Atmospheric trace chemistry in the American humid tropics

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Numerous attempts have been made to define global mean concentrations of trace substances and to incorporate these into global models of net source and sink strengths of the various natural and anthropogenic atmospheric contaminants. One of the most extensive was certainly the work of Robinson & Robbins (1967). However, it now appears with increasing clarity that such models are at best mathematical abstractions. Many substances really do not become a part of the global atmosphere, in the sense that they are mixed meridionally throughout the atmosphere. Their lifetimes are rather short compared with such mixing times. The concept is discussed at rather more length by Kellogg et al. (1972).

It therefore seems more meaningful to discuss zonal mean values, and perhaps to distinguish variations on a still smaller scale.

The authors and their collaborators have conducted extensive studies in the American tropics to determine trace substance concentrations in a variety of tropical environments. The details of these studies are being reported extensively elsewhere (Hutton & Rasmussen, 1970; La Hue et al., 1970; Lodge & Pate, 1966; Lodge et al., 1970; Pate et al., 1967; Pate et al., 1968; Pate et al., 1970; Pate et al., 1971; Pate et al., 1973; Sheesley et al., 1970; Sheesley et al., 1971; Wartburg et al., 1970). All experimental details and methods of analysis are given in those papers. However, it seems appropriate at this time to extract from the lengthy discussion typical values for a variety of environments, to discuss some of the possible reasons for variations among them, and to arrive at some generalized mean values that can be taken as representative of the tropics.

Table 1 shows the basic data. It will be noted that ammonia (NH_3) is the most variable of the species measured. It is distinctly lower under the forest canopy in the Amazon rain forest than in the semi-deciduous forests of Panama. Above the forest canopy, in cleared areas, and in island measurements in the Bay of Panama, it is invariably near 15 ppb. Measurements on and near Barbados (on Advance II) gave similar values.

In contrast to rain forest values, the highly turbid rivers of central Brazil gave elevated levels. In fact, measurements above the Rio Taruma were still higher, while those around the Rio Solimoẽs were somewhat lower than this value. It is interesting that the Rio Taruma is a "black water" river, while the Rio Solimoẽs is a "brown water" river. By contrast, the Chagres River in Panama is clear, and measurements near it were the lowest obtained anywhere.

Measurements at Fort Sherman, Panama were among the highest obtained. Apparently this is not a phenomenon of the Caribbean, of itself, but of the foreshore. Fig. 1 shows a typical series of measurements made simultaneously at the water's edge and at Fort Sherman, less than a kilometer from the shore site. The increment is consistent, and is probably a beach effect. The reason for the low value at other sites near the Caribbean is not clear. The values for nitric oxide spread very little, and vary in much the same sense as the nitrogen dioxide values. Again the Brazilian values are the lowest for both gases, while the maritime sites appear to be the highest. Interestingly, midcontinent U.S. values are lower.

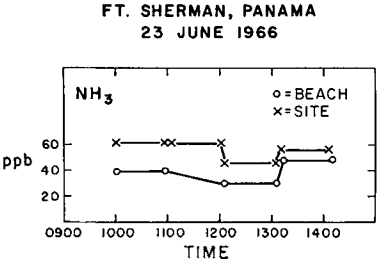

Fig. 1

Table 1. *Comparison of atmospheric trace gases in the American tropics*

	Concentrations (parts per billion by volume = 10^{-9})			
	NH_3	NO	NO_2	SO_2
Forest (under canopy)				
Ducke Forest Res. (Brazil)	9	0.1	0.2	0.3
Albrook Forest (Panama)	16	0.5	0.4	1.1
Other Panama	13	0.3	0.3	0.5
Forest (above canopy)				
Albrook Forest (Panama)	15	0.4	0.5	0.9
Other Panama	15	0.3	0.3	0.3
Interior River				
Rio Taruma/ Solimoẽs (Brazil)	25	0.3	0.3	0.3
Chagres R. (Panama)	5	0.7	0.6	0.3
Savannah/Cleared area				
Panama	15	0.5	0.6	1.0
Maritime				
Caribbean				
Ft. Sherman, Panama	31	0.7	0.5	1.3
Other Panama	9	0.3	0.4	0.4
Barbados	15	0.3	0.3	1.1
Advance II	16			
Pacific				
Bay of Panama	18	0.6	0.7	1.3
Generalized tropical values	15	0.4	0.4	0.9

Sulfur dioxide tended to be higher in Panama than in Amazonia. With a few exceptions, there appeared to be a general downward trend with distance from the ocean. Contamination appears ruled out by the lack of correlation with the other contaminants, particularly the nitrogen oxides. Temperate values are higher. Other things equal, SO_2 anticorrelates with humidity; so does appearance of H_2SO_4.

Unfortunately, at the time the measurements were made, no method for hydrogen sulfide existed with adequate sensitivity to yield non-zero values. Knowledge of the concentration of that substance could well clarify variations in sulfur dioxide concentration. All that can be said was that in all cases the concentration averaged well below the threshold of the available method, which was about 0.5 ppb. Both nitrogen oxides are lower in Amazonas than in Panama, higher in the temperate mid-latitudes.

It will be noted that for no substance was there a persistent gradient through the forest canopy at the Albrook Forest site. This should not be construed to mean that the two air strata were mixed at all times. It rather reflects diurnal mixing, which at times was rapid compared with generation rates. Fig. 2 shows simultaneous measurements made on the tower erected at the Albrook site. The movement of materials back and forth through the canopy is obvious. There is a close resemblance to the carbon dioxide profiles measured in Costa Rica by Lemon et al. (4). There was also a decided

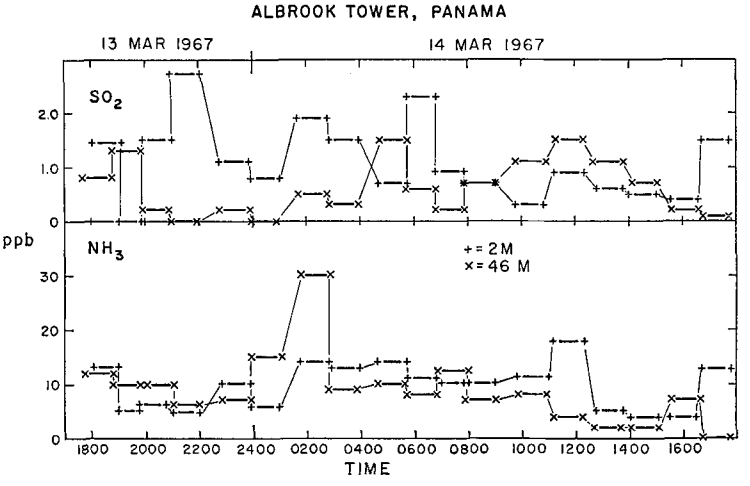

Fig. 2

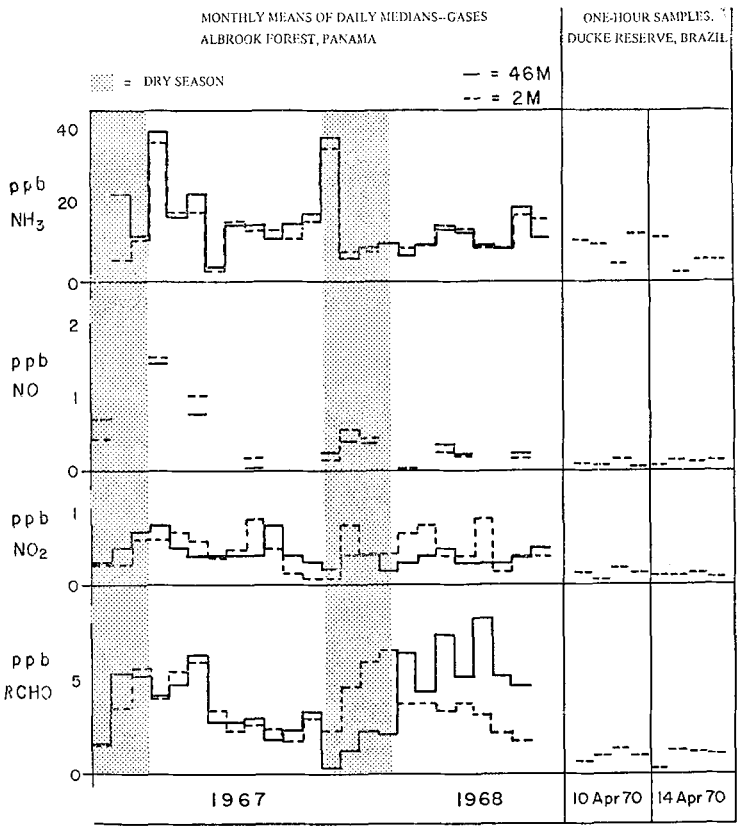

Fig. 3. Comparison of Panama and Brazil gas data.

seasonal pattern to the concentrations of the contaminants, as shown in Fig. 3. The burst of high concentration associated with the dry season is typical. It is not clear whether this coincides with the dropping of leaves from the deciduous plants, or perhaps with the dropping of the ground water table. The apparent shift in the maximum from the end of the dry season the first year to the beginning in the second is apparent, not real. The dry season came late that year, and the artist has shown the dry season as revealed by the calendar rather than by the meteorological record. The persistently lower values in the Amazon Basin during the wet season and the lack of significant seasonal shifts there are also clearly illustrated.

In conclusion, there are many persistent small scale variations in trace contaminant content of tropical atmospheres. However, it seems reasonable, on the basis of the available information, to assume the mean tropical values given in Table 1 as representative of the tropics worldwide, pending measurement in the eastern hemisphere tropics.

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