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TEMPORAL FLUCTUATION OF ATMOSPHERIC ABSORPTION OF SOUND DURING A YEAR

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ABSTRACT
Attenuation coefficients for atmospheric absorption were calculated from hourly meteorological data observed at Nagoya Observatory in central Japan during a year. The calculated results show that the attenuation coefficients at law and high frequencies are higher in winter than those in summer, although the attenuation coefficients at middle frequencies become high in summer, and that the attenuation coefficients at all frequencies in daytime tends to be higher than those at night. Moreover it has been clarified quantitatively that the attenuation coefficients in a sunny day are higher than those in a rainy day. As a result of this study, it has been found that the attenuation coefficients for atmospheric absorption vary strongly due to the changes of real atmospheric conditions during a year in Japan.

1 - INTRODUCTION
Attenuation coefficients for Atmospheric absorption depend strongly on air temperature and humidity. There are large variations with time and place in meteorological conditions. These natural variabilities are often neglected in environmental impact assessments. It is necessary to examine the fluctuation of the attenuation coefficients for atmospheric absorption in order to predict outdoor sound propagation more accurately.

2 - CALCULATION METHOD
Attenuation coefficients for atmospheric absorption were calculated from hourly meteorological data observed at Nagoya Observatory in central Japan from 1 April 1991 to 31 March 1992 by using the calculation method described in the ISO 9613-1. The meteorological data used in the calculations were temperature, humidity and atmospheric pressure at a height of 1.5m above the ground. Nagoya Observatory is in a suburb of Nagoya city and stands on high ground at a height of 51.1m above the sea level.
Fig. 1 shows a scatter diagram of relative humidity versus air temperature observed hourly in the year. Temperature vary within the range from -2.9°C to 36.8°C, relative humidity vary with in the range from 17% to almost 100% in the year. The change of the seasons is quite noticeable in Japan, the air is relatively warm and moist in the summer, and cold and dry in the winter.

3 - CALCULATED RESULTS

3.1 - Temporal fluctuation in the year
Fig. 2 shows the attenuation coefficients for atmospheric absorption at octave band center frequencies form 63 Hz to 8kHz, together with the air temperature and the relative humidity used in the calculation. It can be seen that the attenuation coefficients at law (63,125Hz) and high (4k,8kHz) frequencies in the

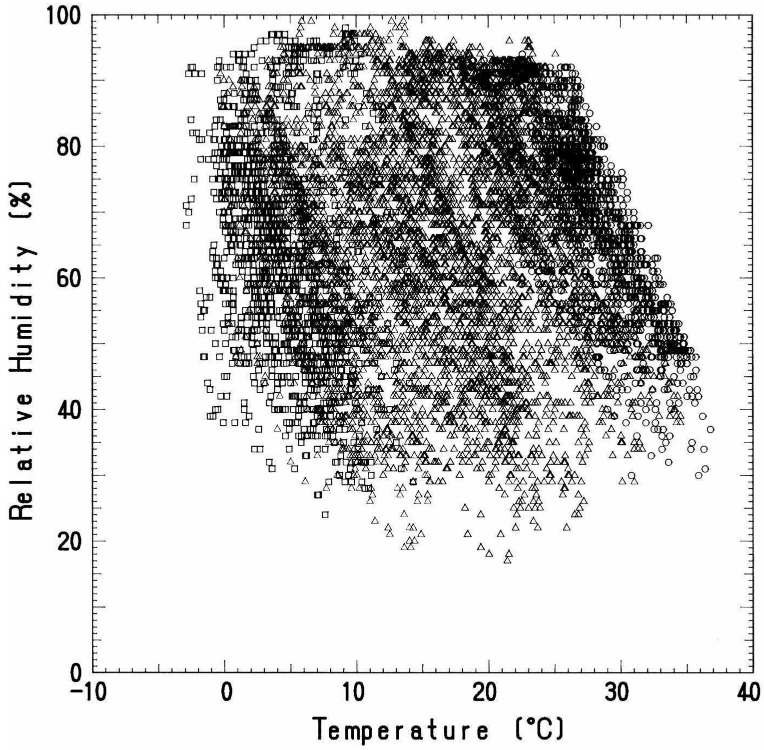

Figure 1: Scatter diagram of relative humidity versus temperature observed hourly at Nagoya in central Japan for the year (April 1991 to March 1992).

winter are higher than those in the summer. On the other hand, the attenuation coefficients at middle frequencies (500,1kHz) become lower in the winter. The temporal fluctuation of attenuation coefficients at all frequencies become greater in the winter than in the summer.
The mean, standard deviation, maximum and minimum of the coefficients (n=24*365=8760) are shown in Fig. 3 and Table 1. The attenuation coefficients vary strongly in the year. For example, attenuation coefficients at 2kHz vary within the range from 7.8 dB/km to 34.0dB/km, while the mean annual attenuation coefficient is 11.5dB/km.

	Temp. [°C]	R.H. [%]	Attenuation Coefficients for Atmospheric Absorption [dB/km]							
			63Hz	125Hz	200Hz	500Hz	1kHz	2kHz	4kHz	8kHz
Mean	16.3	66.9	0.11	0.37	1.05	2.46	5.08	11.47	33.02	104.25
S.D.	8.9	16.9	0.04	0.09	0.16	0.59	1.25	3.26	13.81	38.67
Maximum	36.8	99.0	0.28	0.75	1.70	4.31	10.21	34.04	94.17	227.24
Minimum	-2.9	17.0	0.06	0.22	0.69	1.43	3.22	7.76	19.89	54.75
Max.-Min.	39.7	82.0	0.22	0.53	1.01	2.88	6.99	26.29	74.28	172.49
Standard Atmospheric Condition (20 °C,60%)			0.10	0.38	1.22	2.78	4.80	9.28	25.60	88.90

Table 1: Attenuation coefficients for atmospheric absorption calculated form hourly meteorological data in the year (n=24*365=8760).

3.2 - Differences of attenuation coefficients between summer and winter

In order to examine the changes due to seasons, the calculated mean coefficients in the summer (July and August, n=24*62) and those in the winter (January and February, n=24*59) were compared as shown Fig. 4 and Table 2. The attenuation coefficients at high and law frequencies in the winter are high than those in the summer. On the other hand, the attenuation coefficients at middle frequencies are low in the winter. It can be said that the seasonal changes in the attenuation coefficients depend strongly on the frequency. It is difficult to answer the question whether A-weighted sound pressure level in summer

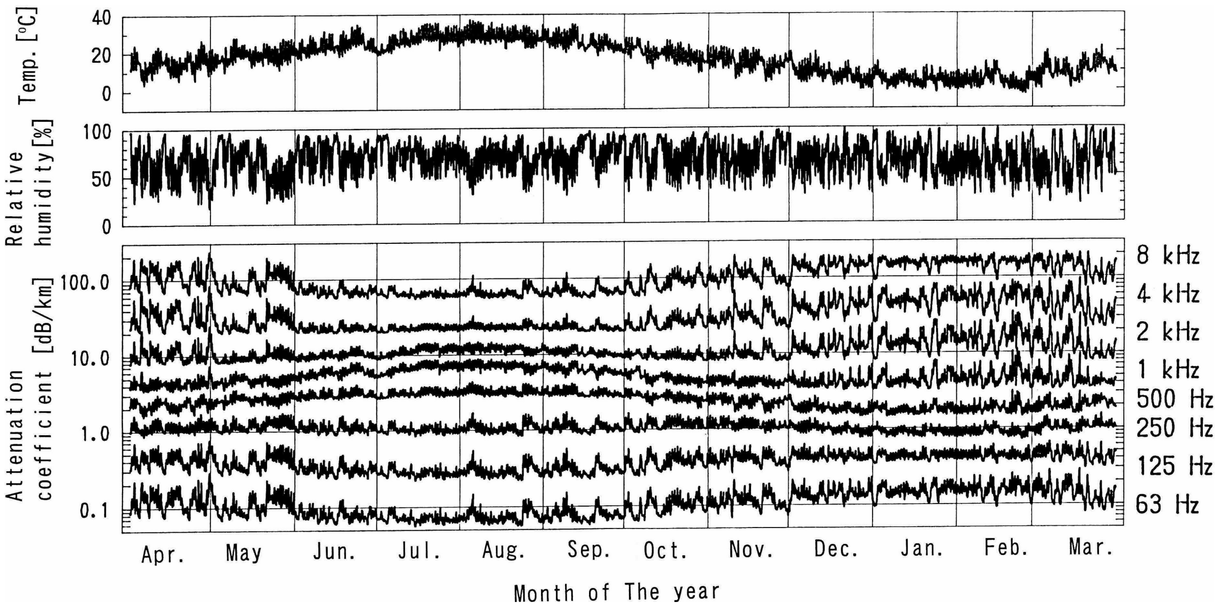

Figure 2: Air temperature, humidity and calculated attenuation coefficients due to atmospheric absorption at octave band center frequencies form 63Hz to 8kHz in the year.

at a distant point form a sound source increase or not, without the information of the spectrum of the sound source.

	Temp. [°C]	R.H. [%]	Attenuation Coefficients for Atmospheric Absorption [dB/km]							
			63Hz	125Hz	200Hz	500Hz	1kHz	2kHz	4kHz	8kHz
Summer	26.7	70.5	0.07	0.29	1.04	3.11	6.59	11.19	22.61	65.25
Winter	6.2	64.1	0.15	0.42	0.93	1.84	4.47	14.16	48.18	144.59

Table 2: Mean attenuation coefficients for summer and winter calculated form hourly meteorological data.

3.3 - Differences of attenuation coefficients between a sunny day and a rainy day

Air temperature and humidity depend strongly on weather conditions. Table 3 and Fig. 5 show mean absorption coefficients of 109 sunny days and those of 87 rainy days in the year. In this study, all days in the year were divided into three weather types (sunny, cloudy and rainy) according to the weather symbols written in the reports of surface daily observation. There is a tendency that the attenuation coefficients are high in the sunny days than in the rainy day. It should be noted that the tendency is clearly seen in the attenuation coefficients at law and high frequencies, although the attenuation coefficients at middle frequencies are not changed drastically by weather conditions.

	Temp. [°C]	R.H. [%]	Attenuation Coefficients for Atmospheric Absorption [dB/km]							
			63Hz	125Hz	200Hz	500Hz	1kHz	2kHz	4kHz	8kHz
Sunny	15.8	58.7	0.13	0.41	1.10	2.42	5.02	12.17	37.04	117.80
Rainy	18.4	79.7	0.08	0.31	1.01	2.57	5.08	9.71	24.55	79.52

Table 3: Mean attenuation coefficients for 109 sunny days and 87 for rainy days.

3.4 - Difference of absorption coefficients between day and night

In order to examine the differences of attenuation coefficients between day and night, mean attenuation coefficients from 1 p.m. to 4 p.m. and those from 1 a.m. to 4 a.m. were calculated, respectively. The results are shown in Table 4. There is a tendency that the attenuation coefficients at night become lower than those during daytime. It should be noted this tendency is not obvious for rainy days.

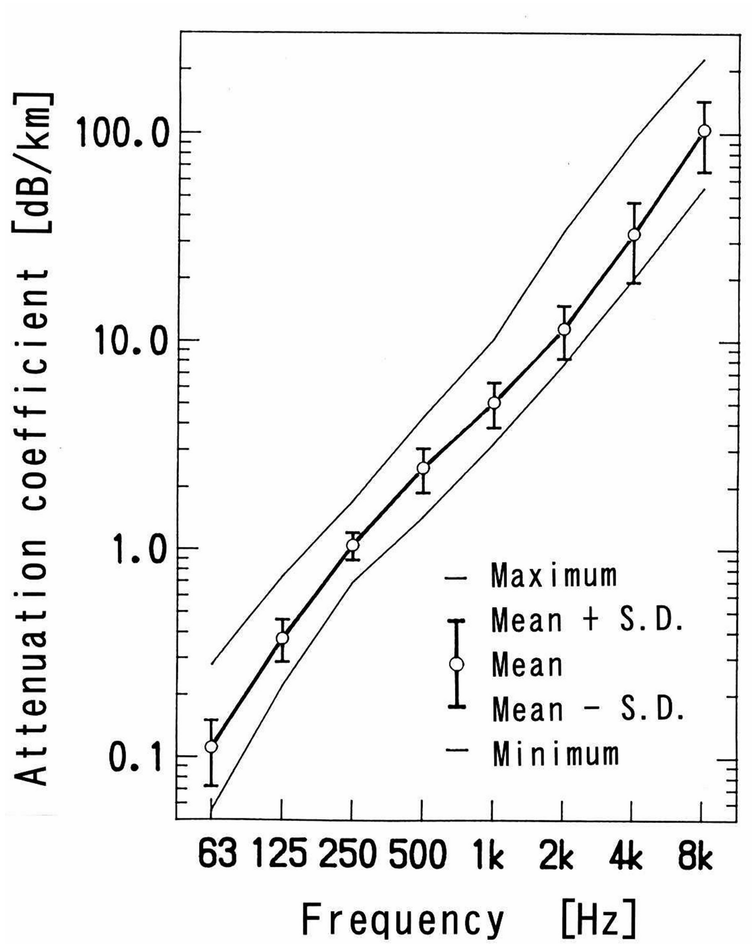

Figure 3: Attenuation coefficients for atmospheric absorption calculated form hourly meteorological data in the year.

		Attenuation Coefficients for Atmospheric Absorption [dB/km]							
		63Hz	125Hz	200Hz	500Hz	1kHz	2kHz	4kHz	8kHz
Year	Day	0.13	0.42	1.16	2.71	5.61	12.70	36.36	112.86
	Night	0.10	0.34	0.97	2.29	4.73	10.72	31.05	99.03
Sunny	Day	0.15	0.48	1.27	2.76	5.71	13.90	42.21	131.85
	Night	0.11	0.36	0.98	2.18	4.52	10.89	33.29	108.04
Rainy	Day	0.09	0.32	1.04	2.68	5.29	9.90	24.42	78.91
	Night	0.09	0.32	1.00	2.50	4.96	9.87	25.96	83.68

Table 4: Mean attenuation coefficients for day and night.

4 - CONCLUSION

The authors have calculated attenuation coefficients for atmospheric absorption from hourly meteorological data observed at Nagoya Observatory in central Japan during a year by using the calculation method described in the ISO 9613-1. As a result of this study, it has been found that the atmospheric absorption coefficients vary strongly due to the changes of real atmospheric condition during a year in Japan.

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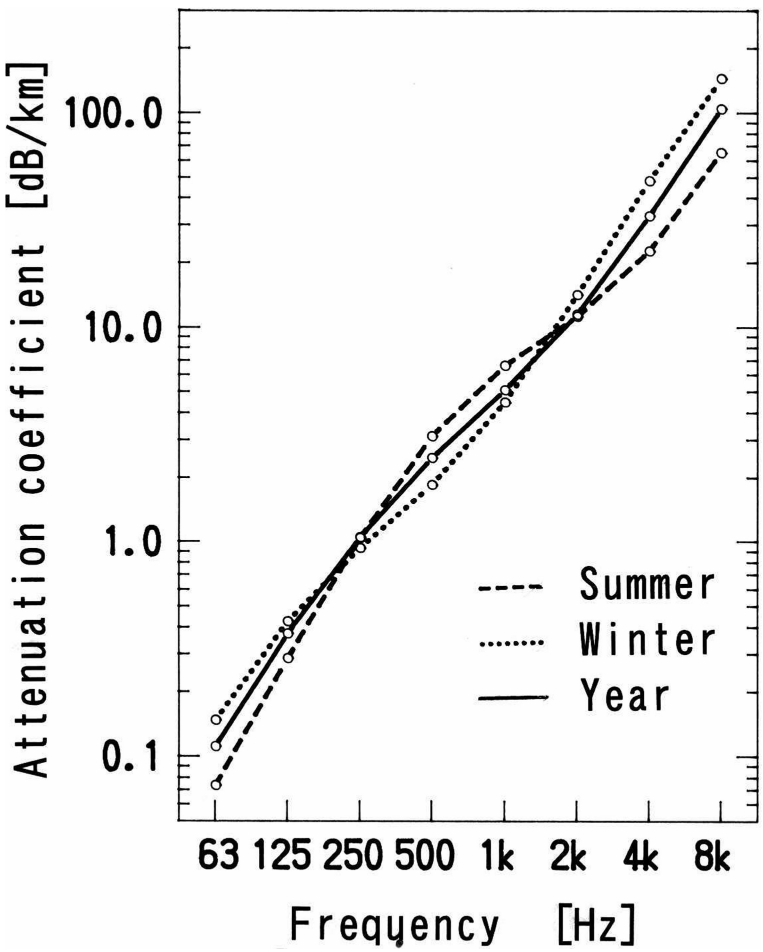

Figure 4: Mean attenuation coefficients for year, summer and winter, respectively.

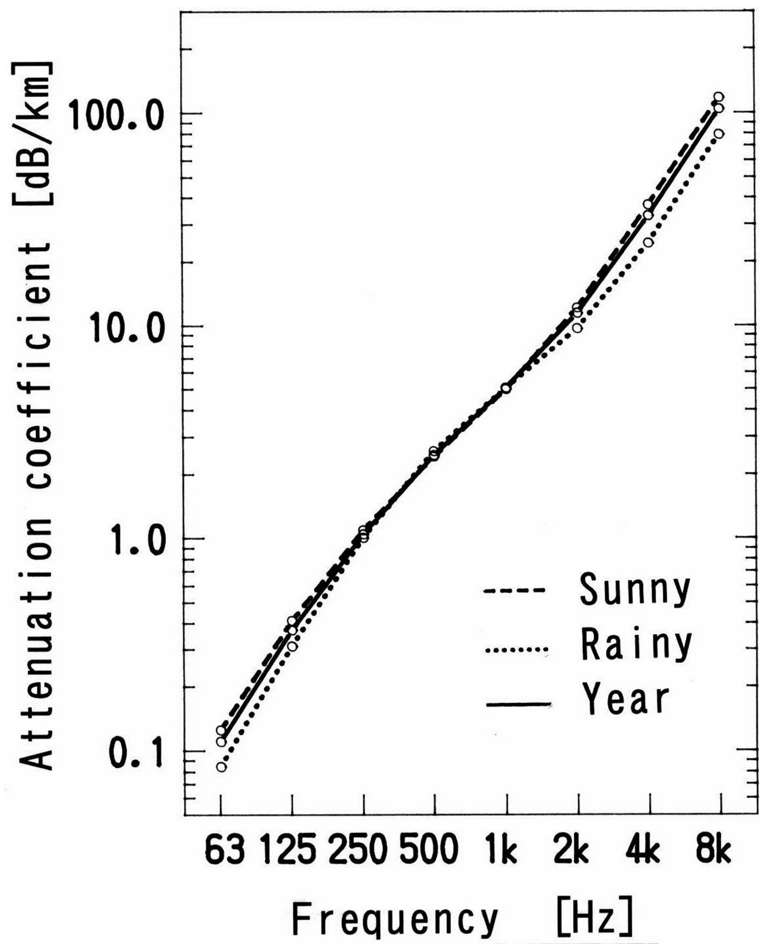

Figure 5: Mean attenuation coefficients for year, 109 sunny days and 87 rainy days.