Presented at EUREF 2004, 2 - 5 June, Bratislava, Slovakia

ON THE FEASIBILITY OF ACCURACY ASSESSMENT OF UPCOMING GRAVITY FIELD MODELS BY MEANS OF ECGN ARRAY

J. Kostelecký[2], J. Klokočník[1], P. Novák[2]

[1)]CEDR, Astronomical Institute of the Czech Acad.of Science, CZ

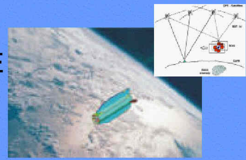
[2)]CEDR, Research Institute of Geodesy, GO Pecný, CZ

Gravity field model is „nothing" without reliable accuracy assessment of its geopotential coefficients and other quantities

Testing the external accuracy of the Earth models becomes more an more important, with increasing accuracy of the models and decreasing access of TESTING data (sub)sets of the highest quality.

Earth's Gravity Field Model evolution

GOCE

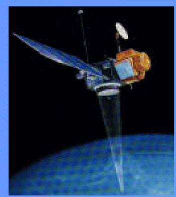


gradiometry
<< near future

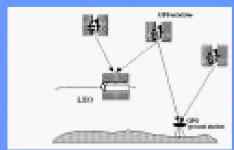
GRACE

CHAMP

LEO (GPS orbitography) +
+ accelerometry << EIGENs

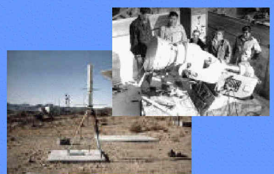


altimetry << GEM T3 ...., Grim 3 ..., TEGs



satellite to satellite tracking << GEM T2, ...

SLR << GEM 5, Grims, OSU



camera and Doppler << first Standard Earths, GEMs, Grims

Evolution of the Earth gravity field models (EM) accuracy assessments

- improving accuracy of EMs with time
- new data – first used for testing EMs
  - then incorporated into the newest EMs of that time
- higher and higher accuracy, resolution, reliability
- large step in quality by altimetry
- large step expected from satellite gradiometry

the basic question

HOW TO TEST EM WHICH IS EXPECTED (DUE TO DATA USED) TO BE THE MOST ACCURATE OF ALL MODELS TILL NOW AVAILABLE WHEN NO TESTING DATA OF COMPARABLE OR HIGHER ACCURACY IS AVAILABLE ?

Status in Earth gravity models (EM) accuracy testing

General requirement: data of accuracy equal or higher than is the accuracy of the tested EMs.

Problem in a near future…

· *What data is used?*

independent orbits, gravity anomalies, satellite-to-satellite tracking, crossover altimetry data (see example), satellite gradiometry in a near future.

Problem: the new data is quickly incorporated into EMs.

dependent data-subsets (Lerch's statistics)

· *What quantities are used?*

1) power spectra, various statistics, orbit overlaps, …

Problem: often not actual test of accuracy, but only a test of internal precision or of consistency

2) Even actual accuracy tests (orbit predictions …) suffer from limited sensitivity to various degrees and orders of C_{lm}, S_{lm} in EMs. Various data types = different spectral sensitivity…

3) Comparison of satellite dynamics data and "GPS-levelling"

How is the perspective? Bad. A new data type (gradiometry) and/or very accurate terrestrial data is needed

How to continue to test the Earth gravity field models (EM) when better (more accurate and reliable) satellite data than those used to compute the models will not be available??

WE NEED TERRESTRIAL DATA

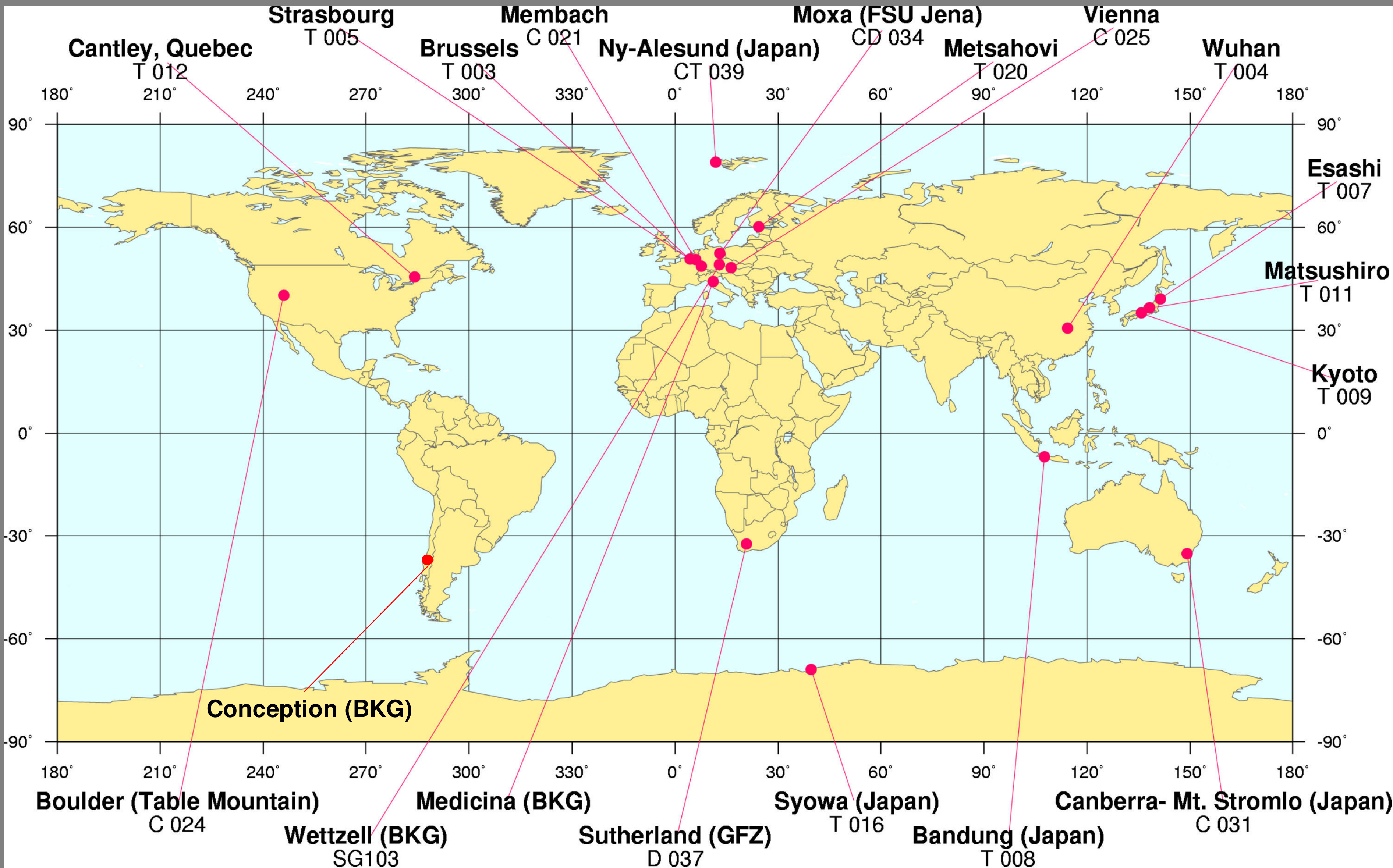
1. Can we compare global ”smothed” EMs based (also) on satellite data with the point measurements on the ground ? **YES**
2. What ground instruments can we use ? **SG and AG**

superconducting gravimeters (SG) as pseudo-continuous data source and absolute gravimeters (AG) as sporadic, additional data source, to use the POINT values after all reductions, no smoothing/averaging (as was frequently used) with the gravity anomalies in the past

3. How the distribution of the ground stations should be? Are new stations needed?

As regular as possible, present situation shown on Figure is not optimum, new stations are needed outside Europe

Superconducting Gravimeter Network



Superconducting Gravimeter (SG)

Gravity resolution: 10^{-11} m/s^2

Measurement range: from seconds to years with a linear transfer function

Drift: ~ 3 µgal/year linear

Absolute Gravimeter (AG)

Gravity resolution: 10^{-10} m/s^2

Accuracy of 1 day measurement: 10^{-8} m/s^2

Measurement range: from one day to years

Drift: ~ 0 µgal/year

Absolute gravimeter FG5

Superconducting gravimeter

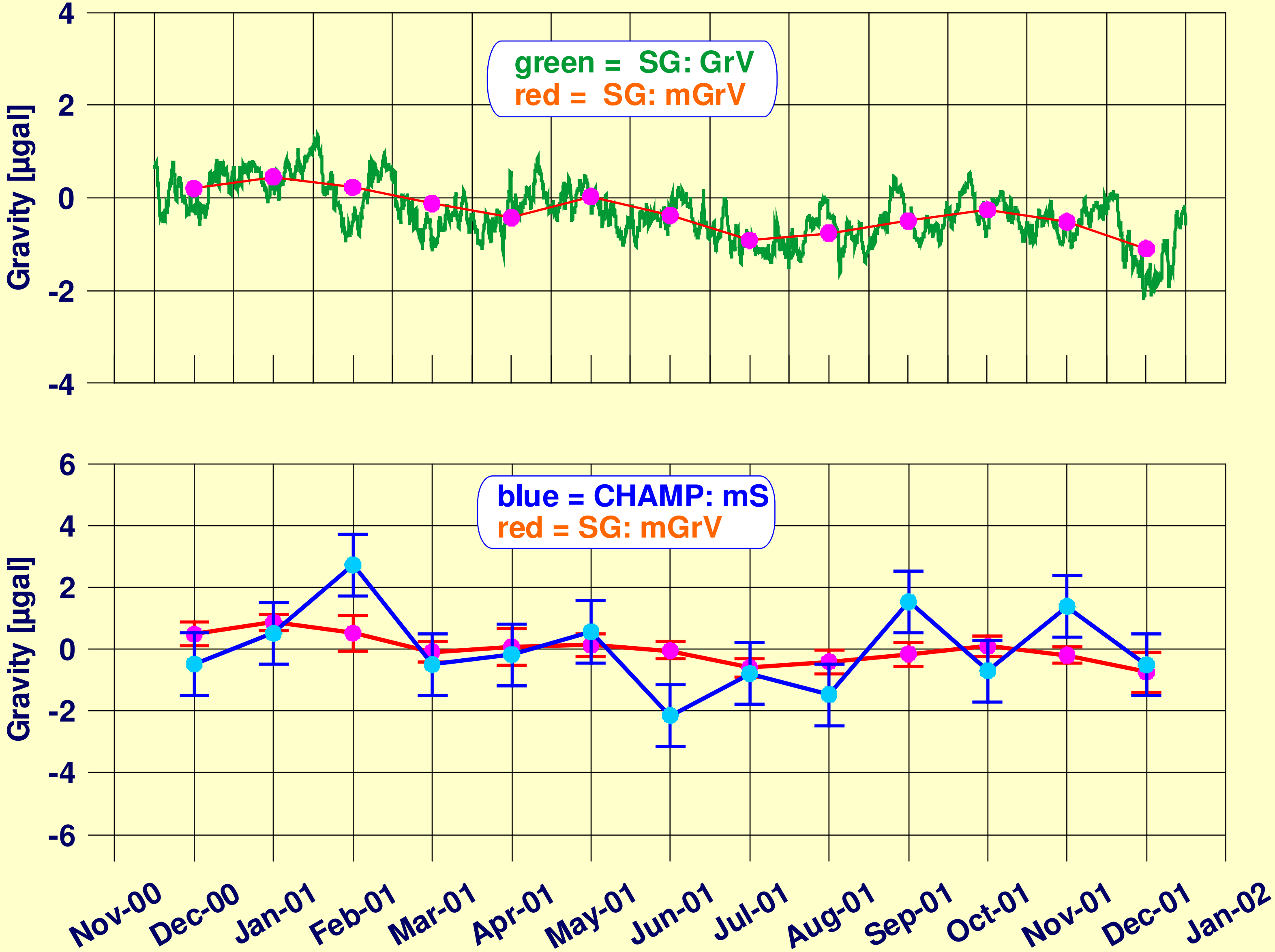
Time variations of the gravity field are already studied using CHAMP and GRACE data – monthly solutions

Performance

	CHAMP		Superconducting Gravimeter
Gravity resolution	300 µgal	1 µgal	1ngal (10^{-11} m/s²)
Space resolution λ/2	500 km	5000 km	point measurement
Sph.harm. coeff.	$l_{max} = 40$	$l_{max} = 4$	--
Time resolution	1 month		10 seconds
Long term stability (drift)	no drift		~ 3 µgal / year (linear)

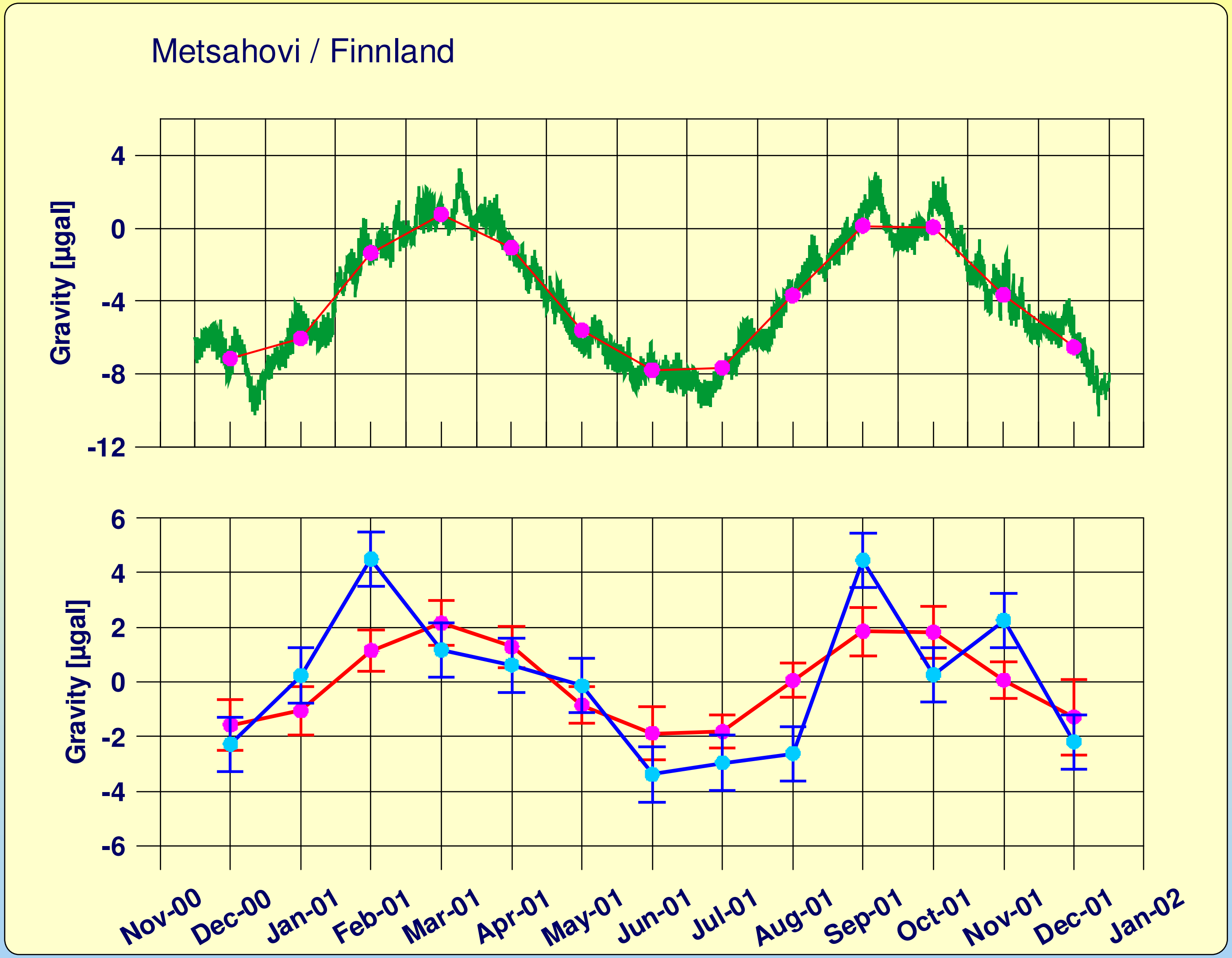
GFZ POTSDAM

Vienna / Austria



GFZ POTSDAM

Comparison by using long periodic tidal waves



Upper graph: **green** = SG: Gravity variations including long periodic tidal waves STA, SSA and SA

red = SG: Monthly mean of gravity variations

Lower graph: **blue** = CHAMP: monthly global gravity field solution for Metsahovi with added long periodic tidal waves

red = SG: Monthly mean of gravity variations (deformation potential part only)

GFZ POTSDAM

Crucial problem

We do not need the variations of the gravity field but the absolute values with utmost accuracy

Elementary error estimate (1)

- Present EMs transformed to geoid: 1 m global, 0.2 – 0.3 m ocean
- EMs (CHAMP, GRACE, combinations) transformed to geoid: 0.2 – 0.3 m global

Elementary error estimate (2)

- Relation between gravity change *dg* and vertical undulation *dN*

$$dg = -\,0.3086\ dN$$

- rms error of vertical (~geoid) undulation

$$m_{dN} = m_{dg}/0.3086$$

- Numerically

$$m_{dg}\ (SG + AG) = 5\ \mu Gal > m_{dN} = 1.5\ cm$$

with error of hydrological corrections: $m_{dN} = 2.5\ cm$

20 – 30 cm versus *2 – 3 cm* great potential of SG+AG for checking EMs

Method

There is a possibility how to invert Stokes's coefficients of geopotential into observed values of ground gravity. The model can be summarized as follows:

1- synthesize the geopotential coefficients on the surface of the reference sphere (geocentric sphere upon which a spherical harmonic expansion of the coefficients reduces to the Laplace harmonics); this step results in mean values of geopotential defined over a selected grid of spherical coordinates

2- invert the mean values of geopotential through an integral equation of Green's kind into the gradient of geopotential at a particular point on the surface of the Earth; direct integration can be used due a band-limited character of geopotential

3- project this gradient into the direction of a local plumb line and compare it with an observed value of gravity.

List of problems to be solved (1)

Spherical harmonic coefficients of geopotential derived from observables of various satellite missions provide a continuous representation of geopotential that is **averaged** both in time and space. For example, for the GRACE mission 30-day estimates of the coefficients up to degree 150 can be recovered that represent the geopotential function spatially averaged to some 100 km. This constitutes the major problem in comparing satellite-based estimates of geopotential with the ground reference. Namely a completely different spatial resolution must be dealt with while time averaging can also be applied to ground data. *Possible solution: remove the high-frequency signal from ground reference (effect of close topographical masses).*

List of problems to be solved (2)

The spherical harmonic description also suggests that geopotential is a harmonic function in a certain domain. This condition results in a uniformly converging spherical harmonic series. Strictly speaking this condition is not satisfied for a general point inside the so-called Brilloiun sphere that may result in an unexpected effect of higher-degree terms in the expansion. It might be a good idea to expend the domain, where geopotential is harmonic, also for a region between the geoid and the Brilloiun sphere. *Possible solution: remove the gravitational effect of global topography from satellite data and ground reference.*

In order to project the recovered potential gradient to the direction of the local plumb line, one should technically know its direction in some reference frame. In other words, one should know a **deflection of verticals** at the gravity station. The precise positioning of gravity stations is expected via GPS positioning. *Possible solution: measuring astronomical coordinates.*

ECGN - Stations

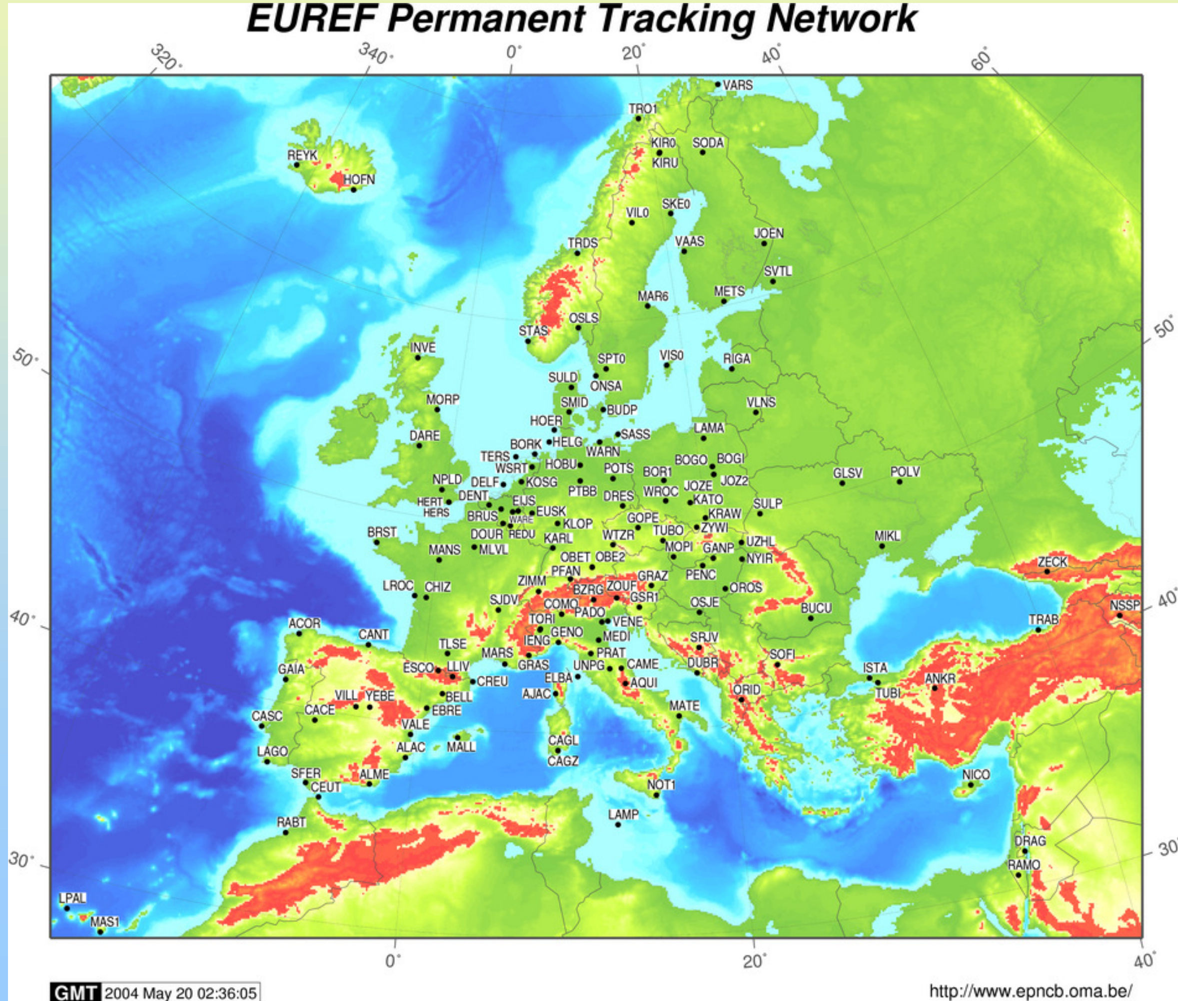
Status: 2004-02-04

Status and Techniques (Standard: GPS, absolute gravity, levelling)

- core station
- station
- candidate station
- proposed station
- super conducting gravimeter
- tide gauge

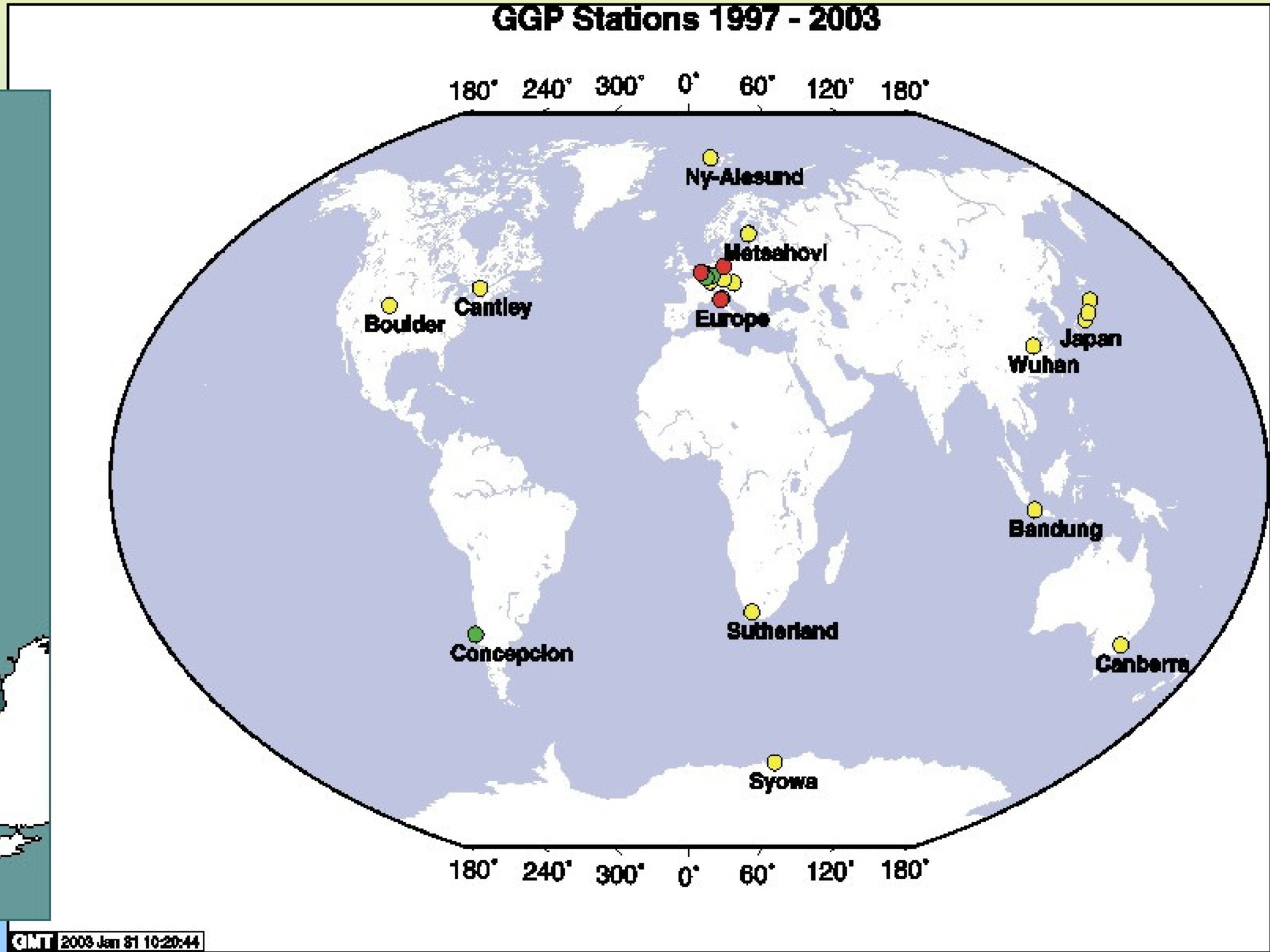
Requirements on ECGN (1)

- Precise geocentric positions from space geodesy



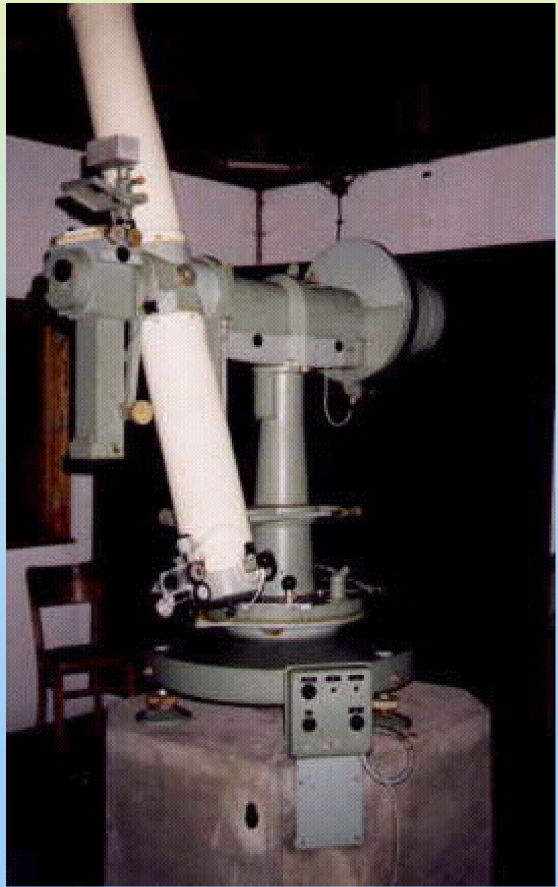
Requirements on ECGN (2)

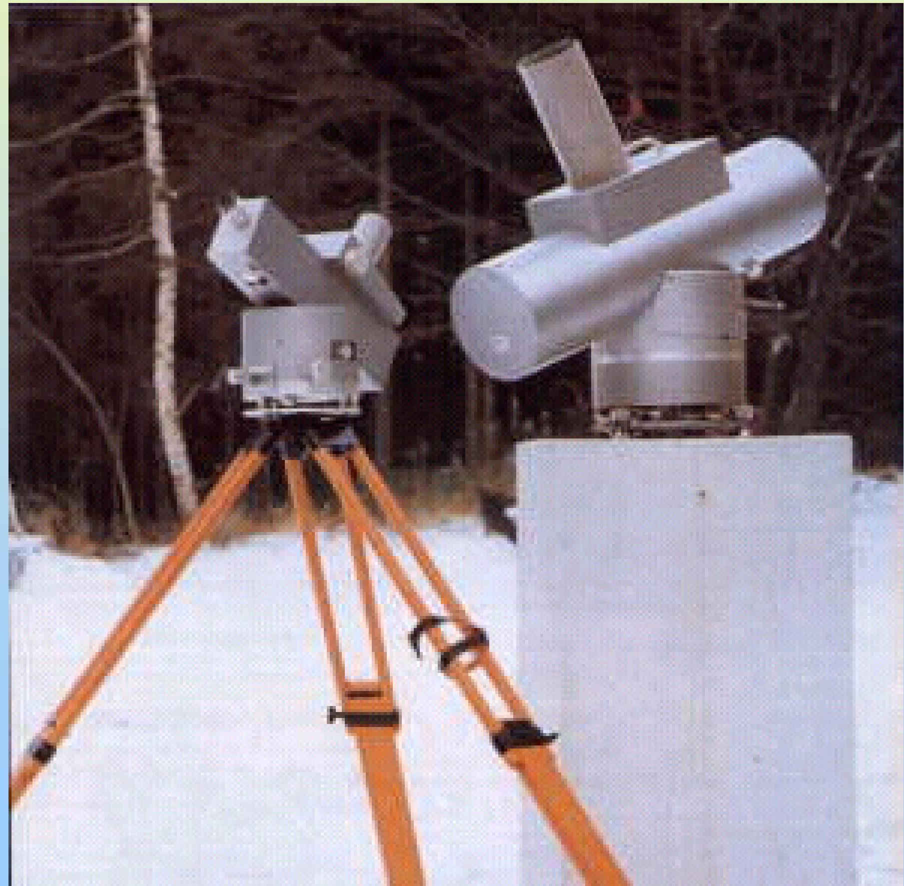
- Precise SG and AG measurements in dense and global network



Requirements on ECGN (3)

- Precise astronomical coordinates of a reference point of SG and AG instruments





Conclusions

Point SG and AG data are potentially accurate enough to test the newest and future gravity field models (EM) based on satellite data (including altimetry and gradiometry).

There is a possibility how to invert C_{lm}, S_{lm} from EMs to the point ground gravity values.

We are aware of various problems connected with such accuracy tests and we have here presented a list of the problems to be solved.

Better distribution of SG data, new SG and AG stations - ECGN sites - are needed and some of the SG/AG gravity reduction models must be improved.