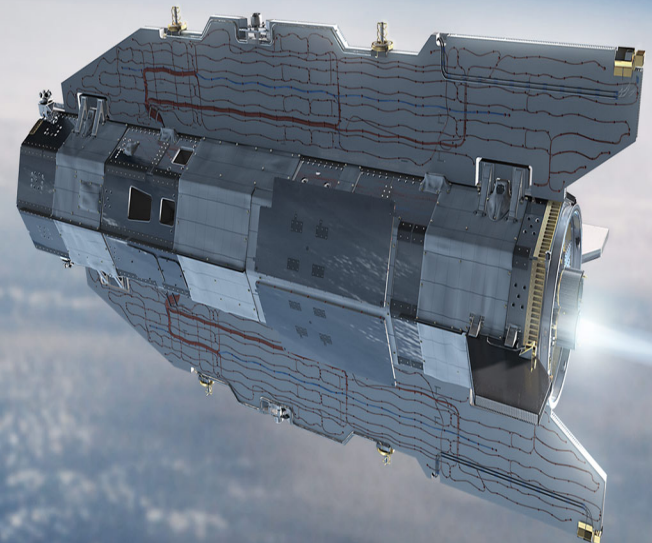
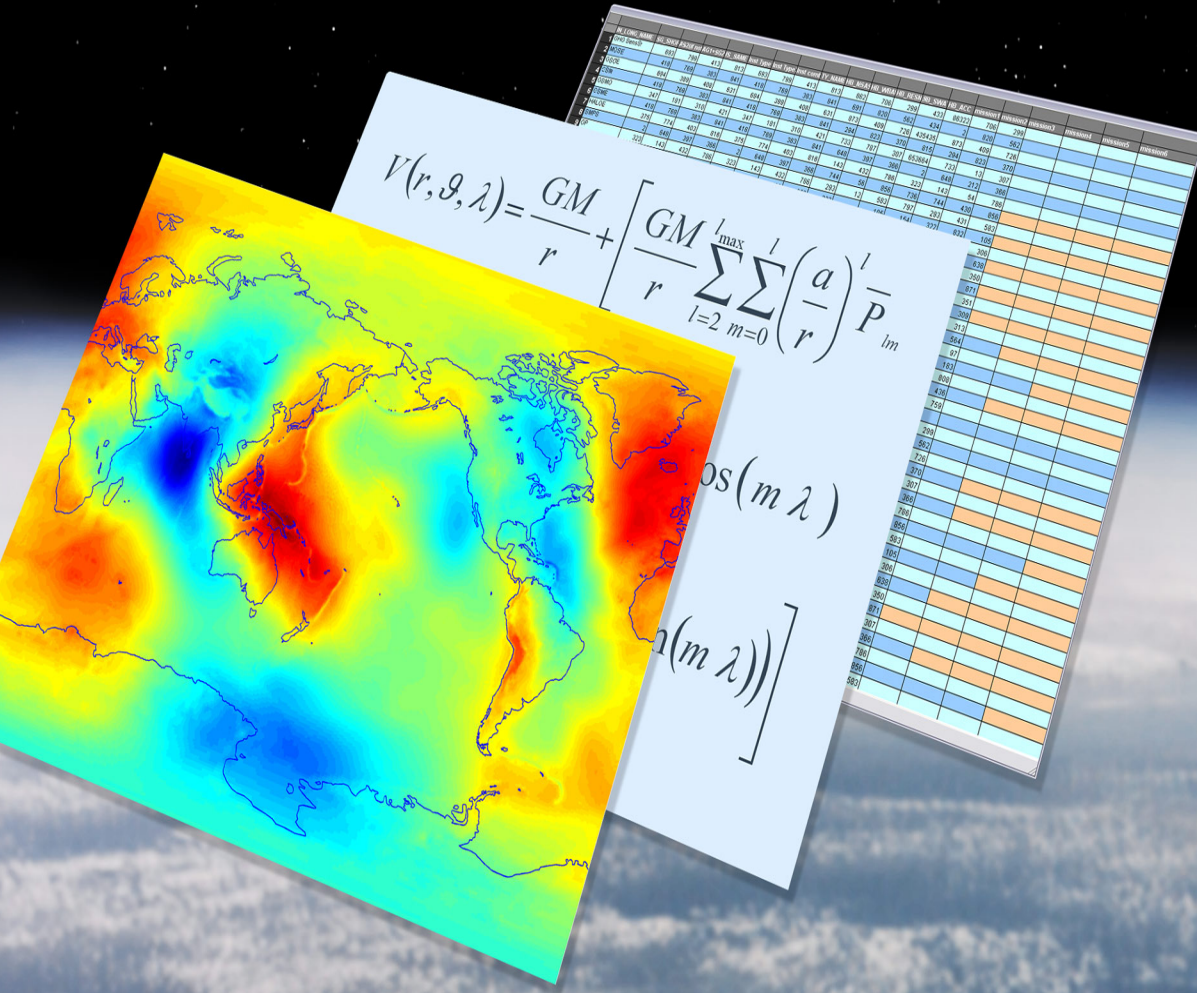


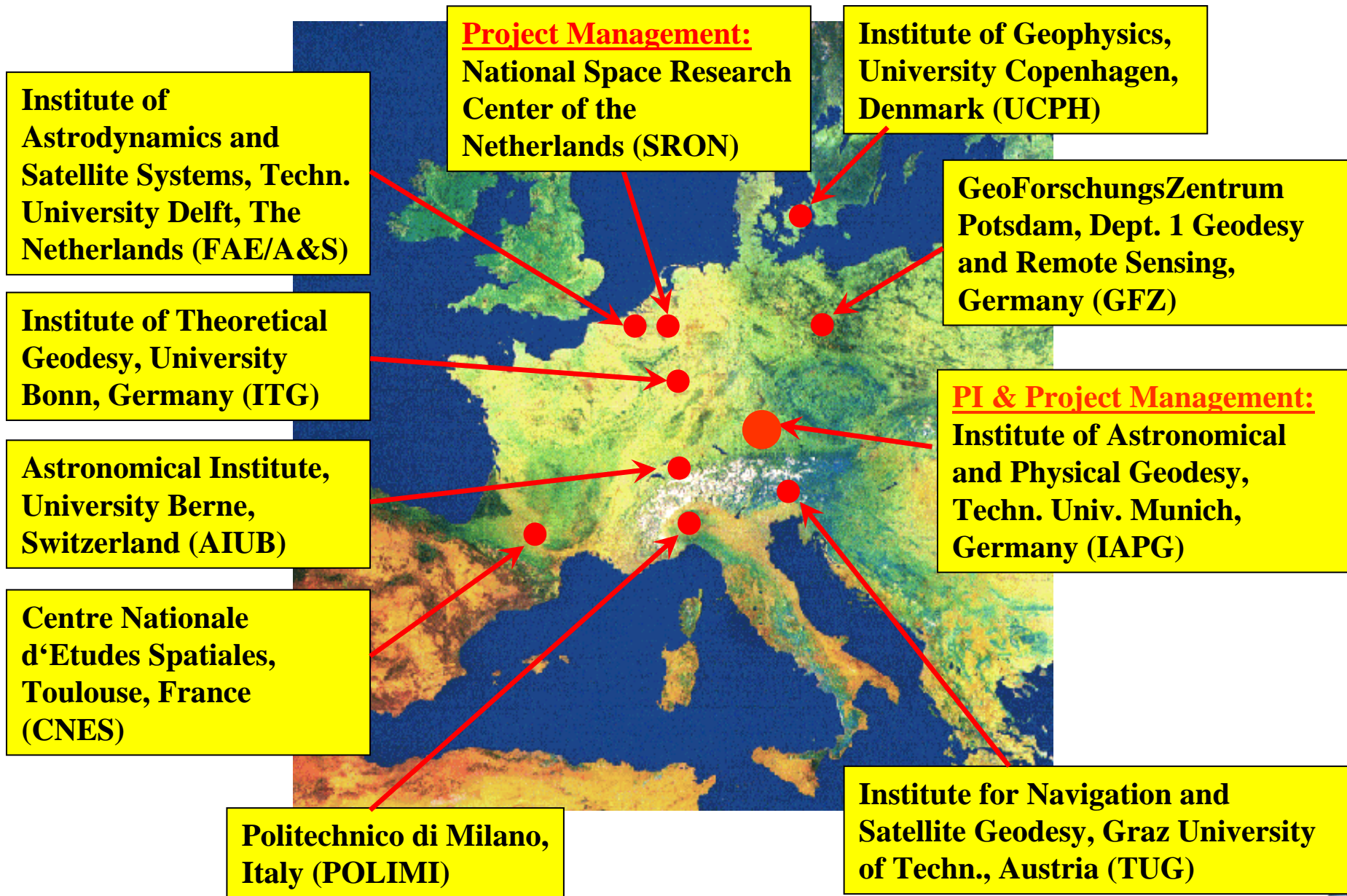
GOCE Science Data Processing System - Status and Plans

Th. Gruber¹, R. Rummel¹,
European GOCE Gravity
Consortium (EGG-C)



¹Institute of Astronomical and Physical Geodesy Technical University Munich

The EGG-C Consortium

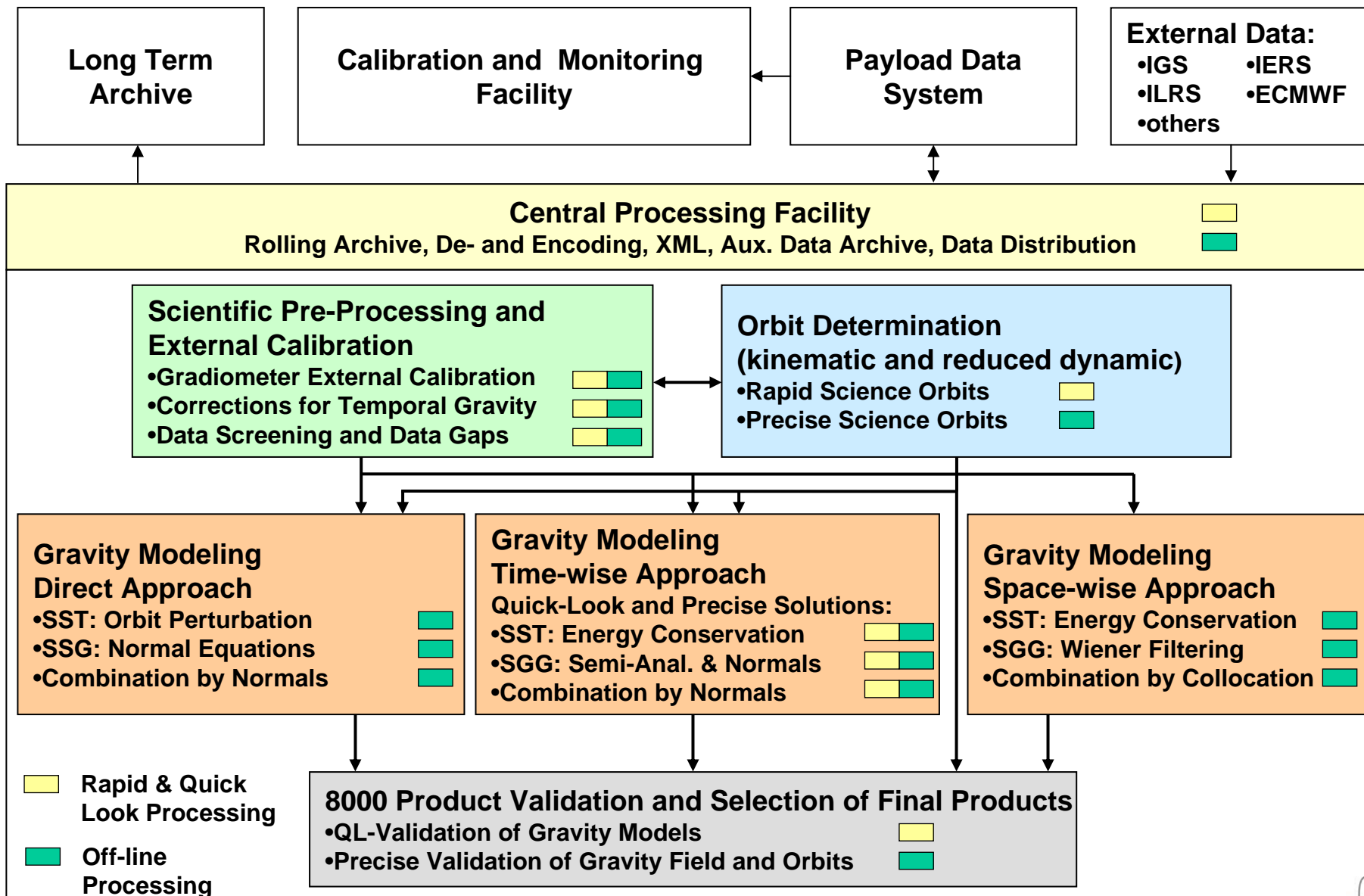


Introduction

Why do we need GOCE Science Data Processing (Level 2)?

- High precision **geo-location of measurements**:
 - Precise science orbits.
- GOCE gradients are **not an easy to use observation**:
 - High precision information only in measurement bandwidth.
 - Various corrections needed on gradients level.
 - Gradients are observed in a moving reference frame.
 - No error information originally available.
- Global **gravity field model** as main result:
 - Pure GOCE model from combination of SST high-low and gradiometry.
 - Derived gravity field quantities and errors for applications.
 - Full variance-covariance matrix for error and correlation analysis.

Science Data Processing System (HPF)



Precise Science Orbits

Identifier	Description
SST_PSO_2	Precise Science Orbits (reduced dynamic and kinematic): <ul style="list-style-type: none">• GOCE precise science orbits final product• Quality report for precise orbits

Detailed Content

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

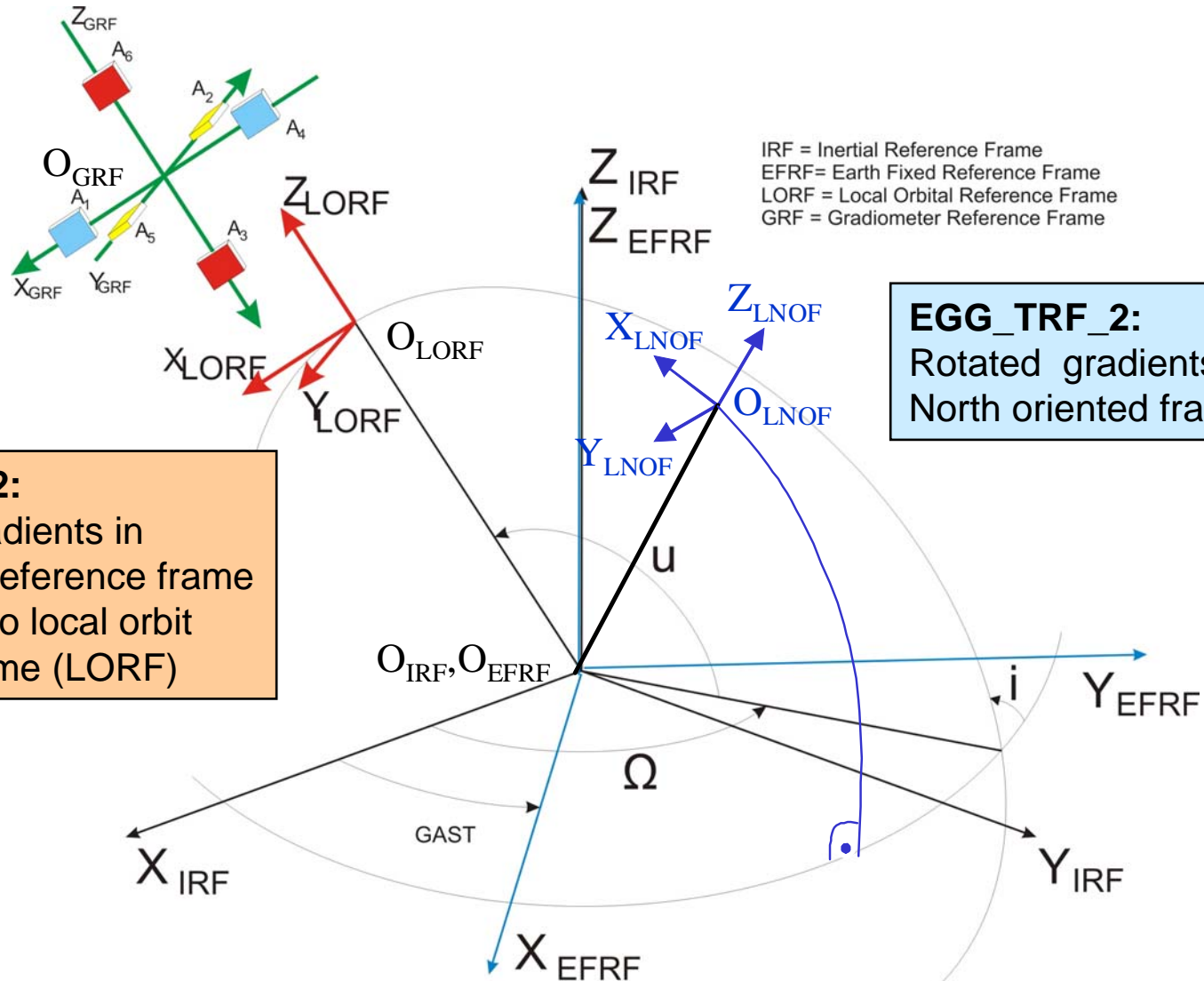
Precise Science Orbits

Remarks

- 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 Level 2 Data Handbook).

Gravity Gradients

Gradiometer Products Reference Frames



Gravity Gradients

Identifier	Description
EGG_NOM_2	Gravity Gradients in Instrument System: <ul style="list-style-type: none">• GPS time.• Externally calibrated and corrected gravity gradients.• Estimated standard deviation for gravity gradient.• Corrections to gravity gradients for temporal gravity variations.• External calibration parameters.• Flags for outliers, fill-in gravity gradients for data gaps with flags.• Inertial attitude quaternions from gradiometer to inertial frame.
EGG_TRF_2	Gravity Gradients in Earth-fixed System: <ul style="list-style-type: none">• GPS time• Location in latitude, longitude height.• Externally calibrated gravity gradients in Earth fixed reference frame.• Estimated standard deviations for transformed gradients.• Flags for gravity gradients• Gradients rotated by replacement of less good observed gravity gradient tensor elements.

For a detailed description refer also to: Bouman, J.; et al.: Preprocessing of Gravity Gradients at the GOCE High-Level Processing Facility; Journal of Geodesy, Vol. 83, Nr. 7, pp 659-678, 2009

Gravity Gradients

Remarks

EGG_NOM_2 (Gradients in Gradiometer Frame)

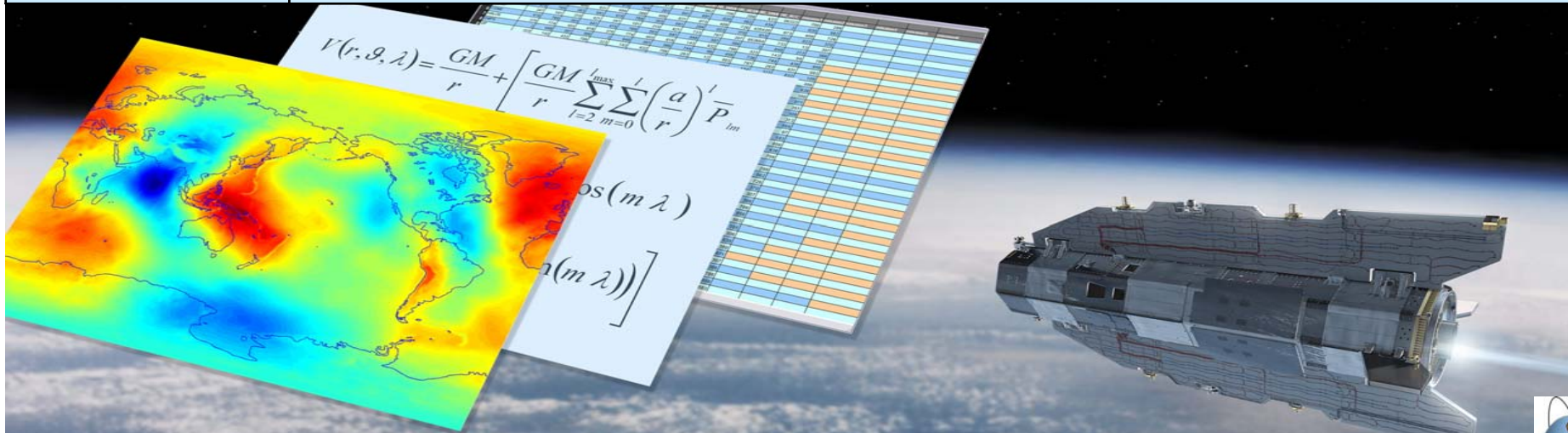
- Gravity gradients are **un-filtered** (original observations plus corrections applied).
- Errors are estimated **from error model**
- All corrections are **individually removable**
- Interpolated records are marked by flags
- GRF to IRF **rotation quaternions are provided** in (L1B MDS - IAQ)

EGG_TRF_2 (Gradients in Terrestrial Frame)

- In order to minimize errors due to gradient transformation (badly observed gradients map to high quality gradients) a **global GOCE 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**.

Gravity Field Model

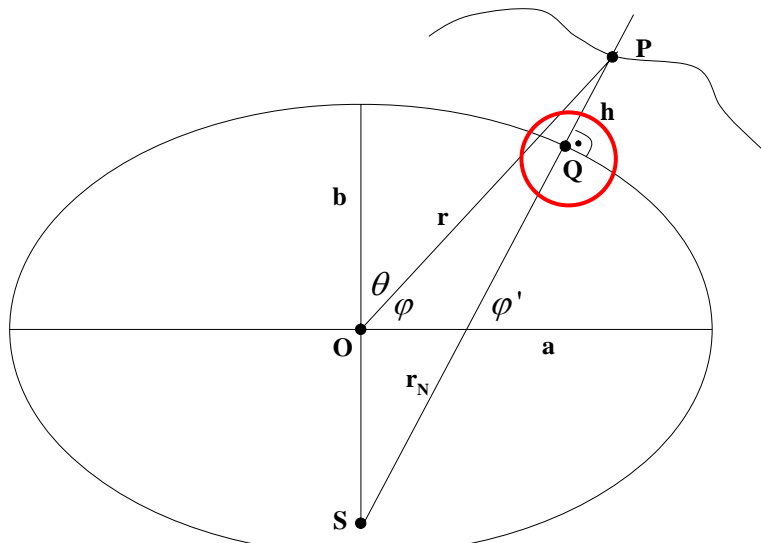
Identifier	Description
EGM_GOC_2	Gravity Field Model: <ul style="list-style-type: none">• Final GOCE Earth gravity field model as spherical harmonic series including error estimates. Target: 1-2 cm / 1 mGal up to degree and order 200 corresponding to 100km spatial resolution.• Grids of geoid heights, gravity anomalies and deflections of the vertical computed from final GOCE Earth gravity field model.• Grid of propagated geoid height error estimates (variances)• Quality report for final GOCE gravity field model
EGM_GVC_2	Gravity Field Error Structure: <ul style="list-style-type: none">• Complete variance-covariance matrix of final GOCE Earth gravity field model



Gravity Field Model

Remarks

- 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)
- For computing derived quantities on Earth surface use **GOCE User Toolbox** together with topography information.



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

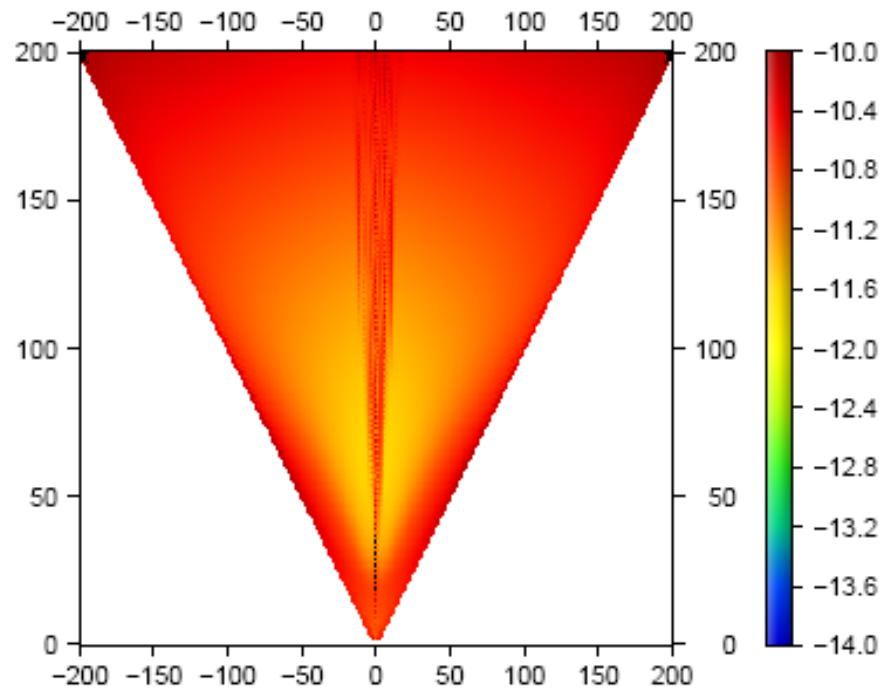
$$\Delta g \approx -\frac{\partial T}{\partial r} - \frac{2}{a^{REF}} T$$

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

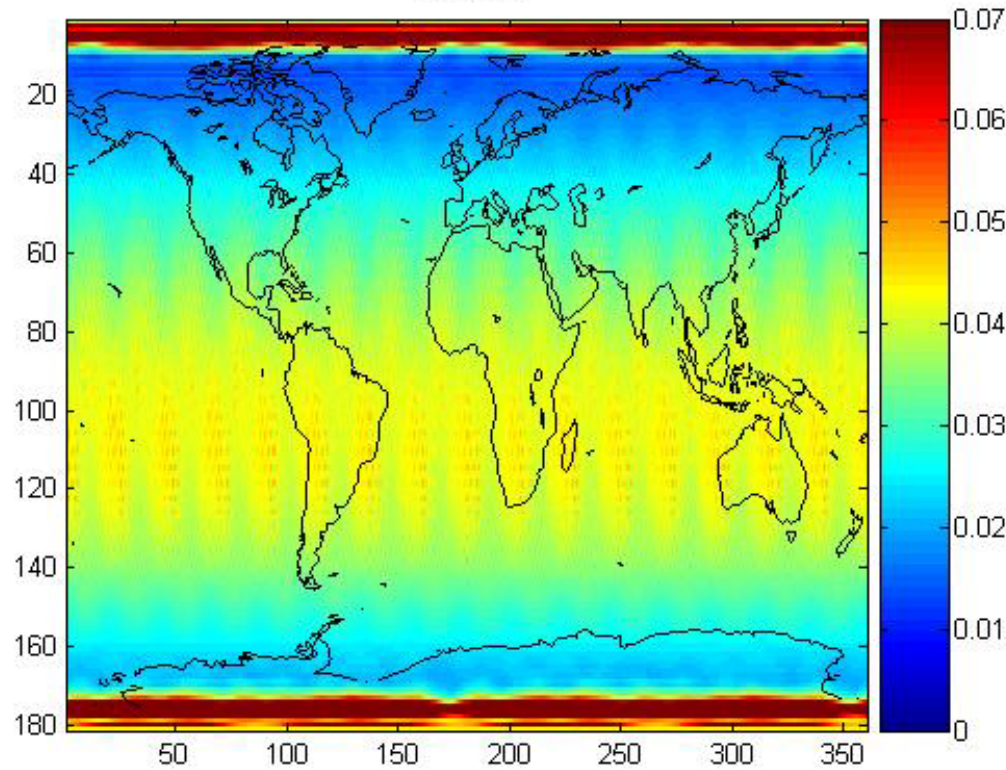
Gravity Field Model

Examples from Simulations

Coefficient Errors



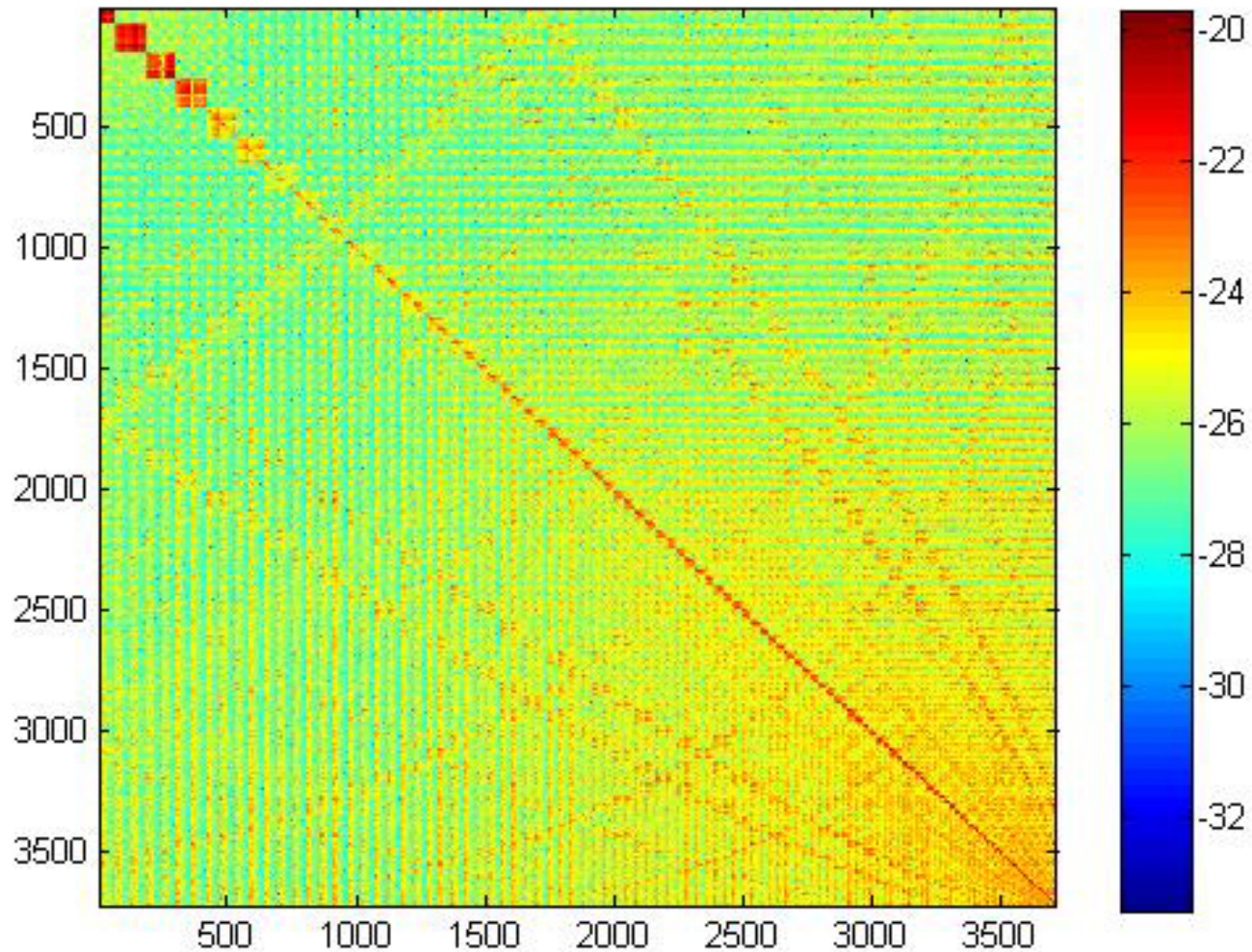
Geoid Height Errors



Gravity Field Model

Examples from Simulations

Variance-Covariance Matrix



Plans for GOCE Product Generation

- First GOCE **measurement phase starts** these days.
- Nominal **level 2 processing** will immediately be initiated after data availability.
- **Rapid orbits and quick-look gravity field** products will be used for monitoring mission performance.
- **Precise science orbits** will be systematically generated with a latency of a few weeks.
- **Gradient products** will be prepared and used for gravity field analysis. Final gravity gradient products will be prepared after positive feedback from mission monitoring.
- **Gravity field generation** will be ongoing during first measurement phase. Goal for **delivery of first GOCE model is (northern) summer next year.**

GOCE Products Documentation

Important Documents - See: <http://earth.esa.int/GOCE/>



GOCE High Level Processing Facility

GOCE Standards



GOCE High Level Processing Facility

GOCE Level 2 Product Data Handbook

Issue 3.1 in April 2009

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

Issue 4.1 in April 2009

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

Prepared by: The European GOCE Gravity Consortium
EGG-C