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Observing the Earth's magnetic field

Pieter Kotzé discusses the role of the geomagnetic observation network operated by the South African National Space Agency

The Earth's magnetic field has its origin in the molten core located ~3 000 km below the planet's surface. Without it, the Earth's atmosphere would be eroded over millions of years by the solar wind – the plasma stream of charged particles constantly escaping from the Sun. The so-called 'geomagnetic' field shields our planet from this damaging radiation and allows life on Earth as we know it to exist.

Convection in the molten core means that the geomagnetic field changes gradually in space and time. These changes, known as secular variation, have practical implications for navigation, geological magnetic surveys and various applications dependent upon precise orientation. Continuous monitoring is therefore conducted by geomagnetic observatories around the world, and the results used to build or update global and regional models of the geomagnetic field.

The geomagnetic observation network operated by SANSA consists of observatories at Hermanus and Hartebeesthoek in South Africa and at Tsumeb and Keetmanshoop in Namibia.

The observatories also play a crucial role in space weather monitoring. The interaction between the solar wind and the geomagnetic field may cause disturbances under certain conditions, with particularly intense magnetic storms occurring where the magnetic field associated with a coronal mass ejection is oppositely directed to the geomagnetic field. These storms can damage electronics and electricity networks, affect navigation and communication systems, and expose astronauts, airline crew and passengers to dangerous levels of radiation.

The geomagnetic observation network operated by the South African National Space Agency (SANSA) monitors the behaviour of Earth's magnetic field in southern Africa over a wide range of time scales, from seconds to several decades. Apart from research and data provision for regional and international use, the information is used to characterise magnetic storms and determine their strength and duration during space weather events. The magnetic field disturbance at a particular point and time is especially important where the broad scientific objective is to understand the sources and processes internal and external to the Earth's surface. The geophysical exploration industry, for example, needs accurate geomagnetic data for directional drilling, which orientates the drill bit deep underground using the Earth's magnetic field – yet this may vary considerably even on a normal day, and much more during a magnetic storm.

Observations past, present and future

The requirements of navigation, rather than any scientific interest in geomagnetism, originally prompted the recording of data of magnetic field components in


SANSA

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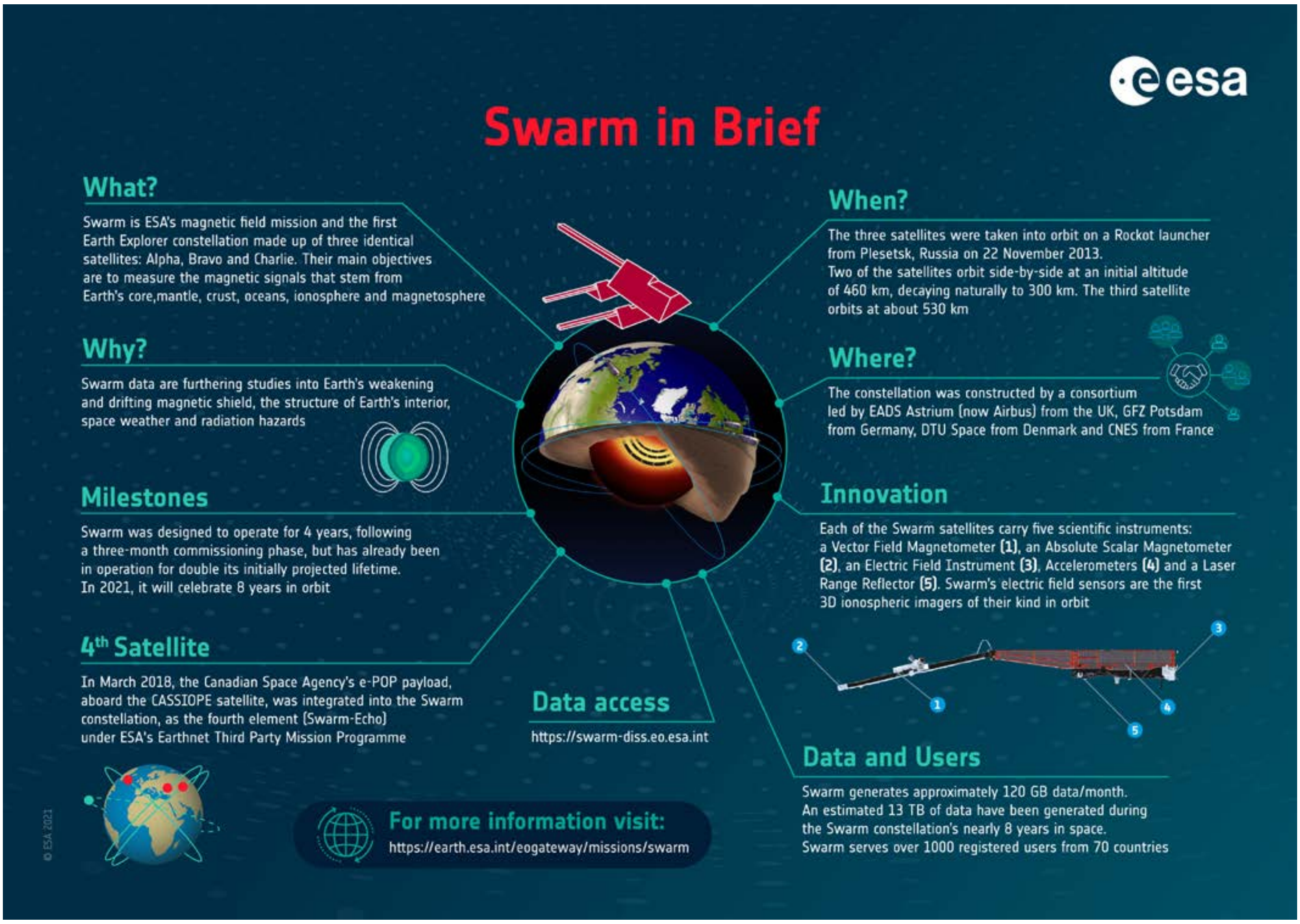
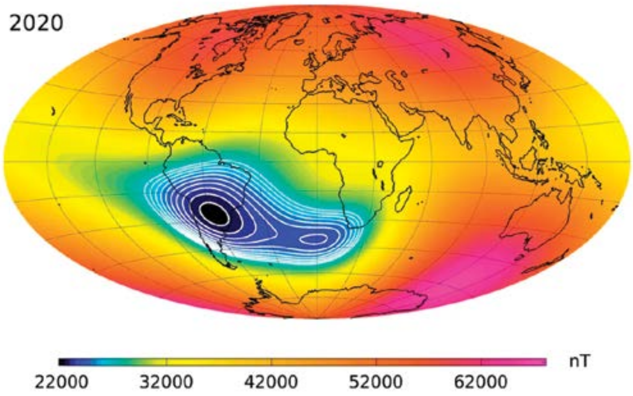
southern Africa. Even before 1600, seafarers were making magnetic field observations at places close to the coast to check the accuracy of their magnetic compasses. The first systematic observations in South Africa resulted from the establishment in 1841 of a worldwide network of geomagnetic observation stations. One of these stations was built on the grounds of the Royal Observatory at the Cape of Good Hope, where observations were carried out intensely for some years and then – after the station burnt down in 1953 – only sporadically until 1870, when the Observatory's director, Sir Thomas Maclear, retired.

The first magnetic survey of southern Africa was carried out by Professors Beattie and Morrison between 1898 and 1906. In 1932, in celebration of the International Polar Year of 1932–1933, a magnetic observatory was established at the University of Cape Town. But the subsequent electrification of the suburban railway network created a disturbing influence, to the extent that accurate observations were becoming almost impossible. A new site was identified in Hermanus because it was sufficiently remote from such disturbances and had been proved by a magnetic survey to be suitable in other respects.

Over the years following the establishment of the Hermanus Magnetic Observatory in 1941, various institutions have administered the facility, but in 2011 it became part of SANSA's Space Science Programme. The observation network in southern Africa has also been expanded since the 1960s, and now includes additional observatories at Hartebeesthoek in South Africa and at Tsumeb and Keetmanshoop in Namibia. This SANSA-operated network is integrated into the International Real-time Magnetic Observatory Network (INTERMAGNET), an organisation dedicated to promoting the operation of geomagnetic observatories according to modern-day, high standards.

Given sufficient resources like funding and human capacity, SANSA may expand the network in the future, the eastern part of Botswana having been identified as a potential





The splitting in two of the South Atlantic Anomaly can be clearly seen in this depiction of the field strength of Earth's magnetic field, as measured by ESA's SWARM satellite constellation.

candidate for a new INTERMAGNET observatory. Some regional space weather projects, such as those focused on potential hazards for the local electric power grid industry, as well as mineral survey companies operating in southern Africa, may benefit from the addition. The expansion could perhaps be achieved through international collaboration, as was the case for the establishment of the Keetmanshoop observatory through the support of the GFZ German Research Centre for Geosciences. SANSA could also expand the time domain of data collection by moving to continuous monitoring at sampling frequencies of 10 Hz or higher, which can be utilised for high time-resolution research and applications.

Currently, SANSA is in the process of upgrading its facility in Hermanus to a 24-hour operational space weather centre. In terms of an agreement with the International Civil Aviation Organisation, this will serve as a regional centre providing space weather services for the African region. The official ground-breaking ceremony for a new, state-of-the-art facility took place on 9 March 2021.

South Atlantic Anomaly

South Africa is also uniquely positioned to study the South Atlantic Anomaly (SAA), where the geomagnetic field is weaker by about 40% relative to other places at equivalent latitudes, due to processes in the Earth's core. Although originally detected by satellite missions in the late 1950s, data from the European Space Agency's Swarm satellite constellation, launched in November 2013, have revealed that the SAA has split in two since 2014. It is also moving westward at a rate of 20 km per year, which increases the anomaly's area of influence demonstrated by an observed weakened magnetic field over southern Africa.

A weaker field means that the shielding effect is severely reduced in this area, allowing high-energy particles to penetrate deeper into the upper atmosphere here than anywhere else on Earth. Although the SAA is no cause for alarm at ground level, most satellites and spacecraft crossing this area at altitudes below 1 000 km have experienced some level of malfunctioning or degradation. For example, their solar panels and computer chips can get damaged, and astronauts are vulnerable to radiation exposure here.

By the year 2100 the SAA will cover most of South America, the southern part of Africa, and the South Atlantic Ocean south of 25°S to the Scotia Sea and Antarctica. The size of the SAA will have increased by a factor of four, suggesting that the radiation hazard to humans in space may be increased by a corresponding amount.

It is unknown where the turning point of this migration is, but it is suspected that it might culminate in a polar reversal, when the north and south magnetic poles switch places, most probably in the next millennium. During the Earth's history, these poles have reversed many times at intervals ranging from about 120 000 years to 660 000 years. Since the last known reversal was 780 000 years ago, such an event is long overdue!

- Read more about space weather monitoring in the article 'SuperDARN' in *Quest* Vol. 16 No. 2, which focused on early warning systems.

Dr Pieter Kotzé retired from SANSA in 2020 but remains active as a researcher through his association with the Centre for Space Research at North-West University and the Physics Department at Stellenbosch University.

CURRICULUM CORNER

PHYSICAL SCIENCES: GRADE 10
Magnetism: Earth's magnetic field