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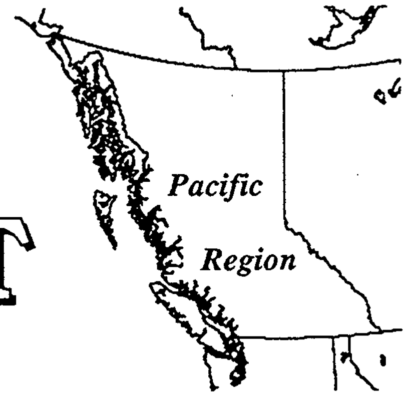

AN INVESTIGATION OF *THE SOUTHWEST BRITISH COLUMBIA RAINSTORM OF NOVEMBER 7-10, 1989*

Rick Drouillard and Colin di Cenzo
Scientific Services Division
Atmospheric Environment Service
Pacific Region

September 7, 1990
Report PAES-90-3

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ABSTRACT

A detailed examination of the meteorological aspects of a coastal British Columbia rainstorm is presented. This particular storm produced a reported $8.7 million in flooding damage along the southwest British Columbia coast between November 7th and 10th, 1989. Rainfall totals in excess of 400 millimeters were recorded over a four day period from a number of locations in the mountains north of Vancouver and west of Victoria. Subtropical moisture, originating southwest of the Hawaiian Islands, appears to have played a major role in this event.

RESUME

Une analyse détaillée des aspects météorologiques d'une tempête de pluie de la côte de la Colombie Britannique est présentée. Cette tempête a produit des inondations le long de la côte sud-ouest de la Colombie Britannique causant des dommages rapportés de $8.7 Million du 7 au 10 de Novembre 1989. Plus de 400 millmètres de pluie a été enregistrée durant cette période de 4 jours par plusieurs stations situées dans les montagnes au nord de Vancouver et á l'ouest de Victoria. L'humidité subtropicale venant du sud-ouest des Iles Hawaii semble avoir joué un rôle important pendant cet événement.

INTRODUCTION

Rainfall events producing 50 to 100 millimeters in a 24 hour period are rather common along the British Columbia coastline during the fall and early winter months. These events occur at a time when the frequency of frontal passages over the British Columbia coast is quite high. The heavier rainfall events are generally initiated when these moist Pacific frontal systems stall over a section of the coast. The heaviest rains normally fall along and within 250 kilometers ahead of the front. The November 7-10th storm which brought heavy rainfalls to northern and western Vancouver Island and the central BC coast is quite typical of these systems. After the deep low center crossed north of the Queen Charlotte Islands, close to 03:00 UTC on November 8th (figure 4), the accompanying cold front stalled over northern Vancouver Island. A common feature of these systems is strong low level winds in the warm sector. More specifically, these strong winds will be oriented perpendicular to the mountain ranges which tower above the British Columbia coastline. When you add a continuous supply of low level moisture to this wind field, conditions are favorable for heavy, orographic rainfalls.

However, extreme rainfall events, of necessity, must have different mechanisms in place which contribute to the greater rainfall accumulations. A factor in the heavy rainfalls of November 9 seems to be the intrusion of a deep layer of subtropical air into the westerly stream the day before.

DATA SOURCES

Daily precipitation data from the Atmospheric Environment Service (AES) climatological network, synoptic weather charts, historical climatological records and satellite imagery are used as the basis for this report.

Not all stations use the same 24 hour period or climatological day when reporting their daily precipitation amounts. Thus individual daily rainfall totals may vary from station to station, depending on the time of day the rain fell and the start and end times of the station's climatological day. This difference is not taken into account.

SYNOPTIC ANALYSIS

UPPER AIR PATTERN

The flow pattern between 500 and 250 millibars was dominated by a broad belt of strong westerly winds over the eastern Pacific that extended from just east of the dateline to the BC coast. This broad belt consisted of three merged streams. The northernmost stream was the driest, with air being drawn south and east from western Alaska and the Bering Sea, across the Alaskan Panhandle and the northern third of British Columbia. The more dominant stream originated west of the dateline and had a trajectory which was entirely over water between the 40 and 50 degrees north latitudes. A third stream of subtropical origin, developed over the eastern Pacific late in the afternoon on November 8th. This stream was instrumental in bringing subtropical moisture northward into the mid latitudes which ultimately moved westward onto the British Columbia coast on November 9th.

At 250 millibars, wind speeds were 90 knots or greater across a wide portion of the Pacific between 45 and 55 degrees north. A core of maximum wind speeds of near 150 knots developed in the stream on November 7th, with the axis between 50 and 55 degrees north. This core translated east-northeastward on November 8th, with the western end of the jet maximum moving inland across the northern third of British Columbia early on November 9th (figure 1a).

A secondary jet maximum of 110 knots developed much further south in an arc extending from 35 degrees north, 165 west to 45 north, 150 west late in the afternoon of November 8th (figure 1a). This jet core intensified to 160 knots then moved eastward across the central British Columbia coast. It was during this period that the heaviest rainfalls were reported over the south coast (figure 1b and figure 14).

A strong west-southwesterly flow pattern also existed at the 500 millibar level over the eastern Pacific. A low amplitude ridge, located along 155 degrees west early on November 7th, moved quickly eastward to the coast late in the day, leaving no significant highs or lows between the coast and a major longwave trough located just west of the dateline. Other significant low pressure centers and troughs remained north of 55 degrees north throughout the period.

A feature of primary importance to this rainfall event was a rather innocuous looking 500 millibar low center, which formed northwest of the Hawaiian Islands near 30 degrees north, 170 west on November 3rd. This low remained quasi-stationary for the next few days. A strong vorticity center and jet maximum digging southward into the longwave trough position near the dateline appears to be the mechanism which resulted in the southern low being ejected northeastward late on November 6th (figure 2). The subsequent numerical analyses indicate that the circulation around the low quickly weakened as it was absorbed into the main belt of westerlies and even disappeared from the analysis as the feature approached northern Vancouver Island on the morning of November 9th. However, using satellite loops and imagery, it is clear that the moisture that had moved northeast with the low did not dissipate but moved onto the southern BC coast about the time the heaviest rainfalls began.

The most prominent feature at 850 millibars was a 500 kilometer wide, but intensive baroclinic zone, which oscillated between northern Vancouver Island and the central British Columbia coast during the period. Corresponding temperature gradients across the front were in excess of 20 Celsius degrees, with readings in the warm sector greater than 10 Celsius degrees on November 9th (figure 3).

Another significant feature at 850 millibars (figure 3) was the strong gradient winds in the warm sector. This isobaric gradient remained very compact throughout the period with the maximum gradient wind approaching 70 knots on November 9th. Also of note, was the fact that this strong gradient covered a large portion of the Pacific, at times extending from the British Columbia coastline southwest to 160 degrees west longitude.

SURFACE

Two major surface low pressure centers developed on the baroclinic zone. The first low entered the eastern Pacific near 52 degrees north, 158 west, early on November 7th, as a well organized 994 millibar center, which deepened explosively to 970 millibars, as it approached the southern Alaskan Panhandle 12 hours later (figure 4). The low then crossed the panhandle and moved into northern British Columbia where it slowly weakened. The accompanying cold front sagged as far south as the northern tip of Vancouver Island where it stalled.

The second low center originated much further to the southwest, about 900 kilometers northwest of Hawaii. Its development was associated with the 500 millibar low center, which had begun to move northeastward. As this second low moved northeastward it deepened slowly reaching 988 millibars by the time it crossed the Queen Charlotte Islands (figure 5). While the low was not as deep as the previous system, pressure gradients along the southwest British Columbia coast remained tight due to persistent ridging along the Washington and Oregon coasts. The strong southwest flow brought a warm moist airmass to the southern British Columbia coast as temperatures and dewpoints rose to the low and mid teens just west of Vancouver Island. Figure 5a depicts the tracks of both low centers.

SATELLITE IMAGERY

An analysis of satellite imagery during the days before and during the event revealed much about the dynamics of the storm. Of particular use, was the ability to observe loops of satellite imagery taken at one hour intervals. The satellite loop documented the large scale movement of a subtropical airmass from west and southwest of the Hawaiian Islands into mid latitudes.

Figures 6 through 11 show the various stages in the movement of this subtropical airmass toward the British Columbia coast. Figure 6 displays the situation at 12:00 UTC on November 5th, several days after the formation of the upper low center. A large area of mid and high level moisture was moving rapidly toward the British Columbia coast between 45 and 55 degrees north. A subtropical feed had developed west of 160 degrees west between 30 and 40 degrees north. This subtropical moisture was distinct and not interacting with the moisture in the main cloud band to the north. A day and a half later (figure 7), there was still no interaction between the subtropical airmass and the polar stream along 50 degrees north. However, this polar stream already contained considerable amounts of moisture, as 24 hour rainfalls between 50 and 100 millimeters were reported over northern Vancouver Island and the central British Columbia coast. In the meantime, the extent and coverage of the subtropical cloud mass west and southwest of Hawaii was growing and there were indications of a developing subtropical jet stream axis. The separation between the two streams was also decreasing.

By 12:00 UTC November 7th (figure 8), the area of subtropical moisture was moving northward and had begun to merge with the westerly stream along 45 degrees north. Aircraft reports indicated that a southwesterly wind maximum in excess of 100 knots had developed in the subtropical airmass. It was also about this time that a surface low began to develop, with the southwesterly gradient increasing markedly in the warm sector.

Early November 8th, the subtropical cloud band had merged with the main baroclinic zone between 45 and 55 degrees north (figure 9). In fact, the imagery shows that the subtropical trough was lifting northeastward. A well defined vorticity maximum (remnants of the 500 millibar low center) is also visible and is marked at 40 north, 159 degrees west. The merging of the two streams also resulted in anticyclonic buckling of the northern belt of westerlies (between 45 and 55 north, 145 and 160 degrees west). This area of moisture then raced rapidly east northeast toward the southern British Columbia coast. By 12:00 UTC on the 9th (figure 10) much of the moisture had crossed the coast. It was at this time that the heaviest rains were beginning over southern Vancouver Island

and the Lower Mainland. At 00:00 UTC November 10th (figure 11) heavy rain had ended over all but the extreme southern British Columbia coast, as the last remnants of the subtropical moisture dissipated.

RAINFALL ANALYSIS

An intriguing aspect of the rainfall pattern was the strong variation in total rainfall amounts over relatively short distances. For instance, the total rainfall over the 4 day period at the Coquitlam Lake Dam was 437 millimeters, while less than 100 kilometers to the southwest, a rainfall of only 9.6 millimeters was recorded on the north end of Galiano Island!

Figures 12 to 15 are isohyetal analyses of the 24 hour rainfall amounts for November 7th, 8th, 9th, and 10, 1989 while figure 16 is an analysis of the total rainfall for the four day period. A tabulation of all stations and values used in the analysis is given in Table 1. Very little data was available from some of the mountainous areas on Vancouver Island and the mainland coast mountains. The analysis in particularly data sparse areas is based on a combination of satellite interpretation and local synoptic experience, and is so indicated by dashed lines.

The analysis for the first three days (figures 12-14) show essentially the same rainfall distribution pattern. Maximum rainfall amounts were recorded along the west side of Vancouver Island and along the mainland British Columbia coast. A very conspicuous rain shadow covered the eastern side of Vancouver Island extending eastward across the Strait of Georgia to parts of the coastal sections of the mainland.

Twenty-four hour rainfall amounts in excess of 100 millimeters occurred on November 7 and 8 over the west side of Vancouver Island and the central coast. These rainfalls were recorded during the period when the first deep surface low moved across the coast north of the Queen Charlotte Islands (figure 5a).

By November 9th, the area of heaviest rainfalls shifted to southern Vancouver Island and the Lower Mainland. Total 24 hour rainfall increased, with amounts of 100 to 200 millimeters reported across a broad area outside of the rainshadow. This period of heavy rain correlates well with the passage of the subtropical moisture over the southern BC coast (figures 5 and 10).

On November 10th, the heavy rain had ended in all areas except the eastern Fraser Valley. At Hope Airport an additional 93.4 millimeters of rain was reported. Subtropical moisture did not appear to play a role in the continuation of the heavy rain. Rather, topography and convergence of the low level wind field in the Fraser Valley contributed to heavy rains lingering in this region.

DISCUSSION

Figure 17 displays the maximum temperatures for November 9th at a number of locations on the southern British Columbia coast. Also plotted are mean maximum temperatures for that date. As can be seen temperatures were well above the seasonal means for the day, reaching as much as 9 degrees above at Lytton which was in the rainshadow of the coast mountain ranges. However, locations which received considerable rain, such as the Hope and Abottsford airports were also 5 degrees above the mean. Not only did these temperatures represent the mildest day for the month, but a number of stations set new maximum temperature records for the date.

Table II gives the a priori return periods[1] for the November 7-10 storm at a number of stations on the coast. The return periods are calculated using the Gumbel method of moments.[2] It is difficult to compare days or stations directly, due to the overlapping nature of this rainfall event from November 7th to 10th. However, it can generally be seen that the return periods for stations on central and northern Vancouver Island, are considerably lower than those for the Lower Mainland stations which were affected by the subtropical airmass. At the extreme end was the 89 year return period for the 24 hour rainfall of 232 millimeters at Coquitlam Lake Dam on November 9th. What is even more remarkable is the fact that 209 millimeters (unverified) was recorded in a 12 hour period from 11:00 UTC to 23:00 UTC. This magnitude of rainfall has a return period well in excess of 100 years!

SUMMARY/CONCLUSIONS

The heavy rainfall amounts which accumulated between November 7th and 10th over the southern and central British Columbia coast were unusual from both the amounts of rain that fell, and the distinct rainshadow pattern produced by the Vancouver Island mountains. Orographic effects were magnified by the very strong southwesterly flow that existed through the entire depth of the airmass, and resulted in sharp differences in rainfall accumulations over small distances. While this is fairly common to British Columbia, the sharpness of the gradient in the rainfall amounts was far beyond what is common.

The other intriguing aspect of this storm was the very high rainfall amounts that fell over the southwest tip of Vancouver Island and in the mountains just north of the city of Vancouver and the Lower Mainland. A total accumulation of 432 millimeters was reported at the Coquitlam Lake Dam north of the city of Vancouver, which included a one day rainfall of 232 millimeters on November 9th. Other sites in the mountains north of Vancouver recorded similar rainfall accumulations, as did sites on southern Vancouver Island. The return period of 19 years for the four day rainfall was not unusual, however the return period for the November 9th rainfall of 89 years makes the event more interesting. In terms of historical rainfall events, this particular storm falls just short of being in the top ten, when 24 hour rainfall amounts are considered (Table III).

A combination of very high rainfall amounts combined with very mild temperatures on November 9th strongly suggests that an airmass of subtropical origin moved over the coast during the rainfall event. This fact is also well supported by satellite imagery. Subtropical airmasses have been noted in past heavy rainfall events over British Columbia[3], however, few in-depth studies or surveys have examined the role of subtropical moisture in extreme rainfall events around British Columbia. Heavy rainfalls occur with a fairly high frequency and significant damage from excessive rainfalls are not that uncommon. In consideration of the importance of these events, further studies need to look at whether the presence of subtropical airmasses dominate extreme rainfall events.

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[1]The statistical method used can not provide a direct estimate of the return period of the observed amounts. In this report, a return period of X years should be taken to mean that the precipitation observed was the same as the a priori X year precipitation amount expected for that location.

[2]Pugsley, W.I., 1981: Flood Hydrology Guide for Canada: Hydrometeorological Design Techniques. Canadian Climate Centre Report, Downsview, Ontario 102 pp.

[3]Horita, M., 1981: Heavy Rainfall over Greater Vancouver October 30 - November 1, 1981. Pacific Region Technical Notes. Atmospheric Environment Service, Vancouver, British Columbia.

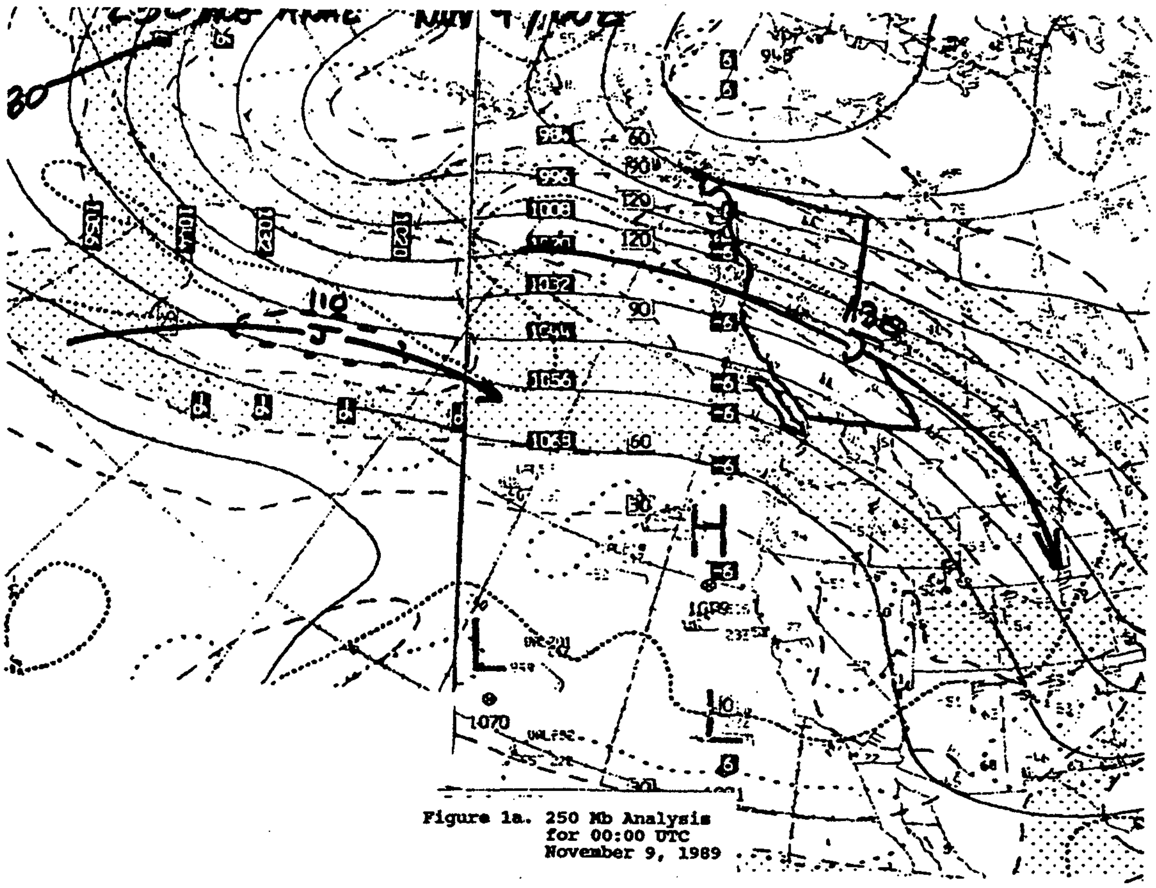

Figure 1a. 250 Mb Analysis
for 00:00 UTC
November 9, 1989

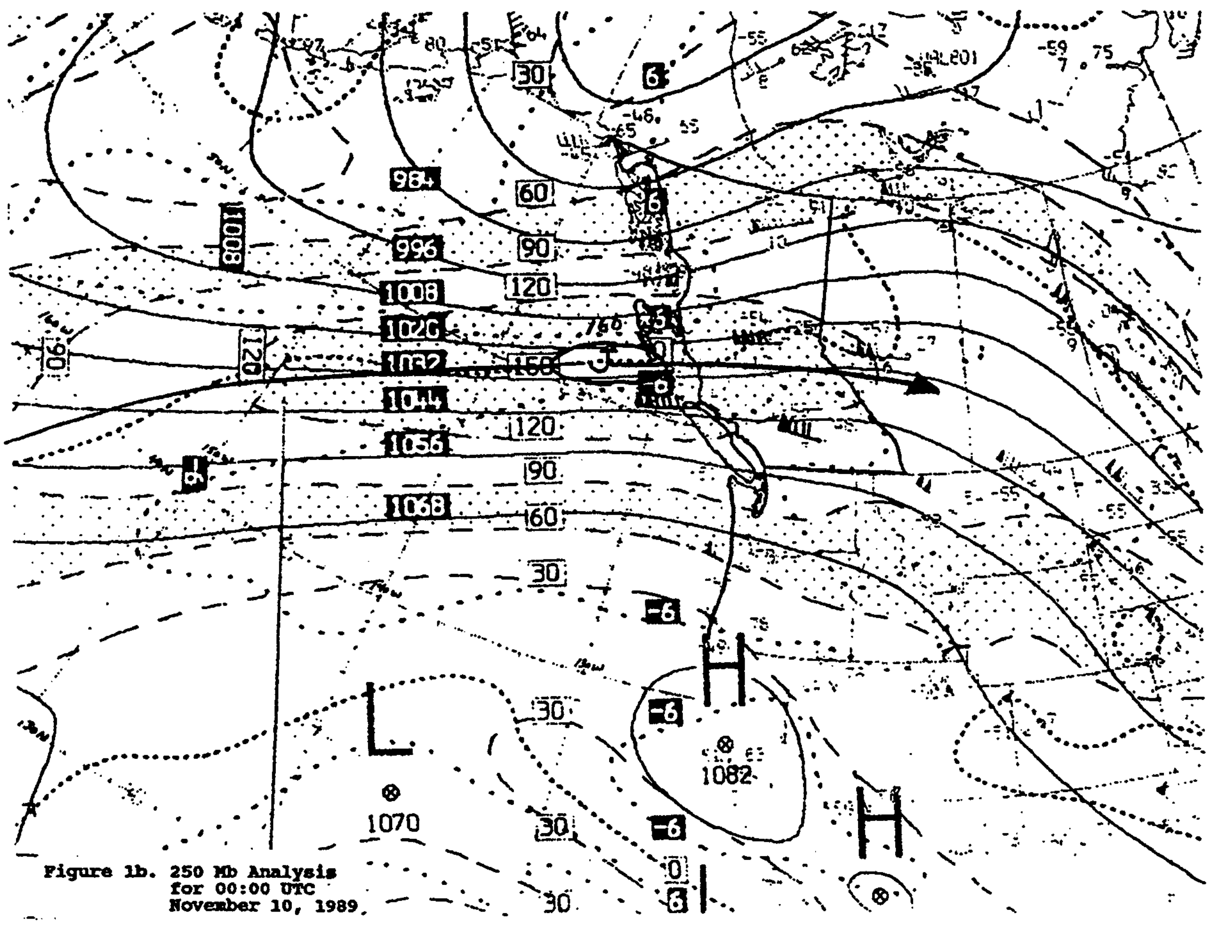

Figure 1b. 250 Mb Analysis
for 00:00 UTC
November 10, 1989

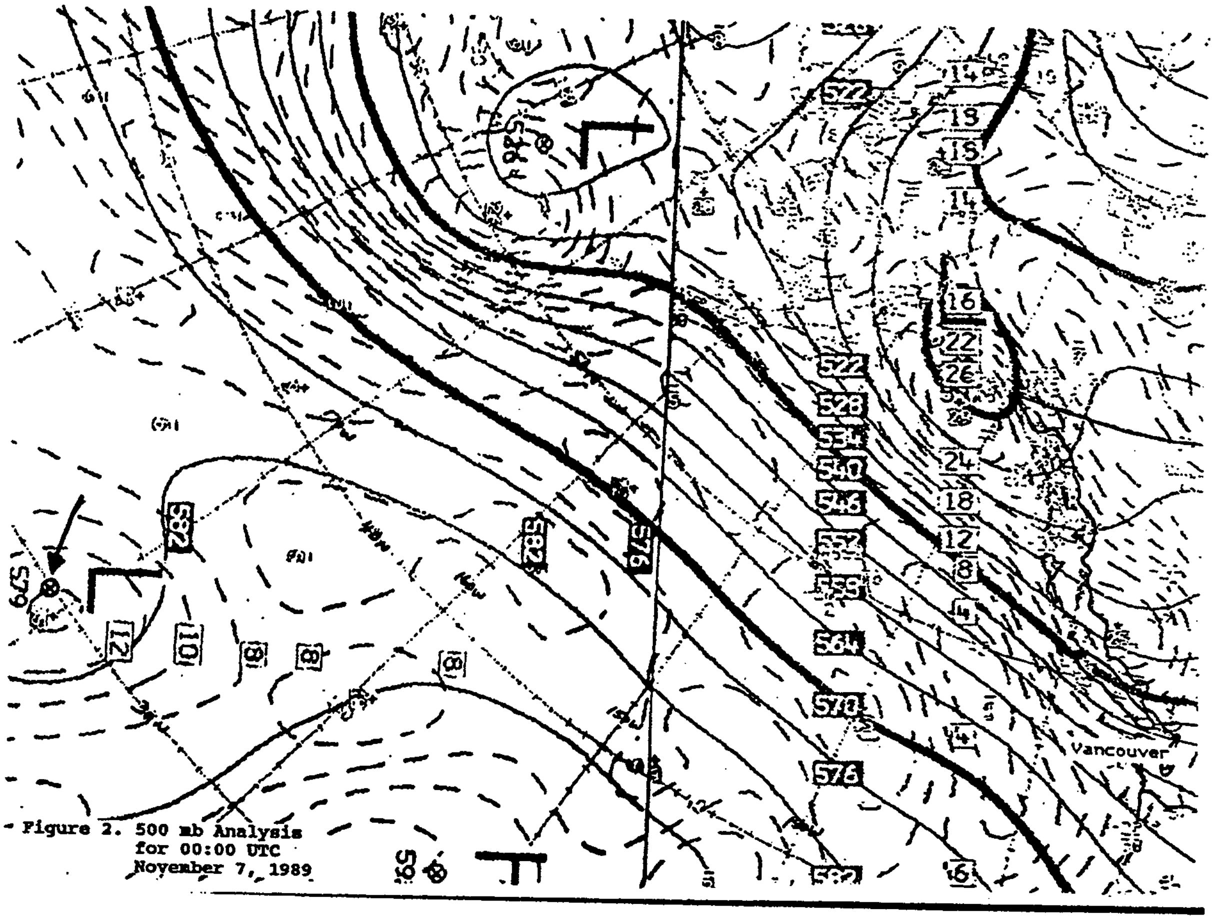

Figure 2. 500 mb Analysis for 00:00 UTC November 7, 1989

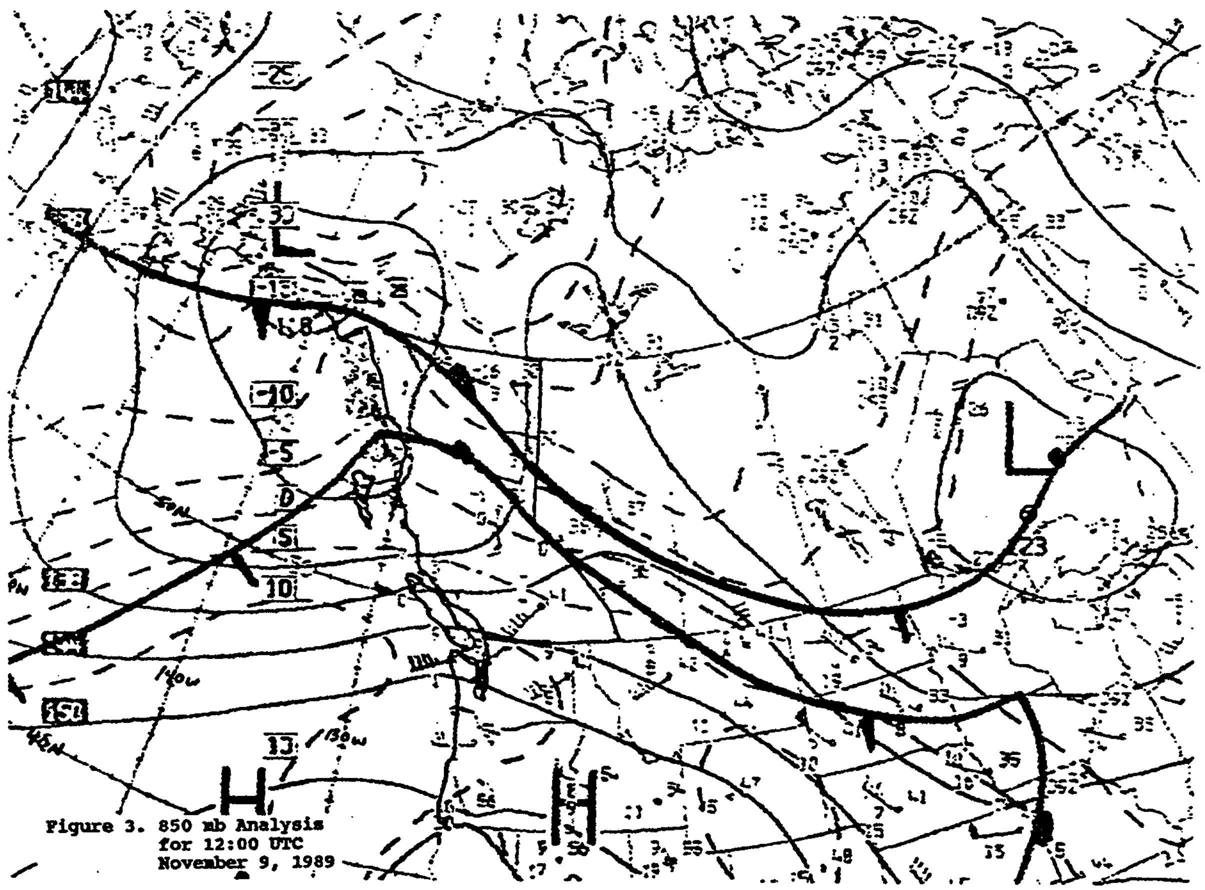

Figure 3. 850 mb Analysis for 12:00 UTC November 9, 1989

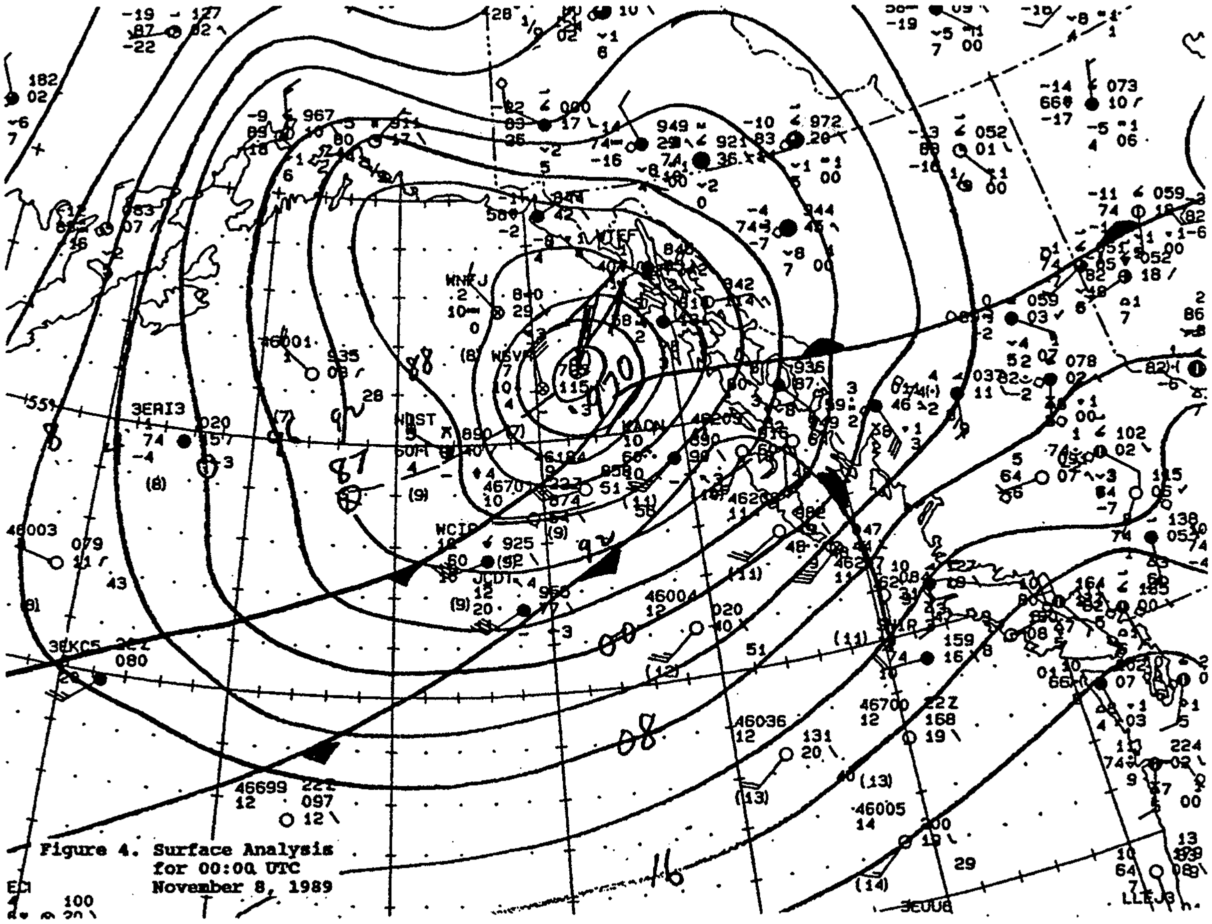

Figure 4. Surface Analysis for 00:00 UTC November 8, 1989

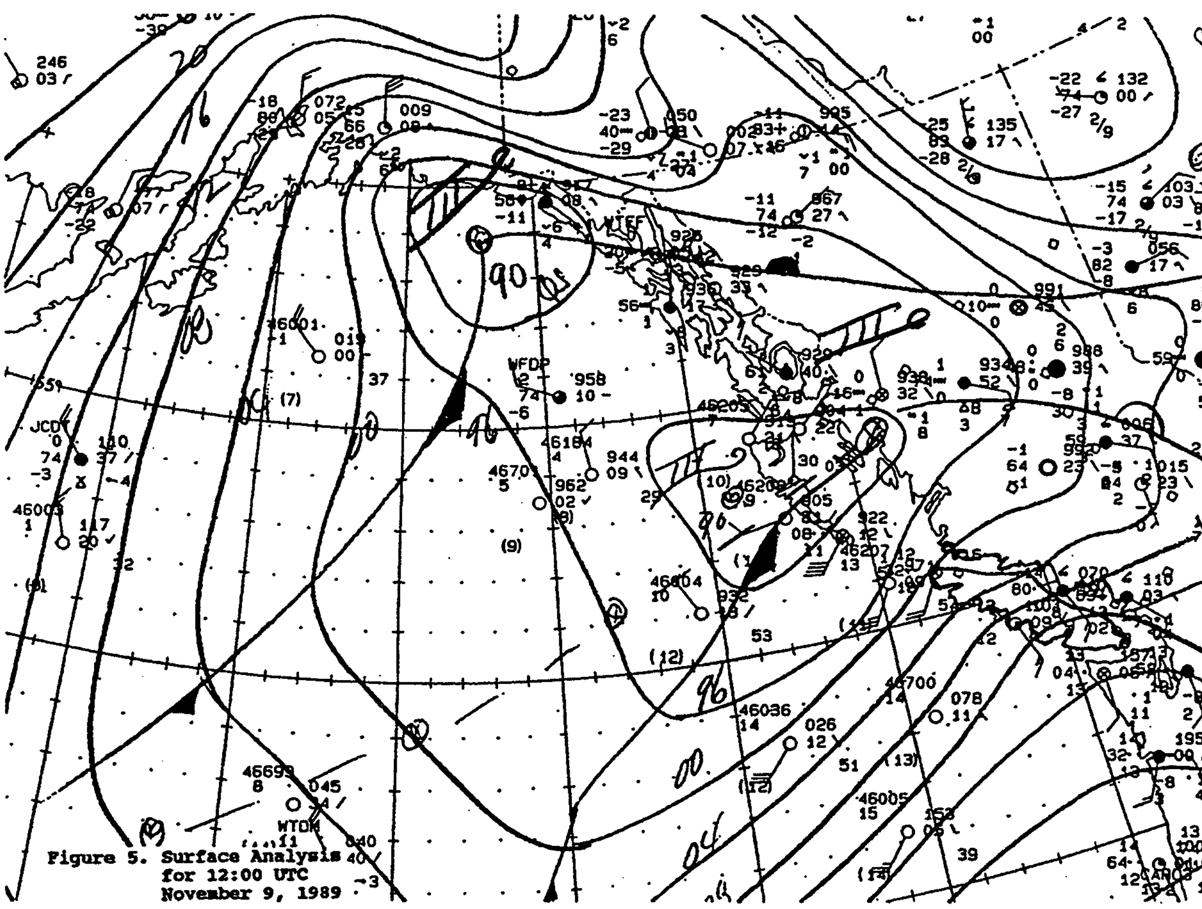

Figure 5. Surface Analysis for 12:00 UTC November 9, 1989

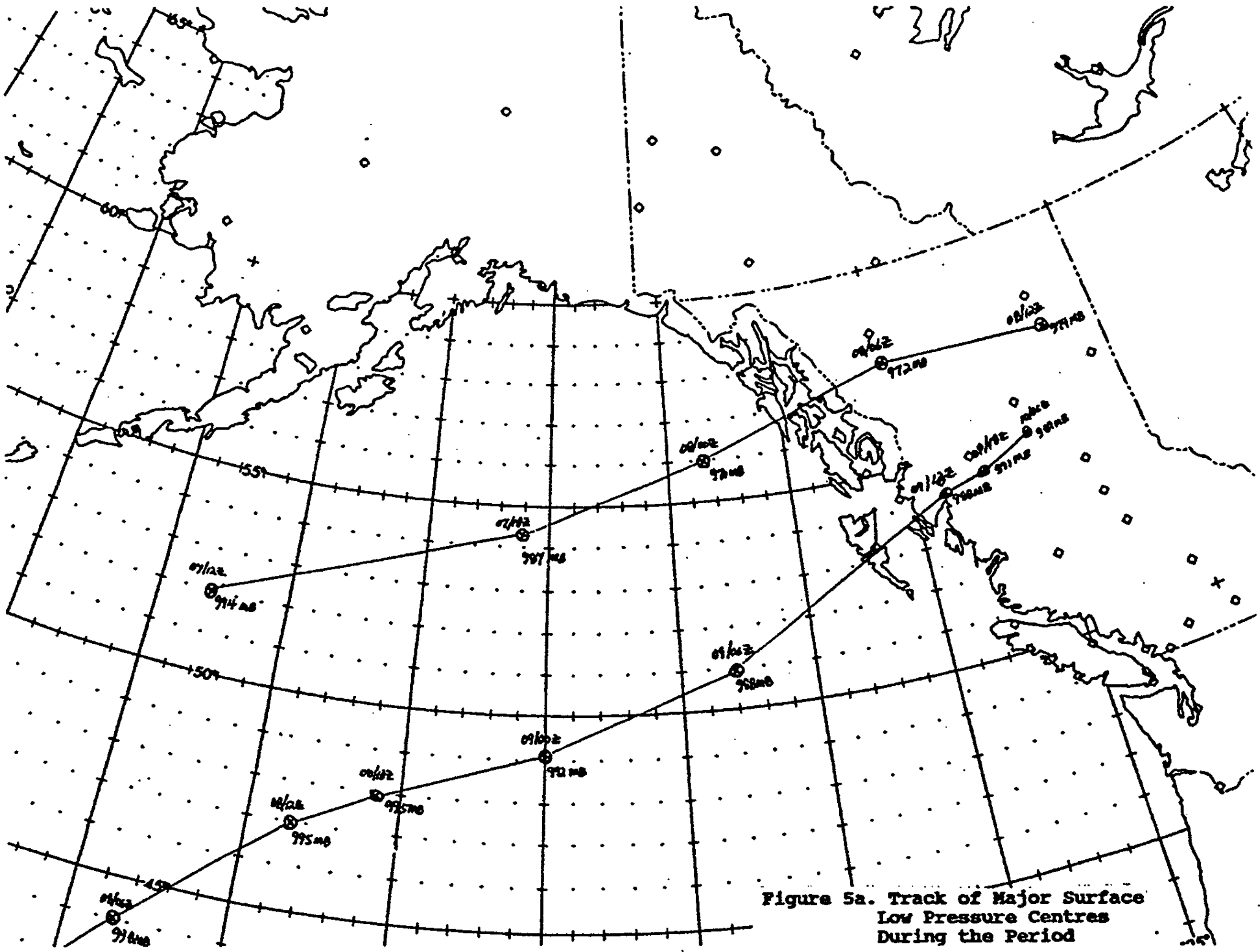

Figure 5a. Track of Major Surface
Low Pressure Centres
During the Period

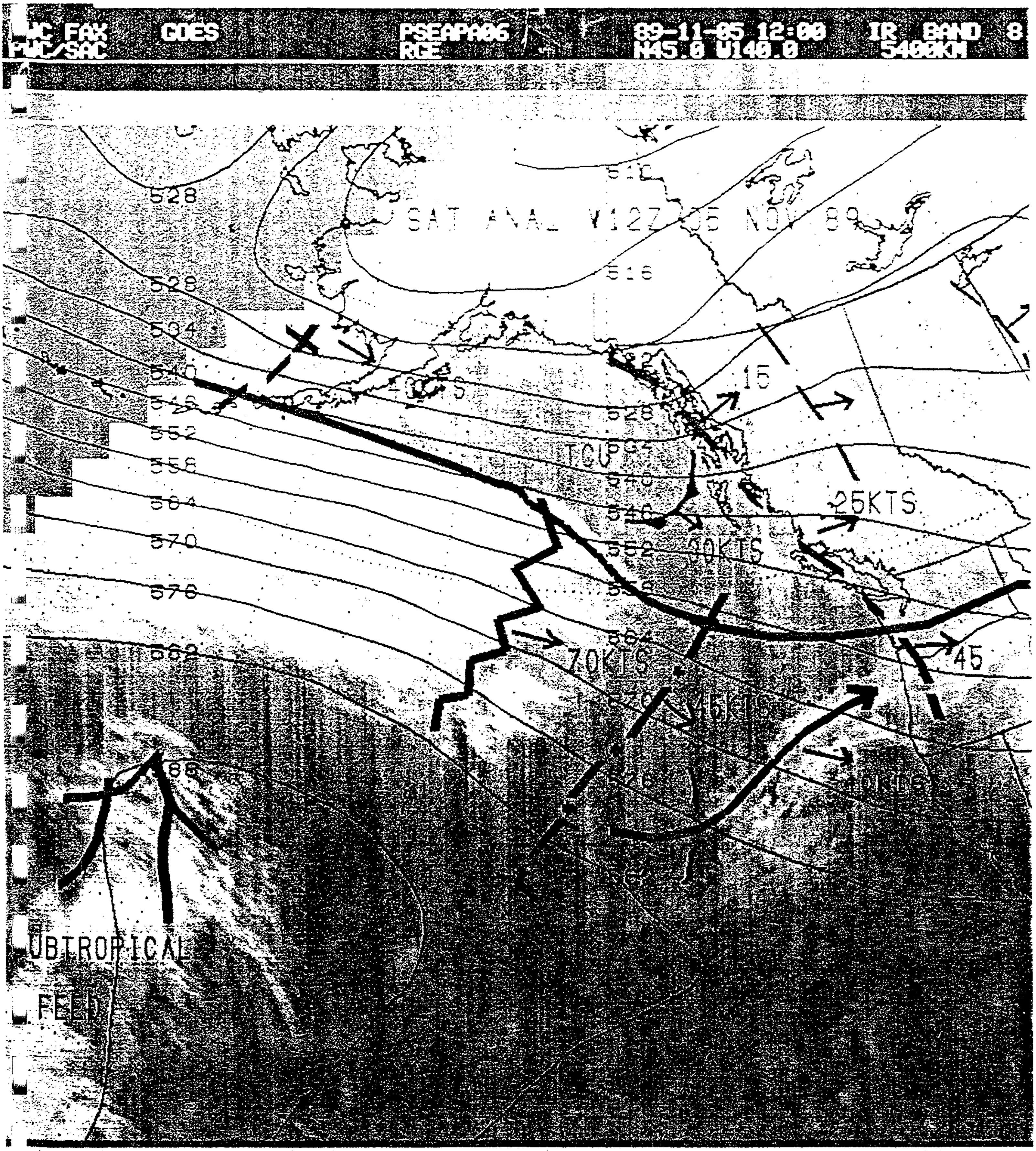

Figure 6. Satellite Image and
Analysis for 12:00 UTC
November 5, 1989

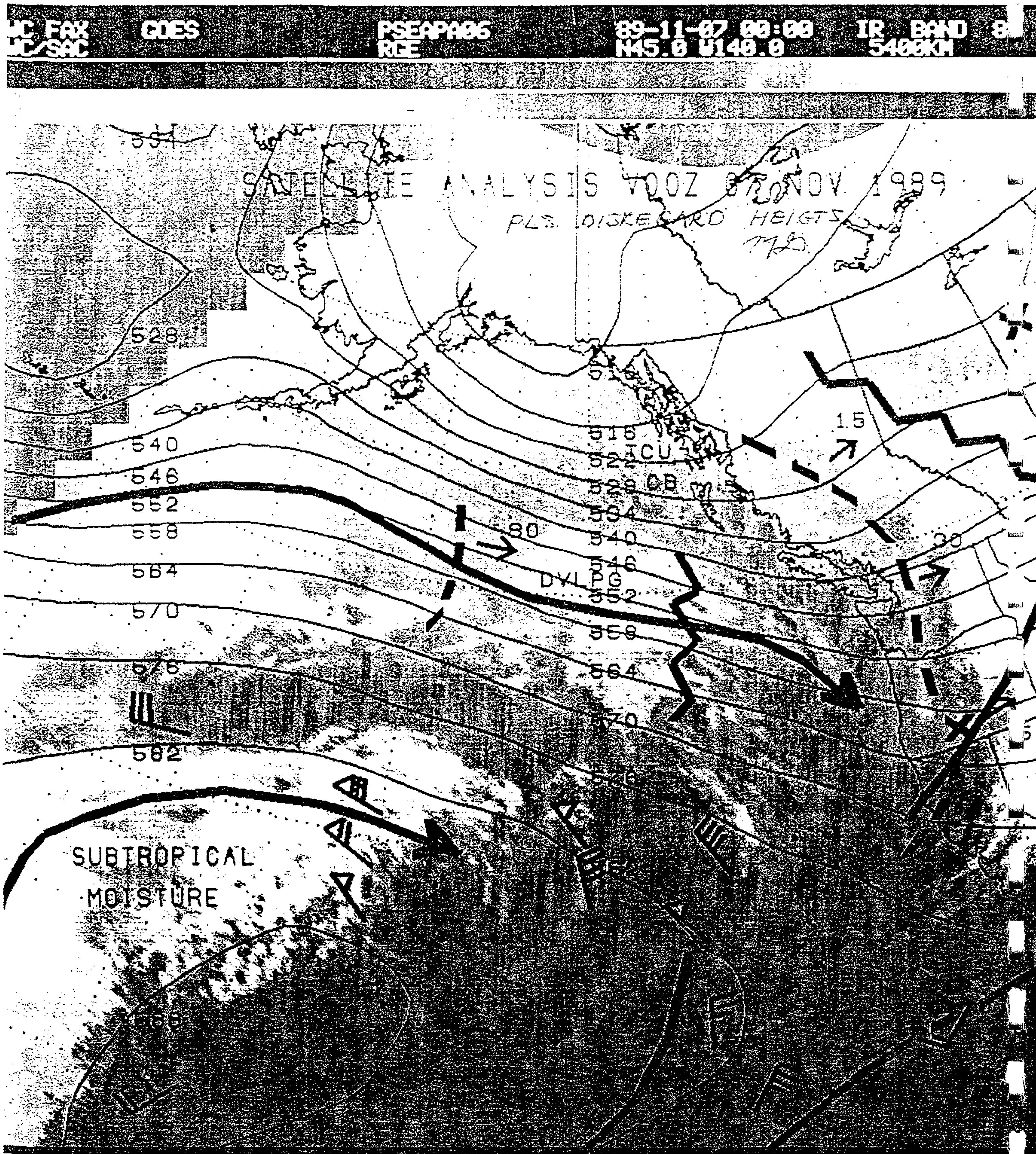

Figure 7. Satellite Image and
Analysis for 00:00 UTC
November 7, 1989

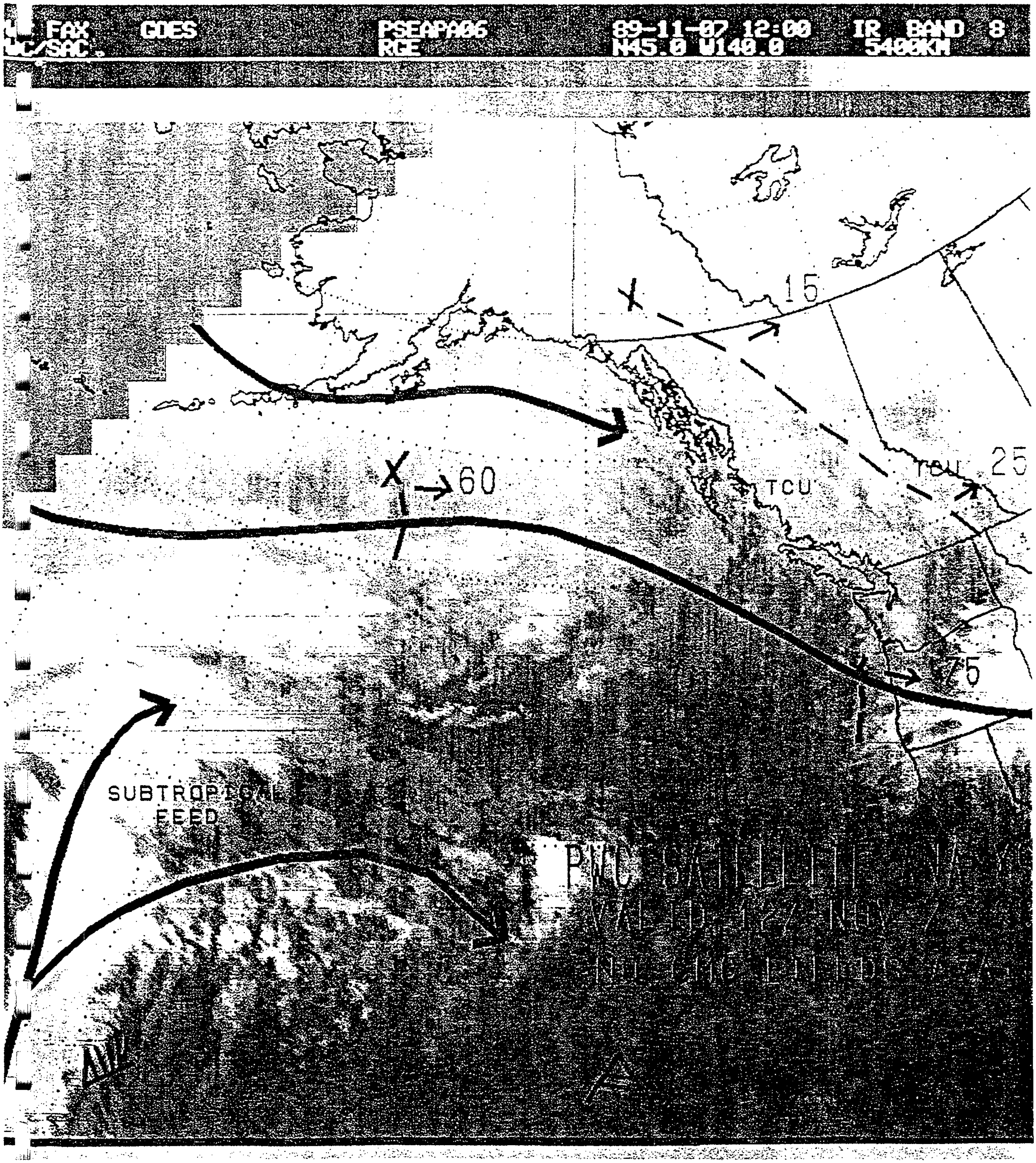

Figure 8. Satellite Image and
Analysis for 12:00 UTC
November 7, 1989

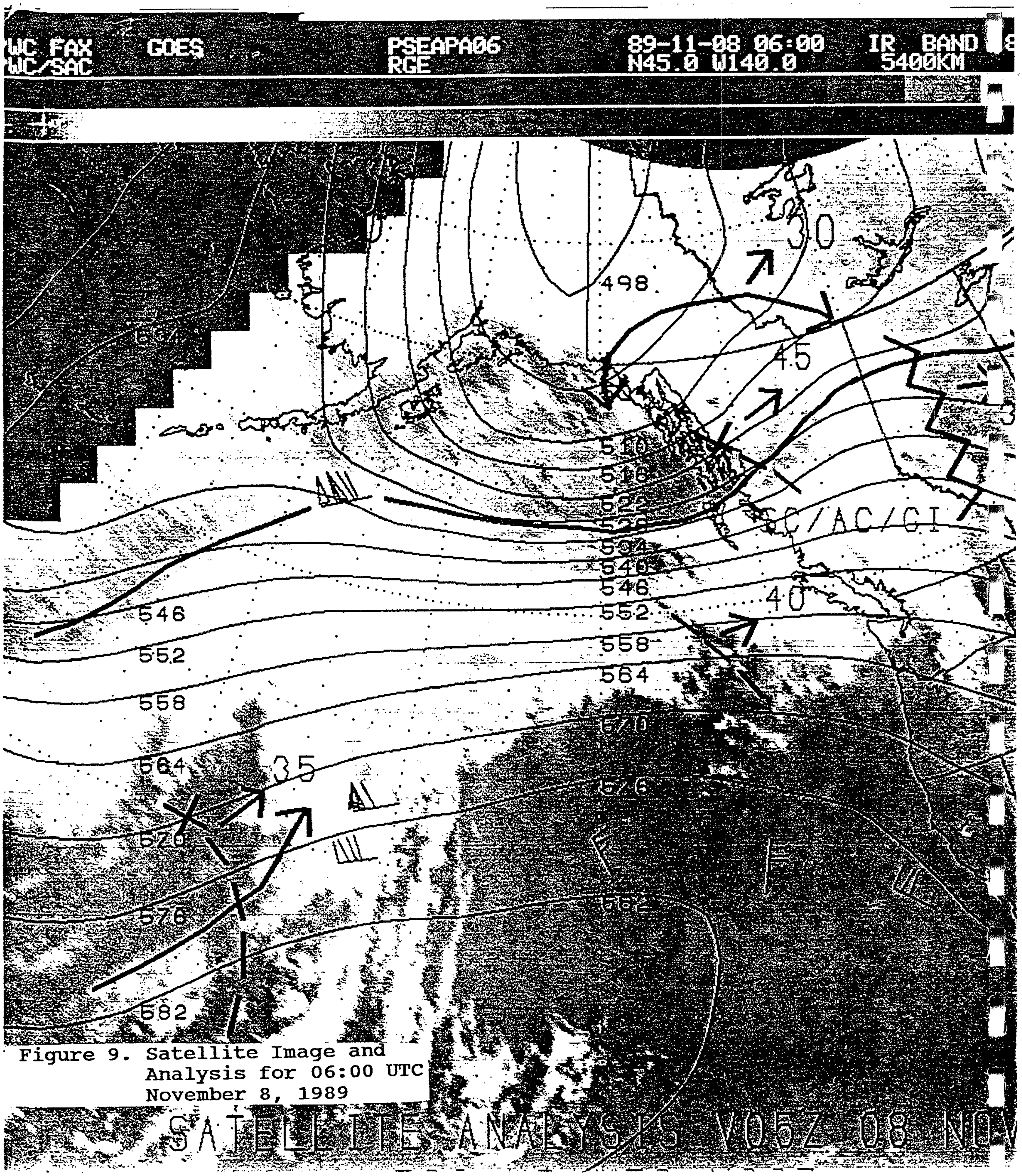

Figure 9. Satellite Image and Analysis for 06:00 UTC November 8, 1989

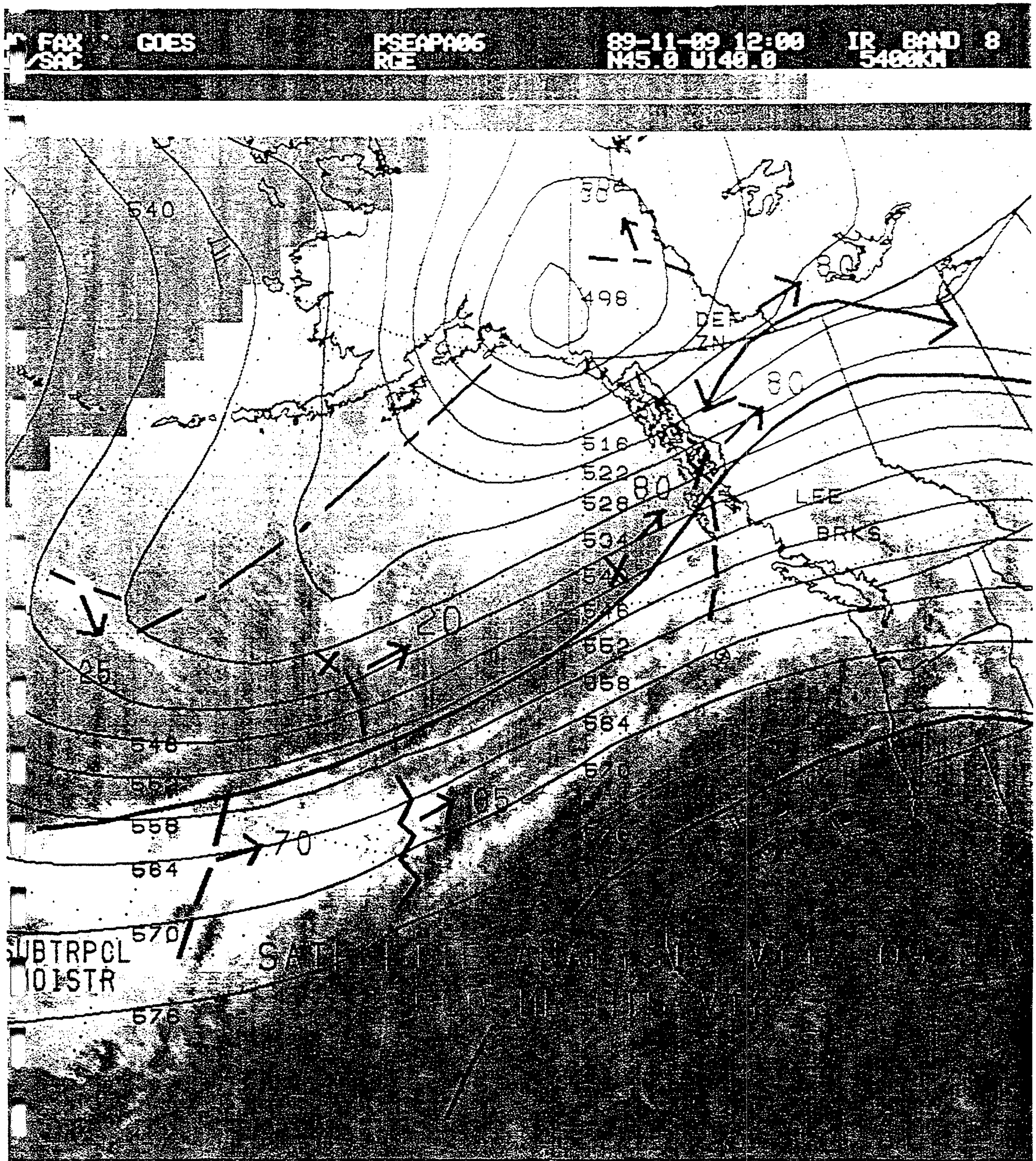

Figure 10. Satellite Image and
Analysis for 12:00 UTC
November 9, 1989

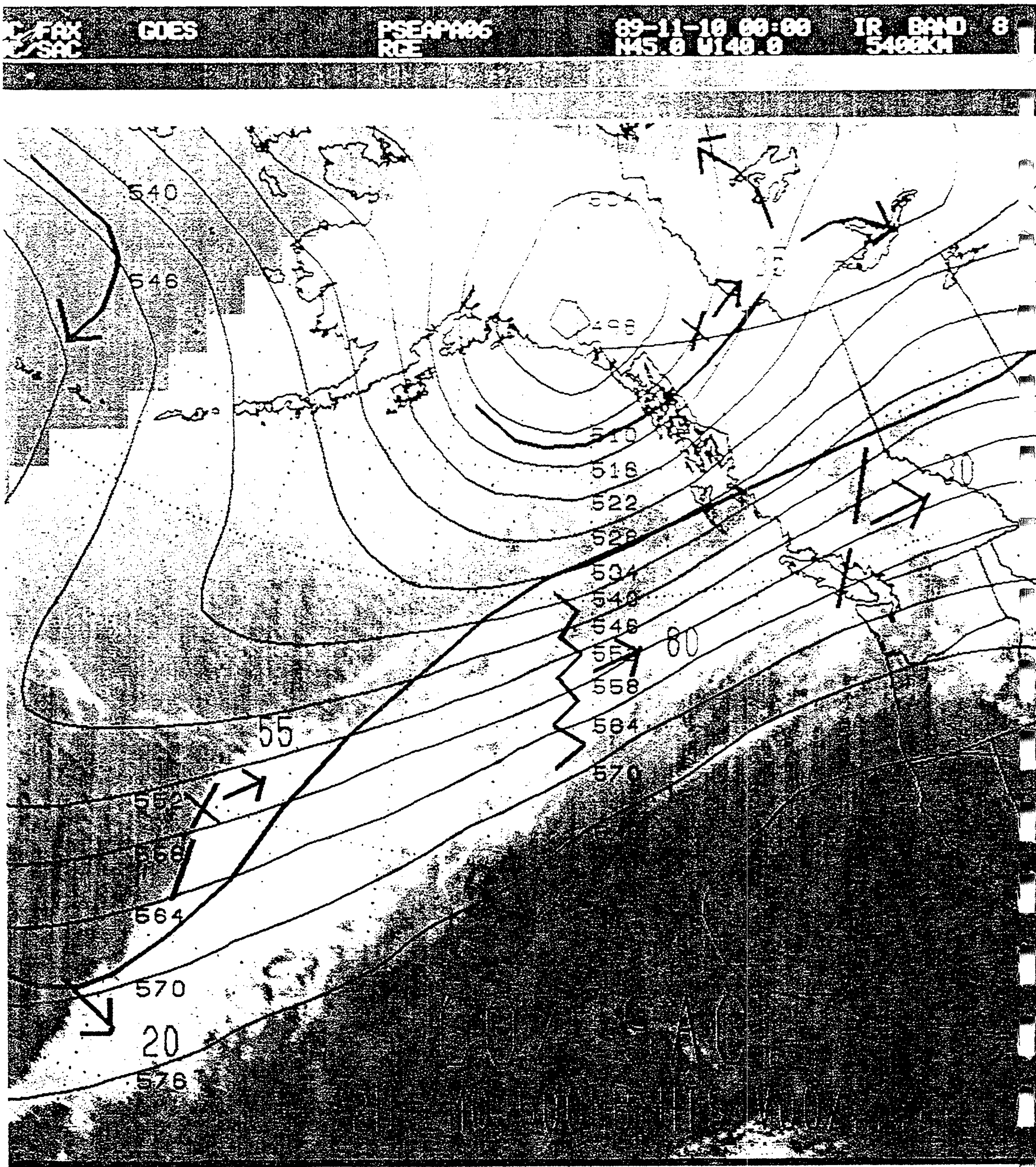

Figure 11. Satellite Image and Analysis for 00:00 UTC November 10, 1989

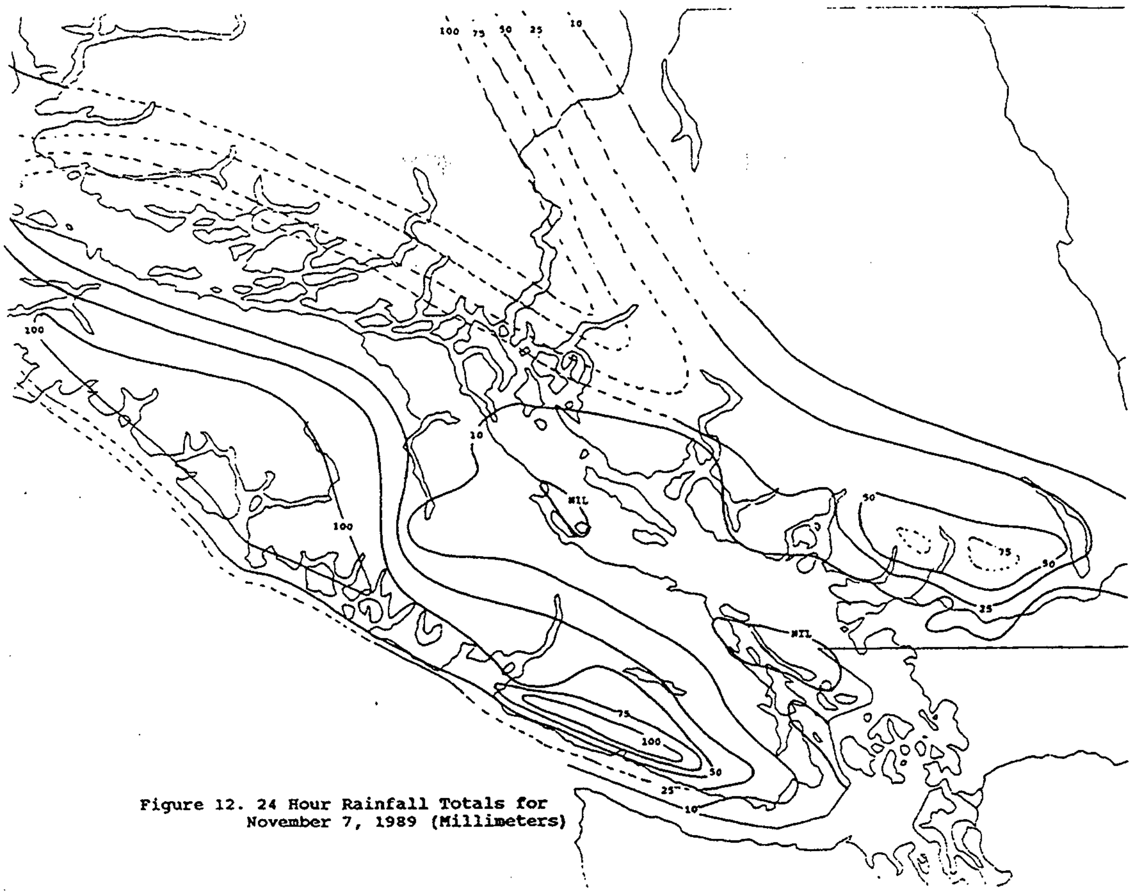

Figure 12. 24 Hour Rainfall Totals for November 7, 1989 (Millimeters)

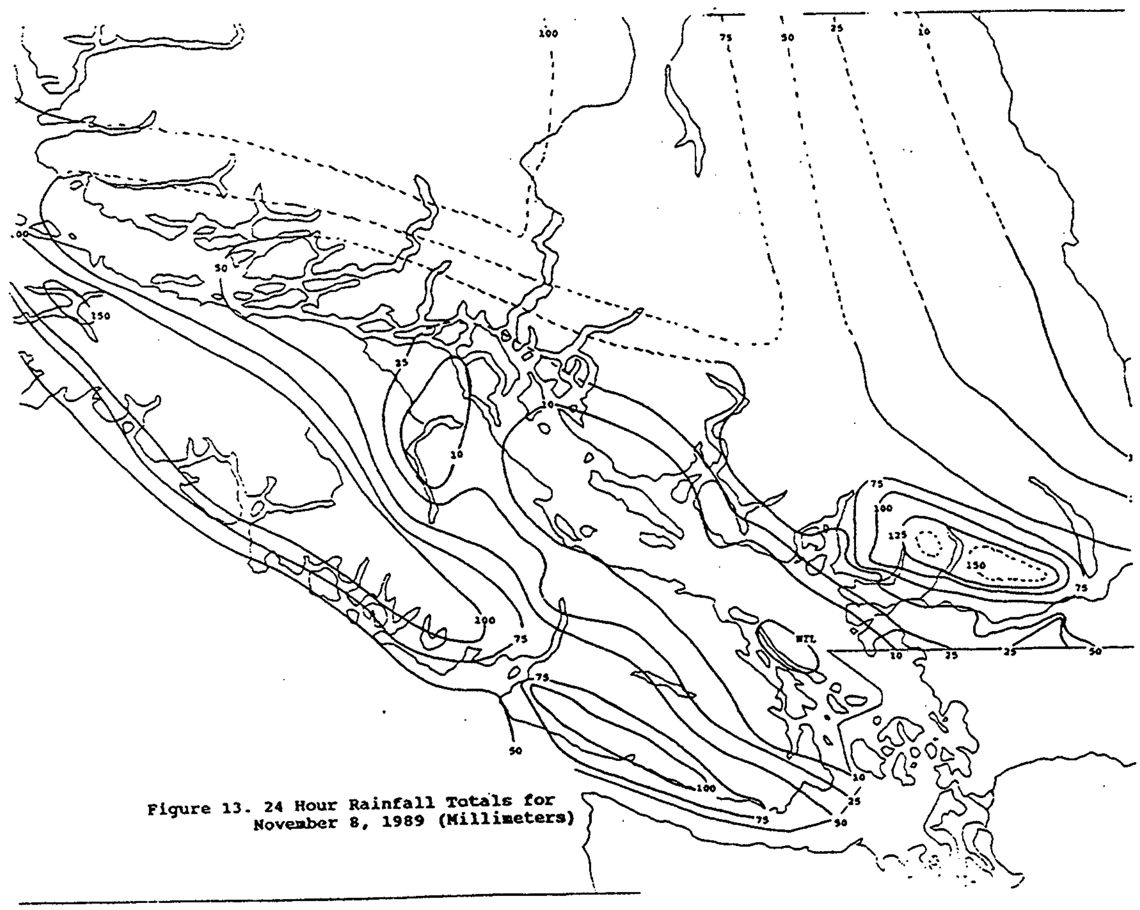

Figure 13. 24 Hour Rainfall Totals for November 8, 1989 (Millimeters)

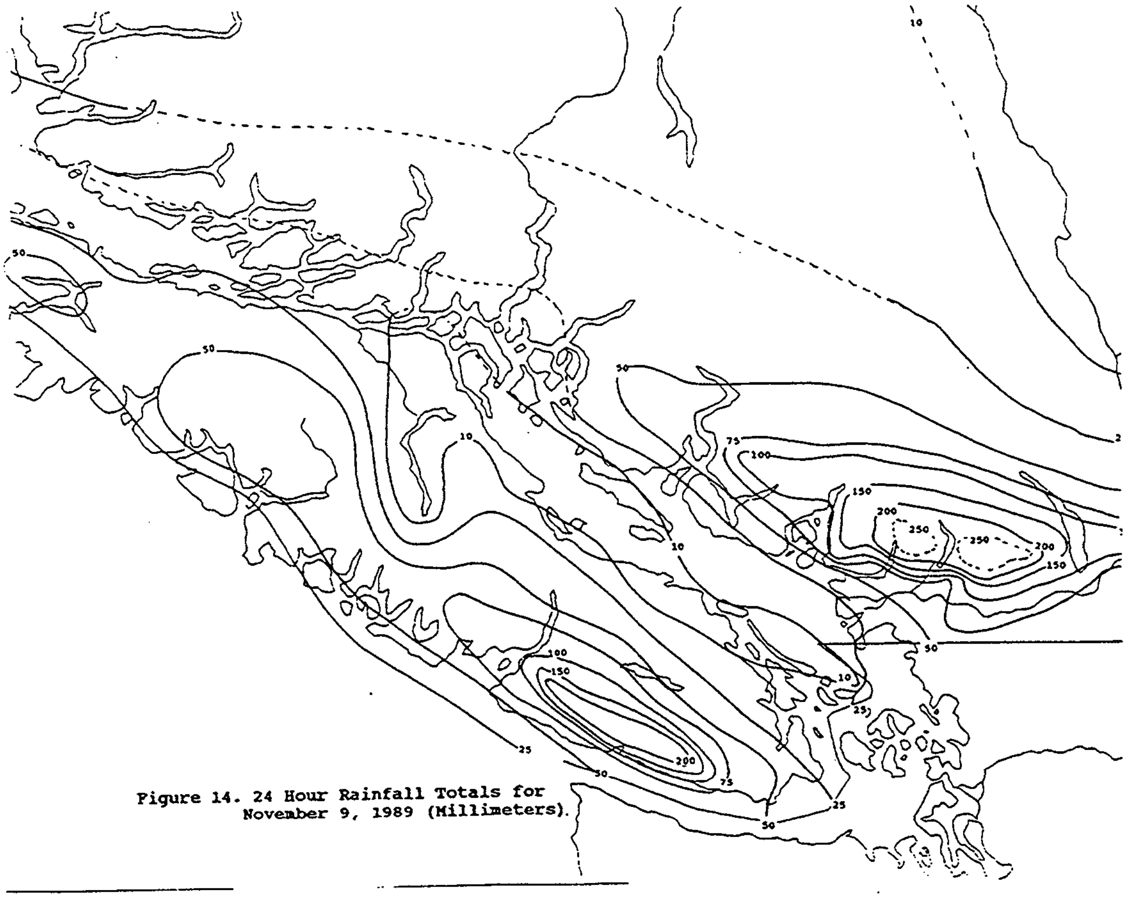

Figure 14. 24 Hour Rainfall Totals for
November 9, 1989 (Millimeters).

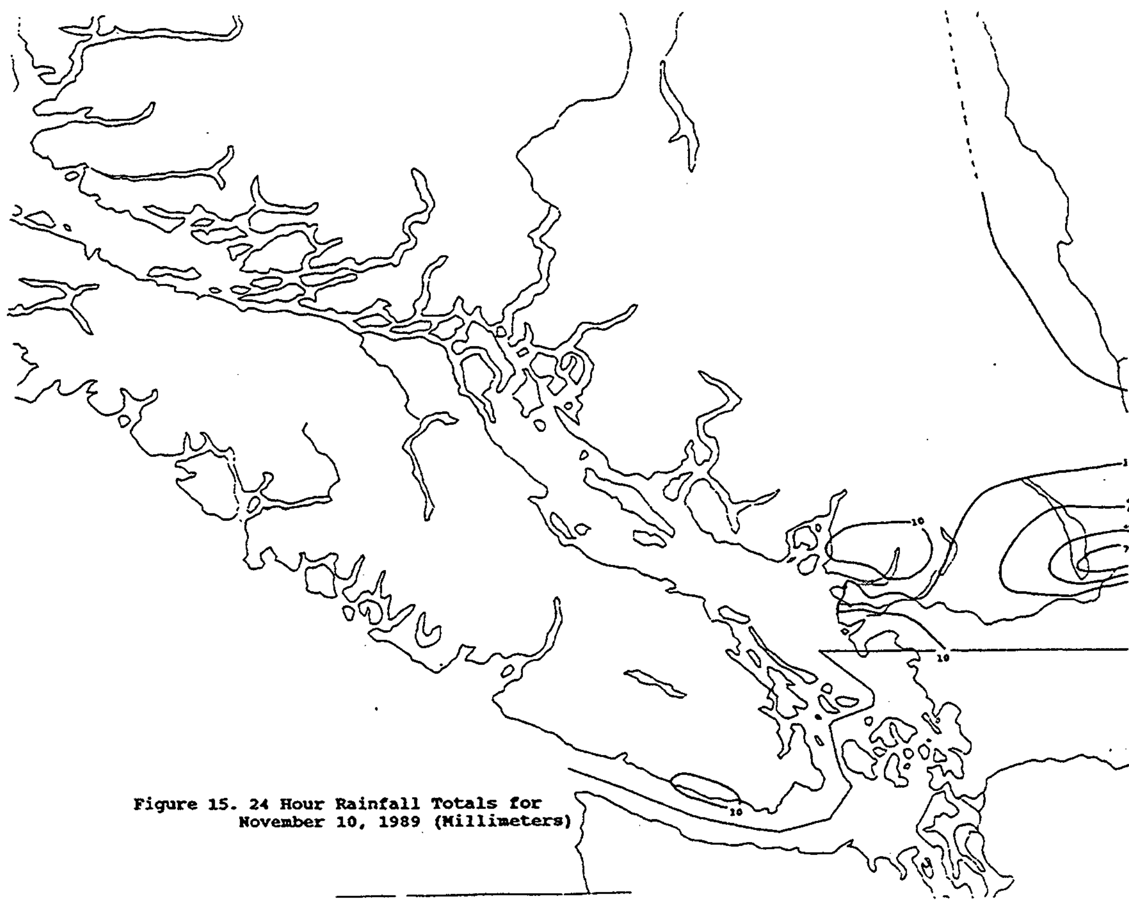

Figure 15. 24 Hour Rainfall Totals for
November 10, 1989 (Millimeters)

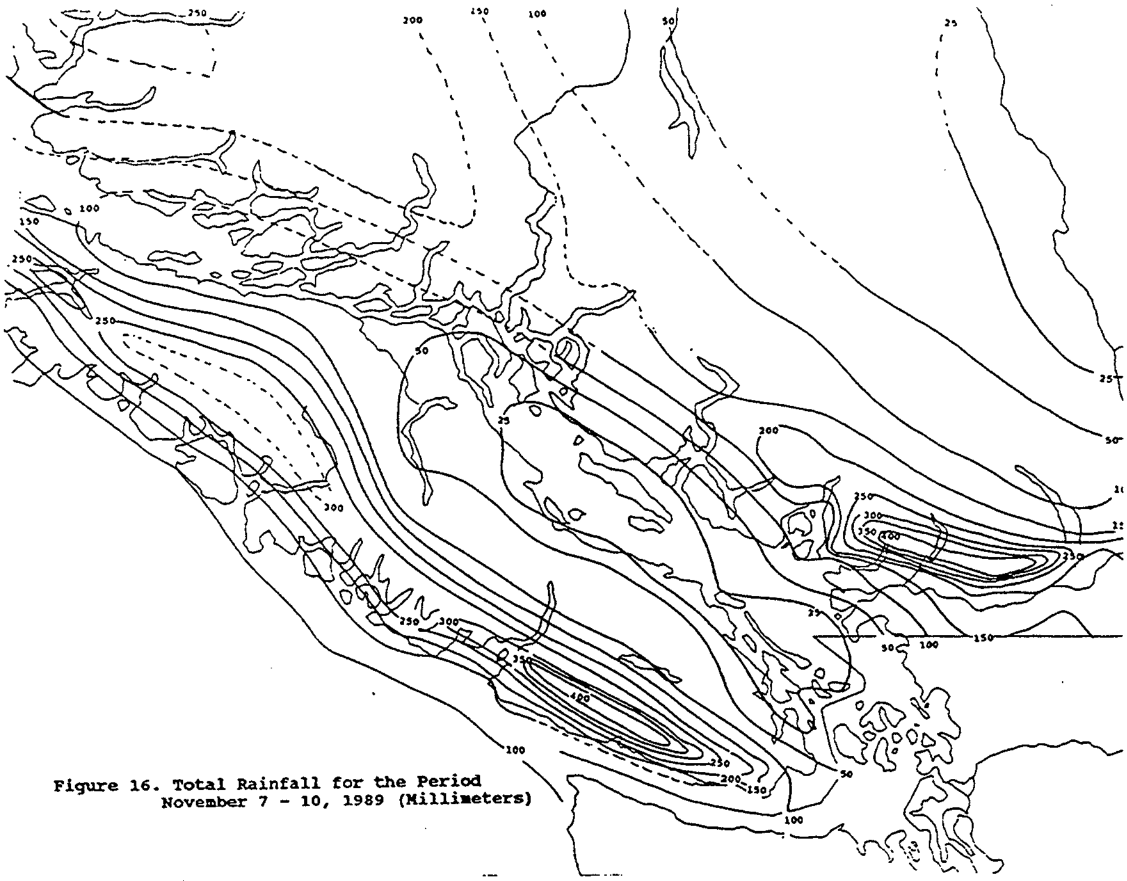

Figure 16. Total Rainfall for the Period November 7 - 10, 1989 (Millimeters)

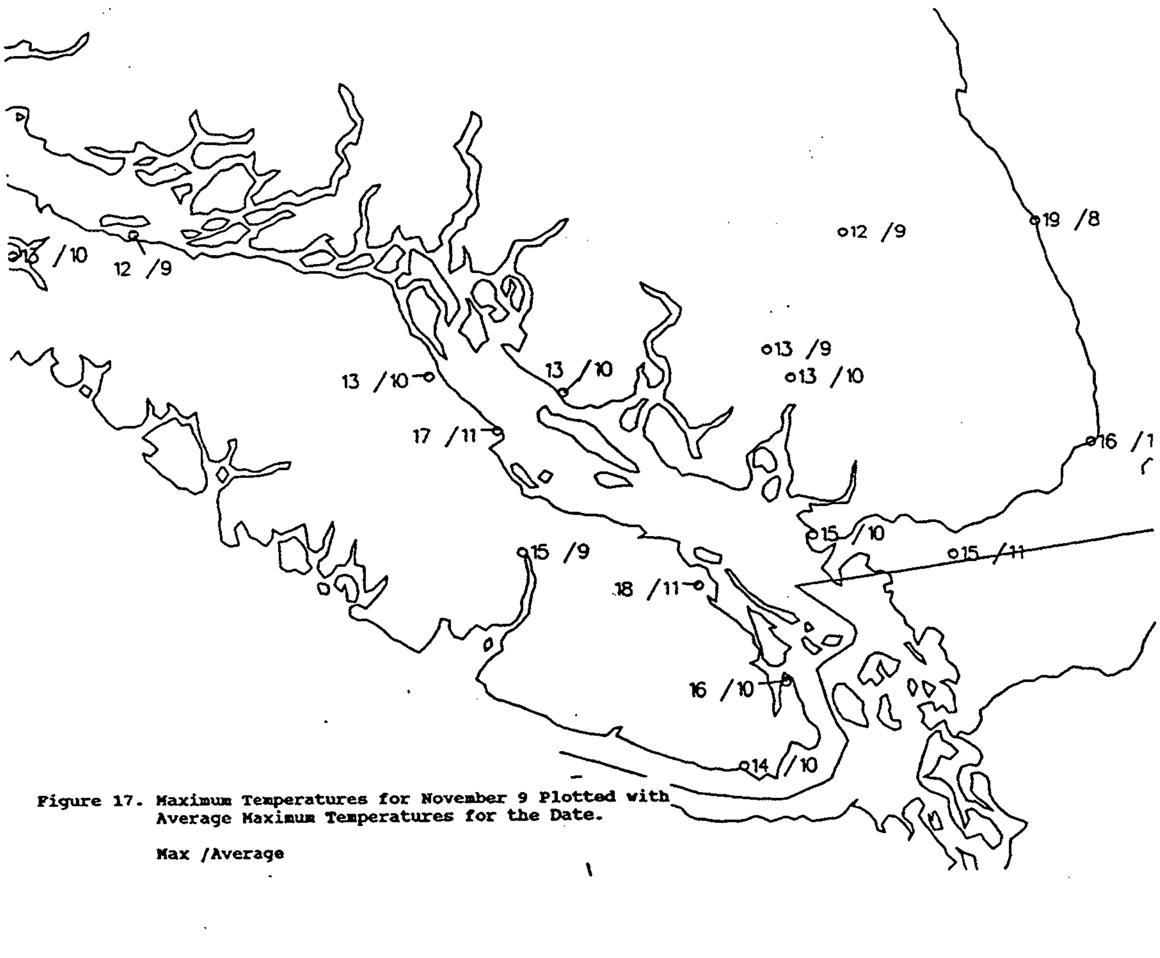

Figure 17. Maximum Temperatures for November 9 Plotted with Average Maximum Temperatures for the Date.

Max /Average

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TABLE I. Summary of 24 hour rainfall amounts (millimeters) for the period November 7 -10 along with totals for the 4-day period.

STATION	NOV 7	NOV 8	NOV 9	NOV 10	TOTAL
ABBOTSFORD A	0.4	39.0	70.8	45.4	155.6
ACTIVE PASS	0.0	6.0	7.4	3.0	16.4
ADENBROOKE ISLAND	101.8	104.4	19.8	6.2	232.2
AGASSIZ	2.8	41.0	84.4	51.4	179.6
AGASSIZ CDA	14.0	53.6	79.2	21.6	168.4
ALBERNI ROBERTSON CREEK	17.0	2.6	45.8	2.0	67.4
ALDERGROVE 48 AVENUE	9.4	45.0	83.0	14.7	152.1
ALERT BAY	2.8	54.0	34.6	2.6	94.0
AMPHITRITE POINT	4.2	75.9	52.4	3.2	135.7
BAMFIELD EAST	80.6	70.0	65.8	0.8	217.2
BELLA COOLA	21.6	41.8	26.4	6.2	96.0
BOWEN ISLAND MILLERS LNDG	10.0	34.0	57.4	7.2	108.6
BRENTWOOD BAY 2	1.9	6.1	12.5	6.1	26.6
BURNABY METROTOWN	7.8	34.3	46.4	10.0	98.5
BURNABY SIMON FRASER U	10.6	70.0	54.0	9.8	144.4
BURQUITLAM VANCOUVER GC	16.0	60.2	65.4	10.9	152.5
CAMPBELL RIVER A	8.4	12.7	8.5	0.6	30.2
CAPE BEAGLE LIGHT	39.0	47.0	36.6	3.2	125.8
CAPE MUDGE	7.6	13.6	9.9	0.6	31.7
CAPE SCOTT	12.7	32.9	15.6	1.5	62.7
CARMANAH POINT	39.2	89.2	60.3	5.6	194.3
CARNATION CREEK CDF	26.8	75.0	98.8	2.8	203.4
CHILLIWACK	6.3	52.0	76.1	19.7	154.1
CHILLIWACK R HATCHERY	3.0	85.8	68.1	21.0	177.9
CHILLIWACK WESTVIEW	7.0	51.0	86.4	24.8	169.2
CLOWHOM FALLS	26.2	60.8	109.2	9.7	205.9
COLWOOD HATLEY DR	18.8	MSG	49.6	4.4	MSG
COMOX A	0.0	7.6	2.2	1.0	10.8
CONUMA RIVER HATCHERY	79.8	139.0	67.6	1.8	288.2
COQUITLAM LAKE DAM	69.0	117.0	232.0	19.0	437.0
COQUITLAM MUNDY PARK	15.1	61.4	48.1	10.2	134.8
CORDOVA BAY SOUTH	2.6	11.8	21.6	7.2	43.2
CORTES ISLAND	12.8	16.8	12.2	0.0	41.8
COURTENAY PUNTLEDGE	6.8	3.6	5.4	0.8	16.6
COURTENAY SANDWICK	5.6	7.1	0.8	0.0	13.5
COWICHAN BAY SE	3.0	3.8	14.2	3.7	24.7
COWICHAN LK FORESTRY	21.4	25.2	47.2	3.4	97.2
COWICHAN LK VILLAGE	19.3	18.1	48.9	1.0	87.3
CULTUS LAKE	5.2	10.8	0.0	0.0	16.0

STATION	NOV 7	NOV 8	NOV 9	NOV 10	TOTAL
DELTA PEBBLE HILL	2.2	5.8	25.2	2.6	35.8
DELTA SUNSHINE HILLS	5.2	22.4	38.2	8.0	73.8
DELTA TSAWASSEN BEACH	0.4	7.0	19.2	9.2	35.8
DENMAN ISLAND	1.8	8.0	12.2	1.2	23.2
DENMAN ISLAND 2	0.4	3.8	11.2	1.0	16.4
DEROCHE	3.8	93.4	89.8	22.8	209.8
DUNCAN BAY	17.8	14.0	8.6	0.5	40.9
DUNCAN KELVIN CREEK	2.0	7.5	14.6	4.2	28.3
DUNCAN LAKE DAM	4.0	28.8	44.5	17.0	94.3
DUNSTER	1.0	12.6	37.2	0.0	50.8
ENTRANCE ISLAND	0.4	1.0	21.9	4.4	27.7
ESQUIMALT METOC	13.2	38.8	38.4	2.4	92.8
ESTEVAN POINT	57.8	46.2	3.6	1.6	109.2
FRASER LAKE NORTH SHORE	0.2	8.0	8.5	0.0	16.7
GABRIOLA ISLAND	0.2	0.6	7.2	4.6	12.6
GALIANO NORTH	0.0	0.0	6.0	5.6	11.6
GAMBIER HARBOUR	17.8	46.6	56.8	0.0	121.2
GANGES MANSELL ROAD	0.4	0.8	10.4	7.0	18.6
GIBSONS	15.0	16.0	36.0	4.0	71.0
GIBSONS GOWER POINT	8.4	15.2	25.7	5.9	55.2
GOLD RIVER TOWNSITE	70.4	106.5	61.0	3.2	241.1
GOLDSTREAM RIVER	0.0	17.1	36.0	3.0	56.1
HANEY EAST	5.4	61.4	73.4	12.0	152.2
HANEY UBC RF ADMIN	27.6	86.0	73.4	11.2	198.2
HARTLEY BAY	31.4	76.8	23.8	4.4	136.4
HATZIC LAKE	17.6	53.4	82.0	19.8	172.8
HOLBERG	64.4	72.2	30.0	1.0	167.6
HOLBERG FIRE DEPT.	64.8	109.0	45.0	1.8	220.6
HOLLYBURN RIDGE	32.6	48.2	133.6	10.4	224.8
HONEYMOON BAY NW	29.0	33.7	57.8	4.0	124.5
HOPE A	13.6	51.9	104.9	93.4	263.8
HOPE SLIDE	9.6	59.2	74.6	22.0	165.4
IOCO REFINERY	7.0	62.0	50.0	8.5	127.5
JERVIS INLET VANC BAY	26.0	61.8	63.4	5.4	156.6
LADNER CREEK	10.1	0.0	96.0	53.7	159.8
LAIDLAW	14.6	53.6	58.7	30.0	156.9
LANGLEY CENTRE	10.6	32.8	58.7	10.4	112.5
LANGLEY RIVER RD	20.2	45.6	78.8	12.0	156.6
LENNARD ISLAND	55.1	68.3	31.2	1.8	156.4
LILLOOET SETON BCHPA	0.0	0.4	5.0	0.0	5.4
LIONS BAY	15.2	35.4	38.0	3.0	91.6

STATION	NOV 7	NOV 8	NOV 9	NOV 10	TOTAL
LIONS BAY 2	11.0	42.4	37.2	11.2	101.8
LITTLE QUALICUM HATCHERY	2.4	18.5	16.5	11.5	48.9
LTL QUALICUM R GANSKE RD	2.6	6.1	15.2	2.6	26.5
LYTTON	0.0	0.0	9.1	0.0	9.1
MALIBU JERVIS INLET	33.5	43.7	42.4	7.2	126.8
MAPLE RIDGE KANAKA CRK	24.0	65.5	93.8	12.2	195.5
MATSQUI ROSS ROAD	15.6	52.6	82.8	14.6	165.6
MAYNE ISLAND	0.0	0.4	12.0	6.4	18.8
MERRY ISLAND	0.4	12.0	17.8	3.0	33.2
METCHOSIN	12.2	65.8	56.9	4.8	139.7
METCHOSIN HAPPY VALLEY	19.8	62.5	62.3	5.3	149.9
MILL BAY 1SW	2.8	3.6	15.6	3.8	25.8
MISSON WEST ABBEY	15.0	51.0	80.0	19.6	165.6
MT WASHINGTON RESORT	10.2	20.0	14.6	1.2	46.0
MYRA CREEK	1.4	50.0	5.0	1.2	57.6
NANAIMO A	0.0	1.4	9.0	2.8	13.2
NANOOSE BAY SOUTH	0.2	1.6	7.2	2.6	11.6
NITINAT RIVER HATCHERY	65.0	70.3	122.3	4.0	261.6
NOOTKA LIGHTSTATION	95.6	103.8	20.6	0.2	220.2
NORTH COWICHAN	3.1	4.4	16.1	3.4	27.0
NORTH PENDER ISLAND	0.4	0.6	15.0	6.4	22.4
N VANCOUVER CLEVELAND	29.0	69.0	106.0	12.0	216.0
N VANCOUVER DOLLARTON	2.5	47.6	44.2	10.0	104.3
N. VANCOUVER GRAND BLVD	29.0	42.0	54.0	8.0	133.0
N. VANCOUVER GROUSE MTN RESORT	67.0	120.0	94.0	10.0	291.0
N VANCOUVER N LONSDALE	61.0	99.0	55.2	6.8	222.0
VANCOUVER 2ND NARROWS	4.8	56.8	48.0	8.4	118.0
N VAN SEYMOUR HATCHERY	39.5	100.4	163.1	13.1	316.1
N VAN SONORA DRIVE	37.8	65.4	105.6	10.8	219.6
N VANCOUVER WHARVES	7.0	35.0	50.0	1.0	93.0
OYSTER RIVER UBC	8.6	9.4	4.0	6.2	28.2
PACHENA POINT	47.6	55.1	47.1	6.2	156.0
PALLANT CREEK	53.6	31.8	6.8	3.2	95.4
PARKSVILLE SOUTH	0.4	0.9	7.8	2.0	11.1
PEMBERTON A	2.5	27.1	31.2	3.0	63.8
PENDER ISLAND	0.4	1.4	19.3	7.0	28.1
PITT MEADOWS STP	14.0	60.8	61.0	10.0	145.8
PITT POLDER	35.5	98.0	115.0	9.0	257.5
POINT ATKINSON	7.2	27.8	41.0	6.6	82.6
PORLIER PASS LIGHT STN	0.0	0.0	5.2	4.3	9.5
PORT ALBERNI A	13.0	9.6	31.4	2.4	56.4

STATION	NOV 7	NOV 8	NOV 9	NOV 10	TOTAL
PORT ALICE	66.8	134.0	39.4	2.2	242.4
PORT COQUITLAM	22.7	72.2	63.9	9.0	167.8
PORT HARDY A	9.2	58.8	16.0	0.6	84.6
PORT MOODY GLENAYRE	18.7	36.6	75.1	9.2	139.6
PORT RENFREW	101.6	123.6	212.0	3.8	441.0
POWELL RIVER A	4.0	6.6	11.4	2.8	24.8
POWELL RIVER GRIEF POINT	4.0	5.8	3.0	2.6	15.4
PRINCETON A	0.0	0.6	0.0	0.8	1.4
QUALICUM R FISH RESEARCH	5.8	14.2	20.4	1.8	42.2
QUATSINO	67.8	161.6	52.6	0.6	282.6
QUATSINO LIGHTSTATION	42.8	49.2	11.6	1.2	104.8
QUINSAM RIVER HATCHERY	15.0	13.2	6.6	0.4	35.2
RACE ROCKS LIGHTSTATION	5.1	57.6	42.8	6.2	111.7
RICHMOND NATURE PARK	4.4	16.8	28.4	8.4	58.0
SALT SPRING ISL CUSHEON LAKE	0.4	2.6	14.0	6.0	23.0
SARDIS	3.4	58.6	60.2	13.3	135.5
SATURNA ISLAND LIGHTSTATION	0.8	0.8	26.6	8.4	36.6
SAYWARD BIG TREE CREEK	22.6	26.1	10.3	0.0	59.0
SECHELT 5W	11.6	7.9	14.0	11.0	44.5
SEYMOUR ARM	2.8	15.8	8.2	2.8	29.6
SEYMOUR FALLS	52.5	100.2	202.8	10.6	366.1
SHAWNIGAN LAKE	2.6	7.6	26.2	3.6	40.0
SOOKE	20.8	82.8	66.6	6.2	176.4
SQUAMISH A	28.4	60.1	108.7	1.2	198.4
SQUAMISH STP	34.0	72.6	102.2	4.4	213.2
SQUAMISH UPPER	29.7	60.6	70.4	5.4	166.1
STAVE FALLS	38.2	97.0	115.0	19.0	269.2
STAVE LK SEVENTYNINE CREEK	62.0	145.0	210.5	20.5	438.0
STEVESTON	3.0	9.7	15.6	7.2	35.5
STUIE TWEEDSMUIR LODGE	11.8	45.4	22.6	0.8	80.6
SUMAS CANAL	8.7	58.1	77.1	20.3	164.2
SURREY GUILFORD	8.2	48.0	57.0	10.4	123.6
SURREY KWANTLEN PARK	8.2	43.4	50.8	11.6	114.0
SURREY MUNICIPAL HALL	5.8	27.0	47.2	8.6	88.6
SURREY NEWTON	3.5	26.0	42.0	9.2	80.7
TAHSIS VILLAGE N	90.9	13.8	163.8	2.2	270.7
TAHSIS WMB	5.0	97.0	MSG	MSG	347.0
TEXADA ISLAND A	2.0	4.0	5.0	2.0	13.0
TOFINO A	68.4	85.8	44.0	2.8	201.0
UCLUELET KENNEDY CAMP	55.8	69.1	44.0	2.8	171.7
UPPER CAMPBELL LAKE	23.6	6.7	8.1	0.0	38.4

STATION	NOV 7	NOV 8	NOV 9	NOV 10	TOTAL
VANCOUVER HARBOUR	0.2	37.2	44.2	12.8	94.4
VANCOUVER INTL A	0.2	15.4	19.6	15.0	50.2
VANCOUVER KITSILANO	4.8	33.8	35.4	0.0	74.0
VANCOUVER UBC	6.4	22.0	25.4	7.4	61.2
VICTORIA FRANCIS PARK	5.2	28.5	31.8	5.9	71.4
VICTORIA HOLLAND 2	3.5	21.1	27.6	5.6	57.8
VICTORIA INTERNATIONAL A	0.0	1.2	10.8	6.8	18.8
VICTORIA MARINE RADIO	3.1	61.3	56.0	27.5	147.9
VICTORIA PHYLLIS STREET	1.0	22.0	23.8	8.4	55.2
VICTORIA PRINCESS AVENUE	6.2	29.5	30.2	8.4	74.3
VICTORIA SHELBOURNE	5.0	16.2	23.0	7.2	51.4
W VAN CAPILANO GCC	19.1	66.6	92.2	8.7	186.6
W VANC CYPRESS PARK	8.2	31.2	51.6	14.8	105.8
W VANC MILLSTREAM	35.0	53.9	120.3	9.5	218.7
WHALLEY FOREST NURSERY	8.1	39.0	52.8	10.4	110.3
WHISTLER	7.8	31.4	43.7	4.8	87.7
WHITE ROCK OCEAN PARK	5.2	17.4	45.4	9.0	77.0
WILLIAM HEAD	10.2	58.2	43.9	9.2	121.5
WOODFIBRE	24.4	71.4	106.6	0.0	202.4
YALE	10.6	33.2	66.0	30.0	139.8

TABLE II. A priori return period (years) for 1 to 4 day precipitation events that give amounts consistent with those observed during November 7-10, 1989.

STATION	RETURN PERIOD (years) 1-DAY	2-DAY	3-DAY	4-DAY
Vancouver Airport	1	1	1	1
North Vancouver Cleveland Dam	7	15	11	7
Coquitlam Lake Dam	89	48	36	19
Whistler/Alta Lake	1	2	2	1
Seymour Falls	11	11	9	6
Squamish	14	9	7	4
Abbotsford	5	9	22	21
Chilliwack	3	6	5	4
Hope	8	23	33	21
Port Alberni	1	1	1	1
Victoria Airport	1	1	1	1

TABLE III. Ten highest rainfall amounts recorded in British Columbia on any one observation day.

STATION	DATE	AMOUNT (millimeters)
Ucleulet Brynnor Mines	Oct 06, 1967	489.2
Henderson Lake	Dec 30, 1926	421.9
Bear Creek	Sep 12, 1956	363.0
Port Mellon	Nov 15, 1983	327.6
McInnes Island	Jan 26, 1984	319.0
Kennedy Lake	Nov 12, 1924	316.2
Seymour Falls	Jan 14, 1961	314.2
Swanson Bay	Nov 17, 1917	269.2
Capilano Intake	Nov 30, 1949	256.5
Tahsis	Oct 30, 1981	245.2