A Joint Satellite and Ground-Based Study of Temporal-Spatial Evolution Patterns of Pre-Earthquake Signals Associated With Major Earthquakes

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Abstract

We present an interdisciplinary study of observations of pre-earthquake processes associated with major earthquakes based on integrating space and ground- data. Recent large magnitude earthquakes in Asia and Europe have emphasized the various observations of multiple types of pre-earthquake signals recorded either on the ground or from space. Four physical parameters were measured from ground and satellite and used in our simulation models: 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). For this analysis we selected six large earthquakes from the last decade with differing geographic and seismo-tectonics regions: (1) M9.3, Off the West Coast of Northern Sumatra, Dec 26, 2004; (2) M9.0 Great Tohoku Earthquake, Japan, March 11, 2011; (3) and (4) M7.8 and M7.3 Gorkha, Nepal, 2015; (5); M8.2 Tehuantepec, Mexico, September 8, 2017 and; (6) M7.1, Puebla central Mexico earthquakes, September 19, 2017. Our preliminary results indicate an enhancements of radon (about a week to ten days prior) coincident (with some delay) with an increase in the atmospheric chemical potential measured near the epicenter from both satellite and subsequently with an increase of outgoing infrared radiation (OLR) observed on the TOA from NOAA/NASA (a week in advance). Finally GPS/TEC data indicate an increase of electron concentration 1-4 days before the earthquakes. Although the radon variations and some of satellite OLR anomalies were observed far (>2000km) from the epicenter areas the anomalies were always inside the estimates of the Dobrovolsky-Bowman area of preparation. We examined the possible correlation between magnitude and the spatial size of earthquake preparation zone in the framework of the Lithosphere –Atmosphere -Ionosphere Coupling hypothesis. The reliable detection of pre-earthquake signals for both sea and land earthquakes was possible only by integrating satellite and ground observations. A detail summary of our approach to this study of pre-earthquake research has just been published as AGU/Wiley Geophysical Monograph Series No. 234.

A Joint satellite and ground-based study of temporal-spatial evolution patterns of pre-earthquake signals associated major earthquakes

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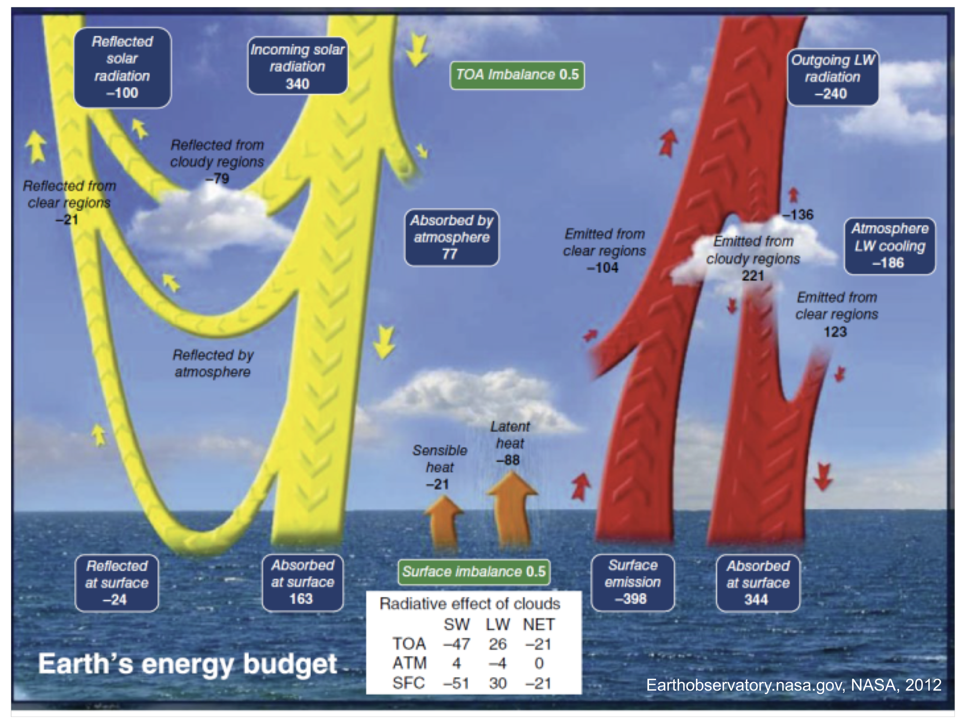
Abstract

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

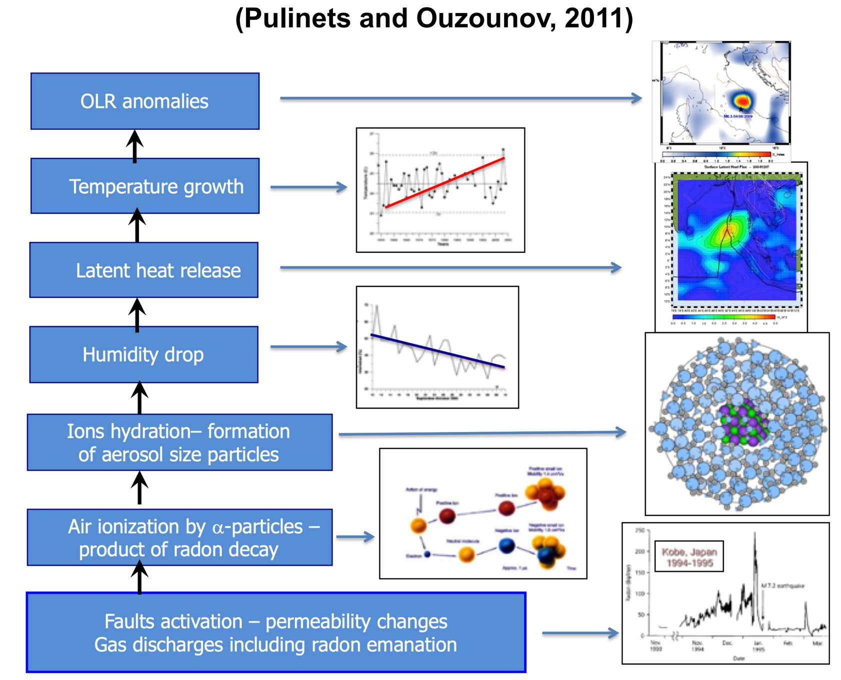
Four ground and satellite observations were used: 1) **Ground Radon variation**; 2) **Outgoing Long-wavelength Radiation** (OLR obtained from NPOES, NASA/AQUA) on top of the atmosphere (TOA); 3) **Atmospheric Chemical Potential** (ACP) obtained from NASA assimilation models and; 4) electron density variations 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

Earth Atmospheric Energies

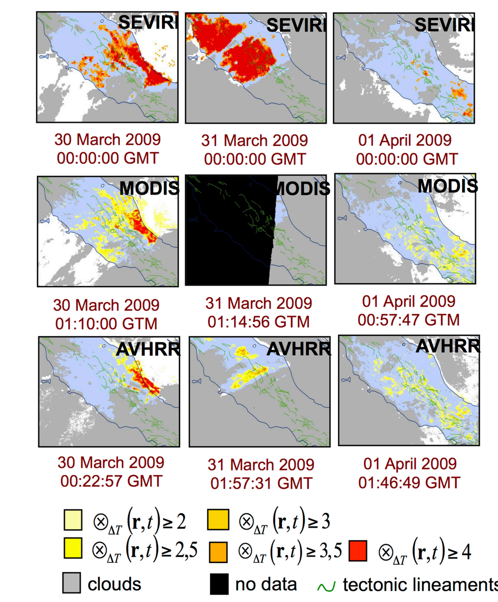


Principle diagram of the Thermal radiation anomalies generation (Pulinets and Ouzounov, 2011)

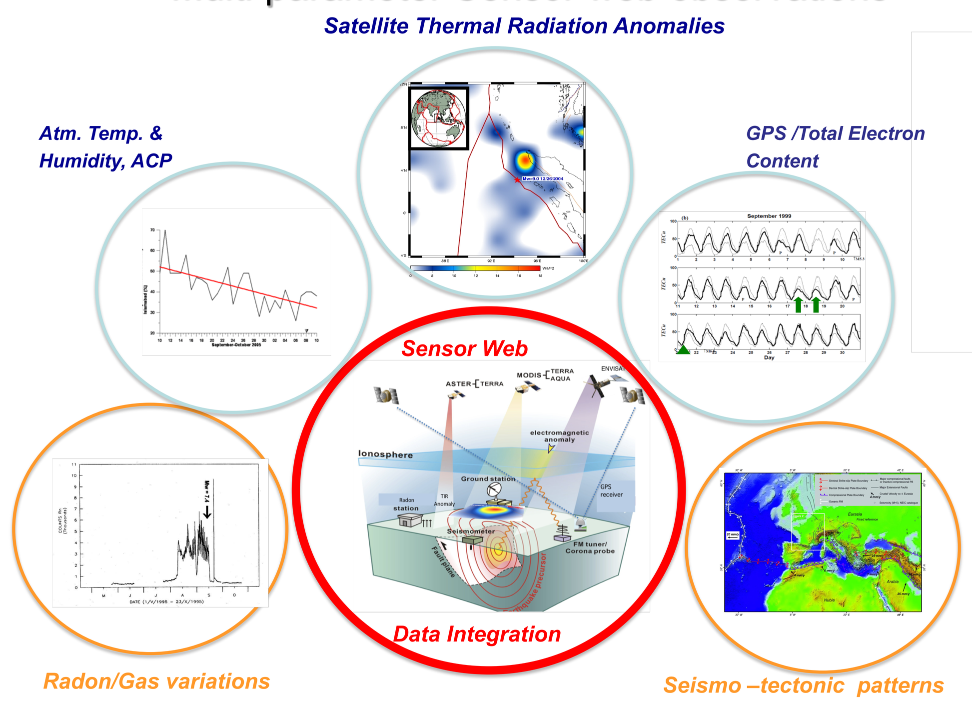


RST applications for earthquake thermal anomalies.

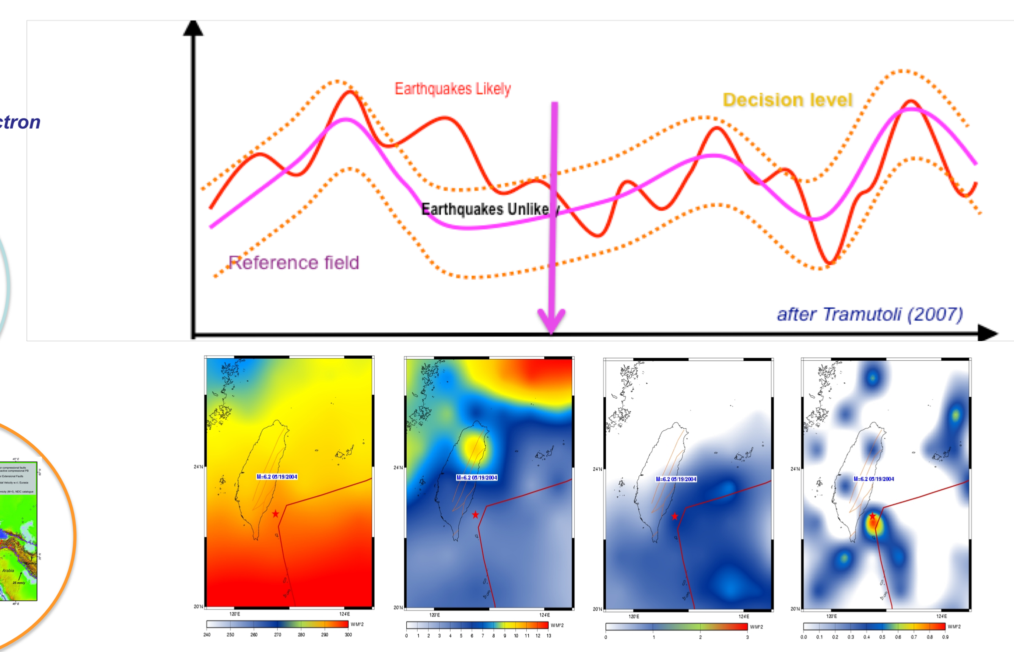
(Lisi et al., 2010; Pergola et al., 2010 Genzano et al., 2009)



Multi-parameter Sensor web observations



Satellite thermal radiation anomalies



Energies comparison for earthquakes in Sumatra 2004, 2005 and Tohoku 2011, Japan

	Events	M_w	E_Q Richter x10[17] J	Rupture length	LH energy x10[18] J	SLHF, Wm[2]	SLHF Durations
1	12.26.2004, Sumatra	9.1 – 9.3	420	~1500km	~310	100	10 days
2	03. 28.2005, Sumatra	8.7	5.7	~300km	~8	80	5 days
3	03.11. 2011, Japan	9.0	150	~500km	~190	90	8 days

Catalog of the analyzed earthquakes (USGS)

Name	Date	Lat/Lon	Time (UTC)	M	H (km)
1. Northern Sumatra	12/26/2004	3.50 N/95.72. E	12:58:51	9.3	10
2. Honshu,Japan	03/11/2011	38.32 N/142.36 E	23:46:24	9.0	30
3. Van, Turkey	10/25/2011	38.62 N/43.48 E	16:41:00	7.2	7.1
4. Aegean Sea, Greece	05/24//2014	40.3 N/25.45 E	09:25:00	6.9	10
5. Napa Valley, CA	08/24/2014	38.21 N/122.31W	10:24:44	6.0	11.11

Conclusion

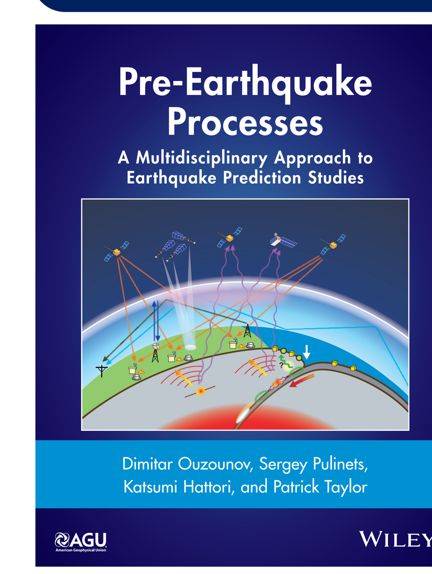
We have found a synergetic anomalous trend between different satellite observational data, weeks before five major earthquakes:

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 σ . 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 day 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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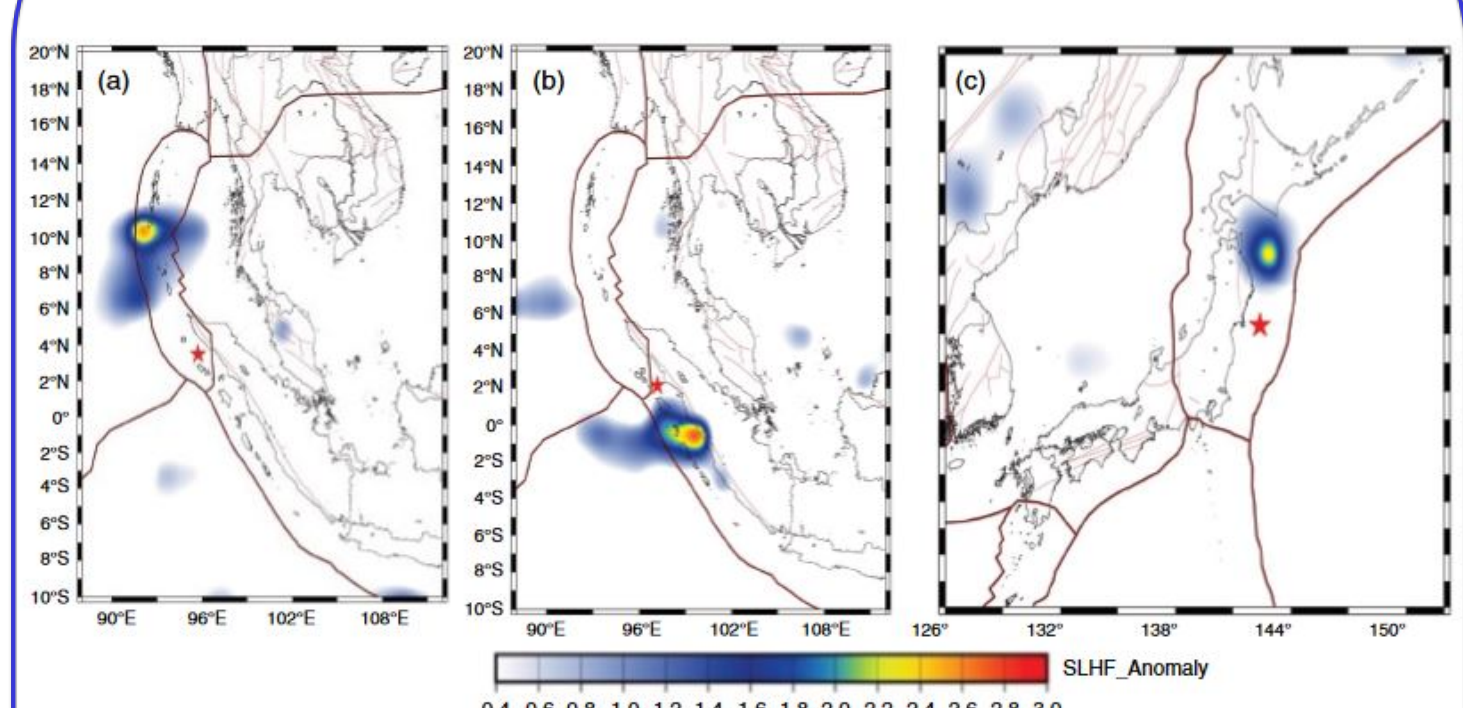
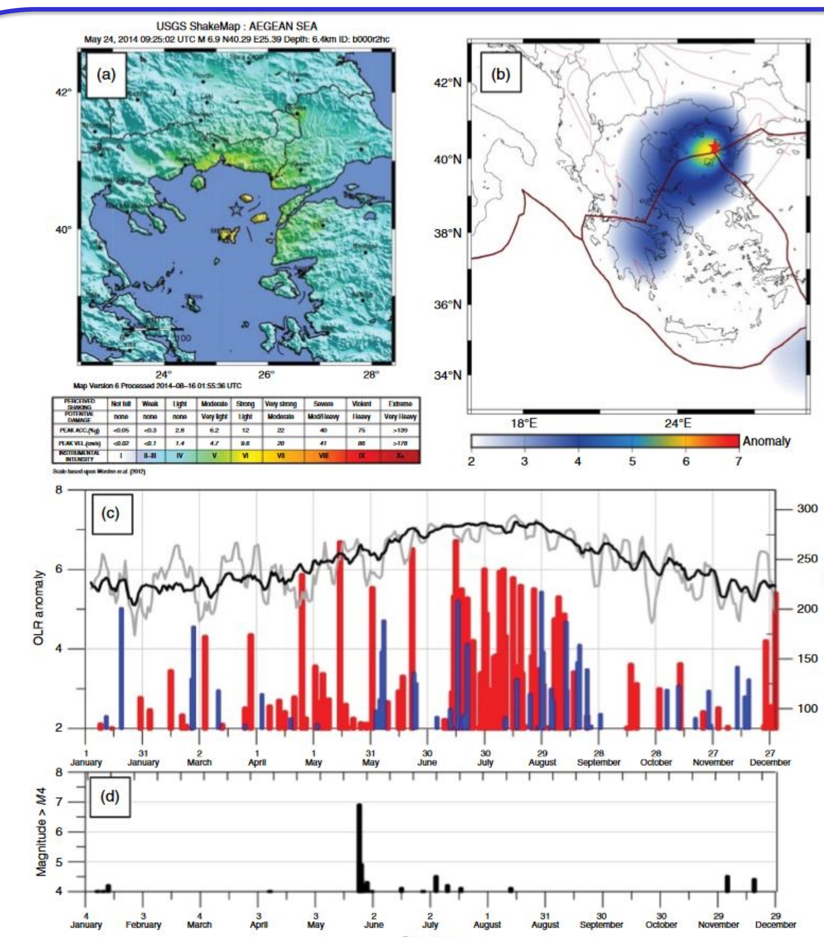
Thermal satellite analysis

Thermal energy associated with some large earthquakes



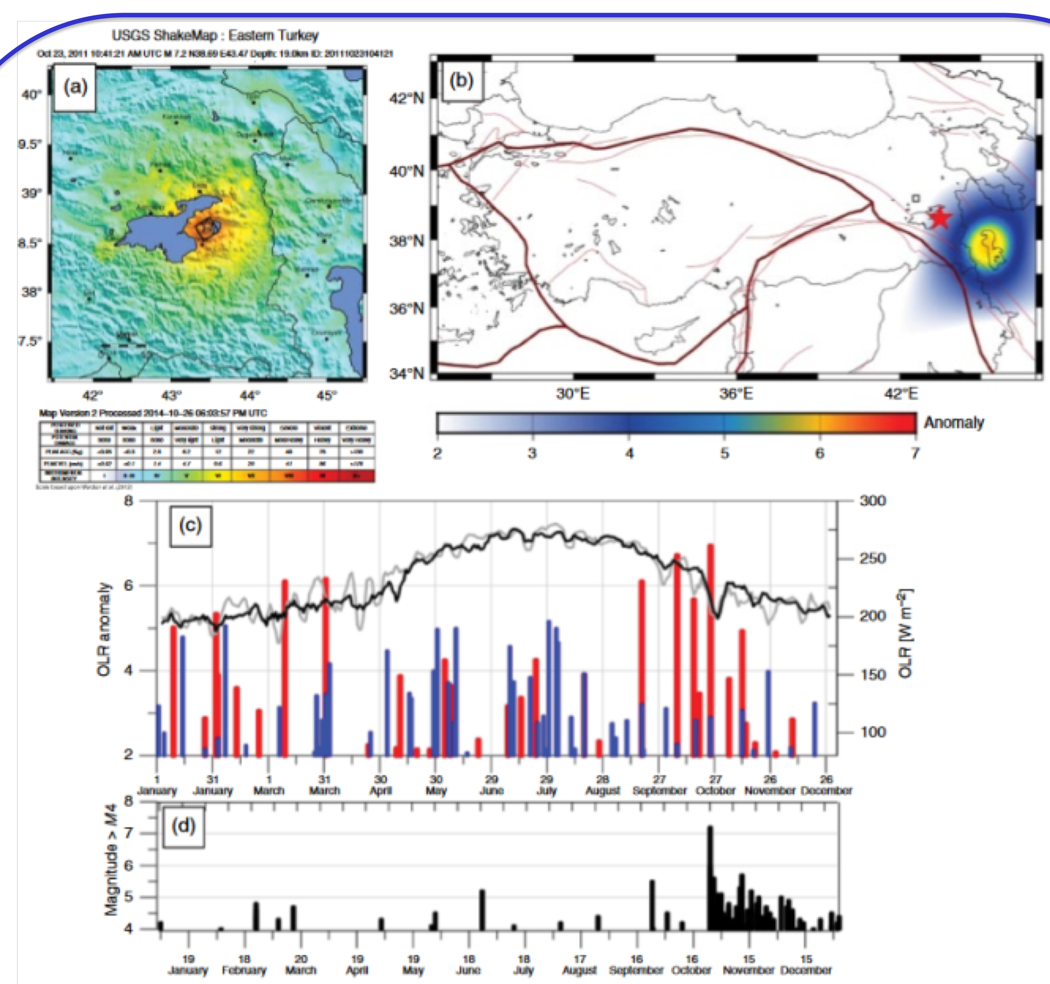
(a)Anomalous daily SLHF 11 days before 2004 Sumatra EQ. (b) 20 days before March 6, 2005 M>8.7 Sumatra E.Q.; (c) Six days before M>9 Tohoku, Japan EQ. Epicentres are marked with red star, tectonic plate boundaries with red line, and major faults with brown colour.

M6.9 Aegean Sea,2014, Greece



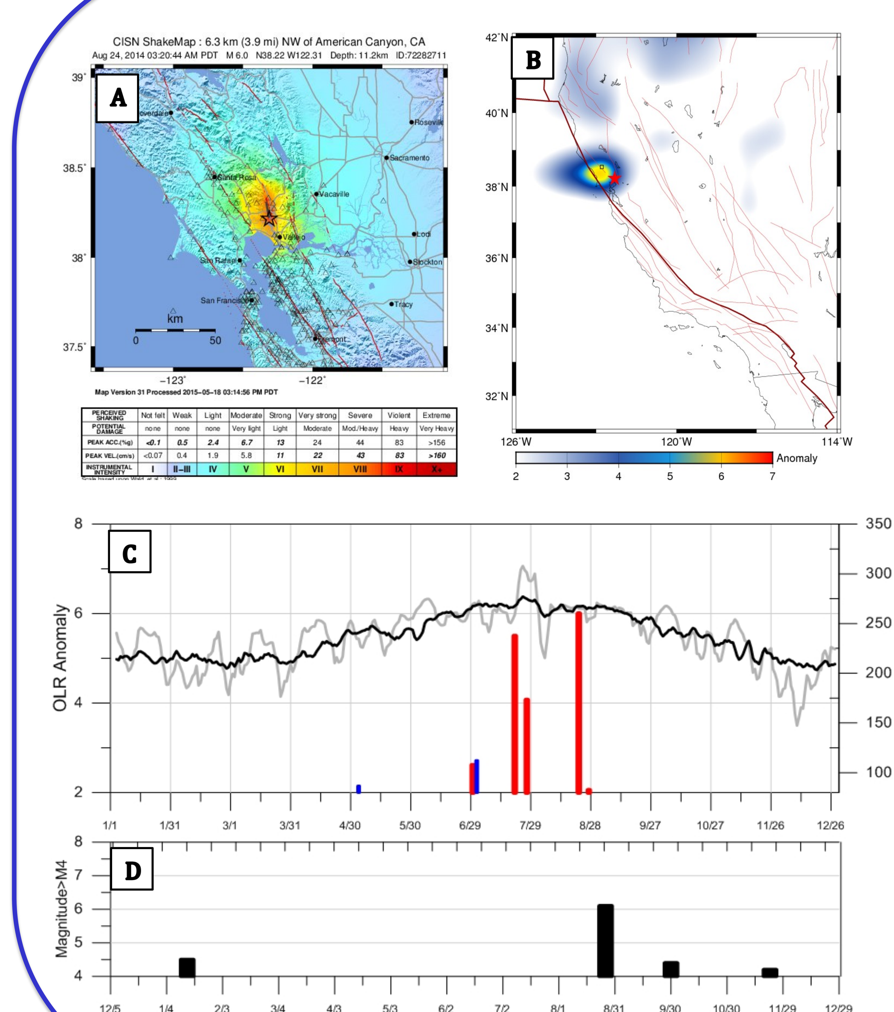
(a) USGS Shake Map, Aegean Sea; (b) Nigh time TRA map 10 days prior to Aegean Sea EQ. (c) Yearly time series of OLR over epicentral area; (d) M>4 seismicity for 2014 near epicentral area

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 feint 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.