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WSR-88D DETECTION OF LLWS

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Introduction

Low-level wind shear (LLWS) is one of the most dangerous hazards to aviation. Historically, it has also been one of the most difficult to forecast. This has been due in large part to the limited capabilities of operational observation systems. Traditional methods for detecting LLWS (rawinsondes, pibals, PIREPs, and surface observations) present obvious limitations of spatial and temporal continuity. The National Weather Service WSR-88D Doppler radar provides supplemental data which in part compensates for these limitations. WSR-88D velocity products permit a comprehensive assessment of LLWS. The following is a demonstration of WSR-88D LLWS detection along a thermal trough moving through southwest Idaho on July 9, 1994.

LLWS Defined

As defined by the National Weather Service Training Center, LLWS is "a change in the vector wind field in any direction in space, e.g., along an aircraft flight path, and between the surface and 2,000 feet above ground level (AGL)." While this definition does not address the varying degrees of LLWS, it is adequate for demonstrating WSR-88D LLWS detection.

Thermal Trough Defined

The typical thermal trough is an elongated area of low pressure that develops at the surface in response to strong diabatic heating (Fig. 1a). It typically resides just upstream of the 500 mb ridge where diabatic surface heating is typically strong. In the northern intermountain region, its movement is generally from west to east, following the 500 mb ridge.

Many features of the thermal trough resemble those of the cold front. Convergence at low levels results in similar surface structure (Fig. 1b). Vertical structure is also similar (Fig. 1c). However, the thermal trough is typically much shallower since it lacks the upper support found with a cold front (Fig. 1d).

A modification of the typical wind field indicated above is observed when a thermal trough is situated over the Snake River Valley of southwest Idaho. The northwest-southeast alignment of the valley forces typical pre-trough southerly winds to back southeast within the valley. Consequently, wind shear associated with the trough is enhanced as northwest winds oppose southeast winds near the trough axis instead of south winds (Fig. 1e). WSR-88D observations displaying the enhanced shear will be shown later.

Background

During the early afternoon hours of July 9, 1994, a thermal trough was poised over southwest Idaho. Surface reports and analyses indicated that the trough was somewhere between Boise and Mountain Home from 1800 to 2200 UTC (Fig. 2a and 2b). Better resolution of the trough position was not possible due to the observational data void between the two sites. Additionally, the data void prevented detection of LLWS associated with the trough. Prior to the WSR-88D, the first report of LLWS related to this trough would have been a PIREP following the firsthand encounter of a pilot. The WSR-88D makes it possible to detect LLWS before it is encountered.

WSR-88D Observations

On the afternoon of July 9, 1994, WSR-88D base velocity products indicated the position of the thermal trough over southwest Idaho. At 1747 UTC, it was just past the radar site (Fig. 3a). Review of the 1747-1913 UTC images show that its movement was southeast at 10-20 kts (Fig. 3a-3d). A well-defined zero line (dark ring) is apparent along the outer periphery of the orange outbound velocities in the 1913 UTC image (Fig. 3d). This line indicated the region of zero velocities toward or away from the radar and, therefore, depicted the precise location of the thermal trough.

WSR-88D output provided the necessary wind profile to determine the magnitude of LLWS that accompanied the trough. At 1747 UTC, base velocity data indicated northwest surface winds of 10-20 kts at the radar site (Fig. 3a). At the same time, velocity azimuth display (VAD) data indicated winds of 160 degrees at 15 kts nearly 2,000 feet above the site (Fig. 4a). Using base velocity data and the 1750 UTC Boise observation to estimate surface wind, the 1747 UTC wind profile above the radar site should have resembled Fig. 5. The change in winds above the site resulted in a wind shear of 24 kts between the surface and 2,000 feet AGL (Fig. 6).

VAD data indicated the length of time that LLWS occurred with the trough. According to the 1844 UTC profile, LLWS of about 24 kts continued over the site until around 1815 UTC (Fig. 4a). Subsequently, the shear gradually decreased until virtually ending around 1913 UTC (Fig. 4b), although surface winds (from Boise observations) remained at 10 knots from 310°. After 1913 UTC, shear continued above the site but was no longer within 2,000 feet of the surface (Fig. 4b and 4c). In summary, LLWS of 24 kts lasted for about one half hour while lesser low-level shear continued for an additional hour.

Effects of LLWS on Aircraft Performance

LLWS can result in a gain or loss of aircraft altitude within close range of the surface. An aircraft experiencing a shift from a tailwind to a headwind gains altitude, while a shift from a headwind to a tailwind will cause the aircraft to lose altitude (Fig. 7). Losing altitude within 2,000 feet of the ground may not allow the pilot enough time to adjust before a collision with the surface ensues. An aircraft in descent along the route from Boise to Mountain Home on July 9, 1994, would have experienced a shift from a headwind to a tailwind between the surface and 2,000 feet AGL, resulting in a drop in indicated airspeed of up to 24 kts (Fig. 8).

Summary and Conclusions

The dangers of LLWS and the difficulty in forecasting it have long been evident. WSR-88D velocity sensing technologies (nonexistent in previous operational radars) clearly increase the ability to detect LLWS. The complement of base velocity data and velocity azimuth display data provide the means for a detailed assessment of LLWS. Consequently, a meteorologist can now provide a pilot with specific information regarding the location, magnitude, and duration of LLWS before it is encountered. Traditional methods for detecting LLWS do not permit this type of resolution. In the case of July 9, 1994, the WSR-88D provided a detailed account of LLWS over southwest Idaho that otherwise would have gone unnoticed. The National Weather Service WSR-88D clearly fills a void with regard to LLWS detection.

References

Holton, J.R., 1992: *An Introduction to Dynamic Meteorology*, Academic Press, 497 pp.

McEwen, L. and the NWS Training Center Staff, 1986: *Low-Level Wind Shear*, NWS Training Center Lesson Plan.

University Corporation for Atmospheric Research: Cooperative Program for Operational Meteorology, Education, and Training (COMET), 1991: *Workshop on Doppler Radar Interpretation*.

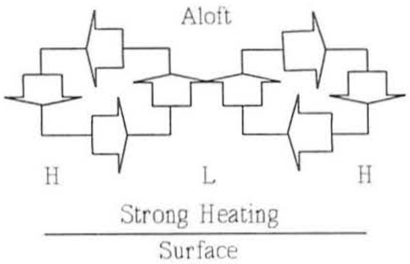

Fig. 1a

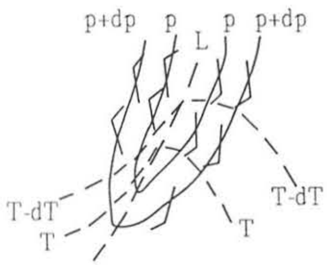

Fig. 1b

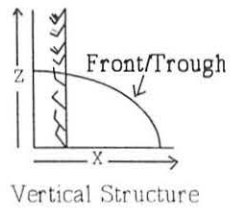

Fig. 1c

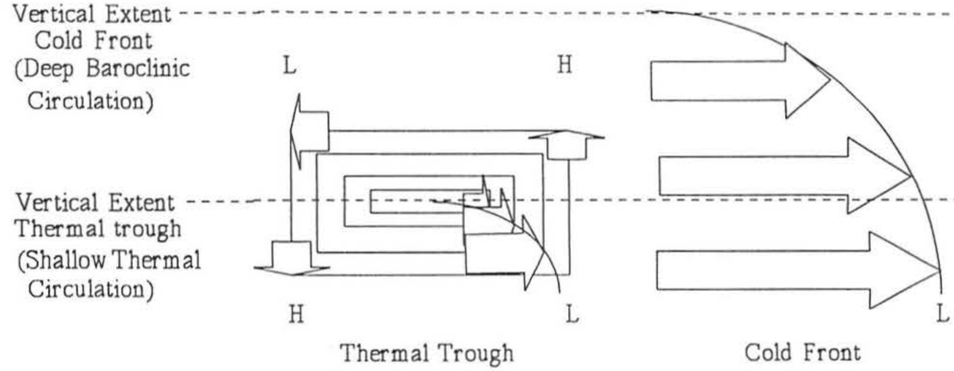

Fig. 1d

Fig. 1e

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TTAA00 KBOI 100100
BOI SA 0050 80 SCT 30 064/98/42/3210/983/K NW-N
BOI SA 2350 80 SCT 30 070/100/44/3311/985/K NW/ 710 1500 01
BOI SA 2250 80 SCT 30 074/100/44/3313/986/MDT CU ALQDS
BOI SA 2150 CLR 30 082/98/42/3412/988/BLDG CU NE-SE ACCAS ALQDS
VIRGA SE
BOI SA 2050 130 SCT 30 082/96/43/3112/988/BLDG CU VIRGA NW-NE-SE
ACCAS ALQDS/ 814 1280
OR
BOI SA COR 1950 E130 BKN 30 098/91/44/3112/992/BLDG CU VIRGA NW-NE
AND S ACCAS ALQDS
BOI SA 1950 E130 BKN 30 098/91/44/3112/992/BLDG VIRGA CU NW-NE AND S
 ACCAS ALQDS
BOI SA 1850 E130 BKN 30 101/87/47/3109/993/CB DSNT NW-NE MOVG E
ACCAS ALQDS VIRGA NW-NE-SE
BOI SA 1750 E120 BKN 30 099/87/44/3110/992/CB DSNT NE MOVG E BLDG CU
 NW-NE ACCAS VIRGA ALQDS/ 002 1380 71
BOI SA 1650 E100 BKN 30 098/87/42/0406/992/ACCAS ALQDS VIRGA OVHD
AND NW-NE
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BOI SA 1450 E120 BKN 30 095/78/43/3012/992/ 500 1070
BOI SA 1350 70 SCT 30 089/81/35/1212/991


BOISAOMUO
SAUS90 KWBC 100100
 MUO SA 0055 65 SCT 90 SCT 250 SCT 70 056/101/34/3513/980=
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    ALQDS MDT CU N-NE=
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    MOVG NE VIRGA ALQDS=
 MUO SP 2124 65 SCT 80 SCT E250 BKN 70 1723G43/985/CB SE MOVG NE
    VIRGA ALQDS=
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    1170=
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Fig. 2a

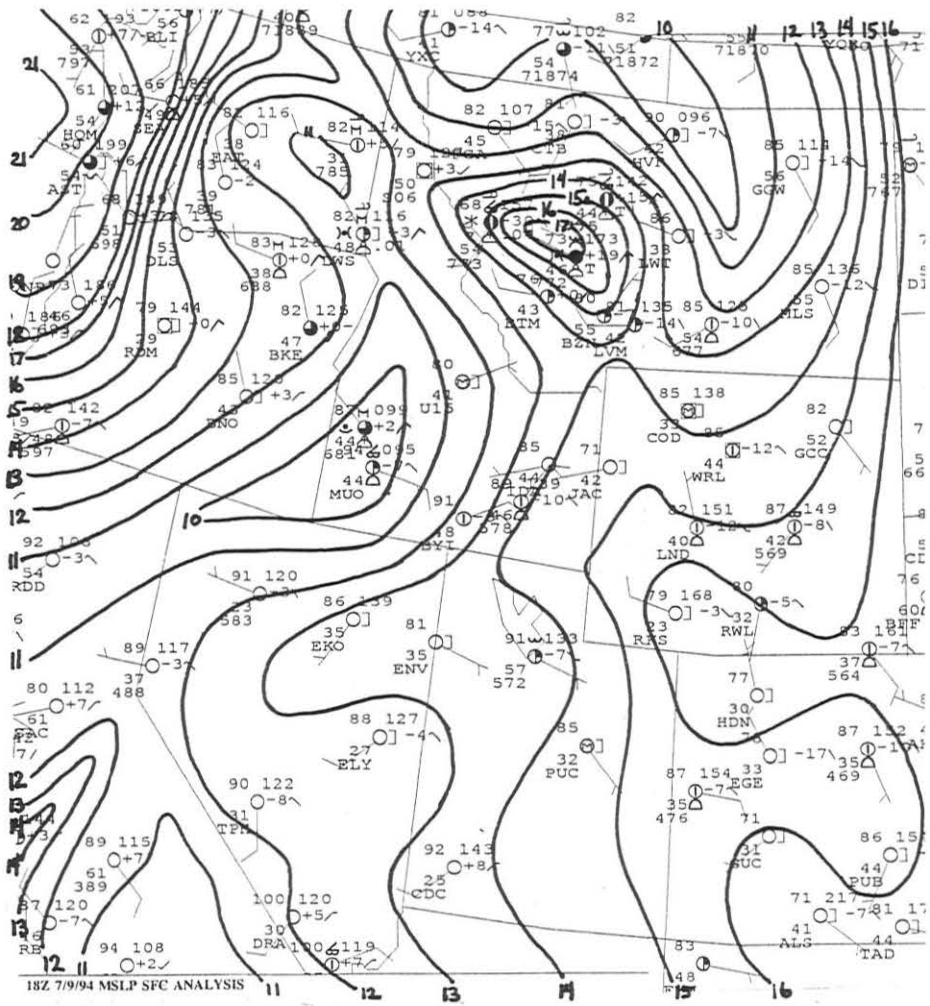


Fig. 2b

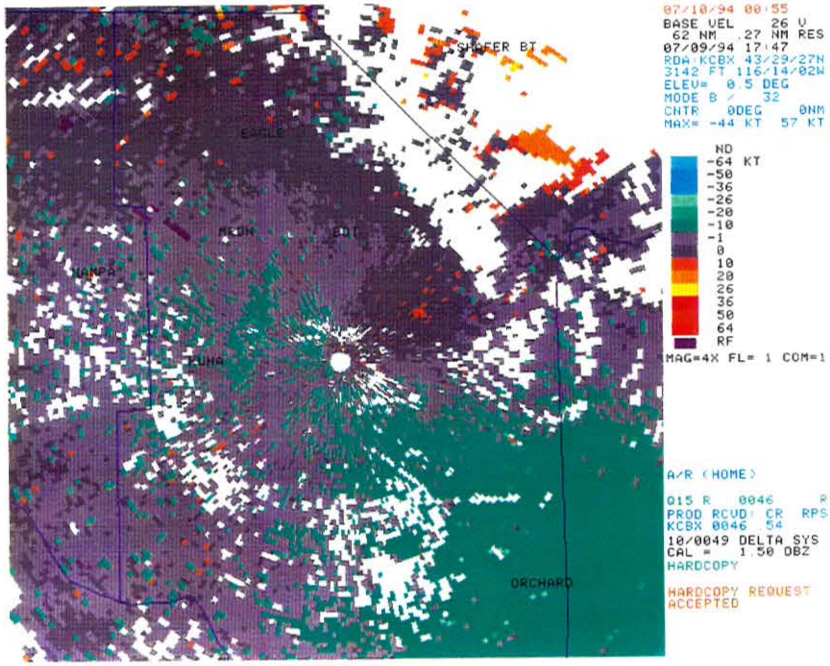


Fig. 3a

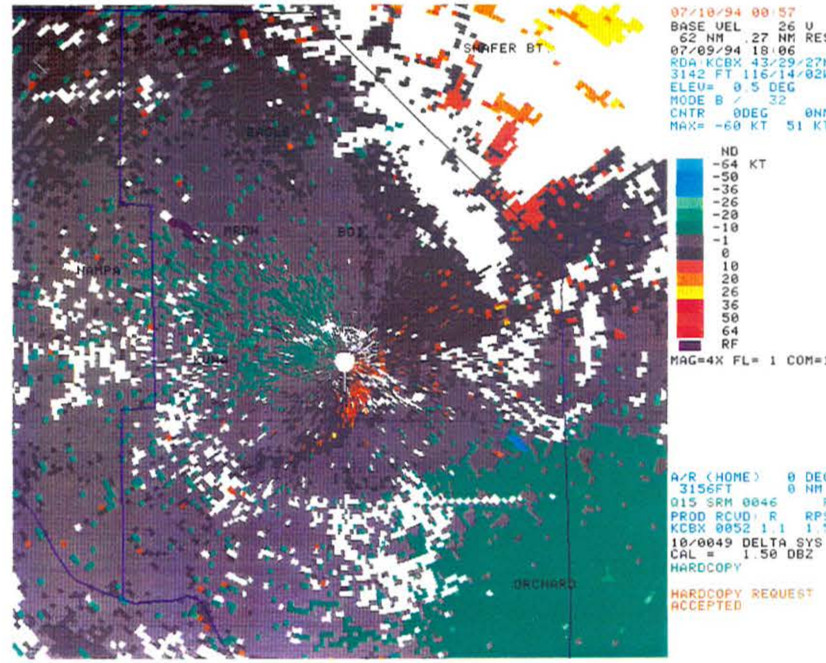


Fig. 3b

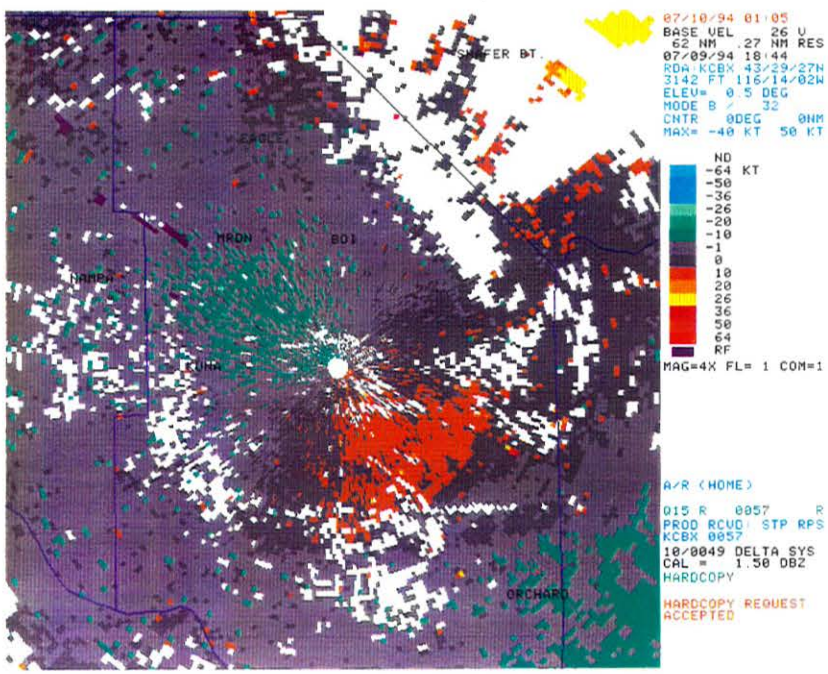
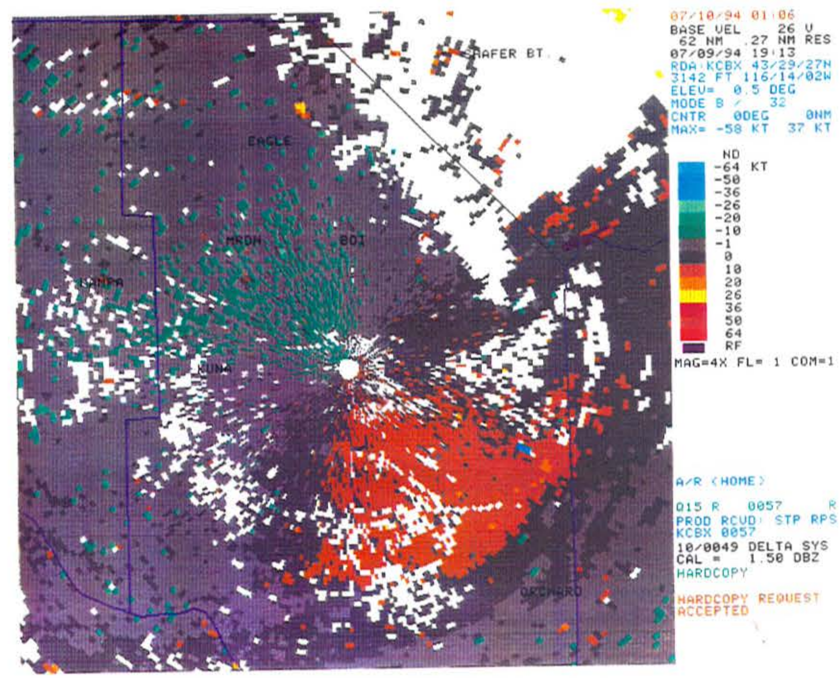


Fig. 3c



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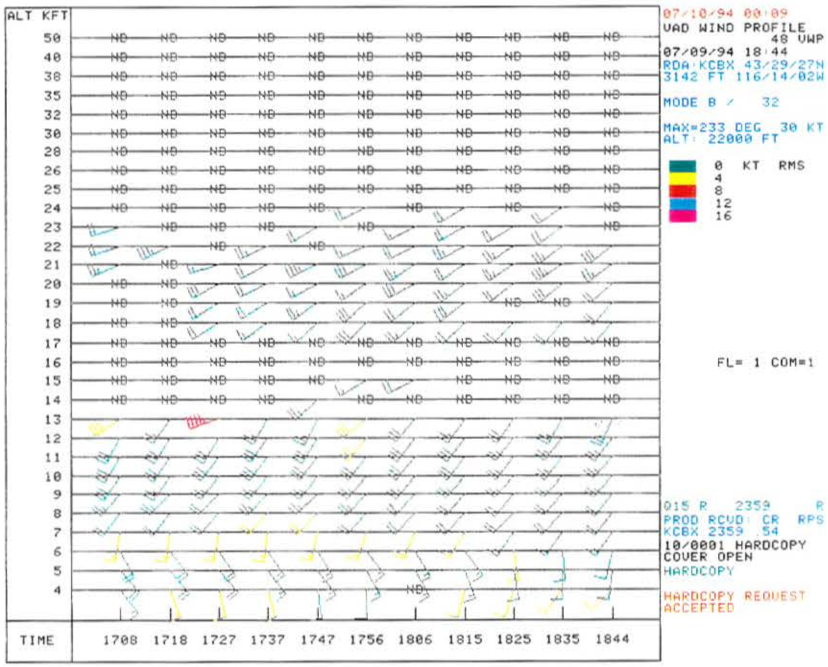


Fig. 4a

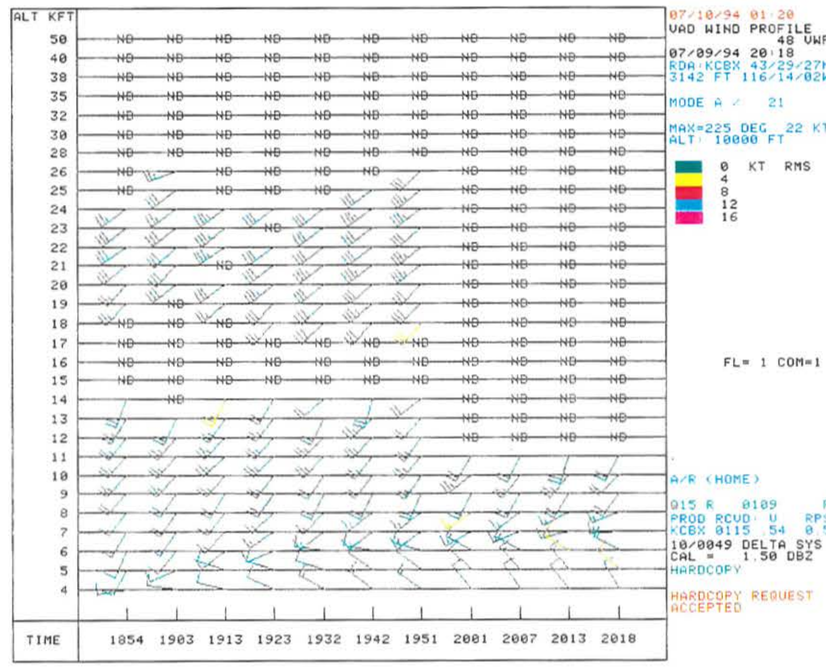


Fig. 4b

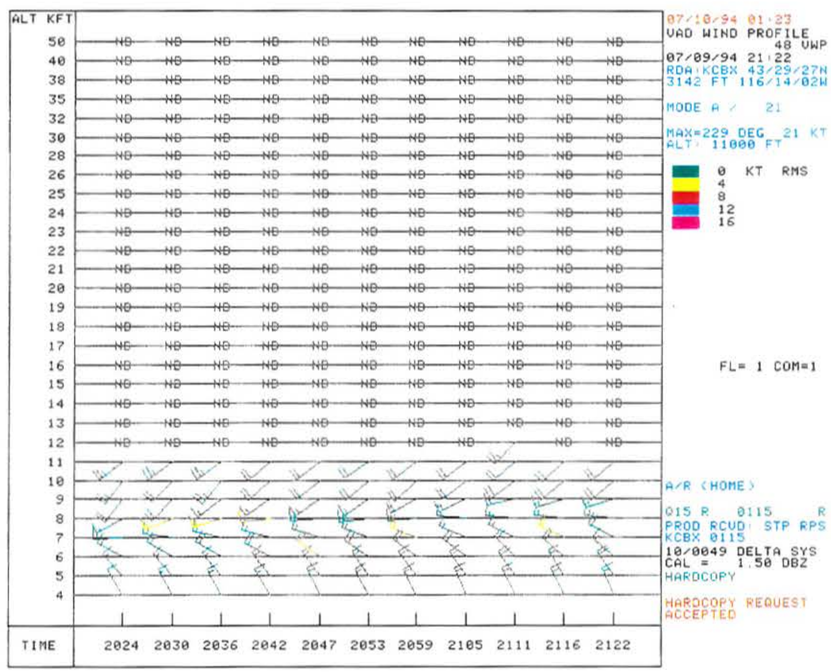


Fig. 4c

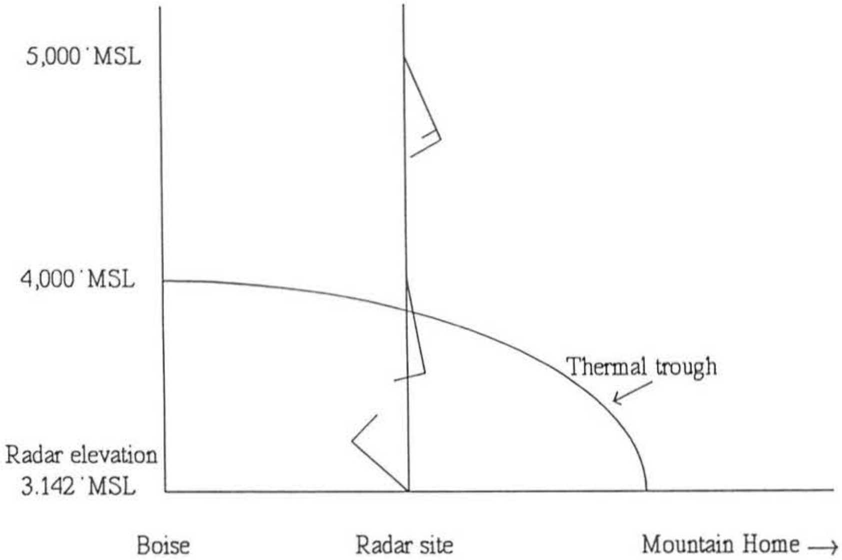
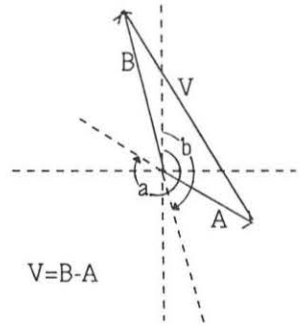


Fig. 5



A = The surface wind vector; 310/10 kts.
B = The wind vector at 2,000 'AGL; 160/15 kts.
a = The surface wind direction; 310 degrees.
b = The wind direction at 2,000 'AGL; 160 degrees.
V = The vector shear that would act upon an aircraft.

$$|V| = \sqrt{|B|^2 + |A|^2 - 2|B||A|\cos(b-a)}$$
$$|V| = \sqrt{15^2 + 10^2 - 2(15)(10)\cos(-150)}$$
$$|V| = 24.18 \text{ kts}$$

Fig. 6

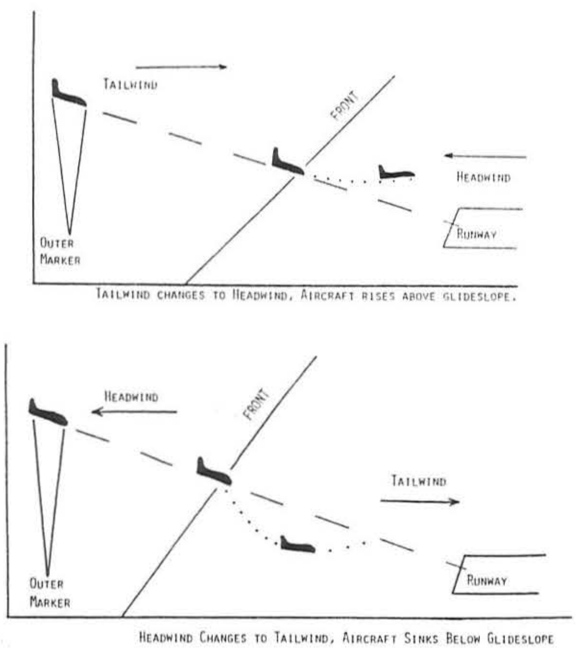
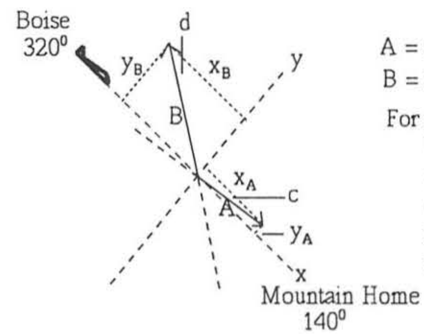


Fig. 7



A = surface wind vector; 310/10 kts.
B = 2,000 'AGL wind vector; 160/15 kts.

For a = surface wind direction and
b = 2,000 'AGL wind direction:

$c = 320^0 - a$ or 10^0
$d = b - 140^0$ or 20^0
$x_B = B\cos(d) = 15\cos(20^0) = 14.10$ kts.
$x_A = A\cos(c) = 10\cos(10^0) = 9.85$ kts.

For an aircraft flying direct from Boise to Mountain Home:
x_B = magnitude of headwind component at 2,000 'AGL; +14.10 kts.
x_A = magnitude of headwind component at surface; -9.85 kts.
$x_B - x_A$ = magnitude of change in headwind component from 2,000 'AGL to surface; 23.95 kts.

For an aircraft in descent, flying direct from Boise to Mountain Home, the change from a headwind at 2,000 'AGL to a tailwind near the surface results in a potential loss of indicated airspeed of approximately 24 kts.

Fig. 8