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IN SITU AND REMOTE SENSING OF THERMOSPHERIC WINDS DURING THE ENERGY BUDGET CAMPAIGN

D. Rees*, C. R. Philbrick**, M. Carlson*,
T. J. Fuller-Rowell* and P. Charleton*

**Department of Physics and Astronomy, University College London,
Gower Street, London WC1E 6BT, U.K.
**Geophysics Research Laboratories, Hanscom Air Force Base,
Bedford, MA 01731, U.S.A.*

ABSTRACT

This paper summarizes the dynamical information obtained in the lower thermosphere during the Energy Budget Campaign, by three experimental techniques: rocket-borne falling spheres instrumented with accelerometers and Tri-Methyl-Aluminium (TMA) trails, and from a ground-based Fabry-Perot interferometer. Winds of 200-400 m/sec, accelerated by the momentum and energy inputs from the magnetosphere, were observed during the 'B' and 'A2' salvos (15/16 Nov 1980 and 30 Nov/1 Dec resp.), with perturbations as low as 100 km altitude during the 'B' salvo. A global model has been used to simulate the wide-scale consequences of these disturbances, and to aid estimation of the integrated energy and momentum inputs.

INTRODUCTION

During the Energy Budget Campaign[1,2], four of the rocket payloads flown from ESRANGE, Kiruna, included instruments for measuring neutral winds in the lower thermosphere. The techniques used have been described elsewhere[3, 4]. Two of the rocket payloads included both falling spheres and TMA trail releases, while the other two payloads only released TMA trails. The rockets, payloads, and other details of the flights are summarized in Table 1. The rocket-borne observations were supported by ground-based Fabry-Perot interferometer (FPI) measurements of thermospheric winds made by studying the Doppler shift of the OI 630 nm emission line[5, 6]. A number of the objectives of the EBC required investigation of the large-scale disturbances of the thermosphere induced by the geomagnetic events studied on a local basis by the rocket experiments. A global three-dimensional time-dependent model of the thermosphere, including a time-dependent magnetospheric input of energy and momentum[7,8], has therefore been used to study the global propagation of the induced disturbances, and to aid the estimation of the rates of energy and momentum transfer from the magnetosphere for the specific disturbances studied with the rocket salvoes of the EBC.

THE EXPERIMENTAL DATA BASE

Salvo C - 10/11 Nov 1980. The quiet reference salvo occurred during a period of perfect optical conditions at all of the observation stations. A modest substorm (100 nT) occurred about 1-2 hrs before the E6-C rocket flight, and the enhanced ion drag in the F region during this negative bay event induced the 200 m/sec eastward winds observed during this period by the FPI (Figure 1). A similar magnitude equatorward wind is also observed at the time of the E6-C flight. There is a general trend that both zonal and meridional winds decrease until about 0130 UT, when a subsequent modest negative bay event enhances the eastward wind. This substorm does not deposit enough energy to influence the trend of a decreasing equatorward wind between 0100 and 0400 hrs UT. The TMA trail wind observations (Figure 2) also demonstrate that the energy and momentum input from the earlier substorm had little effect on the dynamics of the region up to 160 km, which appear to be dominated by tidal and gravity wave components.

Salvo B - 15/16 Nov 1980. The second salvo followed a 400 nT negative bay disturbance. Due to very heavy cloud cover and snowfall at ESRANGE, no useful data was obtained from the FPI. However, data which were obtained from the E6-A1 rocket flight from both the falling sphere (Figure 3), and the TMA trail (Figure 2), both show features which were caused by the disturbance. Above 110 km altitude, both techniques show an equatorward meridional wind, increasing with altitude, with values exceeding 150 m/sec above about 130 km altitude.

Salvo A2 - 30 Nov/1Dec 1980. The thermospheric wind data obtained during this salvo comprised the falling sphere data of the E6-A2 flight (Figure 3), a wind profile which was obtained from the TMA trail of the E6-B flight (Figure 2), and FPI data which was obtained (Figure 1) from the northward and westward viewing directions, during a 30 minute period close to the time of the E6-B rocket flight. Despite the much higher level of magnetic activity, the meridional winds in the altitude range up to 150 km are lower than those observed during the 'B' salvo. Eastward winds, of the order of 100 m/sec above 120 km, are due to ion drag acceleration occurring during the disturbance, which continued throughout the period of both the rocket flights. Even during the clearest period of the night (about 0130 UT), close to the time of the E6-B flight, the 300 m/sec equatorward winds observed in the north and the 200 m/sec eastward winds observed in the west by the FPI (∿240 km) still probably underestimate the true winds. The FPI wind data for the night (29/30 Nov 1980) prior to the A2 salvo are also shown. This night, which was clear until 0400 UT, was much less disturbed than the salvo night, but nevertheless demonstrated the major features of thermospheric dynamics likely to have occurred during the A2 salvo.

DISCUSSION AND INTERPRETATION

The 'C' salvo was launched after a small and isolated substorm. Above 200 km the momentum input during the event caused a 50-100 m/sec acceleration of the pre-existing eastward wind, and no significant change was noted in the equatorward wind which might have reflected the integrated energy input due to the event. Below 200 km, as monitored by the TMA trail wind data, very little influence of the substorm could be detected, except for the eastward tendency of the winds at the top of the trail (merging toward the FPI result above 200 km). The simulated thermospheric wind disturbance for such relatively quiet magnetic conditions, is shown in Figure 4a. At 240 km the general thermospheric circulation away from the subsolar point (1400 LT) is perturbed at high latitudes by ion convection, enhancing the antisunward flow over the polar cap and driving sunward winds within evening and morning parts of the auroral oval. At 120 km the convection-induced winds are rotated clockwise and are smaller in magnitude. Propagating tides and gravity waves from the lower atmosphere have not been included in this global and self-consistent simulation.

The geomagnetic situation prior to the 'B' salvo was also relatively simple. The energy and momentum input from the modest substorm near 2100 UT should have been largely dissipated prior to the onset of the disturbance near 0230 UT. Figure 4b shows the simulated large scale circulation changes expected as a result of this event. The rocket data up to 150 km altitude are in agreement with the simulation of southward and eastward winds, and the latter can be used to estimate the propagation of the atmospheric disturbance at various altitudes and locations. The event should have strongly enhanced the post-midnight equatorward thermospheric winds causing velocities in excess of 300 m/sec at 240 km above Kiruna. Locally in the auroral oval, the eastward wind would increase, but without equatorward propagation. The meridional wind surge would have enhanced the equatorward nighttime wind to at least a latitude of 30-40 degrees before 0600 UT.

Salvo A2 occurred during a period of complex and energetic disturbances. These disturbances started about 1800 UT (30 Nov) and continued past 0500 UT, and at least 10 identifiable substorms appear to have occurred in the 11 hour period. For modelling purposes, the input between 2100 and 0100 UT is considered as a single major event, with its peak input at 2300 UT, some 30 min before the largest single substorm of the night. The resulting wind distribution is very similar to that shown in Fig. 4b, except that the polar cap and auroral oval winds should increase to about 400-500 m/sec, and a similar equatorward wind should cross the post-midnight auroral oval. The night of the A2 salvo had a combination of the greatest total energy input (of the EBC), the greatest total momentum input, and with both heating and dynamical changes being apparent to lower altitudes than for the other salvoes. The limited FPI wind data confirms the high total momentum and energy inputs. At lower altitudes, the complex interactions of wind disturbances set up by successive substorms may have partly cancelled in momentum terms, converting momentum into thermal energy close to the high-latitude source region, rather than further away, as the disturbances propagate. The geomagnetic disturbances during the A2 salvo would have caused major global changes of thermospheric wind, density, temperature and composition.

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TABLE 1 Summary of thermospheric wind observations in salvoes.

Date	Time	Salvo	Geomagnetic Conditions	Rocket Observations	Ground-based FPI Observations
Nov. 11 1980	0028	'C' (E6 - C)	Quiet	TMA	Yes
Nov. 16 1980	0447	'B' (E6 - A1)	Moderate disturbance, ∿200-300γ	Falling sphere + TMA	None - cloudy
Nov.30/Dec.1 1980	0009	'A-2' (E6 - A2)	Moderate disturbance, ∿400γ	Falling sphere	Limited
	0124	'A-2' (E6 - B)		TMA	Yes

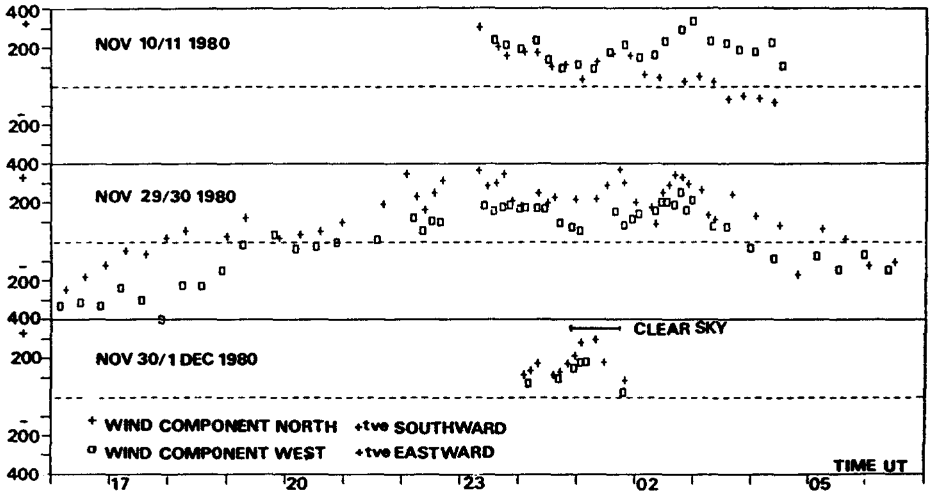

Fig. 1 Thermospheric winds (240 km) obtained from a ground-based Fabry-Perot Interferometer at ESRANGE for the nights of 10/11 Nov, 29/30 Nov and 30 Nov/1 Dec 1980. Wind component NORTH (WEST) refer to observations made in direction looking NORTH (WEST) from Kiruna.

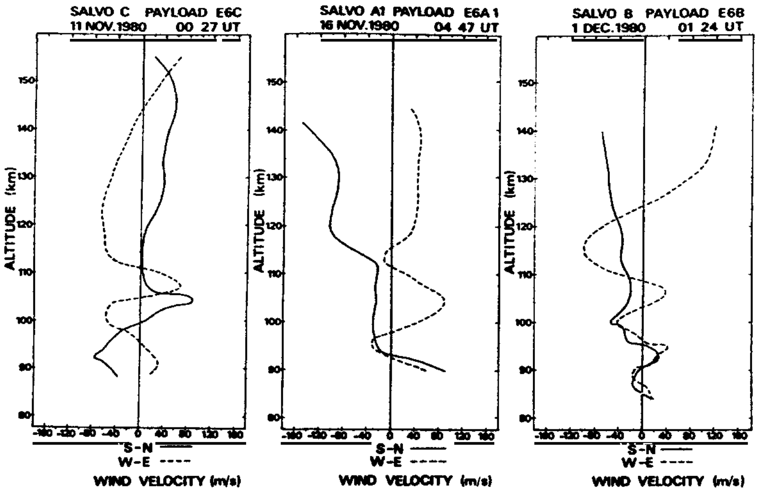

Fig. 2 Meridional and zonal winds from the TMA trails released during the Energy Budget Campaign.

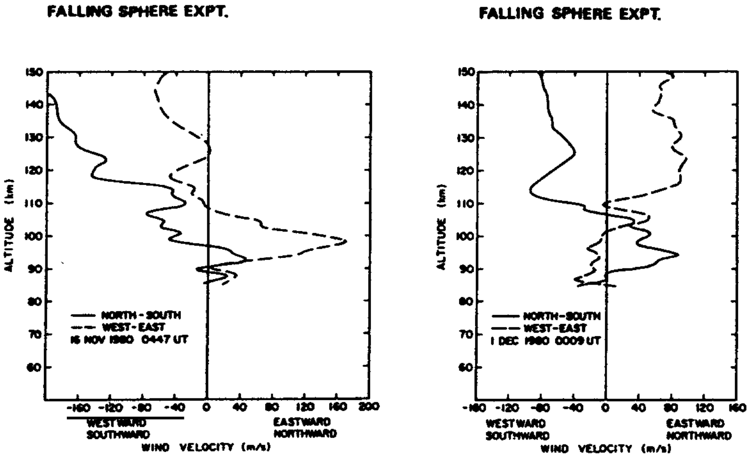

Fig. 3 Wind profiles obtained from the instrumented Falling Spheres of the E6-A1 and E6-A2 payloads. (Preliminary data)

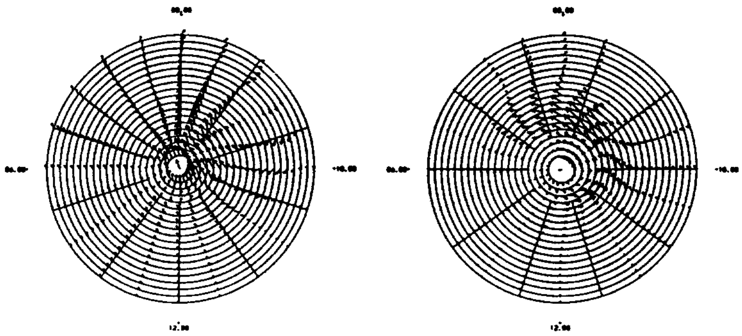

Fig.4a Simulated wind disturbance at 0120 UT for average geomagnetic activity for the Northern Hemisphere. Poleward of 50°N. 240 km on left. 120 km on right.

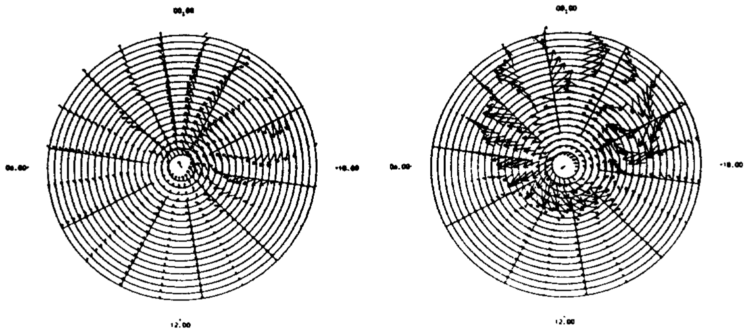

Fig.4b Neutral wind circulation as Fig.4a but for a simulated substorm.

NOTE: The velocity scale for 240 km simulations, on left, is 160 m/s = 2° of latitude. For 120 km, on right, the scale is 40 m/s = 2° of latitude. In each case this is the distance between successive latitude circles.