INTERNATIONAL SCHOOL OF GEOPHYSICS «ENZO BOSCHI»

43rd Course:

# FRONTIERS IN GEOPHYSICS FOR THE THIRD MILLENNIUM

ERICE
SICILY
22-26
SEPTEMBER
2025

UNDER THE PATRONAGE OF:

**Sicilian Regional Government**

**Istituto Nazionale di Geofisica e Vulcanologia**

**University of Bologna**

**Eucentre**

# PURPOSE OF THE COURSE

Enzo Boschi, the former president of the Istituto Nazionale di Geofisica e Vulcanologia (INGV), passed away on 22 December 2018. In 1984 he founded the International School of Geophysics, bringing to Erice the foremost geophysicists worldwide over nearly 30 years. The progress of the School of Geophysics proceeded hand in hand with the development of Italian seismology and volcanology, following the renascence of Istituto Nazionale di Geofisica (ING) in 1982, and then the onset of the Istituto Nazionale di Geofisica e Vulcanologia (INGV) in 2001.

Thanks to the president of the Ettore Majorana Centre – Professor Antonino Zichichi – the School has been recently entitled to Enzo Boschi. The 43rd course is intended to provide an overview of the most recent accomplishments in the main areas of solid and fluid Earth geophysics, extending from seismology to volcanology, from climate changes to space weather. Special emphasis will be given to the mutual interactions of geophysical phenomena, such as the effects of volcanic activity on climate evolution, and to the extraordinary advancements that all Earth observation systems have achieved over the past 40 years.

We will touch upon some of the main challenges faced by geophysicists worldwide: from modeling the dynamics of the Earth interior, to understanding and anticipating fault behavior, to improving our capability to issue early warnings of an impending large earthquake, volcanic eruption, or major solar storm, based on the use of new technologies and big-data strategies. The course will provide a high-level forum for young promising post-doc scientists and PhD students, who will have the opportunity to meet leading scientists in their respective fields of expertise, thus reviving the goals and the atmosphere of previous courses of the International School of Geophysics.

# POETIC TOUCH

According to legend, Erice, son of Venus and Neptune, founded a small town on top of a mountain (750 metres above sea level) more than three thousand years ago. The founder of modern history — i.e. the recording of events in a methodic and chronological sequence as they really happened without reference to mythical causes — the great Thucydides (~500 B.C.), writing about events connected with the conquest of Troy (1183 B.C.) said: «After the fall of Troy some Trojans on their escape from the Achaei arrived in Sicily by boat and as they settled near the border with the Sicanians all together they were named Elymi: their towns were Segesta and Erice.»
This inspired Virgil to describe the arrival of the Trojan royal family in Erice and the burial of Anchise, by his son Enea, on the coast below Erice. Homer (~1000 B.C.), Theocritus (~300 B.C.), Polybius (~200 B.C.), Virgil (~50 B.C.), Horace (~20 B.C.), and others have celebrated this magnificent spot in Sicily in their poems. During seven centuries (XIII-XIX) the town of Erice was under the leadership of a local oligarchy, whose wisdom assured a long period of cultural development and economic prosperity which in turn gave rise to the many churches, monasteries and private palaces which you see today.



In Erice you can admire the Castle of Venus, the Cyclopean Walls (~800 B.C.) and the Gothic Cathedral (~1300 A.D.). Erice is at present a mixture of ancient and medieval architecture. Other masterpieces of ancient civilization are to be found in the neighbourhood: at Motya (Phoenician), Segesta (Elymian), and Selinunte (Greek). On the Aegadian Islands - theatre of the decisive naval battle of the first Punic War (264-241 B.C.) - suggestive neolithic and paleolithic vestiges are still visible: the grottoes of Favignana, the carvings and murals of Levanzo. Splendid beaches are to be found at San Vito Lo Capo, Scopello, and Cornino, and a wild and rocky coast around Monte Cofano: all at less than one hour's drive from Erice.

### More information about the other activities of the

"ETTORE MAJORANA" FOUNDATION AND CENTRE FOR SCIENTIFIC CULTURE
can be found on the WWW at the following address: http://www.ccsem.infn.it

### Please note

Participants are expected to arrive at Palermo or Trapani airport, or directly in Erice, on 22 September, no later than 6 p.m.

# INTERNATIONAL SCHOOL OF GEOPHYSICS «ENZO BOSCHI»

Director: Fabio **FLORINDO**

## 43rd Workshop:
## FRONTIERS IN GEOPHYSICS FOR THE THIRD MILLENNIUM

Directors:

Maria Elina **BELARDINELLI** | Bologna University, Italy

Paolo **GASPERINI** | Bologna University, Italy

Alberto **MICHELINI** | INGV, Rome, Italy

Daniela **PANTOSTI** | INGV, Rome, Italy

Massimo **POMPILIO** | INGV, Pisa, Italy

Gianluca **VALENSISE** | INGV, Rome, Italy

Organizational support:

Silvia **NARDI** | INGV, Rome, Italy

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**FRONTIERS IN GEOPHYSICS FOR THE THIRD MILLENNIUM**

# DAY 1 — 23 September

| MORNING | GLOBAL CHALLENGES | |
|---|---|---|
| 8:30 - 8:45 | **Director & Conveners** | Welcome to the 43rd Course of the International School of Geophysics |
| 8:45 - 9:30 | **G. Spada** | Earth's dynamics in the centennial to millennial time scales |
| 9:30 - 10:15 | **S. Wiemer** | How predictable are earthquakes? |
| 10:15 - 11:00 | **L. Giulia** | Is the worst over? Real-Time events discrimination with the Foreshock Traffic Light System |
| 11:00 - 11:30 | **Coffee break and poster session** | |
| 11:30-12:15 | **G. Ekström** | Global Earthquake Seismology |
| 11:15-13:00 | **J. Tromp** | Global Full Waveform Inversion |
| 13:00 - 15:00 | **Lunch** | |
| AFTERNOON | **UNDERSTANDING GLOBAL ISSUES AND THREATS** | |
| 15:00 - 15:45 | **G. Beroza** | Machine-Learning-based earthquake monitoring |
| 15:45 - 16:30 | **D. Wald** | Evolving strong motion metrics for use in engineering analyses |
| 16:30 - 17:00 | **Coffee break and poster session** | |
| 17:00 - 17:45 | **G. Di Toro** | The contribution of rock mechanics laboratory studies to earthquake research |
| 17:45 - 18:30 | **D. Giardini** | Major research infrastructures for 21st century Geophysics |

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# DAY 2

# 24 September

| MORNING | DEALING WITH ENVIRONMENTAL AND SOCIETAL ISSUES | |
|---|---|---|
| 8:30 - 9:15 | **L. De Santis** | Geophysical and geological data in the polar regions: tools to investigate past and modern environmental changes and ice sheet dynamics |
| 9:15 - 10:00 | **N. Pinardi** | The science of ocean and coastal predictions |
| 10:00 - 10:45 | **A. Neri** | Modelling explosive eruptions and their hazards; achievements and perspectives |
| 10:45 - 11:30 | **Coffee break and poster session** | |
| 11:30 - 12:15 | **M. Rosi** | Managing volcanic risks in densely populated areas |
| 12:15 - 13:00 | **R. Pinho** | From Earthquake Early Warning to Autonomous Seismic Protection: an integrated, evolutionary approach to societal resilience |
| 13:00 - 15:00 | **Lunch** | |
| AFTERNOON | ENZO BOSCHI: MEMORIES AND ACCOMPLISHMENTS | |
| 15:00 - 15:45 | **A. Michelini** | 1982-2025: The evolution of INGV seismological and geodetic networks |
| 15:45 - 16:30 | **S. Branca** | Frontiers of volcanological observatories: the case of INGV's Etna Observatory |
| 16:30 - 17.00 | **Coffee break and poster session** | |
| 17:00 - 17:30 | **T. Pepe**<br>**G. Valensise** | The legacy of Enzo Boschi |
| 17:30-18:00 | **P. Gasperini** | The school of Geophysics in Bologna |
| 18:00-18:30 | **A. Amato** | Enzo Boschi and the l'Aquila trial |

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# DAY 3 25 September

| MORNING | EARTHQUAKE OBSERVATIONS AT DIFFERENT SCALES | |
|---|---|---|
| 8:30-9:15 | **R. Bilham** | The influence of variations of Polflucht-Kraft on lithospheric seismicity |
| 9:15-10:00 | **R. Bürgmann** | Variable fault coupling and earthquake potential along the Hayward Fault |
| 10:00-10:45 | **S. Wesnousky** | Past and future fault rupture lengths for seismic source characterization: insights from Earthquake Geology |
| 10:45-11:30 | **Coffee break and poster session** | |
| 11:30-12:15 | **M.A. Gutscher** | Submarine fiber optic cables: a new technology to study earthquakes and the seafloor environment - The FOCUS project |
| 12:15-13:00 | **R. Arrowsmith** | Adapting new tools to advance Earthquake Geology observations and understanding |
| 13:00-15:00 | **Lunch** | |
| AFTERNOON | **EARTHQUAKE EARLY WARNING AND RISK MITIGATION** | |
| 15:00 - 15:45 | **A. Zollo** | Seconds that matter: the physical basis and effective use of Earthquake Early Warning |
| 15:45 - 16:30 | **R. Allen** | Frontiers in hazard reduction using massive sensor networks |
| 16:30 - 17:00 | **Coffee break and poster session** | |
| 17:00 - 17:45 | **I. Iervolino** | The time-space scales of seismic risk: from Earthquake Early Warning to the life-cycle of civil infrastructure |
| 17:45-18:30 | **Closing remarks** | |

# POSTERS

**1. Abedi F. et al.**
Seismic Behavior of Active Faults Through Multisource Optical Imagery: From Satellite to Drone Resolution (case study: The North Zanjan fault)

**2. Allegra M. et al.**
Leveraging Deep Learning for Detecting Low-Frequency Seismic Events in DAS Data at Vulcano Island, Italy

**3. ARISTOTLE-ENHSP Team**
ARISTOTLE-ENHSP Project: a multi-hazard scientific expert assessment service for the EC Emergency Response Coordination Center

**4. Avella M. et al.**
Crustal anisotropy variations at Mt. Etna for monitoring local stress perturbations

**5. Bevilacqua A. et al.**
Data analysis of volcanic seismicity as a function of ground uplift during the ongoing unrest of Campi Flegrei caldera (Italy)

**6. Biondini E. et al.**
Probabilistic earthquake forecasting in Italy: bridging the gap between alarm-based and probability-based models

**7. Bottari C. et al.**
Earthquakes Lost in Time: A Multidisciplinary Case Study from Segesta (NW Sicily) Combining Archaeoseismology, Structural Geology, and Geophysics

**8. Brooks S.J. et al.**
InSAR analysis on Mt. Etna: preliminary insights into mid-term active faulting dynamics

**9. Caredda E. et al.**
Integrating Deep Learning and Seismological Analysis to characterize microseismicity in the Val d'Agri Region (Southern Italy)

**10. Corsaro M.**
Leveraging Transformer Models and Distributed Acoustic Sensing to improve seismic monitoring in Campi Flegrei

**11. Cuius A. et al.**
Improving Seismic Hazard Assessment Through Physics-Based Source Modeling

**12. D'Amico S. et al.**
Detecting Meteorological Tsunamis Using Coastal Seismometers: The Gulf of Finland Experiment

**13. De Paolo E.**
A trans-dimensional inversion algorithm for volcanic source modeling in finite element domain

**14. D'Ippolito G. et al.**
Laboratory earthquakes under hydrothermal conditions in Neapolitan Yeallow Tuff (Campi Flegrei, Italy)

**15. Dubois Z. et al.**
Hydrological signature in the current surface deformation of the East Adriatic by InSAR and GNSS

**16. Ferrara F. et al.**
Co-Volcanic Ionospheric Disturbances during Mt. Etna eruptions

**17. Ferrara G. et al.**
Reprocessing vintage seismic reflection profiles in the offshore Campi Flegrei Caldera

**18. Fonzetti R. et al.**
Shaking Things Up with Deep Learning: From Training to Model Benchmarking and Seismic Catalog Building

**19. Hronek M. et al.**
Inverse physics-based modeling of the 2016 Mw 6.1 Tottori Earthquake

**20. Lo Bue R. et al.**
Tracking Seismic Velocity Variations during the 2021 Unrest at Vulcano Island through Ambient Noise Analysis

**21. Longobardi V. et al.**
Implementation and Test of an onsite Earthquake Early Warning and Rapid Response system in the volcanic caldera of Campi Flegrei during the unrest

**22. Marcou S. et al.**
Ground Motion Observations from the MyShake Smartphone Network and Future Directions

**23. Menichelli I. et al.**
Seismic imaging of the Adria lithospheric structure from the joint inversion of teleseismic and ambient noise data

**24. Nikolopoulou I. et al.**
The M 5.9 Strofades Earthquake Sequence: Relocation, Focal Mechanism Solutions and Stress Inversion

**25. Parrino N. et al.**
Impressa Seismica: Machine Learning Analysis of Fault-Driven Landscapes

**26. Petito Penna R. et al.**
An automatic waveform modeling method to estimate Earthquake source and attenuation parameters

**27. Rappisi F. et al.**
Crustal structure of the Kivu Rift and Virunga Volcanic Province (DR Congo) from P-wave anisotropic tomography

**28. Ravidà G. et al.**
Imaging the shallow crust in the western Lake Garda region by high-resolution seismic profiling: Preliminary results

**29. Sardeli E. et al.**
The 2025 Santorini Swarm: Spatiotemporal Distribution and Coulomb Stress Changes. Preliminary Results

**30. Scotto di Uccio F. et al.**
An automatic workflow for microseismicity characterization in Southern Apennines (Southern Italy)

**31. Sollai A. et al.**
Earthquake Reflection Imaging and Migration: Application to the Campi Flegrei Caldera

**32. Spassiani I. et al.**
Reconciling the Irreconcilable: Window-Based VS Stochastic Declustering Algorithms

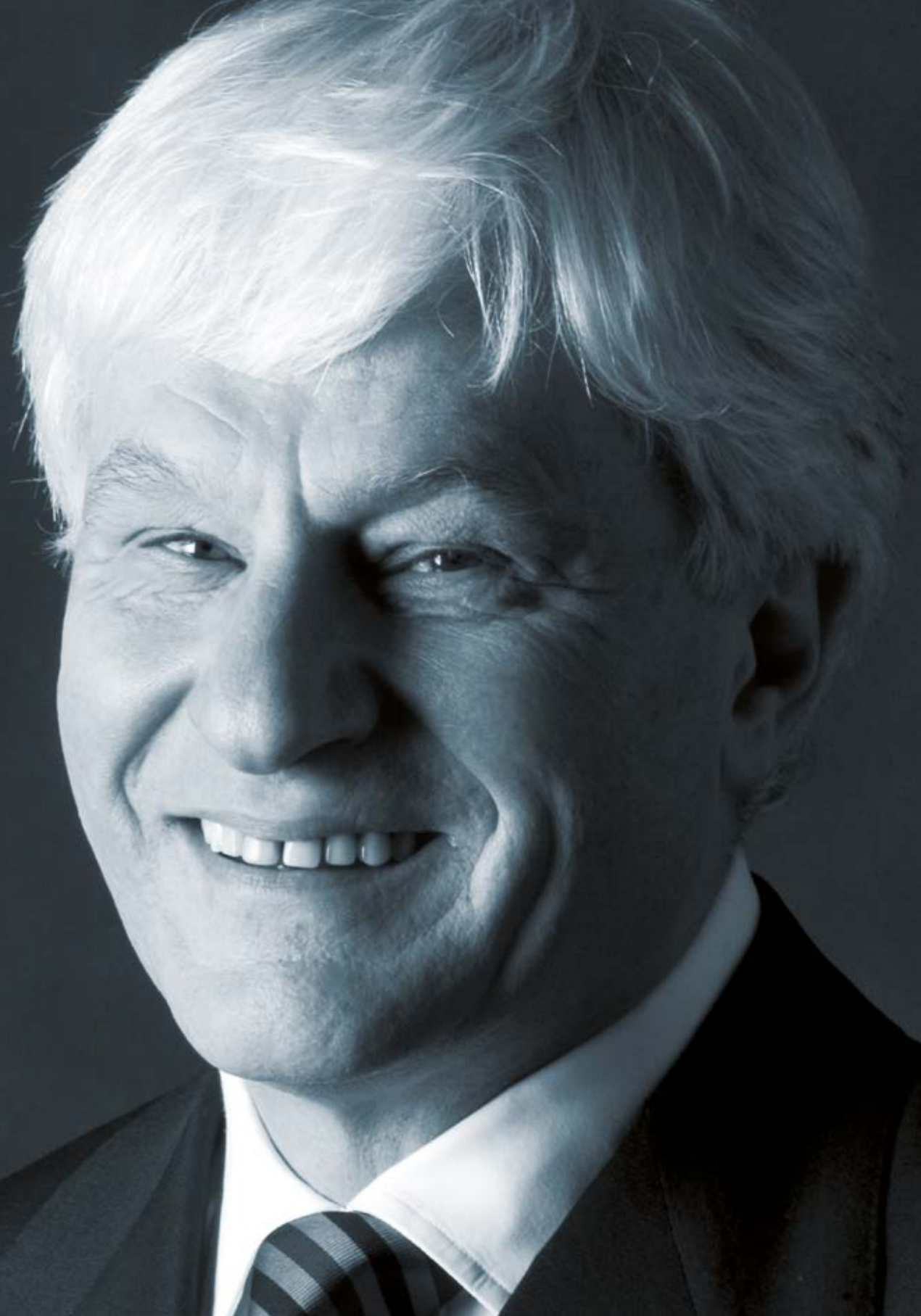
**33. Tavani F. et al.**
Deep Learning Python-Based Workflow for Automated Focal Mechanism Determination of Small to Moderate Earthquakes in Italy

**34. Triantafyllou I. et al.**
The Greek Earthquake Impact Database: AD 1800-2020

**35. Tringali G. et al.**
New paleoseismology and morphotectonic findings along the Fiandaca Fault and their relationships with the Etna volcano flank dynamics

**36. Vallianatos F.**
The Santorini-Amorgos, 2025 volcano-tectonic sequence in terms of statistical physics

**37. Varchetta F. et al.**
Regional High-Quality Ambient Noise Models for Italy: Development and Application to the Italian Seismic Network



# ENZO BOSCHI

Seismologist

**Arezzo 1942 | Bologna 2018**

**Enzo Boschi passed away on 22 December 2018, at the age of 76. Born in Arezzo, Tuscany, he graduated in Physics from Bologna University in 1968. His initial scientific interests included the physics of the Earth's interior, the earthquake source and the mechanisms from which volcano eruptions originate.**

**At the beginning of his scientific career Enzo Boschi was visiting scientist at the Laboratoire des Hautes Pressions (CNRS, Paris), at the Cavendish Laboratory (Cambridge University), and at the Department of Earth and Planetary Sciences (Harvard University). In 1973 he became adjunct professor of Geophysics at the recently-established University of Ancona, and later full professor at the University of Bologna, where from 1977 to 2012 he held the chair of Seismology.**
After engaging in the "Progetto Finalizzato Geodinamica" of Italy's Consiglio Nazionale delle Ricerche (CNR) and in the early activities of the "Gruppo Nazionale per la Difesa dai Terremoti" (GNDT), in 1983 Enzo Boschi became president of the Istituto Nazionale di Geofisica (ING). He remained in charge until 2001, when ING merged with Osservatorio Vesuviano and three institutes from CNR into the new Istituto Nazionale di Geofisica e Vulcanologia (INGV). He then chaired the INGV from its very foundation up to 2011. During his nearly 30 year-long presidency, Enzo Boschi played an active role in the creation of the Protezione Civile (National Civil Protection). From 1986 to 2000 he chaired the Seismic Risk Section of the Commissione Grandi Rischi (Major Risks Commission). Later on, he continued to be a member of the Commission as INGV president. Meanwhile, Enzo Boschi fostered the inception and the

Enzo Boschi con Renato Funiciello, Claudio Eva e Paolo Scandone

development of the modern Italian Seismic Network, supported by the National Civil Protection. Within three decades, this network evolved from a set of sparse, vertical component seismometers, to a dense network of more than 400 digital three-component sensors covering the entire country. This nationwide network was complemented by a state-of-the-art network comprising several very broadband seismometers deployed around the Mediterranean basin (MedNet Network). Later on, INGV extended its research topics to Physical Oceanography and to the investigation of climate changes. Under Enzo Boschi's guidance, INGV had leading roles

in many international research projects within major programs run by the United Nations, UNESCO, NSF, NATO, and the European Commission.
Among several subsequent successful endeavors, his masterpiece was to turn a small institute made up of a few researchers and technicians with limited scientific instruments into one of the top worldwide institutions for geophysics and volcanology, ranking high in terms of publications, citations and reputation.
Starting in 1984, Enzo Boschi was also appointed director of the International School of Geophysics at the Ettore Majorana Cultural Centre in Erice, Sicily, where he gathered

scientists of the highest repute in the Earth Sciences, young scientists at the beginning of their career, and PhD students. The informal yet rigorous setting of the School and of the Centre contributed to creating valuable scientific connections and promoting collaborations; eventually, these liaisons brought a large number of Italian geophysicists abroad, to learn and grow professionally by visiting top level universities and research centers worldwide. In this framework, Enzo Boschi's support to the ideas and ambitions of "his researchers" was always enthusiastic.
As INGV President, on 30 March 2009 Enzo Boschi was invited to attend an expert meeting in L'Aquila: a gathering organized by the National Civil Protection and dedicated to the sequence of earthquakes that had been affecting the area for months. On 6 April 2009 a Mw 6.3 earthquake struck L'Aquila and its surroundings, killing over 300 people. Enzo Boschi and six other meeting attendants were indicted for manslaughter, under the motivation of having put in place an inaccurate appraisal of the seismic risk, and of having reassured the population about the probability of an impending destructive earthquake. All defendants were

initially sentenced to six years of imprisonment: but two years later the decision was overtaken by the second instance sentence, which acquitted six of them on the grounds that the case was unfounded. Enzo Boschi's acquittal was later confirmed by the Supreme Court.
During his long career, Enzo Boschi has received several scientific and civil awards and honors. Member of the Accademia dei Lincei and of the Academia Europaea, fellow of AGU and AAAS, in December 2006 he was nominated Cavaliere di Gran Croce, Ordine al merito della Repubblica Italiana by President Giorgio Napolitano. He was also very popular with TV and media audiences, as he was always interviewed in the aftermath of earthquakes and eruptions.
By combining his passion and rigorousness for scientific research with a full commitment toward the society, he never missed the opportunity to remark that proper building and city planning are the only means to reduce earthquake casualties and material losses: a lesson that the Italians unfortunately have not learned yet. In his last years, he had become popular on Twitter, where he actively and willingly discussed with colleagues, researchers, journalists and citizens. Even by short sentences, he was able to conjugate joviality, pungency and rigor. He was always able to listen and to relaunch the discussion.
Enzo Boschi was endowed with a strong personality, much political courage, farsightedness, and charisma, all spiced up with his genuinely Tuscan character. His inner strength was crucial to overcome the most difficult phases of his career and of his private life. Research in Geophysics owes much to him. It was a great honor to have him as Presidente.



(Adapted by Gianluca Valensise, based on the original text by Marco Olivieri and Massimiliano Stucchi, IASPEI Bios & Obituaries, http://www.iaspei.org/about/bios-obituaries/enzo-boschi_1942-2018, ).

XI Course of the International School on Solid Earth Geophysics
"Active Faulting Studies for Seismic Hazard Assessment"

Erice, 27 September - 5 October, 1995

43rd Course

# FRONTIERS IN GEOPHYSICS FOR THE THIRD MILLENNIUM

www.ingv.it/ricerca/international-school-of-geophysics-enzo-boschi

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