Planet. Space Sci., Vol. 25, pp. 1085 to 1086. Pergamon Press, 1977. Printed in Northern Ireland

RESEARCH NOTE

THE ROLE OF RELATIVE ION FLOWS ON THE THERMAL STRUCTURE OF THE IONOSPHERE

(*Received* 4 *May* 1977)

Abstract—Calculations are presented which show that, contrary to previous suggestions, ion flow velocity differences do not have a significant effect on the thermal structure of the midlatitude topside ionosphere.

In a recent paper St.-Maurice and Schunk (1977) drew attention to the role of relative velocities, among the different ion species, in the determination of the heat flow vector. They obtained an expression for the heat flow vector, using Grad's 13 moments transport formulation (Grad, 1949; Schunk, 1975), which indicates that both thermal conduction and unequal ion flows may make a significant contribution to the ion heat flow. They concluded, considering reasonable flow velocity differences of tens of meters per second, that the resultant heat flow is more important for H^+ than O^+ and that "this induced H^+ heat flow could significantly affect the H^+ energy balance in the ... mid-latitude ionosphere after sunset in a region between the *F*-region and the protonosphere."

In order to test this suggestion we made a series of calculations in which we solved the coupled energy equations using H^+ and O^+ flow velocities measured at Arecibo using radar backscatter techniques (Vickrey *et al.* 1976) The ionosphere input parameters (see Table 1) used in these calculations were taken from radar backscatter data obtained at Arecibo, after sunset on 6 August, 1976. The heat flow values, *q*, calculated for these conditions are also shown in Table 1. The coupled energy equations of the electron, O^+ and H^+ ion gas were solved using the method outlined by Hastings and Roble (1977) and Roble and Hastings (1977). The heat inflow from the topside was assumed to be zero and the only energy inputs considered were the ones due to the relative ion velocities, which were obtained by taking the divergence of the heat flow given in Table 1. The neutral gas temperature was assumed to be the measured ion temperature, while the electron and ion temperatures were calculated and compared to the measured values.

The results of these calculations showed that, for the representative conditions considered here, the difference between the neutral gas, electron and ion temperatures never exceeded 6K. These results may seem at first surprising because, as pointed out by St.-Maurice and Schunk (1977), the relative ion velocities used in these calculations are equivalent to a heat flow due to a temperature gradient in excess of 1K/km. It is well known that such a temperature gradient in the electron gas results in a significant ionospheric heat flow and elevated electron temperatures in the topside ionosphere. However, the heat flow due to a corresponding ion temperature gradient is more than an order of magnitude less and is, therefore, not very important. Furthermore, the differential velocity between O^+ and H^+ results in heat transported *out* of one altitude region and *into* another region; but a combination of an efficient energy coupling among the ion and electron gases along with rapid heat transport via electron thermal conduction acts as a return channel for this induced heat source.

In summary, the purpose of this brief note is to present the results of representative calculations which show that, contrary to initial suggestions, relative ion flows do not significantly affect the thermal structure of the topside mid-latitude ionosphere.

TABLE 1. MEASURED AND CALCULATED IONOSPHERIC PARAMETERS ARECIBO, P. R., 6 AUGUST 1976, 21:44LT

Altitude (km)	$n(O^+)$ (cm^{-3})	$n(H^+)$ (cm^{-3})	$T_e = T_i$* (K)	$v(O^+)$† ($cm\,s^{-1}$)	$v(H^+)$† ($cm\,s^{-1}$)	$q(O^+)$ ($eV\,cm^{-2}\,s^{-1}$)	$q(H^+)$ ($eV\,cm^{-2}\,s^{-1}$)
270	5.32(4)		775				
360	2.04(5)		813				
450	1.83(5)	8.00(3)	816	2.0(2)	4.0(2)	3.54(3)	1.25(5)
540	7.54(4)	1.01(4)	826	1.1(3)	2.9(3)	3.39(4)	1.38(6)
630	2.93(4)	8.40(3)	853	2.1(3)	5.6(3)	4.21(4)	2.16(6)
720	1.08(4)	7.10(3)	881	2.6(3)	8.0(3)	2.89(4)	2.52(6)
810	4.34(3)	6.76(3)	876	1.5(3)	8.8(3)	5.38(3)	2.44(6)
900	1.75(3)	6.27(3)	864	4.0(2)	8.1(3)	−3.95(2)	8.09(4)
990	6.35(2)	5.90(3)	866		5.9(3)	−5.28(3)	5.49(5)
1080	2.91(2)	5.49(3)	898		2.1(3)	−1.17(3)	1.03(5)
1170	9.87(0)	5.16(3)	899				

* T_e and T_i were assumed equal in the data analysis.
† The velocity values given in this table have been smoothed as a function of altitude.

Acknowledgements—The authors wish to thank Drs. Schunk and St.-Maurice for many useful discussions on this subject. The work presented here was supported by NASA Grany NGR 23-005-015 and NSF Grant ATM 75-03986 AO1.

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