NASA TECHNICAL NOTE

NASA TN D-2114

N63 21272

NASA TN D-2114

IONOSPHERIC WINDS: MOTIONS INTO NIGHT AND SPORADIC *E* CORRELATIONS

by N. W. Rosenberg, H. D. Edwards, and J. W. Wright;

Prepared under Grant No. NsG-304-63 by
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia
for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • SEPTEMBER 1963

TECHNICAL NOTE D-2114

IONOSPHERIC WINDS: MOTIONS INTO NIGHT AND SPORADIC E CORRELATIONS

By N. W. Rosenberg, H. D. Edwards,
and J. W. Wright

Prepared under Grant No. NsG-304-63 by
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

IONOSPHERIC WINDS: MOTIONS INTO NIGHT

AND SPORADIC E CORRELATIONS *

by

N. W. Rosenberg, H. D. Edwards
and J. W. Wright

The persistence of night winds and shears for more than five hours after sunset at altitudes between 100 and 150 km was evaluated during the COSPAR synoptic ionospheric winds program in December 1962. The method used was to release chemiluminous trails from rockets between 100 and 150 km with the times of release being 1720, 1801, 2145 and 2245 CST on 3 December 1962. The release times were respectively 13 minutes before sunset at the 100 km level and 28 minutes, 4 hours 12 minutes, and 5 hours 12 minutes post sunset. All rockets were launched from the Air Force Gulf Test Range, Eglin Air Force Base, Florida at a longitude of 86.6°W and a latitude of 29.6°N.

It is believed that this is the first time such a morphology of winds and shears through the E region has been made available. Comparisons are made between the winds and shears observed under night conditions with those for the preceeding twilight period.

Theoretical discussions by Whitehead and others have suggested a wind shear origin for sporadic E. High east-west horizontal wind shears in the ionosphere and the natural magnetic field will act on ionized species to stratify these into relatively high vertical gradients.

The present paper reports on simultaneous measurements of ionospheric wind shears (measured by chemiluminescent trails) and of sporadic E (by sweep-frequency ionosondes). Occurrence at the same altitudes of maximum wind shears and strong sporadic E levels was found. In one case, for example, (86.6°W, 29.6°N, 1720 CST, 3 December 1962), sporadic E was found at 96±1 km to 1.0 mc and at 109±1 km at 6.2 mc. At this time, wind shear maxima of 45 m/s km bearing 85°E at 97±1 km and of 60 m/s km bearing 275°E at 109±1 km were found.

These data tend to verify the correlation between wind shear and sporadic E.

---

*This paper was presented at the COSPAR Meeting, June 1963, Warsaw, Poland.

1. Introduction

The pattern of winds and shears in the E region of the ionosphere, including their time and altitude variation, and their relationship with sporadic E, has been the subject of considerable speculation and theoretical analysis.(1)(2)(3) The availability of sodium trails(4) has provided well-resolved altitude variations of winds in the 90-200 km region at sunrise and sunset. COSPAR-organized programs for simultaneous measurements at different locations have provided data on variation with geographic location of such sodium-trail winds and are being reported by Blamont at this meeting.(5)

This paper reports a series of wind measurements made using recently developed chemiluminous gas trails(6) which permit measurements during the night. The pattern of winds from shortly before sunset into night is presented, and their relationships with simultaneous ionospheric soundings in the 0.2-20 mc region are noted, although no detailed theoretical analysis is given at this time.

2. Experimental

Four releases will be discussed, from rockets launched at 1720, 1801, 2145 and 2245 CST on 3 December 1962 from the Air Force Gulf Test Range, Eglin Air Force Base, Florida, Longitude 86.6°W, Latitude 29.6°N. The first release was a sodium payload(4) 13 minutes before sunset at 100 km, the second and third were $CsNO_3$-Al burners with chemiluminous trails (probably due to an Al-O reaction,(6) and the fourth was a nitric oxide trail.(6) The altitudes over which each gave useful data are presented in Figure 2.

Four photographic tracking stations equipped with modified K-24 aerial cameras(7) were used to take simultaneous photographs of the trails against a star background. Three of these stations were located approximately 100 km N, E, and W of the release, and the fourth was located near the launcher (about 20 km N of the release). Subsequent photogrammetry for winds was performed on a computer.(8)

Two ground-based ionosondes, one located about 20 km N and the other 100 km NE of the release, provided 30 second sweeps of frequencies between 0.2 and 20 mc for some time around each release. These are capable of providing estimates of Normal E-region and sporadic E frequencies and altitudes.

A spaced-receiver drift instrument utilizing a standard ground-based radio technique for making ionospheric drift measurements and operating at 3 mc was installed 20 km N of the release area and operated by Mr. E. Harnischmacher (Ionosphären Inst. Breisach) and Mr. G. H. Stonehocker (NBS, Boulder). Their detailed results will be separately reported, but pertinent data have kindly been made available by them for this report.

3. Observations

3.1 Optical Wind Motions

Figure 1 is a photograph of a typical night wind trail as viewed from 100 km N of the release area. The altitudes and times after launch of various points along the trajectory are shown.

Figure 2 presents hodographs (wind patterns viewed from above) of the four releases. An appropriate presentation of wind patterns presents two problems. First, vertical motions have not yet been measured on these particular clouds, and may not be measurable except in the turbulent region around 100 km. This problem is not considered further here. The second problem is that a given wind vector must be represented by amplitude and direction, or by north-south and east-west components.

Figures 3 and 4 present NS and EW components for the four releases. A pattern varying through the night is better seen in contour displays such as given in Figures 5 and 6. In these figures, time is represented along the x-axis and altitude along the y-axis. Equal wind components at the four times of observation are connected to form a contour map.

3.2 Radio Frequency Recordings of Ionospheric Condition

Figure 7 presents ionospheric sweep-frequency records taken at the time of the 1720 CST release. The scaled records, and the spaced receiver data (at 3 mc) are recorded in Table 1 below.

Table 1 - R.F. Ionosphere Background

Time CST	f_oE(mc)	f_oE_s(mc)	hE_s(km)	Drift Receiver Direction	Drift Receiver Velocity
1720 Sharon	1.4	1.02	96		
		6.2	109	195°	65 m/s
1801 Ivy	0.8	0.8	96		
		6.2	108	195°	42 m/s
2145 Esther	0.8	2.7	103		
2245 Dinah	0.7	2.5	100		

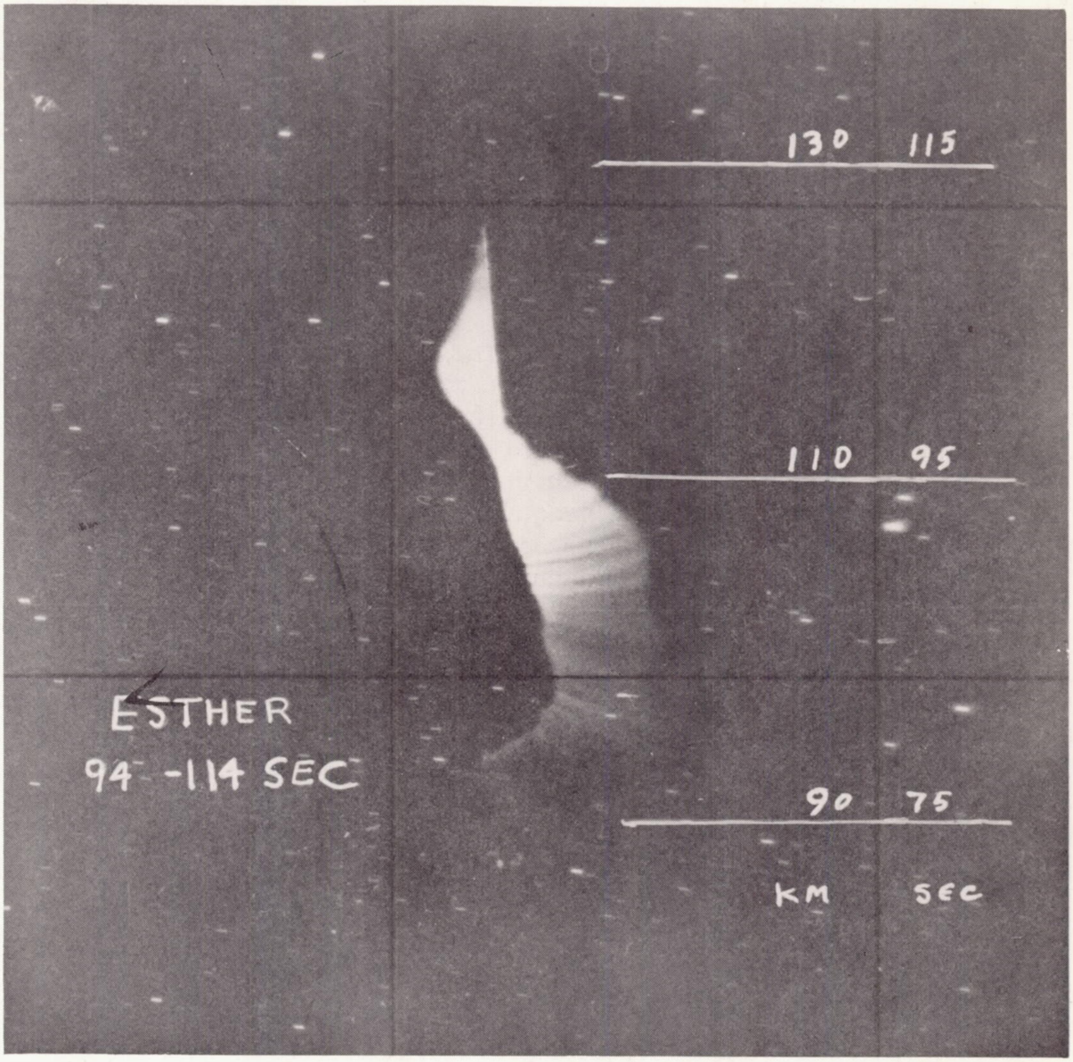

Figure 1. Photograph of a typical night wind trail showing East-West wind motion.

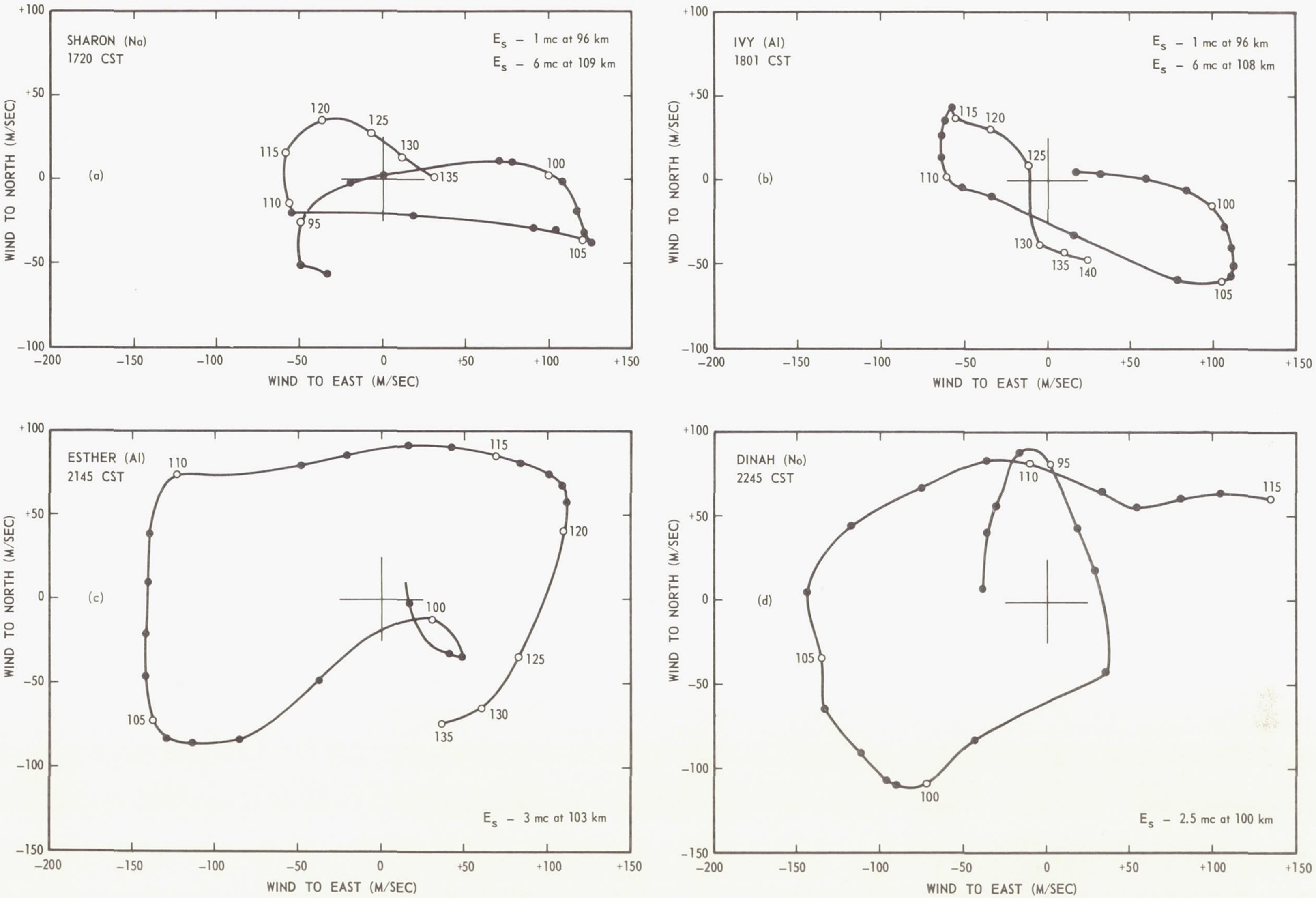

Figure 2. Hodographs of the four releases showing East-West components of the wind vector.

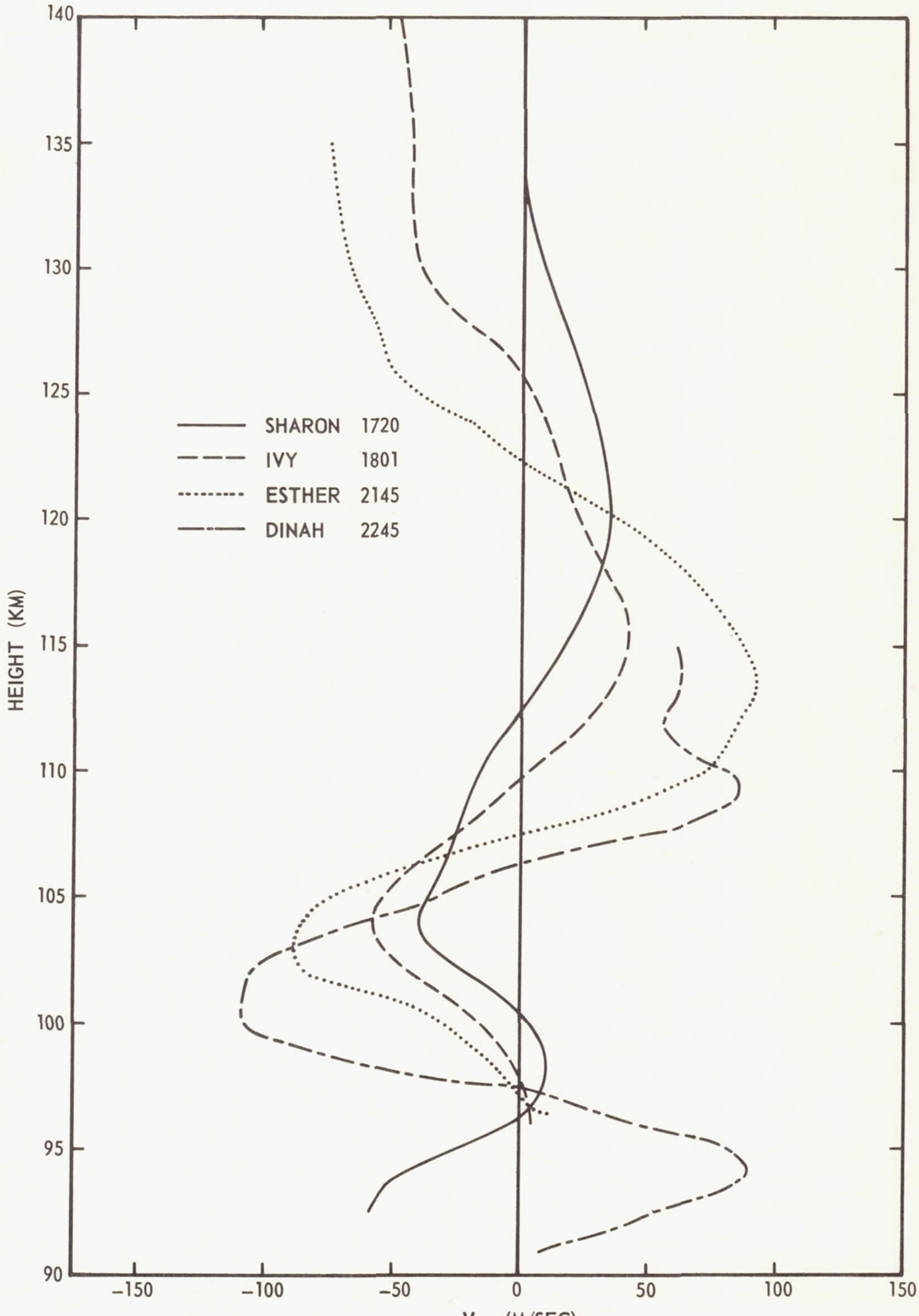

Figure 3. North-South components of the wind velocity as a function of altitude for the four releases.

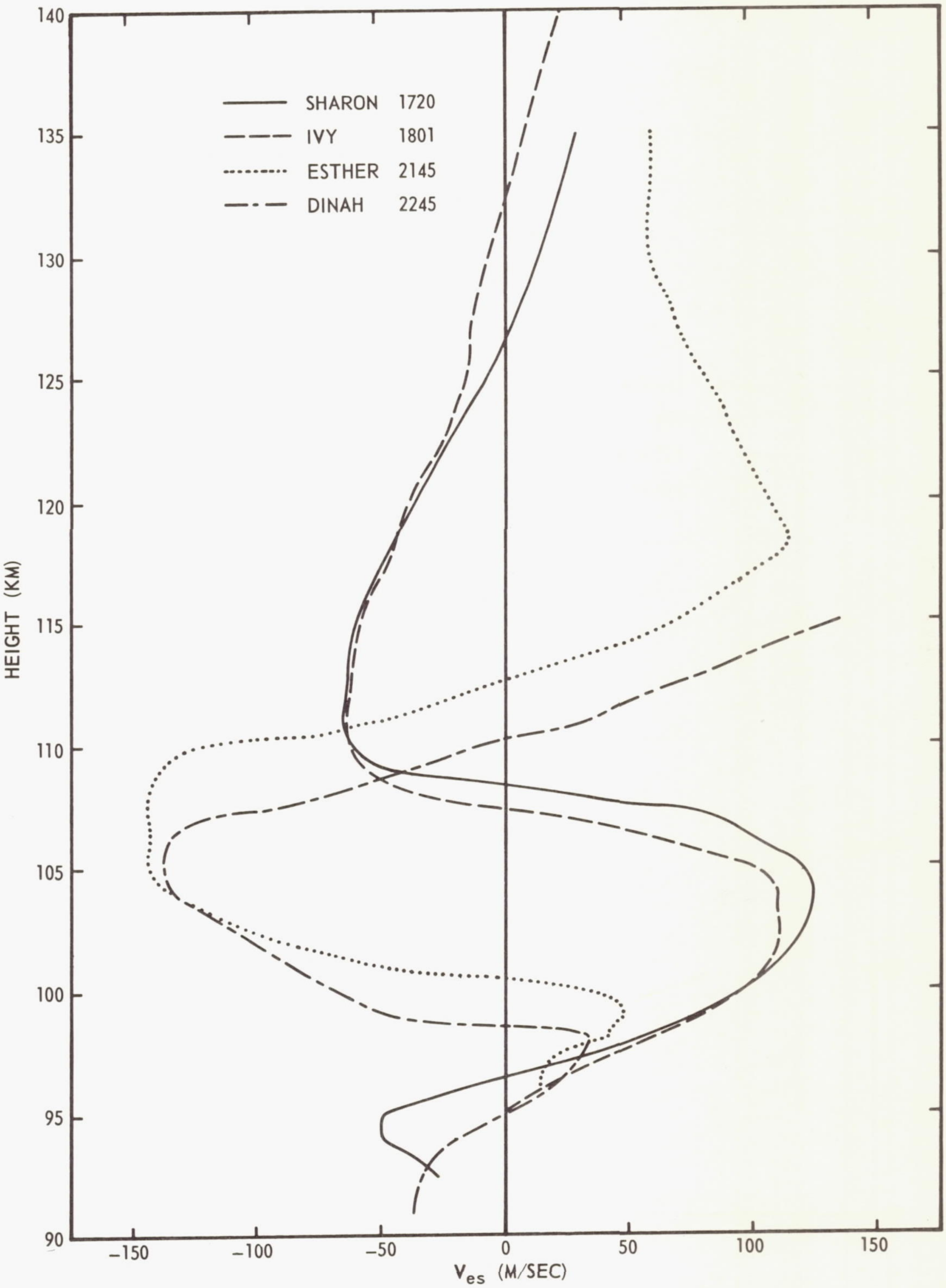

Figure 4. East-West components of the wind velocity as a function of altitude for the four releases.

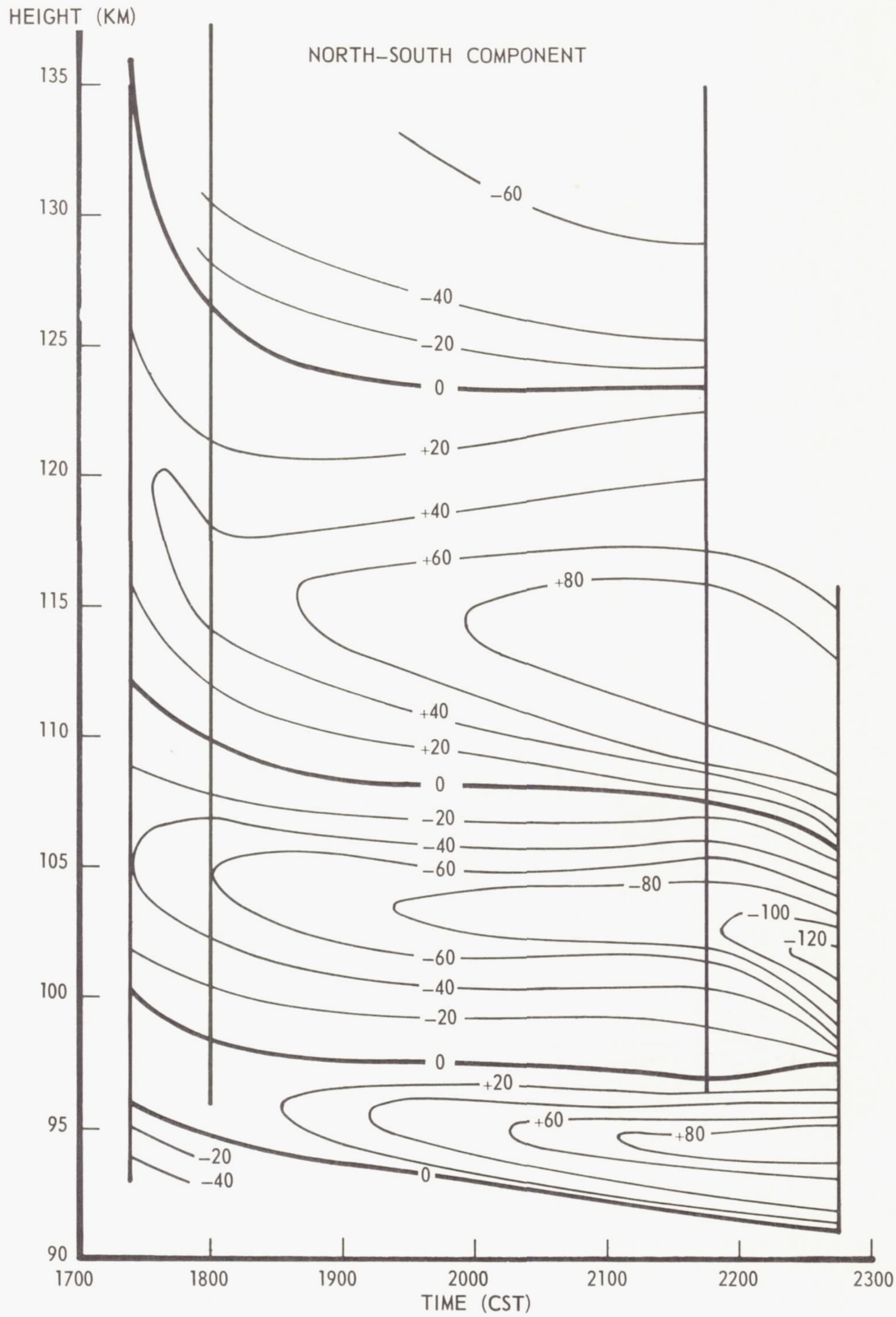

Figure 5. North-South wind contours from 1720 to 2245 CST on 3 December 1962 over Eglin Air Force Base, Florida as a function of altitude.

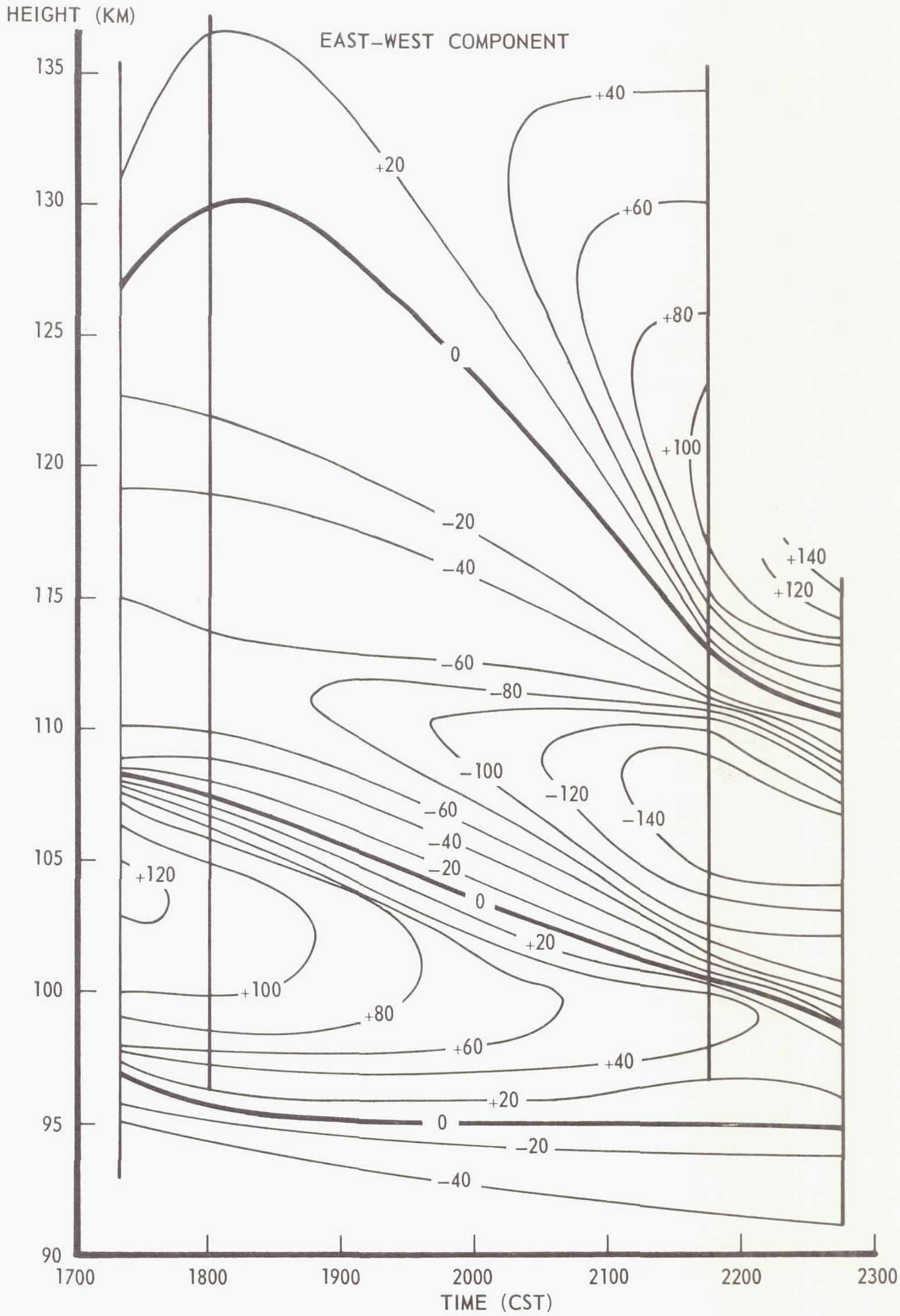

Figure 6. East-West wind contours from 1720 to 2245 CST on 3 December 1962 over Eglin Air Force Base, Florida as a function of altitude.

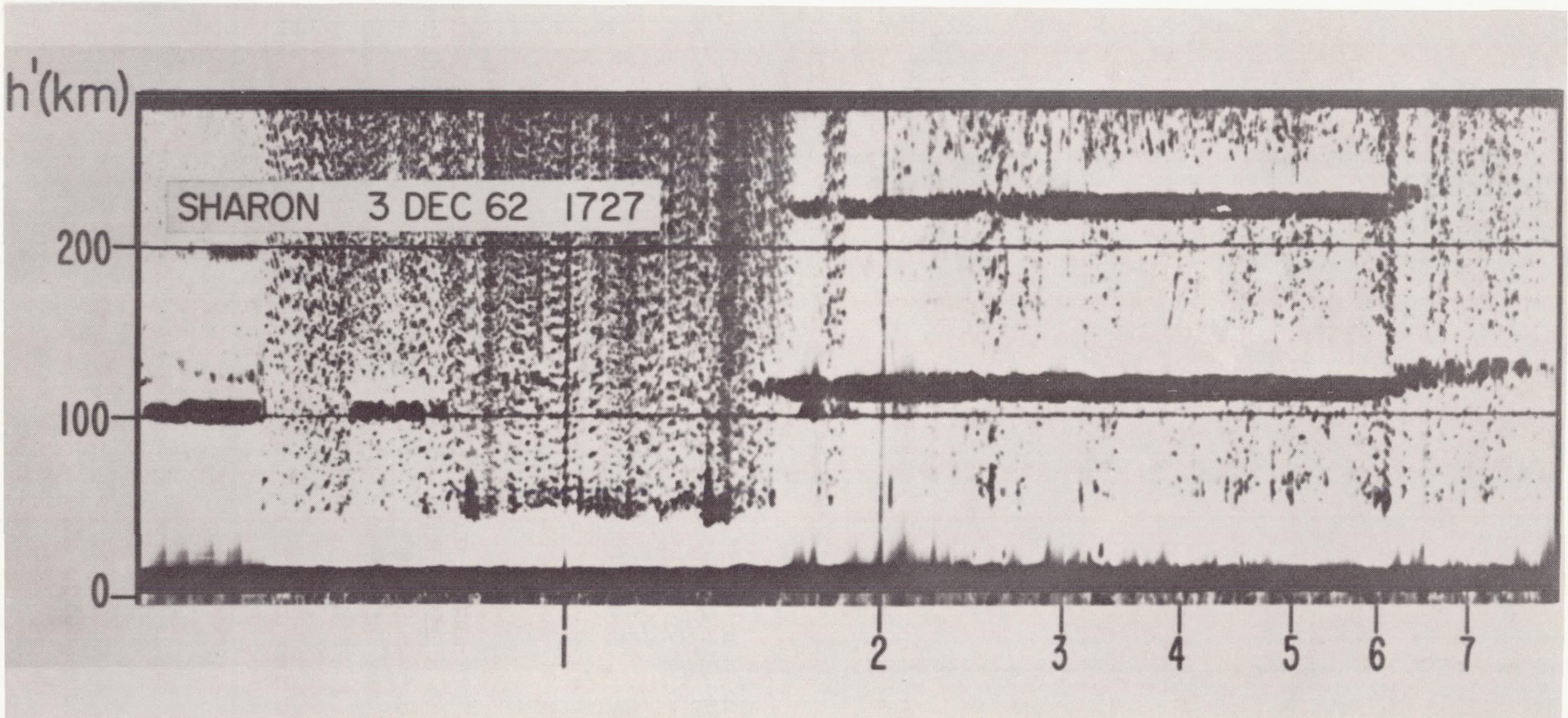

Figure 7. Ionospheric sweep-frequency records taken at the time of release 1720 CST.

For all releases sporadic E was overhead and the assigned heights are probably good to ±1 km.

No retardation corrections were necessary since a simple calculation showed that the underlying ionization could contribute less than 1 per cent of its thickness to retardation at the peak frequencies of the sporadic E.

4. Discussion of Results

4.1 Wind Profiles

The data reported here were for a single night and of course may not be typical of other nights.

Examination of Figures 3 and 5 shows that the altitude at which a given NS wind exists decreases by 5-10 km over the 5-6 hour period of observation. The altitudes at which the maximum NS or SN winds exist also decrease but the maximum strengths (and shears) increase over the time period. The NS winds appear to be quite regular in their variation and a given pattern is sinusoidal with increasing wavelength at increasing altitude. Zimmerman[9] suggests that the period is close to a scale height and varies with the scale height of the ambient.

Examination of Figures 4 and 6 shows a similar effect for the EW wind component except for two anomolies--the velocity of the wind maximum in the 100 km region decreases as the night progresses (all other maximum winds increase in velocity), and in the region above 120 km there is a rise in the altitude of a given contour with time in the early night followed by a decrease in altitude at later times.

It is tempting to associate the decreasing altitude of these winds with a thermal subsidence at night, i.e. that a given wind may exist at a given ambient density, and that a nighttime cooling occurs, these winds move downward together with the air mass in which they are embedded. It is also interesting that Hines[1] suggests a downward velocity of all wind profiles.

The shears are of the order of 10-100 m/s km altitude and NS shears increase at night. The EW contours also suggest this same increase in shears into night.

4.2 Correlation of High Wind Shears with Sporadic E

Comparison of the sequence of sporadic E heights, given in the table in section 3.2, with the EW contours shown in Figure 6, shows that the sporadic E falls along the zero EW wind velocity contour from 1720 to 2245 CST for the altitude range 108 to 98 km.

Similarly there is a striking correlation shown in Figure 8 of the height of observed sporadic E return and of high shears (change of wind speed with height) in the wind profile. The most striking single record is that of the 1720 release where maximum E_s occurred at 96 and 109 km altitude, and the maximum EW and WE shears occurred at essentially the same altitudes. (The cross-hatched areas of Figure 8 are the reported E_s heights ± 1 km, the estimated error in scaling.) Similarly there is a high EW or WE shear wherever E_s is reported at the other times of observation. It is noted that at 2145 and 2245, a high EW shear exists in the vicinity of 110 km and yet there is no obvious E_s at these times and this altitude.

However, since sporadic E was seen at 103 km at 2145 CST and at 100 km at 2245, it is not possible to say definitely that sporadic E was absent at the 110 km region (because of the pulse width of the ionosonde). In both of the above cases the sporadic E may have been present but since it was not observed the electron density must have been lower than for the 103 and 100 km regions.

Sporadic E was also observed at the 96 km level at both 1720 and 1801 CST but not at 2145 and 2245, although the zero EW contour crosses these latter times at approximately 95 km. Presumably the electron density was very low at the latter two times.

The above observations may imply that high EW shear is a necessary but not sufficient condition for sporadic E occurrence.

A second point of interest is that the sporadic E associated with the 1720 release was blanketing for both the 96 km and the 109 km regions. The lower region was in a state of turbulence as shown by a photograph of the developing trail release (Figure 9), while the upper sporadic E was located in a nonturbulent environment.

Another point of interest is that the Whitehead development[(2)] would suggest that an EW wind increasing with increasing altitude would provide a layer of increased electron density, but it is our opinion that this would also imply a decreased electron (and ion) density if the shear were in the reverse sense. The "correct" wind shear is present at 96 km, but a shear of the wrong sign is present at the 109 km height. Similarly, wrong-sign wind shears are present for the other three releases. This point will require further clarification.

Spaced-receiver drift results for Sharon are shown in Figure 10. The direction sensed by the radio method is in good agreement with the cloud drift at the sporadic E altitude and in being mostly southbound agrees with the absence of an EW component implied by the wind shear theory of sporadic E. It would be useful to re-examine the great quantity of available spaced-receiver observations

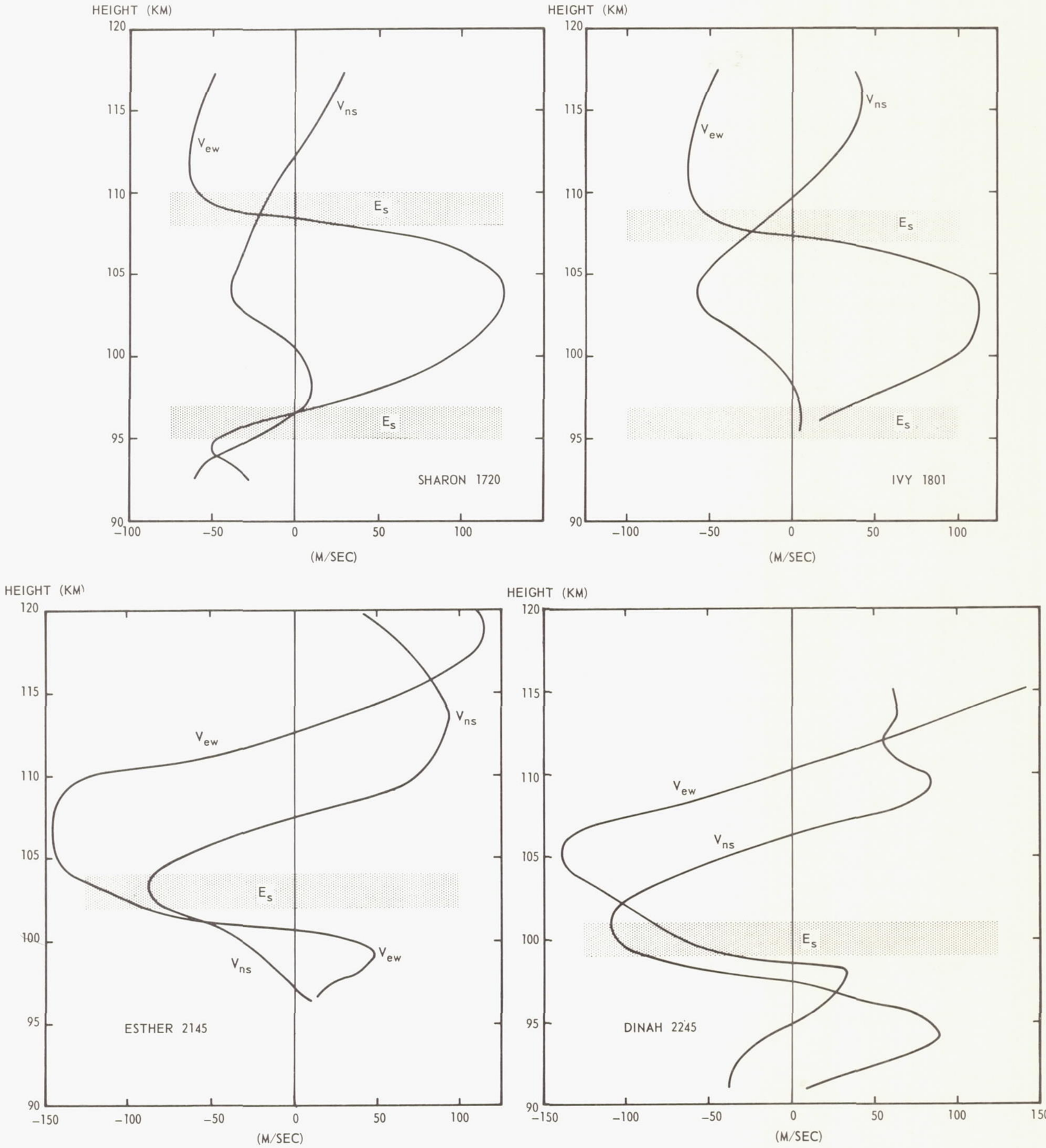

Figure 8. NS and ES plots of wind speed as a function of altitude showing correlation with observed altitudes of sporadic E.

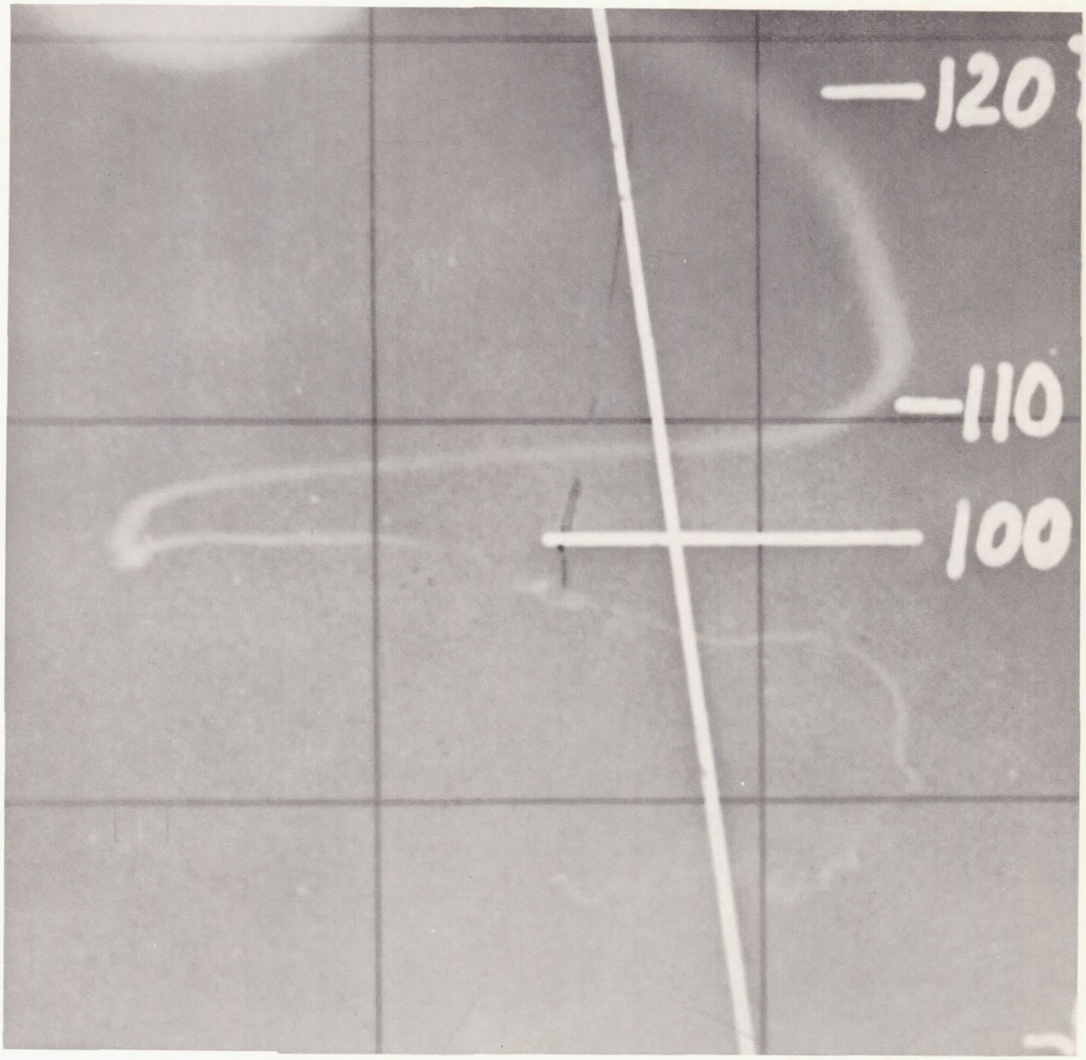

Figure 9. Photograph of the 1720 CST twilight release showing high wind shears at 97 and 109 km.

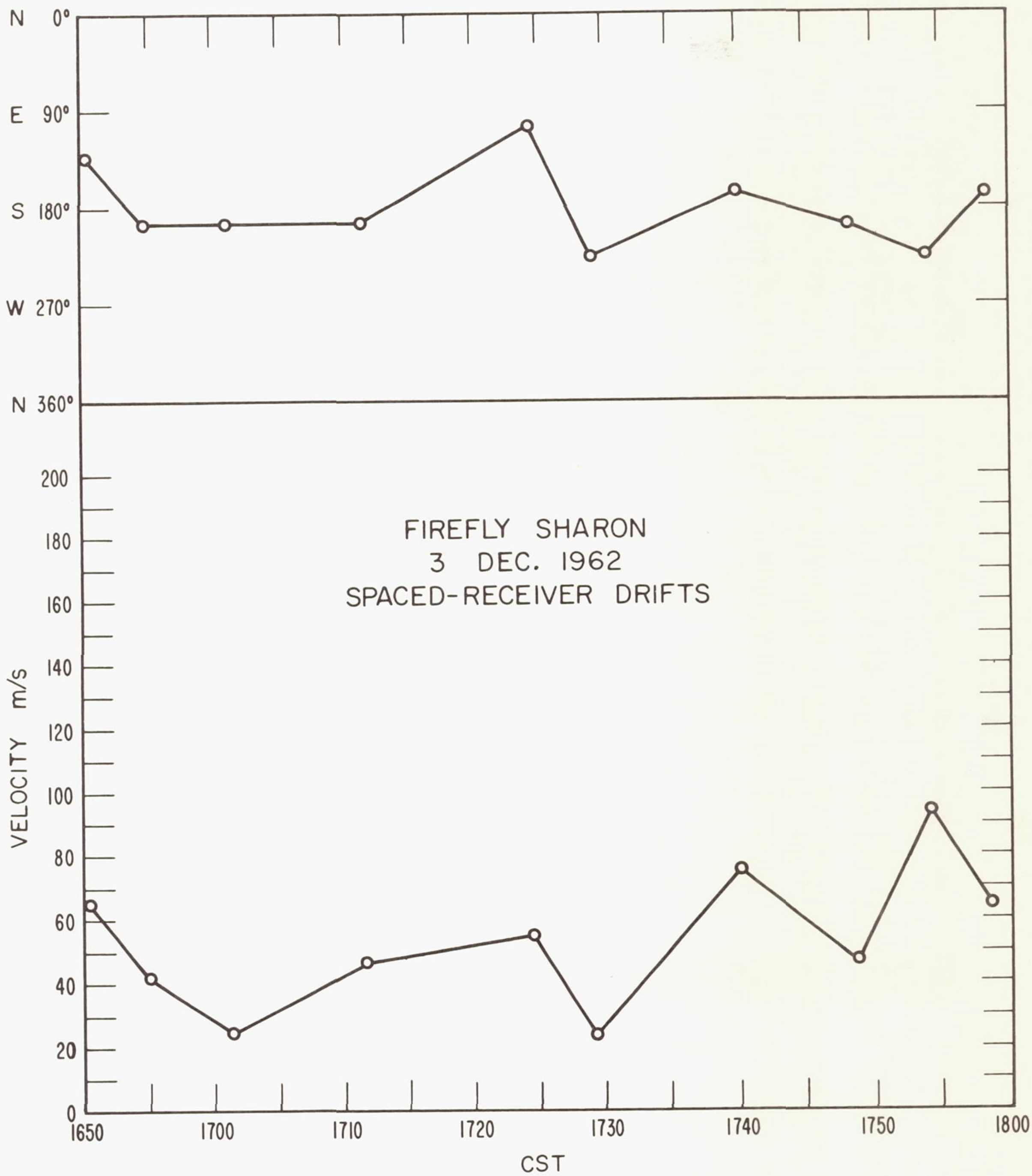

Figure 10. Magnitude and direction of wind velocity as observed by the spaced-receiver techniques for the 1720 CST release.

of sporadic E to determine how frequently the observed velocities are predominantly NS.

The velocities determined by the spaced-receiver technique are larger, however, than those deduced from the trails and this implies (1) there may be a wave motion[10] superimposed upon the neutral drift. If so, a comparison of the two methods would permit the deduction of the wave motion separate from the neutral drift. The direction was observed to be toward the south and (2) the sporadic E reflection level may fluctuate about the level where $V_{E\,W} = 0$, adding a variable EW component to the average NS component.

5. Acknowledgment

Our thanks to Mr. C. G. Justus for his untiring efforts in analysis of the photographic data.

Financial support for the studies conducted at the Georgia Institute of Technology has been supplied by the Air Force Cambridge Research Laboratories under contracts AF19(604)-5467 and AF19(628)-393 and by the National Aeronautics and Space Administration under Grant NsG 304-63.

Georgia Institute of Technology,
Atlanta, Georgia, July 22, 1963.

References

1. C. O. Hines, Can. J. Phys. 38, 1441 (1960)

2. J. D. Whitehead, J. Atmosph. Terr. Phys. 20, 49 (1961)

3. W. I. Axford, J. Geophys. Res. 68, 769 (1963)

4. E. Manring, J. F. Bedinger, H. B. Pettit, C. B. Moore, J. Geophys. Res. 64, 587 (1959)

5. J. E. Blamont, COSPAR Meeting, 6 June 1963, Warsaw, Poland

6. N. W. Rosenberg, D. Golomb, E. F. Allen, J. Geophys. Res., In Press, (1963)

7. H. D. Edwards, M. M. Cooksey, C. G. Justus, R. N. Fuller, D. L. Albritton, N. W. Rosenberg, J. Geophys. Res. 68, May 15, 1963

8. D. L. Albritton, L. C. Young, H. D. Edwards, J. L. Brown, Photogrammetric Engineering, September 1962

9. S. P. Zimmerman, Private Communication

10. C. O. Hines, Private Communication