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VERTICAL DENSITY AND TEMPERATURE STRUCTURE OVER NORTHERN EUROPE

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ABSTRACT

During the Energy Budget Campaign, several profiles of the density and temperature of the upper atmosphere were obtained. The measurements were made using rocket-borne instrumentation launched from ESRANGE, Sweden and Andoya Rocket Range, Norway during November and December, 1980. The techniques included meteorological temperature sondes, passive falling spheres, accelerometer instrumented falling spheres, density gauges, mass spectrometers and infrared emission experiments. The instruments provided data within the altitude range from 20 km to 150 km. The measurements were made during periods which have been grouped into three categories by level of geomagnetic activity. Analysis has been made to compare the results and to examine the oscillations and fluctuations in the vertical profiles for scales ranging between hundreds of meters and tens of kilometers. Most of the features observed fit qualitatively within the range expected for internal gravity waves. The geomagnetic storm conditions may be associated with enhanced wave activity and heating observed in the lower thermosphere.

INTRODUCTION

The overview of the Energy Budget Campaign has been described by Offermann [1]. One of the objectives of the campaign was to measure the density and temperature profiles in the middle and upper atmosphere during the periods which corresponded to major geomagnetic storm conditions (Salvo A), moderate geomagnetic storm conditions (Salvo B), and quiet geomagnetic conditions (Salvo C). The criteria for the conditions and the overall success of the measurements has been described [2]. Table I lists the payloads which provided measurements of density and temperature structure during the campaign. Several measurement techniques were used to obtain data within the altitude range of 20 to 150 km. The datasonde, which consists primarily of a bead thermistor sensor, is the standard meteorological sensor for measurements of temperature between 20 and 70 km [3]. At altitudes above 55 km, significant corrections must be applied in the analysis of the data and therefore, the errors grow rapidly above 60 km. Since all of these measurements were conducted at night, the radiation corrections are small and the measurements should be useful over the reported altitude range. The density profile is determined by use of the hydrostatic equation and is based on a low altitude tie to another technique, either rawinsonde balloon or pressure map analysis. The passive sphere, a one-meter metalized mylar inflated sphere, is released at altitudes above 100 km and tracked by an MPS36 radar to provide acceleration components [4]. The radar-measured accelerations are used to derive the density and wind. The density profile is integrated downward to determine the temperature using the hydrostatic equation, the ideal gas law and an assumed upper level temperature point. The density gauge used for the measurements was a miniature hot filament ionization sensor. It has provided useful measurements over a limited altitude range between 90 and 110 km. The mass spectrometer and infrared spectrometer measurements will provide some information for use in determining the atmospheric structure. However, those results will be considered in future studies and will not be discussed here. The accelerometer sphere measurements were made using a three-axis piezoelectric acceleometer which has the advantages of high sensitivity, high vertical resolution and large dynamic range for making measurements [5]. In addition to the rocket borne techniques, the mesosphere temperature was monitored by use of a ground based near infrared spectrometer measurement of the OH emission.

This paper will present an overview of the structure measurements, intercompare the results, compare the measurements with appropriate models, and infer several points about the response of the atmosphere during the geomagnetic heating periods.

TABLE I Measurements during the Energy Budget Campaign which Provided Information on the Density and Temperature Structure

Date	Time	Site	Salvo	Measurement	Range(km)
7 Nov	2200	ESRANGE	-	Datasonde	23-70
7 Nov	2250	ESRANGE	-	Passive Sphere	44-57
10 Nov	0010	ESRANGE	-	Datasonde	29-70
10 Nov	0218	ESRANGE	-	Passive Sphere	45-87
10 Nov	2200	ESRANGE	C	Datasonde	23-70
10 Nov	2346	ESRANGE	C	Passive Sphere	32-87*
11 Nov	0012	Andoya	C	Mass Spectrometer	95-124
11 Nov	0012	Andoya	C	Density Gauge	88-110
11 Nov	0155	ESRANGE	C	Passive Sphere	40-90
11 Nov	0226	ESRANGE	C	Datasonde	23-70
12 Nov	0020	ESRANGE	-	Datasonde	23-70*
12 Nov	0107	ESRANGE	-	Passive Sphere	33-90
16 Nov	0313	ESRANGE	B	Infrared Spectrometer	60-150
16 Nov	0316	Andoya	B	Infrared Photometer	60-150
16 Nov	0331	Andoya	B	Mass Spectrometer	100-124
16 Nov	0331	Andoya	B	Density Gauge	84-110
16 Nov	0447	ESRANGE	B	Accelerometer Sphere	52-140
16 Nov	0512	ESRANGE	B	Passive Sphere	33-73
16 Nov	0633	ESRANGE	B	Datasonde	23-70
16 Nov	0751	ESRANGE	B	Passive Sphere	38-90
16 Nov	0823	ESRANGE	B	Datasonde	23-70
27 Nov	2245	ESRANGE	A1	Datasonde	23-70
28 Nov	0047	ESRANGE	A1	Passive Sphere	40-88
28 Nov	0325	Andoya	A1	Density Gauge	86-102
28 Nov	0329	ESRANGE	A1	Passive Sphere	35-90
28 Nov	0419	ESRANGE	A1	Datasonde	30-60
1 Dec	0009	ESRANGE	A2	Accelerometer Sphere	55-150
1 Dec	0024	ESRANGE	A2	Passive Sphere	32-61
1 Dec	0139	ESRANGE	A2	Passive Sphere	41-87
1 Dec	0233	ESRANGE	A2	Datasonde	30-70

* Significant gaps exist in the data profile within the given range.

RESULTS

The results for the temperature measurements from the payloads are shown in Figures 1a through 1d and the density results in Figure 2a through 2d. The identification of the various measurement times and salvos is given in Table I. The U.S. Standard Atmosphere, 1976 (USSA 76) has been chosen as the basis for the data comparisons. The density profiles are more easily compared when the ratio to such a reference model is presented. The measurements during the geomagnetically quiet conditions, Fig. 1a, on 10 - 11 November show excellent agreement between the datasonde and passive sphere measurements in the regions of data overlap. The general features in the density and temperature profiles are stable over the period of several hours during that night. However, significant wave activity is present in the data with the largest differences between 50 and 60 km. The time period of the wave activity is comparable to the measurement separation and thus it is not possible to follow the wave behavior. For the background conditions of Salvo C, the range of variation in the temperature is less than 20K except for the stratopause region where differences range to 30K.

In Figures 1b,c,d the temperature structure for the geomagnetically active periods is shown. Figures 1b and d show the range of the temperature results from the ground based IR spectrometer measurements of OH emission during the night of the salvo. During Salvo B, the wave activity was much stronger than for any of the other cases. When the various profiles are compared, the period of the wave activity can be estimated for a few altitude ranges where larger features are observed. These cases indicate periods ranging from about 1 to 4 hours. The better examples are found at 57 and 52 km in Salvo C, at 60 km in Salvo B, at 53 and 47 km in Salvo A1 and at 56 km in Salvo A2.

When the temperature profiles for the two cases of highest geomagnetic activity, Salvos A1 and A2, are compared to the cases of lower activity, Salvos C and B, two features are noted. First, the stratopause temperatures are lowered and the profile in that region is flattened for the cases corresponding to the higher geomagnetic activity. Second, the temperatures in the 70 to 90 km range are increased for the cases of enhanced activity. These few cases could not be used to conclude the correlation with activity exists, but the data would certainly be consistent with that view.

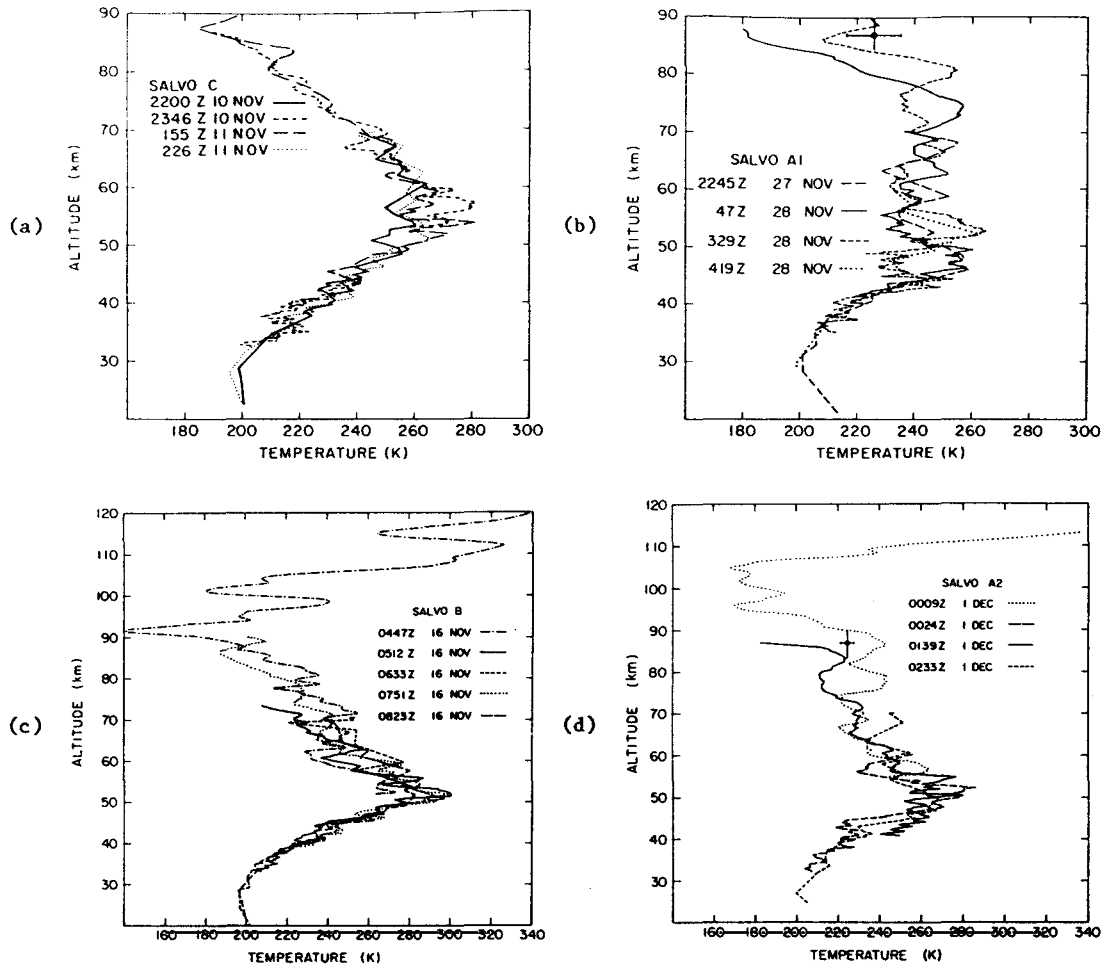

Fig. 1. Temperature profiles measured during the several phases of the Energy Budget Campaign, refer to Table I for details. The symbols shown in (b) and (d) show the range of the temperatures measured from the OH emission.

The density profiles of Figure 2 are shown relative to the USSA76 model. The range of the density variations is less than about 15%, except for differences up to about 25% in Salvo B, and significant wave activity is seen in all of the profiles. The wavelengths and periods which would be inferred from these results are within the range that would be expected for internal gravity waves in the altitude region of the measurements.

The comparison of the Salvo C density measurements with the AF Reference Atmosphere [6] for 75°N latitude and November conditions is shown in Figure 2a. This comparison demonstrates that the major profile difference between all of the campaign results and the USSA76 are due to the mean dependence on latitude and season.

In conclusion, the wave structure observed in the middle and upper atmosphere during the Energy Budget Campaign, high latitude winter conditions, shows that the region is in a highly perturbed dynamical state. The comparisons indicate that the geomagnetic storm conditions may have produced increased temperatures in the 110 to 130 km region and could have been associated with the increase in the 70 to 90 km region, as well as decreased temperatures at the stratopause. The stratospheric and mesospheric changes near the end of November could also have been associated with a change in the cirulation pattern over the northern hemisphere, Labitzke et al [7]. The strong perturbations observed in Salvo B may be associated with the presence of rapid trough flow [8] near the edge of the auroral oval. This latter point is further supported by the measured ratio of the O^+/NO^+ ions [9] indicating the presence of stronger electric fields during Salvo B than during Salvo A.

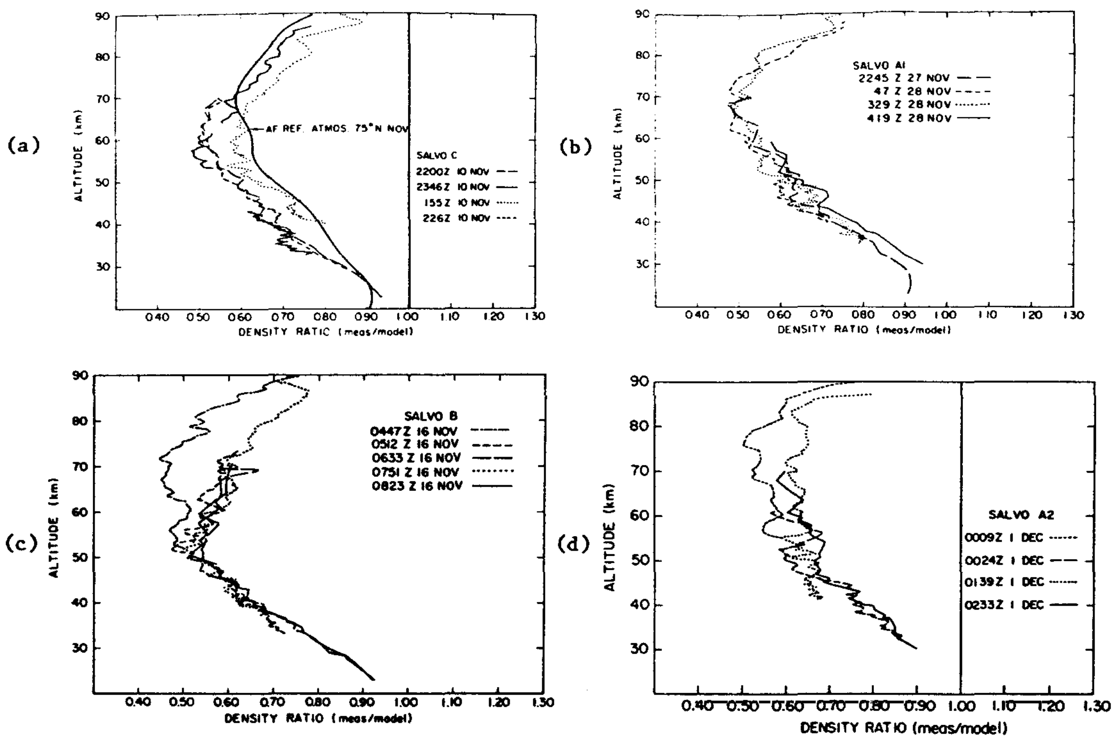

Fig. 2. Density profiles measured during the several phases of the Energy Budget Campaign compared to the USSA76 model, refer to Table I for details.

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