SPECIFIC FEATURES OF THE HIGH ATMOSPHERE

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Summary

One of the most intricate and interesting domains of the entire atmosphere is the mesopause region. This area separates the thermosphere (above) from the mesosphere (below). The temporal variability in the thermosphere is strongly influenced by variations of the solar EUV- and X-ray radiation, including particle impact due to the solar wind. The temporal behavior of the mesosphere is mainly determined by meteorological processes, and its physical and chemical state is marked by strong seasonal variations. A large number of distinct phenomena occur in the mesopause region. Some of them will be introduced in this section.

1 .Introduction

The atmosphere is usually subdivided into the lower, middle, and high atmosphere. Frequently the middle and high atmosphere together are termed the upper atmosphere. The science of the upper atmosphere is also called aeronomy (see *Aeronomic Phenomena*)**.** It investigates the high atmosphere, particularly in relation to its composition, properties, relative motion, and the radiation received from outer space. Here we mainly deal with a domain that includes the mesosphere and thermosphere, meaning the upper part of the middle atmosphere and the lower part of the high atmosphere. We will set up priorities on phenomena occurring in the mesopause region, the transition region between these spheres.

The atmosphere is also subdivided into different spheres and layers by employing various physical and chemical criteria. The most familiar one uses the sign of the vertical temperature gradient as an indicator. According to this, the mesosphere is marked by decreasing temperature with increasing height, and the thermosphere is characterized by increasing temperatures that finally reach around 1000 K or more at its upper domains. Iron would be white-hot at the highest temperatures. Nevertheless these temperatures pose no danger to objects orbiting Earth (for example, satellites) because the air concentration drops to values as low as that of a high vacuum.

Generally, the transition region between two spheres is called the pause of the lower sphere. The domain under consideration includes the mesopause, and the thermosphere finishes with the thermopause. Above the thermopause ranges the exosphere. This is the region from which atomic hydrogen can escape into interplanetary space. The quantity of escaping hydrogen is controlled by the mesospheric total hydrogen content of hydrogen-bearing constituents such as H_2O, H_2, and CH_4. The middle atmosphere, and under certain conditions the mesopause region, is the bottleneck for the total hydrogen flux directed upwards. It limits the escape flux. The escaping hydrogen has its origin in the water reservoir of Earth. Thus, an equivalent level of oxygen remains in the atmosphere, which accumulates over geological time scales to a quantity comparable with the present oxygen content. This is, of course, only one term of the great oxygen balance governing the evolution of our oxygen atmospheres. The main production term, however, results from biological activity. In the process of growth, plants produce oxygen that originates from the CO_2 reservoir. After the death of plants, a small share of organic material is finely dispersed, sedimented in the oceans, leaving an equivalent part of oxygen in the atmosphere.

The mesopause region is one of the most interesting, but also most awkward, domains of the entire atmosphere. Here the lowest temperatures that occur naturally anywhere in the atmosphere have been observed in summer under full solar illumination. We will discuss phenomena occurring within this region in a separate chapter.

There are different viewpoints characterizing the atmosphere that play an important part in this domain. With regard to the creation of plasma due to ionization of atmospheric constituents by solar short-wave radiation, this domain is termed the ionosphere. The thermosphere and mesopause region contains the main part of the ionosphere, which is chiefly subdivided into the F-, E- and D-layers. The F-layer (F_2- and F_1-layer) is the ionospheric main layer. In the domain below the ionosphere the formation of negative ions (in contrast to the charge of the ionospheric ions, which are positive) becomes important. In order to differentiate it from the plasma share (ions and free electrons), the neutral part is sometimes called the neutrosphere.

Within the atmosphere, different waves are generated, which propagate, dissipate, and produce turbulence. The turbulence tends to mix the atmospheric constituents. Up to about 100 km altitude the atmosphere is well mixed. This region is named the homosphere. Above this region, the turbulence rapidly decreases. The constituents start to separate according to their molecular weight, and thus the ratio of comparatively light constituents grows with increasing height. This region above the homosphere is called the heterosphere, and the transition area around 100 km is called the turbopause. The diffusive transport within the homosphere is dominated by turbulent diffusion, which is also called eddy diffusion. In the heterosphere, the molecular diffusion determines the diffusive transport. While within the upper part of the domain under consideration the diffusive (both eddy and molecular diffusion) transport chiefly determines the vertical transport, the lower part is determined by advective transport. The transition region could be termed the advecpause, and should be defined by the fact that the characteristic diffusion time is equal to the characteristic time of the vertical wind. (A characteristic transport time corresponds to the time a molecule needs to traverse a height interval equivalent to the atmospheric scale height, on average 7 km.) In reality, the height of this border varies widely in time and with geographic position. This is also a general characteristic for all pauses. They are variable in height, and the declared heights may be a representative average that says nothing about natural variations.

The atmospheric chemistry is driven by solar short-wave irradiation. The photolysis of relatively inert atmospheric species produces reactive products. Within a cascade of chemical reactions, the reactive constituents recombine or form other inert species, and in doing so, high-grade short-wave energy is transformed into low-grade heat. The terms high-grade and low-grade refer to the ability to force such processes. This heat is irradiated as infrared radiation into space, or it drives the atmospheric circulation by means of pressure fields induced by heat. This energy dissipation process, which causes the atmospheric dynamics and chemistry, is sometimes called the "photon mill."

The formation of new chemical constituents, especially of ozone as the most important minor constituent of the atmosphere, partly takes place via a so-called three-body reaction, including a third chemically neutral reaction partner that absorbs released energy and momentum. With increasing height, such three-body reactions become increasingly inefficient because of the growing mean free path. The boundary of the inefficiency of three-body reactions is close to the mesopause.

On the other hand, the solar short-wave radiation is increasingly absorbed with decreasing height, so that direct dissociation of inert species becomes unimportant. Frequently the region that corresponds to the middle atmosphere is called the chemosphere. It includes the ozonosphere, which is a direct consequence of the chemospheric processes. However, above this domain iono-chemical reactions begin to become important, and within the lower atmosphere photochemical smog formation and other different, partly heterogeneous reactions are of greatest interest.

As described in this section the transition regions of some important spheres, the pauses, are located in the vicinity of the mesopause, meaning a qualitative change of behavior takes place there with respect to the corresponding parameters. Next, we will discuss some properties, features, and related phenomena of this domain in a bit more detail.

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Biographical Sketch

Dr. Gerd R. Sonnemann is a scientist in atmospheric physics at the German Leibniz Institute of Atmospheric Physics at the University of Rostock in Kühlungsborn, Germany. He got his PhD from the University of Rostock in 1976, and his PhD of sciences from the Academy of Sciences of the GDR in Berlin 1984. From 1972 to 1986, Dr. Sonnemann worked at the Satellite Ground Station of the GDR in Neustrelitz, Germany, and dealt with problems of the methodology of the absorption spectroscopy (occultation technique). Since 1987, he has worked at the Institute of Atmospheric Physics in Kühlungsborn. His chief scientific interest concerns nonlinear problems in photochemistry, and pattern formation in systems under global constraints. He has developed a global three-dimensional model of the dynamics and chemistry of the mesosphere/lower thermosphere. Dr. Sonnemann has written two books on the anthropogenic influence on the atmosphere and on the atmospheric ozone. He has authored or co-authored more than 50 scientific articles. Dr. Sonnemann also holds 13 patents.