JOUR. FAC. SCI., SHINSHU UNIV. Vol. 5 pp. 37–64, May 1970

Theoretical Calculation of the Cosmic-Ray Solar Semi-Diurnal Variation-Nucleonic Component

By SATORU MORI and SHIN-ICHI YASUE

Department of Physics, Faculty of Science,
Shinshu University
(Received May 1, 1970)

Abstract

Theoretical calculations of the solar semi-diurnal variation expected at 41 stations for the nucleonic component have been made for two types of spectra, the power- and exponential-type. The latitude distribution of the semi-diurnal anisotropy has also been considered of both forms of the cosine- and the square of the cosine-function of the geographic latitude. Calculated results for four cases of the combination of these spectral and latitude dependences are compared.

It is found that a difference in the results for the two types of the latitude distribution is appreciably large, particularly in the amplitude at high and very high latitude stations. A tendency is also shown in comparison of the results for the two types of spectral dependences that the calculated values with some higher cut-off rigidity in the power-type spectrum rather corresponds to the values with the rigidity giving the peak intensity in the exponential-type spectrum.

Finally the expected relative amplitude and average deflection angle are tabulated for the case where the spectral form is of the exponential-type of $R^{\gamma}\exp(-R/R_0)$ and the latitude distribution has a form of $\frac{\sqrt{3}}{2}\cos^2\lambda$.

§ 1 Introduction

A study of the solar semi-diurnal variation of the cosmic-ray intensity has been carried out by many authors[1~8] since the appearance of neutron and super-neutron monitors. Confirmations of the existence of the semi-diurnal variation and proposals of some hypotheses[1,3,4] which would explain the origin of the variation are several examples achieved so far. Recently, a comprehensive study to get a complete information about the modulation mechanism for a three-dimensional cosmic-ray anisotropy in space, including the origin of the solar semi-diurnal variation was strongly pursued by NAGASHIMA and his Nagoya group[8] (hereafter this series of papers 1–4 is referred to as Paper I). In paper I they developed their general idea of the extensive analysis which utilized effectively all the related components of the daily variation. An axis-symmetric anisotropy in three-dimensional space was formulated generally by means of Legendre function in a new scheme and a framework for an extensive analysis of the observed data was provided. As one of the exciting results achieved in Paper I, we can refer to the crucial test of two hypotheses of the modulation mechanism for the observed semi-diurnal variation; one is the density gradient hypothesis proposed by SUBRAMANIAN ET AL.,[1] PATEL ET AL.,[3] and LIETTI ET AL.[4] and the other is the pitch angle distribution hypothesis advocated by NAGASHIMA ET AL.[8] and SARABHAI ET AL.[9] It is conclusively shown in Paper I that the analysis of the annual modulation of the daily variation, particularly of 'a special diurnal variation', based upon their general formulation for the anisotropy, gives us a definitive evidence which will support the pitch angle distribution hypothesis.

In the present paper, following the general idea proposed by NAGASHIMA in Paper I, we have made a theoretical calculation of the semi-diurnal variation for the nucleonic component. One of the main differences between the present calculation and a previous one[10] can be first attributed to a difference in the assumed form of the latitude distribution of the semi-diurnal anisotropy. According to the general formulation, a form of the latitude distribution should be expressed as that of the square of $\cos\lambda$, where λ is the geographic latitude, while hitherto a form of only $\cos\lambda$ was assumed. The appreciable difference between these two cases would be apparent, particularly for high and very high latitude stations. A choice of the present spectral dependence of the anisotropy is secondly to be noted for another advance. In the recent investigations[5~8] the so-called semi-diurnal anisotropy was reasonably assumed to have the rigidity spectral form of the exponential-type of $R^{\gamma}\exp(-R/R_0)$, and also found to have its peak intensity at about 50~70 GV. Thus we assumed the above exponential-type form for the spectrum in the present calculation against a power law spectral form of R^{γ}, hitherto used.[10] The rigidity R_0 was introduced for an improvement in the artificial setting of the higher cut-off rigidity in the power-type spectrum, particularly for positive γ-values. This was based upon a physical point of view that the finite modulating region should impose some higher limit on rigidity of the modulated particles.[5] Theoretical calculations were performed for four cases combined the above spectral dependences with the two types of the latitude distribution, and were compared with each other. Theoretical amplitude and phase for different parameters have been tabulated for 41 stations.

§ 2 Theoretical Calculation of Solar Semi-Diurnal Variation

An axis-symmetric anisotropy in space was formulated generally by NAGASHIMA in Paper I by means of Legendre function in a new scheme and a framework for an extensive analysis of the observed data was provided. As pointed out in Paper I, so far almost the analyses have exclusively dealt with only the isolated harmonic component, such as the diurnal, or semi-diurnal variation, and so on. As far as such an analysis is concerned, that is enough to simply formulate the daily variation produced from a special anisotropy which has the direction of the maximum intensity in the equatorial plane. In the present paper the so-called semi-diurnal variation are concerned, and our calculations also belong to this category.

According to the general formulation in Paper I, an axis-symmetric anisotropy in interplanetary space fixed in the ecliptic coordinate system has been formulated by means of Legendre function in a new scheme. The anisotropy is then transformed into the equatorial coordinate expression as

$$\frac{\Delta J}{J}(R, \chi, \Lambda)=\sum_{n=0}^{\infty} G(R) F_n(\chi)=\sum_{n=0}^{\infty}\left\{\sum_{m=0}^{n} G(R) f_n{}^m(\chi)\right\} \tag{1}$$

and

$$f_n{}^m(\chi) = \eta_n P_n{}^m(\cos\theta_R) P_n{}^m(\cos\theta_J)\cos\{m(\alpha_J-\alpha_R)\},$$
$$for\ m = 0,\ 1,\ \cdots\cdots,\ \mathrm{n} \tag{2}$$

where χ and Λ are polar coordinates of the incident direction of cosmic-ray particles, and η_n is called the magnitude of the projected component of the space distribution, $F_n(\chi)$. $f_n{}^m$ is also called the projected component of the space distribution. $P_n{}^m(\cos\theta)$ represents the semi-normalized spherical function defined by SCHMIDT.[11] α_J and θ_J, and α_R and θ_R are the right ascension and co-declination of asymptotic directions of incident particles and of a reference axis of anisotropy, respectively. $G(R)$ denotes the differential rigidity spectrum. The solar anisotropy, defined with Eqs. (1) and (2), will produce the daily variation observed at a station on the earth. The m-th harmonic component of the observed daily variation would be originated from a series of the above projected component, $f_n{}^m$, assigned by a definite value of m. Thus, for instance, the semi-diurnal anisotropy, $f^2G(R)$ responsible for the observed semi-diurnal variation (m=2), can be expressed as

$$f^2G(R) = f_2{}^2G_2(R) + f_3{}^2G_3(R) + f_4{}^2G_4(R) + \cdots\cdots \tag{3}$$

This equation could be given approximately by only $f_2{}^2G_2(R)$ for the anisotropy, when being neglected the contributiosn from $f_n^2 G_n(R)$ for $n \geq 3$. The assumption may be reasonable, because so far as yearly mean values are concerned the contribution from f_3^2 becomes almost zero. And f_4^2 and more higher terms might be very small. The semi-diurnal anisotropy then will be expressed as

$$\frac{\Delta J}{J}(R, \theta_J, \alpha_J) = CG(R)\mathrm{L}(\theta_J)\cos\{2(\alpha_J - \alpha_R)\}, \tag{4}$$

$$L(\theta_J) = \frac{\sqrt{3}}{2}\sin^2\theta_J, \tag{5}$$

and

$$C = \eta_2 P_2^2(\cos\theta_R) = \frac{\sqrt{3}}{2}\eta_2 \sin^2\theta_R, \tag{6}$$

where C is the amplitude, $L(\theta_J)$ the so-called latitude distribution, respectively of the projected component on the equatorial plane. $L(\theta_J)$ is described as $L(\theta_J) = \frac{\sqrt{3}}{2}\cos^2\lambda$ by using the relation $\theta_J = \frac{\pi}{2} - \lambda$, where λ is the latitude of asymptotic directions for the incident particles at each station. In the present case the right ascension α_R should be interpreted as that of the direction of anisotropy. It should be noted here that $(\alpha_J - \alpha_R)$ suffers an annual movement owing to the earth's revolution. For simplicity, if we do not take into account the annual movement of $(\alpha_J - \alpha_R)$, Eqs. (4), (5), and (6) are simply reduced into the usual formulation as shown by Eq. (7).

$$\frac{\Delta J}{J}(R, \lambda, \varphi) = CG(R)L(\lambda)\cos\{2(\Psi - \varphi)\}, \tag{7}$$

where Ψ stands for the angle between the meridian plane including the observational stations and that including the direction of the anisotropy, and φ is the longitude of asymptotic direction for the incident particles at each station. From the above consideration, in the present case the latitude distribution was taken as that given by NAGASHIMA,

$$L(\lambda) = \frac{\sqrt{3}}{2}\cos^2\lambda. \tag{8}$$

A numerical factor $\frac{\sqrt{3}}{2}$ in this distribution has a full meaning only when we take care of the mutual relations of all the related components of the daily variation. In the IQSY Manual given by MCCRACKEN ET AL.[9] this dependence was expressed only as $\cos\lambda$. $G(R)$, the spectral dependence of the semi-diurnal anisotropy in space was assumed in two types in the present calculation, where R is in units of GV.[5,6]

$$G(R)=\begin{cases} 0 & \text{for } R<R_l, \\ (R/10)^{\gamma} & \text{for } R_l \leq R \leq R_h, \\ 0 & \text{for } R>R_h, \end{cases} \tag{9}$$

(for brevity this type of spectrum referred to as 'power-type spectrum', hereafter), and

$$G(R)=(R/10)^{\gamma}\exp(-R/R_0), \tag{10}$$

(for brevity this type of spectrum also referred to as 'exponential-type spectrum', hereafter). R_l and R_h in Eq. (9) are lower and higher cut-off rigidity for the spectrum. In Eq. (10) R_0 represents the characteristic rigidity, being introduced for an improvement in the artificial setting of the modulating higher cut-off rigidity in the power-type spectrum. This R_0 characterizes the decaying form in the higher rigidity side for the spectrum, and is based upon a physical point of view that the finite modulating region should impose some higher limit on rigidity of the modulated particles.[5] The differential spectrum in the exponential-type follows mathematically to have its maximum intensity at $R=\gamma R_0$ for the positive γ. The solar semi-diurnal anisotropy defined by Eq. (7) will produce the semi-diurnal variation $D^2(t)$ observed at a station on the earth, being finally formulated in the following conventional form as

$$D^2(t)=CA\cos\{2(\Psi-<\Psi_E>)\}. \tag{11}$$

The informations about the rigidity spectrum $G(R)$, the latitude distribution $L(\lambda)$, and the particles' deflection in the earth's magnetic field are all condensed into the quatities A and $<\Psi_E>$, through the following equations,[12]

$$A=\sqrt{C^2+S^2}, \qquad <\Psi_E>=\frac{1}{2}\tan^{-1}(S/C),$$

$$\begin{Bmatrix} C \\ S \end{Bmatrix}=\frac{1}{I}\frac{1}{\sum_{i=1}^{9}\beta_i}\left[\sum_{i=1}^{9}\beta_i\int_{Rc}^{\infty}Y(R)G(R)L(\lambda_i)\begin{Bmatrix}\cos(2\varphi_i) \\ \sin(2\varphi_i)\end{Bmatrix}dR\right], \tag{12}$$

and

$$I=\int_{Rc}^{\infty}Y(R)\,dR, \tag{13}$$

where $Y(R)$ is a response function and β_i represents the contribution factor of counting rates from the i-th cone of incidence at a station.

The relative amplitude, A, and average geomagnetic deflection angle, $<\Psi_E>$, are calculated for each station for the assumed anisotropy. In the calculation of A and $<\Psi_E>$, all the assumptions and procedures are exactly the same as our

Table 1 Amplitude, A, and average deflection

Station	$\gamma=4.0$ $R_0(GV)$ 10		15		20	
	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
Ahmedabad	0.69	113.8	3.71	89.1	11.12	72.6
Alma Ata	0.77	105.7	2.84	85.4	7.01	71.2
Buenos Aires	0.81	101.5	3.40	79.0	9.14	63.8
Calgary	0.68	43.4	2.23	40.4	5.14	36.7
Chicago	0.75	61.9	2.61	53.8	6.33	47.2
Churchill	0.42	39.4	1.40	35.7	3.30	31.6
Climax	0.78	61.4	2.62	56.2	6.10	48.6
Dallas	0.85	76.7	3.23	62.0	8.26	51.7
Deep River	0.66	62.4	2.18	54.7	5.18	47.3
Denver	0.81	63.2	2.79	54.3	6.62	46.8
Durham	0.69	70.3	2.31	19.2	5.55	49.8
Goose Bay	0.48	69.2	1.53	59.3	3.56	49.9
Hermanus	0.78	66.6	3.08	52.0	8.02	42.6
Huancayo	0.95	114.3	4.43	83.9	12.72	66.1
Inuvik	0.33	23.4	1.06	24.9	2.39	24.4
Kerguelen Is.	0.74	31.6	2.53	30.2	6.04	27.9
Kiel	0.59	87.9	1.82	76.7	4.08	66.1
Lae	0.65	113.8	3.82	84.9	12.03	68.1
Leeds	0.58	89.6	1.78	77.9	4.00	66.9
Lindau	0.64	91.8	2.02	78.6	4.60	67.0
London	0.62	94.3	1.96	80.9	4.46	69.0
Mawson	0.43	1.1	1.39	7.9	3.15	11.1
McMurdo Sound	0.00	−91.7	0.03	−10.3	0.11	−10.5
Mina Aguilar	0.95	109.5	4.11	83.1	11.17	66.5
Moscow	0.63	82.0	1.96	72.0	4.41	62.4
Mt. Norikura	1.00	111.7	4.09	90.4	10.49	75.4
Mt. Washington	0.67	69.3	2.12	59.1	4.92	50.0
Mt. Wellington	0.71	74.6	2.34	63.4	5.51	53.7
Ottawa	0.66	64.1	2.20	54.8	5.25	46.5
Oulu	0.40	74.7	1.18	68.9	2.55	62.0
Pic du Midi	0.70	109.1	2.34	88.1	5.48	72.8
Resolute	0.10	19.8	0.31	16.5	0.76	13.5
Rio de Janeiro	0.92	93.6	4.22	70.6	11.95	56.4
Rome	0.69	106.9	2.54	85.0	6.35	69.6
Sulphur Mt.	0.68	43.3	2.15	40.5	4.86	37.0
Swarthmore	0.74	71.2	2.52	59.4	6.14	49.8
Thule	0.05	54.3	0.16	43.7	0.38	32.8
Uppsala	0.50	80.3	1.51	72.4	3.30	63.9
Ushuaia	0.66	113.4	2.11	97.1	4.74	83.2
Victoria	0.76	48.5	2.58	44.3	6.11	39.7
Yakutsk	0.55	77.1	1.61	71.2	3.46	64.3

angle, $\langle \Psi_E \rangle$, in degrees. 30 degrees correspond to 1 hour.

30		40		50		70	
A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$
49.85	52.5	141.10	41.1	312.56	33.8	1022.65	24.8
25.69	52.5	66.06	41.3	138.62	33.9	427.22	24.8
37.29	45.5	101.47	35.3	220.14	28.8	705.31	21.1
17.20	29.9	41.64	24.8	83.73	21.1	244.83	16.0
23.10	38.3	59.31	32.8	124.22	28.8	382.98	22.9
11.60	24.6	29.40	19.8	61.35	16.4	188.95	12.2
20.64	37.5	50.12	30.3	100.65	25.3	291.16	19.0
31.69	38.2	83.53	30.2	177.95	24.9	559.41	18.4
18.65	35.4	48.29	27.5	102.44	22.3	322.40	16.1
23.00	35.5	56.87	28.2	115.74	23.4	342.02	17.5
20.36	36.3	53.20	28.1	113.45	22.9	359.01	16.5
12.78	35.8	33.36	27.3	71.33	21.9	227.29	15.6
31.19	30.9	82.40	24.3	175.42	20.0	549.65	14.7
54.19	46.6	147.08	36.3	314.06	29.8	967.74	22.0
7.85	21.8	18.85	19.1	37.81	16.8	110.63	13.3
21.17	23.2	52.77	19.5	108.41	16.7	326.05	12.8
13.80	49.5	34.81	38.7	73.06	31.5	228.40	22.8
56.17	48.8	161.41	38.1	360.04	31.3	1185.08	23.0
13.64	49.9	34.65	38.9	73.05	31.5	229.89	22.6
15.89	49.6	40.49	38.6	85.39	31.4	268.10	22.7
15.45	51.1	39.59	39.9	83.88	32.6	264.89	23.9
10.19	13.1	23.93	13.0	47.01	12.3	133.19	10.4
0.69	−10.6	2.30	−9.8	5.65	−8.8	20.81	−7.2
44.73	47.3	117.74	36.8	246.76	30.2	742.90	22.2
14.88	46.3	37.39	35.6	77.98	28.8	239.87	21.0
39.33	55.6	101.09	43.8	210.26	36.1	633.48	26.6
17.06	36.9	42.88	28.8	88.73	23.5	268.23	17.1
19.62	39.6	50.31	30.8	105.81	25.1	328.39	18.1
19.06	34.3	49.46	26.8	104.92	21.9	329.96	15.9
8.07	49.0	19.52	39.4	39.92	32.5	121.50	23.7
19.27	52.4	48.75	40.5	101.08	32.9	305.27	23.9
2.83	9.6	7.36	7.4	15.57	6.0	48.57	4.4
50.90	40.1	140.44	31.2	306.29	25.6	984.10	18.8
24.22	49.8	64.44	38.5	138.68	31.3	442.69	22.6
15.91	30.3	37.95	25.2	75.26	21.5	212.22	16.7
22.76	36.4	59.60	28.4	126.99	23.2	400.84	16.9
1.46	18.4	4.09	11.8	9.14	8.5	30.86	5.6
10.76	49.3	26.51	39.1	54.87	32.1	169.24	23.3
15.92	61.7	40.17	47.9	84.56	38.8	265.68	28.0
21.30	31.9	53.19	26.2	109.60	22.1	331.89	16.7
10.81	51.2	25.77	41.3	52.22	34.2	157.25	25.0

Station	$\gamma = 3.0$ $R_0(GV)$ 10		15		20	
	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
Ahmedabad	0.16	128.6	0.72	105.2	1.77	89.7
Alma Ata	0.27	124.9	0.75	104.7	1.46	91.1
Buenos Aires	0.26	117.5	0.81	97.2	1.71	82.8
Calgary	0.31	44.0	0.74	42.8	1.30	40.9
Chicago	0.33	67.2	0.80	61.4	1.48	56.3
Churchill	0.20	39.9	0.46	38.6	0.82	36.4
Climax	0.33	72.7	0.81	65.3	1.47	59.4
Dallas	0.32	89.8	0.87	75.9	1.72	66.1
Deep River	0.29	66.7	0.70	61.8	1.26	56.9
Denver	0.34	70.0	0.85	63.0	1.57	57.1
Durham	0.30	77.1	0.73	69.7	1.32	62.6
Goose Bay	0.23	73.6	0.52	68.3	0.91	62.3
Hermanus	0.27	80.8	0.79	65.6	1.61	55.9
Huancayo	0.29	137.8	0.94	107.5	2.13	88.0
Inuvik	0.16	20.3	0.36	22.6	0.62	23.5
Kerguelen Is.	0.32	31.4	0.79	31.1	1.44	30.2
Kiel	0.28	95.3	0.62	87.8	1.07	80.8
Lae	0.14	137.5	0.68	103.2	1.78	85.4
Leeds	0.27	97.1	0.61	89.5	1.04	82.1
Lindau	0.29	101.2	0.67	91.8	1.16	83.4
London	0.29	103.5	0.66	94.2	1.13	85.8
Mawson	0.19	−6.2	0.46	0.3	0.81	4.4
McMurdo Sound	0.00	203.2	0.00	256.5	0.01	−21.8
Mina Aguilar	0.29	128.7	0.94	104.0	2.02	87.3
Moscow	0.29	88.7	0.66	81.9	1.14	75.5
Mt. Norikura	0.31	126.7	0.99	107.6	2.04	94.1
Mt. Washington	0.31	75.4	0.71	68.9	1.24	62.5
Mt. Wellington	0.32	82.3	0.74	74.3	1.34	67.1
Ottawa	0.29	69.1	0.70	63.3	1.26	57.5
Oulu	0.19	77.0	0.42	74.2	0.71	70.6
Pic du Midi	0.29	128.6	0.69	109.6	1.25	95.8
Resolute	0.04	20.4	0.10	19.1	0.18	17.2
Rio de Janeiro	0.27	110.9	0.93	88.4	2.09	73.8
Rome	0.25	126.7	0.68	105.9	1.31	91.2
Sulphur Mt.	0.31	43.9	0.72	42.8	1.26	41.0
Swarthmore	0.32	79.1	0.77	70.6	1.42	63.0
Thule	0.03	56.9	0.06	52.6	0.10	46.4
Uppsala	0.24	84.5	0.53	80.0	0.90	75.0
Ushuaia	0.27	126.4	0.66	113.2	1.16	102.8
Victoria	0.33	50.5	0.81	48.0	1.47	45.2
Yakutsk	0.26	79.8	0.58	76.7	0.97	73.0

30		50		100		200	
A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
5.70	69.1	22.87	47.4	137.76	26.7	725.50	15.0
3.61	72.3	11.51	50.3	58.60	28.1	285.00	15.5
4.73	63.2	17.04	42.4	96.13	23.4	492.96	13.0
2.88	36.5	8.06	28.9	35.25	18.1	157.09	10.5
3.51	48.0	10.87	37.4	53.87	24.3	264.03	13.7
1.86	31.4	5.53	23.6	26.81	13.8	129.37	7.8
3.33	49.7	9.48	36.9	41.41	22.0	180.24	12.5
4.40	52.3	14.65	36.5	77.41	20.6	385.98	11.6
2.89	47.5	8.84	33.8	45.08	18.4	224.70	10.0
3.62	47.5	10.60	34.6	48.42	20.2	219.06	11.5
3.07	50.7	9.60	35.0	49.96	18.9	251.32	10.3
2.01	50.8	6.09	34.7	31.69	18.1	161.05	9.6
4.25	43.1	14.44	29.6	76.27	16.5	377.43	9.2
6.42	64.8	24.21	43.3	131.13	24.5	624.14	13.8
1.36	23.3	3.72	20.5	16.07	14.3	71.87	8.9
3.36	27.4	9.96	22.0	46.51	14.1	216.51	8.4
2.28	67.7	6.45	48.3	31.79	26.3	158.97	14.1
6.17	64.4	25.92	43.8	159.55	24.7	844.01	13.9
2.23	68.6	6.38	48.6	31.91	26.1	161.18	13.8
2.53	68.8	7.38	48.3	37.14	26.1	186.80	14.0
2.46	70.8	7.19	49.8	36.63	27.3	185.71	15.3
1.76	8.8	4.75	11.4	19.55	10.2	83.10	7.2
0.06	−12.4	0.36	−10.1	2.80	−7.1	16.83	−4.7
5.65	65.9	19.82	44.5	101.24	25.2	463.45	14.2
2.46	63.4	6.95	44.9	33.48	24.6	161.95	13.6
5.33	75.0	17.39	52.7	86.51	30.1	403.01	16.8
2.75	51.4	7.98	36.2	37.69	20.0	174.80	10.9
3.04	54.8	9.17	38.4	45.79	20.9	223.13	11.3
2.93	47.1	9.02	33.1	46.11	18.2	229.87	9.9
1.45	62.5	3.83	47.8	17.26	27.4	83.11	14.8
2.85	75.4	8.58	51.2	41.89	27.8	196.33	15.1
0.43	13.7	1.36	9.3	6.86	5.1	33.49	2.8
6.19	55.3	23.40	37.1	134.20	20.7	687.60	11.6
3.28	70.6	11.00	47.3	60.39	25.5	310.35	13.8
2.75	36.9	7.46	29.4	30.62	19.0	126.04	11.3
3.37	50.7	10.68	35.1	55.72	19.2	279.35	10.5
0.22	33.8	0.73	18.3	4.27	7.3	23.11	3.4
1.87	64.9	5.07	48.1	23.82	26.9	116.89	14.5
2.52	85.0	7.20	59.8	36.34	32.1	184.74	17.2
3.39	39.6	10.00	30.6	47.13	18.7	222.45	10.7
1.97	64.9	5.10	50.0	22.40	29.0	106.54	15.7

Station	$\gamma = 2.0$ $R_0(GV)$ 10		15		20	
	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
Ahmedabad	0.03	146.3	0.16	121.9	0.34	107.9
Alma Ata	0.12	149.9	0.26	129.4	0.42	116.5
Buenos Aires	0.10	133.9	0.24	116.5	0.42	104.4
Calgary	0.20	45.2	0.36	44.4	0.52	43.6
Chicago	0.19	73.0	0.36	68.8	0.54	65.4
Churchill	0.13	39.7	0.23	39.5	0.33	38.9
Climax	0.18	82.0	0.35	75.5	0.53	71.0
Dallas	0.16	106.0	0.33	93.2	0.52	84.6
Deep River	0.18	70.7	0.34	67.7	0.48	65.1
Denver	0.18	78.5	0.36	72.4	0.55	68.1
Durham	0.18	83.7	0.35	78.9	0.50	74.8
Goose Bay	0.16	76.6	0.27	74.2	0.38	71.6
Hermanus	0.11	101.1	0.26	84.3	0.44	74.3
Huancayo	0.11	160.5	0.27	135.6	0.48	117.4
Inuvik	0.10	17.2	0.18	19.1	0.26	20.3
Kerguelen Is.	0.19	32.1	0.36	31.8	0.54	31.4
Kiel	0.16	103.1	0.30	97.9	0.44	93.7
Lae	0.03	180.7	0.12	129.0	0.29	107.3
Leeds	0.16	104.7	0.30	99.6	0.43	95.4
Lindau	0.17	111.0	0.31	104.2	0.46	98.9
London	0.17	113.1	0.31	106.5	0.45	101.4
Mawson	0.12	−12.6	0.23	−8.2	0.32	−4.9
McMurdo Sound	0.01	205.0	0.01	206.3	0.01	213.1
Mina Aguilar	0.10	147.3	0.28	126.7	0.48	112.2
Moscow	0.17	96.5	0.32	91.4	0.46	87.4
Mt. Norikura	0.11	142.4	0.29	125.5	0.52	114.2
Mt. Washington	0.20	81.3	0.36	77.2	0.50	73.7
Mt. Wellington	0.19	91.0	0.35	85.0	0.51	80.4
Ottawa	0.18	73.7	0.34	70.3	0.49	67.1
Oulu	0.13	79.8	0.23	78.1	0.32	76.4
Pic du Midi	0.15	152.5	0.28	135.2	0.42	123.7
Resolute	0.03	19.2	0.05	19.5	0.07	19.1
Rio de Janeiro	0.10	129.0	0.26	108.9	0.48	95.4
Rome	0.12	151.4	0.24	131.6	0.39	118.6
Sulphur Mt.	0.20	45.2	0.36	44.4	0.52	43.7
Swarthmore	0.18	87.3	0.35	81.3	0.52	76.4
Thule	0.02	57.0	0.03	56.1	0.04	54.2
Uppsala	0.16	89.3	0.28	86.2	0.39	83.7
Ushuaia	0.13	142.0	0.27	130.2	0.41	122.3
Victoria	0.19	53.4	0.36	51.4	0.55	49.8
Yakutsk	0.16	83.0	0.29	80.9	0.42	79.2

30		50		100		200	
A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$
0.85	89.4	2.31	67.8	7.83	43.8	23.75	27.1
0.76	99.5	1.52	78.4	3.89	51.8	10.15	31.8
0.87	87.3	1.97	66.1	5.85	41.8	16.74	25.3
0.84	41.8	1.48	37.8	3.13	29.7	6.84	20.8
0.91	59.8	1.71	51.4	4.08	38.7	10.03	26.2
0.54	37.0	0.96	32.7	2.16	24.3	5.14	16.2
0.89	64.1	1.61	54.4	3.49	39.9	7.71	26.6
0.95	72.4	1.97	56.9	5.21	37.7	13.85	23.3
0.80	60.0	1.45	50.9	3.37	35.4	8.39	21.8
0.94	61.5	1.73	51.6	3.91	37.1	8.98	24.3
0.83	67.5	1.51	55.6	3.59	37.4	9.17	22.6
0.60	66.0	1.04	55.5	2.36	37.6	5.90	22.3
0.86	61.6	1.86	47.1	5.12	30.5	13.67	18.8
1.02	93.0	2.55	67.2	8.00	42.3	22.22	26.4
0.42	21.5	0.71	21.7	1.48	19.3	3.20	14.9
0.90	30.3	1.67	27.7	3.81	21.9	8.89	15.4
0.68	86.5	1.15	74.2	2.43	52.4	5.83	31.9
0.83	84.7	2.48	62.4	8.89	39.9	27.50	24.8
0.68	88.0	1.13	75.2	2.40	52.7	5.83	31.7
0.73	90.2	1.25	75.9	2.72	52.3	6.71	31.4
0.72	92.6	1.21	78.1	2.65	53.9	6.61	32.6
0.52	−0.4	0.90	4.2	1.85	7.8	3.89	8.1
0.01	273.3	0.03	−20.5	0.13	−10.4	0.49	−6.9
1.00	92.3	2.29	69.3	6.55	44.6	17.19	28.0
0.74	80.7	1.24	69.1	2.62	48.9	6.17	30.4
1.03	98.4	2.20	78.3	5.78	52.9	14.80	33.4
0.81	67.3	1.39	56.8	3.02	39.9	6.99	25.0
0.84	72.6	1.49	60.4	3.41	41.4	8.38	25.3
0.81	61.2	1.45	51.2	3.41	35.2	8.56	21.6
0.48	73.0	0.79	66.0	1.53	50.7	3.33	33.2
0.69	107.3	1.24	85.2	2.88	55.6	7.17	33.4
0.12	17.6	0.23	14.7	0.53	10.0	1.31	6.2
1.04	77.4	2.57	57.2	8.08	36.1	23.43	22.1
0.69	100.4	1.39	77.1	3.74	48.4	10.47	28.4
0.82	41.9	1.42	38.2	2.90	30.6	5.97	22.2
0.87	68.2	1.62	55.6	3.95	37.3	10.17	22.6
0.07	49.1	0.11	38.3	0.29	21.6	0.80	10.7
0.60	78.8	0.99	69.7	1.98	51.7	4.50	32.8
0.67	110.6	1.15	92.8	2.51	63.4	6.33	37.6
0.92	46.8	1.68	41.3	3.81	31.3	8.94	21.1
0.65	75.6	1.06	68.4	2.03	53.1	4.34	35.2

Station	$\gamma = 1.5$ $R_0(GV)$ 10		15		20	
	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
Ahmedabad	0.02	159.0	0.07	131.0	0.16	117.1
Alma Ata	0.09	164.8	0.16	144.5	0.25	131.9
Buenos Aires	0.06	142.4	0.14	126.1	0.23	115.3
Calgary	0.17	46.6	0.29	45.6	0.39	44.9
Chicago	0.16	76.6	0.28	72.8	0.38	70.0
Churchill	0.12	39.5	0.19	39.6	0.26	39.4
Climax	0.15	88.3	0.26	81.6	0.36	77.4
Dallas	0.12	115.5	0.23	103.3	0.33	95.3
Deep River	0.16	73.1	0.27	70.6	0.36	68.6
Denver	0.15	84.0	0.27	78.0	0.38	74.1
Durham	0.16	87.5	0.27	83.4	0.37	80.2
Goose Bay	0.14	78.3	0.23	76.5	0.29	74.8
Hermanus	0.08	115.2	0.16	96.7	0.26	86.2
Huancayo	0.07	170.2	0.16	149.3	0.26	133.5
Inuvik	0.10	15.9	0.16	17.4	0.21	18.4
Kerguelen Is.	0.16	33.5	0.28	32.7	0.39	32.2
Kiel	0.15	107.8	0.24	103.0	0.33	99.7
Lae	0.02	211.2	0.05	149.8	0.12	122.2
Leeds	0.15	109.3	0.24	104.6	0.33	101.3
Lindau	0.14	116.7	0.24	110.5	0.33	106.2
London	0.15	118.7	0.24	112.7	0.34	108.5
Mawson	0.11	−14.9	0.18	−11.8	0.24	−9.3
McMurdo Sound	0.01	206.7	0.01	206.5	0.01	207.8
Mina Aguilar	0.07	156.0	0.16	137.7	0.27	124.9
Moscow	0.15	101.4	0.25	96.5	0.35	93.2
Mt. Norikura	0.07	150.6	0.16	134.6	0.29	124.3
Mt. Washington	0.17	84.7	0.29	81.2	0.38	78.5
Mt. Wellington	0.16	96.3	0.28	90.8	0.37	86.9
Ottawa	0.16	76.4	0.27	73.5	0.36	71.2
Oulu	0.12	82.2	0.19	80.3	0.25	79.1
Pic du Midi	0.11	166.1	0.20	149.8	0.28	139.3
Resolute	0.03	18.2	0.04	18.8	0.05	18.9
Rio de Janeiro	0.06	138.0	0.15	119.6	0.25	107.1
Rome	0.09	165.5	0.16	146.6	0.24	134.5
Sulphur Mt.	0.18	46.8	0.29	45.7	0.40	45.0
Swarthmore	0.16	92.0	0.27	86.7	0.37	82.8
Thule	0.02	56.8	0.03	56.6	0.03	55.8
Uppala	0.14	92.7	0.23	89.7	0.30	87.6
Ushuaia	0.10	151.4	0.18	139.7	0.27	132.5
Victoria	0.16	55.9	0.28	53.7	0.39	52.2
Yakutsk	0.15	85.5	0.24	83.4	0.33	81.9

30		50		100		200	
A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
0.36	99.9	0.84	79.9	2.22	56.2	5.18	38.1
0.41	116.0	0.68	97.0	1.29	71.9	2.42	49.5
0.43	100.3	0.81	81.4	1.79	57.3	3.82	38.2
0.57	43.7	0.85	41.3	1.37	36.2	2.17	29.5
0.58	65.7	0.91	59.4	1.59	49.3	2.78	38.0
0.37	38.5	0.55	36.1	0.92	30.7	1.53	23.9
0.55	71.7	0.86	64.1	1.43	52.6	2.30	40.7
0.54	84.4	0.91	70.7	1.78	52.4	3.42	36.4
0.53	65.1	0.81	59.2	1.36	48.0	2.33	35.2
0.58	68.6	0.92	61.1	1.56	49.5	2.59	37.5
0.55	75.0	0.82	66.7	1.40	52.5	2.45	37.4
0.42	71.4	0.61	65.1	0.98	52.7	1.65	38.0
0.44	73.5	0.81	59.4	1.69	42.7	3.36	29.3
0.48	111.0	0.96	85.0	2.32	57.5	5.04	38.7
0.29	19.7	0.42	20.5	0.67	20.1	1.05	17.9
0.58	31.5	0.91	29.9	1.56	26.2	2.63	21.1
0.47	94.5	0.68	86.4	1.04	71.5	1.65	53.1
0.32	97.0	0.84	74.1	2.43	50.9	5.91	34.3
0.46	96.1	0.66	87.8	1.02	72.4	1.62	53.3
0.48	99.7	0.70	89.9	1.11	72.7	1.81	52.7
0.48	102.2	0.69	92.4	1.08	75.0	1.77	54.4
0.36	−5.7	0.52	−1.5	0.83	2.7	1.29	5.0
0.01	216.0	0.01	271.6	0.03	−20.8	0.10	−10.6
0.48	107.2	0.93	85.8	2.02	60.7	4.08	41.8
0.49	88.3	0.72	80.6	1.12	66.5	1.78	49.8
0.51	110.5	0.94	93.1	1.90	70.0	3.60	49.7
0.55	74.1	0.81	67.1	1.28	54.8	2.06	41.1
0.55	81.1	0.82	72.3	1.36	57.7	2.29	41.8
0.53	67.2	0.81	60.4	1.36	48.4	2.36	35.2
0.35	76.9	0.49	72.8	0.73	64.0	1.08	51.3
0.42	125.2	0.62	107.2	1.02	80.9	1.76	55.7
0.08	18.4	0.12	16.8	0.22	13.5	0.37	10.0
0.48	90.4	1.00	71.0	2.40	48.9	5.31	32.7
0.38	118.2	0.62	97.7	1.19	69.5	2.38	45.5
0.56	43.9	0.83	41.6	1.32	36.9	2.00	30.8
0.55	76.7	0.86	67.4	1.49	52.3	2.68	37.0
0.04	53.3	0.07	47.4	0.11	35.1	0.21	22.4
0.42	84.3	0.60	78.7	0.90	67.5	1.38	52.5
0.41	122.8	0.61	109.7	0.96	87.7	1.58	62.2
0.58	50.0	0.91	46.3	1.55	39.2	2.62	30.7
0.46	79.6	0.65	75.4	0.96	66.4	1.42	53.6

Station	$\gamma = 1.0$ $R_0(GV)$ 10		15		20	
	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
Ahmedabad	0.01	179.1	0.03	141.5	0.07	126.7
Alma Ata	0.07	180.4	0.12	161.2	0.16	149.3
Buenos Aires	0.03	151.4	0.09	135.8	0.14	126.0
Calgary	0.16	48.8	0.26	47.4	0.33	46.7
Chicago	0.15	81.3	0.23	77.4	0.30	74.9
Churchill	0.12	39.6	0.18	39.6	0.23	39.5
Climax	0.12	96.3	0.20	89.0	0.27	84.9
Dallas	0.10	125.7	0.17	114.3	0.23	107.0
Deep River	0.16	76.3	0.23	73.8	0.30	72.2
Denver	0.13	90.9	0.22	84.6	0.29	80.9
Durham	0.15	92.1	0.23	88.2	0.30	85.6
Goose Bay	0.14	80.5	0.21	78.9	0.26	77.7
Hermanus	0.06	132.9	0.11	112.5	0.16	101.2
Huancayo	0.05	178.6	0.10	161.6	0.16	148.7
Inuvik	0.10	14.8	0.15	15.9	0.18	16.6
Kerguelen Is.	0.16	35.9	0.24	34.5	0.31	33.8
Kiel	0.13	113.3	0.21	108.7	0.27	105.8
Lae	0.02	237.5	0.03	182.0	0.05	144.6
Leeds	0.13	114.7	0.21	110.2	0.27	107.3
Lindau	0.12	123.1	0.20	117.1	0.26	113.4
London	0.13	125.2	0.21	119.4	0.27	115.8
Mawson	0.11	−16.5	0.16	−14.5	0.21	−12.8
McMurdo Sound	0.01	208.4	0.01	207.8	0.01	207.9
Mina Aguilar	0.04	164.2	0.10	148.1	0.16	137.0
Moscow	0.14	107.4	0.22	102.5	0.28	99.5
Mt. Norikura	0.04	159.2	0.10	143.8	0.16	134.3
Mt. Washington	0.16	88.7	0.26	85.5	0.33	83.3
Mt. Wellington	0.15	102.7	0.23	97.3	0.30	93.9
Ottawa	0.16	79.9	0.23	77.1	0.30	75.2
Oulu	0.12	85.5	0.18	83.4	0.23	82.2
Pic du Midi	0.10	180.6	0.16	165.5	0.21	156.1
Resolute	0.03	17.0	0.04	17.8	0.05	18.1
Rio de Janeiro	0.03	147.1	0.09	130.1	0.15	118.9
Rome	0.07	180.1	0.12	162.8	0.16	151.7
Sulphur Mt.	0.17	49.2	0.26	47.7	0.34	47.0
Swarthmore	0.14	97.7	0.23	92.6	0.29	89.3
Thule	0.02	56.8	0.03	56.7	0.03	56.5
Uppsala	0.14	97.3	0.21	94.1	0.26	92.2
Ushuaia	0.08	162.0	0.14	150.2	0.19	143.4
Victoria	0.15	59.4	0.23	56.7	0.30	55.3
Yakutsk	0.15	89.0	0.22	86.6	0.28	85.2

30		50		100		200	
A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$
0.16	110.3	0.33	92.3	0.71	70.7	1.32	52.9
0.24	134.5	0.36	117.9	0.53	97.0	0.74	77.0
0.23	113.1	0.38	97.3	0.67	76.6	1.07	58.0
0.44	45.7	0.59	44.3	0.80	41.5	1.01	37.9
0.42	71.5	0.58	67.0	0.82	60.3	1.11	52.6
0.29	39.2	0.39	38.2	0.53	35.6	0.68	31.9
0.38	79.8	0.54	73.8	0.74	65.8	0.97	57.6
0.34	97.5	0.50	86.1	0.77	71.1	1.12	56.8
0.41	69.7	0.55	66.1	0.74	59.6	0.98	51.6
0.41	76.1	0.56	70.4	0.81	62.3	1.06	54.0
0.41	81.9	0.55	76.6	0.75	67.8	0.99	57.6
0.34	75.6	0.44	72.2	0.58	65.7	0.74	57.3
0.25	88.1	0.40	74.5	0.67	58.9	1.03	45.7
0.25	129.8	0.42	106.5	0.78	78.8	1.32	57.9
0.23	17.6	0.30	18.6	0.41	19.1	0.51	18.7
0.43	33.0	0.59	32.0	0.84	29.9	1.12	27.0
0.36	101.8	0.47	96.6	0.61	88.3	0.74	78.0
0.12	112.3	0.29	87.4	0.73	63.9	1.45	47.0
0.36	103.4	0.46	98.2	0.60	89.7	0.74	79.1
0.36	108.4	0.47	101.9	0.62	91.8	0.77	79.7
0.36	110.9	0.48	104.6	0.61	94.5	0.76	82.3
0.28	−10.3	0.36	−7.3	0.49	−3.8	0.62	−1.3
0.01	209.4	0.01	216.4	0.01	255.8	0.02	−37.9
0.26	121.9	0.42	103.7	0.74	81.1	1.17	62.3
0.37	95.5	0.49	90.4	0.65	82.4	0.80	72.7
0.28	122.2	0.46	107.9	0.74	89.3	1.11	71.8
0.43	80.2	0.56	75.8	0.74	68.7	0.94	60.5
0.41	89.3	0.55	83.3	0.74	74.1	0.95	63.6
0.41	72.4	0.55	68.2	0.74	61.1	0.98	52.5
0.29	80.5	0.37	78.2	0.47	73.9	0.56	67.9
0.28	144.1	0.37	130.1	0.48	111.3	0.61	91.5
0.06	18.1	0.09	17.7	0.12	16.2	0.16	14.1
0.25	104.0	0.44	86.6	0.84	65.7	1.44	48.9
0.23	137.5	0.33	120.5	0.48	97.6	0.69	74.7
0.44	46.0	0.59	44.5	0.78	42.0	0.98	38.8
0.40	84.7	0.55	78.3	0.76	68.4	1.02	57.4
0.03	55.4	0.05	52.8	0.07	46.8	0.09	38.7
0.34	89.6	0.43	86.1	0.56	80.3	0.68	72.7
0.27	134.9	0.37	125.1	0.49	111.2	0.61	95.0
0.42	53.4	0.58	50.8	0.82	46.5	1.10	41.3
0.36	83.3	0.47	80.8	0.61	76.3	0.74	70.3

Station	$\gamma = 0.6$ $R_0(GV)$					
	10		15		20	
	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
Ahmedabad	0.00	205.5	0.02	152.7	0.03	135.5
Alma Ata	0.06	192.7	0.10	175.3	0.13	164.3
Buenos Aires	0.03	159.1	0.06	143.7	0.10	134.5
Calgary	0.17	51.4	0.25	49.7	0.30	48.8
Chicago	0.14	86.1	0.21	81.9	0.27	79.5
Churchill	0.13	39.8	0.18	39.7	0.22	39.7
Climax	0.11	104.4	0.17	96.4	0.23	92.1
Dallas	0.09	134.2	0.15	123.5	0.19	116.8
Deep River	0.16	79.7	0.23	77.0	0.28	75.5
Denver	0.12	97.7	0.18	90.9	0.24	87.2
Durham	0.15	96.5	0.23	92.6	0.28	90.3
Goose Bay	0.15	82.8	0.21	81.1	0.25	80.1
Hermanus	0.05	149.6	0.09	128.3	0.11	116.3
Huancayo	0.03	184.4	0.08	170.2	0.10	159.5
Inuvik	0.11	14.1	0.15	14.9	0.18	15.4
Kerguelen Is.	0.16	38.7	0.23	36.8	0.29	35.9
Kiel	0.13	118.5	0.19	113.8	0.24	111.0
Lae	0.01	252.4	0.02	212.5	0.03	173.2
Leeds	0.13	119.9	0.19	115.2	0.24	112.5
Lindau	0.11	129.1	0.18	123.0	0.23	119.5
London	0.12	131.3	0.19	125.4	0.23	122.0
Mawson	0.12	−17.2	0.17	−16.0	0.21	−14.9
McMurdo Sound	0.01	209.7	0.01	209.1	0.01	208.9
Mina Aguilar	0.03	170.5	0.07	155.8	0.10	146.1
Moscow	0.13	113.1	0.20	108.0	0.25	105.1
Mt. Norikura	0.03	166.4	0.07	151.3	0.10	142.4
Mt. Washington	0.17	92.5	0.25	89.3	0.30	87.4
Mt. Wellington	0.14	108.9	0.22	103.3	0.27	100.1
Ottawa	0.16	83.5	0.23	80.6	0.28	78.9
Oulu	0.13	89.0	0.18	86.6	0.22	85.3
Pic du Midi	0.10	192.4	0.14	178.6	0.17	170.1
Resolute	0.03	15.9	0.04	16.7	0.05	17.1
Rio de Janeiro	0.03	154.3	0.06	138.4	0.10	128.2
Rome	0.06	191.6	0.10	176.0	0.13	166.1
Sulphur Mt.	0.18	52.0	0.26	50.1	0.32	49.2
Swarthmore	0.13	103.3	0.20	98.1	0.25	95.0
Thule	0.02	57.0	0.03	56.9	0.03	56.8
Uppsala	0.14	102.0	0.20	98.5	0.24	96.5
Ushuaia	0.07	171.1	0.11	159.4	0.15	152.8
Victoria	0.14	63.3	0.21	60.1	0.27	58.5
Yakutsk	0.15	92.7	0.21	89.9	0.26	88.4

30		50		100		200	
A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
0.08	118.7	0.16	102.0	0.31	82.8	0.50	66.8
0.17	150.7	0.23	136.1	0.31	119.2	0.37	104.0
0.15	123.0	0.23	109.7	0.35	92.8	0.47	77.4
0.39	47.8	0.49	46.6	0.61	45.0	0.71	43.1
0.35	76.5	0.45	73.0	0.58	68.3	0.69	63.6
0.28	39.5	0.34	39.1	0.42	37.9	0.48	36.2
0.30	87.1	0.40	81.9	0.51	75.9	0.61	70.6
0.26	108.4	0.35	98.9	0.47	87.2	0.59	76.4
0.36	73.5	0.45	70.9	0.56	67.0	0.66	62.7
0.32	82.7	0.42	77.9	0.55	72.0	0.66	66.6
0.36	87.2	0.45	83.4	0.55	78.0	0.65	72.2
0.31	78.6	0.39	76.5	0.47	73.0	0.54	68.9
0.16	102.6	0.24	89.1	0.36	74.6	0.48	62.8
0.16	144.0	0.24	124.5	0.37	100.1	0.53	79.9
0.23	16.2	0.27	17.0	0.33	17.6	0.38	17.8
0.37	34.9	0.48	33.9	0.61	32.5	0.73	30.9
0.31	107.7	0.39	103.8	0.47	98.7	0.53	93.3
0.05	130.1	0.13	100.2	0.29	75.8	0.51	59.1
0.30	109.2	0.38	105.4	0.47	100.2	0.52	94.8
0.29	115.2	0.37	110.3	0.46	103.9	0.52	97.4
0.30	117.9	0.38	113.1	0.47	106.8	0.53	100.3
0.26	−13.2	0.32	−11.2	0.39	−8.8	0.45	−6.9
0.01	209.2	0.02	210.9	0.01	217.4	0.01	232.8
0.16	133.1	0.25	117.7	0.38	98.9	0.51	82.8
0.32	101.6	0.40	97.7	0.49	92.6	0.55	87.4
0.17	131.4	0.27	119.1	0.41	104.3	0.53	90.9
0.38	84.9	0.48	81.8	0.58	77.5	0.66	73.0
0.35	96.1	0.43	91.5	0.55	85.5	0.62	79.4
0.36	76.6	0.45	73.6	0.55	69.3	0.65	64.6
0.27	83.8	0.33	82.1	0.39	79.6	0.44	76.9
0.23	159.6	0.28	148.3	0.34	135.0	0.36	122.9
0.06	17.4	0.08	17.4	0.10	16.9	0.11	16.0
0.16	114.8	0.25	99.5	0.41	81.1	0.60	65.8
0.17	153.5	0.23	139.5	0.29	122.1	0.34	105.3
0.40	48.1	0.49	47.0	0.61	45.4	0.70	43.7
0.33	91.0	0.42	86.3	0.55	79.8	0.64	73.1
0.03	56.3	0.04	55.1	0.05	52.3	0.06	48.5
0.30	94.2	0.37	91.6	0.45	88.1	0.51	84.3
0.20	145.0	0.27	136.8	0.34	127.1	0.38	117.8
0.36	56.6	0.46	54.5	0.59	51.6	0.70	48.5
0.33	86.7	0.40	84.8	0.48	82.1	0.55	79.2

Station	$\gamma = 0.4$ $R_0(GV)$ 10		15		20	
	A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$	A	$\langle \Psi_E \rangle$
Ahmedabad	0.00	222.2	0.01	160.1	0.03	140.5
Alma Ata	0.06	198.6	0.09	182.3	0.11	171.9
Buenos Aires	0.03	163.3	0.05	147.8	0.08	138.8
Calgary	0.17	53.1	0.25	51.1	0.30	50.1
Chicago	0.14	89.0	0.21	84.6	0.26	82.1
Churchill	0.14	40.0	0.19	39.9	0.23	39.8
Climax	0.10	109.3	0.16	100.7	0.21	96.2
Dallas	0.09	138.5	0.14	128.2	0.17	121.9
Deep River	0.16	81.7	0.23	79.0	0.28	77.4
Denver	0.11	101.7	0.17	94.6	0.23	90.7
Durham	0.16	99.0	0.23	95.1	0.27	92.8
Goose Bay	0.16	84.2	0.22	82.5	0.26	81.5
Hermanus	0.05	158.3	0.08	137.3	0.10	125.0
Huancayo	0.03	187.0	0.06	174.0	0.10	164.3
Inuvik	0.11	13.8	0.16	14.4	0.18	14.9
Kedguelen Is.	0.16	40.4	0.23	38.2	0.28	37.2
Kiel	0.13	121.4	0.19	116.6	0.23	113.9
Lae	0.01	258.2	0.02	226.6	0.02	190.9
Leeds	0.13	122.8	0.19	118.0	0.23	115.4
Lindau	0.11	132.4	0.17	126.3	0.22	122.8
London	0.12	134.7	0.18	128.8	0.23	125.4
Mawson	0.13	−17.5	0.17	−16.5	0.21	−15.7
McMurdo Sound	0.01	210.4	0.01	209.7	0.02	209.5
Mina Aguilar	0.03	173.6	0.06	159.5	0.09	150.4
Moscow	0.13	116.3	0.19	111.1	0.24	108.2
Mt. Norikura	0.03	170.1	0.06	155.1	0.09	146.4
Mt. Washington	0.17	94.7	0.25	91.4	0.30	89.6
Mt. Wellington	0.14	112.4	0.21	106.7	0.26	103.5
Ottawa	0.16	85.7	0.23	82.7	0.27	80.9
Oulu	0.14	91.0	0.19	88.6	0.23	87.2
Pic du Midi	0.09	198.2	0.13	185.2	0.16	177.1
Resolute	0.03	15.4	0.04	16.1	0.05	16.6
Rio de Janeiro	0.03	158.0	0.05	142.5	0.08	132.7
Rome	0.06	197.1	0.10	182.5	0.12	173.2
Sulphur Mt.	0.18	53.7	0.26	51.6	0.31	50.6
Swarthmore	0.13	106.6	0.20	101.2	0.24	98.1
Thule	0.02	57.2	0.03	57.0	0.03	56.9
Uppsala	0.15	104.8	0.20	101.1	0.24	99.1
Ushuaia	0.06	175.9	0.10	164.3	0.13	157.8
Victoria	0.14	65.6	0.21	62.2	0.26	60.4
Yakutsk	0.15	94.8	0.21	91.9	0.25	90.4

30		50		100		200	
A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
0.06	123.1	0.11	106.8	0.21	88.8	0.32	74.0
0.16	159.1	0.20	145.5	0.25	130.5	0.29	117.9
0.12	127.8	0.18	115.6	0.26	100.6	0.33	87.3
0.38	49.1	0.46	48.0	0.55	46.6	0.63	45.2
0.33	79.2	0.42	76.0	0.51	72.1	0.59	68.5
0.28	39.7	0.33	39.4	0.39	38.6	0.44	37.5
0.28	91.2	0.36	86.3	0.44	80.9	0.51	76.6
0.23	114.0	0.30	105.3	0.39	95.2	0.46	86.3
0.35	75.5	0.42	73.2	0.51	70.2	0.58	67.1
0.29	86.3	0.38	81.8	0.48	76.7	0.55	72.4
0.34	90.0	0.42	86.7	0.50	82.4	0.57	78.2
0.31	80.1	0.37	78.4	0.44	75.9	0.49	73.1
0.14	111.0	0.20	97.5	0.28	83.5	0.35	72.6
0.14	150.5	0.19	133.2	0.28	111.3	0.36	92.8
0.23	15.6	0.27	16.2	0.31	16.9	0.35	17.1
0.36	36.1	0.44	35.1	0.55	33.9	0.62	32.7
0.29	110.7	0.36	107.3	0.42	103.1	0.48	99.3
0.03	142.8	0.09	108.1	0.18	82.3	0.31	65.6
0.29	112.2	0.36	108.8	0.42	104.7	0.47	100.8
0.28	118.7	0.34	114.3	0.41	109.1	0.46	104.3
0.29	121.4	0.36	117.2	0.42	112.1	0.47	107.4
0.26	−14.4	0.31	−12.7	0.36	−10.8	0.41	−9.4
0.02	209.5	0.02	210.3	0.02	213.4	0.02	219.2
0.13	138.3	0.20	124.4	0.29	107.6	0.36	93.5
0.30	104.8	0.37	101.2	0.45	97.1	0.49	93.2
0.14	135.9	0.22	124.5	0.30	111.3	0.38	100.0
0.37	87.2	0.45	84.6	0.54	81.2	0.60	78.0
0.33	99.6	0.41	95.5	0.48	90.6	0.55	86.0
0.34	78.8	0.42	76.2	0.50	72.8	0.57	69.4
0.27	85.7	0.32	84.2	0.37	82.2	0.41	80.3
0.21	167.4	0.25	157.2	0.29	146.1	0.31	136.9
0.06	16.9	0.07	17.1	0.09	16.9	0.10	16.3
0.12	120.2	0.19	105.9	0.29	89.1	0.41	75.1
0.16	161.6	0.20	149.0	0.24	134.2	0.27	120.9
0.39	49.5	0.48	48.4	0.56	47.1	0.63	45.8
0.31	94.4	0.39	90.2	0.48	84.9	0.55	79.8
0.03	56.6	0.04	55.8	0.05	54.0	0.06	51.6
0.30	96.8	0.36	94.4	0.42	91.6	0.47	88.9
0.18	150.2	0.23	142.6	0.29	134.3	0.32	127.2
0.33	58.5	0.42	56.5	0.52	54.0	0.60	51.7
0.31	88.6	0.38	86.9	0.45	84.7	0.50	82.7

Station	$\gamma=0.0$ $R_0(GV)$ 50		100		150		200		1000	
	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
Ahmedabad	0.06	116.4	0.10	100.3	0.12	92.7	0.14	88.0	0.21	70.9
Alma Ata	0.16	164.5	0.18	152.9	0.19	147.7	0.19	144.6	0.20	133.4
Buenos Aires	0.11	126.8	0.16	115.1	0.17	109.4	0.19	105.7	0.23	91.7
Calgary	0.44	51.2	0.50	50.1	0.54	49.6	0.55	49.3	0.60	48.1
Chicago	0.36	82.5	0.43	79.6	0.46	78.2	0.48	77.4	0.52	74.2
Churchill	0.34	39.9	0.38	39.6	0.40	39.3	0.42	39.2	0.44	38.3
Climax	0.29	95.9	0.35	91.4	0.37	89.4	0.38	88.3	0.42	84.4
Dallas	0.24	118.0	0.29	110.4	0.31	106.9	0.33	104.6	0.36	96.5
Deep River	0.40	78.2	0.46	76.1	0.48	75.1	0.50	74.5	0.55	71.9
Denver	0.31	90.3	0.37	86.2	0.40	84.4	0.42	83.3	0.46	79.5
Durham	0.39	93.2	0.45	90.4	0.48	89.0	0.48	88.1	0.53	84.6
Goose Bay	0.38	82.2	0.43	80.7	0.45	79.9	0.46	79.4	0.49	77.3
Hermanus	0.14	117.3	0.17	104.2	0.19	98.4	0.20	95.0	0.23	83.1
Huancayo	0.13	148.8	0.16	132.6	0.18	124.5	0.19	119.2	0.23	100.0
Inuvik	0.28	15.0	0.31	15.4	0.33	15.6	0.34	15.7	0.36	15.8
Kerguelen Is.	0.40	38.2	0.47	37.1	0.50	36.6	0.52	36.3	0.57	35.2
Kiel	0.33	114.2	0.38	111.2	0.40	109.9	0.41	109.1	0.43	106.0
Lae	0.03	131.3	0.07	97.9	0.10	86.5	0.11	80.1	0.19	60.4
Leeds	0.32	115.7	0.37	112.8	0.39	111.4	0.41	110.6	0.43	107.5
Lindau	0.29	122.3	0.35	118.6	0.36	116.8	0.37	115.8	0.40	111.9
London	0.31	125.4	0.36	121.7	0.38	120.1	0.39	119.1	0.42	115.3
Mawson	0.32	−15.0	0.36	−13.9	0.37	−13.4	0.38	−13.1	0.42	−12.2
McMurdo Sound	0.02	210.6	0.02	211.3	0.02	211.9	0.02	212.4	0.02	215.2
Mina Aguilar	0.13	136.7	0.17	123.7	0.19	117.4	0.21	113.5	0.24	99.5
Moscow	0.34	108.6	0.39	105.5	0.41	104.2	0.42	103.3	0.45	100.3
Mt. Norikura	0.14	134.9	0.18	124.4	0.21	119.4	0.22	116.3	0.26	105.1
Mt. Washington	0.43	90.1	0.49	87.8	0.52	86.7	0.53	86.1	0.57	83.6
Mt. Wellington	0.36	103.9	0.42	100.3	0.44	98.6	0.46	97.6	0.49	93.9
Ottawa	0.39	81.6	0.45	79.3	0.48	78.2	0.49	77.5	0.53	74.7
Oulu	0.33	88.7	0.36	87.3	0.38	86.7	0.39	86.3	0.42	84.8
Pic du Midi	0.22	174.5	0.24	166.5	0.25	163.0	0.25	161.0	0.26	154.6
Resolute	0.08	16.1	0.09	16.2	0.09	16.1	0.10	16.1	0.10	15.8
Rio de Janeiro	0.12	118.3	0.17	104.7	0.20	98.0	0.21	93.8	0.27	78.4
Rome	0.16	167.2	0.18	156.6	0.19	151.7	0.19	148.7	0.20	137.6
Sulphur Mt.	0.45	51.8	0.52	50.7	0.55	50.2	0.56	49.9	0.61	48.9
Swarthmore	0.35	98.1	0.40	94.4	0.42	92.6	0.44	91.4	0.48	87.2
Thule	0.04	56.8	0.05	56.1	0.05	55.6	0.05	55.2	0.06	53.4
Uppsala	0.35	100.6	0.40	98.5	0.42	97.5	0.42	97.0	0.45	94.9
Ushuaia	0.18	154.3	0.22	147.8	0.23	145.0	0.24	143.3	0.25	137.5
Victoria	0.36	61.1	0.43	59.1	0.46	58.2	0.48	57.7	0.53	55.5
Yakutsk	0.36	91.4	0.42	89.8	0.43	89.1	0.45	88.7	0.48	87.0

Station	$\gamma=-0.6$									
	$R_0(GV)$									
	50		100		150		200		1000	
	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
Ahmedabad	0.02	132.8	0.03	117.0	0.04	110.7	0.04	107.1	0.06	95.6
Alma Ata	0.12	190.7	0.14	183.2	0.14	180.3	0.14	178.7	0.15	174.2
Buenos Aires	0.06	143.0	0.08	134.4	0.09	130.7	0.10	128.6	0.10	121.9
Calgary	0.46	58.1	0.51	57.0	0.53	56.6	0.54	56.4	0.56	55.8
Chicago	0.35	94.3	0.39	91.9	0.41	91.0	0.42	90.5	0.43	89.1
Churchill	0.42	40.9	0.46	40.7	0.47	40.7	0.48	40.6	0.49	40.5
Climax	0.23	114.6	0.27	110.3	0.28	108.7	0.29	107.8	0.30	105.5
Dallas	0.20	136.2	0.23	131.2	0.24	129.2	0.24	128.0	0.26	124.7
Deep River	0.42	87.4	0.46	85.8	0.48	85.2	0.48	84.9	0.51	83.9
Denver	0.26	105.7	0.30	102.1	0.32	100.8	0.33	100.0	0.35	98.0
Durham	0.40	103.9	0.44	101.9	0.46	101.1	0.47	100.7	0.48	99.5
Goose Bay	0.45	88.6	0.49	87.6	0.51	87.3	0.52	87.1	0.54	86.4
Hermanus	0.10	153.6	0.11	143.0	0.12	138.7	0.12	136.3	0.13	129.4
Huancayo	0.08	167.1	0.10	157.6	0.10	153.3	0.10	150.8	0.11	142.7
Inuvik	0.36	13.7	0.38	13.9	0.40	14.0	0.40	14.0	0.42	14.1
Kerguelen Is.	0.40	44.7	0.44	43.6	0.46	43.2	0.48	42.9	0.50	42.3
Kiel	0.31	125.2	0.36	123.0	0.36	122.2	0.37	121.8	0.39	120.5
Lae	0.02	204.9	0.02	150.7	0.02	127.7	0.02	116.4	0.03	89.0
Leeds	0.30	126.9	0.35	124.7	0.36	123.9	0.36	123.4	0.38	122.1
Lindau	0.26	135.4	0.29	132.5	0.30	131.4	0.31	130.8	0.33	129.1
London	0.29	138.9	0.32	136.1	0.34	135.0	0.34	134.5	0.36	132.9
Mawson	0.39	−16.7	0.42	−16.3	0.44	−16.1	0.45	−16.0	0.47	−15.8
McMurdo Sound	0.03	212.0	0.03	212.0	0.03	212.0	0.03	212.0	0.03	212.2
Mina Aguilar	0.07	152.6	0.10	143.8	0.10	140.0	0.10	137.8	0.11	131.1
Moscow	0.33	120.7	0.36	118.3	0.38	117.4	0.39	117.0	0.41	115.6
Mt. Norikura	0.08	149.8	0.10	141.8	0.10	138.5	0.11	136.6	0.12	131.0
Mt. Washington	0.45	98.6	0.49	97.1	0.51	96.5	0.52	96.2	0.55	95.2
Mt. Wellington	0.35	118.1	0.38	115.4	0.40	114.3	0.41	113.7	0.42	112.1
Ottawa	0.40	91.4	0.44	89.7	0.46	89.0	0.47	88.6	0.49	87.6
Oulu	0.39	97.2	0.42	96.1	0.43	95.7	0.44	95.4	0.46	94.8
Pic du Midi	0.20	198.3	0.22	193.0	0.23	191.1	0.23	190.0	0.23	187.3
Resolute	0.10	14.2	0.10	14.4	0.10	14.5	0.10	14.5	0.11	14.6
Rio de Janeiro	0.07	135.6	0.09	125.8	0.10	121.5	0.10	119.0	0.11	110.9
Rome	0.13	191.6	0.15	185.1	0.15	182.5	0.16	181.1	0.16	177.2
Sulphur Mt.	0.48	58.9	0.53	57.8	0.55	57.4	0.56	57.2	0.59	56.7
Swarthmore	0.31	111.8	0.36	108.9	0.37	107.8	0.38	107.2	0.40	105.5
Thule	0.06	58.0	0.06	57.8	0.06	57.7	0.06	57.6	0.07	57.3
Uppsala	0.38	111.7	0.42	110.0	0.43	109.4	0.44	109.1	0.46	108.1
Ushuala	0.15	172.0	0.16	167.1	0.17	165.2	0.18	164.2	0.19	161.5
Victoria	0.34	70.2	0.38	68.4	0.40	67.8	0.41	67.4	0.43	66.4
Yakutsk	0.37	100.0	0.42	98.6	0.43	98.0	0.44	97.8	0.46	97.0

Station	$\gamma=-1.0$									
	$R_0(GV)$									
	50		100		150		200		1000	
	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$	A	$\langle\Psi_E\rangle$
Ahmedabad	0.01	149.9	0.02	129.8	0.02	123.3	0.02	119.8	0.03	119.0
Alma Ata	0.11	205.4	0.12	199.9	0.13	197.8	0.13	196.7	0.14	193.9
Buenos Aires	0.04	153.9	0.05	146.4	0.06	143.4	0.06	141.8	0.07	137.2
Calgary	0.50	64.6	0.55	63.5	0.57	63.0	0.58	62.8	0.60	62.3
Chicago	0.36	104.2	0.39	101.9	0.41	101.1	0.42	100.7	0.43	99.5
Churchill	0.55	41.7	0.58	41.6	0.59	41.6	0.60	41.5	0.61	41.5
Climax	0.22	131.3	0.24	126.7	0.25	125.1	0.26	124.3	0.27	122.2
Dallas	0.19	147.4	0.22	143.5	0.23	142.0	0.23	141.2	0.23	139.1
Deep River	0.46	95.5	0.50	94.0	0.52	93.5	0.53	93.2	0.55	92.4
Denver	0.25	118.5	0.29	114.9	0.29	113.7	0.30	113.0	0.31	111.4
Durham	0.43	111.8	0.48	110.1	0.49	109.4	0.50	109.1	0.52	108.3
Goose Bay	0.56	93.7	0.61	92.8	0.61	92.6	0.62	92.4	0.64	92.0
Hermanus	0.10	177.1	0.10	169.5	0.11	166.5	0.11	164.9	0.11	160.6
Huancayo	0.06	176.3	0.07	169.5	0.08	166.6	0.08	165.0	0.09	160.4
Inuvik	0.47	13.2	0.50	13.3	0.51	13.3	0.51	13.4	0.53	13.4
Kerguelen Is.	0.42	50.6	0.46	49.4	0.48	48.9	0.48	48.7	0.50	48.2
Kiel	0.33	133.3	0.36	131.3	0.37	130.6	0.37	130.3	0.39	129.3
Lae	0.02	241.8	0.01	221.2	0.01	207.7	0.01	197.7	0.01	153.4
Leeds	0.31	135.5	0.35	133.4	0.36	132.7	0.36	132.3	0.38	131.3
Lindau	0.24	145.7	0.28	142.8	0.29	141.8	0.29	141.3	0.30	140.0
London	0.29	149.2	0.32	146.6	0.33	145.6	0.34	145.1	0.35	143.9
Mawson	0.51	−17.0	0.55	−16.8	0.55	−16.8	0.56	−16.7	0.58	−16.6
McMurdo Sound	0.05	213.0	0.05	212.9	0.05	212.9	0.05	212.9	0.05	212.9
Mina Aguilar	0.05	161.9	0.06	154.8	0.07	152.0	0.07	150.4	0.08	145.9
Moscow	0.34	129.5	0.37	127.4	0.39	126.6	0.40	126.2	0.41	125.2
Mt. Norikura	0.05	159.5	0.07	152.6	0.07	149.9	0.08	148.4	0.08	144.4
Mt. Washington	0.48	104.8	0.53	103.4	0.55	102.9	0.55	102.7	0.58	102.0
Mt. Wellington	0.36	129.5	0.39	126.9	0.41	125.9	0.42	125.5	0.42	124.2
Ottawa	0.43	99.9	0.48	98.3	0.48	97.7	0.49	97.3	0.52	96.5
Oulu	0.48	104.0	0.51	102.9	0.52	102.5	0.53	102.3	0.55	101.9
Pid du Midi	0.20	212.1	0.22	208.1	0.23	206.6	0.23	205.8	0.23	204.0
Resolute	0.12	12.9	0.13	13.1	0.14	13.2	0.14	13.2	0.14	13.3
Rio de Janeiro	0.04	146.2	0.06	138.3	0.06	135.0	0.07	133.1	0.07	127.8
Rome	0.12	205.2	0.14	200.4	0.14	198.6	0.15	197.6	0.15	195.2
Sulphur Mt.	0.53	65.6	0.57	64.4	0.59	64.0	0.61	63.8	0.62	63.3
Swarthmore	0.32	123.1	0.36	120.4	0.36	119.4	0.37	118.9	0.39	117.5
Thule	0.08	58.9	0.08	58.8	0.08	58.7	0.08	58.7	0.09	58.5
Uppsala	0.44	120.6	0.48	119.0	0.49	118.4	0.50	118.2	0.51	117.4
Ushuaia	0.13	183.6	0.15	179.4	0.16	177.9	0.16	177.1	0.16	175.0
Victoria	0.34	78.6	0.37	76.7	0.39	76.0	0.40	75.6	0.42	74.7
Yakutsk	0.42	106.9	0.45	105.6	0.47	105.1	0.47	104.8	0.48	104.2

previous treatment in the case of the diurnal variation.[13] The values of asymptotic directions (λ, φ) for nine zenith and azimathal directions were taken from McCRACKEN ET AL. 's[9] and the response function was referred to LOCKWOOD and WEBBER 's.[14] The ratio of the contribution factor of counting rates from three cones; $\theta \leq 8°$, $8° \leq \theta \leq 24°$, and $24° \leq \theta \leq 40°$, where θ is the zenith angle of incidence at the top of the atmosphere, were chosen as 1 : 3.2 : 5.2. The calculation for each station for the nucleonic component were made for the following cases;

$$\gamma = +4.0,\ +3.5,\ +3.0,\ +2.5,\ +2.0,\ +1.5,\ +1.0,\ +0.6,$$
$$+0.4,\ +0.2,\ 0.0,\ -0.2,\ -0.4,\ -0.6,,\ \text{and}\ -1.0,$$

for both types of spectra,

$$R_l = 0,\ 3,\ \text{and}\ 5\ GV,$$

and

$$R_h = 1000,\ 600,\ 300,\ 100,\ 80,\ 50,\ \text{and}\ 30\ GV,$$

for the power-type spectrum,

$$R_0 = 200,\ 150,\ 100,\ 70,\ 50,\ 40,\ 30,\ 20,\ 15,\ \text{and}\ 10\ GV,$$

and R_l is fixed as 0 GV for the exponential-type spectrum. The results are tabulated for the case where the spectral form is of the exponential-type of $R^{\gamma}\exp(-R/R_0)$, and the latitude distribution has a form of $\frac{\sqrt{3}}{2}\cos^2\lambda$. The results are given in Table 1 for various parameters γ and R_0 for 41 stations. Relative amplitudes are normalized at 10 GV, and average deflection angles are doubled and given in degrees for convinience, where 1 hour corresponds to 30 degrees.

§ 3 Results and Discussion

We compared the calculated results for the two types of the latitude distribution of $\frac{\sqrt{3}}{2}\cos^2\lambda$ and $\cos\lambda$. The difference between these two cases is evident in the relative amplitude, particularly for high and very high latitude stations as shown in Fig. 1. For instance, at Thule, one of very high latitude stations, the amplitude for the case of $\frac{\sqrt{3}}{2}\cos^2\lambda$ is less by an amount of about one third than that for $\cos\lambda$ for any combination of γ and R_0. Differences between the deflection angle are less than several degrees. On the other hand, at middle and low latitude stations, whose asymptotic latitudes go down to the equator, the differences are very small in both the amplitude and average deflection angle. The above results are easily understood from the fact that the $\cos^2\lambda$ falls off very sharply with λ than the $\cos\lambda$. We compared the results for the two types of the spectra, the exponential-type and power-type. As shown in Fig. 2, the

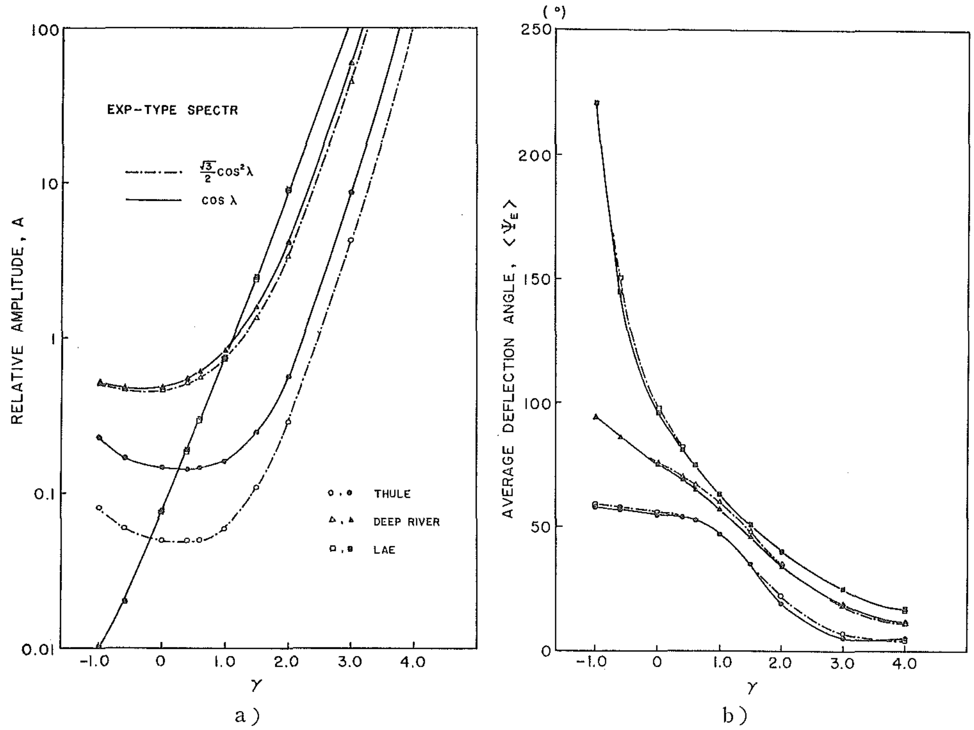


Fig. 1 a) Relative amplitude, A and b) average deflection angle, $\langle\Psi_E\rangle$, for two types of the latitude distributon of $\frac{\sqrt{3}}{2}\cos^2\lambda$ and $\cos\lambda$. Blanck marks are for the former and solid marks for the latter of the exponential-type spectrum with $R_0 = 100\,GV$. At Thule (very high latitude station), at Deep River (middle latitude station), and at Lae (equatorial station) for various spectral exponent γ; ○, Thule, △, Deep River, and □, Lae for $\frac{\sqrt{3}}{2}\cos^2\lambda$, ●, Thule, ▲, Deep River, and ■, Lae for $\cos\lambda$.

difference of the two calculated results is not so evident for negative γ-values, while it is obvious for positive γ-values. For instance, at Thule, for $\gamma = 0.0$, the difference between the two results is only about 5% in amplitude and around 5° in average deflection angle for the case of $R_h = 50\,GV$ and $R_0 = 50\,GV$. For greater positive γ-values the difference becomes larger; for $\gamma = 3.0$, the difference exceeds about 200% in amplitude and around 30° in deflection angle for the same case as above. This tendency can be understood from the following consideration. The exponential-type spectrum has its peak intensity at the rigidity $R = \gamma R_0$ for positive γ-values, and this rigidity may be effective for producing the variation. On the contrary, in the case of the power-type spectrum, the above effective

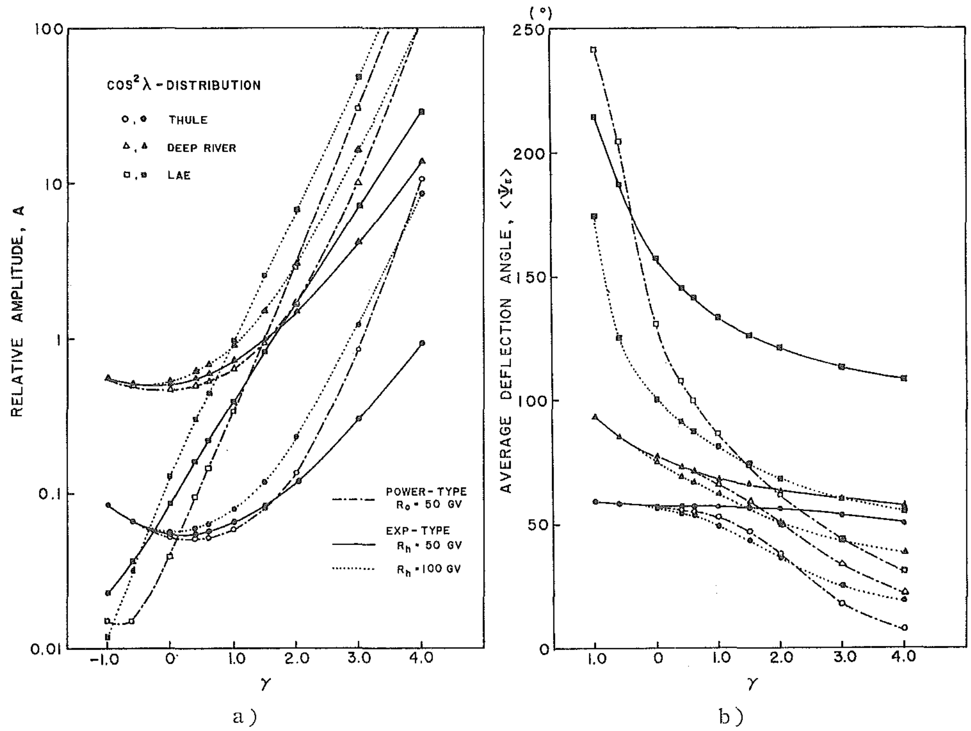
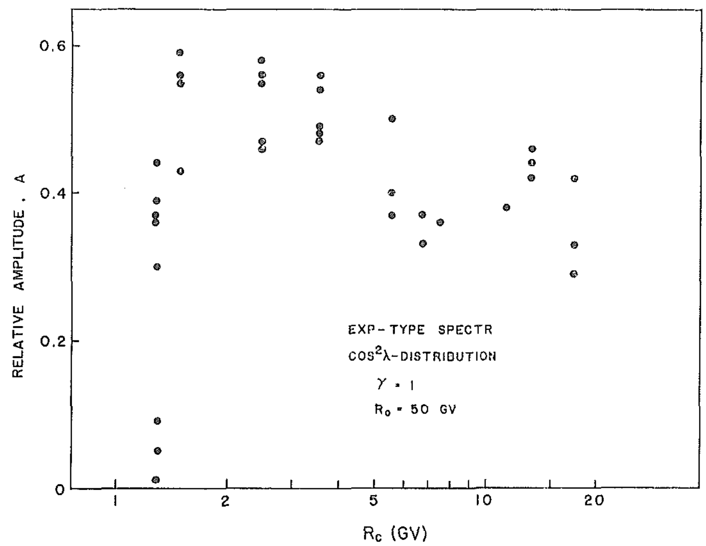


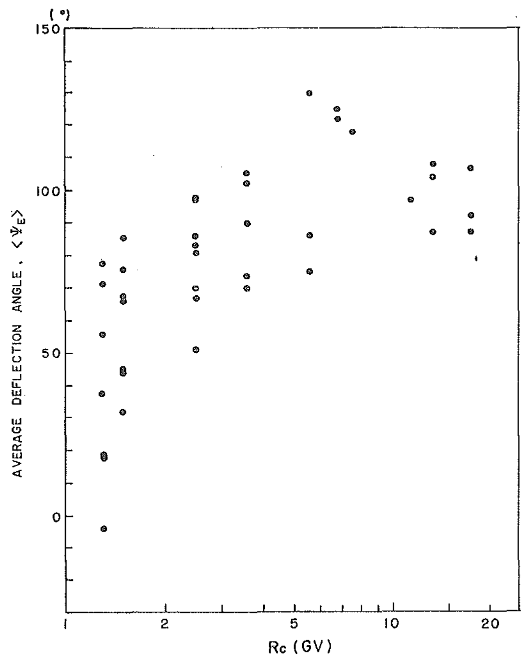
Fig. 2 a) Relative amplitude, A, and b) average deflection angle, $\langle \Psi_E \rangle$, for two types of the spectral dependence with the latitude distribution of $\frac{\sqrt{3}}{2}\cos^2\lambda$, for various spectral exponent γ. For exponential-type spectrum; ○, Thule, △, Deep River, and □, Lae, ······ for $R_0 = 50\ GV$; for power-type spectrum; ○, Thule, △, Deep River, and □, Lae, —— for $R_h = 50\,GV$, and ······ for $R_h = 100\,GV$.

rigidity may be close to $R = R_h$. Thus, the results with some R_h would rather correspond to the results with some γR_0 for the greater positive γ-values. For reference, the calculated amplitude and deflection angle for the case where the latitude distribution is $\frac{\sqrt{3}}{2}\cos^2\lambda$ and the spectrum of $R^\gamma \exp(-R/R_0)$, are plotted in Fig. 3 versus the geomagnetic cut-off rigidity R_c for each station.

In the present calculation, we expressed approximately the semi-diurnal anisotropy with the projected harmonic component f_2^2 only as shown in Eq. (7), and also neglected the annual movement of $(\alpha_J - \alpha_R)$. As described above, the assumption may be reasonable, because so far as yearly mean values of the second harmonic component are concerned the component of the daily variation originated from f_3^2 will vanish by being averaged over throughout one year. Strictly speaking, we should have to take into consideration all the components, f_n^ms, and



a)



b)

Fig. 3 The distribution of A and $\langle\Psi_E\rangle$ versus geomagnetic cut-off rigidity for various stations.

a) Relative amplitude, A, and b) avererage deflection angle, $\langle\Psi_E\rangle$, for the latitude distribution of $\frac{\sqrt{3}}{2}\cos^2\lambda$, and the spectrum of $R^\gamma \exp(-R/R_0)$ versus geomagnetic cut-off rigidity R_c for $\gamma = 1$ and $R_0 = 50\,GV$.

also the annual movement of $(\alpha_J - \alpha_R)$ in Eq. (2). For the sake of an extensive analysis of neutron monitor data we would make a theoretical calculation of all the components of the daily variation produced by $f_n{}^m$s, by taking into accounts the annual movement of $(\alpha_J - \alpha_R)$. The calculations are now in progress and will be published in the near future.

§ 4 Conclusions

It is concluded from the discussions as follows:

At high and very high latitude stations, the relative amplitude for the latitude distribution of $\frac{\sqrt{3}}{2}\cos^2\lambda$ is less by an amount of about one third than that for $\cos\lambda$ for any combination of γ and R_0. On the other hand, for middle and low latitude stations, the differences are very small in both the amplitude and deflection angle.

From comparison of the results in the two types of spectra, a tendency would be noted that the calculated results with some higher cut-off rigidity in the power-type spectrum rather corresponds to the results with the rigidity giving the peak intensity in the exponential-type spectrum.

The results are tabulated for 41 stations for the case where the spectral form is of the exponential-type of $R^\gamma \exp(-R/R_0)$ and the latitude distribution has a form of $\frac{\sqrt{3}}{2}\cos^2\lambda$.

Acknowledgement

The authors wish to express hearty thanks to Prof. KAZUO NAGASHIMA for his helpful suggestions and continuous encouragement during this work. The present calculations were carried out by using HITAC 5020 computer at the Computer Center in the University of Tokyo and some were also calculated by FACOM 231 in Shinshu University.

References

[1] SUBRAMANIAN, G. and SARABHAI, V. (1967) Astrophys. J., **149**, 417.

[2] ABLES, J. G., MCCRACKEN, K. G. and RAO, U. R. (1966) Proc. Intern. Conf. Cosmic Rays, **1**, 208.

[3] PATEL, D., SARABHAI, V. and SUBRAMANIN, G. (1968) Canadian J. Phys., **46**, 981.

[4] LIETTI, B. and QUENBY, J. J. (1968) Canadian J. Phys., **46**, 942.

[5] FUJI, Z. FUJIMOTO, K., UENO, H., KONDO, I. and NAGASHIMA, K. (1969) Proc. Intern. Conf. Cosmic Rays, (Budapest).

[6] YASUE, S., MORI, S., SAGISAKA, S. and ICHINOSE, M. (1970) (To be published).

[7] FUJII, Z. (1970) (To be published).

[8] NAGASHIMA, K. (1970) (To be published).

NAGASHIMA, K. and UENO, H. (1970) (To be published).

FUJII, Z., FUJIMOTO, K., UENO, H., KONDO, I. and NAGASHIMA, K. (1970) (To be published).

FUJIMOTO, K., FUJII, Z., UENO, H., KONDO, I. and NAGASHIMA, K. (1970) (To be published).

[9] SARABHAI, V., PAI, G. L. and WADA, M. (1965) Space Research VI. (North Holland).

[10] MCCRACKEN, K. G., RAO, U. R., FOWLER, B. C., SHEA, M. A., and SMART, D. F. (1965) IQSY Instruction Manual, No. 10.

[11] CHAPMAN, S. and BARTELS, J. (1940) Geomagnetism (Oxford).

[12] NAGASHIMA, K., POTNIS, V. R. and POMERANTZ, M. A. (1961) Nuovo Cimento, **19**, 282.

[13] MORI, S. (1968) Nuovo Cimento, **58**, 1.

[14] LOCKWOOD, J. A. and WEBBER, W. R. (1967) J. Geophys. Res., **72**, 3395.