

# Oceans-Land-Atmosphere interactions and Global Change

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We live on land, feel the breeze and enjoy the presence of blue water. Yet many of us do not realize interactions among these natural physical entities shape our lives. In scientific terms we refer to these entities as geosphere, atmosphere and hydrosphere, respectively. Their interactions span short to geological time scales. Continuing interactions over the geological periods have resulted in the present day earthly conditions we see/experience around us. Unfortunately, human's greed for style of living and better comforts have put the global climate under pressure. This has become a cause for concern internationally, but should be more to us since our monsoons could be threatened. In order to appreciate the interactions among the Earth's surface reservoirs in relation to climate the present lecture is covered through evolution of three spheres, distinction between weather and climate, monsoon (ocean-land-atmosphere interactions) climate of our region, influence of monsoon on the neighbouring Indian Ocean, susceptibility of Indian monsoon to El Nino-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) climatic events, global climate changes in the geological history, distinguish climate change from global change, impacts of global change on our region and mitigation methods to save ourselves from global change.

During the early stages of Earth formation, basic basalt rocks reacted with acid volatiles in the presence of water that resulted in the formation of seawater, sediments and atmosphere. With the gradual cooling of the planet crust and oceans has formed. The composition of early atmosphere was different (Emiliani, 1992) as carbon monoxide (CO) dominated carbon dioxide (CO<sub>2</sub>). Oxygen was not a major component in contrast to its second most abundant status today. As the oxygen content in air increased, mainly because of photosynthetic activities, more CO<sub>2</sub> formation was favoured. However, it remained in trace levels (parts per million) in air because of its continuous removal by plants. Maintenance of CO<sub>2</sub> at trace levels facilitated suitable and sustainable climate for life on this planet.

We often use weather and climate terms interchangeably. Nevertheless, there exists a clear distinction between the two. Weather refers to meteorological conditions (air temperature, humidity etc.) at a particular location at a specified time. Climate, on the other hand, refers to general or average meteorological conditions over a larger area over a specified period. When we discuss environmental variability it is important to distinguish between variability

and change. Any environmental property will change with time depending on processes acting on it or it undergoes. Climate properties vary within a range in a specified period in a region where the range defines the limits of climate variability. If the property's levels shift significantly from its normal range over a longer period of time the shift is referred to as climate change.

One of the best examples of ocean-land-atmospheric interactions is the monsoon system. Monsoon in South Asia is generally referred to as Indian monsoon. Temperature gradients between air over the Indian Ocean and that over the Asian landmass (air-ocean-land interactions involving heat) define the direction and strength of winds. Wind is stronger during summer (June-September) when it blows from southwest (southwest monsoon) but weaker during winter (November-February) when cold dry wind blows from north (northeast monsoon). Heating of land and ocean surfaces is linked to the north-south movement of Tropical Convergence Zones (an atmospheric boundary where surface air masses from northern and southern hemispheres converge and rise). The rain over the land during the monsoon periods determines the socio-economics status of millions of people, as our's is largely agro based economy.

While the monsoon rainfall forms the lifeline of many in the subcontinent, it facilitates plant growth and weathering of rocks. The weathered products (clay minerals) along with soils will be carried down stream by monsoon rain fed rivers. Indian subcontinent houses some of the world largest rivers; many draining into the Bay of Bengal. Consequently, discharge of water and suspended terrigenous minerals are 5-7 times higher into the Bay than into the Arabian Sea. Immense discharge of freshwater into the Bay results in strong surface stratification, which has implications to the generation of atmospheric disturbances. Thus formed cyclones/storms lead to increased rain over land furthering the intensity of land-ocean interactions. Generation of such disturbances over the Arabian Sea is rare; the surface waters of which are slightly cooler than over Bay. Supply of terrigenous minerals to ocean results in scooping of organic carbon and helps in transferring atmospheric carbon to deep-sea sediments (Kumar, 2006).

The Indian monsoon system has been found to have connections with ocean-atmospheric interactions over the Pacific Ocean. The El Nino-Southern Oscillation phenomenon over the Pacific depends on the shifting of

air pressure differences between the east and west. Occurrence of El Niño has been found to reduce the rainfall over India, in general, sometimes leading to severe draughts (Krishna Kumar et al., 2006). On the other hand, Indian Ocean Dipole is a phenomenon when surface waters, south of Equator, in the east are cooler than in the west Indian Ocean. While El Niño has a negative effect on Indian monsoon rainfall, the occurrence of IOD has a positive effect (Ashok et al., 2004). Therefore, rainfall over India is not only influenced by local processes but also by climate change events such as ENSO.

Compared to that in 1920s the Earth's atmospheric envelope has been retaining more heat from the incident solar radiation in late 1990s. Higher heat retention capacity of air in recent times has been attributed to increased levels of CO<sub>2</sub> and other greenhouse gases released from industries. The present CO<sub>2</sub> abundance in air is about 381 ppmv. The geological history, however, known to record about 300 ppmv CO<sub>2</sub> earlier to 650,000 years before and the Earth to have witnessed warmer tropical climates between 60 and ~3 million years ago (Barreiro et al., 2004). The geological climate changes have been a part of the natural cycles, probably related to obliquity and solar insolation. However, the human interfered rate of increase in atmospheric CO<sub>2</sub> in the recent past has been much greater than that occurred in the geological past.

The man thus is changing course of the global climate, which is now referred to as Global Change. In a simple sense, Global Change refers to a change in natural system or process due to interference by humans. Release of fossil fuels and deforestation resulted in redistribution of CO<sub>2</sub> among earth surface reservoirs. Carbon removed from land (~120 Gt) appears to be accumulating in the ocean. The atmosphere has become richer by 150 Gt of CO<sub>2</sub> since the industrialization began in the middle of 19<sup>th</sup> Century. However, analyses of ice-core data revealed that the present atmospheric temperature rise is not proportional and is far less to that expected from rise in CO<sub>2</sub> and CH<sub>4</sub>. This paradox suggests that the Earth might have unknown processes that counter the global warming expected from rise in greenhouse gases (Kirchner, 2002).

While the CO<sub>2</sub> rise in atmosphere is global, the south Indian Ocean atmosphere is shown to be polluted by aerosols released from South Asia. The Asian Brown Cloud (ABC) contained greenhouse gases and black carbon aerosols (Lelieveld et al., 2001) that are expected to trap incoming solar radiation and delay the hydrological cycle or precipitation. We are yet to understand qualitative and quantitative significance of this hypothesis, if proven might have serious implications to rainfall over South Asia. The rising global temperature

is also of concern as it results in melting of ice and rise in sea level, that would adversely affect coastal population in low lying and island countries. Further, severe cyclones have been found to be increasingly destructive in the most recent past, a feature linked to global warming (Emanuel, 2005).

In order to negate the effect of global change it is of immediate necessity to cut down the industrial releases of greenhouse gases. Further, we need to remove the CO<sub>2</sub> that accumulated in air, as it is evaluated to contribute to about 60% of the global warming. The sequestration techniques include transfer of air CO<sub>2</sub> for storage in deep layers of earth and ocean, chemical removal using natural and synthetic materials and ocean fertilization. All these are still at experimental stage and appear to be economically not viable. Suitable technologies need to be developed and serious decisions to be made for making earth habitable in future.

## Further Reading

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