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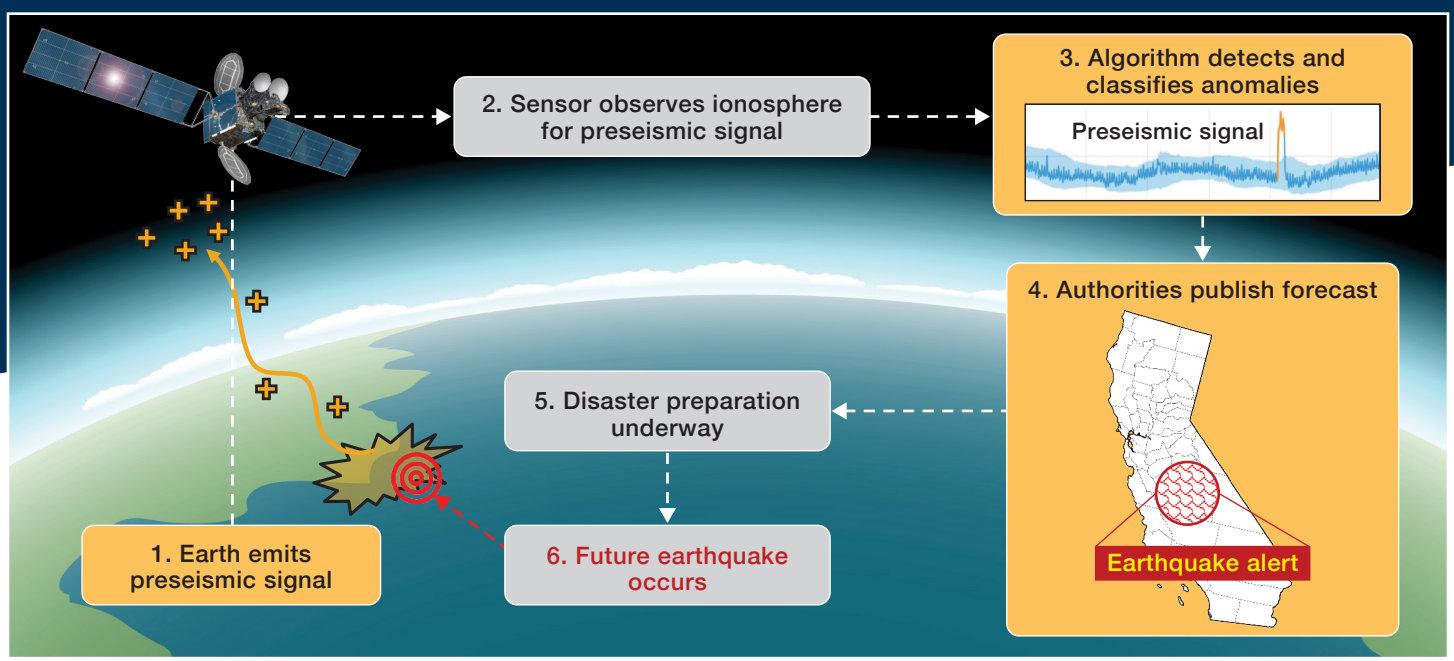


INNOVATION HIGHLIGHT

Technology in Support of National Security

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QuakeCast: Machine Learning to Predict Earthquakes



The illustration shows the forecasting steps in the QuakeCast approach: a signal is detected by sensor aboard a satellite; an algorithm detects and classifies anomalies in the data that could indicate an earthquake is imminent; this alert is then sent to emergency action planners.

Lincoln Laboratory researchers are exploring technology that could provide a warning at least eight hours, and up to a week, in advance of an earthquake. Their approach leverages machine learning to identify and classify anomalous disturbances in total electron content (TEC) in the ionosphere. Such disturbances, which have been observed by the Global Navigation Satellite System (GNSS) preceding strong (magnitude 5 or greater) earthquakes, may be indicators of threatening seismic activity.

KEY FEATURES

- Algorithmic models are trained on more than 10 years of ionosphere TEC data associated with 10,000+ earthquakes
- Goal is to classify preseismic earthquake signals by magnitude, geographical region, and event window
- Multiple types of machine learning methods have been tested, demonstrating viability of using TEC data

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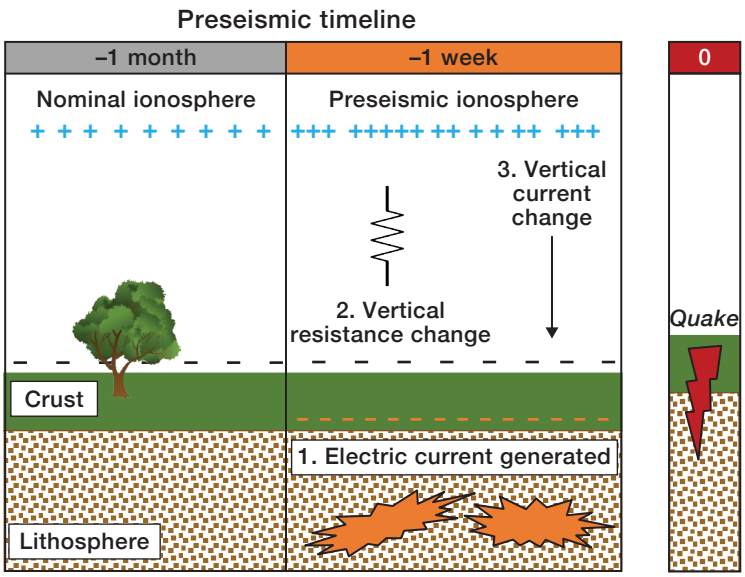
Motivation

In the last 20 years, earthquakes worldwide have caused more than 800,000 deaths and $650 billion in economic damages. Current early-warning systems provide up to a minute's notice by detecting an earthquake's nondamaging seismic waves prior to the arrival of damaging waves. With a system that gives earlier warning, emergency action planners could evacuate regions, prepare recovery resources, and put infrastructure like power plants into safe mode, thus saving lives and minimizing financial losses.

Concept

GNSS satellites offer a new opportunity to study the preseismic stage of earthquakes by sensing changes in the TEC in the ionosphere that may indicate that an earthquake is imminent in the region below. Some theories suggest that microcracking in the lithosphere during preseismic processes generates stress-activated electrical currents resulting from defects in igneous rocks. The ionosphere is coupled to these electrical currents through the global electric circuit. Rapid changes in TEC have been recorded hours to days prior to an earthquake. More than 6,000 GNSS receivers worldwide persistently gather global ionospheric TEC data, which is processed at centers such as the MIT Haystack Observatory, whose TEC database is widely used by the earth sciences community.

Lincoln Laboratory has developed prototype machine learning algorithms to predict impending earthquakes from global ionosphere data. These algorithms perform significantly better than random chance and can be used to identify regions with a high risk of earthquakes in the immediate future.



1. Preseismic microcracking in the lithosphere generates electric current
2. Vertical resistance between atmosphere and ground changes
3. Electrical current flow between ionosphere, atmosphere, and ground causes measurable change in TEC in ionosphere

Next Steps

QuakeCast is the foundation of a new method to forecast earthquakes. Researchers are working to refine system performance to achieve more accurate predictions of earthquake occurrence, location, and timing by incorporating additional data sources and algorithms.

INTERESTED IN ACCESSING THIS TECHNOLOGY?

Contact the MIT Technology Licensing Office
https://tlo.mit.edu/
tlo-inquiries@mit.edu 617-253-6966

INTERESTED IN WORKING WITH MIT LINCOLN LABORATORY?

https://www.ll.mit.edu/partner-us

Contact the Technology Ventures Office
tvo@ll.mit.edu

More Information

J. Reid, J. Liu, and B. Ananthabhotla, "QuakeCast, an Earthquake Forecasting System Using Ionospheric Anomalies and Machine Learning," *Earth and Space Science Open Archive*, 26 Feb. 2021.

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