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On the Ground at the AGU Conference

Forecasting Earthquakes and Space Weather

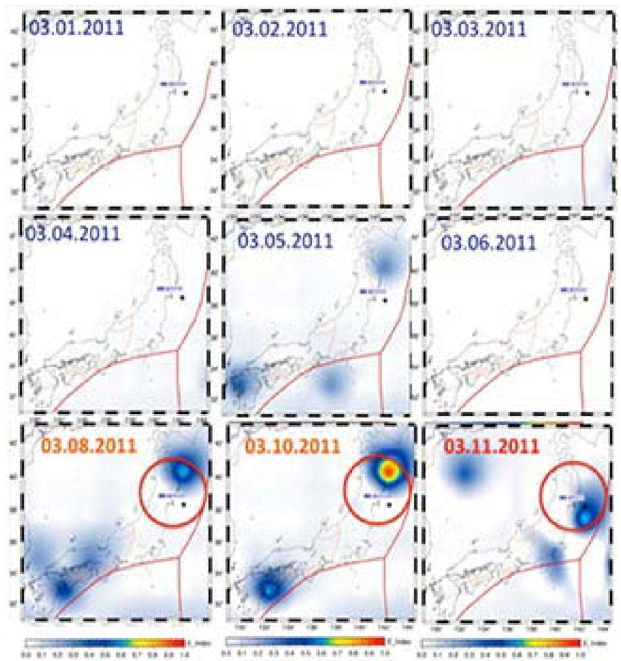
By Peter Martinson

SAN FRANCISCO, Dec. 7, 2011—The most revolutionary and important advances in human knowledge always bear on improving the ability of human civilization, not just to survive in our Universe, but to harness more power over it through knowledge. Two such revolutionary investigations were presented on Tuesday, at the second day of the American Geophysical Union conference in San Francisco: first, the ability to forecast and warn of oncoming devastating earthquakes, up to several days in advance; and second, the ability to forecast and warn of oncoming coronal mass ejections, whose impact could wipe out entire national power grids for weeks to months.

Forecasting earthquakes requires the integration of multiple parameters, measurements of a number of precursory indications emitted by impending earthquake rupture zones, several hours to days before eruption. This was emphasized by the chairman of the session on monitoring mega-earthquake precursors, NASA-Goddard scientist Dimitar Ouzounov, who listed off the usual precursory signals, such as ionospheric variations, infrared radiation anomalies, and ultra-low frequency (ULF) changes in the local geomagnetic field. He also added to the list new parameters, such as anomalous motions of the static vertical pendulum, electrical signals propagating through the ground, measurements of gravitational change with superconducting gravimeters, and others.

Based on test predictions made on 26 major earthquakes between 2003 to 2009, Ouzounov presented findings showing that reproducible combinations of the multiple precursors could have been used to forecast every quake. Even the recent August 2011 earthquake in Mineral, Va., produced reliable signals across the spectrum, several days in advance.

Ouzounov declared that in order for forecasting to move from research to operational, real funding would need to be provided to a relatively small group of graduate students and scientists, to assemble an historical baseline of data with which to compare an array of precursory evidence. In other words, forecasting is almost an immediate proposition, were there financial support.



Dr. Ouzounov's graphic showing the dramatic increase of infrared emissions from above the epicenter of the devastating March 11 earthquake in Japan.

Ouzounov was followed by one after the other presentation of the analysis of individual precursory signals emitted before large earthquakes. Katsumi Hattori of Chiba University, Japan, demonstrated the anomalous changes in ionospheric total electron content (TEC) associated with all the greater-than-magnitude-6 quakes in Japan from 1998-2010, and also with the devastating March 11 Tohoku earthquake.

Then, on behalf of Russian scientist Sergey Pulinets who could not attend the meeting, Ouzounov presented a series of different measurements taken days before the April 2009 L'Aquilla magnitude-6.3 earthquake. The geochemical, atmospheric, very low frequency (VLF) radio, and ionospheric TEC measurements all showed anomalous changes several days before the earthquake. This may indicate a demonstration of the theory of Pulinets, of a coupling between the lithosphere, atmosphere, and ionosphere during the lead-up to an earthquake.

The image that emerged was that, earthquakes are not only able to be forecasted, but they are also potentially predictable. One presenter, Vladimir Kossabokov, compared the location of the 12 deadliest earthquakes in the past decade with the Global Seismic Hazard Assessment Program maps, to show a total disagreement. Indeed, all the magnitude 7.5 or greater quakes that happened in the past decade would have been declared a "surprise" by these maps.

Xuhui Shen presented a China that is moving immediately on earthquake forecasting. It is planning to launch a spacecraft in 2014, named after the Chinese scientist who invented the first seismometer, which is designed specifically to monitor changes in the ionosphere for earthquake precursors. China is also in the process of building a network of ground ionospheric sounders by 2015.

The resounding conclusion of this series of presentations is that, yes, indeed, earthquakes are susceptible to forecast, and the loss of hundreds of thousands of lives in the past decade alone does not need to be repeated. What is needed—in addition to funding and a group of dedicated scientists working together closely in real-time—is a change in fundamental beliefs about the planet we live on. Besides demonstrating that earthquakes can, in principle, be forecast, these presentations showed that our current understanding of earthquakes is limited by an overreliance on pure seismic methods. Our planet is biogeochemical, not simply geological, and these researches are the forefront in discovering what deep processes are driving surface phenomena.

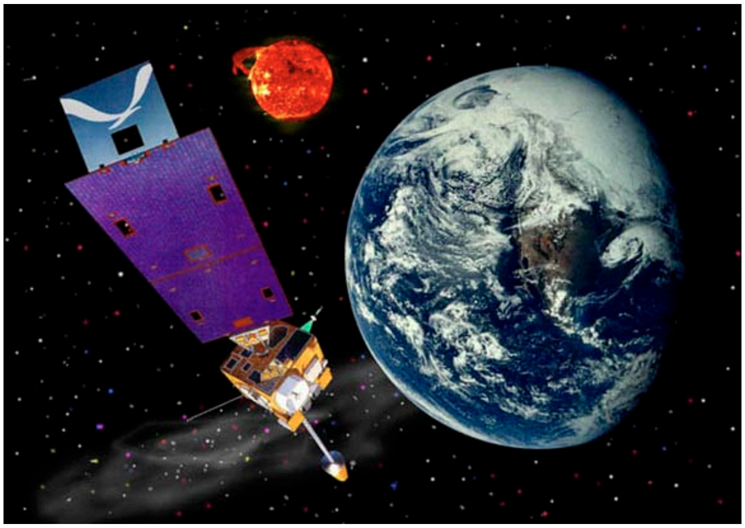
Space Weather Forecasting

The ability to forecast significant space weather events, on the other hand, demonstrates both the need for, and the promise of, direct government involvement with the types of forecasting that requires multiple precursory measurements. A NASA press conference was given by five scientists involved with forecasting space weather, to describe the state of the art, and the implications of forecasting.

By "Space Weather," is meant the impact upon our planet's magnetic field by various transient emissions from the Sun, and the effects upon our satellites, electricity transmission systems, and other systems that depend upon electricity to function. The most important types of this solar radiation are in the form of radiation storms (bursts of energetic particles from active regions of the Sun), coronal mass ejections (large emissions of magnetically charged matter from the corona), and high speed streams of the solar wind.

The press conference panelists drew an image of what it is like living within the outer atmosphere of a star, one that has been going through a mood shift recently. The recent solar minimum was one of the longest on record, but as each of the panelists noted in turn, devastating events can come from a relatively quiet Sun. The 1859 Carrington Event, which would wipe out entire national grids if it happened today, occurred during a weaker solar cycle than the last one. Until about 10 years ago, the results of transient solar events on our electrical systems had become well understood, although the ability to forecast them was about equal to shooting in the dark. All of these radiations had been either difficult or impossible to see before they hit the Earth.

Now, with a growing array of solar observatories, we can begin to model, and perhaps track, the progress of impending radiations that could endanger our planet. The Solar and Heliospheric Observatory (SOHO) was launched in 1995, and has given us the first clear space view of the initial stages of a CME eruption. The GOES spacecraft are equipped to register emissions of high energy X-ray flares as soon as 8 minutes after eruption. The two STEREO spacecraft provide the first three-dimensional view of the Sun, and can show us active regions before they rotate towards the Earth, while at the same time providing the first three dimensional imagery of coronal mass ejections as they occur.



Artist's depiction of a GOES satellite. These satellites provide continuous monitoring, orbiting in a geosynchronous orbit that matches the Earth's rotation.

These spacecraft, among a growing array of others, provide the initial weather-vane data to be entered into serious modeling software at Goddard Space Flight Center to project the prospective tracks of the slower radiations from the Sun, such as high-speed solar wind streams and coronal mass ejections. The Solar Dynamics Observatory (SDO), launched in 2010, provides high-resolution imagery in several bands of radiation, to help us see the mechanisms leading up to solar eruptions in fine detail. Discoveries made from looking at these data have helped improve the models used for tracking storms before they hit the Earth.

For CMEs, our models have improved significantly, such that they are now being issued through NOAA's National Weather Service. Indeed, these scientists claim that the ability to forecast the impact of coronal mass ejections is at about the same place as scientific weather forecasting was in the early days, and will only improve with the production of improved satellite and computer technology.

At this point, only a few minutes of warning are possible for other types of solar events than CMEs, such as radiation storms, which hit only a few minutes after energetic particles are ejected from the Sun. Warning for these storms comes from measurements taken by our Advanced Composition Explorer (ACE), located at the L1 libration point about 1.5 million miles away from the Earth towards the Sun. ACE can register the dramatically increased flux of energetic electrons and protons only a few minutes before they impact our planetary system, where they potentially could blow out satellites.

With the recent spacecraft additions, improvements in "solar storm tracks" are coming steadily. Rodney Viereck, the director of NOAA's Space Weather Prediction test bed, pointed out that, as the current solar cycle began to crank up, the number of subscribers to NOAA space weather forecasts has begun to increase exponentially, now over 19,000 customers. The immediate next steps, according to Michael Hesse, chief of the Goddard Space Weather Laboratory, include getting spacecraft up that can monitor all sides of the Sun continuously, instead of only intermittently, like the STEREO spacecraft.

In reality, both modes of forecasting—earthquakes and the impact of solar emissions—require the same mode of thinking. Both emit a variety of very faint signals minutes to days before impact, many of which signals we recognize, and undoubtedly other signals of which we are as yet unaware. The signals are very faint, and require very sensitive instrumentation to measure. The signals are also produced by other, usually benign, sources. Therefore, in order to eliminate the benign signals from the ones that indicate danger, it is necessary to combine several of the sensed signals in a triangulation. In other words, just because someone may smell like an ape, doesn't mean he is an ape.

We are getting closer to the reality of not just understanding, but controlling our near space environment, to the effect of being able not just to increase our population, but to protect the existing population from currently uncontrollable, devastating events.

Expect more from this conference!