Mission manager **Dr Rune Floberghagen** sets out the results of the GOCE mission, part of European Space Agency's Living Planet programme

GOCE's success

The Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) mission came to a natural end when it ran out of fuel. The satellite began its descent towards Earth from a height of about 224km in mid October 2013. The mission had more than tripled its expected operational lifespan, and in that time, it more than fulfilled its mission objectives. The fifth generation of the gravity field models created from the GOCE data – the fundamental product from this mission – will be released in July 2014.

Dr Rune Floberghagen

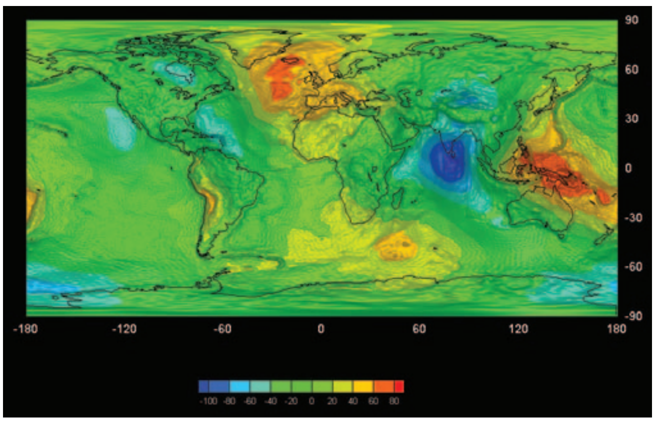
The data, and indeed its quality, that we have generated through GOCE have been enhanced in the last 12-18 months of flight operations, during which time we have periodically lowered the satellite's orbit. This is due to the fact that the closer the sensor to the gravitational force, the bigger the gravitational signal and therefore the better the signal to noise ratio, and thus the better the science.

GOCE's orbit was therefore lowered (it was already the lowest satellite orbit of any existing research satellite) in order to improve the data, and the benefits of this can already be seen in the Generation 5 product and, what is more, we have also shown that GOCE will be of use in many other areas and disciplines.

Map

The core aim for the GOCE mission was to provide a map, or model, of the Earth's gravity field in much better spatial resolution, and at a much higher degree of accuracy, than anything produced before. While gravity can be measured on the ground using a very precise instrument, this is not a practical solution. We therefore opted to put an instrumentation of proper size in a satellite which flies in a polar orbit, from which we are able to create excellent maps of gravitational field variations all around the globe.

The benefits of the GOCE mission are numerous, not least stemming from the fact that while an instrument on the ground could be used to measure the Earth's gravitational field, and while, indeed, before the GOCE mission some areas – such as Germany and other parts of Europe, for instance – were fairly well charted in terms of gravity, this data was not done with the same instrument, with the same quality, or with the same reference system. GOCE, by comparison, has produced much better data than anything else that has been produced at the same spatial scales.



GOCE's first global gravity model

The gravity field mirrors the distribution of mass or of the Earth, and so an accurate map of this field – GOCE has enabled the creation of a model of the gravity field and its variations with a spatial scale of better than 100km – can help kick-start a whole series of studies in solid Earth physics and geodynamics, simply because the gravity field mirrors what is happening underneath our feet in terms of mantle convention, plate tectonics, post-glacial rebound, etc.

Geoid

This model is equally important for research into the older geophysical processes that take place on the surface of the Earth – such as sea level changes, ice movement, melting ice, etc. all of which are processes that should be measured with respect to a proper and common reference. This is computed from the gravity field – known as the geoid – and is an equal energy surface dictated by the distribution of masses inside the planet.

The provision of a physical level surface for the entire globe means that height references – which cannot be measured and included when using ground-based measurements – can also be included, which is of particular interest to those scientists researching processes such as ocean circulation, sea level changes, hydrology, and ice melt – because when they speak about height references they are referring to potential differences due to the gravitational field.

Ocean circulation

GOCE, as the central letters in the acronym (ocean circulation) suggest, is both a gravity field and steady state ocean explorer mission. This is because the data obtained from GOCE, and the model of the geoid that has subsequently been generated, will also result in the ideal reference for modelling the circulation in the world's oceans, which is important because the oceans regulate the climate, transporting about 30% of the heat around the globe, with the remaining 70% being transported via the atmosphere.

The GOCE measurement of the geoid coincides with an ocean surface at rest. Should a sensitive measurement device be flown over the oceans to measure their actual height (for example a radar altimeter), a measurement of the deviations of the physical ocean surface could then be made. The mean dynamic topography of the ocean can be determined from the equipotential or level surface, and the difference between the measured ocean surface and the ocean surface is derived by the gravity field. These are the dynamics that, together with the Earth's rotation, drive the geostrophic currents.

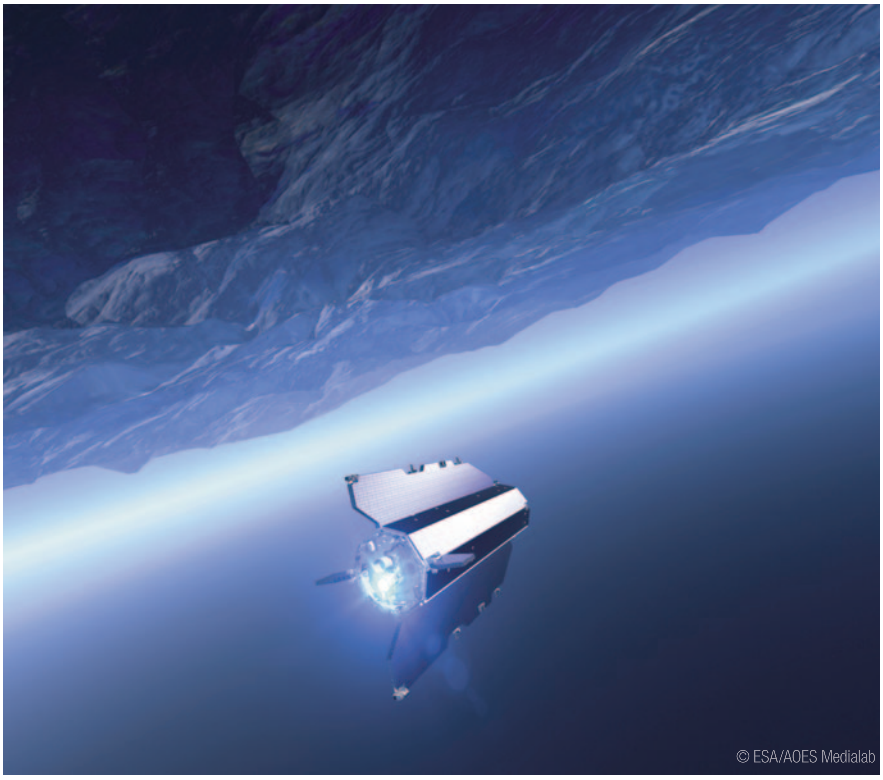
Current systems

GOCE data can be used alongside altimetric information to compute models of the mean dynamic topography, and from that we can derive both the major and smaller current systems around the globe.

In the past, this was impossible because, while the altimetric data was accurate to just a couple of centimetres, the geoid data at the same spatial scales were just not good enough. GOCE has now ensured that oceanography can actually be done from space without putting a single measurement device in the ocean, which is quite spectacular.

This means that it is now possible to follow and verify models for ocean energy using GOCE data, because we are able to determine how much water is circulating anywhere in the oceans, the temperature of the water and the total energy. This is crucial for the future of planet modelling and will continue to become increasingly important in the future.

GOCE will, indeed, have a considerable impact in many diverse scientific fields, especially when it is understood that while gravity may not be considered as the most important data source in many disciplines, it is often the second most important – this is true in fields such as oceanography, geophysics and seismology (for a better understanding of plate tectonics). GOCE was also never intended to be a climate mission, essential climate variable studies and the climate change initiatives use gravity as a valuable input to support their conclusions in a whole range of disciplines and areas.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Oil of the future

Although GOCE does have an immediate successor, the last decade of gravity-based measurements from space have demonstrated that these measurements are directly linked to mass distribution in the Earth's system. Thus, a system that can measure changes in gravity also measures changes in masses wherever they are – such as groundwater. There are many places, such as some parts of China, which are running out of groundwater (for both drinking and agriculture and so on) and it is becoming increasingly important to be able to measure how such masses are moving around the globe.

We are therefore trying to show that gravity measurements will be integral to such measurements in the future in order to understand where water, which will become the oil of the future in terms of it being a valuable resource, is moving to and from.

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