Authors who witnessed and described the 1631 eruption believed that there had been no Vesuvius activity prior to that year 'in the memory of man.' It may be asked if the terms 'memory of man' was used rhetorically to indicate a very long and indefinite length of time, centuries long, or if it had a literal meaning, with no eruptions occurring in the memory of those alive. The question is relevant because the concept of the length of time is relative in various cultural contexts. The measure of time became a precise concept, in the common meaning of the term, only from the half of the nineteenth century and only for urbanized and industrialized areas.

So, in 1631, the statement that Vesuvius had 'not been active in the memory of man' may be difficult to comprehend today, in particular if it is discovered, as in this case, that there was Vesuvius activity 60 years before 1631. Perhaps then the witnesses wanted to refer to two different concepts: (1) There had not been an eruption of comparable strength to that of 1631 since the last eruption in 1139, so for a multi-century long period; or, (2) the expression 'the memory of man' means a period just a few decades long, in which no Vesuvius activity has been detected.

But could the philosophers, scholars, and intellectuals of Naples and the surrounding Vesuvius area (authors of treatises and reports) have witnessed the volcanic activity described by Ligorio, which had occurred 60 years earlier? The average life span in those days was much shorter than today, and the authors of the treatises on the 1631 eruption were at the height of their intellectual development. But it is unknown whether other episodes of activity, such as the one described in Ligorio's treatise, that had occurred at Vesuvius had much chance of being described as an important fact by any intellectual who was living in Naples, since the episodes did not cause any damage to property or people. Ligorio's manuscript, written and preserved in places far from Naples, may have had no bearing on historical memory of such events.

In any case, Vesuvius's 'extraordinarily' long sleep, on which the Neapolitan authors who described the 1631 eruption agreed, had shown some signs of coming to an end at least some 60 years before the eruption actually started. These new data indicate the need for a re-evaluation of potential geological events that took place during the sixteenth century in the area of Vesuvius, including a reassessment of correlations with volcanic earthquakes, hitherto wholly neglected in the historical volcanological research.

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Author information

Emanuela Guidoboni, SGA-Storia Geofisica Ambiente, Bologna, Italy; E-mail: guidoboni@sga-storiageo.it; and Enzo Boschi, Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy.

Preseismic Lithosphere-Atmosphere-Ionosphere Coupling

PAGES 417, 424

Preseismic anomalous states in the atmosphere and ionosphere as well as those in the near-Earth (telluric) currents and ultralow-frequency electromagnetic variations have been, since the 1970s, reported as occurring prior to earthquakes. These preseismic phenomena have not yet been universally accepted, partly because the low occurrence frequency of large earthquakes has hindered establishing their statistical significance. Recent achievements in this respect, however, seem to be highly encouraging for promoting further studies on preseismic lithosphere-atmosphere-ionosphere (LAI) coupling.

LAI Coupling: Research History

Liu et al. [2000] investigated the relationship between large earthquakes and ionospheric anomalies in and around Taiwan. As an index of ionospheric anomalies, they used critical plasma frequency, f_oF_2, measured by ionospheric sounding instruments (ionosondes), corresponding to the maximum electron density of the ionospheric F layer (160–400 kilometers in altitude), a region characterized by ion compositions and plasma dynamics. The F layer, dividing into F_1 and F_2, contains most of the electrons in the ionosphere. Liu and colleagues found that f_oF_2 significantly decreased locally during afternoons within a few days before $M \geq 6$ earthquakes occurred.

For example, Figure 1a shows that f_oF_2 measured above northern Taiwan decreased three and four days before the M 7.6 Taiwan Chi-Chi earthquake of 21 September 1999. Electron density depression above Taiwan also was observed by the global positioning system's (GPS) total electron content (TEC) measurements, as shown in Figure 1b [*Liu et al.,* 2001].

From such observations, *Liu et al.* [2006] constructed a set of quantitative definitions for ionospheric anomalies and examined the statistical correlation between thus defined ionospheric anomalies and all of the Taiwan $M \geq 5$ earthquakes (184 in number) during the period 1994–1999. The results indicated that anomalies appeared within the five days prior to the earthquakes. The statistical correlation was found to be dramatically enhanced for earthquakes with magnitude greater than 5.4 and with epicentral distance from the ionosonde instrument less than 140 kilometers.

Earlier, *Gufeld et al.* [1992] explicitly pointed out the existence of preseismic anomalies in the lower ionosphere, by using the transmission of very low frequency (VLF) electromagnetic waves (10–20 kilohertz), emitted from a radio beacon transmitter, which propagate through the waveguide formed by the conductive Earth-surface and ionospheric D layer (around 50–90 kilometers in altitude). The received intensity and phase of VLF waves are associated with the variation of Earth-ionosphere waveguide between the transmitter and receiver. Therefore, this observation is often used to monitor the plasma variation of the D layer. They observed anomalies in the intensity and phase of the received waves prior to major earthquakes in Russia when the epicenter was located between the transmitter and receiver.

By M. Kamogawa

These studies have been further developed mainly in Russia, Japan, and Italy, and the studies have extended the used frequency from extremely low frequency (ELF; a few hertz to 3 kilohertz) to low frequency (LF; 30–300 kilohertz) bands. For example, variations of the terminator times of VLF waves—the times of sunrise and sunset observed through the wave propagations—between a transmitter installed in Tsushima (west of Japan) and a receiver installed in Choshi (east of Japan) were found before $M > 6$ earthquakes [*Molchanov and Hayakawa,* 1998]. More recently, *Shvets et al.* [2004] also analyzed the VLF transmission anomalies between Tsushima and Choshi. They compared the anomalies with 10 $M \geq 5$ earthquakes that occurred in 1997 in the area within 350 kilometers around the receiver and an elliptical zone surrounding the transmitter and receiver. They showed that the earthquakes were highly correlated with VLF anomalies occurring a few days prior.

Molchanov and Hayakawa [1998] also observed that the terminator time varied within 5–11 day periods before $M > 6$ earthquakes, and they suggested that vertical atmospheric gravity waves—a few minutes – ten hours oscillations by the buoyancy and gravity forces—during the earthquake process caused this variation. Moreover, examining the validity of the preseismic anomalous transmission of very high frequency (VHF) electromagnetic waves beyond the line of sight, originally proposed by *Kushida and Kushida* [2002] in Japan, *Fujiwara et al.* [2004] statistically demonstrated the existence of atmospheric anomalies lasting for a few minutes to several hours before earthquakes. Fujiwara and colleagues monitored the VHF waves (FM radio; around 80 megahertz) in eastern Tokyo that were transmitted from an over-the-horizon radio station in northern Honshu, and thoroughly compared the waves with the seismicity in the surrounding regions. They found that the transmission anomalies were significantly enhanced within five days prior to $M \geq 4.8$ earthquakes.

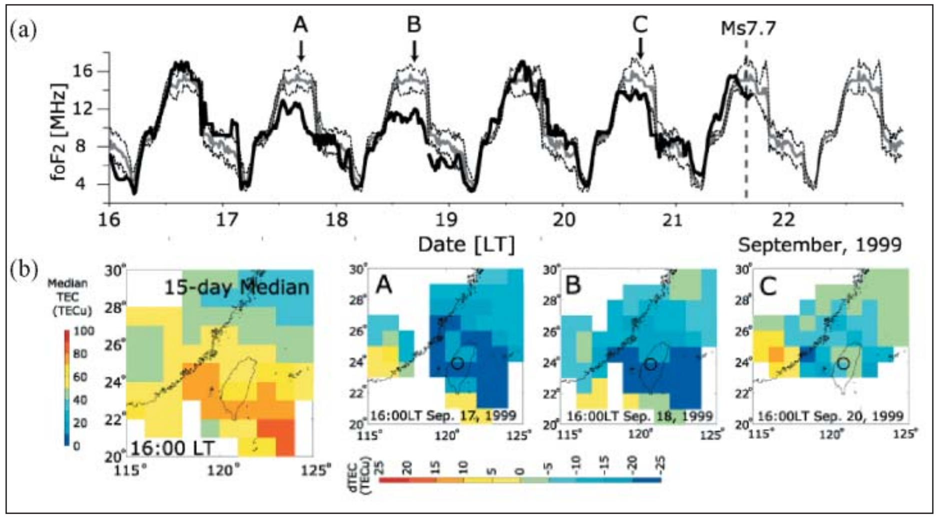

*Fig. 1. Ionospheric anomalies associated with the 1999 M 7.6 Taiwan Chi-Chi earthquake. (a) The f_oF_2 value observed by ionosonde in Taiwan. Solid, gray, and dotted lines are observation data, previous 15-day running median, and its interquartile range, respectively [*Liu et al., *2000]. Three and four days before the main shock, f_oF_2, corresponding to electron density of the F_2 layer, significantly decreased during daytime (A and B). (b) GPS total electron content (TEC) observation during the same period [*Liu et al., *2001]. Left map shows the 15-day median of two-dimensional TEC at 1600 LT. A, B, and C are the difference from the 15-day median for four, three, and one days, respectively, before the main shock. Circles represent the epicenter.*

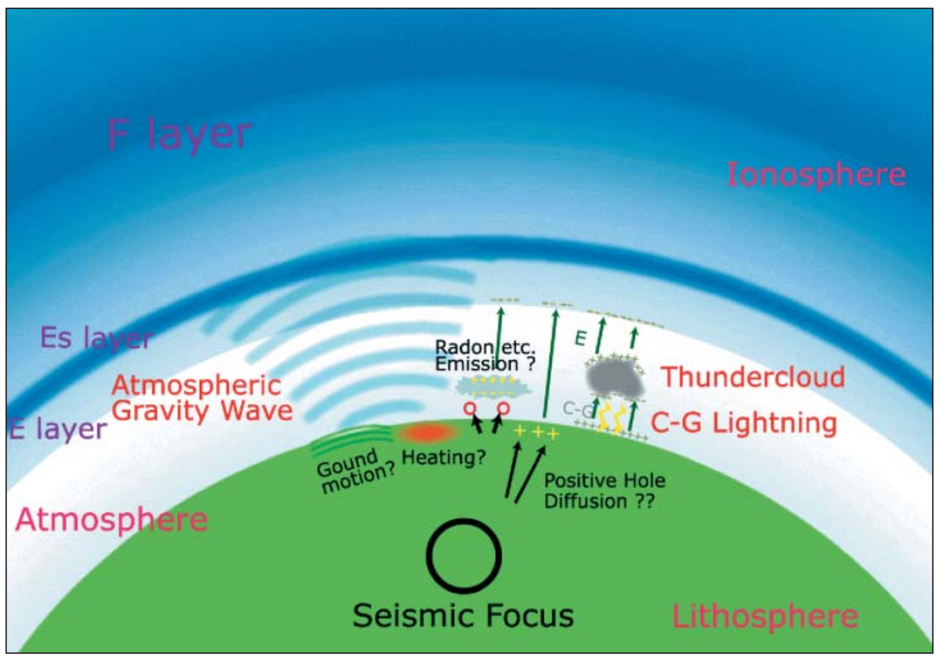

Fig. 2. Diagram of preseismic lithosphere-atmosphere-ionosphere coupling models and proposed mechanisms.

Proposed Mechanisms

If the preseismic atmospheric-ionospheric anomalies are real, some phenomena causing them should be detectable on the ground. If such causal phenomena are identified, the concept of lithosphere-atmosphere-ionosphere coupling could be greatly strengthened. Possible mechanisms for energy-transport channels from the lithosphere to the atmosphere-ionosphere are summarized in Figure 2. One possibility is that the atmospheric electric field generated on or near the ground surface during the preseismic period may cause the ionospheric anomalies. Such an atmospheric electric field may be caused by ions generated from radon emissions. It has also been proposed that positively charged holes, associated with microfracturing prior to earthquakes, diffuse from the focal zone to the ground surface. There are laboratory experiments that support this possibility [*Freund,* 2000]. However, such preseismic electric fields on the ground followed by preseismic ionospheric anomalies have not yet been observed.

Alternatively, it has been proposed that atmospheric gravity waves propagate up to and disturb the ionosphere before earthquakes. The proposed sources of the gravity waves are long-period ground oscillations or thermal anomalies. This proposed linkage is inferred from the observations of coseismic ground vibrations and tsunami-exciting atmospheric gravity waves which propagate into the ionosphere. However, there is no report of preseismic long-period ground oscillations being detected, even by sensitive superconducting gravimeters. Although some reports claim the existence of preseismic rises of temperature, infrared radiation, and surface latent heat flux, it is difficult to explain how such anomalies disturb the ionosphere through the atmosphere.

Atmospheric-Ionospheric Anomalies as Triggered Effects

It is well known that besides tectonic stress accumulation, various events influence seismicity. Examples are far-away large earthquakes, tides, the filling of dams, and even the injection of electric current into the ground. Current injections in Russia by a magnetohydrodynamic power generator actually have activated seismicity [*Avagimov et al.,* 2004]. It has also been proposed that some external phenomena, such as geomagnetic storms and cloud-to-ground lightning, may affect seismicity [e.g. *Sobolev and Zakrzhevskaya*, 2003]. Since these events also disturb the atmosphere-ionosphere, it might be possible that some of the reported preseismic atmospheric-ionospheric anomalies simply were observed as a trigger of the earthquakes.

As discussed in this article, the cause and effect relationships may still be unestablished, but atmospheric-ionospheric anomalies before the earthquakes do exist and their further investigation, involving the lithospheric connection, remains an important research endeavor. Determining these connections possibly will aid with understanding and predicting seismic activity.

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Author information

Masashi Kamogawa, Department of Physics, Tokyo Gakugei University, Tokyo, Japan;
E-mail: kamogawa@u-gakugei.ac.jp

What Do College Students Know About the Ocean?

PAGES 418, 421

A recent survey of students entering a college-level course in introductory oceanography reveals that they feel a strong connection with, and curiosity about, the ocean. To guide this inherent curiosity into understanding and stewardship, educators need to know the 'hooks,' the topics and concepts that catch students' interests. According to a survey of 119 students at North Carolina State University-Raleigh, some useful hooks are students' personal, emotional connection with the ocean, human impacts (especially pollution), exotic biology, and cool technology.

Survey results further indicate that students already are gaining ocean knowledge from a wide variety of sources, and that the topics of interest to them can be organized using the Essential Principles of Ocean Literacy [*Centers for Ocean Sciences Education Excellence (COSEE),* 2005]. The students' general awareness of ocean science is a good basis upon which to build.

Given the declining quality of the marine environment, ocean educators have the responsibility to teach not only the science of the ocean, but also the interdependence between humans and the ocean. This interdependence is at the heart of ocean literacy, as recently defined by a national consensus of marine scientists and educators [*COSEE,* 2005]. An ocean-literate person understands ocean science, can communicate about the ocean, and is able to make informed decisions about ocean policy [*COSEE,* 2005].

BY C. CUDABACK

The scientific understanding that every citizen should have is defined in the seven Essential Principles:

1. The Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean makes the Earth habitable.
5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

Most Americans attain voting age around the same time they complete their formal education in science—at the end of high school or after a few introductory college science courses. A college-level introductory oceanography class is the last chance to promote ocean literacy through formal education, and also provides an opportunity to measure the level of ocean literacy among high school graduates. As these students are self-selected, preclass survey results may indicate an upper bound for ocean literacy in the general population. Postclass surveys should indicate how well college educators are doing their job.

Prior studies of undergraduate classrooms have measured student beliefs and preconceptions about physics [*DeLaughter et al.,* 1998; *Adams et al.,* 2006], as well as their understanding of solid Earth geosciences [*Libarkin and Anderson,* 2005]. High school ocean science classes have been shown to have a significant effect on general scientific literacy [*Lambert,* 2005]. Public concern about the ocean has been shown to exceed public understanding of the ocean [*American Association for the Advancement of Science,* 2004; *Belden et al.,* 1999; *Steel et al.,* 2005], but no prior study has measured ocean literacy in the context of formal education.

A preliminary ocean literacy survey was developed based on the Essential Principles and consisted of open-format questions that allowed students to express their understandings or misunderstandings freely. Students filled out the survey on the first day of an introductory oceanography course at the North Carolina State University at Raleigh (in January 2006), and results from four of the most general questions are discussed here. Only the topics of interest to students are discussed here; their level of understanding will be addressed in a future paper.

Student Interest in Oceanography

The demographics of this class were roughly consistent with the university population as a whole. Students were nearly equally divided between the freshman, sophomore, junior, and senior classes, and half were majoring in science, mathematics, or engineering. One third of the students were in the College of