Introduction to Geophysics

Assignment: Gravity

Problem 1: Gravity from first principles

This problem revisits the fundamental definition of gravity introduced in lecture and emphasizes how gravitational acceleration depends on mass and distance.

Consider two spherical bodies of masses m_1 and m_2, separated by a distance r between their centers.

(a) Write Newton's law of gravitation for the force between the two bodies. From this expression, derive the gravitational acceleration experienced by m_2 due to m_1.

(b) Show explicitly how gravitational acceleration scales with distance r. State clearly what happens to gravity when r increases.

(c) Explain in words (2–3 sentences) why gravity decreases as one moves away from a mass, even though the mass itself does not change.

Now consider the Earth as a spherically symmetric body of radius R_E.

(d) Explain qualitatively why gravitational acceleration decreases as one moves from the Earth's surface toward the center.

(e) What is the value of gravitational acceleration at the center of the Earth? Explain why this value makes physical sense.

Problem 2: Gravity of the Earth as a system

In lecture, we emphasized that gravity measured at the Earth's surface is not a single constant but varies systematically across the planet.

(a) Explain why the gravitational acceleration at the Earth's surface is not exactly $g = 9.81\,\mathrm{m/s^2}$ everywhere.

(b) Explain why gravity is slightly larger at the poles than at the equator. In your answer, explicitly discuss the role of Earth's rotation and shape.

(c) Thinking question: if the Earth suddenly stopped rotating (but kept the same mass distribution), what would happen to the gravity field measured at the surface? Briefly justify your answer.

Problem 3: Interpreting time-variable gravity from GRACE

In the tutorial, you analyzed GRACE/GRAVIS Level-3 data over Greenland using the MATLAB script provided in class. The data represent mass redistribution expressed as *Equivalent Water Height* (EWH).

Using the variables already defined in the tutorial script (`lon`, `lat`, `field_diff`):

(a) Write the MATLAB commands needed to identify the location of the strongest *negative* gravity (EWH) change over Greenland.

Your MATLAB commends must:

- ignore invalid values (`NaN`),
- find the minimum value of the difference field,
- retrieve the corresponding longitude and latitude.

Hints:

- `~isnan(field_diff)` keeps only valid (non-`NaN`) data values.
- `idx = find(field_diff == min_val, 1)` returns the index of the first occurrence of the minimum value.

Report:

- the MATLAB commands you used
- the minimum EWH value,
- the longitude and latitude at which it occurs. (hint: use `fprintf`)

(b) Describe where this region is located geographically (e.g. coastal margins, central ice sheet, north/south Greenland).

(c) Explain physically why gravity change is strongest in this region.

(d) Using the Greenland-averaged time series produced in the tutorial, describe:

- the long-term trend,
- the presence of any variability in time.