Session 16

Process-Oriented Data Handling

Combining performance, flexibility,
code reuse, and collaboration

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Outline

- Six rules of the processing game
- Overview of IGeoS (SIA) system
- Examples of USArray data handling
- Homework
- Appendix: topics not covered today

Examples are provided and also available from

http://seisweb.usask.ca/igeos/pubs/USArray2009

Rule #1: Make processing reproducible

- Design your processing to be easily repeatable in 10 years
- Use batch flows
- Use self-documentation
- Maintain the software

Rule #2: Separate “processing” from “programming”

- Not all good geophysicists are good programmers
- Good code requires a lot of specialized effort
- Data organization may become daunting when hardwired in code
  - Code becomes not portable

Rule #3: Use “software system”

- Combination of many simple components
  - “User” focuses on data an tool interactions, not code
  - New code can benefit many tasks
  - Little duplication of coding
  - High code reuse and chance for spotting problems
- Common parameterization – easy to learn
  - Example: “sia job_name” – the only command I ever use
- Software maintained in consistent manner
  - “sia-update –build <item>” - the only command needed to compile anything
  - Many library classes readily available
  - Documentation and test examples
    - http://seisweb.usask.ca/igeos/index

Rule #4: Think "process"

- "Data access," "filtering," "modeling," "inversion" are all special cases of "processing"
  - Use maximum (reasonable) data abstraction
- "Processing" is just using a combination of tools to achieve a certain result
  - To produce data files, images, publications, interaction with the user, etc.
  - If we learn to manage complex "processes," we can probably solve *any* problem
  - Note that the success of UNIX is due to a similar abstraction

Rule #5: Make redundant effort

- Generalize tasks to help with other tasks in the future
  - For example, when reading a file:
    - think of reading many files at once
    - think of using UNIX pipeline filters.
  - Use flexible parameterization (trace headers, databases)
- This requires a lot of additional effort initially, but eventually magnifies the ability to handle data

Rule #6: Utilize powerful external applications

- SQL databases
- GMT (Generic Mapping Tools)
- PVM (Parallel Virtual Machine)
- OpenGL (open graphical modeling library)
- Qt (probably the most powerful cross-platform C++ graphics library and IDE)

Challenge

- Obeying these rules is not so easy
- It requires years of consistent development
- It requires a group of developers

Quiz

- You have learned about the “traditional” (UNIX shell), “database-driven,” and “reflection processing” approaches
  - Which of them can incorporate the other two?

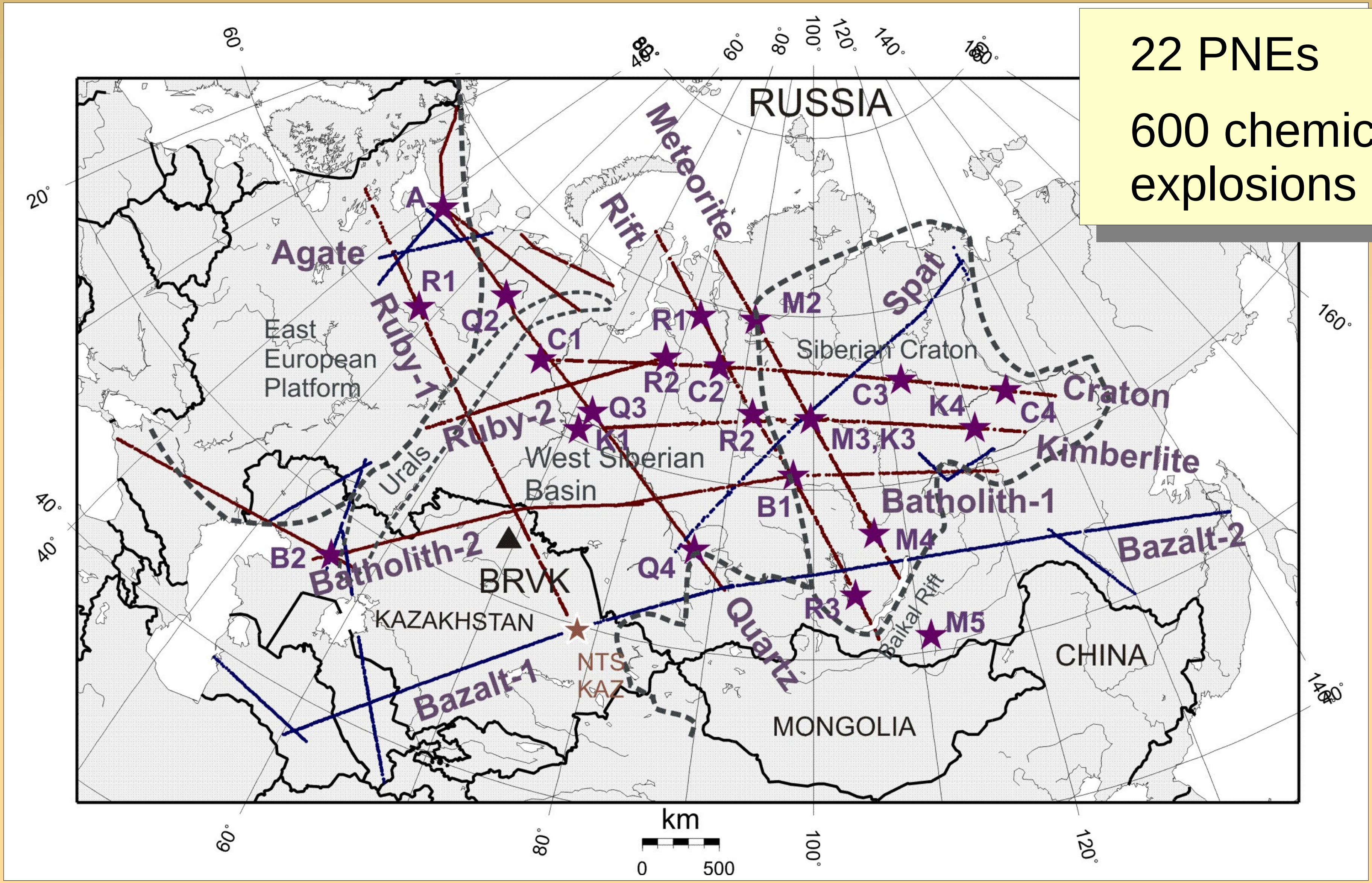
Quiz

- You have learned about the “traditional” (UNIX shell), “database-driven,” and “reflection processing” approaches
  - Which of them can incorporate the other two?
- “Commercial Reflection,” because it allows building custom executables for each processing task
  - But only if we generalize it to “academic” research problems

IGeoS system

- http://seisweb.usask.ca/igeos
- Used in *all* applications I have encountered so far
  - GPR, hi-res, reflection 2D/3D/4D, wide-angle, nuclear-explosion, earthquake, real-time seismic data
  - Field quality control and processing
    - Largest to date 3D survey with over 600 PASSAL "Texans" deployed daily
  - Potential-field and non-geophysical applications
  - Over 250 plug-in tools
- Now, principally a framework for code development, reuse and maintenance

Long-range PNE projects in U.S.S.R.

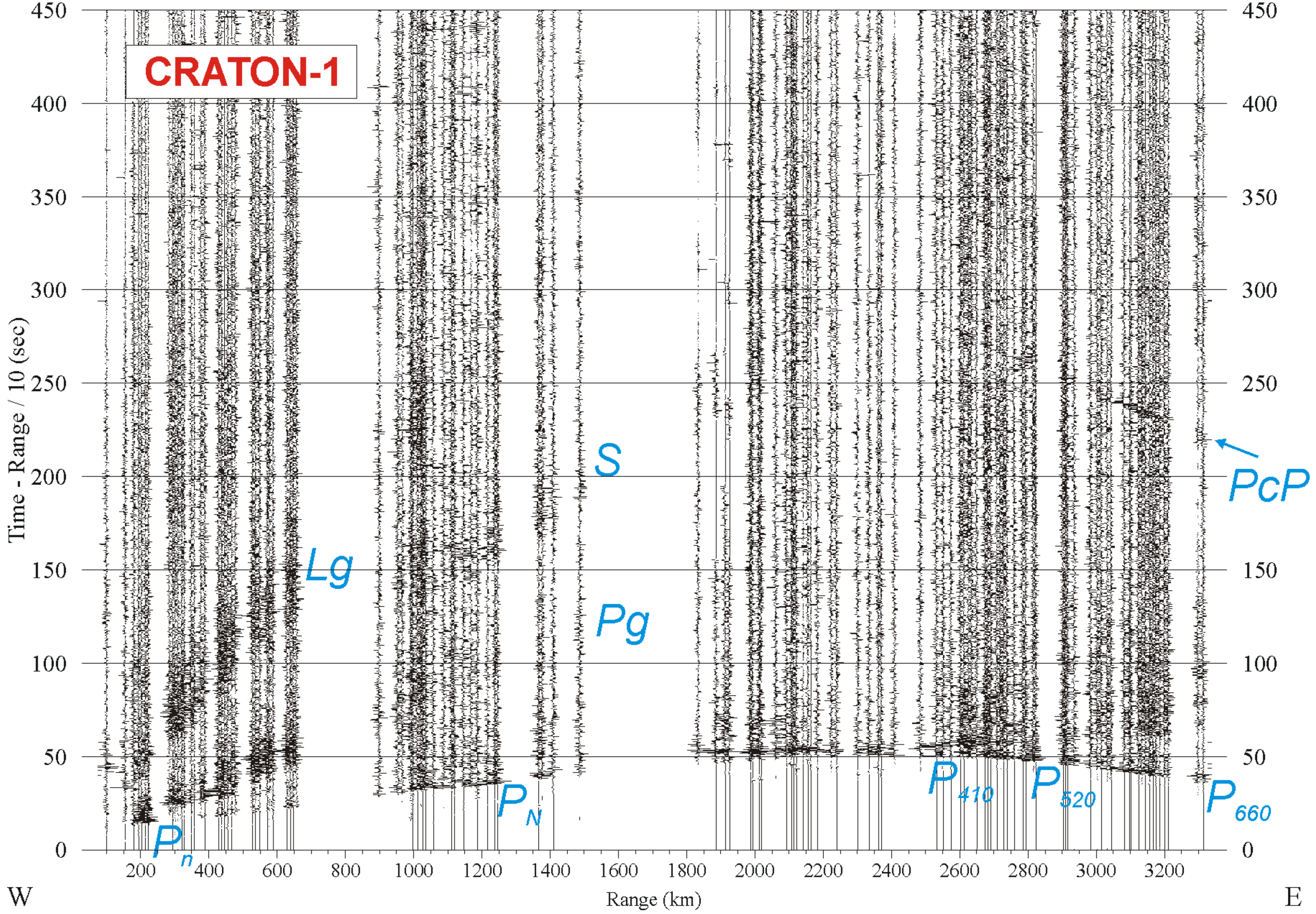


22 PNEs

600 chemical explosions

- Note: controlled-source projects are not always small and simple!

Data example (PNE)



Learn from seismic industry

- Modern datasets:
  - 3D, 4D
  - 3C (three-component)
  - > 30,000 recording channels per shot
  - ~20,000 shots per survey
- Culture of digital data analysis
- Culture of software development

IGeoS History

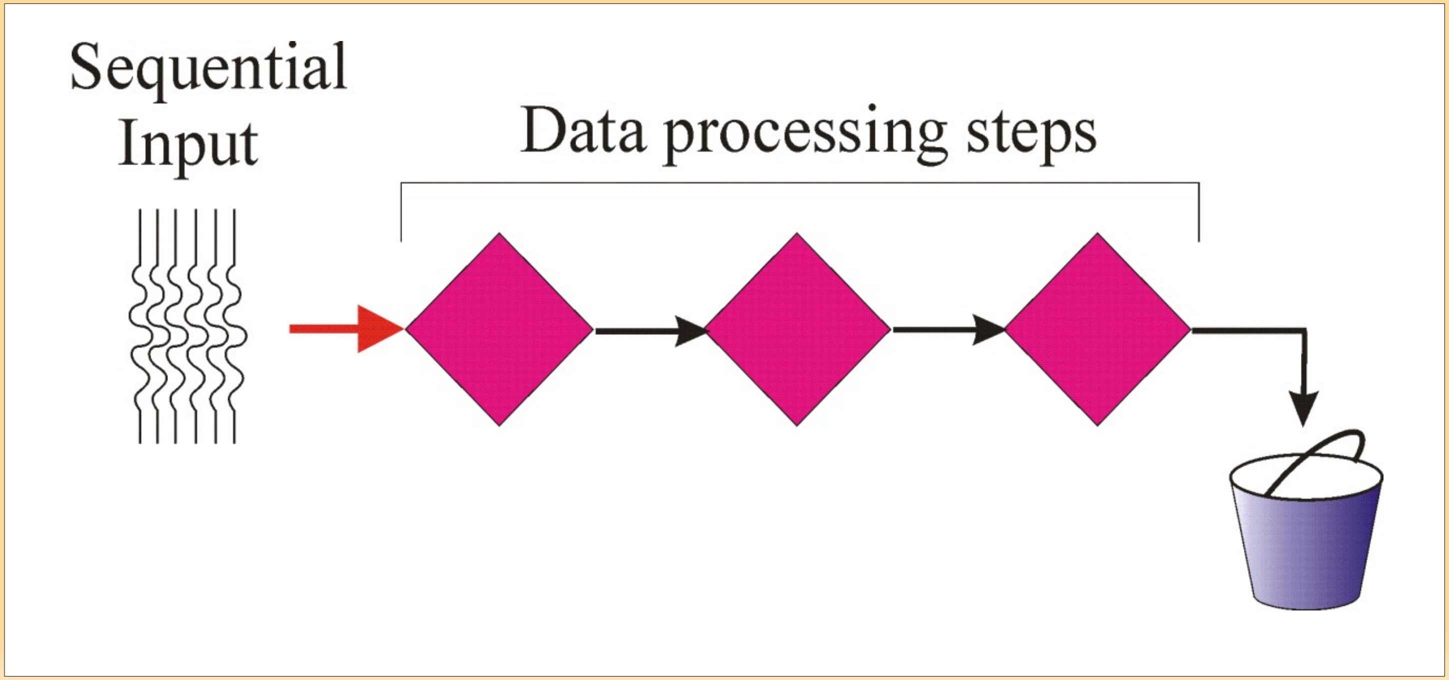
- Over 15 years of intensive development
- Originally a replacement for DISCO (now Echos) reflection processing package
  - Started as a multicomponent wide-angle seismic interface for DISCO on VAX
  - Still supports DISCO job scripts
  - Much more general data and processing models
- Formerly called “SIA” (this name still mostly used inside)

Scope

- Basic seismic processing (like Seismic Unix)
- Synthetic waveform modeling (1D/2D/3D)
- 2D ray tracing (including Receiver Functions!)
- Migration (2D and 3D RF), *Q* tomography
- Well-log package
- Potential-field package
- Visualization system (3D, OpenGL)
- Real-time data system
- Web services
- Code-development collaboration system

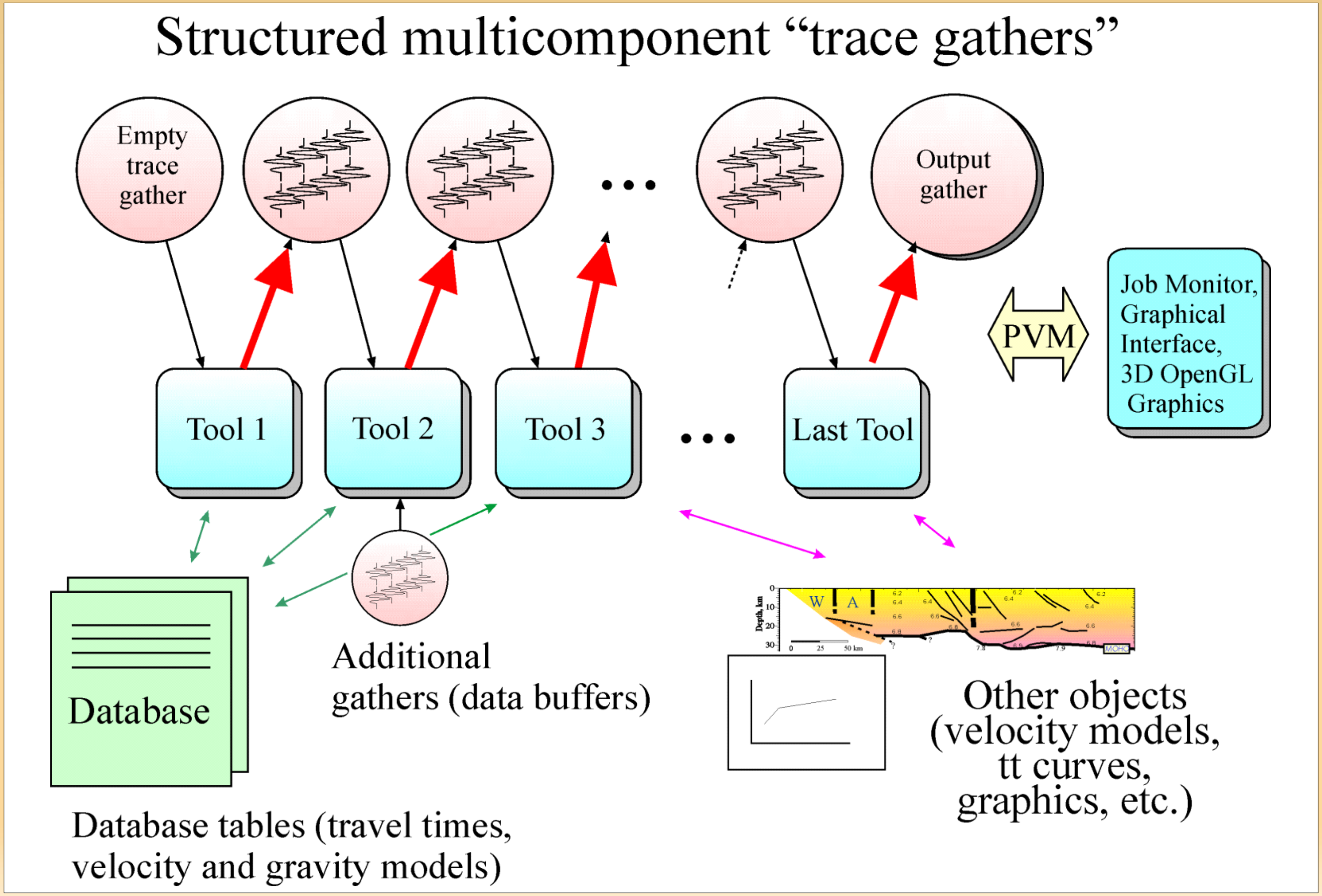
Traditional seismic processing model

- The tools are connected by “data files” or “pipes” of some common format
- Data are fed in through an “input” and discarded on exit
- Examples: SAC, Seismic UNIX, ProMAX, DISCO



IGeoS processing model

- Instead of "pushing" trace data through, try "pulling" some kind of general *"result"* from the end
- There *may not* be any seismic traces in the flow!



Seismic traces in IGeoS

- Arbitrary user-defined headers (as in ProMAX)
  - Headers are *very* extensively used in tool parameterization
- Variable time starts and sampling
- Multicomponent (can also represent data grids for potential-field work or multiple well logs)
- Automatically arranged in multicomponent “ensembles” and “gathers”
  - This makes coding multicomponent applications easy

“Datasets”

- “Dataset” in IGeoS can be anything that can fetch “seismic” traces
  - Formats are resolved individually
- Examples:
  - One or many files (e.g., SAC/*/*.SAC_ASC.gz)
  - File directory trees (as in PASSCAL data)
  - Linear series of files with (optionally) restricted sizes (e.g., file1.sia, file2.sia,...)
  - Database file indexes
  - Trace buffers stored in memory
  - UNIX pipes, Internet connections
  - Combination of other datasets

Tool interactions

- All tools reside in common address space (like in ProMAX but *not* SAC or SU)
- Any tool can talk to any other
- In most cases, a tool simply passes trace objects to the next tool when they are ready
  - Can pass them backward, discard or create
- No notion of input tools (unlike ProMAX, SAC, or SU)
- Tools can work without any 'traces' at all
- Some tools can provide “functions” to the user
  - Example: tool “*refmod*” computes IASP91 travel times broadly used in our exercises

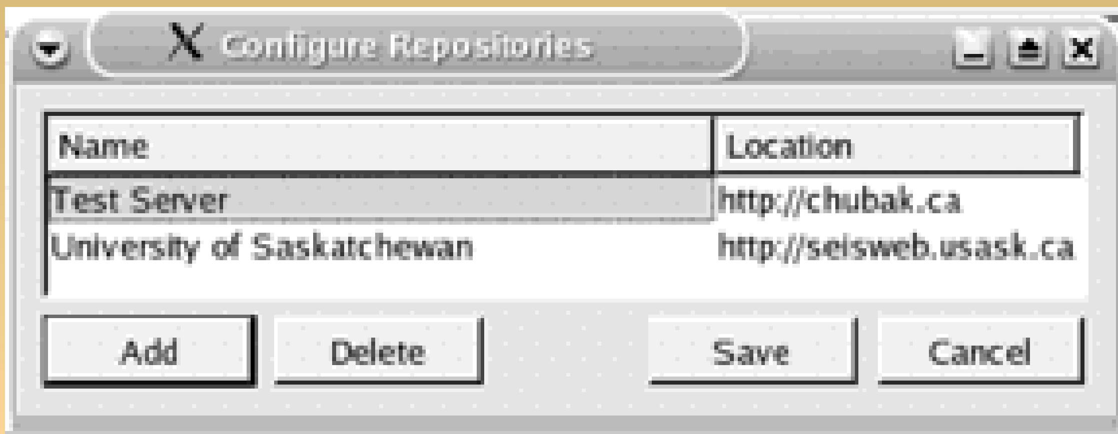
Portability

- Originally developed on Vax, Sun (Solaris), SGI (IRIX), and IBM servers
- Now mostly Linux
  - Mandrake, Mandriva, Fedora, Red Hat Enterprise, SUSE, Ubuntu
  - Laptops, workstations, clusters, field boxes
- Darwin (on your iMacs)
- With GNU compilers, portability does not seem to be a problem
  - Its own build system
  - Auto-detection and self-testing
    - Type *sia-update –test .modules* on your iMac

Collaboration

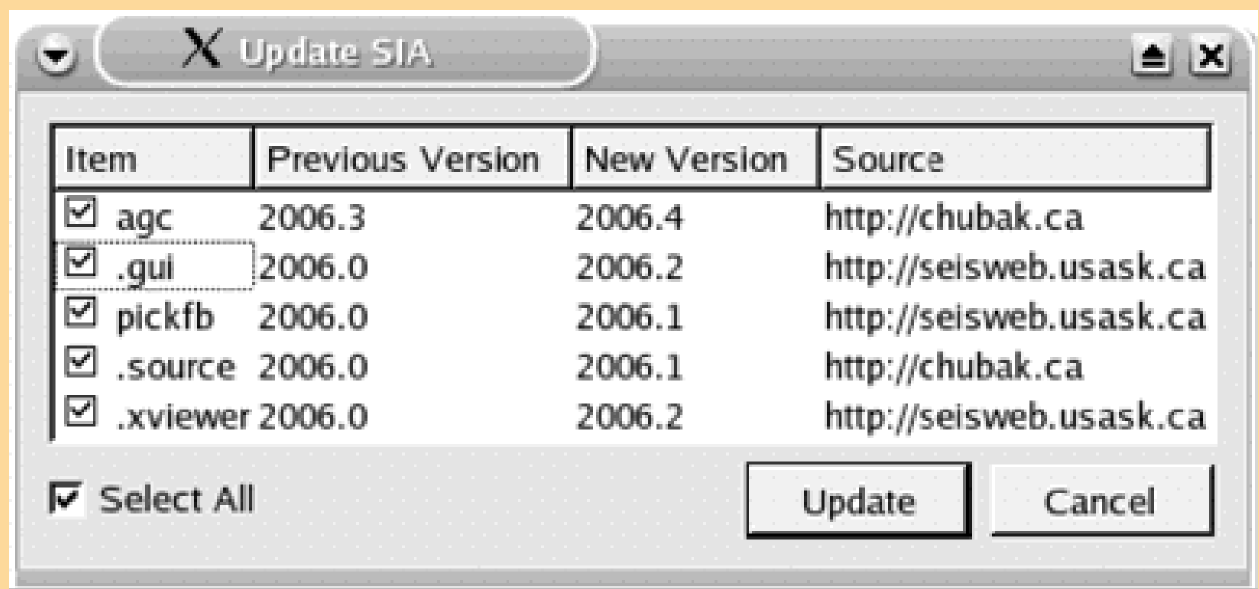
- We all have to develop new code when working on new problems
- IGeoS system has an automatic code updater from multiple repositories
  - Almost like *yum* or *apt-get*
  - Works from source code
  - If someone develops a new tool, it automatically becomes available to everyone
    - Example: IGeoS distribution on http://seisweb.usask.ca is a demo data processor *and* code distributor
    - Type *sia-install - --redo agc* on your iMac

Code update dialog in the GUI



Selecting code repositories

Selecting components to update. These can be modules, libraries, demo examples, etc.



Today's exercises

- USArray data handling using IGeoS
  - Reformatting and organizing data
  - Using SQL databases
  - Extracting events, corridors, and other data subsets
    - Gathering, sorting, component rotations
  - Creating maps and record-section plots
  - Using SOD-like capability and web service for “data mining”
- 1D synthetic waveform modeling example
  - Using parallel computation

Using batch processing

- You can start the entire processing described here in one command:

```
source breq_fast.sh;
source prepare_db.sh;
source events.sh;
source process.sh;
source sod.sh;
source web.sh;
source synthetic.sh;
```

- … and go to the library[1] for a few hours.

[1] 'Library' is a bar on the University of Wyoming campus

Example #1: getting data from IRIS

- Look into *breq_fast.sh*:
  - request.job creates breq_fast requests for emailing to IRIS
  - rdseed.job uses *rdseed* to break SEED into many SAC files
    - Use gzipped ASCII SAC - it is more compact than binary SAC and platform-independent!

Example #2: populating your database

- Look into *prepare_db.sh*:
  - make_tables.job creates all database tables
  - read_sac.job reads in gzipped SAC files, collects metadata from them, writes waveforms and database out
    - Note that it won't fail with “Arguments too long” with too many SAC files
    - However, you don't want the output waveform files to get too big – hence save one year at a time
  - edit_tables.job and connect_waveforms.job perform QC and final tuning of the database

Example #3: extracting event windows

- Look into *events.sh*:
  - event-gather.job extracts time gates for a specified arrival and collects them in a separate file
    - Note the built-in IASP91 travel-time calculator (tool refmod) to which you can add your custom “arrivals”, like *Lg*
    - Note the horizontal component rotation (tool *rotate*)
  - event_gathers.job queries the db for *all* ~400 events and collects gathers for each of them
    - This takes 4 – 18 hours on our machines

Example #4: working with the database

- Look into *process.sh*:
  - show_db.job shows how to make arbitrary db calls and view results
  - extract-waveforms.job gets *all* ~60,000 waveforms in the processing flow, so that you can try doing various things with them
  - make_corridor.job creates “station corridors” along the specified paths and saves them in db tables
  - Various list-*.job's show how to list various items by creating empty data traces and using the normal trace-handling machinery

Example #5: making maps using GMT

- Look into *process.sh*:
  - An easy general approach is to generate a synthetic trace for each item you want to plot and make it print headers in a file
    - This is not the only way; there also is a direct GMT interface (modules image, gmt, graphic)
  - Several map-*.job's show how to obtain various subsets from the database and plot their coordinates
  - map-event.job shows how to plot stations that have recorded a selected arrival from any event

Example #6: plotting time sections

- Look again into *process.sh*:
  - An easy general approach is to generate a synthetic trace for each item you want to plot and make it print headers in a file
  - Several map-*.job's show how to obtain various subsets from the db and plot their coordinates
  - map-event.job shows how to plot stations that have recorded a selected arrival from any event

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- Yes, if we learn to do two things:
  - Deploy our own processing onto the server
  - Retrieve data files/streams from it

Data access

- Can we solve the problem of data access from a remote data source *in principle* (so that no other mechanism would need to be developed)?
- Yes, if we learn to do two things:
  - Deploy our own processing onto the server
  - Retrieve data files/streams from it
- Then:
  - User can entirely control the result. Pre-processing (e.g., QC, filtering, rotation, RF deconvolution, can be done on the server)
  - Data center staff involvement is minimized
  - Internet traffic is minimized

Example #7: SOD-like data access

- Look into *sod.sh*:
  - sod-list.job generates SQL queries based on user's specifications of event and station ranges, distances and azimuths
    - It generates an “anchor trace” for each available time window and lists its attributes
    - Saves the results in text files
    - It again creates maps of events, stations, and raypaths – just in case you may need them
  - sod.job also actually retrieves the requested waveforms and saves them in files

Example #8: web service

- Problem:
  - I have an exactly the same package plus *another dataset* named USArray installed on seisweb.usask.ca
  - We now want to execute some processing with this dataset and obtain some data from it
    - We will implement this via a web (HTTP) connection
  - Think of this as doing processing on a data center's computer
- Look into *web.sh*

Example #8: web service (cont)

- Look into *web.sh*:
  - several web-info-*.job obtain general settings of the server
    - Names, directories available
    - Usage examples for various tools
  - web-flow-usage.job gives a usage example of one of the installed jobs
  - web-flow-exec.job executes a remote job with your parameters and retrieves results (files)
  - web-flow-send.job send *your job* to the server and executes it there
    - Think of this as the “SOD” job above

Example #9: Modeling

- Modeling is another type of “processing” which may require special resources
  - Through the web-service capability, you could use someone else's super-computer
- Look into *synthetic.sh*:
  - reflect-synthetic.job performs 1D “*reflectivity*” modeling of 3-component seismograms in a layered Earth model

Conclusions

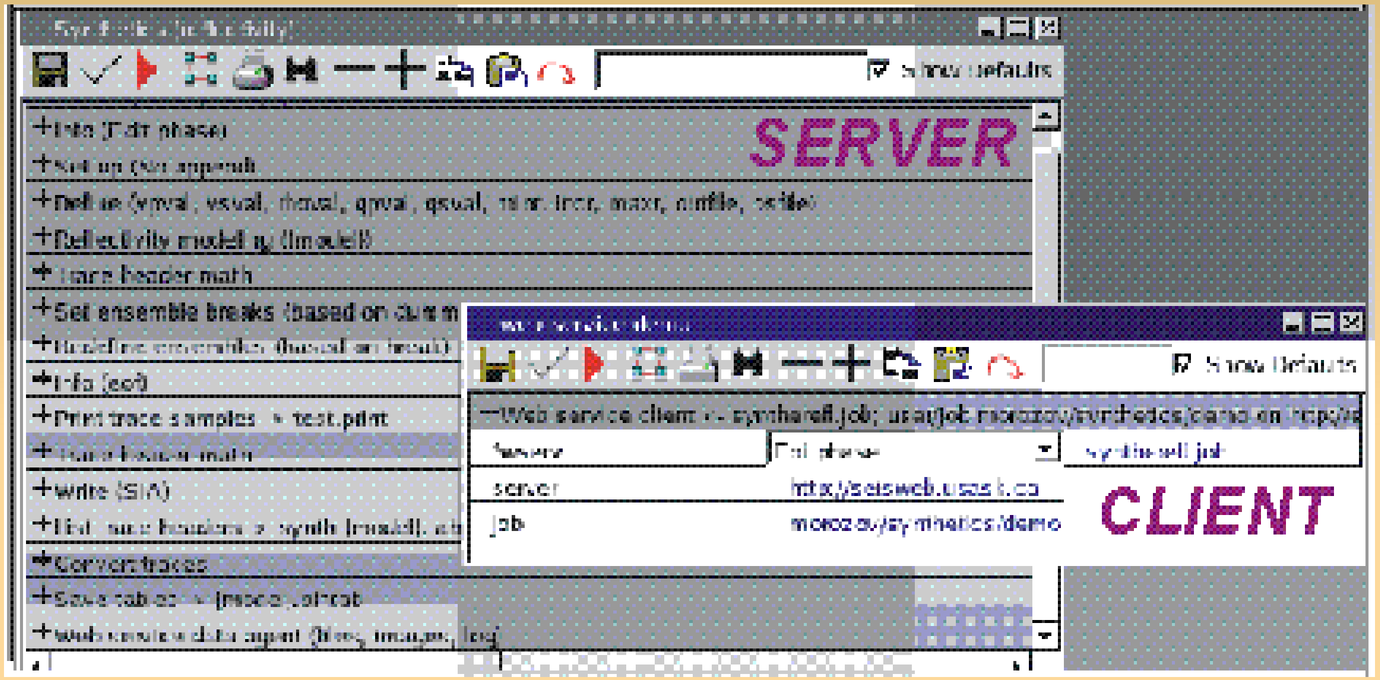
- Process-oriented approach allows solving most earthquake data-handling problems
  - Uniform approach to data access, processing, modeling, and inversion
  - Fully reproducible, self-documented processing
  - USArray data handling tasks are feasible on common hardware
- A large software system suitable for passive and active-source seismology is available
- With web collaboration, sharing data and computer resources is practical

Homework for tomorrow

- Assume that the dataset shown in class contains all of the available data for the ~400 stations in western U.S. (not just selected event windows)
- Propose a sequence of operations needed to construct the “noise” cross-correlation for one selected station with all others
  - Sketch a pseudo-code ('generate anchor trace', 'ask the database for time windows','for each database response, do...', etc.)
    - Note that tool *sgstack* (“shot-gather stack”) discussed in event-gather.job might be helpful here
  - Think of optimizing the process by selecting only a range of group velocities between the stations
  - Think of excluding some strong known arrivals (e.g, *P*, *S*)

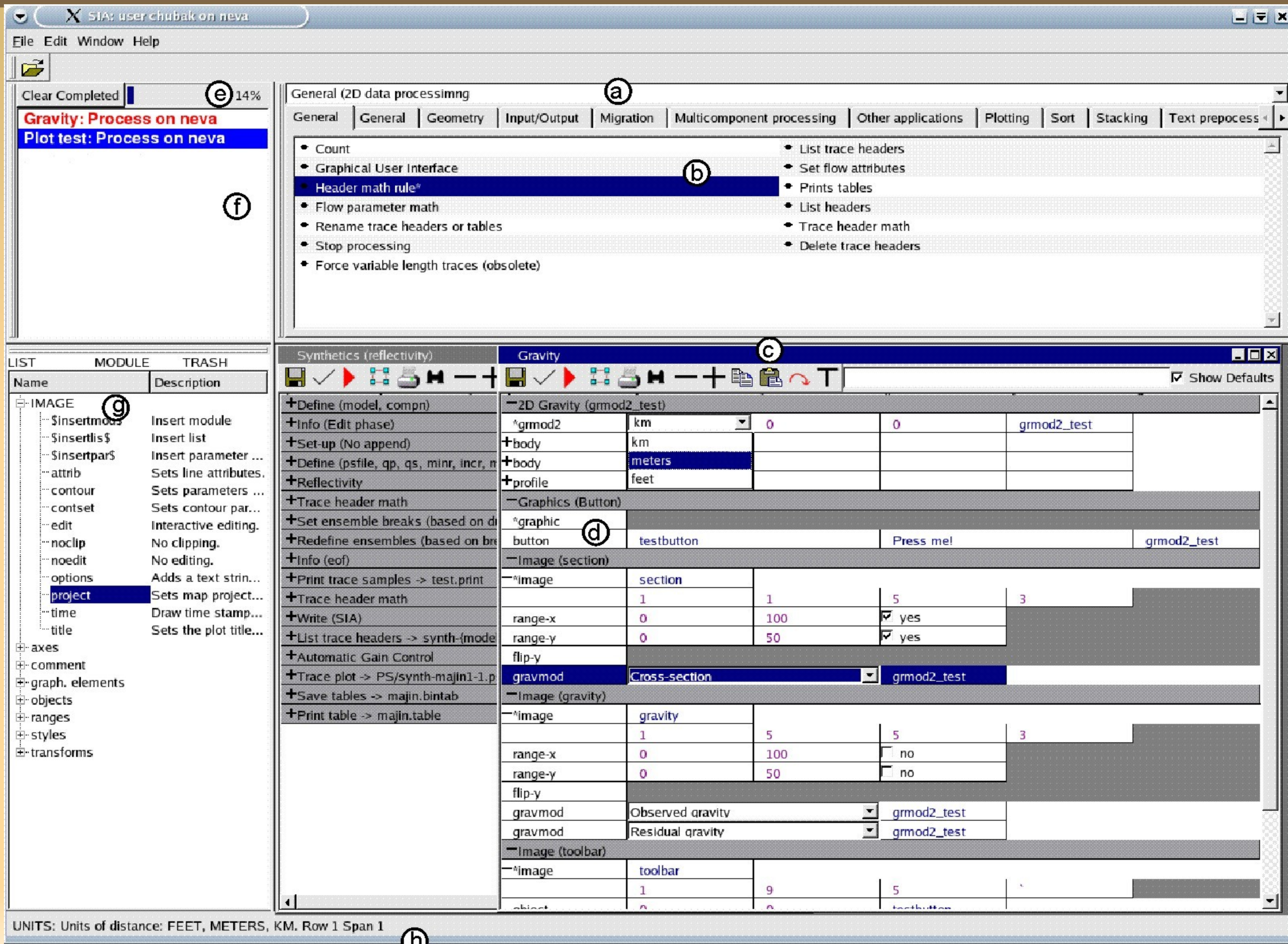
Appendix:
topics not covered today

Web service

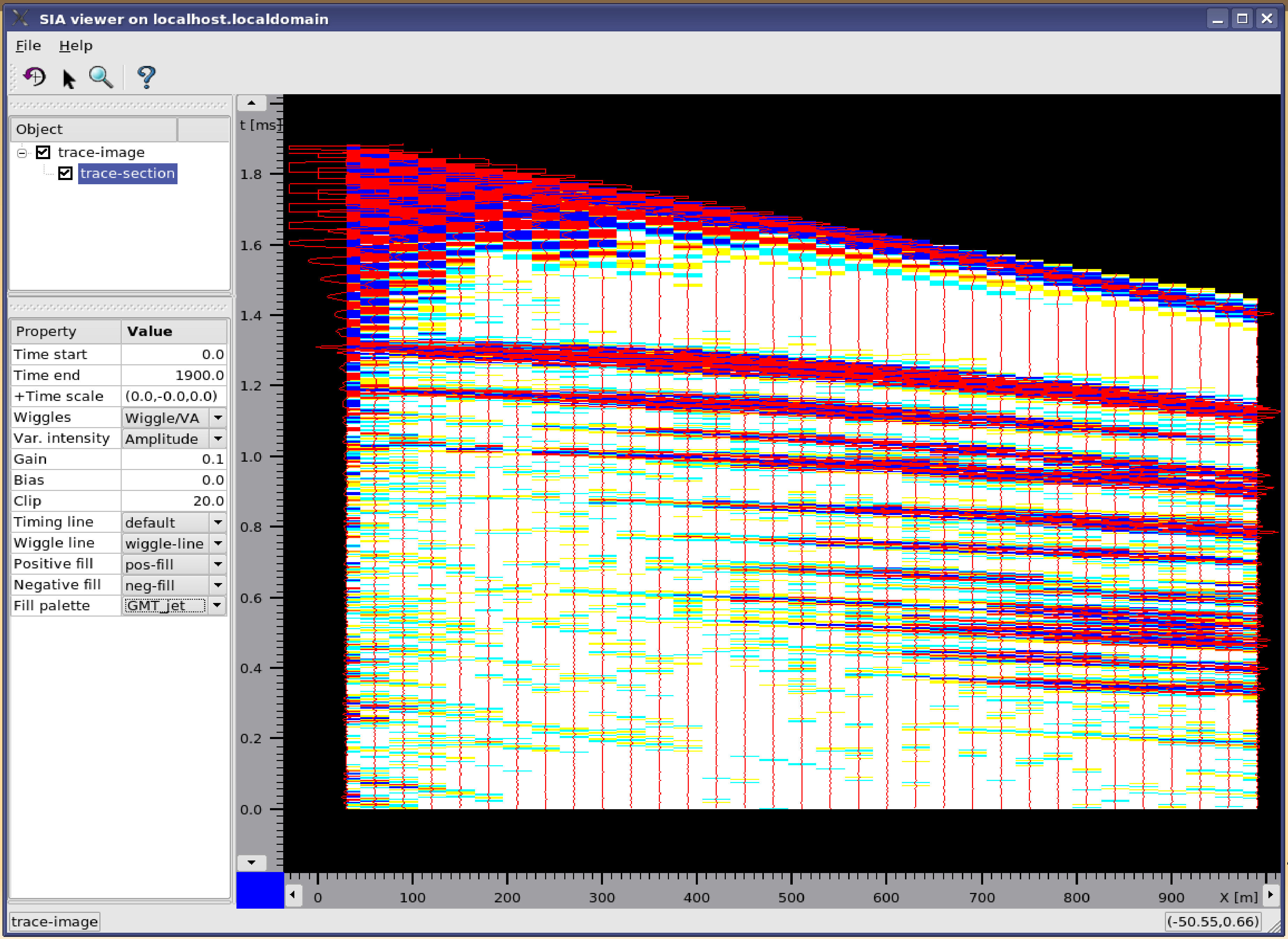


- This is how this web service looks in the GUI

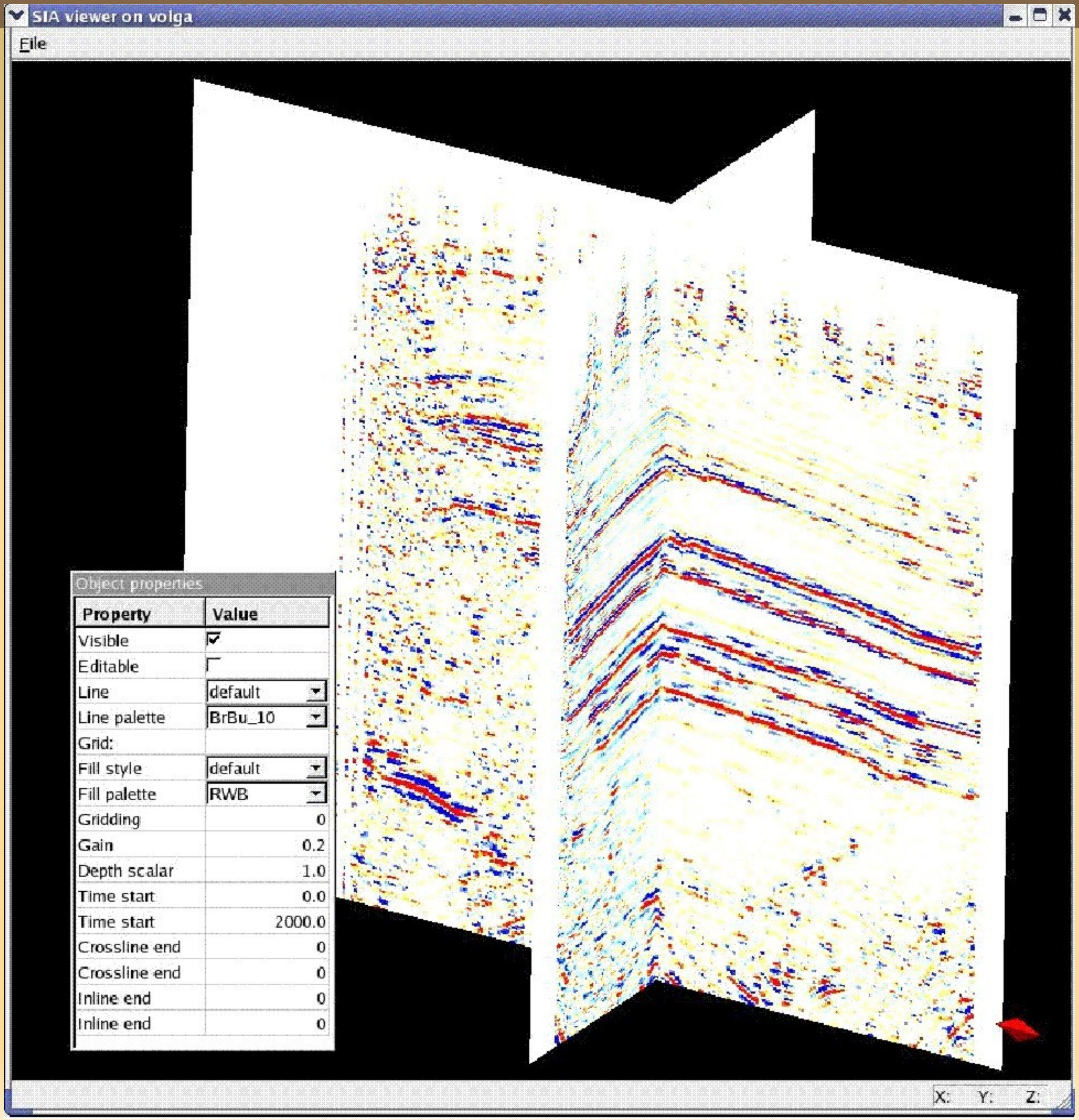
Graphical User Interface



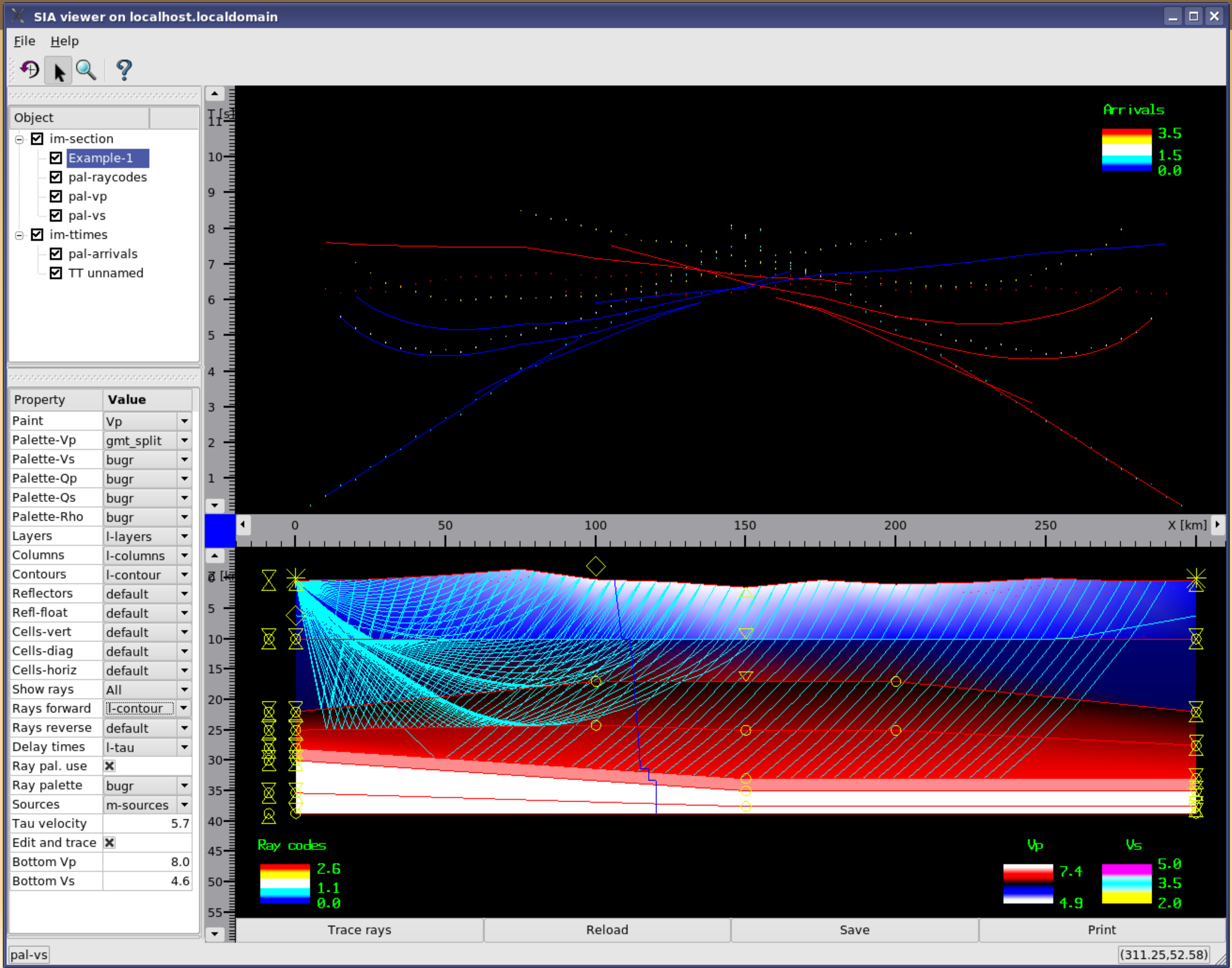
Interactive trace display



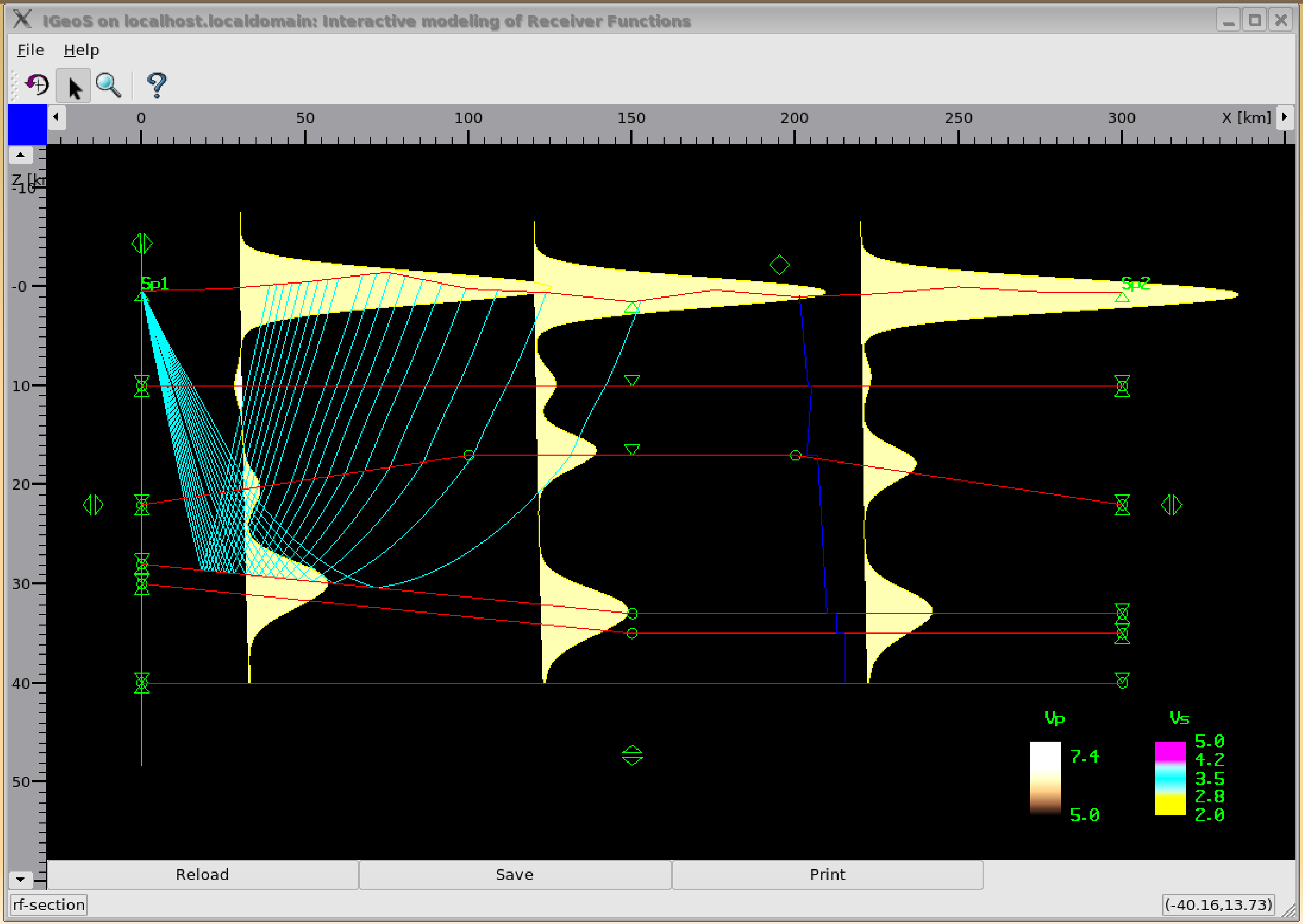
3D reflection visualization (early attempt)



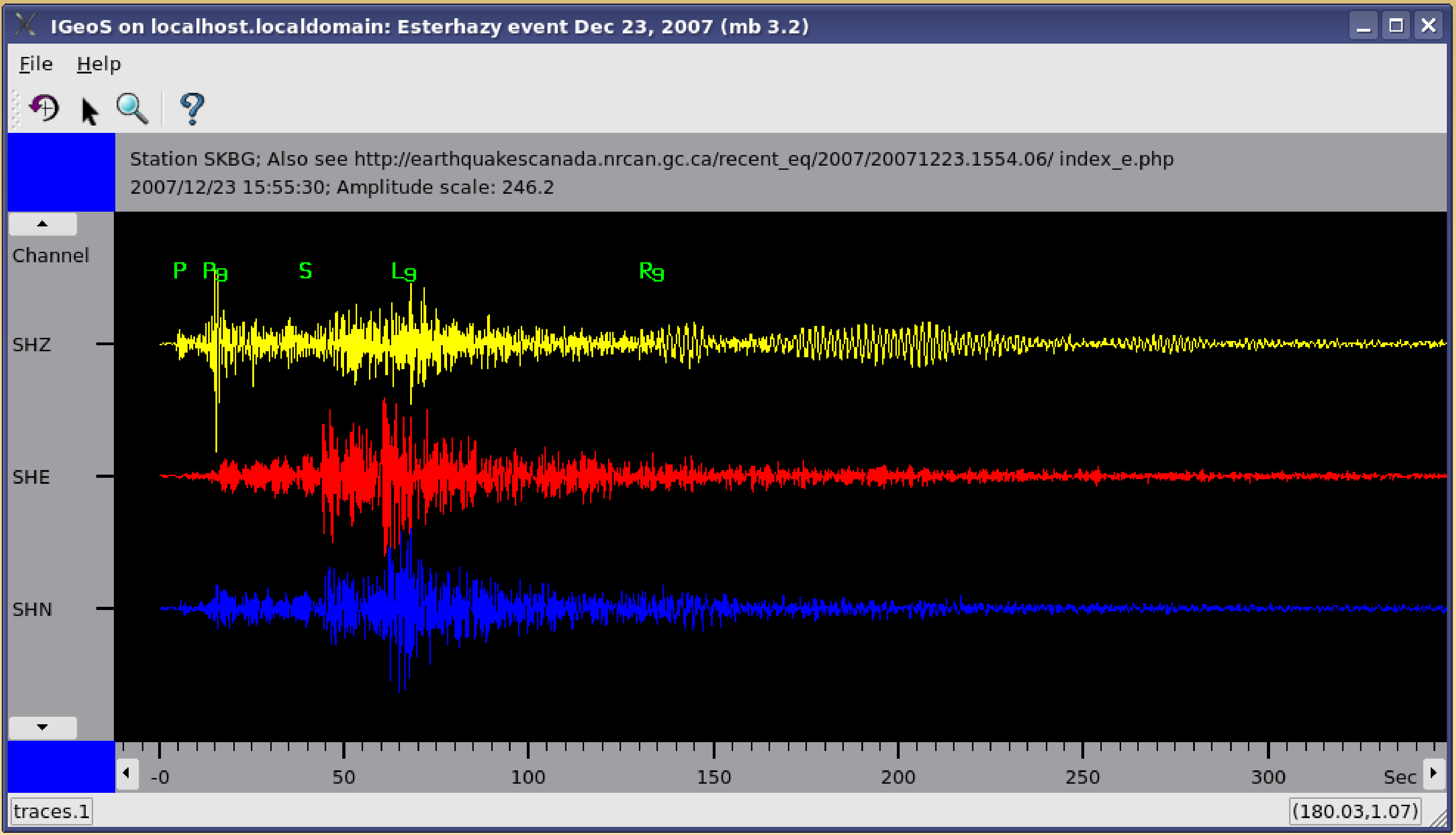
2-D Ray tracing and gravity modeling



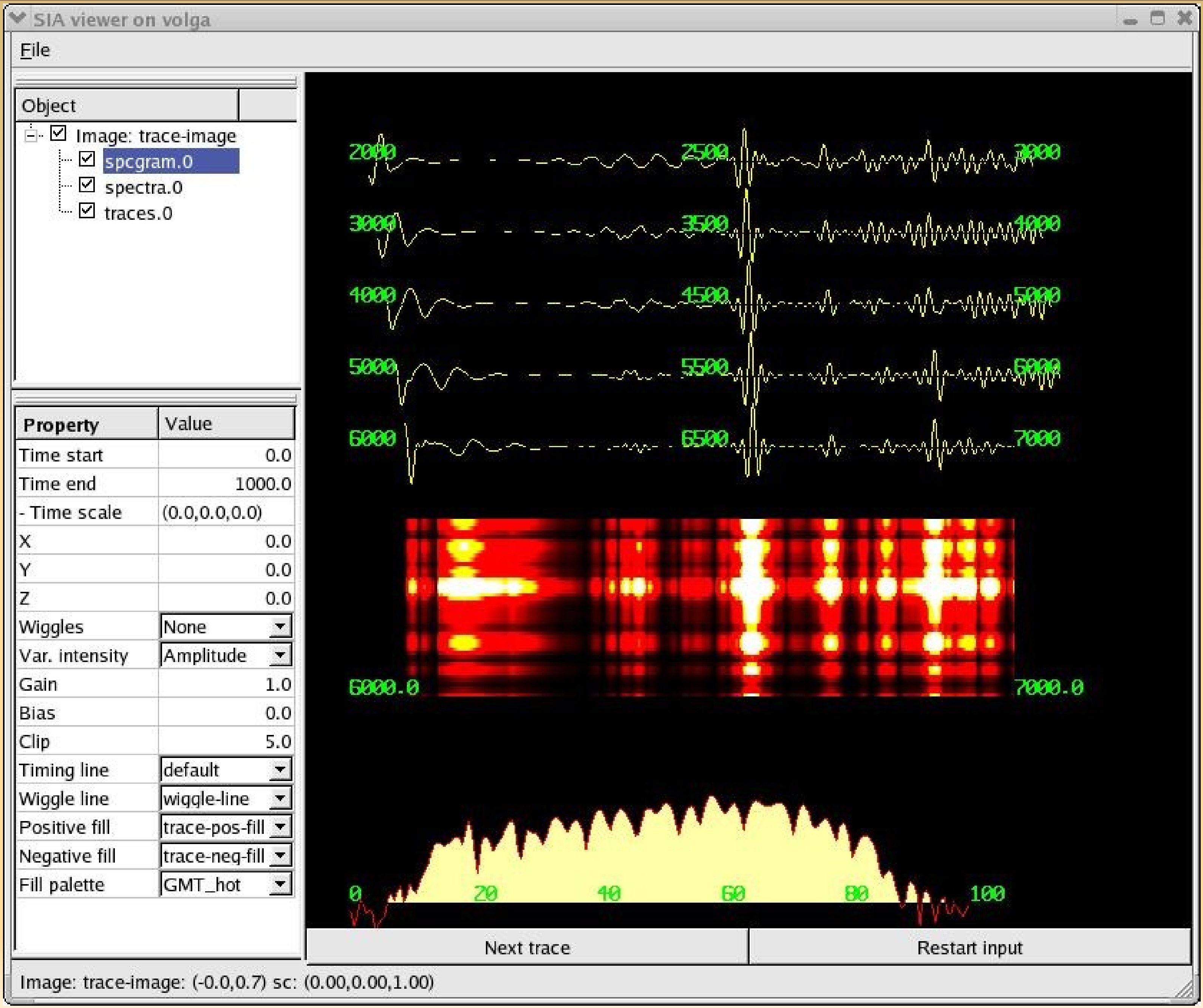
Interactive Receiver Function modeling and inversion (work in progress)



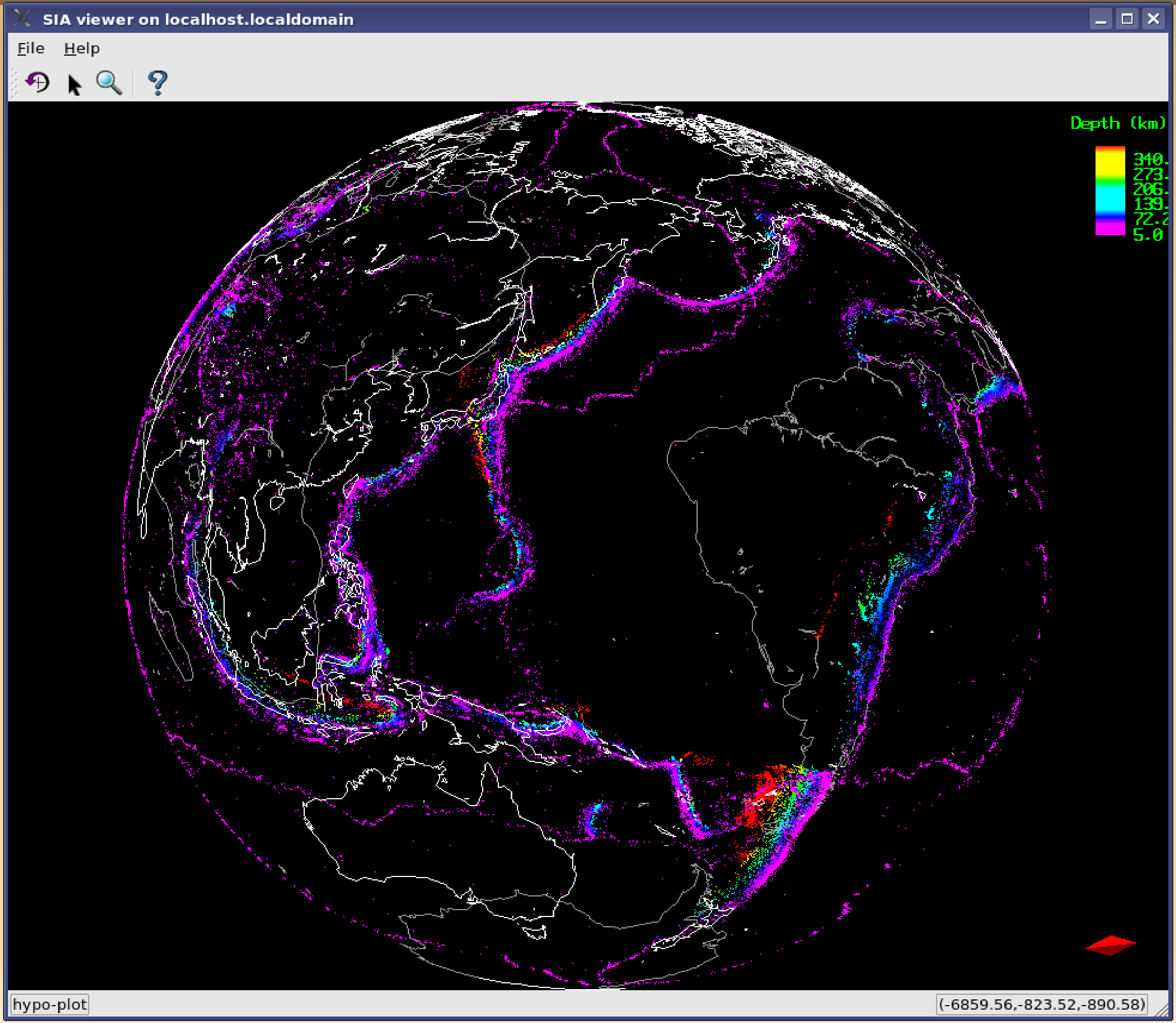
Real-time data display (event in Saskatchewan)



Real-time display (early attempt)



Animated 3D display of 75000 earthquake hypocenters. Georeference data *directly* from GMT



Web processing interface