Meteorological conditions contributing the crash of a Boeing 737 at Denver International Airport

15th Conference on Aviation, Range, and Aerospace Meteorology, 1.3, 1 August 2011

T. L. Keller, W. D. Hall, L. B. Cornman, and R. D. Sharman

Research Applications Lab

National Center for Atmospheric Research

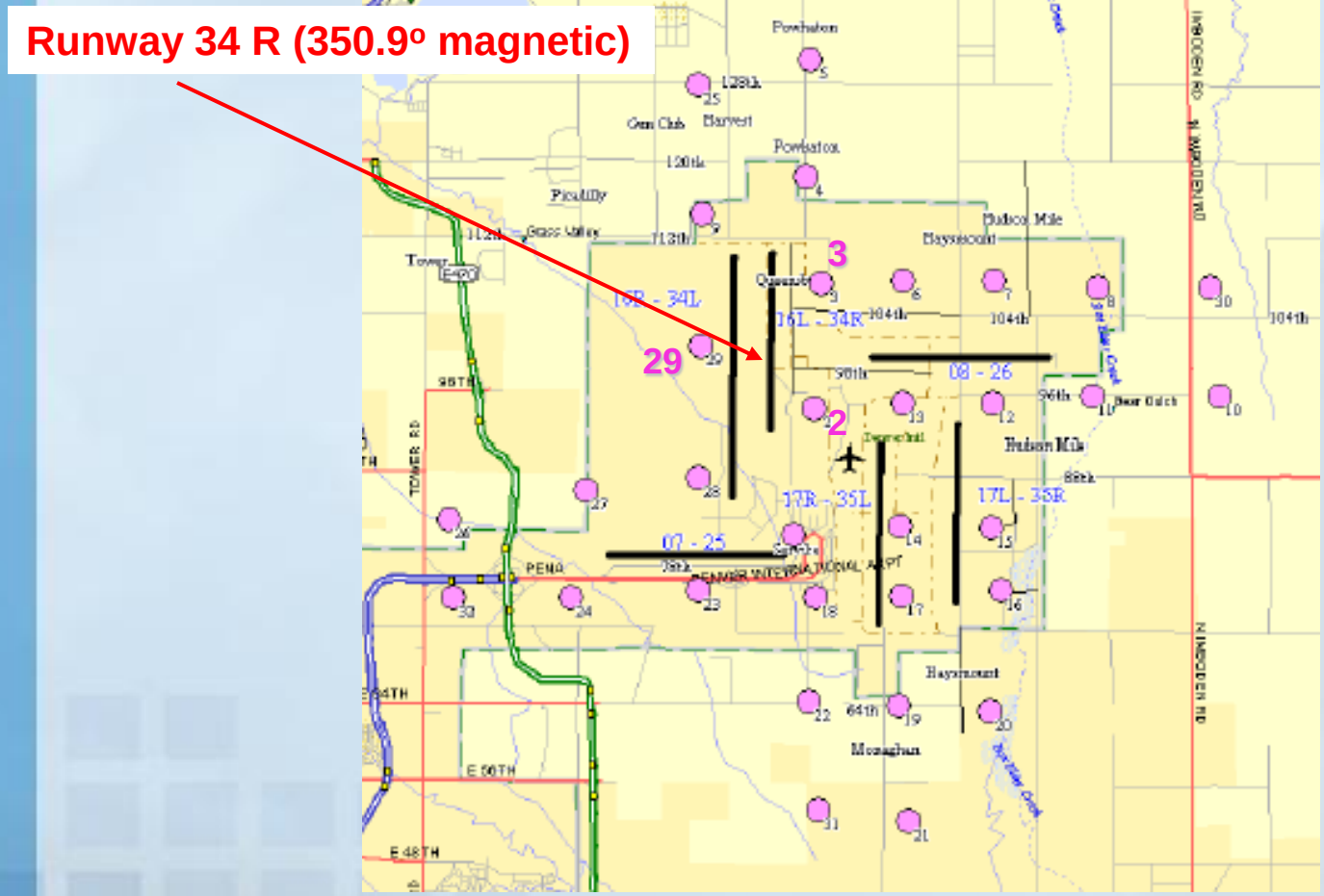
Boulder, CO

Denver Int. Airport accident

20 Dec 2008 - 1818 MST (21 Dec 2008 - 0118 UTC)
Boeing 737-500 departed left side runway 34R during take-off
Strong crosswinds at time of accident

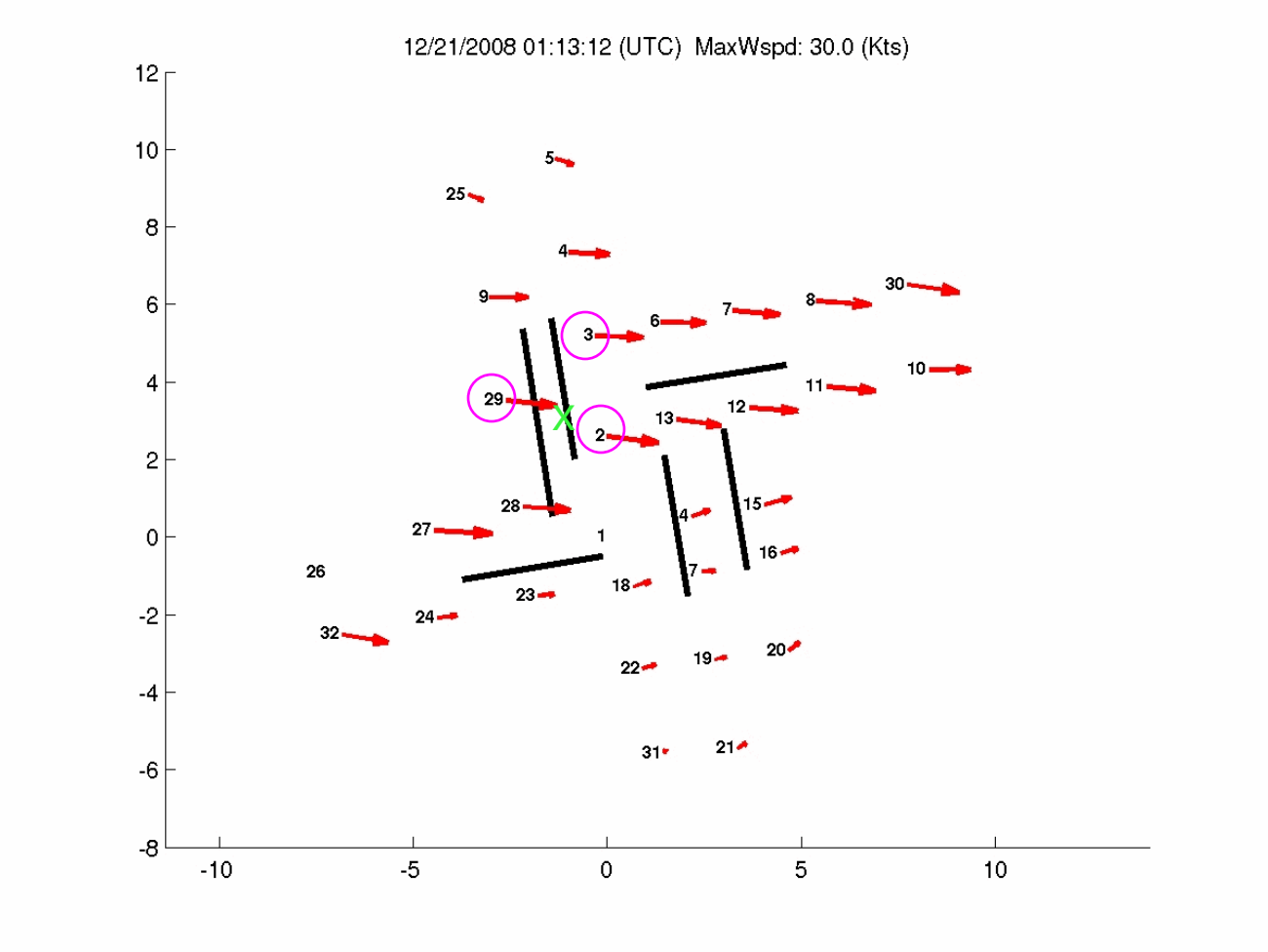
Denver International Airport

LLWAS network (pink circles)



LLWAS winds 1:13 – 1:23 UTC

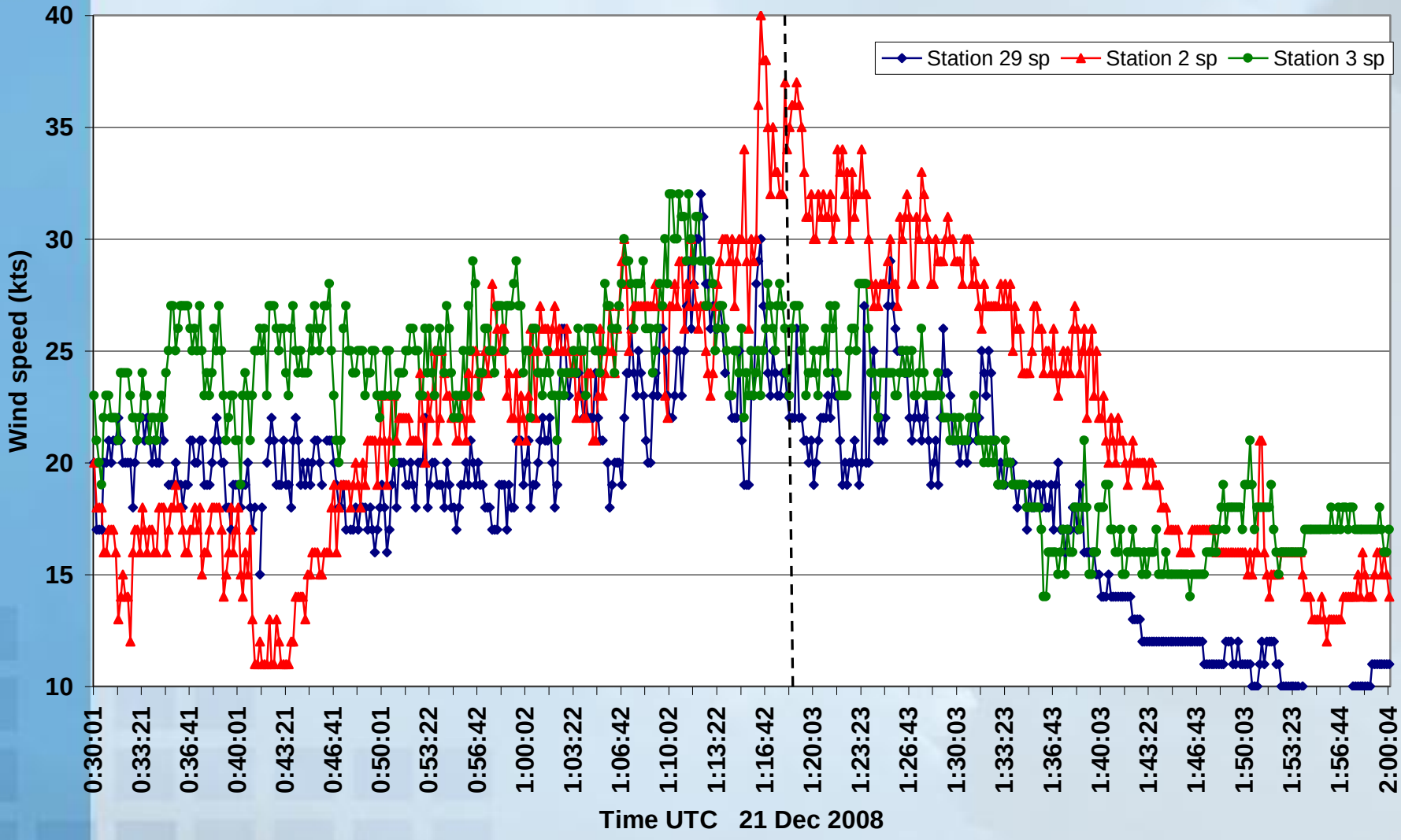
(+/- 5 min of accident)



Weekley, Cornman

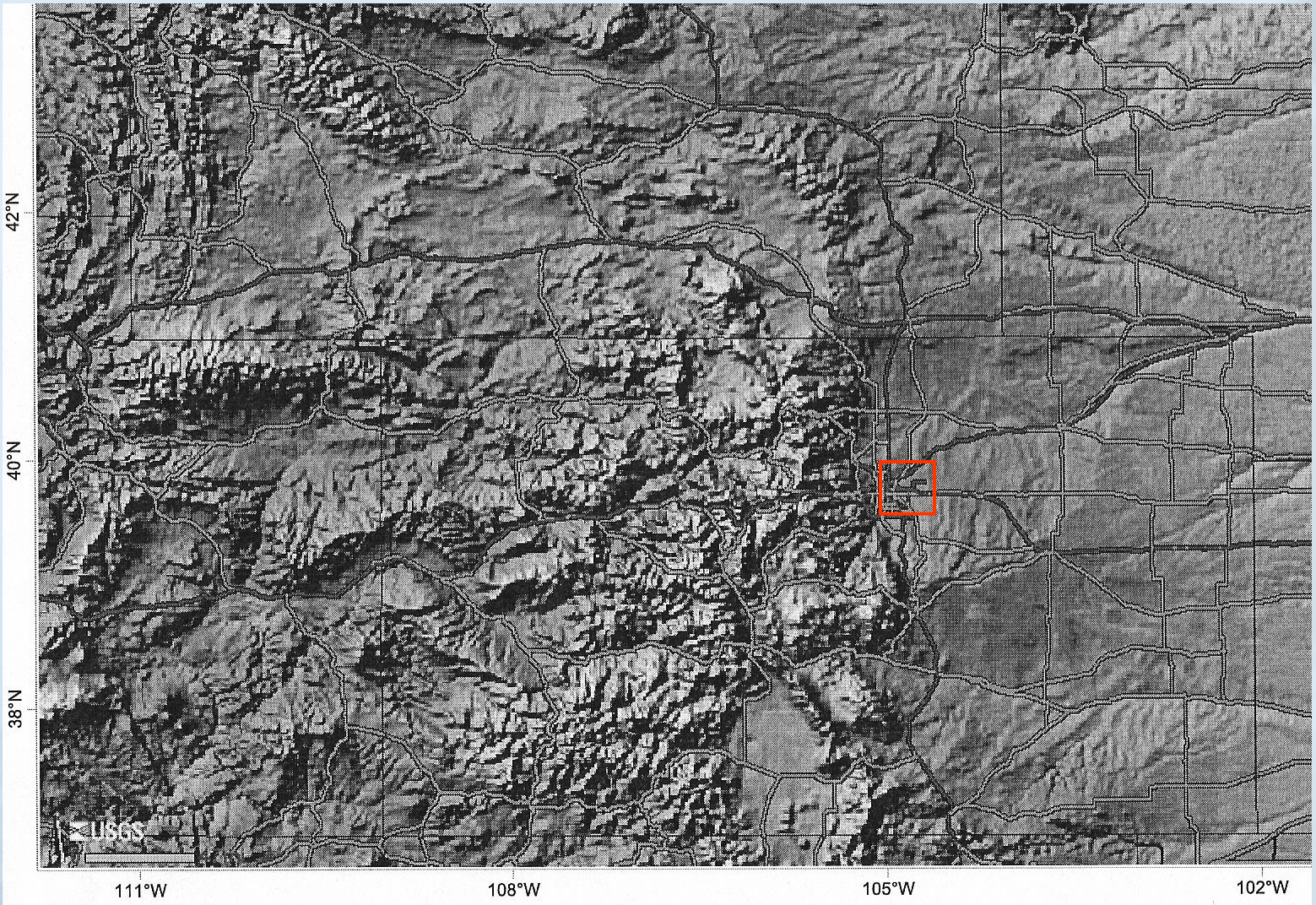
LLWAS wind speed (kts) - 0:30 - 2:00 UTC

NCAR



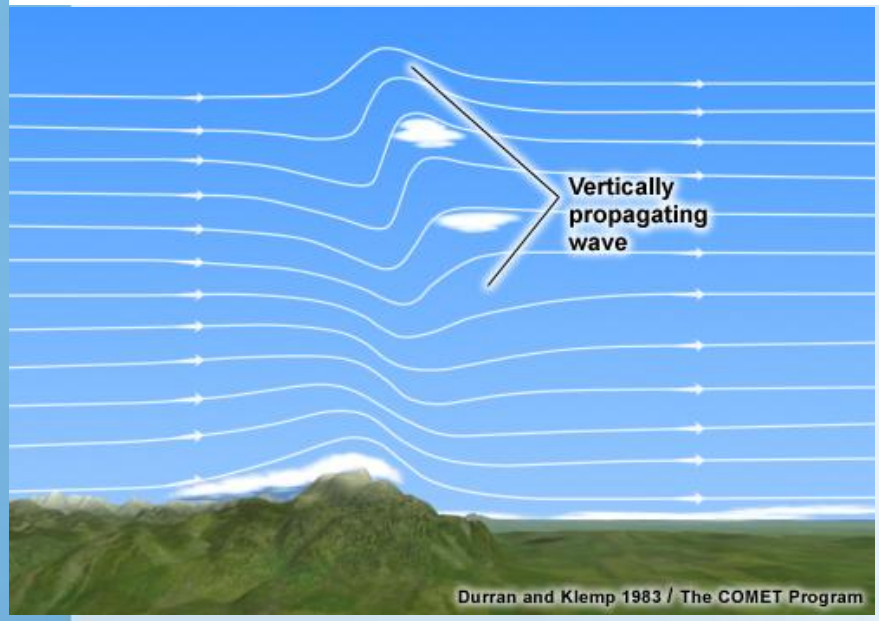
Location of DIA – east of Rocky Mtns

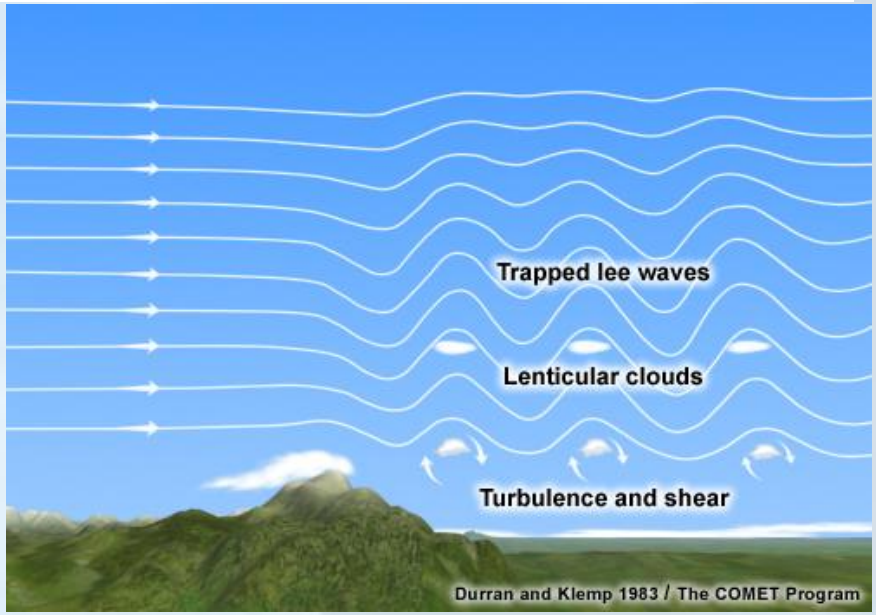
NCAR



Mountain waves – terrain generated gravity waves

Propagation characteristics depends on vertical variation of atmospheric wind and stability:





Vertically propagating – e.g. wind and stability are nearly constant with height

Horizontally propagating (trapped) – e.g. N/U decreases with height (U increasing rapidly with height)

** May or may not be turbulent **

Severe downslope windstorm 11 Jan 1972

- Solid lines – potential temperature
- Large amplitude wave
- + marks where aircraft encountered turbulence
- Note turbulence near Stapleton (under lee waves in stable layer)

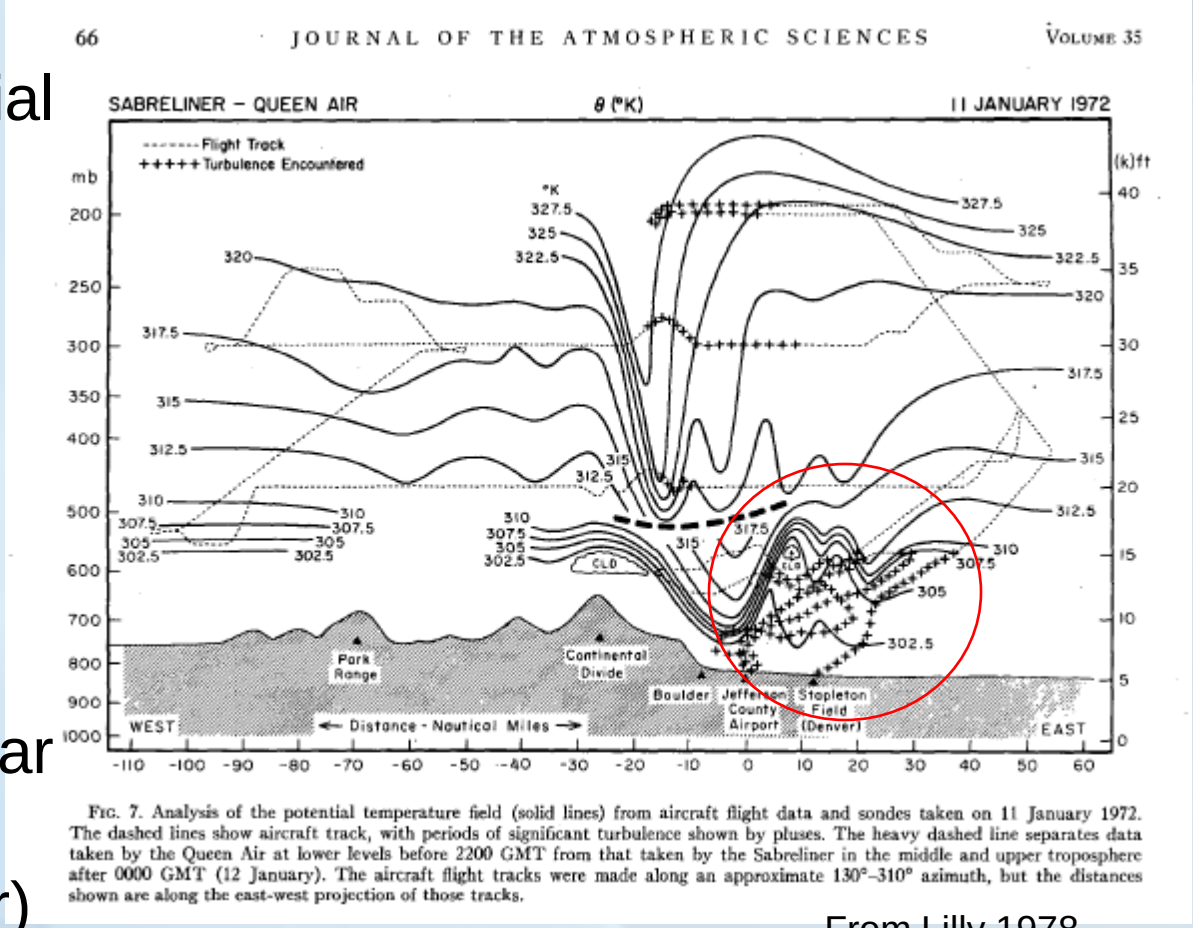


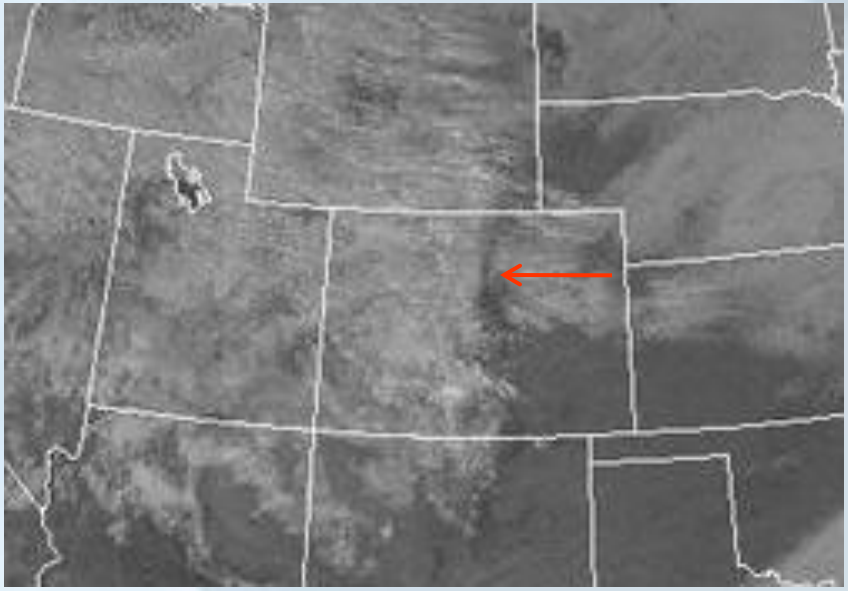
FIG. 7. Analysis of the potential temperature field (solid lines) from aircraft flight data and sondes taken on 11 January 1972. The dashed lines show aircraft track, with periods of significant turbulence shown by pluses. The heavy dashed line separates data taken by the Queen Air at lower levels before 2200 GMT from that taken by the Sabreliner in the middle and upper troposphere after 0000 GMT (12 January). The aircraft flight tracks were made along an approximate 130°–310° azimuth, but the distances shown are along the east-west projection of those tracks.

From Lilly 1978

Visible satellite 2030 UTC 20 Dec 2008

NCAR

- **Persistent clear notch near Denver**
- Probably due to descending air in mountain wave

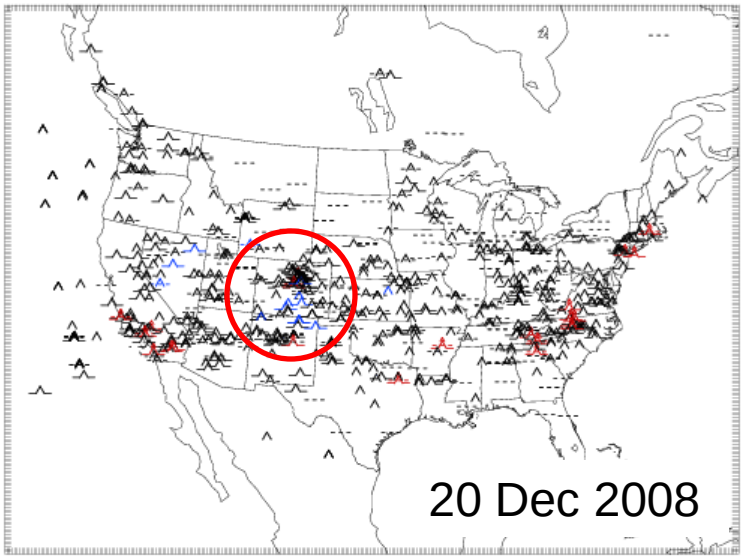


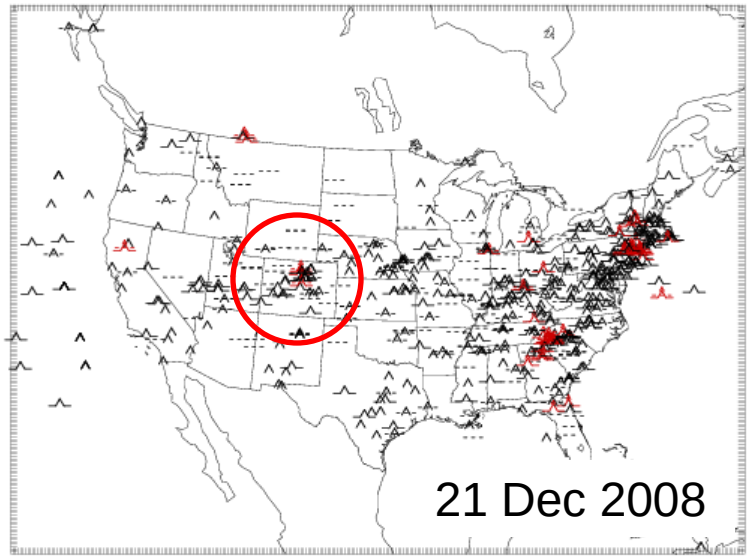
Meteorological conditions:

- **Strong westerly winds near mountain top**
- **Stable layer above mountain top**
- **Vertical speed shear**

Turbulent pilot reports (PIREPs):

Mountain waves with turbulence in blue





- Significant turbulence reported
- Severe to extreme turbulence 3 minutes before accident
- Moderate to severe mountain waves over Rockies
- Associated with altitude and airspeed changes
- Waves encountered from 8,000 to 40,000 ft

Numerical simulation of meteorological conditions on the day of the accident

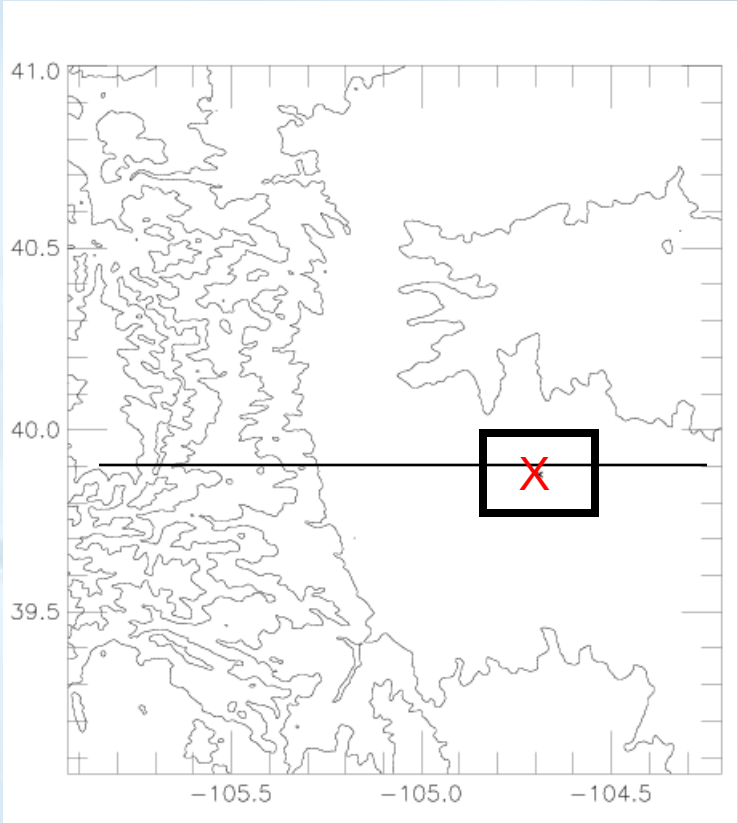
- Allows examination of three-dimensional structure of atmospheric flow

- Can help determine if gustiness at DIA possibly due to large amplitude mountain waves

- **However - can not resolve exact strength and timing of gusts**

Clark-Hall 3-D nonlinear, nonhydrostatic model

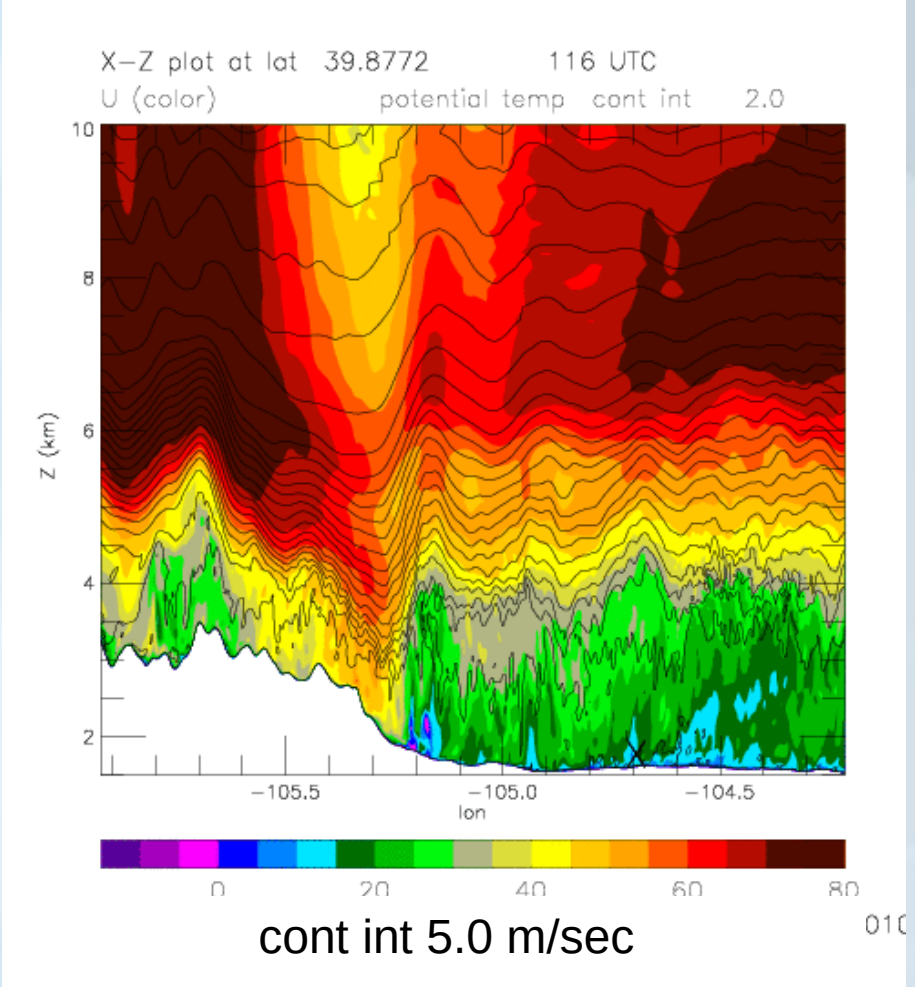
- Terrain following; vertical stretching
- 5 nested domains
- Inner domain **250 m** horizontal resolution
- Initialized with RUC data 2200 UTC 20 Dec
- RUC 1 hr data used to drive boundary conditions



Topography inner domain

East-west wind U - vertical slice

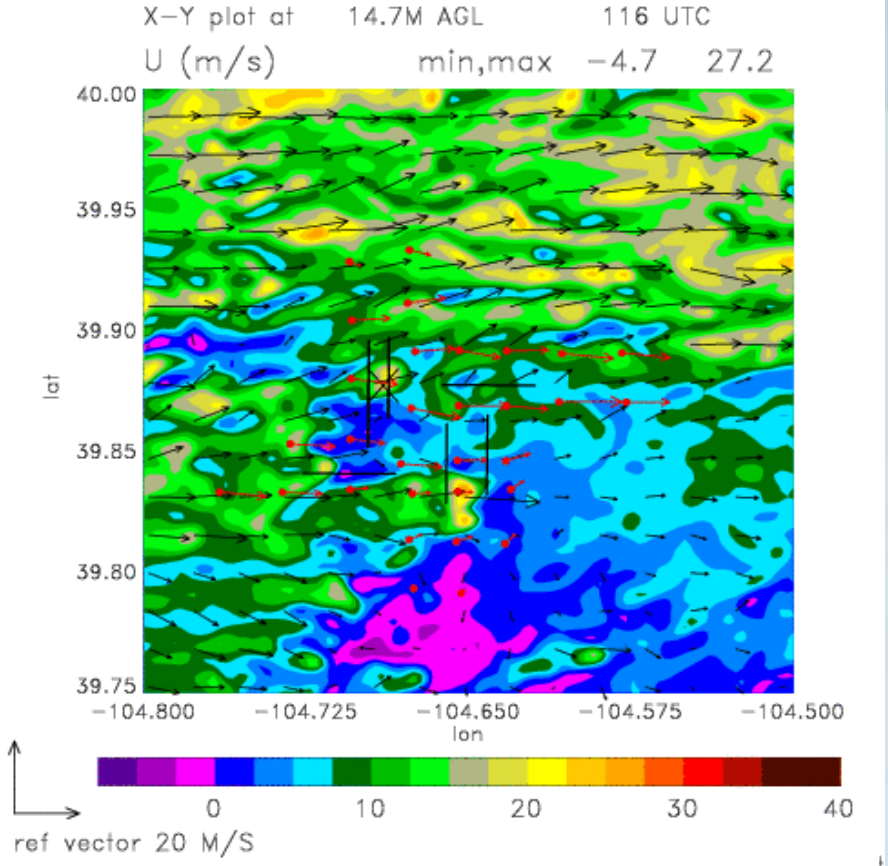
- X marks incident site
- **Note regions of high velocity air moving downward**
- Strong wave signature in potential temperature (black lines)
- X-Z slice at latitude 39.88
- Inner domain 5



1:00 – 1:39 UTC (+/- 20 minutes)

East-west wind U at 14.7 m AGL

- X marks incident site
- Red arrows -LLWAS winds
- Black arrows – model winds
- Runways– black lines
- Pink colors easterly flow
- Part of domain 5



cont int 2.5 m/sec

1:00 – 1:39 UTC (+/- 20 minutes)

High resolution numerical model results show:

- Large amplitude lee waves over DIA
- Associated with downward penetration of high velocity air
- Creates localized gustiness at airport
- May or may not be a common occurrence