Development of Strong South Winds in the Shasta Valley and a Case that Produced Strong South Winds in the Rogue Valley

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The complex terrain of Medford's forecast region makes the prediction of surface winds a challenging task for operational meteorologists. This paper is intended to aid the operational forecaster in recognizing the type of synoptic pattern that normally produces strong south winds in the Shasta valley of northern California and moderate to strong downslope winds in the Rogue valley of southwest Oregon.

There are 4 primary mechanisms that govern the development of valley surface winds in complex terrain. The 4 mechanisms at work are:

1. Thermally induced valley flows. These are winds produced by differential heating within a valley and are known as upvalley/downvalley circulations.
2. Downward transport of momentum. This is the mechanism that causes winds to be gusty. Vertical circulations mix the higher momentum air aloft down to the surface. In addition, mountain wave activity or downslope windstorms can be, in part, due to this mechanism as higher momentum air descends the lees side of mountain ranges.
3. Terrain channeling. This mechanism is responsible for ensuring that the wind direction in a valley is roughly parallel to its sidewalls. It can produce acceleration of the wind when the wind is forced through constricted areas (Venturi effect).
4. Pressure Gradient force. This is a cross-gradient or strongly ageostrophic wind that occurs in mountainous terrain due to friction and the relative smallness of the scale of the circulation.

Case of the Shasta Valley

In investigating the episodes of strong south winds (sustained 35 mph or higher) in the Shasta valley, I concluded that 2 of the above mechanisms were primarily at work. A total of 13 cases from the winter of 1998 were reviewed and another 5 cases from January of 2001. Case after case showed a very familiar pattern associated with the development of the Shasta valley winds. A relatively strong, somewhat negatively tilted, upper level trough is normally approaching the Pacific Northwest coast (figure 1).

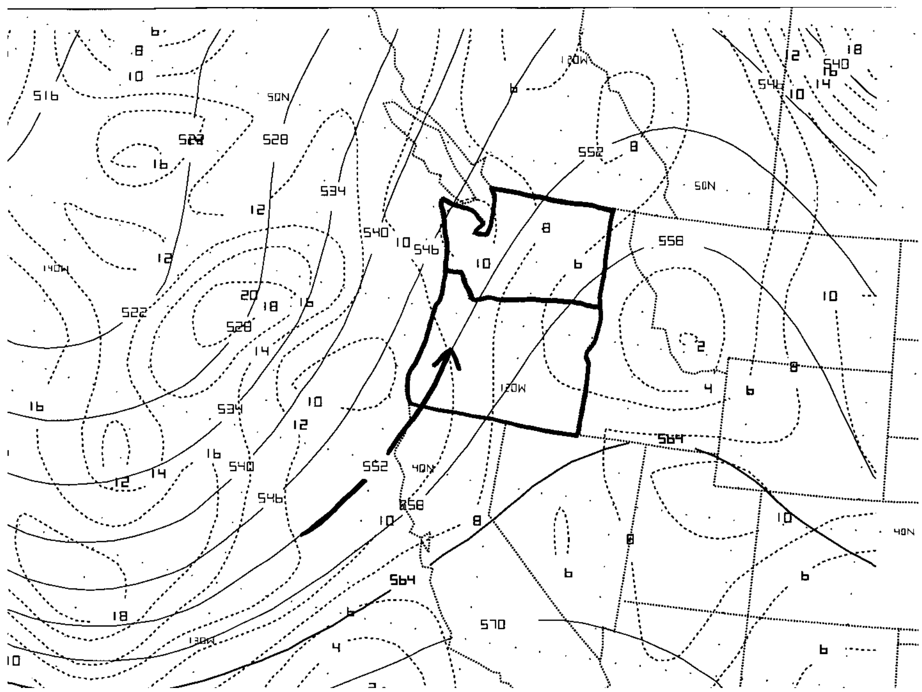

Figure 1. 500 mb Heights and Vorticity

The 700 mb wind flow is generally south or southwest, and, in almost every case, the wind speed was at least 35 knots. Since the correlation between the strong parallel flow aloft and the subsequent strong surface wind was so striking, it was concluded that downward transport of momentum occurred when the direction of the mid level wind was strong and roughly parallel to the Shasta valley. An example of the 700 mb wind flow during a Shasta valley wind event is shown in figure 2.

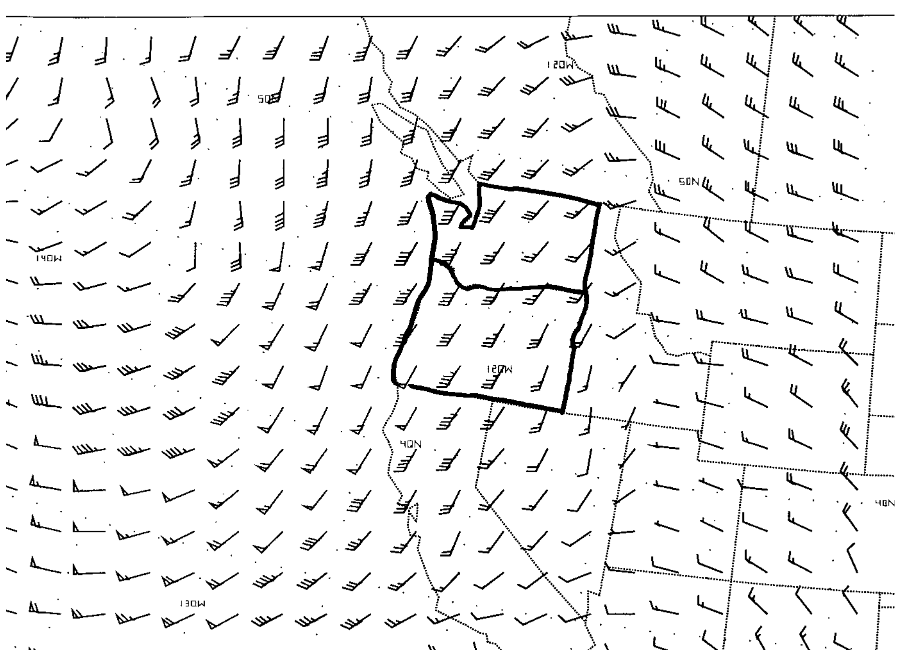

Figure 2. 700 mb Wind

In addition, it was found that the pressure gradient between Medford (MFR) and Redding (RDD) correlated well with the wind speeds that were observed in the Shasta valley. When the synoptic pattern was as described above, surface winds of 15 to 25 mph with gusts to 35 mph were observed when the pressure gradient between MFR and RDD reached 4 millibars. Normally the 700 mb winds were around 35 knots at that point. Wind speeds that met Wind Advisory criteria (sustained wind speeds of 35-39 mph with gusts to 45-57 mph) were associated with pressure gradients of 4 to 6 millibars and 700 mb winds of 40 knots. Pressure gradients of 7 to 10 millibars between MFR and RDD and 700 mb winds of 50 knots were associated with winds reaching High Wind Warning criteria (sustained wind speeds of 40 mph or more with gusts to 58 mph or higher). As a side note, it was found that only truly mesoscale models were capable of successfully predicting surface pressure gradients in complex terrain. Coarser scale models like the GFS smooth pressure gradients. This results in actual gradients that can be twice strong as those predicted by the model. An example of the mean sea level chart during a high wind episode is shown in figure 3. This is the 12 hour forecast from the 80km ETA. Note the smoothness of the contours that produced a RDD-MFR surface gradient of 4 mb, and resulted in under predicting the actual pressure gradient of 6 to 9 mb.

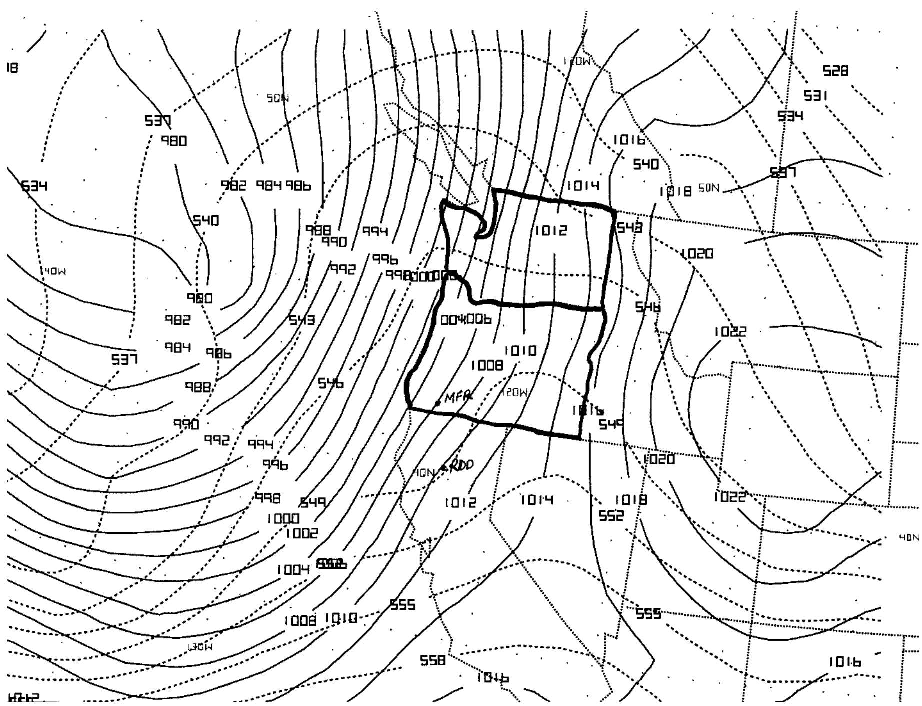

Figure 3. Mean Sea Level Pressure (mb) – solid lines.

Case of the Rogue Valley

The Rogue valley near Medford, being surrounded by mountains, seldom experiences surface winds of any magnitude, particularly in the winter. The one exception occurs when the flow aloft becomes strong and parallel to the valley. This occurs, most commonly, when a negatively tilted trough approaches the coast. This allows the wind direction aloft to back until it becomes parallel to the Rogue valley. The case presented above (figures 1 – 3) occurred on January 28, 1998 and involved a deepening negatively tilted upper level trough. Although winds at the Medford airport did not reach High Wind Criteria, winds were sufficiently strong to produce damage from falling trees and tree limbs and to do damage to a few structures.

On the morning of January 28, 1998, a strong 500 mb trough was located near 140W and an upper level ridge axis was located just east of the Cascades. As the day progressed, the offshore trough became more negatively tilted (figure 1). The 700 mb wind as measured over Medford backed and increased from 230 degrees at 30 knots at 1200 UTC to 190 degrees at 48 knots at 0000 UTC on the 29th (figures 4 and 5 below). At the surface the wind was calm at 1200 UTC. There was a shallow surface inversion that extended to 1000 feet agl. Note that winds just above the inversion were already southeast at about 20 knots at 1200 UTC. As the day progressed and the winds aloft became aligned with the south to north orientation of the valley, the increased downward transport of momentum was able to mix to the surface. At 2100 UTC, the wind suddenly increased to 140 degrees at 23 knots. The temperature jumped 9 degrees F. Winds peaked at the Medford airport around 0100 UTC on the 29th, reaching a maximum of 49 mph. The surface pressure gradient between MFR and RDD was 6.6 millibars at 1200 UTC on the 28th. It increased to 9.0 millibars at 0100 UTC on the 29th.

As an aside, note that there was an inversion aloft near mountain top elevations on the 0000 UTC sounding on the 29th. Some of the wind speeds recorded during this event near Ashland in the upper part of the Rogue valley exceeded the strongest winds on the sounding by 20 percent. We have seen this to be coincident with the mountain top inversion on several occasions. Wave energy is reflecting downward off the inversion much as is the case during the classic “hydraulic jump” downslope wind storms on the east slopes of the Rockies.

Summary

In summary, the strong south winds observed in the Shasta valley and, to a less frequent extent, in the Rogue valley, are strongly correlated with the 700 mb wind and the surface pressure gradient. In addition, mountain top inversions tend to concentrate wave energy and when present during a classic wind scenario, can produce surface winds that are stronger than the winds aloft. For a rough estimate of winds expected in the Shasta valley during one of the strong south wind episodes, use the following:

Surface Pres. Grad. (RDD – MFR)	700 mb Wind	Expected Surface Wind
4 mb or less	S-SW 35 knots	S 25 mph gust 35 mph
4 – 6 mb	S-SW 40 knots	S 35 mph gust 50 mph
6+ mb	S-SW 50 knots	S 40 mph gust 60 mph

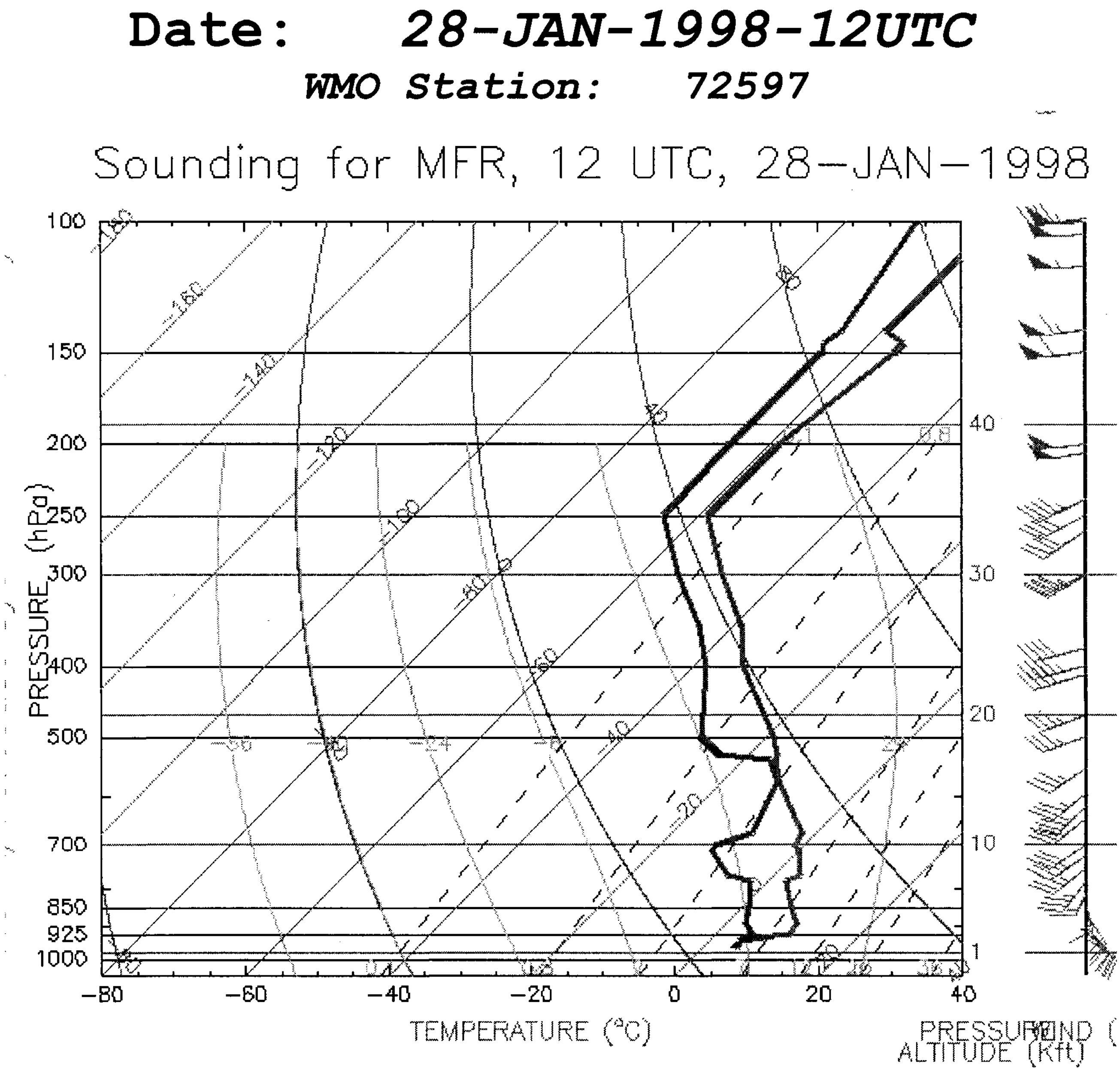

Figure 4. SKEW-T plot January 28 1200 UTC

Date: *29-JAN-1998-00UTC*

WMO Station: 72597

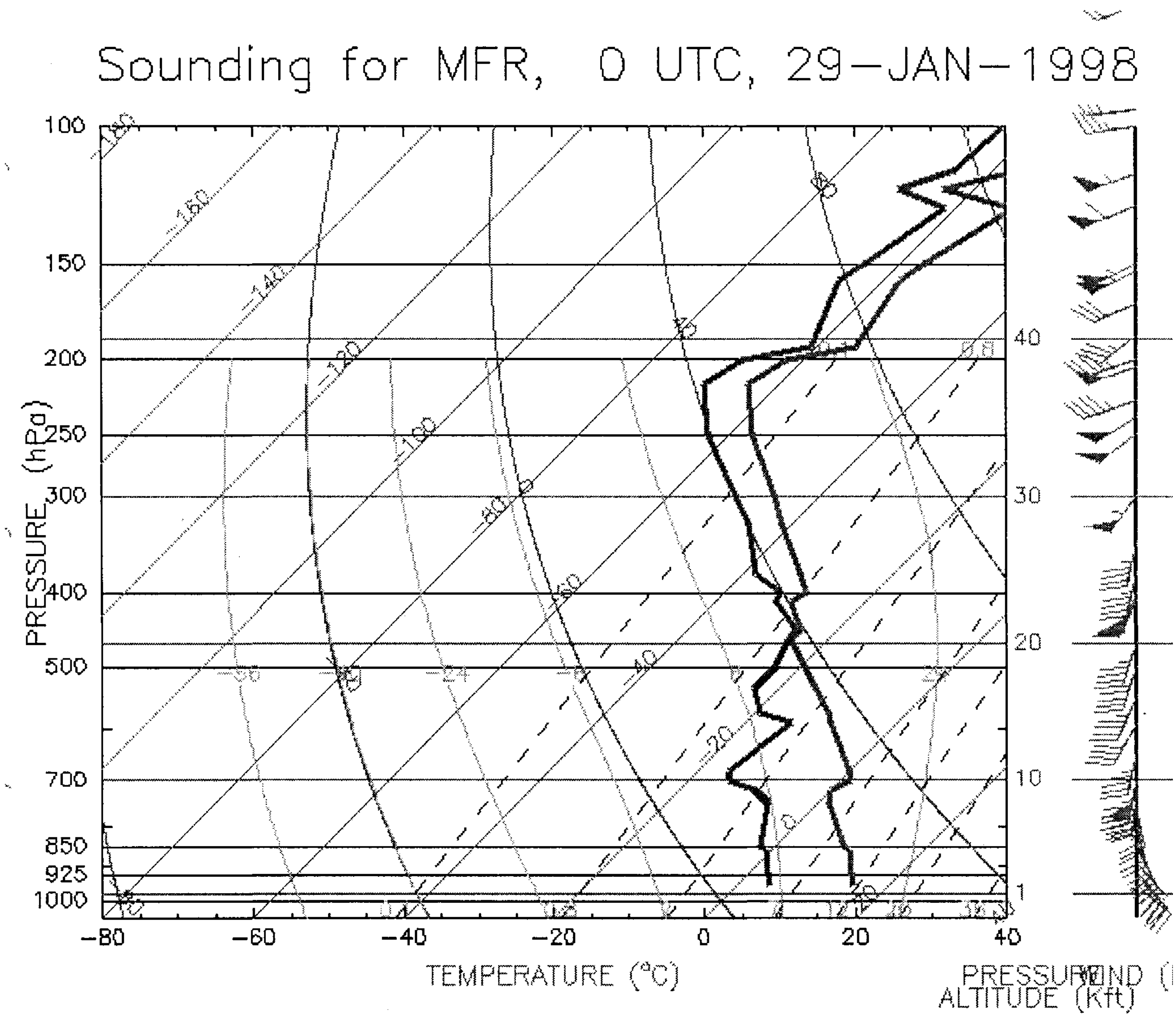

Figure 5. SKEW-T plot January 29 0000 UTC

References:

Whiteman, C.D. and J.C. Doran, 1993: The relationship between overlying synoptic scale flows and winds within a valley. J. Appl. Meteor, 32, 1669-1682

Doran, June 1990: Atmospheric Processes Over Complex Terrain. Meteor. Monographs Vol. 23, No. 45.