# A Wintertime Convergence Zone Investigated With a Sailplane

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## Introduction

Regions at the surface where two different air masses converge are known to be sources of lift for sailplanes. In northeast Colorado, USA, these regions have been identified from soaring flights and surface wind measurements in the summer months. The regions form in the summer primarily due to convergence of large-scale up-slope flows and winds "mixed down" from aloft by deep convection over the Rocky Mountains. A typical summertime convergence zone from Johnson and Toth (1982) is illustrated in Figure 1.

In the winter, convergence zones also form over the High Plains in the lee of the Rocky Mountains. The formation mechanisms, however, are different from those in the summer months. As illustrated in Figure 2, in the winter the ground-based, lee-side inversion can be eroded by a warmer, Chinook flow (Bedard, 1982). The convergence zone exists at the surface along the boundary between the westerlies and the inversion air (last panel in Figure 2). These convergence zones are frequently associated with severe down-slope winds as described by Bedard (1982) and Zipser and Bedard (1982). Consequently, few if any sailplane flights are purposely made into these zones.

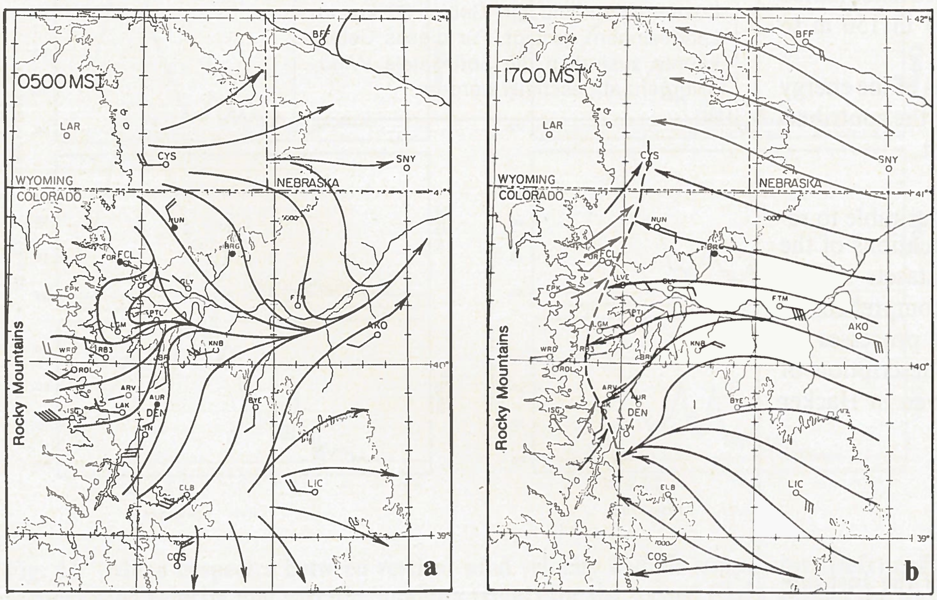
We report here a sailplane flight into one of the wintertime convergence zones which was sufficiently far downwind of the Rocky Mountains to permit safe flight. The results of the flight are detailed in this paper and demonstrate that:
a) surface convergence zones can be a source of lift for wintertime soaring in northeast Colorado,
b) and dense and automatic surface meteorological measurement networks can be used to identify surface convergence zones that may sustain soaring flights.

## Account of the flight

During the morning hours on 23 January 1983 at the soaring site near Briggsdale, Co. (Station BRG in Figure 1), a persistent 5–8 knt drainage flow from the north was occurring. The sky was overcast with mid-level mountain-induced clouds streaming eastward from the Rocky Mountains, which were 100 km to the west. The first winch launch was made by one of the authors (EH) in his HP-14T sailplane at about 10:00 MST. The flight was confined to the pattern by the absence of lift. The Föehn Wall to the lee of the Rockies intensified during the morning and the mid-level clouds cleared to the west of the soaring site.

The second launch occurred at 11:30 MST. The drainage flow had changed to

*Figure 1 Surface streamline analysis for northeast Colorado, July, 1981;*




*a) morning westerly drainage flows,*

*b) afternoon easterly up-slope flows converging with down-slope flows.*

*Plotted winds are one full barb equals 1 ms$^{-1}$ (from Johnson and Toth, 1982).*

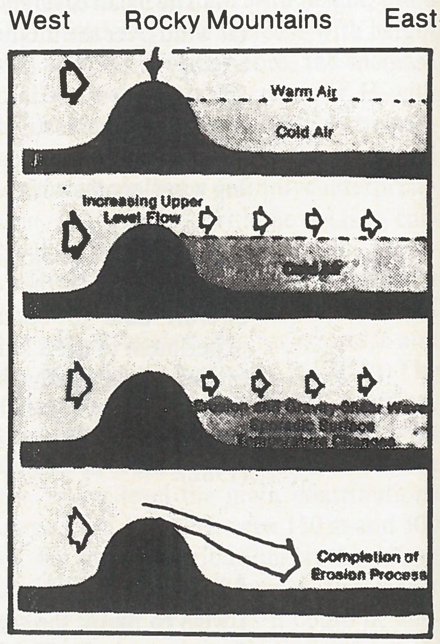
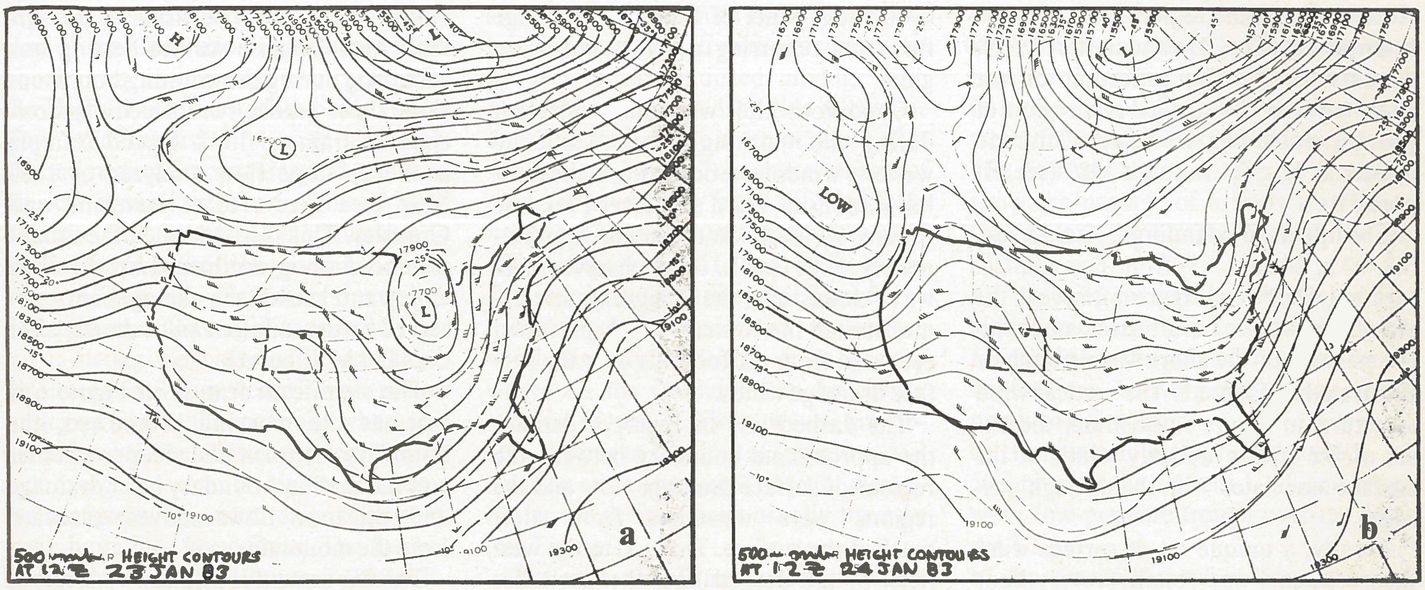



*Figure 2 Artist's view of the erosion of a ground-based, lee-side inversion by a warmer, upper-level, westerly flow (from Bedard, 1982).*

*Figure 3 USA 500 mb height contours at 1200 z on*




*a) 23 January 1983 and* *b) 24 January 1983*

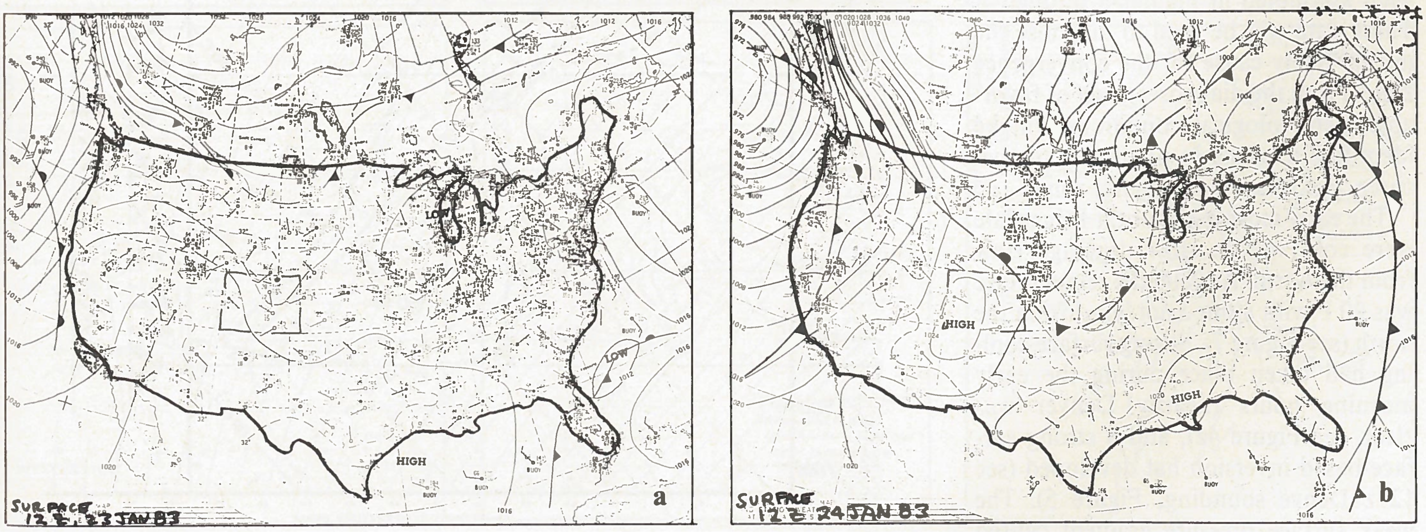
*Heights are given in feet, temperatures in °C, and winds in knots (1 full barb equals 10 knots). The state of Colorado is outlined and the black dot is the location of Briggsdale.*

a 5–10 knt westerly flow at the time of launch. The release was made at 335 m AGL. A «pool» of pollution was noticed by the pilot SW of the field. Smooth, 2–3 knt lift was encountered shortly after release and a climb of 330 m occurred during the next twenty minutes. During the climb, the sailplane drifted quickly east. Upon penetrating back to the soaring site, in the now strong westerly flow, the pollution «pool» had vanished and no sustaining lift was encountered. The landing, 30 minutes after launch, was made into a 10–15 knt west wind. The Föehn Wall was well established at the time of the landing. While returning to Fort Collins (Station FCL in Figure 1) in mid-afternoon, blowing dust was observed just south of Nunn (Station Nunn on Figure 1).

### Meteorological Conditions

The synoptic-scale 500 mb level and surface analyses which bracket the flight (12 z [0500 MST] 23 January 1983 and 12 z [0500 MST] 24 January 1983) are shown in Figures 3 and 4 respectively. Careful inspection of these figures reveals that a long-wave ridge was over the western USA with long-wave trough over the eastern USA. A short-wave

*Figure 4 USA surface weather map at 1200 z on*




*a) 23 January 1983 and* *b) 24 January 1983*

*The isobars are in mb. The state of Colorado is outlined and the black dot is the location of Briggsdale.*

trough at 500 mb moved through the Rocky Mountains region during the 24 hour period (12 z, 23 January to 12 z, 24 January 1983). The reflection of the short-wave at the surface is a region of precipitation along the eastern Colorado border at 12 z, 24 January 1983 (see Figure 3 b).

The upper-air soundings (12 z, 23 Jan. '83, 00 z, 24 Jan. '83) from Denver, Co. (symbol DEN on Figure 1), reveal the significant cooling aloft associated with the passage of the short-wave trough as illustrated in Figure 5. The vertical wind structure, in Figure 5, illustrates the onset of the strong westerly winds at the surface associated with the through passage.

Finally, a unique set of surface wind measurements was obtained every hour between 0900 MST and 1400 MST on 23 January 1983 for the Stations shown in Figure 1. The data were collected by the Program for Regional Observing and Forecasting (PROFS) in the Environmental Research Laboratories of NOAA. The PROFS wind measurements and surface temperatures are illustrated in Figures 6 and 7. These data reveal the meso-scale structure of the convergence zone that moved across the Briggsdale soaring site between 1100 and 1200 MST thus enabling the reported soaring flight.

**Discussion**

The available meteorological data has been assembled in Figures 3 through 7. These data will be used to diagnose the mostly likely cause for the convergence zone. From the diagnoses, a set of favorable meteorological conditions will be identified to assist in predicting the occurence of future convergence zones.

The early morning hours at Briggsdale were cold with a slow drainage flow from the north. At 0800 the temperature was 20 F with a one knot wind from the north (see Figure 7). Strong surface cooling had taken place during the early morning hours (nearby Denver was clear, see Figure 4a), and a strong surface-based inversion hat developed (see 12 z Denve sounding, Figure 5). The weak surface pressure gradient caused the surface winds at Briggsdale to be driven by drainage of cold air down the nearby river valley. In fact, as seen in the 0900 MST panel of Figure 6, drainage flow was occurring over the entire region.

Conditions aloft were much different during the morning hours. Moderate westerly winds were occurring at the foothill stations of Ward and Estes Park (see Figure 6). Both Stations are approximately 8000 MSL. The observed lee-wave clouds over the Briggsdale site demonstrated the westerly winds extended eastward from the foothills over the surface drainage winds.

The dashed line in Figure 6 denotes the approximate boundary between the regions of surface drainage flow and the regions were westerlies from aloft reached the surface. That ist, to the west (left) of the dashed line, the westerlies extended down to the surface and to the east (right) the westerlies remained aloft and drainage flows persisted at the surface. Also, because surface heating was occurring during the morning hours, up-slope flows gradually replaced a majority of the drainage flows. A good example is the up-slope flow analyzed at 1100 MST (see Figure 6) at Loveland and Greenley. This flow advected the urban-produced smog northward up the river valley and caused the «smog front» observed by the sailplane pilot shortly after the 1130 MST launch.

The significant feature in Figure 6 is that, as the morning progressed, the boundary between the deep westerlies and the shallow boundary layer drainage and up-slope flows moved eastward from the mountains.

This movement is primarily a result of the relationship between the time of in-

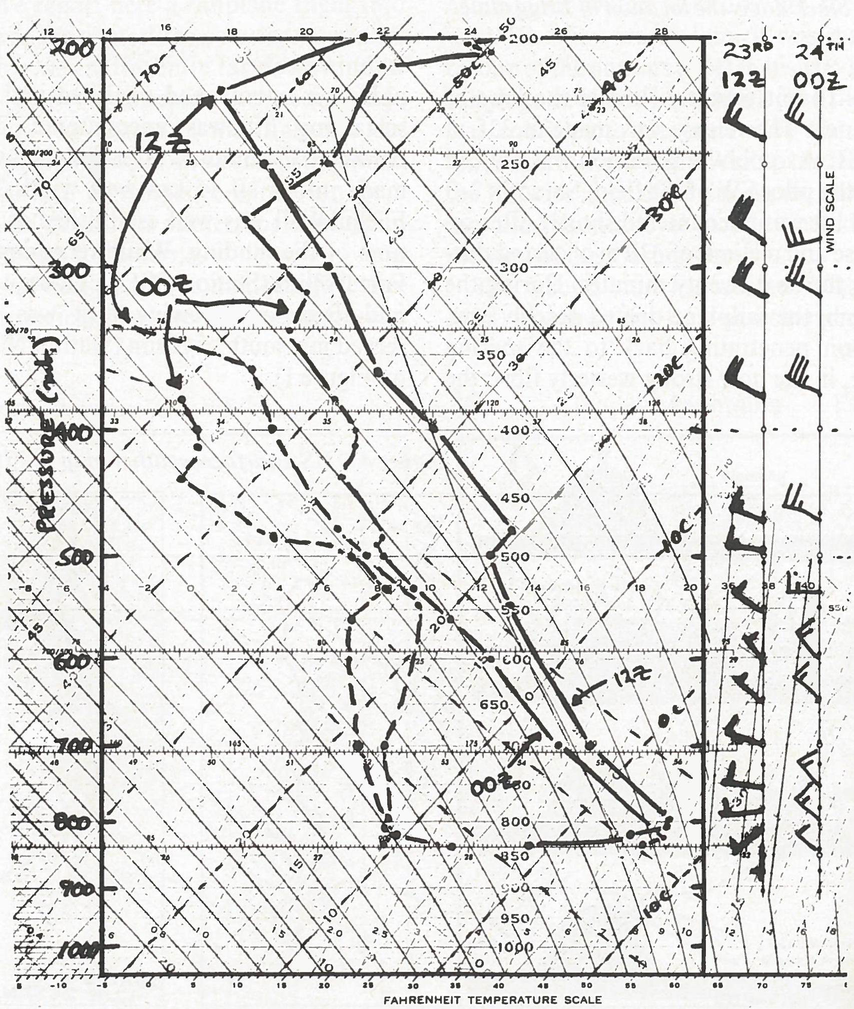



*Figure 5 Denver soundings for 1200 z, 23 January 1983 and 0000 z, 24 January 1983. Windspeeds are given as 1 full barb equals 10 knots.*

version destruction due to surface heating and the eastward decrease in elevation of the Colorado High Plains. With equal rates of inversion destruction in the High Plains, the surface based inversion is destroyed first over the high ground near the mountains and last over the low ground well east of the Briggsdale site. This is because the inversion is shallowest over the high ground and vice versa. Given this pattern of inversion destruction, a convergence zone will occur if strong westerlies exist just above the inversion. Those westerlies are mixed to the surface in the locations where the inversion has been destroyed resulting in a convergence zone: a region of strong surface westerlies west of a region of weak boundary layer flows. The formation of the zone on 23 January 1983 is illustrated in Figure 8.

There are two mechanisms for inversion destruction: "burn off" from below by solar heating, and erosion from above by gravity-wave-induced mixing. Both mechanisms operated on this particular day. The gradual rise in temperature after sunrise (see Figure 7) is characteristic of cases of inversion "burn off" by solar heating. The maximum temperature of 45 °F is just that needed to destroy the inversion seen in the soundings in Figure 5.

The periodic variations in surface wind direction resulting from gravity waves on the inversion can be clearly seen in Figure 7. These waves are observed prior to the time of inversion destruction and consequent onset of westerlies at the surface as ist usually the case (see Figure 2).

The existence of strong westerly winds just above the inversion east of the mountains is related to the passage of a short wave. According to Beenker *et al.* (1978) such a passage leads to enhancement of mountain lee wave flows which in turn accounts for the strong low-level westerlies and observed wave clouds. The 500 mb charts in Figure 3 clearly show the passage of a short wave over the region during the period of the flights.

This brief analysis has shown the following meteorological conditions to be favorable for the formation of soarable, winter-time convergence zones over north-east Colorado:

a) long-wave high-pressure ridge at 500 mb over the western USA and long-wave low-pressure trough over the eastern USA,

b) short-wave through just upstream of Colorado at 12 z,

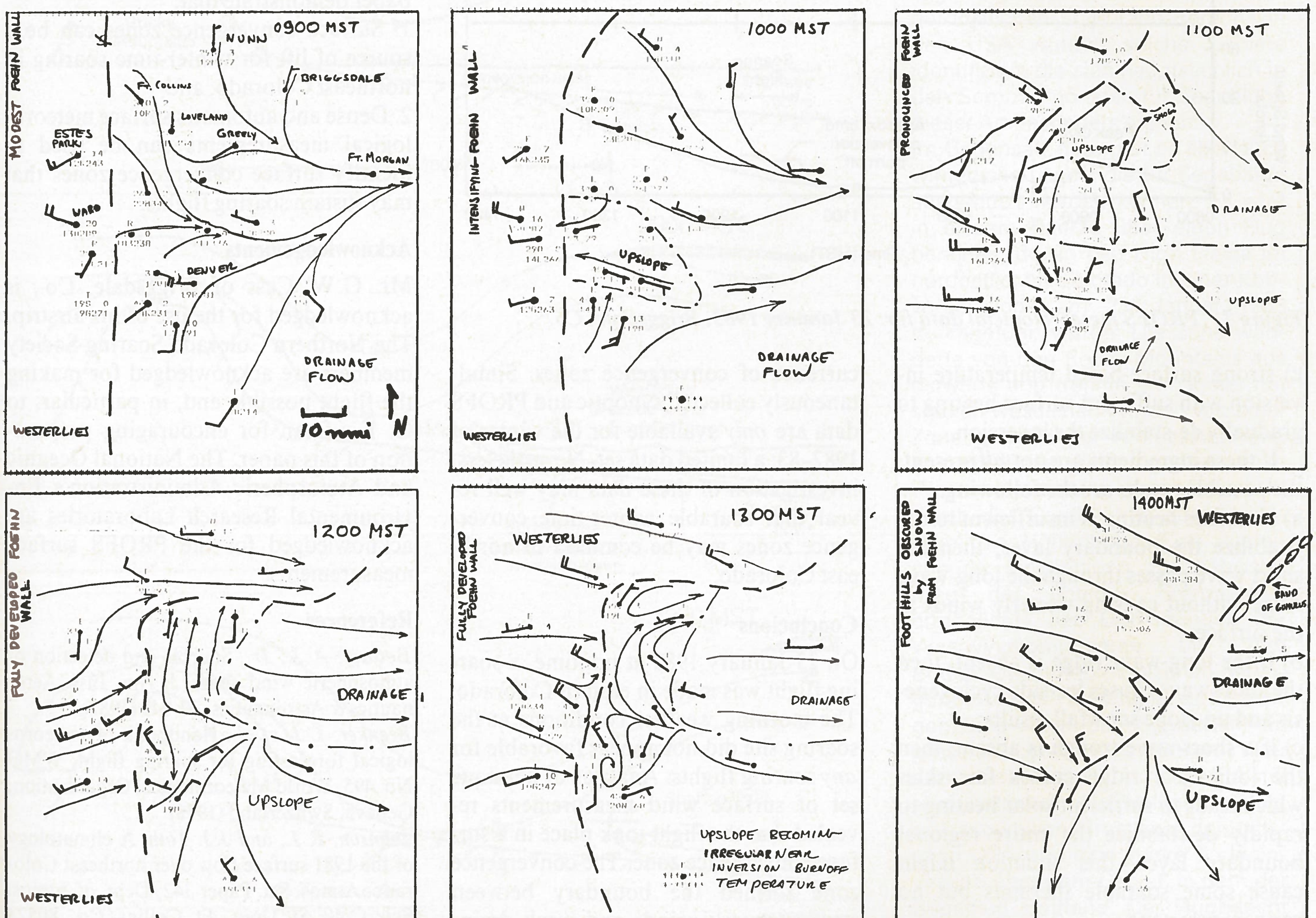


*Figure 6 Surface wind measurements from the PROFS network for 23 January 1983 illustrating the development of the convergence zone. The streamlines are hand-drawn to the data and depict three flow regimes: westerly winds, drainage winds, and up-slope winds. The behavior of the Föehn Wall is noted in the left-hand margins.*

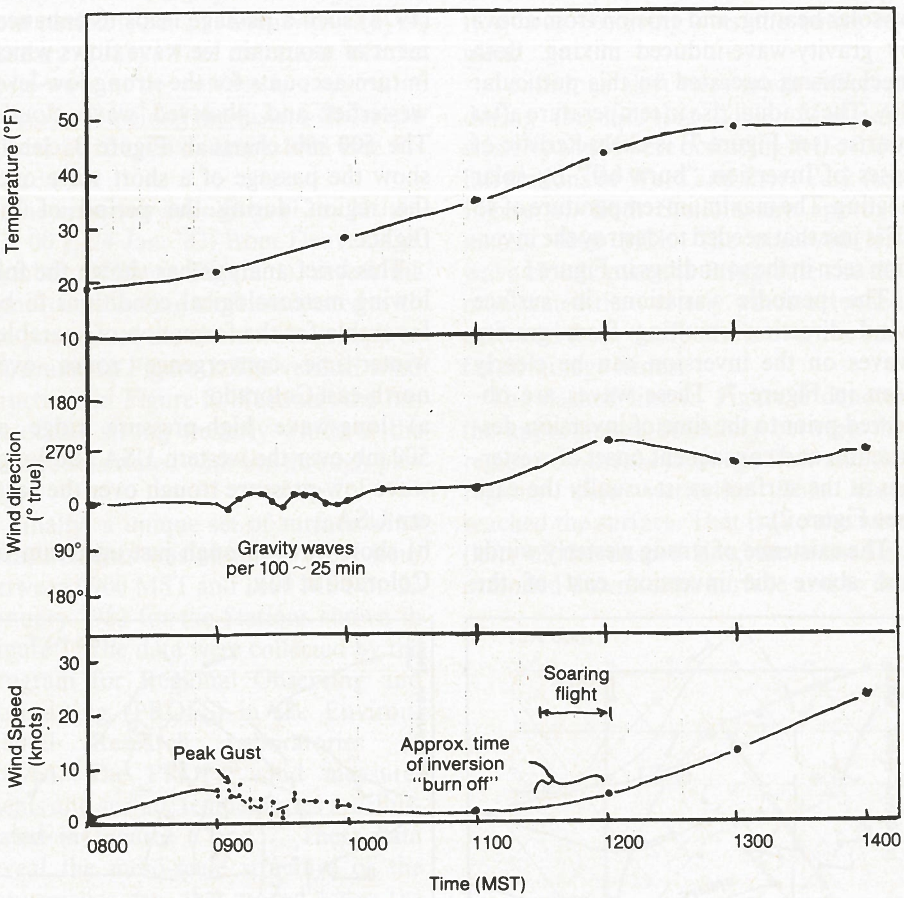



*Figure 7 PROFS meteorologicial data for: 23 January 1983, Briggsdale, Co.*

c) strong surface-based temperature inversion with sufficient surface heating to gradually de-stabilize the inversion.

If these ingredients are not *all* present, the possible results are the following:
a) if surface heating is insufficient to de--stabilize the boundary layer, then the short wave passes through the long-wave ridge without causing westerly winds at the surface;
b) if the long-wave ridge is absent, then the short wave causes lee-side cyclogenesis and up-slope snowfall results;
c) if a short-wave trough is absent, then the long-wave ridge causes fair skies which leads to sufficient solar heating to rapidly de-stabilize the entire regional boundary layer—this situation might cause some soarable thermals but no convergence zone.

These three meteorological conditions should be tested using additional data to determine their frequency of simultaneous occurrence and correlation with occurrence of convergence zones. Simultaneously collected synoptic and PROFS data are *only* available for the winter of 1982–83; a limited data set. Nevertheless, investigation of these data may well reveal that soarable winter-time convergence zones may be common in northeast Colorado.

## Conclucions

On 23 January 1983 at nontime, a soaring flight was made in eastern Colorado. The morning weather conditions at the soaring site did not appear favorable for *any* soaring flights. Analysis of a unique set of surface wind measurements revealed that the flight took place in a surface convergence zone. The convergence zone formed the boundary between strong westerly winds and weak drainage winds. The westerly winds were caused by the passage of an upper-air short-wave trough. Sufficient surface heating occurred to de-stabilize the surface boundary layer and allow the westerlies to reach the surface.

Analysis of available meteorological data from 23 and 24 January 1983 revealed the following sufficient conditions for the formation of winter-time convergence zones:
1. Long-wave ridge at 500 mb over the western USA and a trough over eastern USA,
2. Short-wave trough just upwind of Colorado at 12 z,
3. Strong surface-based temperature inversion with sufficient heating to gradually de-stabilize the inversion.

It is not known how often these conditions occur, but data are available from the winter of 1982–83 for a more thorough analysis than was possible here.

The results of the flight detailed in this paper demonstrate that:
1. Surface convergence zones can be a source of lift for winter-time soaring in northeast Colorado, and
2. Dense and automatic surface meteorological measurements can be used to identify surface convergence zones that may sustain soaring flights.

## Acknowledgements

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**Summary**

*Regions where two different airmasses converge at the surface are known to be sources of lift for sailplanes. In northeast Colorado, these regions have been identified from soaring flights primarily in the summer months.*

*In contrast, we report a soaring flight which occurred in a convergence zone which formed on 23 January 1983 in the High Plains of northeast Colorado. The zone propagated eastward from the Rocky Mountains and separated strong westerly winds from moderate northerly drainage winds. The westerly winds were caused by the passage of an upper-air short-wave trough. Sufficient surface heating occurred to de-stabilize the boundary layer and mix the westerlies to the surface. The meteorological conditions required to form the convergence zone were: a long-wave ridge over the western USA with an imbedded short-wave trough, a long-wave trough over the eastern USA, and a strong surface-based inversion at the soaring site.*

*The reported flight demonstrates that surface convergence zones can be a source of lift for wintertime soaring in northeast Colorado.*

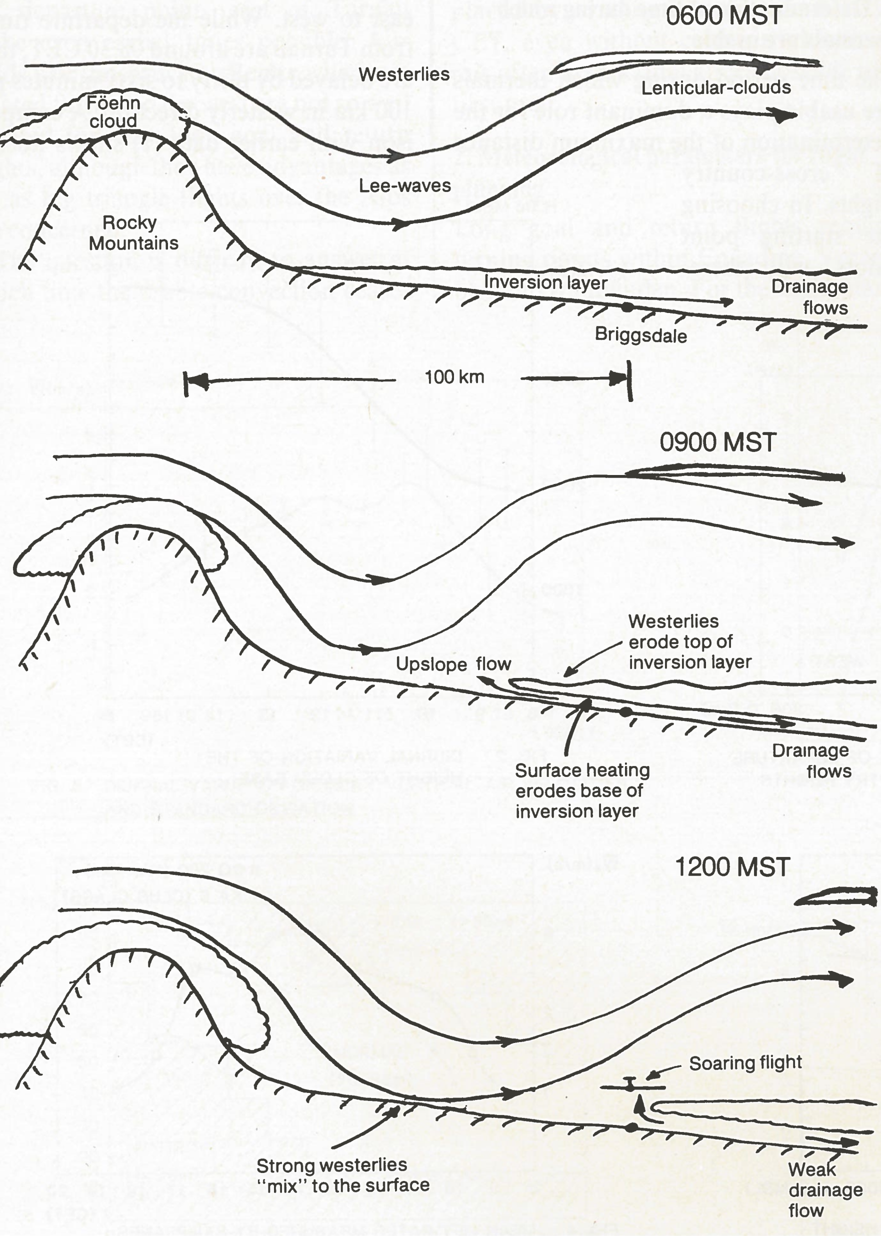


*Figure 8 Sequence of meteorological events which caused the soarable convergence zone on 23 January 1983.*

**Untersuchung einer winterlichen Konvergenzzone mit einem Segelflugzeug**

*Zusammenfassung*

Gebiete, in denen zwei unterschiedliche Luftmassen in der unteren Troposphäre aufeinanderstossen, sind auch meist Aufwindgebiete, die segelfliegerisch nutzbar sind. In der nordöstlichen Colorado-Region in den USA wurden solche Gebiete identifiziert, die sich hauptsächlich in den Sommermonaten für Segelflüge dieser Art besonders eignen.

Im Gegensatz dazu gibt es aber auch winterliche Lagen, die für Segelflüge ausgenutzt werden können. Es wird in diesem Beitrag über einen Flug berichtet, der in den High Plains im nordöstlichen Colorado in einer Konvergenzzone am 23. Januar 1983 durchgeführt wurde. Die Zone wanderte von den Rocky Mountains aus ostwärts und trennte ein Gebiet mit starken westlichen Winden von einer Zone gemässigter Abflussströmung aus nördlicher Richtung. Die starke Westwindströmung war verursacht durch das Durchgehen eines kleinräumigen Höhentrogs. Eine ausreichende Einstrahlung zur Labilisierung der unteren Grenzschicht ermöglichte das Durchdringen der Westwindkomponente bis zum Boden. Die meteorologischen Bedingungen für die Bildung einer Konvergenzzone waren damit gegeben: ein grossräumiger Höhenrücken über dem westlichen Gebiet der USA mit eingebettetem kurzwelligem Trog, ein langwelliger Trog über den östlichen USA und eine starke Bodeninversion über dem Gebiet, in dem der Segelflug stattfand. Der Flugbericht zeigt, dass Konvergenzzonen in der bodennahen Schicht auch zur Winterzeit Thermikflüge erlauben, wie es hier im nordöstlichen Colorado demonstriert wurde.