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Great Sumatra Earthquake Registers on Electrostatic Sensor

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Strong electrical signals that correspond to the M_w = 9.3 earthquake of 26 December 2004, which occurred at 0058:50.7 UTC off the west coast of northern Sumatra, Indonesia, were recorded by an electrostatic sensor (a device that detects short-term variations in Earth's electrostatic field) at a seismic station in Italy, which had been installed to study the influence of local earthquakes on a new landslide monitoring system.

Electrical signals arrived at the station practically instantaneously and were detected up to several hours before the onset of the Sumatra earthquake (Figure 1) as well as before local quakes. The corresponding seismic signals (p-waves) arrived 740 seconds after the start of the earthquake. Because the electrical signals travel at the speed of light, electrical monitoring for the global detection of very strong earthquakes could be an important tool in significantly increasing the hazard alert window.

The 26 December 2004 Great Earthquake

The 26 December 2004 Sumatra earthquake is reported to be the second largest earthquake ever recorded by any seismograph station. Consequently, it was no surprise to find impressive signals on the seismic channels of seismic station UTV1, located in the Upper Tiber Valley (Tuscany, Italy).

This station is also equipped with an electrostatic sensor, which is in a long-term test (see details below). But surprisingly, the seismographic registration was accompanied by strong signals recorded before and during the Sumatra earthquake from this electric sensor.

Figure 1 shows a 12-hour window for the Sumatra earthquake, recorded at UTV1, starting on 25 December 2004 at 1800:00 UTC. The origin time of the Sumatra earthquake is indicated by a vertical dashed line at 0058:50.7 UTC. The electrical signals were recorded practically instantaneously; in contrast, the p-waves arrived after 740 seconds. Considering an epicentral distance of 9235 km (~83°), this is in good agreement with standard p-wave velocity models and the speed of light within Earth for the electrical signals.

The environmental situation at UTV1 did not change within the days before and after the big Sumatra earthquake. No local earthquake occurred in this time span. Further-more, the observed electrical signal from this great

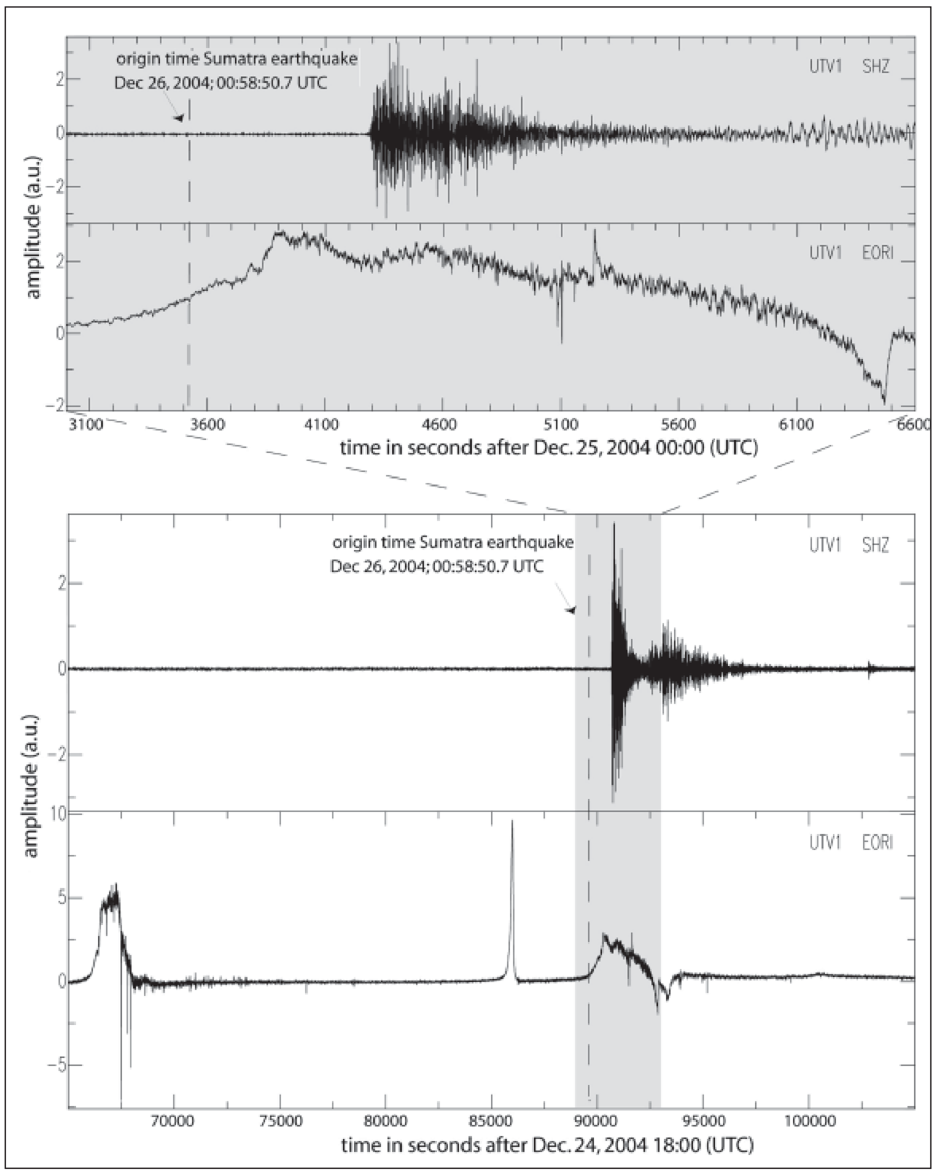

Fig. 1. Seismic (SHZ) and electrical (EORI) traces during the M_w = 9.3 Sumatra earthquake of 26 December 2004, 0058:50.7 UTC. The bottom panel shows a 12-hour record before, during, and after the Sumatra earthquake. The vertical dashed line represents the onset at 0058:50.7 UTC. The upper panel shows a one-hour zoom.

BY H. RÖDER, T. BRAUN, W. SCHUHMANN, E. BOSCHI, R. BÜTTNER, AND B. ZIMANOWSKI

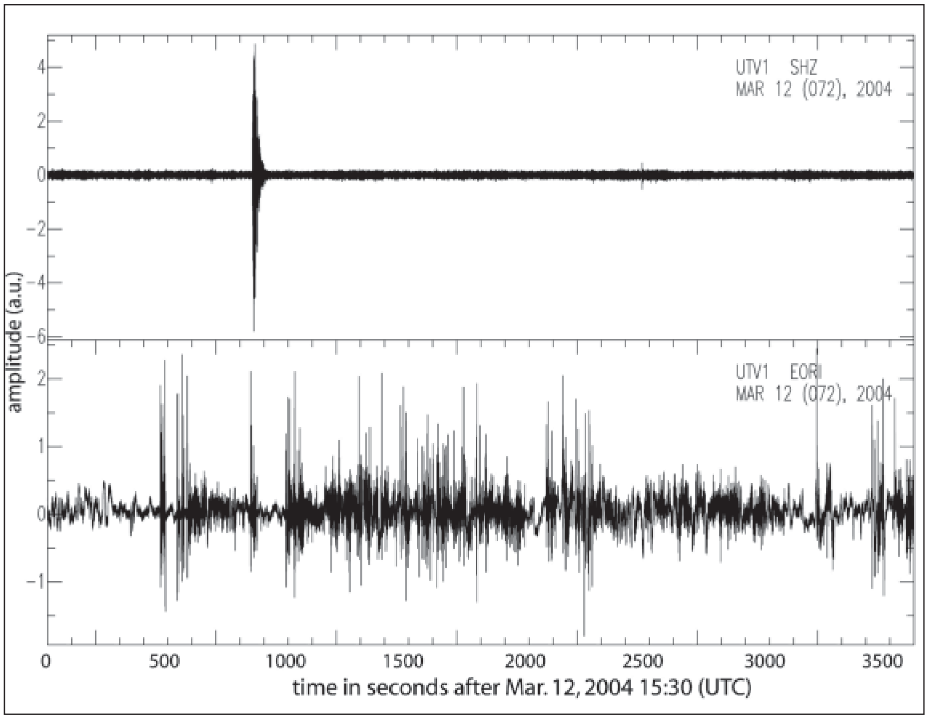

Fig. 2. Example of seismic (SHZ) and electrical (EORI) traces recorded during a local earthquake (epicentral distance 25 km).

earthquake differs significantly from signals recorded during local earthquakes (Figure 2).

The aftershocks and other strong earthquakes that occurred within the days before and after the big earthquake were recorded by the seismic channels, but they did not show any significant electrical signal. For example, on 23 December 2004, at 1459:03 UTC, an M_w = 8.1 earthquake occurred NNE of Macquarie Island, Australia, which was recorded by UTV1 (Figure 3). The upper trace represents the signals of the vertical short-period seismometer (SHZ), and the lower channel shows the signal from the electric sensor (EORI). No signal was recorded on the electric channel.

Summing up all these observations, it is evident that the electrical signal shown in Figure 1 was generated by the M_w = 9.3 Sumatra earthquake. In contrast to the relatively smooth electrical signal recorded during the big earthquake, the signals detected during local earthquakes from a perimeter with an approximately 25 km radius are characterized by many spikes (Figure 2).

Probably, because of the large distance, these features are filtered from the Sumatra earthquake signal during the passage through Earth. The detection limit of the electrical monitoring system (signal-to-noise ratio) is approximately 0.5% of the signals detected during local earthquakes and the big Sumatra earthquake. Obviously, the aftershocks and some other major earthquakes (Figure 3) did not emit this signal strength.

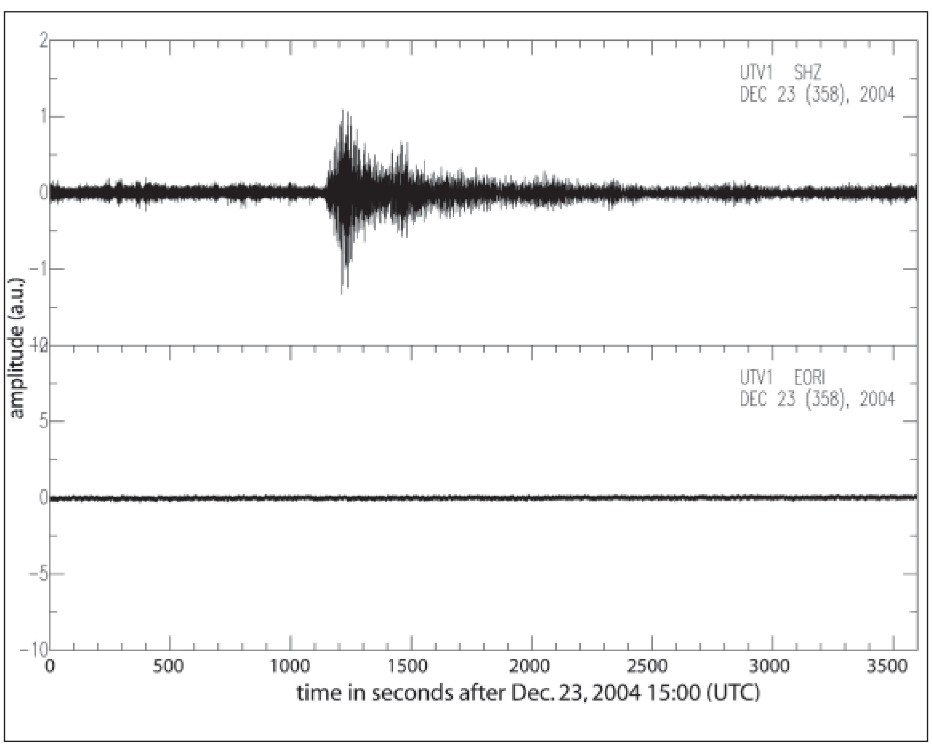

Fig. 3. Seismic (SHZ) and electrical (EORI) traces during the M_w = 8.1 earthquake NNE of Macquarie Island, Australia, 1459:03 UTC.

Background and Details of the Measurements

With the scientific purpose to study the influence of local earthquakes on a new landslide monitoring system [*Röder et al.*, 2002], an electrostatic sensor was deployed at station UTV1, along with one vertical and one horizontal short-period passive seismometer (T0 = 1.3 seconds). In this station, the measured short-time electrical and seismic signals were recorded by a three-channel 24-bit digitizer (Lennartz M24 compact). The time signal was provided by a GPS receiver.

The station was set in continuous recording mode during winter 2004–2005 at a sampling rate of 100 Hz for all three channels. In order to avoid any contamination of the measurements, the station was installed in an uninhabited typical Tuscan stone house without external electric power supply, far from human activity and power lines. Twelve-volt dc power was provided by two conventional car batteries individually connected/disconnected to one solar panel. In this way, galvanic separation and clean dc voltage supply was ensured.

Buried about 20 centimeters below the surface, the electrostatic sensor works like a capacitor with two conductive plain electrodes. The upper plain has a capacitive coupling to the ground, and the lower plain is isolated against the Earth, mounted in a closed glass cylinder. The sensor detects variations of the horizontal component of the electrostatic field. Underground vertical field variations (e.g., self-potential), as well as atmospheric electric fields (e.g., thunderstorms), are blocked by the upper electrode.

Electrical signals were registered that were generated before and during the release of seismic waves. The signals assigned to the 2004 Sumatra earthquake were the only electric signals detected by the method, so far, from a non-local seismic event. An interesting observation is the fact that strong signals were recorded several hours before the major release of seismic energy.

Further investigations are required to answer the question of whether these signals can be regarded as precursors of earthquakes and whether they might be useful for earthquake prediction. In any case, the integration of such measurements into more seismic surveillance stations should be generally considered because interesting additional information to the seismic records can be expected.

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Winter Convection Continues in the Warming Southern Adriatic

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During winters in the eastern Mediterranean, cold winds blow over the waters of the southern portion of the Adriatic Sea, resulting in heat loss of the ocean. This cold surface water becomes denser than surrounding waters and sinks into the deep reaches of the Mediterranean Sea. This forms 'deep water,' or water once at the ocean's surface that now has sunk to depths of 1500 meters and more. The Southern Adriatic Pit (SAP) is the convection site and source for the Eastern Mediterranean Deep Water (EMDW). Since the late 1980s, the SAP has been monitored almost every year because of its importance in driving the eastern Mediterranean deep circulation convection cell.

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This article presents data from a 26 March – 8 April 2005 oceanographic cruise that shows the occurrence of deep convection in this area down to a depth of 800 meters. The article indicates that in the last decade, the water entering the Southern Adriatic from the rest of the eastern Mediterranean has been getting warmer, causing buoyancy to increase.

This increase in buoyancy could play a major role in depressing this convection when the heat loss is limited, such as in mild winters. Indeed, convection did not occur every year during the time span considered in this paper (between 1997 to 2005). However, this study documents that, despite the increase of buoyancy, convection did occur in some winters. The fact that the winter convection continues to take place although the waters are more buoyant suggests a remarkable sensitivity of the SAP to the climatic regime of the area.

Winter Convection in the Southern Adriatic Pit

In the eastern Mediterranean, the southern Adriatic plays a major role in producing new dense waters (Figure 1b). In the center of the SAP (1200 meters deep), winter convection and dense water formation take place. This process is the result of outbreaks of cold continental air from the Balkan Peninsula taking heat from the sea surface layer through cooling and evaporation, and causing movement through the water column in the center of a gyre that rotates counter-clockwise. The movement of this gyre along the ocean floor is governed by bathymetry.

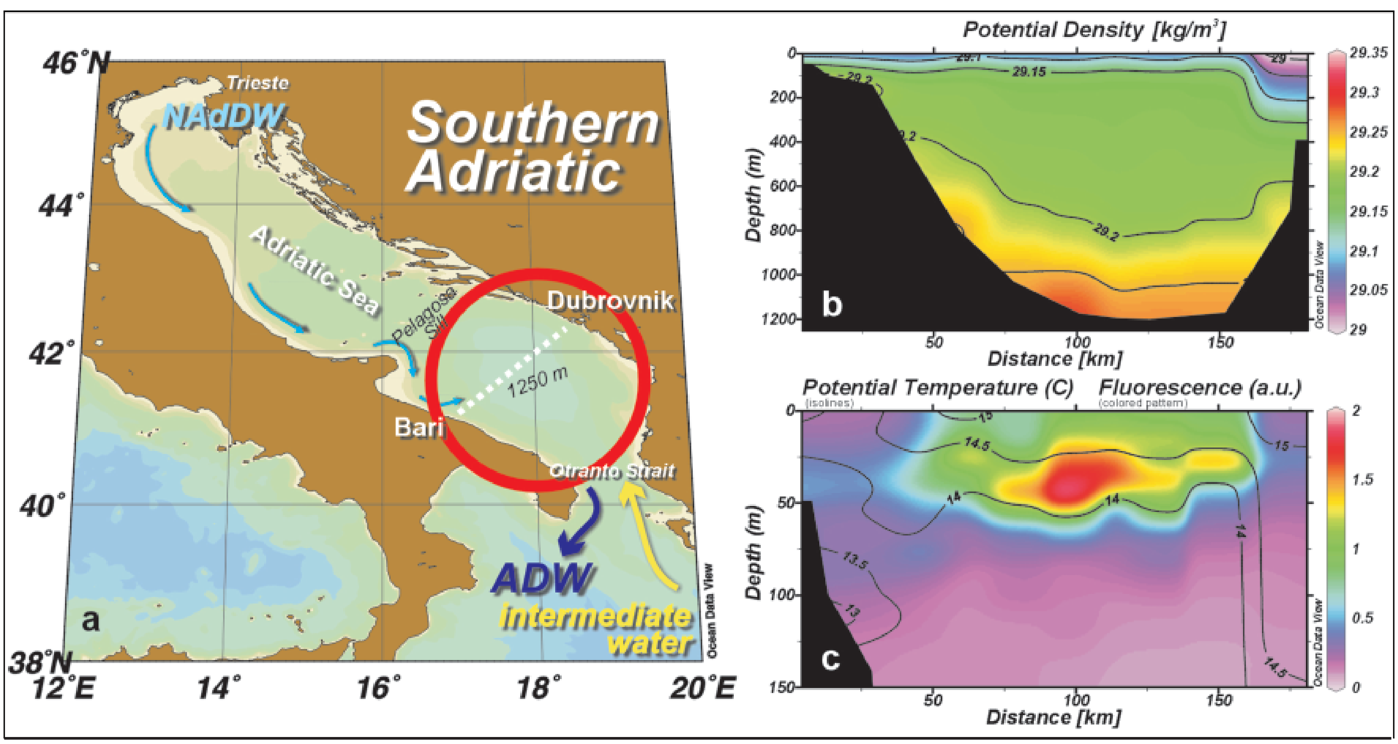

Fig. 1. (a) The winter convection taking place in the Southern Adriatic converts the intermediate water of eastern Mediterranean origin and the local surface water into the Adriatic Dense Water, which feeds the thermohaline cell of the eastern Mediterranean. (b) The potential density distribution along the Bari-Dubrovnik transect on 31 March 2005 shows the homogeneity of the water column down to a depth of 800 meters, indicating the vertical convective mixing prior to the cruise. (c) Fluorescence distribution exhibits a large subsurface maximum that corresponds with the satellite chlorophyll maximum patch.