Tritium in rain as an indicator of airmass source

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ABSTRACT

Tritium analysis of daily rainfall during the 1968/69 rainy season in Rhodesia revealed a correlation between air-mass origin and its tritium content. Tritium values of over 100 tritium units were found on all occasions when a north-westerly airstream had brought lower troposphere air to Rhodesia from Angola or the Congo. When the low-level trajectory suggested an Indian Ocean origin in a north-easterly air stream, the tritium values did not exceed 51 T.U. It is thus suggested that a large proportion of the moisture in north-westerly air is of northern hemisphere origin, whereas the north-easterlies originate in the southern hemisphere. The north-easterlies probably form part of an anticyclonic circulation centred just east of Rhodesia, while the north-westerlies appear to constitute part of an equatorial "drift", having started off as north-easterlies in the northern hemisphere. Analysis of eight years of monthly rainfall samples from Salisbury shows that high tritium values occur during the main rainy season, which is consistent with the airstream explanation.

Introduction

Several different factors determine the tritium content of rainfall. For example the northern hemisphere tritium levels have, in recent years, been higher than those in the southern hemisphere as a result of thermonuclear fallout, and continental values are usually higher than those near the sea. In addition the tritium content of the atmosphere increases with height.

A programme of daily rainfall sampling was introduced at several stations in Rhodesia in 1968/69 to see whether the variations in tritium content could be related to the synoptic situation. It was felt that monthly samples, which have been collected at Salisbury since 1960, were too coarse to permit much more than a broad generalisation in an interpretation of their tritium measurements.

Collection of rainfall samples

The daily samples represent rain that fell during the 24 hours up to 0800, local time. The volume of water required for each tritium measurement is 270 ml, and so when the daily rainfall was low, water from several raingauges was used to make up this quantity. At Meteorological Headquarters, Salisbury, seven standard five-inch (127 mm) diameter raingauges were available and therefore falls of over 3 mm could be analysed for tritium. At the outstations, where only one gauge was avilable, only falls of 22 mm or more gave the required volume.

For the monthly samples, the daily contents of two to three raingauges were integrated in one large vessel from which 270 ml were taken at the end of the month.

The analysis of samples

Following tritium enrichment (approximately 14 times) by single-stage electrolysis the sample was reduced to hydrogen gas and allowed to combine with tritium-free ethylene in stoichiometric proportions to form ethane. The ethane gas was counted in a large volume (two litre) Oeschger proportional counter. The analytical system, the counting procedure and accuracy of measurement are discussed by Ward & Wurzel (1968). The error assigned to the tritium measurements used in this paper is ten percent.

When the period between collection of the

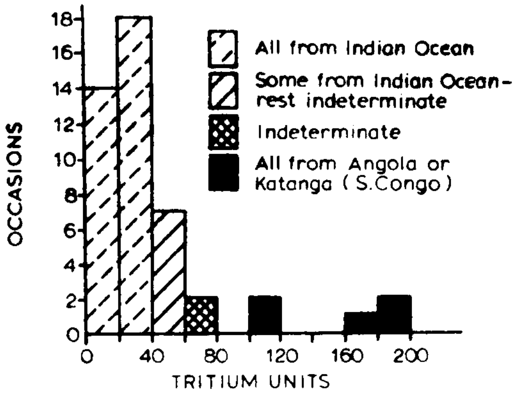

Fig. 1. Tritium distribution according to airmass source, daily samples, 1968/69.

rainfall sample and the actual measurement of the tritium content exceeded three months, the result was normalised to the collection data.

Discussion of results: The equatorial drift

46 daily samples were analysed during 1968/69, 36 of which were collected in Salisbury. The tritium values ranged from 13 T.U. to 197 T.U., and the distribution occurring in each interval of 20 T.U. is shown in Fig. 1.

The wind flow-patterns were examined for each sampling day in an attempt to see whether the tritium content of the rain could be related

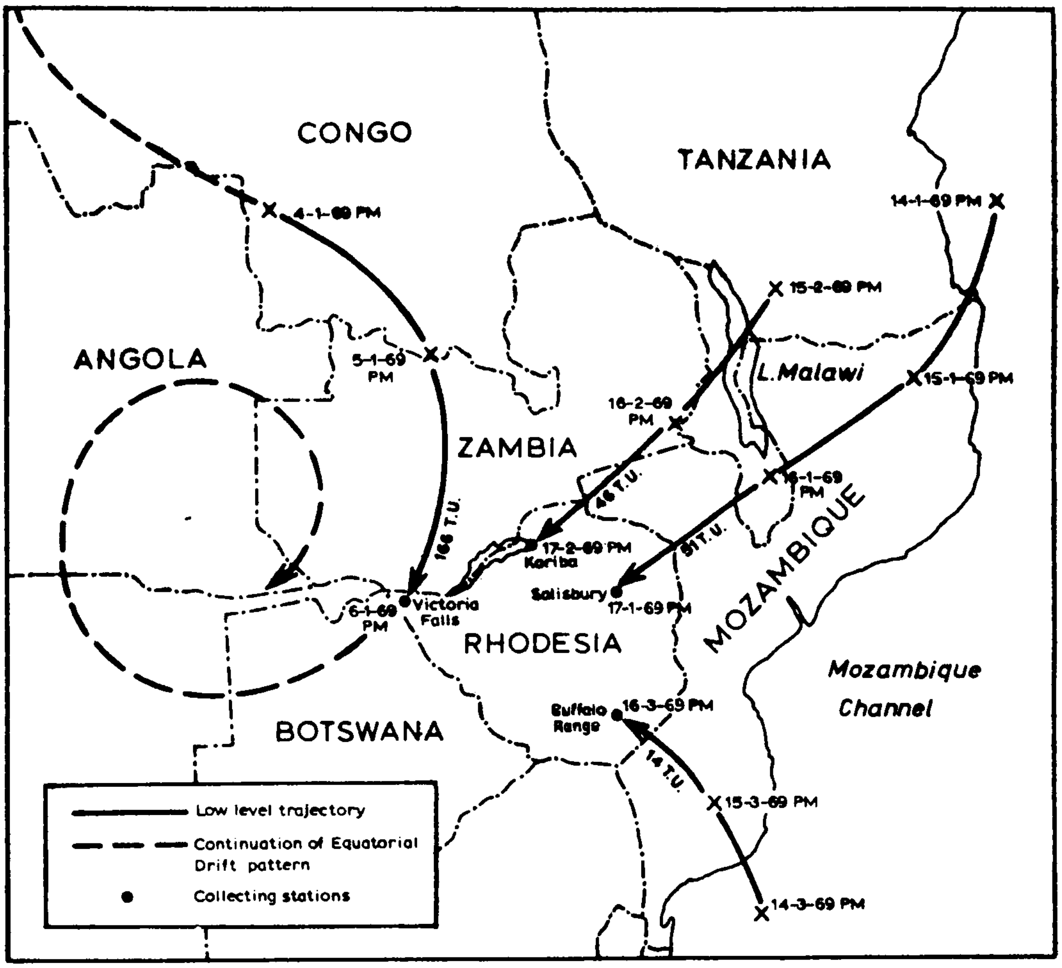

Fig. 2. Some examples of trajectories of air on days when rainfall was analysed for tritium content.

Table 1. *Tritium values in various categories of rainfall sample, Rhodesia, 1968–69*

	No. of samples	Average T.U. content ($\pm 10\%$)	Range of T.U. values
Low-level north-westerly air	5	154	102–197
Low-level east coast air	37	26	13– 51
Indeterminate	4	60	44– 73

to the apparent origin of the air, or to the length of time spent overland. The days were also classified into "Thunder reported" and "No thunder reported", the former representing days when the rain cells reached to a high altitude, and the latter being days when they did not.

The low-level flow showed a fairly close relationship with tritium content. All five rainfall occasions with a tritium count of over 100 units were on days when the winds up to 10 000 feet above sea-level were either north-westerly or cyclonic northerly. Low-level trajectories were constructed for each sample, dating back two or three days, and all suggested an origin either in Angola or in the Congo. However when the low-level winds formed a north-easterly or a south-easterly airstream originating in the Indian Ocean, the largest tritium value was only 51 T.U. There were a few occasions when both a north-westerly and an Indian Ocean airstream could have contributed to the sample, and these were classed as indeterminate. The relative distribution of the various categories are shown in Fig. 1 and Table 1, while Fig. 2 shows some examples of trajectories, labelled according to the tritium content of the associated rain.

No relationship between air-mass trajectory and tritium content emerged upon analysis of the wind levels above 10 000 feet.

The probable explanation for the higher tritium counts in the north-westerlies is that these airstreams formed part of an "equatorial drift" pattern (Johnson & Mörth, 1961) with a cross-equatorial flow culminating in a low-pressure circulation north-west of Rhodesia (see Fig. 2). This was confirmed by the analyses of monthly rainfall samples in seasons prior to 1968/9, the results of which are shown in Table 2.

Rhodesian forecasters have known for a long time that Congo air (north-westerly airstream) occasionally reaches Salisbury, although these invasions are nearly always confined to the main rainy season months December, January and February, and not to the pre-rainy or post-rainy seasons. Table 2 shows that in two seasons, 1961/2 and 1962/3, the three highest tritium values occur in December, January and February. Other seasons suggest high values both in the late spring and during the main rainy months; only 1966/7 departs from this pattern. In all other years the highest values always occurred in either December, January or February.

A spring peak in tritium values does seem to appear in several parts of the world (I.A.E.A., 1967) and has been associated with the disappearance in late winter and early spring of the temperature inversion at the Polar tropopause (Taylor, 1968) allowing an exchange of tritium between the troposphere and stratosphere. The monthly figures suggest that a late spring tritium peak often makes itself felt in Rhodesia, but that incursions of Congo air seem

Table 2. *Tritium in monthly rainfall samples collected in Salisbury*

	1960/1	61/62	62/63	63/64	64/65	65/66	66/67	67/68
October	—	10	—	46	30	35	—	33
November	11	11	26	—	31	18	44	24
December	9	22	28	—	24	37	33	37
January	11	22	53	30	48	35	28	19
February	12	32	49	50	32	26	24	22
March	8	12	25	—	24	26	21	16
April	7	13	25	—	—	19	—	18
May	Suspect	—	—	—	—	25	—	26

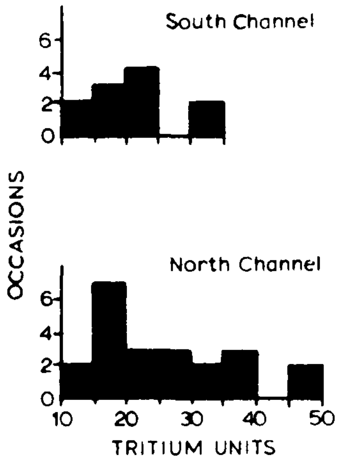

Fig. 3. Comparison of North with South Mozambique Channel samples.

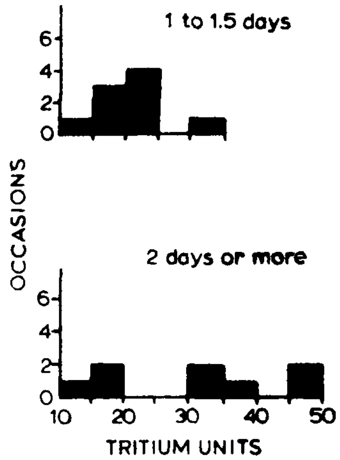

Fig. 5. Tritium distribution according to time taken to travel from the east coast to the collecting station.

to be the dominant factor, although sometimes several weeks of the rainy season can pass without any invasions of Congo air. It should be emphasised in any case that not every Congo airstream over Rhodesia will necessarily form part of an equatorial drift, and therefore some such flows may not exhibit high tritium values. (We considered it unlikely that the French Pacific bomb tests of September 1968 could have explained our results, because these showed large fluctuations persisting for nearly two months, rather than one sudden increase in tritium values.)

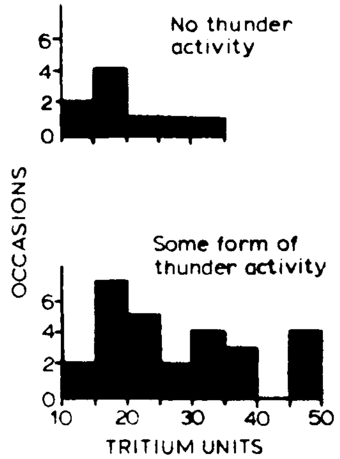

Fig. 4. Comparison of samples with and without thunder activity.

Secondary controlling mechanisms

The attempt to separate occasions of north-easterly airstream from those of an easterly or south-easterly produced no clear-cut relationship with the tritium count. The only difference was that the north-easterlies had a higher upper limit of tritium content, possibly because some samples contained very small quantities of northern hemisphere moisture. It therefore seems that the north-easterly air is largely of southern hemisphere origin, having its source in the anticyclone known to exist over the Indian Ocean.

Division of the samples into categories based, using pilot balloon reports, on the apparent time taken to reach the collecting stations from the Indian Ocean, and on whether or not thunder was reported, indicated slightly higher tritium values, as expected, in the samples which had had more time to lose their maritime moisture and in those associated with thunder activity. However the higher average in the favoured category was again due only to a higher upper limit in its values.

The positive aspect of these secondary investigations, particularly the thunder classification, was their bearing on the extent to which we were justified in regarding the low-level flow as being more important than the higher tropospheric levels, in the relative control exercised on the tritium content of a rainfall sample. This can only be assessed qualitatively, because of the interdependence of the three secondary classifications, thunder being less likely in maritime than in continental air, and being more likely also in poleward flow. (Nearly all the tritium values of over 30 T.U. were associated with at least two of the favoured secondary properties.) However it does seem that the increase in tritium content with altitude over Rhodesia is more than than compensated for by the decrease in moisture content with altitude, making the lower levels of the atmosphere responsible for the first order variations in the tritium content of the rain. The lower levels are the warmest and densest, and also usually have a smaller dewpoint depression than the higher levels; forecasting experience in Rhodesia shows that the key to the supply of moisture lies in the lower levels.

Conclusions

Analysis of the tritium content of daily rainfall at various stations in Rhodesia in 1968/9 revealed a physical difference between the moisture which appeared to traverse the Congo Basin, and that which came from the Mozambique Channel or Indian Ocean, the Congo moisture showing considerably greater tritium values. The probable explanation is that the north-westerly airstreams which brought Congo air into Rhodesia were recurved from northern hemisphere winds.

North-easterly airstreams showed only very slightly higher tritium values than southeasterlies, and there was considerable overlap between the two categories. This suggests that the north-easterlies were anticyclonically curved with a southern hemisphere origin.

A comparison of the tritium content of samples from thunder days and non-thunder days indicated slightly higher values in the former case, possibly due to the higher altitude of the thunder cells, although it could have been due to a smaller proportion of maritime moisture in the rainfall associated with thunder.

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ТРИТИЙ В ДОЖДЕ ИНДИКАТОР ИСТОЧНИКА ВОЗДУШНОЙ МАССЫ

Анализ трития в суточном дожде в течении дождливого сезона 1968–69 в Родезии указал соотношение между источником воздушной массы и её концентрацией трития. Когда северо-западная воздушная масса принесла нижно-тропосферный воздух в Родезию из Анголы или Конго, были найдены концентрации трития более чем 100 Т.Е. Когда нижноуровенная траектория указала источник в Индийском Океане в северо-восточной воздушной массе, концентрация трития никогда не была более чем 51 Т.Е. Поэтому предлагаем что большая пропорция влажности в северозападном воздухе происходит в северном полушарии, тогда как северо-восточный происходит в южном полушарии, вероятно в антициклонической циркуляции, центр которой к востоку от Родезии. Кажется что северо-западные ветры образовывают часть через-экваториального течения (дрейф), у чего в северном полушарии северо-восточные ветры.

Анализ восьми лет ежемесячных образчиков дождя в Солсбери проявляет что высокие концентрации трития случаются в главном дождливом сезоне, что утверждает нашу гипотезу.