A more detailed and quantitative consideration of organized convection: Part V

Microbursts

What is a microburst?

Fujita's definition: a short-lived, strong downdraft with associated outburst of surface winds extending outward 4 km or less and winds as high as 75 m s^{-1}

What they do: Produce damaging surface winds at outflow boundaries. These can become haboobs (dust storms) in Arizona during the monsoon, if the soil is sufficiently dry enough.

Physical cause: sublimation or evaporation of precipitating particles from a convective cloud into dry, unsaturated air below cloud base. The sublimation or evaporation cools the air, causing it to be negatively buoyant relative to the surrounding environment and sink rapidly to the ground.

Wet vs. Dry: Depends on whether there is precipitation that reaches the ground. Wet microbursts, though they precipitate, tend to have more evaporation below cloud base and typically produce stronger winds.

Outflow Microburst

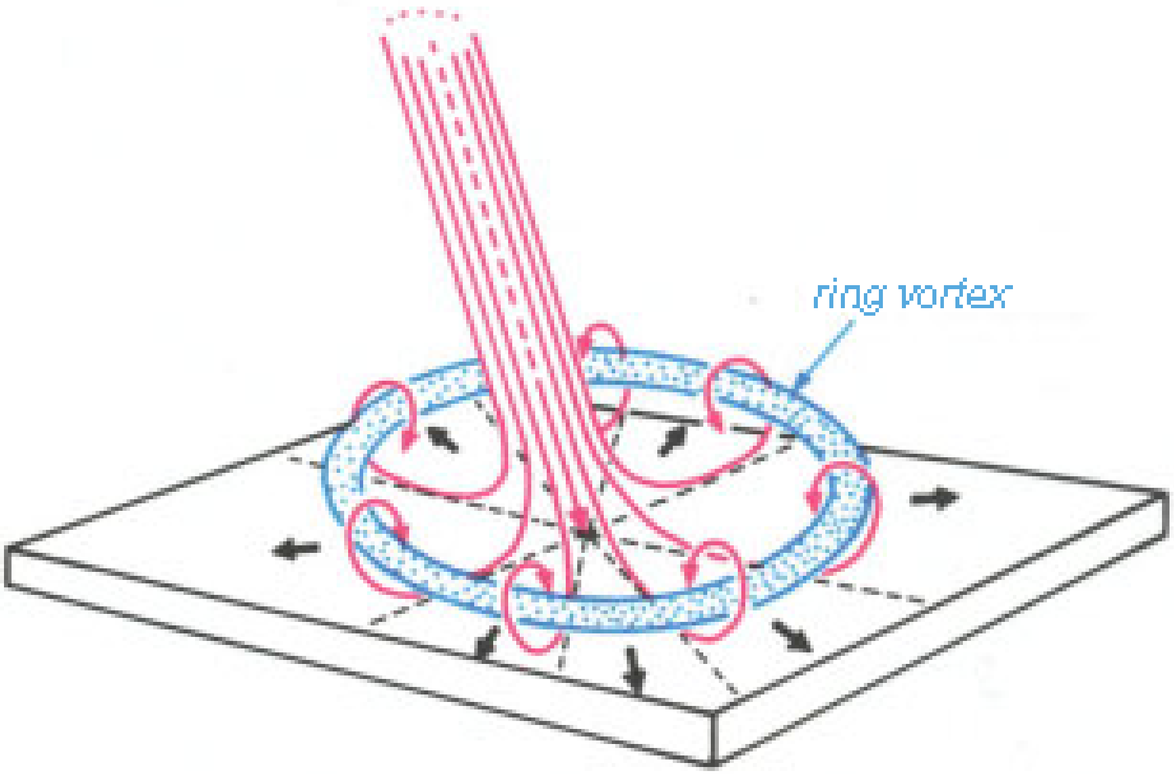


Figure 10.25 Fujita's conceptual model of a microburst, which can be viewed as an intense vortex ring intercepting the ground. (From Fujita [1985].)

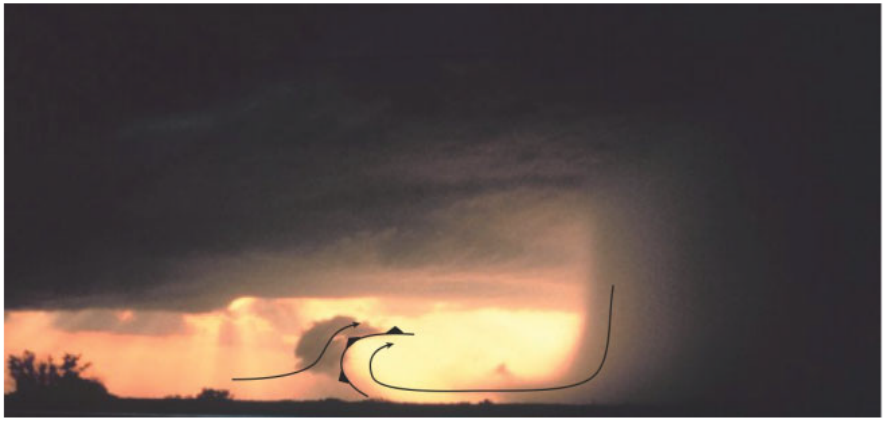


Figure 10.23 Photograph of a wet microburst, with the gust front position and a couple of schematic streamlines drawn. A cloud is situated on the leading edge of the outflow (indicated by the cold frontal symbols) where air is being forced upward. Photograph courtesy of the National Oceanic and Atmospheric Administration (NOAA).

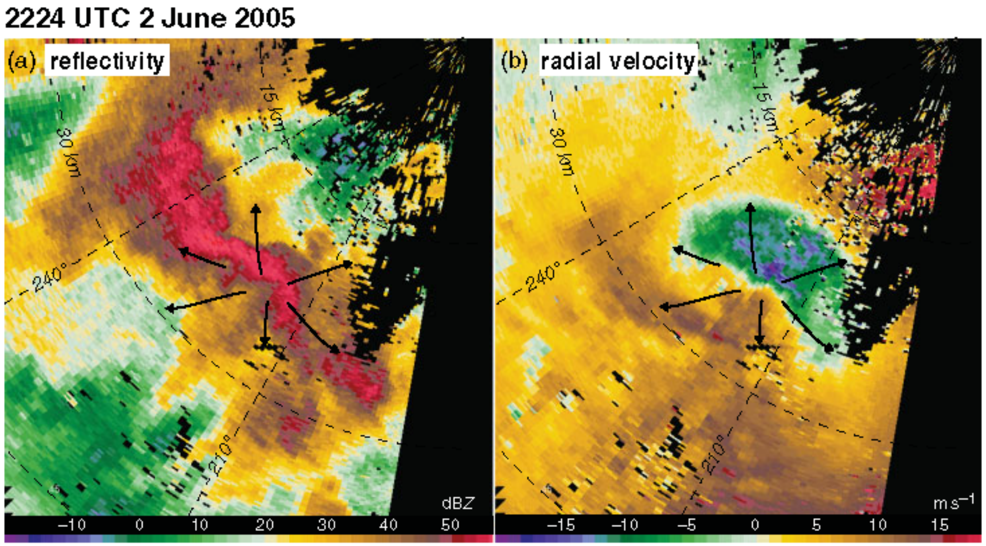


Figure 10.24 A downburst as seen in (a) radar reflectivity (dBZ) and (b) radial velocity (m s^{-1}) imagery obtained at 2224 UTC 2 June 2005 by the Colorado State University CHILL radar in northeastern Colorado (0.5° elevation angle). The radial velocity signature of a downburst on low-altitude scans is an inbound–outbound velocity couplet oriented such that the zero contour is approximately normal to the radials, with inbound (outbound) velocities closer to (farther from) the radar, thereby implying radial divergence.

Dry microburst near Denver, CO.

Wet microburst on the west side of Tucson, near Ryan Field

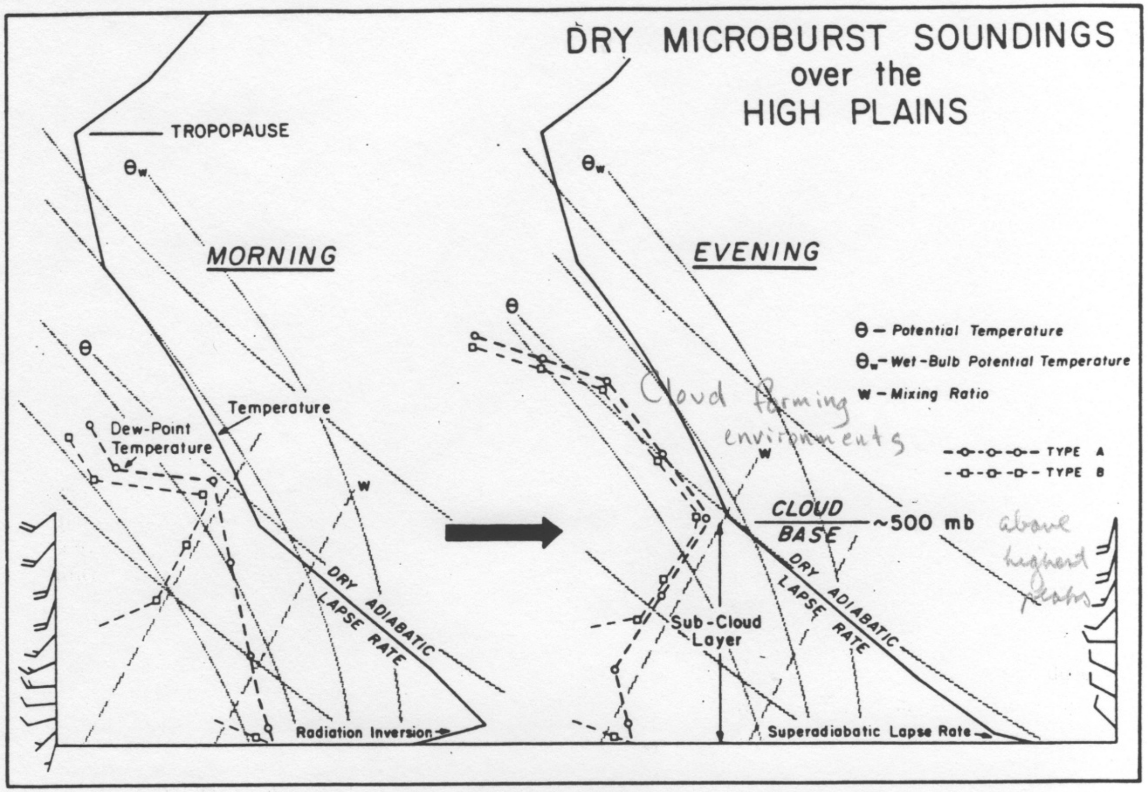
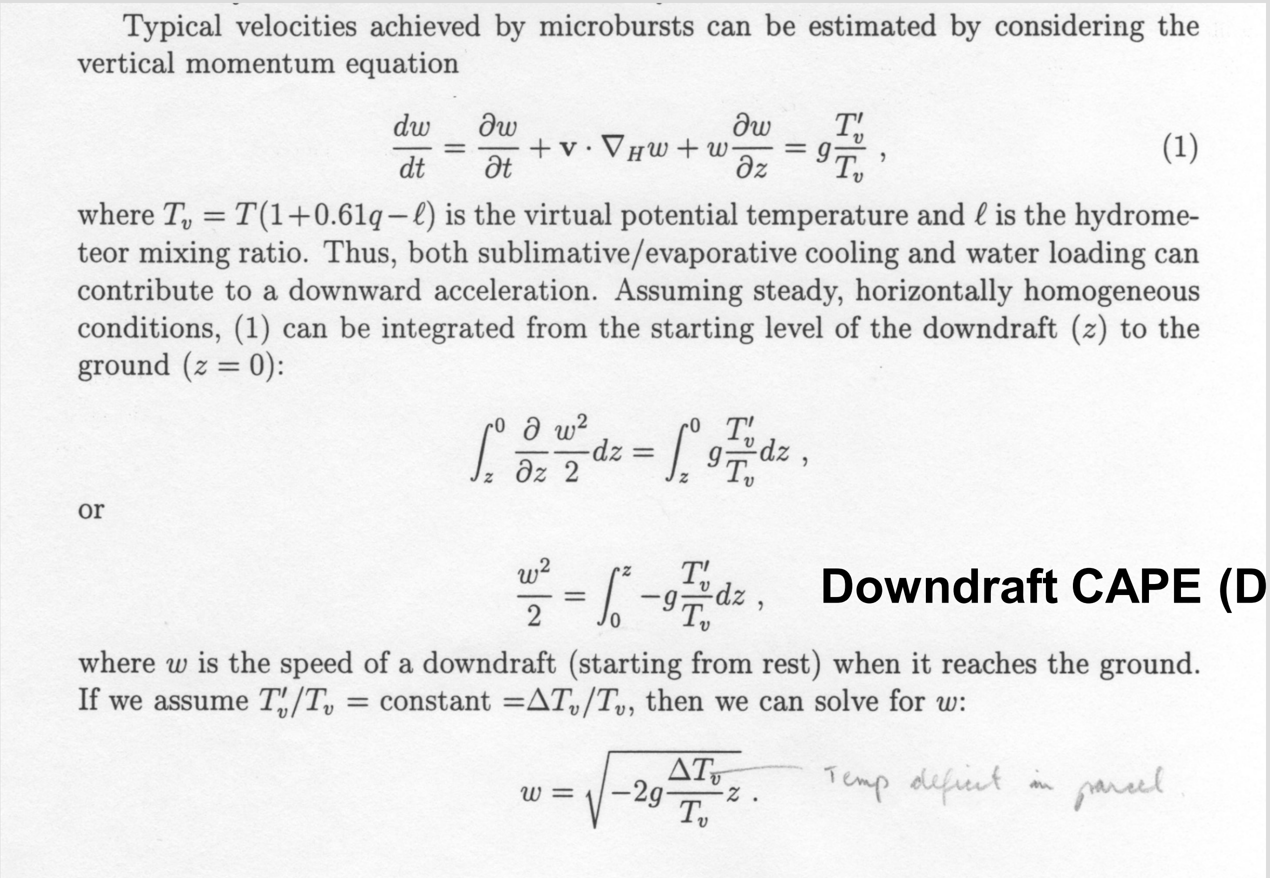


FIG. 8. Model of the characteristics of the morning and evening soundings favorable for dry-microburst activity over the High Plains.

Deep dry adiabatic lapse rate, moist air aloft

→ Result of heating over high terrain

Clouds form over mtns - upslope + lifting, then move out onto plains. Precipitation falls & <u>cools</u> environment



Typical velocities achieved by microbursts can be estimated by considering the vertical momentum equation

$$\frac{dw}{dt} = \frac{\partial w}{\partial t} + \mathbf{v} \cdot \nabla_H w + w\frac{\partial w}{\partial z} = g\frac{T_v'}{T_v} \ , \qquad (1)$$

where $T_v = T(1+0.61q-\ell)$ is the virtual potential temperature and ℓ is the hydrometeor mixing ratio. Thus, both sublimative/evaporative cooling and water loading can contribute to a downward acceleration. Assuming steady, horizontally homogeneous conditions, (1) can be integrated from the starting level of the downdraft (z) to the ground ($z = 0$):

$$\int_z^0 \frac{\partial}{\partial z}\frac{w^2}{2} dz = \int_z^0 g\frac{T_v'}{T_v} dz \ ,$$

or

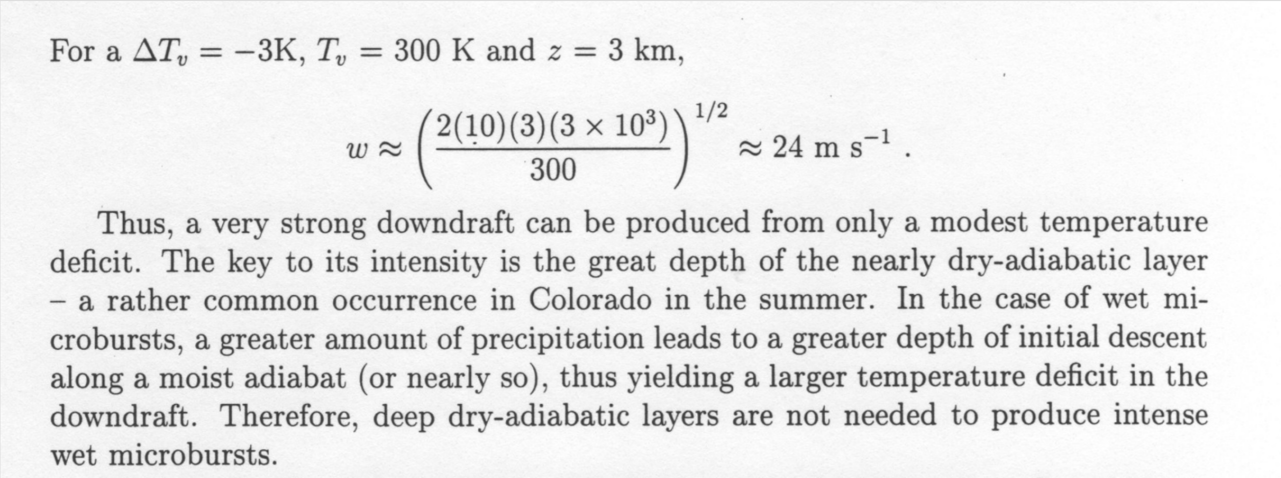
$$\frac{w^2}{2} = \int_0^z -g\frac{T_v'}{T_v} dz \ ,$$

Downdraft CAPE (DCAPE)

where w is the speed of a downdraft (starting from rest) when it reaches the ground. If we assume T_v'/T_v = constant $=\Delta T_v/T_v$, then we can solve for w:

$$w = \sqrt{-2g\frac{\Delta T_v}{T_v} z} \ .$$

Temp deficit in parcel



For a $\Delta T_v = -3$K, $T_v = 300$ K and $z = 3$ km,

$$w \approx \left(\frac{2(10)(3)(3 \times 10^3)}{300}\right)^{1/2} \approx 24 \text{ m s}^{-1} \ .$$

Thus, a very strong downdraft can be produced from only a modest temperature deficit. The key to its intensity is the great depth of the nearly dry-adiabatic layer – a rather common occurrence in Colorado in the summer. In the case of wet microbursts, a greater amount of precipitation leads to a greater depth of initial descent along a moist adiabat (or nearly so), thus yielding a larger temperature deficit in the downdraft. Therefore, deep dry-adiabatic layers are not needed to produce intense wet microbursts.

Quantitative estimation of downdraft CAPE on Skew-T, log-P diagram

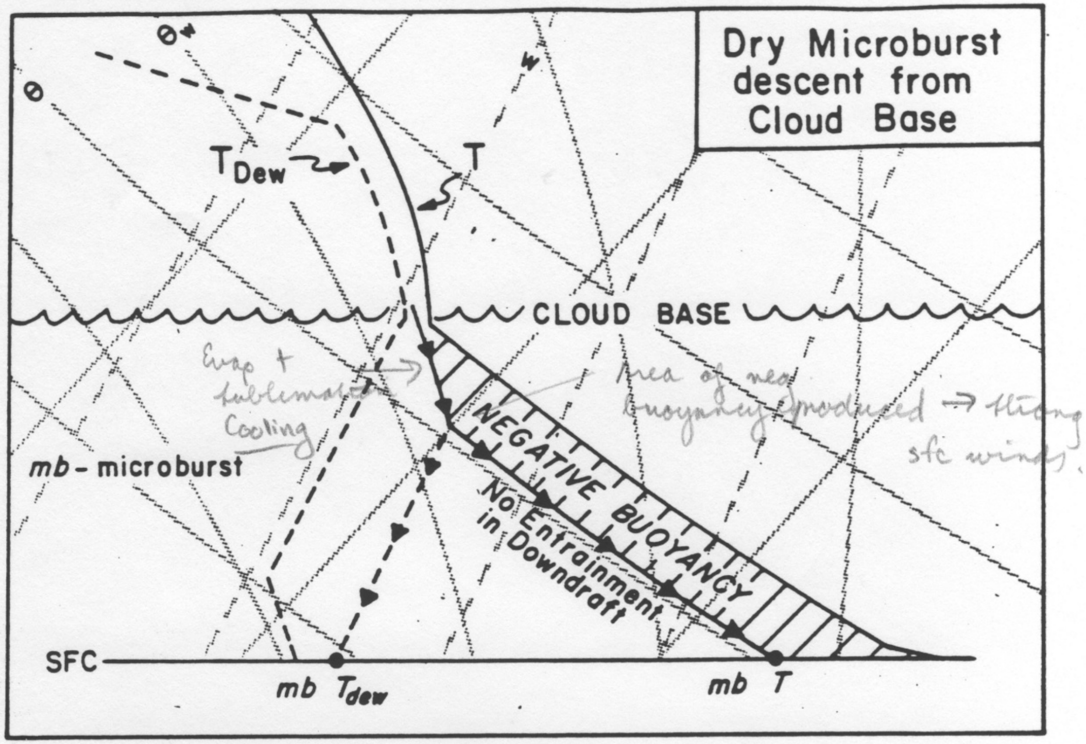
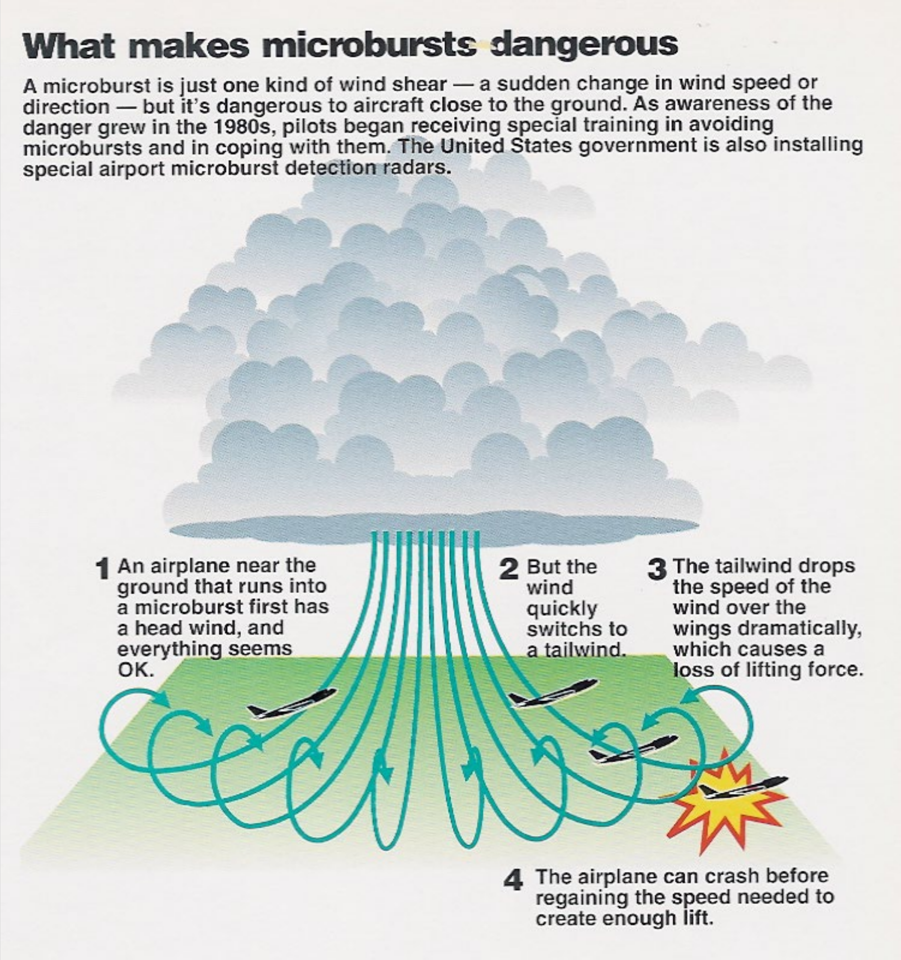


FIG. 10. Model of the thermodynamic descent of a dry microburst from cloud base. Surface temperature and dew-point temperature within the microburst are determined from PAM data. No entrainment into the downdraft is assumed.

Microburst Aviation Hazard



What makes microbursts dangerous

A microburst is just one kind of wind shear — a sudden change in wind speed or direction — but it's dangerous to aircraft close to the ground. As awareness of the danger grew in the 1980s, pilots began receiving special training in avoiding microbursts and in coping with them. The United States government is also installing special airport microburst detection radars.

1 An airplane near the ground that runs into a microburst first has a head wind, and everything seems OK.

2 But the wind quickly switches to a tailwind.

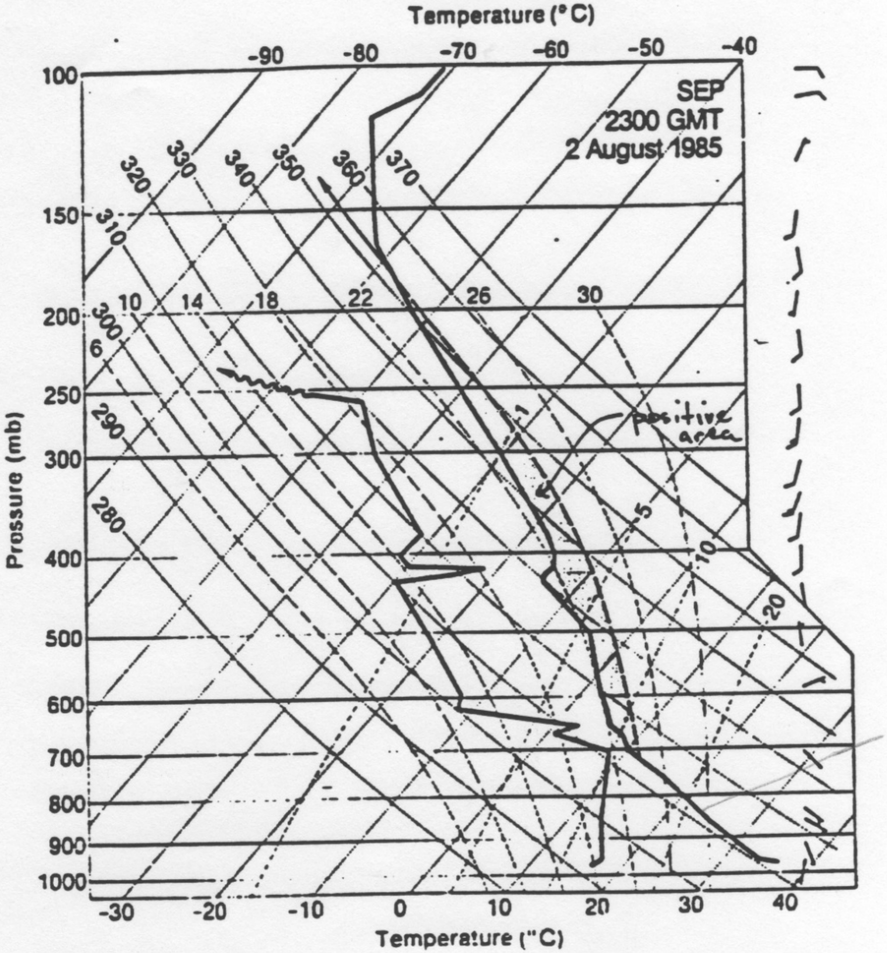
3 The tailwind drops the speed of the wind over the wings dramatically, which causes a loss of lifting force.

4 The airplane can crash before regaining the speed needed to create enough lift.

(Williams)

Delta Flight 191
Crashed August 2, 1985
Cause: Microburst related wind shear and pilot error

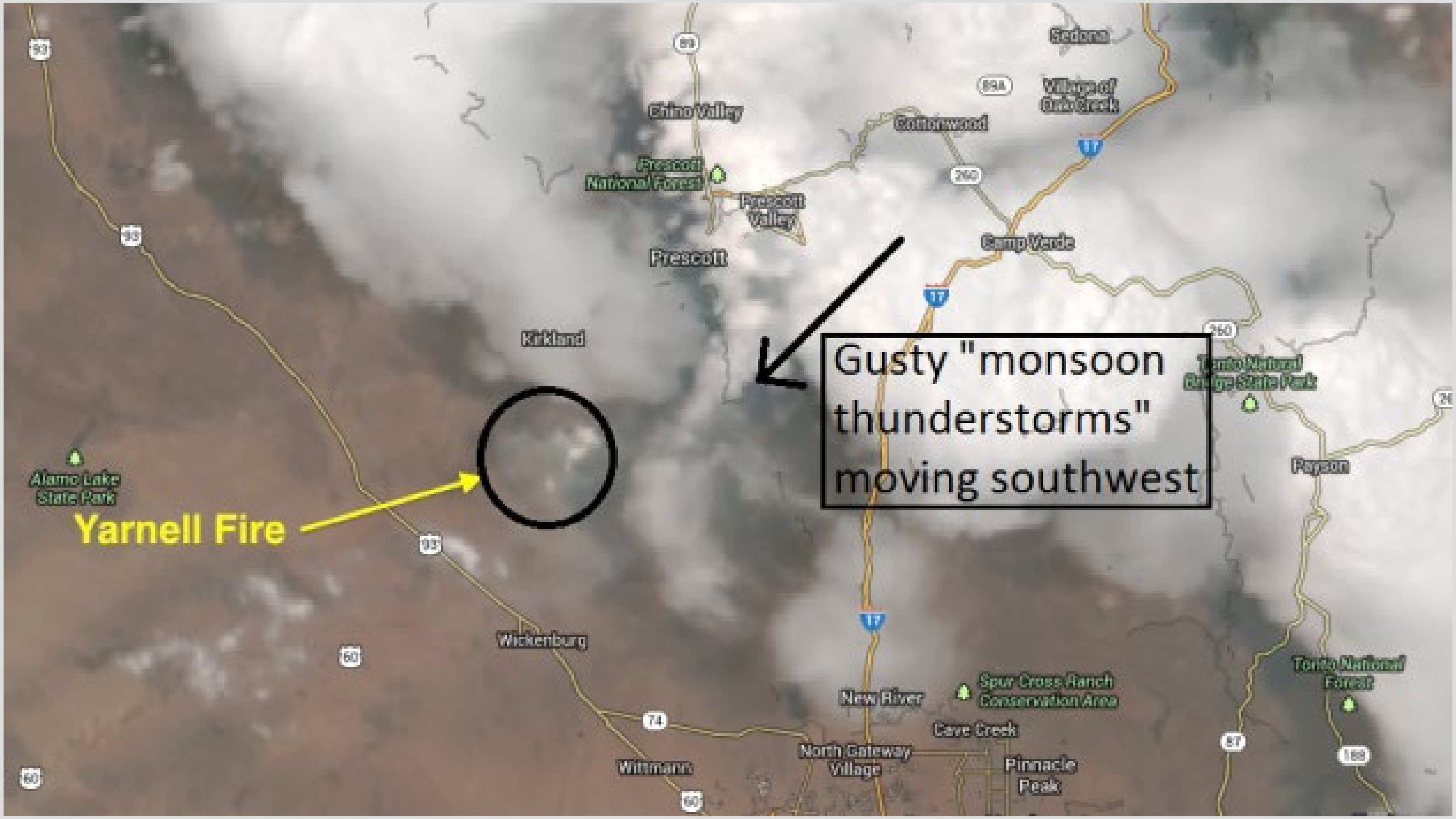
Delta airlines crash sounding



dry microburst structure to 700mb.

Figure 4. Skew-T/log-P plot of the sounding released at 2300 GMT, 2 August 1985, at Stephenville. Positive area in updraft is shaded red.

Microbursts as catalyst for wildfire growth Yarnell Fire example: 30 June 2013



Gusty "monsoon thunderstorms" moving southwest

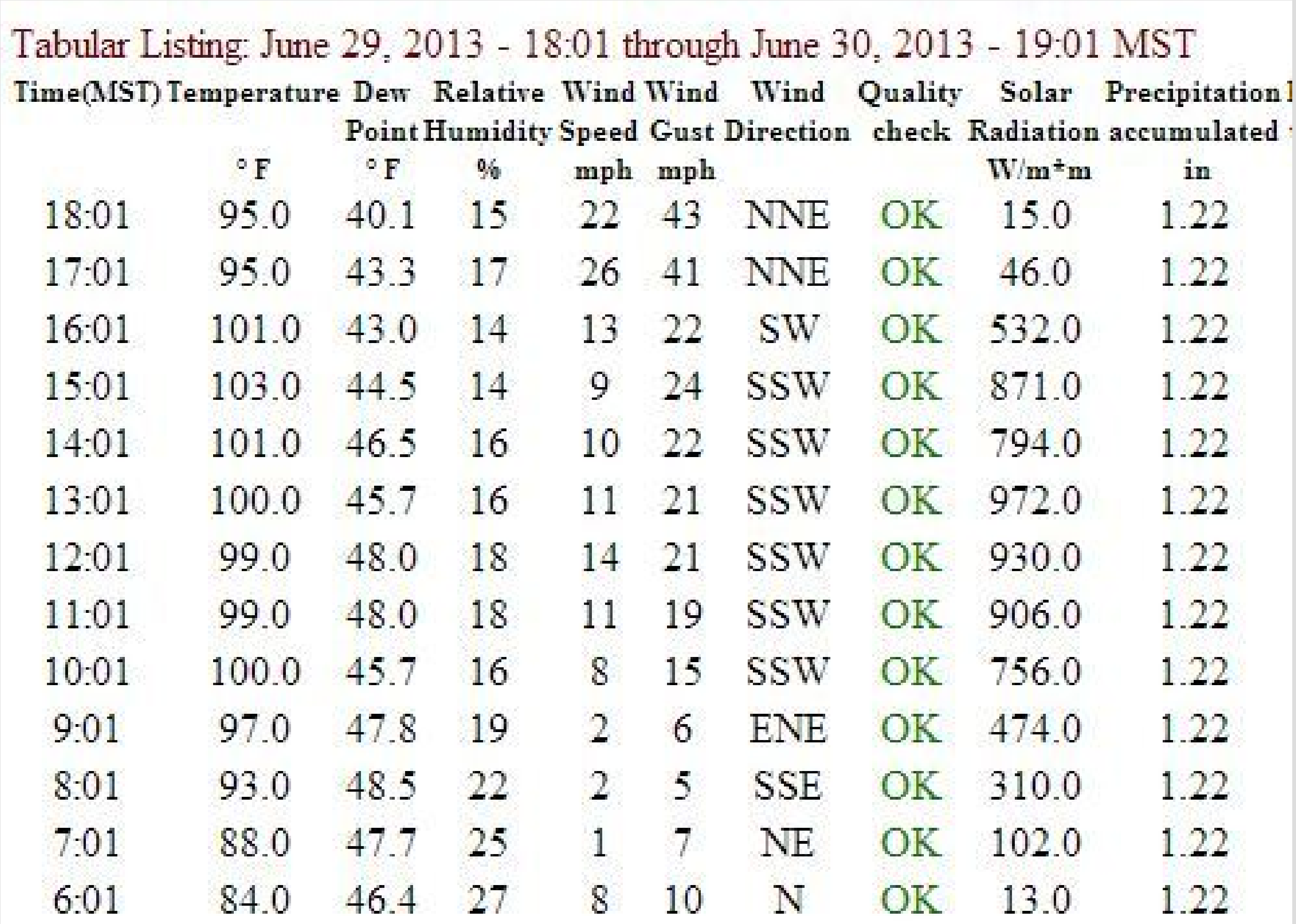
http://cimss.ssec.wisc.edu/goes/blog/archives/13341

Exhibits from official fire investigation report

Figure 8. Christopher MacKenzie took this photo at 1550 on June 30.

https://wildfiretoday.com/documents/Yarnell_Hill_Fire_report.pdf

Data from Stanton, AZ weather station on day of fire
(4 miles from Yarnell)



Tabular Listing: June 29, 2013 - 18:01 through June 30, 2013 - 19:01 MST

Time(MST)	Temperature ° F	Dew Point ° F	Relative Humidity %	Wind Speed mph	Wind Gust mph	Wind Direction	Quality check	Solar Radiation W/m*m	Precipitation accumulated in
18:01	95.0	40.1	15	22	43	NNE	OK	15.0	1.22
17:01	95.0	43.3	17	26	41	NNE	OK	46.0	1.22
16:01	101.0	43.0	14	13	22	SW	OK	532.0	1.22
15:01	103.0	44.5	14	9	24	SSW	OK	871.0	1.22
14:01	101.0	46.5	16	10	22	SSW	OK	794.0	1.22
13:01	100.0	45.7	16	11	21	SSW	OK	972.0	1.22
12:01	99.0	48.0	18	14	21	SSW	OK	930.0	1.22
11:01	99.0	48.0	18	11	19	SSW	OK	906.0	1.22
10:01	100.0	45.7	16	8	15	SSW	OK	756.0	1.22
9:01	97.0	47.8	19	2	6	ENE	OK	474.0	1.22
8:01	93.0	48.5	22	2	5	SSE	OK	310.0	1.22
7:01	88.0	47.7	25	1	7	NE	OK	102.0	1.22
6:01	84.0	46.4	27	8	10	N	OK	13.0	1.22

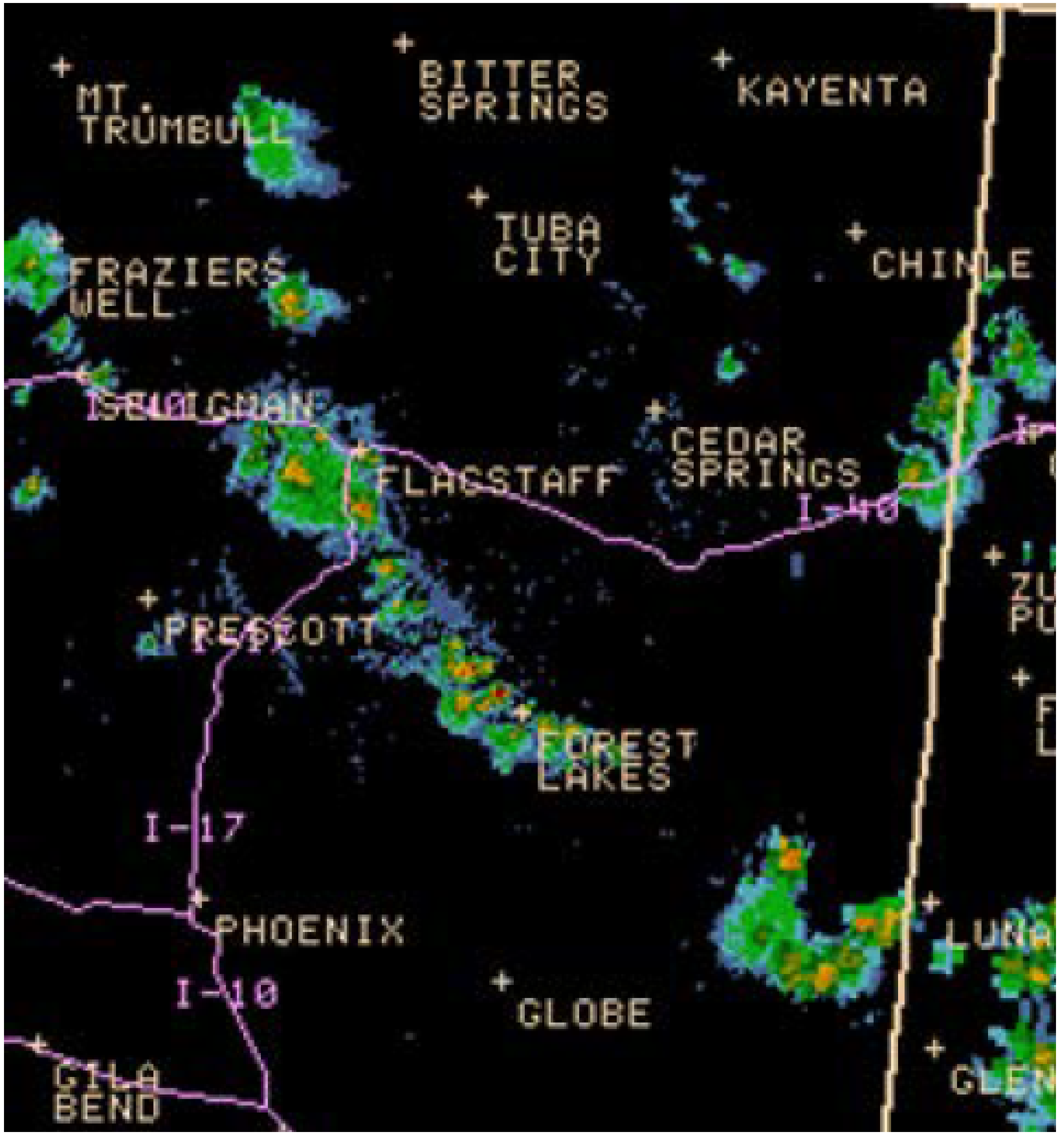


Figure 6. Doppler radar image from June 30 at 1200 MST. Graphic courtesy of NWS-Albuquerque

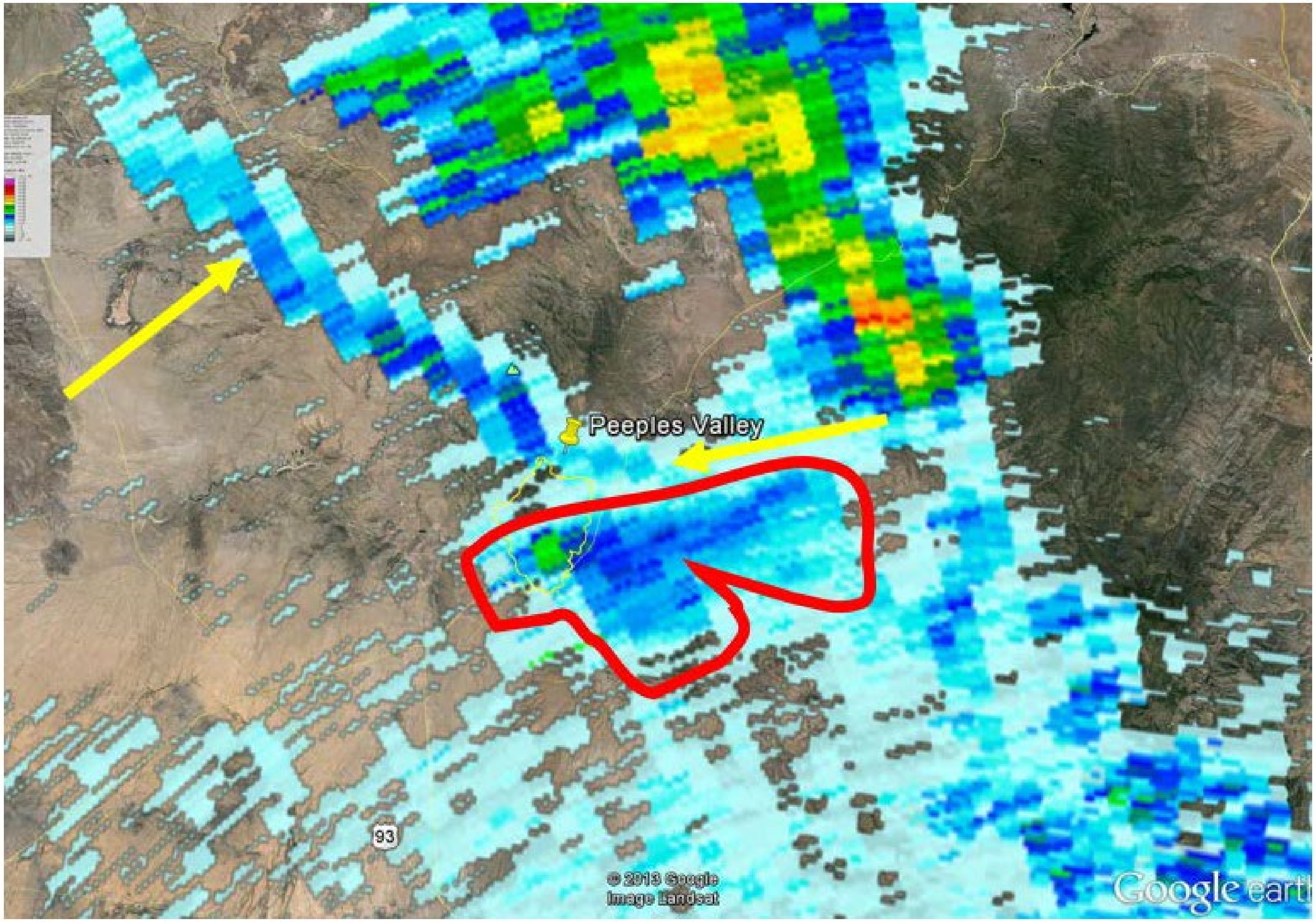


Figure 10. FAA radar detects an outflow boundary very near the northern end of the fire area at 1618 MST.

Figure 15. Initial outflow signature northeast of Congress, Arizona at 1639 MST. Photo courtesy of Matt Oss Photography.

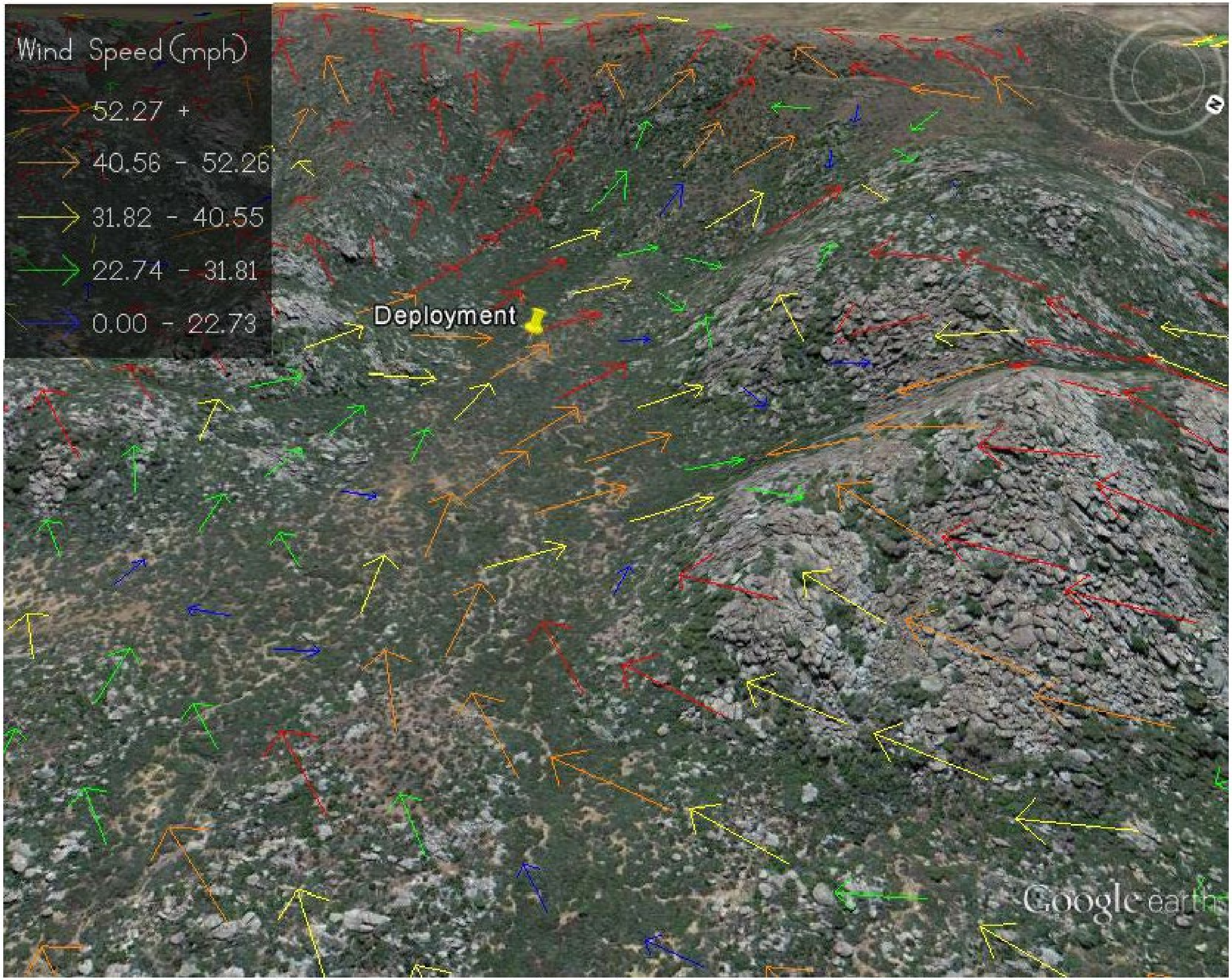
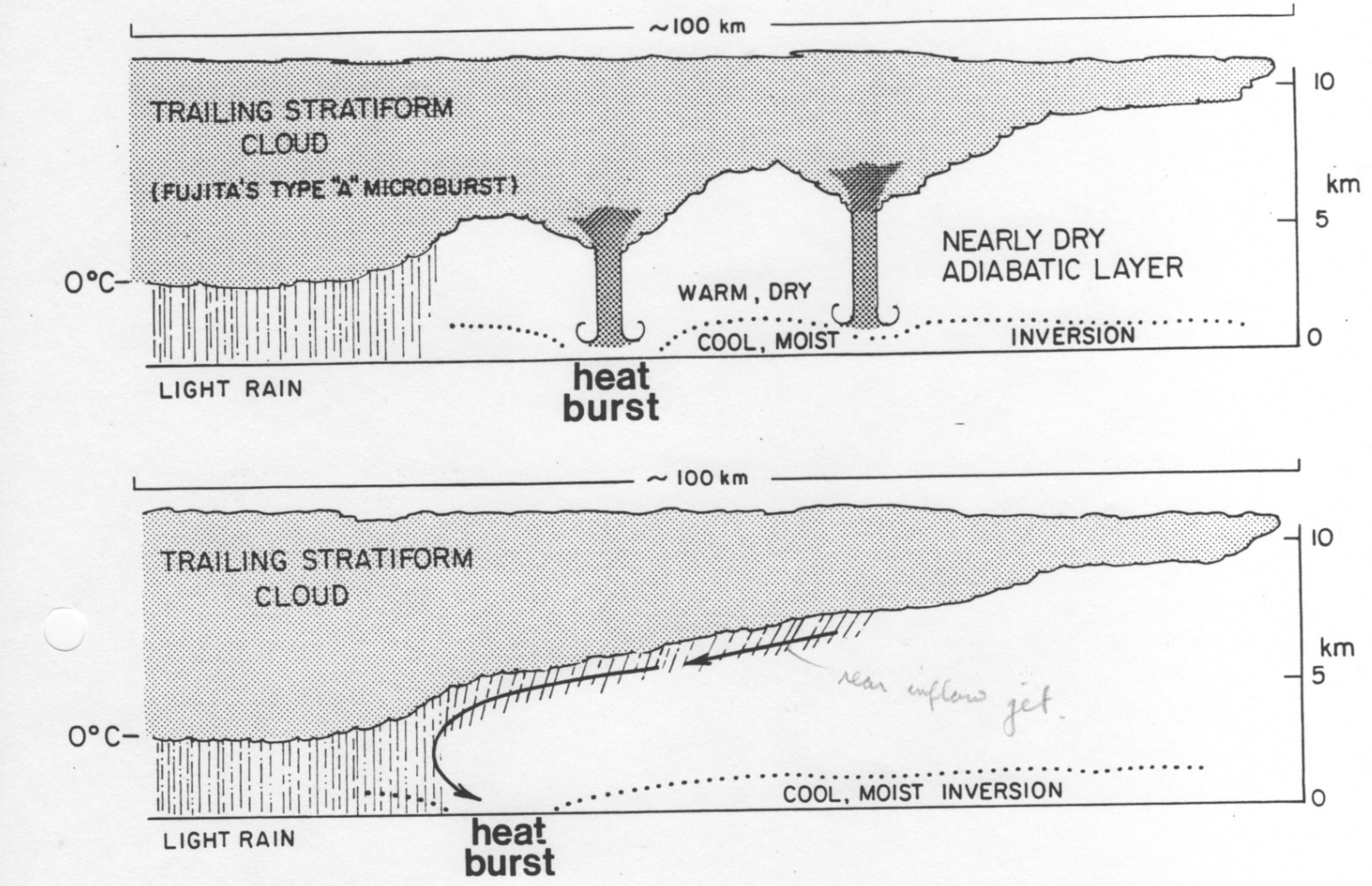
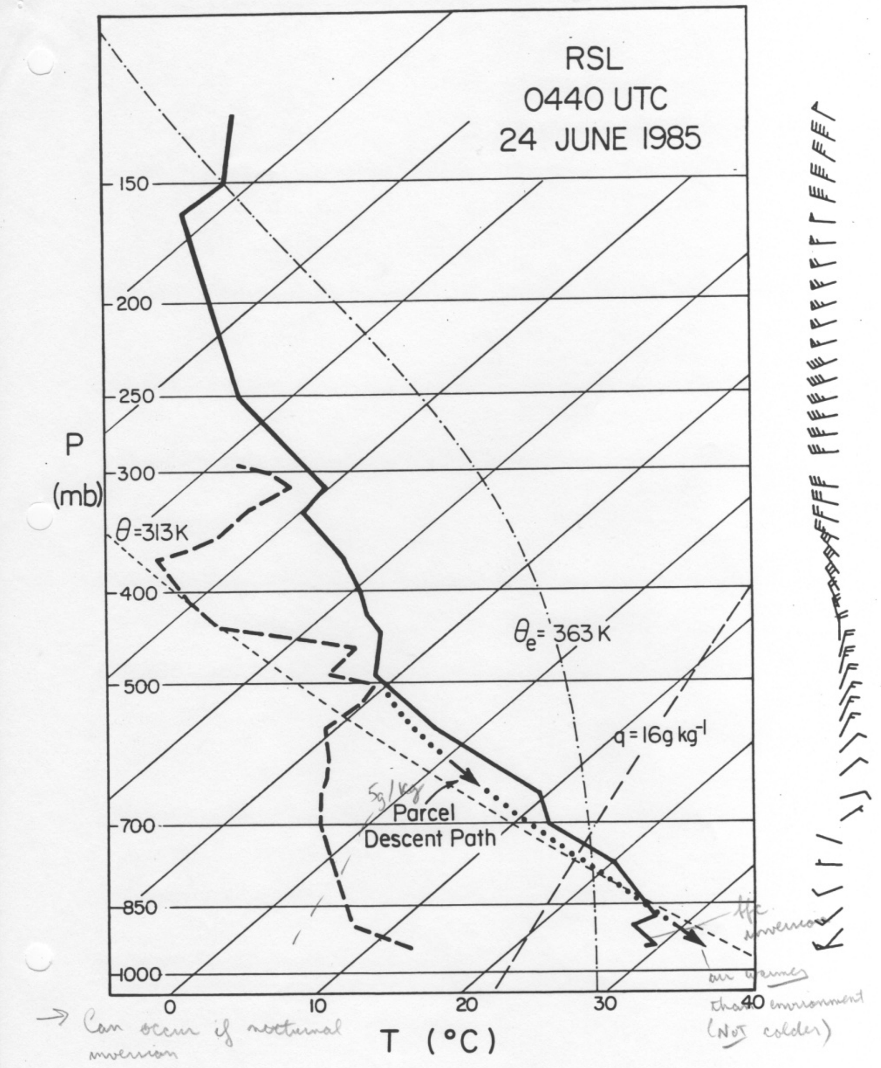


Figure 20. Wind vectors around the deployment site modeled using WindWizard

Can also get microbursts in association with descending air in the trailing stratiform region





Warm microbursts originating in the trailing stratiform region are characterized by the "onion" sounding.

Typical onion sounding

- Moist aloft
- Dry adiabatic in deep layer below cloud base
- Shallow inversion where air is moist near the ground.