Google Explores the 10th Planet

Mermaids and Sea Serpents

NASA has spent tens of billions of dollars exploring Planet Earth and the other 8 planets of our solar system yet there is one last great frontier that has gone almost completely unexplored – Planet Ocean. The disparity between our understanding of Planet Earth and Planet Ocean is highlighted by the computer program and image repository Google Earth. Remote sensing satellites provide high-resolution imagery of all of Planet Earth. Check out the skateboard ramp in our driveway in San Diego (32.839526, -117.100710). The mapping of planet Mars is equally impressive with meter-level vertical resolution topography maps from a 6-year orbiting laser altimeter mission and sub meter-level directed imagery of possible landing sites for robot explorers. Planet Venus was imaged in the early 1990's at 100-m horizontal resolution from the NASA Magellan spacecraft using synthetic aperture radar to penetrate its optically opaque atmosphere.

In contrast more than 2/3 of our planet is largely unknown because it is masked by a 4000 m-deep ocean that is opaque to electromagnetic waves. The traditional method of mapping the seafloor uses echo sounders aboard large vessels to map a profile or swath of seafloor topography (Figure 1 - left). More recently satellite altimeter measurements of ocean surface topography have been used to obtain a very low-resolution estimate of seafloor topography. The ocean's surface has broad bumps and dips that reflect variations in the pull of gravity (Figure 1 - right). In the deep ocean basins, where sediments are thin and seabed geology is simple, satellite altimeter data may be used to predict bathymetry at a scale of 6-9 km. The ability to use Google Earth below sea level provides a new platform for scientists to exchange oceanographic information and also deliver research findings to the general public.

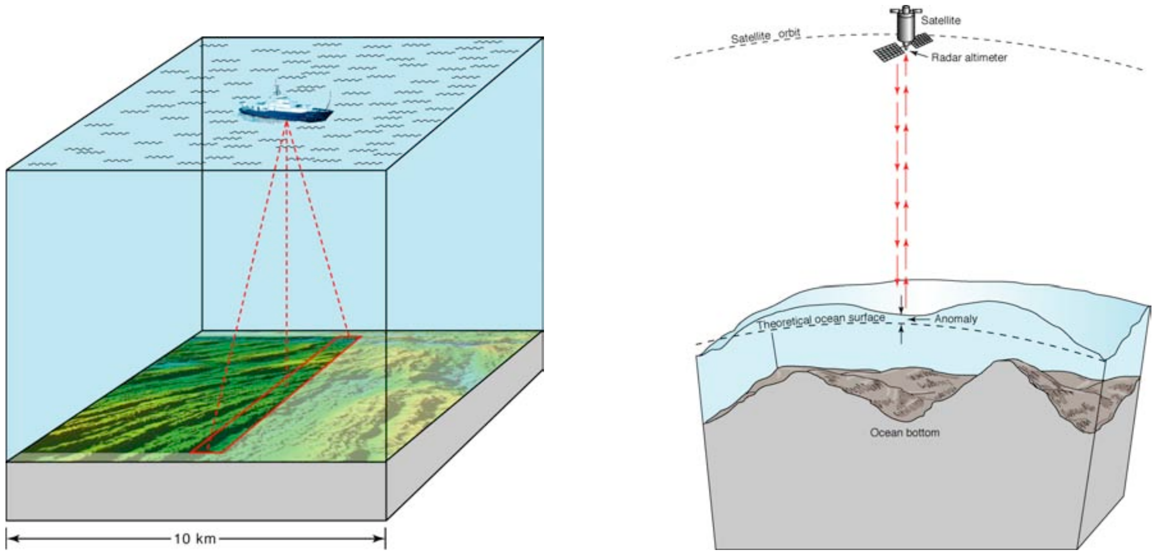
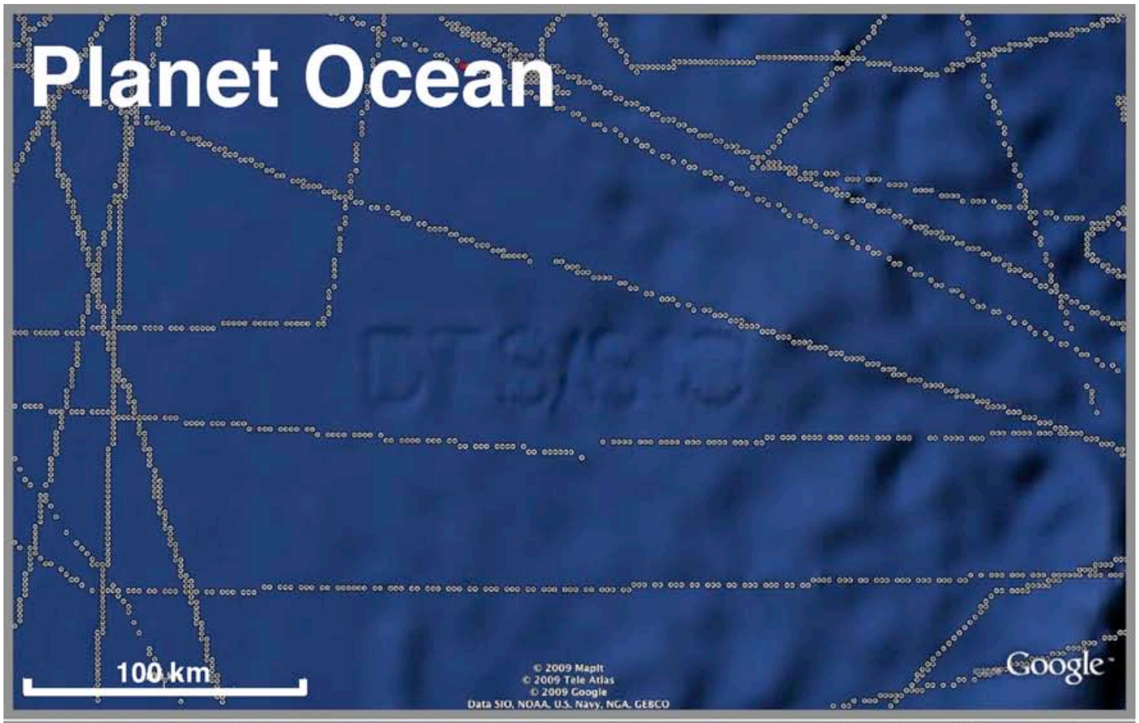


Figure 1. Modern tools for mapping the deep ocean floor. (left) A shipboard multibeam echo sounders uses sound waves to map 10-20 km wide swaths at ~200 horizontal resolution. (right) An Earth-orbiting radar cannot see the ocean bottom, but it can measure ocean surface height variations induced by ocean floor topography. While the resolution of the echo sounder technique is far superior to the resolution of the satellite altimeter technique, complete mapping of the deep oceans using ships would take 120 ship-years at a cost of billions of dollars. Indeed, the shipboard and altimeter methods are highly complementary. When interesting features are discovered in satellite gravity, these can be surveyed in fine detail by ships. The depth of the ocean floor and the roughness of the bottom vary throughout the oceans mostly as a result of plate tectonic processes. This seafloor topography influences ocean circulation and mixing that moderate Earth's climate, and the biological diversity and food resources of the sea. The ocean floor records the geologic history and activity of the ocean basins revealing areas that may store resources such as oil, gas, and generate earthquakes and tsunamis.

Perhaps the most important message that will be provided by this new tool from Google is revealing how little we know about the deep ocean floor away from the continental margins. Ships have sailed across all the oceans so one would imagine that Planet Ocean is well mapped and understood. This assumption could not be further from the truth. Acoustic echo sounders, perfected during World War II, dramatically increased the number of global depth soundings enabling scientists to draw preliminary sketches of the deep ocean basins. The bathymetry charts constructed by Bruce Heezen and Marie Tharp in the 1960's and 70's revealed the Mid-Oceanic Ridge, a line of undersea mountains that runs through Earth's oceans, and mapped the large-scale features of the entire ocean floor. Artistic sketches of the pervasive abyssal fabric of the oceans replaced the voids on these maps, previously filled by mermaids and serpents. The exquisite Heezen and Tharp maps, published by the National Geographic Society, gave the false impression that Planet Ocean was well mapped. Despite GPS-navigated ships with modern swath mapping tools, we still have hundreds of giant voids in our mapping of the ocean basins the size of the state of New Jersey (Figure 2). The typical spacing of ship tracks in the southern ocean is 25,000 m; this is 5,000 times worse resolution than some of the land imagery provided in Google Earth.

The beauty of Google Earth is that it provides a platform to reveal this huge disparity in resolution as illustrated in Figure 2. A 125 km wide (80 mile) signature was imbedded in one of the voids as seen in the Google Earth imagery of the Indian Ocean (N0 E94.75) Figure 2 (top). The center image shows a map at exactly the same scale containing four large cities, Washington DC, Baltimore, Philadelphia, and New York. Finally the lower image is a zoom of the stairs at the front of the Lincoln Memorial at a magnification of 5000 times the top and center figures. Displaying the land and ocean data together in Google Earth boldly highlights the disparity between our mapping of the land and ocean. For example, a Google Earth user could be previewing their next vacation spot in Indonesia or Polynesia and glance into the surrounding ocean abyss to see a giant blur. The truth becomes clear; modern satellite remote sensing coupled with powerful computers and the thousands of computer scientists at Google Earth cannot improve our understand of the deep ocean basins. The relevant data simply do not exist!


Planet Ocean
100 km
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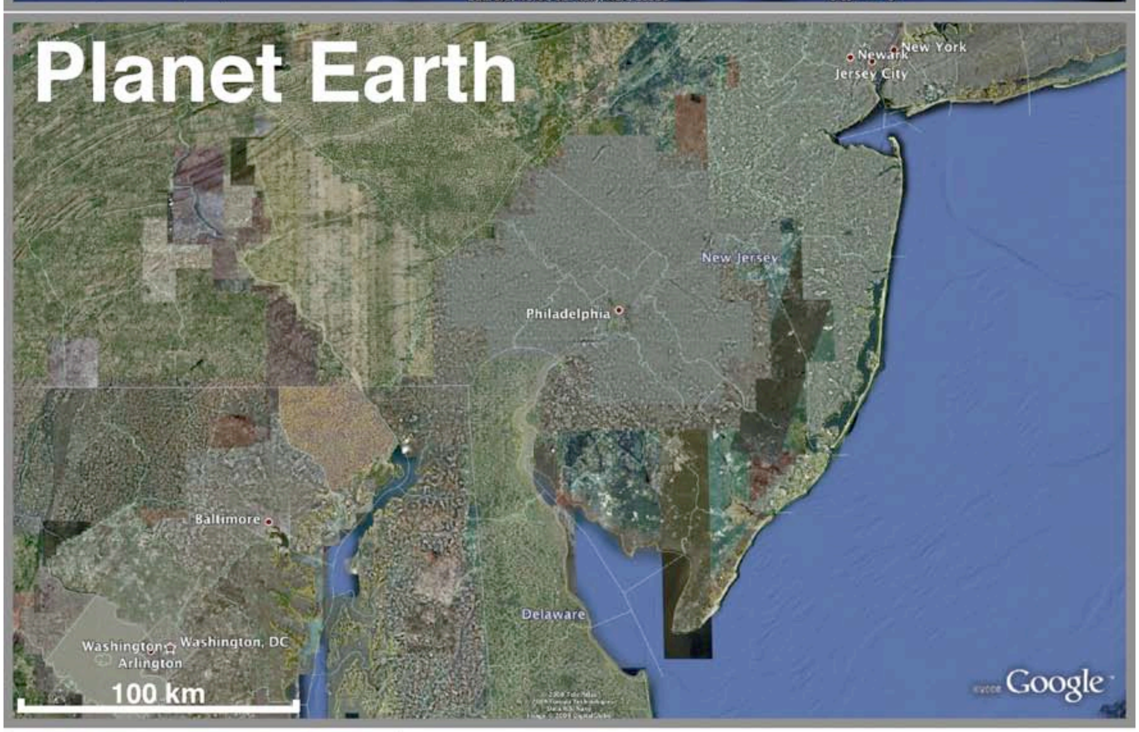
Planet Earth
Newark
New York
Jersey City
New Jersey
Philadelphia
Baltimore
Delaware
Washington
Washington, DC
Arlington
100 km
Google


20 m

Figure 2. Three views of our planet using the Google Earth software. The upper image shows a 400 km (250 miles) wide area of seafloor in the equatorial Indian Ocean just west of Sumatra centered at N0 E94.75. The dots show the sparse ship soundings. A 125 km-wide signature fills one of the voids. The center image shows a 400 km-wide area of eastern North America including 4 cities, Washington DC, Baltimore, Philadelphia, and New York. The full resolution of this satellite imagery can only be seen when magnified 5000 times as shown in the lower image of the front of the Lincoln Memorial where people and their shadows are evident in the morning sunlight. One may call the 80-mile-wide signature geo graffiti or tagging but it serves a purpose to illustrate that we know almost nothing about this regions of ocean floor and hundreds of other areas just like it – call it a digital sea serpent. Improving our mapping of this void to erase the graffiti will require new satellite or ship measurements.

Recipes for Mapping the 10th Planet

There are three approaches for reducing this factor of 5000 disparity in resolution between Planet Earth and Planet Ocean. The first approach is to simply assemble all the data that has been collected by echo sounders since about 1950 and construct the global maps. For example, the US Navy has collected about 100 ship-years of depth sounding and other types of data as part of the Ocean Survey Program (Medea, 1995). These data primarily cover the portions of the northern oceans that were of strategic interest during the cold war. Unfortunately, these data remain classified for military purposes. Great Britain, France, and Australia have collected similar classified or restricted data sets. Other countries such as Japan have recently opened all their sounding data for free access by anyone. These new open contributions are becoming apparent as when flying over the oceans in Google Earth. With the change in administration in Washington, the time is ripe to reconsider the declassification of the 100 ship-years of US data. Recently (January 27, 2009) President Obama released a Memorandum stating "The Freedom of Information Act should be administered with a clear presumption: In the face of doubt, openness prevails. The Government should not keep information confidential merely because public officials might be embarrassed by disclosure, because errors and failures might be revealed, or because of speculative or abstract fears." So while there is hope that existing data may become openly available, there is still the major issue of the oceans south of the equator which are largely uncharted by anyone.

The second approach is to deploy a fleet of ships carrying multibeam echo sounders to map the deep ocean. Modern echo sounders (Figure 3 - left) provide about 200 m resolution topography maps in the deep ocean and higher resolution (~30 m) sonar backscatter images. It would take approximately 120 ship years to map the deep oceans, which could be achieved by 12 ships in a decade at a cost of a few billion dollars. Mapping the shallow seas would take much more time and funding because the swath width of the echo sounder is proportional to the ocean depth. (Most of these ships are *shovel ready* complete with instruments, crew, and scientists all waiting at the dock for research funding.) Of course if all the currently proprietary and classified data were released, the job could be completed in perhaps 5 years.

The third approach is to map the ocean surface topography using radar altimeters. The ocean's surface has broad bumps and dips that reflect variations in the pull of gravity (Figure 3 - right). In the deep ocean basins, where sediments are thin and seabed geology is simple, satellite altimeter data may be used to predict bathymetry at a scale of 6-9 km – still 1000 times worse than Planet Earth but 5 times better than Planet Ocean today. Existing satellite altimeter data have proved the feasibility of the technique and revealed the overall, large-scale tectonic features of the ocean basins. Indeed 80% of the depth information provided in Google Earth is derived from predicted depth based on satellite altimetry. A properly designed mission using existing technology could bring significant new resolution, capturing a critical scale of features, and facilitating new science and applications.

In November of 2009 the European Space Agency will fly the next generation of radar altimeter aboard the CryoSat II spacecraft. This innovative satellite altimeter uses signal processing strategies borrowed from synthetic aperture radar to improve height measurement precision by a factor of two, and to reduce along-track footprint size by a factor of five or more, in marked contrast to a conventional radar altimeter. Unfortunately the CryoSat ground segment cannot capture the full SAR waveforms globally so it will be operated as a conventional altimeter over the oceans. A new altimeter mission combined with targeted high-resolution ship surveys offers the best approach to improving our maps of the ocean basins.

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February 2, 2009