

Free essay about the water cycle and ocean chemistry throughout time

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Water and Its Unique Properties

Water has a unique physical and chemical properties which are essential to life and to the earth processes such as climate change. Water molecules generally consist of one oxygen atoms and two hydrogen atoms. However the atoms do not share equal electrons thereby making water slightly charged—exhibits polarity. Water molecules interact with other water molecule through a weak hydrogen bond. Hydrogen bonds allow water to interact also with other polar substances. Water is known as the universal solvent. Thus, it has the capacity to dissolve various polar substances like ammonia and nonpolar substances such as methane (Freudenrich, 2011). Water is the only substance that can undergo three different phases of matter—solid, liquid and gas. In its liquid phase water the structure of a water molecule is similar to a flat triangle. However, when water freezes or solidifies the structure of molecules changes into a hexagonal shape. In so doing, crystals occupy the space where molecules arrange themselves. Since the ice crystal occupies more space, the density of water in its solid form also becomes lower—the reason ice floats. Since ice floats, this insulates the water below during winter which allows organisms below the icy surface to survive (Freudenrich, 2011).

Another property of water that is essential for survival is the capacity to remain in liquid form over a wide range of temperatures. Water has a high heat capacity which allows thermal regulation by absorbing and releasing heat. This capacity to make thermal conditions in oceans, ponds, lakes and other bodies of water relative constant throughout the season (Freudenrich, 2011; USGS, 2013).

Capillary action and adhesion are both essential to the survival of plants. Adhesion allows water molecules to bind to other substances such as plant tissues and soil. Capillary action allows nutrients to be transported from the roots of the plants to the leaves. That is, water surface which adheres to plant tissues pulls other water molecules until the entire body of water overcomes gravitational force (USGS, 2013). Surface tension determines the strength of water as it interacts with another water molecules to form a film. This property allows water to hold heavier and denser substances. Surface tension permits the wind to create water waves which are essential for oxygen diffusion in lakes and seas (USGS, 2013). Water has a natural pH of 7 yet this condition varies in the ocean. As more salts dissolve in ocean water, the pH level tends to increase slightly (USGS, 2013).

The Water Cycle

The water cycle, also known as hydrologic cycle demonstrates how water molecules in their different phases behave as they circulate from the earth's surface to the atmosphere and back. The hydrologic cycle which is facilitated by solar energy continuously reciprocates moisture between different medium—ocean, atmosphere and land. This exchange in moisture is defined by various processes which are evaporation and evapotranspiration (in plants), condensation and precipitation. As water evaporates from the ocean and land surfaces, water vapor (gaseous form of water) is transported by winds and condenses to form clouds. When clouds reach its dew point, precipitation in the form of rainfall or snow falls to lands and oceans. In land water from rainfall seeps through the ground, some of this ground water also

finds its way back to the ocean. Excess water which did not to the ground is called runoff which forms the streams and rivers. These streams and rivers discharge the freshwater into the oceans (Trenberth, 2007).

Various studies showed that during evaporation—a change of phase in water from liquid to gas—in oceans, seas and other bodies of water accounts for nearly 90% of moisture in the atmosphere. Plants release the remaining 10%) of water vapor through evapotranspiration. As plants take in water through their roots, water is released through small pores on the underside of their leaves. During sublimation a very small amount of water vapor goes to the atmosphere; that is when water changes directly from a solid (ice or snow) to a gas. To cite an example, sublimation occurs when snow banks gradually sinks as a result of temperature decline below freezing point (Ichoku, 2013).

The total amount of available water earth was estimated at 1.5×10^9 km³. Most of this resource is in the ocean while 29×10^6 km³ are locked in ice lands and glaciers while 15×10^6 km³ are stored as groundwater. A net transport of about 38 units from ocean to land where almost the same amount of run-off water is transfer is transferred to the ocean. The amount of precipitation over continents is about three times high which suggested that there is a substantial amount of water that circulates over land. Recirculation of water has a marked annual cycle which significantly differs among continents. During summer, recirculation is larger in tropical areas (Bengtsson, 2010).

Natural process which explains the amount of water vapor in the atmosphere is affected by factors such as evaporation, evapotranspiration, sublimation

and volcanic emissions. Evaporation is essential in transporting water vapor from the surface to the atmosphere in the hydrologic cycle and so is transpiration. As water enters the lower atmospheric region, rising air currents carry it to higher atmospheric regions where air temperature is cooler. Water vapor condenses from gas to liquid forming droplets of clouds. These cloud droplets can grow and precipitate in the form of rain, snow or hail. Thus, water is transported back again to the earth. Precipitation follows different paths as it falls over the land surface. Some evaporates and returns to the atmosphere while some goes directly to the ground as soil moisture while some runs off into rivers and streams. All of the water eventually returns to the ocean or other bodies of water. Humans tap water as a potential resource to quench thirst, and for other domestic purposes such as cooking, irrigation, and cleaning (Ichoku, 2013).

Water in the atmosphere constitutes only 12, 900 cubic kilometers at any moment in time. If it were to rain completely, only a depth of 2. 5 centimeters moisture would cover the earth's surface. 495 cubic kilometers are cycled through the atmosphere every year which accounts to 40 times of the entire amount of water in a year. The balance in the water cycle is achieved as water loss through evaporation, transpiration and sublimation is compensated by the amount of water that condenses and precipitates. The amount of water vapor in the atmosphere remains almost in constant because of this equilibrium yet precipitation is not equally distributed in all continents throughout the world. There are other areas where evaporation exceeds precipitation and vice versa (Ichoku, 2013).

As evaporation exceeds precipitation in oceans, this will leave the oceans

empty when loss water is not replenished. To date, the sea has been overly replenished due to increase in sea level rise—about 17 centimeters over the years. Rise in sea level has been attributed to incidence of ocean warming which cause water to expand and increase in volume. There has been a shift in equilibrium as more water enters the ocean as compared to the amount that leaves the ocean. This has been linked to calving or melting of ice sheets and glaciers. However, the increase or decrease in the annual amount of sea ice does not significantly affect changes in sea level because the ice is already in the ocean (Ichoku, 2013).

Salinity and Archives of Solutes vis-à-vis Climate Change

“ Rivers, submarine hot springs and ocean sediments that add or remove elements to seawater” define the chemical components of the ocean. The more abundant elements in the ocean have near constant ratios to salinity. Salinity is the amount of total dissolved salts in water. Most of seawater has a salinity ranging from 3. 1 to 3. 8 percent. Salinity is not uniform throughout the world especially in estuarine areas where freshwater mixes with saltwater. Salinity and temperature affects the density of surface water and this ranges from approximately 1, 020 kg per cubic meter to 1, 029 kg per cubic meter. Under high pressure, seawater density amounts to 1, 050 kg per cubic meter or higher. Seawater pH has been estimated from 7. 5 to 8. 4 and this could vary depending on the level of salinity and other factors (USGS, 2013).

Water vapor has been identified as a greenhouse gas that is also significant in the earth’s climate system. The fluidity of water vapor is essential in the transport of energy between low and high latitudes. In areas where there is

net evaporation, salinity increases as a result of convection in the upper ocean. However, salinity decreases when there is a net precipitation in a particular site. Water vapor—the dominant greenhouse gas—is influenced by temperature and as such indicates a climate response or feedback mechanism. Water vapor has a positive feedback on climate but the robustness of feedback depends on the sensitivity of the model being made. The model must consider different patterns of low/high-latitude temperature systems and changes in lapse rate feedback. It has been contended that water vapor increases rapidly in areas with warmer climate but global precipitation may be increasing much more slowly (Bengtsson, 2010).

As climate changes at different time scales, variations in the earth's orbit around the sun may affect the amount and distribution of external heating. As a result tectonic processes take place. Tectonic forcing of climate is influence by carbon recycling between the interior and surface of the earth. This is essential for life to survive on earth. " For Earth to avoid the greenhouse conditions in Venus—where carbon dioxide are unable to escape the runaway—a negative feedback must keep runaway warming or cooling in check." Atmospheric CO₂ suggested a balance on the inputs of volcanic activity and silicates removed through weathering. Such shift in balance is a reflection of the chemical composition of the ocean (Elderfield, 2010).

Records of past concentrations of seawater indicates how active the sources and sinks over a long period of time in modifying the amount of salts present in seawater. In determining past seawater chemistry scientists recently measured the ratio of magnesium to calcium and the ratio of strontium and calcium in calcium carbonate (calcite) veins taken from ocean crust under

the sediments. Obtained magnesium-calcium ratio for the past 180 million years is consistent with previous works but not the strontium-calcium ratio. These results may be significant in explaining how the dynamic changes in climate over the years affect the ratio of the elements detected. Calcite veins used to determine ratios were formed by seawater flowing through the upper oceanic crust on the flanks of mid-oceanic ridges. A detailed explanation how sea-water gains magnesium from the river and loses magnesium during hydrothermal circulation in the ocean ridges has been proposed by some scientists (i. e. Mg/Ca ratios approximately 1mmol/mol from 180 million to 60 million years ago; present value 5. 4 mmol/mol). Such uncertainty in the strontium partitioning into biogenic carbonates may explain why the present strontium-calcium ratio is not consistent with the results of previous studies. Hydrothermal vent fluids lowered strontium-calcium ratio more as compared to seawater while increasing seawater strontium/calcium and magnesium/calcium ratio has been linked to decreasing influence of hydrothermal fluids (Elderfield, 2010).

Studies on seafloor spreading rates and seafloor generation illustrated a decrease of 50% or more in ridge production which suggested magnesium removal at ridge crests over the past 100 million years. Results also have been correlated to decrease in CO₂ production and thus, implying a negative feedback on the climate. BLAG geochemical model elucidated how atmospheric CO₂ cycle is affected by the rate of seafloor generation. The constant global ridge production that lead to changing hydrothermal seawater magnesium-calcium ratio has been attributed to the different behavior of fast- and slow-spreading ridges and the changes in oceanic crust

on ridge flanks where flanks buried by sediments remain warm and long enough to promote magnesium removal (Elderfield, 2010).

Evolution of Early Animals: Implications to Ocean Chemistry

Diverse communities of animals and other eukaryotes that have inhabited the earth accompanied the prokaryote microbial community that has previously dominated the Earth during the Neoproterozoic Era (1000 to 542 million years ago). Since then, chemical alterations in the ocean mark this transition. The conditions in deep water turned into an iron-rich anoxic environment after billions of years of having a sulfidic anoxic ambient in the late Neoproterozoic period. This iron-rich ocean may have served as an important reservoir for dissolved organic carbon. Redox conditions have been elucidated in several studies to show the late Neoproterozoic Doushantuo Formation (633-551 million years ago) of southern China. Within the layers are preserved eggs, embryos and probable resting cysts which are also known as the oldest known microscopic animals. The Doushantuo Formation extends most during the Ediacaran Period. Using multiple redox indicators, anoxia was proven to have prevailed throughout the deposition of all sampled shallow-water strata varying from iron-rich to sulfidic anoxic environment. Samples taken from deep water revealed an intermittent iron-rich anoxic ambient. Redox conditions were correlated to different proxies for water depth and results suggested that " a wedge of sulfidic water positioned over the Doushantuo midramp was sandwiched between ferruginous waters (Narbonne, 2010)."

It was further inferred that atmospheric diffusion is likely to occur into a thin

layer of oxygenated surface water above the anoxic iron-rich and sulfidic rich waters. Boundaries between water masses of two different environments was expected to move (horizontally and vertically) in response to sea-level rises and falls while preserving a complex variety of redox conditions in the sediment. Doushantou Formation may elucidate the global heterogeneity of the iron rich ocean mixed with euxinic (sulfidic) and oxic conditions which is present locally (Narbonne, 2010).

Such geochemical study demonstrates the link between the Neoproterozoic chemical evolution of the oceans and atmosphere and the early evolution of animals. Evidence of frequent anoxia has been found also in disturbed surface waters 740 million years ago. That the limited amount of oxygen present at that period also limited animal evolution during Neoproterozoic era. This means that rich animal microfossil in the Doushantuo Formation lived in a surface oxygenated layer. These fossils were transported into nearby anoxic deposits which preserve them. Microfossils have morphological features which could also indicate conditions of periodic anoxia or euxinia. Such conditions may explain the underdeveloped early Ediacaran oxygen layer (Narbonne, 2010).

The underdeveloped oxygen layer and the midramp chunk of hydrogen sulfide-rich water may further restrict life forms. These scientists theorized that oxygen-rich surface layer of the ocean are able to reach the sea bottom near the shoreline when high turbulence and varying conditions of salinity may be detrimental to early benthic organisms. Geochemical proxies suggested that layers of iron in ocean with abundant supply of dissolved organic carbon paves the way to oxygenated deep oceans 580 million years

ago.

Rangeomorphs--oldest large and morphologically complex eukaryotes—is an extinct clade of deep-water, stem-group organisms. It exhibits self-similar branching that allows direct adsorption of dissolved organic carbon from sea water. These organisms have dominated the earliest life forms of the Ediacara period but eventually declined afterwards as they become unfamiliar from Cambrian deposits worldwide. It was probable that rangeomorphs simulates the death of Neoproterozoic reservoir of dissolved organic carbon which is the main driver of their origin and early evolution. The gradual replace of such organisms by segmented and mobile animals during the late Ediacaran period and the well-oxygenated seas determines the end of the Neoproterozoic iron-rich ocean. This phenomenon marks the beginning of the explosion of animals and modernity (Narborne, 2010).

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