Western Region Technical Attachment
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THE RELATIONSHIP BETWEEN VALLEY AND RIDGETOP WIND DIRECTION

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The complex terrain of the western United States makes prediction of surface winds a difficult task for operational meteorologists. This can be particularly true of aviation and fire weather forecasts for valley locations. Recently C. David Whiteman and J. Christopher Doran published a paper entitled "The relationship between overlying synoptic-scale flows and winds within a valley" in the November 1993 issue of the *Journal of Applied Meteorology*. This Technical Attachment presents a brief summary of that paper.

Whiteman and Doran based their results on observations in the Tennessee Valley. They identified four different mechanisms for the relationship between valley surface winds and the free atmosphere (geostrophic) winds at ridgetop level. The four mechanisms are as follows:

1. Thermally forced winds: These are the basic up-valley winds during the day and down-valley winds at night. Sunny days and clear nights are the favorable conditions for this mechanism to be dominant.

2. Downward transport of momentum: Ridgetop winds mix downward to the valley floor with the valley winds becoming parallel to the free atmosphere winds at ridgetop level. Neutral or unstable lapse rates are the favorable conditions for this mechanism to be dominant.

3. Terrain channeling: The geostrophic upper-level winds impinge on the terrain and are channeled to align with the valley axis. The resulting valley surface winds are along the axis of the valley with the component of the upper-level wind that is parallel to the valley. For example, southwest winds impinging on a north-south oriented valley produce southerly valley winds, while northwest winds produce a northerly wind. A significant aspect of this mechanism is that in certain situations a small wind shift aloft can lead to a 180 degree wind shift at the valley floor. Figure 1 shows an example of how a wind shift at ridgetop level from 240 to 290 degrees could change the surface winds in a north-south valley from 180 to 360 degrees.

4. Pressure gradient induced: Valley surface winds blow along the axis of the valley from high to low pressure. In some cases this can lead to "counter-currents" in which the surface wind direction is nearly opposite from the upper-level geostrophic winds. Figure 2 shows three examples of a pressure gradient induced wind. In 2a and 2b both westerly and southwesterly geostrophic winds blowing over a north-south oriented valley produce a southerly surface wind, while in 2c a southeast geostrophic wind produces a northerly surface wind. As in the terrain channeling mechanism, a slight

change in direction aloft can result in a 180 degree wind shift in the valley. In Fig. 2b and 2c, a shift from 200 to 160 degrees results in a valley wind shift from 180 to 360 degrees.

The size of the valley, the amount of solar heating or radiational cooling, the stability, and the strength of the winds aloft all play a role in which mechanism will be most dominant. Whiteman and Doran found the pressure gradient induced mechanism to be dominant most often in the Tennessee Valley, although they speculated the diurnal up-valley/down-valley mechanism would predominate in the drier valleys of the western United States where solar heating/nighttime cooling would produce quicker temperature changes than in the more moist environments of the Southeast. The next time the surface wind seems to be the opposite of what you expect, take a look at the four mechanisms described by Whiteman and Doran to see if they explain what is going on.

Reference:

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.

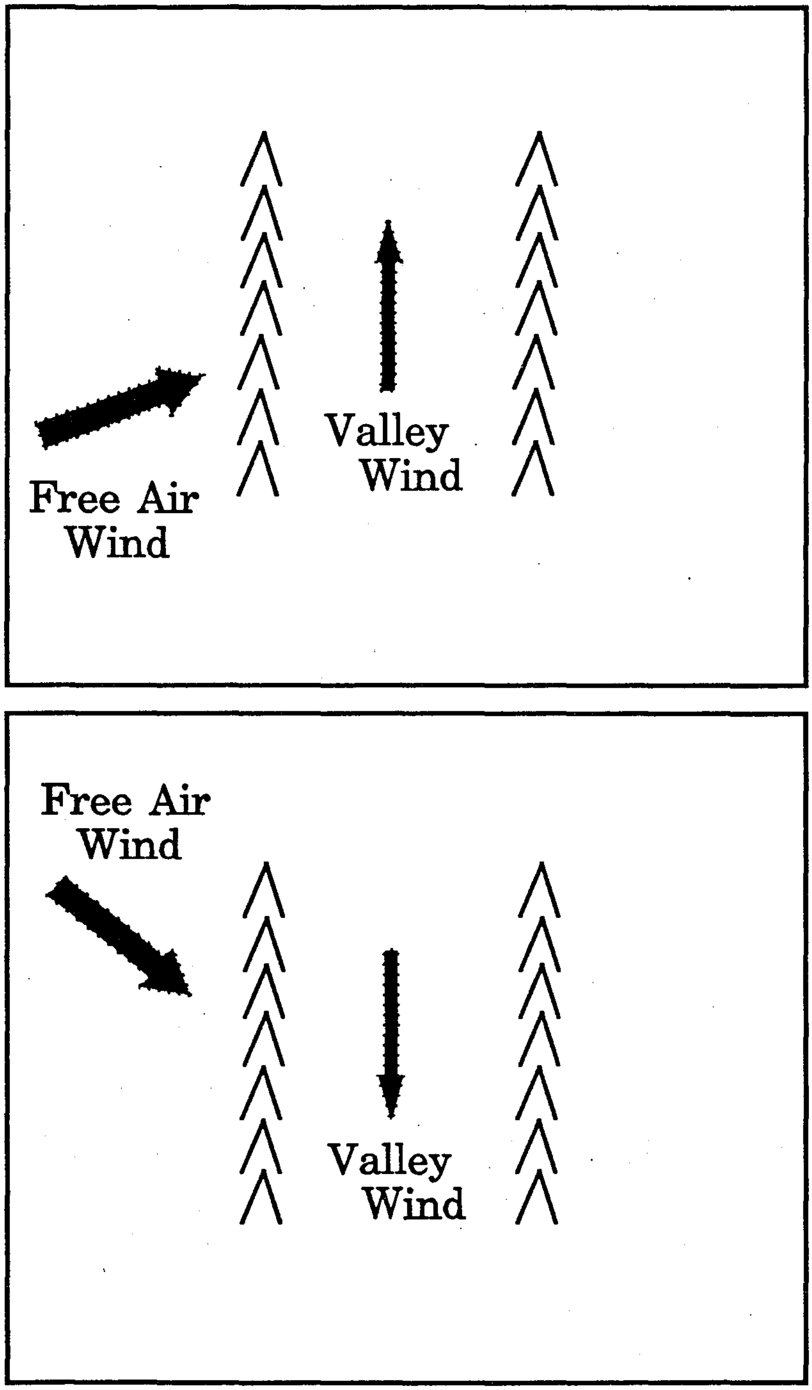
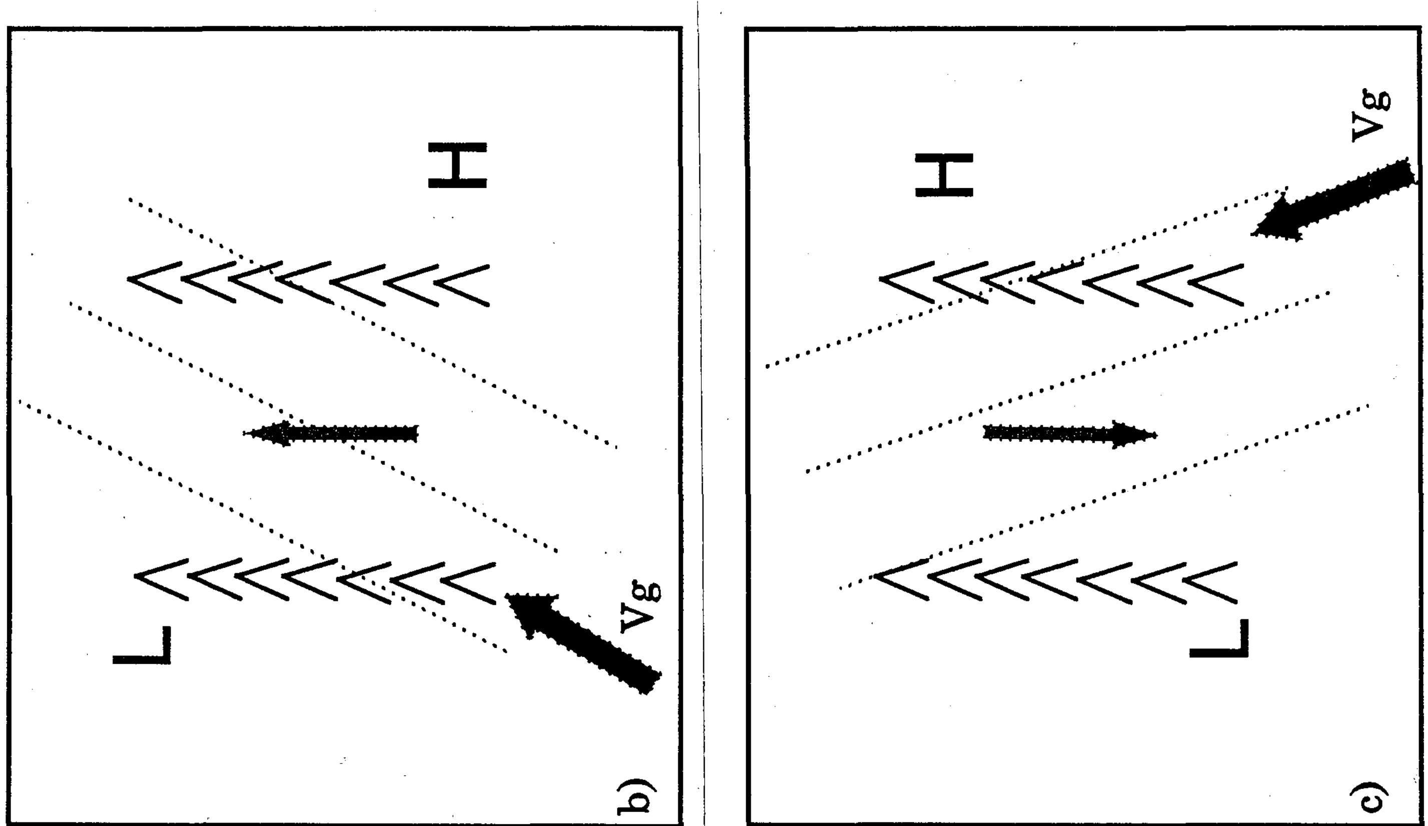


Figure 1. Channeling



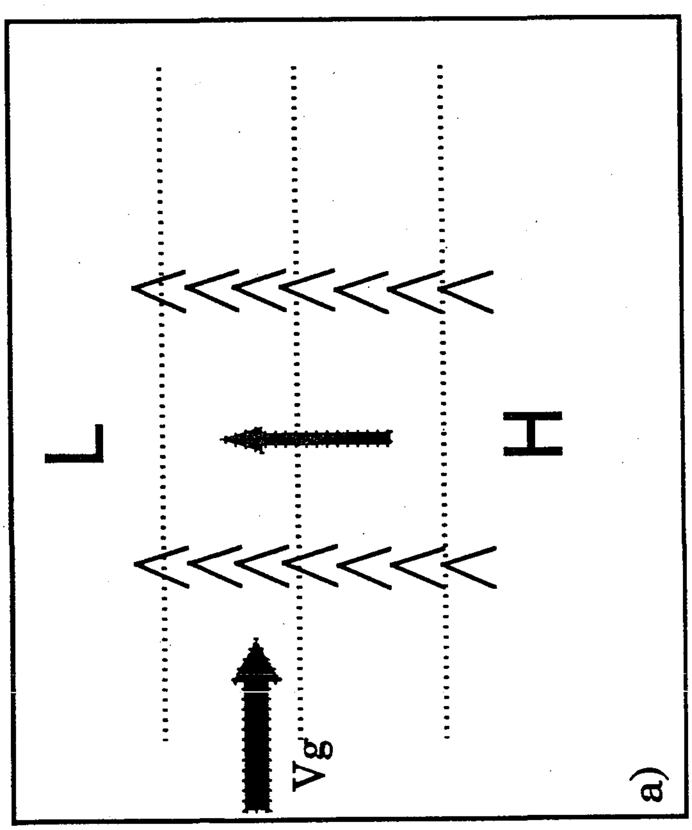


Figure 2. Pressure Gradient