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ARTICLES

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Chemical Releases at High Altitudes

Controlled release of chemicals from research rockets leads to new knowledge about the upper atmosphere.

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Man's attempts at controlled modification of the earth's lower atmosphere are frustrated by the sheer mass, on a geophysical scale, of the air itself. At sea level, a single cubic kilometer contains a million tons of air. In terms of "chemical release" the daily exhaust products of all the motor vehicles of the world, if collected, would barely fill this volume at normal pressures. However, atmospheric pressure decreases so rapidly with height that at an altitude of 150 kilometers, the mass of air in a cubic kilometer totals less than 2 kilograms (*1*). This mass can be completely displaced by the release of the contents of a gas cylinder easily carried to this height by a small research rocket.

Such "artificial modification" can produce effects which may be recorded by simple ground-based instruments and which can tell us much about the region in which they occur. It is emphasized that experiments of this type do not have as an objective the modification of weather in the earth's lower atmosphere and are inherently limited to the role of a research tool in increasing our knowledge about the upper atmosphere. Within that framework, they have been highly successful in the measurement of winds, diffusion, and temperature at altitudes between 80 and 200 kilometers. They have also been useful in studying chemical composition and reaction rates, the characteristics of radio-wave reflections from layers of ionized constituents, and dissipation of sound-wave energy in this region. In some of these studies, they provide unique measurements of properties not readily determined by other methods; in other studies, they provide cross-checks of experimental measurements made by other methods.

It had long been recognized that a major source of light in the twilight sky is a thin layer of free sodium atoms centered at a height of 90 kilometers, which absorbs and reemits sunlight at the sodium resonance wavelength of 5890 angstroms. Since the layer contains only a fraction of a kilogram of sodium per square kilometer across its entire thickness, it was suggested in 1950 by Bates (*2*) that injection of as little as 1 kilogram of sodium vapor from a rocket could visibly increase emission over an area of several square kilometers. The first experiment, made by Edwards, Bedinger, Manring, and Cooper from White Sands, New Mexico, in 1955 (*3*), was the twilight release of 3 kilograms of sodium vapor between 70 and 113 kilometers altitude from an Aerobee rocket. This release created a brilliant yellow trail (5890 A resonance) above 85 kilometers, soon distorted by ionospheric winds, and growing to over 1 kilometer in diameter, disappearing only as sunset at altitude left it in darkness.

The simplicity of the experiment for wind measurements has led to its widespread use as a first step in rocket research by various nations. Cooperative coordinated launches have been organized within the framework of the Committee on Space Research (COSPAR), and between 1958 and 1965 about 100 wind profiles have been obtained and analyzed by groups in the United States, France, Canada, Italy, Great Britain, Japan, Argentina, India, and Pakistan (*4*).

The use of the same sodium trails to estimate diffusion rates and temperatures has also been successful. Measurement of the rate of growth of the trail width provides one of the few experimental methods to test theoretically predicted upper-atmosphere diffusion rates (*5*). Unique determinations of temperature profiles between 100 and 200 kilometers have been made by Blamont (*6*) through measurement of the Doppler broadening of the resonance emission. Many other release experiments have also been carried out with other chemicals which produce light emissions or local changes in the natural electron density of the ionosphere. This article will survey qualitatively the objectives, methods, and results associated with the use of this general technique in upper-atmosphere research.

Geophysics of Chemical Release

Altitudes at which the chemical release technique has been most useful extend from about 80 to 200 km. The temperature of this region increases from 180°K at 80 km to about 1200°K at 200 km, while density falls from 10^{-5} to 10^{-10} of sea-level density over the same interval. At 80 km, atmospheric composition is very similar to that at the earth's surface, but

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