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Earthquake precursor research: ground-satellite observations, laboratory experiments, and theoretical models

Guest Editors

Pier Francesco Biagi

Università di Bari, Dipartimento di Fisica, Bari, Italy

Michael E. Contadakis

Aristotle University of Thessaloniki, Department of Geodesy and Surveying, Thessaloniki, Greece

Masashi Hayakawa

University of Electro-Communications, Advanced Wireless Communications Research Center, Chofu, Tokyo, Japan

Tommaso Maggipinto

Università di Bari, Dipartimento di Fisica, Bari, Italy

Istituto Nazionale di Geofisica e Vulcanologia

PREFACE

Over the last several years, a lot of evidence has indicated that the earthquake generation process is a critical phenomenon, which culminates in a large event that corresponds to a critical point. A fundamental prediction of this hypothesis is that before the event reaches this critical point, a regional system of faults goes through a period of accelerating seismicity and seismic energy release, which forms the signature of the approach to the critical state. By the end of this stage, the critical point has been attained, and the stress exerted by friction on the shear zone, as well as the strain caused by an avalanche of fusing cracks, lead to irreversible instability and rupture. As a consequence of the processes prior to an event, changes in the physical/chemical state of the earth precede earthquakes. These variations can be called the *ground precursors*. There are a variety of such precursors, that are evident in their genesis, such as ground uplift and tilt, gas emissions, underground water-level fluctuations, changes in groundwater chemistry, and changes in electrical resistivity of the rock.

Recently, variations in certain atmospheric parameters have been observed prior to seismic activity. We can call these variations the *atmospheric precursors*. These atmospheric precursors have mainly been indicated by data collected by satellites. Research into the interactions between seismic activity and disturbances in radiobroadcasts has also been carried out recently. These disturbances appear related to variations in certain parameters in the ground, the atmosphere and the ionosphere, and we can call these the *radio precursors*. There appear to be strict connections between the atmospheric precursors and the radio precursors. Indeed, the main disturbances revealed in the atmosphere by satellites generate variations in the propagation medium of the radio signals, and the disturbances in these signals can be detected.

Two different models have been proposed to justify the atmospheric and mainly ionospheric disturbances. The first assumes direct effects of the ionising radiation from gases (mainly radon)/aerosols, or electromagnetic emissions from the crust during the preparatory phase of an earthquake. The second model assumes indirect effects, such as pre-seismic phenomena in the ground that can produce gravity waves in the atmosphere-ionosphere. This second model overcomes the problems of the transport from the ground up into ionosphere of particles or electromagnetic waves in the first model. In any case, the atmospheric and radio precursors indicate that there is *ionosphere-atmosphere-lithosphere coupling*.

Over the last few years, earthquake precursor research has developed greatly. This is seen in particular by the networks for the continuous collecting of data related to different parameters that have been put into operation. In this framework, the Pacific VLF radio network and the European VLF/LF radio network stand out. At the same time, a large number of laboratory experiments have clearly suggested that microscopic failure (micro-fracturing) of the rock is associated with the appearance of spontaneous charge production (electrification) and transient electric-magnetic-electromagnetic emission. So, electric, magnetic and electromagnetic emissions from the ground can also be generated during the preparation phase of earthquakes, and these phenomena must be included as ground precursors. Thus, both the techniques in the laboratory for measuring electromagnetic radiation emitted during rock fracturing and the analysis of anomalies in the transmission of electromagnetic signals are good candidates for investigating seismic-related phenomena. In this respect, an understanding of the physics of rock cracking and deformation is critical for our understanding of the seismic activity in the Earth.

This special issue brings together the work of several groups that have been working in these fields, with the presentation of some of the recent results obtained from around the world. These contributions were mainly presented at the European Geosciences Union General Assembly in April 2011, in Vienna, Austria.

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