

A GRAND TOUR OF THE TERRESTRIAL PLANETS

WITH

Google Earth

An Instructor's guide with lesson plans and learning outcomes.

By

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If your students are new to Google Earth, we recommend they are assigned to practice before class:

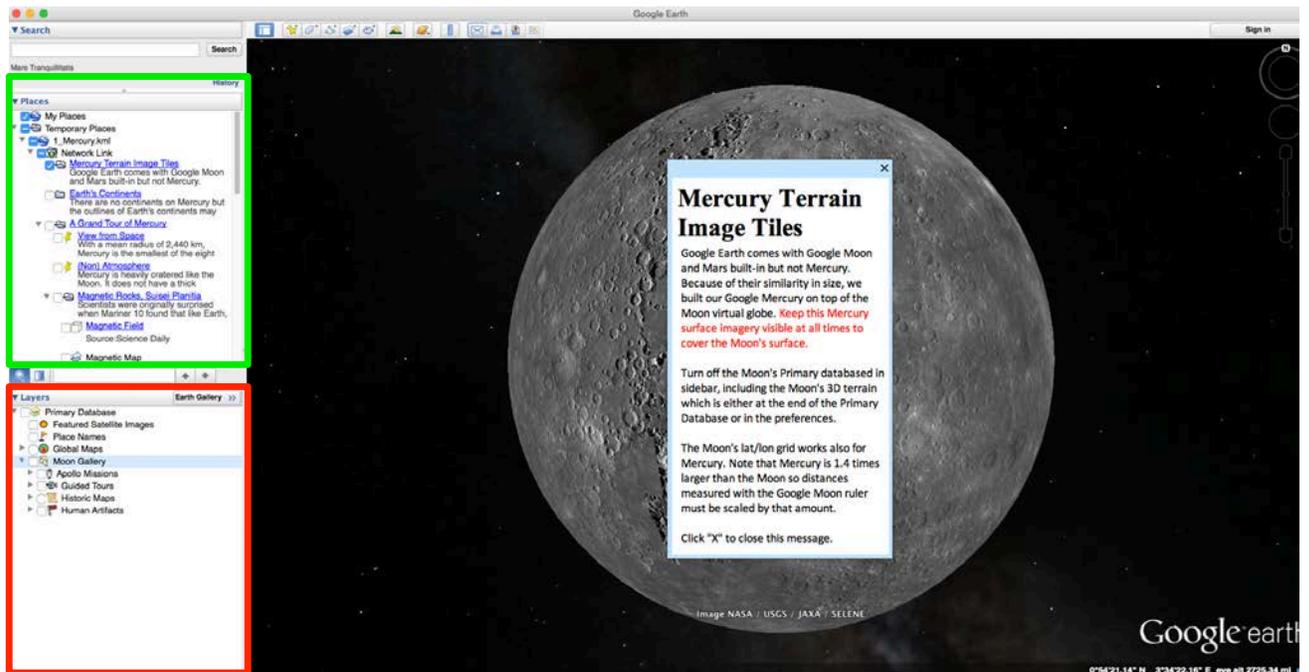
<http://www.bio-nica.info/biblioteca/GoogleEarthUserGuide.pdf>

MERCURY

Tell students to launch the KML file named 1_Mercury.kml using Google Earth or Google Earth Pro. They will be prompted to switch to the “Moon” or stay on “Earth.” They should switch to the Moon. Explain, however, that we are just using the Moon as a base for Google Mercury.



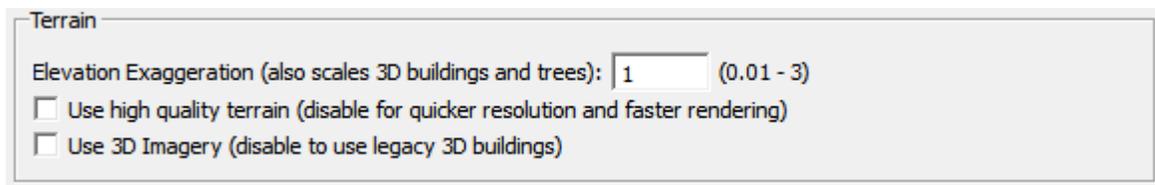
Mercury terrain imagery will appear on top of the Moon as a tiled image overlay and a welcome balloon window will automatically pop up right in front of the planet. Follow the instructions in the balloon, then close it. To reopening, click the blue, underlined “Mercury Terrain Image Tiles” link in the Places sidebar (outlined in green below):



The “Places” sidebar contains all of the terrain imagery, overlays, and tour stops for Mercury. Notice that “Mercury Terrain Image Tiles” option is pre-checked —students should keep it on all the time to cover the Moon’s terrain.

The red Layers sidebar contains features pertaining to the Moon such as landers etc. Make sure that all of these are hidden by unchecking the “Primary Database” for the duration of this Mercury exercise.

In some versions of Google Earth, the 3D terrain is at the bottom this red Layers sidebar and can be unchecked along with the rest of the Layers. If it is not there, go to “Preferences” (Mac) or “Options” (Windows). In the “3-D View” tab, find the terrain options and set Elevation Exaggeration to 0.01. Uncheck “Use high quality...” and “Use 3D...”



Navigation Controls

Have students experiment with the Google Earth controls at this stage by rotating the planet, zoom in and out and get a feeling for navigating around in Google Earth.

In the Places sidebar, your students will see a set of icons next to the different stops, which look like this,



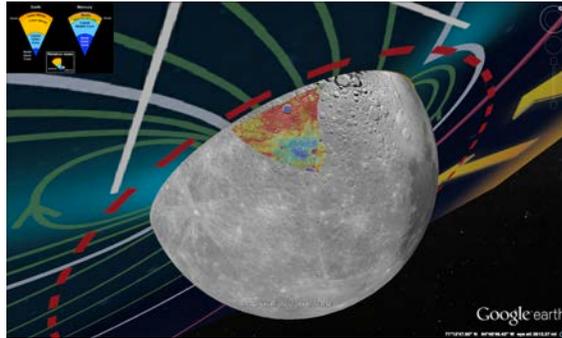
The first two icons are folders—closed and open. A closed folder with a triangle (Mac) or plus (PC) icon can be opened to reveal its contents as shown below:



Some folders have content hidden and no triangle or plus icon.

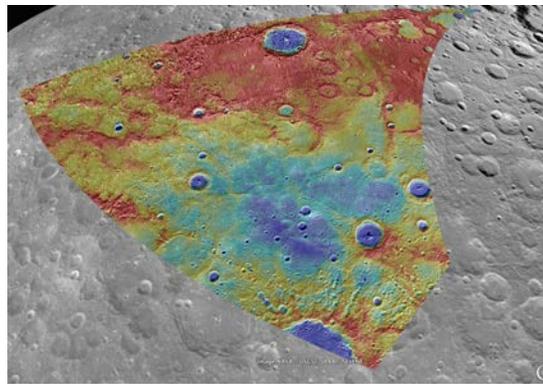
The third icon says that that stop has a **layer** on planet. In order to see it students must check the box and double-click the description to fly to its location. Clicking on names in blue will open balloons with text and images.

The **3-D model** icon (cube) means that the stop includes a 3-D COLLADA model. Remind students that they can best move around models with shift and arrow keys.



Magnetic Map.

Low magnetism of Mercury's rocks (blue) is strongly correlated with impact craters.

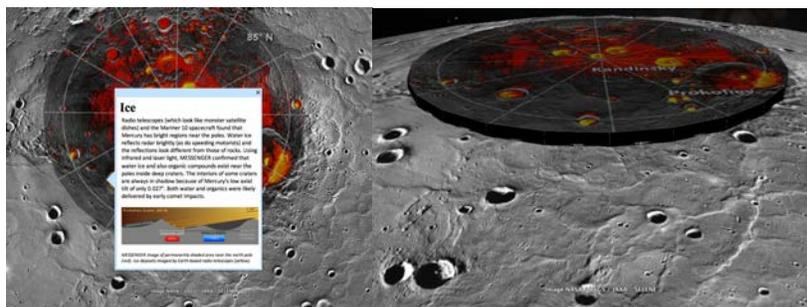


Earth versus Mercury

Magnetic fields are generated in liquid cores and Mercury's is huge.

Ice.

Make sure all the other stops (except for the terrain overlay) are unchecked to minimize clutter.



LO: Water ice and organic compounds have been confirmed near the poles inside deep craters that are in constant shade. It was probably delivered by comet impacts.

Geology

Have students explore the craters on Mercury. Pan and shift-click or use shift-arrow keys to change view.

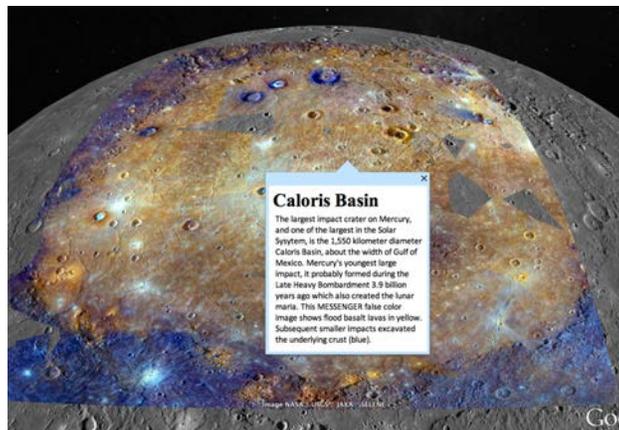
LO: Mercury's geology is quite like the Moon's. The main features are craters, lava flows, rifts, and wrinkle ridges.

Rembrandt

LO: Mercury was poorly known until visited by the MESSENGER mission which discovered this crater for the first time.

Caloris Basin.

Have students double-click the description to fly to view. on the Caloris Basin. The students should see a layer on top of the largest impact crater on Mercury.

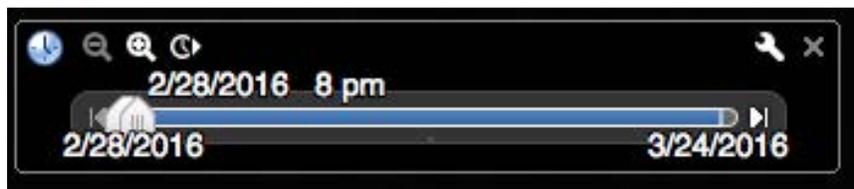


LO: This is Mercury's largest impact. The MESSENGER false color is depicted above, highlighting flood basalt lavas in yellow.

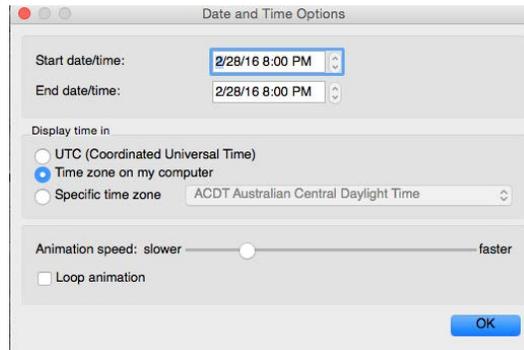
Caloris Seismic.

This folder contains a movie and the controls will appear automatically when students check the box.

1. Double click on the Caloris Seismic. A balloon will pop up describing the seismic wave generated from the impact collision that caused the basin.
2. Check the Caloris Seismic folder. A movie control panel should pop up on the top left hand side and the balloon should now have disappeared.

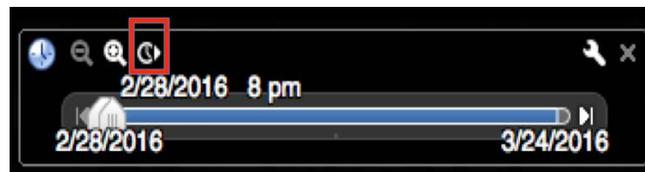


Movies on Google Earth usually play really fast, tell your students to adjust the time first by clicking on the tiny wrench tool and they should see this window:

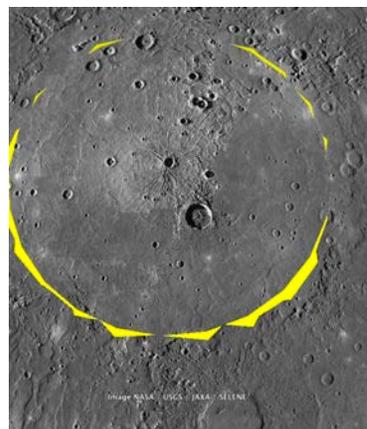


They can adjust the time by moving the slider in the “Animation speed” to the left for slower animation.

3. To play the animation, click the toggle time slider animation (the object in shown in the red square).



The idea here is for your students to “track” the seismic waves shown below in yellow by rotating the planet as the waves propagate through:



LO: The Caloris impact made Mercury ring like a bell and caused the antipodal “chaotic terrain” (the next stop).

Komatiite Lava Plains

LO: MESSENGER discovered a vast area of lava near the north pole, comparable in area to the USA. Yet there are no shield volcanos. The lava must be ultramafic, called komatiite.

Scarps

LO: Kilometer high scarps called rupes are common on Mercury. They indicate planetary shrinkage due to cooling.

Interior

Note that the contents of this folder have radio buttons so that only one can be selected at a time. Students should investigate Mercury's three cores.

LO: Mercury has three cores, a solid inner core, liquid middle core, and solid outer core which is 85% of the planet's radius. Some say the protoplanetary disk from which it accreted must have been richer in metal here than elsewhere in the Solar System. Others think solar radiation and/or a giant impact blasted away much of its mantle

VENUS

Upon opening up the 2_Venus.kml document with Google Earth or Google Earth Pro, students are presented with the welcome balloon and should follow the instructions in the balloon. If they previously ran the Mercury, Moon, or Mars tour, they will be prompted to switch to Earth which we use as a base for Google Venus.

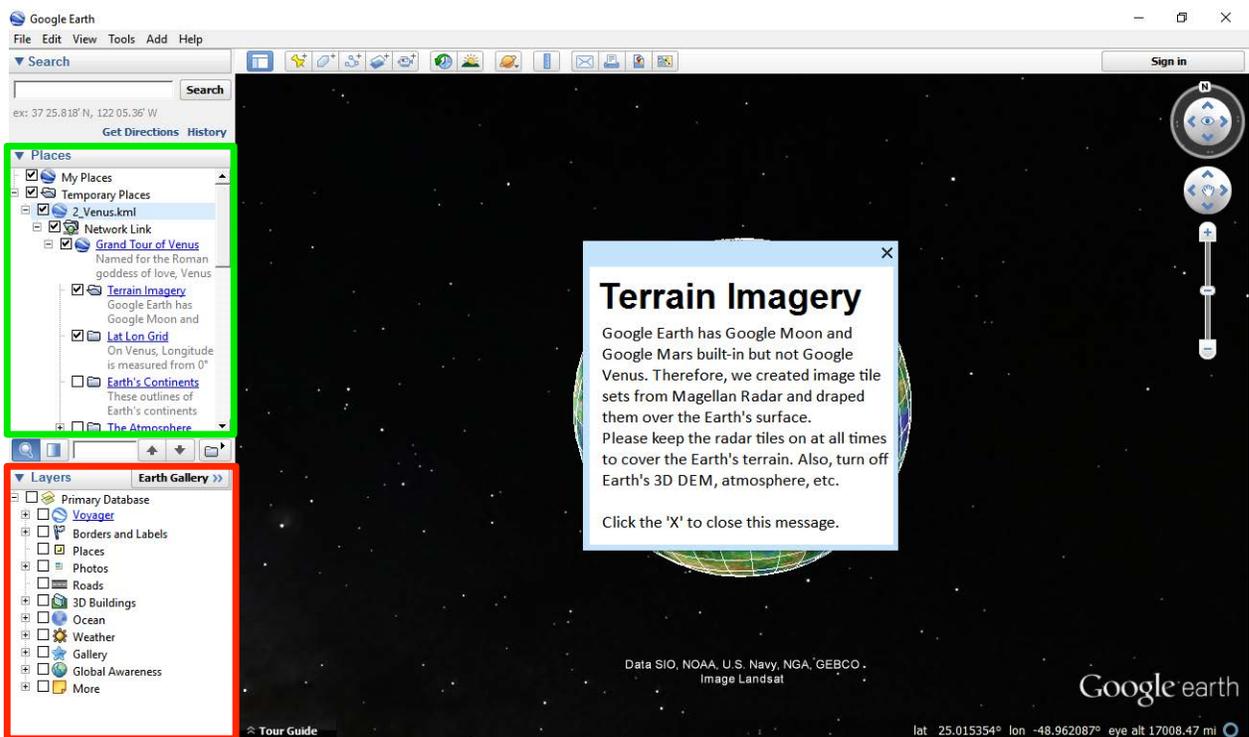


Figure 1. Starting up the KML.

The **GREEN** box contains all of the terrain imagery, overlays, and tour stops in the “Places” sidebar. Notice the “Terrain Imagery” option is checked – keep it on.

The **RED** box contains overlays and features of interest for Earth. Make sure the “Primary Database” is unchecked for the duration of this exercise.

To turn off Earth 3D terrain, either uncheck it in the Layers if it is there or go to “Preferences” (Mac) or “Options” (Windows). In the “3D View” tab, find the terrain options:

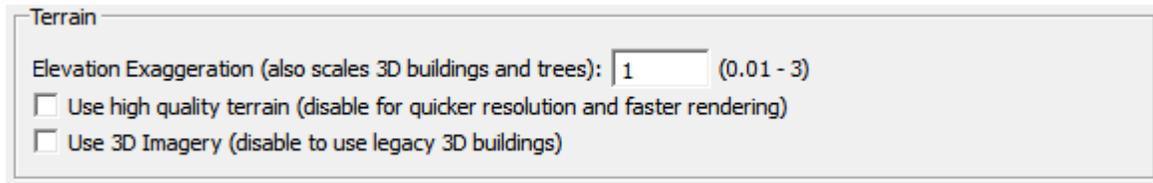


Figure 2. 3-D terrain options. Make sure the 3-D Imagery option is set to 0.01.

See the Mercury tour for basic explanations of icons etc.

Have students uncheck Earth’s “Grid” in the View menu and check the custom Venus lat/lon grid instead.

LO: Venus is upright and therefore does not have tropics or polar circles.

Earth’s Continents

Check the “Earth’s Continents” folder. Click the blue, underlined “Earth’s Continents” link and read the corresponding balloon. Finally, double click on the “Earth’s Continents” folder to introduce the “Fly To” feature of Google Earth. Uncheck when finished.

LO: The students get a sense of scale – how large various Venusian features are compared to Earth’s continents.

The Atmosphere

Have students visit each item in this folder, double-click descriptions to fly to view, and click blue links to open balloons.

LO: The atmosphere of Venus is extremely high pressure and rotates significantly faster than the planet.

LO: Lack of a protective magnetic field allows the solar wind to erode the atmosphere.

LO: There are polar vortices at each pole.

LO: The temperature drops through the troposphere. There are sulfuric acid clouds!

The Surface

Zoom out to view the entire disk of Venus and uncheck “The Atmosphere” folder. Students should visit the three stops in this folder.

LO: Venus has thousands of volcanoes and impact craters, but no small ones because of its thick atmosphere.

LO: Soviet landers find out that the surface is covered in basalt.

Lowlands

Fly to the three features and read the text balloons in any order. Colorized topography map is too low resolution to make out significant detail, so keep the “orange tiles” checked for this.

LO: The lowlands experienced significant volcanism, as evidenced from the basaltic composition, the lava flows, and crustal strain.

MesoLands and Highlands

LO: Large volcanoes can dominate the landscape, but other features of crustal strain can be seen indicating that Venus was once very active.

Fly to the three features and read the text balloons in any order. It might be instructive here to uncheck the “orange tiles” to view the colorized topography in order to compare the relative elevations of the highlands to the lowlands.

Unique Features

Students learn about surface features not seen anywhere else in the Solar System.

LO: Venus experienced different types of volcanism which, coupled with high atmospheric pressure, may lead to the unique shapes. There is little evidence for plate tectonics, so Venus’ volcanoes must be powered differently than the majority of Earth’s volcanoes, e.g. by superplumes in the mantle.

4. Expand the “Artemis” folder. When exploring “Artemis Chasma”, be sure to uncheck the “Artemis Map” overlay.
5. Upon finishing the all surface features, collapse and uncheck the “The Surface” folder to remove the overlay images and placemarks. We are ready move on from the surface!
6. Check “The Interior”, fly to it, and read the text balloon. Explore the details of the 3D models which shows two shapes, each of which constitutes 1/8 of the planet. The students can place the camera in the middle of the two pieces and move the camera (ctrl + click and drag) to see the sides in more detail. The arrows indication motion in the mantle, either an “x” indicating motion into the

volume of the model and a dot indicating motion out of the volume of the model.
Uncheck when finished.

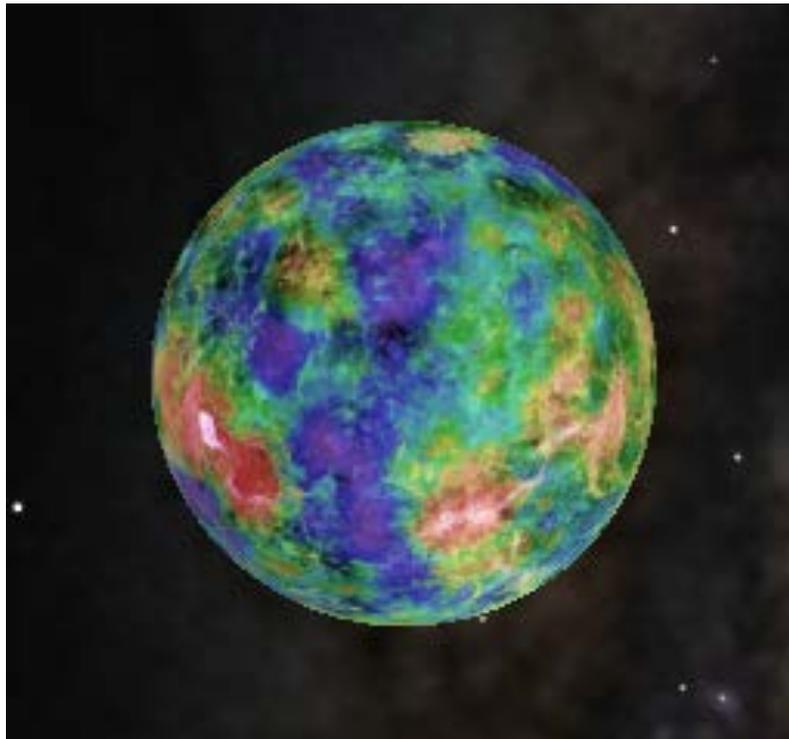
LO: Volcanic The activity is likely driven by mantle plumes. The model shows plumes origination both near the surface and close to the core.

The Runaway Greenhouse.

LO: There is evidence for past water on Venus. A runaway greenhouse effect lead to the present dry planet.

The Transit of Venus

LO: Transits are historically important in astronomy (to measure the distance from the Sun and Venus). They occur in pairs, and the last two occurred in 2004 and 2012. It won't be until 2117 for the next one (from Earth)!



The Moon

Upon opening up the 3_Moon.kml document with Google Earth or Google Earth Pro, the students will be presented with the following warning:

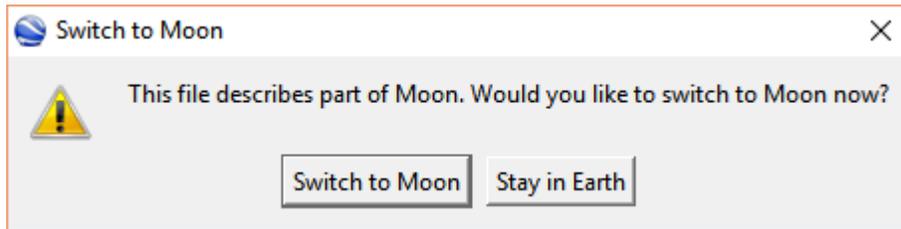


Fig. 1: The word Moon is used four times. Let's switch to the Moon.

Upon switching to the Moon, students are presented with the welcome balloon. They should follow the instructions in the balloon:

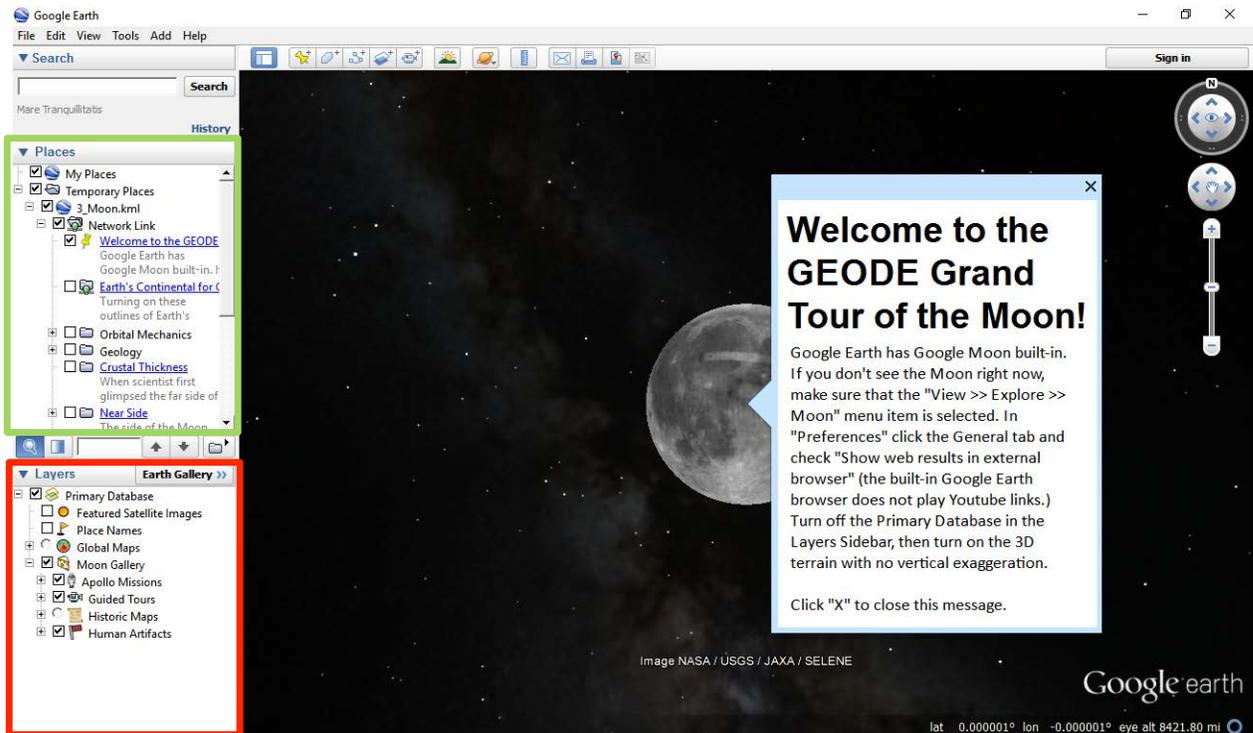


Fig. 2: Starting up the KML.

The **GREEN** box contains all of the terrain imagery, overlays, and tour stops in the “Places” sidebar. Notice the “Terrain Imagery” option is checked – keep it on.

The **RED** box contains overlays and features of interest for the Moon. Make sure the “Primary Database” is unchecked except when tours stops utilize the built in database.

To turn on the terrain, either check it in the Layers sidebar or go to “Preferences” (Mac) or “Options” (Windows). In the “3D View” tab, find the terrain options:

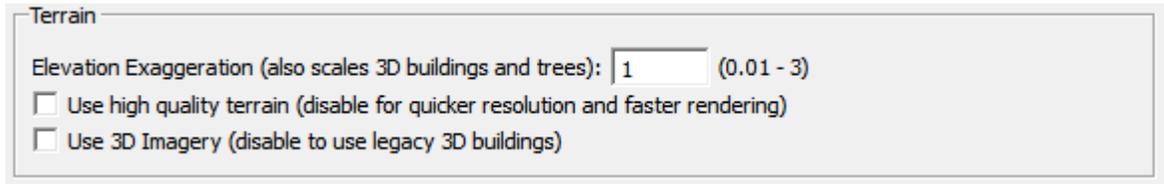


Fig. 3. 3D terrain options. Make sure the elevation option is set to 1.

Click the blue, underlined “Earth’s Continental for Comparison” link. This displays the text balloon. Exit the balloon after reading, and double click the network link to fly to the feature. The “fly to” feature of Google Earth takes the student to a good view of the feature.

Orbital Mechanics

All placemarks should be visited in turn.

LO: The Moon is much smaller than Venus or Earth—about the size of Earth’s inner core.

LO: The Moon shines due to reflected sunlight only

LO: The Moon spins in order to keep the same face pointed towards the Earth. The interaction between the Moon’s orbit and tides cause the Moon to move away from the Earth while lengthening the Earth’s rotation rate.

LO: The Moon is “The Greatest Wanderer”, and it occasionally blocks out some or all of the Sun during eclipse.

LO: “Earthrise” is among the most famous of all space images, and is often credited with kick starting the environmental movement through what is now called “the overview effect.”

Geology

Upon clicking the check box next to the “Geological Timescales” folder, an image will appear on the screen. This presents the named geological eras for both the Earth (left) and the Moon (right). When students expand the folder, two sub-folders and an overlay appears. The students should uncheck “Geological Timescales” overlay when finished. The features inside each sub-folder can be read in any order. Expand each folder in turn when exploring.

Rocks and Regolith folder

Students should fly to and read the text balloon describing each of the four main types of rock found on the Moon: anorthosite, volcanic lavas (basalt), breccia, and polar ice.

The polar ice feature includes a 3D model highlighting regions with detected water ice around the Moon's south pole.

LO: Anorthosite represent the Moon's original light crust

LO: The maria are made of basalt which is often rich in titanium.

LO: Breccias are created but impacts

LO: Orange soil represents volcanic eruptions in a vacuum.

Geological Structure

1. Fly to the "Hadley Rille" placemark. These features are common on the Moon, and appear like a dried river.

LO: What caused these features?

2. The "Apollo 15 Landing Site" is what it sounds like. Two astronauts drove around the Moon and visited the Hadley Rille.
3. Fly to the "Linear and Arcuate Fractures" and "Volcanic Domes" placemarks. Both features are probably a result of volcanism.

LO: How can volcanism affect the surface of the Moon, besides laying down maria?

4. Fly to "Wrinkle Ridges" to zoom in on another surface feature. The Moon has been cooling off since its formation and has shrunk as a result. Wrinkle ridges are how the surface responds to shrinkage.
5. Zoom out and click the check box next to the "Crustal Thickness" folder and read the text balloon. Remind students to uncheck when they are finished exploring the crustal thickness.

LO: There is an asymmetry between two hemispheres. One side has very thick crust and a lot of large craters while the other side contains mostly maria with relatively thin crust.

Near Side

6. Expand the "Near Side" folder: do NOT click the checkmark next to it. The first four placemarks are named craters: Aristarchus, Copernicus, Kepler, and Tycho craters. Fly to each and read their text balloon descriptions!

LO: What do lunar craters look like?

7. Click the check box next to "Oceanus Procellarum" and fly to the feature. The ground overlay displayed is a gravity gradient map – a record of changes in

gravitational acceleration from one place to another. The Oceanus Procellarum is bordered by the dark blue rectangle.

LO: The rectangular shape suggests this is not due to an impact. It is a strange part of the Moon!

8. Uncheck the “Oceanus Procellarum” overlay to return to the normal view of the Moon. Fly to the “Mare” stops: Imbrium, Serenitatis, and Tranquilitatis. Read the descriptions, Mare Tranquilitatis (Sea of Tranquility) is the landing-place of Apollo 11.

LO: Potentially not all maria regions were formed in the same way.

9. Check the box next to “Maria Ages”. This colors the maria according to their ages. The legend can be seen around the Moon’s south pole. The rainbow of colors represents 1 billion years ago (red) through 4 billion years ago (purple/violet).

LO: The maria were created different times in lunar history, though most were created around 3.5 billion years ago.

10. Uncheck “Maria Ages” to reveal the Moon’s surface again.

Far Side

11. Fly to the “South Pole-Aitkens Basin”. The image in the text balloon shows the true extent and depth of this crater. The camera flies to a region on the Moon slightly darker than the surroundings. The entire darker region is the impact basin, and the depth is around 15 km.
12. Read the text balloon for the “Orientale”, a very deep crater on the Moon’s far side.

LO: Learn the structure of a well preserved lunar crater.

Geophysics

13. Expand the “Geophysics” folder. Fly to the “Moonquakes” placemark. Note: the paths taken by astronauts are marked around the Lunar Excursion Module!

LO: What can we find out with seismometers on the Moon?

14. Zoom out! Click on the “GRAIL Gravity Map”. This shows the acceleration due to gravity (relative to 1.6 m/s^2), where red is a larger acceleration and blue smaller.

LO: The acceleration due to gravity largely follows the elevation.

15. Click on the “GRAIL Gravity Anomaly Map”. This effectively shows concentrations of dense minerals (larger anomaly) and clusters of fluffier, less dense material (smaller anomaly).

LO: The anomalies do NOT follow the elevation in the highland regions.

16. The “Lunar Cross Section” placemark shows the interior structure of the Moon. Notice the difference in crustal thickness between the near and far sides of the Moon.

17. The final two placemarks discuss the formation of the Moon and some subsequent evolution.

LO: How did the Moon form? And why do astronomers think that the Moon tilted about 6 degrees roughly 3 billion years ago?



Mars

Upon opening up the 4_Mars.kml document with Google Earth or Google earth Pro, the students will be presented with the following warning:



Fig. 1: Prompt window on a Mac. Let's switch to Mars.

Upon switching to Mars, students will see a 3-D planet Mars and a set of folders and features in the sidebar.

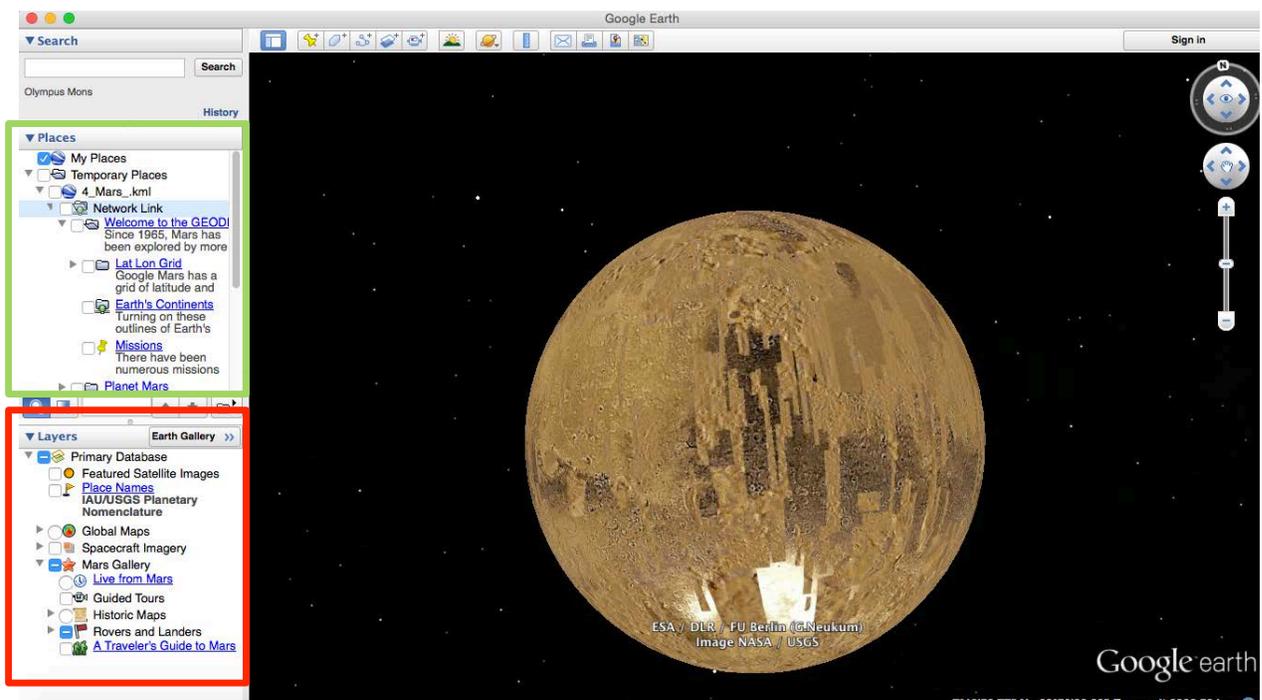


Fig. 2: Starting up the Mars KML.

The **GREEN** box contains all of the terrain imagery, overlays, and tour stops in the “Places” sidebar.

The **RED** box contains overlays and features of interest for Mars which are already built into the Layers sidebar. Make sure for now, the “Primary Database” and all its’

contents (except Terrain if present) are unchecked at the start of the tour. The students will be prompted to check some of these features when necessary.

To turn on the 3D terrain, either find it at the bottom of the Layers sidebar or if not there, go to “Preferences” (Mac) or “Options” (Windows). In the “3D View” tab, find the terrain options and Make sure the Elevation Exaggeration option is set to 1.

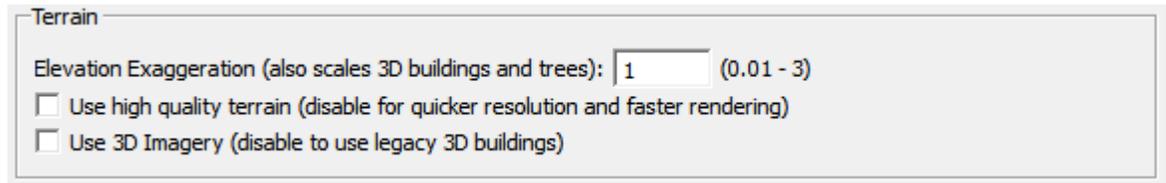


Fig. 3. 3D terrain options.



Lat/Lon Grid

Students should first close the welcome balloon, open the Welcome folder, and click the Lat/Lon Grid. This adds tropics and polar circles to the built in Mars Grid.

LO: With an inclination of 25° , Mars has tropics and polar circles just like Earth.

Earth's Continents

This shows outlines of the Earth's continents, scaled down to match Mars's size. Using the Google Mars ruler, students can estimate the size of features on Mars.

Missions

This placemark directs students to mission data in the Layers sidebar.

Surface Features

Students should visit each site in turn.

Topography

Students are directly to turn on the MOLA “colorized terrain.”

LO: MOLA reveals that Mars topography ranges from 9 km below mean planetary level to 21 km above—much higher than Earth’s Mt Everest. There is a crustal dichotomy between northern lowlands and southern highlands.

Outflow Channels and River Valley Networks

LO: These provide strong evidence for former water on Mars

Volcanoes

Mars hosts the largest volcanoes in the solar system in the Tharsis region. They may have shifted the planet’s rotation axis.

Valles Marineris

LO: Valles Marineris dwarfs Earth’s Grand Canyon. There are many smaller graben.

Chaos Terrains

LO: These are regions of massive permafrost melting and are unique to Mars.

Wrinkle Ridges

LO: Like other planets, Mars developed wrinkle ridges when it cooled and shrank.

Impact Craters

LO: Because of its thin atmosphere, Mars is riddled with small impact craters. Larger impacts melt the permafrost creating aprons of mud. Some meteors break up in the atmosphere. Craters can have layered sediments and dunes. Rovers allow us to map outcrops on Mars.

Planet Mars

Students should visit each site in this folder in turn.

Size and orbit

LO: Mars is about half the size of Earth—close to the size of Earth’s outer core. Its orbit is very eccentric. It’s day, called a “sol” is similar to Earth’s but its year is nearly twice as long.

Moons

Make sure students double-click on the descriptions of Phobos and Deimos to fly to view.

LO: Mars’s moons are small fragments of debris probably thrown up by large impacts.

Wobble

LO: Because it lacks a large stabilizing moon, Mars wobbles on its axis much more than Earth, leading to large changes in climate.

(Non) Phases

LO: Mars does not go through phases as viewed from Earth. It is the first of the superior planets.

Atmosphere

LO: The atmosphere is extremely thin and dominated by CO₂.

Temperature

LO: Temperatures range from balmy to bitterly cold.

Season on Mars

Make sure students turn on the COLLADA model and double click the description to fly to view.

LO: Because of its eccentric orbit, seasons are influenced both by tilt and distance from the Sun, resulting in much warmer southern summers than northern summers.

Ice Caps

LO: Mars has polar ice caps made of water ice with a layer of dry ice, which freezes out in winter and sublimates in summer, leading to strong winds. It experiences ice ages.

Rocks and Outcrops

Students should visit each placemark in turn.

LO: Like Earth, but unlike Venus, Mercury, or Moon, Mars have sedimentary rocks.

Geophysics

LO: Mars has a metallic core and rocky mantle and crust. Its geology can be mapped using overlapping relationships. There is evidence of a former northern ocean and former seas.

Mars Geological Timescale

LO: The history of Mars is divided into four periods. Mars differentiated into core and mantle early in its history. It underwent the Late Heavy Bombardment. It was wet and may have had plate tectonics but is now tectonically dormant.