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Original Investigations

The AEROS Mission

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Abstract. An outline is given of the scientific objectives of the AEROS mission, together with the experiment complement and orbital characteristics required to meet these objectives on both the AEROS-A and B satellites.

Key words: Aeronomy Satellite — Upper Atmosphere — Ionosphere.

Introduction

During the past decade significant advances have been made in our understanding of the earth's upper atmosphere, primarily as the result of the *in situ* measurements on satellites. Although the physical characteristics of the upper atmosphere, i.e., the density, composition and temperature of the neutral and ionized components have been measured on a number of satellites in the past, these measurements were usually isolated and often could not easily be cross-correlated.

Since the ionosphere has its origin in the interaction of solar ionizing (EUV) radiations with the neutral atmosphere, an understanding of its behavior requires experimental data on all observables from which secondary information on the physical and chemical processes occurring can be derived. It has long been the goal of aeronomers to measure *simultaneously* the important parameters of the upper atmosphere, however, only a satellite wholly dedicated to aeronomy has any hope of meeting this goal. While such an ambitious enterprise, including orbital change capability, is being undertaken by the U.S. Atmosphere Explorers (the first of them, the AE-C now being in orbit) [Dalgarno *et al.*, 1973], the joint German-U.S. aeronomy satellite AEROS-A was actually the first to meet some of the objectives of simultaneous measurements of the main aeronomic parameters and the ionizing solar radiation, and to perform orbital adjustment with its limited on-board propulsion system.

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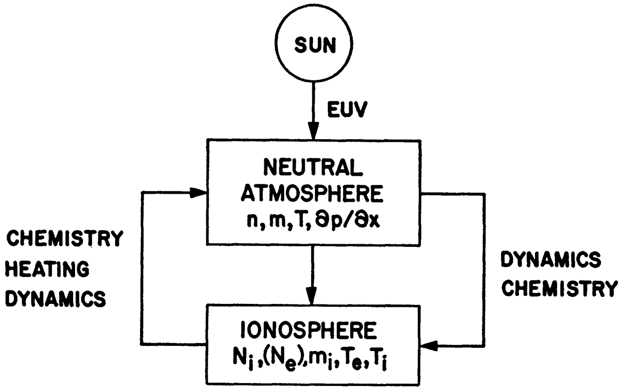

Fig. 1. Schematic block diagram of the interaction of solar ionizing radiations with the neutral atmosphere, responsible for the formation of the ionosphere and heating of the neutral upper atmosphere leading to pressure gradients ($\delta p/\delta x$) which in turn are responsible for dynamic effects in the upper atmosphere

Objectives

The principal objective of the AEROS-A (and B) satellites is the study of the physical and chemical processes in the earth's upper atmosphere and ionosphere by means of simultaneous maesurements of the following parameters:

1. Neutral atmosphere composition (m_j), density (n_j), and temperature (T);
2. Ion composition (m_i), density (N_i), and temperature (T_i);
3. Electron density (N_e) and temperature (T_e), and flux of suprathermal electrons (Φ_e);
4. Solar EUV ionizing radiation (Φ_λ).

The importance of these parameters to the understanding of the behavior of the upper atmosphere can be seen from the following simplified diagram (Fig. 1). This diagram shows that solar EUV radiation is responsible not only for formation of the ionosphere but at the same time is also the principal heat source for the neutral atmosphere and thus affecting its composition and dynamics (in terms of pressure gradient, $\delta p/\delta x$), which in turn affects the behavior of the ionosphere. In addition, heat sources not related to solar EUV radiation, i.e. of "corpuscular" or "magnetospheric" origin, can be inferred from the latitude variation of the measured atmospheric parameters. Thus, we have a complex interactive system (see e.g. Chandra and Herman, 1969; Stubbe, 1970; Stubbe, 1973) for which the AEROS experiments provide important input parameters.

Table 1. Experiments on AEROS

Principal investigator	Instrumentation (Code)	Primary parameters measured
D. Krankowsky	Neutral and ion mass-spectrometer (MS)	Neutral and ion composition (m_j, m_i) in the mass range 1—44 amu, absolute neutral number densities (n_j)
K. Spenner	Retarding potential analyzer (RPA)	Electron temperature (T_e), electron concentration (N_e), suprathermal electrons (Φ_e) up to 30 eV, ion temperature (T_i), concentrations of major ions (N_i, m_i)
E. Neske	RF-impedance probe (IP)	Electron concentration (N_e) with high spatial resolution (8 km)
G. Schmidtke	EUV spectrophotometer (EUV)	Solar energy (Φ_λ) in the wavelength range 160 ... 1062 Å, height profiles of n(O) and n (N_2)
N. Spencer	Velocity-distribution analyzer (NATE)	Neutral gas temperature (T_n), N_2 and total number density ($n(N_2)$, $\sum n_j$)
M. Roemer	Satellite drag, passive (ADA)	Total gas density ($\sum n_j m_j = \varrho_j$) at perigee

Scientific Payload

The first AEROS satellite (AEROS-A) was in orbit from 16 December 1972 through 22 August 1973. The second flight unit, AEROS-B, was launched on 16 July 1974. Both carry the same experiments as listed in Table 1, and only minor modifications have been applied to some of the AEROS-B instrumentation to improve performance.

Although the objective of the mission requires simultaneous measurement of a variety of aeronomic quantities, the payload capacity of the Scout vehicle puts a limit to the number of scientific instruments the spacecraft can carry. It was therefore necessary to develop experiments capable of combining the measurement of different parameters, which is normally achieved by periodic switching the operational modes in intervals of only one or a few spin revolutions (1 rev. corresponding to 6 sec). As Table 1 illustrates, the payload complement to a certain extent provides redundancy for the measurement of some of the aeronomic parameters which is not only an advantage in case an instrument fails but also allows for internal cross-check which improves the confidence in the measured data.

For reasons of telemetry efficiency, measurements of three of the experiments can be synchronized with the minimum angle of attack. This is accomplished through the use of an ion sensor and special circuitry which adjusts the real time bit rate and phase to synchronize the telemetry data format to the spacecraft spin. Data handling is performed by using any one of two measuring programs. In the spin-phase controlled program the experiments which are sensitive to the angle of attack (MS, RPA, and NATE) are measuring every time when the phase of the spin corresponds to their respective favorable orientation. In the other program controlled by the clock the RPA and MS experiments measure intermittently over complete spin revolutions, but with intervals of several spins of no data.

On AEROS-A all experiments performed as expected, except for the impedance probe; electron concentration measurements were obtained by the retarding potential analyzer. *In situ* neutral atmospheric temperature could not be obtained at a sufficient rate due to a malfunction of the spinphase controlled telemetry, and it was therefore decided to operate the velocity distribution analyzer in a mode to measure atmospheric composition. With the exceptions mentioned, AEROS-A yielded the complete set of aeronomic parameters as planned, over its entire lifetime. On AEROS-B all scientific instruments as well as the spin phase control are performing quite satisfactorily.

Orbit

The first AEROS satellite had an initial apogee of 865 km and a perigee of 220 km height, and the inclination of the orbit plane was 96.9 degrees. These parameters were selected in order to obtain measurements at all latitudes and at fairly low altitude over a reasonably extended lifetime, and to provide constant local time at any given latitude.

A low perigee is important as some of the experimental methods are restricted to low altitude and aeronomic parameters there are of greatest interest. Measureable amounts of atmospheric argon which is regarded as a good indicator of temperature, and nitrogen in concentration sufficient for kinetic temperature determination by analysis of the velocity distribution, are only existing at altitudes below approx. 300 km. Thus, the objective to infer the conditions at the lower boundary of the thermosphere from the relative concentrations of neutral constituents measured at higher altitudes (see e. g. Chandra and Sinha, 1974) calls for a perigee not higher than 200—250 km. The orbits of both AEROS satellites meet this requirement but still allow for lifetimes between a half and one year which is necessary to study seasonal phenomena.

In order to guarantee a successful mission even in the event that the initial perigee is much too low or too high which might have resulted from

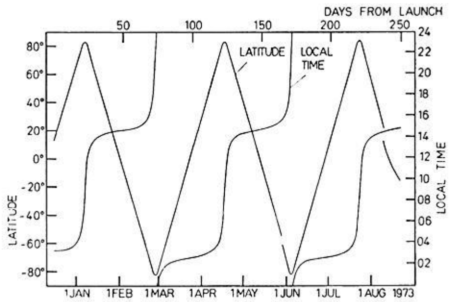

Fig. 2. Plot of variation of perigee latitude and local time during the course of the AEROS-A mission, illustrating the coverage of low altitude measurements. Note that complete latitude coverage is obtained for almost constant day and nighttime conditions, respectively

vehicle injection errors, the satellite has a propulsion system on board for fine adjustment of the flight altitude. On AEROS-A it was used twice: raise of apogee by 155 km after 163 days in orbit extended the mission by about two months, and final perigee kickdown provided a week of maesurements at altitudes as low as 165 km decreasing to 135 km prior to re-entry. The selected inclination causes a precession rate of the orbit plane which just compensates for the mean motion of the sun. The result is an orbit that is stable in local time. At the ascending and descending nodes the local solar time is 1500 and 0300 hours, respectively, which is close to the diurnal extrema of the atmospheric density bulge. It had been concluded that such type of an orbit would considerably facilitate data analysis and interpretation of latitude, altitude, and season effects.

The path of the AEROS-A perigee with respect to latitude and local time is shown in Fig. 2. The orbit parameters of the AEROS-B satellite are practically the same (868 km apogee, 217 km perigee, 97.4 degrees inclination), but it started at a different time in the year.

Summary

Although the detailed scientific results of the AEROS-A mission will begin to appear in the literature in the near future, we want to briefly summarize two of the most significant ones: (1) AEROS-A provided for the first time long-term measurements of EUV fluxes which suggest that the photon fluxes during that time were significantly higher than those used in recent models of the ionosphere; (2) exospheric temperatures derived from the seasonal and latitudinal variation of neutral constituents, specifically N_2 and Ar, clearly show significant contributions to upper atmosphere heating at high latitudes from sources not related to solar EUV.

The AEROS-B satellite will operate simultaneously with other aeronomy satellites such as AE, ISIS, and San Marco, and cross-correlations with them and a host of groundbased observations should contribute to a better understanding of the physical and chemical processes in the earth's upper atmosphere.

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