PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Winds over Heiss Island from Artificial Luminous Cloud Observations

L. A. Andreeva, L. A. Katasyev and D. B. Uvarov

Phil. Trans. R. Soc. Lond. A 1972 **271**, 559-562
doi: 10.1098/rsta.1972.0023

Phil. Trans. R. Soc. Lond. A. **271**, 559–562 (1972) [559]
Printed in Great Britain

Winds over Heiss Island from artificial luminous cloud observations

BY L. A. ANDREEVA, L. A. KATASYEV AND D. B. UVAROV
Institute of Experimental Meteorology, Obninsk, U.S.S.R.

Results are presented of wind velocities and diffusion coefficients observed over Heiss Island (80.5° N) in the altitude range 110 to 174 km during February and March periods in the years 1968 to 1970.

1. INTRODUCTION

In this report basic observational results of winds and diffusion coefficients over Heiss Island in the springs of 1968 to 1970 are presented. Measurements were carried out by means of artificial luminous clouds, which were produced for the purpose of investigating temperatures at polar latitudes. The experiments were carried out in accordance with a Franco–Soviet agreement on scientific collaboration. The same clouds were used for the determination of wind and diffusion coefficients.

AlO clouds had a spherical form and were observed primarily between 120 and 170 km. In some cases the clouds were formed simultaneously in twos at different heights. Some of the atmospheric characteristics at high altitudes over Heiss Island, together with temperature data obtained from artificial luminous cloud observations, have been presented in earlier works (Andreeva, Katasyev & Uvarov 1970; Andreeva & Uvarov 1970; Blamont *et al.* 1970).

2. RESULTS OF WIND OBSERVATIONS

Results of wind observations obtained during experiments at Heiss Island are presented in table 1, where the positive directions of meridional and zonal components coincide with directions to the north and to the east respectively. The azimuth of cloud drift is measured in a clockwise direction from the north.

The results obtained can be used for quantitative evaluation of the wind régime in the polar ionosphere in spring. The nearly complete absence of wind velocity components from the north is a characteristic feature of all measurements. This fact has been noted by other authors (Kochanski 1966; Bedinger 1966) for midlatitudes and polar latitudes (from 30 to 59° N), and attributed to a global polar–equatorial circulation.

In the height region 160 to 170 km for which we have most data the wind velocity lies in the range 47 to 299 m/s, but values of 50 to 100 m/s are most commonly observed. Wind directions at these heights are found mainly in the range 180 to 270°. The wind velocity at 130 km and below is greater as a rule than the wind velocity at 160 to 170 km.

The wind data obtained at Heiss Island are characterized by great changes with time. Much attention has been given to sudden changes of wind direction in individual cases. In the 1968 experiments the wind direction was nearly constant, but in 1969 on the night of 10/11 March at 170 km the wind changed direction by more than 150° and on the night of 13/14 March at 160 km it changed direction by nearly 90°, remaining nearly constant for the next few days. The amplitude of the wind velocity can also change significantly, reaching in some cases very great values, for example, 300 m/s at 171 km in the evening of 19 March 1968. Such great wind velocities are observed comparatively seldomly (Blamont 1966).

Table 1. Results of wind observations obtained at Heiss Island (80.5° N)

date	time of cloud formation (Moscow) h min	height of cloud centre km	wind velocity/m s^{-1} resultant	meridional component	zonal component	azimuth of cloud drift degrees
1967 10 Oct.	17 53	153	110	−104	+34	162
1968 28 Feb.	17 45	171	66	−64	−16	194
1968 16 Mar.	20 45	121	154	+40	−149	285
		172	72	−56	−45	219
1968 19 Mar.	0 30	171	171	−147	−85	210
1968 19 Mar.	21 24	171	299	−161	−267	239
1968 20 Mar.	23 30	172	83	−68	−66	227
1969 8 Mar.	18 35	174	98	+74	−64	319
1969 10 Mar.	19 10	120	109	−13	−108	263
		172	53	+53	0	356
1969 11 Mar.	2 00	172	152	−141	−57	202
1969 13 Mar.	19 45	118	57	+27	−50	298
		157	54	−34	−42	231
1969 14 Mar.	1 23	156	47	−39	+26	146
1969 15 Mar.	1 20	110	110	−83	+58	148
1969 17 Mar.	21 35	165	137	−122	+62	153
1969 20 Mar.	20 50	145	119	−97	+68	145
1969 20 Mar.	23 30	121	164	−89	+136	123
		170	46	−46	−6	188
1970 12 Feb.	6 14	164	73	−35	−63	241
1970 23 Feb.	16 25	130	92	−39	+83	115
		148	90	−31	+85	110
1970 2 Mar.	3 25	150	36	+31	+17	29
1970 2 Mar.	17 31	161	94	−43	+84	117
		144	109	−26	+106	105
1970 6 Mar.	2 51	148	37	−29	+23	142
		128	121	−102	+61	149
1970 7 Mar.	2 37	163	47	−39	−26	213

3. Changes of wind velocity and direction

Significant changes of wind velocity and direction on certain days only cannot be explained by a daily variation, and certainly in our experiments there was no distinct correlation between the values of velocity and wind direction and the time of day. Wind variations may perhaps be linked with a change in the geophysical situation during the observation period and such a correlation would best be seen for sites situated in the Polar Zone. Smith (1968) tried to explain a high wind velocity by local heating of the atmosphere at great heights in the region of the aurora polaris during a magnetic storm. However, correlation between the growth in wind velocity and the increase in magnetic activity is not observed.

During the experiments at Heiss Island in 1968 to 1970 a significant change of the solar activity level and a relatively quiet geomagnetic situation with small short-term disturbances were observed. In 1968 from 14 to 17 March a small recurrent geomagnetic storm was noted; in 1969 from 17 to 20 March small disturbances of the geomagnetic field were registered; while in 1970 significant geomagnetic disturbances were not observed (cosmic data monthly review 1967, 1968, 1969). On 19 March 1968 a wind velocity equal to 300 m/s was measured with a comparatively small value of planetary geomagnetic index K_p (not more than 3 to 4) but with an increased value of the local K index (to 7). During the small magnetic storm on 16 March 1968 with significant K_p indexes (to 6) and a major disruption of the local magnetic field (K index to 8), a wind velocity was measured which was equal to 72 m/s, i.e. a value commonly observed in our experiments. The sharp changes of the wind direction noted in our experiments appear to have no distinct correlation with changes of the geomagnetic field.

4. Results of diffusion coefficient measurements

In table 2 the results of diffusion coefficient measurements are given. The values of height marked by a dagger were obtained by triangulation of the cloud from two sites; the error of height determination in this case was not greater than ±2 km. In other experiments the error in the height was about ±4 km.

Table 2. Results of diffusion coefficient measurements at Heiss Island (80.5° N)

date	time (Moscow) h min	height/km	reagent	D/cm² s⁻¹	σ_D/D (%)‡
1967 10 Oct.	17 53	153†	AlO	2.0×10^7	7
1968 16 Mar.	20 45	172†	AlO	6.2×10^8	7
1968 16 Mar.	20 45	121†	AlO	1.1×10^7	10
1968 19 Mar.	0 30	171†	AlO	5.9×10^8	20
1968 19 Mar.	21 24	171†	AlO	5.8×10^8	7
1968 20 Mar.	23 30	172†	AlO	5.6×10^8	10
1968 28 Mar.	17 50	171†	Na	7.3×10^8	10
1969 8 Mar.	18 35	174	AlO	4.0×10^8	14
1969 10 Mar.	19 10	168	AlO	5.2×10^8	16
1969 13 Mar.	19 45	157	AlO	2.1×10^8	12
1969 14 Mar.	1 23	150†	AlO	2.8×10^8	17
1969 17 Mar.	21 35	165†	AlO	5.6×10^8	8
1969 20 Mar.	20 50	144†	Li	3.3×10^8	16
1969 20 Mar.	23 30	121†	AlO	2.2×10^7	20
1969 20 Mar.	23 30	170†	AlO	4.8×10^8	7
1970 12 Feb.	6 14	164	AlO	4.2×10^8	7
1970 23 Feb.	16 25	130	AlO	6.5×10^7	10
1970 2 Mar.	3 25	150†	AlO	2.3×10^8	7
1970 2 Mar.	17 31	144	AlO	1.0×10^8	20
1970 2 Mar.	17 31	161	Ba	2.1×10^8	7
1970 6 Mar.	2 51	128	AlO	3.0×10^7	30
1970 7 Mar.	2 37	163	AlO	2.2×10^8	20

† Height obtained by triangulation from two sites with an error not greater than ±2 km.
‡ σ_D is the standard deviation of D.

Values of diffusion coefficients are also given in figure 1. D values obtained by means of Na, Li or Ba clouds were reduced to $D_{AlO-air}$ values according to the formula (Golomb & McLeod 1966):

$$D_{AlO-air} = D(\sigma_{AlO-air}/\sigma)^2 (\mu_{AlO-air}/\mu)^{\frac{1}{2}},$$

where the diameter for molecular collisions is considered to be proportional to the cube root of the molecular weight M. The solid curve represents $D_{AlO-air}$ variation with height calculated according to the C.I.R.A. 1965 tables (model 5; 20 h). From figure 1 it follows that all data referred to 170 km are close to each other although obtained in various years, but exceed the values corresponding to the model by 1.3 times on the average. D values for 14 and 17 March

1969 exeed model D values by 1.9 and 1.7 times respectively. Perhaps this results from the increased geomagnetic activity in the days mentioned. It is noted, that in accordance with Poloskov *et al.* (1969) the temperature on 14 March 1969 at the height considered was much

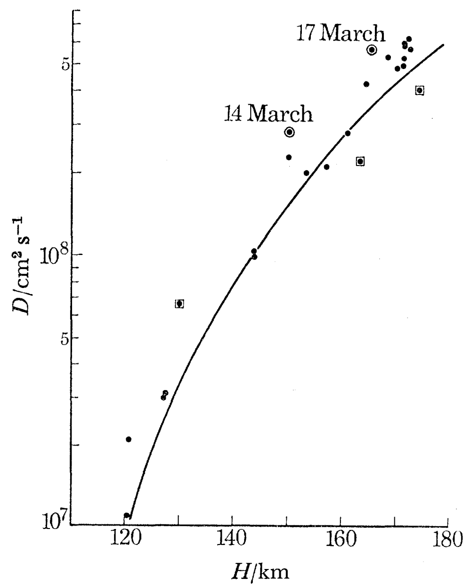

FIGURE 1. AlO diffusion coefficient changes with height.

greater than on the other days. However, such correlations of diffusion coefficients with geomagnetic activity have not always been observed. The scatter of the D data indicated by squares can be explained by the error in height, which in these cases could reach ± 4 km as mentioned already.

REFERENCES (Andreeva *et al.*)

Andreeva, L. A., Katasyev, L. A. & Uvarov, D. B. 1970 Measurement of wind velocity and diffusion coefficient by means of artificial luminous clouds. *Meteor. Hydrol.* **1**, 35.

Andreeva, L. A. & Uvarov, D. B. 1970 Measurement of wind velocity and diffusion coefficient by means of luminous AlO clouds over Heiss Island. *Proc. Inst. expl. Meteor.* **16**, 10.

Bedinger, I. 1966 Compendium of wind data from the vapour trail technique. *Techn. Rep. Geophys. Corp. America* No. 667-N.

Blamont, J. 1966 Structure horizontale des vents au-dessus de 90 km. *Probl. meteorol. stratosphere at mesosphere, Paris*, pp. 151–168.

Blamont, J. E., Shanin, M. A., Maillard, M., Andreeva, L. A., Katasyev, L. A., Polosko, S. M., Tulinov, G. F. & Uvarov, D. B. 1970 Rocket measurements of upper atmosphere temperature and wind in the polar region by the artificial luminous cloud method. *Dokl. Akad. Nauk. SSSR* **193**, 1031.

Golomb, D. & McLeod, M. H. 1966 Diffusion coefficients in the upper atmosphere from chemiluminous trails. *J. geophys. Res.* **71**, 2299–2305.

Kochanski, A. 1966 Atmospheric motions from sodium cloud drifts at four locations. *Mon. Weather Rev.* **94**, 199.

Poloskov, S. M., Tulinov, G. F., Blamont, J. E., Chanin, M. L. & Maillard, M. 1969 Temperature measurements of the upper atmosphere in the Northern Polar Zone. *Space research* **10**, 1970, pp. 519–531. COSPAR Meeting, May 1969.

Smith, L. 1968 An observation of strong thermospheric winds during a geomagnetic storm. *J. geophys. Res.* **73**, 4959–4963.