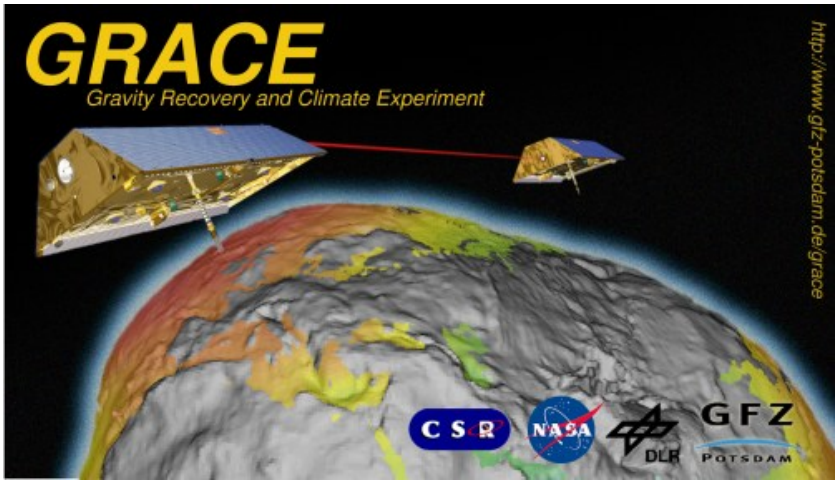
THE GRACE SATELLITE TANDEM:

High-Precision Earth Monitoring for a Better Understanding of Climate



GRACE is a joint project of the American space agency NASA, the German Aerospace Center (DLR), the Center for Space Research (CSR) and the GeoForschungsZentrum Potsdam (GFZ).
(Fig: GFZ Potsdam)

The satellite pair GRACE (Gravity Recovery and Climate Experiment) began its geo-scientific space mission on March 17, 2002 from the Russian launch site Plesetsk. The mission maps the Earth's gravity field and its temporal variations with hitherto unprecedented accuracy. Furthermore GRACE provides information on vertical temperature distribution and global water vapour content of the atmosphere.

The GRACE experiment consists of two identical spacecrafts flying in the same orbit about 220 kilometres apart. Thus the engineers involved called the satellite tandem unofficially "Tom and Jerry". GRACE is the first mission launched under the NASA Earth System Science Pathfinder (ESSP) Program. With GRACE, the GeoForschungsZentrum Potsdam (GFZ) went into its third satellite mission.

Both satellites weigh 485 kg each, fly at an initial altitude of 500 km and orbit the Earth in about 95 minutes.

Gravity and Gravity Mapping

The mass within the Earth and on its surface is not evenly distributed. Molten rock flows in the Earth core, water masses move in the oceans and on the continents and atmospheric masses are also in continuous movement. Since the gravity force of a body depends on its mass, the irregular mass distribution on our planet causes an inhomogeneous gravity field. Therefore regions of slightly stronger gravity will affect the leading GRACE satellite first, pulling it slightly away from the trailing satellite. This is reflected by a small change in the distance between the satellites.

Consequently, by high-precision tracking of the constantly changing distance, tiny mass variations can be measured. For this end, GRACE uses a

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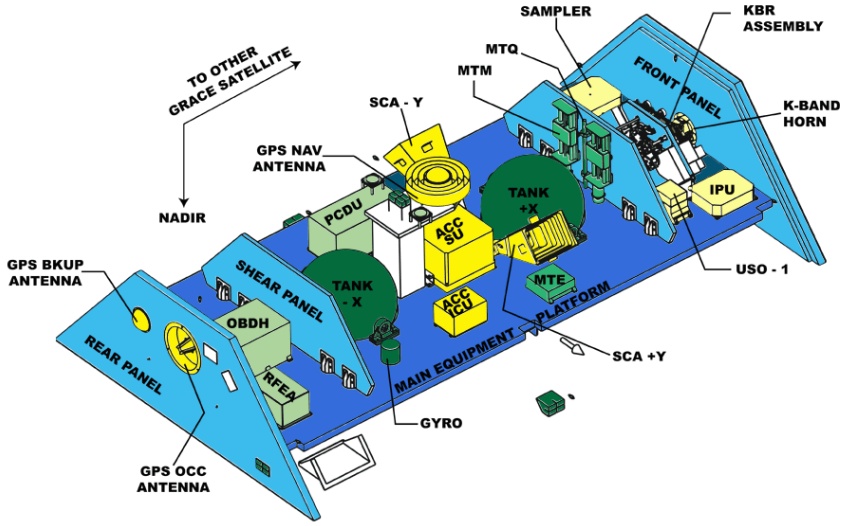
uniquely precise microwave ranging system measuring the distance between both satellites with an accuracy of some microns – about one-tenth the width of a human hair – over a distance of 220 km!

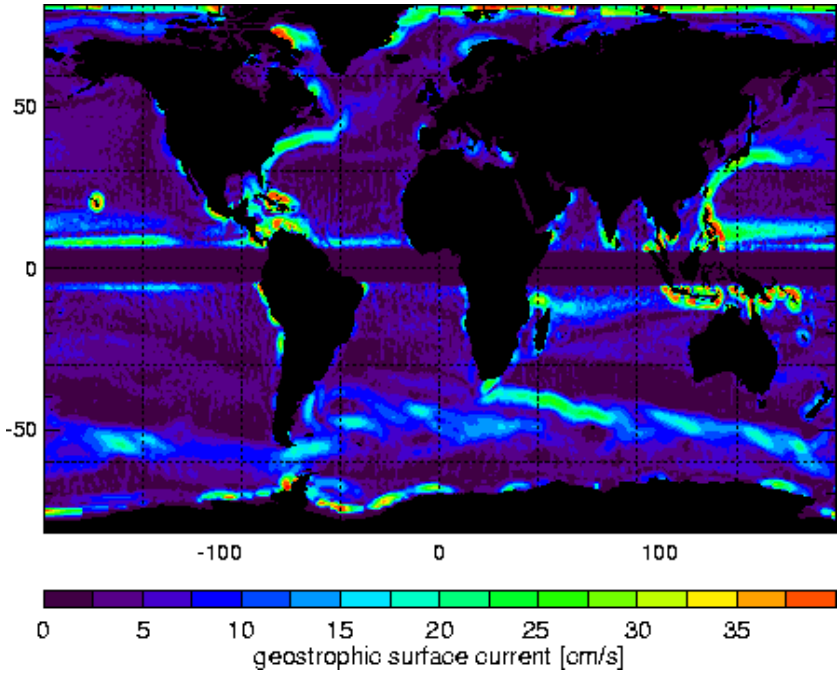
GRACE instrumentation

As its predecessor CHAMP (Challenging Mini-Satellite Payload), each of the GRACE satellites is equipped with a GPS receiver for positioning, an accelerometer approximately 10 times more precise than the CHAMP accelerometer to measure non-gravitational accelerations acting on the GRACE satellites due to air drag or solar radiation pressure, and two star sensors to determine the satellite orientation. The highly-accurate inter-satellite ranging system HAIRS, uniquely designed by the NASA Jet Propulsion Laboratory (JPL), constitutes the core of the instrumentation.

Complementing the payload, the GeoForschungsZentrum Potsdam had provided two laser retro-reflectors (LRR) identical to the CHAMP LRR. They serve both for the direct distance measurement between laser ground stations and the GRACE satellites with a few millimetres accuracy and an independent checking of the satellite orbits as computed on the basis of GPS tracking data.



Schematic view of GRACE instrumentation. (Fig: Astrium)



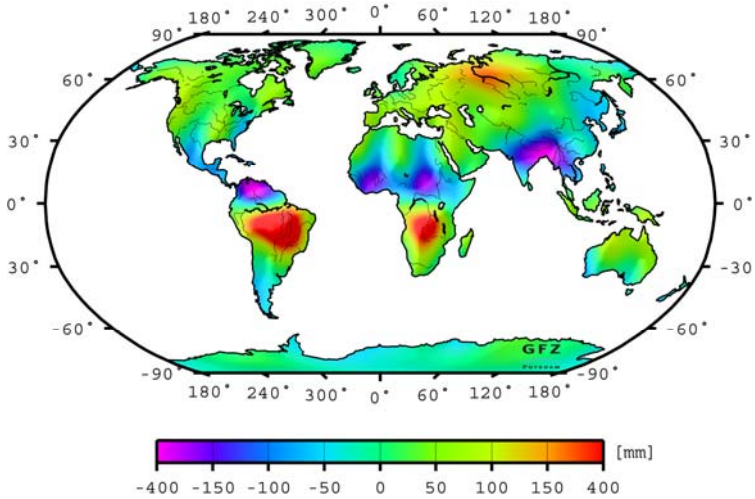
Geostrophic surface currents as derived from GRACE gravity field models. The entire set of major ocean currents can be identified. (Fig: GFZ Potsdam)

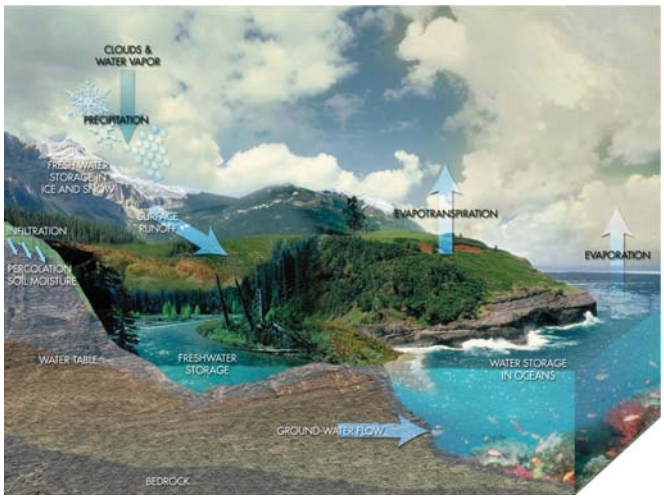
Water – a Main Actor on Climate

The immense accuracy of the distance measurements allows to map the Earth gravity field approximately once a month over a period of several years. From the temporal variations geo-scientists have already derived new insight into dynamic processes in the Earth interior, into water mass transfer processes over land and in the oceans and into the development of ice sheets and glaciers on Greenland and Antarctica. With the GRACE mission, for the first time a systematic and thorough monitoring of the amounts of water, ice and matter moving around is performed and thus a completely new picture of the dynamic processes within and on the Earth emerges.

On the other hand, these parameters serve the mapping of water transfer processes between land, ocean and atmosphere and are key input for climate modelling.

In addition, the GPS signals travelling through the atmosphere and received by CHAMP and GRACE can be used to obtain vertical temperature and humidity profiles of the atmosphere, a technique called atmosphere sounding (occultation measurements).

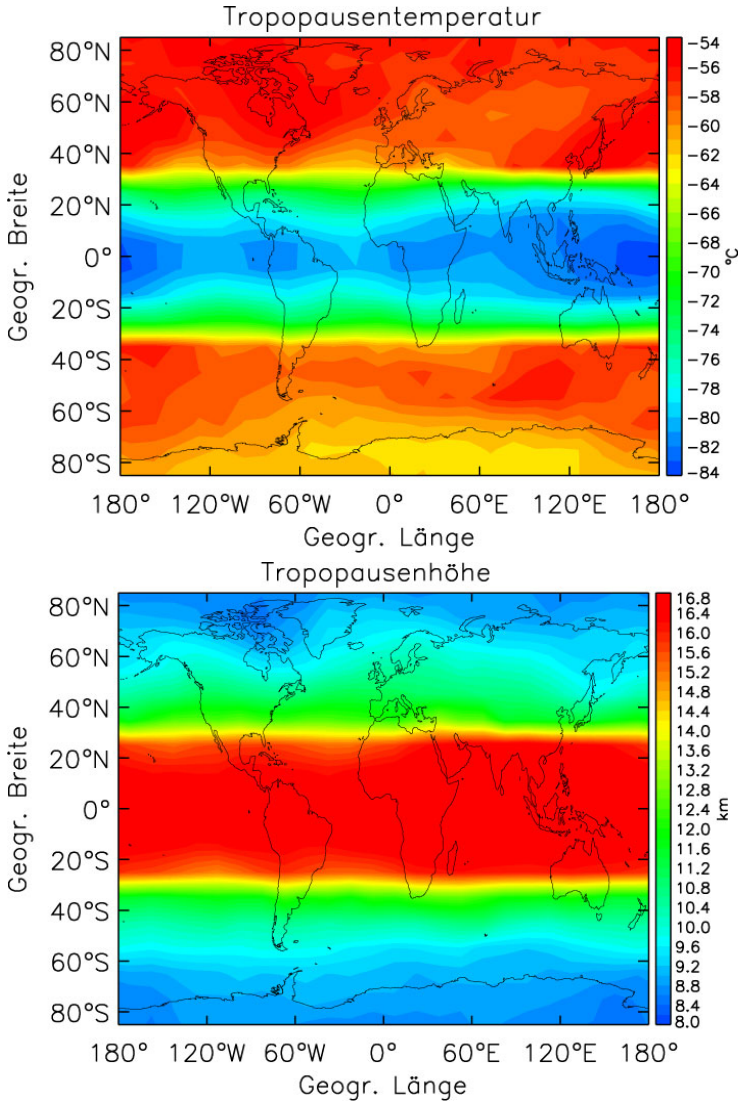




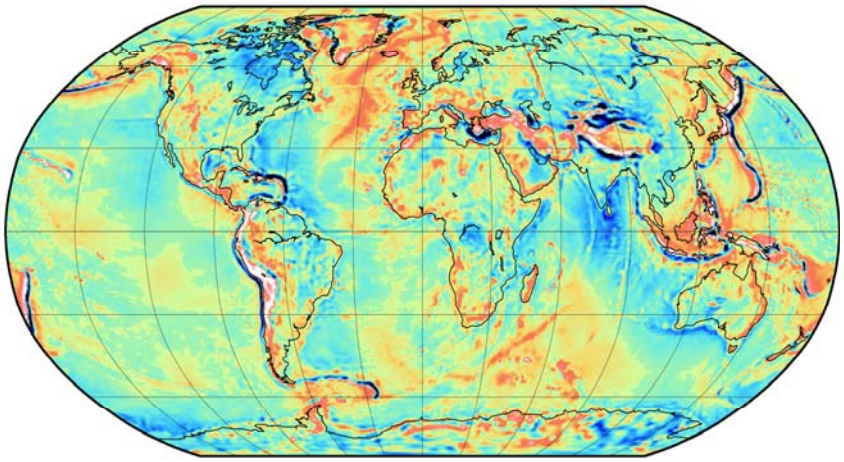
GRACE derived temporal hydrological annual mass variations (left, in mm equivalent water column) due to mass redistribution in the global hydrological cycle (right). (Fig: GFZ Potsdam)

In atmosphere sounding the scientists take advantage of the fact that the radio signal refraction of the GPS satellites differs according to temperature- and humidity-induced density variations.

The figure to the right shows the mean global tropopause temperature (top) and height (bottom) derived from approximately 250.000 CHAMP occultation measurements between May 2001 and December 2005. Temporal variations of these parameters are indicators for climate change. As an example, global warming leads, among others, to an (on an average) increased tropopause height (expansion of tropopause).



Mean global tropopause temperatures (top) and height (bottom) derived from approximately 250.000 CHAMP occultation measurements between May 2001 and December 2005. (Fig: GFZ Potsdam)



Gravity anomalies derived from the EIGEN-GL04C high-resolution gravity field model. (Fig: GFZ Potsdam)

GRACE: International Cooperation for Solving Global Environmental Issues

GRACE is a direct successor of the second satellite of the GFZ Potsdam, CHAMP, and represents a prime example of international cooperation in geo-sciences. The satellite tandem GRACE is a joint project of the American space agency NASA, and the German Aerospace Center (DLR). The German Space Operations Center of DLR is responsible for satellite operation and data reception. Mission Management is performed by the Center for Space Research (CSR), Austin (PI Prof. Byron Tapley) and NASA/JPL. The two satellites were manufactured by the company Astrium GmbH in Friedrichshafen. Rocketing the spacecrafts into orbit was performed by the German-Russian enterprise Eurockot. JPL, CSR and GFZ are responsible for the scientific data analysis. Prof. Ch. Reigber, the GRACE Co-PI and head of the European GRACE Science Team, is in charge of the scientific management at GFZ Potsdam.

The GRACE satellites were developed and manufactured for NASA/JPL by Astrium GmbH in Friedrichshafen and tested at IABG in Ottobrunn. (Fig: Astrium)

Launch on March 17, 2002 from the cosmodrome Plesetsk in northern Russia. (Fig: Eurockot)

The GFZ Potsdam is a member of the Helmholtz-Association of German Research Centres

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