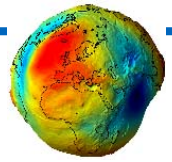




GOCE Gradiometry - A Guide for Users



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Abstract:

The GOCE High-level Processing Facility (HPF) is in charge of the production of the final GOCE level 2 products. The calibrated and corrected gravity gradients form one of these products. Several aspects have to be considered, when using these gradients. E.g. it is important that the nine gradient components can not be measured with equal accuracies. The reason is that the GOCE gradiometer consist of six accelerometers, which only have two high sensitive axes and one less sensitive axis, each. Moreover, the error spectra of the gradients show that an accuracy of a few mE/sqrt(Hz) (E=Eötövös; 1E=10-9/s2) can only be reached within the measurement bandwidth of the gradiometer from 5 to 100 mHz. It is also important to keep in mind that for GOCE several reference frames play a role. The gradients are measured in the Gradiometer Reference Frame (GRF). This reference frame is instrument-fixed and differs by a few degrees from the Local Orbital Reference Frame (LORF), which is defined by the instantaneous direction of the velocity vector. Besides the gravity gradients themselves the product contains also additional information, like corrections to the gradients due to temporal gravity variations. This information can be used to gain the sought-after static gravity field information from GOCE. This poster summarizes the important aspects of gradiometry with GOCE.

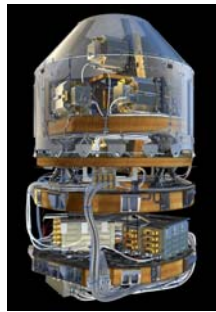
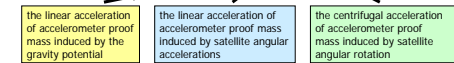


Fig.1: GOCE gradiometer. One of the two key sensors of the GOCE mission is the gravity gradiometer. (The second key sensor is the space GPS receiver). The GOCE gradiometer consists of three pairs of identical accelerometers, which are mounted on three mutually orthogonal arms. This allows the simultaneous measurement of six independent but complementary components of the gravity field.

From acceleration measurement to Gravity Gradients:

Measured accelerations, not taking into account accelerometer bias and scale factors, misalignments, centre of mass displacements, etc.:

$$\mathbf{a} = -\mathbf{V} \cdot \mathbf{r} + \dot{\boldsymbol{\omega}} \times \mathbf{r} + \boldsymbol{\omega} \times (\boldsymbol{\omega} \times \mathbf{r})$$



Differential accelerations, example accelerometer-pair 1-4:

$$a_{d,1,4,x} = \frac{1}{2}(a_{1,x} - a_{4,x}) = \frac{1}{2}(-V_{xx} - \omega_y^2 - \omega_z^2) \frac{L_x}{2} - \frac{1}{2}(-V_{xx} - \omega_y^2 - \omega_z^2) \left(\frac{L_x}{2}\right) = \frac{L_x}{4}(-2V_{xx} - 2\omega_y^2 - 2\omega_z^2) = \frac{L_x}{2}(-V_{xx} - \omega_y^2 - \omega_z^2)$$

$$a_{d,1,4,y} = \frac{1}{2}(a_{1,y} - a_{4,y}) = \frac{L_x}{2}(-V_{yx} + \omega_z \omega_x)$$

$$a_{d,1,4,z} = \frac{1}{2}(a_{1,z} - a_{4,z}) = \frac{L_x}{2}(-V_{zx} - \omega_y \omega_x)$$

green highly sensitive axis
red less sensitive axis
magenta combination of two less sensitive axes

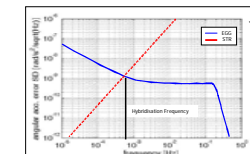
In analogy for accelerometer pairs 2-5 and 3-6: $a_{c,2,5,x}, a_{c,2,5,y}, a_{c,3,6,x}, a_{c,3,6,y}, a_{c,2,5,z}, a_{c,3,6,z}$

=> To get the sought-after Gravity Gradients it is necessary to separate the rotational part from the measurements

Gradiometer angular accelerations:

$$2\omega_x = -\frac{2a_{d,3,6,x}}{L_z} - V_{yz} + \omega_y \omega_z + \frac{2a_{d,3,5,z}}{L_y} + V_{zy} - \omega_y \omega_z; \omega_x = -\frac{a_{d,3,6,y}}{L_z} + \frac{a_{d,3,5,z}}{L_y};$$

$$\omega_y = -\frac{a_{d,1,4,z}}{L_x} + \frac{a_{d,3,6,x}}{L_y}; \omega_z = -\frac{a_{d,1,4,y}}{L_x} + \frac{a_{d,2,5,x}}{L_y}$$



Combination of attitude information from gradiometer and from star sensors:

Sophisticated algorithm which basically takes the attitude information from the star sensor below a certain hybridisation frequency and from the gradiometer above this frequency.

Gravity Gradients (for formulas see fig.2)

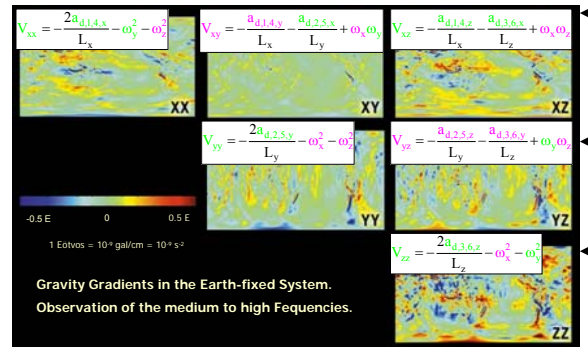
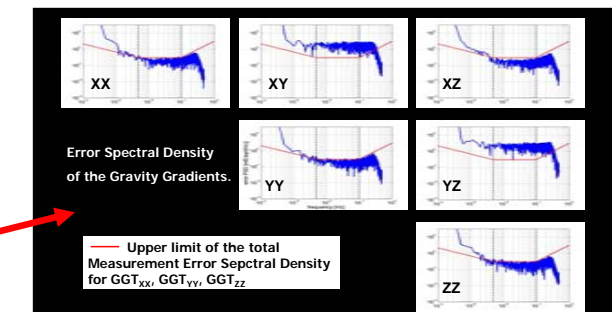


Fig.2: Gravity Gradient Tensor (GGT) components in the Earth-fixed System in a height of approximately 400 km and after subtraction of a Normal Field. Note that the tensor is symmetric, which implies that GGT_{YX}, GGT_{ZX} and GGT_{ZY} equal GGT_{XY}, GGT_{XZ} and GGT_{YZ} respectively and that the sum among the diagonal components is zero. All GGT components in figure 2 are smaller than +/- 0.5 E. GGT_{XX} contains a strong pattern in east-west direction, whereas in GGT_{YY} structures in north-south direction become obvious. GGT_{ZZ} contains both patterns and makes thus visible the tectonic plates. Since the Gravity Field information decreases rapidly with growing height above the Earth, GOCE will be put in a very low orbit of about 270 km.

Fig.6: Note that the extremely high accuracy of a few mE can only be achieved with the components $GGT_{XX}, GGT_{YY}, GGT_{ZZ}$ (and GGT_{XZ}) and only within the MBW (5-100 mHz)!

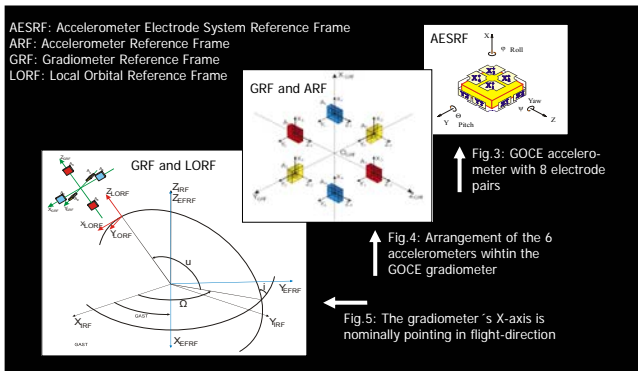


Fig.3, 4, 5: Important GOCE Reference Frames.

The axes of the ARF shown by dashed arrows are aligned with the less-sensitive accelerometer axes (fig.4). The axes of the ARF shown by solid arrows are aligned with the ultra-sensitive accelerometer axes. The GRF is the reference frame in which the gradients are measured and which represents the orientation of the whole instrument with respect to external reference frames (fig5). Because the satellite attitude is controlled by magnetotorques the instrument-fixed GRF differs by a few degrees from the Local Orbital Reference Frame (LORF), which is defined by the instantaneous direction of the satellite's trajectory.