ANALYSIS OF SYNOPTIC DATA FOR SELECTED HAIL DAYS IN NORTHEASTERN COLORADO, 1961

by

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INTRODUCTION

The successive objectives of the research on hail being conducted at Colorado State University are:

1. To obtain the climatology of hailfalls and rainfalls in the High Plains, a region of high frequency of hail

2. To determine the environmental factors which favor the occurrence of hail

3. To design and conduct an experiment in hail modification by cloud seeding.

Work done under National Science Foundation Grant NSF G 17964 was directed at the second of these objectives. This report presents an analysis of synoptic data for selected days with hail in Northeastern Colorado during 1961. A summary of mean values of the various synoptic parameters examined and a discussion of their relative importance are given in the body of the report. The appendix includes data for case studies of six days of severe hail, six days on which hail of moderate intensity occurred, and six days on which no hail occurred during the period 1 May - 31 July 1961.

DATA AND METHODS

Selection of days for study - - Five criteria were used to classify hail intensity for each day during the 1961 hail season from 1 May to 31 July, using data from the Colorado State University network. These criteria were: 1) the number of reports of hail occurrence received from cooperative observers; 2) maximum stone size; 3) maximum energy number; 4) the largest "most common" stone size; 5) the number of damaged hail indicators.

Using these criteria, the following dates were chosen as being a representative sample of hail days of the intensities indicated: Severe--May 13, May 16, May 31, June 2, July 1, and July 14; Moderate--May 21, May 24, June 8, June 13, June 28, and July 8; None--May 22, June 21, June 26, July 3, July 17, and July 23.

Synoptic data - - For each day, the following information was obtained:

1. Surface synoptic patterns gathered from data collected at 1100 and 2300 MST. The surface weather maps for this report were taken from the Daily Weather Map prepared by the U. S. Weather Bureau

2. 500 mb contour patterns at 1700 MST, also taken from the Daily Weather Map.

3. The jet stream configuration and isotach analysis at 1700 MST, obtained from 300 mb facsimile charts.

4. A mean wind profile over the area, obtained by averaging upper wind reports from LND, DEN, BFF, LBF, GLD from the ground surface to the tropopause.

5. Wind profiles along the mean wind direction for each respective upper-air station in the vicinity, including Lander (LND), Denver (DEN), Scottsbluff (BFF), North Platte (LBF), and Goodland (GLD).

6. Vertical air mass structures, obtained from plotted raob soundings (Skew-T, log P diagrams) at 0500 and 1700 MST.

7. A precipitable water and stability index chart, taken from USWB facsimile charts.

8. A chart showing the forecast size of hailstones at stations in and near northeastern Colorado by the Fawbush-Miller method, using the 1700 MST raob soundings.

9. Diagrams showing the daily rainfall amounts and hail occurrences, compiled from reports by cooperative observers and hail indicators in the hail network.

These synoptic data are presented in the appendix for each of the 18 days selected for study.

RESULTS AND CONCLUSIONS

Mean values of synoptic parameters - - Table 1 gives average values of selected synoptic parameters for days classified as having severe, moderate and no hail.

Table 1 shows little difference in the stability index and precipitable water for the three categories of hail intensity. On the other hand, a faster mean jet stream speed and high mean wind speed are associated with the severe hail days. A further distinction between severe and moderate hail lies in the orientation and location of frontal systems with respect to the hail network.

Table 1. Mean synoptic parameters for days with hail of three intensity classifications. Values given are means with six days per category.

Hail Intensity Category	Showalter Stability Index, Deg. C	Precipitable Water, Inches	Jet Stream Speed Knots	Mean Wind, Surface to Tropopane, Direction and Speed, Knots	Fronts	
					Orientation	N. Mi. Distance and Direction From Network
Severe	0.0	.76	57	260/33	NNE-SSW	188 SE
Moderate	0.5	.76	40	270/25	N - S	205 NW
None	0.6	.64	38	310/26	---	---

These observations from Table 1, based on mean values, are substantiated by examination of data from individual days.

Severe hail days - - In examining the severe days, the existence of a jet maximum overhead of about 55-60 knots indicates a day of severe rather than moderate or no hail. Values for moderate and "none" days were approximately 35-40 knots. For severe days, the value of the jet maximum ranged between 30 and 105 knots.

One of the best correlations was found to be the position and orientation of the surface front over the region. In all six severe cases, the front was positioned to the southeast of the area. No distinction was made in this analysis between mP and cP air masses causing the fronts.

The presence of a low pressure system to the south of the area favored the occurrence of severe hail. On 5 of the 6 days studied, low pressure systems were noted to the south of the area, and three of these proved to be of substantial strength producing hail as the low pressure area moved to the east. The average position of low pressure areas was in WSW Kansas (1200Z).

Moderate hail days - - Days with hail of moderate intensity exhibited no strong preference for any of the parameters studied. The mean frontal positions for these days was with an orientation N-S, a distance of about 205 miles to the WNW of the center of the forecast area. This might lead to the conclusion that the storms producing moderate hail were associated with pre-frontal activity. Only one out of the six days had a front which had already passed the area by 1200Z.

The idea of the dew-point front might be suggested as a cause for hailstorms of moderate intensities, since the most intense storms frequently occur after the frontal passage or as the dry denser air behind the front and aloft over the mountains displaces the residual moist air remaining behind the front. Occassionally, low pressure systems were noted SE of the forecast area, but these were static and sluggish systems.

Days with no hail - - A primary difficulty in this study was an inability to find parameters which distinguished days of moderate hail from days of no hail occurrence. As mentioned earlier, there was little difference in the jet speeds, the value for both being 35-40 knots. Frontal and low pressure activity and centers were indefinite for the no-hail days. One positive correlation did appear, however, on the no-hail days. For days of no hail, the direction of the mean wind speed from the surface to the tropopause was from the NW (310^0), while the direction for the moderate and severe days was 270^0 and 260^0, respectively.

Parameters with no apparent correlation with hail intensity - - Some of the parameters showed no correlation with hail intensity. The Showalter Stability Index and the Precipitable Water Amounts were such parameters. The respective values were as follows: Severe--SSI = 0, with range of -3 to +4; precipitable water = .67; Moderate--SSI = 0, with range of 0 to +2; precipitable water = .76; None--SSI = 0, with range of 0 to +4; precipitable water = .64.

Mean soundings - - Finally, computations were made to determine mean soundings for the days in question. By grouping all the days of severe, moderate, and no hail, respectively, three average soundings for the area were constructed to demonstrate a severe hail day sounding, a moderate hail day sounding, and a "no-hail" day sounding. These soundings are given in Figures 1, 2 and 3. These average soundings were determined by taking the soundings for the individual stations of LND, BFF, LBF, DEN, and GLD, for both 1200Z (morning) and 0000Z (evening). After averaging for each station, a weighted average was determined for the six days of the study.

Figures 1 and 2 show remarkable similarity which suggests that they represent typical hail soundings without regard for intensity.

Examination of the soundings indicates no obvious features such as, for example, the typical hail and tornado soundings of the middle West, studied by Fawbush and Miller. It may be noted that the surface temperature tends to increase at 0000Z when the hail intensity decreases. This could be attributed to the fact that on the severe and moderate days a lower surface temperature may be caused by the presence of thunderstorms in and over the area, with the resulting downdrafts cooling the region.

A 10^0 C dew-point spread was common for all levels of the severe hail sounding, increasing to $10\text{-}15^0$ C spread for moderate soundings, and finally to as much as 20^0 C spread for days of no hail. These soundings indicate that the occurrence of no hail is related to the dry soundings, but to determine whether severe or moderate hail would occur cannot be determined from the sounding. Analysis of the soundings also indicates that the mean severe sounding is some $4\text{-}5^0$ C cooler from the surface to 400 mb than the lapse rate for the mean no-hail sounding. This can not be attributed to the presence of thunderstorms, since both the morning and evening soundings for the severe day exhibit this temperature reduction. One important conclusion is that when analyzing the soundings for the CCL (using the 1200Z for predicting purposes) and the convective temperature, T_c , which would initiate cumulus development by heating alone, the T_c lies below the reported surface temperature for the 0000Z observation. Granting that this observation may take place after the afternoon maximum temperature is realized, the meteorological events resulting in this convective activity are not caused by just reaching the T_c and then retreating. This observation leads to the conclusion that other effects must be active in causing rapid convective development.

Synoptic data are presented in the appendix to permit case studies of each day.

SUMMARY OF PROJECT

Period: May 1961 - December 1962

Personnel: Richard A. Schleusener

John D. Marwitz

August H. Auer

Publications (prepared in whole, or in part with sponsorship from Grant NSF G 17964).

1. Schleusener, R. A. On the relation of the latitude and strength of the 500-millibar west wind along 110 degrees west longitude and the occurrence of hail in the lee of the Rocky Mountains. Prepared for Amer. Meteor. Soc. Conference on Severe Storms, Norman, Oklahoma, Feb. 1962. Colo. State Univ., Civ. Engg. Rpt. CER61RAS46.

2. Schleusener, R. A., and T. J. Henderson Hail genesis areas in and near northeastern Colorado. Colo. State Univ. Civ. Engg. Rpt. CER61RAS58, Oct. 1961.

3. Schleusener, R. A., and L. O. Grant Characteristics of hailstorms in the Colorado State University Network, 1960-61. Proc. Ninth Weather Radar Conf., Oct. 1961.

4. Schleusener, R. A., and T. J. Henderson Observational data on the position of hailfalls with respect to precipitation cells. Presented at Amer. Meteor. Soc. Conference on Severe Local Storms, Norman, Oklahoma, Feb. 1962. Colo. State Univ. Civ. Engg. Rpt. CER62RAS1.

5. Schleusener, R. A. Hailstorm characterization and the crystal structure of hail. Pending publication in Amer. Meteor. Soc. Monograph on Severe Local Storms Colo. State Univ. Civ. Engg. Rpt. CER62RAS9, Feb. 1962.

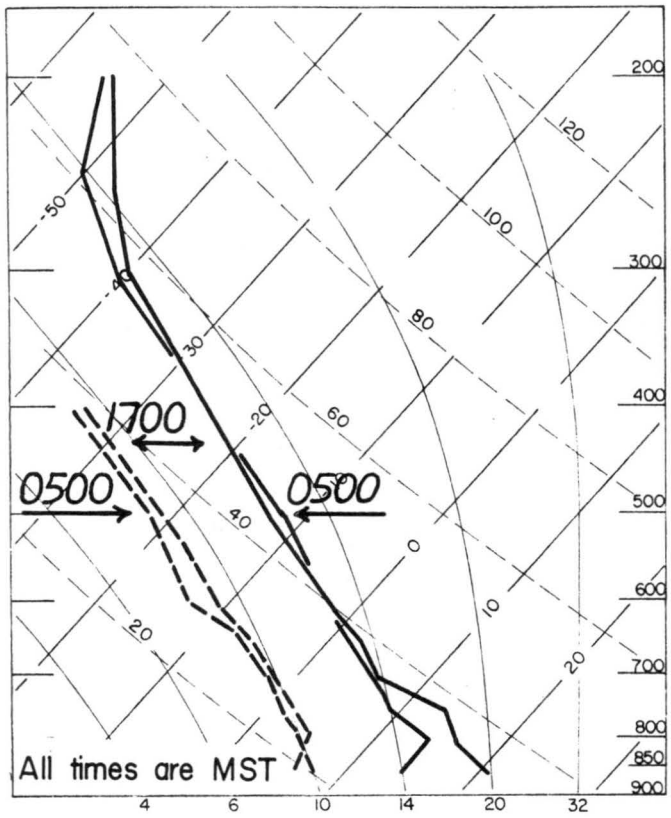


Fig.1 Mean sounding for severe hail days.

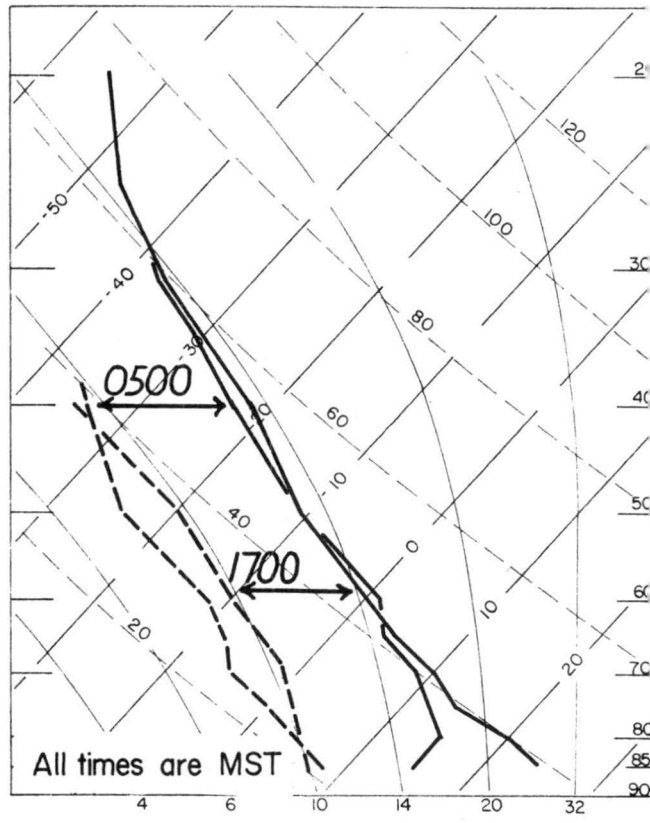


Fig.2 Mean sounding for moderate hail days.

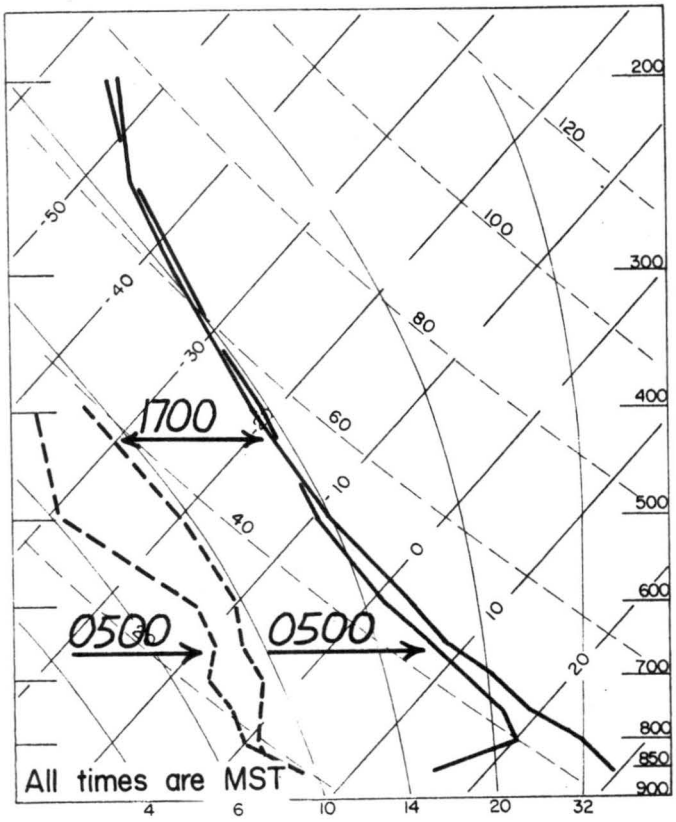


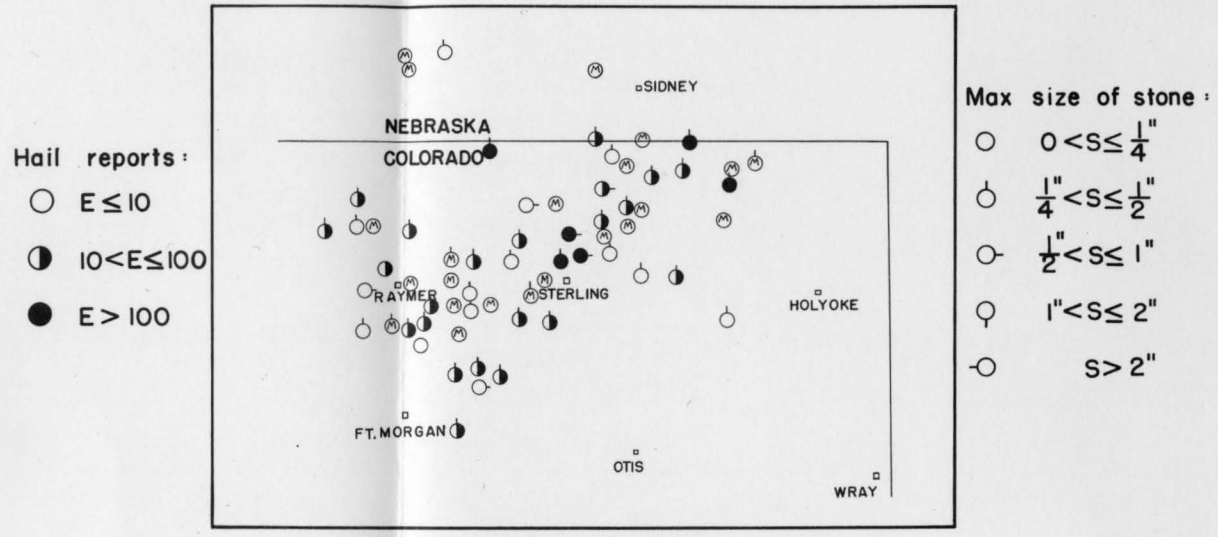
Fig.3 Mean sounding for "no hail" days.

APPENDIX

Data for Case Studies of Selected Hail Days in Northeastern Colorado, 1961

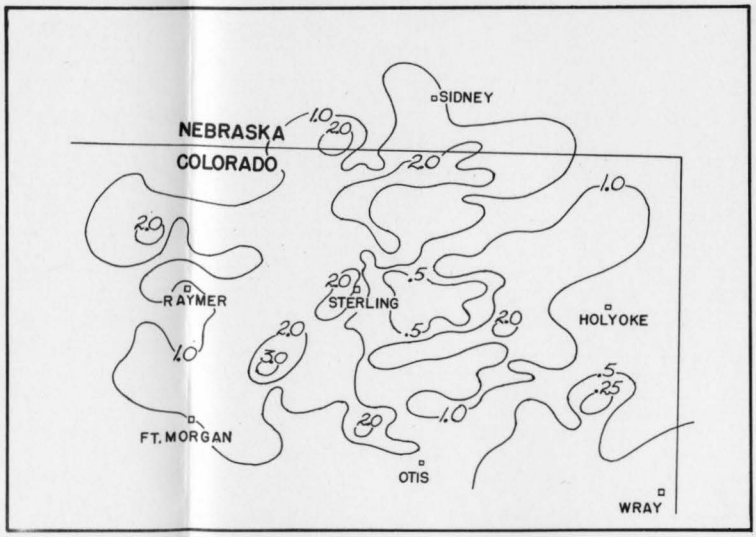
Hail Intensity Category	Dates
Severe	May 13, 16, 31
	June 2
	July 1, 14
Moderate	May 21, 24
	June 8, 13, 28
	July 8
None	May 22
	June 21, 26
	July 3, 17, 23

Case of :	13 May 1961
Hail classification :	Severe
Number of reports from CSU network :	72
Max stone size :	$1\frac{1}{4}$"
Max E, ft-lbs per sq ft. :	1552
Largest "most common" stone size :	$\frac{3}{4}$"
Number of damaged indicators, CSU network :	90



Reports of Hail

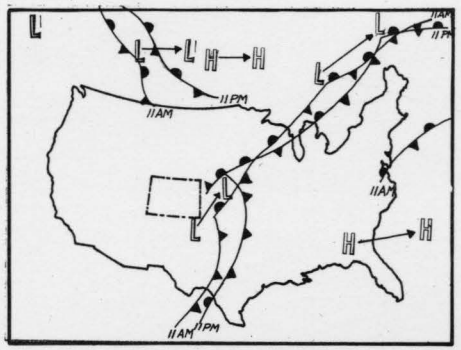
E= impact energy, ft-lbs per sq ft.
S= max stone size, inches.
M= missing data.



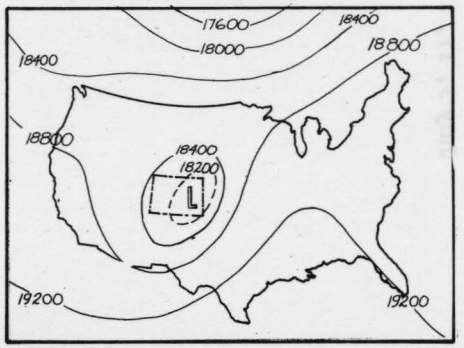
Rainfall Depth (inches)

Case of : 13 May 1961

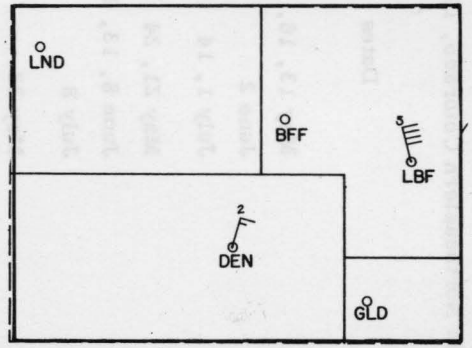
Hail Classification : Severe



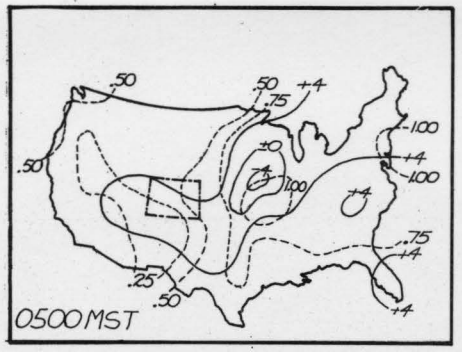
Surface Synoptic Pattern
11 AM & 11 PM MST



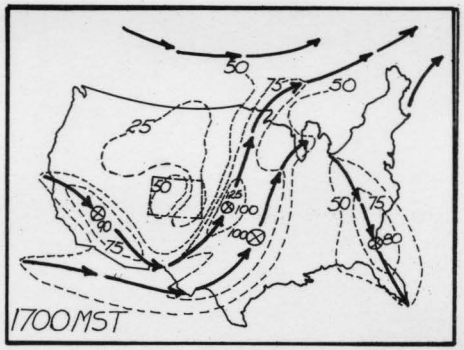
500 MB Flow
1700 MST



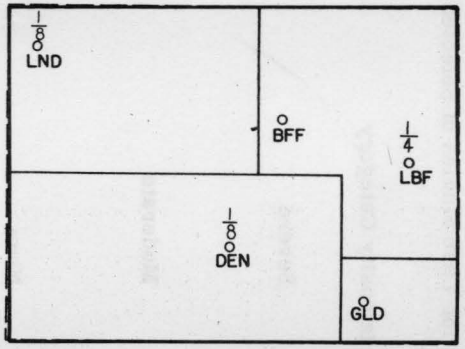
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index



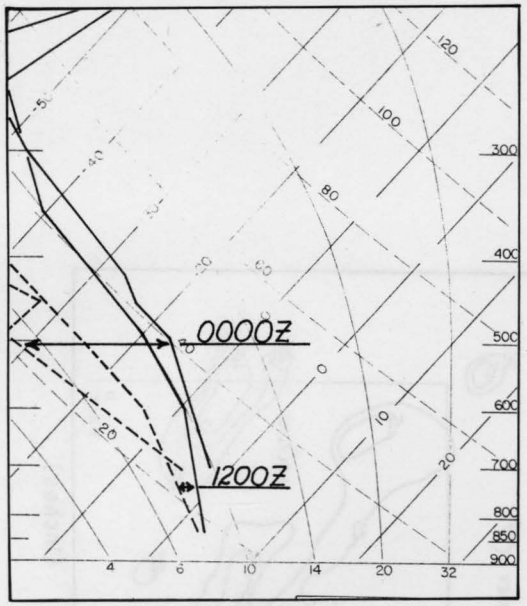
Jet Stream 50 & 100 kt. isotachs



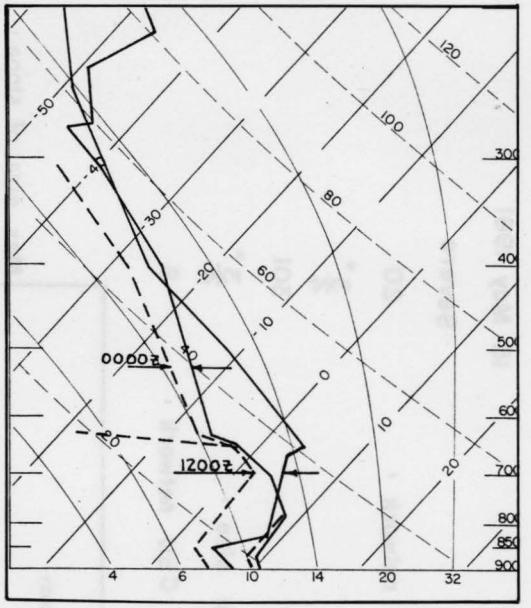
Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

Case of: 13 May 1961

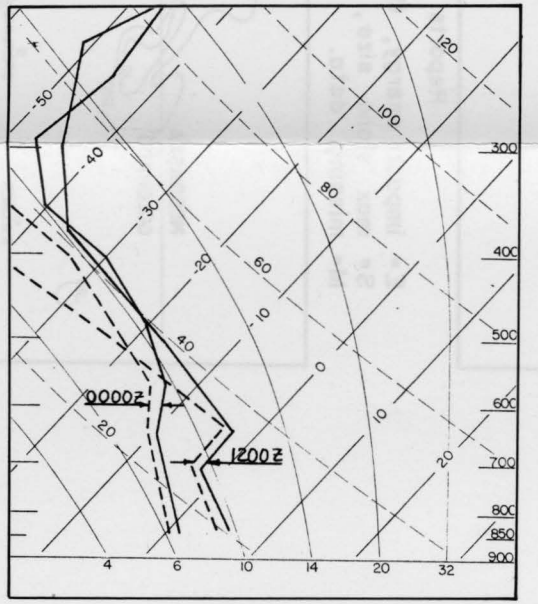
Hail Classification: Severe



Lander



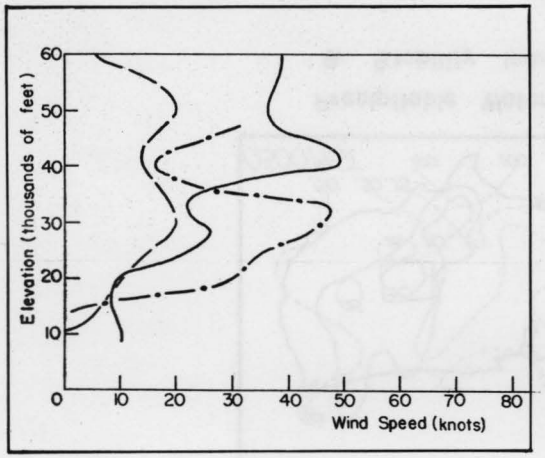
North Platte



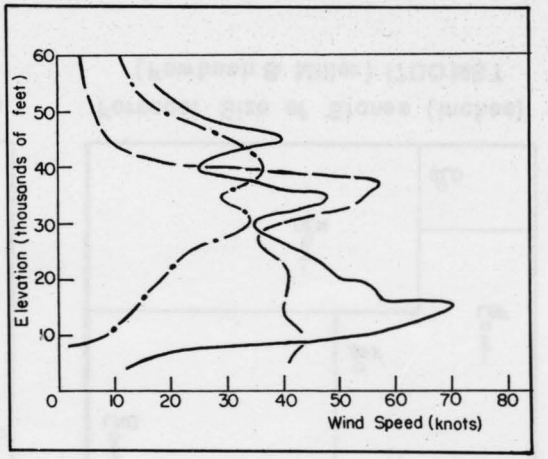
Denver

SKEW-T Diagrams
0500MST=1200Z
1700MST=0000Z

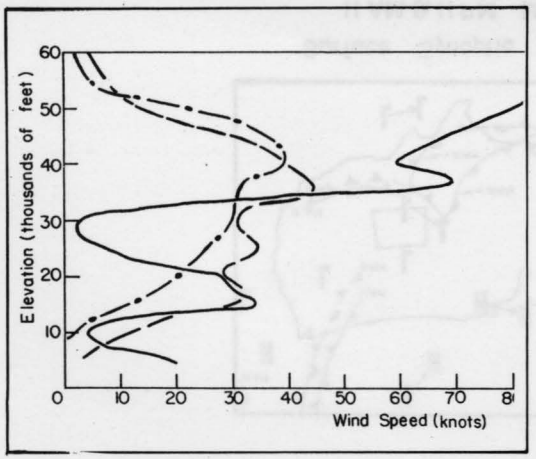
Case of: 13 May 1961
Hail Classification: Severe



Lander



North Platte



Denver

Legend

Day before: —•—•—

Day of severe hail: ———

Day after: — —

Hail Intensity Classification

Day before: Severe

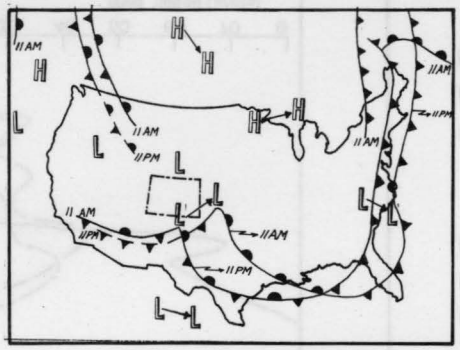
Day of: Severe

Day after: Moderate

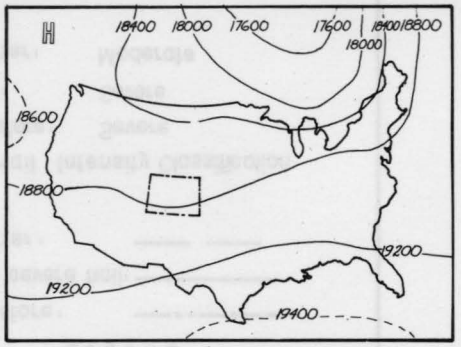
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of : 16 May 1961

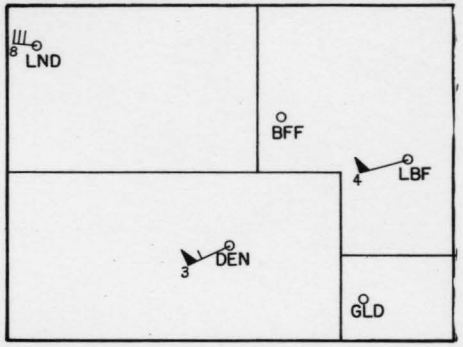
Hail Classification : Severe



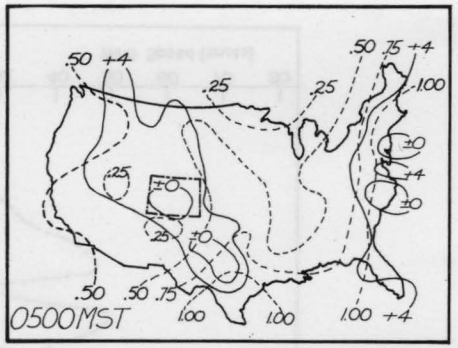
Surface Synoptic Pattern
11 AM & 11 PM MST



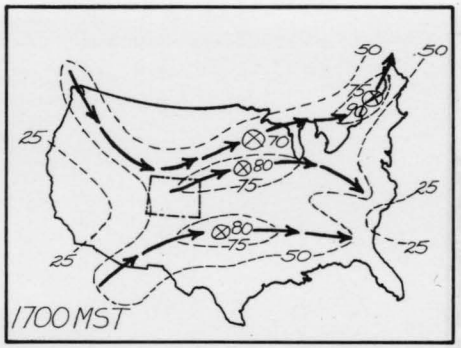
500 MB Flow
1700 MST



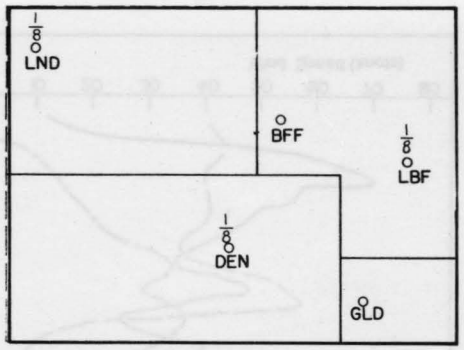
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index



Jet Stream 50 & 100 kt. isotachs



Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

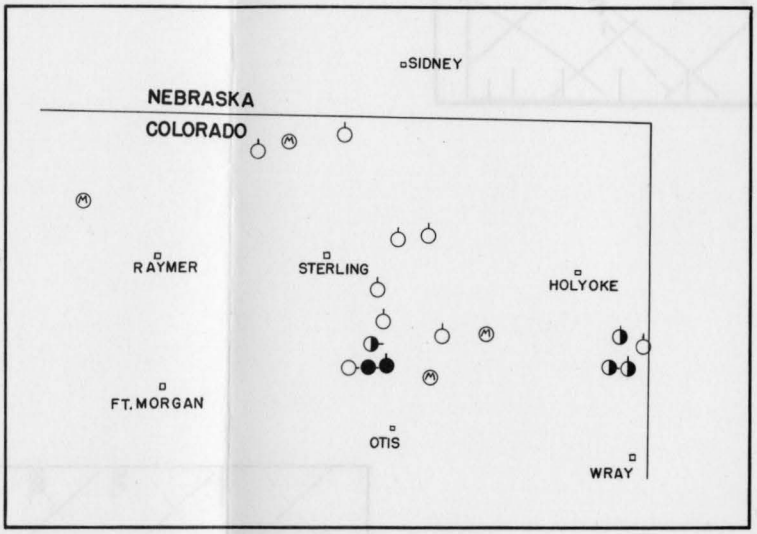
Case of :	16 May 1961
Hail classification :	Severe
Number of reports from CSU network :	20
Max stone size :	$\frac{3}{4}$"
Max E, ft-lbs per sq ft. :	301
Largest "most common" stone size :	$\frac{3}{4}$"
Number of damaged indicators, CSU network :	8

Hail reports :

○ $E \leq 10$

◑ $10 < E \leq 100$

● $E > 100$



Max size of stone :

○ $0 < S \leq \frac{1}{4}$"

○ $\frac{1}{4}$" $< S \leq \frac{1}{2}$"

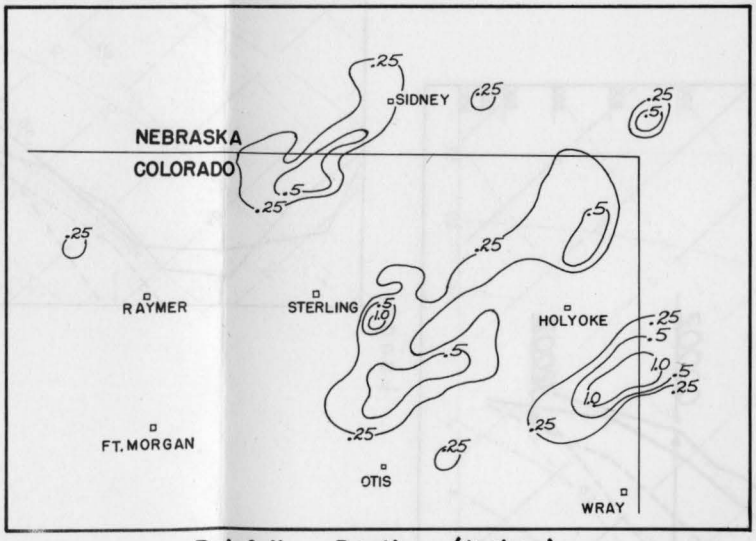
○ $\frac{1}{2}$" $< S \leq 1$"

○ $1" < S \leq 2"$

○ $S > 2"$

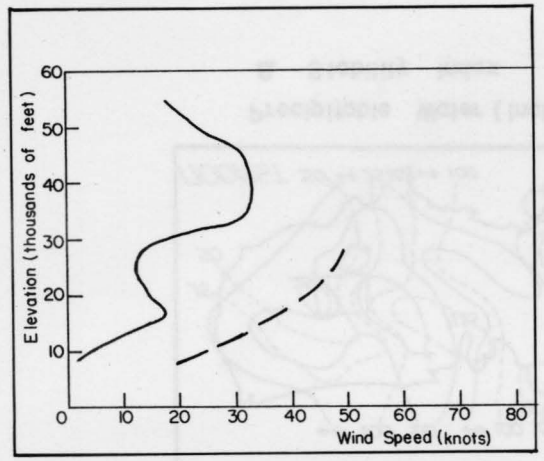
Reports of Hail

E= impact energy, ft-lbs per sq ft.
S= max stone size, inches.
M= missing data.

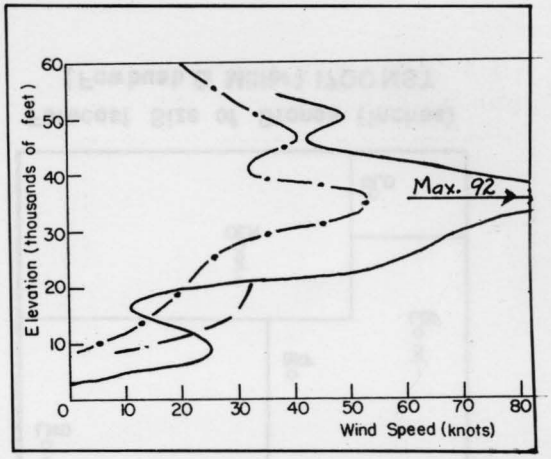


Rainfall Depth (inches)

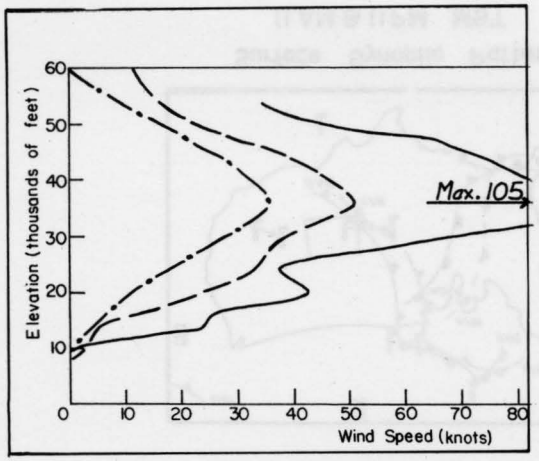
Case of: 16 May 1961
Hail Classification: Severe



Lander



North Platte



Denver

Legend

Day before: —•—•—

Day of severe hail: ———

Day after: — —

Hail Intensity Classification

Day before: None

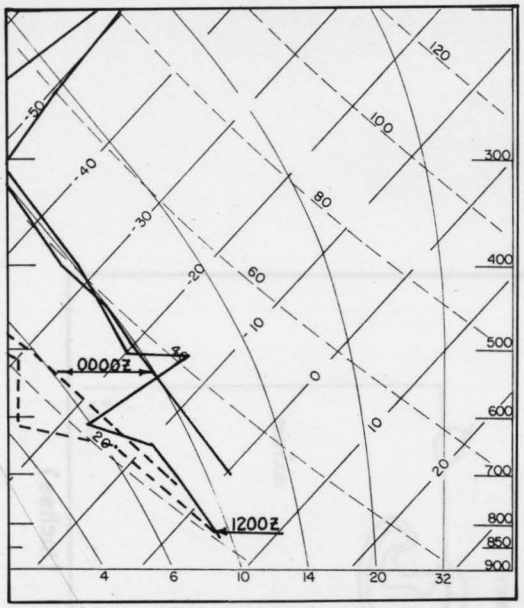
Day of: Severe

Day after: None

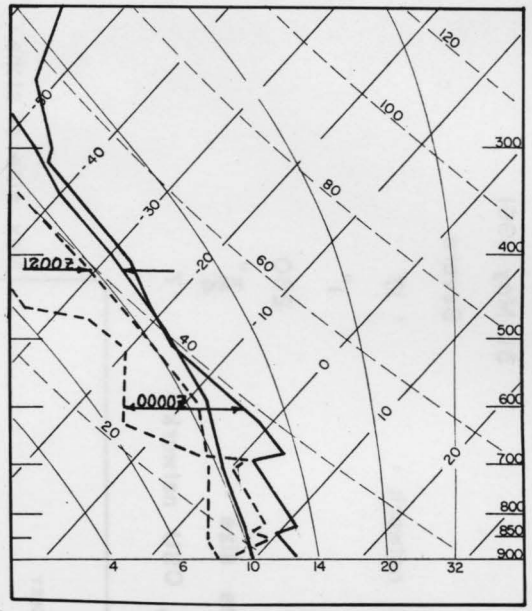
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 16 May 1961

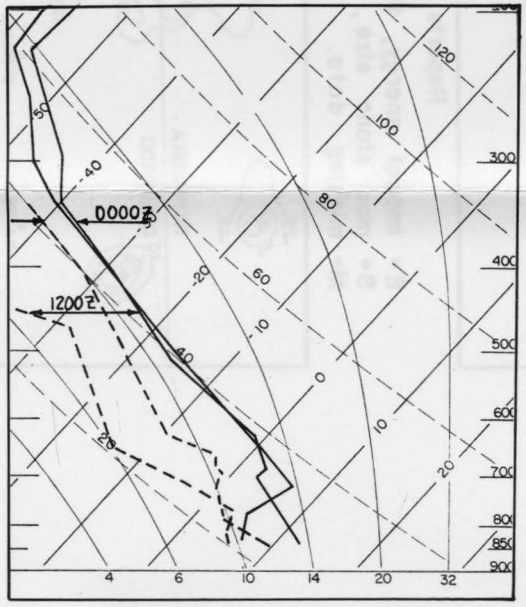
Hail Classification: Severe



Lander



North Platte



Denver

SKEW-T Diagrams
0500MST=1200Z
1700MST=0000Z

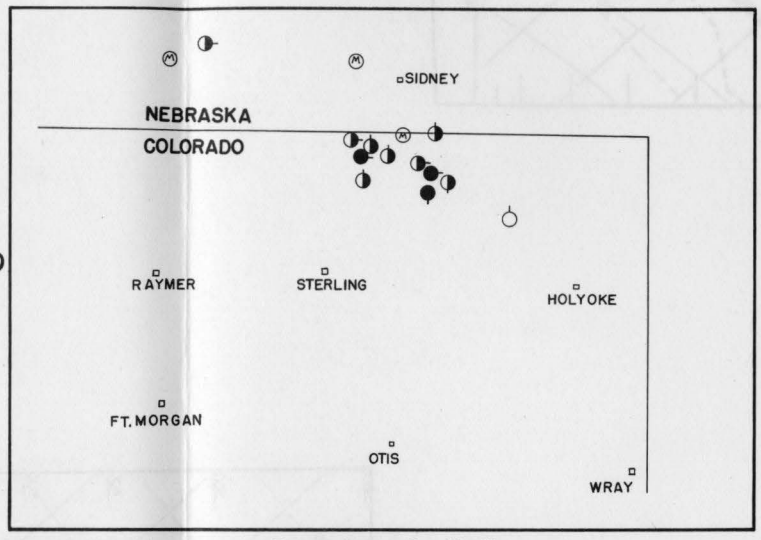
Case of :	31 May 1961
Hail classification :	Severe
Number of reports from CSU network :	17
Max stone size :	1"
Max E, ft-lbs per sq ft. :	260
Largest "most common" stone size :	$\frac{3}{4}$"
Number of damaged indicators, CSU network :	7

Hail reports :

○ $E \leq 10$

◑ $10 < E \leq 100$

● $E > 100$



Max size of stone :

○ $0 < S \leq \frac{1}{4}$"

○ $\frac{1}{4}$" $< S \leq \frac{1}{2}$"

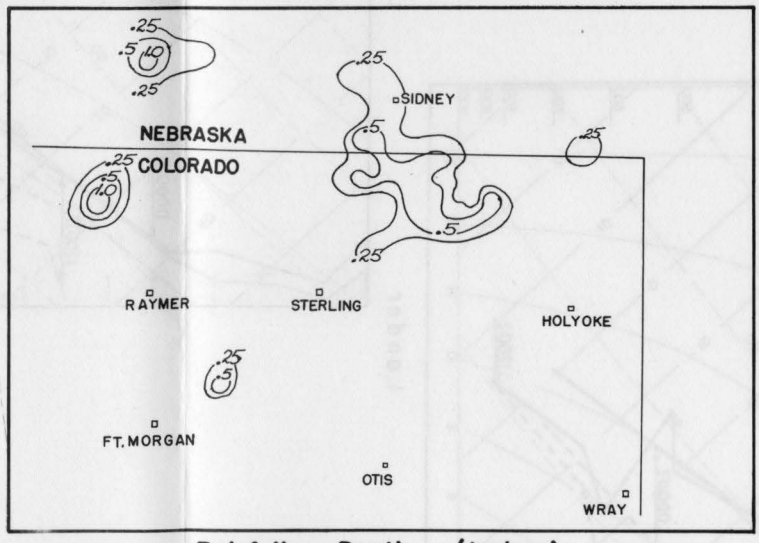
○ $\frac{1}{2}$" $< S \leq 1$"

○ $1" < S \leq 2"$

○ $S > 2"$

Reports of Hail

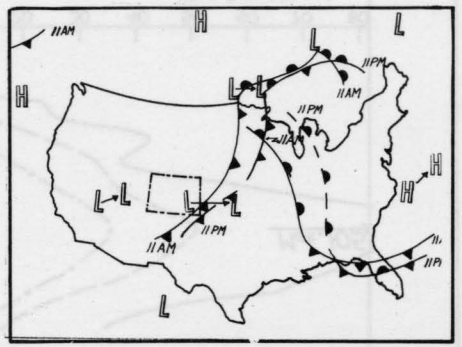
E= impact energy, ft-lbs per sq ft.
S= max stone size, inches.
M= missing data.



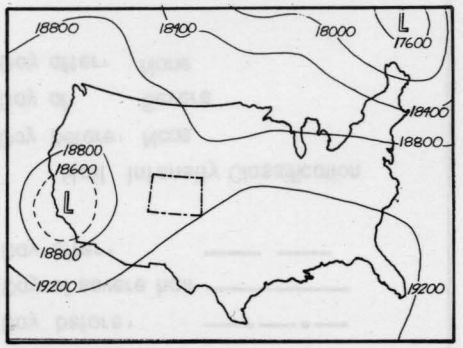
Rainfall Depth (inches)

Case of : 31 May 1961

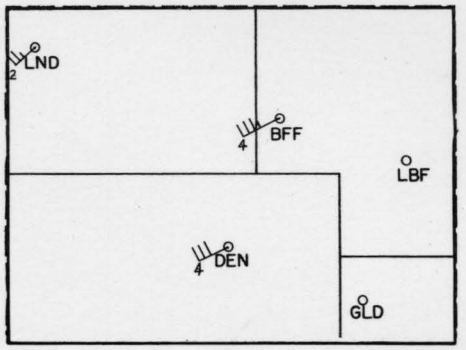
Hail Classification : Severe



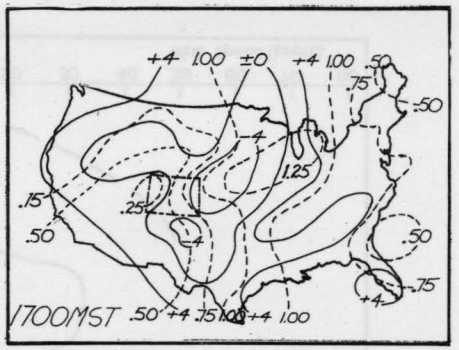
Surface Synoptic Pattern
11 AM & 11 PM MST



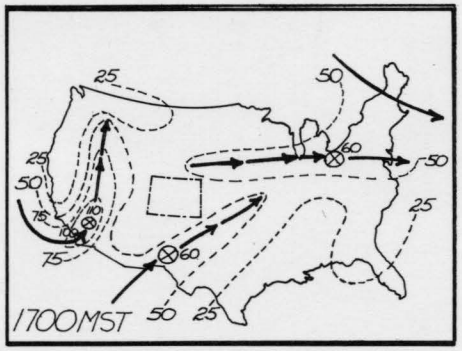
500 MB Flow
1700 MST



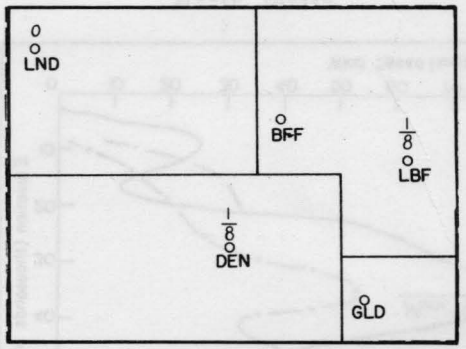
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index

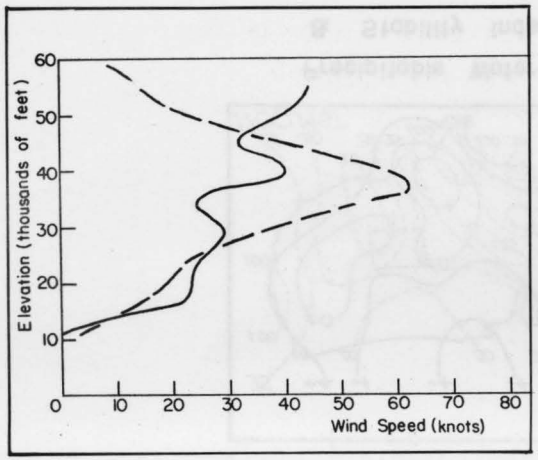


Jet Stream 50 & 100 kt. isotachs

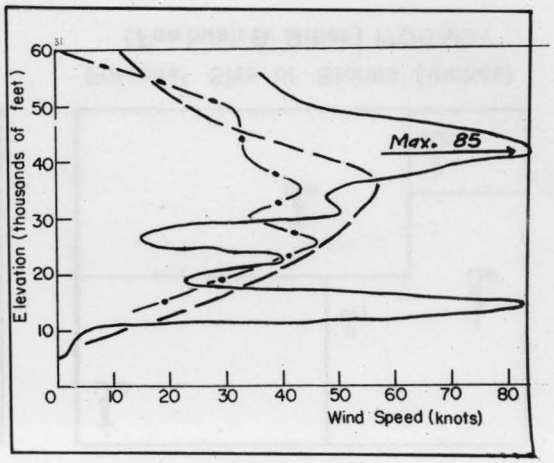


Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

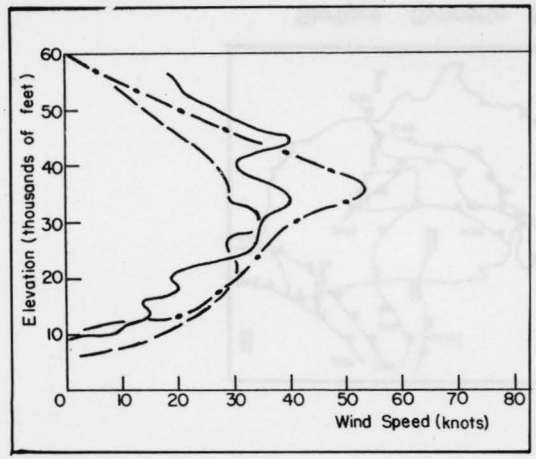
Case of: 31 May 1961
Hail Classification: Severe



Lander



North Platte



Denver

Legend

Day before: —•—•—

Day of severe hail: ———

Day after: — —

Hail Intensity Classification

Day before: Severe

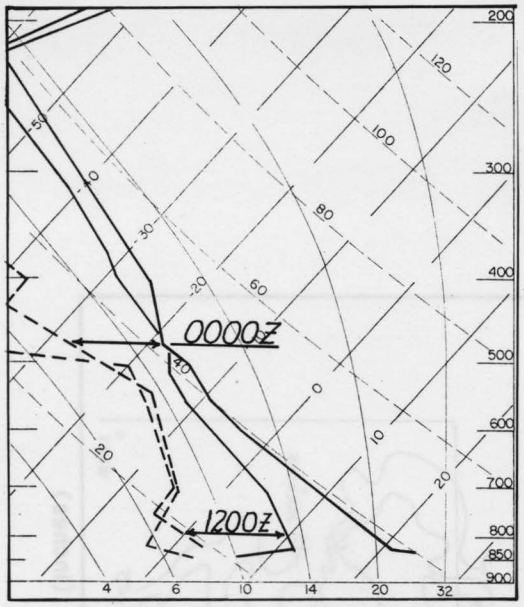
Day of: Severe

Day after: None

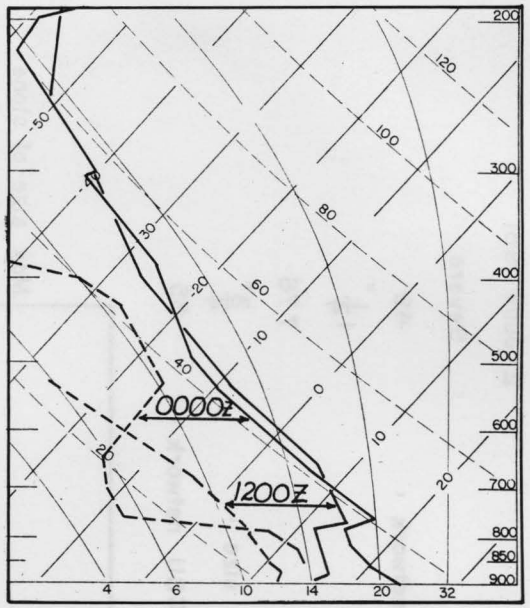
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 31 May 1961

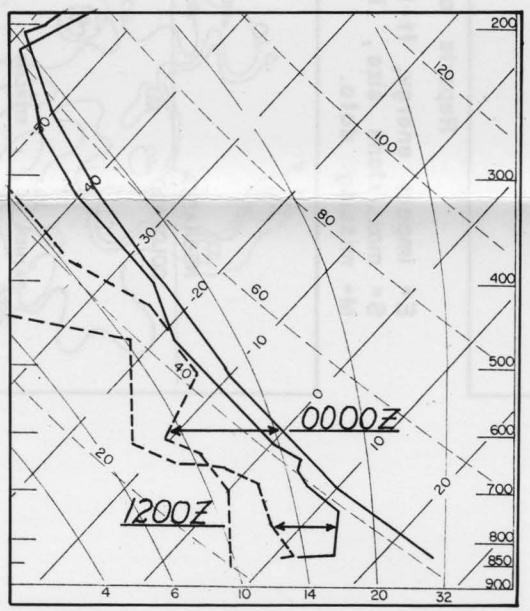
Hail Classification: Severe



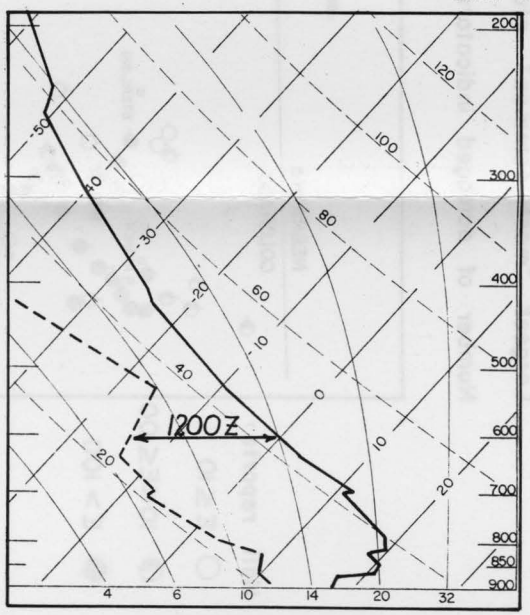
Lander



North Platte



Denver



Goodland

SKEW-T Diagrams

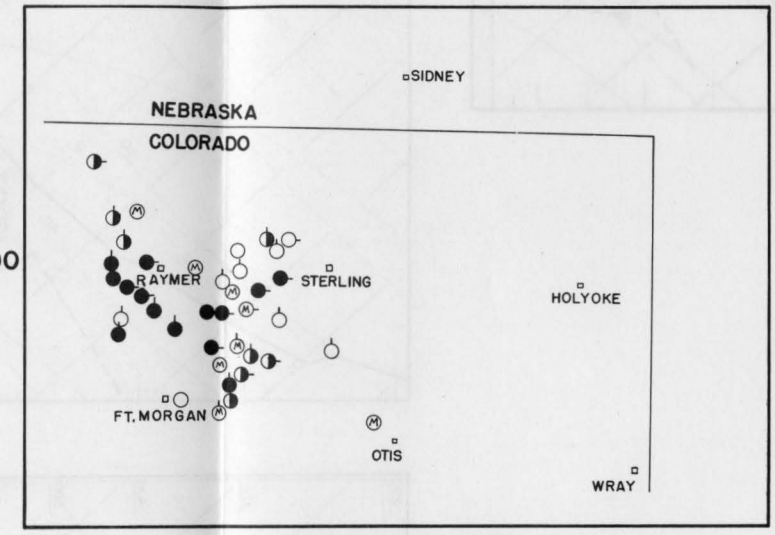
0500MST=1200Z

1700MST=0000Z

Case of :	2 June 1961
Hail classification :	Severe
Number of reports from CSU network :	49
Max stone size :	$1\frac{1}{4}$"
Max E, ft-lbs per sq ft. :	776
Largest "most common" stone size :	$\frac{3}{4}$"
Number of damaged indicators, CSU network :	65

Hail reports :

- ○ E ≤ 10
- ◑ 10 < E ≤ 100
- ● E > 100

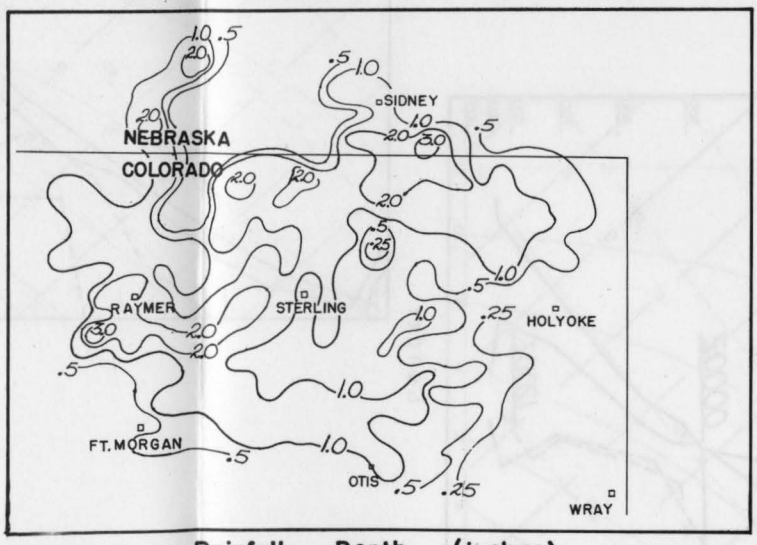


Max size of stone :

- ○ $0 < S \leq \frac{1}{4}$"
- ○ $\frac{1}{4}$" $< S \leq \frac{1}{2}$"
- ○ $\frac{1}{2}$" $< S \leq 1$"
- ○ $1" < S \leq 2"$
- ○ $S > 2"$

Reports of Hail

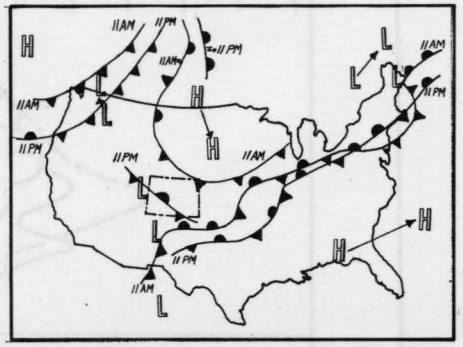
E= impact energy, ft-lbs per sq ft.
S= max stone size, inches.
M= missing data.



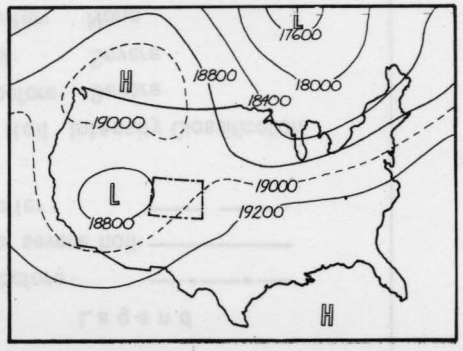
Rainfall Depth (inches)

Case of : 2 June 1961

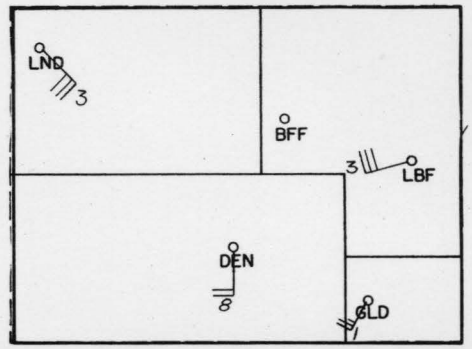
Hail Classification: Severe



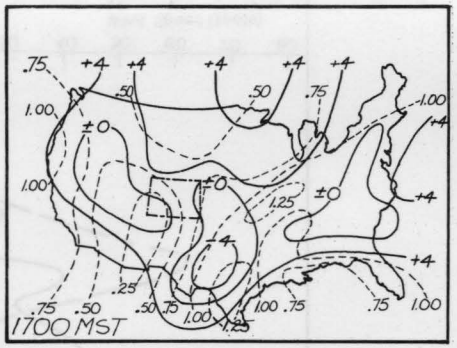
Surface Synoptic Pattern
11 AM & 11 PM MST



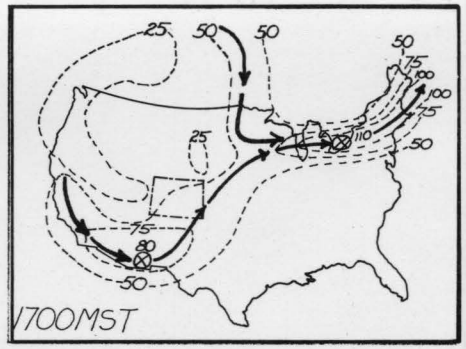
500 MB Flow
1700 MST



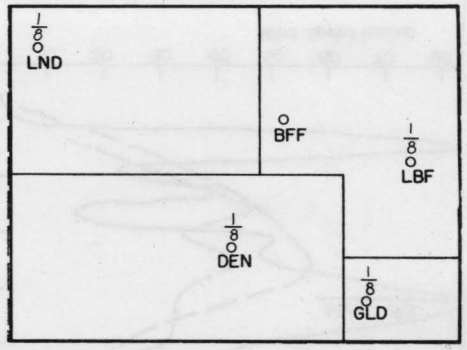
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index



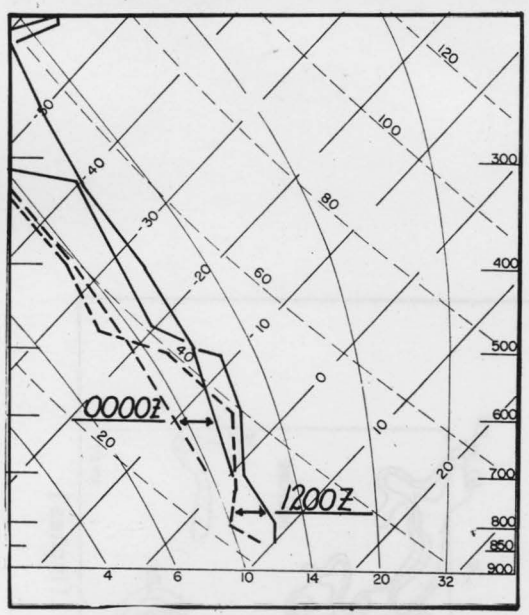
Jet Stream 50 & 100 kt. isotachs



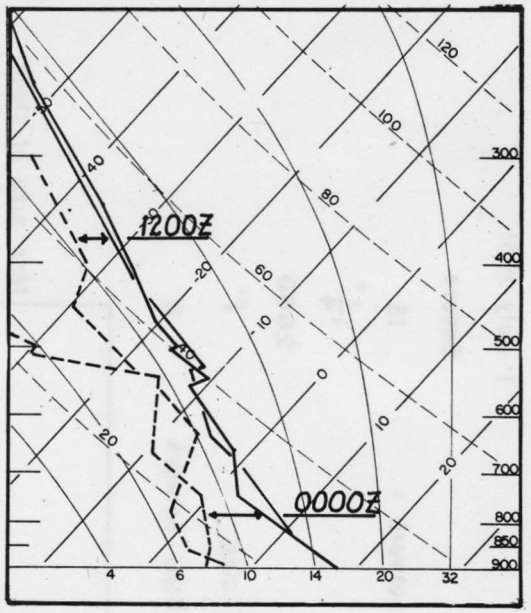
Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

Case of: 2 June 1961

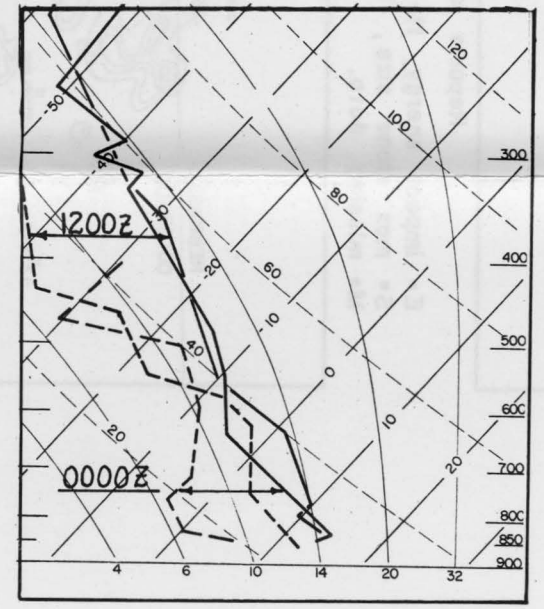
Hail Classification: Severe



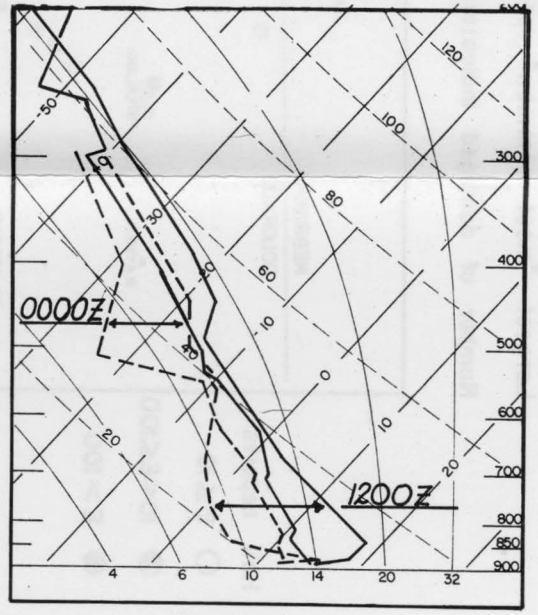
Lander



North Platte



Denver



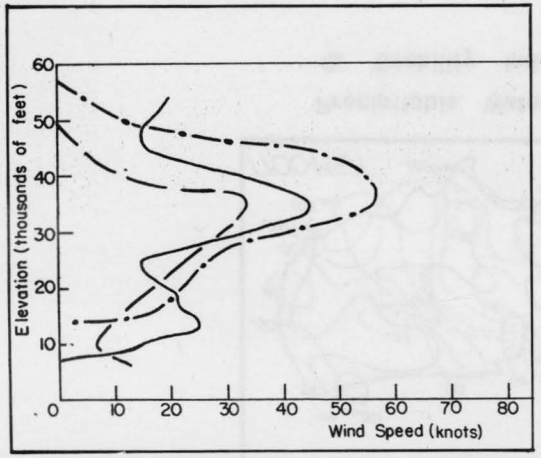
Goodland

SKEW-T Diagrams

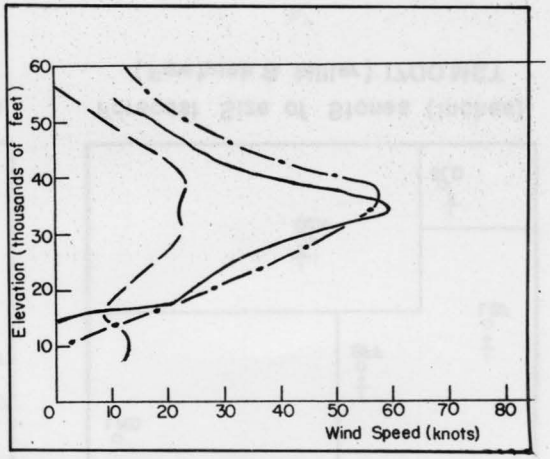
0500MST=1200Z

1700MST=0000Z

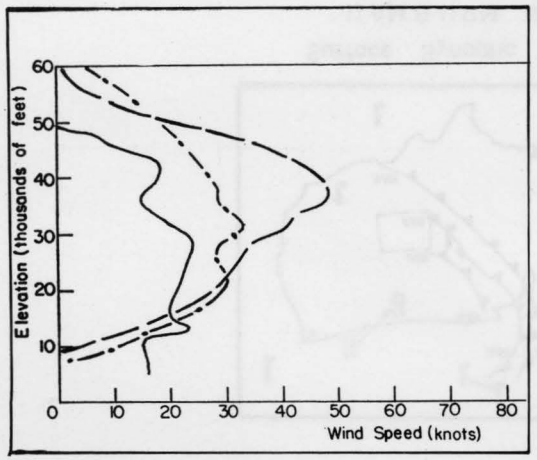
Case of: 2 June 1961
Hail Classification: Severe



Lander



North Platte



Denver

Legend

Day before: —•—•—

Day of severe hail: ———

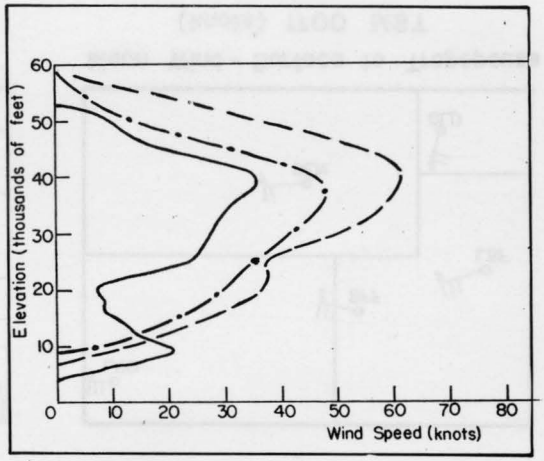
Day after: — —

Hail Intensity Classification

Day before: None

Day of: Severe

Day after: Moderate

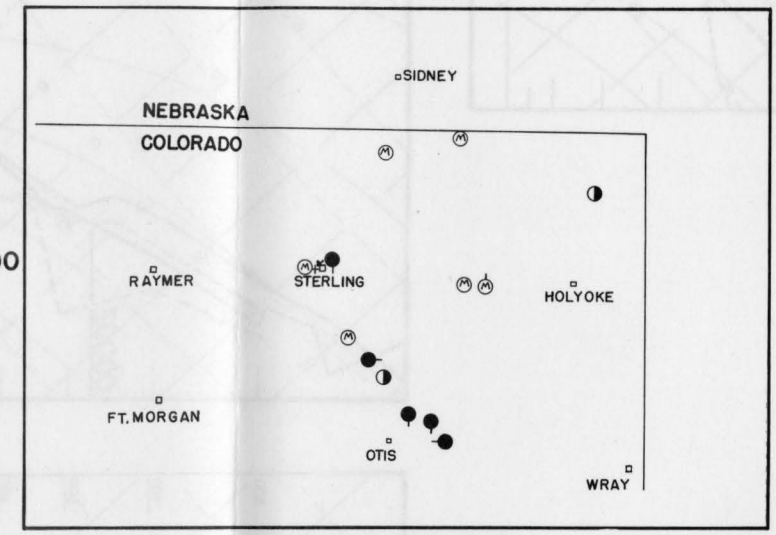


Goodland

Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of :	1 July 1961
Hail classification :	Severe
Number of reports from CSU network :	13
Max stone size :	$1\frac{1}{4}$"
Max E, ft-lbs per sq ft. :	2660
Largest "most common" stone size :	1"
Number of damaged indicators, CSU network :	6

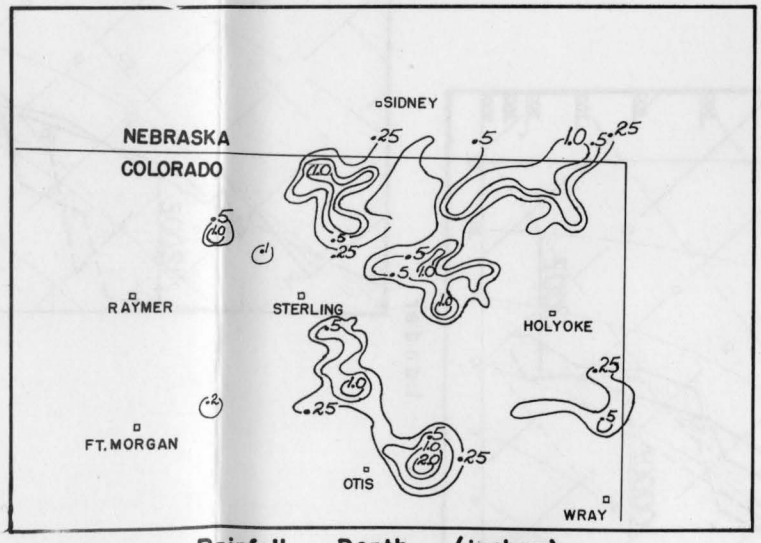
Hail reports :
- ○ E ≤ 10
- ◑ 10 < E ≤ 100
- ● E > 100



Max size of stone :
- ○ $0 < S \leq \frac{1}{4}$"
- ○ $\frac{1}{4}$" $< S \leq \frac{1}{2}$"
- ○ $\frac{1}{2}$" $< S \leq 1$"
- ○ $1" < S \leq 2"$
- ○ $S > 2"$

Reports of Hail

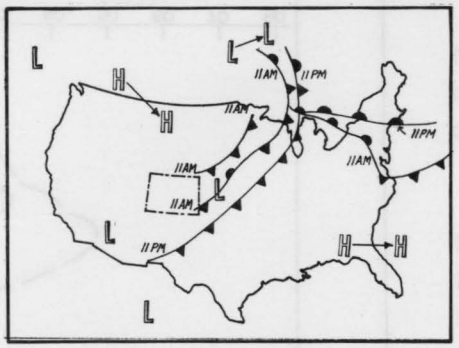
E = impact energy, ft-lbs per sq ft.
S = max stone size, inches.
M = missing data.



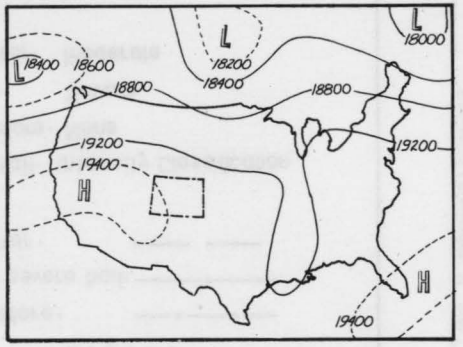
Rainfall Depth (inches)

Case of : 1 July 1961

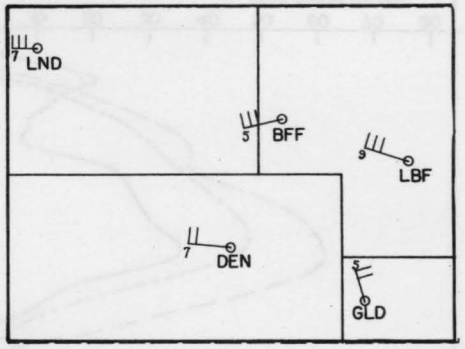
Hail Classification: Severe



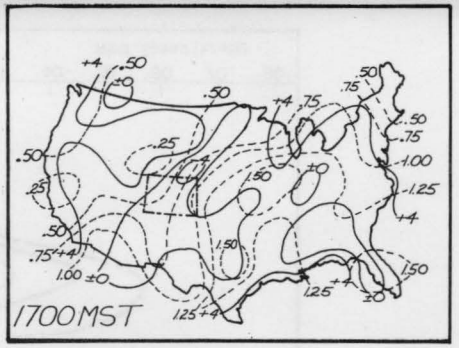
Surface Synoptic Pattern
11 AM & 11 PM MST



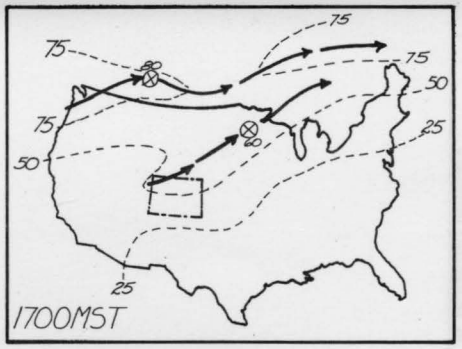
500 MB Flow
1700 MST



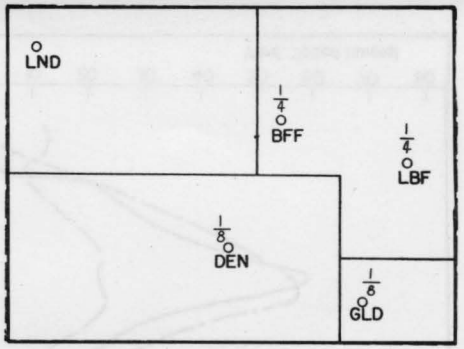
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index

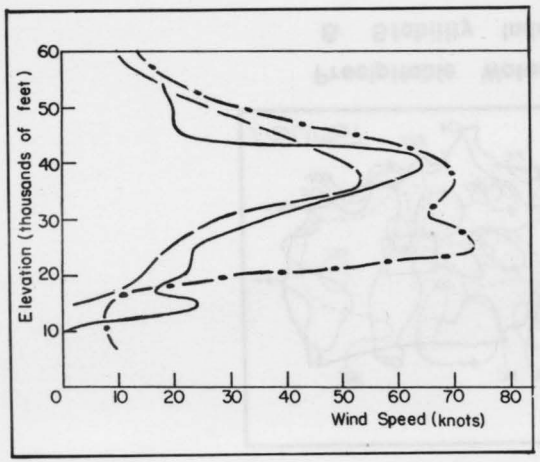


Jet Stream 50 & 100 kt. isotachs

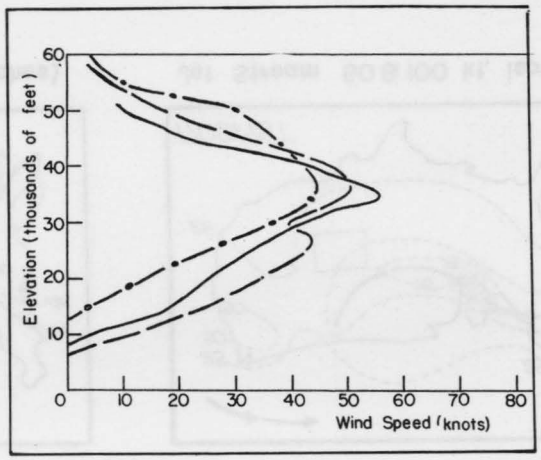


Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

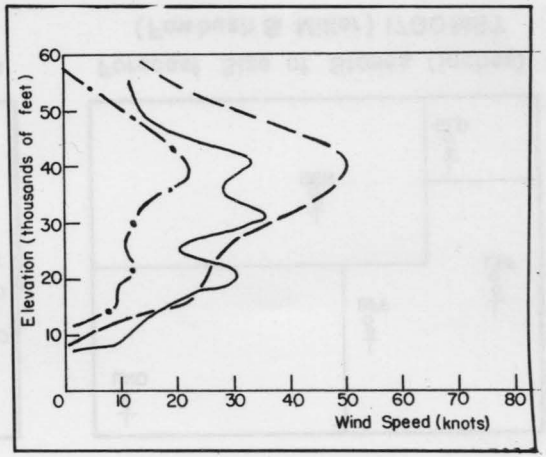
Case of: 1 July 1961
Hail Classification: Severe



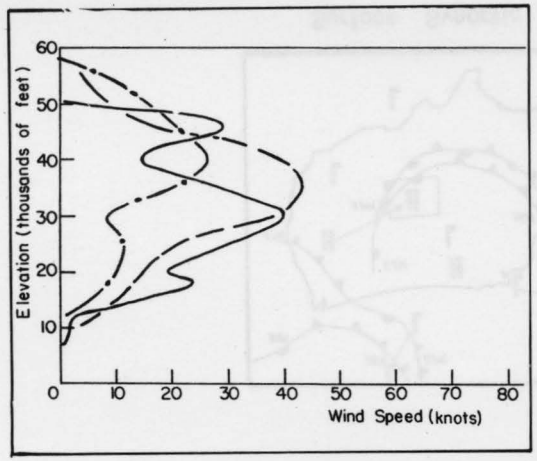
Lander



Scottsbluff



North Platte



Denver

Legend

Day before:

Day of severe hail:

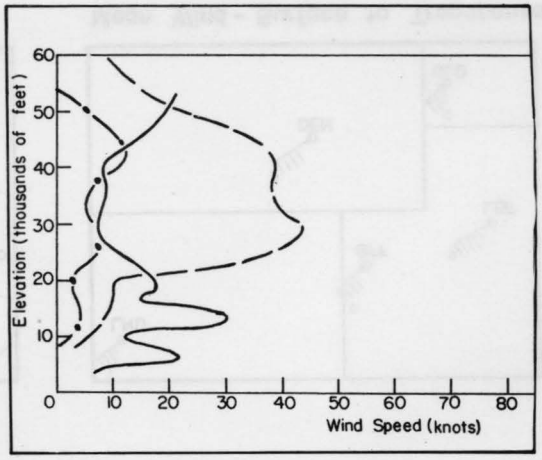
Day after:

Hail Intensity Classification

Day before: Moderate

Day of: Severe

Day after: None

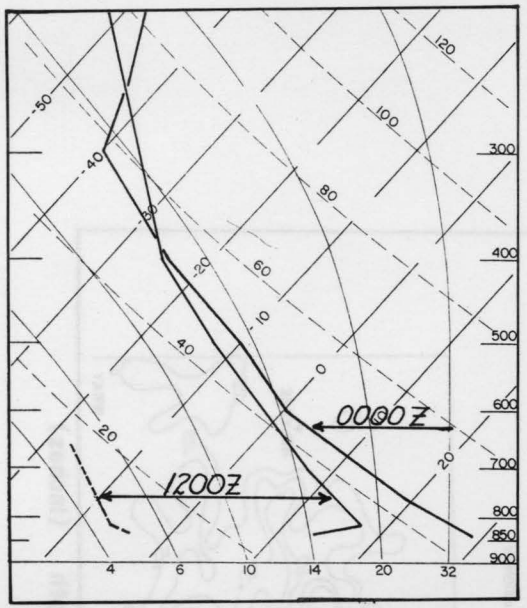


Goodland

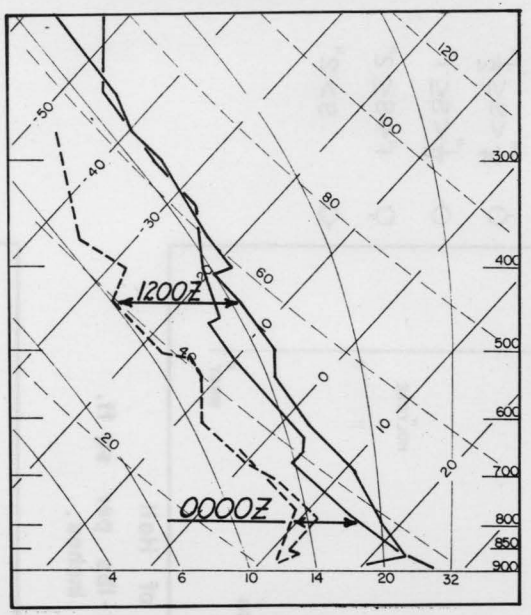
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 1 July 1961

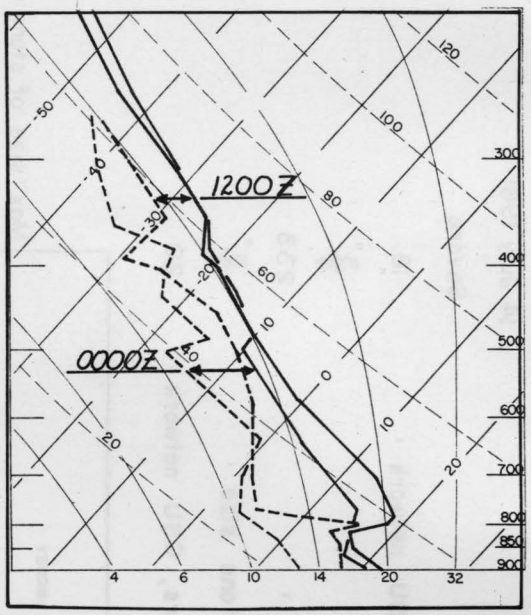
Hail Classification: Severe



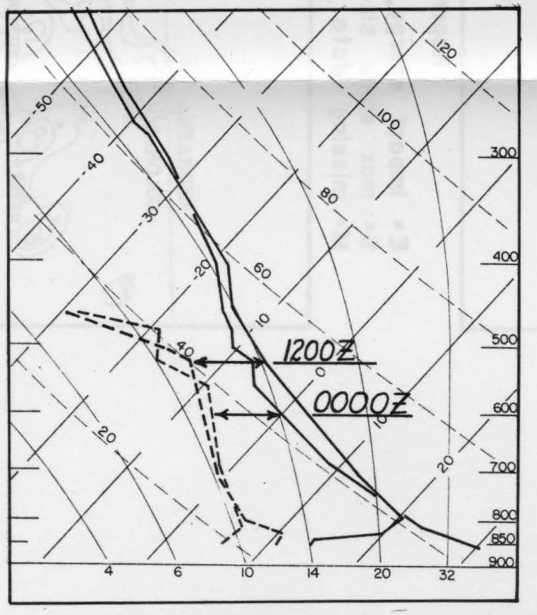
Lander



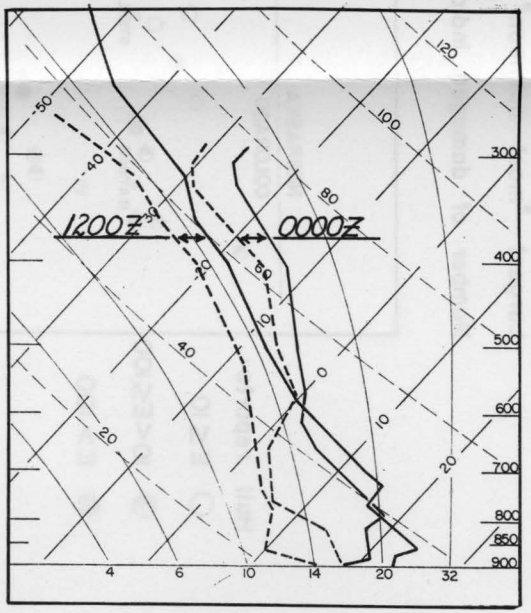
Scottsbluff



North Platte



Denver



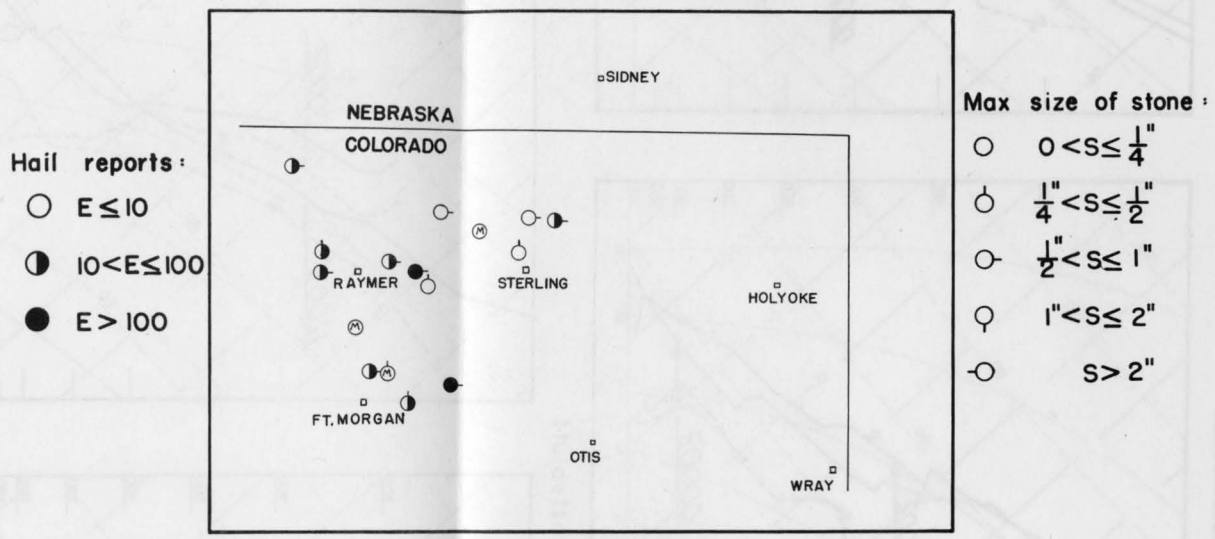
Goodland

SKEW-T Diagrams

0500MST=1200Z

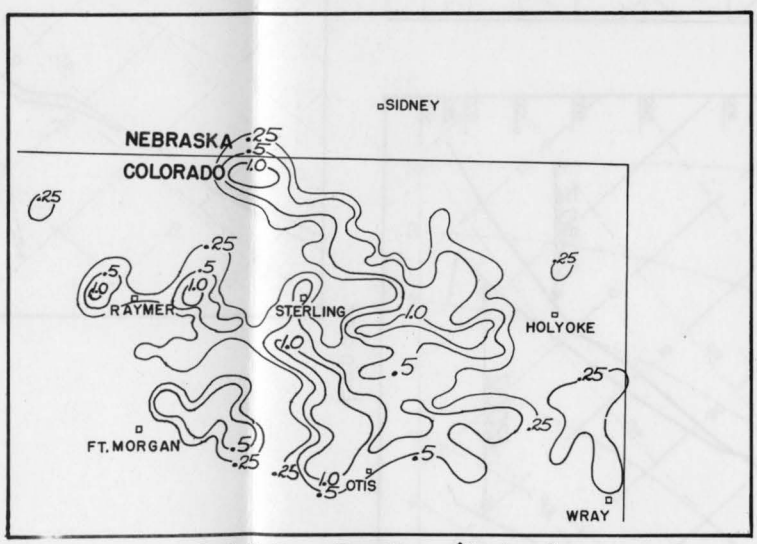
1700MST=0000Z

Case of :	14 July 1961
Hail classification :	Severe
Number of reports from CSU network :	18
Max stone size :	$\frac{3}{4}$"
Max E, ft-lbs per sq ft. :	233
Largest "most common" stone size :	$\frac{3}{4}$"
Number of damaged indicators, CSU network :	20



Reports of Hail

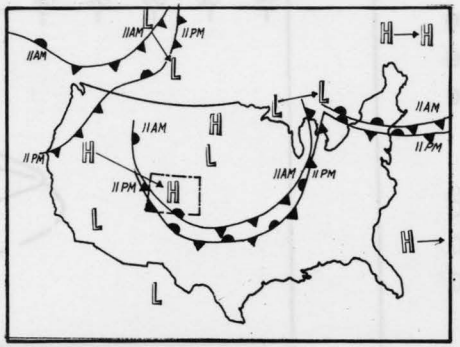
E = impact energy, ft-lbs per sq ft.
S = max stone size, inches.
M = missing data.



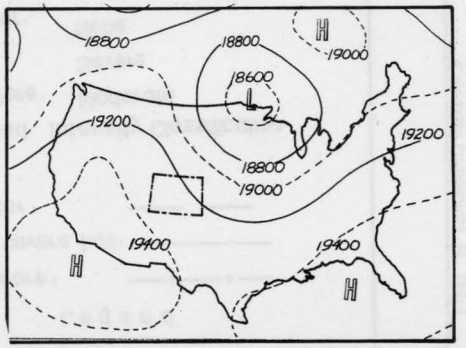
Rainfall Depth (inches)

Case of : 14 July 1961

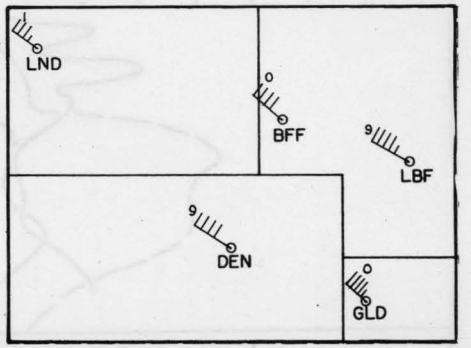
Hail Classification : Severe



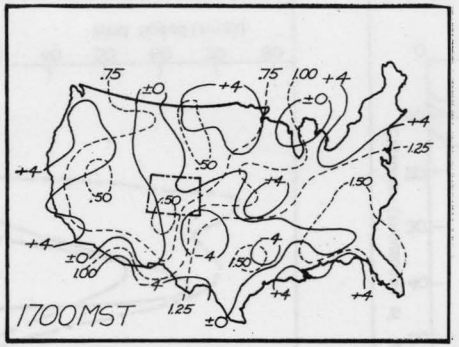
Surface Synoptic Pattern
11 AM & 11 PM MST



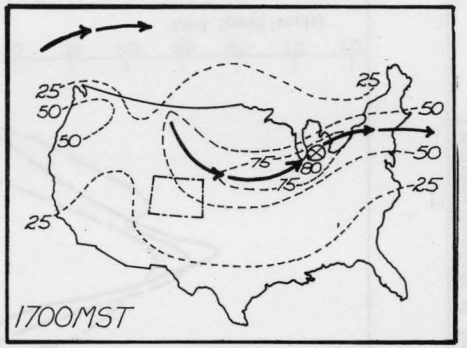
500 MB Flow
1700 MST



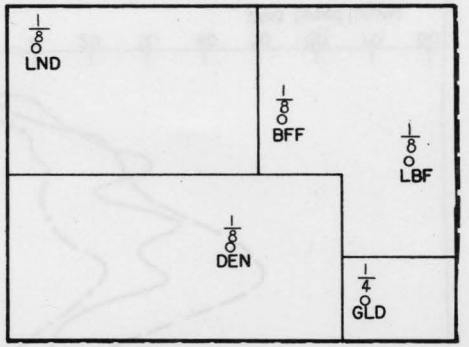
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index



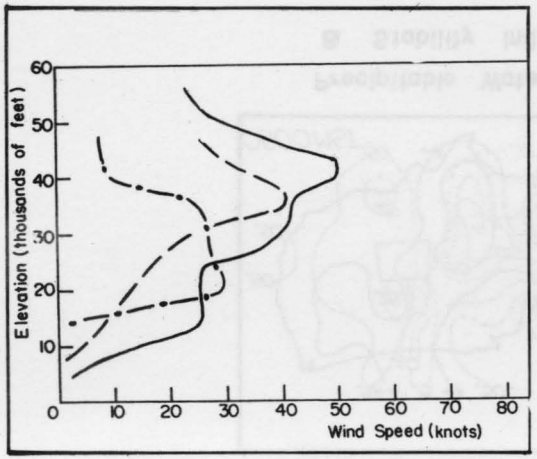
Jet Stream 50 & 100 kt. isotachs



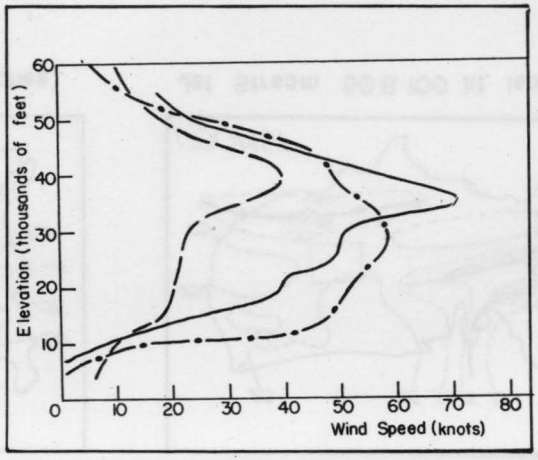
Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

Case of: 14 July 1961

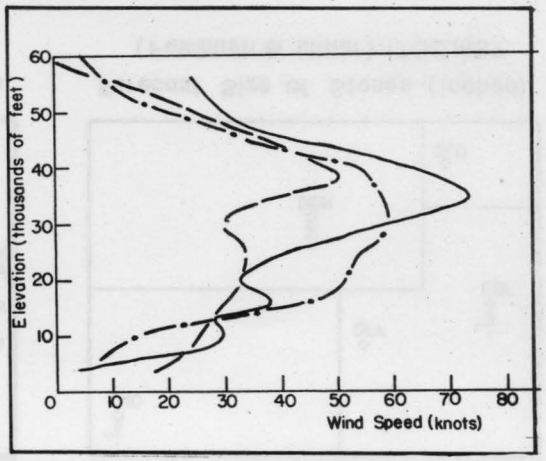
Hail Classification: Severe



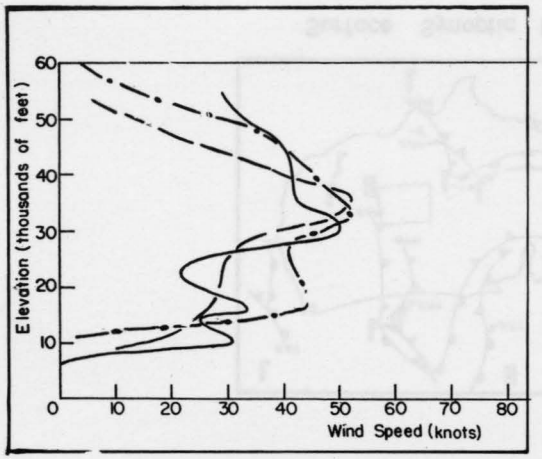
Lander



Scottsbluff



North Platte



Denver

Legend

Day before:

Day of severe hail:

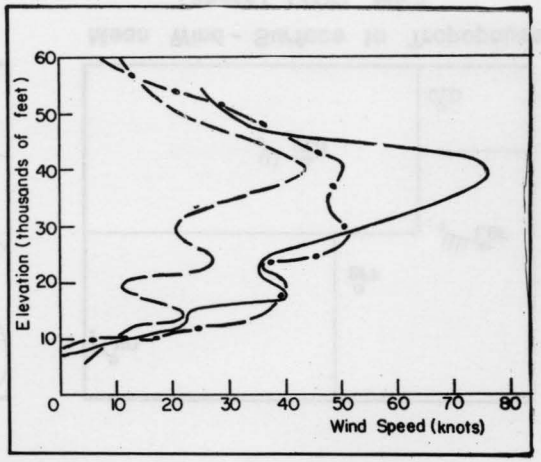
Day after:

Hail Intensity Classification

Day before: Moderate

Day of: Severe

Day after: None



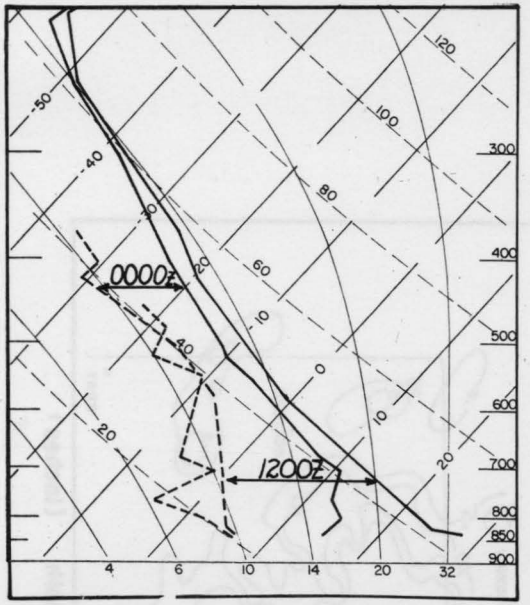
Goodland

Wind Profiles Along Mean Wind Direction

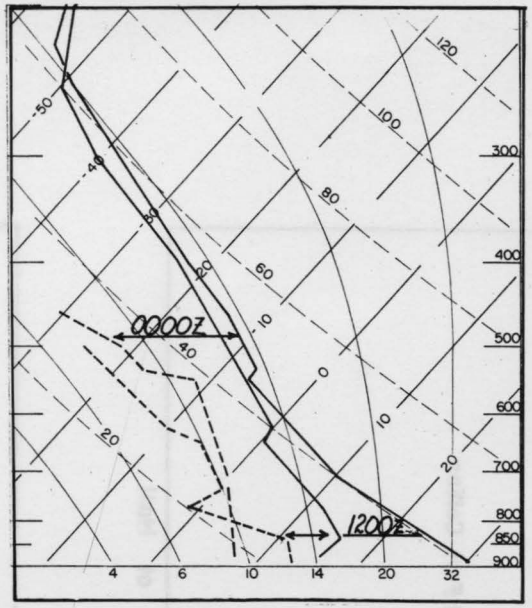
For 1700 MST

Case of: 14 July 1961

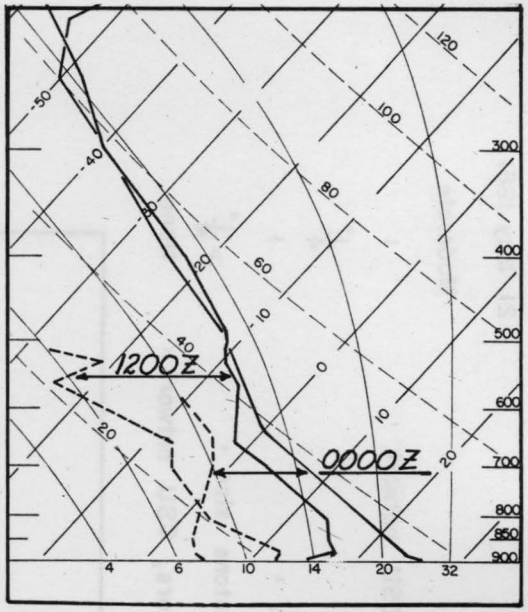
Hail Classification: Severe



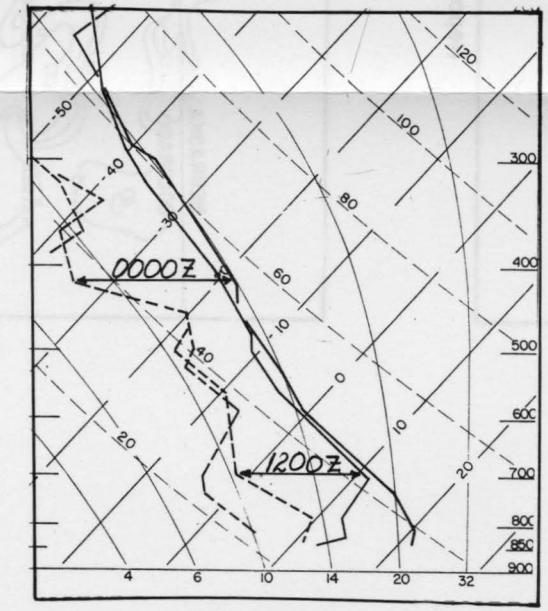
Lander



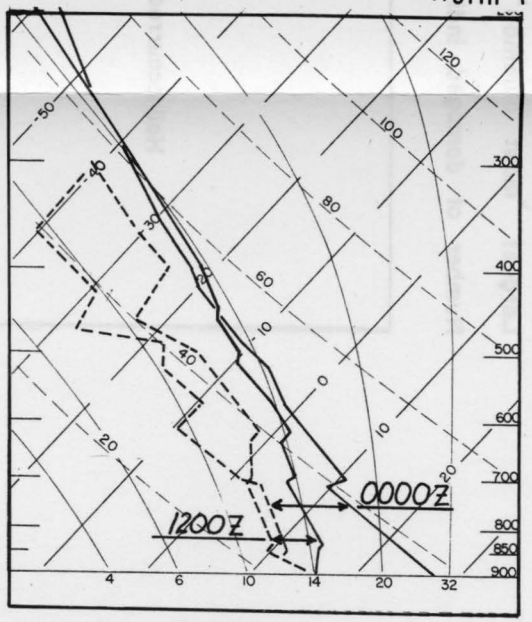
Scottsbluff



North Platte



Denver



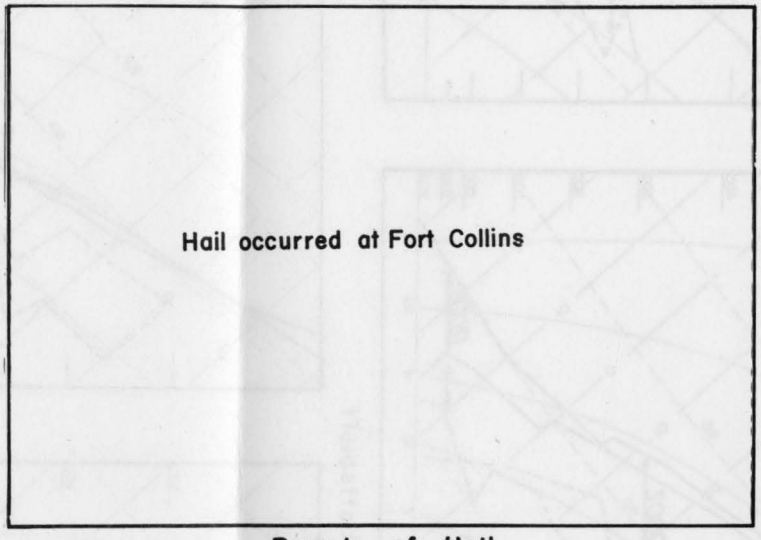
Goodland

SKEW-T Diagrams

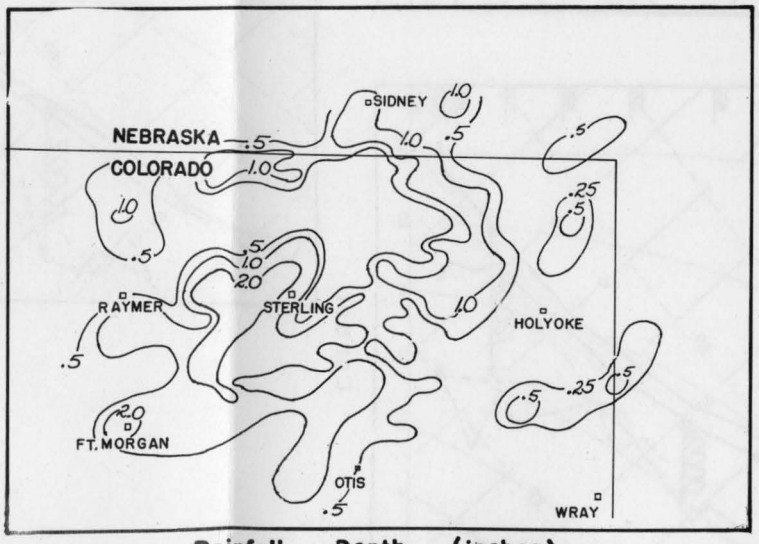
0500MST=1200Z

1700MST=0000Z

Case of :	21 May 1961
Hail classification :	Moderate
Number of reports from CSU network :	1
Max stone size :	$\frac{1}{4}$"
Max E, ft-lbs per sq ft. :	1
Largest "most common" stone size :	$> \frac{1}{4}$"
Number of damaged indicators, CSU network :	None



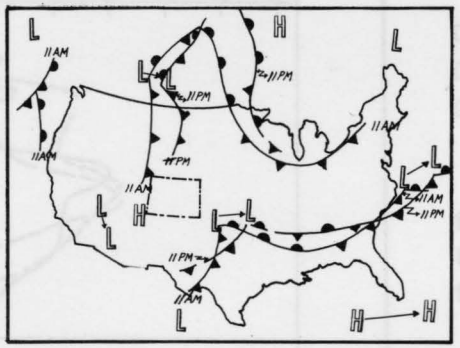
Reports of Hail



Rainfall Depth (inches)

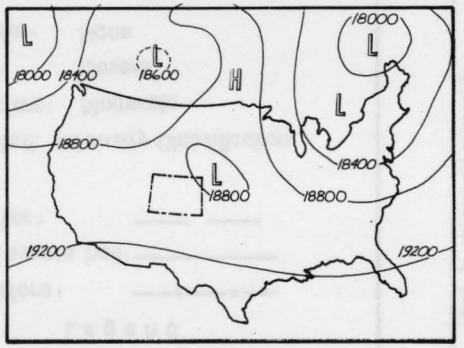
Case of : 21 May 1961

Hail Classification : Moderate



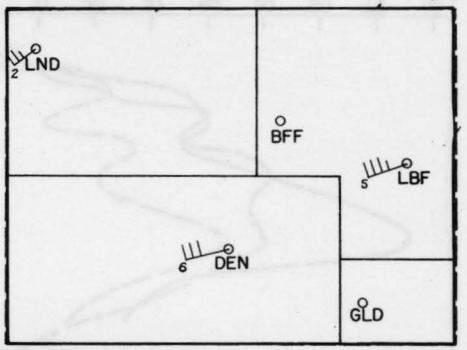
Surface Synoptic Pattern

11 AM & 11 PM MST



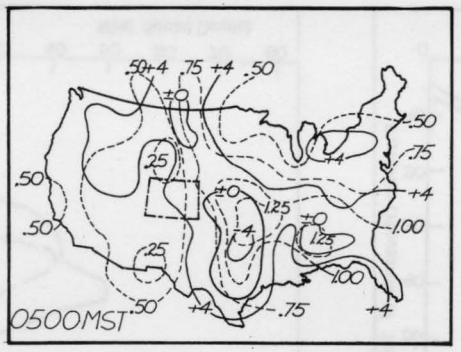
500 MB Flow

1700 MST



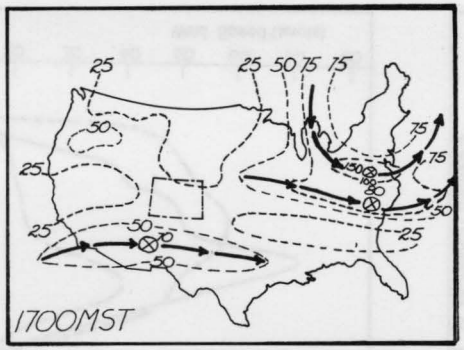
Mean Wind - Surface to Tropopause

(knots) 1700 MST

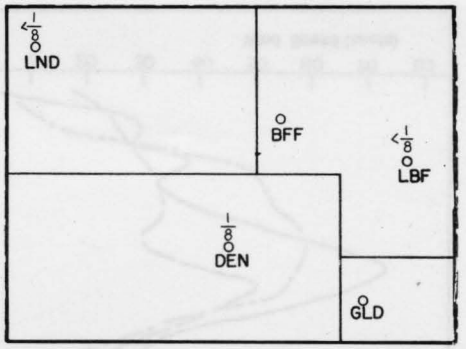


Precipitable Water (inches)

& Stability Index



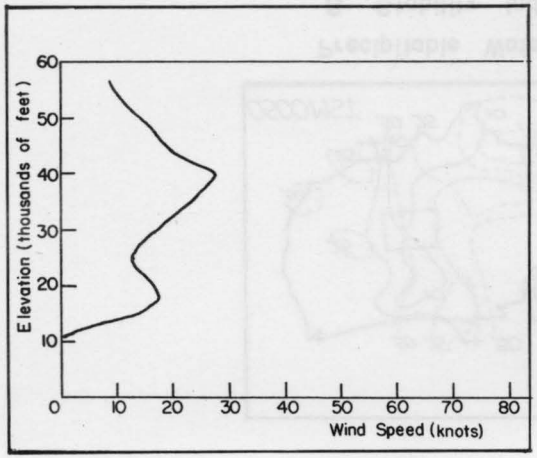
Jet Stream 50 & 100 kt. isotachs



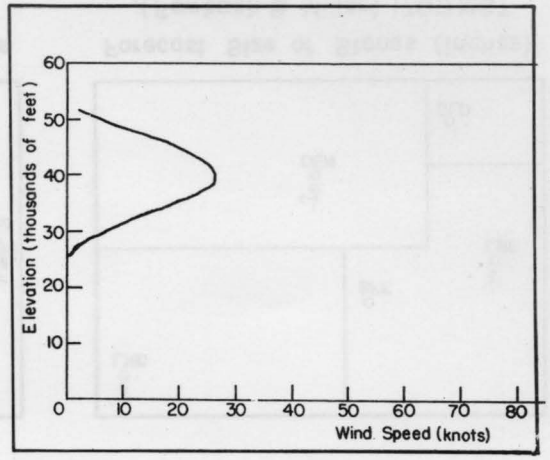
Forecast Size of Stones (inches)

(Fawbush & Miller) 1700 MST

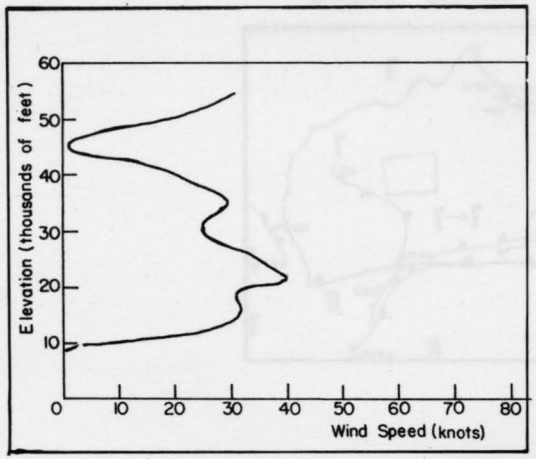
Case of: 21 May 1961
Hail Classification: Moderate



Lander



North Platte

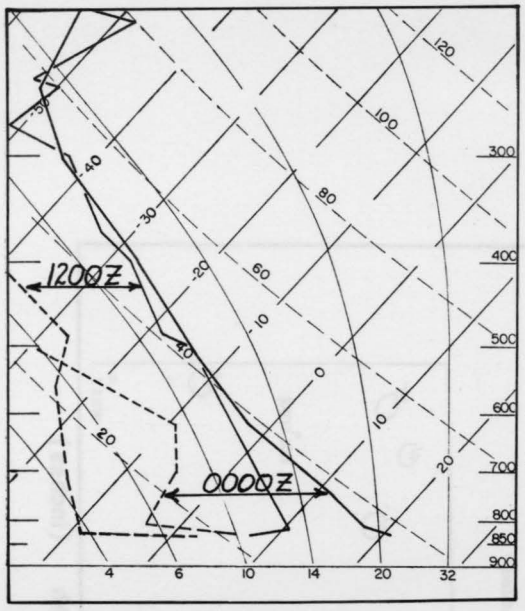


Denver

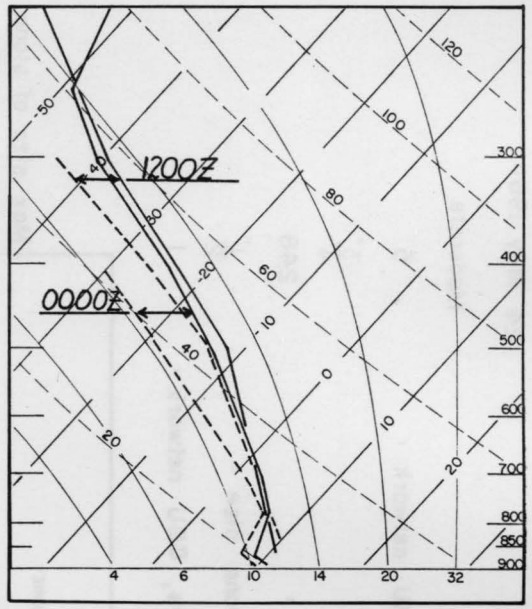
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 21 May 1961

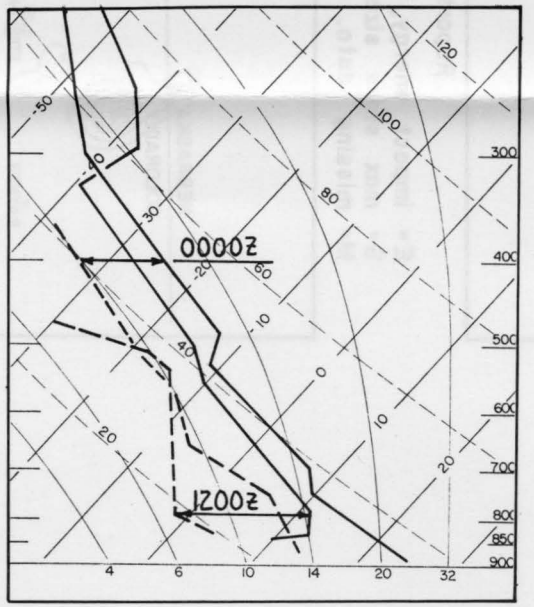
Hail Classification: Moderate



Lander



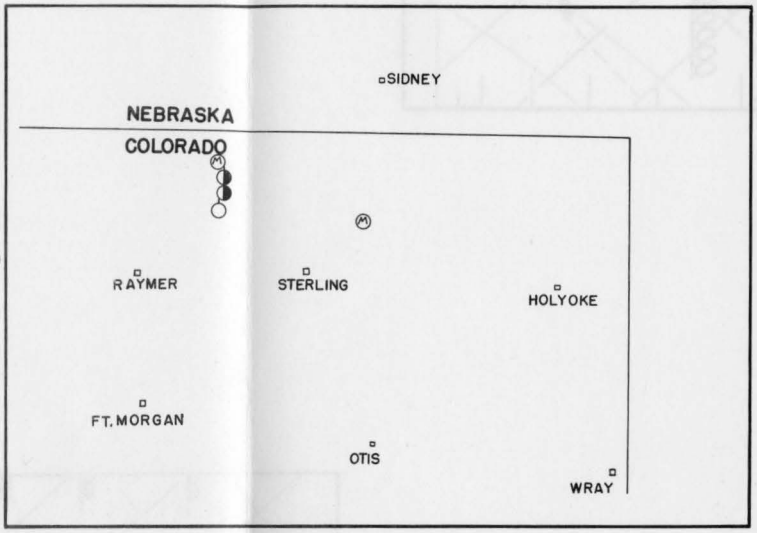
North Platte



Denver

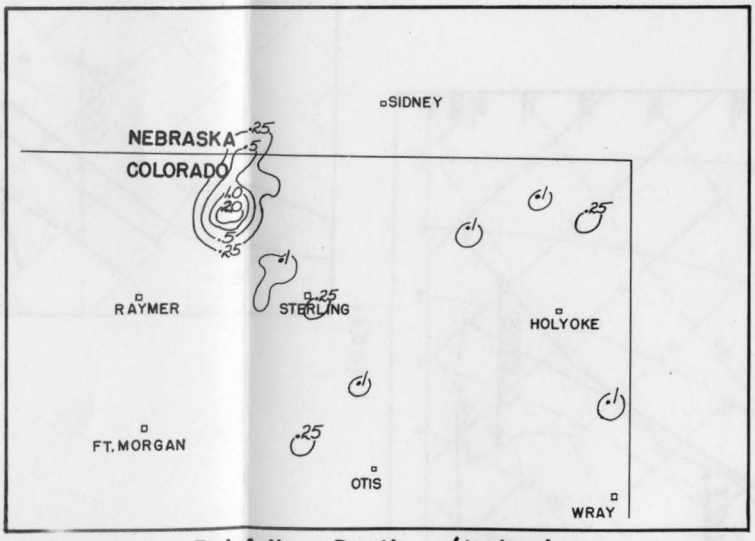
SKEW-T Diagrams
0500MST=1200Z
1700MST=0000Z

Case of :	24 May 1961
Hail classification :	Moderate
Number of reports from CSU network :	5
Max stone size :	$\frac{3}{4}$"
Max E, ft-lbs per sq ft. :	248
Largest "most common" stone size :	$\frac{1}{2}$"
Number of damaged indicators, CSU network :	1



Reports of Hail

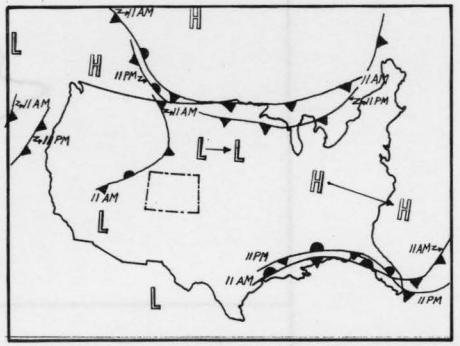
E= impact energy, ft-lbs per sq ft.
S= max stone size, inches.
M= missing data.



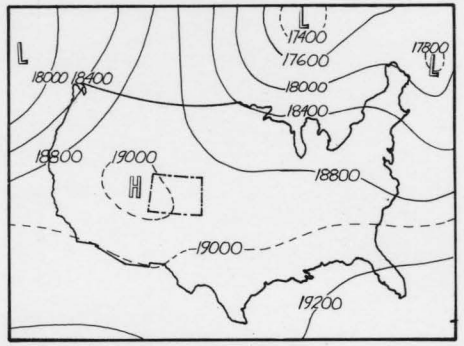
Rainfall Depth (inches)

Case of : 24 May 1961

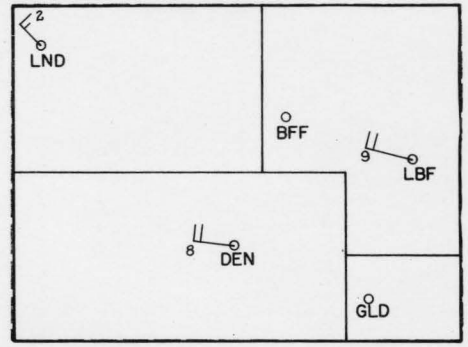
Hail Classification: Moderate



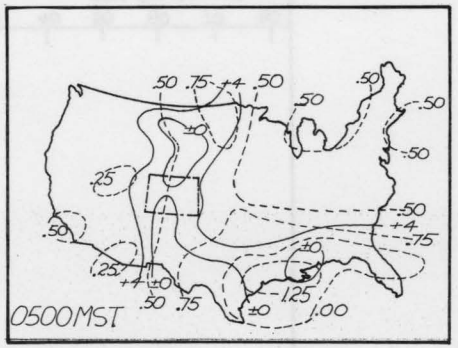
Surface Synoptic Pattern
11 AM & 11 PM MST



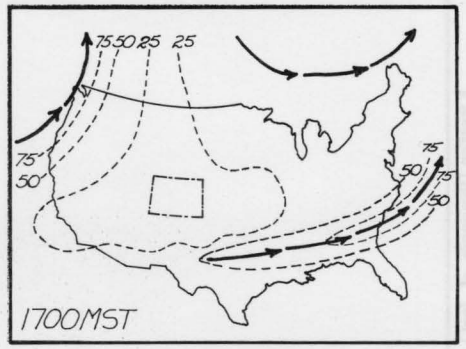
500 MB Flow
1700 MST



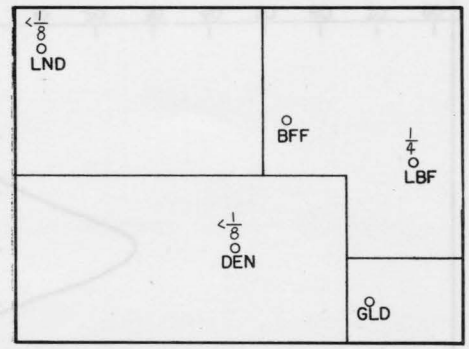
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index

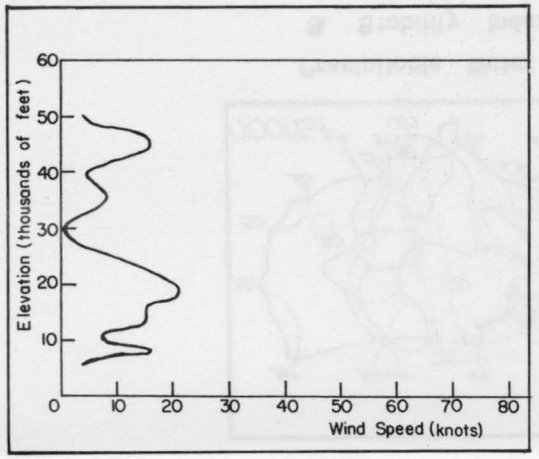


Jet Stream 50 & 100 kt. isotachs

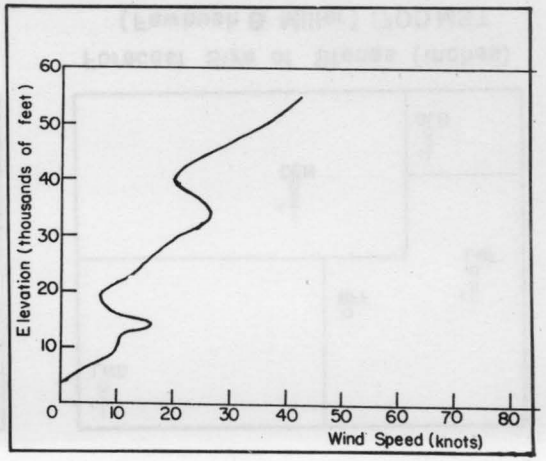


Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

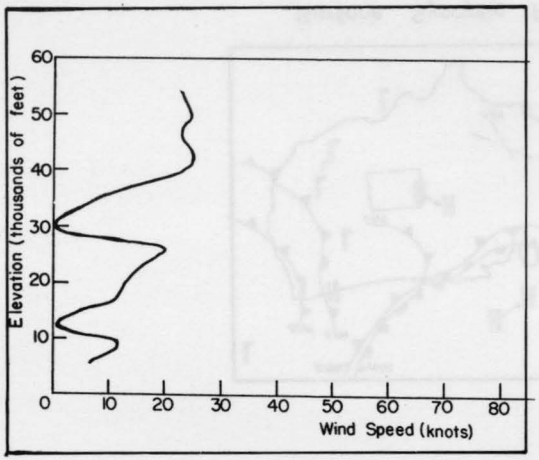
Case of: 24 May 1961
Hail Classification: Moderate



Lander



North Platte

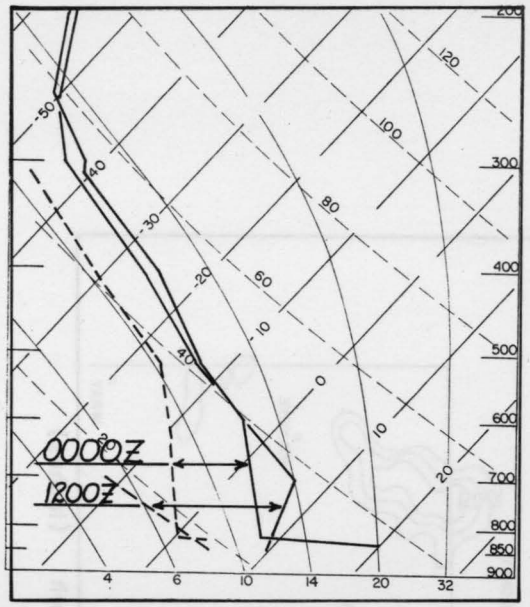


Denver

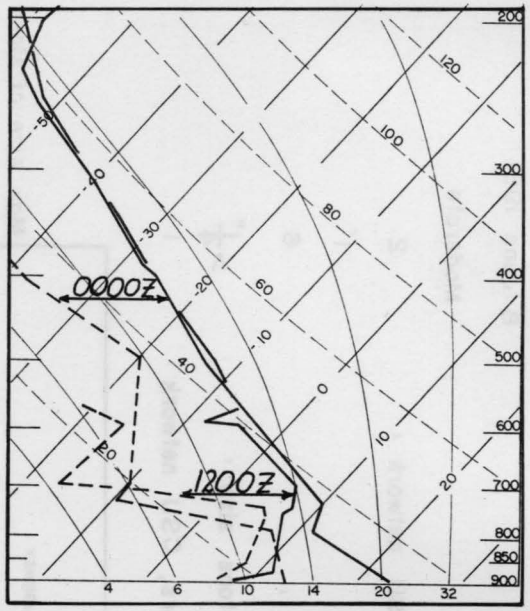
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 24 May 1961

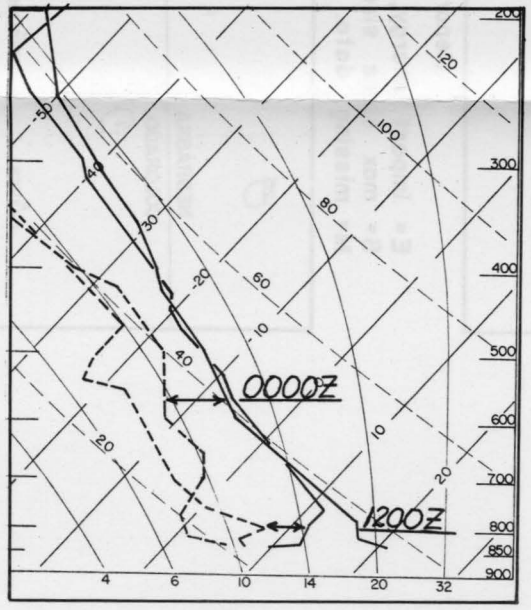
Hail Classification: Moderate



Lander



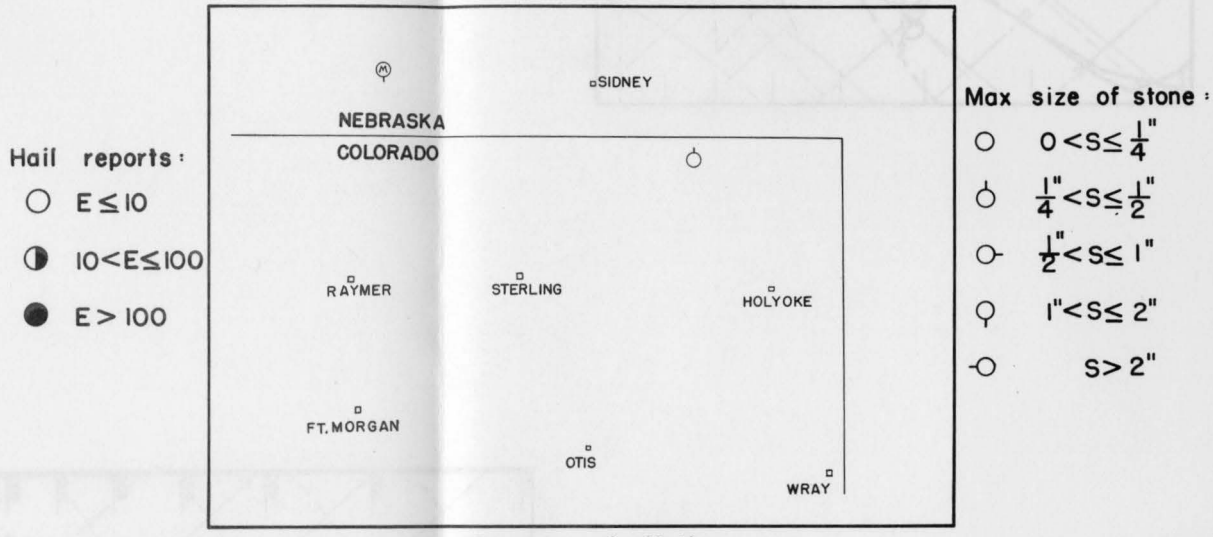
North Platte



Denver

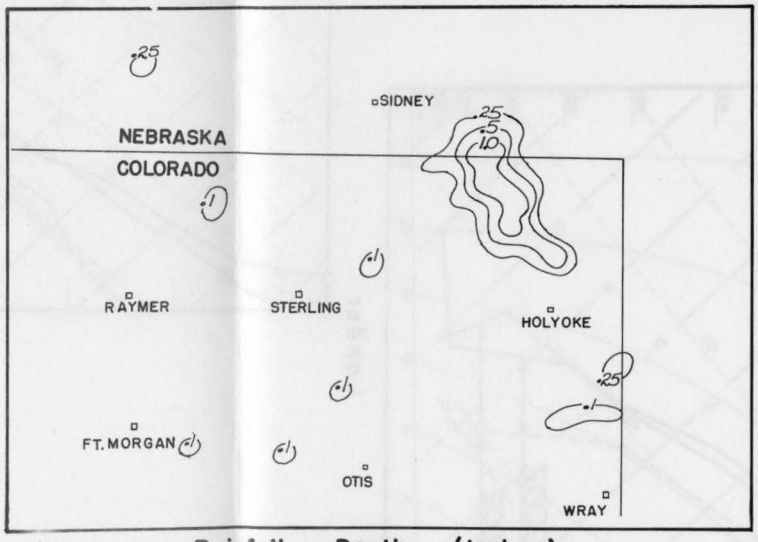
SKEW-T Diagrams
0500 MST = 1200Z
1700 MST = 0000Z

Case of :	8 June 1961
Hail classification :	Moderate
Number of reports from CSU network :	2
Max stone size :	1"
Max E, ft-lbs per sq ft. :	6
Largest "most common" stone size :	$>\frac{1}{4}$"
Number of damaged indicators, CSU network :	1



Reports of Hail

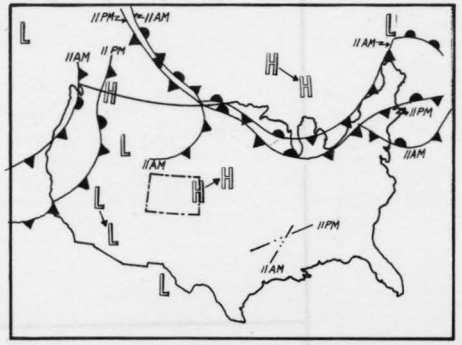
E= impact energy, ft-lbs per sq ft.
S= max stone size, inches.
M= missing data.



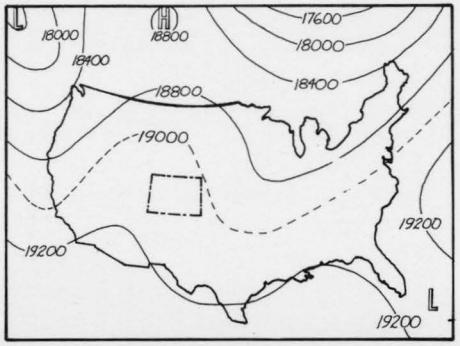
Rainfall Depth (inches)

Case of : 8 June 1961

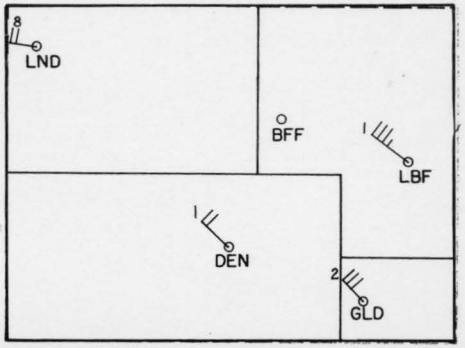
Hail Classification : Moderate



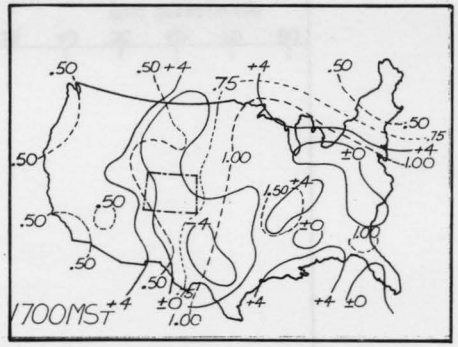
Surface Synoptic Pattern
11 AM & 11 PM MST



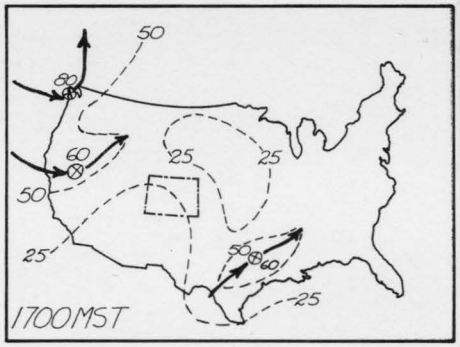
500 MB Flow
1700 MST



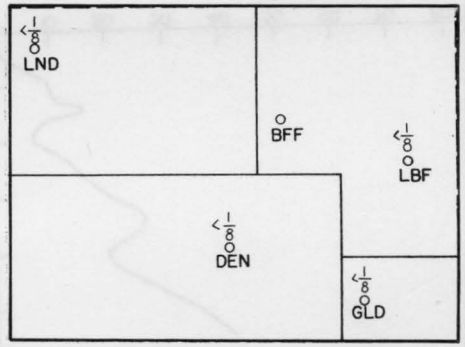
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index

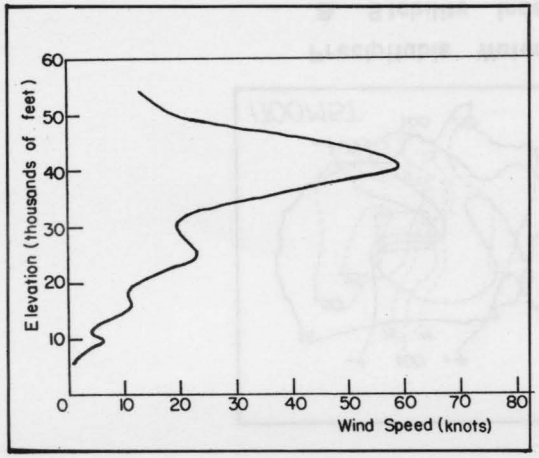


Jet Stream 50 & 100 kt. isotachs

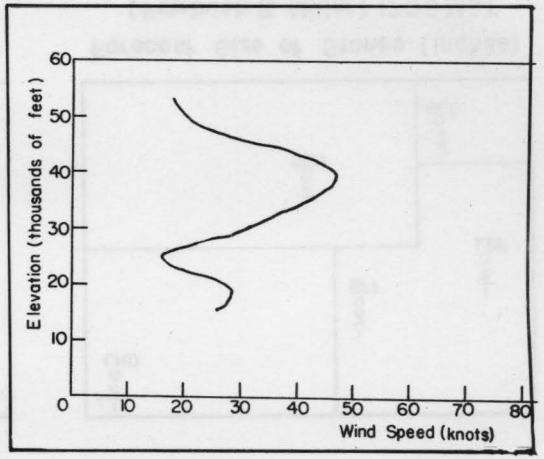


Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

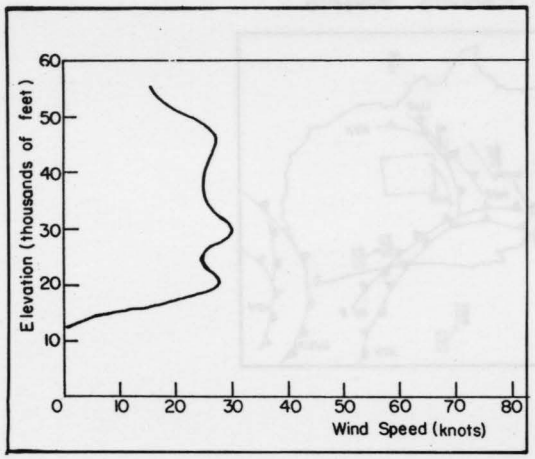
Case of: 8 June 1961
Hail Classification: Moderate



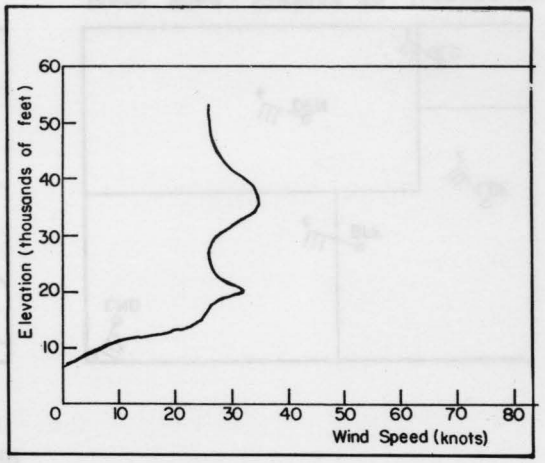
Lander



North Platte



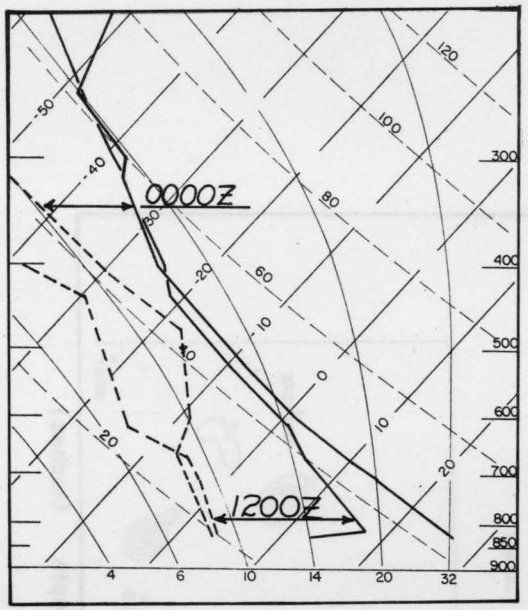
Denver



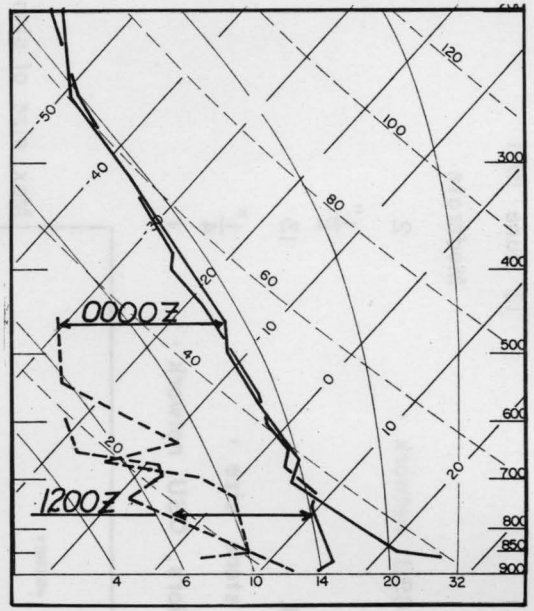
Goodland

Wind Profiles Along Mean Wind Direction
For 1700 MST

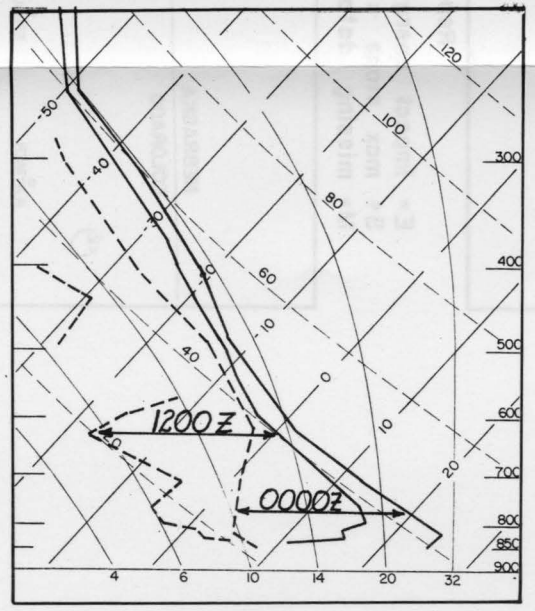
Case of: 8 June 1961
Hail Classification: Moderate



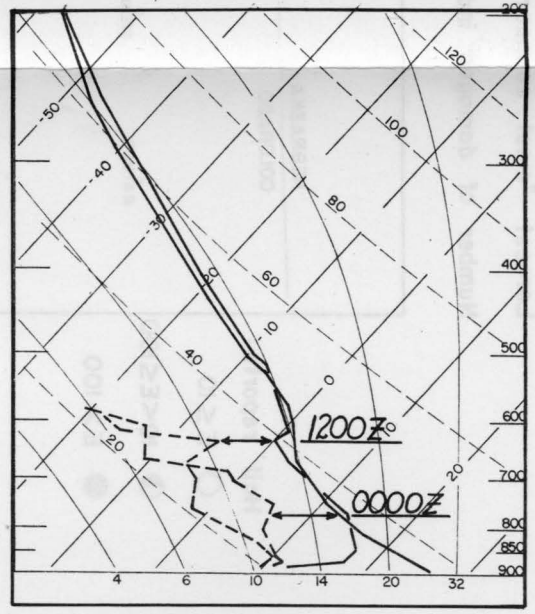
Lander



North Platte



Denver



Goodland

SKEW-T Diagrams
0500 MST = 1200Z
1700 MST = 0000Z

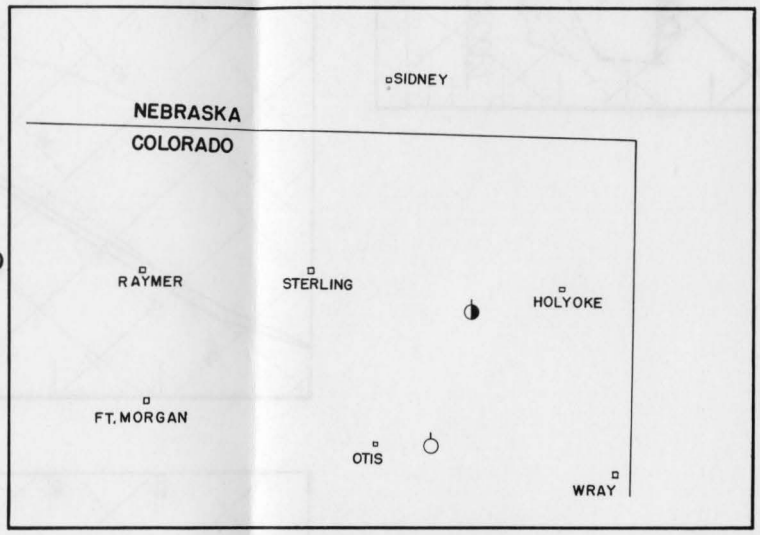
Case of :	13 June 1961
Hail classification :	Moderate
Number of reports from CSU network :	2
Max stone size :	$\frac{1}{2}$"
Max E, ft-lbs per sq ft. :	13
Largest "most common" stone size :	$\frac{1}{4}$"
Number of damaged indicators, CSU network :	1

Hail reports :

○ E ≤ 10

◑ 10 < E ≤ 100

● E > 100



Max size of stone :

○ $0 < S \leq \frac{1}{4}$"

○ $\frac{1}{4}$" $< S \leq \frac{1}{2}$"

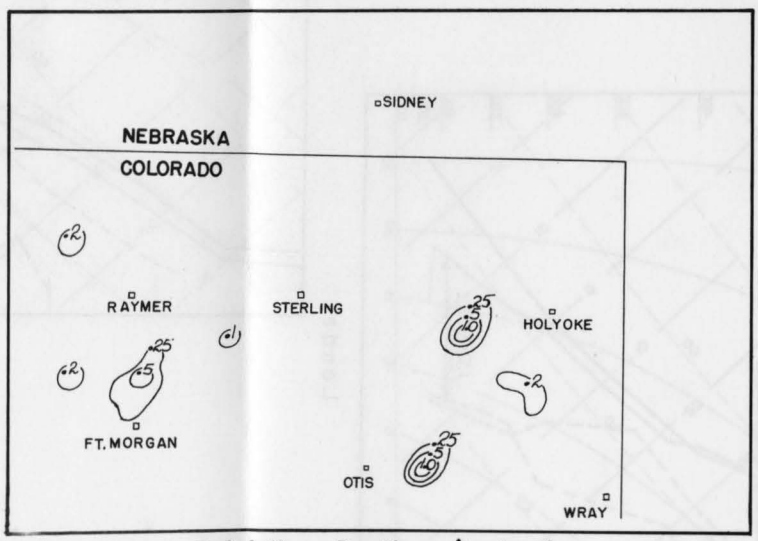
○ $\frac{1}{2}$" $< S \leq 1$"

○ $1" < S \leq 2"$

○ $S > 2"$

Reports of Hail

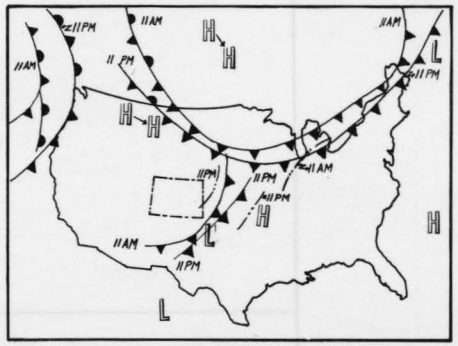
E = impact energy, ft-lbs per sq ft.
S = max stone size, inches.
M = missing data.



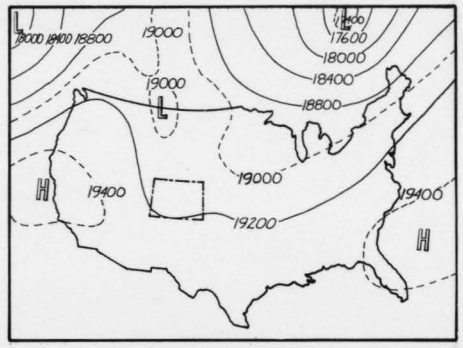
Rainfall Depth (inches)

Case of : 13 June 1961

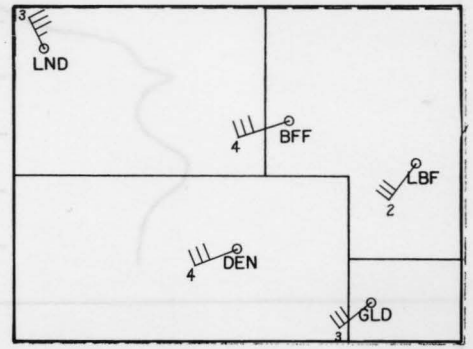
Hail Classification : Moderate



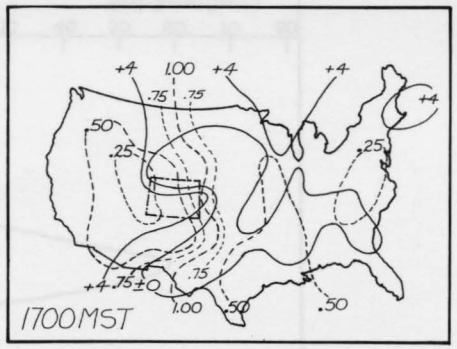
Surface Synoptic Pattern
11 AM & 11 PM MST



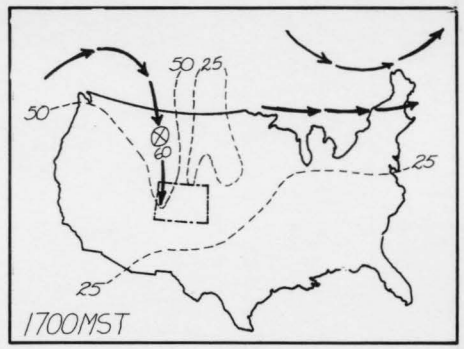
500 MB Flow
1700 MST



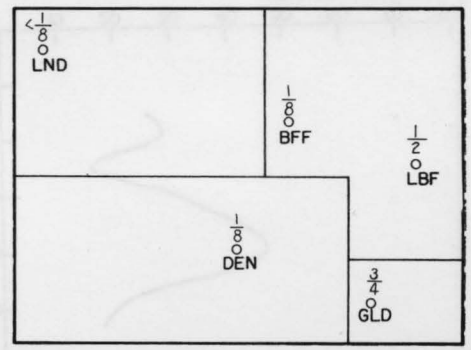
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index

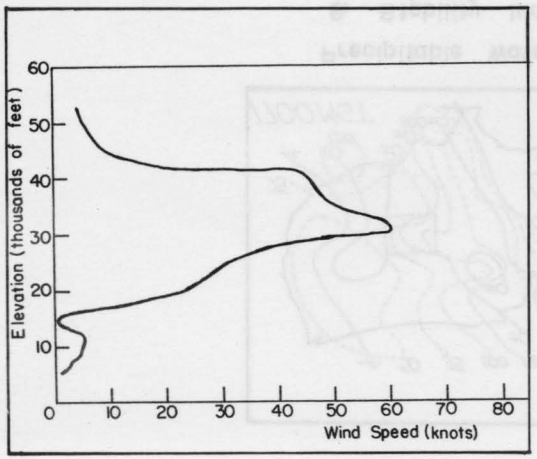


Jet Stream 50 & 100 kt. isotachs

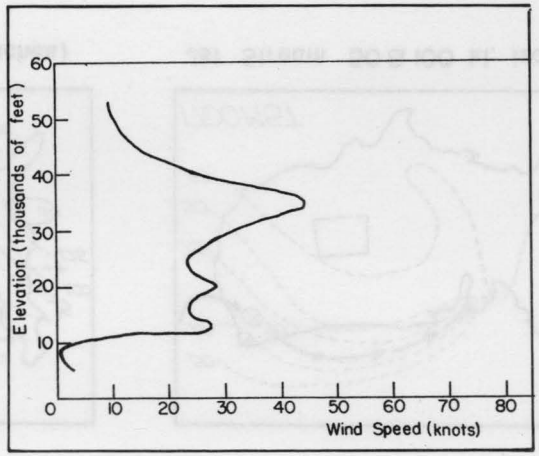


Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

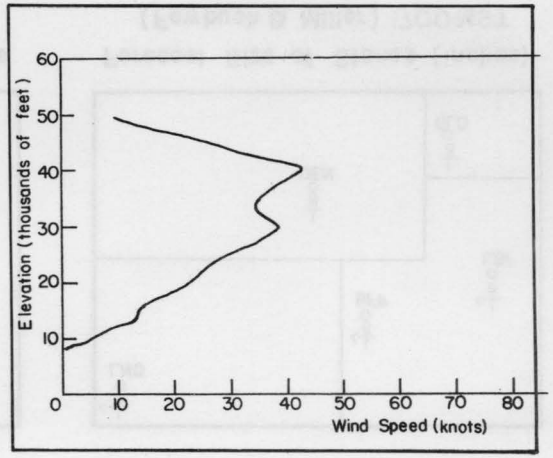
Case of: 13 June 1961
Hail Classification: Moderate



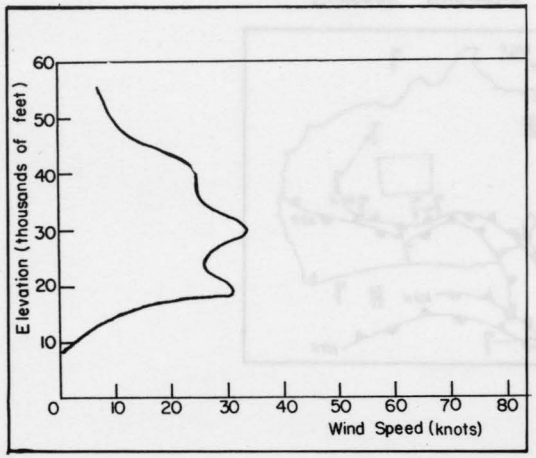
Lander



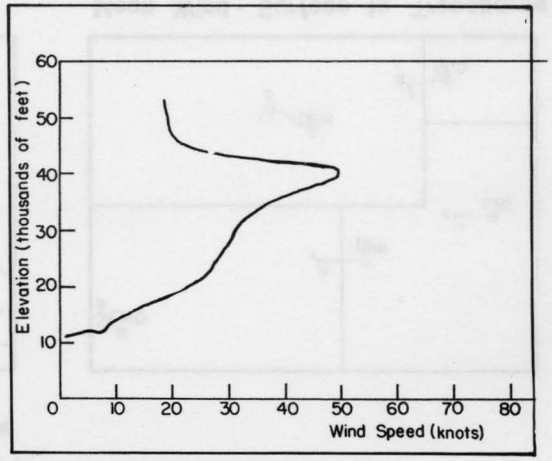
Scottsbluff



North Platte



Denver

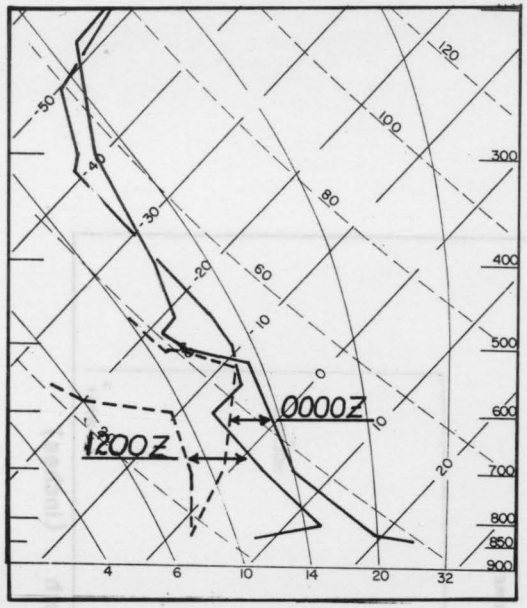


Goodland

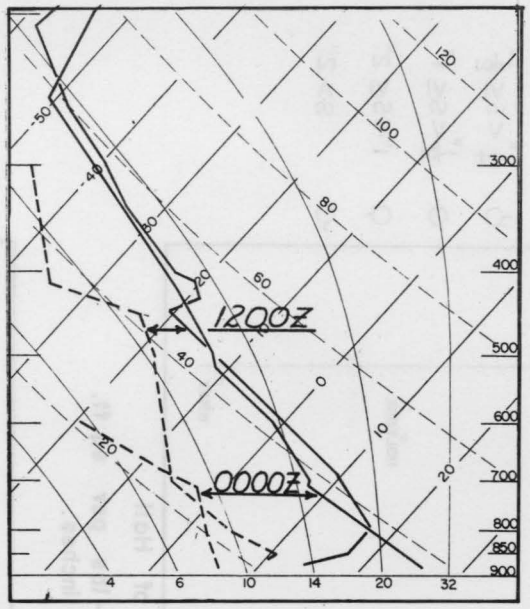
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 13 June 1961

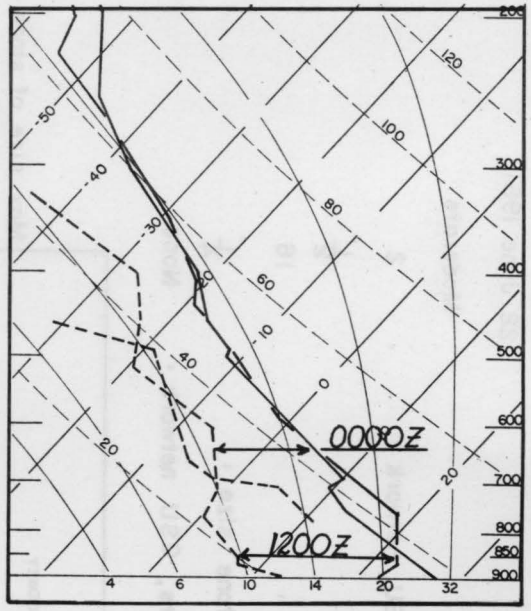
Hail Classification: Moderate



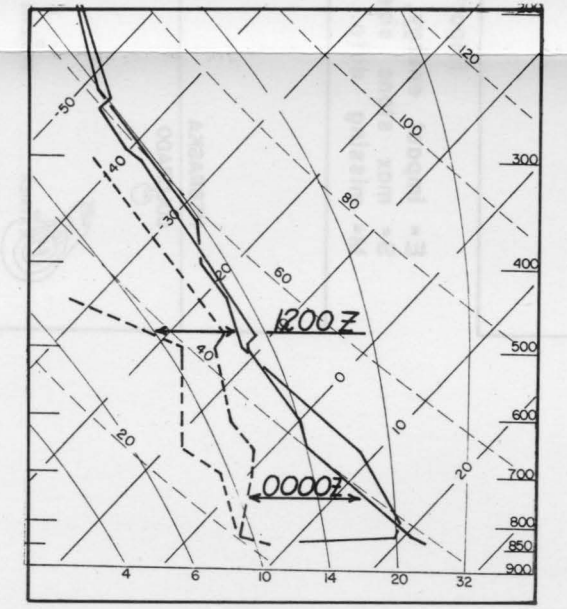
Lander



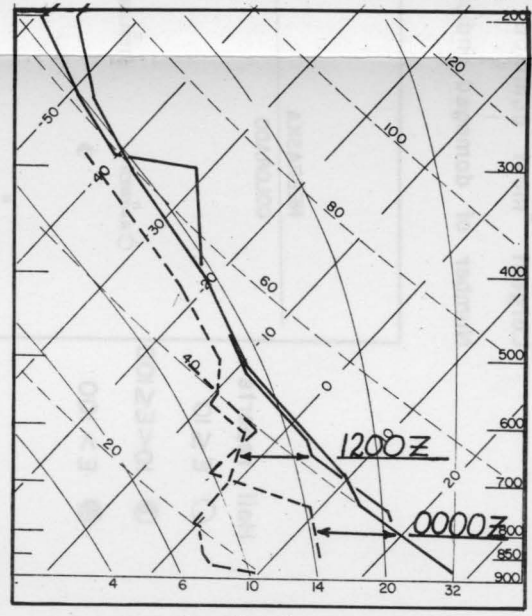
Scottsbluff



North Platte



Denver



Goodland

SKEW-T Diagrams
0500 MST = 1200Z
1700 MST = 0000Z

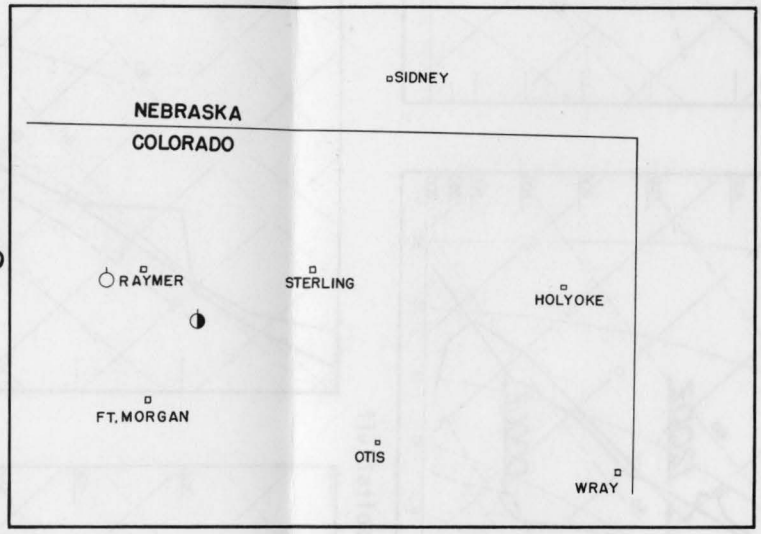
Case of :	28 June 1961
Hail classification :	Moderate
Number of reports from CSU network :	2
Max stone size :	$\frac{1}{2}$"
Max E, ft-lbs per sq ft. :	16
Largest "most common" stone size :	$\frac{1}{4}$"
Number of damaged indicators, CSU network :	None

Hail reports :

○ E ≤ 10

◑ 10 < E ≤ 100

● E > 100



Max size of stone :

○ $0 < S \leq \frac{1}{4}$"

◑ $\frac{1}{4}$" $< S \leq \frac{1}{2}$"

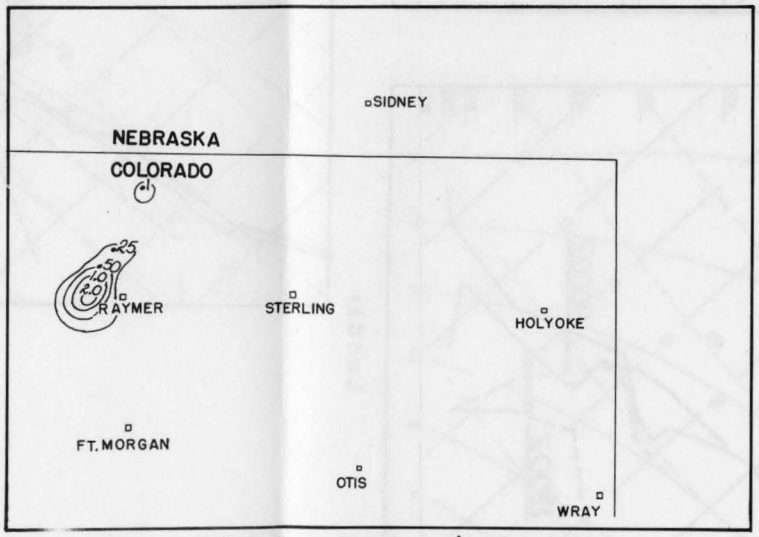
◒ $\frac{1}{2}$" $< S \leq 1$"

◓ $1" < S \leq 2"$

◒ $S > 2"$

Reports of Hail

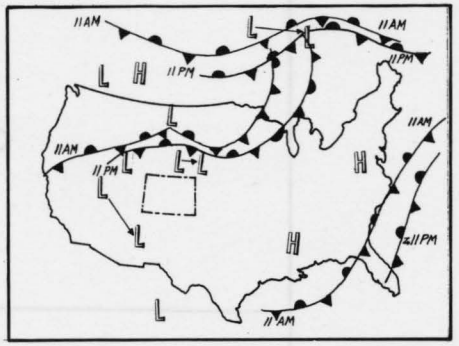
E = impact energy, ft-lbs per sq ft.
S = max stone size, inches.
M = missing data.



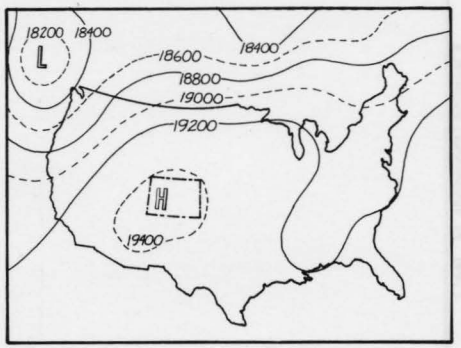
Rainfall Depth (inches)

Case of : 28 June 1961

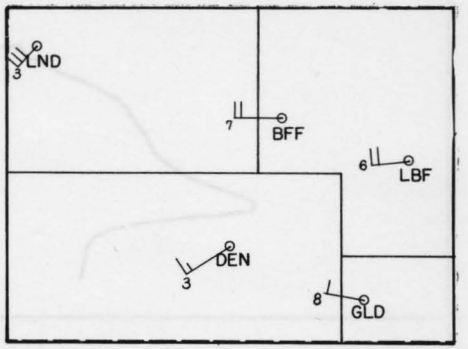
Hail Classification : Moderate



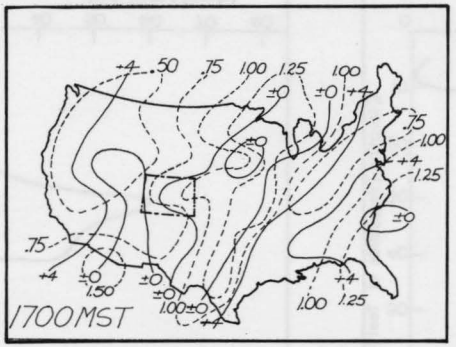
Surface Synoptic Pattern
11 AM & 11 PM MST



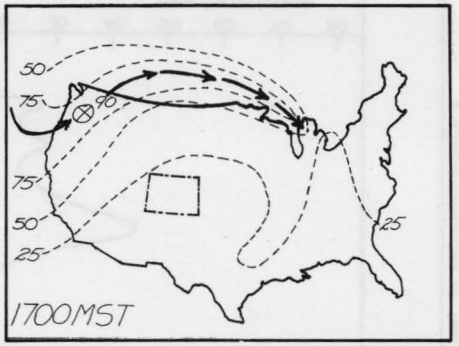
500 MB Flow
1700 MST



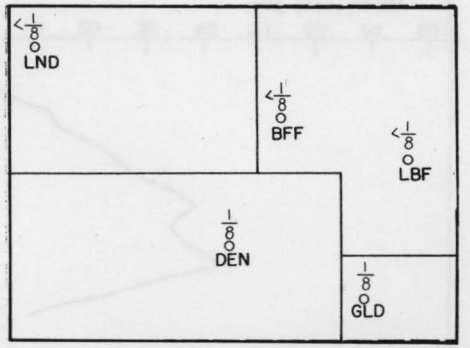
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index



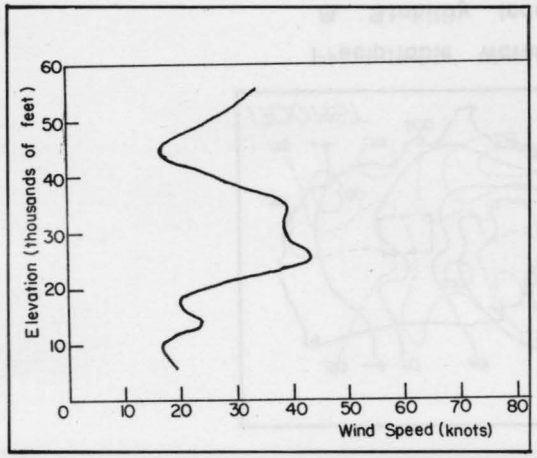
Jet Stream 50 & 100 kt. isotachs



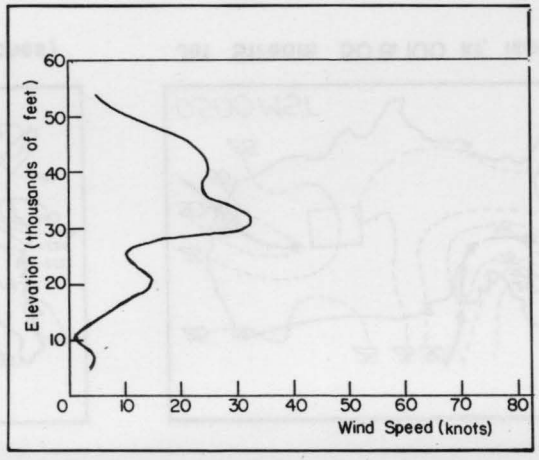
Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

Case of: 28 June 1961

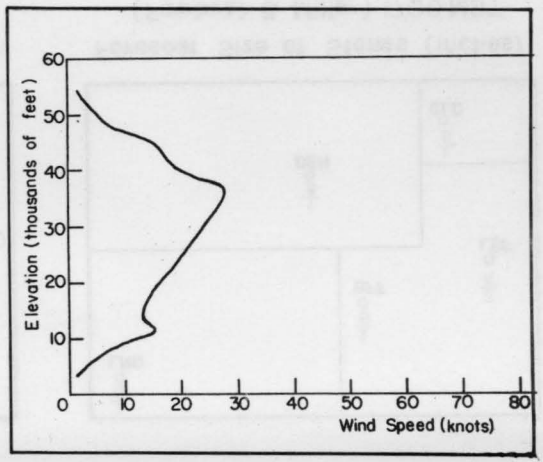
Hail Classification: Moderate



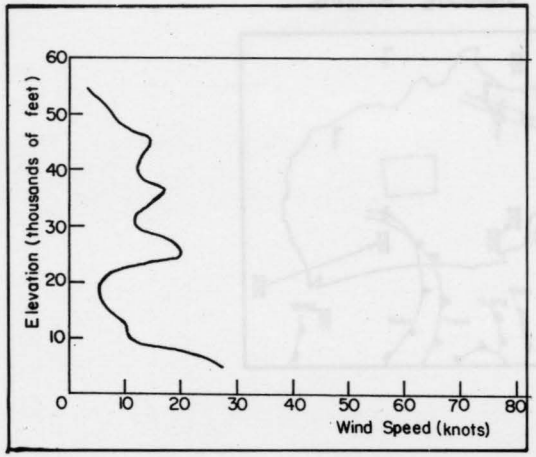
Lander



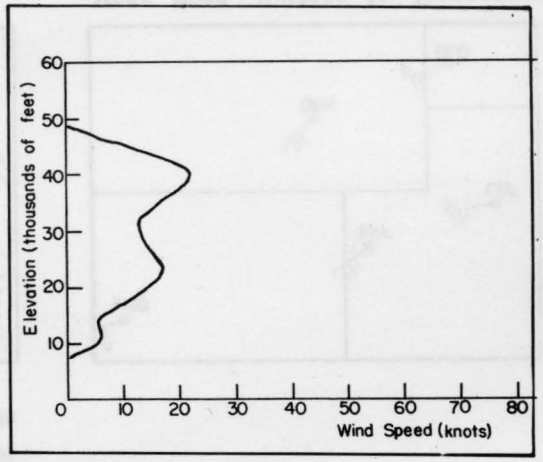
Scottsbluff



North Platte



Denver



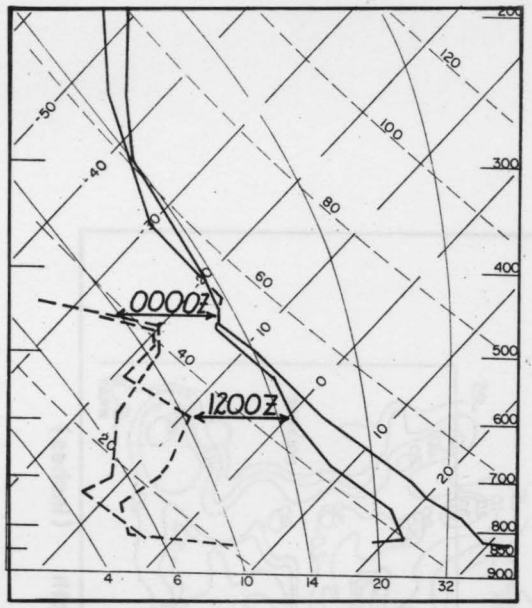
Goodland

Wind Profiles Along Mean Wind Direction

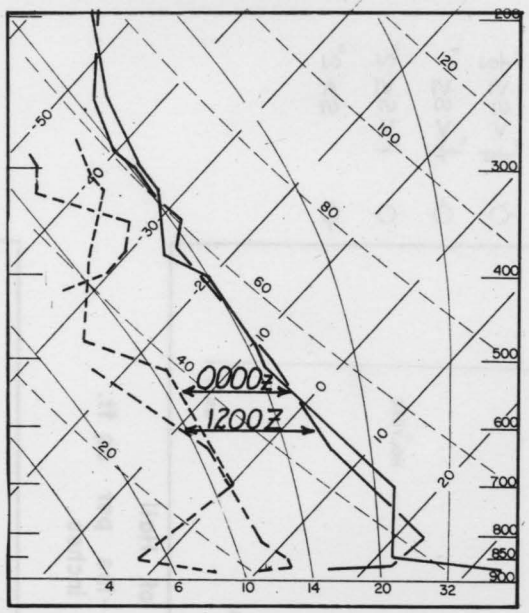
For 1700 MST

Case of: 28 June 1961

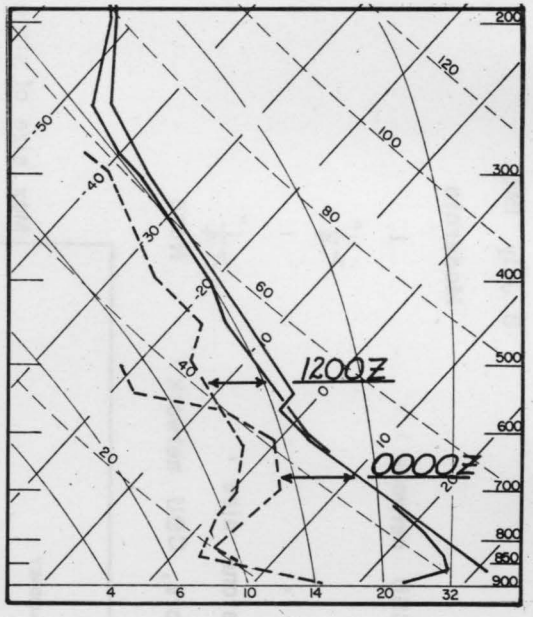
Hail Classification: Moderate



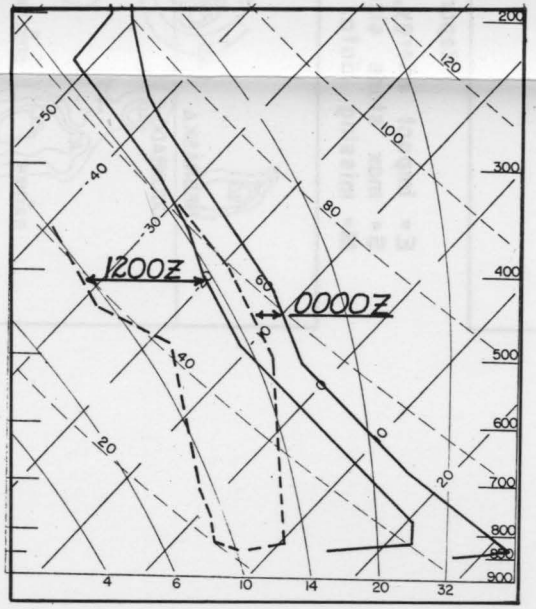
Lander



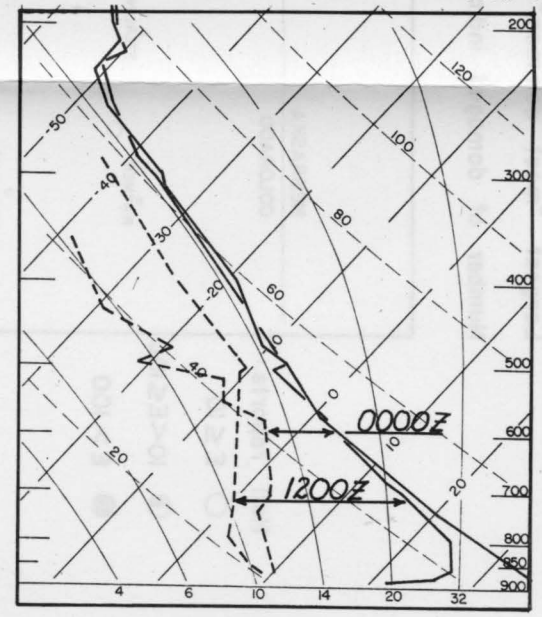
Scottsbluff



North Platte



Denver



Goodland

SKEW-T Diagrams

0500 MST = 1200Z

1700 MST = 0000Z

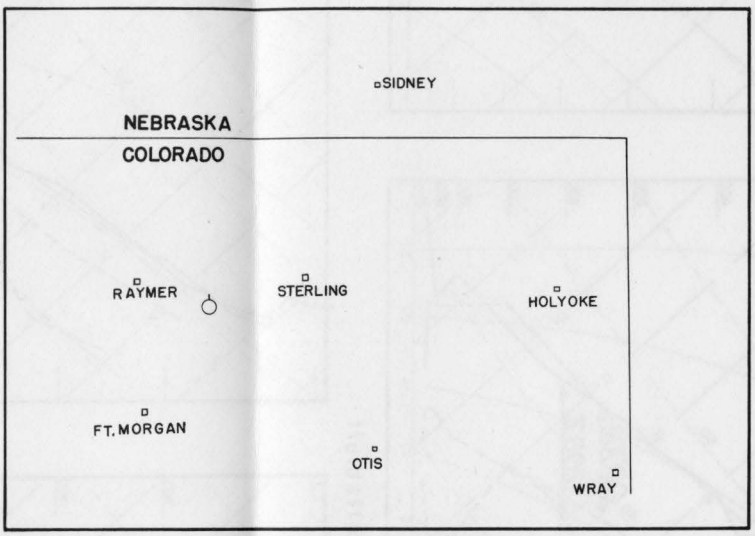
Case of :	8 July 1961
Hail classification :	Moderate
Number of reports from CSU network :	1
Max stone size :	$>\frac{1}{4}$"
Max E, ft-lbs per sq ft. :	1
Largest "most common" stone size :	$>\frac{1}{4}$"
Number of damaged indicators, CSU network :	None

Hail reports :

○ E ≤ 10

◑ 10 < E ≤ 100

● E > 100



Max size of stone :

○ $0 < S \leq \frac{1}{4}$"

$\frac{1}{4}" < S \leq \frac{1}{2}"$

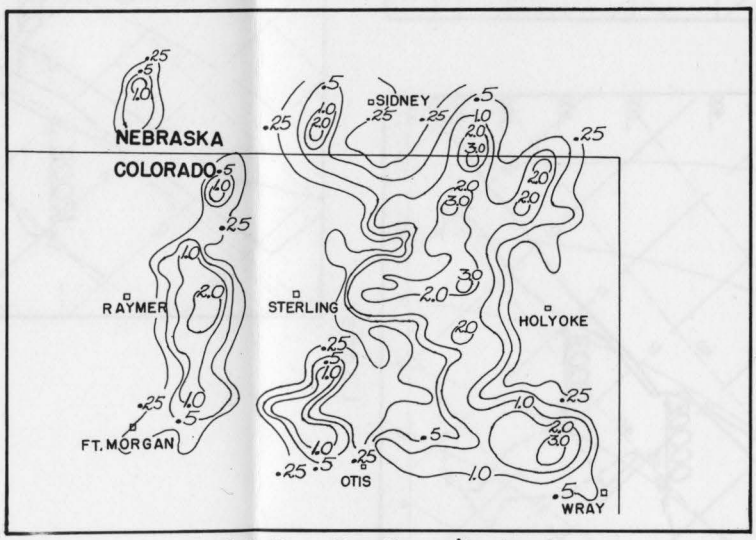
$\frac{1}{2}" < S \leq 1"$

$1" < S \leq 2"$

$S > 2"$

Reports of Hail

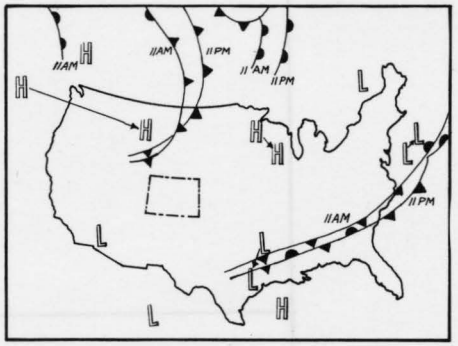
E = impact energy, ft-lbs per sq ft.
S = max stone size, inches.
M = missing data.



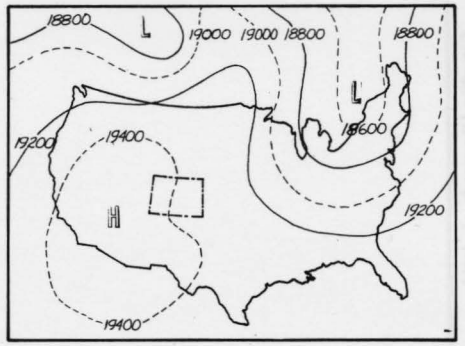
Rainfall Depth (inches)

Case of : 8 July 1961

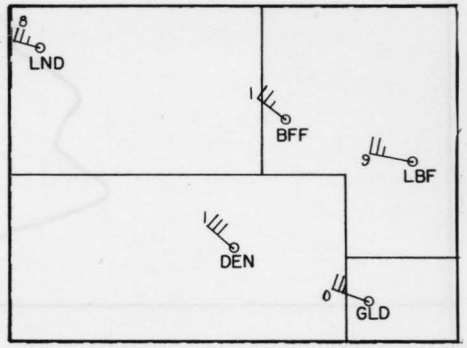
Hail Classification : Moderate



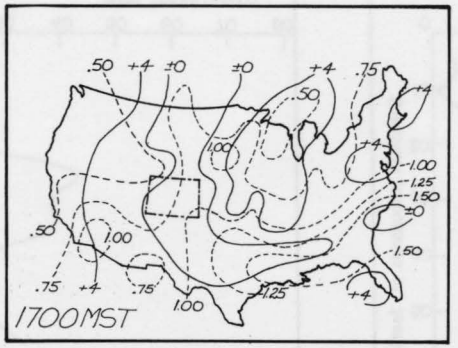
Surface Synoptic Pattern
11 AM & 11PM MST



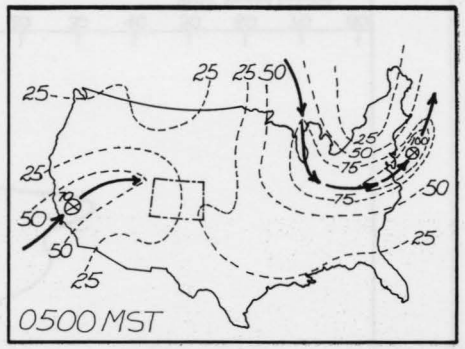
500 MB Flow
1700 MST



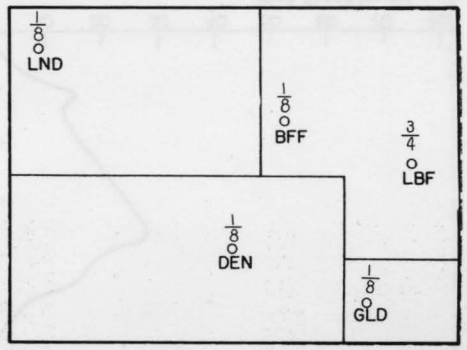
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index

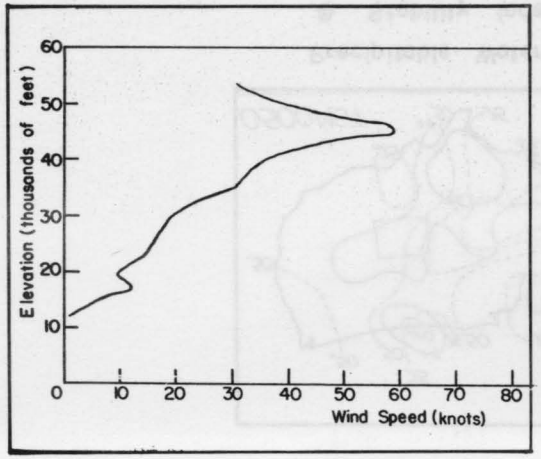


Jet Stream 50 & 100 kt. isotachs

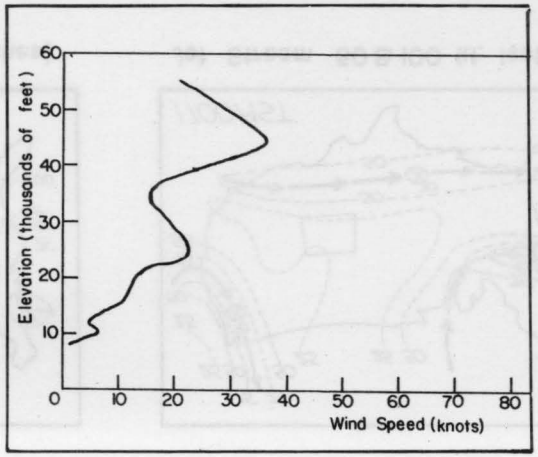


Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

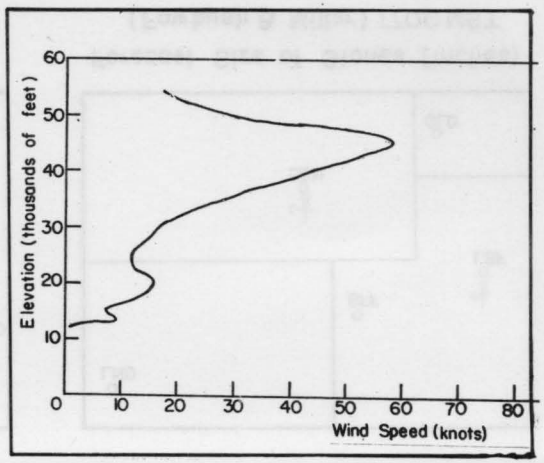
Case of: 8 July 1961
Hail Classification: Moderate



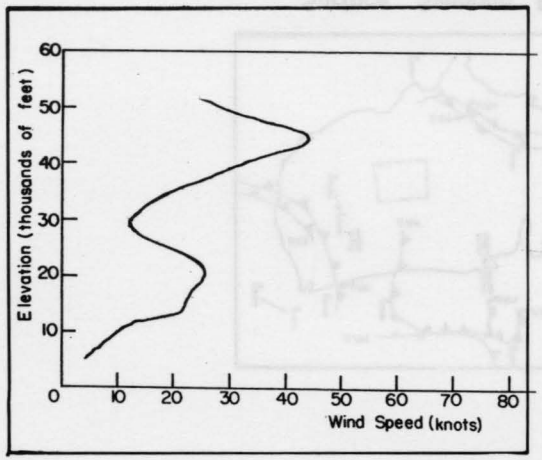
Lander



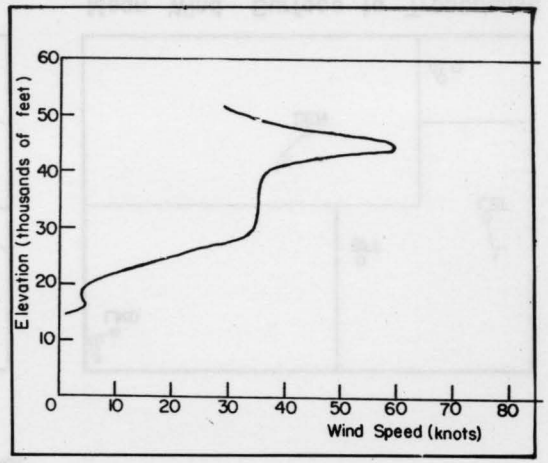
Scottsbluff



North Platte



Denver

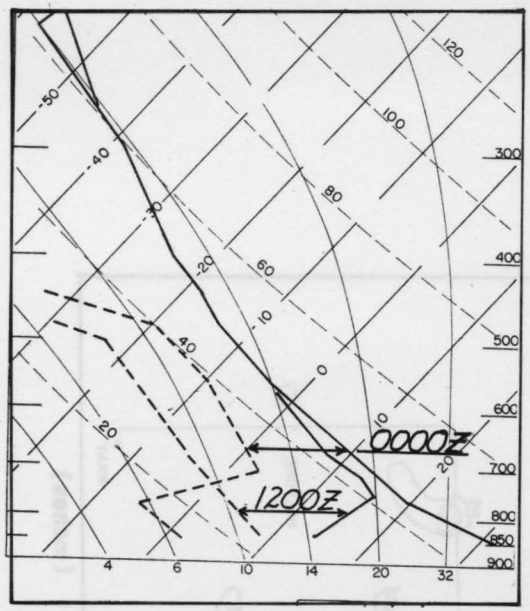


Goodland

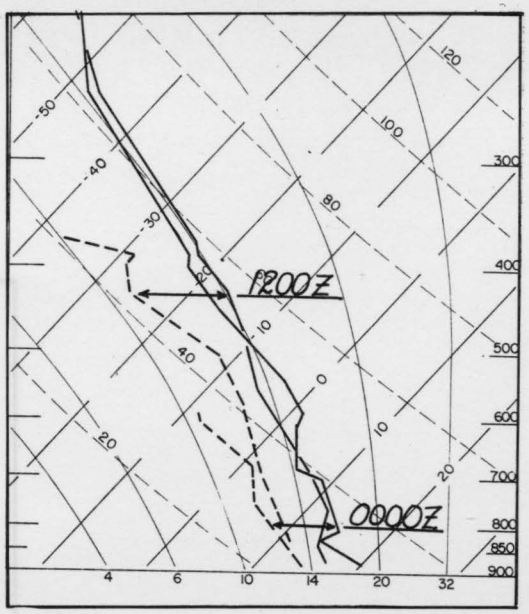
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 8 July 1961

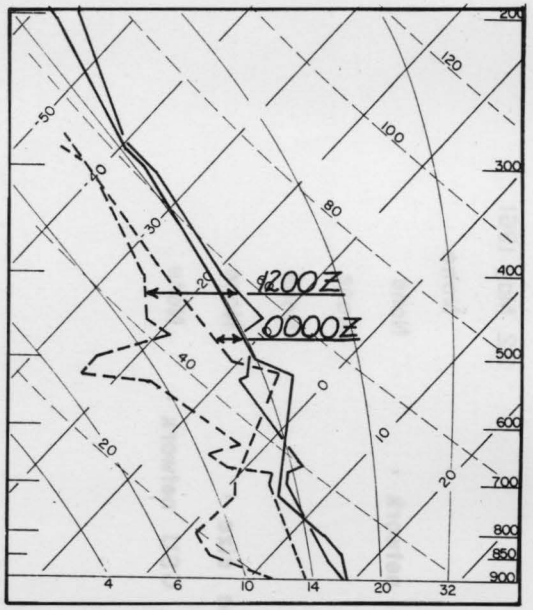
Hail Classification: Moderate



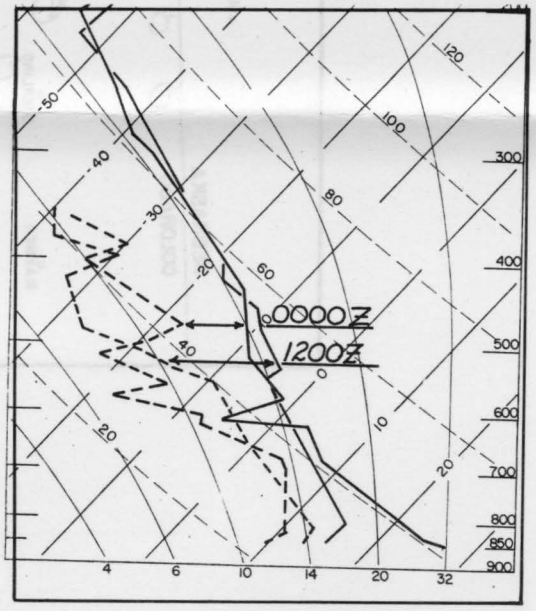
Lander



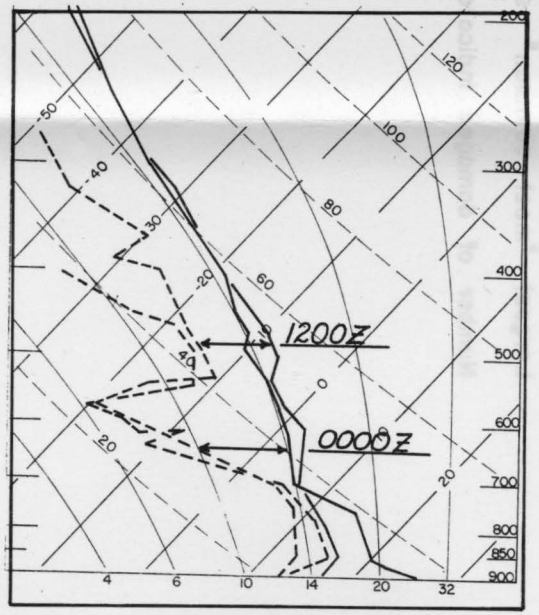
Scottsbluff



North Platte



Denver



Goodland

SKEW-T Diagrams

0500 MST = 1200Z

1700 MST = 0000Z

Case of : 22 May 1961

Hail classification : None

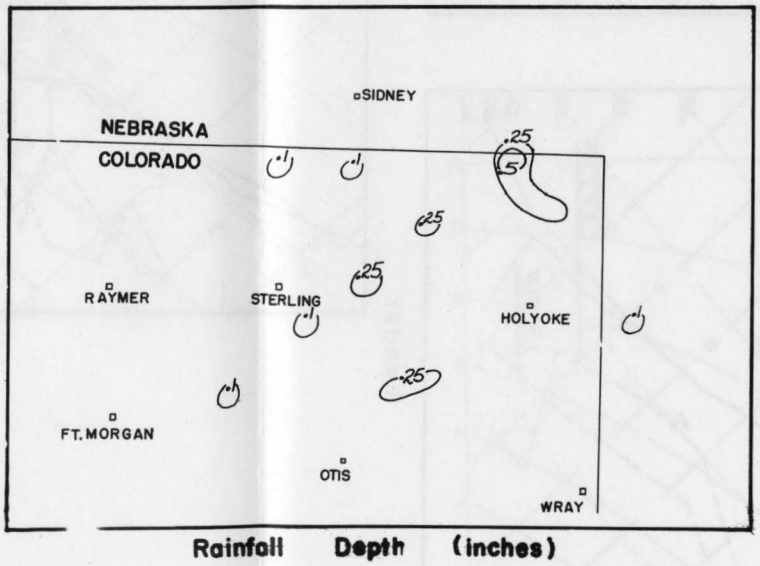
Number of reports from CSU network : None

Max stone size : None

Max E, ft-lbs per sq ft. : None

Largest "most common" stone size : None

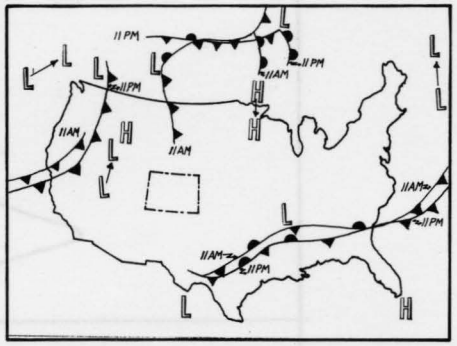
Number of damaged indicators, CSU network : None



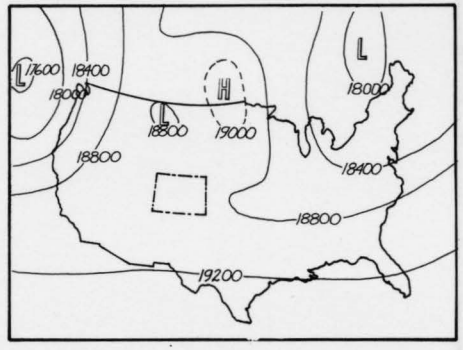
Rainfall Depth (inches)

Case of : 22 May 1961

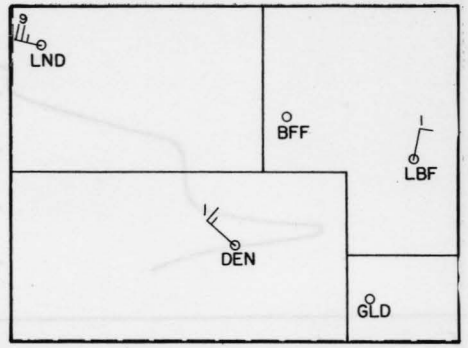
Hail Classification : None



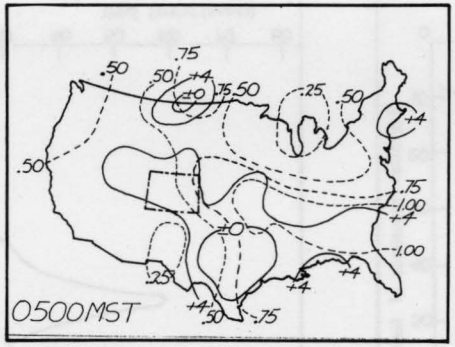
Surface Synoptic Pattern
11 AM & 11PM MST



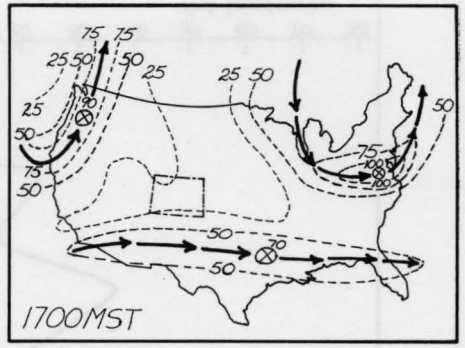
500 MB Flow
1700 MST



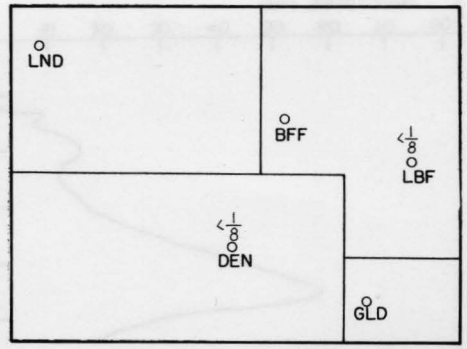
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index

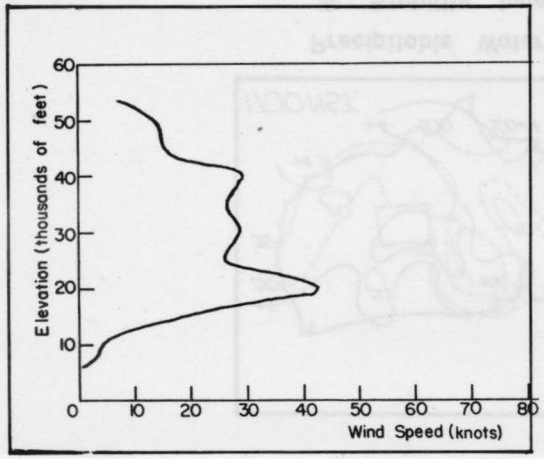


Jet Stream 50 & 100 kt. isotachs

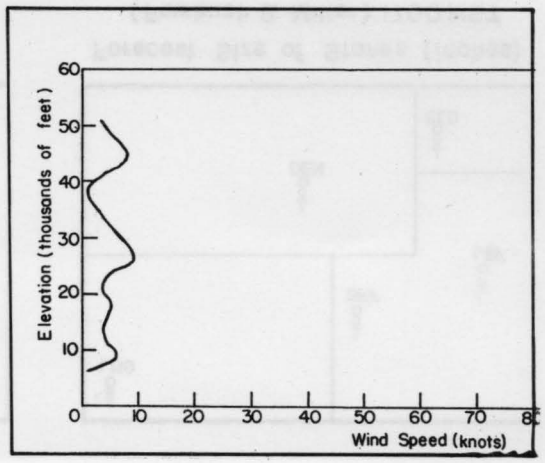


Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

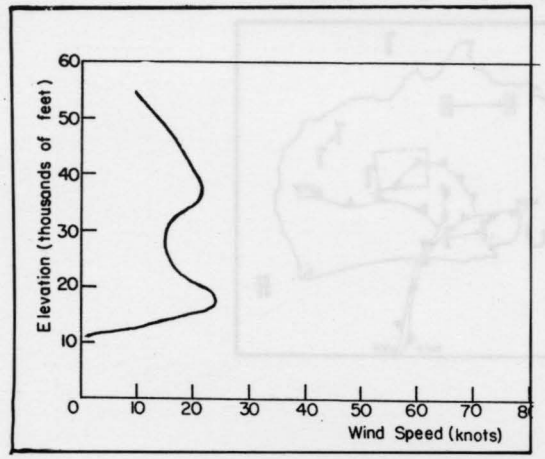
Case of: 22 May 1961
Hail Classification: None



Lander



North Platte

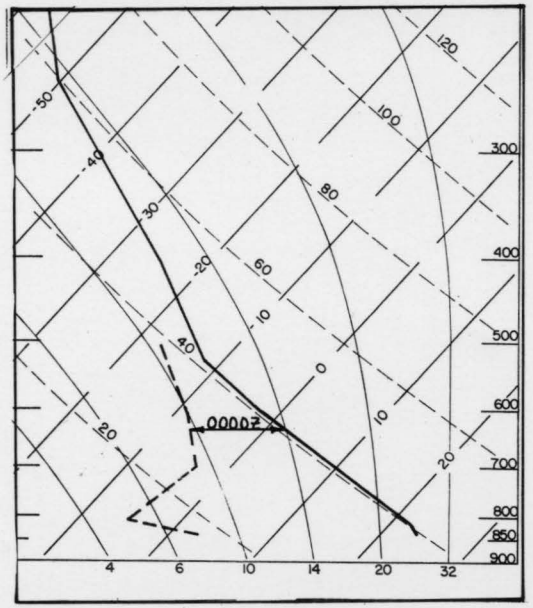


Denver

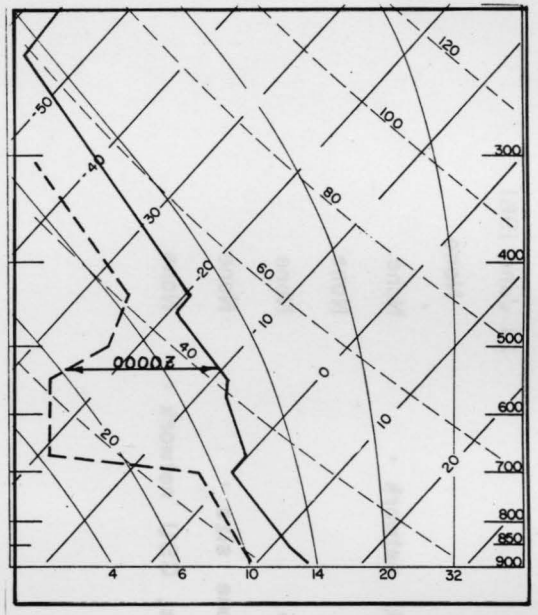
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 22 May 1961

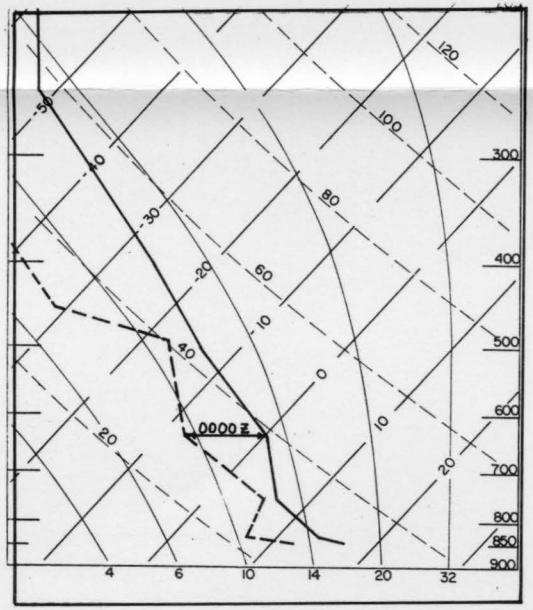
Hail Classification: None



Lander



North Platte



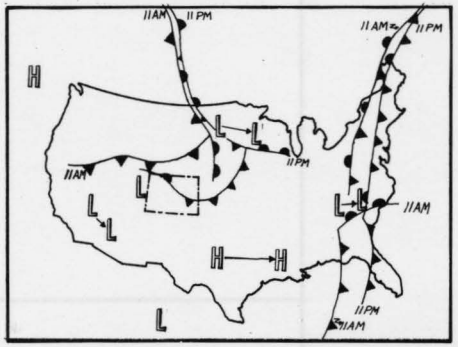
Denver

SKEW-T Diagrams
0500 MST = 1200Z
1700 MST = 0000Z

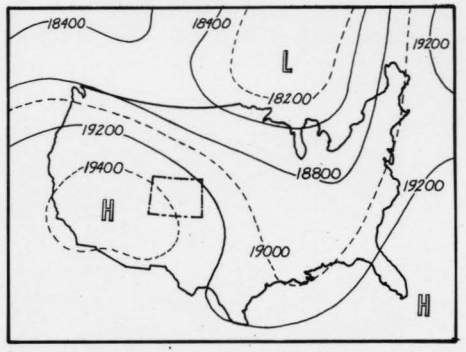
Case of :	21 June 1961
Hail classification :	None
Number of reports from CSU network :	None
Max stone size :	None
Max E, ft-lbs per sq ft. :	None
Largest "most common" stone size :	None
Number of damaged indicators, CSU network :	None

Case of : . 21 June 1961

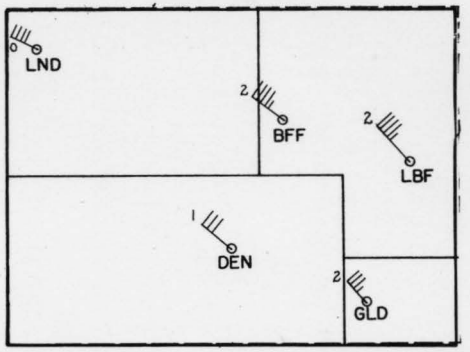
Hail Classification: None



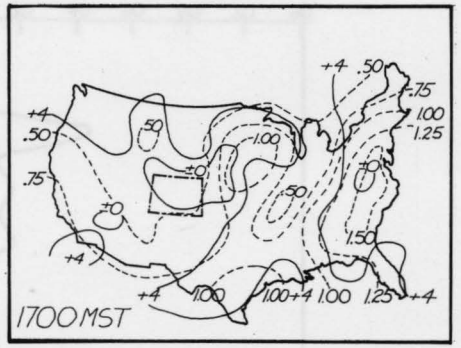
Surface Synoptic Pattern
11 AM & 11PM MST



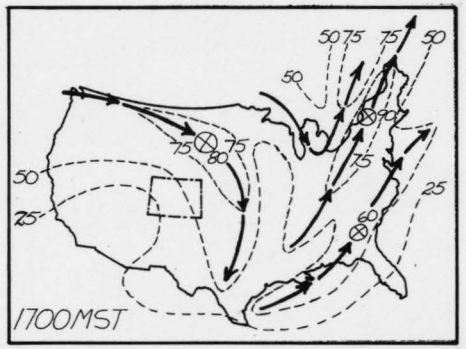
500 MB Flow
1700 MST



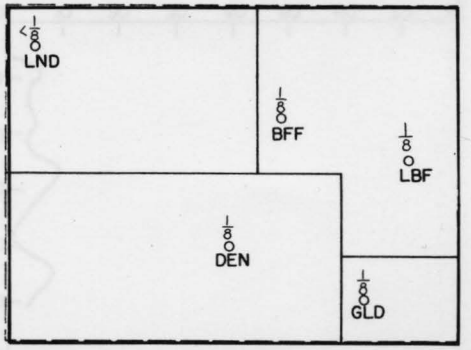
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index



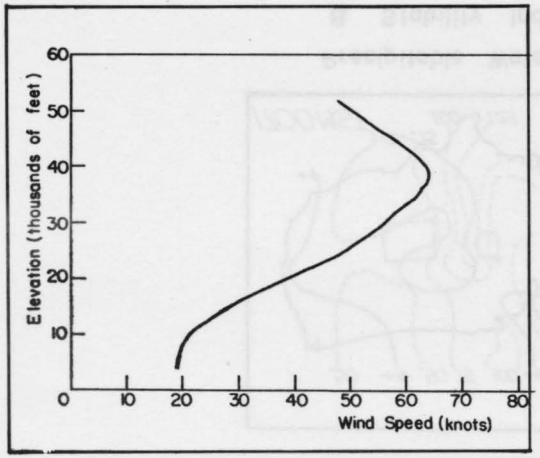
Jet Stream 50 & 100 kt. isotachs



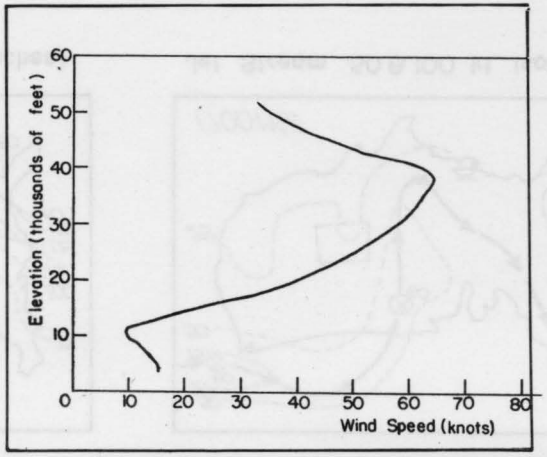
Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

Case of: 21 June 1961

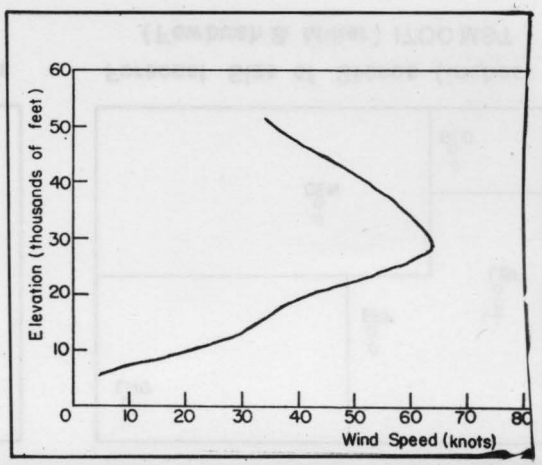
Hail Classification: None



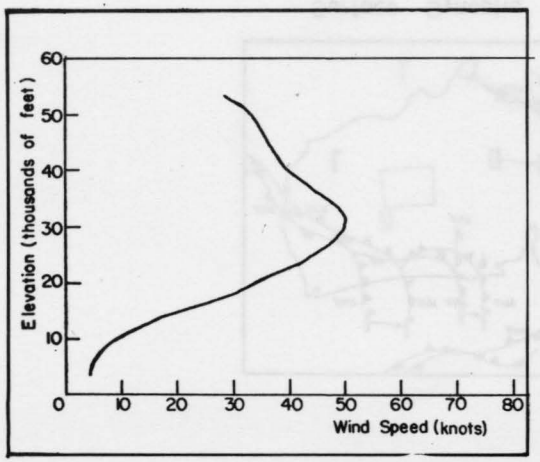
Lander



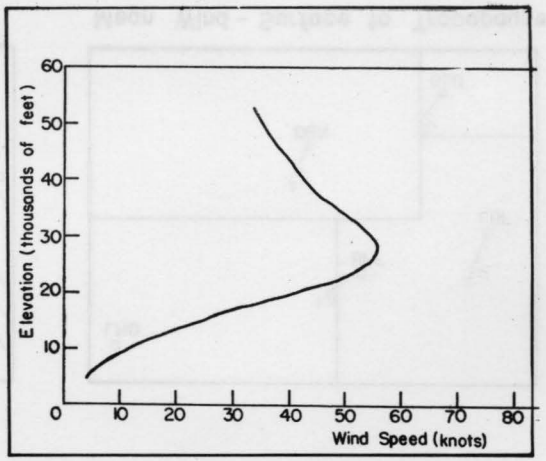
Scottsbluff



North Platte



Denver



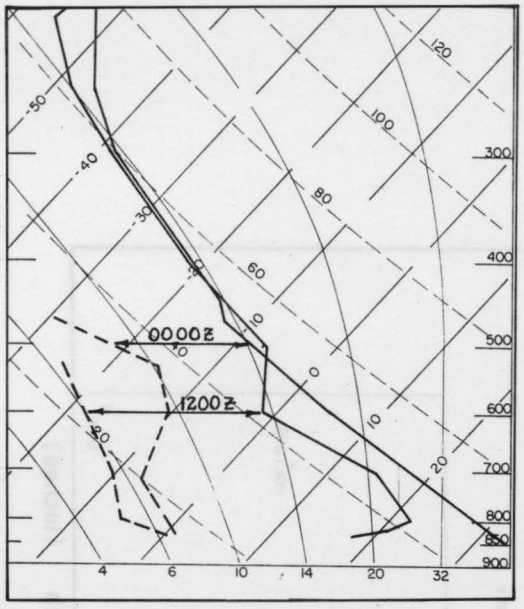
Goodland

Wind Profiles Along Mean Wind Direction

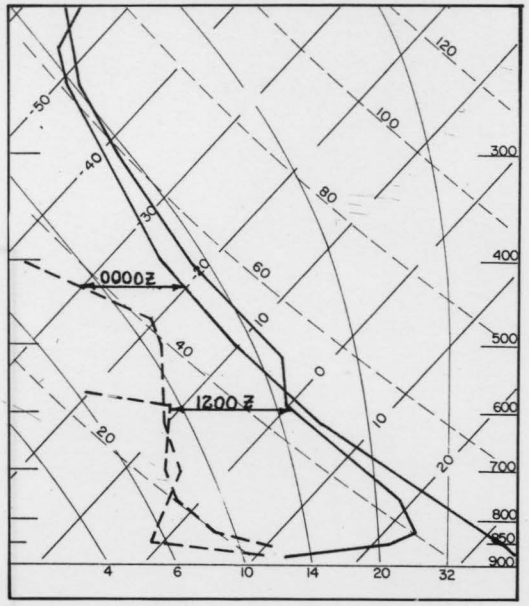
For 1700 MST

Case of: 21 June 1961

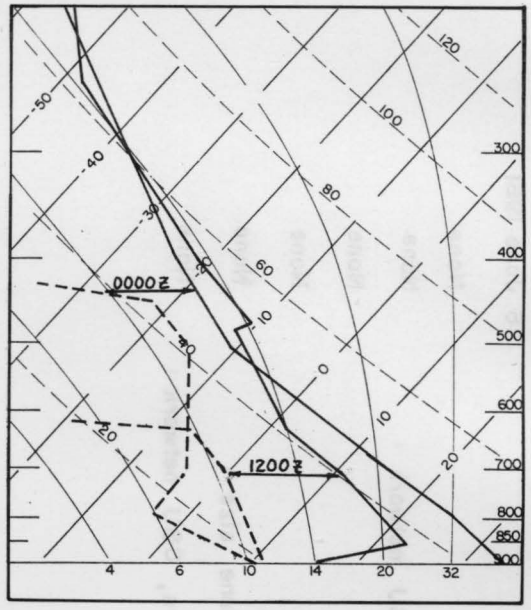
Hail Classification: None



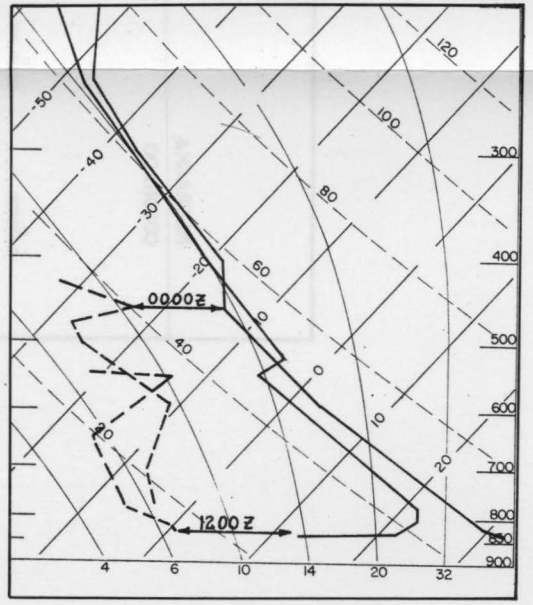
Lander



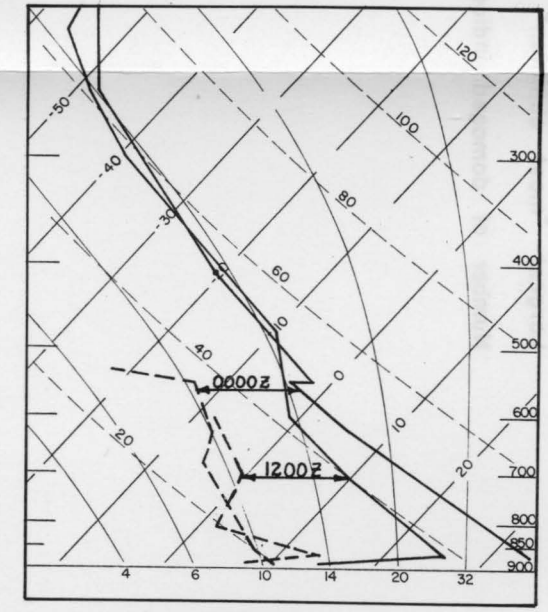
Scottsbluff



North Platte



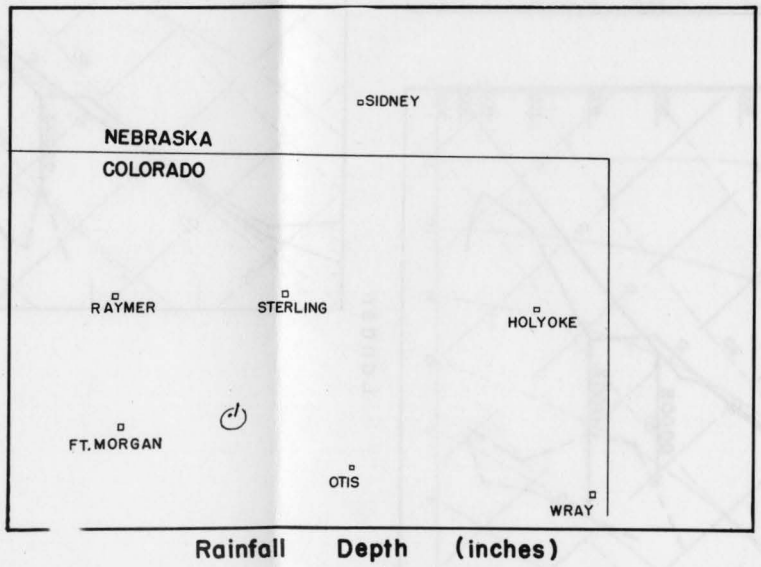
Denver



Goodland

SKEW-T Diagrams
0500 MST = 1200Z
1700 MST = 0000Z

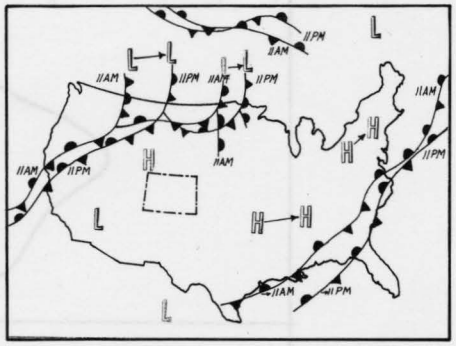
Case of :	26 June 1961
Hail classification :	None
Number of reports from CSU network :	None
Max stone size :	None
Max E, ft-lbs per sq ft. :	None
Largest "most common" stone size :	None
Number of damaged indicators, CSU network :	None



Rainfall Depth (inches)

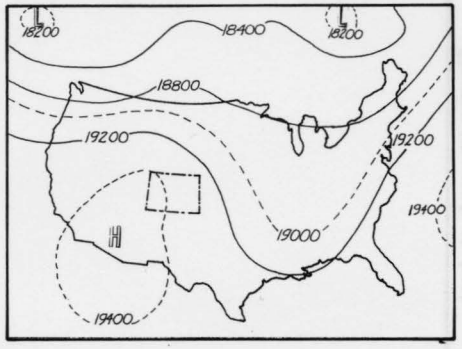
Case of : 26 June 1961

Hail Classification : None



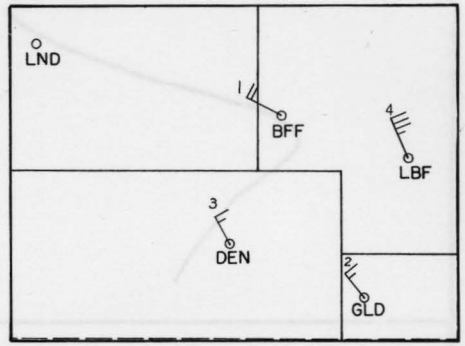
Surface Synoptic Pattern

11 AM & 11 PM MST



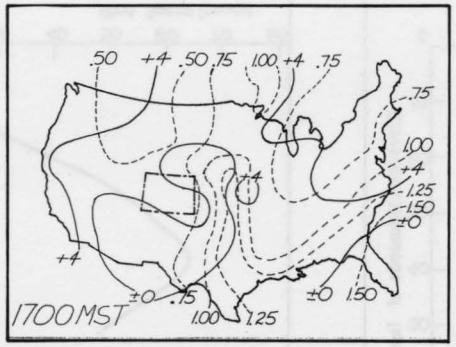
500 MB Flow

1700 MST



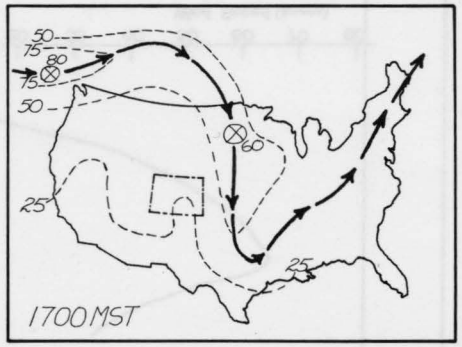
Mean Wind - Surface to Tropopause

(knots) 1700 MST

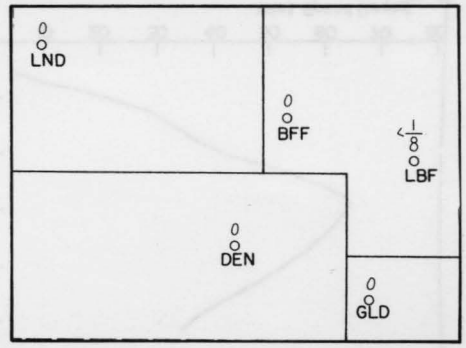


Precipitable Water (inches)

& Stability Index



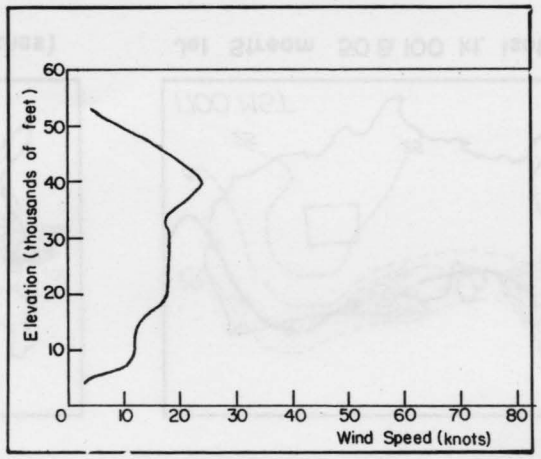
Jet Stream 50 & 100 kt. isotachs



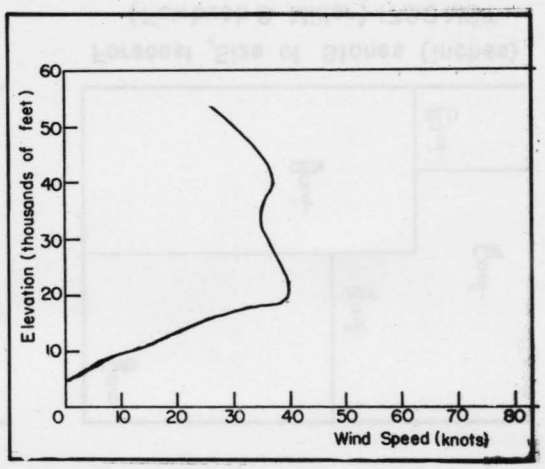
Forecast Size of Stones (inches)

(Fawbush & Miller) 1700 MST

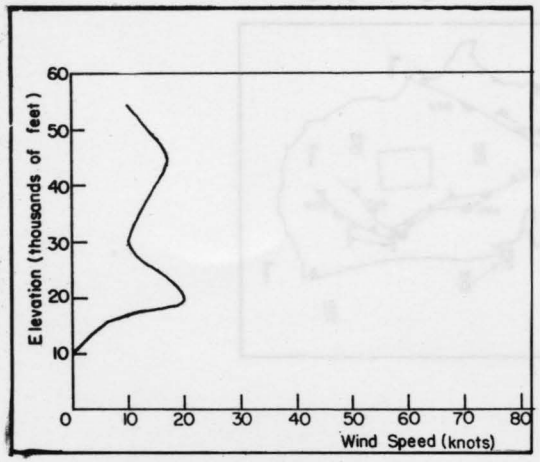
Case of: 26 June 1961
Hail Classification: None



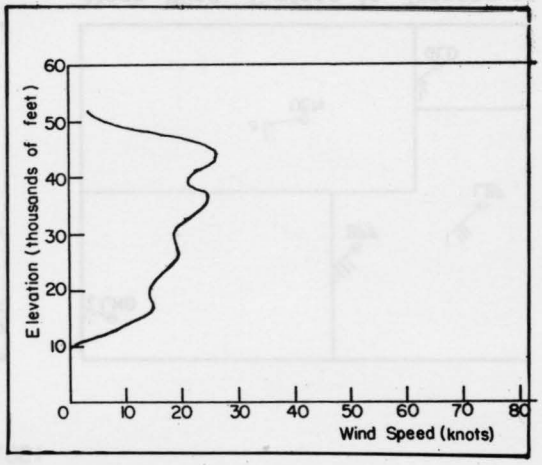
Scottsbluff



North Platte



Denver

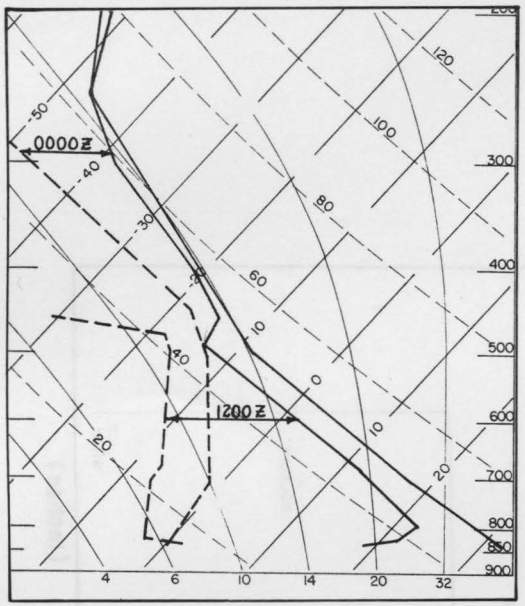


Goodland

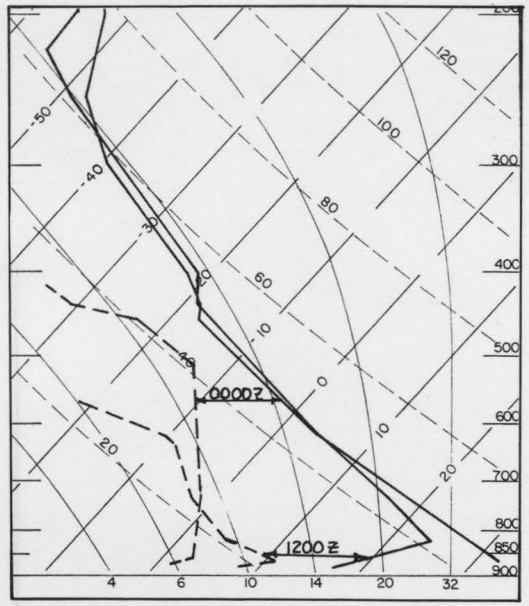
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 26 June 1961

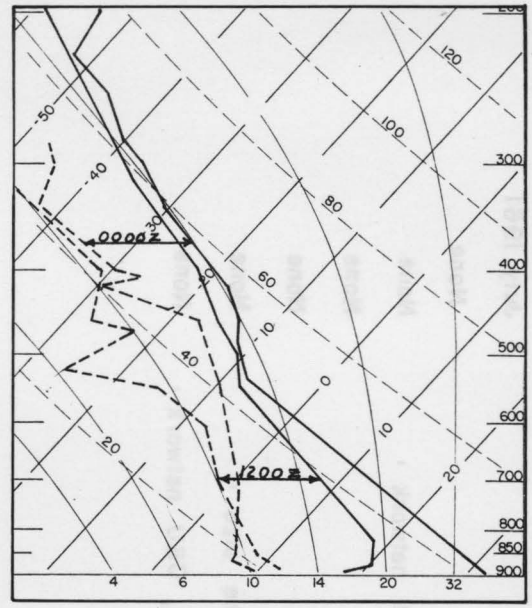
Hail Classification: None



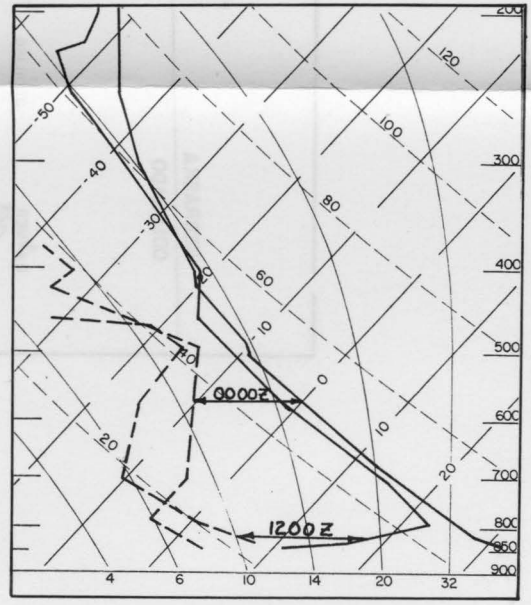
Lander



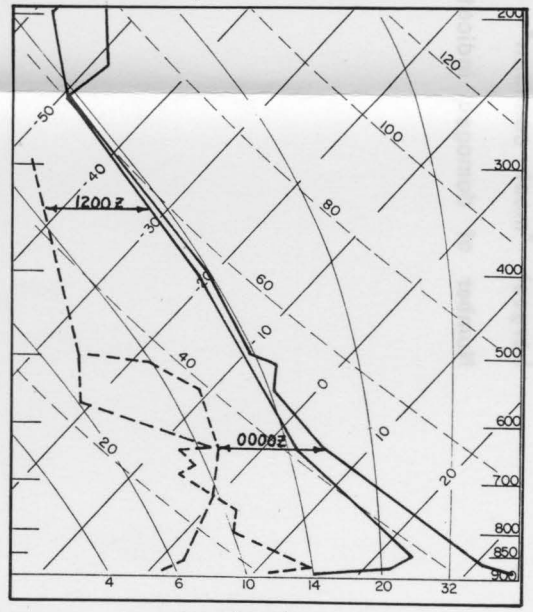
Scottsbluff



North Platte



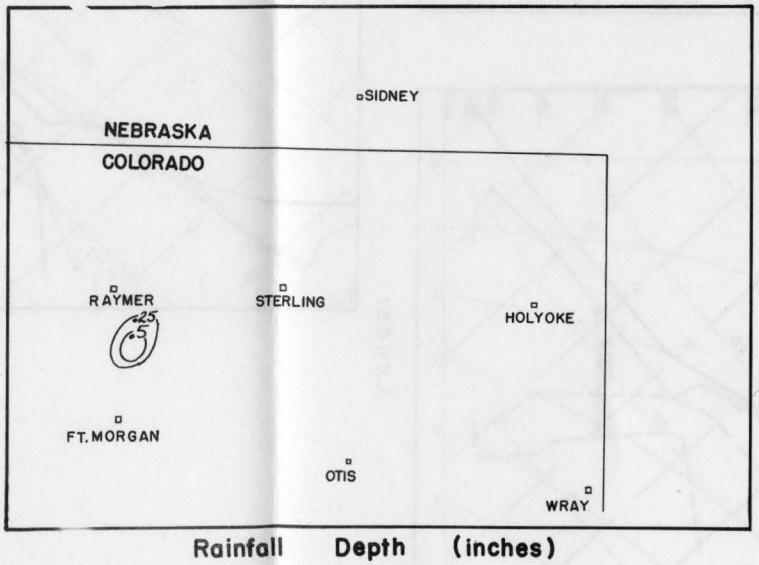
Denver



Goodland

SKEW-T Diagrams
0500 MST = 1200 Z
1700 MST = 0000 Z

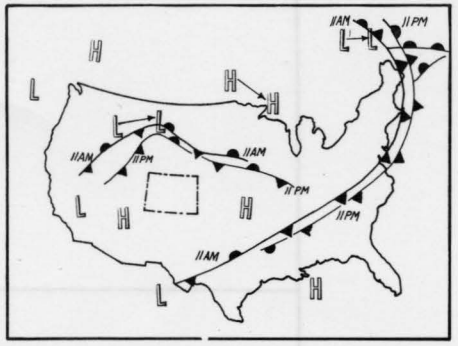
Case of :	3 July 1961
Hail classification :	None
Number of reports from CSU network :	None
Max stone size :	None
Max E, ft-lbs per sq ft. :	None
Largest "most common" stone size :	None
Number of damaged indicators, CSU network :	None



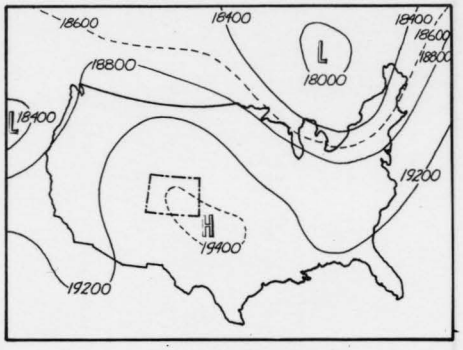
Rainfall Depth (inches)

Case of : 3 July 1961

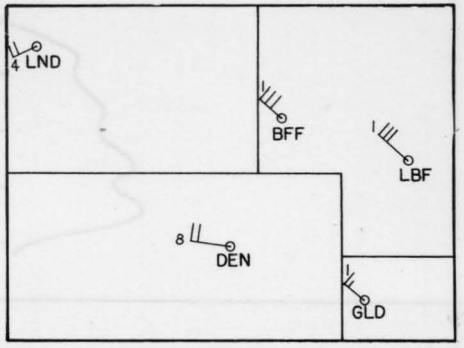
Hail Classification : None



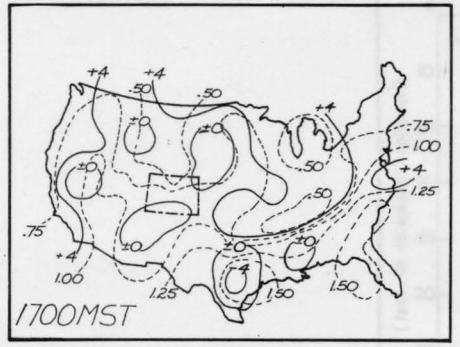
Surface Synoptic Pattern
11 AM & 11 PM MST



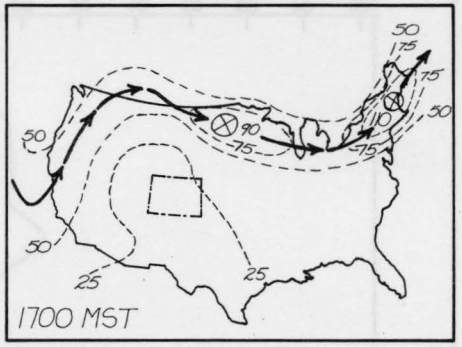
500 MB Flow
1700 MST



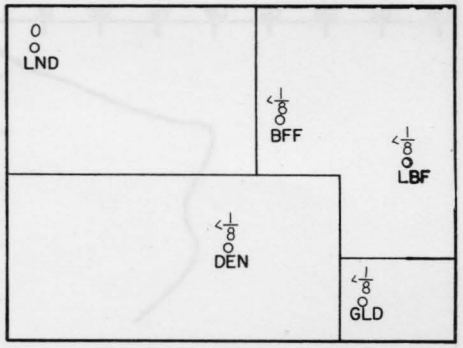
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index

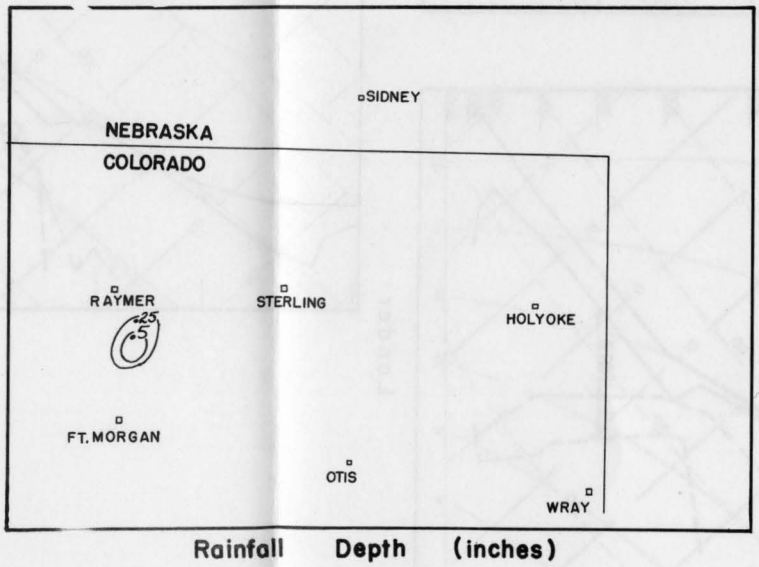


Jet Stream 50 & 100 kt. isotachs



Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

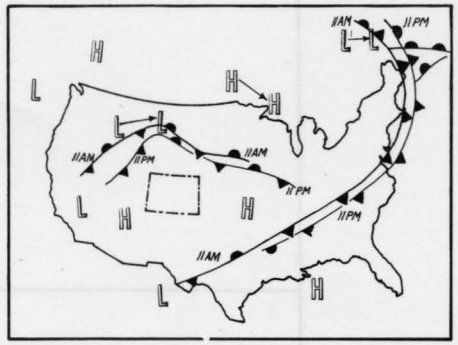
Case of :	3 July 1961
Hail classification :	None
Number of reports from CSU network :	None
Max stone size :	None
Max E, ft-lbs per sq ft. :	None
Largest "most common" stone size :	None
Number of damaged indicators, CSU network :	None



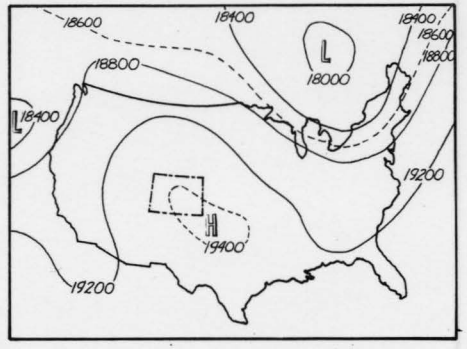
Rainfall Depth (inches)

Case of : 3 July 1961

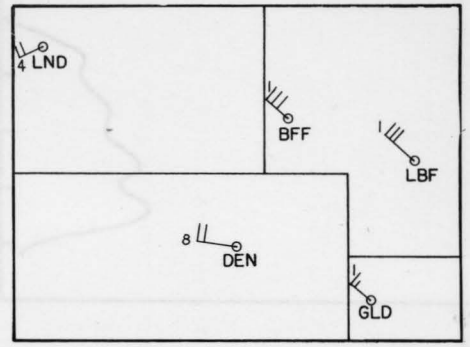
Hail Classification : None



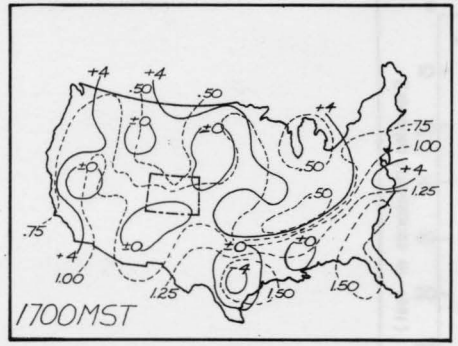
Surface Synoptic Pattern
11 AM & 11 PM MST



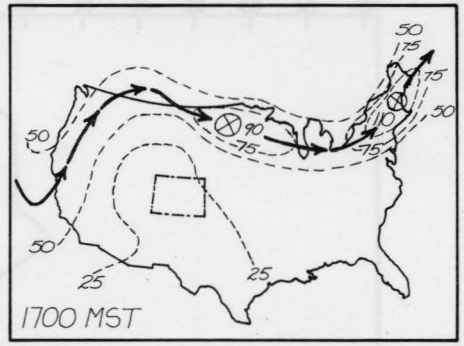
500 MB Flow
1700 MST



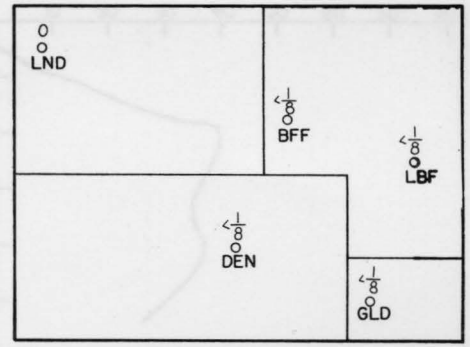
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index



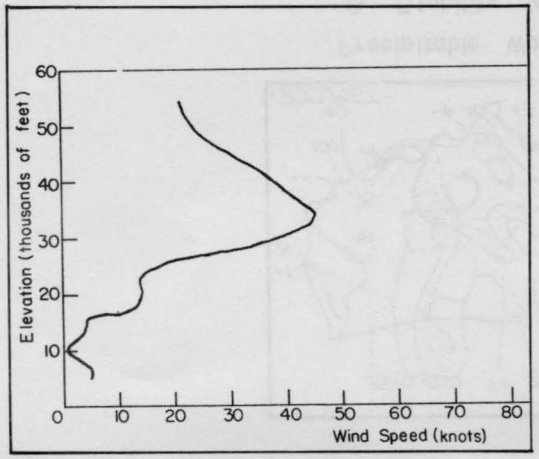
Jet Stream 50 & 100 kt. isotachs



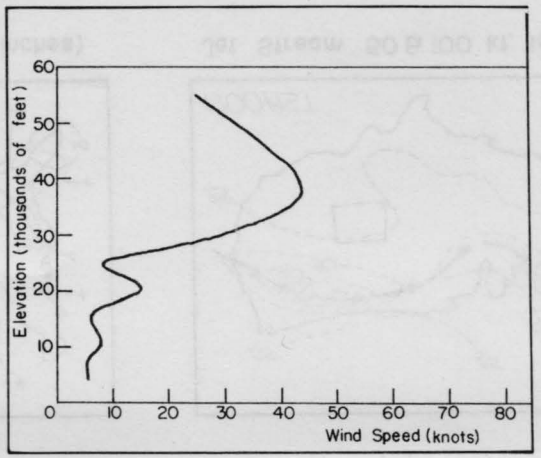
Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

Case of: 3 July 1961

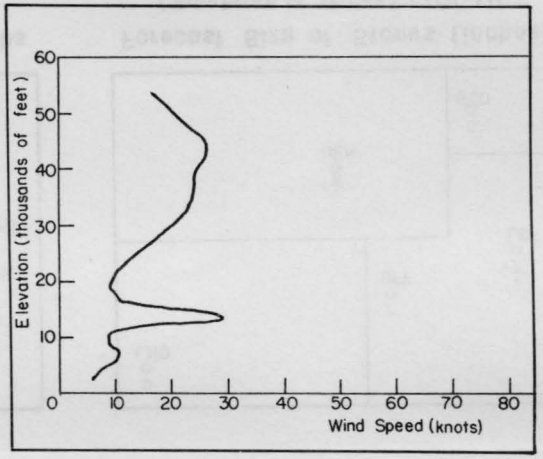
Hail Classification: None



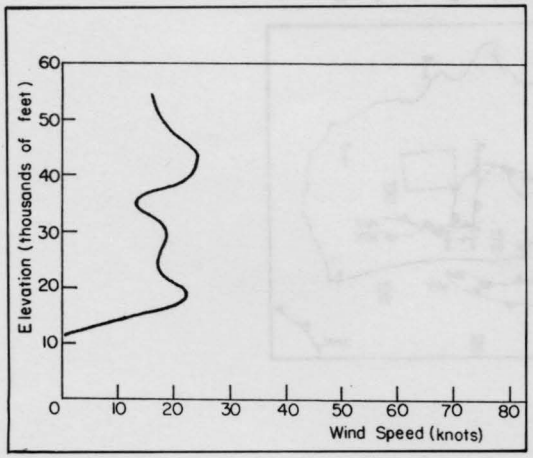
Lander



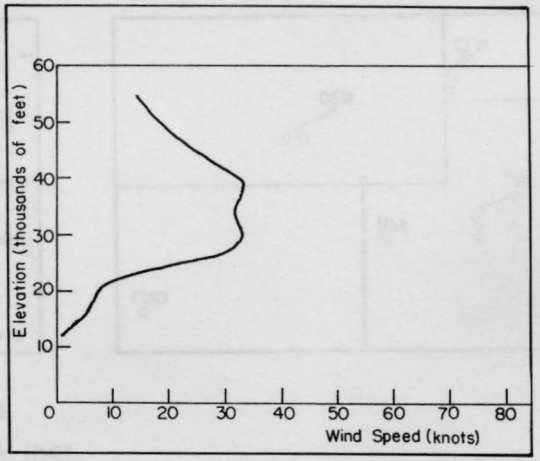
Scottsbluff



North Platte



Denver



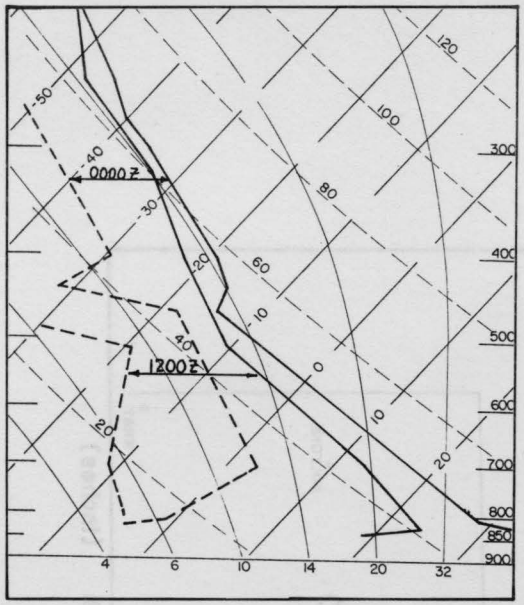
Goodland

Wind Profiles Along Mean Wind Direction

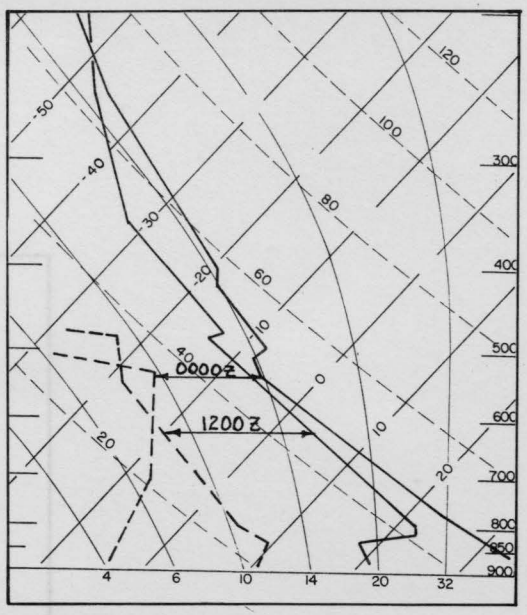
For 1700 MST

Case of: 3 July 1961

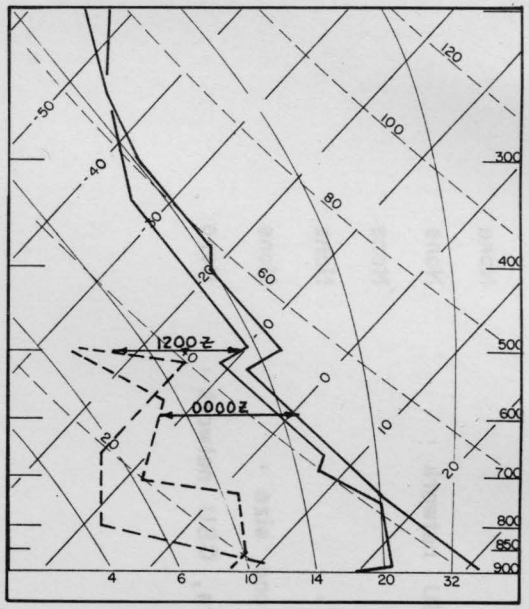
Hail Classification: None



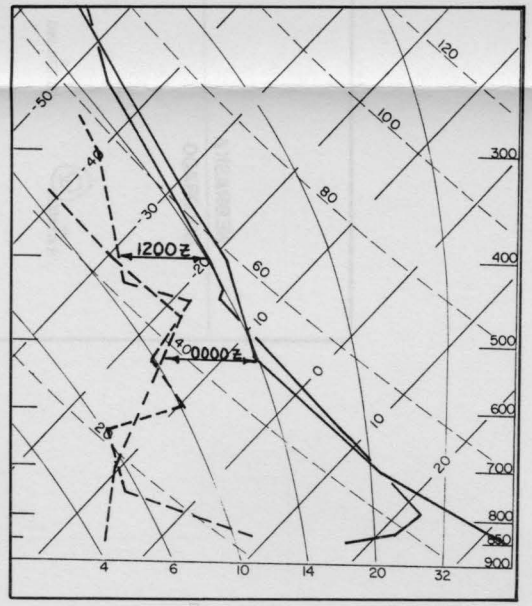
Lander



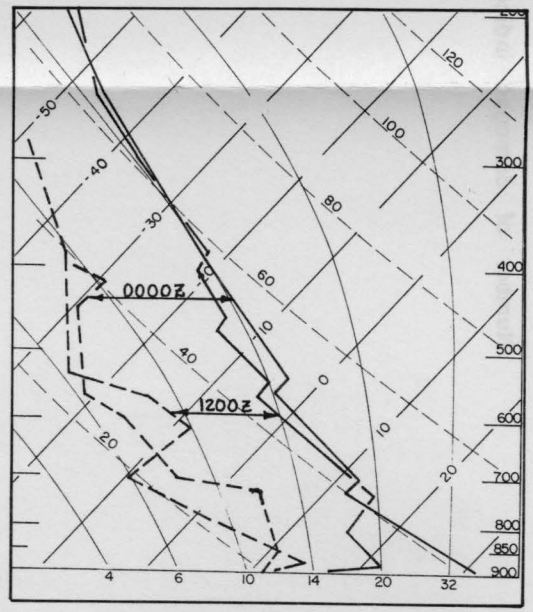
Scottsbluff



North Platte



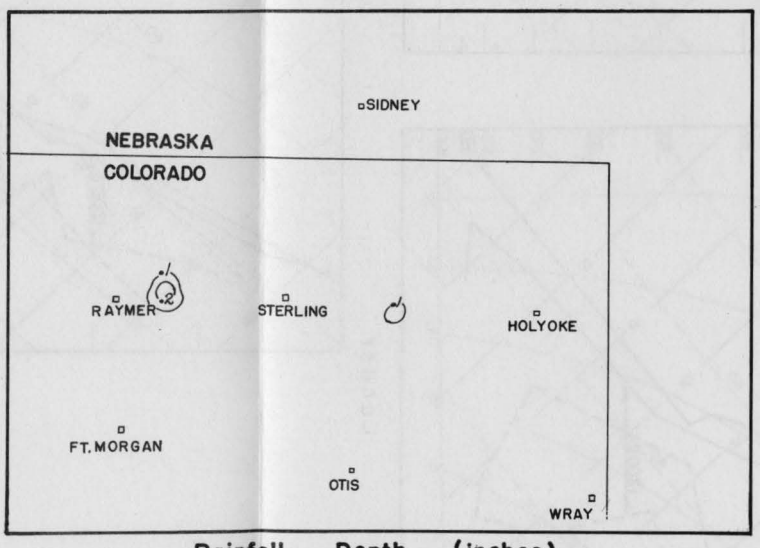
Denver



Goodland

SKEW-T Diagrams
0500 MST = 1200Z
1700 MST = 0000Z

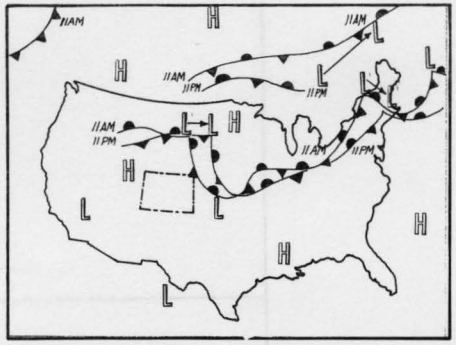
Case of :	17 July 1961
Hail classification :	None
Number of reports from CSU network :	None
Max stone size :	None
Max E, ft-lbs per sq ft. :	None
Largest "most common" stone size :	None
Number of damaged indicators, CSU network :	None



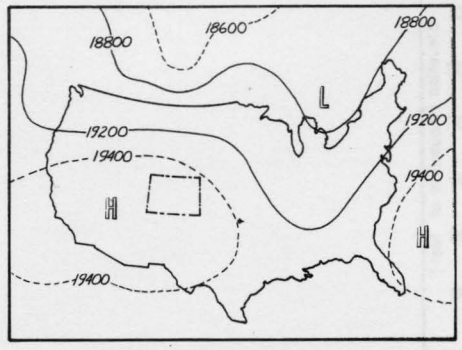
Rainfall Depth (inches)

Case of : 17 July 1961

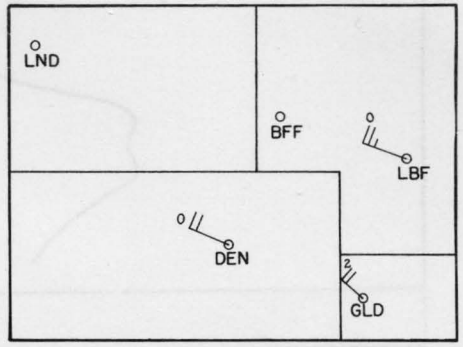
Hail Classification: None



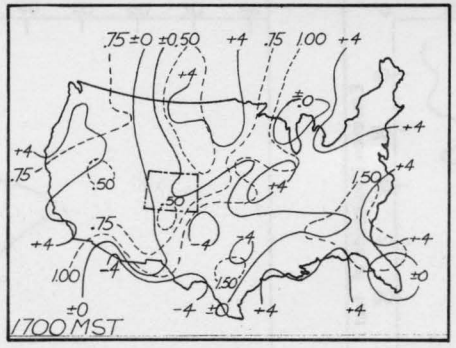
Surface Synoptic Pattern
11 AM & 11PM MST



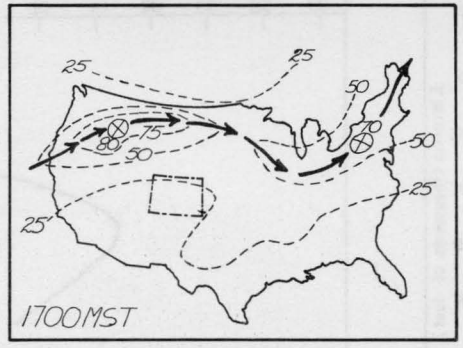
500 MB Flow
1700 MST



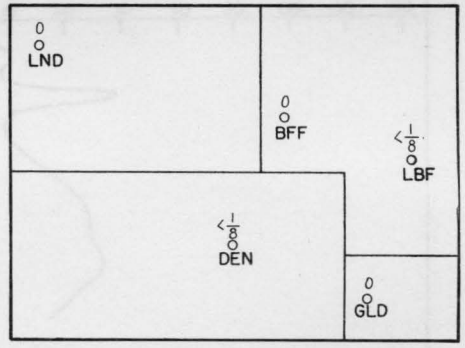
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index

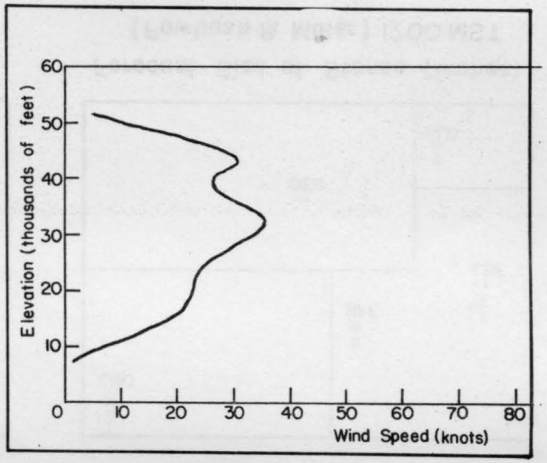


Jet Stream 50 & 100 kt. isotachs

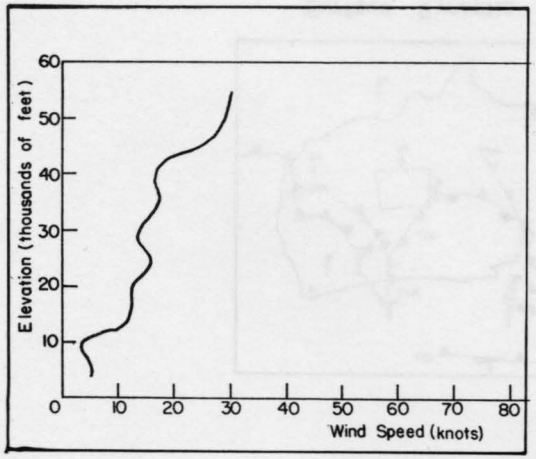


Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

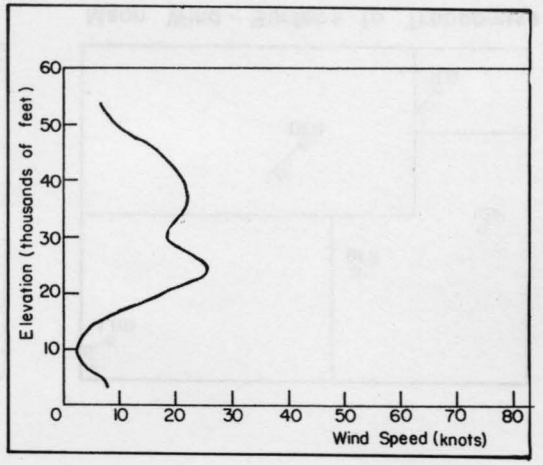
Case of: 17 July 1961
Hail Classification: None



North Platte



Denver

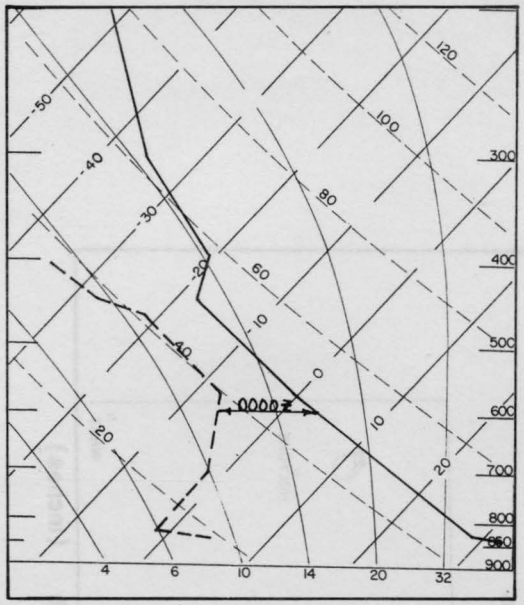


Goodland

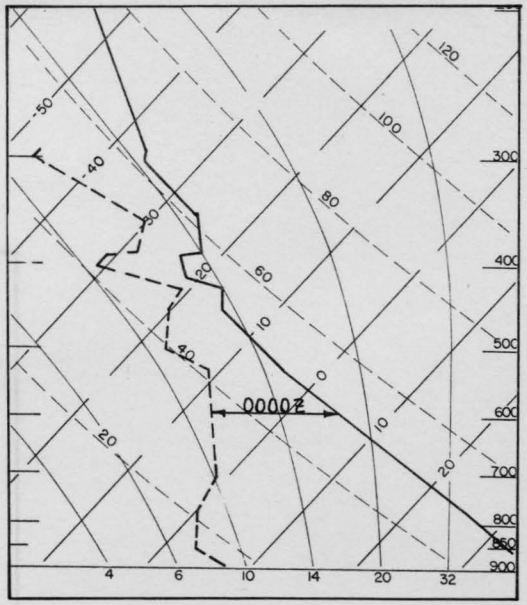
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 17 July 1961

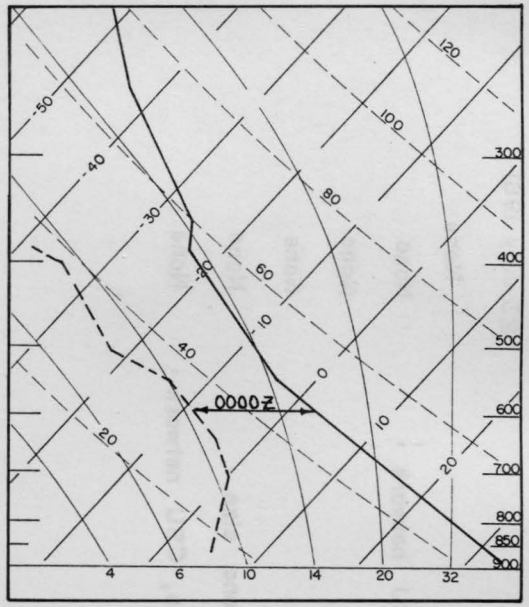
Hail Classification: None



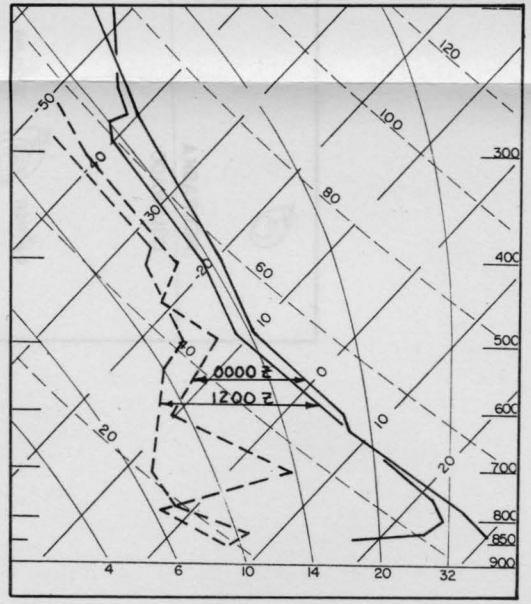
Lander



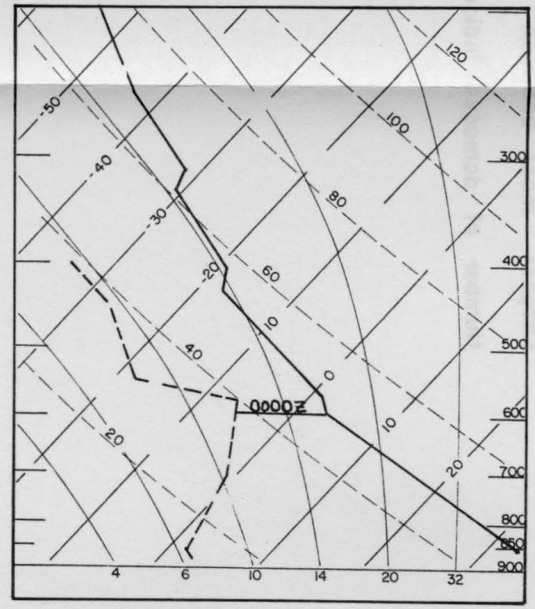
Scottsbluff



North Platte



Denver



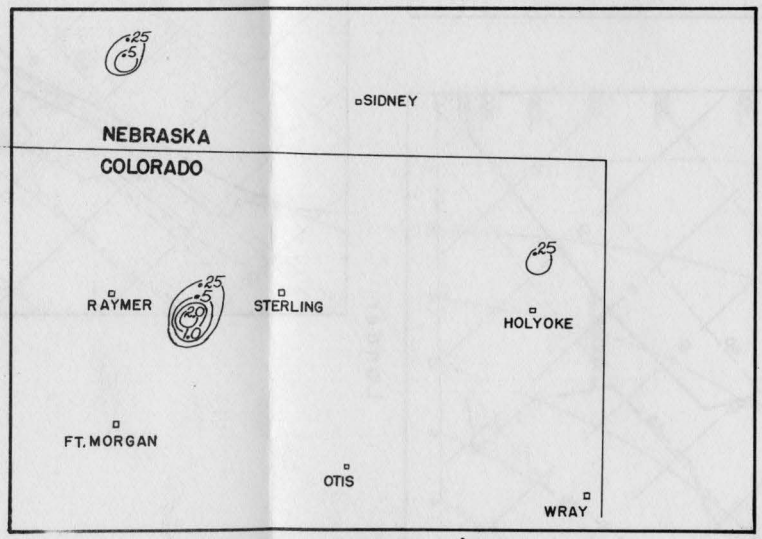
Goodland

SKEW-T Diagrams

0500 MST = 1200Z

1700 MST = 0000Z

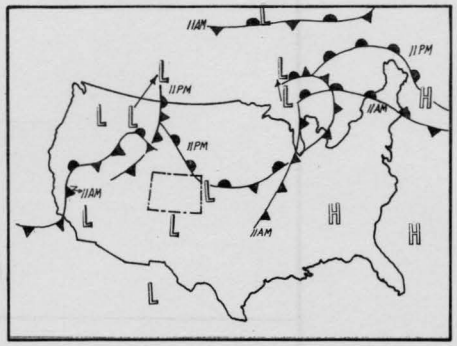
Case of :	23 July 1961
Hail classification :	None
Number of reports from CSU network :	None
Max stone size :	None
Max E, ft-lbs per sq ft. :	None
Largest "most common" stone size :	None
Number of damaged indicators, CSU network :	None



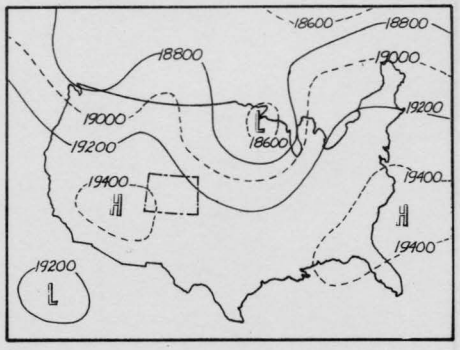
Rainfall Depth (inches)

Case of : 23 July 1961

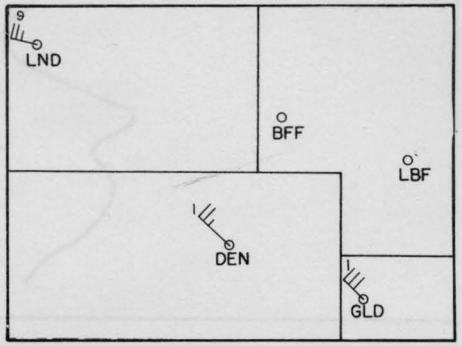
Hail Classification: None



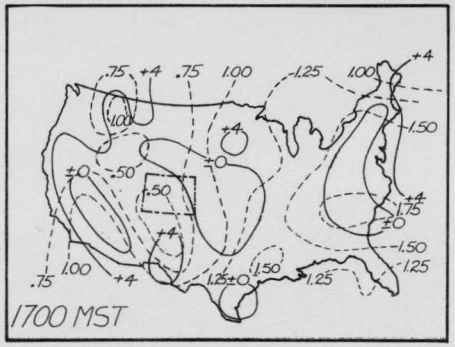
Surface Synoptic Pattern
11 AM & 11PM MST



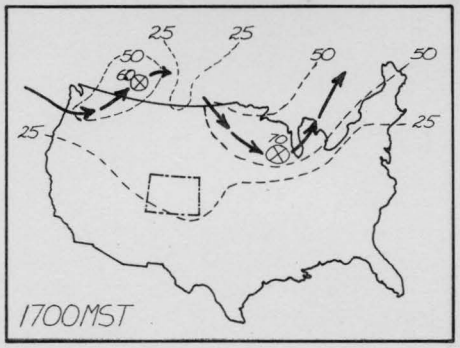
500 MB Flow
1700 MST



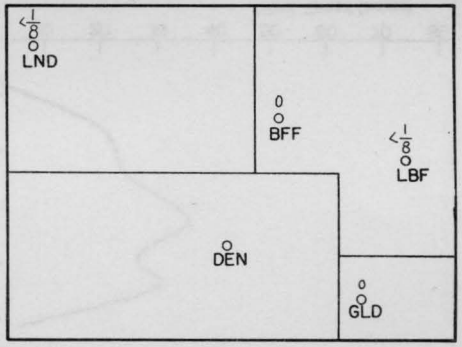
Mean Wind - Surface to Tropopause
(knots) 1700 MST



Precipitable Water (inches)
& Stability Index

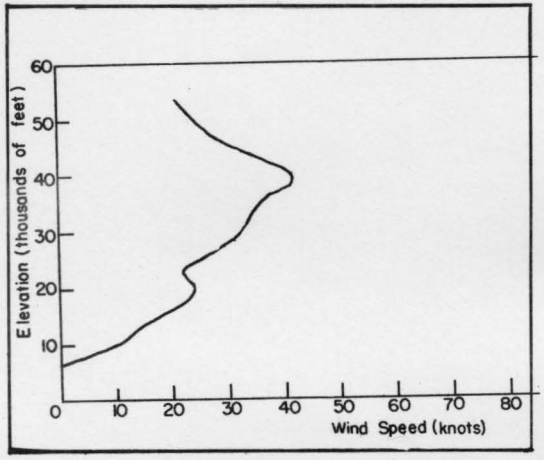


Jet Stream 50 & 100 kt. isotachs

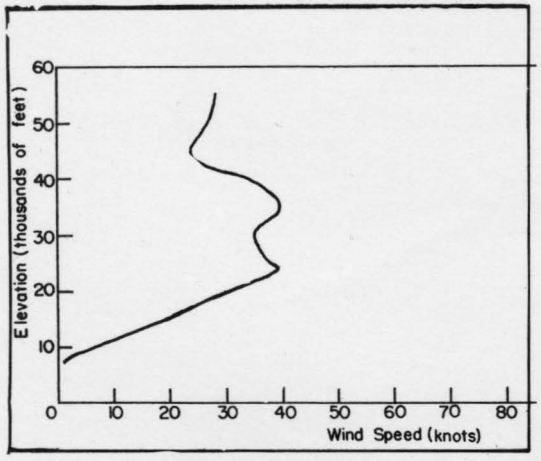


Forecast Size of Stones (inches)
(Fawbush & Miller) 1700 MST

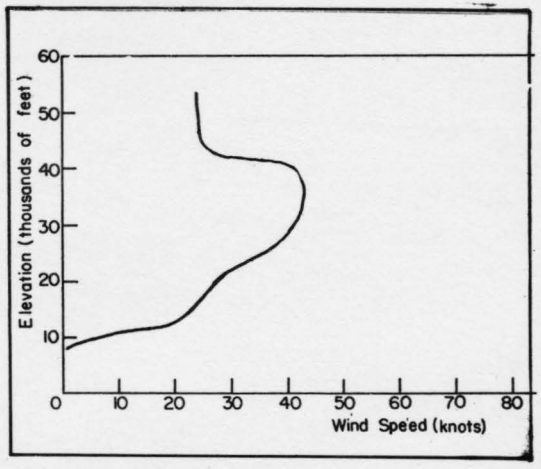
Case of: 23 July 1961
Hail Classification: None



Lander



Denver

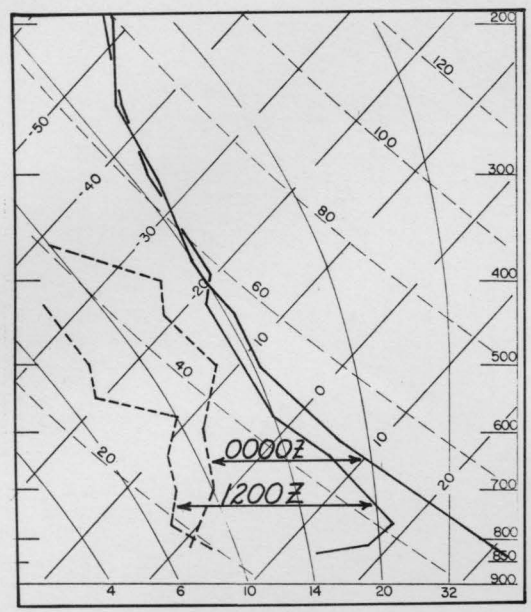


Goodland

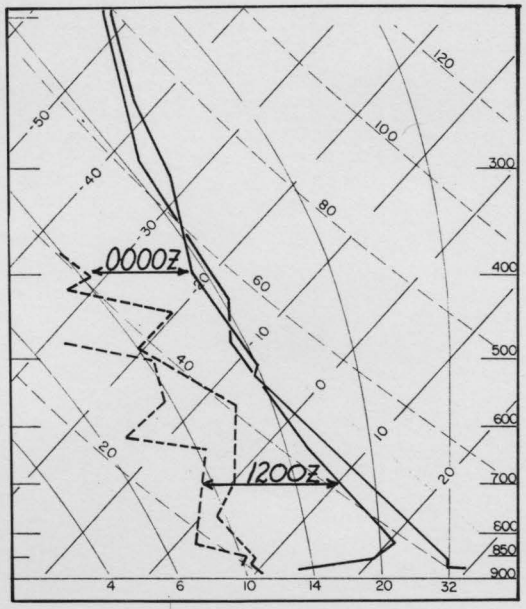
Wind Profiles Along Mean Wind Direction
For 1700 MST

Case of: 23 July 1961

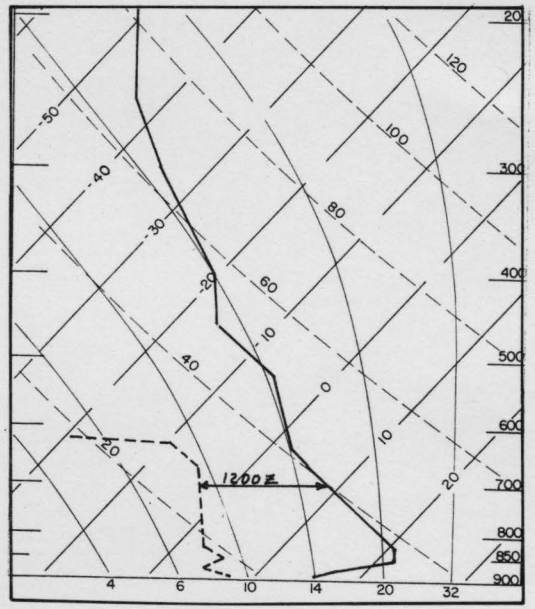
Hail Classification: None



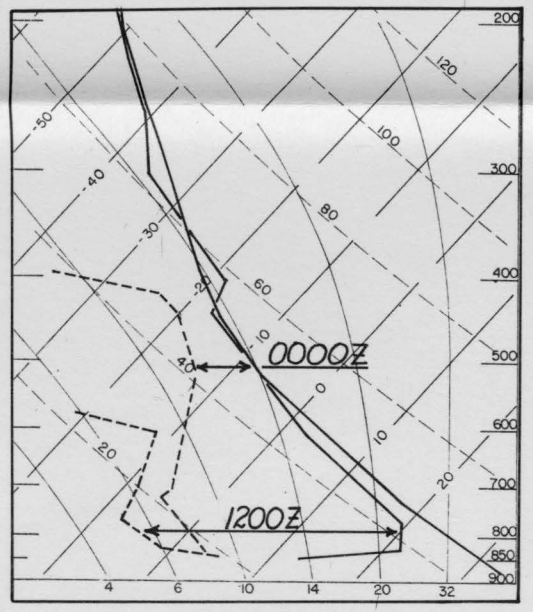
Lander



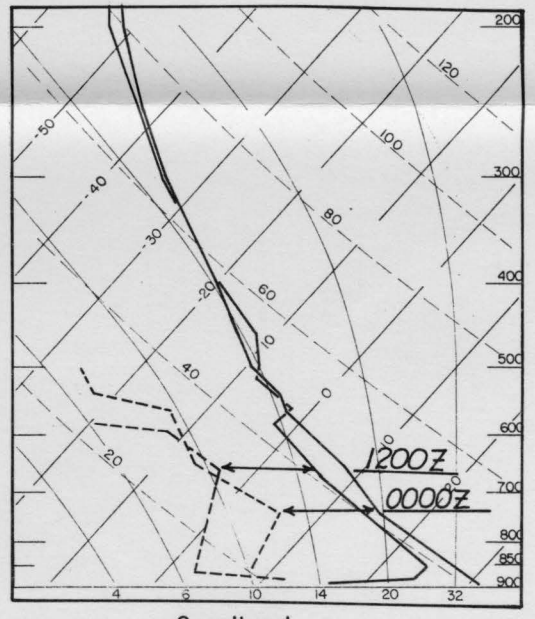
Scottsbluff



North Platte



Denver



Goodland

SKEW-T Diagrams

0500MST=1200Z

1700MST=0000Z