SANAE—

KEY TO A SPACE RESEARCH PUZZLE

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When I received a letter from the C.S.I.R. late in 1960, asking whether the Rhodes Physics Department would be interested in Antarctic research, I had no idea that it would lead us to the forefront of space research. Indeed, I doubted whether it would be worthwhile to embark on a new venture of this kind. For 20 years we had been interested in research on the ionosphere, the part of the atmosphere lying more than 50 miles above the earth's surface and we had been able to make some important contributions during that time, which had received some measure of international recognition. Why go to the Antarctic? There was, of course, an ionosphere there to study, just as there was in South Africa. But many stations had operated in Antarctica, especially during the International Geophysical Year, and there was not much in the way of startling new results from there—one or two interesting peculiarities, yes, but no indication of anything of first-rate importance.

The ionosphere is, of course, important because it reflects radio waves back to the ground instead of letting them escape into space. Thus it makes long-distance radio communication possible. It does this because it contains myriads of those tiny particles, *electrons*, which are building blocks of all matter. The electrons in the ionosphere are not all bound into atoms, as they are in most types of matter. Some of them are separated from their atoms by ultra-violet light from the sun during the daytime. During the night they recombine to form atoms again, but they do it so slowly that many are left even just before dawn the next day. It is the presence of these "free" electrons which makes the ionosphere a good reflector of wireless waves.

As we go upwards away from the earth, we find very few free electrons until we reach a height of about 60 miles, because the sun's ultraviolet light does not penetrade deeper than this. From about 60 to 80 miles we are in the E layer. Above 140 miles comes the F2 layer, the most dense of all. The electron density reaches a maximum at about 200 miles, above which it falls continually until we are outside the atmosphere, in space.

We know all this because we can explore the ionosphere by sending up radio waves and seeing how long it takes them to come back. The times are very short—a couple of thousandths of a second—but by using radar techniques we can time them accurately. The shorter radio waves penetrate further into the ionosphere before they are reflected than the longer ones do, because they need a higher concentration of electrons to turn them back. By changing the wavelength continually we can build up a picture of the way in which the electron concentration varies as we go upwards. Automatic devices are made which do this at suitable intervals, usually every 15 minutes, and record the results in film. They are called "ionosondes".

We were very fortunate in being able to borrow an ionosonde from the National Institute for Telecommunications Research (N.I.T.R.), and some other equipment too.

After the erection of the new base, Duncan got his ionosonde running and it was a great thrill when, late in May, Douglas Torr and I saw the first signals come in at Grahamstown from another special transmitter he had taken down with him. Soon regular reports of the ionospheric conditions at Sanae began to come in by Telex, and we had enough data to publish our first bulletin, for June, 1962. It was sent to interested organizations all over the world, in Britain, the U.S.A., Australia, Japan, South America, and Russia. Since then a constant flow of bulletins about the ionosphere at Sanae has followed it, thanks to the efforts of successive expeditions. Hannes la Grange, leader of SANAE I, wrote to tell us that our telexed bulletin service constituted the fastest publication of Antarctica data of which he was aware, and we still hold that record. The reliability of our system was greatly increased when we received permission for fortnightly telephone calls to the ionosphere physicist at Sanae to check up on doubtful or missing figures.

During this first, hastily-arranged year of ionosphere research at Sanae, we had time to evaluate our methods critically and to put up a well-considered five-year plan for its continuation. This was accepted by the Cabinet and the present arrangement, by which we are given practically all we had asked for, through the Department of Transport, was instituted. I would like to pay tribute to Dr. Frank Hewitt for his advice and co-operation in drawing up this programme, and to the many C.S.I.R. and Department of Transport officials who have helped to keep it running so successfully.

As soon as the five-year programme had been approved, Doug. Torr was appointed to train for the 1963 expedition.

A few weeks after Doug's appointment Duncan Baker was back. While he worked at his figures, Bernard Ezekowitz, known to all as "Zac", was training for the 1964 expedition and data continued to flow in from Doug. down at Sanae. Before we knew where we were it was time for Zac to leave and Doug. was back, while Derek Sharwood began building a new ionosonde as his training in electronics for 1965. Zac liked it so much in Antarctica that he stayed on for another year, as geomagnetician, and so we had two Rhodians in the 1965 team. This year Dave Homann is keeping the flag flying. Meanwhile Allon Poole is finishing off the new ionosonde, which he has already taken to Bouvet Island and back and which will go to Sanae at the end of this year.

Even with all this activity, we might have produced no more than another pile of data from another ionosphere station had it not been for an occurrence which, at first sight, seems quite unconnected with what has gone before. Professor Pieter Stoker went to a cosmic ray conference in Kyoto, Japan in September 1961. While he was there a paper was read by a group of Russians working under Professor Ginzburg. Pieter brought a copy of it back with him and gave it to me. It had been suspected, ever since their discovery in 1958 by Professor

Prof. J. A. Gledhill, guest speaker of the evening at the dinner of the Antarctic Association. On his right Mrs. R. Kirton, wife of the Regional Director of British Petroleum (Southern Africa), and on his left, Mrs. Dr. J. J. Taljaard, secretary of the Association, and Mr. M. C. Strauss, Postmaster-General.

Photo: B.P. (S.A.)

James van Allen, that the particles in the radiation belts surrounding the earth must approach closer to it over the South Atlantic region, than anywhere else. These particles are electrons, like those in the ionosphere, and the other electrically charged building bricks of matter, *protons*. Because they are electrically charged, both kinds of particles are trapped in the magnetic field of the earth and perform a very complicated type of motion round it. These are two radition belts, the inner one about 1,000 miles above the equator (and thus far above the F2 region) and the outer one much further out, 16,000 miles or so above the equator. It was expected that these particles would approach closest the earth in the South Atlantic region because the earth's magnetic field has a weak spot there, the so-called *South Atlantic Magnetic Anomaly*. What Ginzburg and his colleagues had discovered with their satellites was that these particles really did come in close to the earth over this region. But what was unexpected was that they came right down into the ionosphere, even below the F2 region. The place where the inner belt particles did this was just east of Rio de Janeiro. But the place where the outer belt did it was only a few hundred miles north of Sanae—in fact, about a quarter of the way from Sanae to Cape Town.

Having read of some similar work by Professor Fred Seward, of California, I wrote to him and he sent me some large maps of his satellite observations. In one of these the region of penetration by the particles, the so-called South Radiation Anomaly, was directly overhead at Sanae. *Suddenly we found ourselves in a unique position to study the effects they produced.*

One of my research students, Pete van Rooyen, and I looked into the theory carefully. We decided that the most important effects would be the emission of a reddish light (the "airglow") by the oxygen atoms in the upper air, and of ultra-violet rays by the nitrogen molecules. It also seemed possible that the bombardment would heat up the ionosphere considerably, thus decreasing the electron concentration and increasing the height of the F2 layer.

When Doug. Torr returned to Rhodes at the beginning of 1964 we thought we had enough data from Sanae to look for the effects of the bombardment. The results were discouraging. Try as we would we could not find anything that really looked like the expected changes in the ionosphere. The main trouble was that we never knew whether there was a heavy bombardment or a light one at any particular time. We would say to each other "If only we had rockets or satellites to observe the particles coming in, we would know exactly when to look for anything unusual". So we wrote to various groups of research workers who had particle counters in satellites during 1962 and 1963, asking for figures for the Sanae area. Some did not reply, others said they had nothing. But Dr. Ian McDiarmid, of the National Research Council's Physics Division in Ottawa, sent us a thick wad of figures printed by his computer from his electron on the satellite *Alouette*. And at once we made our breakthrough.

Alouette did not observe particles in the Sanae area directly, but it did do so at the other end of the line of force of the earth's magnetic field that runs through Sanae. This comes to earth again in the North Atlantic, between Newfoundland, Greenland and Iceland, the "conjugate area" to Sanae. We counted all the occasions when the satellite passed through this area. There were 77 such occasions. On 28 of these the number of electrons counted each second was obviously "high", on the remaining 49 it was low. And to our delight on every single one of the 28 occasions when it was high, we found that there was an obvious disturbance of the ionospheric layers at Sanae. Most of the disturbances looked as if they were of the type which Van Rooyen and I had predicted, showing heating of the F2 region. There was also

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BROKKIES EN GEBEURE — GROWLERS AND HOWLERS

'n Gedugte hengelkompetisie woed tussen Marion en Gough. In Junie het die Marionette berig: „Die manne hier het alreeds probeer visvang maar ongelukkig was die pogings nie juis 'n sukses nie. Ons beny julle mense daar op Gough waar 'n mens omtrent drie keer per dag vars vis kan eet." Trouens onlangs het Steve Visagie van Gough berig dat hulle vang hulle dik aan kreef, blouvis, kapewers (bietjie draderig om te eet) en vyfvingers van 3 pd. in gewig. Geen wonder dat die Marionette *brand* van begeerte om na Gough te verkas nie!

Verder berig Marion van baie muise en dat dit lyk of man en muis nou letterlik saam woon in die huis. Die muise het hulle intrek in die huis geneem, waar hulle doodluiters rondstap en ook nogal lekkerbekkig is. *Vurige* pogings word aangewend om die muislus te blus.

Meimaand het storms en reën op Gough gebring. „Ons geniet nog besondere goeie weer. Aan die einde van die maand het dit begin reent maar die temperatuur bly lekker warm. Die hoogste daaglikse reënval was 71 mm. met 'n totaal van 225 mm. vir die maand. Op die 26ste het 'n kwaai storm vanuit die suidooste opgekom teen 'n windspoed van 60 m.p.u. Die see was baie rof en het die landingsplatform afgespoel. Kort daarna het die preekstoel die stof gebyt. Dit moes 'n geweldige golf gewees het aangesien die preekstoel 70 voet bo die water teen die kranse is en nou so plat soos 'n pannekoek daar uitsien."

Junie het onverwyld die voorbeeld van Mei gevolg. Baie reent en snaakse winde. „Die probleem is nie om die weerballon in die lug te kry nie, maar as dit eers daar is, kan enige ding daarmee gebeur. Wanneer die ballon in so 'n snaakse windstroming beland speel die radiosonde sommer yo-yo bo-oor die ballon en vou die windmeul daarvan sommer soos papier op, die draad ruk af en die instrument plons daar kort anderkant die kuslyn in die water. Dan moet die manne maar weer gaan mooipraat met die waterstofbom vir 'n ekstra teugie waterstof om weer die dag se pogings van meet af aan te begin."

By SANAE was daar tandmoeilikheid—omdat die medikus self die pasiënt was. Weens 'n wortelabses moes sy tand verwyder word. „Sulke tye tree die werktuigkundige as tandarts op, miskien juis omdat hy uit die aard van sy werk weet hoe om 'n tang te hanteer. By hierdie geleentheid het Henry Fulton hom meesterlik, dog nie sonder professionele teenkanting van sy kant af, van sy vreemde taak gekwyt en die tand pynloos en suksesvol verwyder."

Die son het na twee maande weer sy verskyning kort voor die einde van Julie gemaak. Die manne, belaai met waarnemings- en wetenskaplike werk, naslaan en opskrywe, het die winter geniet. Die temperatuur het af en toe kort duskant minus 50 sentigrade omgedraai en die wind so amper 90 knope gehaal.

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evidence that the electrons precipiated from the outer radiation belt came as low as 50 miles above Sanae. This was the first time that anyone had proved that electron bombardment produces such ionospheric effects, except during auroras. Our paper about it, which I read at the International Space Research Symposium in Argentina last year, was very well received and several of the experts commented that it looked as if we were on to something important.

Our research group had meanwhile been joined by another M.Sc. student, Marsha Harding. During 1965 she and Doug. Torr worked hard at our new discovery. Now that we knew what to look for the pieces of the puzzle began to fit together. They were able to show that similar ionospheric disturbances to those at Sanae occurred at other places beneath the outer radiation belt also: Campbell Island, south of New Zealand; Halley Bay, not far from Sanae; and Winnipeg, Ottawa and St. Johns in Canada. And in every case when *Alouette* observed electrons being precipitated at one of those places, one of the ionospheric disturbances was in progress. The disturbances were much less frequent at those other places, because they do not lie near the South Radiation Anomaly. But when they did occur, they were unmistakable.

Ever since the ionosphere had been studied systematically it has been observed that, while the E and F1 layers are very predictable in their behaviour, changing in a regular manner each day, the F2 layer is quite different. One day it will build up an enormous concentration of electrons about noon, the next it will have very few, perhaps reaching a maximum before 10 a.m. and then falling off again, or building up much more slowly than usual and then suddenly shooting up towards evening. One day it will have its greatest concentration of electrons at a height of 180 miles, the next at 300 miles. It varies erratically from one hour to another. Many suggestions have been put forward, but none has gained general acceptance. Could it be, we asked ourselves, that this erratic behaviour was caused by the dumping into the F2 region of electrons from the radiation belts?

This is a much more difficult question to answer, because we do not have a satellite overhead at each ionosphere station 24 hours a day to watch for incoming electrons. Nor can we afford to fire rockets at 15-minute intervals to heights of 100 miles or more to look for the bombarding electrons every time our ionosonde takes a recording. What Marsha Harding and Doug. Torr did was this. They took a lot of two-hour periods chosen at random at each of the ionosphere stations I have already mentioned, and they classified them as "disturbed" or "quiet" according to the knowledge they had gained in the preliminary study. Then they worked out, for each station, the percentage of the total time for which the ionosphere was disturbed. Then they looked up, from the *Alouette* recordings, the percentage of the total time for which the number of electrons precipitated per second at each station exceeded the limit known to produce a disturbance from the preliminary study. The results were astonishing. In every case the two figures were very close to each other. Thus there could be little doubt that electron bombardment did take place exactly often enough to account for the disturbances. We have written this up for publication and we are confident that it will prove to be the key to the puzzle of the odd behaviour of the F2 region. Had we not gone to Sanae, we would never have found it, for Sanae is the place with the most disturbances of any from which ionosphere records are available.

Marsha Harding went on to show that the electron population observed in the outer radiation belt by various satellites can be accounted for if there is a constant leakage of electrons from outer space into the belt all the way round the earth. This theory is simple to work with and seems to give better answers than more complicated ones worked out by others.

In conclusion, then, we seem to have been extremely lucky to have settled on Sanae as our base, for ionospheric work in particular.

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