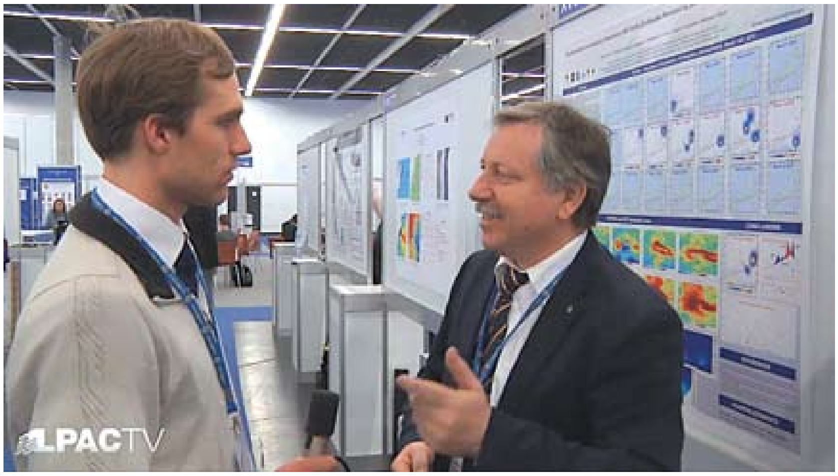
A Multi-Parameter Approach to Earthquake Forecasting

Prof. Sergey Pulinets, a researcher of earthquake precursors at the Fyodorov Institute of Applied Geophysics and the Moscow Center for Ionosphere Monitoring addressed the European Geosciences Conference in Vienna, which took place April 3-8, 2011. Dr. Pulinets was interviewed during the conference by Daniel Grasenack-Tente of the Civil Rights Solidarity Movement (BüSo), the German political party of the LaRouche movement. A video of the interview is available at www.larouchepac.com/node/17944.



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Prof. Sergey Pulinets (right), an expert on earthquake percursors, was interviewed by the BüSo's Daniel Grasenack-Tente, at the European Geosciences Union in Vienna.

Daniel Grasenack-Tente: Professor Pulinets, thank you very much for joining us here. We're at the European Geosciences General Assembly for 2011, and just yesterday there were a number of presentations on the question of the different kinds of precursors in different domains of the electromagnetic spectrum, which we can use to hopefully, at some point, have a real forecasting capability for earthquakes. Let's discuss what you've been looking at. What is the significance of electromagnetic precursors to earthquakes in your work?

Pulinets: Okay, I prefer to talk not only on the electromagnetic precursors, but earthquake preparation is a complex physical chemical process, having been started from the Earth's crust, up to the atmosphere and ionosphere. And they have different kinds of manifestations. Within the period—we are talking now about short-term prediction—so it is something like a few weeks, up to a few days, and hours, before the seismic shock. And because it is a process which generally connects many factors, we try to find an approach which gives us the opportunity to explain what is happening, why we see so many different variations or anomalies during this preparation period.

The first reason is very natural. When you have a release of energy, which is equivalent to several thousand nuclear bombs, it is impossible to store this underground, and in one moment to release it. The Earth is a living matter, and there are some processes—storing of the stress, and this stress has to manifest itself in some parameters.

So, the most natural is that when you have the formation of cracks inside the crust, you change the system of the gas migration inside the Earth's crust. The main components of this are CO_2, helium, hydrogen, and radon, which is a radioactive gas, which is a product of the decay of uranium. It is present everywhere. For sanitary purposes, when you build your house, you monitor for radon to be safe in your house. It is a heavy, odorless gas. But it was detected many, many years ago, that its release increases before an earthquake, because this gas migration carries this radon and water coming up to the Earth's surface. Probably you have seen the video from Japan showing water going up during and before the earthquake. So, water also carries radon with it.

And now starts the very interesting process which is characteristic for many, many natural events. For example, you know that now the variations of the cosmic rays associated with the formation of the cloud cover over our planet—why? Because the cosmic rays produce ionization of water. The ions become the centers of condensation of the water vapor. Water vapor condenses around the ions and you obtain the nucleation which is the center of condensation for the formation of clouds.

The same is happening with the coming of radioactive matter of radon, on the ground surface, close to the ground surface, because radon is very heavy. It also produces ionization of air. Ions become the centers of condensation, and form large clusters of these ions, and envelopes of many, many water molecules.

Hydration of Ions

Grasenack-Tente: You mentioned in your presentation the ionization process, and the hydration of the ions.

Pulinets: Hydration, yes. Because it is not pure condensation, because people who know physics quite well say that there should be saturation vapor to have condensation. But hydration does not need saturation. In any level of humidity, relative humidity of air, you will have hydration of the ions. So, with 30% of humidity, still you will have hydration of ions.

And when the molecules of water become attached to the ion, they release their free energy that they had when they were in the air, which is named latent heat. And this latent heat is a source of the thermal energy which is registered just over active tectonic faults. It can be monitored by the satellites. They show very nicely the configuration of the active tectonic faults during the period of preparation of the earthquakes.

Grasenack-Tente: What period are we talking about?

Pulinets: We are talking about a few weeks before the earthquake. We have activation of the tectonic plate where the epicenter is situated. So, we can see the heating of the borders between the tectonic plates, and active tectonic faults, which is a smaller structure.

So, starting from the ground surface, we see the thermal anomalies along the active tectonic faults, which manifest that we have release of radon along the tectonic faults. And the geophysical perpective shows that we have, at the peaks, a maximum of radon concentration over tectonic faults. They are sources of the radon coming from the ground.

So the first level is the ground surface. Then, this heat starts to accumulate, and because you have a temperature difference between the fault and the area outside the fault, it starts mixing, due to the temperature difference. You have the horizontal motion and convection motion, because the heated air tries to go up, and it is transformed into some small spirals. Chirality is formed, and these small chiral structures tend to merge. In chaos theory, it's named reverse cascade instability. They merge and form a large thermal spot, which could be registered in the upper layers of the atmosphere.

Simultaneously, this transformation of the latent heat also could be registered by satellites. There are some products in some NASA sites, which give you directly the latent heat fluxes over a special region, and we were able to detect these latent heat fluxes before many, many earthquakes.

For example, before the [Dec. 26, 2004] Sumatra earthquake, the total thermal energy released was one order of magnitude was higher than the mechanical energy released during the earthquake itself. So you can imagine what huge power is inside, in such a simple thing as water vapor. People ask, what is the source? It is the Sun. The Sun prepares this water vapor because we have constant evaporation of humidity from the rivers, from lakes, from surf, and all the time we have this water vapor which contains this latent heat, and during condensation it is released. So, the source of this energy is the Sun.

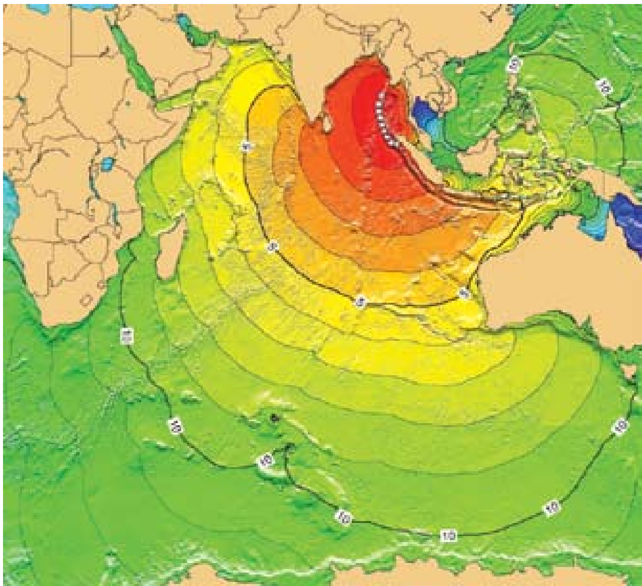
But now we come into the electromagnetic.

Grasenack-Tente: Okay, yes.

Pulinets: So these thermal anomalies could be registered not only in the form of heat, that we measure by temperature, but as radiative heat—infrared radiation, which is in the electromagnetic spectrum, with wavelengths from 8 to 12 microns. This is a window which is transparent for the clouds. And it is possible to measure, even through the clouds. And Dr. [Dimitar] Ouzounov [of NASA/Goddard Space Flight Center's Earth Observing System] is measuring these infrared emissions at the top of the atmosphere. It is something like from 8 to 12 kilometers.

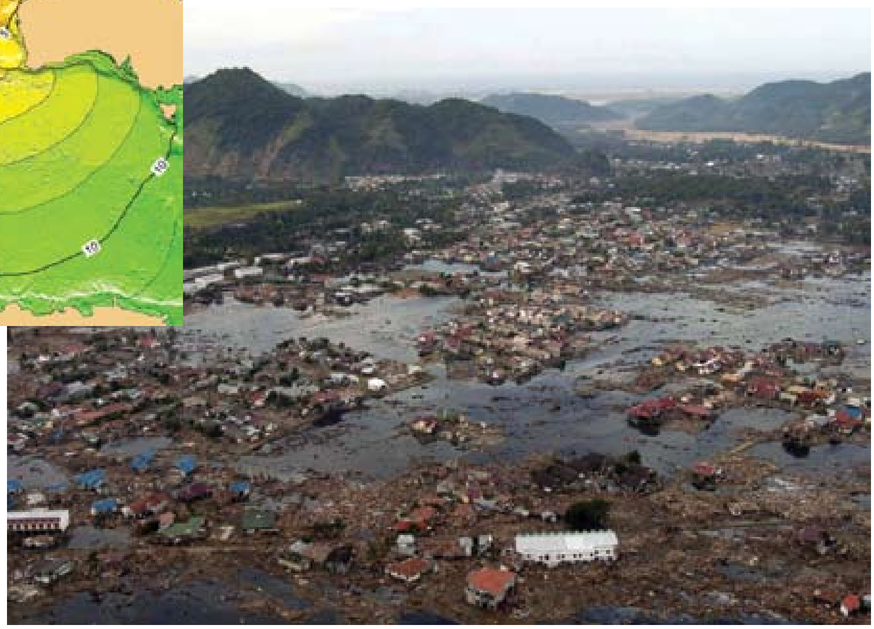
Grasenack-Tente: Under the ionosphere?

Pulinets: No, the ionosphere is much higher, it's



NOAA/National Geophysical Data Center

Before the Dec. 26, 2004 Sumatra earthquake, the total thermal energy released was one order of magnitude higher than the mechanical energy released during the earthquake itself, Pulinets explained. "So you can imagine what a huge power is inside, in such a simple thing as water vapor. People ask, what is the source? It is the Sun." Shown below: a village near the coast destroyed by the tsunami; inset: graphic showing the power of the 9.4 quake in Sumatra.



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100 kilometers. This is 10 to 12 kilometers altitude. And very precise and special techniques were elaborated, using previous measurements—for example, NOAA [National Oceanic and Atmospheric Administration], 20 years ago. We have a very good background, which allows us to estimate that in this place—

Precursor Anomalies

Grasenack-Tente: Sorry, so these precursors, these phenomena, you mean 20 years—

Pulinets: No, for 20 years we have had measurements to calculate the anomaly against this background. We started our study more or less 10 years ago. And we are able to see the dynamics of the development of these heat anomalies on the top of the atmosphere, before the earthquake. These anomalies usually appear a few days before the earthquake. And there are specific features, that they are sitting over the area of the earthquake preparation. They can move a little bit, exactly along the tectonic plate's border, or along the active tectonic fault, but are very close to the future epicenter. So this is a first, a very reliable, signature of the approaching earthquake. And now we have very good statistics for this. For all recent major earthquakes, we have the data showing the appearance of this OLR anomaly, which is outgoing longwave radiation.

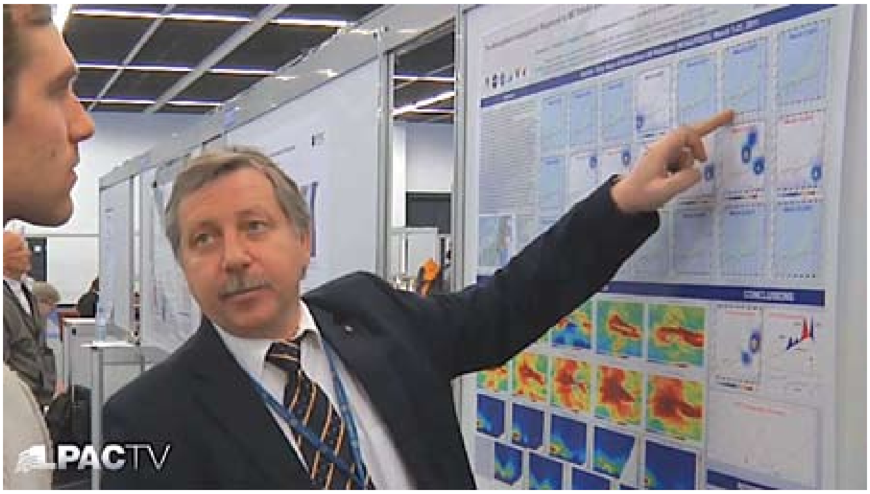
Without any exclusion, we see it over the ocean, inland, near the shore, not dependent on where the epicenter is. It is an advantage in comparison with any other techniques for precursors, because many of these precursors would be detected only inland. But because we deal with the gas, which could be released from water as well, we see anomalies over the water. You can see here, here, here [points to chart on wall], anomalies sitting over the water.

Grasenack-Tente: What instrumentations do you use to measure this?

Pulinets: It is infrared sensors, which are installed on the majority of remote-sensing satellites.

Grasenack-Tente: They all have them?

Pulinets: Like NOAA satellites, Aqua, Terra, it is modest device, a VHRR in NOAA's satellite, and similar devices—for example, on board the Russian Meteor satellite we have a similar device. European satellites, every remote-sensing satellite now has an infrared sensor, and we need the frequency band, or wavelength band, between 8 and 12 microns.



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Professor Pulinets indicates anomalies in precursor techniques.

Now, we are going to the upper layers, the ionosphere. The ionosphere is a part of our atmosphere, but partly ionized. Its ionization comes mainly from ultraviolet radiation, emitted by our Sun. Some part is ionized by X-rays, and energetic particles, but the main source of the ionization is ultraviolet radiation.

So, because we have radiation only during the daytime, we have increase of ionization during daytime, and decrease during nighttime, and the variations of electron concentration look like a sinusoid—as you can see in daily variations. And it has been studied for many, many years. We have very good models, which explain the climatology of the ionospheric behavior. Also, we know very well the behavior in this sphere during active solar events, like solar flares, geomagnetic storms; for any point, we have the regional models, which can explain what will be the behavior of the ionosphere during the magnetic storms.

So, we know the behavior of the ionosphere during the quiet time condition, and during the magnetic storm condition.

And starting from this, we are looking at some anomalies which are associated with the earthquake, how these anomalies in general can appear in the ionosphere.

Grasenack-Tente: Because there could be different sources for—

Pulinets: No, the source is the same. We live in an electrical environment. We never think about this, but when you're standing here, it is a vertical electric field which has a gradient of 100 to 150 volts per meter. So, between the top of your head and your legs, you have a potential difference of 220 volts, like a power source.

The problem is, that the conductivity of air is very low. So, the current which we have inside the atmosphere is 10^{-12} amperes per square meter. What is the source of this potential difference? We have a potential difference between the ground and the ionosphere. This potential difference is created by thunderstorm activity. All over the world we have global thunderstorm activity—in Africa, in America—mainly thunderstorm activity is over the land. But this is not so important. The thunderstorm discharges provide the positive potential of the ionosphere in relation to the Earth.

And we have the potential difference between the ground and the ionosphere, which is something like 250, up to 500 kilovolts. And this potential difference is dropped into this bulk of atmosphere, from the ground surface, up to more or less 60 kilometers, for this global electric circuit. Usually, they take the lower border of the ionosphere, near 60 kilometers. But the most potential drop we have is in the so-called boundary layer of the atmosphere. The boundary layer is the layer where we have turbulent motion of the air. In the upper layers, we have no such turbulent motion; it is a continuous gradient, without the mixing that we have in the ground source.

And so, you can imagine—you have a potential difference. You have a resistor, which is our atmosphere. And if you change the value of this resistance, it means you change the conductivity of this layer, near-ground layer, and this conductivity is changed by the appearance of these ions produced by radon. First, you will observe the increase of conductivity, and then, when these ions grow, and become large clusters which are not moving, and cannot carry the electrical current, you will have the drop of conductivity. Like, for example, in sandstorms, when you have a lot of sand and dirt. For example, in dirty cities, the electric field is larger than in the open field, because due to the presence of dust and aerosols, the conductivity drops.

It's the same thing when you have the formation of these large clusters, which we spoke of before, a drop of conductivity leads to a change of the ionospheric potential relative to the Earth.

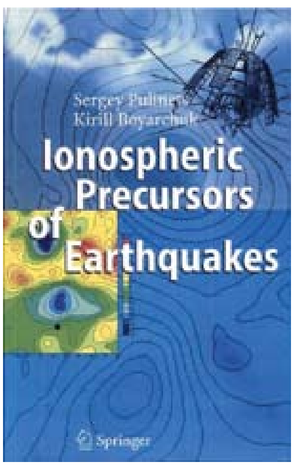
So the ionosphere feels the earthquakes through the global electric circuit, through the change of conductivity of the atmosphere. But the ionosphere is a highly conductive medium. It tries to maintain its equipotentiality. If you have a good conductor, all the parts of this conductor have the same electrical potential. If something changes, it tries to redistribute the electron concentration and ions to maintain its equipotential.

What does it mean to redistribute? There is the appearance of the drift or electric currents within the ionosphere, and you have a formation of irregularity over the area where you have the anomaly of conductivity.

Grasenack-Tente: And that's what you've been talking about with the total electron content.

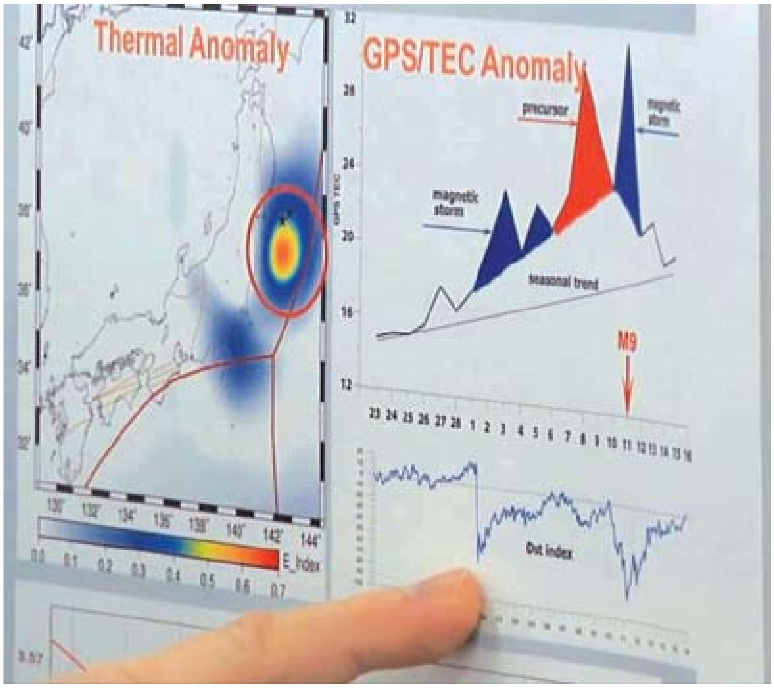
Pulinets: Yes. And the parameters of the ionosphere could be measured by a multitude of techniques. It is a ground-based vertical sounding, called ionsondes. We can put the same ionsondes on the satellite, and it will be topside ionospheric sounding. You can measure the total electron content between the satellite and the ground. You can make ionospheric tomography from the low-orbiting satellites.

So there are a lot of techniques; all of them were tested, and all of them show the anomalies in the ionosphere.



I have a book published by Springer, *Ionospheric Precursors of the Earthquake*. You can find there everything explained, and what is happening. But I also can say, that from the majority of earthquakes, we see ionospheric anomalies which are very close to the thermal anomalies in their position, and they are also coherent in time. But we see propagation of these anomalies from the ground surface up to the ionosphere, so usually the ionospheric anomalies appear one day later, or the same day as the thermal one.

FIGURE 1



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The Japanese Earthquake

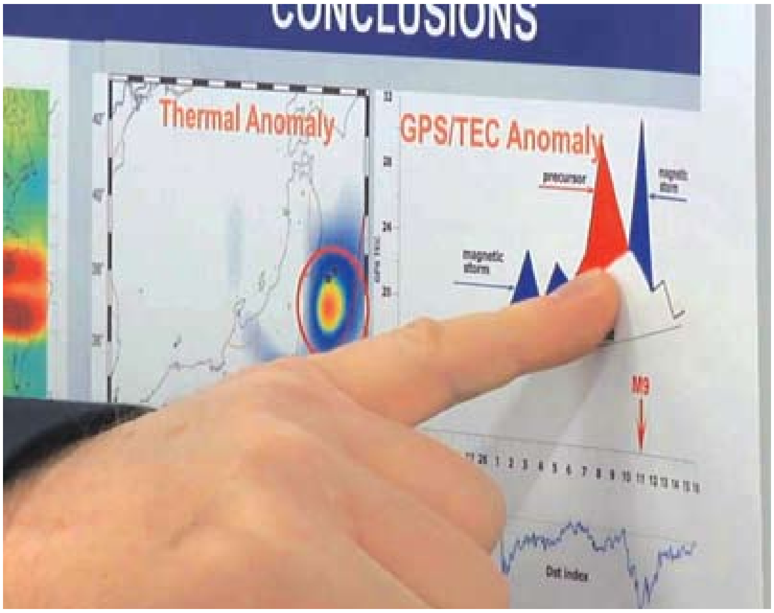
Grasenack-Tente: Now you have on this poster here, some things related specifically to the 9.0 earthquake in Japan.

Pulinets: Yes, it was a very difficult case for analysis, for many reasons. One of them is that the earthquake happened between two geomagnetic storms. One of the indicators of the geomagnetic storm, is global equatorial geomagnetic index, which is named the "Dst Index." And this is a graph of this geomagnetic index (**Figure 1**), and when we have the sharp drop, it means the start of the geomagnetic storm. And then we have the recovery phase; we have quiet geomagnetic conditions; and then the next storm, which happened exactly at the moment of the earthquake.

Grasenack-Tente: That's very interesting, because that brings up, as with a lot of these things that we can't see directly, it requires that we need as broad a range of sensory instruments as possible, to correlate and make sure that we can annihilate things—

Pulinets: Okay, the correlation of solar and geomagnetic activity with seismic activities is a very difficult task. Because statistically, some people show the existence of correlation, while other people show there is no correlation. A very careful study of this

FIGURE 2



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should be carried out. But I can confirm, that very often, it happens that a geomagnetic storm is very close to the earthquake, but we cannot say that geomagnetic storm [equals] earthquake, no. Sometimes the geomagnetic storms could be one, two days before the earthquake.

Grasenack-Tente: Sometimes after.

Pulinets: Sometimes, one, two days after. Sometimes, like we have here, simultaneously with the earthquake.

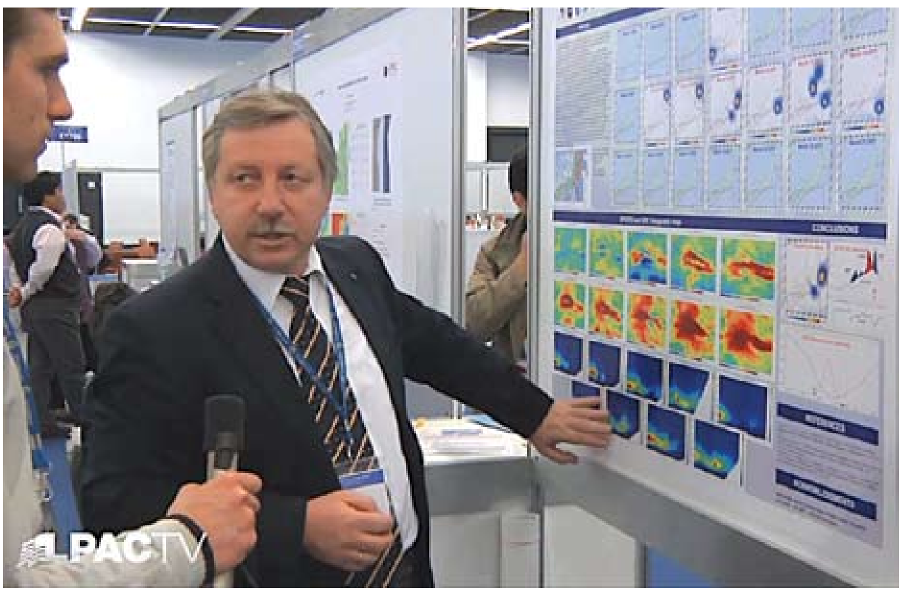
So, it looks like we have the common source of origin, which provokes both these events, and they appear close in time.

But, why do we, for example, interpret this as a precursor? Because here (**Figure 2**) this effect of the geomagnetic storm, which is blue, should decay, because here we have a quiet condition. But contrary our expectation, we have the sharp growth of electron concentration on the 8th of March, that is, three days before the earthquake. And this is supported, the GPS TEC, is supported by ionospheric tomography, which is another technique to study the ionosphere—it is a low-orbiting satellite—and they have a two-frequency transmitter onboard, and you put it on the ground, like a line or a chain of receivers, which receive the satellite signal, and you can, from this registration, reconstruct the vertical cross-section of the ionosphere in the plane of the satellite orbit.

Like tomography, you have many, many rays between the satellite and several receivers, and you process, by tomography technique, this multitude of rays, and reconstruct from this, by special mathematical procedures, the vertical structure. And this [points to wall chart] is the tomography reconstruction for the chain which is in the Sakhalin region, the Sakhalin Island of Russia, which is very close to the northern part of Japan. These receivers belong to the corporation Russian Space Systems. Our co-authors Romanov and Shahr are responsible for this result. And they also observed the large positive anomaly, again, on the 8th of March.

So, we have completely different techniques [pointing at the chart]: this is GPS TEC (Total Electron Content), this is tomography; and they demonstrate the same thing.

And the next one is the ground-based ionosondes.



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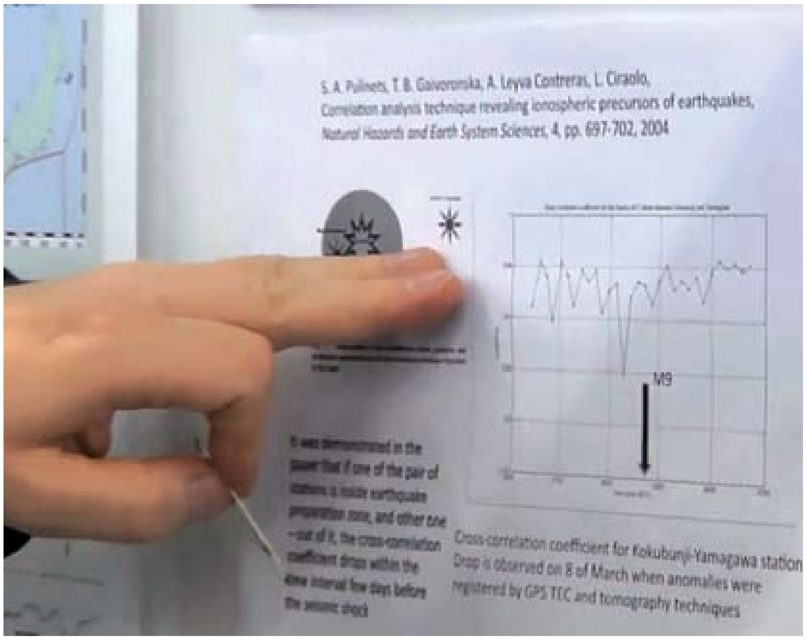
Professor Pulinets points to tomography reconstructions of the Sakhalin region.

FIGURE 3



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An ionosonde is radar working in the shortwave-frequency band, from 1 to 20 MHz. It is broadcasting, and they actually were designed to monitor and predict the propagation of radio waves. When we had no VHF broadcasting and FM broadcasting in the '30s, '40s, and '50s of the last century, the broadcasting was in the HF [high-frequency] waveband. And these devices were designed especially to monitor the state of the ionosphere, to predict the radio-wave propagation in this frequency band. And now, they are used to monitor space weather, because the ionosphere is very sensitive to solar effects, and every country has its own network of ionosondes. In Japan, we have four ionospheric stations: Wakkanai, Kokubunji (Tokyo), Yamagawa, and Okinawa.

And we were able to elaborate the technique, which shows that, due to the specific variability of the ionosphere before the earthquake, when you have a station close to the epicenter, and try to correlate this station with another station which is far from the epicenter, the cross-correlation coefficient drops before the earthquake. This (**Figure 3**) is a cross-correlation coefficient between Kokubunji, which is close to the epicenter, and the Yamagawa station, which is far from the epicenter. We have the configuration described in our publication.

And again, on the 8th of March, we see the drop of cross-correlation coefficient, like in GPS TEC and ionospheric tomography. So, three independent techniques show the same thing for this earthquake, three days before the main shock.

And the last result: We tried to compare, in the same season, for example, of the year, and mainly, more or less for the same solar activity, because the ionospheric density depends on the solar activity, but last year and this year are not too different in this, so we took the variations of the electron concentration for year 2010, for the period from the 23rd of February to the 23rd of March, and for year 2011, for all four ionospheric stations. And simply, we subtracted from 2011, the 2010 data. And this is the difference.

Grasenack-Tente: Can you say where the origin is, of what's originating the high-frequency waves?

Pulinets: I told you: This wave is emitted; it is like a radar. It's an installation, it sends pulses to the ionosphere, and obtains the reflection—

Grasenack-Tente: Where the radar is, is not—

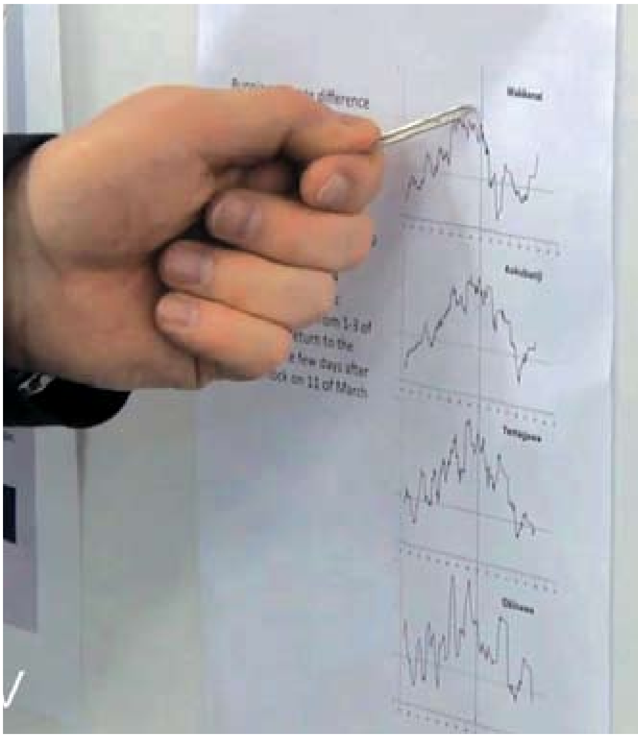
Pulinets: No, no. Different frequencies are reflected on the different altitudes of the ionosphere. The higher the electron density, the higher frequency you need to reflect from the ionosphere. So, the ionosonde is starting to send pulses from 1 MHz, and goes up to 20 MHz, and received the reflections from the ionosphere. And the specific frequency is named "critical frequency"—the ionosphere is no longer able to reflect the radio waves, and they pass through it. And these are the main parameters used by the ionosonde, and we use just the critical frequency, which reflects the maximum electron concentration in the ionosphere.

So, from 2011, we subtract 2010. And you can see (**Figure 4**), starting from something like the 5th of March, the increase and then decrease. And this is the moment of the earthquake. So, this is from North to South: Wakkanai, Kokubunji, Yamagawa, Okinawa.

Grasenack-Tente: Yes, a pretty big spike. Okinawa's a bit more erratic.

Pulinets: Yes, but Okinawa is at a low latitude, which is affected by the so-called equatorial anomaly, which

FIGURE 4



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appears in the equatorial ionosphere. So, it's much higher variability than at the mid-latitude stations.

A Multi-Parameter Analysis

So, what I would like to underline more: that our approach is a multi-parameter analysis. We can say that it's very difficult, almost impossible, to make some kind of prediction using only one parameter, for example: thermal, ionospheric, VLF propagation, so on, so on. But if you have something like what we name "synergy" of the processes, we see that all of them are connected, and show the same area, within the same time-interval, and we see some development of the processes, starting from the ground surface, like surface temperatures, and air temperatures, and at the top of the atmosphere, then the ionosphere, and we see these dynamic, all this complex of the effect, we may say that this is a multi-parameter precursor of the earthquake. This is our approach.

Grasenack-Tente: And it's interesting, because you noted that also with the geomagnetic storms. It poses the question: Well, where's the physical cause? That still needs to be investigated? Where's the principal cause?

Just one thing I wanted to say, because Professor [Pier Francesco] Biagi was saying that their main problem is they just don't have enough sensors. They have very few sensors—throughout Europe there are only seven. And if you had a global array of these things, then they could be looking where all the things are happening all around the world.

Pulinets: There is a difference between ground-based measurement and satellite. With the satellite, we have a global picture, without exclusion. This is an advantage.

Grasenack-Tente: You're saying you have the instrumentation, is that right? Because right now, we're seeing that NASA's getting huge cuts to its budget.

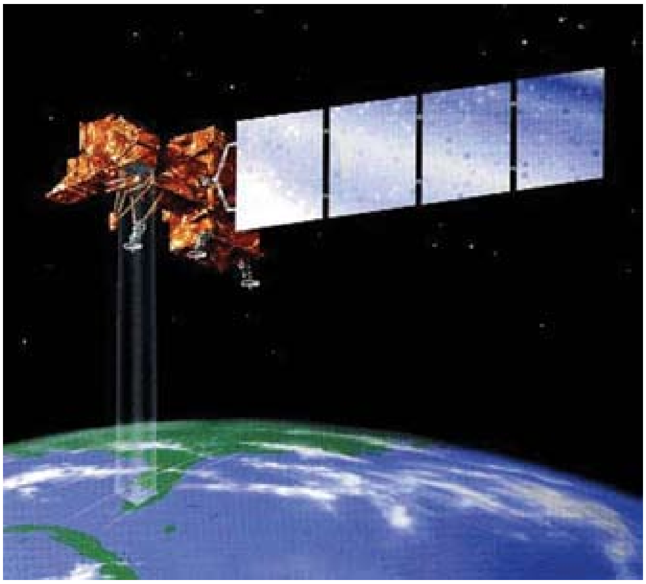
Pulinets: It's a big pity, because we can develop these technologies, and many other countries are trying to build their own satellites—for example, China is now on the way, building specific and directed satellites to measure electromagnetic precursors of earthquakes, to be launched in 2014. But, I think, looking from the perspective of what we have now in Japan, what a tragic event, how many people, in such a highly developed country—but this demonstrates that nature makes no difference between the poor and the rich country, whether developed, not developed, we cannot fight with nature, we cannot overcome this very strong and disastrous event. So, we need to take *urgent* actions to start our activity now. We have demonstrated that we are able, *at least*, to give some kind of warnings. We can't say about predictions, but we can say, in this area, in the next few days, we expect some seismic shock, and we are able to even estimate the future magnitude.

Of course, many, many things are not clear, but we cannot prolong, into infinity, our investigation. How many victims do we need, to continue our investigations?

Grasenack-Tente: I think it's very important. I think it's clear with the number of victims we have, that we have to do it right now. That we should escalate.

Pulinets: Yes.

Grasenack-Tente: The question I have to you on that, specifically, one, are all the instrumentations there, in place, that you need? And if you didn't have money restrictions, what would you want to see implemented, so that you could immediately begin setting up things that we could use to recognize precursors all around the



NASA

Remote-sensing satellites are among the array of detection techniques used for forecasting weather events. Shown: Goddard's Earth Resources Technology Satellite, launched in 1982.

world? Every nation, along the Rim of Fire, and beyond? What would you need for that?

Pulinets: Okay, at the present moment, we have quite enough remote-sensing satellites, and many countries, including the United States have plans, for example, in the Polis [satellite mapping] project, to launch more satellites having the infrared sensor onboard.

Grasenack-Tente: There was one called DESDynI, that was a [proposed] satellite that was cut, that was actually not launched. Then you had the GOES-11, which was launched, but they didn't have the ground crew to analyze the data! So, it's up there doing stuff, but, you don't have people analyzing the data. And one thing you mentioned before is that, you've done this work, but there's only so much that two or three people can do.

Pulinets: Yes. In principle, we can start now, if we have at least some specific laboratory, with staff, more or less, I estimate, of ten people: It's enough to start to analyze the data on infrared, GPS TEC, VLF propagation. It is enough to do some kind of warning, at least of some areas like California, Japan, the Mediterranean, Mexico. We have enough instrumental means. It does not mean we should now stop, should not develop other types of measurements, and increase our ground-based network.

But we should take, as an example, medicine; for example, the problem of cancer: It was thought that it was *impossible* to overcome! Then, the doctors start to—one kind of cancer now is treatable, then the second one . . . and it is expanding! Because people do not stop! They are doing what they can do, at the present moment! And we should do the same: We should do what we can do at the present moment.

But at the present moment, we need some support, because we are very few, we are under pressure from different sources for different reasons. We need to be living in quiet, good conditions to work, to have more human resources—I said something like a ten-person laboratory. And I'm sure that we are now able to make good progress, improving this technology and elaborating the techniques, especially application techniques for the short-term work.

The 62-Million-Year Cycle

Grasenack-Tente: Well, this is great. You basically answered all my questions. I've just one more. I've sent you some material on the kind of work that [the Basement Team] has been looking into, especially looking at the fossil records showing biodiversity, volcanic activity from volcanic rock, which shows some very clear cycles, of 60-62 million years of increase and decrease of biodiversity and also increase of volcanic activity at around the same time. And because you mentioned that there's also the phenomenon of the geomagnetic increased activity, which goes along with the things that you guys are measuring with some kind of phase-shift, have there been any thoughts to look into that, that there may be an increase in general sensitivity within a longer time frame, due to some external sources?

Pulinets: Okay, yes. What we know from historical data—let's start from the shorter periods, for example, the Maunder minimum of solar activity. In the 16th-17th Century, you know that in Holland we had ice; we have a lot of literature showing the people ice-skating, and so on, and now it's very warm. And from the historical measurements of the solar activity, we have seen that it was very low, extremely low, not at all like the 11-year solar-cycle activity. What we observe now, is that we had an extremely long period of low solar activity; it was not predicted by anybody.

We had a [solar] minimum which lasted at least two years, or up to three years longer than it was expected. One reason is that there is some variability in the activity of our star, which provides the life on the Earth. The second, which is more important, and probably may have more grave consequences, is reversals of the geomagnetic field. From polar geomagnetic data, we have seen that the polarity of the geomagnetic field was changed several times during the history of our planet, and during this period, it's very dangerous because, during the transition, we'll have some period—nobody knows how long it will be—when we will have almost no geomagnetic field.

Grasenack-Tente: There's no polarity, is that what you mean?

Pulinets: Yes, yes. It is flipping.

Grasenack-Tente: It's in flux.

In the 16th and 17th centuries, during the last "Little Ice Age," much of Europe experienced extreme cold periods, with ice covering the ground for months at a time. Here, the Flemish artist Pieter Bruegel portrays a scene from the severe Winter of 1565-66.

Pulinets: Yes, and this geomagnetic field protects us from the extreme solar energetic particles.

Grasenack-Tente: Cosmic rays.

Pulinets: And cosmic rays. It deflects them. And we will have some period when the geomagnetic field of the Earth will be very low, and this may give rise to changes of biodiversity of our planet.

So, if we do not talk about periodicity, we also have such events, like asteroids and so on, encountering our planet, which can produce huge devastation and changes in our environment, but it is not periodical, it is stochastic.

And another periodic change is a movement of our Solar System, through the arms of our galaxy. Inside the arms, we have the larger concentration of matter, and so, the lower flux of the cosmic rays. And, we know that cosmic rays do have an effect on the cloud coverage and the temperature on our planet. So there are some theories—I have not developed these, but I have seen publications—that in an ice period, and in the higher temperature periods, there were changes with the periodicity of the passing of the Solar System through the arms of the galactic: Between the arms, we have lower [temperature], so higher flux of cosmic rays; inside the arms, lower flux of cosmic rays. This is another source of the variability.

But all these things are more speculations than science. We should make more investigation to say something definite, but your question was, what I think about this.

Grasenack-Tente: Yes. I agree, we need more investigations.

Pulinets: I told you about the possible reasons for periodicity of life.

Grasenack-Tente: We can start with Moon and Mars, looking to see if there's seismic activity there. It would be interesting to see if there's similar activity right now on other planets.

Pulinets: Yes, but it is not so easy.

Grasenack-Tente: But that's human civilization!

Pulinets: Yes, you are young, so you will have more interesting information, and probably the next probes would be able to investigate other planets of our system!

Grasenack-Tente: It depends on if we have politicians who just keep spending money on bank bailouts, and not on science, and investigating the Solar System: Then we have a definite problem, for that perspective. All right. Thanks very much.

Pulinets: Thank you.