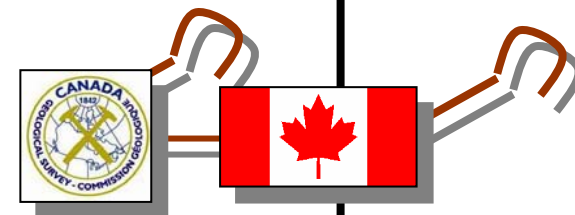
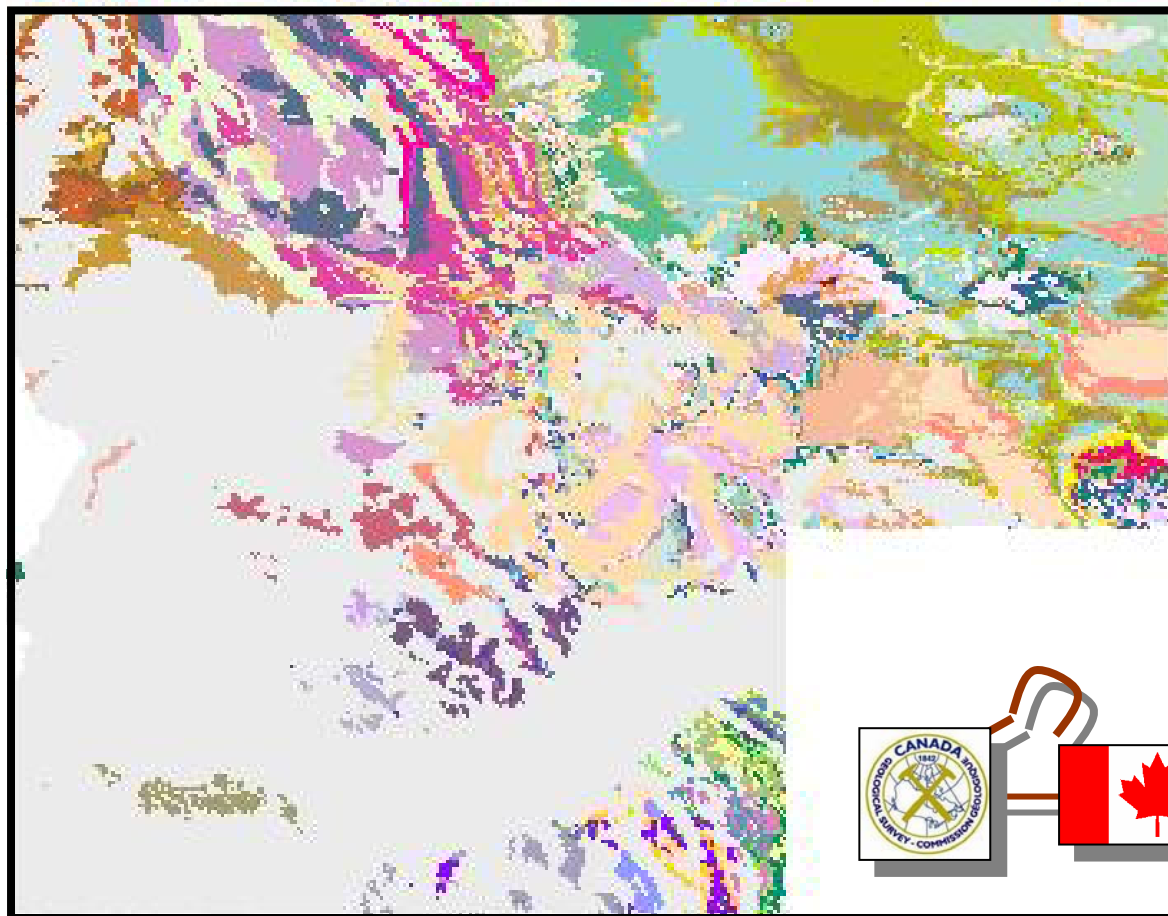
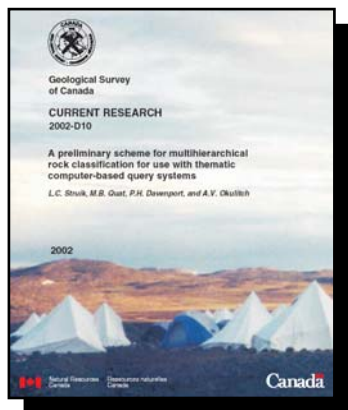
GeologicAge:

Genesis:

Composition:

Fabric:

Texture:



GEON Portal...

A UNAVCO example of a one approach to go from data to visualization (3-D)

UNAVCO/GEON PoP

Access to UNAVCO/GEON resources provided via the GEONgrid Portal



GEONgrid Portal

GEON CYBERINFRASTRUCTURE FOR THE GEOSCIENCES

Welcome charles meertens: [Logout](#)

[GEONsearch](#) [GEONworkbench](#) [GEONscience](#) [GEON EOT](#) [GEON Systems](#) [GEONdocs](#) [GEONforums](#) [UserProfile](#)

[Home](#) [Rockies Test Bed](#) [Mid Atlantic Test Bed](#) [GEON SYNSEIS](#) [Earth History](#) [NAVDAT](#)

UNAVCO

UNAVCO CYBERINFRASTRUCTURE FOR THE GEOSCIENCES

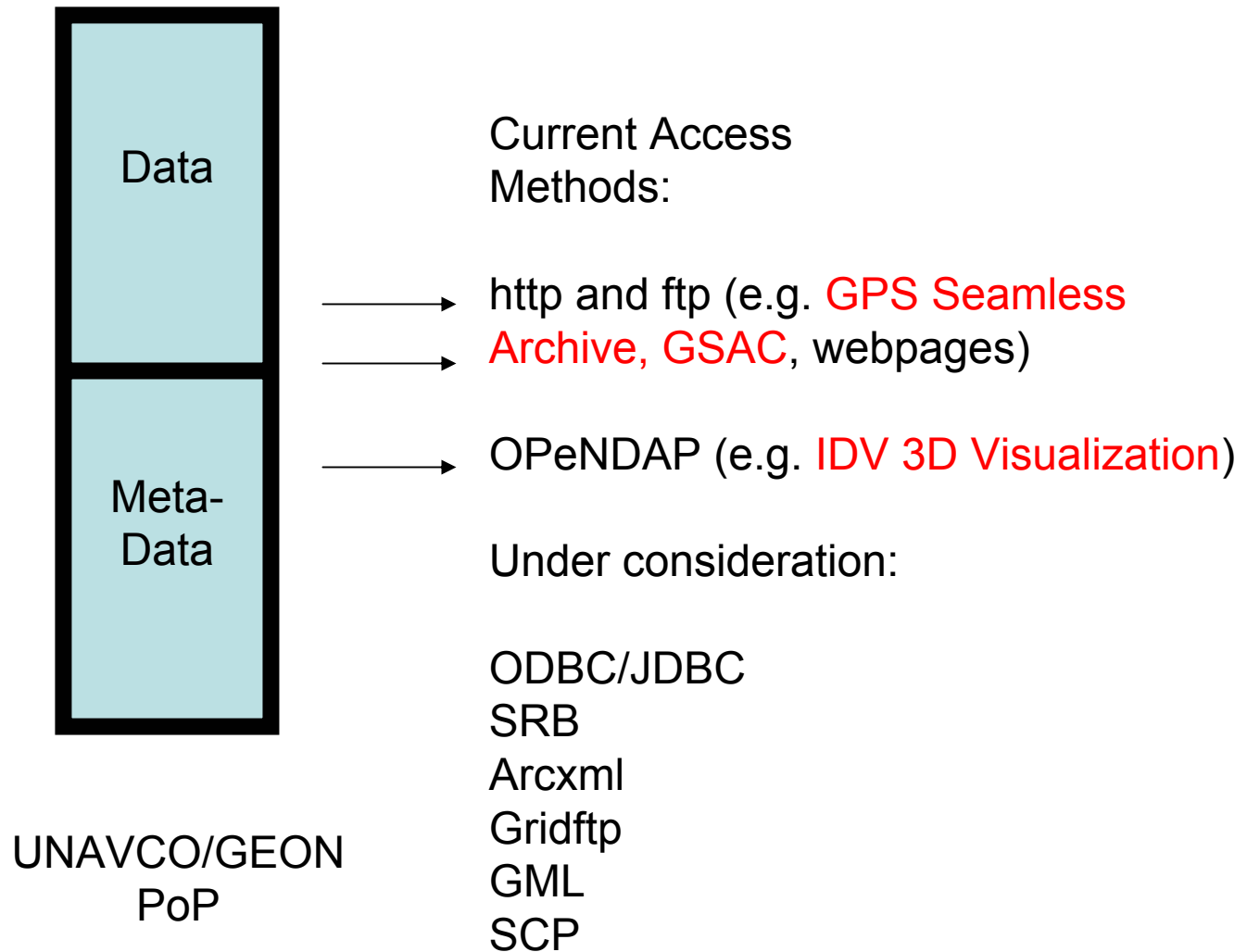
[Home](#) | [Overview](#) | [Data and Products](#) | [Visualization](#) | [Research](#) | [Education and Outreach](#)

GEON work at UNAVCO

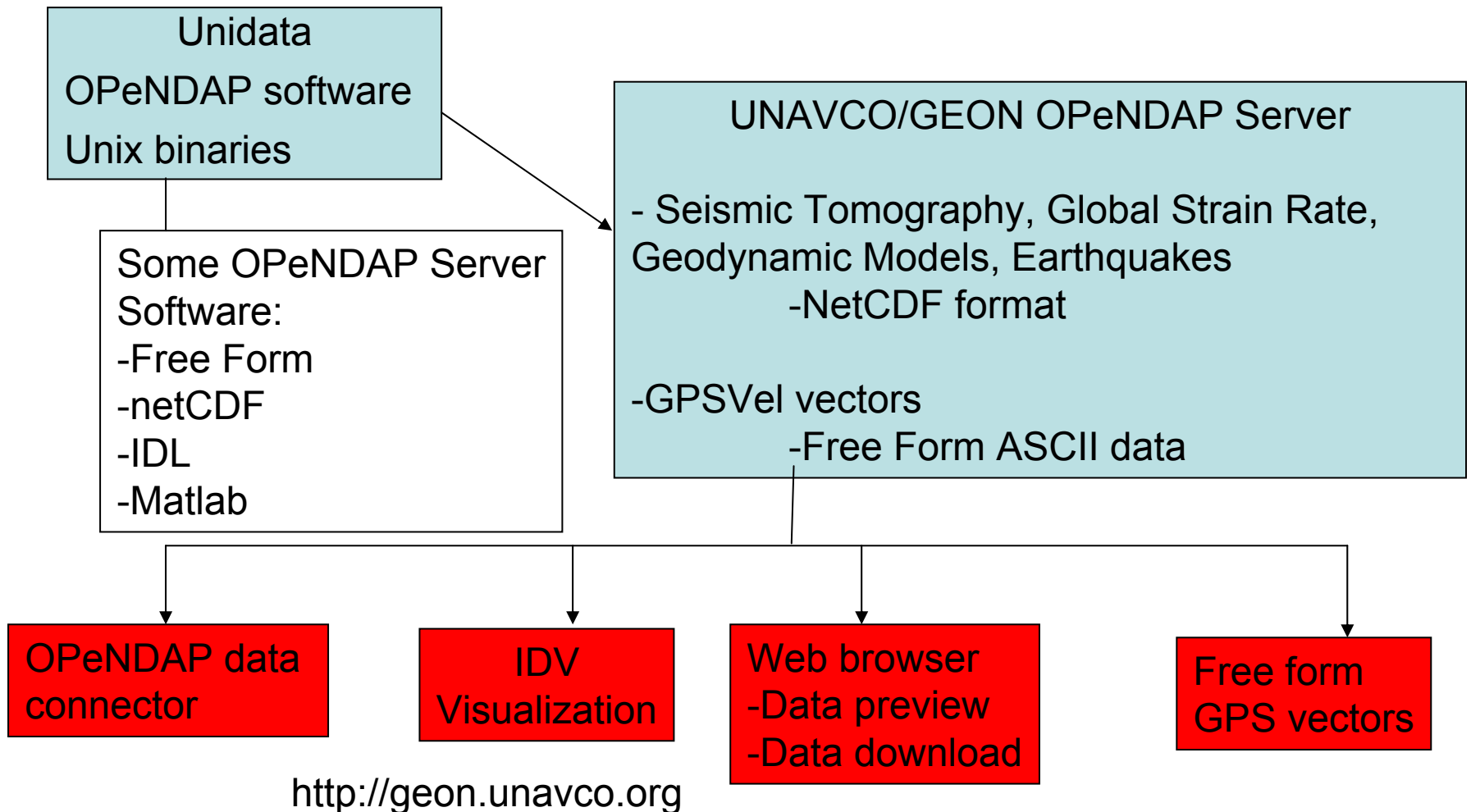
This website has been compiled for the GEON work currently underway at the UNAVCO Boulder, Colorado facility. Dr. Charles Meertens is the UNAVCO principal investigator of the GEON project in the areas of Geodynamics, GPS vector database creation, strain modeling, and active tectonics. Working with him is Greg Bensen, a graduate research assistant and geophysics graduate student in the Department of Geologic Sciences at the University of Colorado, Boulder. For a more complete list of those involved, see our people page.

This image was made with the the Integrated Data Viewer. It shows two S-wave tomography models, GPS plate motion vectors and the Global Strain Rate Map. [\[click image to enlarge\]](#)

UNAVCO Data Access Methods

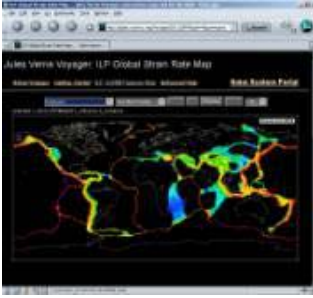

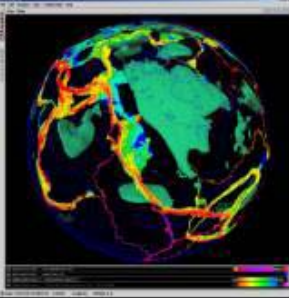
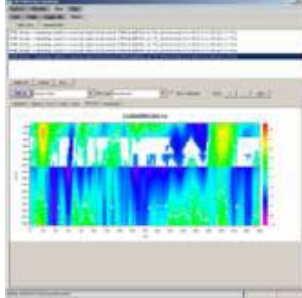
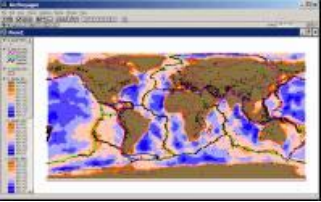


UNAVCO/GEON OPeNDAP Server



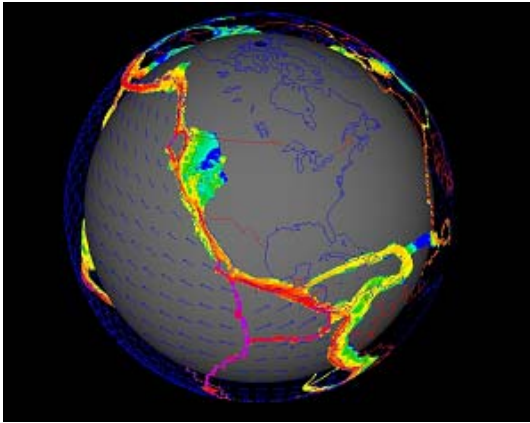
Data Visualization

Same data or model => many uses ...but currently
same data + graduate students => fewer uses!

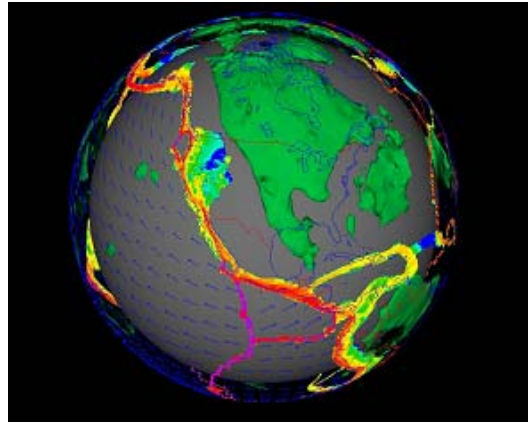
				
<p>Jules Verne Voyager</p> <p>Java Applet -> GMT Server</p> <p>Versions:</p> <ul style="list-style-type: none"> Voyage to Earth Voyage to the Solar System Global Strain Rate Map (GSRM, Kreemer, et. al. 2003). 	<p>Jules Verne Voyager, Jr.</p> <p>EarthScope Voyager, Jr.</p> <p>Javascript -> data server</p> <p>Shown are the velocities from the GSRM and planned EarthScope sites.</p>	<p>Interactive Data Viewer (IDV)</p> <p>Global and Map versions</p> <p>Java Application -> OPeNDAP Server</p> <p>Shown are S-wave anomaly isosurfaces of Ritzwoller, et. al. 2002 and the GSRM strain rates using the Global IDV.</p>	<p>OPeNDAP Data Connector</p> <p>C application -> OPeNDAP Server</p> <p>Shown is the S-wave velocity model converted to netCDF files.</p>	<p>ArcVoyager, ArcMap</p> <p>ESRI Application</p> <p>DLESE/GEON, with UNAVCO contributions, is building an education module for the Earth Exploration Toolkit</p>

IDV Visualization

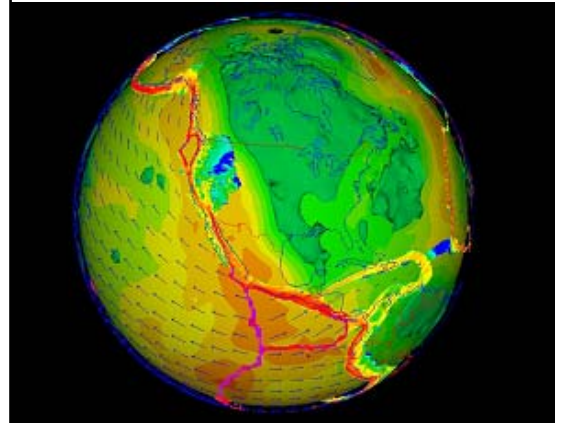
An example of an end-to-end solution: data/models -> NetCDF -> OPeNDAP server -> Visualization & Collaboration (developed by UNIDATA using U. of Wisc. VISAD)



Color contours of the second invariant of the **strain rate** tensor (blue to red show low to high strain rate). Blue arrows indicate global **plate motion** from with respect to the North American Plate. Results are from the UNAVCO-supported Global Strain Rate Map (GSRM) project (Kreemer, et al. 2003).



Isosurfaces of 5% positive **S-wave anomalies** (green surfaces) in the upper mantle from a global tomographic model of Ritzwoller, et. al. 2002. The higher velocity regions are typically associated with colder denser regions underlying continental interiors such as the Canadian shield.



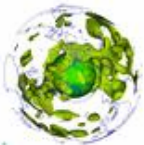
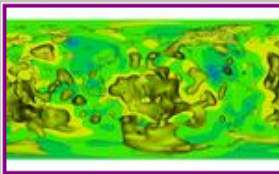
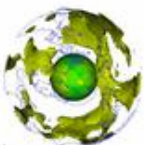
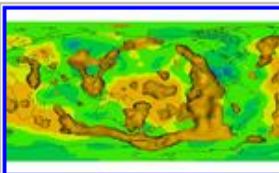

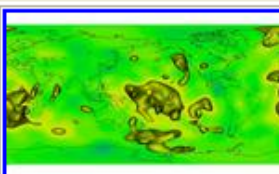

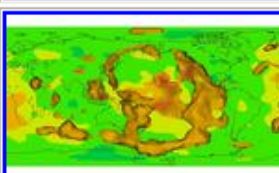
All data from the above figures shown together with a color contour surface of the S-wave anomalies at 100 km depth. The IDV has powerful capabilities to show integrated views of volume and surface data. There is a clear correlation between areas of high strain rate and low S-wave velocities in the upper mantle under W. North America and the east Pacific rise

Data Visualization

Example: Mantle Tomography with IDV

Example data on UNAVCO/GEON node and IDV xml configuration files simplify getting started with the IDV

Metadata embedded in NetCDF file is returned from the OPenDAP Server in response to URI

Data	Globe Picture	Globe IDV File	Map Picture	Map IDV File
BK 2 Degree		IDV File		IDV File
BK 4 Degree		IDV File		IDV File
CA 2 Degree		IDV File		IDV File
CA 4 Degree		IDV File		IDV File

Action:

Data URL:

Global Attributes:

title: "Global shear wave tomography model from CalTech on a 4 degree grid"
 record: "Caltech (S20K2): Ritsema, J., and van Heijst, R.-J., 2000. 'Seismic imaging of structural heterogeneity in Earth's mantle: Evidence for large-scale mantle flow', Science Progress, 83,

Variables: ☐ vel: Grid
 lev: lat: lon:
 long_name: "Vs perturbation (% deviation from layer mean)"
 precision: 5

☐ lat: Array of 16 bit Integers [lat = 0.89]
 lat:
 long_name: "Latitude"
 actual_range: -09, 09
 units: "degrees_north"

☐ lon: Array of 16 bit Integers [lon = 0.180]
 lon:

IDV Visualization

Mantle Geodynamics: Convection with geologic plate motions over 120 m.a.

Purpose: "resolving multiple scale (both temporal and spatial) physics in mantle convection and lithospheric deformation"

scale: "whole mantle with plates"

resolution: "~40-50 -km, spherical geometry"

method: "Numerical (finite element)"

material_properties: "temperature and depth dependent viscosity (linear, no elasticity)"

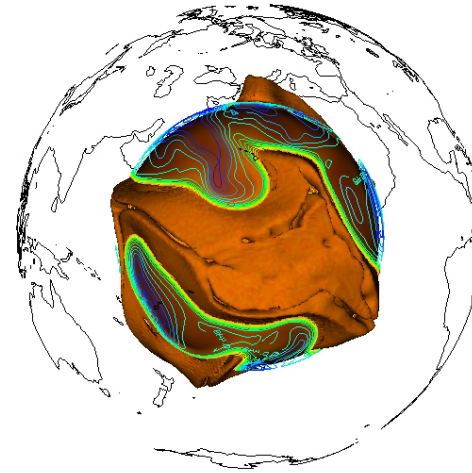
code: "CitcomS [Zhong, Zuber, Moresi and Gurnis, 2000], 5000 time steps, over 4 million nodes!"

output: "normalized thermal and composition structure of the mantle from convection"

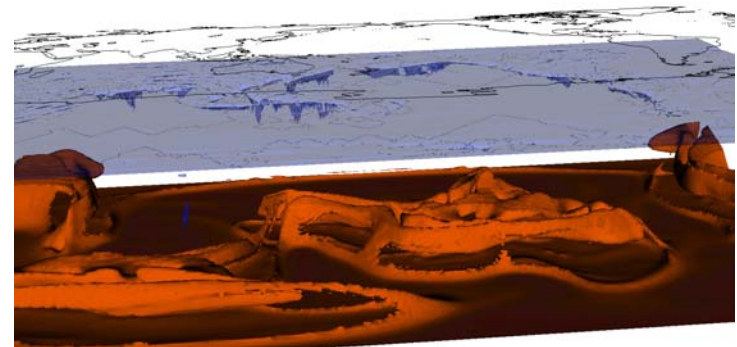
credits: "McNamara and Zhong (2004) - Allen McNamara and Shijie Zhong"

location: "Department of Physics at University of Colorado at Boulder, Campus box 390 Boulder Co, 80309-0390 USA"

website: "<http://anquetil.colorado.edu/szhong>"



Mantle Temperature



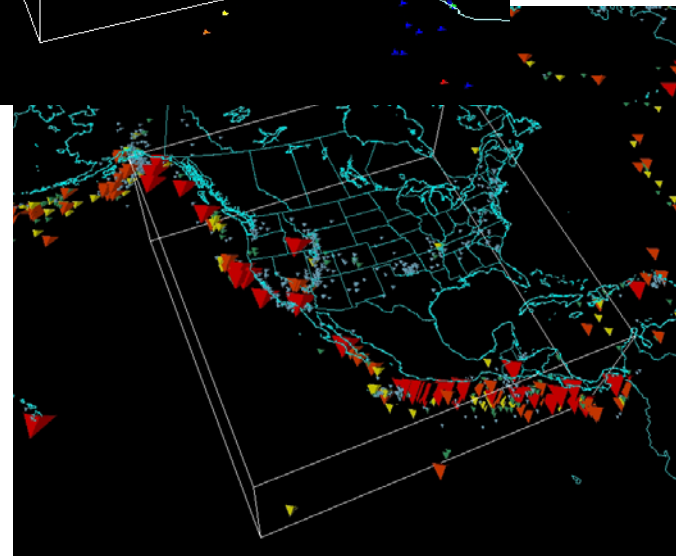
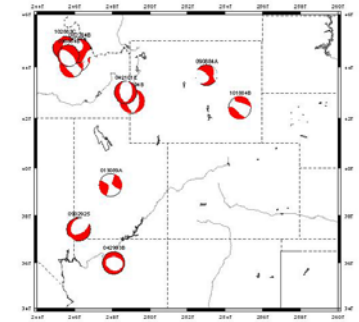
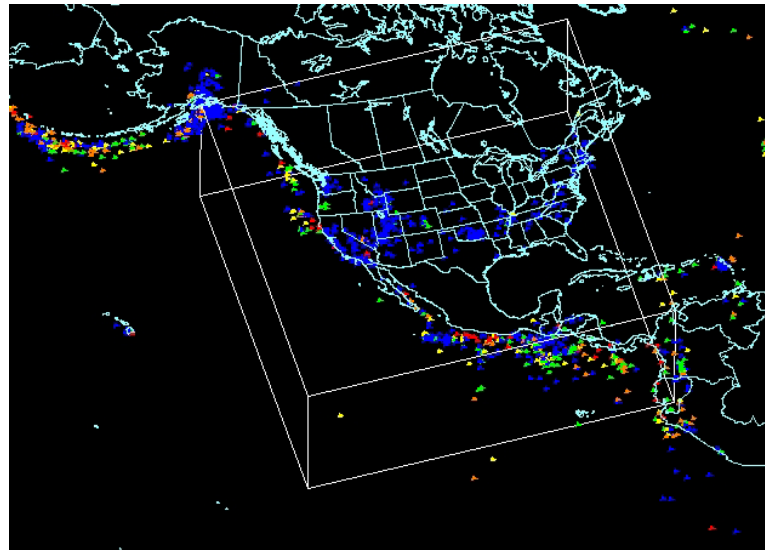
IDV Visualization

UNAVCO/GEON Enhancements to UNIDATA's Java Code

UNAVCO is adding new
features to UNIDAT's IDV

(Dr. Stuart Wier, under
contract to UNAVCO)

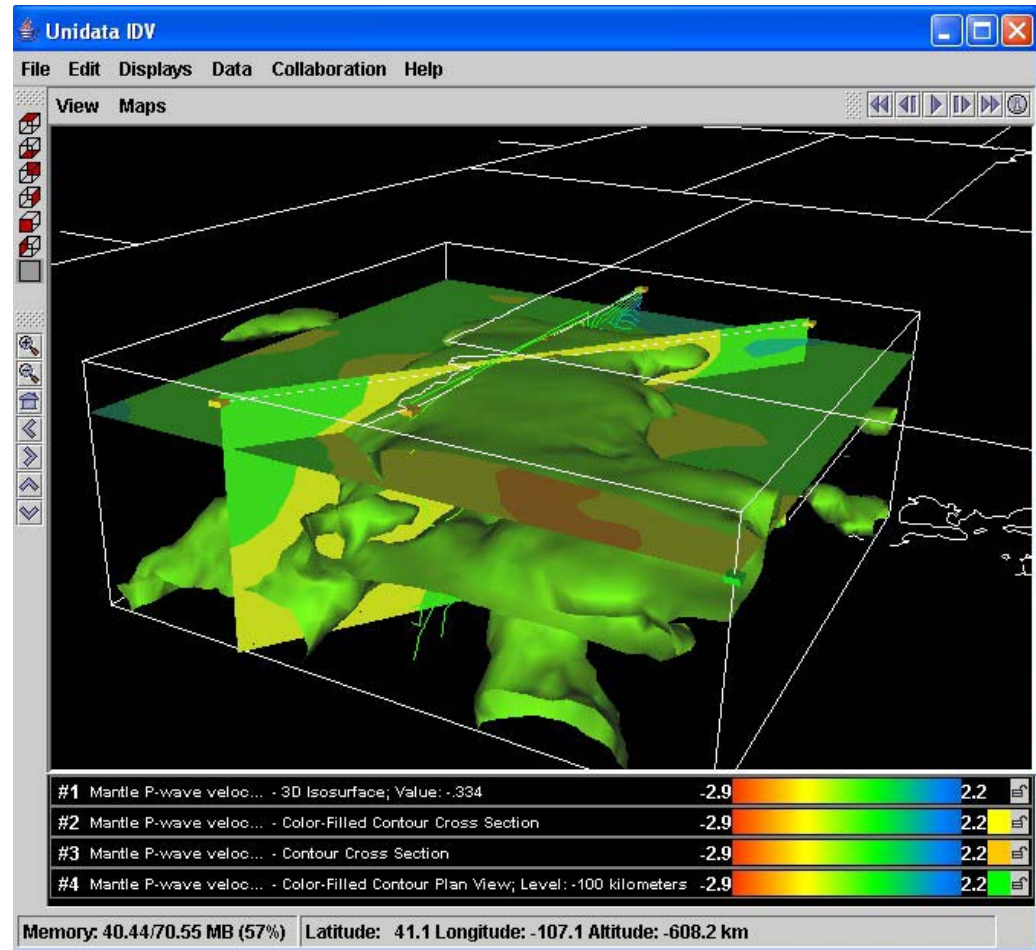
- Earthquakes
(done)
- GPS vectors with
error ellipses
- Earthquake focal
mechanisms
- Customize
interface for earth
science users



The IDV Interactive Dataviewer developed by Unidata using U. of Wisc. VisAD java platform

**Shear wave
topography of the
Yellowstone plateau.
The IDV allows the user
to make cross-
sections, probe the
data, and to make 3-D
isosurfaces of constant
velocity anomaly.**

**From M. Jordan and R.
Smith, U. of Utah – new
research, 2004**

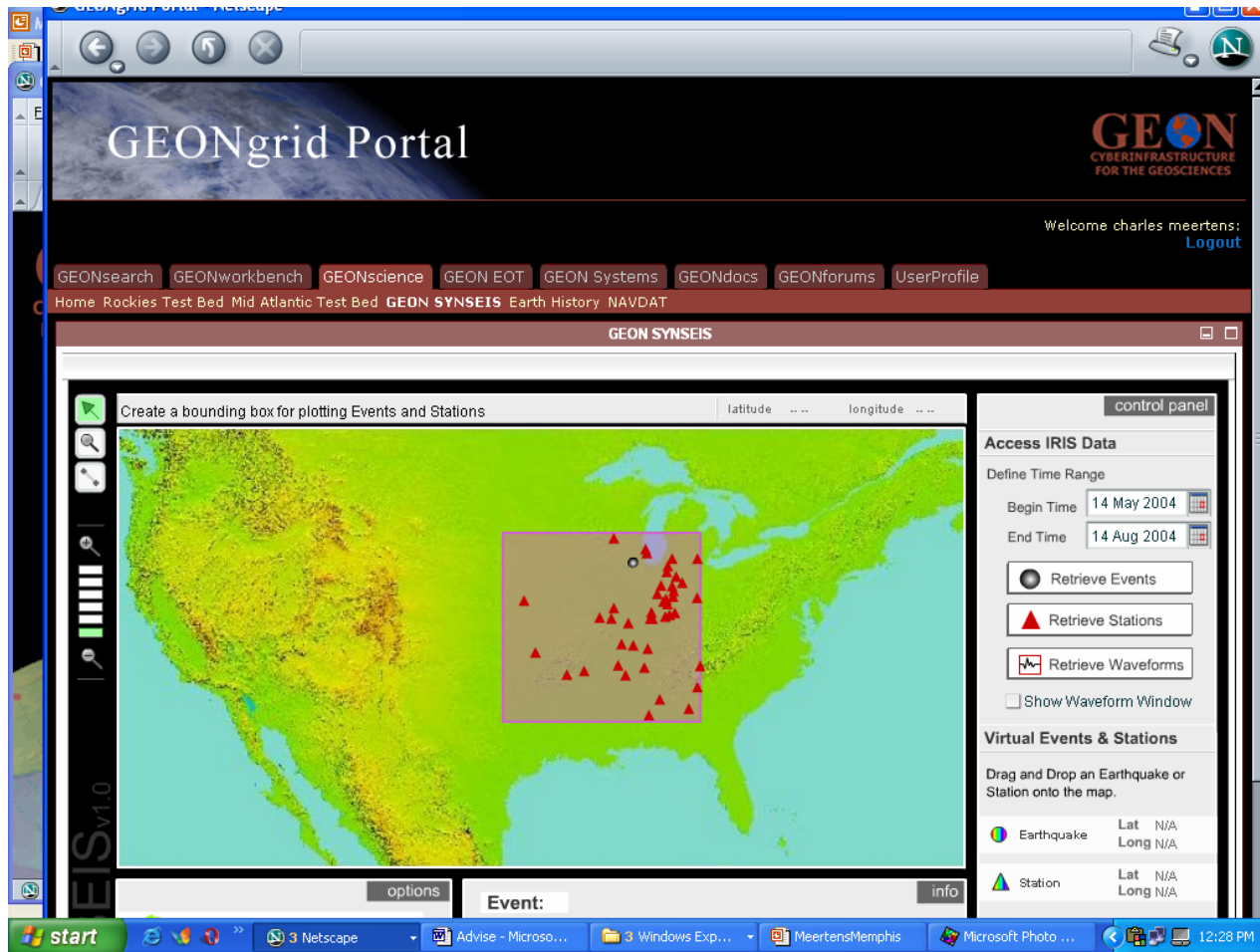


GEON Portal - SYNSEIS

**An example of an integrated
computational tool using
distributed Grid resources.**

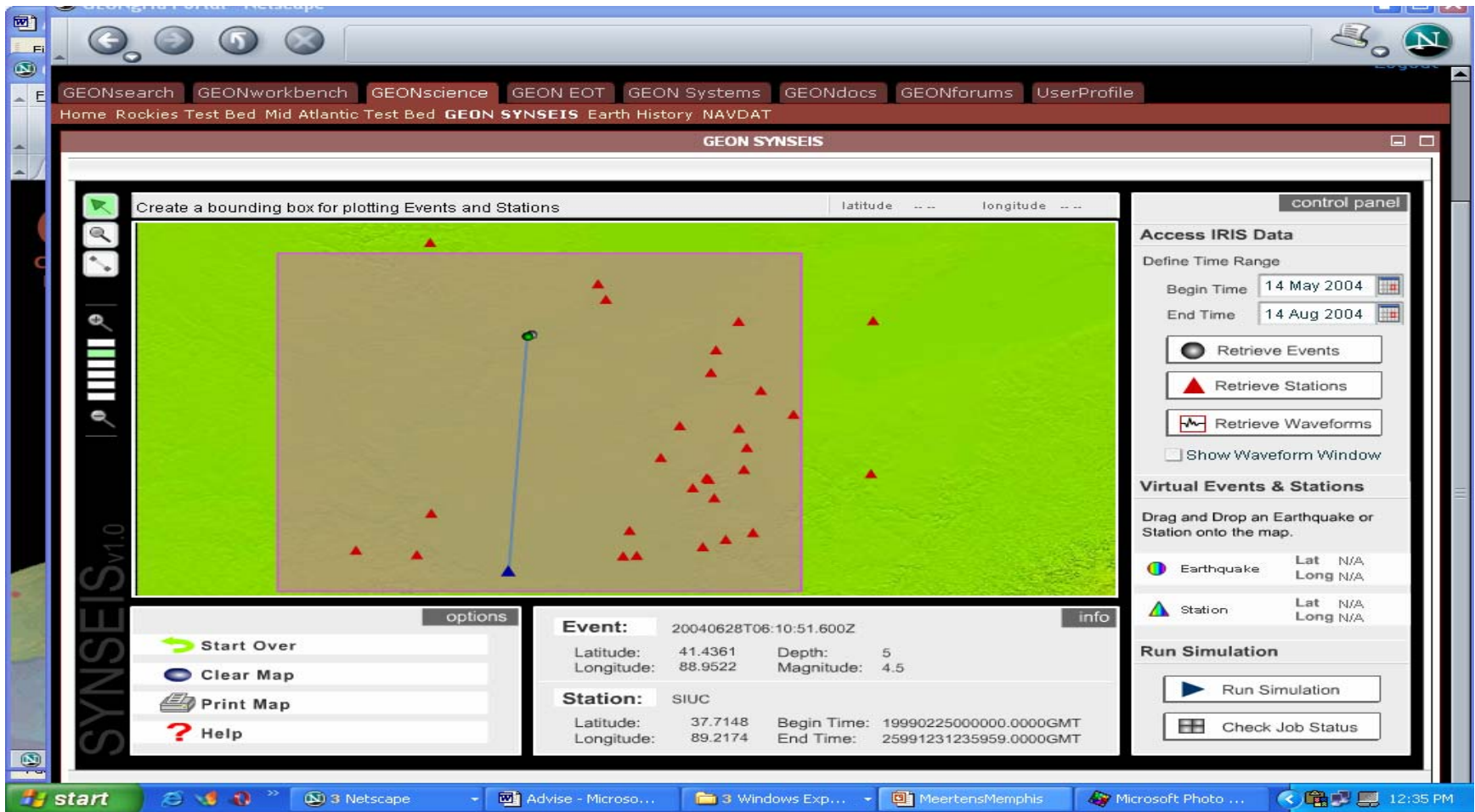
GEON Synseis Example

Log into Geon Portal and select region (shown is Mid Continent)



Synseis effort headed by Dogan Seber

Select time window, then specific earthquake and station pair
(Example from June, 2004)



The screenshot shows the GEON SYNSEIS web application running in a Netscape browser. The browser's address bar shows the URL: <http://geon.synseis.org>. The application's navigation bar includes links to GEONsearch, GEONworkbench, GEONscience, GEON EOT, GEON Systems, GEONdocs, GEONforums, and UserProfile. The main content area is titled "GEON SYNSEIS" and features a map with a bounding box for plotting events and stations. The map shows a green background with a brown rectangular bounding box. Inside the bounding box, there are several red triangles representing stations and a blue line representing an event. The control panel on the right allows users to define a time range (Begin Time: 14 May 2004, End Time: 14 Aug 2004) and retrieve data (Events, Stations, Waveforms). The bottom section displays details for a specific event (20040628T06:10:51.600Z) and a station (SIUC).

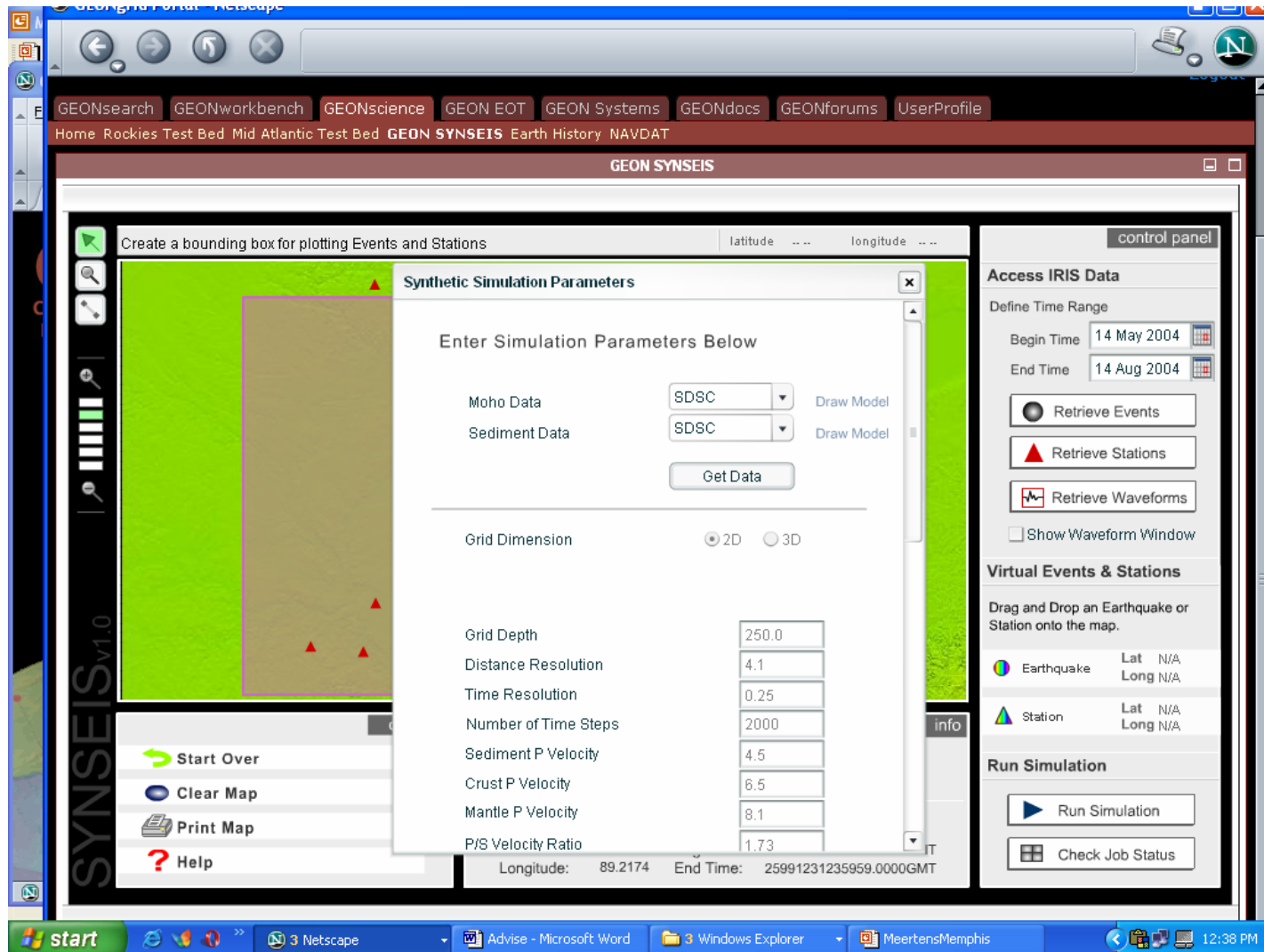
Event: 20040628T06:10:51.600Z

Latitude:	41.4361	Depth:	5
Longitude:	88.9522	Magnitude:	4.5

Station: SIUC

Latitude:	37.7148	Begin Time:	19990225000000.0000GMT
Longitude:	89.2174	End Time:	25991231235959.0000GMT

Select crustal velocity model



GEON SYNSEIS

Create a bounding box for plotting Events and Stations

Synthetic Simulation Parameters

Enter Simulation Parameters Below

Moho Data: [Draw Model](#)

Sediment Data: [Draw Model](#)

[Get Data](#)

Grid Dimension: ☒ 2D ☐ 3D

Grid Depth:

Distance Resolution:

Time Resolution:

Number of Time Steps:

Sediment P Velocity:

Crust P Velocity:

Mantle P Velocity:

P/S Velocity Ratio:

Longitude: 89.2174 End Time: 25991231235959.0000GMT

control panel

Access IRIS Data

Define Time Range

Begin Time: [Calendar](#)

End Time: [Calendar](#)

[Retrieve Events](#)

[Retrieve Stations](#)

[Retrieve Waveforms](#)

☐ Show Waveform Window

Virtual Events & Stations

Drag and drop an Earthquake or Station onto the map.

	Lat	Long
Earthquake	N/A	N/A
Station	N/A	N/A

Run Simulation

[Run Simulation](#)

[Check Job Status](#)

[Start Over](#)

[Clear Map](#)

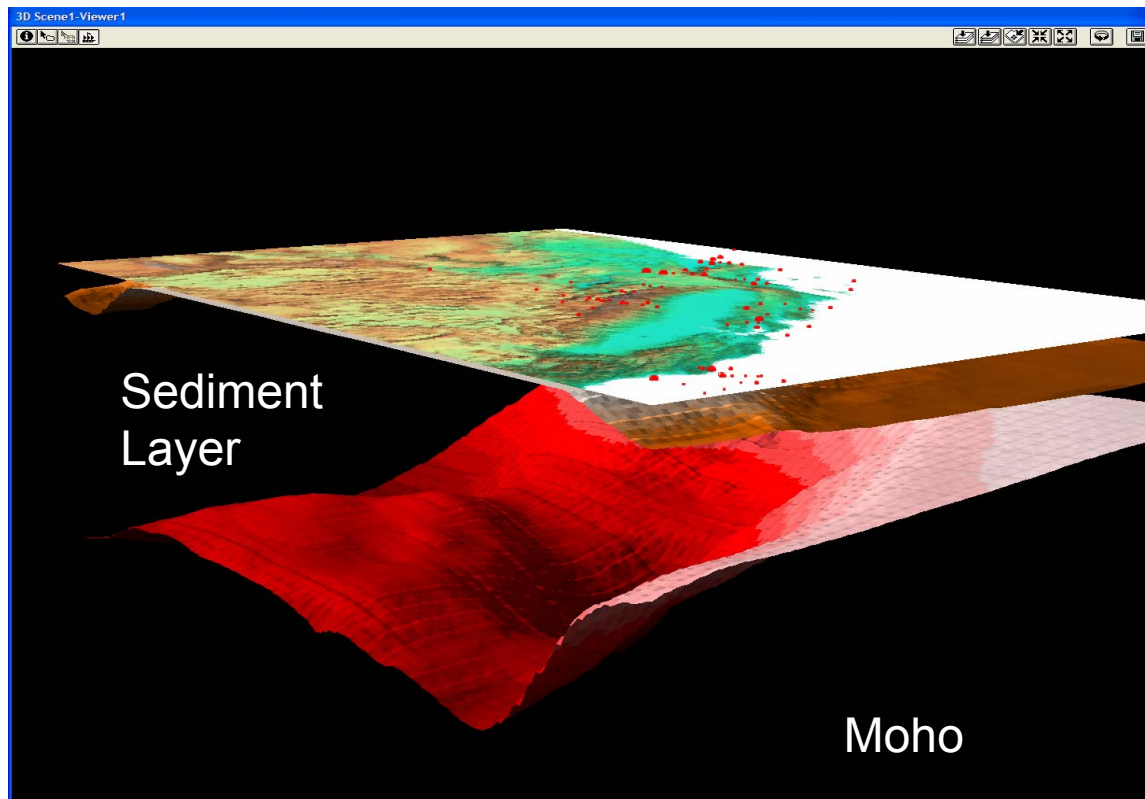
[Print Map](#)

[Help](#)

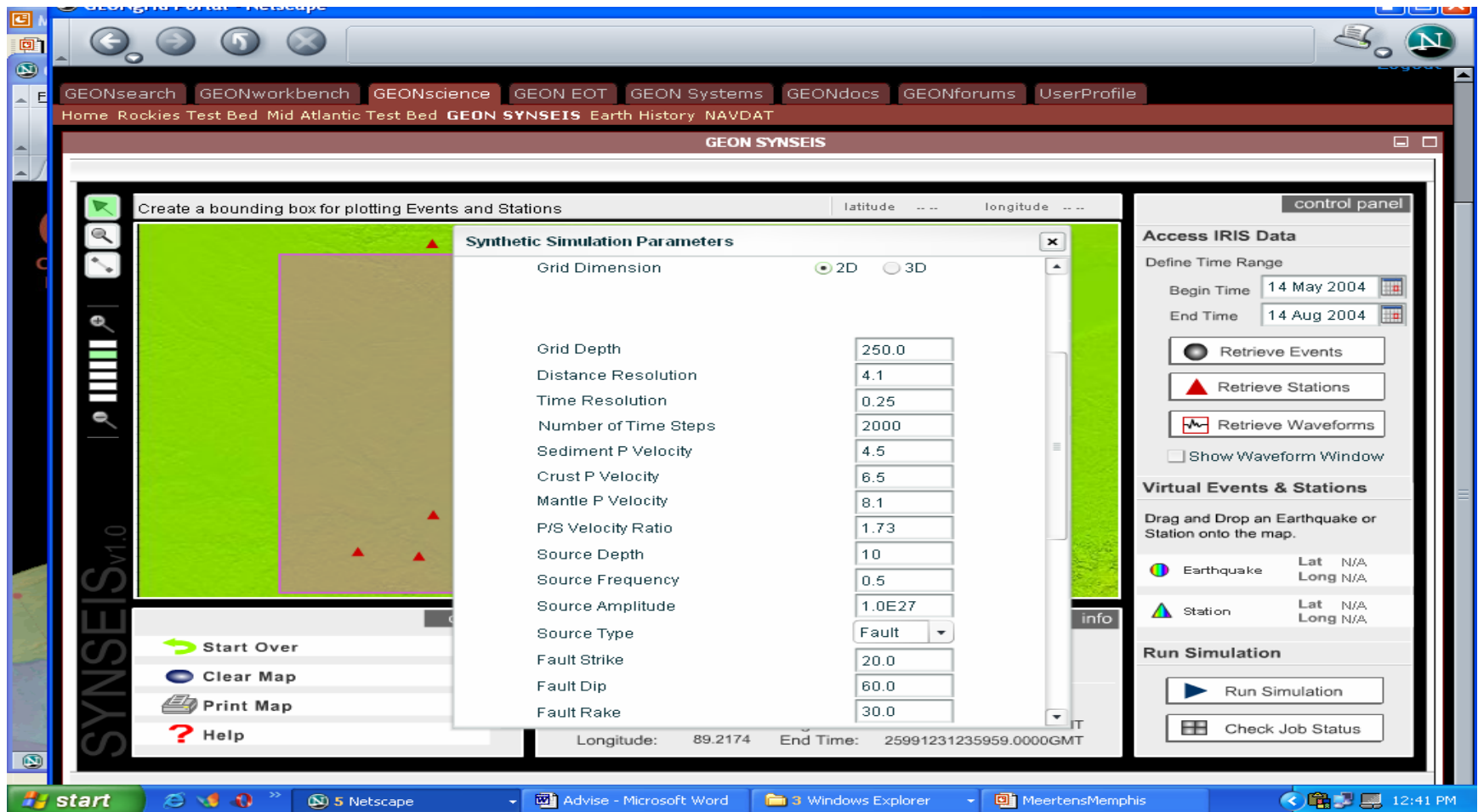
Velocity
Model
For
Selected
Region
From
ArcIMS
webservice

Synseis

Region-specific structure Model from GEON ArcIMS webservice



Enter simulation parameters, select supercomputer, run job



The screenshot shows the GEON SYNSEIS web interface within a Netscape browser window. The browser's address bar shows the URL: <http://geon.unc.edu/synseis/>. The page has a navigation bar with links: GEONsearch, GEONworkbench, GEONscience, GEON EOT, GEON Systems, GEONdocs, GEONforums, and UserProfile. Below the navigation bar is a breadcrumb trail: Home > Rockies Test Bed > Mid Atlantic Test Bed > GEON SYNSEIS > Earth History > NAVDAT.

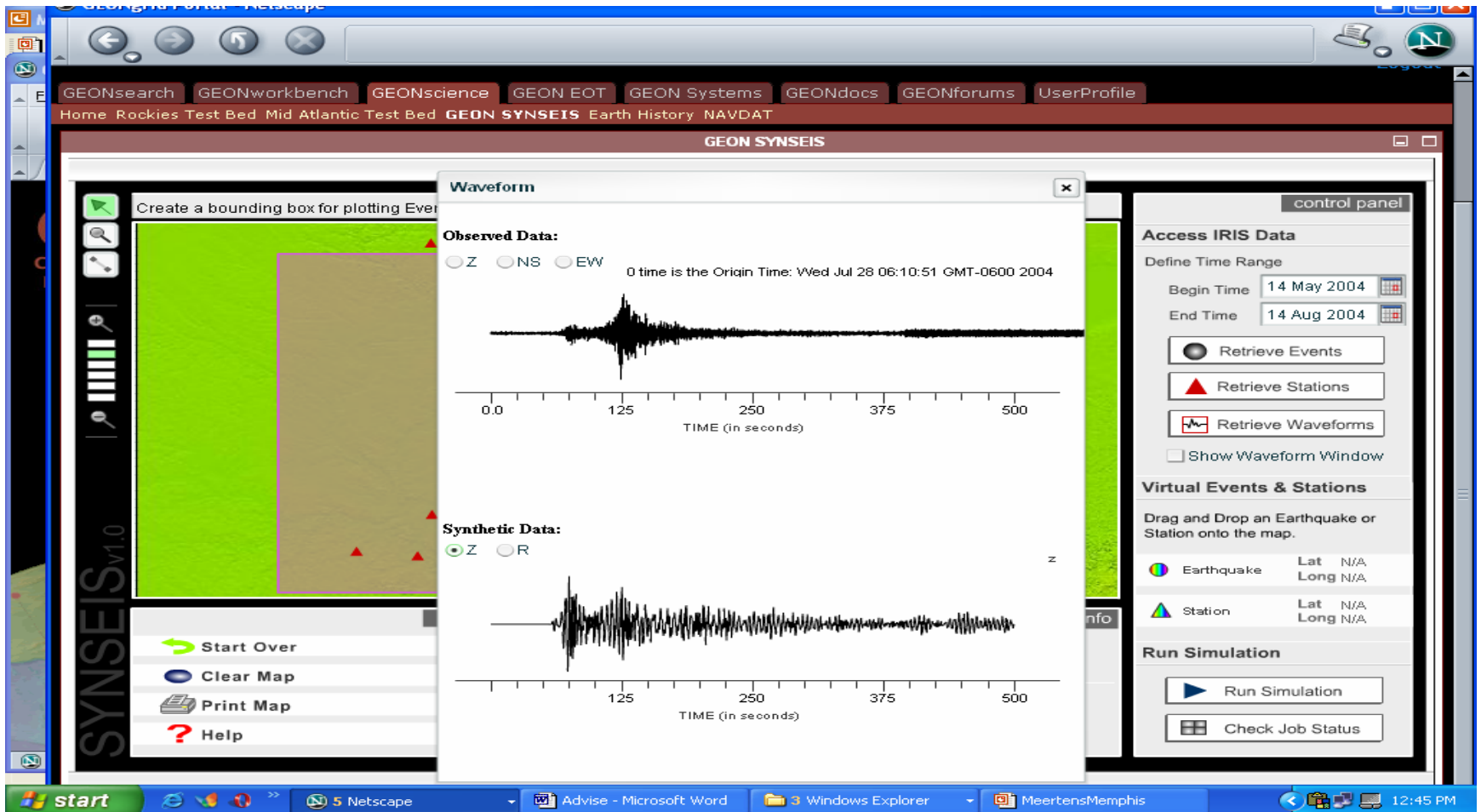
The main content area is titled "GEON SYNSEIS". It features a map on the left with a green bounding box and red triangles representing events and stations. A "Synthetic Simulation Parameters" dialog box is open, allowing users to configure simulation parameters. The parameters include:

- Grid Dimension: ☒ 2D ☐ 3D
- Grid Depth: 250.0
- Distance Resolution: 4.1
- Time Resolution: 0.25
- Number of Time Steps: 2000
- Sediment P Velocity: 4.5
- Crust P Velocity: 6.5
- Mantle P Velocity: 8.1
- P/S Velocity Ratio: 1.73
- Source Depth: 10
- Source Frequency: 0.5
- Source Amplitude: 1.0E27
- Source Type: Fault (dropdown menu)
- Fault Strike: 20.0
- Fault Dip: 60.0
- Fault Rake: 30.0

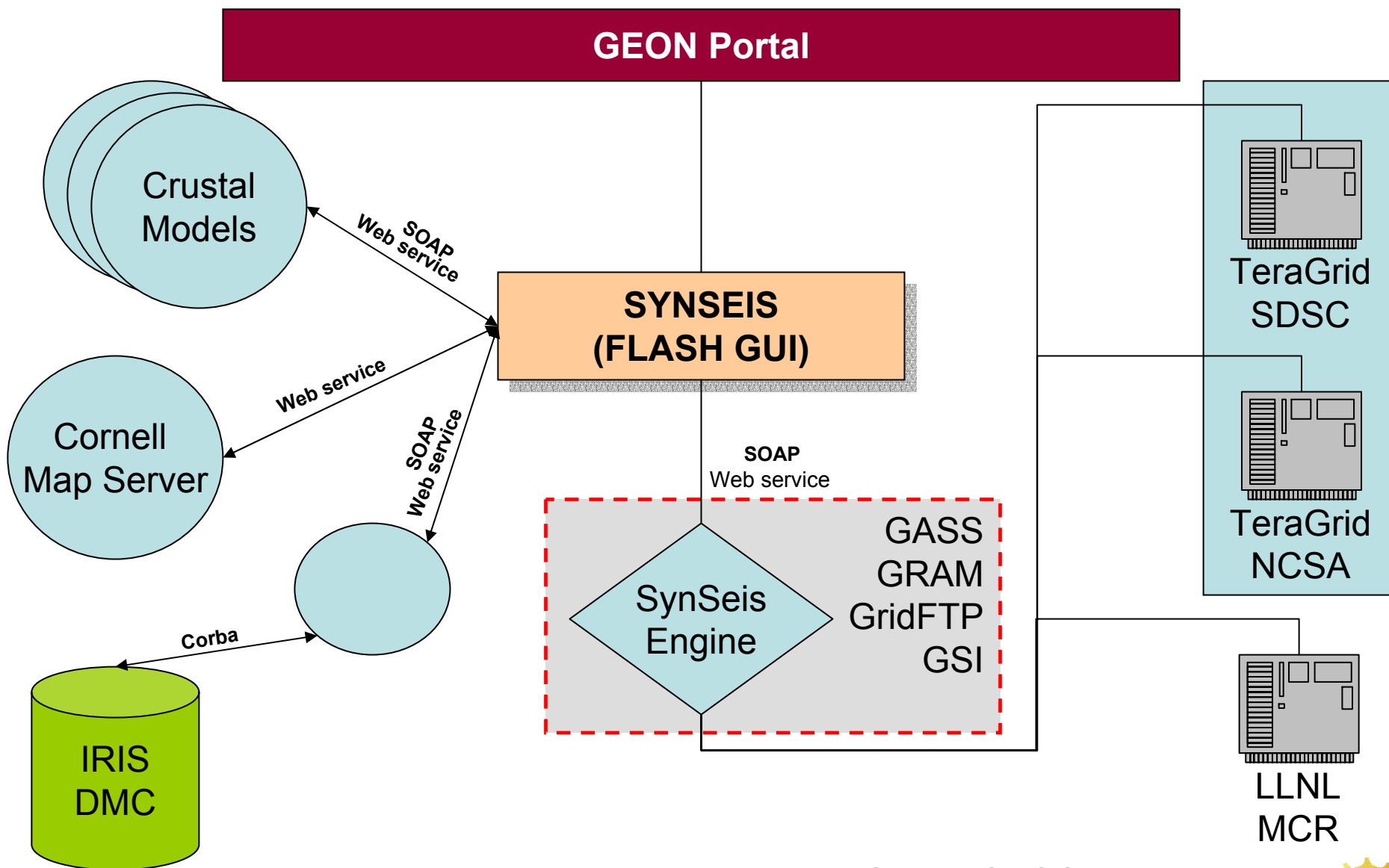
At the bottom of the dialog box, the "Longitude" is set to 89.2174 and the "End Time" is 25991231235959.0000GMT. The "control panel" on the right includes sections for "Access IRIS Data" (with buttons for Retrieve Events, Retrieve Stations, and Retrieve Waveforms), "Virtual Events & Stations" (with a table for adding events and stations), and "Run Simulation" (with buttons for Run Simulation and Check Job Status).

The browser's status bar at the bottom shows the Windows taskbar with the start button, open applications (Netscape, Advise - Microsoft Word, Windows Explorer, MeertensMemphis), and the system clock (12:41 PM).

Compare IRIS waveform with synthetic waveform



SYNSEIS Architecture



Dogan Seber, SDSC

GEON Portal Development- Finite Element Models

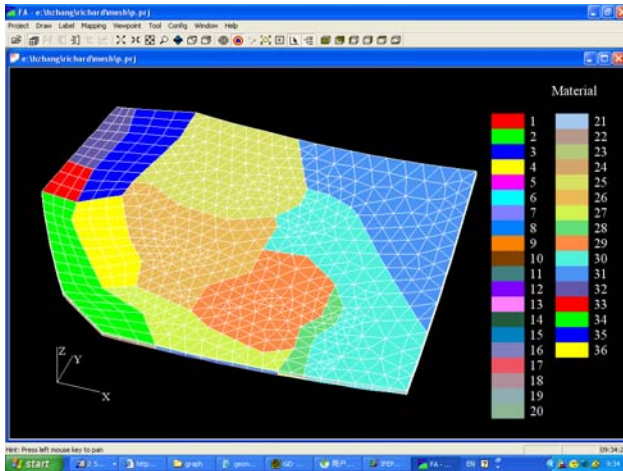
Another example of an integrated computational tool using distributed Grid resources and new flexible numerical problem solving methods.

**4D simulation of continental deformation in the western US
Mian Liu, Huai Zhang & Youqing Yang**

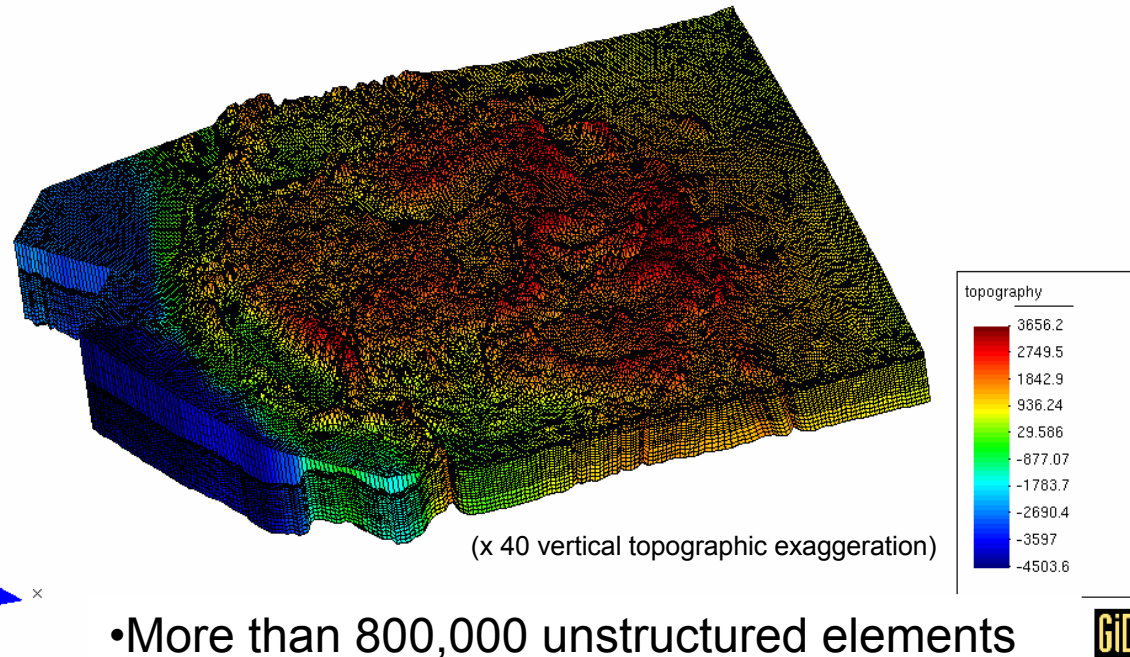
**University of Missouri-Columbia
San Diego Supercomputer**

The Power of GEON Cluster Nodes

Original model
(single CPU)



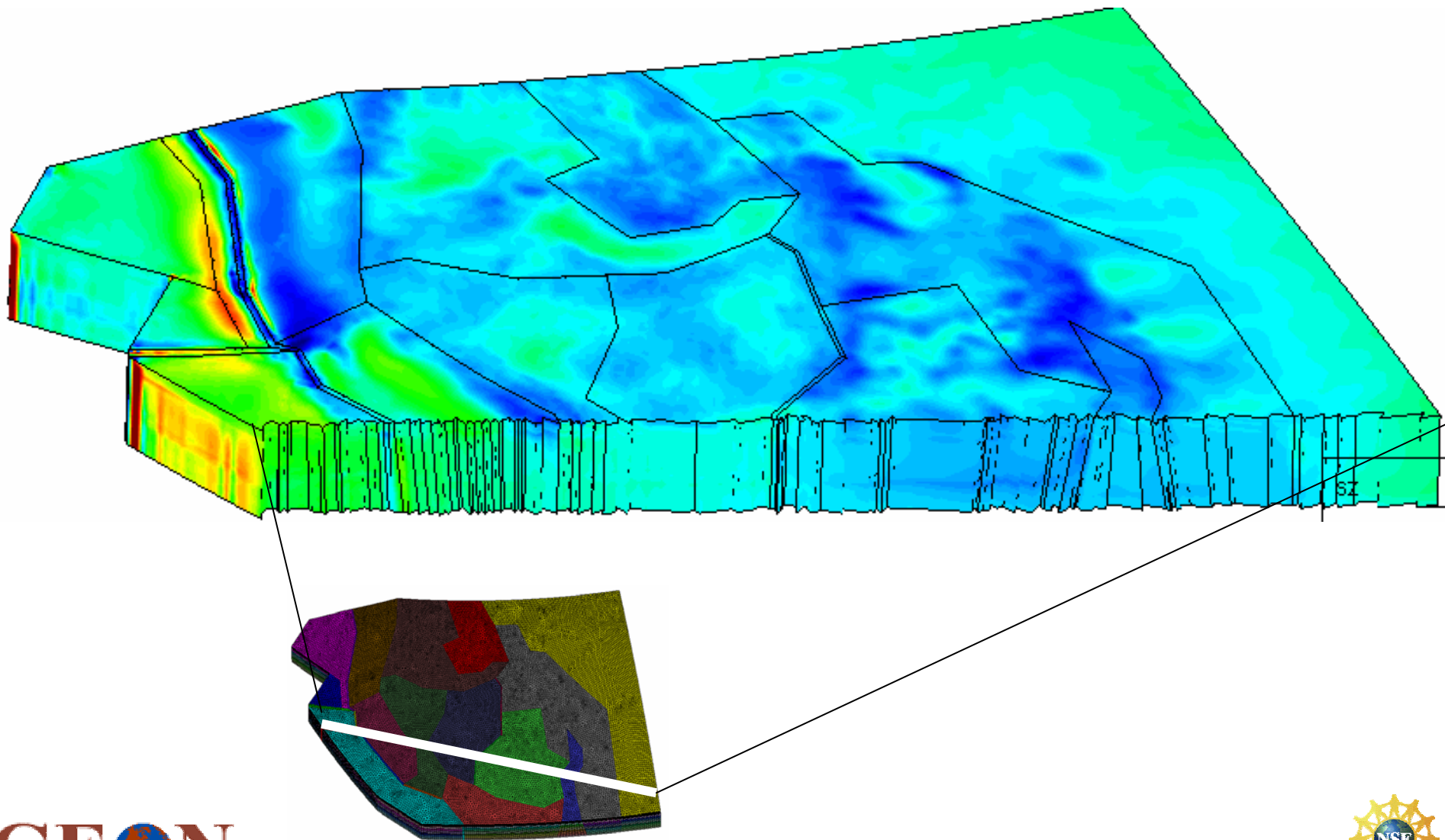
Current model (2-nodes, 4CPUs)

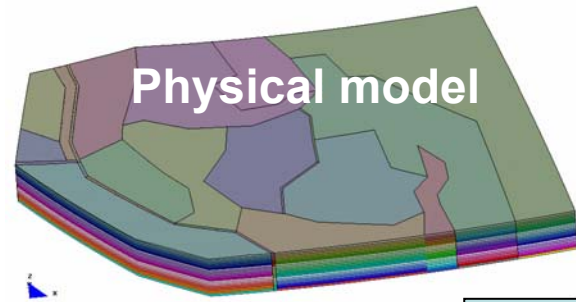
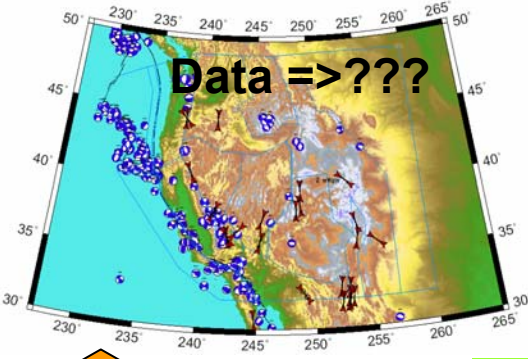


- Less than 3000 elements
- Three layers in R-direction
- 2 min for per time step

- More than 800,000 unstructured elements
- Major Faults and more deformation zones
- Subduction of Juan de Fuca slab
- 21 layers in R-direction
- 15 min per time step

The model now allows simulation of large scale continental deformation with unprecedented detail





PDEs

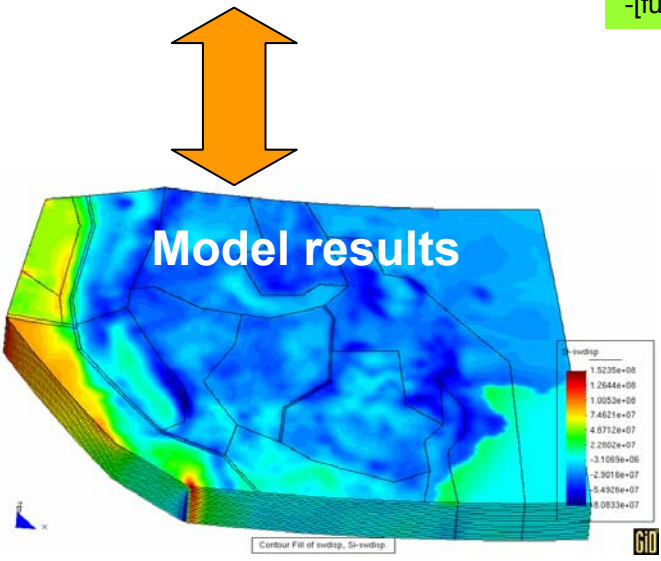
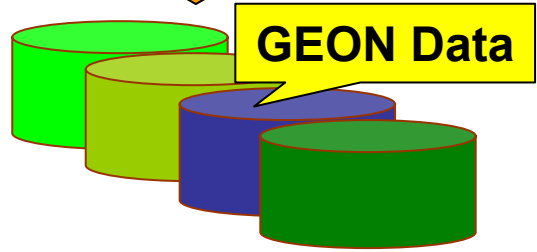
$$\begin{aligned} \frac{\partial \sigma_{xx}}{\partial x} + \frac{\partial \sigma_{xy}}{\partial y} + \frac{\partial \sigma_{xz}}{\partial z} + f_x &= 0 \\ \frac{\partial \sigma_{xy}}{\partial x} + \frac{\partial \sigma_{yy}}{\partial y} + \frac{\partial \sigma_{yz}}{\partial z} + f_y &= 0 \\ \frac{\partial \sigma_{xz}}{\partial x} + \frac{\partial \sigma_{yz}}{\partial y} + \frac{\partial \sigma_{zz}}{\partial z} + f_z &= 0 \end{aligned}$$

FEM Modeling Language

```

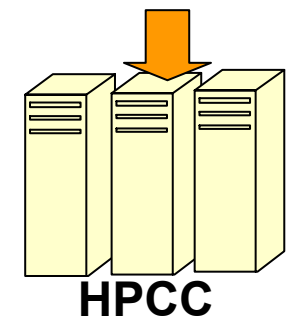
func
funa=+[u/x]
.....
funf=+[u/y]+[v/x]
.....
dist
=+[funa;funa]*d(1,1)+[funa;funb]*d(1,2)+[funa;func]*d(1,3)
+[funb;funa]*d(2,1)+[funb;funb]*d(2,2)+[funb;func]*d(2,3)
+[func;funa]*d(3,1)+[func;funb]*d(3,2)+[func;func]*d(3,3)
+[fund;fund]*d(4,4)+[fune;fune]*d(5,5)+[funf;funf]*d(6,6)

load = +[u]*fu+[v]*fv+[w]*fw-[funa]*f(1)-[funb]*f(2)-[func]*f(3)
-[fund]*f(4)-[fune]*f(5)-[funf]*f(6)
    
```

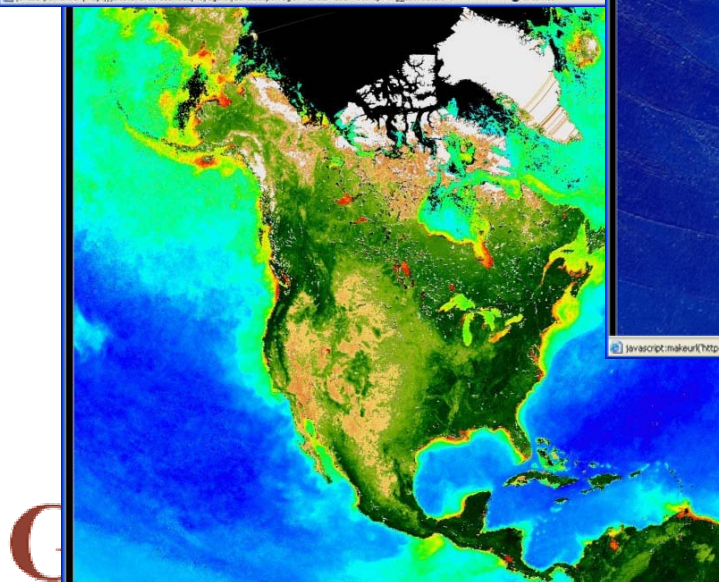
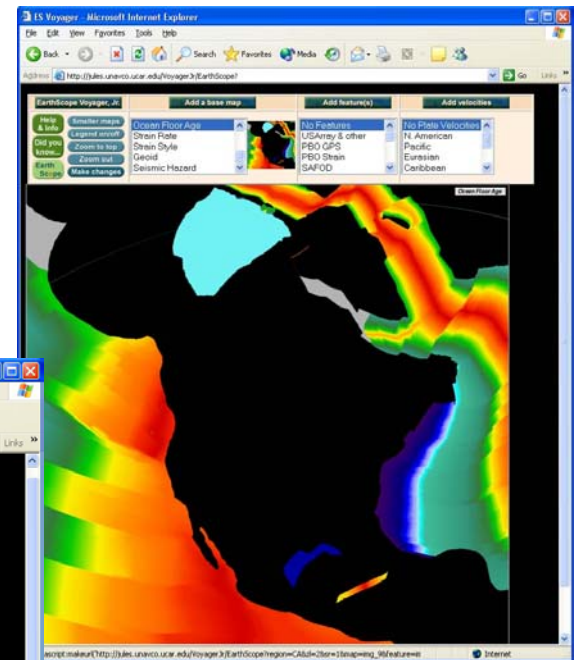
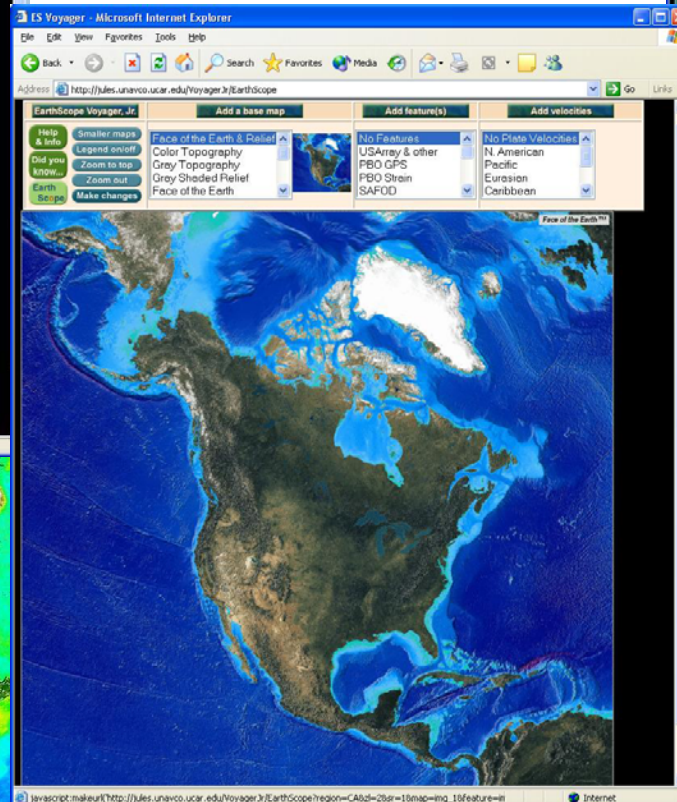
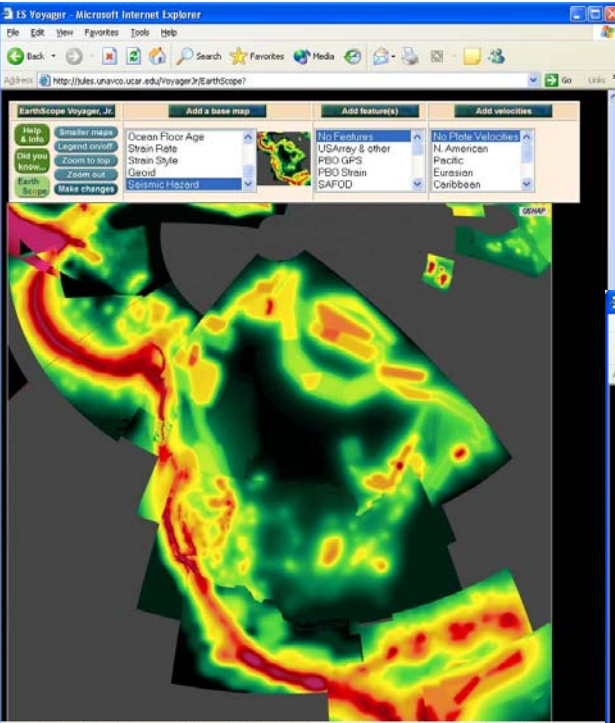


Automatic source code generator

Complete source code



EarthScope Voyager



Conclusions

Efforts to create an integrated cyberinfrastructure for the earth sciences face enormous challenges due to the heterogeneous nature of the data, the sheer volume of data , computational requirements, and cultural issues ...

But efforts like GEON and EarthScope can be “centripetal” forces that will bring the community together to help solve complex science, IT and Education problems.