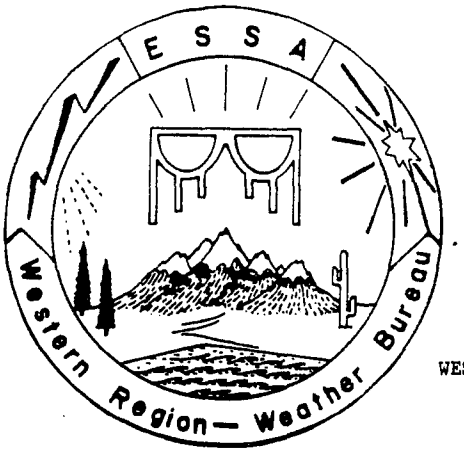
WEATHER BUREAU
WESTERN REGION

Salt Lake City, Utah
April 1966 (Revised October 1969)

Station Descriptions of Local Effects on Synoptic Weather Patterns

PHILIP WILLIAMS, JR.

Technical Memorandum WBTM WR-5
(Revised)
U.S. DEPARTMENT OF COMMERCE / ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION



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*Out of Print
**Revised

A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

U. S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU

Weather Bureau Technical Memorandum WR-5
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STATION DESCRIPTIONS OF LOCAL EFFECTS ON SYNOPTIC WEATHER PATTERNS

Philip Williams, Jr.
Scientific Services Division
Western Region Headquarters, Salt Lake City, Utah

WESTERN REGION
TECHNICAL MEMORANDUM NO. 5 (REV.)

SALT LAKE CITY, UTAH
APRIL 1966
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WESTERN REGION
NOVEMBER 1967

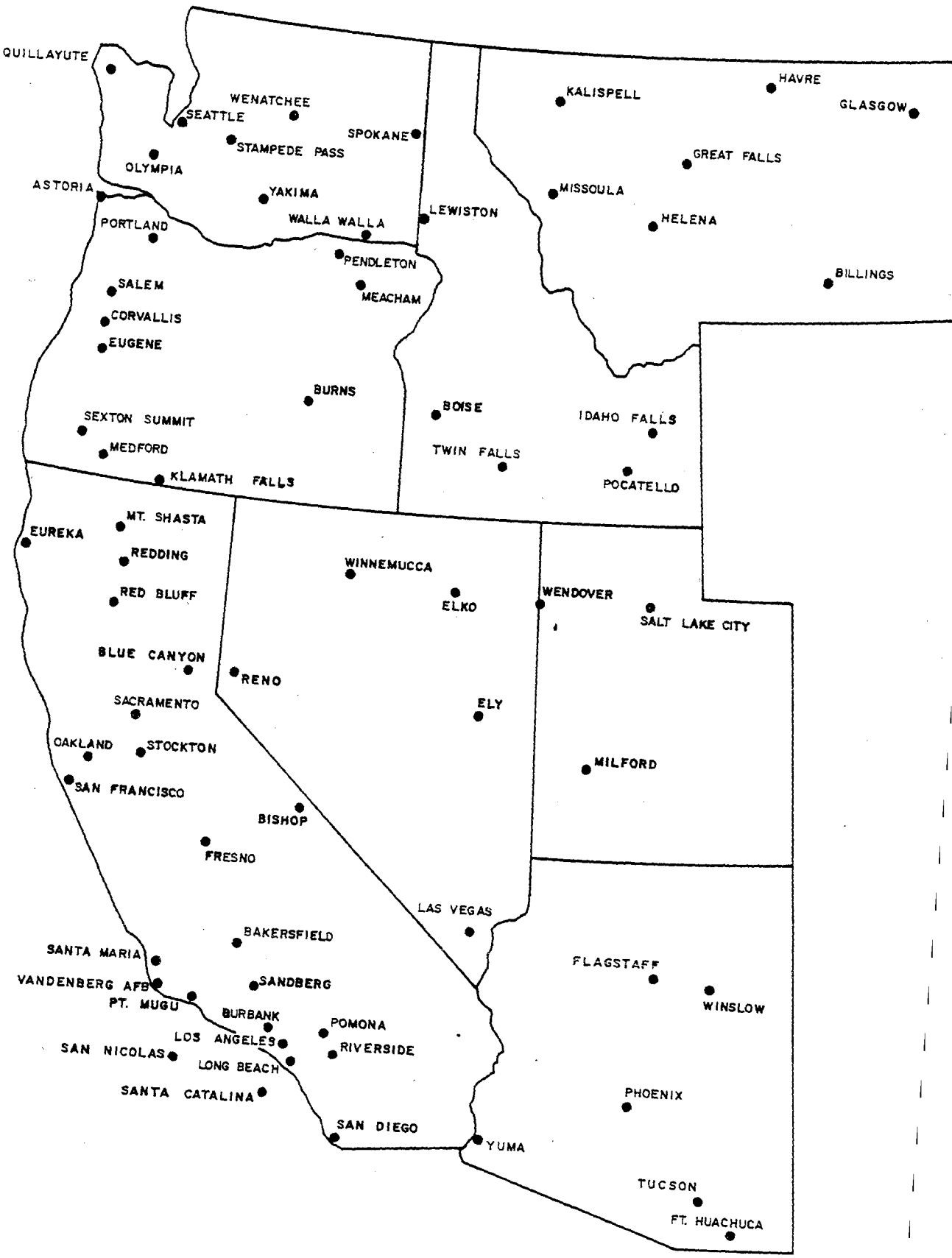


FIG. 1.

2ND ORDER STATIONS

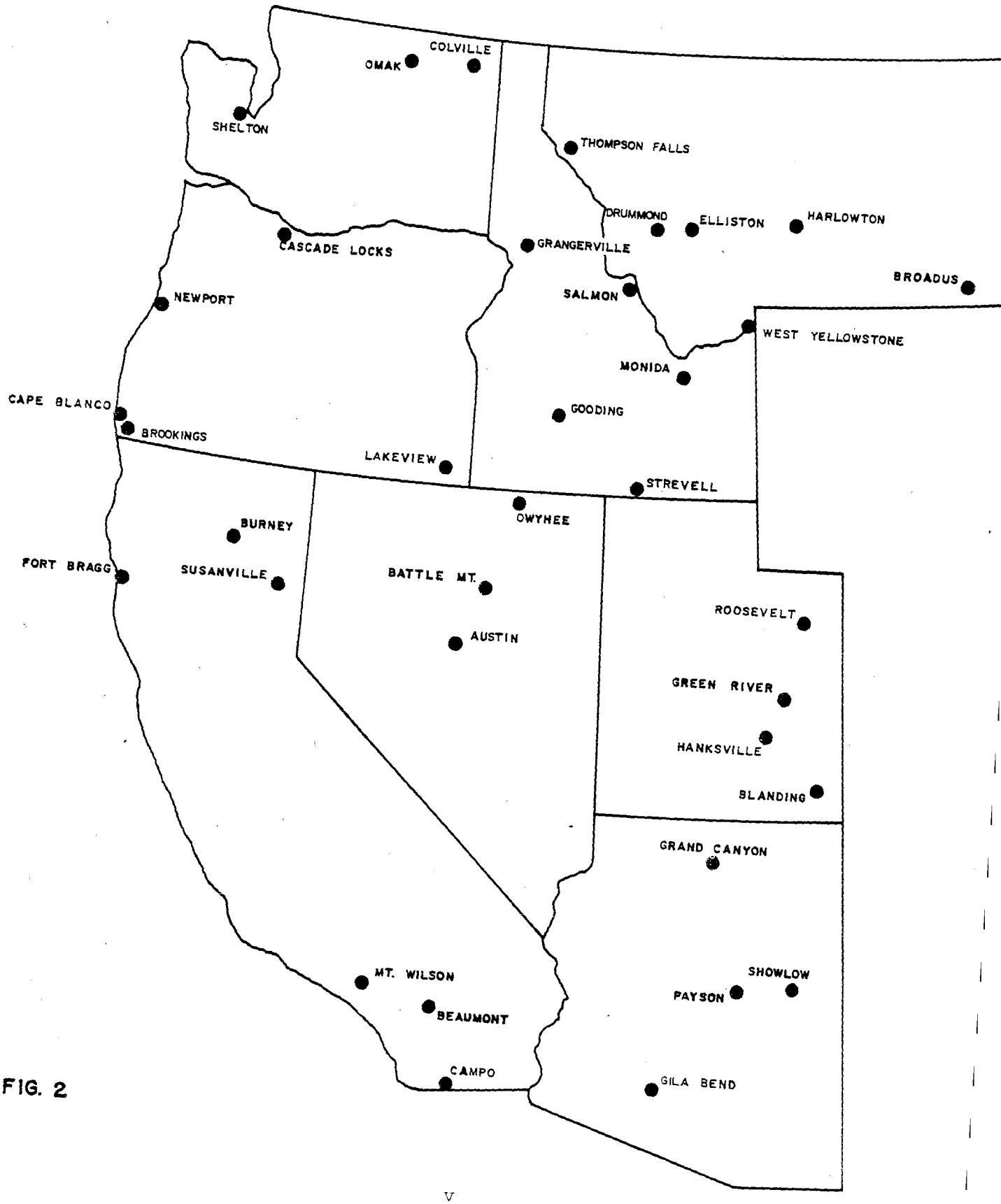


FIG. 2

FAA REPORTING STATIONS

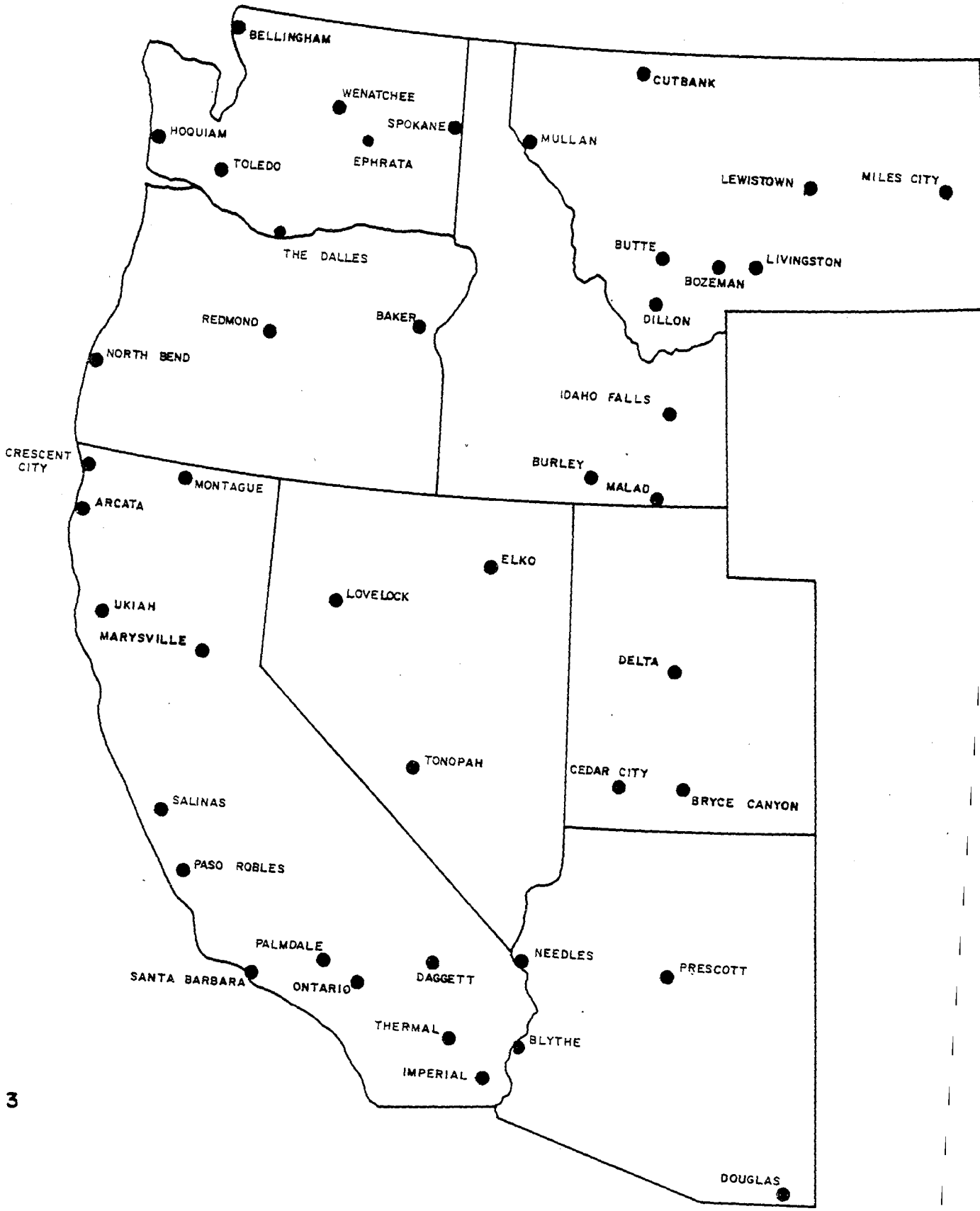


FIG. 3

CANADIAN STATIONS, SAWRS AND LAWRS

FIG. 4

STATION DESCRIPTIONS OF LOCAL EFFECTS ON SYNOPTIC WEATHER PATTERNS

INTRODUCTION

In the Western Region, with its rugged topography, the diurnal and terrain effects on standard synoptic surface observations are frequently equal to or greater than those associated with migratory synoptic systems. Forecasters must take these local effects into account if a proper synoptic analysis is to be made. For the preparation of very short-range forecasts (6 - 12 hours), an accurate analysis is one of the most important factors.

The first edition of this Technical Memorandum was issued in April 1966, based on descriptive information supplied by MIC's at stations in the Western Region. This revised edition includes descriptions not available at that time. Also, descriptions of some Canadian reporting stations have been included, based on information kindly supplied by Mr. F. W. Benum of the Department of Transport, Toronto, Ontario.

The information in this Memorandum should be of considerable value for the Small-Scale Analysis and Prediction Program. We expect that forecasters in the Region will become familiar with local effects in their area of concern. We also hope that NMC analysts will find this material helpful in preparing surface charts distributed by facsimile.

Two examples are given in which local topographic and diurnal effects mask those associated with the migratory synoptic systems.

The appendix illustrates a method of coding some of the described station information. It is recommended that forecasters encode this information on a map covering the local area of interest.

ARCATA, CALIFORNIA (FAA)

The airport is located on a bluff overlooking the Pacific Ocean. The terrain slopes upward to the east, reaching an elevation of 1,200 feet 6 miles to the northeast and east, and 5,000 feet 28 miles southeast. During summer, prevailing winds are northwesterly with speeds generally less than 10 knots. Strong winds in winter tend to blow north or south, parallel to the coast. With approach of a frontal system, winds may be strong southerly, shifting to southwest--northwest after frontal passage depending on the speed of the front and rate of pressure rise behind the front. Summer fogs are frequent with onshore winds.

ASTORIA, OREGON (WBAS)

The station is located four miles east of the Pacific Coast on the south bank of the Columbia River. The mountains of the coast range are 14 or more miles away to the south and east. There is a pronounced west-northwest sea breeze in the late afternoon during spring and summer, which may reach speeds of 15-20 knots. Stratus from the ocean is frequent with an onshore flow. Occasionally in summer the thermal trough will push northward along the Oregon coast and winds at Astoria will be east to northeast with warm dry weather.

The station is well exposed to southerly gales from winter storms moving in from the southwest.

BAKER, OREGON (FAA)

The Baker airport is located near the southern end of a long egg-shaped north-south valley at an elevation of 3,400 feet. The Blue Mountains, 10 miles west, rise to 6-9,000 feet, and the Wallowa Mountains, 20-45 miles northeast, rise to 7-9,800 feet. Surface winds are primarily from the north or southeast.

Fronts approaching from the west and northwest are forced aloft by the high terrain, and pressure rises are more significant of frontal passage than wind shifts, which may be delayed 2-4 hours. Winds are sometimes northerly ahead of fronts and increase in speed with the frontal passage. Upslope weather, with low ceilings and continuous precipitation, is usually associated with an easterly or southeasterly flow.

BAKERSFIELD, CALIFORNIA (WBAS)

The station is located in the southern portion of the San Joaquin Valley, which is oriented north-northwest, south-southeast and is about 50 miles wide. The average elevation of the coastal range to the west and southwest is about 4,500 feet, the Tehachapi Range to the south and southeast about 6,000 feet and the Sierra Nevada to the east and northeast near 10,000 feet. Passes to the east, south and west-northwest have considerable effect on local weather conditions.

During spring, summer and fall the prevailing wind is northwesterly 8-12 knots, but with a very light southeasterly breeze in the early morning. Marine air breaking through the pass to the west-northwest acts like a cold front at times in the summer, with northwesterly winds 20-25 knots and blowing dust.

In winter and early spring, with a strong basin high and a low to the west, winds up to 70 knots may blow out of the passes to the east and south. These narrow currents fan out over the valley, and speeds of 25-30 knots are recorded at the airport, accompanied by blowing dust. Wind shifts with frontal passages occur only when a strong cold front moves southward through the valley, and velocities may be northwesterly 20-30 knots behind the front. Stable air trapped in the valley in winter is moved out only by a strong cold front, since weak fronts ride over the top of the inversion.

BELLINGHAM, WASHINGTON (FAA)

The airport is located on the northeast shore of Puget Sound, with the Cascade Mountains rising about 25 miles to the east. Winds ahead of Pacific fronts are frequently strong southerly and diminish in speed with the frontal passage, but remain southerly. Arctic air occasionally drains out of the Fraser River Valley to the northeast causing gale winds and very low temperatures.

There are no visibility markers between 1-1/2 and 9 miles.

BILLINGS, MONTANA (WBAS)

The airport, elevation 3,600 feet, is located on a rimrock about 400 feet above the valley of the Yellowstone River which flows in a northeasterly direction. Fifty to seventy miles to the southwest a range of the Rocky Mountains rises to over 12,000 feet. Mountains 35 miles to the south rise to 8,700 feet, and mountains 35 miles to the northeast rise to 6,000 feet. The Yellowstone Valley has a marked channeling effect on the surface wind. Fair weather predominates with southwesterly chinook winds; low ceilings and visibilities

and precipitation occur with upslope north through easterly winds. The winds are representative with regard to frontal passages.

Fog is infrequent, occurring with easterly winds, or briefly when winds are shifting from southeast to southwest as a shallow polar air mass is lifted over the rimrock while retreating eastward.

BISHOP, CALIFORNIA (WBAS)

The station is located in a narrow north-south valley at an elevation of 4,000 feet with the crest of the 12-14,000 foot Sierra Nevada 15 miles to the west, and mountains nearly as high and close to the east. There is a marked channeling of the wind up and down the valley. Northerly drainage winds about 15 knots occur at night, and the normal afternoon surface wind is southerly 10-15 knots. Frontal passages from the west are usually delayed several hours by the Sierras with the actual passage at the station difficult to determine. Frontal passages from the north can be followed more easily. Due to the rain shadow effect from the Sierras, very little precipitation falls with a west-to-northwest flow. A strong mountain wave is usually noted in the lee of the Sierras when high-speed west to southwest winds aloft are observed.

BLANDING, UTAH (2nd. ORDER)

The station is located at an elevation of 6,000 feet with the Abajo Mountains rising to an elevation of 11,000 feet about 14 miles to the north and northwest. In the immediate vicinity of the station, the ground slopes gently downward to the south. A southerly flow is markedly upslope, and the heaviest precipitation occurs in flows of this type. Nocturnal drainage winds are light northwesterly.

BLUE CANYON, CALIFORNIA (WBAS)

The station is located on the west slope of the Sierra Nevada at an elevation of 5,300 feet. The airport has AMOS wind equipment. West-to-southwest winds are markedly upslope, and east winds are downslope. The diurnal flow is upslope from 10:00 a.m. to early evening. Wind shifts with frontal passages are not well marked.

BOISE, IDAHO (WBAS)

The Boise Municipal Airport, elevation 2,900 feet, is located on a bench about 150-feet above the northwest-southeast-oriented Boise River Valley. To the west and northwest, the terrain is fairly level. To the southeast, the terrain is hilly and to the north and northeast, mountains rise to about 7,500 feet within 15 miles.

There is a pronounced diurnal wind regime, with northwesterly upslope winds 5-15 knots from midmorning until 2-4 hours after sunset, then southeasterly drainage winds of 3-8 knots until sunrise. These wind patterns frequently mask changes that would normally occur with frontal passages. Pooling of cold air in the valley in winter will cause weak fronts to pass aloft.

BROOKINGS, OREGON (2nd. ORDER)

The station is located on a bluff overlooking the Pacific Ocean. Winds from all directions except south-southeast to southwest are unrepresentative because of nearby trees. Speeds of strong northwesterly winds are estimated to be less than half of the true gradient. There is a marked increase in precipitation due to orographic lifting by the Coast Range.

BRYCE CANYON, UTAH (FAA)

The airport is located on a plateau at an elevation of 7,600 feet. The ground drops sharply about 3 miles to the southeast. Mountains rise to 10-11,000 feet within 20 miles in most directions. There is little local effect on winds, and representative shifts occur with frontal passages. Weather and temperature are also representative of synoptic-scale conditions.

BURLEY, IDAHO (FAA)

The airport lies at an elevation of 4,000 feet in the east-west Snake River Valley of southern Idaho. There is a strong channeling of the wind up and down the valley. Afternoon west to west-southwest upslope winds are 10-25 knots and easterly downslope winds 5-15 knots prevail during night and early morning hours. Diurnal and topographic effects mask weak frontal passages. Even strong fronts may cause only short-lived wind shifts. During the warm season, southwesterly winds from extensive irrigated areas can cause cooling, giving false indication of frontal passages.

BUTTE, MONTANA (FAA)

The station is located in a narrow north-south mountain valley at 5,600 feet elevation with the Continental Divide 2-1/2 miles to the east and 2,600 feet above the airport. There are also passes through the Divide 6 and 8 miles to the southeast and south, respectively, at elevations near 1,000 feet above the airport. There is a good exposure to weather systems moving in from the northwest only, which is the upslope direction. Many Pacific fronts are either forced aloft or made diffuse by the mountainous terrain. In the colder half of the year, less than 15 percent of such fronts lower the ceiling to 2,500 feet or less. Persistent low clouds and precipitation can result from eastward moving waves on a polar front in southeast Idaho, or occasionally from stratus moving over the Divide from the northeast, with a low to the southwest of Butte. Fog is very infrequent, occurring only with a northwesterly upslope gradient flow.

CAPE BLANCO, OREGON (COAST GUARD)

The station is located on a narrow point of land jutting out into the Pacific Ocean. It is well exposed to winds from all directions, but speeds appear to be well above gradient values at times. Afternoon northerly winds of 30 knots occur during summer when the thermal trough extends northward into Oregon. The orographic effect of the Coast Range causes an increase in precipitation.. The surface pressure often appears too low (at present, it has not been determined if this is a real effect, possibly due to strong winds, or erroneous observations).

CEDAR CITY, UTAH (FAA)

The airport is located in a north-south valley at an elevation of 5,600 feet. Mountains to the east and west rise to above 10,000 feet with the closest mountains about 5 miles east-southeast.

The most marked upslope flow is from the west through north. Ahead of a cold front, there is a strong channeling of winds up the valley from the south. Winds usually shift to northwest with frontal passage, and the Pacific fronts usually weaken considerably by the time they reach Cedar City.

COEUR D'ALENE, IDAHO (SAWRS)

The station is located in a broad, level, north-south valley at an elevation of 2,300 feet. Winds tend to blow up or down the valley, but respond fairly well to the pressure gradient. West-to-southwest flow is upslope since the highest mountains are located to the east of the station.

COLVILLE, WASHINGTON (2nd. ORDER)

The station is located in a generally north-south valley in the mountainous northeast part of Washington. Light northeast drainage winds prevail at night with light southerly or westerly winds during the day. The large-scale upslope flow is from the southwest. The protected valley location causes definite modifications of synoptic-scale winds.

CORVALLIS, OREGON (SAWRS)

The airport station is located near the western edge of the north-south Willamette Valley, which is nearly level and about 30 miles wide at this point. The Cascade Mountains lie to the east. The Coast Range to the west averages near 2,000-foot elevation, but coastal fog and low clouds flow through passes and over the range. Strong west and southwest winds, blowing through these passes, are observed at the airport with a low-pressure center to the north. The diurnal wind regime results in northerly 10-15 knot winds during the afternoons. The anemometer exposure 60 feet above ground gives higher wind speeds than would be observed with the normal 20-foot exposure. Freezing rain occasionally develops in winter with Arctic air in the Willamette Valley and overrunning moist Pacific air.

CRESCENT CITY, CALIFORNIA (FAA)

The airport station lies on a small peninsula jutting out into the Pacific Ocean giving it a marine exposure on the south, west and north. The foothills of the Coast Range begin 15 miles to the east and rise to 6,000-foot elevation about 30 miles away.

Prevailing winds during summer are northwesterly, and fog is frequent. Occluded fronts associated with deep lows off the coast are preceded by strong southerly winds which diminish in speed and shift to southwest with the frontal passage. The passage of fast-moving well-developed fronts is usually marked by a sharp wind shift to the northwest.

CUTBANK, MONTANA (FAA)

The station is located in the plains 40 miles east of the Continental Divide. A low east-west ridge lies 35 miles to the north. The wind is representative of the prevailing flow. There is a strong downslope effect with southwest to west winds. The strongest upslope effect occurs with east-to-southeast flow.

DAGGETT, CALIFORNIA (FAA)

Daggett air field is located in the Mojave Valley at an elevation of 1,900 feet. The valley slopes downward gradually to the east-northeast and east-southeast with a 4,000-foot mountain range 25 miles east of the station. Mountains 12-17 miles south and southeast reach to 6,000 feet. Under weak pressure gradients, winds will be west-southwest to west-northwest downslope at night, becoming nearly calm from 10 a.m. to noon and east-southeast upslope in the afternoon.

With a cold front moving in from the Pacific, wind at Daggett will usually exceed 20 knots from the west-southwest 6-12 hours before the front arrives, shifting to the west or west-northwest and occasionally reaching 30-40 knots with the frontal passage. Wind speeds frequently continue above 20 knots for 24-36 hours, especially with a wave formation on the front to the northeast of Daggett.

With a strong stagnant basin high in winter, east-northeast winds 15-20 knots prevail.

THE DALLES, OREGON (FAA)

The Dalles Airport is located on the north side of the Columbia River on a point of land nearly enclosed by a loop in the generally east-west river and about 6 miles southeast of the Columbia Gorge. The field is about 150 feet above the river with a 3,200-foot east-west ridge 5 miles to the north. The crest of the Cascades is 30 miles west. Channeling of the air through the Columbia Gorge is very pronounced, and west-to-northwest winds prevail. Easterly winds are usually less than 15 knots. Winds are often west to northwest ahead of a Pacific front and merely increase in speed with the frontal passage. Pronounced wind shifts with a frontal passage are rare.

DELTA, UTAH (FAA)

The airport station, elevation 4,800 feet, is located near the center of a large, flat desert-like valley. A north-south mountain range lies about 12 miles to the east. Winds are generally representative of the synoptic situation. The station is subject to strong southerly winds and blowing dust during the spring, summer and fall.

The second-order station is 4 miles southwest of Delta with a similar exposure.

DOUGLAS, ARIZONA (FAA)

The Bisbee-Douglas airport, elevation 4,100 feet, is located in a north-south valley 30-miles wide and sloping downward to the south. The nocturnal drainage wind is light northerly. Smoke from a smelter to the south occasionally lowers visibility to one mile or less. Most frontal passages are dry and diffuse, with a gradual wind shift. When cold air is trapped in the valley, fronts usually pass aloft.

EL CAJON, CALIFORNIA (GILLISPIE FIELD, SAWRS)

The station is located in the northern part of the El Cajon Valley at an elevation of 400 feet, and about 16 miles east of the Pacific Ocean. The valley is 2-4-miles wide and about 7 miles long with 800-foot hills to the west and 1,200- to 1,400-foot hills, 2 miles east-northeast and 4 miles south.

Coastal stratus frequently reaches the field from mid-April to early October.

Strong winds are infrequent because of protection afforded by surrounding hills. However, with a strong high over the plateau and low off the southern California coast, northeasterly Santa Ana winds reach 30 to 40 miles per hour, with visibility restricted by blowing dust. Strong westerly winds occasionally occur during winter and spring following the passage of a short cold front.

ELKO, NEVADA (FAA)

The station lies in the northeast-southwest Humboldt River Valley, at an elevation of 5,000 feet. Mountains to the northwest reach to 10,000 feet, and the Ruby Mountains to the southeast range up to 12,000 feet. West-to-southwest flow is generally upslope. With weak pressure gradients, winds are light southwesterly during late forenoon and afternoon. There is a 3-5 knot east-to-northeast wind from about 4:00 a.m. to an hour after sunrise. The local wind regime has only a small effect on fronts. Northwest winds behind cold fronts are usually short-lived because of small-scale wave formations on the front with the wind frequently veering to the northeast or southeast shortly after frontal passage. South-to-southwest winds are increased by the topography when lows pass eastward to the north of the station. This effect at times retards the south portion of cold fronts associated with such lows.

On rare occasions persistent fog forms in the Elko area under a stagnant basin high. However, even relatively weak frontal passages will cause clearing, as compared to the more persistent fog in the lower valleys of western Utah and western Nevada.

ELY, NEVADA (WBAS)

The station is located in the center of a north-south valley 8 miles wide at an elevation of 6,200 feet. Mountains to either side rise to 4,500 feet above the valley. There is a marked southerly drainage wind during the night and early morning hours which usually occurs when the pressure difference, Elko minus Ely, is less than 5 mbs.

Northeast-southwest-oriented fronts, unless very strong, produce only light or no precipitation. In general, the airport is relatively dry compared to nearby areas.

EPHRATA, WASHINGTON (FAA)

The airport is located in the northwest portion of the Columbia Basin at an elevation of 1,300 feet. Nearby hills to the west and northwest reach to 2,900 feet. An east-west ridge 35 miles south rises to 2,700 feet. The Cascades lie about 80 miles to the west.

When a Pacific front approaches the Cascades, a weak northeast-southwest trough frequently forms over eastern Washington, and the wind at Ephrata becomes southerly to easterly, shifting to west or north when the trough moves to the east of the station, regardless of the frontal position. Wind shifts with frontal passages from the west occur only when the front is well marked and located in the surface trough. With east-west isobars and a low to the north, the wind at Ephrata is often directly across isobars from the south.

EUGENE, OREGON (WBAS)

The station is located at the southern end of the north-south Willamette Valley. The Cascade Mountains rise to the east, and the Coast Range to the west at an elevation of 1,500 to 2,500 feet acts as a barrier to fog and low clouds. There is a strong topographic effect on winds which are predominantly from the north or southwest. Afternoon up-valley winds are northerly 5-15 knots. Occasionally during winter, Arctic air is trapped in the valley. With moist overrunning Pacific air, freezing rain may occur.

FLAGSTAFF, ARIZONA (WBAS)

Flagstaff airport lies at an elevation of 7,000 feet on the backbone of the Coconino Plateau. The 12,000-foot San Francisco Peaks are 14 miles to the north. The terrain drops sharply about 10-miles south of the station. South-to-west flow is markedly upslope. A strong cold front will shift the wind to northwesterly, but the wind will not persist from this direction. A northerly flow is deflected to northeasterly by the San Francisco Peaks.

Strong solar heating of the black volcanic areas surrounding Flagstaff contributes materially to the high frequency of summer thunderstorms.

FORT HUACHUCA, ARIZONA (ARMY)

The station is located at an elevation of 4,700 feet on a plain sloping downward to the northeast. The diurnal wind regime results in light southwesterly-or-westerly-downslope winds at night, with easterly winds prevailing in the morning and westerly winds in the afternoon. In winter and spring, supergradient gusty west to southwest winds accompany the passage of well-defined Pacific cold fronts. On rare occasions, Polar frontal passages in winter bring northerly upslope winds.

FRESNO, CALIFORNIA (WBAS)

The station is located in the San Joaquin Valley with the crest of the Sierras 50-to-70-miles east and the Coast Range 45 miles to the west. Transpiration from irrigated farm crops on the airport during the growing season may result in dewpoints being unrepresentatively high.

Winds tend to blow up or down the valley, i.e., northwest or southeast. A strong high over Nevada and Oregon brings strong northerly winds to the west side of the valley, but an eddy results in southeasterly 5- to 15 knot winds at Fresno. Wind directions seldom reflect a frontal passage. In many cases, the front is imbedded in a strong northwesterly flow, and the wind will not shift with the frontal passage although the speed may increase. At times during the winter cold, stable air is entrapped in the valley, accompanied by persistent fog, and weak fronts will pass aloft with no effect on the surface wind. Pressure change, allowing for diurnal effects, is one of the best indicators of frontal passages.

In summer evenings, there is a persistent northwesterly jet wind extending from about 500 feet to 4,000 feet above the valley floor. Winds are nearly calm at the surface but reach a peak speed of 20 knots or more at 2,000 feet.

GILA BEND, ARIZONA (2nd. ORDER)

The station is located in nearly flat desert terrain at an elevation of 800 feet. Isolated mountain ranges are visible in all directions. The diurnal wind is south-southeast 8-12 knots at night and morning with a west-southwest wind during afternoons and evenings. Strong winds associated with summer thunderstorms and winter frontal passages frequently reduce visibilities in dust.

GOODING, IDAHO (2nd. ORDER)

The airport is located at an elevation of 3,700 feet on a plateau north of the Snake River which runs in a general east-west direction. Predominant winds are westerly 10-20 knots from midmorning until after sunset with downslope easterly winds 5-15 knots during night and early morning hours. This flow pattern often masks wind changes that occur with weak frontal passages. Diurnal wind changes plus extremely varied ground cover make temperatures unrepresentative for synoptic analyses.

GRAND CANYON, ARIZONA (SAWRS AND 2nd. ORDER)

The airport station is 7 miles south of the National Park at an elevation of 6,600 feet in rolling heavily forested country. There are no visibility markers beyond the confines of the airport except for a narrow view of the north rim 23 miles away. North-south winds are accentuated by a cut in the hills.

GREAT FALLS, MONTANA (WBAS)

Great Falls International Airport is located on an extensive V-shaped plateau between the Sun and Missouri River Valleys, about 2 miles southwest and 300 feet above the confluence of the two rivers. Station elevation is 3,700 feet. The Continental Divide is 80 miles west with the Belt Mountains 30-40 miles to the south and east. South through northwest winds are downslope; north through east-southeast winds are upslope. Most Pacific fronts moving in from the west are accompanied by little or no precipitation. Most precipitation and clouds accompany fronts moving down from a northerly direction.

GREEN RIVER, UTAH (2nd. ORDER)

The station is located at an elevation of 4,100 feet, with the Green River flowing north-south about a mile to the east. About 6-12 miles to the northwest through east-southeast, the ground rises sharply to about 2,000 feet above the station. The Wasatch Plateau, 70 miles west, rises to above 10,000 feet. Cold fronts approaching from the west are weakened considerably by this range, and many frontal passages are dry at the station. There is a strong channeling of southerly winds ahead of cold fronts, frequently bringing blowing dust into the area.

HAILEY, IDAHO (SAWRS)

The station is located at an elevation of 5,300 feet in a narrow north-south valley with hills 1/2 mile to the east and 1 mile to the west, rising to near 2,500 feet above the valley floor. The drainage wind is from northwest to southeast.

HANKSVILLE, UTAH (2nd. ORDER)

The airport, elevation 4,400 feet, is located in desert country in the center of a shallow bowl with the ground rising to about 5,000 feet within a radius of 10 miles. Drainage is towards the southeast. The isolated 11,000-foot Henry Mountains are 20 miles south-southwest. A high mountain barrier 40-50 miles to the southwest through northwest shields Hanksville from the weather associated with Pacific cold fronts or a moist westerly flow. There is a strong channeling of southerly winds ahead of cold fronts, frequently accompanied by blowing dust in spring and early summer.

HAVRE, MONTANA (WBAS)

The airport lies on gently rolling plains at an elevation of 2,600 feet, approximately 150 miles east of the Continental Divide. The Bear Paw Mountains lie 30 miles to the south, reaching 2,000 to 4,000 feet above the station. Upslope winds are north through east; downslope winds from south through west. Wind observations are representative with respect to frontal passages.

HELENA, MONTANA (WBAS)

The observation site is located at the airport, elevation 3,800 feet, in a valley entirely surrounded by mountains and 11 miles east of the Continental Divide. The normal diurnal wind regime has a light northeasterly flow in the afternoon with a southwest drainage wind at night. Westerly chinook winds usually develop with higher pressures to the southwest of Helena. During winter, very cold Arctic air may be trapped for days in the valley. The chinook wind at times overrides the trapped cold air, which then may not be displaced until the arrival of a strong Pacific front.

Because of the protective mountains, Arctic air from the north will not move en masse into the Helena Valley unless the cold air reaches a depth of about 6,500 feet above sea level. There is a marked orographic increase in precipitation in a southwesterly direction from the airport toward the mountains.

HOQUIAM, WASHINGTON (FAA)

The airport is located on the north shore of a bay 10 miles east of the Pacific coastline. The field is nearly surrounded by water and tidelands, and the surrounding terrain within about 20 miles is fairly flat. Westerly sea breezes of 10-15 knots are common during summer afternoons. Frontal passages are usually well marked by wind shifts except when a deep trough or low remains off the coast.

IMPERIAL, CALIFORNIA (FAA)

The airport is located in the broad, relatively flat Imperial Valley. The southern tip of the Salton Sea is 25 miles north of the station. The Laguna Mountains rise to above 6,000 feet and are 20-40 miles west of the station. The nearby terrain is desert-like, slightly modified by irrigation.

Winter cold fronts bring showers and squalls to the area when the moist marine air is deep and unstable. Strong westerly winds often precede late winter and spring frontal passages with the wind occasionally continuing strong long after the frontal passage, accompanied by blowing dust and sand. Mountain waves are formed east of the Lagunas with a strong westerly flow aloft.

KALISPELL, MONTANA (WBAS)

Flathead County Airport, elevation 3,000 feet, is located in a long north-south valley with mountains to the east rising to 7,500 feet and to the west near 6,000 feet. The valley width is close to 20 miles. Under a weak pressure gradient, March through September, the prevailing wind from about 11:00 a.m. to 7:00 p.m. is southeasterly off Flathead Lake. Wind speeds often reach 15-20 knots in the afternoon. The nocturnal drainage wind is from the north.

Under a persistent high in winter, cold air stagnates in the valley. A strong cold front is required to clear the trapped air out under these conditions. Occasionally during the winter when Arctic air is banked up against the east slope of the Rockies and spills over the low points in the Continental Divide, very strong winds reach the airport from the canyon to the northeast.

KLAMATH FALLS, OREGON (WBAS)

The station is located in a basin at an elevation of 4,000 feet. The crest of the Cascade Range is about 30 miles to the west. Nearby mountains cause fluctuations in the local wind when speeds are light, making the observations unrepresentative at times. Under strong pressure gradients, the wind usually blows at right angles to the isobars, toward lower pressure. There is a strong rain-shadow effect from the Cascades with a westerly flow. Cold front passages from the north and west are usually dry.

LAS VEGAS, NEVADA (WBAS) (McCARRAN FIELD)

McCarran Airport, elevation 2,200 feet, is located near the center of a broad desert valley which is almost surrounded by mountains ranging from 2,000 to 10,000 feet higher than the airport. The valley is open to the northwest and has low mountains to the southwest. These features partially account for the fact that most frequent winds are from the southwest with a secondary maximum from the northwest. The highest mountains in the vicinity are to the west and straight westerly winds are infrequent.

The lowest part of the valley is in the northeastern quadrant and nighttime temperatures there can be considerably lower than those at the airport.

Cold fronts moving in from the northwest are frequently diffuse in this area and mixed cooler air sometimes arrives ahead of other frontal manifestations.

Southerly winds reach a rather pronounced maximum speed during afternoon hours while northerly winds tend to be slightly stronger during early mornings.

High pressure systems over the Great Basin in winter are accompanied by cold northerly winds. These winds are most pronounced through the north-south valleys of Lake Mead and Lake Mohave.

There are abundant sources of dry soil in Las Vegas Valley and blowing dust with reduced visibilities occurs frequently.

LEWISTON, IDAHO (WBAS)

The Lewiston-Nez Perce County Airport, elevation 1,400 feet is located on a nearly flat plateau near the confluence of the Snake and Clearwater Rivers about 700-feet above the bottom of these steep-sided river valleys. The plateau rises very gently to the southeast of the airport. The Blue Mountains rise quite abruptly to 6,000 feet about 25 miles distant in the southwest quadrant from the airport. The north rim of the Clearwater River Canyon rises very sharply to a prairie some 5 miles north of the airport. Mountains to the south rise sharply to 5,000 feet at a distance of 15-20 miles.

A light easterly drainage wind, generally under 15 knots, occurs almost nightly between midnight and 10:00 a.m. Under favorable gradient conditions, with a low-level inversion present and a low off the Washington-Oregon coast, easterly winds as high as 25 knots are observed and continue until the east-west gradient is reduced or strong southerly winds in advance of a front break through the inversion. These strong easterly gradient winds that persist through the daylight hours during winter months have a pronounced effect upon the diurnal temperature range, with maximum temperatures at Lewiston far below stations in the Columbia Basin and on the surrounding prairies. On days with light winds, Lewiston temperatures will lag several degrees behind basin stations until near noon due to the drainage wind and rather strong surface inversion.

LEWISTON, IDAHO (WBAS) (Continued)

Pacific storms that drop substantial precipitation across the Columbia Basin frequently cross Lewiston with no more than a trace. This is especially true if strong southerly surface winds precede the passage of the cold or occluded front. Although winds will shift to the west with the frontal passage, both south and west winds are downslope into this valley and precipitation will likely be very light or nonexistent. Precipitation from such storms frequently is substantial to the east of Lewiston where the terrain begins to rise. If southerly winds in advance of strong Pacific fronts break through the surface inversion, the Lewiston temperature will rise far above temperatures at stations to the west, north or east. This situation is frequently accompanied by a break in the prefrontal cloudiness.

The strongest winds to occur at this station are from 270 to 320 degrees. Winds straight out of the north are rare and generally under 15 knots.

Arctic air can enter the Lewiston area from either the northwest or northeast. If the push through the Columbia Basin is strong, Arctic air will enter Lewiston on a west to northwest wind of 15 to 25 knots. If the push through the Columbia Basin is slow or relatively weak, Arctic air will enter Lewiston from the northeast with a wind of 15 to 25 knots.

Under strong wintertime inversions, extensive periods of stratus, fog and industrial smoke will cover the Lewiston Basin, while communities on the surrounding prairies remain above the inversion. Lewiston generally remains stratus-free until 24 to 48 hours after stratus has become solid throughout the Columbia Basin.

LEWISTOWN, MONTANA (FAA)

The station, at an elevation of 4,200 feet, is located in a saddle-like formation with mountains to the north, northeast and south. The exposure is open to the northwest, and winds from 295 to 320 degrees can produce strong upslope effects with low ceilings and visibilities. Due to channeling effects, the surface wind behind a cold front moving southward from Canada will remain from the northwest for several hours after the wind at nearby stations has shifted to northeast.

LOS ANGELES, CALIFORNIA (WBAS)

The International Airport is located on the coastal plain with the main Coast Range extending from west-northwest to east-southeast, the nearest point being about 30 miles north. 2,000-foot hills rise 25 miles to the east and 12 miles to the north, and 1,500-foot hills

LOS ANGELES, CALIFORNIA (WBAS) (Continued)

11 miles to the south. The Pacific Coast is 3 miles west of the station.

The normal afternoon sea breeze is west-southwest. However, when the "Catalina Eddy" is present, light southerly winds blow up along the coastline. This eddy is caused by strong northerly winds blowing past Point Arguello.

Twenty-to-thirty knot northwest-to-north winds with occasional gusts to 50 knots are observed at the airport following a cold frontal passage when there is a fairly strong high behind the front and a low over Nevada. Strong northeast to easterly Santa Ana winds occur occasionally from October through March with a strong plateau high. The airport is relatively protected from these winds as regards to both frequency and peak speeds. The latter seldom exceeds 25 knots.

LOVELOCK, NEVADA (FAA)

The airport, elevation 3,900 feet, is located near the entrance of a valley which extends northeastward with mountains to the northwest and southeast rising to above 6,000 feet. The region is semiarid with many dry lakes. Southerly winds may reach 30-40 knots in advance of Pacific storms accompanied by blowing dust. Cold front passages are usually marked by wind shifts to the west or northwest with the speed seldom exceeding 25 knots and decreasing within a few hours.

MALAD CITY, IDAHO (FAA)

The station, elevation 4,500 feet, is located near the center of a north-northwest, south-southeast-oriented valley which is about 8 miles wide. Drainage is toward the south-southeast but is slight. Mountains to either side of the valley rise to about 9,000 feet.

Diurnal winds are very light and tend to be up and down the valley. Because of high mountains to the west, typical wind shifts with the passage of a cold front are not usually observed, but the wind will become north-northwest and fairly strong sometime after the frontal passage.

MEACHAM, OREGON (WBAS)

Meacham Airport is located on the southern end of a meadow in the heart of the Blue Mountains at an elevation of 4,000 feet. The

terrain slopes downward to the north. Dense forest, less than half a mile to the north and east, causes rapid fluctuations in the wind direction. Because of surrounding hills, air movement is generally light, with wind speeds rarely exceeding 20 miles per hour.

Cold front precipitation at Meacham continues longer than at stations in the Columbia Basin to the west because of orographic effects. Convective showers are numerous in the summer.

MEDFORD, OREGON (WBAS)

Medford Airport, elevation 1,300 feet, is located in a valley with mountains ranging in height from 3,000 to 6,000 feet on all sides and at distances of 4-20 miles from the station. The principal diurnal wind effect consists of 10- to 20-knot northwesterly winds during many summer afternoons. Due to pooling of cold air, there is little wind at night.

During late fall and winter, with a strong basin high, cold air is entrapped in the valley, accompanied by persistent fog and smoke. A strong cold front or southeast foehn wind is required to clear out the valley under such conditions. There is a strong rain-shadow effect from the surrounding mountains. Summer coastal low stratus or fog does not penetrate inland to Medford.

MILES CITY, MONTANA (FAA)

The airport is located on the western edge of the Great Plains at an elevation of 2,600 feet. The airport is a few hundred feet above the Yellowstone River in a southwest-northeast-oriented valley. The valley is too shallow to produce a marked channeling of the wind. The primary upslope flow is from the northeast. Most weather is associated with fronts from the north rather than Pacific fronts from the west.

MILFORD, UTAH (WBAS)

The Milford Airport, elevation 5,000 feet, is located in a north-south valley with mountains 10 miles to the east and 15 miles to the west rising 5,000 feet above the valley floor. Drainage is to the north. The station is 200 feet above the dry river course in the valley bottom to the east. There is a marked north-south channeling of the winds.

MISSOULA, MONTANA (WBAS)

The Missoula Airport is located near the northwest side of a bowl-like valley at an elevation of 3,200 feet. Nearby mountains range mostly between 3,000 to 5,000 feet above the valley floor. The narrow Bitterroot Valley opens to the south and there is a one-half mile gap in the mountains to the east. When Arctic air east of the Divide builds to sufficient height to spill westward across the mountains, strong easterly winds blow through this gap.

During the warmer months, diurnal up-valley winds from the northwest may reach 10- to 15-knots in the afternoon. Nocturnal downslope winds are light and variable. Due to the sheltered location of the station, wind speeds are usually less than that indicated by the pressure gradient in the area.

In late fall and winter, under the influence of a stagnant anticyclone, persistent fog and smoke occur under a strong inversion. Weak or moderately strong Pacific cold fronts do not destroy this stable layer, but merely ride over the inversion as a front aloft.

MONTAGUE, CALIFORNIA (FAA)

Siskiyou County Airport, elevation 2,200 feet, is located in the north end of a north-south valley with mountains 12 miles to the east rising to 8,000 feet. Mountains 10- to 15-miles to the west rise to 6,000 feet, and mountains to the north rise to 7,000 feet. 14,000-foot Mt. Shasta lies 30 miles to the southeast. Drainage is to the north, and southeasterly winds usually prevail both day and night under weak gradients.

Winds are southwesterly ahead of a Pacific front and will shift to northwesterly for a few hours behind a strong cold front. Fog is confined to the months December-May.

MOUNT SHASTA, CALIFORNIA (WBO)

Mount Shasta, elevation 3,500 feet, is located in a narrow north-south valley with the rugged northern California coastal mountains rising to 10,000 feet on the west and Mount Shasta towering 14,100 feet to the northeast. The station is greatly influenced by topographic features, especially with regard to winds being channeled through the valley. Northerly drainage winds 5- to 15-miles per hour are prevalent during night and early morning hours.

A cinder cone rising 2,900 feet above the valley floor 4 miles north of the station has a pronounced small-scale effect on the winds,

caused by constricting the surface flow in the valley. Thus, northwesterly wind speeds are two to three times as fast at the station than at locations either to the north of the cinder cone, or at locations two or three miles south of the station.

Pacific storms accompanied by strong southerly winds blowing up the narrow Sacramento River Canyon produce a marked orographic increase in precipitation from valley stations 50 miles to the south up to the vicinity of Mount Shasta. The valley slopes gradually downward to the north of Mount Shasta.

Frontal systems moving across the mountains to the north or west frequently dissipate and produce only light amounts of precipitation at the station.

Fog is a rare occurrence at the station. Nocturnal inversions are frequent and pronounced, but nearly always dissipate before noon.

NEEDLES, CALIFORNIA (FAA)

The airport, elevation 900 feet, is located in desert terrain several miles west of the north-south Colorado River. The area to the east and northeast is generally mountainous with peaks rising to 5,000 feet within 35 miles of the field. There are lower mountains 15 miles south-southeast, and mountains rise to 6,800 feet 30 miles to the west.

Cold fronts moving through the area in winter produce strong gusty winds and occasional rain. Remnants of tropical storms from the south occasionally produce heavy thunderstorms in late summer and early fall.

NEWPORT, OREGON (2nd. ORDER)

The station is located on the immediate Pacific Coast, with the Coast Range rising to 2,000 to 3,000 feet 12 miles to the east. Wind exposure is good. Coastal fog and stratus are frequently present during summer. This station is 4 miles north of the Newport airport, and at the same elevation and distance inland from the coast. Weather conditions at the 2nd-order station are likely to be representative of those of the airport.

NORTH BEND, OREGON (FAA)

The North Bend Airport is located on a bay 2-1/2 miles from the Pacific Ocean. The terrain is low and rolling with 700-foot hills 3-7 miles to the east. The Coast Range rises up to 3,000 feet about

NORTH BEND, OREGON (FAA) (Continued)

15 miles east of the station. Frontal passages are usually well marked by wind shifts. During summer afternoons, wind speeds usually reach 10- to 25-knots from the northwest or north. Coastal fog and stratus are present on most summer nights, with daytime clearing usually occurring.

OLYMPIA, WASHINGTON (WBAS)

The Olympia Airport lies five miles south of the southern tip of Puget Sound, in flat to gently rolling terrain. The foothills of the Cascades are about 10 miles to the southeast, with hills 12 miles to the west ranging up to 2,600 feet. Topography masks the effect of frontal passages on the wind, with a southwesterly direction usually prevailing both before and after the frontal passage. Only with a very strong circulation will the wind agree with the gradient. The temperature also usually shows very little change with frontal passages, and the best indicators for the latter are rising pressures and improved ceilings and visibilities. The Olympia area is especially prone to fog under stable conditions. Smoke from slash burning may reduce the visibility to near zero at times.

OMAK, WASHINGTON (2nd. ORDER)

The station is located in the narrow north-south Okanogan Valley at an elevation of 1,200 feet on a small plateau about 300 feet above the river bottom. There is strong channeling of the winds up and down the valley, and winds do not readily blow from the west or east in response to pressure gradients. Frontal passages from the west are seldom indicated by wind shifts. Frontal passages from the north show good wind shifts. Stratus and fog are often persistent under strong winter inversions, and fronts usually pass aloft over the entrapped cold air unless accompanied by a strong north-south pressure gradient.

ONTARIO, CALIFORNIA (FAA)

Ontario International Airport is located in the northeast end of the Los Angeles Basin. Mountain ranges to the north and east average 5,000 feet in elevation with peaks over 10,000 feet. Lower mountains 15 miles to the south average 2,000 feet. Cajon Pass, 20 miles to the north, opens into the Mojave Desert. Afternoon visibility is usually 2-4 miles because of smoke and haze, especially with a

southerly or southwesterly flow. During cold weather in winter, smoke from nearby orchard heaters may reduce visibilities to less than a mile.

With a strong basin high over the plateau, north-to-northeasterly Santa Ana winds are channeled through Cajon Pass and may reach 60-70 knots in gusts and persist for 2-3 days with visibilities near zero in blowing dust and sand.

ONTARIO, OREGON (SAWRS)

The station is located in a flat valley between the Malheur and Snake Rivers, at an elevation of 2,200 feet. The valley is open to the north through east to south. Westerly winds tend to channel down the valley to the west. The wind is usually indicative of frontal passages except under a stagnant basin high in winter when cold air is entrapped in the valley. Weak cold fronts will then pass aloft without breaking up the inversion.

OWYHEE, NEVADA (2nd. ORDER)

The station is located at an elevation of 5,400 feet, with a broad valley to the southwest through northwest and a 1,000-foot ridge rising abruptly to the east. The Owyhee River flows through a canyon to the southeast. The surface wind is not generally representative of the air flow in the area because of nearby buildings, trees and the ridge to the east. The diurnal wind regime has a southeast drainage wind at night and a northwest to north wind during the day. A northwesterly flow is upslope. Cold fronts approaching from the west are frequently accelerated in the Snake River Valley to the north and retarded by the mountains east of Owyhee, thus becoming oriented in an east-west direction.

PALMDALE, CALIFORNIA (FAA)

The airport is located in a valley at the western edge of the Mojave Desert at an elevation of 2,500 feet. High mountains from the north through west to south act as a barrier to fronts and invasions of coastal stratus. In late spring and summer, the local winds are usually southwest to west-southwest, becoming gusty in the late afternoon under the influence of the thermal low to the east. Winds in spring in excess of 25 knots cause low visibilities in blowing dust.

Cold fronts moving in from the north through west are retarded markedly by the mountains and frequently become quasi-stationary.

PASCO, WASHINGTON (SAWRS)

Tri-Cities Airport is located near the junction of the Snake, Yakima, and Walla Walla Rivers with the Columbia River. Its elevation is 403 feet, one of the lowest in eastern Washington. Since the surrounding terrain is all higher, winds from all directions provide downslope effects, resulting in generally higher ceilings than over adjacent areas, except in fog situations.

Winds from the southwest occur more frequently than from any other direction; of the occurrences of wind speeds in excess of 16 knots, almost half (47 percent) are from the southwest, and 93 percent are from south through northwest. The surface wind tends to shift direction only with the stronger frontal passages. Winds frequently become strong and gusty behind active fronts, and sometimes ahead of fronts. Blowing dust up to 8,000 feet often occurs with gusty winds, especially in spring; occurrence of wind speeds in excess of 16 knots reach a maximum in April.

Fog and stratus occur from late fall to early spring, especially when a high-pressure system stagnates over the area, and frequently last for a week or more at a time. Fog tops usually range from 3,500 to 5,000 feet msl. Freezing drizzle occasionally occurs during fog situations, especially when the fog is relatively thick, as a temperature inversion is normal in these conditions and surface temperatures are often at or below freezing. Moisture from irrigation as well as from natural water surfaces, and smoke from local industrial sources, may tend to induce and intensify fog conditions.

PASO ROBLES, CALIFORNIA (FAA)

The station is located near the southeast end of the long, narrow Salinas Valley, which opens into the Pacific 100 miles to the northwest. Mountains rising to 2,500 feet separate the Salinas Valley from the San Joaquin Valley to the east. Mountains to the west shield Paso Robles from the Pacific, but there are low passes to the southwest and south.

Afternoon winds during the warm season are usually light northwesterly, becoming southwesterly when the marine layer is deep. Nighttime stratus from the Pacific reaches the station at times. The strongest winds are from the south in advance of an approaching Pacific storm in winter.

PAYSON, ARIZONA (2nd. ORDER)

The station is located in the Tonto Basin at an elevation of 4,900 feet. The Mogollon Rim 10 miles to the north rises to an elevation of about 8,000 feet. Mountains to the west, southwest and southeast are nearly as high. The diurnal wind regime at Payson is very slight

and is almost always masked by the broad-scale wind field. A flow from the south or southwest is markedly upslope, and most of the cold season low clouds and precipitation occur with a flow from this direction. Conversely, a northeast flow is downslope.

PENDLETON, OREGON (WBAS)

The airport station lies at the southeast end of the Columbia Basin at an elevation of 1,500 feet. Twelve miles southeast of the station the Blue Mountains begin their rise to an elevation of 4,000-5,000 feet. The Columbia River changes its course from south to west 20 miles to the northwest of the station. The diurnal wind regime associated with weak pressure gradients has a westerly wind of 8-15 knots from about 9:00 a.m. until shortly after sunset. The nocturnal drainage wind is southeast, 3-5 knots. Westerly winds associated with frontal passages are magnified by the Columbia River Valley, and wind speeds of 25-30 knots persist with even weak cold fronts. Gusts frequently reach 50 knots with the passage of a strong cold front. The wind often shifts to westerly an hour or two before other frontal indicators such as pressure rise and precipitation occur. A northwesterly flow is upslope.

During late fall and winter, under a stagnant high, a strong inversion forms over the Columbia Basin. Persistent dense fog frequently occurs under this inversion. Weak or even moderately strong cold fronts will not destroy the inversion, but merely pass over as a front aloft. Surface winds under the inversion are persistently northwest 8-12 knots. A strong cold front or strong southerly chinook wind will destroy the stable layer.

PHOENIX, ARIZONA (WBAS)

Sky Harbor Airport, elevation 1,100 feet, is located near the middle of the normally dry east-west Salt River Valley, which is actually a nearly flat plain. Mountains rise to an elevation of 4,500 feet above sea level 17 miles to the southwest, to 2,300 feet 8 miles to the north-northwest, and to 2,600 feet 6 miles to the south. Under the usual weak pressure gradient, the diurnal wind flow is from the east at night and west during the day. Speeds are generally light, with the shift to west occurring around 11:00 a.m. in summer and 2:00 p.m. in winter, and to the east around 11:00 p.m. in summer and 9:00 p.m. in winter. Cold fronts moving through the area are frequently weak and diffuse, and frontal passages are difficult to determine. More than half of the fronts fail to produce any rain in the valley. Dry fronts are frequently accompanied by strong winds and blowing dust.

POCATELLO, IDAHO (WBAS)

The airport is located in the southwest-northeast-oriented Snake River Valley at an elevation of 4,500 feet. From May to October, with light gradients, up-valley (southwesterly) winds prevail during the daytime and northeasterly winds at night. During winter, strong pressure gradients usually mask any diurnal effect, and there is strong channeling of the wind up and down the valley. A strong westerly component of the wind at 700 mbs will induce a southwesterly flow at the surface.

Frontal passages are more easily determined by indices such as rising pressure rather than by abrupt wind shifts. Southwest winds prevail prior to and following the passage of a front from the Pacific, and subside as the 700-mb flow assumes a more northerly direction. The passage of Arctic cold fronts is shown by wind shifts to the north and northeast.

PORTLAND, OREGON (WBAS)

Portland International Airport is located on the south side of the east-west flowing Columbia River with the crest of the Coast Range about 40 miles to the west and the Cascades about the same distance to the east. The Willamette Valley opens up to the south. With a westerly flow, marine air masses from the Pacific Ocean readily move into the area. The Columbia River Gorge through the Cascade Range to the east allows a near sea-level passage for continental air masses to reach the Portland area. With a strong winter anticyclone, easterly gorge winds reach very high speeds, and Arctic air fills the northern Willamette Valley. If a Pacific front overrides this cold air mass, freezing rain sometimes occurs. Strong southerly winds tend to channel down the Willamette Valley in advance of Pacific fronts advancing from the west.

After a summer hot spell, a "marine push" of cool air often surges into the valley from the Pacific Ocean, acting much like a synoptic scale cold front.

PRESCOTT, ARIZONA (FAA)

The airport, elevation 5,000 feet, lies in the southern part of a relatively flat valley about 15 miles wide and 30 miles long. Mountains 7 miles to the west rise to an elevation of 7,600 feet, and mountains rise to 8,000 feet 17 miles south of the station. The nocturnal wind is from the southwest, which is also the prevailing direction. Afternoon wind speeds in the spring frequently reach 25-35 knots.

PULLMAN, WASHINGTON (SAWRS)

Pullman-Moscow Airport is located at an elevation of 2,551 feet in the Palouse Hills of southeastern Washington. Terrain rises gradually from west to east, and wind directions between southwest and northwest are upslope, while winds from other directions are downslope. The prevalence of westerly winds over the rise in terrain have a pronounced effect on the amount of cloudiness, ceiling heights, visibility, and precipitation.

Extensive periods of fog and stratus may occur from late fall to early spring in connection with stagnate high-pressure systems over the area. Freezing drizzle may also occur during fog and stratus situations.

QUILLAYUTE, WASHINGTON (WBAS)

Quillayute Airport is located in rolling wooded country on the Olympic Peninsula, about 10 miles inland from the Pacific Ocean, at an elevation of 200 feet. The Olympic Mountains rise to elevations of 5,000 to 7,000 feet 30 to 40 miles east of the station. The overall exposure is good and representative of the surrounding area.

Since the station has only been operating a year or so, local effects have not been thoroughly documented as yet.

RED BLUFF, CALIFORNIA (WBAS)

The Red Bluff Airport, elevation of 350 feet, is located two miles west of the Sacramento River in the northern end of the Sacramento Valley. Mountains surround the station on three sides, forming a huge horseshoe. The Coast Range is about 30 miles to the west, Cascades 50 miles northeast, and Sierra Nevada 40 miles east. Lassen Peak rises to an elevation of 10,500 feet 50 miles to the east-northeast.

Prevailing winds are up and down the valley, southeasterly and northwesterly respectively. Highest wind speeds are from the south in conjunction with frontal activity. Definite wind shifts are usually not observed following frontal passages, as most fronts pass the station aloft. Usually, the only noticeable change after a frontal passage is a gradual decrease in speed of the prefrontal southeasterly winds. Generally, the barometric pressure holds steady for 2 or 3 hours, even after a strong front has passed the station.

RED BLUFF, CALIFORNIA (WBAS) (Continued)

Most precipitation occurs with Pacific fronts moving across the area in winter. However, much of the moisture is removed from Pacific air masses as they cross the coastal mountains into the valley.

Persistent radiation fogs occur during winter under the influence of a stagnant high-pressure system, particularly if the ground is wet from recent rains.

With a ridge aloft and a surface high over the Pacific Northwest, and a thermal low over the Sacramento Valley, strong northerly downslope winds occur. In summer, these winds are accompanied by very high temperatures and low humidities.

REDMOND, OREGON (FAA)

The airport is located in a north-south valley at an elevation of 3,100 feet. The valley slopes down to the north. The Cascade Range, with an elevation of 6,000 to 10,000 feet, lies 35 miles to the west. A westerly flow from the Cascades is markedly downslope. Weak fronts from this direction produce little precipitation or low clouds in the Redmond area. Even with stronger fronts, precipitation is usually of brief duration, with ceiling of 3,000 feet or higher. A flow from the south also shows downslope effects.

RENO, NEVADA (WBAS)

Reno Municipal Airport, elevation 4,400 feet, is located near the northern end of a narrow north-south valley, with the Virginia Range three miles to the east rising to an elevation of 6,000 feet, and the Sierras four miles to the west rising to over 9,000 feet. The Truckee River flows eastward through canyons in both ranges. During summer a pronounced westerly wind blows down the Truckee River canyon from about 2:00 p.m. to 11:00 p.m. The wind reaches speeds of 20-25 knots at the airport, but does not materially affect temperatures.

During winter, with a deep low aloft off the coast, supergradient southerly winds are channeled down the valley. Conversely, the airport is shielded by the mountains from strong northwesterly gradient winds. A westerly flow is markedly downslope, and frontal passages from this direction frequently leave only a trace of precipitation at the airport. Pacific frontal passages will usually be noted by a marked decrease in wind speed, erratic direction for a brief period, and a return to the original direction and speed. Winds behind Arctic fronts will shift to northeasterly.

ROOSEVELT, UTAH (2nd. ORDER)

The second-order station is located in the sheltered Uintah Basin at an elevation of 5,100 feet. The crest of the east-west Uintah Range lies 35 miles to the north with peaks ranging up to 13,000 feet. Mountains 50 miles to the south through southwest reach to nearly 10,000 feet.

Cold fronts are weakened by the surrounding mountains, and winds are generally light, although they may become strong westerly behind a cold front. Under a stagnant winter basin high, very persistent fog is experienced.

ROSEBURG, OREGON (SAWRS)

The airport is located in the upper Umpqua Valley at an elevation of 500 feet. Hills surrounding the station rise to 1,500 feet within 2-1/2 miles of the airport. The Coast Range to the west is almost 3,000 feet in elevation. The crest of the Cascade Range is about 70 miles east. Coastal fog and low stratus can reach Roseburg through the Umpqua Valley which opens towards the northwest to the Pacific Ocean.

Under light pressure gradients, daytime winds are usually 5-10 knots from the north. Nocturnal winds are light variable. Smoke from nearby sawmill burners causes low visibilities under stable conditions.

SACRAMENTO, CALIFORNIA (WBAS)

Sacramento Municipal Airport is located in the Central Valley, 85 miles east of the Pacific Ocean. Carquinez Straits and the Golden Gate provide a sea-level opening southwestward through the Coast Ranges to the Ocean. The crest of the Sierra Nevada is about 80 miles to the east.

During winter, frontal passages from the northwest are accompanied by narrow precipitation bands, with rapid post-frontal clearing. Prefrontal winds are southeasterly and are relatively strong; after the frontal passage, winds shift to southwesterly and diminish rapidly. Temperature contrasts are weak across frontal zones, and pressure tendencies are the most reliable indicators of frontal passages.

During summer, frontal passages are normally cloudless with winds shifting to north behind the front.

Sharp drops in temperature occur in summer when low-level marine air from the Pacific reaches Sacramento through the gap to the southwest. No true fronts are involved, but wind speeds will reach 20-25 knots as the cool air moves in.

Under the influence of a stagnant winter high, fog may be trapped in the valley for long periods of time. A strong cold frontal passage is required to scour out the stable air.

SALEM, OREGON (WBAS)

The airport is located in the broad central Willamette Valley, about 60 miles from the coast. The crest of the Cascade Range lies about 60 miles to the east. In summer with weak pressure gradients, there is a light northerly breeze from late morning until sunset. The nocturnal wind is light southerly. Cool marine air flowing into the valley several hours in advance of a front will often mask the actual passage of the front, which may not be clearly evident until it has passed east of the Cascades.

In winter, winds often show little change with a frontal passage from the west. At times the wind shifts from south to southwest or west for only a few minutes, and then returns to the south. Temperatures may rise with this type of frontal passage, especially if cool air has been trapped in the valley before the front reaches that area. Fronts moving in from the north usually show a good wind shift and temperature drop. Under stagnant situations in winter, fog may persist in the valley for several days.

SALINAS, CALIFORNIA (FAA)

The airport is located near the mouth of the Salinas Valley, which is about 100 miles long and 10 miles wide, being oriented north-northwest to south-southeast and opens into Monterey Bay. Mountains to the east rise to 3-4,000 feet.

From March through October, the prevailing winds are northwesterly with speeds generally less than 10 knots. In winter, downslope southeasterly winds predominate. The strongest winds are southeasterly ahead of fronts moving in from the Pacific and briefly from the west or northwest after the frontal passage.

Night and early morning fog and low stratus from the nearby Pacific Ocean are frequent during the summer months.

SALT LAKE CITY, UTAH (WBAS)

The Salt Lake Municipal Airport, elevation 4,200 feet, lies at the north end of a valley between the 9-11,000-foot Wasatch Mountains to the east and the 8-10,000-foot Oquirrh Mountains to the southwest. The Great Salt Lake lies to the northwest of the airport. The valley terminates at the narrows of the Jordan River, 20 miles south of the airport.

The diurnal wind regime under conditions of weak pressure gradients results in a light northwesterly breeze from about 10:00 a.m. until shortly after sunset. At night, a southeasterly drainage wind predominates, sometimes reaching speeds of 15 - 20 knots. Consequently, when a weak cold front passes during the night or early morning hours,

the synoptic effect is masked by the diurnal effect, and the wind frequently does not shift to a northwesterly direction until midmorning following frontal passage. A strong cold front, however, will shift the wind at any hour, as the synoptic effect will overcome the diurnal effects. Usually, on the first night following a frontal passage, the southeast drainage wind will set in, although weaker than normal. The presence of a southeast wind should not, of course, be taken to mean that the front has moved back to the north of Salt Lake City.

Because of the high Wasatch Range to the east of Salt Lake City, post-cold-frontal precipitation continues much longer than at stations with no orographic effect. Following passage of a slow-moving front in the fall, winter or spring, precipitation may continue for as long as 24 hours at Salt Lake City, while stations 50-100 miles to the west are reporting clear or scattered clouds.

In spring strong, dry, southerly winds frequently precede cold fronts moving into the plateau from the Pacific Ocean. Under such conditions, especially after a dry winter, blowing dust may limit visibility at the Salt Lake Airport to less than one mile.

During winter, a persistent Great Basin high frequently forms, lasting from one to three weeks. This situation leads to the formation of a strong inversion over the valley, with the top usually from 5,000 to 7,000 feet msl. Smoke accumulates under this inversion, frequently accompanied by dense fog. Weak or even moderately strong cold fronts will not destroy the stable layer, but will merely ride over the top of the inversion as a front aloft. Only a strong cold front, with pronounced upper trough, will scoop out the stable air trapped in the valley.

With the buildup of a strong high over the Wyoming Plateau and/or the development of a cut-off low over southern Utah or northern Arizona, strong easterly canyon winds develop over the Wasatch Mountains. Usually these winds do not reach out of the airport, some ten miles west of the Wasatch crest. The wind at the airport may be light and variable, while a few miles to the east the wind is 40-60 knots from the east. A strong mountain-wave effect may be noted on the lee (western) side of the Wasatch Range under these conditions.

SANDBERG, CALIFORNIA (WBO)

The station is located on top of Bald Mountain, at an elevation of 4,500 feet, in the range of mountains that separates the Los Angeles Basin from the Mojave Desert and the Southern San Joaquin Valley. Except for the Mojave Desert to the east, the station is completely surrounded by mountains and canyons. The terrain to the south gradually slopes down to the San Fernando Valley, 35 miles away and near sea level. The mountains to the west and northwest are approximately

SANDBERG, CALIFORNIA (Continued)

3,000 feet above the station; consequently, fronts coming from this direction are frequently depleted of their moisture before reaching the station. Because of the very exposed location and high altitude, Sandberg is frequently the only station south of Fresno to record the passage of weak frontal systems.

From November through May high winds accompanying storms occasionally reach 75 knots due to the funneling effect of winds being forced through the mountain passes to the north.

Sandberg is frequently near the dividing line between maritime air masses to the west and south and the continental air masses to the east and north. During fall and early spring months, upslope southerly winds preceding frontal passages cause the marine layer to move inland over the station accompanied by low clouds over the surrounding mountains.

SAN DIEGO, CALIFORNIA (WBAS)

International Airport (Lindbergh Field) is located on the northeast shore of San Diego Bay. A peninsula rising to about 400 feet lies 6 miles to the west and southwest. Low hills rise to the north and east within 3/4 mile of the field. These hills partially shield the airport from strong easterly Santa Ana winds. The Laguna Mountains, sixty miles east, rise to 6,000 feet.

Fog and stratus occur persistently in the late spring, summer and early fall, being interrupted by occasional frontal passages and Santa Ana winds.

SAN FRANCISCO, CALIFORNIA (WBAS)

San Francisco International Airport is located on flat tideland on the west shore of San Francisco Bay, 10 miles east of the Pacific Ocean. Hills 5 miles to the north and northwest rise to 1,300 feet, and ridges of the Coast Range rise to 1,900 feet west and southwest of the airport. There is a broad gap through the hills to the northwest.

During periods of weak gradients, nocturnal winds are 5-10 knots from the southwest. From May through September, afternoon winds are channeled through the gap in the coastal hills and normally reach about 25 knots from the west-northwest. North-to-northeast foehn winds occasionally reach the station from October through June.

The approach of a cold front from the west is commonly preceded by southeast winds, while southerly winds usually precede a well-defined front from the northwest. In both instances, winds may blow across the isobars at an angle of more than 60 degrees. Passage of a front from the west frequently brings no wind shift--only a gradual decrease in speed. With the approach of a front, cloudiness may decrease if there has been a stratus deck under an inversion which was dissipated by the large-scale vertical motion ahead of the front. Such clearing should not be interpreted to mean that the front is inactive.

During the cool season, with a long-wave trough near the coast, rain is quite persistent. Care should be taken to avoid entry of a nonexistent front to explain such precipitation, which may be caused by convergence in the large-scale circulation, instability, orographic lifting, etc.

At all times of the year, caution is advised in applying observations taken at the airport to describe weather conditions in the surrounding area, as local variations of wind, temperature, and precipitation can be very pronounced.

SANTA BARBARA, CALIFORNIA (FAA)

The airport is on an east-west coastal plain three to five miles wide, with the Pacific Ocean one mile to the south. The Santa Inez Mountains rise to 4,000 feet about 10 miles to the north. Forty miles west of the station, the coastline turns abruptly northward at Point Arguello. Northerly winds on summer afternoons at this point frequently reach speeds of 30-40 knots, but the effect of the "Catalina Eddy" results in a light southwesterly afternoon sea breeze at Santa Barbara. The wind becomes easterly after dark, delaying the arrival of coastal fog and stratus. Rapid heating of the nearby southern slopes of the Coastal Mountains induces a morning breeze from the south.

Fronts moving in from the west or northwest are preceded by increasing east-southeasterly winds, with supergradient speeds. Clearing is rapid with northerly or northwesterly winds behind cold fronts, because of downslope effects.

SANTA CATALINA ISLAND, CALIFORNIA (WBAS)

Catalina Airport is located on an island 30 miles south of Los Angeles, on a plateau at an elevation of 1,600 feet. Mountains 2 miles south and 1 mile southeast rise to 2,000 feet.

With light pressure gradients, the diurnal regime in summer shows light variable winds at night and 10-15 knot southwesterly winds in the afternoon. The afternoon sea breeze is less pronounced in winter.

Even though the large-scale gradients indicate northerly or northwesterly flow, the winds at Catalina frequently back to southwesterly as a result of the "Catalina Eddy". This offshore eddy is basically a result of the eastward turning of the California coast below Point Arguello.

With the building of a strong high over the southern plateau, strong northeasterly Santa Ana winds occasionally reach the island.

Frontal passages are confined mostly to the winter months. Strong northwest winds follow the more vigorous cold fronts.

Winter fogs are common, and the station may be above the fog top or "in the soup", depending on the inversion height. With the approach of a frontal trough, the base of the inversion rises sufficiently so that the airport is usually below the cloud deck.

In summer, the top of the marine layer is usually below the station and, as a result, there is little fog.

SANTA MARIA, CALIFORNIA (WBAS)

The airport, elevation 200 feet, is located in a northwest-southeast-oriented valley 18 miles long and 11 miles east of the Pacific Ocean. Hills to the south rise to 1,200 feet, and a mesa to the north rises to 600 feet. There is a marked channeling of winds from the ocean up the valley. Winds are usually light variable at night and during the early morning. In the late morning, the wind shifts to west-northwest and increases in speed. Maximum temperatures in spring and summer frequently occur shortly after the onset of the sea breeze. Gusty northeast winds occur under "Santa Ana" conditions in spring and fall, with a large high over the plateau.

SEATTLE-TACOMA AIRPORT, WASHINGTON (WBAS)

The station is located on a north-south ridge 400 feet above and 2 miles east of Puget Sound. About 35 miles to the west and northwest the Olympic Mountains rise abruptly to 5,000 to 7,000 feet. The foothills of the Cascades start 10-15 miles east, with the crest 40-50 miles east.

Under weak gradients, nocturnal winds are light variable. There is a northwesterly afternoon sea breeze from late morning until early evening, reaching 10-15 knots. Large-scale winds are affected by the mountains and are generally north or south.

The wind shift associated with winter occlusions from the Pacific is only about 60 degrees, blowing from the south-southeast or southeast ahead of the front, and south-southwest to southwest after the frontal passage. Wind speeds are generally greatest following the fronts. Southerly winds at the airport are usually lighter than over nearby Puget Sound.

The Olympic Mountains present a barrier to air moving inland from the coast, and the low-level flow is split into two streams to the west and south of the mountains. These air streams tend to converge in the Puget Sound area; and if sufficient moisture is present, an area of cloudiness and showers result.

On clear nights minimum temperatures are often 10-15 degrees higher than in the valley to the east.

SEXTON SUMMIT, OREGON (WBO)

The station is located on a mountaintop at an elevation of 3,800 feet, 60 miles east of the Pacific Ocean. The nearest high mountain is 10 miles northeast. The valley floor is 2,700 feet below the station. The wind exposure is excellent and is highly representative of the free air movement. North-through-southeast winds are generally associated with dry, stable conditions, with smoke and/or fog trapped in valley below. South-to-southwest winds are associated with storm conditions and the highest wind speeds.

SHELTON, WASHINGTON (2nd. ORDER)

The station is located in hilly, tree-covered terrain at an elevation of 300 feet. Hills rise to 1,500 feet 3-5 miles to the west and southwest. About 15 miles northwest, the southeast fringe of the Olympic Mountains rise abruptly to over 3,000 feet. The Cascade Range is 80 miles east, and a broad valley extends southwest of the Pacific Ocean, about 50 miles away.

Topography strongly masks wind and temperature changes with frontal passage. Winds are usually southwesterly both before and after the passage of Pacific fronts, and temperatures show little change. Orographic effects greatly increase rain and snowfall, as compared with low-level stations in the area.

SPOKANE, WASHINGTON (WBAS)

International Airport, elevation 2,400 feet, is on a level plateau near the eastern edge of the Columbia Basin--a large bowl about 150 miles in diameter, with the Cascades over 100 miles to the west and the Rockies 30 miles to the east. The airport is about 400 feet higher than the Spokane River Valley. Winds from south through west are upslope. Snowfall amounts in Spokane are frequently several times greater than those 60-100 miles to the south or west. With a weak pressure gradient, southwest winds of 5-15 knots prevail during afternoons, with a 3- to 8-knot northeast-to-southeast drainage wind at night.

Many Pacific fronts crossing the Cascades appear to dissipate in the lee of the range, but can be identified again as they approach the Spokane area. Wind shifts associated with Pacific fronts are slight, with the wind tending to remain southwesterly after the frontal passage.

The summertime squall line or "marine push" is a phenomenon of the Columbia Basin, with high pressure along the Pacific Coast. Temperatures rise to much above normal in eastern Washington, while cool marine air dams up against the west side of the Cascades and finally surges eastward through the passes, generating a cold front or squall line east of the mountains. This generally occurs in late afternoon or evening, and winds may reach 30-50 knots.
Under a stagnant winter high, cold, moist air is trapped under a strong inversion, and the basin becomes filled with persistent fog. Weak fronts will ride over the stable layer and only a strong Pacific front will break up the inversion and remove the fog.

SPOKANE, WASHINGTON (FELTS FIELD, FAA)

The station is 11 miles east-northeast of Spokane International Airport and 400 feet lower, in the broad east-west Spokane River Valley. Hills rise 800 feet above the airport one mile north and 6 miles to the south. There is some channeling of winds up and down the valley.

STAMPEDE PASS, WASHINGTON (WBO)

The Weather Bureau Office is located in mountainous country on top of a small hill in Stampede Pass on the main Cascade Divide at an elevation of 4,000 feet. The nearby land is old burn with young growth of fir, hemlock and pine. East of the station is an abrupt drop into the Yakima River Valley, 2,000 feet below and two miles distant. The land drops rapidly 2,000 feet to the west over a distance of four miles into the Green River Valley.

Due to the station location in a shallow pass, there is a funnel effect upon winds, tending to increase the speed. Winds are predominantly from the east or southeast and the west or southwest. The abrupt lifting of air moving over the pass tends to intensify weather processes and increases the formation of clouds, fog and precipitation. Upslope fog is common the year around. Drainage of cold air at night from the pass down into the nearby river valleys keeps minimum temperatures relatively mild.

STOCKTON, CALIFORNIA (WBAS)

Metropolitan airport is located near the geographic center of the north-northwest to south-southeast-oriented flat Central Valley 60 miles east of the Pacific Ocean. The foothills of the Sierra Nevada rise 25 miles to the east with the crest about 90 miles east. In summer, a light northwesterly breeze prevails from midmorning until sunset, and nights are generally calm. Occasionally, marine air from the Pacific will break through a gap in the Coast Range 50 miles to the west, reaching Stockton as a northwest wind of 15-20 knots, accompanied by marked lowering of afternoon temperatures.

Under stagnant conditions in winter, the area is subject to persistent thick fogs. A strong front from the Pacific is required to clear the fog from the valley.

STREVELL, IDAHO (2nd. ORDER)

The station is located in a northwest-southeast-oriented pass at an elevation of 5,300 feet. Mountains to the west and south rise to above 9,000 feet. Winds tend to be channeled through the pass.

SUSANVILLE, CALIFORNIA (2nd. ORDER)

The station, elevation 4,100 feet, is located just east of a low pass in the southern Cascades. A broad valley extends to the southeast and northeast; to the south and west, the mountains rise to 8,000 feet within 10 miles.

Nocturnal drainage winds are from the west or northwest. The airport is protected from strong southerly winds. The strongest winds are southeasterly, occurring in advance of a Pacific storm. The passage of most cold fronts is fairly well marked by a wind shift to the west or northwest.

TAHOE VALLEY, CALIFORNIA (LAWRS)

The airport is 3 miles south of the southern shore of Lake Tahoe at an elevation of 6,300 feet. Peaks of the Sierra Nevada rise abruptly on all sides of the lake to 9,000 feet or higher.

Drainage winds are light southerly; 30-50 knot southerly winds precede the more vigorous storms from the Pacific. Marked wind shifts do not usually occur with a frontal passage; the wind generally decreases in speed over a period of several hours; 20-30 knot northerly winds sometimes occur with a low over Nevada.

THERMAL, CALIFORNIA (FAA)

The station, 17 feet below sea level, is located in the southern portion of the northwest-southeast Coachella Valley near the northwest end of the Salton Sea. Mountains to the north rise to 5,500 feet and to the southwest to 8,700 feet.

Daytime winds are normally light variable; nighttime winds are normally north at 10-20 knots. In winter, with the approach of a cold front from the northwest, the wind at Thermal will shift to northwest long before the frontal passage. The actual frontal passage is usually accompanied by stronger northwest winds, frequently with blowing sand.

In late summer and fall, the remnants of tropical storms from the south may cause severe thunderstorms.

TOLEDO, WASHINGTON (FAA)

The airport is located in the main north-south interior valley of southwest Washington at an elevation of 400 feet. The coastal hills lie to the west and the Cascade Mountains rise to the east.

In most cases, the wind is southerly both before and after the passage of a Pacific front, especially when a portion of the trough remains offshore. However, when there are large pressure rises behind the front and marked falls east of the Cascades, the wind will shift to west or northwest within or a few hours after the frontal passage. When a front approaches from the southwest, prefrontal winds are east or northeast, shifting to southerly after the frontal passage.

TONOPAH, NEVADA (FAA)

Tonopah Airport is located in a north-south-oriented valley at an elevation of 5,400 feet. It is surrounded by mountains on all sides except the south, and winds from all other directions but south are markedly downslope. Southerly winds of 25-35 knots usually cause restriction in visibility by blowing dust.

Fronts moving in from the northwest are generally dry, but occasionally will be accompanied by a brief shower. Most winter precipitation and clouds occur with a low passing eastward to the south of Tonopah.

TUCSON, ARIZONA (WBAS)

International Airport, elevation 2,600 feet, is situated in the south-central portion of the Santa Cruz River Valley, which slopes gently upward to the south and southeast. Mountains 25-40 miles distant to the north, east and south rise to 7,500-8,500 feet. Hills to the northwest afford some protection from strong winds from this direction. Under weak pressure gradients, the diurnal wind regimes are as follows:

TUCSON, ARIZONA (Continued)

Spring and Fall - west or northwest upslope winds from noon to midnight; southeast, midnight to noon.

Summer - west-northwest 10 a.m. to 3 a.m. or slightly earlier; southeast, 3 a.m. until late morning.

Winter - west and northwest noon until 10 p.m.; southeast, 10 p.m. until noon.

In spring, strong southeast winds often reduce visibility in dust. Cold fronts in the area are usually weak and diffuse. Rough terrain produces erratic variations in temperature, dewpoint, pressure and wind in the frontal zones, often making analysis difficult.

TWIN FALLS, IDAHO (SAWRS)

The airport is located at an elevation of 4,200 feet in the east-west Snake River Valley. Westerly upslope winds of 20-30 knots occur frequently during the afternoons, and easterly downslope winds of 5-10 knots prevail at night and early morning hours. These diurnal winds frequently mask the passage of weak fronts.

UKIAH, CALIFORNIA (FAA)

The airport, elevation 600 feet, is located in a north-northwest to south-southeast-oriented valley five miles wide and thirty miles long. Hills one mile to the west rise to 1,000 feet, and 1-2 miles to the east hills rise to 3,500 feet. Surface winds are limited to either a northwesterly or southeasterly direction because of the orientation of the valley.

Winter frontal systems cause much bad weather, and southward-moving cold fronts tend to stall in the area. Fog and low stratus are persistent under stagnant conditions in winter, and a strong frontal passage is necessary to scoop out the stable air.

VERNAL, UTAH (SAWRS)

The airport, elevation 5,300 feet, is located in the Uintah Basin about 25 miles south of the crest of the east-west Uintah Mountains, which rise to over 10,000 feet. The basin is 60-70 miles in diameter and is almost completely surrounded by high mountains. The Green River is 10 miles southeast and flows toward the southwest. Wind

speeds are generally less than gradient values because of the protecting mountains. Cold fronts weaken as they pass over the mountains to the north and west. Strong north winds are observed at the station with a cold high over Wyoming. Cold air tends to be trapped in the basin in winter, and persistent fog is observed under stagnant conditions.

WALLA WALLA, WASHINGTON (WBO)

The station, elevation 1,000 feet, is in a valley about 40 miles long, extending generally in an east-west direction, with the western end reaching the Columbia River. The Blue Mountains to the south and east reach elevations of 3,500 feet to 6,000 feet, approximately 15-20 miles distant. To the north is slightly rolling grain land.

There is a significant increase in mean precipitation toward the Blue Mountains, since the prevailing flow from the main moisture source, the Pacific Ocean, is lifted by these mountains. In addition to simple orographic lifting, additional vertical motion is caused by cyclonic turning of the prevailing flow by the Blue Mountains.

There is a prominent diurnal wind pattern in the absence of strong pressure gradients. A light drainage wind from south to southeast blows at night. During the daytime, winds are predominantly southwesterly or westerly.

The frequency distribution of the time of day for cold frontal passages at nearby Hanford, Washington, shows a pronounced maximum in the late afternoon and early evening during the warm season. Many cold fronts at this time of year are actually invasions of marine air or "marine pushes", and exhibit a strong tendency to progress mainly in the afternoons and evenings. There is a significant tendancy for a clockwise shift of wind direction during daytime.

One of the most significant features of winter weather over the Walla Walla area is rapid warming associated with a strong flow of air from the Pacific Ocean. The foehn effect, as the air descends from the higher elevations of eastern Oregon, is secondary to advection effects. In the final stages of a cold wave, it is not unusual for a Chinook to be observed over the higher elevations of the local area above a shallow layer of Arctic air.

The ground west of the local area is frequently very dry and, especially when freshly cultivated, is a source of dust that can sometimes be carried into the air by wind speeds as low as about 15 m.p.h. Strong winds over the local area are almost invariably westerly.

A sea-level High centered to the north or northeast of Walla Walla results in an easterly downslope flow which, in summer, can cause hot winds and extremely low humidities.

WALLA WALLA, WASHINGTON (Continued)

Radiation fogs are frequent from November through January. The top of the fog is frequently below the higher elevations to the southeast. The fogs form in maritime polar air, and are associated with a high pressure system that is usually centered to the southeast of Walla Walla. It is not unusual for fog to develop at night over the lower elevations to the west and then drift over Walla Wabla after sunrise. In those cases, the upslope factor is significant.

Nocturnal stratocumulus clouds over the north and west slopes of the Blue Mountains occur frequently with upslope flow, usually extending only a few miles to the west and north of Walla Walla. These clouds are dissipated by morning sunshine.

WENATCHEE, WASHINGTON (FAA)

The Wenatchee Airport lies on a bench above the Columbia River at an elevation of 1,200 feet, 7 miles southeast of the confluence of the Wenatchee River with the Columbia. Higher terrain virtually surrounds the airport. The Wenatchee River descends a valley between two ridges that extend southeastward from the Cascades to the Columbia. Both of these ridges have elevations generally between 5,000 and 8,000 feet. The southernmost ridge, called the Wenatchee Mountains, with its crest about 13 miles southwest of the airport, has the most influence on winds near the airport, particularly during periods of strong southwest flow aloft. Another ridge which begins 13 miles north of the airport, near the Columbia River, with elevations of 4,400 feet, lowers to 2,900 feet east of the airport. The only routes out of Wenatchee airport over low terrain are up and down the Columbia River.

In late spring and summer, afternoon west winds are normal. Fronts approaching from the west generate a lee trough, causing a wind shift and increase in speed prior to the frontal passage.

East-west pressure gradients result in very little wind at the airport. Westerly winds are strong downslope, and precipitation is infrequent with a flow from this direction. Under stagnant winter highs, cold air is trapped in the valley and fog and stratus are common.

WENDOVER, UTAH (WBO)

The airport lies on the western edge of ancient Lake Bonneville at an elevation of 4,200 feet. The Bonneville Salt Flats are immediately east of the field, and a north-south mountain range rising to a height of nearly 8000 feet lies 15 miles to the west. A broad canyon extends northwestward into the range. Two ridges extend eastward from this range--one about 30 miles south of the station and the other just to the north. These ridges effectively block any strong southerly winds from reaching the station.

WENDOVER, UTAH (Continued)

The diurnal wind regime under a weak pressure gradient results in a weak southeasterly upslope breeze from 10 a.m. until shortly before sunset. A light northwesterly downslope wind begins about 2-3 hours after sunset, but usually lasts only a few hours.

A flow from the west is strongly downslope, and cold fronts moving from this direction frequently give no precipitation to the station. A temperature rise usually accompanies the frontal wind shift. Northwesterly winds are supergradient because of channeling down the canyon. Under a winter basin high, persistent fog is frequent, and a strong frontal passage is required to clear out the stable air.

WEST YELLOWSTONE, MONTANA (2nd. ORDER)

The station lies near the edge of an extensive plateau averaging about 6,600 feet in elevation, with the Continental Divide 7 miles southwest. The plateau is rimmed by mountains about 1,000 feet higher than the plateau itself, and low-level drainage is to the northwest through the narrow Meacham River Canyon. The sheltering effects of surrounding heavy timber reduce wind speeds below gradient values. Under inversions in the cold season, there is little or no wind; and nocturnal cooling under clear skies is exceptionally strong.

Under stormy conditions, inversions are easily dissipated; and the station temperature becomes representative of the high elevation. Hebgen Reservoir, 4 miles to the north is a source of moisture abetting the formation of early-morning fogs, during the period when the reservoir is not frozen.

WINNEMUCCA, NEVADA (WBAS)

The Winnemucca Airport, elevation 4,300 feet, is located in the Humboldt River Valley near where it turns from a generally east-west direction to a northeast-southwest direction. Surrounding mountains rise to 9,400 feet eleven miles to the east-southeast, to 8,400 feet sixteen miles to the northeast and to 8,800 feet twelve miles to the southwest. Winds tend to be channeled up and down the Humboldt River Valley.

Much of the moisture from winter storms moving in from the Pacific Ocean is removed as they cross the Sierra Nevada and Cascade ranges. Consequently, cold frontal passages from the west at Winnemucca are accompanied by relatively light precipitation, with many "dry" frontal passages.

Strong southwesterly to westerly winds in spring are frequently accompanied by restrictions to visibility in blowing dust.

WINSLOW, ARIZONA (WBAS)

The Municipal Airport, elevation 4,900 feet, is located in the broad northwest-southeast-oriented valley of the Little Colorado River. The Mogollon Rim, 40 miles to the southwest, rises to an elevation of about 8,000 feet. Mountains to the northeast are lower and more distant. A southwesterly flow is markedly downslope. Most upslope weather comes with a northwesterly flow up the Little Colorado River Valley. The nocturnal drainage wind is light east-southeasterly.

Frontal systems are weakened considerably by the surrounding mountains, and frontal passages are seldom accompanied by definite wind shifts. Arctic fronts from the northeast occasionally reach the station. The strongest winds are southwesterly and are frequently accompanied by blowing dust.

YAKIMA, WASHINGTON (WBAS)

The Municipal Airport, elevation 1,100 feet, is located in a small bowl-like east-west valley in the upper part of the Yakima Valley. The crest of the Cascade Mountains lies 50 miles to the west. Local topography is very complex, and drainage out of the bowl is through a gap 4 miles southeast. On nights favorable for radiation, Yakima temperatures are several degrees lower than other stations in the area. Drainage winds from the west-northwest are common in spring and early summer starting about 8 p.m. Speeds may reach 15-20 knots.

A westerly flow is markedly downslope, and cold fronts from this general direction, especially from the northwest, bring little or no precipitation. Rapidly moving fronts in spring are accompanied by 35 to 45-knot winds. In winter, cold air is frequently trapped in the valley, accompanied by fog and low stratus. Weak occluded fronts from the west will pass aloft over the cold dome, and clearing will only follow the passage of a strong frontal system.

YUCCA FLAT, NEVADA (WBO)

The station is located in the southwest corner of a desert basin at the western edge of normally dry Yucca Lake. The 20-mile-by-10-mile basin, elevation 4,000 feet, is oriented north-northwest to south-southeast. North-south ridges bound the basin, rising to 7,800 feet to the northwest.

The local wind regime is very pronounced and frequently masks the synoptic-scale effects. Northerly drainage winds are observed at night with southerly upslope flow during the day.

YUCCA FLAT, NEVADA (Continued)

Nocturnal inversions are pronounced due to the strong pooling of cool air in the valley. Minimum temperatures under these conditions are characteristically 10-20 degrees lower than nearby slope locations.

YUMA, ARIZONA (WBAS)

Yuma International Airport, elevation 200 feet, is located on a sandy mesa about 1-1/2 miles east and 4 miles south of the Colorado River. Mountains 10-12 miles west-northwest and east rise to 2-3,000 feet. There is but little diurnal wind under weak pressure gradients. With high pressures to the north, there is a funneling effect along the Colorado River Valley; and winds at the airport will be northerly 10-20 knots higher than in areas outside the valley. Southeasterly winds, especially during summer, exceed gradient values by 5-15 knots.

There are no local orographic effects on precipitation. Strong west winds across the Imperial Valley will bring blowing dust into the Yuma area. Remnants of tropical storms from the south produce occasional heavy thunderstorms in late summer and early fall.

CANADIAN STATIONS

CALGARY, ALBERTA

Calgary is located approximately 60 miles east of the Continental Divide at an elevation of 3,330 feet. The terrain reaches 5,000 feet 30 miles to the west, with peaks in the Rockies reaching to 10,000 feet 50 miles to the west.

Upslope effects are associated with winds from northwest through north to southeast, particularly with northeast-to-southeast winds. Clearing occurs when winds veer to the southwest.

Low stratus and fog are fairly frequent with winds from the southeast to northeast.

Strong southwest-to-west Chinook winds blow frequently, but the wind does not break through to the surface as frequently as at Lethbridge. Pacific fronts normally pass Calgary with little weather unless the front becomes oriented northeast-southwest, or the polar front lies to the south and the Pacific front overruns it.

Polar cold frontal passages are accompanied by gusty north winds, turbulence, and temporary very low ceilings which may be reestablished later as upslope conditions develop. Dust storms sometimes occur in spring with polar fronts.

CLARESHOLM, ALBERTA

Claresholm Airport is located 45 miles east of the Continental Divide, at an elevation of 3,300 feet. The terrain is relatively flat to the north, east and south, while to the west the foothills rise rapidly, the Porcupine Hills reaching an elevation of 6,000 feet 20 miles to the west. Tornado Mountain, at the crest of the Rockies, has an elevation of 10,000 feet.

Claresholm lies in the Chinook Belt, but strong west winds often skip over the airport, reaching the ground just to the east. Chinook winds at Claresholm are generally lighter than at Lethbridge and Calgary. These winds often blow ahead of Pacific fronts moving through British Columbia.

Winds from the north-northwest to southeast are upslope, especially from the northeast and east. Low clouds and precipitation accompany persistent flow from these directions. Radiation fog is infrequent.

CLARESHOLM, ALBERTA (Continued)

The "Chinook Arch" is a well-developed phenomenon of the region, often occurring ahead of a Pacific front. This arch, accompanying a strong mountain wave, is formed by lenticular clouds, the western edge being quasi-stationary in the lee of the Rockies. The "arch" breaks up or moves eastward when the Pacific front goes by.

LETHBRIDGE, ALBERTA

Lethbridge is located about 80 miles east of the Continental Divide at an elevation of 3,000 feet. Upslope effects occur with north-northwest through east winds. Clearing occurs when winds shift to the southeast. Strongest downslope effects occur with south to west winds.

Radiation fog is rare on the airport. Low stratus and fog usually occur with a persistent upslope circulation, especially a northeasterly flow.

Strong Chinook winds, south-southwest to west, 40 to 60 m.p.h., funneling through Crows Nest Pass in the Rockies, are a predominant feature in the fall months but can occur at any season. These winds are accompanied by marked turbulence both surface and aloft. An associated phenomenon is the Chinook Arch with cloud base about 14,000 feet.

Pacific fronts normally pass Lethbridge with little weather. There is normally an increase in wind speed prior to frontal passage with a decrease in speed as the pressure rises. Exceptions to these rules occur when a Pacific front becomes oriented northeast-southwest or a fast-moving secondary cold front passes Lethbridge. In these cases, low clouds, precipitation and strong northerly winds follow the front. Another exception occurs when the polar front is south of Lethbridge and the Pacific front overruns it. This is a winter phenomenon, usually accompanied by snow.

Polar cold front passages are marked by strong windshifts, and marked pressure rises. Rapid deterioration in the weather occurs. Dust storms sometime occur in April and May with polar fronts. Precipitation normally occurs with upslope winds.

MEDICINE HAT, ALBERTA

Medicine Hat lies about 200 miles east of the Continental Divide at an elevation of 2,350 feet. Cyprus Hills rise to an elevation of 4,700 feet 30 miles to the southeast. Conditions are similar to those at Lethbridge, but since Medicine Hat is farther from the mountains,

upslope effects are less pronounced. Upslope flow is from northwest through north to east, while southeast through south to west-southwest flow is downslope.

Chinook winds affect Medicine Hat but not so often or so vigorously as Lethbridge. Radiation fog is negligible.

Normally there is little weather with Pacific fronts, but precipitation and low ceilings occur with Arctic frontal passages.

SWIFT CURRENT, SASKATCHEWAN

Swift Current is located on the Great Plains at an elevation of 2,680 feet. Cypress Hills lie to the southwest with a southeastward extension beginning at a point 30 miles south of Swift Current. Terrain is about 1,000 feet higher on these ridges.

Upslope flow is from west-northwest through north to east. Definite downslope effects occur with winds from southeast through south to west-southwest; other directions are neutral.

Chinook winds sometimes reach Swift Current. Most frontal passages which cause a wind shift to northwest in spring, fall and winter can be expected to give low ceilings, and these can be very persistent. Persistent fog conditions may develop with a shallow polar front in winter. Radiation fog is not a marked problem.

Strong south-to-southeast winds develop on the returning side of persistent polar anticyclones as Pacific fronts move into Alberta. Precipitation and low cloudiness are of little consequence except with overrunning over a fairly deep polar air mass.

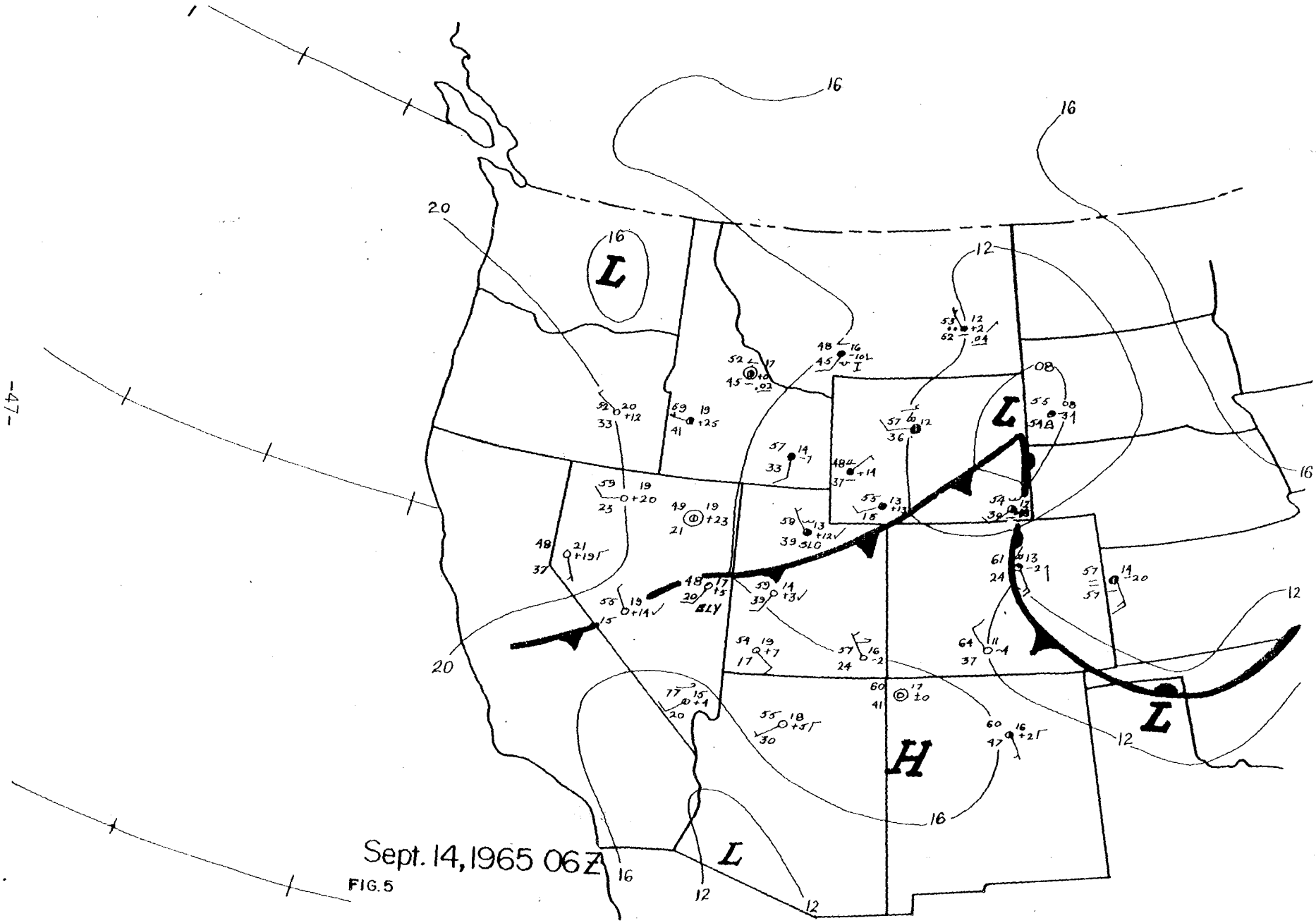
EXAMPLES OF LOCAL EFFECTS MASKING SYNOPTIC EFFECTS

Knowledge of local effects can assist materially in a synoptic-scale analysis, as shown in Figures 5 - 10. This is possible even using only the data plotted on NMC fax charts, as shown in the examples. In the first example, effects of diurnal factors on the analysis are illustrated. At 0600 MST, September 14, a cold front has just passed Rock Springs, Salt Lake City and Tonopah. The front is just strong enough to shift the wind at Salt Lake City to light northwesterly, overcoming the southeasterly drainage wind which normally becomes established in the early evening. The front can also be located by the large pressure rises behind the front and much smaller rises ahead. In fact, the front is held north of Ely, not so much because of the southerly direction of the wind, which is the direction of the drainage wind, but because of the small pressure rise. The gradient indicates that the front should move slowly southeastward; and on Figure 6 for 0900Z, and Figure 7 for 1200Z, it has been advanced in this direction for kinematical consistency. The large pressure rise at Delta at 0900Z is also indicative of the frontal passage. Note that the wind at Salt Lake City has become light southeasterly as the drainage wind has now become strong enough to overcome the pressure gradient. This is also true at Ely. The temptation to move the front back against the gradient to the north of Salt Lake City must be resisted.

The second example illustrates some orographic effects. In Figure 8, for 1200Z, October 6, a rapidly moving Pacific occlusion is located over Washington and northwest Oregon. Winds aloft at this time were very strong westerly. By 1800Z, the front has moved eastward to western Montana, northern Idaho, and central Oregon (Figure 9). Note the pronounced trough in the lee of the Cascades, and that the winds at GEG, YKM and OMK are still south-southwesterly. The wind at Spokane characteristically does not shift under these conditions. OMK is in a narrow north-south valley with a strong channeling effect--winds tend to blow up the valley as long as pressure is lower to the north. By 00Z, October 7 (Figure 10), the front lay nearly east-west through southern Montana to central Oregon. Spokane and Ephrata winds are still southwesterly. Omak has shifted to northerly, the wind now being channeled down the valley, with higher pressure to the north. The trough is still apparent over eastern Washington.

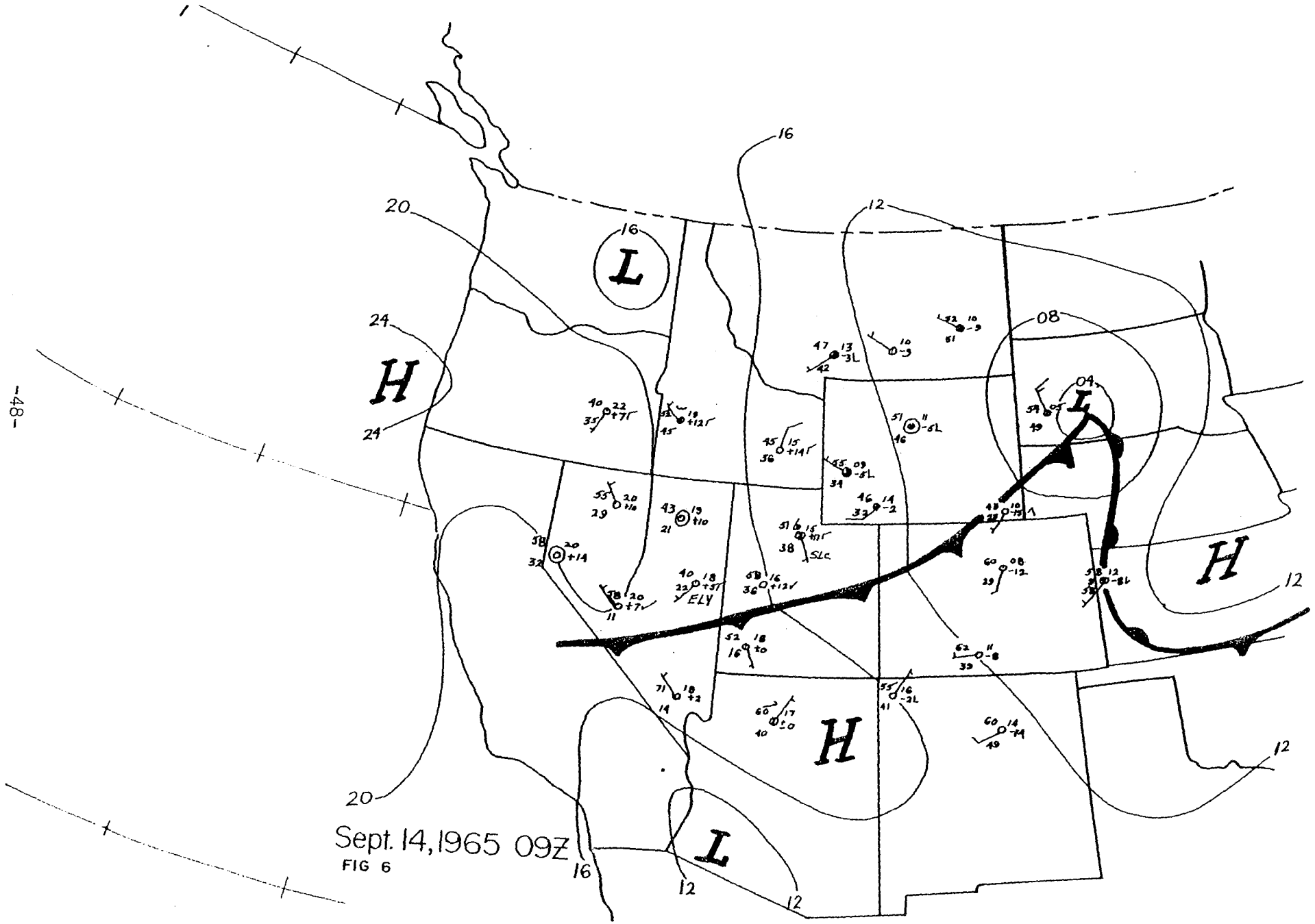
Some analysts unfortunately tend to hold fronts in the lee trough, waiting for the wind at stations like Spokane to shift to westerly or northwesterly. By the time the wind does shift at some of these eastern Washington stations, the front may be several hundred miles farther east. The same is true for stations in the lee of the Sierras, like Bishop and Reno.

These are merely brief examples to indicate the value to the analyst of detailed knowledge of small-scale effects masking the synoptic effect.



Sept. 14, 1965 06Z

FIG. 5



Sept. 14, 1965 09Z

FIG 6

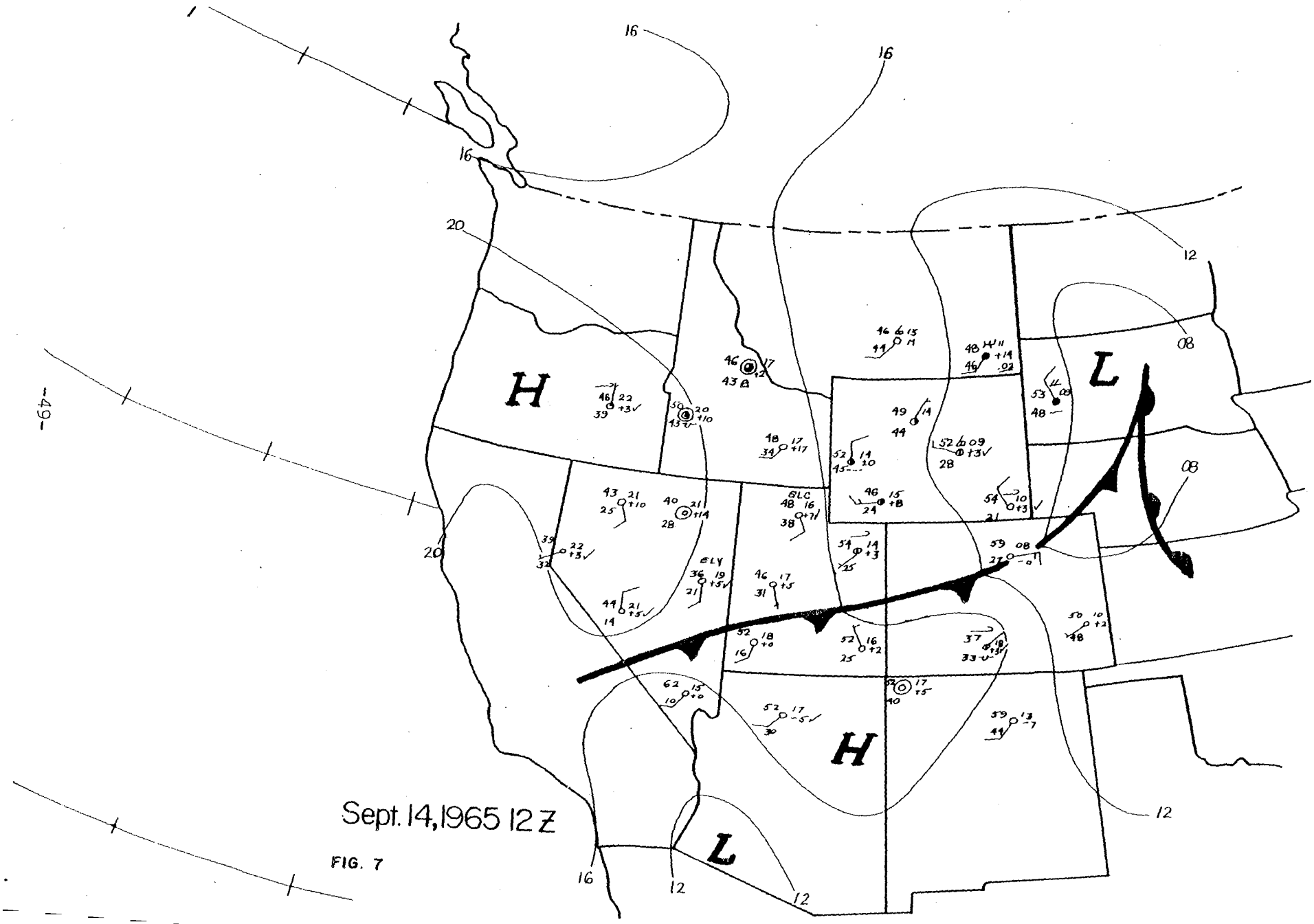
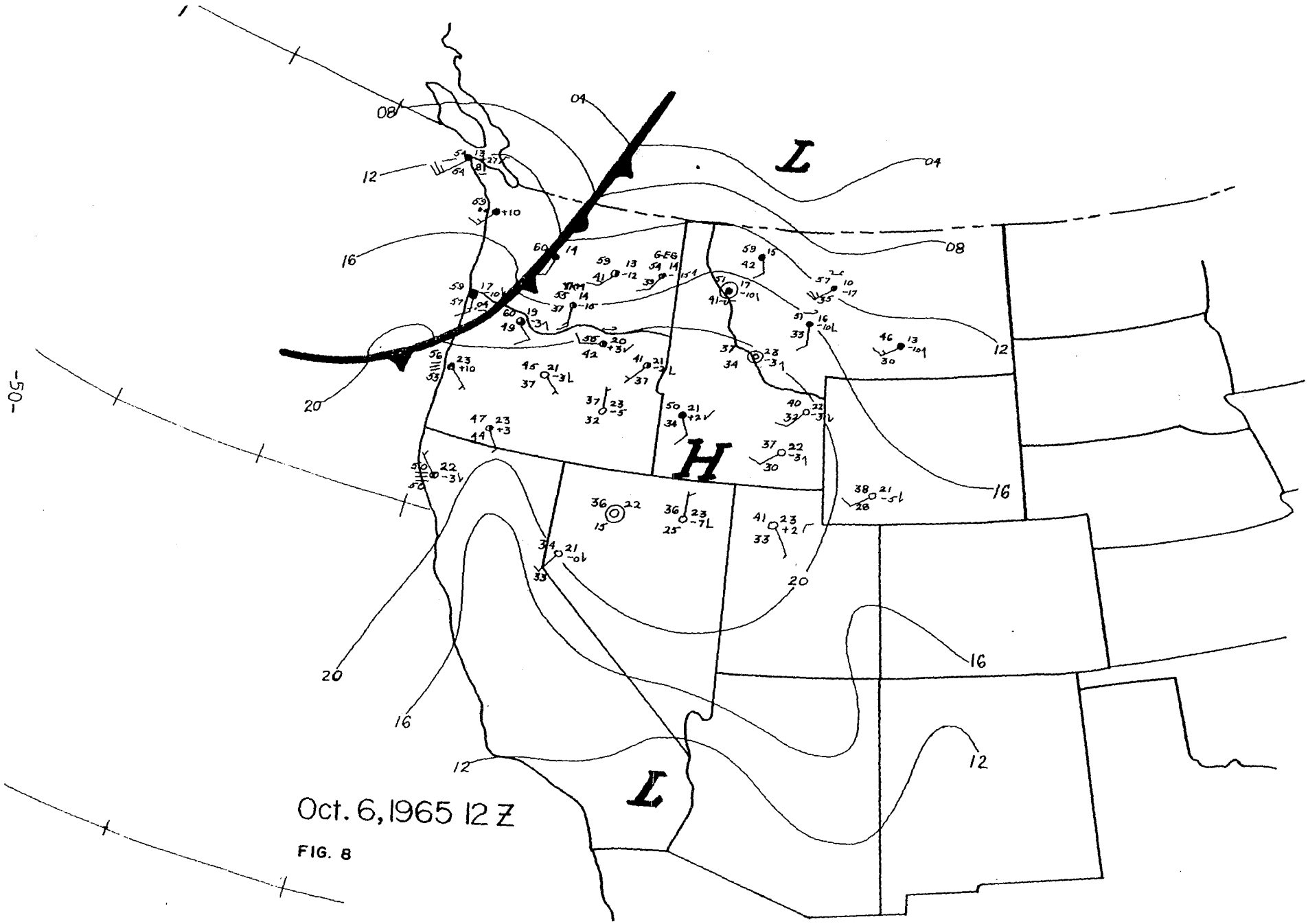
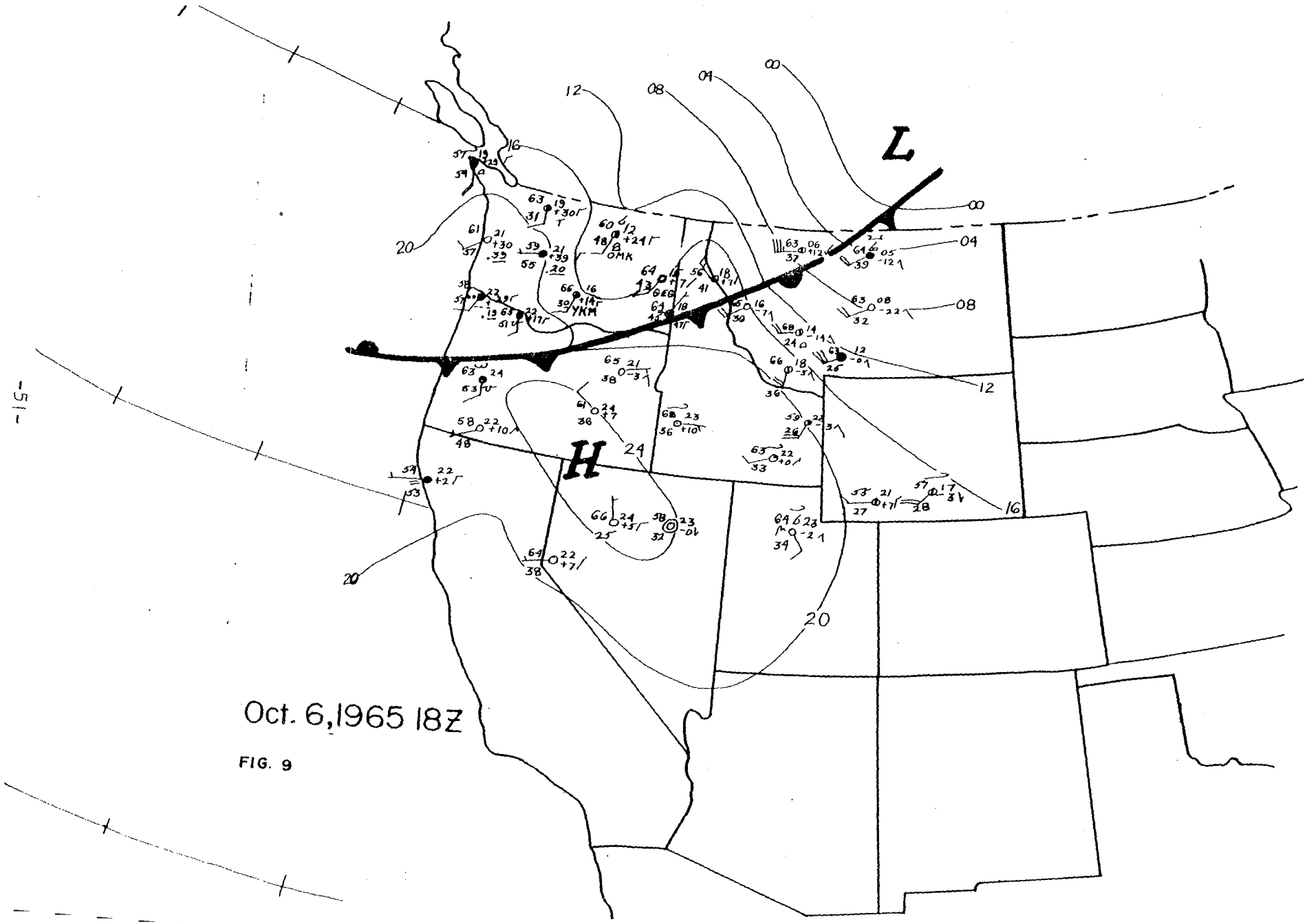


FIG. 7



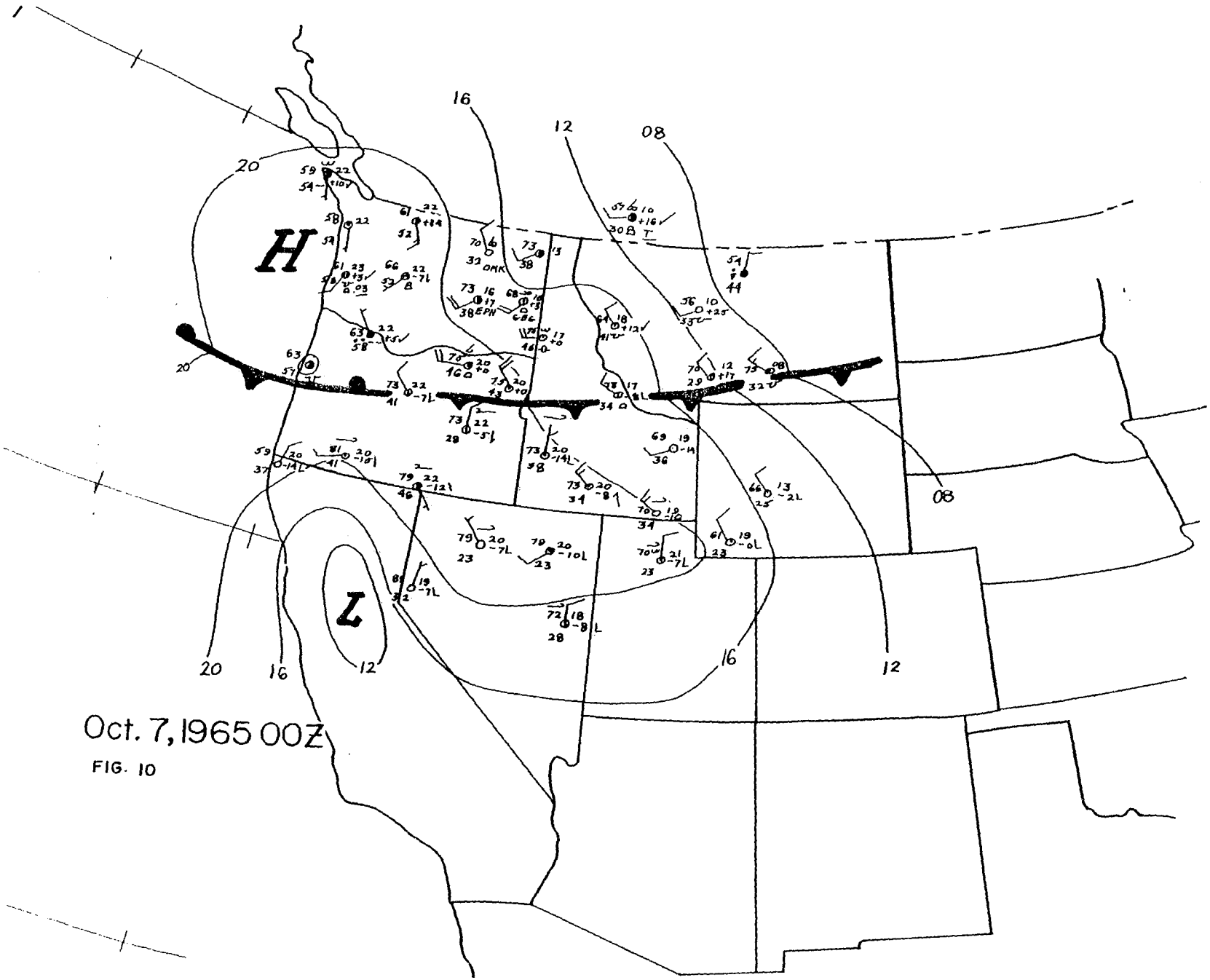
Oct. 6, 1965 12 Z

FIG. 8



Oct. 6,1965 18Z

FIG. 9



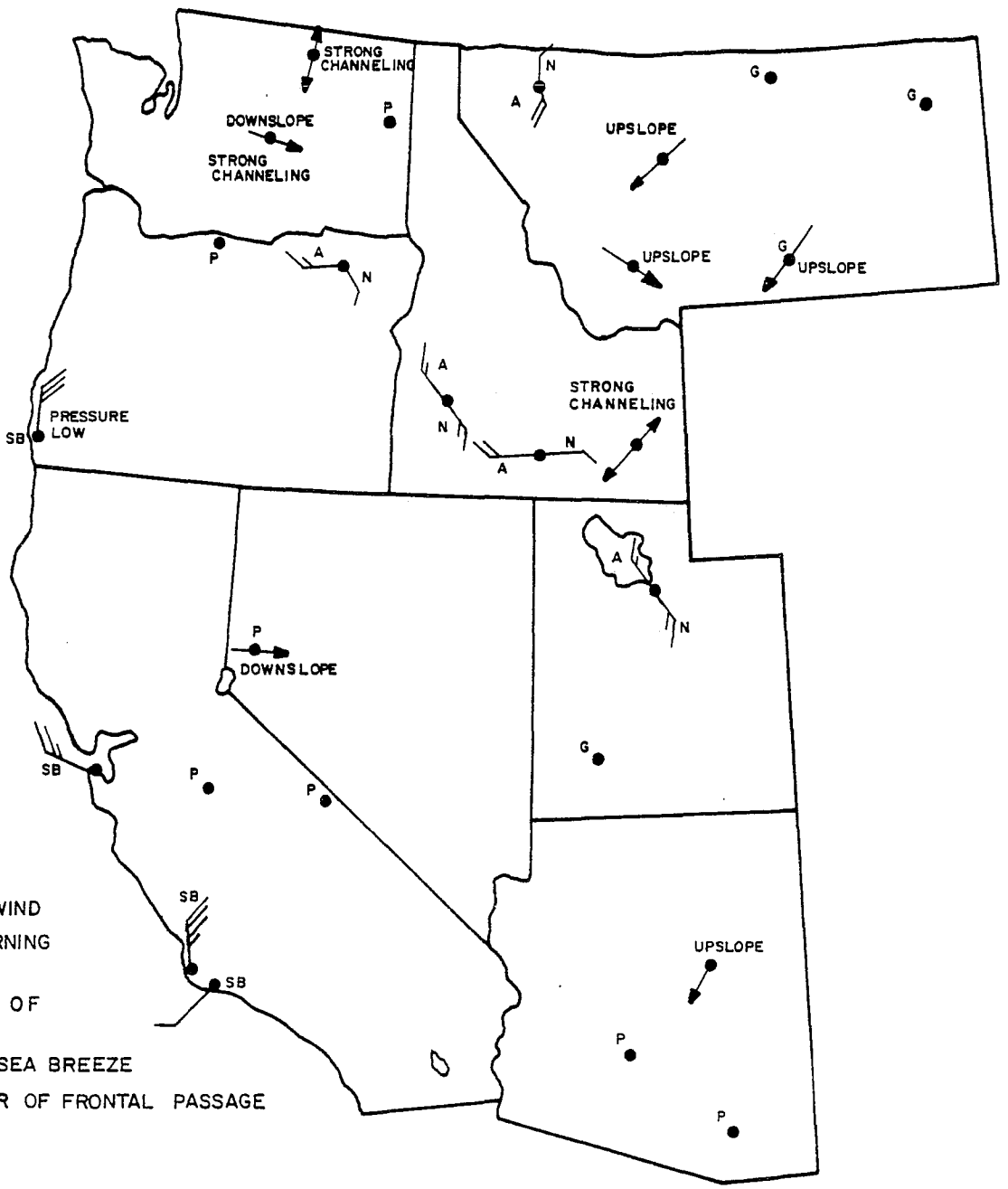
Oct. 7, 1965 00Z

FIG. 10

APPENDIX

Maximum use can be derived from the material presented in this Technical Memorandum by coding the descriptive information for stations in the area of interest and entering the coded data on a map. An example is given in Figure 11. The afternoon and nighttime diurnal winds, summer afternoon sea breezes, reliability of wind shifts as indicators of frontal passage, up and down valley wind channeling effects, miscellaneous remarks, etc., are indicated. The map can then be displayed in the forecaster's working area as a ready visual aid for preparing small-scale analyses.

EXAMPLES OF CODED STATION DESCRIPTIONS



A = AFTERNOON DIURNAL WIND

N = NIGHT AND EARLY MORNING DIURNAL WIND

P = WIND POOR INDICATOR OF FRONTAL PASSAGE

SB = SUMMER AFTERNOON SEA BREEZE

G = WIND GOOD INDICATOR OF FRONTAL PASSAGE

FIG. II

Western Region Technical Memoranda: (Continued)

No. 24 Historical and Climatological Study of Grinnell Glacier, Montana. Richard A. Dightman. July 1967.

No. 25 Verification of Operational Probability of Precipitation Forecasts, April 1966 - March 1967. W. W. Dickey. October 1967.