



How to Use GOCE Level 2 Products

Thomas Gruber¹⁾, Reiner Rummel¹⁾, Radboud Koop²⁾

¹⁾ Institute of Astronomical and Physical Geodesy, Technical University Munich

²⁾ Netherlands Institute for Space Research (SRON)

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		<i>GOCE Level 2 Product Data Handbook</i> Doc. No.: GO-MA-HPF-08-0110 Issue: 2.1 Date: 22.09.2006 Page: 1 of 60
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GOCE High Level Processing Facility

GOCE Level 2 Data Handbook

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Prepared by: The European GOCE Gravity Consortium
EGG-C

Content

- GOCE Mission Overview
- GOCE Data Processing Overview
- Reference Frames and Time Systems
- Mathematical Conventions
 - Quaternions,
 - Spherical Harmonic Series,
 - Error Propagation
- Geophysical Conventions
 - Approximations for derived quantities
 - Accurate Formulations
- Level 2 Product Definitions
 - Orbits
 - Gravity Fields & Covariance Matrix
 - Format Descriptions (XML, other)



GOCE Standards



		<p>GOCE Standards Doc. Nr: GO-TN-HPF-GS-0111 Issue: 2.0 Date: 22.09.2006 Page: 1 of 72</p>
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GOCE High Level Processing Facility

GOCE Standards

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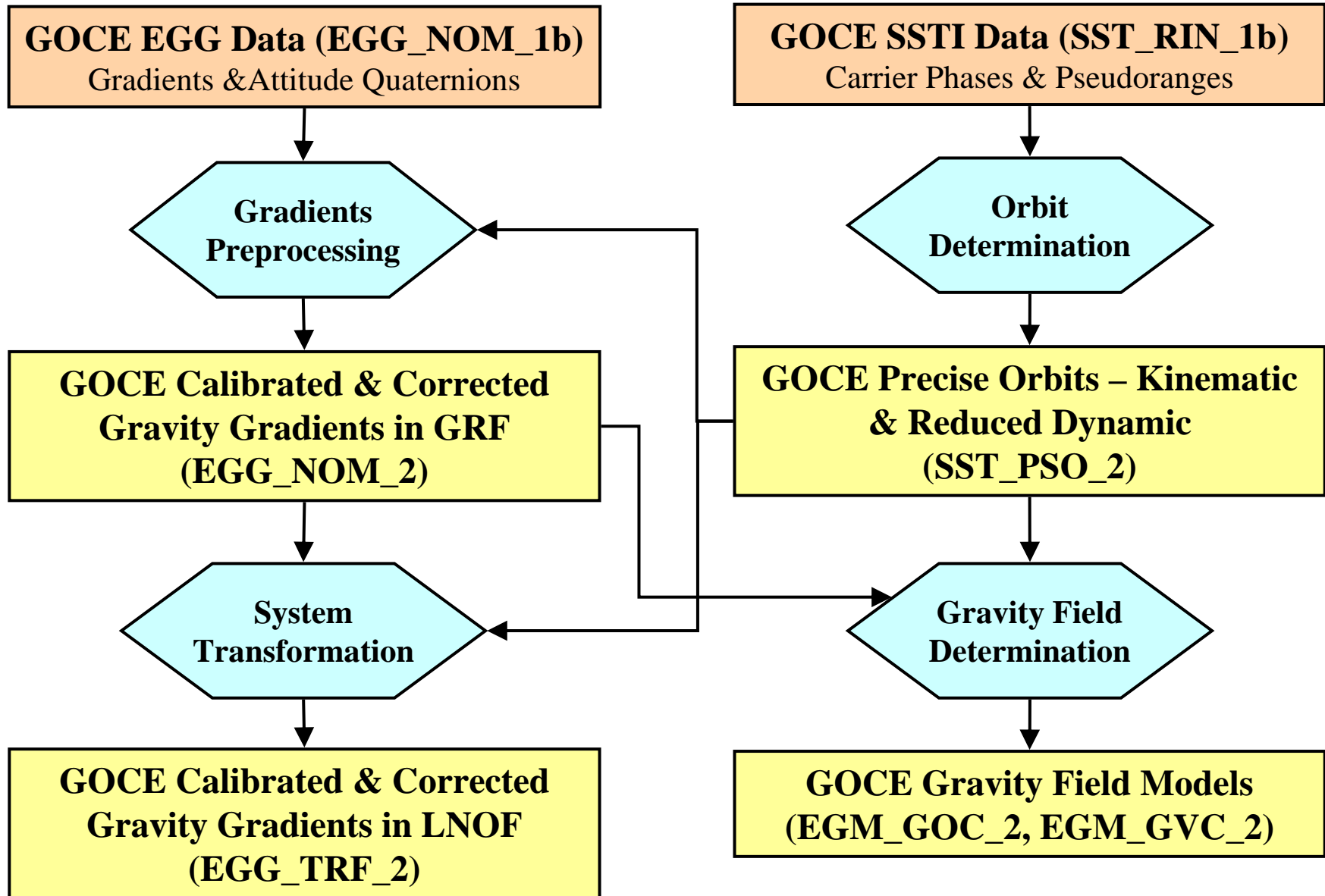
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GOCE Standards implemented for ESA's High level Processing Facility:

- Numerical Standards
- Time Systems
- Reference Systems Definitions
- Transformation between Reference Systems
- Geometrical Models
- Dynamical Models
- Height, Gravity & Tide Systems
- GOCE Reference & Time Systems



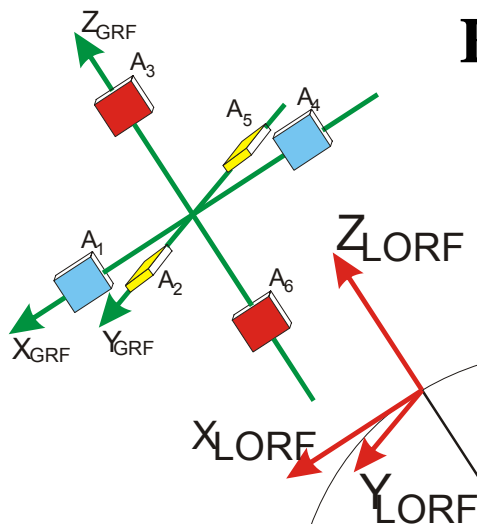
Level 2 Processing – Simplified View





— Calibrated & Corrected Gravity Gradients —

EGG_NOM_2

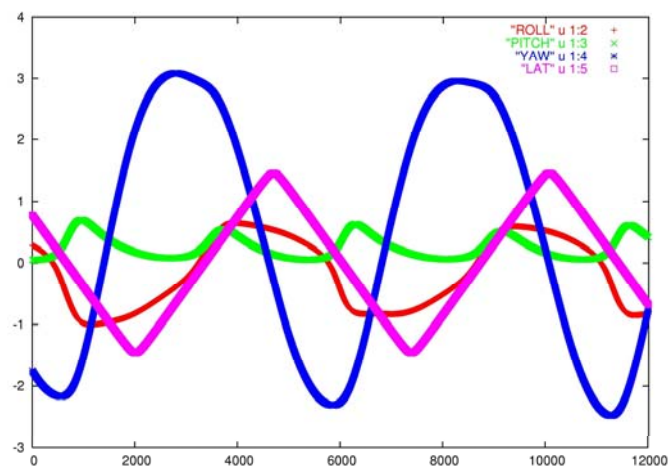


IRF = Inertial Reference Frame
 EFRF = Earth Fixed Reference Frame
 LORF = Local Orbital Reference Frame
 GRF = Gradiometer Reference Frame

GRF vs. IRF

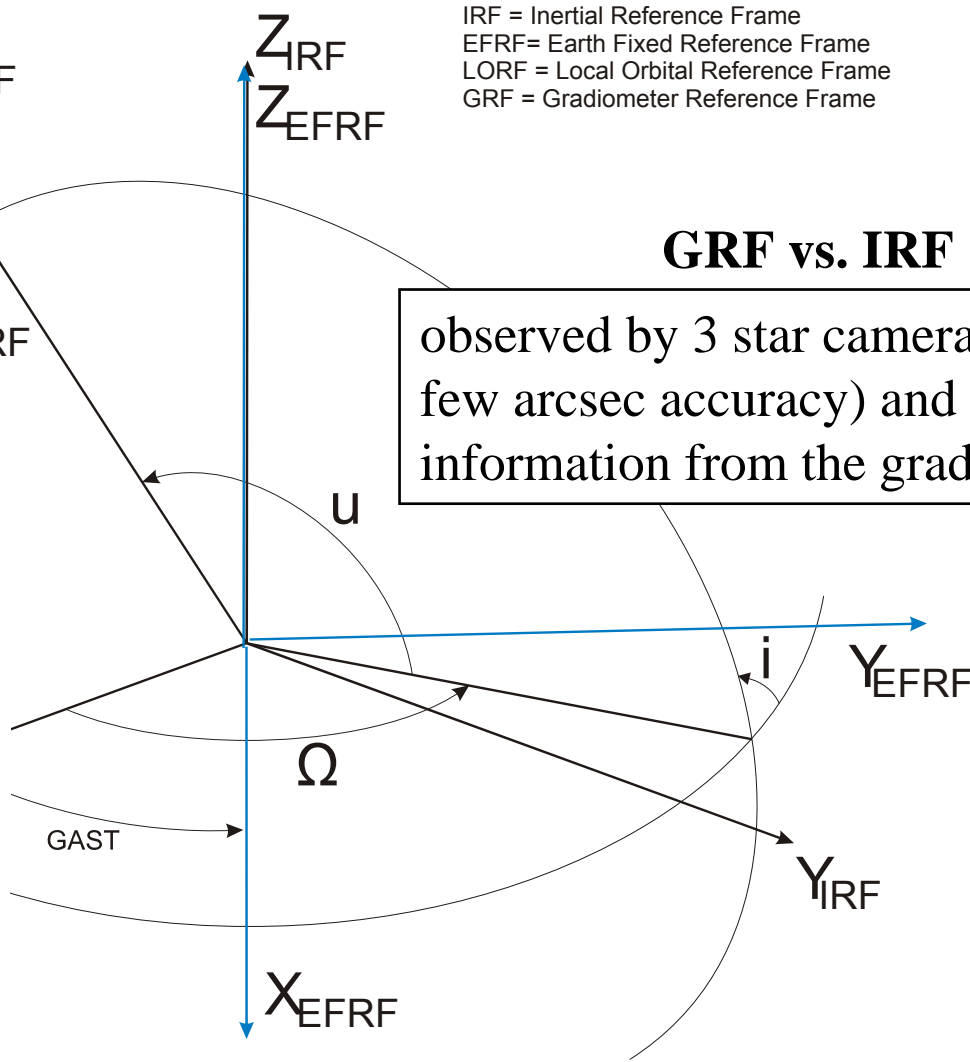
observed by 3 star cameras (with a few arcsec accuracy) and rotational information from the gradiometer.

GRF vs. LORF



Courtesy: P. Visser / DEOS

GAST





— Calibrated & Corrected Gravity Gradients —



Content of EGG_NOM_2

Gravity Gradients in the Gradiometer Reference Frame (GRF) corrected for temporal gravity field variations, outliers, data gaps and externally calibrated

GPS Time	Gradient observation time in [sec]
Gravity Gradients	Externally calibrated & corrected gravity gradients T_{xx} , T_{yy} , T_{zz} , T_{xy} , T_{xz} , T_{yz} in [1/sec]
Errors of Gravity Gradients	Sigmas of all 6 gravity gradients derived from a-priori or HPF estimated gradiometer error model in [1/sec]
Gradient Flags	Flags for each gravity gradient as 1 byte integer. Meaning of bits: Bit 0: Original gradient (from L1B product) Bit 1: Original gradient with temporal corrections added Bit 2: Original gradient with temporal and ext. calibration added Bit 3: Outlier suspected, fill-in provided (from spline interpolation) Bit 4: Outlier suspected, no fill-in, as for bit 2 Bit 5: Data gap, fill-in provided (from spline interpolation) Bit 6: Data gap, no fill-in provided.



— Calibrated & Corrected Gravity Gradients —



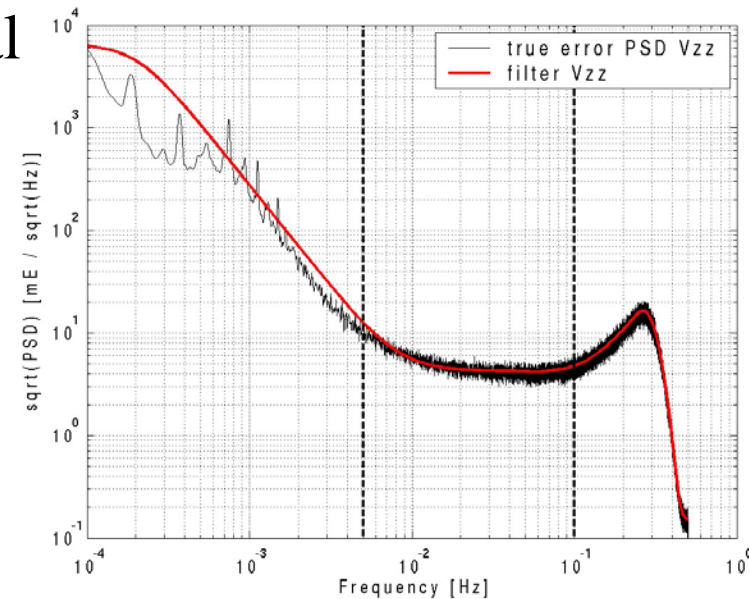
Content of EGG_NOM_2 (Cont.)

Gravity Gradients in the Gradiometer Reference Frame (GRF) corrected for temporal gravity field variations, outliers, data gaps and externally calibrated

Direct Tides	Correction applied for direct tides for all 6 gradients in [1/sec]
Solid Earth Tides	Correction applied for solid Earth tides for all 6 gradients in [1/sec]
Ocean Tides	Correction applied for ocean tides for all 6 gradients in [1/sec]
Pole Tides	Correction applied for pole tides for all 6 gradients in [1/sec]
Non-Tidal Mass Variations	Correction applied for combined atmospheric & oceanic mass variations for all 6 gradients in [1/sec]
External Calibration	Correction applied due to external calibration using global models for all 6 gradients in [1/sec]

How to Use EGG_NOM_2

- Gravity gradients are **un-filtered** (original observations plus corrections applied).
- Errors are estimated **from error model**
- All corrections are **individually removable**
- Interpolated records are marked by flags
- GRF to IRF rotation has to be taken from EGG_NOM_1b product: Inertial Attitude Quaternion Measurement Data Set (IAQ).





Gravity Gradients in Earth-fixed Frame

EGG_TRF_2

Gravity Gradients transformed from the GRF to the LNOF

What is the LNOF ?

Right-handed North-West-Up frame:

- The origin is located at the nominal satellite centre of mass (CoM)
- the Z-axis is Up (from geocenter through satellite CoM).
- the Y axis points to the West (parallel to the normal vector to the plane of the geocentric meridian of the satellite center of mass).
- the X-axis points to the North (parallel to normal vector to the plane defined by Y- and Z-axis).

In geocentric latitude and East longitude (φ , λ) of the GOCE centre of mass in the CTRS the 3 axes are defined as follows:

$$\mathbf{Z}_{\text{LNOF}} = \begin{pmatrix} \cos \varphi \cos \lambda \\ \cos \varphi \sin \lambda \\ \sin \varphi \end{pmatrix}; \quad \mathbf{Y}_{\text{LNOF}} = \begin{pmatrix} \sin \lambda \\ -\cos \lambda \\ 0 \end{pmatrix}; \quad \mathbf{X}_{\text{LNOF}} = \begin{pmatrix} -\sin \varphi \cos \lambda \\ -\sin \varphi \sin \lambda \\ \cos \varphi \end{pmatrix}$$



Gravity Gradients in Earth-fixed Frame



EGG_TRF_2

Gravity Gradients in Local North-Oriented reference Frame (LNOF) corrected for temporal gravity field variations, outliers, data gaps and externally calibrated

GPS Time	Gradient observation time in [sec]
Position	Geocentric latitude in [deg], longitude in [deg], height in [m]
Gravity Gradients	Externally calibrated & corrected gravity gradients T_{xx} , T_{yy} , T_{zz} , T_{xy} , T_{xz} , T_{yz} in [1/sec]
Errors of Gravity Gradients	Sigmas of all 6 gravity gradients derived from a-priori or HPF estimated gradiometer error model in [1/sec]
Gradient Flags	Flags for each gravity gradient as 1 byte integer. Meaning of bits as for EGG_NOM_2.



— Gravity Gradients in Earth-fixed Frame —

How to Use EGG_TRF_2

- In order to minimize errors due to gradient transformation (badly observed gradients map to high quality gradients) a **global model is used as reference**.
- Gravity gradients are filtered, i.e. GOCE observations only in MBW, long wavelength part from a model.
- Product **not applicable for gravity field determination**, but for **geophysical/oceanographic applications**.

SST_PSO_2

Precise science orbits from reduced dynamic approach (positions and velocities) and kinematic approach (positions), both in EFRF. Additionally included is variance-covariance information for the kinematic orbits (over 9 epochs) and the rotation matrix for each epoch from the EFRF to the IRF in terms of quaternions.

Kinematic Orbit	GPS time in [sec] X,Y,Z position in [m] in Earth fixed frame Clock correction Standard deviation of position and clock Variance-covariance matrix for positions (over 9 Epochs)
Reduced Dynamic Orbit	GPS time in [sec] X,Y,Z position in [m] in Earth fixed frame X,Y,Z velocity in [m/sec] in Earth fixed frame Standard deviation of position and clock
Rotation Matrix from EFRF to IRF	GPS time in [sec] Quaternions (4) describing rotation angles



How to Use SST_PSO_2

- Positions, velocities and variance-covariance matrix information are given **in EFRF** (1 sec time resolution).
- The **Rotation Matrix** is defined in terms of **Quaternions**. Earth Orientation Quaternions are provided for every integer second of GPS time and are computed according to **IERS Conventions 2003**.
- Rotation Matrix Quaternions have to be interpolated to time of positions applying the **Kinematic Equation** (see L2 Data Handbook).



GOCE Gravity Field Model



EGM_GOC_2

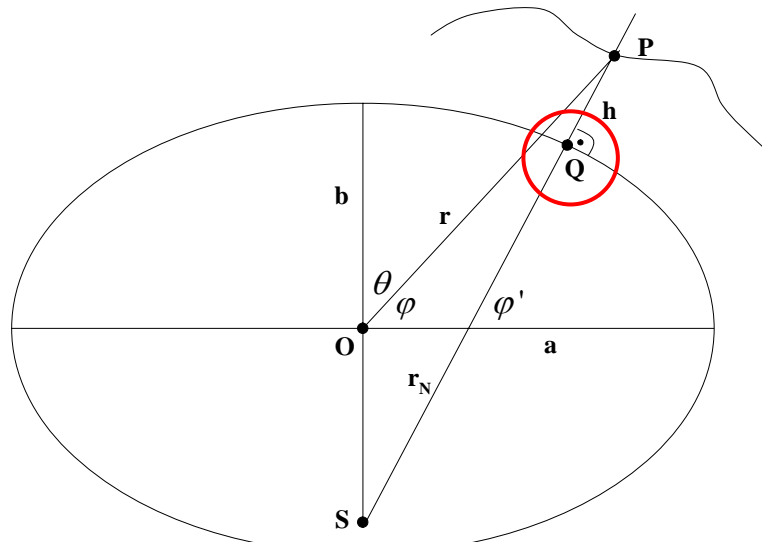
GOCE gravity field model in different representations including geoid error:

Spherical Harmonic Series (SHS)	Degree; order; C/S- coefficients ; Sigmas of coefficients (dimensionless)
Geoid Heights	30'x30' global grid with geoid heights computed from SHS in [m] using wgs84 as reference ellipsoid.
Gravity Anomalies	30'x30' global grid with gravity anomalies computed from SHS in [m/s ²] using wgs84 as reference ellipsoid.
North-South Deflection of the Vertical	30'x30' global grid with North-South deflections of the vertical computed from SHS in [arc-sec] using wgs84 as reference ellipsoid.
East-West Deflection of the Vertical	30'x30' global grid with East-West deflections of the vertical computed from SHS in [arc-sec] using wgs84 as reference ellipsoid.
Geoid Height Error	30'x30' global grid with geoid height standard deviation computed from error propagation of full variance-covariance matrix in [m].

Precise Science Orbits

How to Use EGM_GOC_2

- Spherical harmonic series represents the main result of GOCE.
- For computation of derived quantities approximations are applied.
 - **Computation point on reference ellipsoid**
 - **Spherical approximation** of fundamental equation of physical geodesy (approximating real plumb line by geocentric vector)



$$\Delta g = g_P - \gamma_0 = -\frac{\partial T}{\partial h} + \frac{1}{\gamma_0} \frac{\partial \gamma}{\partial h} T$$

$$\Delta g \approx -\frac{\partial T}{\partial r} - \frac{2}{a^{REF}} T$$

$$\xi \approx -\frac{1}{a^{REF}} \frac{\partial N}{\partial \varphi} \quad ; \quad \eta \approx -\frac{1}{a^{REF} \cos \varphi} \frac{\partial N}{\partial \lambda}$$



GOCE Gravity Field Model



EGM_GVC_2

Complete variance-covariance matrix for the coefficients of the spherical harmonic series of the GOCE gravity field model EGM_GOC_2

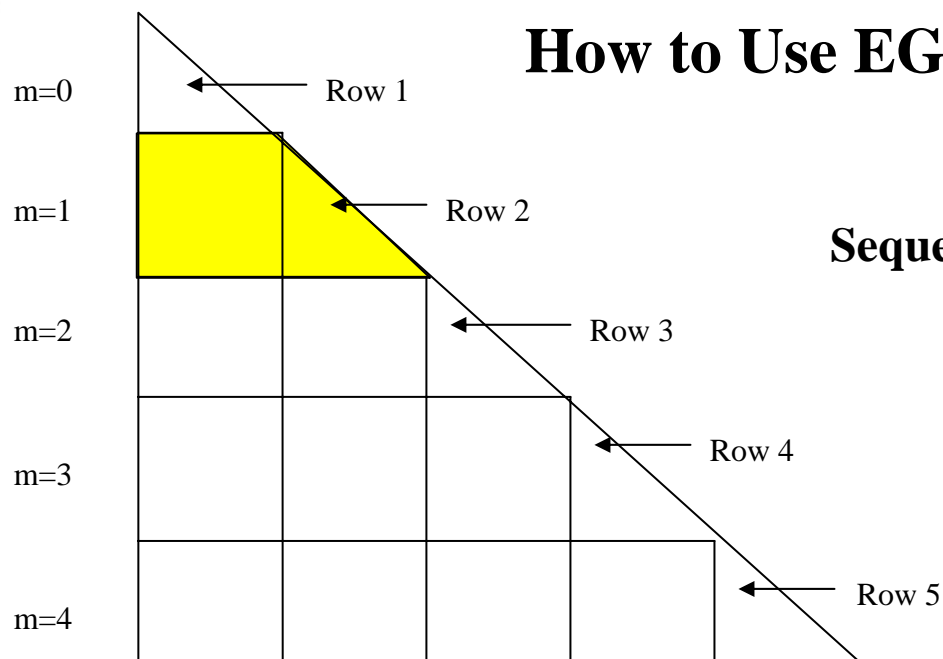
Header File

GM (Earth mass times gravity constant)
a (Radius)
Maximum degree
Sequence of coefficients
Sequence of files

Data File(s)

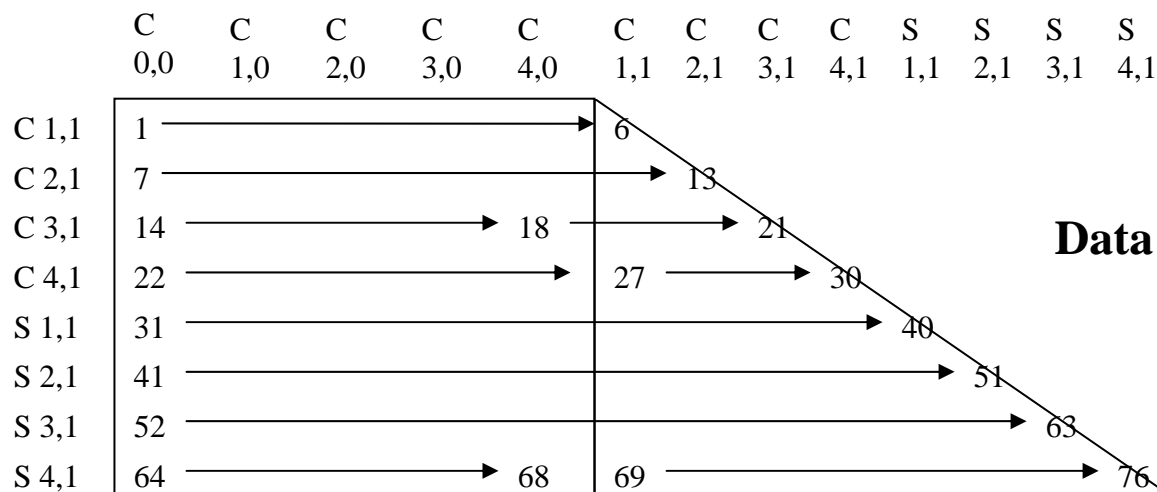
Harmonic order of the file
Number of data values
Data entries for this order

How to Use EGM_GVC_2



Sequence of Files

File Size < 250 MB
Total Product Size: several GB



Data Sequence in File



Conclusions



Complete description of products and formats is provided in the **GOCE Level 2 Product Data Handbook**.

Standards and Models applied in Level 2 processing are defined in the **GOCE Standards Document**.

Gradients are provided in two products:

- **Observed gradients** external calibrated and corrected
- **Transformed gradients** for applications in geophysics & oceanography

Gravity field is provided as spherical harmonic series and derived quantities on grids.

Variance-covariance matrix first time will be available to all users.