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DEPLETION OF OZONE AND ITS EFFECT ON NIGHT AIRGLOW INTENSITY OF Na 5893 A° AT TRIVANDRUM (8.25° N, 76.9° E) AND HALLEY BAY (76° S, 27° W)

1. In a dark moonless night away from city light, a certain amount of light is observed to come from space. Excluding the light from stars, zodical belt, galaxy and that scattered by atmospheric particles, the remaining light of about 40% is produced by the self luminiscence of atmospheric atoms and molecules and it is called airglow. Na 5893A° line is one of the important emissions of airglow spectrum. The excitation mechanism of sodium airglow line indicates that the intensity of Na 5893A° line is affected with the depletion of ozone. The global ozone assessment confirms that ozone is declining everywhere with smaller amount (Jana *et al*., 2001). But Farman *et al*. (1985) first reported that dramatic decrease of ozone concentration takes place at Antarctica during spring time. Afterwards it was verified by different investigators

TABLE 1

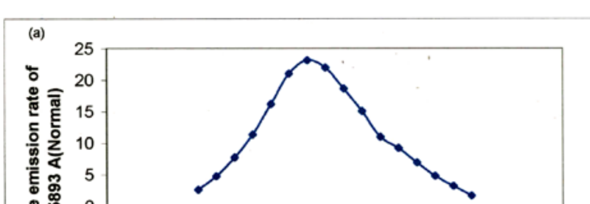
Volume emission rates of Na 5893A°

Altitude (km)	Number densities (atoms / cc)					Volume emission rates (Q) of Na 5893A°		
	n(Na)×10^{-3}	n(O) ×10^{-11}	n(O_3) ×10^{-7}	Trivandrum n(O_3) × 10^{-7} at peak emission light	Halley Bay n(O_3) ×10^{-7} at peak emission light	Normal	Trivandrum	Halley Bay
85	1.0	1.00	10.0	10.221	11.429	2.60	2.657	2.971
86	1.4	1.29	10.2	10.425	11.657	4.76	4.865	5.440
87	1.8	1.58	10.4	10.630	11.886	7.69	7.860	8.790
88	2.2	1.87	10.6	10.834	12.115	11.34	11.590	12.960
89	2.6	2.16	10.8	11.040	12.343	16.18	16.540	18.492
90	3.0	2.45	11.0	11.243	12.572	21.02	21.480	24.024
91	3.5	2.99	8.5	8.688	9.714	23.12	23.621	26.424
92	4.0	3.52	6.0	6.133	6.857	21.96	22.445	25.090
93	3.6	3.98	5.0	5.110	5.714	18.63	19.042	21.292
94	3.3	4.43	4.0	4.090	4.572	15.07	15.400	17.224
95	3.1	4.54	3.0	3.070	3.429	10.98	11.223	12.550
96	3.7	4.85	2.7	2.759	3.086	9.19	9.393	10.500
97	2.3	4.86	2.4	2.453	2.743	6.90	7.052	7.890
98	1.8	4.88	2.1	2.146	2.400	4.79	4.896	5.474
99	1.4	4.76	1.8	1.840	2.050	3.21	3.281	3.670
100	0.9	4.63	1.5	1.533	1.714	1.63	1.667	1.863

TABLE 2

Yearly variation of intensity of Na 5893 A° line at Trivandrum and Halley Bay

Year	Mean O_3 (DU) at Trivandrum	% O_3 depletion from mean at Trivandrum	Mean O_3 (DU) at Halley Bay	% O_3 depletion from mean at Halley Bay	Peak volume emission rate of Na 5893A° at Trivandrum	Peak volume emission rate of Na 5893A° at Halley Bay	Intensity of Na 5893A° at Trivandrum	Intensity of Na 5893A° at Halley Bay
1979	266.34	0.72	303.73	15.04	23.29	26.59	163.01	186.18
1980	270.27	2.21	301.75	14.29	23.63	26.42	165.42	184.97
1981	266.13	0.64	298.42	13.03	23.27	26.13	162.87	182.93
1982	266.01	0.60	286.09	8.36	23.26	25.05	162.81	175.37
1983	260.33	-1.55	289.70	9.72	22.76	25.37	159.33	177.57
1984	257.52	-2.61	272.28	3.12	22.52	23.84	157.61	166.89
1985	267.34	1.10	263.72	-0.12	23.37	23.09	163.62	161.65
1986	260.18	-1.60	270.77	2.55	22.75	23.71	159.25	165.97
1987	262.51	-0.72	254.54	-3.59	22.95	22.29	160.67	156.03
1988	262.94	-0.56	282.24	6.89	22.99	24.71	160.93	172.99
1989	267.81	1.28	261.90	-0.81	23.42	22.93	163.91	160.53
1990	271.25	2.58	250.39	-5.17	23.72	21.92	166.02	153.47
1991	267.43	1.14	257.21	-2.58	23.38	22.52	163.68	157.66
1992	261.85	-0.97	250.62	-5.08	22.89	21.95	160.27	153.62
1993	258.35	-2.29	247.82	-6.14	22.59	21.70	158.13	151.90
1994	259.12	-2.00	233.48	-11.57	22.66	20.45	158.60	143.12
1995	-	-	-	-	-	-	-	-
1996	263.25	-0.44	203.68	-22.86	23.02	17.83	161.13	124.84
1997	269.57	1.94	250.84	-4.99	23.57	21.97	164.98	153.76
1998	265.89	0.55	237.32	-10.12	23.25	20.78	162.73	145.46



Figs. 1(a-c). Volume emission rates of Na 5893A° at (a) normal period, (b) Trivandrum (8.25° N, 76.9° E) and (c) Halley Bay (76° S, 27° W) respectively

throughout the world (Midya and Jana, 2002). If ozone hole is created at any place in the atmosphere, O_3 concentration also decreases in other regions due to atmospheric diffusion and circulation (Midya *et al*. 2001). From the excitation mechanism of Na 5893A°, the volume emission rate of Na 5893A° is calculated for normal period. From the volume emission rate curve, the intensity of Na 5893A° is calculated. Following this process, the intensity of the same line for the two stations namely, Trivandrum (8.25° N, 76.9° E) and Halley Bay (76° S, 27° W), are calculated for other years, considering the depletion of O_3. The nature of variations of the intensity of Na 5893A° line are compared for the above stations. Ions, atoms and molecules are not visible to us. From the variation of intensity of airglow emission line which is related to O_3 concentration, one can estimate the variation of number density of different types of ions, atoms and molecules. In this paper, we have calculated the variation of airglow intensity of Na 5893A° for above stations and compared the nature of variations. This process may be continued for other stations also.

2. *Discussions and conclusion* - Chapman (1939) first discussed the photochemistry of Na. The excitation mechanism is as follows:

$$NaO^* + O \xrightarrow{K_1} Na^*\left(^2P\right) + O_2$$

$$Na^*\left(^2P\right) \longrightarrow Na\left(^2S\right) + h\upsilon\left(5893A^{\circ}\right)$$

NaO* may be produced by other way :

(*i*) $$Na + O + M \xrightarrow{K_2} NaO^* + M$$

(*ii*) $$Na + O_2 + M \xrightarrow{K_3} NaO_2 + M$$

$$NaO_2 + O \xrightarrow{K_4} NaO^* + O_2$$

(*iii*) $$Na + O_3 \xrightarrow{K_5} NaO^* + O_2$$

where M represents a third body required to carry away excess energy and momentum. K_1, K_2, K_3, K_4 and K_5 are the rate co-efficients having numerical values 4×10^{-11} cm^3 s^{-1}, 7×10^{-33} cm^6 s^{-1}, 2×10^{-33}cm^6 s^{-1}, 1×10^{-11} cm^3 s^{-1} and 6.56×10^{-12} cm^3 s^{-1}, respectively (Kvifte, 1973). Ghosh and Midya (1987) showed that the volume emission rate of reaction (*iii*) at 90 km is greater than those of reactions (*i*) and (*ii*). Thus it may be concluded that O_3 plays an important role for the emission of 5893A° line. The volume emission rate of NaO* by reaction (*iii*) is given by

$$n\,(NaO^*) = K_5\, n\,(Na)\, n\,(O_3)$$

Ignoring the quenching terms, the rate of production of Na * is

$$n(Na^*) = K_1\, n(NaO^*) \times n(O)$$

$$= K_1 K_5\, n(Na)\, n(O)\, n(O_3)$$

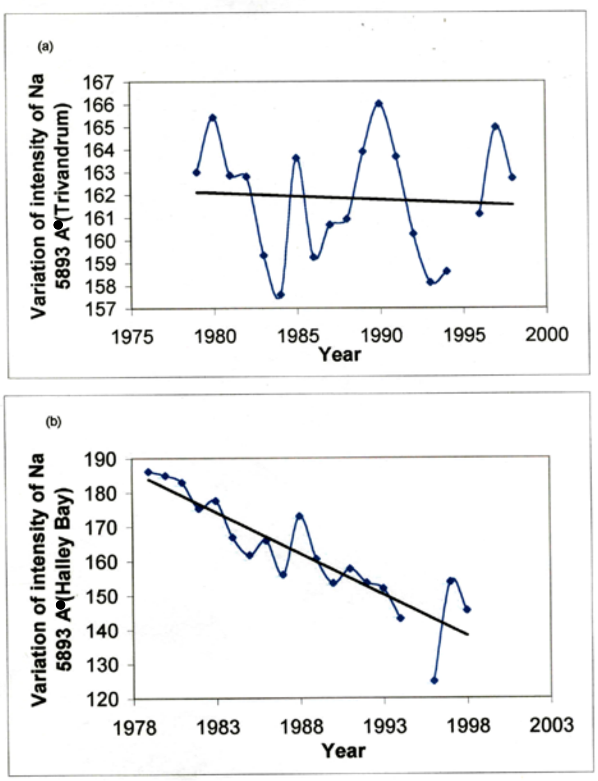
Using the number densities of Na, O and O_3 given in Table 1, the volume emission rate of n(Na*) for normal period and for the year 1979 are calculated for the said two stations and are shown in Figs. 1(a-c), respectively. Night time n(Na) is taken from rader laser data of Gibson and Sandford (1971), $n(O_3)$ and n(O) are taken from Krassovosky (1971) and Jachia (1977), respectively. Intensity is then calculated from the volume emission rate curve with the help of the following equation.

Intensity = ½ × layer thickness × peak volume emission rate.

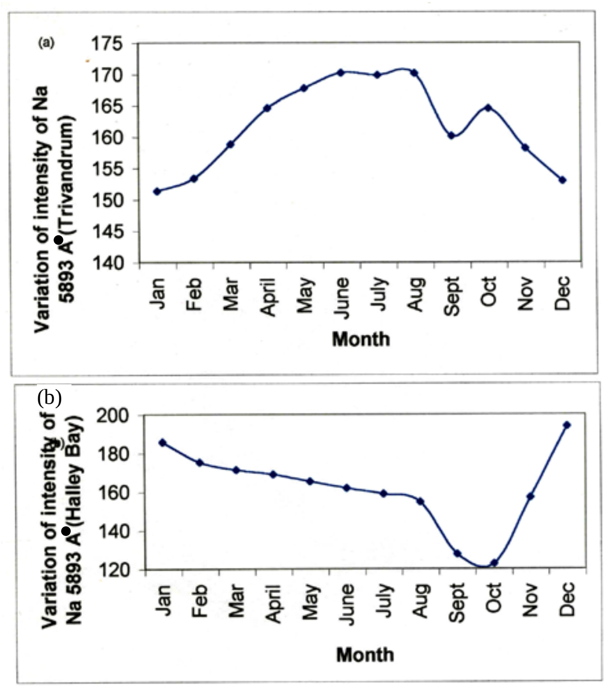
TABLE 3

Seasonal variation of intensity of Na 5893A° line at Trivandrum and Halley Bay

Month	Mean O^3 (DU) Trivandrum	% O_3 depletion from mean at Trivandrum	Intensityof Na 5893A° at Trivandrum	Mean O^3 (DU) at Halley Bay	% O_3 depletion from mean at Halley Bay	Intesity of Na 5893A° at Halley Bay
January	245.99	-6.50	151.32	306.43	14.70	185.63
February	249.35	-5.22	153.39	289.39	8.32	175.30
March	258.17	-1.87	158.81	282.61	5.79	171.21
April	267.60	1.71	164.60	278.68	4.32	168.83
May	272.76	3.67	167.78	272.78	2.10	165.24
June	276.68	5.17	170.21	266.88	-0.10	161.68
July	276.16	4.97	169.88	261.98	-1.94	158.70
August	276.67	5.16	170.19	255.07	-4.52	154.52
September	260.34	-1.05	160.14	210.70	-21.13	127.64
October	267.52	1.68	164.56	202.59	-24.17	122.72
November	257.13	-2.26	158.18	258.99	-3.05	156.90
December	248.71	-5.47	152.99	319.87	19.73	193.77



Figs. 2(a&b). Yearly variations of intensity of Na 5893A° line at (a) Trivandrum (8.25° N, 76.9° E) and (b) Halley Bay (76° S, 27° W)



Figs. 3(a&b). Seasonal variations of intensity of Na 5893A° line at (a) Trivandrum (8.25° N, 76.9° E) and (b) Halley Bay (76° S, 27° W)

The intensity of 5893A° line is calculated for the normal period and it is 161.84 R, which fairly agrees with accepted value and that for the year 1980 becomes 165.42 R for the station Trivandrum and 184.97 R for the station Halley Bay (76° S, 27° W). Following this process, the intensity of 5893A° line for different years are calculated theoretically for the stations Trivandrum and Halley Bay for the period 1979-1998 shown in Table 2. The variations of intensities are shown in Figs. 2(a&b). It is clear from Fig. 2 that the rate of decrease of intensities of Na 5893A° line for Trivandrum and Halley Bay are 0.0299R and 2.4038R per year, respectively. The excitation mechanism clearly reveals that the volume emission rate of Na* is directly proportional to the concentration of O_3. So the intensity of Na 5893A° line will be governed by the concentration of O_3. If the concentration of O_3 decreases, the intensity of Na 5893A° line will also decrease. Since the rate of decrease of O_3 at Trivandrum is less than that at Halley Bay, the rate of yearly decrease of Na intensity at Trivandrum will be less than that at Halley Bay, which has been shown in our result. The intense decrease at Halley Bay is due to the dramatic decrease of ozone at Antarctica.

The intensities of Na 5893A° line are calculated theoretically for different months in a year with the help of ozone depletion for the above months for the period 1979- 1998, for Trivandrum and Halley Bay, respectively and shown in Table 3. The variation of intensity of Na 5893A° line for the above two stations for different months are shown in Figs. 3(a&b). It is clear from Fig. 3 that maximum intensity occurs for the month of May and minimum intensity occurs for the month of December at Trivandrum (8.25° N, 76.9° E) but in case of Halley Bay (76° S, 27° W), maximum intensity occurs during the month of December and minimum occurs for the month of October. Intensity gradually increases from the month of January, attains its maximum for the month of June, then gradually decreases and attains its minimum value for the month of December at Trivandrum (8.25° N, 76.9° E). But for Halley Bay (76° S, 27° W) maximum ozone concentration occurs for the month of December and January, then gradually decreases, attains minimum for the month of October, then gradually increases. The minimum intensity during the month of October at Halley Bay is due to the dramatic decrease in ozone concentration at Halley Bay during spring time because of special atmospheric climatic condition at Antarctica during spring time. The special atmospheric conditions of Antarctica are as follows (Jana *et al.*, 2001).

(*i*) During Antarctic spring, temperature becomes very low (-80° C).

(*ii*) Concentrations of C1 and oxides of chlorine are elevated.

(*iii*) Concentrations of oxides of nitrogen becomes low and

(*iv*) Large amount of polar stratospheric clouds appear. These are supported by several expeditions.

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