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
Ramon Arrowsmith (Arizona State University)—report author
ramon.arrowsmith@asu.edu
Koji Okumura (Hiroshima University)
Edwin Nissen (Colorado School of Mines)
Chris Crosby (UNAVCO)
Tadashi Maruyama (MEXT)
Mike Oskin (UC Davis)
Shinji Toda (Tohoku University)

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) 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.

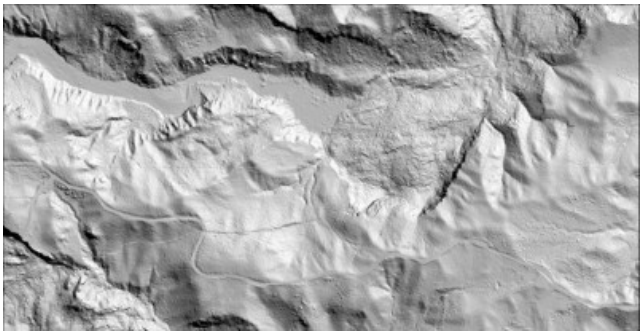
Table 1. Workshop on high resolution topography applied to earthquake studies participants

L: lecturer, W: Workshop participant							
L	Arrowsmith	Ramon	Arizona State University	School of Earth and Space	professor	active tectonics	ramon.arrowsmith@asu.edu
L	Chigira	Masahiro	Kyoto University	Disaster Prevention Research Institute	professor	landslides	chigira@slope.dpri.kyoto-u.ac.jp
L	Crosby	Chirstopher	UNAVCO	Geodetic Infrastructure	project manager	geoinformatics	crosby@unavco.org
L	Edwin	Nissen	Colorado School of Mines	Department of Geophysics	assistant professor	active tectonics	enissen@mines.edu
L	Koji	Okumura	Hiroshima University	Department of Geography	professor	earthquake geology	kojiok@hiroshima-u.ac.jp
L	Maruyama	Tadashi	National Institute of Advanced Industrial Science and Technology	Active Fault and Earthquake Research Center	researcher	structural geology	t-maru@mext.go.jp
L	Mukoyama	Sakae	Kokusai Kogyo Co. Ltd.		enginieer	geoinformatics	sakae_mukoyama@kk-grp.jp
L	Oskin	Michael E.	University of California Davis	Department of Geology	associate professor	structural geology	meoskin@ucdavis.edu
L	Toda	Shinji	Tohoku University	International Research Institute of Disaster Science	professor	active tectonics	toda@irides.tohoku.ac.jp
L	Yoshimi	Masayuki	Ministry of Education, Culture, Sports, Science and Technology	Earthquake and Disaster-Reduction Research Division	Senior Specialist for Earthquake Research	seismology	yoshimi3@mext.go.jp
W	Aoto	Kazutaka	Tokyo University of Agriculture and Technology	Department of International Environmental and Agricultural Science	MC student	landslides	50013539001@st.tuat.ac.jp
W	Chiba	Tatsuro	Asia Air Survey Co. Ltd.	Disaster Prevention & Geological Features Dept.	engineer	volcanology	ta.chiba@ajiko.co.jp
W	Goto	Hideaki	Hiroshima University	Department of Geography	associate professor	active faults	hgoto@hiroshima-u.ac.jp
W	Goto	Tomoko	The University of Tokyo	Graduate School of Frontier Science	DC student	tsunami deposit	t-goto@eri.u-tokyo.ac.jp

W	Hanai	Kenta	Asia Air Survey Co. Ltd.	Disaster Prevention & Geological Features Dept.	engineer	slope hazard	knt.hanai@ajiko.co.jp
W	Hayakawa	Yuichi S.	The University of Tokyo	Center for Spatial Information Science	associate professor	landform evolution	hayakawa@csis.u---tokyo.ac.jp
W	Ishimura	Daisuke	Chiba University	Department of Earth Sciences	research scientist	active faults and tephra	ishimura@chiba-u.jp
W	Kim	Haeng Yoong	Hot Springs Research Institute of Kanagawa Prefecture		researcher	acitive tectonics	kimu@onken.odawara.kanagawa
W	Niwa	Yuichi	Tohoku University	International Research Institute of Disaster Science	Assistant Professor	sedimentology	niwa@irides.tohoku.ac.jp
W	Peng	Wei	Tohoku University	Deparment of Geophysics	DC student	seismology	havepeng@gmail.com
W	Purnama Sidiq	Teguh	The University of Tokyo	Earthquake Research Institute	research student	geodesy and geomatics	teguh@eri.u-tokyo.ac.jp
W	Sasaki	Natsuki	The University of Tokyo	Graduate School of Frontier Science	DC student	wetland environment	nsasaki@nenv.k.u-tokyo.ac.jp
W	Sato	Hiroshi P.	Japan Map Center	Cartographic Research Institute	engineer	landslides	hsato@jmc.or.jp
W	Sato	Rina	The University of Tokyo	Graduate School of Frontier Science	DC student	geomorphology	sato47137604@csis.u-tokyo.ac.j
W	Sato	Takamichi	Aero Asahi Corporation	Airborne Lidar Survey Department	Data Processing Supervisor	Lidar Survey	takamichi-satou@aeroasahi.co.jp
W	Yumi	Mayuko	Aero Asahi Corporation	Airborne Lidar Survey Department	engineer	geomorphology	mayuko-yumi@aeroasahi.co.jp

OpenTopography (http://www.opentopography.org/index.php)

A Portal to High-Resolution Topography Data and Tools



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)

Time	Title	Speaker
10:00am	Welcome and introductions	Takehiro Koyaguchi (Earthquake Research Institute)
10:10am	**A review of the mapping of faults since 1980s: plane table, TS, RTK-GPS, Lidar, and the future** (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/Okumura09182013.pdf)	Koji Okumura (Hiroshima University)
10:40am	**Tectonic geomorphology, structural geology, and paleoseismology of fault zones from high resolution topography** (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/20130917_ArrowsmithVISES.pdf)	Ramon Arrowsmith (Arizona State University)
11:10am	*BREAK*	
11:30am	**Application of high-resolution topography to earthquake geology: examples from recent study in Japan** (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/20130918Maruyama.pdf)	Tadashi Maruyama (AIST)
12:00pm	**Near-field cosiesmic deformation from airborne and terrestrial lidar of the El Mayor-Cucapah surface rupture** (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/OSKIN_2013EMC.pdf)	Mike Oskin (University of California, Davis)
12:30pm	Discussion	
12:50pm	*Lunch*	
2:00pm	Estimation of ground displacement caused by the large earthquakes, using the Geomorphic Image Analysis of multi-temporal LiDAR DEM	Sakae Mukoyama (Kokusai Kogyo)
2:30pm	**Fault zone deformation and shallow slip from LiDAR differencing** (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/nissen-sep-2013-VISES.pdf)	Edwin Nissen (Colorado School of Mines)
3:00pm	Gravitational slope deformation detected by LiDAR	Masahiro Chigira (Kyoto)
3:30pm	*BREAK*	
3:45pm	**Superfine mapping of the earthquake surface ruptures in the forest with terrestrial LiDAR** (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/20130918LiDARsympoERI-submit-s.pdf)	Masayuki Yoshimi (AIST, MEXT)
4:15pm	**Facilitating access to high-resolution topography: Data collection support and online data distribution** (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/13SCECVISES_Crosby.pdf)	Chris Crosby (UNAVCO, OpenTopography)
4:45pm	Discussion	
5:30pm	*End of meeting followed by optional dinner*	

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

Time	Activity	Instructor(s)
10:00am	Introduction of participants (Name, project, and experience, expectations) Introduction to acquisition of high resolution topographic data (ALS and TLS) and demonstration of OpenTopography • **Intro to ALS** (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/13SCECVISES_ALSintro.pdf) • **TLS Principles** (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/TLSPrinciples_Crosby.pdf)	Christopher Crosby, UNAVCO/OpenTopography
11:15am	Aerial survey company presentations	
11:45am	*BREAK*	
12:00pm	Handling and processing of high resolution topographic data grids: square km dataset examples • **See exercises from 2011 SCEC short course** (http://www.opentopography.org/index.php/resources/short_courses/11scec_course/) • **Video demonstrations** (http://stockdale.sese.asu.edu/transfer/video_demos.html) • **Sanborn DEMs** (http://stockdale.sese.asu.edu/OT/VISES_for_ex/Data/Standard_DEMs(Sanborn).zip) • **db data** (http://stockdale.sese.asu.edu/OT/VISES_for_ex/Data/db.zip)	Ramon Arrowsmith, Arizona State University

1:00pm	*Lunch*	
2:00pm	ArGIS analysis and fault trace mapping • **Fault Zone Mapping with Differential Lidar** (https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/VISES_JPN13/FaultMappingExercise.pdf) • **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/) , **LAStools Download** (http://www.cs.unc.edu/~isenburg/lastools/download/) • **Points2Grid (WinP2G)** (http://opentopo.sdsc.edu/gridsphere/gridsphere?gs_action=viewTool&cid=contributeframeportlet&toolId=21) • **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

Time	Activity	Instructor(s)
10:00am	Keck Caves Lidar viewer training and demonstration and swath profiles • **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)	Mike Oskin, University of California, Davis
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 SfM 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/CloudCompate.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 (http://topography.csis.u-tokyo.ac.jp/misc/130921_program.pdf) (program in Japanese and English).

For presentations slides see Sept 18th program.

Sections: 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=tools) | Resources (http://www.opentopography.org/index.php/resources/) | Community (http://www.opentopography.org/index.php/community/) | Support (http://www.opentopography.org/index.php/support/)

(http://www.asu.edu) (http://www.sdsc.edu) (http://www.nsf.gov)

Resources: myOpenTopo (http://opentopo.sdsc.edu/gridsphere/gridsphere?cid=myopentopo) | Tutorials (http://opentopography.sdsc.edu/index.php/resources/tutorials)

RSS Feeds: News (http://www.opentopography.org/index.php/news/rss_2.0) | Blog (http://www.opentopography.org/index.php/blog/rss_2.0/) | Follow us on Twitter (http://twitter.com/opentopography)

OpenTopography is supported by the National Science Foundation under Award Numbers 0930731 & 0930643
For further information about OpenTopo news and updates, please e-mail info_at_opentopography.org (mailto:info@opentopography.org)
For comments/questions about the opentopography.org website, please e-mail webmaster_at_opentopography.org (mailto:webmaster@opentopography.org)

OpenTopography Facility
San Diego Supercomputer Center
University of California, San Diego
9500 Gilman Drive, MC 0505
La Jolla, CA 92093-0505