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## **Chemical Releases at High Altitudes**

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N. W. Rosenberg

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## SCIENCE

## Chemical Releases at **High Altitudes**

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

N. W. Rosenberg

Man's attempts at controlled modification of the earth's lower atmosphere are frustrated by the sheer mass, on a are trustrated by the sheer mass, on a geophysical scale, of the air itself. At sea level, a single cubic kilometer con-tains 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 de-creases so rapidly with height that at an altitude of 150 kilometers, the mass of air in a cubic kilometer totals less than 2 kilograms (I). 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.

"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

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winds, diffusion, and temperature at al-titudes 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 measure-ments of properties not readily de-termined by other methods; in other studies, they provide cross-checks of experimental measurements made by

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 con-tains 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 I 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 Mexi-co, in 1955 (3), was the twilight re-lease 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 al-titude left it in darkness.

The simplicity of the experiment for

wind measurements has led to its widespread use as a first step in rocket re-search by various nations. Cooperative coordinated launches have been organized within the framework of the Comized within the framework of the Com-mittee 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

The use of the same sodium trails to estimate diffusion rates and temper-atures 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 diffu-sion 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 experi-ments have also been carried out with other chemicals which produce light other chemicals which produce light emissions or local changes in the natural electron density of the ionosphere. This article will survey qualitatively the ob-jectives, methods, and results associated with the use of this general technique in upper-atmosphere research.

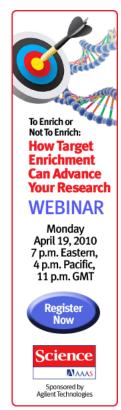
## Geophysics of Chemical Release

Altitudes at which the chemical re-Attitudes at winen the chemical re-lease 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-å to 10-10 of sea-level den-sity over the same interval. At 80 km, atmospheric composition is very simiatmospheric composition is very simi lar to that at the earth's surface, but

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