

Carbon inventories and atmospheric temperatures: A global and regional perspective

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Dr. Maripi Dileep Kumar (born 1954) obtained his M. Sc. (1978) and Ph D (1988) from Andhra University. He was one of the earliest trained in the multidisciplinary marine science at his post graduation. Starting his scientific career at N.I.O. as Junior Research Fellow (1979), he is currently Scientist F there. His early research covered factors controlling seawater composition. In the last two decades his major focus is on marine biogeochemistry with a major focus on carbon dioxide and dimethylsulphide in the Indian Ocean. His current focus is on the biogeochemistry of the coastal ecosystems of India. He has been involved with Scientific Committee on Oceanic Research (SCOR), International Geosphere Biosphere Programme (IGBP) and climate research activities. He was actively involved with Surface Ocean – Lower Atmosphere Study (SOLAS) since its formulation and served as a member of its Scientific Steering Committee (SSC). Currently, he is a member of the SSC of Global Climate Observing System of World Meteorological Organization. He published over 54 original research papers, most of them in international journals, and produced two Ph D students. He visited the Universities of Hawaii and Tokyo as a Visiting Scientist. Dr. Kumar was awarded Young Scientist Award by CSIR in 1988 and Prof. B. N. Ghosh 80th Birthday medal for 2002 by the Indian Chemical Society. He has been elected as FASc. (Bangalore) and FNA (New Delhi).

Carbon is present in all reservoirs of the earth in different forms. It predominantly occurs as carbon dioxide gas in atmosphere, as dissolved carbonates in hydrosphere and carbonate rocks in the geosphere. At the earth's surface, its abundance on land (soils) is about two and a half times more than in pre-industrial atmosphere (600 Gt C) whereas the ocean water contains over 60 times more to that in the latter (Siegenthaler and Sarmiento, 1993). The oceans are known to buffer the atmospheric carbon dioxide levels through the geological history. The equilibration of this gas between air and seawater is largely regulated by solubility equilibria. Bicarbonate ion is the most abundant followed by carbonate ion and dissolved carbon dioxide in seawater. Terrestrial plants account for ~600 Gt C while the oceans contain 3 Gt C of organic materials. However, organic carbon cycle or regeneration of biologically produced carbon materials in the ocean is faster than that on land.

Although carbon occurs in several gaseous forms such as Carbon dioxide, methane, carbon monoxide and volatile organic substances, the first one has received attention the most in view of its global warming potential. Interestingly, carbon dioxide was not present in the earth's primitive atmosphere. Instead, the atmosphere at that time contained carbon monoxide emanated from the earth's interior due to violent volcanic activity. This carbon monoxide reacted with oxygen, which was produced by photolysis of water in atmosphere, to produce carbon dioxide. Availability of carbon dioxide facilitated organic material production through chemosynthesis initially and photosynthesis later and in the emergence of life. Steady build up of oxygen in atmosphere, as a result of photosynthesis becoming the most dominant over chemosynthesis, facilitated carbon dioxide production in atmosphere. However, simultaneous removal of this gas from atmosphere through biological and abiological processes helped maintain its status as a trace gas in atmosphere. The fortuitous distance of the Earth from sun together with greenhouse warming by atmospheric gases (moisture, carbon dioxide etc.) helped this planet maintain a habitable climate (average: ~15°C).

Global atmospheric records reveal a general rise in temperature by about 0.6–0.8°C over the last century. A concomitant rise in sea surface temperature has also been confirmed. A continuous rise in carbon dioxide in air from the middle of the 19th century, when the industrialization began, has been reasoned for the global warming. Although, other greenhouse gases such as nitrous oxide, methane etc. (that have much higher warming potentials than carbon dioxide on a molecular basis) are also being released the atmosphere carbon dioxide merits recognition as it contributes to about 60% of the global warming. However, studies on ice core records from Antarctica (Petit et al., 1999) have clearly shown fluctuations in atmospheric carbon dioxide and methane that are positively related to air temperatures (derived from proxies) over the last four glacial cycles. Abundances of these gases in air trapped in ice were maximal during warm periods. These trends resulted in questioning the theory that whether the carbon dioxide released by human activities is responsible for the present global warming or not. But the present day atmospheric carbon dioxide concentration of ~380 ppmv is significantly more than the maximal levels (~280 ppmv) found in ice cores. However, the present day air temperature is much less than expected from the regression curves obtained between temperature (estimated from its proxy, δD), and carbon dioxide and methane in air trapped in ice (Kirchner, 2002). These observations clearly reveal that there might be some natural processes, not understood so far, that reduce the expected rise in temperature in proportion to the abundance of greenhouse gases in air. We, however, cannot afford to be complacent to rising levels of air carbon dioxide and allow that to play, to whatever extent, with our natural climate.

Changes in inventories of carbon between pre-industrial period and 1980's reveal its depletion in terrestrial pools and accumulation in atmosphere and oceans. Interestingly, the atmosphere got richer by $\frac{1}{4}$ (or 150 Gt C) of its carbon dioxide. Of the anthropogenic carbon emitted in 1980's about 2 Gt C/y seems to have been absorbed by the oceans while ~3.4 Gt C/y has been accumulating in air (Siegenthaler and Sarmiento, 1993). There has been an increase of ~1 Gt C in the carbon dioxide emitted by fossil fuel combustion between 1980's and 1990's, which appears to have been absorbed by land biota (<http://www.rice.edu/energy/research/energyprogram/docs/Masiellotopost.pdf>). Therefore, significant amounts of carbon dioxide released by human activities are being removed from air by photosynthetic fixation. Despite the gradual and consistent increase in burning of fossil fuels from 1950s the atmospheric anthropogenic carbon dioxide inventory fluctuated significantly. The major mechanism of its removal is biological fixation, which at global scale is largely regulated by the occurrence of El Nino. In El Nino years global primary production (land+ocean) is reduced and anthropogenic carbon dioxide remains in air.

Carbon dioxide emissions from South Asia have been estimated to be 0.72 Gt C/y. The two arms of the North Indian Ocean, at their air-sea interfaces, behave differently (Kumar, 2006); the Arabian Sea emits (0.18 Gt C/y) but the Bay of Bengal acts as a sink (0.02 Gt C/y). Overall the North Indian Ocean contributes ~20% of the total emitted to atmosphere in South Asia region. On the other hand, biological productivity of the North Indian Ocean is one of the highest in the world oceans. The biological (or export) pump is highly effective in transporting carbon dioxide from surface layers to deep and bottom layers of the ocean. Concentration of dissolved carbon dioxide in deep waters of the Arabian Sea and Bay of Bengal are the highest in the world thus making these layers a significant dissolved carbon sink (Sarma et al., 2006).

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