AN ABSTRACT THESIS OF

ROBERT RUSSELL QUINN for the degree of DOCTOR OF PHILOSOPHY
(Name of Student) (Degree)

in Geography presented on Aug. 16, 1976
(Major Department) (Date)

Title: THE LATE SPRING SECONDARY PRECIPITATION MAXIMUM IN THE INTERIOR PACIFIC NORTHWEST

Redacted for Privacy

Abstract approved: James F. Lahey

The Late Spring Secondary Precipitation Maximum in the Interior Pacific Northwest results from a complex system of climatic controls. The Secondary Maximum is most strongly developed over the high plateau of Oregon immediately in the lee of the Cascade Mountains. Local topographic organization exerts strong control over the magnitude and timing of the secondary maximum in the intermontane region. There is a detectable poleward shift of the precipitation maximum in the interior Northwest from April to June.

A synoptic precipitation climatology was developed for the Pacific Northwest for the months of February to July. Surface and 500 millibar circulation maps indicate reorganization of atmospheric flow from strongly zonal flow in midwinter to more highly meridional

flow in May and June. Precipitation producing synoptic disturbances manifest a decided evolution from those dominated by warm advection in winter to those dominated by strong, cool advection in May and June. Spokane radiosonde data indicate that increased destabilization of the atmosphere accompanied by increased precipitable moisture is primarily responsible for the increase in average rainfall in May and June. The Secondary Precipitation Maximum is characterized by an increase in precipitation intensity, but is not accompanied by an increase in precipitation frequency. A case history of an early and late spring precipitation producing synoptic sequence is presented.

Seasonal changes in precipitation intensity west and east of the Cascades must be related to corresponding changes in the sensible and latent heat budget of the region. Average monthly equivalent potential temperature data indicate pronounced reorganization of the surface temperature field west and east of the Cascades during the period of February to July. Large sensible and latent heat additions occur east of the Cascades in May and June and should be effective in destabilizing maritime polar air masses moving across the interior.

The Late Spring Secondary Precipitation Maximum in the Interior Pacific Northwest

by

Robert Quinn

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

June 1977

APPROVED:

Redacted for Privacy

Professor of Geography, in charge of major

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Date thesis is presented Aug. 16, 1976

Typed by Lynne Bjork and Sally Quinn for Robert Russell Quinn

ACKNOWLEDGMENTS

The author expresses his thanks to the many individuals who offered their time and expertise during the research and writing of this study.

In the early phases of the study, Bill Wantz provided access to climatological data under the jurisdiction of the Bonneville Power Administration. Thanks is expressed to Jim Sasser for assisting in the statistical portion of the study.

I wish to express special thanks to the members of my committee. Dr. Robert Frenkel's guidance was most appreciated in the early conceptualization of the thesis problem. Dr. Henry Froenlich is thanked for his time in reviewing the first draft of the study, and Dr. Richard Highsmith for his supervision and assistance concerning the geographic scope of the study.

An enormous debt of gratitude is owed to Dr. James Lahey, the Chairman, for his meteorological knowledge, moral support and very special friendship. I wish also to thank Dr. Bill Quinn for taking on the role of the graduate representative at such a late date. I wish that special thanks be given to Carol Bellinger for her excellent cartographic work and to Lynne Bjork for her efficient typing.

Last, I wish to offer very special thanks to my wife, Sally, for her typing and editing efforts and for giving me the support to persevere.

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Chapter I

INTRODUCTORY STATEMENT

A. Rationale

In the Pacific Northwest the Cascade Mountain Range separates the humid mesothermal climates of the western portion from the dry and humid microthermal climates of the intermontane region to the east. Both regions exhibit similar annual precipitation regimes characterized by mid-winter maximums and summer drought (Trewartha, 1968, p. 316-318; Kerr, 1951, p. 28-29). The dominance of cyclonic storms in the winter months and the dry subsiding northeastern limb of the subtropical high in summer account for the strong seasonal variation of precipitation.

In the seasonal transition period of spring and early summer, significant differences in the organization of the precipitation regimes between the interior intermontane and the region west of the Cascades become apparent. The regional differences are reflected in mean monthly precipitation statistics with virtually all stations west of the Cascade crest indicating systematic decreased in precipitation from midwinter maximums through the spring months to midsummer minimums in July (Philips, 1948, p. 144). In contrast, stations east of the Cascade crest decrease from midwinter maximums through the months of February, March and April and then typically record increases in precipitation in May and (or) June.

The secondary spring maximum of the Pacific Northwest Interior has been identified by John C. Sherman (1947, p. 66-72) and Glen T. Trewartha (1962, p. 275-278). Using 1910-1940 as a normal period, Sherman presented isohyetal maps for each month of the year for eastern Washington. Many stations within the region exhibited increasing monthly precipitation means in May and June, and Sherman inferred that this phenomenon was due to increased frequency of thunderstorms. Trewartha treated the Pacific Northwest Interior as a precipitation subtype (2C), and indicated that the secondary maximum was the result of surface low pressure and the formation of a 500 millibar trough over the region in May and June.

The regional integrity of the secondary maximum of the Pacific Northwest Interior is also verified by the work of Bryson and Horn (1960, p. 157-171). The authors analyzed precipitation using the method of harmonic analysis. The harmonics represent the contribution of the annual, biannual, and triannual variation in yearly rainfall. Figure 3 in Bryson and Horn is the ratio of the second harmonic to the first harmonic (biannual/annual), and the large contribution of the biannual term in the interior of the Pacific Northwest is quite evident (Fig. 1 in Appendix). Only a few Northwest stations were analyzed by Bryson and Horn; consequently detailed regional characteristics could not be ascertained.

Rudd noted the inadequacy of utilizing the climatic classification scheme of Koppen for Oregon (Rudd, 1959, p. 31-38; Koppen and Geiger, 1931, p. 195). Utilizing the winter maximum formula of

Koppen, much of eastern Oregon falls within the classification of a humid microthermal climate. Rudd questioned the validity of most of eastern Oregon being classified as humid and suggested the use of the even distribution rainfall formula of Koppen, noting that the biannual nature of the rainfall regime supported this modification. Rudd noted that some eastern Oregon stations actually indicated a primary maximum in May and June and that a relative three-month breakdown of seasons indicated: 28% of the annual precipitation in January, February, and March; 28% in April, May and June; 13% in July, August, and September. Rudd did not investigate the origin or regional extent of the May-June secondary maximum.

The secondary late spring maximum of precipitation of the Pacific Northwest Interior is particularly unique in that virtually all cyclonic disturbances are Pacific in origin, moving from southwest (west) to northeast (east) across the region (Klein, 1957, p. 145-169). This meteorological fact would indicate that the secondary maximum of the interior is a consequence of physical processes operating within the region itself, coupled with seasonal changes occurring upwind to the west. The physical processes of the interior are operating on meteorological disturbances moving eastward across this region, causing an increased precipitation yield in the interior in contrast to decreasing yields west of the Cascades.

B. Precipitation Climatology and Mean Value Analysis

The traditional view of climate classification focuses on the analysis of mean monthly values of climatological parameters. The commonly utilized classification systems of Koppen (1931), Trewartha (1965, p. 223-238), and Thornthwaithe (1931, p. 633-655), are all based on monthly means derived from a significant period of record (at least 30 years). While long term mean values are quite useful in delineating broad regional groupings which may correspond to slow response indicators (natural vegetation, landforms and soil types), the system is inadequate when analysis is confined to smaller regions and to temporal characteristics of meteorological parameters. This inadequacy is especially acute with respect to precipitation climatology.

Precipitation is a descrete event that is associated with a particular atmospheric circulation pattern. In arid, semi-arid, and even most humid mesothermal climates, precipitation events (days) are outnumbered by non-precipitation events (days)/ The analysis of meteorological parameters derived from mean values will describe only minimally the controls and atmospheric kinematics that are producing the precipitation even since non-precipitation events contribute the majority of the input to the mean climatology. This problem is especially significant in arid and semiarid climates.

Hence, it is doubtful that examination of mean monthly circulation maps will elucidate the meteorological processes which are producing the increased springtime precipitation of the interior of the Pacific Northwest. The precipitation circulation features will be masked by the preponderance of non-precipitation circulation events incorporated in the mean. In order to detect the characteristics of atmospheric circulation which typify the changing precipitation climatology, the atmospheric characteristics of precipitation events (as well as non-precipitation events) must be assessed separately.

The categorization of circulation features from synoptic data for the western United States has been compiled by Richard Sands (1969). Sand categorized a total of 105 upper air and surface circulation features from daily synoptic charts. Circulation features were correlated for only maximum precipitation producing patterns, and since winter months are maximum precipitation periods in the Northwest the features tend to be biased toward winter patterns.

A direct correspondence between springtime precipitation and springtime circulation features is not available from Sands' data. Some insight into the type of feature that may be responsible for the April to May-June precipitation increases can be detected by simply examining those circulation features that have peak occurrences in May and June and especially those features that have large relative increases in occurrence across the March through June period. The upper air features which satisfy this criterion are features 3, 4, 16 and 19 on pages 17, 19, 43 and 49 (Fig. 2-5 in Appendix). Feature 4 is particularly noteworthy in that the frequency profile coincides almost perfectly with the change in mean monthly precipitation for the Northwest interior. Basic atmospheric kinematics would imply that the precipitation should be maximized over the interior for this particular feature. The total number of occurrences of this feature is not particularly high for the five-year period and might not contribute significantly to a mean circulation map, yet it may be that this feature or other similar types are responsible for the majority of the springtime precipitation of the interior of the Pacific Northwest. This study will, in part, identify the prevailing circulation patterns both at the surface and at 500 millibars that are responsible for precipitation in the period from March through June.

This research inquiry will investigate the unique springtime precipitation regime of the interior Pacific Northwest with emphasis placed on the following topics:

A. An evaluation will be made of the regional extent and temporal progression of the secondary maximum in the Pacific Northwest utilizing both mean monthly precipitation statistics and short term means for selected stations. Analysis will include an evaluation of relative change characteristics from west to east of the springtime precipitation of the Northwest and temporal precipitation intensity characteristics of selected regions.

B. An evaluation of the mean atmospheric circulation patterns at the surface and 500 millibars will be undertaken for the period March through June. Synoptic patterns will be stratified and compiled on the basis of precipitation and non-precipitation producing events in order to categorize a precipitation and non-precipitation climatology for the period under consideration.

C. An analysis of the vertical distribution of meteorological variables will be undertaken. Primary consideration will be given to the temporal changes in organization of precipitable moisture, vertical temperature gradient, and an appropriate measurement of atmospheric stability for precipitation events.

D. A case study of a representative late spring precipitation event in the Pacific Northwest will be presented.

E. An assessment will be undertaken of the springtime terrestrial heat inputs. The regional temperature field will be expressed as a function of both sensible and latent heat contributions. This will be undertaken to ascertain whether the coastal and interior heat budgets have seasonal change characteristics similar in nature to the springtime changes in mean precipitation. Equivalent potential temperature data are available from a doctoral theses by Val Mitchell for the Western United States (Mitchell, 1969).

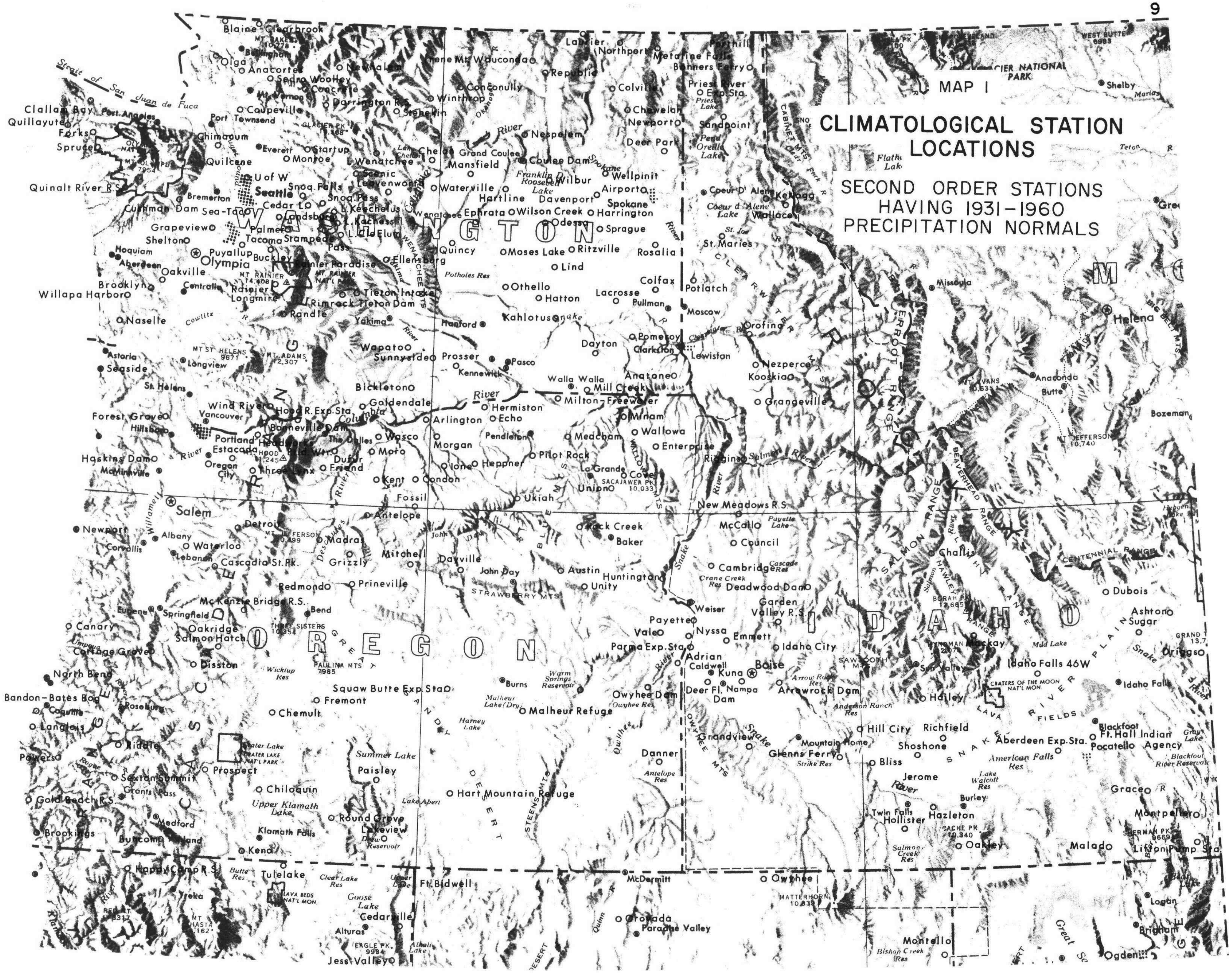
Chapter II

TEMPORAL AND REGIONAL CHARACTERISTICS OF THE SECONDARY MAXIMUM OF PRECIPITATION AS DEFINED BY MEAN PRECIPITATION STATISTICS

A. Relative Change in Mean Monthly Precipitation in the Pacific Northwest, Utilizing the Normal Period 1931-1960

The secondary spring maximum of precipitation of the interior of the Pacific Northwest has been identified by Sherman (1947), Trewartha (1962), and Rudd (1959), but little research has been done on the regional distribution and temporal change characteristics of the phenomenon. The question remains: does the secondary maximum have a defined regional organization or does the distribution reflect a randomness that might be explained by the moderately high variance one finds in monthly precipitation means in arid and semi-arid regions?

In responding to the above question, monthly precipitation normals for the (1931-1960) period were examined for over 300 stations in the Pacific Northwest, utilizing climatological summaries for Washington, Oregon, Idaho, Nevada, and California. Map 1 indicates the locations of the stations utilized. Table 1 in the appendix gives a complete list of the stations and their elevations.


MAP I
CLIMATOLOGICAL STATION LOCATIONS
SECOND ORDER STATIONS HAVING 1931-1960 PRECIPITATION NORMALS
Strait of San Juan de Fuca
Blaine
Clearbrook
Bellingham
Olga
Anacortes
Sedro Woolley
Concrete
Newhalem
Mt Vernon
Darrington R.S.
Coupeville
Port Townsend
Clallam Bay
Port Angeles
Quillayute
Forks
Spruce
Chimacum
Quilcene
Everett
Startup
Monroe
U of W
Seattle
Snoq. Falls
Snoq. Pass
Cedar L.
Quinault River R.S.
Bremerton
Cushman Dam
Sea-Tac
Landsburg
Palmer
Tacoma
Stampede Pass
Grapeview
Shelton
Hoquiam
Aberdeen
Oakville
Puyallup
Olympia
Buckley
Paradise
Centralia
Rainier
Longmire
Brooklyn
Willapa Harbor
Naselle
Randle
Rimrock
Tieton Dam
Tieton Intake
Yakima
Ellensburg
Wenatchee
Leavenworth
Cle Elum
Winthrop
Stehekin
Chelan
Conconully
Republic
Laurier
Northport
Metaline Falls
Colville
Chewelah
Newport
Deer Park
Nespelem
Grand Coulee
Coulee Dam
Mansfield
Wilbur
Wellpinit
Waterville
Hartline
Davenport
Airport
Spokane
Ephrata
Wilson Creek
Odessa
Harrington
Sprague
Quincy
Moses Lake
Ritzville
Rosalia
Lind
Othello
Hatton
Lacrosse
Colfax
Pullman
Potholes Res
Hanford
Kahlotus
Dayton
Pomeroy
Clarkston
Prosser
Pasco
Kennewick
Wapato
Sunnyside
Bickleton
Goldendale
Walla Walla
Mill Creek
Milton-Freewater
Anatone
Hermiston
Arlington
Echo
Astoria
Seaside
Longview
St. Helens
Wind River
Vancouver
Hood R. Exp. Sta.
Bonneville Dam
The Dalles
Wasco
Moro
Forest Grove
Hillsboro
Portland
Estacada
Haskins Dam
McMinnville
Oregon City
Three Lynx
Dufur
Friend
Morgan
Ione
Heppner
Pendleton
Pilot Rock
Meacham
Wallowa
Enterprise
Minam
La Grande
Cove
Union
Kent
Condon
Fossil
Ukiah
Salem
Antelope
Newport
Albany
Corvallis
Waterloo
Lebanon
Cascadia St. Pk.
Detroit
Madras
Grizzly
Mitchell
Dayville
John Day
Austin
Unity
Rock Creek
Baker
Huntington
Redmond
Prineville
McKenzie Bridge R.S.
Bend
Eugene
Springfield
Oakridge
Salmon Hatch
Canary
Cottage Grove
Disston
North Bend
Bandon-Bates Bog
Roseburg
Langlois
Riddle
Powers
Prospect
Sexton Summit
Grants Pass
Gold Beach R.S.
Medford
Ashland
Brookings
Squaw Butte Exp. Sta.
Fremont
Chemult
Burns
Malheur Refuge
Crater Lake
Chiloquin
Summer Lake
Paisley
Hart Mountain Refuge
Round Grove
Lakeview
Klamath Falls
Keno
Happy Camp R.S.
Tulelake
Ft. Bidwell
Yreka
Cedarville
Alturas
Jess Valley
McDermitt
Orovada
Paradise Valley
Owyhee
Montello
Porthill
Bonners Ferry
Priest River
Exp. Sta.
Sandpoint
Coeur D' Alene
Kellogg
Wallace
St. Maries
Potlatch
Moscow
Orofino
Lewiston
Nezperce
Kooskia
Grangeville
Riggins
New Meadows R.S.
McCall
Council
Cambridge
Deadwood Dam
Garden Valley R.S.
Weiser
Payette
Vale
Nyssa
Emmett
Idaho City
Parma Exp. Sta.
Adrian
Caldwell
Kuna
Boise
Deer Fl. Nampa Dam
Arrowrock Dam
Owyhee Dam
Grandview
Glenns Ferry
Mountain Home
Danner
Hill City
Richfield
Shoshone
Bliss
Jerome
Twin Falls
Hollister
Hazelton
Burley
Oakley
Hailey
Mackay
Challis
Dubois
Ashton
Sugar
Driggs
Idaho Falls 46W
Idaho Falls
Blackfoot
Ft. Hall Indian Agency
Pocatello
Aberdeen Exp. Sta.
American Falls Res
Grace
Montpelier
Malad
Lifton Pump. Sta.
Logan
Brigham
Ogden
Missoula
Helena
Anaconda
Butte
Bozeman
Shelby
GLACIER NATIONAL PARK
WASHINGTON
OREGON
IDAHO
CASCADE RANGE
BLUE MTS
SNAKE RIVER PLAIN
GREAT SANDY DESERT
BITTERROOT RANGE
SALMON RIVER MTS

The examination of actual precipitation totals would shed very little light on the regional extent and magnitude of the secondary maximum since orography will strongly regionalize the magnitude of a given monthly mean. Therefore, for each station the relative monthly changes in mean precipitation were calculated (Dixon, 1945, p. 293). The monthly total was adjusted to a 30-day month (Conrad and Pollack, 1950, p. 237). Relative changes in precipitation were expressed as the percentage increase or decrease in mean monthly precipitation from one month to the succeeding month for each station. Example: February to March percentage change = $\frac{(\text{March} - \text{February})}{\text{February}} \times 100$.

The following is a presentation of the pattern of change of precipitation from February through July with emphasis on the states of Oregon and Washington. For the sake of brevity, westside will refer to the region west of the Cascade crest in either Washington or Oregon, and eastside will refer to the region east of the Cascade crest in either Washington or Oregon. More specific regions will be identified in the text.

During the winter months in the Pacific Northwest, cyclonic storms frequently move across the region on a southwest to northeast trajectory (Klein, 1957, p. 145). These storms transport warm, moist air masses which are caused to rise pseudoadiabatically over orographic barriers and frontal surfaces. This process results in pronounced precipitation variation in windward and leeward locations of orographic barriers (Saucier, 1962, p. 295-302; Petterssen, 1940, p. 298-302). The month of maximum precipitation in the Pacific Northwest shows little variation from west to east indicating that the west to east trajectory of frontal impulses is very consistent through the winter months of December, January and February. West to east variation in precipitation in these months is almost totally the result of the constraints of elevation and exposure.

A slight north to south variation in the month of maximum precipitation exists in the Pacific Northwest. Philips noted that while cyclonic control from the west and southwest is maintained in the Pacific Northwest for all winter months, a migration of the storm track southward occurs in the fall and winter reaching a maximum southerly position in February (Philips, 1948, p. 144). Consequently, most Washington and northern Oregon stations show a December maximum, and southern and central Oregon stations record a January maximum. More properly, a greater percentage of storms follow a more southerly track in January and February, the mean track still being across northwestern Washington.

In the following presentation of the monthly change characteristics of precipitation in the Pacific Northwest, sufficient regional gradients of change exist to identify distinct precipitation regions. A statistical evaluation of the magnitude of the gradient between precipitation regions was undertaken although in any statistical evaluation of precipitation data certain difficulties arise. Precipitation data rarely satisfy the assumptions of independence, randomness or gaussian normality.

Utilizing relative values does tend to normalize distributions (Conrad and Pollack, 1962, p. 201-212), but the difficulties of randomness and lack of independence remain. The standard technique for solving the lack of independence and randomness in precipitation data is to utilize non-sequential daily data from differing time periods. This necessitates the use of long periods of record. The number of precipitation events in dry climates is so small that the use of a moderately long average period (at least 30 years) is necessary to arrive at a consistent probably mean (Conrad and Pollack, 1962, p. 240; Court, 1960, p. 4017-4024). The use of data prior to the 1931-1960 normal period is questionable due to inadequate station density, poor recording techniques, and a large number of station relocations. Statistical analysis of the precipitation means calculated from the 1931-1960 normal period utilizing the standard normal distribution was undertaken with the knowledge that the data were not derived by independent averaging.

The regional organization of precipitation change in the spring is predominantly oriented west to east with the Cascade Mountain Range typically coinciding with the maximum change gradient. The State of Oregon was selected for analysis since the strongest gradients of change exist across the Oregon Cascades. The west to east gradient of change is two to three times the magnitude of the north to south gradient of change. Relative change data were stratified into two sets: thirty-one Eastern Oregon stations and thirty-one Western Oregon stations. Descriptive statistics were calculated for monthly precipitation changes for each regional unit and are presented in Table I (Guthrie, 1973, p. 70-79).

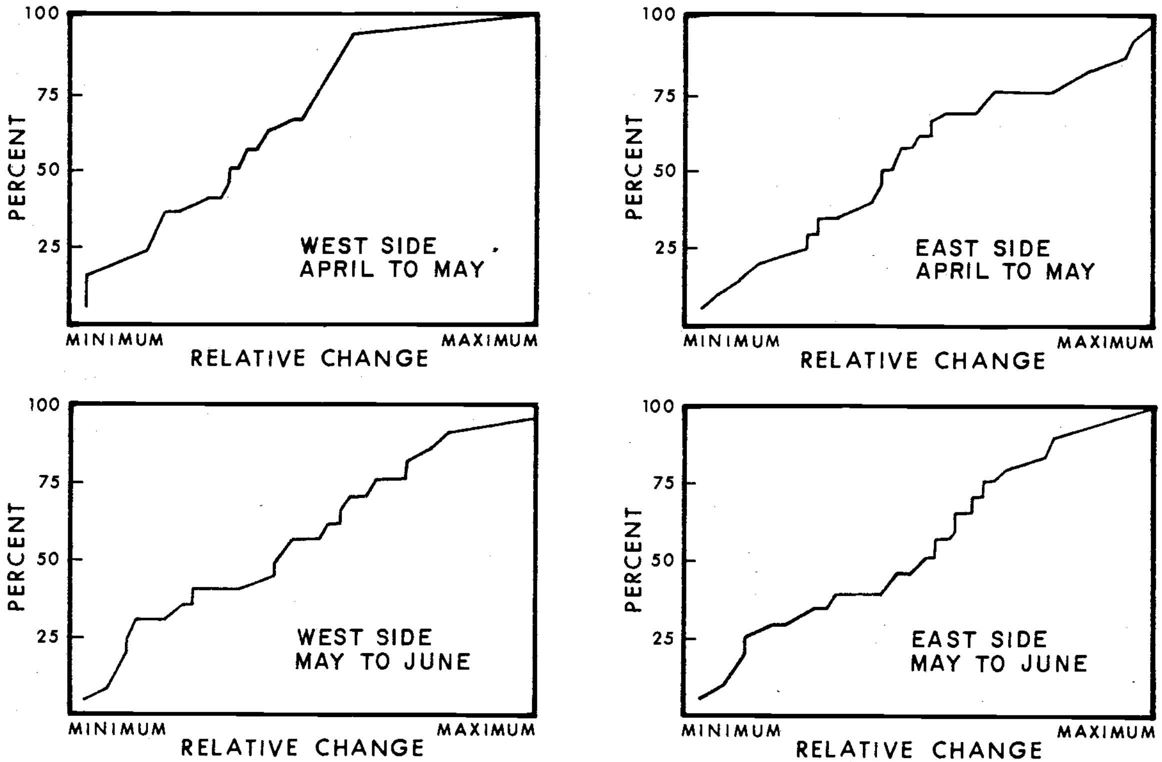
Table 1

Relative Change in Monthly Precipitation for Western and Eastern Oregon

	Mean Percentage Change	Standard Error of Mean	Standard Deviation	Range
Dec. to Jan. Westside	- 6	1.3	7.7	33
Dec. to Jan. Eastside	- 4	1.8	9.8	38
Jan. to Feb. Westside	-21	.64	3.5	17
Jan. to Feb. Eastside	-16	2.1	11.7	43
Feb. to Mar. Westside	- 8	1.3	7.5	33
Feb. to Mar. Eastside	- 7	3.1	17.4	77
Mar. to Apr. Westside	-45	1.09	6.1	27
Mar. to Apr. Eastside	-21	2.69	15.0	53
Apr. to May Westside	-18	2.3	12	60
Apr. to May Eastside	+38	4.35	24	91
May to June Westside	-30	2.1	11.7	44
May to June Eastside	- 5	2.1	11.9	47
June to July Westside	-75	1.3	7.4	28
June to July Eastside	-72	1.4	7.8	30

In Table 1 sample standard deviations for both units are tabulated. Eastern Oregon standard deviations average higher throughout the period as expected, due to the greater variability of precipitation in arid and semiarid regions. Small standard deviations characterize the December through April period in the west with moderate increases in May and June associated with increasing gradients of change across the Coast Range and western Cascades. Variability increases slowly on the eastside from December through February and increases rapidly from March through May. The high variability of the March through May period is associated with the establishment of strong gradients of change across the eastern Cascades and the more erratic nature of low frequency, moderate intensity rainfall. The large decrease in variability of the June

NORMAL PLOT OF RELATIVE CHANGE IN MEAN PRECIPITATION



ABCISSA: Relative change in monthly precipitation.
ORDINATE: Inverse of the cumulative standard normal distribution.

FIGURE 1

to July period reflects the abrupt dominance of the entire Pacific Northwest by the Pacific High pressure system.

Comparative analysis of the monthly change in precipitation of westside and eastside units was undertaken utilizing the "students T" test. The students T test assumes the data are normally distributed (Stringer, 1967, p. 110). Figure 1 is a normal plot of monthly relative changes for selected regional units and selected months. The plots are sufficiently linear to accept the normal distribution as an acceptable model (Guthrie, 1973, p. 41). Calculated T statistics and table T statistics are presented on the maps of monthly relative change in precipitation which will be discussed in detail in the following section.

1. Monthly Relative Change in Precipitation: February to March

In the winter months of January, February and March, monthly means progressively decrease with both westside and eastside locations exhibiting similar temporal changes. The regional differences that do exist are organized with respect to orography with those stations in the more arid locations tending to show greater percentage decreases than those stations in humid windward locations.

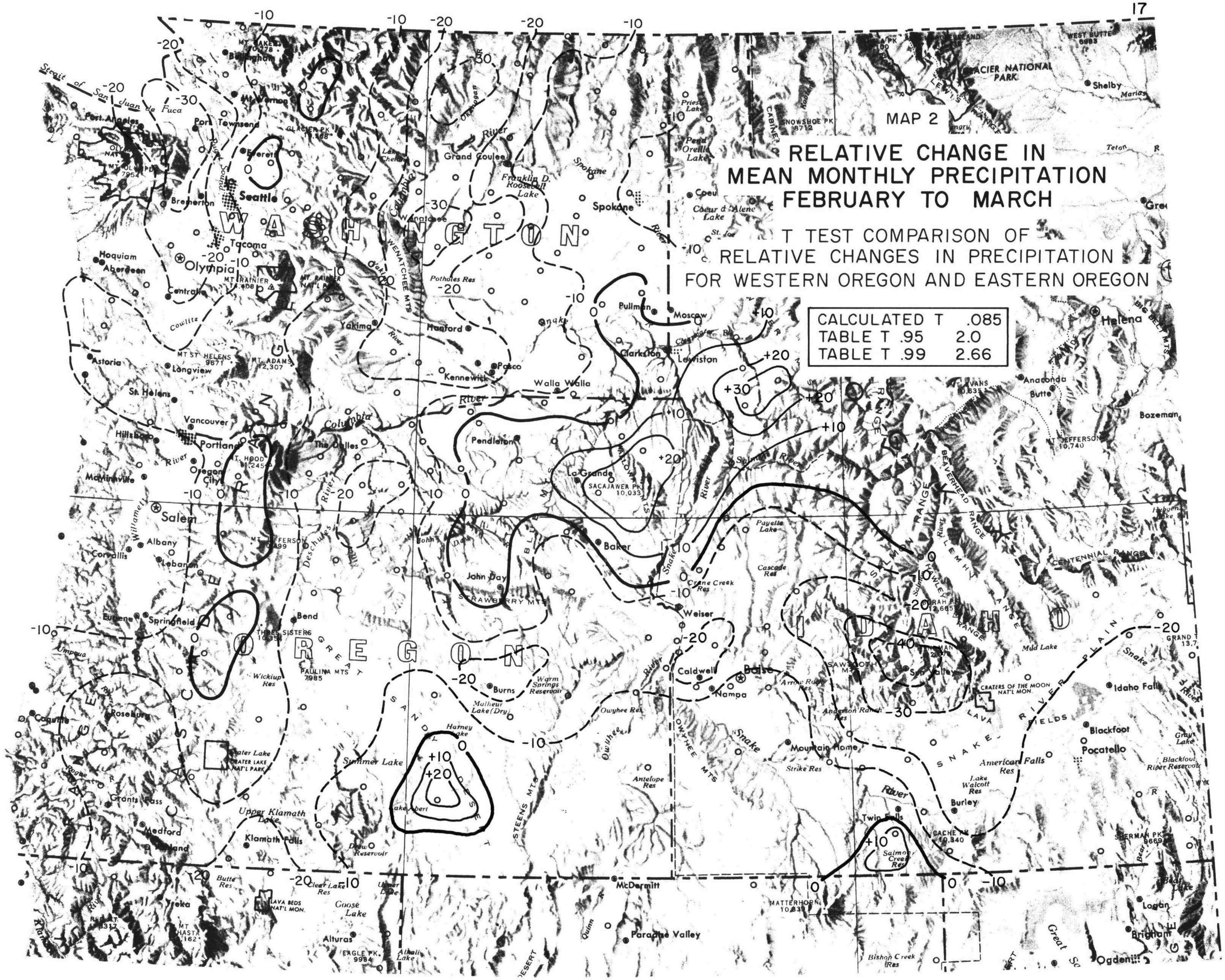
Map 2 indicates isopleths of the percentage change of precipitation from February to March for Washington, Oregon and Idaho. In Washington, both westside and eastside stations indicate small to moderate negative values. Regional differences that do exist are organized on the basis of topography; thus, the Sequim-Port

Angeles lowlands and the Pasco basin and Okanogan valley have moderate decreases on the order of -30%. The remainder of the state has decreases on the order of -10%. A few stations in the Blue Mountains of Washington and the higher elevations in central Idaho indicate small to moderate increases.

In Oregon the February to March period is characterized by an erratic pattern of small decreasing means with a few areas of small increases. The strongest decreases are associated with the lower elevations and more arid locations. All stations west of the Cascades have decreases on the order of -5% to -15%. The immediate lee of the Cascades from Klamath Falls north to Friend indicate moderate decreases on the order of -20%. Low elevation stations in central Oregon and eastern Oregon also indicate moderate decreases.

Small increases are noted in three regions; the Cascade crest, northeastern Oregon in the Wallowa and Blue Mountains, and the high plateau near Lake Abert. It would appear that many increasing means are a function of higher elevation.

The gradual decrease in cyclonic activity in combination with a slow rise in equivalent potential temperature may offer a plausible explanation for the above anomaly of increased precipitation at high elevation interior locations. The rise in equivalent potential temperature would appear to be more productive with respect to increasing precipitable moisture at higher elevations while lower elevations are more responsive to the decrease in cyclonic activity. While small regional patterns are discernable, both westside and eastside units are characterized by weak gradients of change indicating uniform air mass characteristics both west and east of the


MAP 2
RELATIVE CHANGE IN
MEAN MONTHLY PRECIPITATION
FEBRUARY TO MARCH
T TEST COMPARISON OF
RELATIVE CHANGES IN PRECIPITATION
FOR WESTERN OREGON AND EASTERN OREGON
CALCULATED T .085
TABLE T .95 2.0
TABLE T .99 2.66
WASHINGTON
OREGON
IDAHO
Strait of San Juan de Fuca
Port Angeles
Port Townsend
Everett
Seattle
Bremerton
Tacoma
Olympia
Hoquiam
Aberdeen
Centralia
Astoria
Longview
St. Helens
Vancouver
Hillsboro
Portland
McMinnville
Salem
Albany
Corvallis
Lebanon
Eugene
Springfield
Roseburg
Coquille
Grants Pass
Medford
Klamath Falls
Upper Klamath Lake
Summer Lake
Bend
Wickiup Res
Burns
Harney Lake
Malheur Lake (Dry)
Warm Springs Reservoir
Owyhee Res
Antelope Res
McDermitt
Paradise Valley
Alturas
Goose Lake
Yreka
The Dalles
Pendleton
La Grande
Baker
John Day
Walla Walla
Kennewick
Pasco
Hanford
Yakima
Wenatchee
Grand Coulee
Franklin D. Roosevelt Lake
Spokane
Pullman
Moscow
Clarkston
Lewiston
Coeur d'Alene Lake
Weiser
Caldwell
Nampa
Boise
Mountain Home
Twin Falls
Burley
American Falls Res
Pocatello
Blackfoot
Idaho Falls
Mud Lake
Salmon
Butte
Anaconda
Helena
Bozeman
Shelby
Logan
Brigham
Ogden
GLACIER NATIONAL PARK
CRATERS OF THE MOON NAT'L MON.
LAVA BEDS NAT'L MON.
SNAKE RIVER PLAIN
Columbia River
Snake River
Salmon River
Deschutes River
Willamette River
STRAWBERRY MTS
STEENS MTS
WENATCHEE MTS
PAULINA MTS
OWYHEE MTS
CENTENNIAL RANGE
BEAVERHEAD RANGE
LEMHI RANGE
CASCADE RANGE

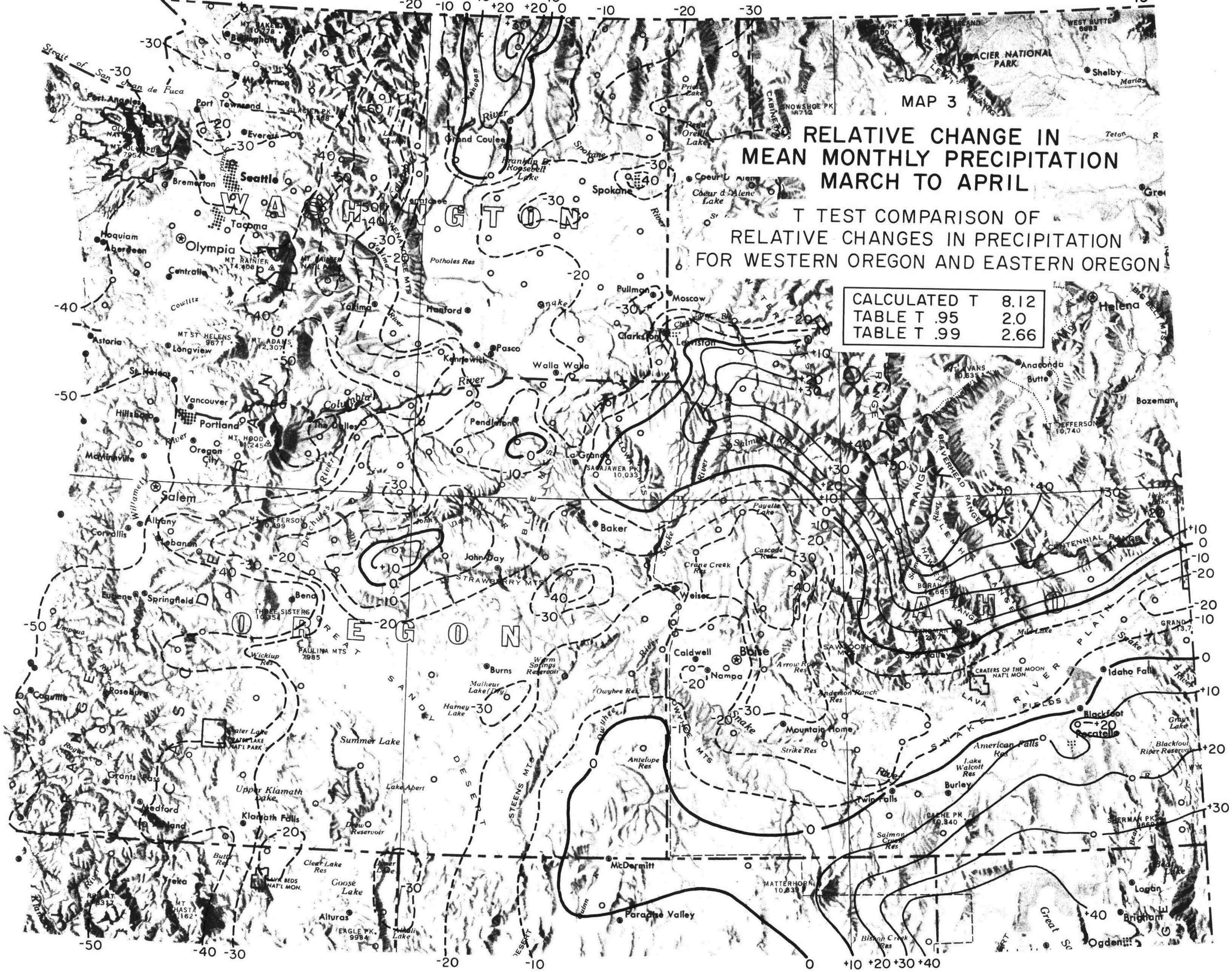
Cascades. Comparative T statistics indicate nonsignificant differences between the regional units of Western Oregon and Eastern Oregon.

2. Monthly Relative Change in Precipitation: March to April

In the period from March to April, monthly means of precipitation continue to decrease in both western and eastern Oregon and Washington (Map 3). The rate of decrease drops markedly for all stations with virtually all western Oregon and Washington stations indicating decreases on the order of -40%. Eastside stations indicate decreases as well, but of the order of -15% to -30%. The magnitude of the decrease of both westside and eastside locations for March to April is indicative of a significant decrease in cyclonic storm intensity and frequency throughout this period. The decrease is very extensive across the Pacific Northwest, although more effective on the westside.

A few areas of precipitation increases are noted at high elevations in extreme northeastern Washington, in extreme northeastern Oregon and in east central Idaho. These high elevation stations are characterized by late winter means of precipitation which are quite low in absolute amount. These high elevation interior stations with rather low monthly means may be responding more effectively to the slow rise in equivalent potential temperature across the February to April period, despite the general regional decrease in cyclonic activity.

Other interior stations of central Oregon indicate either small increases or slight decreases in precipitation including:


MAP 3
RELATIVE CHANGE IN
MEAN MONTHLY PRECIPITATION
MARCH TO APRIL
T TEST COMPARISON OF
RELATIVE CHANGES IN PRECIPITATION
FOR WESTERN OREGON AND EASTERN OREGON
CALCULATED T 8.12
TABLE T .95 2.0
TABLE T .99 2.66
WASHINGTON
OREGON
IDAHO

Redmond, Prineville, Dayville and Madras. These stations will show spectacular increases in the April to May period, and it appears that atmospheric processes which will result in increasing precipitation yields in the April to May period are being initiated in that region as early as April. Comparative T statistics indicate significant differences between western Oregon and eastern Oregon regional units.

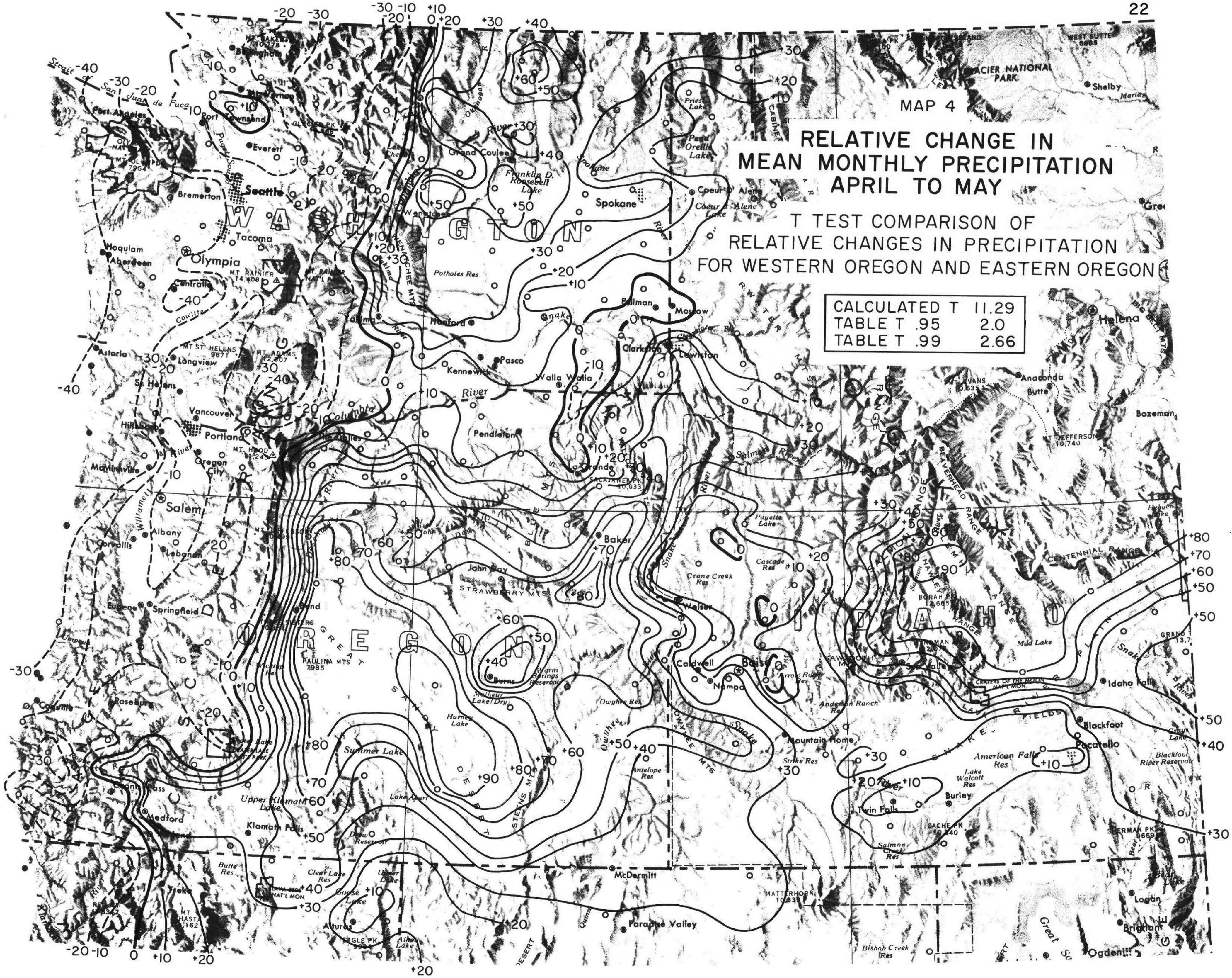
It should be noted that by the March to April period, a reversal has occurred in the west to east organization of precipitation. In the February to March period, the western lowlands and arid lee locations are typified by the largest negative values, and the westside locations and high elevations indicate either small negative or even positive values. In the March to April period this situation begins to reverse in that the westside and Cascade crest indicate large negative values, and it is the lee side and low elevation interior locations which now show small negative values or even positive values. This would seem to be reflective of fundamental changes in the origin of precipitation with respect to air mass characteristics. There is an evolution from a relatively warm oceanic source being advected into a cool interior during December, January and February (Chapman, 1952, p. 8-37; Connor, 1938, p. 695), to a cool oceanic source being advected into a progressively warming interior in March, April, May and June. March is the period of the weakest west to east temperature gradient. Atmospheric parameteres will be investigated in later portions of this paper to substantiate the above statement.

3. Monthly Relative Change in Precipitation: April to May

In considering the precipitation change characteristics of the April to May period in the Pacific Northwest, a summary of the previous three months is in order. The period of January through April is characterized by decreasing monthly means, both west and east of the Cascades. Particular areas show increasing means, but these are not large increases and may well be the result of elevation controls and variance in using 30-year mean periods. The most persistent aspect of the pattern is the decreasing precipitation tendency with fairly small gradients of change across the Pacific Northwest, indicating that both eastside and westside locations are responding in a similar manner to the cyclonic controls to the west.

In the April to May period, a very strong west to east organizational structure appears with the eastside responding in a manner quite distinct as compared to stations west of the Cascades. A very pronounced west to east gradient of precipitation change is established which is two to three times the magnitude of any previous gradient of change.

The relative change map for April to May (Map 4), indicates the following major characteristics. All stations west of the Cascades continue to indicate decreasing means, although less in magnitude than the previous month's changes. All interior stations indicate positive values with the exception of the Blue Mountains of Oregon and extreme southeastern Washington. Interior positive values


MAP 4
RELATIVE CHANGE IN
MEAN MONTHLY PRECIPITATION
APRIL TO MAY
T TEST COMPARISON OF
RELATIVE CHANGES IN PRECIPITATION
FOR WESTERN OREGON AND EASTERN OREGON
CALCULATED T 11.29
TABLE T .95 2.0
TABLE T .99 2.66
WASHINGTON
OREGON
IDAHO
Seattle
Spokane
Portland
Salem
Boise
Helena

are moderately large with highest values in the immediate lee of the Cascades in both Oregon and Washington. Very strong west to east gradients of change are organized parallel to the Cascade Mountains with the strongest gradient located immediately leeward of the Oregon Cascades.

The area to the west of the Cascades has decreasing means but a regional organizational structure is quite recognizable. Coastal stations and coastal mountain stations have the highest negative values with values of -40% in northwestern Washington, and values of -20% to -30% for coastal and Coast Range stations of southern Washington and western Oregon. Puget Sound and Willamette Valley stations indicate negative values of the order of -5% to -20% in Washington and -5% to -15% in the Willamette Valley of Oregon.

The few western Cascade stations indicate moderate negative values of -15% to -30% which are higher than Willamette Valley values, but smaller than coastal and coast range values.

East of the Cascades a complex pattern of positive values exists. Highest values, on the order of +50% to +80%, are in the immediate lee of the Cascades in Oregon, centered in the Bend-Redmond-Prineville area. In Washington highest positive values are in the lee of the Cascades, but slightly further downwind centered on the Waterville Plateau. Moderate positive values extend eastward to Spokane.

Small negative values to slightly positive values are characteristic of the Columbia River gorge in both Oregon and Washington. Small negative to small positive values are also found in the southeast Palouse region of eastern Washington and the northern edge of the Blue Mountains of Oregon.

The highest positive values of interior Washington and Oregon seem to be found at intermediate elevations from 2,000 to 4,000 feet and in the immediate lee of the Cascades. Lower values are located on a west to east track following the Columbia River and extending eastward flanking the Snake River. The Columbia gorge would appear to effectively extend westside processes eastward into the Snake River tableland and adjoining Palouse.

The west to east organization of the change characteristics is not simply a product of increasing distance from the west coast. Figure 2 is a plot of the relative changes in monthly precipitation from December-January to June-July for the four regional divisions in Oregon. Monthly changes were summed and averaged for all stations within each division. Through the months of December-January to February-March, all divisions show similar negative values of -10% to -30%. In the March to April period all divisions show large decreases of -10% to -50% with a slight increase in the west to east differences. In April to May the maximum west to east gradients of change exist, but the ordering of change from negative to positive is: Coastal, Cascades, Willamette Valley, Central Interior, and Leeside Cascades. The processes which produce increasing precipitation yields are not only controlled by interior distance but by the existence of north-south orographic barriers which produce leeside effects. These leeside positions are productive independently in augmenting precipitation yields. Studies on the effect of mountains on precipitation are quite abundant but focus either on trajectory of air flow (Queney, et al.,

MONTHLY PERCENTAGE CHANGE IN PRECIPITATION FOR PHYSIOGRAPHIC DIVISIONS OF OREGON

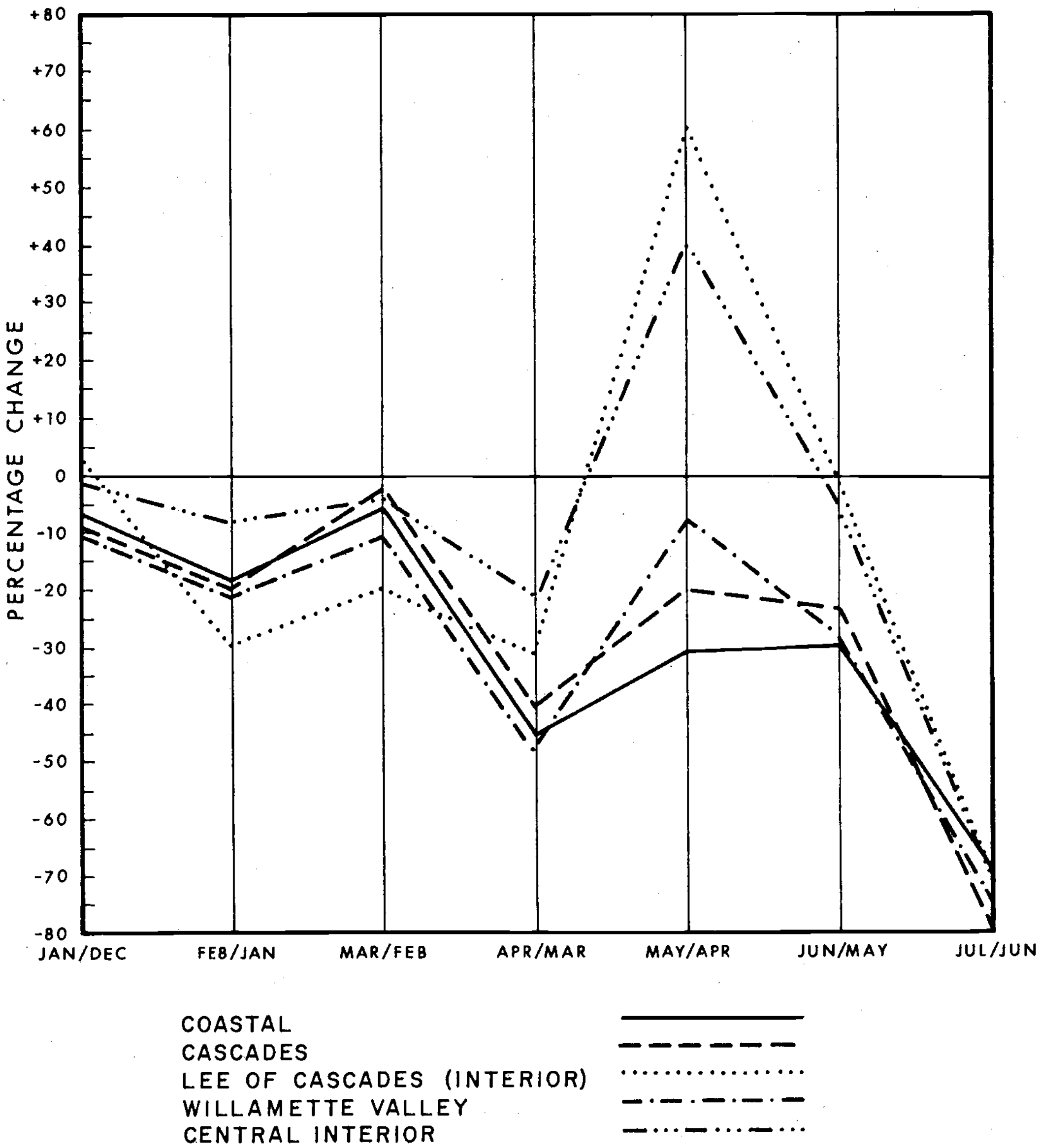


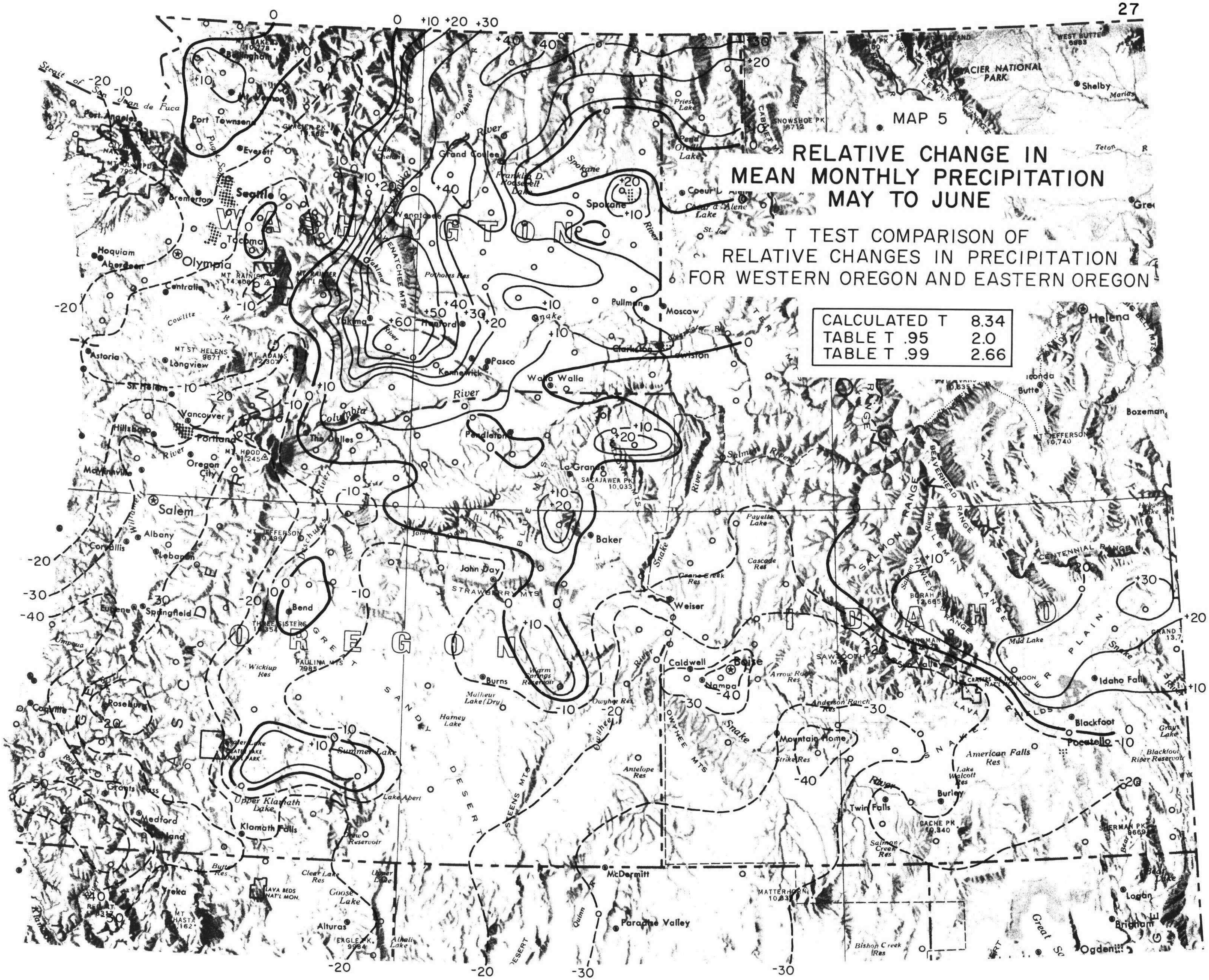
FIGURE 2

1960, p. 130), katabatic effects (Buettner, et al., 1966, p. 125-147), or airflow and precipitation under uniform air mass characteristics in windward locations (Myers, 1962, p. 4267-4291). The problem of the effect of mountain ranges on precipitation under conditions of strong frontal discontinuities characterized by unstable lapse rates, particularly in the leeward position, is in need of investigation. The problem is further complicated by the lack of radiosonde stations in mountainous terrain. Comparative T statistics, as might be expected, indicate highly significant differences in the means of the western Oregon regional unit and the eastern Oregon regional unit.

4. Monthly Relative Change in Precipitation: May to June

In the period from May to June, the west to east organizational structure of the previous two months is maintained with some modification (Map 5). All westside stations of Washington and Oregon indicate moderate to large decreases with the exception of the Puget lowlands in the lee of the Olympics. Interior stations of Oregon show a complex pattern of small positive to small negative values, indicating that interior processes which produced spectacular increases in May are still occurring in June, but at slightly lower rates.

The maximum west to east gradient of change has shifted northward into Washington with a similar profile across the Cascades for this period, as was observed in April to May in Oregon. Largest negative values are in western Washington and the Olympic Highlands. Moderate negative values are in the Washington Cascades; smallest


MAP 5
RELATIVE CHANGE IN
MEAN MONTHLY PRECIPITATION
MAY TO JUNE
T TEST COMPARISON OF
RELATIVE CHANGES IN PRECIPITATION
FOR WESTERN OREGON AND EASTERN OREGON
CALCULATED T 8.34
TABLE T .95 2.0
TABLE T .99 2.66
WASHINGTON
OREGON
IDAHO
GLACIER NATIONAL PARK
Seattle
Tacoma
Olympia
Spokane
Yakima
Portland
Salem
Eugene
Bend
Boise
Pocatello
Idaho Falls
Helena
Klamath Falls
Medford
Walla Walla
Pendleton
John Day
Burns
Baker
Lewiston
Moscow
Pullman
Twin Falls
Logan
Ogden

negative values in the Puget Lowlands; and moderate positive values in the eastern portion of the Columbia Plateau. Highest positive values are in the immediate lee of the Cascades with Yakima, Ellensburg, Waterville Plateau, and Okanogan Highlands being the core areas. Figure 3 illustrates the monthly averages for the major climatological divisions of Washington. While the strongest gradient of change is now centered across the state of Washington, comparative T statistics still indicate highly significant differences in the means of western Oregon as compared to the eastern Oregon regional unit.

5. Monthly Relative Change in Precipitation: June to July

In the period from June to July (Map 6), the abrupt termination of the late spring rainy season is quite apparent. All stations, both west and east of the Cascades, show decreases on the order of -60% to -80%. The large magnitude of the decreases and the lack of any west to east gradient is indicative of the extensive aridifying synoptic pattern which is now dominating the Pacific Northwest (Lydolph, 1957, p. 215-216; Trewartha, 1968, p. 316-318). The 700 millibar Atlas of North America (Wahl & Lahey, 1960, p. 72) readily indicates the sudden northward shift of the Pacific High across the last few weeks of June. The shift northward of the northeast subsiding limb of the subtropical high into the Pacific Northwest is simultaneously accompanied by the onset of the summer rainy season in Arizona. This atmospheric singularity was studied in some detail by Bryson and Lowry (Bryson, 1955, p. 329-339). The June to July

PERCENTAGE CHANGE IN MEAN PRECIPITATION
FROM MAY TO JUNE FOR
CLIMATOLOGICAL DIVISIONS OF WASHINGTON

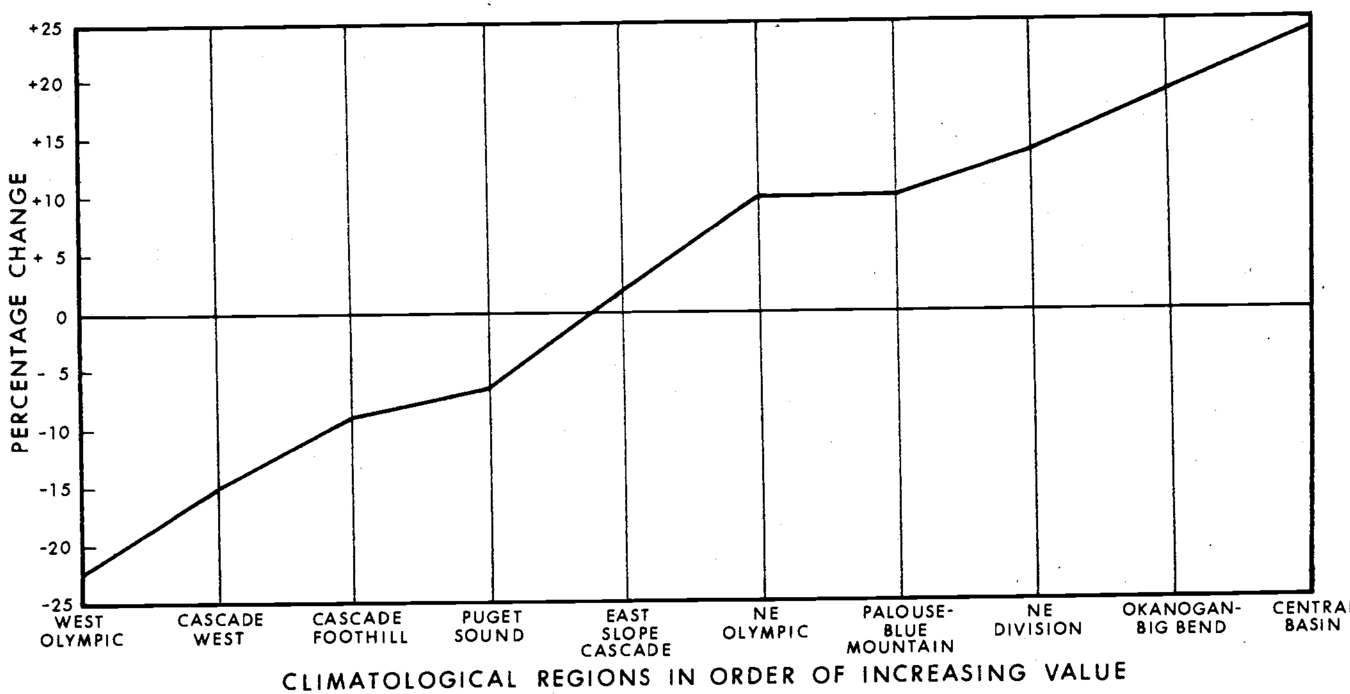
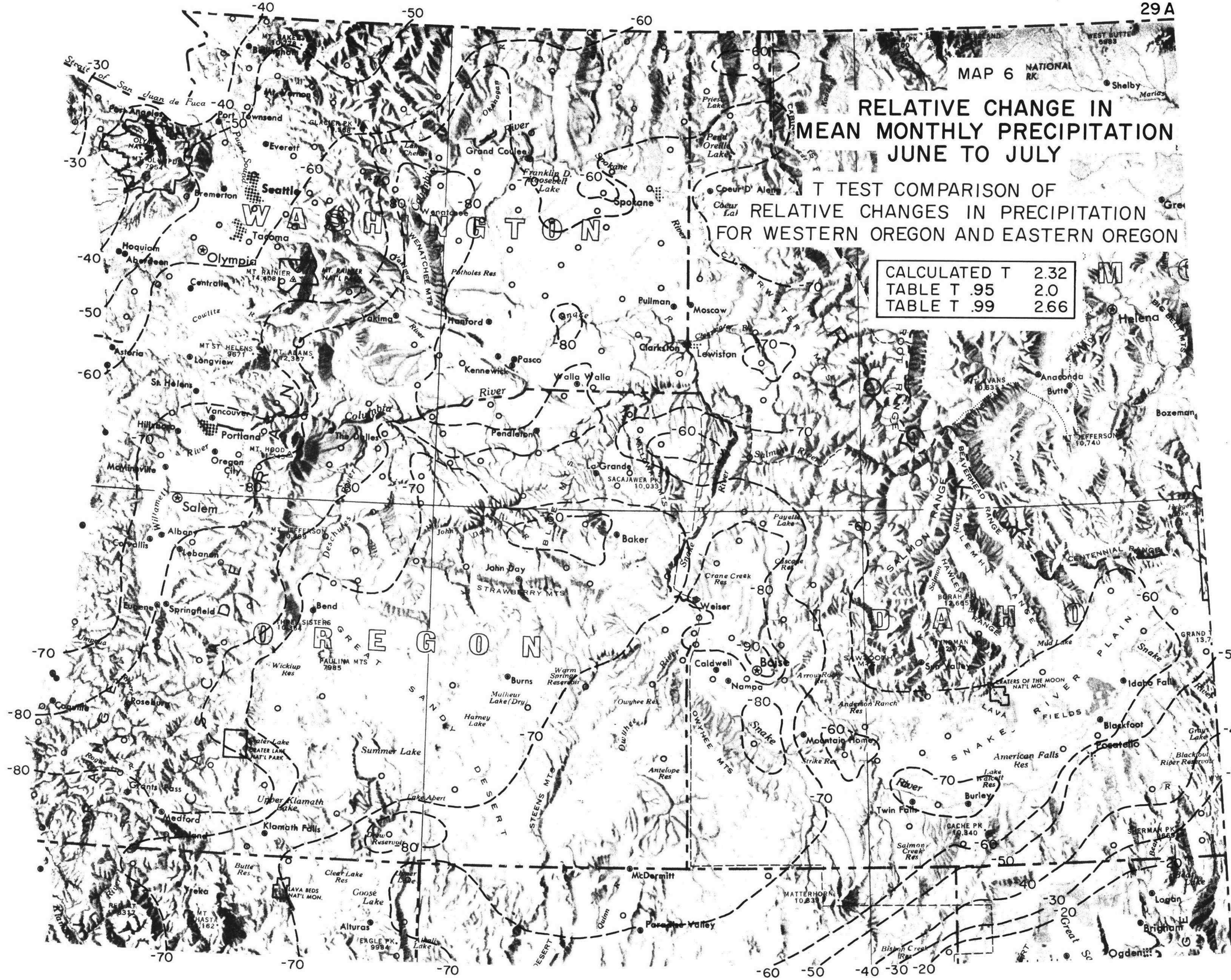


FIGURE 3


MAP 6
RELATIVE CHANGE IN
MEAN MONTHLY PRECIPITATION
JUNE TO JULY
T TEST COMPARISON OF
RELATIVE CHANGES IN PRECIPITATION
FOR WESTERN OREGON AND EASTERN OREGON
CALCULATED T 2.32
TABLE T .95 2.0
TABLE T .99 2.66
WASHINGTON
OREGON
IDAHO
Seattle
Tacoma
Olympia
Spokane
Portland
Salem
Eugene
Bend
Burns
Baker
Boise
Pocatello
Helena
Medford
Klamath Falls
GREAT SANDY DESERT
SNAKE RIVER PLAIN
SALMON RIVER MTS
STRAWBERRY MTS

relative change maps reflect the dominance of the Pacific High pressure system across the Pacific Northwest, but in the portion of northern Nevada included, there exists a strong north-south gradient of precipitation change which is indicative of the increase of precipitation in Arizona and southern Nevada referred to by Bryson and Lowry.

The northern limit of the strong subsiding effects of the Pacific High are apparent in a moderate southeast to northwest gradient of change across the Olympic Peninsula. While the Puget lowlands are dominated by the subsiding air of the Pacific High with decreases on the order of -50% to -60%, the Olympic Peninsula decreases are only on the order of -20%, indicating a return to a more westerly circulation across the peninsula.

The major features of the springtime precipitation changes in the Pacific Northwest may be summarized as follows: (1) Small decreases in precipitation in the winter months of January, February, and March, both west and east of the Cascades, with greater variability to the east in the more semiarid locations. (2) The establishment of an increasingly strong west to east gradient of change in the months of April, May and June, characterized by increased positive values east of the Cascades. (3) The establishment of region-wide large nagative values in the month of July as a result of the sudden dominance of the Northwest by the Pacific High.

B. Analysis of Short Terms Means of Precipitation for Selected Stations in the Pacific Northwest

The use of monthly means, while being the standard climatological seasonal time interval, may be too large to accurately assess the initiation and culmination of a secondary maximum that is only about two months in length. Shorter term means would be useful in attempting to precisely determine the temporal extent and change characteristics of the secondary maximum in the Pacific Northwest.

Seven-day, fourteen-day, and twenty-one-day means have been calculated for selected stations in the Pacific Northwest utilizing the 1931-1960 normal period. These values are available in "Volume II, Columbia Basin Handbook, Columbia Basin Inter-Agency Committee, 1969," prepared by Bonneville Power Administration. Figure 4 is a plot of weekly means for western Oregon and Washington. As the mean period is reduced in length, increasing variability is introduced into the system since the average period (1931-1960) has remained constant.

The weekly averages for eastern Washington and Oregon confirm, and more precisely outline, some of the major features which were discussed with respect to the monthly means (Figure 5). Figure 5 indicates that the secondary maximum begins in mid-April with weekly averages increasing to a maximum in late May in eastern Oregon and early June in eastern Washington. The means rapidly decrease from June 21 through mid-July. The decrease in means through February and March is gradual but persistent with a sudden increase in the rate of decrease from April 5th through April 19th. It is interesting to note that part of the large magnitude of the May increase can be attributed to the drought in early April. Whether the low April values reflect consistent physical processes is difficult to assess, but means derived from the period prior to 1934 indicate consistently higher April values. This would imply that part of the strong decrease in

WESTERN WASHINGTON AND OREGON WEEKLY PRECIPITATION MEANS: 1931-1960 NORMALS

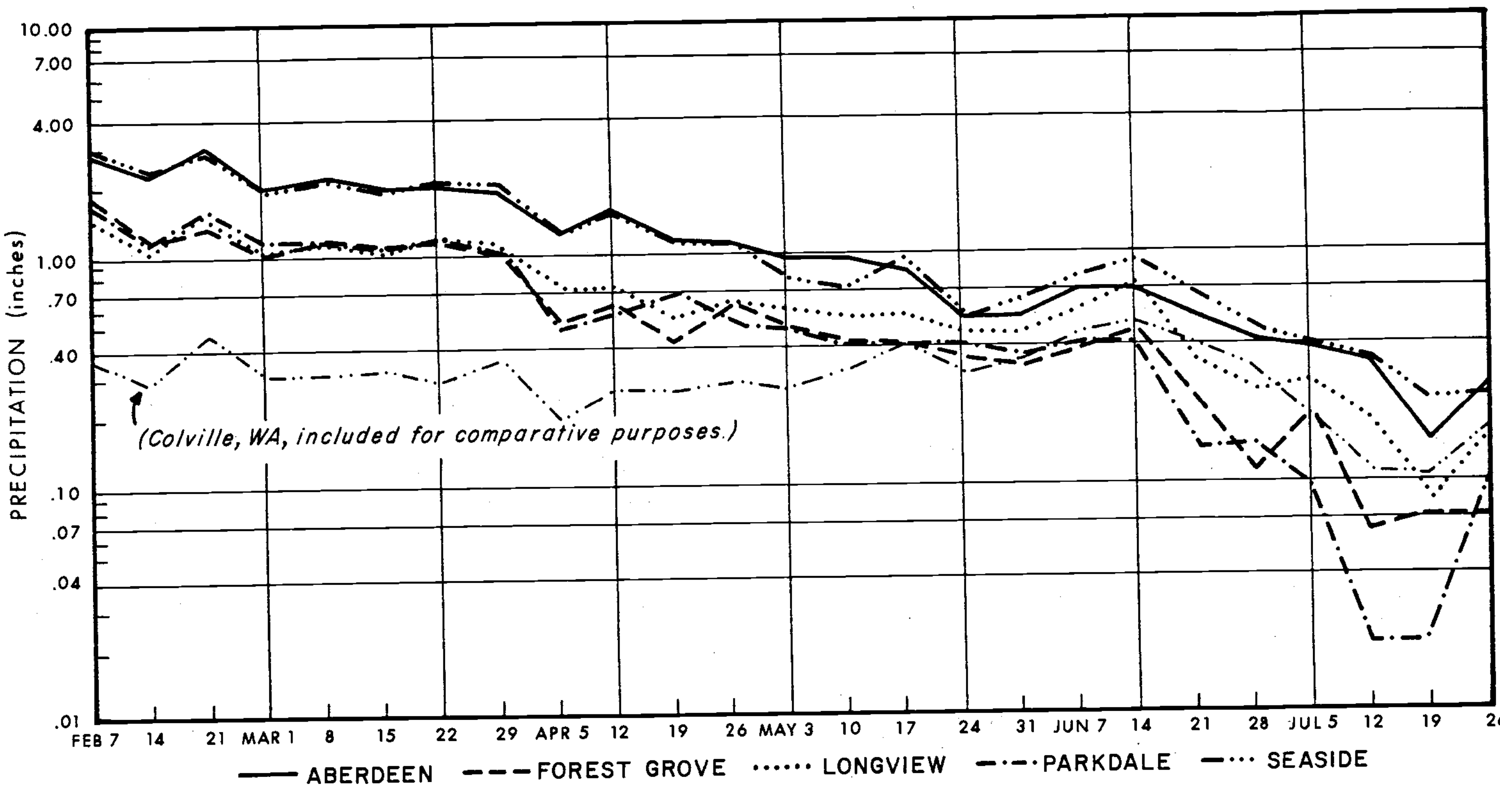


FIGURE 4

EASTERN WASHINGTON AND OREGON WEEKLY PRECIPITATION MEANS: 1931-1960 NORMALS

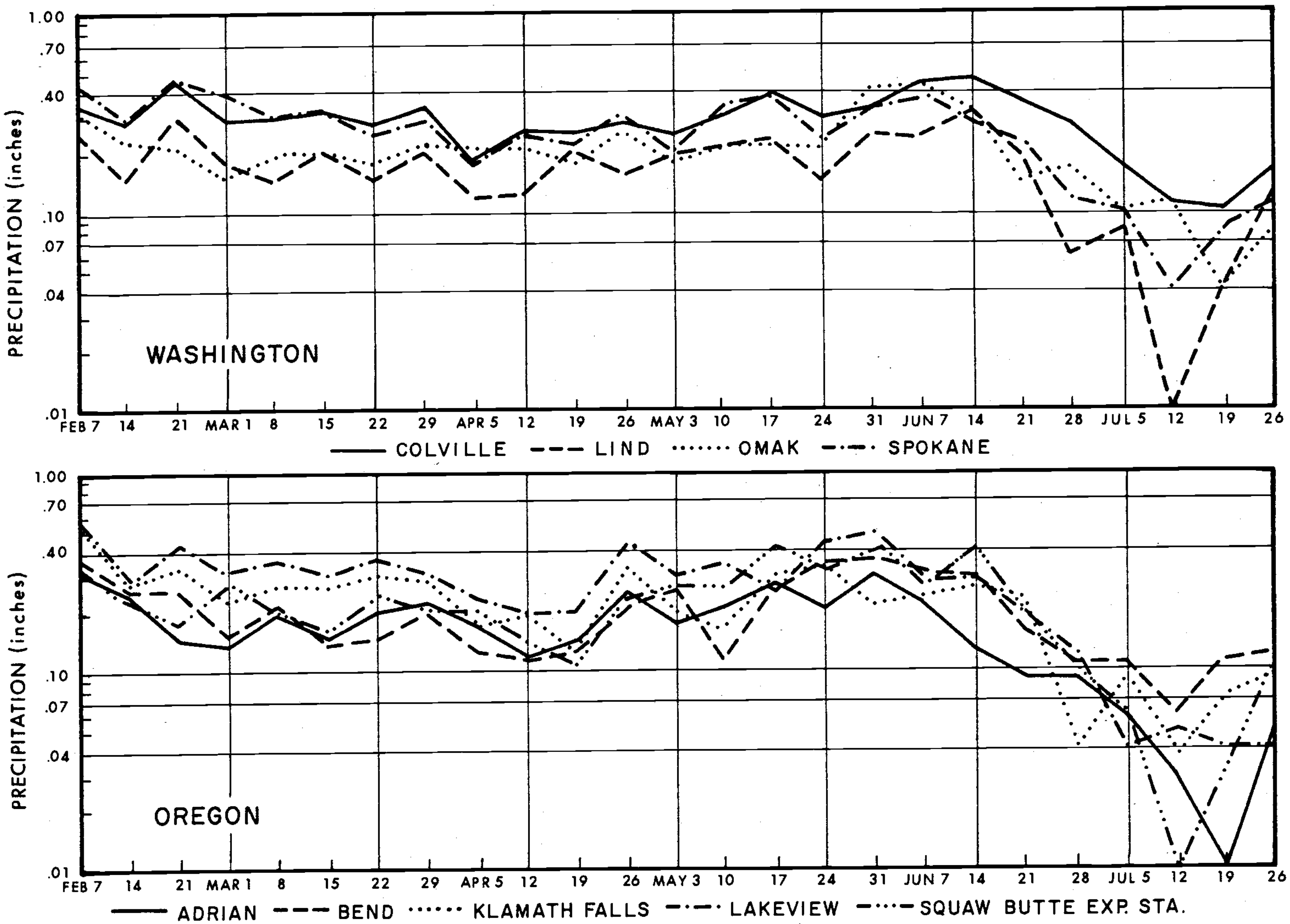


FIGURE 5

April is unique to the 1931-1960 period.

Figure 4 is a February through July plot of weekly means for western Oregon and Washington stations, and while much week to week variability exists due to the short mean period the trend of decreasing means is quite discernable. Westside stations also indicate a rather large decrease in the April 5th through April 19th period. The most interesting aspect of the western stations is that the secondary maximum does exist on the westside, but on a much reduced scale. Weekly means do indeed increase from about May 24 to June 14, but the increase is small enough in magnitude and short enough in time to be reflected only as a lessening in the rate of decrease through May and June on a monthly scale. It would appear that processes which produce large increases in precipitation means of the eastside are also present on the westside but are smaller in magnitude.

Relative changes were not calculated for weekly means as the large week to week variability would be even more excessive for relative values. Relative changes were calculated for three-week means, and both the station values and average regional values for Washington and Oregon are presented in Tables 2 and 3. Average changes for western Washington and eastern Washington have been calculated although the number of western Washington stations is admittedly small. Figure 6 presents a plot of the relative changes for western Washington and eastern Washington, and Figure 7 presents similar data for Oregon. Figure 8 presents subtracted (eastside-westside) relative changes for both Washington and Oregon. From

Table 2

Relative Change in Three-Week Means of Precipitation in Washington, 1931-1960

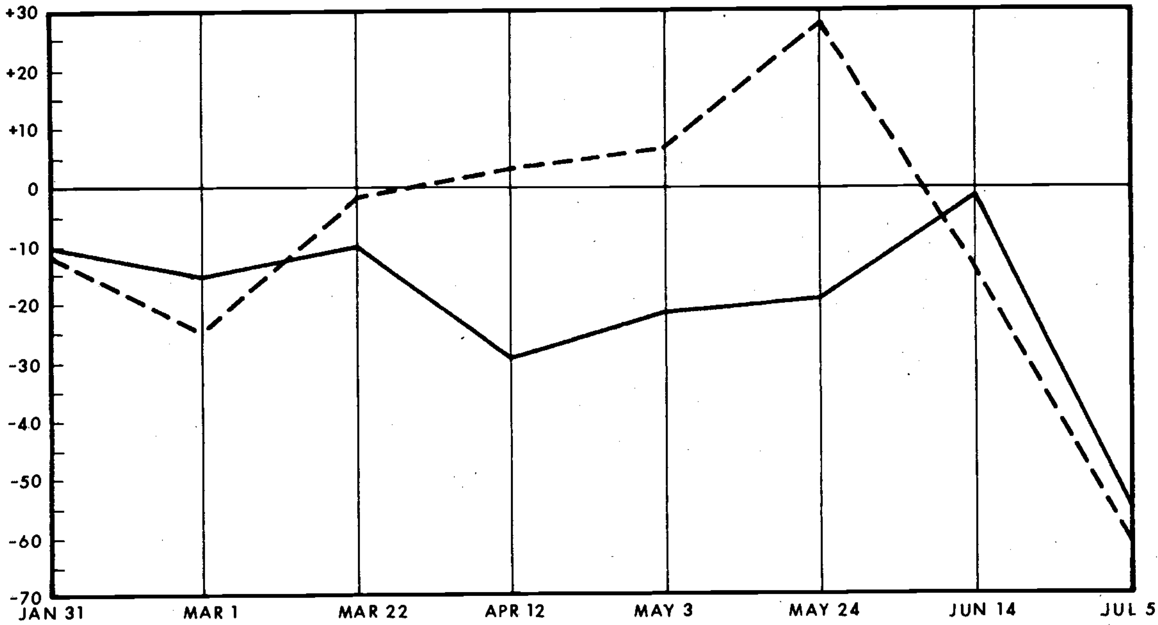
	Jan. 31	Mar. 01	Mar. 22	Apr. 12	May 03	May 24	June 14	July 05
Western Washington								
Aberdeen	-10	-21	-15	-26	-34	-31	- 4	-46
Longview	+ 1	-23	- 7	-38	-10	-15	- 7	-61
Puyallup	-13	-21	- 6	-24	-24	-21	- 0	-50
Sedro Wooley	-15	0	-13	-21	-20	-10	+19	-60
Average	-10	-16	-10	-29	-22	-19	- 2	-55
Eastern Washington								
Omak	-14	-48	+16	+ 6	- 9	+77	-38	-59
WallaWalla	-10	-15	+ 3	- 2	- 4	- 6	-29	-79
Spokane	-13	-17	-30	+ 6	+17	+ 7	-35	-67
Colville	-22	-66	+ 0	+ 9	+29	- 3	-13	-19
Ellensburg	- 5	-48	+22	-31	+11	+44	-30	-76
Ephrata	- 9	- 7	-30	+30	-10	+40	+41	-55
Average	-12	-25	- 3	+ 3	+ 6	+27	-15	-60

Table 3

Relative Change in Three-Week Means of Precipitation in Oregon, 1931-1960

	Jan. 31	Mar. 01	Mar. 22	Apr. 12	May 03	May 24	June 14	July 05
Western Oregon								
Forest Grove	- 3	-31	-18	-41	-24	-19	-23	-60
Eugene	- 1	-29	-22	-33	-17	-13	-29	-84
Parkdale	-11	-81	-45	-10	-26	-42	-16	-31
Salem	- 4	-34	-13	-37	-10	-33	-15	-74
Seaside	0	-26	-10	-32	-36	-19	0	-56
Average	- 3	-40	-20	-30	-22	-25	-16	-62
Eastern Oregon								
Bend	-20	-45	- 4	- 6	+40	+60	-45	-50
Baker	+80	-59	- 6	+ 3	+25	+45	-35	-69
Squaw Butte	- 2	-25	- 2	-23	+90	+ 4	-27	-83
Union	+43	- 8	+31	+ 1	+13	+22	-28	-76
KlamathF.	-16	-37	- 4	-15	+ 4	+20	-33	-62
JohnDay	- 8	- 2	+ 2	0	+39	- 3	-44	-75
Lakeview	- 2	-25	- 6	-12	+10	+30	-48	-80
Average	+ 7	-29	+ 2	- 7	+22	+28	-36	-70

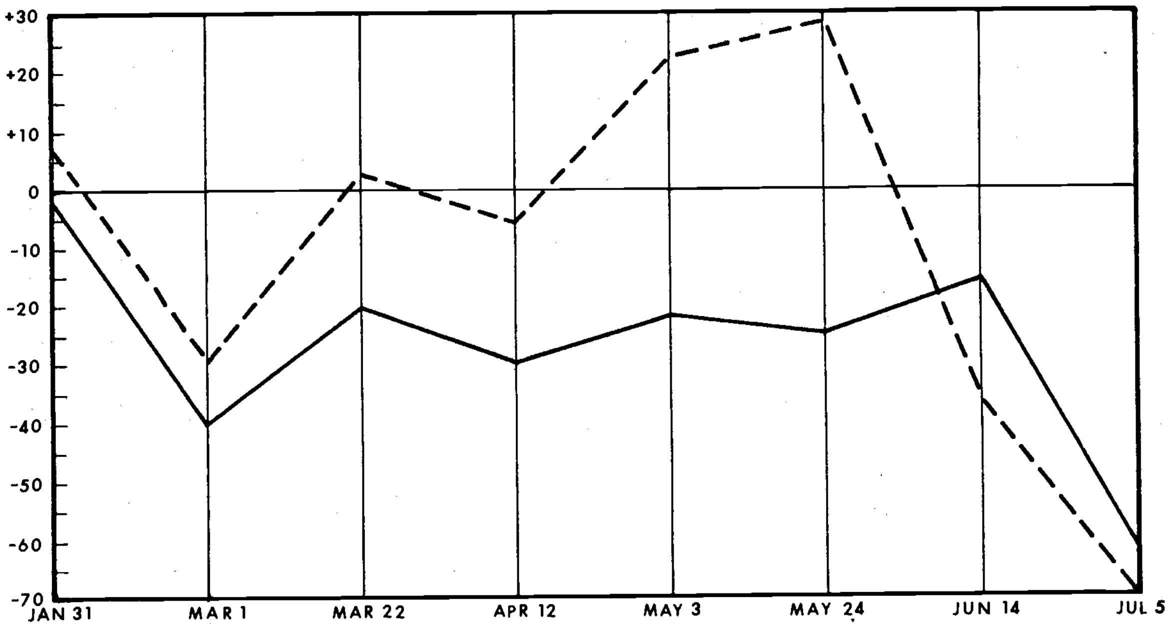
WASHINGTON: THREE WEEK PERCENTAGE CHANGE IN PRECIPITATION



EAST SIDE DIVISION (dashed line): Colville, Ellensburg, Ephrata, Omak, Spokane, Walla Walla

WEST SIDE DIVISION (solid line): Aberdeen, Longview, Puyallup, Sedro Walley

OREGON: THREE WEEK PERCENTAGE CHANGE IN PRECIPITATION

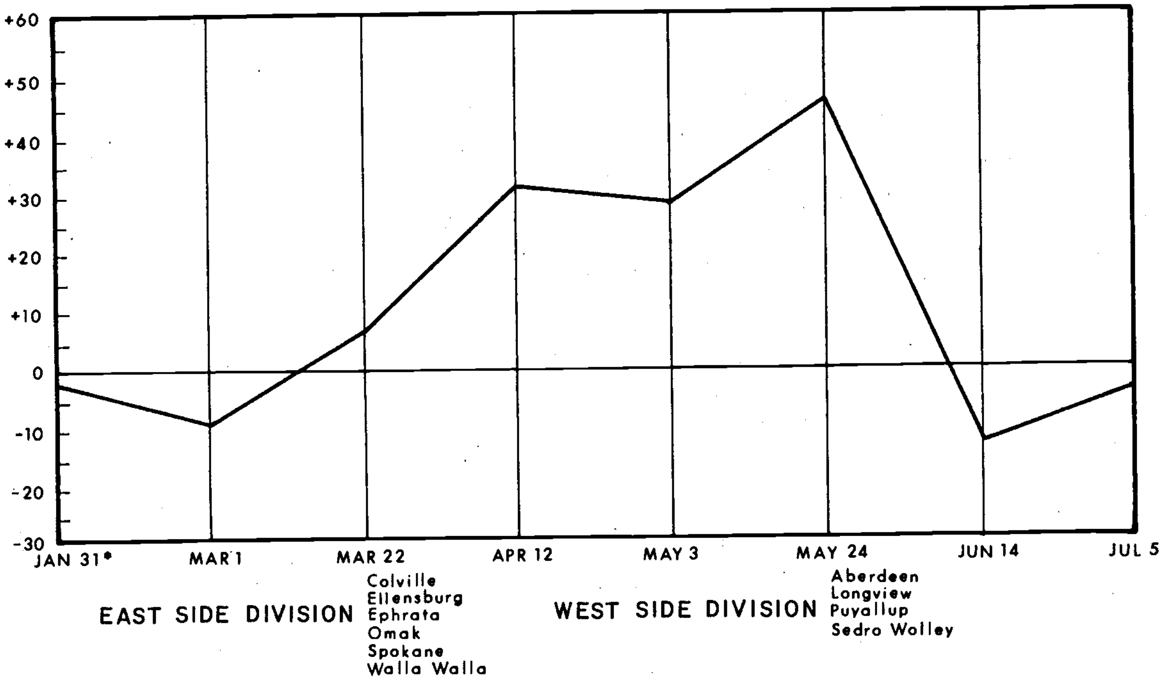


EAST SIDE DIVISION (dashed line): Baker, Bend, John Day, Lakeview, Klamath Falls, Squaw Butte, Union

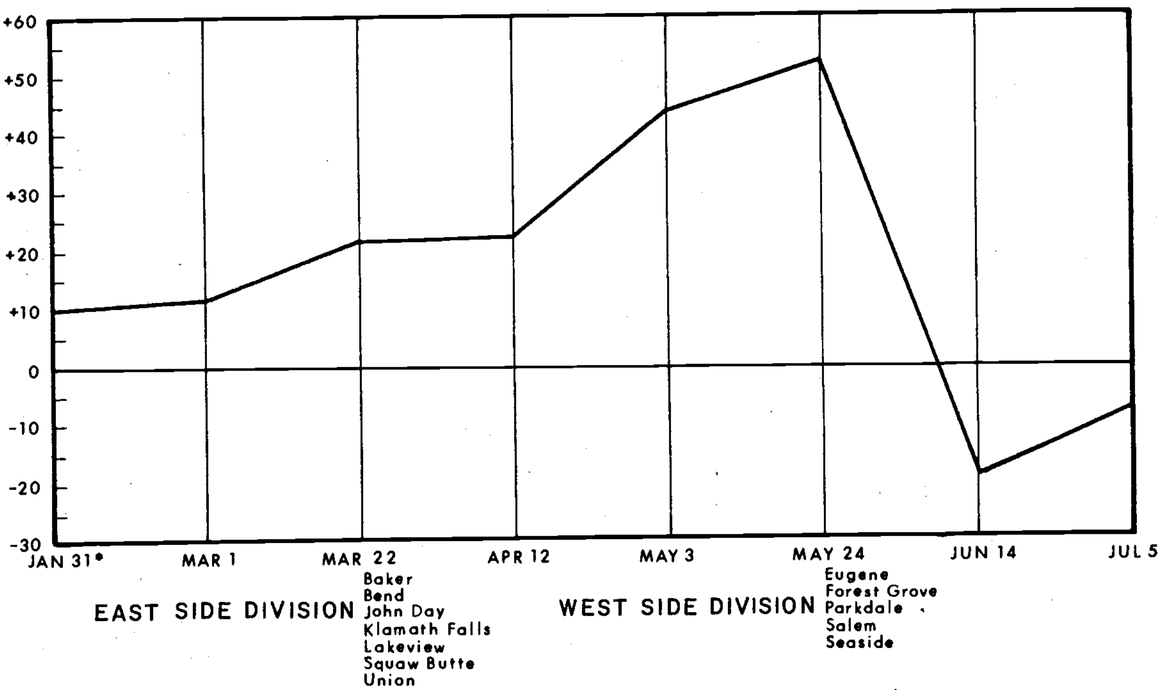
WEST SIDE DIVISION (solid line): Eugene, Forest Grove, Parkdale, Salem, Seaside

FIGURE 6 & 7

WASHINGTON: COMBINED THREE WEEK PERCENTAGE CHANGE IN PRECIPITATION (EAST SIDE-WEST SIDE=)



OREGON: COMBINED THREE WEEK PERCENTAGE CHANGE IN PRECIPITATION (EAST SIDE-WEST SIDE=)



*Data point is for indicated three week interval divided by previous three week interval.

FIGURE 8

January through March 22 both westside and eastside stations change at about the same rates, differing by less than 10%. Significant differences in the rate of change appear by March 22 through April 12 and increase to a maximum from May 24 through June 14. Throughout this period the sign of the west to east gradient is positive, indicating increasing precipitation yields on the eastside. From June 14 through July 23 the west to east gradient rapidly diminishes and actually reverses sign, indicating slightly increased relative yields for the west.

The use of short term means in order to discern temporal details of precipitation climatology can only be as physically significant as the consistency, both regionally and temporally, of the repetitive existence of that mean. A trade-off exists between short term precision and actual expectancy.

C. Analysis of Monthly Changes in Precipitation Intensity for Selected Stations in the Pacific Northwest

Monthly precipitation intensity statistics have been calculated for selected Pacific Northwest in "Volume II, Columbia Basin Handbook, Columbia Basin Inter-Agency Commission, 1969." In Figure 9, the percentage of precipitation days on which selected precipitation amounts occurred has been calculated for three Oregon stations for the months of February through July. Newport, Oregon was selected as a representative westside station. Bend and Redmond were selected as representative eastside stations strongly reflecting the secondary maximum of precipitation.

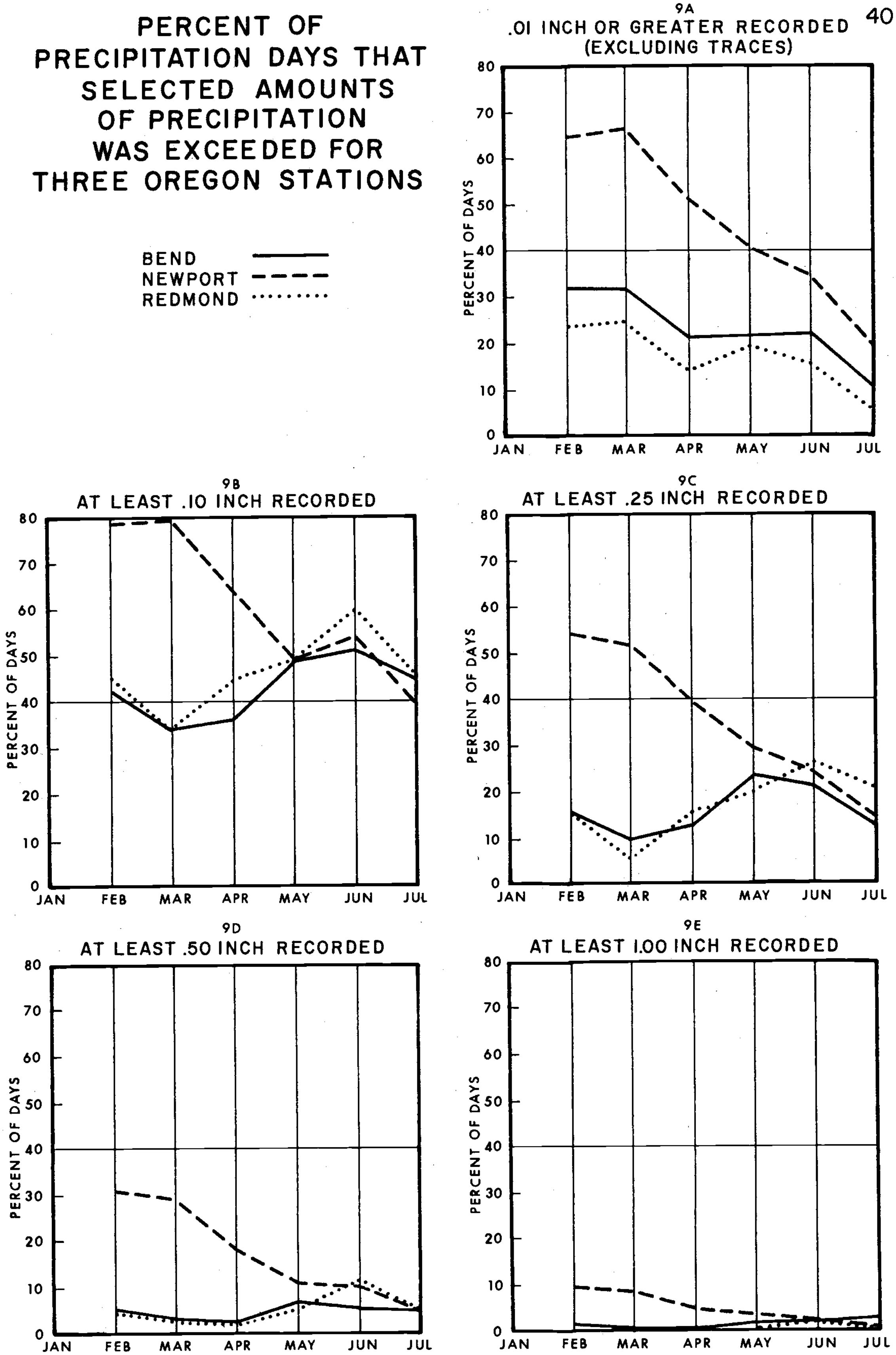
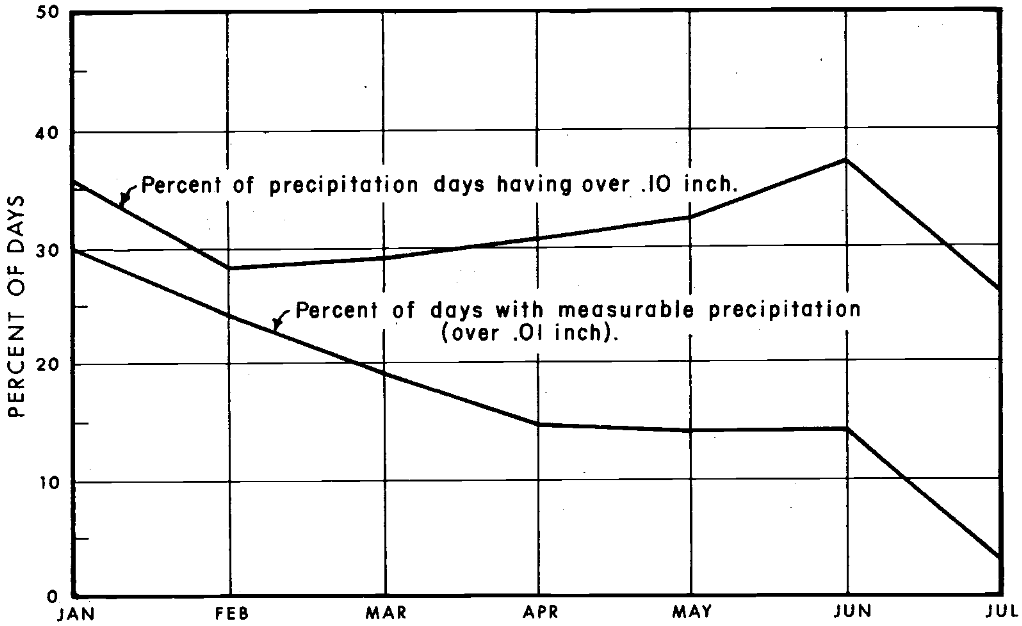

PERCENT OF PRECIPITATION DAYS THAT SELECTED AMOUNTS OF PRECIPITATION WAS EXCEEDED FOR THREE OREGON STATIONS
BEND
NEWPORT
REDMOND
9A
.01 INCH OR GREATER RECORDED (EXCLUDING TRACES)
9B
AT LEAST .10 INCH RECORDED
9C
AT LEAST .25 INCH RECORDED
9D
AT LEAST .50 INCH RECORDED
9E
AT LEAST 1.00 INCH RECORDED
PERCENT OF DAYS
0
10
20
30
40
50
60
70
80
JAN
FEB
MAR
APR
MAY
JUN
JUL

FIGURE 9

PRECIPITATION OCCURRENCES FOR HANFORD, WASHINGTON



PERCENT OF PRECIPITATION DAYS EQUALING STATED AMOUNTS

	J	F	M	A	M	J	J
.01"	53%	58%	50%	45%	50%	50%	50%
.10"	18	17	18	18	20	20	25
.25"	6	8	4.5	4.5	10	10	10
.50"	3	4	4	4.5	5	5	0
1.00"						5	

FIGURE 10

In Figure 9A, the percentage of precipitation days (days .01 inches) for each month has been calculated for February through July. Newport and Redmond-Bend indicate a slower rate of decrease through the period with relatively constant values in the May-June period.

In Tables 9B through 9E, the percentage of precipitation days for which selected precipitation amounts have been exceeded is plotted for the period of February through July. In these graphs of the moderate to heavy intensity interval, the change in the precipitation delivery of the interior, both temporally and regionally, is quite apparent. Percentages of all precipitation intensity intervals decrease throughout the period for western Oregon, with the exception of a small increase in June in the .10 inch intensity interval.

Bend and Redmond indicate large increases for all precipitation intensity intervals for the March through June period. In the May and June period the percentage of days in the moderate to heavy intensity interval is as high or higher for Bend and Redmond than it is for Newport, despite the fact that Newport exhibits a greater number of total precipitation days.

The change in the precipitation delivery characteristics of late spring sotrm events is verified by data compiled at Hanford, Washington, by Battelle Pacific Northwest Laboratories (Stone, Jenne, and Thorp, 1972, p. 4.1-4.8). The Hanford-Richland site is the driest area of the Pasco basin of eastern Washington with annual totals on the order of 6.5 inches. The annual profile shows a decided winter maximum and a well developed secondary maximum in June. If one calculates the percent of days in which measurable precipitation occurs, the secondary maximum is hardly apparent (Fig. 10). The number of precipitation days decreases through the January through July period. If the percentage of precipitation days is plotted for each month in which .10 inches is exceeded, the nature of the secondary maximum becomes apparent. A large increase in the percent of precipitation days delivering higher intensity rainfall exists in the April through June period. Also included in Figure 10 is the percentage of precipitation days in which higher intensity (.25 inches, .50 inches and 1.00 inch) rainfall occurs. The increase of high intensity rainfall in May and June is quite apparent.

In summary, the increase in mean monthly precipitation in May and June which characterizes much of the Pacific Northwest interior is not accompanied by a significant increase in precipitation days. The secondary maximum is a consequence of the increase in moderate to heavy intensity rainfall per precipitation event. The meteorological process which produces the increase in precipitation yield are strongly organized regionally west to east and imply that diabatic processes are occurring on the eastside at this time at a greater rate than west of the Cascade Mountains.

D. Relative Changes in Mean Precipitation for the Pre-1931-1960 Normal Period

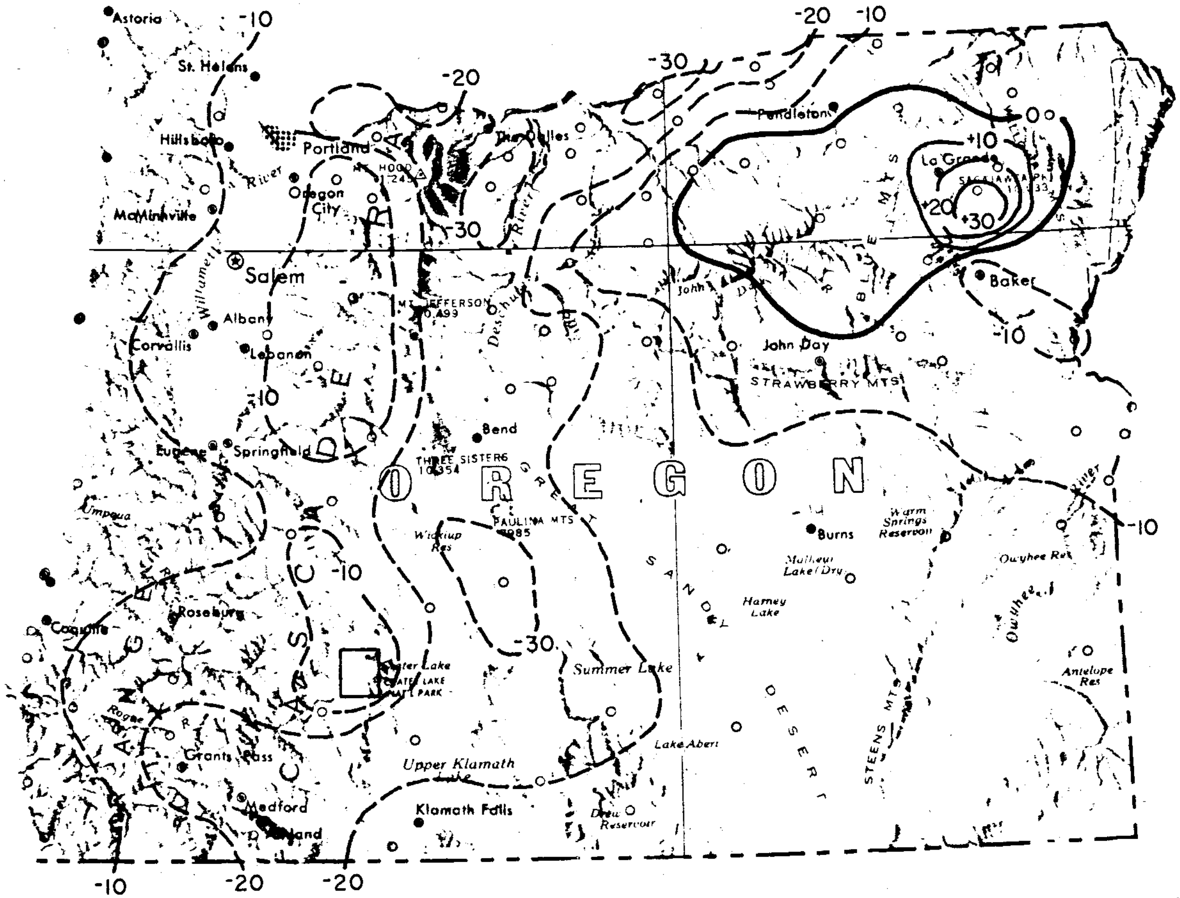
Bryson has noted the standard normal period (1931 to 1960), is quite atypical in the last thousand years of the climatological record (Bryson, 1972, p. 754-755). The secondary maximum of precipitation of the interior of the Pacific Northwest may well have organizational characteristics which are unique to the 1931-1960 period. An attempt was made to assess the regional organization as distinct from the purely temporal organization by examining precipitation means for an earlier period.

Precipitation means were available for Oregon stations derived from a variable mean period prior to 1934 (Climatological Data, 1940). The reliability of the precipitation means derived from the earlier period is more questionable due to variable length average period, inadequate station density, and poorer recording techniques (Court, 1960, p.4023). Comparison with the more complete 1931-1960 period can therefore be only qualitative and broad in scope.

Maps 7 through 10 show relative changes in mean precipitation for the period February through June derived from the earlier period of record. The most notable differences in the two periods occur in the March to April period and the May to June period.

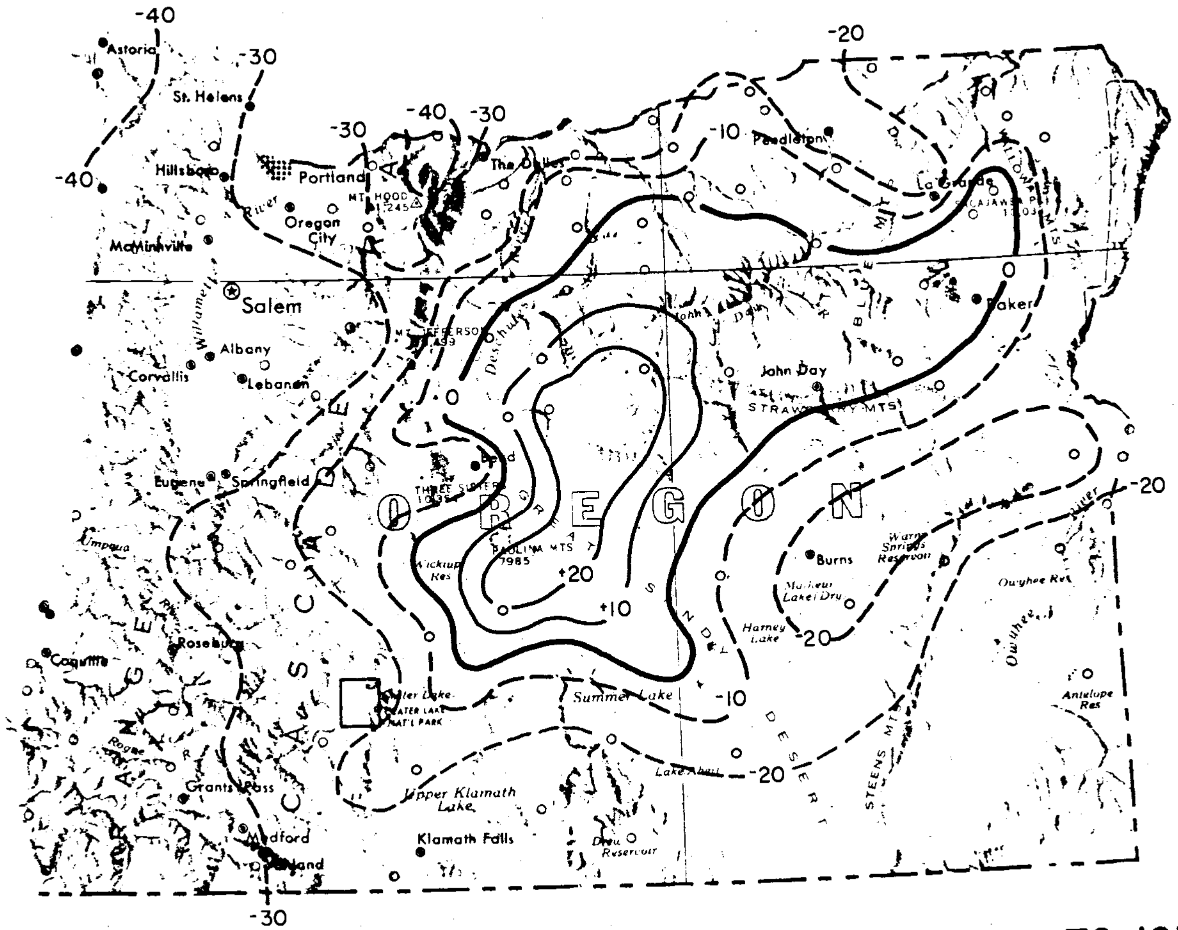
The large decreases in mean precipitation throughout the Pacific Northwest from March to April may partially reflect conditions unique to the 1931-1960 period. Table 4 presents subtracted 1930-1960 percentage changes in precipitation from 1934 percentage changes for various climatological divisions of Oregon. The earlier period averages about +5% to +10% above the 1931-1960 period.

In the earlier period all westside stations indicate moderate decreases on the order of -30%, and over 80% of the eastside stations of Oregon indicate decreasing means on the order of -10% to -20%. Several areas of significantly increasing means do exist in the Redmond, Prineville and Dayville area and thehigh plateau, including



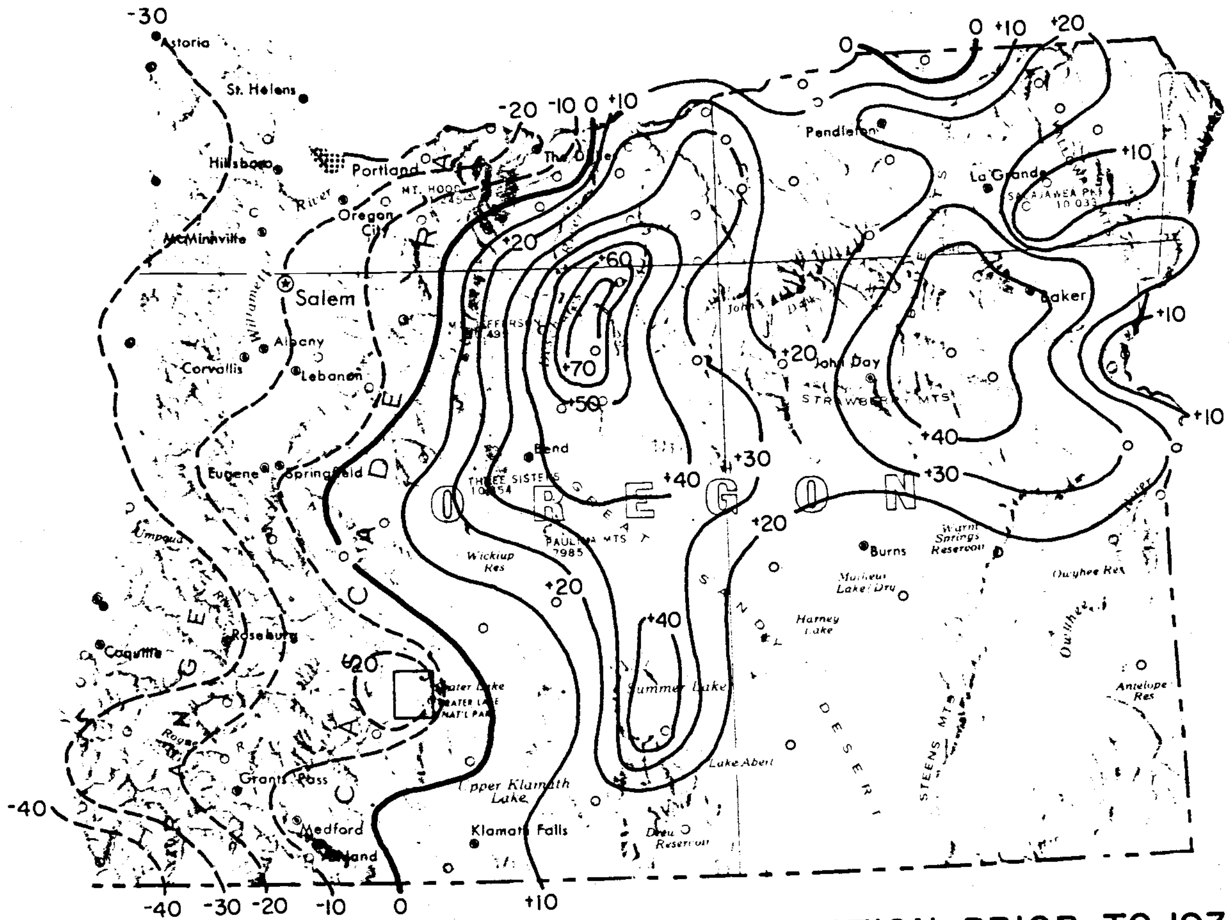
RELATIVE CHANGE IN MONTHLY PRECIPITATION PRIOR TO 1934 —
FEBRUARY TO MARCH

MAP 7



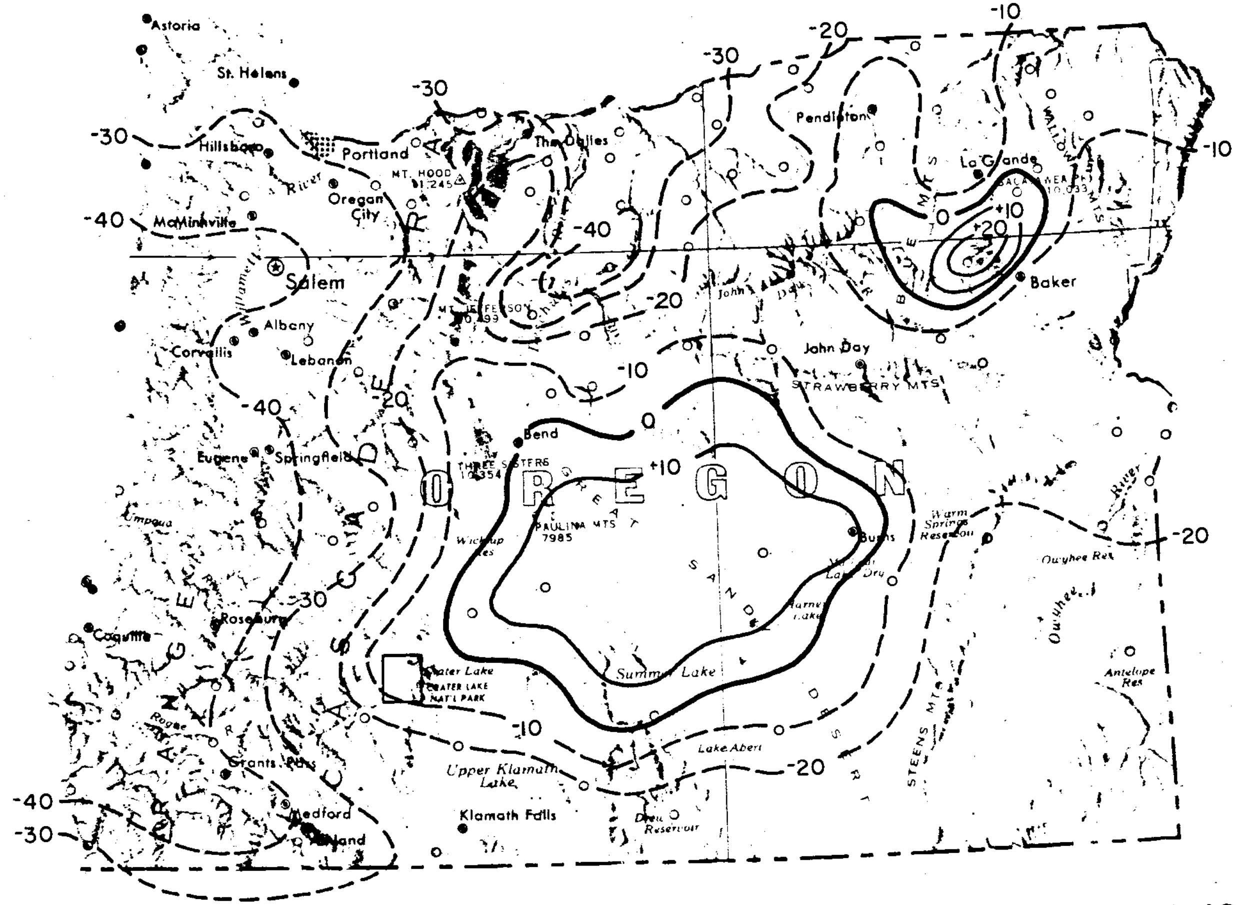
RELATIVE CHANGE IN MONTHLY PRECIPITATION PRIOR TO 1934—
MARCH TO APRIL

MAP 8



RELATIVE CHANGE IN MONTHLY PRECIPITATION PRIOR TO 1934—
APRIL TO MAY

MAP 9



RELATIVE CHANGE IN MONTHLY PRECIPITATION PRIOR TO 1934–
MAY TO JUNE

MAP 10

Fremont and Round Grove. Interestingly, the 1931-1960 period shows the smallest decreases in the Redmond-Prineville area. Small increases are also noted in the Baker-Union area of northeastern Oregon for both the 1931-1960 period and the 1934 means.

It is apparent that processes which will produce increasing means from April to May over most of eastern Oregon and will be most intensely developed in the Redmond-Prineville area are being initiated in that region as early as April.

In the period from May to June some significant discrepencies exist between the two normal periods. In the 1934 period the basic west to east organizational structure is still present, but both west and eastside stations show more negative tendencies. Westside stations have values on the order of -30% to -50% while eastside stations have values on the order of -30% to +20%. It would appear that prior to 1934, the secondary spring maximum in Oregon initiated earlier in the season in March to April and terminated sooner in May to June compared to the period 1931-1960. The slightly higher spring (March-April-May) termperature of the 1910-1935 period is not inconsistent with this observation (Table 5).

Table 4

Oregon March to April Relative Changes in Precipitation:
Subtracted 1931-1960 Normals from Prior to 1934 Normals

Climatological Division	1934 - (1931-1960)
Northeast, 8 stations	+ 1.5%
Southcentral, 9 stations	+12%
Northcentral, 11 stations	+ 5%
High Plateau, 6 stations	+ 6%
Willamette Valley, 8 stations	+14%
Coastal, 6 stations	+10%

Table 5

Mean Monthly Temperatures for Hanford, Washington

Average Period	March	April	May	June
1912-1934	46.3^0 F	53.9^0 F	61.6^0 F	69.8^0 F
1930-1960	44.2^0 F	52.5^0 F	61.7^0 F	69.2^0 F

Chapter III

MEAN MONTHLY CIRCULATION PATTERNS OF SEA LEVEL ATMOSPHERIC PRESSURE AND 500 MILLIBAR HEIGHTS FOR CLASS A AND B PRECIPITATION EVENTS

The secondary spring maximum of precipitation in the interior of the Pacific Northwest is the result of increased moderate and high intensity precipitation events in the May through June period. Surface and upper air atmospheric circulation should manifest changes in organization during this period which reflect increased dominance of the more unstable sectors of traveling surface and mid-tropospheric disturbances.

In examining mean monthly surface, 700 millibar, and 500 millibar pressure maps, certain difficulties arise. The total array of synoptic patterns incorporated to produce a monthly mean will be strongly biased by the large number of non-precipitation events. The averaging of migratory mid and upper level tropospheric wave disturbances tends to highly zonalize (ie, orient from west to east) the mean pattern of flow, removing much of the actual latitudinal (north-south) flow characteristics. Monthly and five day mean pressure maps are available for sea level, 700 millibars and 500 millibar for North America (Lahey, et al., 1969; Lahey, Bryson and Wahl, 1958). These maps adequately detect the progressive weakening of the midlatitude pressure gradient through the spring months. The poleward migration of the Pacific subtropical anticyclone during the late June period is also readily detected (Lahey, et al., 1958, Map A - June 25-29). However, very little information can be deduced with respect to seasonal changes in the flow characteristics of individual precipitation producing disturbances.

In order to more clearly ascertain the flow characteristics of precipitation producing synoptic patterns, monthly mean surface and 500 millibar precipitation pressure maps were derived utilizing six years of U.S. Weather Bureau synoptic maps (Daily Weather Map, NOAA, 1967-1972). Precipitation events were defined by stations east of the Cascade Mountains in Washington and Oregon which were recording precipitation at the time of the plotted surface map; either 4 A.M. or 4 P.M., P.D.T. Utilizing the twelve first order stations in the interior of Oregon and Washington, precipitation events were arbitrarily stratified into classes A, B, C, and D. The criteria for classification were: class A (6 or more stations recording measurable precipitation); class B (4 to 5 stations recording measurable precipitation); class C (2 to 3 stations recording measurable precipitation); and class D (only 1 station recording measurable precipitation). Class A and B events were more representative of extensive precipitation producing events over the interior and in many cases class C and D events reflected rather isolated regional shower activity or initiating and terminating phases of more extensive precipitation systems. Therefore, only class A and B events were utilized to derive mean surface and 500 millibar circulation maps. Synchronous maps for both 500 millibar and surface pressure were available only for the period of 1967 to 1972, so the data source included only six years.

The maps derived are mean surface and 500 millibar circulation patterns for precipitation events only. In Appendix C, Map 1 includes representative arid circulation patterns over the Pacific Northwest for the months of March through June. These have been included only as comparative examples of arid synoptic patterns for these respective periods of the year.

Surface and 500 millibar maps were derived for the months of March, April, May and June for a latitude grid of 35^{0} N to 50^{0} N and longitude grid of 115^{0} W to 130^{0} W. Pressure data were plotted from each map at $2\frac{1}{2}^{0}$ intersections of latitude and longitude. Small to moderate variations in axial position and amplitude characteristics of individual disturbances tend to produce strong west to east (zonal) characteristics in the mean flow patterns so the maps derived have strong west to east biases which would not be as pronounced in the individual disturbances. Five hundred millibar isotherms were plotted utilizing an interval of 5^{0} C.

In order to assess the magnitude of latitudinal and meridional transport characteristics of 500 millibar flow patterns, wind directions and velocities were tabulated at each $2\frac{1}{2}^{0}$ grid point. Mean wind velocities and resultant wind direction were then calculated for each grid point. The amplitude characteristics of the 500 millibar waves are more realistically identified by the resultant wind directions than by inferred geostrophic winds produced by averaging 500 millibar height contours (Conrad, 1962, p. 178-180).

Cyclonic curvature between 130^{0} and 115^{0} West longitude at 50^{0} N, 45^{0} N, and 40^{0} N, was calculated at 500 millibars for all class

A and B precipitation events for the months of March through June. The curvature values were calculated in degrees of rotation in the counter clockwise direction from the westernmost longitude grid points to the easternmost longitude grid point. Average curvature values were calculated for each month of March through June at 50^{o} N, 45^{o}N and 40^{o}N.

Zonal and meridional indexes can be calculated from 500 millibar height contours (Namias, 1950, p. 130-139; and Rossby, 1939, p.39). Utilizing monthly average 500 millibar heights for class A and B precipitation events, zonal/meridional height ratios were calculated for the months of March through June. These values are presented in Tables 6 and 7.

A. Average 500 Millibar Heights and Sea Level Pressures for March Precipitation Events

1. Average 500 Millibar Heights and Flow Characteristics for March

In the period from 1968 through 1972, seventeen cases of class A and B precipitation events were detected. Five hundred millibar heights, wind velocities and directions, and temperatures were tabulated and averaged for $2\frac{1}{2}^{o}$ latitude and longitude grid intersections. Wind rose data were tabulated for each 5^{o} latitude and longitude intersection.

Map 11 presents averaged 500 millibar heights for the seventeen cases. The 500 millibar flow indicates prevailing west or southwest flow across the entire Pacific Northwest during precipitation

Table 6

500 Millibar Latitudinal and Meridional Height Differences in Meters for Class A and B Precipitation Events

Latitude and Longitude Grid Points	March	April	May	June
40°N 130°W-50°N- 130°W	28.7	24.8	15.5	11.3
40°N 122½°W-50°N 122½°W	25.8	20.8	8.9	8.5
40°N 115°W-50°N 115°W	22.4	18.0	8.5	8.8
50°N 122'°W-50°N 130°W	7.6	6.5	3.5	- .6
50°N 115°W-50°N 122½°W	3.9	6.5	3.6	3.5
40°N 122½°W-40°N 130°W	4.7	2.5	-2.1	-3.4
40°N 115°W-40°N 122½°W	.5	3.7	5.6	3.8

Table 7

Zonal - Meridional Height Ratios

<u>Latitudinal Difference</u> Meridional Difference	March	April	May	June
(40°N 122°W - 50°N 122½°W 122½°W 45°N - 130°W 45°N+ 115°W 45°N - 122½°W 45°N)	2.82	1.57	1.11	1.16

events. The major trough axis is centered west of 130^{o}W longitude with a flat ridge centered at 155^{o}W longitude. Lowest heights are centered to the northwest of the grid in the Gulf of Alaska.

Five hundred millibar temperatures indicate a warm ridge centered at 177^{o}W longitude with a cold trough centered at 130^{o} W longitude. The warm ridge located in the interior indicates that precipitation is favored by strong, warm advection in the midlevels of the troposphere. Warm advection is indicated by the poleward displacement of the isotherms from 125^{o}W longitude to 117^{o}W longitude. The strong latitudinal temperature gradient is indicative of the winter position of the polar front and the prevailing west to east trajectory of migratory cyclonic disturbances.

As was previously mentioned, averaging of individual 500 millibar trough positions tend to highly zonalize the mean 500 millibar flow pattern. Individual wind direction and velocities were tabulated for the seventeen cases and are presented on Map 11. Highly variable 500 millibar wind directions typify the northernmost grid points, especially the northwesterly corner of the grid. Very consistent wind directions typify the southern noundary of the grid and is particularly true of the southwestern portion of the grid. The wind velocity data indicate that the highest wind speeds aloft are located in the southern and western sectors of the grid which implies the westerly jet maximum is commonly across southern Oregon and southern Idaho when precipitation is at a maximum in the Northwest interior. Observation of the individual seventeen cases indicated that the center of lowest pressure at 500 millibar was typically in the northern sector of the

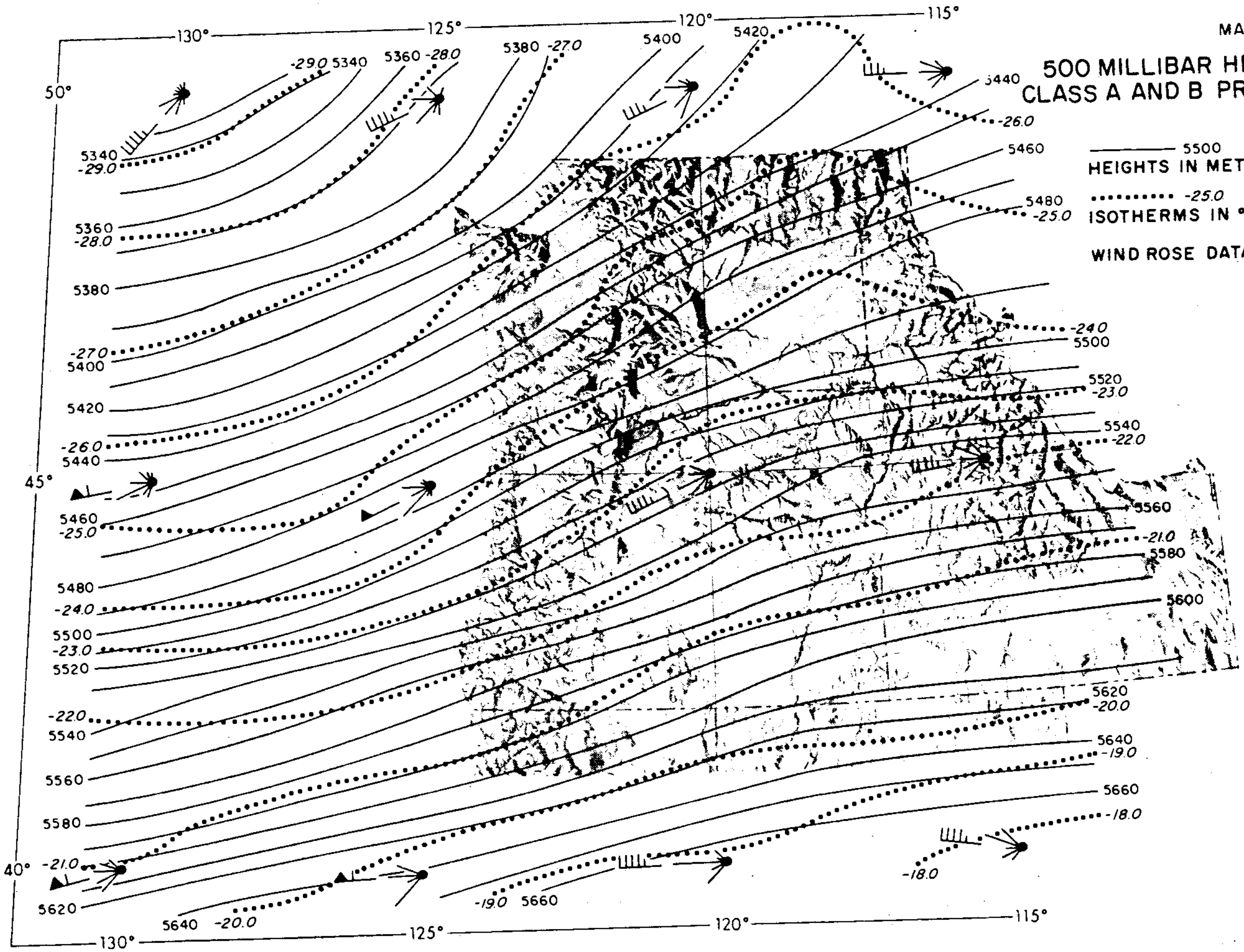
MAP II

500 MILLIBAR HEIGHTS FOR MARCH CLASS A AND B PRECIPITATION EVENTS

——— 5500 HEIGHTS IN METERS ABOVE SEA LEVEL

••••••••• -25.0 ISOTHERMS IN °C

WIND ROSE DATA BY 22 1/2° QUADRANTS



grid and that small variations in the position of the low account for the high variability of the wind directions in that sector. Regardless of the position of the upper level low, southwesterly winds dominated the southwestern portion of the grid and westerly to west-northwest winds dominated the southeastern portion of the grid.

2. Meridional and Latitudinal Transport Characteristics and Curvature Characteristics for March

In Table 6, 500 millibar height differences are presented for selected meridians and parallels. Table 7 presents ratios of latitudinal height difference divided by meridional values for the months of March, April, May and June.

The north-south pressure gradient at the three selected meridians is greater in March than any of the other three months, and is about three times the magnitude of the west to east pressure gradient. The west to east pressure gradient is strongest in the western limits of the grid with the orientation of the flow being from the south. While west to east transport is the dominant feature of the 500 millibar flow, the contribution of warm advection across the western limits of the grid is quite apparent.

Table 8 presents averaged curvature values for 130^{o}W minus 155^{o}W at latitudes 50^{o}N, 45^{o}N and 40^{o}N. Over 60% of the sixteen cases indicate anticyclonic curvature values. The dominance of weak anticyclonic flow across the meridional limits of the grid indicate that the 500 millibar trough axis is to the west of the western limit of the grid and the ridge axis is slightly to the west of the eastern limit of the grid. Precipitation in the interior Northwest is associated with strong southwesterly flow at 500 millibars offshore and across the Pacific coast, with more westerly or even northwesterly flow dominating the interior and eastern sectors of the grid. The absolute magnitude of the curvature values are small, indicating that large changes in the direction of flow across the grid are not common. Waves with large amplitude characterize the flow at 500 millibars in March with southwesterly and westerly flow dominating the entire Northwest. Precipitation is maximized for upper level disturbances which are dominated by strong warm advection at 500 millibars across the entire Pacific Northwest region.

Table 8

Curvature Values in Degrees of Rotation

	(130°W Longitude - 115°W Longitude) for Respective Latitudes					
	50°N	45°N	40°N	Avg.	Frequency Anti-cyclonic	Frequency Cyclonic
March 17 cases	-10.7	- 2.0	-20.1	-10.9	32	19
April 20 cases	- 1.0	+20.0	+13.0	+ 7.4	28	32
May 19 cases	+100.5	+85	-172.1	+86.1	2	55
June 16 cases	+108	+98	+ 58	+88	2	52

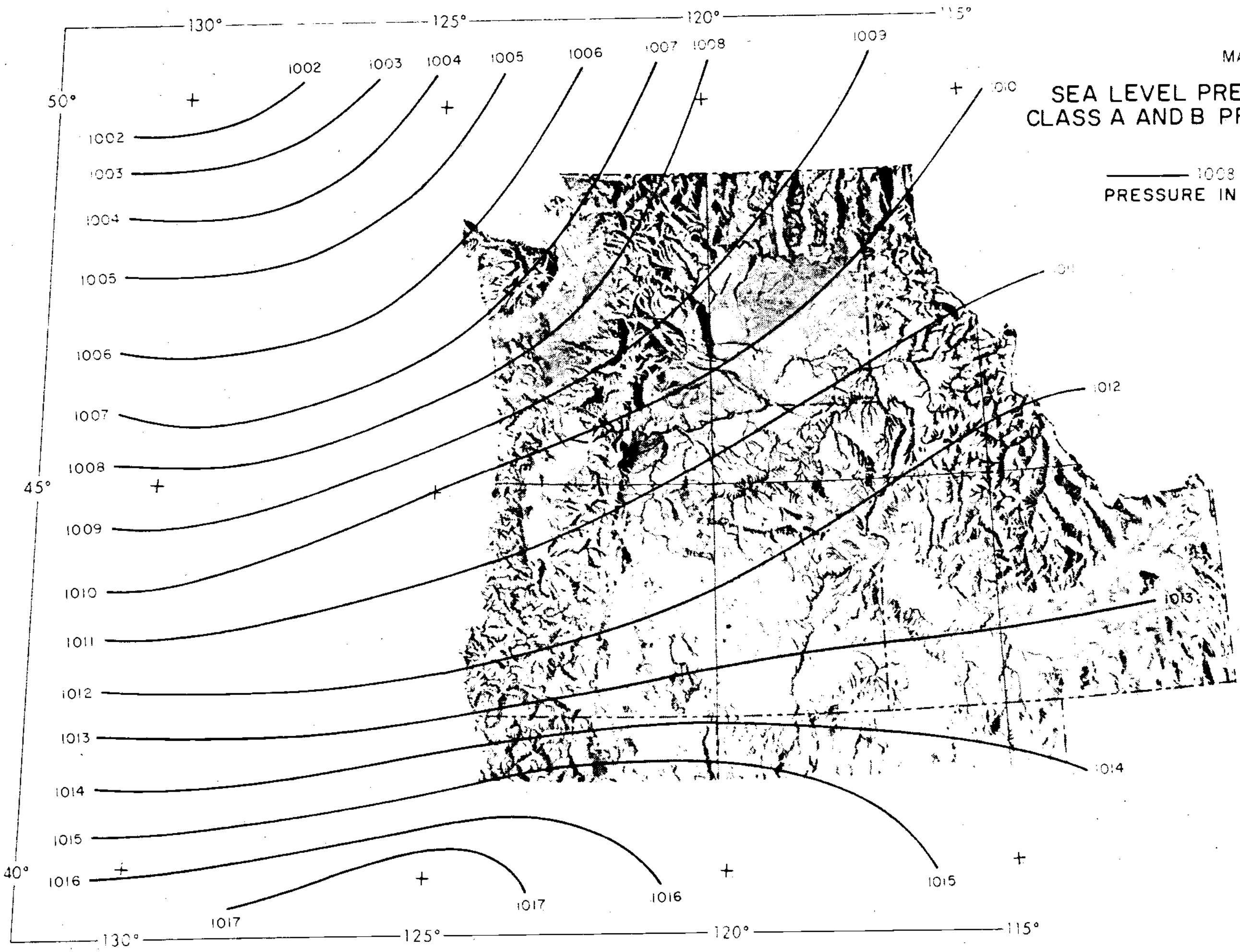
3. Average Sea Level Surface Pressure for Class A and B Events for March

Utilizing 1968 through 1972 synoptic weather maps, fourteen cases of class A and B precipitation events were detected. Map 12 presents average sea level pressure for the 14 cases. While the variable positions of surface troughs introduce strong west to east orientation to the isobars, some salient features can be detected. Lowest pressure is typically northwest of Vancouver Island and a southwest to northeast orientation of isobars exists across the states of Washington and Oregon. Sea level pressure averages higher in the interior than offshore, indicating that most cyclonic storms which produce precipitation in the interior tend to be centered offshore. The wintertime oceanic and continental heat budget, which produces cool interior temperatures and warmer oceanic temperatures, favors the persistence of higher pressure in the interior despite the advection of warmer air into the interior aloft during precipitation events.

The existence of the Pacific High pressure system can be identified by the ridge of high pressure across northwestern California and the initial stages of the southwest desert heat low can be detected by the slightly lower pressure in eastern Nevada. While the orientation of the flow across the entire Pacific Northwest is from the southwest, the major trough axis is centered well offshore. Individual examination of the 14 cases of precipitation occurrence indicated that precipitation was often associated with the passage of a Pacific occluded front in the interior with an associated minor

MAP 12

SEA LEVEL PRESSURE FOR MARCH CLASS A AND B PRECIPITATION EVENTS



——— 1008 PRESSURE IN MILLIBARS

trough of low pressure. Lowest pressure typically remained offshore and with the variability of the position of the occluded front in the interior, the associated minor trough was effectively removed in the averaging of the fourteen cases.

B. Average 500 Millibar Heights and Sea Level Pressure for April Precipitation Events

1. Average 500 Millibar Heights and Flow Characteristics for April

Twenty cases of class A and B precipitation were identified for the month of April. Map 13 presents averaged 500 millibar heights for the twenty cases in the Pacific Northwest. The height pattern is quite similar to the March pattern, although the latitudinal pressure gradient is weaker, reflecting the beginning of normal spring seasonal warming.

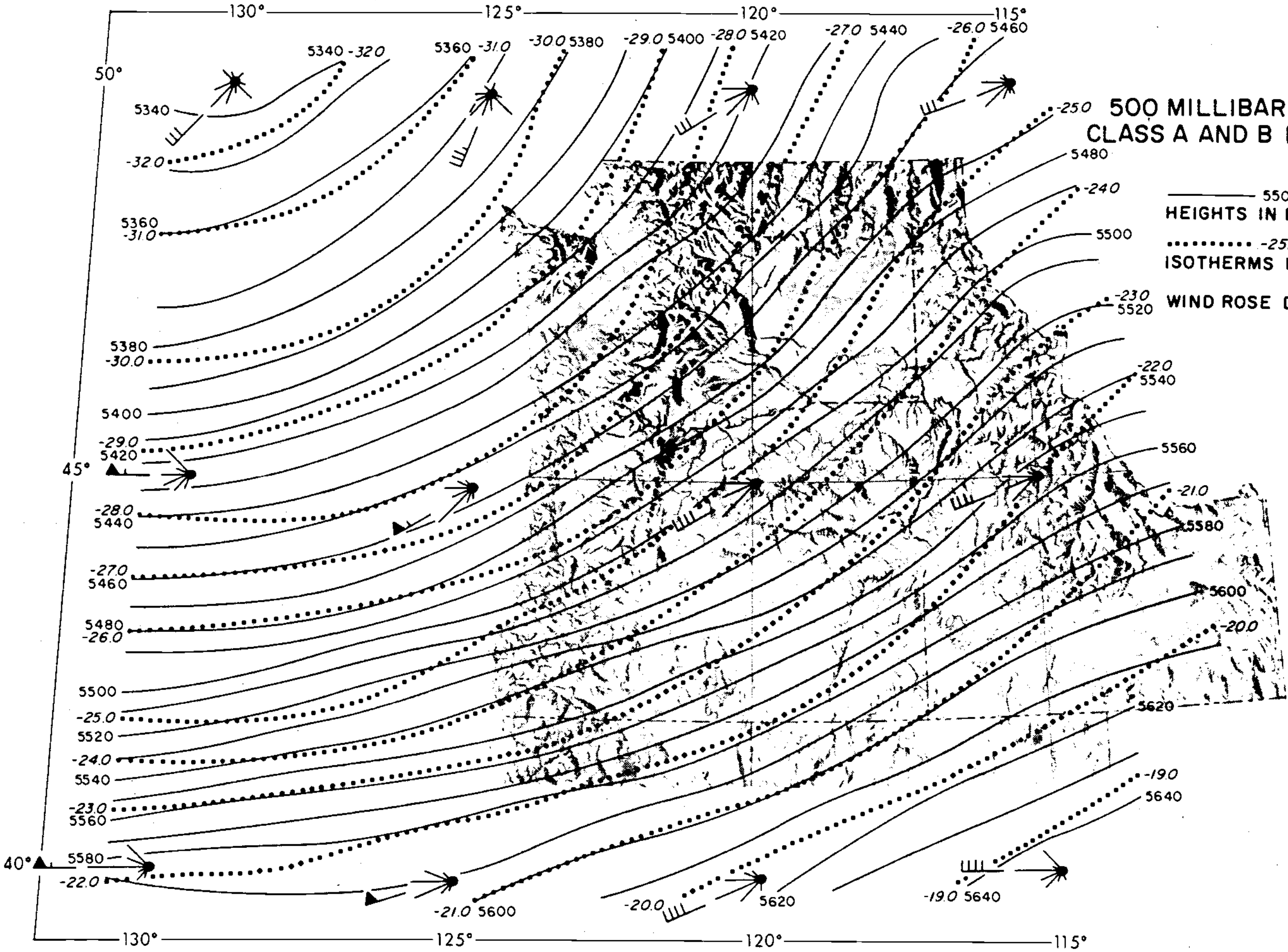
The 500 millibar height contours indicate prevailing west-southwest flow dominating the Pacific coast and offshore and more southwest to south flow dominating the interior and eastern sectors of the grid. Lowest pressure continues to be in the northwestern sector of the grid.

The major long wave trough axis is still to the west of 13o^{O}W longitude although the ridge axis is now centered to the east of 115^{O}W longitude. The amplitude of the major long wave has increased from the March pattern, but one half a wave length is still outside the meridional limits of the grid.

Five hundred millibar temperatures are plotted on Map 13. The isothermal pattern at 500 millibars in April is similar to the March

MAP 13

500 MILLIBAR HEIGHTS FOR APRIL CLASS A AND B PRECIPITATION EVENTS



——— 5500
HEIGHTS IN METERS ABOVE SEA LEVEL

•••••••••• -25.0
ISOTHERMS IN °C

WIND ROSE DATA BY 22 1/2° QUADRANTS

pattern with poleward displacement of the isotherms from west to east across the grid. The poleward displacement of the isotherms in the eastern portion of the grid indicates that cool air is being advected into a region with warmer temperatures aloft.

2. Meridional and Latitudinal Transport Characteristics And Curvature Characteristics for April

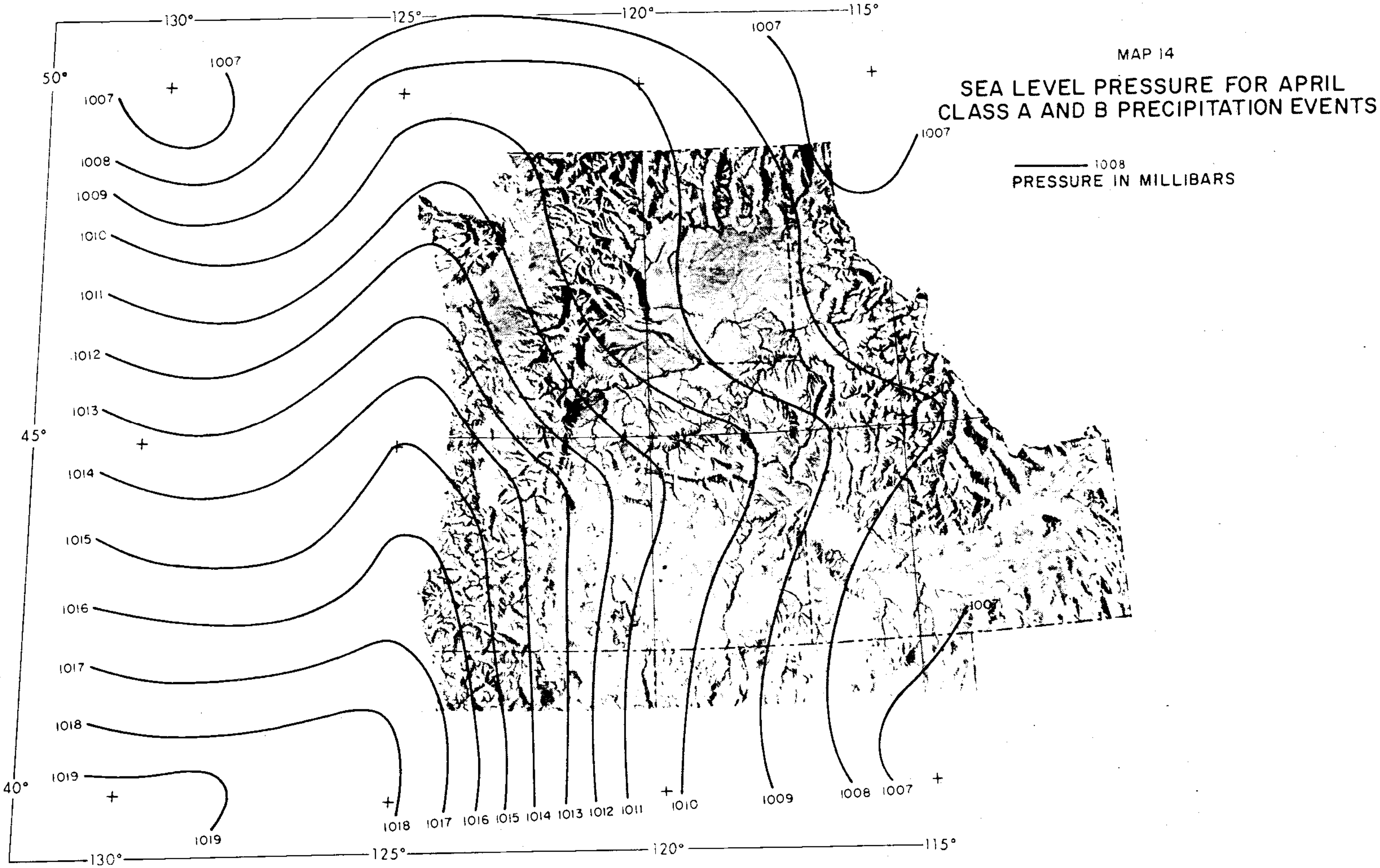
Tables 6 and 7 indicate that strong westerly flow is quite dominant in April with only small decreases in north-south 500 millibar heights from March values. The west to east pressure gradient has not decreased significantly, indicating that north-south transport is of the same magnitude as in March. In fact, it has increased slightly in the eastern sector of the grid. The latitudinal/meridional height ratio reflects this change as having decreased from 2.82 to 1.57.

Table 8 presents averaged curvature values for the individual precipitation events for April. Curvature values indicate approximately equal distribution of cyclonic and anticyclonic flow. Average values indicate that weak cyclonic flow is predominant, but that the values are small in magnitude. Interestingly, the cases which are dated before the 15th of the month are more frequently anticyclonic while those occurring after the 15th are more frequently cyclonic. April appears to be a transition month from the predominantly wintertime flow pattern in March, and the strong cyclonic flow which will dominate the later months of May and June.

3. Average Sea Level Surface Pressure for Class A and B Events for April

Map 14 presents averaged class A and B events of sea level pressure for the month of April for the Pacific Northwest. Significant changes have occurred in the pattern in comparison to the March map. The orientation of the isobars has taken on strong north-south character in contrast to the prevailing west to east orientation in March. A surface ridge of high pressure dominates the Pacific coast with strong northwest to southeast flow immediately to the east of the Cascades and a trough of low pressure centered over Nevada and a weaker trough over western Montana and southeast British Columbia. A trough of low pressure remains to the northwest of Vancouver Island with westerly to southwesterly flow dominating the offshore region to the west of the ridge located on the Pacific coast.

In the averaging of individual synoptic events, large variability in the position of migrating frontal systems and associated troughs, tends in the mean to only very subtly reflect the intensity of the migratory surface disturbances in the interior. April is a transition period in which both wintertime and later spring synoptic controls are operative. The low pressure to the northwest of Vancouver Island and the prevailing west-southwest flow offshore is a wintertime feature indicative of the normal winter deep low pressure in the Northeast Pacific. The ridge of high pressure extending from southwest to northeast across California and southwest Oregon, is indicative of the poleward migration of the Pacific high which will eventually dominate the entire Pacific Northwest in summer. The low pressure over Nevada is most likely the initial stage of the semi-permanent desert heat low which will be well established east of the Sierra


MAP 14
SEA LEVEL PRESSURE FOR APRIL
CLASS A AND B PRECIPITATION EVENTS
1008
PRESSURE IN MILLIBARS
130°
125°
120°
115°
50°
45°
40°
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019

Nevada Mountains by mid summer (Jurwitz, 1953, p. 96-99; Bryson and Lowry, 1955, p. 329-339). The lower pressure in the northeast portion of the grid is most likely indicative of migratory surface frontal systems and associated surface troughs. Southwest flow and low pressure will typically dominate west of the Cascades, while in the interior a frontal or short wave impulse is crossing the interior region at the time of actual precipitation.

The orientation of isobars indicates that northwesterly flow dominates the interior during precipitation events. The examination of actual precipitation occurences reveals that this is not entirely the case. Typically, precipitation is associated with a migratory frontal or short wave impulse moving across the interior. Northwest flow and a surface ridge of high pressure dominates the post cold front or cold occlusion sector, and southwest or even southerly flow dominates the precold frontal sector in which most precipitation is occurring. The variability in position of these disturbances tends to mask their amplitude on the mean map and prevailing northwesterly flow is the result.

The April map does show a consistent aspect of the flow pattern which is repeated throughout the March through June period. Regardless of the direction of flow in the interior, for any given meridian, higher pressure must exist to the south. As long as the flow has a component directed out of the south, precipitation is possible, but if higher pressure exists to the north, precipitation likelihood approaches zero. The boundary across extreme southeastern Oregon and northern Nevada, in a statistical sense, represents a common southern limit of precipitation which is occurring over the interior of Washington and Oregon (Richter, 1960, p. 32).

The rapid change in the direction of flow to a more latitudinal (north-south) transport pattern reflects the rapidly increasing continent-oceanic temperature gradient. The interior is now heating up rapidly, producing a much stronger north-south orientation to the isobaric field.

C. Average 500 Millibar Heights and Sea Level Pressure for May Precipitation Events

1. Average 500 Millibar Heights and Flow Characteristics for May

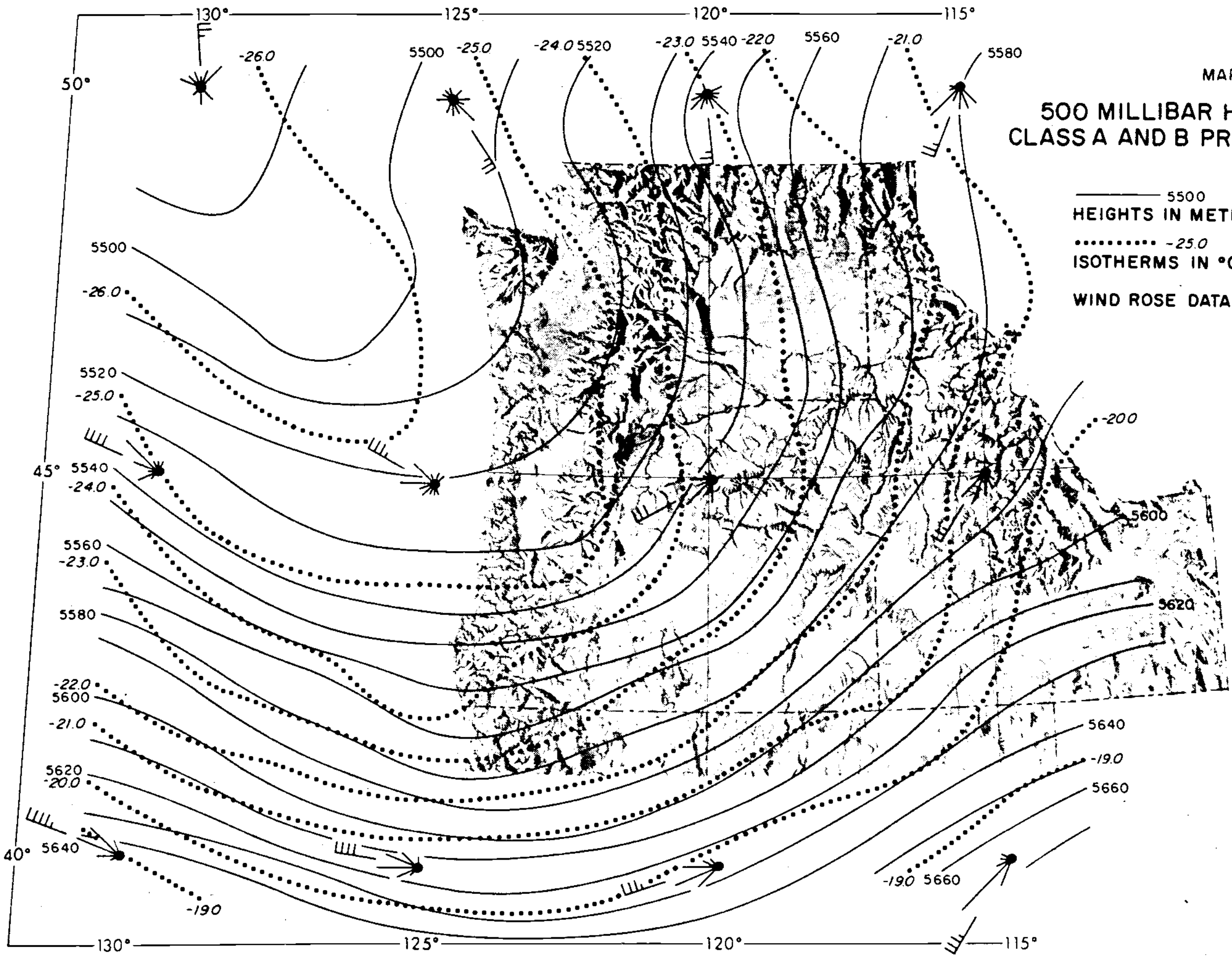
Sixteen cases of class A and B precipitation events were identified in the month of May. Map 15 presents averaged 500 millibar heights for the sixteen cases. Distinct changes in the contour pattern are detectable in comparison to the earlier March and April period.

The latitudinal pressure gradient has weakened, reflecting continued seasonal warming and the weakening of the midlatitude north-south temperature gradient. The north-south orientation of the contours has increased markedly with a shortening of the wave length. The trough axis has shifted eastward and is now located on the west coast. Lowest pressure continues to be centered in the northwestern sector of the grid.

March and April are dominated by southwest flow across much of the Pacific Northwest, while in May a significant variation in flow between the western and eastern limits of the grid exists. West of 127^{o} 30" west longitude, northwest or west-northwest flow predominates.

MAP 15

500 MILLIBAR HEIGHTS FOR MAY CLASS A AND B PRECIPITATION EVENTS



5500 HEIGHTS IN METERS ABOVE SEA LEVEL

-25.0 ISOTHERMS IN °C

WIND ROSE DATA BY 22 1/2° QUADRANTS

Westerly flow predominates along the coast with strong southwest to even southerly flow in the central and eastern sectors of the grid. Strong southerly flow is especially marked in the northeastern portion of the grid.

The increased amplitude of the flow pattern is indicative of greater latitudinal transport of air masses, with cold advection dominating the flow to the west of the Cascades and periodic intrusions into the interior. Warm advection apparently dominates the flow east of the Cascade mountain range.

The 500 millibar isotherms reflect the dominance of strong north-south temperature advection with equatorward displacement of isotherms characteristic of the region west of the coast, with the thermal trough extending inland to the Cascade mountain range. Strong poleward displacement of isotherms is characteristic of the region east of the Cascade mountains and most intensely developed in the northeastern portion of the grid.

Precipitation in May in the interior is maximized by strong cold advection west of the Cascades coincident with sharp temperature discontinuities aloft east of the Cascades. It is evident that the more unstable sectors of cyclonic storms play a larger role in precipitation events in contrast to the extensive warm sector dominance in previous months.

The wind rose data plotted on Map 15 verifies the dominance of west to northwest flow west of the Cascade range, and southwest flow and southerly flow dominating the region to the east of the Cascade range. As was the case in previous months, the highest variability of wind direction is in the northern and northwest sector of the grid, indicating that closed 500 millibar lows are typically centered in the northern sector. The most consistent wind direction is in the southern sector of the grid, indicating prevalence of northwest flow west of the coast and southwest flow in the interior. As was the case in previous months, high wind velocities are centered across southern Oregon and northern California. The highest wind velocities are located over the ocean in the extreme southwest portion of the grid.

2. Meridional and Latitudinal Transport Characteristics and Curvature Characteristics for May

Tables 6 and 7 reveal the strong decrease in the north to south pressure gradient. May values have decreased by a factor of two as compared to April values. The west to east pressure gradient has decreased in the northern sector of the grid but has not decreased in the southern portion of the grid. The relative increase in the west to east pressure gradient is reflected in the zonal index which is now very close to unity.

The increasing north-south transport characteristics of the 500 millibar height map are more clearly portrayed in the tabulated and averaged curvature data (Table 8). Of the nineteen cases of class A and B precipitation events tabulated, eighteen of the cases indicate positive (cyclonic) curvature values. The west to east cyclonic curvature is characteristic of precipitation producing events at 500 millibars across the Pacific Northwest in May. The curvature values are large in magnitude indicating significant variation in (north-south) latitudinal transport from west to east. Many precipitation producing disturbances are characterized by 500 millibar upper level closed lows centered over the interior of Oregon and Washington. North to northwest winds aloft dominate offshore, and southwest or southerly winds dominate over the central and eastern interior. Precipitation is maximized by cold advection to the east of the Cascades. Individual precipitation events commonly show that precipitation is associated with Pacific cold fronts or cold type occlusions with cold advection aloft immediately to the west of the migrating front. This indicates that strong destabilization aloft is responsible for significant overturning in the lower troposphere, resulting in cummulonimbus development and subsequent shower activity. The displacement of the thermal trough slightly to the east of the mean 500 millibar height trough is indicative of the destabilization aloft necessary for moderate to heavy intensity rainfall events in the interior.

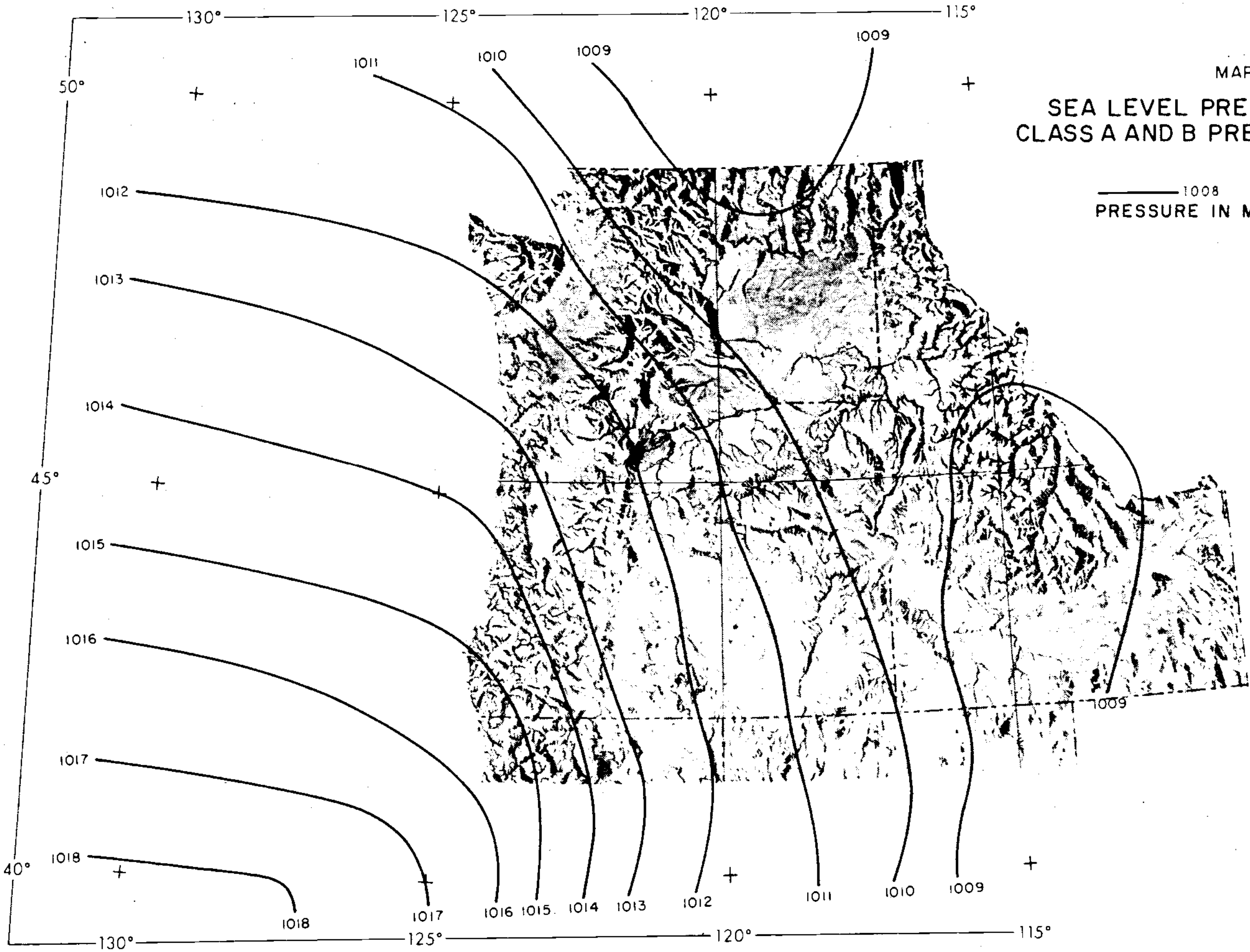
3. Average Sea Level Pressure for Class A and B Precipitation Events for May

Map 16 presents averaged sea level pressure date for May. The orientation of the isobars in May takes on a more summer like pattern and few of the wintertime characteristics remain. The prevailing west to southwest flow offshore and the low pressure in the area of Vancouver Island has disappeared to be replaced by a high pressure ridge dominating the west coast. A very strong northwest to southwest orientation in the isobars prevails along the west coast and Cascade mountain range. Low pressure is centered over interior Nevada and southern Idaho and low pressure is also centered over northeastern

MAP 16

SEA LEVEL PRESSURE FOR MAY CLASS A AND B PRECIPITATION EVENTS

——— 1008
PRESSURE IN MILLIBARS



Washington and southeastern British Columbia.

The high pressure ridge dominating the offshore and coastal area is indicative of the northward migration of the Pacific high system in response to the change in the thermal environment of the sea and land. By May the ocean is decidedly cooler than the land with increased low level stability over the ocean and corresponding instability over the rapidly heating continent. The low pressure over southern Idaho and Nevada is a direct manifestation of the southwest desert heat low which is a permanent fixture of the sea level pressure maps during late spring and summer.

The low pressure over northeastern Washington and southern British Columbia is most likely an indication of migratory Pacific frontal impulses. The front is typically oriented from northeast to southwest across central Washington and central Oregon with lowest pressure associated with the more northerly portion of the frontal wave. In the examination of individual synoptic events, surface low pressure in the form of migrating cold fronts or cold type occlusions were present in the interior of Washington and Oregon with a high pressure ridge to the west of the front. This is in contrast to the earlier period when, typically, low pressure remains offshore, and a migrating frontal system is generated out of the major low pressure system and moves across the interior. The May precipitation events are characterized by cold frontal or cold type occlusion precipitation with stronger air mass temperature differences across frontal boundaries than in the earlier winter period. Cold advection aloft at 500 millibars insures that destabilization takes on a larger role in precipitation events, in contrast to the primarily warm advection which characterizes precipitation producing disturbances in the earlier winter period.

The tendency for precipitation to be favored by the existence of higher pressure to the south along any given meridian continues in May. Some southerly component of flow must exist to trigger upward vertical movement; once the pattern changes to one of high pressure to the north along any given meridian, precipitation is virtually always terminated.

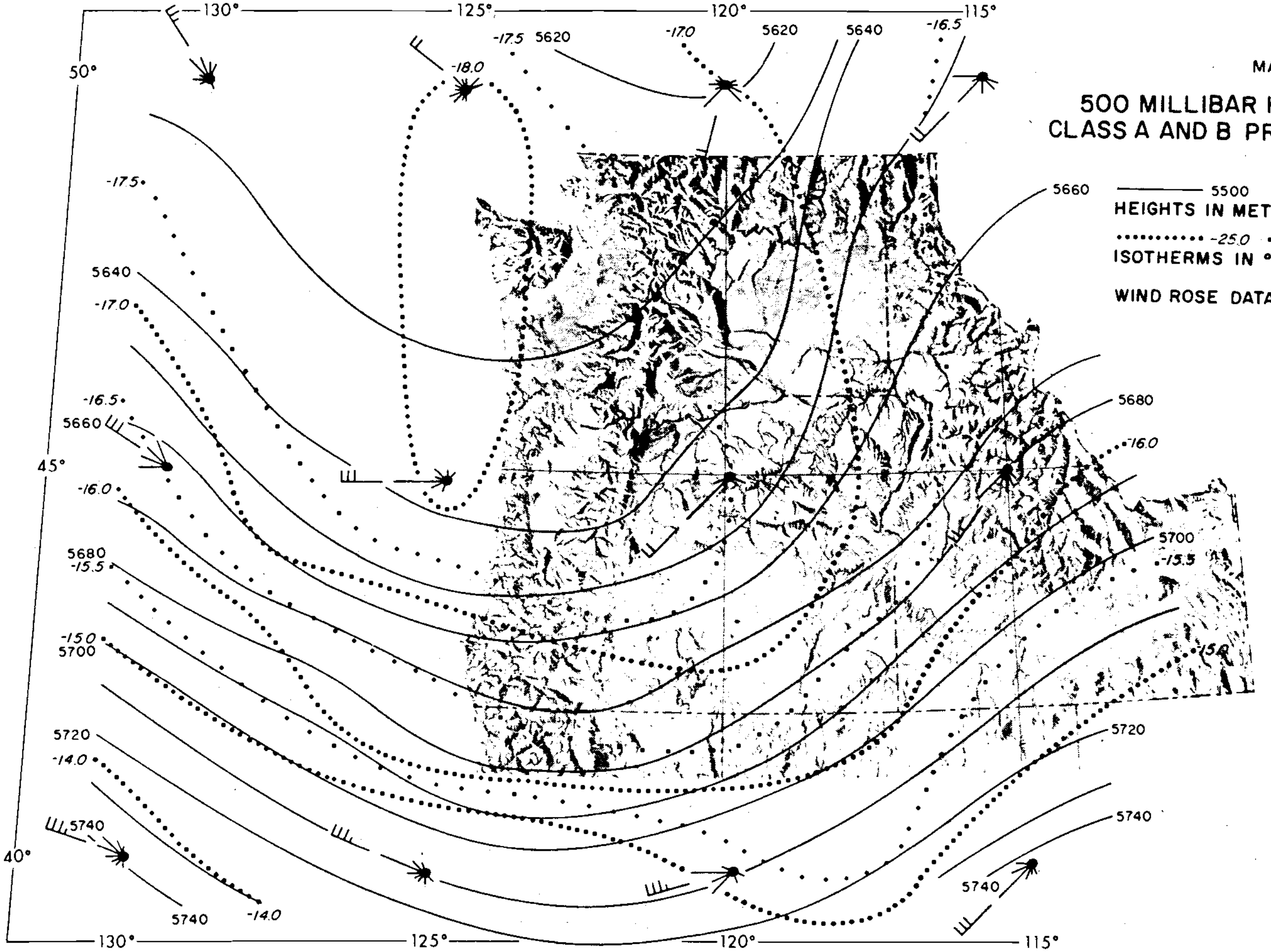
D. Average 500 Millibar Heights and Sea Level Pressure for June Precipitation Events

1. Average 500 Millibar Heights and Flow Characteristics for June

Map 17 presents averaged 500 millibar heights for 21 class A and B precipitation events for June. The latitudinal temperature gradient has weakened considerably as the cyclonic storm belt shift poleward.

The June height pattern is similar in character to the May pattern with northwest flow characteristic west of 125^{o} west longitude, and southerly or southwest flow east of 122^{o} 30" west longitude. The major trough axis has migrated to the east of the May position and is centered approximately over the Cascade mountain range. The southerly flow east of the Cascades would imply warm advection aloft in that sector. The 500 millibar isothermal map indicates that this is not entirely the case.

The thermal trough is well developed with very strong north-south temperature gradient. Cold advection dominates offshore but



MAP 17

500 MILLIBAR HEIGHTS FOR JUNE CLASS A AND B PRECIPITATION EVENTS

5500 HEIGHTS IN METERS ABOVE SEA LEVEL

-25.0 · · · · · -25.5 ISOTHERMS IN °C

WIND ROSE DATA BY 22 1/2° QUADRANTS

also extends into the interior including the region dominated by southerly flow. Intense destabilization in the interior associated with cooling at 500 millibars seems to be a prerequisite for moderate to heavy rainfall in the interior. Individual synoptic cases typically show small, intense closed lows at 500 millibars, centered over the interior plateaus of Oregon and Washington with pronounced cooling aloft.

Map 17 also presents plotted wind rose data for the 21 cases of class A and B precipitation events for June. Wind velocities have weakened considerably, which is indicative of the weakening and poleward shift of the midlatitude cyclonic storm track. The strongest winds during precipitation events are still located to the south at about 40^{0}N latitude. This belt of high speed westerly winds across the southern limits of the grid is consistent for all months (March through June). Despite the changes in organization of the 500 millibar thermal field, the control of a southerly jet position is consistent in that maximum cyclonic shearing will exist to the north of the jet with consequential vertical stretching and accelerated upward vertical motion (Saucier, 1962, p. 343; Byers, 1957, p. 308-310).

The most highly variable winds are located in the northerly sector of the grid coinciding in most cases to the center of upper level closed lows or the axis of sharp amplitude 500 millibar troughs. The most consistent widns are again in the central and southern portions of the grid. Cold advection is characteristic in the offshore and coastal locations with northwesterly winds predominating. Strong southwesterly flow dominates the central and interior location although the more southerly flow is predominately in the eastern portion of the grid, indicating that cold advection extends into the interior.

2. Meridional and Latitudinal Transport Characteristics and Curvature Characteristics for June

Tables 6 and 7 indicate that the north to south pressure gradient is about the same magnitude as the May values. The west to east pressure gradient is also equivalent in absolute value to the May situation. The stronger north to south transport characteristics of the flow are indicated by the change in sign of the pressure gradient from the western portion of the grid to the eastern portion of the grid.

The average curvature values clearly illustrate the strong cyclonic trajectory typical of the 500 millibar systems as well as the predominance of northerly and northwesterly winds aloft in the western portion of the grid (Table 8). Only 2 of the 21 cases indicate negative curvature values, implying that very strong cyclonic turning from west to east aloft is a prerequisite for precipitation in the interior in June. Average curvature values are quite large, from 58 to +108. Despite variations aloft in the actual wind directions, the establishment of significant west to east temperature discontinuities related to migratory surface cold fronts or cold type occlusions, is a prerequisite for moderate to heavy precipitation in the interior.

3. Average Sea Level Pressure for Class A and B Precipitation Events for June

The sea level pressure pattern for June is dominated by the existence of a strong high pressure ridge offshore extending well to the northwestward limits of the grid (Map 18). The seasonal poleward shift of the Pacific High as a result of the strong contrast in temperature of the ocean and continent is not inconsistent with the above pattern. The strongest gradient of pressure is notable along the west coast which coincides with the strongest gradient of temperature. Northerly to northwesterly flow dominates the offshore region as well as the west coast eastward to the Cascade Mountains.

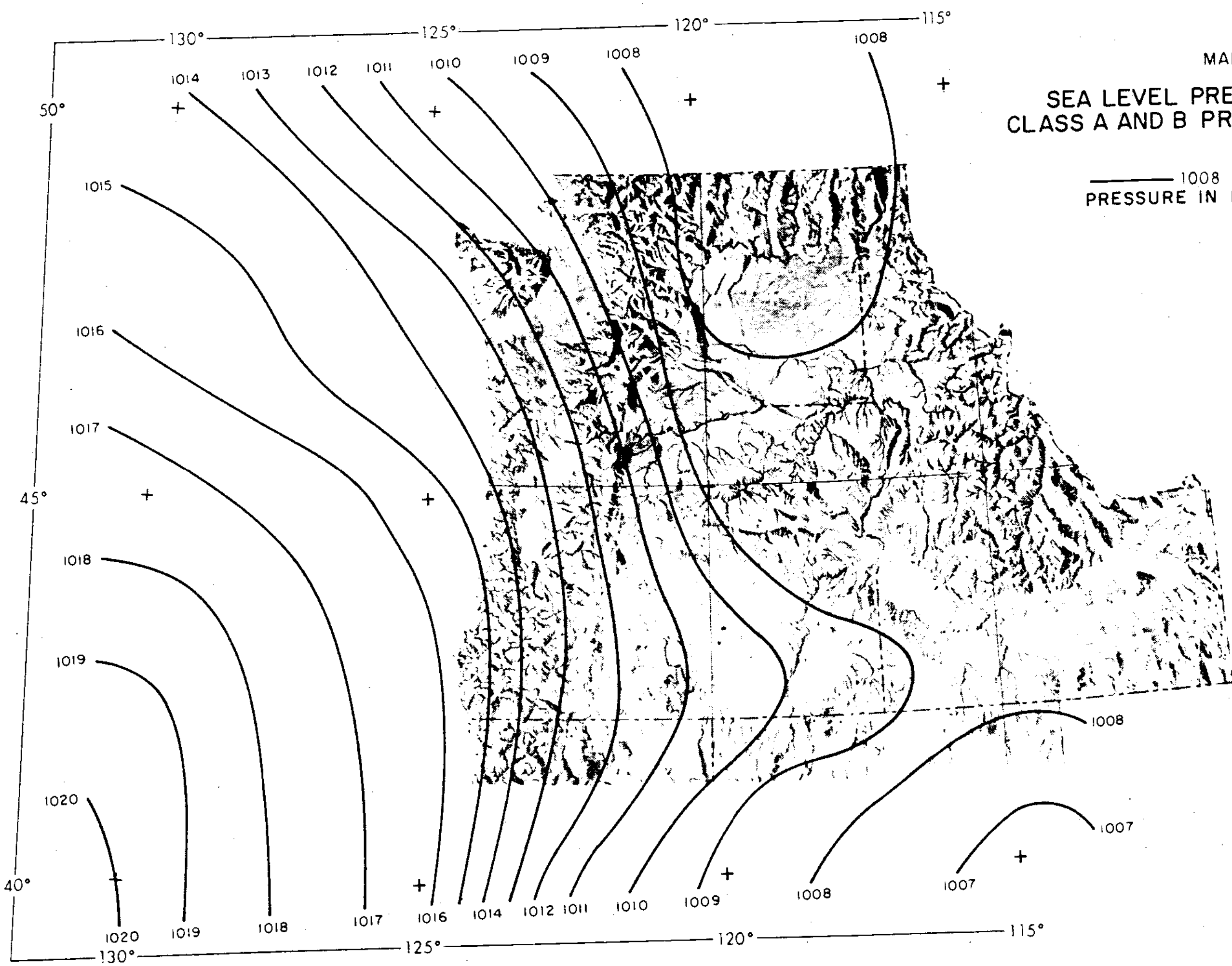
Low pressure dominates Nevada and extreme southeast Oregon, and the interior of eastern Washington and southern British Columbia. The Nevada low is the result of the intensification of the semi-permanent summer desert heat low (Namis and Wexler, 1938, p. 164-170). The low in the northeastern portion of the grid is more likely the average position of traveling cyclonic disturbances, principally in the form of surface cold fronts or cold type occlusions. The pressure ridge extending eastward across northern California and southeastern Oregon reflects the southern limit of precipitation as strong anti-cyclonic and seaward flow dominates the sector south of the pressure ridge. To the north of the pressure ridge cyclonic and southerly or southwesterly flow would dominate, and precipitation is more highly favored.

In the examination of actual synoptic events, the existence of a northeast to southwest oriented cold front or cold occlusion is typically detected. The cold front is commonly centered in the interior of Washington and Oregon with strong southwesterly flow in advance of the cold front and westerly to northwesterly flow dominating the post frontal sector. While the precipitation is most commonly

MAP 18

SEA LEVEL PRESSURE FOR JUNE CLASS A AND B PRECIPITATION EVENTS

——— 1008
PRESSURE IN MILLIBARS



in the pre-cold front sector, the existence of a cold upper level trough at 500 millibars insures that moderate instability is quite typical of the air mass well in advance of the passage of the cold front. As was indicated in Chapter 2, June is the month of maximum thunderstorm occurrence in Washington with cold front or cold type occlusion being the most commonly associated weather disturbance triggering these thunderstorms.

E. Summary of 500 Millibar Flow Characteristics: March through June

The major changes in the 500 millibar flow pattern which characterize the March through June period may be summarized as follows:

1. Progressive weakening of the latitudinal height gradient reflecting the spring weakening of the midlatitude north-south temperature gradient.

2. The evolution from strong zonal flow, i.e. (west to east), in March and April to a much larger meridional flow (north-south) pattern in May and June.

3. The evolution from long wave length 500 millibar troughs with small amplitude variations in the direction of flow across the entire Pacific Northwest during March and April, to shorter wave length troughs with increased meridional variation in the direction of flow between the western and eastern limits of the grid.

4. The migration of the 500 millibar trough axis eastward from a position well off the coast in March to a position centered on the Cascades in June.

5. The change in temperature advection from that of dominant, warm advection across the entire Pacific Northwest in March to strong, cold advection aloft in western and central sectors in May and June.

6. The reorientation of the upper level flow pattern from one characterized by westerly flow and weak meridionally oriented temperature gradients in March and April, to a pattern of strong variation in meridional flow and the establishing of strong north-south oriented temperature discontinuities.

F. Summary of the Sea Level Pressure Pattern: March through June

The major changes in the sea level pressure pattern which characterize the March through June period may be summarized as follows:

1. The dominance of low pressure offshore with prevailing southwest flow across the Pacific Northwest in March.

2. The development of a strong ridge of high pressure along the west coast which increases in strength and progressively shifts northward from April through June.

3. Precipitation in the interior is associated with the passage of a Pacific cold front or cold type occlusion which is typically located in the interior aligned from southwest to northeast. Variable position of the associated short wave trough tends to "mask" its existence on the average pressure maps.

4. The strengthening and poleward migration of the desert heat low from April to June in the southeast sector of the grid.

5. The tendency for precipitation to be associated with higher pressure to the south along a given meridian.

6. The increased dominance of northwesterly steering and associated cold advection across the western portion of the grid in association with well developed Pacific cold fronts.

7. The increased tendency for precipitation to be more closely associated with the unstable air in immediate proximity to the cold front, in contrast to the dominance of the warm pre-frontal sector in March.

Chapter IV

MARCH-JUNE SOUNDINGS FOR CLASS A AND B PRECIPITATION EVENTS FOR SPOKANE AND QUILLAYUTE, WASHINGTON

A. Rationale

The secondary spring maximum of precipitation in the interior of the Pacific Northwest is associated with an increase in the relative frequency of moderate and high intensity rainfall over the region. Sea level and 500 millibar pressure charts exhibit changes in the organization of precipitation producing disturbances during the late spring period. Winter months are characterized by strong warm advection at the surface and at 500 millibars, while late spring is characterized by cold advection at 500 millibars associated with the passage of a surface Pacific cold front. It appears that appreciable destabilization of the lower troposphere, accompanied by an increase in precipitable moisture, is associated with precipitation producing disturbances in the months of May and June.

In order to ascertain the seasonal change in the vertical distribution of atmospheric parameters, radiosonde date were obtained for Spokane and Quillayute, Washington, from the Spokane Weather

Bureau (U.S. Weather Bureau, Pseudo-Adiabatic Chart). Hourly precipitation observations were also obtained for Spokane (Local Climatological Data, Spokane). Radiosonde data were available for an intermittent period from 1971 through 1975. Atmospheric parameters which were analyzed included: vertical lapse rate of temperature and dewpoint; relative humidity and precipitable moisture; thickness of the moist layer; and vertical stability. Due to the absence of radiosonde charts for certain years, approximately three years of data were available for any given month. A longer period of record would have been desirable, but seasonal changes in lapse rate, precipitable moisture, atmospheric stability, and moist layer thickness should be responsive to normal seasonal heating. The existence of a secondary maximum, a frequency relationship for three years, was therefore not considered to be a significant restriction.

B. Analysis Procedure

Radiosonde data were analyzed for the months of March through June for Class A and B precipitation events. A sounding was selected if measurable precipitation (T.) occurred within at least one hour of the sounding time, either 4 a.m. or 4 p.m., P.D.T. Cumulative totals of hourly precipitation were recorded for a consecutive four-hour period across the radiosonde release time for Spokane, Washington. For each precipitation sounding, atmospheric variables were recorded and averaged at standard 50 millibar atmospheric levels for each month. Data were also recorded at 920, 910 and 900 millibars in order to ascertain low level diurnal changes in the sounding for Spokane, Washington. It should be noted that most soundings indicated extensive saturated layers but of variable heights, and in the process of averaging produce a mean sounding which is unsaturated.

The U.S. Weather Bureau commonly utilizes the Showalter index of atmospheric stability. The Showalter index is derived by lifting the air at 850 millibars to its lifting condensation level and then pseudo-adiabatically to 500 millibars. The index is the difference in the lifted temperature and the observed 500 millibar temperature (Decker, 1973, p. 4-2). Smaller indexes indicate increased instability. The Showalter index considers only 850 temperature and moisture and 500 millibar temperature and does not consider conditions in between these two levels. The K index (Decker, 1973, p. 4-2) was derived to consider moisture at 700 millibars, which was more relevant to the prediction of severe thunderstorms in the midwest (Miller and Fawbush, 1953). The K index is calculated by the following formula:

K = (850 temperature - 500 temperature) +
(850 dewpoint - 700 dewpoint)

Increasing values of the index indicate greater instability. The U.S. Weather Bureau has provided thunderstorm probabilities based upon the K index. The probabilities are as follows:

K	15-20	21-25	26-30	31-35	36-40	40
Probability of Thunderstorm	20%	20-40%	40-60%	60-80%	80-90%	100%

Both indices are adequate predictors of thunderstorms, especially in the midwest, where the usual factors conducive to thunderstorms are: low level moisture (maritime tropical air), and cool dry air aloft (continental polar), coupled with a strong lapse of temperature in the dry air (Battan, 1961, p. 55; Beebe, 1955, p. 349-350).

Cramer has pointed out the difficulty of these indices when applied to the Pacific Northwest (Cramer, 1973, p. 16). The usual conditions for thunderstorms in the interior Pacific Northwest are characterized by warm, dry air in the lower levels of the atmosphere, coupled with cool, moist advection aloft (commonly between 850 and 500 millibars) and cool, dry air above 500 millibars. When the moist layer extends down to 850 millibars, the Showalter index will be reliable; but often the air is dry at 850 and saturated at 800 or 750 millibars, and the Showalter will be quite misleading.

In Technical Attachment No. 74-19, put out by the Western Region Forecast Center, various techniques of thunderstorm prediction were evaluated. The three most relaible predictors of thunderstorm occurrence were the K index, 850 millibar dewpoint, and inches of precipitable water. Of the six variables evaluated utilizing some combination of low level temperature and moisture and high level temperature, none considered moisture at any other level than 850 millibars.

In the following analysis, average Showalter indices, K values, 850 millibar dewpoints, precipitable moisture and moist layer thickness were all calculated and averaged for the months of March through June. While very definite changes occur across the March through June period with respect to all of these variables, individually any one is not necessarily a consistent predictor of high intensity rainfall.

C. Average Spokane Soundings for Class A and B Precipitation Events: Temperature and Dewpoint, March through June

In Figures 11 through 14, average temperature and dewpoint for precipitation soundings at Spokane for the months of March through June are plotted. Solid lines are temperature and dashed lines are dewpoints. A dry adiabat and a pseudo-adiabat have also been plotted as well as two constant saturation mixing ratio lines. In cases where motor boating was indicated, a dewpoint corresponding to 20% relative humidity was used in agreement with standard Weather Buread procedures (Technical Attachment No. 73-17). Figure 15 is a plot of all four average monthly precipitation soundings combined.

Table 9 presents average data on temperature minus dewpoint, relative humidity, and average 12 level totals of precipitable water in grams of water per kilogram of dry air, for Class A and B precipitation events. Figures 16, 17 and 18 present average soundings of temperature minus dewpoint, relative humidity, and actual mixing ratios for the months of March through June. Figures 19 and 20 indicate frequency data for the thickness of the moist layer, and both Showalter and K index stability values.

1. Spokane Precipitation Soundings for March

A total of 33 cases were available for the month of March encompassing the years 1970, 1972, 1973 and 1975. The average precipitation sounding for March is plotted on Figure 11. In all months large variability exists in the sounding characteristics which can produce precipitation. Lapse rates can be either quite unstable or very stable, depending on the specific synoptic conditions occurring at the time. A moist, nearly saturated layer must exist, but it may be extensive or shallow, or have a base near the surface or some distance aloft. The average sounding is the mean of a quite variable set of precipitation conditions.

TABLE 9

Average Monthly Mixing Ratio, Relative Humidity and Temperature Minus Dewpoint for Spokane, Washington, for Class A & B Precipitation Events

Pressure Level	Temperature-Dewpoint Degrees ^{o}C				Mixing Ratio Grms/Kg				Relative Humidity Percent			
	March	April	May	June	March	April	May	June	March	April	May	June
920	2.3	4.6	5.5	5.2	4.3	4.6	6.0	7.1	86	70	67	69
910	2.2	4.3	4.9	4.4	4.3	4.6	5.7	6.7	86	74	74	74
900	2.1	4.4	4.5	4.4	4.3	4.5	5.5	6.2	86	75	76	73
850	1.5	3.6	3.8	4.6	3.9	4.4	5.1	5.5	90	80	76	73
800	1.3	2.8	2.5	3.6	3.4	3.6	4.6	4.9	90	80	80	75
750	1.0	2.2	2.0	2.3	3.0	3.1	4.0	4.3	91	82	80	82
700	1.5	2.5	2.8	1.8	2.5	2.5	3.2	4.0	90	81	82	89
650	1.4	3.4	2.4	2.5	2.1	1.9	2.6	3.1	91	74	81	83
600	2.7	5.0	3.3	2.9	1.5	1.3	2.1	2.4	79	68	78	75
550	2.9	5.4	5.1	6.2	1.1	.8	1.4	1.5	77	58	67	61
500	4.0	5.5	5.0	7.8	.7	.6	1.0	1.0	70	56	62	50
450	7.0	6.8	6.4	10.0	.3	.3	.6	.6	40	40	54	46
Totals					31.5	32.3	41.8	47.3				

Despite the variability in individual precipitation conditions, certain consistent trends do appear in the soundings when analyzed across the March through June period. March is a period during which wintertime precipitation conditions are still prevailing but with some indication of springtime warming beginning to assert itself. Precipitation is associated with warm advection between 850 and 600 millibars, and a surface radational inversion is quite common on the 4 a.m. soundings, and frequently will exist even on the 4 p.m. soundings. The saturated layer is quite thick, averaging about 300 millibars in thickness. Frequently, the saturated layer extends from near 850 millibars up to at least 600 millibars. It is not unusual to find either isothermal layers or even temperature inversions located within the saturated layer, indicating very strong, warm advection aloft. These sounding characteristics correlate with the prevalent light moderate intensity rainfall or snowfall associated with the warm sector of wintertime cyclonic disturbances (Saucier, 1962, p. 291; Conover and Wallaston, 1949, p. 249-260). The average sounding for March in Figure 11 has the smallest lapse rate of the four months, averaging 3.42^{o} C per 100 millibars. In Figure 18, the actual mixing ratio values are the lowest of the four months, but above 800 millibars are equal to or greater than the April mixing ratios, indicating that precipitation is associated with warm, moist advection above 800 millibars.

Figure 21 is a plot of both K indices and Showalter indices versus four hour precipitation totals. A very wide range of stabilities from Showalter indices of +1 to +19 and K indices of 11 to 45 exists, but the heavier precipitation is more commonly associated with

AVERAGE MARCH TEMPERATURE AND DEW POINT SOUNDING FOR SPOKANE, WASHINGTON

CLASS A AND B PRECIPITATION EVENTS

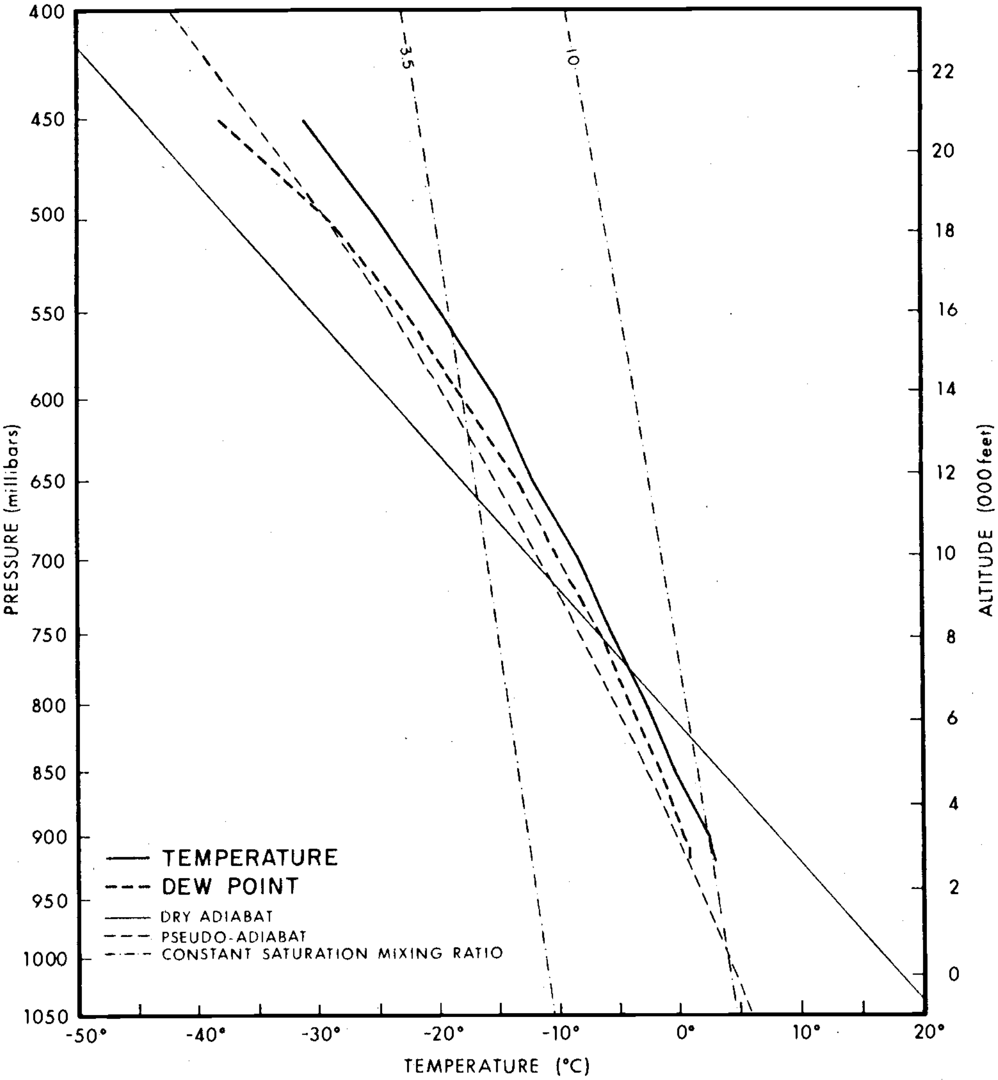


FIGURE 11

AVERAGE APRIL TEMPERATURE AND DEW POINT SOUNDING
FOR SPOKANE, WASHINGTON
CLASS A AND B PRECIPITATION EVENTS

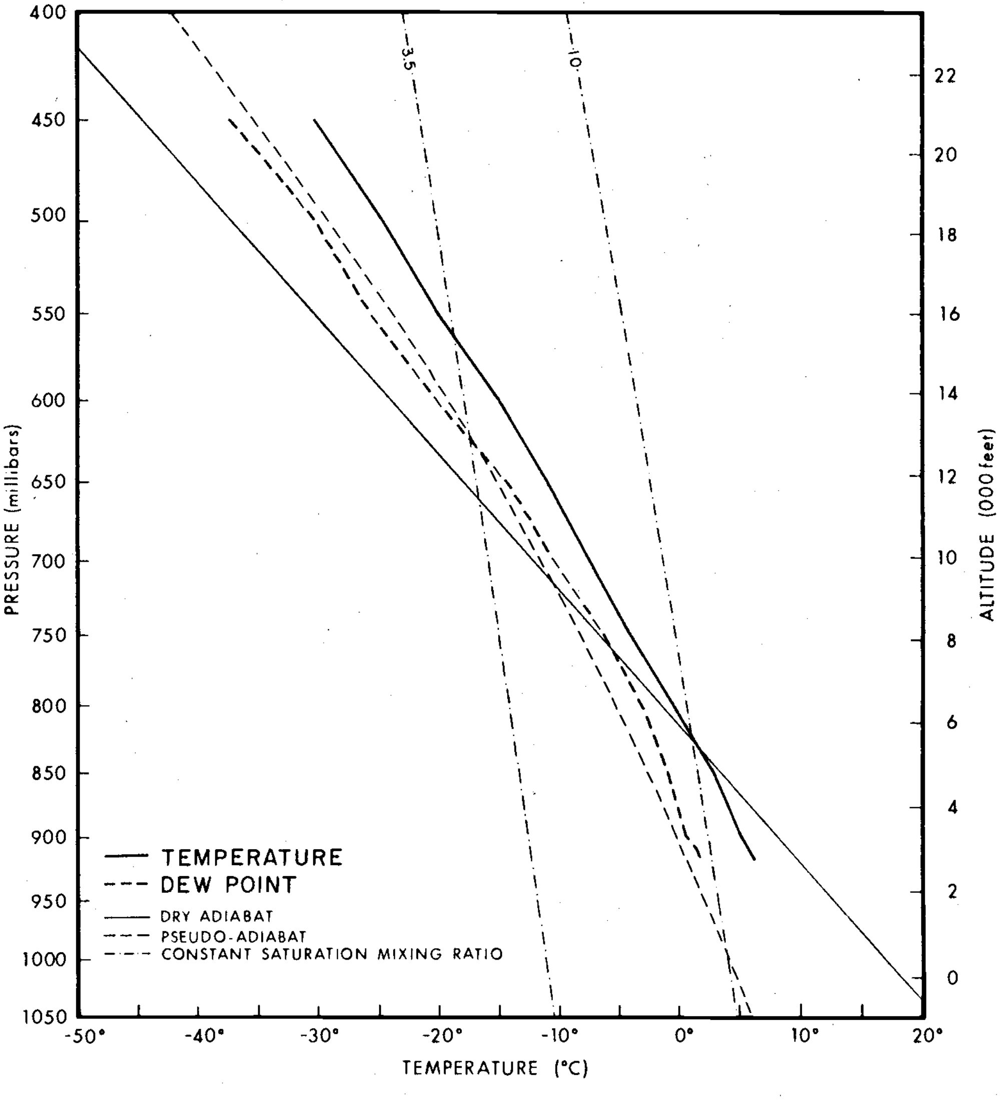


FIGURE 12

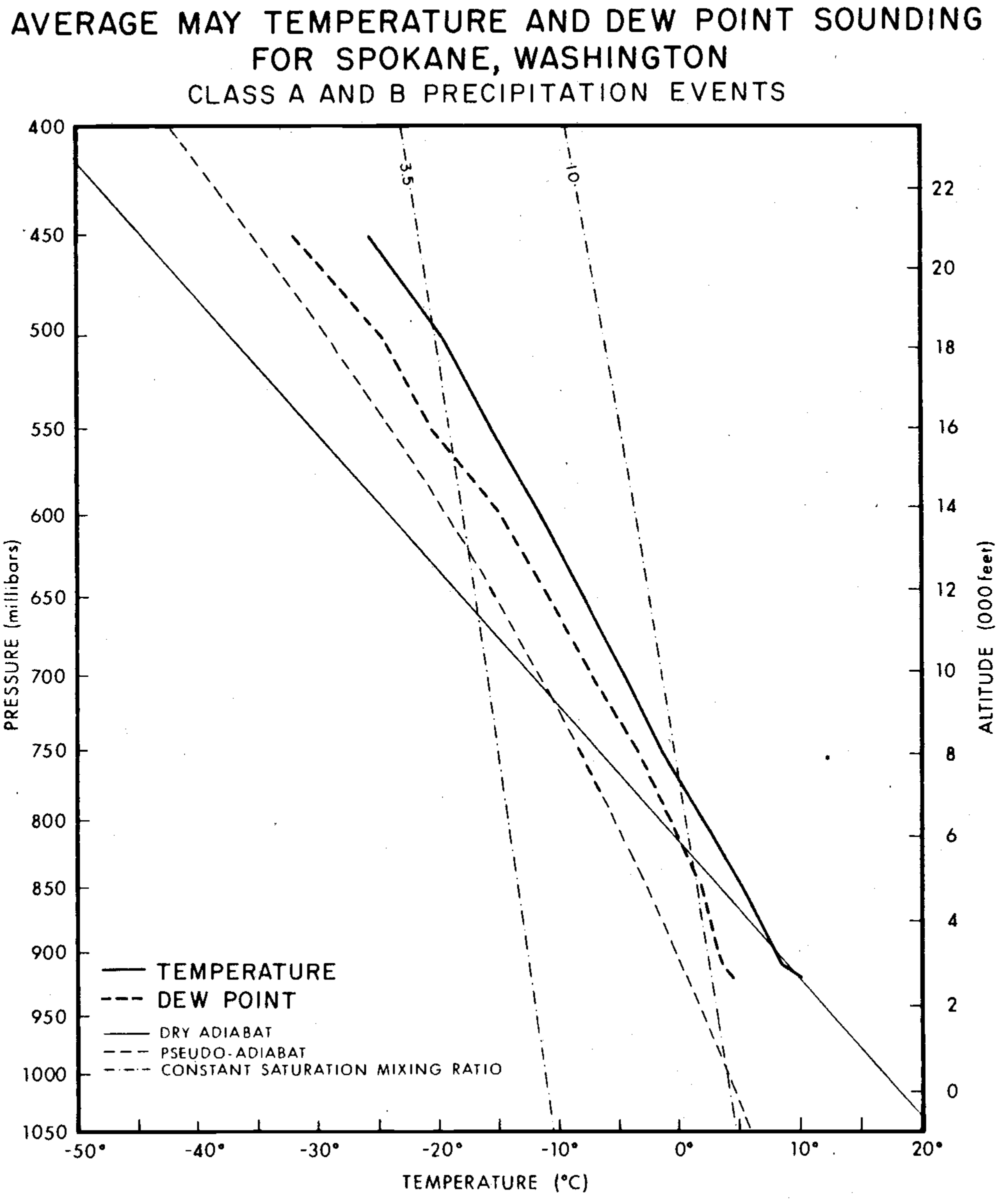

AVERAGE MAY TEMPERATURE AND DEW POINT SOUNDING
FOR SPOKANE, WASHINGTON
CLASS A AND B PRECIPITATION EVENTS
PRESSURE (millibars)
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
ALTITUDE (000 feet)
22
20
18
16
14
12
10
8
6
4
2
0
3.5
10
TEMPERATURE
DEW POINT
DRY ADIABAT
PSEUDO-ADIABAT
CONSTANT SATURATION MIXING RATIO
-50°
-40°
-30°
-20°
-10°
0°
10°
20°
TEMPERATURE (°C)

FIGURE 13

AVERAGE JUNE TEMPERATURE AND DEW POINT SOUNDING
FOR SPOKANE, WASHINGTON
CLASS A AND B PRECIPITATION EVENTS

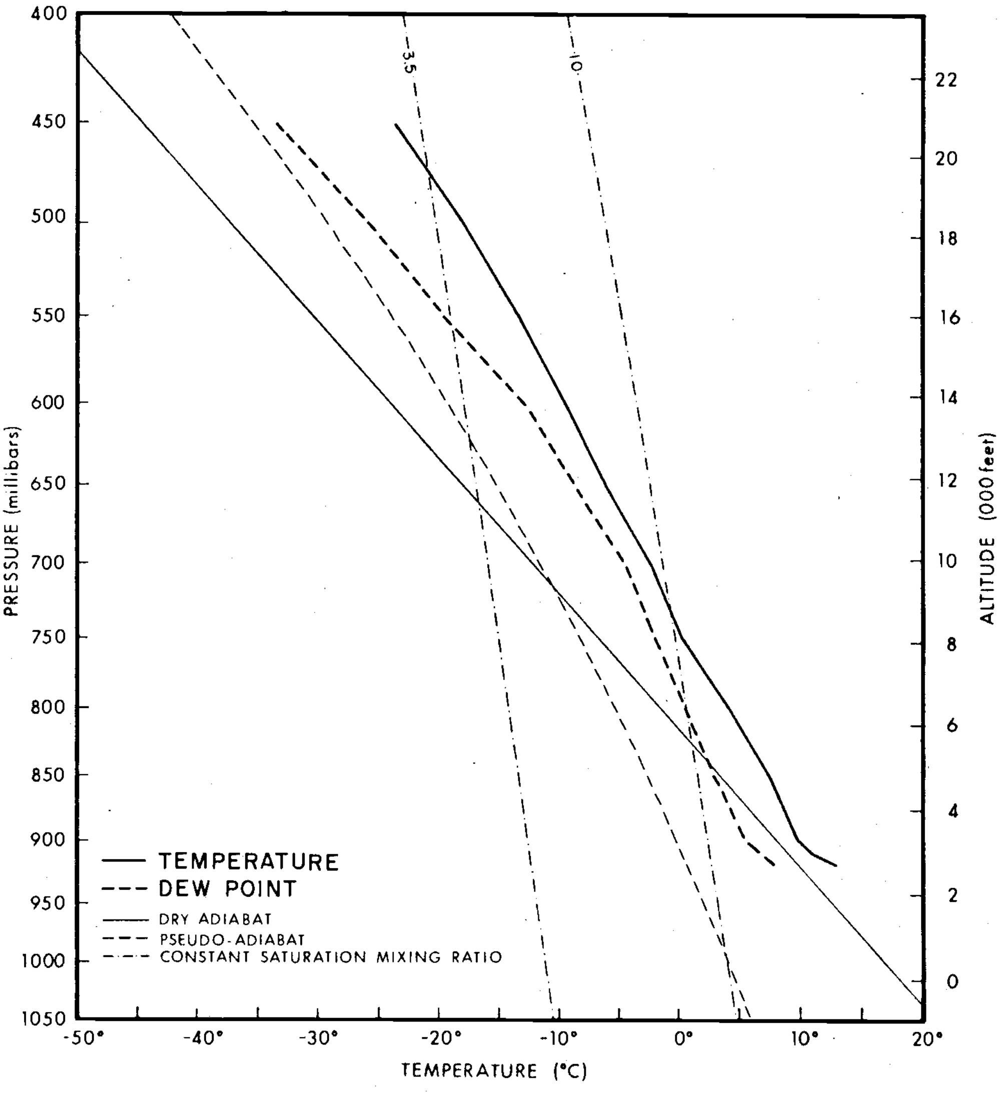


FIGURE 14

COMBINED MARCH THROUGH JUNE
AVERAGE TEMPERATURE AND DEW POINT SOUNDINGS
FOR SPOKANE, WASHINGTON
CLASS A AND B PRECIPITATION EVENTS

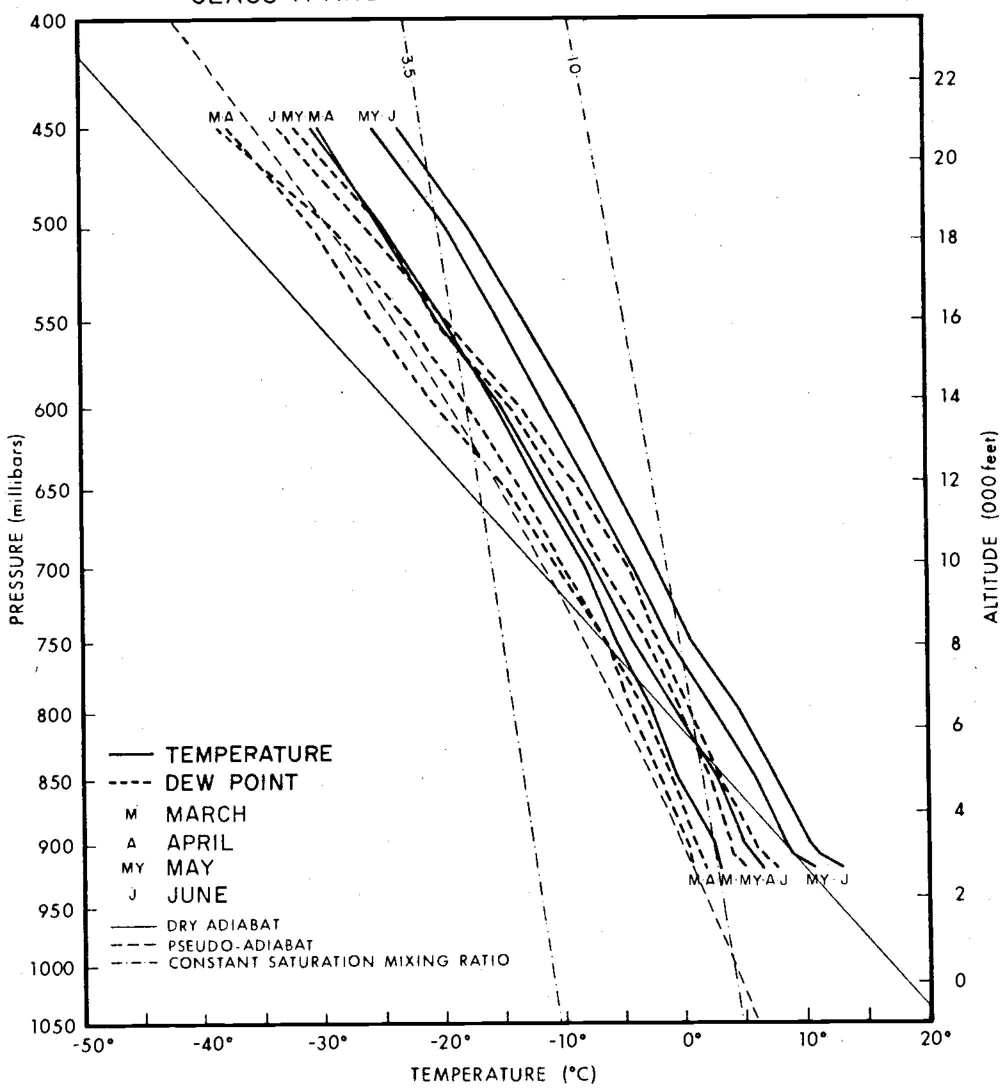


FIGURE 15

moderately stable indices and only very rarely do highly unstable indices coincide to high intensity precipitation. This relationship will be reversed in the May and June period. The average Showalter index is +5.6, the most stable of the four months. Figure 22 gives the average K and Showalter indices for precipitation intensities. Only very tentative conclusions can be reached due to the wide scatter on the original diagram, but one can conclude that higher stabilities are more often associated with larger precipitation values. One would expect a very pronounced scattering in the lower intensity ranges as both very stable and unstable conditions can produce light intensity rainfall. It does appear that rarely do unstable indices produce high intensity rainfall. It is also apparent that March is typified by light intensity rainfall most frequently.

Figure 23 is a plot of four representative soundings for the months of March through June. Each sounding was selected for having both stability indices and temperature dewpoint conditions which were representative of those commonly occurring in each month. The March sounding is typical of many which produce precipitation in March but occur with decreasing frequency through the remaining spring months. The sounding has a Showalter index of +6 and a K index of +30. The air is saturated from 850 to 700 millibars, unsaturated but quite moist from 700 to 550 millibars, and saturated from 550 to 500 millibars. The saturated layer between 850 and 750 millibars has a very weak lapse rate indicating warm advection in that layer. Between 700 and 650 millibars, the lapse rate steepens and the vertical wind shear from the west-northwest is indicative of a cooler, dryer air being advected

AVERAGE MARCH THROUGH JUNE
TEMPERATURE MINUS DEW POINT SOUNDINGS
FOR SPOKANE, WASHINGTON
CLASS A AND B PRECIPITATION EVENTS

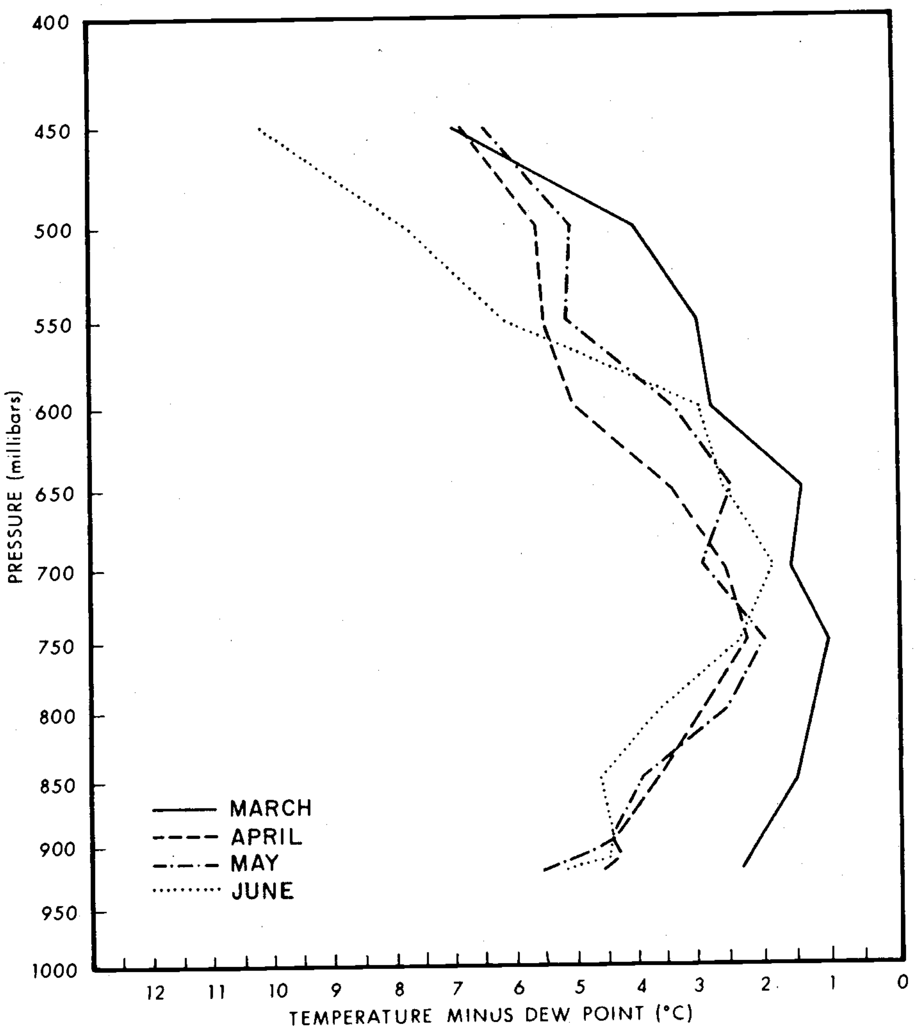


FIGURE 16

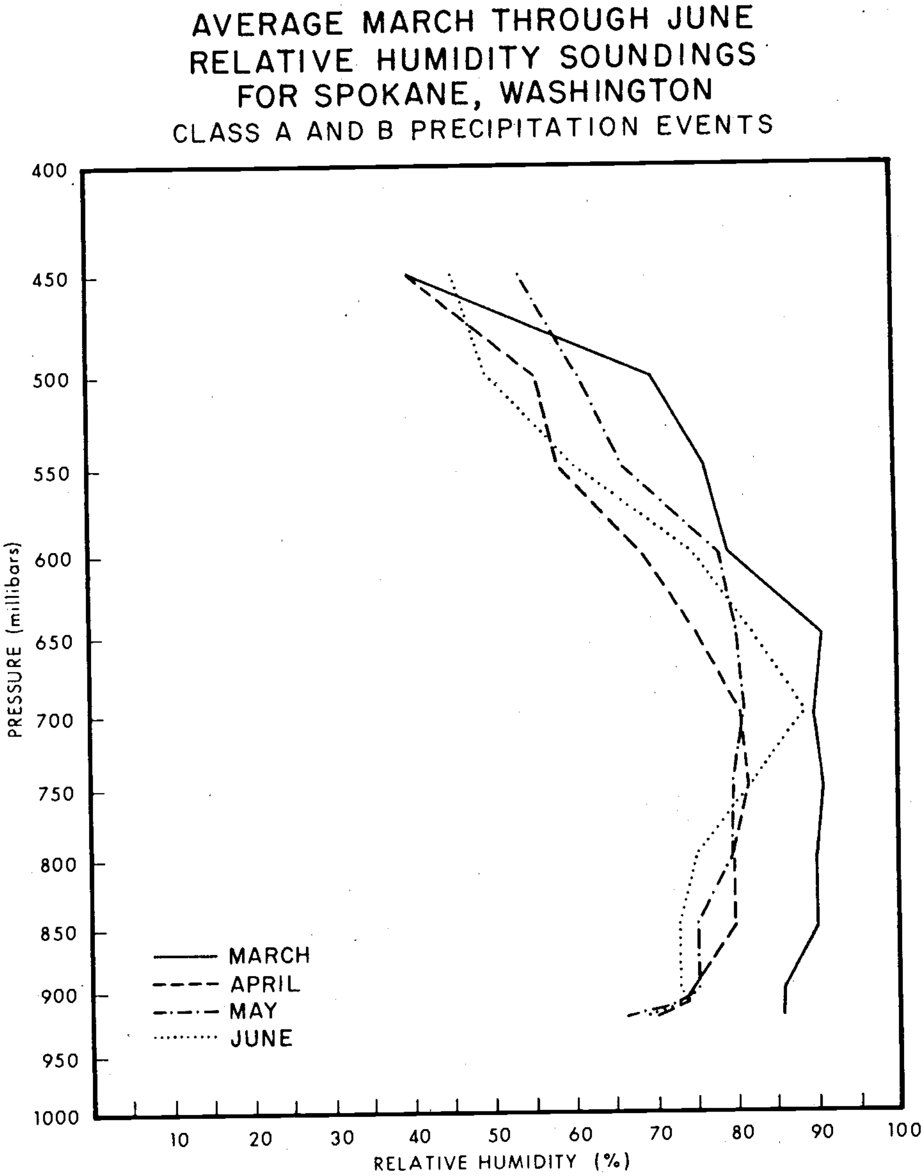

AVERAGE MARCH THROUGH JUNE
RELATIVE HUMIDITY SOUNDINGS
FOR SPOKANE, WASHINGTON
CLASS A AND B PRECIPITATION EVENTS
PRESSURE (millibars)
400
450
500
550
600
650
700
750
800
850
900
950
1000
MARCH
APRIL
MAY
JUNE
10
20
30
40
50
60
70
80
90
100
RELATIVE HUMIDITY (%)

FIGURE 17

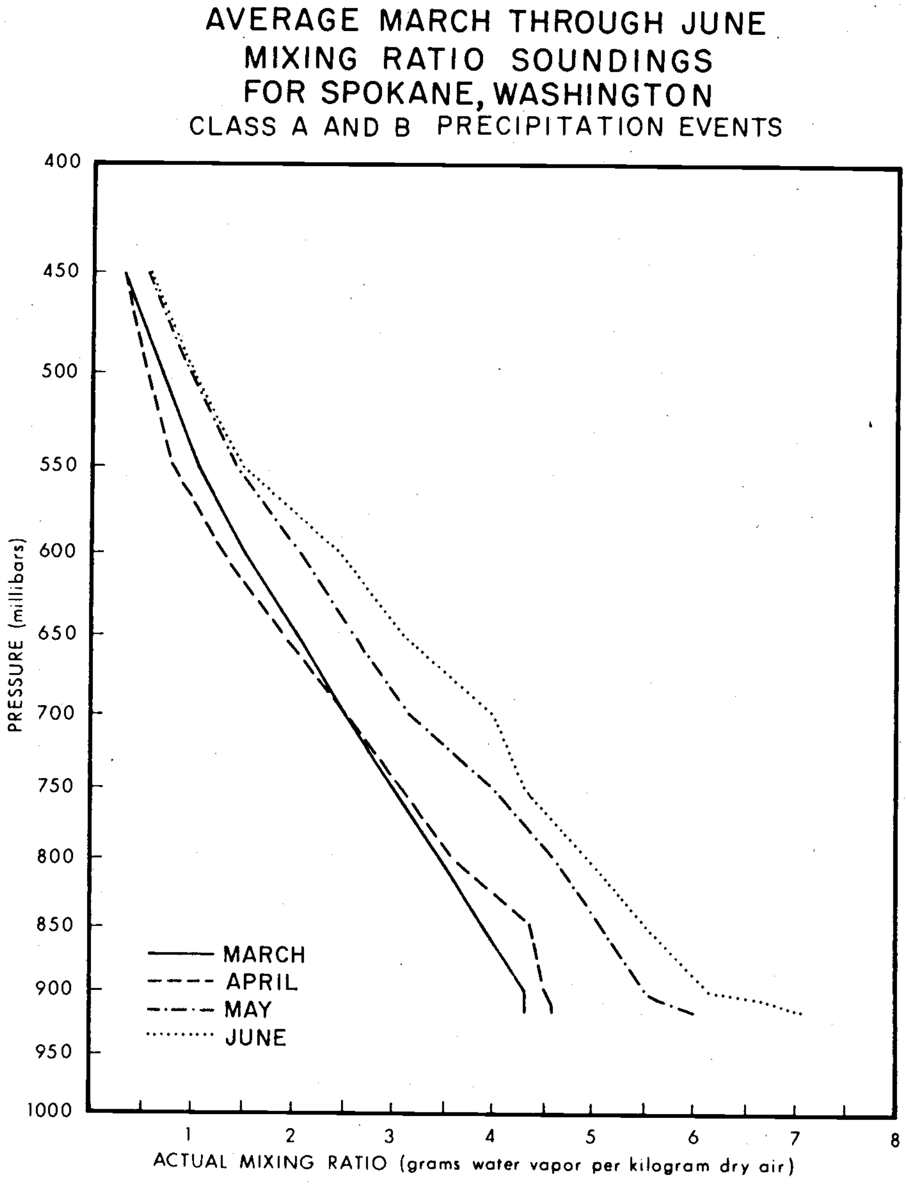
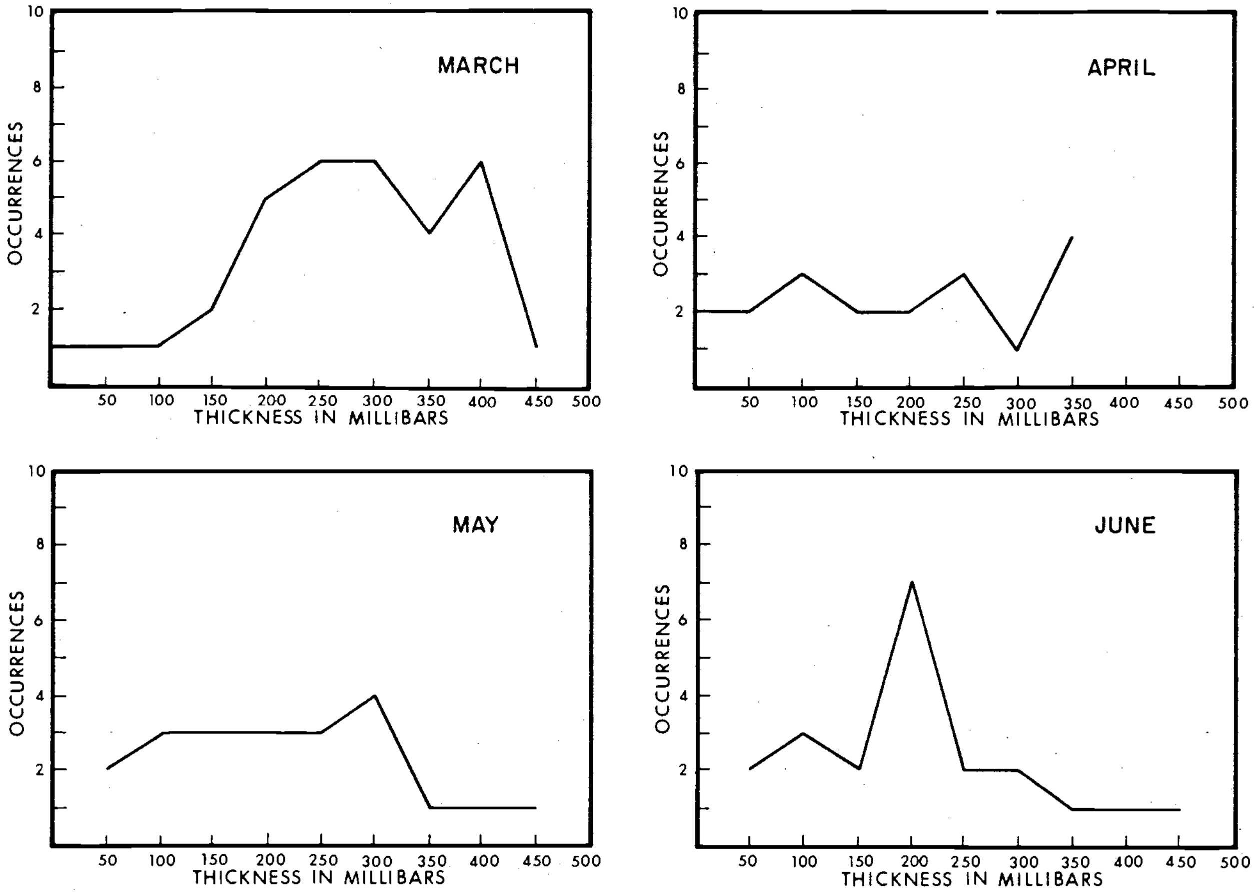

AVERAGE MARCH THROUGH JUNE
MIXING RATIO SOUNDINGS
FOR SPOKANE, WASHINGTON
CLASS A AND B PRECIPITATION EVENTS
PRESSURE (millibars)
400
450
500
550
600
650
700
750
800
850
900
950
1000
MARCH
APRIL
MAY
JUNE
1
2
3
4
5
6
7
8
ACTUAL MIXING RATIO (grams water vapor per kilogram dry air)

FIGURE 18

MARCH THROUGH JUNE MOIST LAYER* THICKNESSES FOR SPOKANE, WASHINGTON

CLASS A AND B PRECIPITATION EVENTS



*LESS THAN 2°C DIFFERENCE BETWEEN TEMPERATURE AND DEW POINT

FIGURE 19

MARCH THROUGH JUNE SHOWALTER AND K-INDEXES OF VERTICAL STABILITY FOR SPOKANE, WASHINGTON

CLASS A AND B PRECIPITATION EVENTS

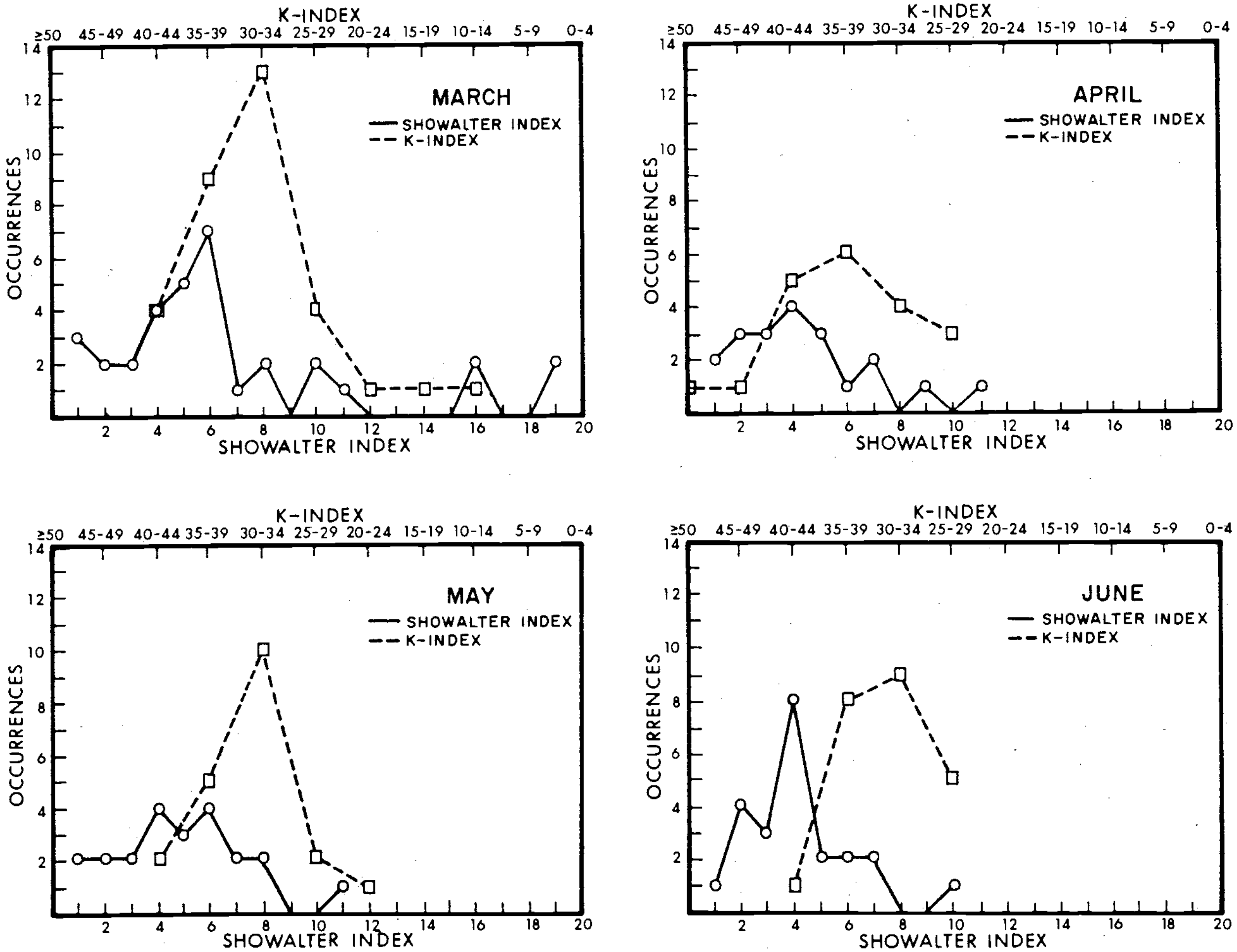


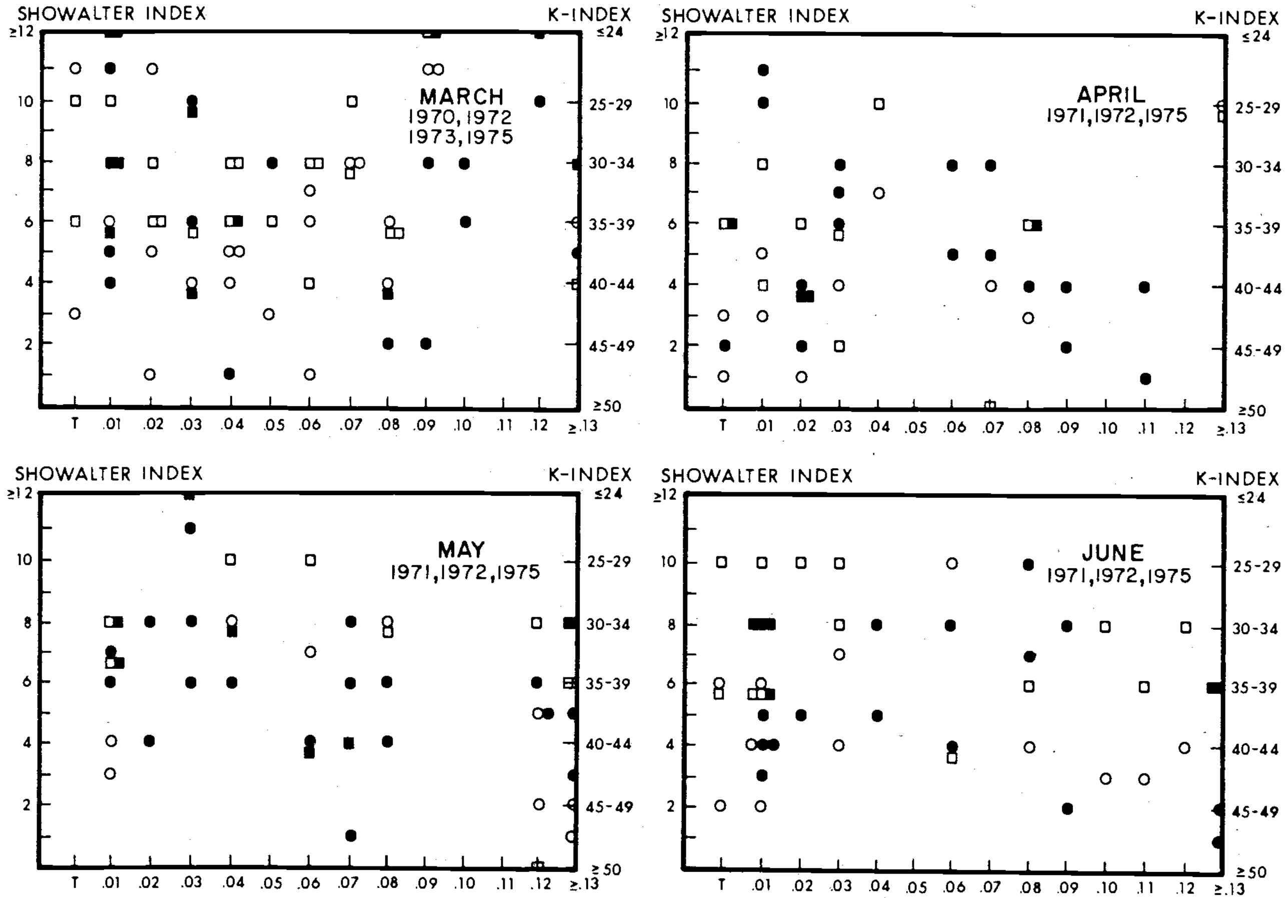
FIGURE 20

in that layer. From 600 to 500 millibars, the lapse rate again weakens and the moisture content again increases to saturation, and this is evident in the wind shear in that layer as the winds return to a southwesterly direction again advecting in warmer, moist air. Many precipitation soundings in March indicate strong changes in layer advection with height with northeast winds often prevailing in the first 50 to 100 millibars, and variable west to southwest winds above 850 millibars indicating warm advection aloft. Very unstable lapse rates do occur in March, but tend to be associated with cold core 500 millibar lows with quite low precipitable moisture values and do not usually result in substantial precipitation (Saucier, 1962, p. 379-380).

2. Spokane Precipitation Soundings for April

A total of 20 cases of precipitation soundings were available for the month of April, encompassing the years 1971, 1972, and 1975. The average precipitation sounding from this sample is plotted on Figure 12. Wide variability exists in the sounding characteristics which can produce precipitation. The month of April is a transition month with both residual wintertime characteristics and spring warming detectable. The average lapse rate has increased to 3.67^{0} C per 100 millibars, but as the mean sounding indicates it is primarily the result of surface warming of the first 200 millibars. Above 650 millibars, the sounding is as cool as the March sounding. The wintertime conditions still prevail above 650 millibars, and while this destabilizes the sounding, low precipitable moisture values are maintained above 650 millibars. Precipitation in April, indeed for all

MARCH THROUGH JUNE FOUR HOUR PRECIPITATION TOTALS
ON SHOWALTER AND K-INDEXES FOR SPOKANE, WASHINGTON
CLASS A AND B PRECIPITATION EVENTS



○ 4 AM SHOWALTER — ● 4 PM SHOWALTER — □ 4 AM K-INDEX — ■ 4 PM K-INDEX

FIGURE 21

AVERAGE MARCH THROUGH JUNE FOUR HOUR PRECIPITATION TOTALS ON SHOWALTER AND K-INDEXES FOR SPOKANE, WASHINGTON

CLASS A AND B PRECIPITATION EVENTS

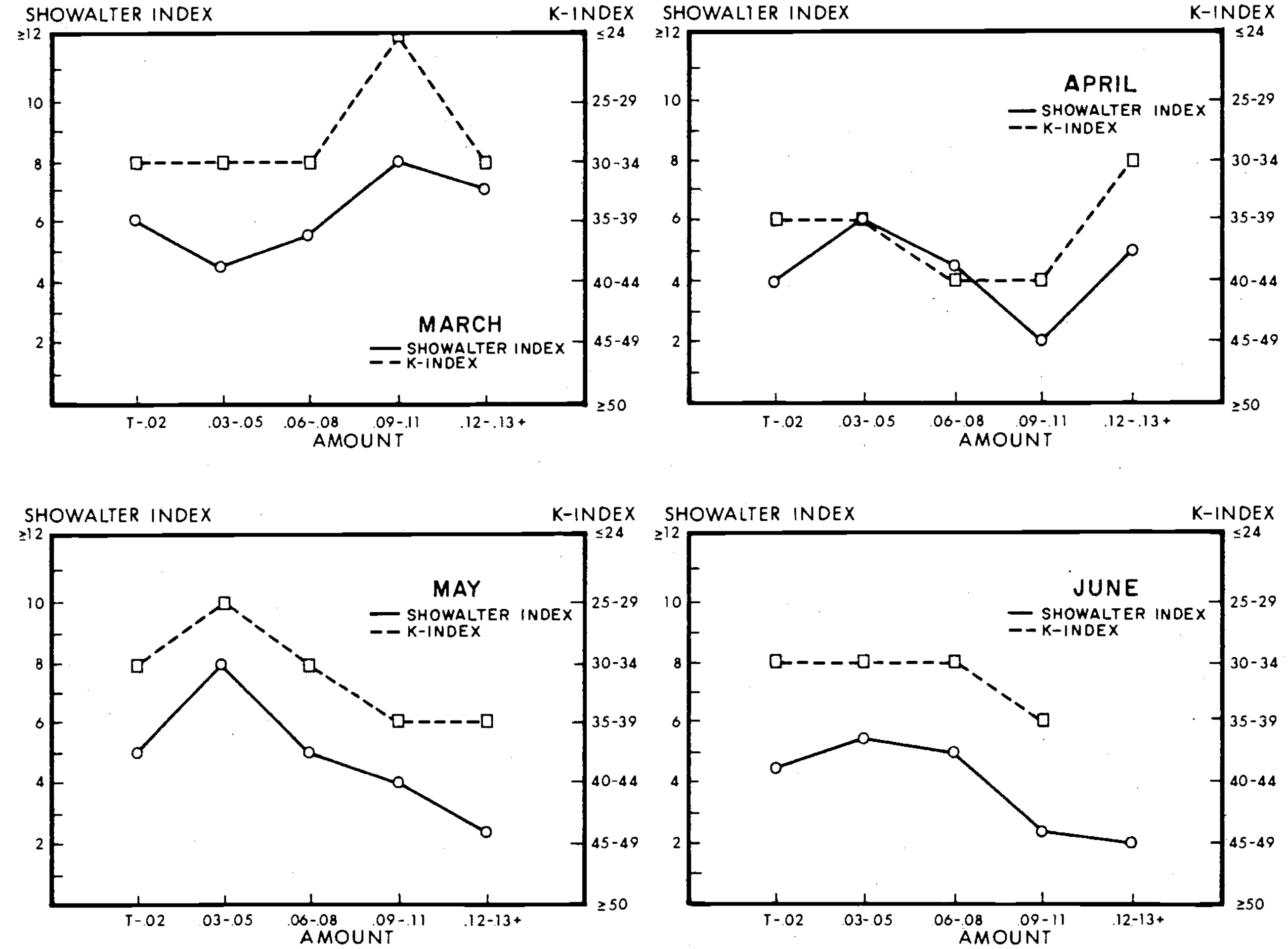


FIGURE 22

REPRESENTATIVE MARCH THROUGH JUNE PRECIPITATION SOUNDINGS FOR SPOKANE, WASHINGTON

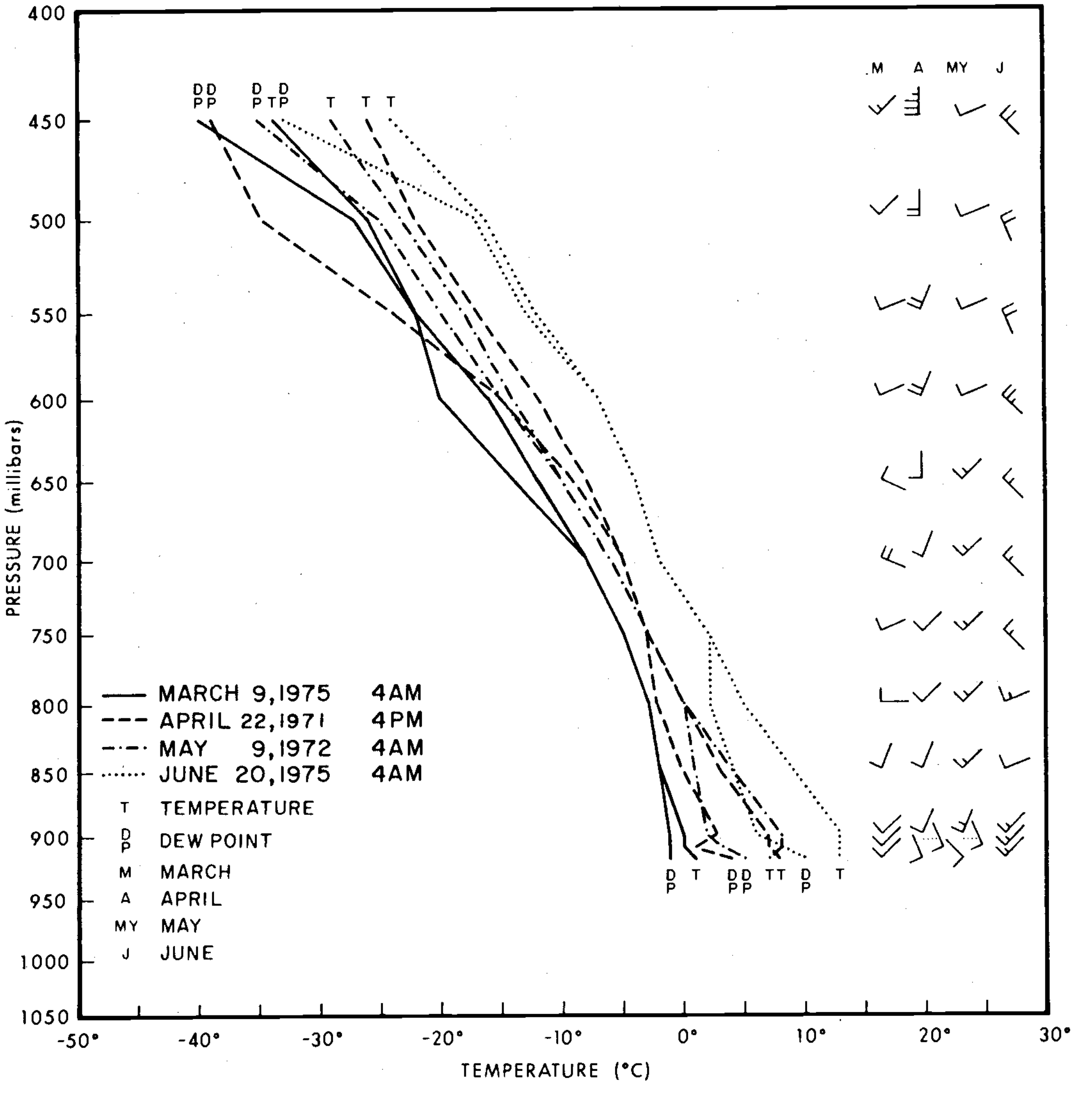


FIGURE 23

months, is associated with moist advection above 850 millibars. In April the average thickness of the moist layer is less than 200 millibars and quite commonly is sandwiched between dry air below 850 millibars and dry air above 600 millibars (Fig. 19).

The most notable aspect of the April mean sounding is that despite the decrease in stability due to the warming of the lower layers, the dewpoint curve does not show a comparable warming and, in fact, above 750 millibars is less than the March sounding. Precipitable moisture values are only .8 grm/kg above the total of the March sounding, despite an increase in 3.4° C of the 920 millibar surface temperature. In Figure 18, the actual mixing ratio values illustrate how increased precipitable moisture has not kept pace with the increase in temperature and therefore the vapor capacity of the air. In Figure 17, the relative humidity curve indicates that at all levels the April sounding averages less than the March sounding, despite the increase in temperature in the lower layers and the residual March-like temperature distribution above 650 millibars.

April exhibits a wide range of stability values ranging from Showalter values of +1 to +11 and K indices of 25 to 51 (Fig. 20). No discernible trend can be identified in the relationship of precipitation intensity and stability indices. Both unstable and stable indices can produce moderate intensity rainfall. Figure 21 would seem to indicate that high intensity rainfall is rather rare in April with a large clustering in the light to moderate intensities. The average Showalter index of +5.1 and K index of 35 is decidedly more unstable than the March average indices, but does not seem to result in a significant increase in the intensity of precipitation.

Figure 23 includes a plot of a representative precipitation sounding for the month of April. The sounding has a Showalter index of +6. The sounding illustrates several common features of the mean April sounding. The sounding has a moderately high surface temperature, but is unsaturated below 750 millibars. It is saturated or near saturated from 750 to 650 millibars, but is quite dry above 600 millibars. The lack of a thick moist layer, so typical in March, but not compensated by increased low level dewpoints, typical of May and June, would apparently explain the lack of a substantial increase in precipitation yield from March to April. April is a transition month, a hybrid, characterized by increased surface heating and delayed upper tropospheric warming, which while increasing instability is not compensated by a proportional increase in low or high level moisture content.

3. Spokane Precipitation Soundings for May

Twenty-two cases of precipitation soundings were available for May, encompassing the years 1971, 1972 and 1975. The average precipitation sounding for this sample is plotted on Figure 13. The May sounding shows substantial warming at all levels averaging 4° C warmer than the April sounding. The average lapse rate is about the same as the April sounding averaging 3.6° C per 100 millibars. Warming has taken place at about the same rate at all levels, indicating that vertical mixing is quite efficient during most precipitation events. While the lapse rate is no steeper than the April sounding, several characteristics are clearly indicative of the increase in vertical instability. Dewpoint temperatures have increased substantially at all levels, indicating that pseudo-adiabatic conditions will be more prevalent, due to the increase in absolute humidity. As both temperature and dewpoint increase, the slope of a given pseudo-adiabat is not as steep; therefore, wet adiabatic processes can be triggered by an environmental lapse rate which need not be as steep as in earlier, colder months (Byers, 1959, p. 177).

Certain decidedly springtime characteristics are identifiable in the sounding data for May, which were being initiated in April. Saturation most commonly occurs above 850 or even 800 millibars (Fig. 17) and generally extends to about 600 millibars. Dry air is commonly found above 600 millibars. Interestingly, the average thickness of the moist layer is about 275 millibars, which is thicker than the April value (Fig. 20). A wide range of values for the thickness of the moist layer is noticeable, however. Figure 17 illustrates the increased convective instability in May as the relative humidity values average quite high between 850 and 600 millibars, but drop off rapidly above 600 millibars. This is more conducive to cumulonimbus development, especially if this layer is lifted by a Pacific cold front. In this event, the moist layer will cool wet adiabatically and the dry layer aloft will cool dry adiabatically, thus steepening the lapse rate and promoting increased vertical motion (Byers, 1959, p. 190-192).

Table 9 illustrates the large increase at all levels in actual water vapor content in May. The 12 level mixing ratio total is 41.8 grams of water/kg. of dry air, an increase of 9.5 grm/kg over April, amounting to about a 30% increase, which, probably coincidentally, is precisely the percentage increase in mean precipitation in Spokane from April to May. Figure 19 is a frequency plot of Showalter indices and K values for the month of May. May has an average Showalter index of 4.8 which indicates that destabilization is quite frequently associated with precipitation events. Very rarely is precipitation associated with Showalter indices greater than +7 and most events occur with indices less than +6. Additional insight into the type of disturbances which produce the more significant rains in May comes from Figure 21. There is a clustering of data points in the middle stability ranges about the light intensity precipitation values, but the most noticeable aspect is the second clustering about the low stability indices and the high intensity precipitation values. High intensity precipitation is consistently associated with unstable indices. Very rarely can heavy precipitation occur with highly stable indices. It is also quite clear that heavy intensity precipitation occurs proportionately more frequently in May than in either March or April. It is under conditions of cool advection aloft, coupled with warm, moist air at intermediate levels, that favor the most intense precipitation in the month of May.

In Figure 23, a representative sounding for a May precipitation event has been included. The sounding has a Showalter index of +4 and a K index of 34. The sounding is unsaturated below 800 millibars, which is fairly common due to the moderate surface heating occurring at this time of year. It is saturated from 800 to 600 millibars and nearly saturated to 500 millibars. The sounding is parallel to a pseudo-adiabat indicating that saturated parcels, given some initial positive buoyancy, will rise freely. The distribution of wind with height indicates that southwest to west-southwest winds are prevailing at all heights. However, the winds turn clockwise with height, indicating that progressively cooler air is being advected as one rises vertically. This is in contrast to the March situation where commonly the winds indicated increased warm advection with height.

May is a month that is characterized by decreasing cyclonic storm frequency, but due to the rapidly increasing difference in temperature of the land and sea, the interior is dominated by cold frontal passages of Pacific origin. As cold, moist air is advected aloft the increased heat loads in the lower levels destabilize the air mass, and coupled with increased precipitable moisture permits precipitation events of increased intensity.

4. Spokane Precipitation Soundings for June

A total of 23 precipitation soundings were available for the month of June for the years 1971, 1972, and 1975. The average precipitation sounding for this sample is plotted in Figure 14. The June sounding averages 2^{o} C warmer than the May sounding, but is only half the increase in temperature which occurred from April to May. The lapse rate is about the same as the May sounding, averaging 3.63^{o} C per 100 millibars. The surface layer indicates a strong heating now occurring. The mean lapse rate above the surface layer is very nearly parallel to a pseudo-adiabat, indicating that with sufficient mositure availability, upward vertical motion through considerable heights is assured.

The dewpoint curve indicates that the highest relative humidities are found from about 800 to 600 millibars, but a greater spread exists between the temperature and dewpoint curve indicative of a higher frequency of both dry air at the surface and above 600 millibars. In Figure 17, the relative humidity distribution with height indicates a decided tendency for precipitation to be associated with moderate moisture in the first 100 millibars, high moisture values above 550 millibars. This condition is more conducive to thunderstorm and cumulonimbus type rainfall. Frontal lifting of a moist layer at intermediate levels coupled with a dry layer aloft will cause a steepening of the lapse rate and convective overturning.

Figure 18 plots the actual mixing ratio at the 12 standard levels. June records the highest mixing ratio values for the four months. The increase in moisture is evident from the surface to 550 millibars and above 500 millibars approximates the May values. The 12 level total of precipitable moisture has increased from 42 grms of water/kg of dry air to just over 47 grms of water/kg of dry air, or an increase of 13%. This increase in precipitable moisture is partially compensated by the greater spread between temperature and dewpoint indicating that saturated conditions do not occur as extensively through the vertical atmospheric column in June. This fact is verified in Figure 17. The base of the moist layer is at 800 millibars and the highest relative humidities are typically above 700 millibars, a bit higher in elevation than earlier months. Figure 19 also verifies the fact that, while a wide variability in thickness of moist layer exists for precipitation soundings, most commonly the thickness of the saturated layer is about 200 millibars.

Figure 21 is a plot of both Showalter and K indices against four hour precipitation totals. June is the most unstable of the three months with an average Showalter index of +3.5 Figure 20 illustrates that precipitation is very rare with Showalter indices greater that +6, and the majority of precipitation events have indices of less than +5. It is evident from Figures 21 and 22 that the highest intensity precipitation events are associated with unstable Showalter indices of +4 or less. The clustering around the .01 inch per 4 hour precipitation values are of note, indicating that light intensity precipitation is common as a result of limited moisture supply. If the moist layer is extensive and the air unstable, the high precipitable moisture values permit quite high intensity rainfall, but quite often the limiting factor appears to be the lack of a thick saturated layer. Figure 20 gives the frequency of occurrence of both Showalter and K indices, and the predominance of unstable Showalter indices is quite evident. The K index peak has shifted to the right (increased stability) of the Showalter peak, but in examining the soundings it was quite evident that frequent existence of saturated conditions at 700 millibars tended to give rather low K indices. The K index is most responsive to predicting thunderstorms when low level moisture exists (below 700 millibars) and a dry layer exists from 700 millibars up to 500 millibars. These conditions are rarely encountered in the interior Pacific Northwest as the Cascade Mountains tend to restrict moisture advection to a layer above 850 millibars.

A representative sounding for June is plotted in Figure 23. The sounding has a Showalter index of +3 and a K index of +31. The Showalter index is probably more indicative of the actual stability of the sounding as quite high intensity rainfall, .11 inches in four hours, was occurring. The sounding is unsaturated from the surface to 750 millibars and saturated from 750 millibars to 500 millibars, and quite dry to above 500 millibars. The lapse rate is greater than the pseudo-adiabatic rate between 800 and 700 millibars and between 650 and 500 millibars. Upward vertical motion is occurring quite freely within these layers. The vertical wind distribution indicates the role that cool advection of air aloft plays in producing precipitation disturbances in June. The surface winds are from the southeast; they become southwesterly at 850 to 800 millibars, and then turn to northwesterly above 750 millibars. One would not expect to find northwesterly winds aloft associated with most precipitation events in June. However, one does consistently find that the winds will veer with height, indicating increased, cool advection aloft.

June is characterized by precipitation bearing disturbances associated with cold, upper level 500 millibar lows and the passage of a Pacific cold front on the surface. Conditions which are favorable to widespread moisture advection above 850 millibars and cooling aloft, result in unstable lapse rates which can trigger cumulonimbus development. These conditions are responsible for the majority of the moderate to high intensity precipitation in the month of June.

D. Average Quillayute Soundings for Precipitation Events: Temperature and Dewpoint March through June

The characteristics of precipitation soundings for the period of March through June in the interior of the Pacific Northwest can be correlated to the changes in average mean monthly rainfall in the interior. The intensity relationships which appear to be associated with increased destabilization and increased precipitable moisture are in the mean reflected in increased average monthly precipitation in May and June in the interior of Oregon and Washington. Stations west of the Cascades indicate decreasing monthly means of precipitation across the May through June period, so it is relevant to examine precipitation soundings for a westside station to see if there are significant differences in the temporal change of vertically distributed atmospheric variables.

Quillayute, Washington, is located at the northwest tip of the Olympic peninsula at sea level. The station records radiosonde data twice daily and is the only coastal radiosonde station north of Eureka, California. Radiosonde data were available for Quillayute for the year 1975, but certain problems arose in that no hourly precipitation data were accessible. Daily weather map series were available so the existence of precipitation at the sounding release time could be documented, but no information could be ascertained concerning precipitation intensities. Precipitation events were selected on the basis of precipitation occurring on the 4 a.m., P.S.T. weather map at Quillayute, Washington.

Figure 24 gives plotted values of average temperature and dewpoint for precipitation soundings from 1000 millibars to 450 millibars for Quillayute for the months of March through June. A minimum of 10 cases of precipitation occurrence were available for each month. Average Showalter values and K index values are included on Figure 24 for each month.

Quillayute is located at sea level on the northwest tip of the Olympic peninsula and is therefore strongly influenced by the dominant Pacific marine environment. The ocean warms very slowly in the spring, and local upwelling effect can produce very cold sea surface temperatures, even in the mid spring period (Staley, 1957, p. 458-459; Sverdrup, et al, 1942, p. 724-725). The soundings often indicate low level marine characteristics which are quite distince from conditions above 900 millibars. Due to the Olumpic Mountains immediately inland from the coast, a strong ornographic effect is available. It is not uncommon to record precipitation with a saturated marine layer which only extends from 1000 to 900 millibars.

1. Quillayute Precipitation Soundings for March

The average March temperature and dewpoint sounding is plotted on Figure 24. A lapse rate greater than the pseudo-adiabat exists in the first 100 millibars, but above 900 millibars is less than a pseudo-adiabatic lapse rate. The air is nearly saturated at the surface and is saturated up to 800 millibars. From 800 millibars up to 450 millibars the dewpoint curve gradually slopes away from the temperature curve. In the examination of the actual cases which produce the mean, two sets of conditions emerge: (1) Commonly soundings are either very stable and saturated from near the surface to about 900 millibars and then gradually decrease in relative humidity above that level; or, (2) are moderately unstable and nearly saturated from 950 millibars up to about 600 millibars. The frequency plot of stabilities in Figure 25 indicates the dual nature of the soundings. A group of soundings have Showalter indices of greater than +8 and another group have indices of less than +5. The high index values coincide to soundings which have low level moisture and dry air above 900 millibars and the low index soundings coincide to those soundings with near pseudo-adiabatic lapse rates and saturated conditions from 950 to 600 millibars. This dual tendency is repeated through the remaining three months with an increasing proportion of the low level moisture and stability

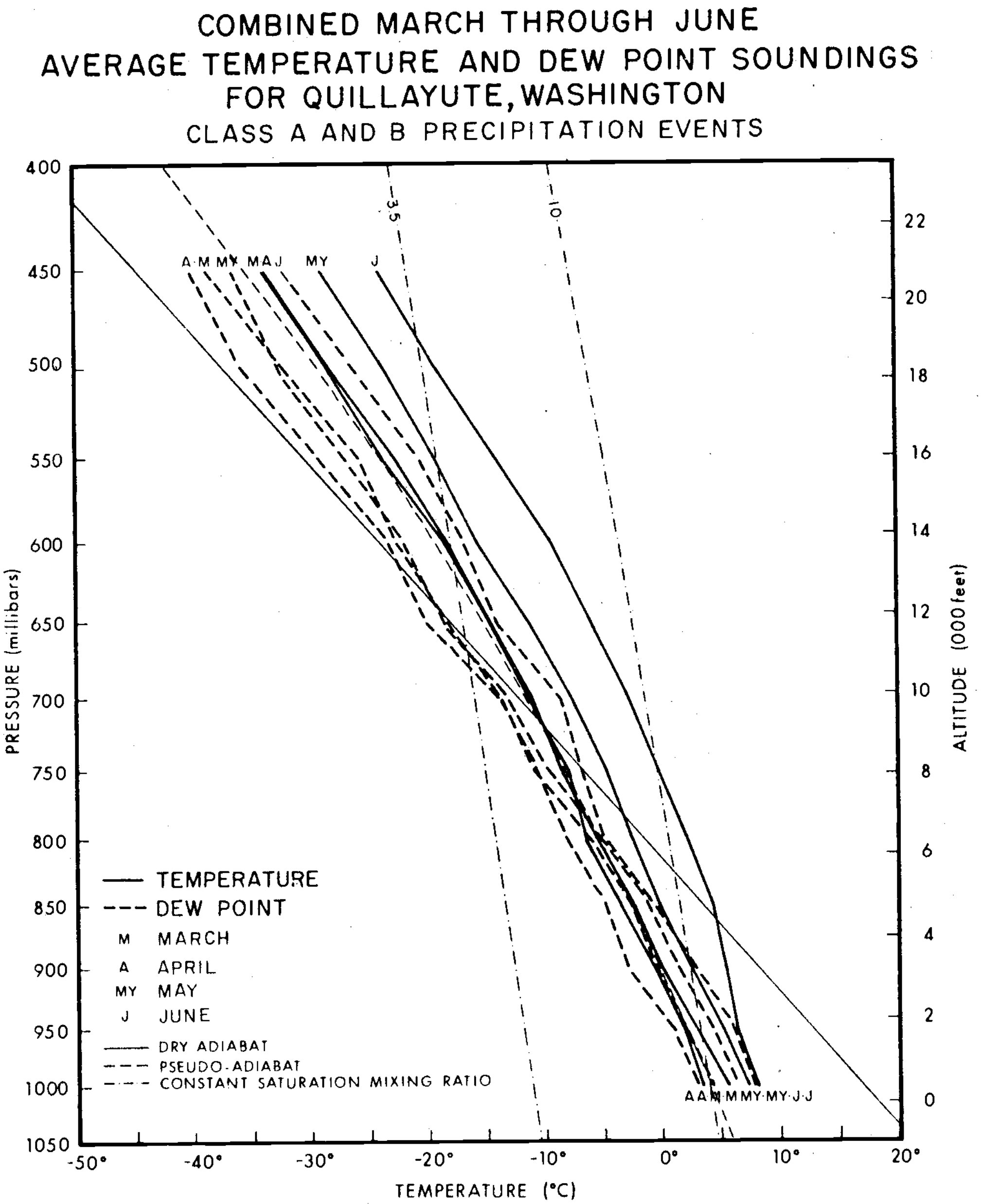

COMBINED MARCH THROUGH JUNE
AVERAGE TEMPERATURE AND DEW POINT SOUNDINGS
FOR QUILLAYUTE, WASHINGTON
CLASS A AND B PRECIPITATION EVENTS
PRESSURE (millibars)
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
ALTITUDE (000 feet)
22
20
18
16
14
12
10
8
6
4
2
0
-50°
-40°
-30°
-20°
-10°
0°
10°
20°
TEMPERATURE (°C)
3.5
10
A M MY MA J MY J
A A M M MY MY J J
TEMPERATURE
DEW POINT
M MARCH
A APRIL
MY MAY
J JUNE
DRY ADIABAT
PSEUDO-ADIABAT
CONSTANT SATURATION MIXING RATIO

FIGURE 24

indices dominating the sample. The average Showalter index for March for Quillayute is +5.0, which is slightly more unstable than the average Spokane value. The ocean may still be a heat source from below at this time as average biweekly sea surface temperature indicates a poleward displacement of the isotherms along the Washington coast at this time (Renner, 1974).

2. Quillayute Precipitation Soundings for April

The average April sounding curve for Quillayute, Washington, is plotted on Figure 24. The temperature curve is quite similar to the March curve with actual cooler conditions prevailing in the first 100 millibars. The sounding data were derived from the year 1975, and April of that year was one of the coldest on record for the past 20 years in the Pacific Northwest (Monthly Weather Review, 1975). The sounding curve is not truly representative of the typical mean April temperatures, but the vertical change in temperature is probably representative of typical April precipitation soundings. The most noticeable difference in the April sounding from the March sounding is wider spread in temperature and dewpoint. Highest relative humidities exist in the first 50 millibars and drop off gradually to 700 millibars. Above 700 millibars, the temperature-dewpoint spread widens up to 450 millibars.

The frequency plot of Showalter indices for April again indicates the dual nautre of precipitation events at Quillayute. Two groups of values exist, one with stability indices greater than +10 and another group with values less than +4. The high stability values are again associated with soundings with low level moisture between

MARCH THROUGH JUNE SHOWALTER INDEX OF VERTICAL STABILITY FOR QUILLAYUTE, WASHINGTON
CLASS A AND B PRECIPITATION EVENTS

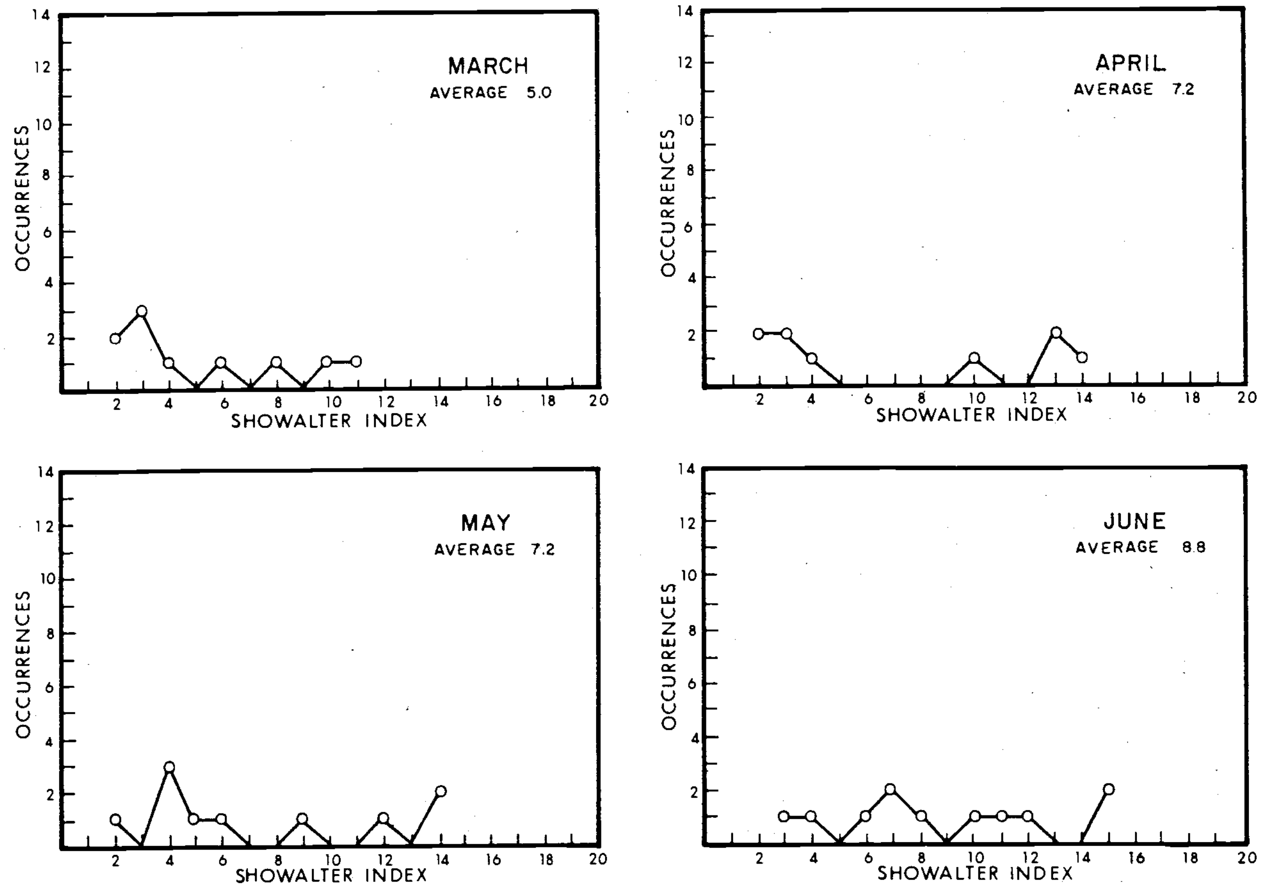


FIGURE 25

1000 and 850 millibars and dry air above; and the low stability values are associated with pseduo-adiabatic lapse rates and near saturated conditions from 950 to 600 millibars. The proportion of higher stability condition has increased slightly from the March period. The average Showalter index has increased to +7.2 while the average stability index for Spokane has decreased from +5.5 to +4.9. It appears that while the lapse rate is quite similar to the March sounding, precipitable moisture again has decreased and convective processes are not as efficient in producing thick, saturated layers, and therefore mean precipitation continues to decrease. A trend has initiated in April that will continue through the months of May and June. Westside locations are experiencing increased stability with precipitation producing disturbances primarily as a result of the stabilizing effect of the cool oceanic surface waters. The interior locations are rapidly destabilizing as a result of the rapidly increasing latent and sensible heat additions in the lower layers of the atmosphere.

3. Quillayute Precipitation Soundings for May

The average May temperature and dewpoint is plotted on Figure 24. The temperature curve indicates a pseudo-adiabatic lapse rate from 950 to 850 millibars, but above 850 millibars is less than the pseudo-adiabat. The air is nearly saturated from 1000 to 800 millibars, but above 800 millibars the relative humidity drops off to below 50% and is under 45% at 450 millibars. The preponderance of precipitation events are not characterized by those with low level moisture between 1000 and 850 millibars and dry air above 800 millibars. If one examines actual sounding events, one often finds a pronounced temperature inversion separating the moist, marine layer below from the dryer air above 800 millibars. The vertical stratification of air masses is a common occurrence in summer along the Pacific Coast and, quite often, it is only a thickening of the marine deck which will give light precipitation to the coastal environment (Lowry, 1962, p. 162).

The stability values in Figure 25 reflect the dual nature of the rain events along the coast. The lower stability values are associated with strong frontal surges which can break up the marine inversion and saturate air to higher levels; the stable indices are associated with weak disturbances which increase the onshore flow and simple thicken the low level marine layer sufficiently to give light precipitation at coastal stations. The average Showalter stability index is +7.2 for all events, which is decidedly more stable than the +4.9 for Spokane, Washington. Mean precipitation is increasing from April to May in the interior locations, but is continuing to decrease in coastal locations primarily as a result of the increasing low level stability imposed upon Pacific air masses moving into the cool, coastal environment where the prevailing coastal northwesterlies produce substantial upwelling (King, 1965, p. 266; Sverdrup, 1942, p. 724-725). In contrast, those Pacific air masses which can break across the Cascades are rapidly destabilized over the interior and the result is an increase in cumulonimbus activity and higher intensity rainfall.

4. Quillayute Precipitation Soundings for June

The average June precipitation sounding is plotted in Figure 24. The sounding has a decided summerlike profile. The temperature curve has a very small lapse rate in the first 100 millibars, and from 950 to 850 millibars is close to isothermal. The lapse rate increases above 850 millibars, but remains less than the pseudo-adiabats throughout the sounding. The dewpoint curve indicates that saturation occurs in the first 100 millibars, but relative humidities rapidly decrease above 900 millibars, remaining below 55% for the rest of the sounding. In the examination of specific soundings, one finds that a strong temperature inversion typically exists between 950 and 850 millibars. This layer separates the cool, saturated marine layer below from much dryer air above 850 millibars. The marine layer can produce precipitation with a thickness of 50 millibars, but under strong onshore flow the moist layer will thicken and extend up to 850 millibars in some cases. Very rarely are Pacific disturbances strong enough to destroy the marine inversion entirely and saturate air extensively above 850 millibars.

The plot of Showalter stability indices in Figure 25 illustrates the increased dominance by low level marine layers. The majority of precipitation events have Showalter indices of +7 or greater, indicating that the marine inversion is quite persistent and tends only to increase in height during precipitation events. The average Showalter value is +8.8 for all cases, while the Spokane average index was +3.5.

It is clear that air masses which produce precipitation in the coastal region indicate increasing vertical stability in the period from

March through June. In contrast, the interior indicates increased destabilization associated with precipitation producing disturbances in the same period. The mean monthly precipitation values in the Pacific Northwest respond to the west to east gradient of stability in this period by continuing to decrease in May and June west of the Cascade Mountains, while interior stations indicate increasing precipitation means.

E. Diurnal Characteristics of Precipitation Soundings for Spokane, Washington

Radiosonde data are obtained at 4 a.m. and 4 p.m. Pacific Standard Time. The diurnal heating cycle might be expected to exert some control on the frequency of rainfall intensity (Geiger, 1966, p. 69-77; Trewartha, 1968, p. 162-163; Brien and Simpson, 1969, p. 125).

Figure 26 presents relative frequencies of four hour precipitation totals occurring at either 4 a.m. or 4 p.m., radiosonde time, for the months of March through June. Four years of data were utilized from 1970 through 1973. The percentage of all rainfall events occurring at either 4 a.m. or 4 p.m. is included on Figure 26. All months indicate an afternoon bias in rainfall, and, as might be expected, the percentage of afternoon rain increases from March through May. The percentage differences are not large, considering the size of the sample. There is also a tendency for higher intensity rainfall to be relatively more frequent in May and June than in March and April. Higher intensity rainfall is also more likely in the afternoon in May and June while it is about equally probably in the a.m. or p.m. in March and April. The differences in the empirical probabilities are

MARCH THROUGH JUNE RELATIVE FREQUENCY OF 4 AM AND 4 PM FOUR HOUR PRECIPITATION TOTALS FOR SPOKANE, WASHINGTON

DATA PERIOD 1970-1973 • CLASS A AND B PRECIPITATION EVENTS

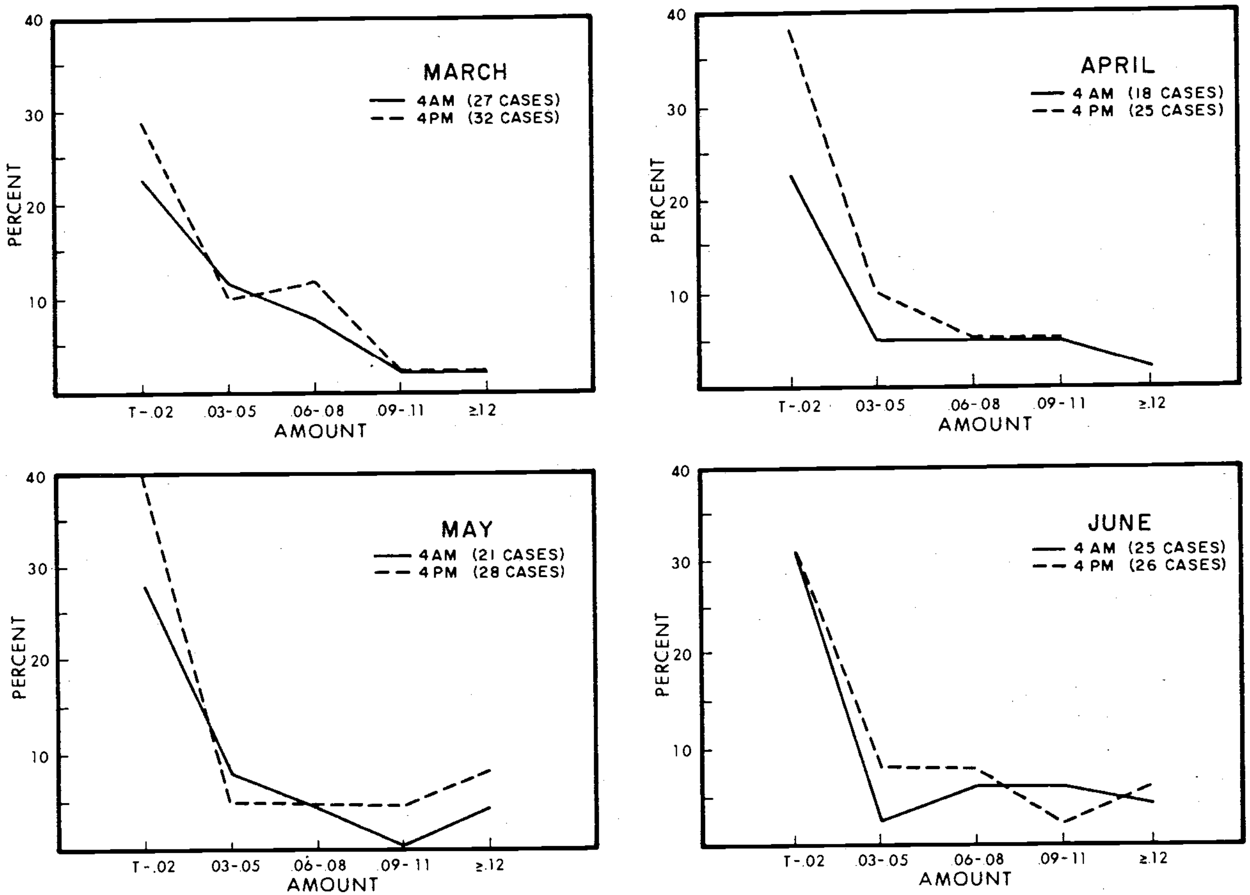


FIGURE 26

not large, however, so one cannot assume that afternoon rainfall is consistently more intense in May and June than morning rainfall.

Table 10 gives average Showalter indices for 4 a.m. and 4 p.m. precipitation events for Spokane for the period of March through June. Surprisingly, there is no obvious monthly trend of increased destabilization of the afternoon soundings in comparison to the morning soundings until the month of June. The Showalter index is calculated using the 850 millibar pressure level, and most of the diurnal heating effects occur in the first 100 millibars. Most precipitation soundings in the spring months will indicate temperature differences amounting to +3 or +4^{0} C at 920 millibars in the afternoon in comparison to 4 a.m. soundings, but this effect rapidly disappears above 900 millibars. The regional destabilization which occurs in the interior of the Pacific Northwest in May and June results in increased high intensity rainfall when an appropriate Pacific frontal disturbance is moving across the region. These disturbances appear to have no diurnal biases, and therefore the diurnal heating cycle, while detectable in the frequency curves of precipitation intensity in Figure 26, is apparently not a major control in itself.

Table 10

Average Monthly Showalter Indices for 4 a.m. and 4 p.m. Precipitation Soundings for Spokane, Washington

Month	4 a.m.	4 p.m.
March	+ 6.5	+ 4.9
April	+ 4.8	+ 5.0
May	+ 4.4	+ 5.0
June	+ 5.1	+ 3.4

Chapter V

CASE STUDIES OF EARLY AND LATE SPRING PRECIPITATION EVENTS IN THE INTERIOR OF THE PACIFIC NORTHWEST

A. Rationale

The secondary maximum of precipitation in the interior of the Pacific Northwest is defined through the analysis of longterm mean precipitation statistics. The synoptic weather events which produce the mean are organized on a day-to-day time scale and exhibit quite variable patterns of atmospheric organization from one given precipitation event to another. The processs of averaging will quite often remove local synoptic scale features whose variance in space and time are quite large, but whose existence are nonetheless quite persistent. If individual precipitation events are examined on a daily basis, one detects subtle but significant differences in the organization of atmospheric variables which will produce precipitation in early spring compared to the late spring period. Two individual synoptic cases were selected in March and in early June because they represented rather typical conditions which characterize precipitation events in both these periods. Their selection was based on quite subjective criteria which integrated the author's assessment of meteorological conditions of temperature and moisture advection at the surface and aloft, plus observed radiosonde characteristics and hourly precipitation amounts. The selection was made from ten years of weather maps and over 50 radiosonde charts.

B. Analysis Procedure

Surface and 500 millibar weather maps were available on a daily basis with plotted synoptic weather data recorded at selected stations in the United States at 7:00 a.m., E.S.T. (4 p.m., P.S.T.). Maps of Maximum and minimum daily temperature and 24 hour precipitation totals for the 24-hour period preceding 1 a.m., E.S.T. were also available (U.S. Weather Bureau Daily Weather Map). Radiosonde data and hourly precipitation data were available for the selected period for Spokane, Washington (U.S. Weather Bureau Pseudo-Adiabatic Charts; March 1975 and June 1971). The daily surface and 500 millibar charts, 24 hour precipitation totals, and 24 hour maximum and minimum temperature maps are presented in Maps 19 through 30. Spokane actual radiosonde data and hourly precipitation totals are presented in Figures 27 through 32, and Tables 11 and 12. Three hour temperature and relative humidity records for Spokane are presented in Table 13. In the following discussion of surface and 500 millibar synoptic maps, only the Pacific Northwest region was included on Maps 19 through 30, due to space limitations. The text occasionally refers to events occurring outside the limits of the maps shown in order to more clearly portray the complete synoptic situation at the time of observation.

C. Synoptic Analysis of the Precipitation Event of March 7-8-9, 1975

1. Surface and 500 Millibar Charts

Maps 19 through 21 are the surface charts for the period of March 7 through March 9, 1975. The surface map for the 7th shows an intense Pacific cyclonic storm approaching the northern California coast. The associated Pacific front is occluded, indicating that the

TABLE 11

Hourly Precipitation for Spokane, Washington
March 7th, 8th and 9th, 1975
(in inches)

Date	Hour											
7th												
A.M.	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm
Precip.	-	-	-	-	-	-	-	-	-	-	-	-
P.M.	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12am
Precip.	-	-	-	-	-	-	-	-	-	-	-	-
8th												
A.M.	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm
Precip.	T	T	-	T	.01	.03	.03	.05	.01	.03	.03	T
P.M.	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12am
Precip.	T	-	-	-	-	-	-	T	T	.04	.04	.02
9th												
A.M.	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm
Precip.	.01	T	.02	.03	T	.01	.01	.03	.04	.01	T	T
P.M.	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12am
Precip.	T	T	T	T	T	T	-	-	-	-	-	-

TABLE 12

Hourly Precipitation for Spokane, Washington
June 9th, 10th and 11th, 1971
(in inches)

Date	Hour											
9th												
A.M.	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm
Precip.	-	-	-	-	-	-	-	-	-	-	-	-
P.M.	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12am
Precip.	-	-	-	-	-	-	-	-	-	-	-	-
10th												
A.M.	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm
Precip.	-	-	-	T	T	.03	.01	.02	.03	.07	.09	.05
P.M.	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12am
Precip.	.08	T	.07	.63	.02	T	-	-	-	-	-	-
11th												
A.M.	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm
Precip.	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 13

Three Hourly Temperature and Relative Humidity
for Spokane, Washington
(in ^{o}F)

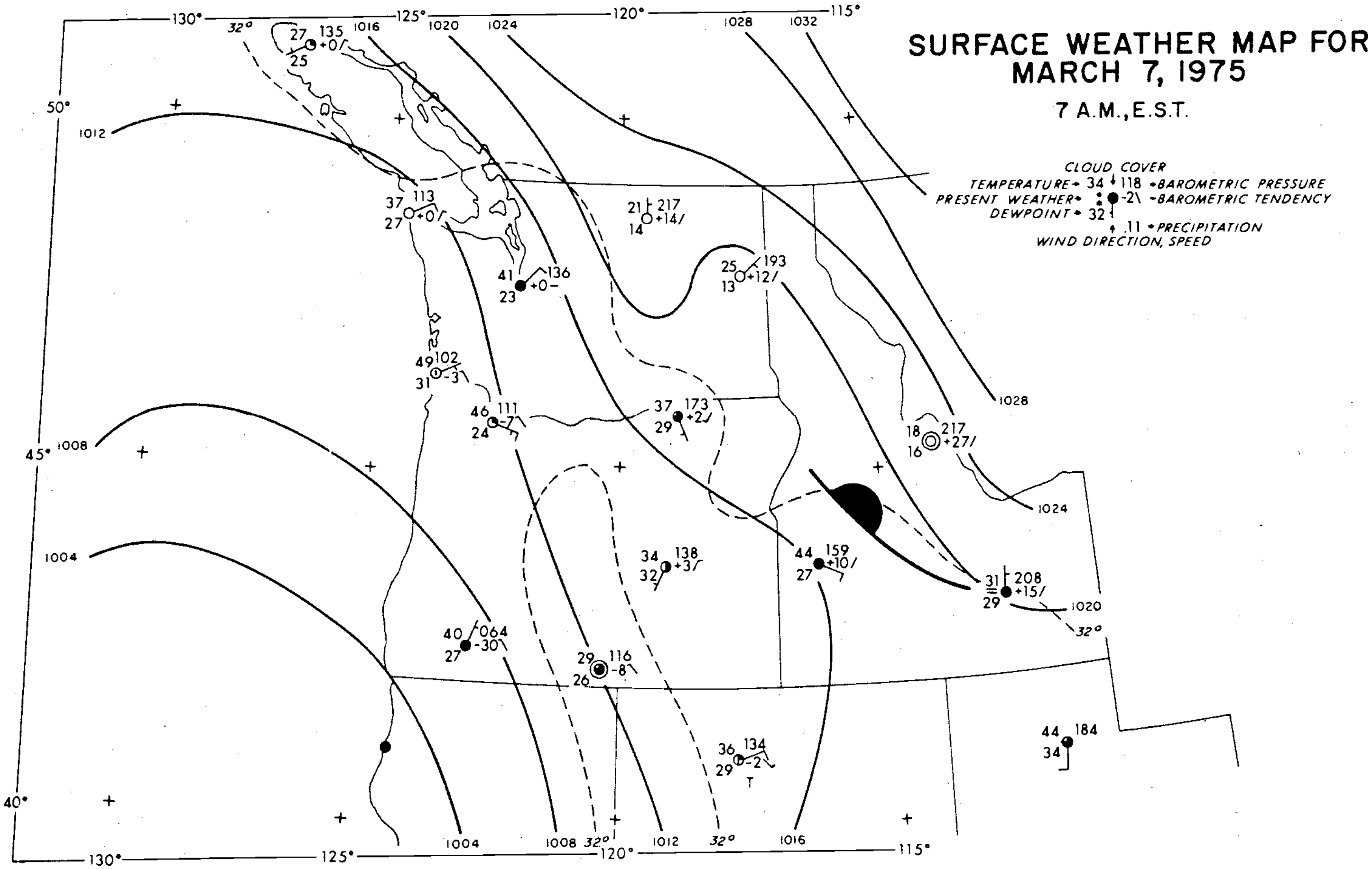
Date	Hour							
March 1975								
7th	1am	4am	7am	10am	1pm	4pm	7pm	10pm
Temp.	26°	25°	26°	34°	40°	41°	34°	35°
R.H.	60%	60%	58%	48%	43%	43%	51%	52%
8th	1am	4am	7am	10am	1pm	4pm	7pm	10pm
Temp.	34°	34°	32°	32°	33°	35°	34°	33°
R.H.	57%	62%	85%	89%	89%	89%	89%	92%
9th	1am	4am	7am	10am	1pm	4pm	7pm	10pm
Temp.	32°	34°	34°	35°	38°	37°	36°	34°
R.H.	92%	92%	89%	89%	86%	85%	89%	89%
June 1971								
9th	1am	4am	7am	10am	1pm	4pm	7pm	10pm
Temp.	51°	44°	55°	64°	69°	68°	61°	57°
R.H.	59%	76%	57%	38%	35%	35%	46%	47%
10th	1am	4am	7am	10am	1pm	4pm	7pm	10pm
Temp.	54°	54°	51°	52°	53°	53°	53°	53°
R.H.	59%	62%	83%	83%	83%	83%	78%	83%
11th	1am	4am	7am	10am	1pm	4pm	7pm	10pm
Temp.	52°	47°	52°	60°	64°	65°	61°	54°
R.H.	77%	80%	72%	60%	68%	43%	56%	72%

storm had developed well offshore and has had a life history of several days. Precipitation is occurring in northern California and southwestern Oregon. The Pacific Northwest is dominated by a weak ridge of high pressure and cool modified maritime polar and continental polar air. Strong high pressure composed of cold continental Arctic air dominates western Canada and has moved south into the northern Rockies and Great Plains. Twenty-four hour maximum and minimum temperatures in the interior of the Pacific Northwest indicate a large diurnal range with minimums well below freezing and maximums in the forties and fifties. Warm air is being advected from the south, but skies have remained clear over most interior stations, permitting efficient radiational cooling at night. Most interior stations indicate light winds which appear to be responding to both local air drainage conditions and the prevailing pressure gradient which is directed from northerly and easterly quadrants. Cool air is draining from the north and east, and the north winds at Omak, northeast at Spokane, and southeasterly winds at Portland are all responding to major downslope topographic controls.

At 500 millibars on the 7th (Map 22), a deep upper level low and associated trough is centered west of the Pacific coast. Two upper level lows are present, one centered in the Gulf of Alaska at 50°N, 140°W, and another centered at 37°N and 130°W. An assymetrical ridge of high pressure, the axis trending northwest by southeast, dominates the Pacific Northwest. Strongest winds at 500 millibars are located to the south over southern California with wind velocities of 90 knots from the southwest located over Santa Maria. The winds aloft indicate strong, warm advection aloft over most of California and

SURFACE WEATHER MAP FOR MARCH 7, 1975

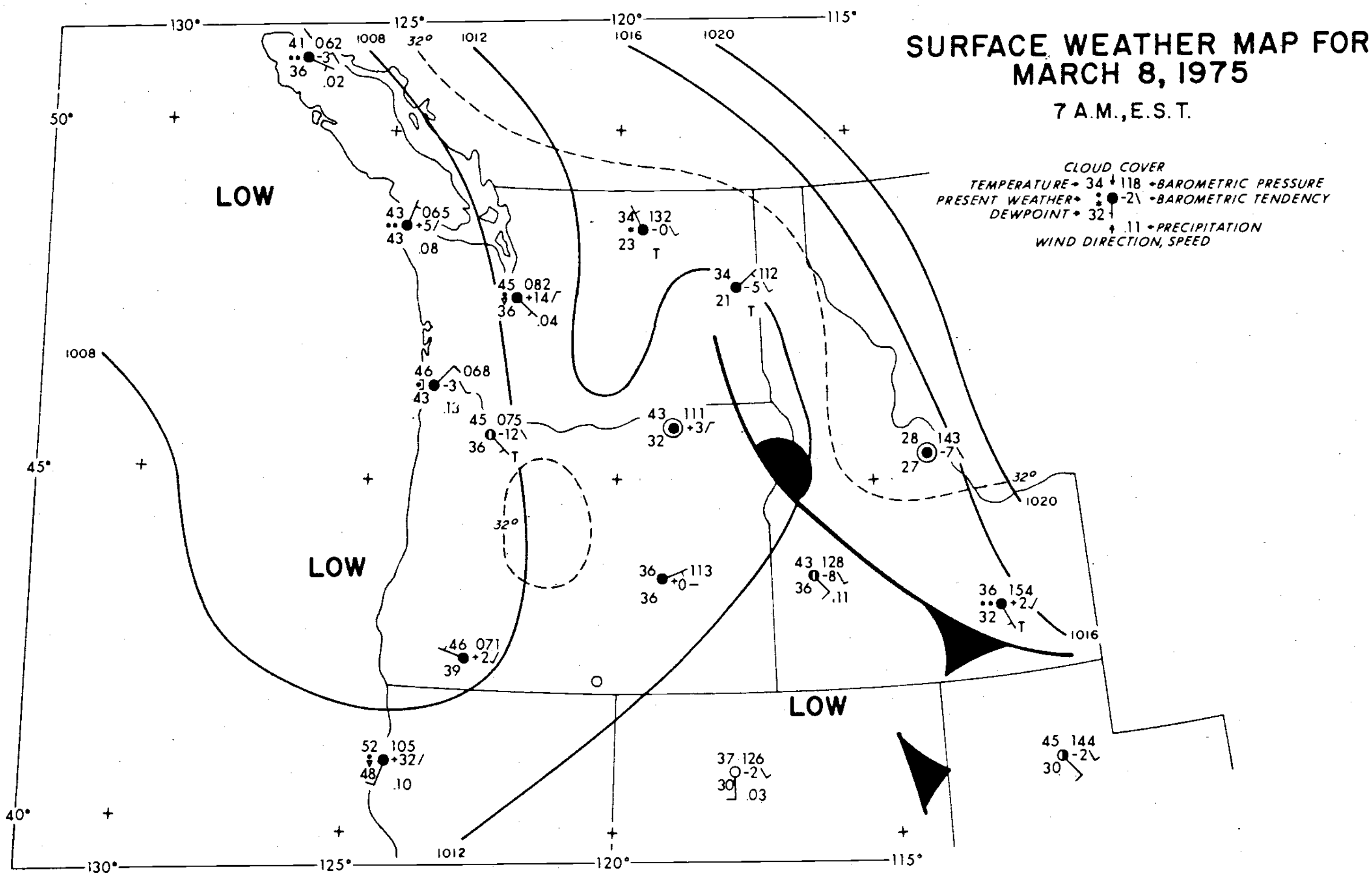
7 A.M., E.S.T.



MAP 19

SURFACE WEATHER MAP FOR MARCH 8, 1975

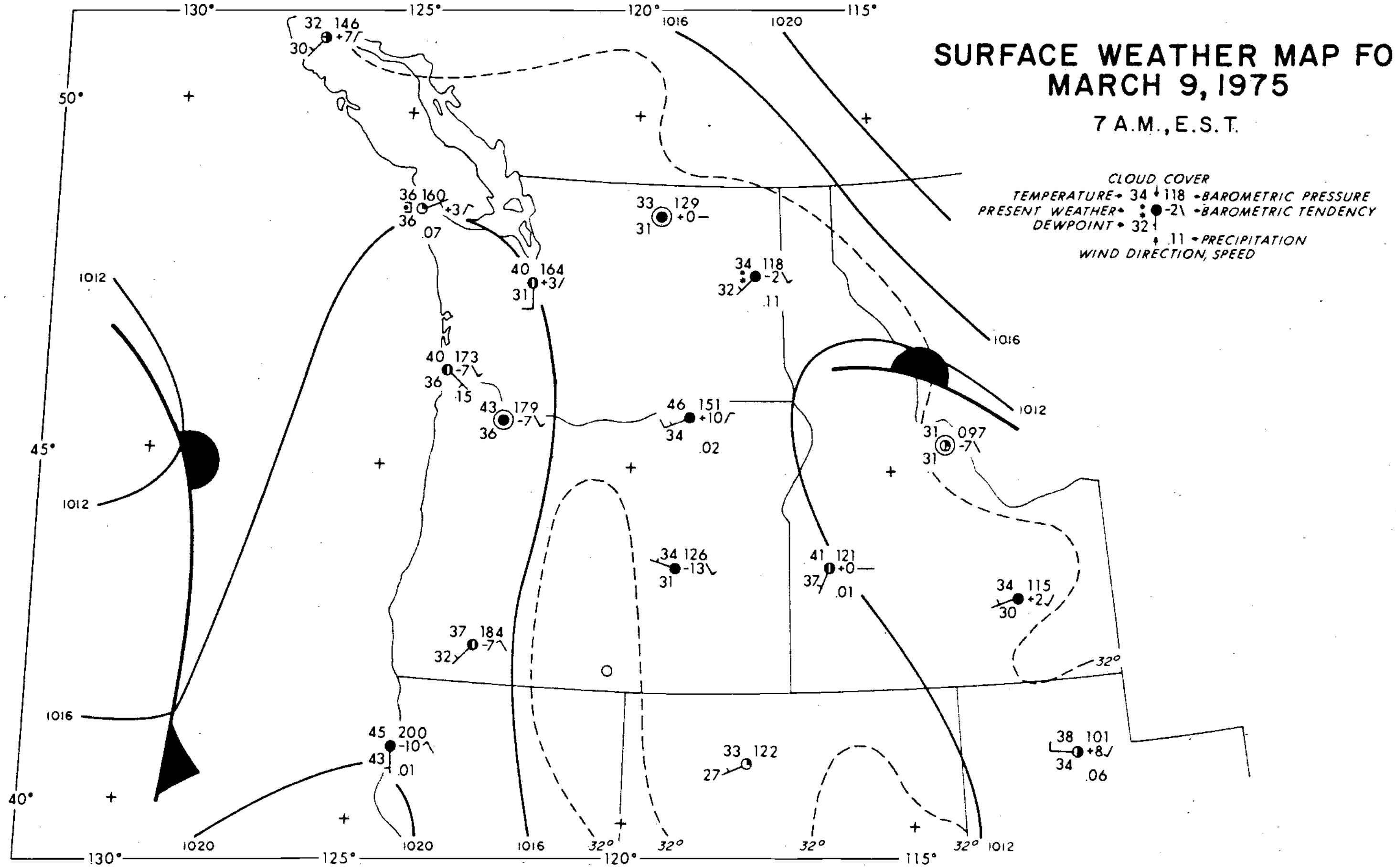
7 A.M., E.S.T.



MAP 20

SURFACE WEATHER MAP FOR MARCH 9, 1975

7 A.M., E.S.T.



MAP 21

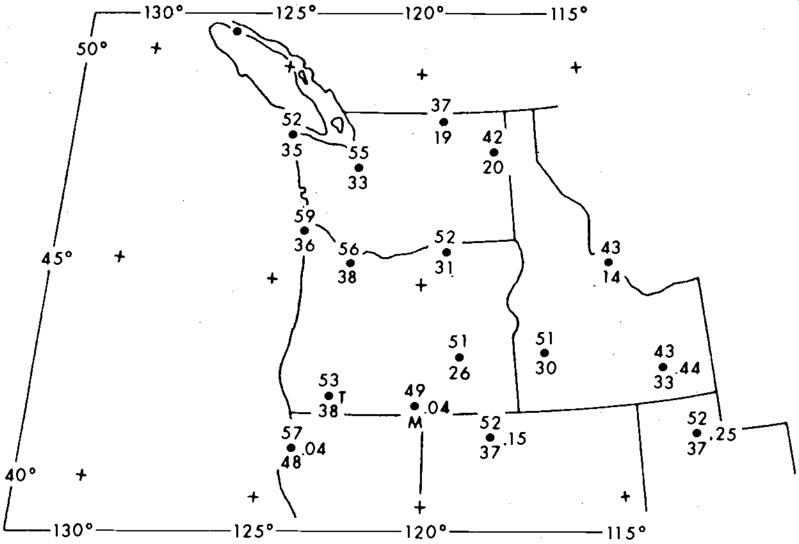
southern Oregon. The 500 millibar isotherms are displaced poleward along the Pacific coast with the thermal ridge coinciding to the 500 millibar pressure ridge. There is a strong difluent circulation over the interior Northwest poleward of the 500 millibar maximum wind velocity belt, indicating strong, positive vorticity advection and favorable conditions for upward vertical motion (Saucier, 1962, p. 350).

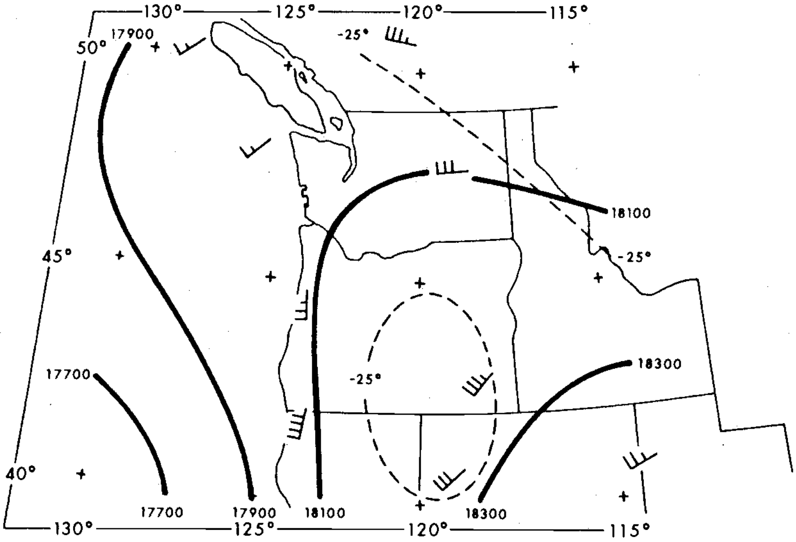
Precipitation has been occurring quite heavily during the previous 24 hours in a zone extending from southern California to southern Oregon and eastward across the Great Basin of Nevada, Utah, Wyoming and northern Colorado. No precipitation has occurred in the Pacific Northwest north of southern Oregon.

On the 8th of March (Map 20), the surface map indicates that the California low has filled and moved northeastward, and is now centered along the central Oregon coast with several minor centers located over northeastern Washington and northeastern Nevada. A warm front has moved northeastward from the northern California coast and is centered across southwestern Idaho and northeastern Washington. A cold front has swept southeastward and extends from the low in northeastern Nevada southwestward through extreme southern California. Precipitation is widespread throughout the Pacific coast states, both west and east of the Cascades and Sierra Nevada mountain ranges. Most stations are cloudy and are either recording precipitation or have recorded precipitation in the last six hours.

Over most of the Pacific Northwest, temperatures have risen both west and east of the Cascades under the strong advection of central Pacific air from southwest to northeast. Westside stations indicate

HIGHEST AND LOWEST TEMPERATURES AND 500 MILLIBAR HEIGHTS AT 7 A.M., E.S.T., FOR MARCH 7, 1975





MAP 22

temperature increases from previous 4 a.m. readings, with changes of: $+6^{O}F$ at Medford; $+3^{O}F$ at Astoria; $+6^{O}F$ at Quillayute; and $+14^{O}F$ at Port Hardy. Interior Pacific Northwest stations also indicate temperature increases of: $+2^{O}F$ at Burns; $+6^{O}$ F at Pendelton; $+13^{O}F$ at Omak; and $+9^{O}F$ at Spokane. Wind directions and velocity still tend to be quite light and variable in the interior Pacific Northwest as a consequence of the weak surface pressure gradients. Winds in Oregon appear to be from a more southerly quadrant than the previous day while northeastern Washington still seems to be responding to cold air drainage from the north and northeast. Omak is reporting snow and Spokane is reporting no precipitation at the observation time, but in the next hour reported freezing rain and ice pellets (Table 12). At 500 millibars on the 8th (Map 23), the upper low has filled, but a deep trough remains along the Pacific coast. The trough is oriented north-south and is centered about $130^{O}W$. The ridge dominating the Pacific Northwest has shifted eastward to $110^{O}W$. The west coast, including the Pacific Northwest, is under the influence of southwesterly winds with southerly winds dominating the coastal areas of Washington and Oregon. The previous day, southwesterly winds were restricted to southern Oregon and westerly circulation prevailed over Washington. The wind speeds at 500 millibars over Washington have not changed, but the highest wind speed, while still located over central California, has shifted further north. Strong positive vorticity advection to the north of the maximum wind velocity belt should be occurring, which would favor upward vertical motion and shower activity in the moist air mass.

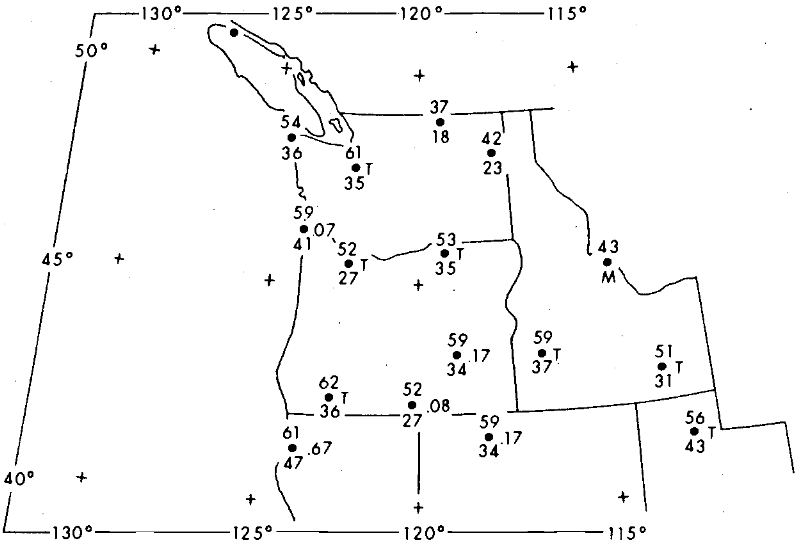
The 500 millibar isotherms show strong equatorward displacement in the trough axis offshore, indicating cold advection between $130^{O}W$ and

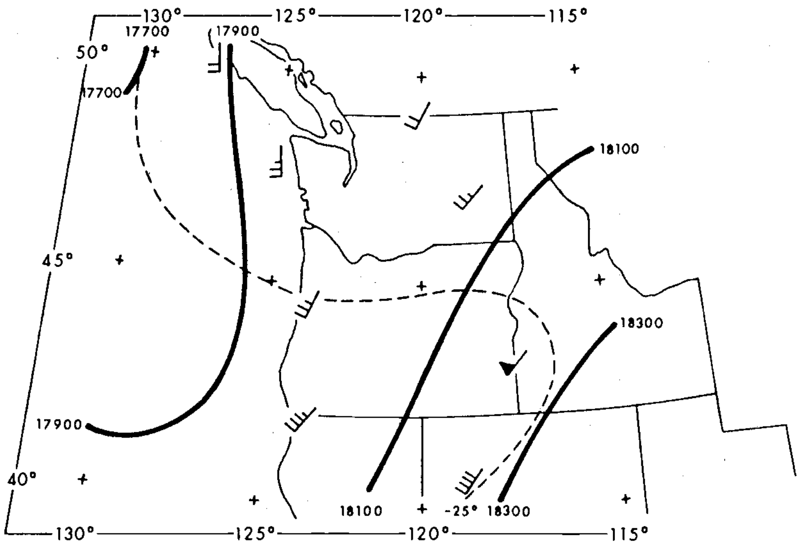
$135^{o}W$. The isotherms are displaced poleward over the west coast and interior of the Pacific Northwest with a warm thermal ridge extending northwestward over Vancouver Island. Warm advection is occurring at 500 millibars over all of the interior Pacific Northwest. Absolute temperature readings at 500 millibars over the interior are $-25^{o}C$, which is sufficiently cool to give a freezing level of below 4000 feet and snowfall at mid elevations.

On March 9th, the surface map (Map 21) indicates a weak ridge of high pressure extending up the Pacific Coast. A trough of low pressure remains over the interior and the low over northeastern Nevada has intensified and moved southeastward into Colorado. Most stations along the Pacific coast remain cloudy with shower activity. Northwesterly winds prevail in northern California with southerly winds dominating the interior of Washington and northeastern Oregon. Most stations in the Pacific Northwest have recorded light precipitation in the last six hours, but only the Washington coast and Spokane are recording precipitation at the time of observation. Temperatures have not changed significantly, but cooler, unstable air has swept across the region associated with the eastward movement of the 500 millibar trough (Map 24). Representative 24 hour temperature changes are: $-6^{o}F$ at Quillayute; $-6^{o}F$ at Astoria; $-9^{o}F$ at Port Hardy; $-2^{o}F$ at Burns; $-2^{o}F$ at Boise; $-1^{o}F$ at Omak; and $0^{o}F$ at Spokane. A new Pacific storm is approaching the southern British Columbia coast but is still some 300 miles offshore. Spokane is representative of the cooler, unstable air as snow is falling with winds out of the southwest.

At 500 millibars, the major trough has filled and moved rapidly eastward, centered now over southern Nevada at about $115^{o}W$. A

HIGHEST AND LOWEST TEMPERATURES AND 500 MILLIBAR HEIGHTS AT 7 A.M., E.S.T., FOR MARCH 8, 1975





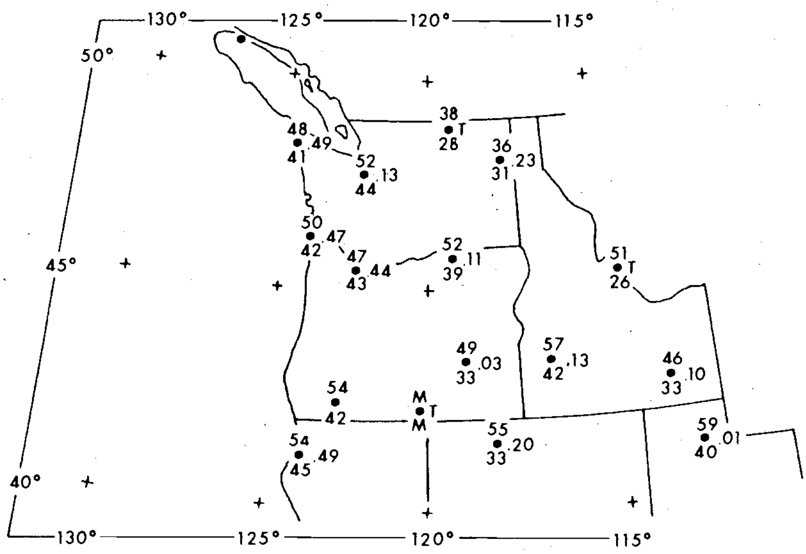
MAP 23

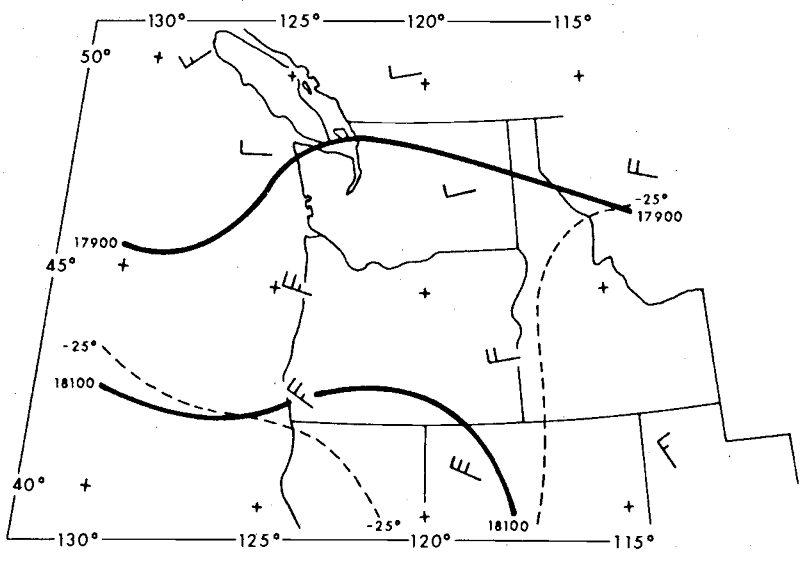
disorganized pattern of westerly flow exists over the Pacific Northwest with very light winds of less that 15 knots over Washington and slightly higher velocity winds of 25 knots over Oregon. The trough has moved eastward and is·centered over the Pacific Northwest interior. The strongest cold advection aloft is associated with the more southerly portion of the trough over Nevada and western Arizona. A very weak north-south temperature gradient exists over the Pacific Northwest with the entire region dominated by air between $-25^{o}C$ and $-28^{o}C$ at 500 millibars.

2. Hourly Precipitation Data and Radiosonde Data for Spokane for March 7-8-9, 1975

The 24-hour precipitation map for March 9th (Map 24) indicates that extensive and fairly heavy precipitation occurred over all of the far west at both coastal and interior locations. The precipitation totals are from 1a.m., E.S.T. on the 8th (10pm,P.S.T. on the 7th) to 1am, E.S.T. on the 9th (10 pm, P.S.T. on the 8th). It appears that most of the precipitation occurring on the 8th was associated with strong, warm advection from the southwest. This fact is verified by analyzing the hourly precipitation records at Spokane. Precipitation began at 1 am. P.S.T. on the 8th with .19 inches of precipitation being recorded from 5 am to 11 am. No measurable precipitation was recorded between 11 am on the 8th and 9 pm on the 9th. Table 13 gives three hourly temperature and dewpoint records for Spokane for the 7th, 8th and 9th of March. March 7 is characterized by cool conditions with a moderate diurnal range of 16^{o} F. Relative humidities are consistently in the 45% to 60% range. On the 8th, temperatures warm and maintain a minimal diurnal range of $3^{o}F$. Precipitation begins at 1 am, but is

HIGHEST AND LOWEST TEMPERATURES AND 500 MILLIBAR HEIGHTS AT 7 A.M., E.S.T., FOR MARCH 9, 1975





MAP 24

in the form of steady precipitation from 4 a.m. to 11 a.m. Relative humidity increases to 85% at 7 am, and persists above 89% for the next 24 hours. On the 9th, temperatures remain in the 30's, but a slightly larger diurnal range is apparent (+6^{0}F).

Figures 27 through 29 give the 4 a.m. radiosonde data for Spokane for the March 7 through March 9 period. On the 7th (Fig. 27), the sounding shows a strong radiational temperature inversion in the first 10 millibars and is nearly isothermal up to 850 millibars. Winds are out of the east and northeast in this layer, indicating regional drainage of cool air from high pressure to the northeast. Between 850 and 750 millibars, a weak lapse rate exists with winds from the southeast and south. In this layer, the temperature - dewpoint difference decreases, indicating that some moisture advection from the south is already occurring. From 750 to 650 millibars nearly isothermal lapse rate exists, and moisture rapidly decreases above 720 millibars. There is nearly pseudo-adiabatic lapse rate above 650 millibars associated with quite dry conditions. The winds rapidly veer above 700 millibars and are consistently from the west from 650 to 450 millibars at 25 to 30 knots. This sounding indicates a three layered system with: (1) dry continental polar air from the surface to 850 millibars and strong radiational cooling; (2) a moist layer (but unsaturated) from 850 to 720 millibars associated with southerly winds and the approaching storm off of northern California; and (3) dry mP air from 700 to 450 millibars associated with moderate westerly winds. The sounding has a Showalter index of +15.

ACTUAL MARCH 7 TEMPERATURE AND DEW POINT SOUNDING FOR SPOKANE, WASHINGTON
4 AM – 1975

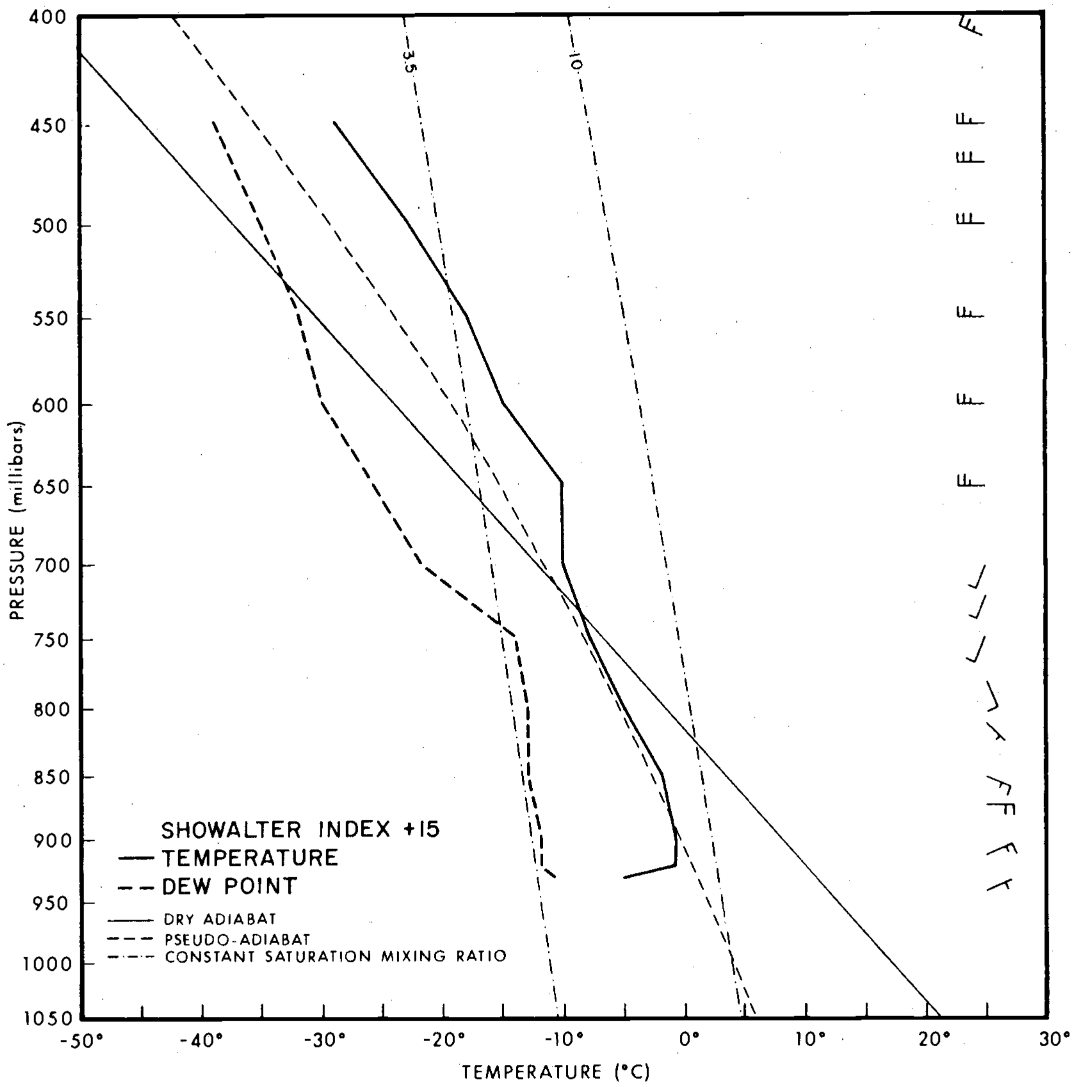


FIGURE 27

The 4 a.m. sounding for the 8th of March is shown in Figure 28. Precipitation began at 1 am and was intermittent until 5 a.m. when steady precipitation continued for six hours. The sounding has a temperature inversion from the surface to 850 millibars. The low level radiational inversion is absent so the temperature increase with height is preimarily the result of cool continental polar air being rapidly overrun by warm Pacific air above 800 millibars. The winds are from the northeast from the surface to 900 millibars and rapidly veer around to southerly and south-southwesterly winds above 900 millibars. Wind velocities increase to 15 to 25 knots above 900 millibars. The temperature-dewpoint difference also illustrates the two-layered system. The continental polar air is quite dry below 850 millibars, but temperature and dewpoint rapidly close to saturation from 850 to 750 millibars. The air is saturated and uniformly less than pseudo-adiabatic from 750 to 550 millibars. The warm advection in the midlayers is quite apparent if one examines temperatures from the 4 a.m. sounding on the 8th and temperatures from equivalent levels on the 7th (Table 14).

The most significant warming has occurred between 850 and 900 millibars associated with the strong southerly flow dominating the layer. Temperatures have not changed appreciably above 700 millibars, indicating that the westerly advection of the previous day and the southerly advection of the 8th were not significantly different in temperature qualities, but were quite different in moisture qualities. The sounding for the 8th has a Showalter index of +8, quite stable, principally as a result of the warming at 850 millibars.

ACTUAL MARCH 8 TEMPERATURE AND DEW POINT SOUNDING FOR SPOKANE, WASHINGTON
4 AM – 1975

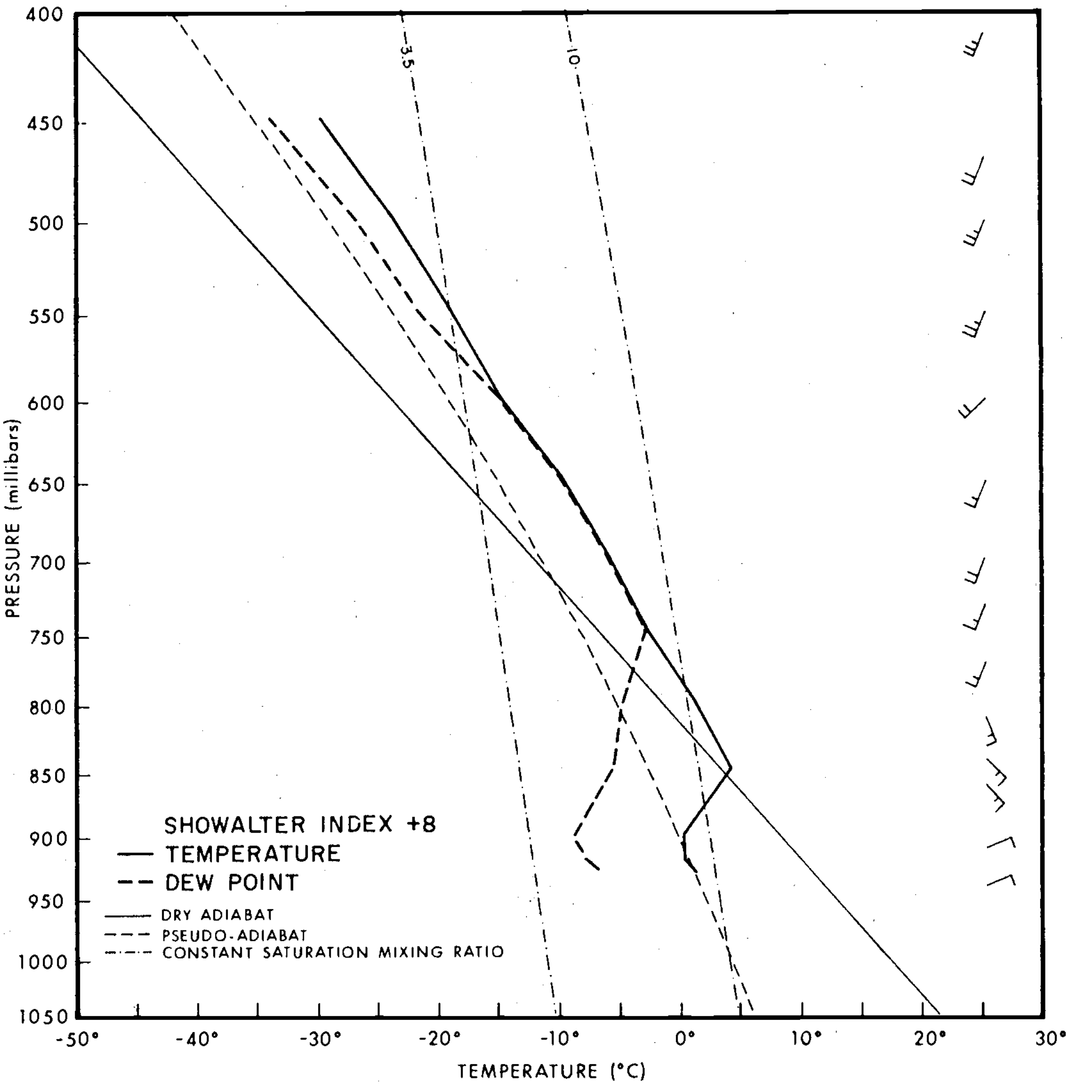


FIGURE 28

TABLE 14

Temperature and Temperature Changes
for Spokane Radiosonde
March 7-8-9, 1975

Height in Millibars	7th	8th	ΔT	9th	ΔT
930	$-5^{o}C$	$+1^{o}C$	$+6^{o}C$	$0^{o}C$	$-1^{o}C$
920	$-1^{o}C$	$0^{o}C$	$+1^{o}C$	$0^{o}C$	$0^{o}C$
900	$-1^{o}C$	$0^{o}C$	$+1^{o}C$	$0^{o}C$	$0^{o}C$
850	$-2^{o}C$	$+4^{o}C$	$+6^{o}C$	$-2^{o}C$	$-6^{o}C$
800	$-5^{o}C$	$+1^{o}C$	$+6^{o}C$	$-3^{o}C$	$-4^{o}C$
750	$-8^{o}C$	$-3^{o}C$	$+5^{o}C$	$-6^{o}C$	$-3^{o}C$
700	$-10^{o}C$	$-6^{o}C$	$+4^{o}C$	$-9^{o}C$	$-3^{o}C$
600	$-15^{o}C$	$-15^{o}C$	$0^{o}C$	$-17^{o}C$	$-2^{o}C$
500	$-23^{o}C$	$-24^{o}C$	$-1^{o}C$	$-27^{o}C$	$-3^{o}C$

Figure 29 gives the radiosonde data for March 9 at 4 a.m. Snow was occurring at Spokane at the sounding time and continued until noon. The advection of cool, unstable air is quite evident as the sounding has cooled at all levels with the exception of the surface layer from the previous day (Table 14).

The sounding has a very weak lapse rate of $2^{o}C$ per 100 millibars from the surface to 700 millibars. From 650 to 450 millibars, the lapse rate is nearly pseudo-adiabatic. The sounding is saturated from 850 to 650 millibars and saturated from 550 to 470 millibars. The cool advection associated with the rear quadrants of the 500 millibar trough is evident in the winds which are from the southwest from the surface to 850 millibars, and become westerly and northwesterly from 800 millibars to 500 millibars. The sounding has a Showalter index of +4.

The synoptic sequence which has been presented is indicative of many which produce wintertime precipitation in the interior Northwest. Salient features which are quite typical of these events are: (1) a surface depression located off the Oregon-Washington coast with prevailing south to southwesterly flow dominating the Pacific coast region; (2) cool, modified polar or continental polar air present in the first 100 millibars over the interior with easterly to northerly winds blowing at the surface; (3) warm, moist advection above 850 millibars from the south or southwest which results in steady, moderate intensity precipitation, but stable lapse rates; (4) the passage eastward of an upper level trough or closed low and cold advection from the west or northwest which terminates extensive precipitation, but due to the moist, unstable character of the air mass, can result in localized shower activity of rain or snow; and (5) the most extensive and heavy precipitation is associated with the warm sectors of both surface and upper air depressions.

D. Synoptic Analysis of the Precipitation Event of June 9-10-11, 1971

1. Surface and 500 Millibar Charts

Maps 25 through 27 give the surface charts for the period of June 9 through June 11, 1971. In the previous three days, a series of Pacific cold fronts have been moving across the Pacific Northwest, associated with a very intense, closed 500 millibar cold low located over northwestern Washington. On the 9th of June, this low has filled and moved into southwestern British Columbia. Temperatures have remained cool over all the Pacific Northwest and skies are cloudy at

ACTUAL MARCH 9 TEMPERATURE AND DEW POINT SOUNDING FOR SPOKANE, WASHINGTON
4 AM – 1975

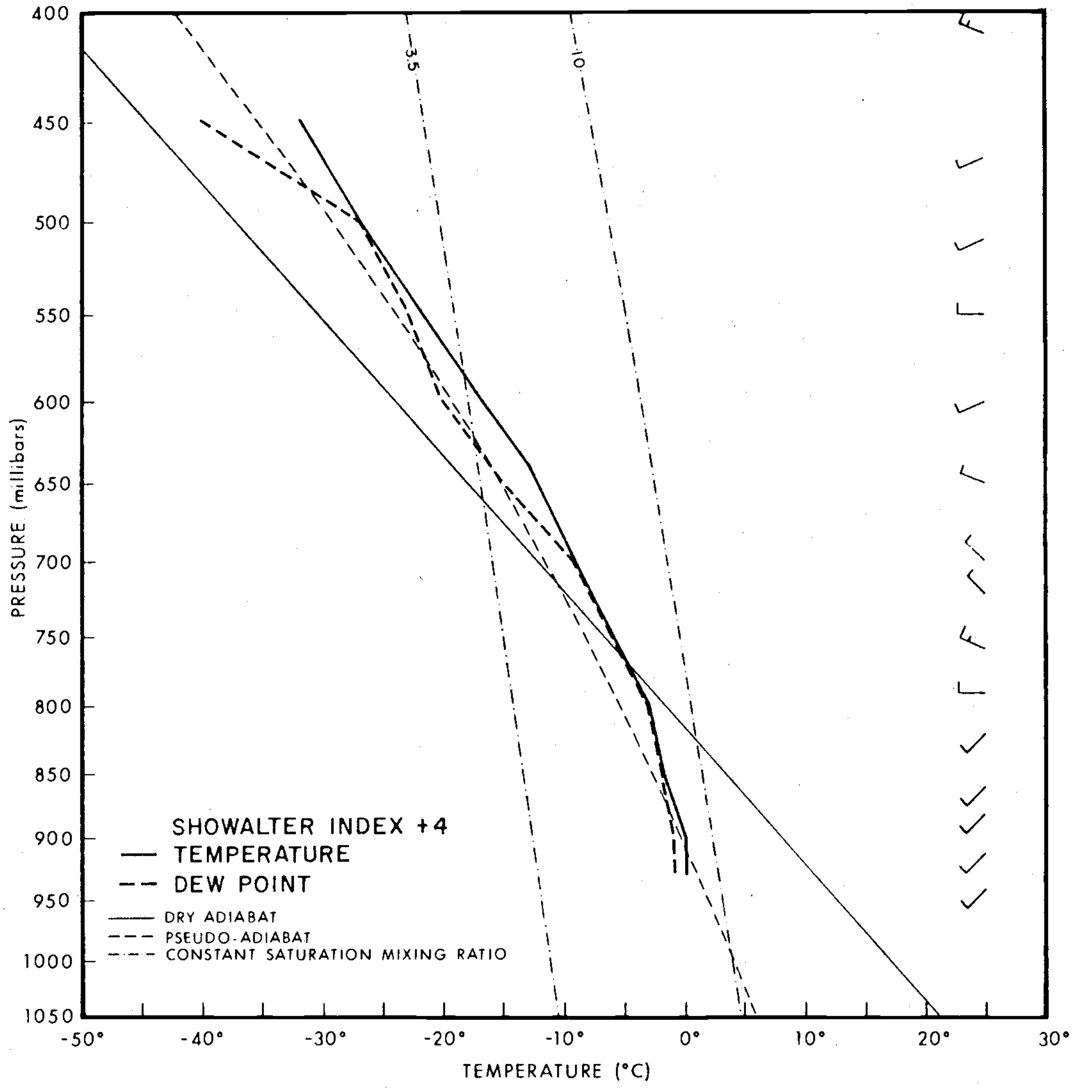
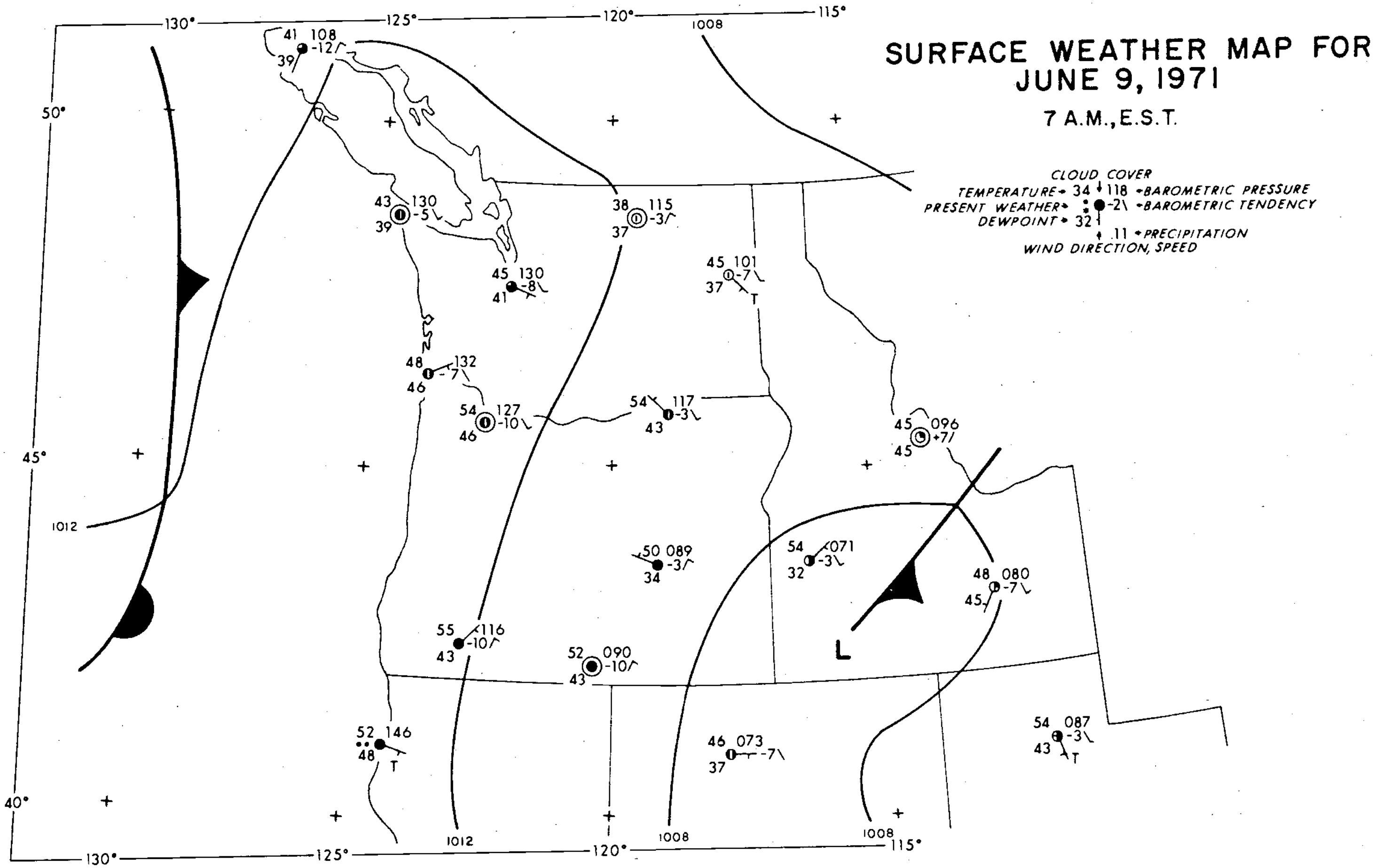
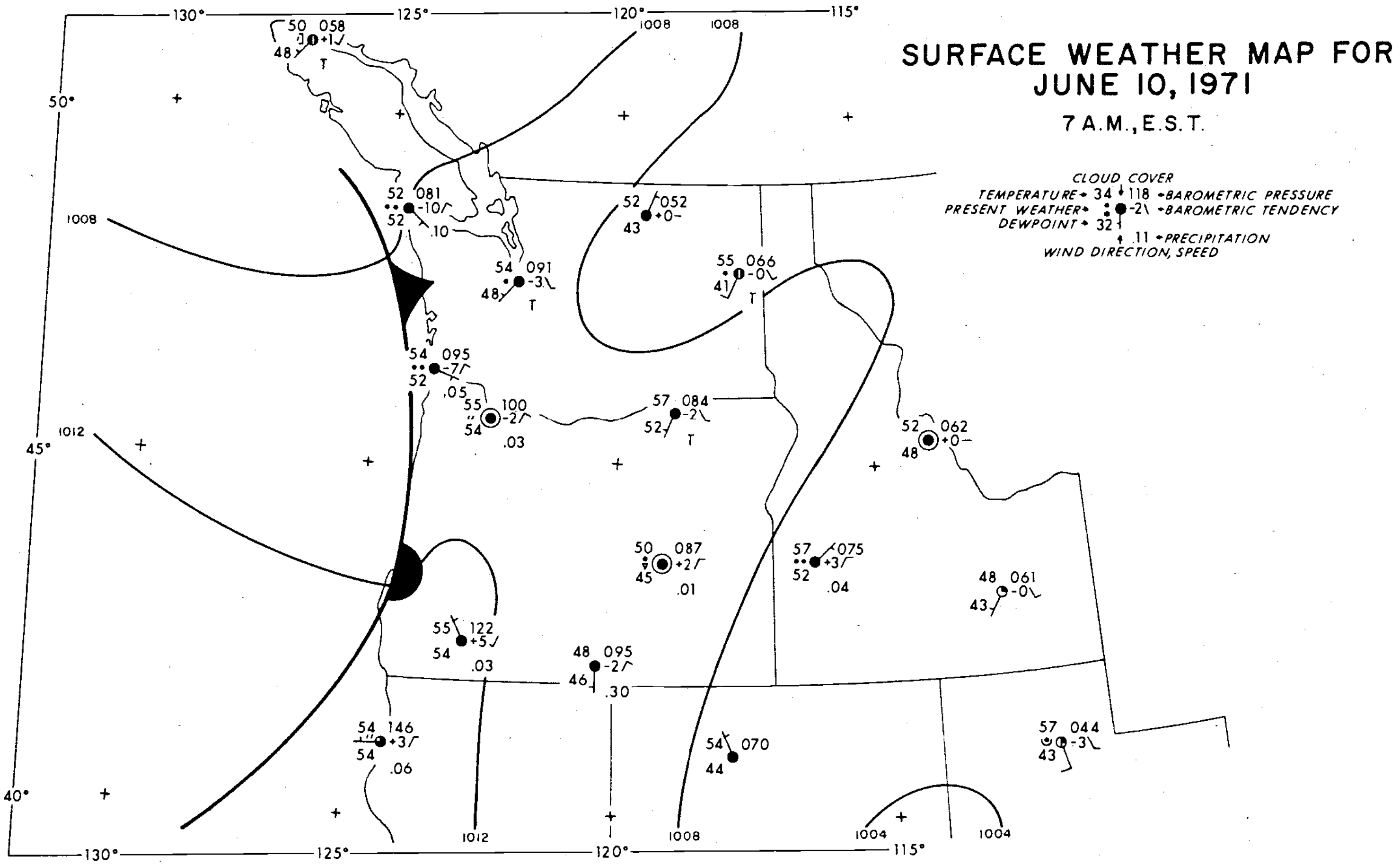


FIGURE 29


SURFACE WEATHER MAP FOR
JUNE 9, 1971
7 A.M., E.S.T.
CLOUD COVER
TEMPERATURE
BAROMETRIC PRESSURE
PRESENT WEATHER
BAROMETRIC TENDENCY
DEWPOINT
PRECIPITATION
WIND DIRECTION, SPEED
130°
125°
120°
115°
50°
45°
40°
1008
1012
L

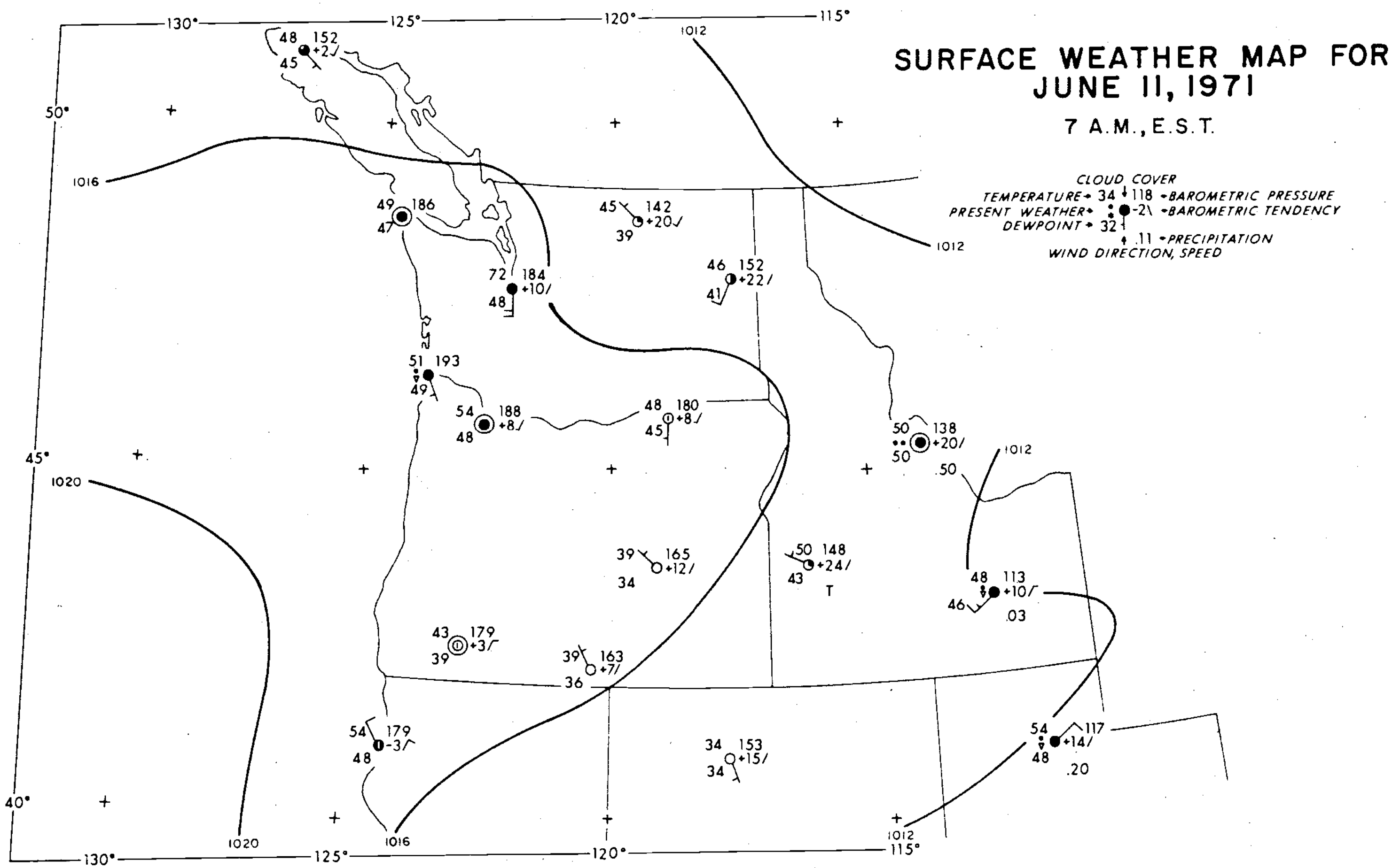
MAP 25


SURFACE WEATHER MAP FOR JUNE 10, 1971
7 A.M., E.S.T.
CLOUD COVER
TEMPERATURE
BAROMETRIC PRESSURE
PRESENT WEATHER
BAROMETRIC TENDENCY
DEWPOINT
PRECIPITATION
WIND DIRECTION, SPEED
130°
125°
120°
115°
50°
45°
40°
1008
1012
1004

MAP 26

SURFACE WEATHER MAP FOR JUNE 11, 1971

7 A.M., E.S.T.



MAP 27

most stations, both west and east of the Cascades (Map 25). The latest Pacific cold front, which gave light rain on the 8th, by the 9th has moved into central Montana and a weak ridge of high pressure has extended into western Oregon and Washington. The next Pacific occlusion is about 200 miles off the coast of Washington and approaching from the west. Winds are very light and variable, both west and east of the Cascades in response to the very weak pressure gradient.

At 500 millibars (Map 28), the closed low over southeastern British Columbia is filling, but a well developed thermal trough remains over the interior Pacific Northwest. A new upper trough in the Gulf of Alaska is shifting southeastward and by the 10th will be along the west coast. Temperatures are cool at 500 millibars ($-15^{\circ}C$ to $-20^{\circ}C$) and winds are from the west and southwest.

On the 10th of June (Map 26), the surface map shows a cold occlusion on the west coast of Washington and Oregon with precipitation occurring at most stations west of the Cascades. Precipitation is also occurring in the interior ahead of the front at Burns, Boise and Spokane. Most interior stations report light, southwest winds as low pressure still exists to the northeast. All stations, both west and east of the Cascades, report cloudy skies, indicating that moisture advection from the southwest is quite extensive.

The 500 millibar map (Map 29) shows a northwest-southeast oriented trough extending from northwestern Washington into southwestern Oregon. Strong cyclonic wind shear is present in the trough as western Oregon stations indicate northwest winds, and central Washington and eastern Oregon indicate southwest winds. A thermal trough is present over the interior, indicating that unstable lapse rates are present some distance in advance of the surface front.

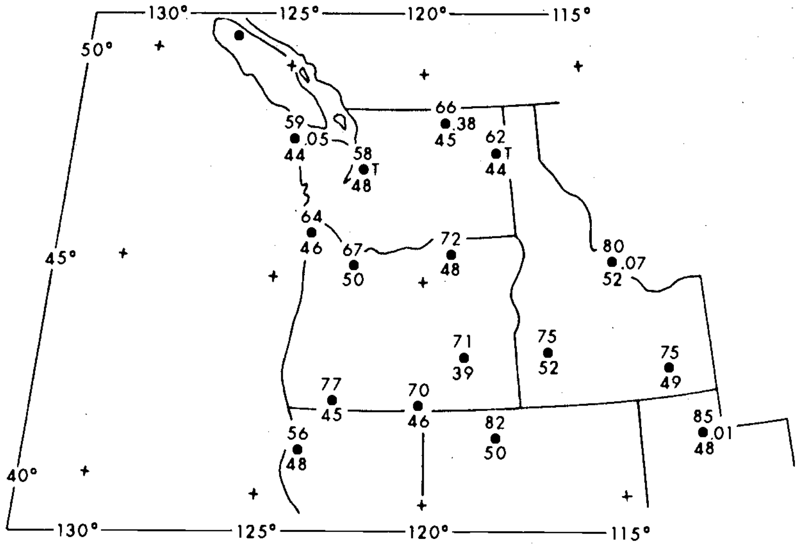
Map 27 presents the surface map for the 11th of June, 1971. The Pacific front has moved rapidly southeastward and is now located in southern Wyoming, central Utah, and southern Nevada. High pressure has built in over western Washington and Oregon with northwest winds prevailing across most of central and southeast Oregon. Southerly winds still exist at Pendelton and Spokane as low pressure persists to the northeast. Most interior Oregon stations report clear skies, with Washington stations reporting cloudy skies and showers west of the Cascades and partly cloudy skies east of the Cascades. Temperatures are significantly cooler than the previous day with representative decreases of: -9^{O}F at Spokane; -11^{O}F at Pendelton; -11^{O}F at Burns; and -7^{O}F at Omak. The dominance by post, cold frontal, maritime polar air is quite apparent.

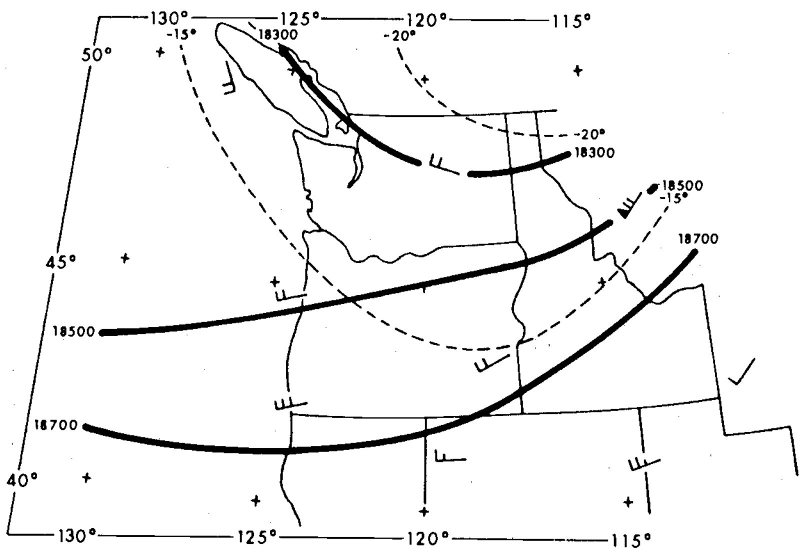
At 500 millibars (Map 30), the trough has moved eastward and is now centered over central Idaho and eastern Nevada. Shower activity is occurring on the surface map over eastern Idaho and northern Utah, despite being in the post, cold frontal zone, indicating the role the cold, upper trough plays in destabilizing the air mass. A weak ridge of high pressure is dominating most of the region. A cool, thermal trough does remain over the interior Pacific Northwest.

2. Hourly Precipitation Data and Radiosonde Data for Spokane for June 9-10-11, 1971

The synoptic weather sequence which produced the rains on the 10th is more clearly illustrated by examining the hourly precipitation, temperature and radiosonde data. Most of the precipitation which occurred on the 10th fell between the times of the synoptic maps for

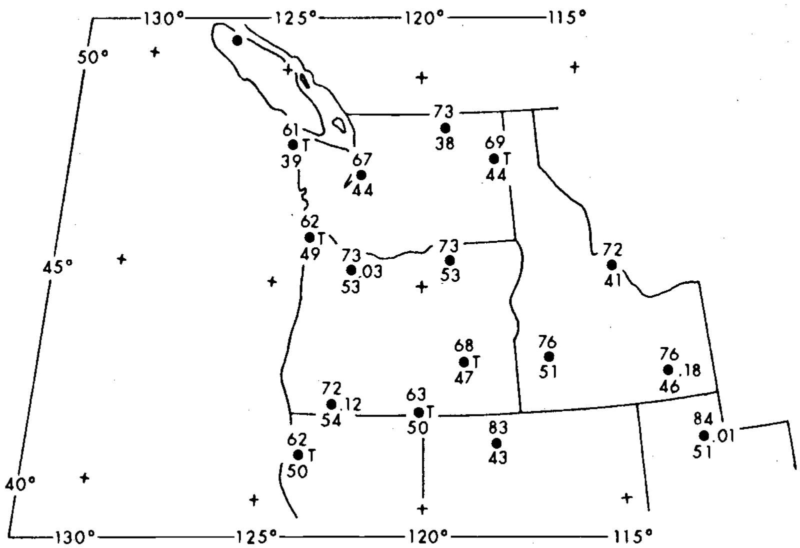
HIGHEST AND LOWEST TEMPERATURES AND 500 MILLIBAR HEIGHTS AT 7 A.M., E.S.T., FOR JUNE 9, 1971

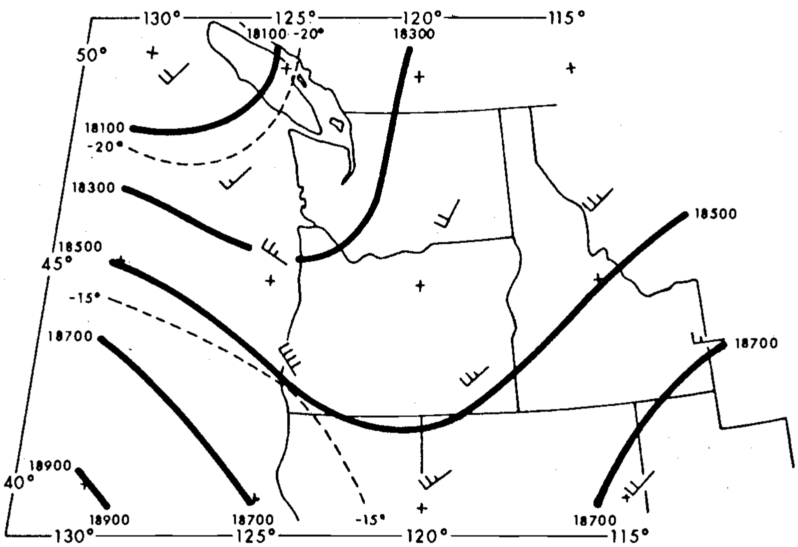




MAP 28

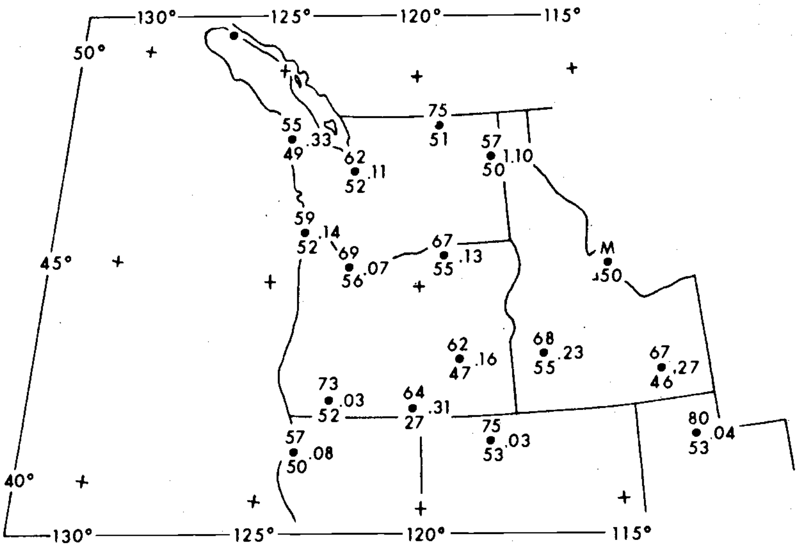
HIGHEST AND LOWEST TEMPERATURES AND 500 MILLIBAR HEIGHTS AT 7 A.M., E.S.T., FOR JUNE 10, 1971

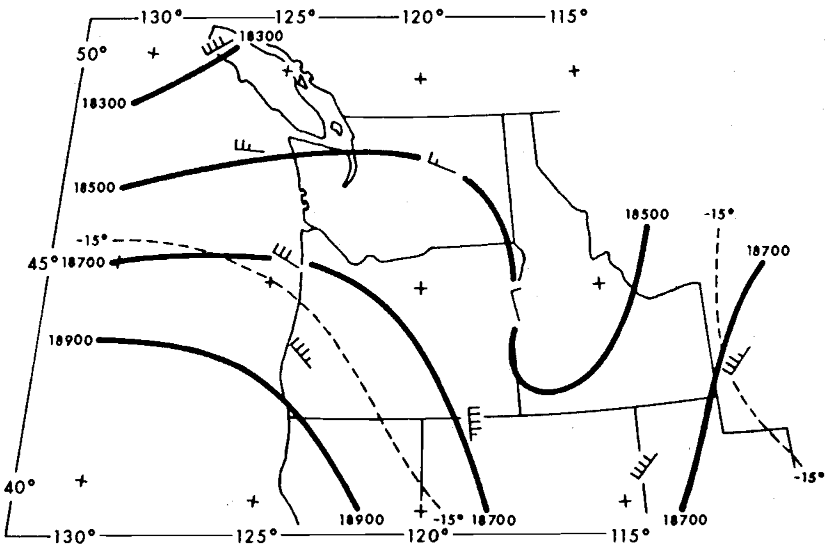




MAP 29

HIGHEST AND LOWEST TEMPERATURES AND 500 MILLIBAR HEIGHTS AT 7 A.M., E.S.T., FOR JUNE 11, 1971





MAP 30

the 10th and 11th of June.

Table 12 presents hourly precipitation totals for Spokane on the 9th, 10th, and 11th of June, 1971. Precipitation began on the 10th at 4 a.m. and for the first 6 hours was steady but light in intensity. At 10 a.m., the intensity increased and quite heavy rain fell until 4 p.m., at which time a thunderstorm occurred, dropping .63 inches in an hour. Precipitation terminated two hours after that event, indicative of the passage of the cold front and the intrusion of dryer air.

Three hour temperature for the 9th, 10th and 11th are plotted in Table 13. On the 9th, a 26^{o}F diurnal range of temperatures occurred with warm, moist air moving in during the late afternoon and evening hours. On the 10th, precipitation began at 4 a.m. and continued during most of the day. The diurnal range of temperatures was very small, amounting to 5^{o}C with cool air in the mid-50's dominating most of the day. By the 11th, cool but dry Pacific air had swept across the region and Spokane had a diurnal range of 18^{o}F, from 47^{o}F to 65^{o}F.

Figures 30 through 32 give the 4 p.m. sounding on the 9th, 4 a.m. sounding on the 10th, 4 p.m. sounding on the 10th, and 4 a.m. sounding on the 11th of June, 1971, for Spokane. The 4 p.m. sounding for the 9th has a dry adiabatic lapse rate from the surface to 750 millibars, indicating strong surface heating and vertical convection. The air is quite dry throughout the sounding with the highest relative humidity at the top of the surface mixed layer, reflecting some fair weather cumulus development. The lapse rate is quite stable above 750 millibars, averaging less than 3^{o}C per 100 millibars. The air is also quite dry above 750 millibars as the winds veer to the west and northwest with height. The 4 p.m. sounding for the 9th has a Showalter index of +8.

The sounding for 4 a.m. on the 10th indicates widespread moisture advection from the south and southwest, as it is saturated from 750 to 500 millibars. The sounding is dry from the surface to 750 millibars, indicative of the common extent to which moisture is advected into the interior well above the 850 millibar level. Surface temperatures are cooler since it is the early morning sounding, but temperatures above 850 millibars have changed very little from the previous day. This lack of temperature change is indicative of warm advection above 750 millibars, and the southerly winds above 700 millibars verify this. Precipitation is just beginning at this time and will be steady and light for the next 5 hours in the warm pre-cold front sector. The Showalter index is +8, which is quite stable.

The 4 p.m. sounding on the 10th, during which time thunderstorm rainfall was occurring, is markedly different from the 4 a.m. sounding. The air is saturated from 920 to 630 millibars and a pseudo-adiabatic lapse rate exists between 920 and 700 millibars (Table 15). Cooling has occurred both in the first 150 millibars and above 550 millibars, indicating that vertical motion is occurring quite freely. The warmer temperatures from 750 to 650 millibars may be a bit misleading as the radiosonde may well be in the top of the cumulonimbus cloud in those levels and therefore be indicating a saturated parcel temperature and not environmental temperatures. The rapid cooling above 600 millibars is indicative of the destabilization that has occurred aloft which is

ACTUAL JUNE 9 TEMPERATURE AND DEW POINT SOUNDING
FOR SPOKANE, WASHINGTON
4 PM - 1971

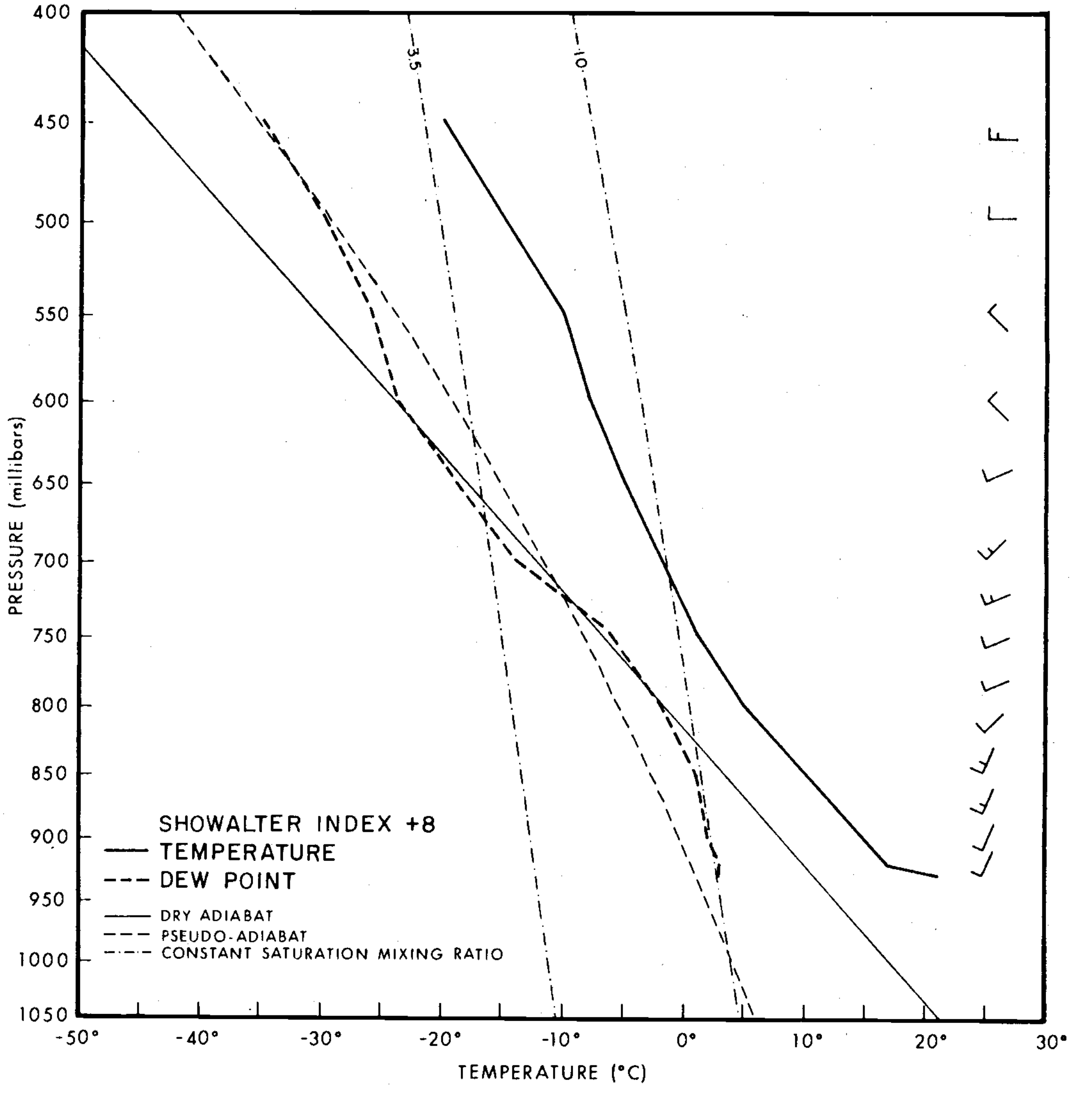


FIGURE 30

ACTUAL JUNE 10 TEMPERATURE AND DEW POINT SOUNDINGS FOR SPOKANE, WASHINGTON

4 AM, 4 PM - 1971

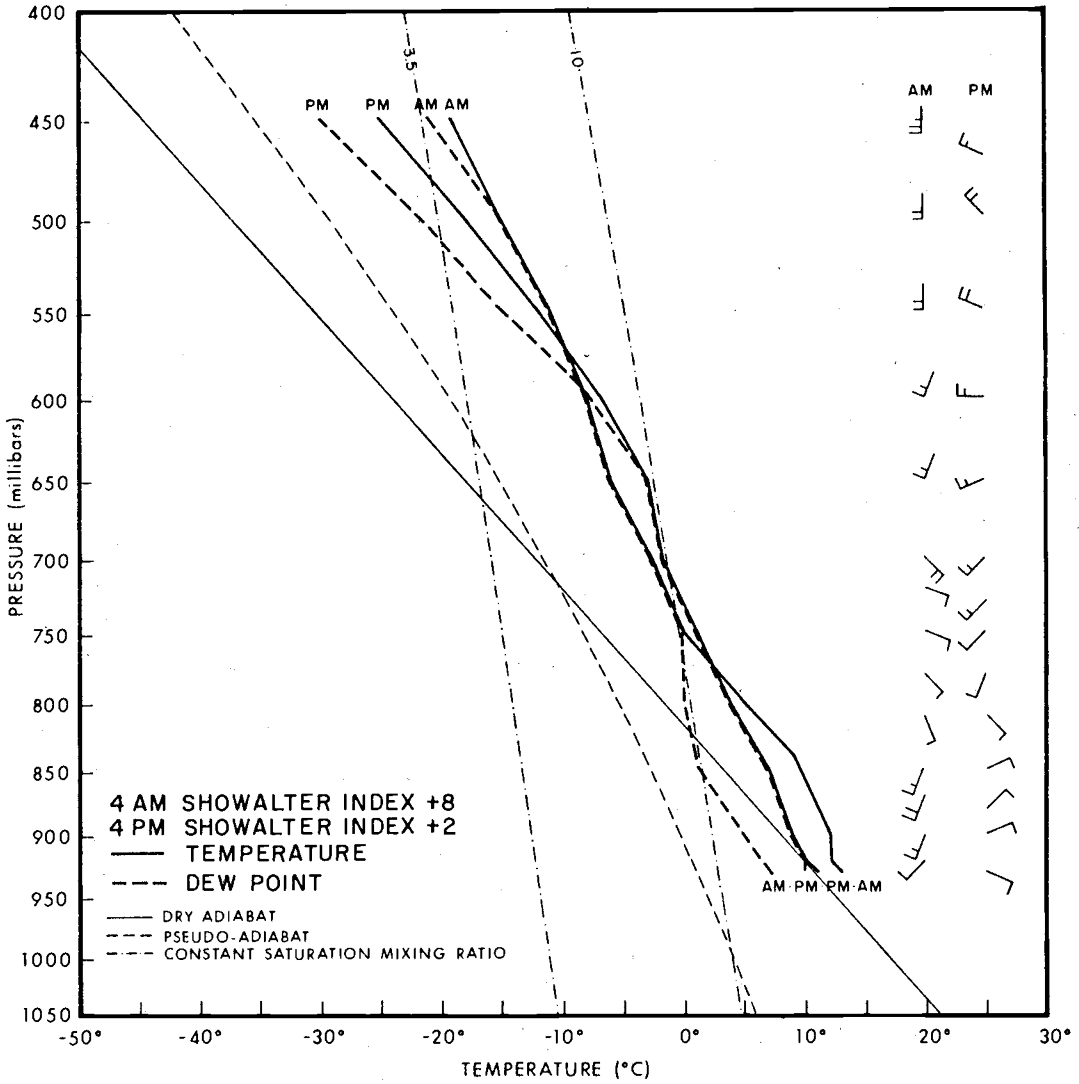


FIGURE 31

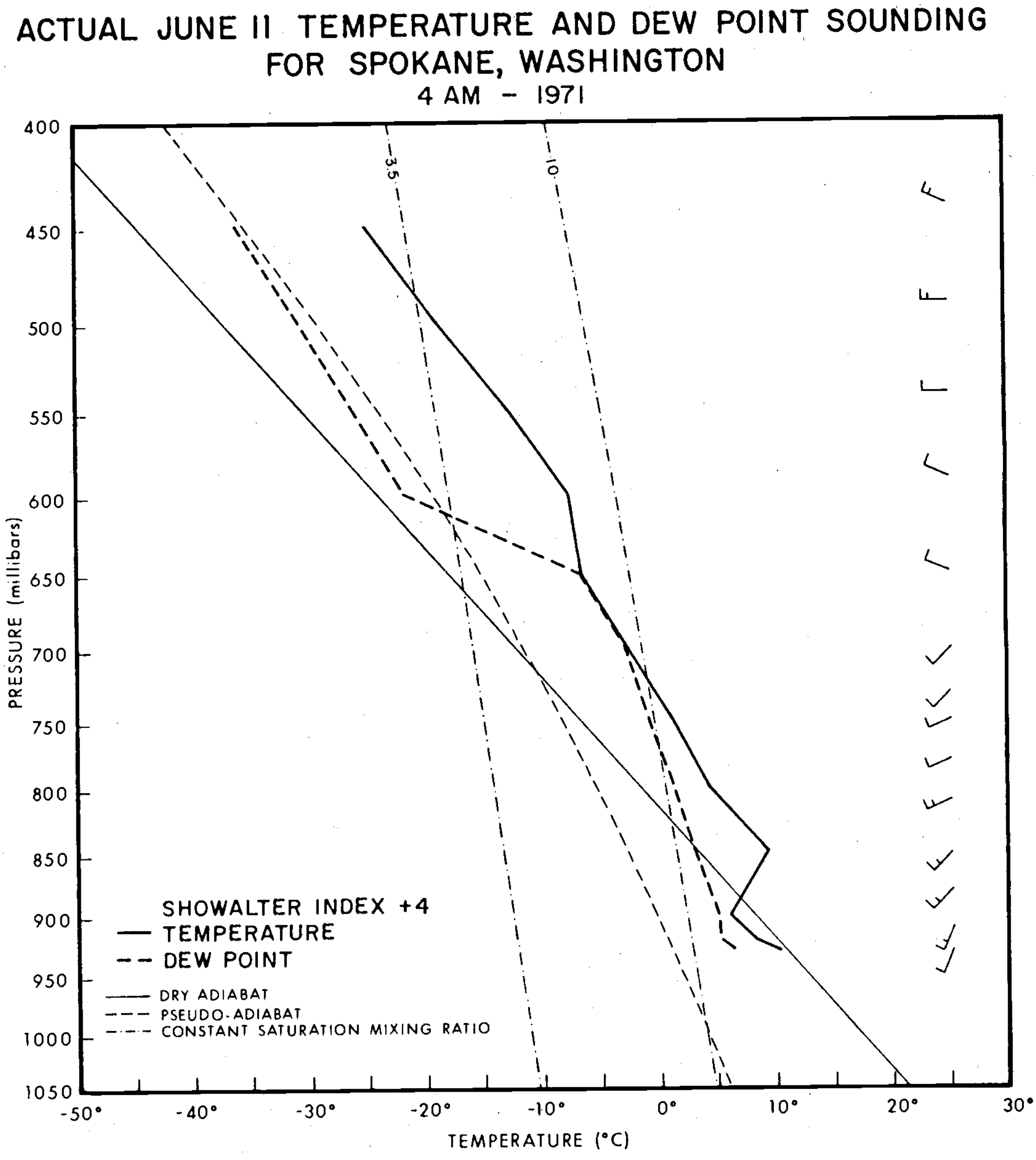

ACTUAL JUNE 11 TEMPERATURE AND DEW POINT SOUNDING
FOR SPOKANE, WASHINGTON
4 AM - 1971
PRESSURE (millibars)
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
-3.5
10
SHOWALTER INDEX +4
TEMPERATURE
DEW POINT
DRY ADIABAT
PSEUDO-ADIABAT
CONSTANT SATURATION MIXING RATIO
-50°
-40°
-30°
-20°
-10°
0°
10°
20°
30°
TEMPERATURE (°C)

FIGURE 32

promoting rapid upward vertical motion.

TABLE 15

Spokane Sounding Temperature Change for June 10th and 11th, 1971

Pressure Level	4 a.m. 10th	4 p.m. 10th	ΔT	4 a.m. 11th	ΔT
920	+13°C	-10°C	- 3°C	+ 8°C	- 2°C
900	+12°C	+ 9°C	- 3°C	+ 6°C	- 3°C
850	+10°C	+ 7°C	- 3°C	+ 9°C	+ 2°C
800	+ 5°C	+ 4°C	- 1°C	+ 4°C	0°C
750	+ 1°C	+ 1°C	0°C	+ 1°C	0°C
700	- 3°C	- 2°C	+ 1°C	- 3°C	- 1°C
650	- 5°C	- 3°C	+ 2°C	- 7°C	- 4°C
600	- 8°C	- 7°C	+ 1°C	- 8°C	- 1°C
550	-11°C	-12°C	- 1°C	-13°C	- 1°C
500	-14°C	-18°C	- 4°C	-19°C	- 1°C
450	-19°C	-25°C	- 6°C	-25°C	+ 1°C

The distribution of the winds aloft is also indicative of the advection of cooler air aloft. From the surface to 800 millibars, the winds are from the east, and between 800 and 700 millibars, veer to the southwest. Above 700 millibars, the winds are westerly and even northwesterly, reflecting rapid cooling with height. The Showalter index now manifests very unstable conditions of +2.

By the 11th, the air mass has cooled a bit more as the front has moved eastward, but the principal change is the advection of dryer air aloft. The sounding is unsaturated from the surface to 750 millibars, saturated from 700 to 650 millibars, and very dry from 600 to 450 millibars. From the surface to 700 millibars, the winds are from the southwest, but turn westerly to northwesterly above 700 millibars. The sounding is still unstable with a Showalter index of +4, but a thick, moist layer is lacking so only scattered clouds exist between 700 and 650 millibars.

The synoptic sequence which has been presented is typical of many which produce precipitation in the interior in the mid and late spring. While the 24 hour rainfall total at Spokane of 1.10 inches was quite large, many interior stations reported moderate rainfall totals with this particular synoptic sequence: .13 inches at Pendelton; .23 inches at Boise; .16 inches at Burns; and .31 inches at Lakeview. The salient features of this synoptic sequence which typify many precipitation events in the late spring are: (1) a Pacific cold front or cold occlusion moving across the region from the west; (2) a cold upper level low or trough at 500 millibars along the west coast with cold advection aloft extending into the interior; (3) a period of warm, moist advection from the southwest in advance of the approaching cold front when light-steady precipitation occurs; (4) the approach of the Pacific cold front and cooling aloft at 500 millibars which destabilizes the air mass and produces heavier intensity precipitation and possibly thunderstorms; (5) a period of cooling as the post-frontal zone occupies the region associated with westerly or northwesterly winds and dryer air aloft; and (6) most heavy intensity precipitation events are associated with strong cyclonic wind shear in the upper trough and strong, cool advection aloft in close proximity to the surface cold front.

Chapter VI

AN ASSESSMENT OF THE MONTHLY CHANGES IN SURFACE SENSIBLE AND LATENT HEAT VALUES IN THE PACIFIC NORTHWEST UTILIZING EQUIVALENT POTENTIAL TEMPERATURE DATA

A. Rationale

The Secondary Spring Maximum in the interior of the Pacific Northwest reflects a complex set of climatological controls. Certain climatological controls are quite conservative in their temporal variations while others have very large, short-term variability.

The major physiographic provinces and seasonal incoming radiation values are quite conservative in the period of historical record. Surface albedo, absorptivity, and transmissivity should be moderately conservative from year to year, but may vary due to the duration of snow cover, soil moisture, and thermal characteristics of the sea surface. The location and configuration of upper tropospheric longwaves and surface pressure systems are characterized by very large, short term variability. The variation in the intensity and location of atmospheric circulation patterns will necessarily result in very large year-to-year variations in monthly precipitation values. It is only through the analysis of long-term precipitation means that regional precipitation types can be ascertained. The secondary maximum of precipitation in the interior of the Pacific Northwest should therefore be related to relatively conservative climatological controls.

The thermal regimes of the eastern Pacific Ocean and the continental portion of western North America are quite distinct. The thermal gradients across the land-sea boundary are further intensified by the existence of the north-south cordilleras of the Cascade Mountains and Sierra Nevada Mountains. The thermal heat budget of the continental-ocean boundary has been investigated by many researchers (Budyko, 1962; Landsberg, 1958; and Riehl, 1965).

In the winter season, the land cools more rapidly than the sea, due primarily to convective mixing of the sea surface and the strong downward longwave radiation flux from the atmosphere. This is the result of high water vapor values. By midwinter, the eastern Pacific is a large thermal reservoir for air masses moving across the Pacific Northwest. These warm Pacific air masses are forced to rise over the Cascade Mountains and also rise over the colder continental polar or modified maritime polar air masses which dominate the lower layers of the atmosphere in the interior. The moderate intensity rainfall and snowfall associated with the warm sector of cyclonic storms is therefore the most prevalent precipitation type during winter and early spring.

The angle of solar radiation and length of day increase rapidly in the mid-spring period so that by late spring incoming radiation greatly exceeds outgoing terrestrial radiation. During this period, the thermal gradient of the land and sea rapidly reverse and by late spring the land is a heat source and the sea a heat sink. The air mass characteristics of precipitation producing disturbances during this period evolves from that of prevailing warm sector precipitation in winter to that of cold frontal dominance in late spring. This is quite apparent by the data presented in the preceding chapters.

The assessment of seasonal changes in the low level heat budget of the Pacific Northwest region is further complicated by the great variability in the elevation of observation points. The effect of mountains on precipitation has been treated extensively (Donley, 1939; Crow, 1961; Dickinson, 1959; and Linsley, 1958). These studies and many others have centered on orographic relationships. Very little work has been done concerning the regional sensible and latent heat budgets in mountainous areas, and how seasonal changes in the surface heat budget relate to the organization of synoptic weather disturbances moving across the region.

In a doctoral thesis titled "The Regionalization of Climate in Montane Areas" by Val Mitchell (1969), the author used the technique of potential temperature to assess the horizontal distribution of common air mass characteristics and frontal boundaries in the western United States. Mitchell analyzed individual synoptic weather disturbances as well as monthly mean values of equivalent potential temperature.

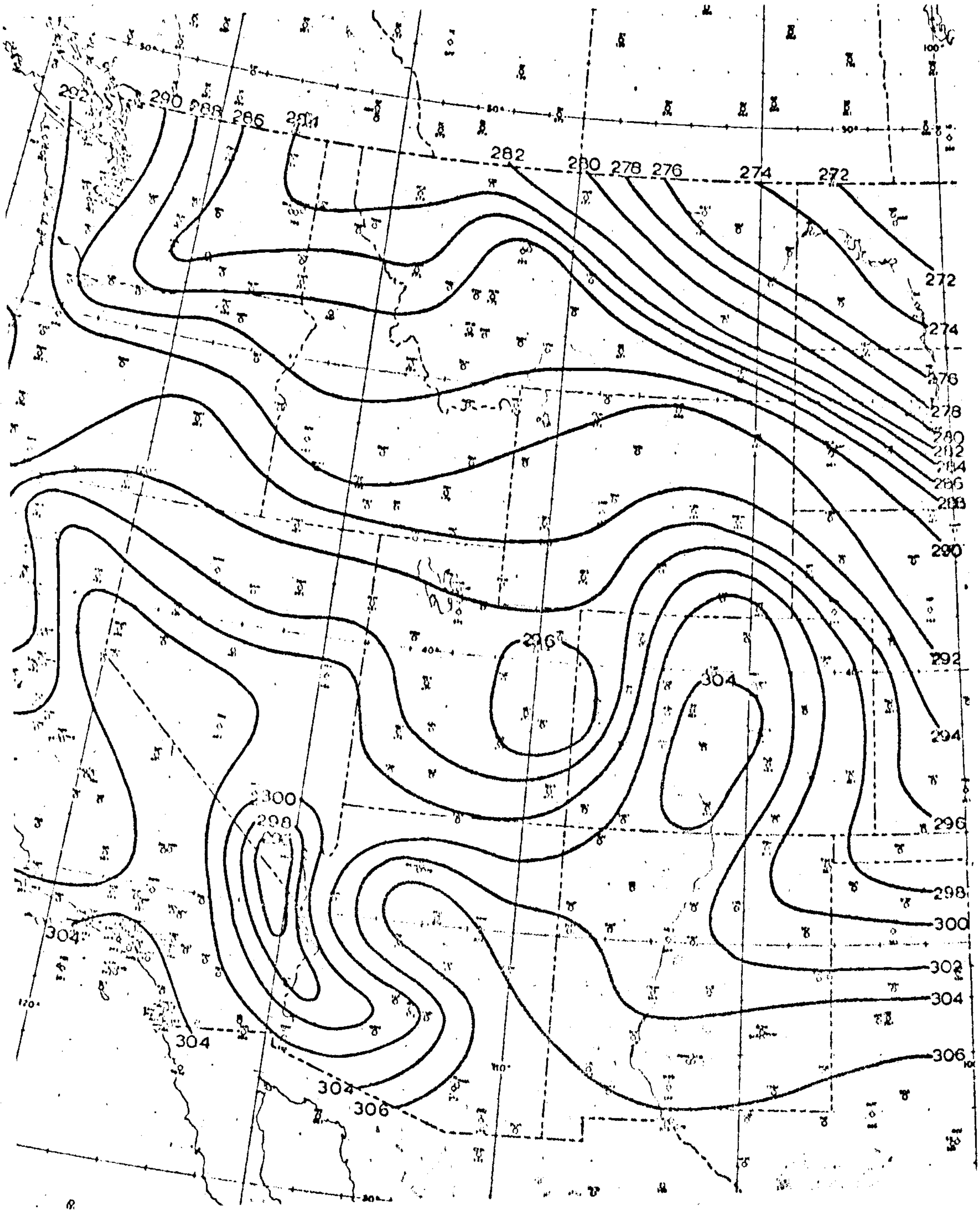
The equivalent potential temperature of an air parcel is derived by lifting the parcel dry-adiabatically to its lifting condensation level and then pseudo-adiabatically to 200 millibars. The parcel is then reduced dry-adiabatically to 1000 millibars, and its temperature at that level is its equivalent potential temperature (Saucier, 1962, p. 14). The equivalent potential temperature of air mass is a combined measure of both sensible and latent heat contributions. Equivalent potential temperature is conservative with height under conditions of adiabatic lapse rates. It is not single-valued with height nor is conservative for diabatic processes (Mitchell, p.

Mitchell produced mean monthly maps of equivalent potential temperature for the western United States, utilizing first order weather stations for the period of 1931-1938. The maps for the period of January to July have been included as Figure 33 through Figure 38. For a complete discussion of the monthly maps, the reader is referred to Mitchell, Chapter III, pages 60 to 105.

B. Mean Equivalent Potential Temperature: January to July

The pertinent features of Mitchell's maps which apply to this study center around the reorganization of the thermal regime of the land and sea, and the establishment of a strong thermal gradient across the western cordillera in the months of February to July. The equivalent potential temperature maps for January, February, and March are quite similar. The isotherms have a strong west to east orientation over the Pacific Northwest, indicative of uniform air mass characteristics, both west and east of the Cascades. Cooler air does dominate the interior as a result of the more effective heat loss of the continent during the winter. March is the month of the least land-sea temperature difference in the Northwest, while continental heating is recognizable over the southwestern United States.

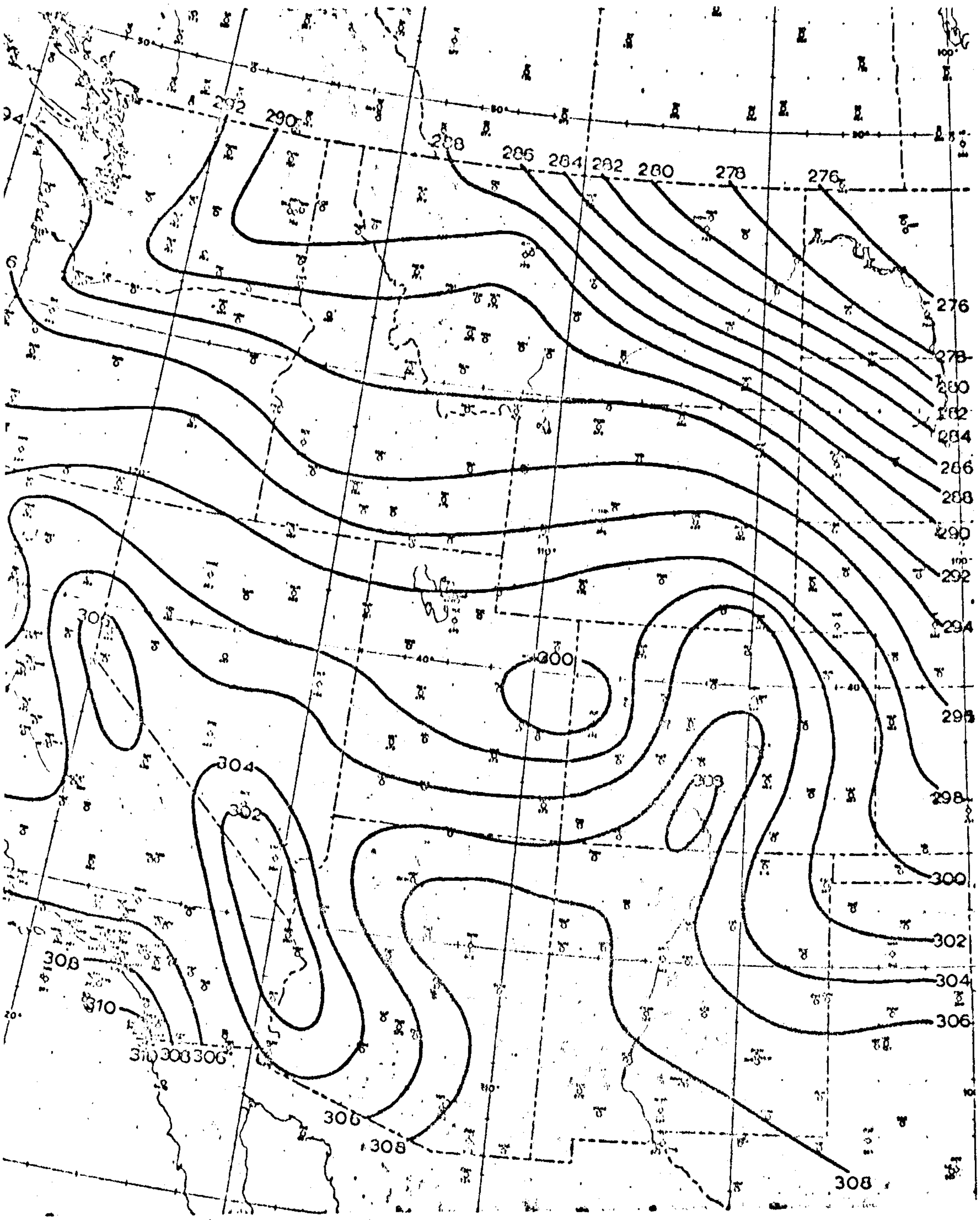
The April map indicates the beginning of the reorganization of the land-sea temperature field as the interior is now warming at a faster rate than the sea. While strong west to east temperature gradients are confined to northern California, the heating of the interior Northwest is evident in the poleward displacement of the



January mean equivalent potential temperature.

(Mitchell, 1969, Figure 3.3a, p. 65)

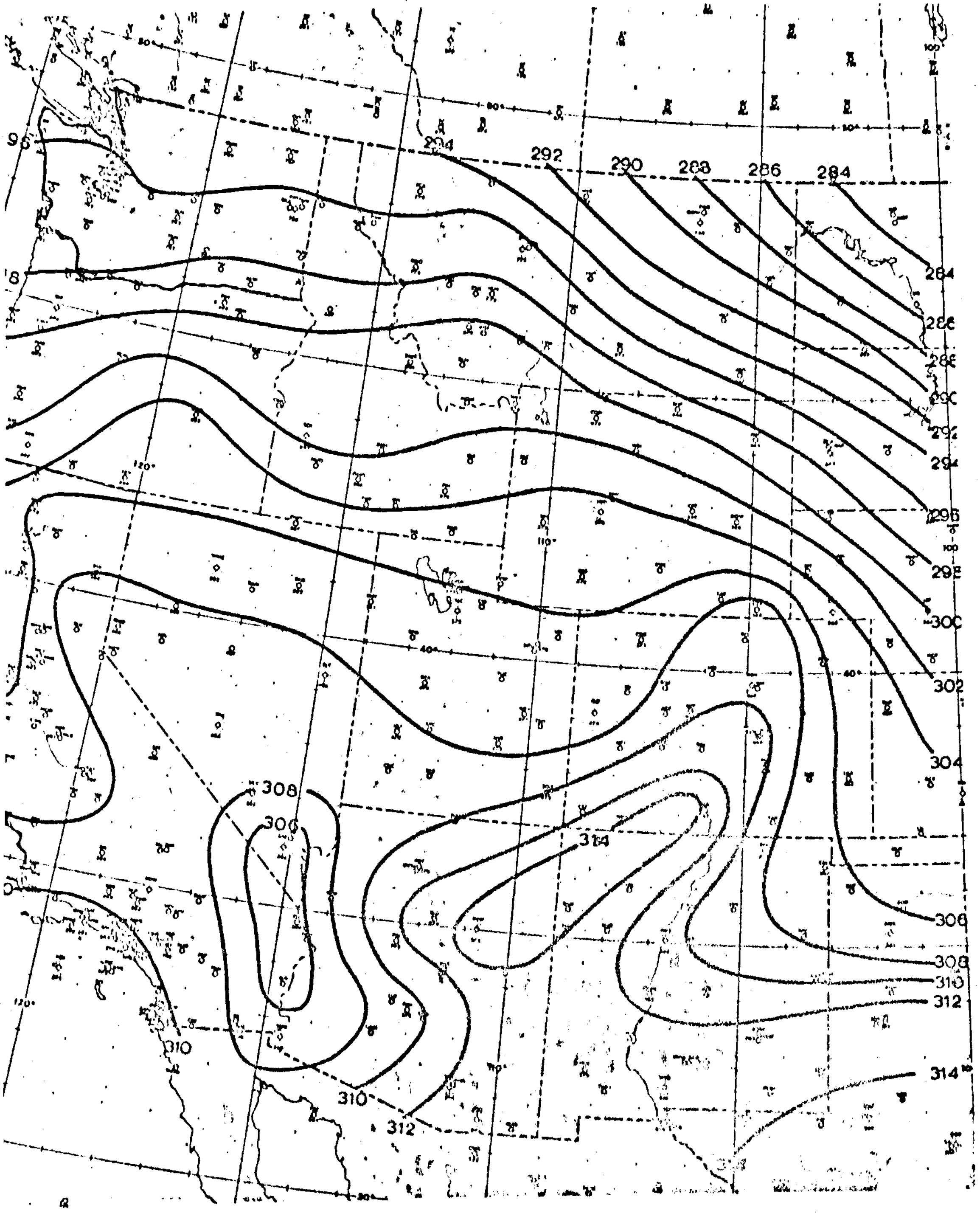
FIGURE 33



February mean equivalent potential temperature.

(Mitchell, 1969, Figure 3.4a, p. 67)

FIGURE 34



March mean equivalent potential temperature.

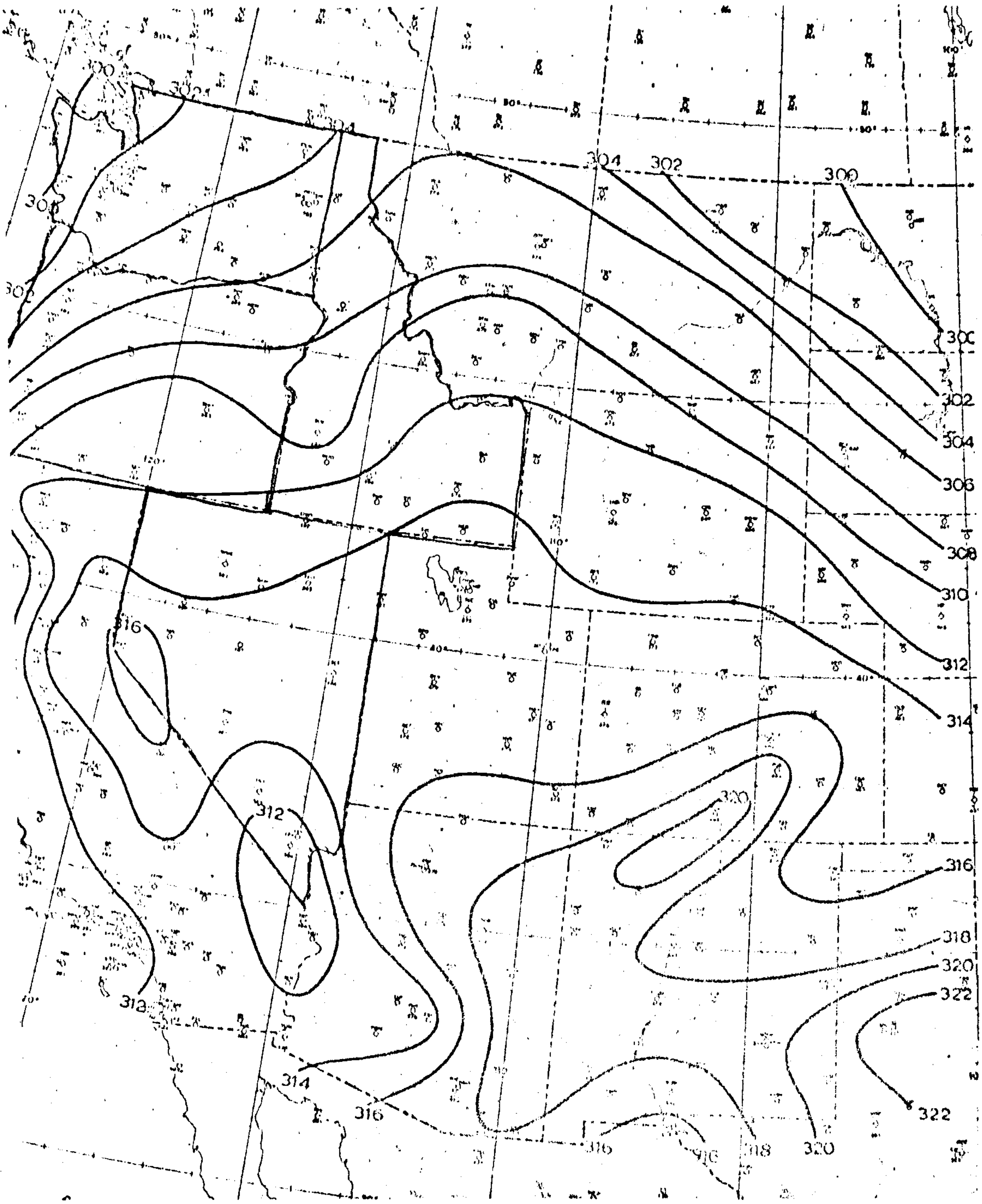
(Mitchell, 1969, Figure 3.5a, p. 69)

isotherms across Oregon and Washington.

The May map indicates a well developed land-sea equivalent potential temperature gradient. The isotherms are oriented north-south with very strong temperature gradients covering the entire Pacific Northwest. The strongest gradient is located in northern California and southern Oregon. Distribution of equivalent potential temperature will not coincide to the precipitation change gradient, as the number of stations used to derive the equivalent potential temperature map were far less than the number of stations used to derive the precipitation change maps. Mountain stations were lacking for Mitchell's data, so the gradients across the Cascades are probably stronger than indicated on Mitchell's map.

The June map indicates continued north-south orientation of the isotherm, especially in western Oregon and Washington. Northeastern Oregon and central and eastern Washington indicate a more west to east orientation, reflecting a more uniform heating gradient east of the Cascades. The dry thermal trough of the interior southwest is readily apparent east of the Sierra Nevada and extends northward into southern Oregon. The strong equivalent potential temperature gradient north of southeastern Oregon, separating the thermal trough of Nevada and southeastern California, is likely a transition zone between the periodic cyclonic activity still occurring in the northern sectors of Oregon and most of Washington and the dry, subsiding, northeastern limb of the subtropical high to the south.

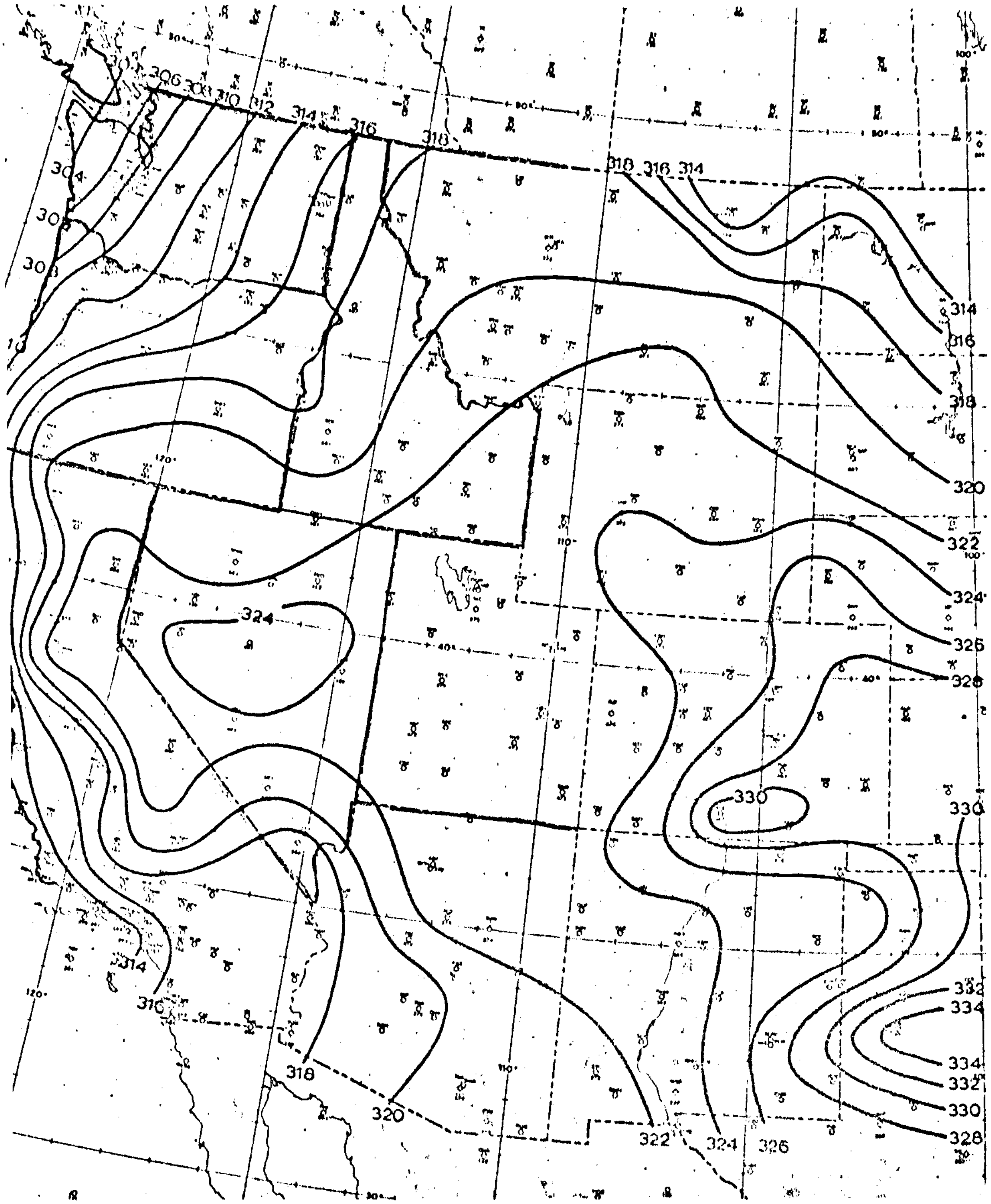
The distribution of equivalent potential temperature should not be expected to spatially corresoond to the detailed precipitation



April mean equivalent potential temperature.

(Mitchell, 1969, Figure 3.6a., p. 71)

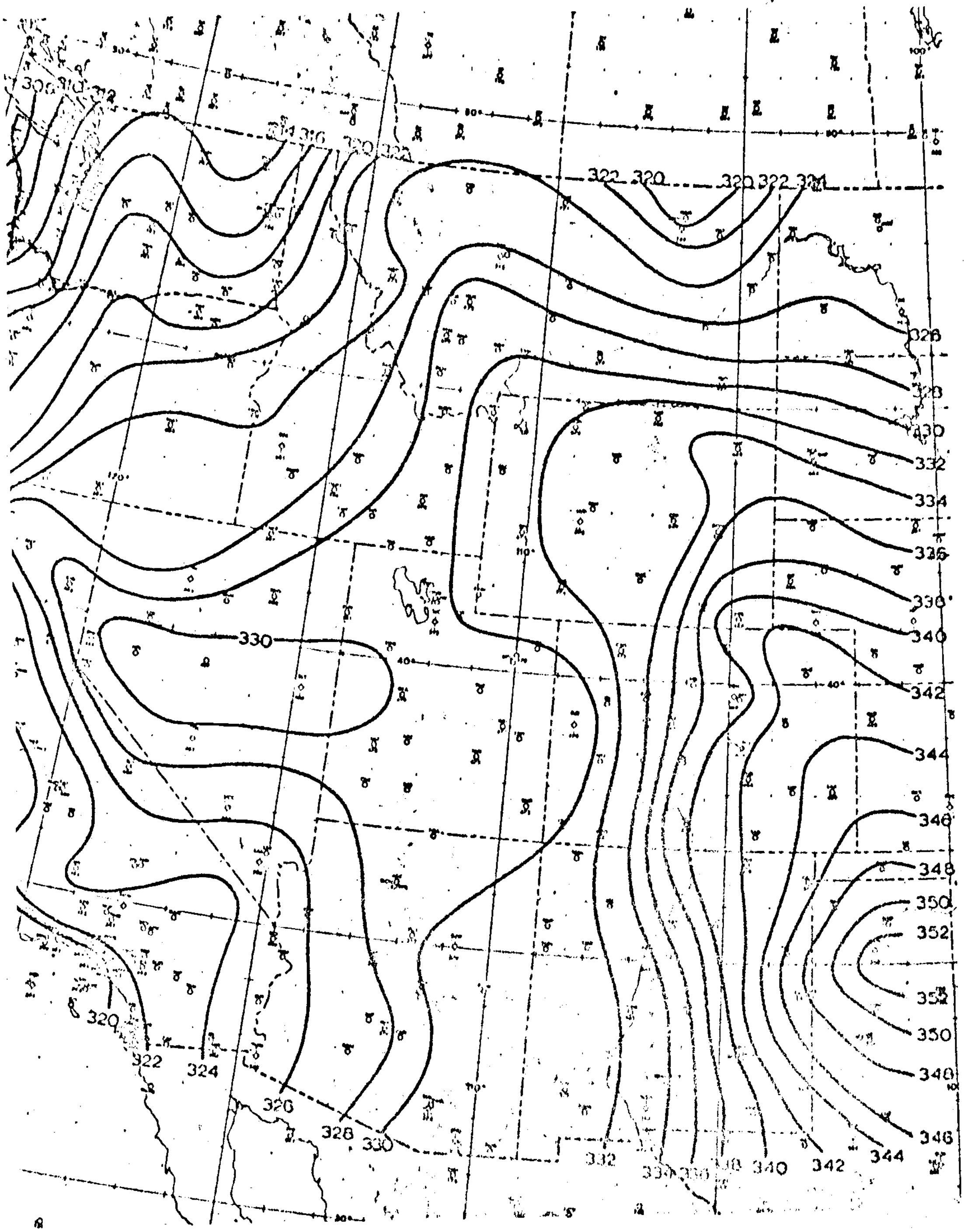
FIGURE 36



May mean equivalent potential temperature.

(Mitchell, 1969, Figure 3.7a, p. 73)

FIGURE 37



June mean equivalent potential temperature.

(Mitchell, 1969, Figure 3.8a, p. 75)

FIGURE 38

change characteristics in the interior Northwest. Mitchell's data was derived by utilizing only a few stations in the interior Northwest. The data is not stratified according to precipitation events, and so represents the total array of monthly, sensible, and latent heat contributions. Most significantly, it is difficult to specify the proportion of sensible and latent heat additions in a given region since equivalent potential temperature is a combined measure. The latent heat contribution is critical in permitting precipitation processes to occur, since without sufficient moisture no precipitation is possible despite large, surface, sensible heat additions.

C. Change in Mean Equivalent Potential Temperature: January to July

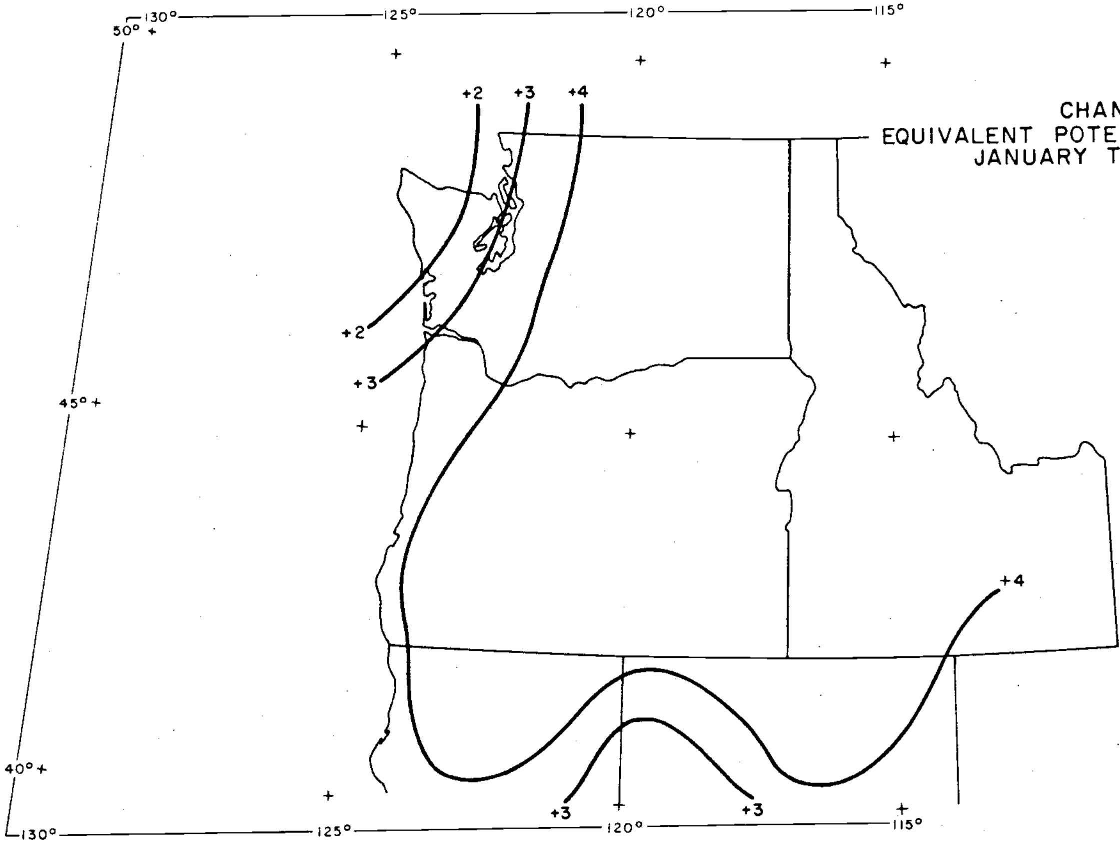
Mitchell did not calculate monthly changes in mean equivalent potential temperature. These maps have been calculated from Mitchell's data and are presented in Maps 31 through 36. The monthly changes in equivalent potential temperature can be used to assess rather large scale regional organizations of latent and sensible heat changes. Small scale regional changes will not be adequately defined and those that do exist will not necessarily correspond to boundaries of precipitation changes, since far fewer stations were available for Mitchell's analysis.

Map 31 indicates the change in mean equivalent potential temperature from January to February. The whole Northwest region manifests uniform temperature increases of $+4^{O}C$. Only extreme Northwestern Washington indicates slightly weaker temperature increases of $+2^{O}C$, reflecting the very strong marine dominance and consequent smaller, sensible heat additions. The uniformity of the temperature change would imply very little west to east (or north to south) change in the characteristics of air masses dominating the region in the January to February period. While the interior is indeed warming at a faster rate than the coastal region, the interior is still cooler than the westside, so that little destabilization is available for air masses being advected into the interior.

Map 32 presents changes in equivalent potential temperature from February to March. The west to east gradient of temperature change has increased particularly across northwestern Washington. The interior is now heating up more rapidly than the westside, but strong topographically induced gradients are not yet apparent. At this time the least actual equivalent potential temperature gradient exists between the westside and the interior.

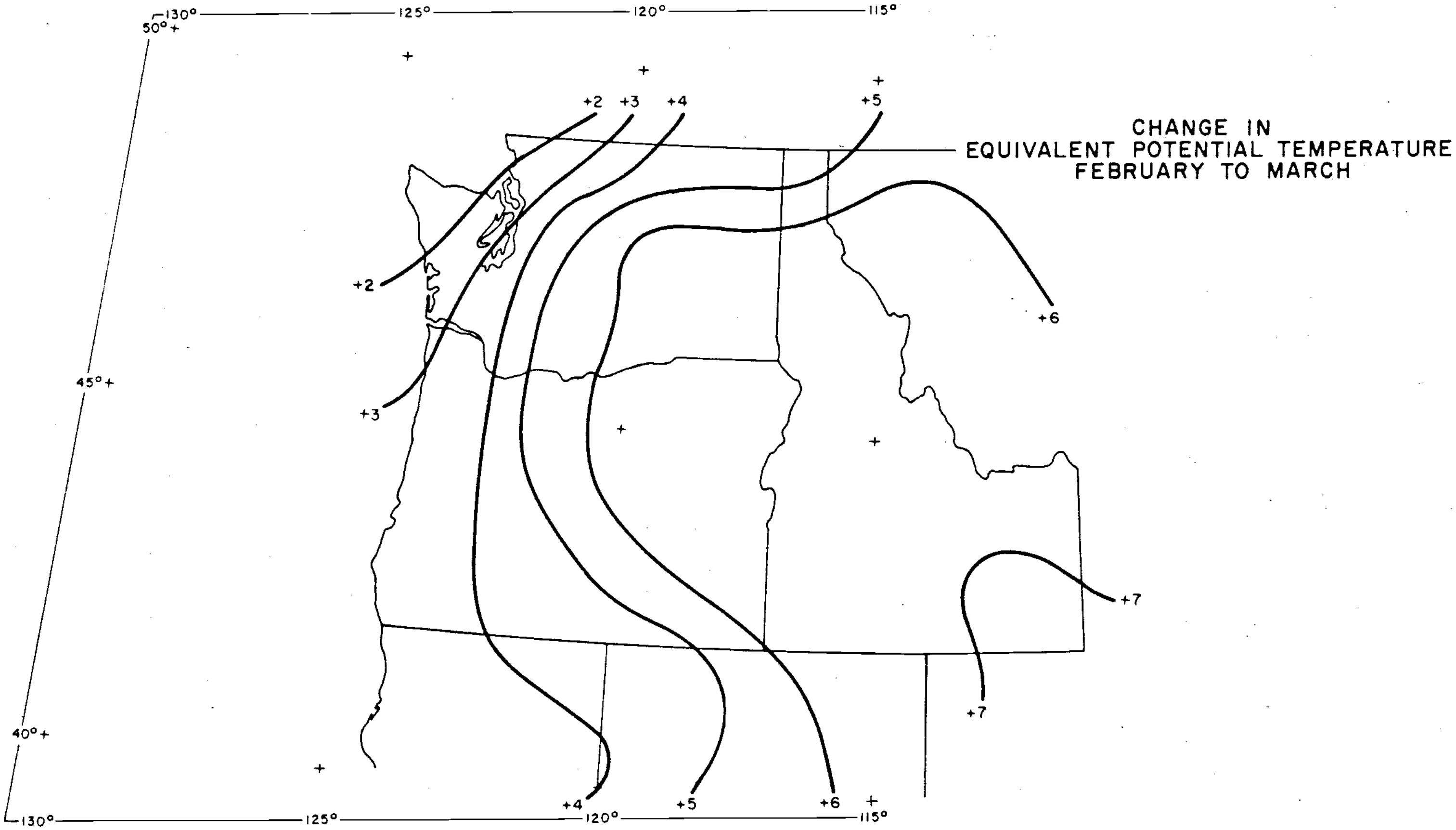
The interior of Washington and Oregon are now heating at a faster rate than the westside but are achieving only parity in actual equivalent potential temperatures. Air masses advected from west to east across the Cascades would not be expected to experience significant destabilization as actual interior surface heat additions are roughly equivalent to westside values.

Map 33 presents changes in equivalent potential temperature from March to April. The temperature field exhibits a rather distinctive organizational pattern. Equivalent potential temperature rises are large but are separated into two distinct regions. The coastal area is characterized by small increases and a distinct gradient of change exists which roughly coincides with the Cascade Mountains.



CHANGE IN
EQUIVALENT POTENTIAL TEMPERATURE
JANUARY TO FEBRUARY

MAP 31


CHANGE IN
EQUIVALENT POTENTIAL TEMPERATURE
FEBRUARY TO MARCH
130°
125°
120°
115°
50°
45°
40°
+2
+3
+4
+5
+6
+7

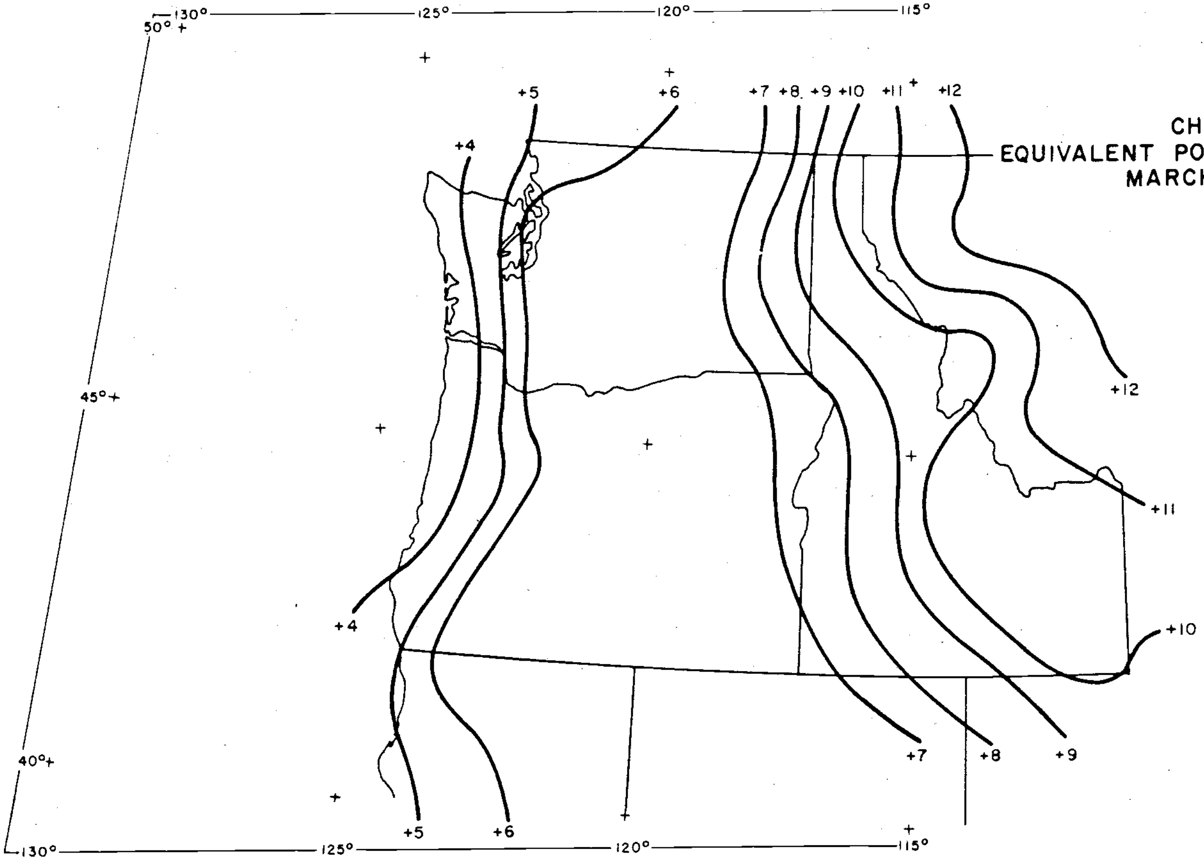
MAP 32

Central Oregon and Washington have uniform temperature increases and a second, strong gradient of change exists across Idaho and western Montana. The large increases in northeastern Idaho and western Montana should not be interpreted as large additions of sensible heat which would be available to destabilize the atmosphere. This region was a heat sink in March due primarily to its higher elevations, and therefore is responding in a delayed manner to the increasing solar radiation loads and loss of snow cover. This region is realizing larger increases in equivalent potential temperature from March to April in order to achieve actual equivalent potential temperatures about equal to those at equivalent latitudes in central Oregon and Washington.

Map 34 presents the change in equivalent potential temperature from April to May. Coinciding with the Cascade Mountains is a very strong gradient of change. Values west of the Cascades average less than $+5^{o}C$, while values east of the Cascades average above $+8^{o}C$. Univorm values of $+8^{o}C$ to $+9^{o}C$ are located over most of central and eastern Oregon, northern Nevada, and southern Idaho. Large sensible and latent heat additions are occurring east of the Cascades at this time and are producing significantly higher actual equivalent potential temperatures than the region west of the Cascades.

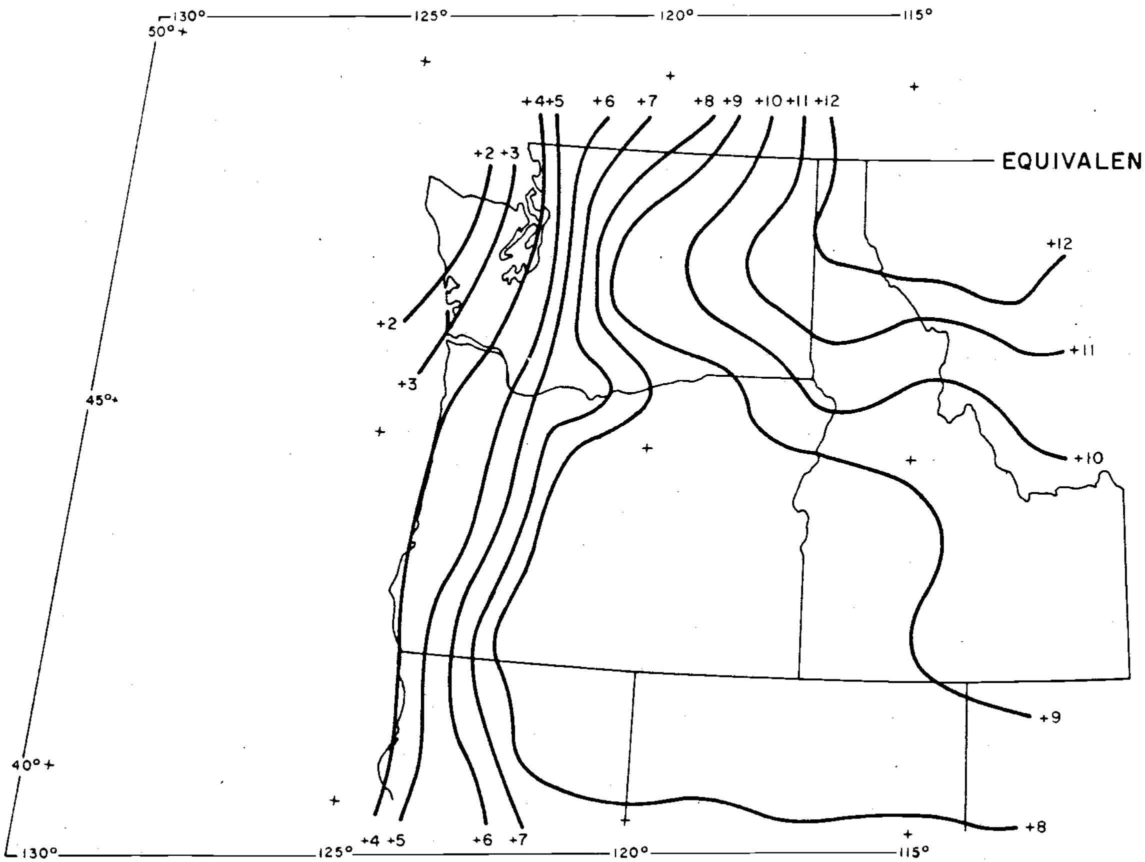
Destabilization of Pacific air masses penetrating into the interior is quite likely, although the precipitation yield will be dependent upon the thickness of advected moisture accompanying the individual disturbance. A more uniform gradient of temperature change characterized northern Idaho and western Montana. The higher elevation of this region may result in a greater potential for temperature rises due to a lag in seasonal heating.

CHANGE IN
EQUIVALENT POTENTIAL TEMPERATURE
MARCH TO APRIL



MAP 33

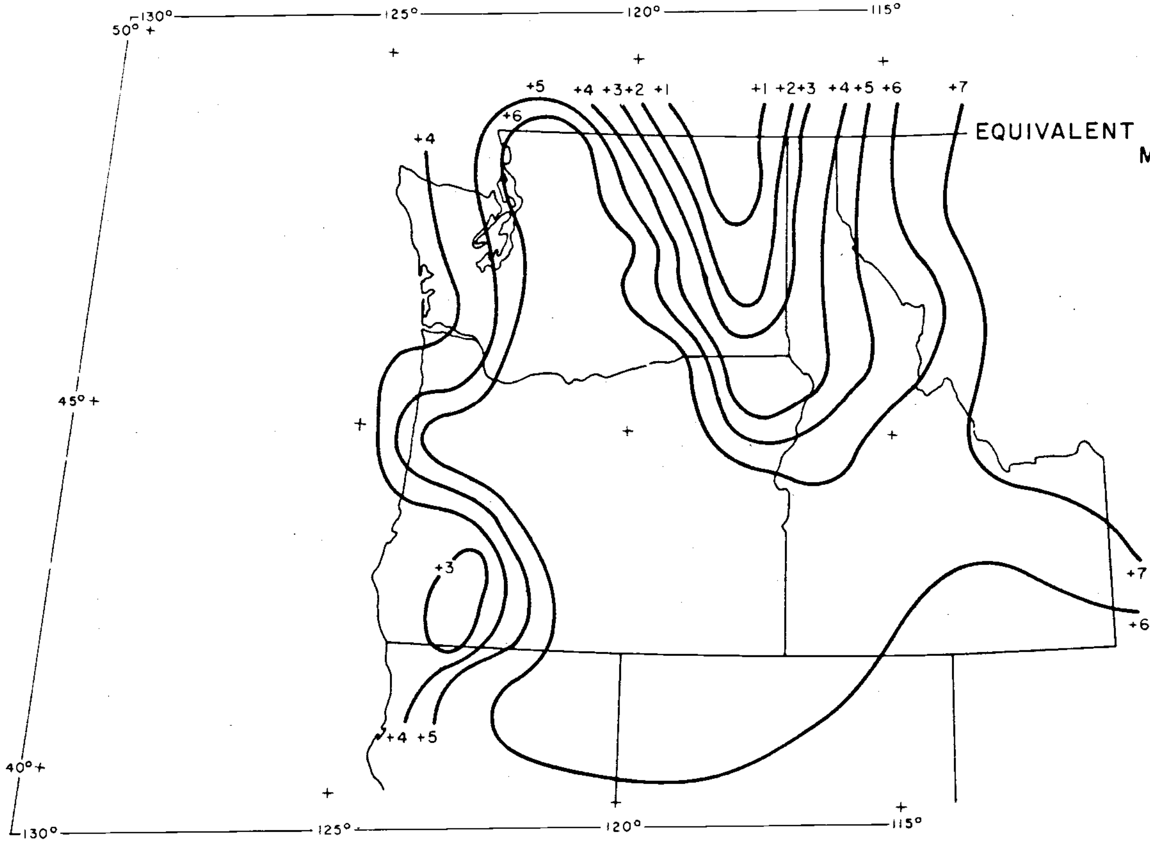
CHANGE IN
EQUIVALENT POTENTIAL TEMPERATURE
APRIL TO MAY



MAP 34

Map 35 presents the change in equivalent potential temperature from May to June. A less organized pattern of temperature increases is apparent over the Pacific Northwest. The coastal region still indicates only moderate increases although the dominance of the dry, subsiding air from the Pacific High has produced a weaker west to east temperature gradient across the Cascade Mountains. The interior of Oregon, central Washington, and southern Idaho indicate moderate temperature increases of 6^{o}C, although not as large as the April to May values. A curious (anomalous?) area of very small temperature increases is located in northeastern Washington. This lobe of cool, equivalent potential temperatures is derived from two observation stations in northeastern Washington. There is insufficient information to attribute the anomaly to either local mountain effects or some observational error, but the readings are certainly anomalous to similar locations in Montana.

Map 36 presents the change in equivalent potential temperature from June to July. During this period, stations both west and east of the Cascades are recording large decreases in mean monthly precipitation. This is the result of the rapid northward shift of the Pacific High Pressure System and the diversion of the cyclonic storm track well into southern Alaska. The prevailing clear skies and high zenith angle of the sun permits further sensible heat additions over most of the Northwest. Only the coastal region and Puget Sound area indicate small rises in equivalent potential temperature. This is most likely due to the low clouds and stratus beneath the prevailing subsidence inversion.

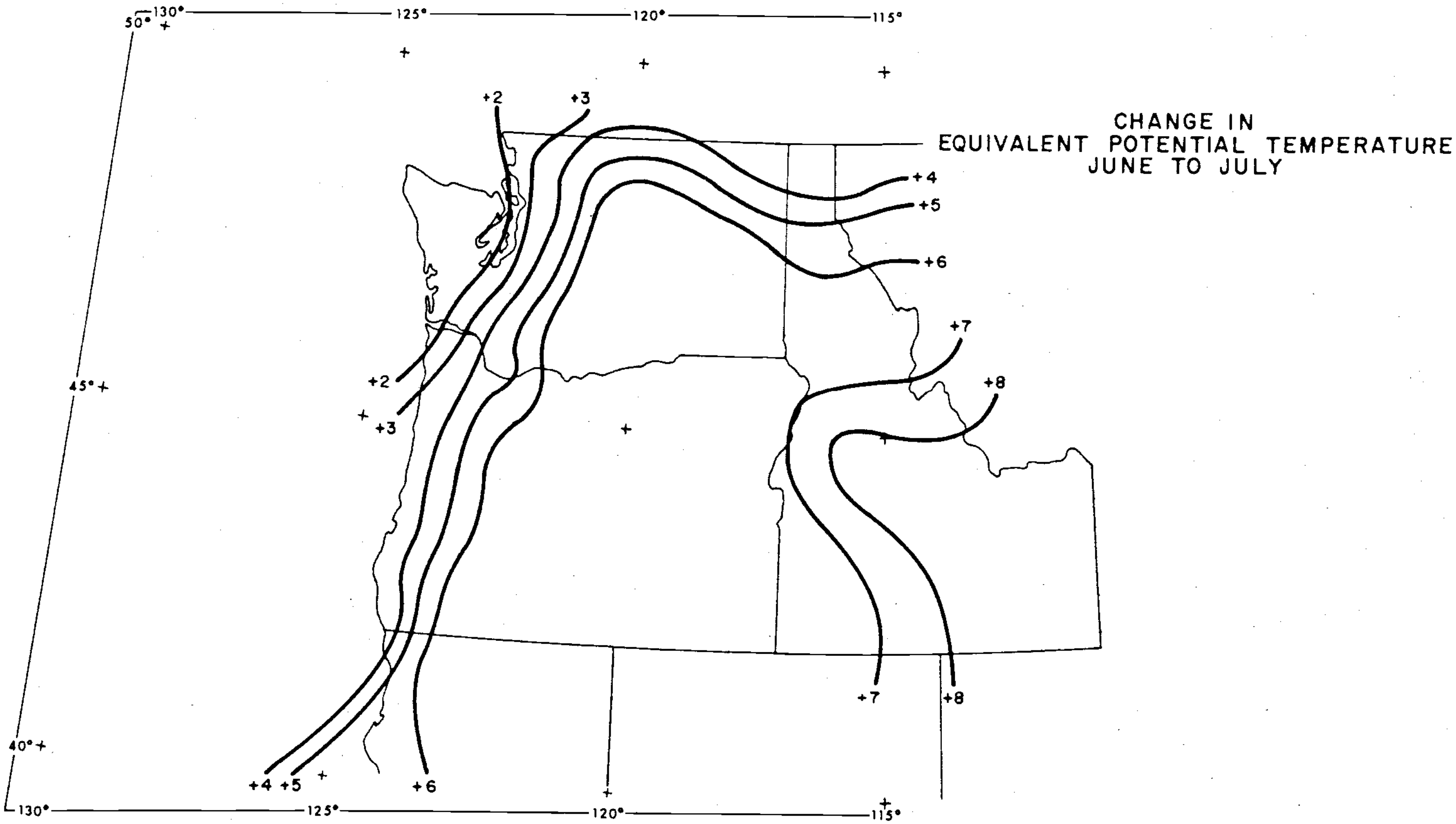


CHANGE IN
EQUIVALENT POTENTIAL TEMPERATURE
MAY TO JUNE

MAP 35

Additional instability of the lower atmosphere is realized but this does not result in additional precipitation. The frontal disturbances and associated advection of moisture are not available at this time, having been deflected well to the north by the prevailing Pacific High Pressure System.

The monthly changes in equivalent potential temperature in the Pacific Northwest demonstrate the strong reorganization of the thermal regime of the land and sea across the spring period. The intensification of the land-sea thermal gradient by the Cascade Mountains is also quite detectable, particularly in the period of May through July. The potential destabilization of air masses crossing the Cascade Mountains is also apparent by the large increases in equivalent potential temperature in the interior, especially in the month of May. Detailed regional changes in sensible and latent heat cannot be ascertained and related to observed precipitation changes, due to inadequate density.


CHANGE IN
EQUIVALENT POTENTIAL TEMPERATURE
JUNE TO JULY
130°
125°
120°
115°
50°
45°
40°
+2
+3
+4
+5
+6
+7
+8

MAP 36

Chapter VII

CONCLUSION

The Secondary Spring Maximum of Precipitation in the interior of the Pacific Northwest illustrates the highly complex system by which atmospheric processes are coupled to seasonal changes in the heat budget of the land and sea. The existence of major topographic structures and highly variable terrain in the interior reorganize atmospheric flow in a complex manner whose fine structure cannot be detected with the present widely spaced network of radiosonde stations. Year to year variations in the latent and sensibl heat capacities of the land may well lead to significant temporal and spatial variability of atmospheric disturbances moving across the region. Large year to year variability characterizes the thermal organization of the sea and can significantly reorganize the atmospheric circulation on time scales ranging from days to seasons (Namias, 1959, 1963, 1969, 1971; and Quinn and Burt, 1972). The year to year expectancy of precipitation phenomena is, therefore, quite low and necessitates the definition of most regional precipitation types from long term mean statistics. The search for rational explanations of atmospheric process utilizing long term averages of meteorological data is hampered by the unstratified character of the data, giving inordinate bias to non-precipitation climatology.

This study has attempted to define the magnitude and spatial limits of the Secondary Maximum of Precipitation in the interior of the

Pacific Northwest, utilizing traditional 30 year normals of precipitation. In addition, this study has utilized synoptic meteorological data in developing a synoptic precipitation climatology of the Secondary Maximum. Quite marked changes in the organization of surface and upper air disturbances are present during the spring period. Marked changes also occur in the vertical distribution of atmospheric moisture and stability. These changes result in an increase in precipitation yield and must ultimately relate to changes in the surface heat budget of the land and sea over which disturbances pass. An examination of the average monthly changes in surface, equivalent potential temperatures for the Pacific Northwest indicates pronounced reorganization of the sensible and latent heat field across the March through June period. These changes result in significant destabilization of maritime-polar air masses moving across the interior in May and June. The limited number of radiosonde stations did not permit detailed regional heat budget characteristics to be ascertained, which might relate to some of the more detailed regional patterns apparent in the precipitation change maps in Chapter II.

Many questions have arisen from this study which hopefully will stimulate additional inquiry into the nature of regional precipitation processes. The following specific areas could well be productive in shedding further insight into the complexities of regional precipitation climatology.

(1) The major north-south cordilleras of the Cascades, Sierra Nevada and western Rocky Mountains reorganize air flow, and many studies have focused on their vorticity, katabatic, and trajectory character-

istics. Little work has been done on the reorganization of individual synoptic disturbances, including variable upstream and downstream surface heat budget characteristics. Changes in stability and vertical motion must be analyzed under actual synoptic conditions, as the sharp gradients of temperature and moisture advection tend to be lost in the analysis of average flow patterns. Recent work by Egger has begun to focus on this problem (Egger, 1974, p. 847-860).

(2) The separation of precipitation climatology from non-precipitation climatology should be stressed. In climate regimes other than the most humid, non-precipitation days outnumber precipitation days. The traditional approach is to utilize mean monthly atmospheric charts for interpretive analysis, which in fact, gives inordinate bias to non-precipitation events. Precipitation patterns are often quite unique and distinctive from the "normal" array of weather patterns, particularly in arid and semi-arid regions. Therefore, the average precipitation producing circulation pattern may bear little resemblance to the average circulation pattern. The work of Sands (1966) and Bryson and Lahey (1958), has stressed the "discreet" nature of precipitation climatology.

(3) There is a need for research focusing on "meso-scale" meteorological and climatological systems. The large-scale regional climatological patterns are ultimately derived from atmospheric disturbances whose organizational limits are less than a few hundred square miles. Very few meteorological studies are geared to assess changes in the organization of weather system on a scale less than the

normal synoptic grid (100's to 1000's of square miles). Studies like those of Cramer (1970 and 1973) and Fujita (1956 and 1963) can shed much needed insight into the effects that moderate scale terrain features can exert on the organization of atmospheric disturbances such as those which commonly occur in the interior of the Pacific Northwest.

(4) This study has presented evidence which links the seasonal changes in precipitation delivery west and east of the Cascade Mountains to corresponding changes in the surface heat budget west and east of the Cascades. Additional research into the variable thermal conditions of the sea itself, and to a lesser extent, variable latent heat capacities of the land, may begin to clarify the large year to year variations in weather patterns for equivalent seasonal periods (months). The large thermal capacity of the sea and highly variable short term mixing characteristics would seem to offer likely opportunities for atmospheric reorganization over a variety of time scales (Namias, 1963, 1969, and 1971; Clark, 1972). The reorganization of major atmospheric flow patterns over the northeastern Pacific could well explain year to year variations in the timing and intensity of the Secondary Maximum in the interior Pacific Northwest.

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APPENDIX A

SUPPLEMENTAL TABLES

List of Climatological Stations and Elevations
for the States of Idaho, Montana, Oregon and Washington

Source: Climatological Handbook, Columbia Basin States, Vol. II, Precipitation, 1974.

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
ABERDEEN EXPERIMENT STATION	BINGHAM	4400	42°57' N / 112°50' W
AFTERTHOUGHT MINE	OWYHEE	7280	43°00' N / 116°42' W
ALBION	CASSIA	4650	42°24' N / 113°34' W
ALMO	CASSIA	5530	42°07' N / 113°39' W
ALPHA 2 NE	VALLEY	4780	44°24' N / 115°59' W
AMERICAN FALLS 1 SW	POWER	4318	42°47' N / 112°52' W
ANDERSON DAM	ELMORE	3882	43°21' N / 115°28' W
ARBON 2 NW	POWER	5170	42°30' N / 112°34' W
ARCO 3 NW	BUTTE	5300	43°40' N / 113°20' W
ARCO	BUTTE	5320	43°38' N / 113°18' W
ARGORA	CLARK	7000	44°25' N / 112°39' W
ARROWROCK DAM	ELMORE	3275	43°36' N / 115°55' W
ASHTON 1 S	FREMONT	5270	44°04' N / 111°27' W
ATLANTA	ELMORE	5390	43°48' N / 115°08' W
ATLANTA 1 E	ELMORE	6000	43°48' N / 115°07' W
ATLANTA 3	ELMORE	5470	43°48' N / 115°07' W
ATLANTA SUMMIT	ELMORE	7590	43°45' N / 115°14' W
AVERY RANGER STATION	SHOSHONE	2492	47°15' N / 115°48' W
BAKERS RANCH	CUSTER	6014	44°02' N / 114°28' W
BALD MOUNTAIN	BLAINE	8700	43°39' N / 114°24' W
BANCROFT	CARIBOU	5285	42°43' N / 111°54' W
BAYVIEW MODEL BASIN	KOOTENAI	2070	47°59' N / 116°34' W
BEAR	ADAMS	4322	45°01' N / 116°40' W
BEAR VALLEY	VALLEY	UNK.	UNK. / UNK.
BEAVER CREEK	VALLEY	UNK.	UNK. / UNK.
BENTON DAM	BONNER	2640	48°21' N / 116°50' W
BIG CREEK 1 S	VALLEY	5686	45°06' N / 115°20' W
BIG SMOKY RANGER STATION	BLAINE	5500	43°37' N / 114°53' W
BIG SPRINGS	FREMONT	6440	44°30' N / 111°16' W
BIRCH CREEK	FREMONT	UNK.	UNK. / UNK.

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
BLACKFOOT 2 SSW	BINGHAM	4495	43°11' N / 112°23' W
BLACKFOOT DAM	CARIBOU	6200	43°00' N / 111°43' W
BLANCHE	GOODING	UNK.	43°05' N / 114°56' W
BLISS	GOODING	3269	42°56' N / 114°57' W
BLUZ LAKES	JEROME	3225	42°37' N / 114°28' W
BOCK'S RANCH	ELMORE	UNK.	43°24' N / 115°35' W
BOGUS BASIN	BOISE	6196	43°46' N / 116°06' W
BOGUS CREEK	BOISE	4200	43°46' N / 116°07' W
BOISE KING	ELMORE	4000	43°50' N / 115°20' W
BOISE LUCKY PEAK DAM	ADA	2840	43°33' N / 116°04' W
BOISE WEATHER BUREAU AIRPORT STATION	ADA	2842	43°34' N / 116°13' W
BOISE WEATHER BUREAU OFFICE	ADA	2713	43°37' N / 116°12' W
BONANZA	CUSTER	6200	44°21' N / 114°44' W
BONNERS FERRY 1 SW	BOUNDARY	1810	48°41' N / 116°19' W
HOSTETTER	CASSIA	7600	42°10' N / 114°10' W
BOULDER MINE	BOISE	4830	43°55' N / 115°45' W
BRIDGE 1 SW	CASSIA	4900	42°08' N / 113°21' W
BROWNLEE	WASHINGTON	3900	44°44' N / 116°49' W
BRUNEAU	OWYHEE	2525	42°53' N / 115°48' W
BUHL	TWIN FALLS	3500	42°36' N / 114°46' W
BUNGALOW RANGER STATION	CLEARWATER	2285	46°38' N / 115°30' W
BURKE 2 ENE	SHOSHONE	4093	47°32' N / 115°48' W
BURLEY	CASSIA	4180	42°32' N / 113°47' W
BURLEY FACTORY	CASSIA	4140	42°33' N / 113°48' W
BURLEY FEDERAL AVIATION AGENCY AIRPORT	CASSIA	4146	42°32' N / 113°46' W
BURNSIDE	CLARK	5700	44°24' N / 112°11' W
CABINET GORGE	BONNER	2257	48°05' N / 116°04' W
CALDWELL	CANYON	2370	43°40' N / 116°41' W
CAMAS	JEFFERSON	4818	44°02' N / 112°15' W
CAMBRIDGE	WASHINGTON	2650	44°34' N / 116°41' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
CASCADE 1 NW	VALLEY	4865	44°32' N / 116°03' W
CASCADE RANGER STATION	VALLEY	4740	44°31' N / 116°03' W
CAYUSE CREEK	CLEARWATER	3714	46°40' N / 115°04' W
CEDAR CREEK DAM	TWIN FALLS	5220	42°14' N / 114°53' W
CENTERVILLE (ARBAUGH)	BOISE	4300	43°58' N / 115°51' W
CHALLIS	CUSTER	5175	44°30' N / 114°14' W
CHATTIN'S FLAT	ELMORE	2600	43°02' N / 116°04' W
CHATTIN'S RANCH	ELMORE	2600	43°02' N / 116°04' W
CHESTERFIELD	BANNOCK	5424	42°51' N / 111°55' W
CHILLY-BARTON FLAT	CUSTER	6140	44°00' N / 113°50' W
CLARK FORK 1 ENE	BONNER	2125	48°08' N / 116°10' W
CLARKIA RANGER STATION	SHOSHONE	2810	47°01' N / 116°15' W
CLAWSON	TETON	6000	43°40' N / 111°05' W
CLAYTON	CUSTER	5661	44°16' N / 114°29' W
CLEMENTSVILLE 4 SE	TETON	5904	43°51' N / 111°16' W
CLIFFS	OWYHEE	5197	42°40' N / 117°00' W
COBALT	LEMHI	4910	45°06' N / 114°14' W
COBALT BLACKBIRD MINE	LEMHI	6810	45°07' N / 114°21' W
COBALT 6 W	LEMHI	6810	45°07' N / 114°21' W
COEUR D'ALENE AIRPORT	KOOTENAI	2273	47°46' N / 116°49' W
COEUR D'ALENE RANGER STATION	KOOTENAI	2158	47°41' N / 116°45' W
CONDA	CARIBOU	6200	42°43' N / 111°33' W
COOLIN	BONNER	2448	48°30' N / 116°52' W
COOLWATER	IDAHO	6930	46°10' N / 115°25' W
COTTONWOOD	IDAHO	3411	46°03' N / 116°21' W
COTTONWOOD CREEK	BOISE	3500	43°38' N / 115°49' W
COTTONWOOD 2 WSW	IDAHO	3610	46°02' N / 116°23' W
COUNCIL	ADAMS	2936	44°44' N / 116°26' W
CRAIGMONT	LEWIS	2900	46°14' N / 116°28' W
CRATERS OF THE MOON	BUTTE	5897	43°28' N / 113°34' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
CRAWFORD	BOISE	UNK.	UNK. / UNK.
CRONK'S CANYON	LEMHI	4600	44°42' N / 114°03' W
CROUCH 2 NNW	BOISE	3100	44°08' N / 115°58' W
CULDESAC	NEZ PERCE	1520	46°23' N / 116°40' W
CUPRUM	ADAMS	4276	45°05' N / 116°42' W
DAIRY	OWYHEE	UNK.	UNK. / UNK.
DEADWOOD DAM	VALLEY	5375	44°19' N / 115°38' W
DEADWOOD SUMMIT	VALLEY	7000	44°32' N / 115°34' W
DEARY	LATAH	2854	46°48' N / 116°34' W
DECEPTION CREEK	KOOTENAI	3060	47°44' N / 116°29' W
DEER FLAT DAM	CANYON	2510	43°35' N / 116°45' W
DEER LICK RANCH	ADAMS	4322	45°00' N / 116°38' W
DEER POINT	BOISE	7150	43°45' N / 116°06' W
DENT	CLEARWATER	1200	46°39' N / 116°15' W
DEWEY	OWYHEE	5900	43°02' N / 116°46' W
DICKEY	CUSTER	UNK.	UNK. / UNK.
DIXIE	IDAHO	5610	45°33' N / 115°28' W
DOLLARHIDE SUMMIT	CAMAS	8650	43°36' N / 114°41' W
DOWNEY	BANNOCK	4854	42°25' N / 112°06' W
DRIGGS	TETON	6097	43°44' N / 111°07' W
DUBOIS	CLARK	5148	44°10' N / 112°13' W
DUBOIS EXPERIMENT STATION	CLARK	5452	44°15' N / 112°12' W
DUBOIS FEDERAL AVIATION AGENCY AIRPORT	CLARK	5122	44°10' N / 112°13' W
EDEN	JEROME	UNK.	UNK. / UNK.
EDEN 6 NNW	JEROME	4000	42°41' N / 114°15' W
EDIE	FREMONT	6700	44°25' N / 112°36' W
ELK CITY	IDAHO	4000	45°50' N / 115°25' W
ELK RIVER 1 S	CLEARWATER	2918	46°46' N / 116°11' W
ELLERSLIE	ELMORE	3500	43°18' N / 115°47' W
EMMETT 2 E	GEM	2500	43°52' N / 116°28' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
FAIRFIELD RANGER STATION	CAMAS	5065	43°21' N / 114°47' W
FAIRYLAWN	OWYHEE	4900	42°33' N / 116°38' W
FALLS RANGER STATION	BONNER	2296	48°17' N / 116°57' W
FELT	TETON	6000	43°53' N / 111°07' W
FENN RANGER STATION	IDAHO	1580	46°06' N / 115°33' W
FERNWOOD	BENEWAH	2170	47°07' N / 116°22' W
FISH LAKE	CLEARWATER	5925	46°49' N / 114°54' W
FLOWERS	BLAINE	UNK.	43°43' N / 114°27' W
FORNEY	LEMHI	6800	45°00' N / 114°26' W
FORT HALL INDIAN AGENCY	BINGHAM	4460	43°02' N / 112°26' W
FORT SHERMAN	KOOTENAI	2130	47°41' N / 116°47' W
FRASER	SHOSHONE	UNK.	46°23' N / 116°05' W
FRASER RANGER STATION	TWIN FALLS	6600	42°13' N / 114°21' W
GALENA SUMMIT	BLAINE	8800	43°53' N / 114°42' W
GARDEN VALLEY RANGER STATION	BOISE	3212	44°04' N / 115°55' W
GARNET	ELMORE	2575	42°58' N / 116°00' W
GENEVA	BEAR LAKE	6171	42°23' N / 111°04' W
GEORGETOWN	BEAR LAKE	6006	42°28' N / 111°23' W
GIBBONSVILLE	LEMHI	4500	45°33' N / 115°55' W
GIBBS	KOOTENAI	2175	47°41' N / 116°47' W
GILMORE SUMMIT RANCH	CUSTER	6600	44°19' N / 113°31' W
GIMLET	BLAINE	6539	43°36' N / 114°21' W
GLENNS FERRY	ELMORE	2569	42°57' N / 115°19' W
GOODING	GOODING	3564	42°58' N / 114°43' W
GOODING AIRPORT	GOODING	3668	42°55' N / 114°46' W
GRACE	CARIBOU	5400	42°35' N / 111°44' W
GRAND FORKS	SHOSHONE	3275	47°21' N / 115°43' W
GRANDVIEW	OWYHEE	2365	42°59' N / 116°06' W
GRANDVIEW 3 NW	OWYHEE	2375	43°00' N / 116°10' W
GRANDVIEW RANGER STATION	TETON	7200	43°49' N / 111°20' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
GRANGEVILLE	IDAHO	3355	45°55' N / 116°08' W
GRASMERE	OWYHEE	5126	42°23' N / 115°53' W
GRAY (GRAY'S LAKE)	BONNEVILLE	6300	43°02' N / 111°23' W
GRAY 6 NNW	BONNEVILLE	6375	43°08' N / 111°26' W
GRIMES PASS	BOISE	4980	44°01' N / 115°50' W
GROUSE	CUSTER	6100	43°32' N / 113°37' W
GUFFEY	OWYHEE	2381	43°17' N / 116°33' W
GUNNEL GUARD STATION	CASSIA	5880	42°06' N / 113°12' W
HAGERMAN	GOODING	2964	42°52' N / 114°51' W
HAILEY RANGER STATION	BLAINE	5328	43°31' N / 114°19' W
HAMER 4 NW	JEFFERSON	4791	43°58' N / 112°15' W
HAWLEY GULCH RANGER STATION	MADISON	6200	43°39' N / 111°34' W
HAZELTON	JEROME	4060	42°36' N / 114°08' W
HEADQUARTERS	CLEARWATER	3138	46°38' N / 115°48' W
HEREFORD	CASSIA	6700	42°15' N / 113°42' W
HILL CITY	CAMAS	5000	43°18' N / 115°03' W
HOLLISTER	TWIN FALLS	4550	42°21' N / 114°35' W
HOPE	BONNER	2150	48°19' N / 116°20' W
HOT SPRINGS	OWYHEE	2590	42°48' N / 115°42' W
HOWE	BUTTE	4820	43°47' N / 113°00' W
HUNT	JEROME	4000	42°41' N / 114°15' W
IDAHO CITY	BOISE	3965	43°50' N / 115°50' W
IDAHO CITY 11 SW	BOISE	5000	43°43' N / 116°00' W
IDAHO FALLS	BONNEVILLE	4730	43°31' N / 112°04' W
IDAHO FALLS 2 ESE	BONNEVILLE	4765	43°29' N / 112°01' W
IDAHO FALLS 16 SE	BONNEVILLE	5712	43°21' N / 111°47' W
IDAHO FALLS FEDERAL AVIATION AGENCY AIRPORT	BONNEVILLE	4730	43°31' N / 112°04' W
IDAHO FALLS 42 NW WEATHER BUREAU	BUTTE	4790	43°50' N / 112°41' W
IDAHO FALLS 46 W WEATHER BUREAU	BUTTE	4933	43°32' N / 112°57' W
IDA VADA	OWYHEE	6000	42°01' N / 115°19' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
IMUS BROTHERS RANCH	CUSTER	7150	44°14' N / 113°37' W
INDIAN COVE	OWYHEE	2480	42°56' N / 115°33' W
INDIAN VALLEY	ADAMS	2999	44°34' N / 116°28' W
IRWIN 2 SE	BONNEVILLE	5326	43°24' N / 111°18' W
ISLAND PARK DAM	FREMONT	6300	44°25' N / 111°24' W
JACKSON PEAK	BOISE	7050	44°03' N / 115°27' W
JEROME	JEROME	3785	42°44' N / 114°31' W
JUNCTION	LEMHI	6329	44°42' N / 113°21' W
JUNIPER BUTTES	FREMONT	5301	44°02' N / 111°49' W
KAMIAH	LEWIS	1212	46°14' N / 116°02' W
KELLOGG	SHOSHONE	2305	47°32' N / 116°08' W
KETCHUM 17 WSW	BLAINE	8421	43°37' N / 114°41' W
KILGORE	CLARK	6150	44°24' N / 112°07' W
KIMAMA	LINCOLN	4272	42°50' N / 113°47' W
KIRKHAM	BOISE	3794	44°06' N / 115°38' W
KIRKHAM #1	BOISE	4100	44°04' N / 115°33' W
KIRKHAM #2	BOISE	4300	UNK. / UNK.
KOOSKIA	IDAHO	1261	46°09' N / 115°59' W
KUNA 2 NNE	ADA	2685	43°31' N / 116°24' W
LAKE	FREMONT	6700	44°41' N / 111°21' W
LAKEVIEW	BONNER	2450	47°57' N / 116°30' W
LANDMARK RANGER STATION	VALLEY	6600	44°40' N / 115°33' W
LANDORE	ADAMS	5300	45°08' N / 116°38' W
LAPWAI	NEZ PERCE	891	46°24' N / 116°48' W
LARDO	VALLEY	5010	44°55' N / 116°07' W
LEADORE	LEMHI	6115	44°41' N / 113°22' W
LEMHI	LEMHI	5200	44°49' N / 113°40' W
LEWISTON (water plant)	NEZ PERCE	738	46°25' N / 117°02' W
LEWISTON	NEZ PERCE	755	46°25' N / 117°02' W
LEWISTON WEATHER BUREAU AIRPORT STATION	NEZ PERCE	1413	46°23' N / 117°01' W
LEWISTON WEATHER BUREAU OFFICE	NEZ PERCE	756	46°25' N / 117°02' W
LIFTON (pumping station)	BEAR LAKE	5926	42°07' N / 111°18' W
LITTLE CAMAS	ELMORE	5000	43°17' N / 115°23' W
LITTLE WOOD	BLAINE	5220	43°26' N / 114°01' W
LOLO PASS	IDAHO	5700	46°38' N / 114°33' W
LONG GULCH	ELMORE	4300	43°33' N / 115°39' W
LOON CREEK	CUSTER	6000	44°34' N / 114°50' W
LOST RIVER	BUTTE	5700	43°40' N / 113°27' W
LOVELL	BENEWAH	2500	UNK. / UNK.
LOWMAN	BOISE	3794	44°06' N / 115°38' W
LOWMAN 3 E	BOISE	3870	44°05' N / 115°34' W
LOWRY	OWYHEE	4700	42°33' N / 117°00' W
MACKAY RANGER STATION	CUSTER	5897	43°55' N / 113°37' W
MAGIC	BLAINE	4800	43°15' N / 114°21' W
MALAD	ONEIDA	4420	42°12' N / 112°16' W
MALAD FEDERAL AVIATION AGENCY AIRPORT	ONEIDA	4476	42°10' N / 112°19' W
MALTA	CASSIA	4540	42°19' N / 113°21' W
MALTA RANGER STATION	CASSIA	4540	42°19' N / 113°22' W
MARTIN	BUTTE	5600	43°03' N / 113°03' W
MARYSVILLE	FREMONT	5400	44°05' N / 111°25' W
MAY RANGER STATION	LEMHI	5110	44°36' N / 113°35' W
MC CALL	VALLEY	5025	44°54' N / 116°07' W
MC CAMMON	BANNOCK	4774	42°39' N / 112°12' W
MEADOWS	ADAMS	3975	44°58' N / 116°16' W
MERIDIAN 1 W	ADA	2620	43°37' N / 116°25' W
MESA	ADAMS	3224	44°37' N / 116°26' W
MIDDLE FORK	IDAHO	1397	46°07' N / 115°37' W
MIDWAY	BINGHAM	5025	43°24' N / 112°50' W
MILNER	TWIN FALLS	4200	42°32' N / 114°01' W
MILNER DAM	TWIN FALLS	4200	42°32' N / 114°01' W
MINIDOKA	MINIDOKA	4280	42°45' N / 113°30' W
MINIDOKA DAM	MINIDOKA	4280	42°40' N / 113°30' W
MOHLER	LEWIS	3000	46°17' N / 116°16' W
MONTPELIER RANGER STATION	BEAR LAKE	6053	42°19' N / 111°18' W
MONTEVIEW	JEFFERSON	4786	43°56' N / 112°53' W
MOORE	BUTTE	5700	43°45' N / 113°22' W
MOORE CREEK SUMMIT	BOISE	5990	45°56' N / 115°40' W
MOOSE CREEK RANGER STATION	IDAHO	4280	46°08' N / 114°55' W
MOSCOW UNIVERSITY OF IDAHO	LATAH	2628	46°44' N / 117°00' W
MOUNTAIN HOME 1 SE	ELMORE	3180	43°08' N / 115°42' W
MUD LAKE	JEFFERSON	4790	43°50' N / 112°25' W
MULLAN FEDERAL AVIATION AGENCY	SHOSHONE	3586	47°28' N / 115°46' W
MULLAN	SHOSHONE	2950	UNK. / UNK.
MULLAN JUNCTION	SHOSHONE	2950	47°30' N / 115°53' W
MULLAN PASS	SHOSHONE	5962	47°27' N / 115°40' W
MURPHY	OWYHEE	2427	43°13' N / 116°34' W
MURRAY	SHOSHONE	2750	47°38' N / 115°52' W
MURTAUGH	TWIN FALLS	4630	42°32' N / 114°12' W
MUSSELSHELL	CLEARWATER	3171	46°22' N / 115°45' W
NAMPA	CANYON	2482	43°35' N / 116°33' W
NAMPA 2 NW	CANYON	2470	43°37' N / 116°35' W
NEVINS RANCH	BOISE	3000	43°38' N / 115°48' W
NEW MEADOWS RANGER STATION	ADAMS	3870	44°58' N / 116°17' W
NEZPERCE	LEWIS	3220	46°14' N / 116°14' W
NEZPERCE PASS	IDAHO	6575	45°43' N / 114°30' W
NORTH FORK	LEMHI	3600	45°29' N / 113°58' W
OAKLEY	CASSIA	4191	42°15' N / 113°54' W
OBSIDIAN 3 SSE	CUSTER	6900	44°03' N / 114°49' W
O'HARA BAR	IDAHO	1557	46°05' N / 115°30' W
OLA	GEM	3100	44°11' N / 116°16' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
OLA 5 S	GEM	2975	44°08' N / 116°17' W
OROFINO	CLEARWATER	1027	46°29' N / 116°15' W
OXFORD	BANNOCK	4750	42°17' N / 112°01' W
OXFORD RANGER STATION	CLEARWATER	3735	46°37' N / 115°38' W
PALISADES DAM	BONNEVILLE	5397	43°20' N / 111°12' W
PARIS	BEAR LAKE	5966	42°14' N / 111°24' W
PARMA EXPERIMENT STATION	CANYON	2215	43°48' N / 116°57' W
PAUL 1 ENE	MINIDOKA	4210	42°37' N / 113°45' W
PAYETTE	PAYETTE	2150	44°05' N / 116°56' W
PEBBLE	CARIBOU	5299	42°45' N / 112°02' W
PELTON RANCH	CUSTER	7100	43°55' N / 114°01' W
PETE KING RANGER STATION	IDAHO	1550	46°09' N / 115°36' W
PICABO	BLAINE	4875	43°18' N / 114°04' W
PIERCE RANGER STATION	CLEARWATER	3171	46°23' N / 115°37' W
PIERSON	CUSTER	UNK.	44°04' N / 114°48' W
PINE 1 N	ELMORE	4220	43°30' N / 115°18' W
PLEASANT VALLEY	ADA	3000	43°31' N / 116°18' W
PLUMMER 3 WSW	BENEWAH	2970	47°19' N / 116°57' W
POCATELLO NURSERY	BANNOCK	5396	42°52' N / 112°29' W
POCATELLO 2	BANNOCK	4440	42°52' N / 112°28' W
POCATELLO WEATHER BUREAU AIRPORT STATION	POWER	4444	42°55' N / 112°36' W
POCATELLO WEATHER BUREAU OFFICE	BANNOCK	4503	42°52' N / 112°27' W
POLLOCK	IDAHO	2200	45°23' N / 116°23' W
POPLAR	BONNEVILLE	5500	43°34' N / 111°37' W
POPLARS	CANYON	2425	43°38' N / 116°42' W
PORCUPINE	FREMONT	5500	44°05' N / 111°14' W
PORTHILL	BOUNDARY	1800	49°00' N / 116°30' W
POTLACH	LATAH	2520	46°55' N / 116°54' W
PRAIRIE	ELMORE	4670	43°30' N / 115°35' W
PRESTON 2 SE	FRANKLIN	4718	42°04' N / 111°51' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
PRICHARD RANGER STATION	SHOSHONE	2400	47°42' N / 115°59' W
PRIEST LAKE	BONNER	UNK.	48°35' N / 116°52' W
PRIEST RIVER	KOOTENAI	2078	UNK. / UNK.
PRIEST RIVER EXPERIMENT STATION	BONNER	2380	48°21' N / 116°50' W
PRINCETON	LATAH	2496	46°55' N / 116°50' W
PRINCETON 5 SE	LATAH	2600	46°52' N / 116°49' W
PUNGO CREEK	VALLEY	4800	44°45' N / 115°04' W
PUTNAM MOUNTAIN	BINGHAM	5667	43°03' N / 112°07' W
PYLE CREEK	BOISE	UNK.	UNK. / UNK.
RATTLESNAKE	ELMORE	4000	43°37' N / 115°44' W
REACTOR TESTING STATION	BUTTE	4925	43°33' N / 112°57' W
REXBURG	MADISON	4913	43°49' N / 111°47' W
REYNOLDS	OWYHEE	3910	43°12' N / 116°45' W
RICE	FREMONT	5600	44°13' N / 111°38' W
RICHFIELD	LINCOLN	4306	43°04' N / 114°09' W
RIDDLE	OWYHEE	6200	42°11' N / 116°08' W
RIGGINS	IDAHO	1801	45°25' N / 116°19' W
RIRIE	JEFFERSON	4962	43°38' N / 111°47' W
RIRIE 12 ESE	BONNEVILLE	5676	43°32' N / 111°32' W
ROBERTS	JEFFERSON	4775	43°43' N / 112°08' W
ROLAND (WEST PORTAL)	SHOSHONE	4150	47°21' N / 115°40' W
ROOSEVELT	VALLEY	UNK.	44°57' N / 115°00' W
ROSEBERRY	VALLEY	4872	44°44' N / 116°05' W
ROSWORTH	TWIN FALLS	4650	42°22' N / 114°58' W
RUBY CREEK	BOISE	UNK.	43°40' N / 116°03' W
RUPERT	MINIDOKA	4204	42°37' N / 113°41' W
RUTHBURG	WASHINGTON	UNK.	UNK. / UNK.
ST. ANTHONY	FREMONT	4968	43°58' N / 111°40' W
ST. MARIES	BENEWAH	2085	47°29' N / 116°34' W
ST. MICHAELS PRIORY	IDAHO	4000	46°02' N / 116°23' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
SALEM	FREMONT	5000	43°52' N / 111°45' W
SALMON	LEMHI	3961	45°12' N / 113°52' W
SALMON RIVER DAM	TWIN FALLS	4960	42°29' N / 114°50' W
SALUBRIA	WASHINGTON	2750	44°33' N / 116°38' W
SANDPOINT EXPERIMENT STATION	BONNER	2100	48°17' N / 116°34' W
SNAKE CREEK RANGER STATION	ELMORE	4730	43°37' N / 115°10' W
SHEEP HILL	BOISE	UNK.	UNK. / UNK.
SHOSHONE 1 WNW	LINCOLN	3950	42°58' N / 114°26' W
SHOUP	LEMHI	3340	45°23' N / 114°17' W
SILVER CITY	OWYHEE	6400	43°01' N / 116°44' W
SLATE CREEK RANGER STATION	IDAHO	1568	45°38' N / 116°17' W
SMITH CREEK	VALLEY	5500	45°09' N / 115°19' W
SMITHS FERRY	BOISE	4400	44°19' N / 116°06' W
SMITH PRAIRIE	ELMORE	4000	43°29' N / 115°32' W
SODA SPRINGS	CARIBOU	UNK.	UNK. / UNK.
SOLDIER	CAMAS	5200	43°22' N / 114°48' W
SOLDIER CREEK AIRPORT STATION	CAMAS	5755	43°30' N / 114°50' W
SPENCER RANGER STATION	CLARK	5883	44°21' N / 112°11' W
SPIRIT LAKE	KOOTENAI	2560	47°58' N / 116°52' W
SPRINGFIELD 1 SE	BINGHAM	4405	43°04' N / 112°41' W
SPRING HILL	ADA	3607	43°40' N / 116°17' W
STANDROD	CASSIA	UNK.	UNK. / UNK.
STANLEY	CUSTER	6200	44°13' N / 114°55' W
STIBNITE	VALLEY	6550	44°54' N / 115°20' W
STONE	ONEIDA	4520	42°03' N / 112°39' W
STREVELL	CASSIA	5280	42°01' N / 113°13' W
SUBLETT GUARD STATION	POWER	5800	42°22' N / 112°58' W
SUGAR	MADISON	4890	43°53' N / 111°45' W
SUN VALLEY	BLAINS	5821	43°41' N / 114°21' W
SUNNYSIDE	ELMORE	3500	43°19' N / 115°50' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
SUNSET PEAK	SHOSHONE	6424	47°34' N / 115°50' W
SWAN FALLS POWER HOUSE	ADA	2323	43°15' N / 116°23' W
SWAN VALLEY 1 W	BONNEVILLE	5240	43°27' N / 111°22' W
TETONIA	TETON	6200	43°49' N / 111°10' W
TETONIA EXPERIMENT STATION	TETON	5904	43°51' N / 111°16' W
THREE CREEK	OWYHEE	5420	42°05' N / 115°09' W
THUNDER MOUNTAIN	VALLEY	UNK.	44°57' N / 115°00' W
TRIANGLE RANCH	OWYHEE	5290	42°47' N / 116°37' W
TRINITY LAKE GUARD STATION	ELMORE	7400	43°38' N / 115°26' W
TRIPOD MOUNTAIN	GEM	4000	44°15' N / 116°16' W
TROUTDALE GUARD STATION	ELMORE	3475	43°43' N / 115°38' W
TWIN FALLS 2 NNE	TWIN FALLS	3770	42°35' N / 114°28' W
TWIN FALLS 3 SE	TWIN FALLS	3765	42°32' N / 114°25' W
TWIN FALLS FACTORY	TWIN FALLS	UNK.	UNK. / UNK.
VAN WYCK	BOISE	4777	44°31' N / 116°04' W
VERNON	FREMONT	UNK.	44°04' N / 111°30' W
VIENNA MINE	BLAINE	8800	43°49' N / 114°51' W
WALLACE	SHOSHONE	2770	47°28' N / 115°56' W
WALLACE WOODLAND PARK	SHOSHONE	2950	47°30' N / 115°53' W
WARREN	IDAHO	5352	45°16' N / 115°40' W
WAYAN	CARIBOU	6430	42°59' N / 111°22' W
WEISER 2 SE	WASHINGTON	2120	44°14' N / 116°57' W
WENDELL	GOODING	3467	42°45' N / 114°40' W
WESTLAKE	IDAHO	UNK.	46°07' N / 116°30' W
WESTON	FRANKLIN	4604	42°03' N / 111°57' W
WHITEBIRD	IDAHO	3000	45°57' N / 116°19' W
WHITES	OWYHEE	UNK.	42°26' N / 116°12' W
WILLOW FLAT	FRANKLIN	6100	42°09' N / 111°38' W
WINCHESTER 1 SE	LEWIS	3950	46°14' N / 116°36' W
WOLF LODGE SUMMIT	KOOTENAI	4650	47°43' N / 116°30' W
WOODLAND PARK	SHOSHONE	2950	47°30' N / 115°53' W
WOODROW	FREMONT	5200	44°02' N / 112°00' W
WRENSTED RANCH	POWER	5950	42°33' N / 112°26' W
YELLOW JACKET	LEMHI	6800	45°00' N / 114°26' W
YELLOW PINE	VALLEY	4760	44°58' N / 115°29' W

STATION LOCATIONS

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
ALBERTON	MINERAL	3040	47°00' N / 114°29' W
ANACONDA	DEER LODGE	5330	46°08' N / 112°57' W
BEAR DANCE	LAKE	3060	47°53' N / 114°02' W
BELTON	FLATHEAD	3154	48°30' N / 113°59' W
BIGFORK 12 S	LAKE	3060	47°53' N / 114°02' W
BISON MOUNTAIN	POWELL	7243	46°24' N / 112°25' W
BUTTE SCHOOL OF MINES	SILVER BOW	5765	46°01' N / 112°33' W
BUTTE 8 S	SILVER BOW	5700	45°54' N / 112°33' W
BUTTE FEDERAL AVIATION AGENCY, AIRPORT	SILVER BOW	5530	45°57' N / 112°30' W
CATARACT CREEK	JEFFERSON	UNK.	UNK. / UNK.
CHESSMAN RESERVOIR	LEWIS & CLARK	6275	46°28' N / 112°11' W
CHRISTENSEN	FERGUS	UNK.	UNK. / UNK.
COLLEGE OF MONTANA DEER LODGE	POWELL	4529	46°21' N / 112°44' W
COLUMBIA FALLS	FLATHEAD	3095	48°22' N / 114°14' W
COLUMBIA FALLS 5 SW	FLATHEAD	3080	48°19' N / 114°12' W
COMO	RAVALLI	3750	46°07' N / 114°10' W
CONNER	RAVALLI	4029	45°56' N / 114°08' W
CORVALLIS	RAVALLI	3575	46°19' N / 114°07' W
CRESTON	FLATHEAD	2991	48°11' N / 114°08' W
DARBY - NEAR	RAVALLI	4137	45°54' N / 114°10' W
DARBY	RAVALLI	3815	46°02' N / 114°11' W
DAYTON	LAKE	2925	47°54' N / 114°17' W
DEER LODGE	POWELL	4530	46°23' N / 112°44' W
DEER LODGE 3 W	POWELL	4850	46°23' N / 112°48' W
DRUMMOND FEDERAL AVIATION AGENCY AIRPORT	GRANITE	4240	46°37' N / 113°12' W
DRUMMOND 1 SW	GRANITE	UNK.	UNK. / UNK.
EAST ANACONDA	DEER LODGE	5511	46°06' N / 112°55' W
ELLISTON	POWELL	5075	46°34' N / 112°26' W
ESSEX	FLATHEAD	3865	48°17' N / 113°36' W
EUREKA	LINCOLN	2577	48°53' N / 115°03' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
EUREKA RANGER STATION	LINCOLN	2532	48°54' N / 113°04' W
FISH CREEK	SILVER BOW	5664	45°48' N / 112°20' W
FORTINE 1 NNE	LINCOLN	3000	48°47' N / 114°54' W
GARNET	GRANITE	4060	46°49' N / 113°21' W
GIBBONS PASS	RAVALLI	7000	45°42' N / 113°57' W
HAMILTON	RAVALLI	3529	46°15' N / 114°09' W
HAT CREEK	POWELL	5075	46°34' N / 112°26' W
HAUGAN	MINERAL	3150	47°23' N / 115°24' W
HERON 2 NW	SANDERS	2240	48°05' N / 116°00' W
HUNGRY HORSE DAM	FLATHEAD	3160	48°21' N / 114°00' W
KALISPELL WEATHER BUREAU AIRPORT STATION	FLATHEAD	2965	48°18' N / 114°16' W
KALISPELL	FLATHEAD	2960	48°12' N / 114°19' W
LIBBY 1 NE RANGER STATION	LINCOLN	2080	48°24' N / 115°32' W
LIBBY 32 SSE	LINCOLN	3600	47°58' N / 115°14' W
LINCOLN 14 NE	LEWIS & CLARK	5130	47°02' N / 112°25' W
LINCOLN RANGER STATION	LEWIS & CLARK	4540	46°57' N / 112°39' W
LINDBERGH LAKE	MISSOULA	4500	47°26' N / 113°43' W
LOLO HOT SPRINGS 2 NE	MISSOULA	4085	46°45' N / 114°30' W
LONEPINE 1 WNW	SANDERS	2875	47°43' N / 114°39' W
LONEPINE	SANDERS	2840	47°42' N / 114°38' W
LOST CREEK	DEER LODGE	5200	46°10' N / 112°54' W
MCGINNIS MEADOWS	LINCOLN	UNK.	UNK. / UNK.
MIKE HORSE	LEWIS & CLARK	5045	47°01' N / 112°21' W
MISSOULA 2 WNW	MISSOULA	3172	46°53' N / 114°02' W
MISSOULA WEATHER BUREAU AIRPORT STATION #	MISSOULA	3200	46°55' N / 114°05' W
MOUNT SILCOX	SANDERS	6855	47°38' N / 115°17' W
OLNEY 1 SE	FLATHEAD	3175	48°32' N / 114°34' W
OPHIR	POWELL	5200	46°41' N / 112°32' W
OVANDO 1 SW	POWELL	4101	47°01' N / 113°09' W
OVANDO 7 WNW	POWELL	4000	47°03' N / 113°17' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
PARADISE	SANDERS	2890	47°23' N / 114°48' W
PHILIPSBURG RANGER STATION #	GRANITE	5280	46°19' N / 113°18' W
PLAINS RANGER STATION	SANDERS	2475	47°28' N / 114°53' W
PLAINS	SANDERS	2473	47°27' N / 114°51' W
PLEASANT VALLEY	FLATHEAD	3600	48°08' N / 114°55' W
PLEASANT VALLEY 4 SE	FLATHEAD	3650	48°05' N / 114°52' W
POLEBRIDGE	FLATHEAD	3690	48°47' N / 114°16' W
POLSON AIRPORT	LAKE	2932	47°41' N / 114°11' W
POLSON (KERR DAM)	LAKE	2730	47°41' N / 114°15' W
REXFORD RANGER STATION	LINCOLN	2350	48°53' N / 115°12' W
ROGERS PASS	LEWIS & CLARK	5470	47°04' N / 112°22' W
ROUND BUTTE 1 NNE	LAKE	3100	47°32' N / 114°27' W
ST. IGNATIUS	LAKE	2900	47°19' N / 114°06' W
ST. REGIS RANGER STATION	MINERAL	2664	47°18' N / 115°06' W
SALTESE	MINERAL	3600	47°26' N / 115°30' W
ST. REGIS	MINERAL	2647	UNK. / UNK.
SEELEY LAKE RANGER STATION	MISSOULA	4030	47°13' N / 113°31' W
SILVER LAKE	DEER LODGE	6480	46°10' N / 113°13' W
SNOWSHOE	LINCOLN	4500	48°12' N / 115°41' W
SPOTTED BEAR MOUNTAIN	FLATHEAD	6000	47°55' N / 113°28' W
SPOTTED BEAR RANGER STATION	FLATHEAD	3725	47°55' N / 113°31' W
STEVENSVILLE #	RAVALLI	3370	46°31' N / 114°06' W
STRYKER	FLATHEAD	3275	48°38' N / 114°42' W
SULA 2 SE #	RAVALLI	4600	45°49' N / 113°57' W
SULA	RAVALLI	4400	45°50' N / 113°59' W
SUMMIT	FLATHEAD	5213	48°19' N / 113°21' W
SUNSET ORCHARDS	RAVALLI	4000	46°27' N / 114°00' W
SUPERIOR #	MINERAL	2730	47°12' N / 114°54' W
SWAN LAKE	LAKE	3100	47°55' N / 113°50' W
THOMPSON FALLS POWER HOUSE	SANDERS	2380	47°36' N / 115°21' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
TRAPPERS CREEK	RAVALLI	4137	45°54' N / 114°10' W
TROUT CREEK 2 W	SANDERS	2485	47°50' N / 115°38' W
TROUT CREEK RANGER STATION	SANDERS	2356	47°52' N / 115°37' W
TROY	LINCOLN	2000	48°23' N / 115°52' W
TROY	LINCOLN	1929	48°29' N / 115°55' W
TROY 18 N	LINCOLN	2719	48°44' N / 115°53' W
UPPER COLUMBIA SNOWLAB	FLATHEAD	4846	48°18' N / 113°22' W
UPPER HOLLAND LAKE	MISSOULA	6000	47°28' N / 113°31' W
UPPER LAKE MACDONALD	FLATHEAD	3164	48°39' N / 113°53' W
UPPER YORK RIVER	LINCOLN	2800	48°50' N / 115°43' W
VICTOR (NEAR)	RAVALLI	3600	46°25' N / 114°12' W
WEST GLACIER	FLATHEAD	3154	48°30' N / 113°59' W
WHITEFISH 5 NW	FLATHEAD	3080	48°29' N / 114°23' W
YOAK	LINCOLN	3030	48°50' N / 115°42' W

STATION LOCATIONS

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
ADAMS (WOODWARD RANCH)	UMATILLA	1700	45°49' N / 118°36' W
ADEL 1 S	LAKE	4500	42°11' N / 119°53' W
ADRIAN	MALHEUR	2231	43°44' N / 117°04' W
AGATE BEACH U.S. COAST GUARD	LINCOLN	87	44°41' N / 124°04' W
AGENCY PLAINS	JEFFERSON	2363	44°45' N / 121°15' W
AGNESS	CURRY	200	42°30' N / 124°02' W
ALBANY	LINN	212	44°35' N / 123°04' W
ALBANY NO. 2	LINN	212	44°35' N / 123°04' W
ALBEE (ALBA)	UMATILLA	3600	45°21' N / 118°54' W
ALKALI LAKE	LAKE	4332	42°58' N / 120°00' W
ALLEGANY	COOS	50	43°25' N / 124°02' W
ALLINGHAM	JEFFERSON	3600	44°25' N / 121°40' W
ALOHA	JACKSON	1310	42°24' N / 122°46' W
ALPHA	LANE	250	44°10' N / 123°45' W
ALPINE	BENTON	400	44°20' N / 123°18' W
ALSEA FISH HATCHERY	LINCOLN	230	44°24' N / 123°45' W
ALVORD RANCH	HARNEY	4180	42°37' N / 118°30' W
ANA RIVER	LAKE	4200	43°00' N / 120°45' W
ANDREWS	HARNEY	4100	42°27' N / 118°37' W
ANDREWS 23 ESE	HARNEY	4275	42°18' N / 118°13' W
ANNA SPRINGS	KLAMATH	6016	42°52' N / 122°10' W
ANTELOPE 1 N	WASCO	2758	44°55' N / 120°43' W
ARLINGTON	GILLIAM	350	45°43' N / 120°09' W
AMITAGE BRIDGE	LANE	440	44°07' N / 123°03' W
ASHLAND 1 N#	JACKSON	1750	42°15' N / 122°45' W
ASHWOOD	JEFFERSON	2484	44°44' N / 120°45' W
ASTOR EXPERIMENT STATION	CLATSOP	50	46°08' N / 123°48' W
ASTORIA	CLATSOP	20-150	46°11' N / 123°50' W
ASTORIA WEATHER BUREAU AIRPORT STATION	CLATSOP	8	46°09' N / 123°53' W
ATHENA NEAR	UMATILLA	UNK.	45°48' N / 118°28' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
ATHENA FARM CHEMICAL	UMATILLA	1950	45°49' N / 118°30' W
AURORA	MARION	90-150	45°14' N / 122°45' W
AURORA NEAR	MARION	UNK	45°20' N / 122°50' W
AUSTIN 3 S#	GRANT	4333	44°35' N / 118°30' W
BAGLEY'S RANCH	BAKER	3900	44°43' N / 117°42' W
BAKER WEATHER BUREAU OFFICE	BAKER	3466	44°46' N / 117°51' W
BAKER RADIO STATION KBKR	BAKER	3444	44°47' N / 117°50' W
BAKER FEDERAL AVIATION AGENCY	BAKER	3368	44°50' N / 117°49' W
BAKER 1 S	BAKER	349[illegible]	44°46' N / 117°50' W
BANDON (1878-1900)	COOS	25	43°07' N / 124°25' W
BANDON	COOS	12	43°07' N / 124°25' W
BARNES STATION	CROOK	4970	43°57' N / 120°13' W
BATES 6 SW DIXIE PASS	GRANT	5250	42°32' N / 118°36' W
BAY CITY	TILLAMOOK	14-225	45°31' N / 123°52' W
BEAR CREEK	CROOK	4500-4800	43°57' N / 120°[illegible]' W
BEAR SPRINGS RANGER STATION	WASCO	3110	45°07' N / 121°31' W
BEAR VALLEY	GRANT	5000	44°14' N / 119°07' W
BECKLEY	HARNEY	4300	42°38' N / 119°04' W
BEECH CREEK	GRANT	4710	44°34' N / 119°07' W
BELLFOUNTAIN	BENTON	320	44°21' N / 123°23' W
BELKNAP SPRINGS 8 N	LINN	2152	44°15' N / 122°02' W
BEND	DESCHUTES	3600	44°04' N / 121°19' W
BEULAH	MALHEUR	3260-3700	44°35' N / 118°09' W
BIG BASIN	GRANT	2800	44°30' N / 119°38' W
BIG CAMAS RANGER STATION	DOUGLAS	3050	43°14' N / 122°28' W
BIG EDDY	WASCO	125	45°38' N / 121°06' W
BIRCH CREEK	WHEELER	2900	44°30' N / 119°45' W
BIRKENFELD 1 WNW	COLUMBIA	540	46°00' N / 123°26' W
BLACK BUTTE 1 NW	LANE	1200	43°35' N / 123°04' W
BLALOCK	GILLIAM	950	45°41' N / 120°24' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
BLITZEN	HARNEY	4300	42°38' N / 119°04' W
BLUE MOUNTAIN SAWMILL	UMATILLA	4200	45°47' N / 118°12' W
BLY RANGER STATION	KLAMATH	4356	42°24' N / 121°04' W
BONITA	LANE	2700	UNK. / UNK.
BONNEVILLE DAM	MULTNOMAH	85	45°38' N / 121°57' W
BORING 2 N	CLACKAMAS	595	45°27' N / 122°22' W
BREITENBUSH	MARION	2220	44°47' N / 121°59' W
BRIGHTWOOD	CLACKAMAS	1065	45°22' N / 122°01' W
BROCKMAN RANCH	WALLOWA	1310	45°30' N / 116°34' W
BROGAN	MALHEUR	2625	44°15' N / 117°30' W
BROOKINGS	CURRY	120	42°03' N / 124°17' W
BROTHERS	DESCHUTES	4640	43°48' N / 120°36' W
BROWNS ORCHARD	JACKSON	1500	42°21' N / 122°48' W
BROWNSVILLE	LINN	326	44°23' N / 122°59' W
BUCKHORN FARM	JOSEPHINE	1292	42°10' N / 123°29' W
BUG	WALLOWA	4500	45°39' N / 117°17' W
BUENA VISTA	HARNEY	4130	43°00' N / 119°00' W
BUENA VISTA STATION	HARNEY	4135	43°04' N / 118°52' W
BUENA VISTA	UNION	3700	45°03' N / 118°05' W
BULLRUN	CLACKAMAS	719	45°[illegible]' N / [illegible]
BUNCOM 2 SE	JACKSON	1925	42°0[illegible]' N / 122°5[illegible]' W
BURGESS FARM	WHEELER	2450	44°54' N / 120°22' W
BURNS WEATHER BUREAU OFFICE	HARNEY	4151	43°35' N / 119°03' W
BURNS MILL	HARNEY	5000	43°47' N / 119°19' W
BUTTE	LAKE	4500	43°14' N / 120°01' W
BUTTE FALLS 1 SE#	JACKSON	2500	42°32' N / 122°33' W
BUTTER CREEK (McCARTY RANCH)	UMATILLA	1175	45°39' N / 119°24' W
BUXTON	WASHINGTON	325	45°41' N / 123°11' W
BUXTON - MOUNTAINDALE	WASHINGTON	300	45°41' N / 123°04' W
BUXTON 5 E	WASHINGTON	300	45°41' N / 123°05' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
CALIFORNIA GULCH	UMATILLA	3222	45°22' N / 118°50' W
CAMAS VALLEY	DOUGLAS	1093	43°03' N / 123°41' W
CAMP HARNEY	HARNEY	UNK.	43°40' N / 118°49' W
CAMP WARNER	LAKE	5730	42°24' N / 120°09' W
CANARY	LANE	100	43°56' N / 124°02' W
CANBY	CLACKAMAS	130	45°14' N / 122°41' W
CANYON CITY	GRANT	3194	44°24' N / 118°57' W
CAPE BLANCO	CURRY	166	42°50' N / 124°34' W
CARLTON 13 W#	YAMHILL	1950	45°13' N / 123°26' W
CASCADE LOCKS	HOOD RIVER	100	45°41' N / 121°54' W
CASCADE SUMMIT	KLAMATH	4841	43°35' N / 122°02' W
CASCADIA	LINN	1050	44°24' N / 123°30' W
CASCADIA RANGER STATION	LINN	750	44°22' N / 123°30' W
CAVE JUNCTION	JOSEPHINE	1325	42°10' N / 123°39' W
CAZADERO	CLACKAMAS	414	45°16' N / 122°19' W
CENTRAL POINT	JACKSON	1255	42°24' N / 122°52' W
CHAMPION MINE	LANE	4375	43°35' N / 122°39' W
CHARLESTON	COOS	10	43°20' N / 124°20' W
CHEMULT	KLAMATH	4760	43°13' N / 121°47' W
CHERRY GROVE 2 SE	YAMHILL	900	45°25' N / 123°15' W
CHILOQUIN	KLAMATH	4200	42°35' N / 121°52' W
CHRISTMAS LAKE	LAKE	4350	43°13' N / 120°37' W
CLARNO	WHEELER	1344	44°53' N / 120°30' W
CLASSIC LAKE	TILLAMOOK	60	45°45' N / 124°10' W
CLATSKANIE 3 W#	COLUMBIA	50	46°06' N / 123°16' W
CLEAR LAKE	KLAMATH	3030	45°22' N / 122°00' W
CLIFF	LAKE	4300	43°22' N / 120°27' W
CLOVERDALE 1 NW#	TILLAMOOK	20	45°13' N / 123°34' W
COBURG 2 SE	LANE	440	44°07' N / 123°03' W
COLTON	CLACKAMAS	654	45°10' N / 122°26' W
COLUMBIA CITY	COLUMBIA	UNK.	UNK. / UNK.
COLUMBIA MINE	BAKER	6000	44°50' N / 118°12' W
COMBS FLAT	CROOK	4027	44°15' N / 120°41' W
COMSTOCK	DOUGLAS	468	43°43' N / 123°10' W
CONDER	MORROW	UNK.	45°36' N / 119°30' W
CONDON	GILLIAM	2844	45°14' N / 120°11' W
COOMBS CANYON (BLANCHET RANCH)	UMATILLA	980	45 39' N / 118 53' W
COPPER	JACKSON	1780	42°03' N / 123°07' W
COQUILLE	COOS	80	43°11' N / 124°11' W
COQUILLE RIVER LIFE BOAT STATION	COOS	12	43°07' N / 124°25' W
CORNUCOPIA	BAKER	4700	45°00' N / 117°12' W
CORPORATION RANGER STATION	UMATILLA	2370	45°47' N / 118°04' W
CORVALLIS (RIVER)	BENTON	220	44°34' N / 123°15' W
CORVALLIS	BENTON	275	44°34' N / 123°17' W
CORVALLIS STATE COLLEGE	BENTON	205	44°39' N / 123°12' W
CORVALLIS BEACH EXPERIMENT AREA	LINN	215	44°34' N / 123°15' W
CORVALLIS LEWIS-BROWN EXPERIMENT AREA	LINN	220	44°33' N / 123°13' W
CORVALLIS WATER BUREAU	BENTON	592	44°31' N / 123°27' W
COTTAGE GROVE 1 S#	LANE	650	43°47' N / 123°04' W
COTTAGE GROVE DAM	LANE	831	43°43' N / 123°03' W
COUGAR DAM	LANE	1262	44°08' N / 122°45' W
COUSE CREEK (SHUMWAY RANCH)	UMATILLA	[illegible]	45°57' N / [illegible] W
COVE 1 ENE#	UNION	3100	45°18' N / 117°43' [illegible]
COYOTE	GRANT	2600	44°39' N / 119°38' W
CRACKER CREEK	BAKER	4800	44°46' N / 118°13' W
CRANE	HARNEY	4135	43°23' N / 118°27' W
CRANE PRAIRIE	DESCHUTES	4460	43°45' N / 121°47' W
CRATER LAKE	KLAMATH	6475	42°54' N / 122°08' W
CRATER LAKE NATIONAL PARK HEADQUARTERS	KLAMATH	6475	42°54' N / 122°08' W
CRESCENT	KLAMATH	4452	43°27' N / 121°42' W
CRESCENT LAKE	KLAMATH	4784	43°30' N / 121°58' W
CRESWELL	LANE	480	43°55' N / 123°02' W
CROOK	CROOK	4750	44°00' N / 121°29' W
CRUSSETT	CLATSOP	418	46°08' N / 123°52' W
CROW 4 NE	LANE	443	44°01' N / 123°15' W
CROWLEY RANCH	MALHEUR	4140	43°18' N / 117°54' W
CRUZATTE	LANE	4104	43°36' N / 122°05' W
CULVER	CROOK	2625	44°28' N / 121°11' W
CURTIN	DOUGLAS	440	43°44' N / 123°12' W
DAIRY 3 NE YONNA	KLAMATH	4150	42°16' N / 121°28' W
DALE	UMATILLA	2920	45°00' N / 118°54' W
DALLAS	POLK	325	44°56' N / 123°19' W
DANNER	MALHEUR	4397	42°56' N / 117°20' W
DAYVILLE	GRANT	2434	44°[illegible]' N / 119°3[illegible]' W
DEADWOOD	LANE	500	44°[illegible]' N / 123°[illegible]' W
DEE	HOOD RIVER	[illegible]	45°36' N / 121°35' W
DEER ISLAND	COLUMBIA	[illegible]	4[illegible]°02' N / 122°58' W
DENMARK	CURRY	25	42°[illegible]' N / 124°25' W
DEPOE BAY	LINCOLN	25	44°48' N / 124°04' W
DETROIT	MARION	1590	[illegible] / 122°09' W
DETROIT DAM POWERHOUSE	MARION	1300	44°43' N / 122°15' W
DETROIT 19 NE	JEFFERSON	4985	44°40' N / 121°47' W
DEVILS FLAT	DOUGLAS	2080	42°49' N / 123°03' W
DIAMOND 4 WNW#	HARNEY	4130	43°03' N / 118°46' W
DIAMOND LAKE	DOUGLAS	5200	43°11' N / 122°09' W
DIAMOND LAKE LODGE	DOUGLAS	5105	43°11' N / 122°08' W
DILLEY 1 S	WASHINGTON	220	45°28' N / 123°07' W
DISSTON 5 NE#	LANE	1212	43°42' N / 122°45' W
DISSTON 10 SE	LANE	4375	43°35' N / 122°39' W
DIXIE PASS	GRANT	5250	42°32' N / 118°36' W

STATION LOCATIONS

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
DORAVILLE	COLUMBIA	750	46°02' N / 123°07' W
DORENA DAM	LANE	757	43°47' N / 122°58' W
DRAIN 1 NNE#	DOUGLAS	372	43°41' N / 123°18' W
DRAIN 10 NW	DOUGLAS	750	43°47' N / 123°26' W
DREWSEY	HARNEY	3508	43°47' N / 118°22' W
DUFUR	WASCO	1325	45°27' N / 121°08' W
DUNCAN	UMATILLA	3242	45°32' N / 118°20' W
DURKEE 3 NNW#	BAKER	2740	44°37' N / 117°29' W
EAST PORTLAND	MULTNOMAH	100	45°32' N / 122°39' W
ECHO	UMATILLA	601	45°44' N / 119°12' W
EDEN	WALLOWA	3400	45°57' N / 117°27' W
ELGIN	UNION	2670	45°34' N / 117°55' W
ELKHEAD	DOUGLAS	780	43°32' N / 123°11' W
ELKHORN RANCH	COOS	600	43°22' N / 124°01' W
ELKTON	DOUGLAS	185	43°40' N / 123°33' W
ELKTON 3 SW#	DOUGLAS	114	43°36' N / 123°35' W
ELKTON 4 S	DOUGLAS	170	43°35' N / 123°34' W
ELLA	MORROW	830	45°38' N / 119°48' W
ELLENSBURG	CURRY	60	42°26' N / 124°25' W
EMBODY	LAKE	5300	43°17' N / 121°12' W
ENTERPRISE	WALLOWA	3760	45°26' N / 117°16' W
ENTERPRISE 21 NE#	WALLOWA	3520	45°41' N / 117°06' W
EOLA	POLK	500	44°57' N / 123°05' W
ESTACADA 2 SE	CLACKAMAS	414	45°16' N / 122°19' W
ESTACADA 24 SE	CLACKAMAS	2200	45°05' N / 121°59' W
EUGENE	LANE	450	44°03' N / 123°05' W
EUGENE WEATHER BUREAU AIRPORT STATION	LANE	364	44°07' N / 123°13' W
EULA	LANE	880	43°50' N / 122°57' W
FAIRVIEW	COOS	140	43°25' N / 124°10' W
FAIRVIEW	UNION	3700	45°03' N / 118°05' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
FALL RIVER HATCHERY	DESCHUTES	4300	43°46' N / 121°38' W
FALLS CITY	POLK	650	44°52' N / 123°27' W
FERGUSON RANCH	UMATILLA	1050	45°47' N / 118°47' W
FERN RIDGE DAM	LANE	350	44°07' N / 123°18' W
FIFE	CROOK	3375	43°43' N / 119°57' W
FIR GLEN	DOUGLAS	2300	43°05' N / 123°39' W
FISH LAKE	JACKSON	4839	42°23' N / 122°21' W
FLAT CREEK RANGER STATION	LANE	1320	43°40' N / 122°30' W
FLORENCE 3 NNW#	LANE	60	44°01' N / 124°07' W
FLOURNOY VALLEY	DOUGLAS	700	43°11' N / 123°33' W
FOLLEY FARM	HARNEY	3710	43°06' N / 118°10' W
FOOTHILLS ORCHARD	JACKSON	1510	42°16' N / 122°52' W
FOREST GROVE	WASHINGTON	175	45°32' N / 123°06' W
FORT HOSKINS	BENTON	380	44°40' N / 123°28' W
FORT KLAMATH	KLAMATH	4200	42°40' N / 121°50' W
FORT KLAMATH 7 SW	KLAMATH	4160	42°37' N / 122°05' W
FORT ROCK	LAKE	4300	43°12' N / 121°04' W
FORT ROCK 6 W#	LAKE	4492	43°21' N / 121°10' W
FORT STEVENS	CLATSOP	12	46°11' N / 124°00' W
FORT UMPQUA	DOUGLAS	8	43°42' N / 124°10' W
FORT YAMHILL	YAMHILL	375	45°25' N / 123°36' W
FOSSIL	WHEELER	2660	45°00' N / 121°12' W
401 RANCH	JACKSON	1350	42°25' N / 122°47' W
FOX	GRANT	4389	44°39' N / 119°09' W
FREMONT	LAKE	4300	43°19' N / 121°09' W
FRENCHGLEN	HARNEY	4200	42°51' N / 118°53' W
FRIEND 1 W#	WASCO	2430	45°20' N / 121°18' W
GALICE	JOSEPHINE	2000	42°35' N / 123°35' W
GARDINER	DOUGLAS	15	43°44' N / 124°18' W
GARDNER'S RANCH	JACKSON	1800	42°17' N / 122°45' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
GERBER DAM	KLAMATH	4850	42°12' N / 121°08' W
GIBBON	UMATILLA	2000	45°42' N / 118°17' W
GLASS BUTTE	CROOK	4200	43°30' N / 120°07' W
GLENCOE	MORROW	1700	45°25' N / 119°45' W
GLENDALE 2 NNW	DOUGLAS	1500	42°46' N / 123°24' W
GLENORA	TILLAMOOK	575	45°20' N / 123°50' W
GLENWOOD	WASHINGTON	477	45°39' N / 123°16' W
GOBLE 6 SW	COLUMBIA	493	45°58' N / 122°56' W
GOLD BEACH	CURRY	60	42°25' N / 124°25' W
GOLD BEACH RANGER STATION	CURRY	50	42°26' N / 124°26' W
GOLDEN FALLS	COOS	650	43°28' N / 123°53' W
GOOSEBERRY	MORROW	1925	45°19' N / 119°51' W
GOVERNMENT CAMP#	CLACKAMAS	3900	45°18' N / 121°45' W
GRANDE RONDE	POLK	340	45°04' N / 123°37' W
GRANDVIEW	JEFFERSON	2576	44°32' N / 121°20' W
GRANITE	GRANT	4680	44°50' N / 118°28' W
GRANITE 4 WSW	GRANT	4939	44°48' N / 118°30' W
GRANTS PASS	JOSEPHINE	925	42°26' N / 123°19' W
GRASS VALLEY	SHERMAN	2381	45°21' N / 120°46' W
GREENHORN	BAKER	6250	44°41' N / 118°30' W
GREENLEAF	LANE	250	44°05' N / 123°39' W
GREEN PETER DAM	LINN	811	44°28' N / 121°31' W
GREEN SPRINGS POWER PLANT	JACKSON	2439	42°07' N / 122°34' W
GRESHAM	MULTNOMAH	310	45°30' N / 122°24' W
GRIZZLY	JEFFERSON	3639	44°31' N / 120°56' W
GUMBOOT	WALLOWA	4500	45°10' N / 116°51' W
GUNTER	DOUGLAS	750	43°48' N / 123°28' W
GURDANE	UMATILLA	3500	45°12' N / 119°03' W
HALFWAY	BAKER	2671	44°53' N / 117°07' W
HALFWAY (1936-41)	BAKER	3000	44°55' N / 117°10' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
HAMPTON	DESCHUTES	4420	43°40' N / 120°15' W
HAPPY HOME	COOS	2100	42°46' N / 123°58' W
HAPPY VALLEY	HARNEY	4200	42°55' N / 118°39' W
HARBOR	CURRY	78	42°03' N / 124°17' W
HARDMAN (1890-92)	MORROW	UNK.	UNK. / UNK.
HARDMAN (1962)	MORROW	3580	45°10' N / 119°41' W
HARE	CURRY	1342	42°55' N / 124°20' W
HARNEY BRANCH EXPERIMENT STATION	HARNEY	4139	43°35' N / 118°56' W
HARPER#	MALHEUR	2510	43°52' N / 117°37' W
HARRIMAN	HARNEY	4135	43°23' N / 118°27' W
HARRIS	LANE	1200	43°35' N / 123°04' W
HARRISBURG	LINN	308	44°16' N / 123°10' W
HART MOUNTAIN REFUGE	LAKE	5555	42°33' N / 119°39' W
HASKINS DAM	YAMHILL	721	45°19' N / 123°21' W
HASKINS CREEK DAM	YAMHILL	750	45°17' N / 123°20' W
HAY CREEK	JEFFERSON	2936	44°37' N / 120°54' W
HAZELDELL	LANE	1280	43°43' N / 122°46' W
HEADWORKS (PORTLAND WATER BUREAU)	CLACKAMAS	748	45°27' N / 122°09' W
HEISLER	CROOK	1870	44°40' N / 120°55' W
HELIX (LEAKE RANCH)	UMATILLA	1860	45°53' N / 118°42' W
HENDRICKS BRIDGE	LANE	560	44°04' N / 122°50' W
HEPPNER	MORROW	1950	45°21' N / 119°33' W
HEPPNER (NEAR)	MORROW	1950	45°19' N / 119°24' W
HERMISTON 2 S#	UMATILLA	624	45°49' N / 119°17' W
HERMISTON PENDLETON GRAIN GROWERS	UMATILLA	624	45°49' N / 119°17' W
HILGARD	UNION	2997	45°21' N / 118°14' W
HILLCREST ORCHARD	JACKSON	1595	42°20' N / 122°48' W
HILLSBORO	WASHINGTON	203	45°31' N / 123°00' W
HILLS CREEK DAM	LANE	1275	43°45' N / 122°30' W
HOOBACK	DOUGLAS	865	43°18' N / 122°56' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
HOLLEY	LINN	527	44°20' N / 122°48' W
HOLLEYWOOD ORCHARD	JACKSON	1400	42°20' N / 122°54' W
HOLLOWAY ORCHARD	JACKSON	1486	42°17' N / 122°50' W
HOOD RIVER (1940-41)	HOOD RIVER	393	45°42' N / 121°30' W
HOOD RIVER	HOOD RIVER	350	45°41' N / 121°31' W
HOOD RIVER 2 SW	HOOD RIVER	500	45°41' N / 121°31' W
HOOD RIVER EXPERIMENT STATION	HOOD RIVER	500	45°41' N / 121°31' W
HOOD RIVER AIRWAYS	HOOD RIVER	388	45°42' N / 121°30' W
HOOVER	MARION	1642	44°42' N / 122°07' W
HORSE PRAIRIE	DOUGLAS	2212	42°56' N / 123°36' W
HOSKINS	BENTON	250	44°41' N / 123°28' W
HOWARD PRAIRIE DAM	JACKSON	4567	42°13' N / 122°22' W
HOWARDVILLE	WALLOWA	3574	45°39' N / 117°40' W
HUBBARD	MARION	270	45°12' N / 123°46' W
HUNTINGTON	BAKER	2150	44°21' N / 117°16' W
IBEX MINE	GRANT	6000	44°46' N / 118°17' W
IDLEYLD PARK 2 NE	DOUGLAS	895	43°21' N / 122°59' W
IDLEYLD PARK 4 NE	DOUGLAS	1080	43°22' N / 122°58' W
IDLEYLD PARK ROCK CREEK	DOUGLAS	1140	43°23' N / 122°58' W
ILLAHE 1 N#	CURRY	300	42°39' N / 124°04' W
IMNAHA	WALLOWA	1980	45°34' N / 116°50' W
IMNAHA NO. 2	WALLOWA	1965	45°34' N / 116°50' W
IMPERIAL	CROOK	4500	43°46' N / 120°25' W
INTAKE	CLACKAMAS	2200	45°05' N / 121°59' W
IONE 18 S	MORROW	1925	45°19' N / 119°51' W
IRONSIDE	MALHEUR	3500	44°20' N / 117°57' W
IRONSIDE 2 W	MALHEUR	3916	44°19' N / 117°59' W
IRRIGATION HEADQUARTERS	LAKE	4900	42°07' N / 120°31' W
IRVINGTON	MULTNOMAH	75	45°35' N / 122°38' W
JACKSONVILLE	JACKSON	1640	42°18' N / 122°59' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
JEFFERSON	MARION	235	44°43' N / 123°00' W
JENSEN RANCH	LINCOLN	75	44°22' N / 123°50' W
JEWELL	CLATSOP	560	45°55' N / 123°32' W
JEWELL GUARD STATION	CLATSOP	491	45°56' N / 123°30' W
JOHN DAY	GRANT	3065	44°26' N / 118°57' W
JOHN DAY DAM	SHERMAN	186	45°43' N / 120°42' W
JORDAN VALLEY	MALHEUR	4397	42°59' N / 117°03' W
JOSEPH	WALLOWA	4198	45°21' N / 117°15' W
JUNCTION CITY	LANE	353	44°05' N / 123°04' W
JUNIPER (HELIX)	UMATILLA	1300	45°57' N / 118°49' W
JUNIPER LAKE	HARNEY	4100	42°56' N / 118°20' W
JUNIPER RANCH	HARNEY	3700	43°52' N / 118°15' W
KAMELA	UNION	4204	45°23' N / 118°23' W
KELLOGG	DOUGLAS	UNK.	UNK. / UNK.
KENO	KLAMATH	4040	42°06' N / 121°57' W
KENT	SHERMAN	2707	43°12' N / 120°41' W
KERBY	JOSEPHINE	1265	42°13' N / 123°39' W
KINGMAN	MALHEUR	2231	43°44' N / 117°04' W
KINZUA	WHEELER	3450	45°02' N / 119°55' W
KLAMATH AGENCY	KLAMATH	4169	42°36' N / 121°56' W
KLAMATH FALLS 2 SW#	KLAMATH	4098	42°12' N / 121°47' W
KLAMATH FALLS FEDERAL AVIATION AGENCY AIRPORT	KLAMATH	4085	42°08' N / 121°45' W
LACOMB 1 WNW#	LINN	665	44°35' N / 122°45' W
LAFAYETTE	YAMHILL	170	45°14' N / 123°07' W
LA GRANDE#	UNION	2782	45°20' N / 118°06' W
LA GRANDE AIRPORT	UNION	2709	45°17' N / 118°02' W
LA GRANDE 6 SE	UNION	2709	45°17' N / 118°02' W
LA GRANDE 16 WSW#	UNION	3460	45°15' N / 118°24' W
LA GRANDE 19 SW	UNION	3475	45°14' N / 118°27' W
LAIDLAW	CROOK	3171	44°10' N / 121°30' W

STATION LOCATIONS

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
LAKE	LAKE	4316	43°14' N / 120°38' W
LAKE CREEK 5 SW	JACKSON	1923	42°22' N / 122°33' W
LAKEVIEW	LAKE	4756	42°11' N / 120°21' W
LANGLOIS (1891-1904)	CURRY	500	42°58' N / 124°17' W
LANGLOIS 2	CURRY	88	42°56' N / 124°27' W
LA PINE	DESCHUTES	4229	43°40' N / 121°30' W
LARCH MOUNTAIN	MULTNOMAH	UNK.	UNK. / UNK.
LAYNG CREEK	LANE	1212	43°42' N / 122°45' W
LEABURG 1 SW	LANE	675	44°04' N / 122°41' W
LEBANON	LINN	314	44°32' N / 122°54' W
LEE'S CAMP	TILLAMOOK	665	45°36' N / 123°32' W
LILYGLEN	JACKSON	4537	42°16' N / 122°27' W
LINKVILLE	KLAMATH	4160	42°14' N / 121°40' W
LITTLE RIVER	DOUGLAS	1250	43°14' N / 122°56' W
LITTLE VALLEY	MALHEUR	2500	43°53' N / 117°29' W
LONDON	LANE	904	43°39' N / 123°05' W
LONEROCK	GILLIAM	3114	45°05' N / 119°59' W
LONG CREEK (1908-15)	GRANT	3500	44°43' N / 119°06' W
LONG CREEK (1957)	GRANT	3722	44°43' N / 119°06' W
LONG VALLEY	LAKE	5500	42°06' N / 120°47' W
LONGWOOD	HOOD RIVER	600	45°39' N / 121°30' W
LOOKING GLASS VALLEY	DOUGLAS	680	43°11' N / 123°29' W
LOOKOUT POINT DAM	LANE	712	43°55' N / 122°46' W
LORELLA	KLAMATH	4350	42°16' N / 119°20' W
LOST CREEK RANCH	LANE	1800	44°10' N / 122°01' W
LOWELL 1 E	LANE	740	43°55' N / 122°47' W
LOWELL 2 N	LANE	666	43°57' N / 122°47' W
LOWER HAY CREEK	JEFFERSON	1896	44°47' N / 120°59' W
LOWER TROUT CREEK	JEFFERSON	1684	44°47' N / 121°00' W
MADRAS	JEFFERSON	2256	44°38' N / 121°08' W
MADRAS 2 N	JEFFERSON	2500	44°40' N / 121°09' W
MALHEUR BRANCH EXPERIMENT STATION	MALHEUR	2251	43°59' N / 117°04' W
MALHEUR REFUGE HEADQUARTERS	HARNEY	4103	43°17' N / 118°58' W
MALIN	KLAMATH	4050	42°01' N / 121°25' W
MAPLETON	LANE	18	44°02' N / 123°50' W
MARBLE CREEK	BAKER	4320	44°49' N / UNK.
MARCOLA	LANE	530	44°10' N / 122°51' W
MARIAL 8 NNE	COOS	2080	42°49' N / 123°51' W
MARION FORKS FISH HATCHERY	LINN	2475	44°36' N / 121°57' W
MARKS CREEK GUARD STATION	CROOK	4600	44°30' N / 120°23' W
MARSHFIELD	COOS	38	43°22' N / 124°17' W
MAUPIN	WASCO	1030	45°10' N / 121°51' W
MAURY	CROOK	4300	44°04' N / 120°16' W
MAYVILLE	GILLIAM	2946	45°06' N / 120°16' W
McCREDIE SPRINGS	LANE	2121	43°43' N / 122°17' W
McDERMITT 26 N	MALHEUR	4464	42°28' N / 117°38' W
McKENZIE BRIDGE (1954-62)	LANE	1370	44°11' N / 122°10' W
McKENZIE BRIDGE	LANE	1400	44°10' N / 122°10' W
McKENZIE BRIDGE RANGER STATION	LANE	1375	44°10' N / 122°11' W
McKINLEY	COOS	140	43°11' N / 124°02' W
McMINNVILLE	YAMHILL	162	45°12' N / 123°10' W
McNAMERS	TILLAMOOK	542	45°36' N / 123°29' W
McNARY DAM	UMATILLA	480	45°55' N / 119°20' W
MEACHAM	UMATILLA	3680	45°31' N / 118°26' W
MEACHAM WEATHER BUREAU AIRPORT STATION	UMATILLA	4050	45°30' N / 118°24' W
MEACHAM RANCH	WASHINGTON	310	45°42' N / 123°04' W
MEADOWBROOK RANCH	HOOD RIVER	850	45°42' N / 121°50' W
MEADOW LAKE	WASHINGTON	1950	45°19' N / 123°26' W
MEDFORD	JACKSON	1379	42°20' N / 122°51' W
MEDFORD EXPERIMENT STATION	JACKSON	1457	42°18' N / 122°52' W
MEDFORD WEATHER BUREAU AIRPORT STATION	JACKSON	1315	42°22' N / 122°52' W
MEHAMA	MARION	620	44°47' N / 122°57' W
MERLIN	JOSEPHINE	850	42°32' N / 122°32' W
MERRILL 2 NW	KLAMATH	4080	42°03' N / 121°38' W
METOLIUS 1 W	JEFFERSON	2500	44°35' N / 121°11' W
MIKKALO (1907-12)	GILLIAM	1400	45°28' N / 120°15' W
MIKKALO (1916-48)	GILLIAM	1550	45°28' N / 120°21' W
MIKKALO 6 W	GILLIAM	1550	45°28' N / 120°21' W
MIKKALO LARSON RANCH	GILLIAM	1550	45°28' N / 120°21' W
MIKKALO NISH RANCH	GILLIAM	1400	45°28' N / 120°15' W
MIKKALO YOUNGMAN RANCH	GILLIAM	1550	45°28' N / 120°15' W
MILL CITY	MARION	835	44°45' N / 122°15' W
MILLER PRAIRIE	MORROW	4200	45°02' N / 119°40' W
MILTON	UMATILLA	1100	45°56' N / 118°24' W
MILTON 6 SE	UMATILLA	1315	45°52' N / 118°17' W
MILTON-FREEWATER 4 NW	UMATILLA	962	45°58' N / 118°26' W
MINAM 7 NE	WALLOWA	3584	45°41' N / 117°36' W
MIRAMONTE FARM	CLACKAMAS	162	45°16' N / 122°45' W
MISSOURI GULCH (CASE)	UMATILLA	1050	45°48' N / 118°08' W
MIST	COLUMBIA	450	45°59' N / 123°16' W
MITCHELL	WHEELER	2744	44°34' N / 120°10' W
MODOC ORCHARD	JACKSON	1215	42°27' N / 122°53' W
MOLALLA 1 NW	CLACKAMAS	365	45°09' N / 122°35' W
MONMOUTH 1	POLK	200	44°51' N / 123°14' W
MONMOUTH 2	POLK	UNK.	44°49' N / 123°12' W
MONROE	BENTON	544	44°19' N / 123°18' W
MONTGOMERY RANCH	JEFFERSON	1900	44°37' N / 121°29' W
MONUMENT	GRANT	1990	44°49' N / 119°25' W
MONUMENT RANGER STATION	GRANT	1990	44°49' N / 119°25' W
MONUMENT 2	GRANT	1995	44°49' N / 119°25' W

STATION LOCATIONS

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
MORGAN	MORROW	793	45°34' N / 119°55' W
MORO EXPERIMENT STATION	SHERMAN	1858	45°29' N / 120°43' W
MOUNTAIN HOME	COLUMBIA	1000	46°02' N / 123°15' W
MOUNTAIN RANCH	JOSEPHINE	2710	42°07' N / 123°32' W
MOUNTAIN PARK	HOOD RIVER	1440	45°32' N / 121°40' W
MOUNT ANGEL	MARION	485	45°04' N / 122°45' W
MOUNT HOOD	HOOD RIVER	1650	45°35' N / 122°45' W
MUSICK	DOUGLAS	5530	43°34' N / 122°42' W
MYRICK (HAWKINS RANCH)	UMATILLA	1725	45°48' N / 118°42' W
MYRTLE CREEK 12 ENE	DOUGLAS	1120	43°03' N / 123°04' W
NEHALEM	TILLAMOOK	150	45°43' N / 123°55' W
NELSCOTT	LINCOLN	38	44°57' N / 124°00' W
NEWBERG	YAMHILL	192	45°12' N / 123°00' W
NEWBRIDGE	BAKER	1900	44°47' N / 117°11' W
NEWHALL ORCHARD	JACKSON	1335	42°23' N / 124°54' W
NEWHALL RANCH	JACKSON	1335	42°23' N / 124°54' W
NEW PINE CREEK	LAKE	4880	42°00' N / 120°18' W
NEWPORT	LINCOLN	124	44°38' N / 124°04' W
NISH RANCH	GILLIAM	1400	45°28' N / 120°15' W
NOLIN	UMATILLA	735	45°40' N / 119°08' W
NORTH BEND	COOS	20	43°25' N / 124°14' W
NORTH BEND FAA AIRPORT	COOS	20	43°25' N / 124°14' W
NORTH POWDER	UNION	3250	45°03' N / 117°52' W
NORTHRUP CREEK	COLUMBIA	540	46°00' N / 123°26' W
NOTI 2 ESE#	LANE	480	44°03' N / 123°28' W
NYSSA (1916-20)	MALHEUR	2220	43°44' N / 117°05' W
NYSSA (1937-62)	MALHEUR	2185	43°52' N / 117°00' W
OAKRIDGE	LANE	1310	43°45' N / 122°26' W
OAKRIDGE SALMON HATCHERY	LANE	1275	43°45' N / 122°27' W
OCEANLAKE	LINCOLN	75	45°00' N / 124°00' W
OCHOCO	CROOK	3200	44°22' N / 120°25' W
OCHOCO CREEK	CROOK	3700	44°19' N / 120°33' W
OCHOCO DAM	CROOK	3051	44°18' N / 120°44' W
OCHOCO RANGER STATION	CROOK	3979	44°24' N / 120°26' W
ODELL EXPERIMENT AREA	HOOD RIVER	730	45°39' N / 121°34' W
ODELL LAKE NO. 1 (LAND)	KLAMATH	4792	43°35' N / 122°03' W
ODELL LAKE NO. 2 (WATER)	KLAMATH	4788	43°35' N / 122°02' W
OLEX	GILLIAM	1600	45°30' N / 120°10' W
OLIVE LAKE	GRANT	5937	44°47' N / 118°36' W
OLALLIE LAKE	MARION	4985	44°49' N / 121°47' W
ONTARIO AIRPORT 2 W	MALHEUR	2194	44°01' N / 117°01' W
ONTARIO CAA AIRPORT	MALHEUR	2194	44°01' N / 117°01' W
ONTARIO RADIO STATION KSRV	MALHEUR	2145	44°03' N / 116°58' W
"OO" RANCH	HARNEY	4136	43°17' N / 119°19' W
ORCHARD HOME	JACKSON	1437	42°19' N / 122°52' W
OREGON AMERICAN CAMP	CLATSOP	1680	45°50' N / 123°25' W
OREGON CAVES	JOSEPHINE	4030	42°06' N / 123°25' W
OREGON CITY	CLACKAMAS	167	45°21' N / 122°36' W
ORESCO	LANE	4370	43°35' N / 122°10' W
ORTLEY	WASCO	1600	45°39' N / 121°17' W
OTIS	LINCOLN	20	45°02' N / 123 56' W
OWYHEE	MALHEUR	2220	43°44' N / 117°05' W
OWYHEE DAM	MALHEUR	2400	43°38' N / 117°13' W
PAISLEY	LAKE	4371	42°42' N / 120°33' W
PAISLEY (NEAR)	LAKE	4209	42°42' N / 120°33' W
PARKDALE	HOOD RIVER	1740	45°35' N / 121°30' W
PARKDALE 9 SSW	HOOD RIVER	5800	45°24' N / 121°39' W
PAULINA (1910-11)	CROOK	4000	43°51' N / 120°58' W
PAULINA (1961-62)	CROOK	3684	44°08' N / 119°58' W
PELTON DAM	JEFFERSON	1410	44°44' N / 121°14' W
PENDLETON (1889-1935)	UMATILLA	1056	45°40' N / 118°48' W
PENDLETON (1935-40)	UMATILLA	1489	45°41' N / 118°51' W
PENDLETON AIRPORT	UMATILLA	1489	45°41' N / 118°51' W
PENDLETON BRANCH EXPERIMENT STATION	UMATILLA	1487	45°43' N / 118°38' W
PENDLETON FIELD STATION	UMATILLA	[illegible]	[illegible]
PENDLETON HOUSE(?) PARK	UMATILLA	1050	45°40' N / 118°48' W
PENDLETON WEATHER BUREAU AIRPORT STATION	UMATILLA	1489	45°41' N / 118°51' W
PENDLETON GRAIN GROWERS	UMATILLA	1056	45°40' N / 118°48' W
PERSIST#	JACKSON	3000	42°46' N / [illegible]
PHILOMATH 2 [illegible]#	BENTON	260	44°32' N / 123°[illegible] W
PHIPPS ORCHARD	JACKSON	1310	42°24' N / 122°47' W
PILOT ROCK 1 SE#	UMATILLA	1697	45°29' N / 118°49' W
PILOT ROCK (ADKINSON RANCH)	UMATILLA	1980	45°28' N / 118°50' W
PINE	BAKER	2600	44°51' N / 117°05' W
PITTSBURG	WALLOWA	1250	45°38' N / 116°30' W
PLACER	JOSEPHINE	1450	42°35' N / 123°19' W
PLUSH#	LAKE	4400	42°24' N / 119°54' W
POMPEI	CLACKAMAS	3979	45°22' N / 121°43' W
PORTLAND WEATHER BUREAU AIRPORT STATION	MULTNOMAH	21	45°36' N / 122°36' W
PORTLAND WEATHER BUREAU CITY OFFICE	MULTNOMAH	98	45°32' N / 122°40' W
PORTLAND GAS AND COKE COMPANY	MULTNOMAH	49	45°30' N / 122°39' W
PORTLAND NORTHWEST NATURAL GAS COMPANY	MULTNOMAH	49	45°30' N / 122°39' W
PORT ORFORD	CURRY	292	42°44' N / 124°31' W
POST	CROOK	3512	44°07' N / 120°14' W
POWELL BUTTE	CROOK	3125	44°15' N / 121°03' W
POWER HOUSE	UMATILLA	1315	45°52' N / 118°17' W
POWERS	COOS	300	42°53' N / 124°04' W
PRAIRIE CITY	GRANT	3425	44°27' N / 118°42' W
PRAIRIE CITY RANGER STATION	GRANT	3556	44°27' N / 118°43' W
"P" RANCH REFUGE#	HARNEY	4220	42°49' N / 118°53' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
PRINCETON 13 E	HARNEY	3910	43°16' N / 118°20' W
PRINEVILLE 2 NW#	CROOK	2868	44°19' N / 120°52' W
PROSPECT 2 SW#	JACKSON	2482	42°44' N / 122°31' W
PROUDFOOT (ECHO)	UMATILLA	1000	45°37' N / 119°17' W
QUARTZVILLE 11 SW#	LINN	861	44°30' N / 122°28' W
RAGER CREEK	CROOK	3776	44°14' N / 119°45' W
RAGER RANGER STATION	CROOK	4000	44°14' N / 119°44' W
RAINBOW	LANE	1200	44°11' N / 122°13' W
RAMSEY	WASCO	1350	45°20' N / 121°14' W
RANGE	GRANT	3500	44°54' N / 118°58' W
RAY CREEK	MORROW	2000	45°18' N / 119°44' W
REDMOND	DESCHUTES	2994	44°18' N / 121°10' W
REDMOND FEDERAL AVIATION AGENCY AIRPORT	DESCHUTES	3075	44°16' N / 121°08' W
REEDSPORT	DOUGLAS	55	43°42' N / 124°06' W
RESERVOIR NO. 3	MALHEUR	3100	44°22' N / 117°38' W
RESTON	DOUGLAS	856	43°08' N / 123°38' W
REW (LORENZEN RANCH)	UMATILLA	1130	45°45' N / 119°01' W
REX	YAMHILL	490	45°18' N / 122°55' W
RICHLAND	BAKER	2215	44°46' N / 117°10' W
RIDDLE (1899-1948)	DOUGLAS	700	42°58' N / 123°21' W
RIDDLE (1950-1956)	DOUGLAS	700	42°57' N / 123°22' W
RIDDLE 2 NNE	DOUGLAS	700	42°58' N / 123°21' W
RIDDLE 4 SW	DOUGLAS	683	42°55' N / 123°26' W
RILEY	HARNEY	4425	43°33' N / 118°59' W
RIO HERMOSO	JEFFERSON	2110	44°39' N / 121°32' W
RIVERDALE RANCH	CROOK	4225	43°48' N / 120°02' W
RIVERSIDE	MALHEUR	3000	43°30' N / 118°04' W
ROADS END	LINCOLN	30	45°01' N / 124°00' W
ROARING SPRINGS RANCH	HARNEY	4630	42°39' N / 118°59' W
ROBVILLE	DESCHUTES	4000	43°58' N / 121°00' W
ROCK CREEK	BENTON	625	44°28' N / 123°32' W
ROCK CREEK	BAKER	4150	44°54' N / 118°05' W
ROCK CREEK	DOUGLAS	1140	43°23' N / 122°58' W
ROCK CREEK RANCH	HARNEY	4575	42°41' N / 119°11' W
ROME	MALHEUR	3378	42°50' N / 117°38' W
ROME FEDERAL AVIATION AGENCY	MALHEUR	4043	42°35' N / 117°53' W
ROSEBURG	DOUGLAS	479	43°13' N / 123°20' W
ROSEBURG WEATHER BUREAU AIRPORT STATION	DOUGLAS	505	43°14' N / 123°22' W
ROSEBURG WEATHER BUREAU OFFICE	DOUGLAS	479	43°13' N / 123°20' W
ROSLAND	DESCHUTES	4198	43°47' N / 121°27' W
ROUND GROVE	KLAMATH	4888	42°20' N / 120°53' W
RUJADA	LANE	1212	43°42' N / 122°45' W
SAGINAW	LANE	614	43°50' N / 123°03' W
SAINT HELENS	COLUMBIA	40	45°52' N / 122°48' W
SALEM WEATHER BUREAU AIRPORT STATION#	MARION	200	44°55' N / 123°01' W
SALEM (b)	MARION	180	44°56' N / 123°03' W
SALMON	UNK.	UNK.	UNK. / UNK.
SAND CREEK	KLAMATH	4682	42°50' N / 121°59' W
SANTIAM JUNCTION	LINN	3780	44°26' N / 121°56' W
SANTIAM PASS	LINN	4748	44°25' N / 121°52' W
SAUVIES ISLAND	MULTNOMAH	40	45°40' N / 122°51' W
SCOTTS MILLS 8 SE	CLACKAMAS	2315	44°57' N / 122°32' W
SEASIDE	CLATSOP	10	45°59' N / 123°55' W
SELMA 4 W	JOSEPHINE	1501	42°17' N / 123°42' W
SENECA	GRANT	4666	44°09' N / 118°58' W
SEXTON SUMMIT WEATHER BUREAU AIRPORT STATION	JOSEPHINE	3836	42°37' N / 123°32' W
SHANIKO	WASCO	3470	45°01' N / 120°45' W
SHEAVILLE	MALHEUR	4600	43°08' N / 117°03' W
SHERIDAN	YAMHILL	207	45°05' N / 123°30' W
SHERMAN	CROOK	4225	43°48' N / 120°02' W
SILETZ	LINCOLN	95	44°43' N / 123°55' W
SILVER CREEK FALLS	MARION	1340	44°52' N / 122°39' W
SILVER LAKE	LAKE	4476	43°09' N / 121°05' W
SILVERTON	MARION	408	45°00' N / 122°46' W
SILVERTON 4 SE#	MARION	1070	44°58' N / 122°44' W
SIMNASHO	WASCO	2400	44°58' N / 121°21' W
SISKIYOU	JACKSON	4125	42°03' N / 122°36' W
SISKIYOU SUMMIT WEATHER BUREAU OFFICE	JACKSON	4480	42°03' N / 122°36' W
SISTERS (1958-62)	DESCHUTES	3180	44°17' N / 121°32' W
SISTERS (1906-20)	DESCHUTES	2700	44°15' N / 121°34' W
SITKUM 1 SW#	COOS	550	43°08' N / 123°52' W
SITKUM 6 W	COOS	150	43°06' N / 123°57' W
SIUSLAW LIFE BOAT STATION	LANE	12	44°01' N / 124°07' W
SLED SPRINGS	WALLOWA	4710	45°42' N / 117°21' W
SMITH RIVER FALLS	DOUGLAS	80	43°47' N / 123°48' W
SOD HOUSE	HARNEY	4103	43°17' N / 118°50' W
SOUTH DEER CREEK	DOUGLAS	710	43°10' N / 123°14' W
SOUTH RESERVATION (HOBBY RANCH)	UMATILLA	1585	45°37' N / 118°40' W
SPARTA	BAKER	4150	44°52' N / 117°20' W
SPRAGUE RIVER	KLAMATH	4374	42°27' N / 121°30' W
SPRAY	WHEELER	1770	44°50' N / 119°47' W
SPRINGBROOK	YAMHILL	192	45°12' N / 123°00' W
SPRINGFIELD	LANE	476	44°03' N / 123°02' W
SPRING GLADE ACRES	YAMHILL	900	45°25' N / 123°15' W
SQUAW BUTTE EXPERIMENT STATION	HARNEY	4675	43°29' N / 119°41' W
STAFFORD	CLACKAMAS	413	45°25' N / 122°45' W
STANFIELD	UMATILLA	592	45°47' N / 119°12' W
STAR	LANE	856	43°44' N / 122°52' W
STARKEY	UNION	3400	45°14' N / 118°23' W
STAUFFER	CROOK	4200	43°30' N / 120°07' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
STAYTON	MARION	625	44°48' N / 122°48' W
STEAMBOAT RANGER STATION	DOUGLAS	1235	43°21' N / 122°44' W
STIMPSON CAMP	WASHINGTON	1725	45°32' N / 123°20' W
SUMMER LAKE 1 S	LAKE	4192	42°54' N / 120°49' W
SUMMIT	BENTON	720	44°38' N / 123°35' W
SUMMIT GUARD STATION	CLACKAMAS	3900	45°18' N / 121°45' W
SUMMIT PRAIRIE	CROOK	4570	44°22' N / 120°11' W
SUNDOWN RANCH	CLACKAMAS	2400	44°57' N / 122°31' W
SUNRISE VALLEY	HARNEY	3710	43°06' N / 118°10' W
SUNSET	HARNEY	4110	43°23' N / 118°58' W
SUNSET VALLEY	HARNEY	4110	43°23' N / 118°58' W
SUNTEX	HARNEY	4310	43°36' N / 119°38' W
SUNTEX JUNIPER HILLS RANCH	HARNEY	4620	43°40' N / 119°52' W
SUSANVILLE	GRANT	3756	44°43' N / 118°48' W
SUTHERLIN 2 ENE	DOUGLAS	545	43°24' N / 123°16' W
SUTHERLIN 14 ENE	DOUGLAS	1035	43°28' N / 123°04' W
SUTHERLIN CAMP	DOUGLAS	1065	45°28' N / 123°03' W
SUVER (NEAR)	POLK	210	44°47' N / 123°14' W
TABLE ROCK	JACKSON	1215	42°28' N / 122°53' W
TALENT	JACKSON	1550	42°16' N / 122°46' W
TAMARACK	WHEELER	3859	45°01' N / 119°58' W
TELOCASET	UNION	3440	45°06' N / 117°49' W
THE DALLES	WASCO	102	45°36' N / 121°12' W
THE HEADS	CURRY	300	42°44' N / 124°30' W
THE POPULARS	LAKE	4316	43°16' N / 120°56' W
THREE LINKS	CLACKAMAS	1135	45 07' N / 122 04' W
THREE LYNX	CLACKAMAS	1135	45°07' N / 122°04' W
TIDEWATER#	LINCOLN	50	44°25' N / 123°54' W
TILLAMOOK	TILLAMOOK	15	45°28' N / 123°51' W
TILLAMOOK NO. 1	TILLAMOOK	665	45°35' N / 123°32' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
TILLAMOOK NO. 2	TILLAMOOK	475	45°27' N / 123°39' W
TILLAMOOK 12 E#	TILLAMOOK	320	45°26' N / 123°37' W
TILLAMOOK ROCK	TILLAMOOK	156	45°56' N / 124°01' W
TILLER	DOUGLAS	1040	42°56' N / 122°57' W
TILLER 15 ENE	DOUGLAS	2500	43°00' N / 122°42' W
TIMBER	WASHINGTON	960	45°43' N / 123°18' W
TIMBERLINE LODGE	CLACKAMAS	5935	45°21' N / 121°42' W
TIN ROOF CABIN	UMATILLA	3500	45°17' N / 118°56' W
TOKETEE	DOUGLAS	1950	43°16' N / 122°26' W
TOKETEE FALLS	DOUGLAS	1950	43°16' N / 122°26' W
TOLEDO	LINCOLN	85	44°36' N / 123°57' W
TOLLGATE	UMATILLA	4900	45°47' N / 118°06' W
TOLLGATE NO. 2	UMATILLA	5020	45°47' N / 118°07' W
TRAIL 14 NE#	JACKSON	1855	42°47' N / 122°40' W
TRASK	TILLAMOOK	360	45°26' N / 123°37' W
TRIANGLE LAKE	LANE	200	44°08' N / 123°37' W
TROUTDALE	MULTNOMAH	89	45°32' N / 122°23' W
TROUTDALE NO. 2	MULTNOMAH	235	45°32' N / 122°23' W
TROUTDALE AVIATION	MULTNOMAH	29	45°33' N / 122°24' W
TROUTDALE WEATHER BUREAU AIRPORT STATION	MULTNOMAH	29	45°33' N / 122°24' W
TROY	WALLOWA	1586	45°57' N / 117°27' W
TULE LAKE	KLAMATH	4055	42°03' N / 121°35' W
TYGH RIDGE	WASCO	2700	45°20' N / 121°06' W
UKIAH	UMATILLA	3212	45°08' N / 118°56' W
UMATILLA	UMATILLA	285	45°55' N / 119°21' W
UMPQUA	DOUGLAS	110	43°42' N / 124°10' W
UNION	UNION	2765	45°13' N / 117°05' W
UNITY	BAKER	4031	44°26' N / 118°11' W
UPPER OLALLA	DOUGLAS	900	42°59' N / 123°35' W
UPPER STEAMBOAT CREEK	LANE	1855	43°29' N / 122°36' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
UPPER TROUT CREEK	JEFFERSON	2900	44°19' N / 120°49' W
VALE 1 W#	MALHEUR	2300	43°59' N / 117°16' W
VALLEY FALLS	LAKE	4326	42°29' N / 120°17' W
VALSETZ	POLK	1135	44°50' N / 123°40' W
VAN	HARNEY	4095	43°59' N / 118°41' W
VANSYCLE	UMATILLA	UNK.	45°56' N / 118°41' W
VERNONIA	COLUMBIA	840	45°52' N / 123°12' W
VIDA	LANE	871	44°07' N / 122°28' W
VISTILLAS	LAKE	5280	42°12' N / 120°50' W
VOLTAGE 2 NW SOD HOUSE	HARNEY	4103	43°17' N / 118°58' W
WAGONER	GRANT	UNK.	43°50' N / 119°50' W
WAGONTIRE	HARNEY	4726	43°15' N / 119°53' W
WALDO	JOSEPHINE	1600	42°02' N / 123°37' W
WALDO LAKE	LANE	5494	43°40' N / 122°05' W
WALLACE ORCHARD	POLK	173	44°58' N / 123°03' W
WALLA WALLA 13 ESE	UMATILLA	2400	46°00' N / 118°03' W
WALLOUPA	WALLOWA	2700	45°49' N / 117°33' W
WALLOWA	WALLOWA	2923	45°34' N / 117°32' W
WALTERVILLE	LANE	560	44°04' N / 122°50' W
WAMIC	WASCO	1800	45°12' N / 121°15' W
WARM SPRINGS	JEFFERSON	1500	44°44' N / 121°14' W
WARM SPRINGS AGENCY	JEFFERSON	1500	44°44' N / 121°14' W
WARM SPRINGS RESERVOIR	MALHEUR	3352	43°35' N / 118°13' W
WARREN	COLUMBIA	82	45°49' N / 122°51' W
WASCO	SHERMAN	1272	45°35' N / 120°42' W
WATERLOO	LINN	420	44°30' N / 122°49' W
WATERVILLE	LANE	560	44°04' N / 122°50' W
WEDDERBURN	CURRY	10	42°25' N / 124°25' W
WELCHES	CLACKAMAS	1385	45°21' N / 121°56' W
WESTFALL	MALHEUR	3000	43°52' N / 117°44' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
WESTFALL 4 NW	MALHEUR	3140	44°03' N / 117°45' W
WESTFIR	LANE	1064	43°45' N / 122°30' W
WEST FORK	DOUGLAS	1045	42°48' N / 123°35' W
WEST LINN	CLACKAMAS	66	45°20' N / 122°39' W
WESTON (1889-1948)	UMATILLA	1800	45°50' N / 118°25' W
WESTON	UMATILLA	1866	45°49' N / 118°26' W
WESTON 2 SE	UMATILLA	2100	45°48' N / 118°24' W
WESTON 5 SE	UMATILLA	3222	45°47' N / 118°19' W
WESTON (WOOD RANCH)	UMATILLA	2000	45°47' N / 118°26' W
WHITAKER	CROOK	4250	43°50' N / 120°45' W
WHITESON 2 NW#	YAMHILL	160	45°11' N / 123°12' W
WICKIUP DAM	DESCHUTES	4330	43°41' N / 121°42' W
WICOPEE	LANE	2877	43°40' N / 122°16' W
WILLAMETTE SNOW LABORATORY 1B	LINN	4100	44°21' N / 122°08' W
WILLAMINA 2 S#	POLK	285	45°03' N / 123°30' W
WILLIAMS 2 SW#	JOSEPHINE	1370	42°14' N / 123°16' W
WILLOW CREEK	CURRY	25	42°53' N / 124°28' W
WINCHESTER	DOUGLAS	460	43°17' N / 123°22' W
WINONA	JOSEPHINE	1429	42°34' N / 123°21' W
WOLF CREEK	JOSEPHINE	1320	42°44' N / 123°23' W
YAQUINA HEAD LIFE BOAT STATION	LINCOLN	87	44°41' N / 124°04' W
YONNA	KLAMATH	4180	42°17' N / 121°29' W
ZIGZAG	CLACKAMAS	1385	45°21' N / 121°56' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
ABERDEEN	GRAYS HARBOR	12	46°59' N / 123°49' W
ABERDEEN 20 NNE	GRAYS HARBOR	435	47°16' N / 123°42' W
ADNA (near)	LEWIS	250	46°37' N / 123°06' W
AHTANUM RANGER STATION	YAKIMA	3100	46°31' N / 121°01' W
ALDER CREEK	OKANOGAN	2400	48°21' N / 120°09' W
ALDER DAM CAMP	PIERCE	1301	46°48' N / 122°19' W
ALPHA	LEWIS	720	46°37' N / 122°37' W
ALPOWA RANCH	ASOTIN	730	46°25' N / 117°12' W
AMANDA PARK	GRAYS HARBOR	185	47°27' N / 123°53' W
ANACORTES	SKAGIT	30	48°31' N / 122°37' W
ANATONE	ASOTIN	3590	46°08' N / 117°08' W
APPLETON	KLICKITAT	2336	45°49' N / 121°16' W
ARIEL DAM	COWLITZ	224	45°58' N / 122°34' W
ARLINGTON	SNOHOMISH	100	48°12' N / 122°08' W
ASHFORD	PIERCE	1775	46°45' N / 122°10' W
ATTALIA	WALLA WALLA	360	46°06' N / 118°57' W
AUBURN	KING	87	47°18' N / 122°14' W
AUSTIN PASS	WHATCOM	4730	48°51' N / 121°39' W
AZURITE MINE	WHATCOM	4364	48°41' N / 120°47' W
BAINBRIDGE ISLAND	KITSAP	50	47°36' N / 122°40' W
BAKER	SKAGIT	390	48°32' N / 121°45' W
BAKER LAKE	WHATCOM	670	48°43' N / 121°37' W
BAKER RIVER (STAKE)	SKAGIT	3640	48°41' N / 121°39' W
BATTLEGROUND	CLARK	295	45°47' N / 122°32' W
BEAR CREEK	KING	1100	47°17' N / 121°48' W
BEAVER PASS	WHATCOM	3675	48°54' N / 121°16' W
BEDAL STAKE	SNOHOMISN	1241	48°07' N / 121°26' W
BEEHIVE RANGER STATION	CHELAN	4250	47°20' N / 120°22' W
BEEHIVE MOUNTAIN (BASE)	CHELAN	2760	47°20' N / 120°22' W
BELLINGHAM	WHATCOM	159	48°45' N / 122°29' W
BELLINGHAM 2N	WHATCOM	112	48°47' N / 122°29' W
BELLINGHAM FEDERAL AVIATION AGENCY	WHATCOM	150	48°48' N / 122°32' W
BENTON CITY 2NW	BENTON	680	46°17' N / 119°30' W
BERNE	CHELAN	2818	47°46' N / 121°00' W
BEVERLY (Near)	GRANT	1175	46°54' N / 119°49' W
BICKLETON	KLICKITAT	3023	46°00' N / 120°18' W
BIG FOUR	SNOHOMISH	1748	48°04' N / 121°30' W
BIG LOG	MASON	1500	47°33' N / 123°21' W
BILLY GOAT MOUNTAIN	OKANOGAN	5280	48°47' N / 120°20' W
BLAKELY	KITSAP	UNK.	UNK. / UNK.
BLAINE 1E	WHATCOM	45	49°00' N / 122°44' W
BLEWETT	CHELAN	2328	47°25' N / 120°39' W
BLEWETT PASS	CHELAN	4071	47°21' N / 120°40' W
BLUE GLACIER	JEFFERSON	6900	47°49' N / 123°46' W
BOGACHIEL	JEFFERSON	UNK.	47°52' N / 124°19' W
BONITA	WHATCOM	5505	48°45' N / 120°45' W
BOTHELL 2N	SNOHOMISN	100	47°47' N / 122°13' W
BOUNDARY	STEVENS	1385	49°00' N / 117°38' W
BREMERTON	KITSAP	162	47°34' N / 122°40' W
BREWSTER	OKANOGAN	878	48°06' N / 119°47' W
BRIDGEPORT	DOUGLAS	UNK.	48°04' N / 119°42' W
BRINNON	JEFFERSON	80	47°42' N / 122°56' W
BROOKLYN	PACIFIC	190	46°46' N / 123°31' W
BRYSON'S RANCH	OKANOGAN	3800	48°33' N / 119°40' W
BUCHANANS FARM	ADAMS	1825	47°07' N / 118°25' W
BUCKLEY 1NE	PIERCE	685	47°10' N / 122°00' W
BUMPING LAKE	YAKIMA	3440	46°52' N / 121°18' W
BURLINGTON	SKAGIT	28	48°28' N / 122°19' W
CAMP EIGHT	KING	1200	47°26' N / 121°39' W
CAMP GRISDALE	GRAYS HARBOR	820	47°22' N / 123°36' W
CAMP LEWIS	PIERCE	250	47°22' N / 122°33' W
CANTO	GRAYS HBR.	12	46°48' N / 123°51' W
CARBONADO	PIERCE	1187	47°05' N / 122°04' W
CARNATION 1NW	KING	75	47°40' N / 121°55' W
CARNATION 4NW	KING	35	47°42' N / 121°59' W
CARNATION 15E	KING	1100	47°42' N / 121°37' W
CASCADE TUNNEL	CHELAN	3373	47°46' N / 121°04' W
CASHMERE	CHELAN	1000	47°32' N / 120°28' W
CASTLE ROCK	COWLITZ	43	46°16' N / 122°55' W
CATHLAMET 9 NE	WAHKIAKUM	476	46°19' N / 123°16' W
CATHLAMET 6 NE	WAHKIAKUM	180	46°16' N / 123°18' W
CAYUSE PASS	PIERCE	4800	46°52' N / 121°32' W
CEDAR FALLS 4 SE	KING	1700	47°23' N / 121°43' W
CEDAR FALLS 5 SE	KING	3000	47°24' N / 121°41' W
CEDAR FALLS 7 SE	KING	1800	47°21' N / 121°40' W
CEDAR LAKE	KING	1560	47°25' N / 121°44' W
CEDAR RIVER	KING	535	47°23' N / 121°58' W
CEDAR RIVER BEAR CREEK	KING	1900	47°21' N / 121°33' W
CEDONIA	STEVENS	2000	48°08' N / 118°08' W
CENTERVILLE 2 SW	KLICKITAT	1647	45°44' N / 122°57' W
CENTRALIA	LEWIS	185	46°43' N / 122°57' W
CERES	LEWIS	250	46°37' N / 123°08' W
CHEHALIS	LEWIS	178	46°40' N / 122°59' W
CHARLEY CREEK	KING	1600	47°15' N / 121°47' W
CHELAN	CHELAN	1120	47°50' N / 120°02' W
CHELAN MINE	CHELAN	3436	48°12' N / 120°47' W
CHENEY	SPOKANE	2400	47°29' N / 117°35' W
CHESAW	OKANOGAN	2900	48°57' N / 119°03' W
CHESAW 4 NNW	OKANOGAN	3960	49°00' N / 119°04' W
CHEWELAH 2 S	STEVENS	1635	48°15' N / 117°43' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
CHIEF JOSEPH DAM	DOUGLAS	810	48°00' N / 119°39' W
CHIMACUM 4 S	JEFFERSON	250	47°57' N / 122°46' W
CHIWAUKUM	CHELAN	1829	47°41' N / 120°44' W
CHIWAWA RIVER	CHELAN	2712	48°02' N / 120°50' W
CHOPAKA	OKANOGAN	1200	49°00' N / 120°00' W
CINEBAR	LEWIS	1000	46°36' N / 122°30' W
CLALLAM BAY 1 NNE	CLALLAM	30	48°16' N / 124°15' W
CLARKSTON HEIGHTS	ASOTIN	1186	44°23' N / 117°05' W
CLEAR BROOK	WHATCOM	64	48°58' N / 122°20' W
CLEARWATER	JEFFERSON	78	47°35' N / 124°18' W
CLE ELUM	KITTITAS	1935	47°11' N / 120°57' W
CLYDE	WALLA WALLA	1238	48°25' N / 118°27' W
COLFAX 1 NW	WHITMAN	1955	46°53' N / 117°23' W
COLVILLE	STEVENS	1635	48°33' N / 117°54' W
COLVILLE AIRPORT	STEVENS	1874	48°32' N / 117°53' W
CONCONULLY	OKANOGAN	2275	48°34' N / 119°45' W
CONCRETE	SKAGIT	270	48°32' N / 121°45' W
CONCRETE 12 NE	WHATCOM	4500	48°40' N / 121°35' W
CONCRETE 12 NNW	WHATCOM	3400	48°42' N / 121°49' W
CONGER'S RANCH STAKE	OKANOGAN	3500	48°31' N / 119°51' W
CONNELL	FRANKLIN	888	46°40' N / 118°53' W
CONNELL 4 NNW	FRANKLIN	1125	46°44' N / 118°54' W
CONNELL 12 SE	FRANKLIN	1078	44°30' N / 118°46' W
COUGAR	SKAMANIA	596	46°03' N / 112°12' W
COUGAR 1 E	COWLITZ	495	46°04' N / 122°17' W
COUGAR 4 SW	COWLITZ	520	46°01' N / 122°21' W
COUGAR 6 E	SKAMANIA	659	46°04' N / 122°12' W
COUGAR 16 NE	SKAMANIA	1400	46°09' N / 122°02' W
COULEE CITY	GRANT	1596	47°36' N / 119°19' W
COULEE DAM 1 SW	GRANT	1702	47°57' N / 119°00' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
COUPEVILLE 1 S	ISLAND	50	48°12' N / 122°42' W
COWICHE	YAKIMA	1874	46°39' N / 120°38' W
CRESCENT	LINCOLN	2200	47°45' N / 117°55' W
CRYSTAL CREEK	PIERCE	3150	46°55' N / 121°32' W
CRYSTAL SPRINGS	KITSAP	100	47°36' N / 122°36' W
CURRENT FLATS	YAKIMA	2400	46°51' N / 121°00' W
CUSHMAN DAM	MASON	760	47°25' N / 123°13' W
CUSICK	PEND OREILLE	2056	48°21' N / 117°19' W
DALLESPORT FEDERAL AVIATION AGENCY	KLICKITAT	222	45°37' N / 121°09' W
DALLESPORT 9 N	KLICKITAT	1919	45°45' N / 121°09' W
DANVILLE	FERRY	1749	48°59' N / 118°31' W
DARRINGTON RANGER STATION	SNOHOMISH	550	48°15' N / 121°36' W
DAVENPORT	LINCOLN	2450	47°39' N / 118°09' W
DAVIS RANCH	WHATCOM	872	48°43' N / 121°09' W
DAYTON 1 WSW	COLUMBIA	1557	46°19' N / 118°00' W
DAYTON 5 NW	COLUMBIA	1710	46°22' N / 118°04' W
DAYTON 8 SW	COLUMBIA	2100	45°13' N / 118°03' W
DAYTON 9 SE	COLUMBIA	2335	46°13' N / 117°51' W
DEER PARK 2 E	SPOKANE	2114	47°57' N / 117°26' W
DEMING	WHATCOM	201	48°49' N / 122°13' W
DEMING 4 W	WHATCOM	UNK.	48°51' N / 122°17' W
DENNY CREEK	KING	2200	47°24' N / 121°27' W
DESTRUCTION ISLAND	JEFFERSON	71	47°40' N / 124°29' W
DETROIT	MASON	20	47°20' N / 122°49' W
DIABLO DAM	WHATCOM	891	48°43' N / 121°09' W
DIRTY FACE MOUNTAIN	CHELAN	1990	UNK. / UNK.
DISAUTEL 9 NE	OKANOGAN	3490	48°26' N / 119°06' W
DIXIE	WALLA WALLA	5000	46°09' N / 118°01' W
DIXIE 4 SE	WALLA WALLA	2350	46°06' N / 118°06' W
DOEBAY	SAN JUAN	80	48°37' N / 122°48' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
DOMKE LAKE	CHELAN	2244	48°11' N / 120°35' W
DORRANCE	WALLA WALLA	500	46°02' N / 118°37' W
DRYDEN	CHELAN	920	47°32' N / 120°32' W
DUCKABUSH	JEFFERSON	380	47°39' N / 122°57' W
DUVALL 3 NE	KING	814	47°46' N / 121°56' W
EAGLE GORGE	KING	1110	47°16' N / 121°46' W
EAST CLALLAM	CLALLAM	30	48°15' N / 124°16' W
EASTON	KITTITAS	2170	47°15' N / 121°11' W
EAST SOUND	SAN JUAN	500	48°40' N / 122°56' W
ELECTRON HEADWORKS	PIERCE	1730	46°54' N / 122°02' W
ELLENSBURG	KITTITAS	1627	47°00' N / 120°31' W
ELLENSBURG FEDERAL AVIATION AGENCY	KITTITAS	1727	47°02' N / 120°31' W
ELLENSBURG (Near)	KITTITAS	1700	UNK. / UNK.
ELMA	GRAYS HARBOR	68	47°00' N / 123°24' W
ELTOPIA	FRANKLIN	598	46°25' N / 119°00' W
ELTOPIA 6 W	FRANKLIN	920	46°28' N / 119°08' W
ELWHA RANGER STATION	CLALLAM	345	48°02' N / 123°35' W
EPHRATA	GRANT	1250	47°18' N / 119°33' W
EPHRATA FEDERAL AVIATION AGENCY	GRANT	1259	47°18' N / 119°32' W
EUREKA	WALLA WALLA	1065	48°18' N / 118°39' W
EVERGREEN FARM	THURSTON	160	47°00' N / 122°40' W
EVERETT	SNOHOMISH	99	47°59' N / 122°12' W
EVERETT FEDERAL AVIATION AGENCY	SNOHOMISH	598	47°54' N / 122°17' W
EWAN	WHITMAN	1720	47°07' N / 117°44' W
FAIRFAX	PIERCE	1420	47°00' N / 122°00' W
FARMINGTON	WHITMAN	2900	47°03' N / 117°03' W
FERRY	LEWIS	UNK.	UNK. / UNK.
FORKS 1 E	CLALLAM	350	47°57' N / 124°22' W
FORT BELLINGHAM	WHATCOM	80	48°45' N / 122°30' W
FORT CANBY	PACIFIC	179	46°17' N / 124°03' W

STATION LOCATIONS

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
FORT LEWIS	PIERCE	266	47°07' N / 122°33' W
FORT SIMCOE	YAKIMA	1300	46°21' N / 120°50' W
FORT SPOKANE	LINCOLN	1600	47°50' N / 118°15' W
FORT STEILACOOM	PIERCE	300	47°11' N / 122°34' W
FORT WALLA WALLA	WALLA WALLA	865	46°03' N / 118°24' W
FRANCES	PACIFIC	231	46°33' N / 123°30' W
FRIDAY CREEK	KING	1750	47°13' N / 121°27' W
FRIDAY HARBOR	SAN JUAN	100	48°32' N / 123°02' W
GALENA	KITTITAS	UNK.	UNK. / UNK.
GARDEN CITY HEIGHTS	WALLA WALLA	1050	46°05' N / 118°19' W
GARLAND HOT SPRINGS	SNOHOMISH	1480	47°53' N / 121°20' W
GEROME	STEVENS	1200	48°02' N / 118°18' W
GLACIER RANGER STATION	WHATCOM	937	48°53' N / 121°57' W
GLENOMA	LEWIS	775	46°30' N / 122°11' W
GLENWOOD	KLICKITAT	1896	46°01' N / 121°17' W
GOAT LAKE	SNOHOMISH	2900	48°01' N / 121°21' W
GOLD BASIN	SNOHOMISH	1511	48°05' N / 121°34' W
GOLD CREEK	YAKIMA	2600	46°55' N / 121°03' W
GOLD HILL	YAKIMA	4454	46°55' N / 121°28' W
GOLDENDALE	KLICKITAT	1635	45°49' N / 120°50' W
GOVERNMENT SPRINGS	SKAMANIA	1360	45°54' N / 122°00' W
GRAND COULEE DAM	DOUGLAS	1200	47°57' N / 118°59' W
GRAND MOUND	THURSTON	162	46°47' N / 123°01' W
GRANGER (NEAR)	YAKIMA	842	46°23' N / 120°08' W
GRANITE FALLS	SNOHOMISH	350	48°10' N / 121°58' W
GRAPEVIEW	MASON	20	47°20' N / 122°49' W
GRAYLAND 2 S	PACIFIC	15	46°46' N / 124°05' W
GRAYS RIVER	WAHKIAKUM	50	46°22' N / 123°34' W
GRAYS RIVER HATCHERY	PACIFIC	100	46°23' N / 123°34' W
GREENWATER	KING	1708	47°09' N / 121°39' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
GREENWOOD FARM	THURSTON	160	47°00' N / 122°40' W
GROTTO	KING	849	47°44' N / 121°25' W
GULER	KLICKITAT	1960	46°00' N / 121°32' W
GUNN'S RANCH	OKANOGAN	2670	48°31' N / 120°18' W
HANFORD	BENTON	727	46°34' N / 119°35' W
HARRINGTON 1 N	LINCOLN	2177	47°29' N / 118°55' W
HARRINGTON 2 S	LINCOLN	2240	47°26' N / 118°15' W
HARRINGTON 5 S	LINCOLN	2167	47°25' N / 118°15' W
HARRINGTON 4 ENE	LINCOLN	2260	47°29' N / 118°11' W
HARTLAND	KLICKITAT	1800	45°46' N / 121°09' W
HARTLINE	GRANT	1910	47°41' N / 119°06' W
HASSAM	OKANOGAN	2900	48°38' N / 119°39' W
HATTON 8 E	ADAMS	1428	46°46' N / 118°40' W
HEADWORKS	PIERCE	1301	46°48' N / 122°19' W
HEATHER MEADOWS	WHATCOM	4200	48°52' N / 121°41' W
HIGLEY PEAK	GRAYS HARBOR	3800	47°30' N / 123°53' W
HOLDEN	CHELAN	3436	48°12' N / 120°47' W
HOLDEN VILLAGE	CHELAN	3230	48°12' N / 120°47' W
HOOPER	WHITMAN	1083	46°45' N / 118°08' W
HORSE HEAVEN	BENTON	-	46°06' N / 119°33' W
HOQUIAM FEDERAL AVIATION AGENCY	GRAYS HARBOR	14	46°59' N / 123°56' W
HUNTERS	STEVENS	1610	48°07' N / 118°12' W
HUNTSVILLE	COLUMBIA	1400	46°18' N / 118°07' W
ICE HARBOR DAM	WALLA WALLA	368	46°15' N / 118°52' W
INCHELIUM 2 NW	FERRY	1685	48°17' N / 118°13' W
INDEX	SNOHOMISH	532	47°49' N / 121°33' W
INDEX 1 SSE	SNOHOMISH	730	47°49' N / 121°33' W
IRENE MT. WAUCONDA	OKANOGAN	2700	48°49' N / 118°54' W
ISSAQUAH	KING	96	47°32' N / 122°02' W
JAY	OKANOGAN	3800	48°14' N / 119°55' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
KAHLOTUS 4 SW	FRANKLIN	1340	46°36' N / 118°36' W
KALAMA 3 ENE	COWLITZ	900	46°03' N / 122°45' W
KELLY'S RANCH	JEFFERSON	254	47°36' N / 124°03' W
KELSO WEATHER BUREAU OFFICE	COWLITZ	17	46°08' N / 122°54' W
KENNEWICK	BENTON	392	46°13' N / 119°08' W
KENNEWICK 10 SW	BENTON	1500	46°08' N / 119°08' W
KENT	KING	40	47°22' N / 122°14' W
KETTLE FALLS	STEVENS	1265	48°34' N / 118°08' W
KEYPORT	KITSAP	35	47°42' N / 122°37' W
KEYSTONE	ADAMS	1937	47°14' N / 118°11' W
KID VALLEY	COWLITZ	690	46°22' N / 122°37' W
KIONA	BENTON	430	46°15' N / 119°29' W
KLOSHE NANITCH	CLALLAM	3300	48°04' N / 124°08' W
KOMA KULSHAN	WHATCOM	850	48°39' N / 121°42' W
KOSMOS	LEWIS	775	46°30' N / 122°11' W
LACENTER	CLARK	200	45°51' N / 122°39' W
LACROSSE 3 ESE	WHITMAN	1546	46°48' N / 117°49' W
LACROSSE WEATHER BUREAU OFFICE	WHITMAN	1476	46°49' N / 117°53' W
LA GRANDE	PIERCE	960	46°50' N / 122°19' W
LAKE CLE ELUM	KITTITAS	2255	47°15' N / 121°04' W
LAKE DOUGLASS	SKAGIT	440	48°28' N / 122°36' W
LAKE KACHESS	KITTITAS	2270	47°16' N / 121°12' W
LAKE KEECHELUS	KITTITAS	2475	47°19' N / 121°20' W
LAKE SUTHERLAND	CLALLAM	572	48°05' N / 123°42' W
LAKE WENATCHEE	CHELAN	2005	47°50' N / 120°48' W
LAKE WHATCOM	WHATCOM	316	48°41' N / 122°18' W
LAKESIDE	CHELAN	1110	47°50' N / 120°02' W
LAKIN RANCH	GARFIELD		
LAMONT 4 SSW	WHITMAN	1947	47°09' N / 117°57' W
LANDSBURG	KING	535	47°23' N / 121°58' W

STATION LOCATIONS

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
LAPUSH	CLALLAM	15	47°55' N / 124°40' W
LAUREL	KLICKITAT	1900	45°56' N / 121°25' W
LAURIER	FERRY	1644	49°00' N / 118°14' W
LEAVENWORTH 3 S	CHELAN	1128	47°34' N / 120°40' W
LEMANASKY LAKE #1	OKANOGAN	4000	48°43' N / 119°38' W
LEMANASKY LAKE #2	OKANOGAN	3640	48°43' N / 119°37' W
LEMANASKY LAKE #3	OKANOGAN	3800	48°43' N / 119°37' W
LESTER	KING	1626	47°12' N / 121°29' W
LESTER 2 E	KING	1750	47°13' N / 121°27' W
LESTER 5 NW	KING	2100	47°16' N / 121°34' W
LESTER 5 NE	KING	1980	47°15' N / 121°24' W
LESTER 7 NNW	KING	2400	47°18' N / 121°31' W
LESTER 8 N	KING	3400	47°20' N / 121°28' W
LESTER 8 NNW	KING	2400	47°19' N / 121°30' W
LESTER 10 NNW	KING	1900	47°21' N / 121°33' W
LESTER U. S. GEOLOGICAL SURVEY	KING	1630	47°12' N / 121°29' W
LEWIS	LEWIS	680	46°17' N / 119°30' W
LIBERTY RANGER STATION	KITTITAS	2412	47°15' N / 120°45' W
LIND 3 NE	ADAMS	1625	47°00' N / 118°35' W
LITTLE FISH RANGER STATION	YAKIMA	-	46°51' N / 121°00' W
LOCKE	PEND OREILLE	3000	48°28' N / 117°23' W
LONE TREE	GRAYS HARBOR	9	46°57' N / 124°08' W
LONG BEACH 3 NNE	PACIFIC	25	46°23' N / 124°02' W
LONGMIRE	PIERCE	2762	46°45' N / 121°49' W
LONGMIRE SPRINGS	PIERCE	2762	46°45' N / 121°49' W
LONGVIEW	COWLITZ	12	46°10' N / 122°55' W
LOOMIS	OKANOGAN	1310	48°49' N / 119°38' W
LOST CREEK (AENEAS)	OKANOGAN	2650	48°29' N / 119°01' W
LOVERINGS RANCH	PACIFIC	55	46°19' N / 124°01' W
LOWDEN	WALLA WALLA	443	46°02' N / 118°40' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
LUCERNE 2 NNW	CHELAN	1085	48°14' N / 120°36' W
LYLE	KLICKITAT	UNK.	45°50' N / 121°15' W
MADRONE	KITSAP	50	47°36' N / 122°40' W
MALOTT	OKANOGAN	845	48°17' N / 119°43' W
MANSFIELD	DOUGLAS	2265	47°49' N / 119°38' W
MANSFIELD - NEAR	DOUGLAS	2400	47°46' N / 119°37' W
MARBLE	STEVENS	1450	48°51' N / 117°54' W
MARBLEMOUNT RANGER STATION	SKAGIT	330	48°32' N / 121°27' W
MARCUS	STEVENS	1206	48°40' N / 118°04' W
MARIETTA 3 NNW	WHATCOM	20	48°50' N / 122°36' W
MARYHILL	KLICKITAT	600	45°43' N / 120°47' W
MATLOCK 3 W	MASON	340	47°14' N / 123°29' W
MAYFIELD	LEWIS	600	46°29' N / 122°31' W
MAZAMA 2 W	OKANOGAN	2175	48°36' N / 120°26' W
MAZAMA 6 SE	OKANOGAN	1960	48°32' N / 120°20' W
McCHORD FIELD	PIERCE	300	47°08' N / 122°29' W
McCONIHE	GRANT	1072	47°12' N / 119°22' W
McCUMBERS RANCH	YAKIMA	2181	46°05' N / 121°20' W
McMILLIN RESERVOIR	PIERCE	579	47°08' N / 122°16' W
McNART DAM	BENTON	361	45°57' N / 119°18' W
MERRITT	CHELAN	2175	47°47' N / 120°51' W
MESA 4 W	FRANKLIN	875	46°36' N / 119°05' W
METALINE FALLS	PEND OREILLE	2107	48°52' N / 117°22' W
METHOW	OKANOGAN	1160	48°08' N / 120°00' W
METHOW 2 W	OKANOGAN	1230	48°08' N / 120°03' W
MILL CREEK	WALLA WALLA	2000	46°01' N / 118°07' W
MILL CREEK DAM	WALLA WALLA	1175	46°05' N / 118°16' W
MINERAL 1 SW	LEWIS	1500	46°42' N / 122°12' W
MINTER CREEK	PIERCE	17	47°22' N / 122°42' W
MOCLIPS	GRAYS HARBOR	1500	47°14' N / 124°12' W

STATION NAME	COUNTY	ELEVATION	LATITUDE AND LONGITUDE
MOLD	DOUGLAS	2400	47°43' N / 119°19' W
MONROE	SNOHOMISH	120	47°51' N / 121°59' W
MONTE CRISTO	SNOHOMISH	2872	47°59' N / 121°23' W
MONTESANO 3 NW	GRAYS HARBOR	40	47°01' N / 123°39' W
MOSES LAKE 3 E	GRANT	1208	47°07' N / 119°12' W
MOSSYROCK	LEWIS	680	46°32' N / 122°29' W
MOTTINGER	BENTON	307	45°56' N / 119°09' W
MT. ADAMS RANGER STATION	KLICKITAT	1960	46°00' N / 121°32' W
MT. BAKER LODGE	WHATCOM	4150	48°52' N / 121°40' W
MT. BONAPARTE	OKANOGAN	4000	48°17' N / 119°09' W
MT. PLEASANT	CLALLAM	500	48°04' N / 123°25' W
MT. PLEASANT	SKAMANIA	650	45°34' N / 122°15' W
MT. ROSE	MASON	3000	47°31' N / 123°14' W
MT. SPOKANE	SPOKANE	5280	47°55' N / 117°08' W
MT. SPOKANE SUMMIT	SPOKANE	5890	47°55' N / 117°07' W
MT. VERNON 3 WNW	SKAGIT	14	48°26' N / 122°23' W
MOUNTAIN LAKES	KING	814	47°46' N / 121°56' W
MOXEE (NEAR)	YAKIMA	1000	46°35' N / 120°26' W
MOXEE CITY 10 E	YAKIMA	1550	46°31' N / 120°10' W
MUD MOUNTAIN DAM	KING	1308	47°09' N / 121°56' W
MUDDY RIVER	SKAMANIA	UNK.	46°04' N / 122°00' W
NACHES 10 NW	YAKIMA	2375	46°52' N / 120°48' W
NACHES HEIGHTS	YAKIMA	1874	46°39' N / 120°38' W
NADA LAKE	CHELAN	5500	47°30' N / 120°45' W
NASELLE	PACIFIC	20	46°22' N / 123°49' W
NEAH BAY 1 E	CLALLAM	15	48°22' N / 124°37' W
NEPPEL	GRANT	1070	47°08' N / 119°08' W
NESPELEM 2 S	OKANOGAN	1890	48°08' N / 118°59' W
NEWHALEM	WHATCOM	525	48°41' N / 121°15' W
NEWPORT	PEND OREILLE	2135	48°11' N / 117°03' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
NEW WHATCOM	WHATCOM	UNK.	UNK. / UNK.
NIGHTHAWK	OKANOGAN	UNK.	48°57' N / 119°37' W
NOOKSACK HATCHERY	WHATCOM	412	48°54' N / 122°09' W
NORTH BEND	KING	550	47°30' N / 121°45' W
NORTH FORK CEDAR RIVER	KING	2400	47°19' N / 121°30' W
NORTH HEAD WEATHER BUREAU OFFICE	PACIFIC	194	46°18' N / 124°18' W
NORTHPORT	STEVENS	1347	48°55' N / 117°47' W
NORTHUP RANCH	JEFFERSON	200	47°34' N / 124°17' W
NORTH YAKIMA	YAKIMA	-	46°37' N / 120°31' W
NORTH SUNDALE	KLICKITAT	-	UNK. / UNK.
NUTLAND	KLICKITAT	UNK.	UNK. / UNK.
OAKVILLE	GRAYS HARBOR	130	46°51' N / 123°13' W
ODESSA	LINCOLN	1540	47°20' N / 118°40' W
OHANAPECOSH	LEWIS	1925	46°44' N / 121°34' W
OKANOGAN	OKANOGAN	835	48°22' N / 119°35' W
OLDMAN PASS	SKAMANIA	3100	46°00' N / 121°55' W
OLGA 2 SE	SAN JUAN	80	48°37' N / 122°48' W
OLYMPIA FOREST HQ	THURSTON	208	47°04' N / 122°46' W
OLYMPIA PRIEST PT. PARK	THURSTON	27	47°04' N / 122°53' W
OLYMPIA WEATHER BUREAU AIRPORT STATION	THURSTON	190	46°58' N / 122°54' W
OLYMPIA	THURSTON	88	47°03' N / 122°54' W
OMAK 2 NW	OKANOGAN	1228	48°26' N / 119°32' W
OMAK	OKANOGAN	850	48°25' N / 119°32' W
ORCAS ISLAND	SAN JUAN	UNK.	UNK. / UNK.
ORIENT	FERRY	1441	48°51' N / 118°13' W
OROVILLE 1 S	OKANOGAN	920	48°55' N / 119°26' W
OROVILLE 3 NW	OKANOGAN	-	48°58' N / 119°30' W
ORTING 5 S	PIERCE	400	47°02' N / 122°12' W
OTHELLO	ADAMS	1110	46°50' N / 119°10' W
PACKWOOD	LEWIS	1060	46°37' N / 121°40' W
PACKWOOD LAKE	LEWIS	3000	45°35' N / 121°34' W
PALISADE FARM	PIERCE	1775	46°45' N / 122°10' W
PALMER 3 SE	KING	895	47°18' N / 121°50' W
PALMER 5 SE BEAR CREEK	KING	1100	47°17' N / 121°48' W
PALMER 7 SE CHARLEY CREEK	KING	1600	47°15' N / 121°47' W
PARADISE INN	PIERCE	5550	46°47' N / 121°44' W
PARKWAY	PIERCE	2640	46°59' N / 121°32' W
PARKWAY 6 S	PIERCE	3150	46°56' N / 121°32' W
PASCO	FRANKLIN	360	46°13' N / 119°06' W
PATEROS	OKANOGAN	825	48°03' N / 119°54' W
PEARL	OKANOGAN	UNK.	48°01' N / 119°31' W
PEOLA	GARFIELD	400	46°20' N / 117°28' W
PETERSON'S RANCH	SKAMANIA	596	46°03' N / 122°12' W
PILCHUCK CREEK	SKAGIT	830	48°21' N / 122°06' W
PLAIN	CHELAN	1800	47°46' N / 120°40' W
PLEASANT VIEW	WALLA WALLA	1650	46°31' N / 118°20' W
POINT GRENVILLE	GRAYS HARBOR	100	47°18' N / 124°17' W
POMEROY	GARFIELD	1805	46°28' N / 117°38' W
PORT ANGELES	CLALLAM	99	48°07' N / 123°26' W
PORT ANGELES (EDIZ HOOK) WEATHER BUREAU OFFICE	CLALLAM	11	48°08' N / 123°24' W
PORT ANGELES 11S	CLALLAM	5100	47°58' N / 123°30' W
PORT ANGELES 14 SE	CLALLAM	5270	47°57' N / 123°16' W
PORT CRESCENT	CLALLAM	259	48°07' N / 123°41' W
PORT TOWNSEND WEATHER BUREAU OFFICE	JEFFERSON	98	48°06' N / 122°46' W
PORT TOWNSEND	JEFFERSON	71	48°07' N / 122°45' W
POULSBO	KITSAP	20	47°45' N / 122°39' W
PRIEST RAPIDS DAM	GRANT	462	46°39' N / 119°54' W
PRINDLE	SKAMANIA	250	45°35' N / 122°10' W
PROSSER	BENTON	675	46°12' N / 119°46' W
PROSSER 4 NE	BENTON	830	46°15' N / 119°45' W
PULLMAN 2 NW	WHITMAN	2545	46°46' N / 117°12' W
PULLMAN 2 E	WHITMAN	2520	46°43' N / 117°09' W
PUYALLUP 2 W EXPERIMENT STATION	PIERCE	50	47°12' N / 122°20' W
PUYALLUP 3 W	PIERCE	26	47°12' N / 122°20' W
PYSHT	CLALLAM	30	48°12' N / 124°07' W
QUEETS RIVER	JEFFERSON	UNK.	47°31' N / 124°21' W
QUILCENE 2 SW	JEFFERSON	123	47°49' N / 122°55' W
QUILCENE 5 SW DAM	JEFFERSON	1028	47°47' N / 122°59' W
QUINAULT RANGER STATION	GRAYS HARBOR	221	47°28' N / 123°50' W
QUINAULT RIVER STAKE	JEFFERSON	2175	47°30' N / 123°46' W
QUINCY 1 NE #27	GRANT	1315	47°15' N / 119°50' W
QUINCY 1 S	GRANT	1274	47°13' N / 119°51' W
RACK CREEK	KING	1700	47°23' N / 121°43' W
RAINBOW FALLS PARK 2 E	LEWIS	301	46°38' N / 123°14' W
RAINIER CARBON RIVER ENTRANCE	PIERCE	1735	47°00' N / 121°55' W
RAINIER LONGMIRE	PIERCE	2762	46°45' N / 121°49' W
RAINIER OHANAPECASH	LEWIS	1925	46°44' N / 121°34' W
RAINIER PARADISE RANGER STATION	PIERCE	5550	46°47' N / 121°44' W
RAINIER SUNSHINE POINT	PIERCE	2000	46°44' N / 121°54' W
RANDLE 1 E	LEWIS	944	46°32' N / 121°56' W
RATTLESNAKE MOUNTAIN	BENTON	2800	46°23' N / 119°43' W
REARDAN	LINCOLN	2510	47°40' N / 117°54' W
REFLECTOR BAR	WHATCOM	872	48°43' N / 121°09' W
RENTON	KING	33	47°29' N / 122°12' W
REPUBLIC	FERRY	2600	48°39' N / 118°44' W
REPUBLIC RANGER STATION	FERRY	2630	48°39' N / 118°44' W
REX CREEK	CHELAN	1100	48°11' N / 120°32' W
RICHARDSON 3 SE	SAN JUAN	30	48°26' N / 122°50' W
RICHLAND	BENTON	370	46°16' N / 119°18' W
RIMROCK TIETON DAM	YAKIMA	2730	46°39' N / 121°08' W

STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
RITZVILLE	ADAMS	1825	47°07' N / 118°22' W
RITZVILLE - NEAR	ADAMS	1825	47°03' N / 118°25' W
ROBERTSVILLE	KLICKITAT	UNK.	45°58' N / 121°12' W
ROCK ISLAND	DOUGLAS	647	47°23' N / 120°09' W
ROCKDALE	KING	2100	47°24' N / 121°26' W
ROCK LAKE	WHITMAN	1750	47°10' N / 117°42' W
ROSALIA	WHITMAN	2400	47°14' N / 117°22' W
ROSS DAM	WHATCOM	1236	48°44' N / 121°03' W
RUBY CREEK	WHATCOM	1272	48°44' N / 121°03' W
RUBY HILL	OKANOGAN	2850	48°28' N / 119°45' W
RUFF 3 SW	GRANT	1342	47°08' N / 119°03' W
RUSSELL'S RANCH	YAKIMA	2870	46°38' N / 121°12' W
ST. HELENS	COWLITZ	892	46°20' N / 122°31' W
SAPPHO 8 E	CLALLAM	760	48°04' N / 124°07' W
SATSOP	GRAYS HARBOR	40	47°00' N / 123°30' W
SATSOP 1 W	GRAYS HARBOR	40	47°00' N / 123°30' W
SATUS PASS	KLICKITAT	3095	46°00' N / 120°39' W
SAUK (NEAR)	SKAGIT	226	48°25' N / 121°34' W
SCENIC	KING	2224	47°42' N / 121°09' W
SEATTLE JACKSON PARK	KING	335	47°44' N / 122°19' W
SEATTLE MAPLE LEAF RESERVOIR	KING	422	47°42' N / 122°19' W
SEATTLE NAVAL AIR STATION	KING	21	47°41' N / 122°16' W
SEATTLE-TACOMA WEATHER BUREAU AIRPORT STATION	KING	386	47°27' N / 122°18' W
SEATTLE UNIVERSITY OF WASHINGTON	KING	60	47°39' N / 122°18' W
SEATTLE WEATHER BUREAU AIRPORT STATION	KING	14	47°32' N / 122°18' W
SEATTLE WEATHER BUREAU OFFICE	KING	14	47°36' N / 122°20' W
SEAVIEW	PACIFIC	8	46°20' N / 124°02' W
SEDRO WOOLLEY 1 E	SKAGIT	56	48°30' N / 122°13' W
SEQUIM	CLALLAM	180	48°05' N / 123°06' W
SHELTON	MASON	22	47°12' N / 123°06' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
SHUKSAN	WHATCOM	2030	48°55' N / 121°42' W
SIGNAL PEAK	YAKIMA	4011	46°14' N / 121°08' W
SILCOTT	ASOTIN	730	46°25' N / 117°12' W
SILVANIA	SNOHOMISH	35	48°12' N / 122°15' W
SILVER CREEK	LEWIS	678	46°32' N / 122°35' W
SILVER SPRINGS LODGE	PIERCE	2678	47°00' N / 121°32' W
SILVERTON	SNOHOMISH	1500	48°04' N / 121°34' W
SIXPRONG	KLICKITAT	1100	45°50' N / 120°07' W
SKAGIT POWER PLANT	WHATCOM	525	48°41' N / 121°15' W
SKYKOMISH 8 W	KING	2900	47°42' N / 121°31' W
SKYKOMISH	KING	933	47°42' N / 121°22' W
SMYRNA	GRANT	560	46°50' N / 119°40' W
SNIDERS RANGER STATION	CLALLAM	760	48°04' N / 124°08' W
SNOHOMISH	SNOHOMISH	55	47°55' N / 122°05' W
SNOQUALMIE FALLS	KING	440	47°33' N / 121°51' W
SNOQUALMIE PASS	KING KITTITAS	3020	47°25' N / 121°25' W
SNOQUALMIE PASS 4 W	KING	2200	47°24' N / 121°27' W
SNYDERS RANCH	OKANOGAN	2200	48°22' N / 120°20' W
SODA SPRINGS CAMP	YAKIMA	3170	46°31' N / 121°00' W
SOUTH ELLENSBURG	KITTITAS	1700	UNK. / UNK.
SOUTH OLYMPIC TREE FARM	GRAYS HARBOR	580	47°14' N / 123°35' W
SOUTH FORK - CEDAR RIVER	KING	2400	47°18' N / 121°31' W
SOUTH BEND	PACIFIC	150	46°41' N / 123°47' W
SPIKEMAN RANGER STATION	OKANOGAN	2300	48°33' N / 119°40' W
SPIRIT LAKE RANGER STATION	SKAMANIA	3240	46°16' N / 122°09' W
SPOKANE	SPOKANE	1875	47°40' N / 117°25' W
SPOKANE FALLS	SPOKANE	1909	47°40' N / 117°25' W
SPOKANE WEATHER BUREAU AIRPORT STATION	SPOKANE	2357	47°37' N / 117°31' W
SPOKANE FELTS FIELD	SPOKANE	1955	47°40' N / 117°20' W
SPRAGUE	LINCOLN	1925	47°18' N / 117°59' W

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
SPRUCE	JEFFERSON	410	47°48' N / 124°04' W
STAMPEDE	KING	2800	47°16' N / 121°22' W
STAMPEDE PASS WEATHER BUREAU OFFICE	KITTITAS	3958	47°17' N / 121°20' W
STAMPEDE TUNNEL	KING	2506	47°16' N / 121°22' W
STARBUCK	COLUMBIA	640	46°31' N / 118°08' W
STATE UNIVERSITY	KING	160	47°39' N / 122°18' W
STARTUP 1 E	SNOHOMISH	170	47°52' N / 121°43' W
STEHEKIN 3 NW	CHELAN	1150	48°20' N / 120°42' W
STELIKO RANGER STATION	CHELAN	UNK.	47°45' N / 120°26' W
STEVENS PASS	CHELAN	4085	47°45' N / 121°05' W
STEVENSON WEATHER BUREAU OFFICE	SKAMANIA	100	45°33' N / 121°50' W
STILLAGUAMISH	SNOHOMISH	35	48°12' N / 122°15' W
STOCKDILL RANCH	OKANOGAN	2200	48°22' N / 120°20' W
STOKES RANCH	OKANOGAN	2670	48°31' N / 120°18' W
SULLIVAN LAKE	PEND OREILLE	2600	48°51' N / 117°18' W
SULTAN	SNOHOMISH	178	47°50' N / 121°50' W
SUMNER	PIERCE	77	47°12' N / 122°15' W
SUNNYSIDE	YAKIMA	747	46°19' N / 120°00' W
SWEAT CREEK RANGER STATION	OKANOGAN	3244	48°23' N / 119°48' W
TACOMA CITY HALL	PIERCE	420	47°15' N / 122°26' W
TACOMA WEATHER BUREAU OFFICE	PIERCE	277	47°15' N / 122°26' W
TAHOLAH	GRAYS HARBOR	15	47°20' N / 124°17' W
TATOOSH ISLAND WEATHER BUREAU OFFICE	CLALLAM	101	48°23' N / 124°44' W
TALYOR CREEK	KING	1100	47°23' N / 121°50' W
TEKOA	WHITMAN	2610	47°13' N / 117°05' W
TIETON INTAKE	YAKIMA	2280	46°40' N / 121°00' W
TIETON CANTON	YAKIMA	2000	46°42' N / 120°56' W
TIMENTWA	OKANOGAN	2700	48°12' N / 119°28' W
TOLEDO FEDERAL AVIATION AGENCY	LEWIS	351	46°29' N / 122°48' W
TOLT (NEAR)	KING	98	47°40' N / 121°56' W

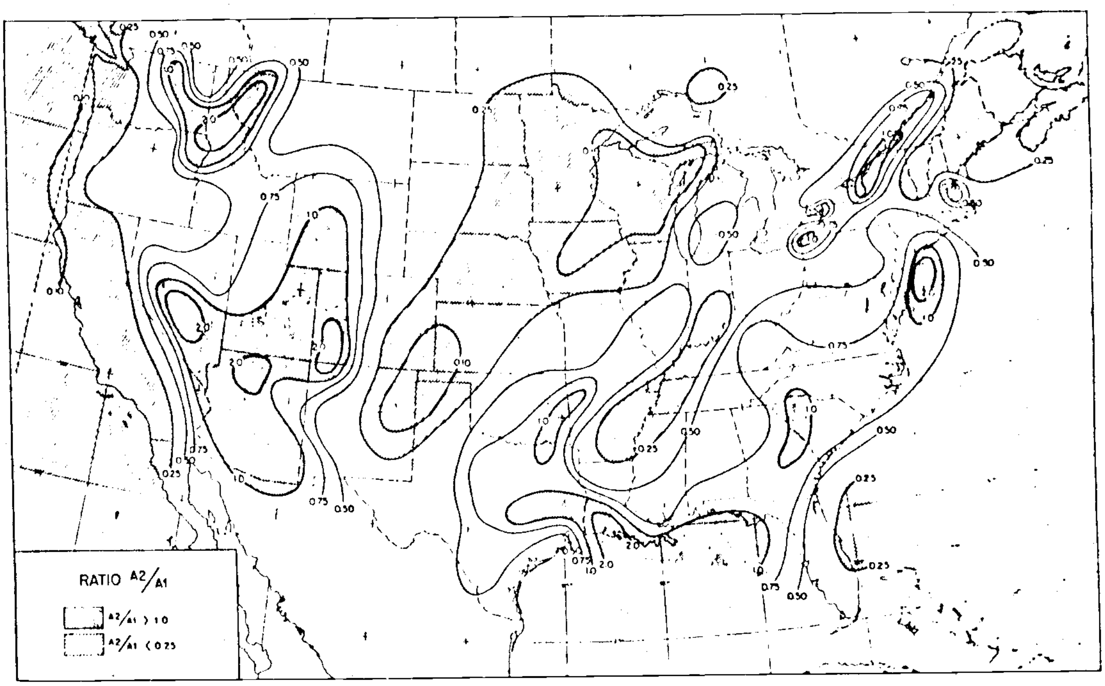
STATION LOCATIONS

STATION NAME	COUNTY	ELE-VATION	LATITUDE AND LONGITUDE
TOMASKET	OKANOGAN	945	48°42' N / 119°27' W
TOMASKET 11 WSW	OKANOGAN	3380	48°40' N / 119°40' W
TOPPENISH	YAKIMA	765	46°22' N / 120°17' W
TOUCHET	WALLA WALLA	443	46°02' N / 118°40' W
TOUCHET RIDGE	COLUMBIA	3600	46°07' N / 117°59' W
TRINIDAD 2 SSE	GRANT	555	47°13' N / 120°00' W
TROUT LAKE 13 NNW	SKAMANIA	3500	46°09' N / 121°41' W
TROUT LAKE 19 WNW	SKAMANIA	2600	46°09' N / 121°51' W
TWENTY-FIVE MILE CREEK	CHELAN	2000	45°57' N / 120°17' W
TWIN	CLALLAM	UNK.	UNK. / UNK.
TWIN RIVERS	CLALLAM	UNK.	UNK. / UNK.
TWIN SISTER LAKE	YAKIMA	4500	46°45' N / 121°20' W
TWISP	OKANOGAN	1610	48°22' N / 120°07' W
TYE	KING	3126	47°44' N / 121°08' W
TYEE	CHELAN	UNK.	47°56' N / 120°30' W
UNDERWOOD 4 W	SKAMANIA	1260	45°44' N / 121°36' W
UNION CITY	MASON	10	47°21' N / 123°10' W
UPPER BAKER RIVER	WHATCOM	850	48°40' N / 121°43' W
UPPER CLE ELUM VALLEY	KITTITAS	5300	47°32' N / 121°03' W
UPPER PINE CREEK	OKANOGAN	3080	48°39' N / 119°39' W
UPPER PINE CREEK #2	OKANOGAN	3440	48°40' N / 119°38' W
USK	PEND OREILLE	UNK.	UNK. / UNK.
VAIL	THURSTON	435	46°50' N / 122°40' W
VANCOUVER	CLARK	100	45°38' N / 122°41' W
VANCOUVER PORT DOCK	CLARK	26	45°37' N / 122°40' W
VASHON ISLAND	KING	231	47°27' N / 122°30' W
WACONDA	OKANOGAN	4170	48°45' N / 118°58' W
WAHLUKE (NEAR)	GRANT	416	46°39' N / 119°43' W
WALLA WALLA FEDERAL AVIATION AGENCY	WALLA WALLA	1185	46°06' N / 118°17' W
WALLA WALLA 3 W	WALLA WALLA	800	46°03' N / 118°24' W
WALLA WALLA WEATHER BUREAU OFFICE	WALLA WALLA	949	46°02' N / 118°20' W
WALLA WALLA (GARDEN CITY HEIGHTS)	WALLA WALLA	976	46°04' N / 118°20' W
WALLACE	OKANOGAN	4000	48°43' N / 119°38' W
WAPATO	YAKIMA	850	46°26' N / 120°25' W
WASHOUGAL (NEAR)	SKAMANIA	650	45°34' N / 122°15' W
WASHOUGAL 8 ENE	SKAMANIA	760	45°36' N / 122°11' W
WATERVILLE	DOUGLAS	2605	47°39' N / 120°05' W
WAUNA 3 W	PIERCE	17	47°22' N / 122°42' W
WAWAWAI 2 NW	GARFIELD	695	46°39' N / 117°24' W
WELLPINIT	STEVENS	2450	47°53' N / 117°59' W
WENAS #1	YAKIMA	2375	46°52' N / 120°48' W
WENATCHEE	CHELAN	634	47°25' N / 120°19' W
WENATCHEE EXPERIMENT STATION	CHELAN	870	47°26' N / 120°21' W
WENATCHEE FEDERAL AVIATION AGENCY	CHELAN	1230	47°24' N / 120°12' W
WENATCHEE (NEAR)	CHELAN	2200	47°22' N / 120°22' W
WEST FERNDALE	WHATCOM	50	48°51' N / 122°36' W
WEST HAVEN	GRAYS HARBOR	---	46°54' N / 124°06' W
WESTPORT 2 N - UNITED STATES COAST GUARD	GRAYS HARBOR	17	46°54' N / 124°06' W
WEST SOUND	SAN JUAN	100	48°47' N / 122°54' W
WHATCOM	WHATCOM	60	UNK. / UNK.
WHEELER	GRANT	1315	47°08' N / 119°05' W
WHITE BLUFFS	BENTON	390	46°39' N / 119°27' W
WHITE RIVER ENTRANCE	PIERCE	3060	46°56' N / 121°32' W
WHITE SALMON 4 NNE	KLICKITAT	2011	45°46' N / 121°29' W
WHITE SALMON 8 NNE	KLICKITAT	2020	45°49' N / 121°24' W
WHITE SWAN	YAKIMA	974	46°23' N / 120°44' W
WILBUR	LINCOLN	2163	47°45' N / 118°42' W
WILLAPA HARBOR	PACIFIC	150	46°41' N / 123°47' W
WILLARD	SKAMANIA	1320	48°47' N / 121°38' W
WILLARD FISH LAB.	SKAMANIA	765	45°46' N / 121°38' W
WILSON CREEK	GRANT	1276	47°25' N / 119°07' W
WIND RIVER	SKAMANIA	1145	45°48' N / 121°56' W
WINTHROP 1 WSW	OKANOGAN	1755	48°28' N / 120°11' W
WISHKAH	GRAYS HARBOR	435	47°16' N / 123°43' W
WITHROW 4 WNW	DOUGLAS	2660	47°44' N / 119°54' W
WYNOOCHE	GRAYS HARBOR	600	47°20' N / 123°30' W
WYNOOCHEE OXBOW	GRAYS HARBOR	670	47°20' N / 123°38' W
WYNOOCHEE POWER PLANT	GRAYS HARBOR	670	47°20' N / 123°38' W
YACOLT	CLARK	737	45°52' N / 122°24' W
YALE	COWLITZ	355	46°01' N / 122°20' W
YAKIMA TERRACE HEIGHTS	YAKIMA	1200	46°37' N / 120°26' W
YAKIMA WEATHER BUREAU AIRPORT STATION	YAKIMA	1061	46°34' N / 120°32' W
YELM	THURSTON	355	46°56' N / 122°36' W
ZILLAH	YAKIMA	800	46°24' N / 120°15' W
ZINDEL	ASOTIN	715	46°14' N / 117°03' W

APPENDIX B

SUPPLEMENTAL FIGURES

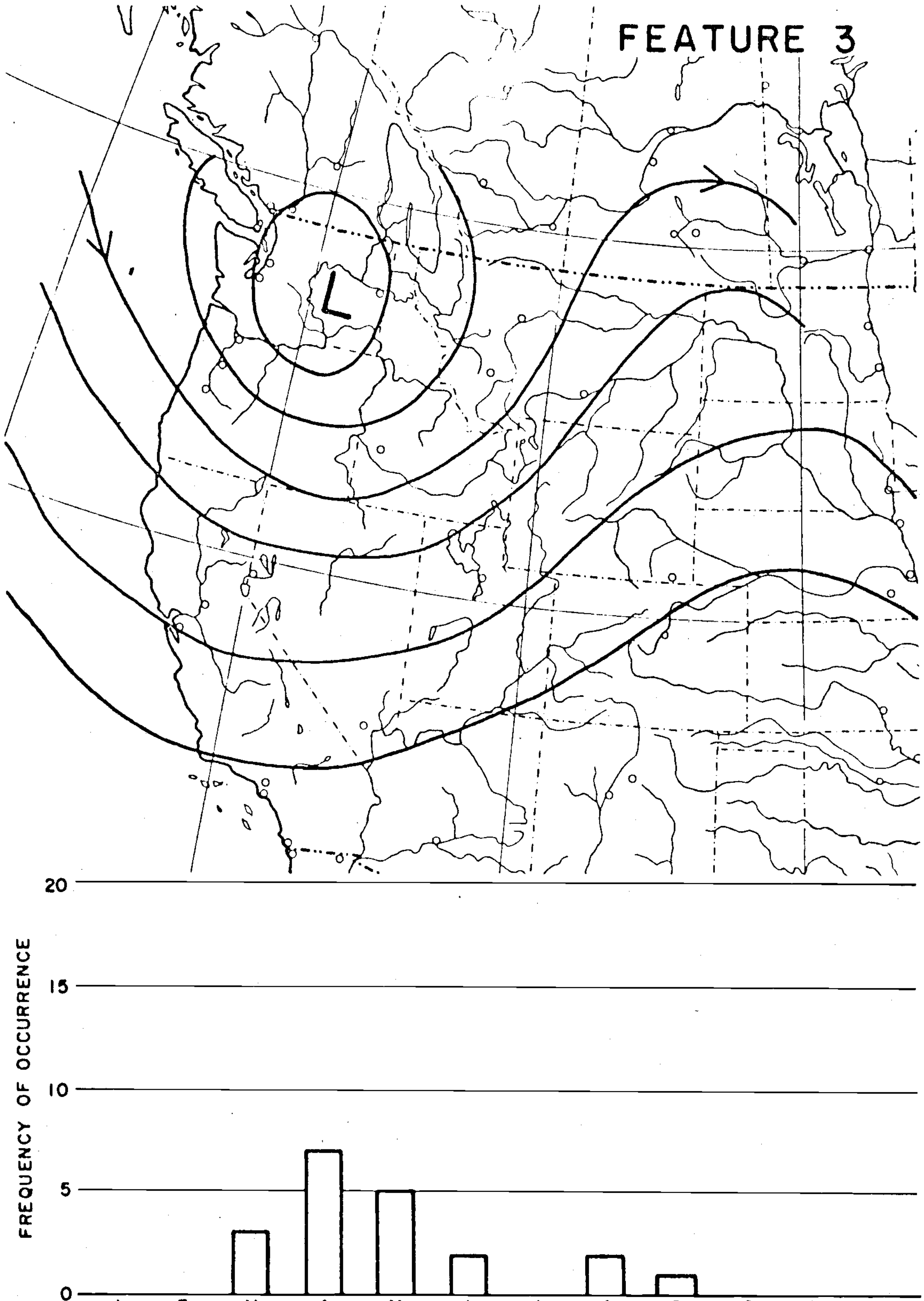
APPENDIX B. SUPPLEMENTAL FIGURES



Ratio Chart A_2/A_1

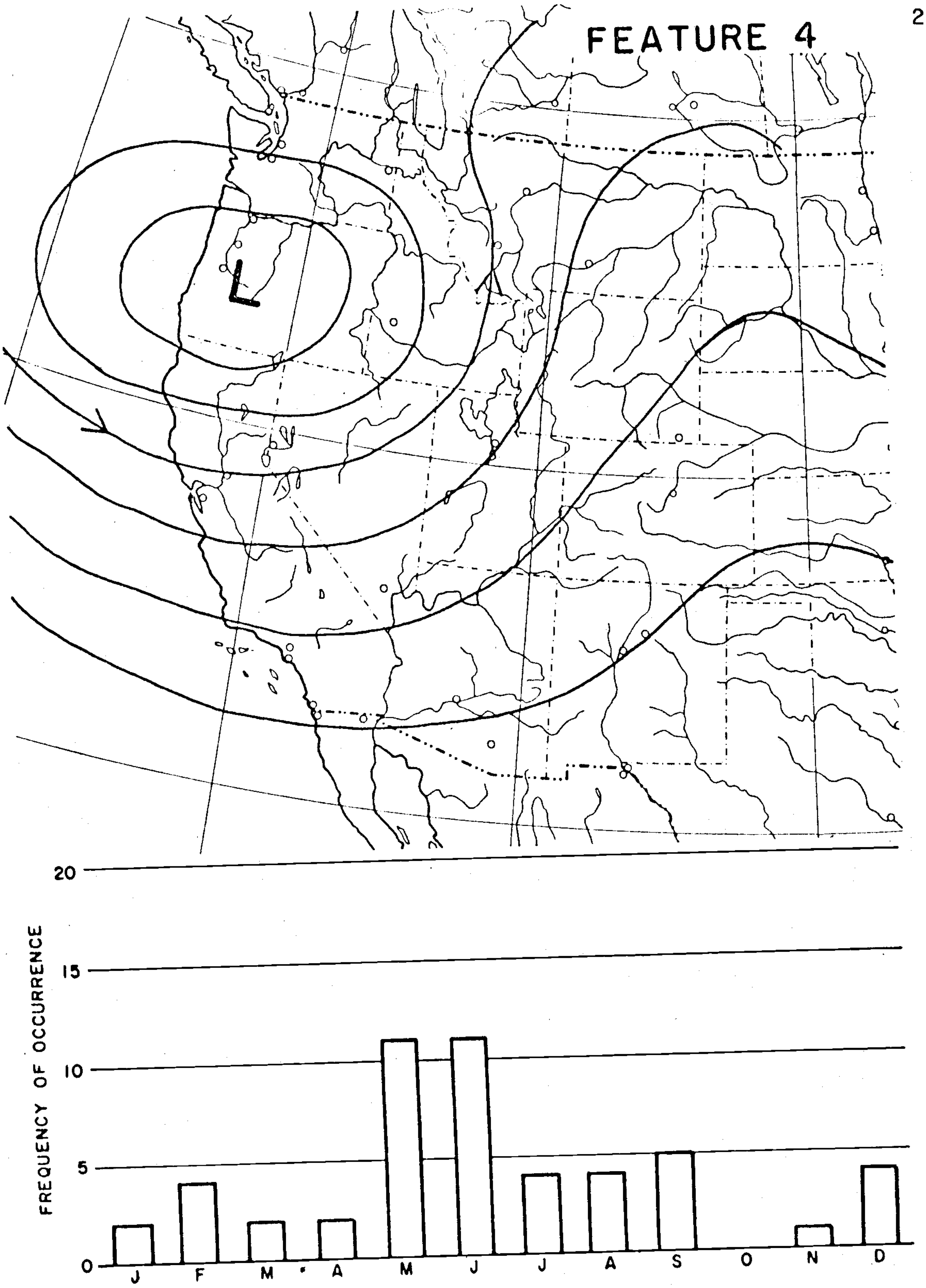
(Horn, L., and Bryson R., 1960, p. 161)

FIGURE I



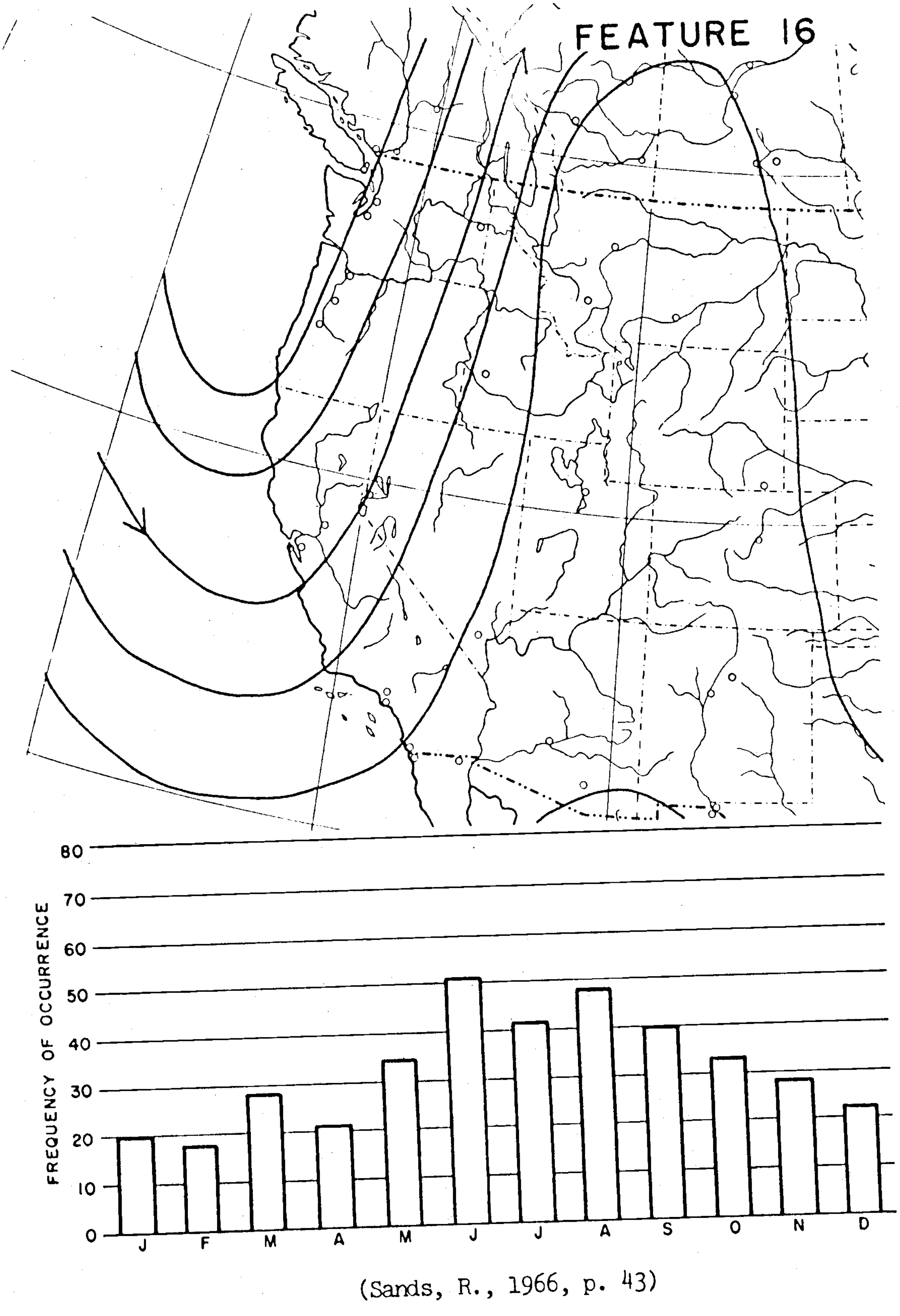
(Sands, R., 1966, p. 17)

FIGURE 2



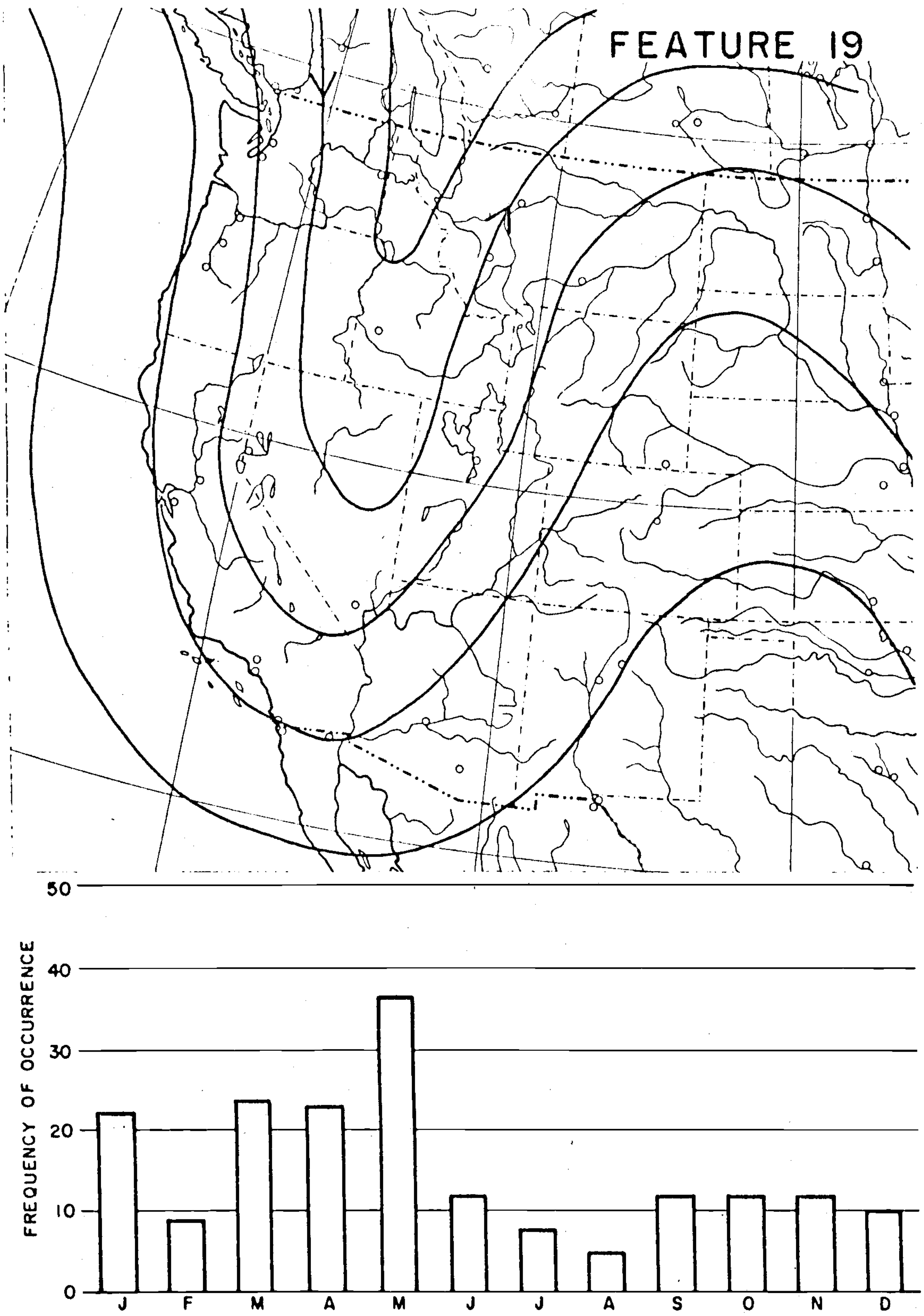
(Sands, R., 1966, p. 19)

FIGURE 3



(Sands, R., 1966, p. 43)

FIGURE 4



(Sands, R. 1966, p. 49)

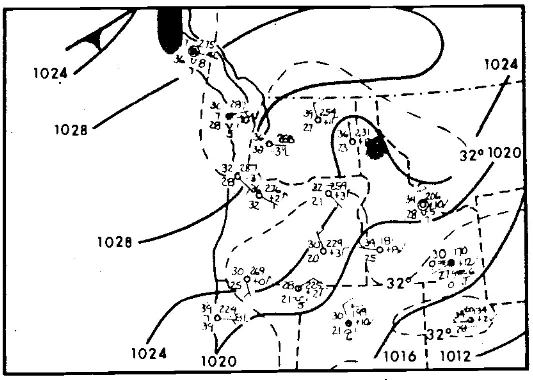
FIGURE 5

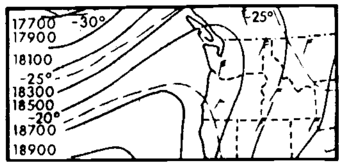
APPENDIX C

SUPPLEMENTAL MAPS

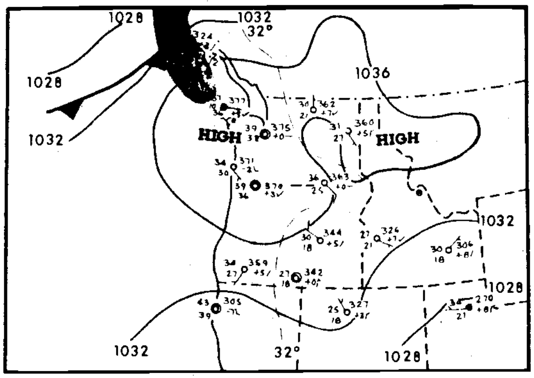
SURFACE WEATHER MAP AND STATION WEATHER, 7:00 A.M., E.S.T.

500-MILLIBAR HEIGHT CONTOURS, 7:00 A.M., E.S.T.

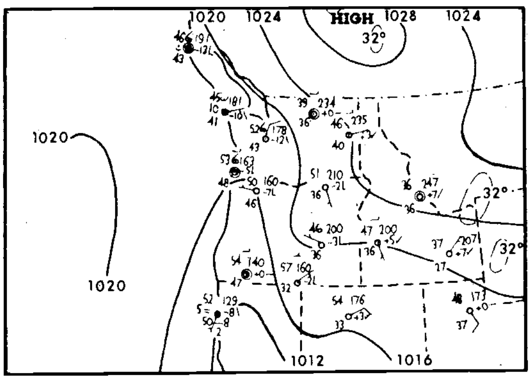


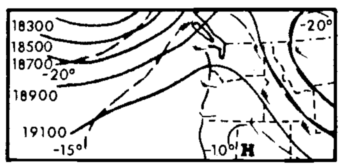


MARCH 23, 1973

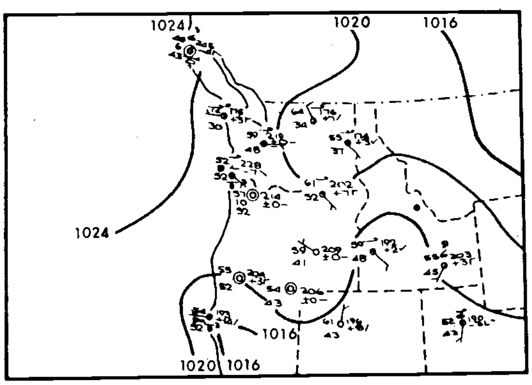


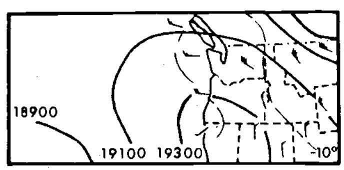
APRIL 3, 1973





MAY 29, 1973





JUNE 19, 1970

MAP I