Federal Agency for Cartography and Geodesy

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Wir geben Orientierung.

Geodetic Observatory Wettzell

Federal Agency for Cartography and Geodesy and Technical University of Munich

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and Technical University of Munich

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Preface

Prof. Dr. Torben Schüler

Since the Geodetic Observatory Wettzell began measuring operations in 1972, it has continuously increased its importance. Not without reason, it was officially categorised as a „critical infrastructure“ in 2020. We make an important contribution to the functioning of satellite navigation and provide new scientific insights.

We achieve this together with our colleagues from the Technical University of Munich. The co-operation ensures dynamic development. The Federal Agency for Cartography and Geodesy guarantees long-term operation. In this way, together we ensure high-quality measurements at the cutting edge.

Even as a student I travelled to Wettzell. Even then, a fellow student mentioned that this was exactly the right job for me. 16 years later, the time had come. In fact, the work at this observatory is almost unique in the world and very varied.

The following pages will give you an impression of exactly that. And of course, you are welcome to visit us here if you would like to find out more.

Yours 

Prof. Dr. Torben Schüler
Head of the Geodetic Observatory Wettzell

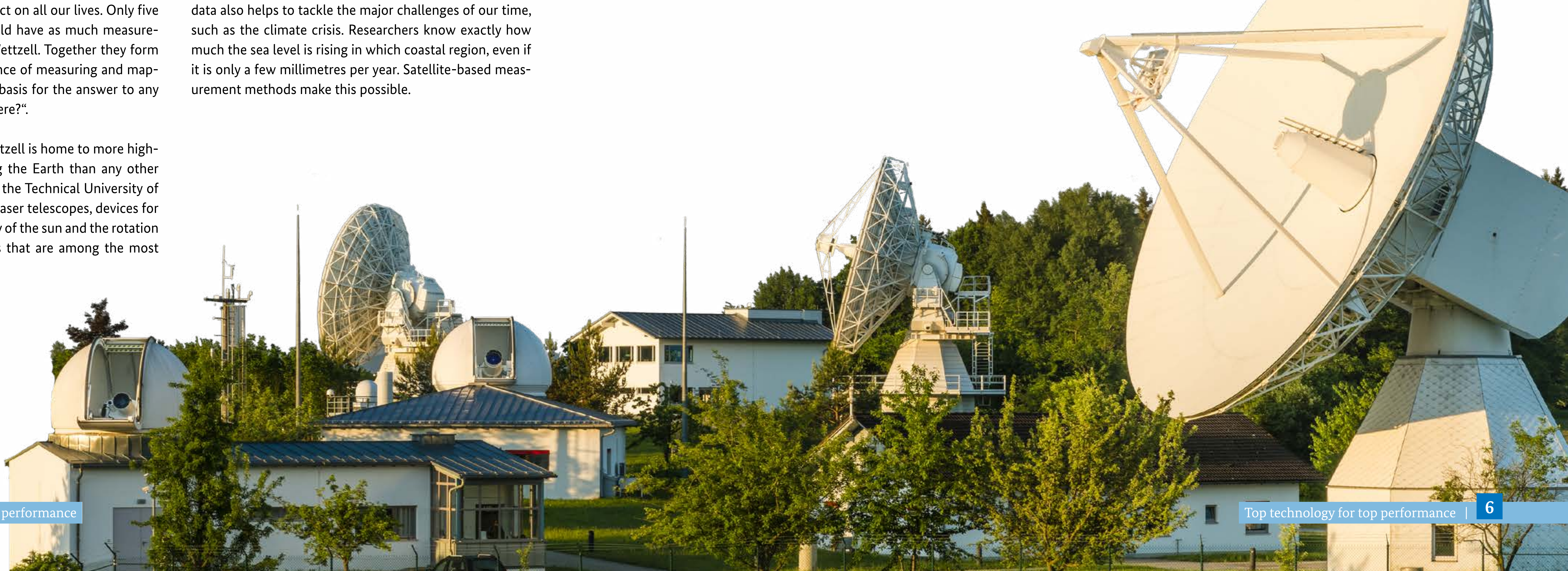
Top technology for top performance

Wettzell in the Bavarian Forest, Greenbelt in the USA and Yarragadee in Western Australia: geoscientists‘ eyes light up when they hear these names. As small as these places are and as far away from the world‘s metropolises as they are, they still have a huge impact on all our lives. Only five other observatories in the world have as much measurement technology to offer as Wettzell. Together they form the basis for geodesy, the science of measuring and mapping the Earth. They form the basis for the answer to any question that begins with „Where?“.

The Geodetic Observatory Wettzell is home to more high-tech equipment for measuring the Earth than any other place in Europe: together with the Technical University of Munich, we operate radio and laser telescopes, devices for determining gravity, the activity of the sun and the rotation of the Earth, as well as clocks that are among the most accurate in the world.

The results of the measurements are used in basic geoscientific research. However, they also have very practical applications in everyday life. Without them, there would be no satellite navigation, for example. The measurement data also helps to tackle the major challenges of our time, such as the climate crisis. Researchers know exactly how much the sea level is rising in which coastal region, even if it is only a few millimetres per year. Satellite-based measurement methods make this possible.

We also take care of events in space from Wettzell. For example, solar storms have to be detected in time to protect the power supply on Earth, navigation systems, radio and mobile communications technology from damage.



Safely to your destination

Almost every mobile phone is also a navigation device and both have become an integral part of everyday life. Within a few years, it has become a matter of course for us to have precise position information at all times and to be guided by the telephone.

But how does the phone know our position?
Firstly, the answer is: from navigation satellites. They orbit the Earth and send their signals to receivers all over the globe. So far so easy?

No, much more is needed! The position and orientation of the Earth as a whole in space must be known. Because the movement of our planet is anything but uniform. Changes in the speed of rotation and fluctuations in the Earth's axis of rotation are therefore determined with the help of impressive radio telescopes. They are located in geodetic observatories around the world and three of these telescopes are based in Wettzell.

The next step is to determine the position of the satellites. This must also be known exactly if navigation on Earth is to work. For this purpose reference stations are spread around the globe.These Global Navigation Satellite System (GNSS) receivers look inconspicuous, but they play an important role. The exact position of the satellite in space can be determined from the transit time of the signals from the satellite to the reference station. In Wettzell, ten GNSS antennas perform this task; there are tens of thousands of them worldwide. In addition, the orbits of the navigation satellites are checked using laser distance measurements.

Thanks to international co-operation, precise navigation is possible all over the world.

How exactly these measuring methods work can be found on page 12.

Source: Yuri Bizgaimer / stock.adobe.com

High-tech for climate and weather

We are all feeling the signs that the climate crisis is accelerating. There are significantly more extreme weather events, such as drought and heavy rainfall. Sea levels are also affected. Although it is only rising by a few millimetres per year, these are quickly adding up. Special altimeter satellites are used to measure a rise of just a few millimetres on the huge water surface. They send radar pulses vertically downwards, which are reflected back to the satellite by the surface of the water. The distance between the satellite and the water surface can be determined very precisely from the propagation time of the radar pulses. Ice altimetry works in a very similar way; it is used to measure how much ice is melting in the polar regions, for example.

In order to calculate heights and changes in height using these distance measurements, the position of the altimeter satellites must be precisely determined at all times. The navigation satellite systems and laser distance measurements are also used for this purpose. As part of the global network of reference stations, the station in Wettzell helps to determine the satellite orbits with the necessary accuracy and long-term stability to be able to observe global climate change processes.

In addition, the fact that the signals from the navigation satellites react sensitively to the water vapour content of the atmosphere is used. These analyses are therefore incorporated into weather forecasts.

Another way of tracking the shift in the amount of water on the globe is to measure the Earth's gravitational field using gravimeters. At the Geodetic Observatory, we measure the absolute value of gravitational acceleration, but also the smallest changes.

Source: Ulia Koltyrina /stock.adobe.com

Weather and debris in space

Weather not only takes place in the Earth's atmosphere, but also in near-Earth space. Space weather is largely determined by the sun, which we observe using high-tech measurement technology in Wettzell.

The sun emits charged particles called the solar wind. It usually has no major consequences. Sometimes, however, it becomes a solar storm and thus a danger for our highly technical and networked world. The power supply, navigation systems and, of course, satellites of all kinds can be severely disrupted or even damaged.

In future, we will use the solar observation telescope to measure the intensity of the radio radiation emitted by the sun. The measured values will be used to predict solar storms and assess the potential danger. In this way, instruments on the ground and in space can be switched off in good time and protected from damage.

However, there is a second danger in space that is increasingly becoming a problem: Debris, so-called space junk, which comes from previous space missions, among other things. Using laser distance measurement, we can determine the orbits of the debris in Wettzell.

This measurement data helps to warn satellites and space stations of collisions in good time. This gives them the opportunity to move to safety by correcting their orbits. In addition, people on Earth can be warned in the event of an uncontrolled re-entry of space debris into the atmosphere.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The three radio telescopes

With the „Very Long Baseline Interferometry“ (VLBI) method, two distant radio telescopes are aligned to the same radio source in space (a quasar). The radio waves emitted by the quasars reach one of the two telescopes slightly earlier than the other. A mathematical method for comparing signals (correlation) is used to determine the difference in the arrival times of the signal at the telescopes. If the speed of the signal (speed of light) is known, the distance between the telescopes is derived very precisely from this time difference via the geometry.

However, we not only supply data, but are also involved in analysing the data collected worldwide. For this purpose, the Geodetic Observatory Wettzell has a powerful computer for correlating the VLBI data.

In a further step, the BKG derives information about the Earth‘s rotation, such as the speed of rotation and changes in the position of the axis of rotation. This information is required for satellite navigation, among other things. In addition, we contribute to the determination of plate tectonics with VLBI.

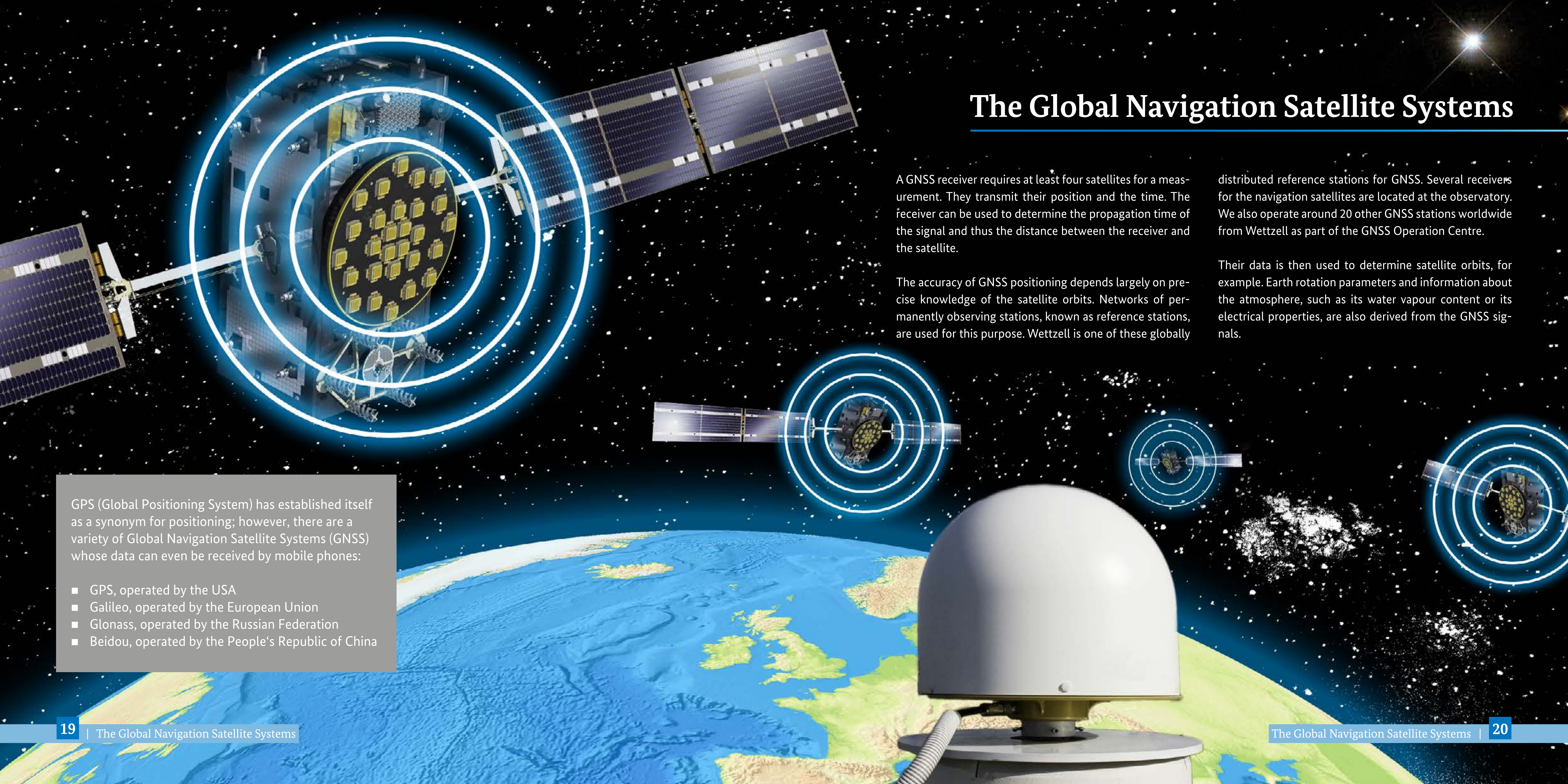
We operate three radio telescopes in Wettzell. Since 1983, a radio telescope with a diameter of 20 metres, which has so far recorded the most geodetic observations worldwide. The two TWIN telescopes have been in operation since 2013. They have smaller reflectors with a diameter of 13 metres, which can rotate faster in order to target different radio sources. This allows more measurements to be taken in less time. Measurements are taken in sessions in which several radio telescopes around the world simultaneously target the same radio sources.

The laser measurement systems

To measure distances with lasers, short pulses of light are emitted into space. The targets are reflectors on the moon or on satellites. The light is reflected by the reflectors and returns to the measuring station. The speed of light is known; therefore, the distance the light has travelled can be calculated from the time that elapses between sending and receiving the laser pulse. From this, we in turn derive the distance to the satellite, or the moon.

With these measurements from various globally distributed stations, satellite orbits, the Earth‘s rotation, the coordinates of the observation stations and the Earth‘s centre of mass can be determined very precisely. Measurements of satellites, for example, serve as an independent verification procedure for their orbits, which are used both for navigation systems and for Earth observation satellites.

We operate two laser ranging systems at the Geodetic Observatory Wettzell. With the Laser Ranging System, which has been in operation since 1990, we measure distances to satellites and to the moon. The Satellite Observing System has been in operation since 2015 and is specially designed for fast satellites in low orbits. Both systems can determine the distance of a satellite orbiting the Earth at an altitude of 20,000 kilometres to an accuracy of less than one centimetre.



GPS (Global Positioning System) has established itself as a synonym for positioning; however, there are a variety of Global Navigation Satellite Systems (GNSS) whose data can even be received by mobile phones:

- GPS, operated by the USA
- Galileo, operated by the European Union
- Glonass, operated by the Russian Federation
- Beidou, operated by the People's Republic of China

The Global Navigation Satellite Systems

A GNSS receiver requires at least four satellites for a measurement. They transmit their position and the time. The receiver can be used to determine the propagation time of the signal and thus the distance between the receiver and the satellite.

The accuracy of GNSS positioning depends largely on precise knowledge of the satellite orbits. Networks of permanently observing stations, known as reference stations, are used for this purpose. Wettzell is one of these globally distributed reference stations for GNSS. Several receivers for the navigation satellites are located at the observatory. We also operate around 20 other GNSS stations worldwide from Wettzell as part of the GNSS Operation Centre.

Their data is then used to determine satellite orbits, for example. Earth rotation parameters and information about the atmosphere, such as its water vapour content or its electrical properties, are also derived from the GNSS signals.

The DORIS system

The configuration of the DORIS system (Doppler Orbitography and Radiopositioning Integrated by Satellite) is the reverse of that of global navigation satellite systems: The radio signals are not emitted from the satellite, but from the ground station. For particularly accurate results, the antenna transmits signals on two frequencies. In orbit, they are registered by special measuring units on the satellites. The movement of the satellites causes a change in the frequencies of the recorded radio waves due to the Doppler effect. The orbit and speed of the satellite are derived from this frequency shift. The measurement data is sent to Earth. More precisely, to Toulouse in France, where the French space agency receives and analyses the data.

With the DORIS antenna, we are part of an international network of 60 ground stations. They are evenly distributed around the globe and therefore make a particularly important contribution to the various reference systems in the geosciences.

DORIS can be used to determine the orbits of satellites, for example those of the altimeter satellites mentioned on page eight. For more than 25 years, the system has been helping to monitor the height of the Antarctic ice sheet and register changes in sea level.

The ring laser

The large ring laser is one of the few of its kind in the world and was developed over many years at the Geodetic Observatory Wettzell. It is used to determine changes in the Earth's rotation and, unlike the other methods, does not require external landmarks such as satellites or quasars.

The ring laser consists of a four by four metre system in which two laser beams circulate in opposite directions. One beam travels with the Earth's rotation and therefore has a slightly longer path than the beam travelling against the Earth's rotation. The superposition of the two beams can be used to derive, among other things, changes in the Earth's rotational speed and the movement of the rotation poles. In this way, changes in the length of the day of 0.1 milliseconds can be observed.

To achieve this accuracy, the ring laser is located in an underground laboratory that shields it from environmental influences such as temperature fluctuations.

The solar observation telescope

Our sun constantly emits high-energy radiation and charged particles. The latter form the so-called solar wind, the most beautiful manifestation of which is the aurora borealis. The solar flux telescope measures the radio waves emitted by the sun. A stronger solar wind is also accompanied by stronger radio radiation. At night, when the sun is not visible, the telescope is also used to characterise the signals from navigation satellites such as Galileo.

In the past, scientists constantly counted the sunspots to determine the sun's activity. But measurements with a telescope are, of course, more objective. The measurements from the solar flux telescope provide an important parameter for models that predict how space weather will affect the Earth. The regular measurements help to predict space weather events more precisely.

Eruptions on the sun can amplify the solar wind. The radio radiation that is emitted reaches the Earth after eight minutes. This is how long it takes for the signal to travel the distance from the sun to the Earth at the speed of light. With our telescope we can measure the radio radiation and are forewarned. This is because the actual solar storm, which can cause damage, only arrives after a certain delay.

Gravity measurements in the gravimeter house

Gravimeters measure the Earth‘s gravitational pull. Even the smallest fluctuations can be registered with superconducting gravimeters. Superconductivity is achieved when a current flows without electrical resistance. This requires temperatures close to absolute zero. The measurement is therefore carried out in a vessel containing liquid helium. A hollow sphere floats there in a magnetic field. Changes in gravity are compensated for by minute changes in the magnetic field. The electrical current required for this is measured. Variations in gravitational acceleration can have various causes:

Tidal forces, fluctuations in the Earth‘s rotation or variations in the water balance of the subsurface as well as changes in altitude.

The gravimetry station at the Observatory Wettzell serves as a reference station for the national gravity networks of the federal and state governments. For this purpose, the absolute values of gravitational acceleration are regularly determined by observing the free fall of a test mass in a vacuum. The results of the absolute and relative measurements are fed into the gravity reference function. It provides an absolute reference gravity value with maximum accuracy at all times and allows the gravimeters to be checked.

How everything is connected

An observatory, from the Latin observare, „to observe“, is a place to record scientific phenomena. The observations carried out in Wettzell cover many facets of geodesy. This puts the small town on the edge of Bavaria at the centre of the global geodetic community, as Wettzell is one of only six stations worldwide where all four geodetic spatial methods are operated in one place:

- Radio interferometry on long baselines (VLBI) ●
- Laser distance measurement, that so called Satellite Laser Ranging (SLR) ●
- Global Navigation Satellite System (GNSS) ●
- Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) •

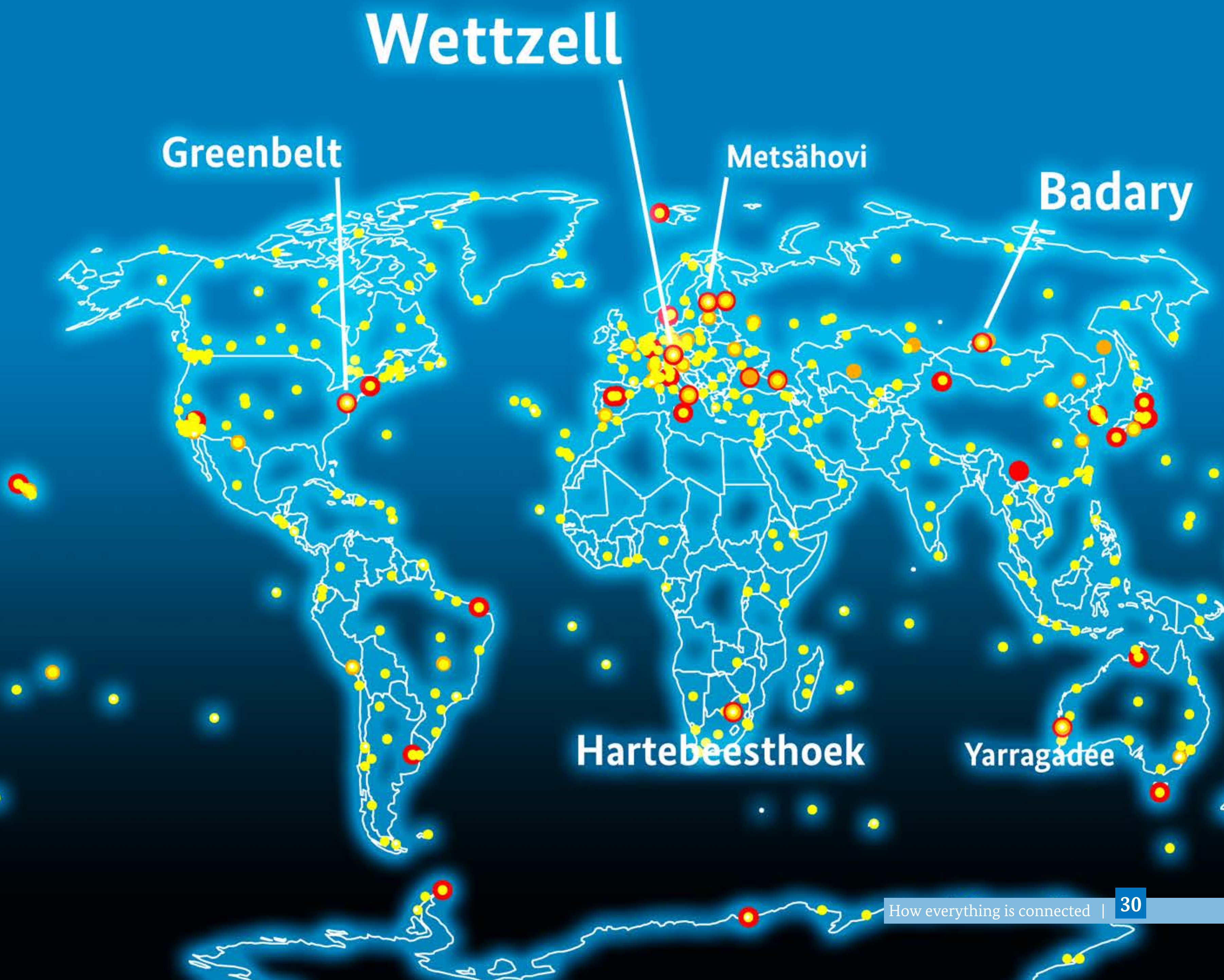
Wettzell‘s outstanding position is further enhanced by the operation of gravimeters. The interplay of different methods provides insights into major social issues. For example, climate researchers use GNSS and gravimeter data. For the precision navigation is important to accurately describe the Earth‘s tumbling motion through space.

The results of the radio wave measurement on long baselines (VLBI) contribute to this. They show how the position of the Earth‘s axis of rotation changes and also its rotational speed.

To be strong together

Climate and navigation are just a few examples of the countless topics to which geodesists make a decisive contribution worldwide.

Geodesy is teamwork, both in terms of data generation and data analysis. Only cooperation between different observatories and data processing centres around the globe leads to valuable data and products. This is why we at BKG also participate in many international services, for example the International VLBI Service for Geodesy and Astrometry, the International Laser Ranging Service and the International GNSS Service. These services coordinate the observations of the various stations, organise the collection of data, ensure the quality of the data and coordinate their further processing. In addition, the data and products are made available to users.



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