OCEAN ACIDIFICATION

- As carbon dioxide (CO_2) dissolves in sea water, it forms **carbonic acid**, decreasing the ocean's pH, a process collectively known as ocean acidification.
- Present ocean acidification occurs approximately **ten times** faster than anything experienced during the last 300 million years, jeopardising the ability of ocean systems to adapt to changes in ocean chemistry due to CO_2.
- Ocean acidification has the potential to **change marine ecosystems** and impact many ocean-related benefits to society such as coastal protection or provision of **food and income**.
- Increased ocean **temperatures and oxygen loss** act concurrently with ocean acidification and constitute the 'deadly trio' of climate change pressures on the marine environment.
- To combat the worst effects of the deadly trio, CO_2 emissions need to be cut significantly and immediately at the source.
- Sustainable management, conservation, restoration and strong, permanent protection of at least 30% of the ocean are urgently needed.

What is the issue ?

Ocean acidification is a direct consequence of increased human-induced carbon dioxide (CO_2) concentrations in the atmosphere. The ocean absorbs over 25% of all anthropogenic emissions from the atmosphere each year. As CO_2 dissolves in sea water it forms carbonic acid, thereby decreasing the ocean's pH, leading to a suite of changes collectively known as ocean acidification. Ocean acidification is happening in parallel with other climate-related stressors, including ocean warming and deoxygenation. This completes the set of climate change pressures on the marine environment – **heat, acidity and oxygen loss** – often referred to as the 'deadly trio'. Interaction between these stressors is often cumulative or even multiplicative, resulting in combined effects that are more severe than the sum of their individual impacts.

Why is it important ?

Present ocean acidity change is unprecedented in magnitude, occurring at a rate approximately **ten times faster** than anything experienced during the last 300 million years.

This rapid timeline is jeopardising the ability of ocean systems to adapt to changes in CO_2 – a process that naturally occurs over millennia. Changes in ocean pH levels will persist as long as concentrations of atmospheric CO_2 continue to rise. To avoid significant harm, atmospheric concentrations of CO_2 need to get back to at least the 320-350 ppm range of CO_2 in the atmosphere.

Compared to other similar events in Earth's history, ocean acidification, over hundreds of years, has been happening very fast. However, its **recovery has been very slow** due to the inherent time lags in the carbon and ocean cycles.

Ocean acidification has the potential to change marine ecosystems and impact many ocean-related benefits to society such as coastal protection or provision of food and income. Although more knowledge on the impacts of ocean acidification on marine life is needed, changes in many ecosystems and the services they provide to society can be extrapolated from current understanding. Some of the strongest evidence of the potential effects of ocean acidification on marine ecosystems stems from experiments on calcifying organisms.

Increased sea water acidity has been demonstrated to affect the formation and dissolution of calcium **carbonate shells and skeletons** in a range of marine species, including corals, molluscs such as oysters and mussels, and many phytoplankton and zooplankton species that form the base of marine food webs.

Changes in **species growth and reproduction**, as well as structural and functional alterations in ecosystems, will threaten **food security, harm fishing** industries and decrease natural shoreline protection. They will also increase the risk of inundation and erosion in low-lying areas, thereby hampering climate change adaptation and disaster risk reduction efforts.

Increased ocean temperatures are likely to have direct effects on the physiology of marine organisms and influence the geographical distribution of species. Some species such as reef-forming corals, already living at their upper tolerance level, will have more difficulties 'moving' fast enough to new areas. Drastic changes in ocean temperature can also lead to coral bleaching events, where corals expel the symbiotic algae living in their tissues, causing them to turn completely white. The role of coral reefs in buffering coastal communities from storm waves and erosion, and in supporting income generation (fisheries and tourism) for local communities and commercial businesses, is jeopardised. The potential recovery of such bleaching events is hampered due to the declining calcification rates on reefs caused by ocean acidification.

What can be done?

The long time lags inherent in the marine carbon cycle put an added penalty on delaying **limits on CO_2 emissions** and a premium on early action if the worst damages associated with ocean acidification are to be avoided. While climate change is the consequence of a range of greenhouse gas (GHG) emissions, ocean acidification is primarily caused by increased concentrations of atmospheric CO_2 dissolved in sea water. It becomes evident, however, that the objective of the United Nations Framework Convention on Climate Change (UNFCCC) to achieve 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' cannot be encapsulated by a single 'one-size-fits-all' climate indicator. The current emissions targets need significant tightening if they are to tackle the issue of ocean acidification and ocean warming. Limiting the global average temperature increase to well below 2°C, rather than a lower level, will significantly harm the ocean life on which we all depend in some form or another. Scientists even suggest that a **healthy ocean needs an atmospheric carbon concentration of much less than 400 ppm**. This benchmark has recently been exceed.

Other initiatives such as the Ocean Acidification international Reference User Group (OAIRUG), composed of scientists and various stakeholders, need to be engaged as a key means of conveying scientific results. The OAIRUG examines in detail the types of data, analyses and products that are most useful to managers, policy advisers, decision makers and politicians, and ensure an appropriate format and distribution pathways.

Sustainable management, conservation and restoration of the ocean are needed. At the IUCN World Conservation Congress 2016, IUCN Members approved a resolution calling for the protection of 30% of the planet's ocean by 2030.

The Biological Impacts

Ocean acidification is expected to impact ocean species to varying degrees. **Photosynthetic algae and sea grasses may benefit from higher CO_2** conditions in the ocean, as they require CO_2 to live just like plants on land. On the other hand, studies have shown that lower environmental calcium carbonate saturation states can have a dramatic effect on some calcifying species, including oysters, clams, sea urchins, shallow water corals, deep sea corals, and calcareous plankton. **Today, more than a billion people worldwide rely on food from the ocean as their primary source of protein**. Thus, both jobs and food security in the U.S. and around the world depend on the fish and shellfish in our oceans.

Pteropods

The pteropod, or "sea butterfly", is a tiny sea creature about the size of a small pea. Pteropods are eaten by organisms ranging in size from tiny krill to whales and are a food source for North Pacific juvenile salmon. The photos below show that a pteropod's shell dissolves over 45 day when placed in sea water with pH and carbonate levels projected for the year 2100.

In recent years, there have been near total failures of developing oysters in both aquaculture facilities and natural ecosystems on the West Coast. These larval oyster failures appear to be correlated with naturally occurring upwelling events that bring low pH waters undersaturated in aragonite as well as other water quality changes to nearshore environments. Lower pH values occur naturally on the West Coast during upwelling events, but a recent observations indicate that anthropogenic CO_2 is contributing to seasonal undersaturation. Low pH may be a factor in the current oyster reproductive failure; however, more research is needed to disentangle potential acidification effects from other risk factors, such as episodic freshwater inflow, pathogen increases, or low dissolved oxygen. It is premature to conclude that acidification is responsible for the recent oyster failures, but acidification is a potential factor in the current crisis to this $100 million a year industry, prompting new collaborations and accelerated research on ocean acidification and potential biological impacts.

Coral

Many marine organisms that produce calcium carbonate shells or skeletons are negatively impacted by increasing CO_2 levels and decreasing pH in seawater. For example, increasing ocean acidification has been shown to significantly reduce the ability of reef-building corals to produce their skeletons. In a recent paper, coral biologists reported that ocean acidification could compromise the successful fertilization, larval settlement and survivorship of Elkhorn coral, an endangered species. These research results suggest that ocean acidification could severely impact the ability of coral reefs to recover from disturbance. Other research indicates that, by the end of this century, coral reefs may erode faster than they can be rebuilt. This could compromise the long-term viability of these ecosystems and perhaps impact the estimated one million species that depend on coral reef habitat.

https://www.youtube.com/watch?v=6SMWGV-DBnk

https://www.youtube.com/watch?v=mQ10xBl8XMQ

PRECIPITATION PATTERN

Major types for rainfall by - Convectional rainfall – orographic rainfall – Cyclonic rainfall

There are many types of precipitation: **rain, snow, sleet, and hail,** to name a few. In this lesson we will learn about the mechanisms that produce various types of precipitation. It is important to note that the presence of clouds and their associated condensation nuclei alone do not always produce precipitation. Very specific conditions must occur in order for a cloud to produce precipitation

In order for cloud droplet to form a non-equilibrium condition, where condensation exceeds evaporation, must exist. The curvature of a cloud droplet affects its rate of evaporation. The more curved the droplet, the more evaporation that occurs. Smaller cloud droplets will evaporate quickly unless the air is *supersaturated* (the relative humidity exceeds 100%). Because of the curvature effect, air that is saturated with respect to a flat surface is unsaturated with respect to a curved cloud droplet. An ordinary cloud droplet 100 times smaller than raindrop.

Though supersaturation is required in order for cloud droplets to sustain themselves, relative humidity rarely approaches 101%, even in very wet clouds. How do cloud droplets ever grow to raindrop size? The answer lies in the *Hygroscopic* nature of certain condensation nuclei.

Recall that condensation on hygroscopic particles will commence when the relative humidity is below 100%. This is known as the *solute effect.*

Consider a parcel of air unsaturated air rich with condensation nuclei. As the air cools the relative humidity increases. At some point below 100% saturation, condensation commences on the most hygroscopic of the available nuclei. These nuclei continue to grow as the air cools further and the relative humidity approaches 100%. The curvature effect becomes negligible for larger droplets but remains appreciable for smaller nuclei. The rise in relative humidity within the air mass is slowed by the fact that the larger particles begin to remove lots of water vapor from the air. Soon, the particles are removing water vapor from the air as fast as it can be replaced from external sources. At this point the relative humidity actually begins to decrease. Condensation in clouds is such an inefficient precipitation producing process that it is very unlikely to produce, by itself, precipitation in any appreciable amount. Another mechanism is clearly responsible for producing precipitation from clouds. Two additional mechanisms are responsible for producing precipitation from clouds the *collision-coalescence process,* and the *ice-crystal process.*

The collision-coalescence process occurs in warm clouds. As cloud droplets form within clouds they become electrically charged. The cloud droplets grow larger by sticking to each other in the aftermath of collisions due to electrical attraction. As time passes the droplets grow larger and larger. Updrafts help keep the droplets suspended in the cloud longer. If the cloud is thick the droplets will also stay suspended longer. Finally, the droplets will grow large enough that they can no longer remain suspended and will begin to fall. As soon as they leave the cloud base they begin to shrink due to evaporation. Raindrops that reach the ground are smaller than those leaving the base of the cloud.

The ice-crystal process occurs in colder clouds that exist mainly in the middle to high-latitudes. Even in these extremely cold clouds there are liquid water droplets (existing well below freezing). These are referred to as *supercooled* water droplets. The temperature of a cloud, in fact, must exceed -4O°C in order for it to consist entirely of ice crystals. Such clouds are referred to *glaciated.*

When the temperature drops low enough within a cloud, large numbers of water molecules begin to bond in a rigid form within supercooled liquid water droplets. This leads to the formation of *ice embryos,* i.e., small ice crystals in the center of supercooled water droplets

The water molecules must have very low rms speeds in order for ice embryos to remain intact since even slight thermal motions disrupt them. Even colder temperatures enable the crystal to become a *freezing nucleus*. The presence of these ice embryos enhances the freezing process. The presence of *ice nuclei* also enhance the freezing process. Ice nuclei may be clay (kaolinite), biological material, or anything that looks like an ice crystal. *Contact freezing* is another important method by which ice crystals to form in a cloud, involving collisions between ice nuclei (freezing nuclei) and supercooled droplets.

As we have seen, when precipitation first begins to fall it is usually in a frozen state. Often precipitation begins in the form of either *graupel* or *snowflakes.* Snowflakes are an aggregation of ice crystals. Much precipitation falling at middle latitudes, even in mid-summer, falls as snow flakes in the beginning. Graupel is formed by collisions between supercooled cloud droplets and ice crystals.

In a precipitation theory known as the *Bergeron Process* all raindrops begin as ice crystals. When the ratio of ice crystals to water droplets in clouds is on the order of 1:100,000, conditions are right for precipitation to begin. When there are too few ice crystals, the existing crystals grow large and fall out of the cloud, leaving it unaffected. When there are too many crystals, a cloud of ice crystals is formed, and no precipitation occurs because the individual crystals are all too small to fall to the ground.

Cloud seeding is an important process used quite often in the winter to create precipitation. The object is to find clouds that are deficient with ice crystals and inject artificial ice nuclei to produce the ratio of 1:100,000. (Silver iodide is usually the artificial ice nuclei used because it resembles an ice crystal so well.) A cold cloud is needed for this to work effectively.

Drizzle is a liquid drop with diameter **less than 0.5mm**. Virga is precipitation that doesn't reach the ground. If updrafts in a cloud change to downdrafts rainfall amount may increase to a shower. If a shower is excessively heavy it is referred to as a cloudburst.

Rain is liquid drop precipitation with diameter greater than or equal **to 0.5mm.**

Snow consists of **frozen ice** crystals falling to the ground. Because snow scatters light more effectively than rain one may easily observe where snow changes to rain below a cloud (above the freezing line is darker). If, however, one looks directly up into the precipitation from below the snow appears lighter because it scatters light in all directions below the cloud. As a result the bottom of a rain cloud appears much darker than a cloud with snow in it.

Fallstreaks are a virgalike phenomenon consisting of snow rather than rain.

Flurries are brief snow showers, typically from cumuliform clouds. A *snow squall* is a more intense snow shower, essentially the equivalent of a cloudburst. Continuous snowfall is associated with nimbostratus and altostratus clouds. A *blizzard* is a snowstorm accompanied by low temperatures, strong winds, blowing and drifting snow.

Sleet is melted snow that re-freezes into a tiny ice pellet. *Freezing rain* occurs when raindrops fall through a freezing layer that supercools them and subsequently freeze on contact with the ground.

Freezing drizzle is freezing rain with drop diameters less than 0.5mm. *Rime* is an accumulation of small, supercooled cloud droplets that are milky and granular in appearance. *Snow grains* and *snow pellets* are the solid equivalent to drizzle. Snow grains have a diameter of less than 1 mm and stick upon hitting a surface, while snow pellets have diameters of greater than 5mm and bounce upon hitting a surface.

Hail is produced when **large, frozen raindrops**, graupel, etc. act as accretion nuclei. In order for a hailstone to form, the accretion nuclei must remain in a cloud a long time and thus travel a large distance within the cloud. This process is facilitated by strong updrafts of the type common within cumulonimbus clouds. Hail is most often associated with such clouds and is therefore more common during the spring and summer than in winter. *Hailstreaks* are long narrow bands of land struck by hail as the precipitating cloud moves along.

About 80 per cent of the precipitation that falls on Idaho each year is in the form of snow. It takes about one foot of snow to make one inch of water when it melts. Since water is Idaho's single most important resource a system has been developed to measure snow depths in the mountains of Idaho. This system almost guarantees that water will be used efficiently, and that it will be well conserved so that everyone will have enough water each year. We all rely on the water that falls on our state each year, not just the farmers who use it for irrigation. We also use water for power, to fish in, and to help wildlife survive. Idaho's industries need water to operate and you and I need it to drink, to bathe in, to do our dishes and to water our lawns.

In addition to water supply, precipitation plays a significant role in shaping the landscape around us.

The state precipitation map at left underscores the greatest natural deficiency suffered by the West. The region lacks sufficient precipitation for most of the basic needs of human beings. It has been responsible for the treeless plains and, naturally, the desert. In the Snake River Valley for example there is a yearly average of only eight inches. Where the annual amount is less than fifteen inches and irrigation is not possible, dry farming and grazing are the dominant agricultural activities

The highest amount of precipitation ever recorded in Idaho was on Deadwood Summit in Valley County in the winter of 1964-65. Precipitation of 98.6 inches was recorded that year. Much of that precipitation was in the form of snow (if it takes one foot of snow to make one inch of water when it melts, imagine how much snow fell on Deadwood Summit that winter).

Just 75 miles to the east of Deadwood Summit, Challis has the lowest average yearly precipitation in Idaho, just 7.09 inches. Of the larger cities and towns in Idaho, Boise has an average precipitation of less than 12 inches and Wallace in Shoshone County has the heaviest annual precipitation of 41.64 inches. Snow depths vary widely throughout the state, ranging from skiffs in the lower dry areas to very deep in the central mountains.