Lecture 2.4. **Gravity field observations.** **T/M, Ch. 5.**

1. Plumb-line direction: Astronomical latitude and longitude (direction of gravity vector).
2. Magnitude of gravity, (BGI, DTU-Space, etc.).
3. Satellite altimetry (RADS, ESA)
4. Acceleration and velocity (vectors) of body in free fall (satellite) (CHAMP)
5. Gravity potentials 2.'orden partial derivatives or first order derivatives of gravity vector (GOCE)
6. Height anomalies (GPS/Levelling)
7. Potential-differences (Precision or hydrostatic levelling), and variations of kinetic energy. (GRACE)
8. Topography/bathymetry

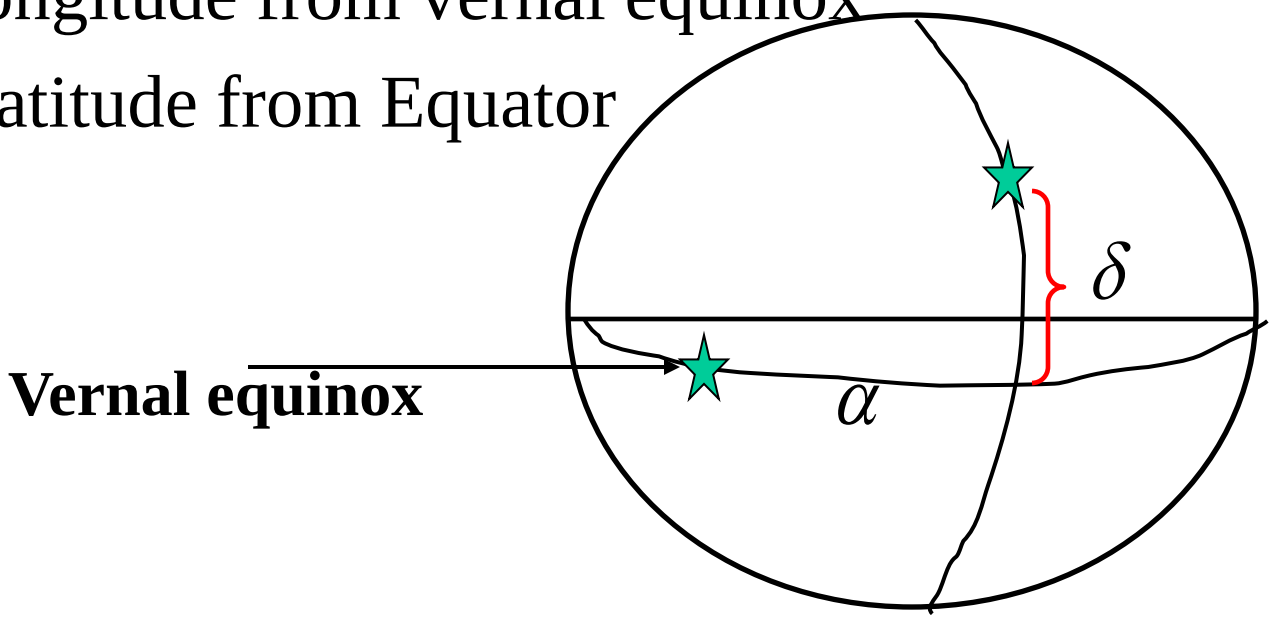
Star-coordinates from star-catalogue:

$$(\alpha, \delta, parallax, eigen - movement)$$

Refer to ekliptika

α longitude from vernal equinox

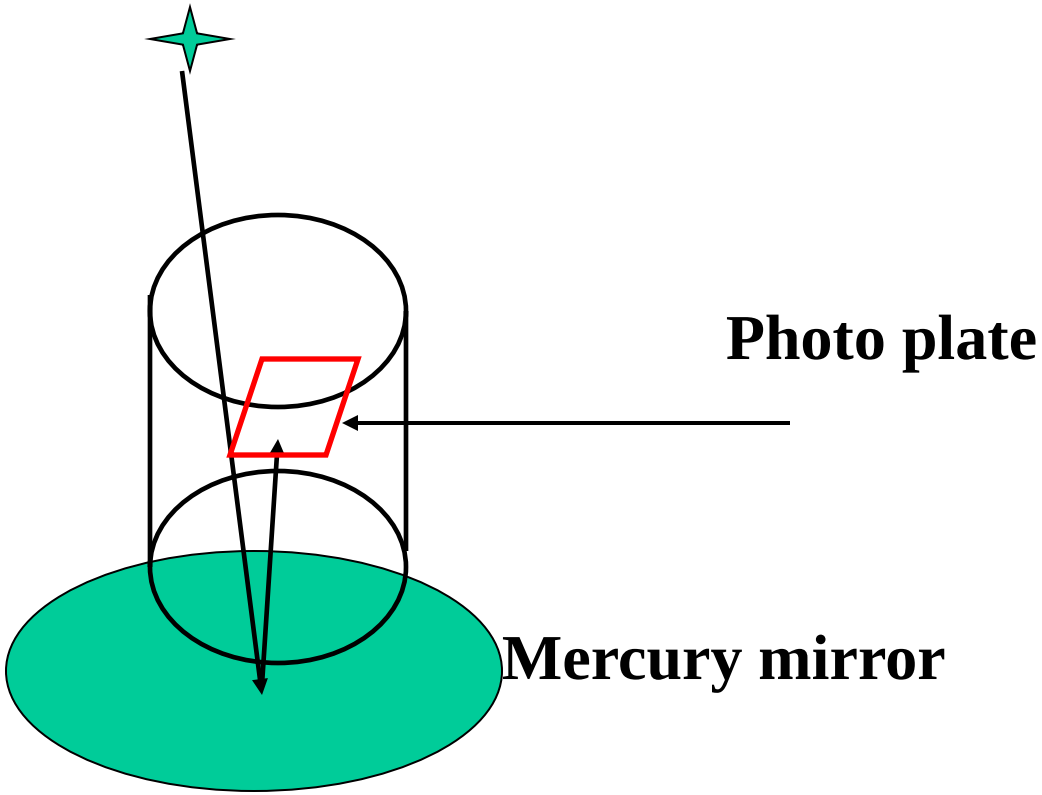
δ latitude from Equator



Zenith-camera., p. 165.

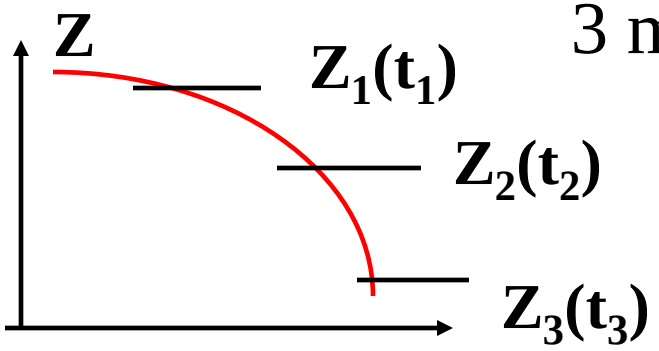
Positioned in level, so refraction is small.

Stars, symmetric about Zenith to be used. Only ~ 1 mgal.



Gravity from Free fall. Vakuum, Seismic protected., p. 176.

Free fall: **Height measured as a function of time**.



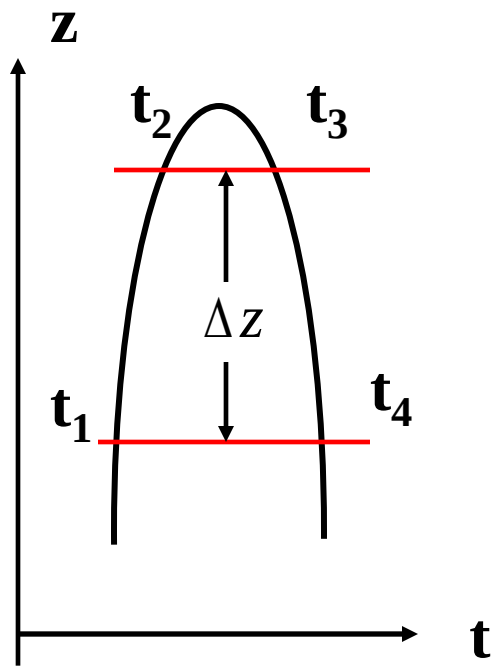
3 measurements, eliminate z_0 $\dot{z}_0$

$$z = z_0 + \dot{z}_0 t + \frac{g}{2} t^2$$

$$g = 2\frac{(z_3 - z_1)(t_2 - t_1) - (z_2 - z_1)(t_3 - t_1)}{(t_3 - t_1)(t2 - t_1)(t_3 - t_2)}$$

Gravity measurements, throw, vakuum, seismic protec., p. 176.

60 measurements over 0.5 m gives $\pm 0.1 \mu m / s^2$



$$g = \frac{8\Delta z}{(t_4 - t_1)^2 - (t_3 - t_2)^2}$$

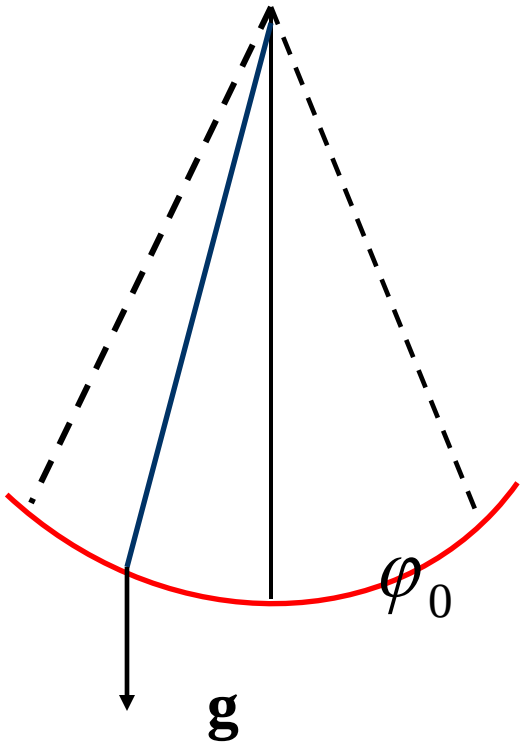
Gravity: Pendulum.

1. Matematical Pendulum: point-mass, weightless thread.

$$l\ddot{\varphi} + g\sin\varphi = 0$$

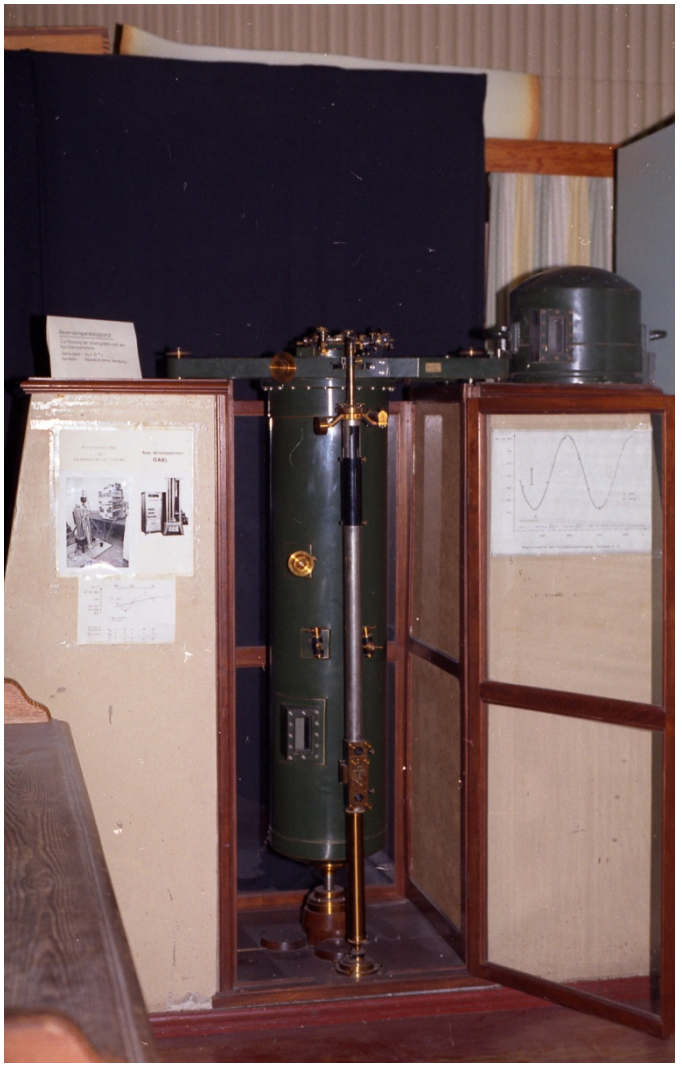
Period:

$$T = 2\pi\sqrt{\frac{g}{l}}\left(1 + \frac{\varphi_0^2}{16} + \ldots\right), \varphi_0 < 30'$$



Pendulum at Potsdam, Germany..

Time of occillation
depends on gravity.



Lacoste-Romberg gravimeter., p. 185.

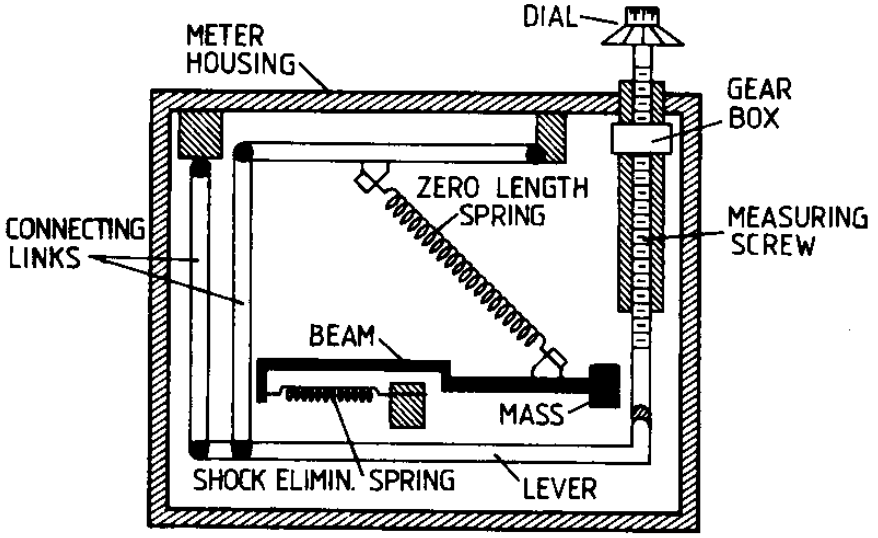
Astatizing: $l_0=0$ (0-spring)

δ *small*, $\alpha \approx 90^0$

$a = 0.1\,m, \quad \alpha + \delta = 90^o,$

$\delta \approx 100''$

Displacement: $\pm 2\,\mu m.$



Sensitivity 2000 x larger !!

Relative gravity measurements at sea or in the air. (see Lecture 4.3)

Gyrostabilised board necessary

Spring limited to only move in one plane (direction of movement)

We must take into account the Eötvös effect – which may be determined from position and velocity.

$$g' = \ddot{r}' - R_b^l f^b + (2\omega_{ie}' + \omega_{el}') \times \dot{r}'$$

Skalar for gyro close to Earth

$$:\delta g_{Eöt} = 40 \cos\varphi \sin\alpha + 0.012 v^2 \ \mu m s^{-2}$$

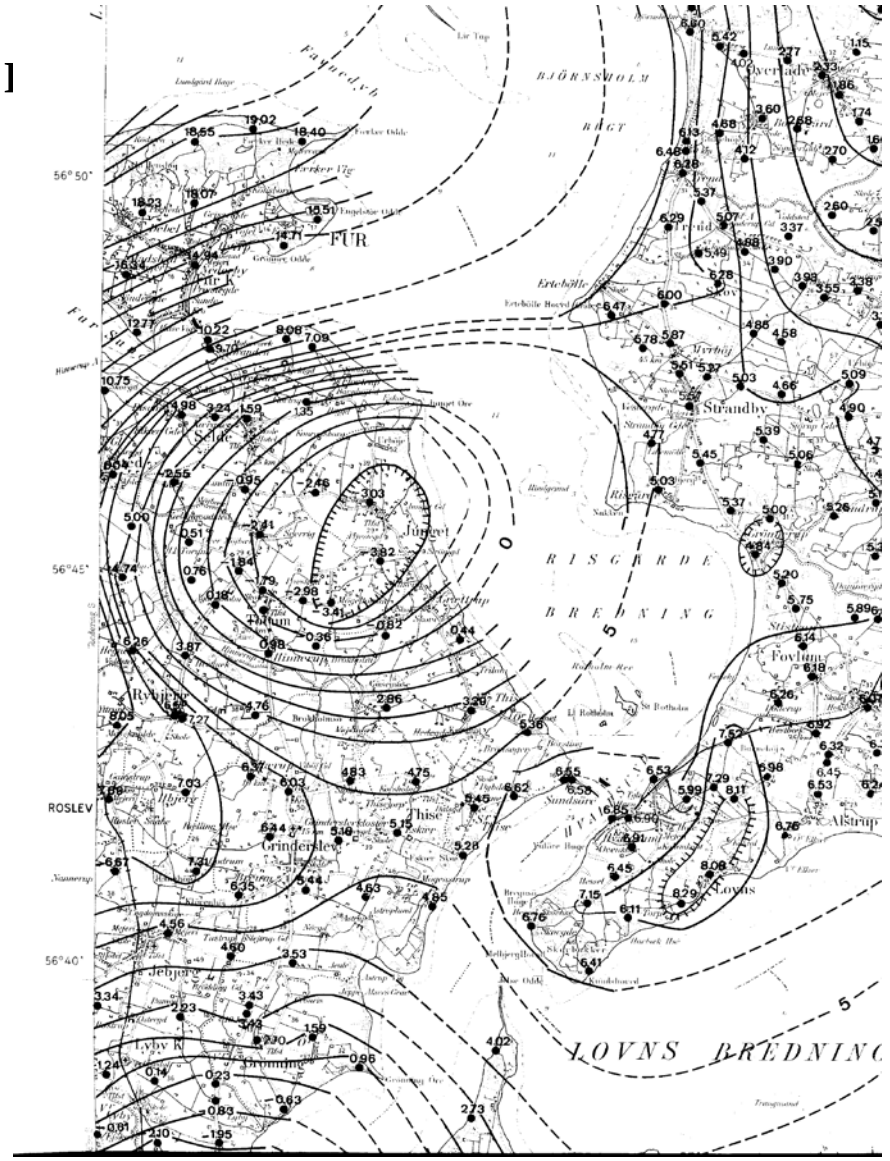
$$(v \quad in\ km/h)$$

Gravity databases.

Globally: Bureau Gravimetrique Internationale
http://bgi.cnes.fr:8110/bgi_f.html
NGA – USA,
Denmark: DTU-Space. Gravity from Altimetry.

Gravity-data-standard GRAVSOFT format:
Latitude, longitude in decimal degrees
height above sea or depth, gravity, gravity anomaly.
Source-code, correction to IGSN71 (if necessary).

Gravity


FUR
Strandby
RISGÅRDE
BREDNING
Thisted
Grinderslev
ROSLEV
Jebjerg
LOVNS BREDNING
56° 50'
56° 45'
56° 40'

Gravity data, example from DK.

TABLE 9.

Principal data for detail stations of the Worden gravimeter network in Central Jylland.

Number of Station	Longitude East of Greenwich	Northern Latitude	Height in metres	Normal Gravity in Gals	Observed Gravity in Gals	Bouguer Correction in mGals	Bouguer Anomaly in mGals
	λ	φ	H	γ_0	g	B.C.	Δg
M 1111							
1.....	09°44'.18	57°02'.21	14.05	981.68527	981.67605	3.16	− 6.06
2.....	44.77	02.20	6.37	68525	67762	1.43	− 6.20
3.....	43.30	02.16	26.05	68520	67383	5.86	− 5.51
4.....	42.73	01.92	19.33	68487	67544	4.35	− 5.08
5.....	40.86	01.71	2.66	68458	68040	0.60	− 3.58
M 1112							
1.....	09°53'.44	57°03'.10	3.12	981.68649	981.67819	0.70	− 7.60
2.....	52.41	02.95	2.51	68629	67804	0.56	− 7.68
3.....	47.63	02.62	1.26	68583	67733	0.28	− 8.22
4.....	49.04	02.60	0.94	68581	67718	0.21	− 8.41
5.....	46.03	02.45	5.02	68560	67726	1.13	− 7.21
6.....	52.55	02.38	14.00	68550	67411	3.15	− 8.24
7.....	51.32	02.32	1.97	68542	67619	0.44	− 8.79
8.....	46.88	02.29	3.82	68538	67686	0.86	− 7.66
9.....	50.63	02.24	1.82	68531	67627	0.41	− 8.63
10.....	48.20	02.08	2.80	68509	67681	0.63	− 7.65
11.....	53.59	02.07	29.19	68508	67104	6.56	− 7.47
12.....	48.87	02.03	2.43	68502	67656	0.55	− 7.91
13.....	52.67	01.84	15.74	68476	67282	3.54	− 8.40
14.....	53.82	01.80	55.31	68470	66394	12.44	− 8.33
15.....	48.04	01.78	3.77	68468	67689	0.85	− 6.94
M 1113							
1.....	10°01'.51	57°04'.28	1.57	981.68812	981.68461	0.35	− 3.15
2.....	09 58.90	04.08	1.35	68784	68320	0.30	− 4.34
3.....	58.59	03.87	1.87	68755	68249	0.42	− 4.64
4.....	10 00.04	03.74	2.45	68737	68253	0.53	− 4.91
26.....	09°56'.79	57°01'.92	38.58	981.68487	981.66975	8.68	− 6.4
27.....	58.53	01.81	29.77	68472	67239	6.70	− 5.6
M 1114							
1.....	10°05'.26	57°01'.84	2.83	981.68476	981.68255	0.64	− 1.5
M 1208							
1.....	09°17'.29	56°58'.95	3.51	981.68078	981.68177	0.79	+ 1.7
2.....	14.95	58.15	1.29	67968	68430	0.29	+ 4.9
3.....	17.14	58.10	7.35	67961	67919	1.65	+ 1.2
4.....	16.25	58.06	4.19	67955	68136	0.94	+ 2.7
5.....	16.57	57.66	8.57	67900	67859	1.93	+ 1.5
6.....	14.87	57.60	17.98	67892	67980	4.04	+ 4.9
7.....	15.22	57.57	23.85	67888	67772	5.36	+ 4.2
8.....	15.85	57.46	28.89	67873	67522	6.50	+ 2.9
M 1209							
1.....	09°25'.94	57°00'.65	1.26	981.68312	981.68446	0.28	+ 1.6
2.....	25.25	00.50	1.30	68291	68418	0.29	+ 1.5
3.....	24.56	00.38	0.94	68275	68442	0.21	+ 1.8
4.....	23.07	00.09	1.36	68235	68406	0.31	+ 2.0
5.....	21.76	56 59.94	1.73	68214	68323	0.39	+ 1.4
6.....	17.86	59.93	4.93	68213	68303	1.11	+ 2.0
7.....	20.58	59.81	1.48	68196	68292	0.33	+ 1.2
8.....	26.07	59.68	5.91	68179	68353	1.33	+ 3.0
9.....	19.51	59.55	3.31	68161	68206	0.74	+ 1.2
10.....	26.43	59.52	15.14	68157	68148	3.40	+ 3.3
11.....	25.45	59.47	5.28	68150	68364	1.19	+ 3.3
12.....	23.32	59.45	1.89	68147	68339	0.43	+ 2.3

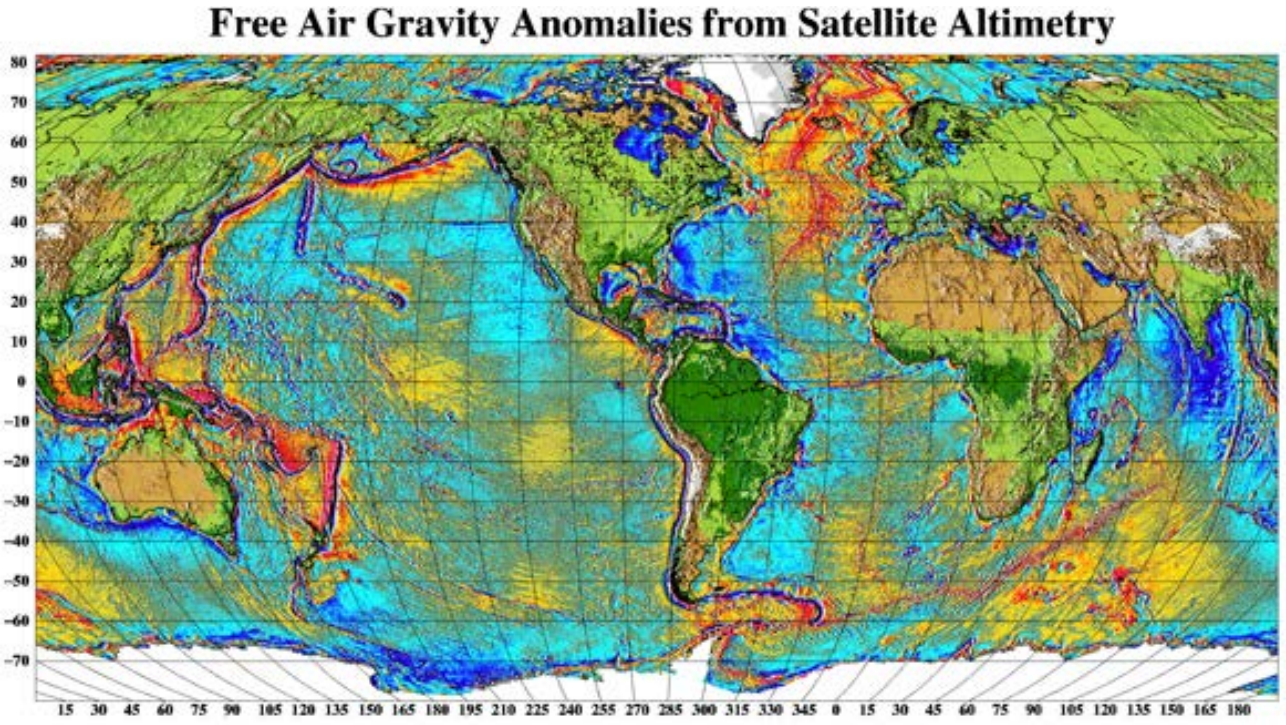
Altimetry databases.

Satellite altimetry:

TU Delft:
http://rads.tudelft.nl

ESA:
http://earth.esa.int/EOLi/EOLi.html

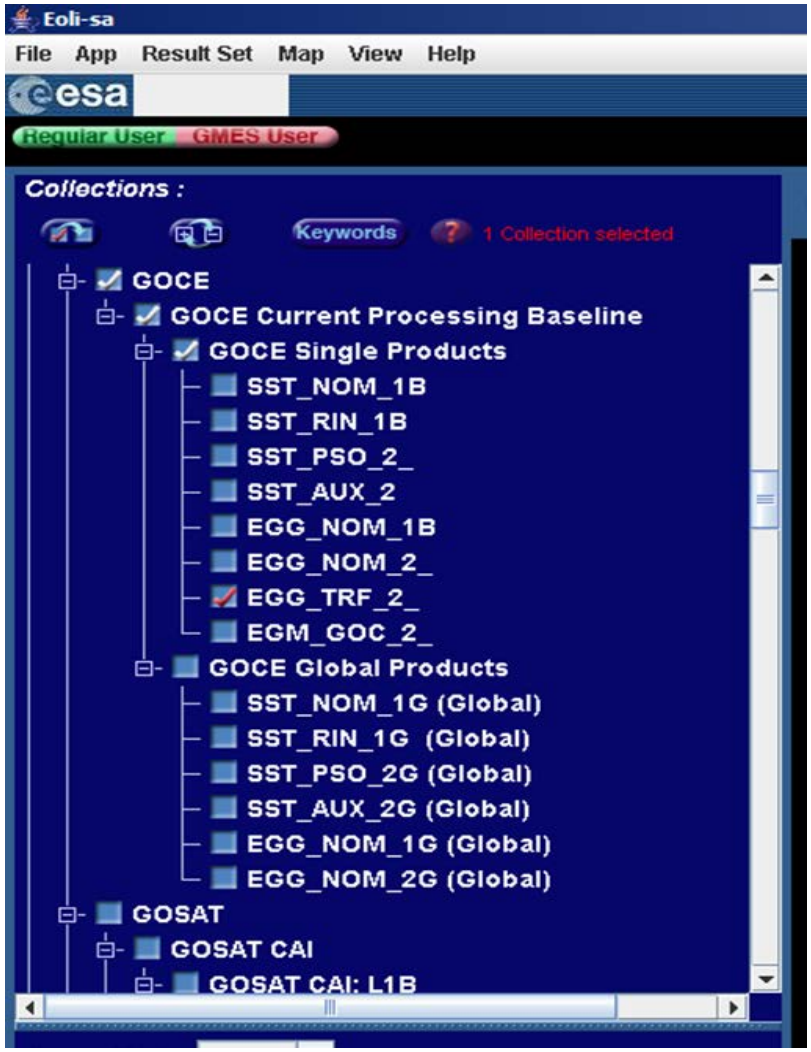
Gravity databases.



Source: DTU-Space. Ole Andersen.

Important databases.

GOCE gradient data:
http://eo-virtual-archive1.esa.int/Index.html
http://earth.esa.int/EOLi/EOLi.html



Gravity gradient database.

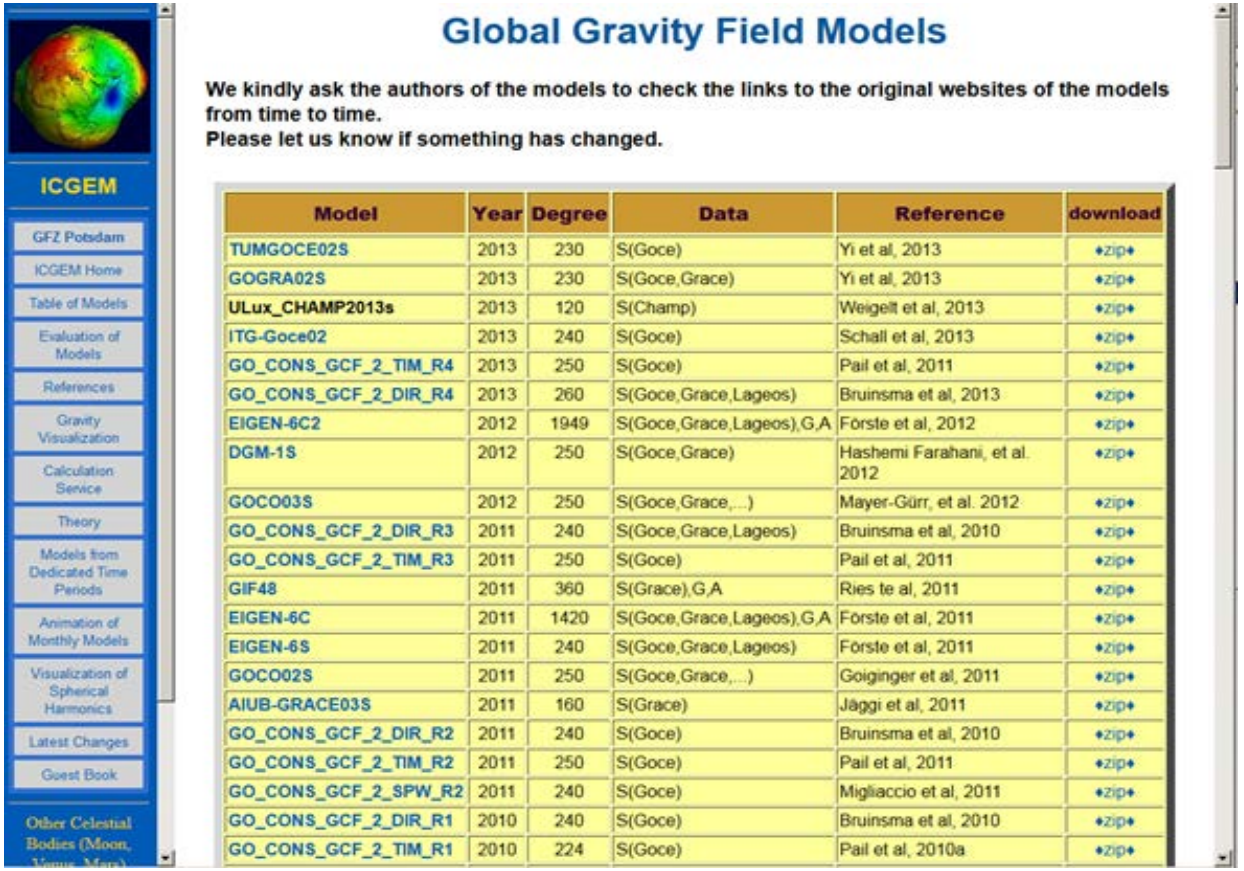
GRACE database.

GRACE L1b data.

http://podaac.jpl.nasa.gov/gravity/grace-documentation

Gravity model database.

Spherical harmonic coefficients:
http://icgem.gfz-potsdam.de/ICGEM/



ICGEM

- GFZ Potsdam
- ICGEM Home
- Table of Models
- Evaluation of Models
- References
- Gravity Visualization
- Calculation Service
- Theory
- Models from Dedicated Time Periods
- Animation of Monthly Models
- Visualization of Spherical Harmonics
- Latest Changes
- Guest Book

Other Celestial Bodies (Moon, Venus, Mars)

Global Gravity Field Models

We kindly ask the authors of the models to check the links to the original websites of the models from time to time.
Please let us know if something has changed.

Model	Year	Degree	Data	Reference	download
TUMGOCE02S	2013	230	S(Goce)	Yi et al, 2013	•zip•
GOGRA02S	2013	230	S(Goce,Grace)	Yi et al, 2013	•zip•
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•
GIF48	2011	360	S(Grace),G,A	Ries te al, 2011	•zip•
EIGEN-6C	2011	1420	S(Goce,Grace,Lageos),G,A	Förste et al, 2011	•zip•
EIGEN-6S	2011	240	S(Goce,Grace,Lageos)	Förste et al, 2011	•zip•
GOCO02S	2011	250	S(Goce,Grace,...)	Goiginger et al, 2011	•zip•
AIUB-GRACE03S	2011	160	S(Grace)	Jäggi et al, 2011	•zip•
GO_CONS_GCF_2_DIR_R2	2011	240	S(Goce)	Bruinsma et al, 2010	•zip•
GO_CONS_GCF_2_TIM_R2	2011	250	S(Goce)	Pail et al, 2011	•zip•
GO_CONS_GCF_2_SPW_R2	2011	240	S(Goce)	Migliaccio et al, 2011	•zip•
GO_CONS_GCF_2_DIR_R1	2010	240	S(Goce)	Bruinsma et al, 2010	•zip•
GO_CONS_GCF_2_TIM_R1	2010	224	S(Goce)	Pail et al, 2010a	•zip•

Topography databases.

http://www2.jpl.nasa.gov/srtm/
Only topography !

http://topex.ucsd.edu/WWW_html/srtm30_plus.html
Topography and bathymetry.