THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

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Meteorology and Oceanography

Quarterly Report

HIGH ALTITUDE RADIATION MEASUREMENTS

1 October 1968 - 31 December 1968

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Abstract

This report summarizes project activity during the period 1 October, 1968 to 31 December, 1968.

Progress on the following tasks is described:

a) Medium resolution measurement of spectra of self-broadened and foreign gas broadened CO_2

b) Microwave occultation

c) Measurement techniques and existing data on molecular collision rates

Preparations, environmental tests and field operations at Casper, Wyoming and Rapid City South Dakota are described and the results of the 20 November 1968 radiation measurements balloon flight are evaluated.

1. Introduction

This is the 24th Quarterly Progress Report on Contract No. NASr-54(03) covering the period 1 October, 1968 to 31 December, 1968. The project effort during this period of time was divided among the following tasks.

1. Medium resolution measurements of spectra of self-broadened and foreign-gas-broadened CO_2
2. Microwave Occultation Studies
3. The study of measurement techniques and existing data on molecular collision rates.
4. Final preparations, field operations and initial data analysis for the balloon flight on 20 November, 1968.

Although the Quarterly Progress Reports for the previous two quarters have not yet been submitted, this report is submitted first in order to provide documentation of the extensive field operations and an initial evaluation of the results of the 20 November balloon flight, as agreed with Mr. W. Bandeen, NASA's technical monitor of this work.

II. Medium Resolution Measurements of Spectra of Self-Broadened and Foreign Gas Broadened CO_2 (by Henry Reichle)

Wavelength dependent foreign gas broadening coefficients were determined for Nitrogen, Argon, Helium and Oxygen in the 15 micrometer band of CO_2. The results are in qualitative agreement with band averaged broadening coefficients previously measured by other experimenters. The results for Nitrogen agree quite well with the work of Burch, et al at Ohio State University, the differences that do exist may easily be explained by differences in instrumentation resolution Other experimental data is not available for Argon, Helium and Oxygen.

A technical report summarizing the last years effort on 15 micrometer CO_2 absorption measurements will be written during the next quarterly work period.

III Microwave Occultation Studies:(by Fred F. Fischbach)

The inversion of microwave phase delay data transmitted between satellites in low circular orbits to obtain density-height profiles was analyzed. In particular, the recovery of density in the presence of water vapor both spherically stratified and not spherically stratified was attacked, as well as the problem of delineating the gross regions of the atmosphere where water vapor would create inversion difficulties and where it could be safely ignored.

The effort toward inverting phase-delay data was addressed principally toward the proposals of Stanford University (B. B. Lusignan) to NASA in which two-satellite and multi(6)-satellite methods were the subject. This effort was in conjunction with the NASA Microwave Occultation Study Group in which we are participating.

Among the noteworthy results was the agreement that above 300 mb. all water vapor effects could be ignored with no substantial degradation of the data. Below 500 mb. it was agreed that uncorrected phase-delay data was not invertable to yield densities with meteorological significance. The region from 300 to 500 mb. is disputed between the Michigan and Stanford analysts. Also still in dispute is the efficacy of water-vapor corrections below 500 mb. from climatological prediction alone. These two disputed areas were discussed in a meeting at Stanford and further effort agreed upon, the results to be formally presented before the Study Group at its next meeting.

The correction of phase-delay data for water-vapor effects based upon two-frequency microwave methods was withdrawn from further consideration because the technique will not be formally proposed at this time.

The results described above are applicable to spherically-stratified water vapor. Analysis of the non-spherically-stratified case has been done 1) by ray tracing on a path in which refractive index is assumed to have a constant horizontal gradient throughout the atmosphere and 2) by application of actual water vapor data to the analysis reported in our Technical Report 04963-2-T of December 1962 in which the gradient at the tangent point was expanded in a power series. These analyses are grossly in disagreement and the reason for this is under study. The results are to be reported at the next Study Group meeting.

The basic inversion technique can be done by model matching or by an Abelian integral. A definitive error analysis can only be conducted by the integral inversion because several parameters must be varied. The model-matching method is costly in computer time and cannot be used for this purpose. The Abel inversion used in the optical method will be reprogrammed for phase-delay data which differs because retardation as well as refraction enters the equation. A unique solution exists, and therefore the method is equally susceptible to analytic error analysis as was the optical refraction method. The error analysis will be conducted similarly, except that the input parameters are different and greater in number.

Also, during this report period the times of moon occultation by the earth as viewed from the ATS satellites were computed and a request made for special photography of the occultation. If this photography is successful, the refraction of lines of sight to prominent lunar features will be input to the present inversion program in an attempt to recover the density. Angular resolution appears to be marginal, however.

IV Study of Measurement Techniques and Existing Data on Molecular Collision Rates (by William R. Kuhn)

Although some experimental results for collisional relaxation times are available, these measurements are not generally made with regard to atmospheric application. Collisional relaxation phenomena are important to atmospheric studies for elevations above approximately 60-70 km, and in this region of the mesosphere, temperatures (150-250K) are much lower than those used in existing measurements (300K). There is also the difficulty that measurements have usually been made for a single constituent, whereas relaxation times for atmospheric studies must include the collisional effects of foreign gases.

The uncertainties in our knowledge of these relaxation rates which are important in atmospheric studies can be demonstrated by considering the 4.3 μm CO_2 transition, which is only one of the many infrared bands which influences the mesospheric heat budget. Taylor and Bitterman (1967)[1] indicate that the reaction $CO_2^*(\nu_3)+N_2 \rightarrow CO_2+N_2^*$, which is important near the mesopause, has a relaxation time for a temperature of 300K approximately twice as large as the relaxation time one would find if these data were extrapolated to 200K. Furthermore, the relaxation time associated with this reaction may be two orders of magnitude smaller than the relaxation time associated with the pure CO_2-CO_2 collision (Houghton, 1967),[2] so that both reactions may be important in determining the relaxation time appropriate to atmospheric studies. Collisions of CO_2 with other atmospheric constituents may also be significant although there are few measurements available (see, e.g. Slobodskaya, 1967).[3] The influence of uncertainties in this relaxation time on the radiative heating in the mesosphere is demonstrated in the Fig. 1. The heating by the 4.3 μm band is comparable to the 15 μm band of CO_2 (Kuhn and London, 1969),[4] in the upper mesosphere if the relaxation time is on the order of 10^{-7} sec; the vertical distribution of the radiative heating is also influenced by different relaxation times. These effects clearly demonstrate the need for an experimental program to determine relaxation times of those transitions for atmospheric gases for temperature and composition distributions which simulate mesospheric conditions.

V. Balloon Flight Preparations and Field Operations

A. Highlights of Preparations and Field Operations

Sept. 14-26	Environmental Tests at Bendix Missile Systems Division
Sept. 26-Oct. 9	Tests and Repairs at Ann Arbor
Oct. 9-14	Environmental Tests at Bendix Missile Systems Division
Oct. 14-17	Travel to Casper, Wyoming
Oct. 17-22	Assembly and Initial Tests of Gondola
Oct. 23	T. I. IRIS Arrives at Casper
Oct. 24	NRL Personnel Arrive at Casper
Oct. 25	Complete Test of Gondola (Interferometers Cooled)
Oct. 26-27	R. F. Interference Tests
Oct. 30	Down Range Ground Station Arrives at Rapid City, S. D.
Oct. 31	Winzen Launch Crew Arrives at Casper
Nov. 2	Telemetry Test Flight
Nov. 3-8	Radiosonde Flights at Casper
Nov. 8	Balloon Flight Operations - Cancelled because of High Wind Shear Near Surface.
Nov. 10	Radiosonde Flight
Nov. 11	Balloon Flight Operations - Cancelled - High Surface Winds and Clouds
Nov. 12	Move to Rapid City for launch - Down Range Ground Station to North Platte, Neb.
Nov. 13	Gondola Assembled and Tested
Nov. 14	Complete Test of Gondola (Interferometers Cooled)
Nov. 15	Balloon Flight Operations - Cancelled - FAA Cloud Cover Restrictions
Nov. 18	Balloon Flight Operations - Cancelled - Ground Fog, poor weather down range, battery failure.
Nov. 19	Balloon Flight Operations - Cancelled-Snow
Nov. 20	Balloon Launched
Nov. 21-24	Travel to Ann Arbor.

B. Environmental Tests at Bendix

Two series of environmental tests were run at the Bendix Missile Systems Division in Mishawaka, Indiana. The first set was carried out during September 15-26, the second set during the period October 9-14 after a return to Ann Arbor for repair and testing of some of the instruments.

Short preliminary tests with warm interferometers were run at Bendix on September 17 and 24. Complete environmental tests were attempted on September 18, 19, 25 and October 11, 12. The following problems were encountered.

1. Loss of Control of the T. I. IRIS Warm and Cold Blackbodies.

This failure first occurred in the test on September 18. The failure was thought to be due to overheated Germanium transistors and therefore they were moved to a large heat sink. The same failure occurred on 19 September, however, and so the Germanium transistors were replaced with Silicon transistors. Also at this time, a liquid nitrogen by-pass line was removed from the system, since it was felt that this line resulted in too much cooling of the cold blackbody. In the next test on 25 September, however, the blackbodies still did not work properly.

During the next two weeks, while in Ann Arbor for interferometer repairs, tests on the Mercury cells, which were used for a bias voltage in the temperature control unit, indicated that these cells did not have sufficient current capacity for this application and a change was made to silvercell batteries. Also, additional insulation was put on the T. I. IRIS cold blackbody and on the lines of the liquid nitrogen supply system.

In the next environmental test on 11 October, the warm blackbody operated properly. The cold blackbody temperature control worked well at high pressure but not at the low pressures simulating balloon float altitude. This failure was attributed to a flow meter. The indicator of the one used was a small sphere in a tapered tube. Under low ambient pressure conditions this sphere was moved up into a portion of the flowmeter where the flow of nitrogen was restricted. This problem was solved by removing the indicating sphere from the flowmeter, and on the next environmental test on 12 October, the temperature control of the T. I. IRIS blackbodies was satisfactory.

2. Noisy Detectors in the U. M. IRIS

During the second environmental test on 19 September, the U. M. IRIS detector became very noisy. Another was tried but was also noisy. A third detector was tried and found to be satisfactory. While changing detectors, the "divide by 10" circuit was disabled and had to be repaired.

The new detector burned out during the test on 25 September, burning out the preamplifier in the process.

During the return to Ann Arbor, the noisy detectors were baked in an oven for several days, and one improved, becoming less noisy. Another detector, the one used on the previous balloon flight in 1966 was found to be quite satisfactory and was mounted in the interferometer. The pre-amplifier was repaired. The two bad detectors were returned to the manufacturer for repair.

The "1966 flight" detector worked satisfactorily in the environmental tests on 11 and 12 October and during the balloon flight operations.

3. Failure of the T. I. Interferometer Scan Mirror Control Circuit

During the third environmental test on 11 October, the T. I. IRIS scan mirror control circuit did not work properly. Examination revealed that several I. C. units had been destroyed. A review of events during the environmental test indicated that liquid nitrogen had been spilled on the T. I. IRIS electronics package. The resulting thermal shock had destroyed several I. C. s in the scan mirror control circuitry.

These circuits were not repaired until after the conclusion of the environmental tests on 12 October. After the repair, which restored them to satisfactory operating condition, balloon flight operations were begun.

4. Loss of Synchronism between IRIS Programming and Gondola Programming

During the environmental tests it was found, that occasionally a phase delay was introduced between the IRIS programming and the Gondola programmer which controls all other operations on the balloon gondola. This phase delay was caused by interference from a relay which operated the linear actuator for the T. I. IRIS warm blackbody. This interference was eliminated by installation of a capacitor.

5. Failure of "Stop" Switches on FAT booms

During the environmental test on 25 September, the "stop" switches on the FAT (free air temperature) booms failed to stop the motor driving these booms. Since the measurement of free air temperature by bead thermisters on the large gondola has not been satisfactory in the past (and may still not be) and since air temperature measurements were to be obtained on the many other radiosonde, ozonesonde and frost point hygrometer flights, the booms and FAT thermister beads were removed from the gondola.

6. Environmental Test Conditions and Housekeeping Data

The environmental test chamber pressure and temperature during the 25 September test are listed in table I. Conditions for the other environmental tests on 19 September and 11 and 12 October were similar to those shown.

Housekeeping data, temperatures and voltages for various instruments and portions of the gondola are shown in figures 2-6, for the 25 September test. The influence of chamber temperatures on the gondola and its instruments is apparent from examination of the figures.

C. Operations at Casper, Wyoming

1. Examination of Cameras

After each set of environmental tests, film exposed in each of the cameras was processed to determine whether or not the camera operation was normal.

The six cameras used on this balloon flight are listed in table II for purpose of identification.

The 35mm cameras (#5 and #6) worked properly at all times during the environmental tests and the balloon launching operations.

Checks of the film from the first set of environmental tests showed that one or more of the Maurer 70mm cameras had improperly adjusted shutter curtains, which allowed a small amount of light to leak into the film along one edge of the film during the time interval between photographs (64 seconds for cameras #1 and #2, and 128 or 192 seconds for cameras #3 and #4). A record was not made of these adjustments.

Checks made at Casper of the film from the last set of environmental tests showed that camera #2 again had such a light leak and that camera #1 had sustained a failure of the shutter mechanism requiring service by the manufacturer. The camera was forwarded to Maurer for repairs and was returned to Casper on 9 November.

In an additional test of the gondola and its instruments Camera #3 failed and was shipped to Maurer for repairs. It was returned on 7 November.

A special test with Etachrome ER film was made with camera #4. The film was processed without producing any images. This was thought to be the

Table I

25 September Environmental Test Chamber Data

Time (EST)	Pressure PSIA	Pressure Mb	Air Temperature Above Gondola °F	Air Temperature Above Gondola °C	Air Temperature Near Wall °F	Air Temperature Near Wall °C
1355	14.41	993.5	70	21.1	65	18.3
1400	14.41	993.5	64	17.8	60	15.6
1405	14.39	992.2	50	10.0	48	8.9
1410	14.39	992.2	42	5.6	40	4.4
1415	14.39	992.2	32	0.0	31	-0.6
1420	14.39	992.2	20	-6.7	19	-7.2
1425	14.39	992.2	13	-10.6	12	-11.1
1430	14.39	992.2	5	-15.0	5	-15.0
1435	14.39	992.2	-5	-20.6	-7	-21.7
1440	12.43	857.0	-13	-25.0	-8	-22.2
1445	9.80	657.7	-23	-30.6	-21	-29.4
1450	8.4	579.2	-31	-35.0	-29	-33.9
1455	6.75	465.4	-40	-40.0	-40	-40.0
1500	5.68	391.6	-43	-41.7	-41	-40.6
1505	4.7	324.1	-46	-43.3	-45	-42.8
1510	4.0	275.8	-50	-45.6	-47	-43.9
1515	3.35	231.0	-54	-47.8	-55	-48.3
1520	2.82	194.4	-58	-50.0	-59	-50.6
1525	2.40	165.5	-60	-51.1	-60	-51.1
1530	2.04	140.7	-62	-52.2	-59	-50.6
1535	1.6	110.3	-71	-57.2	-60	-51.1
1540	1.24	85.5	-71	-57.2	-60	-51.1
1545	1.00	68.9	-61	-51.7	-55	-48.3
1550	.817	56.3	-60	-51.1	-55	-48.3
1555	.647	44.6	-59	-50.6	-53	-47.2
1600	.500	34.5	-58	-50.0	-51	-46.1
1605	.410	28.3	-55	-48.3	-47	-43.9
1610	.313	21.6	-49	-45.0	-43	-41.7
1615	.250	17.2	-44	-42.2	-40	-40.0
1620	.190	13.1	-38	-38.9	-36	-37.8
1625	.155	10.7	-33	-36.1	-32	-35.6
1630	.125	8.6	-28	-33.3	-28	-33.3
1635	.103	7.1	-25	-31.7	-27	-32.8
1640	.103	7.1	-22	-30.0	-23	-30.6
1645	.106	7.3	-22	-30.0	-23	-30.6
1650	.166	11.4	-18	-27.8	-19	-28.3
1655	.11	7.6	-21	-29.4	-20	-28.9
1700	.170	11.7	-17	-27.2	-17	-27.2
1705	.104	7.2	-20	-28.9	-18	-27.8
1710	.103	7.1	-18	-27.8	-20	-28.9
1715	.103	7.1	-18	-27.8	-20	-28.9

Table I (continued)

25 September Envorinmental Test Chamber Data

Time	Pressure		Air Temperature Above Gondola		Air Temperature Near Wall	
(EST)	PSIA	M6	°F	°C	°F	°C
1720	.107	7.4	-18	-27.8	-21	-29.4
1725	.180	12.4	-15	-26.1	-15	-26.1
1729	.103	7.1	-18	-27.8	-18	-27.8
1735	.193	13.3	-13	-25.0	-13	-25.0
1740	.140	9.7	-17	-27.2	-17	-27.2
1745	.103	7.1	-14	-25.6	-13	-25.0
1750	.106	7.3	-14	-25.6	-18	-27.8
1755	.103	7.1	-13	-25.0	-13	-25.0
1800	.110	7.6	-12	-24.4	-18	-27.8
1805	.103	7.1	-11	-23.9	-18	-27.8
1810	.103	7.1	-8	-22.2	-18	-27.8
1815	.108	7.4	-8	-22.2	-8	-22.2
1820	.104	7.2	-10	-23.3	-9	-22.8
1825	.160	11.0	-10	-23.3	-6	-21.1
1830	.78	53.8	-18	-27.8	-17	-27.2
1835	1.38	95.1	-30	-34.4	-28	-33.3
1840	2.04	140.7	-30	-34.4	-34	-36.7
1845	3.18	219.3	-20	-28.9	-27	-32.8
1850	4.7	324.1	0	-17.8	-4	-20.0
1855	5.64	388.9	8	-13.3	8	-13.3
1900	6.08	419.2	24	-4.4	20	-6.7
1905	7.1	489.5	40	4.4	33	0.6
1910	8.0	551.6	50	10.0	44	6.7
1915	9.0	620.5	60	15.6	60	15.6
1920	9.36	645.3	65	18.3	65	18.3
1925	9.8	675.7	74	23.3	74	23.3
1930	10.16	700.5	80	26.7	80	26.7
1935	10.45	720.5	80	26.7	80	26.7
1940	10.64	733.6	75	23.9	78	25.6
1945	11.00	758.4	78	25.6	78	25.6
1950	11.24	774.9	77	25.0	79	26.1
1955	11.60	799.8	76	24.4	78	25.6
2000	11.96	824.6	78	25.6	80	26.7
2005	12.80	882.5	77	25.0	78	25.6
2010	13.65	941.1	77	25.0	78	25.6
2012	14.37	990.8				

Table II

Identification of Cameras Used on Balloon Flight 11 (20 November, 1968)

Camera No.	Model No.	Manufacturer	Film Size	Magazine Size	Lens Description	Flight Film	Exposure Time	Exposure F/No.	Purpose
1	P-2	J. P. Maurer	70mm.	100ft.	75mm. f/2.8 Finitar	IR Etachrome	1/500	F/5.6	Aerial Photography
2	220	J. P. Maurer	70mm.	100ft.	150mm. f/2.8Xenotar	Plus X	1/500	F/8	Aerial Photography
3	220	J. P. Maurer	70mm.	50ft.	38mm. f/4.5 Biogon	Plus X	1/500	F/8	Aerial Photography
4	220	J. P. Maurer	70mm.	50ft.	38mm. f/4.5 Biogon	Etachrome ER	1/500	F/11	Aerial Photography
5	TL35	Wollensack	35mm.	50ft.	35mm. f/3.5 Amaton with portrait attachment	Tri-X	1/25	F/4	Photography, Clock and Pressure Gauge
6	TL35	Wollensack	35mm.	50ft.	35mm. f/3.5 Amaton with Auxiliary Wide Angle Lens.	Etachrome EF	1/50	F/5.6	Photograph Balloon

fault of the film or of the processing. It was never suspected that the shutters on this camera had also been mis-adjusted, with the result that when the camera operated, the focal plane shutter never opened to expose the film. Later events proved that this was the case however no photographs were obtained with this camera during the balloon flight.

2. R.F. Interference Tests

On 23 October, the T.I. IRIS instrument arrived at Casper, the gondola assembly was completed and a short test was run to check out the assembly. On the next day a complete test was run with warm interferometers and on 25 October a "cold" test was run. All instruments tested satisfactorily. R. F. Interference tests were started on 26 October.

It has always been a difficult problem to establish that the instruments on the balloon gondola will be free of R. F. interference. Tests in an enclosed room will almost always show R. F. pickup in the more sensitive instruments and circuits. Usually this is due to reflections of the R. F. radiation from the walls and nearby objects in the room. Ideally one would test the entire gondola in a reflection-free area to simulate balloon flight operation conditions, however such an area is usually not available.

The large hanger at Casper was of wooden construction primarily. The testing technique used was to suspend the gondola from the ceiling of the hanger with transmitting antennas located in their normal position on the gondola and to take data as the gondola height above the floor is gradually changed. If R.F. interference is not experienced in any position, the gondola is suitable for flight. If R. F. interference is obtained, but varies periodically as the gondola height is changed, the interference is due to reflections. It is then necessary to determine whether the minimum level provides satisfactory operations. If so, again the gondola is suitable for flight.

R. F. tests were run with only the U of M 240.2 megahertz 2 Watt transmitter on 26 October, with satisfactory results. On 28 October the Winzen transmitting antenna was added and similar tests were run. With the Winzen antenna R. F. interference was obtained, however it could be eliminated if the antenna were suspended at a point 10 feet below one corner of the gondola. Under these conditions the instruments were free from R. F. interference when the gondola was sufficiently far from reflecting objects as it would be during the balloon flight.

Figures 7a and 7b show the gondola, suspended from the rafters of the hanger. The antennas can be seen in figure 7a. Figure 7b shows the truck with the winch used to raise and lower the gondola.

3. Telemetry Test Flight

Preparations for balloon flight operations were completed on 1 November. The balloon gondola had been completely tested, the launch vehicles had been set up and the down range telemetry station had been completely checked out.

Suitable weather conditions were obtained for the telemetry test flight on 2 November. Although nominally termed a "telemetry test flight", this flight really serves a much broader purpose. It checks out almost all field personnel and their equipment, and in addition provided up to date information on upper air winds at the flight location.

The package flown is shown in figure 8. For telemetry checkout, a 240.2 Megahertz transmitter (with one VCO modulated by the standard radiosonde pressure sensing element) was used. In addition to this unit, a standard radiosonde was flown and tracked with a GMD ground station receiver, so that temperature and humidity vs pressure were also obtained. The gondola was heavy enough to require the conventional balloon control equipment, consisting of Radio Command Receiver, VHF transmitter pressure-height instrumentation and Termination Timer. In figure 8, the U. M. Telemetry antenna is at bottom left; the Winzen antennae at the bottom, just to the right of center, the U. M. transmitter package is mounted at the left end of the rack with Winzen control equipment at the center and right end of the rack. The radiosonde unit is suspended from the right end of the rack.

The flight was launched from the Casper airport at about sunrise on 2 November (see figure 9). It reached its float altitude of 105, 000 feet about 2 hours after launch. At this time the telemetry signal became weak and shortly thereafter dropped to zero. Shortly thereafter, the balloon was turned over to the Winzen crew for flight termination at their discretion (i. e. for them to terminate at the first opportunity of favorable recovery conditions). About twenty minutes later the flight was terminated, by command.

During the parachute descent of the gondola, the U. M. telemetry signal was received again. Recovery was made, without undue difficulty, near Medicine Bow, Wyoming.

Examination of the payload showed that it had been subjected to very high temperatures during the flight. Either the Mercury cell batteries or the transmitter itself became inoperative because of the high temperatures. The instruments then cooled off, this cooling was accentuated by the descent through the colder air and then the transmitter operated again. Since no failure occurred in the telemetry ground station, which received signal properly as long as the telemetry transmitter was operable, it was decided that this flight constituted a successful check out of the ground station.

The altitude vs time curve for the flight is shown in figure 10 along with air temperatures measured by the radiosonde unit. The ground trace of the balloon trajectory is shown in figure 11. This trajectory information was the significant result of the flight, for it indicated that the wind at float altitude was from the northeast instead of from the west as expected at this time of the year.

Other information regarding the telemetry test flight is summarized in table III.

4. Upper Air Winds - Radiosondes at Casper

The fact that the wind at altitude on the 2 November telemetry test flight was from an azimuth of 30° was a surprise of great significance for the balloon operations, since it was expected that winds would be westerly at this time of the year at that altitude. Casper, Wyoming had been picked as a launch site so that these westerly winds would carry the balloon over the barren surface east of Casper and perhaps over the Badland area in South Dakota. With the 2 November wind situation, however, this objective would not be achieved. In addition, on a flight of about 10 hours duration the gondola descent would be in the Rocky Mountains west of Denver. Recovery of the gondola would be extremely difficult or impossible.

The predictions that winds would be predominately westerly at this latitude in November is illustrated by figures 12 and 13 (see references 5 and 6, respectively). Figure 12 shows estimated mean zonal wind speeds for Palestine, Texas at 110, 000 feet. Figure 13 shows estimates of wind direction as a function of latitude and time of the year for altitudes above 100, 000 fett. Note that at the latitude of Casper, Wyoming (latitude $42^{\circ}50'$) we would expect westerlies to be established by the end of October. According to figure 13, the transition would take place in September or October. Although there might be short periods of time when the winds would not be from the west, from the first part of November

Table III

TELEMETRY TEST FLIGHT PARAMETERS

FLIGHT NO. 1081

University of Michigan

General Information:

Date - 2 November 1968
Launch Location - Casper Wyoming
Launch Time - 1356Z
Reach Float - 1546Z
Float Duration - 0 hr. 22 min.
Termination - 1608Z
Impact Time - 1648Z
Impact Location - 41^{o}-48'N, 105^{o}-56'W

Balloon Data:

Model No. 2333-545-386
Raven Industries
Serial No. - 208
Volume - 240, 000 cu. ft.
Material - .75 Mil X-124 Poly
Load Tapes - None
Weight - 86 lbs.

Flight Data:

Payload Wt. - 103 lbs.
Gross Load - 212 lbs.
Free lift - 23 lbs.
Ballast wt. - 0 lbs.

Remarks:

Telemetry Transmitter inoperative above 60, 000 ft.

on through the winter, we should expect westerlies at this altitude.

Before leaving on the field trip, upper air wind data had been monitored daily. Table IV shows wind data at 109, 500 feet for six stations surrounding the launch and estimated flight area for the month of September 1968. Although radiosondes do not get to these altitudes very often, the data available show that by 15 September, the westerly winds appear to have been established. Thus when the 2 November flight indicated otherwise, it was important to estimate how long this anomolous condition might exist.

Discussion with ESSA Weather Bureau personnel revealed that, although the westerlies had indeed been established in September, a change had taken place on 22 October and had persisted since that time. Although it was not expected that the anomolous situation would persist much longer, it could not be predicted when the westerlies would again be obtained. Thus it became important to monitor the upper air winds closely. In addition it seemed desireable to launch radiosondes from Casper itself, since we would then know exactly what the ascent portion of the flight would be. In addition, additional data on the winds at high altitudes would be obtained.

Six radiosonde flights were carried out in the next 8 days. Their trajectories are shown in figures 14 and 19. Wind data obtained from these flights at Casper as well as the Weather Bureau data for stations near Casper are given in Tables V, VI and VII for 109, 500, 105, 000 and 95, 000-100, 000 feet altitude respectively.

5. Launch Attempts

Examination of the data shows that on 7 and 8 October the combination of wind during ascent and at altitude would have provided a reasonably "safe" trajectory as far as recovery is concerned. On 7 November, weather predictions were favorable for an 8 November launch and flight preparations were begun at 2330 MST. However, at 0600 MST on 8 November the flight was cancelled because of high wind shear in the first 500 feet above the surface which made the launch operation too hazardous.

On 10 November, weather predictions for 11 November were favorable for a launch. However, high altitude winds were marginal and, when by 2200 MST, weather predictions were again unfavorable, the flight operation was again cancelled.

At this time it was decided that because of the difficulty at Casper, of obtaining upper air winds for a safe trajectory and of obtaining low altitude and

Table IV

Winds at 109,500 Feet During the Month of September, 1968

Date	Bismark, N. D.		Lander, Wyo.		N. Platte, Neb.		Omaha, Neb.		St. Cloud, Minn		Rapid City, S.D.	
Sept.	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots
1	280	4	160	12	290	11						
2	35	4							315	16		
3	325	16										
4	315	10										
5	240	6	290	9			240	19				
6	185	13			310	4						
7												
8	310	17										
9	270	15							315	14		
10	280	10					050	14				
11												
12	320	12										
13												
14	225	9										
15	235	13										
16	270	13							195	27		
17												
18												
19	285	25										
20											240	34
21												
22	255	27										
23			265	25								
24												
25												
26			295	8								
27					265	17						
28												
29	290	20	250	6							010	07
30	265	11							290	22	285	16

Table V

Winds at 109,500 Feet During the Month of November, 1968

Date	Bismark, N. D.		Lander, Wyo.		Casper, Wyo.		Denver, Colo.		Rapid City, S. D.		N. Platte, Neb.	
Nov.	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots
1												
2												
3												
4	285	44			347	70						
5												
6					344	13						
7					282	24						
8	320	41			312	110	290	45				
9												
10					017	36	340	83				
11	130	16										
12	340	16										
13			265	41							245	14
14			280	23								
15	280	21										
16	300	33										
17	360	38										
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
29												
29												
30												

Table VI

Winds at 105, 000 Feet During the Month of November, 1968

Date	Bismark, N.D.		Lander, Wyo.		Casper, Wyo.		Denver, Colo.		Rapid City, S. D.		N. Platte, Neb.	
Nov.	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots
1												
2												
3	345	27			025	37						
4												
5												
6	360	45	025	10			005	38				
7			305	39	256	5	330	35				
8												
9	060	8										
10	360	23					350	70				
11												
12			260	46								
13									240	15	215	14
14												
15												
16												
17												
18									295	16		
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												

Table VII

Winds at 95,000-100,000 Feet During the Month of November, 1968

Date	Bismark, N. D.		Lander, Wyo.		Casper, Wyo.		Denver, Colo.		Rapid City, S. D.		N. Platte, Neb.	
Nov.	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots	Az.	Knots
1												
2												
3	335	24	010	23								
4	360	37	020	43	016	39			010	30	330	21
5	360	31	020	31			040	39				
6	350	43	030	28	360	31	005	34			030	29
7			055	13	315	27	320	21	310	27	305	35
8	325	25			306	33	290	26				
9	340	34	005	15					350	23	280	16
10	360	39	045	18	255	38	020	32	005	29	015	31
11	275	09	315	18			070	11	340	14	360	13
12	310	08	285	21			360	06				
13	270	35	305	10			240	10	280	09	235	09
14	250	15	290	11					250	14		
15	315	16					300	23	270	12		
16	305	19	340	28			310	21			300	18
17	010	22	355	10								
18	010	35					320	27	010	18	030	18
19			070	32							070	30
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												

and surface winds suitable for launch, that launch operations would be moved to Rapid City, South Dakota. Accordingly, on 11 November all equipment was packed and 12 November was spent travelling to Rapid City. At the same time, the down range telemetry station was moved from Rapid City to North Platte, Nebraska.

In retrospect it is interesting to look back and note that the high altitude winds were suitable for a launch from Rapid City on 13 to 16 November. Communication with Mr. Neil Coulter of the U. S. Weather Bureau Station at Casper indicates that surface weather and cloud conditions were also suitable for launch on 14 November. It seems very likely that a successful flight could have been carried out at Casper on that day.

D. Operations at Rapid City, South Dakota

1. Preparations and Attempts to Launch

The gondola was assembled and a warm test was run on 13 November and on 14 November a complete test with cold interferometers was run. All equipment operated properly except the gondola programmer and the "miscellaneous" control box. Counting and switching devices in these units experienced additional operations due to pulses apparently induced by static discharges caused by people working near the gondola. The static discharges were due to the very low humidity in this cold dry winter air.

This type of counting error had been experienced before at the Bendix environmental tests. At that time a circuit had been set up so that the gondola programmer could be commanded to stop counting for specified time internal to correct for the false pulses previously counted. In this fashion, synchronism could again be established between the interferometer master clock and the gondola programmer. Thus a solution to the problem already existed. This command could be operated through the Winzen radio link with the gondola and thus could also be used during the balloon flight. Later events proved this command "sync" control to be very valuable. It was used on numerous occasions during the balloon flight.

Operations were carried out for possible balloon launches on 15, 18, 19 and 20 November. In each case operations were started at about 2200 MST the evening before.

On the 15 November attempt, operations were carried out almost to completion, the balloon had been laid out ready for inflation, the gondola preparations were almost complete (it had been moved out of the hanger to the launch area.), and a final check was being made on weather conditions over the area of the forecast trajectory. At this time a layer of high clouds rapidly moved in over the airport and a report of high thin broken clouds was issued by the Airport Weather Bureau Office. The Rapid City FAA Controller, then refused clearance for the flight, according to his interpretation of Federal Aviation Regulations, Part 101.

Needless to say, this decision evoked a warm disucssion of the meaning of "high thin broken" clouds. The FAA controller maintained that "broken" meant more than 50% and that therefore we could not launch. Our contention was that the "thin"meant that the clouds were "non-obscuring" and that since it was the intent of the FAA regulation to prevent balloon flights only when conditions were "obscuring" we should be allowed to fly. When Mr. Fred McNally, the man in charge of the Rapid City Weather Bureau arrived during the discussion, he volunteered the information that in an analogous situation, if the statement thin ground fog were used, flight under visual conditions would be allowed, whereas ground fog without the word thin would prevent such flight. At this time the cloud cover was even greater than before, the balloon programmer timer sequencing was no longer suitable for a launch and there was indeed no doubt, that launch operations should be stopped and the balloon returned to its box.

On the 17 November attempt, operations were carried through to within a few minutes before launch and the balloon was again laid out. Again prior to balloon inflation, the flight was cancelled due to a forecast of high winds and clouds in the recovery area. Ground fog had moved in during the last moment consultation with the Weather Bureau officials so that again there was no doubt about the decision. Shortly thereafter, the voltage of the T. I. interferometer battery pack (a brand new battery) became marginal and so, indeed, it was fortunate that the launch had not been made.

For the 19 November attempt, weather predictions were at first unfavorable. On the late afternoon and early evening, however "ideal" launch conditions were forecast and therefore operations were started. Late in the evening snow and overcast were forecast for the launch time. After waiting a short time to be convinced, flight operations were cancelled at 0130 MST.

Althouth the weather bureau forecast for 20 November was unfavorable, another try seemed reasonable, and so operations were again started. This time a little early, so that an early release might be possible. Several difficulties in operations caused a loss of time. The launch crew was late in beginning their operations, and the rapidly decreasing voltage of the gondola programmer battery caused a change of this battery. However the launch crew gained time in their operations and a successful launch was finally made about 40 minutes before sunrise.

2. 20 November Balloon Flight

The flight (Winzen #1082, U of M #11) was launched at 0608:30 MST. The 4 million cubic foot balloon ascended to float altitude at the average rate of 840 feet per minute. It arrived at float altitude (111, 000 feet) at about 0814MST. It remained at altitude for 5 hours 17 minutes. The flight was terminated by radio command at 1331 MST, with parachute descent to impact 10 miles southeast of Kimball, Nebraska. Surface winds were high at the impact site, and the gondola was dragged a considerable distance by the billowing parachute. Equipment was torn off of the gondola. The gondola, some of the control equipment and the electronics portion of the U of M interferometer were severely damaged. All other instruments survived with only minor damage.

The balloon configuration, altitude vs. time curve, and the trace of the balloon trajectory over the ground are shown in figures 20, 21 and 22. Flight Parameters are given in table VIII and the Winzen tracking aircraft observations are given in table IX.

The float altitude obtained by Winzen measurements differed from that obtained by the U of M pressure gauge (see fig. 21). The average of the two measurements of mean float altitude was 110, 860 feet. (33. 8 km), the average pressure at float was 6. 55 millibars.

Trajectory data was obtained by Winzen personnel with three techniques; observations from the tracking aircraft using radio direction finding equipment, theodolite observations from the launch site, and an electronic phase shift ranging system. An additional trace of the balloon trajectory has been obtained from aerial photographs taken from the balloon. The Winzen data differ at most by only a few miles from the more accurate camera data.

Table VIII

FLIGHT PARAMETERS

Flight No. 1082; U of M No. 11

For: University of Michigan

General Information:

Date - 20 November 1968
Launch Location - Rapid City South Dakota
Launch Time - 1308:30Z
Reach Float - 1514Z
Float Duration - 5hr. 17 min.
Termination - 2031Z
Impact Time - 2111Z
Impact Location - 10 Miles - 110^{o}
From Kimball Nebraska

Balloon Data:

Model No. SF - 212.85-070-NSC-01
Serial No. -6
Volume - 4,000,000 Ft.^{3}
Material - 0.7 Mil Stratofilm
Load Tapes - 250 lbs.
Weight - 680 lbs.

Flight Data:

Payload Wt. - 1132 lbs.
Gross Load - 2164 lbs.
Free lift - 197 lbs.
Ballast wt. - 153 lbs.

Remarks:

Payload was dragged by chute
approximately 1 mile after impact
Ballast remaining at impact #80

Table IX

CHASE PLANE OBSERVATIONS

Flight 1082, U of M 11, November 20, 1968 Rapid City, S. D.

Time Z	Position (Statute Miles)	Cloud Cond.	Terrain
1400Z	10 mi N of Oglala, S. D.	Clear	Brn.
1455Z	17 mi W of Oglala, S. D.	Widely Sct. -10K	Brn.
1545Z	17 mi 303° from Chadron, Neb.	Widely Sct. -10K	Brn.
1700Z	13 mi 223° from Chadron, Neb.	Widely Sct. -10K	Brn.
1740Z	15 mi S of Crawford, Neb.	Widely Sct. -10K	Brn.
1820Z	25 mi N of Scottsbluff, Neb.	Widely Sct. -10K	Brn.
1930Z	9 mi W of Bayard, Neb.	Widely Sct. -10K	" Farmland
2030Z	6 mi N of Kimball, Neb.	Widely Sct. -10K	Brn.
2110Z	10 mi 110° from Kimball, Neb.	Widely Sct. -10K	Brn.

All instrumentation operated continuously throughout the flight. Minor interruptions of data due to radio frequency interference from aircraft fueling gasoline trucks occurred occasionally during the flight and on one occasion when the mobile telemetry ground station was moved to a location more remote from these trucks. Towards the end of the flight, when the telemetry signal amplitude had decreased, some of the higher frequency channels again were noisy.

The down range telemetry ground station at North Platte, Nebraska received data from 0800 MST to 1340 MST with some interference from a high power transmitter located at the North Platte airport.

Although observations from the Winzen tracking aircraft indicate scattered clouds throughout most of the flight, scattered clouds were observed in aerial photographs of a 20 degree field of view under the balloon gondola only for a 1.5 hour period from 0755-0925 MST (1455-1625Z). Most of the flight was over barren surface. On two occasions the balloon passed over fairly large bodies of water.

3. N.R.L. Frost Point Hygrometer Soundings

Two special water vapour soundings were made from the Rapid City Airport on 20 November after the main instrumentation had been launched. These soundings were carried out by H. J. Mastenbrook and W. W. Werner of the Naval Research Laboratory.

This flight package is designed to collect data during the balloon descent in order to avoid contamination from the balloon and auxiliary instrumentation.[7] The ascent portion of the flight data is subject to large contamination errors in the stratosphere, however at lower levels the contamination is usually negligible.

On the first flight, which was launched at 0900MST, the instrument operated as expected on the ascent portion of the flight. However, the "turn-around control" failed and the resulting fast parachute descent did not yield reliable data. Useable data was obtained for the lower tropospheric ascent.

The second flight was launched at 1300 MST and worked properly throughout its flight trajectory. Data are available from the surface to 10.7mb. (somewhat higher than 100,000 feet).

4. Ozonesonde Flights

Since the water vapour sondes at Rapid City require almost 4 hours for each flight, there was not enough time to carry out an ozonesonde on 20 November after the 2 water vapour flights without interferring with the regular Weather Bureau radiosonde flight in the evening. The ozonesonde was postponed to the next day.

Three other ozonesondes were released on the day of the balloon flight, however; one each at Boulder, Colo., Bismark, N. D., and North Platte, Nebraska.

An ozonesonde was flown at Rapid City on 21 November and for comparison purposes another ozonesonde was flown at North Platte on this same day.

Initial evaluation of the results, indicates that only three of the flights provided data. The two flights from North Platte were apparently failures. The Denver flight produced excellent results, the Rapid City and Bismarck results are somewhat doubtful because the total integrated ozone amount does not agree with Dobson spectrophotometer data.

5. Other Radiosonde Data

Other Weather Bureau radiosonde data was requested from the National Weather Records center at Asherville, North Carolina. Data for 0000Z and 1200Z on 20 November and for 0000Z on 21 November have been obtained for Bismarck, N. D., Rapid City, S. D., North Platte, Neb., Denver, Colo., and Lander, Wyoming.

6. Supporting Aircraft Flight

The Colorado State University Atmosphere Research group, under Dr. William Marlatt, made supporting measurements from the instrumented aircraft on the day of the balloon flight, flying under the balloon gondola at several altitudes. Measurements of radiation, aerosol content and atmospheric structure were made and will be reported on by that group.

VI Initial Evaluation of Data for 20 November, 1968 Balloon Flight

A. Trajectory Data

Pressure altitude vs. time data and the trajectory of the sub-balloon point over the earth are shown in figures 21 and 22, respectively.

Pressure altitude was measured with two independent instruments. The two readings of float altitude pressure differ by about 0. 5 mb. An attempt has not yet been made to resolve this difference. For the time being, the average value of the two readings should be used. The accuracy of this average will be better than ± 0. 2mb. (± 750 feet).

The balloon was tracked with three devices during the flight, and a more accurate trajectory has been calculated from the aerial photographs. The nature of the surface under the balloon gondola can be determined from the photographs.

B. Housekeeping Data

General housekeeping data for the balloon gondola was recorded for the entire balloon flight in both analogue and digital form. On occasion a portion of the data was lost because of noisy telemetry signals.

Data recorded include:

1. Voltages of various batteries used to power the radiation instruments, cameras and control circuitry
2. Temperatures at various points on the balloon gondola and on the radiation measuring and control instrumentation
3. Signals monitoring the operation of cameras and of the opening and closing of various instrument doors

The program of operations for the flight is shown in figure 23. Filter wedge spectrometer data in figure 24. Figures 25, 26, 27 show MRIR data, and the gondola temperatures in two groups, thermistor group 1 and thermistor group 2 as indicated on the program of operations.

Housekeeping data for the 2 interferometers is digitized within the instruments and transmitted with the instrument data. It is not discussed in this report.

C. Filter Wedge Spectrometer Data

The filter wedge spectrometer obtained data from launch time at 0808:30EST to 1049:41 EST, when its door closed and remained closed for the remainder of the flight.

This door closing is unexplained. It happened at exactly the same as the MRIR was opened by timer control, however there should not be any relation between these 2 functions. All operations had been carried out many times in laboratory and environmental chamber tests without such a malfunction.

The filter wedge housekeeping data is shown in figure 24. The filter wedge door was closed for calibration purposes at two intervals after the balloon launch, from 0833:46-0839:46 EST and 1033:35 to 1039:33 EST.

Magnetic tapes of the analog IR data and commutated housekeeping data, and Brush recorder records of these signals were sent to Goddard Space Flight Center Personnel on 7 December, 1968 for data analysis and interpretation

D. Interferometer Data

Interferometer data was transmitted over IRIG Channel E (70Kz. center frequency). Recordings were made on three separate magnetic tape recorders, as described below.

In the mobile telemetry ground station, the discriminated output was recorded on the Ampex FR1300 tape recorder at 60 inches per second. In this recording mode, a single tape lasts for 15 minutes and requires 5 minutes to rewind. Three sequences of 16 interferograms each were recorded on each tape. A new tape was started after each 5 sequences (thus two of each five sequences was not recorded on the FR 1300). Even numbered tapes had 2 sequences of T. I. IRIS data and 1 sequence of U M IRIS data. Odd number tapes had 2 sequences of U M IRIS data and 1 sequence of T. I. IRIS data.

The transmitter multiplex was also recorded on the H. P. 5955 tape recorder in the mobile telemetry bus. The bandwidth of this tape recorder is such that the T. I. IRIS data can be recovered, but the U M IRIS data cannot.

The transmitter multiplex was recorded on the down range ground station using a C. E. C. VR 3300 tape recorder at 30 i. p. s. The bandwidth capability of this unit is sufficient to normally record both the T. I. and U M IRIS data. However it has been determined that the signal to noise ratio of the data obtained is not adequate for playback of the U of M IRIS data, with one exception. For a short time interval this tape recorder was inadvertently run at 60 i. p. s. At this speed recovery of U of M IRIS data is possible, since the signal to noise ratio is improved.

All of the interferometer data for the balloon flight can be recovered from one or another of these three recordings. So far, only the FR1300 data has been used.

1. T. I. IRIS Data

The T. I. IRIS interferometer worked properly throughout the balloon flight. A total of 10 magnetic tapes were sent to G. E. on about 1 December 1968 for processing at the Nimbus ground station. The data was sent in two sets. The first set contained the most noise free data. This data has been forma reduced to spectra and the results transmitted to Goddard Space Flight Center. One hundred and twenty seven of the interferograms were error free.

The first set of magnetic tapes have been returned to the U of M along with spectra and the ground station record. A cross reference between U of M interferogram identification numbers and the G. E. identification numbers has been prepared and was sent to GSFC on 11 December 1968.

The temperatures of the T. I. IRIS blackbodies were monitored through the gondola general housekeeping data as well as in the instrument housekeeping data. The blackbody temperatures obtained from the gondola housekeeping data were cross referenced to the interferogram identification numbers by means of standard time signal references. This information has also been sent to GSFC.

2. U of M IRIS Data

The U of M IRIS interferometer worked properly throughout the balloon flight. Some of the data may prove to be noisy when processed.

A sequence of interferograms recorded at 1005EST, shortly after the balloon reached float altitude, were selected for analysis. This data was formatted with the M&O Departments CDC 160A computer and plotted on its Calcomp plotter. Looking at the interferogram data in this fashion indicated an error due to the gain switching amplifier; i. e., the quiescent voltage of the law and high gain conditions were not equal. All of the interferograms from this sequence were examined and a probable off-set voltage was established. A correction was incorporated into the CDC program. The formatting program was rerun with the correction and the interferograms appeared to be satisfactory.

Ten interferograms were selected for further examination and processing. Low resolution spectra were calculated, plotted, and used to determine the over all instrument phase function. The phase information is needed in processing the interferogram to determine the polarity of the measured spectrum as a function of wavelength. High resolution relative spectra were calculated.

The next step in the data processing is to apply in flight blackbody calibrations. Unfortunately a defect in the electronic commutator used for the interferometer housekeeping data has produced an error in the blackbody temperature data. Analysis has shown how to apply a correction for this error, however the overall accuracy of the spectral data will be less than was obtained on the 5 May 1966 balloon flight. It is estimated that the uncertainty of spectral measurements will correspond to $\pm 1^{\circ}C$ instead of the $0.5^{\circ}C$ obtained previously.

All of the interferograms have now been formatted and plotted. These results are now being inspected to select sequences of data for further processing.

E. MRIR Data

The MRIR instrument worked properly throughout the balloon flight. Data was obtained with all 5 channels from the time when the MRIR door opened at 1049:46EST until the balloon was cut-down. MRIR housekeeping data are shown in figure 25. Sun (azimuth angle) data relative to the balloon gondola, which is needed for analysis of the reflected solar radiation data are also available from the rotating photo-cell signals. This data has not yet been analyzed.

F. Aerial Photography

Cameras 1, 2 and 3 obtained photographs from shortly after sunrise to the end of the balloon flight. Although camera 4 appeared to be operating, however when the film was processed, each frame was found to be unexposed. This was found to be due to the fact that the shutter curtains did not open during the time that the focal plane was moved over the film.

The negatives from cameras 1, 2 and 3 have been developed. Contact prints of each frame of the film from camera 1 have been made and sent to Goddard Space Flight Center.

G. Supporting Atmospheric Structure Data

The following atmospheric structure data was obtained in support of the balloon flight.

1. Special Frost Point Hygrometer data, 2 flights. The first flight yielded data only for the ascent portion of the flight, the second one for both ascent and descent.
2. Special Ozonesonde flights. Only one flight, at Boulder, Colorado, gave excellent data. The two flights at North Platte, Nebraska did not work properly. The Bismarck, N. D. and Rapid City, S. D. flights are somewhat doubtful. Air temperature and relative humidity data are available from all five of these flights.
3. ESSA Weather Bureau Radiosonde Flights. Regular Radiosonde data (temperature and relative humidity) is available as indicated in section V, D above.

VII Reports Published

Three reports were written during this work period. They were printed late in December, 1968 and distributed early in January 1969.

1) Bartman, F. L. "Earth Reflectance Patterns Measured by Radiometer on High Altitude Balloon Flights," Report 05863-13-T, University of Michigan, Department of Aerospace Engineering, Contract NASr-54(03), December 1968.

2) Drayson, S. R. and Kuhn, W. R., "The Influence of Water Vapor on the Long Wave Stratospheric and Mesospheric Radiation Budget," Report 05863-14-T, University of Michigan, Department of Aerospace Engineering, Contract NASr-54(03), December 1968.

3) Kuhn, William, "Radiative Transfer in the Mesosphere", Report 05863-15-T, University of Michigan Department of Aerospace Engineering, Contract NASr-54(03), December 1968.

VIII References

1. Taylor, R. L. and Steven Bitterman, "Survey of Vibrational relaxation data for processes important in the CO_2-N_2 laser system," 1967, Arco Research Rep. No. 282.

2. Houghton, J. T., "Flourescence from the $_3$ vibration of carbon dioxide," 1967, Proc. Phys. Soc. 91, 439-448.

3. Slobodskaya, P. V., "Study of the relaxation time of the vibrational state corresponding to the 4. 3nm absorption band of carbon dioxide using a spectrophone," 1967, Optics and Spectrosc. 22, 120-123.

4. Kuhn, W. and J. London, "Infrared radiative cooling in the middle atmosphere (30-110km)," 1969, J. A. S. (in press).

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6. Frisby, E. M., "Climatology for Ballooning," Raven Industries Technical Paper No. 23, January 1961, Raven Industries, Sioux Falls, South Dakota.

7. Mastenbrook, H. J., "Water Vapor Distribution in the Stratosphere and High Troposphere, J. Atmos. Sci. Vol 25, No. 2, pp 299-311, March 1968.

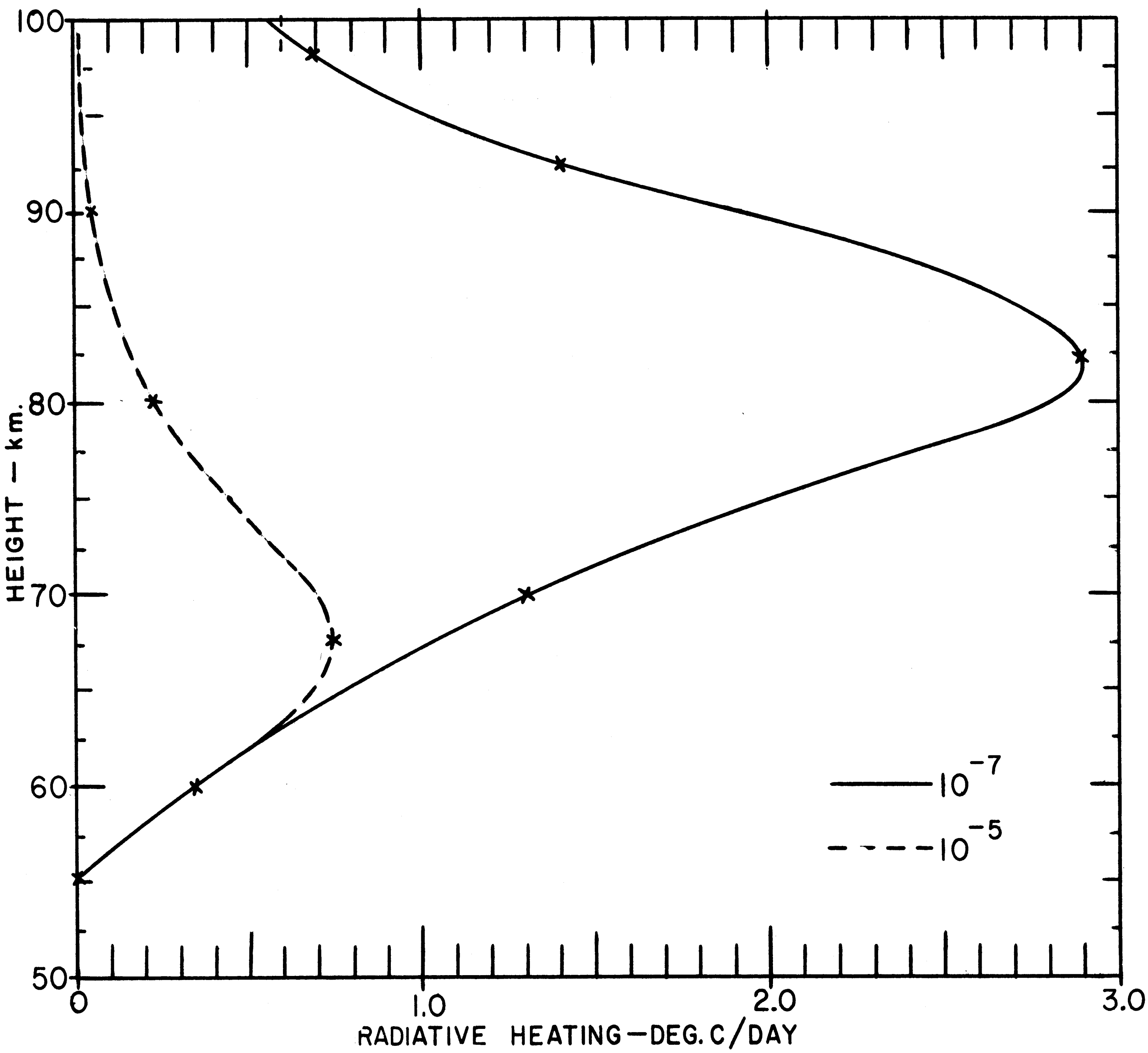

Figure 1 -Radiative heating by the 4. 3 m CO_2 band for collisional relaxation times of 10^{-7} and 10^{-5} sec (NTP).[2] Temperature structure is from the U. S. Standard Atmosphere. (A technical report summarizing this work is in progress).

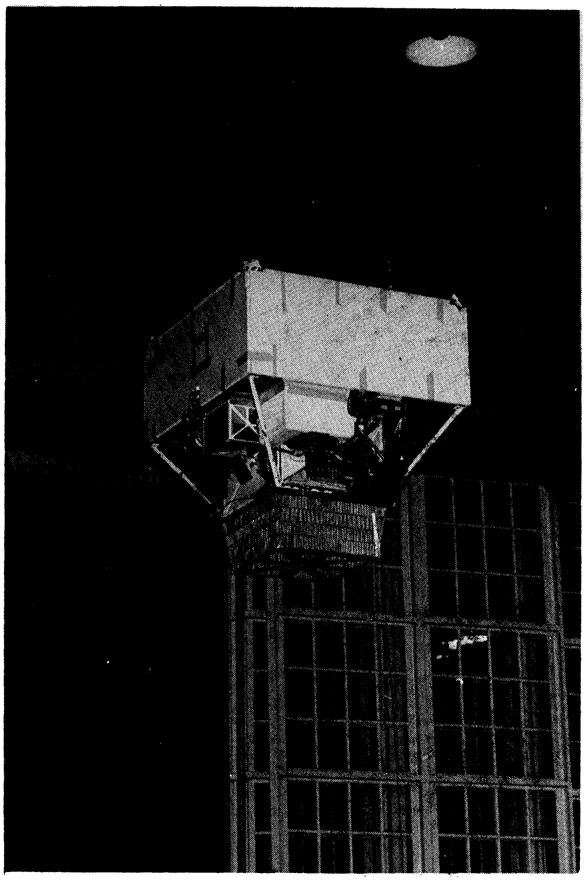

Figure 7a -Gondola Suspended from Rafters of Wooden Hanger for R. F. Interference Tests

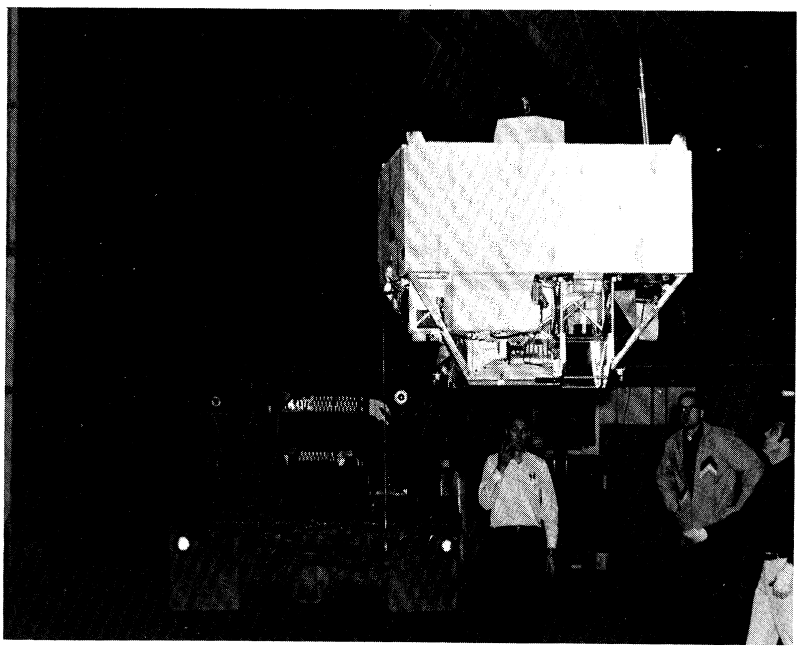

Figure 7b - Gondola and Truck with Winch during R. F. Interference Tests

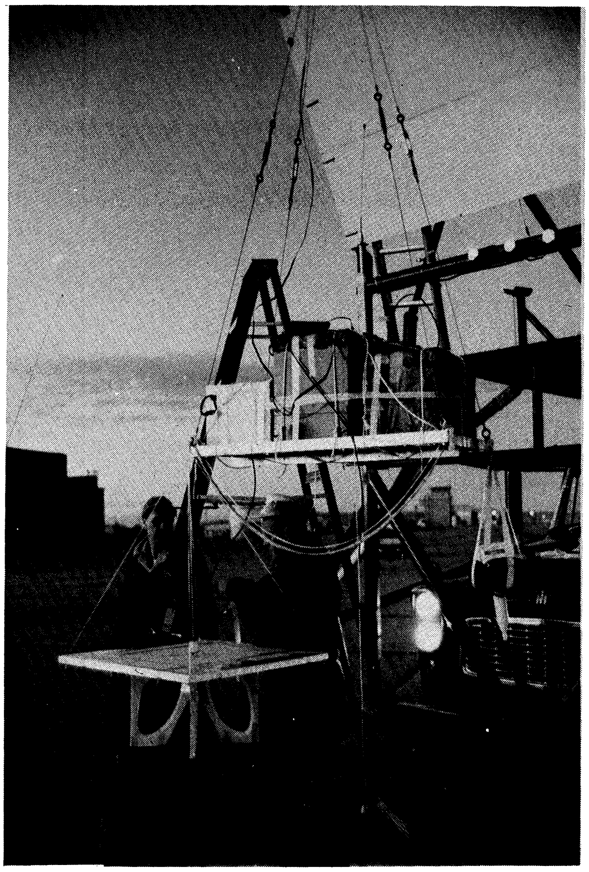

Figure 8 - Telemetry Test Payload on Back of Winzen Launch Truck

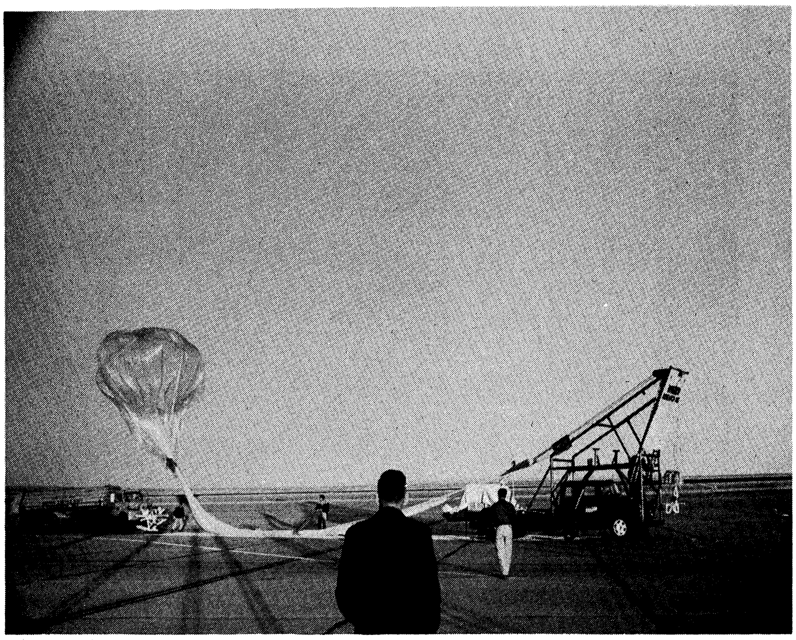

Figure 9 - Balloon Release, 2 November 1968 Telemetry Test Balloon Flight

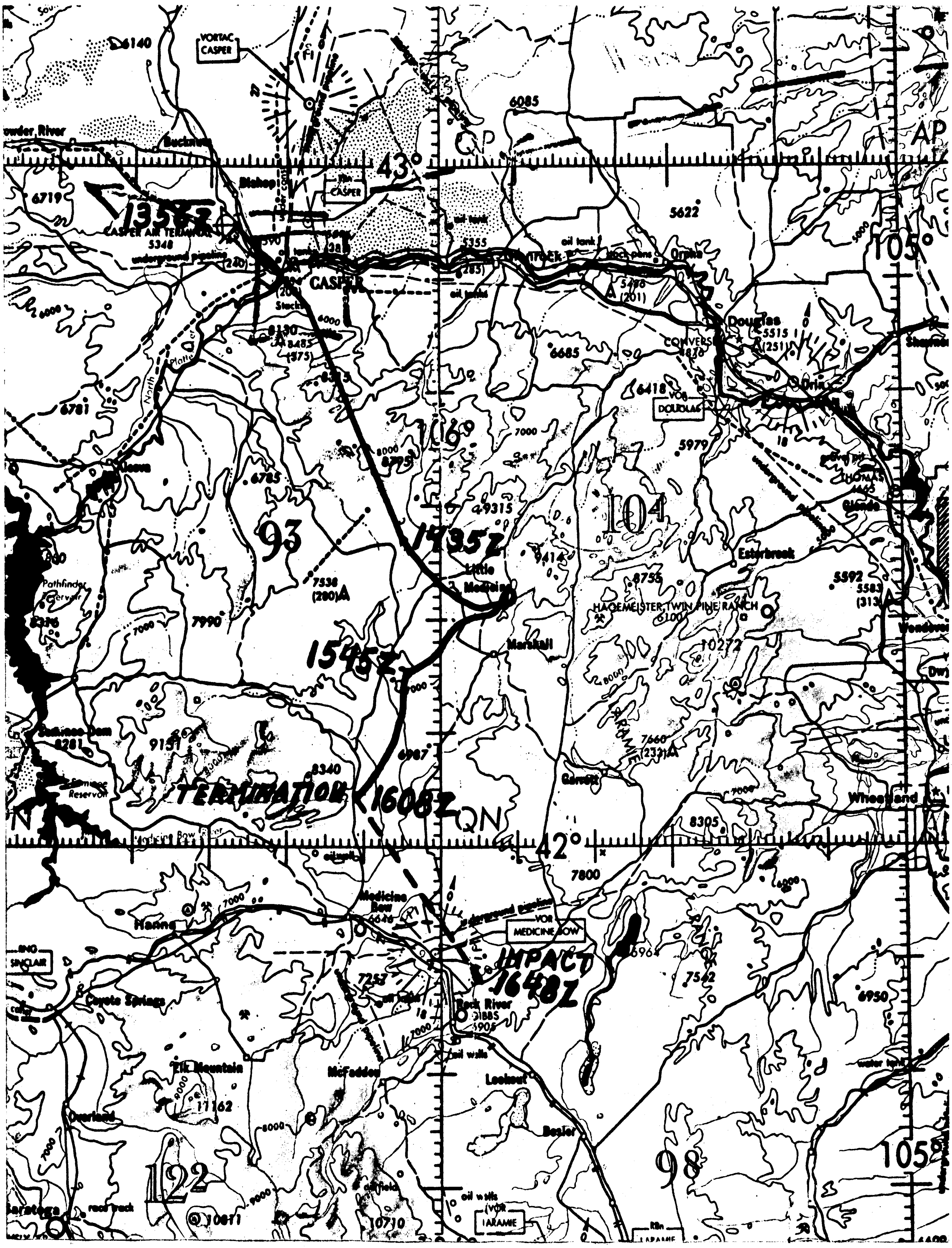

Figure 11 - Ground Trace of Balloon Trajectory, 2 November 1968 Balloon Flight

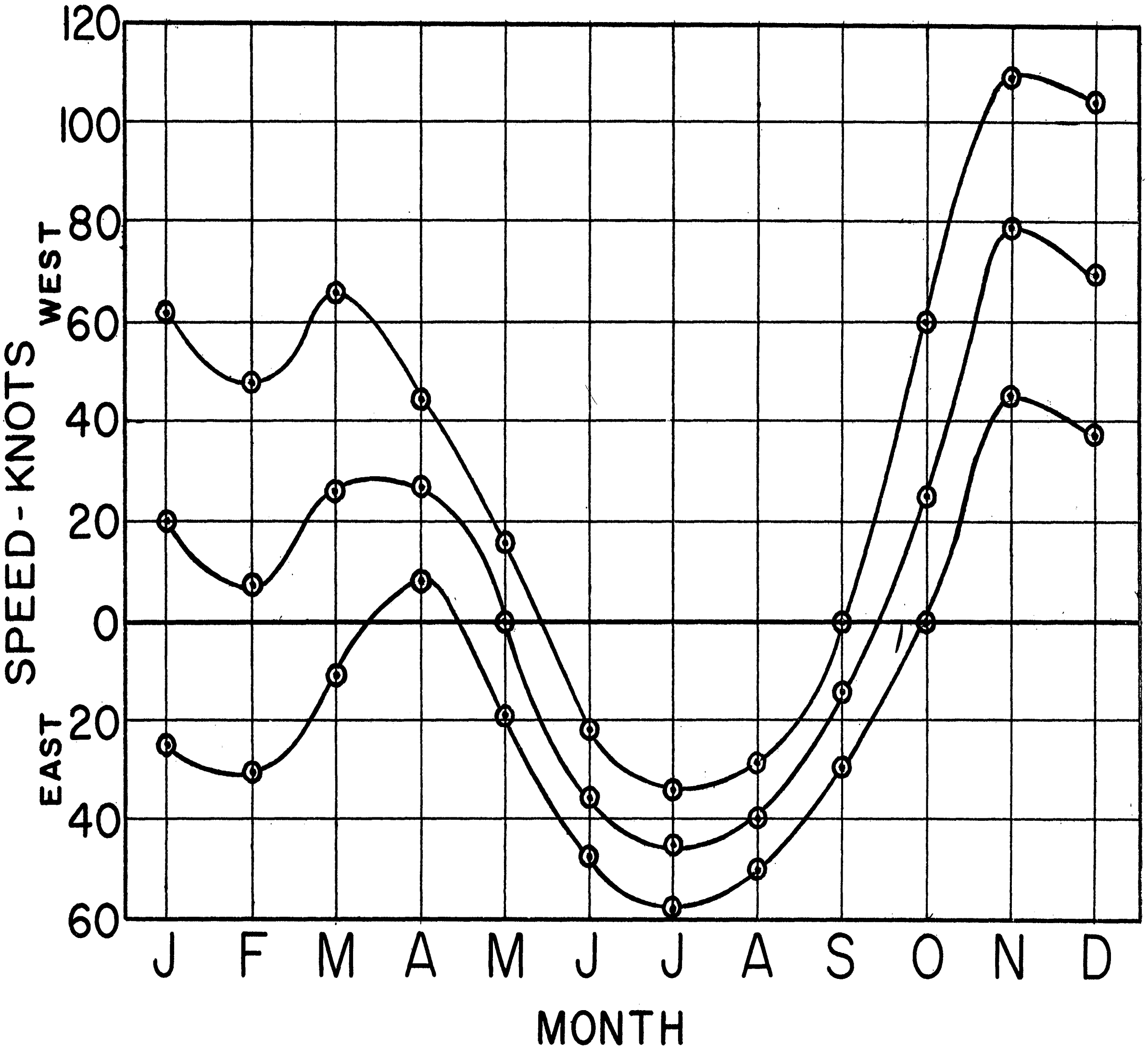

Figure 12-Float Winds for 110, 000 Feet at Palestine Texas

100,000 TO 150,000 FEET

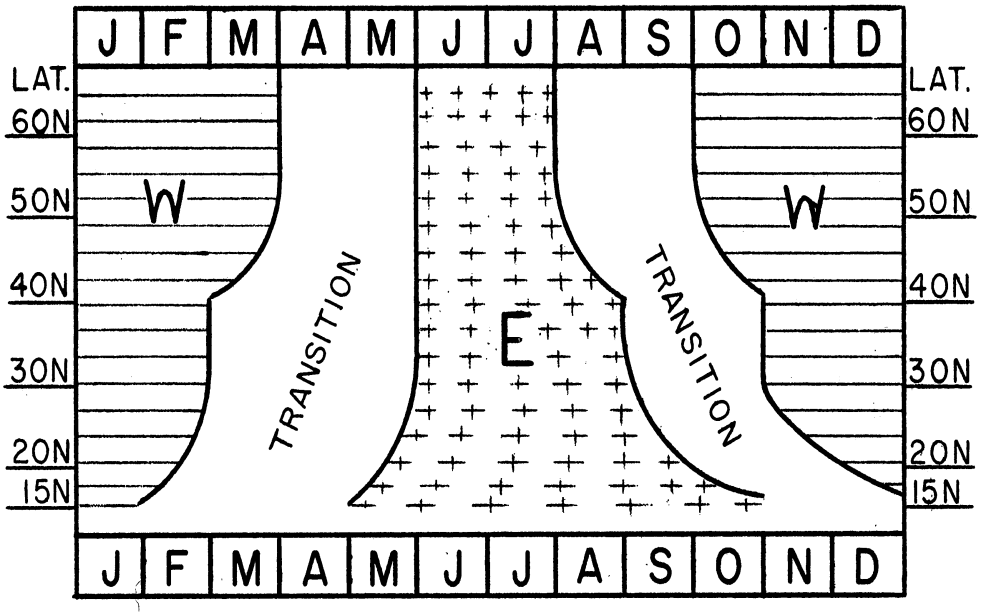

DIAGRAM IS TO SHOW THE MONTHS AT LATITUDES FROM 15N to 60N AT WHICH ZONAL WINDS FROM 100, 000 TO 150, 000 FEET CAN BE EXPECTED TO BE WESTERLY, EASTERLY, OR IN TRANSITION FROM ONE REGIME TO THE OTHER. (THERE WILL ALWAYS BE SHORT-TERM EXCEPTIONS TO EVERY RULE.)

THE DIAGRAM HAS BEEN EXTENDED SOUTHWARD AS FAR AS 15N TO INCLUDE THE RESULTS OF AN EARLIER STUDY OF STRATOSPHERIC EASTERLIES IN THE TROPICS.

Figure 13-High Altitude Winds at 100, 000-150, 000 Feet Altitude

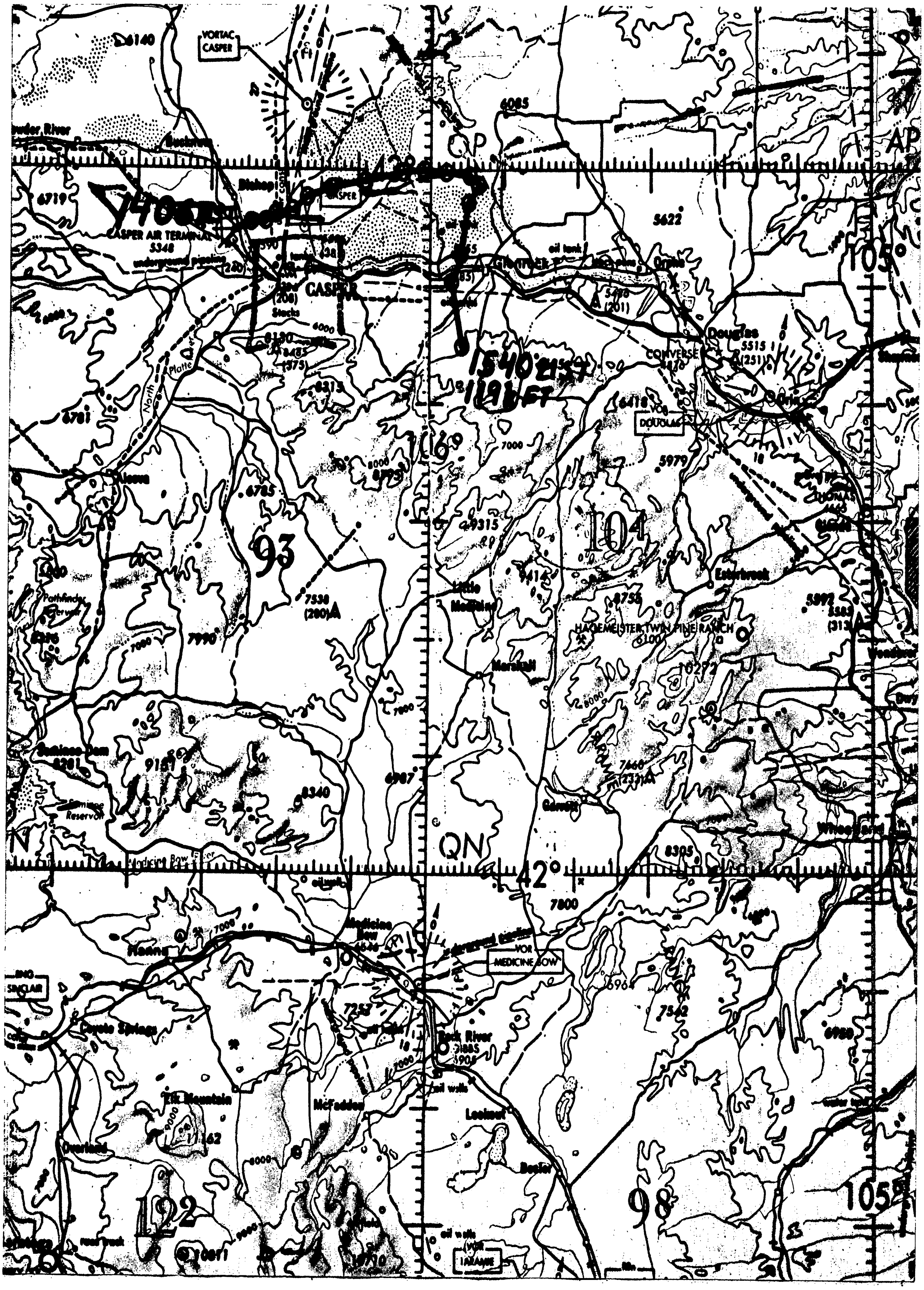

Figure 14-Ground Trace of 4 November Radiosonde From Casper, Wyoming

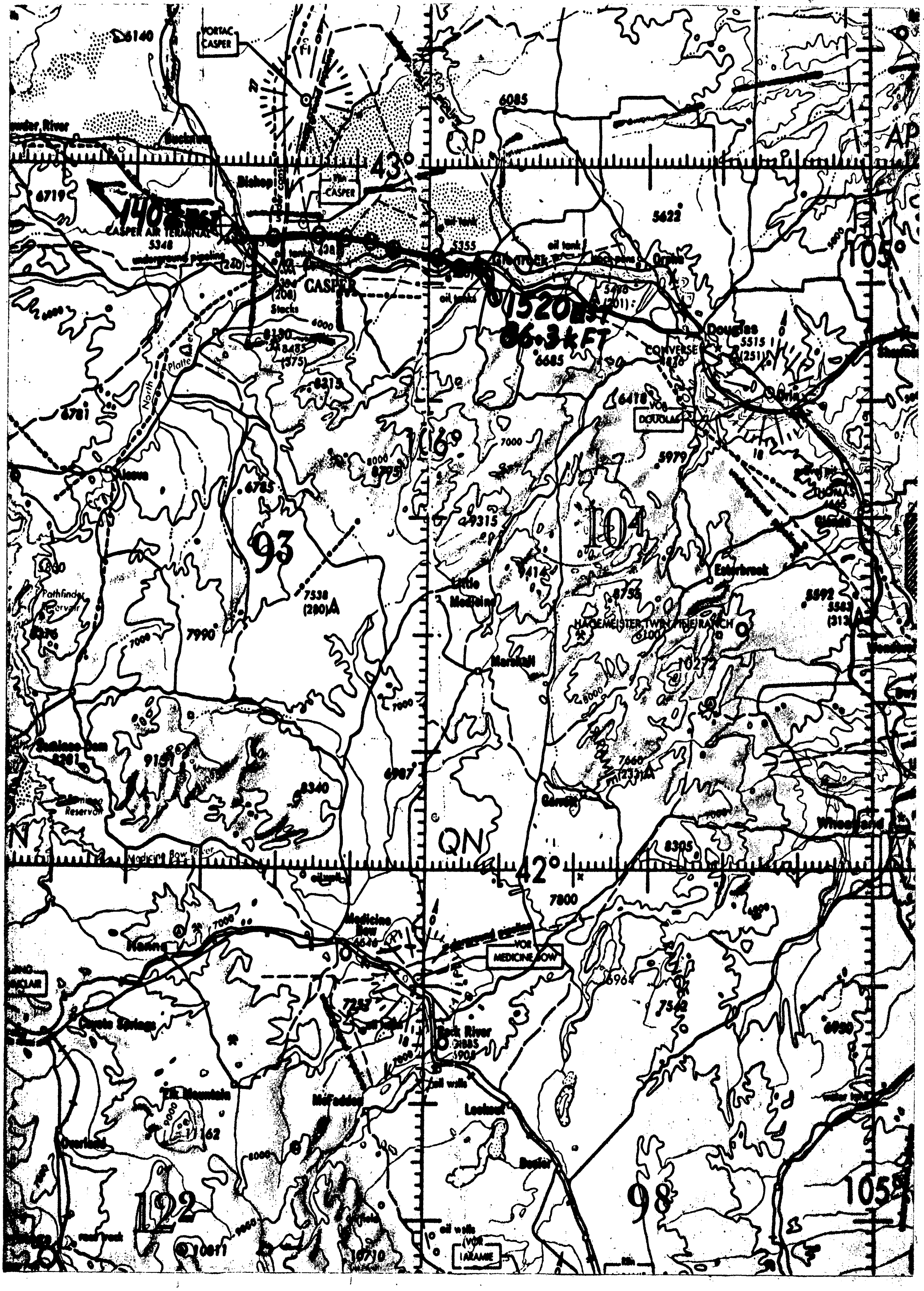

Figure 15-Ground Trace of 5 November Radiosonde From Casper, Wyoming

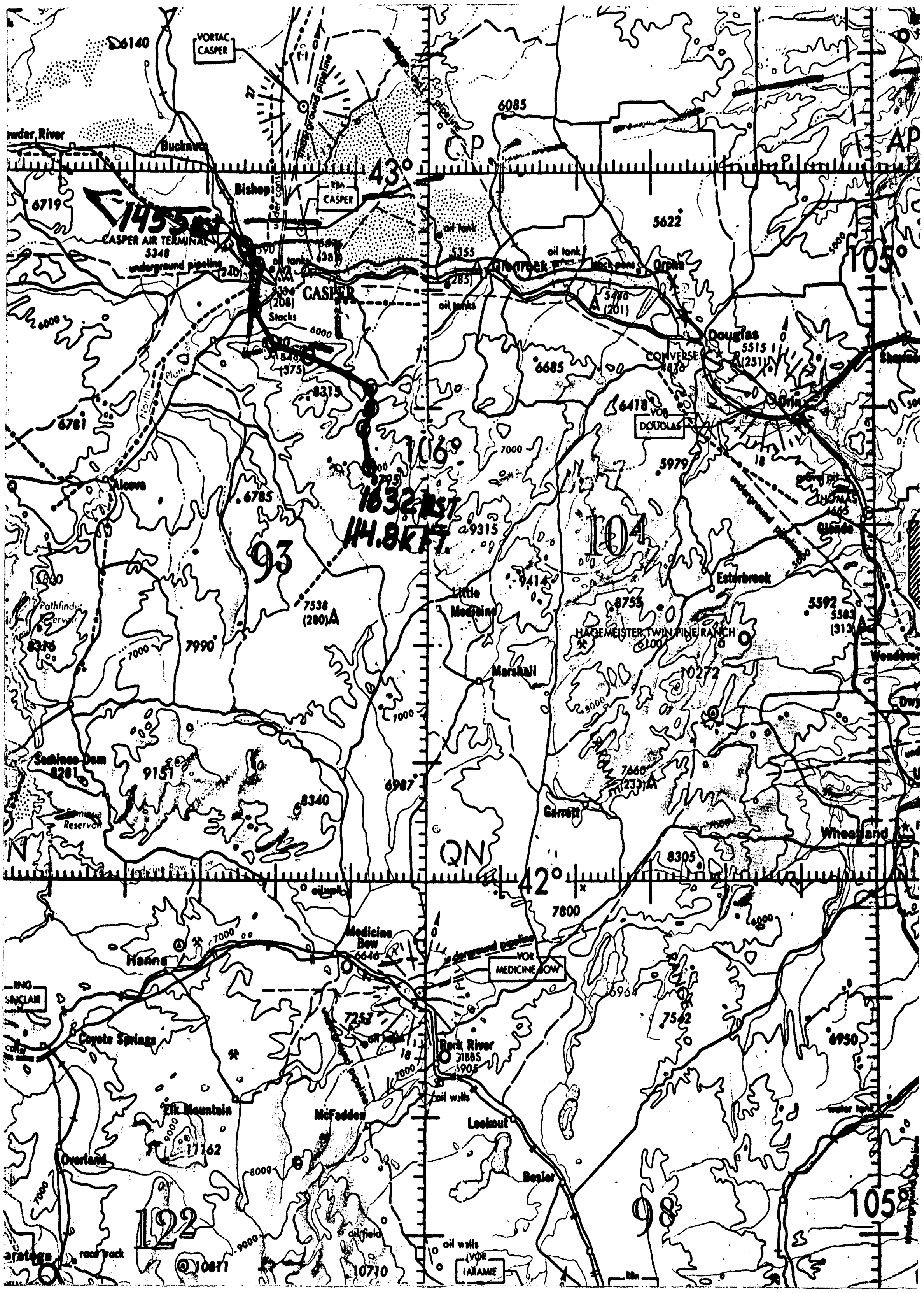

Figure 16-Ground Trace of 6 November Radiosonde from Casper, Wyoming

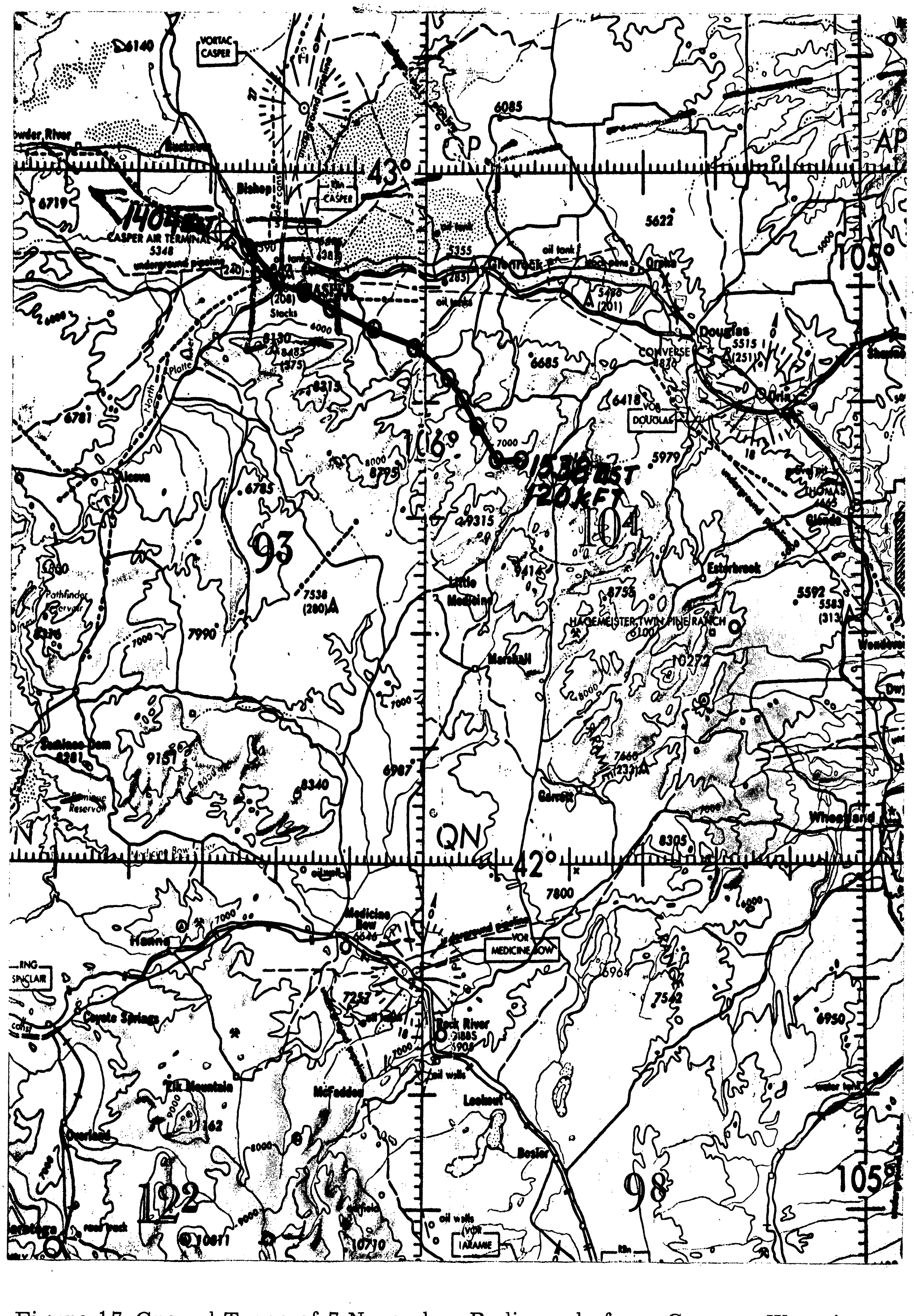

Figure 17-Ground Trace of 7 November Radiosonde from Casper, Wyoming

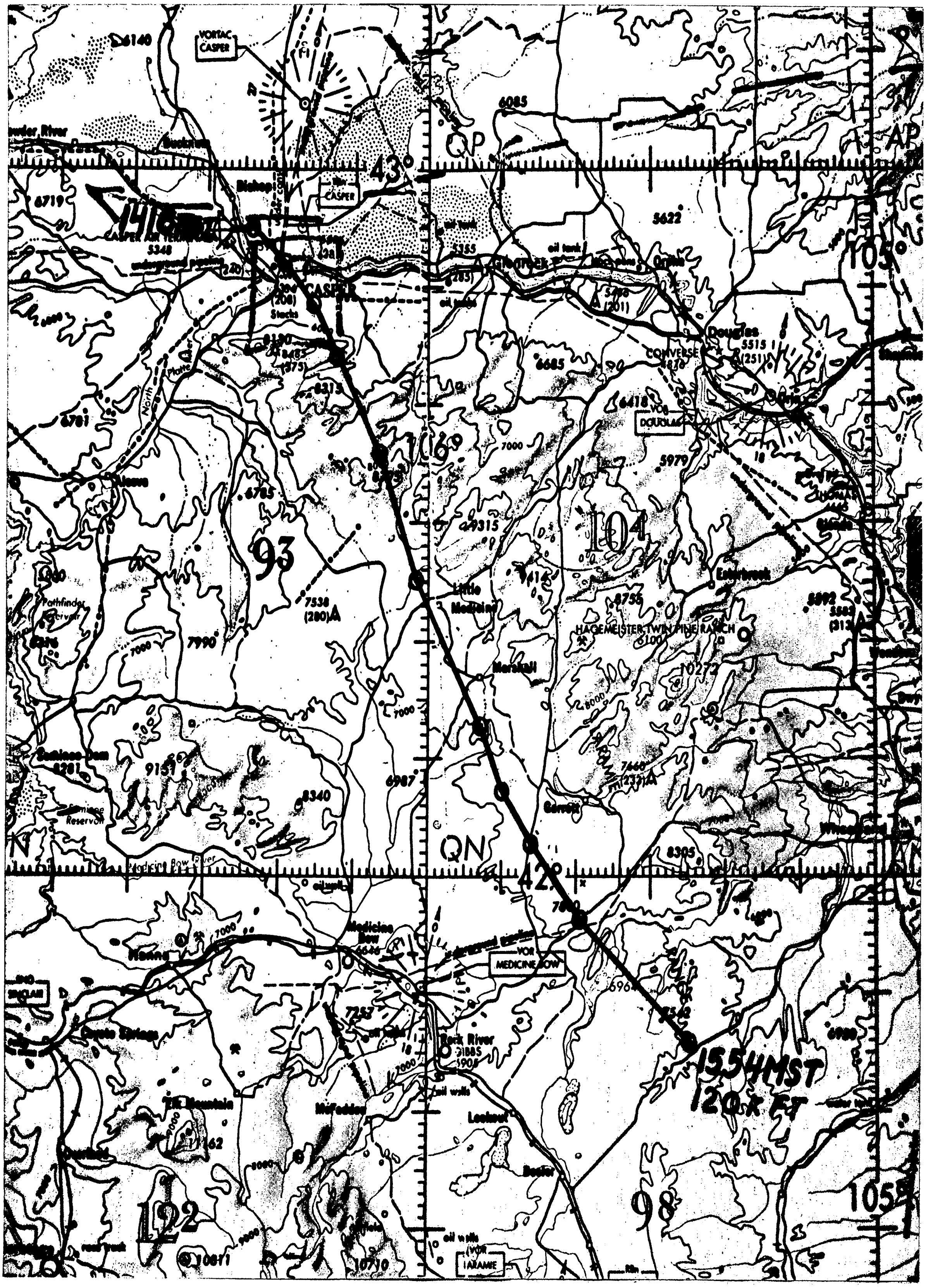

Figure 18-Ground Trace of 8 November Radiosonde from Casper, Wyoming

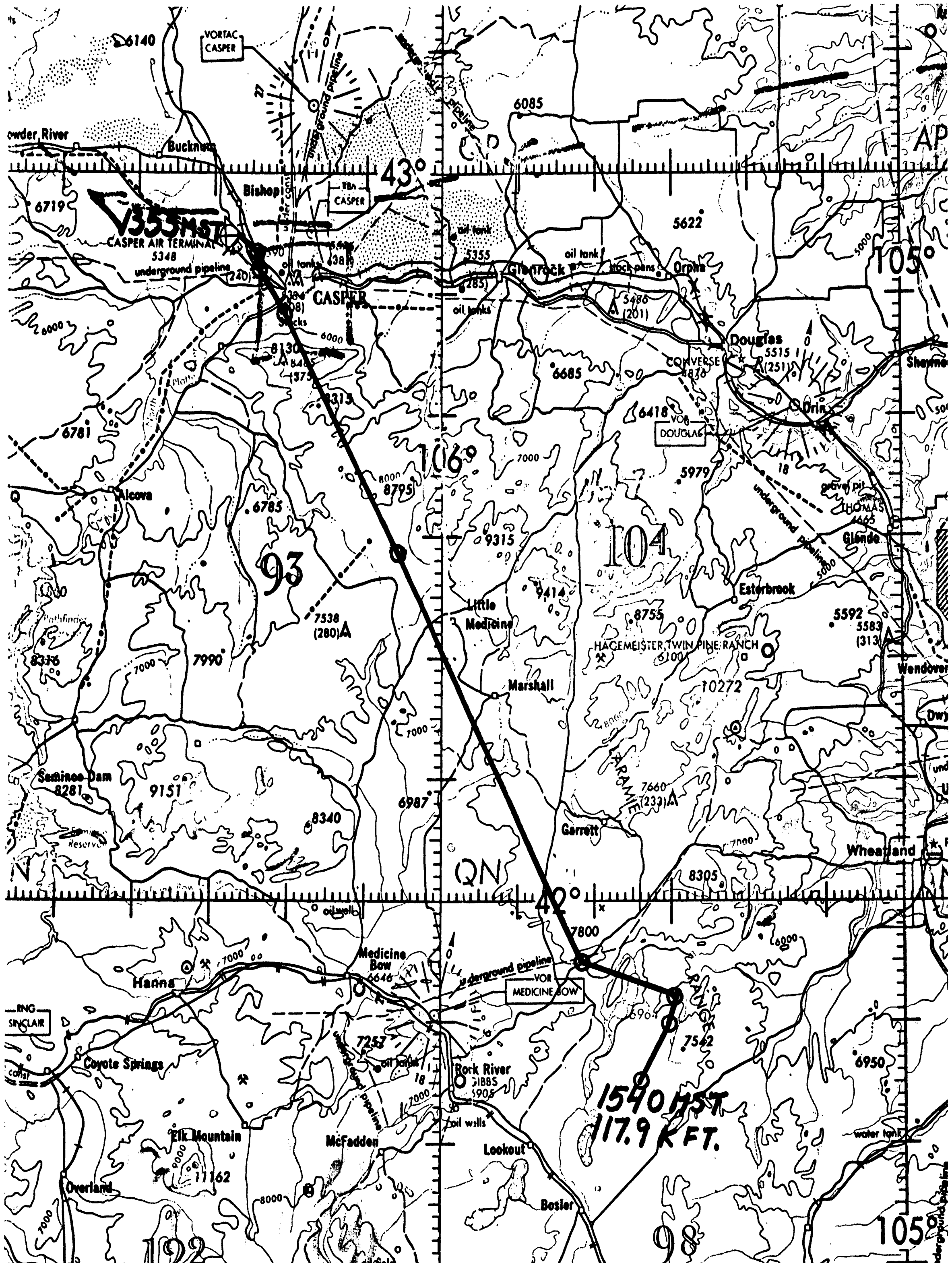

Figure 19-Ground Trace of 10 November Radiosonde from Casper, Wyoming