Visualization and Sonification of the Global Seismic Wave Field

Contributed by Ben Holtzman

A team at the Seismic Sound Lab (http://www.seismicsoundlab.org) constructs representations of global seismic waves through sound and animated images. The animated images are renderings made with “yt” of simulations using the CIG-hosted code SPECFEM3D_GLOBE. The sounds are time compressed seismic data with minimal additional processing. Synchronizing the sounds and images reveal complex patterns and illustrate numerous aspects of the seismic wave field bringing new insights to both the public and, hopefully, researchers.

At the global scale, the SPECFEM3D_GLOBE code can model wave fields with a broad range of frequencies, for realistic crustal structure. The python environment “yt”, designed to process, analyze and visualize volumetric data in astrophysical simulations, is adapted here to spherical geometries relevant to seismology. To visualize this data, techniques used in the visualization of astrophysical phenomena such as star formation and galaxy evolution were applied to the seismic wave fronts. The visualization was created using a volume rendering technique, wherein an image plane traversed the volume and at each step in the traversal the individual pixels of the image were evolved according to the radiative transfer equation, accumulating from absorption and attenuating due to emission, as shown in the figure. Colormaps are constructed using Gaussian and linear functions of RGB values and are mapped to the amplitude of net displacement in each voxel and time step. In a given filter, the color shows the radiative value (local emission at each point) and the curvature of the top of the filter shows the alpha value that describes the transparency (alpha=1 is completely opaque, alpha=0 is completely transparent). The combination of the color map and the alpha function is called the transfer function. This approach results in a smooth highlighting of specific displacement values throughout the volume, illustrating the global wave field for one time step. The example snapshots shown in the above figure were generated from a SPECFEM3D_GLOBE simulation of the 2011 Tohoku Magnitude 9.1 earthquake (USGS finite fault model).

A basic pedagogical exercise is to visually and sonically distinguish between surface waves and body waves. To demonstrate this difference, using the data and the simulation from the Tohoku earthquake, our initial efforts involve filtering both the images and the sounds in parallel. To make the sounds, we run a low pass and high pass filter on the following page.
Code Corner

NEW RELEASES

- Axisem 1.1 2014-08-27
- CitcomS 3.3.0 2014-10-09
- PyLith 2.0.3 2014-08-20
- SPECFEM ongoing via git
- VirtualQuake 1.1 2014-10-27

User Meetings

ASPECT User Meetings are held once a month on Fridays from 10-11am. Contact Eric Heien: emheien@geodynamics.org.

Dates, time and connection information can be found on the Event calendar:
http://geodynamics.org/cig/events/calendar/

SW4

NEW@CIG! SW4. The seismology code SW4 implements substantial capabilities for 3-D seismic modeling, with a free surface condition on the top boundary, absorbing super-grid conditions on the far-field boundaries, and an arbitrary number of point and/or point moment tensor source terms. Each source time function can have one of many predefined analytical time dependencies, or interpolate a user defined discrete time series.

SW4 solves in the seismic wave equation in Cartesian coordinates and is appropriate for local and regional simulations where the curvature of the earth can be neglected.

You can download a tar-ball with the source code and manual from:
http://geodynamics.org/cig/software/sw4/

N. Anders Petersson and Bjorn Sjogreen

PyLith

I am pleased to announce the release of PyLith 2.0.3; a finite-element code designed to solve dynamic elastic problems and quasi-static viscoelastic problems in tectonic deformation.

This release provides several small updates for (1) improved CUBIT/Trelis compatibility in example journal files, (2) building with recent versions of automake, and (3) additional examples from the 2014 Crustal Deformation Modeling Workshop tutorials.

You can download the source code and binaries from:
http://geodynamics.org/cig/software/pylith

Detailed installation instructions for the binary packages are in the User Manual with detailed building instructions for a few platforms in the INSTALL file bundled with the PyLith Installer utility.

Brad Aagaard

XSEDE

CIG’s XSEDE Research Request has been awarded allocations for the period October 1, 2014 - September 30, 2015:

- Stampede: 1,886,789 SUs
- Ranch: 500 GB
- Maverick: 5,000 SUs

If you are interested in using these systems for small-scale research through the CIG allocation, or if you need your own larger allocation on an XSEDE system, please contact Eric Heien for assistance: emheien@geodynamics.org

and other internal issues. The removal of Python should simplify the code while retaining most functionality.

Changes include:
- Removed Python sections of CitcomS
- Wrote Python to standard parameter file conversion tool (Py2C)
- Converted Python cookbooks parameter files to original style parameter files
- Added output of parameters to a pidXXXXXX style file
- Updated the manual to correspond to the new changes

For more details please see the ChangeLog included with the release and the website manual.
Software Citations
An interdisciplinary team of social, library and computer scientists, which includes CIG Staff, has recently been awarded an NSF EAGER grant to study issues in citing open source software. As part of this project, researchers will be surveying the geodynamics community on issues surrounding current practices in software usage, sharing, and citation. Survey results will help inform participants at a 2015 workshop to discuss use cases and metadata standards for citing open source software. Participants will include stakeholders from industry, publishing, granting agencies and domain experts. The geodynamics community, as the community of practice, will have the opportunity to pilot and provide feedback to the developed process. Subscribe to cig-all@geodynamics.org to be included in the upcoming survey!

Governance
Letter from the EC Chair
Dear Colleagues,
It is hard to believe that we are approaching the 10th year of CIG. As we reflect back on the past, it is time to be thinking about the second renewal proposal to NSF. CIG has been funded by two cooperative agreements the first between NSF and Caltech (CIG-I) and the second with UC Davis (CIG-II). Louise Kellogg has agreed to continue and will serve as Director of CIG III with the unanimous support of EC and SSC. We see the continuity of leadership and staff as a significant foundation as plans develop. Our thanks also to Lorraine, Eric, and Carla for their hard work on our behalf.

Over the past 10 years many people have been involved in CIG, serving on a working group, SSC, or EC. Others have donated code and/or code developments, presented a webinar, or a talk or tutorial at one of our workshops. CIG’s success has been a result of the hard work and dedicated effort of the CIG staff and its many volunteers. I tried to guestimate how many volunteers have contributed over the years. I’m sure it is more than 200 and probably less than 4,000. So, we can safely say, we know the number about as well as we know the viscosity of the mantle. Thanks to all of you.

The Executive Committee and Science Steering Committee have begun planning earlier this year (see Positioning CIG online). This is an important time for everyone to voice their input. We have learned over the past 10 years that CIG works best when people roll up their sleeves and get involved. Our most successful projects have champions who are passionate, step up and partner with CIG staff, and engage the user community. Look for upcoming information about the proposal writing team and how to communicate with them. Also, plan to attend the joint IRIS/CIG reception followed by the CIG business meeting on the Monday of AGU. AGU is a busy time (somewhere I heard that it’s the most wonderful time of the year), but we need the community’s input to go forward with a strong renewal that addresses its needs.

Scott King
Chair, Executive Committee

2014 Elections
CIG Member Representatives are voting for 1 new Executive Committee and 4 new Science Steering Committee Members. EC candidates Omar Ghattas or Carl Gable will join returning members Scott King, Bruce Buffet, Claire Currie and David Bercovici. SSC candidates Jon Arnou, Tom Clune, Carl Tape, Artie Rogers, Jed Brown, Timo Heister, Dave May, and/or Eunseo Choi will join returning members Brad Aagaard, Magali Billen, Jolante van Wijk and Tim Ahern.

Candidate statements can be viewed at:
http://geodynamics.org/cig/about/governance/elections/

Elections close on December 3, 2014.

Many thanks to outgoing EC member Wolfgang Bangerth and SSC Members Jon Arnou, Jed Brown, Roger Buck, and Carl Tape; and to our Nominating Committee – Marc Spiegelman, Gary Glatzmaier and Rowena Lohan.

New EC and SC members will be announced at the CIG Business Meeting during 2014 AGU Fall Meeting.

Events

ASPECT @GEOMOD
An ASPECT short course was given during GEOMOD in Potsdam, Germany on September 4-5, 2014. Course instructors Juliane Dannberg and Anne Glerum delivered a hands-on tutorial to 14 participants, 9 of which were students. The tutorial covered an introduction to using ASPECT, demonstrated its modern numerical methods and illustrated possible applications. A one-day strategy meeting was held on the next day for advanced users.

ASPECT & Calypso
This summer’s CIDER 2014 Summer Program Dynamics of Planetary Interiors in Santa Barbara, California on June 22 to August 1, 2014, and ELSI Summer School in Tokyo, Japan August 2-3, 2014, included tutorials delivered by CIG Staff. For both meetings, CIG Staff configured virtual machines for participants that included most of the software for all the offered tutorials and provided installation support. Tutorials on ASPECT delivered by Dr. Eric Heien and Calypso by Dr. Hiro Matsui introduced new users to the software and steered them through example runs. AxiSEM tutorials, delivered by Tarje Nissen-Meyer, were also offered at ELSI. A total of 21 early career scientists attended tutorials over 2 days at ELSI. CIDER participants included 41 early career and 40 senior scientists.

SeismoDome 2
Around the New York City area on November 3... Don’t miss the show at the Hayden Planetarium at the American Museum of Natural History – SeismoDome: Sights and Sounds of Earthquakes and Global Seismology. SPECFEM researchers will fill the planetarium dome with images and sound of seismic waves moving through the earth from several large earthquakes as viewed from the interior and exterior of our planet. See amnh.org and seismicsoundlab.org
CIG Webinars
CIG webinars draw from a pool of experts from mathematicians, to computer scientists, and to geoscientists, among others to bring together a cross-cutting community of faculty, students and researchers to both inform and disseminate knowledge on the tools and methodologies employed to further the study of problems in geodynamics.

The one hour webinars will be held the 2nd Thursday of each month October through May (no webinar in December due to AGU) at 2pm PT unless otherwise noted. Webinars will be recorded for later viewing. Reminders and details are sent through the cig-all mailing list.

This year’s series features topics in software infrastructure and development that enable our science. Webinars focus on bridging communities, laying foundations for robust and usable software that address active areas of geodynamic research and HPC for big data.

Webinar Schedule
October 9 - Anna Kelbert, OSU
November 13 – Jed Brown, ANL
January 8 – Louise Kellogg & Pierre Arrial, UC Davis
February 12 – Eric Heien & Hiro Matsui, UC Davis
March 12 – Cedric Thieulot, U. Utrecht
April 9 – Lucy Flesch, Purdue
May 14 – Arben Pitarka, Stanley Ruppert, & Douglas Dodge, LLNL

Next Webinar
Thursday, November 13, 2014 @ 2pm PT
Software Design and packaging for extensibility, provenance, and sharing
Jed Brown
Argonne National Lab
There is more to developing successful scientific software than the core numerical implementation. Slapping an open source license on the code does not mean an army of talented developers will swoop in and turn your work into a wonderful package that everyone loves. This talk will discuss techniques to improve extensibility so that users and developers can extend your software to solve problems you never imagined; provenance so that published results can be understood, reproduced, and extended; and facilitate sharing of enhancements, configurations, and benchmarks to advance the software capability and encourage a vibrant and insightful community.

For more details on this and all CIG webinars see:
http://www.geodynamics.org/cig/communit y/Webinar

Visualization and Sonification
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seismic data, above and below about 1.0 – 0.5 Hz. The surface waves clearly propagate as a wave packet, and the coherent motion is clear when listening in spatialized sound environments. To make the images, we apply different transfer functions centered on different bands of displacement amplitude, as shown in the figure. The larger displacement amplitudes correspond to the lower frequency surface waves (right column), with a transfer function designed to look like a plasma. The smaller displacement amplitudes correspond to the higher frequency body waves (left column), with a transfer function designed to render semi-transparent, semi-reflective sheets moving through space (a bit like a jellyfish). The wave fields, when separated like this, look very different and sound very different. Furthermore, the movies with sounds play back at different speeds. The surface wave movies actually have to be shifted more to be in the audible range and thus play back faster than the body wave movies. The synchronization is tight; the sounds correspond to events in the wave motion, and the meaning of the two aspects of the wave field becomes clear. However, much potential for improvement remains in the development of quantitative relationships between the audio and image filters, such that we can explore the behavior of lower frequency (band-pass) aspects of the wave field.

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Upcoming Meetings

December 15-19, 2014. Fall AGU, San Francisco, California
Network with more than 22,000 Earth and space scientists, educators, students and other leaders at the Moscone Center in San Francisco for 5 days of presentations, workshops, and town hall meetings.

December 15, 2014. CIG Annual Business meeting
The CIG Annual Business Meeting will be held on Monday, December 15 during Fall AGU. Please join us for light hors d’oeuvres beginning at 6pm followed by the Business Meeting at 7:30pm at the San Francisco City Club. cityclubsf.com

February 5-6, 2015. Geodynamo Benchmarking Workshop, Boulder, Colorado
Please check the website for workshop details.

April 27–28, 2015. Developing Software Citation Methodology Workshop, Davis, California
Discussions with scientists and industry leaders on creating a framework for citing open source software.

June 1–July 31, 2015. CIDER 2015 Summer Program, Berkeley, California
Next summer’s theme - Solid Earth Dynamics and Climate. deep-earth.org
For more information on CIG hosted events, please go to geodynamics.org

Recently Published


