Earthquake Precursors: 'The Science Is Ready, and Needs to Be Applied'

Geophysicist Dimitar Ouzounov works as an associate professor at Chapman University in California and a staff scientist at NASA's Goddard Space Flight Center in Maryland. Since conducting an accidental precursor study in 2000, while he was analyzing thermal image data from NASA's MODIS (Moderate Resolution Imaging Spectroradiometer) satellite, Ouzounov has emerged as a leading figure in the field of non-seismic earthquake precursor research.

Dr. Ouzounov was interviewed by Oyang Teng on Dec. 8, 2011, at the American Geophysical Union Fall conference in San Francisco.

Dimitar Ouzounov at the AGU meeting.

21st Century: What is your overview of the current state of precursor research?

Ouzounov: Precursor research is based on the science of studying the signals associated with the appearance of major earthquakes, and historically it was developed in the last 20 years. At the current status of earthquake prediction today, it's not possible to give you the same information as a weather forecast about a possible earthquake.

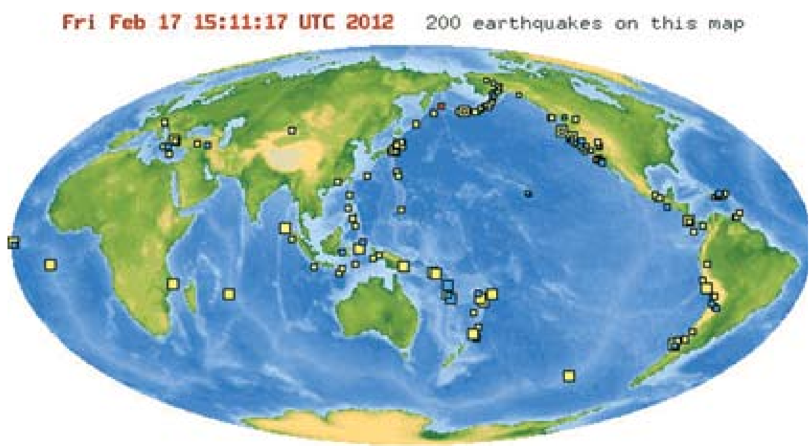
So, a lot of research has been proposed, mostly about any physical phenomena associated with earthquakes. The idea has been research dedicated to any physical connection between different signals with earthquake preparation processes. The idea is that there is something ongoing related to earthquakes, and that these kind of mega-events could be detected in advance. And 2011 also became very important because of the Japanese earthquake.

What's different today? Twenty years ago we had no satellite measurements. Today we have lots of data from satellites, and many scientists are trying to use satellites for this kind of research. What is new in earthquake science in 2011, is that many scientists are applying methodology using satellite data.

The second new technology is that GPS (global positioning systems), became very affordable and very convenient. Now Japan, California, Europe, Asia, South America, have so many GPS receivers, that people are trying to use GPS, not only for ground deformation studies, but also to study ionospheric science. So the new technology provides a new opportunity for scientists to study and to analyze new data.

Today, we have seen during this meeting new methods proposed for using satellite data, using GPS, but this methodology is still far from validation; it needs time to be studied. In other words, we need more statistics, more earthquakes, in order to decisively confirm that any methods, any new ideas, have systematic value for earthquake prediction.

21st Century: I was struck by how



EARTHQUAKES WORLDWIDE (REAL TIME)

There is good data about earthquakes when they happen, as this [real time map](#) *shows. The challenge is to predict major earthquakes* before *they happen to warn the affected populations. Ouzounov and other scientists at the AGU conference are collaborating on this task.*

Source: USGS

NASA

There are 24 satellites, orbiting 20,000 km above the Earth in 12-hour circular orbits. The satellites are divided into six groups of four, each with a different path, creating six orbital planes which completely surround the Earth.

Boeing

Artist's illustration of a GPS satellite.

quickly China seems to be moving in this direction, as far as policy. Where is the most active area of research internationally?

Ouzounov: Yes, China became a very important player in this field. Historically, it's been the case for many years, but we didn't pay it any attention, for the simple reason that we had no globalization in science. Now we do have, which means it's much easier to integrate our ideas over the Internet, to interact with people in China.

And now, Chinese scientists can speak English; before, it was a problem! China opened the opportunity, and I'm very delighted to have visited China this year, for two reasons. I was part of a review team for their satellite system. They're planning a very ambitious satellite system to study earthquakes. But not only with satellites: they're trying to build satellite and ground data measurements. And they've put in lots of money, but they realize they don't have enough knowledge. So they invited experts from different parts of the world to China, and are trying to learn.

We gave several presentations over the last few years, and this year was very important because China's government funded the next five years of its system. One satellite is going to be launched in 2014, and there will be two more in 2017 and 2018. And the question is, "Why are they doing that?"

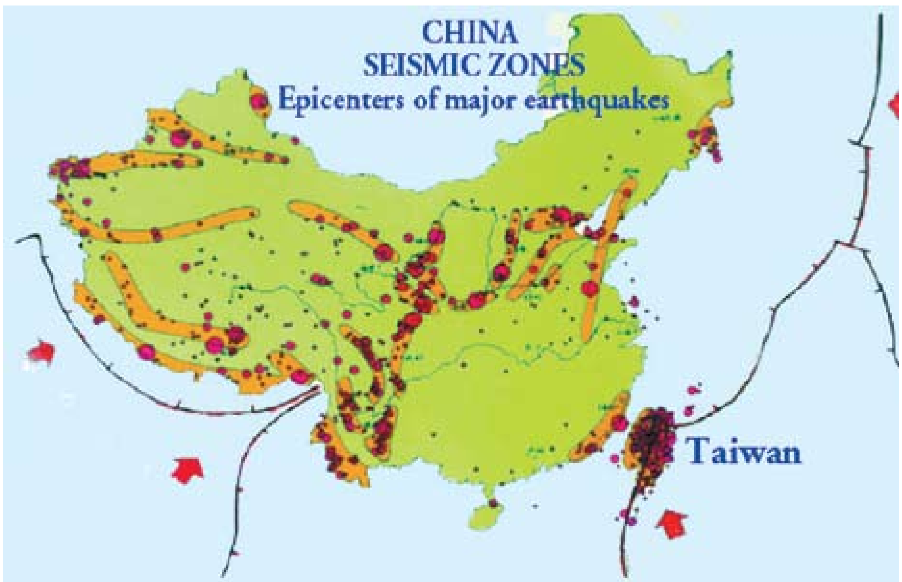
They're doing this because they realize that the technology today is affordable, and the science is ready, and needs to be applied. Why China? Because they have the economic potential to put about $100 million into this project. But also because they're not afraid to test new ideas, new methodologies.

I didn't know that until I visited China and found that they've been doing this for 20 years. I saw animals, I saw birds, I saw very old design techniques and hardware, working for 15 years on this. But because we had no connection with the Chinese, we didn't know about that. And now they said, "We're interested, we'd like to cooperate."

What's going to happen in China means very much to us, because with the end of the French mission DEMETER [an earthquake precursor monitoring satellite, decommissioned in December 2010—ed.], their satellite system will be mostly the only one we can work with for the next five years. And they are very open for that.

21st Century: They'll be the only country with a dedicated earthquake monitoring satellite?

Ouzounov: The Russians are also doing it, actually. But the Chinese will be doing it much more openly, and the scale will be different. The Russians now have many satellites, and they integrate these measurements over their areas of inter-



SEISMIC ZONES IN CHINA

China has a large-scale program to monitor earthquakes and precursor phenomena.

Damage to the Agriculture Development Bank of China branch in Bei Chuan after the devastating earthquake, May 12, 2008. The U.S. Geological Survey reported that there were "at least 69,195 people killed, 374,177 injured and 18,392 missing and presumed dead in the Chengdu-Lixian-Guangyuan area. More than 45.5 million people in 10 provinces and regions were affected. At least 15 million people were evacuated from their homes and more than 5 million were left homeless. An estimated 5.36 million buildings collapsed and more than 21 million buildings were damaged. . . . The total economic loss was estimated at $86 billion."

est, as in Kamchatka in Eastern Russia where they have so many earthquakes, and try to understand how different satellites and ground data work together. Russia has the experience of doing this for many years.

But China provides the large scale, much more than satellites. They are building a ground data center which is pretty big. And they have a simple reason to do that: economics. They have two areas of major concern. One is central China, and the second is western China, which is high elevated mountains. And there is no other way to study it; it's very difficult to investigate on the ground, and satellite technology is pretty cheap today. So they can do that.

It's much cheaper to do it from space, and they can cover a large territory, and then they can bring in international scientists, because these satellites are not only for China, they can study other places, like Europe, and the United States, so it's a double win for China.

21st Century: On the actual precursor parameters that are studied—and the field is as broad as animal behavior, to actual seismic foreshocks, to the electrodynamics of the atmosphere, to thermal emissions—are these different precursor parameters telling us something new about the geophysical processes involved? In other words, do they give us new insight into the actual nature of the physical preparation, not just of earthquakes, but maybe the way the planet as a whole is organized?

Ouzounov: Yes, this is giving new insight about the Earth. You name it exactly correctly: it's preparation. We're talking about for mega-earthquakes, we're talking about preparation for large-scale events. Usually large-scale events need much more time for preparation, and many more parameters are sensitive to this preparation. So this means we've seen multi-parameter changes, not because we're looking in specific fields, but because nature provides this opportunity. So that means we have to have a better physics to understand nature.

So let's suppose, "Is this only earthquakes?"

No, precursory science is the same as medical science; just the language is different. When you go to the doctor, he looks for symptoms. Symptoms is just another name for precursor, right? And when you go to the doctor, you're sick, but you don't know what's wrong with you. And usually what they do is a CT scan, temperature, other analysis—exactly what we do.

We check different wavelengths, we check different medicine, we check dif-

Logan Abassi/U.N. Photo

The magnitude 7 earthquake in Haiti on Jan. 12, 2010, qualifies as a mega-quake because of the tremendous destruction of people and buildings. Here, a poor neighborhood in Port au Prince, flattened by the earthquake.

ferent symptoms, different precursors, different physics. So the approach is the same.

I learned a lot about earthquake prediction from my doctor, because I had some problems with my health, and several times I had to do four or five different checks. And then he said, "Okay, we have some problem, but I don't trust that; we need to double check." In our language, he said *the anomaly is not statistically significant.*

So now, we're trying to take the anomaly, but we need to check with the normal. And my doctor did the same tests three times, because he said, "Maybe it's the wrong instrument, maybe you had much more coffee in the morning, maybe the lab did it in the wrong way." And on the fourth time, he said, "Yes, you're okay, it was error."

NASA

A video grab of aurora borealis over Northern North America and Canada taken by the crew of Expedition 30 on board the International Space Station. The sequence of shots was taken Jan. 29, 2012, on a pass from the North Pacific Ocean, approximately 1,000 miles west of western Quebec. The video can be seen here.

That's why we're following the same analysis in our work. We're trying to integrate different physical measurements—but to integrate, we need to validate. How significant are they to the normal?—in which normal means no major event.

Major earthquakes are relatively rare cases, if you compare with the everyday events, so you should be able to distinguish what is the normal, for example, if you check background seismicity over a certain area. That's easy to say, but more complicated to do. But we do it the same way as my doctor checking my blood pressure or blood test; we're trying to take long periods of data, define what is the normal status of these parameters, and then see if we see abnormal behavior, and if this abnormal behavior has anything to do with earthquake processes.

We found that some events happen without earthquakes, which means that some parameters are influenced by weather, by the general geodynamic activity, and we learn this when we do statistical analysis. So, in other words, better physics provides better science, but also proves that seismic waves are not the only waves that can give information about earthquakes. And that's why we're exploring electromagnetics, that's why we're exploring atmospheric physics, ionospheric physics. Because we found that the Earth interacts between mega-events like volcanoes, earthquakes, so we're looking for this coupling between physics environments.

21st Century: On the issue of mega-earthquakes, there seems to have been an apparent rise in the incidence of both large earthquakes and large volcanoes in roughly the last 10 years. Earlier this week, there was a poster session at the conference, where somebody disputed the claim that there has been an increase in large earthquakes, based on a statistical analysis, but also motivated by a skepticism that any kind of global process could be at work, that the mega-earthquakes in different parts of the globe could be related to a unified process.

Could you speak to the difference, at least on the mega-quake scale, between something that's acting only regionally, and the possibility that you're dealing with a global phenomenon?

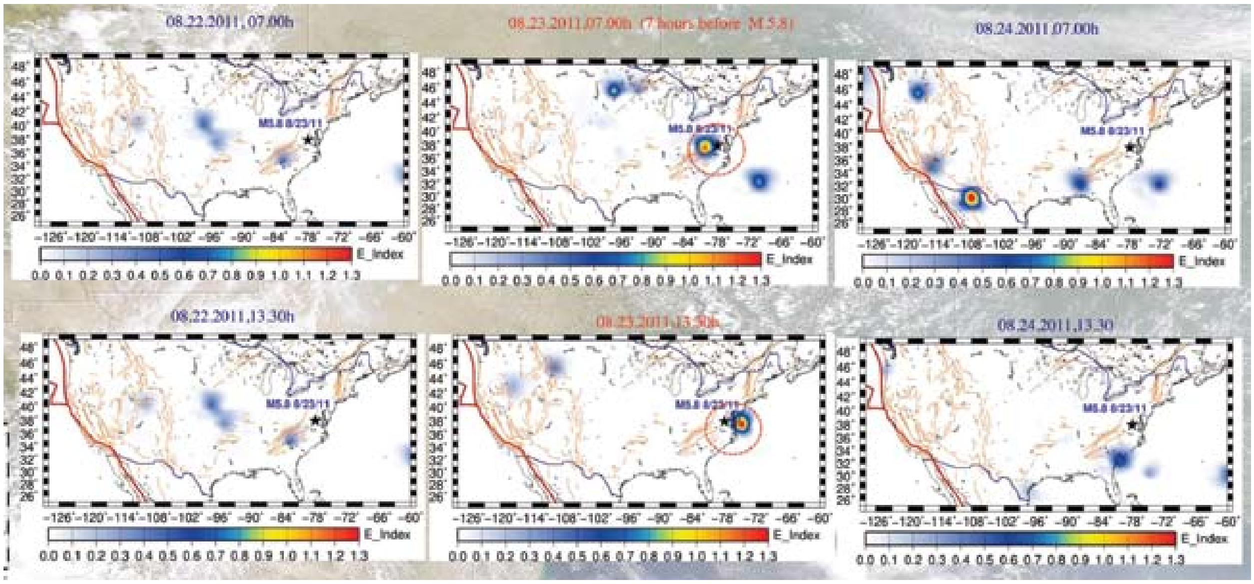
Ouzounov: This is exactly the same question as global change: In other words, whether we see global warming, or not. It depends on what your time scale of analysis is. We see global warming, but is it global, or is it natural or is it artificial? We have a perception of something going very high in terms of earthquakes or volcanoes, but when you scale up to the 100 years or 50 years, we can see there is just a fraction of change.

I'll say it this way: that we consider mega-earthquakes not only by the size, but also by their location. If you have a 9.0 earthquake in the middle of nowhere, in the Pacific Ocean, with zero population, we don't consider this a mega-earthquake. We consider a mega-earthquake to be one which has an extremely vast impact on society.

So if we consider the mega-impact of an earthquake, probably the earthquake in Haiti qualifies, even though the magnitude is not so high. We consider the mega-impact of the Wenchuan earthquake in China, where so many people died. So magnitude matters, but it also matters where the earthquake is located. This is what we've been discussing with Prof. Seyia Uyeda: The increasing density of population brings warning that as we move to big cities, the risk of having more casualties is much higher.

Because there is a global change of area of population, it becomes a much higher concern to have an alert system for a mega-earthquake. Because a mega-city like Istanbul, Cairo in Egypt, Tehran, or the two biggest cities in Pakistan, which are very close to thrust faults—that becomes a problem, because of the constant growth of population density, and concern that even magnitude 6, 7 will play a huge role. So this is one of the trends of statistics.

Another trend of statistics is that of course, we have been very busy with earthquakes for the last few years, and one of the possible explanations for this



THERMAL ANOMALIES BEFORE THE VIRGINIA EARTHQUAKE

Satellite data show a rapid change in the anomalous flux rate of infrared radiation above the epicentral area, in Mineral, Virginia, seven hours before the Aug. 23, 2011 M 5.8 earthquake. This was determined by comparison with a reference field of infrared observations for the month of August between 2004 to 2011.

Source: "Satellite Thermal and GPS/TEC Observations of Atmospheric Process during the time of M5.8 Mineral, Virginia Earthquake of Aug. 23, 2011. Preliminary Results," poster presentation at AGU conference, Dec. 6, 2011.

by people working with space science, is that there is increasing solar activity. Many scientists consider the link between Sun and Earth as a possible interaction and activity on the global scale. But this is a connection that's been in science for many, many years.

Now this connection is more fresh, keeping in mind climate change, because, as you see at this meeting, one of the very interesting topics in many sessions, is the solar-Earth connection to climate change: Maybe we see an increasing in temperature because of increasing solar activity.

There are many questions we cannot answer now, but that doesn't mean we stop looking for solutions. We're looking for solutions, and science today is better than yesterday, but next year will be better than this year.

21st Century: You brought up the solar-Earth connection. Again, we don't have answers, but I'd like your view on two related points: First, is it possible that a lot of the precursor activity that's measured, including especially things like ground current and other electrodynamic effects in the atmosphere, aren't simply an end result of seismic activity, but may play some role in actually causing seismic activity, or triggering seismic activity?

Second, one of the most obvious areas where this might be mediated is through the Sun-Earth relationship, because, as you mentioned, we're still now finding out a lot more about how closely you have this coupling to this larger system. Larger than just the Earth itself, larger than just indigenous processes within the deep Earth. How far should we expand our scope in terms of looking at—minimally—the solar environment?

Ouzounov: That's a very good question. Even if you gave me a few hours, I could not actually finish this, because it's endless, there are so many opportunities!

Now, we have good interaction with the Sun, and for many things that happen here we can claim the Sun is guilty, but we need to have evidence that it's actually really happening. We can talk about different subjects about this interaction; it goes to different layers, among climate, with the environment, with the food, temperature, earthquakes, all these natural disasters.

Well, let us say there are two major components: one component is connected to earthquakes. There are two different categories which most of the mainstream seismologists don't agree with: that there are precursors, and that there is triggering of earthquakes. In other words, that there is something deterministic in the way that earthquakes happen, and that could be blamed on the Sun, or on solar-planet interactions, and things like that.

And by the way, there is a lot of work, published at some conferences, and some work shows that planetary position, and solar activity, could play a role. The Moon, of course, could play a role in the triggering of earthquakes. And somebody says: "OK, c'mon guys, this probably contradicts your precursor studies. If you have a precursor, how does the trigger actually work? Precursor means that there is a physical environment preceding the earthquake, leading to the release of the event. And then you say also there is triggering, which comes from outer space, or from the Sun or the Moon. How does this work together? Is there not a contradiction?”

No there’s not!

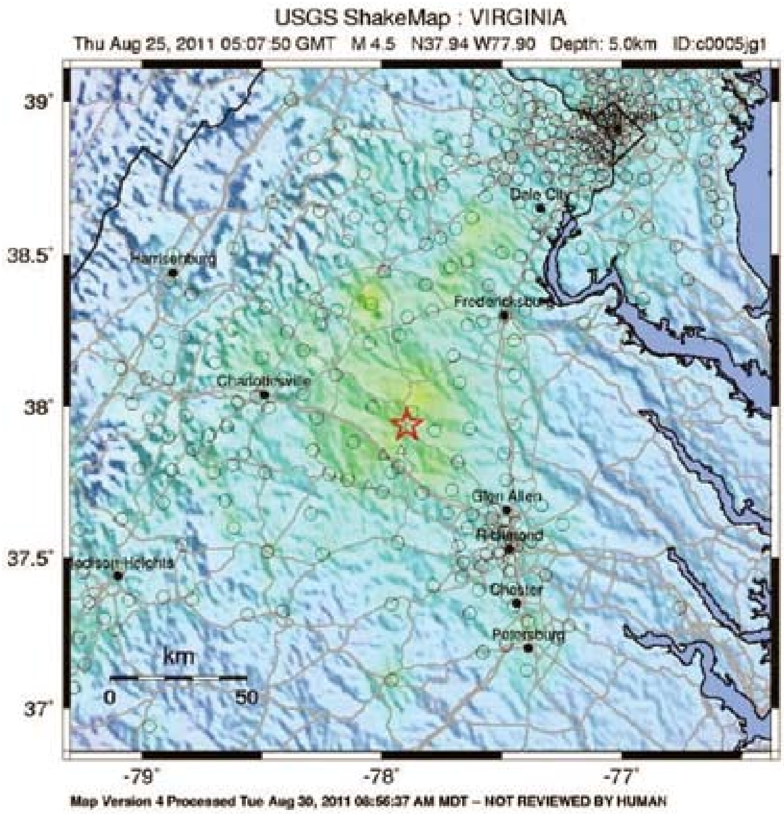
Basically when you see interference between the Sun or other planets, there is definitely interference with Earth, with tidal waves, gravitational waves, electromagnetic coronal mass ejections (CMEs) from the Sun and other activities—they play a role because the Earth is one electromagnetic system, and many scientists are trying to do statistics between solar activity, tidal activity, and Earth, and they found interesting results.

One of the results shows that in most of the cases, we have a magnetic storm during the time of earthquake or before the earthquake, and that’s a manifestation that there’s an interaction between solar activity and Earth, on some level. It’s not clear yet if this is something to do with preparation of an earthquake, with triggering of an earthquake; all this is, is there is some interaction.

And the second question is, “How to use this information?” Sometimes science works with a very high level of uncertainty. You know that the Sun or Moon or other planets can play a role, but you don’t know what kind of role, or how to quantify it. So in our research, we don’t have pure evidence that solar activity and planetary position has a role, but that doesn’t mean we don’t use this information.

In our analysis of multiple precursors, we use Moon phase, tidal waves, and solar cycle as potential additional sources influencing the precursor activity and the triggering of earthquakes. That doesn’t mean I’m 100 percent in favor of that, but I have a few cases in our work which shows a real connection, but also cases in which I see no connection.

There is a very famous way of making a decision, called “Occam’s razor.” When you have two hypotheses, you have to choose one of them. You take the hypothesis that is much simpler, less entropy. So in this case I try to work within what I know, but I also consider from time to time to check what I don’t know. Basically we’re checking the solar activity, and the Moon, and I think this is very helpful information.



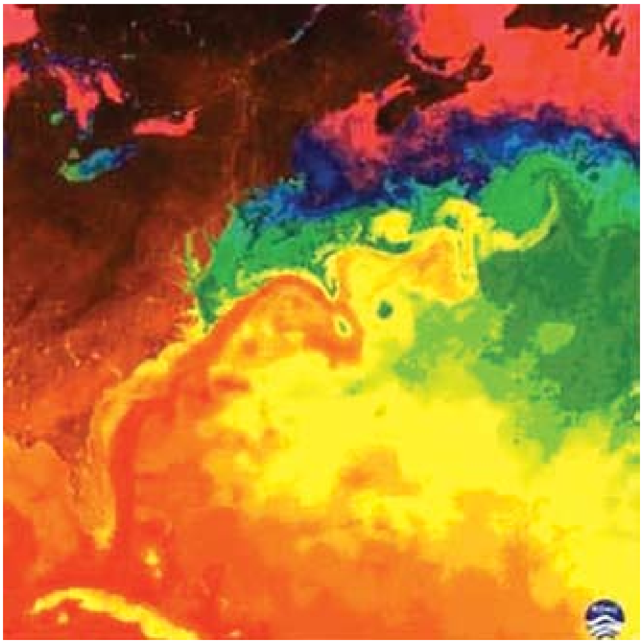
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

‘SHAKEUP’ MAP OF VIRGINIA FOR AUG. 25, 2011 EARTHQUAKE
The star marks the epicenter of the magnitude 5.8 earthquake, which surprised seismologists, because it is in an intraplate region. Now, Ouzounov said, this area and others like it will be monitored for precursor anomalies.
Source: USGS

21st Century: The poster that you presented earlier in the week was on the precursor hindcasting of the Mineral, Virginia earthquake. That’s interesting because that was a pretty anomalous earthquake. Like the New Madrid Seismic Zone, it’s an intraplate region. So it seemed like an anomalous earthquake to begin with, and you have a study showing that there are validatable precursors for that. Could you briefly describe what you found, and say whether there’s any distinction of precursors for intraplate earthquakes versus those that occur on plate boundaries?

Ouzounov: Yes, this is an interesting study, for the same reason. I was in Virginia when this earthquake happened, so I have real experience! It was interesting, because I was well trained for that, I was out of my house in 8 seconds. I was first on my street and all my neighbors came and they said, “What was it?” and I said it was a 5.8 earthquake in Virginia. And they asked, “How do you know that?” And I said, “Well, that’s what I do.”

But going back to the real scientific question: It was a real surprise for us, because we don’t expect strong earthquakes in Virginia. First, it’s an intraplate region, like the earthquake we are probably going to expect in the New Madrid zone—and some geologists say, maybe soon. These are very dangerous because usually these regions are not prepared. Their houses and business buildings are not built like those in California, according



Source: GSFC/NASA

THERMAL VARIATIONS ON EAST COAST, AS SEEN FROM SATELLITE

Many meteorological satellites, including most geostationary satellites, have at least one thermal channel. This is a map of thermal variations off the U.S. East Coast, based on meteorological data. When an earthquake is happening, Ouzounov says, some very strong thermal signals will be seen in places where they usually are not, because the atmosphere is artificially heated.

to seismic engineering models, because they're very expensive. And then people are totally unprepared.

We saw what happened in Washington, D.C., when this earthquake happened—panic, traffic jams, and all kind of things. What we have found is that we are able to detect, to hindcast thermal anomalies a few hours and days before the earthquake. In other words, if we had the chance to monitor the area, we should be able to get a signal in advance which is going to tell us that in a few hours an earthquake will happen.

We presumed Virginia was not active. But now we're seriously considering to study Virginia, Maryland, and Pennsylvania as well, in our analysis in the United States. And what we have found is a thermal signal with a significant anomaly near the epicenter, and it was the biggest signal over the entire United States, which normally is not the case. This anomaly shows exactly the reason we do this analysis.

When we study the thermal field and we get lots of different anomalies, that's normal. It's very good to have different anomalies in different places, that are not connected to earthquakes. But when an earthquake is happening, because the atmosphere is artificially heated, we see some very strong signals in places where usually they should not be.

21st Century: So you correct for effects that might be weather induced?

Ouzounov: Yes, we take the weather out. We've been criticized at this meeting that we're not doing very well, but we're doing this. We're taking the weather out by averaging the thermal field. What's happening is that these kind of signals, these kind of anomalies, build very rapidly. If someone is doing this kind of research for different purposes, he's going to filter out these data, this anomaly, as an error, because there's no explanation for why it's happening.

We take this not as error, because we understand the physics. It's happening because we have an increase in gas release during the final stage of preparation. Gas is coming out on a regular basis. Especially in Virginia, where they have so many uranium-type of rocks, radon gas is very high.

But, what is different is that gas is coming out very rapidly, and the concentration is very high, and that makes a big difference. So when you have more gas concentrated, that immediately changes the atmospheric chemistry of the region, and latent heat is released very quickly. We saw this a few hours in advance.

The good news is, why do you see this signal as very strong? Because we don't have too much background seismicity in this region, so the background is clear. If you had the same event in California, it would be very difficult to distinguish, because in California we have earthquakes almost every week, of about 3-magnitude.

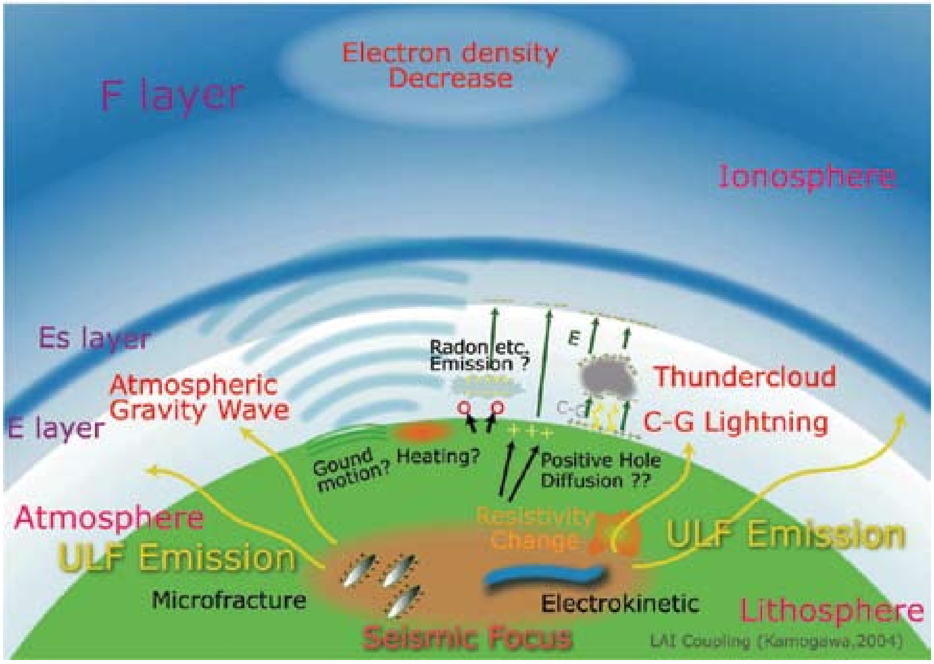
In Virginia, that's not the case, so we have a very clear background and it's very easy to distinguish what is normal vs. abnormal. So, this is the first good finding.

The second was, it's an intraplate earthquake. We don't have much experience with intraplate earthquakes. Usually we do earthquakes in California or other places where we have collision between different platforms on a regular basis, and we expect them, we know the earthquake might happen. That's not the case in Virginia.

There are similar earthquakes in the New Madrid zone, also in India, in Pakistan, far away from major plate tectonic boundaries, and these earthquakes are dangerous; they're strong, and scientists still don't know too much about this. So that's why we presented this work, which shows that we still can see thermal signals before intraplate earthquakes. That's the lesson learned from this presentation.

21st Century: In terms of this field of precursor research, in order to make it full fledged for real-time forecasting, but also in terms of the fundamental science involved, do you think the most important work to be done now is in improved statistical methods to analyze the data, or in coming up with better models of the physical processes involved? What's needed to go forward?

Ouzounov: Everything is important. There are two points, I can have two opinions about this question. What do we think needs to be done in the short-term? What do we do next?



LITHOSPHERE, ATMOSPHERE, IONOSPHERE COUPLING MODEL

Illustration of various phenomena related to earthquake prediction.

Source: "Electromagnetic Phenomena Related to Earthquake Prediction," eds. M. Hayakawa and Y. Fujinawa (Tokyo: TERRA Scientific Publishing Company).

I think in terms of the model, from our perspective, we completed our work. There are a few things we need to justify in terms of tuning the physics of some processes, but most likely, from our perspective, the data we analyze are pretty connected with the concept we have [the Lithosphere-Atmosphere-Ionosphere Coupling, or LAIC model, see accompanying article—ed.].

Another question is, what do other people think about this model? Do they agree with that or not? I'm just giving our inside opinion on that.

The second point: we need to demonstrate that this really works *before* the earthquake. I don't agree with many other kinds of criticism, but I do agree with this kind of criticism: that all of our work is hindcasting. So we need to specifically focus on pre-event analysis.

What are we trying to do right now? We're able to get consent with other scientists in the field, that we need to do joint validation in the field before the earthquake, to get a knowledge, to understand our science before the event, and to verify if our physical understanding is really relevant to the ongoing processes. And then, when the event has already happened, to step back and say, "Okay, what was wrong?"

That's number one right now. Number two is to open this kind of work to the seismologists, because we don't see this as a silver bullet. I think this study can play a very important role as a complementary study to seismology. Our vision of this work in its practical meaning is like a hybrid system. When you have seismological measurements which are definitely everywhere and you are trying to set up a system or analysis of a different kind of precursor which is not seismic, or any pre-earthquake precursor in the area of interest, it will basically benefit the seismic measurements and also give a chance to seismologists to explore also different physics.

Now we're expanding our knowledge to our colleagues in seismology, to try to work with them, to try to have them understand that the signals we are working on are part of earthquake processes, and that they measure data which are pretty relevant to what we do from space. So basically these are the two major goals we're focussed on right now.

21st Century: Are there certain types of crucial experiments that you think could be done and either aren't being done for lack of funding, or for some other reason, that get at the physics of the process? One that comes to mind that some people have done in materials science is rock compression studies.

Ouzounov: A lot of their measurements are very important in terms of clarifying the general physics. But the real work is more complicated than laboratory measurements. We're very interested to do the real measurements, active measurements in the real environment. So what we're trying to set up now in Japan, are measurements that are going to verify the LAIC model. Along with Dr. Pulinets, we had a very good reception in Japan for the last year, especially after the Tohoku earthquake. What's happening now is that our Japanese friends from Hokkaido University and Chiba University, are setting up the types of measurements we recommended. And these measurements will give a long base of verification of the LAIC model. So that's the way to go.

I mean, that in the lab you can see many things, but because of the scale, you're probably not able to see other things. So, our Japanese friends are now setting up measurements, ion measurements on the ground, at the same time they are studying GPS-TEC (total electron content), and ionospheric variability over southern areas.

Of course, we cannot put instruments everywhere, but they know the seismicity in Japan very well, so they chose two areas. And there will be continuous measurements over these two areas probably for one year, five or six independent measurements, and they're going to provide

Oyang Teng

Some of the participants in the American Geophysical Union's 2011 Fall conference sessions on earthquake precursors, which included scientists from the United States, Russia, China, Japan, Greece, and France. One of the goals of the participants was to strengthen international collaboration for real-time analysis of impending earthquake threats in order to validate methods that have been proven in hindcasts for various medium- and large-scale earthquakes.

the results for us.

The idea is, whether they are going to see independently what we have projected to see: in terms of different kinds of precursors, the time observation, how these signals are related to the earthquake process; if they see, without earthquakes, what is the significance of the signals related to the magnitude, and what is the significance of the signals related to overall seismicity.

We can do that in Japan because of the high rate of seismicity in Japan, and because after the Tohoku earthquake they started to look for other options, not only seismic measurements and seafloor measurements; they're looking for any other measurements that are credible, they're open to verify some new methodologies. So that's what we plan to do as an experiment.

21st Century: What agency in the U.S. or internationally should be primarily responsible for earthquake forecasting? Is there some new agency that needs to be created?

Ouzounov: That's the million-dollar question, for the simple reason that the world operates differently than the United States.

Here's the example: in Japan, earthquakes are under the weather bureau, and that's a very right way to do that, in my personal opinion. The weather bureau in Japan actually collects all seismic information, all weather information, all ocean data information, because they are built as an organization responsible for monitoring the data, any kind of data.

In European Geological Surveys, EGS, we have separate agencies, and each agency has—as you know very well, they want to survive—special responsibilities, and sometimes we have a war of agencies. So there are different interests, there's no consensus, they're very powerful, and they're well-funded.

Now in Europe, they show a very good example. They have a financial problem now, but they've built a system for natural hazard monitoring. After the Iceland volcano they found that each country has its own disaster management team, but they cannot talk to each other. So they start to integrate over different boundaries, over different countries the same umbrella, and earthquakes became part of that, also fires, all natural hazards. This means that if there's something happening, or research needed for these kinds of hazards, they respond for all European Union members.

In the United States, this kind of research related to earthquakes is under the umbrella of the U.S. Geological Survey. They have funding, they have priority, and they have expertise doing that. So everything which is going to be developed by us and other teams on some level needs to be presented, and approved by the USGS. We're not successful yet at doing that.

Basically, the practical application, the outcome of this kind of research, needs to be presented to USGS and be approved. We like to talk about global-scale problems, but it's very complicated to coordinate this kind of research on a global scale. Because we have a global problem, but we have not global funding.

We failed to propose something to Japan because the Japanese people have a problem getting funding for this kind of research. And we proposed joint projects several times this year, but they didn't go through.

Because we don't have the same system of funding, we also have a problem working together. Basically, we're not working together. We're exchanging papers, exchanging data, but we don't have a joint team which is actually solving the problems because we always have a problem in the funding, and that could be done by an international organization.

The United Nations, World Bank, UNESCO, or the Global Disaster Reduction Fund—they have the capacity to invest all over the world in different kinds of disasters, but the question is: We're talking about prevention, we're not talking about after the event.

They're very good after the event. We're talking *in advance,* and that's very difficult, because you have to convince international organizations that something is going to happen, so they need to react prior to the earthquake. And that's not been very successful, because people are usually skeptical of this kind of work, and we have not demonstrated, at least once, that our alert made a difference.

If we had a chance to do that, it would be much easier. So we're working on this one alert, one event, for which we can actually provide information in advance and bring more credibility on a global scale.