Measurement of Upper Atmospheric Winds at 160 and 275 Kilometers

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Changes in the orbital inclinations of satellites were analyzed by *King-Hele* [1970] who deduced an average angular velocity of the upper atmosphere. The results suggest that the atmosphere at heights between 200 and 400 km rotates faster than the earth with an excess speed ranging, respectively, from 10 to 50%. *King-Hele* [1970] finds that his result agrees with the theoretical model of winds at 250 km computed by *Challinor* [1969]. Wind measurements performed by making observations of artificial clouds released from rockets can provide more information. There are only a few measurements of this kind at altitudes higher than 200 km; two have been reported by *Bedinger* [1970] and two others by *Rees* [1970].

Another aspect of the dynamics of the upper thermosphere, on which even fewer data have been obtained, concerns the vertical motions. *Blamont and Baguette* [1961], however, reported the observation of vertical winds above 120 km.

Information on these two subjects was obtained by photographically tracking AlO clouds released from two Skylark rockets launched from Sardinia (39.5°N, 10°E) by the European Space Research Organisation. The releases took place for the S 64-1 payload on July 6 and for the S 64-2 payload on July 13, 1969. The observations were made after sunset when the solar depression angles were 10° or larger; the local mean launch times were 0830 and 0821 P.M., respectively.

Tracking of the low-altitude clouds was performed by means of cameras equipped with objectives of 50 cm focal length and 10 cm diameter by using plates of 8 × 10 inches. An angular coordinate system was defined on each plate by measurement of the positions of more than 50 star images by means of the Zeiss Asco Record measuring machine of the Observatoire Royal de Belgique. These measurements lead to an uncertainty smaller than 1 m sec^{-1} as to the speed of the point released clouds for an observation time of 190 sec. A larger uncertainty results from the location of the cloud centers on the plates. This was performed by means of a Joyce and Loebl isodensitracer with an accuracy leading to a probable error of the order of ±3 m sec^{-1} on the cloud velocity relative to the earth. The upper clouds were faint and it was necessary to use a lens with a larger aperture. However, since the focal length was smaller (8 cm), the probable error is ±20 m sec^{-1}. The results are presented in Table 1.

For the measurements at the low altitudes, the southward velocity components associated with a small zonal component confirm previous observations [*Kochanski*, 1964; *Procumier and McDermott*, 1969] made in Sardinia. The upward motions are difficult to relate with intrinsic atmospheric motions since buoyancy effects must also be considered. Vertical winds of 30 m sec^{-1} or more do not seem unrealistic, however, and have been deduced from release experiments by *Rees* [1969]. They may greatly affect the diffusion coefficient and must be seriously considered when the altitude must be assigned to the atmospheric densities deduced from diffu-

TABLE 1

		Components of motion	
Payload	Altitude, km	Direction	Speed, m sec^{-1}
S 64-1	161	eastward	11
		southward	111
		upward	37
	275	eastward	111
		northward	48
S 64-2	157	westward	9
		southward	68
		upward	22
	278	eastward	110
		northward	28

sion rate measurements. For the experiments reported here such effects will be discussed in more detail by *Ackerman and Simon* [1971].

The eastward component of the wind observed at the highest altitudes is comparable in size to those observed by *Bedinger* [1970] at 260 km and by *Rees* [1970] at 240 km, both at evening twilight for approximately the same latitudes in the northern and southern hemispheres, respectively. These two determinations, however, were made at different periods of the year: February 13 and May 31, respectively.

The components of the wind vector to be expected in Sardinia at the local mean times considered should be, according to the revised model computed by *Challinor* [1970], 170 m sec^{-1} eastward and 30 m sec^{-1} southward, approximately. The observed zonal component is smaller and the observed meridional component is directed in the opposite direction; these differences could be attributed to local fluctuations. It must be noted, however, that *Rees* [1970] observed eastward components in the evening as well as in the morning, while *Challinor* [1970] predicts a westward component in this last case.

The eastward components observed at 275 and 278 km would correspond to an instantaneous and local ratio of the atmospheric angular velocity to the earth's angular velocity equal to 1.3, while *King-Hele* [1970] deduces a global ratio of 1.4 from the analysis of satellite orbits.

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REFERENCES

Ackerman, M., and P. Simon, Upper atmospheric densities between 155 and 165 km by observation of A10 clouds, *Planet. Space Sci.*, (in press), 1971.

Bedinger, J. F., Measurement of winds above 200 kilometers, *J. Geophys. Res.*, *75*, 683, 1970.

Blamont, J.-E., and J.-M. Baguette, Mesures déduites des déformations de six nuages de métaux alcalins formés par fusées dans la haute atmosphère, *Ann. Geophys.*, *17*, 319, 1961.

Challinor, R. A., Neutral-air winds in the ionospheric *F*-region for an asymmetric pressure system, *Planet. Space Sci.*, *17*, 1097, 1969.

Challinor, R. A., Neutral-air winds in the ionospheric *F*-region for an asymmetric global pressure system, *Planet. Space Sci.*, *18*, 1485, 1970.

King-Hele, D. G., Average rotational speed of the upper atmosphere from changes in satellite orbits, *Space Res.*, *10*, 537–549, 1970.

Kochanski, A., Atmospheric motions from sodium cloud drifts, *J. Geophys. Res.*, *69*, 3651, 1964.

Procunier, R. W., and D. P. McDermott, Wind and temperature profiles above Sardinia on 30 September and 2 October 1965, *J. Atmos. Terr. Phys.*, *31*, 15, 1969.

Rees, D., Vertical winds in the lower ionosphere, *J. Brit. Interplanet. Soc.*, *22*, 275, 1969.

Rees, D., R. G. Roper, K. H. Lloyd, and C. H. Low, Determination of the structure of the atmosphere between 90 and 250 kilometers using contaminant releases, *Phil. Trans. Roy. Soc. London*, 1970.

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