Workshop report
Virtual Institute for the Study of Earthquake Systems (VISES; http://www.scec.org/vises/)

Workshop on high resolution topography applied to earthquake studies
(Earthquake Research Institute, Tokyo, Sept. 18-20, 2013)
http://www.opentopography.org/index.php/resources/VISES_JPN13

Planning team
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Overview
Sharing high resolution topography and topographic differencing data, tools, and knowledge between SCEC and Japanese scientists addresses the goals of the VISES program. The growing availability of pre and post earthquake high resolution topography (derived from LiDAR or other methods) means that we should strengthen our joint knowledge about the data handling and its analysis.

In September 2013, 4 SCEC scientists (Arrowsmith, Nissen, Crosby, and Oskin) traveled to Japan as part of this workshop activity. Koji Okumura from Hiroshima University and a frequent attendee at SCEC meetings was our main collaborator for the workshop and meetings. Shinji Toda from Tohoku University was also involved in the planning and the events. Many of the topics we covered are also in the purview of the OpenTopography project (www.opentopography.org). We built a rich and persistent workshop website (with most of the presentations on line, etc. here: http://www.opentopography.org/index.php/resources/VISES_JPN13). I also include an extended agenda from that web site as an appendix to this report.

We had three workshop goals which we confidently achieved: 1) Review the scientific opportunities and recent results coming from the analysis of high resolution topography (<1 m/pixel; past earthquake reconstruction, tectonic geomorphology, and especially lidar differencing, etc.).
2) Train students and other young scientists on the technologies associated with gathering, processing, and analyzing high resolution topography for earthquake applications. And 3) Plan future collaborative research.

The workshop comprised 5 main days of activities (see the end of the text for a few photographs). The first day was a field trip with a small group to the Boso Peninsula to see uplifted shorelines from subduction zone earthquakes. We had a one day scientific symposium emphasizing earthquake geology and tectonic geomorphology followed by two days of training workshop (both at ERI). The meeting was opened by Professor Takehiro Koyaguchi (Director of the Earthquake Research Institute). The talks were delivered by both US and Japanese scientists and covered a range of topics from the needs for high
resolution topography to fault trace mapping, landscape reconstruction, tectonic geomorphology, landslide recognition, and topographic differencing methods and results for Japanese and the El Mayor Cucupah earthquakes (see the agenda/web site for more detail). On Saturday, we had a meeting at the University of Tokyo Center for Spatial Information Science and reprised our presentation and had some good discussions. The ERI symposium had 35 people including the lecturers. Our training workshop was 27 persons including the lecturers. 18 people attended both and most of the participants were graduate students and young scientists. See Table 1 for a list of the principal participants.

**Recommendations**

Several opportunities for discussions during the various meetings fueled the accumulation of the following thoughts on the topic of high resolution topography applied to earthquake studies:

1) There has been an interesting evolution of methodology for study of active faulting and topography. LiDAR has revolutionized many tasks and our ability to measure surface features at the fine scale at which the surface processes and earthquake deformation operate.

2) The challenge of identifying active faults in topography (especially in areas of low fault slip rates and high surface process rates and heavy vegetation) remains. A standardized approach of morphology delineation followed by detailed surficial geologic mapping should yield defendable fault traces and indication of potential detailed study sites.

3) Once faults are identified, reconstructing offset and deformed features is necessary. A combination of field and virtual approaches was advocated. Uncertainty assessment in the reconstructions is an active area.

4) A substantial emphasis has been on surface rupture characterization in high resolution topography acquired shortly after an earthquake. This effort includes airborne and terrestrial laser scanning data integration. Examination of tilted trees in the vegetation (Yoshimi; [https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/20130918LiDARsympoERI-submit-s.pdf](https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/20130918LiDARsympoERI-submit-s.pdf)) was a clever use of the three dimensional data to characterize surface deformation along the earthquake rupture.

5) High relief areas such as parts of Japan and southern California are susceptible to landslides and their interaction with active faults is notable. In addition, their methods of study using high resolution topography are similar.

6) Topographic differencing along Japanese and the El Mayor Cucupah earthquake ruptures is yielding exciting results that seem to document variable continuity of slip along fault surfaces in the upper several hundred meters below the Earth surface. These results are complementary with the wide aperture INSAR results typically coming from earthquake studies. The various approaches for differencing (Iterative closest point, image correlation, pixel matching, particle image velocimetry, etc.) should be systematically compared.

7) Ongoing training and knowledge exchange of the sort done here is valuable.

8) It is important to facilitate community access to high-resolution, Earth science-oriented, topography data, and related tools and resources. This is the mission of OpenTopography. We discussed these ideas and that open access was desirable, but topographic data in particular in Japan tends to be difficult to obtain for scientists without purchasing it (despite the data having been paid for initially by public funds).
Acknowledgements
This workshop was supported by the Southern California Earthquake Center through the Virtual Institute for the Study of Earthquake Systems program. Thank you very much to Tran Huynh, Deborah Gormley and the SCEC meetings staff along with John McRaney, Greg Beroza, and Tom Jordan for their help and encouragement. Emily Kleber provided important help on the OpenTopography side. Thanks also to all of the Japanese colleagues who contributed to the workshop and made it a success.

Photographs from the workshop (all taken by Koji Okumura, Hiroshima University)

Figure 1. The team is looking at shoreline features at the Boso Peninsula uplifted in recent subduction zone earthquakes. Such fine features and their absolute elevations can be measured using terrestrial or airborne lidar.
Figure 2. The team is examining at shoreline features at the Boso Peninsula uplifted in recent subduction zone earthquakes. Such fine features and their absolute elevations can be measured using terrestrial or airborne lidar.
Figure 3. Workshop participants hard at work learning high resolution topography data processing and interpretation.
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OpenTopography (http://www.opentopography.org/index.php)

A Portal to High-Resolution Topography Data and Tools

- [Home](http://www.opentopography.org/index.php)
- [About](http://www.opentopography.org/index.php/about/)
- [Data](http://opentopo.sdsc.edu/gridsphere/gridsphere?cid=datasets)
- [Tools](http://opentopo.sdsc.edu/gridsphere/gridsphere?cid=contributeframeportlet&gs_action=listTools)
- [Education](http://www.opentopography.org/index.php/resources/)
- [Community](http://www.opentopography.org/index.php/community/)
- [Support](http://www.opentopography.org/index.php/support/)

In this section
- [Overview](http://www.opentopography.org/index.php/resources/)
- [Tutorials](http://www.opentopography.org/index.php/resources/tutorials)
- [Resources](http://www.opentopography.org/index.php/resources/education)
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VISES SCEC Workshop on High Resolution Topography Applied to Earthquake Studies

Part of the Southern California Earthquake Center (http://www.scec.org)’s Virtual Institute for the Study of Earthquake Systems (http://www.scec.org/vises/)

September 18-20, 2013
Earthquake Research Institute (ERI) (http://www.eri.u-tokyo.ac.jp/eng/), The University of Tokyo, Japan

September 21, 2013
Center for Spatial Information Science (http://www.csis.u-tokyo.ac.jp/english/), The University of Tokyo, Japan

Workshop planning team: Ramon Arrowsmith (Arizona State University), Koji Okumura (Hiroshima University), Edwin Nissen (Colorado School of Mines), Tadashi Maruyama (AIST), Christopher Crosby (UNAVCO), Mike Oskin (UC Davis), Shinji Toda (Tohoku University)

Scientific Program: September 18, 2013 (10:00am - 5:30pm)
Workshop Program: September 19-20, 2013
ERI, Tokyo, Japan

For the workshop, students will have to bring their own laptops with appropriate software. This course program can evolve depending on our sense of the participants' interests and expertise.

Day 1: September 19, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:00am</td>
<td>Introduction of participants (Name, project, and experience, expectations)</td>
<td>Christopher Crosby, UNAVCO/OpenTopography</td>
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<tr>
<td></td>
<td>Introduction to acquisition of high resolution topographic data (ALS and TLS) and demonstration of OpenTopography</td>
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<tr>
<td></td>
<td>• Intro to ALS <a href="https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/13SCECVISES_ALSintro.pdf">link</a></td>
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<td>• TLS Principles <a href="https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/13SCECVISES_TLSPrinciples_Crosby.pdf">link</a></td>
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<tr>
<td>11:15am</td>
<td>Aerial survey company presentations</td>
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<tr>
<td>11:45am</td>
<td>BREAK</td>
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<tr>
<td>12:00pm</td>
<td>Handling and processing of high resolution topographic data grids: square km dataset examples</td>
<td>Ramon Arrowsmith, Arizona State University</td>
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<td></td>
<td>• See exercises from 2011 SCEC short course <a href="http://www.opentopography.org/index.php/resources/short_courses/11scec_course/">link</a></td>
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<tr>
<td></td>
<td>• Video demonstrations <a href="http://stockdale.sese.asu.edu/transfer/video_demos.html">link</a></td>
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<td></td>
<td>• Sanborn DEMs <a href="http://stockdale.sese.asu.edu/OT/VISES_for_ex/Data/Standard_DEMs(Sanborn).zip">link</a></td>
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<td></td>
<td>• db data <a href="http://stockdale.sese.asu.edu/OT/VISES_for_ex/Data/db.zip">link</a></td>
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</tbody>
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For more information, please visit [www.opentopography.org/index.php/resources/VISES_JPN13](http://www.opentopography.org/index.php/resources/VISES_JPN13).
1:00pm | Lunch

2:00pm | ArGIS analysis and fault trace mapping
- **Fault Zone Mapping with Differential Lidar**
- **Fault Zone Mapping with Differential Lidar - Sample Data**
  (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/FaultMappingExercise_data.zip)
  (730 MB)

Mike Oskin,
University of California, Davis

4:00pm | ArcGIS-based analysis with extensions to gridding via OpenTopography Points2Grid and other point analysis using LAStools
- **LAStools**
  (http://www.cs.unc.edu/~isenburg/lastools/)
- **Points2Grid**
  (http://opentopo.sdsc.edu/gridsphere/gridsphere?gs_action=viewTool&cid=contributeframeportlet&toolId=211)
- **LAS format and processing DTMs from tins and local binning**
  (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/20130918_LAS_DEMO.pptx)
- **Mill Gulch Data**
  (http://stockdale.sese.asu.edu/OT/VISES_for_ex/Data/MillGulch.zip)

Ramon Arrowsmith,
Arizona State University

5:30pm | End of workshop; go to reception

Day 2: September 20, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Instructor(s)</th>
</tr>
</thead>
</table>
| 10:00am | Keck Caves Lidar viewer training and demonstration and swath profiles | Mike Oskin,
University of California, Davis |
- **Lidar Viewer Tutorial**
  (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/LidarViewerIntroTutorial.pdf)
- **Lidar Viewer sample data and droplet**
  (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/LidarViewer.zip)
  (930 MB)
- **Lidar Viewer webpage**
  (http://keckcaves.org/software/lidarviewer)
- **Tahoepoints.las**
  (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/Tahoepoints.las)
  (sample data)

1:00pm | Lunch

2:00pm | Structure from Motion
- **Structure from Motion lecture**
  (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/20130625_StructurefromMotion_Ed.pdf)
- **ERI Seismometer 3D PDF**
  (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/eri_seismometer.pdf)
- **ERI Seismometer SIM sample data**
  (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/seismometer.zip)

Ramon Arrowsmith,
Arizona State University

Edwin Nissen,
Colorado School of Mines

3:00pm | CloudCompare training and demonstration
- **CloudCompare website**
  (http://www.danielgm.net/cc/)
- **CloudCompare notes**
  (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/CloudCompareNotes.pdf)
- **CloudCompare sample data**
  (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/CloudCompare.zip)
- **Useful reference**
  (http://www.geosciences.univ-rennes1.fr/spip.php?article1125&lang=fr)

Ramon Arrowsmith,
Arizona State University

Edwin Nissen,
Colorado School of Mines

5:30pm | End of workshop

Scientific Program: September 21, 2013 (10:00am - 2:50pm)

**Geomorphological Applications of High-Definitions Topography**

For presentations slides see Sept 18th program.