The Superconducting Gravimeter

The Superconducting Gravimeter (SG) works as a relative gravimeter with high sensitivity and temporal stability. The SG uses magnetic levitation to suspend a proof mass (Neodymium hollow sphere) in a magnetic field of superconducting coils. A change in gravity or motion of the ground generates a voltage in a feedback loop which is recorded with high precision.

Properties:
- extremely sensitive: ca. 0.1 mm/s²
- high signal-to-noise ratio
- long-term stability
- low, almost linear drift
- broad frequency range

Design:
- sensor (inside Dewar filled with liquid helium (4.2 K))
- cooling system, capable to re-liquefy helium gas
- temperature regulation (0.001 K)
- feedback system and registration

Feedback System:
- The AC signal (position of the sphere in the capacitor) is amplified, demodulated, filtered and applied to an integrator
- Feedback coil: • Upper and lower plates: hemispherical cap surrounding the sphere (10 kHz reference signal)
• Center plate: spherical cap around the center of the sphere (10 kHz reference signal)
- The DC output is connected to a precision resistor in series with a five-nanowatt feedback coil (below the sphere).
- The resulting feedback force is proportional to acceleration of the sphere.
- The voltage is measured by a high precision voltmeter
- Increased linear dynamic range and rapid response.

Global Geodynamics Project – The international Network of Superconducting Gravimeters

The purpose of Global Geodynamics Project (GGP) is to record the Earth's gravity field variations with high accuracy at a number of worldwide stations using superconducting gravimeters (SGs). The data is used in an extensive set of studies of the Earth, ranging from global motions of the whole Earth such as the Chandler wobble to the gravity effects of the atmosphere, and water storage changes. The GGP stations are run independently by national groups of scientists. GGP is proposed as a candidate new permanent service in the International Association of Geophysics.

World-wide distribution of SG sites in the Global Geodynamics Project

Signals measured by Superconducting Gravimeters

Superconducting gravimeters cover a wide range of signals, starting from long period tides over seasonal and daily variations and ending in the band of the seismic normal modes: • Earth tides: 18.6 years (lunar period) to quarter diurnal periods • Ocean tide loading • Atmospheric mass changes and deformations • Polar motion (diurnal, annual, Chandler period) • Water storage changes • Precise oscillations of the Earth core

The residual gravity signal of the superconducting gravimeter is a global network of reference sites. It provides important information about mass transport and height changes within the system Earth. It can be used for comparison with time dependent satellite gravity field models, global hydrological models or observations related to changes of the hydrosphere and cryosphere.

Measuring Principle

Suspension force:
• Currents “trapped” in the superconducting coils, inducing secondary currents on the surface of the superconducting sphere (Faraday induction law)
• The sphere is floating!

The levitation force is extremely stable in time since no resistive (ohmic) losses are present which would cause a decay of the currents over time.

The superconducting elements are made of Niobium (Nb), which has superconducting properties (zero resistance) below 9.2 K:
- Levitated mass: Hollow sphere with a diameter of 2.54 cm and mass about 5 g
- Field coils: Axially aligned, below the center of the sphere and about 2.5 cm below the sphere.
- Magnetic shield: Generated by two Niobium wire coils

Displacement transducer
• Capacitance bridge is placed around the sphere (three plate capacitor, phase-sensitive lock-in amplifier)
• Upper and lower plates: hemispherical cap surrounding the sphere
• Center plate: spherical cap around the center of the sphere
• The AC signal from the center ring is proportional to the displacement of the sphere from the center of the bridge.

The Superconducting Gravimeter is the most sensitive, stable instrument for measuring Earth's gravity changes.