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Stratospheric Tritium Sampling

Final Report

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ABSTRACT

Stratospheric tritium sampling was part of Project Airstream (sponsored by the US Department of Energy) between 1975 and 1983. Data from the final deployment in November 1983 are reported here, and the results of the 9 years of effort are summarized.

I. INTRODUCTION

Between 1975 and 1983, tritium sampling was carried out as a part of Project Airstream. The project was the aircraft component of the US Department of Energy's High Altitude Sampling Program. The project, aircraft, and sampling equipment have been described in previous publications.^{1,2} Flight activities were suspended after a cycle of sampling flights conducted in November 1983. This report presents the tritium data collected on that cycle and summarizes the findings of 9 years' activity.

The sampler was developed by the University of Miami under sponsorship of the former US Atomic Energy Commission and was managed by the University from 1974 to 1980. In 1981 the sampler management was assumed by Los Alamos. Laboratory support was provided by the Tritium Laboratory of the University of Miami throughout the entire period.

II. EXPERIMENT RESULTS

Stratospheric tritium data obtained before November 1983 have been reported in earlier publications: Airstream missions 4 through 16 (April 1975–August 1979),³ missions 17 through 19 (October 1979–August 1980),⁴ missions 20 through 23 (October 1980–November 1981),⁵ and missions 24 through 27 (April 1982–March 1983).⁶ Mission 28 was an abbreviated series of equipment tests, and insufficient data were obtained for interpretation. Mission 29, reported herein, was conducted between November 15 and 30, 1983. Table I contains the tritium data obtained on that mission, and Fig. 1 presents the tritiated water vapor isopleths calculated from those data. Although both tritiated water vapor (HTO) and tritium gas (HT) are present in the atmosphere and between them comprise the bulk of the entire tritium burden, the HT distribution in the stratosphere is essentially featureless and therefore is not depicted. The HT data are included in Table I.

TABLE I

TRITIUM GAS AND TRITIATED WATER VAPOR
SAMPLED BY AIRSTREAM MISSION 29

Flight	Sample Number	North Lat.	West Long.	Alt. (km)	Pressure (mbar)	Temp. (°C)	θ (K)	Tritium (pci/scm)			
								HTO	σ	HT	σ
1	1	40.5	95.4	16.6	93	-55.8	428	9.75	0.40	1.26	0.06
1	2	43.5	95.5	16.6	93	-55.0	429	3.79	0.18		
1	3	45.0	96.1	19.0	65	-55.3	477	2.74	0.13		
1	4	41.1	95.8	19.2	63	-55.7	480	4.30	0.19	1.31	0.07
1	5	34.3	95.3	19.5	60	-59.2	479	4.44	0.21		
1	6	31.5	95.1	19.7	58	-57.8	485	5.61	0.28		
2	1	31.5	97.9	15.2	116	-65.3	384	0.55	0.03		
2	2	36.0	102.9	15.2	116	-64.9	385	1.07	0.06		
2	3	40.0	108.4	15.2	116	-60.4	393	1.58	0.08	1.17	0.06
2	4	42.0	111.3	15.2	116	-57.0	400	1.71	0.09		
3	1	48.0	124.9	13.7	148	-48.3	388	3.83	0.19		
3	2	56.0	137.2	13.7	148	-50.6	384	2.45	0.13		
4	1	63.5	149.8	12.2	188	-46.1	366	0.51	0.02		
4	2	66.5	149.4	12.2	188	-47.7	364	1.14	0.06	1.26	0.06
4	3	73.0	148.4	12.2	188	-53.8	354	1.63	0.09	1.02	0.05
4	4	73.0	148.5	16.8	92	-50.3	441	2.91	0.16	1.11	0.05
4	5	66.5	149.0	16.8	92	-46.9	448	3.99	0.19	1.20	0.05
4	6	63.5	149.2	16.8	92	-45.2	451	3.37	0.17		
5	1	67.7	148.7	15.2	116	-49.0	414	2.80	0.13		
5	2	73.5	148.0	15.2	116	-52.9	407	3.16	0.17		
5	3	70.0	149.0	18.5	69	-45.3	488	7.46	0.34		

TABLE I (cont)

Flight	Sample Number	North Lat.	West Long.	Alt. (km)	Pressure (mbar)	Temp. (°C)	θ (K)	Tritium (pci/scm)			
								HTO	σ	HT	σ
5	4	63.0	149.4	19.1	63	-42.5	507	9.89	0.48		
7	1	56.0	138.2	16.8	92	-48.2	445	1.79	0.10		
7	2	48.0	125.2	16.8	92	-57.2	427	2.38	0.11	1.13	0.06
8	1	58.0	150.0	15.2	116	-46.2	420	3.09	0.15	1.17	0.06
8	2	52.5	150.0	15.2	116	-52.0	409	3.32	0.18		
8	3	48.5	150.0	19.2	63	-53.3	485	3.30	0.18		
8	4	54.5	150.0	19.2	63	-49.1	495	3.75	0.18		
8	5	57.5	150.0	19.2	63	-47.6	498	4.55	0.24	1.24	0.06
8	6	60.0	149.9	16.5	96	-44.0	447	2.02	0.12	1.52	0.11
9	1	43.5	131.5	18.3	72	-57.8	456	1.18	0.06		
9	2	40.5	136.9	18.3	72	-59.6	453	1.82	0.09	1.12	0.05
9	3	34.5	145.1	18.3	72	-63.2	445	2.59	0.19		
9	4	31.5	148.4	18.3	72	-65.7	440	4.95	0.27		
9	5	25.5	154.2	18.3	72	-67.8	435	5.41	0.27	1.25	0.06
10	1	18.0	158.7	15.2	116	-75.3	366	2.27	0.11	0.95	0.05
10	2	10.0	158.3	15.2	116	-74.7	367	0.83	0.04		
10	3	3.7	157.7	15.2	116	-76.4	364	0.71	0.04	1.03	0.06
10	4	3.7	157.6	18.3	72	-71.7	427	0.63	0.04	1.12	0.06
10	5	10.3	157.5	18.3	72	-71.6	427	0.73	0.04		
10	6	18.0	157.9	18.3	72	-71.5	427	1.26	0.07	1.17	0.06
11	1	17.7	158.1	16.8	92	-75.0	392	0.97	0.05	1.11	0.06
11	2	10.0	158.4	16.8	92	-79.3	384	0.74	0.04		

TABLE I (cont)

Flight	Sample Number	North Lat.	West Long.	Alt. (km)	Pressure (mbar)	Temp. (°C)	θ (K)	Tritium (pci/scm)			
								HTO	σ	HT	σ
11	3	3.7	158.6	16.8	92	-82.8	377	0.32	0.02		
11	4	4.0	158.6	18.8	66	-65.5	451	1.65	0.09		
11	5	10.0	158.5	19.7	58	-56.8	489	2.82	0.15		
11	6	18.0	157.6	20.1	54	-56.9	498	2.53	0.13		
12	1	21.5	157.9	15.2	116	-71.5	373	0.46	0.03		
12	2	21.0	157.9	16.8	92	-74.2	394	0.26	0.02		
12	3	21.0	158.3	18.3	72	-68.4	434	0.54	0.03		
12	4	21.2	157.9	19.2	63	-60.3	470	1.54	0.08		
13	1	27.0	149.8	16.8	92	-70.7	401	1.99	0.09	1.11	0.05
13	2	31.0	143.1	16.8	92	-65.9	410	4.51	0.21		
13	3	35.0	133.7	16.8	92	-63.7	414	4.08	0.19		
14	1	25.5	94.0	15.2	116	-70.0	375	0.68	0.04	1.09	0.06
14	2	25.5	94.0	19.8	57	-55.9	493	3.85	0.18	1.07	0.05

III. INTERPRETATION

The HTO data obtained in November 1983 show the continuing depletion of the stratospheric burden that typifies periods lacking significant tritium input. The highest mixing ratios were found in the most northerly latitude and highest altitude samples. This fact likely reflects input that occurs during wintertime exchange from altitudes above the aircraft's ceiling. The HT data show an essentially well-mixed distribution, which is consistent with the assumption that the major source is leakage from tritium production and handling and, thus, is at ground level.

Table II and Fig. 2 show the historical HTO burdens calculated from 9 years of Airstream tritium sampling. Burdens for sampling missions between October 1976 and August 1980, originally calculated manually,⁷ have been recalculated by a computer technique⁸ that analyzes all data on a consistent basis. Error bars shown for the burdens are subjectively assigned, drawing on experience from manual calculations by analysts working independently.⁹ Generally, data density is the major consideration in assigning an error estimate. The dashed arrows show estimates of stratospheric

Fig. 1. Airstream mission 29 HTO contours.

Fig. 2. Measured HTO burdens and injection estimates.

TABLE II
NORTHERN HEMISPHERE STRATOSPHERIC HTO BURDEN

<u>Mission Number</u>	<u>Year</u>	<u>Sampling Peroid</u>	<u>Measured Burden (kCi)</u>	<u>Estimated Error (%)</u>
4	1975	Apr. 19 - May 7	8412	20
5	1975	Jul. 15 - Aug. 8	3879	20
6	1976	May 24 - June 9	4089	20
7	1976	Aug. 13 - Aug. 31	1651	10
8	1976	Oct. 28 - Nov. 16	2872	15
10	1977	Jul. 7 - Jul. 22	16340	15
11	1977	Oct. 12 - Oct. 27	7628	15
12	1978	Apr. 5 - Apr. 21	5041	15
13	1978	Jul. 11 - Jul. 31	3918	15
14	1978	Oct. 11 - Nov. 7	4452	20
15	1979	Apr. 5 - Apr. 25	3385	15
16	1979	Jul. 3 - Aug. 1	2351	20
17	1979	Oct. 10 - Nov. 18	862	20
18	1980	Apr. 9 - May 13	1048	15
19	1980	Jul. 23 - Aug. 12	836	10
21	1981	Apr. 8 - Apr. 28	1871	20
22	1981	Jul. 8 - Jul. 29	1302	10
23	1981	Oct. 14 - Nov. 2	1187	10
24	1982	Apr. 15 - May 7	1256	10
25	1982	Jul. 15 - Aug. 3	957	10
26	1982	Oct. 13 - Oct. 30	513	10
27	1983	Mar. 8 - Mar. 28	891	10
29	1983	Nov. 15 - Nov. 30	553	10

injections resulting from atmospheric thermonuclear tests conducted by the Peoples' Republic of China on November 17, 1976 and October 16, 1980, as reported in earlier publications.^{8,9} The unusual increase in burden between October 1982 and March 1983 was attributed to enhanced stratospheric circulation caused by debris from the El Chichon volcano.⁸

Table II does not show a burden estimate for mission 9, on which a sampler malfunction precluded collection of an adequate data set, or mission 20, which was conducted largely in the Southern Hemisphere. Mission 21 is assigned a large error estimate because its latitude coverage was limited to 19 to 75° north. Larger error estimates in the earlier missions reflect the fact that fewer samples were collected than on later flights.

IV. CONCLUSIONS

Nine years of regular atmospheric tritium sampling have produced a large base of data from which several significant conclusions have been drawn. Estimates have been made of the quantity of tritium injected into the stratosphere by two atmospheric thermonuclear tests.^{8,9} Such tests inject essentially all of that tritium in the form of tritiated water vapor.³ A possible effect of large volcanic eruptions on stratospheric dynamics was also noted.⁸ The distribution of tritium gas in the stratosphere is essentially uniform, leading to the conclusion that the atmospheric lifetime of tritiated hydrogen gas is long when compared to stratospheric mixing times.

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