The High Frequency Active Auroral Research Program

HAARP

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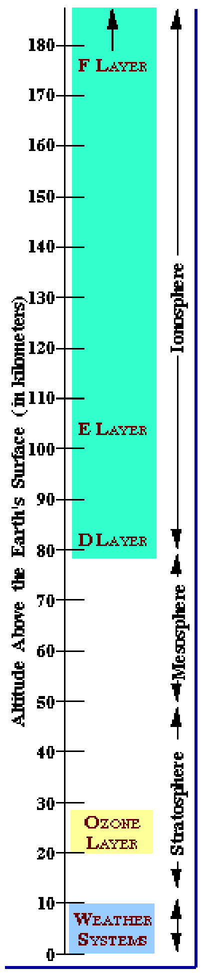
About the Ionosphere



What is the Ionosphere?

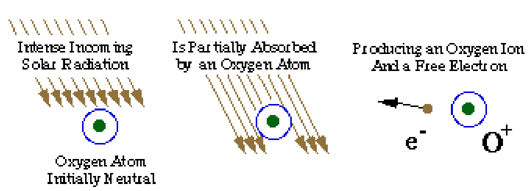
Earth's atmosphere varies in density and composition as the altitude increases above the surface. The lowest part of the atmosphere is called the troposphere (the light blue shaded region in the figure to the left) and it extends from the surface up to about 10 km (6 miles). The gases in this region are predominantly molecular Oxygen (O_2) and molecular Nitrogen (N_2). All weather is confined to this lower region and it contains 90% of the Earth's atmosphere and 99% of the water vapor. The highest mountains are still within the troposphere and all of our normal day-to-day activities occur here. The high altitude jet stream is found near the tropopause at the the upper end of this region.

The atmosphere above 10 km is called the stratosphere. The gas is still dense enough that hot air balloons can ascend to altitudes of 15 - 20 km and Helium balloons to nearly 35 km, but the air thins rapidly and the gas composition changes slightly as the altitude increases. Within the stratosphere, incoming solar radiation at wavelengths below 240 nm. is able to break up (or dissociate) molecular Oxygen (O_2) into individual Oxygen atoms, each of which, in turn, may combine with an Oxygen molecule (O_2), to form ozone, a molecule of Oxygen consisting of three Oxygen atoms (O_3). This gas reaches a peak density of a few parts per million at an altitude of about 25 km (16 miles). The ozone layer is shown by the yellow shaded region in the figure to the left.

The gas becomes increasingly rarefied at higher altitudes. At heights of 80 km (50 miles), the gas is so thin that free **electrons** can exist for short periods of time before they are captured by a nearby positive **ion**. The existence of charged particles at this altitude and above, signals the beginning of the ionosphere a region having the properties of a gas and of a plasma. The ionosphere is indicated by the light green shading in the figure to the left.

How is the Ionosphere Formed?

At the outer reaches of the Earth's environment, solar radiation strikes the atmosphere with a power density of 1370 Watts per meter^2 or 0.137 Watts per cm^2, a value known as the "solar constant." This intense level of radiation is spread over a broad spectrum ranging from radio frequencies through infrared (IR) radiation and visible light to X-rays. Solar radiation at ultraviolet (UV) and shorter wavelengths is considered to be "ionizing" since photons of energy at these frequencies are capable of dislodging an electron from a **neutral** gas atom or molecule during a collision. The conceptual drawing below is a simplified explanation of this process.



Incoming solar radiation is incident on a gas atom (or molecule). In the process, part of this radiation is absorbed by the atom and a free electron and a positively charged ion are produced. (Cosmic rays and solar wind particles also play a role in this process but their effect is minor compared with that due to the sun's electromagnetic radiation.)

At the highest levels of the Earth's outer atmosphere, solar radiation is very strong but there are few atoms to interact with, so ionization is small. As the altitude decreases, more gas atoms are present so the ionization process increases. At the same time, however, an opposing process called recombination begins to take place in which a free electron is "captured" by a positive ion if it moves close enough to it. As the gas density increases at lower altitudes, the recombination process accelerates since the gas molecules and ions are closer together. The point of balance between these two processes determines the degree of "ionization" present at any given time.

At still lower altitudes, the number of gas atoms (and molecules) increases further and there is more opportunity for absorption of energy from a photon of UV solar radiation. However, the intensity of this radiation is smaller at these lower altitudes because some of it was absorbed at the higher levels. A point is reached, therefore, where lower radiation, greater gas density and greater recombination rates balance out and the ionization rate begins to decrease with decreasing altitude. This leads to the formation of ionization peaks or layers (also called "Heaviside" layers after the scientist who first proposed their existence).

Because the composition of the atmosphere changes with height, the ion production rate also changes and this leads to the formation of several distinct ionization peaks, the "D," "E," "F1," and "F2" layers.

Additional information about the Ozone layer is available from the National Oceanic and Atmospheric Administration (NOAA).

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References:

[1] Kelley, M. C., **The Earth's Ionosphere**, Academic Press, Inc:San Diego, 1989.

[2] Davies, Kenneth, **Ionospheric Radio**, Peter Peregrinus Ltd.:London, 1990.

Pioneering Ionospheric Radio Science Research for the Twenty-First Century

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