Week Nine Oceanography Notes
Note Taker: Julia Winberg

Class November 5, 2018

A Tale of Two Pumps: CO_2 In the Ocean

- Two Pumps are **biological** and **physical**
- There has been a rapid increase in current atmospheric CO2 concentrations
  - No debate around this (although some think there is)
  - CO2 is increasing at an unprecedented rate because of our activities
- Manalo'a Hawaii, CO2 monitor measures 405.51 ppm of CO2 in the atmosphere as of early October
- Earth's CO2 levels fluctuate with the seasons as the earth breathes and experiences greater rates of photosynthesis
- Sunlight+ Nutrients + CO2 (from the sun and in the ocean) → Phytoplankton
- There is FIFTY times more inorganic carbon in the ocean than in the atmosphere.
- The ocean is really good at fixing CO2 and doing stuff with it
  - This fact is supported by a figure shown on the slides from class
- CO2 is fixed (partially) by phytoplankton life cycle, sinking to sea floor and also by being recycled (eaten)
- Solubility Pump
  - Gas exchange allows CO2 to enter the ocean
  - Cold water holds more gas than warm water
  - Solubility increases in cold water: thus, polar regions are sinks, equator is a source
- Upwelling pumps **out** CO2 (source)
- Deep ocean is a **sink**
- Ocean naturally acts as a carbon sink for CO2 but locations of sinks and sources is not uniform
- Solubility is increased in colder water because there is less activity between the molecules making room for more things

- Biological Pump (also a figure in the slides)
  - Phytoplankton dies and sinks or is consumed as food and recycled back into the water column
  - The deeper in the ocean, the longer the CO2 will stay out of the atmosphere
  - CO2 is "trapped" in the bottom. The ocean buries the CO2, preventing extreme heat and warming had the same CO2 been in the atmosphere
  - Without the biological pump the world would be over-saturated with CO2, and the CO2 in the atmosphere would be around 600ppm

    - The biological pump is **crucial and imperative to climate stabilization**
- Inverted pyramid of ocean sink
    - Carbon Uptake (Primary Producers)
    - Carbon Flux (between 5 and 15% of Carbon, hidden for decades)
    - Deeper Carbon Flux (less than five percent, centuries)
    - Carbon Burial (around 1 percent, millenium)
- Is there any way we could increase the efficiency of the pump in order to help our warming climate?
- Impacting Phytoplankton Productivity
    - Temperature
    - Light
    - Nutrients (N,P, Si)
    - Grazing by zooplankton
- HNLC areas
    - HIgh Nutrient (Nitrate), Low Chlorophyll.
    - Area of high nutrients, not phytoplankton biomass
    - Chlorophyll is a proxy (or a measure) of phytoplankton biomass
- Major Limiting Nutrients, vs. Micro Limiting Nutrients
    - Iron Presence (micro
        - Other minor limiting nutrients: Iron, Zinc, other metals
    - We discovered that Iron and Zinc profiles are a function of depth, similar to those of major nutrients (depleted at the surface, abundant at the deep)
    - This tells us that Iron and Zinc are important in photosynthesis
- Remineralization at Depth
    - John Martin, scientists: "give me half a tanker of iron, and I will give you an ice age."
    - Why Would this work?
        - Iron is a limiting nutrient
        - Increases photosynthesis
        - Making organic carbon
        - Earth gets a lot colder
    - Adding iron in the ocean?
    - Draw-down of iron, increase in phytoplankton biomass?
        - Bringing more carbon to deep ocean
        - Could more iron cause more harmful algal blooms or ecosystem collapse?
    - We tried adding Iron to the ocean
        - Super large scale, expensive projects
        - Increases chlorophyll and phytoplankton, but little to no increase in carbon export
        - Impact not yet consistent, varying
        - Hotly debated

Class November 7, 2018

Life in Hydrothermal Vents and The Deep Sea

- All life does **not** depend on sunlight. This is proven by the animals in the deep sea, at hydrothermal vents
- Chemosynthesis
    - Oxidizing chemicals, usually hydrogen sulphide, and making energy from it
    - Discovered by Colleen Cavanaugh, a professor at Harvard, when she was a first year graduate student
- Deep Ocean
    - Cold and Dark
    - 0-3 degrees C
    - No photosynthesis
    - Most food is stuff that has fallen from the surface
- 1977: Alvin
    - Galapagos
    - Discovers Black Smokers
        - Chimneys deep underwater that pump out super hot water, full of chemicals
- At the Black Smokers: Tube Worms (Riftia) and shrimp, crabs
- When we would expect to find nothing down there we actually found a pretty well founded ecosystem, supported by microbes
- Early evidence of Deep Sea Heat: 1880s, Hot Brines
- Red Sea deep water was measured at 44 degrees C in 1964
- 1965, more hot water, warmer than expected
- Metal-rich sediments
    - 1968-1983 Deep sea drilling and the Golmar Challenger
    - Hot water present wherever there was seafloor spreading, not just in red sea
    - Found metal-rich sediments
- Unusual Rocks
    - Sometimes geologists would find rocks that had a grooved, eclectic pattern
    - Brown,orange,dark green
    - Metal deposits in the rock
- Ophiolites
    - Ocean crust on land (very metal-rich), brought up on to continents during tectonic movement

- Missing Heat: Other pattern of heat moving away from mid-ocean ridges, unexpected
- 1977, Woods Hole and Bob Ballard, Angus Discovery Cruise

    - They find black smokers taller than the cathedral of Notre Dame, new production of chemicals, plumes like from Mt. St. Helens
    - Microbes, Microbial mats supporting ecosystems
    - Magma heating waters, microbes harnessing energy from chemicals
    - 350-400 degrees C, O_2 completely gone
        - Really acidic
        - Animals picking up dissolved metals and fixing hydrogen sulfide
        - Water exits the plume and mixes with cold, oxygen-rich water

- Black Smokers are super metal-rich, really hot. Inside them, metals and sulfides mix.
- White smokers are made up of Anhydrite and Silica, but they are not as hot
- Smokers depend on chemicals
    - Black: Most common, 400-350 degrees C, hydrogen sulfide
    - White: more rare, cooler (100s range C), Silicate, Anhydrite gives white color
- Actual distribution of Smokers unknown
- Chemosynthesis
    - Using Chemical Energy instead of Solar Energy
    - $H_2O + CO_2 + H_2S + O_2 \rightarrow$ Carbohydrates and Sulfuric Acid
    - Dominated by microscopic archaea (bacteria-like organisms)
- Galapagos rift is thriving
- Tube Worms or *Riftia*
    - Have hemoglobin (blood, humans have this too)
    - No mouth, gut, or anus
    - Filter oxygen, hydrogen sulfide and CO_2 from seawater
    - Plume contains the hemoglobin
    - Blood transports chemicals to bacteria in cavity
    - Bacteria produces sugar and the tube worms use it
    - Actual Tubes are made of Chitin
    - Trophosome with crystals of Sulfur
- Colleen Cavanaugh: remember who she is? There is a great video about her work in the lecture slides

Class November 9, 2018

More Hydrothermal Vents, Cold Seeps

- Hydrothermal Vents
    - Short Life Span, dependent on sporadic volcanic activity of mid-ocean ridges
    - Only last as long as years, we think
    - They die when they run out of chemicals, hot water stops flowing
- Sustaining Vent Life
    - How do vent communities move from one vent to another?
    - Dead Whale Hypothesis

        - Whale Falls boast a similar environment to Hydrothermal Vents, perhaps a stepping stone when the ecosystem needs to move after the vent dies
    - Perhaps Larvae flow in deep sea currents
    - Temporal Changes
        - Cycle, process
        - Successional community in the deep sea, just like in many other coastal ecosystems
    - Longevity, Estimated by:
        - Heat loss in rocks (decades)
        - Isotopes in Sulphide (15-60 years)
        - Clam, deep sea organisms, age 4-40 years, clams lay down growth rings, counting them
- West-Pacific back-arc basins
    - Anemones, snails, riftia
    - Species variation
- Mid-Atlantic Ridge
    - Hydrogen Sulphide
    - Clams
- Crabs at the bottom of the sea
    - Yeti Crabs
    - Bacteria line their claws and legs, and yeti crabs feed them (symbiotic microbes)
- Cold Seeps
    - Discovered 1984
    - Hypersaline environments (high salinity)
    - Normal temperature by hydrogen sulphide rich
    - Leaking out of ocean crust
    - Hydrocarbon Seeps
        - 1984
        - Hydrogen Sulphide and Methane as energy sources
- Seeps are disparate and flat, way flatter than a hydrothermal vent
- We watched a video in class about a cold seep 1400m deep in Pakistan, go watch it!
- Seeps rely on methane, methane hydrate forms making a structure similar to ice
- Deep Ocean
    - 1-3% of surface H2O food makes it to the ocean floor
    - Outside the photic zone, everyone is hungry
- Whale Fall
    - Carcass decomposition
    - Gases build up inside the whale
    - Several Stages
    - Mobile Scavenger Stage
        - Months to years
        - Sharks, fish, snails, microbes, etc.
        - Whale is consumed at high rate

        - Scavengers remove soft parts of whale
        - Messy eaters
    - Messy Eaters expand the footprint of the whale
    - Enrichment Stage
        - Bones colonized by bacteria, other organisms, opportunists
    - Sulphophilic Stage
        - Emitting sulphide
        - Chemoautotrophs present
        - Microbial mat on whale skeleton
        - Organic matter = stepping stone
- Chemosynthesis has now been found in various organisms, ecosystems
- Could these communities be linked to the origin of life?
    - Hydrothermal vent communities, mimicking early Earth?
    - Prebiotic soup
    - Low ph, O2
    - Driven by chemical energy
    - Formation of organic molecules