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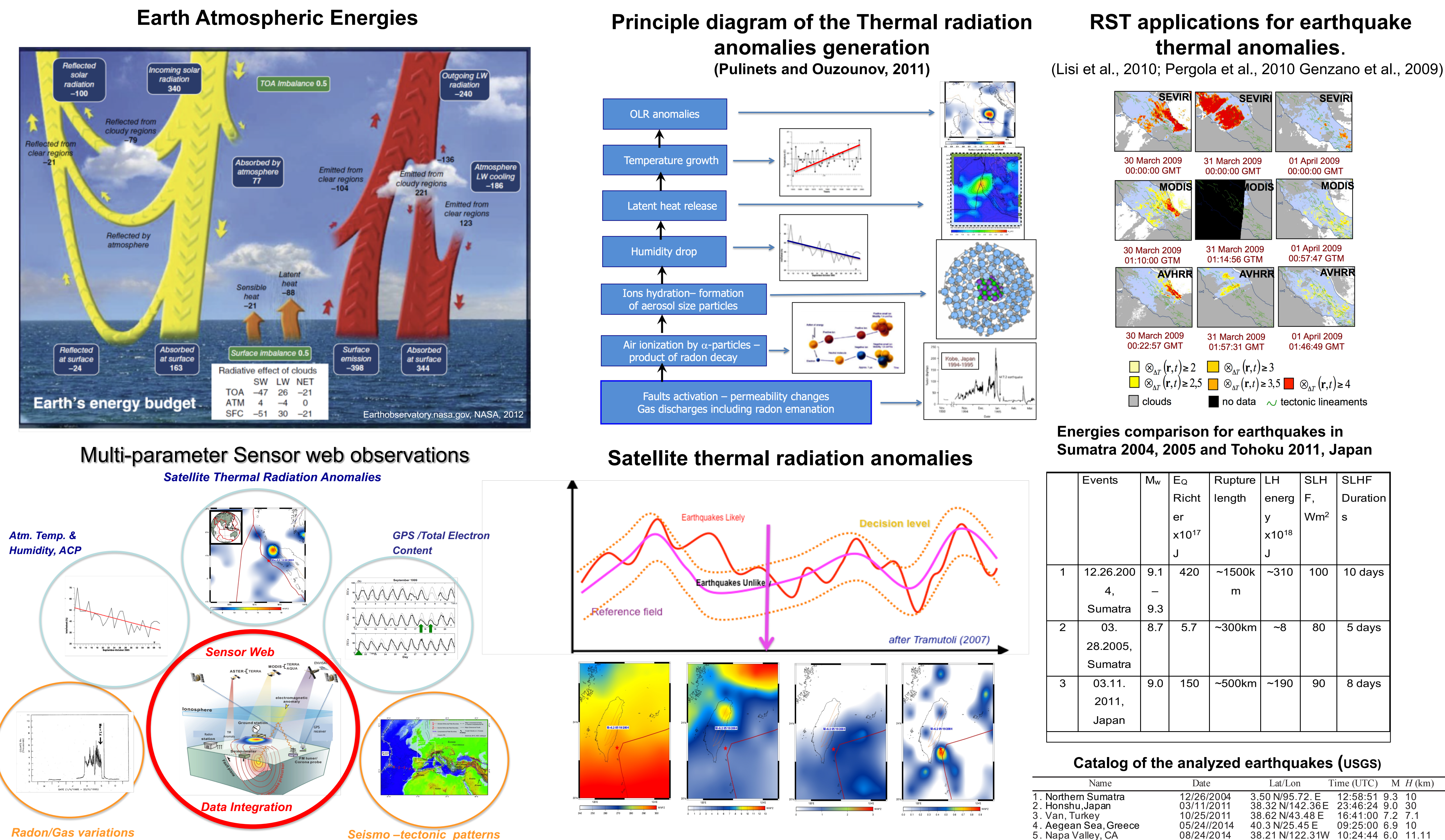
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Abstract

We are exploring both the temporal-spatial and evolution patterns of recent pre-earthquake signals based on integrating space and ground-based data as a function of their type and magnitude.

Four ground and satellite observations were used: 1) **Ground Radon variation**; 2) **Outgoing Long-wavelength Radiation** (OLR obtained from NPOES, NASA/AQUA) on top of the atmosphere (TOA); 3) **Atmospheric Chemical Potential** (ACP) obtained from NASA assimilation models and; 4) electron density variations in the ionosphere via **GPS Total Electron Content** (GPS/TEC). Five large earthquakes were selected: (1) M9.3, Off the West Coast of Northern Sumatra, Dec 26, 2004; (2) M9.0 Great Tohoku Earthquake, Japan, March 11, 2011; (3) M7.1 on October 24, 2011 in Van, Turkey; (4) M6.9 on May 24, 2014 Aegean Sea, Greece and (5) M6.0 on August 24, 2014 in Napa, CA. An enhancement of both radon (about a week to ten days prior) and atmospheric chemical potential were reported near the epicenters from both satellite and surface data additionally there was an increase in outgoing infrared radiation (OLR) observed on the TOA from NOAA/NASA satellites (a week in advance). GPS/TEC data analysis reported an increase of electron concentration 1-4 days before these earthquakes. Although the radon variations and some of satellite OLR anomalies were observed >2000km from the epicenters these anomalies were always inside the estimates of the Dobrovolsky-Bowman area of preparation. A detail summary of our approach to this study of pre-earthquake research has just been published in AGU/Wiley Geophysical Monograph Series No. 234.

Methodology



Conclusion

We have found a synergetic anomalous trend between different satellite observational data, weeks before five major earthquakes:

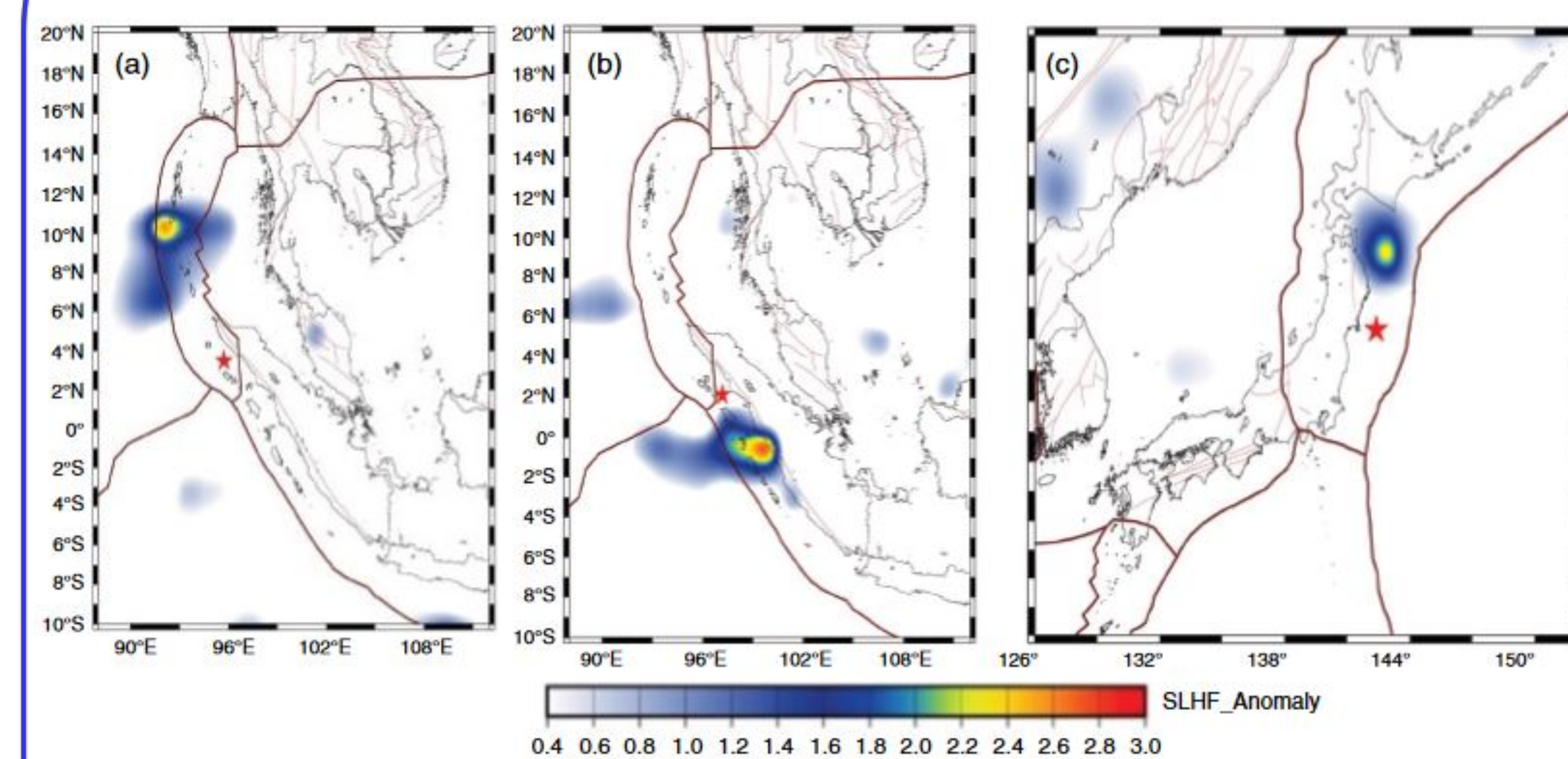
1. Our analysis shows that Surface latent heat (SLHF) has been detected several days prior to the M9.3 Sumatra 2004 and M9.0 2011 Tohoku earthquake. On Dec 15, 2004, eleven days before the M9.3 Sumatra earthquake a strong anomaly was observed along the rupture zone north of the future epicenter, with a value >4. For the 2011 Tohoku similar a strong SLHF anomaly was observed on March 5, only 6 days before the main shock, north of the epicentral area, along the future rupture zone;
2. We found that several days before the major earthquakes the outgoing long wave radiation (OLR) data from NOAA/POESS satellites formed anomalous OLR hotspots over the regions. The OLR hot spots appeared quickly, stayed over the same regions from several hours up to a few days, and then disappear rapidly. The time lag for the M7.3 earthquake in Van, Turkey was 4 days; the M6.9 earthquake in the Aegean Sea, Greece was 10 days and the M6.0 earthquake in California was 2 days;
3. Our preliminary analysis demonstrated near real-time observation of several parameters implying their connection with the earthquake preparation process. We are considering possible correlation between different pre-earthquake signals in the frame of a multidisciplinary investigation of the Lithosphere-Atmosphere-Ionosphere Coupling concept. Such a hypothesis needs more near real-time validation.

References

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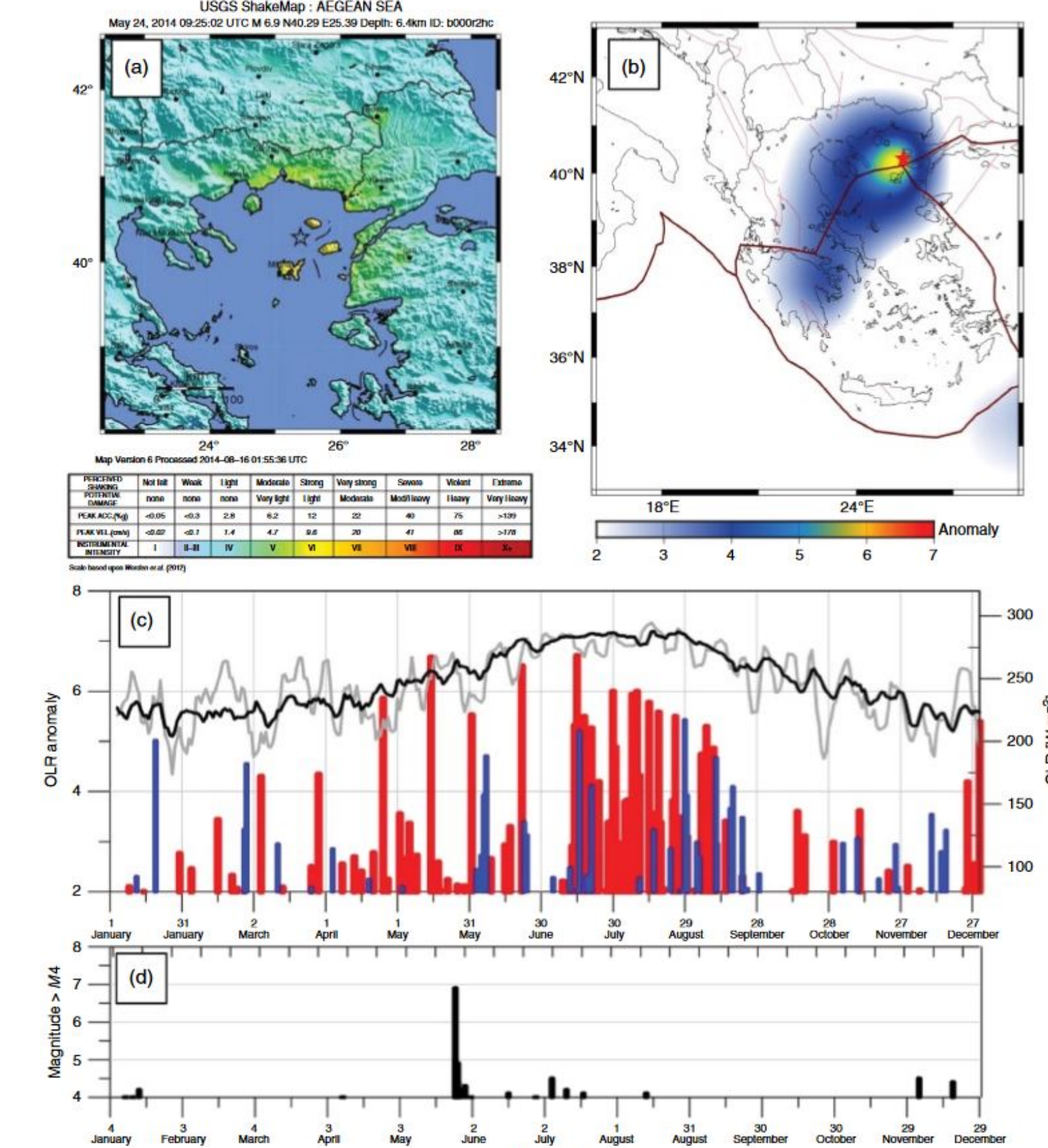
Thermal satellite analysis

Thermal energy associated with some large earthquakes



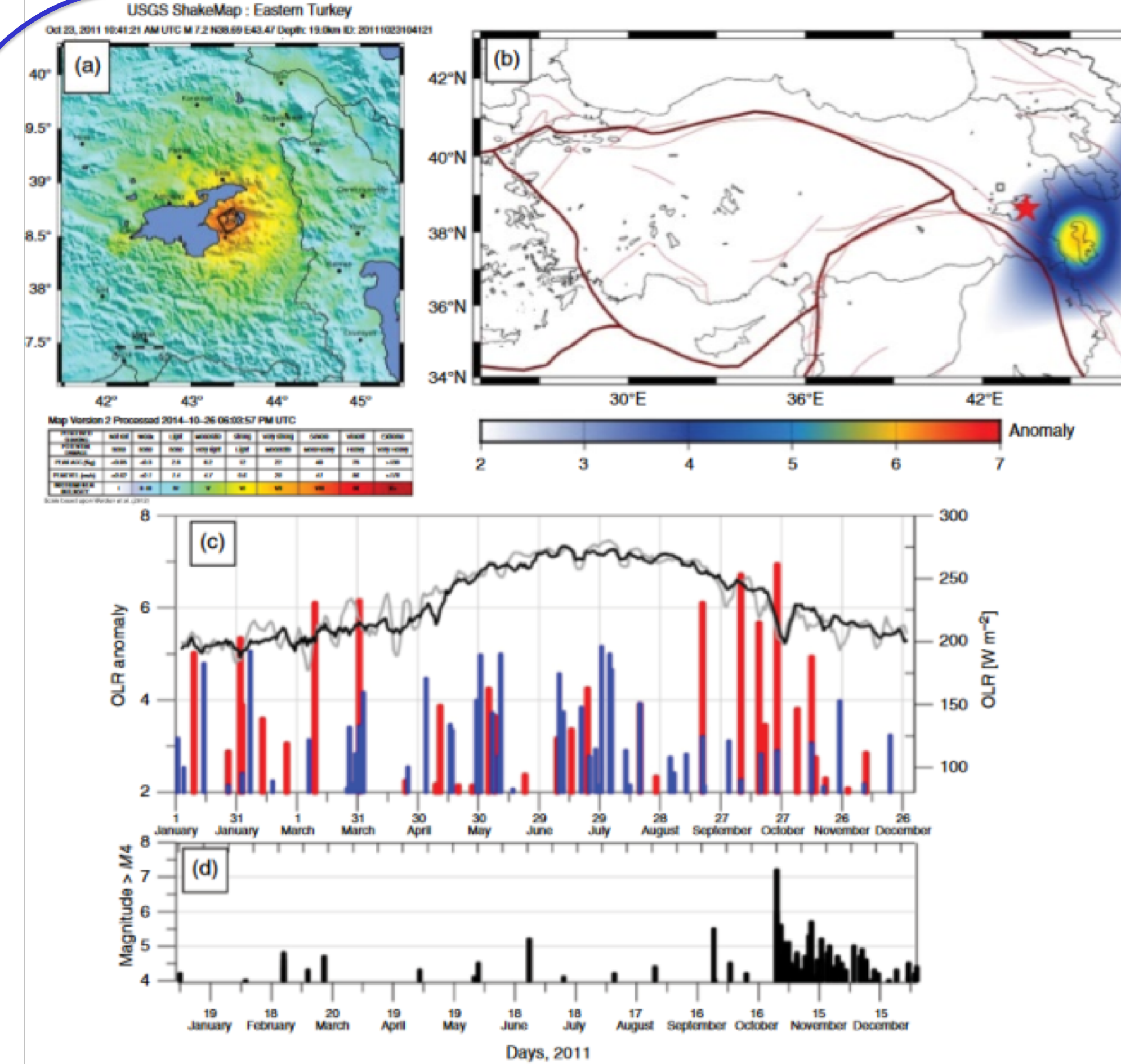
(a) Anomalous daily SLHF 11 days before 2004 Sumatra EQ. (b) 20 days before March 6, 2005 M>8.7 Sumatra E.Q.; (c) Six days before M>9 Tohoku, Japan EQ. Epicentres are marked with red star, tectonic plate boundaries with red line, and major faults with brown colour.

M6.9 Aegean Sea, 2014, Greece



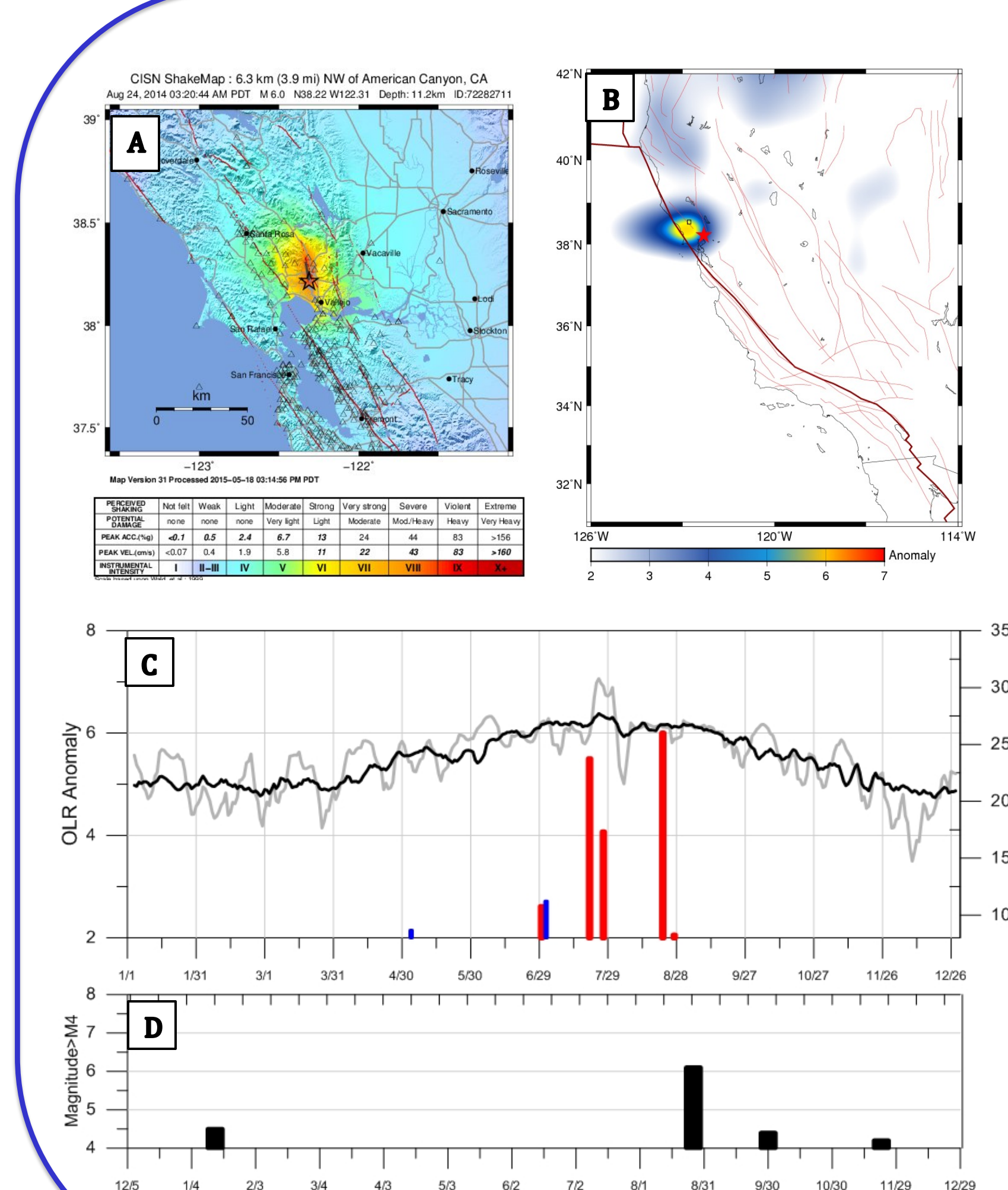
(a) USGS Shake Map, Aegean Sea; (b) Night time TRA map 10 days prior to Aegean Sea EQ. (c) Yearly time series of OLR over epicentral area; (d) M>4 seismicity for 2014 near epicentral area

M7.3 Van, 2011, Turkey



(a) USGS shake map, Turkey; (b) TRA 4 days before the EQ (c) Yearly OLR time series of night OLR over epicentral area; (d) M>4 seismicity near epicentral area.

M6.0 Napa Valley, 2014, CA



Thermal radiation anomalies (TRA) associated with the M 6 Napa Valley, California, earthquake of 24 August 2014. (a) US Geological Survey shake map. (b) Nighttime TRA anomaly map observed on 22 August 2014; 2 days before. Epicenter is marked with red star, tectonic plate boundaries by heavy red line, and major faults by faint brown lines. (c) Yearly time series of nighttime OLR over the epicentral area: (red) anomalous values; (gray) 2014 mean value OLR; (black) 2006-2014 mean value; (blue) 2013 anomalous trend with no major seismicity for comparison; and (d) M>4 seismicity (European-Mediterranean Seismological Centre catalog) near the epicentral area, 2014.