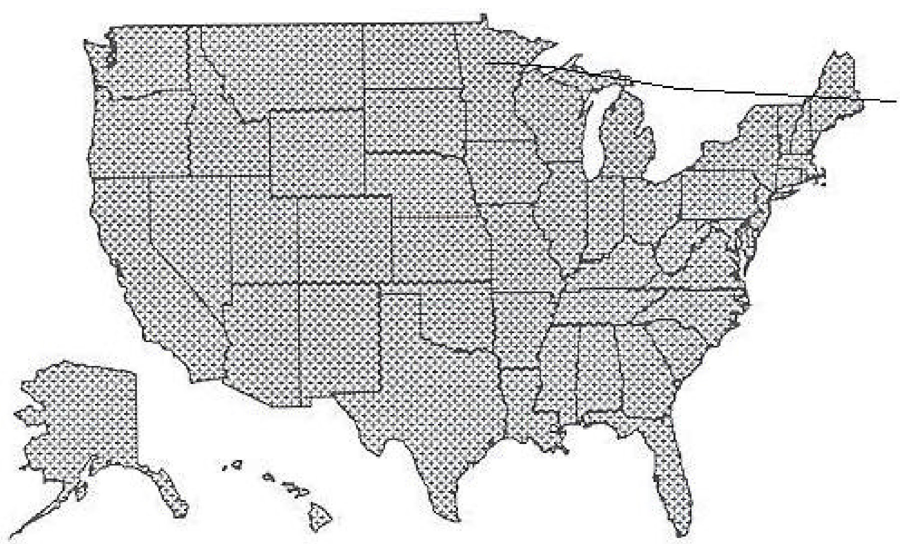
Critical Fire Weather Patterns of the United States



Reference: National Weather Service's (NWS) Fire Weather Forecasters Course Presented at Boise March 30 – April 2, 1999.

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THE BIG DRY

BILLINGS FIRE WEATHER

DESCRIPTION: A dry pacific weather front has moved across eastern Montana with a persistent and strong northwest flow aloft (i.e. "The Big Dry") that is forecast to remain for two to four days. Normally the pacific weather front will have enough instability for a few dry thunderstorms. However, about 60 percent of our project fires are man caused. Generally, eastern Montana has to be in a moderate to extreme drought for a major fire outbreak to occur.

SURFACE: Great basin high normally shifts from the eastern great basin to the western portion of the great basin. This cuts down on the persistent southwest winds on the east slopes of the Rockies. Surface lows associated with the weak disturbances are usually in northern Alberta and Saskatchewan. Strong northwest gradient winds blow continually, although the winds diminish somewhat at night.

UPPER AIR: Flat ridge of high pressure aloft centered over the great basin or central west coast (northern California and southern Oregon) with a strong west northwest flow aloft from British Columbia across Montana (**Fig 1**). Minor disturbances will move across British Columbia and Alberta, but only produce a little middle and high cloudiness over eastern Montana.

PATTERN RECOGNITION: Flat almost zonal flow is usually handled quite well by the NGM/AVN prog packages. This flow, when coupled with the basin high shifting to the west, allows for basically dry downslope flow to cover all of eastern Montana.

OBJECTIVE TECHNIQUES: Airmass will be warm but not hot under this weather pattern. Humidities will continually bottom out at 10 to 15 percent and nighttime recoveries of 35 to 45 percent are common. In this pattern fires continue to run through most of the night and daily blowups can be expected by noon or shortly thereafter.

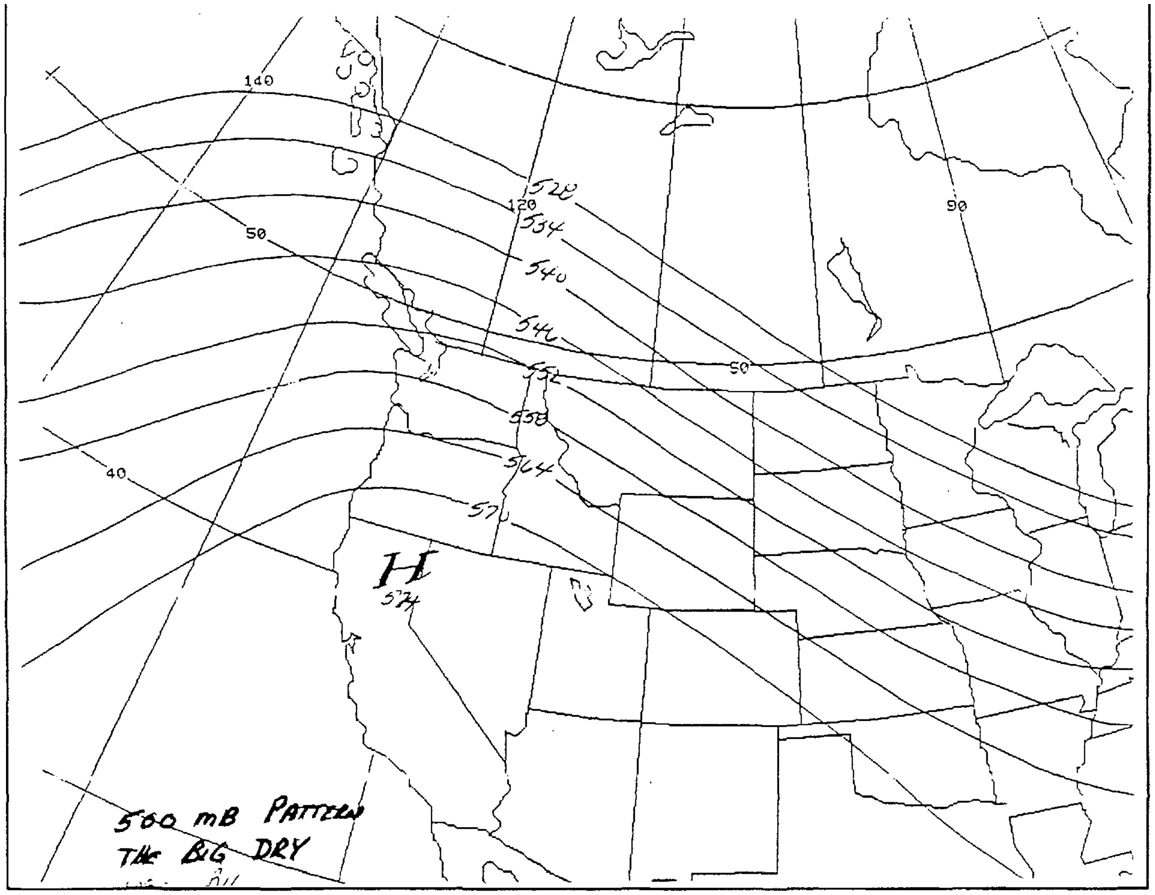


Fig 1. 500 mb pattern for persistent west to northwest flow aloft ("The Big Dry").

BREAKDOWN OF THE UPPER RIDGE

BOISE FIRE WEATHER

DESCRIPTION: One of the critical fire weather patterns in the Boise district, as well as much of the rest of the West, is the breakdown of the upper ridge in conjunction with a moderate (5) to high (6) Haines Index (**Fig 1**). A section on calculating the Haines Index is included (**Figs 2,3**).

SURFACE: When the upper ridge builds over the West, the surface thermal trough will frequently push into the eastern portions of Oregon and Washington. When the ridge breaks down and shifts east, this thermal trough shifts into Idaho. Though fires may be active with the thermal trough to the west, fires become much more active with the thermal trough overhead (**Fig 1**).

An increase in moisture usually accompanies an upper short wave, but at times a "tongue" of very dry air wraps around the leading edge of the short wave resulting in low relative humidities at the surface (**Fig 1**). The best map to use for analyzing the dry tongue is the SFC—500 mb average relative humidity chart (AFOS graphic POD). A good rule of thumb is to watch for RH values less than 20 percent.

UPPER AIR: Look for an approaching **weak** short wave. While both a strong and weak short wave will breakdown the ridge and shift it east, the weak wave will bring upper level cooling while allowing the lower levels to remain hot (i.e., increase fire intensity).

Use water vapor imagery to locate dark areas as potential regions of moderate/high Haines Index. WV imagery shows mid and upper level moisture with a maximum around 400 mb. Be careful as WV imagery will occasionally show light gray (i.e. moist) areas, yet the Haines Index is 5 or 6. This is typically due to moisture above 500 mb (remember that the 700-500 mb Haines Index is used in Idaho), so always check the upper air data. Another good rule of thumb is to examine the WV pictures very carefully for totally black areas (use an enhancement curve and/or adjust the contrast of the monitor). These black regions are frequently associated with a 5 or 6 Haines Index.

Another factor to look for is the subtropical jet (STJ). A STJ over the fire can lead to increased fire activity much in the same way as the STJ affects severe thunderstorms (i.e., increased vertical motion due to divergence aloft). The best way to track the STJ is with water vapor imagery and, to a lesser degree, with the 200 mb isotach analysis. A STJ is often more effective at increasing fire activity than a polar jet. The polar jet, like the strong short wave, is more apt to bring low level cooling as opposed to the STJ.

PATTERN RECOGNITION: This critical fire weather pattern is composed of several ingredients, much like a severe thunderstorm is produced by several factors. In each case, the more ingredients you have, the more likely the event will occur. These are the items to be on the lookout for:

- Short wave (preferably weak) approaching followed by the breakdown or eastward shift of the upper ridge.
- Moderate (5) or high (6) Haines Index, either currently over the fire site or expected to be advected over the area. Examine the AFOS Haines Index chart (AFOS graphic HNI).
- Surface thermal trough over or just west of fire.
- Tongue of dry air (use WV imagery/average RH SFC—500 mb).
- Subtropical jet (use WV imagery/200 mb isotach analysis).

OBJECTIVE TECHNIQUES: Aside from Haines Index, no other objective aids have been developed for this weather pattern.

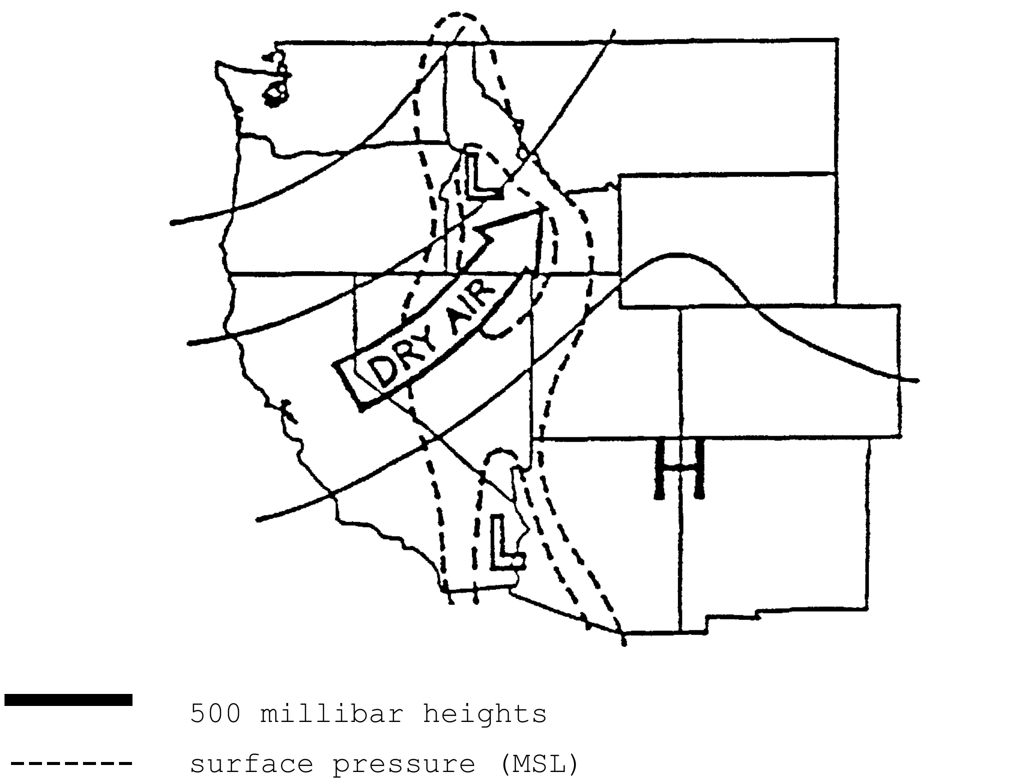


Fig 1. Schematic pattern showing breakdown of upper ridge. This situation usually produces a moderate to high Haines Index. The STJ and dry tongue are shown by the large arrow.

Fig 2. Calculating the Haines Index

$$\text{HAINES INDEX} = \text{STABILITY} + \text{MOISTURE} = (Tp_1 - Tp_2) + (Tp_1 - Tdp_1) = A + B$$

where T is the temperature at two pressure surfaces (P_1,P_2); and Tp_1 and Tdp_1 are the dry bulb temperature and dew point temperature at a lower level. All temperature values are centigrade.

Illustrated below are the lapse rate and moisture limits used in the low, mid and high elevation Haines Indexes. The U.S. is divided into three regional elevations (**Fig 3**).

ELEVATION	STABILITY TERM	MOISTURE TERM
LOW	950 — 850 mb TEMP	850 mb TEMP – DEW POINT
	A=1 when 3 deg C or less	B=1 when 5 deg C or less
	A=2 when 4-7 deg C	B=2 when 6-9 deg C
	A=3 when 8 deg C or more	B=3 when 10 deg C or more
MID	850 — 700 mb TEMP	850 mb TEMP – DEW POINT
	A=1 when 5 deg C or less	B=1 when 5 deg C or less
	A=2 when 6-10 deg C	B=2 when 6-12 deg C
	A=3 when 11 deg C or more	B=3 when 13 deg C or more
HIGH	700 – 500 mb TEMP	700 mb TEMP – DEW POINT
	A=1 when 17 deg C or less	B=1 when 14 deg C or less
	A=2 when 18-21 deg C	B=2 when 15-20 deg C
	A=3 when 22 deg C or more	B=3 when 21 deg C or more

Add the factor values (A + B):

(A + B)	Class of day (potential for large fire)
2 or 3	very low
4	low
5	moderate
6	high

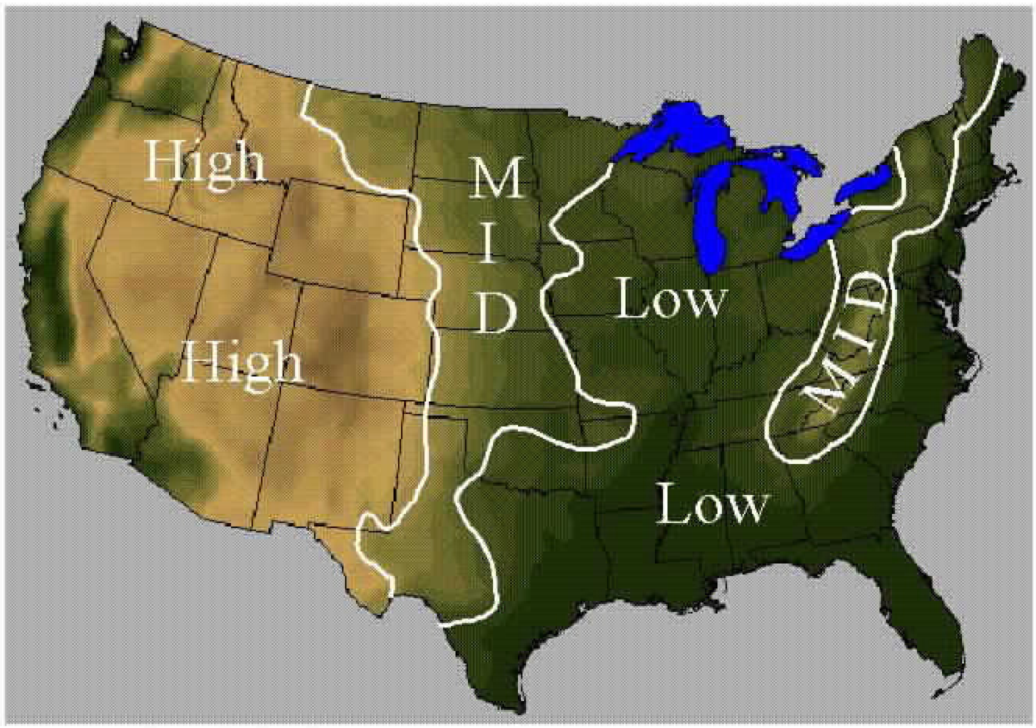


Fig 3. Map of United States divided into three regional elevation (from Haines 1988).

Low — Most of the eastern U.S., excluding the Appalachian Mountains.

Mid – Great Plains and Appalachian Mountains.

High – Western U.S.

PACIFIC COLD FRONTS

CHEYENNE FIRE WEATHER

DESCRIPTION: Critical fire weather situations occur in Wyoming from late June through September. Dry west or southwest flow aloft and the resultant winds on the surface produce critical fire danger. Examples showing the approach of Pacific cold fronts occurred on June 27, 1990 (**Fig 1**) and August 26, 1990 (**Fig 2**).

SURFACE: The surface pattern conductive for extreme fire danger occurs with the approach of a Pacific cold front. Strong south to southwest winds tend to blow ahead of the front. The surface winds may be even further enhanced by the upper level winds mixing down to the surface. Thunderstorms usually form by afternoon over the mountains. Almost all critical fire weather days occur with the approach of the Pacific cold front.

UPPER AIR: Extreme fire danger occurs when the normal upper level ridge over the Rockies breaks down and shifts east to the plains, resulting in southwest winds aloft. Temperatures average well above normal with varying amounts of moisture. If subtropical moisture becomes entrained in the flow, then substantial rainfall will occur. If this moisture is only at very high levels, then dry thunderstorms will result. In any case, convective temperatures are usually reached, and the likelihood of dry thunderstorm occurrence is just a matter of moisture availability.

PATTERN RECOGNITION: Look for the breakdown of the upper ridge and the approach of a Pacific cold front.

OBJECTIVE TECHNIQUES: A key forecasting guide to thunderstorm activity is precipitable water.

P W (% of normal)	Expected weather
> 100%	Significant rainfall
50—100%	Dry thunderstorms lower elevations Wet thunderstorms higher elevations
< 50%	Dry thunderstorms

Remember that most storms above 9000 feet msl will produce some rainfall.

Other guidance values are helpful in forecasting fire weather parameters. MOS temperatures are usually fairly close in this situation, but relative humidities tend to be on the high side. FWC (NGM model) wind guidance is superior to FPC (LFM guidance).

WEDNESDAY, JUNE 27, 1990

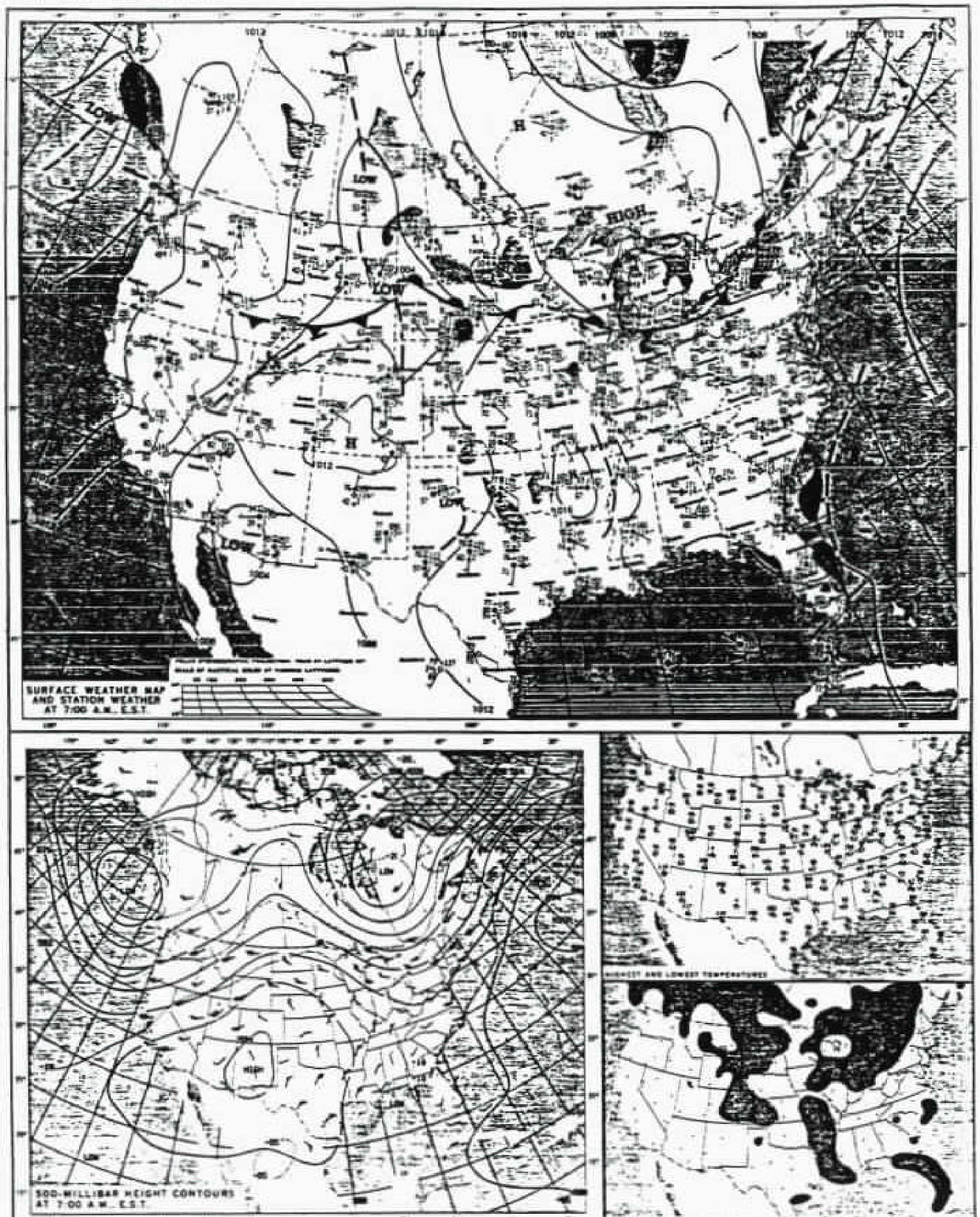


Fig 1. Example of approaching Pacific cold front (6/27/90 12Z).

SUNDAY, AUGUST 26, 1990

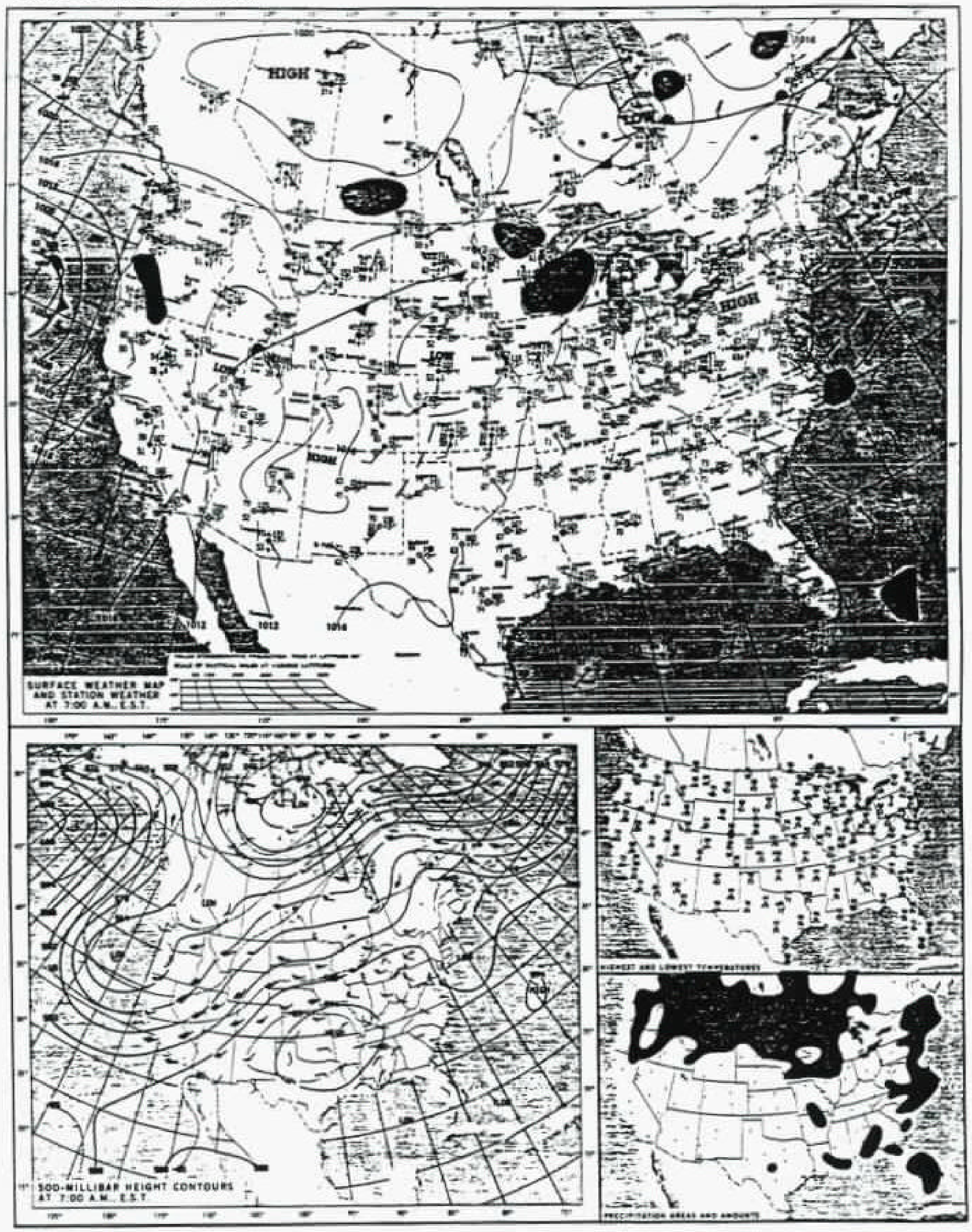


Fig 2. Example of approaching Pacific cold front (8/26/90 12z).

CHINOOK WINDS

DENVER FIRE WEATHER

DESCRIPTION: Post frontal and prefrontal chinook winds have contributed to runaway fires in the populated Colorado Front Range Foothills and adjacent plains during the last few years. The fires occurred in September and November, when fuels were abundant and dry.

SURFACE: A leeside trough lies over eastern Colorado with high pressure and a strong gradient to the west. Quite often the high is centered near Grand Junction (GJT). This scenario corresponds best with northwest flow aloft. Southwesterly chinooks often have a surface high over the south—central plains with a well developed cold front and trough over the southwestern U.S.

UPPER AIR: This pattern occurs with strong west-southwest to west-northwest winds aloft (i.e., a tight 700 mb gradient with winds 35 kts or greater). When the flow is southwesterly, the onset of chinook winds is often before the passage of a weak cold front. When the flow is northwesterly, the onset of the winds is often during and after the passage of a weak 700 mb trough.

PATTERN RECOGNITION: Look for strong winds at mountain top level with a large component normal to the Continental Divide. Geostrophic winds at 700 mb need to be at least 30 kts from 250 to 340 degrees. The winds should not increase too rapidly with height above the mountain top level. Also needed is a very stable layer near or just above mountain tops. The stronger the subsidence east of the divide, the greater the chinook. The axis of strongest 500 mb winds is often north of the threat area. A shallow arctic airmass is NOT present over the Colorado plains adjacent to the foothills.

OBJECTIVE TECHNIQUES: Use the Sangster Wind Model output employing the pressure gradients between Salt Lake City (SLC), Grand Junction and Lander (LND).

MONSOON SOUTHWEST FLOW

DENVER FIRE WEATHER

DESCRIPTION: After a protracted period of the Great Basin High with associated hot and dry conditions, a well developed trough or cutoff low forms along the west coast and pushes inland. The ridge is forced southeast and sets up a strong southwest windflow which carries Baja California moisture into the region. Peak fire danger occurs during the initial onset of the southwest flow, when moisture is concentrated above 600 mb and winds are increasing aloft. The lower atmosphere remains hot, dry and unstable, thus leading to dry thunderstorms and good downburst conditions.

SURFACE: High pressure is located over the south-central plains with a south—southwest to southeast flow over Colorado.

UPPER AIR: The upper pattern shows a 500 mb trough west of Utah with a long train of mid and upper level moisture from old Mexico into the intermountain region. Strong southwest flow occurs over Colorado. The majority of low level monsoon moisture has not made it into Colorado. Due to the position of the upper ridge, the moisture may be forced east or west of the state.

PATTERN RECOGNITION: Look for the inverted V sounding at Grand Junction (GJT) and/or Denver (DEN). The moisture should be concentrated at or above 600 mb with very dry lower levels. This will lead to a downburst potential of 35 kts or more.

OBJECTIVE TECHNIQUES: None at this time.

POST THERMAL TROUGH WINDS

WENATCHEE FIRE WEATHER

DESCRIPTION: Strong west to northwest winds across eastern Washington during the fire season usually warrant Red Flag consideration. Some of the strongest of these winds occur when a surface thermal trough shifts eastward across the Cascade Range to the Idaho border. During this shift, pressure differences across Washington switch dramatically. Sustained west to northwest winds 20 to 30 mph along the East Slopes are likely. Many times these winds are enhanced by the marine "push" on the West Side. It is not uncommon for gusts to 40 mph to occur depending on the depth of the incoming marine "push."

SURFACE: Significant heating at the surface allows the summer—time thermal trough of the San Joaquin Valley to work its way northward along the coast to western Washington and southwestern British Columbia. When the upper ridge begins to drift eastward, it will drag the thermal trough with it to eastern Washington.

UPPER AIR: There exists a vertically consistent upper ridge that has been fairly stationary along the West Coast for several days.

PATTERN RECOGNITION: As the thermal trough works its way northward, check the wind at Stampede Pass (SMP). A moderate east wind (10-15 mph) through the pass will exist when the thermal trough is well established over western Washington. When the trough begins to drift eastward across the Cascades, the winds at SMP will shift and become southwesterly.

Also watch the SMP dew point. A sudden rise could be the leading edge of the marine "push" inland. The marine layer associated with this "push" can be between 2500 and 4000 feet deep. Cooler air showing up at the 850 mb and 700 mb level on the Quillayute (UIL) upper air sounding is an indicator of the marine air moving onshore behind the thermal trough.

OBJECTIVE TECHNIQUES: Keep checking the west to east gradients across Washington for changes. Especially watch the differences between Seattle (SEA) and Wenatchee (EAT). Look for offshore gradients to become onshore. This is the main clue as to when the trough crosses over the Cascades. In essence, this is a shift in a lee side trough.

Also, check the North Bend (OTH) surface pressure. When you see 1-3 mb rise in 3 hours, it may be that the surface trough is beginning to shift. If the upper winds are also shifting, movement of the surface trough is likely.

HIGH AND DRY

FAIRBANKS FIRE WEATHER

DESCRIPTION: Dry weather followed by dry thunderstorms is the classic pattern that brings lighting fire starts to Alaska's northern Interior. In Alaska, most fires are caused by humans, but lightning is the major starter in sparsely populated areas. Further, fires started by lightning consume the majority of acres burned every year. Understanding the unique weather patterns that contribute to critical lightning strikes is essential to fire weather in Alaska.

SURFACE: A low in the north Pacific moving into Bristol Bay is associated with one of the critical weather patterns. There is usually a thermal low over northern Alaska. But this surface pressure feature does not play a major role in critical situations.

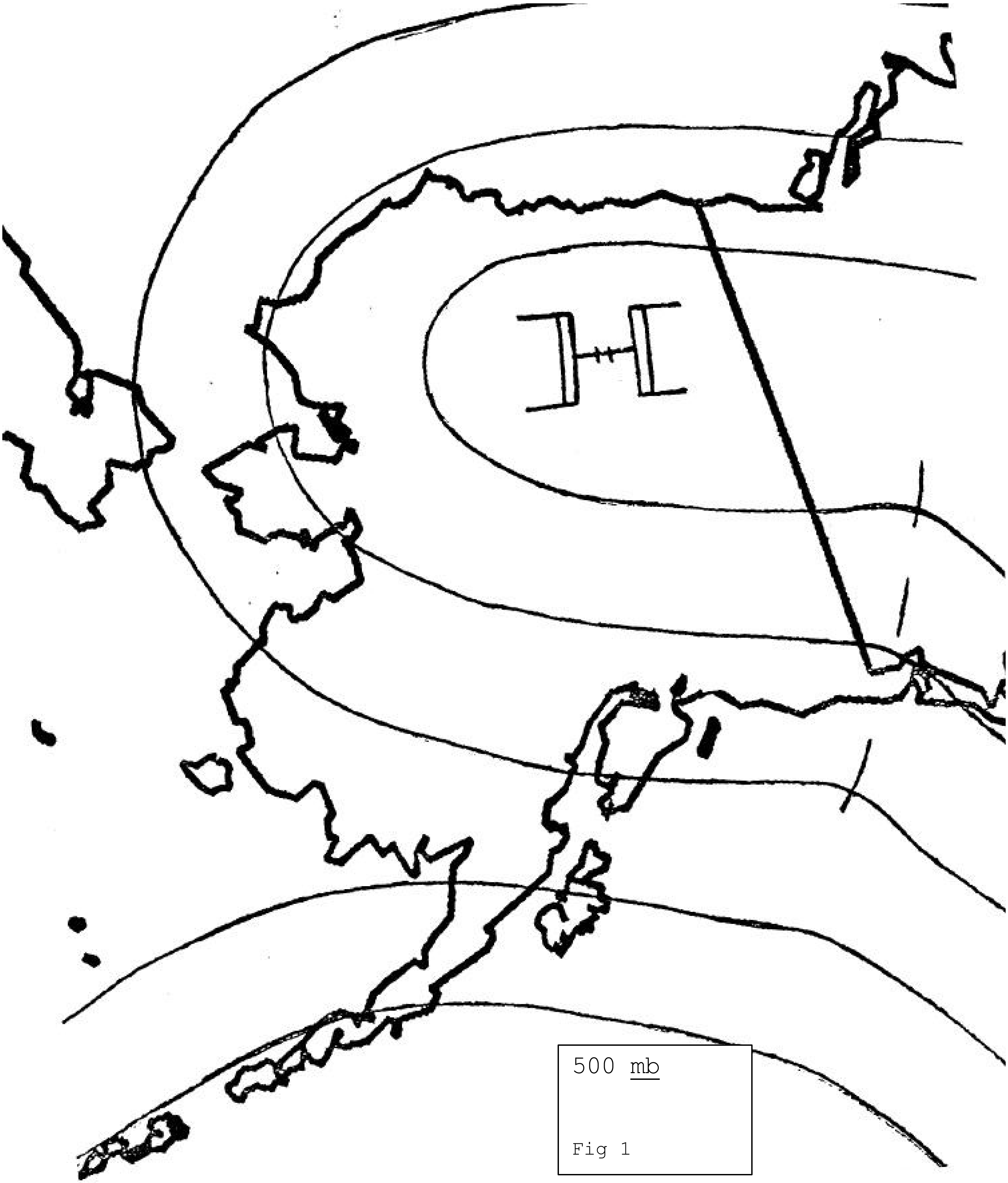
UPPER AIR: The upper air circulation patterns are most often associated with critical lightning fire starts in interior Alaska. Common to both patterns is the formation of a high at 500 mb over north central Alaska. This high is thermally reinforced and can last for a week or more. Directly under the high, convective development and precipitation are suppressed. The dry conditions combined with very long days can rapidly dry fuels. The most common critical fire weather pattern associated with this high aloft in the influx of mid and upper level moisture accompanied by upper level short waves traveling from the Gulf of Alaska along the southern edge of the high and into the heated dry interior (**Fig 1**). The increase in moisture and the presence of upper level divergence associated with this critical pattern can produce thunderstorms. North of the Alaska range and west of Tok the moisture is often sufficient for only dry thunderstorms. Areas to the east and south of the Alaska Range generally have enough moisture to produce wet thunderstorms. A strong short wave with sufficient moisture can produce more than two thousand lightning strikes over Interior Alaska in one day.

The second pattern is less common but can develop quickly. This involves transport of mid and low level moisture into the western and central interior of Alaska as the high aloft retreats north and/or east (**Fig. 2**). This pattern can produce very active dry thunderstorms on the still warm and destabilizing trailing edge of the high, with wetter thunderstorms closer to a low aloft over Bristol Bay. If the southwest flow continues and the high collapses, the pattern will rapidly (less than 24 hrs) evolve into a stratiform rain event.

PATTERN RECOGNITION: As the interior of Canada and Alaska heat up, the Trans-Pacific jet stream weakens. An upper level high begins to form over Canada and then gradually shifts westward in Alaska. This pattern is slow to develop and is usually forecast well by the long range computer models. Drying of fuels normally occurs in a few days after this pattern is established. Once this happens, nearly all lightning strikes will start fires. The first critical pattern is usually well forecast by mid range computer models. The moisture influx is generally handled well, especially by the ETA, and can be verified by satellite imagery. The second critical pattern of southwest flow must be watched, because the NGM/ETA often have a poor handle on systems coming out of the data sparse North Pacific. Additionally, the southwest flow if forecast, will often not materialize, or break down. The flow can become southerly over the central gulf coast and develop a Chinook on the north side of the Alaska Range as the low moves east. The low can also weaken and move into the Bering Strait producing winds and poor flying weather along the west coast.

OBJECTIVE TECHNIQUES: There are not yet any purely objective techniques for forecasting these patterns. Some factors must be considered in Alaska. In the Interior, the Alaska Range has a major impact and often blocks moisture from even the most vigorous lows from entering the Interior. The low sun angle makes south and southwest slopes, not only the earliest, but often the only areas to develop convection. Convective indices are much lower here than in the continental United States. Finally, the moisture content of the atmosphere over Interior Alaska must be sufficient (generally above .5 inches) to fuel airmass convection that is vigorous enough for thunderstorms to develop.

Because of the remoteness and inaccessibility of most areas in Alaska (**Fig. 3**), fire fighting is usually very expensive and time consuming. Often fires are only monitored.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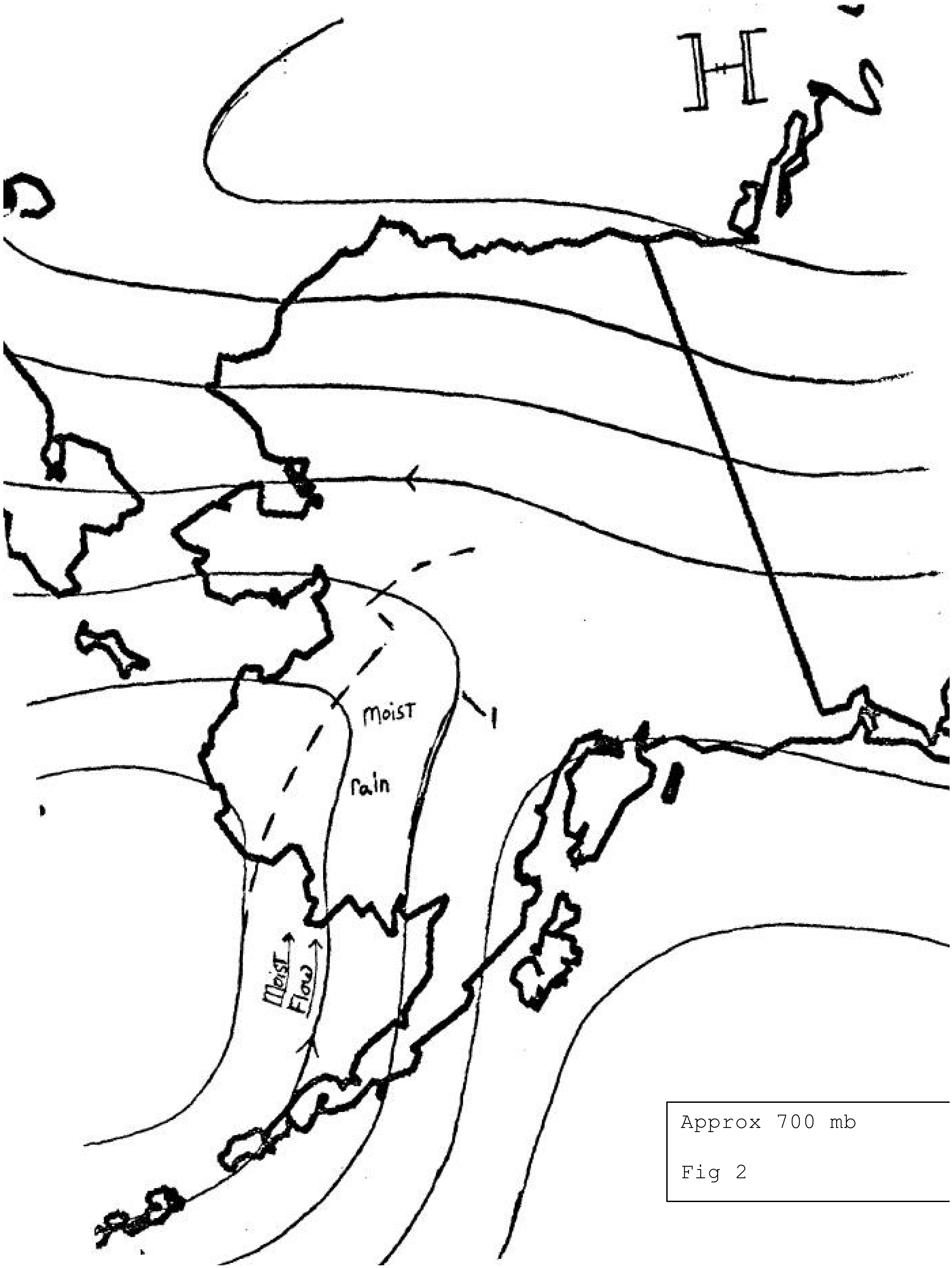
500 mb
Fig 1



Approx 700 mb

Fig 2

Fig 3

SUNDOWNER WINDS

FRESNO FIRE WEATHER

DESCRIPTION: Sundowner winds are strong foehn-like winds which affect coastal sections of Santa Barbara County. Local topography, including both the west & south facing coastlines and the east—west running Santa Ynez range, play an important role in the development of the Sundowner. As its name implies, the Sundowner most typically occurs in the evening and early nighttime hours. Past cases reveal at least two "patterns" in which Sundowner winds may occur. The first type may be dependant more on the local stability of the airmass in that particular area (type I), while the second type is more dependant on synoptic weather features (type II).

SURFACE: High pressure builds over central California/western Nevada and noses into the California deserts. Meanwhile, the thermal trough extends from Baja to the southern California coastline. As a result, pressure gradients increase along the Santa Ynez range. Surface pressure gradients between Santa Maria (SMX) and Santa Barbara (SBA) may approach 4—5 mb or greater. Surface winds at Santa Maria will generally be northwest at 15—20 mph and gusty, while Santa Barbara will generally be southwest under 10 mph. These conditions are most often observed up to 2 hours before the onset of the Sundowner.

UPPER AIR:

Type I - Stability At 500 mb, a ridge builds over the district with a northwest or northerly flow aloft. The 500 mb winds may or may not be strong. The surface to 4000 ft agl winds are the key to Sundowner development. Mean sfc-4000 ft winds of 15-20 mph are a good indicator. Stability is an important factor as many type I cases have a subsidence inversion around 3000—4500 ft agl along with a surface based inversion. **See figure 1.**

Type II - Synoptic This pattern has a developing coastal trough shifting east. Strong northwest winds on the backside of the trough bring low level cold advection to the area. **See figure 2.**

PATTERN RECOGNITION: For type I, check Vandenberg (VBG) sounding for mean SFC—4000 ft agl winds of 15—20 kts or greater. For type II, check for cold air advection plus type I VBG winds. However, Sundowners appear to be more closely linked to the surface pattern. Look for lower pressure along the southern California coastline and higher pressure building across central California. Surface patterns show more consistency than do the 500 mb patterns.

OBJECTIVE TECHNIQUES:

Pressure gradients: SMX — SBA = 4 mb or greater.

Temperature: SMX cooler than SBA. Several hours prior to Sundowner, the temperature difference may only be 3—4 degrees. Onshore flow at SMX causes difference to approach 6—8 degrees or more.

Look for cold air advection as upper trough develops over inland sections (Type II).

Wind: VBG sounding mean sfc—4000 ft agl..
320—010 degrees at 15 kts or greater
010—040 degrees at 20 kts or greater

Strong afternoon winds at SMX usually 310—350 degrees/15—20 kts or more with higher gusts possible.

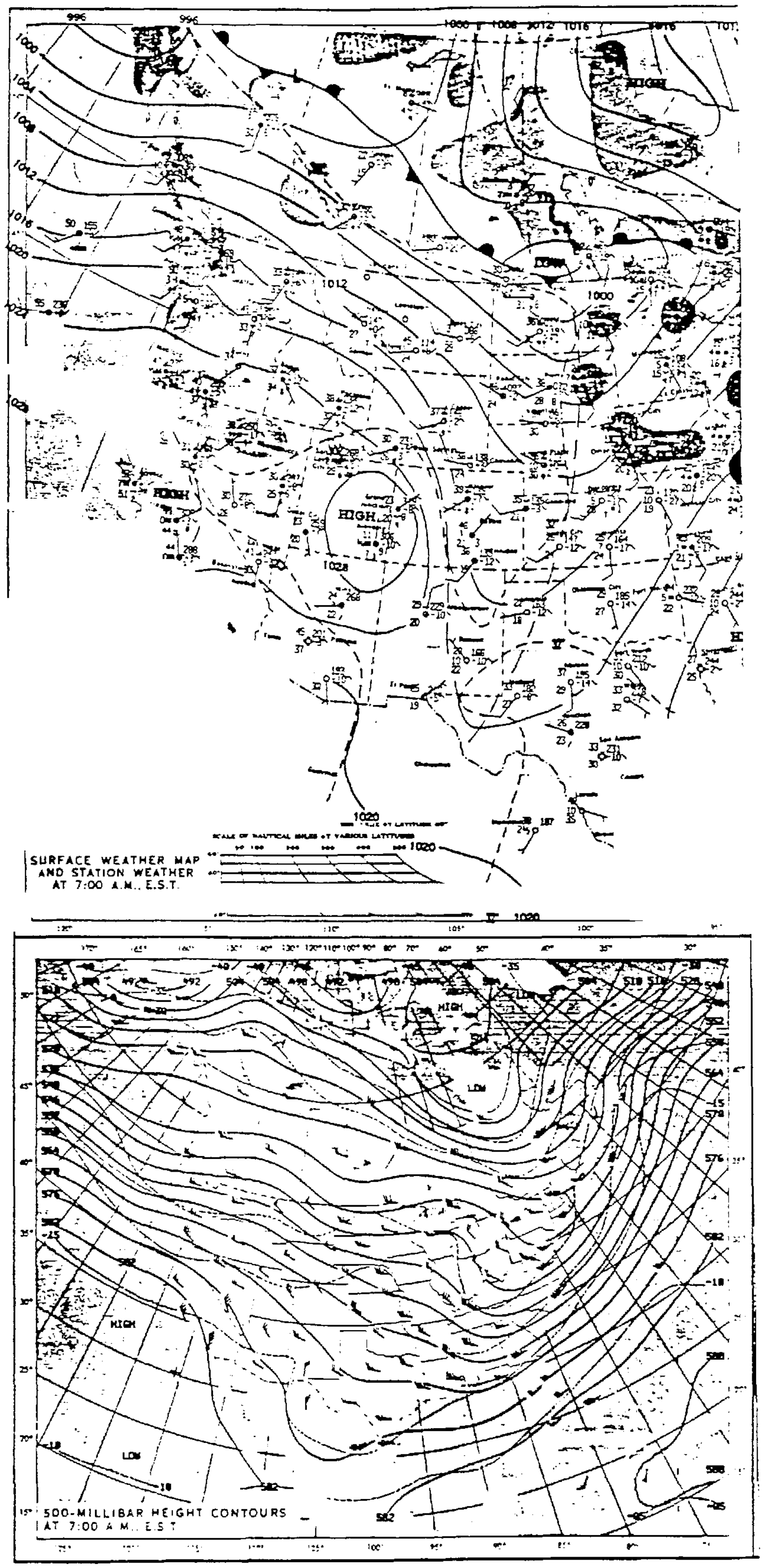


Fig 1. Example of Type I Sundowner (1/13/91 12Z).

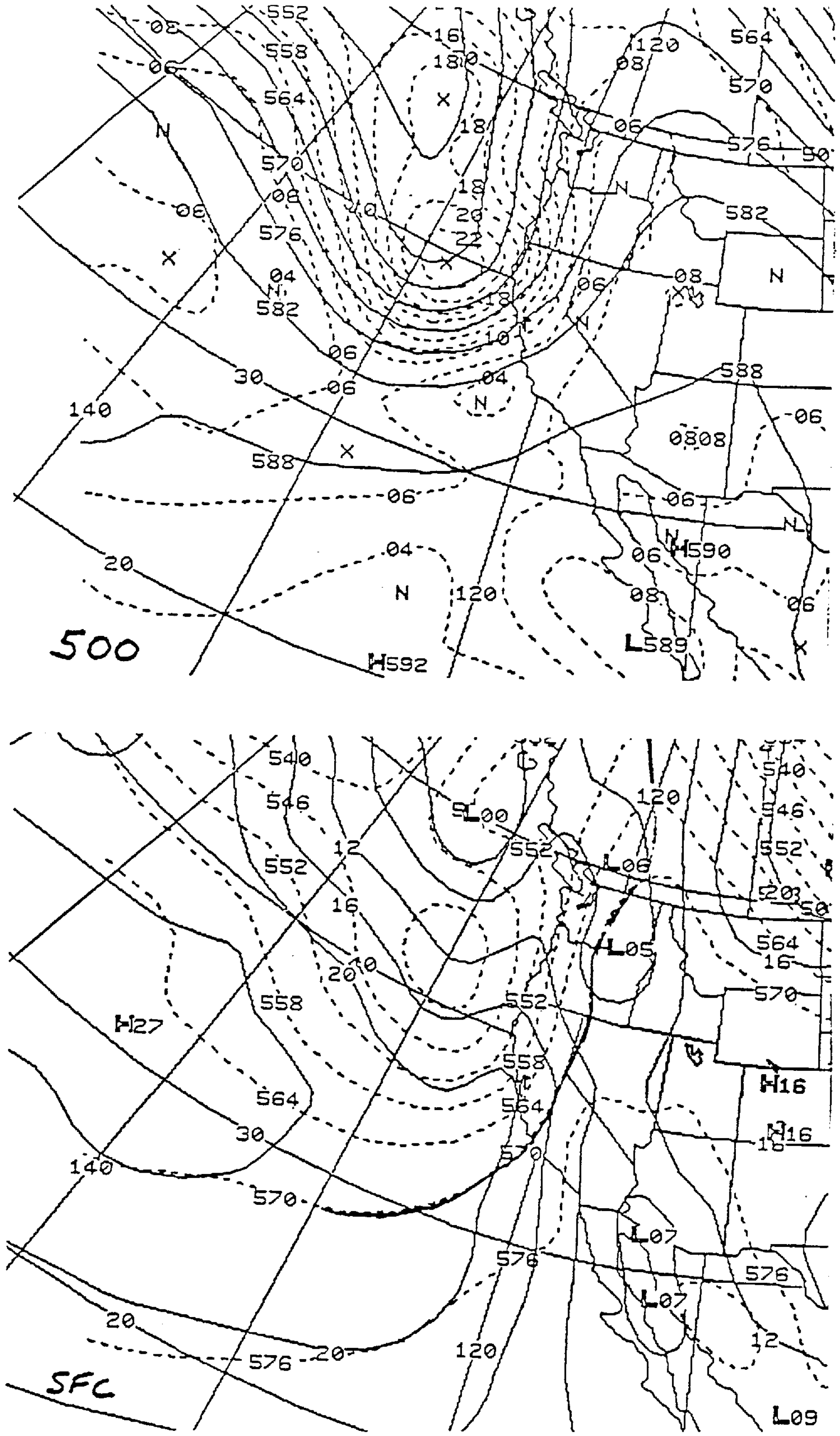


Fig 2. Example of Type II Sundowner (5/13/88 12Z).

SOUTHEASTERN U.S. PATTERNS

LITTLE ROCK FIRE WEATHER

DESCRIPTION: The “traditional” fire season in the Southeast is spring and fall. However, wildfires can occur at almost any time of the year during a drought. Wildfires in the months of December, January, and early February burn relatively few acres due to the short burning period of the day.

Wildfires during a summer drought may be numerous, but will be largely restricted to dormant grass and brushy areas.

Although some fires are ignited by lightning, most are started by the activities of man, either intentionally, or by accident.

SPRING FIRE SEASON: The spring season may begin as early as late February or March along the Southeast coast, including the Carolinas. The “height” of the fire season during the Spring is usually the weeks preceding “greenup”. The beginning of the Spring season in the Northeast and Great Lakes is traditionally around the months of April and May.

Typically a high pressure system has become dominant over the area. The source of the high may be the Pacific, or Canada. But whatever the case, the critical fire weather period occurs during the period of sunny skies and low humidity. A day with an extreme diurnal temperature range is a good candidate for extreme fire behavior. A major fire in North Carolina occurred on a day with a morning low in the mid 30’s and an afternoon high in the upper 70s.

The Bermuda High may be a factor at times. The high building into the Gulf of Mexico, keeps frontal precipitation to the north of the Southeastern states. Westerly flow through the lower layers across the Southeast brings a period of excessively low humidities to the region.

SUMMER FIRE SEASON: During July and August, a drought of three weeks or more may cure grasses to the point of being easily ignited. Peaks in fire activity occur during this period whenever the surface gradients increase and surface winds become moderately strong.

FALL FIRE SEASON: The peak in the Fall fire season typically occurs during the weeks after a frost and before the rains of November. Frost cures grasses at about the same time that leaf litter begins to build on the forest floor.

Once again, high pressure following on the heels of a cold front settles over the region and may dominate the weather for several days and even a week or more. The high originates from the Pacific or Canada.

There may be a dramatic increase in fire spread, as the high migrates off the Atlantic coast. The pressure gradient increases across the region in response to another approaching frontal system. However, a higher humidity regime soon follows and this critical fire weather pattern is modified after a day or two.

OBJECTIVE TECHNIQUES: None.

EAST WINDS

MEDFORD FIRE WEATHER

DESCRIPTION: The development of moderate to strong easterly foehn winds over the western and especially southwestern portions of the Medford Fire Weather District is one of the more frequent critical fire weather patterns that require red flag warnings. East wind patterns evolve slowly, although the onset of the winds is often abrupt. The east winds pattern produces dry downslope winds which are usually strongest in the late night and early morning hours. This is a terrain induced pattern that combines subsidence and forced downslope adiabatic warming to produce warm, dry winds. Stable air is piled up east of the Cascades and forced across the ridgelines and through the channeled areas. At the same time when nocturnal cooling in normally providing an increase in relative humidity, as east wind pattern instead brings dry, warm and windy conditions that carry moisture away from the fuels and push the fire.

The east winds pattern evolves as a slow moving upper level ridge builds up along the Oregon coast and extends inland. As the pattern develops, the thermal trough over the Sacramento and San Joaquin valleys of California moves north over the southwest portions of Oregon. Often an east wind event will follow on the heels of an onshore push of marine air. On the first night of the event, moisture from the Willamette Valley is pulled south across the ridges of the district to maintain good nighttime relative humidity recovery. The next day, the thermal trough pushes farther north over the western valleys with continued warming of the airmass. Surface high pressure off the Oregon coast noses inland over northern Oregon and extends southward east of the Cascades producing a northeast flow across the ridges.

Nighttime cooling reinforces the east wind pattern in several ways. It strengthens the surface high pressure area east of the Cascades, while at the same time the thermal trough moves farther west, nearer the ocean where less cooling has taken place. This pulls air away from the base of the ridgelines which has to be replaced by air coming down the slopes. This assists in allowing the east winds to dip down to lower elevations. The stabilization of the nighttime airmass also helps to move east winds down to lower elevations on the lee side after it is pushed across the ridgelines.

The stronger east wind patterns often develop after a slow moving upper level ridge has developed along the coast. At the same time, an inland upper level disturbance from the Gulf of Alaska has pushed inland through the northern extension of the ridge to cross Washington and move down over eastern Oregon. This carries cooler air east of the Cascades to reinforce the offshore gradient. During the stronger eastwind events, the thermal trough usually extends vertically to the 850 mb level or higher. As the pattern continues, the 500 mb ridge builds over the western portions of Oregon and Washington, the thermal trough pushes farther along the Oregon coast, and the low level flow veers from northeast, to east to southeast. The demise of the east wind pattern comes about as the upper level ridge moves inland accompanied by the thermal trough, or when a strong shortwave breaks through the mean ridge position to tune low level flow onshore.

SURFACE: High pressure over the eastern Pacific noses inland over northern Oregon east of the Cascades. The thermal trough over California extends over southwest Oregon, and north along or near the Oregon coastline (**Figs 1,2**).

UPPER AIR: An upper level ridge shown at the 500 mb level over the eastern Pacific builds along the coast with slow eastward movement. Flow aloft begins northerly then turns northeast as the upper level ridge builds inland (**Fig 3**). In the stronger patterns, a weak upper level disturbance often moves inland over the northern end of the ridge through Washington and pushes cooler air southward east of the Cascades.

PATTERN RECOGNITION: Look at the 500 mb level for a slow moving upper level ridge to build from the eastern Pacific over the Pacific Northwest. The NGM model does a fairly good job of predicting the thermal trough and its intensity. The ERL often has the thermal trough pattern correct but it is too weak on the gradient. The AVN is usually somewhere between the two models.

OBJECTIVE TECHNIQUES: No objective techniques currently are being used. Looking ahead, we are interested in looking at the 850 mb east wind component as an input to the strength of the pattern. The surface gradient has not always been a good predictor of the windspeeds for east winds. The 850 me height change and a closer look at the strength of the subsidence inversion may also lead to some objective techniques.

An example of east winds at the Onion Mtn RAWS site is shown in **Fig 4**. Thanks to John Werth (OLM) for use of his RAWS plotting software in displaying the east wind pattern.

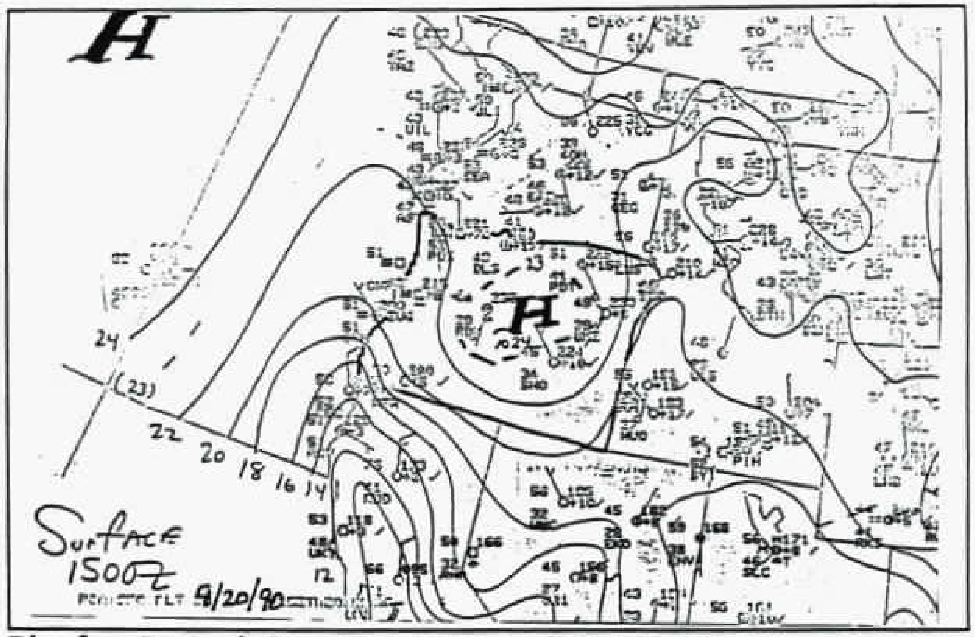


Fig 1. East wind surface pattern (9/20/90 15z).

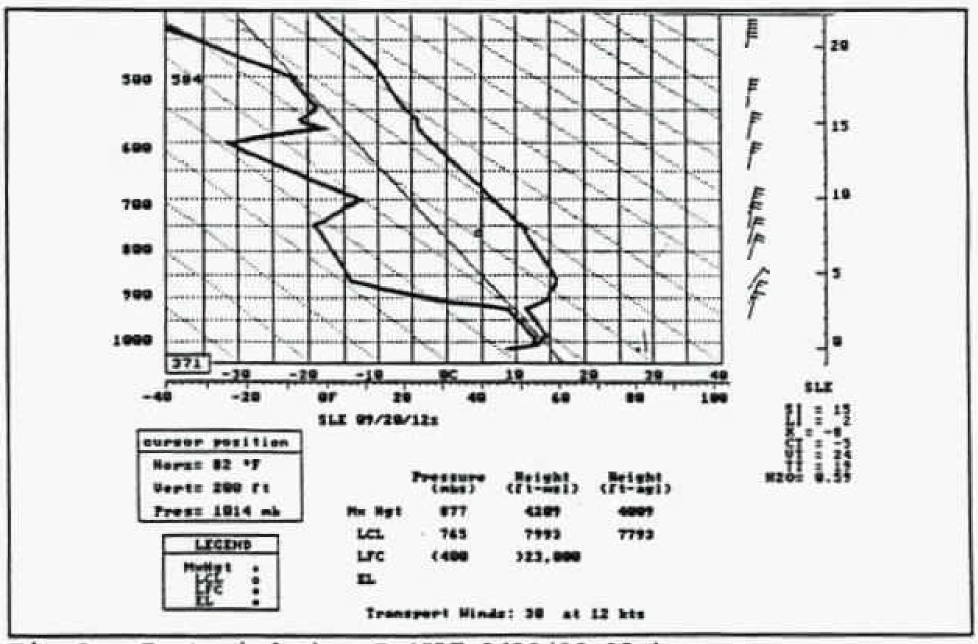


Fig 2. East wind skew-T (SLE 9/20/90 12z).

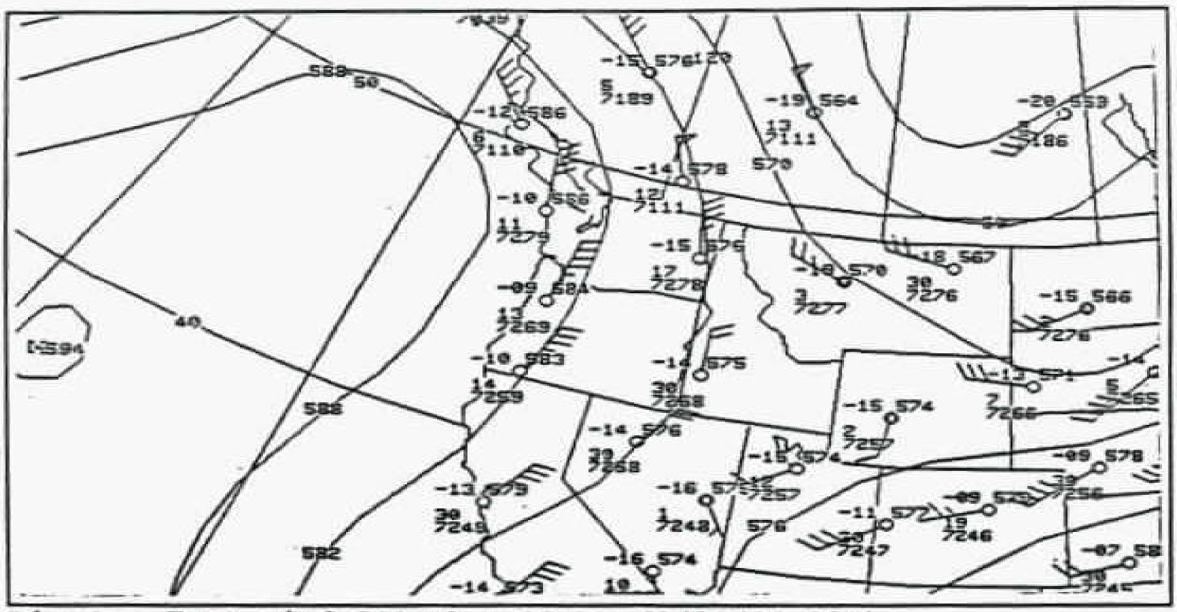


Fig 3. East wind 500 mb pattern (9/20/90 12z).

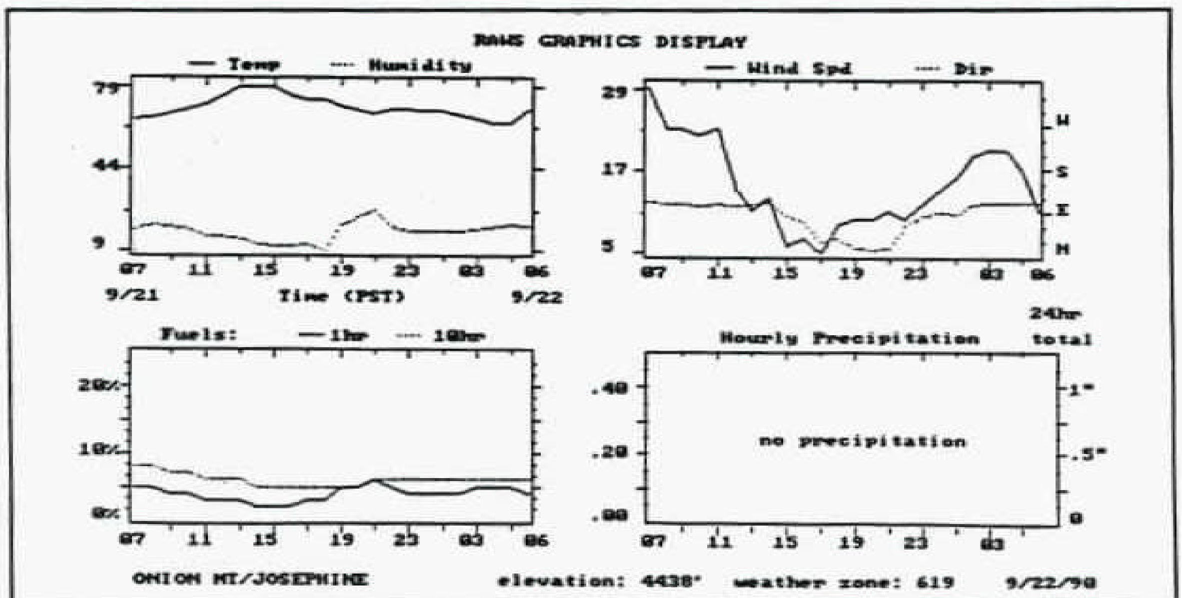


Fig 4. Onion Mtn/Josephine RAWS (9/22/90)

EAST WINDS

OLYMPIA FIRE WEATHER

DESCRIPTION: Historically, most of the great fires in Western Washington have been driven by strong, dry, east winds. These occur during the warm season, usually from May through October. These winds are typically associated with anticyclonic conditions over the Pacific Northwest and occur most frequently September or early October and to a lesser degree in late April and May. The strongest episodes occur when a center of surface high pressure moves to a position northeast of the Cascade Mountains. Winds in excess of 50 mph and humidities in the low teens are typical at lookouts along the lee slopes of the Cascades and Olympics.

SURFACE: Most severe east wind patterns begin with high pressure at the surface bulging inland from the west behind a cold front which passes by to the northeast. Surface pressure begins to rise as cold advection from the west to northwest increases. Surface pressures rise over the entire area, but rise most rapidly to the north and east. East winds develop across the Cascades and eventually surface pressure begins to fall sharply in the lee of the Cascades as the heat trough begins to develop over the area. The surface high eventually moves east of the Continental Divide and the pattern begins to weaken. The source region for the highs is an area to the northwest or southwest, but in all cases the surface high tracks to a location east to northeast of the Cascades.

UPPER AIR: The strongest east wind episodes are thought to be associated with stagnating upper air lows or troughs in the mid—Pacific, usually just south of the Aleutian Islands, which result in the downstream amplification of a ridge over the eastern Pacific. The ridge intensifies between 130 and 140 west longitude, then begins to take on a positive tilt as the northern portion begins to move onshore into British Columbia. One other type of ridge amplification leading to east winds and very high temperatures occurs when an upper—air high builds into the Pacific Northwest from the southeast. In this pattern, higher pressure gradually develops over eastern Washington.

PATTERN RECOGNITION: Watch for a high amplitude flow pattern at 500 millibars with strong with a stagnating high or trough in the central Pacific and the downstream amplification of high pressure aloft over the northeast Pacific. Warming and drying aloft usually show up first on the Quillayute (UIL) or Port Hardy (YZT) sounding as a gradually lowering subsidence inversion. Check for strong northeast winds (outflow) from the Frasier River valley at Bellingham (BLI). RAWS stations at Sumas Mountain (300063B8) and Sekiu LO (30020B2) are very sensitive to east or northeast winds and if the pattern builds from the south, pay close attention to Red Mountain (32617342).

OBJECTIVE TECHNIQUES: Watch the Quillayute to Bellingham gradient. When it becomes negative, east winds will begin to blow thru the Soleduck cut across the Olympic Peninsula. Other gradients to watch; North Bend (OTH) to Seattle (SEA) and Portland (PDX) to Bellingham (BLI). These too should be negative. Pay close attention to the Seattle to Spokane (GEG) gradient. Minus 8–10 millibars across the Cascades is typical in strong east wind episodes.

Note: **Fig 1**. shows surface and 500 mb charts during an east wind episode on September 27–28, 1985.

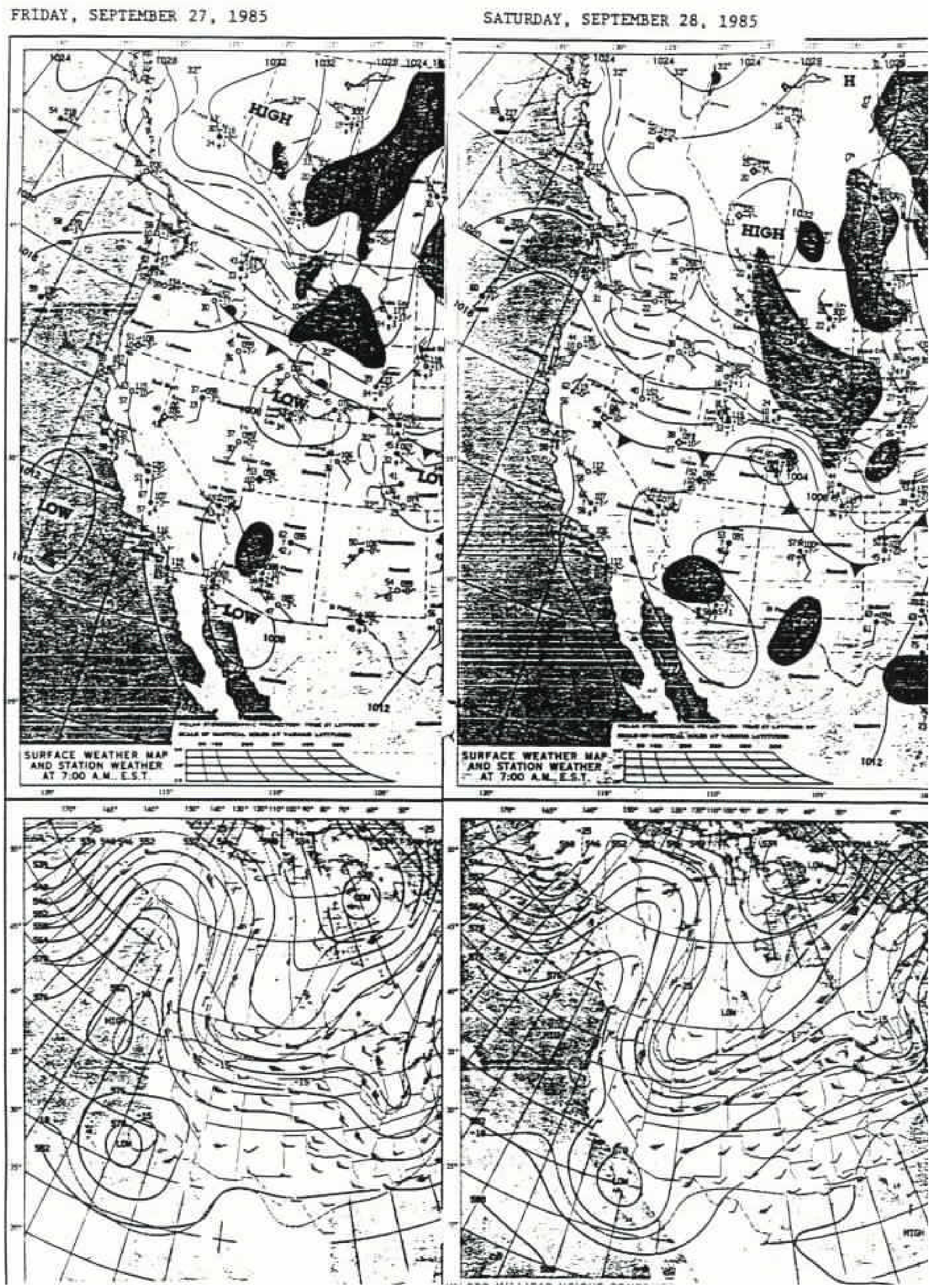


Fig 1. Surface and 500 mb charts during an east wind episode on September 27-28, 1985.

TYPICAL SUMMER WEATHER CYCLE

PENDLETON FIRE WEATHER

DESCRIPTION: Each part of the cycle has different subtleties which may have a profound impact on forecasting on—site weather at an incident.

The most important weather during the course of a typical fire weather season is really all part of one large cycle. It hinges on the Desert Southwest Ridge, or the Western U.S. Ridge, or the western part of the Bermuda High, or whatever you wish to call it. The most probable time of year for this pattern to occur is July and the first two weeks of August. The duration may vary from just a few days to over a week.

The Cycle can be broken up into three parts;

Part I: Whenever the ridge builds northward and extends into the Pacific Northwest, a hot unstable airmass forms over the region.

Part II: Moisture is usually not present at first but is eventually advected into southern Oregon through northern California and western Nevada.

Part III: Eventually a short wave embedded in the westerlies will move across the area, providing the extra instability needed for a "lightning Bust" to occur.

For much of the rest of the season, except for a couple of weeks or so in mid—August, the region is under a cooler more stable west to northwest flow aloft, or even a stronger southwest flow aloft. While still possible, depending strongly on other factors, thunderstorms generally are not a problem during these periods.

SURFACE:

Part I A thermal trough will form over central and northern California and eventually a tongue will push northward into southwest Oregon. This is best depicted best on the NGM surface progs.

Part II Once the thermal trough has moved northward into the western Oregon valleys a couple of things can occur. Eventually the trough will shift eastward across the Cascade Mountains into eastern Oregon. The shift will either be well-defined (in response to a strong short-wave embedded in the westerlies, see PART III); or ill-defined, in which minor shifts of the ridge position, very weak short—waves, or just extremely hot temperatures in eastern Oregon have moved the center of the thermal trough across the mountains.

Part III As the upper ridge shifts east in response to the upstream trough, so will the surface thermal trough. This shift of the thermal trough increases the onshore gradient west of the Cascades; bringing in a cooler, moister, more stable marine airmass. This is also known as a "Marine Push". This airmass will eventually spill into eastern Oregon through places like the Columbia River Gorge and the McKenzie Pass near Redmond (RDM). The location of the thermal trough is the key to pin-pointing the area of greatest instability. When the short—wave moves across the area, the more stable conditions in the marine airmass will prevent thunderstorm development, while the unstable conditions associated with the thermal trough will promote thunderstorms. Look closely at your surrounding terrain when you look for the thermal trough. Since the marine push is a low level phenomenon, the crest of the Blue Mtns can <u>sometimes</u> form a natural boundary between the differing airmasses. Otherwise look at temps/dewpoints in the surface analysis.

UPPER AIR:

Part I This is when the normal summertime ridge over the southwest U.S. builds northward over the region. Look for the center of the upper air high to move from its normal position near the Four Corners to much further northwest. The ridge axis has to be far enough west so that eastern Oregon is exposed to the southerly component of flow around the ridge. The ridge must also be far enough north for the same reason; otherwise the most unstable air ends up in Idaho and not over eastern Oregon. This part is usually well forecast by the longer range MRF.

Part II In this stage the ridge has been established over the Pacific Northwest. Wind flow over eastern Oregon at 500 mb will be quite weak, and can vary from west to southeast. At 700 mb the flow should be from the south to southeast. This is a requirement for thunderstorm development since your moisture must be advected into the region. The moisture that eventually reaches the area originates either from off the northern California coast or from the monsoon over the Desert Southwest. In any case you can often track its movement using a variety of methods. As the moisture moves northward thunderstorms will often develop first over northern California and western Nevada, finally edging into southern Oregon. Track these using satellite imagery and data from the lightning detection network. You can sometimes track the moisture using satellite water vapor imagery. Finally, the NGM sometimes does a decent job of forecasting the moisture increase.

Part III This part does not always occur spectacularly. Eventually the westerlies will strengthen a little and a short-wave will pass over the region. If the 500 mb vorticity center is especially weak you may have just a few more afternoon thunderstorms. If it is of moderate strength, you will have more thunderstorms with the possibility of nocturnal storms if the timing is right. If it is a strong short-wave you will likely have a lightning bust. This assumes one of two things about available moisture: 1) that enough moisture has advected over the area from the south (mainly critical in weaker short-waves), or 2) that the incoming short-wave is deep enough so that it bring in its own mid level moisture. I have found it useful to evaluate the vertical motion generated by these short-waves by advecting 500 mb vorticity with the thermal wind (500 mb vorticity/1000-500 thickness). Look for strong cross—contour patterns with higher vorticity values upstream. For the strongest short—waves, look for a 500 mb trough axis shifting eastward to around 130W with southwest flow increasing across Oregon. Note that the trough will shift the 500 mb ridge axis to the east. Naturally any type of upper air disturbance crossing the region will increase the instability in an already marginally unstable airmass.

PATTERN RECOGNITION:

Part I This part of the pattern will usually take about two to three days to complete. Once in place, temperatures will be in the 80’s and 90’s in eastern Oregon with some of the lower level stations possibly reporting temps near 100. Minimum RH values will range from the single digits to the low teens. The airmass is still basically stable, although it will become increasingly unstable during the afternoons as the heat builds.

Part II This is a dangerous period. You have a hot unstable airmass in place over the region. Moisture is seeping northward. If you are deployed on an incident during this period the normal morning surface—based inversion will lift sometime after 1030. If you combine low humidities and the hot temperatures with a going fire (especially under the 1987-1991+ drought conditions), you can create a very strong convection column during the afternoon. This occurred at least twice on the Sheep Mountain Complex in 1990. Fire behavior was described as, “outside the envelope of the models”, by the Fire Behavior Analyst. Now mix in a trickle of moisture from the south. This will result in further instability, and in isolated high—based thunderstorms during the afternoon, mainly over the southern two thirds of eastern Oregon.

The downbursts from these storms will naturally wreak havoc if they occur near a fire (as they did on more than one occasion on the 1990 Pine Springs Complex near Burns, 60+ mph). One benefit of “just enough moisture but not too much” is that CU and maybe a few TCU will form during the afternoon, providing a little shade for the fire and moderating the peak afternoon heat. This may result in a slightly weaker afternoon convection column if you are lucky.

I suggest asking Air Attack (if you have a unit operating on your fire) to take an aircraft sounding on their first morning flight (temps every 500’ will do).

You can have “PART II” weather for a week or so, followed by somewhat more stable conditions as the upper ridge weakens. Thus it is possible to never really get into a fullblown “PART III” condition. You may have some weak upper air disturbances move across the area, but none really strong enough to trigger widespread thunderstorms.

Part III This is a critical period. Thunderstorms will develop in the unstable airmass associated with the thermal trough, aided by the short—wave overhead. The storms can range from wet to dry. Lightning will be frequent. As the thermal trough continues to shift east, so will the resulting area of thunderstorm development. Behind the thermal trough the advancing marine push can have west to southwest winds in the 25-35 mph range. These speeds are felt primarily at lower levels in the Columbia Basin.

OBJECTIVE TECHNIQUES: None at this time.

DRY THUNDERSTORMS

PHOENIX FIRE WEATHER

DESCRIPTION: After a hot and dry spell, by the end of June, when the monsoon wind pattern is just starting to get underway, a red flag watch or warning may be issued if a number of dry lightning strikes are expected.

SURFACE: Not usually too important in this case. However, if low level winds such as the 850 mb level and/or surface winds are from the southeast, then there could be an import of low level moisture and thus the thunderstorms may be wet instead of dry.

UPPER AIR: The subtropical high pressure center starts to move to the east of Arizona, with clockwise winds coming into Arizona from the east or more likely southeast direction (**Fig 1**). This high center could be as far west as the 4 Corners area. Usually, the first two or three days after the high sets up in this position, moisture import is often limited, so any thunderstorms are usually high—based and are mostly dry.

PATTERN RECOGNITION: Watch where the subtropical high center sets up. If it sets up in a favored position mentioned above which could produce southeast winds aloft for Arizona, and the state has been in a long hot and dry spell, be prepared for the possibility of dry lightning. Pay attention not only to the 500 mb level, but to the 700 mb level as well. Sometimes, the 500 mb level may not appear to be favorable for southeast winds, whereas the 700 mb level could be favorable.

OBJECTIVE TECHNIQUES: It is important here to look at the soundings, especially at TUS (Tucson) and CUU (Chihuahua, Mexico) soundings (**Fig 2**). If these soundings show mid and high level moisture, and dry below, and if the steering winds are from the southeast, then this is a fairly good chance of dry lightning storms.

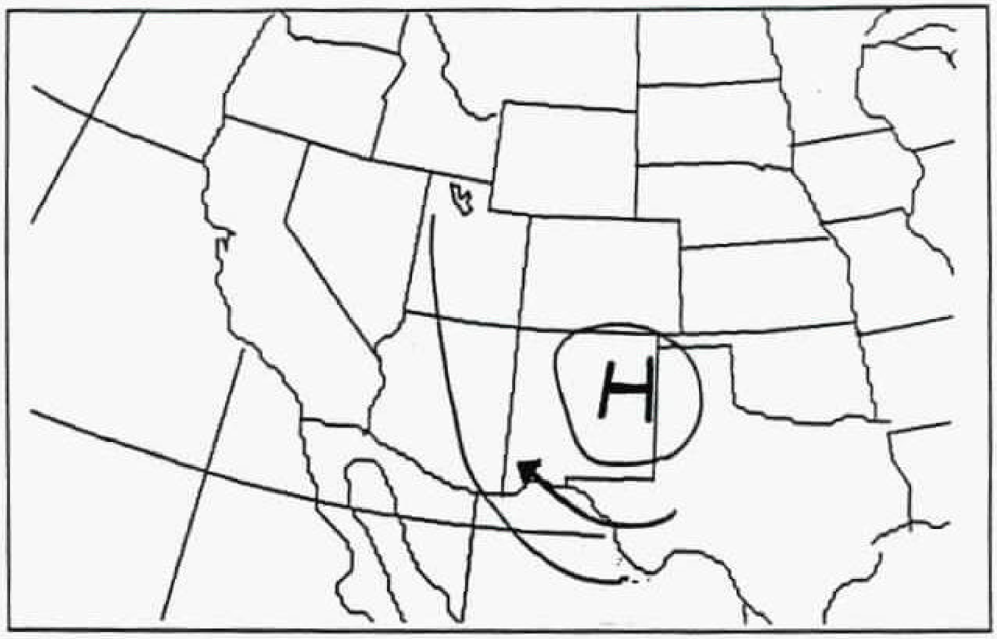


Fig 1. Typical 500 or 700 mb pattern for dry thunderstorms.

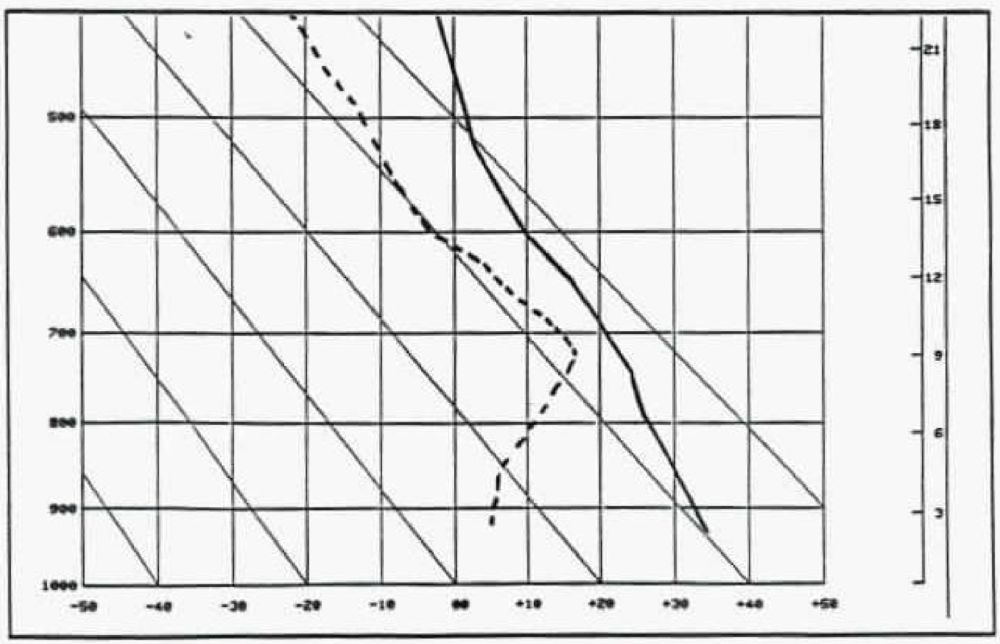


Fig 2. Typical TUS or CUU sounding for dry thunderstorms.

NORTH WINDS

PHOENIX FIRE WEATHER

DESCRIPTION: Gusty northerly winds of 25-35 mph or greater will occur at times down the Colorado River Valley of western Arizona. There are three reporting weather stations along this valley — Yuma (YUN), Blythe (BLH) and Needles (EED). Along with these northerly winds are normally very low humidities, with dew points sometimes down into the single digits. Although this normally occurs during the cold season, this area is at low elevations where snow is not a factor. Thus, with vegetation along the river at risk, this could be a red flag event.

SURFACE: A strong high over the Great Basin states with considerably lower pressure over northwest Mexico and also strong north to south pressure gradient over Arizona. This is very similar to the surface pattern for Santa Ana winds in southern California.

UPPER AIR: High pressure aloft over the far western states or along the California coast with northerly winds over Arizona.

PATTERN RECOGNITION: Watch the forecast charts for bringing a strong surface high into the Great Basin and creating a strong north to south pressure gradient over Arizona. It will also help to look at the 850 mb temperature and height gradient southward across Arizona. A strong thermal gradient with lower temperatures to the north and warmer to the south will tend to add to the northerly winds.

OBJECTIVE TECNIQUES: Look for a pressure gradient of 6 mbs or greater between Las Vegas and Yuma for these north winds to blow. It is possible that even with a gradient of 4 mb, moderately strong north winds are possible, especially if there is enough thermal gradient available. Look at the YUN MOS output.

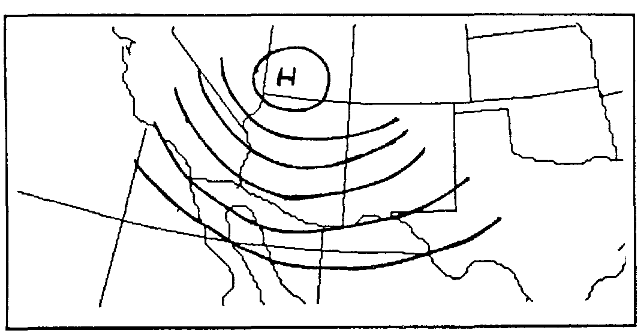


Fig 1. Typical surface pattern for north winds in western Arizona.

SOUTHEAST WINDS

PHOENIX FIRE WEATHER

DESCRIPTION: Strong southeast winds in the lower elevations in southeast Arizona normally occur during the cool season and at lower elevations where snow is not normally a factor. Southeast winds from 25 to 35 mph can sometimes occur in this area below the 4000 foot elevation given the right conditions. This is often evident in the Tucson area and in the Saguaro National Monument. It probably also occurs in other lower elevations of southeast Arizona where grass is the main carrier of fires. Dew points can sometimes be quite low, though usually not as low as in the first came mentioned above for the Colorado River Valley.

SURFACE: A cold and sometimes arctic surface high moving into the southern Plains with a strong surface pressure gradient from that high westward to the thermal low over southwest Arizona. There may also be a strong thickness gradient between lower thicknesses to the east and higher thicknesses to the west.

UPPER AIR: Not always definite but generally a large trough over the eastern half of the nation and ridging in the west. Sometimes a good thermal gradient exists westward across New Mexico into southeast and even south central Arizona at the 850 mb level with lower temperatures to the east.

PATTERN RECOGNITION: Look for Canadian surface highs moving southward into the southern Plains for the possibility of strong southeast winds developing over southeast Arizona. This is especially true if very cold air is associated with this high and the surface high is far enough west such as in eastern New Mexico or western Texas.

OBJECTIVE TECHNIQUES: Strong easterly winds at such places as Deming (DMN) and Truth or Consequences (TCS) New Mexico and at Guadalupe Pass (GDP) Texas could be used as a clue that strong east southeast winds may soon blow in Arizona, but only if the strong gradient continues westward into at least eastern Arizona. There are also a few RAWS stations in southeast Arizona that can be looked at for strong east or southeast winds, such as the Guthrie station (327D03D0), Black Hills (327D40DA), Empire (327C5156), and a few others in that region (refer to PHX operations plan). Although not really studied at this office, looking for a certain pressure gradient between two stations such as Deming and Tucson or Deming and Phoenix, for example, may be useful if forecasting these winds. Look at the TUS MOS output.

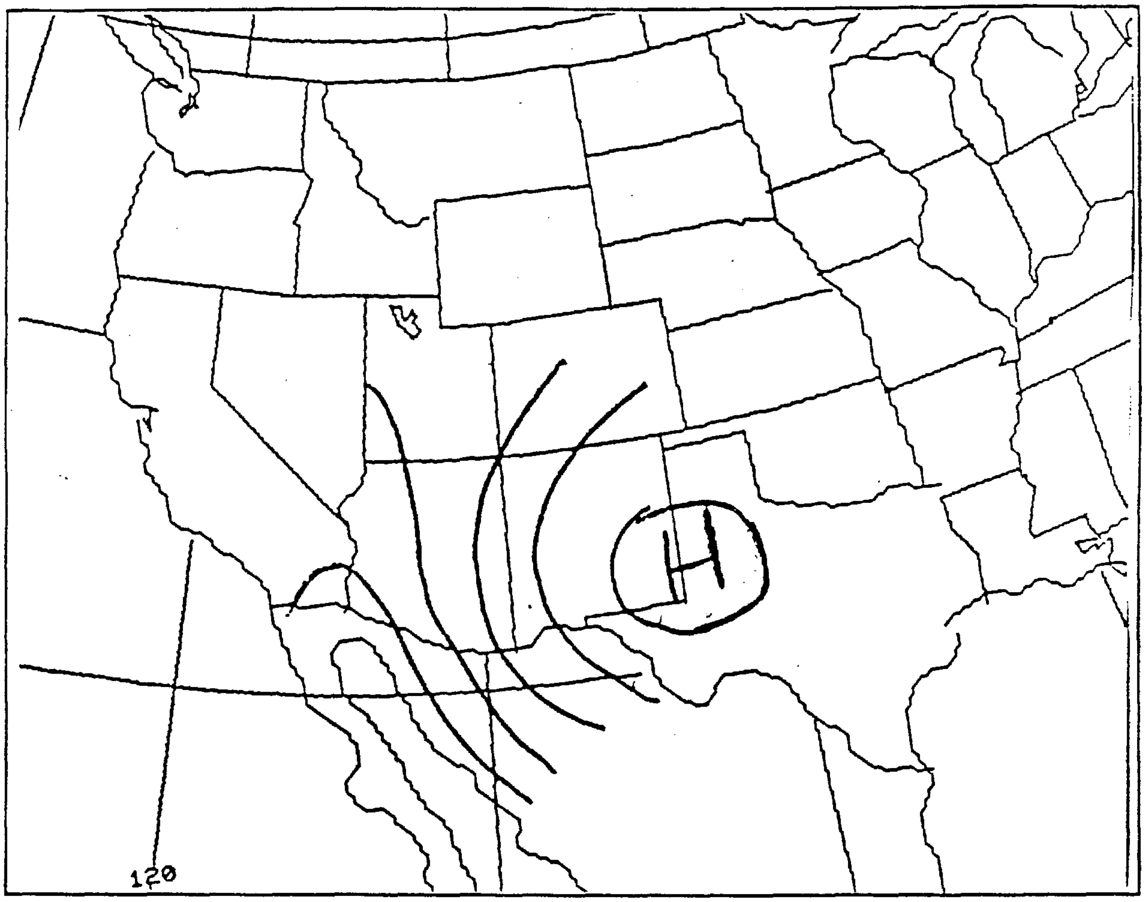


Fig 1. Typical surface pattern for southeast winds in SE Arizona.

SOUTHWEST WINDS

PHOENIX FIRE WEATHER

DESCRIPTION: In late spring, when fuel moisture at higher elevations are becoming low, moderately strong low pressure troughs moving into the west may bring strong southwest winds to Arizona. Usually, these troughs this late in the year are dry for Arizona, and thus the main weather associated with them is wind. Depending upon the strength of these systems, winds in the Arizona mountains could exceed 40 or 50 mph, and even much higher if the system is strong enough.

SURFACE: Not really too important in this case.

UPPER AIR: Usually a moderately strong low pressure trough moving through the western states with Arizona mostly on the southern end of the trough, with precipitation staying north of the state (**Fig 1).** Usually, 500 mb heights will be higher than 558 as lower heights normally would lead to some showers if enough moisture is available. The 700 mb gradient is also important so that any forecast of a moderately strong gradient at this level could mean strong winds for the mountains. Again, a trough of this strength during the late spring is most often a dry system for a good portion of Arizona.

PATTERN RECOGNITION: Just look at the forecast charts for the 500 and 700 mb levels. Also, check for any wind max at the 300 mb level. A relatively strong height gradient, say of 4 or more height lines across the state would likely create winds.

OBJECTIVE TECHNIQUES: None developed for this pattern...mainly looking at upstream raobs seeing how strong those winds are. Also, looking at forecast 500 mb and 700 mb positions. Look at the FLG and INW MOS output.

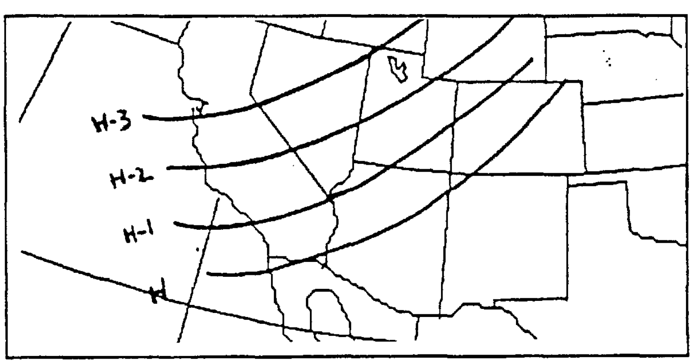


Fig 1. Typical 500 or 700 mb pattern for southwest winds in Arizona.

NORTH WINDS

REDDING FIRE WEATHER

DESCRIPTION: The most common critical fire weather pattern in the Redding Fire weather district is the north and northeast foehn winds in the upper Sacramento valley. They occur when surface high pressure builds into the Pacific Northwest. What is commonly already dry air moves from Oregon downward into the northern Sacramento Valley and is warmed further. Humidities of 10% or less with temperatures of 110 degrees in the valley can occur under these conditions. Wind speeds depend on local topography, pressure gradient and upper level flow. When upper level flow is oriented in such a way as to join with the surface pressure gradient, wind speeds in excess of 40 mph have occurred.

SURFACE: Surface high pressure in the Eastern Pacific nosed into the Pacific Northwest **(Fig 1)**.

UPPER AIR: The north wind foehn wind can and often does develop with no connection to the upper air pattern. When an upper level north wind pattern does develop (**Fig 2**) the upper level winds join with the surface pressure gradient to give even stronger winds at the surface.

PATTERN RECOGNITION: Look for the development of a northerly pressure gradient from Medford (MFR) to Red Bluff (RBL) to Sacramento (SAC). Also, watch for a pressure increase in Spokane (GEG) which is an indication of surface ridging into the Pacific Northwest. An increase in the Reno (RNO) to Medford pressure gradient is an indication that the high-pressure cell is shifting into the Great Basin and that north winds will diminish.

OBJECTIVE TECHNIQUES: A study was conducted by Christopher E. Fontana from 1972—1974 in which pressure data from the above mentioned stations was analyzed and plotted on a chart **(Fig 3)** representing winds for the following day. When the study was put to use in the 1975 fire season, a 92 percent success rate was achieved for predicting whether north winds would occur the following day. Further manipulation of the pressure data (in north wind expected cases) as well as change in Medford to Oakland (OAK) 700 mb temperature was used to determine the type of north wind to be expected (North wind all day or North wind switching to South wind) and to get an estimate of the magnitude of the north wind.

To use this forecast method pressure data is plugged into the equations shown on figure 3 to get a value for the x and y coordinates. If the point calculated is in section C then no north winds are expected. If the point calculated lands in section A or B then north winds are expected and the figures 4 or 5, respectively, are then used. The equations corresponding to sections A and B are then used to calculate the X and Y coordinates. The type of north wind (strong, north becoming south etc.) to be expected can then be estimated from the points position on the graph.

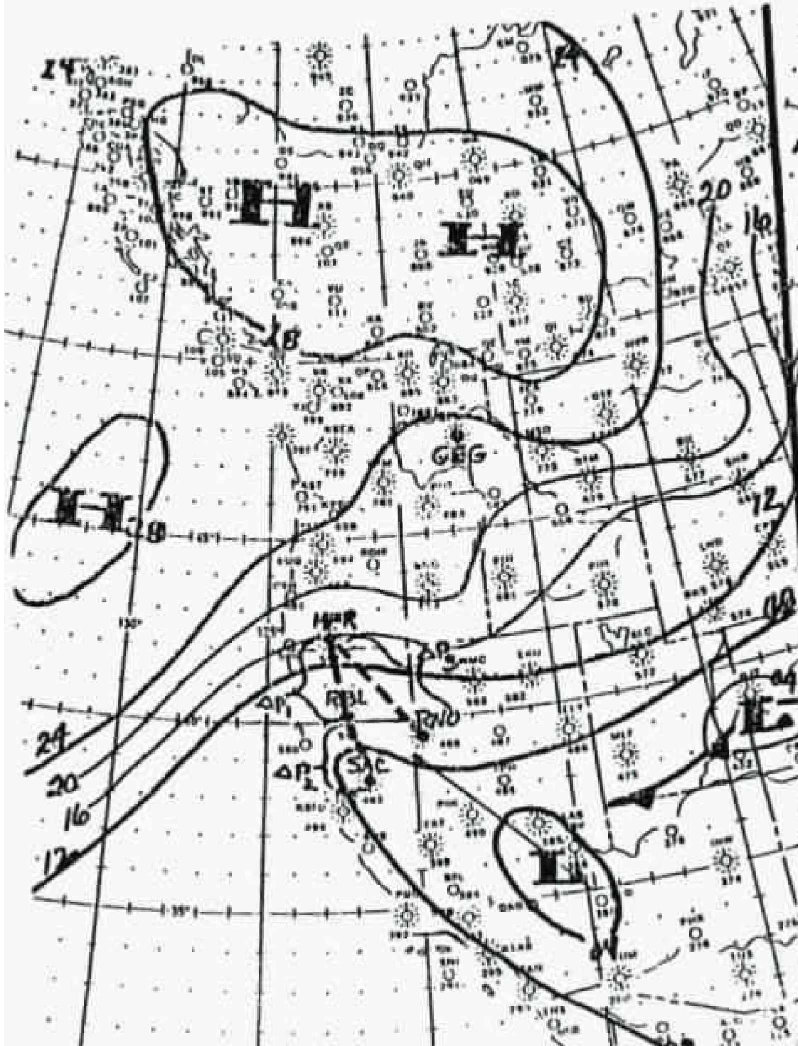


Figure 1. Example of surface pattern associated with onset of northerly foehn-type winds, 1200Z September 11, 1974.

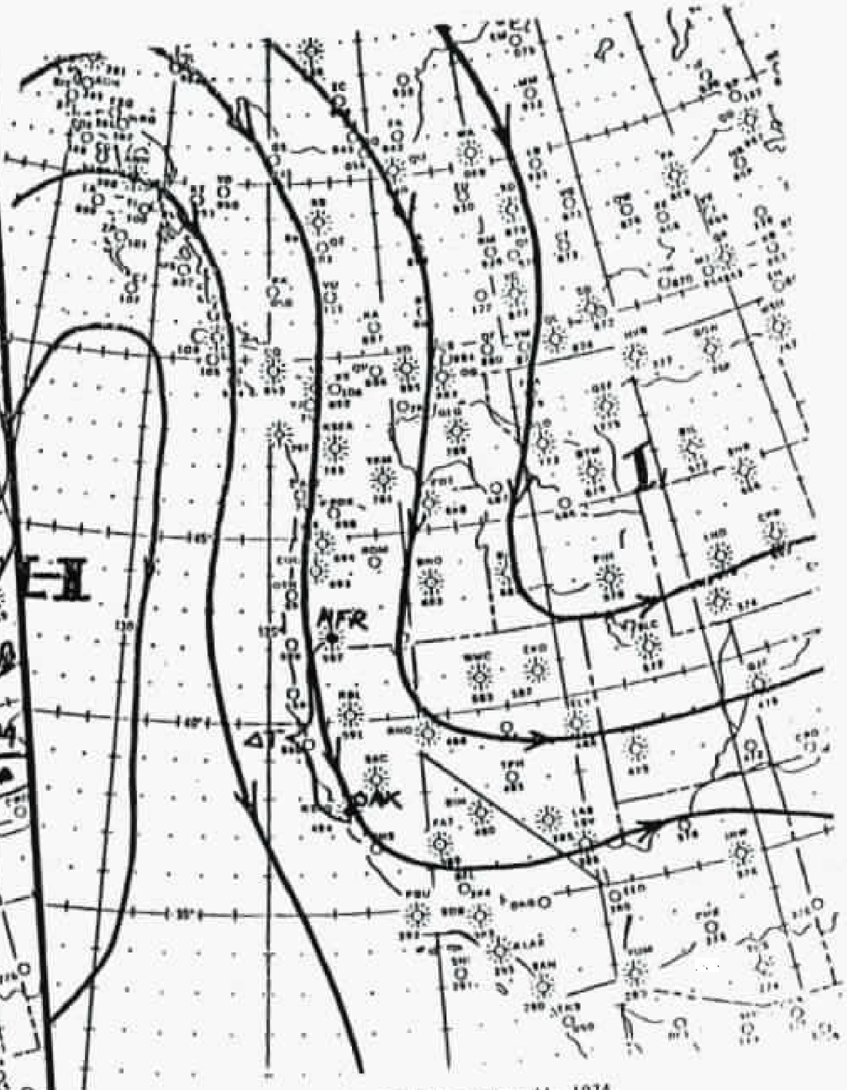


Figure 2. 70 kPa map for 1200Z September 11, 1974.

PLOTTED VALUE IS WIND THAT OCCURRED THE NEXT DAY WITH NORTH BEING 330° to 040°.

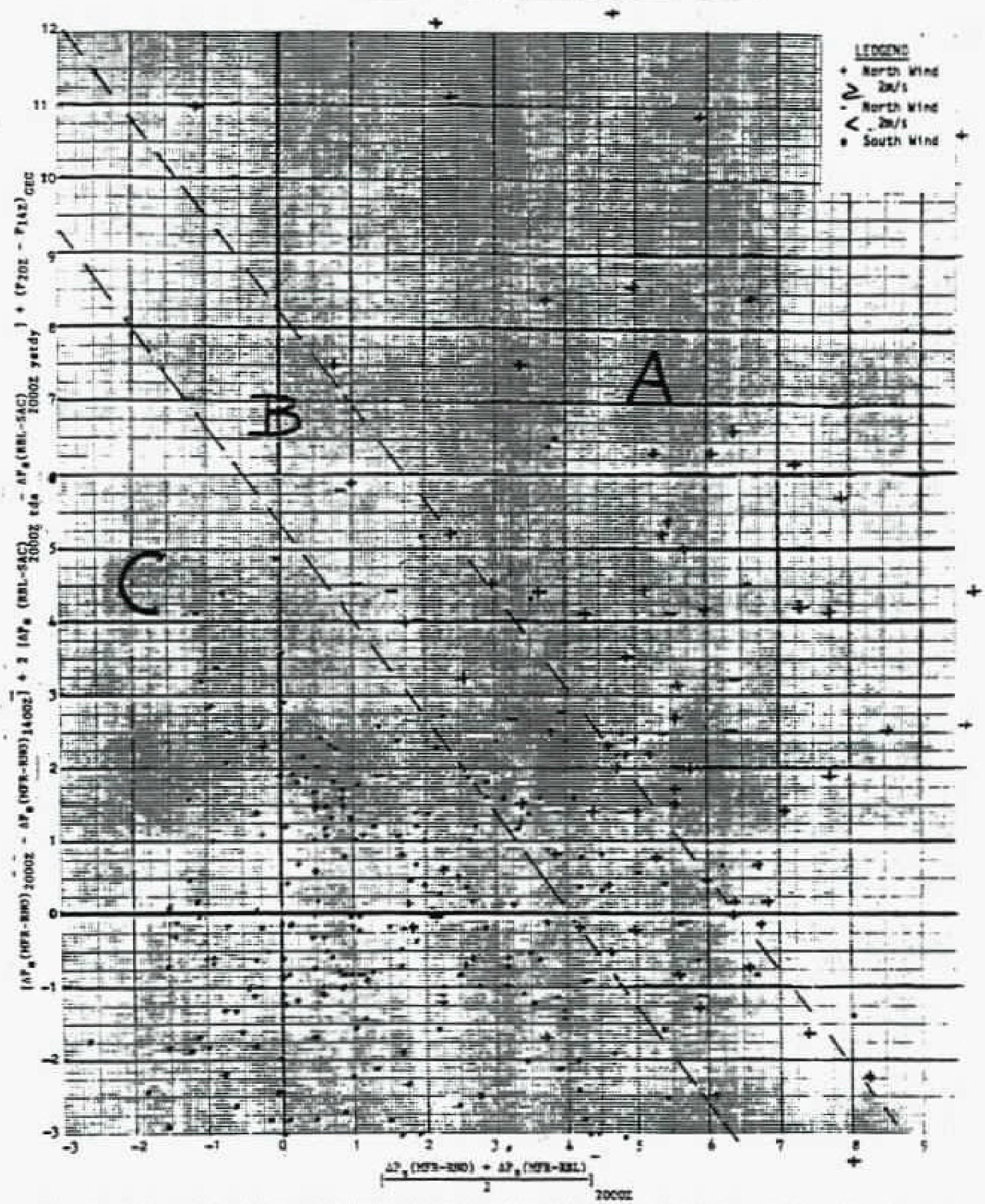


Figure 3. Scatter diagram relating north wind days in the northern Sacramento valley to selected pressure gradients and pressure changes.

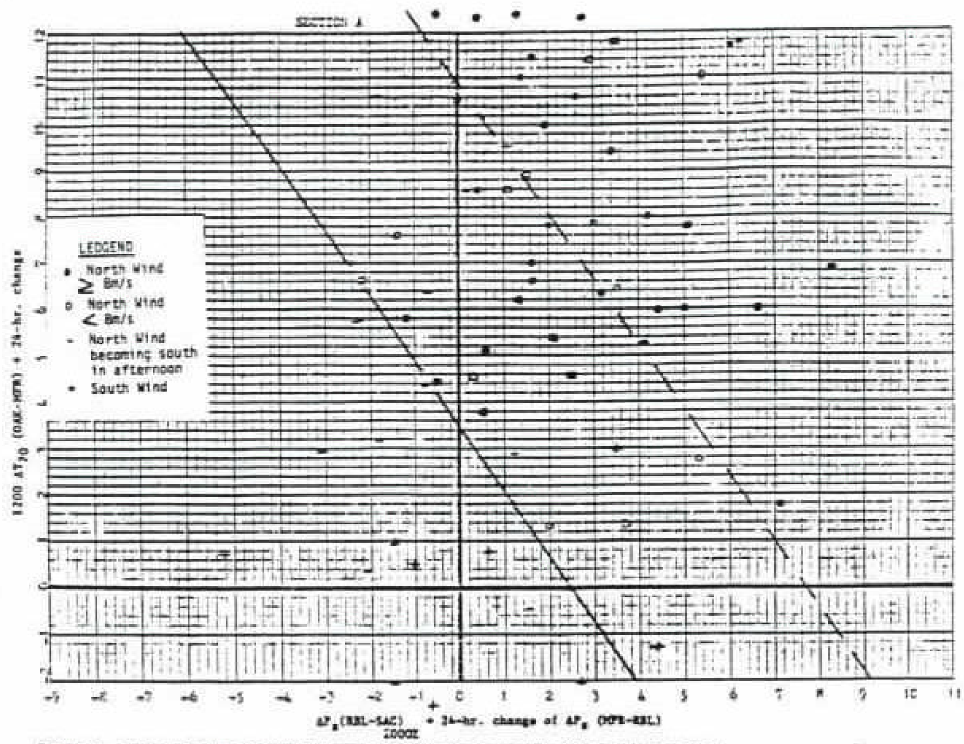


Figure 4. Scatter diagram separating north wind days from non-north wind days in section A.

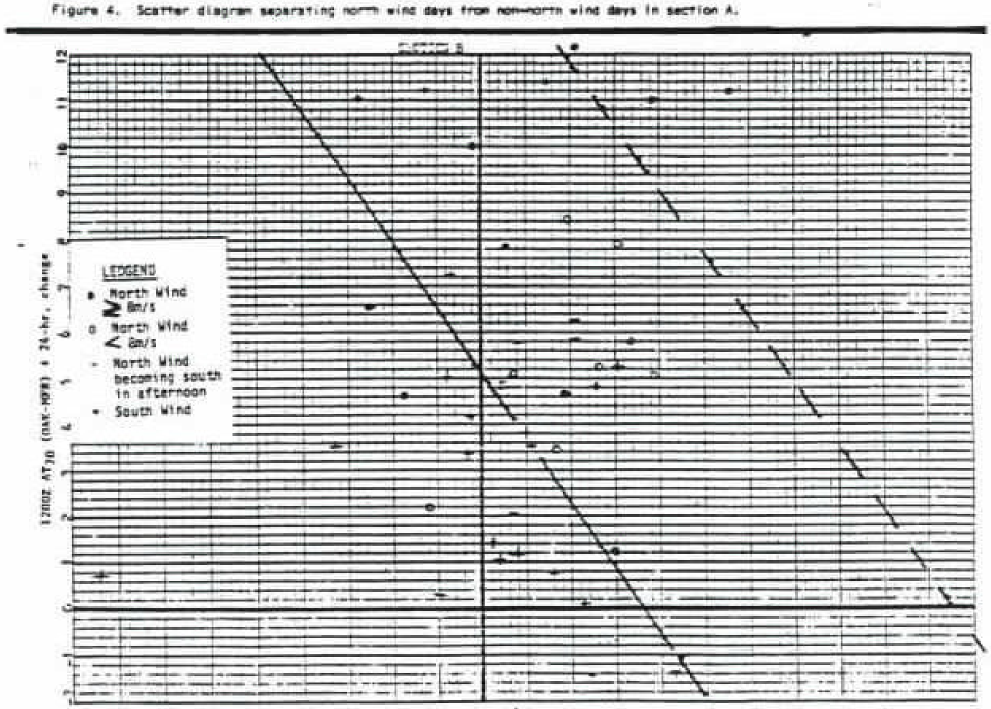


Figure 5. Same as Figure 4, except for section B.

SANTA ANA WINDS

RIVERSIDE FIRE WEATHER

DESCRIPTION: Santa Ana winds are a term given to strong, dry north to east winds which blow across southern California, generally below the 4000 ft level, which includes mountain passes leading from the deserts into the Los Angeles basin. Santa Ana winds also affect the extreme southern portions of southern California when the wind direction becomes more northeast to easterly.

"Strong" in fire weather terms mean sustained winds above 25 mph. However, Santa Aria winds do not have to be "strong," to pose extreme fire danger. Santa Ana winds are associated with compressional heating as air flows from higher desert areas down into the Los Angeles basin and coastal areas. This in turn results in extremely low humidities. "Low humidities" in fire weather generally mean less than 10%. An example of Santa Ana winds shown on a typical airways observation:

VNY SA 2049 CLR 50 029/88/5/3628G39/014

Santa Ana winds can be either very localized or widespread, and can be best defined by "pattern recognition." In general, Santa Ana winds are seasonal and caused by cold air moving southward through the great basin area (Utah, Nevada and northern Arizona).

This phenomena can begin as early as September and continue into May, but is most frequently observed during the months of November through February. It begins when the first good fall/winter storm comes out of the Gulf of Alaska and moves southeastward across the great basin. Such a weather system many times will not affect southern California directly in terms of clouds or moisture, as the main low tracks several hundred miles or more east of the affected area, but will be responsible for the strong winds over southern California.

Santa Ana winds are usually strongest around sunrise to early afternoon. Winds may diminish during the afternoon, as a result of surface heating, producing weaker surface pressure gradients between the great basin and southern California. However, winds may begin, end, increase or decrease at any time of the day.

SURFACE: Main features to watch ahead of the occurrence:

1. On the surface models, watch for surface high pressure building over Nevada and northern Arizona behind the frontal system. Also a weak low pressure system off the coast of southern California will induce stronger winds.

2. Surface winds will always blow perpendicular to the surface isobaric pattern. In mountain passes leading from the deserts down into the valley, the Bernoulli affect is very distinct, in addition to outflow eddy circulations at the base of the passes.

3. The relative humidity progs are usually too moist initially, but gradually improve as the event's duration lengthens.

UPPER AIR: Main features to watch for 2-3 days before the occurrence:

1. Ridge of high pressure begins to show up over the western Alaska region on the medium range models.

2. A west—east aligned through emanates from central/eastern Alaska and drives southeastward. The trajectory will carry the trough or low pressure area through the southern great basin.

3. At the 850 mb level, look for cold air advection into southern Nevada and possibly the extreme eastern portions of southern California. Usually, the progs have a warm bias with this upper air pattern during the fall and early winter season. Thus, there is a tendency to under estimate surface pressure gradients and the upper air thermal gradient.

4. Although somewhat rare, some of the strongest Santa Ana winds occur when a weak low pressure system hangs just off the southern California coast, enhancing the offshore surface pressure gradient.

5. One of the most important upper air features for timing the event is to look at the leading edge of NVA at 500 mb using the vorticity progs. Immediately behind the back edge of PVA and the leading edge of the NVA, the winds usually begin within 2 hours.

6. Quite often, a low pressure system will close off somewhere between the lower Colorado river valley and the Four Corners area and result in a series of weak PVA spokes rotating over the area. Winds usually will not begin between closely spaced PVA passages, but will usually begin with a real vengeance behind the last area of PVA or leading edge of NVA, when a long (at least 12 hour) lull occurs.

7. If the direction of the 300 mb jet stream is somewhat in phase with lower elevation winds, expect a strong wind condition.

8. If a low level northerly jet occurs between about 700 mb and 500 mb, winds could surface in mountain passes and down the slopes of mountains. When this coincides with strong “offshore” flow, extremely strong winds (in excess of 60 to 70 mph) can occur, mainly along the northern end of the LA basin.

9. The most important feature in upper air progs to look for is the isobaric alignment at all levels, the timing of the back end of PVA or leading edge of NVA, and location of possible low level jet cores.

PATTERN RECOGNITION: Some flags in addition to the above are:

1. Surface progs indicate high pressure building over the southern great basin area.

2. Cold air advection (CAA) or the zero degree isotherm dips into extreme southeastern California, the southern Inyo County area and/or into the Las Vegas area. Colder values with ensuing CAA behind, hints at stronger gradients than what surface progs indicate.

3. When any vort max sliding down over the eastern California deserts, or the southern Nevada/western Arizona area with a northwest to southeast trajectory, chances are that stronger winds will occur than indicated by surface pressure gradients.

4. The AFOS products “LAXPRGLAX” and “GRADIENTS” are indications of offshore pressure gradient trends and changes over the past 3 and 24 hours.

5. Satellite indicates some kind of line of clouds, probably associated with upper level disturbance. Immediately behind this line, expect winds to commence, if in conjunction with aforementioned parameters.

6. A more widespread Santa Ana condition exists when there is good thermal support (CAA over the southern great basin), upper level support (winds aloft are directionally in phase), and a weak low pressure system is sitting off the southwest coast.

7. More localized events occur when one or two of the above parameters exist and are not real strong.

8. Watch the trend of the key surface observations. If winds at Van Nuys - VNY, Burbank -BUR, Sandberg -SDB, Point Mugu -NTD, or other northern mountain/valley areas begin veering from a 270—300 degree direction to a 340—020 degree direction, Santa Ana winds are usually beginning.

9. NTD, VNY or BUR usually are the first stations to show Santa Ana winds in northern areas, while Campo — CZZ is a good indicator of a more easterly Santa Ana over extreme southern California areas.

10. The following RAWS stations are also good wind indicators.

Name	NESS ID	NFDRS No.
Casitas	3247F476	045308
Mill Creek	3248416A	045409
Temescal	3247E700	045307

11. Strawberry and Butler Peaks of the San Bernardino mountains experience winds if the upper level jet core is low. Strong winds at these stations can lead to strong surfacing wind at lower elevation, valley areas.

12. Alert stations "A:OSO" on AFOS, such as Beaumont and other pass/canyon areas should be watched, for strong winds.

13. A more northeasterly Santa Ana shows up on the CDF RAWS stations at Valley Center (VAL — CA451330, Anza (ANZ —CA4467A2), Juniper Flats (JUN - CA44E14E) and Rancita.

OBJECTIVE TECHNIQUES: Observe the AFOS products "LAXPRGLAX" and "GRADIENTS" for values of offshore gradients. If the LAX to TPH (Tonopah, NV) pressure gradient exceeds 10 mbs, the potential for Santa Ana winds will exist. A value greater than 12 indicates a very strong potential for wind.

When forecasting for the northern mountain passes, look at the LAX to WJF (Landcaster) or LAX to PMD (Palmdale) gradients. If the value exceeds 5 mbs, winds are likely.

Watch the SAN to IPL (Imperial), SAN to LAS and NID (China Lake) to RNO gradients. If values exceed 8 or 9 mbs, winds are likely.

When the SAN to IPL gradient becomes large, the Santa Ana wind direction is veering more to the northeast or east, which means it may end over the northern and western sections, but will likely continue over northeastern passes, eastern valley's and southern areas.

If the 850 mb northerly winds are greater than 50 knots at Edwards - EDW, Vandenberg - VBG and China Lake, then these strong winds aloft may surface at higher elevations of the LA basin and lower elevations of the mountains. A 360—020 degree direction in these winds can produce extremely strong winds just to the lee of the mountains.

DRY THUNDERSTORMS

RENO FIRE WEATHER

DESCRIPTION: The occurrence of high-based dry thunderstorms in the Reno Fire Weather District is not all that uncommon and not always a prerequisite for RED FLAG WARNINGS. However, forecasts of Lightning Activity Level 6 ("dry lightning") will usually grab the quick attention of fire protection agencies throughout the district. Of equal or greater concern is the strong gusty outflow winds that often accompany these thunderstorms. Wind gusts over 60 mph from these high-based thunderstorms can severely hamper fire-fighting efforts, including both ground and air operations. A RED FLAG WARNING is usually reserved for the initial onset of this pattern, with as much lead time as possible.

SURFACE: If no other upper level dynamics are involved in the high pressure circulation, this pattern can be characterized by random air—mass thunderstorms. Any concentration of thunderstorms often tends to be over the higher mountainous terrain, stretching from east—central Nevada to the central Sierra Nevada range in California. Further organization of thunderstorm activity will align with the position of the thermal surface low pressure trough. A critical pattern for the Sierra Nevada portion of the district occurs when the thermal trough crosses over into California; or aligns with the crest of the Sierra Nevada. If the thermal trough sits over central or eastern Nevada, there is often enough dry westerly flow aloft over the Sierra Nevada to prohibit widespread activity there.

UPPER AIR: The primary moisture source for thunderstorms in Nevada is linked to the Southwest Monsoon, which typically runs from mid-July through early September. This occurs when high pressure becomes centered over the four—corners area (where Utah, Arizona, Colorado, and New Mexico borders meet). If this pattern is uninterrupted for any length of time, moisture will eventually circulate clockwise into Nevada from Arizona and southeast California. The area of concern for a dry thunderstorm outbreak is typically at the outer periphery of the high pressure circulation, where low level moisture lags the mid and upper level moisture. If the high pressure remains nearly stationary, the diurnal thunderstorm activity will normally become wetter with time.

PATTERN RECOGNITION: The NMC models will usually handle the synoptic scale features of this pattern, namely, the high pressure developing over the four—corners area. Unfortunately, ground truth is severely lacking for small scale analysis; since the only upper air site between Arizona and the Sierra Nevada is Desert Rock, Nevada (DRA). Compounding the situation is the lack of surface observations in the Sierra Nevada. The forecaster must pay close attention to the location of the surface thermal trough. Any visible indicators, such as altocumulus debris from the prior afternoon's thunderstorm activity, can also useful tools,

OBJECTIVE TECHNIQUES: One source of data that may provide some clue of increasing thunderstorm activity in the Sierra Nevada is the wind direction at Slide Mountain (appended to the Reno Surface Observation RNOSAORNO). A light southeast flow indicates the circulation around the high pressure in the four corners areas has reached the Rena area. It also implies the thermal trough is over California and any mid—level moisture will advect northwestward into the area.

WASHOE ZEPHYR

RENO FIRE WEATHER

DESCRIPTION: The steep eastern slopes of the Sierra Nevada are prone to a local surface wind known as the "Washoe Zephyr". This wind typically occurs on hot summer days from mid to late afternoon and diminishes just after sundown. Windspeeds are generally in the 15—25 mph range but winds can be much stronger through exposed canyons, or if accompanied by upper level trough support.

Although the Washoe Zephyr does not warrant the issuance of a RED FLAG WARNING, its occurrence can have major impact on wildfires in progress. The rapid onset and moderate strength of these winds can cause sudden fire runs, loss of firelines, and downwind spotting. The occurrence of the Washoe Zephyr can also be crucial when forecasting the location of thunderstorms along the Sierra front.

SURFACE: The Washoe Zephyr occurs when the thermal surface low pressure trough lies east of the Sierra Nevada range, typically over central Nevada. This induces a west—east gradient along the eastern Sierra Nevada slopes and develops a circulation similar to a sea breeze. The winds may be aided by the reversal of upslope winds to downslope as the steep east—facing slopes become shadowed in the late afternoon. The 850 mb analysis can also be used to track the position of the thermal trough, since much of the terrain in Nevada lies at or above 5,000 feet.

UPPER AIR: The Washoe Zephyr typically occurs under high pressure ridging, leaving Nevada with sunny, hot afternoons. However, the Zephyr winds can be reinforced by upper winds during the transition from a high pressure ridge aloft to an approaching upper trough.

PATTERN RECOGNITION: The onset of the Washoe Zephyr is linked to the position of the thermal trough. When the thermal trough is located over the central California valley, winds will be generally light southeasterly over western Nevada and the east Sierra Nevada slopes. If this pattern persists, it often leads to thunderstorms gradually spreading northward along the Sierra Nevada range. These thunderstorms may eventually continue over the crest to the western slopes of the Sierra Nevada. This is a CRITICAL FIRE WEATHER PATTERN of its own; particularly if the thunderstorms are high-based or numerous. The shift of the thermal trough into Nevada will coincide with the eventual breakdown of the thermal low in California. The cool marine air push through the Delta region of the Sacramento Valley is usually the first sign of this breakdown.

The passage of a weak upper level trough can also cause a shift of the thermal trough into Nevada. This may or may not be picked up in the NMC guidance, and use of water vapor satellite imagery is highly recommended.

Once the Zephyr develops, the resulting subsidence over the Sierra Nevada will quickly halt thunderstorm development and shift low level convergence into west—central Nevada, where thunderstorms will often redevelop in the early evening hours. In terms of fire behavior, the development of an afternoon Zephyr can quickly spread small lightning fires into the wildland-urban interface areas along the eastern Sierra Nevada slopes. Recent fire history has shown many of the larger fires in this area have been linked to man-caused fires which quickly escaped initial attack; due primarily to the strong gusty afternoon winds and erratic fire behavior.

OBJECTIVE TECHNIQUES: LFN and NGM MOS guidance will often pick up on the afternoon winds at Reno during the OOZ forecast time period. A rule of thumb is to double the wind speed for gusts. When forecasting the shift of the thermal low pressure trough into Nevada and the onset of the Zephyr, look at the Travis Air Force Base observation (SFOSAOSUU) for gusty southwest winds through the Sacramento Delta. Note that mountain top winds (Slide Mountain and Peavine Peak are appended to the Reno SAO) will often not reflect the occurrence of the Washoe Zephyr, unless associated with the approach of an upper trough. In this case, the mountain top winds will back to the southwest and increase.

WINDS & THUNDERSTORMS

SACRAMENTO FIRE WEATHER

DESCRIPTION: Critical fire weather patterns in the Sacramento district falls into two main categories - winds (north, east and southwest) and dry thunderstorms.

NORTH WINDS: Main effect is on coastal ranges south of Clear Lake to south of Mt. Diablo. North winds in the Sacramento Valley do not affect the Tahoe, Eldorado or Stanislaus NFs except on northerly aspects and at the peak/ridge levels.

There are two objective techniques for estimating north winds. One is a nomogram (**Fig 1**) while the other is given below. Note that the units are millibars in the first line of the equation and degrees C in the second.

There is a good chance of strong north winds the next day if:

$$\frac{(140N,140W) - GTF}{3} + \textit{24-hr change of gradient } (40N,140W) - GTF > 12$$

$$\textit{and } 700\ \textit{mb temp UIL} + \frac{MFR}{2} < 2,$$

EAST WINDS: After a couple of days, north winds in the Sacramento Valley veer to the northeast and east. East winds affect the forests above 5000 feet to the Sierra Nevada crestline. Strong east winds have driven fires westward and downslope to elevations as low as 1500 feet.

SOUTHWEST WINDS: Southwest winds are usually moist but there are several instances of dry southwest winds each fire season. These winds occur in advance of a trough and affect the forests and Mother Lode foothills of the Sierra Nevada. They usually last a day or so before a cooling sea breeze pushes onshore. On the west side of the Sacramento Valley these same winds can move down the east facing slopes as dry foehn winds and cause fire problems (i.e., Rattlesnake fire, Skinner Mills fire). They can also return on the west side of the Sacramento Valley as northerly wind from Stonyford to Leesville.

DRY THUNDERSTORMS: High level moisture from the Gulf of California or from Arizona/Mexico moves into southern California on south to southeast winds aloft. This is usually after a period of low humidities over the Sierra Nevada. The 12 and 36 hour objective aids (**Figs 2, 3**) are useful for forecasting thunderstorms (wet and dry) in the short term. The composite K chart using a combination of the Oakland sounding plus various morning lookout reports and weather stations such as Blue Canyon (BLU) and Slide Mtn (see RNO) is a useful tool for tracking the northward advance of high level tropical moisture.

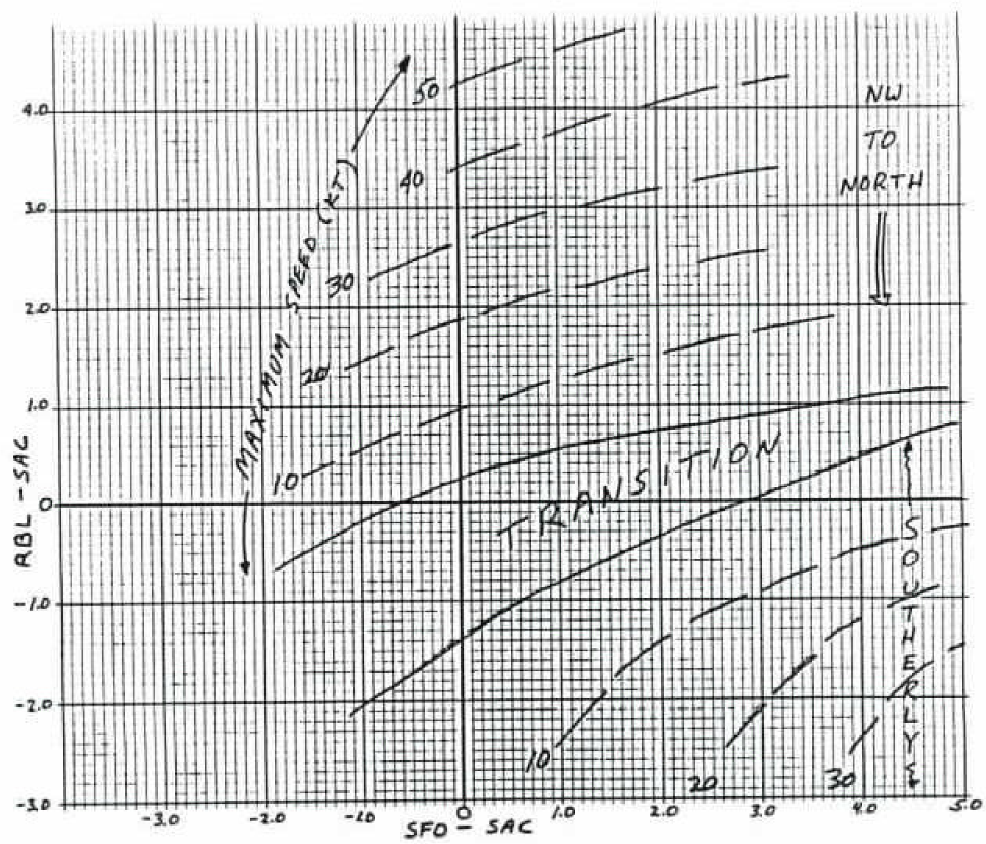


Fig. 1 Nomogram for predicting the maximum afternoon wind speed (in knots) based on the 0400 local time surface pressure gradients.

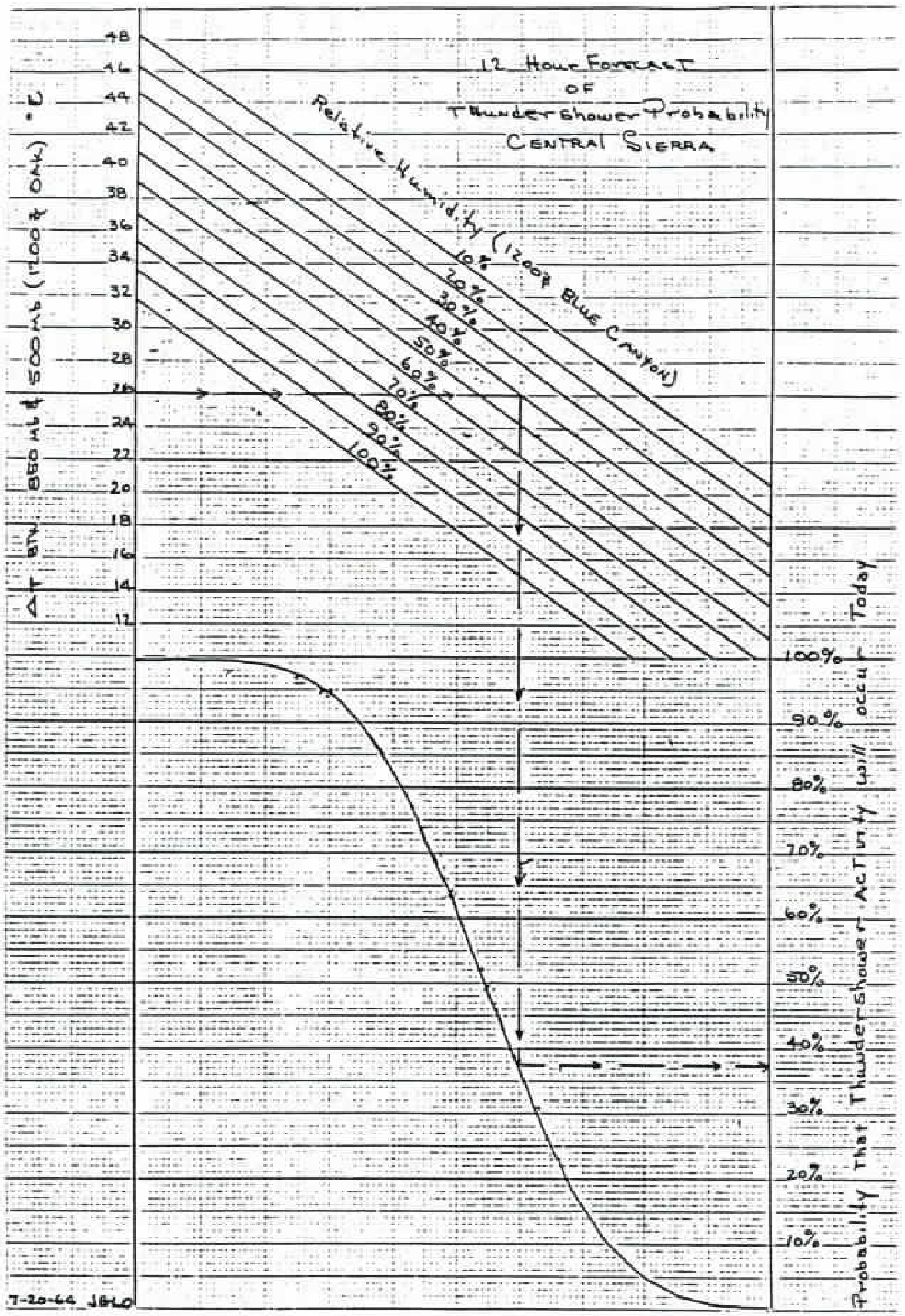


Fig. 2 12 hour forecast of thundershower probability in central

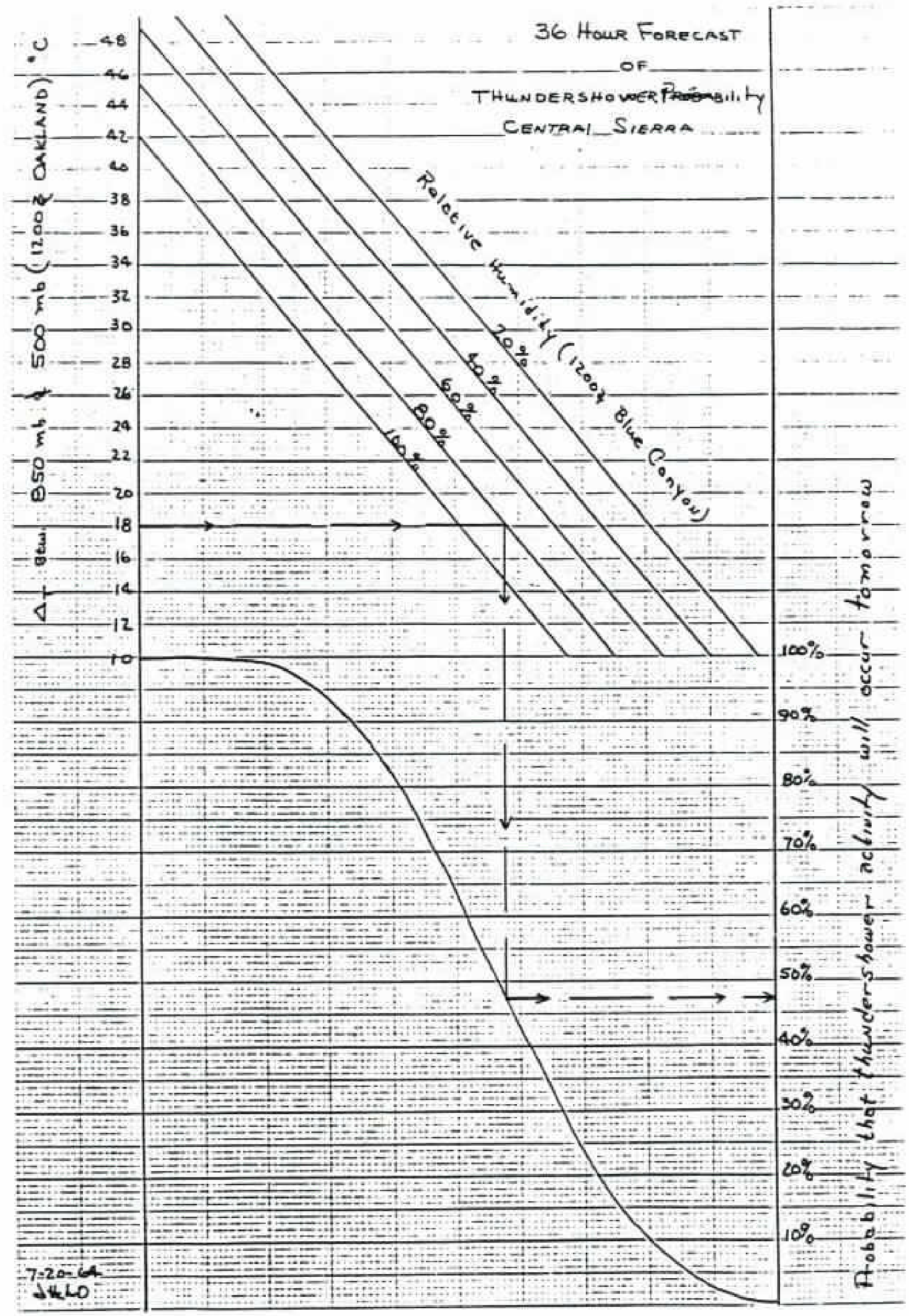


Fig 3. 36 hour forecast of thundershower probability in central

PRE-FRONTAL WINDS

SALT LAKE CITY FIRE WEATHER

DESCRIPTION: During the several days preceding a summertime cold front passage in western Utah, south winds will gradually increase and become quite strong (typically 15-25 MPH sustained with stronger gusts). Early in the event these winds are seldom a red flag condition because they are not strong enough. However, as time goes by, the wind increases in speed and rapidly desiccates fuels. Once the sustained winds are greater than 15 MPH, fire spread rapidly increases in many Utah fuel types. The combination of quickly drying fuels and stronger winds warrants red flag conditions. There is a good potential for 30—40 mph sustained winds, especially in the 24 hours before frontal passage. Many times the cold front is essentially dry, but the winds will shift to the west or northwest with frontal passage then sharply decrease during the next hour or two.

These hot, dry, strong south winds have the greatest effect on fire conditions from about the first of May through October. They are most common in western Utah, but can also be seen in eastern Utah, where they are usually less strong.

SURFACE: The surface pattern is usually not a key player in this event. Surface gradient support usually does not come into play until close to frontal passage if at all. It is not unusual to see a surface high pressure feature over Utah during much of the wind event.

UPPER AIR: The upper atmospheric level to key upon in this case is 700 mb. The 700 mb progs can give an excellent indication several days in advance of onset. In general, the 700 mb pattern to look for is a progressive trough to the northwest of Utah with a quasi-stationary ridge to the east **(Fig 1)**. This will bring about a south to southwest flow over Utah. A similar pattern at 500 mb helps support the situation but is not necessary to sustain the winds. However, without this typical 700 mb pattern, the south winds will have a difficult time getting started.

PATTERN RECOGNITION: Again, the key is to keep an eye on the 700 mb pattern. Note that figure 1 does not have a marked gradient across the state. However, this pattern shown will often easily increase sustained winds to 10-15 MPH. The gradient tightens as the trough pushes east into the ridge, usually a day or two into the event, then winds really increase and reach red flag criteria (hot, dry winds of 15+ MPH…see **Fig 2**).

OBJECTIVE TECHNIQUES: When the SLC 700 mb winds have increased, the surface winds will also reflect generally about two thirds that increase (more is possible) once mixing occurs during the day. When four 700 mb 30-meter contours lay across Utah from west to east (**Fig 2**), then sustained winds of 30-40 mph are likely with some gusts around 50 mph possible. Terrain funneling plays a key part in this event, and that largely explains why western Utah valleys are more susceptible than eastern Utah locations.

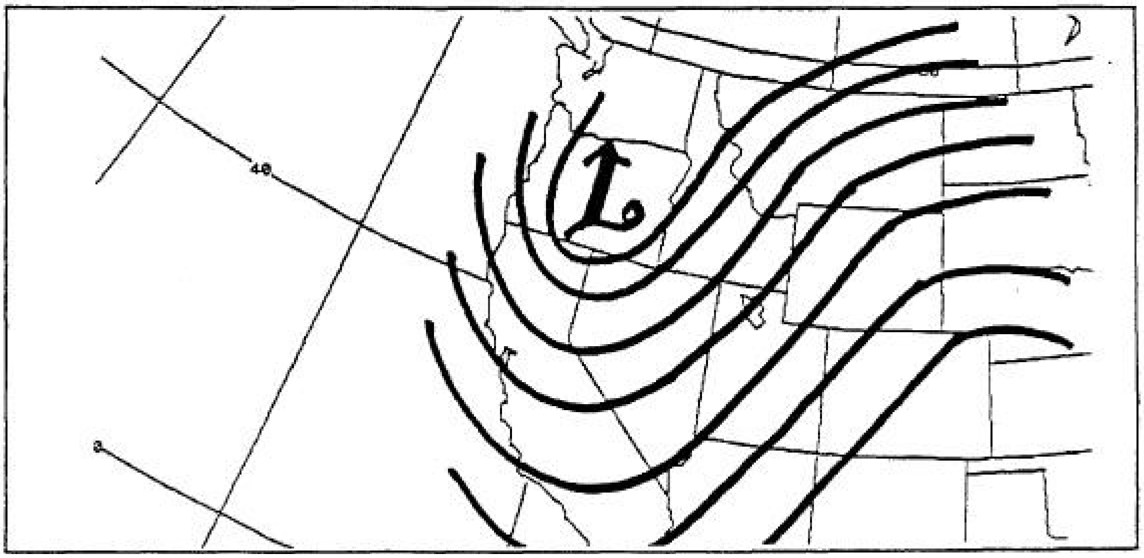


Fig 1. Typical 700 mb pattern for onset of south winds (10—15 mph) in western Utah.

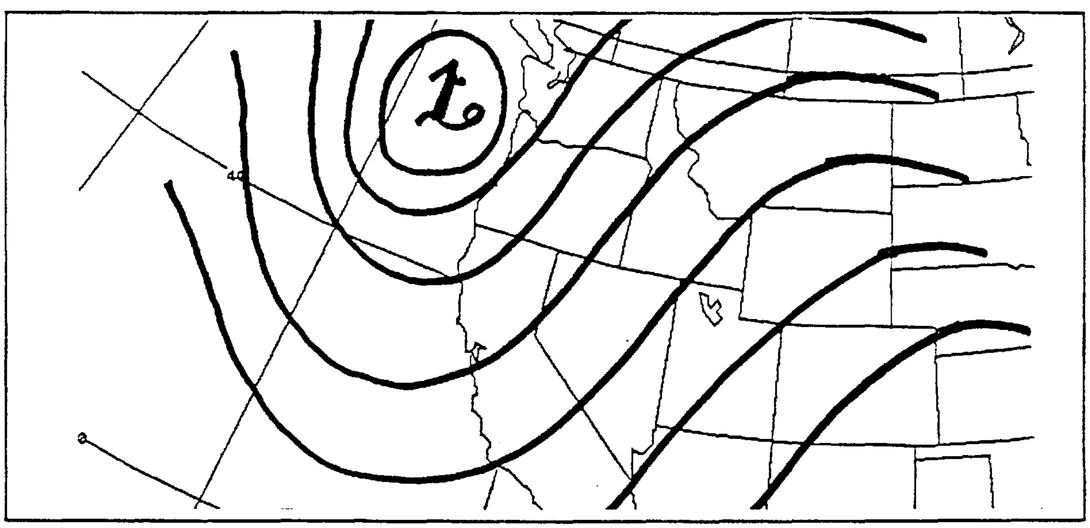


Fig 2. Typical 700 mb pattern for onset of strong south winds (sustained 30-40 mph) in western Utah.

EAST WINDS

SALEM FIRE WEATHER

DESCRIPTION: Most critical pattern found in the Salem district. Full fledged east wind conditions result in very strong and very dry NE-E windflow that blows across and down the west slopes of the Cascades and continue all the way through the coast range to the coastline. Typical speeds can easily be 30—60 mph at exposed higher elevation sites or through major corridors such as the Columbia Gorge. As important as the speeds are the low humidities, typically in the teens or low 20s during the day with little or no recovery at night. Most of the time these winds will peak during the nighttime and early morning hours. September and October are the favorite fire season months for east wind occurrence. It is rare to get significant east winds in July and August.

SURFACE: The key factor is location of the surface based thermal trough. The optimum surface pattern would show a north—south oriented thermal trough located along the entire Oregon coast, preferably just offshore (**Fig 1.**). Strong surface high pressure usually located in eastern Washington and eastern Oregon. This results in strong surface offshore pressure gradients.

UPPER AIR: Normally a strongly meridional type of flow consisting of a sharp ridgeline somewhere between western Oregon and about 135° W and troughiness farther east, i.e. extreme eastern Oregon and Idaho (**Figs 2,3**). It is possible to have significant east winds even if there is a cut-off H5 low off the northern California coast as long as the main long wave ridgeline is still located as described above.

PATTERN RECOGNITION: First signs of possible development would be strong and sharp H5 ridge building northward offshore into Gulf of Alaska and southern B.C. coast. As this occurs you should see evidence of California surface heat low building sharply northward off the extreme southern Oregon coast. By the time the thermal trough reaches the central Oregon coast, east winds probably already beginning to blow at higher elevations of the Cascades. If thermal trough continues to build northward along the entire coastline, east winds are likely any exposed areas on the district. Usually the first location to get east winds is the Red Mountain RAWS site located at 4900 ft in the Gifford Pinchot NF, just north of the Columbia Gorge. They may preceed other areas by 12-24 hours. It is not unusual to see them blowing a steady 45-60 mph hour after hour.

East winds will begin to subside as upper ridgeline and surface thermal trough, in conjuction, drift inland and finally move east of the cascades returning area to onshore surface pressure gradients.

OBJECTIVE TECHNIQUES: We have found that east winds often abruptly begin at Red Mountain RAWS as soon as H5 heights in southern B.C. become higher than those over Salem. Also watch both the SEA-OTH and GEG—OTH surface pressure gradients for the gradual switch to increasingly offshore surface flow.

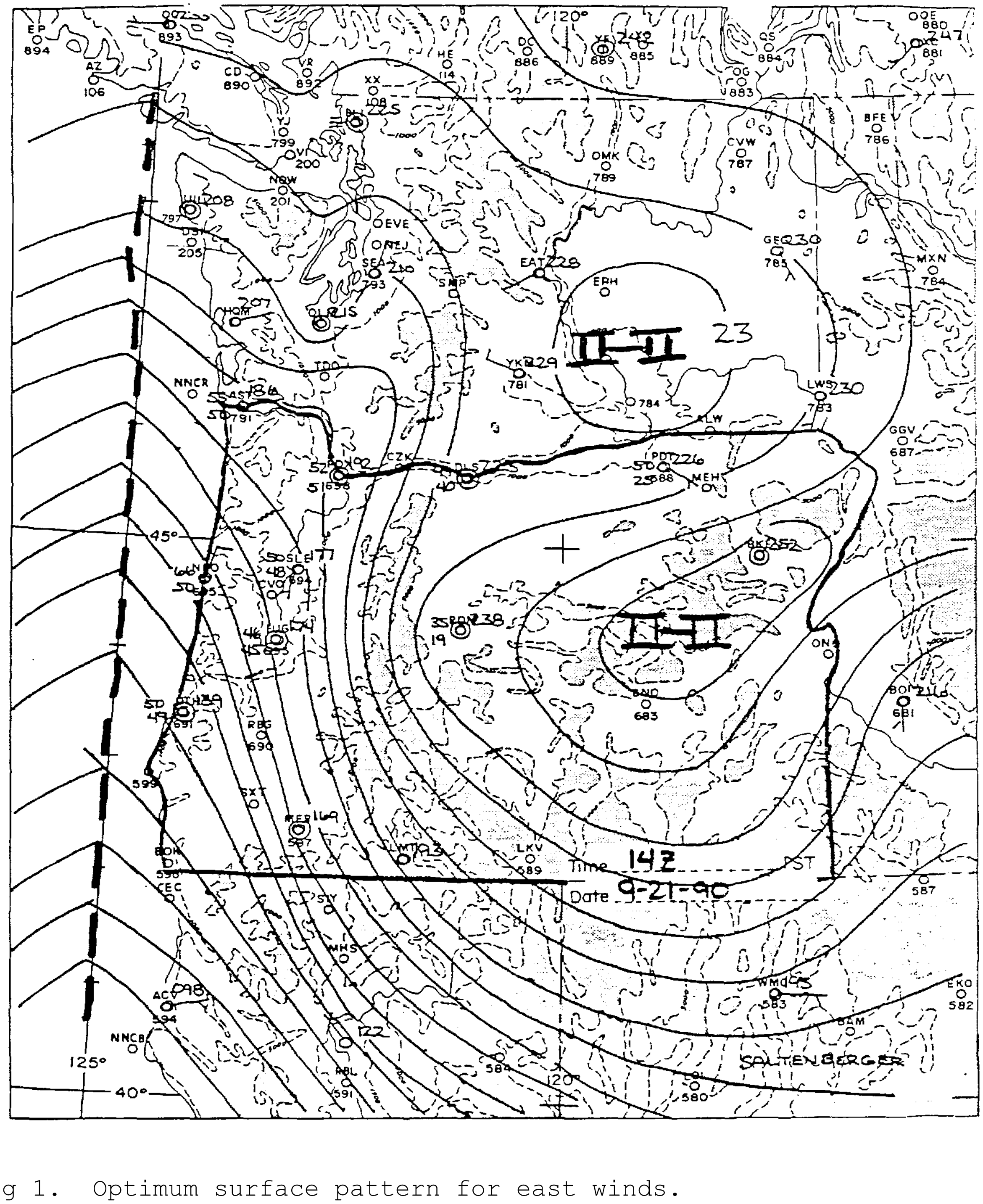


Fig 1. Optimum surface pattern for east winds.

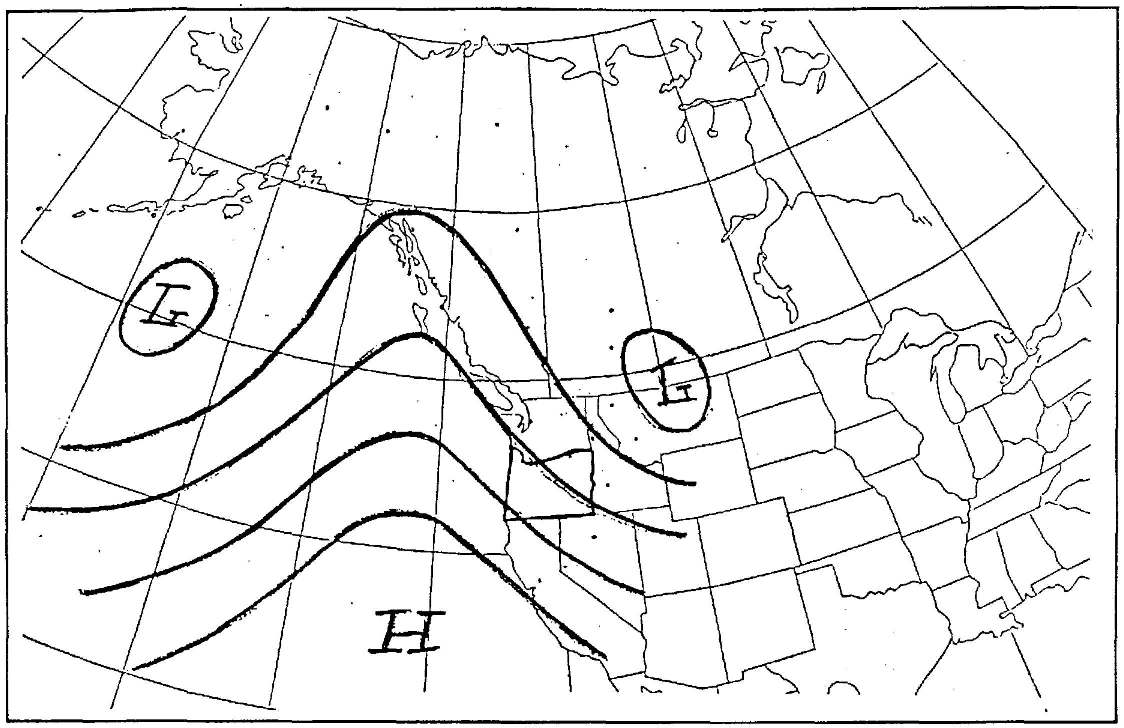


Fig 2 - Schematic 500 mb analysis at start of east winds.

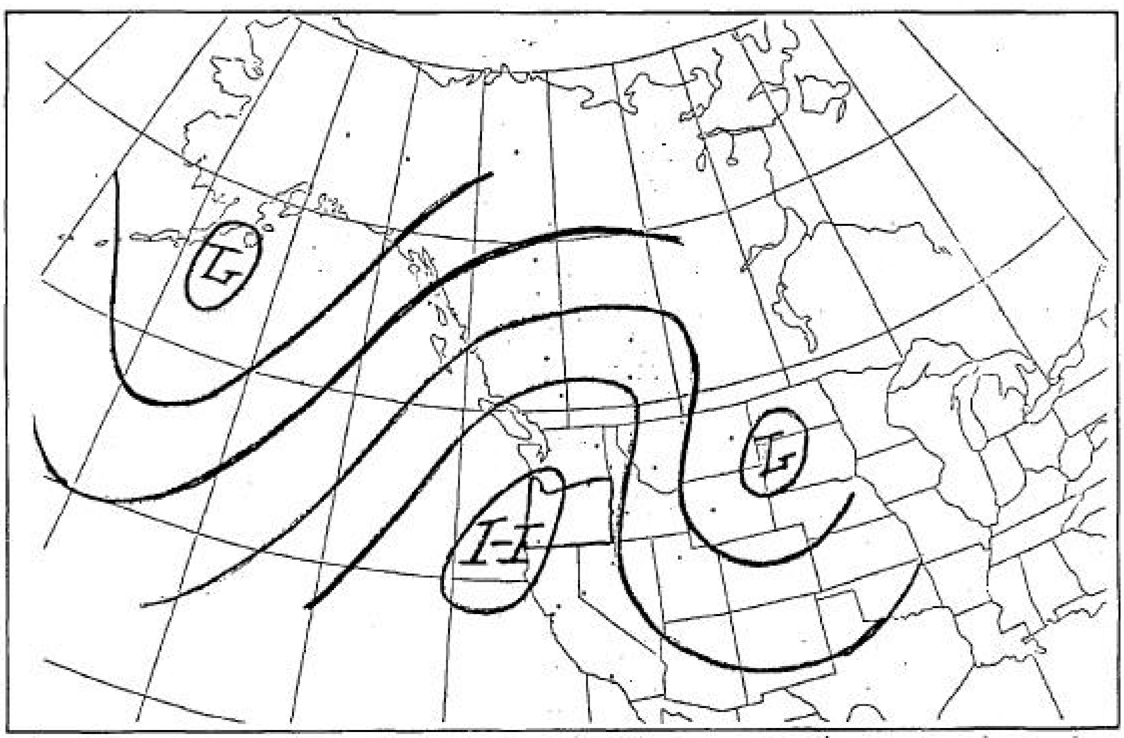


Fig 3 - Schematic 500 mb analysis when east winds reach peak.

MARINE PUSH - EAST SIDE CASCADES

SALEM FIRE WEATHER

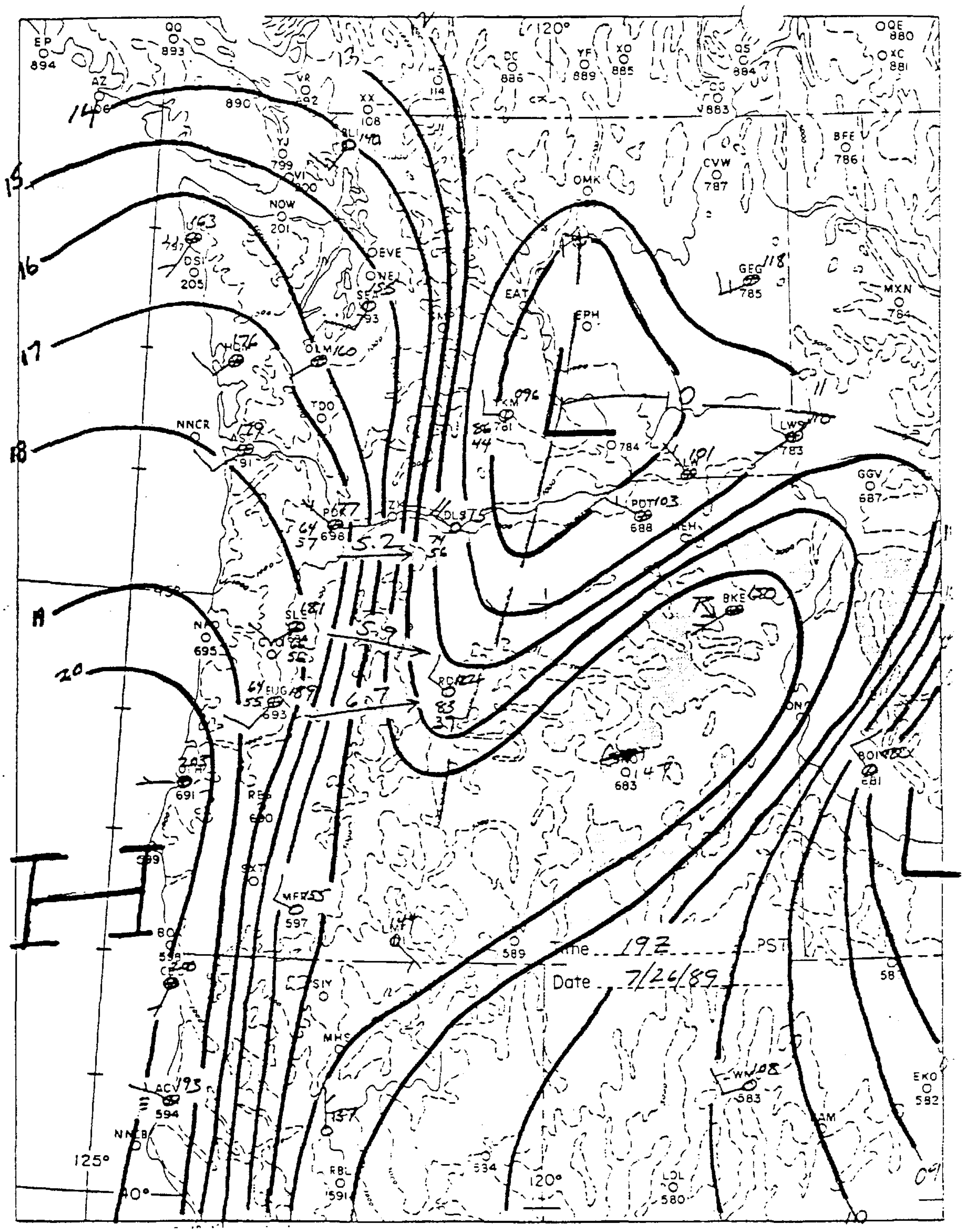
DESCRIPTION: Equally *as* important to our eastside zones as east winds are to our westside zones, is the occurrence of a strong foehn type west wind that blows down the east slopes of the Cascades and across zones 609 and 610. This occurs in conjunction with a strong "marine push" west of the Cascades. The leading edge of this dense marine air acts as a dry frontal zone. Strong thermal gradients build up between areas west of the Cascades and areas east, leading to moderately strong west winds on the eastside. The Cascades act as a temporary block to the more moist marine air so that there is a period of time where the east slopes experience strong and dry west winds. This critical period is usually about 6-9 hours when west winds can blow typically 15-30 mph with humidities in the teens. Normally, after that period of time, modified marine air is able to finally get across the Cascades. When this happens, the winds subside abruptly and humidities recover to above normal levels and fire danger lessens significantly.

SURFACE: Strong Pacific high pressure cell builds abruptly into western Oregon (**Fig 1**). Thermal trough rapidly exits our eastside zones toward eastern Oregon so that onshore surface gradients cover our entire district (eastside zones as well as westside zones). This situation can often occur following the conclusion of an east wind episode over western Oregon.

UPPER AIR: For a significant marine push to occur normally takes a strong H5 trough to approach the Oregon coast while an equally sharp and strong H5 ridge moves eastward toward Idaho (**Figs 2,3**). As in the case with east winds, the surface thermal trough tends to be situated under the H5 ridgeline and they move in conjunction. This, again, tends to be a strongly meridional type pattern.

PATTERN RECOGNITION: Antecedent conditions usually show a strong upper ridge over the area that may have been persisting for an extended time. In conjunction with this would likely be a well defined surface thermal trough located along the east slopes of the Cascades. Given this situation look for the approach of a vigorous and often rapidly moving H5 short wave trough. This is the key, dynamically, and will serve as a kicker to move the thermal trough far enough eastward to allow marine air to move inland. Coastal fog will have lifted into a stratus deck 1000 ft or higher before a push occurs. The push is imminent when surface pressures begin to rise rapidly along the southern Oregon coast. A good strong push is actively underway if you observe the sudden onset of SW-W winds at Eugene by late afternoon. Temps will drop rapidly and humidities will rise rapidly. It usually is only a matter of a few hours until strong dry west winds will begin to show up on the east slopes of the Cascades.

OBJECTIVE TECHNIQUES: We really have not used any objective rules but rather have just relied on pattern recognition.



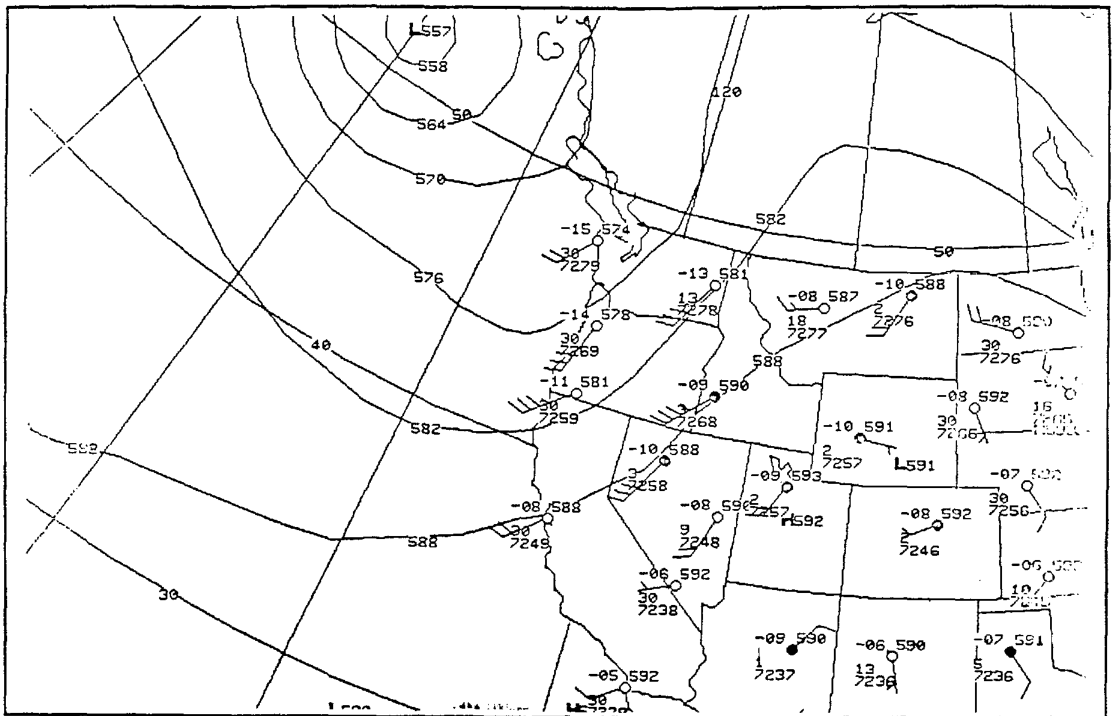


Fig 2 - 500 mb analysis for strong marine push (7/27/89 12z).

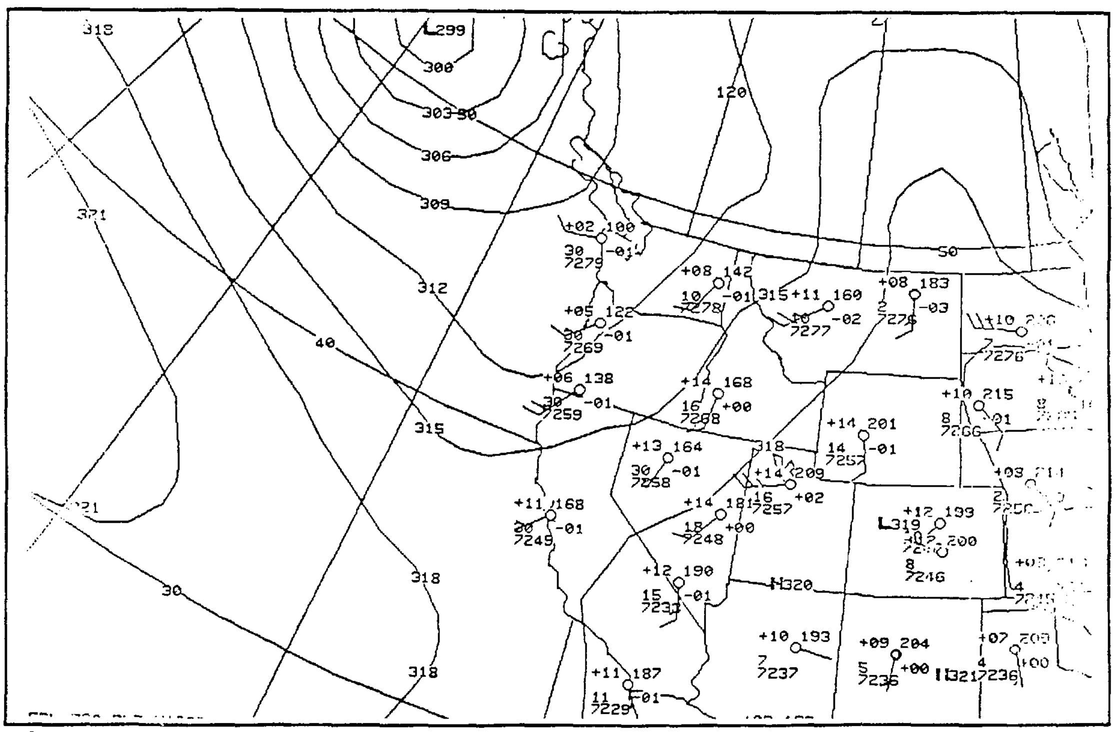


Fig 3 - 700 mb analysis for strong marine push (7/27/89 12z).