What Is the Weather in Space?

Research physicist Dr. Lee-Anne McKinnell was interviewed by EIR's Marsha Freeman Oct. 6, during the International Astronautical Congress in Cape Town, South Africa.

Dr. McKinnell is the managing director of space science at the South African National Space Agency (SANSA), and former acting managing director at the Hermanus Magnetic Observatory. Her area of research is in the development of an ionospheric model for application to communication in the ionosphere.

In addition to her scientific research, she plays a leading role in developing a new generation of young scientists from the nations of Africa.

EIR: Can you give us a bit of the history of the Hermanus Magnetic Observatory, and why it was built in South Africa?

McKinnell: . . .It was started in 1937 at the University of Cape Town, for measuring the Earth's magnetic field, which was needed at that time. But by 1940, they realized that when you measure the Earth's magnetic field, you want to do it as accurately as possible, in an area where there are not outside influences.

In Cape Town, where the University was based, there was an electric railway line, and the system was causing inaccuracies in the measurements they were trying to make. So they decided to move the observatory to a place which is what we call "magnetically clean," where there are no serious external influences on the Earth's magnetic field. They looked for a town that didn't have a railway line. And Hermanus, which is 120 kilometers from Cape Town, off the coast, had no electric railway in those days—and still doesn't today, thankfully, so the Observatory was placed there. . . .

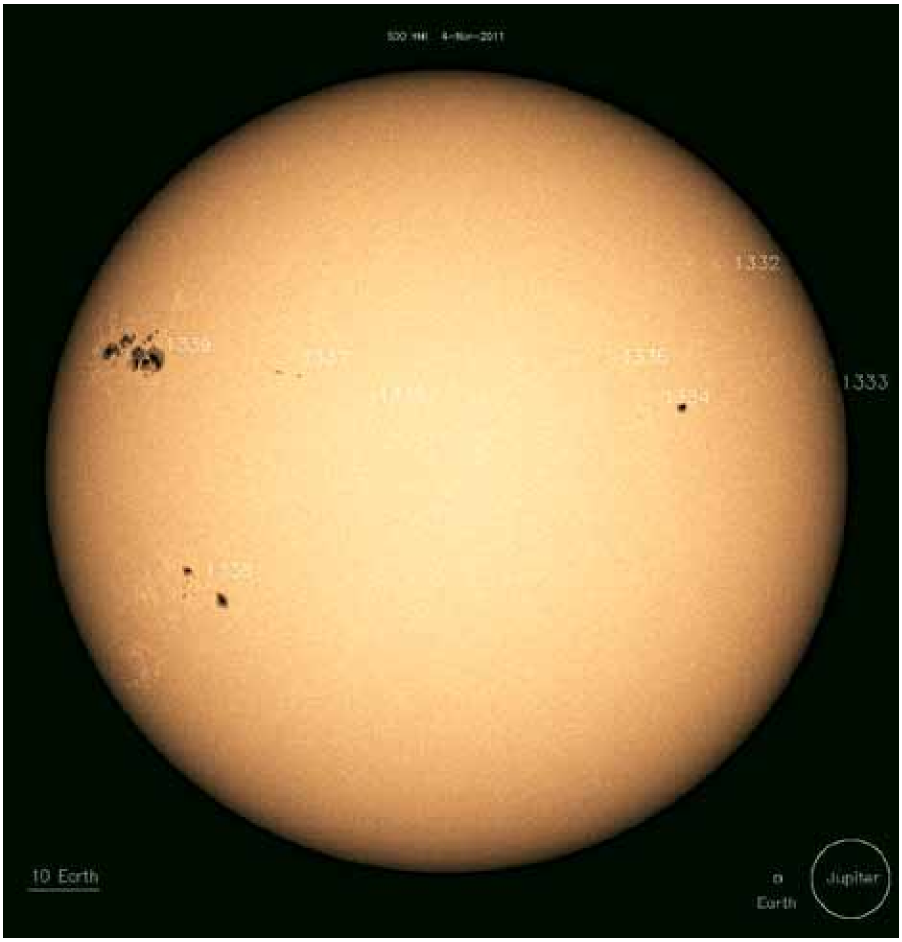
SANSA

Dr. Lee-Anne McKinnell

At Hermanus, we have 16 hectares of land, and in the middle, we have a magnetically clean area, which is where we take the measurements of the Earth's magnetic field. All of the buildings use non-magnetic material and are built with non-magnetic material, and we restrict activities in that area. We don't allow people to dig and put up structures that have magnetic components. We preserve the pristine nature of that. . . .

Changes in the Earth's Magnetic Field

EIR: I believe there have been changes over time in the strength of the Earth's magnetic field. Have



NASA

Scientists at the Hermanus Magnetic Observatory keep a careful eye on the Sun's activity, using data such as this Nov. 4 image of sunspots from the Solar and Heliospheric Observatory to develop models predicting when solar storms will reach the Earth.

you seen this in your measurements?

McKinnell: You are absolutely right. The reason why we want to measure the Earth's magnetic field in different places is because it's changing, and it's different in different places. SANSA, at the moment, operates four permanent field observatories, where we have accurate instrumentation to take measurements, in South Africa and in Namibia. Hermanus is one of them; and then we have one in Hartebeesthoek, which is north of Pretoria, and then there are two in Namibia, at Tsumeb and Keetmanshoop. All four these have INTERMAGNET [International Real-Time Magnetic Observatory Network] status, which is an international organization that dictates the standards for measurements. It's a bit like having a standard measure for the kilometer, or the meter. . . .

EIR: Where is the data collected?

McKinnell: There is a global database of magnetic field measurements, called the INTERMAGNET Data Base, and all of this data from these four observatories, plus many other observatories around the world, contributes to that. There are a number of magnetic observatories which do very similar things to what we do, all around the world. A number of them, including the one in Hermanus, had been chosen to use their data to calculate what we call the DST index, the Disturbance Storm Time index. It is a global index for magnetic field measurements, and if you have that index, you can correlate with any other space environment data and see the effects the magnetic field is having on the rest of the space environment.

The Earth's magnetic field is a very important parameter in space measurements. And we're very proud of the fact that Hermanus is of such a standard that it can be used for that calculation.

In terms of the change in the magnetic field, we have people on our staff whose specialty is geomagnetic data, and every magnetic observatory should have somebody like that. But we go one step further—we have people on the staff who simulate the Earth's magnetic field. They will have a look at how it's changing with time, and try to predict how it is going to change in the future, and then will update it with new measurements, as they become available.

What they have noticed is that the Earth's magnetic field is changing, and that in Hermanus, it has changed by up to 20% over the last 75 years. Apparently, this is something that they've seen in geologic ages. I think they say around 100,000 years ago, the Earth's magnetic field actually switched and that it will switch from time to time, in geological time-spaces, and that we're due for a change—a switch of the Earth's magnetic field, again. When it's going to happen, they're not so sure, but they say we're about 200,000 years overdue, and that it might happen in the next 100,000 years. So I don't think we have to lose any sleep over it tonight, but it is going to happen.

What will happen when the Earth's magnetic field switches, is a question we get asked, and of course, we have no scientific evidence; none of us were around [the last time]; we didn't have the measurements we have today. All they know from geological records is that the last switch of the Earth's magnetic field did not coincide with the extinction of any life form. They feel we're probably going to be safe. It's not life-threatening.

International Space Environment Service

The Hermanus Observatory is one of 12 regional facilities of the International Space Environment Service (ISES)'s Regional Warning Centre Network. The centers are responsible for issuing warnings of geomagnetic storms that can affect radio communications, long-distance pipelines, and electric-power grids on Earth.

The Earth's magnetic field has a purpose—it keeps the atmosphere to the Earth, and the atmosphere protects us from the Sun's rays. So we're probably going to get stronger rays coming through [the atmosphere], more extreme ultraviolet light coming through [as the magnetic field weakens]. But probably not for a very long period of time. . . .

The Earth's Space Environment

EIR: The Observatory is also part of an international network of regional warning centers for space weather. How does that function?

McKinnell: Space weather is the term we give to changing conditions in the Earth's space environment. It is a very hostile environment, and conditions that happen in that environment can affect our technology on Earth.

It starts with the Sun as the driver, propagates through interplanetary space, and affects the atmosphere. The atmosphere maybe receives an increased number of particles. We're putting satellites into the atmosphere that we're dependent on for communications, the Global Positioning System, the Internet, etc. We have long pipelines on Earth, and they are susceptible to currents.

Space weather has been around for a long time, of course, but we recently coined the term. It's become a hot topic, because of the effects it's having on technology, and our dependence is growing. So, therefore, we really need to know and understand the effects it has on technology.

In order to coordinate global activities—because really every country is, or should be, interested in space weather—there is an international body, called the International Space Environment Service, ISES, and they have set up regional warning centers around the globe. They try to go for at least one on every continent, whose job it is to coordinate space-related data for each continent. You call it the applied side of research.

They take the models the researchers have developed, and they take the data that is coming in from the instrumentation that we deployed, and turn it into information. We call it the operational and forecasting and predicting side of space weather.

In Humanus, in 2007, ISES approached us because they didn't have a regional warning center in Africa, and Africa is a continent a lot of people are interested in, because it's very sparsely populated with geophysical instrumentation, and the data is still a little bit scarce. We are playing a major role in putting infrastructure in Africa. . . .

Cosmic Radiation

EIR: People have been looking at how galactic cosmic radiation affects Earth's climate, and geophysical phenomena, and have noted changes in the ionosphere, for example, preceding earthquakes. Have you looked into that?

McKinnell: We've not really concentrated on precursors to earthquakes or the effects of cosmic rays. But there are people globally who are studying just that, particularly precursors to earthquakes—the huge disasters that have happened in Argentina and Japan, for example. We do run networks of ionospheric equipment that tell us about changes in the ionosphere. But we're interested in the ionosphere for another reason, in South Africa.

We're interested for our ability to communicate through the ionosphere, with radio waves. In Africa, that's very important. Because not all African countries can afford satellite communications, a lot of them are still using high-frequency [hf] radio-wave propagation through the atmosphere. In South Africa, we still use hf radio-wave propagation quite a bit. So our space weather center, up until now, has concentrated on being able to predict communication via the ionosphere; being able to predict frequency changes. And then also just looking at warnings, in relation to space weather.

For example, we monitor the Sun. We don't have any solar satellites ourselves. We use the data from U.S. and European satellites. . . .

Space weather starts with the Sun. So no matter what your interest is, you're always going to start by looking at the Sun. We do have requests to notify people when there is a coronal mass ejection from the Sun. We are trying to give some indication of how long it will be before it hits the Earth. We've concentrated on the communications side. Anybody who wants to know, can find out from our website or from contact with us, or from subscription services we offer: "This thing has left the Sun, and is heading towards Earth."

Then there is a whole range of things that come after that. What happens when it hits the Earth. . . . If you're using GPS, is it going to be affected? If you have a long pipeline, and you're piping something from here to North Africa, should you stop it for a few days? We provide the information up to a point. The customer, the client, the person on the other side, will decide how serious it is, and what to do.

Then, on top of that, we are also running an investigation where we gather data from different people who are affected by these things, and look at ways in which we can tell you, "Okay, a coronal mass ejection has left the Sun. It's going to hit the Earth. Now it has hit the Earth. This is the effect it had on the ionosphere, and because of those effects, this is the likelihood that something will happen to your equipment." We're not quite there yet, but we're working on that.

We hope to be at a point where we can say to you: "This afternoon at 2:00, there was a coronal mass ejection; we saw it, we know it's there. It is likely to hit the Earth's atmosphere four days later," and give you a probability: "These are the effects that are likely to happen," be it to satellites, to power lines, be it to whatever it is that you're operating.

We also, at SANSA, will be looking at satellite programs for South Africa. Every country that has a satellite program, has a direct link to the space-weather center. You're not going to spend a lot of money on your satellite, and then put it into an environment that is currently unstable. You want your satellite launch window to happen at a stable period of the Sun's activity. So you will keep in constant contact with your space-weather center. . . .

Extreme Weather Events

EIR: Changes in the Earth's magnetic field have an impact on the amount of cosmic radiation that reaches the Earth's atmosphere, which appears to have an effect on the process of nucleation to create clouds, for example.

McKinnell: There are three things in your question. The first, is that currently there's been no scientific evidence that relates space weather to terrestrial weather. The weather all around us we now phrase as "terrestrial weather," to distinguish it from space weather. But that's not to mean that there isn't [a correlation]; and there is a group of people who are trying to correlate terrestrial weather data and space weather data.

For example, we do do some science that involves lightning strikes, and waves in the atmosphere. There is a group in South Africa that is studying what we call the heliosphere, the Sun's atmosphere. A portion of that group was looking at cosmic rays, solar cosmic rays, and the effect on the Earth's magnetosphere, and trying to model the effects.

There are two spacecraft that have recently gone into [the edge of] this heliosphere—Voyager 1 and Voyager 2. Those spacecraft have released a whole lot of new data that these scientists are very excited about, and probably will show us much more than what we've seen before. At least that will validate the models, anyway.

Our atmosphere protects us from the solar comsic rays. We have done no studies to see whether those cosmic rays are penetrating further down [in the atmosphere] than we believe they are. However, the reason we believe they are not penetrating down very far, is because of the ionosphere, which are the dense layers that protect us.

So, at the moment, what I can tell you is that the extent of the cosmic ray effects on people on Earth is very small. The Earth's atmosphere is doing a good job of protecting us.

The effects of any kind of particles that the Sun ejects are first felt in the magnetosphere, usually in the form of a magnetic storm. The study of magnetic storms is something we do know a lot about, and have done a lot of work on, because that's the first time you feel the effects of space weather. A magnetic storm compresses and expands the Earth's magnetosphere, and that has an effect on the ionopsphere; and that, in turn, has an effect on radio communications and other things. We can measure it, we can see the Earth's magnetic field, and that is part of what the space-weather center does. It will look at raw magnetic data. It turns it into what we call an index, and the level of that index tells us the severity of the event—whether it's a minor, or moderate, or severe magnetic storm.

There have been a lot of studies of coronal mass ejections coming off the Sun, which is particles being thrown at the Earth's magnetic field, geomagnetic storms or events, and the ionosphere. That link is fairly well known. There are lots and lots of scientific papers published on that link. What we're trying to do now—and we have got some scientists working on it in SANSA—is looking at the lower atmosphere, which is still above terrestrial weather, looking at that effect and whether what we see is different when we have a geomagnetic storm.

And we've recently installed a piece of equipment in Hermanus called a Doppler radar, which will basically sound the atmosphere at a very low frequency, continuously at certain times, but only at that one single frequency, and bring us back spectrograms that will allow us to see disturbances and irregularities in the ionosphere, mostly in the lower ionosphere. We're hoping to see a correlation between those, and the geomagnetic storms, which happen much higher up. So we haven't gotten down to terrestrial weather yet, but we're coming down in our science!

Particularly in this kind of science, we specialize in two ways: in the area in which you have expertise, so if we have scientists who are interested in certain aspects of the space environment, we tend to build a specialty around them; and then, in terms of the needs of that particular country. That's why our space-weather center has done so much hf propagation work, because that happens to be a need in this particular area.

The 'Extended Solar Minimum'

EIR: There was a lot of concern about the lateness of the onset of this current solar cycle. Is that an area that you also can measure and confirm, looking at the changes in the Earth's magnetic field?

McKinnell: We monitored that. It's been termed "the extended solar minimum of 2007." I think 2007 was when we thought the end of it would come, but it was a much longer solar minimum than the previous one, which was 11 years before. The concern was that the last time such a long solar minimum had been seen was what we called the Maunder Minimum, [beginning in 1645] which was the mini-ice age.

Another concern was that after a solar minimum, the next thing you worry about is the solar maximum. The question was: What is this going to do to our solar maximum? Does this mean we get an enlarged solar maximum or that the solar maximum will be delayed, because the whole cycle has now been shifted by the extended solar minimum?

As far as measurements are concerned, of course we were measuring throughout that period and we monitored the Sun. Space-weather enthusiasts and operators don't get very excited during that time, because nothing is happening on the Sun, so everything else is quiet. During that time, everybody was complaining that there was no activity on the Sun. "What's happening?" was a question we got asked a lot.

We have a period of solar data which we didn't collect ourselves, which we have access to, and the whole array of geomagnetic data which we did collect ourselves. So now, there is a whole research study into whether it's possible to model the effects during the solar minimum. What effects did it have on ionospheric propagation? You don't assume that nothing is going on. Let's have a look at the data, and see.

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Dr. McKinnell and the staff of the Hermanus Observatory supervise the education and training of young scientists, like those shown here, who come to the facility, from many nations in Africa.

And also, what are the effects now? I think it's going to open up a whole interesting area of study now, going into the next solar maximum, because I've seen quite a few scientific papers coming through, where they refer to the extended solar minimum and its effect on the magnetosphere and on the ionosphere. They're looking at the correlation between data during that period; but we're also looking at what happens immediately after that period. . . .

EIR: The Sun doesn't often make front-page news, but this extended solar minimum was very heavily publicized.

McKinnell: Yes. And the Sun is going to be making more front-page news in the coming years, as we go towards the solar maximum. Because now the Sun is getting more and more active, and the solar maximum is predicted for the end of 2012, beginning of 2013. There is a six-month uncertainty on the prediction, because of how these things work. And that prediction has been shifted up because of the extended solar minimum. All indications are that the solar maximum will be at the same level of the previous one. The majority of predictions have shown that, but, of course, we don't know.

The difference between now and 11 years ago, is that now we are really dependent on technology that could be disrupted by solar events. Now we do need to be aware. Eleven years ago, we were doing research on it, of course, but it wasn't making front-page news, and we weren't concentrating on the forecasts and predictions. Eleven years ago, you used a normal phone, or waited until you got home to make a call. Now there is a good chance that you don't have a phone at home, because you're dependent on your cell phone. So our technological dependence has grown remarkably in the last 11 years.

That's why we need to be up-to-date with space weather. That's why we need regional warning centers. That's why we need people who are trained to forecast and predict. You know, a researcher—he knows his data—but most researchers cannot look at the Sun and tell you exactly what it's going to do to technology in four days time. A good forecaster can. And that's why we are trying to develop good forecasters here to work alongside the researchers and interpret.

EIR: I'd bet that your goal is to do better than the weather forecasters, who are about 50% accurate!

McKinnell: . . .The thing that we don't fully understand yet, and we are still grappling with, is the history of data, keeping the history of what's happened before. The Sun is very predictable, except for the lower solar minimum, I guess. But every 11 years, it will do something. We have all of that solar data, going back to the 1600s. There's a very good reason why it's been kept, and we should be keeping ours, and we are, by the way, keeping our data as well as delivering real-time data. Archiving the data is just as fundamentally important. The really good models take the physics into account, but they use the history and data, of what came before, to help us decide what's going to come in the future. And that's also going to really, really help us.

EIR: It is quite remarkable that this data, from the 1600s, has been preserved.

McKinnell: The curiosity and the need for scientific knowledge have always been there. One of the first things scientists were sensitive to was the presence of the Sun. And I think it's great that they had the presence of mind to keep it. And I think it was scientific curiosity that drove that, rather than the thought that "400 years from now, they're going to want this data."

Typically, we don't use the data from 400 years ago; we only use the data from three or four solar cycles. But the sunspot number data base is the longest archived data base, ever. Ionospheric data, we only started archiving in the '50s. Geomagnetic data, I don't think even goes back as long as that. There is also the whole thing of how you keep and record the data, and technology has helped us with that.

EIR: At the Hermanus Observatory, how many people are involved? Do you have people from other countries?

McKinnell: Absolutely. We have a number of international collaborations. It's very important for space science. In fact, next week, we are hosting an international workshop of 65 delegates, 60 of whom come from other countries. So this weekend we are going to have a huge influx of visitors to the facility and to Hermanus. . . .

Our permanent staff is South African, but we have students that come from the rest of Africa. One of the ways in which we work with the rest of Africa is through training and helping them to build capacity in their countries, and the exchange of expertise. We are going to have at least 25-30 African scientists joining us next week for the international workshop, all of whom are contributing in their own right. In our student exchange, we have a number of students from other African countries, who are getting PhDs and Masters degrees in space science, and want to go back to their countries and work in the space-science programs. In any given month, we have a good flow of people traveling and people coming in, and I think that's what keeps the science alive.

The Southern Hemisphere

EIR: The International Astronautical Congress here in Cape Town was organized for all of Africa, so there is a large role for South Africa to play on the continent. You have a special geographic position globally, but there are other countries, such as in Latin America, that are also relatively close to the South Pole. Are there other, sister, observatories in the Southern Hemisphere?

McKinnell: Argentina, Brazil, and Australia have very vibrant space science programs, and we work very closely with them. Two years ago, when I needed to send a young person to learn about space weather operations, I sent her to Australia, because they have quite a fantastic space weather center there, and they know about space weather forecasting in the Southern Hemisphere, and I wanted her to get a Southern Hemisphere perspective. They were very happy to help.

We run a very active program in Antarctica. We have a suite of equiment down at the South African National Antarctic Expedition Base, and one of those is in high frequency radar which is used to observe irregularities at the poles. It is part of the International Super DARN [Dual Auroral Radar Network]. We run one of the Southern Hemisphere radars. The other one is the Halley Research Station run by the U.K. And the two of them have overlapping beam patterns, which allows you to see a certain kind of irregularities, which is the way that Super DARN works. It's an international network of polar high frequency radars. We send people down there every year, to look after the equipment and to maintain it. It's very much a part of what we do.