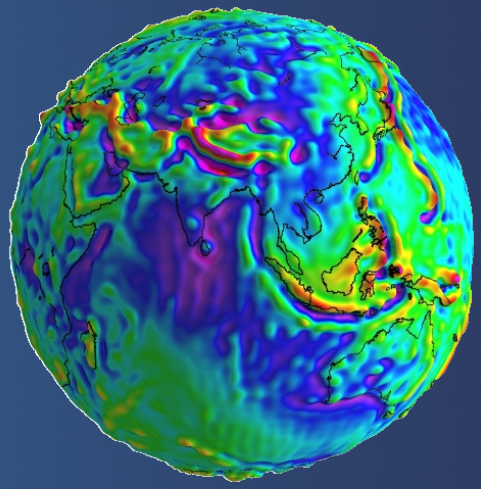
DANISH NATIONAL SPACE CENTER

International Association of Geodesy

IGFS



THE DANISH NATIONAL SPACECENTER IS A RESEARCH CENTER UNDER THE MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION

IGFS – A service for gravity and mass relocation

Rene Forsberg – National Space Institute (DTU-Space), Denmark
Steve Kenyon – National Geospatial-Intelligence Agency, USA
Corinna Kroner, GFZ; S Bonvalot, CNES; H. Wilmes, BKG;
R. Barzaghi, Polimi ..

www.igfs.net

Structure of the IGFS - International Gravity Field Service

International Gravimetric Bureau (BGI) – *Director S. Bonvalot, Toulouse*

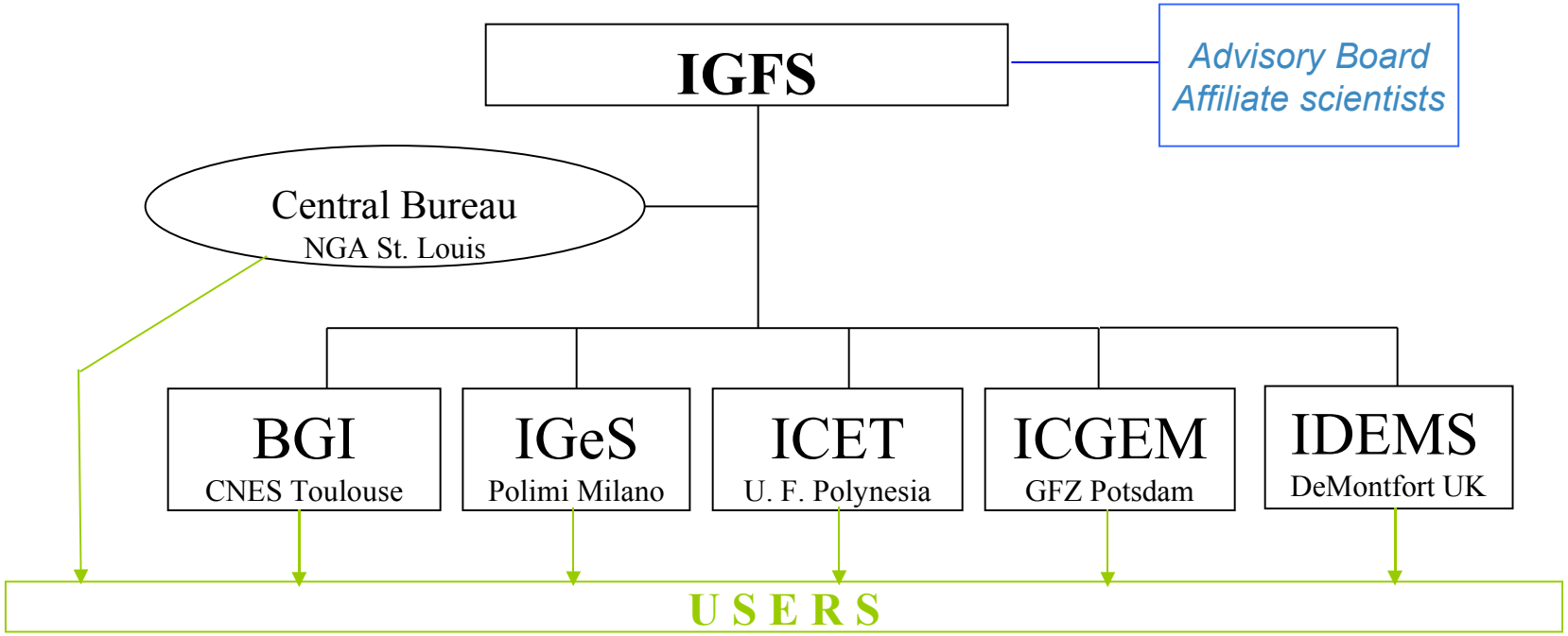
International Geoid Service (IGeS) – *Director R. Bazarghi, Milano*

International Center for Earth Tides (ICET) – *Director J. P. Barriot, Papeete*

International Center for Global Earth Models (ICGEM) – *Director J.Kusche, GFZ*

International DEM Service (IDEMS) – *Director P. Berry, De Mont Fort, UK*

Central Bureau/Technical Centre of the IGFS – chief geodesist S. Kenyon, NGA, USA



International Gravity Field Service

International Association of Geodesy

DANISH NATIONAL SPACE CENTER

IGFS chair: Rene Forsberg
Geodynamics Department
Danish National Space Center

IGFS is a new unified "umbrella" IAG service, which will
- Coordinate collection, validation, archiving and dissemination of gravity field related data
- Coordinate exchange of software of relevance for gravity field actitivities
- Coordinate courses, information materials and general public outreach relating to the earth's gravity field

The overall goal of IGFS is to coordinate the servicing of the geodetic and geophysical community with gravity field-related data, software and information. The combined data of the IGFS entities data will include both satellite-derived global models, terrestrial, airborne, satellite and marine gravity observations, earth tide data, GPS leveling data, digital models of terrain and bathymetry, as well as ocean gravity field and geoid from satellite altimetry. Both the static and the temporal variations of the gravity field will be covered by the IGFS.

IGFS is *not* handling gravity field data distribution directly - IGFS will function as a unifying service for the following gravity-field related IAG services - *"IGFS Centres"*:

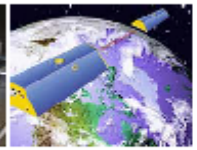
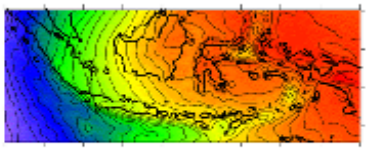
BGI - International Gravity Bureau - collection, archiving and distribution of gravity data
IGeS - International Geoid Service - collection and distribution of geoid models, geoid schools
ICET - International Center for Earth Tides - collection and archiving of global earth tide data
ICGEM - International Centre for Global Earth Models - distribution of satellite and surface spherical harmonic models
IDEMS - International DEM Service - Global Digital Terrain Models

IGFS Technical Centre - National Geospatial-Intelligence Agency [geodesy - G&G dept] - advise on global models, geoid and gravity, supplementing other services

The IGFS was established by the International Association of Geodesy Executive Board at the General Assembly in Sapporo, Japan, August 2003, and is an IAG "level-2" service under IAG Commission 2 - Gravity Field. One of the main arguments for establishing IGFS was to provide a more focussed role of the gravity field, as one of the three fundamental pillars in IAG's first project - GGOS, the Global Geodetic Observing System. For more background information on GGOS and IGFS click here (presentation for Cairns 2005)

Another important role of the IGFS is to take initiative and coordinate international data collection projects, such as e.g. the Arctic Gravity Project, and the ongoing development of the new NGA high-resolution spherical harmonic reference model EGM06, complete to degree and order 2160.



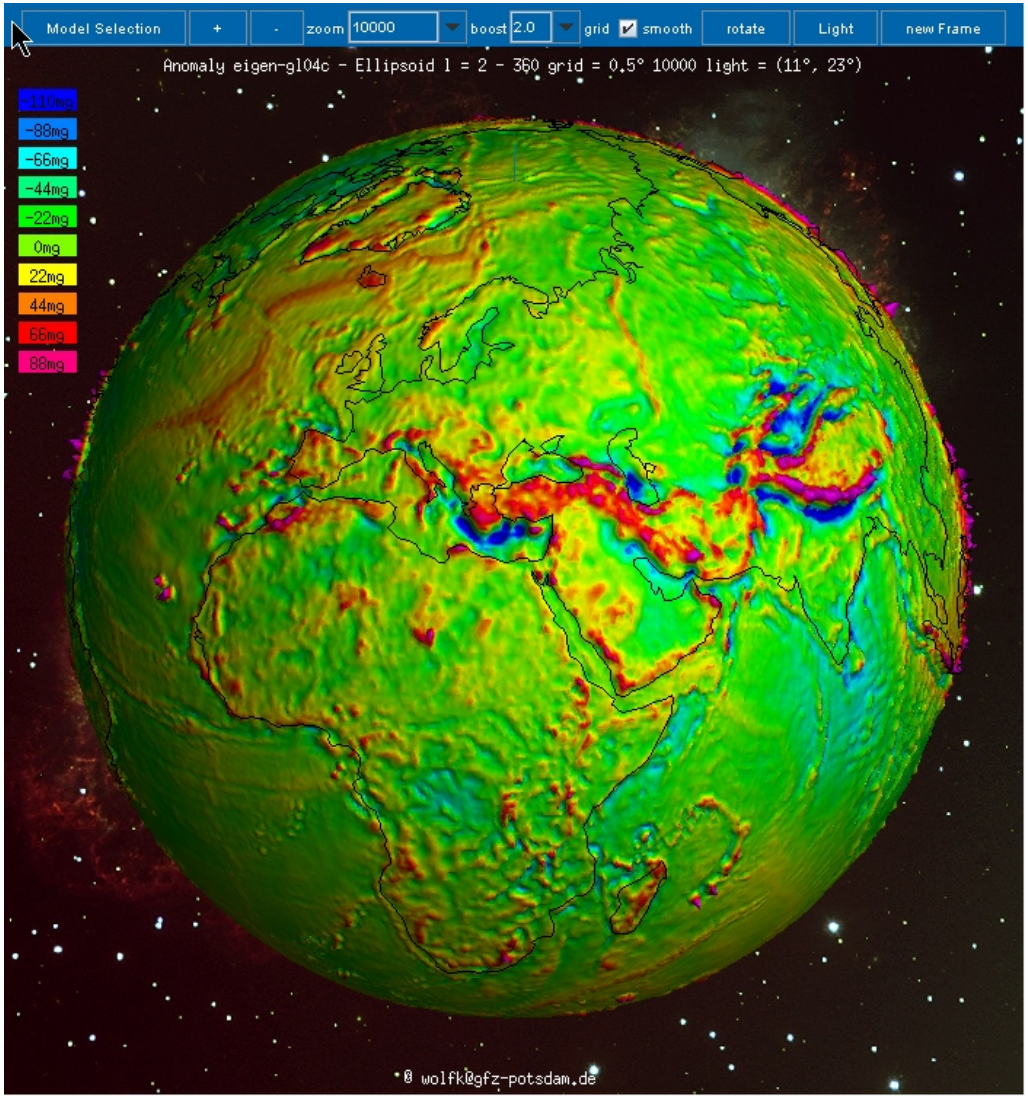




For IGFS information contact rf@dnsc.dk

www.igfs.net

ICGEM

- Collecting and archiving all global gravity field models
- making them available on the web
- use of standardized format (self-explanatory)
- interactive visualisation
- web-interface to calculate gravity functionals
- evaluation of models



ICGEM

- at present 102 models available

Model	Year	Degree	Data	Reference	download
ITG-Grace03	2007	180	S(Grace)	Mayer-Gürr et al, 2007	X
AIUB-CHAMP01S	2007	70	S(Champ)	Prange, L. et al, 2007	X
ITG-Grace02s	2006	170	S(Grace)	Mayer-Gürr et al, 2006	X
EIGEN-GL04S1	2006	150	S(Grace,Lageos)	Förste et al, 2006	X
EIGEN-GL04C	2006	360	S(Grace,Lageos),G,A	Förste et al, 2006	X
EIGEN-CG03C	2005	360	S(Champ,Grace),G,A	Förste et al, 2005c	X
GGM02C	2004	200	S(Grace),G,A	UTEX CSR, 2004	X
GGM02S	2004	160	S(Grace)	UTEX CSR, 2004	X
EIGEN-CG01C	2004	360	S(Champ,Grace),G,A	Reigber et al, 2006	X
EIGEN-CHAMP03S	2004	140	S(Champ)	Reigber et al, 2005b	X
EIGEN-GRACE02S	2004	150	S(Grace)	Reigber et al, 2005a	X
TUM-2S	2004	70	S(Champ)	Wermuth et al., 2004	X
DEOS_CHAMP-01C	2004	70	S(Champ)	Ditmar et al, 2006	X

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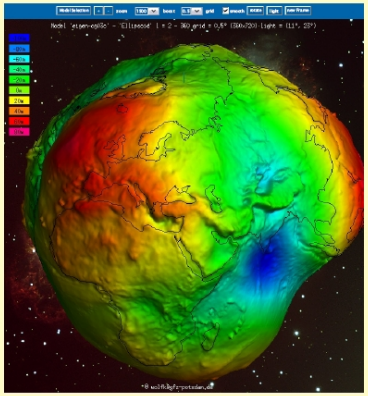
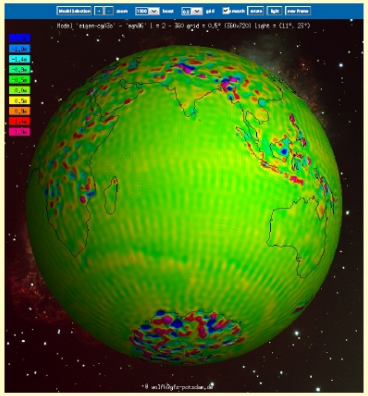
ICGEM

International Association of Geodesy

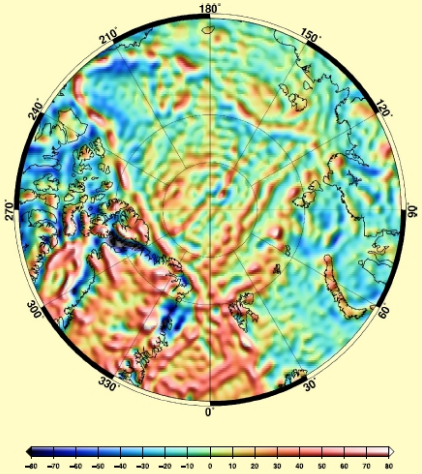
Models



Differences



Adapted Plot-Projection



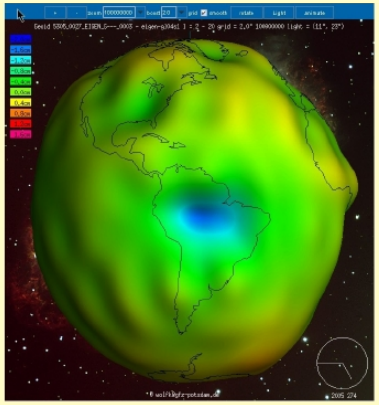
eigen–gl04c
Δg_{SA}, 0.1° x 0.1°
wrms about mean / min / max = 25.53 / –136.6 / 146.9 mgal

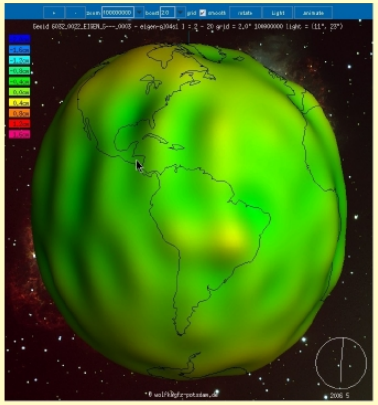
Self-explanatory Grid Format

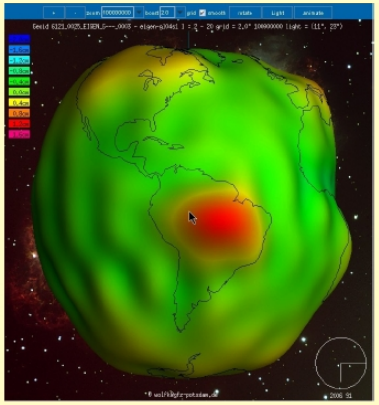
```
*********** Grid on the Ellipsoid ***********
generating_institute     gfz-potsdam
     generating_date     2006/03/24
        product_type     gravity_field
             shmname     eigen-cg03c
     max_used_degree          360
          tide_system    tide_free
           functional    gravity_anomaly
                 unit    10E-5*m/s**2
          refsysname     wgs84
             gmrefpot     3.98600500000E+14 m**3/s**2
          radiusrefpot    6378137.000 m
            flatrefpot     3.35281066474748OE-03
                                (1/298.25722356300)
           omegarefpot     7.29211500000E-05 1/s
     subtract_refpot       yes
          coordinates      ellipsoidal
       long_lat_unit       degree
      latlimit_north        90.0000
      latlimit_south        70.0000
      longlimit_west      -180.0000
      longlimit_east       180.0000
             gridstep        0.1000
  latitude_parallels          201
 longitude_parallels         3601
number_of_gridpoints        723801
            point_mean     point
             gapvalue       9999.9999
        weighted_mean        2.55987E+00 10E-5*m/s**2
              maxvalue       1.53532E+02 10E-5*m/s**2
              minvalue      -1.38542E+02 10E-5*m/s**2
           signal_wrms       2.56510E+01 10E-5*m/s**2
           grid_format     long_lat_value

          longitude     latitude     grav.anom.
            [deg.]       [deg.]    [10E-5*m/s**2]
end_of_head ==============================================
          -180.0000      90.0000        8.484689
          -179.9000      90.0000        8.484689
          -179.8000      90.0000        8.484689
             .
             .
             .
           179.4000      81.9000        4.337991
           179.5000      81.9000        4.762458
           179.6000      81.9000        5.193202
             .
             .
             .
           179.8000      70.0000       -2.190425
           179.9000      70.0000       -1.701154
           180.0000      70.0000       -1.263329
```

Visualisation of monthly Solutions







EGM96S

spectral comparison with the model EIGEN–GL04C

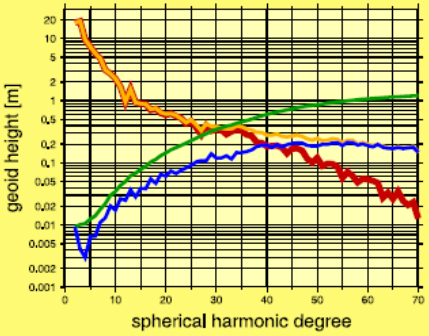
The graphs show:

Signal amplitudes per degree of EGM96S

Signal amplitudes per degree of EIGEN–GL04C

Difference amplitudes per degree of EGM96S vs. EIGEN–GL04C

Difference amplitudes as a function of maximum degree of EGM96S vs. EIGEN–GL04C



GFZ POTSDAM

BGI

Home Page - Géodésie en Amérique Latine - Mozilla Firefox

Fichier Édition Affichage Historique Marque-pages Outils ?

BGI

International Gravity Bureau
Bureau Gravimétrique International

sitemap

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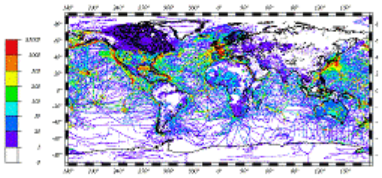
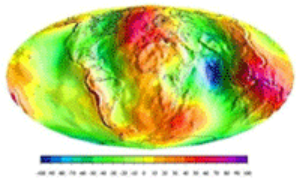
- Annexes

French English

Search

Collection, Validation, Archiving and Distribution of Gravity Data





News/Highlights!

- Absolute Gravity Database (Collab. BGI / BKG)
- World Gravity Map project (Collab. BGI / CGMW)
- Satellite GRACE Solutions (GRGS products)

A service center of

- The International Gravity Field Service (IGFS) of the International Association of Geodesy (IAG)
- The Federation of Astronomical and Geophysical Data Analysis Service (FAGS) of the International Council of Science (ICSU)

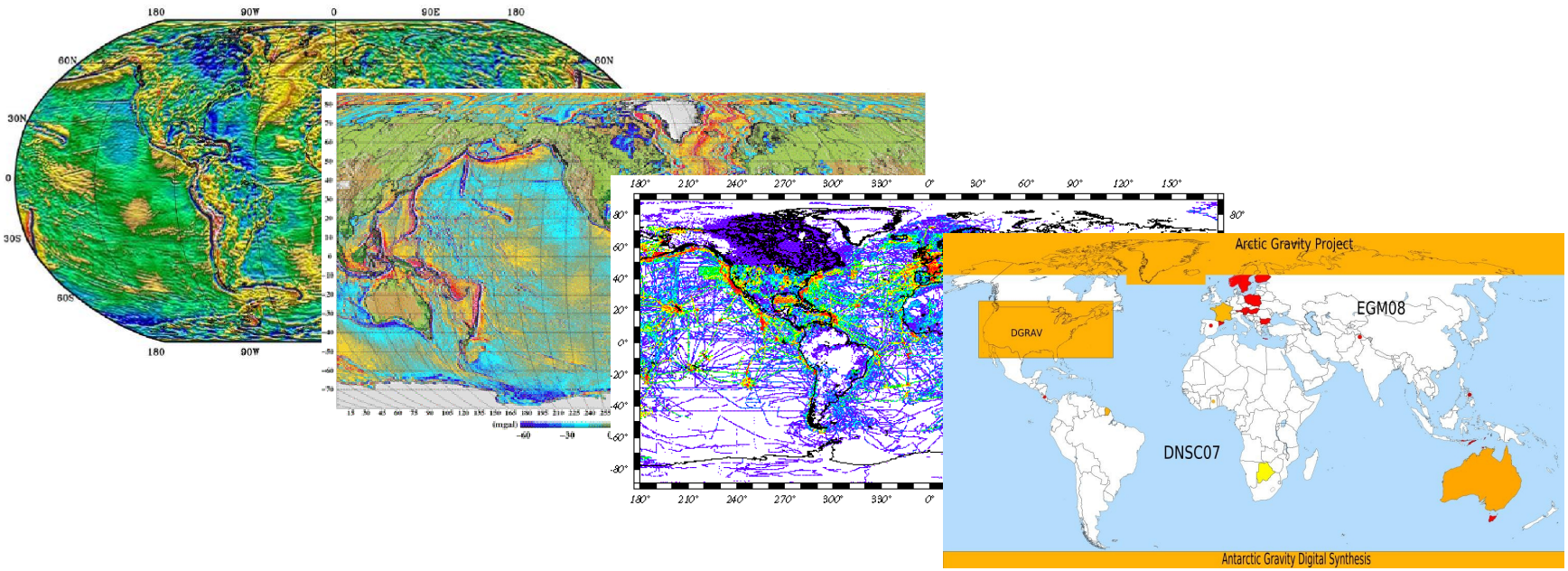
xxx

Webmaster: webmaster@bgi.fr
xxx: xxx

Last Updated: Sunday, March 23, 2008

Available gravity data

- Ultimate objective: combination of near-surface marine and terrestrial data, complemented by satellite data - 3' resolution grid
- Expected contributions: BGI/NGA databases, global model EGM08, DNS07 satellite-derived marine gravity, GETECH syntheses (South Amer., Europa, others? Subsets?)
- Terrestrial data: Land / Sea / Airborne measurements - Relative & Absolute gravity data
- Wide call for contributions launched in January '08 - Positive answers in progress

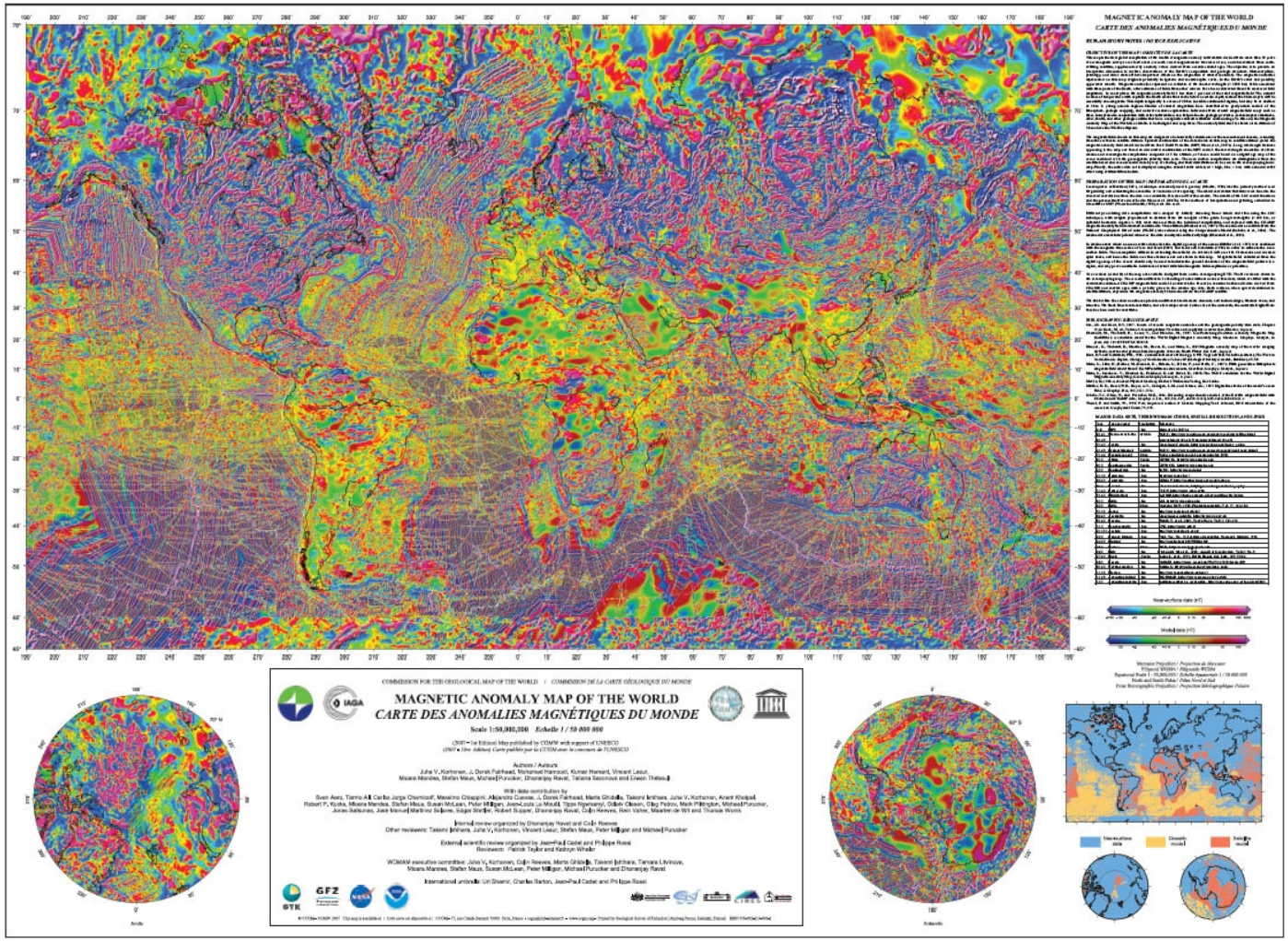


BGI – March 2008

Example: World Digital Magnetic Anomaly Map (WDMAM)

Building

- Coordination through scientific committee
- Numerous contributions & sponsors
- Workshops for data gathering, corrections, reference model
- Combination of near-surface data, satellite data, and models
- Released at IUGG meeting, Perugia 2007
- Next workshop at IGC2008: interpretation of previously unknown magnetic features



Current IGFS activities

- Meetings:
- Workshop on Height systems, Geoid and Gravity of the Asia-Pacific - Mongolia, June 2006
- 1st International Symposium of the IGFS in Istanbul, Turkey, September 2006.
- International Workshop on Gravity and Geoid in South America - Buenos Aires, Sep 25-29, 2006
- **IGFS retreat – Bertinoro, March 24-25, 2008**
- Gravity, Geoid and Earth Observation – Chania, Greece, June 2008

Current IGFS activities (2)

- Working groups:
- Global absolute gravimetry network and standardization (H. Wilmes, BKG)
- Evaluation of new ultra-high spherical harmonic gravity field model EGM08 (J. Huang, NRCan)

- Service activities:
- *Schools: Microgravimetry school (BGI), BGI/ICET, Geoid schools (IGeS)*
- *Joint bulletin: Newton's Bulletin – technical journal of the BGI and IGeS.*
- *Arctic: New Arctic Gravity, Geoid (ArcGP/IGFS) and bathymetry grids (IBCAO)*
- *World gravity project (BGI / IGFS) … new 3' global gravity grid*
- *Global DEM service operational … tools and software*

- International Altimetry Service being formed (steering group appointed, IGFS repr. O. Andersen)

Absolute gravity WG (H. Wilmes, BKG)

- Importance of gravity for the monitoring of global change processes
  - Increasing number of worldwide AG observations
  - Growing importance of the gravity field for a better understanding of the system Earth
  - Use of gravity field products in geosciences
- Development of the sensitivity of terrestrial gravimetric technology
  - Absolute gravimeters (AG)
    (resolution at a few µGal-level)
  - Superconducting gravimeters (SG)
    (continuous observation, resolution at sub-µGal level)
- GGOS

Combination of gravity and geometry

	Observations / Parameter (t)		Geodetic Space Techniques			Satellite radar		SGM	Terrestrial Gravimetry				
			VLBI 10^{-9}	SLR 10^{-9}	GNSS 10^{-9}	I-SAR 10^{-10}	ALT 10^{-9}	SST Gradio	Lev. 10^{-7}	grav. rel. 10^{-6}	AG 10^{-9}	SG 10^{-10}	Tide Gauge 10^{-9}
Terrestrial Reference System (TRF)	Datum												
	Geo center	X_0		✓	✓		✓	✓					
	Scale		✓	✓									
	Polar Motion		✓	✓	✓								
	UT1		✓										
	Stations	Xp	✓	✓	✓	✓					$\dot{h}$	$\dot{h}$	$\dot{h}$
Earth Surface	DTM					✓	✓						
Vertical Referene System (VRF)	Datum	W_0			✓		✓	✓	✓		✓	✓	✓
	Stations	Hp			✓		✓	✓	✓		✓		✓
Gravity Reference system (GRF)	Datum	g_0		✓							✓		
	Stations	g_p			✓					✓	✓	✓	
Gravity Field	GGM	T		✓	✓		✓	✓	✓	✓	✓	✓	✓
	Reg. Geoid	T			✓		✓	✓	✓	✓	✓		✓
Atmosphere			✓		✓		✓				✓	✓	
Hydrosphere					✓		✓	✓			✓	✓	✓
Cryosphere					✓		✓	✓					
Lithosphere			✓	✓	✓			✓			✓		✓

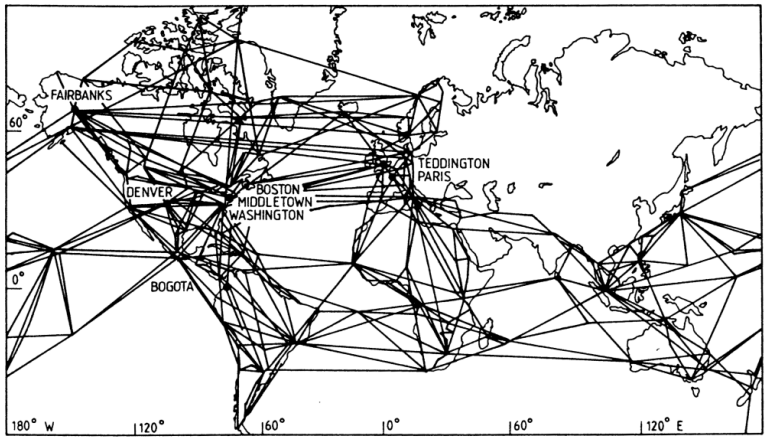
(After Rottacher and Ihde)

X ... position, W ... Earth gravity potential, T ... disturbance potential, H ... phys. height, $\dot{h}$ ... Variation of the geom. geom. height

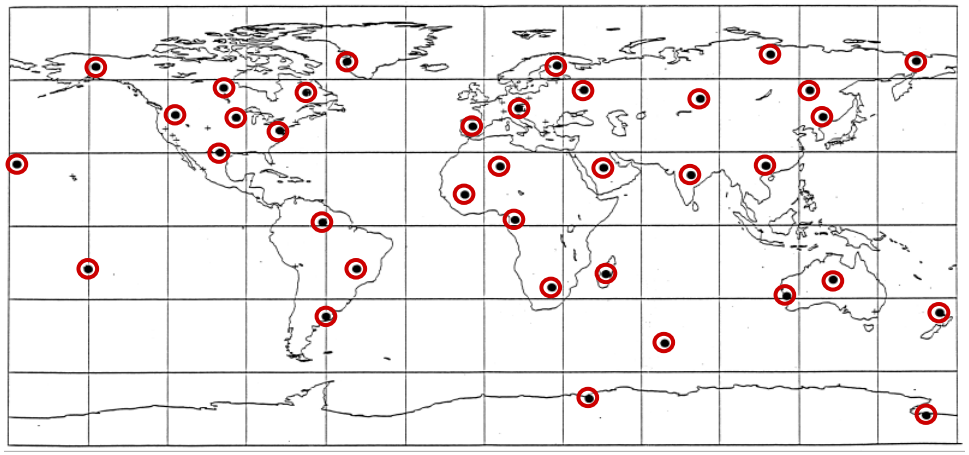
Abs Grav

(2) Presently defined gravity reference system

- IAG standard is the IGSN71 – station accuracies ±1 µm/s² (±100 µGal)
- Next step: proposal by Boedecker to establish the IAGBN



IGSN71 reference network Ref. Morelli



1986 **IAGBN (A)** Ref: Boedecker

Today's Possibilities:

- AG measurements with ±20 nm/s² (±2 µGal)
- AG Comparisons confirm the high reliability of observations

- Determine time variations at specific stations
- Correlation with time variations of the spatial gravity field

- Combination with other geodetic techniques requires consistent definition!

Abs Grav

Definition of the gravity reference system

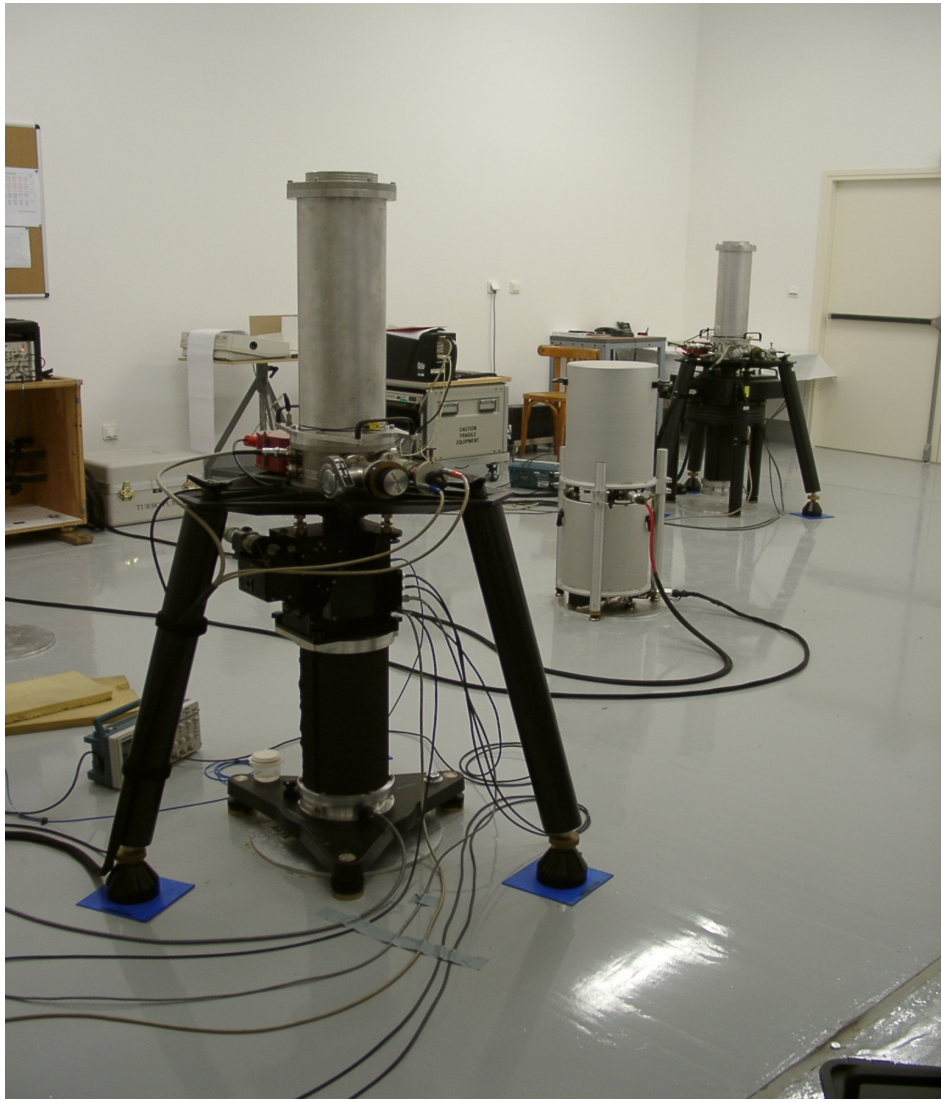
ICAG: International comparisons of absolute gravimeters every four years at BIPM

BIPM
Bureau International des Poids et Mesures

CCM-Working Group on Gravimetry

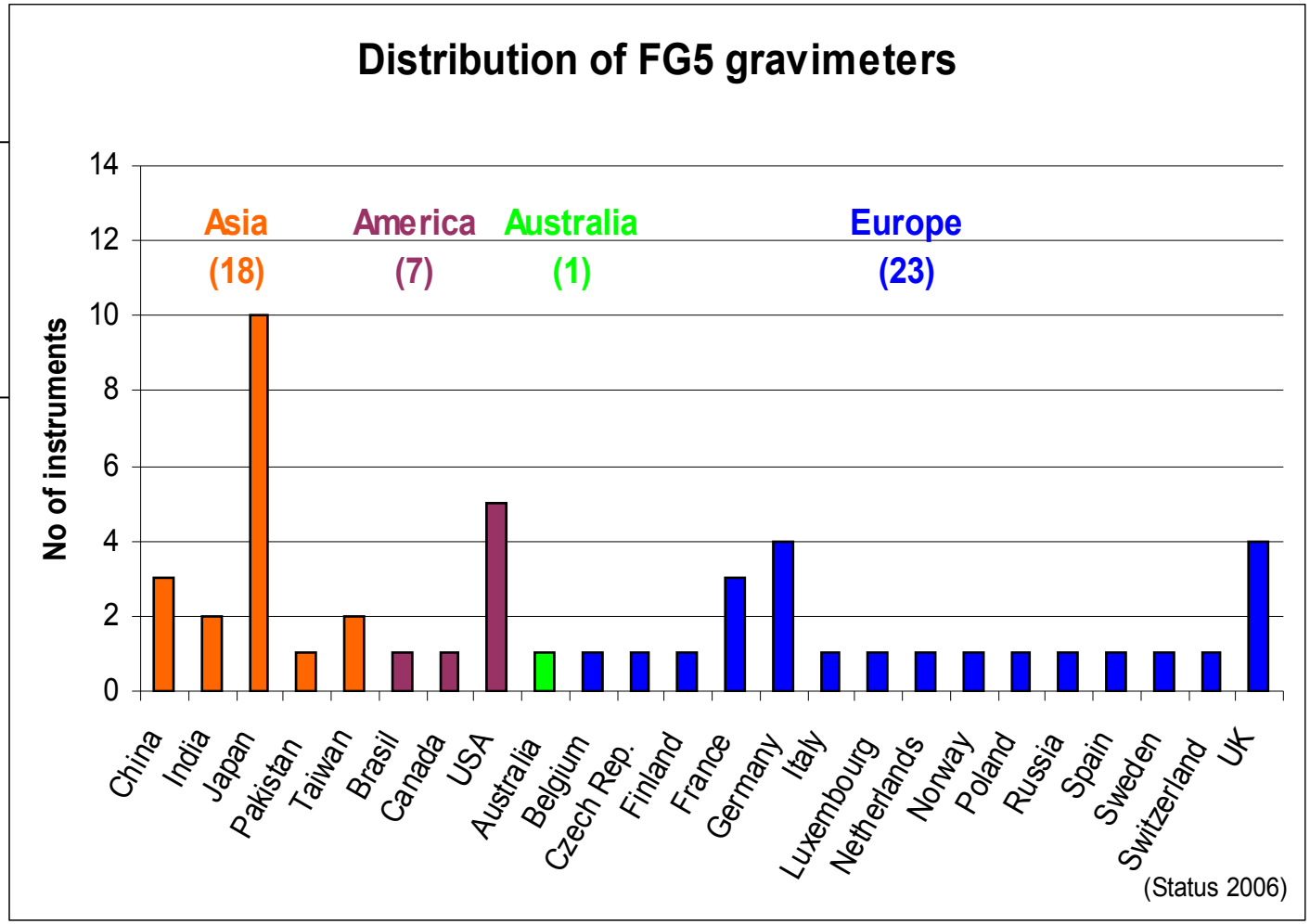
IAG-SG 2.1 Comparison of Absolute Gravimeters

Special role: standardization



Growing number of absolute gravimeters

Complemented by other instrument types: e.g. JILA-G, A10, IMGC, GABL, Faller etc.



Owners:

- Metrological,
- Geodetic,
- Geologic and
- Geophysical Institutions

Will the absolute gravimeters data remain available on the long run?

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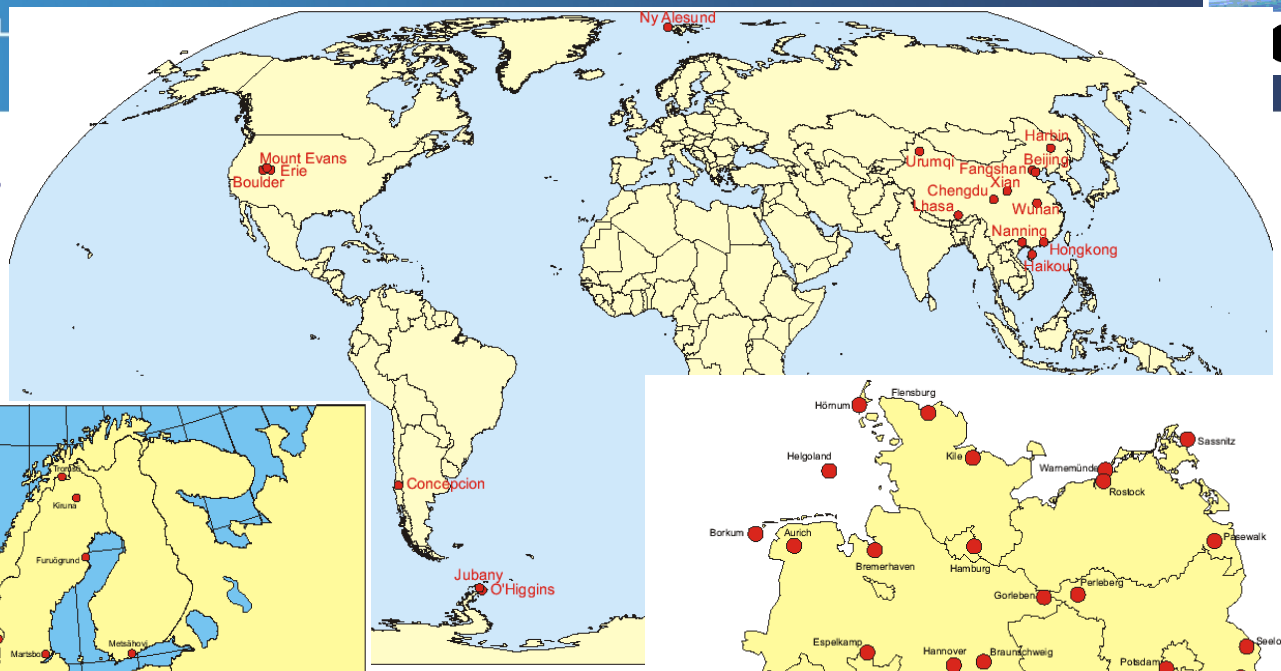
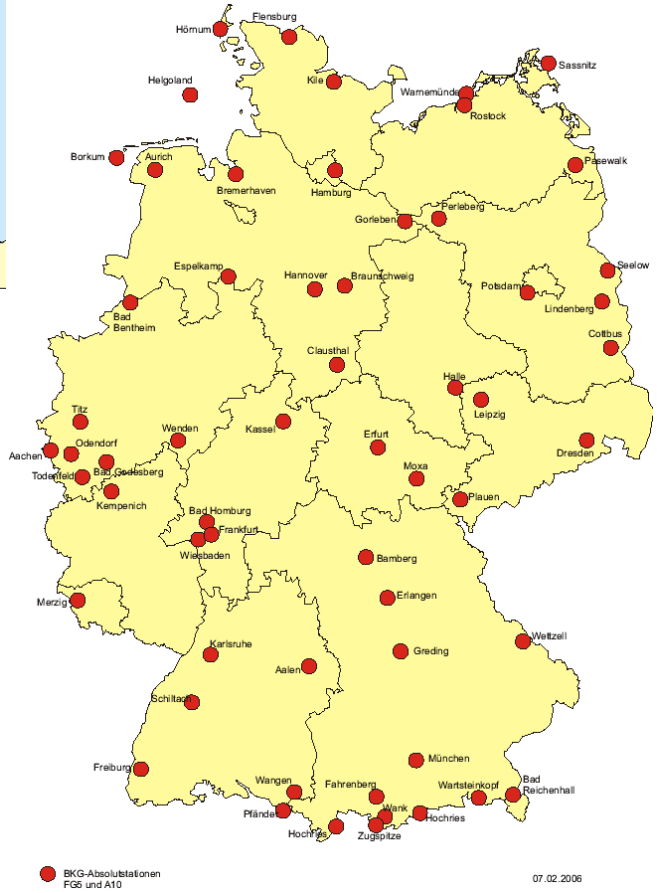
GFS

AG observations by BKG, 1993 - 2006



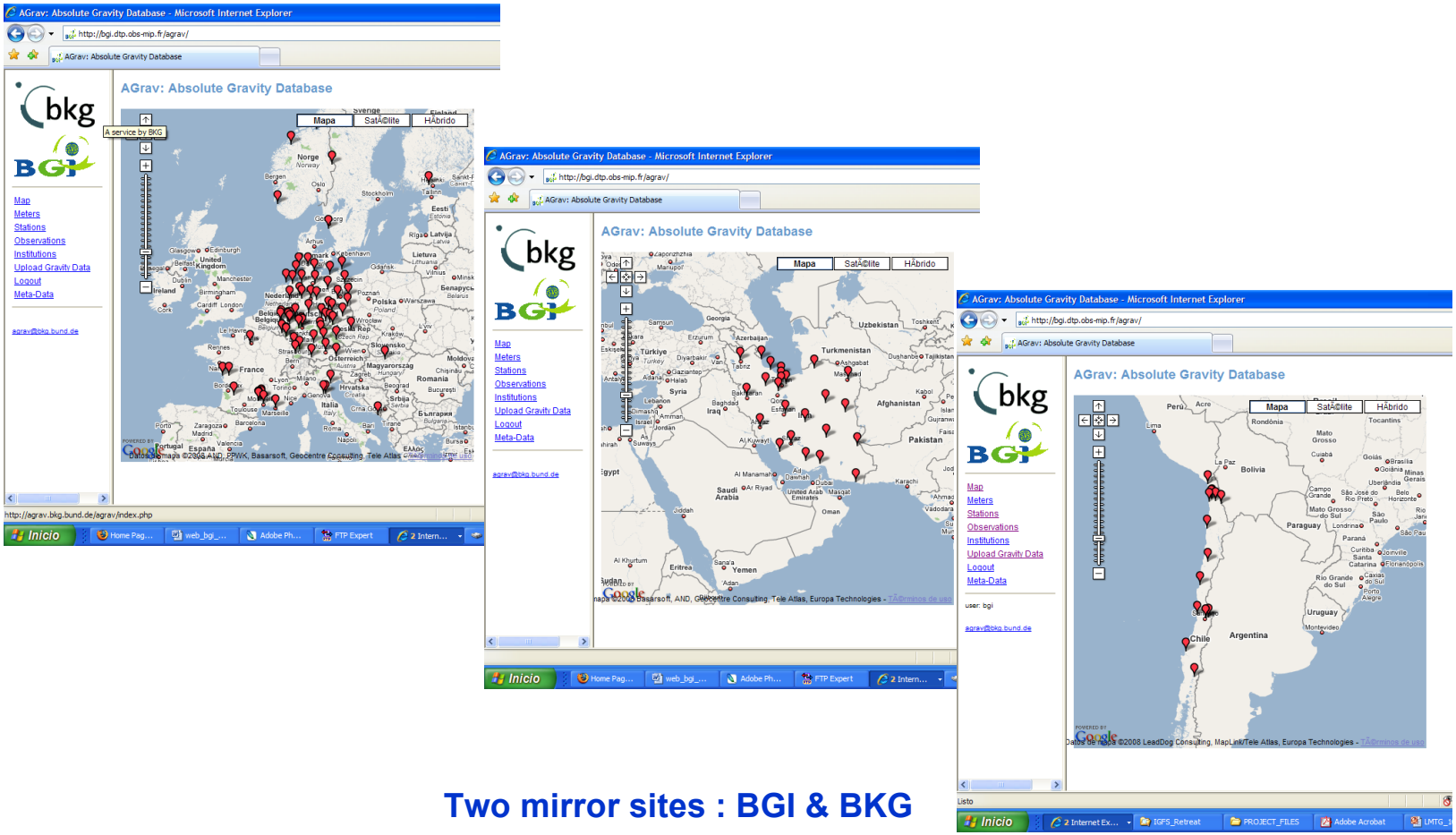
Observations with FG5 and A10 absolute gravimeters



Absolute Gravity Database

BKG database prototype installed & tested at BGI (visit of H. Wziontek – Oct. 2007) – Additional functionalities

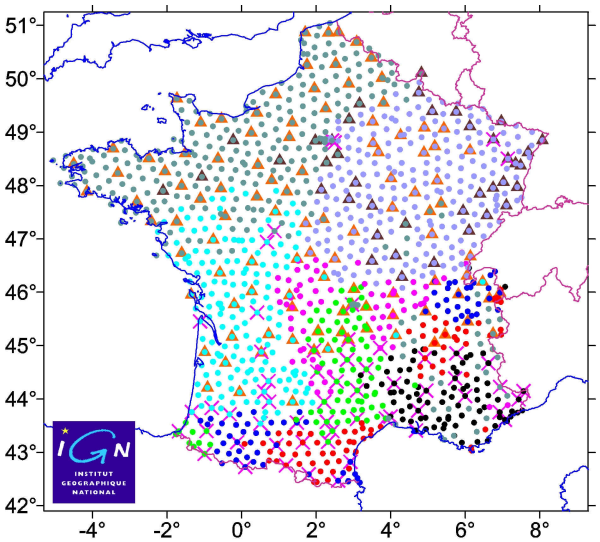
Worldwide data collection in progress at BGI



Two mirror sites : BGI & BKG

Absolute Gravity Database

Increasing number of observations: laboratory and field absolute gravity instruments



Gravimétrie absolue

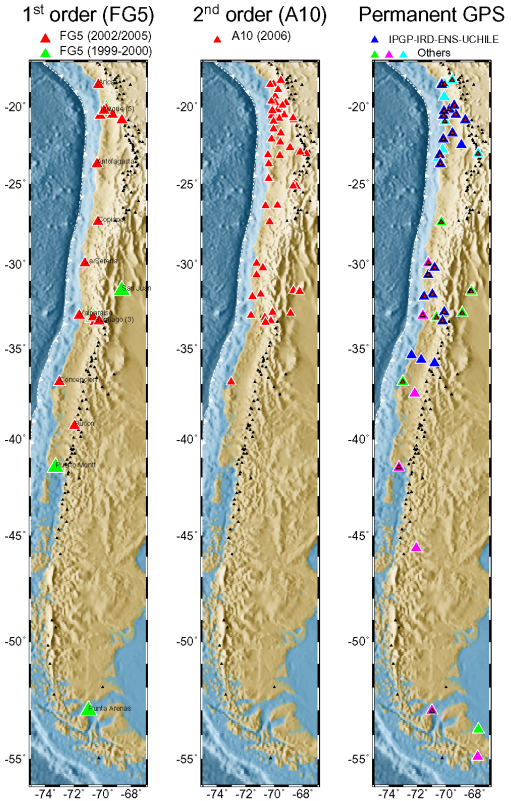
Année de mesure :

- 2005
- 2006
- 2007

Gravimétrie relative

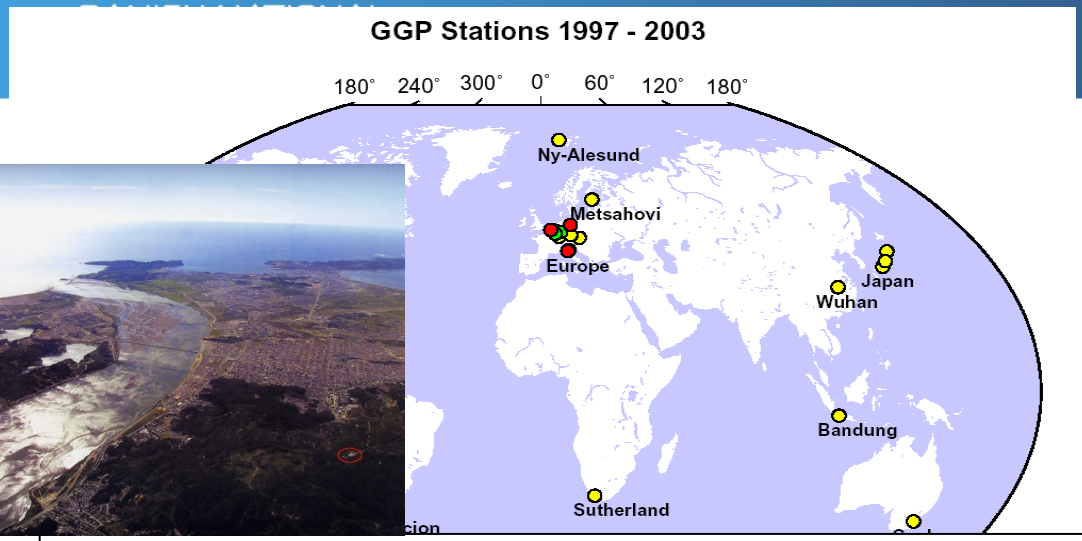
Année de mesure :

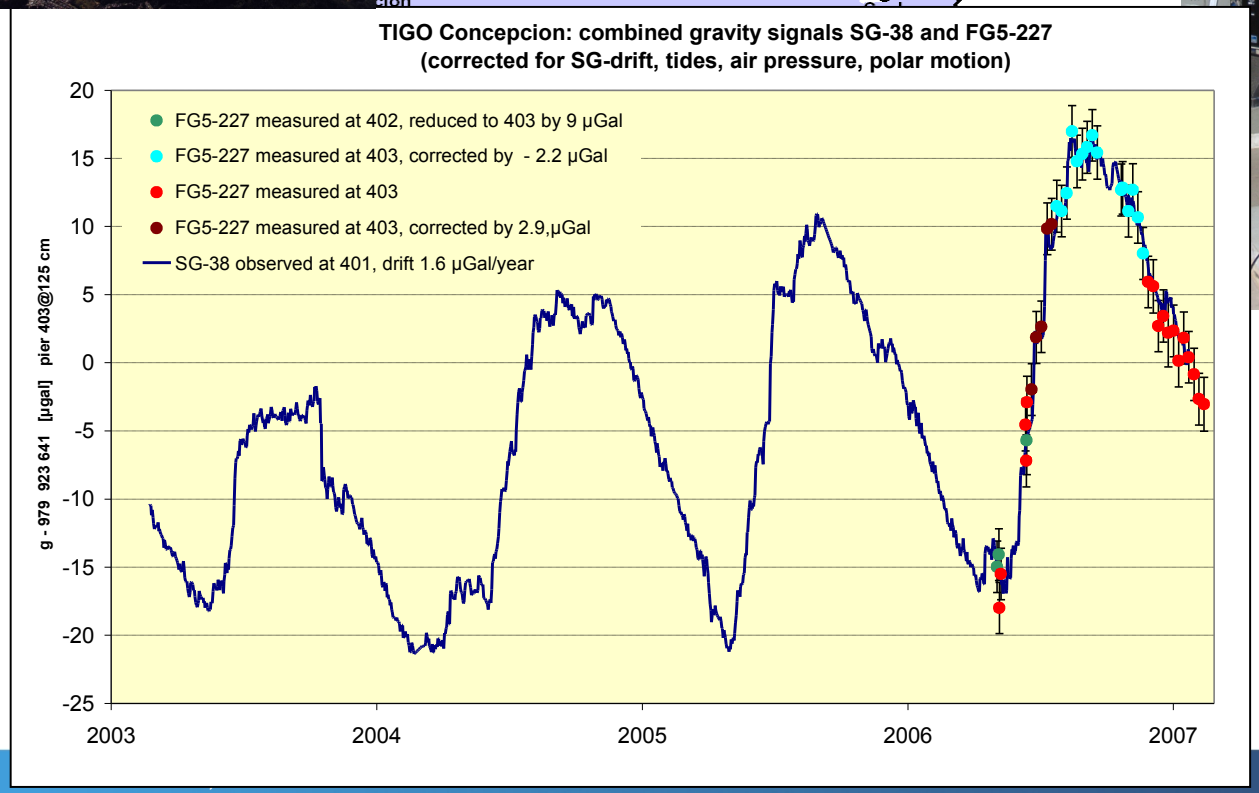
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007



17 stations | 60 stations | 31 colocated stations

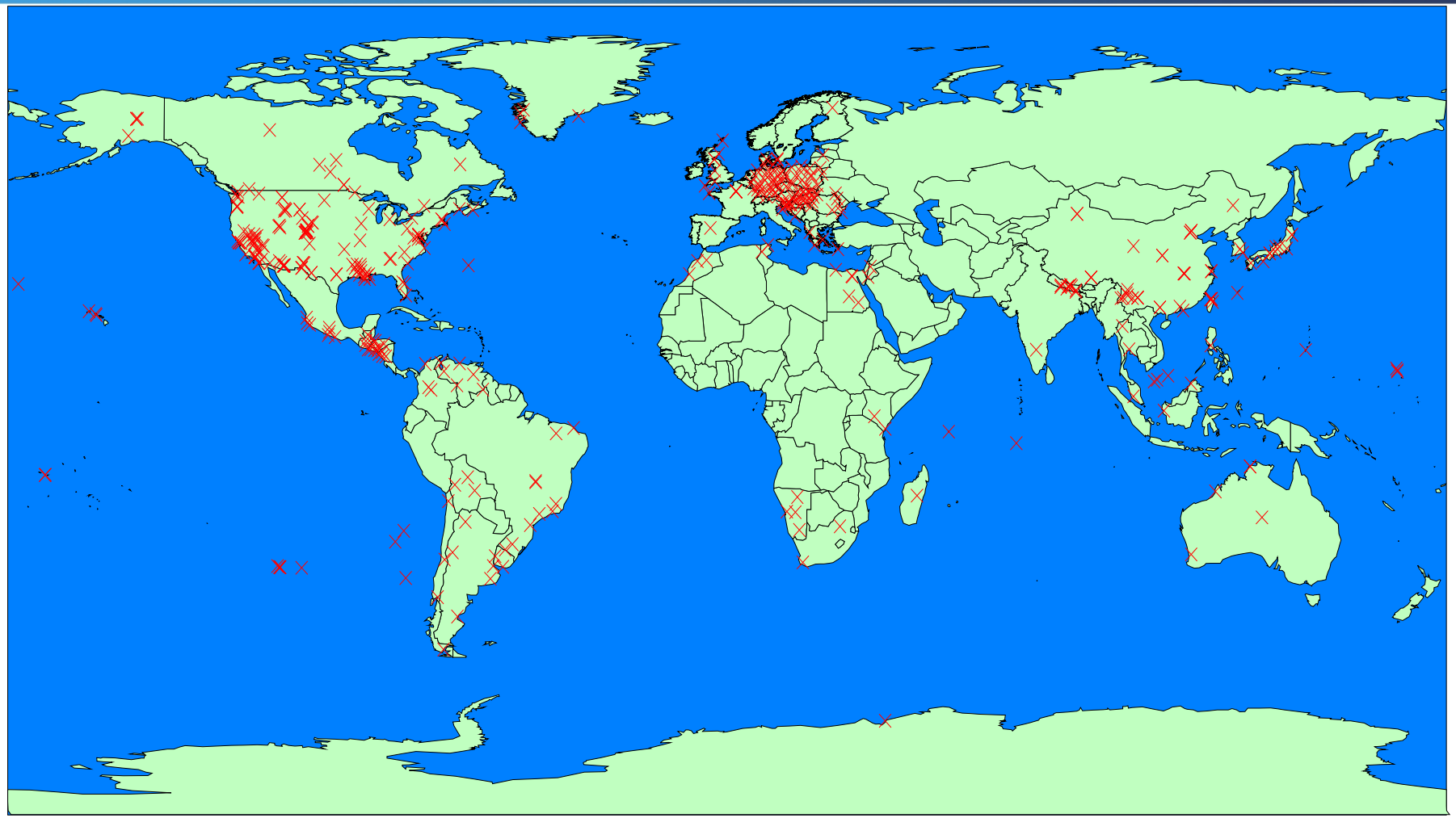
Combination of SG and AG in Concepcion (Chile)





Example for strong gravity variations at a geodetic reference station

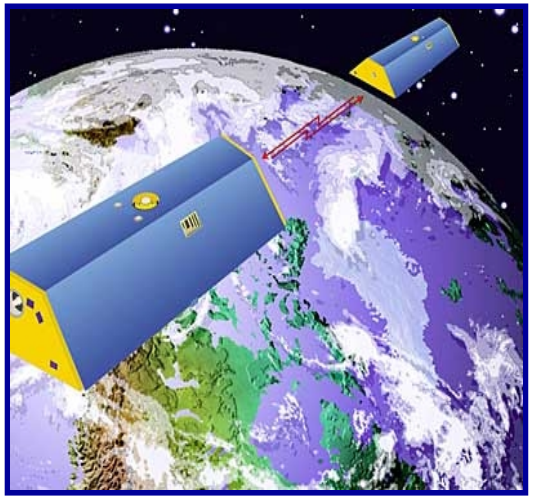
Absolute gravimetry network (NGA)



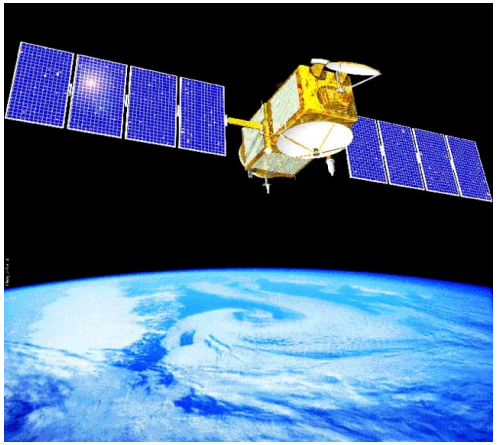
Need more co-located observatories (VLBI, Laser, GPS, abs.grav., …)
Many regional initiatives (”5-D networks”) - ECGN/Europe, NGOS/Nordic ..) ..

Earth Gravitational Model

Next … EGM 2008 (NGA)



- **CHAMP and GRACE satellite gravity missions**
  - **100x improvement in the accuracy with which large regional features of the gravitational field can be modeled**



- **High-resolution model of the gravitational field and geoid**
  - **5’ x 5’ resolution in many regions**
  - **15’ x 15’ aided by topography in other regions**
  - **New marine satellite altimetry solution**
  - **n=m=2160**
  - **15 cm global RMS accuracy goal for geoid**

Progression of EGMs

EGM96

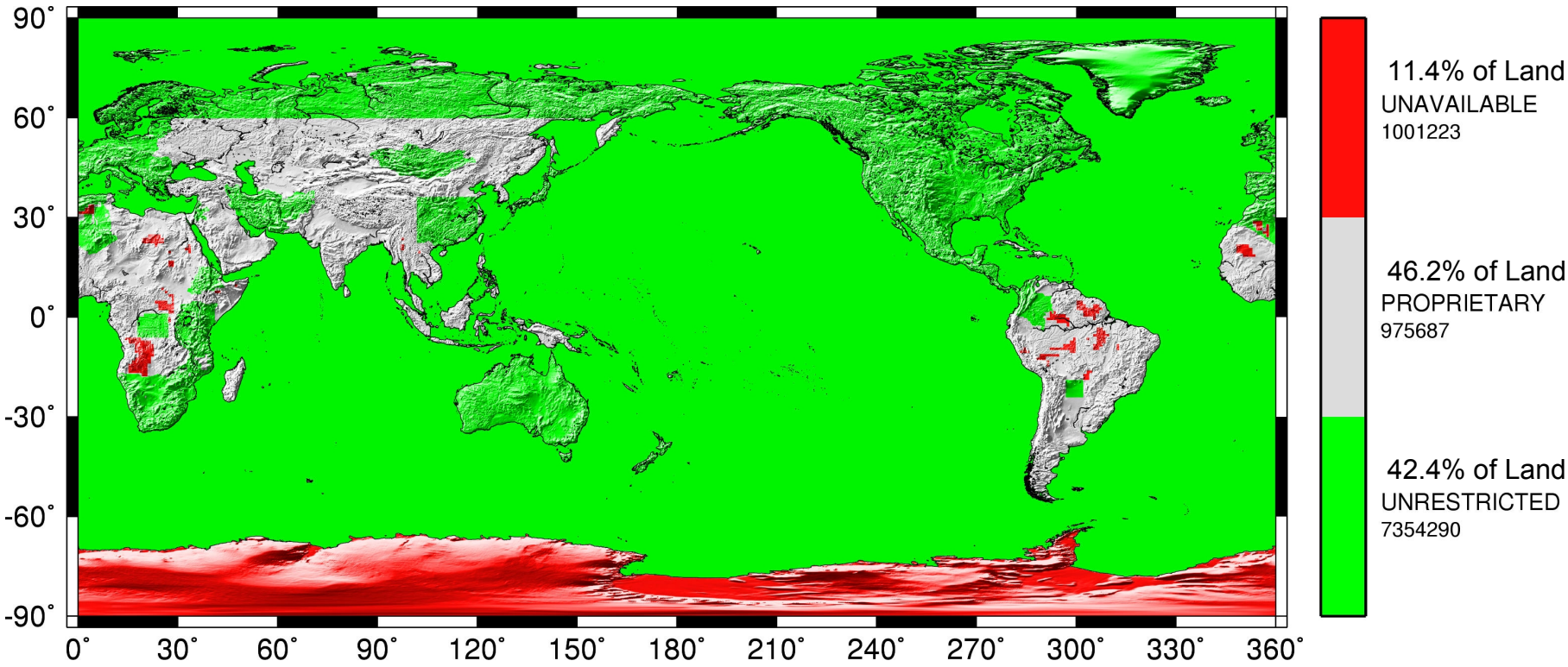
- **30'x30' resolution**
- **50 cm RMS accuracy**
- **70 x 70 error propagation**
- **40 satellites used for long λ's**
- **GEOSAT**
- **30 M surface gravity values**
- **29 elevation codes**
- **130 K coefficients**

EGM08

- **5'x5' resolution**
- **15 cm RMS accuracy**
- **2160 x 2160 error propagation**
- **GRACE used for long λ's**
- **MSS from retracked ERS-1, GEOSAT, TOPEX, etc.**
- **55 M surface gravity values**
- **SRTM, ICESAT**
- **4.7 M coefficients**

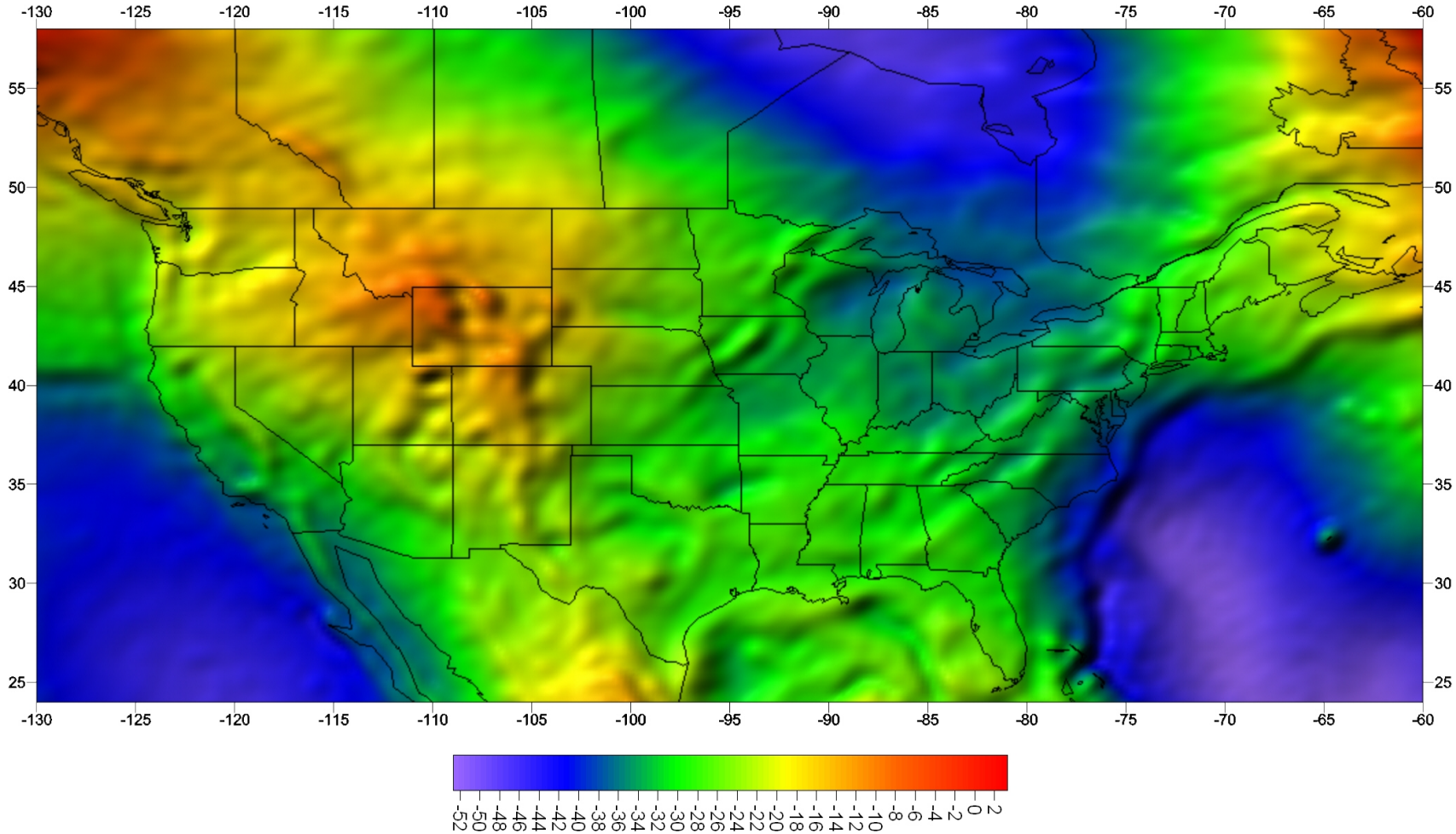
EGM08 to be released April 2008

5′×5′ Gravity Anomaly Data Availability (v052407)



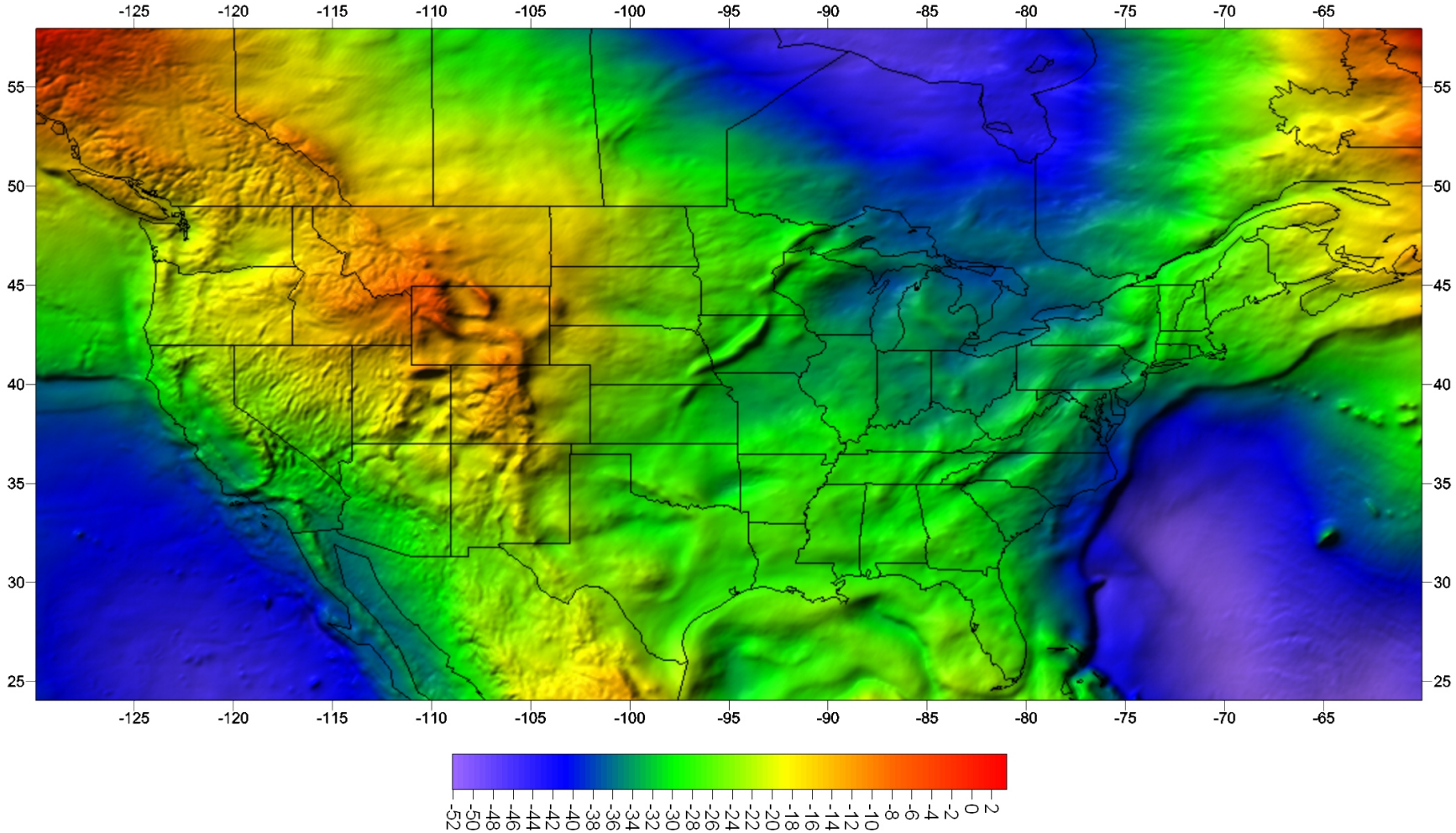
Earth Gravitational Model 1996

15‘x15’ Geoid Height Grid for the US



Earth Gravitational Model 2008

5‘x5’ Geoid Height Grid for the US



GPS/Leveling Comparisons Globally

Thinned set consisting of 12032 points. ±2 m edit applied.

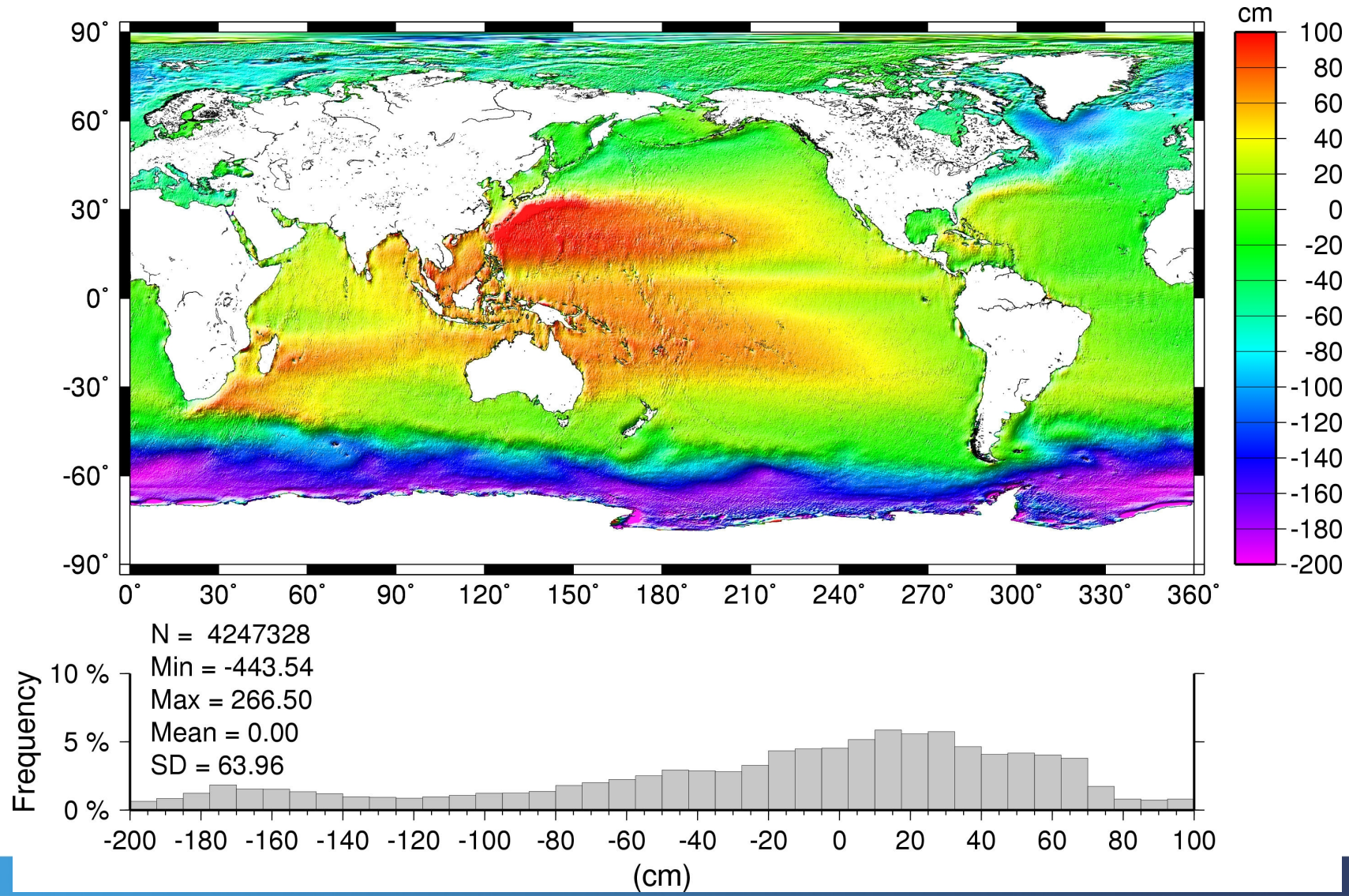
Conversion of Height Anomalies to Geoid Undulations applied in PGMs using DTM2006.0 elevation coefficients to Nmax=2190.

Model (Nmax)	Bias Removed		Linear Trend Removed	
	Number Passed Edit	Weighted Std. Dev. (cm)	Number Passed Edit	Weighted Std. Dev. (cm)
EGM96 (360)	11879	30.0	11835	26.8
PGM2004A (2190)	11986	16.3	11942	13.6
PGM2006A (2190)	11994	15.4	11950	13.0
PGM2006B (2190)	11994	**14.0**	11950	**11.4**

DANISH NATIONAL SPACE CENTER

International Association of Geodesy
IGFS

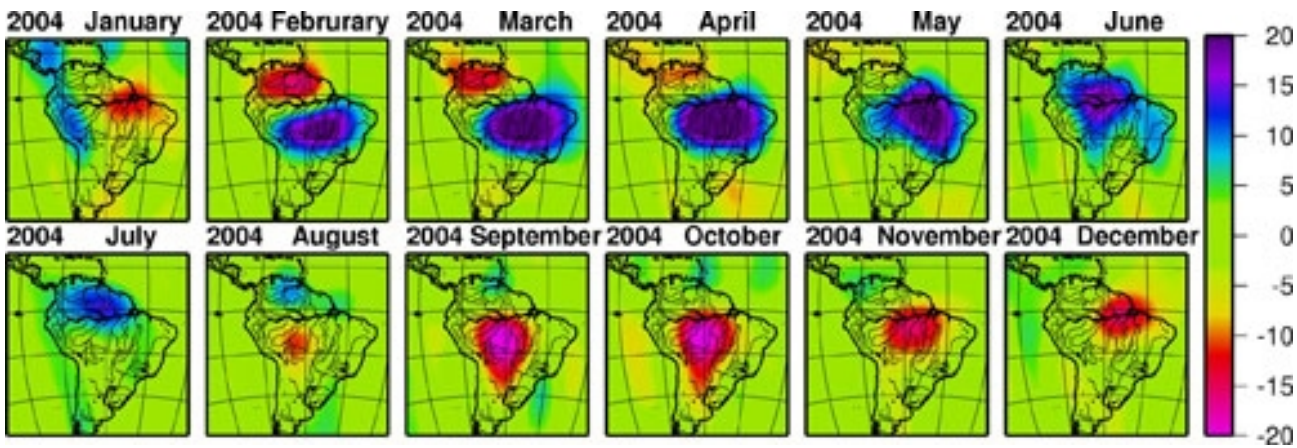
6′×6′ ΔSSH: MSS07C - PGM2007A



Mass changes: ICGEM/BGI provides monthly or 10-day geopotential solutions for GRACE ..

Conversion to mass changes straightforward – but separation of source problems
Need models (tides, post-glacial rebound, hydrology …)

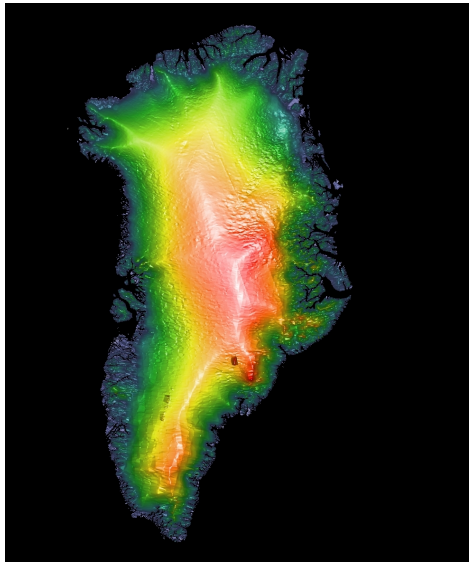
Data providers: CSR, GFZ, CNES, NASA-JPL, NASA-Goddard (masscons) ….
IGFS services should focus on gravity changes …



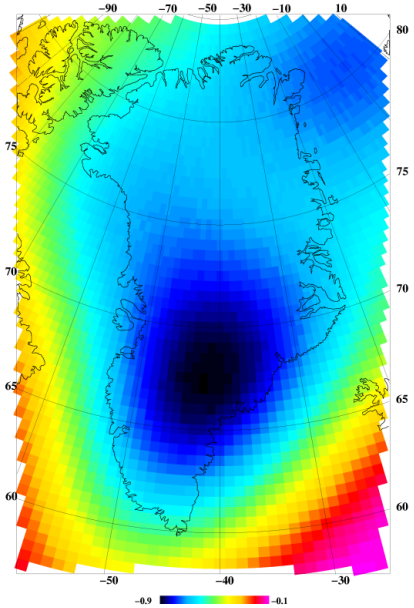
GRACE geoid height differences between monthly gravity solutions in 2003 and a 14-month mean for equatorial South America show changes in water storage in the Amazon and Orinoco basins.
Credit: The University of Texas Center for Space Research

Gravity change from GRACE: Greenland example - glaciology

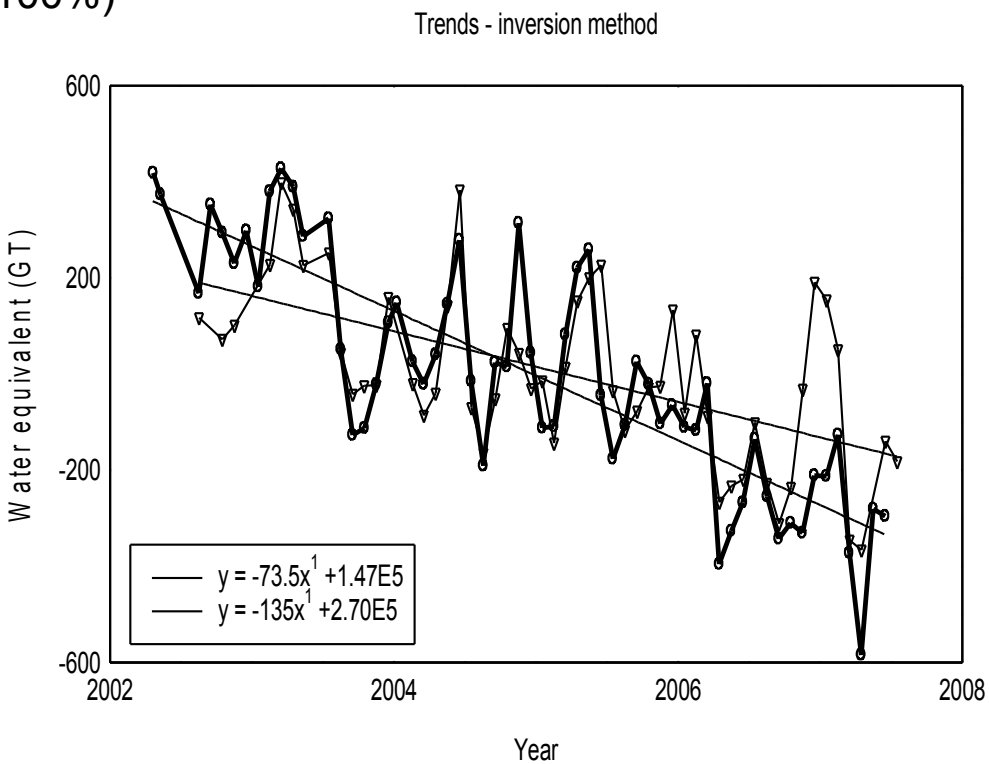
- Mass change of the Greenland ice sheet from GRACE ~ 80-150 km^3/yr
- Large difference between models ..
- Large difference between methods (up to 100%)
- *Combination solutions not practical (yet)*



DEM from ICESat (NASA)

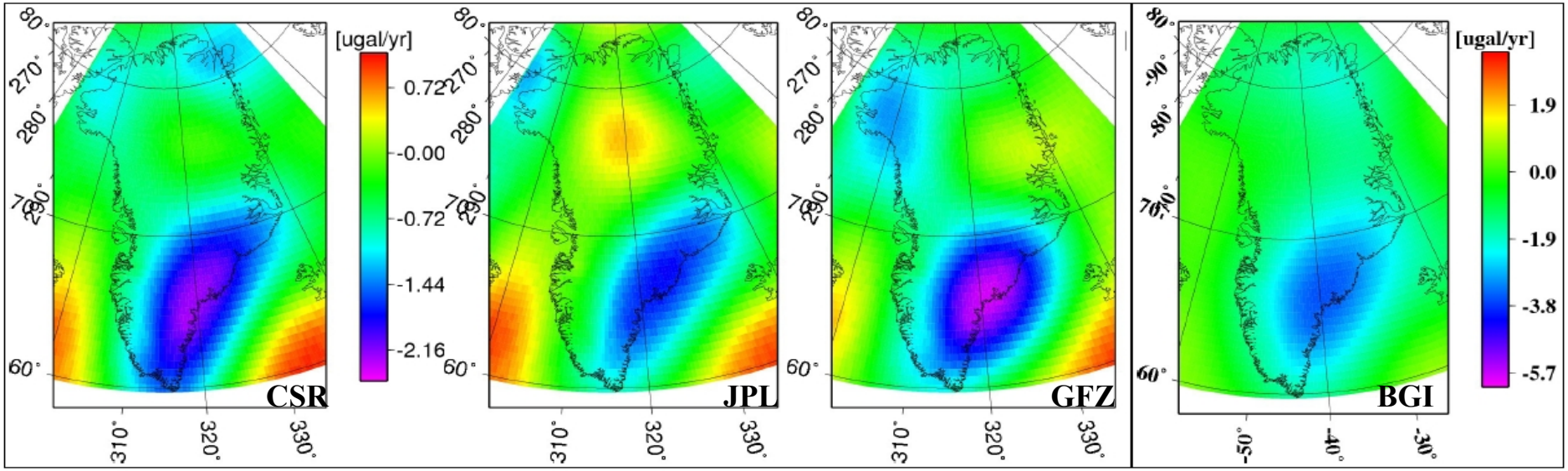


CSR RL-4 trend in δg at 480 km (μgal/yr), deg 30



Greenland total mass change in water equivalent for CSR and GFZ solutions. y-unit: km**3 water (DNSC)

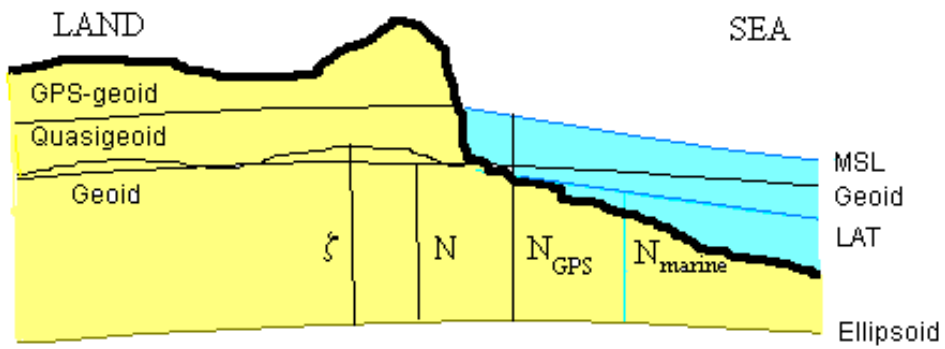
Greenland trend observations – harmonic degree 30, unfiltered, 2002-6

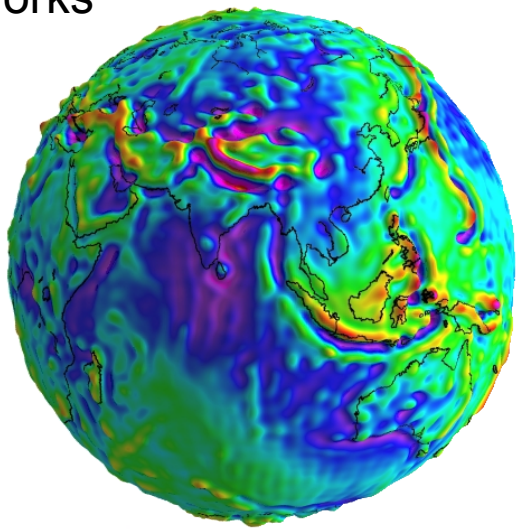


Gravity field ”products” for GGOS

Essential to limit products to ”globally relevant” quantities:

- Global gravity field models – spherical harmonics – consistent methodology … *satellite-only (n ~ 200), combination (n ~ 360 or 2160)*
- Mean gravity field needs an *epoch*
- Global vertical datum (6 mm ~10^{-9}) … *EGM08 first realization*
- Precise refined geoid models .. *especially around key GGOS station sites*
- Global absolute and superconducting gravity networks





The future GGOS service for gravity field and mass monitoring

• ”Seamless” online link service to a broad set of users: *scientific, government and commercial .. through a distributed set of service centers (BGI, IGeS, ICGEM ..)*

• Global coordinated and repeated absolute gravimetry, co-located with superconducting meters at GGOS ”supersites”

• Coordinated effort for global surveys and data exchange
- Data collection activities (airborne surveys, e.g. Antarctica)
- Regional meetings and schools

• Standards and conventions recommendations
Endorsement of International Earth Geopotential Models

• Temporal gravity field combinations solutions and mass changes – monthly or shorter intervals (GRACE, GRACE-follow-on …)


Thanks for your attention …
Airborne EGM gravity survey – Mongolia 2005