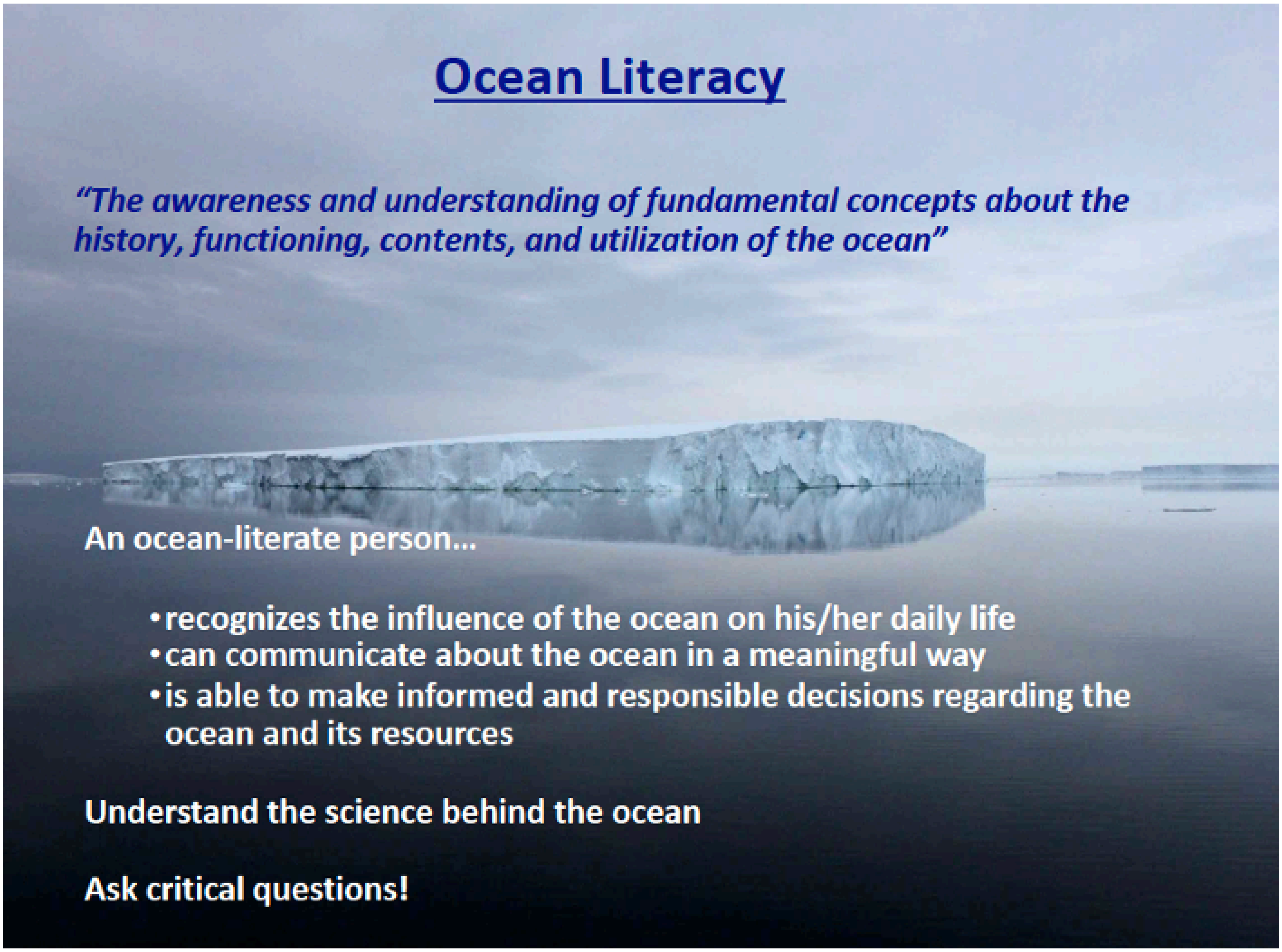
Lecture 1 - Introduction & Navigation

Welcome to 11:628:120:90

Introduction to Oceanography

Lecture 1: Introduction



Let's start our ocean voyage with the concept of **Ocean Literacy**. Simply put, ocean literacy is understanding how the ocean shapes our planet. Sometimes we forget we live on a water planet and it is the presence of water which is one of the fundamental reasons that we have life on Earth. Therefore, some of the key principles of ocean literacy I hope you will appreciate are:

1) Earth essentially has one big ocean with many features

While we talk about different oceans (Atlantic, Pacific, etc.), the oceans do not have boundaries and waters flow between the ocean basins.

2) The ocean also plays a role in physically structuring the Earth

3) The ocean is central to weather and climate

4) The ocean makes Earth habitable

5) The oceans supports great biological diversity

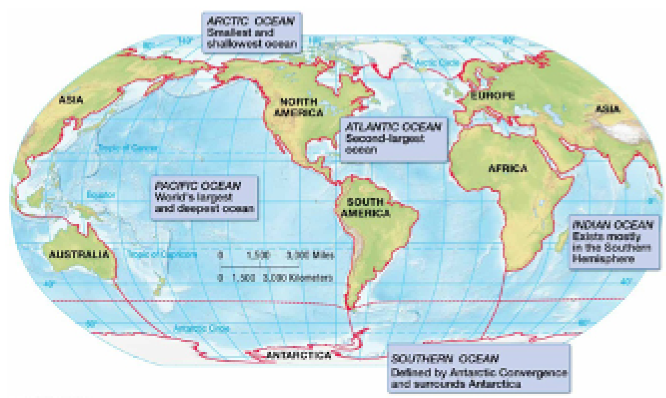
6) Humans can, and have, changed the oceans

7) The oceans remain relatively unexplored

To understand these concepts we will review the physics, geology, chemistry, and biology of the worlds oceans. Throughout the course, I will also provide lots of examples of the technologies we use to study the ocean.

THE OCEAN IS BIG, NAVIGATING THE BIG OCEAN IS HARD AND THOSE WHO DO IT WELL, BUILD EMPIRES

1) The ocean is big: The word ocean is defined by the Greek word "*okeanos*" which is translated Oceanus and contains over 97% of all of the water on the planet. Ocean water is differentiated from the other water on Earth by being saline, more to come in future lectures. The saline ocean covers about 71% of the Earth's surface (~3.6 * 10^14 m^2). The ocean is a continuous body of water, even though we divide it up into different regions. The regions are divided by into several oceans (Pacific, Atlantic, Indian, Southern, Arctic) and smaller seas. There are many and many seas - see if you can name them all.



The major oceans are:

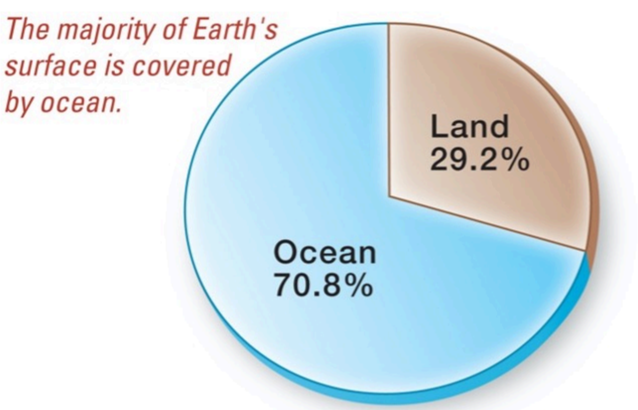
Pacific ocean: The world's largest oceanic division. It spans 169.2 million square miles, and covers over half of the ocean surface on Earth. The pacific was sighted by Europeans in early 16th century, by the Spanish explorer Vasco Nunez de Balboa, he called it the South Sea, but we use the name given to it by the Portuguese explorer Ferdinand Magellan who named it *Tepre Pacificum* (peaceful sea). It contains the deepest ocean point on Earth, known as the Mariana Trench which lies 11,022 meters below the surface. James Cameron of Avatar and Titanic fame recently ventured down there, check out the story **here.** (http://www.deepseachallenge.com/) And this **crazy story** (https://www.smithsonianmag.com/smart-news/kathy-sullivan-becomes-first-woman-reach-challenger-deep-180975061/) of Kathryn Sullivan who is the only person who has been both to space, and the deepest part of the ocean! Note the average depth of the world's ocean is 3682 meters deep.

Atlantic ocean: Second largest ocean, covering 41 million square miles and holds around 26% of the Earth's water. The first part of its name refers to Atlas of Greek mythology, which essentially makes the Atlantic the "Sea of Atlas". The oldest mention of the Atlantic is around 450 BC. The average depth of the Atlantic is 3844 meters, its deepest point is the Puerto Rico trench which has a depth of 8605 meters.

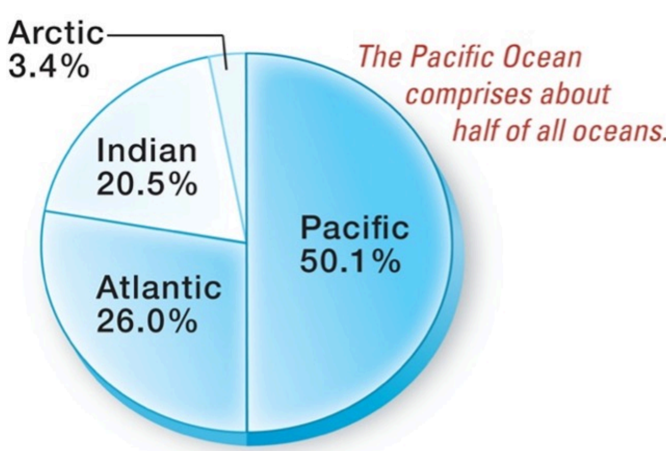
Indian ocean: Third largest ocean spanning about 28.4 million square miles. It has around 20% of the world's water. Some of the earliest human civilizations of Earth, Mesopotamia, ancient Egypt and the Indian subcontinent developed around the Indian ocean. It became the first trans-ocean economic pathway with early Egypt sailors who headed to cities of Punt in present day Somalia.

Southern ocean: Also known as the Antarctic ocean or the South Polar ocean. There is still debate among geographers about the northern boundary, but it is generally the southern ocean is taken to be south of the 60 degree S latitude line. It has typical depth around 4000 m and has its greatest depth at 7236 m in the Sandwich Trench. Most of the Southern ocean is governed by international conventions which set aside much of the ocean for conservation and scientific research.

Arctic ocean: This is the smallest of the world ocean regions. It is in the northern hemisphere is bounded by many land masses. Earliest accounts are from around 325 BC by Pytheas of Massillia who called it "Eschate Thule". Fridtjof Nansen (**Ocean explorer superstar** **(http://en.wikipedia.org/wiki/Fridtjof_Nansen)**) is credited for making the nautical crossing in in 1896. It covers around 5.4 million square miles and averages 1117 meters depth.

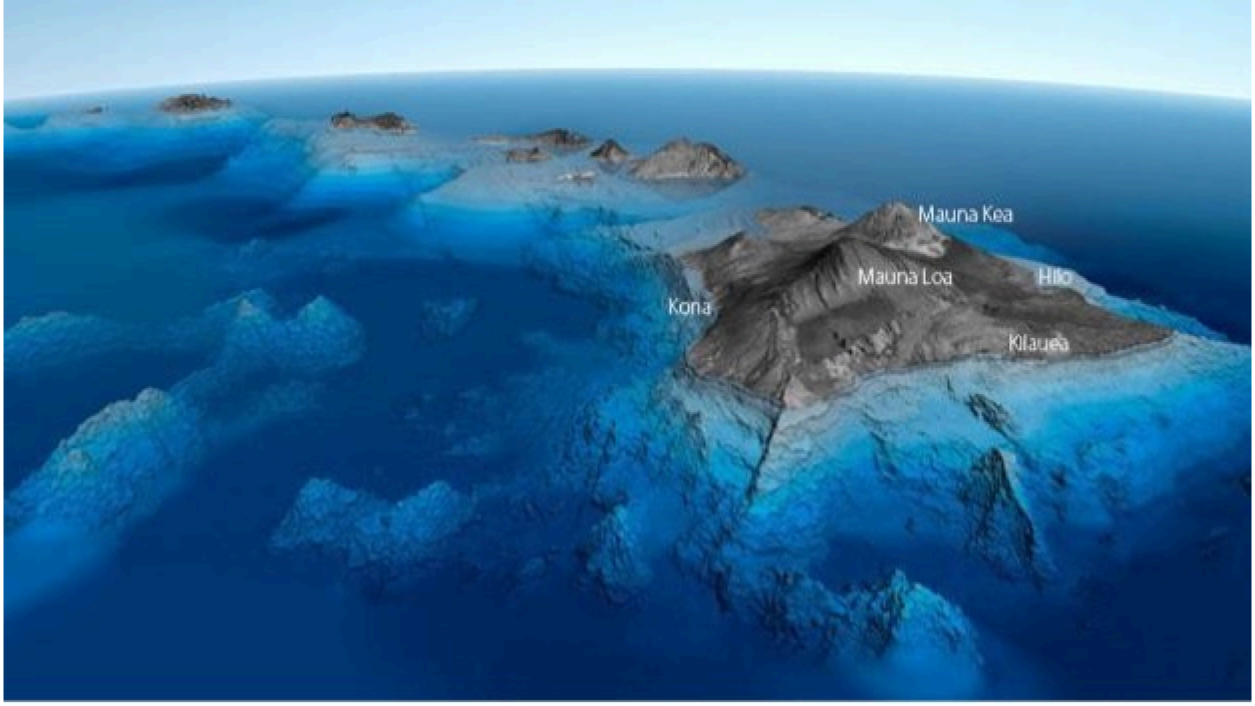


(a) Percentage of Earth's surface covered by ocean and land.

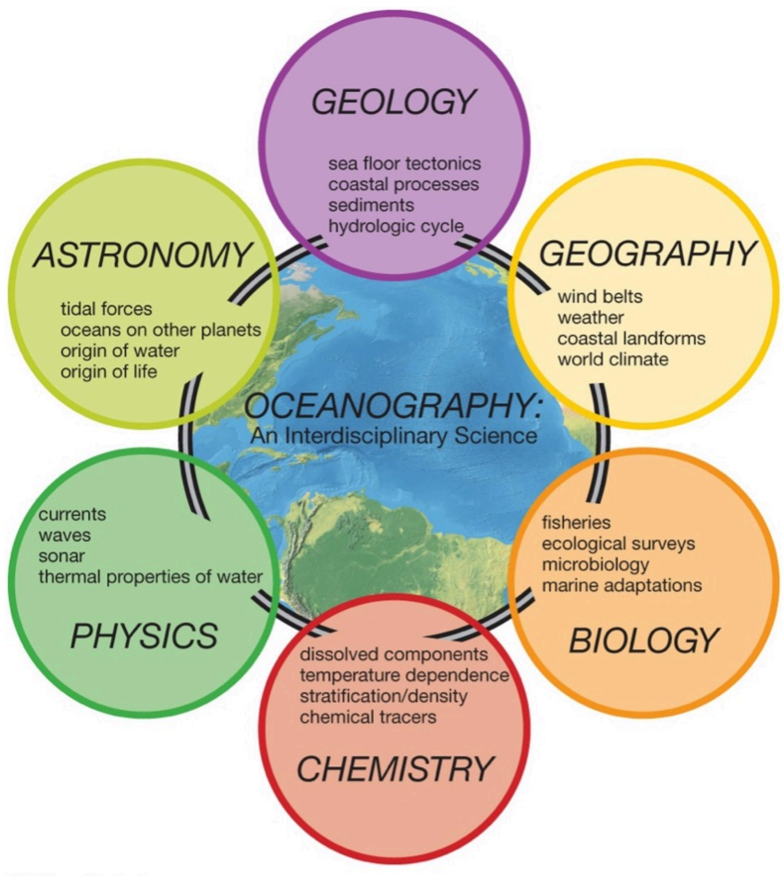


(b) Comparing the relative size of each ocean.

The ocean contains some vast vertical structures – much greater in height and depth than what we find on land. The average height of land on the continents is only 840 meters, and the tallest mountain on earth is Mt. Everest at 8850 meters. The Mariana Trench, the ocean's deepest point, is 2172 meters deeper than Mt. Everest is tall. The mountain with the greatest total height on Earth is actually Mauna Kea, a volcanic mountain located on Hawaii. The base of Mauna Kea is actually on the bottom of the ocean, and the mountain is so tall it sticks all the way up through the surface of the ocean. In total, Mauna Kea is 9632 meters tall – and 5426 meters of that is below the ocean. But even at 9632 meters, Mauna Kea still is not as tall as the Mariana Trench is deep, and James Cameron took a dive in a sub all the way to the bottom (there is a link in the welcome lecture to the trailer – check back there to see it if you missed it)!



Ocean science is highly multi-disciplinary. What does that mean? It means that scientists from all sorts of background and training study the ocean together. Ocean science includes geology, biology, chemistry, geography, physics, astronomy, and even social science. Check out some of the different disciplines and how they might study the ocean in the image below.



In oceanography, we study the oceans using small ships, big ships, sometimes we even work with commercial fishing partners to sample the ocean. We collect samples of water to study, or we collect and count animals in the ocean (yes, fish are animals). We use remote sensing tools like satellites or robots to sample the ocean. There are a great many ways to study the oceans, and some of the major oceanographic science institutions in the US are:

Woods Hole Oceanographic Institution

Scripps Institute of Oceanography

Lamont-Doherty Earth Observatory (Columbia)

University of Washington

Oregon State University

University of Miami

Texas A&M

University of Rhode Island

University of Southern California

University of Maryland

University of California (Santa Barbara and Santa Cruz)

University of Hawaii

University of Delaware

And of course - **Rutgers University**- Department of Marine and Coastal Science

***Navigating a deep and big ocean*.**

It is very difficult and dangerous (less so now, thanks to technology) to navigate the world's ocean. Early explorers faced many perils, which included getting lost which left them open to be sunk by storms, starving to death (usually lack of water is the worst), or simply rotting (scurvy is a disease resulting from a deficiency of vitamin C, which is required for synthesis of collagens in humans, loose the collagen, you kind of start to fall apart,,,, literally). It was a major problem for early sailors who did not have access to fresh fruit and vegetables since they lived on cured or salted meats and dried grains. This was one reason English sailors sailed with limes as they took a long time to spoil and provided vitamin C. That is the reason the English were referred to as "limeys".

So how do we navigate?

The nautical miles is still used by sailors and aviators, because it is very convenient to use when using navigational charts. Most charts use a **mercator** (http://en.wikipedia.org/wiki/Mercator_projection) projection, which has its scale vary by approximately a factor of 6 from the equator to 80 degrees north or south (Why?). A nautical mile is convenient as it represents a minute of latitude (see below), making it easy to measure distance on a chart. 1 nautical mile = 1.151 land miles. One important thing to appreciate thinking about distance when at sea, is that ships are VERY slow.

A good research vessel moves at 10-15 knots (nautical mile/hour), which translates into 11-17 miles per hour (you are probably faster on your bike!). So oceans are very big and ships are very slow.

Latitude and Longitude are reference guides for traveling on the surface of Earth.
Latitude begins at the Equator (0 degrees at the Equator, 90 degrees at the poles, so you have designate North or South). Latitude lines are often referred to as parallels as they parallel the equator.

Longitude lines are referred to meridians. The 0º Longitude is a line that passes from the poles through the Royal Naval Observatory in Greenwich England. This line is known as the prime meridian. The other side of the Earth is at 180º, and corresponds to the International Date Line. Like Latitude you specify location by degree and either East or West, relative to the prime meridian. The circles of longitude are often referred to as the great circles, because all the circles are the same size. Note the same is not true for latitude. Remember for navigation 1 degree latitude is equal to 60 nautical miles, *why is the same not true for longitude?*

Early modes for measuring latitude: It was known by early navigators that the North Star (Polaris) appeared in the sky above the North Pole and did not vary significantly from this position. In the Northern hemisphere measuring the angle of Polaris above the horizon could give a decent estimate of Latitude, and then you could plot direction North or South until desired location and then sail East or West. This was lucky as people could measure Latitude very early on in human exploration, which meant they could north or south. Global exploration was tied to understanding the stars in heavens or the elevation of the sun on the horizon. At the equator at the equinoxes the sun at noon is directly above or at altitude 90 degrees, while at the north Pole the sun is totally invisible in winter and always visible in summer. In between, the altitude of sun can be noted, then compared to astronomical tables that can tell you how far you are north and south of the equator. Measuring the elevation was accomplished with a series of tools, that have evolved. Medieval sailors used cross staff, also know as Jacob's Staff which is two rods hinged at one end which one could use to measure angle of declination when the observer leveled the bottom rod on the horizon and the upper rod on the sun or star. These became fancier over time, and some of you may have seen or used a sextant, which gives you the elevation and thus ideas of where you are north and south.

Early Modes of measuring Longitude: This one is hard, as longitude lines are rotating 360º over 24 hours with the Earth's rotation. Therefore it becomes necessary to know the position of the sun (or stars) with time relative to one's longitude line. This will also vary with season! Early clocks did not work well on rolling ships. Gemma Frisius (Flemish astronomer) linked longitude to time in 1530. If a clock is set to exactly noon at the suns zenith above a reference longitude and then the clock is carried to a new location East or West, and the zenith time of the sun is determined at the new location, the time difference between the reference and the new position can be used to determine the Longitude at the new location. Early rewards to solve this problem were chased by the King Phillip III of Spain (who offered 100,000 Spanish crowns in 1598) and the British Parliament (offered 20,000 pounds sterling in 1714). A Yorkshire clockmaker John Harrison took the challenge in 1735, but did not have success until 1761 (when his clock lost only 51 seconds on a 81-day voyage) when he built his first chronometer. Parliament tried to screw him, giving only a partial award, it took him until 1775 when he received the full award. You can watch a film about Harrison and the **quest for measuring longitude here (https://archive.org/details/LostatSeaTheSearchforLongitude)** (note- this is not required, but is really interesting). The reference longitude used today is the prime meridian. The clock time is set for 12 noon at the prime meridian, and is referred to as Greenwich Mean Time (GMT) now called coordinated universal time (or zulu time). Since the sun time changes by 1 hour for each 15 degrees of longitude, the Earth is divided into time zones that are 15 degrees of longitude wide, note these lines do change locally with politics.

Modern modes of travel, have chronometers that calibrate based by broadcasted time signals when close to shore. The LORAN network measures the difference in the arrival time of two different radio signals broadcasted from different locations. We now use satellites. A satellite orbiting the earth emits a coded signal of a precise frequency, picked up by the receiver on the ship. The ship follows frequency shift and determines the frequency shift as the satellites passes overhead and backs out location (meter accuracy). Now we have many satellites called the Global Positioning System. The idea grew out 2 professors at the Applied Physics Lab monitoring the passage of Sputnick overhead. They used the shift in the satellite signal as it moved overhead to calculate the orbital transit. This lead the Navy to develop NAVSAT which eventually lead to the **Global Positioning System (http://en.wikipedia.org/wiki/Global_Positioning_System)**.