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THE INFLUENCE OF THERMOSPHERIC WINDS ON THE AURORAL RED-LINE PROFILE OF ATOMIC OXYGEN

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Abstract—The effect of thermospheric winds on the emission profile of $\lambda 6300$ is discussed. It is shown that meridional winds play a significant role in determining the shape of this emission and the conventional diffusion of $O(^1D)$ hypothesis, though important, is not adequate to explain the observed features completely.

Rees (1961) and Rees, Walker, and Dalgarno (1967) noted that the spatial distribution of the atomic oxygen red line emission in an aurora is strongly influenced by diffusion due to the long lifetime of $O(^1D)$. We wish to point out that horizontal winds are of equal importance and may have an observable influence on the shape of 6300 Å emission profile observed from the ground.

Recent doppler observations (Hays and Roble, 1971) of meridional winds in the thermosphere during magnetic storms indicate that speeds in excess of 300 m/sec are not infrequent During the 110 sec lifetime of an $O(^1D)$ atom it can drift meridionally of the order of 30 km. This is the same order as the diffusive drifts noted by Rees *et al.* (1967). Consequently, we have repeated the calculation of the red line plume for the aurora investigated by the above authors and introduced the influence of a lateral drift. Ignoring the vertical component of motion one solves the continuity equation:

$$D\frac{\partial^2 n}{\partial x^2} - v\frac{\partial n}{\partial x} - [A_{1_D} + n(N_2)\cdot K_Q]n = -P_{1_D}$$

where D is the diffusion coefficient for $O(^1D)$ in $O(^3P)$, n the $O(^1D)$ density, v the horizontal wind speed, x the lateral coordinate, $A_{1_D} = 1/\tau_D$ the inverse of the ^1D radiative lifetime, K_Q the quenching coefficient for $O(^1D)$ on N_2, $n(N_2)$ the molecular nitrogen density and P_{1_D} the $O(^1D)$ production rate. This equation has the solution:

Case 1. $|x| > \Delta$ and $v \neq 0$

$$n = \frac{Q}{D(\alpha - \beta)}\frac{e^{\beta x}}{\beta}(e^{-\beta\Delta} - e^{\beta\Delta})\,.$$

Case 2. $|x| < \Delta$ and $v \neq 0$

$$n = \frac{Q}{D(\alpha - \beta)}\left[\frac{e^{\alpha x}}{\alpha}(e^{-\alpha x} - e^{-\alpha\Delta}) - \frac{e^{\beta x}}{\beta}(e^{-\beta x} - e^{\beta\Delta})\right].$$

Where,

$$\alpha = \frac{\dfrac{v}{D} + \sqrt{\left(\dfrac{v}{D}\right)^2 + 4[A_{1_D} + K_Q\cdot n(N_2)]}}{2}$$

and

$$\beta = \frac{\dfrac{v}{D} - \sqrt{\left(\dfrac{v}{D}\right)^2 + 4[A_{1_D} + K_Q\cdot n(N_2)]}}{2}$$

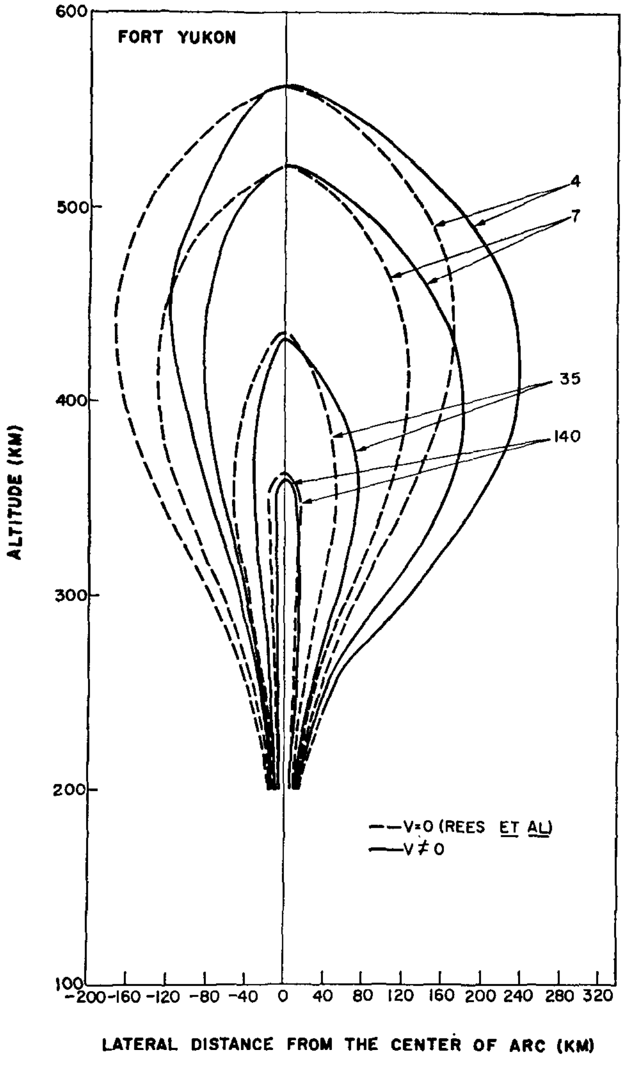

FIG. 1. THE ISOPHOTE CONTOURS (GIVING THE VOLUME EMISSION RATE OF λ6300 IN PHOTONS cm^{-3} sec^{-1}) ILLUSTRATE THE SKEWNESS RESULTING FROM THE THERMOSPHERIC WINDS.

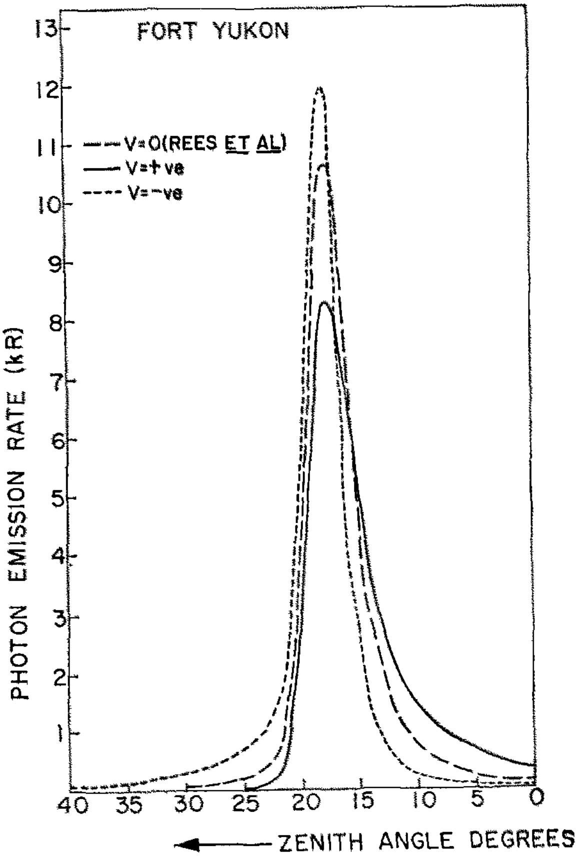

FIG. 2. THE INTENSITY OF λ6300 IN kR VS. LOCAL ZENITH ANGLE FOR NON-ZERO THERMOSPHERIC WINDS AND THE CORRESPONDING CURVE FOR NO-WIND AT FORT YUKON.

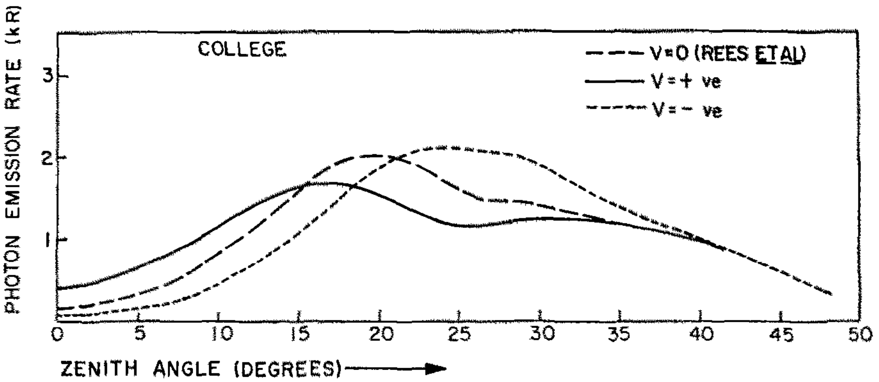

FIG. 3. THE INTENSITY OF λ6300 IN kR VS. LOCAL ZENITH ANGLE FOR NON-ZERO THERMOSPHERIC WINDS AND THE CORRESPONDING CURVE FOR NO-WIND AT COLLEGE, ALASKA.

where we have applied the boundary conditions that $n(^1D) = 0$ as $|x| \rightarrow \infty$ and assumed a production rate $P_{1_D} = Q(z)$ for $x \leqslant \Delta$, where Δ is the semi-width of the arc = 3 km. $P_{1_D} = 0$ otherwise.

These results have been applied to the aurora discussed by Rees *et al.* (1967). In our calculations we have used a Bates model atmosphere as modified by Walker (1965) with $T(120\ \text{km}) = 350°\text{K}$ and $T_\infty = 1200°\text{K}$. The meridional wind field was calculated using the assumption that the latitudinal exospheric temperature gradient was 0·1°K/km to generate a pressure field. This allows one to evaluate the meridional wind profile shown in Table 1 directly from the neutral gas horizontal momentum equation (Geisler, 1966). The ionosphere used for ion drag was that given by Rees, Walker and Dalgarno (1967).

TABLE 1

Altitude Z(km)	Wind velocity V(m/sec)	Altitude Z(km)	Wind velocity V(m/sec)
120	0·0	280	379
140	15·8	300	398
160	21·2	320	415
180	56·3	340	431
200	140	360	448
220	226	380	466
240	299	400	483
260	350	420	499
		440	513

The Plume contour is illustrated on Fig. 1. Here the solid curve refers to the case where the meridional wind is non zero and the dotted contours are those obtained by Rees *et al.* (1967) for $v = 0$. The skewness caused by the wind is obvious. This effect is further illustrated in Figs. 2 and 3 where the theoretical intensity curves discussed by Rees *et al.* (1967) at Fort Yukon and College, Alaska are presented. These stations were used by Belon, Romick and Rees (1966) in the original observations. We note that the agreement with the observations is not greatly better than that obtained previously, but the effect of winds is obviously significant. Romick (1964) has mentioned that the arc under investigation was not truly stable, it is suspected that the motion of the arc will contribute somewhat to the observed broadening. Consequently, one should analyze the more complex situation which includes the motion of the primary excitation source with time.

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