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Monthly variation of the total mass of the atmosphere over India

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सार — भारत के ऊपर के विकिरण बजट में वायुमन्डलीय कार्बन डाइआक्साइड (CO_2) की भूमिका के अध्ययन का काम हाथ में लिया गया है। भारत के ऊपर वायु की कुल राशि की माहवार गणना की गई है। मानालोआ (हवाई) पर CO_2 के मिश्रणी अनुपातों को अपनाकर भारत के ऊपर CO_2 की मात्रा के मासिक परिवर्तन का आकलन किया गया है। फिर आकलित मानों को प्रस्तुत किया गया है।

ABSTRACT. A programme of work has been undertaken to study the role of atmospheric carbon dioxide (CO_2) in the radiation budget over India. The total mass of air over India has been calculated monthwise. Adopting the mixing ratio values of CO_2 over Mouna Loa (Hawaii), the likely monthly variation of the mass of CO_2 over India has been estimated. The values obtained are presented.

1. Introduction

Atmospheric carbon dioxide plays a crucial role in the radiation budget of the earth's atmosphere and in the ecosystem. Its concentration is increasing every year; also it varies with region and with season. No study has been reported on the effect of increase in atmospheric carbon dioxide on the radiation budget over India. A programme of work has, therefore, been undertaken to examine this aspect with the help of a primitive radiation model. One of the basic requirements for the development of this model is a knowledge of the total mass of air over the country and its seasonal variation. An attempt has been made in this paper to evaluate these quantities.

Many studies have been reported on the total mass of the earth's atmosphere (Mascart 1882, Ekholm 1902, Humphreys 1929, 1940, Van Hann and Surring 1943, Verniani 1966, Sidorenkov and Stekhnousky 1971). A good review on the subject has appeared (Trenberth 1981). The investigators working on the problem have used computed values of pressure at mean sea level. Also, they have used average topography of the earth in the calculation of gravity field strength. The present study takes into account detailed topographic features and pressure values at the surface.

2. Method of computation

The climatological values of surface pressure for 235 stations, spread over the Indian land, have been considered. The island stations are omitted. The country has been divided into 375 boxes of one degree square of latitude and longitude each. At the boundary of the land, the boxes are not of full size. The sum total of the areas of all the boxes considered is found to comprise 99.9 per cent of the total area of the Indian land. The monthly pressure values for each station have been taken from *"Climatological Tables"* published by India Meteorological Department (IMD). Wherever climatological values are not available, the mean values from the available published data have been incorporated. In so far as the extreme northern part of India is concerned (35-37 deg. N), the extrapolated pressure values have been used.

The total mass of the atmosphere over the Indian land is calculated using the following formula :

$$M_a = \sum_{i=1}^{375} \frac{1}{g_i} P_i S_i \qquad (1)$$

where, M_a = mass of the atmosphere over India,
g_i = gravity field strength in the i^{th} box,
P_i = pressure in the i^{th} box,
S_i = area of the i^{th} box.

The gravity field strength g_i at the mean height of each box is obtained by the following equations :

$$g_{\phi,0} = 980.51\ (1 - .0026373 \cos 2\phi + 0.0000059 \cos^2 2\phi) \qquad (2)$$

$$g_{\phi,z} = g_{\phi,0} - (3.085462 \times 10^{-4} + 2.27 \times 10^{-7} \times \cos 2\phi) \times z + (7.254 \times 10^{-11} + 1.0 \times 10^{-13} \cos 2\phi)\, z^2 - (1.517 \times 10^{-17} + 5 \times 10^{-20} \cos 2\phi)\, z^3 \qquad (3)$$

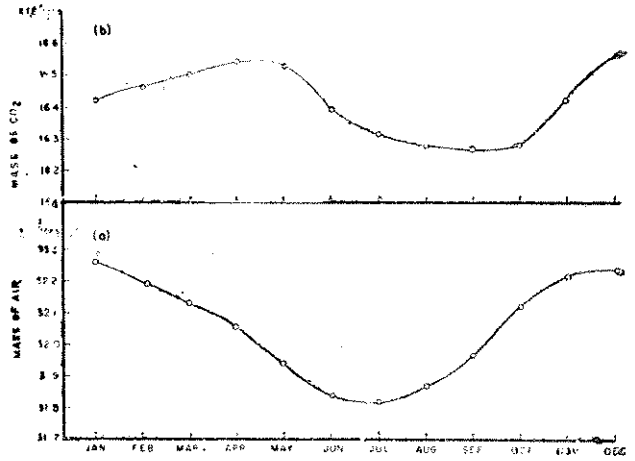

Fig. 1. Monthly variation of mass of (a) air and (b) CO_2 over India

where,

ϕ = latitude, z = altitude

$g_{\phi,z}$ = gravity field strength at latitude ϕ and altitude z

The topographical data for each box are taken from a recent publication (Gates and Nelson 1975).

3. Results and discussion

(a) *Mass of the atmosphere*

The total mass of the atmosphere, monthwise, is given in Table 1 and also in Fig. 1. Its value is maximum (3.227×10^{13} tons) in December and minimum (3.183×10^{13} tons) in July, which are respectively winter and summer months. The analysis points out that a mass of 4.390×10^{11} tons of air exchanges between the Indian land and the surroundings with the turn of the season.

The average mass of the atmosphere over India is found to be 3.204×10^{13} tons, as against the reported mass for the entire earth's atmosphere of 5.137×10^{15} tons (Trenberth 1981).

The ratio values of (*i*) mass of the atmosphere over India to that over the earth and (*ii*) surface area of the Indian land to that of the earth are :

(*i*) Mass : 0.624×10^{-2}

(*ii*) Surface area : 0.643×10^{-2}

The ratio value for the masses (0.624×10^{-2}) is slightly smaller than that for the surface area (0.643×10^{-2}). This feature is consistent, for most of the Indian land is situated in the tropical region and the tropical air is lighter than the air over the higher latitudes.

(b) *Mass of CO_2*

There have been no systematic measurements of atmospheric carbon dioxide over India. Adopting the monthly mixing ratio values of CO_2 as reported for Mauna Loa, Hawaii (Bacastow and Keeling 1981) the likely monthly variation of the CO_2 mass over India has been estimated and the values obtained are given in Table 1 and also shown in Fig. 1. The value of CO_2 is maximum (1.654×10^{10} tons) in April (pre-monsoon) and minimum (1.6267×10^{10} tons) in September (end of monsoon). These values are to be confirmed by measurements. The pattern of variation suggested in the CO_2 mass appears to be consistent because the process of photosynthesis should be minimum in pre-monsoon (maximum CO_2) and maximum towards the end of summer monsoon (minimum CO_2).

TABLE 1

Monthwise total mass of the (M_a) atmosphere $\times 10^{13}$ tons and carbon dioxide (M_{co_2}) $\times 10^{10}$ tons

Month	M_a	M_{co_2}	Month	M_a	M_{co_2}
Jan	3.2254	1.6419	Jul	3.1826	1.6317
Feb	3.2193	1.6461	Aug	3.1871	1.6277
Mar	3.2133	1.6504	Sep	3.1974	1.6267
Apr	3.2058	1.6538	Oct	3.2122	1.6278
May	3.1941	1.6526	Nov	3.2221	1.6427
Jun	3.1839	1.6386	Dec	3.2265	1.6571

4. Conclusion

The mass of the atmosphere over the Indian land is maximum in December and minimum in July. There is an exchange of 4.49×10^{11} tons of air between the Indian land region and its surroundings with the turn of the season. The mass of atmospheric CO_2 over India is likely to be maximum (1.654×10^{10} tons) in April and minimum (1.627×10^{10} tons) in September.

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