EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Introduction to applied Geophysics

R. Drews

Gravity Method

Problem: What is beneath the surface?

Reference:

Public Domain (credit: Mainconfz)

Problem: Ice-sheet Mass loss

Reference:

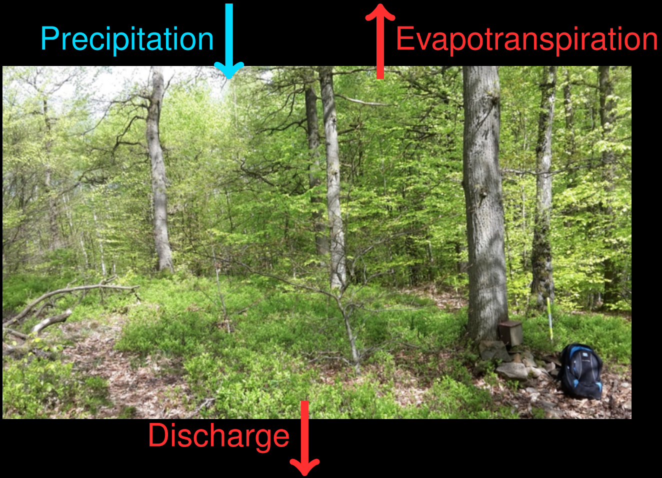
NASA/Goddard Space Flight Center Scientific Visualization Studio (NASA/GSFC).

Problem: Evapotranspiration

Reference:

Van Camp et al., Geophys. Res. Lett., https://doi.org/10.1002/2016GL070534, 2016

Problem: Evapotranspiration



Reference:
Van Camp et al., Geophys. Res. Lett., https://doi.org/10.1002/2016GL070534, 2016

Learning Goals

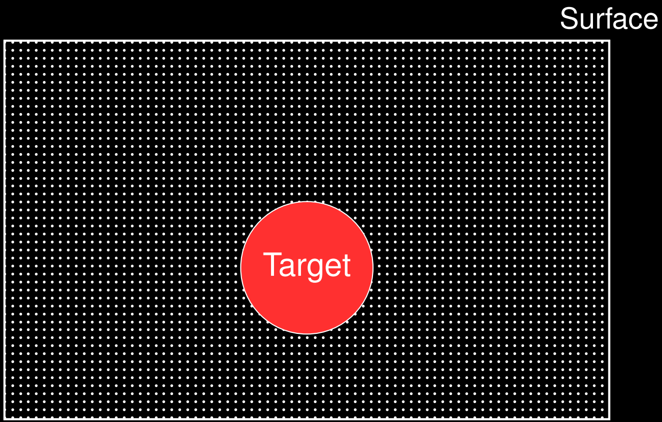
Learning goals today:

Understand how the gravity methods maps spatial and temporal changes in density/mass

Understand the physical background gravitational force, its potential field

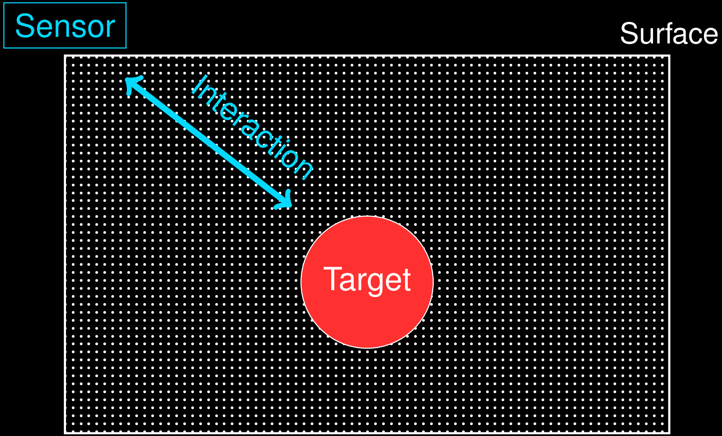
Internalize one measurement principle.

Mapping differences in density



Target has a contrast in density.

Mapping differences in density



Target has a contrast in density.

What is a force?

[Newton (1642-1726) / G. Johnson.]

$$\vec{F} = \frac{d}{dt}\vec{p} = m\vec{g}$$

$\vec{F}$: Force (N; $\mathrm{kg\,m\,s^{-2}}$)

$\vec{p}$: Momentum (N; $\mathrm{kg\,m\,s^{-1}}$)

$\vec{g}$: Acceleration ($\mathrm{m\,s^{-2}}$)

m : Mass (kg)

The gravitational force

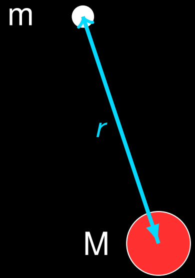
[Newton (1642-1726) / G. Johnson.]

$$\vec{F} = G\frac{mM}{r^2}\hat{r}$$

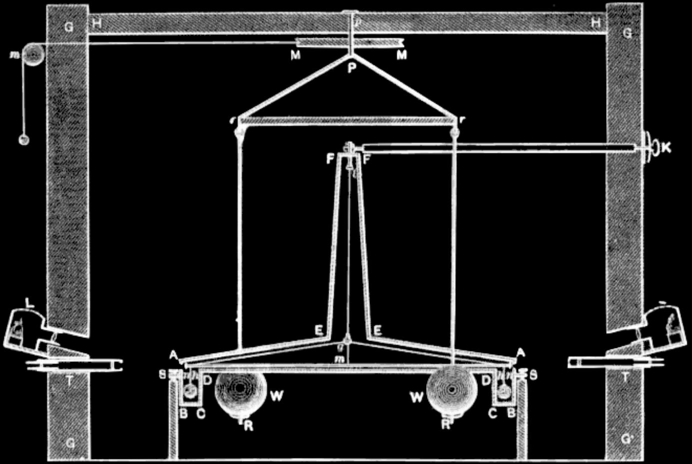
$G = 6.674 \cdot 10^{-11}\ (m^3 kg^{-1} s^{-2})$

$\hat{r}$: unit vector

r : distance between point masses



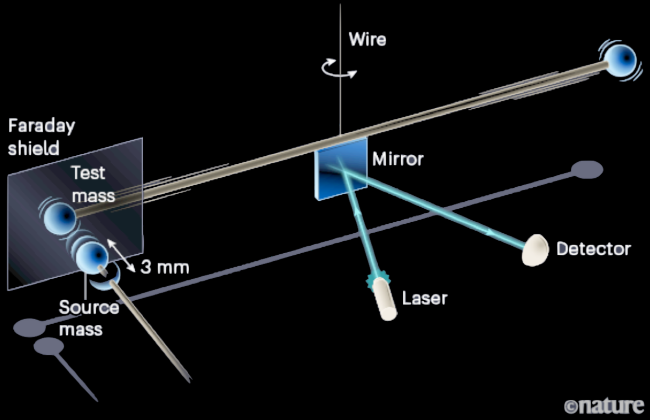
The gravitational constant



Reference:

Cavendish, The Proceedings of the National Academy of Sciences , 1798

The gravitational constant



Reference:
Westphal et al., Nature, 2021

Specialty of the gravitational force

G is the worst known constant in physics:

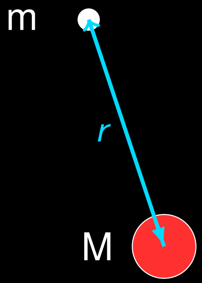
The gravitational force cannot be shielded.

It averages over ”comparatively” large areas.

Example: Measuring acceleration

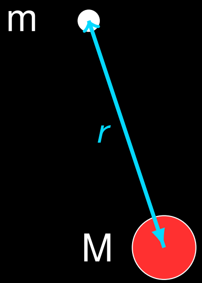
$$\vec{F} = m\vec{g}$$

$$\vec{F} = G\frac{mM}{r^2}\hat{r}$$



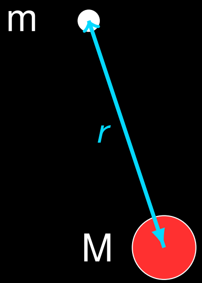
Example: Measuring acceleration

$$\vec{g} = G\frac{M}{r^2}\hat{r}$$



Example: Measuring acceleration

$$g = G\frac{M}{r^2}$$



This is a 1D problem.

Example: Measuring acceleration

$$g = G\frac{M}{r^2}$$

Example: Measuring acceleration

$$g = G\frac{M}{r^2}$$

$$\frac{d^2 r(t)}{dt^2} = G\frac{M}{r^2}$$

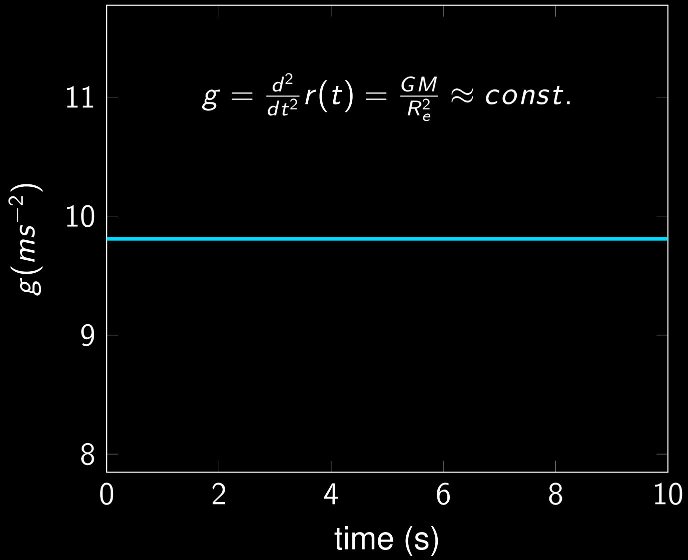
This is a differential equation.

Example: Measuring acceleration

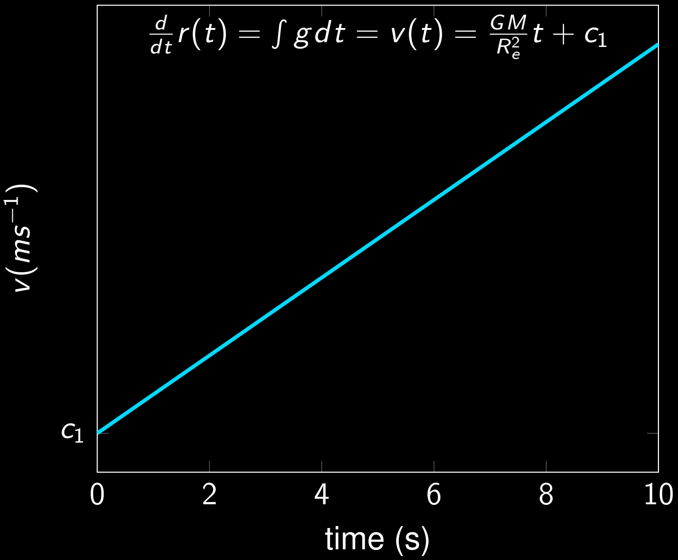
$$\frac{d^2 r(t)}{dt^2} = G\frac{M}{R_E^2} \approx const.$$

At the Earth's surface (R_E) g is close to constant and only vertical. (Later we will see that none of this is quite true).

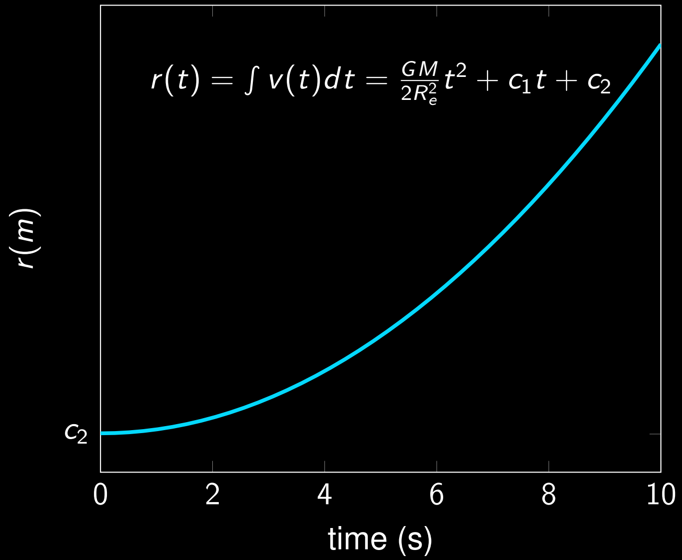
Example: Measuring acceleration



Example: Measuring acceleration



Example: Measuring acceleration



Example: Measuring acceleration

$$r(t) = \frac{GM}{2R_e^2} t^2 + c_1 t + c_2$$

Setting, e.g., $c1 = 0$ (initial velocity) and $c_2 = 0$ (initial position) is quite convenient.

By measuring the change of position over time, the mass of the Earth (M) can estimated (given that the radius is known.)

This is the principle of a free-fall gravimeter.

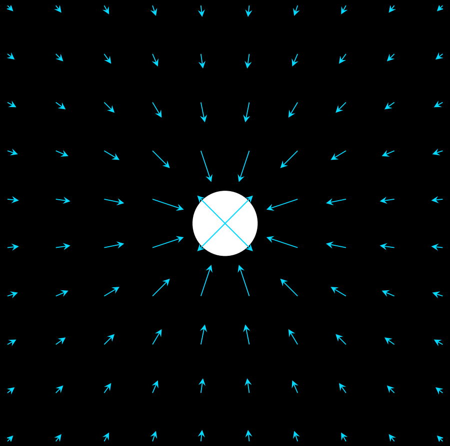
$$r(t) = \frac{G\,M}{2R_e^2}t^2$$

Go ahead and determine the mass of the Earth M with your Smartphone!

There is an important first-order finding in Earth Sciences that you can (re-) discover. Which one?

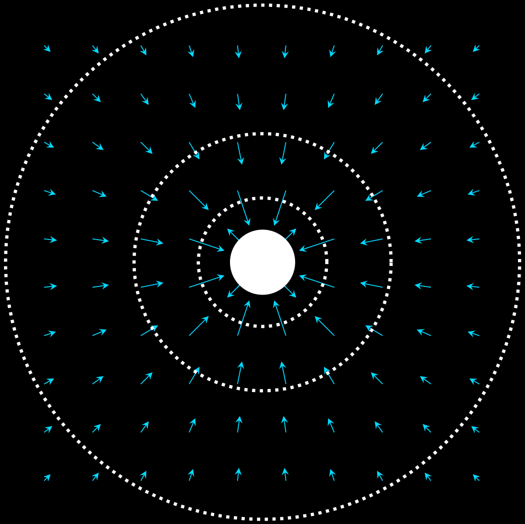
Vector fields

$$\vec{g} = G \frac{M}{r^2} \hat{r}$$



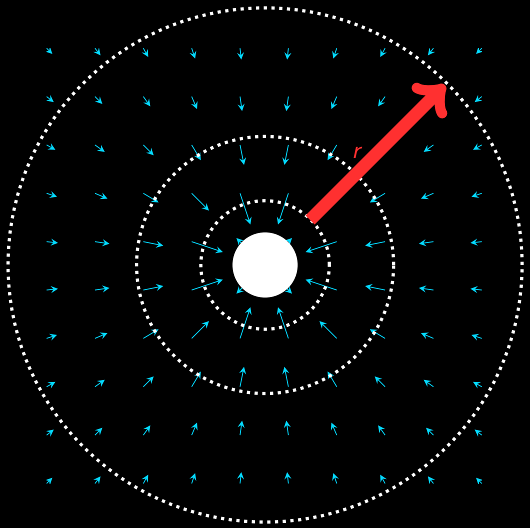
Potential Field

$$\vec{g} = G\frac{M}{r^2}\hat{r}$$



Potential Field

What is the amount of work required?



$$
\begin{aligned}
U(r) &= -\int_{\infty}^{r} \vec{g}\, d\vec{r} \\
&= -\int_{\infty}^{r} g\, dr \\
&= -GM \int_{\infty}^{r} \frac{1}{r^2} dr \\
&= -GM \left[-\frac{1}{r}\right]_{\infty}^{r} \\
&= GM \frac{1}{r}
\end{aligned}
$$

Potential for a *spherical* mass.

Potential Fields

$$\vec{g}(r) = -\frac{\partial}{\partial r}U(r) = -\nabla U(r)$$

It is sometimes easier to calculate the potential of an anomaly and to infer the acceleration via the gradient.

Equipotential lines are *perpendicular* to the field direction.

Take aways from this video

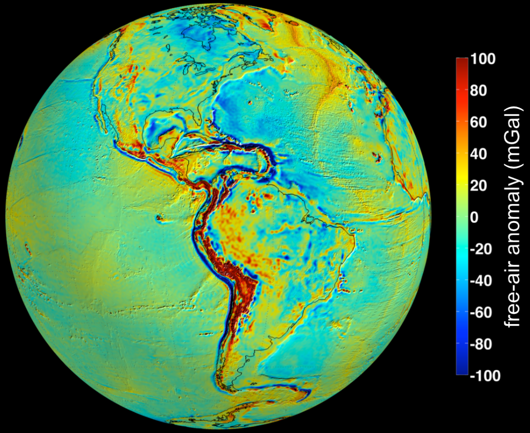
- ✓ Force, gravitational force/acceleration, gravitational potential
- ✓ Gravity method maps spatiotemporal variability in density/mass
- ✓ Free-fall gravimeters is one measurement principle
- × Spatially distributed structures, sensitivities, data reduction,..

Problem: What is beneath the surface?

Reference:

Public Domain (credit: Mainconfz)

Problem: What is beneath the surface?



Reference:

Jet Propulsion Laboratory, California Institute of Technology, GRACE-FO (a)

Problem: Ice-sheet Mass loss

Reference:

NASA/Goddard Space Flight Center Scientific Visualization Studio (NASA/GSFC).

Problem: Ice Sheet Mass Loss

You will see the Grace time series in JavaScript enabled PDF viewers such as Acrobat or Okular.

Reference:

NASA, Jet Propulsion Laboratory (https://grace.jpl.nasa.gov/resources/31/antarctic-ice-loss-2002-2020/) accessed 2022.

Example: Evapotranspiration

Precipitation

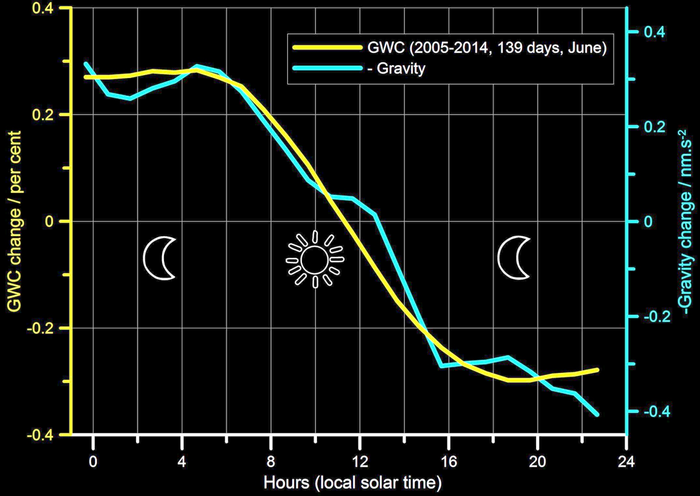
Evapotranspiration

Discharge

Reference:

Van Camp et al., Geophys. Res. Lett., https://doi.org/10.1002/2016GL070534, 2016

Example: Evapotranspiration



Reference:

Van Camp et al., Geophys. Res. Lett., https://doi.org/10.1002/2016GL070534, 2016

End of Video 1

Learning Goals

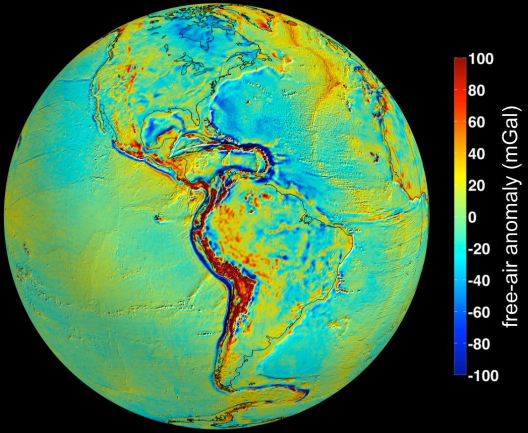
Learning goals today:

Understand how different subsurface structures (e.g. caves, sediment infill of valleys, geometry of subduction zones,..) appear in gravity datasets.

Understand the principle of forward and inverse models.

Understand the principle of equivalence.

Problem: What is beneath the surface?



Reference:

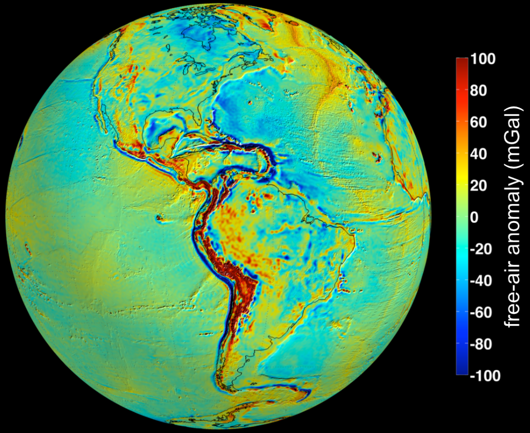
Jet Propulsion Laboratory, California Institute of Technology, GRACE-FO (a)

$$1 \quad Gal = 1 \quad \text{cm} \quad \text{s}^{-2} = 0.01\text{m s}^{-2}$$

$$1 \quad mGal = 0.001 \quad \text{cm} \quad \text{s}^{-2} = 0.00001\text{m s}^{-2}$$

1 mGal is about 1 millionth of the mean acceleration at the Earth's surface.

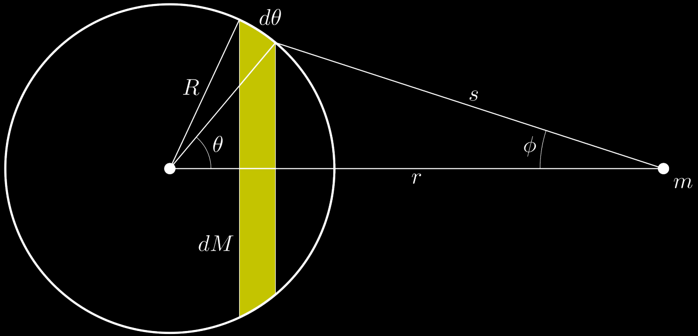
Problem: What is beneath the surface?



Reference:

Jet Propulsion Laboratory, California Institute of Technology, GRACE-FO (a)

Example: Shell



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Reference:

Xaononl (CC BY-SA 4.0, February 2017)

Newton's shell theorem calculates the gravitational field inside and outside a *spherical shell*.

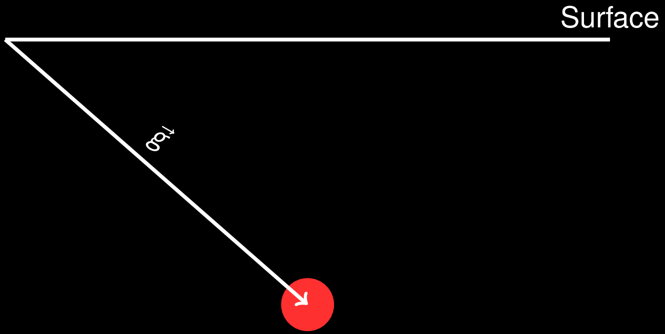
Newton’s Shell Theorem

The field outside a shell is the same as the one from an equivalent point mass

The field inside a shell is zero. Everywhere.

This is useful, e.g., for predicting the gravitational field inside the Earth for different density distributions (i.e. exercises.)

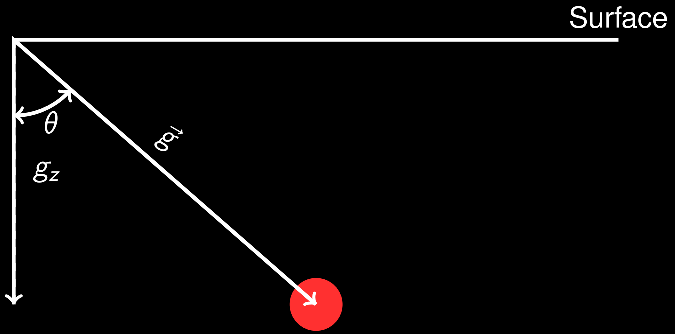
Gravity anomaly of spherical object in sub-surface



$$\vec{g} = G\frac{M}{r^2}\hat{r}$$

Gravimeters typically only measure the **vertical** component.

Gravity anomaly of spherical object in sub-surface



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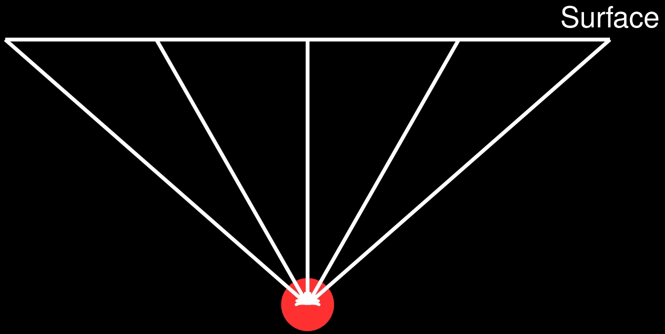
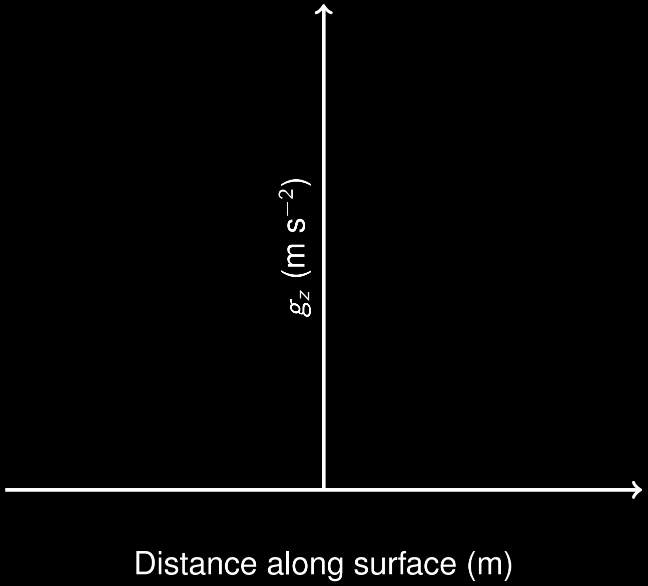
Gravity anomaly of spherical object in sub-surface



$$\vec{g} = G\frac{M}{r^2}\hat{r}$$

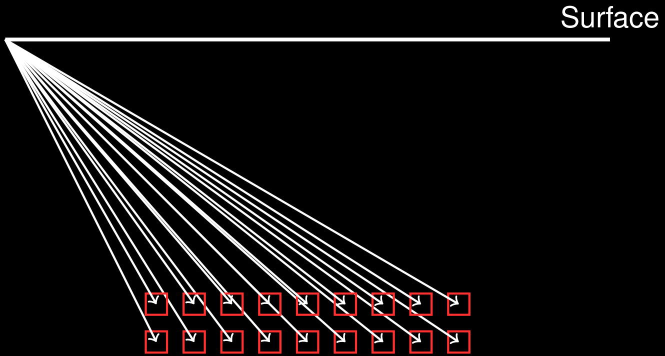
Profiling across a sub-surface target results in a specific shape of the *vertical* gravity anomaly ($\rightarrow$ Exercises).

Exercise: Gravity anomaly of spherical object in sub-surface



Beyond point masses

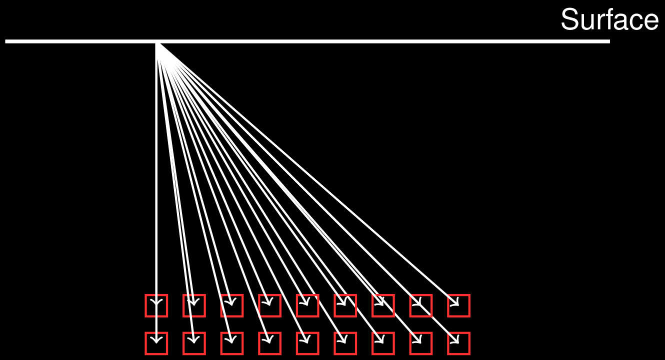
Beyond point masses



$$\vec{g}(\vec{r}) = \sum_i G \frac{dM_i}{r_i^2} \hat{r}_i$$

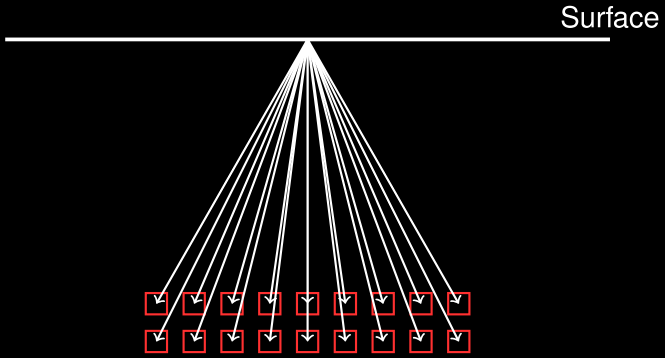
For *i* point masses the effect adds up.

Beyond point masses



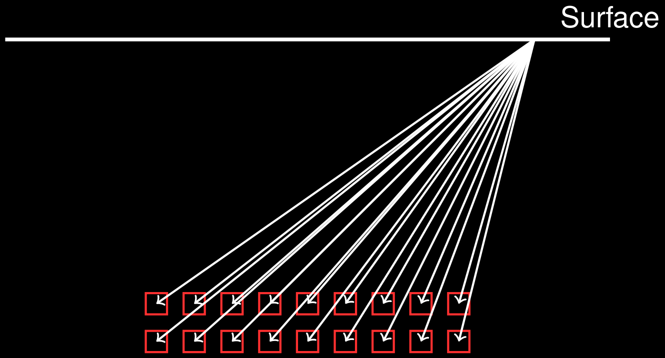
$$\vec{g}(\vec{r}) = \sum G \frac{dM_i}{r_i^2} \hat{r}_i$$

Beyond point masses



$$\vec{g}(\vec{r}) = \sum G \frac{dM_i}{r_i^2} \hat{r}_i$$

Beyond point masses

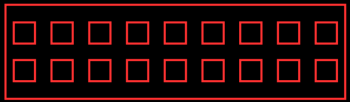


$$\vec{g}(\vec{r}) = \sum G \frac{dM_i}{r_i^2} \hat{r}_i$$

Beyond point masses

Surface

$$\vec{g}(\vec{r}) = G \int \rho \frac{1}{r^2} \hat{r} dV$$

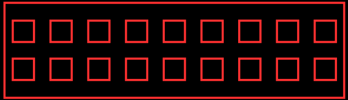


The summation can be replaced by an integration over a volume enclosing a continuous density.

Beyond point masses

Surface

$$\vec{g}(\vec{r}) = G \int \rho \frac{1}{r^2} \hat{r} dV$$

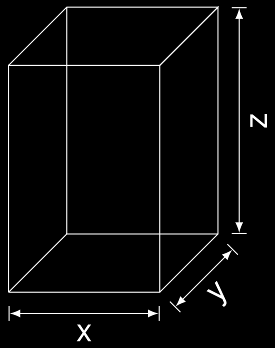


The integration is a triple integral. Integration limits and coordinates depend on the viewpoint. Example is a Bouger plate, in general not easy to solve ($\rightarrow$ Exercises).

Other shapes

There are analytical solutions for other shapes (e.g., Nagy 1966 for Prism).

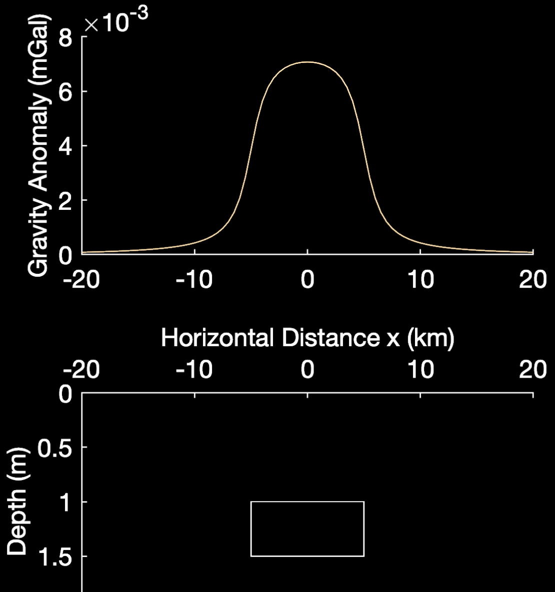
Surface



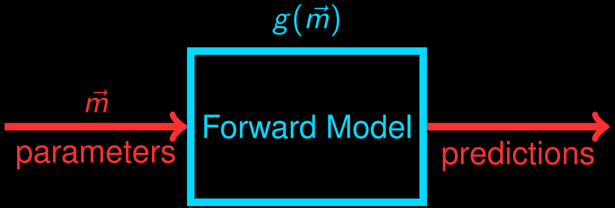
Forward modelling (→ Ex)


```
def gravprism(drho, dx1, dx2, dy1, dy2, dz1, dz2):

    # gravitational attraction due to "m" prisms at "n" observation point
    # x1,x2,y1,y2,z1,z2 are coordinates of edges of prisms relative to
    # observation points.  They are m x n matrices.

    # Downloaded from: https://www.soest.hawaii.edu/GG/FACULTY/ITO/

    # Underlying equations stem from a cartesian integration as detailed in:
    # Nagy 1966, "The gravitational attraction of a right rectangular prism"
    # Geophysics VOL. XXX, SO. 2


    gam=(6.6732e-11)*1e5  # mGal m^2/kg #What is this?!
    g=0 # This is superfluous?

    # Calculate distances to all eight corners of the prisms
    R111 = np.sqrt(dx1**2+dy1**2+dz1**2)
    R112 = np.sqrt(dx2**2+dy1**2+dz1**2)
    R121 = np.sqrt(dx1**2+dy2**2+dz1**2)
    R122 = np.sqrt(dx2**2+dy2**2+dz1**2)
    R211 = np.sqrt(dx1**2+dy1**2+dz2**2)
    R212 = np.sqrt(dx2**2+dy1**2+dz2**2)
    R221 = np.sqrt(dx1**2+dy2**2+dz2**2)
    R222 = np.sqrt(dx2**2+dy2**2+dz2**2)

    # Calculate the gravitational acceleration excerted from each corner (?!
    g111 = -(dz1*np.arctan((dx1*dy1)/(dz1*R111))-dx1*np.log(R111+dy1)-dy1*n
    g112 = +(dz1*np.arctan((dx2*dy1)/(dz1*R112))-dx2*np.log(R112+dy1)-dy1*n
    g121 = +(dz1*np.arctan((dx1*dy2)/(dz1*R121))-dx1*np.log(R121+dy2)-dy2*n
    g122 = -(dz1*np.arctan((dx2*dy2)/(dz1*R122))-dx2*np.log(R122+dy2)-dy2*n
```

Forward modelling (→ Ex)

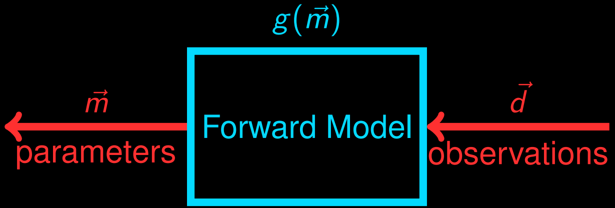


Forward Models, Parameters and Predictions



Often deterministic.

Forward Models, Parameters and Observations



Often non-unique (i.e. multiple parameter sets may explain observations). This means *equivalent* options need to be considered.

Take aways from this video

- ✓ Gravity profiling, gravity anomalies of sub-surface structures
- ✓ Forward modelling (here: Prisms) as a tool for prediction and interpretation.
- ✓ Principle of forward & inverse modelling paired with principle of equivalence.
- × Gravitational field of the Earth, removal of camouflaging effects...

End of Video 2

End of video 2

Learning Goals

Learning goals today:

A gravity reading gives you an integrated effect of many processes.

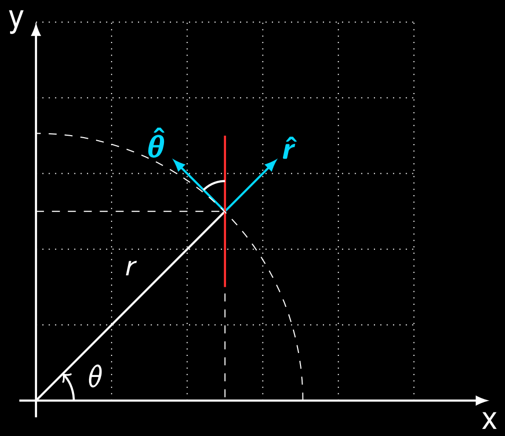
In order to account for a single process (e.g., density variability in sub-surface) corrections are required.

Reduction of gravity data

Every gravity survey measures:

- latitudinal variability,
- dependency on elevation,
- the surrounding terrain,
- excess mass above anomaly,
- earth & ocean tides,
- (instr. drift, motion compons.).
- density variability in the subsurface.

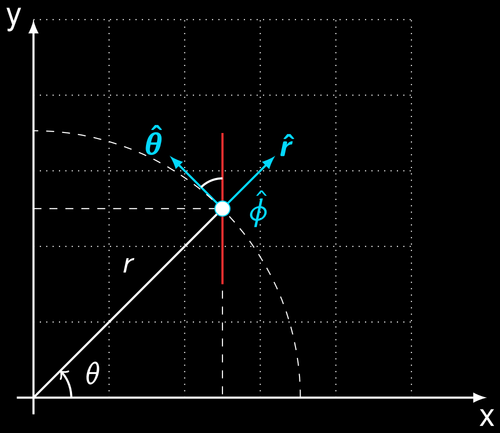
Excursion: Spherical coordinates



$\hat{r}$ points radially outwards.

$\hat{\theta}$ corresponds to latitude.

Excursion: Spherical coordinates

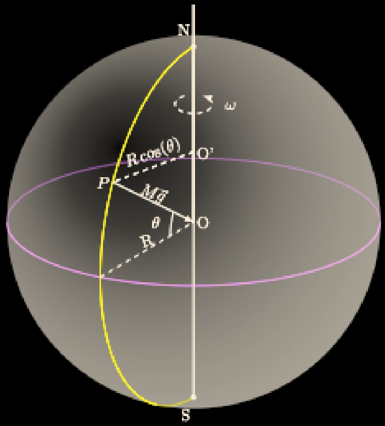


$\hat{\phi}$ points into or out off the plane.

Direction changes with time during the rotation.

Latitudinal variability

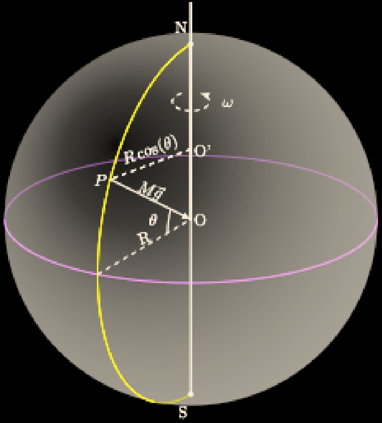
The Earth rotates with angular velocity $\omega = \frac{2\pi}{T}$.



This results in an inward direction acceleration component perpendicular to the rotation axis.

Latitudinal variability

The Earth rotates with angular velocity $\omega = \frac{2\pi}{T}$.



This requires as correction as a function of *latitude*.

Gravitational field of a spherical Earth

Centripedal acceleration at P perpendicular to rotation axis parallel to O'-P (Exercises):

$$g_{r.} = \omega^2 R \cos(\theta)$$

Centripedal acceleration at P perpendicular to rotation axis parallel to O'-P:

$$g_{r.,proj.} = \omega^2 R \cos^2(\theta)$$

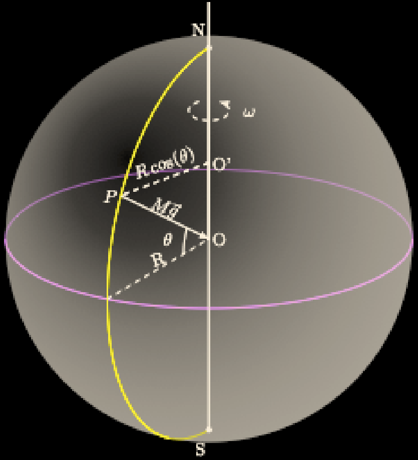
Angular Frequency: ω

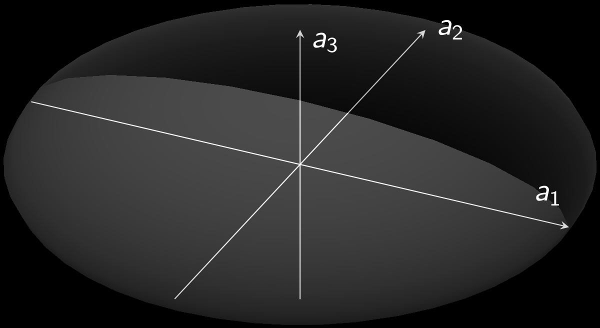
Angular Velocity: $\vec{v}_r = \vec{\omega} \times \vec{R} \cos(\theta)$

Angular Acceleration: $\vec{g}_r = \dot{\vec{v}}_r = \vec{\omega} \times \vec{\omega} \times \vec{R} \cos(\theta)$

Latitudinal variability

The latitudinal correction is largest at the equator and zero at the poles.





The *reference ellipsoid* describes the flattening:

$$a_1 = 6357 \text{ km}$$
$$a_2 = 6378 \text{ km}$$
$$a_3 = 6371 \text{ km}$$

Consequence: An ellipsoidal Earth

Due to the ellipsoidal shape the latitudinal correction is slightly more complicated (but contains no new physics:)

$$g_n = g_e(1 + A\sin^2(\theta) - B\sin^2(2\theta))$$

g_e statistical reference value at the equator

this forms the basis a reference field relative to which anomalies can be define.

Reduction of gravity data

Every gravity survey measures:

latitudinal variability,

dependency on elevation,

the surrounding terrain,

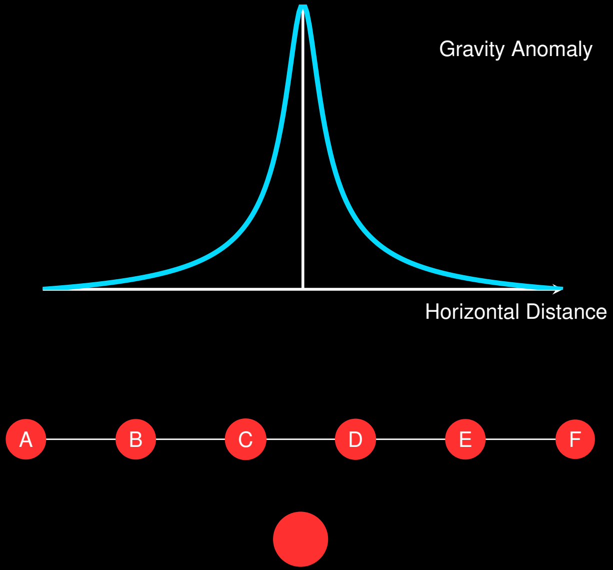
excess mass above anomaly,

earth & ocean tides,

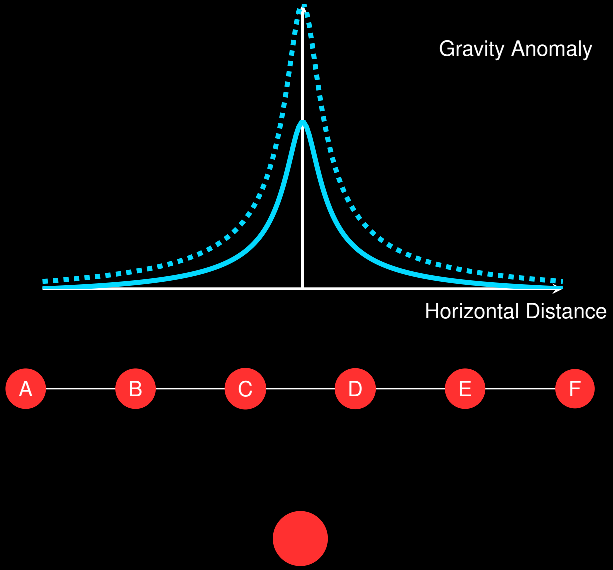
(instr. drift, motion compons.).

density variability in the subsurface.

Elevation correction (i.e. free-air)



Elevation correction (i.e. free-air correction)



The elevation correction references the gravity anomaly to the same datum (e.g., the geoid).

How does the gravitational acceleration change with elevation near the Earth's surface?

Elevation correction via Taylor expansion

Taylor expansion near $r = R_E$:

$$g(r) = G\frac{M}{r^2}$$

Elevation correction via Taylor expansion

Taylor expansion near $r = R_E$:

$$g(r) = g(R_E) + \frac{dg}{dr}|_{R_E}(r - R_E) + ...$$

Elevation correction via Taylor expansion

Taylor expansion near $r = R_E$:

$$g(r) \approx G\frac{M}{R_E^2} - 2G\frac{M}{R_E^3}(r - R_E) + \ldots$$

Elevation correction via Taylor expansion

Taylor expansion near $r = R_E$:

$$g(r) \approx \underbrace{G\frac{M}{R_E^2}}_{\text{g at Earth's surface}} - 2G\frac{M}{R_E^3}(r - R_E) + \ldots$$

Elevation correction via Taylor expansion

Taylor expansion near $r = R_E$:

$$g(r) \approx G\frac{M}{R_E^2} - \underbrace{2G\frac{M}{R_E^3}(r - R_E)}_{\text{change with elevation}} + \ldots$$

Elevation correction via Taylor expansion

Taylor expansion near $r = R_E$:

$$g(r) \approx G\frac{M}{R_E^2} - \underbrace{2G\frac{M}{R_E^3}(r - R_E)}_{\text{change with elevation}} + \ldots$$

Evaluation at let's say $r = R_E + 1$ (m) returns a change of $\delta g(r) \approx -0.3$ mGal per m.

Elevation correction via Taylor expansion

Taylor expansion near $r = R_E$:

$$g(r) \approx G\frac{M}{R_E^2} - \underbrace{2G\frac{M}{R_E^3}(r - R_E)}+\ldots$$

$\delta g(r) \approx -0.3$ mGal per m is large compared to the sensitivity of gravimeters, therefore the gravimeter elevation needs to be determined within centimeters using GNSS.

Reduction of gravity data

Every gravity survey measures:

latitudinal variability,

dependency on elevation,

the surrounding terrain,

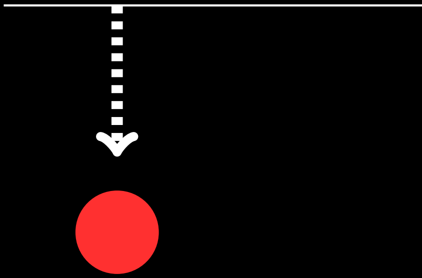
excess mass above anomaly,

earth & ocean tides,

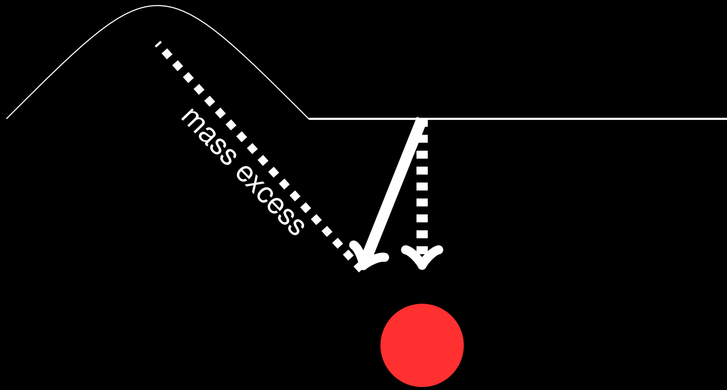
(instr. drift, motion compons.).

density variability in the subsurface.

Reduction of gravity data: Terrain correction

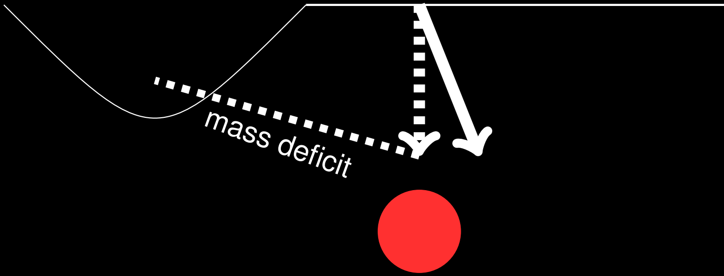


Reduction of gravity data: Terrain correction



A neighboring mountain will reduce the measured g_z independent of target properties.

Reduction of gravity data: Terrain correction



A neighboring valley will reduce the measured g_z independent of target properties.

Reduction of gravity data: Terrain correction

The terrain correction requires an elevation model and assumptions about the broad-scale sub-surface density.

The terrain correction is positive both for surrounding valleys and mountains.

Reduction of gravity data

Every gravity survey measures:

latitudinal variability,

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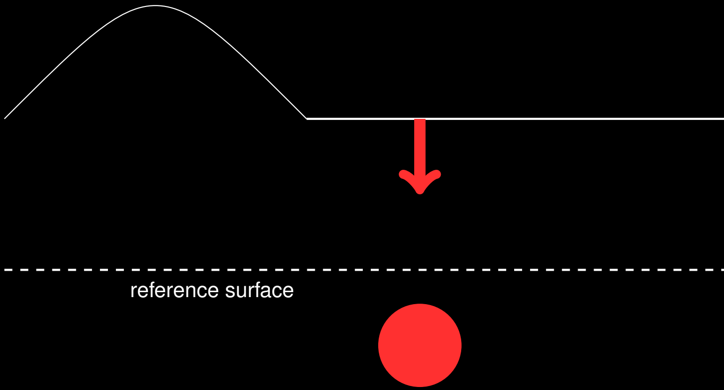
excess mass above anomaly,

earth & ocean tides,

(instr. drift, motion compons.).

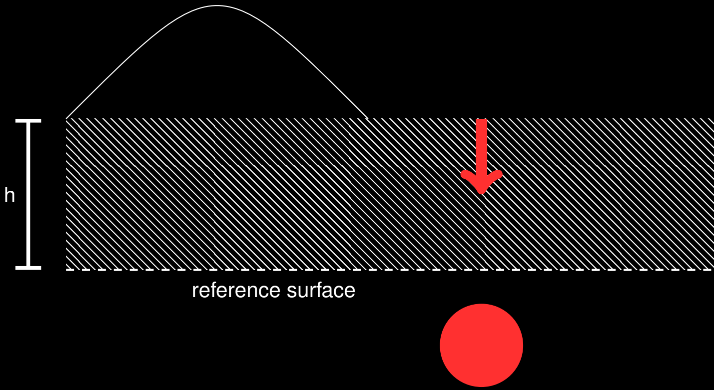
density variability in the subsurface.

Reduction of gravity data: Gouguer correction



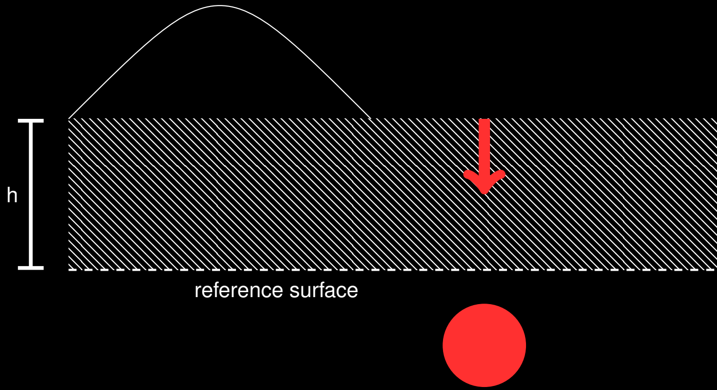
Elevation and terrain correction do not yet account for the mass between the measurement surface and the reference surface.

Reduction of gravity data: bouguer correction



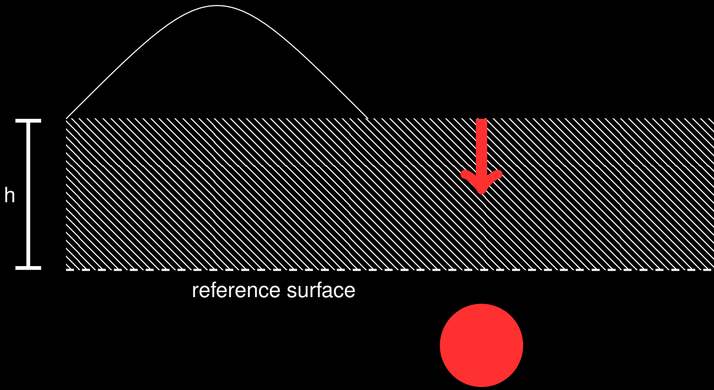
What is the effect δg_z of a horizontal plate with constant density?

Reduction of gravity data: bouguer correction



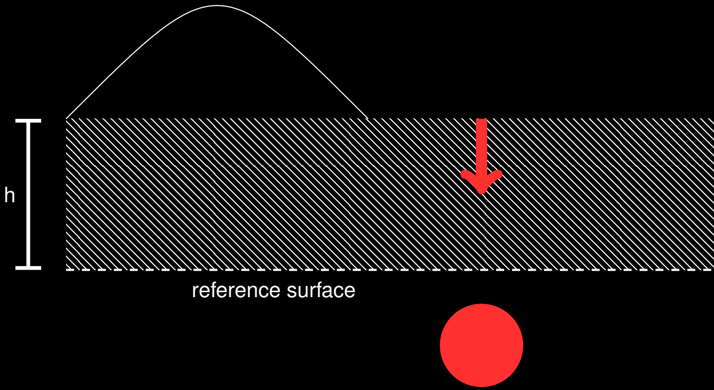
$$g_z = G\rho \int\int\int \frac{1}{r^2}\cos(\phi)dV = ?$$

Reduction of gravity data: bouguer correction



$$g_z = G\rho \int \int \int \frac{1}{r^2} \cos(\phi) dV = 2\pi G \rho h$$

Reduction of gravity data: bouguer correction



Bouguer anomaly represents the gravitational attraction of the material below sea level

Reduction of gravity data

Every gravity survey measures:

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(instr. drift, motion compensation),

density variability in the subsurface.

The origin of tides

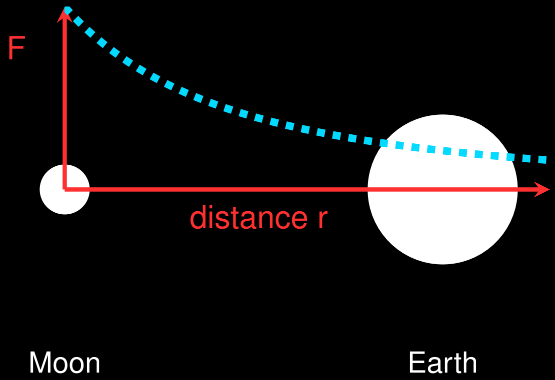
Tides are caused by gravity celestial bodies (i.e. Sun & Moon).

Tidal forces vary across a spatially extended body.

Tidal forces are balanced by centrifugal forces of two (three) body rotations.

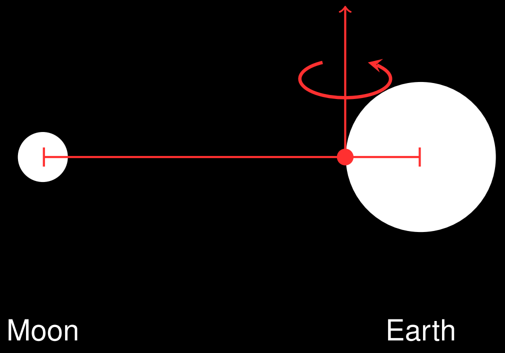
The origin of tides

The origin of tides

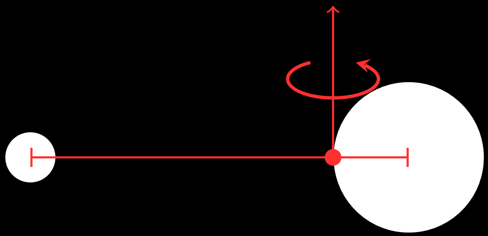


Gravitational attraction is stronger on the nearside than the farside.

The origin of tides



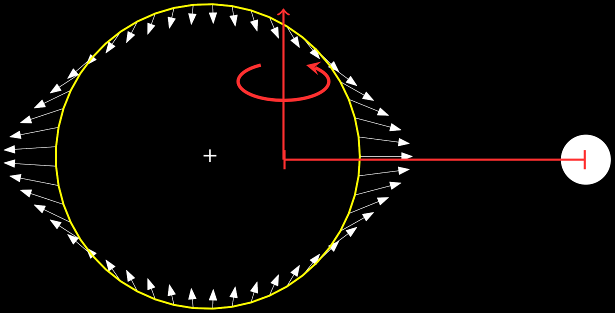
The origin of tides



Moon Earth

Centrifugal force can be projected into radial (i.e. parallel to Earth's gravitation) and parallel component. This leads to the force balance.

The origin of tides



Moon

The lunar gravity differential field is responsible for two tidal bulges (i.e. tides twice a day).

The origin of tides

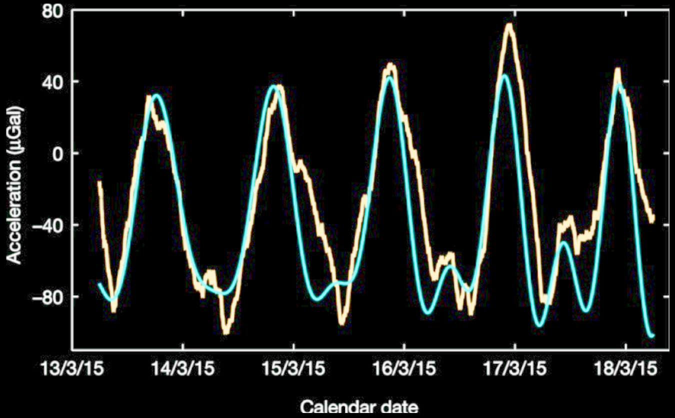
Tidal forces vary across a spatially extended body.

Tidal forces are balanced by centrifugal forces of two (three) body rotations.

There is lots of confusion regarding the origin of tides (cf. Matsuda et al. 2015 $\rightarrow$ Ilias).

Tide models or reference measurements can be used for correction

Tidal signal in gravimetry



Reference:

Middlemiss et al., Nature, 2016

Reduction of gravity data

Every gravity survey measures:

latitudinal variability,

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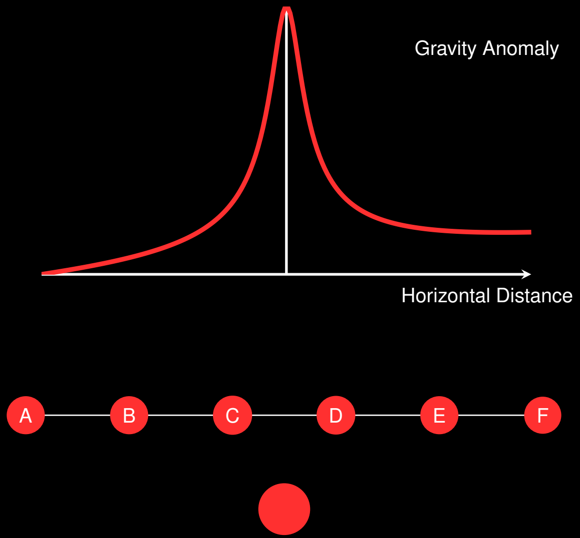
earth & ocean tides,

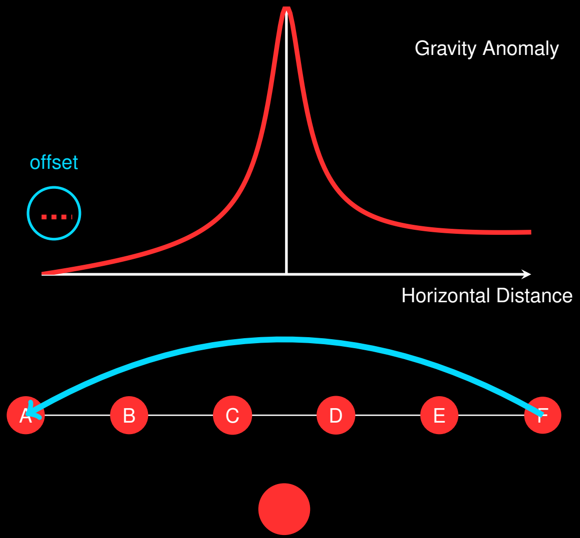
(instr. drift, motion compensation),

density variability in the subsurface.

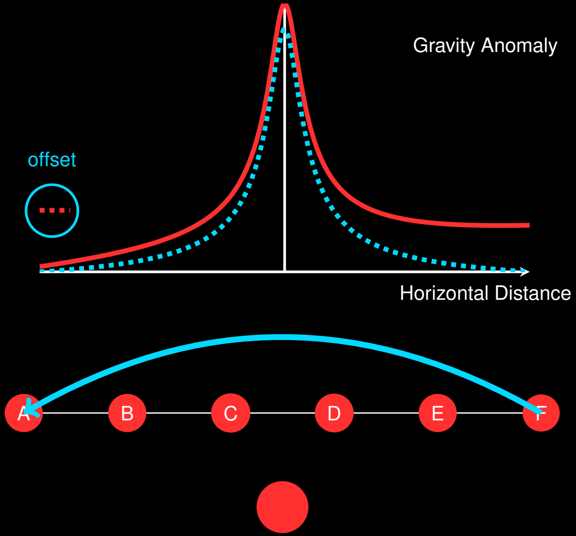
Instrument drift / temporal variability



Instrument drift / temporal variability



Instrument drift / temporal variability



Reduction of gravity data

Every gravity survey measures:

latitudinal variability,
dependency on elevation,
the surrounding terrain,
excess mass above anomaly,
earth & ocean tides,
(instr. drift, motion compons.),
density variability in the subsurface.

$$
\begin{aligned}
\delta g_{z,reported} = & \delta g_{z,measured} \\
& - \delta g_{z,lat} \\
& \pm \delta g_{z,elev} \\
& \pm \delta g_{z,tides} \\
& + \delta g_{z,terrain} \\
& - \delta g_{z,bouguer}
\end{aligned}
$$

Reduction of gravity data

$$
\begin{aligned}
\delta g_{z,reported} = &\delta g_{z,measured} \\
&- \delta g_{z,lat} \\
&\pm \delta g_{z,elev} \\
&\pm \delta g_{z,tides} \\
&+ \delta g_{z,terrain} \\
&- \delta g_{z,bouguer}
\end{aligned}
$$

free-air: $\delta g_{z,lat} \pm g_{z,elev} (\pm g_{z,terrain} \pm g_{z,tides})$
bouguer: free-air + bouguer plate (rel. sea level)

Take aways from this video

- ✓ The gravity method integrates over many processes and data reduction is required.
- ✓ Principle of ellipsoidal flattening & tides.
- ✓ Representation as *free-air* or *bouguer* anomaly maps.
- × Different gravimeter types and applications (e.g. mapping of Geoid).

END OF VIDEO 3

Learning goals today:

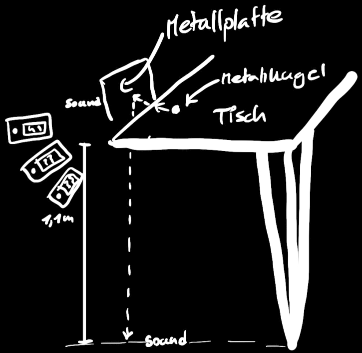
- Gravimeter designs
- Mapping and definition of the geoid
- Application examples

Gravimeter design

Gravimeters are accelerometers

- free-fall, pendulum, springs
- satellite orbit perturbations
- ...

Free-fall gravimeters (→ Ex.)



Reference:

Gneis & Happy SS 2021

Free-fall gravimeters (→ Ex.)

Reference:

S. Wuestney SS 2021

Free-fall gravimeters ($\rightarrow$ Ex.)

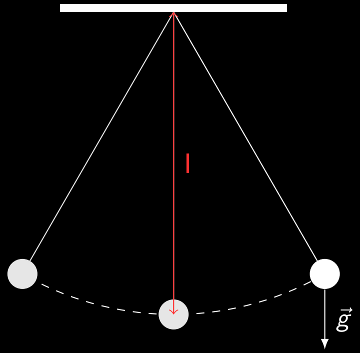
Reference:
J. Noll SS 2023

Free-fall gravimeters ($\rightarrow$ Ex.)

Reference:

Van Camp et al., EOS, 2017 Credit: Olivier Francis

Pendulum-based gravimeters



Eigenfrequency & Length.

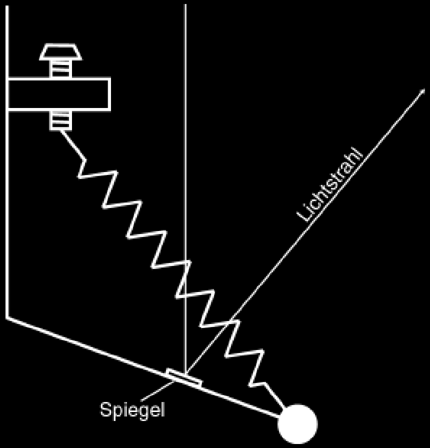
$$\omega = \sqrt{\frac{g}{l}}$$

Pendulum-based gravimeters (→ Ex.)

Reference:

M. Roth SS 2023

Spring-based gravimeters



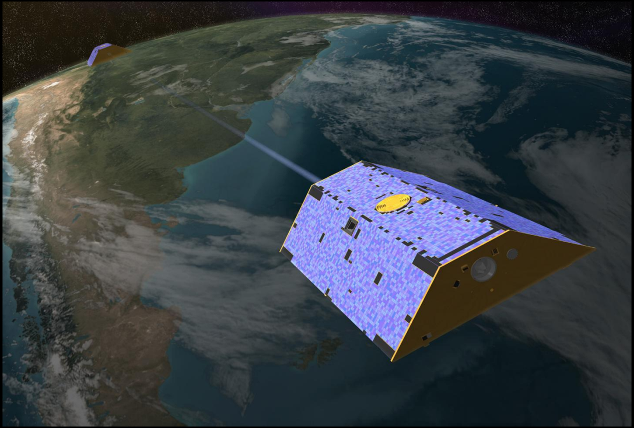
Springconstant & Extension.

Gravimeters: spring-based

Reference:

Sandeep CC-BY-SA 3.0]

Gravimeters: satellite-orbit perturbation



Reference:
NASA GRACE FO / Jet Propulsion Laboratory

Gravimeters: satellite-orbit perturbation

Watch Video 15 Years of GRACE

https://www.youtube.com/watch?v=MaxBOvQ2a_o

Absolute vs. relative

Absolute gravimeters are needed

- if loop closure if impossible (e.g. intercontinental surveys),
- for long-term changes such as isostatic uplift,
- as basestations for relative surveys.

Relative surveys are always easier to conduct and loop closure can cancel many error sources (e.g., instrument drift).

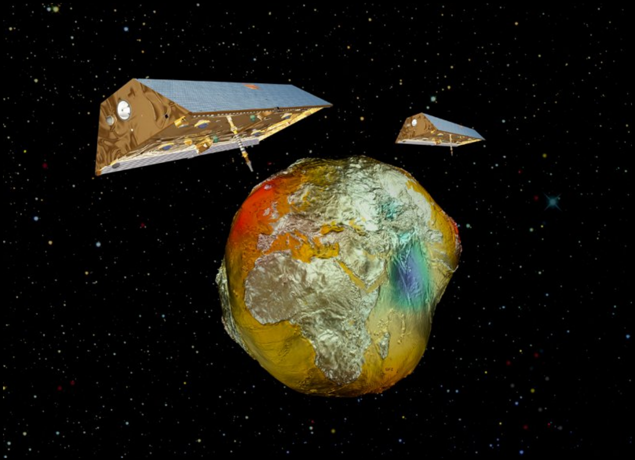
Gravimeters

Top *absolute* gravimeters $\sim 1\mu$Gal ($10^{-9}g$)

Top *relative* gravimeters $\sim 10\mu$Gal ($10^{-8}g$)

Typically only g_z is measured.

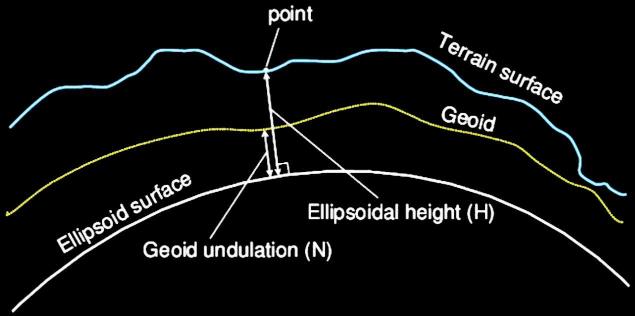
Application examples: Geoid



Reference:

Result from GRACE-FO (Credit: GFZ Potsdam)

An ellipsoidal Earth

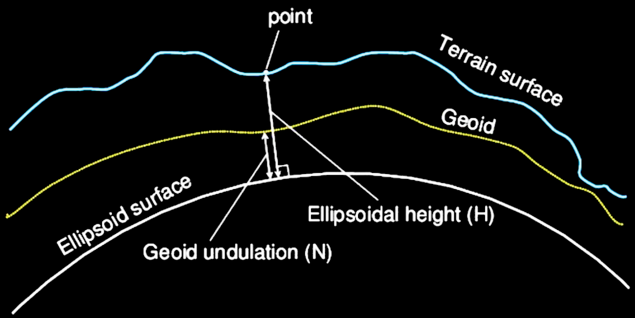


[Ziebart et al., 2004]

Geoid is a real-world equipotential line approximating sea level.

It is referenced to the geometric ellipsoid.

An ellipsoidal Earth

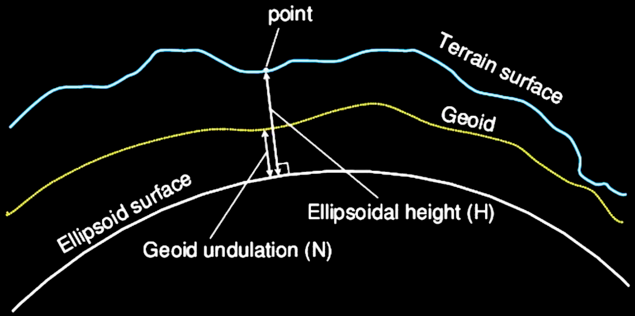


[Ziebart et al., 2004]

The reference of elevation is a constant source of confusion.

The geoid defines the local vertical direction.

An ellipsoidal Earth

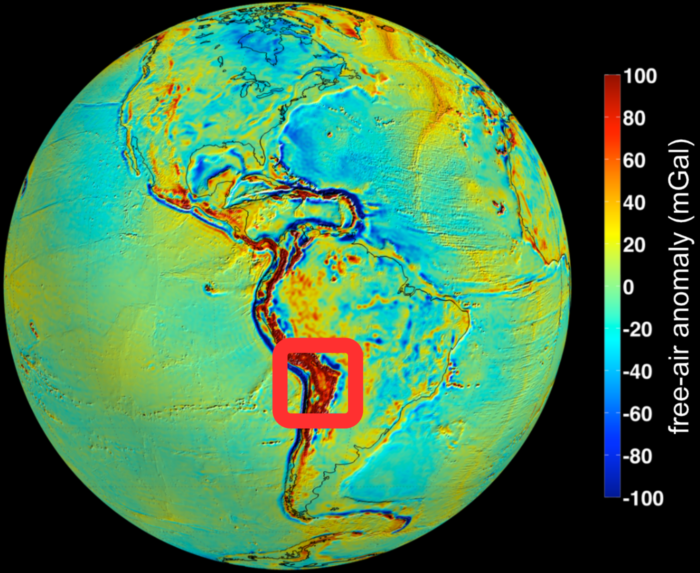


[Ziebart et al., 2004]

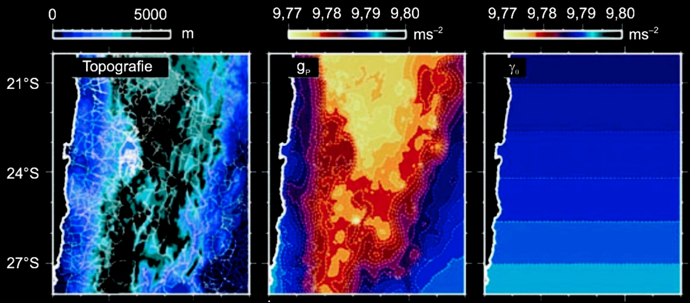
Upwarping of geoid indicates mass excess.

Downwarping of geoid indicates mass deficit.

Application examples: Andes



Application Examples: Andes



(a) Topography.

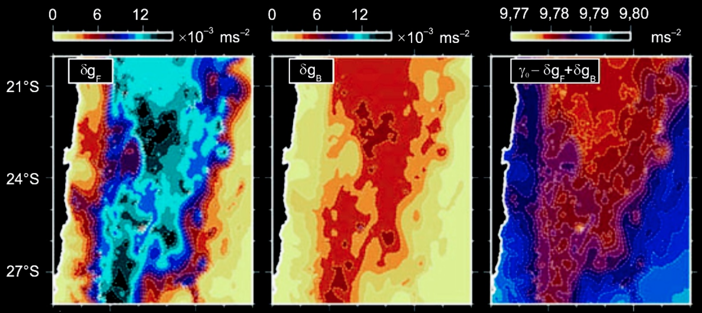
(b) Measured g_z.

(c) Reference gravitational field.

Reference:

From Clauser 2018 (after Schmidt and Götze 2006 in Hackney 2011)

Application Examples: Andes



(a) Free-air reduction

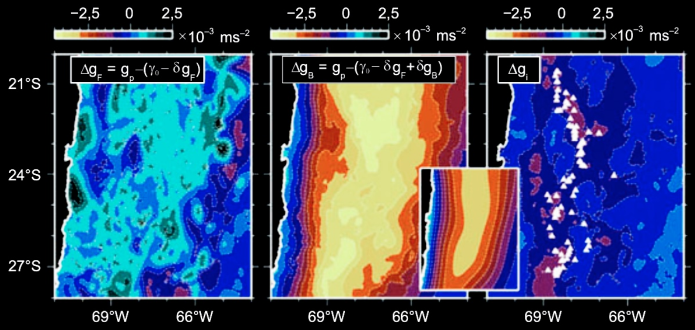
(b) Bouguer reduction

(c) Free-air + Bouguer reduction

Reference:

From Clauser 2018 (after Schmidt and Götze 2006 in Hackney 2011)

Application Examples: Andes



(a) Free-air anomaly

(b) Bouguer anomaly

(c) Isostatic anomaly (assuming 20 km root depth)

Reference:

From Clauser 2018 (after Schmidt and Götze 2006 in Hackney 2011)

Application Examples: Andes

In mountains the elevation correction dominates

A negative Bougues anomaly is indicative or mountain roots

Isostatic anomaly is not hypothesis free, but markes the Andes as an active orogen which is not yet in isostatic equilibrium

Bouguer anomaly map of Germany will be treated in exercises.

Summary

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Take aways from this video:

- There are different types of gravimeters (absolute vs. relative).
- The geoid is an important equipotential line.
- Bouguer and free-air anomaly maps offer important insights into sub-surface structures.

END OF VIDEO 4