NOAA Technical Memorandum ERL CMDL-5

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Abstract. The fourth Arctic Gas and Aerosol Sampling Program (AGASP-IV) was conducted over Alaska and the Beaufort Sea during March and April 1992. The NOAA WP-3D aircraft made nine flights. On the first eight flights special aerosol and gas sampling instrumentation was installed, and extensive time was spent over the pack ice. Measurements of wind, pressure, temperature, relative humidity, ozone, and condensation nucleus (CN) concentration were used to identify the air mass type, recent origin, and existence of pollution-derived aerosols, i.e., haze. While small patches of elevated CN concentrations and higher aerosol scattering coefficients were observed, significantly large regions, of the type found in previous AGASP missions, were not observed during this series. On most flights the CN concentrations in the troposphere were representative of "clean" background conditions at this latitude. Significant concentrations of CN (CN>7000 cm^{-3}) found above the tropopause on three flights indicated the presence of volcanic aerosol probably from the Pinatubo volcanic plume at high latitudes. In four instances low ozone concentrations suggest the destruction of ozone in the surface layer.

1. INTRODUCTION

The Arctic sampling expeditions known as the Arctic Gas and Aerosol Sampling Program (AGASP) were organized and directed by the National Oceanic and Atmospheric Administration (NOAA) and by the Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, to determine the distribution, chemistry, radiative effects, and transport of Arctic air pollution. The first field research program, AGASP-I, March-April 1983, consisted of airborne measurements in conjunction with baseline measurements at Barrow, Alaska; Alert northwest Territories (NWT); and Ny Alesund, Svalbard (Schnell, 1984). The second sampling program, AGASP-II, April 1986, was conducted over Alaska and northwest Greenland in the vicinity of the Canadian baseline station at Alert, NWT (Schnell et al., 1989). The third sampling program, AGASP-III was conducted over the Scandinavian Arctic in the vicinity of Svalbard, (Herbert et. al., 1993) as part of the Coordinated Eastern Arctic Experiment (Williams et al., 1991).

On the basis of aerosol chemistry measurements from the Geophysical Monitoring for Climatic Change (GMCC) station at Point Barrow, Alaska (BRW), for the period 1978-1979, Rahn and McCaffrey (1980) described Arctic haze as the abundance of tropospheric aerosol of midlatitude origin that has been transported to the Arctic. Over northern Alaska the haze exhibits a pronounced seasonally; late winter-spring values are an order of magnitude larger than the typical summer values (Bodhaine, 1986). The vertical distribution of haze in the vicinity of Barrow was measured for the first time during the AGASP-I flights (Schnell and Raatz, 1984). For the period when the highest concentrations of aerosol were observed aloft, air mass trajectory analysis indicated a likely source region to be northeastern Europe (Harris, 1984). During AGASP-II, Aitken nuclei concentrations in excess of 6000 cm^{-3} were observed in conjunction

with strong evidence of gas-to-particle conversion in polluted air of northwestern European origin (Herbert et al., 1989).

AGASP-IV was conducted as part of a larger atmospheric/oceanographic Leads Experiment (LEADEX). The main objective of LEADEX was to study energy fluxes from open leads, and the impact of synoptic-scale and mesoscale meteorological systems on the Arctic ice pack. The purpose of the AGASP-IV was to measure the properties of Arctic aerosol and gases, with particular reference to Arctic haze and its composition, source, and transport, and to determine the Arctic springtime radiation budget, with particular attention to surface reflectance, air chemistry, and aerosol physics under cloud and cloud free conditions. When the aircraft was in the vicinity of the NOAA/CMDL observatory at Point Barrow, comparative ground-based measurements were made there. To the maximum degree possible, aerosol and chemistry measurements were made on every flight. A detailed discussion of the instrumentation aboard the aircraft which was the same as in AGASP-II, can be found in Schnell et al. (1989).

In this paper we present a description of eight of the nine flights conducted and a discussion of meteorological conditions in the Alaska region at the time of each flight. Aerosol and gas sampling instruments were not operated on the ninth flight. The distribution of meteorological variables as a function of height and distance along the aircraft flight track was analyzed to delineate the changes in air mass encountered. Changes in air mass connote changes in the source regions of influence to aerosol and gas sampling. For that reason the discussion was focused on the discontinuities in meteorological variables encountered along the flight track.

The data used in this analysis were obtained from the printed copy of selected measurements taken from the WP-3D onboard printer, and a recording of selected meteorological variables made as part of the process of compiling a real-time metalog, contained in the flight log for each flight. Although both records had interruptions, by combining the two it was possible to account for all but about 30 minutes of the total flight time. In some instances during the first two flights, and for brief periods during subsequent flights, data from some of the instruments were not being recorded on the printer or aircraft display. These lapses affected the aerosol and ozone measurements more often than the standard meteorological variables. Because the data used have received only a preliminary quality check, the results presented may undergo slight alteration when tested against the values obtained from the more complete magnetic tape record. Thus the report deals only with changes in values that can be attributed to significant changes in the structure of the atmosphere, i.e., changes of 10% or greater.

2. FLIGHT 401, MARCH 30-31, 1992

2.1 Objective

The NOAA WP-3D arrived in Anchorage (ANC) on March 18. After 2 days of crew rest and instrumentation preparation, the aircraft was available for the first sampling mission. There was considerable moisture and cloudiness over the Beaufort Sea during this period, because of persistent southerly flow over Alaska. An AGASP mission was not flown immediately because of the cloudiness and the inability to make representative turbidity measurements.

The first flight eventually was called by the LEADEX crew to study the structure of the mesoscale wind field over the pack ice using dropwindsondes and the boundary layer structure in a region of open leads. The region in the vicinity of the "Ice Camp" (72.53°N, 144.38°W) was selected for this study. The flight track (Fig. 2.1) was from ANC to over Fairbanks (FAI) and then to a point over the crest of Brooks Range at 69°N 144°W, in the vicinity of Mt. Michelson. From that point the NOAA WP-3D aircraft proceeded to 74°N 141.3°W where a crossing pattern was begun to provide the proper distribution to the dropwindsondes, centered on the Ice Camp.

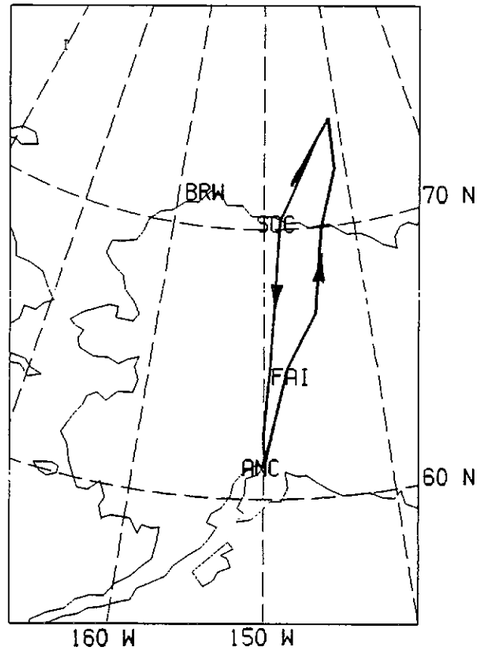

Figure 2.1. Horizontal projection of the aircraft flight track on a latitude-longitude grid, March 30-31, 1992.

The aircraft reached cruising altitude of 5.8 km at 62.3°N, 149.5°W, 21 minutes into the flight and maintained this pressure altitude (PA) until the descent to the surface was begun at 72°N, 145.7°W. The slow, uniform descent from 485 mb to 1020 mb took 34 minutes, an average rate of ~16 mb min^{-1} (171 m min^{-1}). The low-level survey was confined to the lowest 70 m. After only 31 minutes at low altitude the number one engine failed and low-level sampling was terminated (73.2°N, 143.4°W). The aircraft returned to ANC via a southerly track over FAI.

2.2 Flight Log

Because of technical difficulties with the metalog software, a detailed flight log is available only for select portions of the flight. The header for each entry in the flight log contains the time HH:MM in UTC, the latitude in degrees north, the longitude in degrees west, and the static pressure in millibars at flight level. For each flight, log comments can be referenced to the aircraft profiles in the respective latitude-altitude cross-section of potential temperature using these variables. Note that UTC and Z are used interchangeably for times in this report.

17:11	Take off from ANC.
17:43 63.22 149.00 485	Ozone as plotted on the strip chart recorder on this flight has an 18 ppbv offset from the panel reading. Example: panel - 48 ppbv; chart - 66 ppbv. Offset is linear.
18:30 66.55 145.28 485	Problems encountered on this flight: 1) nephelometer strip chart is not recording; 2) ozone plots to strip chart with an offset; 3) CN data not being recorded by aircraft data acquisition system (ADAS); 4) belt on aerosol transfer pump (ATP) is loud (need to tighten)!; 5) check to verify that ADAS is seeing Dasibi signal; 6) CO_2 flasks can't be fully pressurized at high altitudes - change inlet to forward-facing.
20:36 72.00 145.50 486	Down at lowest legs; (radar altitude (RA): 15-20 m, RA: 60 m); ozone was at 5-10 ppbv.
20:38 72.05 145.80 485	Starting descent over the Beaufort Sea.
20:40 72.15 145.52 500	Hazy or cloudy at this level, hard to tell which.
20:46 71.99 146.31 600	Slight increase in ozone, aerosol scattering is holding steady.
20:48 71.85 146.48 620	Very white, milky obscured visibility.
20:57 72.10 146.12 770	Still milky white, can barely discern the horizon, no evidence of layering.
20:59 72.00 146.36 811	Out of clouds, horizon is now clearly visible. aerosol scattering decreasing.
21:02 71.86 146.68 850	Scattered high cirrus overhead, aerosol scattering dropping fast.
21:05 71.86 146.38 900	Maximum temperature, light turbulence, in clouds again, clouds are thickening.
21:08 71.86 146.75 950	Very cloudy, overcast, horizon is not visible.
21:09 71.81 146.85 960	Winds SE 17 kt. Aerosol scattering increasing in the boundary layer.
21:11 71.80 146.75 1000	Horizon not visible, cloudy, light turbulence.

21:14 71.90 146.41 1021	Beginning low-level patterns, 16 m.
21:17 72.10 146.11 1021	Level at 20 m, horizon is not visible, estimated visibility 0.25 mi.
21:30 72.60 144.90 1014	Opening up to the north, the ice is uniform here, getting brighter.
21:33 72.72 144.60 1017	Brighter now. Heading toward the Ice Camp.
21:35 72.80 144.40 1016	Out from under the clouds. Slight turbulence. Ice Camp to left of plane, at 21:3514.
21:38 72.93 144.12 1017	Scattered to broken clouds aloft.
21:40 73.02 144.10 1017	Ozone was shut off because the ATP was really loud.
21:42 73.10 143.72 1017	Getting into low cloud again, aerosol scattering going up.
21:45 73.21 143.38 1018	Aerosol scattering climbing to 90×10^{-6} m^{-1} momentarily, patches of ice crystals are possibly the cause, just lost the #1 engine.
21:46 73.28 143.28 989	End of low-level run, returning to ANC by the most direct route.
21:52 73.07 143.46 773	Aerosol scattering at background levels.
22:04 72.46 144.60 514	Returning to ANC at 18,000 ft. No stratospheric data on this flight.
00:46 61.29 150.25 916	At 1 km during descent into Anchorage, nephelometer turned off.
00:50 61.11 150.10 957	ASASP and FSSP probes off for landing.
00:51	Landing at Anchorage.

2.3 Synoptic Situation

A weak low-pressure trough positioned over central Alaska was the dominant mid-tropospheric feature at the time of this flight. The trough was part of a larger low pressure system at 80°N, 175°W (Fig. 2.2). During the 24-h period centered on the time of the flight, the region of lowest pressure moved from west of ANC to a point north of FAI. The pressure gradient in the trough and over the state was weak with 500 mb winds at all stations less than 15 ms^{-1}.

At the surface (Fig. 2.3) a low pressure region on the Canadian-Alaskan border and extending north to over Banks Island was associated with the trough aloft. North of the coast in the vicinity of the Ice Camp, and to the west of the trough, winds were easterly 10-15 m s^{-1}. Broken to overcast low clouds were reported in this region. To the south along the coast, winds were very light (<3 m s^{-1}) from the southeast. Skies were overcast with bases reported to be less than 1 km. Satellite images indicated that the source of the coastal moisture was an extensive area of open water to the west of Banks Island.

There was considerable cloudiness below flight altitude over the Alaska Range, south of FAI. At the time both ANC and FAI were reporting scattered clouds. Between FAI and the crest of the Brooks Range conditions were less cloudy. To the north of the Brooks Range there was considerable cloudiness below 500 mb. Deadhorse (SCC), Lonely, and Barrow (BRW) were reporting low overcasts at 0000Z March 31. Patches of ice fog were encountered during the low-level flight legs near the Ice Camp.

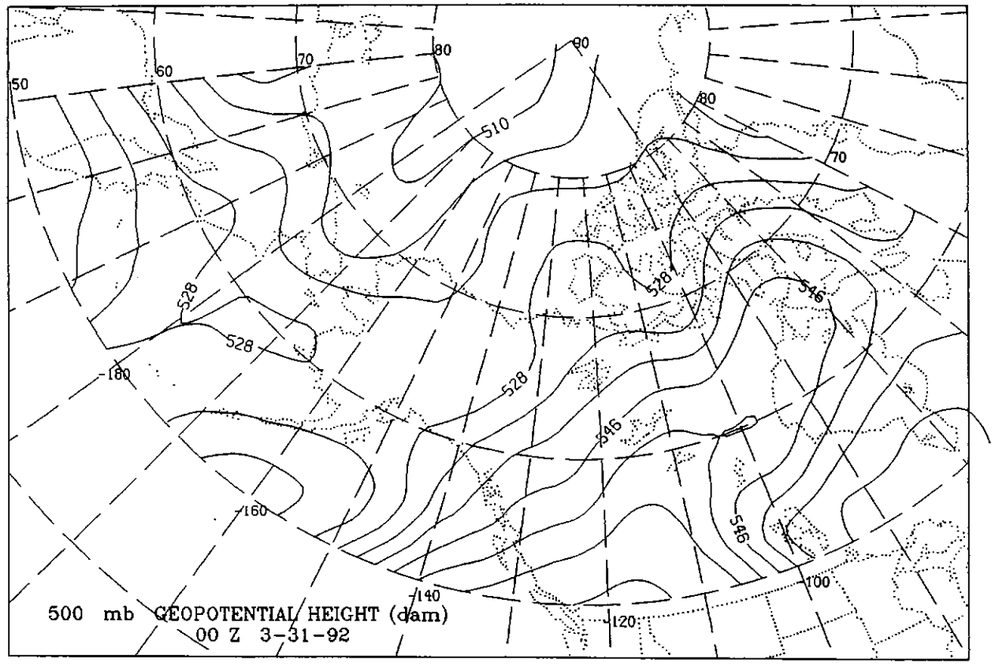

Figure 2.2. 500 mb synoptic map for 0000 UTC, March 31, 1992. Indicated are height contours in geopotential decameters.

2.4 Atmospheric Cross Section

In Fig. 2.4 data at different times and locations are combined to present a composite cross section of the thermal structure of the atmosphere. Each measurement platform is shown by a dashed line. The observations of wind and temperature from rawinsondes were shown to extend from the surface to the top of the chart, 250 mb. The three rawinsondes were from ANC, FAI, and the Ice Camp (CAM). They were launched at 0000Z, March 31. The second form of sounding represented in the cross section is an Omega dropwindsonde (ODW) that was released from the WP-3D at 2004Z March 30 at 74°N. ODWs measure wind, temperature, and humidity as a function of pressure. Rawinsonde and dropwindsonde data used in this report are plotted on adiabatic diagrams in the Appendix. The third set of data plotted on the cross section was that from the aircraft itself, which spans the time from takeoff to landing, 1711Z March 30 to 0051Z March 31. Since there were as much as 6-h time discrepancies between platform intersection points, it is not surprising that there are differences in the winds and temperatures. The analysis is in terms of potential temperature, which tends to be conserved in stable layers associated with frontal zones.

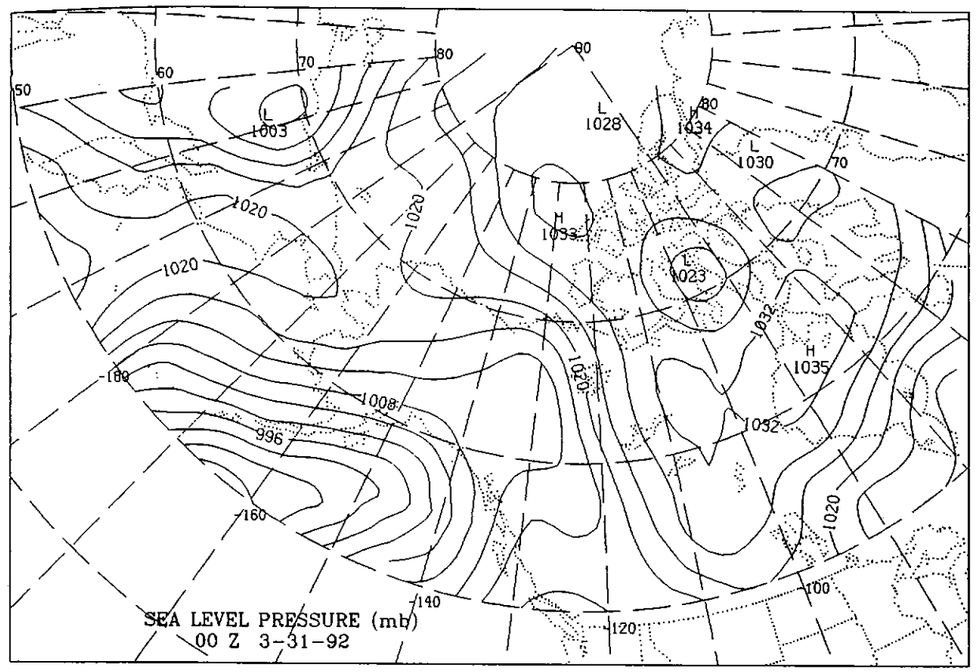

Figure 2.3. Surface synoptic map for 0000 UTC, March 31, 1992. Indicated are surface pressure contours in millibars.

During the climb to transit altitude, the aircraft encountered a weak stable layer at 900 mb (Fig. 2.4). A second layer at 700 mb was possibly associated with a frontal zone to the south of ANC. The tropopause position was determined by the changes in lapse rate measured by the three rawinsondes. The temperature changed less than 4°C along the transit segment, indicating the absence of any significant discontinuities. The soundings over the Beaufort Sea depict an elevated stable layer at 730 mb and the top of the Arctic inversion at 850 mb.

2.5 Discussion of Sampling Conditions

Because of an unresolved problem in acquiring the condensation nuclei (CN) concentration and ozone data, records were not available for much of this flight. For a limited period (1730-1935Z), though, during the northbound transit segment, the ozone values were observed to be in the mid-30's to mid-40's ppbv range, indicative of the midtroposphere. There is no indication in the wind or temperature field, as measured along the northbound or southbound transit segments at 485 mb, of any significant discontinuities. The tropopause position at 450 mb over FAI supports the wind shift in the FAI sounding at that level. Ozone concentrations were not recorded during the remainder of the flight. The aerosol scattering coefficient increased to

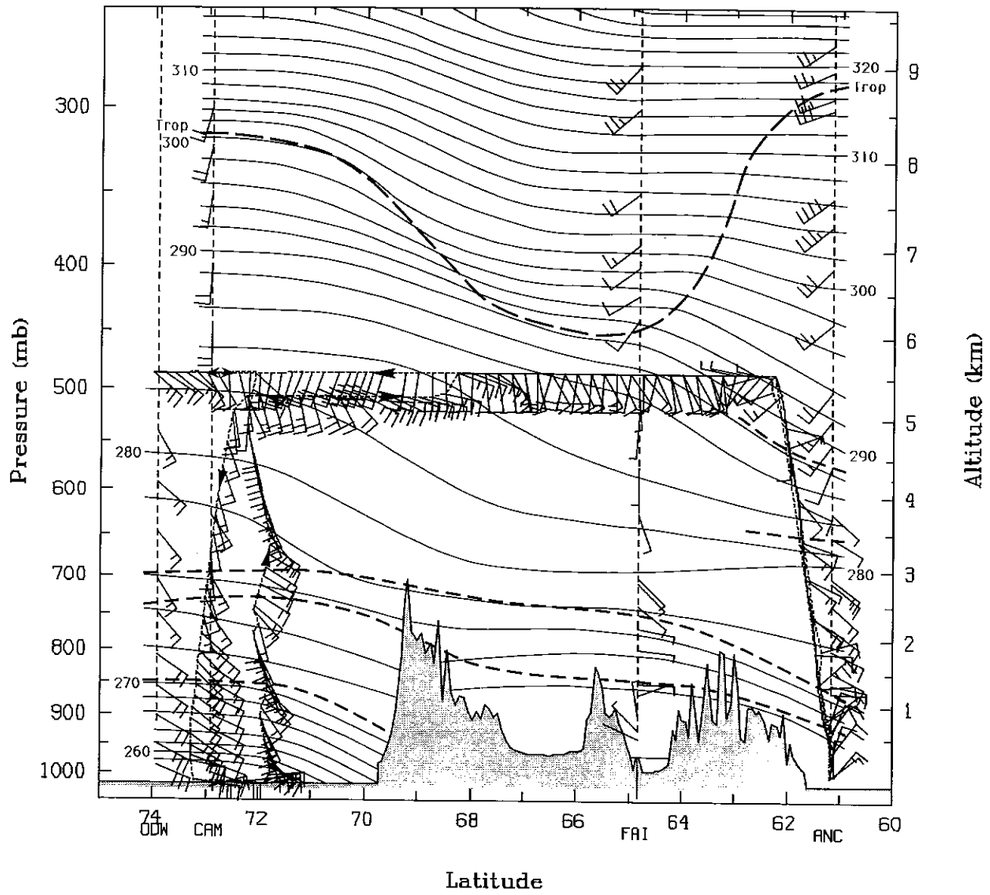

Figure 2.4. Latitude-altitude cross section of potential temperature (K, solid contours) and wind (1 barb = 10 knots) between Anchorage and 74°N, 1709-0052 UTC March 30-31, 1992. The tropopause and top of the Arctic boundary layer are indicatd by thick long-dashed lines, stable layers and frontal zones by thick short-dashed lines, and the aircraft flight track by thin dashed lines. Arrows indicating the direction of the aircraft are placed at the beginning of each hour. The vertical dashed lines show the aircraft dropwindsonde location (ODW) and rawindsonde locations (CAM, FAI, ANO).

more than 10^{-5} m^{-1} shortly before the Beaufort Sea descent was begun, but returned to significantly lower values by 600 mb.

Changes in the lapse rate at 730 and 850 mb marked the top of the two most significant layers encountered during the descent over the Beaufort Sea. Aerosol scattering coefficients

changed little during the descent, remaining in the 10^{-5} to 10^{-6} m^{-1} range throughout. There was no evidence of the layering observed in earlier AGASP flights (Herbert et al., 1989). According to the flight log, there was considerable moisture in the form of ice crystals observed during the descent. During the low-level sampling segment the aerosol scattering coefficients were more variable than during the descent. But according to the flight log, the visibility was also reduced by "Arctic smoke" or steaming fog from the open leads at this time. It is most likely that the variations in aerosol scattering were caused by ice crystals in the optical path of the nephelometer. For the remainder of the return to ANC, the values were in the (2-12) $\times$ 10^{-5} m^{-1} range. Meteorological conditions during the southbound transit were similar to those on the outgoing leg.

Weak southerly winds along the entire length of the transit segments, coupled with cloudiness at flight level, suggest the air mass to be of North Pacific origin. Below 700 mb over the Beaufort Sea winds to the east indicate that local transport was along the North Coast, where there are significant regions of open water, extending back 48-72 hours over northern Canada.

3. FLIGHT 402, APRIL 10-11, 1992

3.1 Objective

On April 5 the replacement engine was successfully flight tested and the WP-3D was certified ready to continue the sampling program. For the next few days conditions north of the Brooks Range were less than favorable for monitoring Arctic haze. For the period April 6-10, BRW reported broken to overcast conditions with westerly winds, changing to clear to scattered conditions early on April 7. Later in the day (1700Z) the wind shifted to easterly and the cloud cover returned. By 1000Z April 8, BRW was reporting light snow. Light snow and fog continued until 00004Z April 10. On the basis of a forecast for clearing and a shift to northerly winds of 5-10 m s^{-1} in the surface layer and northeasterlies of 8-15 m s^{-1} aloft during the next 24 hours in the BRW region, an AGASP flight was scheduled for April 10-11.

The WP-3D took off at 1715Z April 10 and followed a flight plan taking it over Fairbanks, at which point the plane turned toward the north, following latitude 148°W to 72°N (Fig. 3.1). The aircraft reached flight altitude (6.1 km, 465 mb) 20 minutes after takeoff. During the period 1757 to 1815Z, the aircraft climbed to 7.3 km in search of the tropopause. At 1834 the aircraft left that altitude, climbing to 7.95 km (1839Z). The WP-3D remained at that altitude until 1951Z when the descent profile was begun.

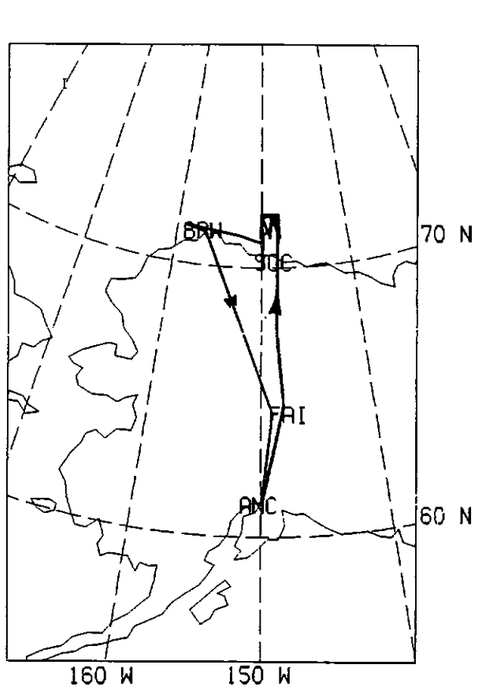

Figure 3.1. Horizontal projection of the aircraft flight track on a latitude-longitude grid, April 10-11, 1992.

The portion of the flight path over the Beaufort Sea consisted of three segments, starting with a vertical profile 220 km upwind, northeast of BRW, followed by a low-level traverse on a north-south heading to sample the plumes from the Prudhoe Bay region. The third leg consisted of a cross-wind traverse to the north of BRW at the top of the planetary boundary layer. The profile began with a westerly segment from 1942 to 1952Z, to provide a clear view of the sun for turbidity measurements. The aircraft descended at an average rate of about 200 m min^{-1} (16 mb min^{-1}). At 2022Z, the aircraft conducted a second westerly segment for turbidity measurements. The descent was continued at 2033Z, reaching the lower sampling level of 1015 mb (0.15 km) at 2057Z. A third radiation segment was flown from 2107 to 2119Z.

The second portion of the flight consisted of a level segment along 150°W from 72°N to 70°N, at 150 m altitude, and back to 71°N, at 330 m altitude (991 mb). This segment started at 2119Z, reaching the southernmost point at 2202Z and ending at 2224Z. From 71°N, 150°W the aircraft took a heading of 290° to sample a cross section of air upwind of BRW. At 156.61°W, the longitude of BRW, the WP-3D passed about 13 km to the north of the station. The first half of this segment was flown at a height of 150 m (1018 mb), the second part at 90 m (1029 mb). At 159°W (2330Z) the aircraft turned toward the east and began a gradual climb to a maximum altitude of 9.5 km. (0040Z), after which the airplane began a gradual descent into Anchorage via Fairbanks. The WP-3D landed at 0242Z.

3.2 Flight Log

17:15				Take off, flight 402.
17:31	62.10	149.60	503	Undercast, partly cloudy to here.
17:34	62.27	149.49	466	Horizon is not visible.
17:35	62.36	149.43	464	Ice crystals, cirrus in this region.
17:38	62.58	149.24	464	Ground not visible.
17:53	63.67	148.76	464	Clear at flight altitude now.
17:53	63.69	148.74	465	Clouds below over Alaska Range.
17:59	64.12	148.47	443	Clear at altitude, scattered clouds below
18:00	64.15	148.45	435	Started detecting higher ozone. Gradually climbing through 6.5 km, which appeared from the FAI sounding to be roughly the base of the tropopause.
18:10	65.00	147.99	426	1200Z Fairbanks sounding shows a stable layer from 410 to 360 mb.
18:11	65.13	147.10	423	Cannot discern the horizon now, clearer south of Fairbanks.
18:12	65.19	148.01	418	Orographic clouds below.
18:15	65.43	148.07	391	Orographic undercast, horizon obscured.
18:31	66.67	148.33	391	Horizon obscured, cirrus.
18:32	66.68	148.33	391	Brownish layer on the horizon.
18:33	66.72	148.34	391	Seems obscured at altitude.
18:34	66.82	357.00	391	Undercast over the Brooks Range.
18:41	67.34	148.44	358	Clear above, thin undercast below, ozone peak.
18:46	67.72	148.48	358	Brooks Range is obscured, over crest of mountains now.
18:49	68.01	148.48	358	Brooks visible through thin clouds.

18:53	68.30	148.48	358	Brooks are barely visible.
18:58	68.68	148.46	358	Thin obstruction below.
18:59	68.77	148.45	358	Dropwindsonde no. 1 released.
19:05	69.22	148.45	358	Thin obstruction below.
19:06	69.31	148.45	358	Dropwindsonde no. 2 released.
19:22	70.64	148.34	358	Breaks in the undercast.
19:27	71.04	148.25	358	Horizon is obscured, Pat Sheridan thinks it is haze.
19:35	71.70	148.10	359	Approx. 5 minutes to start of radiation profile pattern.
19:42	72.07	147.72	359	Begin radiation (RAD) pattern at 7950 m.. Start RAD run #1.
19:52	71.99	150.31	359	Starting the descent profile, following the level radiation leg.
19:52	71.99	150.35	361	Visibility is obscured. Ozone in a range of 70-90 ppbv.
19:56	71.99	150.05	387	Visibility obstruction is uniform, increase in aerosol scattering, drop in ozone.
19:58	71.83	149.65	404	Tropopause at 395 mb.
20:00	71.71	149.40	414	For the past half hour, ozone has shown a very strong anticorrelation with nephelometer channel #3 (larger particles.
20:02	71.62	149.22	427	Inverse correlation in ozone and aerosol scattering at the tropopause.
20:09	71.71	148.60	1011	Visibility obscuration is uniform.
20:17	71.99	148.05	704	Ice looks slightly fuzzy.
20:20	72.02	147.88	795	Start RAD run #2 at 1536 m PA.
20:21	71.99	148.11	841	Begin midlevel radiation run.
20:34	72.03	150.15	852	Descent to 500 ft.
20:55	71.68	148.66	1008	Slight turbulence.
20:56	71.72	148.58	1012	Aerosol scattering holding steady at about 10×10^{-6} m^{-1}.
21:07	71.99	148.00	1014	Start RAD run #3 at ~150 m radar altitude (RA) (~500 ft).
21:10	71.99	148.50	1014	Slight turbulence.
21:20	71.97	149.96	1015	Turning toward Deadhorse, run at 500 ft.
21:22	71.82	149.97	1015	Visibility 3-4 mi, cloudy or hazy.
21:23	71.80	149.97	1015	Slight turbulence.
21:47	70.61	149.88	1013	Visibility down to about 1 mi.
22:13	70.46	150.02	987	Slight turbulence.
22:17	70.64	150.02	990	Slight turbulence.
22:23	70.89	150.02	991	Over the ice, visibility slightly improved, est. 3-4 mi.
22:24	70.93	150.06	991	Visibility est. 3-4 mi.
22:29	71.00	150.70	991	At 1000 ft RA.
22:43	71.21	152.80	1016	Visibly increased to 5-6 mi.
23:00	71.35	155.03	1018	Track: 281°. Not many leads at east end of run, but by ~156°W, we are flying over leads.
23:18	71.47	157.59	1031	Descend from 100 ft RA to 17 m RA. Collect DMS sample for ~5 minutes over ice with leads.
23:41	71.35	157.55	899	While north of BRW, visibility est. 6-8 mi.

23:44	71.32	157.22	881	Significant patches of open water north of BRW.
23:43	71.33	157.32	887	At this point there is a brownish layer above us.
23:44	71.31	157.15	878	The brownish layer contrasts with the white haze looking into the sun.
23:49	71.21	156.50	819	Passed directly over BRW.
23:50	71.15	156.45	799	Ground obscured by clouds or haze. Slight increase in CN and aerosol scattering.
23:57	70.78	156.05	682	Hazy looking into the sun.
00:02	70.00	155.67	608	The nephelometer and CN counter don't operate well at these rates of climb.
00:03	70.47	155.62	572	Nephelometer and CN counters are responding irrationally.
00:05	70.39	155.51	510	Ground is barely visible.
00:15	69.74	154.66	343	Obscured here, cirrus clouds.
00:17	69.58	154.46	343	Now it appears we are above the layer.
00:25	69.05	153.80	313	PA: 8875 m. In stratosphere, high ozone. Nephelometer channel #2 and CN showing increases. Nephelometer channel #3 still low.
00:37	68.15	152.81	287	Still climbing in the stratosphere. PA: 9377 m (~31,000 ft), CN concentrations were sustained over the past ~15 minutes at 2000-4000 cm^{-3}.
01:01	66.43	150.95	374	We are descending looking for an aerosol layer.
01:03	66.26	150.78	388	Out of stratosphere, very light turbulence.
01:03	66.31	150.82	383	Visibility obscured by ice crystals or haze, est. about 1 mi.
01:06	66.12	150.63	406	Descending through 7000 m PA. Larger particles (nephelometer #3) increased in a layer at ~6800 m PA. Another layer at ~6000-6200 m PA.
01:16	65.47	149.91	482	Scattered Cu clouds below.
01:17	65.45	149.88	484	Some Ci at altitude.
01:30	64.71	149.16	490	PA: 5700 m. Slight nephelometer larger particle enrichments.
01:54	63.37	149.64	605	Obscured at this level now.
01:58	63.15	149.75	641	Clouds at this level.
02:03	62.88	149.93	641	Obscured by Sc.
02:08	62.64	149.90	641	We are above the clouds now.
02:16	62.21	150.11	641	Back in the clouds again.
02:42				Land in Anchorage.

3.3 Synoptic Situation

Two days preceding this flight, the 500 mb flow over northern Alaska was determined by a ridge over the Bering Sea and eastern Siberia, with a 516 decameters closed high off the southwest coast, and a small low north of BRW at 75°N. During the next 36 hours the ridge intensified over eastern Siberia and the East Siberian Sea while the closed central portion moved to a position over the Aleutians at 53°N. The low drifted slowly to the southeast to a position over the Beaufort Sea north of Barter Island. With the high forecast to continue to increase in

intensity, and the low forecast to move slowly to the south, the synoptic conditions were favorable for trans-Arctic transport for the first time in a week.

At the time of the analysis (Fig. 3.2), the low was located over north central Alaska, with a central height of 511 decameters. The ridge to the west has split into two segments, a dominant center over central Siberia and a weaker high center south of the Aleutians. A minor ridge over the Beaufort Sea followed the low as it moved to the south.

Anchorage was reporting easterly winds at 5 m s^{-1} and overcast skies, consisting of altostratus clouds with tops below the 500 mb level, at takeoff. Also, according to the flight log, the undercast extended to just south of Fairbanks, where at 1800Z scattered clouds were reported. Skies were generally clear aloft in this region. Approaching the Brooks Range the low-level cloudiness increased to an undercast, and scattered high cirrus was encountered at flight altitude. At the time the WP-3D passed to the west of Prudhoe Bay, Deadhorse was reporting a cirrus overcast with northeasterly winds of 1-2 m s^{-1}. No obstruction to visibility was indicated. One hour later while the aircraft passed Barrow, the observatory there was measuring a wind of 8 m s^{-1} from the north. The observer was reporting scattered clouds, and no obstruction to visibility was indicated.

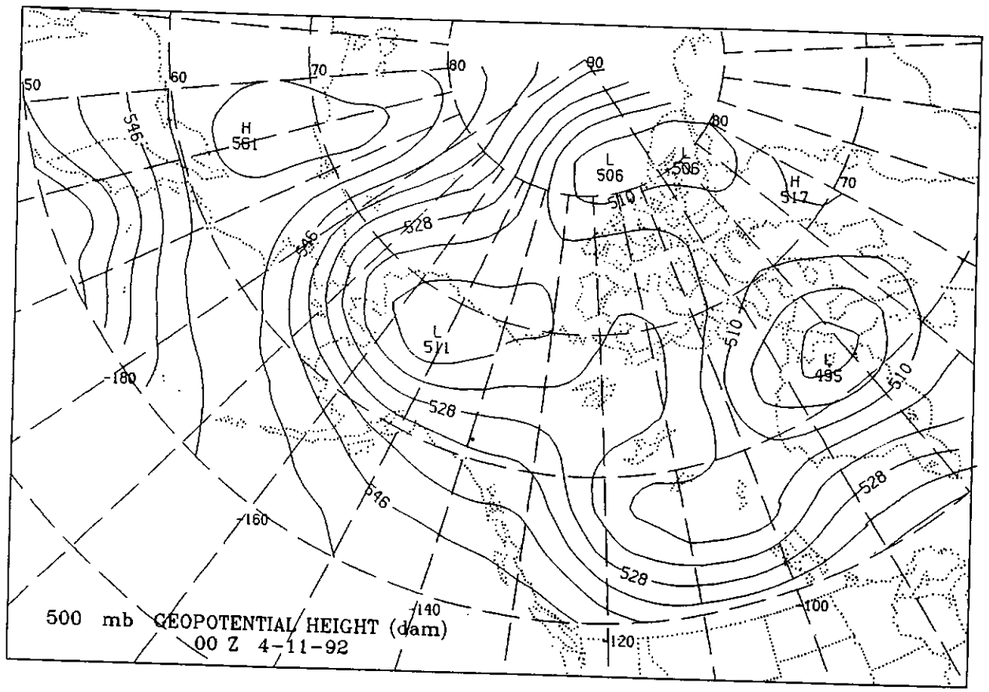

Figure 3.2. 500 mb synoptic map tor 000 TUC, April 11, 1992. Indicatead are height contours in geopotential decameters.

Coupled with the low at 500 mb, a weak low-pressure system was analyzed at the surface on the Alaska-Canada border southeast of Fairbanks (Fig. 3.3). Although not shown in Fig. 3.3, according to the NWS regional analysis, a cold front extended to the west, and a stationary front extended to the southeast along the coastal mountains, from the low. The position of a frontal zone across central Alaska at the time of the flight was indicated by the decrease in cloudiness observed at 64°N. Along the north coast the flow was determined by the Siberian High.

3.4 Atmospheric Cross Section

The cross section of potential temperature along the track of the WP-3D (Fig. 3.4) was determined by the observations obtained aboard the aircraft and the ANC, FAI, SCC, and BRW rawinsondes launched at 0000Z April 11. One dropwindsonde released at 68.8°N was used as well. The aircraft intercepted two stable zones on the ascent from ANC: the lower, a weak stationary front; the upper, at 700 mb, a cold front of significant intensity. The tropopause was first encountered at 67°N, at 400 mb, during the northbound segment. But at 67°N, the concentrations of ozone began to fluctuate between levels typical of the troposphere and the stratosphere. The aircraft was close to the tropopause until the beginning of the descent at 72°N.

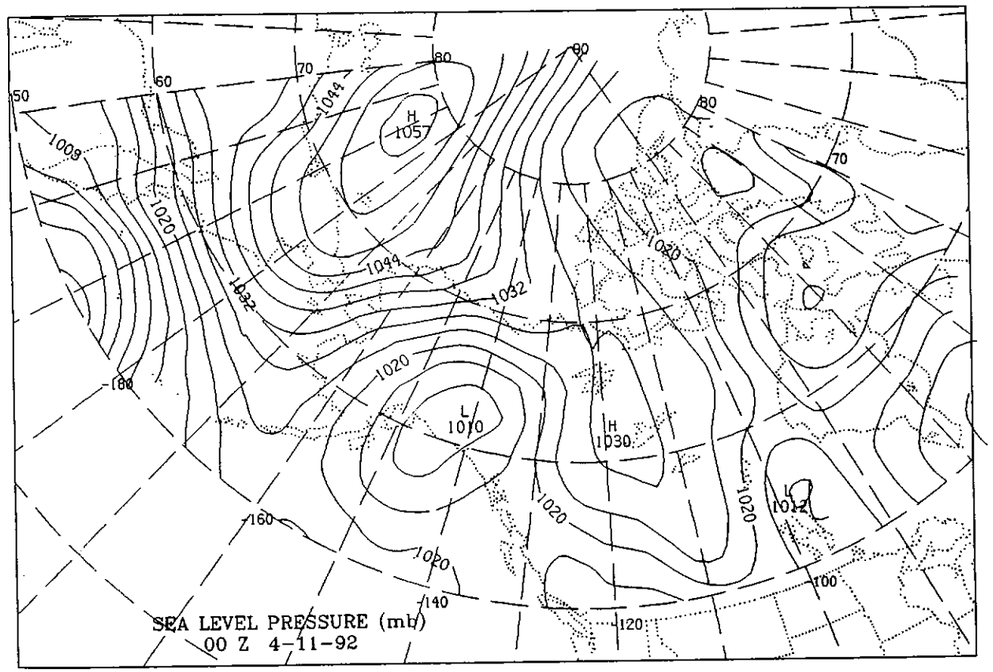

Figure 3.3. Surface synoptic map for 0000 UTC, April 11, 1992. Indicated are surface pressure contours in millibars.

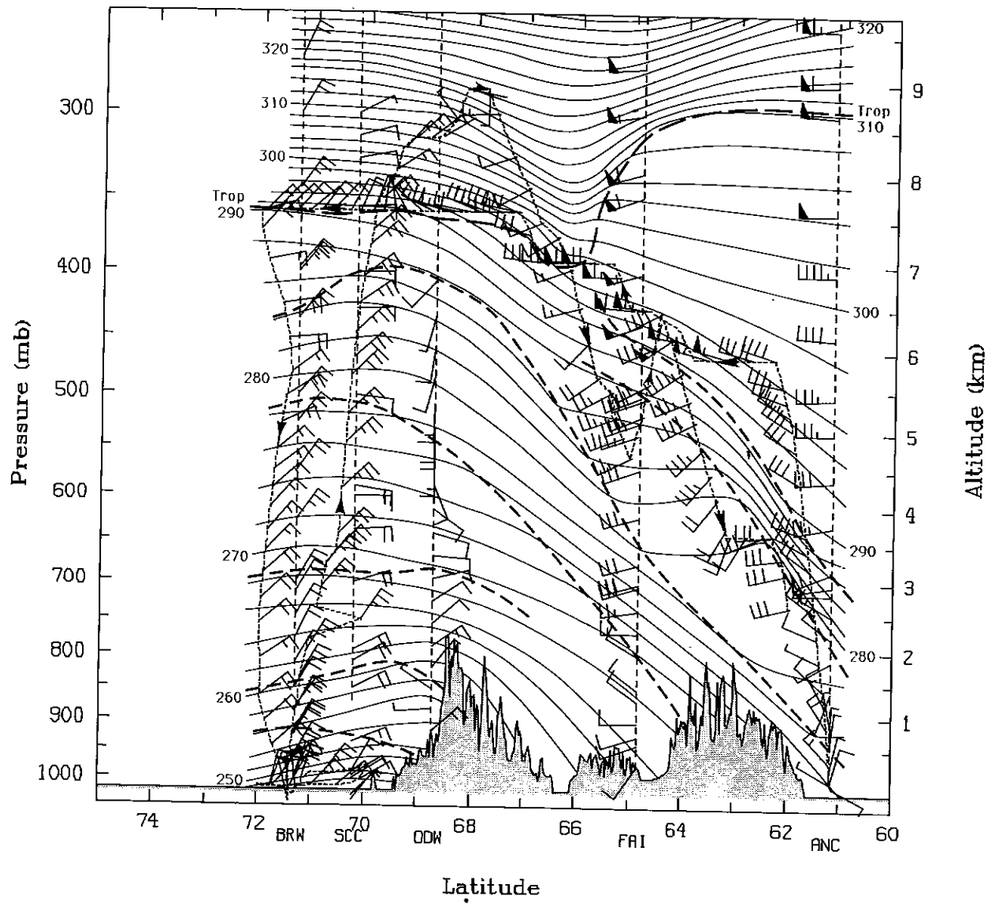

Figure 3.4. Latitude-altitude cross section of potential temperature (K solid contours) and wind (1 barb = 10 knots) between Anchorage and 74°N, 1714-0221 UTC April 10-11, 1992. The tropopause and top of the Arctic boundary layer are indicated by thick long-dashed lines, stable layers and frontal zones by thick short-dashed lines, and the aircraft flight track by thin dashed lines. Arrows indicating the direction of the aircraft are placed at the beginning of each hour. The vertical dashed lines show the aircraft dropwindsonde location (ODW) and rawinsonde locations (BRW, SCC, FAI, ANC).

Two principal stable layers were detected by the soundings over the Beaufort Sea. The first, between 430 and 510 mb, was the upper extension of the stationary front. The second was the top of Arctic boundary layer at 700 mb. The surface layer was capped by a steep inversion at 900 mb. On the return flight leg the tropopause was identified by an abrupt increase in ozone concentration at 69.8°N, at 351 mb. This was only 7 mb above the level at which the tropopause was encountered on the northbound segment. The aircraft remained in stratospheric air until reaching 66.2°N, at 400 mb, when an abrupt ozone decrease was encountered. The upper extent of the cold front was encountered on the descent into Anchorage.

3.5 Discussion of Sampling Conditions

In the period between the first and second flights problems acquiring the signals from the CN counter and the ozone detector were solved; thus the values were available throughout the flight. The frontal zone encountered at 700 mb on the climb from ANC was associated with the surface low to the east. It separated air of local continental influence from air of North Pacific origin. The dewpoint depression at 500 mb was only -3°C. Shortly thereafter, at 65.9°N and 391 mb, the aircraft penetrated the tropopause. Ozone concentrations increased by 30 ppbv at that point. For the remainder of the northbound transit segment of the mission, large variations in the ozone concentrations indicated the proximity of the tropopause. Because of the light wind north of 78°N, the tropopause was analyzed as following the flight track at 359 mb; small undulations reflect increases and decreases in ozone. Disregarding the variations of aerosol scattering in the moist air immediately above the frontal zone, the values were generally less that 10^{-6} m^{-1} for this segment. Upper-tropospheric CN concentrations were generally less than 300-500 cm^{-3} from 64° to 72°N.

During the descent at 72°N the stable layer between 430 and 510 mb was the upper extent of the weak frontal zone extending across the state to the Alaska Range. A second layer at 700 mb marked a change in stability associated with the Arctic boundary layer; the top of the surface inversion was at 900 mb. As found in earlier AGASP flights, the ozone concentrations gradually decreased during the descent, from approximately 70 to 30 ppbv. Aerosol scattering coefficients underwent some significant variations in the 500-700 mb layer, but dewpoint depressions were 2-3°C in that layer as well. Because of the intermittent nature of the variations, ice crystal contamination of the samples is suspected. In these moist layers the concentration of CN was generally low (<200 cm^{-3}) and without much variability.

Inversion moisture levels were high below the surface. Because of variations in visibility, fog from the open leads was indicated in the flight log. During the low-level sampling, ozone concentrations ranged from 10 to 50 ppbv, indicating that if there was ozone destruction at the surface, which was likely at that time, there was sufficient mixing from aloft at the lowest flight level (15 m) to elevate the concentration gradient. Variations in the aerosol scattering coefficient at that altitude were largely attributed to ice crystal contamination. For reasons that are not yet understood, the CN concentrations reached levels of 5000 cm^{-3} while the aircraft sampled below 900 mb, the highest CN concentrations measured during low-level sampling during the series of flights. For the hour 2230-2330Z the WP-3D was upwind of the CMDL observatory at BRW. The flow during this period was from the northeast with a 2 or 3 day trajectory into the Arctic

Basin. This was one of the best periods for which aircraft and surface-based observations could be compared, because of the steady onshore flow. Below 400 mb the measurements made during the ascent sounding added little to what was learned during the descent. This sounding was begun directly over the BRW observatory. Although there were weak stable layers between 900 mb and the tropopause, the temperature gradient was overall relatively uniform when compared with conditions in this region during AGASP-II when significant variations in aerosol scattering were observed (Herbert et al., 1989).

At 353 mb on the ascent to cruising altitude, the WP-3D intercepted the tropopause. That was 5 mb above the level at which the aircraft followed the tropopause on the northbound segment. Above 300 mb, ozone concentrations increased to more than 200 ppbv, and CN concentrations were observed to exceed 1500 cm^{-3}. The aircraft departed the stratosphere at 380 mb and 66.3°N. Again these levels correspond well with the point at which the troposphere was detected on the northbound segment. The polar front over ANC was detected between 440 and 500 mb during the descent.

4. FLIGHT 403, APRIL 13-14, 1992

4.1 Objective

On the basis of a forecast of increasing surface wind speeds from the southeast, a flight was scheduled by the LEADEX staff to study the flux of heat and moisture from a large lead. Leads 120 km to the east of the Ice Camp (72.9°N, 145.9°W) and 80 km to the west were prime candidates for study. Because of the forecast of low clouds, fog, and light snow in the Barrow region at the time, it was decided to locate the aerosol profile in the vicinity of the Ice Camp (72.78°N, 145.98°W) where drier conditions were reported.

In addition to the transit segments to the region of study, the flight consisted of a slow-descent profile for aerosol, turbidity, and gas measurements and extensive time for monitoring the plume from a large lead (Fig. 4.1). The flight departed Anchorage at 1709Z reached transit altitude of 6.1 km (466 mb) at 1734Z, and remained at that altitude, on a northerly bearing, until 1806Z (65.2°N, 148°W). At that point, about 40 km north of FAI, the WP-3D began a climb to 7.3 km (392 mb). From 1815Z (65.84°N, 148°W) to 1906Z (69.75°N, 145.40°W) the aircraft maintained 7.3 km, and from 1911Z (70.10°N, 145.01°W) to 2001Z (72.95°N, 147.08°W) it was

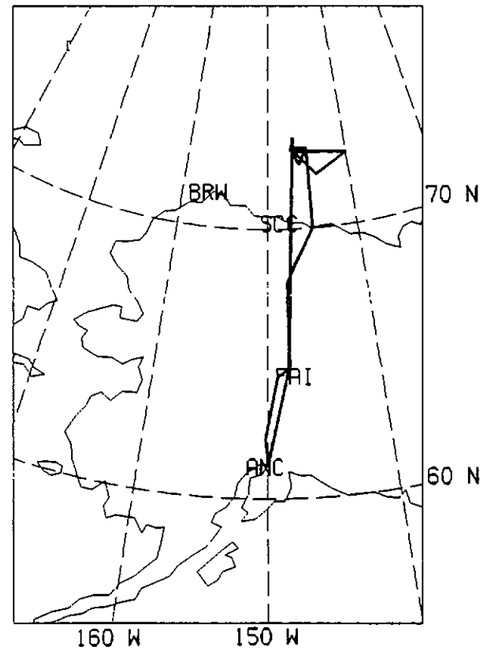

Figure 4.1. Horizontal projection of the aircraft flight track on a latitude-longitude grid, April 13-14, 1992.

at 7.9 km (359 mb). The descent profile, which followed, was conducted at an average rate of 234 m min^{-1} (18 mb min^{-1}) to a level of 1002 mb at 2204Z. Level segments for the purpose of turbidity measurements were flown at the top (359 mb) and bottom (997 mb) of the profile and at 1.5 km (826 mb) as well.

Low-level searching and sampling of leads began at 2206Z and continued until 2348Z, during which time the WP-3D was between 15 and 300 m altitude. At 2348Z (73.40°N, 146.75°W) the aircraft began the ascent profile, and reached a cruising altitude of 7.9 km (359 mb) was reached at 0023Z. This altitude was maintained with a southerly heading until 0109 when the aircraft climbed to 9.1 km (300 mb). After a brief climb to 10.1 km at 0205Z (65.05°N, 148.07°W) the aircraft began the descent to Anchorage. The plane landed at 0321Z.

4.2 Flight Log

17:09	Takeoff from ANC, flight 403.
17:14 61.41 150.06 26	High cloud cover ANC.
17:14 61.45 150.03 800	Good visibility at low levels.
17:21 61.85 149.82 611	Air is very dry yet hazy at this level.
17:24 62.06 149.00 556	Aerosol scattering is steady.
17:25 62.13 149.67 546	Slight turbulence.
17:27 62.24 149.60 522	Entering a Ci cloud.
17:27 62.27 149.59 519	Turbulence is slight.
17:34 62.67 149.33 465	Clouds above.
17:35 62.79 149.27 465	Aerosol scattering dropped.
17:36 62.87 149.24 465	Ozone up.
17:38 63.06 149.12 465	East of Denali and level with the top.
17:39 63.10 149.09 465	Ozone has climbed to >90 ppbv. Is this air of stratospheric origin? Winds are southwesterly at this level.
17:41 63.26 148.100 465	The high ozone values the last 3 minutes were directly downwind of Denali.
17:49 63.92 148.60 465	Clear at the surface.
17:49 63.93 148.59 465	Hazy or thin Ci at flight level.
17:52 64.11 148.47 465	Aerosol scattering and ozone continue to drop, a very clean period.
17:54 64.29 148.34 465	Aerosol scattering and ozone climbing now.
17:55 64.33 148.31 465	CN is <100 cm^{-3}.
17:59 64.64 148.08 465	From all appearances there is no Ci here.
17:59 64.66 148.06 465	It is clear below as well.
17:59 64.69 148.05 465	But there is a haze layer on the horizon.
18:01 64.81 147.99 465	Over Fairbanks.
18:01 64.86 147.96 465	Beginning run up 148°W.
18:03 64.97 147.97 465	Ground appears hazy.
18:16 65.96 147.99 392	Visibility at flight altitude is estimated to be 2-4 mi.
18:19 66.18 147.99 392	Significant haze, Ci at this altitude.
18:21 66.33 147.99 392	Nephelometer and ozone sensors operational after a 2-3 min break.
18:22 66.38 147.99 392	Large aerosol scattering peak.
18:22 66.40 147.99 392	Horizon capped with a brownish haze.
18:24 66.55 147.99 392	Aerosol scattering decreasing.
18:24 66.57 147.99 392	No change in humidity to indicate ice crystals.
18:30 67.06 147.98 392	Ozone and aerosol scattering unchanged.
18:31 67.11 147.98 392	Still clear to surface, hazy at flight altitude.
18:34 67.35 148.00 392	Aerosol scattering steady.
18:44 68.15 147.78 392	Started leg C, 2 min ago.
18:46 68.29 147.60 392	Aerosol scattering of (2-2.5) × 10^{-6} m^{-1} for the last 30 min.
18:52 68.72 146.10 392	There is a brown layer below the tropopause.
18:52 68.75 146.96 392	It is hazy over the Brooks Range.
18:54 68.91 146.72 392	Passed the crest of the Brooks.
18:56 69.03 146.54 392	Dropwindsonde no. 1 released.
19:02 69.51 145.80 392	Dropwindsonde no. 2 released.
19:04 69.62 145.62 392	Leaving the Brooks at this point.
19:06 69.77 145.38 390	Considerable obscuration at flight level. Slight turbulence at his level.
19:12 70.14 144.98 359	Crossed the northern Alaskan coast at 7940 m PA. Some open and lots of refrozen leads near the coast.
19:13 70.20 144.95 358	Slight turbulence.
19:13 70.26 144.95 358	Began leg D, 3 min ago. Still not in stratosphere.
19:15 70.39 144.97 359	Top of climb heading north.
19:17 70.49 144.98 358	Visibility good to surface.
19:17 70.51 144.98 358	Two brownish layers visible on the horizon.
19:19 70.66 144.99 358	Dropwindsonde no. 3 released.
19:20 70.69 144.99 358	Hitting some stratospheric air. Ozone is up.
19:24 71.00 145.01 358	Ozone and aerosol scattering dropping.
19:25 71.10 145 .00 358	Top of troposphere, seem to be losing the brownish layer.
19:30 71.48 145.01 359	Aerosol transfer pump off. Ozone and CN down.
19:33 71.70 145.02 359	Dropwindsonde no. 4 off.
19:34 71.81 145.03 359	Visibility to surface is good.
19:36 71.98 145.02 359	Go with descent as planned.
19:37 72.06 145.01 359	Ozone sensor temporarily inoperative.
19:37 72.07 145.01 359	Aerosol scattering is steady.
19:38 72.10 145.00 359	Ozone and CN back up. Pump is quieter.
19:39 72.22 145.00 358	No indication of plumes off leads.
19:41 72.34 145.03 359	Ozone back, climbing to >140 ppbv range.
19:44 72.56 144.99 359	Ozone between 110 and 130 ppbv.
19:46 72.76 144.98 359	Very slight turbulence.
19:49 72.97 144.69 359	Turned to start RAD run #1
19:49 73.00 144.99 359	Beginning turn to leg E.
19:51 72.99 144.69 359	Performed nephelometer clean-air check at 7940 m.
19:54 72.97 145.36 359	Beginning radiation segment.
19:56 72.97 145.86 359	Horizon is obscured, visibility estimate is 5 mi.

19:56	72.97	145.95	359	Clear.
20:06	72.85	146.68	416	Into leg F, descending. Ozone dropped to about 70 ppbv, now climbing.
20:13	72.45	145.86	494	Ozone dropping over the last 3 min.
20:14	72.41	145.89	502	Aerosol scattering climbing now 6×10^{-6} m^{-1}.
20:15	72.44	146.02	519	Stratosphere at about 6 km.
20:16	72.54	145.82	552	Is this leg G?
20:17	72.56	145.78	560	ATP off to tighten connector. Ozone and CN down.
20:19	72.67	145.56	613	ATP back on. Ozone and CN working.
20:20	72.71	145.48	641	Cannot see horizon.
20:20	72.74	145.43	656	Nephelometer off.
20:29	72.99	145.11	826	Start RAD run #2 at 1687 m
				Horizon is visible now, no appreciable haze.
20:30	72.99	145.30	826	Layer on horizon just below the tropopause.
20:32	72.97	145.67	826	Inversion at 800 mb.
20:35	72.97	146.07	826	Basically clear here.
20:35	72.97	146.18	826	End of radiation segment.
20:42	73.02	147.04	826	Beginning leg I.
20:42	73.02	147.04	826	Radiation segment completed.
20:43	72.97	146.90	833	Horizon now obscured.
20:48	72.75	146.45	864	Horizon obscured.
20:53	72.52	146.03	897	Haze, diffuse visible.
21:11	72.08	144.40	996	Start 150 m elevation radiation #3 segment.
21:13	72.96	145.36	996	Clear aloft, visibility estimated 5-7 mi.
21:20	72.95	146.52	996	Univ. of Wash. Convair off the port wing.
21:23	72.95	147.01	996	End of radiation segment.
21:24	72.99	146.10	996	Entering leg L.
21:48	72.22	144.62	996	Visibility is improving to 5-7 mi, estimated.
21:50	72.18	144.53	996	Ozone steady.
21:50	72.16	144.48	996	Aerosol scattering and CN steady.
21:52	72.10	144.30	996	Nearing the end of leg L.
22:04	72.18	142.95	999	Descend to 60 m RA.
22:11	72.33	141.92	1009	Background boundary layer, not much open water at all.
				Lots of refrozen leads, few are open.
22:35	72.76	140.69	1010	Change of plans. We will head back toward Ice Camp where there was lots of open water.
22:39	72.79	141.42	999	During the low pass visibility was 5-7 mi.
22:42	72.00	141.89	998	Visibility about 5 mi, clear aloft.
22:44	72.83	142.27	998	Ozone got as low as 1-2 ppbv during the low pass.
23:08	72.95	146.91	998	Over an open lead.
23:13	73.06	146.88	1010	Descend to 16 m RA. In plume from open lead.
23:14	73.11	146.79	1016	Light turbulence in the plume from the lead.
23:15	73.18	146.73	1016	In plume from lead at this time.
23:16	73.22	146.73	1016	Climb to turn. Back in plume.
23:17	73.24	146.73	1016	In plume.

23:17	73.27	146.73	1016	In plume.
23:18	73.32	146.75	1014	Out of plume.
23:22	73.37	146.79	1005	North of lead, repositioning for a run back.
23:24	73.26	146.73	997	Beginning the ascent.
23:26	73.16	146.75	984	Heading back along the lead.
23:27	73.11	146.80	972	Visibility reduced in this region.
23:28	73.11	146.81	970	Cannot discern the horizon.
23:30	73.00	146.02	950	This is the end of Nick's climb.
23:30	72.98	146.93	945	We are downwind of the lead.
23:34	72.45	147.18	938	Spiraling down for another low pass.
23:36	72.90	147.14	947	Heading down for a second low pass at the lead.
23:39	73.04	146.91	1001	Ozone dropping fast.
23:40	73.06	146.88	1005	At 50 m RA, descending to 16 m RA.
				Air temperature (TA): -24°C over lead.
23:41	73.12	146.77	161	Ozone at 10 ppbv.
23:42	73.13	146.75	1015	Downwind from the lead.
23:43	73.19	146.69	1011	Turning to reposition on the lead.
23:44	73.24	146.73	1016	In lead plume.
23:44	73.25	146.73	1016	In lead plume.
23:45	73.26	146.73	1016	In lead plume.
23:45	73.28	146.74	1016	Over lead.
23:48	74.01	146.08	1015	Over the ice.
23:49	73.45	146.73	990	Climbing at 500 ft min^{-1}.
00:01	72.89	146.86	757	Horizon obscured, visibility estimated at 6 mi.
00:05	72.71	146.91	692	Change in climb rate to 1000 ft min^{-1}.
00:07	72.62	146.93	641	Visibility obscured 3-5 mi.
00:16	72.06	147.06	429	Cloudy
00:21	71.80	147.12	360	Leveling at this altitude.
00:25	71.52	147.14	359	Still in upper tropospheric air.
00:28	71.34	147.16	358	Slight turbulence, possibly approach tropopause.
01:00	69.32	147.50	358	Obscured at flight altitude in Ci.
01:03	69.10	147.55	358	Still in upper tropospheric air. Decide to climb more.
01:05	68.95	147.58	358	No low clouds visible. The horizon generally obscured.
01:06	68.88	147.60	358	Brown haze at top of troposphere.
01:09	68.73	147.11	355	Climbed 9 km PA.
01:13	68.44	147.66	310	Power outage - lost converter. Power back on 6 min later.
01:22	67.92	147.64	299	Tropopause?
01:28	67.42	147.80	299	Good visibility toward the ground.
01:39	66.71	147.92	300	PA: 9168 m, Ozone: 160 ppbv.
01:43	66.45	147.92	300	Ozone: back down to 60 ppbv.
01:53	65.82	148.02	300	Still in upper tropospheric air.
02:04	65.12	148.07	261	At 33,000 ft PA! Ozone still low at 40 ppbv.
02:06	64.97	148.09	260	We can't stay in the stratosphere.
02:06	64.93	148.10	260	At the tropopause.
02:12	64.66	148.43	270	Turned toward SW, toward ANC

14:29	64.60	148.76	286	Out of the stratosphere.
02:14	64.59	148.81	286	No low- or mid-level clouds, light haze.
02:28	63.87	149.48	390	Sun dogs below indicate a Ci layer.
02:41	63.11	149.84	485	Due east of Denali now.
02:42	63.10	149.85	485	Some low clouds over the peaks.
02:44	62.10	149.90	485	Significant haze at this level.
02:44	62.98	149.91	485	Visibility obscured by Ci.
02:56	62.30	150.16	608	Lower clouds, broken.
02:59	62.11	150.30	661	Just passed through a cloud layer.
03:01	61.99	150.39	690	Another cloud layer.
03:21				Land in Anchorage.

4.3 Synoptic Situation

The analysis of 500 mb heights at 0000Z April 14 (Fig. 4.2) shows a high-pressure ridge extending from east to west across southern Alaska, and a low-pressure region over the Chukchi Sea at 70°N, 170°W with an associated trough extending to the east to a low just south of Banks

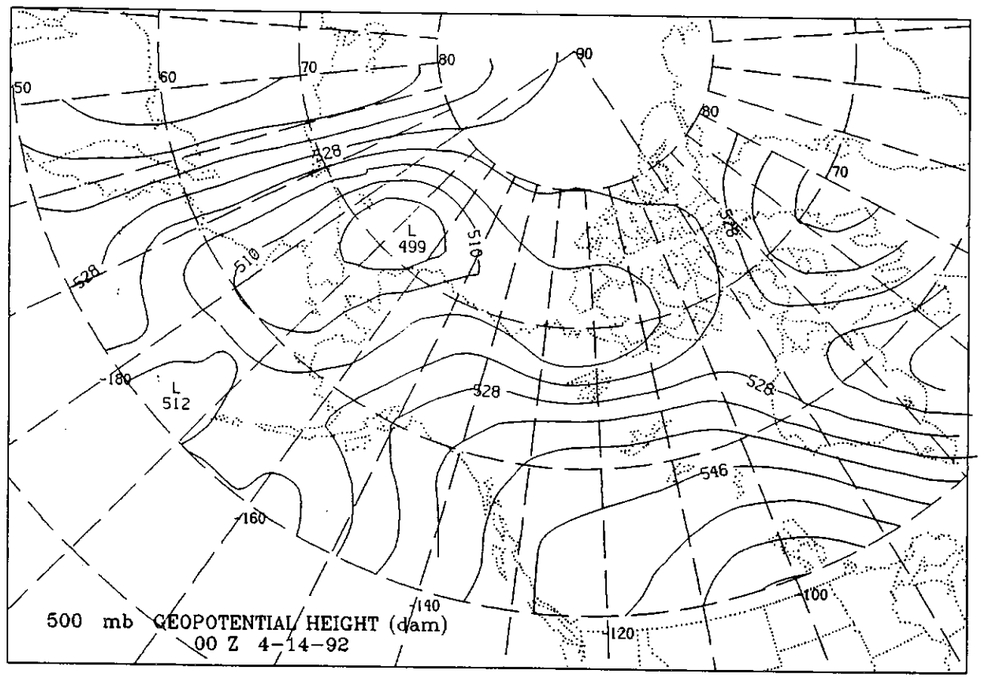

Figure 4.2. 500 mb synoptic map for 0000 UTC, April 14, 1992. Indicated are height contours in geopotential decameters.

Island. As was the case 3 days earlier during the previous flight, a large region of high pressure dominated eastern Siberia. The low-pressure center west of BRW moved to this position from the northeast. The combination of the ridge along the southern coast and the low and trough along the northern coast placed all of central and western Alaska under a southwesterly flow regime.

A surface low in the Bering Sea at St. Lawrence Island (Fig. 4.3) corresponded to the 500 mb low in the Chukchi Sea. A trough was analyzed through the Beaufort Sea to the north of the trough aloft. A high-pressure ridge extending out of western Canada covered most of central Alaska. As indicated in the log, most inland sites were reporting clear or broken cloudiness and light wind at the time of the flight. The only extensive cloudiness was along the northern coast. Deadhorse was reporting winds from the south at 1-2 m s^{-1} and clear skies during the time the WP-3D was north of the Brooks Range.

The infrared satellite image of 1734Z April 13 (Fig. 4.4) shows low clouds along the coast. It also shows the clear region to the north of 72°N where a good view of the leads is apparent. The location of the Ice Camp is shown.

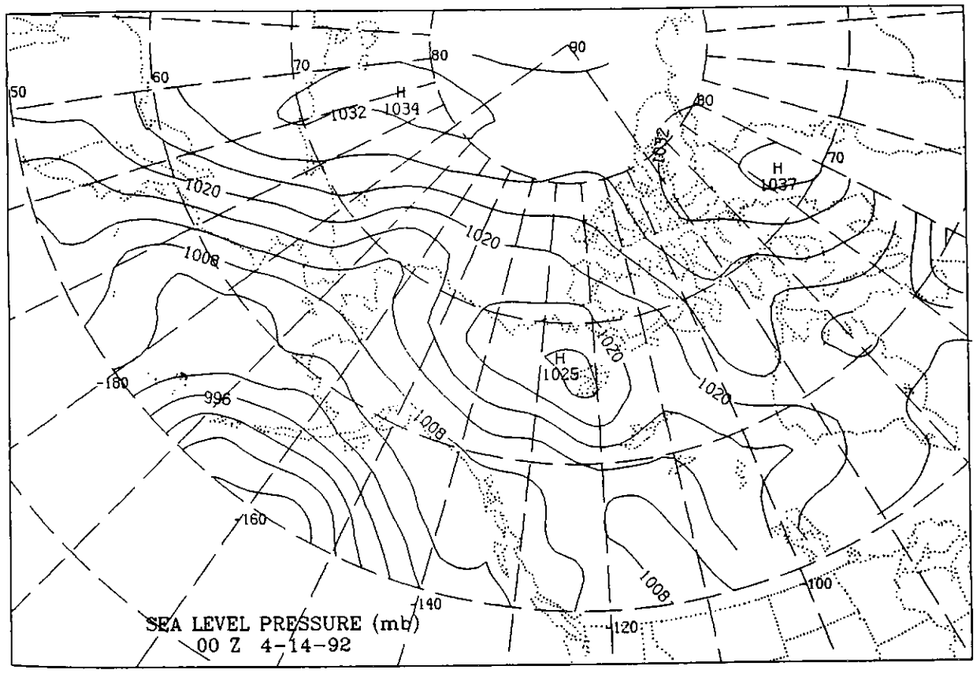

Figure 4.3. Surface synoptic map for 0000 UTC, April 14, 1992. Indicated are surface pressure contours in millibars.

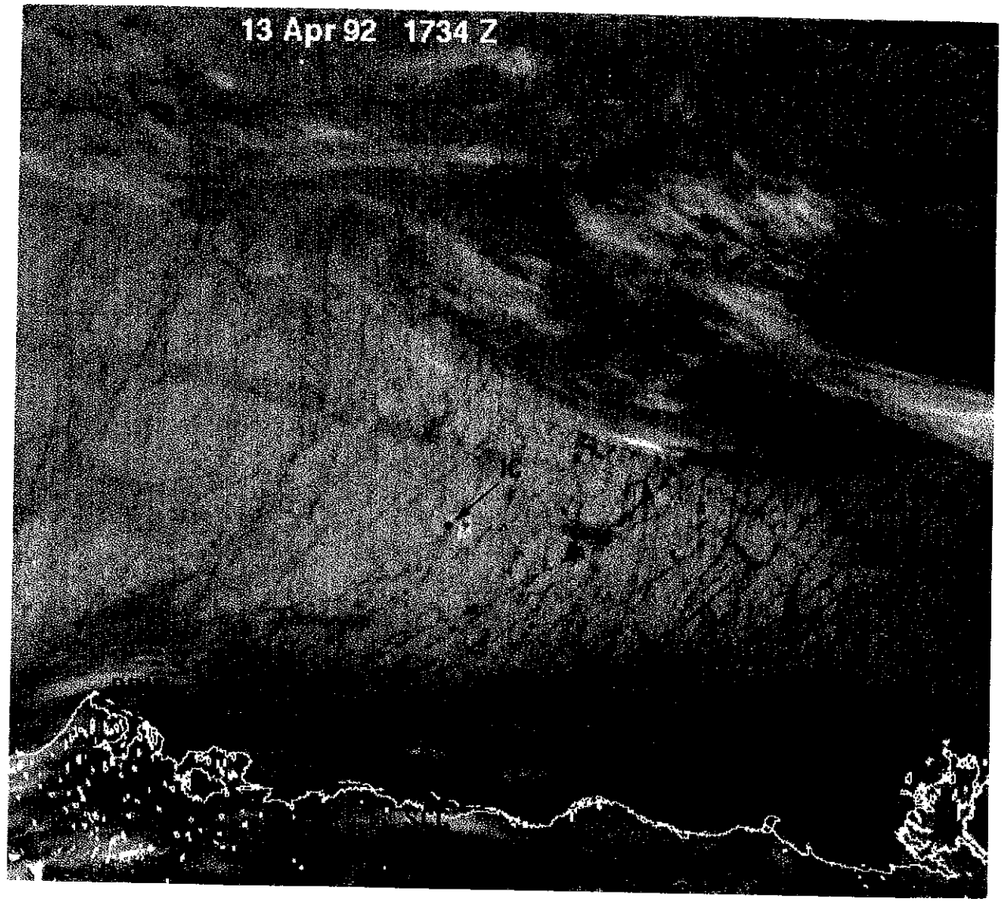

Figure 4.4. Infrared satellite image of the Alaska North Slope and Beaufort Sea taken at 1734Z, April 13, 1992. The location of the Ice Camp is shown.

4.4 Atmospheric Cross Section

Figure 4.5 shows the distribution of potential temperature along the flight track based on the observations from the WP-3D and the ANC, FAI, SCC, and CAM rawinsondes for 0000Z April 14, and one dropwindsonde released at 69°N (1856Z). The two stable layers encountered by the aircraft during the climb from ANC are associated with a moderately stable region extending across Alaska and a stationary front to the south of ANC, respectively. Just above the stationary front at 63°N the ozone concentration jumped to levels indicating the presence of stratospheric air. The next discontinuity encountered was the tropopause at 72.3°N, 359 mb.

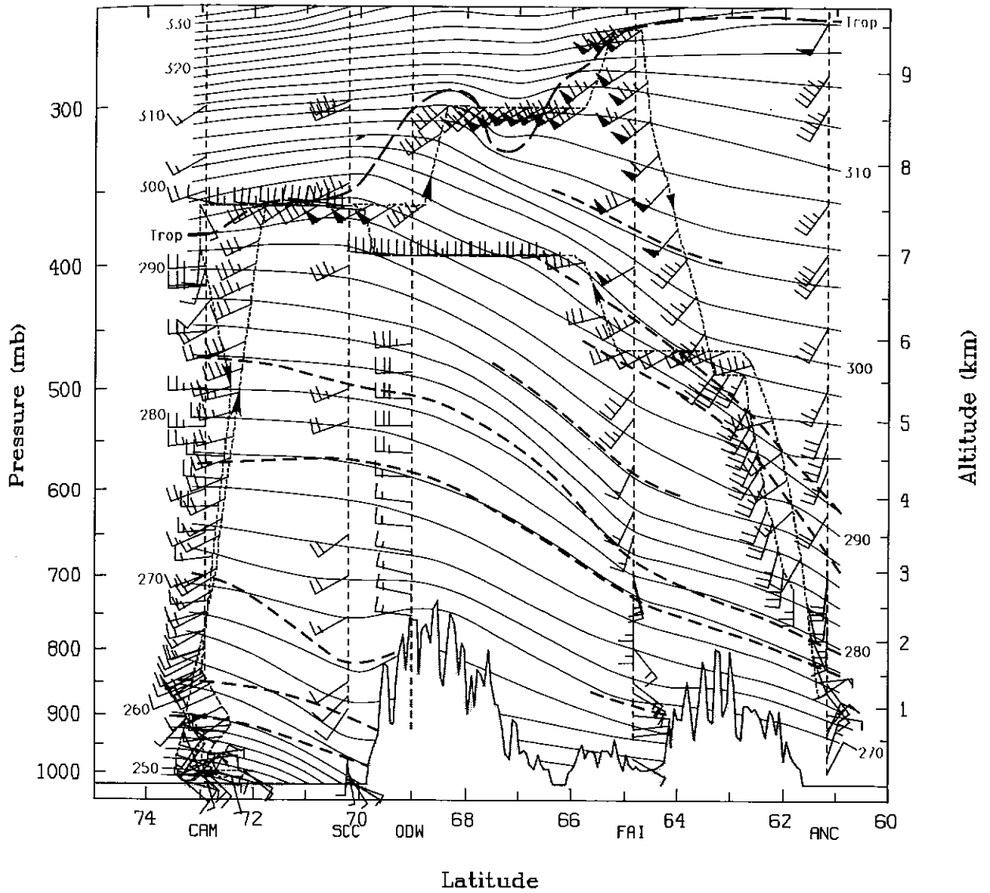

Figure 4.5. Latitude-altitude cross section of potential temperature (K, solid contours) and wind (1 barb = 10 knots) between Anchorage and 74°N, 1712-0305 UTC April 13-14, 1992. The tropopause and top of the Arctic boundary layer are indicated by thick long-dashed lines, stable layers and frontal zones by thick short-dashed lines, and the aircraft flight track by thin-dashed lines. Arrows indicating the direction of the aircraft are placed at the beginning of each hour. The vertical dashed lines show the aircraft dropwindsonde location (ODW) and the rawinsonde locations (CAM, SCC, FAI, and ANC).

The aircraft left the stratosphere shortly thereafter at 394 mb during the descent over the Beaufort Sea. The upper troposphere was relatively stable with multiple layers encountered between 400 and 600 mb. The top of the lower stable layer was at 700 mb, and the top of the Arctic boundary inversion was at 900 mb. The temperature decreased 4°C in the boundary layer. Although a similar thermal structure was encountered on the climb segment of the return flight, the tropopause was not encountered until reaching 299 mb at 68°N, and then only for a brief period to 66.5°N, and again at 270 mb at 65.3°N for a 1-min period. The analysis of the tropopause was

drawn to include these regions. No significant new features were discovered on the descent to Anchorage.

4.5 Discussion of Sampling Conditions

During the climb from ANC the WP-3D passed through two stable layers, the upper of which, 700-600 mb, was considered to be the remnants of a stationary front. Immediately above the front the ozone concentrations increased by more than 20 ppbv, indicating the possibility of recent stratospheric influence in this region of dry, subsiding air. Dewpoint depressions were of the order of 10°C or more.

For a brief period (1737-1740Z), while the aircraft was downwind of Mt. McKinley on the northbound transect, ozone concentrations jumped from midtropospheric values in the mid-50's to more than 90 ppbv. This was possibly a remnant of stratospheric air undergoing terrain-induced or dynamic advection to this level. As is clear from Fig. 4.5, the depression in the tropopause at 71°N was north of the low at 500 mb. The two weak stable layers (460-550, 700-900 mb) observed during the descent at 73°N do not seem to be associated with any significant changes in aerosol scattering or CN concentration. Aerosol scattering coefficients were $<10^{-5}$ m^{-1} and CN concentrations were in the range of 50 to 500 cm^{-3}. The wind shifted from westerly aloft to easterly in the Arctic boundary layer, below 900 mb.

During the low-level segment, which was carried out below the Arctic inversion and at the beginning of the ascent portion of the return segment (2315 and 2348Z, respectively), ozone concentrations fell to below 1-2 ppbv, indicating ozone destruction in lead plumes with little mixing of ozone-rich air from aloft. The greater stability, in comparison to the previous flight, was consistent with the lower wind speeds near the surface; see Fig. 4.5. These were some of the lowest ozone concentrations observed during AGASP-IV. Throughout this flight the aerosol scattering coefficient seldom exceeded 10^{-5} m^{-1}; the high value was 12×10^{-6} m^{-1} during the low-level segment. CN concentrations were generally in the 100 to 500 cm^{-3} range except for a brief period during the low-level segment when they reached 1000. Caution must be exercised in interpreting CN concentrations, since occasionally the aircraft intersected its own plume; this was most common during the low-level maneuvers. The 1-min period beginning at 2312Z was such a case.

During the return to ANC the aircraft was in and out of the stratosphere on several occasions. Stratospheric concentrations of ozone got as high as 160 ppbv on this flight. Between 68° and 67°N at 300 mb in the stratosphere, CN concentrations got as high as 1500 cm^{-3}. On the descent from 260 mb the upper troposphere was relatively dry. The humidity increased abruptly at 500 mb and remained high until the aircraft entered the second inversion at about 850 mb.

As in the previous flight, the temperature gradient between the tropopause and the top of the Arctic inversion was relatively uniform, and the wind was from the west at 5-12 m s^{-1}. With the low-pressure system crossing to the north of BRW during the preceding 2-3 days, the transport history would be from the north, across the Arctic basin at all levels above 900 mb. At the surface the flow was along the coast.

5. FLIGHT 404, APRIL 15-16, 1992

5.1 Objective

The speed of the surface winds in the LEADEX study area was forecast to increase over the next 24 hours. The direction of the low-level winds was shifting from the southeast to northeast, placing the LEADEX study area upwind of the Barrow observatory. The LEADEX staff called the flight to study the changes in the flow as air passed over a large lead. The strong winds were consistent with the maximum extent of open water and large sea-to-air fluxes of heat and moisture.

The NOAA WP-3D aircraft took off from Anchorage at 1806Z on April 15, and began the now familiar track to the North Slope via FAI (Fig. 5.1). Cruising altitude of 6.1 km (465 mb) was reached at 1828Z. The aircraft remained at this altitude to 69.9°N, 145.5°W (2003Z) when it descended to 5.5 km (506 mb). This altitude was maintained until the beginning of the descent profile at 2132Z at 71.72°N, 148.40°W. An average descent rate of 200 m min^{-1} or 17.6 mb min^{-1} was used until 18 m (1019 mb) was reached at 2208Z. Level, cross-sun segments were flown at 5.5 km (506 mb) and at 1.6 km (834 mb) for the purpose of obtaining consistent turbidity measurements. For the next 2 hours and 56 minutes the WP-3D conducted profiles in the first 300 m in the vicinity of the large lead to the west of the Ice Camp (72.80°N, 146.60°W).

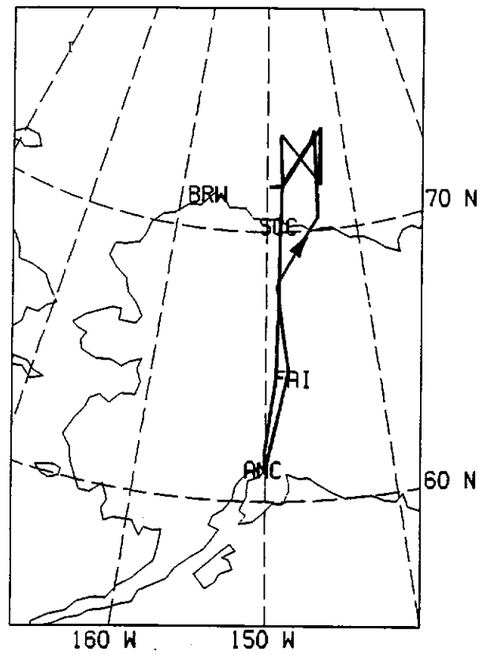

Figure 5.1. Horizontal projection of the aircraft flight track on a latitude-longitude grid, April 15-16, 1992.

The return flight was begun at 0104Z, from 71.80°N, 148.18°W, when the aircraft began the climb to cruise flight altitude (7.65 km, 374 mb), which was reached at 0137Z. The climb was interrupted at 0113Z with a level segment at 3.1 km (696 mb), lasting 11 minutes. The aircraft remained at 7.6 km until beginning the descent to Anchorage (0312Z). The NOAA WP-3D landed at 0339Z.

The extent of the lead to the west of the Ice Camp can be seen in the satellite image of 2330Z, April 15 (Fig. 5.2). By all appearances the lead opened during the 54 hours after the previous image Fig. 4.4, when it was difficult to locate. Surface visibility was better north of 71°N than along the coast. Clear conditions were reported at the Ice Camp.

5.2 Flight Log

18:06			Takeoff.
18:07	61.17	149.97 984	Raining in Anchorage at take-off.
18:13	61.56	149.99 714	Entered cloud base.
18:15	61.67	149.94 665	At top of Sc.
18:23	62.18	149.59 527	Sc below; Cs above.
18:34	63.01	149.17 465	Broken clouds below; As/Cs above.
18:35	63.07	149.11 465	In upper tropospheric air.
19:00	65.11	148.08 465	Entered base of As.
19:24	67.06	148.70 465	Clear below; Ci above.
19:28	67.24	148.81 465	Clear above and below; at Ci level.
19:32	67.71	148.91 465	Visibility medium (cannot see horizon).
20:14	70.62	144.22 505	In cloud layer; visibility low.
20:24	71.34	143.88 505	Still in clouds.
20:38	72.35	143.67 505	Leg A-B parallel to long. 143.
21:02	73.43	144.05 505	"Medium-low" visibility.
21:16	72.62	146.24 506	Ozone starting to climb. Nephelometer channel. No. 3 shows anticorrelation with ozone.
21:49	71.71	149.40 791	Descent near ice camp. Passing through 2100 m PA.
21:51	71.67	149.68 830	Descending through 1900 m PA.
22:02	71.61	148.15 956	Descending through 400 m PA.
22:20	72.23	147.00 1015	DMS system is not working. Inlet has frozen up probably because of rainy morning in Anchorage. Will stop trying to take DMS measurements. For the next 1.5 hours, we flew several 50 ft and 200 ft (RA) legs.
00:34	73.55	148.25 1007	We smelled our own exhaust during the constant-altitude turn.
00:42	73.09	148.17 1018	No clouds - good visibility.
00:52	72.49	148.17 1015	Crossed big lead.
01:04	71.77	148.17 1005	Climbing to 3060 m.
01:06	71.65	148.21 913	At higher altitudes, reduced visibility due to haze.
01:22	70.62	148.36 696	Level at 3060 m.
01:34	69.82	148.47 411	Above Sc.

01:40	69.32	148.54 374	Clear above and below.
01:50	68.58	148.63 374	Very thin Cs above.
01:51	68.48	148.65 374	Entering Ci.
02:00	67.79	148.72 374	Still in Ci.
02:01	67.73	148.72 374	In upper tropospheric air.
02:14	66.74	148.85 374	Coming into and leaving As/Cs.
02:19	66.35	148.00 374	Cirrostratus above.
02:40	64.85	149.04 374	Scattered cloud below; As/Cs above.
02:40	64.83	149.04 374	Entered Ci.
02:42	64.69	149.05 374	Just left Ci.
02:43	64.61	149.06 374	Ac just below.

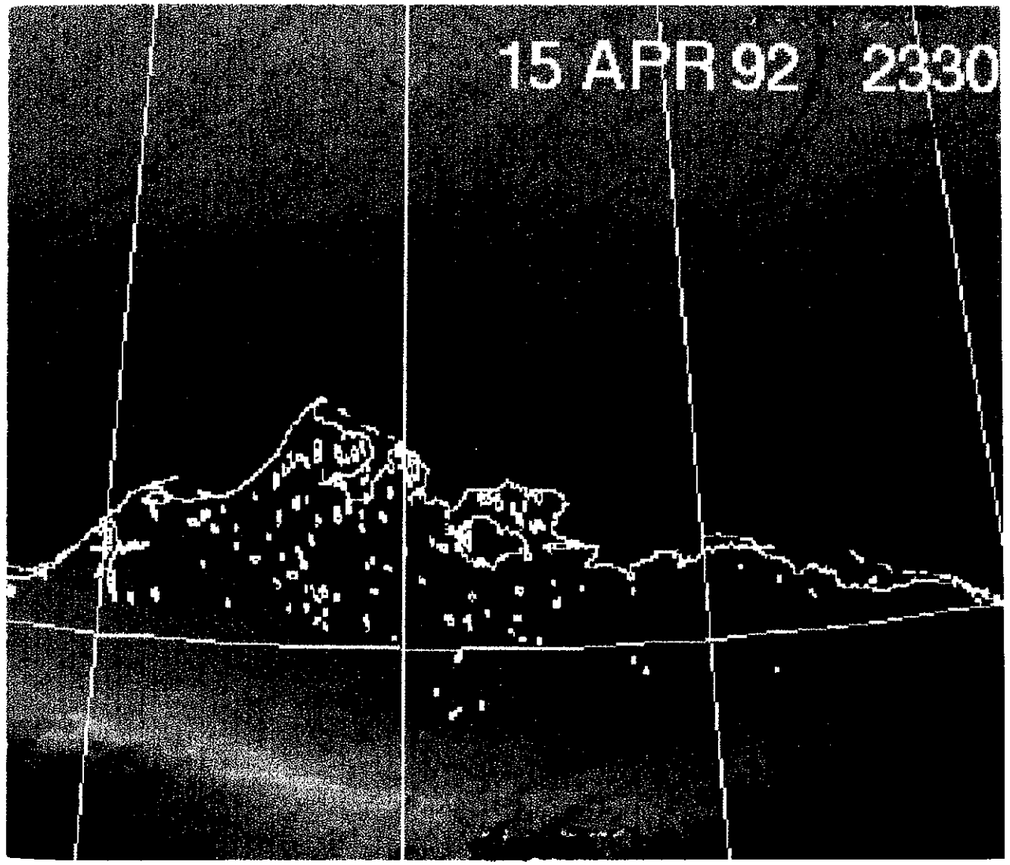

Figure 5.2. Infrared satellite image of the Alaska North Slope and Beaufort Sea taken 2330Z, April 15, 1992. The Ice Camp is shown.

02:58 63.54 149.57 374	Entering very thin As.
03:19 62.02 150.33 533	Sc below.
03:31 61.34 150.41 865	Cloudy on final approach to Anchorage.
03:39:	Landed in ANC.

5.3 Synoptic Situation

Because much of the time spent in transit from Anchorage to the Beaufort Sea was between 400 and 500 mb, a detailed discussion of the 500 mb analysis serves best to represent meteorological conditions for these segments. By 0000Z April 16, (Fig. 5.3) the high-pressure ridge over the Canadian Rockies, noted during the previous flight, extended over northern Alaska and across the Beaufort Sea. While the contour gradient was more pronounced over Southwestern Alaska, than during the previous flight, according to the NMC analysis the gradient was weak over the Beaufort Sea. Low-pressure centers, at 50°N, 180°W and southwestern Siberia, made up the low-pressure complex west of Alaska. Considerable warm-air advection occurred over the southern half of the state.

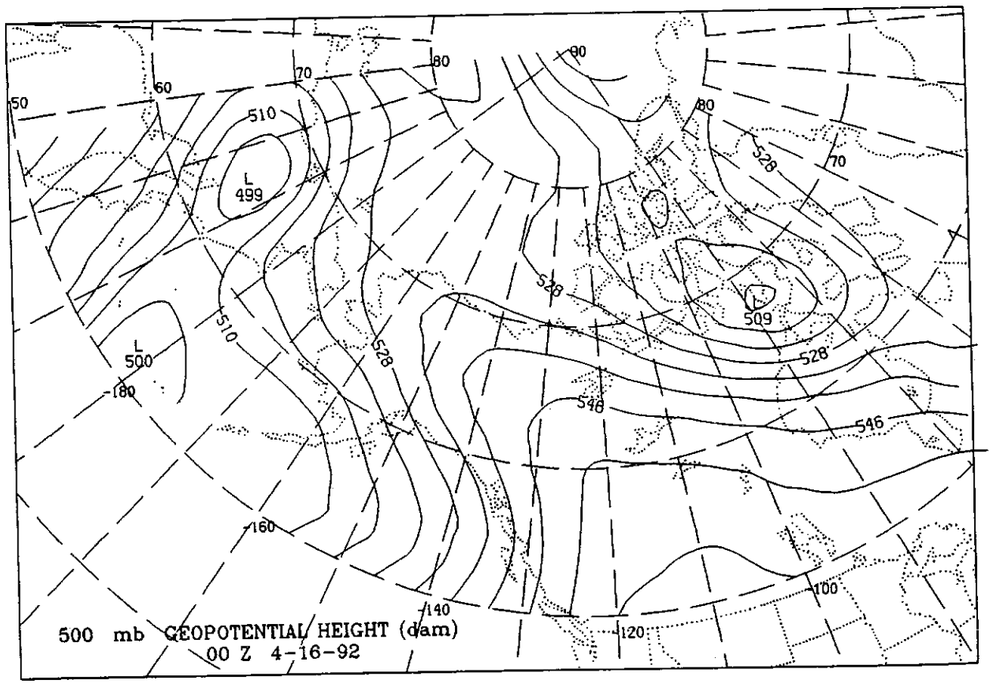

Figure 5.3. 500 mb synoptic map for 0000 UTC, April 16, 1992. Indicated are height contours in geopotential decameters.

At the surface (Fig. 5.4) the main center of action was a low-pressure system over the Aleutians, with a stationary front extending to the east (not shown in this figure). A second stationary front was analyzed in the region of the Alaskan Range. High pressure extended from Banks Island to over the Beaufort Sea, producing a strong easterly geostrophic gradient north of the Brooks Range.

Rain and low clouds were reported in the Anchorage area at the time of takeoff. Although the flight log indicated some breaks in the overcast between ANC and FAI, FAI was observing an overcast at the time. To the north, conditions at the surface cleared, with the intermediate stations, including SCC and BRW, reporting clear to broken cloud conditions before 0000Z April 16. Nevertheless the flight-based observations indicated some cloudiness at higher levels. The satellite image also indicated obstruction of the structure of the ice surface along the coast, which was most likely surface ice fog or haze. Conditions at Deadhorse changed from clear to overcast with blowing snow at 0000Z.

5.4 Atmospheric Cross Section

The analysis of the potential temperature along the flight track was based on the 0000Z, April 16 rawinsondes from ANC, FAI, SCC, and CAM in addition to the aircraft data for the

Figure 5.4. Surface synoptic map for 0000 UTC, April 16, 1992. Indicated are surface pressure contours in millibars.

duration of the flight (Fig. 5.5). The aircraft passed through a stationary frontal zone shortly after takeoff. Above 800 mb winds increased to in excess of 25 m s^{-1} and remained at that level throughout the climb. North of the Alaska Range, in the center of the low at 500 mb, the winds decreased to less than 5 m s^{-1} and veered to a westerly direction. A well-defined cold front, below this low pressure region, had recently passed FAI. Passing through the northern extent of the cold front between 500 and 600 mb during the descent the winds backed to an easterly direction. The top of the planetary boundary layer was encountered at 840 mb on the descent. Winds below that level backed to an east-northeast direction. During the climb to return to ANC, both stable layers were encountered at about the same levels that they were encountered on the descent. Although there was a significant increase in the wind speeds south of 65°N, on the southbound segment there was no change in the ozone concentration to indicate the presence of the tropopause. During the descent to ANC the wind speeds were in the 10-15 m s^{-1} range, significantly less that during the ascent 9 hours earlier.

5.5 Discussion of Sampling Conditions

Two weak, stable layers were encountered on the climb from ANC. It was raining at the time of takeoff. The aircraft remained in the clouds up to 660 mb according to the flight log. Conditions were drier above that level. During the northbound transect the ozone values were in the 45-85 ppbv range with no discontinuities that would indicate penetration of the tropopause. Aerosol scattering coefficients in the (1-6) × 10^{-6} m^{-1} range were typical of background levels in the midtroposphere. From 2007 to 2131Z the aircraft was at 506 mb flying a rectangular pattern to release dropwindsondes. Sampling during this period was in dry air in or above the polar front that intersected the surface south of FAI. Westerly flow at that level was determined by high pressure to the north. This was subsiding air of high Arctic origin.

Below 550 mb on the descent and 600 mb on the ascent the aircraft was in an easterly wind regime. The recent history of that air was from eastern Alaska after a brief period over the Beaufort Sea. Concentrations of all three parameters were consistent with background values throughout the profiles and low-level sampling over the Beaufort Sea. The ozone concentrations were as low as 5 ppbv at some points during the low-level sampling, indicating ozone destruction and limited mixing of ozone-rich air from above. At the lowest levels the winds backed to a more northerly direction, indicating a longer trajectory over the Beaufort Sea into the Canadian Northwest Territories.

No serious effort was made to intercept the tropopause on the return flight. Elevated aerosol scattering coefficients between 0150Z (68.4°N) and 0215Z (66.6°N) were probably caused by ice crystals in the nephelometer, since cirrus clouds were observed at flight altitude in this period; see the flight log. Otherwise, ozone concentrations were in the 30-55 ppbv range during the southbound segment. No significant variations in aerosol scattering or CN concentrations were measured during the southbound transit or descent. During those periods when the aircraft was above or to the south of the frontal zone the history of the air sampled was from over Central Alaska and the North Pacific.

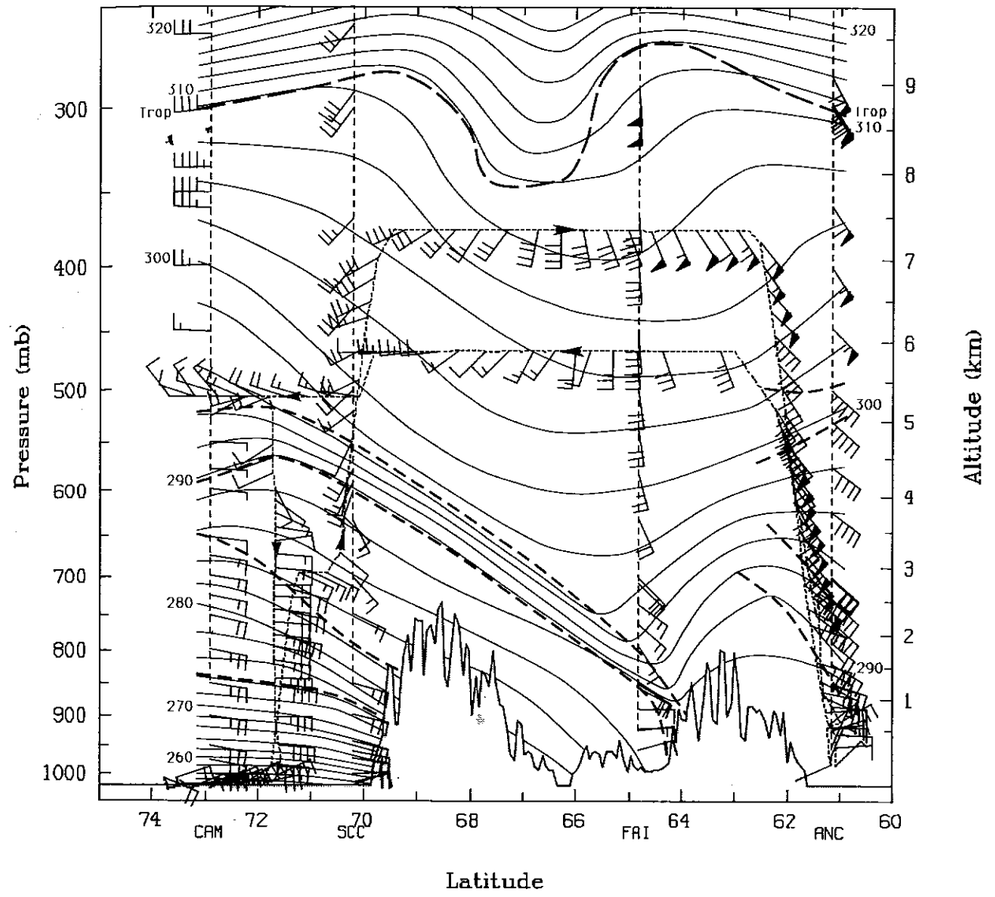

Figure 5.5. Latitude-altitude cross section of potential temperature (K, solid contours) and wind (1 barb = 10 knots) between Anchorage and 74°N, 1805-0342 UTC April 15-16, 1992. The tropopause and top of the Arctic boundary layer are indicated by thick long-dashed lines, stable layers and frontal zones by thick short-dashed lines, and the aircraft flight track by thin dashed lines. Arrows indicating the direction of the aircraft are placed at the beginning of each hour. The vertical dashed lines show the aircraft dropwindsonde location (ODW) and the rawinsonde locations (CAM, SCC, FAI, and ANC).

6. FLIGHT 405, APRIL 16-17, 1992

6.1 Objective

With the surface winds at the Ice Camp (72.80°N, 146.62°W) forecast to increase to 15-18 m s^{-1}, backing to a more northerly direction in the 24-h period after flight 404, the LEADEX staff decided to study the drag coefficient and lead plumes under those conditions. With the forecast of cold-air advection came the expectation of continued drying in the lower troposphere over the Beaufort Sea. It was agreed to perform the drag coefficient measurements over solid ice 100-200 km upwind of Barrow.

Takeoff on April 16 was delayed until 2029Z because of the required 15 hours of crew rest between flights on successive days. The NOAA WP-3D reached the transit altitude of 6.1 km (466 mb) at 2050Z and remained at that altitude until 2129Z at 65.40°N, 148.8.1°W (Fig. 6.1). At that point the aircraft climbed to 7.3 km (392 mb), reaching that level at 2140Z. The aircraft remained at that altitude until 2243Z (71.16°N, 147.75°W), at which time it climbed to 7.6 km (375 mb). This altitude was maintained until the beginning of the descent profile at 2311Z at 73.20°N, 146.30°W. The profile was completed at 2349Z with level segment at 967 mb for the

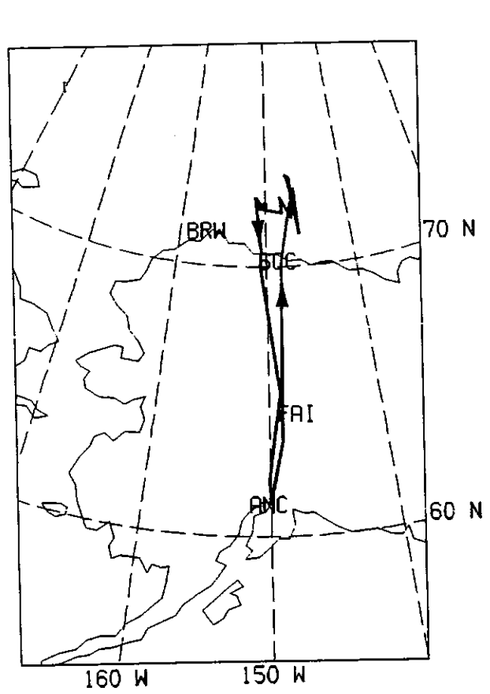

Figure 6.1. Horizontal projection of the aircraft flight track on a latitude-longitude grid, April 16-17, 1992.

purpose of turbidity measurements. From 2350Z (73.55°N, 147.10°W) to 0116Z (72.53°N, 146.92°W) the WP-3D traversed a major lead west of the Ice Camp, remaining below 0.9 km the entire time. The individual traverses were conducted at altitudes of 20, 60, 130, 160, and 850 m. Following a brief sounding to 800 mb at 0112Z, a series of drag coefficient measurements were made at various heights over solid ice. The drag coefficient profiles took the form of a series of "L"-shaped patterns with the major axis oriented cross wind. The L patterns were flown at heights of approximately 20, 60, 110, and 180 m, from 0137 to 0313Z.

The climb to cruise altitude for the return to Anchorage began at 0314Z at 72.39°N, 151.30°W. At that point the aircraft was about 220 km northeast of Barrow. From 0347 to 0414Z (70.75°N, 150.30°W, 572 mb) the WP-3D conducted a series of maneuvers to test the effects of aircraft motion on the turbulence sensing instrumentation. At 0426Z the aircraft leveled off at 7.9 km (359 mb), at 0440Z it climbed to 8.6 km (328 mb), and then at 0454Z to 9.2 km (300 mb). The descent to Anchorage began at 0537Z after a brief climb to 10.8 km (237 mb) at 63.57°N, 149.86°W. The aircraft landed about 0625Z.

6.2 Flight Log

20:29				Takeoff.
20:32	61.17	149.97	879	Just left the Cook Inlet.
20:32	61.17	149.97	853	Good surface visibility, mid-level cloud overcast, Ac.
20:36	61.56	149.10	684	Thick overcast.
20:37	61.65	149.94	644	Ozone down from >90 ppm.
20:39	61.75	149.88	604	In the clouds.
20:39	61.76	149.87	600	Surface partially obscured.
20:41	61.91	149.82	561	Ground is almost totally obscured from view now.
20:42	61.95	149.79	551	Still in cloud.
20:45	62.14	149.67	508	Still in cloud.
20:45	62.14	149.67	508	Surface totally obscured.
20:47	62.28	149.60	487	Surface is now barely visible directly below plane.
20:48	62.32	149.58	481	Still in the clouds, but about to break out.
20:48	62.33	149.57	479	Slight turbulence.
20:48	62.37	149.56	475	Just above the clouds now.
20:50	62.44	149.51	467	Big jump in aerosol scattering at the top of cloud layer, ice crystals.
20:51	62.53	149.46	465	Totally obscured below, bright sun above.
20:51	62.55	149.44	465	Horizon not visible.
20:52	62.64	149.39	465	Horizon not visible.
20:54	62.78	149.31	465	Still above the main cloud layer.
20:55	62.81	149.29	465	Aerosol scattering up, ice crystals?
20:55	62.83	149.28	465	In clouds now.
20:57	62.94	149.21	465	Slight turbulence.
20:59	63.10	149.12	465	Immediately below the top of the clouds.
20:59	63.13	149.10	465	Ground is partially obscured.
21:03	63.47	148.90	465	Still in the clouds.
21:09	63.91	148.88	466	Just turned north to 149°W.

21:10	63.95	148.88	465	Aerosol scattering variations indicate ice crystals are being sampled.
21:10	63.97	148.88	466	Ozone dropping.
21:10	63.10	148.88	465	Ground barely visible.
21:10	64.01	148.88	465	Cloud observation at flight altitude.
21:11	64.06	148.88	466	Horizon is barely visible.
21:11	64.07	148.88	465	Still in clouds, but thinner now.
21:12	64.14	148.88	465	Breaking out of the clouds.
21:12	64.15	148.88	465	Big drop in aerosol scattering.
21:12	64.16	148.88	465	Ozone steady.
21:13	64.19	148.88	465	Patchy clouds at the surface.
21:13	64.24	148.88	465	Thin Ci above, low Cu on the horizon.
21:16	64.43	148.86	465	Clear underneath the plane, clear to the right.
21:17	64.50	148.85	465	Thin Ci aloft.
21:17	64.51	148.08	465	Patchy clouds below now.
21:17	64.55	148.84	465	Clouds on the horizon both right and left.
21:18	64.59	148.84	465	Ground is locally obscured.
21:18	64.00	148.83	465	Clouds just below flight level.
21:19	64.69	148.82	465	Cu form below, patchy.
21:19	64.73	148.81	465	Clear below now.
21:20	64.81	148.81	465	CN fluctuating now.
21:22	64.90	148.81	465	Ozone up.
21:22	64.95	148.81	465	Back in the Ci again.
21:22	64.97	148.82	465	Horizon obscured.
21:23	65.01	148.82	465	Ozone steady.
21:24	65.08	148.82	465	Above Ci now.
21:24	65.09	148.82	465	Patchy undercast.
21:25	65.17	148.82	465	Slight turbulence.
21:25	65.21	148.82	465	Very light turbulence.
21:28	65.39	148.82	465	Breaks in undercast.
21:28	65.41	148.82	465	Clouds below are aligned with the topography.
21:29	65.51	148.81	455	Aerosol scattering variable Because of ice crystals in the sample.
21:30	65.56	148.81	450	Undercast Because of low and mid clouds.
21:31	65.64	148.79	437	Aerosol scattering back to normal.
21:34	65.83	148.76	422	Climbing, looking for the tropopause.
21:35	65.96	148.75	412	Slight turbulence.
21:36	66.02	148.75	408	Horizon obscured. Ci below.
21:37	66.09	148.74	404	Tropopause at 6.9 km.
21:39	66.23	148.74	396	Undercast, horizon not discernible.
21:40	66.28	148.74	393	Possibly still in Ci.
21:48	66.94	148.71	391	Undercast, horizon still not visible.
21:49	66.98	148.71	391	Surface visible now.
21:50	67.07	148.71	391	Variations in aerosol scattering indicate ice crystals in the sample.
21:51	67.10	148.70	391	Cloudy, surface obscured.
21:51	67.12	148.70	391	Slight turbulence.
21:53	67.25	148.68	391	Visibility obscured by Ci clouds now.

21:53	67.26	148.68	391	Ice crystal contamination of nephelometer here.
21:55	67.44	148.66	391	Still obscured.
21:56	67.47	148.66	391	Winds backing, Ci clearly above.
21:57	67.60	148.64	392	Nephelometer returning to normal.
21:59	67.73	148.62	391	In Ci, visibility obscured.
22:01	67.85	148.61	391	Over the crest of the Brooks Range.
22:02	67.98	148.60	392	Ci obscuring visibility.
22:05	68.20	148.00	391	Still in Ci.
22:07	68.32	148.57	391	Breaking top of clouds.
22:08	68.38	148.56	392	Nephelometer off for calibration.
22:08	68.40	148.56	392	Small breaks in the low clouds.
22:12	68.69	148.55	391	Scattered clouds below.
22:14	68.89	148.54	391	Ci just below flight level.
22:21	69.48	148.45	392	Clear aloft.
22:22	69.50	148.45	391	Horizon still fuzzy.
22:22	69.53	148.45	392	Low clouds confined to north slope of the Brooks Range.
22:23	69.65	148.46	392	Horizon is now visible.
22:24	69.69	148.46	392	No indication of haze. No layers visible.
22:25	69.81	148.45	392	Surface now obscured by clouds.
22:28	70.02	148.42	392	Surface obscured by clouds.
22:35	70.62	148.16	392	Clear view of surface now.
22:36	70.64	148.15	392	Horizon obscured by clouds.
22:36	70.68	148.13	392	Coast visible. ozone is 35 ppm.
22:38	70.83	148.02	392	Obscured now.
22:38	70.85	147.10	392	Horizon obscured.
22:39	70.88	147.97	392	View of surface is clear.
22:41	71.04	147.85	392	Thin Ci haze.
22:42	71.19	147.76	391	Moving out of the Ci.
22:43	71.24	147.73	386	Brighter now, still in thin Ci.
22:44	71.29	147.71	381	Ice surface is visible.
22:45	71.36	147.66	374	Climbing.
22:46	71.43	147.61	374	Still in Ci haze.
22:47	71.53	147.54	374	Nephelometer measuring ice crystals in the sampling path.
22:47	71.57	147.52	374	Drop in aerosol scattering at this point.
22:48	71.61	147.49	374	Aerosol scattering down.
22:49	71.69	147.44	374	The horizon has a grayish sublayer topped by a whitish layer.
22:50	71.74	147.40	374	Leads are visible below.
22:51	71.85	147.32	374	We seem to be out of the Ci now.
22:52	71.94	147.25	374	Many leads are visible.
22:54	72.04	147.17	374	Slight discoloring to haze. Large lead 4 mi east.
22:56	72.24	147.02	374	Slight turbulence.
23:05	72.90	146.46	374	Thin Ci haze.
23:05	72.91	146.43	374	Surface is clearly visible.
23:06	72.94	146.35	374	Horizon is obscured.
23:08	73.05	146.03	374	From ODW, wind shift at 680 mb, top of stable layer 780 mb.

23:09	73.15	145.91	374	Variations in ozone and nephelometer values possibly due to turning of the aircraft.
23:10	73.19	146.14	375	Starting the descent.
23:12	73.23	146.41	389	Base of isothermal layer at 930 mb.
23:18	73.25	146.89	484	Ozone and aerosol scattering are steady.
23:22	73.33	146.80	555	Sharp top to the haze.
23:23	73.37	146.85	568	Brownish tinge at top of haze.
23:27	73.37	147.12	678	Significant backscatter from haze.
23:30	73.42	147.14	764	Horizon obscured.
23:31	73.37	147.19	790	Horizon obscured.
23:32	73.36	146.97	827	Light turbulence.
23:37	73.41	146.90	966	All steady.
23:38	73.42	146.99	966	Level.
23:39	73.36	147.13	966	Horizon obscured, estimated visibility 3-4 mi.
23:40	73.32	147.13	966	maximum aerosol scattering during descent was at 2.5 km, 730 mb.
23:43	73.24	147.31	966	Visibility increased to 5-6 mi.
23:44	73.30	147.37	966	All steady.
23:45	73.33	147.41	966	Starting down.
23:45	73.36	147.43	973	Drag pattern to #2.
23:46	73.37	147.38	987	Generally hazy condition on the surface.
23:46	73.37	147.32	1000	Turbulence at this level.
23:49	73.29	147.10	1023	Moderate turbulence.
23:50	73.23	147.09	1014	Point B.
23:52	73.18	147.01	1007	Horizon is visible at this altitude.
23:53	73.20	147.13	1012	Northbound leg at 20 m.
23:54	73.25	147.13	1023	Over leads.
23:55	73.30	147.12	1024	Drag pattern no. 3.
23:55	73.31	147.12	1023	Drag pattern point A.
23:56	73.35	147.01	1004	Steady turbulence.
00:00	73.22	147.14	1003	Ozone and aerosol variables are steady.
00:01	73.18	147.08	1004	Horizon is visible.
00:02	73.19	147.11	1004	Moderate turbulence.
00:02	73.22	147.11	1014	Steady.
00:10	73.22	147.12	1012	Steady at previous values.
00:13	73.19	147.15	1018	Downwind of lead at 30 m.
00:28	73.30	147.01	1011	Steady.
00:31	73.27	147.39	1016	CN reacts to the turns.
00:36	73.32	147.04	1014	Steady.
00:44	73.27	146.93	1010	Steady.
00:55	73.22	147.09	915	Going to do the drag measurements.
00:57	73.13	147.02	916	Dark gray layer on the horizon.
01:03	72.82	146.83	953	Approaching the Ice Camp.
01:12	72.70	146.89	914	Blowing snow is visible.
01:13	72.65	146.90	914	No apparent ozone depletion at 18 m. Why?

01:22	72.23	146.91	800	The previous pattern was the detailed lead study.
01:22	72.20	146.90	800	The next pattern is the stacked "L" pattern.
01:23	72.15	146.88	800	This is to be run over uniform ice as a background study.
01:38	72.20	147.53	1013	Drag pattern no. 3.
01:41	72.35	147.81	1018	Down wind of the large lead.
01:42	72.37	147.87	1018	Local obstruction, Arctic fog.
01:42	72.39	147.90	1018	Visibility 0.5 mi.
01:44	72.45	148.02	1018	Only aerosol scattering is climbing gradually.
01:45	72.48	148.07	1019	Moderate turbulence.
01:46	72.52	148.15	1019	Point B, drag pattern 3.
01:48	72.59	148.17	1002	Steady.
01:48	72.60	148.23	1002	Obstruction, blowing snow, Arctic steam.
01:59	72.04	148.07	1000	End of leg 4 of the drag pattern.
02:00	72.03	147.97	1000	At point A.
02:04	72.12	148.35	1011	Moderate turbulence.
02:04	72.13	148.36	1011	Steady.
02:05	72.16	148.42	1011	Visibility estimated 1-2 mi.
02:13	72.47	149.11	1007	End of leg 5.
02:14	72.50	149.13	1005	Point B.
02:15	72.47	149.11	1005	Begin leg no. 6.
02:18	72.39	149.81	1012	Steady.
02:19	72.38	149.87	1012	This is a 40 mi run to end 60 mi NE of BRW.
02:20	72.36	150.05	1012	Estimated visibility to be 1 mi.
02:26	72.24	151.08	TAS	End of leg 6.
02:26	72.24	151.12	1003	At point C.
02:29	72.22	151.18	1016	Begin leg 7.
02:34	72.28	150.71	962	CN is increasing.
02:34	72.29	150.68	959	Sampled the P-3 plume on the last two turns.
02:39	72.37	150.13	1015	Visibility about 0.5-1 mi.
02:40	72.39	150.00	1005	Point B.
02:41	72.42	150.07	988	Begin leg 8.
02:43	72.34	150.13	985	Light turbulence on this leg.
02:44	72.32	150.13	985	Steady ozone and aerosol concentrations.
02:49	72.06	150.06	983	End of leg 8.
02:49	72.05	150.04	983	At point A.
02:52	72.03	150.14	187	Steady.
02:53	72.10	150.29	1010	Begin leg 9.
02:54	72.11	150.31	1013	Moderate turbulence.
02:57	72.26	150.59	1015	Estimated visibility 1-2 mi.
02:59	72.33	150.74	1014	Visibility at 1 mi.
03:00	72.40	150.85	1016	Aerosol scattering gradually increasing.
03:01	72.43	150.92	1016	Visibility down to < 1 km, estimated.
03:03	72.49	151.02	1014	End leg 9.
03:03	72.51	151.08	1015	Begin leg 10.
03:04	72.56	151.18	996	Point B.

03:06	72.61	151.14 998 Visibility about 1 mi up here.
03:09	72.60	151.34 998 Horizon is not visible, estimated visibility about 1-2 mi here.
03:11	72.49	151.37 1014 Begin leg 10.5.
03:12	72.45	151.34 1015 Moderate turbulence.
03:12	72.44	151.34 1015 Proceeding from B to A.
03:14	72.37	151.28 1015 A/C plume sampled in the last turn.
03:10	71.97	151.20 979 Lost data signal for a few min.
03:28	71.73	151.14 880 Top of inversion at 926 mb.
03:30	71.62	151.10 860 Secondary temperature inversion at this level.
03:42	71.03	150.77 651 Aerosol scattering dropping.
03:43	70.10	150.77 637 Ground partially obscured.
03:44	70.94	150.76 615 Obstruction increasing.
04:14	69.69	150.49 526 Just completed 15 min of maneuvers to test the flux-measuring instruments. During these tests 0 G was reached. Scattered clouds near the surface.
04:19	69.39	150.39 415 Undercast now.
04:19	69.37	150.38 410 Sc or low Ac.
04:21	69.24	150.36 398 Horizon is not visible.
04:25	68.99	150.27 372 Aerosol scattering and ozone seem to be out of phase.
04:25	68.95	150.25 372 Tropopause, ozone at >90 ppbv.
04:25	68.93	150.24 361 Stratosphere penetration.
04:31	68.52	150.09 358 Ac undercast.
04:35	68.22	150.01 358 Brooks Range visible in isolated spots.
04:41	67.82	149.89 327 Obstruction, ice crystals.
04:43	67.67	149.87 328 Nephelometer highly variable, normal now.
04:43	67.63	149.87 328 Ozone steady.
04:47	67.37	149.78 328 Obstruction again.
04:47	67.35	149.77 328 Aerosol scattering heading up.
04:56	66.74	149.59 316 Undercast of Ac.
05:21	65.00	149.70 284 Made stratosphere.
05:29	64.28	149.81 247 In stratosphere at last.
05:47	62.87	150.02 318 Out of stratosphere.
06:25		Landed in ANC.

6.3 Synoptic Situation

The 500 mb analysis for 0000Z April 17 (Fig. 6.2) shows the high-pressure ridge that extended from the Canadian Rockies across the Alaskan North Slope to a high center at 80°N, 180°W. The ridge had moved slightly northward from its position 24 hours earlier. Otherwise the low to the southwest of Anchorage on the previous analysis (Fig. 5.3) had not changed in intensity or position. This had resulted in a reduced geopotential gradient over central Alaska from that observed during flight 404.

At the surface the predominant feature was high pressure over the Beaufort Sea centered at 80°N (Fig. 6.3). This, in conjunction with a weak, ill-defined, low-pressure area in southern

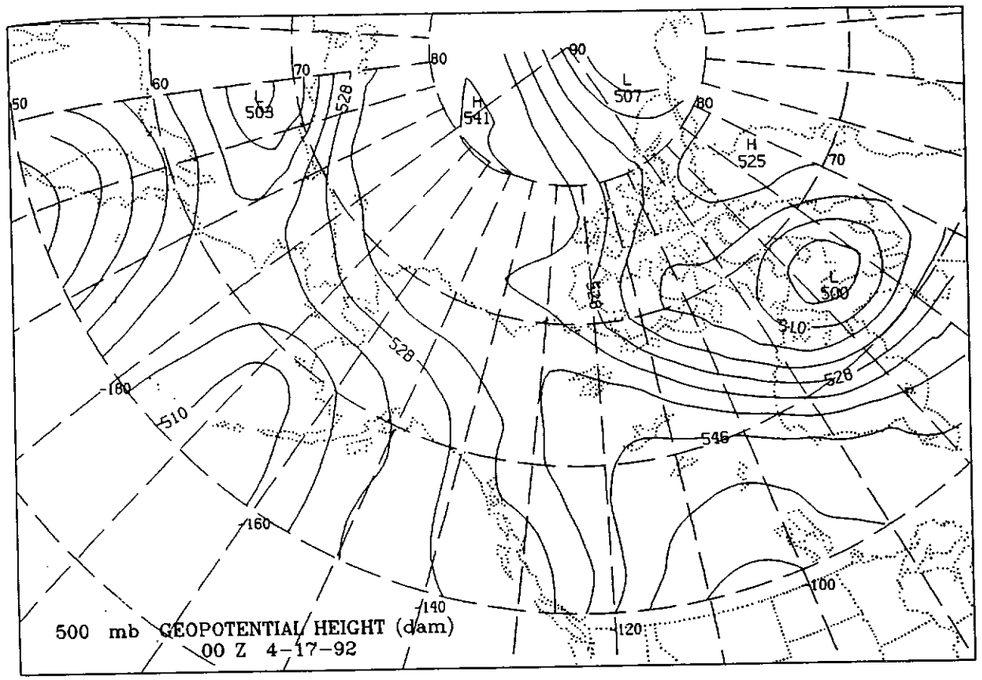

Figure 6.2. 500-mb synoptic map for 0000 UTC, April 17, 1992. Indicated are height contours in geopotential decameters.

Alaska, placed the Alaskan North Slope and LEADEX study area under a strong easterly geostrophic gradient.

Broken-to-overcast cloud conditions were observed at various levels on the ANC to FAI leg. Much of the variation could be attributed to topographic influence. At the time FAI was reporting overcast skies and light snow. The low clouds undercast with only occasional breaks extended to 68°N. Patchy cirrus were present at or just below flight altitude for this segment as well. Just to the south of the Brooks Range the low clouds became scattered; to the north it was overcast again. The surface was obscured by low clouds to 71.7°N; to the north the surface was visible. Deadhorse was reporting overcast, a ceiling of about 1 km, and an east-northeasterly wind of 10 m s^{-1}. Patchy cirrus at flight altitude continued to obscure the horizon at times, according to the flight log. The region near the Ice Camp, where the sounding was made, was relatively clear of mid- and low-level clouds. At the surface the visibility varied from less than 1 km to unlimited, on the basis of WP-3D's position with respect to open leads. During the return to ANC the variations in cloudiness along the southbound segment were similar to those on the northbound leg.

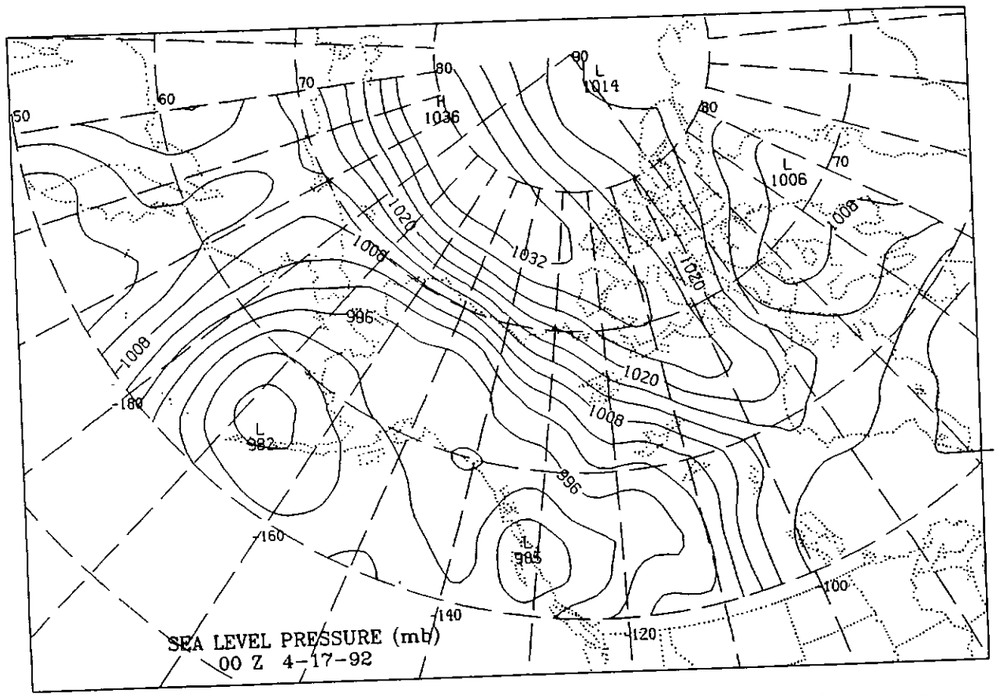

Figure 6.3. Surface synoptic map for 0000 UTC, April 17, 1992. Indicated are surface pressure contours in millibars.

6.4 Atmospheric Cross Section

The analysis of the distribution of potential temperature along the flight track (Fig. 6.4) was based on the 0000Z April 17 ANC, FAI, SCC, and BRW rawinsondes and the meteorological observations from the WP-3D. A shift in wind direction between 700 and 600 mb, during the climb from Anchorage, indicated a stable layer aloft. A second discontinuity was encountered at 64.7°N when the wind speeds decreased and the concentration of ozone increased. Shortly thereafter the aircraft left that layer, only to reenter it again at 65.9°N when the ozone concentrations increased substantially, reaching levels typical of the lower stratosphere. The aircraft departed that layer at 66.7°N. At 69.5°N the winds backed to a westerly direction. At 500 mb on the descent the wind turned again to the east.

The flight intercepted the top of the Arctic boundary layer at 900 mb. A 7°C temperature inversion existed between 900 and 1022 mb, the highest pressure obtained on this flight. The top of the Arctic boundary layer was at 890 mb during the climb at 72.4°N. The next significant feature was a 20-mb-thick layer of elevated ozone concentrations at 370 mb. That layer was within 15 mb of the pressure of the ozone-rich layer encountered on the northbound segment.

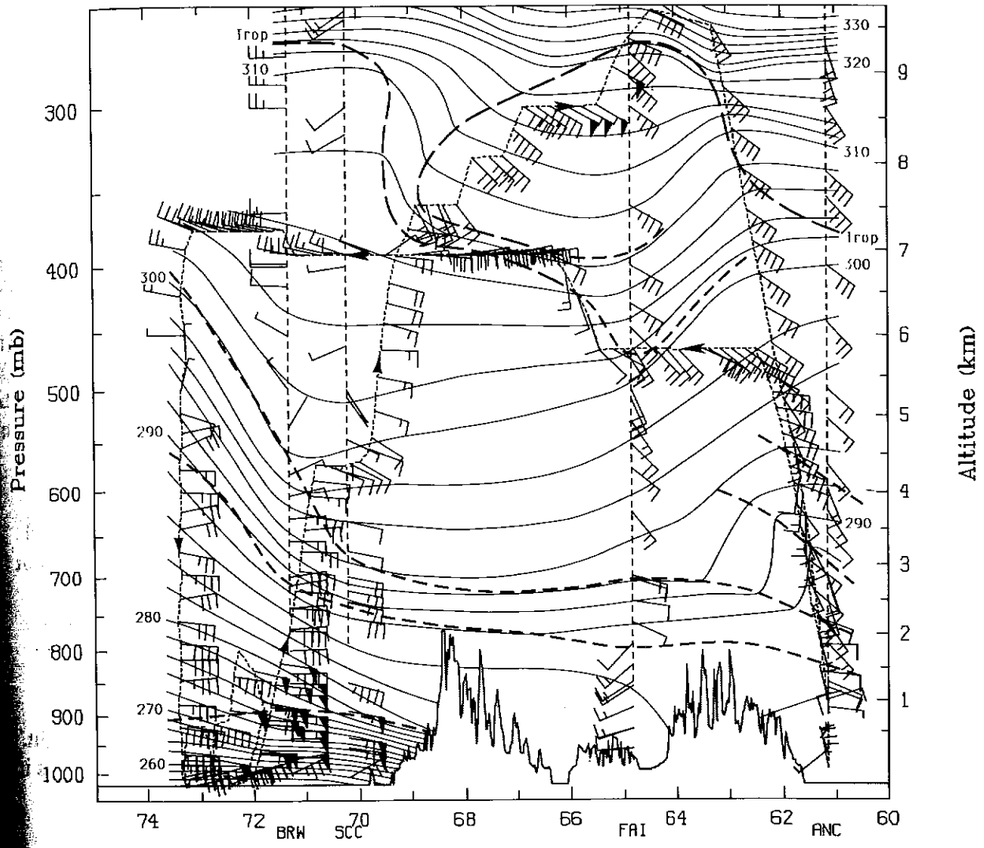

Figure 6.4. Latitude-altitude cross section of potential temperature (K) and wind (1 barb = 10 knots) between Anchorage and 74°N, 2029-0614 UTC April 16-17, 1992. The tropopause and top of the Arctic boundary layer are indicated by thick long-dashed lines, stable layers and frontal zones by thick short-dashed lines, and the aircraft flight track by thin-dashed lines. Arrows indicating the direction of the aircraft are placed at the beginning of each hour. The vertical dashed lines show the rawinsonde locations (BRW, SCC, FAI, and ANC).

It would appear that this constituted a layer of air of stratospheric origin that was advected to lower levels by subsiding air to the north of the low at 500 mb. On the basis of a sharp increase in ozone concentration at 267 mb at 64.9°N, the tropopause was intersected again at that level. The aircraft was in stratospheric air until descending to 347 mb at 62.7°N. (A short portion of

this flight, 0528-0541Z, was not shown in Fig. 6.4 because of the 250 mb upper limit of the plot.) The stable layer at 700 mb encountered on the climb was also measured on the descent.

6.5 Discussion of Sampling Conditions

The stable layers observed on the climb out of Anchorage (Fig. 6.4) were the cold and stationary fronts shown in the previous analysis; see Fig. 5.5. As in the previous flight there was considerable cloudiness and moisture observed above the frontal zones, causing sporadic jumps in the aerosol scattering observations. For a brief time (2135-2145Z), about 100 km north of Fairbanks on the northbound segment, the ozone concentrations increased abruptly to above 80 ppbv, indicating the presence of air of stratospheric origin. This region was coupled with a brief segment of elevated ozone concentrations at 380 mb and during the southbound flight to indicate a fold in the stratosphere. Drawing the tropopause to fit the ozone observations in this way also separates the southeasterly jet at 300 mb over Fairbanks from the much weaker westerly winds over the north slope. Otherwise the aircraft was in the troposphere for most of this flight.

At the northern edge of the cross section, the weak westerlies in the upper troposphere gave way to easterlies at 500 mb. The transition was marked by a weak stable layer from 400 to 570 mb. Except for a potential haze layer from 600 to 750 mb on the descent, where the aerosol scattering coefficients exceeded 10^{-5} m^{-1}, values were generally less than 5×10^{-6} m^{-1} throughout the descent, low-level maneuvers, and subsequent ascent. The visibility was good while the aircraft crossed the Brooks Range, and no distant haze layers were observed. CN concentrations were in the 100-500 cm^{-3} range throughout. In the upper troposphere south of the frontal zone the winds indicated a westerly transport over the Bering Sea.

Ozone concentrations remained above 25 ppbv during the low-level segment of the flight. Below 800 mb the winds were frequently in excess of 30 m s^{-1}. Barrow reported surface winds in excess of 15 m s^{-1} at the time. Boundary layer winds of this intensity and the associated turbulence made it difficult for the WP-3D to operate below 25 m. At that level there was vigorous mixing of air from aloft with that in contact with the surface. Thus the stability was reduced and the ozone was well mixed, resulting in elevated minimum values. The climbout sounding began 220 km northeast of Barrow; thus with a 20 m s^{-1} wind from 70°, the transit time to Barrow was between 2 and 2.5 hours. With winds of this magnitude the transit time to Northern Canada would be 12-18 hours. By all indications the transport beyond that time would be much slower if the wind were from the south off the Canadian Rockies.

During the southbound segment of the flight a deep penetration of the stratosphere was accomplished. Ozone concentrations in excess of 230 ppbv and CN concentrations in excess of 7000 cm^{-3} were measured above 300 mb. These were some of the highest concentrations of these respective constituents ever measured in the stratosphere during the AGASP series of missions. On the basis of records aboard the NOAA WP-3D, the 237 mb pressure (10.7 km) measured at the highest point was the lowest static pressure ever attained by this aircraft. It was also the lowest pressure ever attained during the AGASP flight series.

7. FLIGHT 406, APRIL 18-19, 1992

7.1 Objective

Although flight 406 had the same objectives as flight 405, including the aircraft maneuvers to test the effect of aircraft orientation on the turbulence measurements, it was conducted in a different location. The low-level segment was moved to a more northerly position on the lead to take advantage of the stronger surface winds in the vicinity.

The flight originated at 1711Z and reached cruising altitude for the northbound transit at 17:27Z (see Fig. 7.1). Starting at 6.1 km (465 mb), the aircraft soon (1737Z) climbed to 6.7 km (427 mb). The aircraft remained at that altitude until the start of the slow descent at 1955Z (73.33°N, 144.79°W). At 2033Z the aircraft reached 1025 mb, the base of the profile. From 2034Z to 2152Z the WP-3D flew a series of traverses upwind and downwind of a major lead at heights of approximately 20, 60, 140, and 160 m. Following a brief sounding to 800 mb, at 2205Z, a series of L-shaped patterns were flown at altitudes of approximately 20, 60, 110, 150, and 260 m. In all cases the long segment of the pattern was flown perpendicular to the mean wind direction at that level. This segment of the flight ended at 0026Z when the aircraft began

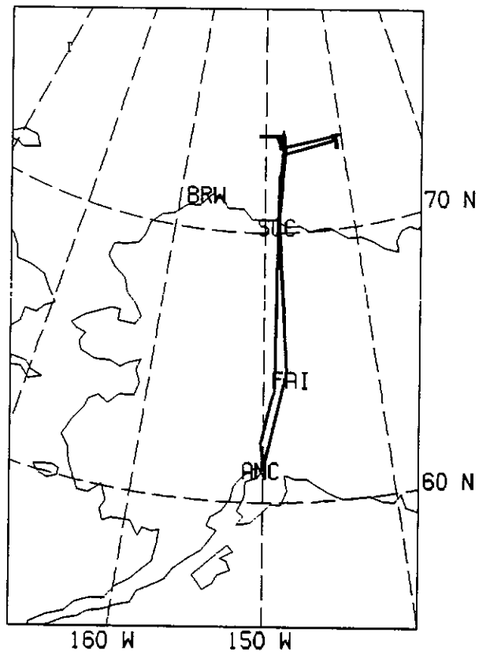

Figure 7.1. Horizontal projection of the aircraft flight track on a latitude-longitude grid, April 18-19, 1992.

the climb for the return to Anchorage. The ascent profile started at 73.11°N, 147.60°W, and ended 20 minutes later at 72.22°N, 148.26°W at 4.6 km (571 mb). The WP-3D passed about 7 km to the east of the Ice Camp (72.96°N, 148.09°W) at 0029Z. As in flight 405, a series of maneuvers were performed to test the influence of the aircraft motion on the turbulence instrumentation; they lasted 28 minutes. At 0114Z, 71.23°N, at 148.32°W the aircraft resumed the climb to cruise altitude. At 7.6 km (375 mb) at 70.60°N, 148.40°W the WP-3D leveled off and remained at that altitude until 0135Z when it climbed to 8.2 km; 20 minutes later it climbed to 10.1 km (261 mb). The aircraft remained at that altitude until 0242Z at 64.76°N, 149.04°W, when the descent into Anchorage was begun. The aircraft landed at 03:41Z.

7.2 Flight Log

17:11				Takeoff.
17:16	61.42	149.86	731	Entering midlevel Ac cloud layer.
17:18	61.59	149.89	647	Atop middle cloud layer.
17:19	61.61	149.89	643	Overcast above.
17:20	61.69	149.88	600	Scattered Cu below now.
17:23	61.92	149.78	513	Scattered Cu below, thin Ci overcast above.
17:24	61.99	149.74	492	Partially obscured here.
17:25	62.02	149.72	480	Light turbulence in Ci.
17:26	62.11	149.69	465	Still in Ci.
17:27	62.14	149.67	465	Ozone and aerosol scattering are not being displayed.
17:30	62.38	149.05	464	Nearing top of Ci.
17:31	62.43	149.51	465	Atop Ci layer.
17:31	62.44	149.50	465	Clear above.
17:35	62.71	149.36	436	Looks like the dew point instrument has about a 3 min delay at these temps.
17:36	62.73	149.34	430	Level at 6700 m.
17:42	63.18	149.07	426	Horizon is obscured.
17:43	63.20	149.05	426	Back in the Ci.
17:43	63.28	149.00	426	Above the obscuration again.
17:44	63.36	148.95	426	Stratocumulus layer below.
17:44	63.37	148.95	426	Undercast.
17:46	63.52	148.86	426	Back in the obscuration again.
17:46	63.53	148.85	426	Slight turbulence.
17:47	63.59	148.82	426	Horizon obscured.
17:48	63.66	148.77	426	Still in clouds.
17:51	63.90	148.62	426	Still in clouds.
17:52	63.92	148.60	426	Getting brighter.
17:53	64.05	148.53	426	Nearing top of clouds.
17:54	64.11	148.49	426	Near the top of clouds.
17:55	64.15	148.46	426	Horizon still not visible.
17:57	64.30	148.37	426	Horizon still obscured
17:59	64.49	148.24	426	Still in clouds, horizon is not visible.
18:00	64.53	148.21	426	Ground is partially visible.

18:02	64.65	148.11	426	Clouds are thin at this point.
18:02	64.67	148.09	426	Horizon is in view.
18:02	64.74	148.00	426	Low scattered clouds.
18:03	64.75	147.99	426	Clearing at flight level.
18:06	64.95	147.99	426	Widely scattered clouds below, thin obscuration at flight level.
18:06	65.01	148.02	426	Horizon is visible.
18:39	65.16	148.06	426	Hazy on the horizon.
18:08	65.19	148.07	426	Scattered clouds below.
18:10	65.32	148.08	426	Brown tinge to haze atop clouds looking toward SE.
18:11	65.43	148.10	426	Horizon obscured again.
18:12	65.46	148.10	426	Clouds at flight level seem to be decreasing as we go north.
18:12	65.52	148.11	426	Widely scattered low cumulus below.
18:31	67.07	148.39	426	Clear at flight level.
18:31	67.11	148 21	426	Undercast of low clouds at the surface.
18:38	67.67	148.47	426	Undercast with top at about 6000 ft.
18:39	67.72	148.47	426	Cloud layer on the horizon.
18:49	68.54	148.45	427	Low clouds edge at ridge of Brooks.
18:50	68.65	148.00	427	Clear above.
18:52	68.84	148.45	426	Clear below.
18:53	68.89	148.45	427	Clouds ahead, low stratus.
18:56	69.16	148.44	427	Sc undercast now.
18:57	69.21	148.44	426	Horizon is not visible to starboard.
19:02	69.65	148.44	426	There is a reddish brown tint to the haze to the SE.
19:09	70.17	148.39	427	Nephelometer clean-air check performed at 1906Z.
19:14	70.66	148.29	427	St undercast at this location.
19:19	71.03	148.19	426	Dropwindsonde no. 1 released.
19:26	71.59	148.01	427	Horizon not visible.
19:26	71.61	148.01	427	Undercast, Sc.
19:31	72.06	147.85	427	Ice surface is barely visible now.
19:35	72.34	147.74	427	Horizon barely visible.
19:35	72.36	147.73	427	Surface obscured.
19:35	72.41	147.71	427	No indication of haze layers on the horizon.
19:41	72.87	147.00	427	Clearing some below.
19:41	72.92	147.54	427	Horizon barely visible.
19:42	72.97	147.52	427	Dropwindsonde #2 released.
19:43	73.04	147.49	427	Top of inversion is at 907 mb based on the sonde.
19:45	73.18	147.43	427	Turning toward NE.
19:45	73.21	147.25	427	Mid-level Ac layer optically obscuring surface.
19:48	73.23	146.67	427	Surface is clear, scattered to broken midlevel clouds.
19:51	73.27	145.87	427	Clearing as we go north.
19:55	73.34	144.71	435	Start descent over ice, some cloud streaks on surface.
19:55	73.34	144.62	441	Whitish layer on the horizon topped by a single brownish layer.
19:59	73.40	143.56	515	Clear now.
20:04	73.45	142.52	602	Aerosol scattering decreasing.
20:04	73.45	142.41	613	Slightly elevated aerosol scattering for last 8 min.

20:05	73.46	142.21 632	Ozone steady.
20:10	73.50	141.09 756	Aerosol scattering gradually increasing.
20:15	73.51	140.13 843	Turning.
20:15	73.50	140.14 843	Aerosol scattering increasing, may be turn influenced.
20:19	73.45	140.86 876	Aerosol scattering gradually increasing.
20:21	73.42	141.46 949	Aerosol scattering starting to drop.
20:23	73.46	141.30 959	Grayish brown layer visible.
20:30	73.51	140.72 990	Thin brownish haze layer visible.
20:33	73.38	140.82 1024	Light turbulence.
20:35	73.30	140.87 1007	Observation pass upwind of lead.
20:35	73.29	140.78 1006	Estimated visibility 2-4 mi.
20:38	73.36	140.87 1023	Start 50 ft (RA) run over large open lead, light turbulence downwind of lead.
20:40	73.45	140.76 1024	Ozone, aerosol scattering, and CN steady last 5 min.
20:41	73.48	140.73 1018	End downwind leg, climb to 500 ft (RA) to turn.
20:43	73.52	140.58 1008	Steady for last 12 min.
20:45	73.50	140.72 1020	Back down at 50 ft (RA) - over more slushy part of lead. Ice crystal haze here, estimated visibility 2-3 mi.
20:46	73.44	140.00 1024	Beginning 18 m run over slush.
20:50	73.30	140.91 1020	Climbed to 500 ft (RA) to turn.
20:51	73.25	140.82 1007	Beginning 32 m run over downwind edge of lead.
20:54	73.29	140.86 1020	Start 100 ft (RA) run over downwind edge of lead. About half open water and half slush.
20:57	73.45	140.75 1023	End of run.
20:58	73.47	140.73 1012	Climb to 500 ft (RA) to turn.
20:59	73.49	140.60 1005	32 m on downwind side.
21:00	73.50	140.73 1005	Ozone and aerosol scattering very steady.
21:01	73.48	140.79 1013	P-3 plume contaminated samples during the last turn.
21:01	73.41	140.83 1023	Start 100 ft (RA) run over downwind edge of lead. Trying to stay more over the slush now.
21:02	73.41	140.85 1023	Turning into the SW, intercepted the P-3 plume again.
21:04	73.32	140.89 1022	Moderate turbulence.
21:05	73.29	140.89 1021	End of 32 m run.
21:05	73.24	140.89 1017	End of 100 ft run. Climb to turn.
21:07	73.24	140.91 1008	Starting run.
21:07	73.26	140.91 1018	64 m level.
21:08	73.28	140.91 1018	Intercepted the P-3 plume again on the last turn.
21:09	73.32	140.90 1018	61 m over the slush.
21:12	73.47	140.82 1016	Slight climb in aerosol scattering.
21:17	73.46	140.81 1024	Start run at 50 ft (RA) on upwind side of big lead. Mostly over open water, saw plume again on turn.
21:18	73.41	140.80 1025	50 ft downwind.
21:18	73.38	140.83 1024	50 ft upwind.
21:19	73.36	140.86 1024	End of run.
21:20	73.33	140.89 1019	Climb for turn and reverse course.

21:24	73.24	140.86 1007	Beginning a run.
21:24	73.26	140.89 1012	Descending to 50 ft (RA) for run over mostly open water. Sniffed P-3 exhaust again.
21:25	73.31	140.88 1024	18 m center of lead.
21:29	73.47	140.76 1023	End of run.
21:29	73.50	140.72 1008	Next is 18 m over pack downwind of lead. Climb to turn.
21:32	73.48	140.89 1022	Start 50 ft run over solid ice on downwind side of lead.
21:33	73.44	140.93 1025	Light turbulence to moderate turbulence, good lead plume signal.
21:33	73.42	140.94 1024	Rougher over ice than lead.
21:35	73.35	140.99 1024	Ice is rough in this region.
21:36	73.29	141.00 1015	End of run. Climb to turn.
21:38	73.29	141.09 1018	P-3 exhaust intercepted again on the last turn.
21:38	73.29	141.01 1024	P-3 exhaust again.
21:39	73.30	140.89 1024	Crisscrossing the lead. Start 50 ft run at an angle to the lead. Could only sample for a short time over the lead.
21:40	73.29	140.88 1017	Now over ice. Lead aerosol sampling stopped.
21:43	73.28	141.20 1006	Caught P-3 plume again.
21:45	73.30	141.10 1021	31 m perpendicular to lead.
21:46	73.29	140.97 1022	Start 100 ft (RA) perpendicular run over lead. 30 s later over ice. Lead aerosol sampling stopped.
21:47	73.29	140.80 1022	CN is variable, check P-3 exhaust displacement.
21:48	73.27	140.69 1006	Visibility reduced looking into the sun.
21:49	73.28	140.70 1006	Visibility estimated to be 2-3 mi.
21:50	73.30	140.95 1022	Another 15 m run over lead. Then climb 61 m per min.
21:51	73.30	141.11 1014	CN was very high last 2-4 min. Start ascent.
21:52	73.31	141.40 1008	Ozone and aerosol scattering steady.
21:53	73.30	141.53 994	Ozone and aerosol scattering steady during climb.
21:59	73.24	142.60 891	Haze layer here.
22:00	73.23	142.82 869	The haze layer is at 1.1 km.
22:03	73.19	143.53 803	Out of haze layer.
22:05	73.18	143.80 799	CN steady through this layer.
22:06	73.17	144.19 800	Top of layer.
22:07	73.16	144.26 799	Ozone continuing to increase.
22:07	73.16	144.33 798	Going down to 30 m.
22:14	73.09	145.81 831	Still in haze layer.
22:17	73.04	146.55 846	Few patchy Ci aloft.
22:17	73.04	146.59 847	Haze bands visible on horizon.
22:18	73.03	147.00 857	Descending.
22:21	72.96	147.49 936	Estimated visibility 4-6 km.
22:22	72.94	147.69 960	Aerosol scattering decreasing.
22:28	72.92	147.73 1000	Ozone and aerosol scattering steady for last 5 min.
22:30	73.01	147.51 1005	Beginning stacked "L"s.
22:33	73.16	147.61 1018	Steady.
22:34	73.17	147.61 1018	Light turbulence.

22:34	73.24	147.61	1018	Scattered thin Ci aloft.
22:50	73.29	147.99	1006	Estimated visibility 4-6 km.
22:50	73.27	148.01	1006	Scattered Ci aloft.
22:57	73.13	148.23	1013	Light turbulence this leg.
23:10	73.55	148.87	1013	CN gradually decreasing.
23:12	73.54	149.36	1013	Ozone and aerosol scattering steady.
23:39	73.60	148.92	986	Ci thickening, broken now.
23:51	73.49	147.50	987	Broken Ci overhead, visibility 4-6 km.
23:52	73.46	147.50	987	Visibility variable.
00:05	73.52	147.58	1020	Gradual increase in aerosol scattering.
00:24	73.19	147.50	1013	Overcast midlevel Ac.
00:32	72.87	148.20	989	Just passed the Ice Camp.
00:32	72.85	148.20	986	Sun obscured.
00:33	72.81	148.20	972	Broken midlevel clouds now.
00:36	72.68	148.22	918	Ozone and aerosol scattering increasing.
00:39	72.56	148.22	851	Sun obscured.
00:39	72.54	148.23	829	Big jump in aerosol scattering.
00:41	72.47	148.23	778	Both aerosol scattering and ozone dropping.
00:44	72.02	148.26	602	Out of layer.
00:45	72.24	148.26	578	Begin maneuvers to test the flux-measuring system (pitch, yaw, turns, etc.).
01:13	71.30	148.33	572	End maneuvers.
01:16	71.05	148.37	532	Undercast of Ac.
01:17	71.00	148.37	508	Clear above.
01:17	71.00	148.37	508	For the previous 30 min we have been doing maneuvers to test the flux system.
01:18	70.92	148.38	470	It might be interesting to see how this affects the aerosol measurements.
01:19	70.83	148.39	433	ODW no. 3 dropped at 71.2°N.
01:22	70.62	148.41	375	Undercast stratocumulus.
01:23	70.59	148.41	374	Aerosol scattering decreasing to threshold levels.
01:34	69.81	148.52	374	Climbing for the stratosphere.
01:35	69.70	148.53	357	Ozone is low for this altitude.
01:36	69.64	148.54	345	Ozone dip.
01:38	69.50	148.56	343	Aerosol scattering dropping.
01:38	69.49	148.56	343	Dropwindsonde #4 for the day.
01:39	69.44	148.57	343	Big decrease in ozone and aerosol scattering.
01:39	69.42	148.57	343	Did dip in ozone and aerosol scattering coincide with the ODW release?
01:42	69.23	148.60	343	Ozone and aerosol scattering values have recovered.
01:48	68.81	148.63	343	Second nephelometer clean-air check at 8247m PA.
02:14	66.88	148.87	300	Observing higher ozone values with continued climbing.
02:15	66.79	148.87	299	By all visual observations we are at the tropopause.
02:15	62.00	148.87	296	Ozone is going up.
02:16	66.71	148.88	292	Ozone and aerosol scattering increasing fast.

02:16	66.68	148.88	289	In stratosphere now, ozone is >90 ppbv.
02:18	66.57	148.90	282	Ozone over 190 ppbv.
02:18	66.54	148.88	280	Aerosol scattering steady.
02:22	66.28	148.91	272	Horizon obscured by Cs.
02:22	66.26	148.91	272	Opaque below.
02:23	66.21	148.92	271	Brownish haze layer at the tropopause.
02:25	66.07	148.93	266	In stratospheric air. Ozone: 250 ppbv.
02:29	65.70	148.98	260	CN is high >12,000 cm^{-3}.
02:37	65.16	149.01	261	PA: 10,088 m. Ozone: 220 ppbv.
02:40	64.87	149.04	260	Still in stratosphere.
02:41	64.79	149.04	263	Starting down.
02:47	64.35	149.07	286	Cloud cover to the west.
02:48	64.32	149.07	286	Clear below and to the east.
02:49	64.25	149.08	291	Ozone: 200 ppbv.
02:50	64.15	149.10	301	Going down to try to skim the tropopause.
02:54	63.90	149.19	313	Approaching the tropopause.
02:55	63.83	149.23	313	Slight turbulence.
02:59	63.59	149.48	326	At the tropopause.
03:00	63.00	149.56	335	Below the tropopause but CN is still high.
03:01	63.46	149.57	338	Ozone dropped to 75 ppbv.
03:02	63.36	149.62	343	Scattered Cu around Mt. McKinley.
03:06	63.10	149.75	363	Clear above, scattered Cu below.
03:12	62.70	149.94	439	Slight turbulence.
03:13	62.67	149.96	446	Ground is obscured.
03:14	62.62	150.00	461	Still above the clouds.
03:16	62.47	150.10	494	Ground visible below the plane.
03:16	62.45	150.11	499	Clouds to the west.
03:17	62.42	150.12	504	Clear above.
03:21	62.10	150.29	600	Lower patchy Cu, clear above.
03:24	61.99	150.36	636	Slight turbulence, end of log.
03:41				Landed in Anchorage.

7.3 Synoptic Situation

In the 48-h period after the last flight, the 510 decameters low off the southwest coast moved to a position due south of Anchorage at 60°N and filled to a central height of 522 decameters (see Fig. 7.2) while a minor trough was making its way across southern Alaska. The high-pressure ridge over the Beaufort Sea changed little in height or position during the period after the previous flight (see Fig. 6.2). The result was a reduction in the geostrophic gradient over central Alaska. As a further result, while the winds remained from the south the speeds were significantly less than during the previous flight.

At the surface, a weak region of low pressure with an associated stationary front was positioned to the north of Fairbanks; it determined conditions in the central part of the state (Fig. 7.3). North of the Brooks Range, a weak low over the Chukchi Sea and an associated trough

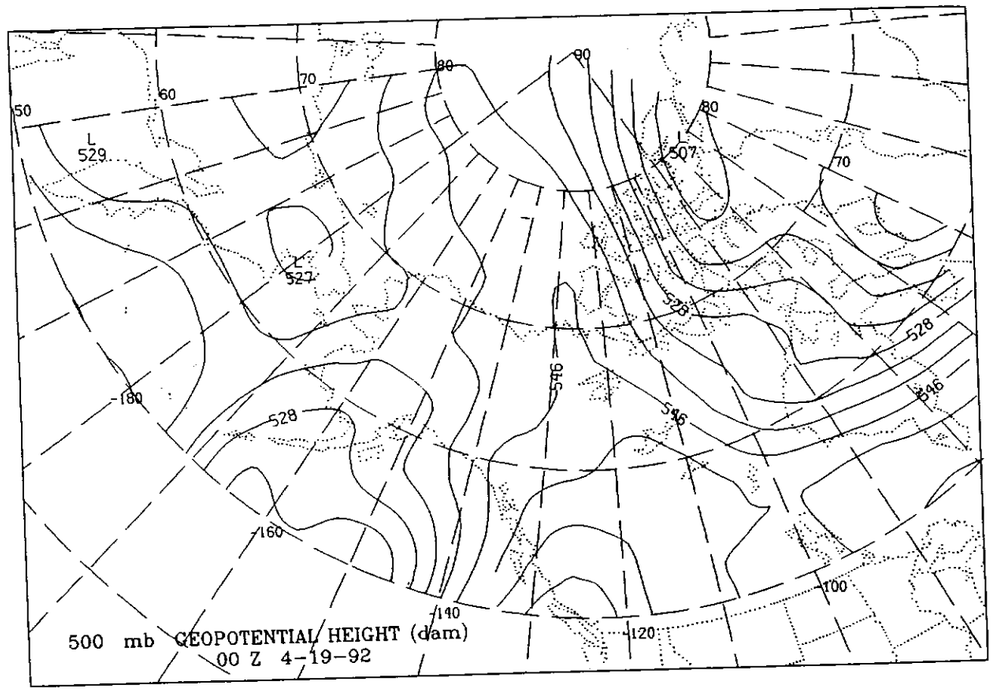

Figure 7.2. 500 mb synoptic map for 0000 UTC, April 19 1992. Indicated are height contours in geopotential decameters.

along the coast defined the southern edge of a region of pronounced pressure gradient, which extended to the high at 80°N in the Beaufort Sea. As the pressure gradient along the coast decreased in the previous 24 hours, surface wind decreased from 10-15 m s^{-1} to < 3 m s^{-1}. At the same time the wind speed at the Ice Camp increased. During the flight the Ice Camp was reporting a northeasterly wind at 10 m s^{-1}.

On the basis of surface observations at the time of the flight and the observations from the aircraft, conditions along the flight track were generally cloudy. ANC, FAI, and SCC were reporting overcast condition at the time. Except for isolated regions where the topography produced local cloud-free regions, an undercast was present for most of the flight. At flight altitude visibility was frequently reduced in cirrus clouds.

7.4 Atmospheric Cross Section

The atmospheric cross section of potential temperature (Fig. 7.4) was drawn using one dropwindsondes at 71.2°N and the Deadhorse and Ice Camp soundings for 0000Z, April 19 in addition to the Anchorage and Fairbanks soundings for the same time. The first discontinuity

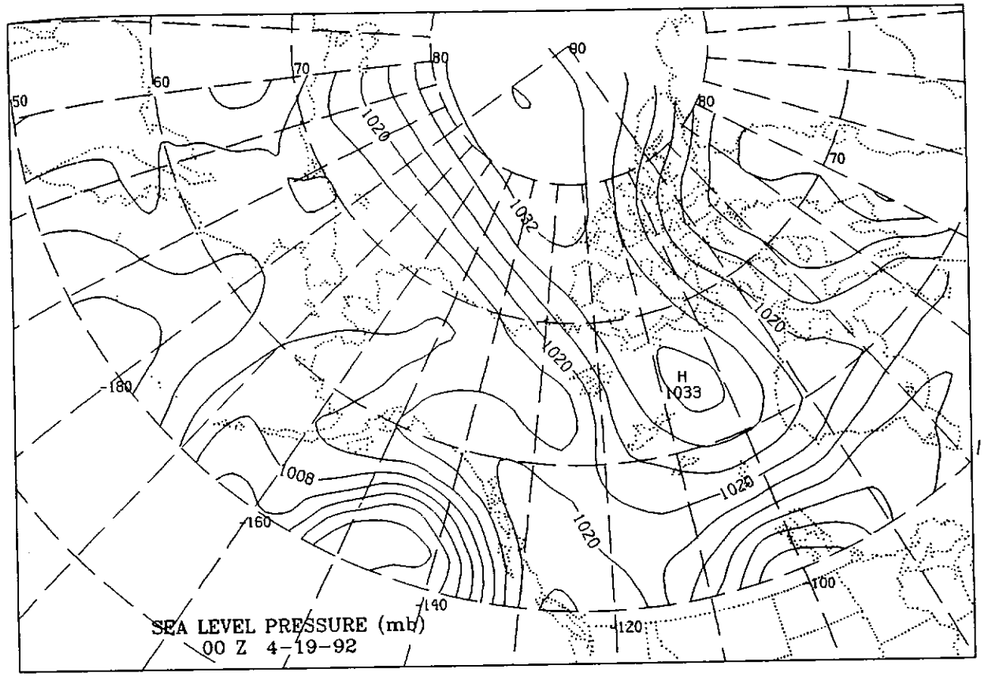

Figure 7.3. Surface synoptic map for 0000 UTC, April 19 1992. Indicated are surface pressure contours in millibars.

encountered was the cold front between 700 and 800 mb over Anchorage. The stationary cold front intersected the surface just to the south of Fairbanks. A much weaker stable layer aloft was identified by a shift in the wind direction to more easterly at 500 mb. The winds returned to a southerly direction at 67°N on the northbound segment, but back to the southeast during the descent at 73°N. The aircraft entered the Arctic boundary layer at 790 mb. The layer was isothermal to 960 mb, where the temperature began to decrease rapidly. The temperature decreased 9°C in the surface layer. For the period the aircraft was in the Arctic boundary the winds were consistently from the east-southeasterly direction in the 15-20 m s^{-1} range. During the ascent the top of the Arctic boundary layer was encountered at 770 mb. A slight veering of the wind at 550 mb on the ascent cannot be tied to any particular feature in the potential temperature analysis. The next significant discontinuity was the interception of the tropopause at 300 mb (66.7°N). This interception was determined by an abrupt increase in the ozone concentration. The ozone concentration remained above 90 ppbv until the aircraft reentered the troposphere at 340 mb, at 63.4°N. A lower tropopause was therefore indicated in the region north of the Alaskan Range where subsidence could be expected to the north of the trough aloft. The winds shifted again at 800 mb, as the aircraft passed through the stationary front over Anchorage.

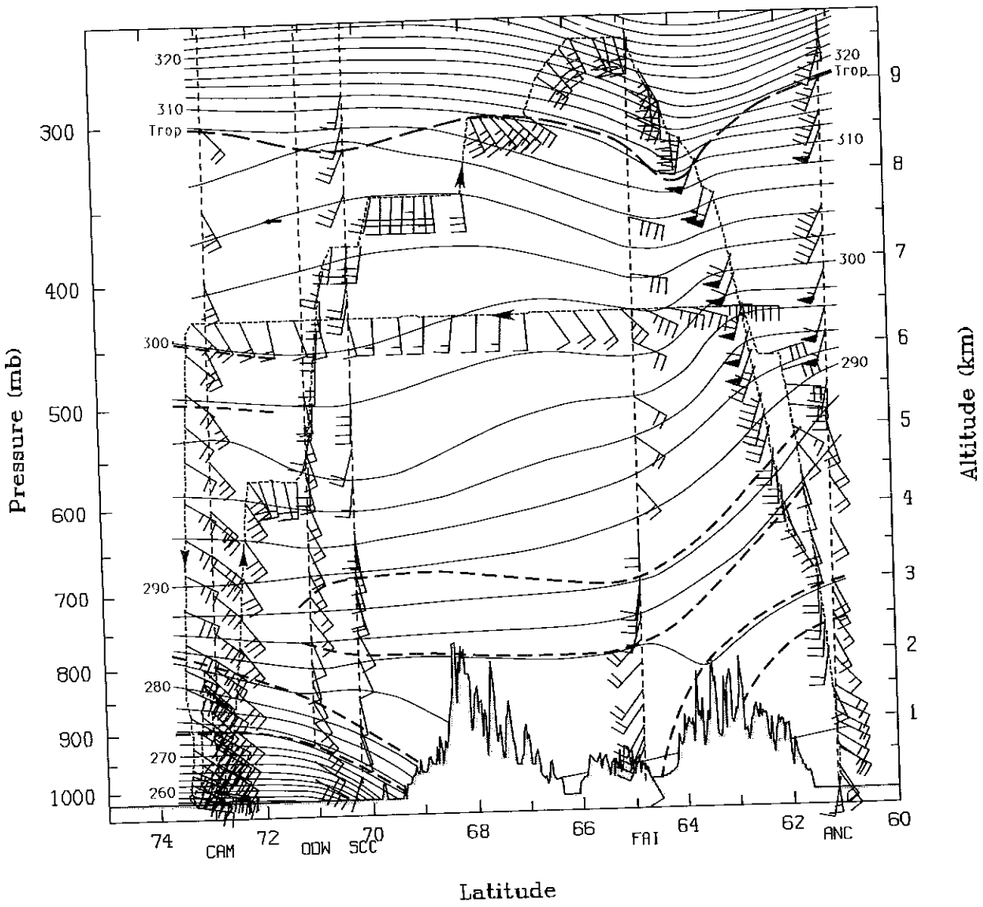

Figure 7.4. Latitude-altitude cross section of potential temperature (K) and wind (1 barb = 10 knots) between Anchorage and 74°N, 1710-0324 UTC April 18-19, 1992. The tropopause and top of the Arctic boundary layer are indicated by thick long-dashed lines, stable layers and frontal zones by thick short-dashed lines, and the aircraft flight track by thin dashed lines. Arrows indicating the direction of the aircraft are placed at the beginning of each hour. The vertical dashed lines show the aircraft dropwindsonde locations (ODW) and the rawinsonde locations (CAM, SCC, FAI, and ANC).

7.5 Discussion of Sampling Conditions

The aircraft passed through two stable layers on the ascent out of Anchorage. The first was a well-defined stationary front associated with a trough at 500 mb (see Fig. 7.2). The trough

was south of Fairbanks at 0000Z, but by the time of the aircraft descent over the Alaska Range, wind had shifted to the west-southwest, indicating that the trough axis had passed that location. The WP-3D remained in the troposphere for the duration of the northbound segment of the flight. Ozone concentrations ranged from the high 30's to low 70's ppbv. For the first 20 minutes at cruising altitude variable aerosol scattering coefficients were observed, values as high as 40×10^{-6} m^{-1}. During this same period the flight log indicates the evidence of scattered cirrus clouds at flight level causing the periodic obstruction of the horizon. It is our belief that the nephelometer was contaminated by ice crystals during this period. CN concentrations were in the 400-1000 cm^{-3} range in this segment, which is slightly higher than was observed during the preceding flights. The generally uniform weak flow at 427 mb on the northbound segment supported the small change in the gradient of potential temperature in the upper troposphere over this region.

During the subsequent descent, low-level, and climb segments, ozone concentrations were generally between 25 and 60 ppbv, the aerosol scattering coefficient was in the (2-18) $\times 10^{-6}$ m^{-1} range and the CN concentration was between 50 and 700 cm^{-3}. A weak stable layer was encountered between 680 and 780 mb. The top of the Arctic inversion was at 780 mb. Winds below the inversion had shifted to a more southerly direction and had decreased somewhat in speed after the preceding flight. Light to moderate turbulence was nevertheless observed during the lowest level traverses; see the flight log. Once again the lowest ozone concentrations were sufficiently high to indicate that the aircraft was unable to get into the surface layer. At various times during the low-level segment the WP-3D intersected its own plume, resulting in intermittent spikes in the CN concentration record. Some occurrences, in the 2100Z to 2200Z period, were noted in the flight log.

The stratosphere was entered on the southbound segment at 300 mb, at 66.8°N. Ozone concentrations as high as 260 ppbv were observed at the 261 mb level. The aerosol scattering coefficient was in the (0.5-3) $\times 10^{-6}$ m^{-1} range and the CN concentrations were between 100 and 6000 cm^{-3}. The highest CN counts were observed in the stratosphere at 261 mb. The WP-3D departed the stratosphere at 340 mb, at 63.4°N.

For the first time in this series of flights the slope of the potential temperature surfaces indicated the troposphere below 500 mb was colder over Anchorage than over the North Slope. While winds were weak in the midtroposphere they had a southerly component at all levels. The reports of extensive cloudiness along the transit segment indicates that maritime Pacific air was what was being sampled above 500 mb. Below that level in the vicinity of the Ice Camp the winds suggest a Northern Canadian source region 24-48 hours upwind. Under the influence of the high-pressure region 2 days earlier the transport may have been from the north beyond that time period.

8. FLIGHT 407, APRIL 21-22, 1992

8.1 Objective

The seventh flight in the series was dedicated to aerosol and gas sampling in the Barrow region and to providing a comparison of measurements with those from a Russian aircraft sampling the Siberian Arctic at the same time. A secondary interest was in sampling the plume from a large Palynya, to the west of BRW.

The WP-3D took off from Anchorage at 1742Z and climbed to a cruising altitude of 6.1 km (466 mb). This altitude was maintained from 1800Z, at 62.18°N, 149.62°W, to 1934Z, at 68.92°N, 153.28°W. The aircraft followed the same track as in previous flights as far as Fairbanks, after which it turned toward Barrow (see Fig. 8.1). By 1929Z the aircraft had climbed to 6.3 km (427 mb) and remained at this altitude until the beginning of the descent profile. The slow descent began at 2021Z at 71.45°N, 158.90°W, and concluded at 2223Z, 71.21°N, 157.63°W, and at an altitude of 16 m (1018 mb). Level segments of 10-15 min duration were interspersed in the sounding at 3.0 km (702 mb), 1.5 km (848 mb), and 0.15 km (999 mb). At the conclusion of the sounding the aircraft was about 34 km west of Barrow. For the next 40 minutes

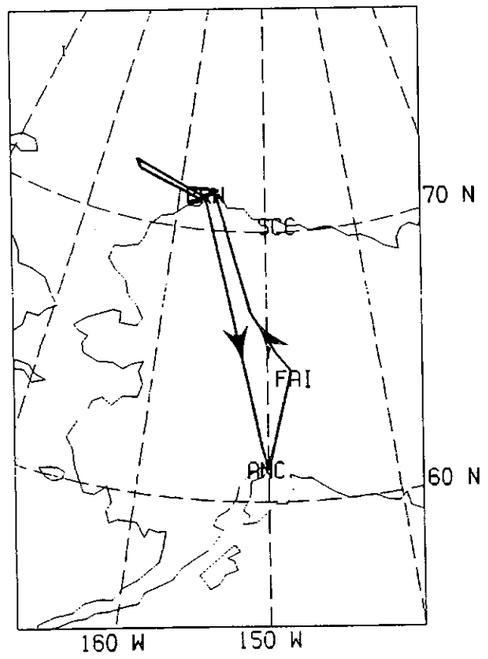

Figure 8.1. Horizontal projection of the aircraft flight track on a latitude-longitude grid, April 21-22, 1992.

the WP-3D conducted along- and cross-wind sampling segments at 16 m. A brief sounding from the surface to 5.9 km was begun at 2304Z, at 71.19°N, 157.60°W, after which at 2358Z, at 71.93°N, 165.90°W, the WP-3D descended to an altitude of 0.1 km to rendezvous with the Russian plane.

Following the sounding, the aircraft turned to the south and then southeast to return to Anchorage. The ascent to cruise altitude began at 0004Z, at 72.25°N, 165.92°W. Cruise altitude of 7.6 km (375 mb) was attained after only 14 minutes, a climb rate of 0.5 km min^{-1} (45 mb min^{-1}). After 18 minutes at 7.6 km the aircraft climbed to 9.5 km (286 mb). The aircraft maintained this altitude from 0055Z, at 71.06°N, 156.53°W, to 0138Z, at 68.06°N, 154.02°W. After a brief climb to 10.1 km (261 mb), and a 14 min segment at that level, the aircraft began the descent to Anchorage at 0204Z (66.18°N 152.77°N). The aircraft landed at about 0329Z.

8.2 Flight Log

No electronic metadata were taken on this flight. The flight notes are those of PS.

17:42	Takeoff.
18:08 62.74 149.33 465	Clean-air check performed on nephelometer.
18:44 65.30 148.80 466	Power interruption - all scientific systems will have a glitch.
19:07 66.83 151.40 466	Printout resumes.
20:03 71.10 155.54 427	Nearing Barrow coastline. High thin clouds almost up to aircraft level.
20:42 71.49 157.48 701	Just north of Barrow coastline. PA: 10,000 ft.
21:05 71.50 156.33 848	Descending through 5,000 ft (RA). Very near Barrow. Fly for a while at 500 ft RA.
22:21 71.30 157.27 1001	Start offshore run at 60 ft RA.
22:25 71.13 157.63 1017	Climb to turn.
22:32 71.18 158.03 1016	Start 50 ft RA run.
22:36 71.31 157.66 1017	Climb to turn.
22:40 71.22 157.31 1002	Start 50 ft RA run.
22:50 71.00 158.55 1017	Climb to turn.
22:53 71.02 158.62 1015	Start 60 ft RA run over open water.
23:02 71.12 157.40 1009	End 60 ft run. Climb.
23:10 71.30 158.50 951	Ascending through 650 m PA. Rendezvous with Russian Aircraft AN-26
00:12 72.20 164.63 497	Rendezvous with Russian Aircraft AN-26. Ascending through 5800 m PA.
00:33 71.76 160.55 375	PA: 7636 m; ozone: 90 ppbv.
00:37 71.69 159.80 375	Dropped below the tropopause. Ozone: 40 ppbv.
00:45 71.50 158.25 326	8800 m and climbing. Ozone: 90 ppbv.
00:53 71.20 156.70 292	Ozone now up to 126 ppbv.
00:54 71.12 156.61 288	Ozone: 150 ppbv; PA: 9475 m.

01:01	70.66	156.19	286	Severe yaw maneuvers started. Strange signals on nephelometer and possibly other systems.
01:06	70.21	155.80	286	In stratospheric air. Ozone: 145 ppbv; PA: 9475 m.
01:52	67.07	153.33	261	Ozone: 220 ppbv.
02:04	66.17	152.77	261	Ozone: 240 ppbv.
02:50	63.25	151.18	365	Passed over Denali summit.
03:13	61.79	150.52	670	Descending through 3600 m. Ozone: 56 ppbv.
03:29				Land in Anchorage.

8.3 Synoptic Situation

The dominant synoptic features at 500 mb (Fig. 8.2) at the time of this flight were a high-pressure ridge over the Bering Sea and an accompanying low-pressure region over the Gulf of Alaska. The ridge had developed as a result of a significant low to the west. This low was the remnant of the low at 60°N, 150°W at the time of the preceding flight (Fig. 7.2). The central pressure of the low was now 526 decameters at that time. The remnant of the high pressure ridge that was over northern Alaska during the preceding flight had become a weak high with a central

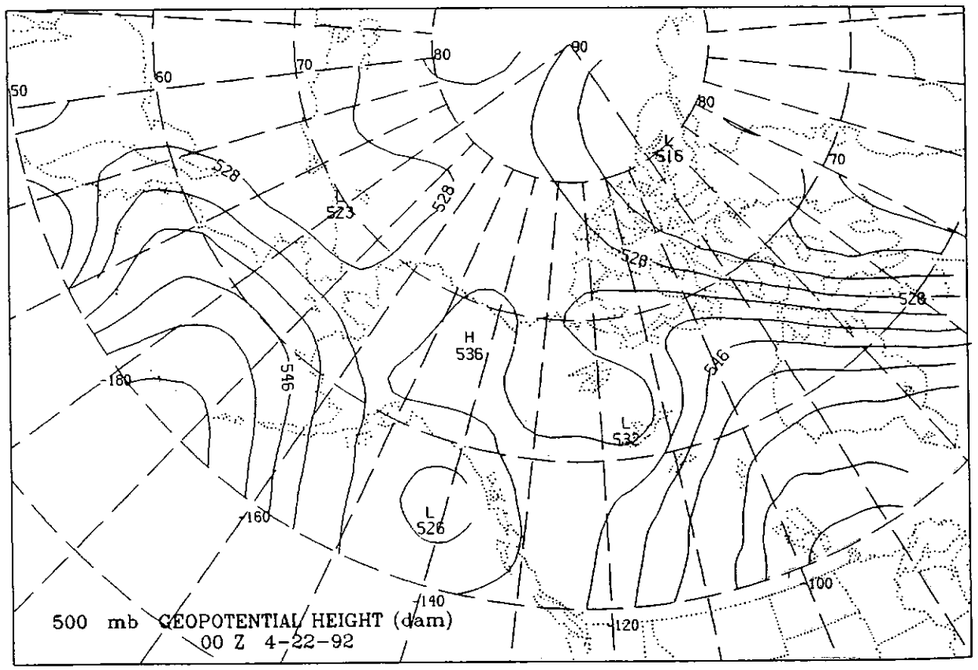

Figure 8.2. 500 mb synoptic map for 0000 UTC, April 22, 1992. Indicated are height contours in geopotential decameters.

height of 536 decameters. As a result of the decrease in the height gradient over the state, the steady southeasterly geostrophic gradient present during the preceding two flights was gone. Winds at 500 mb were generally light and variable.

At the surface, low pressure centered to the south and east of Anchorage (Fig. 8.3), in alignment with the low at 500 mb, continued to advect low-level moisture into southern Alaska. This low and a secondary low in western Canada coupled with a large high-pressure cell in the vicinity of the pole resulted in an northeasterly geostrophic flow over most of the state. A minor trough was analyzed in the BRW region at the time of the flight. Barrow was reporting light snow with winds from the southeast at 3 m s^{-1}.

Overcast and broken sky conditions were reported at Anchorage and Fairbanks at 1800Z. While some regions between Fairbanks and the Brooks Range were reporting clear or broken cloud conditions, the region north of the Brooks Range had extensive cloud cover.

8.4 Atmospheric Cross Section

The cross section of isentropic temperatures (Fig. 8.4) was based on the 0000Z April 22 soundings from ANC, FAI, SCC, BRW, and the data from the WP-3D. No dropwindsondes

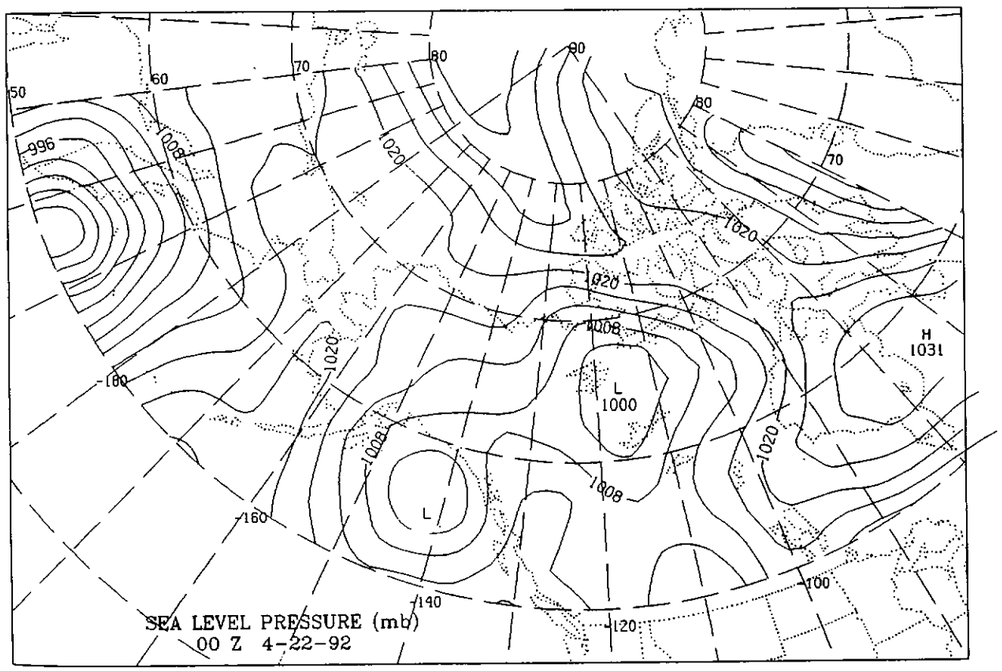

Figure 8.3. Surface synoptic map for 0000 UTC, April 22, 1992. Indicated are surface pressure contours in millibars.

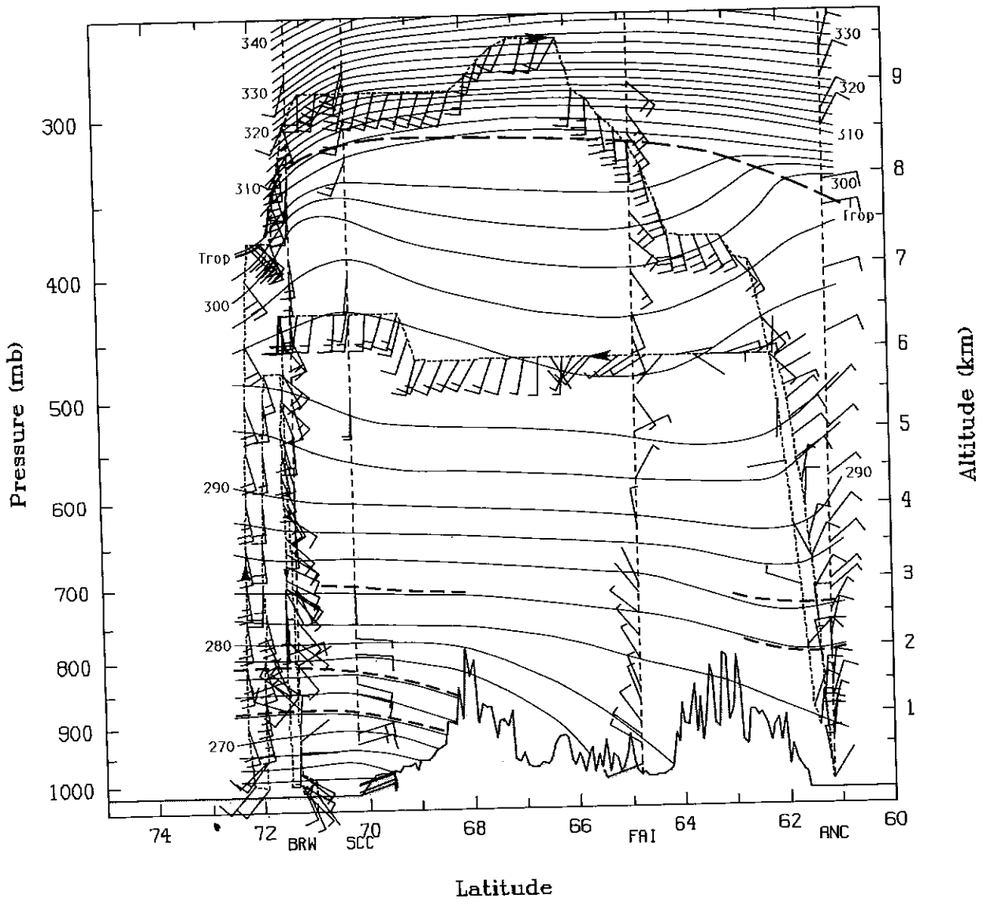

Figure 8.4. Latitude-altitude cross section of potential temperature (K) and wind (1 barb = 10 knots) between Anchorage and 74°N, 1742-0320 UTC April 21-22, 1992. The tropopause and top of the Arctic boundary layer are indicated by thick long-dashed lines, stable layers and frontal zones by thick short-dashed lines, and the aircraft flight track by thin dashed lines. Arrows indicating the direction of the aircraft are placed at the beginning of each hour. The vertical dashed lines show the rawinsonde locations (BRW, SCC, FAI, and ANC).

were released during this flight. Because of its position to the east of the flight track, the SCC sounding is not given the same weight as the other data in the analysis. For the most part winds were light and variable in the troposphere south of 66°N. To the north they were southerly in the 5-8 m s^{-1} range. The top of the planetary boundary layer was encountered at about 810 mb, and the layer was isothermal to the surface. Winds in the boundary layer were generally light and variable, with a preference for southerly directions nevertheless. Except for the planetary

boundary interface and the tropopause, there were no intermediate layers of significance encountered during this flight. An abrupt increase in ozone concentrations at 375 mb while the aircraft was in a level flight segment would indicate a region of stratospheric air. But before the end of the level segment, ozone concentrations decreased to tropospheric values. The concentrations increased again at 328 mb at 71.5°N. The analyzed position of the tropopause in this region was drawn to show this discontinuity in the ozone concentrations, though the winds generally do not support this analysis. On the basis of an abrupt decrease in the concentration of ozone, the WP-3D departed the stratosphere at 310 mb over FAI. Winds were southerly at 15 m s^{-1} to 400 mb where they decreased to less than 2 m s^{-1} for the remainder of the descent into ANC.

8.5 Discussion of Sampling Conditions

The troposphere had warmed considerably after the preceding flight. There was no longer any remnant of the frontal zones that were in the ANC region for so long. As a result, winds throughout the troposphere over the southern half of Alaska were light and variable. The WP-3D was unable to attain sufficient altitude to penetrate the tropopause during the northbound segment; thus ozone concentrations were in the high 30's to high 50's ppbv throughout most of the first four segments.

Because this was a gas and aerosol sampling flight, significantly less time was spent in the planetary boundary layer than on the preceding flights. For a brief period at low levels near Point Barrow, ozone concentrations dipped to single-digit values, indicating ozone depletion at low levels. The aerosol scattering coefficients were in the $(0.5\text{-}3) \times 10^{-6}$ m^{-1} range throughout most of the first three segments of the flight. These values were significantly lower than on the preceding flights. Aerosol scattering coefficients were not recorded on the climb and southbound segments. CN concentrations were typical of the midtroposphere, 50-500 cm^{-3} for most of the first four flight segments. Winds on both descent and subsequent climb were southerly, indicating transport from lower latitudes.

At 375 mb on the climb to cruise-altitude ozone concentrations increased to stratospheric levels and then decreased again before reaching those levels again at 330 mb. Later, while in the stratosphere, ozone concentrations exceeded 240 ppbv, and CN concentrations exceeded 4000 cm^{-3}. At that time the aircraft was about 1 km above the tropopause. The atmosphere over Alaska at that time was void of active dynamics and a significant Arctic boundary layer.

On the basis of the history of the weak high-pressure system over central Alaska, the mid- to upper-tropospheric air had been over Alaska for the previous 24-48 hours. The high moisture levels would indicate a North Pacific origin 3 to 5 days earlier. In the surface layer near BRW a northern Canada source region would be suggested by the easterly winds.

9. FLIGHT 408, APRIL 22-23, 1992

9.1 Objective

Flight 408 was a dedicated AGASP flight. The objective was to monitor the chemical composition of the aggregate plume from the energy complex in the Prudhoe Bay region. Recent observations of NO and NO_x at Barrow tended to suggest the influence of the Prudhoe Bay complex on measurements made under what were previously thought to be "clean" wind directions (Jaffee et al., 1991). Because of the limited number of flight hours remaining, this flight was shorter than the preceding flights.

The NOAA WP-3D took off at 2041Z and followed the same general track of the preceding flights toward FAI (see Fig. 9.1). Cruising altitude of 6.1 km (465 mb) was reached at 2058Z and was maintained until the start of the descent profile at 2301Z (70.93°N, 148.66°W). The profile was terminated at an elevation of 350 m (982 mb) at 2314Z (70.78°N, 147.03°W). A series of level L-shaped traverses were made to the north and west of the Prudhoe Bay complex to sample the effluent downwind of the facility, after a brief upwind sample to the east. From

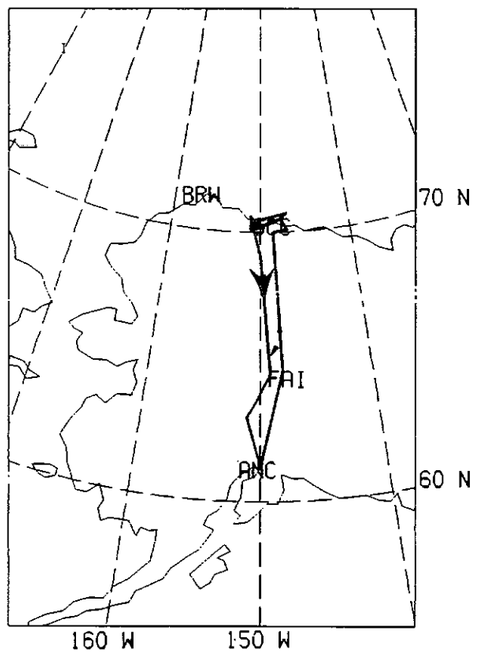

Figure 9.1. Horizontal projection of the aircraft flight track on a latitude-longitude grid, April 22-23, 1992.

2314Z to 2339Z the aircraft sampled a 73 km line along 147°W, which was about 54 km east of Deadhorse (70.20°N, 148.47°W) at the closest point. The aircraft was at an altitude of 345 m on the southbound leg and at 457 m on the return. Sampling segments were flown to the north and west at 450 m (2340Z to 0043Z) and at 160 m (0046 to 0203Z) altitude. The climb for the return flight began immediately thereafter.

At 70.46°N (150.84°W) the aircraft began a rapid climb of only 18 minutes to cruise altitude of 7.6 km. At 0249Z (67.60°N, 149.63°W) the WP-3D climbed to 8.9 km, and at 0309Z (66.26°N, 149.38°W) it climbed again to 9.5 km. At these levels the search for the top of the troposphere was realized, but after only 6 minutes at 65.25°N, 149.17°W, the aircraft departed the stratosphere on the descent into Anchorage. The aircraft landed at 0431Z.

9.2 Flight Log

20:41				Takeoff.
20:45	61.33	150.18	848	Noticed that PMS (aerosol optical probes) clock is 7 minutes 42 seconds ahead of the airplane clock. This must be taken into account when analyzing the PMS probe data.
21:14	63.16	149.08	466	Data system for PMS probes was given the correct time.
21:41	64.99	148.04	466	Performed nephelometer clean-air check.
23:01	70.94	148.67	466	Started descent over Prudhoe Bay facility.
23:03	71.03	148.47	518	Descending through 5100 m PA.
23:05	71.03	148.01	586	Descending through 4400 m PA.
23:43	70.46	147.89	976	Halfway through diagonal leg entering downwind region. RA: 462 m (1200 ft level legs).
23:53	70.46	149.49	976	Crossed over Pipeline at 1200 ft RA on westbound leg of upper (higher altitude) bowtie pattern.
00:44	70.55	147.74	983	Descending through 340 m PA.
01:02	70.44	147.96	1007	On level 500 ft. RA leg.
02:03	70.46	150.96	1005	Started climb for home.
02:13	70.04	150.24	481	Climbing through 6000 m.
02:18	69.79	150.15	405	Ascending through 7200 m PA.
04:11	62.02	150.52	544	Descending through 5000 m PA. Lat.: 62°N.
04:14	61.89	150.43	604	Descending through 4000 m PA. Lat.: 61.8°N.
04:31				Landing in Anchorage.

9.3 Synoptic Situation

In the 24-h period after the previous flight the contours of geopotential height at 500 mb had changed little over central Alaska (Fig. 9.2). The low in the Gulf of Alaska remained stationary and continued to fill with a reported central height of 534 decameters, and a weak ridge persisted over central and northern Alaska. The contour gradient at 500 mb had changed very little after the last flight. Except for along the west coast, the winds were reported to be less than 10 m s^{-1} over the state.

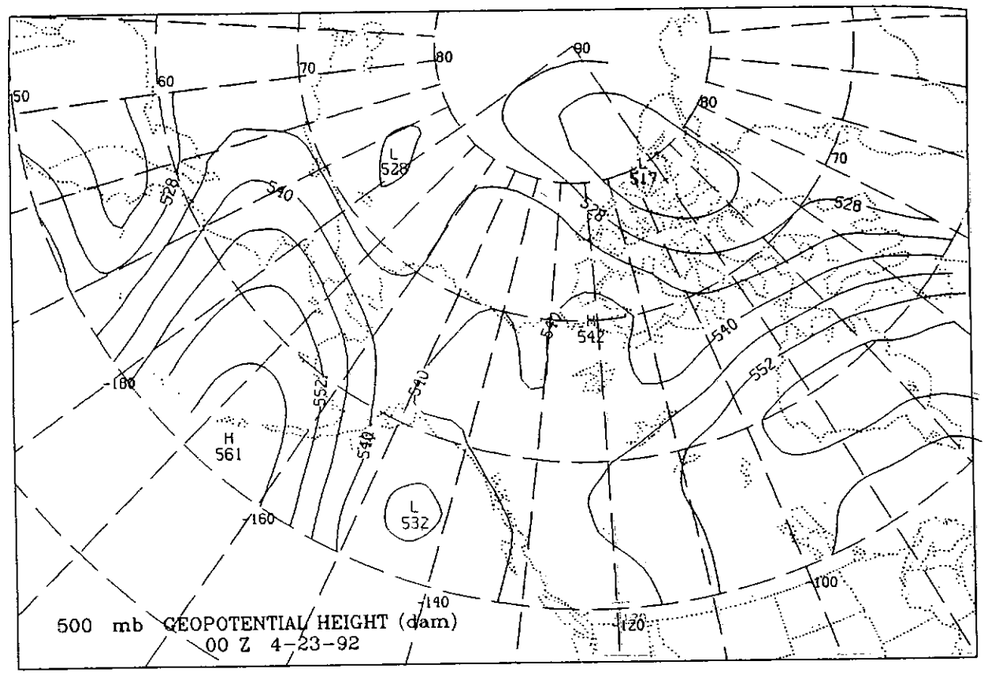

Figure 9.2. 500 mb synoptic map for 0000 UTC, April 23 1992. Indicated are height contours in geopotential decameters.

At the surface the low to the southwest of ANC, which was previously moving northward, had stalled in the preceding 24 hours (Fig. 9.3). The central pressure was 1000 to 1012 mb. Over the Beaufort Sea, where previously only a minor trough of low pressure was analyzed, high pressure from farther north had dropped into this region.

Surface weather observations from most stations south of the Brooks Range reported clear or broken low-level cloudiness. North of the Brooks Range low-level coastal fog and light snow were reported.

9.4 Atmospheric Cross Section

The analysis of potential temperature along the flight track consisted of rawinsonde data from ANC, FAI, and SCC at 0000Z April 23, in addition to the aircraft observations for the duration of the flight (Fig. 9.4). Wind conditions along the flight track changed little in the 24 hours from the previous flight (Fig. 8.4). The winds north of FAI were 1-3 m s^{-1} faster than before, and in the boundary layer around Prudhoe Bay the wind direction was easterly, for the most part. The top of the boundary layer was at 700 mb. The rawinsonde observations indicated

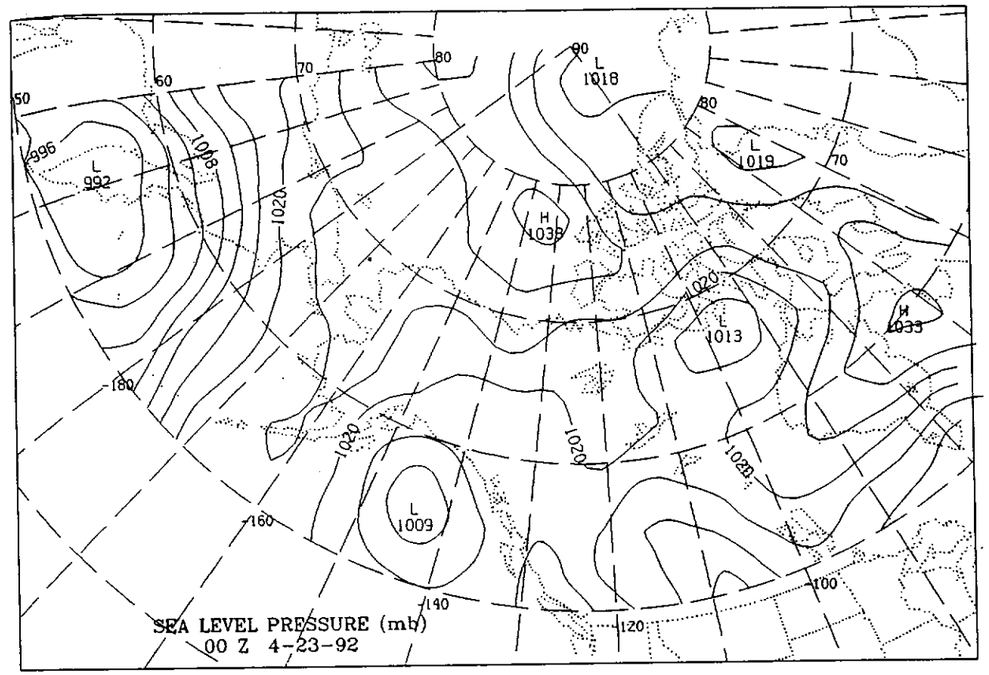

Figure 9.3. Surface synoptic map for 0000 UTC, April 23 1992. Indicated are surface pressure contours in millibars.

the tropopause to be at between 300 and 320 mb. The aircraft encountered an abrupt increase in ozone concentrations at 293 mb at 66°N and the concentration returned to tropospheric values at 301 mb at 65.2°N on the descent into ANC.

9.5 Discussion of Sampling Conditions

Under the influence of a weak, stagnant high-pressure system over central Alaska the troposphere continued to warm and destablize. The tropopause height continued to increase as spring arrived, generally exceeding the WP-3D's height ceilings on the northbound segment. Thus ozone and aerosol concentrations were typical of the midtropospheric values for the first four segments of the flight. Ozone concentrations ranged from 20 to 60 ppbv, aerosol extinction coefficients were 0.5-20 10^{-6} m^{-1}, and CN concentrations were 80-6000 cm^{-3}. The CN concentrations in excess of 200 cm^{-3} occurred in and around the industrial complex at Prudhoe Bay.

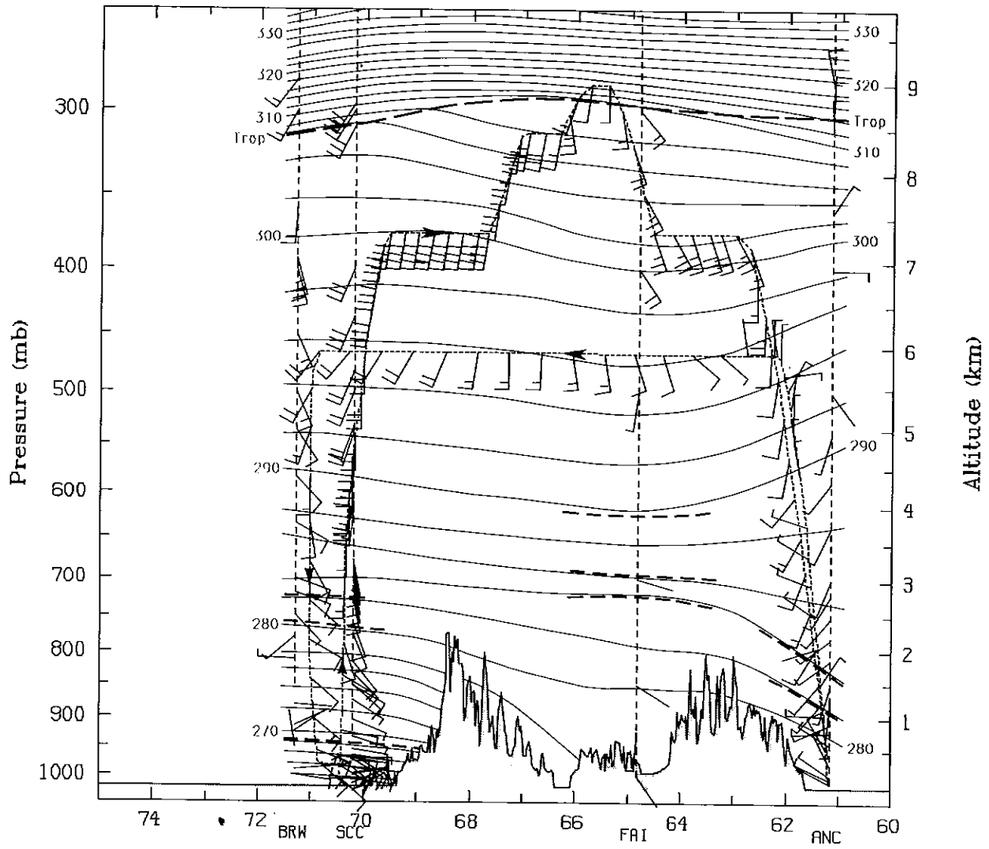

Figure 9.4. Latitude-altitude cross section of potential temperature (K) and wind (1 barb = 10 knots) between Anchorage and 74°N, 2041-0426 UTC, April 22-23, 1992. The tropopause and top of the Arctic boundary layer are indicated by thick long-dashed lines, stable layers and frontal zones by thick short-dashed lines, and the aircraft flight track by thin dashed lines. Arrows indicating the direction of the aircraft are placed at the beginning of each hour. The vertical dashed lines show the rawinsonde locations (SCC, FAI, and ANC).

The surface-based stable layer was approximately 100 mb deep over Prudhoe Bay at the time of sampling. There were no other discontinuities of note in the potential temperature field. On the southbound segment the aircraft entered the stratosphere at 294 mb, remaining there until reaching 300 mb on the descent. Ozone concentrations as high as 120 ppbv were recorded. The CN concentrations exceeded 2000 cm^{-3} only above 300 mb. As in flight 407 the midtropospheric air along the flight track was of Northern Pacific origin 2-4 days earlier. Below 700 mb in the Prudhoe Bay region the suggested transport was from the east along the Brooks Range to the Canadian Archipelago.

10. SUMMARY

Arctic haze was not prevalent during the AGASP-IV sampling periods over the Beaufort Sea. Otherwise, extremely high condensation nuclei concentrations were measured in the polar stratosphere and ozone depletion was encountered in the planetary boundary layer. Because of the relatively warm troposphere over Alaska during AGASP-IV, a higher tropopause than on previous AGASP missions made it difficult to obtain stratospheric samples. On three flights the NOAA WP-3D climbed above 280 mb, where CN concentrations in excess of 7000 cm^{-3} were observed (flights 405, 406, and 407). At the 10 km level during flight 405, 1 km above the tropopause, ozone concentrations were in excess of 200 ppbv, and CN concentrations were in excess of 7000 cm^{-3}. These are the highest CN concentrations ever measured in the stratosphere during AGASP flights.

The troposphere was considerably warmer and more moist than was encountered during AGASP-I and -II. On seven of the eight missions winds along the northbound transit segment of the flight, often at about 480 mb, were generally in the southwesterly quadrant. Clouds at various levels were reported south of the Brooks Range on most flights, indicating the presence of maritime Pacific air aloft. North of the Brooks Range tropospheric winds were northerly throughout the descent only on flight 402, but indications were that the tropospheric transport above the Arctic boundary layer was also from the north on flight 203 as well. Otherwise the winds were easterly on four of the remaining flights, indicating transport over Northern Canada and Alaska of maritime Pacific air. Boundary layer winds were from the southeast quadrant in all instances except flights 402 and 404 when they were northeasterly. Because of extensive open leads along the coast and the Grand Banks Polynya upwind in the southeast quadrant, the atmosphere below the inversion (850-900 mb) was near saturation throughout most the period. Such conditions would be considered favorable for significant observations of low ozone concentrations. And this was the case on flights 403 and 407 when ozone concentrations decreased to single-digit values for short periods near the surface. In those cases light winds indicated the absence of significant mixing of ozone-rich air from higher in the troposphere. Much stronger winds, >5 m s^{-1}, during other low-level sampling periods denoted the downward transport of ozone-rich air, precluding the observation of very low ozone concentrations in the surface layer.

When the NOAA WP-3D crossed the Brooks Range in AGASP-I and -II stacked layers of brownish gray haze were a common sight on the horizon. This was not the case during AGASP-IV. The typical view was of low-level cloudiness obscuring a clear view of the ice, and clear skies above with an occasional cirrus layer. Layer structure was observed on only two flights, 402 and 405. For only a brief period before flight 402 and 403 the transport looked to be from the high Arctic. During the descent northeast of BRW on flight 402 some variations in the aerosol scattering could have indicated the presence of Arctic haze. Variations of lesser magnitude were observed on flights 403, 404, and 406. Accurate calibration of the aerosol scattering signal will be necessary before the analysis can proceed further. Otherwise transport in the lower troposphere was generally of Pacific maritime origin and aerosol concentrations were typical of such air masses.

Except for flight 401, all low-level sampling in the vicinity of the Ice Camp was generally upwind of the Point Barrow observatory. Flights 402, 405, and 407 offer the best comparison between aircraft and surface measurements, being within 2-h transit time to Point Barrow in prevailing winds.

11. ACKNOWLEDGMENTS

Meteorological data and synoptic analyses supporting the operations phase of the program were supplied by the staff at the National Weather Service Alaska Regional Forecast Center. A special thanks to Ed Diemer for his assistance in providing workspace and access to the forecast center. Our appreciation as well to Robert Fett of the Naval Oceanographic Research Program for his assistance in accessing satellite images and in interpreting conditions north of the Brooks Range. Our thanks to Daniel Wolfe of the Wave Propagation Laboratory, NOAA, for rawinsonde observations from the Ice Camp and Tom Mefford of CIRES, University of Colorado, for his assistance plotting the rawinsonde data. A special thanks to Phil Bogert and the NOAA Office of Aircraft Operations staff, and to the WP-3D crew, for making the program a successful one.

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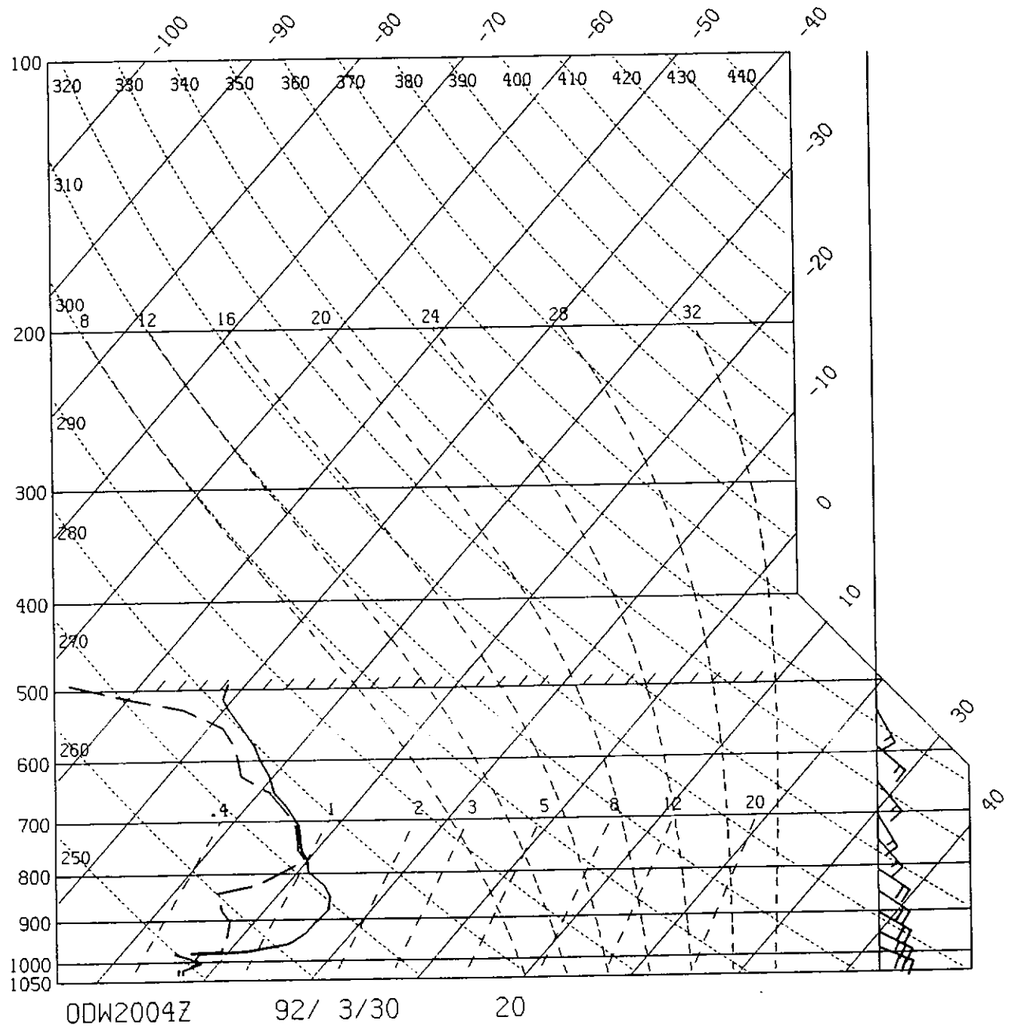
13. APPENDIX

Rawinsonde and dropwindsonde observations made at the times corresponding to AGASP-IV flights are plotted on skew T, log P diagrams. Rawinsonde data are from Anchorage, Alaska (ANC); Barrow, Alaska (BRW); Fairbanks, Alaska (FAI); Deadhorse, Alaska (SCC); and the LEADEX Ice Camp (72.95°N, 147.90°W). Dropwindsonde data are labeled ODW with the release time indicated. Temperatures are in kelvins; full-length wind barbs equal 10 knots.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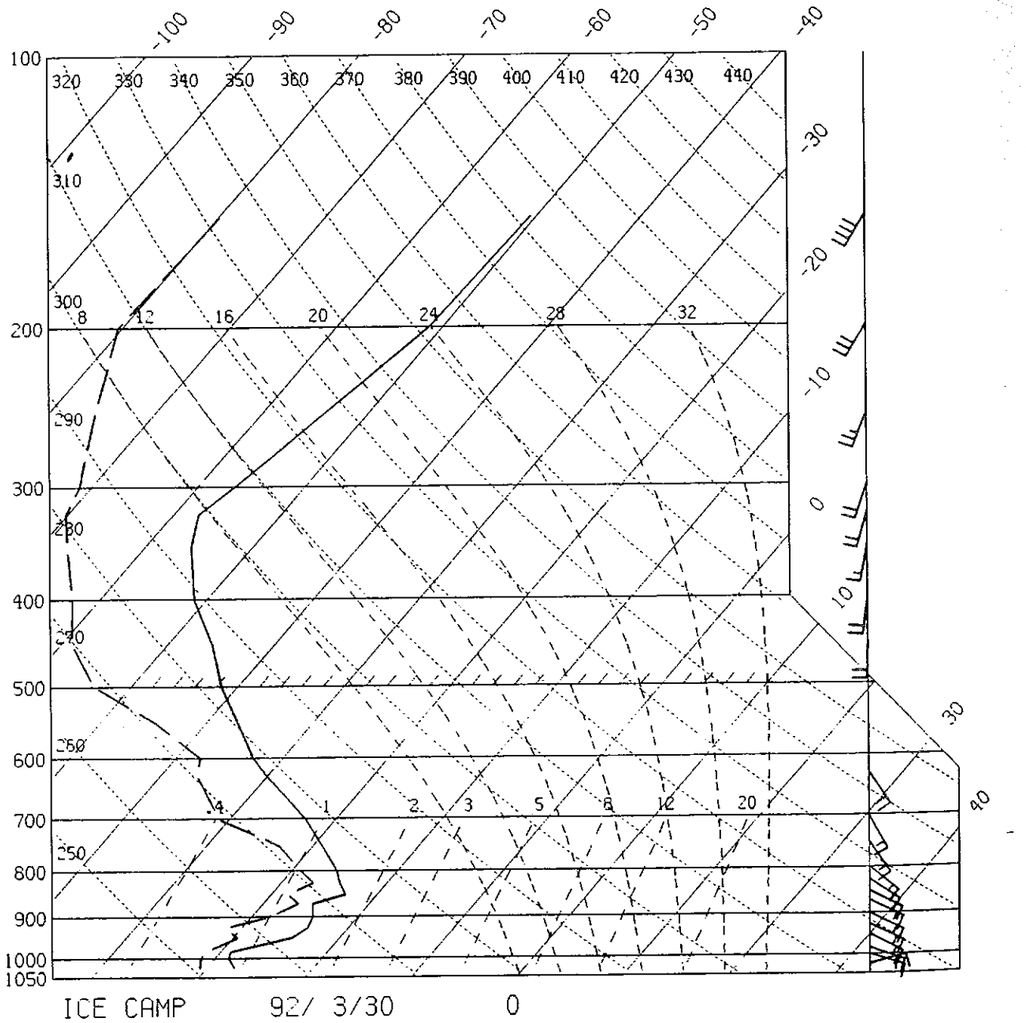
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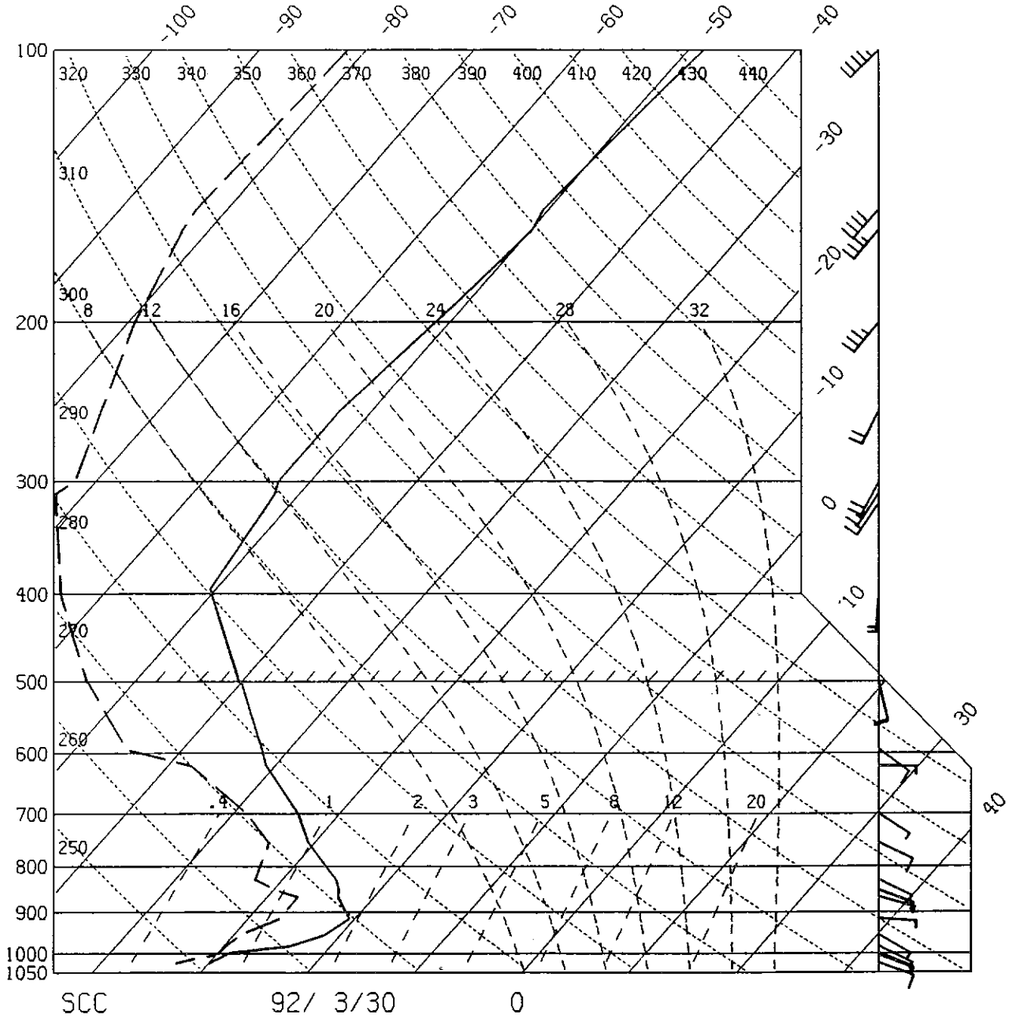
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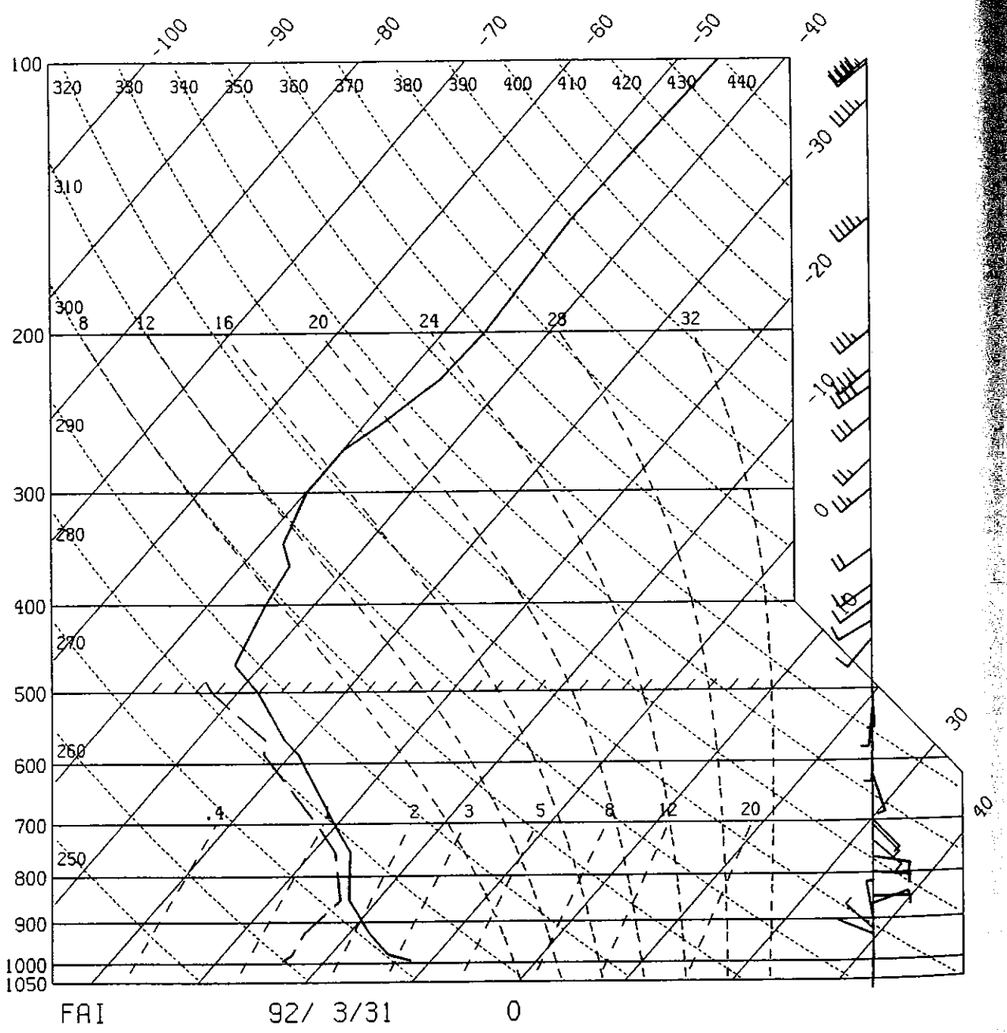
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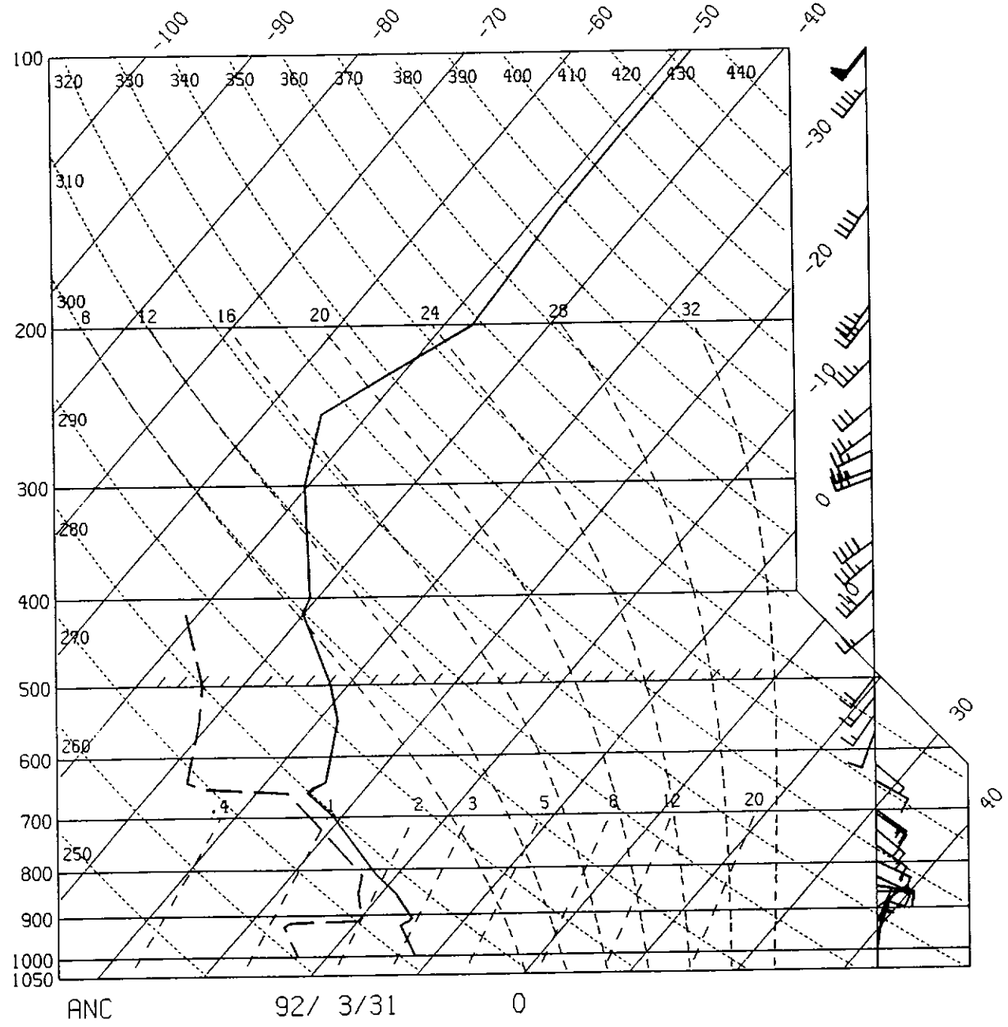
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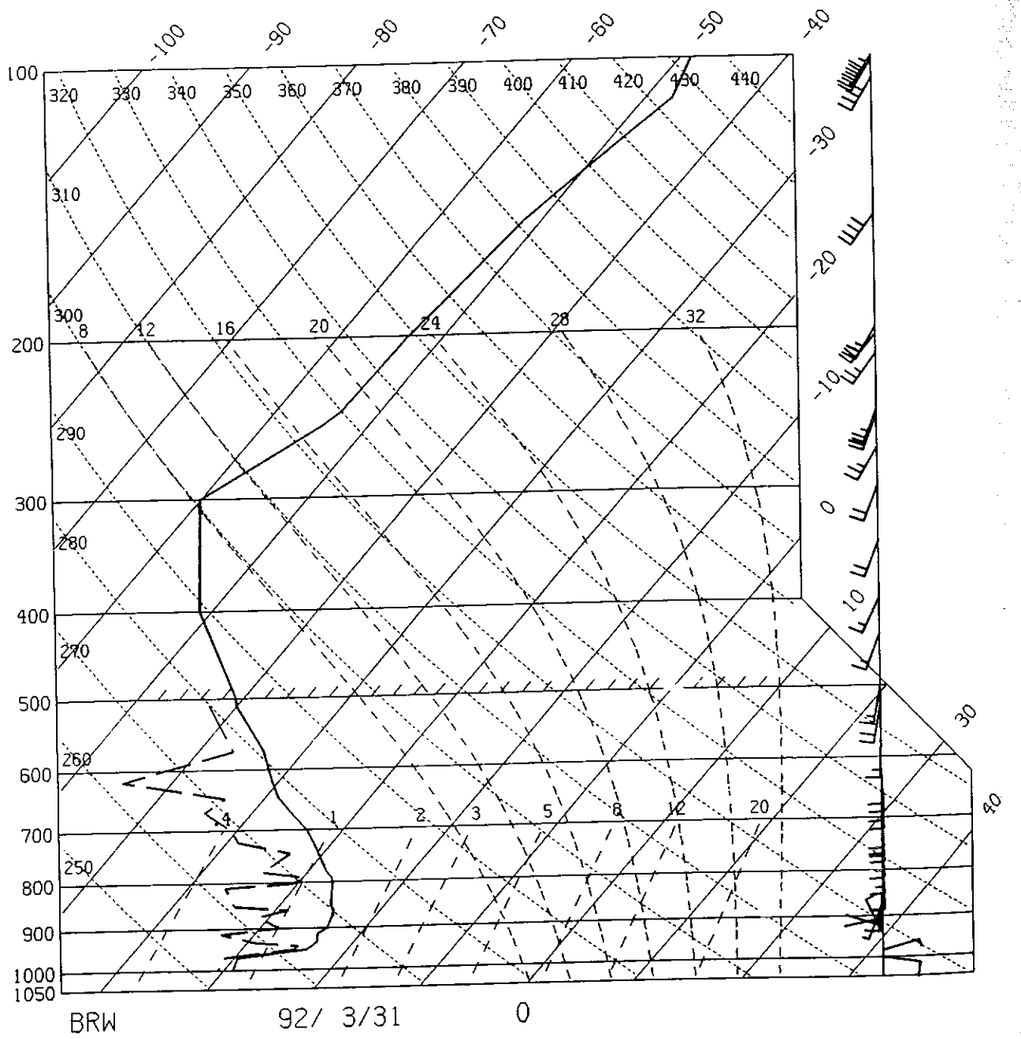
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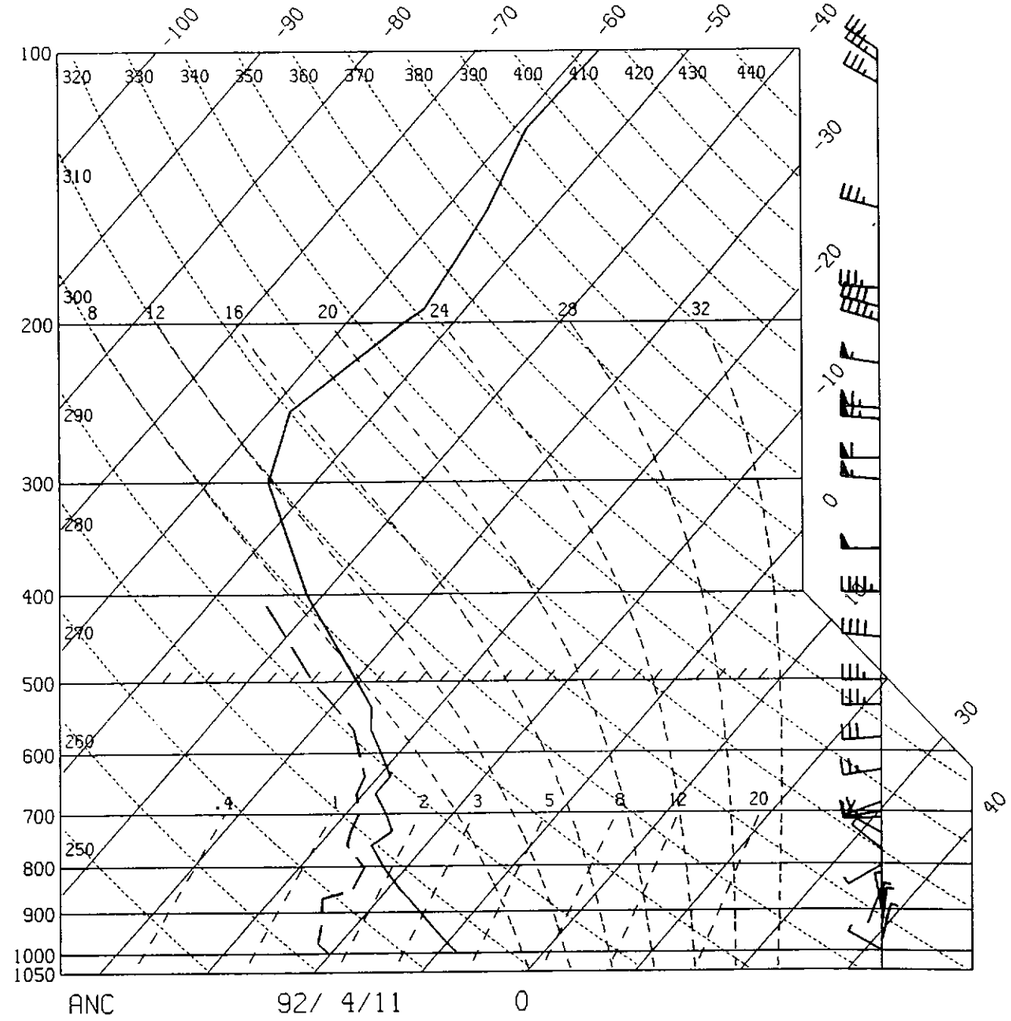
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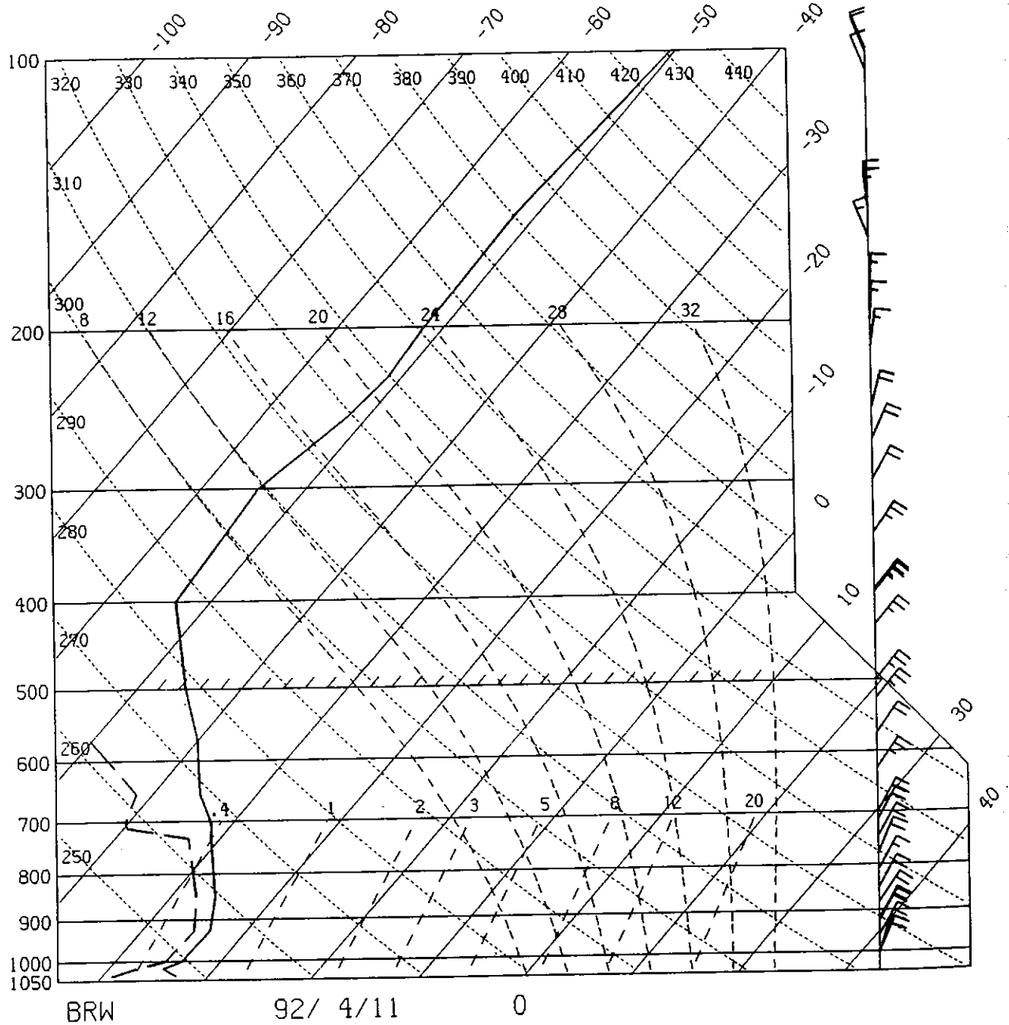
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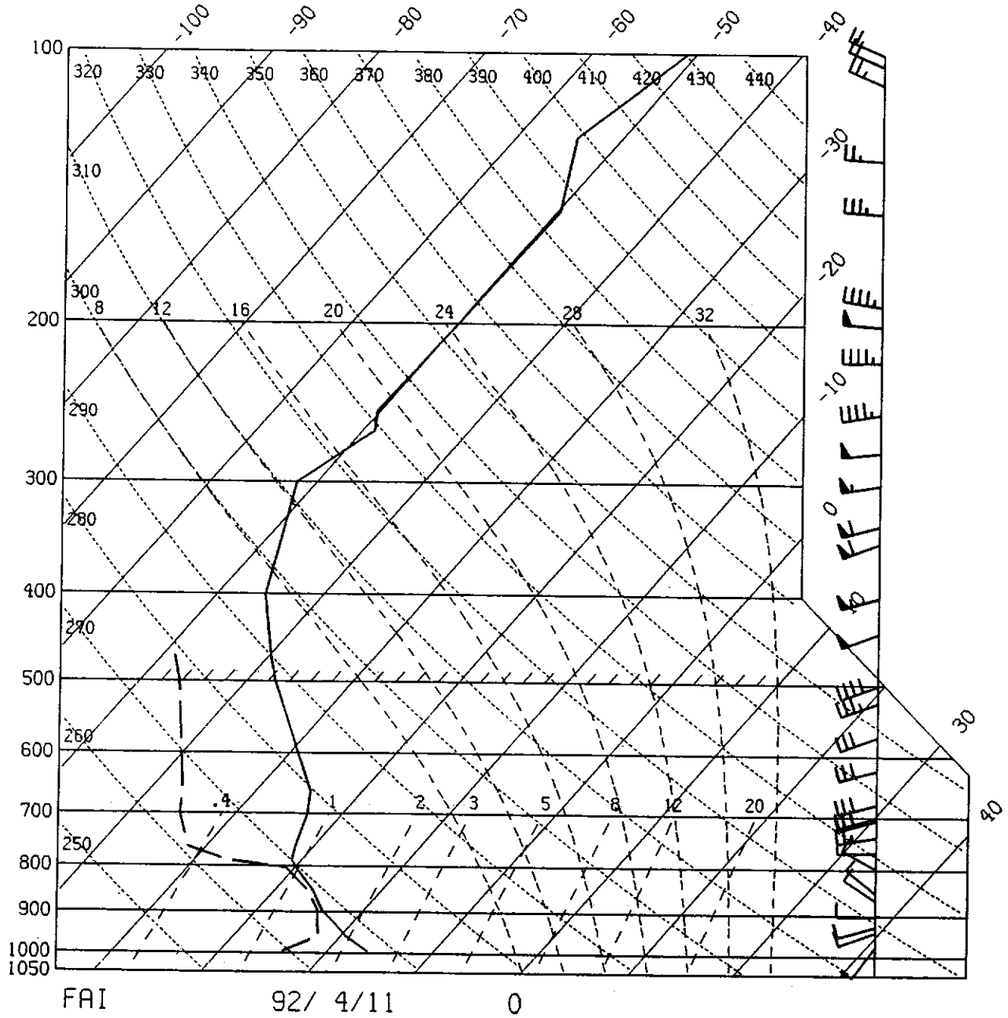
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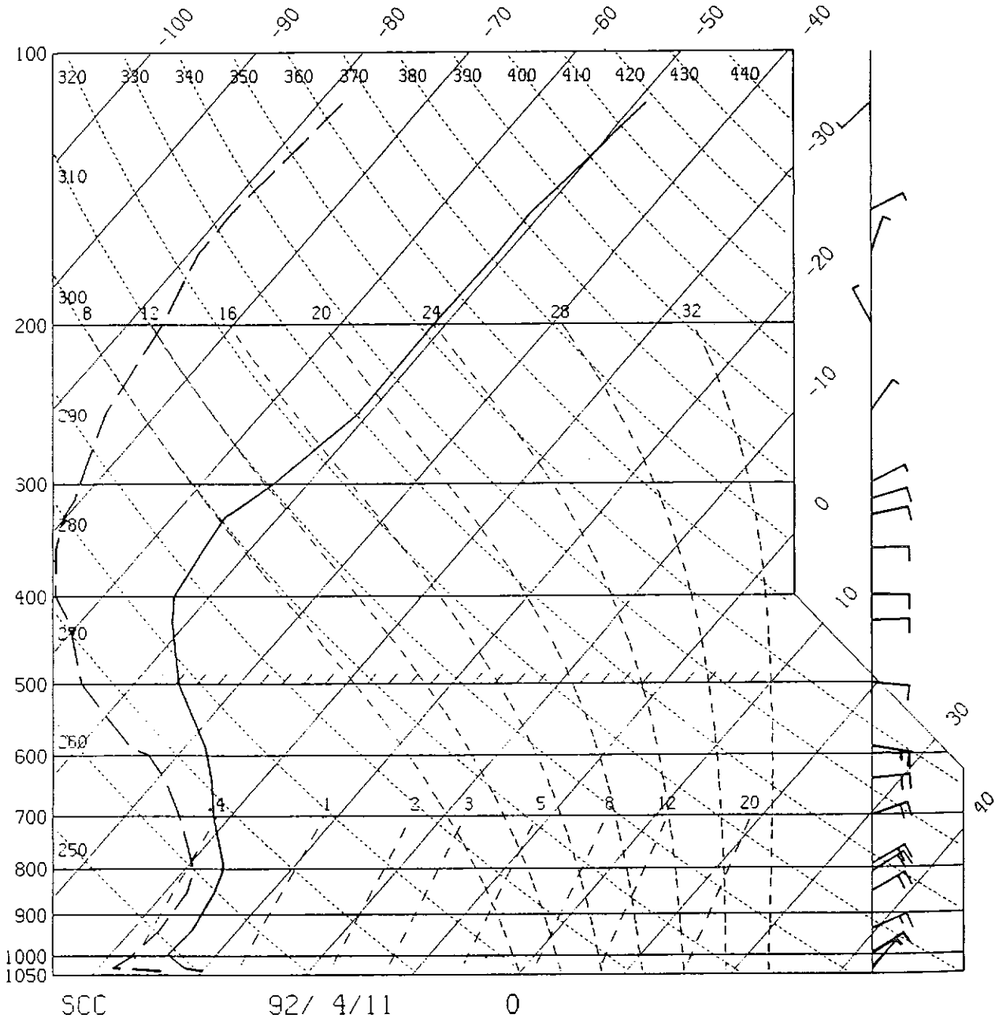
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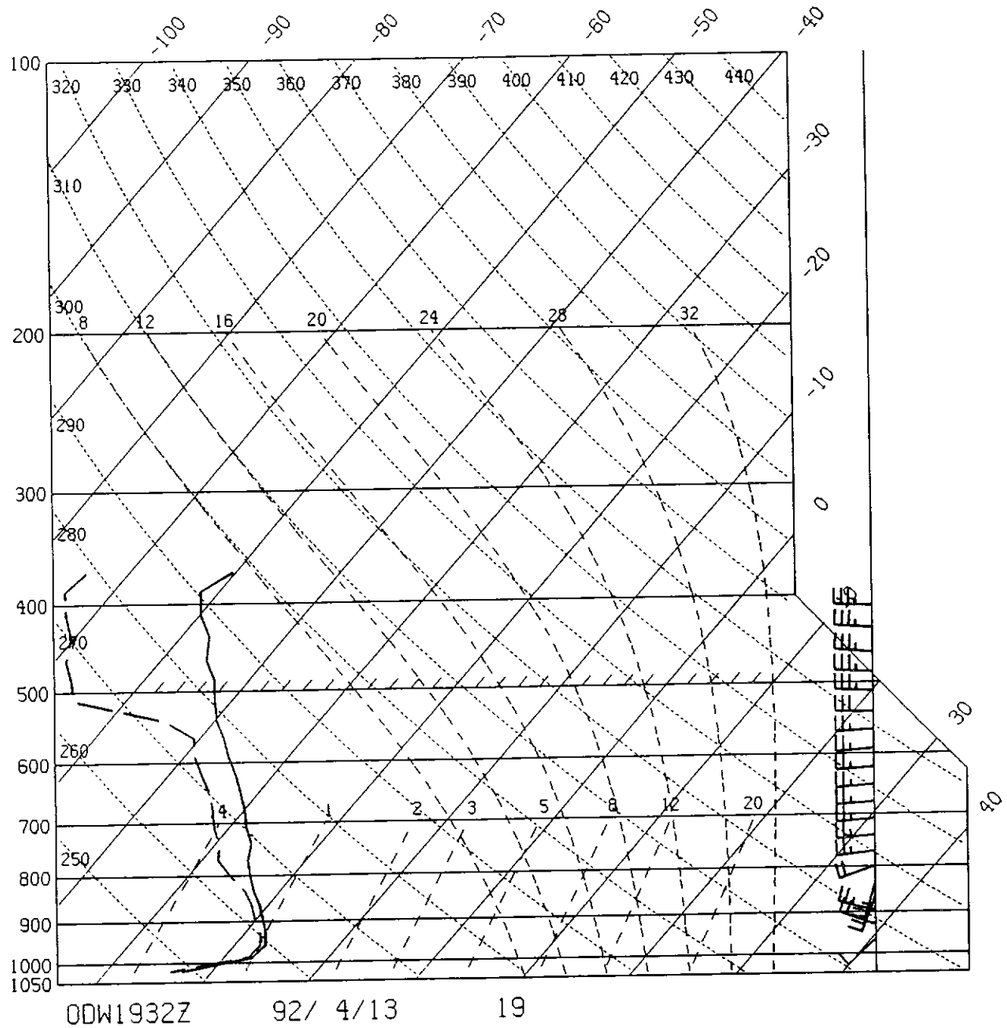
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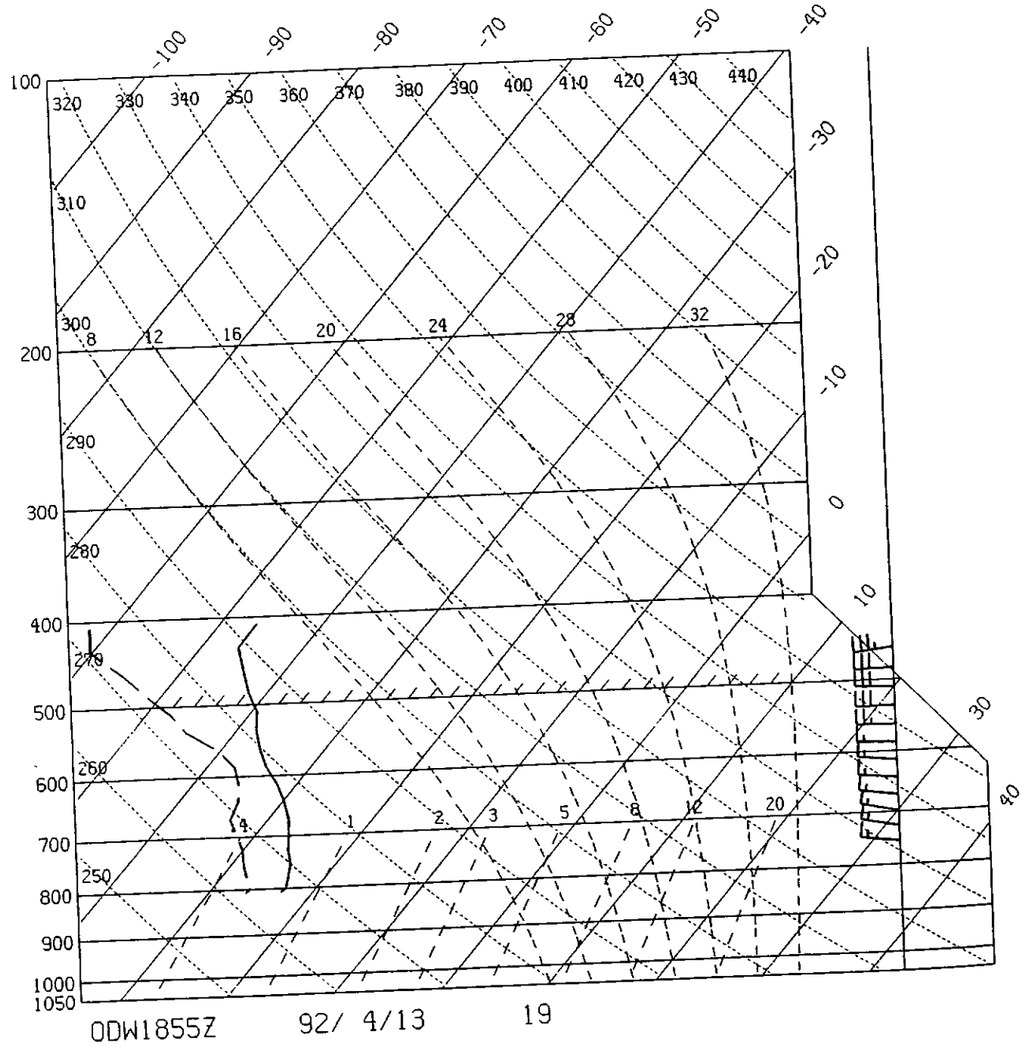
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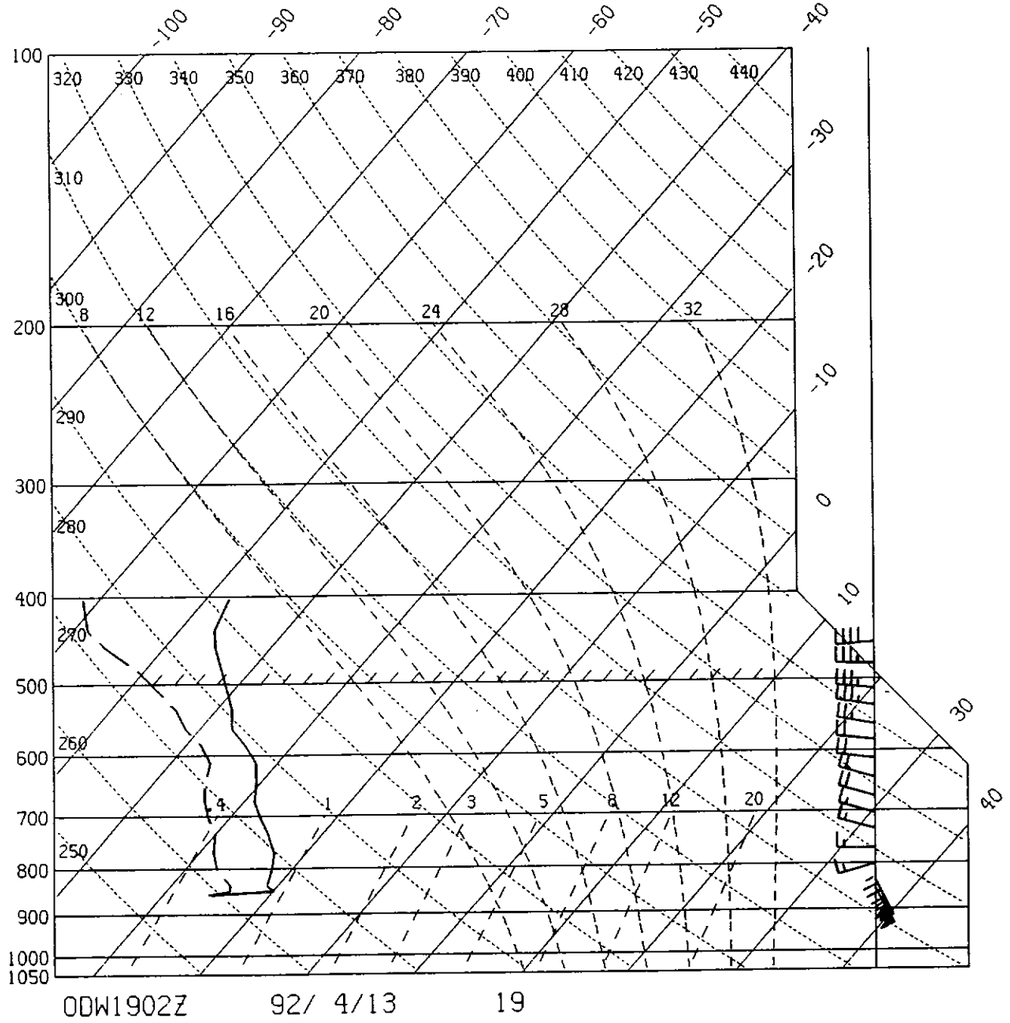
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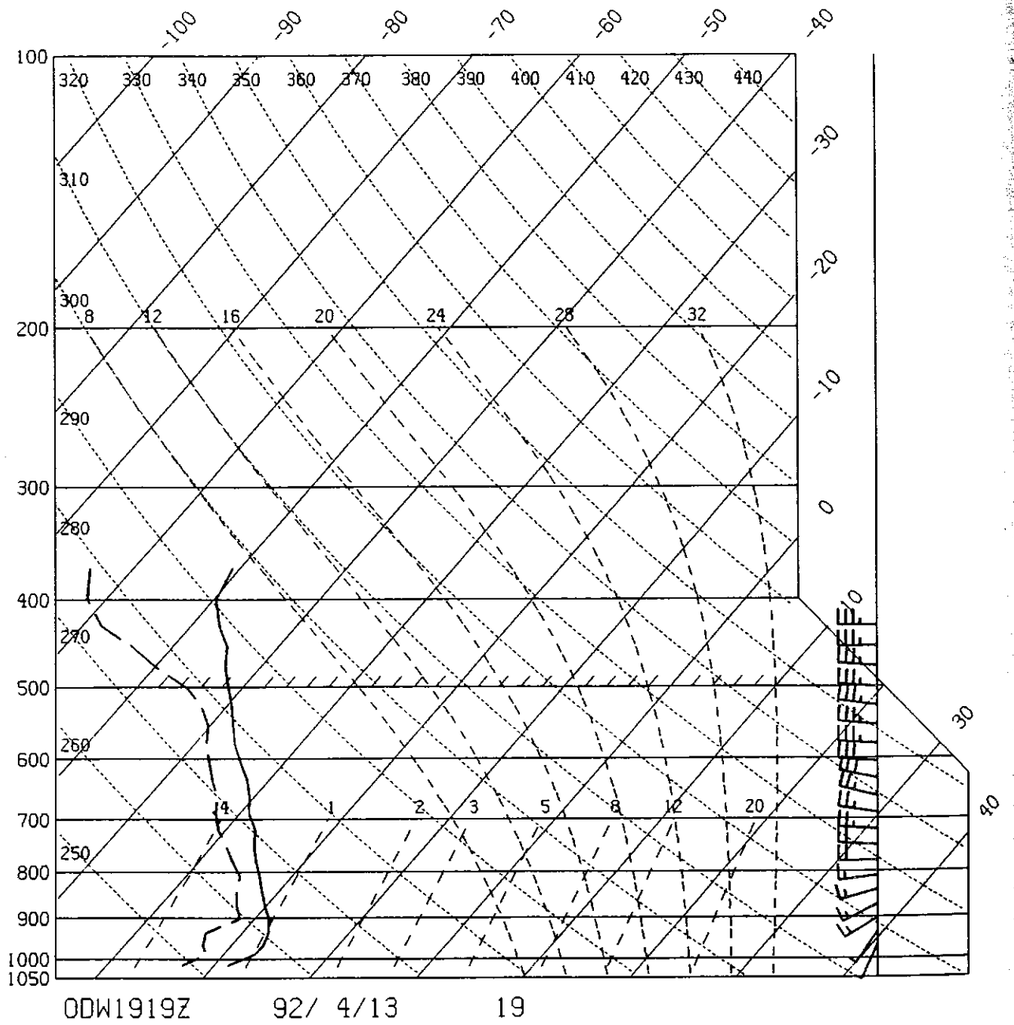
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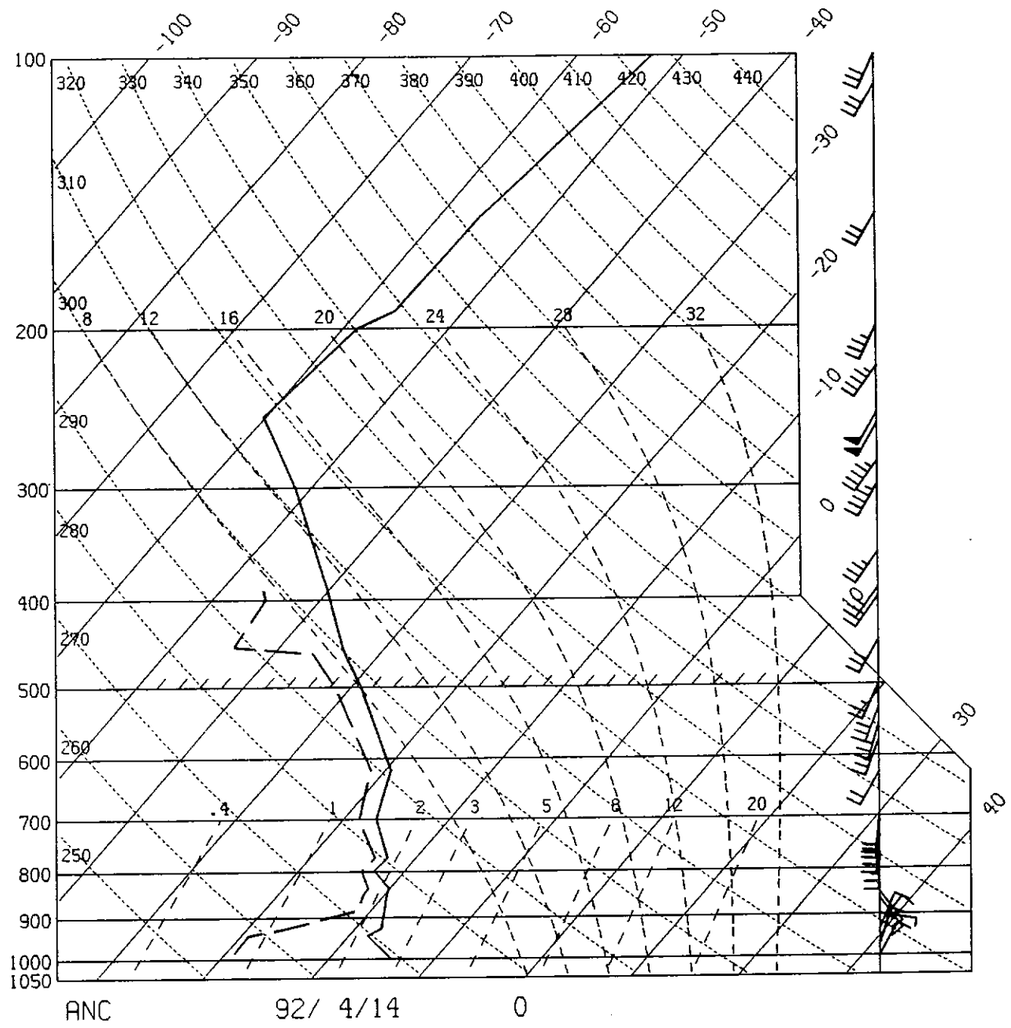
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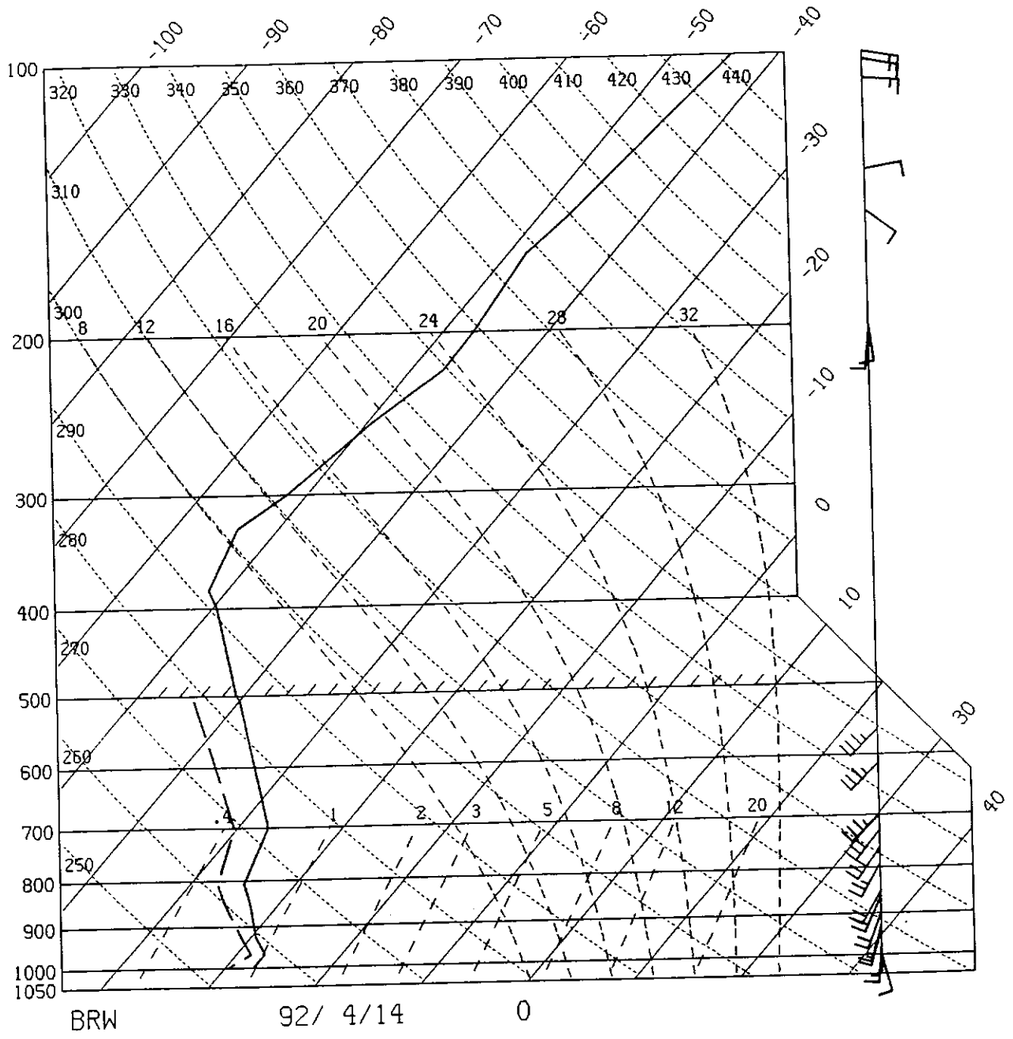
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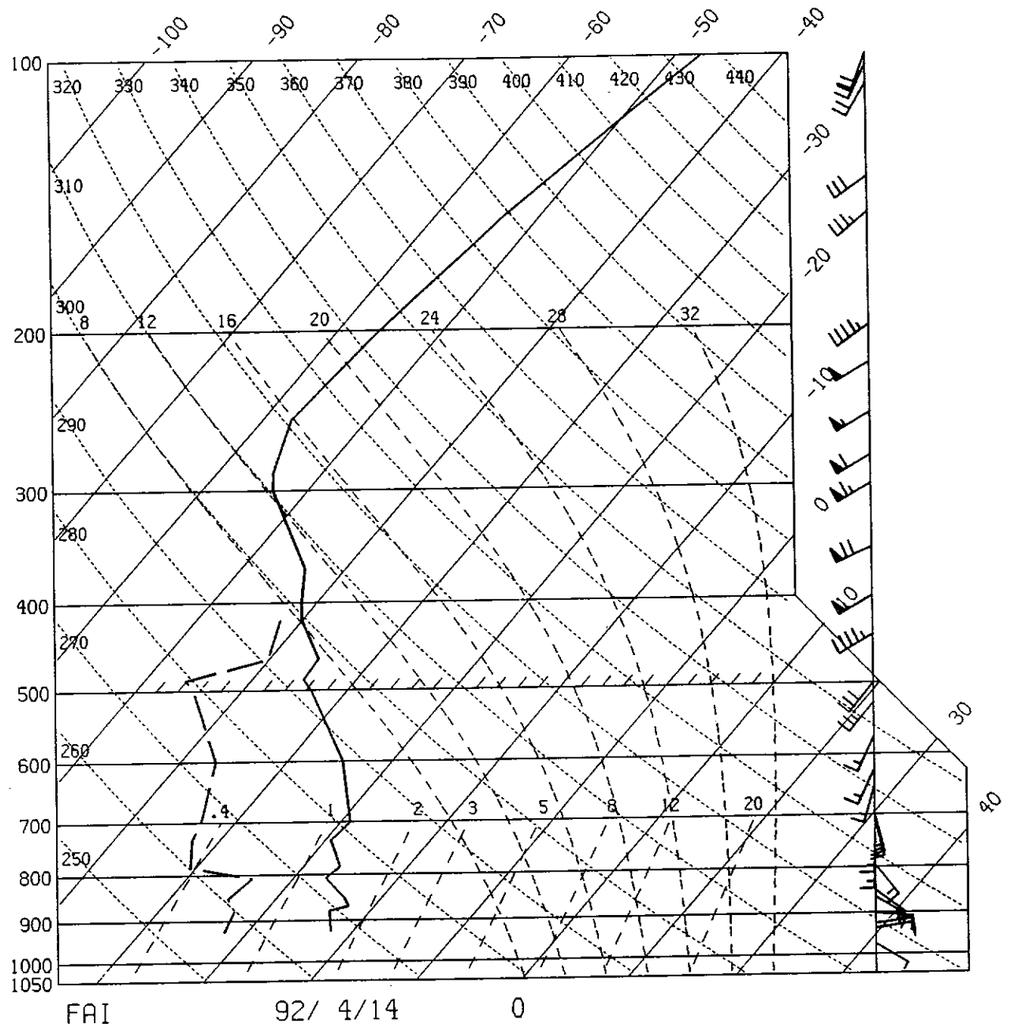
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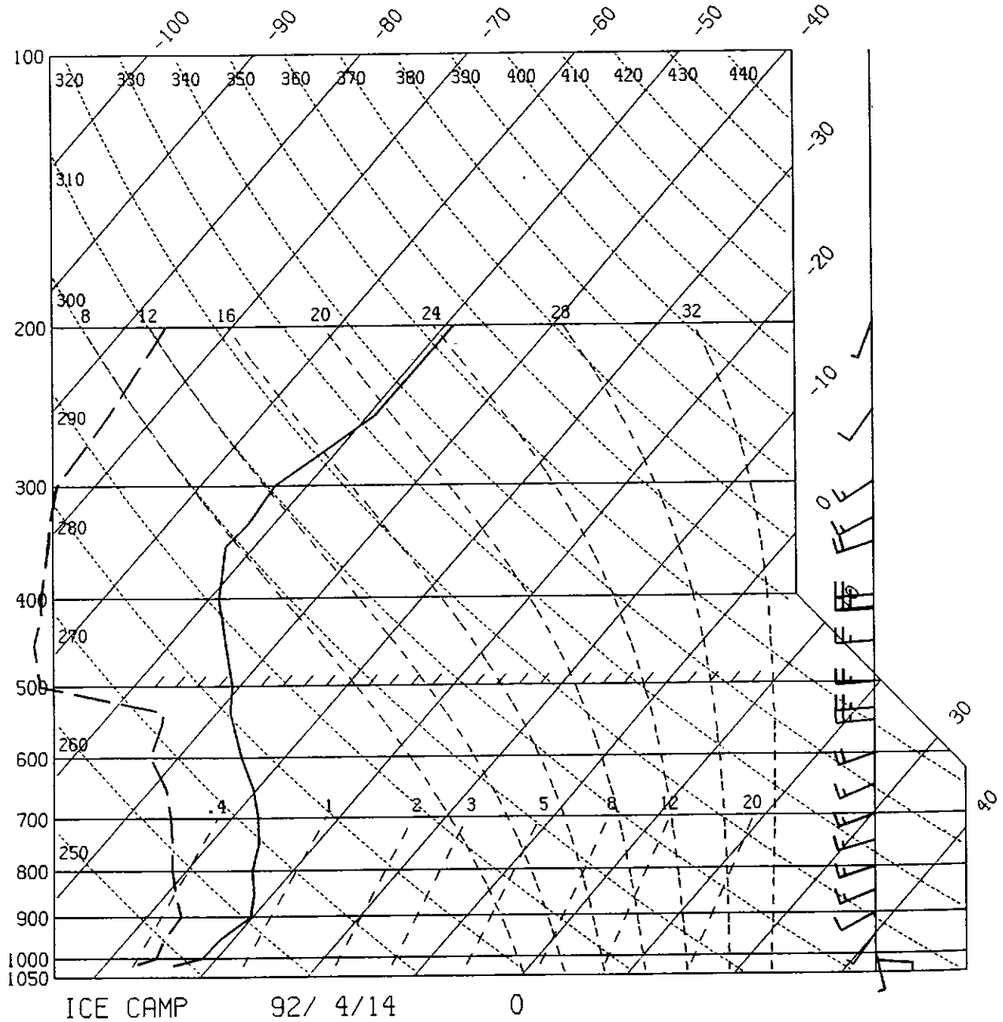
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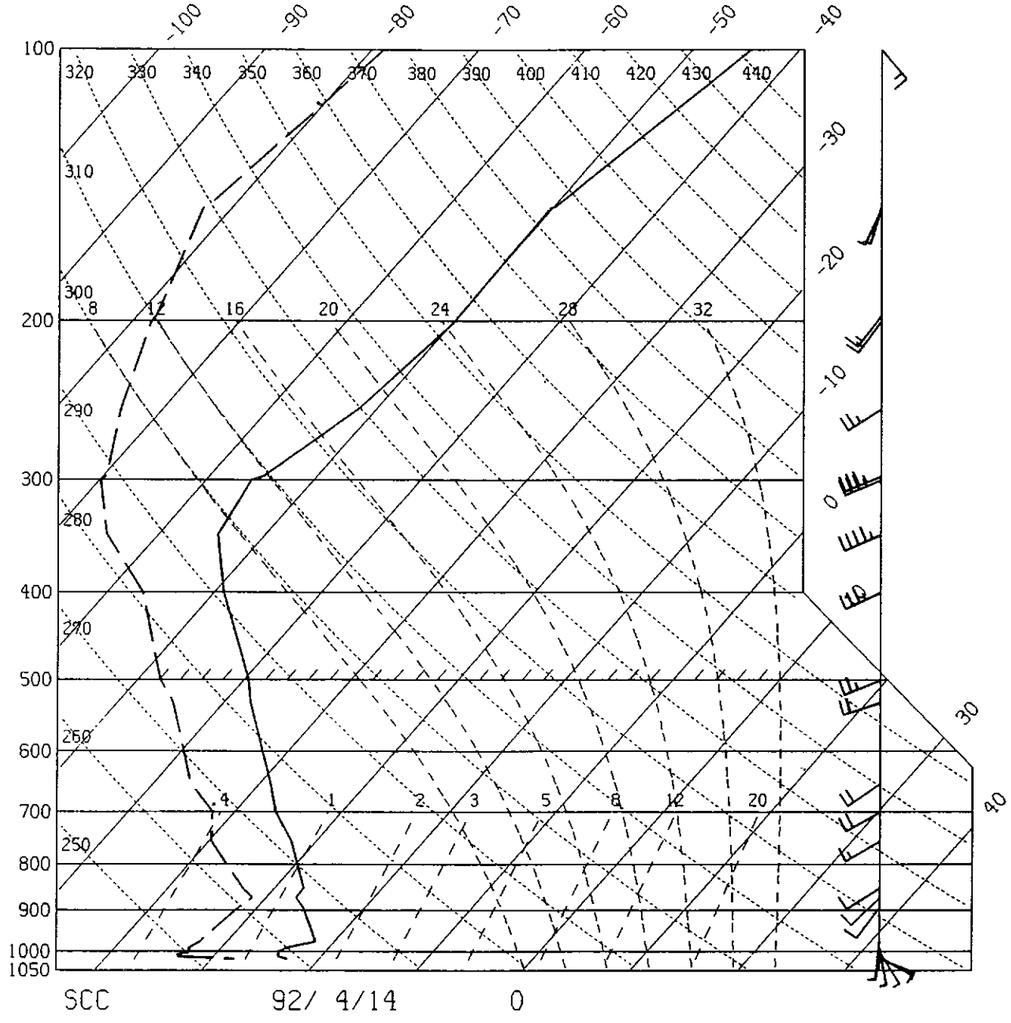
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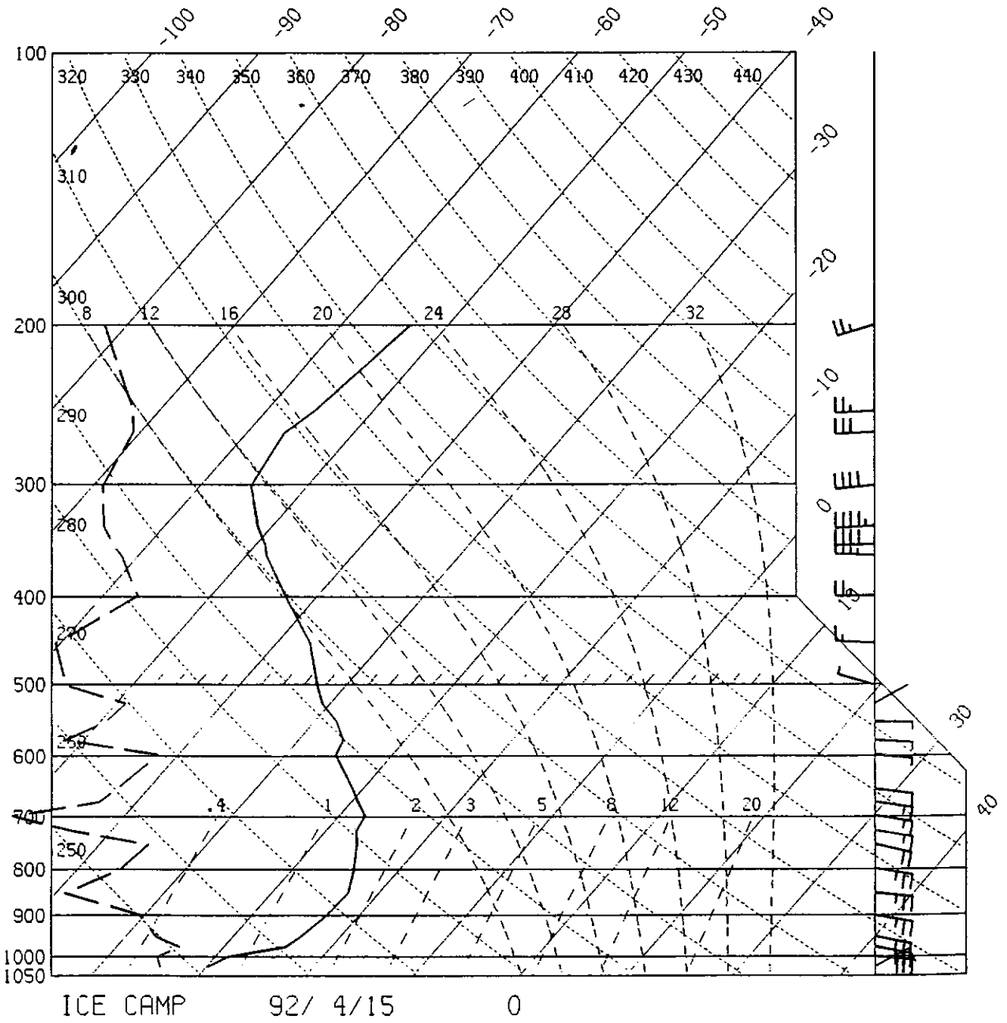
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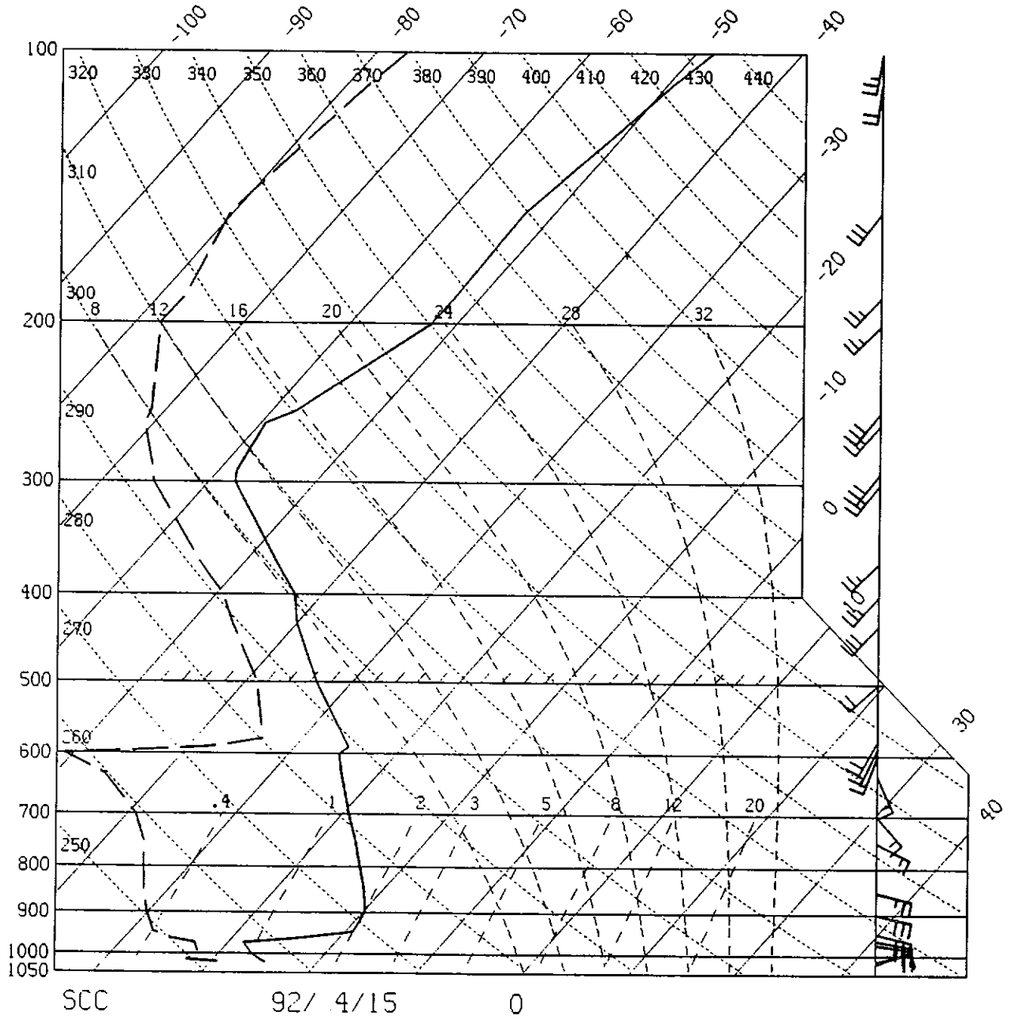
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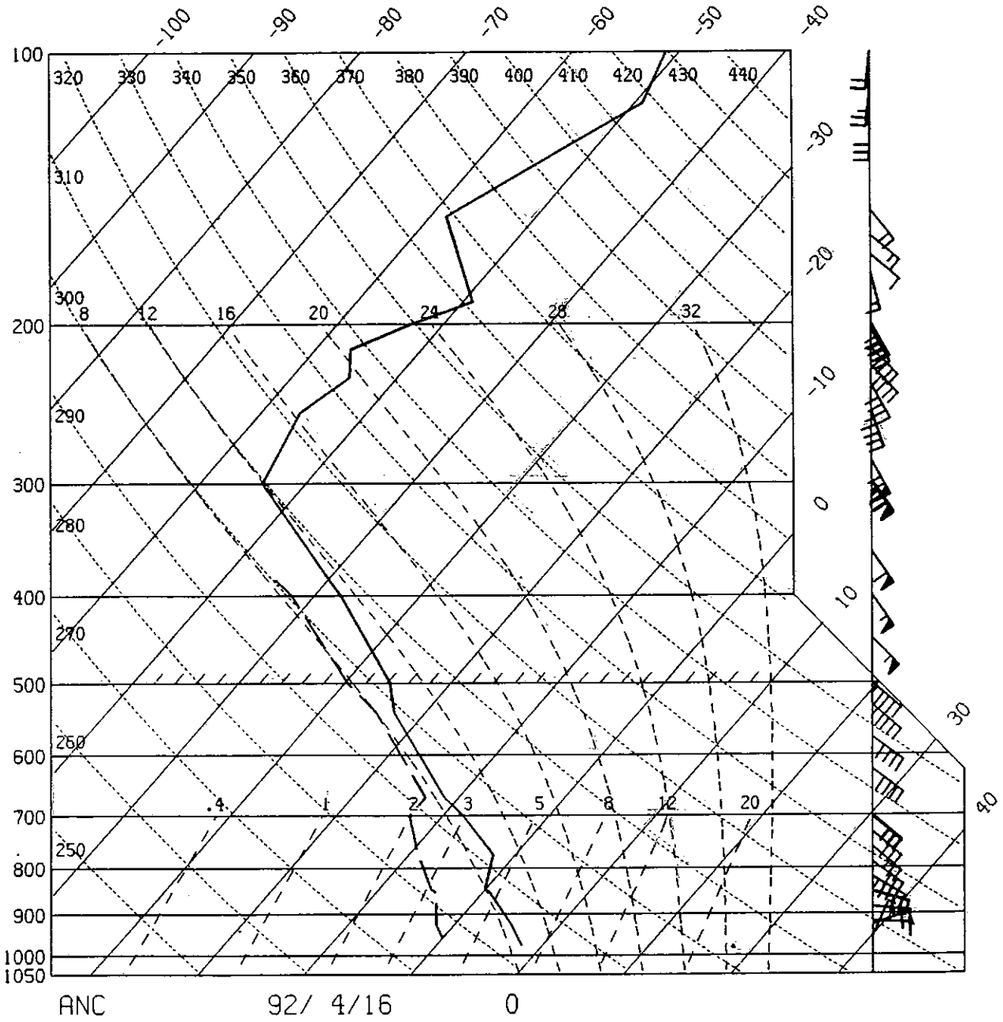
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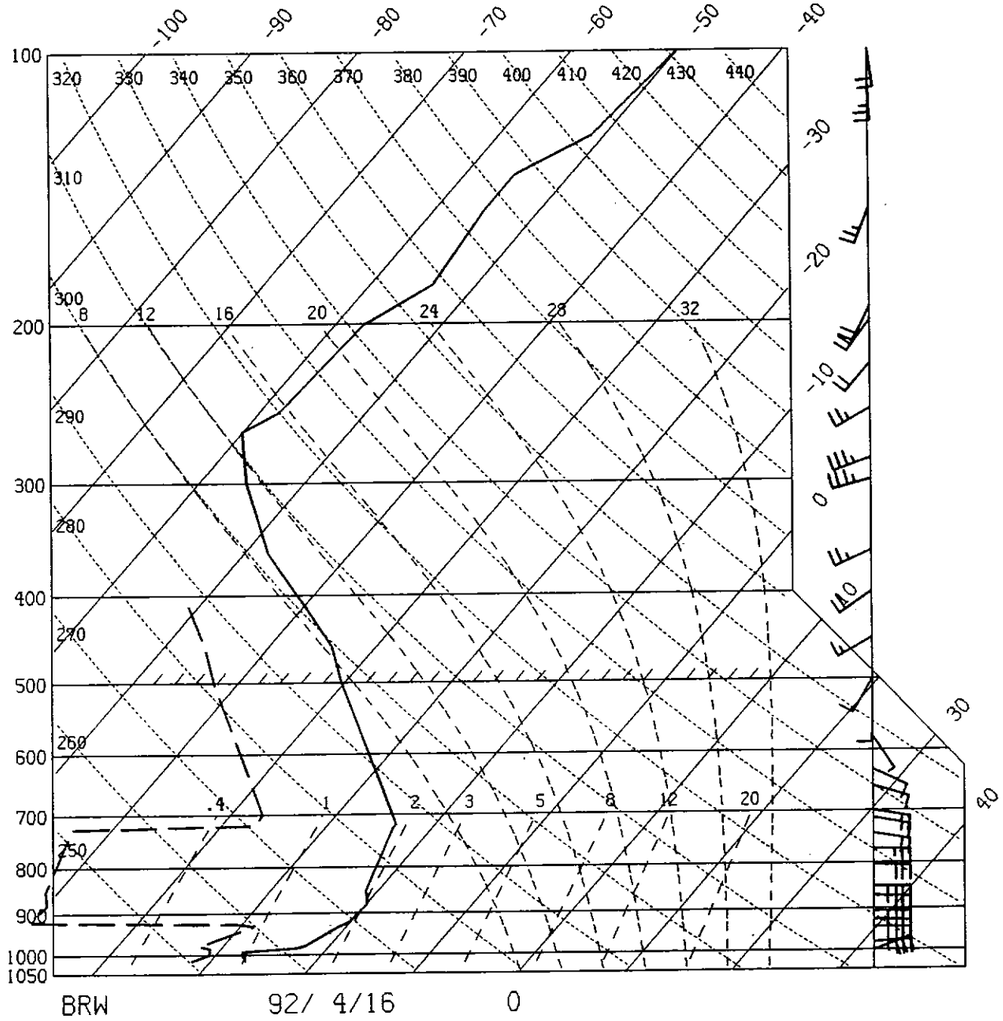
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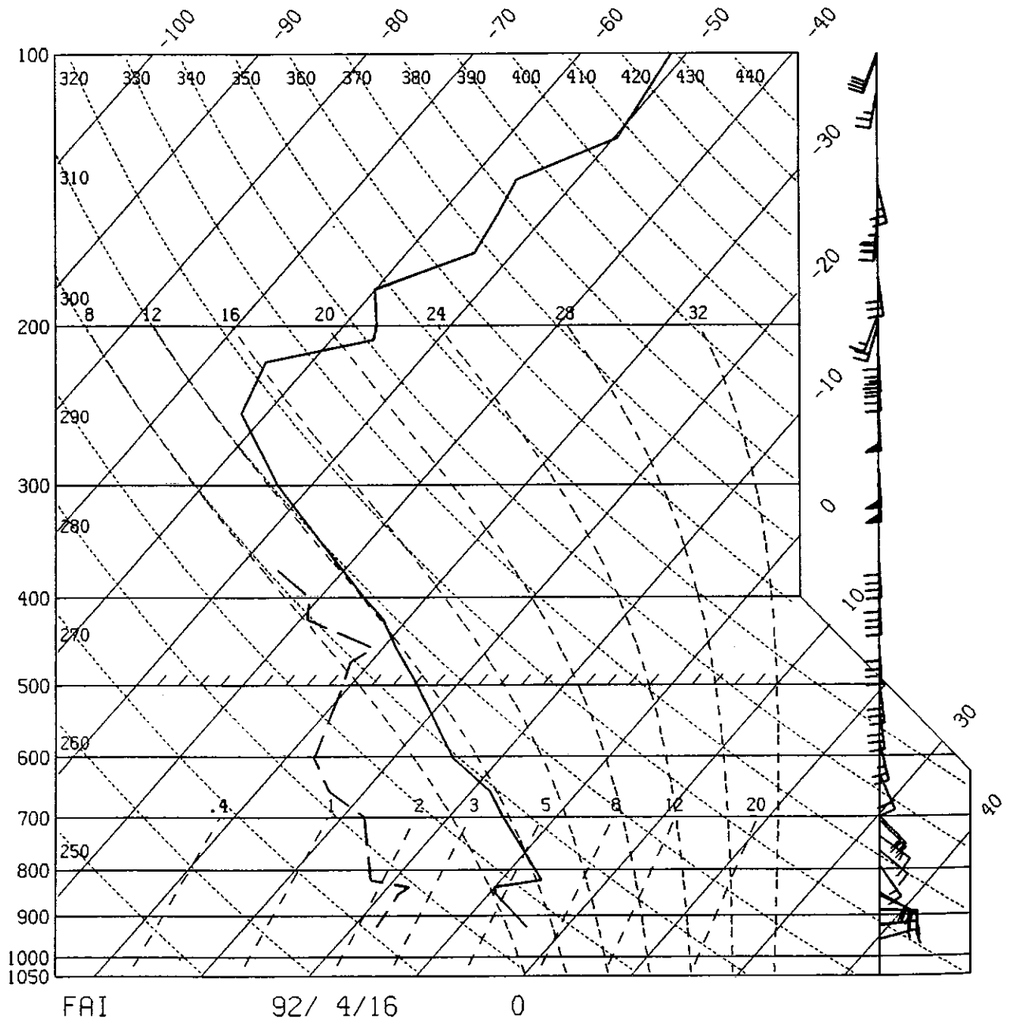
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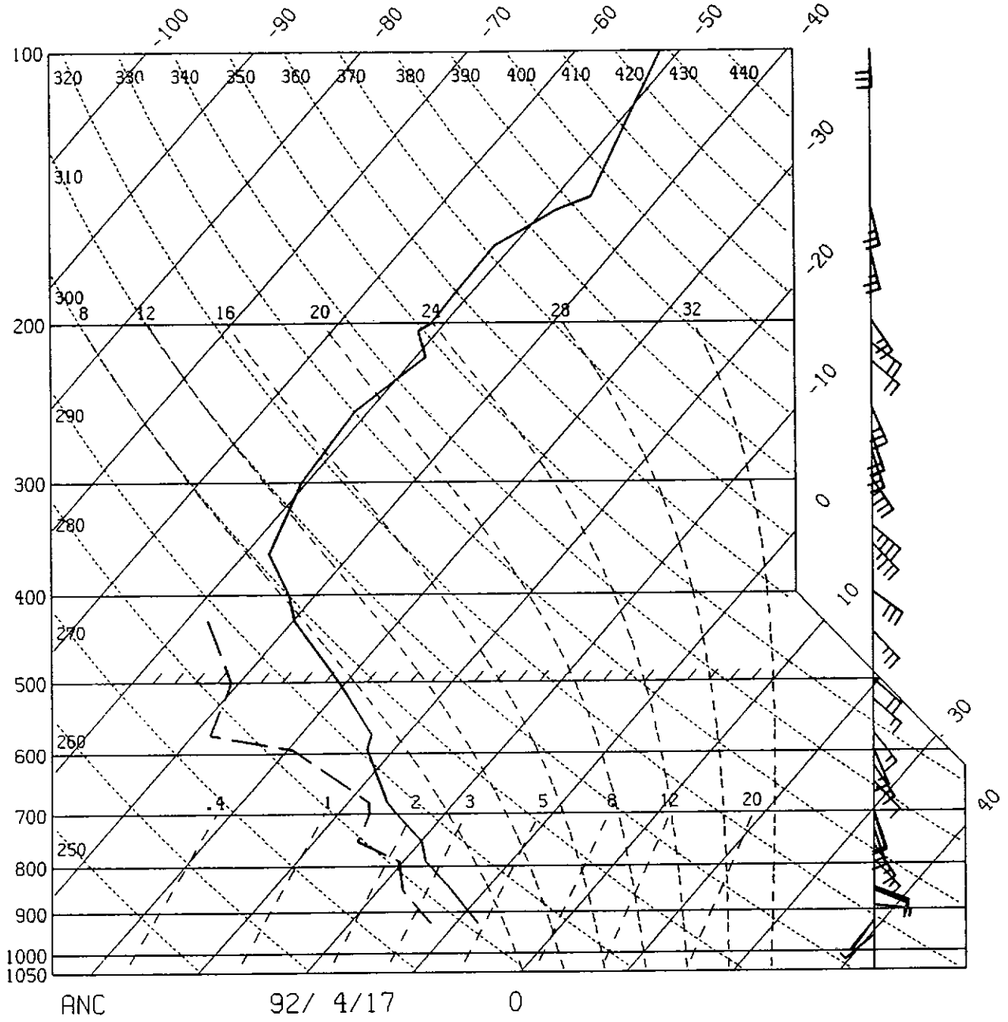
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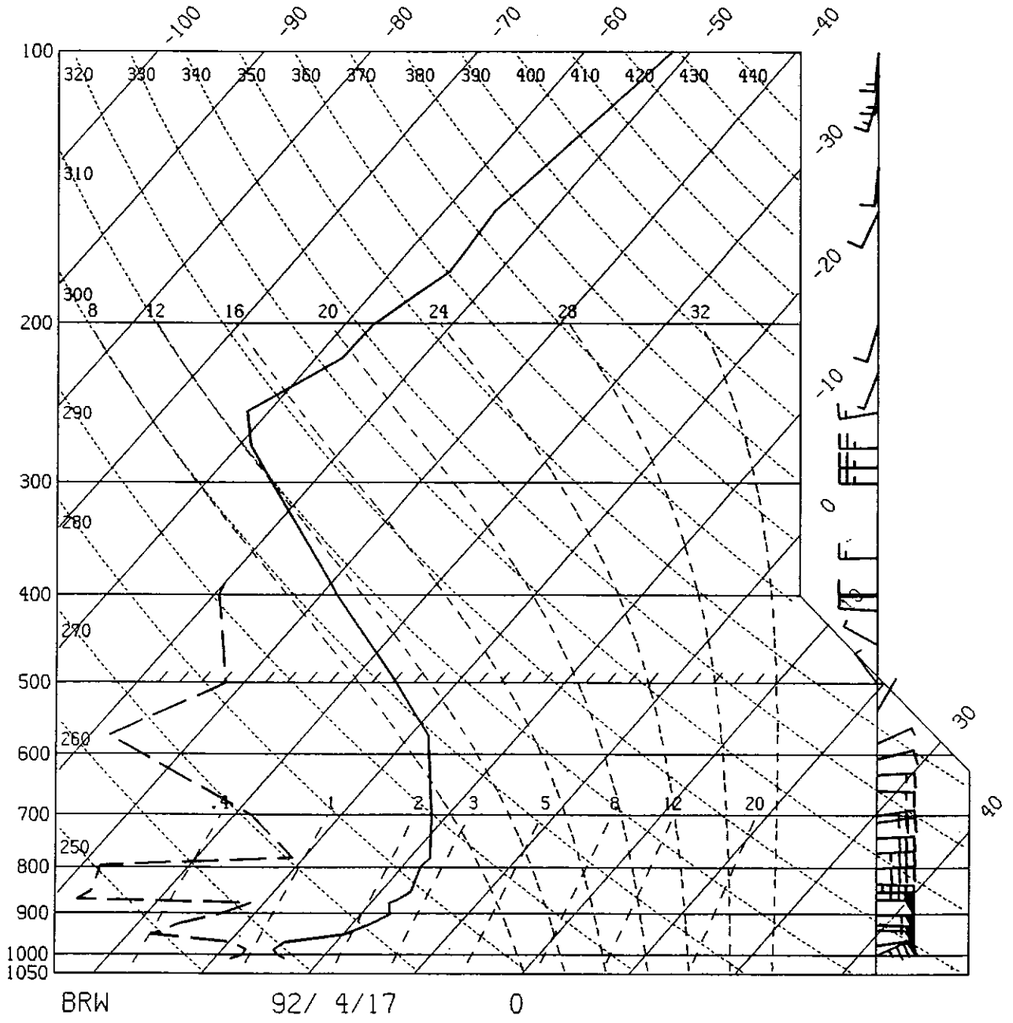
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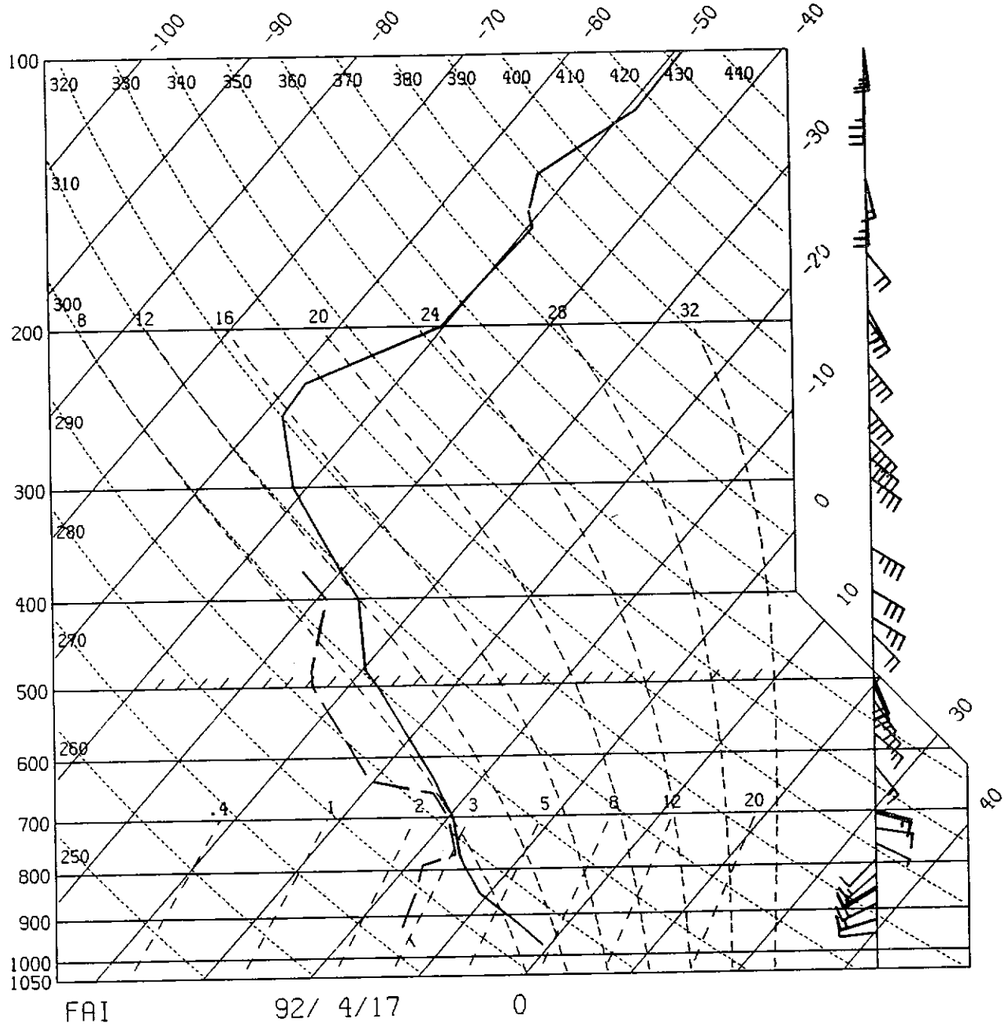
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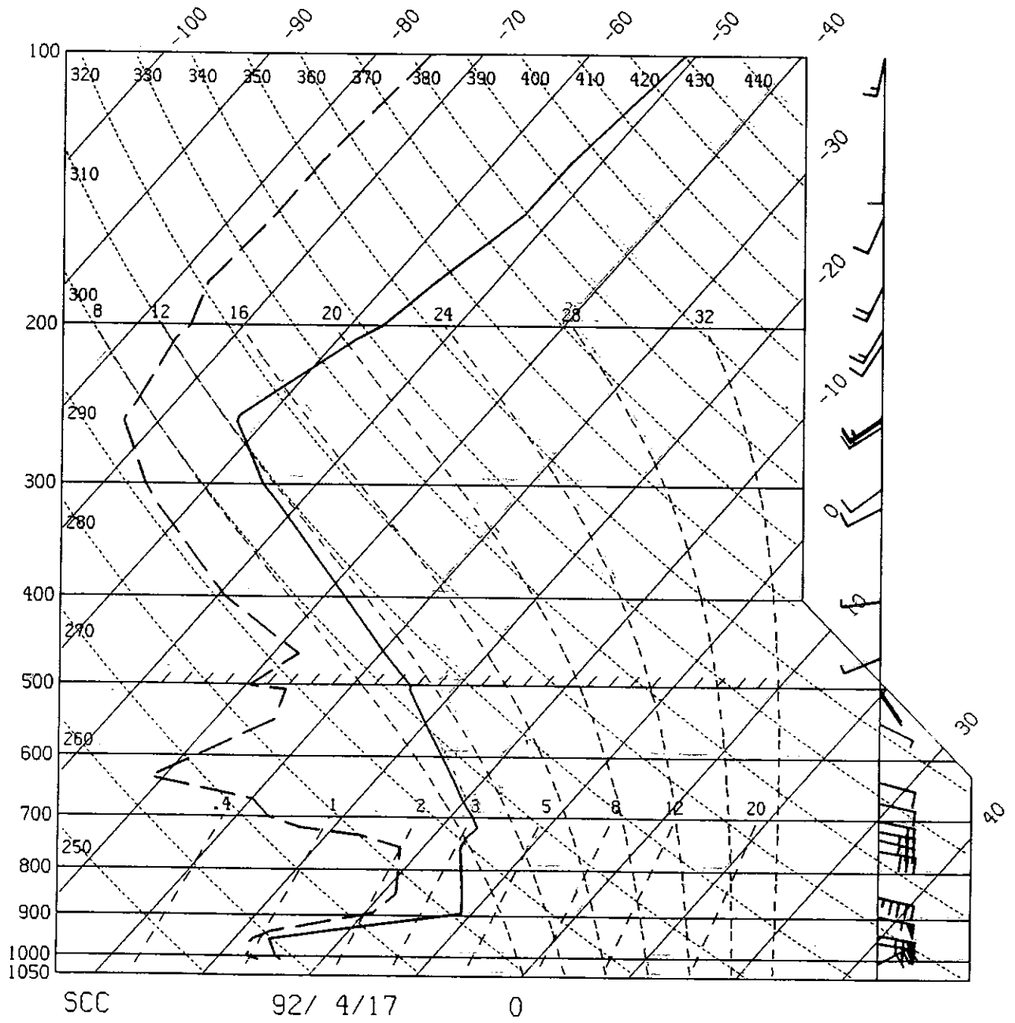
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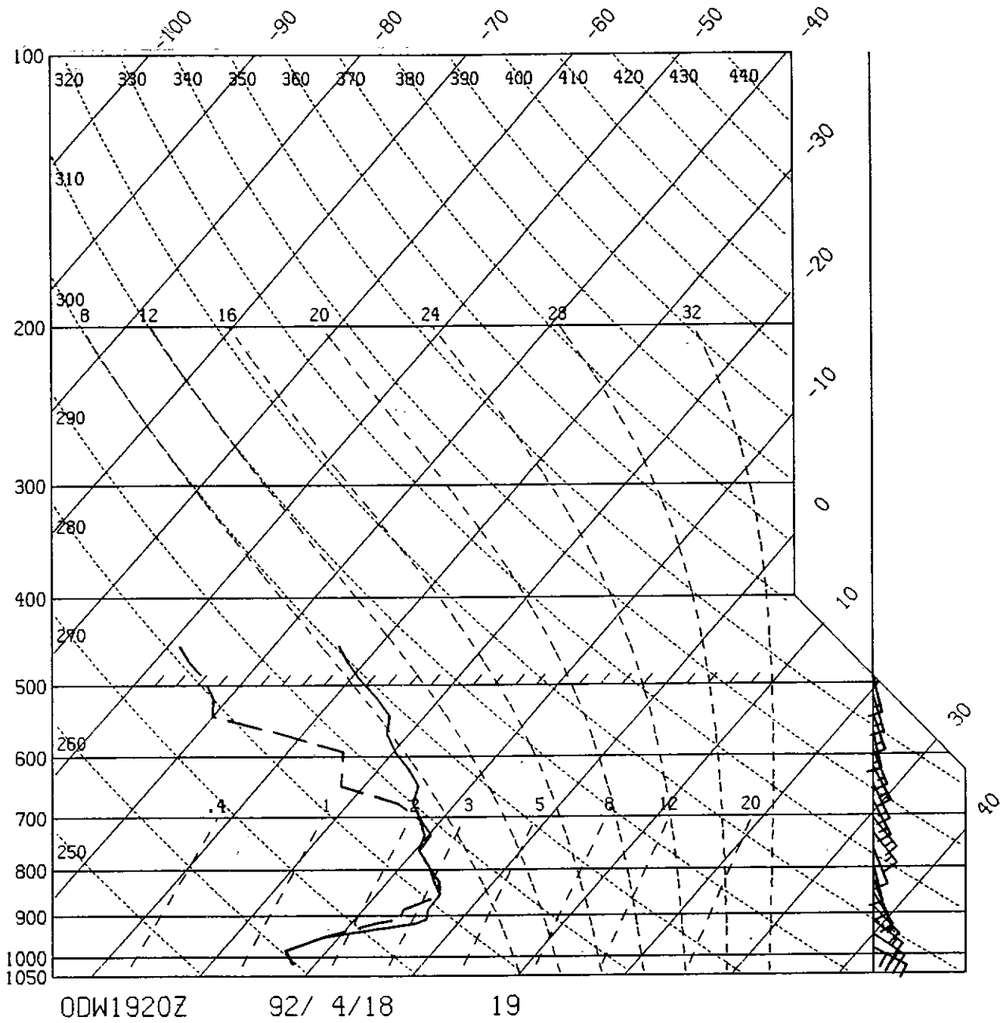
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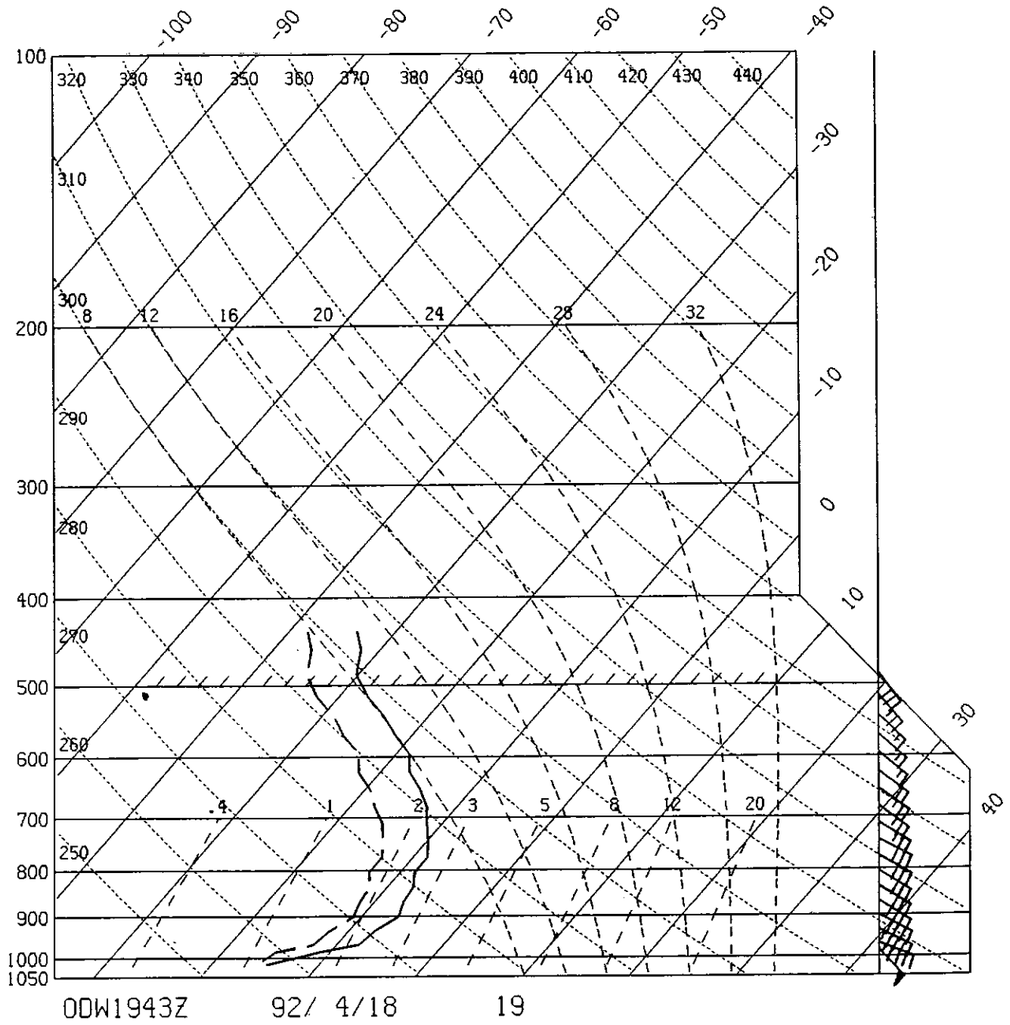
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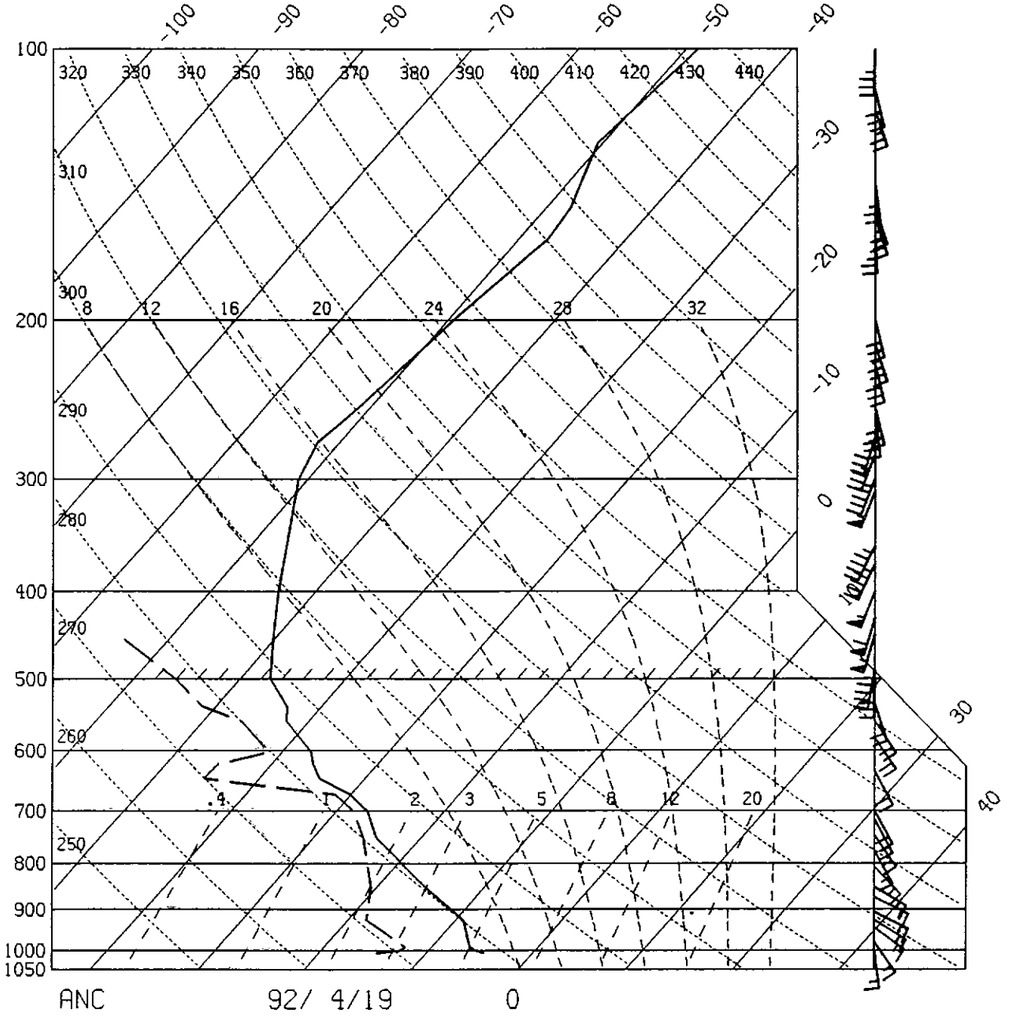
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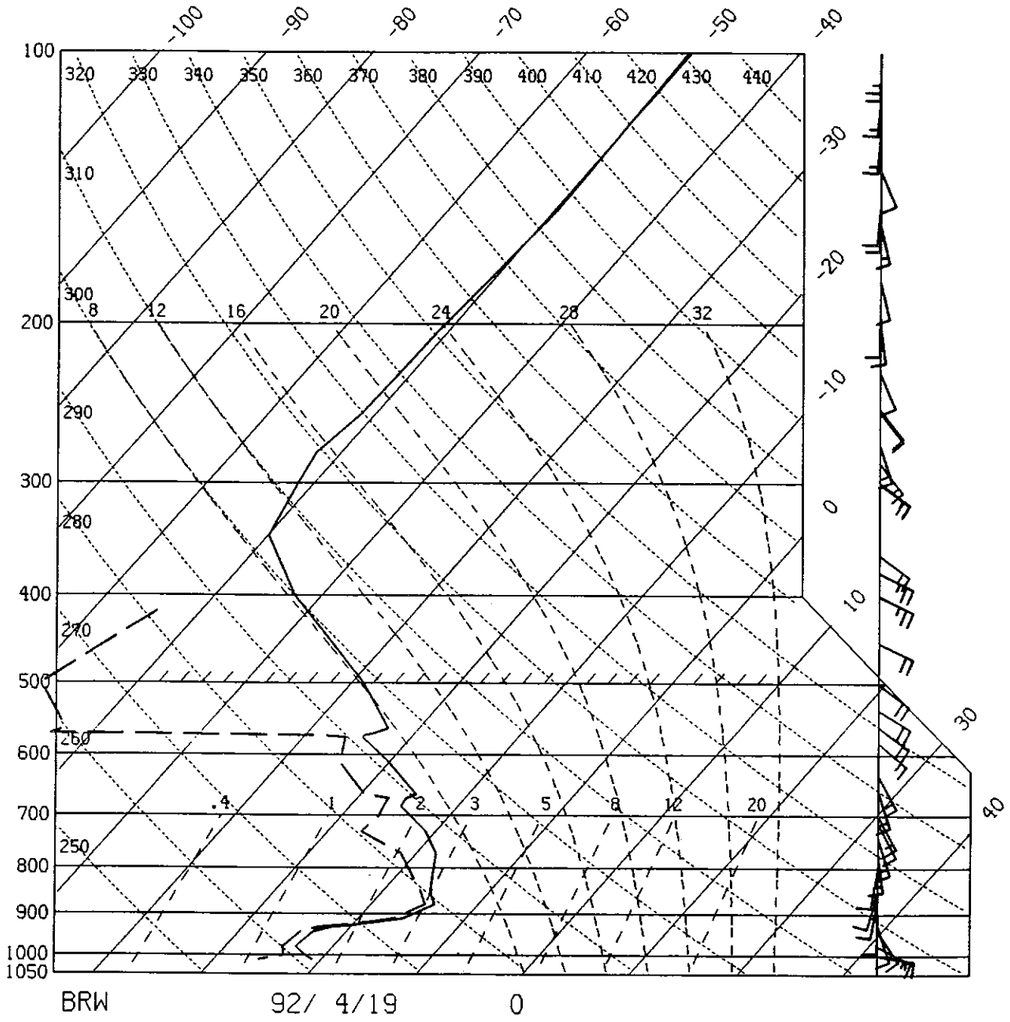
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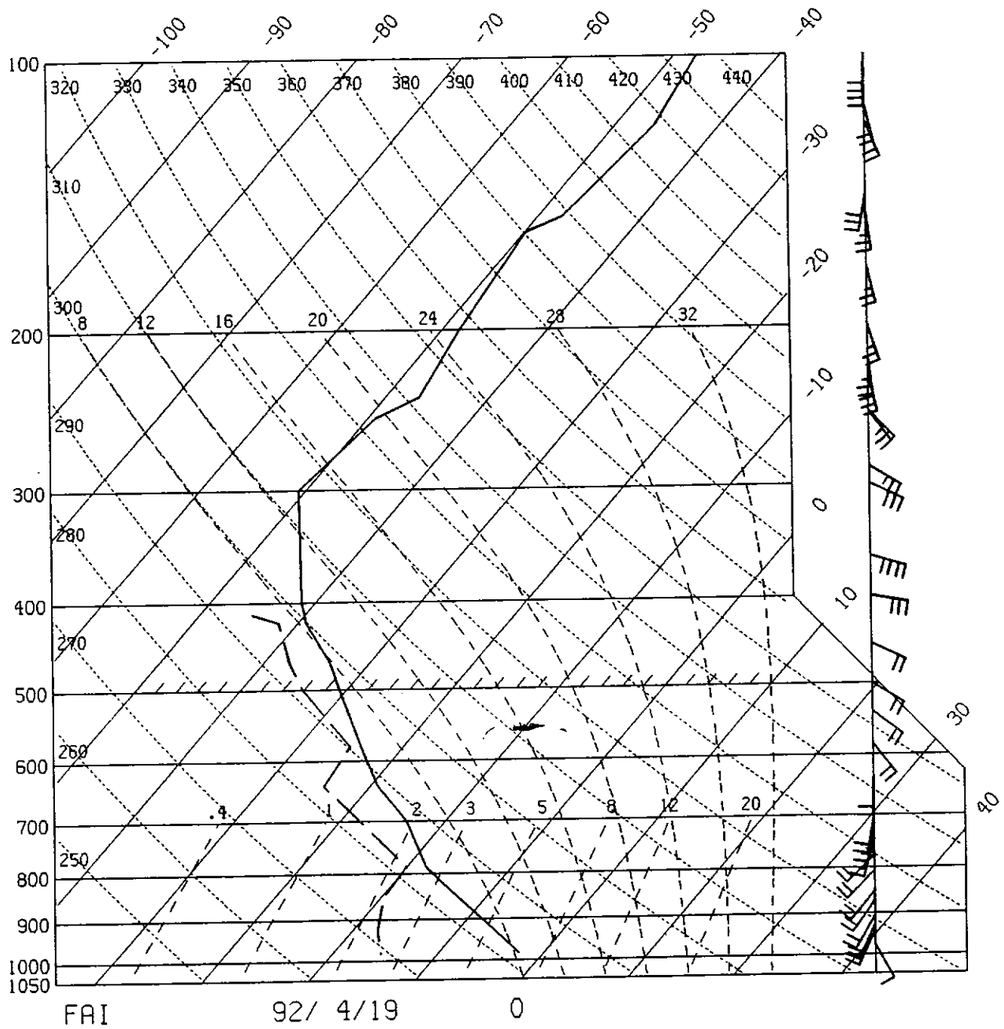
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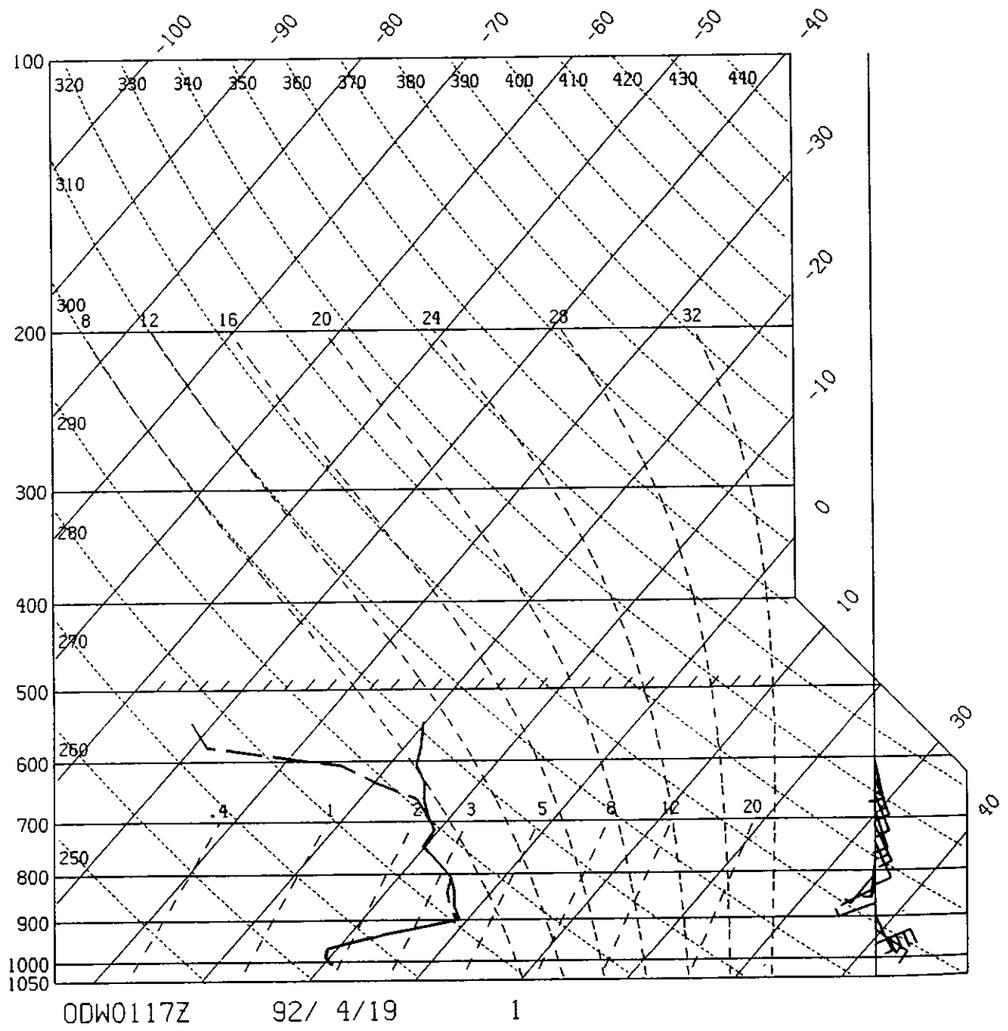
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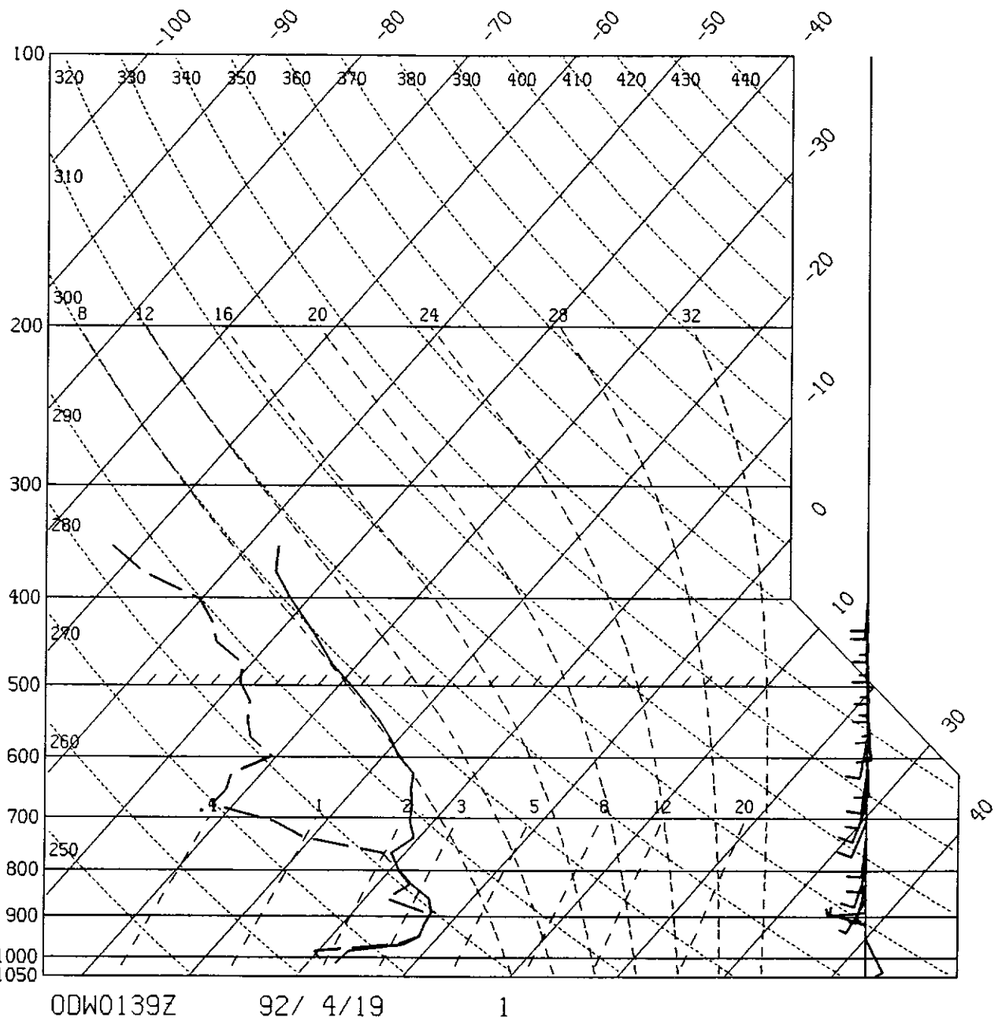
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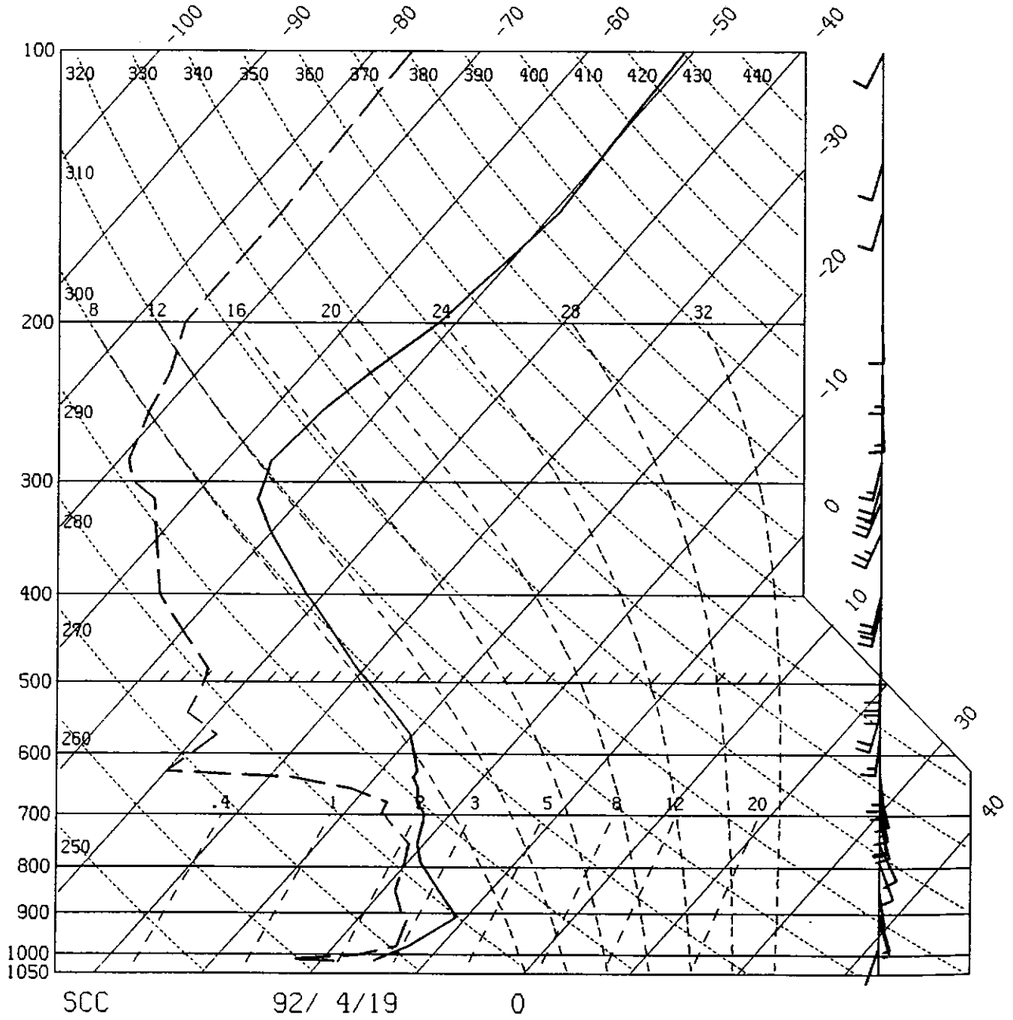
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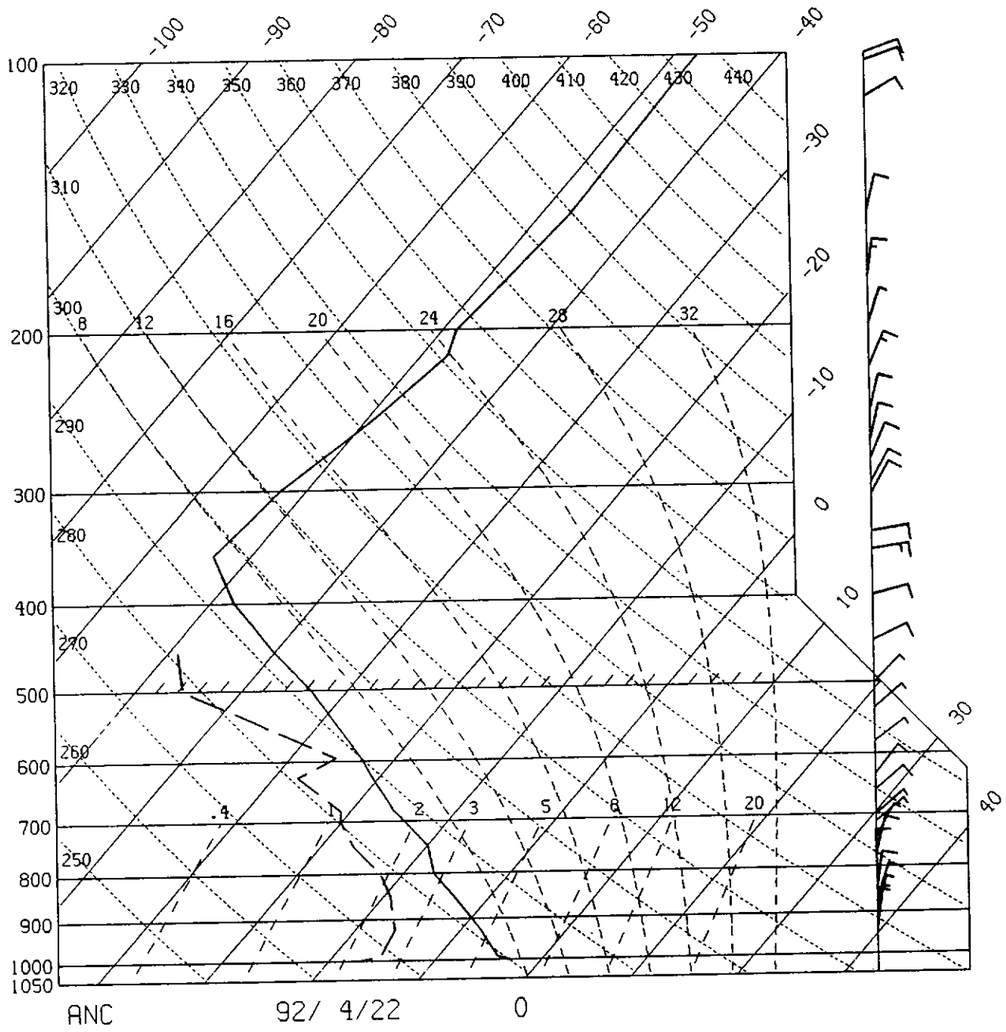
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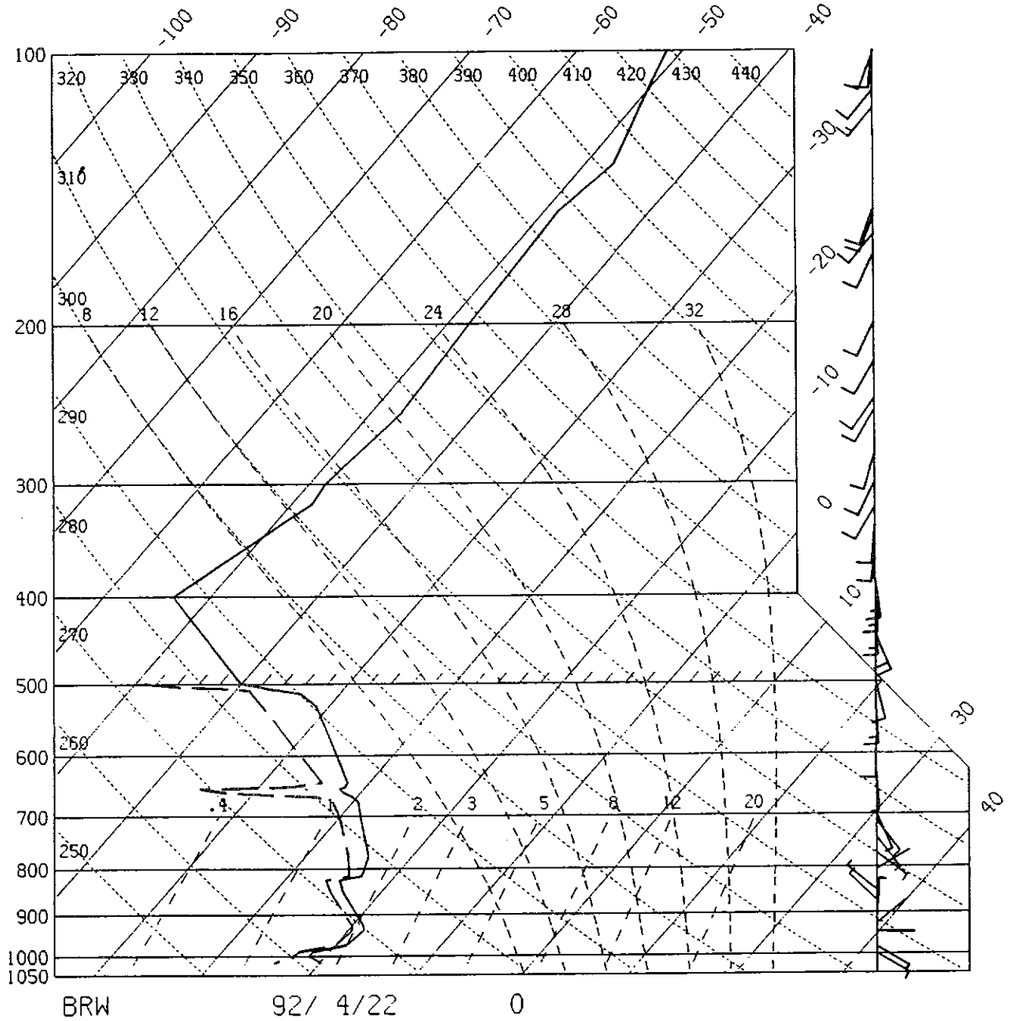
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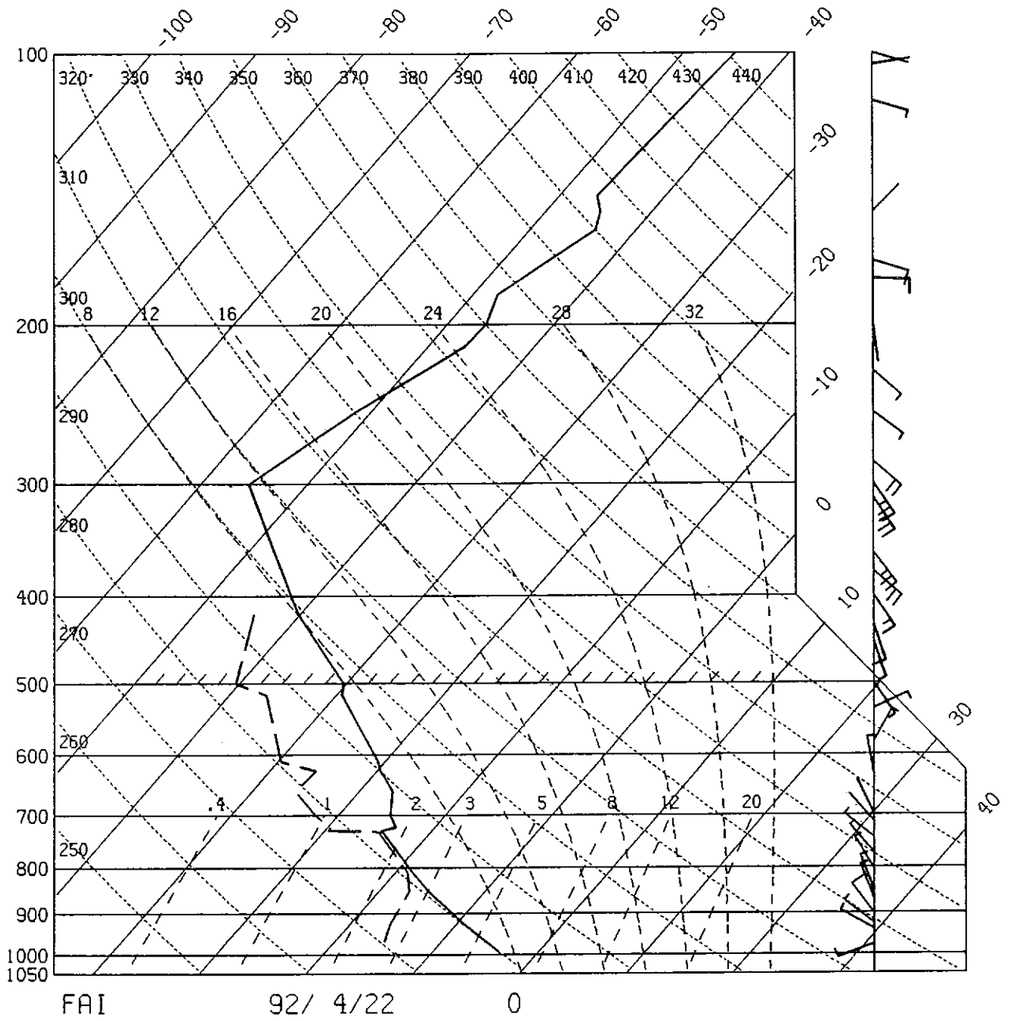
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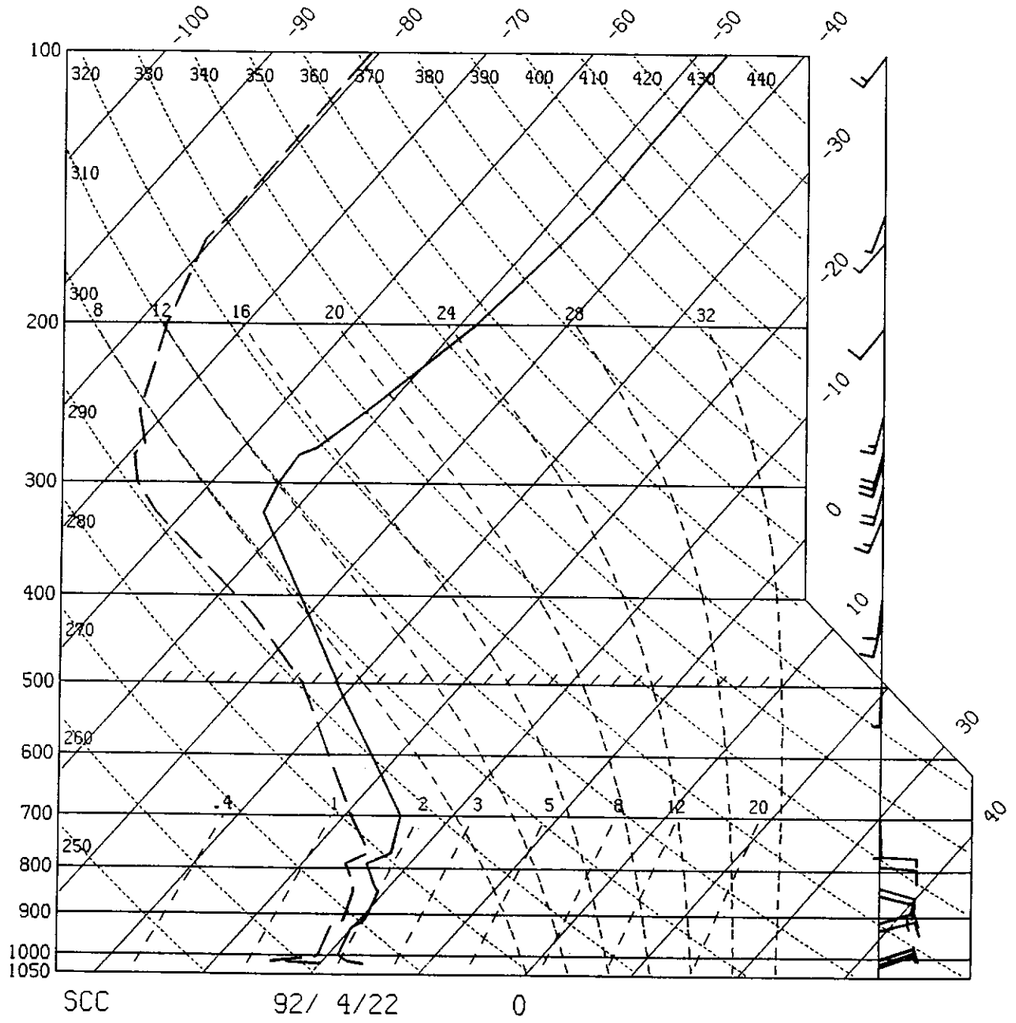
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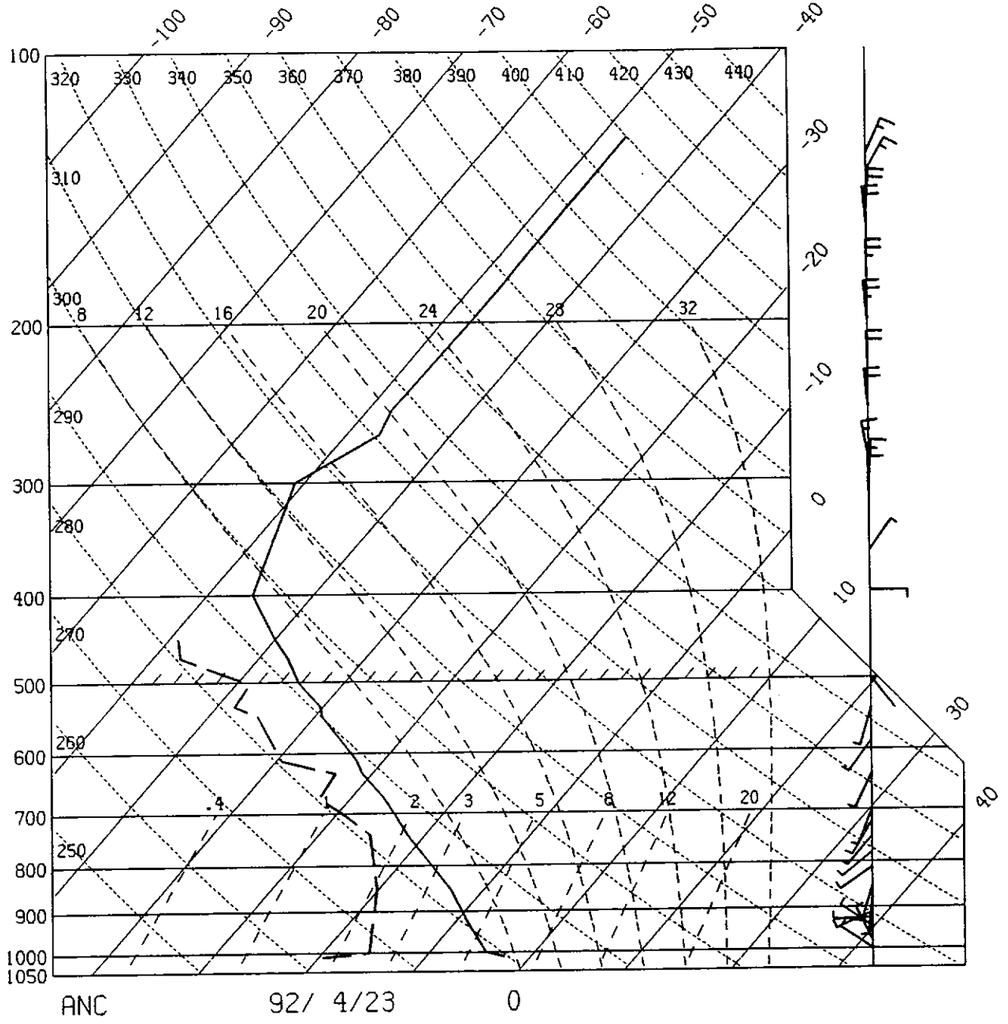
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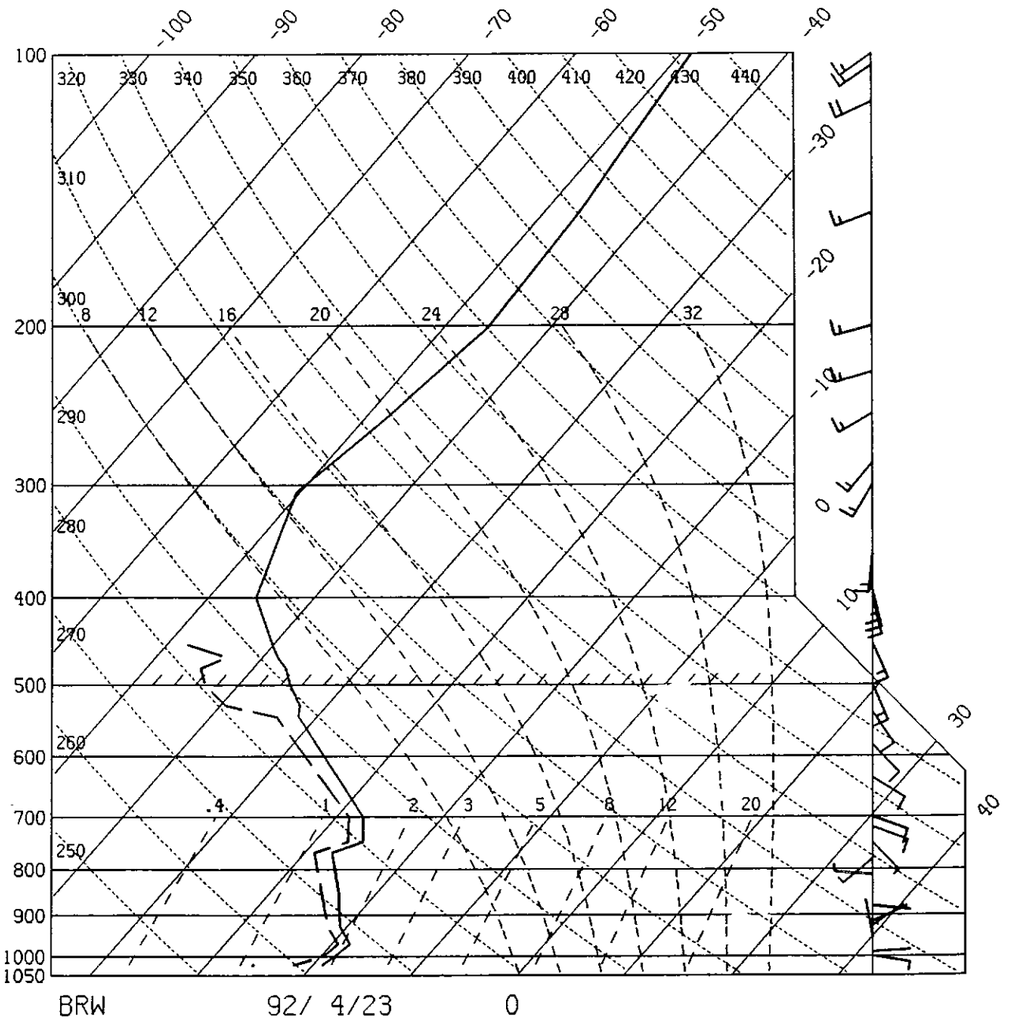

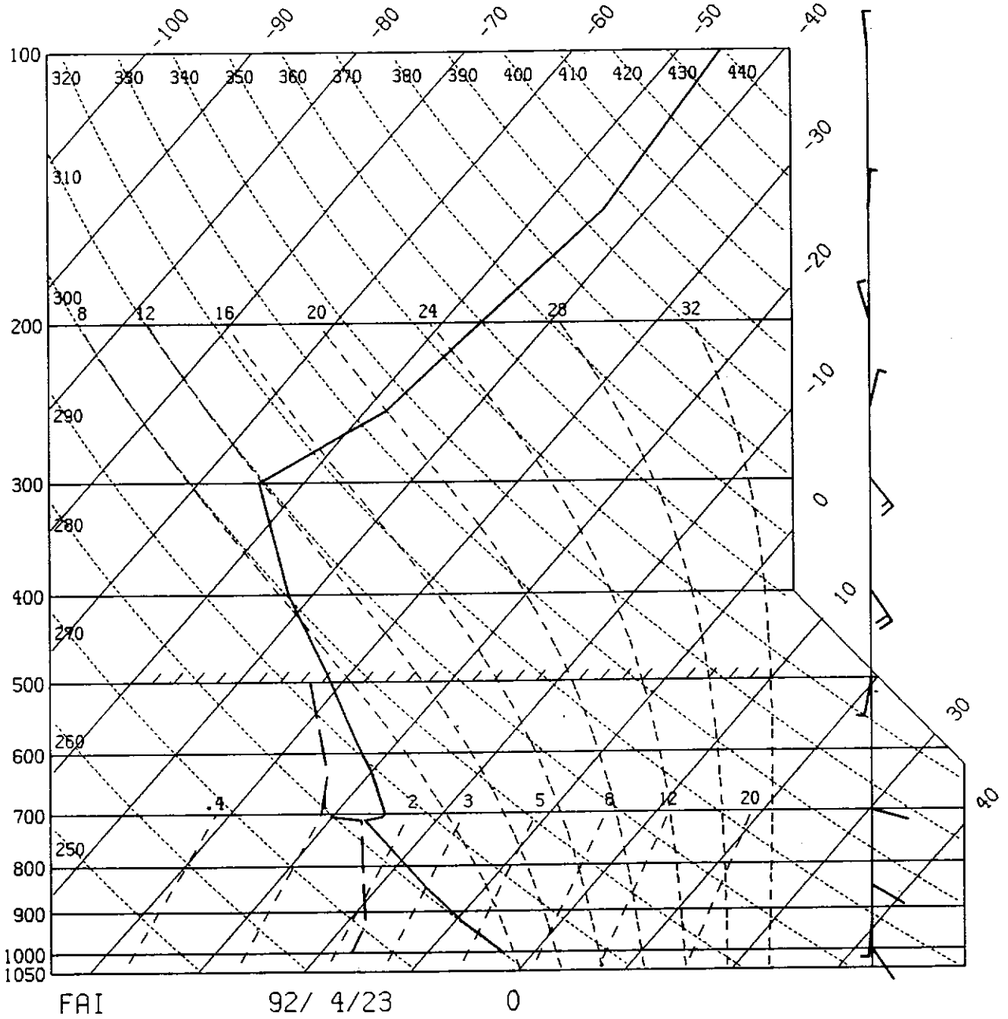

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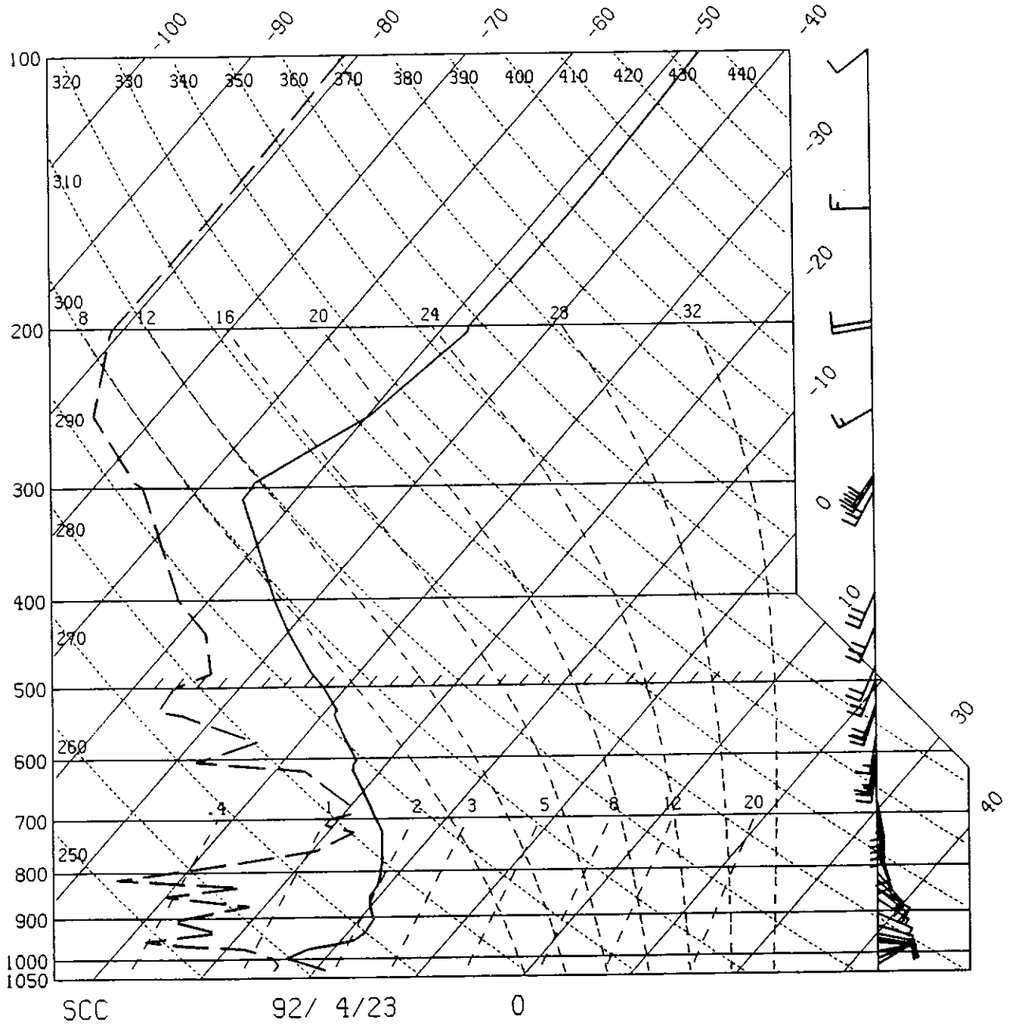
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