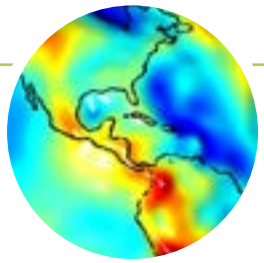
Earth's Gravitational Field

A Carolina Essentials™ Activity

Student Worksheet



Overview

All objects that have mass exert a gravitational force on other objects. For the objects we interact with daily, the force is so small it usually goes unnoticed. You don't notice the desk attracting your pencil, but when you drop your pencil, you notice the gravitational attraction between the pencil and Earth. Earth's gravitational field attracts the pencil to the Earth's surface, which is called gravitational acceleration.

Newton demonstrated that the force of gravity, F_g, between two objects is attractive, directly proportional to the product of their masses, m_1 and m_2, and inversely proportional to the distance, d, between them squared.

$$F_g = -G\frac{m_1 m_2}{d^2} \qquad G = 6.67 \times 10^{-11}\ Nm^2/kg^2$$

The masses of objects and distance between them are key considerations for understanding the strength of the gravitational force. Newton's formula can be applied to very large bodies like the Earth and moon system or even the Earth and sun system because of the substantial masses of the objects and the distances between them.

For less massive bodies on or near the Earth's surface, we often use the local *gravitational field of Earth*, g, the attractive force a body placed in Earth's gravitation field experiences. The gravitational field strength at a given point is calculated as the gravitational force per unit of mass or:

$g = F/m$ $\quad g = 9.80665\ N/kg$ $\quad F =$ in Newtons $\quad m =$ mass in kg

Since gravity is an attractive force and bodies near the Earth's surface fall to Earth, g is also referred to as the average acceleration due to gravity. At sea level the standard acceleration of gravity is 9.80665 m/s^2. Latitude, altitude, and local geology can impact the value of g. Local variations in values of g are called **anomalies**. They are measured in units of milliGalileo, mgal, which has an acceleration value of about 1×10^{-6} g or $1 \times 10^{-5} m/s^2$.

Now, with satellite imaging from GRACE satellites, launched in 2002, we have a much more detailed picture of Earth's gravitational field. The Gravity Recovery and Climate Experiment (GRACE) mission satellites recorded data on the entire Earth every 30 days from a polar orbit. The twin satellites measured the gravitational field and variations in the field, providing more accurate and sensitive measurements than those made on Earth. GRACE data were used to produce gravity anomaly maps that show Earth's actual gravity field compared to a gravity field of a uniform, featureless surface.

The maps provided for this activity are color coded to indicate anomalies, areas with higher (red) or lower (blue) than expected values of g. Patterns in anomalies help scientists identify shifts in locations of water and ice as processes like global currents redistribute them. Massive rockslides or volcanic eruptions can be detected, even if they occur in the ocean.

With imaging from GRACE satellites and a shaded relief map, you will establish and confirm patterns among Earth's gravitational acceleration, topography, and geology.

SAFETY REQUIREMENTS

No PPE is required for the activity.

MATERIALS

Raised relief map or world shaded relief map

Gravity field anomaly maps

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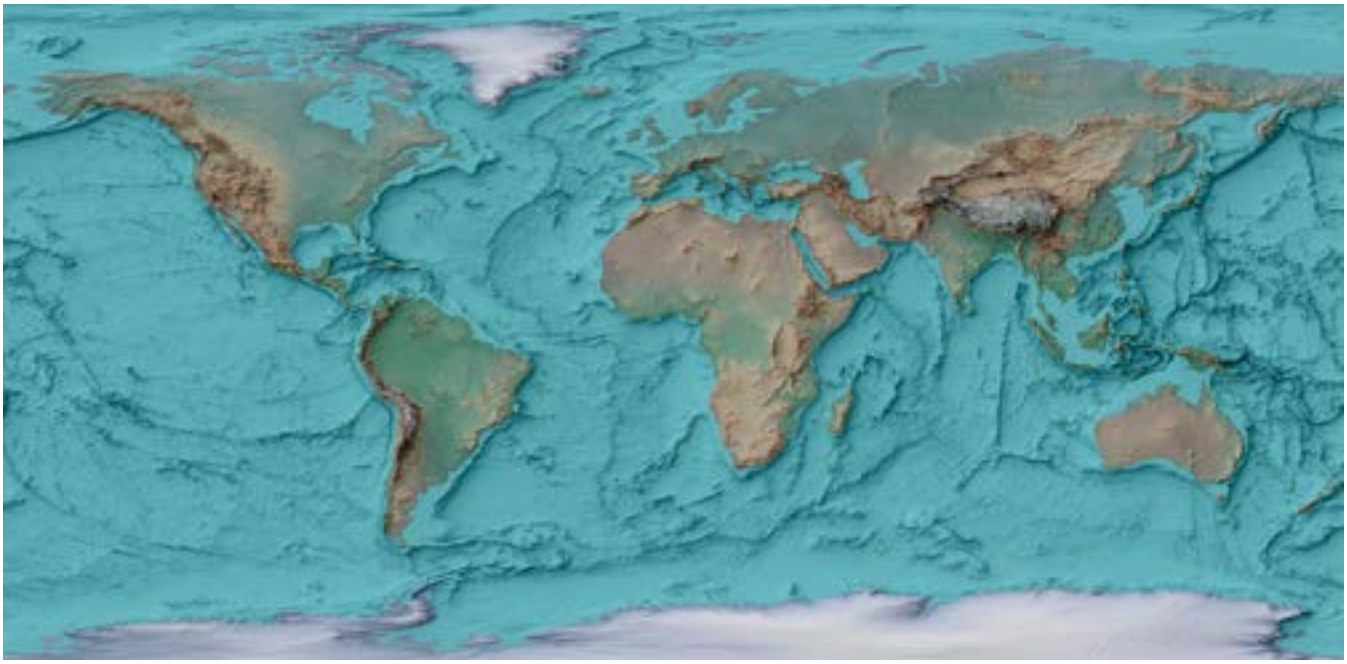
Phenomenon

What can you tell about the distribution of mass on Earth by looking at a relief map?



Relief map of the world

Essential Question

How can variations in Earth's gravitational force be explained and predicted?

Activity Objectives

1. Using GRACE satellite data, explain variations (anomalies) and patterns in Earth's gravitational field.
2. Explain how the gravity field anomalies could be addressed by Newton's law of universal gravitation.

Activity Procedures

1. Carefully examine the 3 gravity field maps of the different regions of the world. Notice that the key is for gravity anomalies, a difference in values (milligal, or mgal, used as the unit for acceleration in the science of gravimetry) above or below the expected value for a featureless, uniform surface on Earth.
2. Record any variations or patterns you notice.
3. Compare the gravity field maps to a world relief map.
4. Record any variations or patterns you notice.

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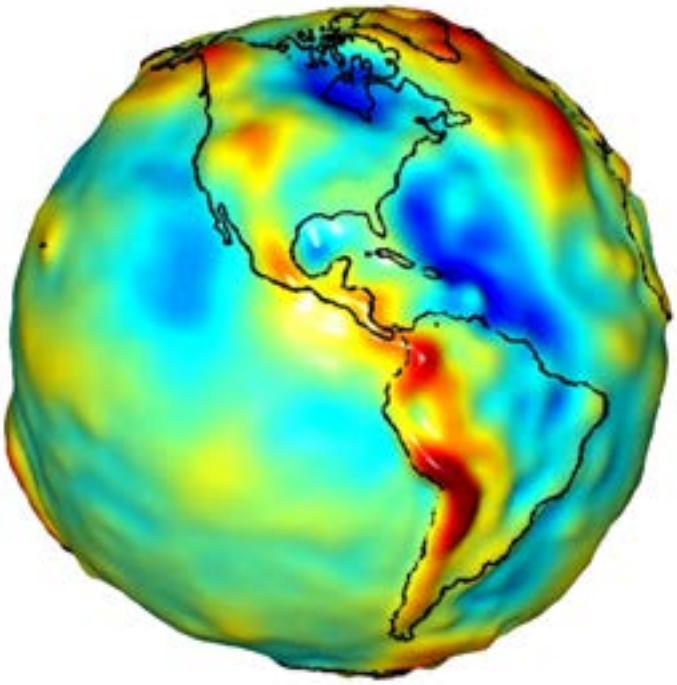
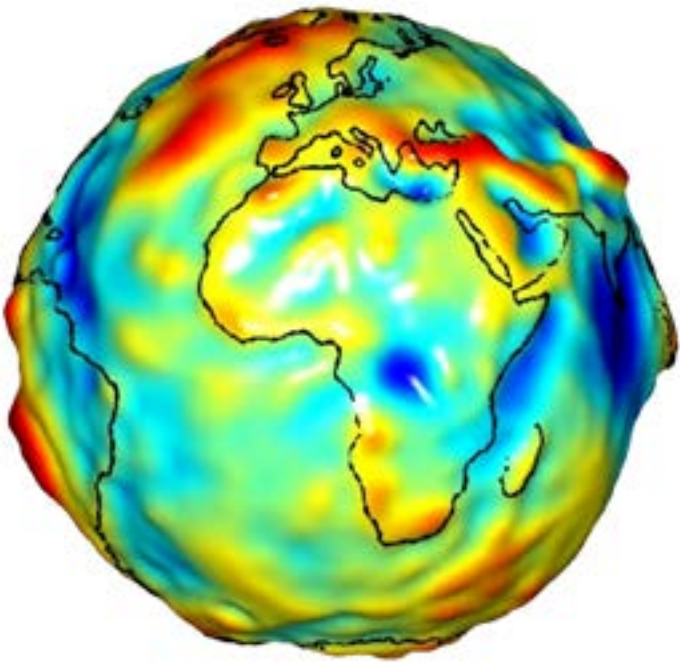
Gravity field maps of the different regions of the world

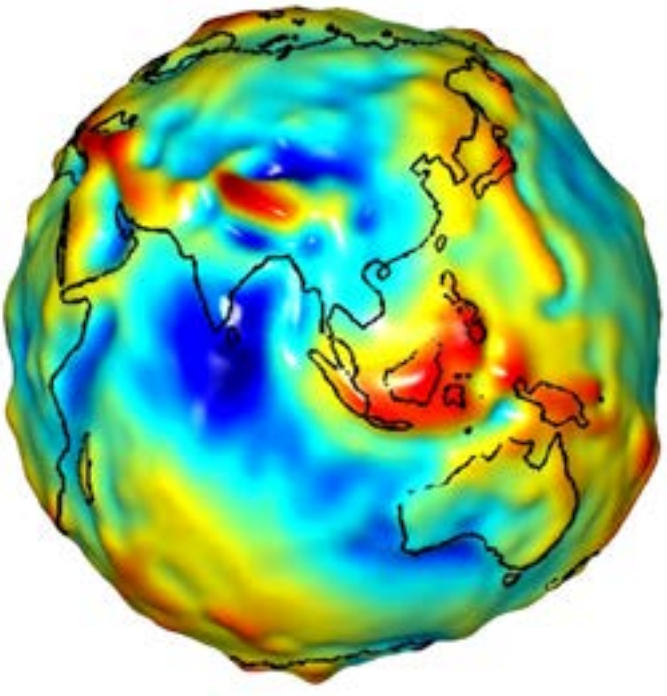
North and South America



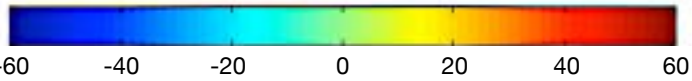
Europe and Africa



Asia



Gravity Anomalies (mgal)



Figures prepared by The University of Texas Center for Space Research, as part of a collaborative data analysis effort with the NASA Jet Propulsion Laboratory and the GeoForschungsZentrum Potsdam.

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Data and Observations

Densities of Earth Materials (at the surface and approximately 24° C)	
Granite	2.6–2.7 g/cm^3
Basalt	2.8–3.0 g/cm^3
Fresh Water	1.0 g/cm^3
Salt Water	1.027 g/cm^3

1. Gravity field map observations

2. Gravity field map and relief map comparisons

Analysis and Discussion

How can Newton's law of universal gravitation be used to explain the anomalies in the global gravity field map? Use the table of densities to help support your claims.