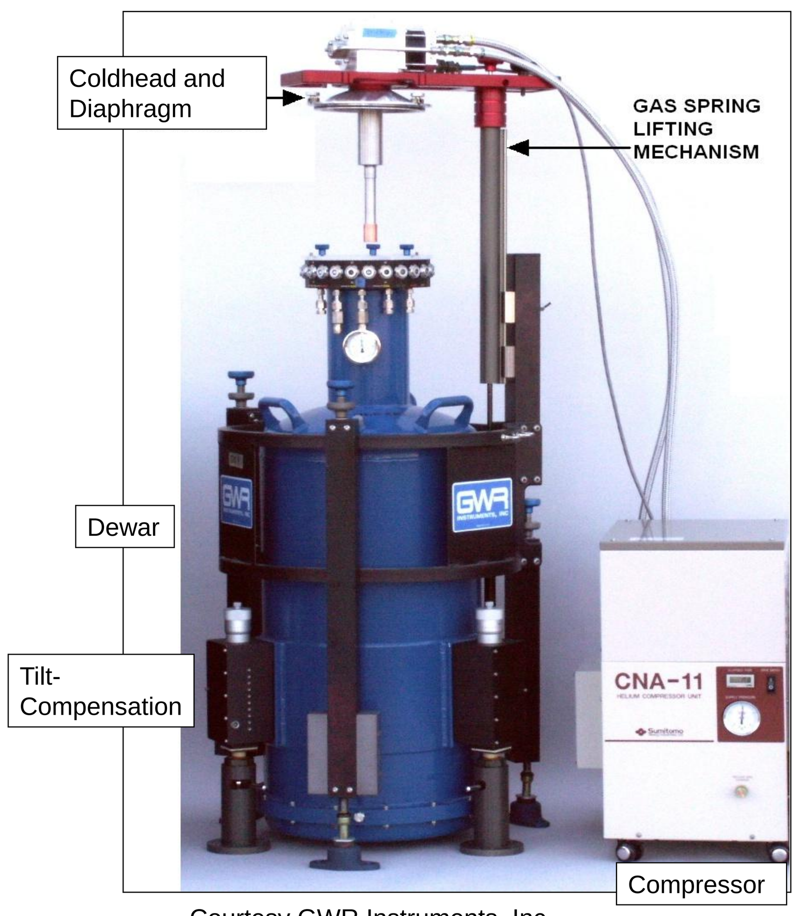
Federal Agency for
Cartography and Geodesy

The Superconducting Gravimeter

The most sensitive, stable instrument for measuring Earth's gravity changes

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.



Courtesy GWR Instruments, Inc.
http://www.gwrinstruments.com/

Present day observatory SG with a small dewar, efficient cooling system which allows to re-liquefy Helium gas.
Cold head in lifted position.
No transfer of liquid Helium is required during operation.

Properties:

- enormous sensitivity: ca. 0.1 nm/s^2
- high signal to noise ration
- 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;

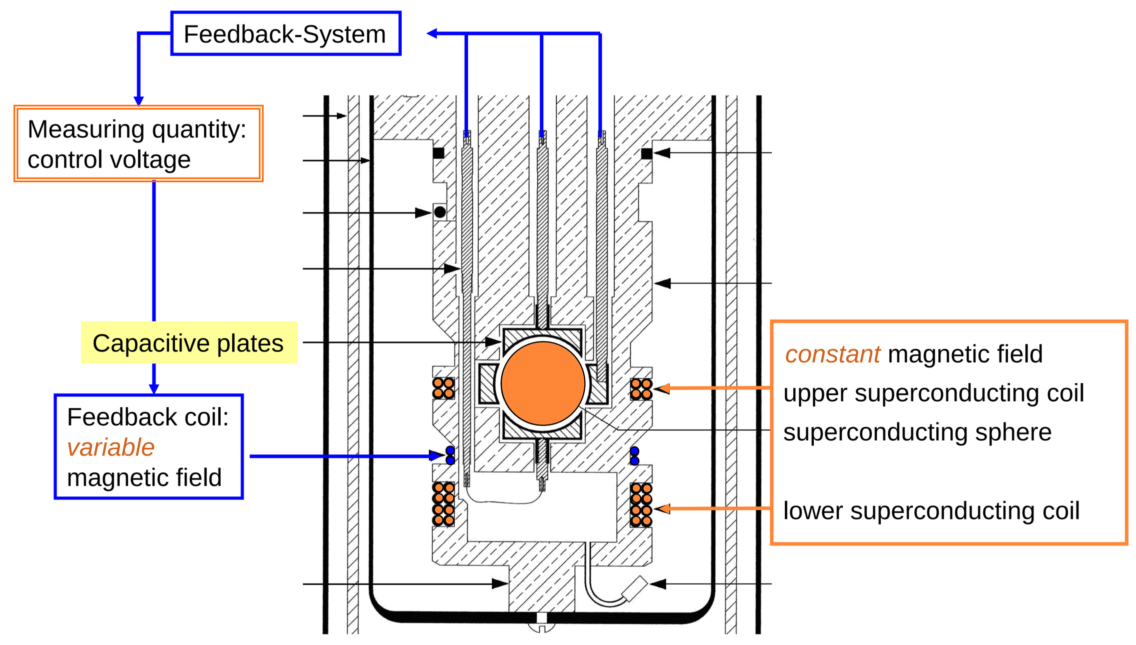
Measuring Principle

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



Cross section through the measuring system of a superconducting gravimeter

Displacement transducer

Capacitance bridge is placed around the sphere (three plate capacitor, phase-sensitive lock-in amplifier):
- Upper and lower plates: hemispherical caps surrounding the sphere (10 kHz reference signal)
- Center plate: spherical ring around the equator of the sphere, 1mm clearance to the sphere.
- The AC signal from the center ring plate is proportional to the displacement of the sphere from the center of the bridge.

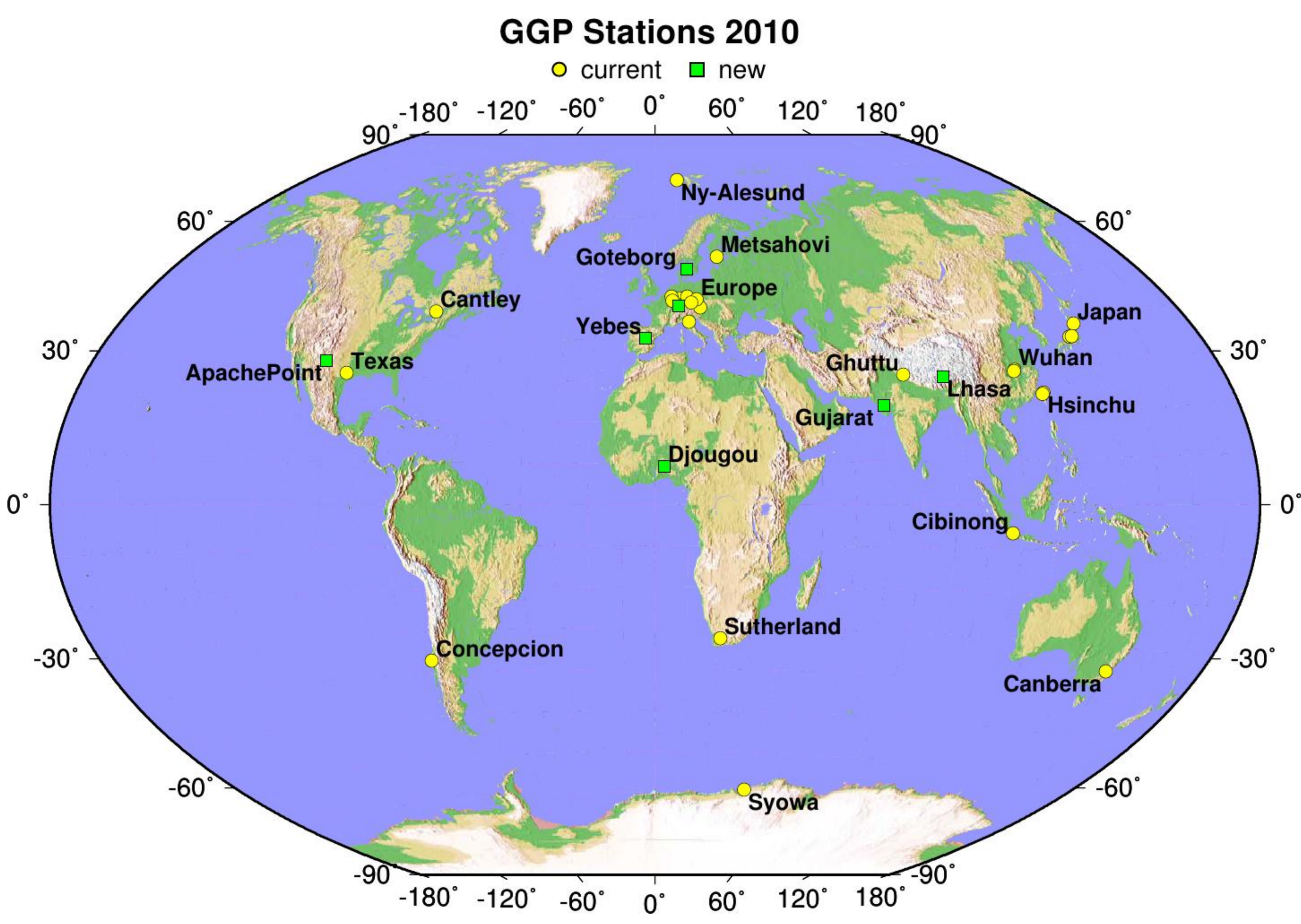
Feedback System:

The AC signal (position of the sphere in the capacitor) is amplified, demodulated, filtered and applied to an integrator network.
The DC output is connected to a precision resistor in series with a five-turn feedback coil (below the sphere).

The resulting feedback force is proportional to acceleration of the sphere (gravity changes and displacement).
The voltage is measured by a high precision voltmeter.
Advantage of the feedback control:
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 atmospheric and water storage changes. The SG stations are run independently by national groups of scientists. GGP is proposed as a candidate new permanent services in the International Association of Geodesy.
Station TIGO / Concepcion is one out of 5 stations located at the southern hemisphere.

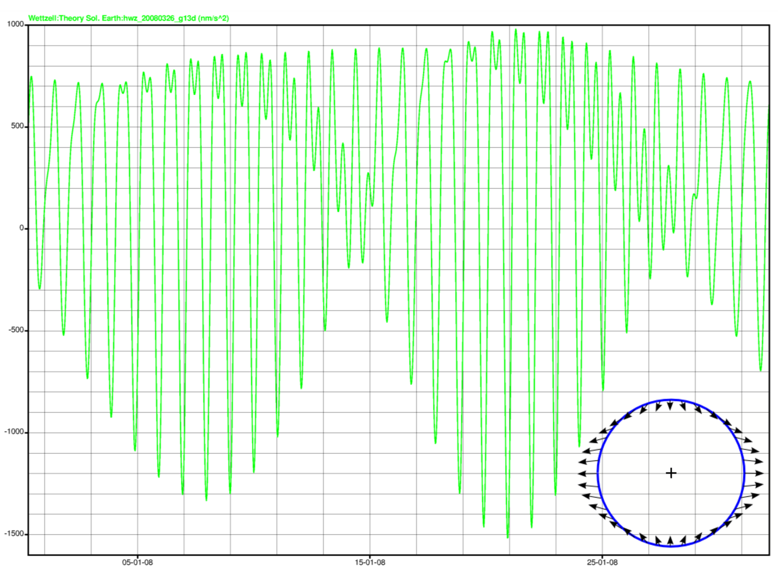


Worldwide distribution of SG sites in the Global Geodynamics Project

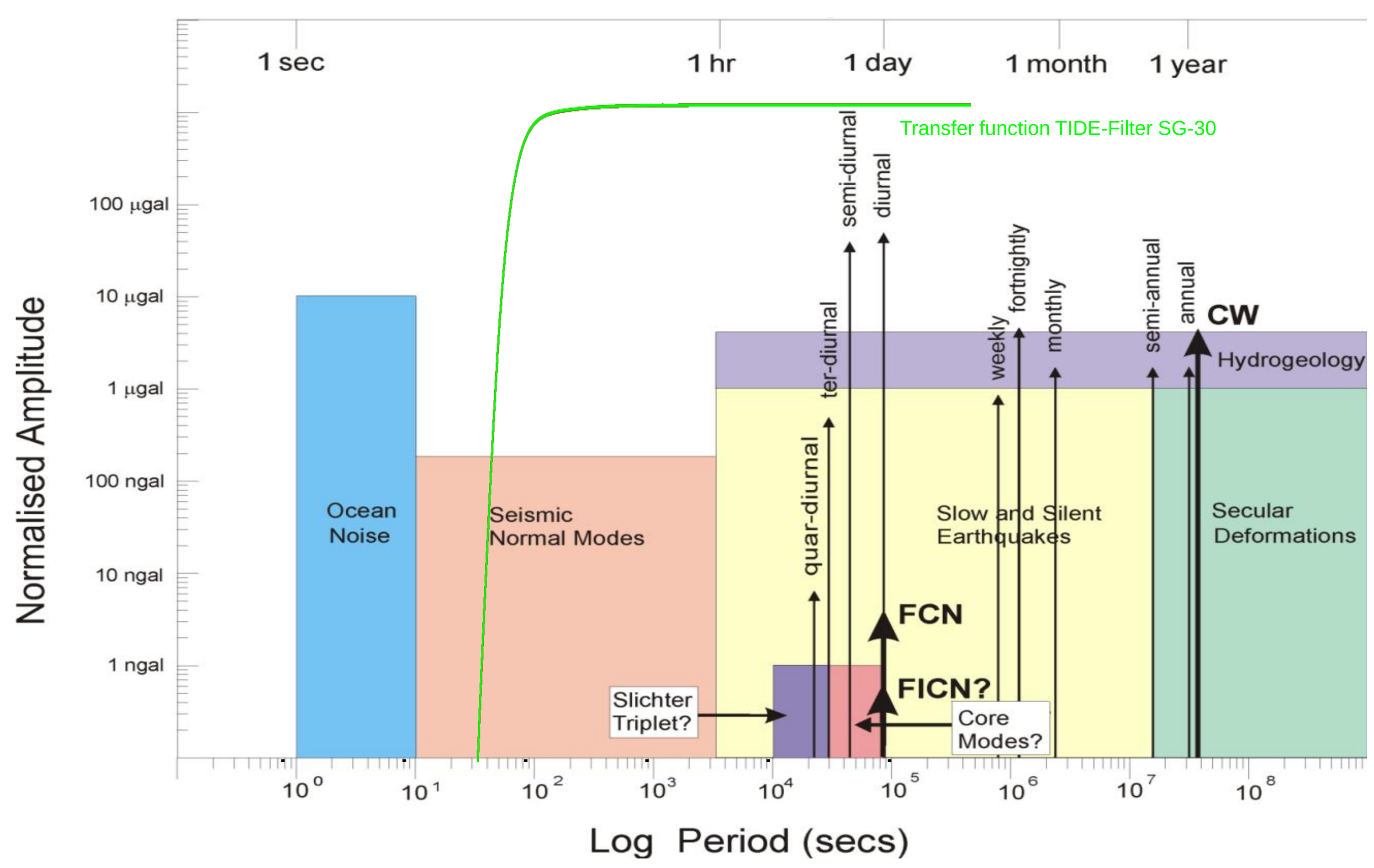
Signals measured by Superconducting Gravimeters

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
- Free oscillations of the Earth core

The residual gravity signal of the superconducting gravimeter in a global network of reference sites provides important information about mass transports 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.



Signal variation due to the Earth tides: ca. 2.5 · 10^{-6} m/s^2



Spectral distribution of signals recorded with Superconducting gravimeters, after Crossley et. al., EOS, 1999.
The green line indicates the frequency transfer function of an SG

Department G4 - National Reference Systems Gravity

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