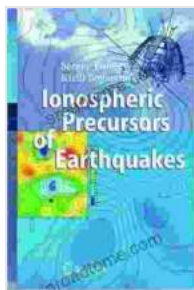


# Ionospheric Precursors of Earthquakes: Unraveling the Enigma

The Earth's ionosphere, a dynamic layer of charged particles high above our planet, has emerged as a promising frontier in earthquake prediction. Recent groundbreaking research has uncovered a fascinating link between ionospheric disturbances and impending seismic events, opening up new possibilities for mitigating the devastating impacts of earthquakes.



## Ionospheric Precursors of Earthquakes by Sergey Pulinetz

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In this comprehensive article, we delve into the captivating world of ionospheric precursors of earthquakes. We explore the pioneering work of Dr. Sergey Pulinetz, a renowned scientist who has dedicated his career to unraveling the enigmatic connection between space and Earth. Through a meticulous examination of case studies, field observations, and cutting-edge research, we uncover the potential of ionospheric monitoring as a transformative tool in earthquake science.

## The Pioneering Work of Dr. Sergey Pulinetz

Dr. Sergey Pulinets, a leading seismologist and space physicist at the Institute of Terrestrial Magnetism, Ionosphere, and Radio Wave Propagation (IZMIRAN) in Russia, has been instrumental in establishing the field of ionospheric earthquake precursors.

In the early 1990s, Dr. Pulinets embarked on a series of groundbreaking studies that revealed a correlation between ionospheric anomalies and subsequent earthquakes. His research demonstrated that disturbances in the ionosphere, such as electron density variations, could occur several days to weeks before the onset of seismic activity.



## Ionospheric precursors of earthquakes and Global Electric Circuit

Sergey Pulinet<sup>a,\*</sup>, Dmitry Davidenko<sup>b</sup>

<sup>a</sup>Space Research Institute, Russian Academy of Sciences, Moscow, Russia

<sup>b</sup>S.P. Korolyov Institute of Space Cosmics (IKS) of the Russian Academy of Sciences, Moscow, Russia

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### Abstract

The electromagnetic coupling between the ionosphere and the ionosphere is considered within the framework of the Global Electric Circuit (GEC) concept. First we consider the seasonal variations in the ionosphere associated with the earthquake preparation process, their temporal and spatial characteristics along the ionospheric height profile. Then the GEC description is presented directly with account for ionospheric processes which play key role in the coupling chain of physical (and chemical) phenomena changing the electric properties of the planetary boundary layer of atmosphere. We treat this part of ionosphere as an equivalent system of distributed sources and sinks of charges, producing distributed leading to delay and fast changes of electric parameters including the electric properties of the boundary layer. The new concept named Spatial-Spatial Ionosphere is introduced in the last part of the paper. In general, this paper may be considered as a short review of the related phenomena of ionospheric and the space weather.

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*Keywords:* Ionospheric precursors of earthquakes; Global Electric Circuit; Ionosphere; Ionospheric coupling

### 1. Introduction

The history of ionospheric precursors of earthquakes (IP) studies includes more than 50 years. Its early stages of development are described in [Pulinets and Stetsko, 2003](#). It is summarized the main trends in the ionospheric layer anomalies driven mechanisms to the ionospheric coupling. The results of this is very simple: ionospheric coupling mechanisms that showed recently its very low efficiency – [Chernitsin and Stetsko, 2004](#) and [Tolstik, 2011](#) (namely say as well: 0.1–0.4 TECU for Sumatra earthquake [Hsu et al., 2004](#); [Aizawa and Kusunoki, 2005](#)), and 0.5–1.5 TECU with for Tohoku Earthquake ([Chernitsin et al., 2012](#)), that it is difficult to expect that before earthquake happens something that can be used to produce an early of ionospheric precursors to the ionosphere.

\* Corresponding author. Tel.: +7 495 438 5000; fax: +7 495 438 5000.  
E-mail: [sergey.pulinets@yandex.ru](mailto:sergey.pulinets@yandex.ru) (S. Pulinet).

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which are really observed before earthquakes. Another argument is that Auroral Gravity Wave (AGW) above ionospheric disturbance should have wave-like structure and should move with velocity of sound, while pre-earthquake ionospheric anomalies have permanent character and do not show any tendency of movement; they are stationary in space. So further in the paper only electromagnetic driven ionospheric disturbances associated with earthquakes will be discussed.

The very early variants of ionospheric coupling models were based on direct ionospheric of ionospheric electric field effect from the ground surface to the ionosphere ([Hsu et al., 2004](#); [Aizawa and Kusunoki, 2005](#); [Chernitsin et al., 2003](#)). All of them are based on the possibility of electric field penetration into the ionosphere from ionospheric ground surface. However, the most recent version of this approach ([Chernitsin et al., 2012](#)) where ionospheric of the ionospheric conductivity is taken into account more correctly than in previous publications. In this approach is modification from

Dr. Pulinet's pioneering work laid the foundation for the development of ionospheric monitoring systems designed to detect and analyze these precursors, potentially providing valuable lead time for earthquake preparedness.

## Case Studies and Field Observations

Numerous case studies have corroborated the existence of ionospheric precursors to earthquakes. One notable example occurred in 2011, when the Tohoku earthquake in Japan was preceded by significant ionospheric disturbances observed by the Japanese Aerospace Exploration Agency (JAXA).

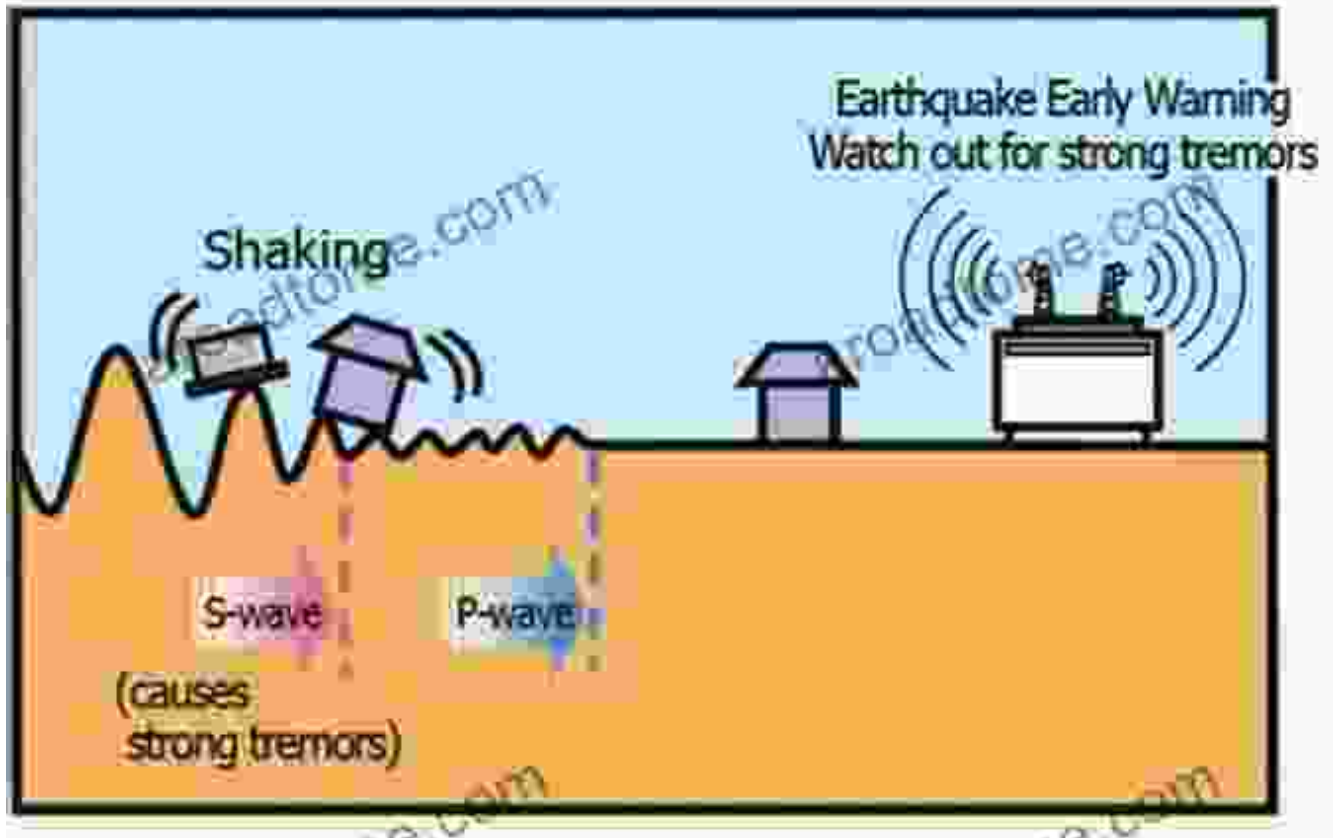
In another instance, a team of researchers at the University of California, Berkeley, analyzed ionospheric data from the Global Navigation Satellite System (GNSS) and found that electron density anomalies occurred over the epicenter of the 2015 Nepal earthquake, several weeks before the event.

Field observations further support the link between ionospheric disturbances and seismic activity. Researchers have deployed specialized instruments in earthquake-prone regions to monitor ionospheric parameters in real-time. These instruments have captured valuable data that has helped refine our understanding of the ionospheric precursors and their relationship to earthquake occurrence.

## **Implications for Earthquake Prediction**

The discovery of ionospheric precursors has profound implications for earthquake prediction. By monitoring ionospheric disturbances, scientists may be able to identify areas at risk and provide early warnings of impending seismic events.

While the field is still in its infancy, the potential benefits of ionospheric monitoring are immense. Early warnings could give communities valuable time to prepare for an earthquake, evacuate vulnerable populations, and mitigate potential damage.



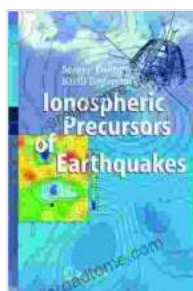
Researchers are actively developing and refining ionospheric monitoring systems to improve their accuracy and reliability. As these systems mature, they may become an indispensable tool in the arsenal of earthquake preparedness measures.

The discovery of ionospheric precursors of earthquakes has opened up a new frontier in seismology, offering a promising path towards improved earthquake prediction and disaster mitigation.

Through the groundbreaking work of Dr. Sergey Pulinets and other dedicated scientists, we are gaining a deeper understanding of the complex relationship between space and Earth. Ionospheric monitoring systems

have the potential to revolutionize earthquake preparedness, saving lives and protecting infrastructure in regions around the globe.

As we continue to unravel the mysteries of the ionosphere and its connection to seismic activity, we move closer to a time when earthquakes can be predicted with greater accuracy and confidence, empowering us to build more resilient communities and mitigate the devastating impacts of these natural disasters.



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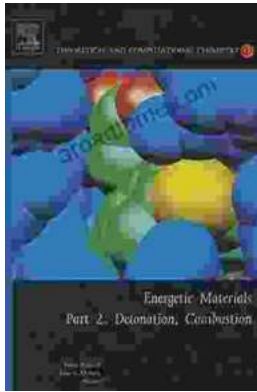
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