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Variation with Longitude of Aerosol Radioactivity over the Atlantic Ocean

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Aerosols in surface air over the North Atlantic Ocean were collected on air filters on board *J. Charcot* in September and October 1969 and *France* during about five months in 1970. The longitudinal variations of fission products and ⁷Be concentrations confirm the existence on the earth's surface of 'hot spots' where fallout is very important.

In an earlier paper [Nguyen Ba Cuong and Lambert, 1970] it was shown that the radioactive fallout rate varies as a function of not only the latitude but also the longitude of the sampling place. These geographical inhomogeneities could explain the discrepancies sometimes observed when the ⁹⁰Sr accumulation over continental areas is compared with data obtained over the oceans even at the same latitude. In the paper mentioned above, the study of data published by HASL (Health and Safety Laboratory) enabled us to emphasize the existence of five peaks of ⁹⁰Sr deposition in the vicinity of 0°, 80°, and 150° east and west between 30° and 60°N. The phenomenon was attributed to the effect of the jet stream standing waves described by Rossby [1947].

However, it was recognized in our study that a great difficulty was caused by the very poor number of sampling oceanic stations. On the other hand, the radioactive fallout depends highly on the cloud systems.

We have therefore undertaken the measurement of artificial radioactive aerosol concentrations in the lower atmosphere on board oceanographic ship *Jean Charcot* during a crossing of the North Atlantic Ocean (September–October 1969), then more systematically aboard *France* during the trips between Le Havre and New York from May to October 1970, i.e., just before the Chinese thermonuclear test of October 14, 1970. The preceding nuclear test was

made on September 29, 1969: therefore it can be ascertained that nuclear debris collected at sea level 8 months later had a stratospheric origin.

EXPERIMENTAL PROCEDURE

Aerosols were collected every 24 hours on a 50- by 50-cm Poelmann-Schneider blue filter. The flow of the turbine was 250 m³ h⁻¹. After about 2 weeks these filters were burned and measured by γ spectrometry by means of a Ge-Li junction detector (resolution of 3 keV) and a 4000-channel analyzer. It was therefore possible to distinguish the emitters of very close energy such as ⁷Be (477 keV) and ¹⁰⁶Ru (498 keV) (see Figure 1).

RESULTS

Figure 2 shows the trips of *Jean Charcot* from Saint John, Canada, to Brest, France, during the whole period from September 21 to October 28, 1969, and of *France* between Le Havre, France, and New York from April to October 1970. Data were obtained on board *France* during trips in both directions. Details of the results are shown in Table 1. The errors indicated in this table correspond to 2 σ (i.e., associated risk of 5% for Poisson's law) and are between $\pm 3\%$ for ¹⁴⁴Ce and $\pm 10\%$ for ⁷Be, ¹³⁷Cs, and ⁹⁶Zr.

Figure 3 shows the mean values of the atmospheric concentrations of fission products and ⁷Be for two different seasons (May to July and August to October) in the five following longitude bands: 1°–15°W, 15°–30°W, 30°–45°W, 45°–60°W, and 60°–74°W. In both periods, there is a minimum of fission products and ⁷Be

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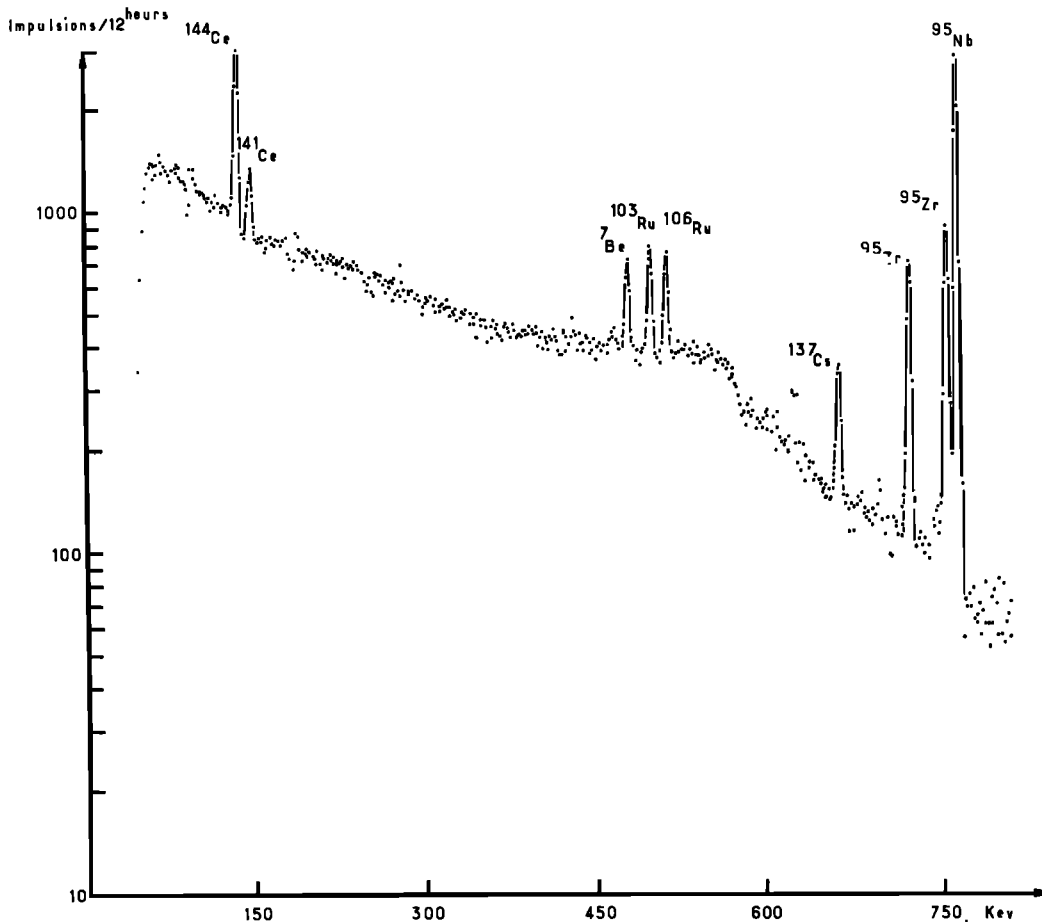


Fig. 1. Gamma spectrum. Collection date: from June 2, 1970 (1200) to June 3, 1970 (1200). Ship's position: $41^{\circ}51'\text{N}$, $62^{\circ}31'\text{W}$ at the start; $40^{\circ}27'\text{N}$, $73^{\circ}50'\text{W}$ at the finish.

near the French coast and two peaks, one on the eastern coast of the United States (from 1.8 to 3 times higher) and the other at about 20°W (from 1 to 1.8 times higher).

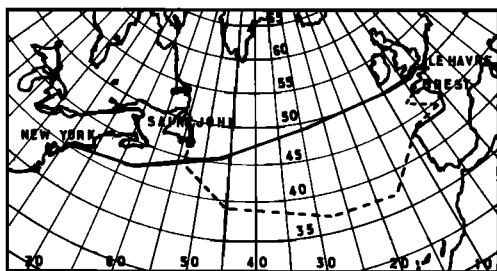


Fig. 2. Trips of oceanographic ships *Jean Charcot* (dashed line) and *France* (solid line).

Data from HASL [Volchok and Krajewski, 1972] on fallout at the stations near 80°W confirm that the well-known latitudinal effect (about 30% between New York and Moosonee in 1964 and 1965) cannot entirely explain such a maximum.

The fact that the ratios between ^7Be and fission products are higher at both minimums of radioactivity (Figure 3) shows a not negligible contribution of tropospheric ^7Be .

CONCLUSION

First, it is quite remarkable to find a systematic clear variation in the concentration of artificial radioactive aerosols in places less than 1000 km apart. Such a trip is made by an air mass in about 2 days. This confirms the very

short lifetime of 1 day for atmospheric aerosols already measured in the southern hemisphere [Lambert et al., 1972] at low altitude over oceanic areas.

Hence the observed variations of those con-

centrations clearly confirm the existence of hot spots at the earth's surface. The maximum concentrations observed at 70° and 20°W coincide rather well with the areas where we had previously found a higher radioactive fallout.

TABLE 1. Concentrations of Radioactive Aerosols over the Atlantic Ocean*

Collection Date	Position		Concentration, pC/10 ³ m ³			
	Start	Finish	¹³⁷ Cs	¹⁴⁴ Ce	⁹⁵ Zr	⁷ Be
Sept. 21 to 22, 1969	45°37'N, 55°29'W	43°37'N, 53°01'W	2.6 ± 0.3	29.5 ± 2.1	16.7 ± 1.7	50.5 ± 5.1
Sept. 25 to 26	39°35'N, 46°44'W	38°34'N, 45°20'W	2.5 ± 0.3	17.1 ± 1.2	7.9 ± 0.8	22.4 ± 2.2
Sept. 30 to Oct. 1	38°15'N, 36°05'W	38°02'N, 33°37'W		6.2 ± 0.4	1.5 ± 0.2	17.9 ± 1.8
Oct. 2 to 3	37°21'N, 29°55'W	36°47'N, 27°10'W	2.6 ± 0.3	23.9 ± 1.7	13.8 ± 1.4	58.8 ± 5.9
Oct. 6 to 7	37°56'N, 26°11'W	37°53'N, 21°02'W		10.9 ± 0.8	6.7 ± 0.7	
Oct. 8 to 9	37°33'N, 17°02'W	36°40'N, 14°14'W	1.3 ± 0.1	10.7 ± 0.7	4.8 ± 0.5	34.4 ± 3.4
Oct. 20 to 21	41°51'N, 10°27'W	43°46'N, 08°54'W	3.2 ± 0.3	20.1 ± 1.4	14.2 ± 1.4	67.6 ± 6.8
Oct. 27 to 28	43°46'N, 03°52'W	44°35'N, 03°54'W		18.4 ± 1.3	7.2 ± 0.7	47.9 ± 4.8
Oct. 31 to Nov. 1	46°54'N, 09°21'W	47°41'N, 08°09'W	2.1 ± 0.2		6.9 ± 0.7	47.9 ± 4.8
May 25 to 26, 1970	49°55'N, 10°00'W	50°55'N, 1°25'W	12.6 ± 1.3	67.4 ± 2.0	113.5 ± 11.4	133.2 ± 13.3
May 30 to 31	50°02'N, 10°22'W	49°46'N, 29°20'W	14.6 ± 1.5	246.9 ± 7.4	106.8 ± 10.7	170.5 ± 17.1
May 31 to June 1	49°46'N, 29°20'W	46°01'N, 46°51'W	9.8 ± 1.0	149.7 ± 4.5	63.1 ± 6.3	110.8 ± 11.9
June 1 to 2	46°01'N, 46°51'W	41°51'N, 62°31'W	8.4 ± 0.8	175.7 ± 5.3	68.0 ± 6.8	138.5 ± 13.9
June 2 to 3	41°51'N, 62°31'W	40°27'N, 73°50'W	24.0 ± 2.4	358.5 ± 10.8	171.3 ± 17.1	245.0 ± 24.5
June 4 to 5	40°27'N, 73°50'W	41°55'N, 62°15'W	6.5 ± 0.7	70.5 ± 2.1	30.2 ± 3.0	40.0 ± 4.0
June 7 to 8	48°29'N, 28°57'W	40°45'N, 9°35'W	7.0 ± 0.7	105.2 ± 3.2	36.9 ± 3.7	82.0 ± 8.2
June 12 to 13	50°55'N, 1°25'W	49°40'N, 10°12'W	4.5 ± 0.5	102.7 ± 3.1	34.2 ± 3.4	90.5 ± 9.1
June 13 to 14	49°40'N, 10°12'W	48°05'N, 28°30'W	8.1 ± 0.8	130.1 ± 3.9	57.0 ± 5.7	69.8 ± 6.9
June 14 to 15	48°05'N, 28°30'W	43°22'N, 48°38'W	9.8 ± 1.0	163.5 ± 4.9	68.4 ± 6.8	88.0 ± 8.8
June 15 to 16	43°22'N, 48°38'W	41°50'N, 59°45'W	4.8 ± 0.5	87.3 ± 2.6	43.1 ± 4.3	64.7 ± 6.5
June 16 to 17	41°50'N, 59°45'W	40°40'N, 73°50'W	16.9 ± 1.7	276.9 ± 7.4	118.9 ± 11.9	187.6 ± 18.8
June 19 to 20	40°37'N, 64°52'W	43°35'N, 48°27'W	4.5 ± 0.5	98.6 ± 3.0	47.3 ± 4.7	84.6 ± 8.5
June 20 to 21	43°35'N, 48°27'W	47°46'N, 31°44'W	9.8 ± 1.0	138.1 ± 4.1	58.0 ± 5.8	140.4 ± 14.0
June 21 to 22	47°46'N, 31°44'W	49°38'N, 15°00'W	5.3 ± 0.5	129.9 ± 3.9	48.3 ± 4.8	91.9 ± 9.2
July 10 to 11	50°55'N, 1°25'W	49°56'N, 10°34'W	7.3 ± 0.7	86.6 ± 2.6	27.4 ± 2.7	107.2 ± 10.7
July 11 to 12	49°56'N, 10°34'W	48°40'N, 28°50'W	11.5 ± 1.2	134.5 ± 4.0	56.0 ± 5.6	82.1 ± 8.2
July 12 to 13	48°40'N, 28°50'W	44°45'N, 45°05'W	9.3 ± 0.9	125.4 ± 3.8	44.9 ± 4.5	92.1 ± 9.2
July 13 to 14	44°45'N, 45°05'W	41°50'N, 61°10'W	4.8 ± 0.5	48.8 ± 1.5	17.3 ± 1.7	37.3 ± 3.7
July 14 to 15	41°50'N, 61°10'W	40°40'N, 73°50'W	13.2 ± 1.3	145.7 ± 4.4	57.5 ± 5.8	77.0 ± 7.7
July 16 to 17	40°40'N, 73°50'W	41°10'N, 64°50'W	4.2 ± 0.4	151.0 ± 4.5	44.0 ± 4.4	72.7 ± 7.3
July 17 to 18	41°10'N, 64°50'W	44°10'N, 48°25'W	8.1 ± 0.8	135.9 ± 4.1	45.0 ± 4.5	79.0 ± 7.9
July 18 to 19	44°10'N, 48°25'W	48°09'N, 31°38'W	3.6 ± 0.4	81.3 ± 2.4	22.9 ± 2.3	45.5 ± 4.6
July 19 to 20	48°09'N, 31°38'W	49°47'N, 13°00'W	3.1 ± 0.3	50.8 ± 1.5	22.1 ± 2.2	52.7 ± 5.3
July 20 to 21	49°47'N, 13°00'W	50°55'N, 1°25'W	1.4 ± 0.1	30.4 ± 0.9	12.2 ± 1.2	16.7 ± 1.7
Aug. 22 to 23	49°55'N, 9°05'W	49°50'N, 28°50'W	2.5 ± 0.3	35.4 ± 1.1	8.9 ± 0.9	25.3 ± 2.5
Aug. 23 to 24	49°50'N, 28°50'W	47°00'N, 45°44'W		15.1 ± 0.5	3.0 ± 0.3	27.6 ± 2.8
Aug. 24 to 25	47°00'N, 45°44'W	42°15'N, 61°25'W	2.5 ± 0.3	28.3 ± 0.8	6.7 ± 0.7	39.1 ± 3.9
Aug. 25 to 26	42°15'N, 61°25'W	39°27'N, 73°50'W	5.1 ± 0.5	61.2 ± 1.8	15.4 ± 1.5	65.9 ± 6.6
Aug. 27 to 28	39°27'N, 73°50'W	41°20'N, 64°30'W	5.9 ± 0.6	62.6 ± 1.9	15.9 ± 1.6	44.9 ± 4.5
Aug. 28 to 29	41°20'N, 64°30'W	46°10'N, 49°15'W		14.5 ± 0.4	3.3 ± 0.3	7.8 ± 0.8
Aug. 29 to 30	46°10'N, 49°15'W	47°55'N, 31°00'W		7.2 ± 0.2		5.2 ± 0.5
Aug. 30 to 31	47°55'N, 31°00'W	49°43'N, 12°35'W		17.0 ± 0.5	8.4 ± 0.8	29.6 ± 3.0
Aug. 31 to Sept. 1	49°43'N, 12°35'W	50°40'N, 1°00'W		22.3 ± 0.7	5.9 ± 0.6	48.4 ± 4.8
Sept. 7 to 8	47°30'N, 44°00'W	42°55'N, 59°50'W	1.1 ± 0.1	19.2 ± 0.6	2.4 ± 0.2	33.2 ± 3.3
Sept. 8 to 9	42°55'N, 59°50'W	39°28'N, 73°45'W		8.2 ± 0.2		5.2 ± 0.5
Sept. 10 to 11	39°28'N, 73°45'W	41°50'N, 53°00'W	3.4 ± 0.3	62.8 ± 1.9	13.2 ± 1.3	89.1 ± 8.9
Sept. 11 to 12	41°50'N, 53°00'W	46°30'N, 47°45'W	2.0 ± 0.2	22.7 ± 0.7	6.6 ± 0.7	57.6 ± 5.8
Sept. 12 to 13	46°30'N, 47°45'W	49°37'N, 30°23'W	1.4 ± 0.1	13.3 ± 0.4		26.0 ± 2.6
Sept. 13 to 14	49°37'N, 30°23'W	50°05'N, 11°10'W		15.9 ± 0.5	4.1 ± 0.4	23.4 ± 2.8
Sept. 14 to 15	50°05'N, 11°10'W	50°40'N, 0°55'W		9.7 ± 0.3		15.9 ± 1.6
Sept. 21 to 22	45°40'N, 48°50'W	42°20'N, 61°05'W	4.5 ± 0.5	50.4 ± 1.5	15.1 ± 1.5	100.8 ± 10.1
Sept. 24 to 25	40°27'N, 73°50'W	44°10'N, 55°45'W	1.1 ± 0.1	17.3 ± 0.5	4.0 ± 0.4	33.2 ± 3.3
Sept. 25 to 26	44°10'N, 55°45'W	48°30'N, 39°00'W	1.7 ± 0.2	25.4 ± 0.8	7.2 ± 0.7	25.2 ± 2.5
Oct. 17 to 18	50°04'N, 11°36'W	49°30'N, 41°20'W		22.5 ± 0.7	4.6 ± 0.5	53.9 ± 5.4
Oct. 18 to 19	49°30'N, 41°20'W	46°06'N, 49°25'W	1.4 ± 0.1	27.2 ± 0.8	4.7 ± 0.5	43.0 ± 4.3
Oct. 19 to 20	46°06'N, 49°25'W	41°48'N, 63°37'W	3.4 ± 0.3	41.1 ± 1.2	5.4 ± 0.5	75.8 ± 7.6
Oct. 20 to 21	41°48'N, 63°37'W	40°40'N, 73°50'W	3.9 ± 0.4	44.1 ± 1.3	7.5 ± 0.8	64.4 ± 6.4
Oct. 22 to 23	40°40'N, 73°50'W	44°36'N, 54°23'W	3.6 ± 0.4	53.9 ± 1.6	6.2 ± 0.6	100.1 ± 10.0
Oct. 23 to 24	44°36'N, 54°23'W	48°40'N, 37°22'W		35.8 ± 1.1		83.1 ± 8.3
Oct. 24 to 25	48°40'N, 37°22'W	50°13'N, 18°49'W	2.0 ± 0.2	27.4 ± 0.8	9.0 ± 0.9	83.1 ± 8.3
Oct. 25 to 26	50°13'N, 18°49'W	50°55'N, 1°25'W		10.7 ± 0.3	4.2 ± 0.4	36.2 ± 3.6

*All data corrected to date of collection.

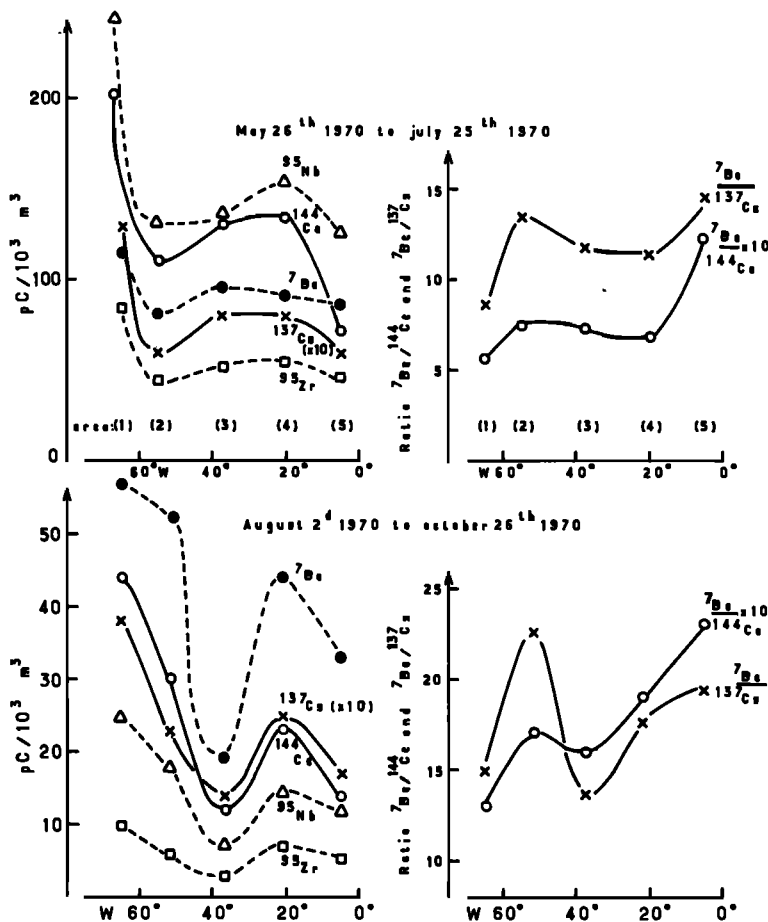


Fig. 3. Variation with longitude of aerosol radioactivity (oceanic samples collected between Le Havre and New York aboard the ship *France*).

However, this phenomenon is not observable in autumn, when stratospheric injections are very poor. Therefore, it now seems possible that the origin of the longitudinal inhomogeneities is not only due to the jet stream standing waves. Anyway, such inhomogeneities have to be taken into account for all global estimations of radioactive debris deposition.

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