GOEN: Grid Computing in Geosciences
&
SYNSEIS: *a 3D Seismic Waveform Propagation Analysis Tool*

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Outline

- GEON: Cyberinfrastructure for Geosciences
  - Grid technologies for distributed access to data and resources
- SYNSEIS
  - Part of the GEON infrastructure
  - An application for doing seismic analysis
  - Demo at the break

An Overview of GEON

- Designed to create a cyberinfrastructure for the Geosciences
- NSF Large ITR project – collaborative effort
- GEON is creating an IT infrastructure to "enable" interdisciplinary geoscience research -- not a group of researchers, but the entire community will benefit
- Project started in October 1, 2002 and will continue until September 30, 2007

Current GEON member institutions

Members

- 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)

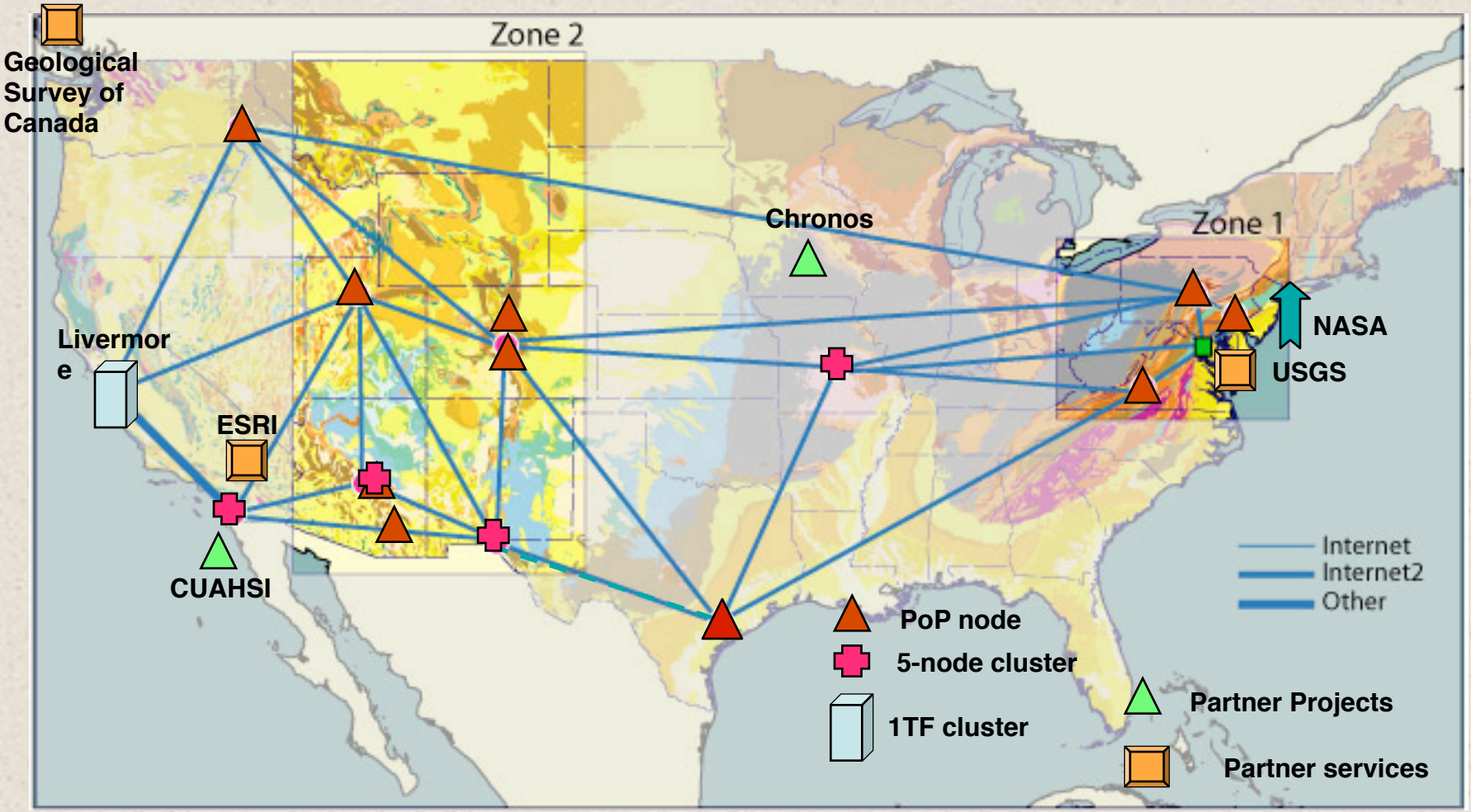
Partners

- 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)
- CIG

Other Affiliates

- Southern California Earthquake Center (SCEC), EarthScope, IRIS, NASA

GEONgrid


Geological Survey of Canada
Zone 2
Chronos
Zone 1
NASA
USGS
Livermor e
ESRI
CUAHSI
Internet
Internet2
Other
PoP node
5-node cluster
1TF cluster
Partner Projects
Partner services

SYNSEIS

- A grid application that provides an unprecedented opportunity for seismologists and other earth science partners to compute and study 3D seismic records
- Built using a service-based architecture.
  - Provides users an easy-to-use GUI to access data, models and compute resources
  - Provides “connectors” (APIs) for developers should they choose to utilize any of its components in other applications.

Modeling earthquakes in 2D/3D environment to study the interior of the Earth

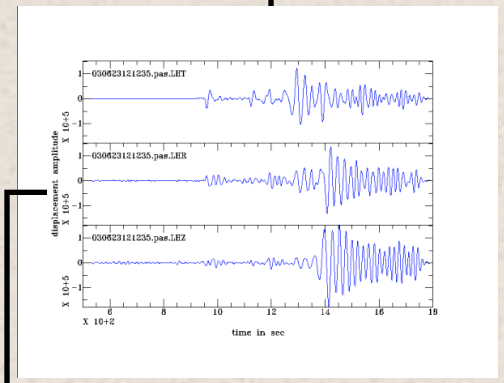
IRIS
- Earthquakes
- Stations
- Waveform

SYNSEIS

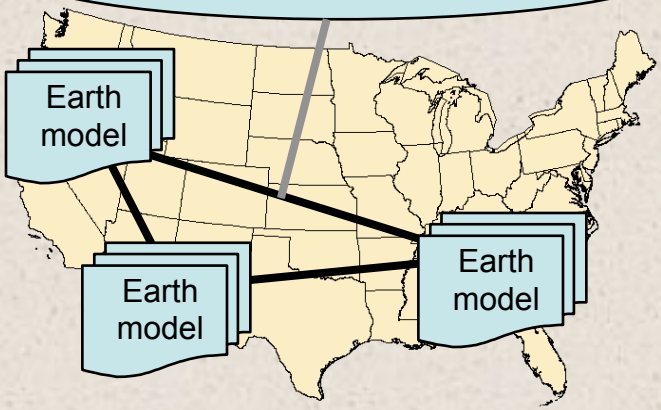
e3d

HPC Centers

NCSA SDSC

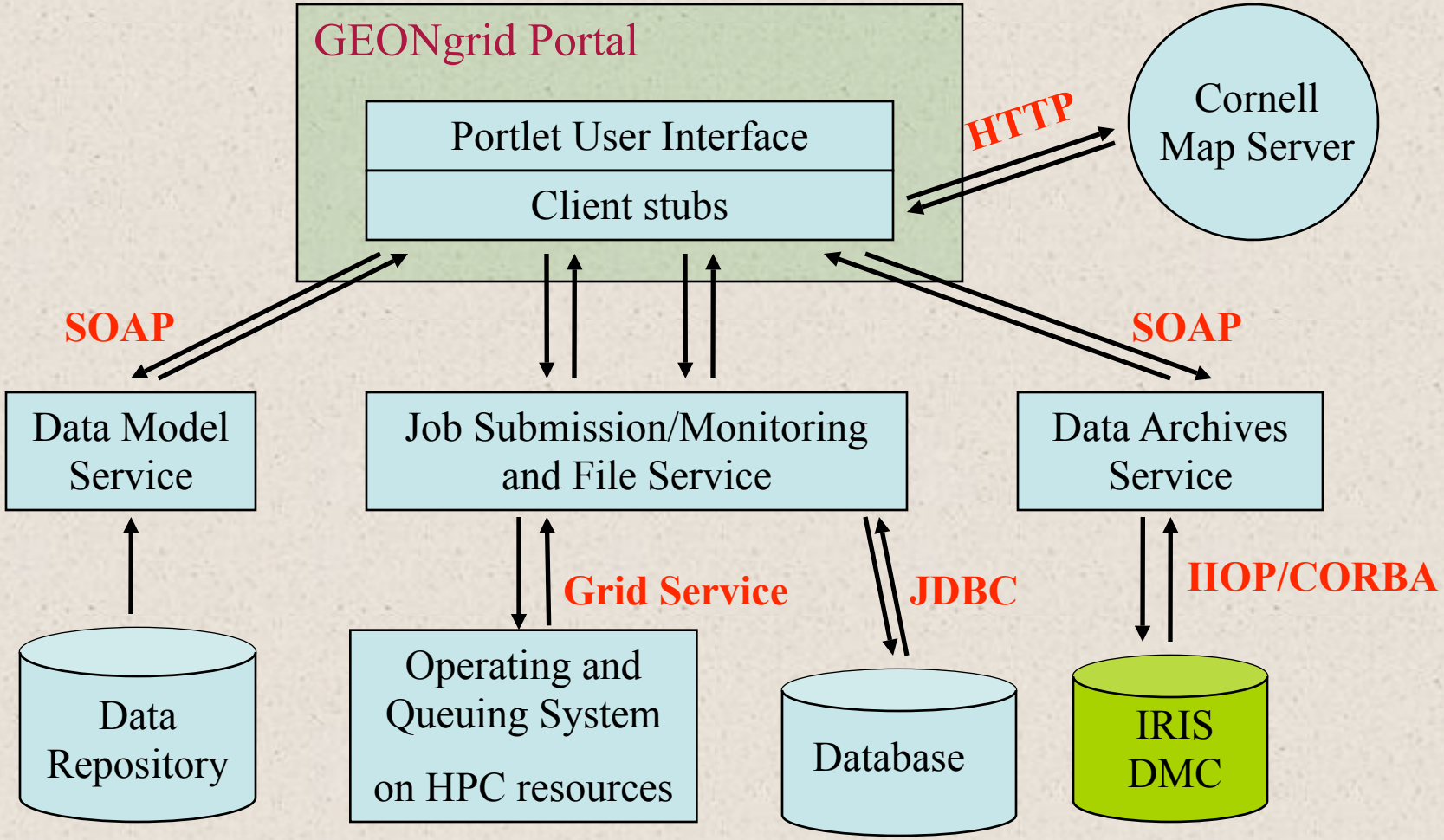


Digital Libraries/GEON Data Grid

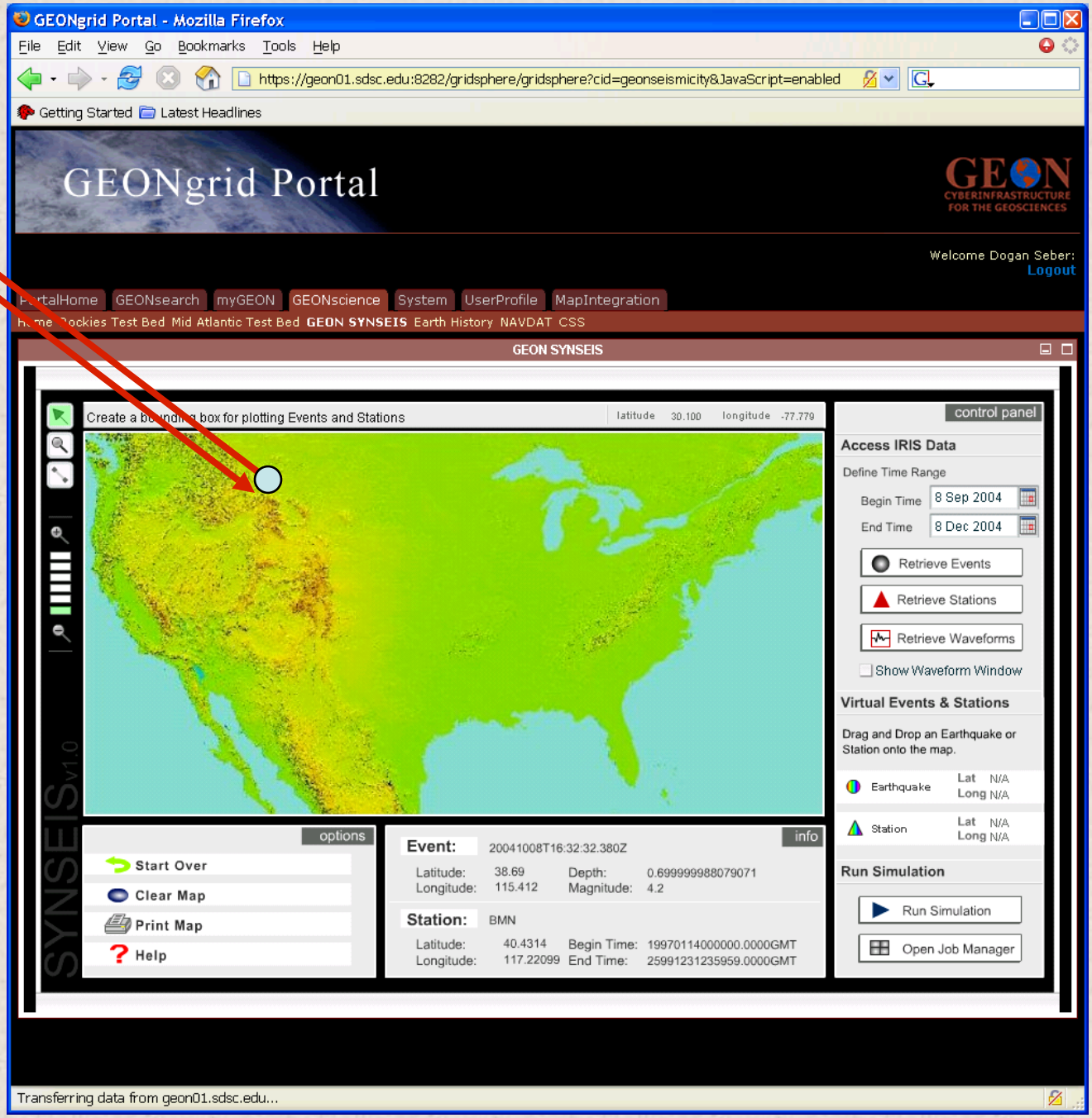


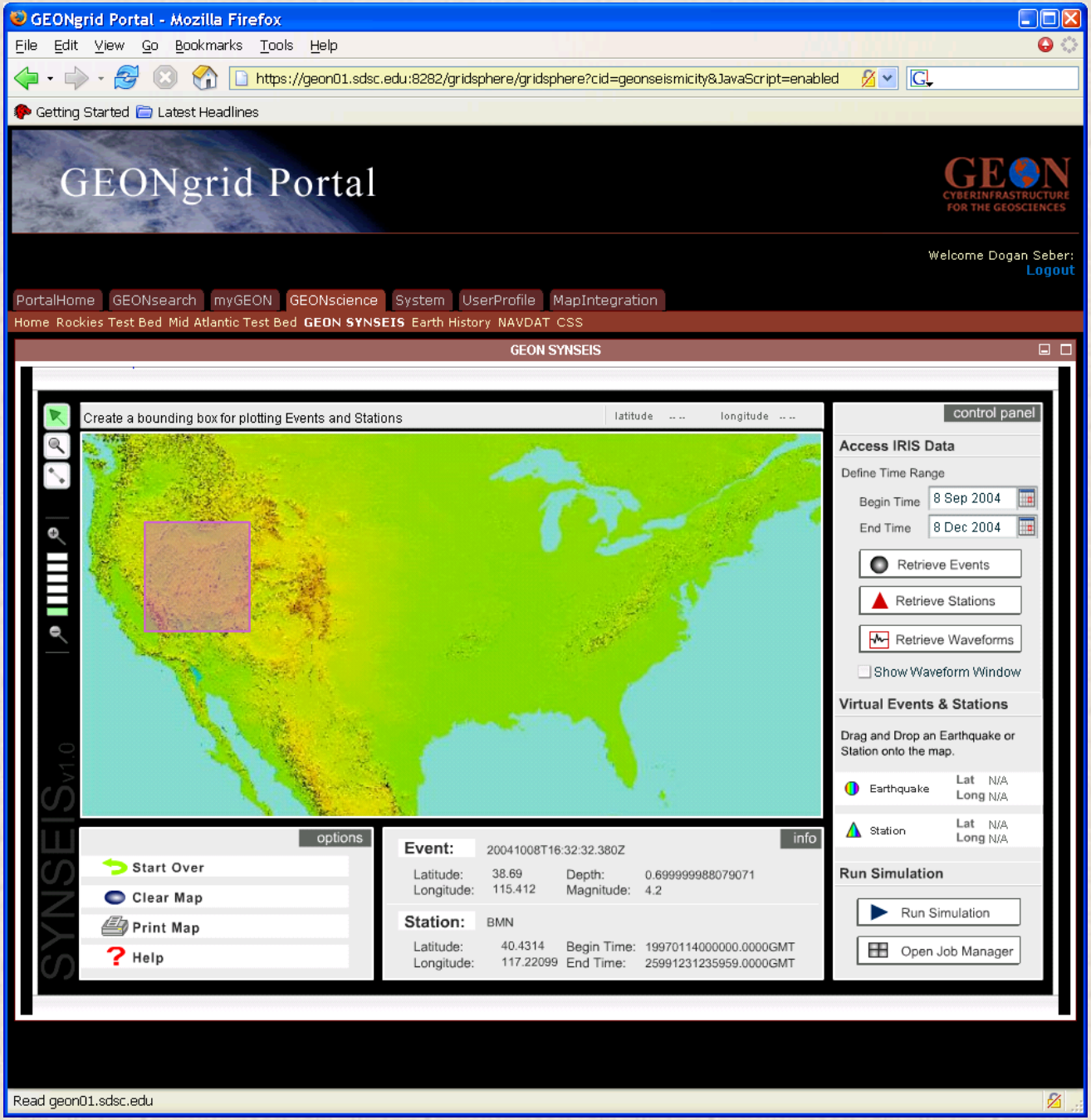
The Architecture of SYNSEIS

User Access (via Web Browser)

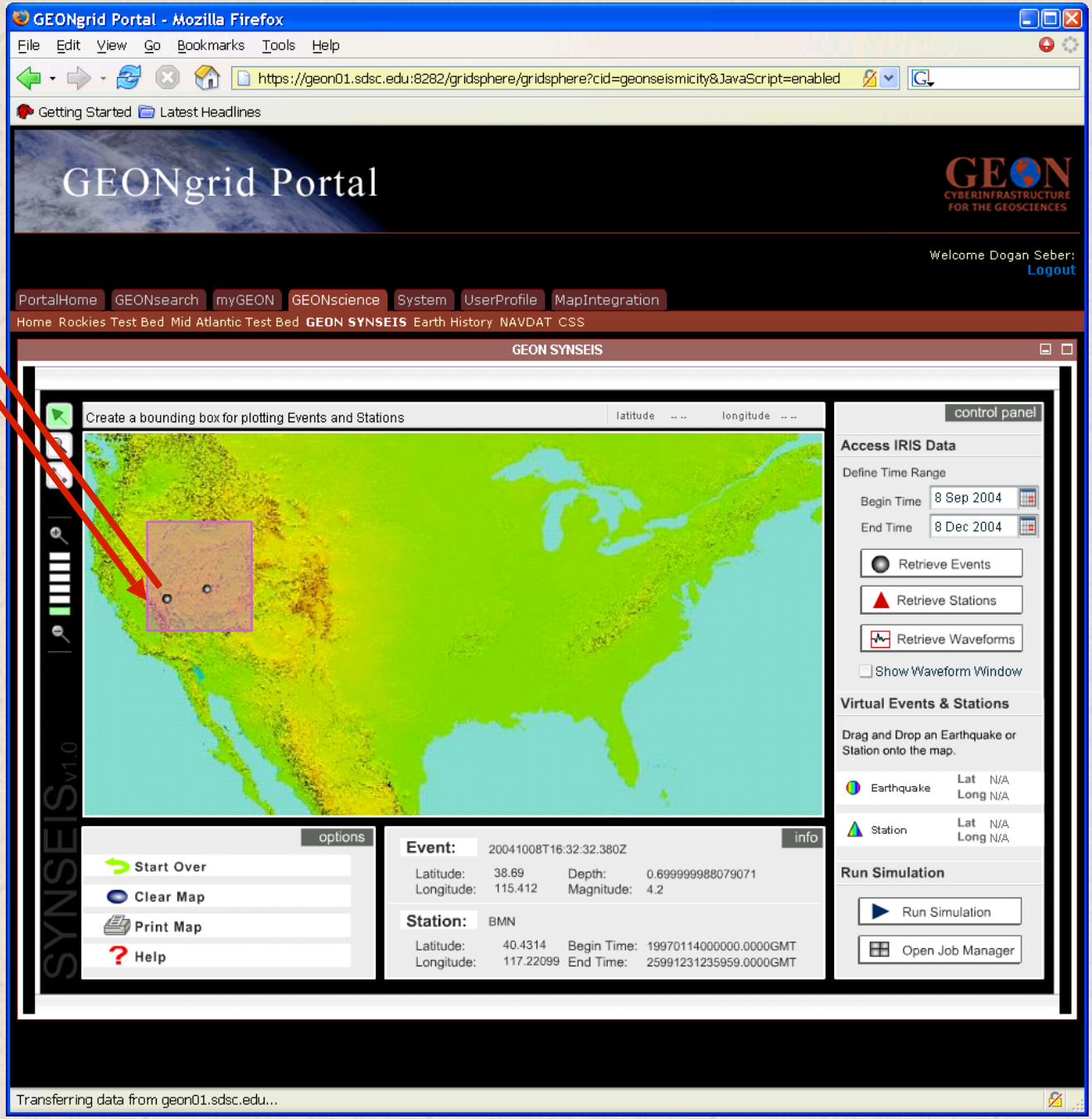


Mapping Service At Cornell U.

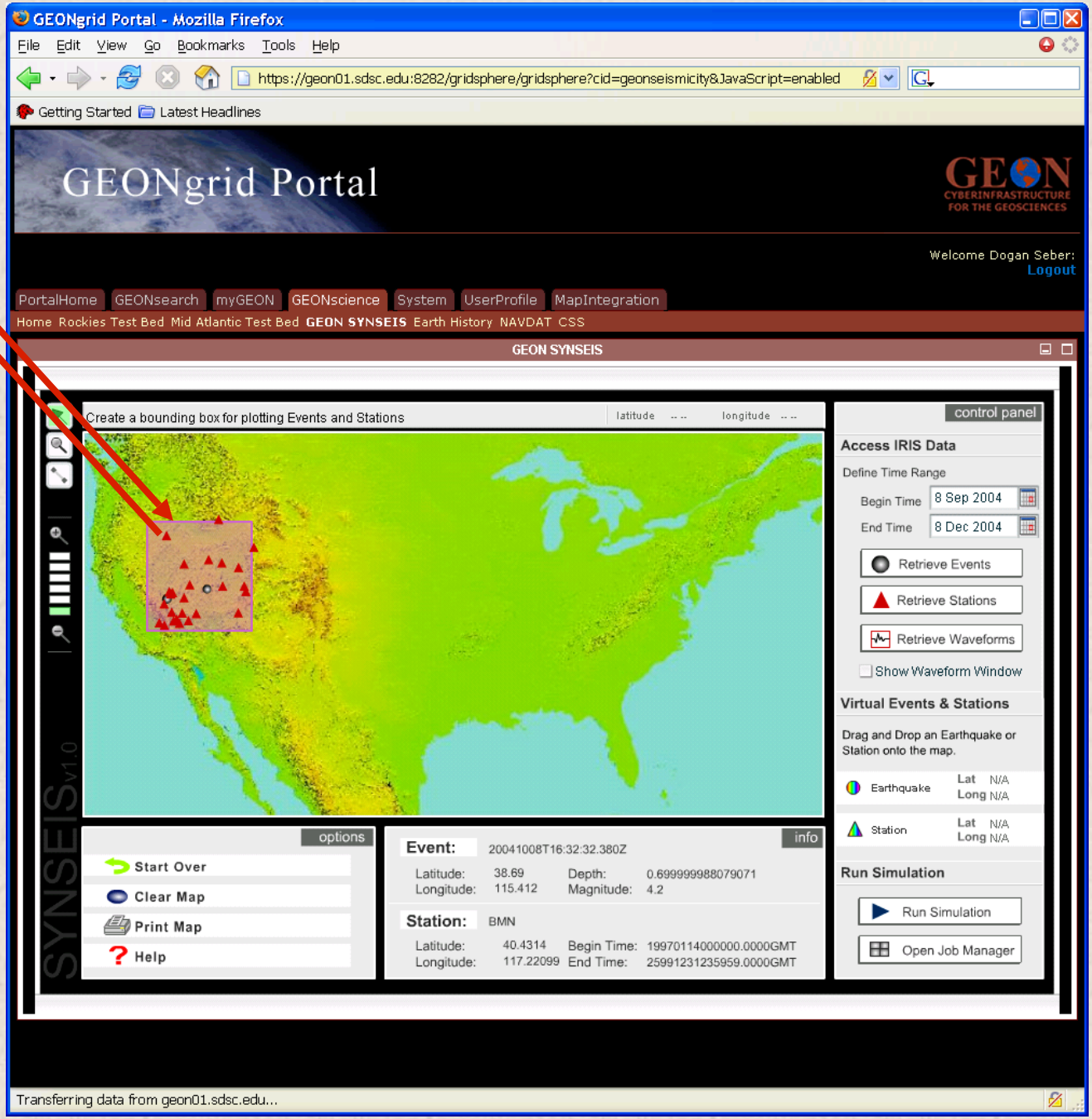


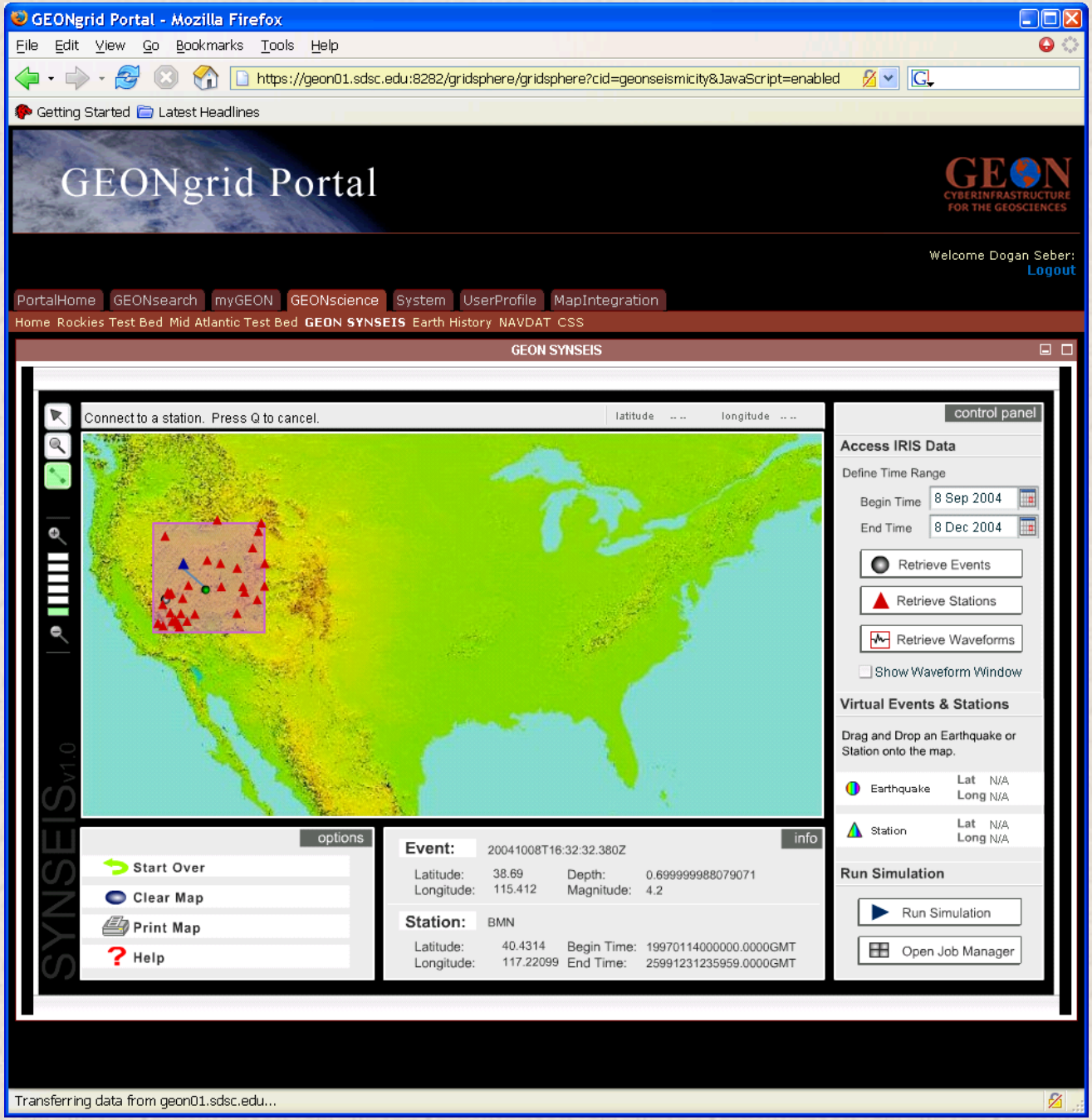

GEONgrid Portal - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
https://geon01.sdsc.edu:8282/gridsphere/gridsphere?cid=geonseismicity&JavaScript=enabled
Getting Started Latest Headlines
GEONgrid Portal
GEON CYBERINFRASTRUCTURE FOR THE GEOSCIENCES
Welcome Dogan Seber:
Logout
PortalHome GEONsearch myGEON GEONscience System UserProfile MapIntegration
Home Rockies Test Bed Mid Atlantic Test Bed GEON SYNSEIS Earth History NAVDAT CSS
GEON SYNSEIS
SYNSEIS v1.0
Create a bounding box for plotting Events and Stations
latitude -- -- longitude -- --
control panel
Access IRIS Data
Define Time Range
Begin Time 8 Sep 2004
End Time 8 Dec 2004
Retrieve Events
Retrieve Stations
Retrieve Waveforms
Show Waveform Window
Virtual Events & Stations
Drag and Drop an Earthquake or Station onto the map.
Earthquake Lat N/A Long N/A
Station Lat N/A Long N/A
Run Simulation
Run Simulation
Open Job Manager
options
Start Over
Clear Map
Print Map
Help
info
Event: 20041008T16:32:32.380Z
Latitude: 38.69 Depth: 0.699999988079071
Longitude: 115.412 Magnitude: 4.2
Station: BMN
Latitude: 40.4314 Begin Time: 19970114000000.0000GMT
Longitude: 117.22099 End Time: 25991231235959.0000GMT
Read geon01.sdsc.edu

Events from IRIS DMC



Stations from IRIS DMC/ SDSC

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GEON SYNSEIS
Connect to a station. Press Q to cancel.
latitude -- -- longitude -- --
control panel
Access IRIS Data
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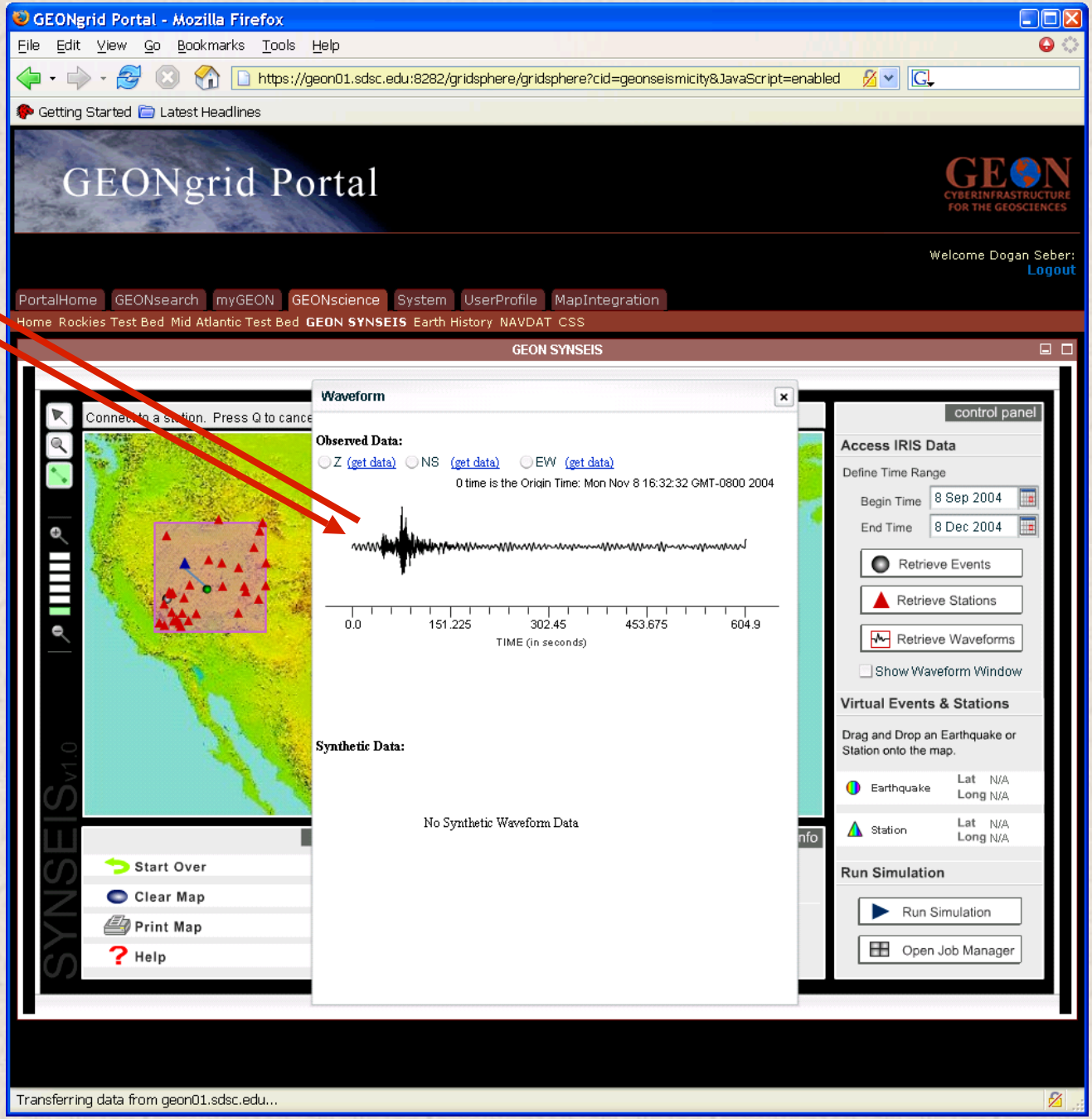
Latitude: 38.69 Depth: 0.699999988079071
Longitude: 115.412 Magnitude: 4.2
Station: BMN
Latitude: 40.4314 Begin Time: 19970114000000.0000GMT
Longitude: 117.22099 End Time: 25991231235959.0000GMT
Transferring data from geon01.sdsc.edu...

Waveforms from IRIS DMC



The Architecture of SYNSEIS

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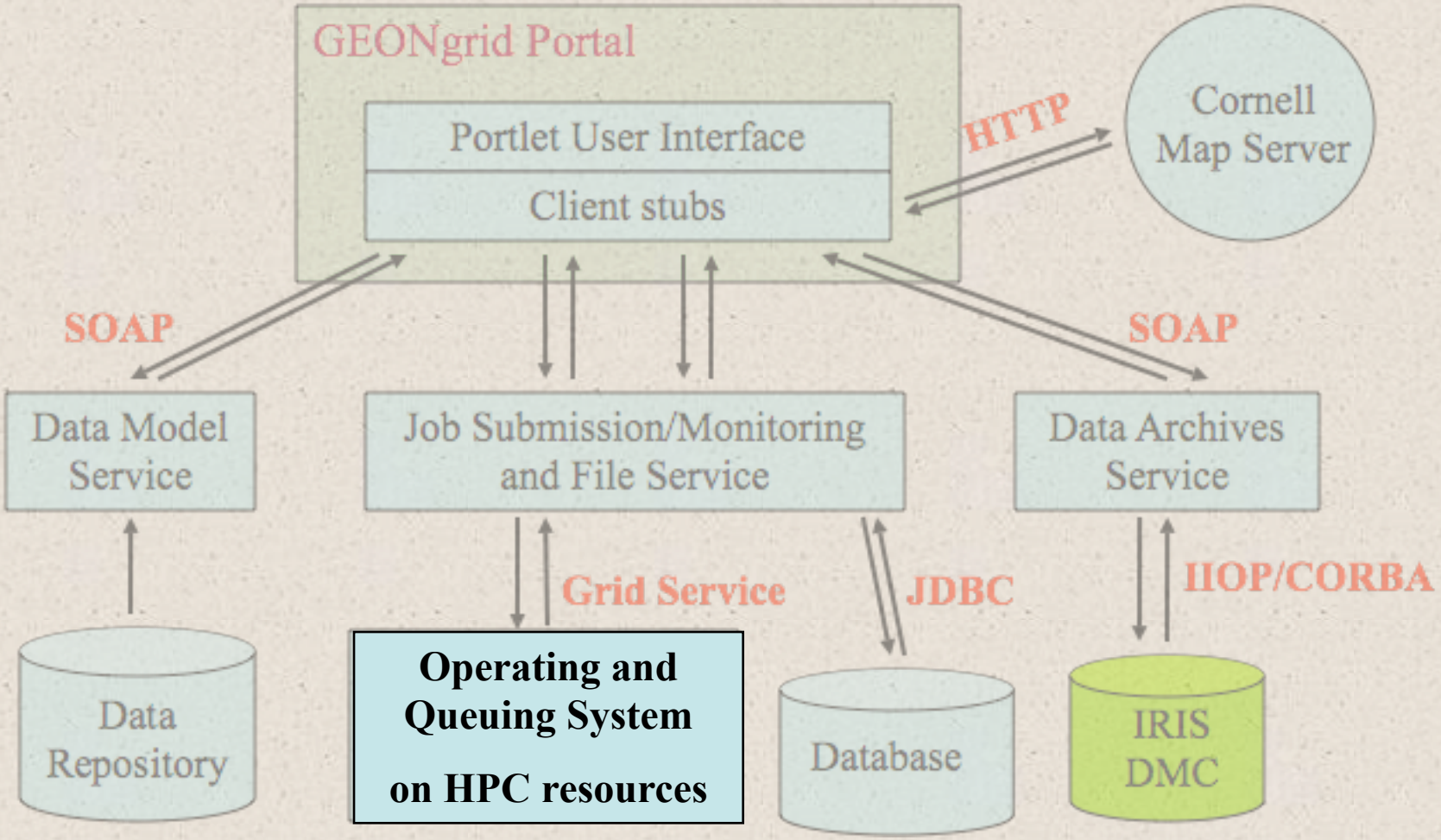


Model behind SYNSEIS is E3D

- Shawn Larsen of Lawrence Livermore National Laboratory
- E3D is an explicit 2D/3D elastic finite-difference wave propagation code used for the modeling of seismic waves
  - 4th order accurate in space
  - 2nd order accurate in time
    - It is based on the elastodynamic formulation of the wave equation on a staggered grid [Madariaga, 1976, BSSA; Virieux, 1986, Geophysics; Levander, 1988, Geophysics; Larsen and Harris, 1993, UCRL]

E3D more of the story

- Mostly C a few short Fortran routines
  - about 650 routines
  - 28,000 lines
- Has wrappers for various communications packages
  - Sun
  - MPI

E3D - SDSC changes

- "Portable-iz" it
  - Worked fine on LLNL resources
  - Idiosyncrasies in compilers can cause problems
  - Made in more compiler proof
  - Helps me understand the application
  - Runs using Intel, gcc (Intel/OSX), xlf/xlc (IBM)
  - Actually found some **compiler** bugs
- Volume output routines
  - MPI IO
  - Single processor does output

E3D - SDSC changes

- New boundary conditions
  - Surface on top and reflecting on sides and bottom
  - Add attenuation in the input earth model using variable Qp and Qs
- Create the earth model on the fly inside of E3D
  - Creation based on two layer files
  - Creation now done in parallel
  - Were reading in large 3D volumes

E3D is only a component of SYNSEIS

- Could be supplemented with...
  - Pick your favorite simulation

What happens once we get to the HPC platform?

- Complete job description comes in as XML and processed by a perl script (1200 lines)
- Script
  - Creates E3D input
  - Parse out Moho.dat and Sediment.dat layer files
  - Build scripts to create the 3D earth models
    - R, P, S, Qp, Qs
  - Creates pbs batch script
  - Runs pbs batch script

E3D input file

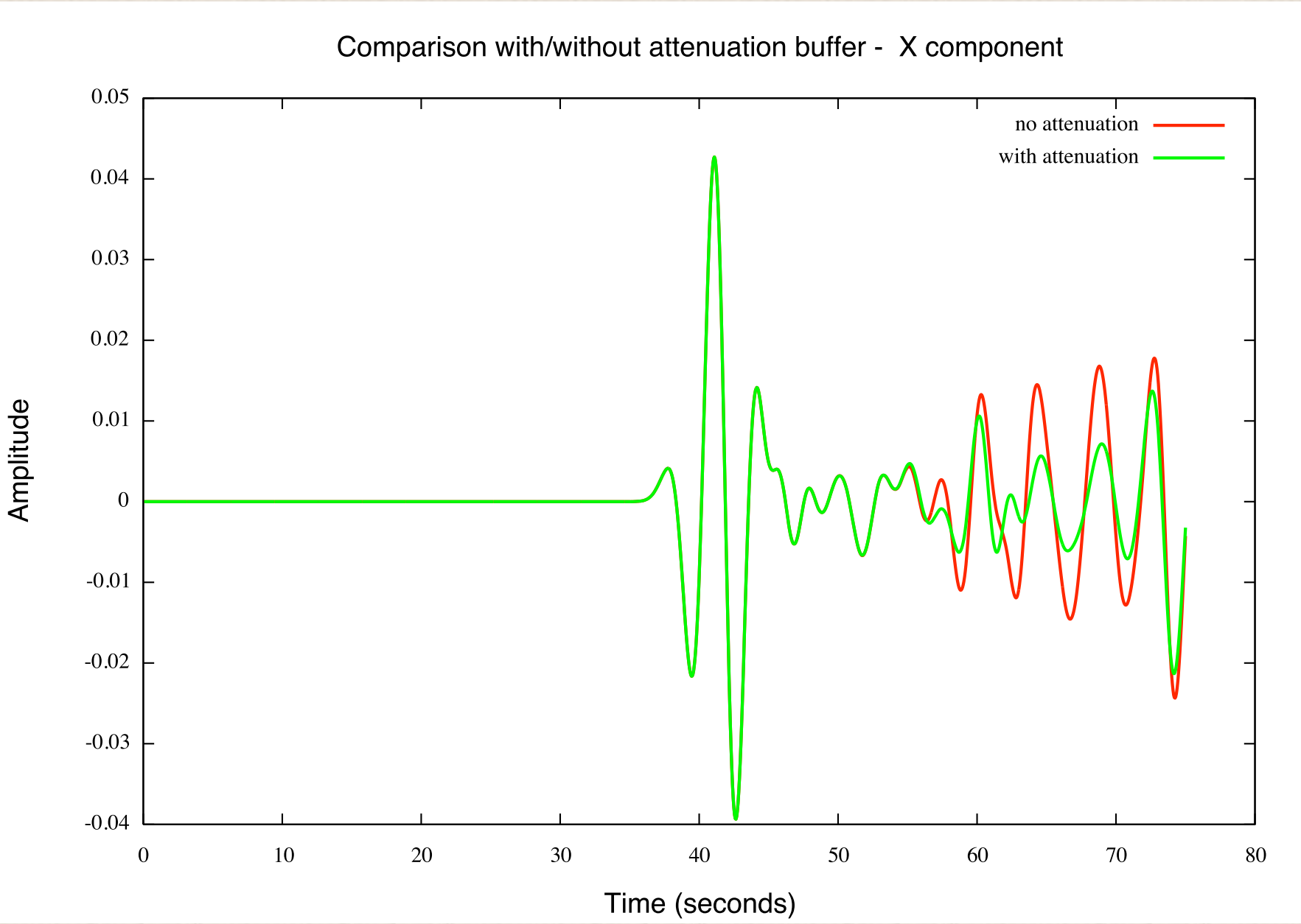
```
 grid q=1 n=323 l=410 m=250 dh=1 b=10
 time dt=0.05  t=1500
 source type=1 freq=0.225 amp=1.0E27 n=109 l=104 m=10
#source type=6 freq=0.225 amp=1.0E27 n=109 l=104 m=10
strike=SOURCE_STRIKE dip=SOURCE_DIP rake=SOURCE_RAKE
 vfile type=p file="earth" n1=0 n2=322 m1=0 m2=249 l1=0 l2=409
 parallel nx=1 ny=2 nz=7
 sac l=314 m=0 n=199 mode=1 file="station_1_sim_dat.1.bin"
 vfile type=s file=earths n1=0 n2=322 m1=0 m2=249 l1=0 l2=409
 vfile type=Qs file=earthqs Qf=0.225 n1=0 n2=322 m1=0 m2=249 l1=0 l2=409
 vfile type=Qp file=earthqp Qf=0.225 n1=0 n2=322 m1=0 m2=249 l1=0 l2=409
 vfile type=r file=earthr n1=0 n2=322 m1=0 m2=249 l1=0 l2=409
 volume movie=10.0 mode=2 file="volume1"
 image movie=10.0 m=0  mode=2  file="surface1"
```

What does batch script do?

- Optionally runs scripts to create R, P, S, Qp, Qs description files
- Run E3D
- Convert binary (SAC) traces to text
- Creates movies
  - x, y, z for surface, P potentials for volumes
  - Convert parallel volumes/surfaces to serial
    - (not required for MPI-IO)
  - Get slices (Volumes)
  - Convert slices or surface data to PNG
  - Convert PNG to AVI

Constant “Y” slice

P potential


Comparison with/without attenuation buffer - X component
no attenuation
with attenuation
Amplitude
Time (seconds)
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
0
10
20
30
40
50
60
70
80

Conclusions

- Using the Grid technology we were able to bring an extremely complex and cumbersome seismic data analysis procedure to a level that can be used by anyone efficiently and effectively
- SYNSEIS has allowed us to practice building distributed data and computational resources. We are now ready to expand such development efforts within the GEONgrid environment
- Demo to follow later.

Conclusions (2/2)

- SYNSEIS also has a high potential to be used in educational environments allowing students to experiment with data and make their own earthquakes.
- SYNSEIS has allowed us to practice building distributed data and computational resources. We are now ready to expand such development efforts within the GEONgrid environment