Case Study: Severe Thunderstorm Over Fairbanks, AK on 8th of June, 1997

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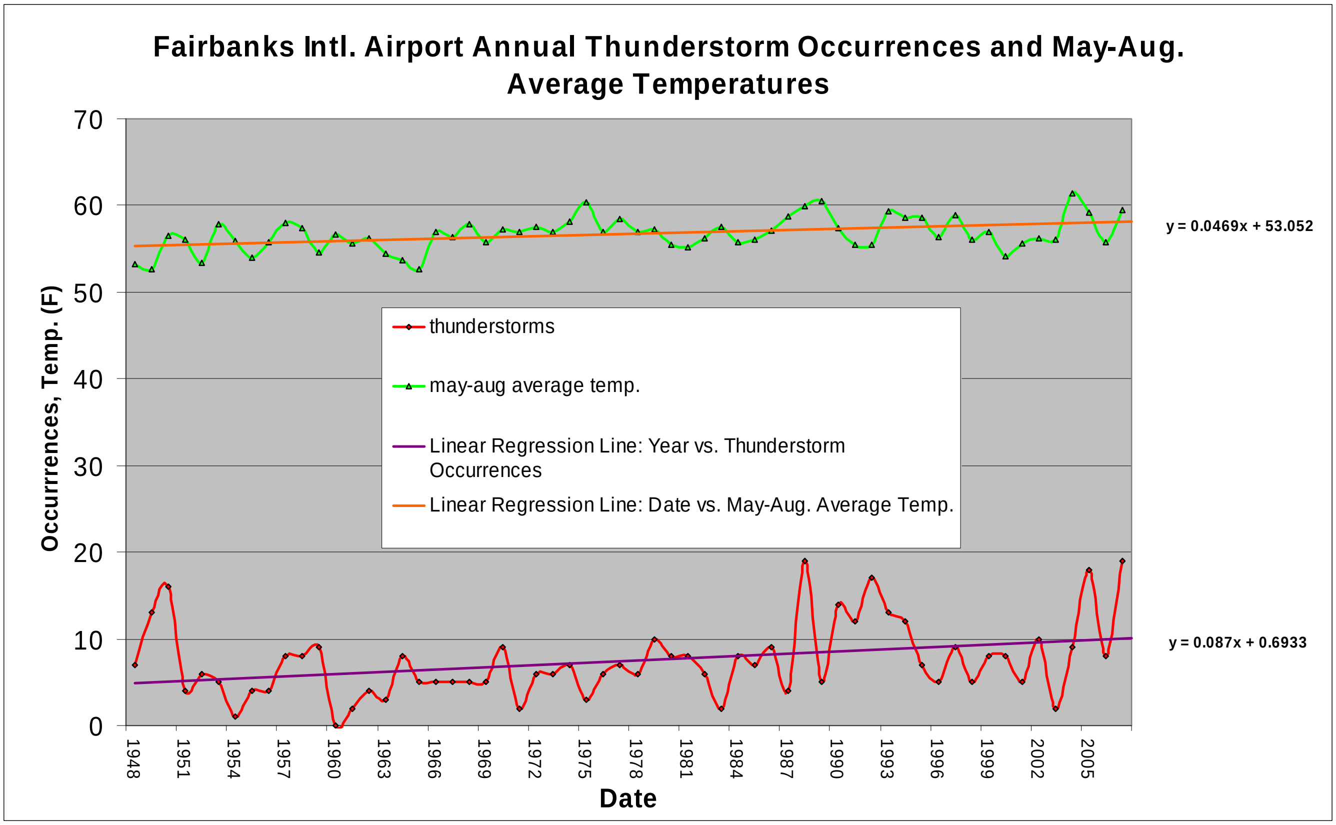
Introduction: Thunderstorms are a prominent feature of the Alaska Interior climate, as can be seen from the graph below, of Fairbanks annual thunderstorm occurrences, since 1948 (the year observations began at the Fairbanks airport), plotted with may-august average temperatures. In fact, there seems to be an increasing trend in thunderstorms occurrences over Fairbanks, with a noticeable pattern shift toward higher frequencies in the late 1980s. There also seems to be a slight correlation of these with the may-august surface temperature.



With that in mind, examination of cases of severe thunderstorm occurrences at a location is useful to assess the potential for recurrence of such phenomena, and to aid meteorologists in forecasting their potential. An excellent example of a severe thunderstorm in Fairbanks, AK, which has never before been examined in great detail, is the one that occurred on the 8th of June, 1997.

Event Analysis: The best description of the event comes from the National Climatic Data Center's Storm Data on-line archive:

Event:	**Tstm Wind/hail**
Begin Date:	**08 Jun 1997, 07:13:00 PM AST**
Begin Location:	**Fairbanks**
End Date:	**08 Jun 1997, 07:58:00 PM AST**
End Location:	**Fairbanks**
Magnitude:	**50**
Fatalities:	**0**
Injuries:	**0**
Property Damage:	**$ 2.0M**
Crop Damage:	**$ 0.0**

State:	**Alaska**
	Map of Counties
County:	**Fairbanks/Tanana Valley**

Description:
A Thunderstorm moved from north of downtown Fairbanks, southwest over the west part of the city. Rainfall of 1.31 to 2.17 occurred, much of it in less than an hour. Hail of 1/4 to 3/8 inch diameter was common, with some spots receiving stones of 3/4 to 7/8 inch diameter. Hail covered the west half of town and in some places was two to six inches deep. Some residence basements were flooded, and brief urban flooding occurred in town where storm drains backed up from the hail. The Sewage system backed up at several buildings at the University of Alaska, including the Rare Books section of the Library. Water and Hail ponding on the roofs of some larger buildings leaked into the structures, or caused a part of the roof to fall, including a high school and a restaurant attached to a hotel. An art gallery in one mall declared their stock a total loss. Wind gusts felled trees across town (a dozen just at the University), resulting on power outages in some areas - downtown Fairbanks was without power for 80 minutes.

The data available to examine and describe the causal mechanisms of this event are a daily lightning summary from the Alaska Fire Service archive, 1 KM high-resolution polar-orbiting satellite imagery, surface, equivalent potential temperature, and upper-air analyses, and Fairbanks skew-T upper-air soundings. Unfortunately, archived radar data from the Fairbanks WSR-88D is not available; inquiries were made to many different sources, all to no avail.

Even without radar data however, a useful description can emerge. The first item to examine is the daily lightning summary for 08JUN97, obtained from the BLM/Alaska Fire Service archive (figure 1, end of paper). One interesting thing to note is there are no lightning strikes to the north and east of Fairbanks. Inspection of the skew-T analysis for that day (figure 2) shows a 500-700 mb steering flow of north to northeast at 15 to 25 knots. Thus, it appears that this storm formed locally, over the uplands slightly to the north to northeast of Fairbanks, and was not in an area of organized convection focused by a larger-scale disturbance (e.g., an easterly wave). This is apparent in figure 4, the 2300 GMT POES 1 KM image (4 hours before the storm formed/moved over Fairbanks). There are no large clusters or lines of showers or thunderstorms upstream, but cells are forming just to the northeast over the uplands, aided by the upsloping low-level southwest flow. The number of cloud-ground lightning strikes detected in this storm looks to be about 15-25, which is a fair number, but not spectacular. Many storms in the Alaska Interior during peak convection season (late May-July) can generate much higher lightning strike densities than this one. So the first significant characteristic of this storm, is that it seems to have formed locally, and was not dynamically-enhanced. Figures 3, 4, and 5, the POES 1 KM visual imagery from the hours preceding and during the event illustrate this. Rather than a line of organized convection sweeping through Fairbanks, the satellite imagery seems to depict a storm that forms near Fairbanks and slowly moves southwest, rapidly growing in size and strength between 0145 and 0325 GMT.

Further inspection of the Skew-T analysis from the 0000 GMT 09JUN97 Fairbanks radiosonde (3 PM AKST 08JUN97, 4 hours before the storm), reveals some interesting characteristics. The low-level flow (surface-850 mb) that afternoon was southwest to west (see also figure 9, 850 mb analysis), with great instability at the lowest levels (note the shallow superadiabatic layer from the surface to about 400-500 meters) while the mid-upper levels had a north to northeast flow of 15 to 25 knots that was moist between 800 and 640 millibars. The storm moved southwest over Fairbanks in the northeasterly steering flow. An outflow boundary generated from the first cell to form, just to the northeast of Fairbanks (see figures 4 and 5, POES 1KM visual images), would encounter these low-level southwest-west winds, containing very unstable and fairly moist air. An area of convergence and new convection initiation would likely result. This may also help explain how such heavy rainfall and hail accumulations could occur in an environment where the precipitable water was fairly low for moist convection, only .67 inch. **The low-level southwest-west feed of very unstable air was critical in maintaining a longer-lived storm updraft than more typical pulse-type thunderstorms that are usually seen in the Alaska Interior. In the pulse-type storms usually seen in the Alaska Interior, rain-cooled air in the downdraft eventually cuts off the updraft and the storm decays. Hodograph inspection and analysis would also be useful in forecasting these. Figure 3 shows the hodograph from 00Z 09JUN97. The low-level southwest-west winds show up very distinctly opposed to the overlying north and northeast flow.**

Stability indices calculated from the 0000 GMT sounding were not overly impressive. Using guidelines from Gordon and Albert's NOAA/NWS Central Region Technical Service Publication 10, "A Comprehensive Severe Weather Forecast List and Reference Guide", gives the following. Surface-based Convectively Available Potential Energy (CAPE) was only about 200 J/kg, which is on the low end for thunderstorm development, weakly unstable. However, these are probably calculated using the average dewpoint in the lowest 50-100 millibars. If CAPE were re-calculated using just the surface dewpoint (+7C), this value would increase significantly. The moister air near the surface was being lifted in the strong updrafts in this storm, and to have produced the great amounts and large sizes of hail that occurred, the CAPE would have to have been much higher. The Lifted Index was only -1.2, which is marginally unstable, but the K index of 30.9 is described as producing a 60 percent chance of thunderstorm development. The total totals however, are more descriptive of this situation. This index accounts for both static stability and 850 millibar moisture. The value from the 0000 GMT sounding of 53.6 is described as "Thunderstorms more likely (some severe)".

Two other local environmental characteristics to examine that day that are often used in Fairbanks to forecast thunderstorm potential are 850 millibar equivalent potential temperature (theta-e), and the 850-500 millibar temperature difference (delta-T). A local study, written by then general forecaster Cary Freeman, in 1993, identified theta-e ridges at 850 millibars as favored regions for thunderstorm development in the Alaska Interior. Figure 10, the 850 millibar theta-e analysis for 0000 GMT 09JUN97, shows a well-developed theta-e ridge centered just to the north and east of Fairbanks. Cary's study found that theta-e ridge values of 315K or more lead to the greatest lightning strike accumulations, but ridges with lower values, as this one was, were associated with thunderstorm development throughout their area, usually with somewhat lower strike densities. Another local study, analyzing the importance of 850-500 millibar delta-T in thunderstorm forecasting, was written by then seasonal fire weather forecaster Scott Ritz, in 1995. This is a simple measure of stability, influenced by surface heating and cold advection or a cold pool aloft. Scott found this to be a fairly reliable tool for thunderstorm forecasting; convection is focused in delta-T ridges, with values of 28 deg. C or higher leading to the greatest lightning strike densities. The 850-500 millibar delta-T from the 0000 GMT 09JUN97 sounding over Fairbanks was 30.9, a value definitely associated with high convective potential.

Now that the local environmental characteristics that drove this storm's formation and behavior have been ascertained, the next question to ask, is what synoptic pattern produced these? To start, an inspection of figure 7, the 0600 GMT 09JUN97 (3 hours after the storm formed) surface analysis (hand-drawn by one of the forecasters then on duty at WFO Fairbanks), is in order.

The first thing that stands out is that Fairbanks is just to the south of the center of a well-developed surface thermal low. These thermal lows in the summer months are produced by strong surface heating in the interior, at times augmented with weak dynamic forcing from lee-side troughing effects if the mid-level flow is from a direction that is on the leeward side of higher terrain. In this case, with the north to northeast mid-level flow, the interior surface thermal low was likely enhanced in this manner due to the flow across the Brooks Range to the north. A surface ridge over Prince William Sound and the Alaska Gulf Coast helped enhance the surface pressure gradient between it and the thermal low over the Interior. The steady low-level southwest-west inflow winds to the storm were maintained due to Fairbanks location in the area of the tightest pressure gradient between these two features.

Figure 9, the 0000 GMT 09JUN97 500 millibar analysis, shows a weak inverted trough centered just to the east of Fairbanks. This would be associated with a slight cold-pool aloft, which combined with the strong surface heating experienced that day in Fairbanks (the high temperature that afternoon reached 74F), would lead to strong instability (hence the high 850-500 millibar delta-T value of 30.9). In addition, Fairbanks location on the front-side of this feature produced the north to northeast mid-level flow identified as an important characteristic in the behavior and strength of this storm (when combined with the low-level southwest-west inflow).

Conclusion: The severe thunderstorm of June 8, 1997 occurred on a day that had at first glance what appeared to be only marginal potential to develop such weather. On closer inspection however, the factors that produced this event became more apparent. Now that these have been ascertained, any similar recurrence of a storm of this type may hopefully be effectively forecast.

These factors are, locally:

1. **Low level southwest to west flow of warm unstable air, beneath a deep layer of moderate north to northeast flow (at least 15 knots) containing enough moisture to initiate convective development. This low-level flow is critical in maintaining strong updrafts to maintain storm strength and increase duration. ** (critical element)**

2. Convective indices indicating at least marginal instability, with total totals index 50 or greater.

3. Location in a well-developed 850 millibar theta-e ridge.

4. High value of 850-500 millibar delta-T (28C or greater)

and synoptically:

1. Well-developed surface thermal low just to the north, indicating low-level instability and also sustaining low-level southwest-west inflow winds. Surface ridging to the south also, to maintain a moderate to strong surface pressure gradient.

2. Location on front-side of inverted 500 millibar trough. Indicates mid-level cold advection or cold pool aloft to increase instability, and area of mid-level north to northeast flow, that combined with the low-level southwest-west inflow winds, helped produce the unique nature of this severe storm over Fairbanks.

Thanks to forecasters Jim Brader and Rick Thoman, of WFO Fairbanks, who were present during this event and provided useful advice/input.

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Gordon, John D. and D. Albert, 2003: A Comprehensive Severe Weather Checklist and Reference Guide. NOAA/NWS Central Region. [Available on-line at http://www.crh.noaa.gov/techpapers].

Reap, Ronald M., 1991: Climatological Characteristics and Objective Prediction of Thunderstorms over Alaska. *Weather and Forecasting*., **6**, 309-319.

Ritz, Scott, 1995: A Discussion of the Delta-T Analysis and Lightning Forecasting in Alaska. Local Study, NOAA/NWS Forecast Office, Fairbanks, AK.

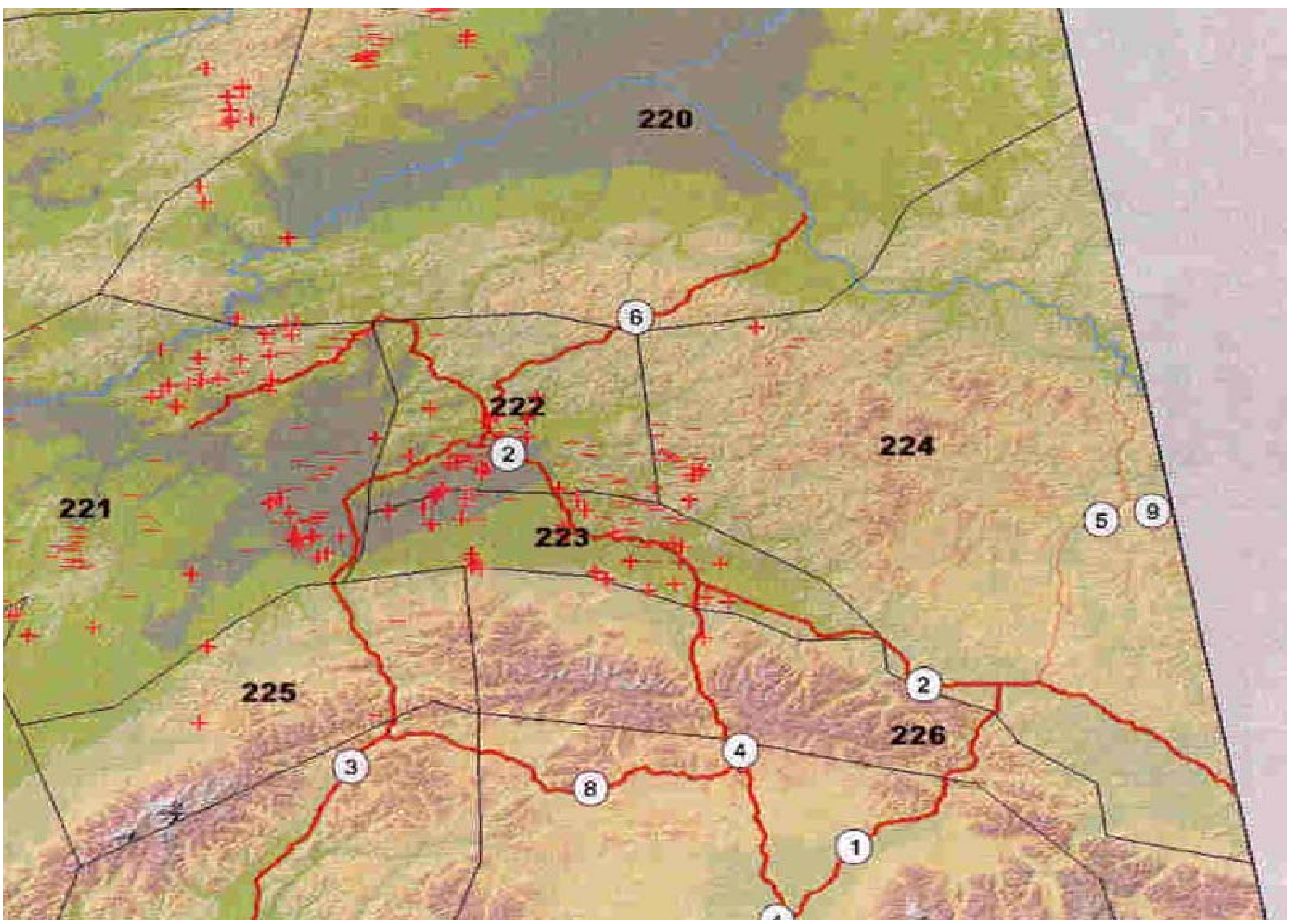

Figure 1, Daily Lightning Accumulation centered over Fairbanks, 08JUN97

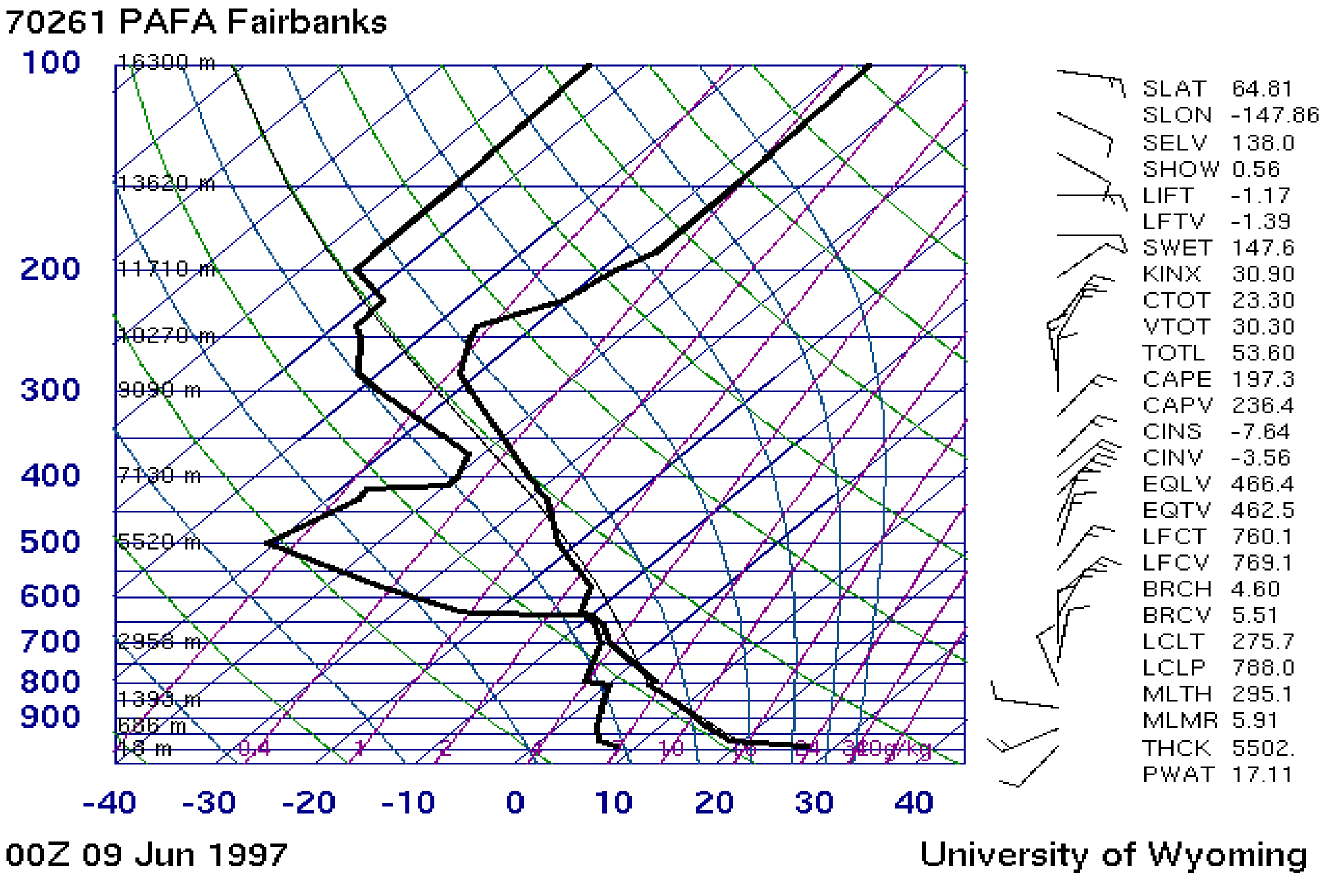

Figure 2, Skew-T for Fairbanks, 09JUN97 00Z

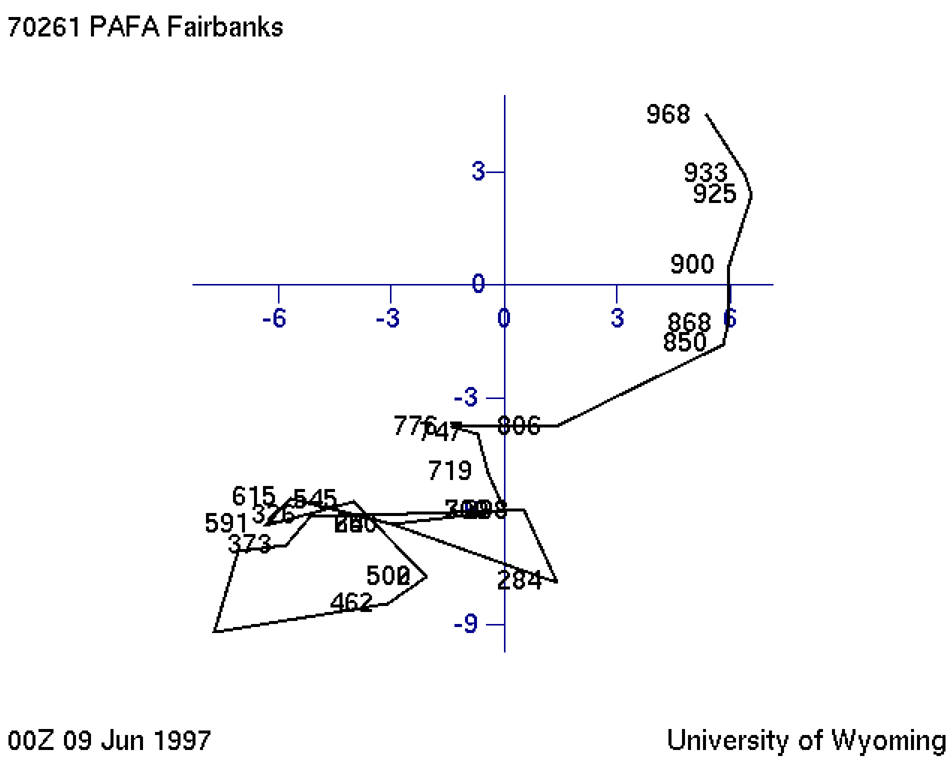

Figure 3, Hodograph for Fairbanks, 09JUN97, 00Z

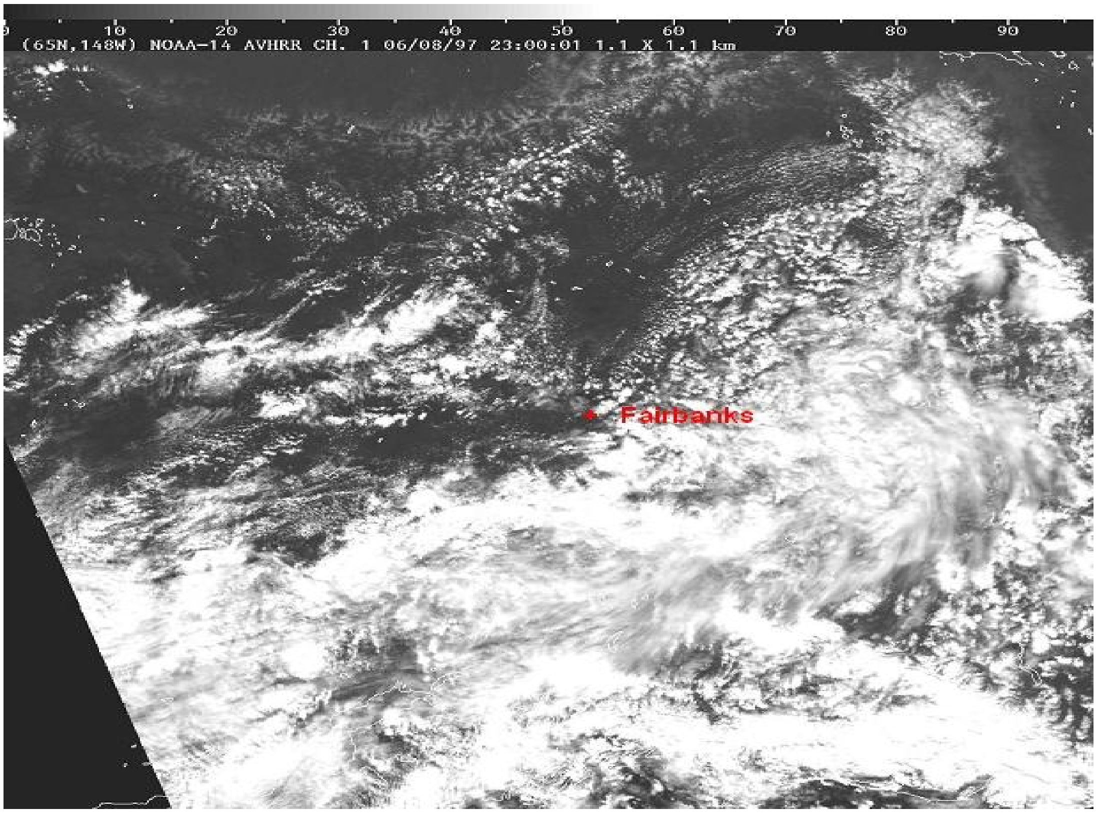

Figure 4, 1 KM POES Visual Image centered over Fairbanks, 2300GMT 08JUN97

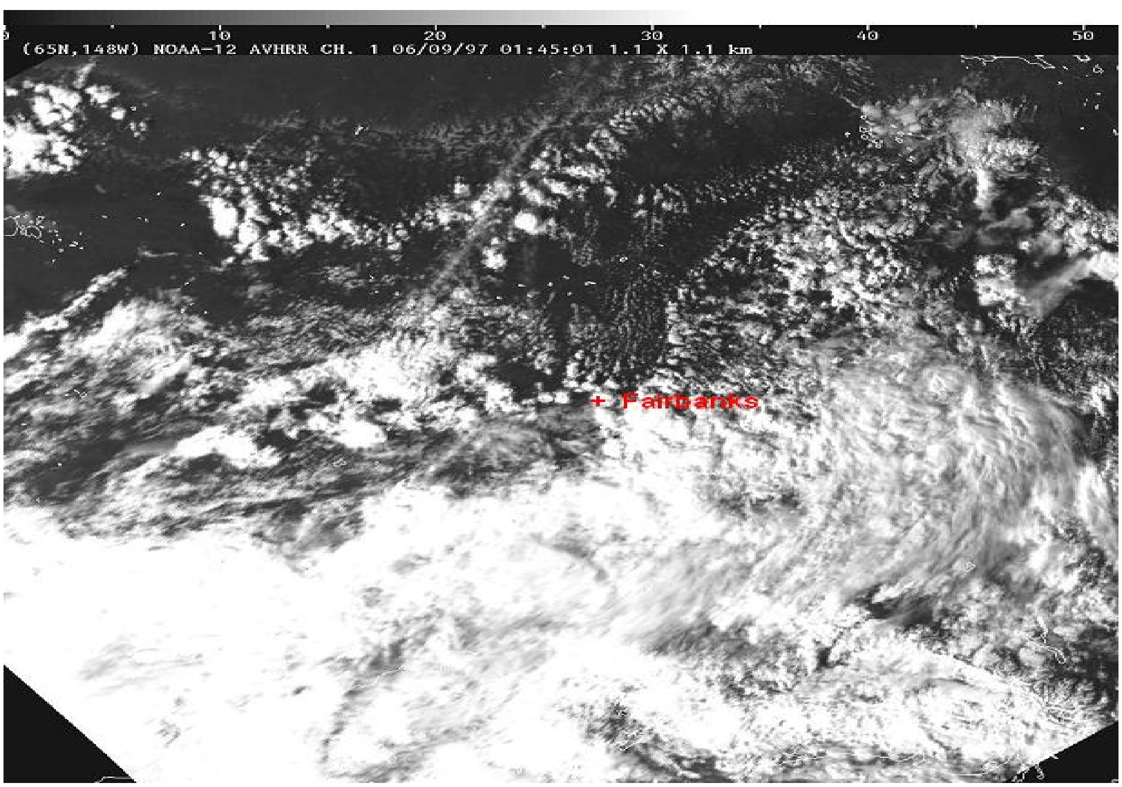

Figure 5, 1KM POES Visual Image centered over Fairbanks, 0145GMT 09JUN97

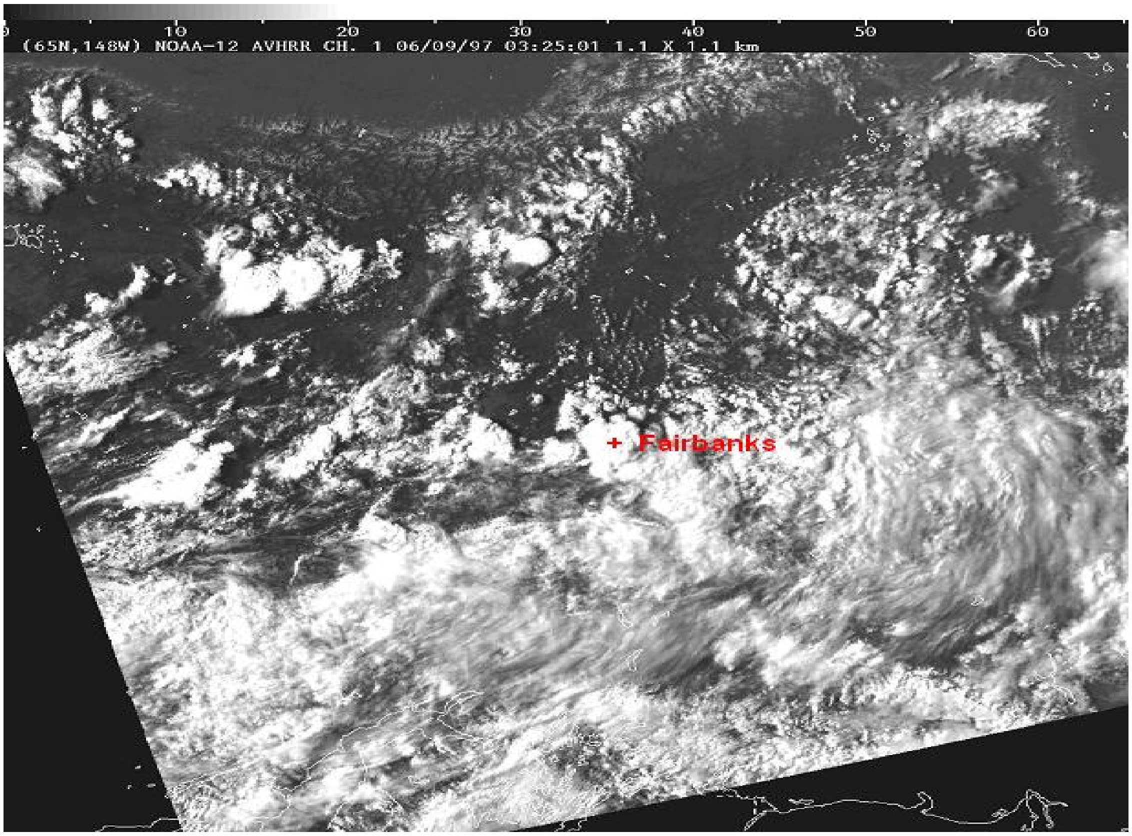

Figure 6, 1 KM POES Visual Image centered over Fairbanks, 0325GMT 09JUN97

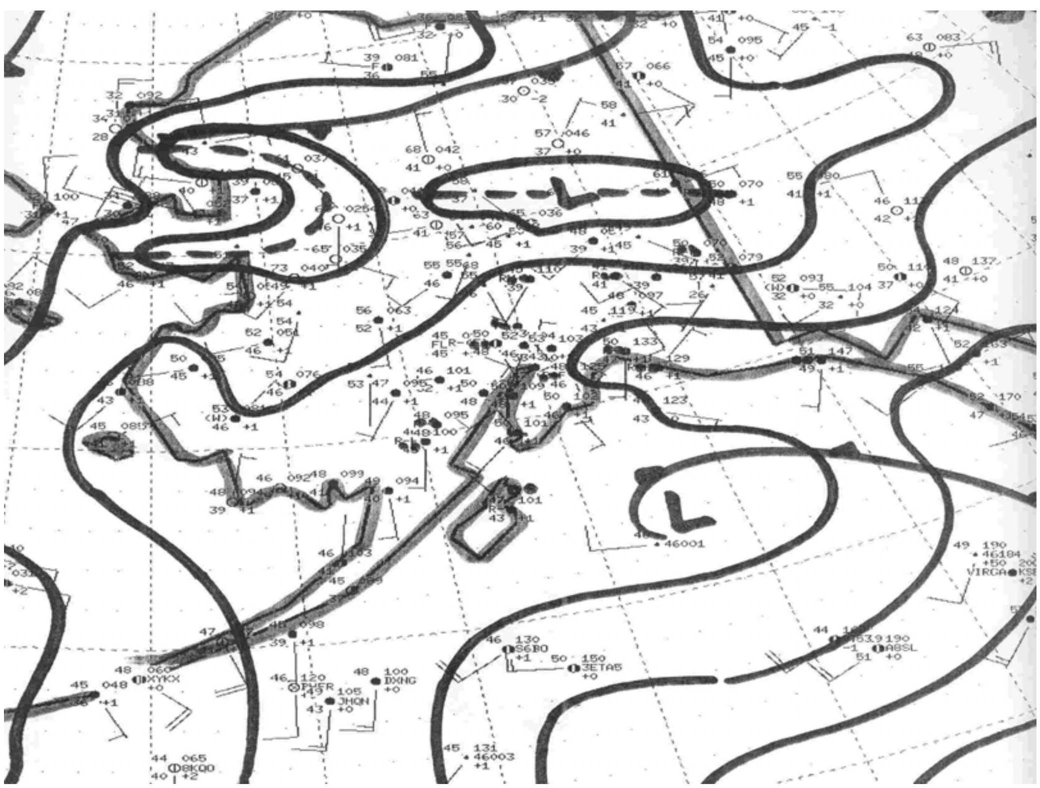

Figure 7, Surface Analysis, 0600GMT 09JUN97

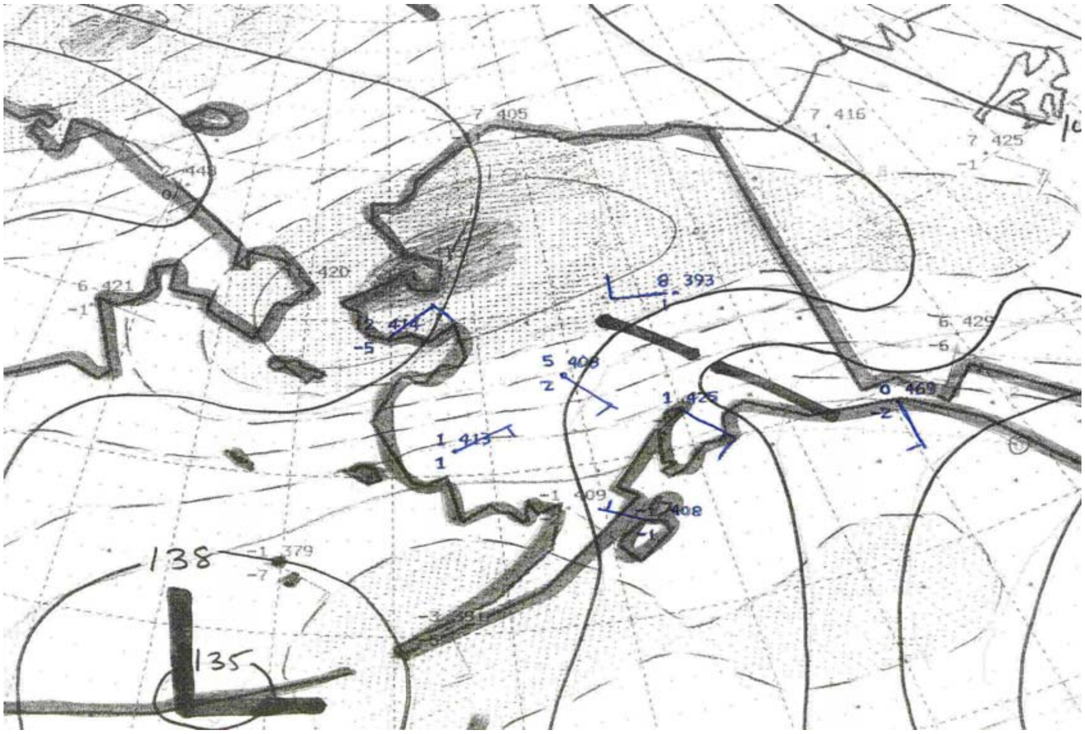

Figure 8, 850 millibar analysis, 0000GMT 09JUN97

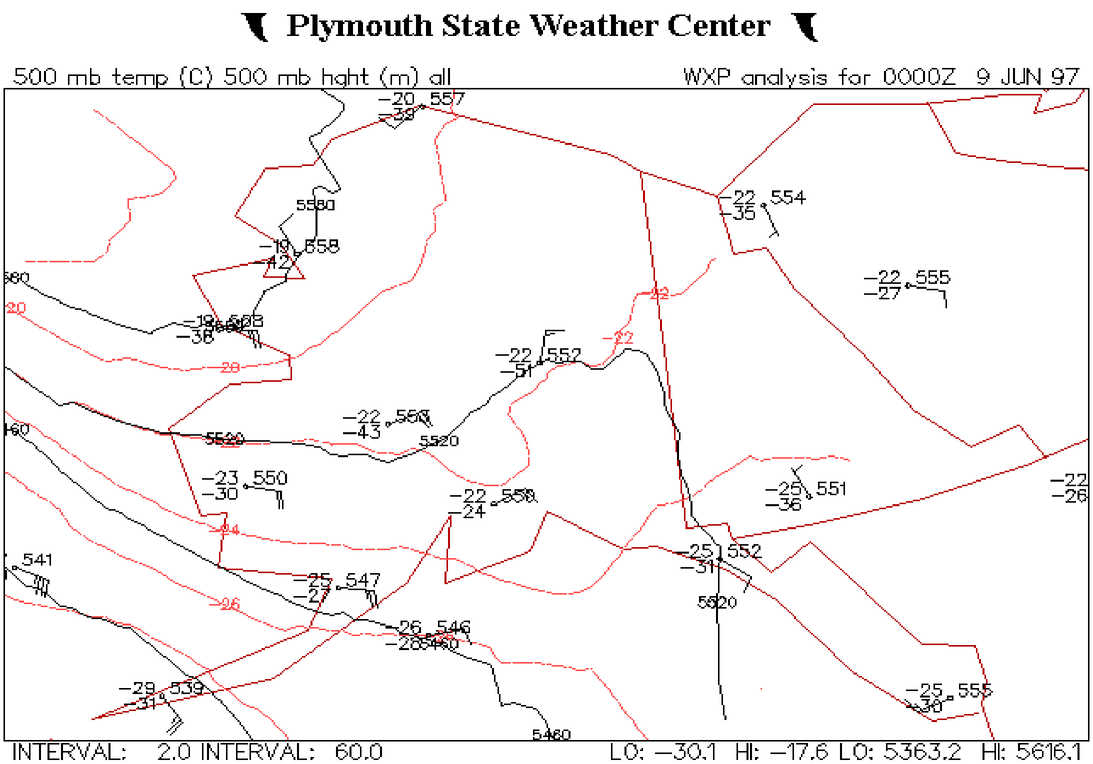

Figure 9, 500 millibar analysis, 0000GMT, 09JUN97

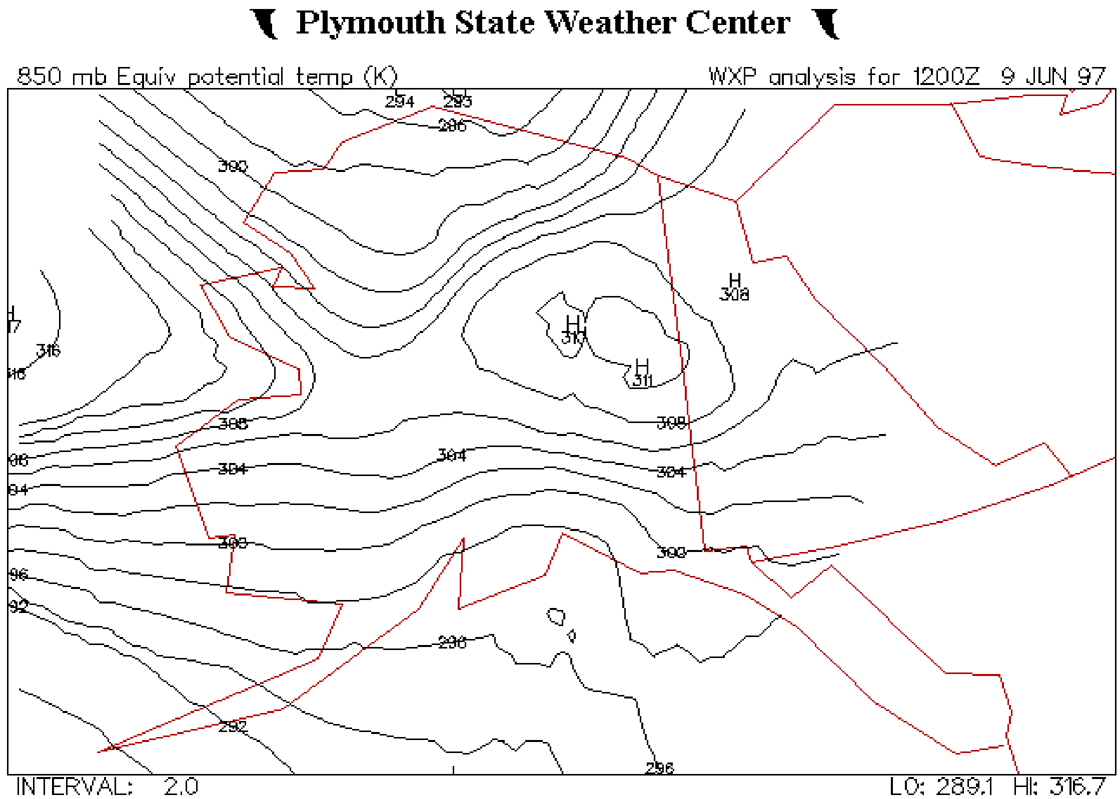

Figure 10, 850 millibar Equivalent Potential Temperature Analysis, 0000GMT 09JUN97