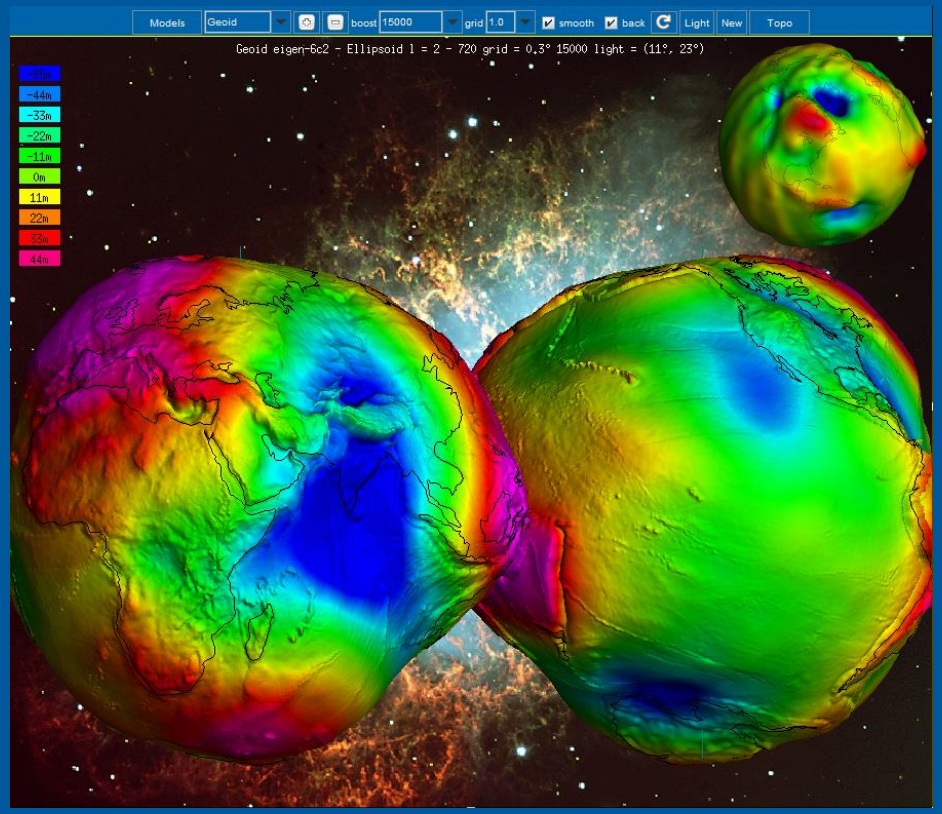
I C G E M

ICGEM – status of the IAG service for global Earth gravity field models after the first decade



Franz Barthelmes
Wolfgang Köhler

GFZ German Research Centre for Geosciences
Telegrafenberg
14473 Potsdam
Section 1.2

ICGEM – A Service of the IAG

Since 2003

International Association of Geodesy

Commission 2 "Gravity Field"

IGFS - International Gravity Field Service

BGI	IGeS	ICET	ICGEM	IDEMS	IGFS
International Gravity Bureau	International Geoid Service	International Centre for Earth Tides	International Centre for Global Earth Models	International DEM Service	Technical Centre
CNES Toulouse	Polimi Milano	U.F. Polynesia		DeMontfort UK	NGA

Objectives / Status of ICGEM

- collecting and archiving of all existing global gravity field models
- making them available on the web **135 listed 120 downloadable**
- use of standardised format (self-explanatory) (→ accepted for GOCE / ESA)
- interactive visualisation of the models, their differences, and their time variation
- web-interface to calculate different gravity field functionals from the spherical harmonic models on freely selectable grids (filtering included)

- evaluation of the models (→ differences in the frequency domain, comparison with GPS/levelling)
- answering of questions (online discussion forum / guest book)

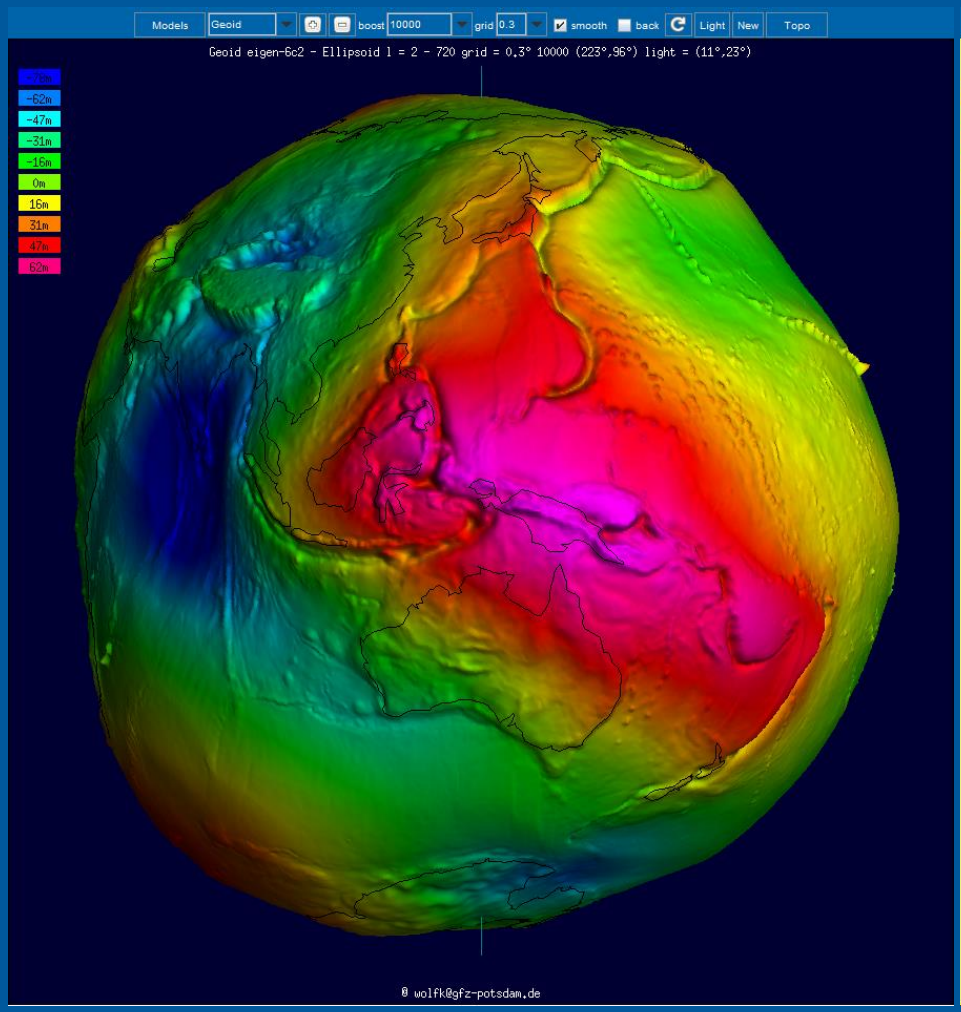
Table of available Models

Model	Year	Degree	Data	Reference	download
ULux_CHAMP2013s	2013	120	S(Champ)	Weigelt et al, 2013	♦zip♦
ITG-Goce02	2013	240	S(Goce)	Schall et al, 2013	♦zip♦
GO_CONS_GCF_2_TIM_R4	2013	250	S(Goce)	Pail et al, 2011	♦zip♦
GO_CONS_GCF_2_DIR_R4	2013	260	S(Goce, Grace,Lageos)	Bruinsma et al, 2013	♦zip♦
EIGEN-6C2	2012	1949	S(Goce, Grace,Lageos),G,A	Förste et al, 2012	♦zip♦
DGM-1S	2012	250	S(Goce, Grace)	Hashemi Farahani, et al. 2012	♦zip♦
GOCO03S	2012	250	S(Goce, Grace,...)	Mayer-Gürr, et al. 2012	♦zip♦
GO_CONS_GCF_2_DIR_R3	2011	240	S(Goce, Grace,Lageos)	Bruinsma et al, 2010	♦zip♦
GO_CONS_GCF_2_TIM_R3	2011	250	S(Goce)	Pail et al, 2011	♦zip♦
GEM1	1972	12	S	Lerch et al, 1972a	♦♦♦♦
KOCH71	1971	11	S,G	Koch and Witte, 1971	♦♦♦♦
KOCH70	1970	8	S,G	Koch and Morrison, 1970	♦♦♦♦
SE2	1969	16	S,G	Gaposchkin and Lambeck, 1970	♦♦♦♦
OSU68	1968	14	S,G	Rapp, 1968	♦♦♦♦
WGS66	1966	24	G	WGS Committee, 1966	♦♦♦♦
SE1	1966	8	S	Lundquist and Veis, 1966	♦♦♦♦

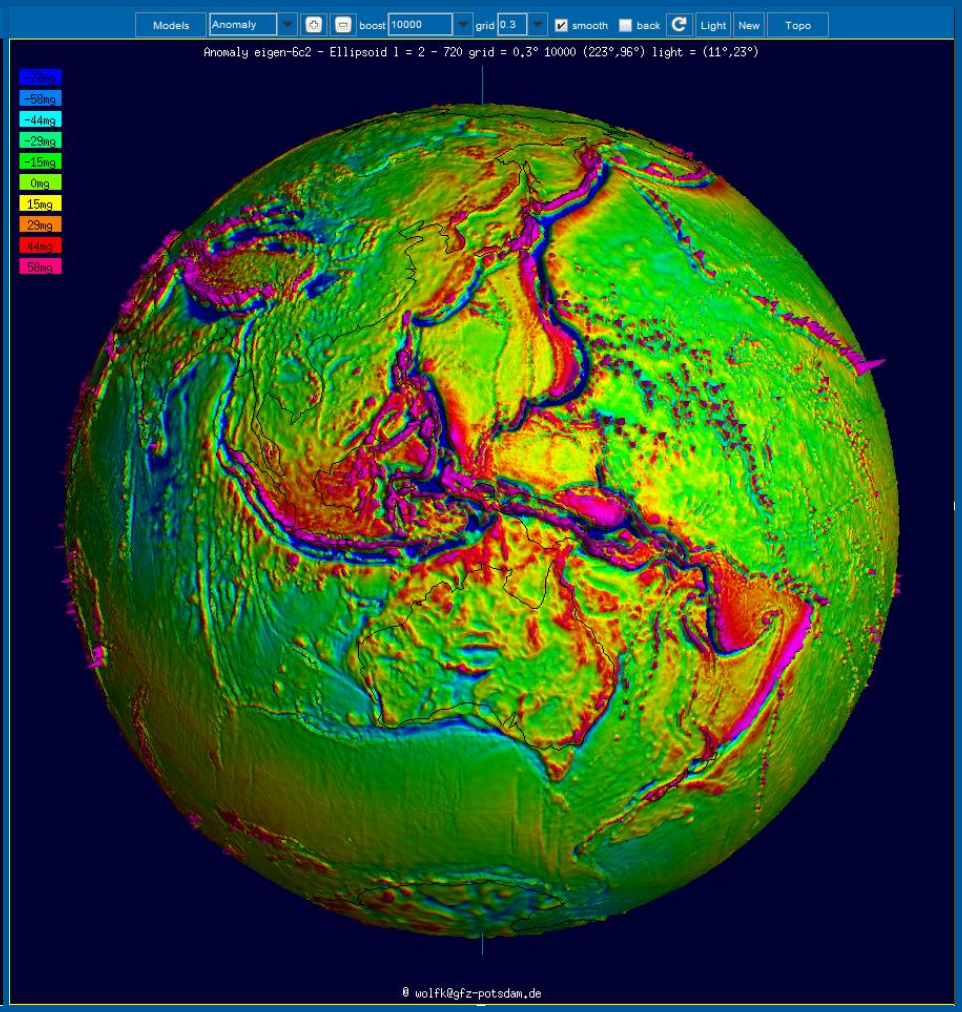
135 models

Interactive Visualisation Service

Geoid

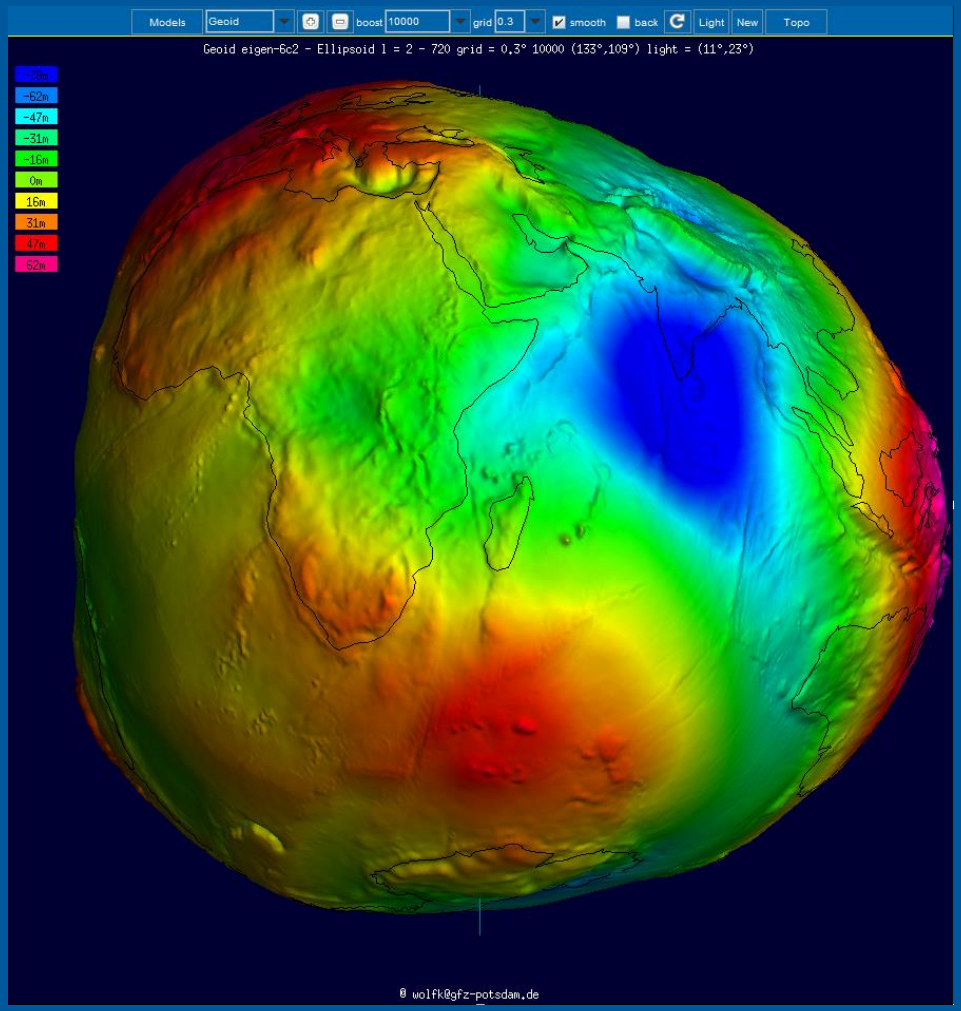


Gravity Anomaly

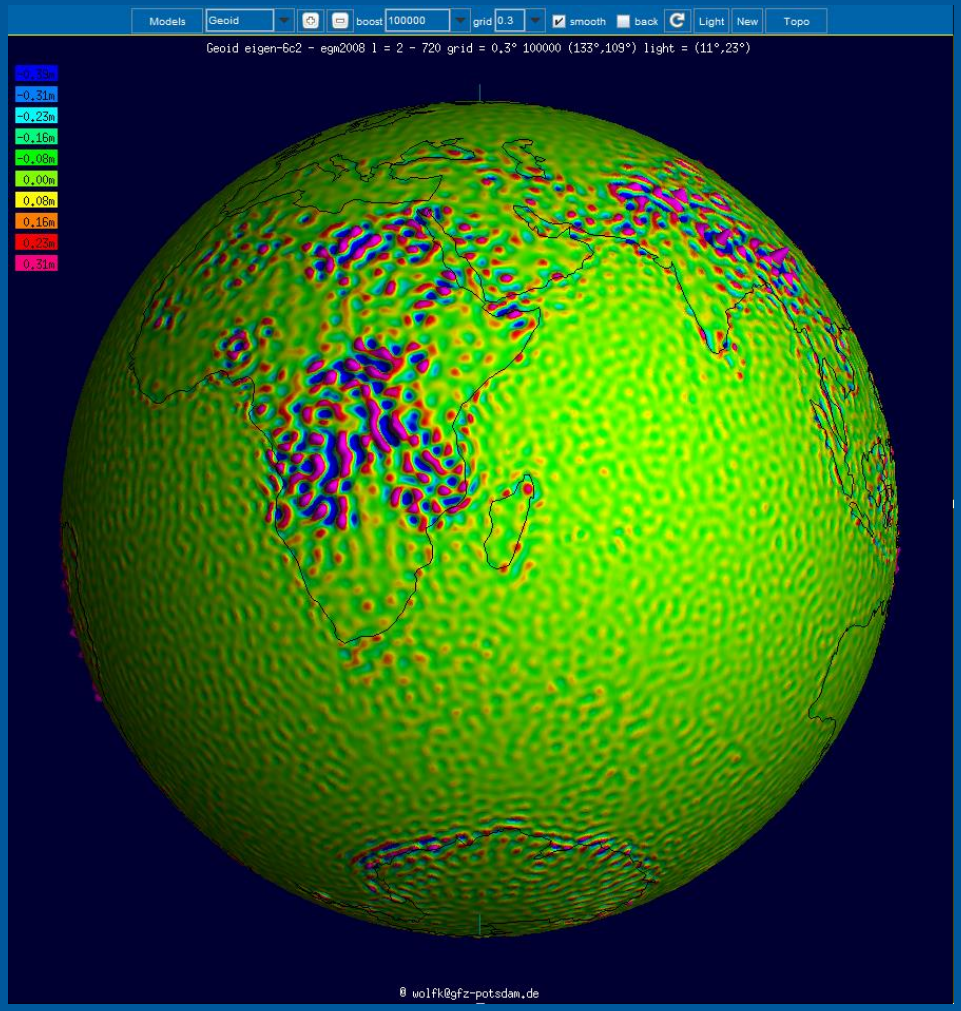


Interactive Visualisation Service

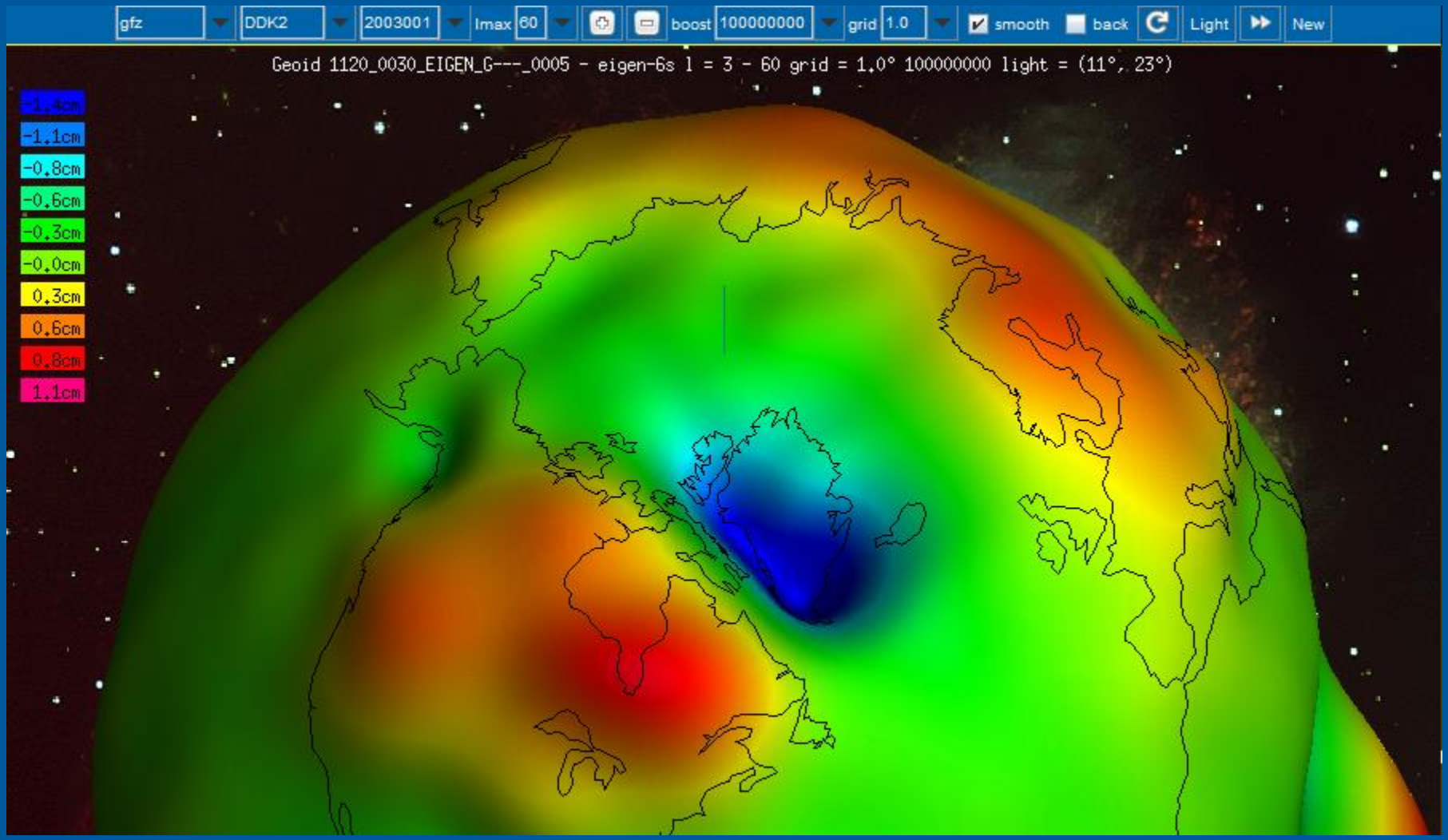
Geoid



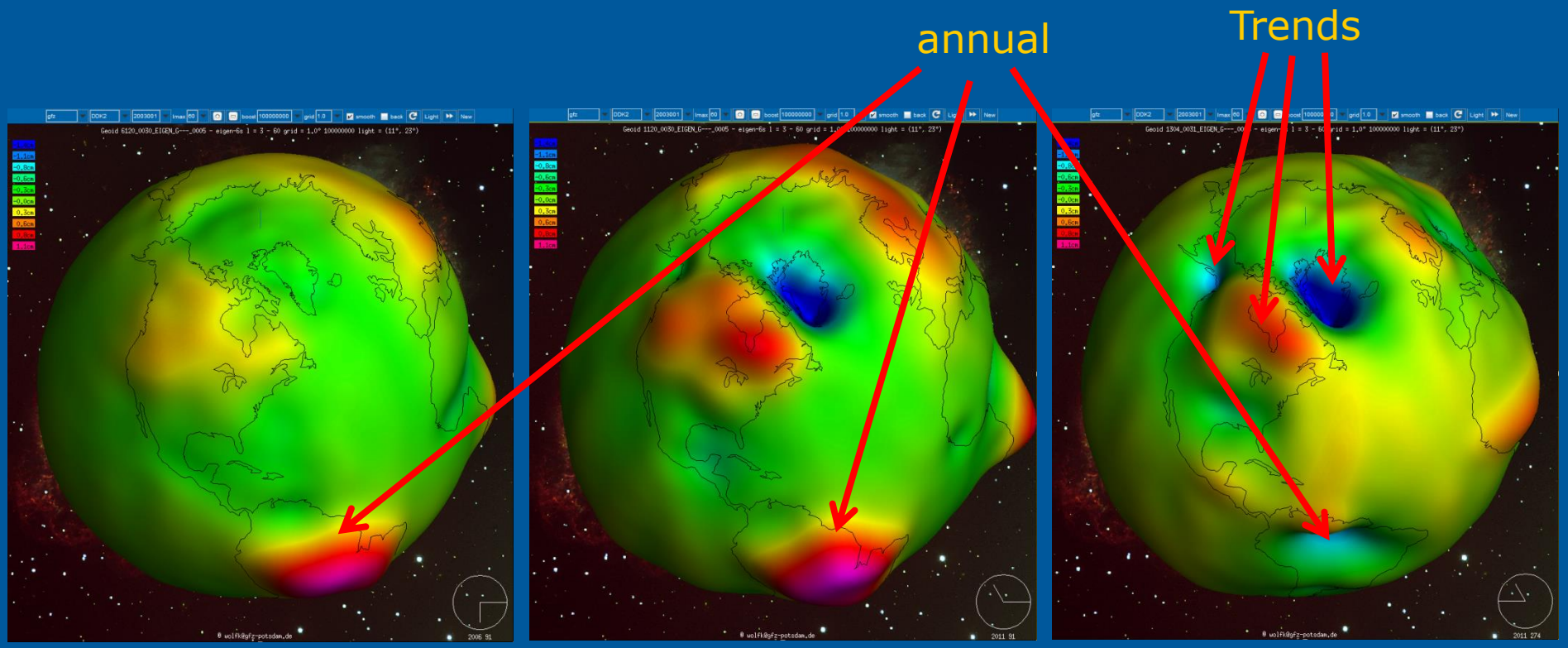
Differences of 2 Models



Animated Visualisation of Monthly Solutions

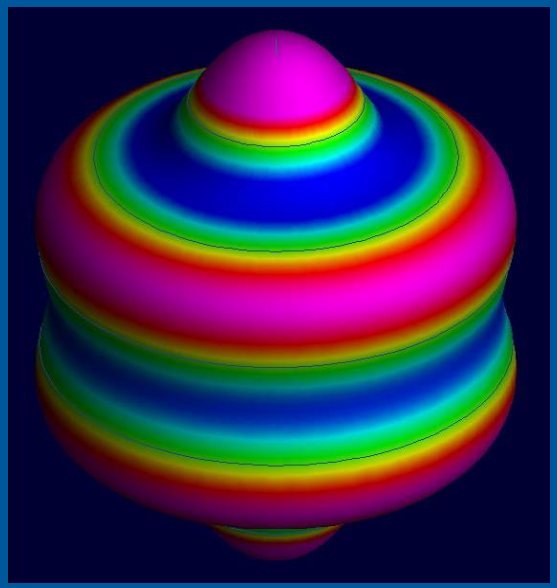


Animated Visualisation of Monthly Solutions

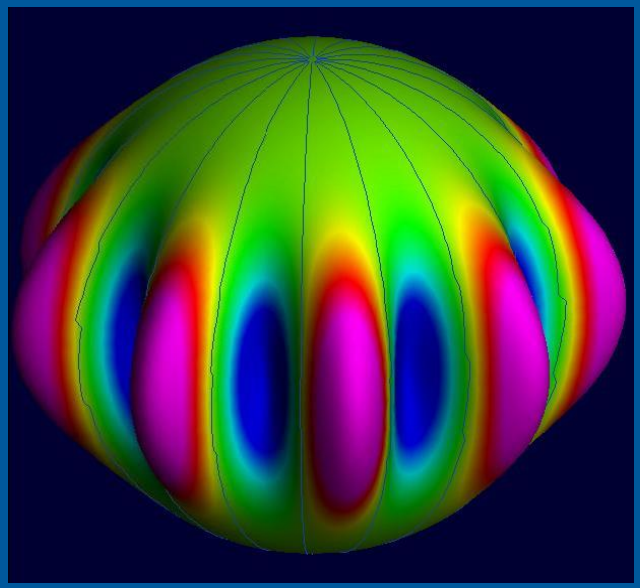


Interactive Visualisation Service

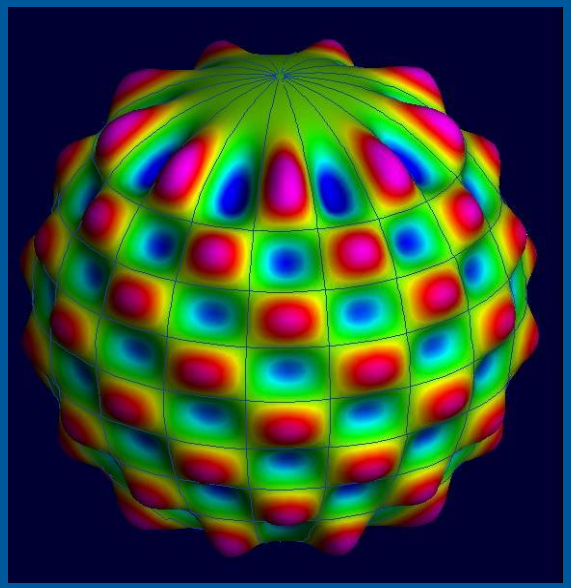
Spherical Harmonics as Tutorial



zonal: $\ell = 6$, m = 0

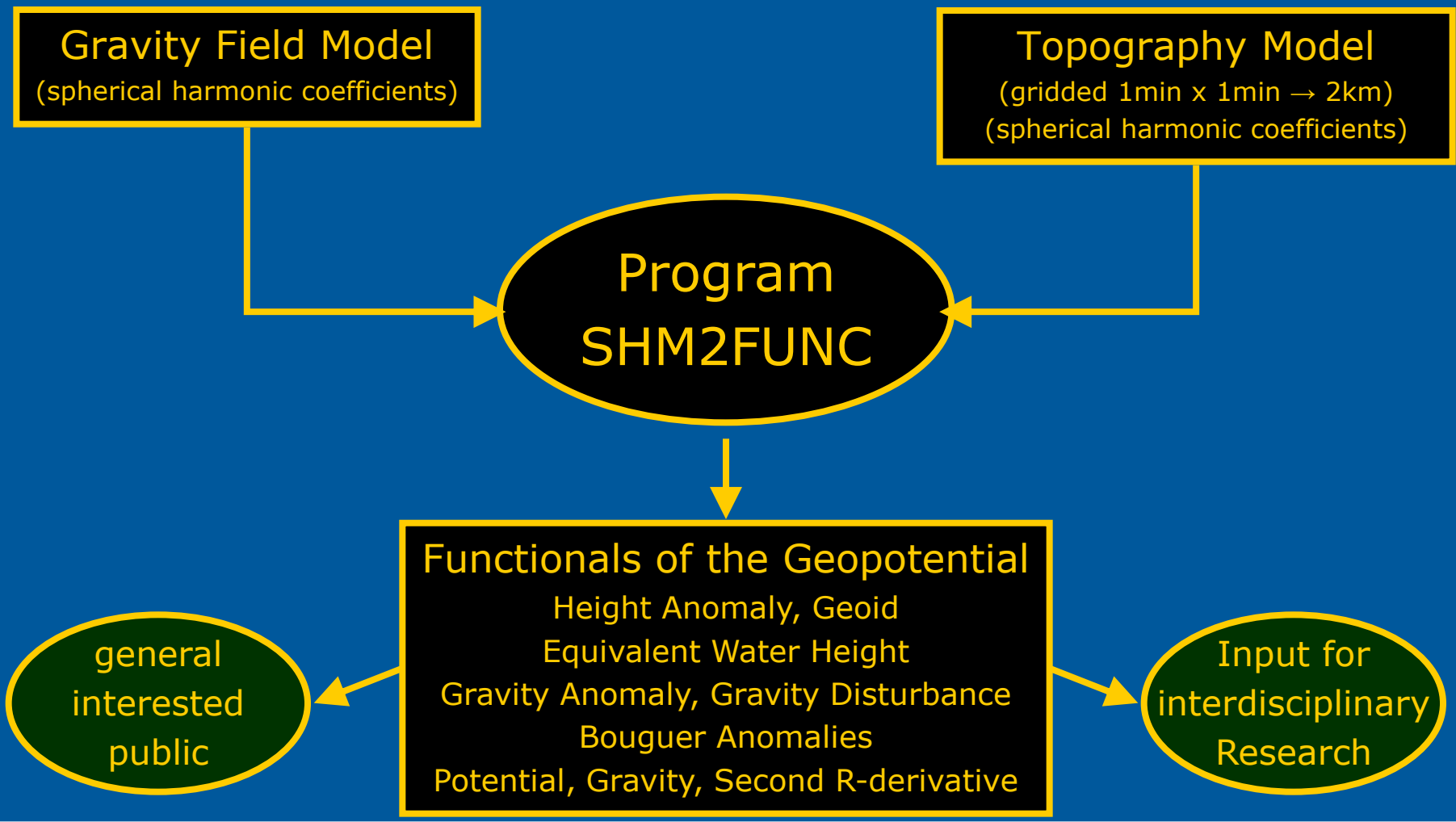


sectorial: $\ell = 9$, m = 9

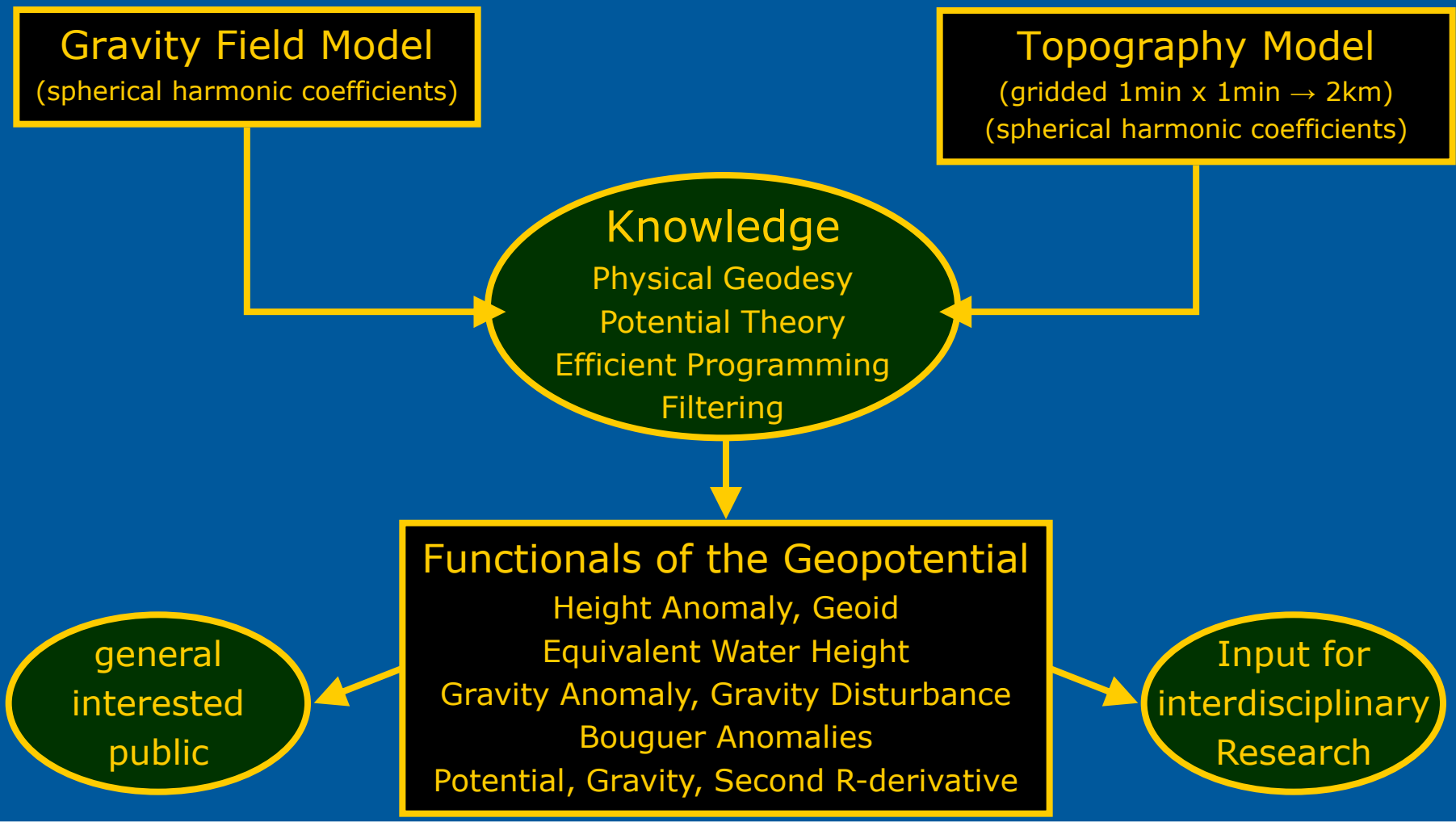


tesseral: $\ell = 16$, m = 9

Calculation Service



Calculation Service



Calculation Service

Web-Interface

Reference System

Model

Functional

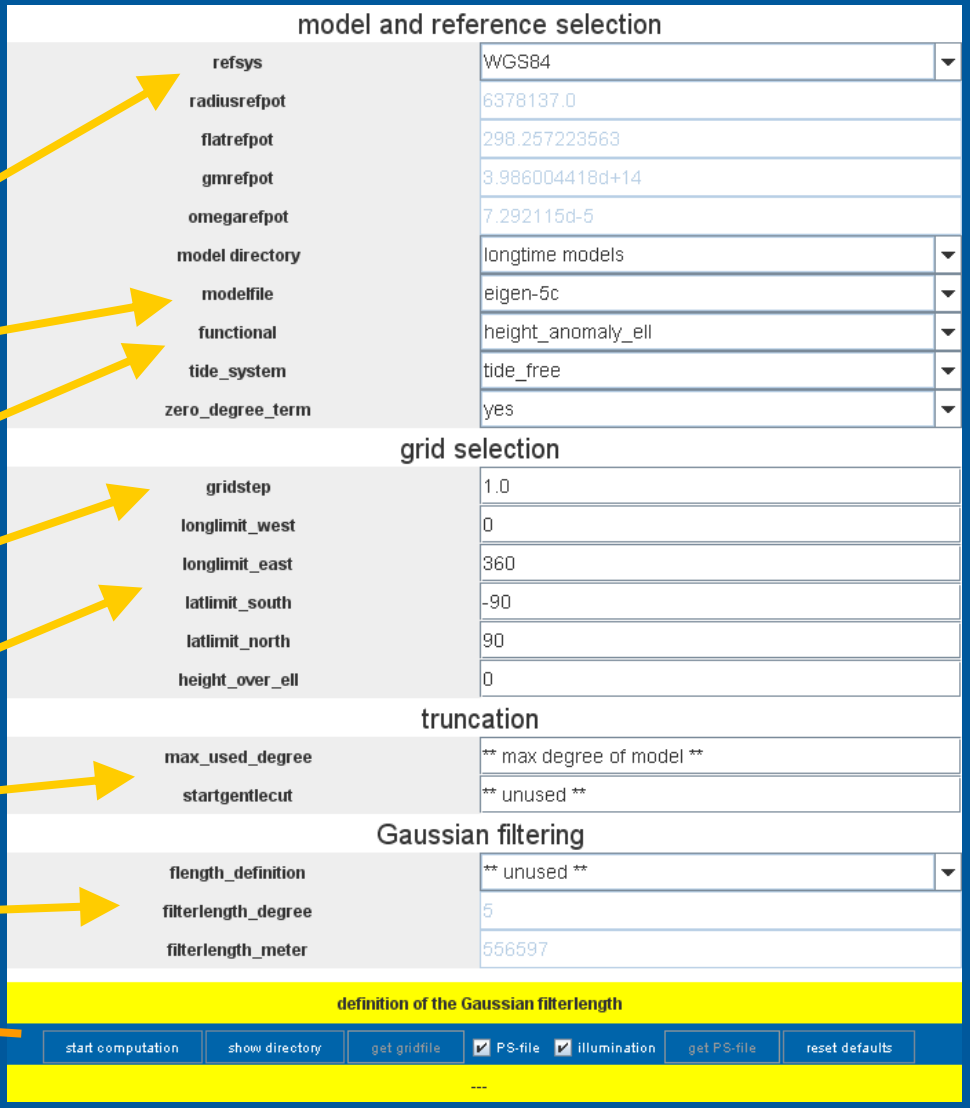
Grid Density

Grid Area

Truncation

Filtering

Grids and Plots



Calculation Service

available functionals

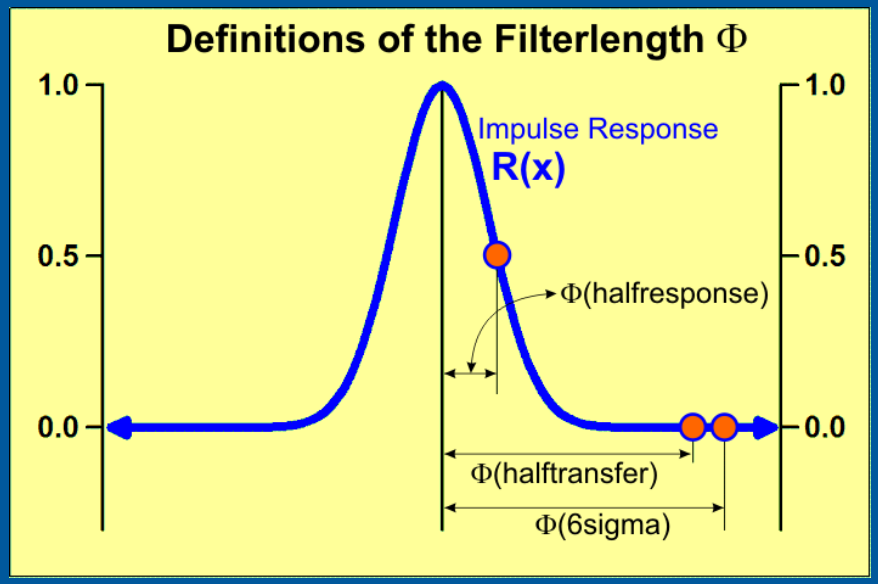
- height anomaly (on the Earth's surface, on the ellipsoid)
- geoid undulation
- gravity anomaly (Molodensky, classical ≈ free air, spherical approximation, Bouguer)
- gravity disturbance (on the Earth' surface, spherical approximation)
- gravity (on the Earth' surface, on or above the ellipsoid)
- gravitation (on or above the ellipsoid)
- second radial derivative (on or above the ellipsoid)
- equivalent water height (including elastic deformation)
- potential (on or above the ellipsoid)

Calculation Service

Explanation of the Functionals

keyword	explanation
height_anomaly	The so called "height anomaly" is an approximation of the geoid according to Molodensky's theory. It is equal to the geoid over sea. Here it will be calculated, as defined, on the Earth's surface approximated by Bruns' formula on the ellipsoid plus a first order correction (eqs. 81 and 119 of STR09/02).
height_anomaly_ell	The height anomaly can be generalised to a 3-d function, (sometimes called "generalised pseudo-height-anomaly"). Here it can be calculated on (h=0) or above (h>0) the ellipsoid, approximated by Bruns' formula (eqs. 78 and 118 of STR09/02).
geoid	The Geoid is one particular equipotential surface of the gravity potential of the Earth. Among all equipotential surfaces, the geoid is those which is equal to the undisturbed sea surface and its continuation below the continents. Here it will be approximated by the height anomaly plus a topography dependent correction term (eqs. 71 and 117 of STR09/02).
gravity_disturbance	The gravity disturbance is defined as the magnitude of the gradient of the potential at a given point minus the magnitude of the gradient of the normal potential at the same point. Here it will be calculated on the Earth's surface (eqs. 87 and 121 – 124 of STR09/02).
gravity_disturbance_sa	The gravity disturbance calculated by spherical approximation (eqs. 92 and 125 of STR09/02) on (h=0) or above (h>0) the ellipsoid.
gravity_anomaly	The gravity anomaly (according to Molodensky's theory) is defined as the magnitude of the gradient of the potential on the Earth's surface minus the magnitude of the gradient of the normal potential on the Telluroid (Earth's surface minus height anomaly) (eqs. 101 and 121 – 124 of STR09/02).
gravity_anomaly_cl	The classical gravity anomaly is defined as the magnitude of the gradient of the downward continued potential on the geoid minus the magnitude of the gradient

Explanation of the Filtering



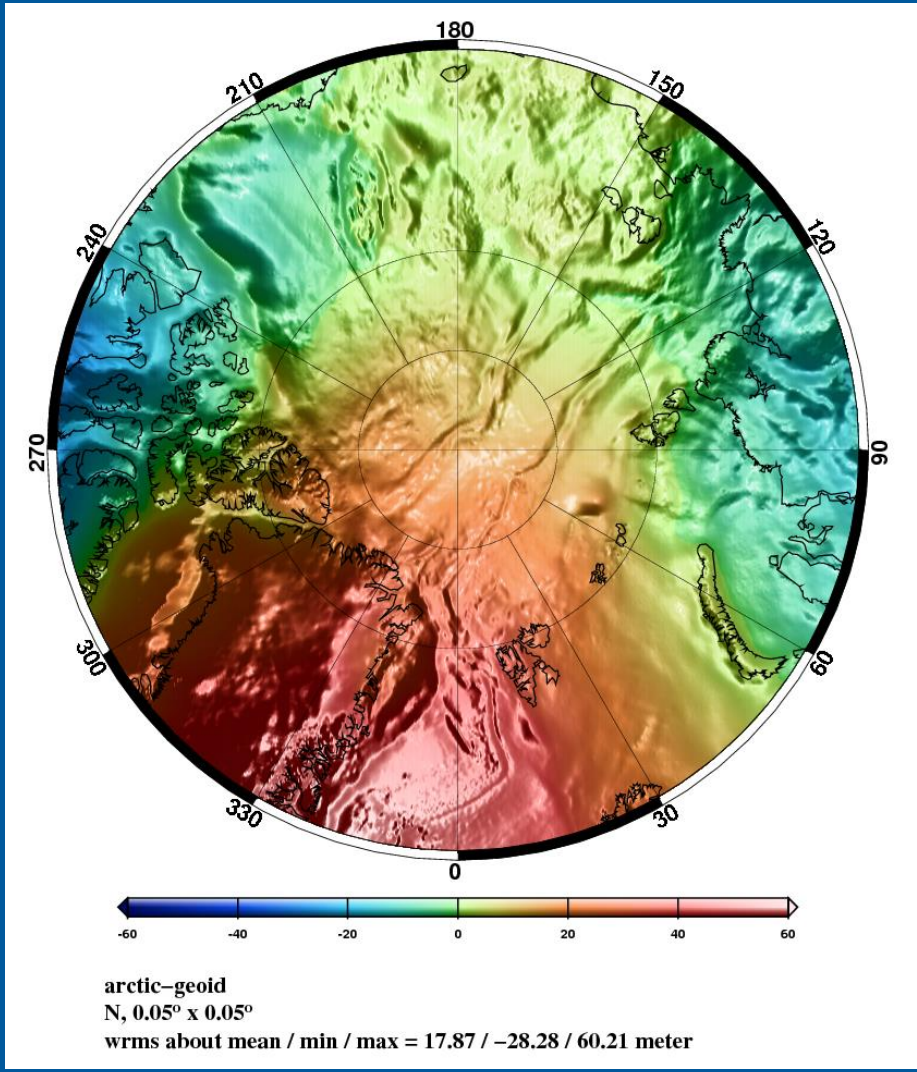
Theory and Formulas

➔ Link to: Report STR09/02

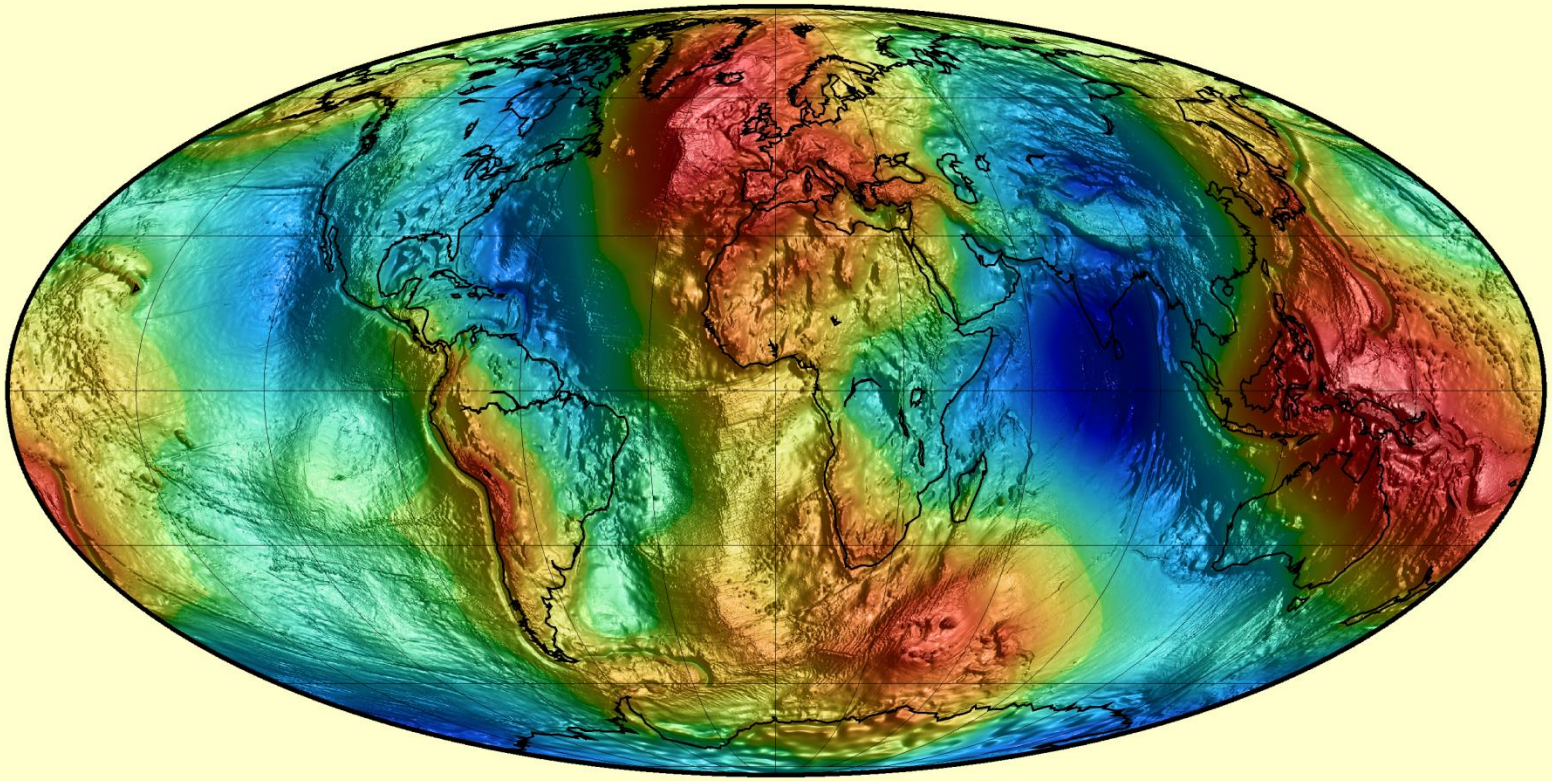
Calculation Service

Calculation of downloadable Grids

- freely selectable grid areas
- automatic generation of plots

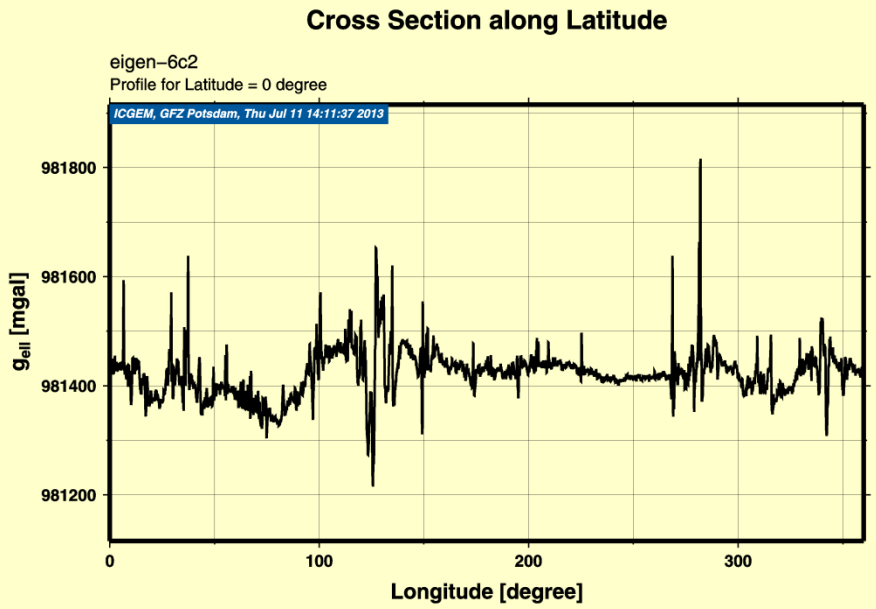


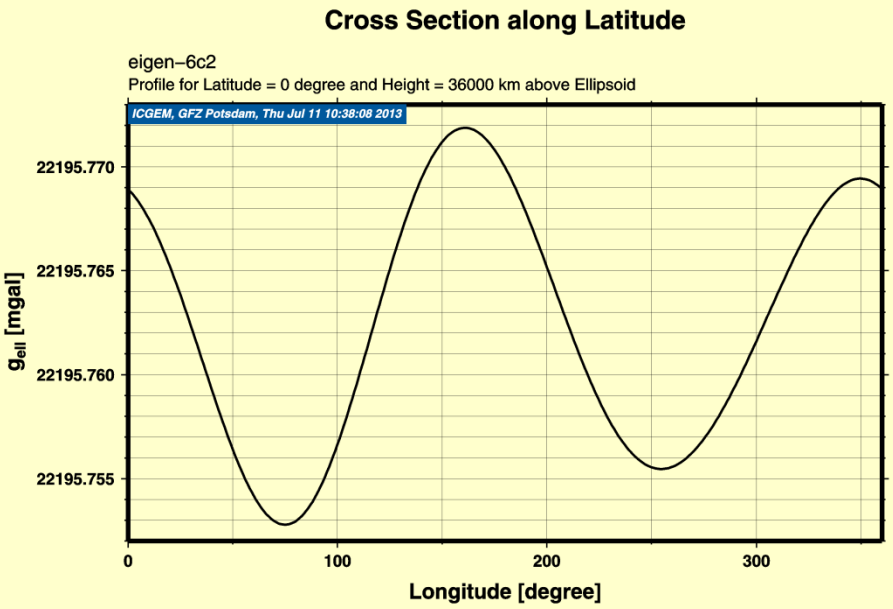
Calculation Service



Calculation Service

Cross Sections
(here: gravitation on and above the ellipsoid)





Evaluation of the Models

Comparisons in the spectral domain

→ plot for each model

GO_CONS_GCF_2_DIR_R4
spectral comparison with the model EIGEN–6C2

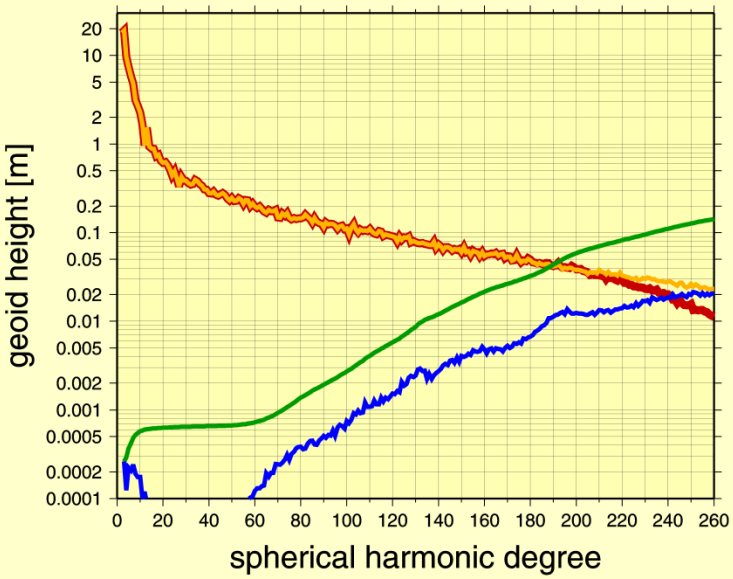
The graphs show:

Signal amplitudes per degree of GO_CONS_GCF_2_DIR_R4

Signal amplitudes per degree of EIGEN–6C2

Difference amplitudes per degree of GO_CONS_GCF_2_DIR_R4 vs. EIGEN–6C2

Difference amplitudes as a function of maximum degree of GO_CONS_GCF_2_DIR_R4 vs. EIGEN–6C2



Evaluation of the Models

Comparisons with GPS-levelling data

Model	Nmax	USA 6169 points	Canada 1930 points	Europe 1235 points	Australia 201 points	Japan 816 points
ULUX_CHAMP2013S	120	0.778 m	0.688 m	0.994 m	0.770 m	1.288 m
ITG-GOCE02	240	0.429 m	0.354 m	0.434 m	0.371 m	0.511 m
GO_CONS_GCF_2_TIM_R4	250	0.407 m	0.325 m	0.399 m	0.331 m	0.486 m
GO_CONS_GCF_2_DIR_R4	260	0.404 m	0.314 m	0.393 m	0.337 m	0.476 m
EIGEN-6C2	1949	0.249 m	0.127 m	0.212 m	0.214 m	0.080 m
DGM-1S	250	0.441 m	0.352 m	0.430 m	0.366 m	0.513 m
GOCO03S	250	0.428 m	0.340 m	0.418 m	0.355 m	0.500 m
GO_CONS_GCF_2_DIR_R3	240	0.431 m	0.347 m	0.423 m	0.355 m	0.506 m
GO_CONS_GCF_2_TIM_R3	250	0.430 m	0.343 m	0.417 m	0.357 m	0.496 m
EIGEN-6C	1420	0.247 m	0.135 m	0.214 m	0.219 m	0.082 m
GIF48	360	0.319 m	0.230 m	0.275 m	0.236 m	0.275 m
EIGEN-6S	240	0.446 m	0.373 m	0.449 m	0.397 m	0.520 m
GOCO02S	250	0.435 m	0.352 m	0.434 m	0.371 m	0.516 m
AIUB-GRACE03S	160	0.650 m	0.514 m	0.713 m	0.486 m	0.835 m
GO_CONS_GCF_2_DIR_R2	240	0.443 m	0.374 m	0.449 m	0.391 m	0.519 m
GO_CONS_GCF_2_TIM_R2	250	0.436 m	0.355 m	0.434 m	0.375 m	0.515 m
GO_CONS_GCF_2_SPW_R2	240	0.457 m	0.376 m	0.473 m	0.376 m	0.553 m
GO_CONS_GCF_2_DIR_R1	240	0.407 m	0.319 m	0.402 m	0.319 m	0.489 m
GO_CONS_GCF_2_TIM_R1	224	0.455 m	0.378 m	0.474 m	0.371 m	0.578 m
GO_CONS_GCF_2_SPW_R1	210	0.471 m	0.399 m	0.498 m	0.384 m	0.569 m
GEM2	22	2.910 m	3.226 m	3.720 m	3.003 m	4.080 m
GEM1	22	4.180 m	4.691 m	3.164 m	3.449 m	4.847 m
KOCH71	11	17.179 m	10.337 m	12.101 m	11.823 m	6.075 m
KOCH70	8	15.783 m	12.880 m	10.683 m	13.334 m	2.854 m
SE2	22	3.897 m	4.988 m	4.434 m	3.325 m	4.924 m
OSU68	14	4.261 m	9.115 m	3.654 m	5.097 m	4.013 m
WGS66	24	3.206 m	5.326 m	3.360 m	3.982 m	5.853 m
SE1	15	3.895 m	4.851 m	8.339 m	3.826 m	5.003 m

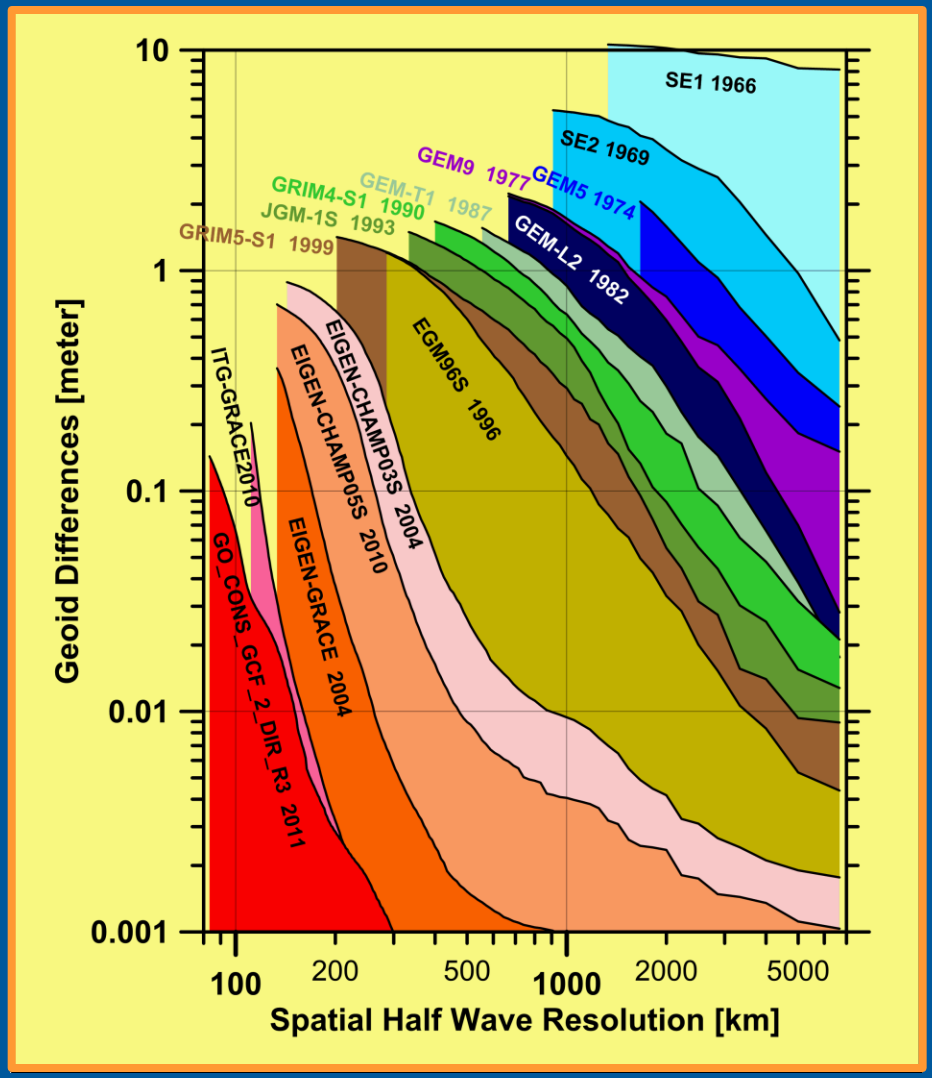
Latest Changes

- **2. August 2013:**
  Two new models with degree and order 660 for the Moon (GRGM660PRIM, GL0660B), based on the GRAIL mission, have been included.
- **30. April 2013:**
  New model **ULux_CHAMP2013s** and the CHAMP monthly solutions **ULux2013s_2003_01 ... ULux2013s_2009_12** from the University of Luxembourg included.
- **24. April 2013:**
  New model **ITG-GOCE02** included.
- **15. April 2013:**
  Visualization applet for **monthly models (Animation)** improved.
  Now also filtered solutions of all 3 processing centers (GFZ, JPL, CSR) and GFZ weekly solutions can be inspected.
- **28. March 2013:**
  GRACE weekly solutions from GFZ included.
- **21. March 2013:**
  New models **GO_CONS_GCF_2_TIM_R4 and GO_CONS_GCF_2_DIR_R4** included.
- **11. February 2013:**
  Revised Edition of the **STR09/02** is available ⇒ **Button "Theory"**.
- **11. January 2013:**
  On the evaluation site comparisons with **GPS/levelling data** from **Japan** are included.
- **11. December 2012:**
  New model **EIGEN-6C2** included.
- **21. September 2012:**
  New model **DGM-1S** included.
- **14. July 2012:**
  The value **gmrefpot** for the **reference system EGM2008** was not correct.
  Due to accidentally erroneous rounding
  gmrefpot=3.986004415E+14 instead of gmrefpot=3.986004415d+14
  the (slightly wrong) value 3.98600446149d+14 m**3/s**2 was used.
  ⇒ **error has been corrected**

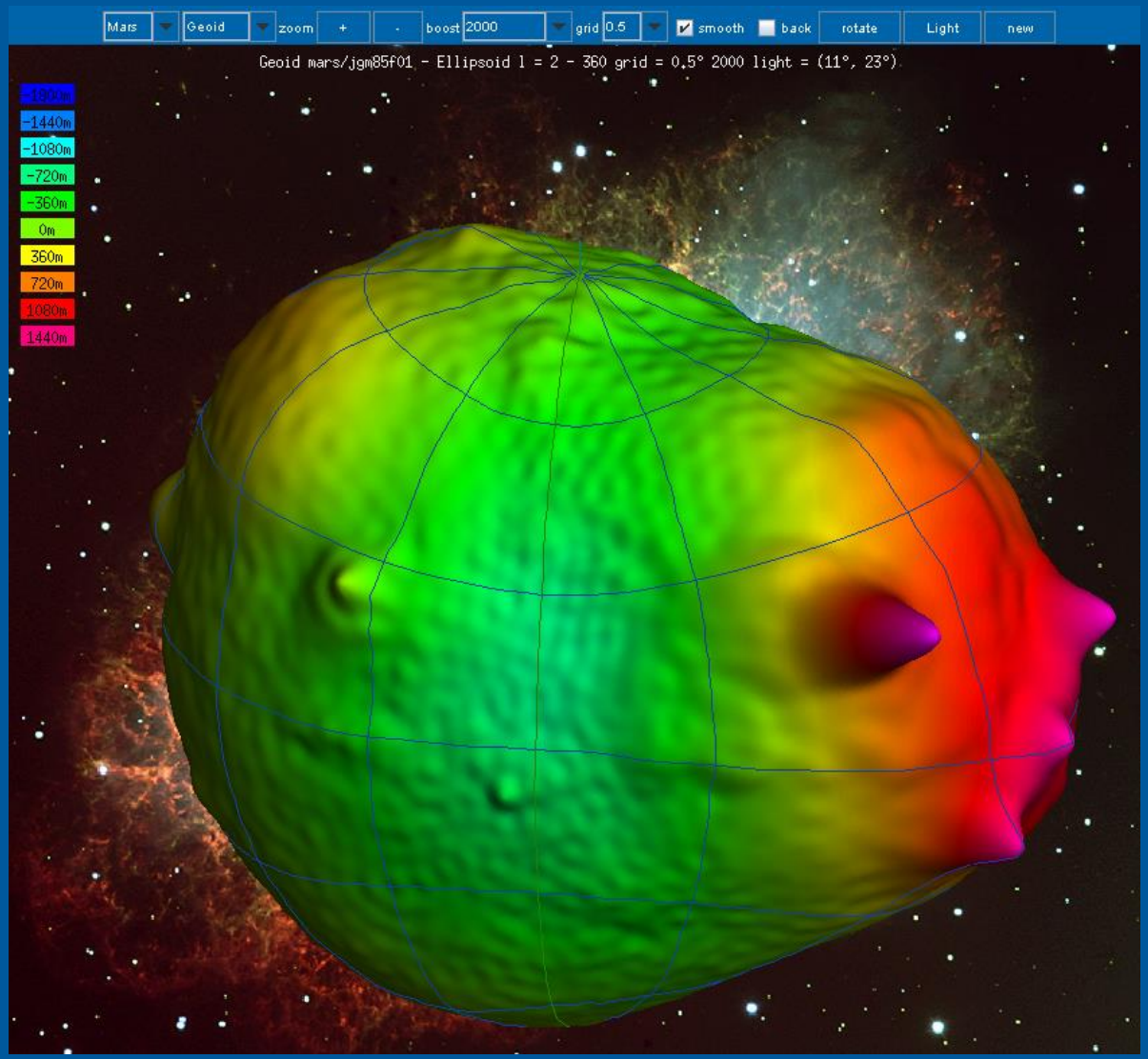
Global Models – Improvement in History

Geoid differences of satellite-only models of the past to recent ("best") combination solution as a function of spatial resolution

→ **differences to EIGEN-6C2**

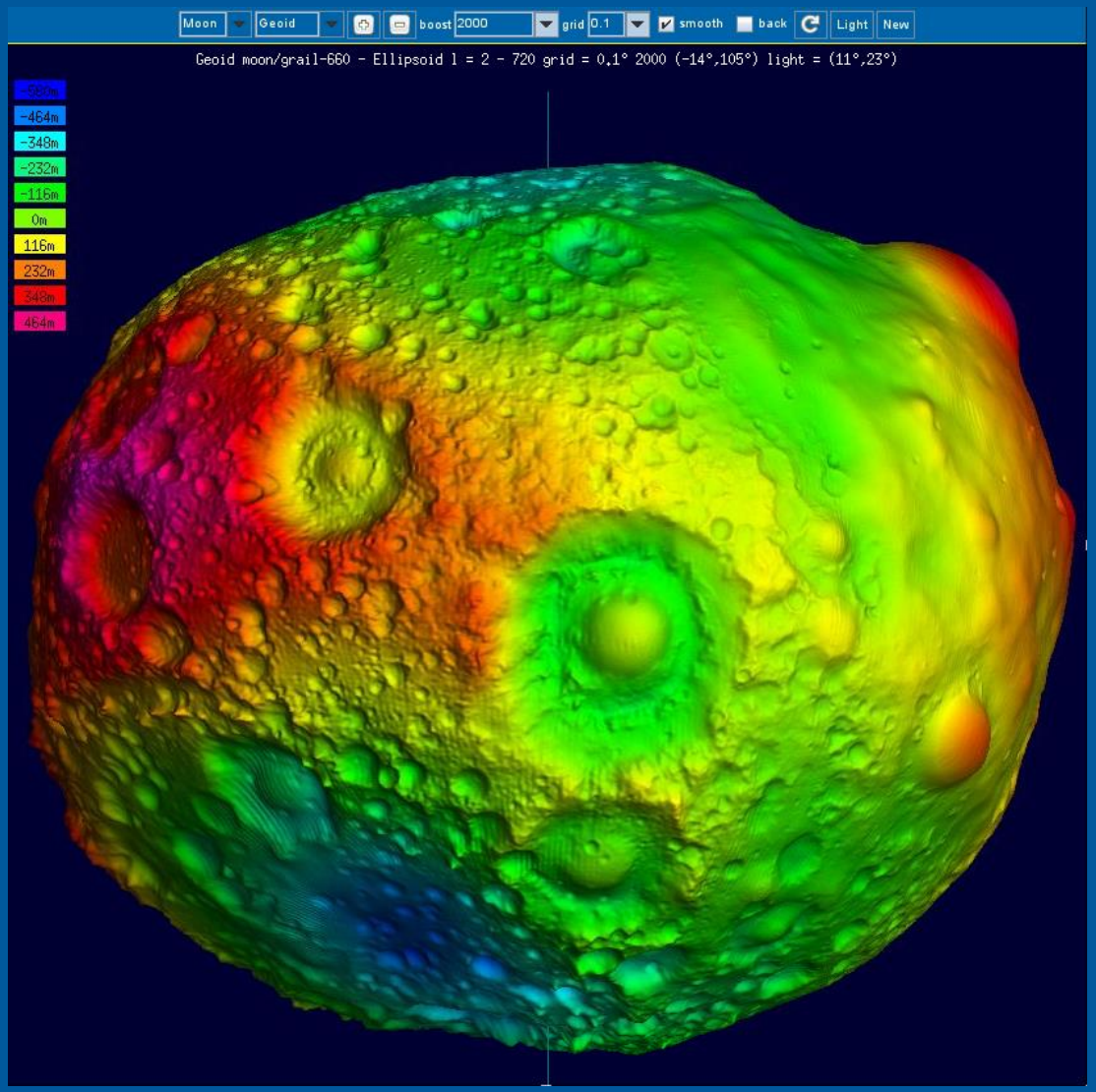


Byproducts: Models of Moon, Mars and Venus



Mars

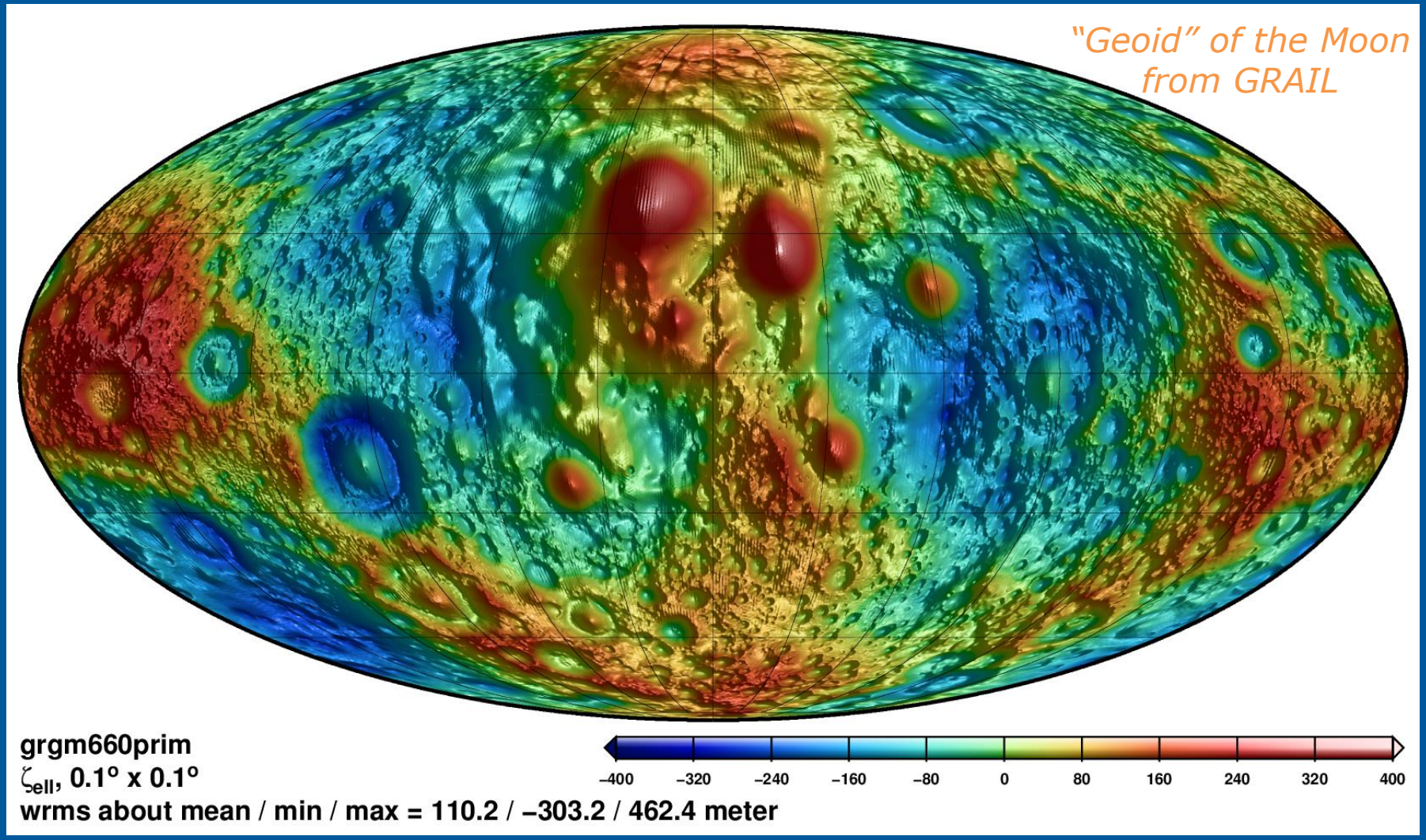
Byproducts: Models of Moon, Mars and Venus



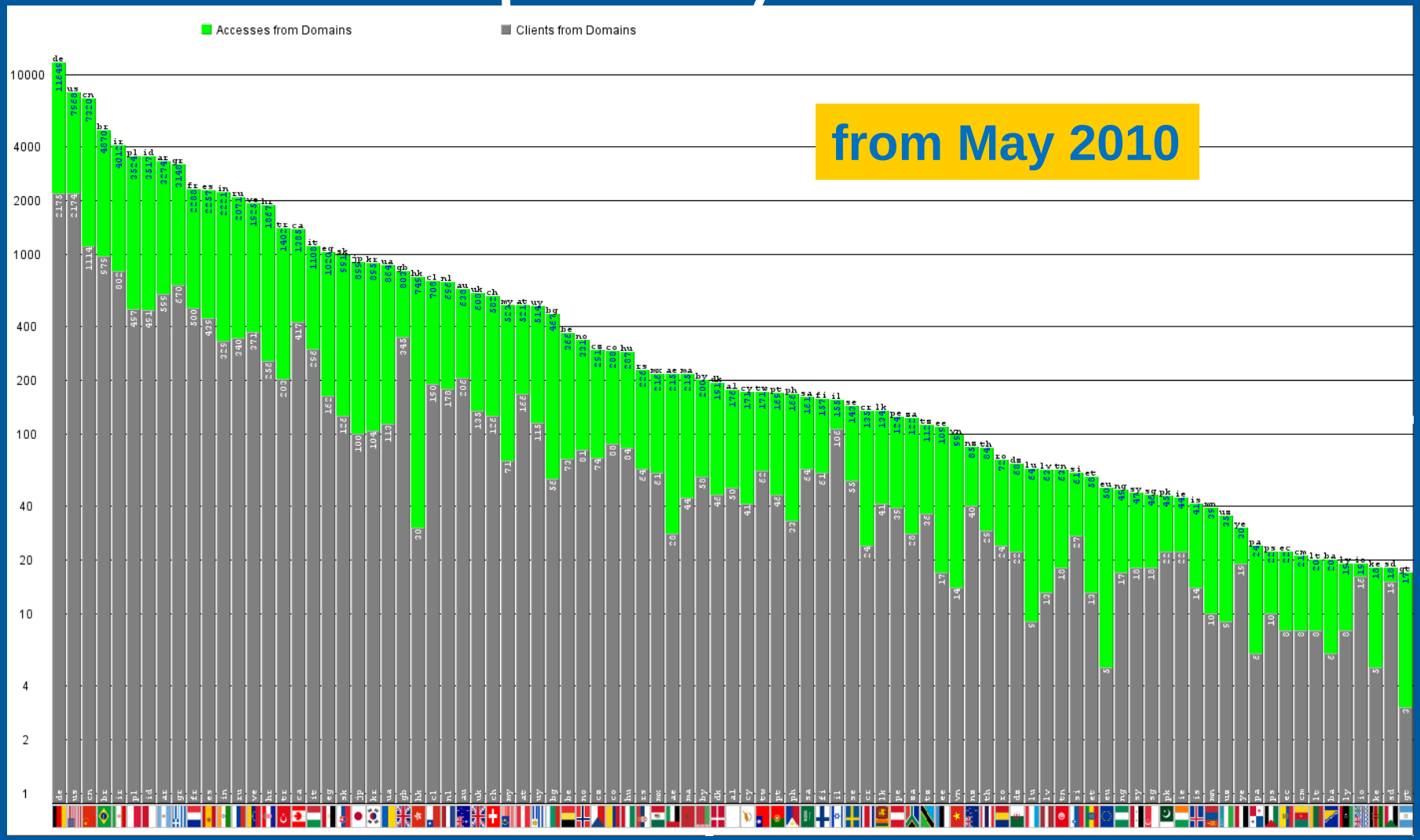
Moon

(GRAIL-mission)

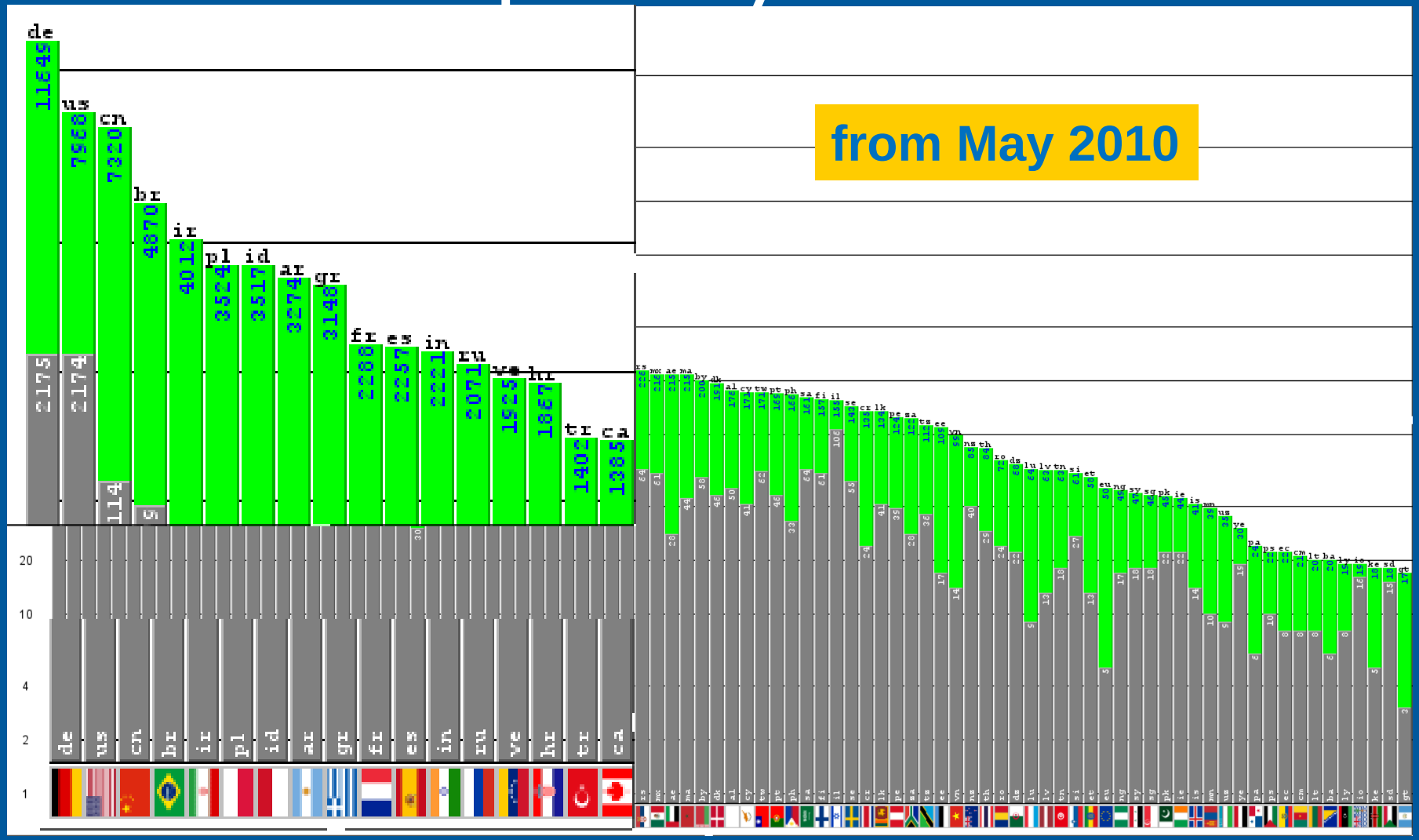
Byproducts: Models of Moon, Mars and Venus



Frequency of use



Frequency of use

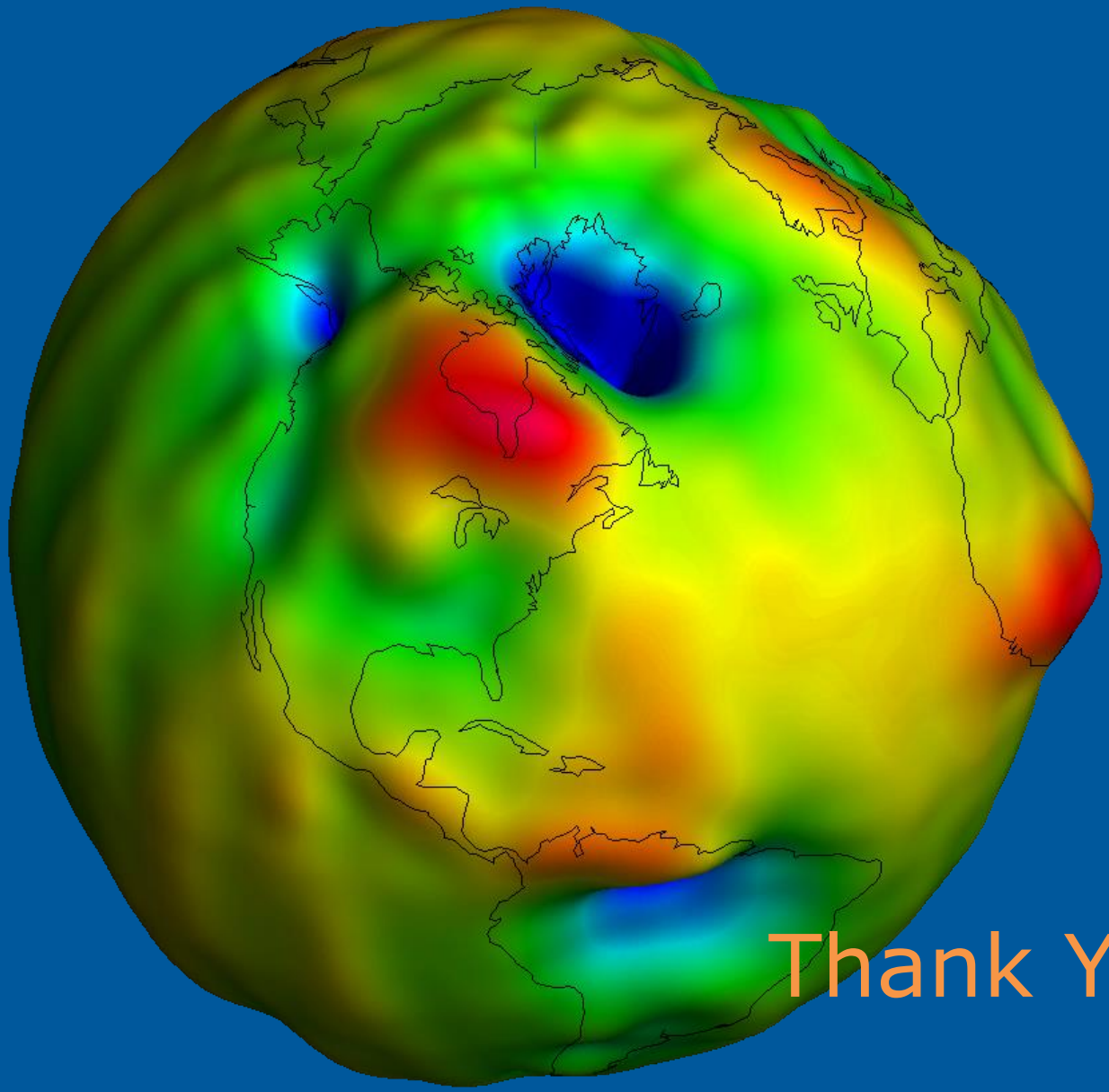


Conclusion

ICGEM do NOT offer:
research at the push of a button

But (hopefully) ICGEM:

- is useful for educational purposes
- helps to overcome obstacles in using the global gravity field models
- enables and stimulates research



Thank You