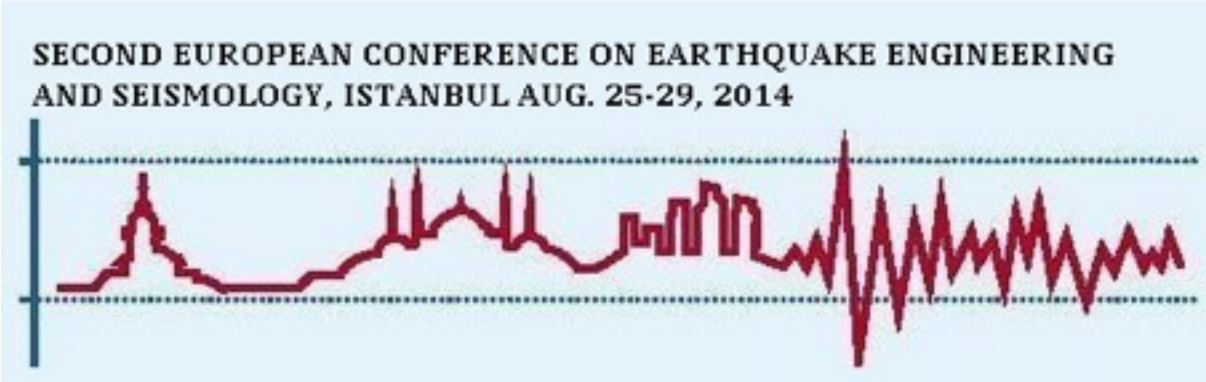

BALKANS-OQ: A COLLABORATIVE SEISMIC HAZARD ASSESSMENT OF THE BALKAN COUNTRIES USING THE OPENQUAKE SOFTWARE AND THE GEM STRAIN RATE MODEL

Volkan Sevilgen[1], R.A. Bennett[2], I. Brlek[3], Laurentiu Danciu[4], V. Kastelic[5], S. Kovacevic[6], C. Kreemer[7], K. Kuk[8], N. Kuka[9], Z. Milutinovic[10], S. Mustafa[11], B. Sket-Motnikar[12], R.S. Stein[13], and L. Vucic[14]

The Balkans region has suffered damaging earthquakes throughout its long history.The ancient fortified city-state of Dubrovnik (Croatia) was destroyed in 1667 and damaged six other times beginning in 373 BCE; the capital cities of Skopje (Macedonia) was destroyed in 1963, Zagreb (Croatia) was heavily damaged in 1880, and Ljubljana (Slovenia) was heavily damaged in 1895. The region is also vulnerable because of the poor quality of many of its buildings, and the lack of enforced construction codes in many countries. Despite the seismic threat, in some countries broadband seismic monitoring has only recently begun, and there has been little geomorphic analysis of active faults and almost no paleoseismic investigation of their slip rates and prehistoric ruptures. Thus, forecasting seismic hazard in the region is challenging but critical.

For two years, an international group of earth scientists has been developing a seismic hazard assessment for the eight Balkan countries (Albania, Bosnia, Croatia, Kosovo, Macedonia, Montenegro, Serbia, and Slovenia), with a scientist from each country participating in the collaboration. The group drew on the software, and seismic and strain-rate datasets of the Global

Seismologist, Seismicity.net, San Carlos CA, volkan@seismicity.net

[2] Associate Professor, Department of Geosciences, University of Arizona, Tucson, AZ, rab@geo.arizona.edu

[3] Seismologist, Federal Hydro-meteorological Institute, Sarajevo, Bosnia & Herzegovina, ivanbrlek@yahoo.com

[4] PhD, Swiss Seismological Service, ETH Zurich, laurentiu.danciu@sed.ethz.ch

[5] PhD, INGV, L'Aquila, vanja.kastelic@ingv.it

[6] Seismologist, Seismological Survey of Serbia, Belgrade, svetlana.kovacevic@seismo.gov.rs

[7] Research Associate Professor, Nevada Bureau of Mines and Geology, and Seismological Laboratory, University of Nevada, Reno, kreemer@unr.edu

[8] Seismologist, Seismological Survey of Croatia, University of Zagreb, Zagreb, Croatia, kresok@irb.hr

[9] Prof. Dr., Institute of Geosciences, Energy, Water and Environment, Polytechnic University of Tirana, Tirana, Albania, nekikuka@live.com

[10] Prof. Dr., IZIIS, University "Ss. Cyril and Methodius", Skopje, milutin@iziis.edu.mk

[11] Seismologist, Geological Survey of Kosovo, Pristina, Kosovo, shemsi_mustafa@hotmail.com

[12] PhD, Environmental Agency of Slovenia, Ljubljana, Slovenia, barbara.Sket-Motnikar@gov.si

[13] Geophysicist, US Geological Survey, Menlo Park, CA, rstein@usgs.gov

[14] Seismologist, Montenegro Seismological Observatory, Podgorica, Montenegro, vucic@seismo.co.me

Earthquake Model (GEM Foundation, Pavia, Italy) for the model development. The group also benefitted from the newly released 2013 European Seismic Hazard Model (ESHM13) as delivered by the SHARE program (www.share-eu.org) and regional BSHAP hazard assessments, and shares some participants from these allied programs. Our group studied past earthquakes and the accumulation of crustal strain and identified active faults, focusing particular attention on faults and seismicity near the capital cities. The goals of the project are not just to build the best possible a hazard assessment, but also to foster collaboration among countries formerly at war; to encourage the sharing, rather than selling, of data; and to promote the use of such seismic assessments for urban and disaster response planning.

An innovative element of our modeling strategy is to use the strain rate determined from horizontal GPS velocities to infer slip rates along recognized faults. In most Probabilistic Seismic Hazard Assessments, fault length controls the maximum earthquake magnitude, and fault slip rate controls the earthquake activity rate along those faults. As a starting model, we used faults (strictly, 'composite seismic sources') from the SHARE model, which we slightly adjusted by adding new faults and changing some of the fault geometries, based on the availability of new data. The composite nature of these sources inherently keeps the maximum magnitudes high, which is important because the seismic history is too short to assess maximum magnitudes directly. We then used the 'backslip' method in the free software, Coulomb 3.3, to calculate the strain rate expected for the SHARE faults, and compared this to the observed strain rate. The comparison gave us an opportunity to identify areas where observed-predicted strain rates disagree. Adjusting fault slip rates as a tool to minimize the observed-predicted strain rate residual allows us to explore slip rate uncertainties through inclusion of both values as branches of the seismic hazard logic tree.

Ultimately, this fault-based model branch will be combined with a seismicity-based model branch. Where the two independent approaches yield similar hazard assessments, our confidence in the model will be higher; where they disagree, our model confidence will be lower. We hope that the model will provide an impetus for additional earthquake research and seismic, geodetic, and paleoseismic data collection, as well as an independent reference for comparison to the national hazard models in each of the Balkan countries. We used OpenQuake (Pagani et al. 2013) to perform the seismic hazard computation.

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