

RADAR OBSERVATIONS OF TURBULENCE USING MST AND FMCW RADAR

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Technical Paper

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Radar Observations of Turbulence Using MST and FMCW Radar

Frank D. Eaton

Directed Energy Directorate
Air Force Research Laboratory



Gregory D. Nastrom

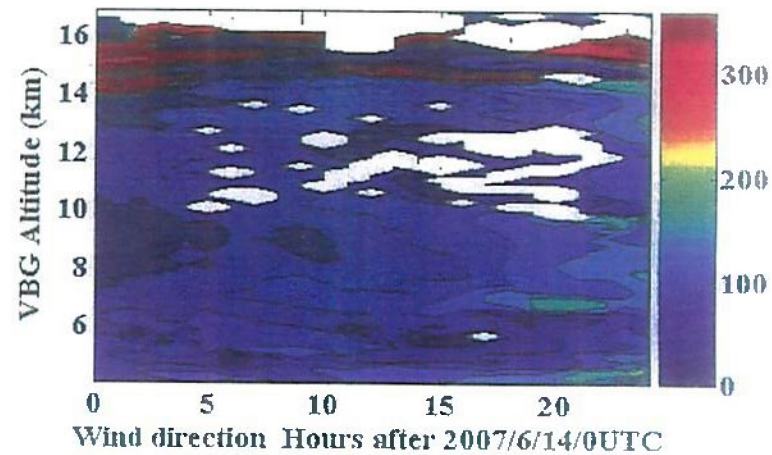
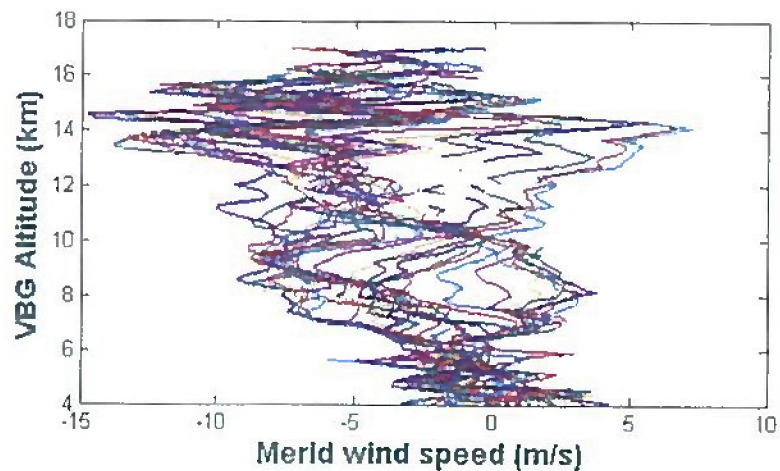
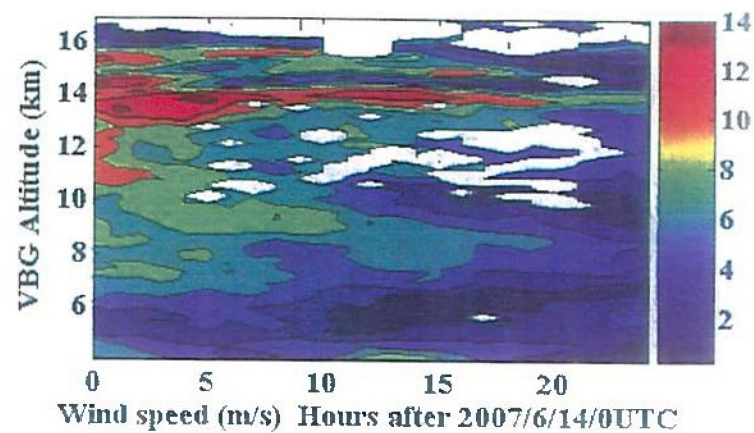
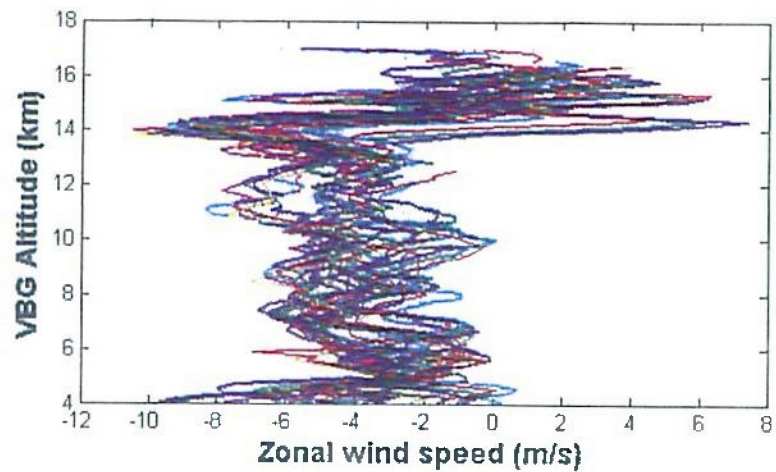
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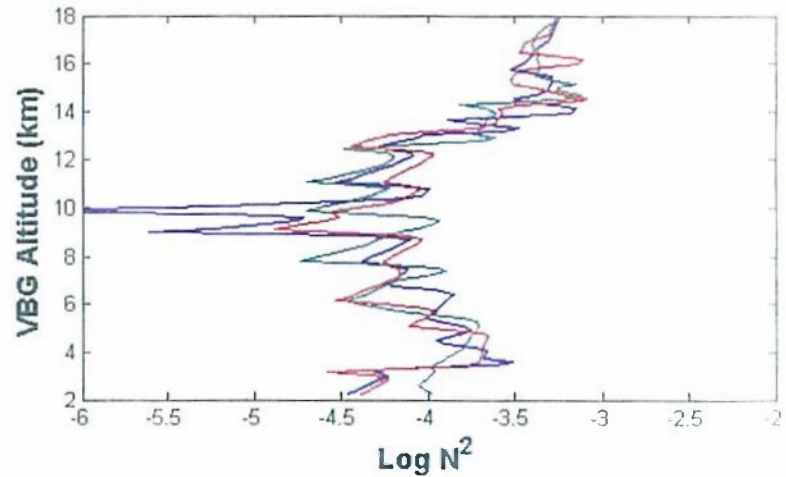
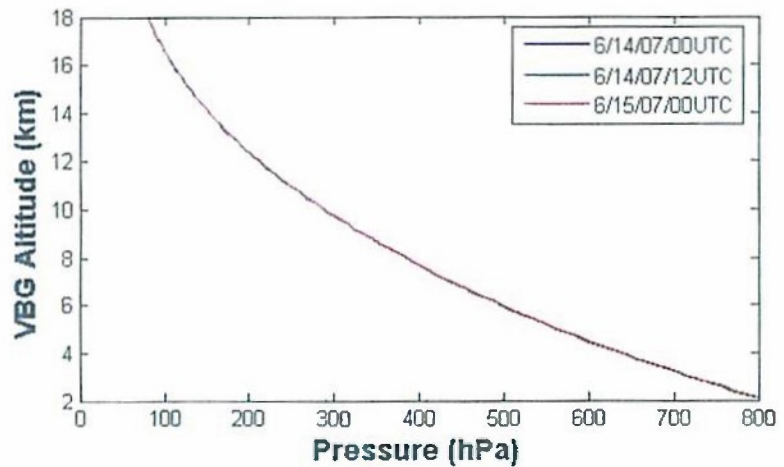
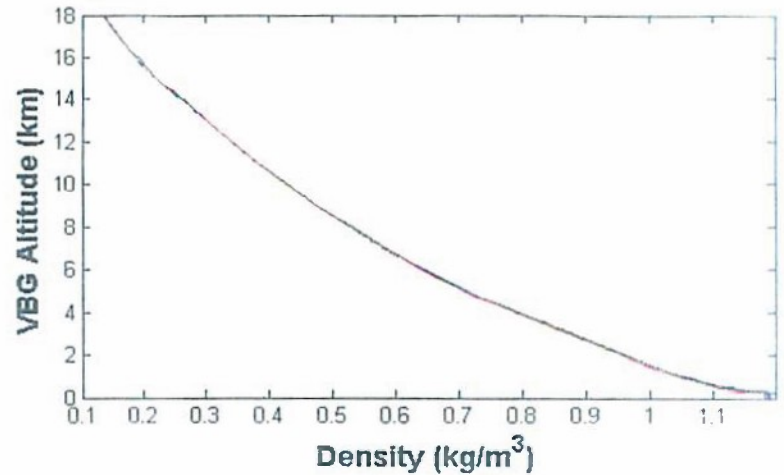
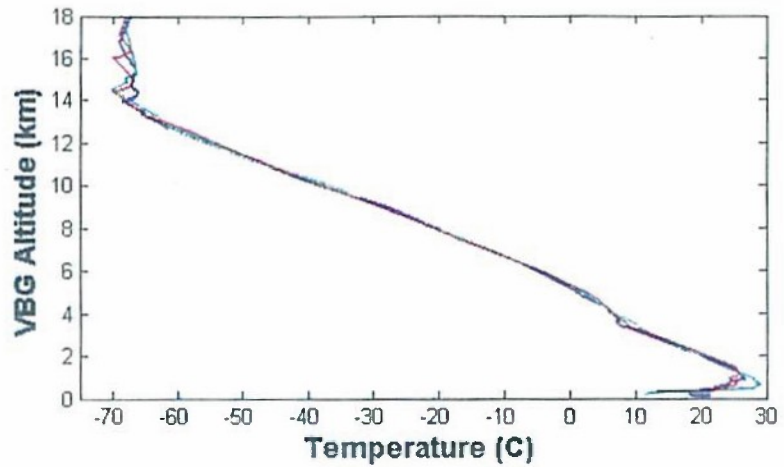


Vandenberg Radar Site

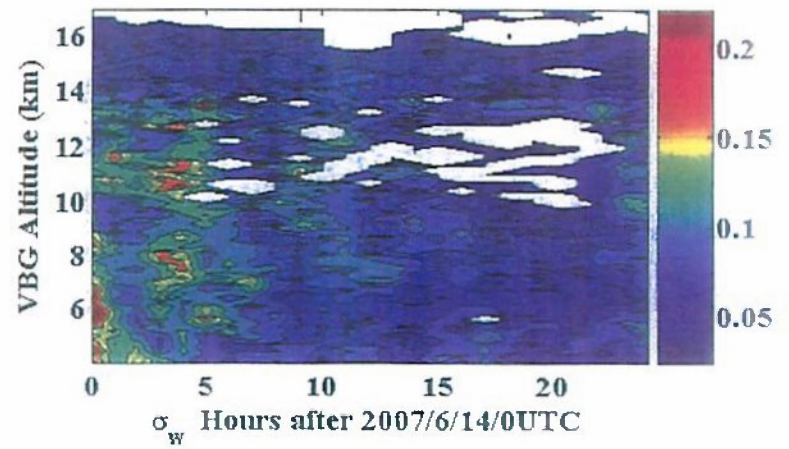
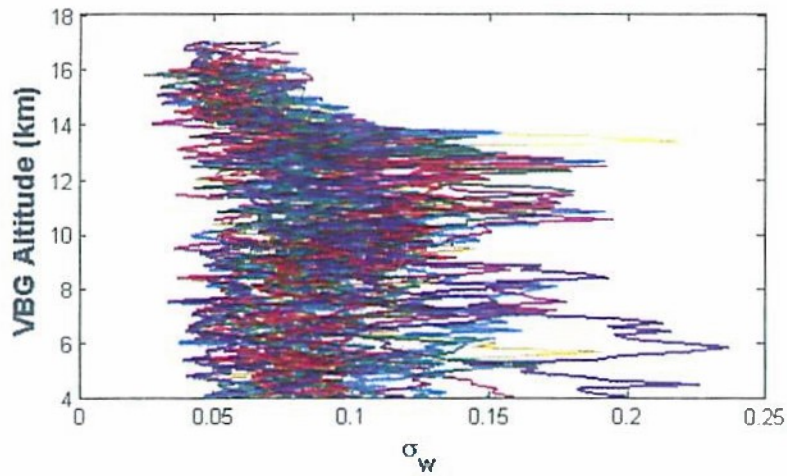
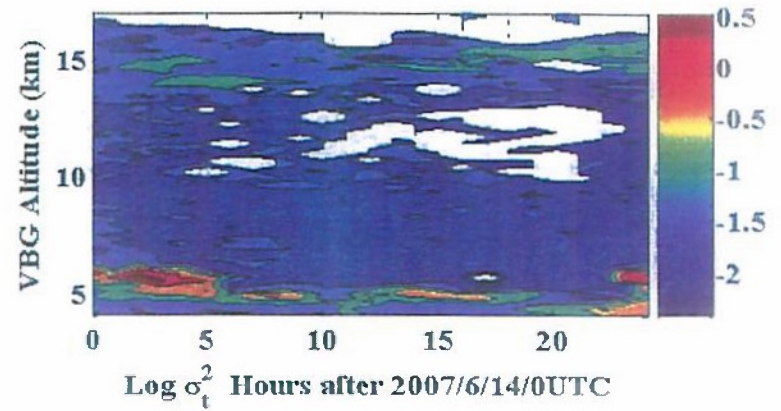
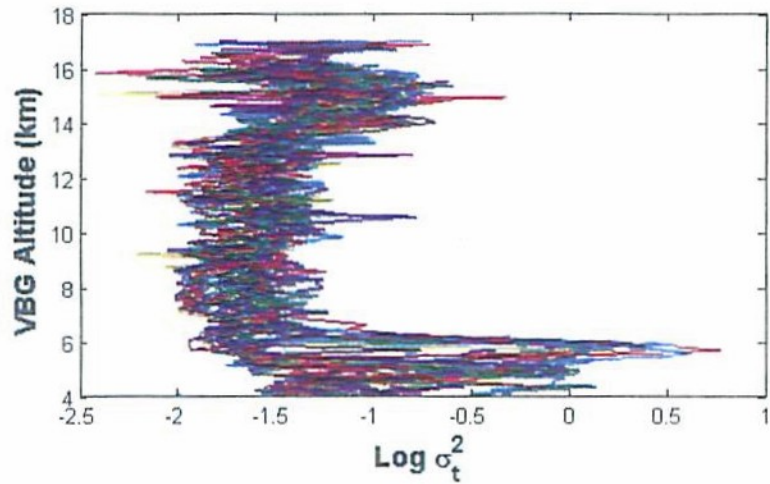




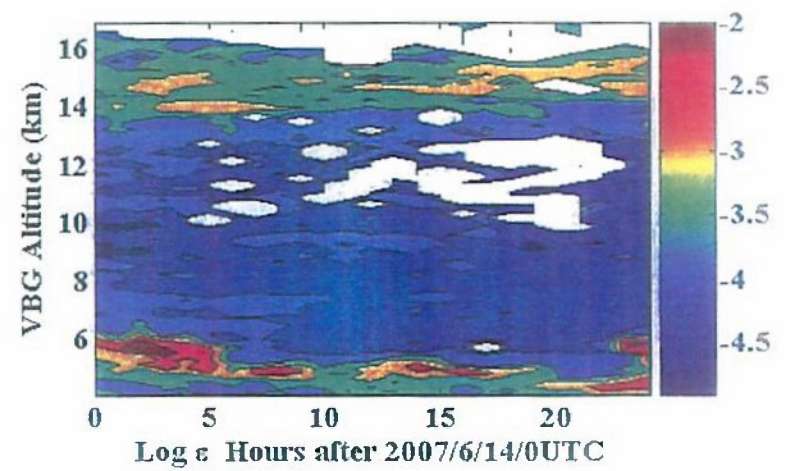
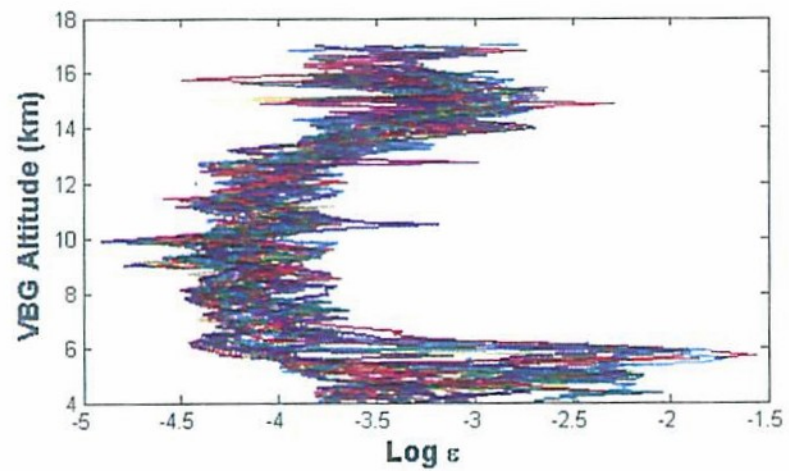
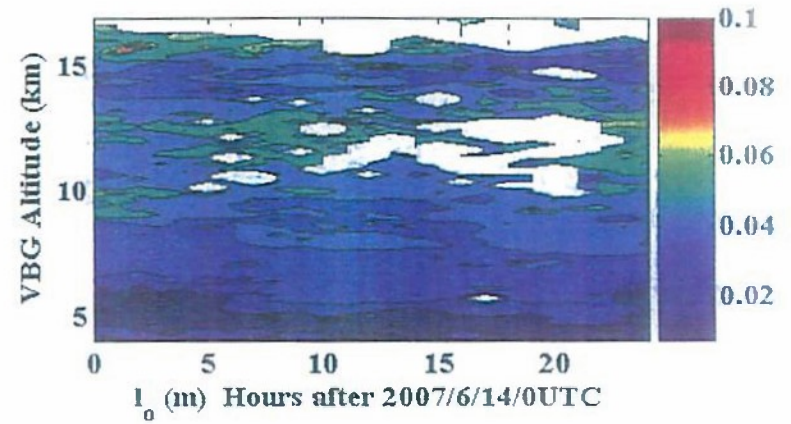
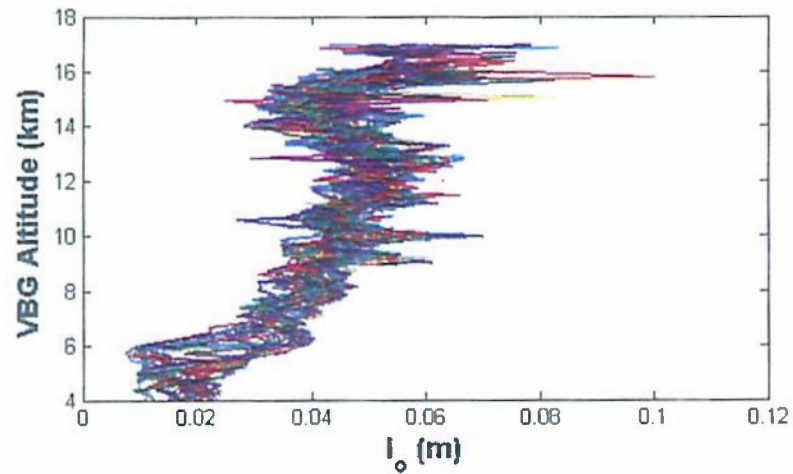
Wind Speed and Direction at Vandenberg AFB on June 14, 2007.



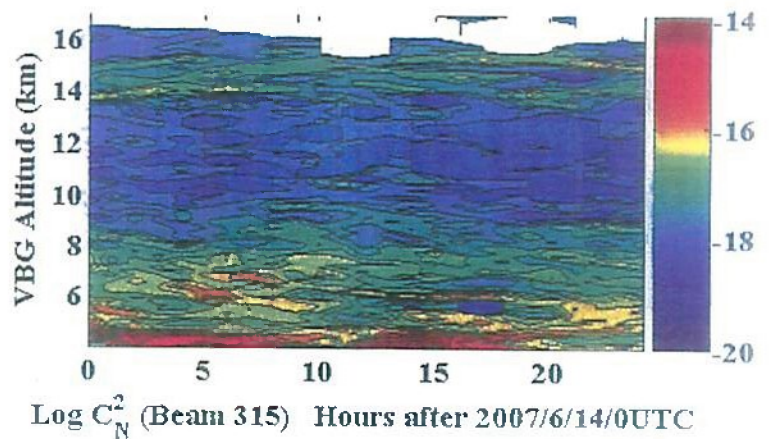
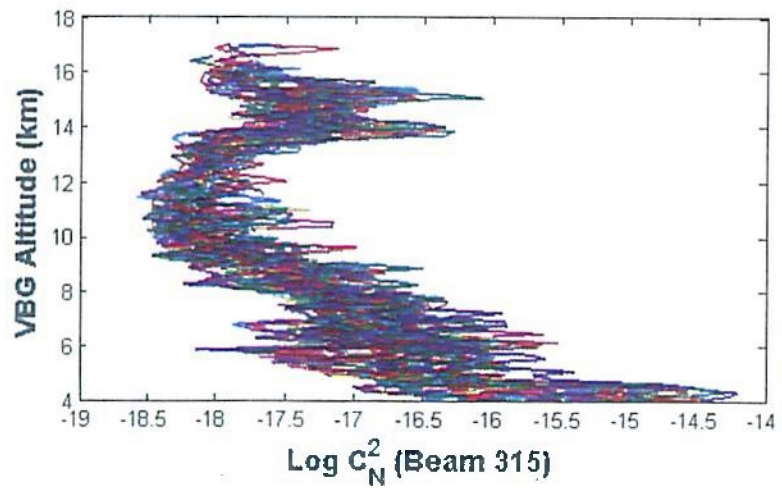
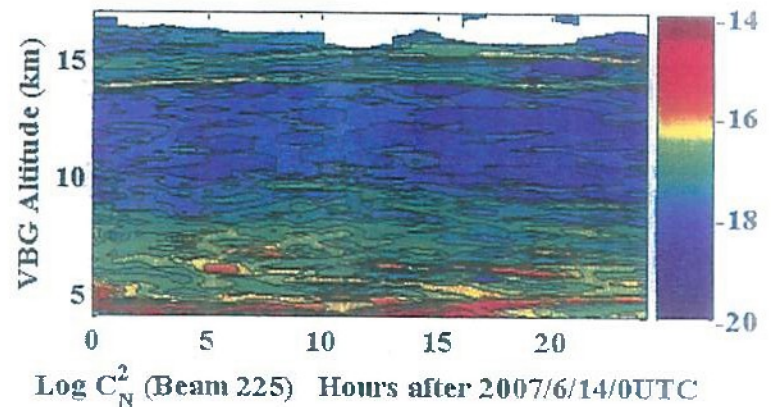
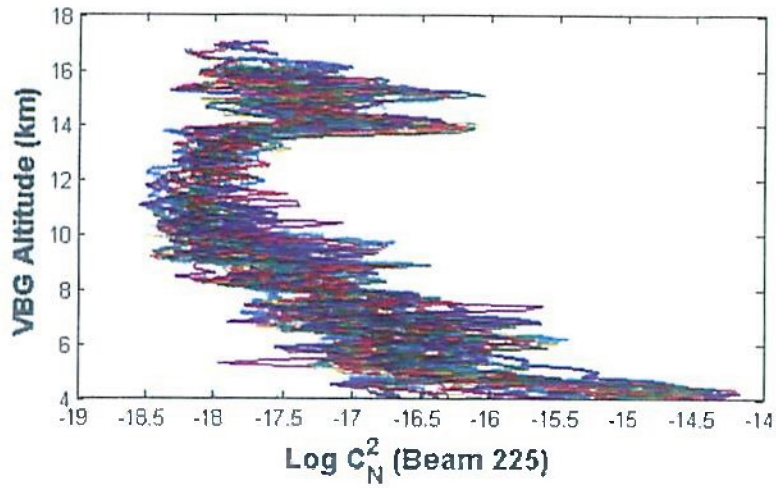
Temperature, density, pressure, and Brunt Vaisala Frequency from RAOBs at Vandenberg AFB.



Spectral width and standard deviation of vertical wind for June 14, 2007 at Vandenberg AFB.



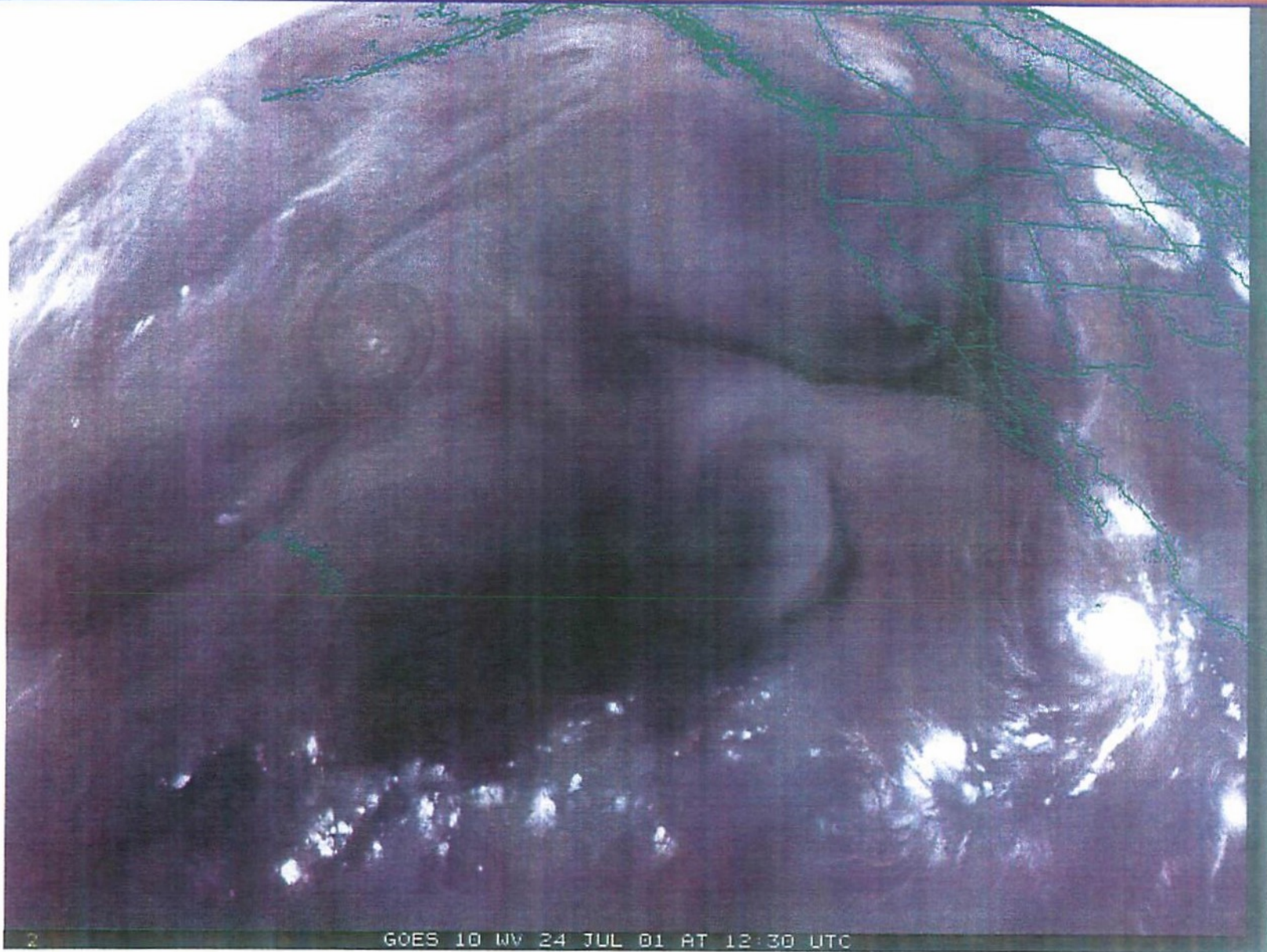
Inner scale and eddy dissipation rate profiles at Vandenberg AFB for June 14, 2007.



Profiles of C_n^2 at Vandenberg AFB on June 14, 2007.



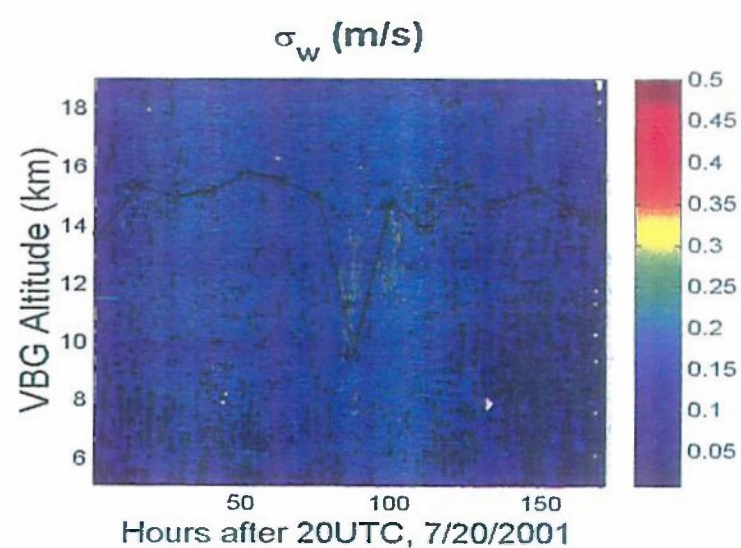
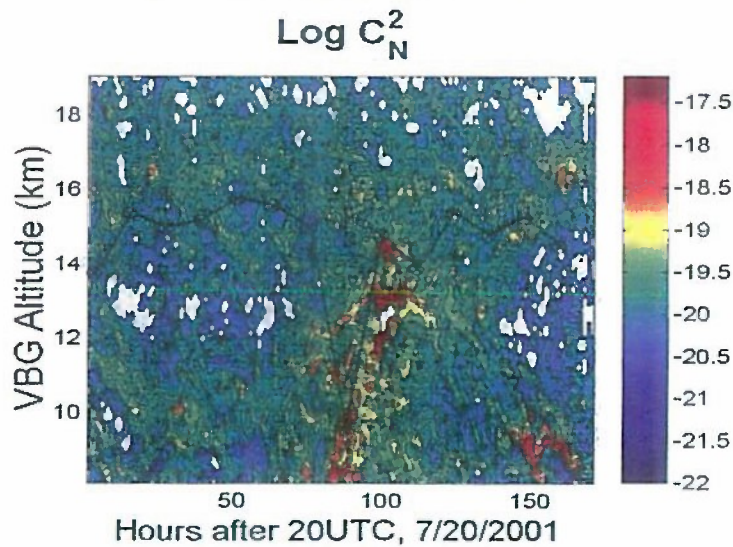
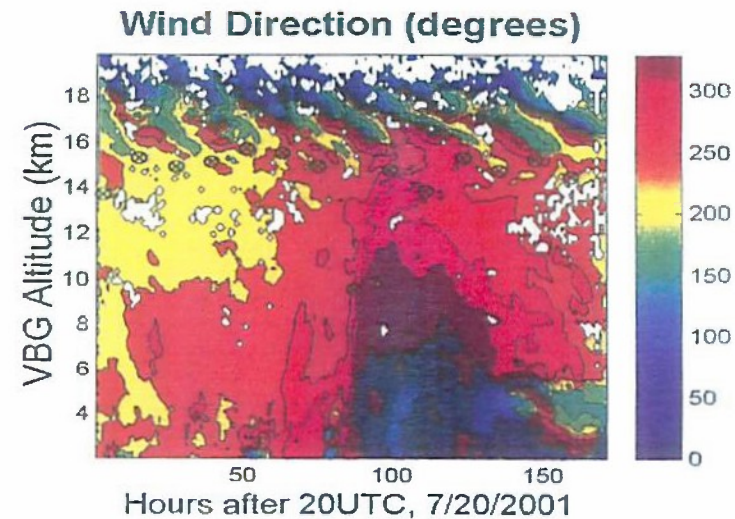
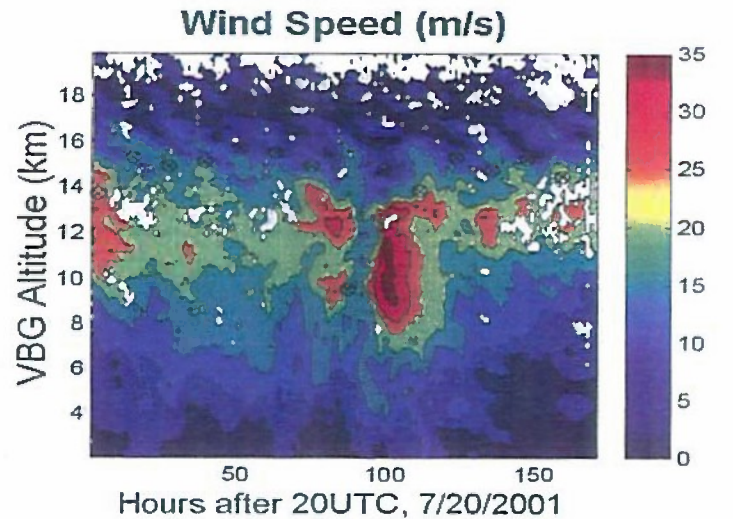
Satellite Imagery – Water Vapor





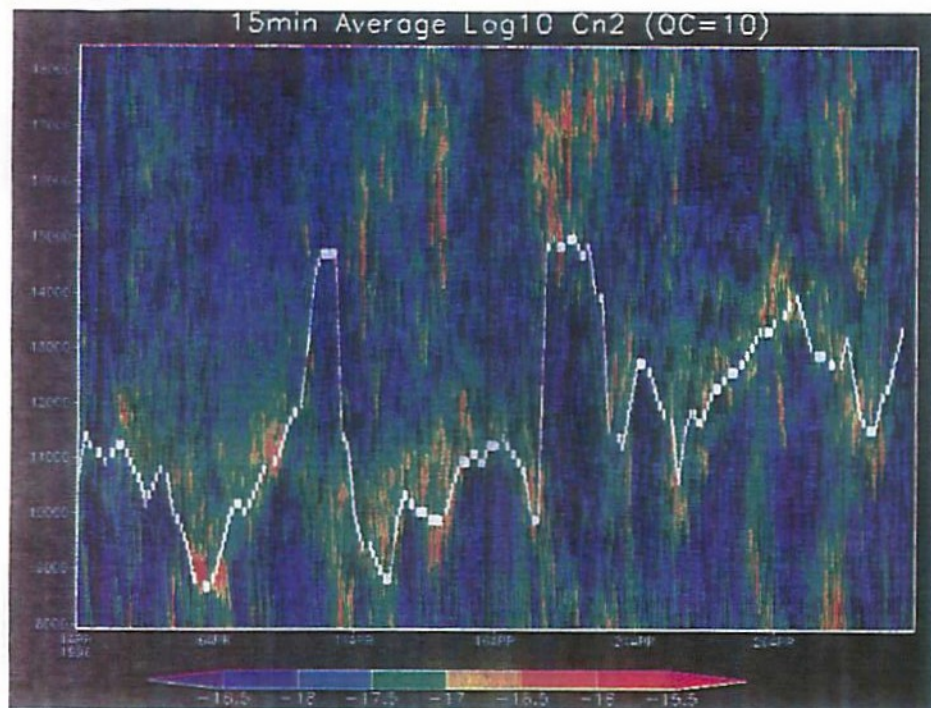
Vandenberg Radar Data

Nastrom, G. D. and F. D. Eaton, 2003: A case Study of Atmospheric Conditions at 4-19 km over Vandenberg Air Force Base during passage of a cyclone, JAM, Vol. 42, pp. 467-475.





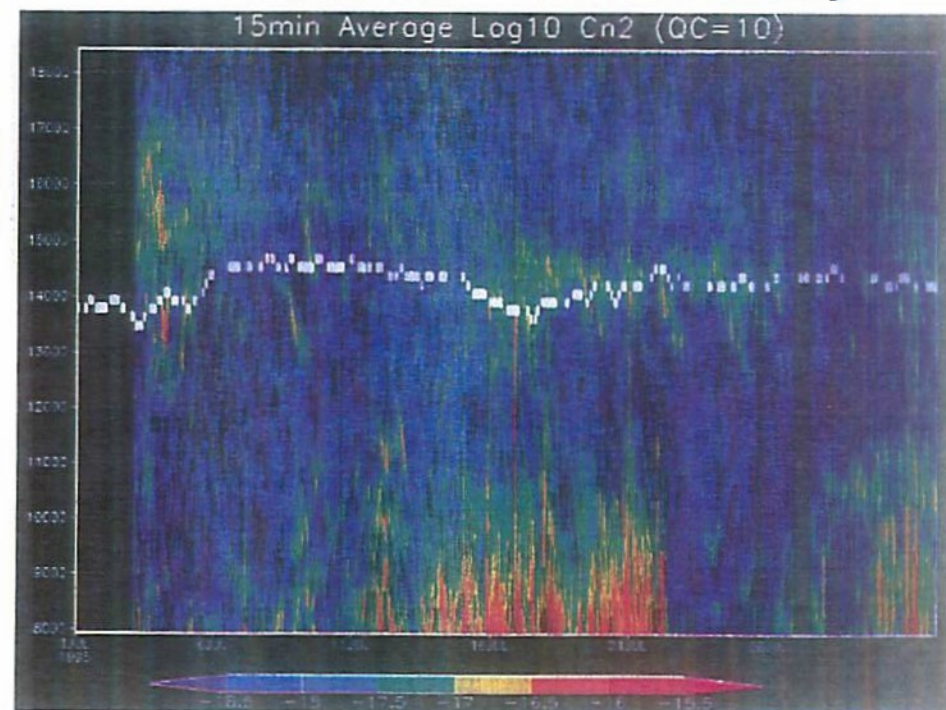
Seasonal Changes in Turbulence



Spring – Month of April

The white line represents the tropopause level

Summer – Month of July



WSMR SEASONAL MEANS OF LOG C_N^2 1991-1993

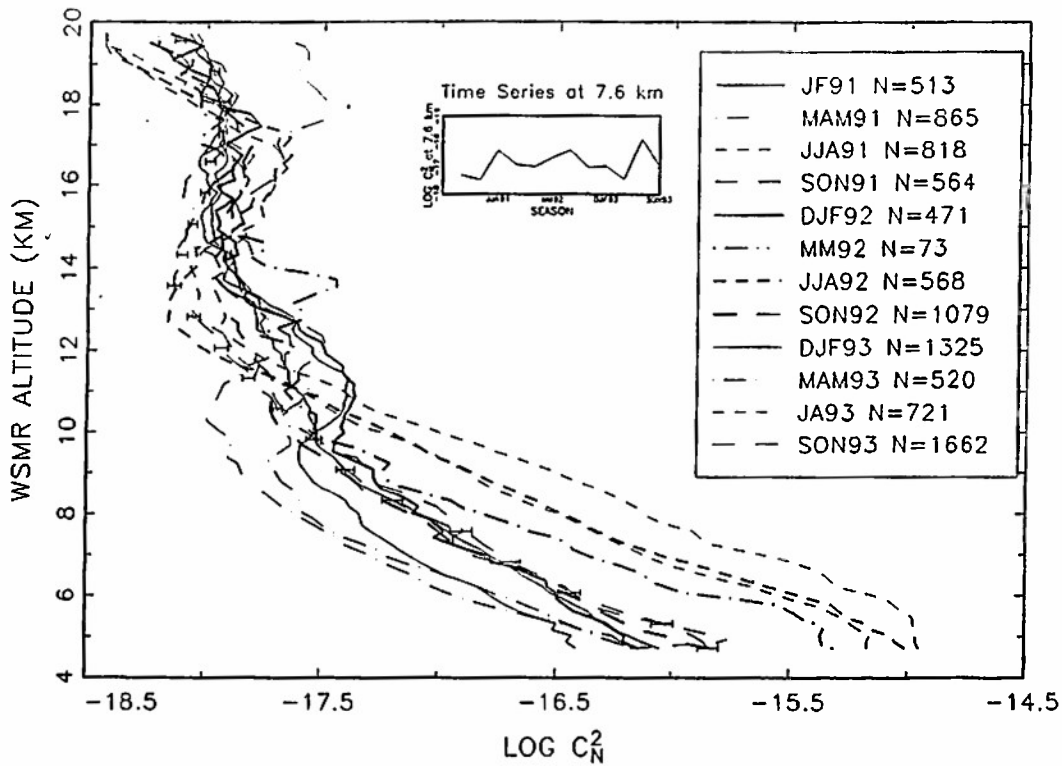


FIG. 10. Seasonal mean profiles of C_N^2 for 1991-93 at WSMR. Notice there is no obvious interannual trend. Here, N is the number of hourly means used at 7.6 km for each season; error bars are for autumn 1993 (SON93). The inset shows a time series at 7.6 km.

Nastrom, G. D., and F. D. Eaton, 1995: Variations of Winds and Turbulence Seen by the 50-MHz Radar at White Sands Missile Range, New Mexico, *Journal of Applied Meteorology*, Vol. 34, No. 10, pp. 2135-2148.

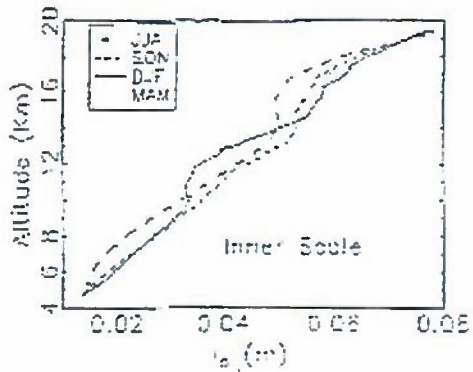


Figure 2. Seasonal vertical profiles of the inner scale of atmospheric turbulence derived from VHF radar measurements over a 4-year period.

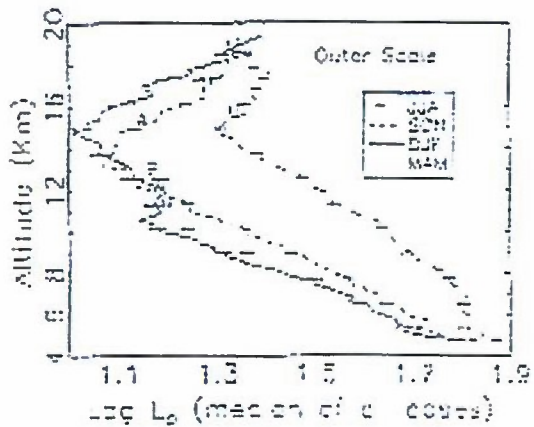
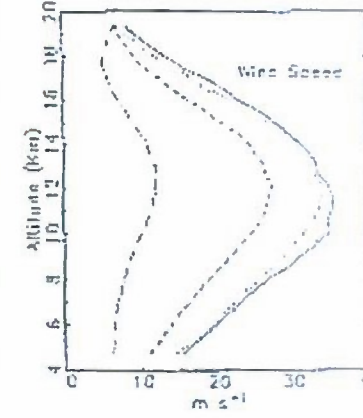
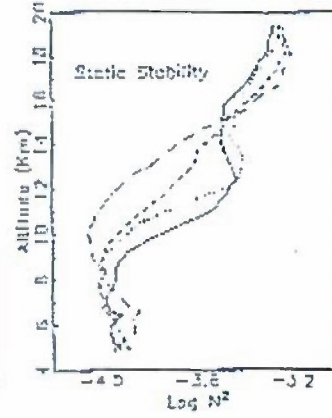
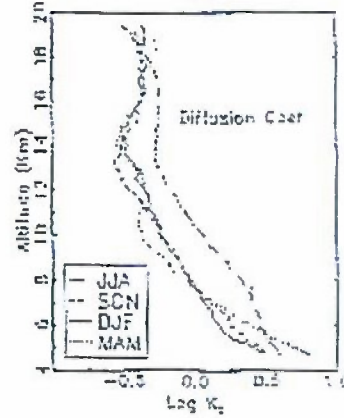
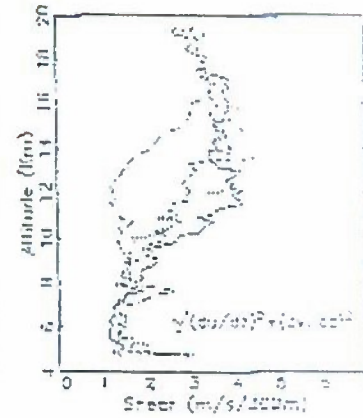
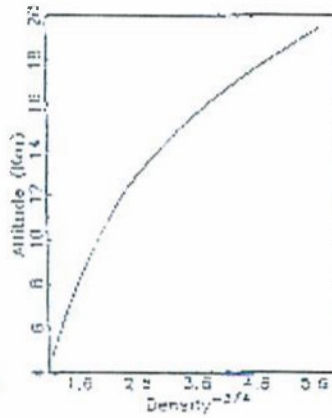
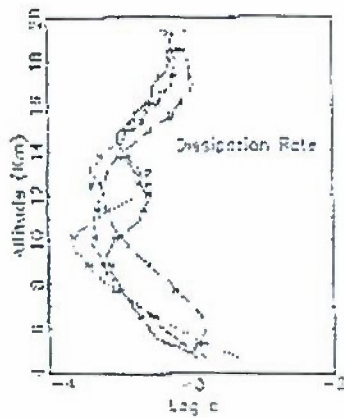


Figure 4. Seasonal profiles of the outer scale of atmospheric turbulence derived from VHF radar measurements over a 4-year period. The error bars plotted relative to each seasonal curve extend ± 1 standard error of the mean. Also indicated are symbols showing average seasonal turbulence heights.



Frank D. Eaton and Gregory D. Nastrom, 1998: Preliminary estimates of the vertical profiles of inner and outer scales from White Sands Missile Range, New Mexico, VHF radar observations, *Radio Science*, Vol. 33, No. 4, pp. 895-903.



FMCW Antennas

Eaton, F. D., S. A. McLaughlin, and J. R. Hines, 1995: A new frequency-modulated continuous wave radar for studying planetary layer morphology, *Radio Science*, Vol. 30, No 1, pp. 75-88.



Plate 1. The White Sands frequency-modulated continuous wave (FMCW) radar side-by-side 10-foot-diameter parabolic antennas mounted on a steerable mount.

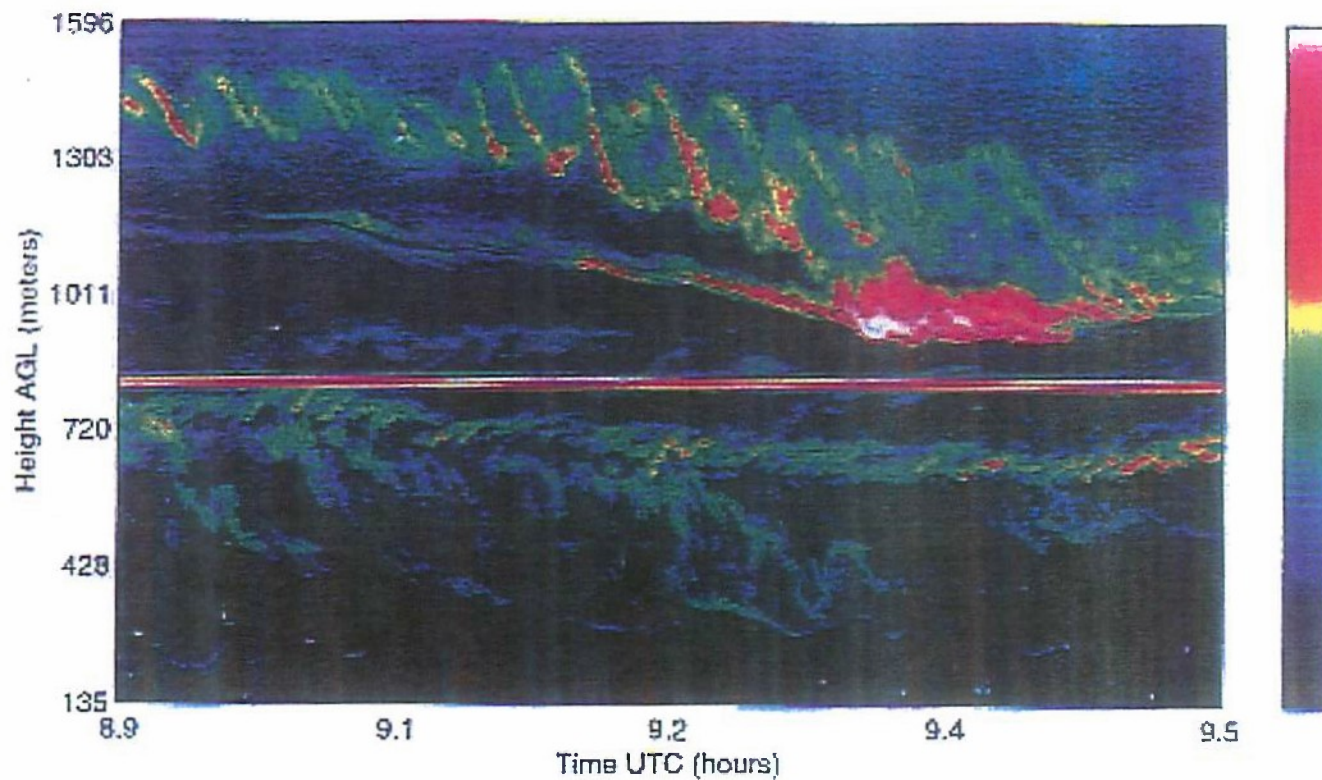


Plate 2. FMCW radar record showing the braided pattern of a Kelvin-Helmholtz instability on April 3, 1992. A color bar chart showing the order of colors used is included.

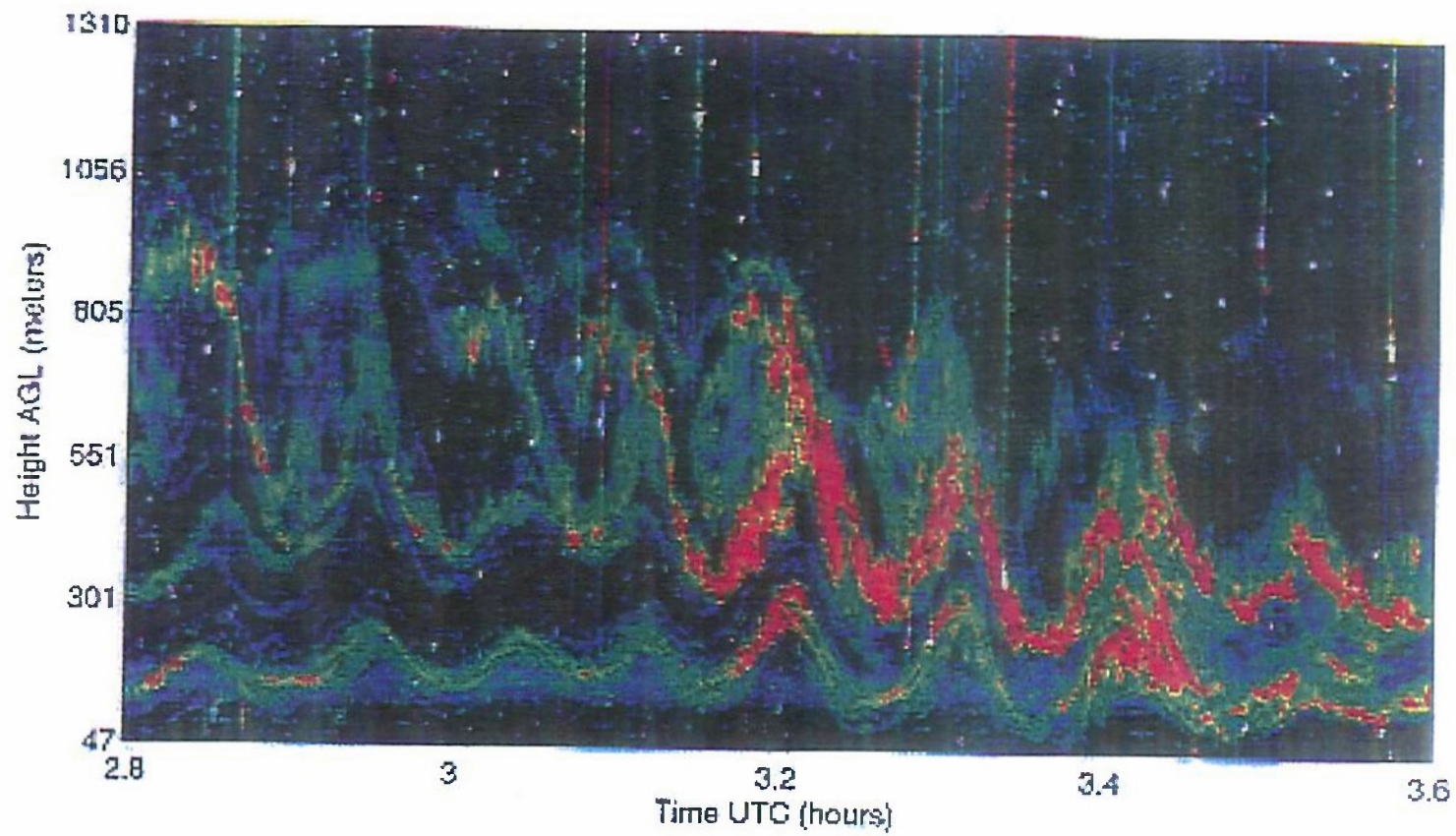


Plate 3. 15MCW radar record showing low-level waves on October 20, 1992.



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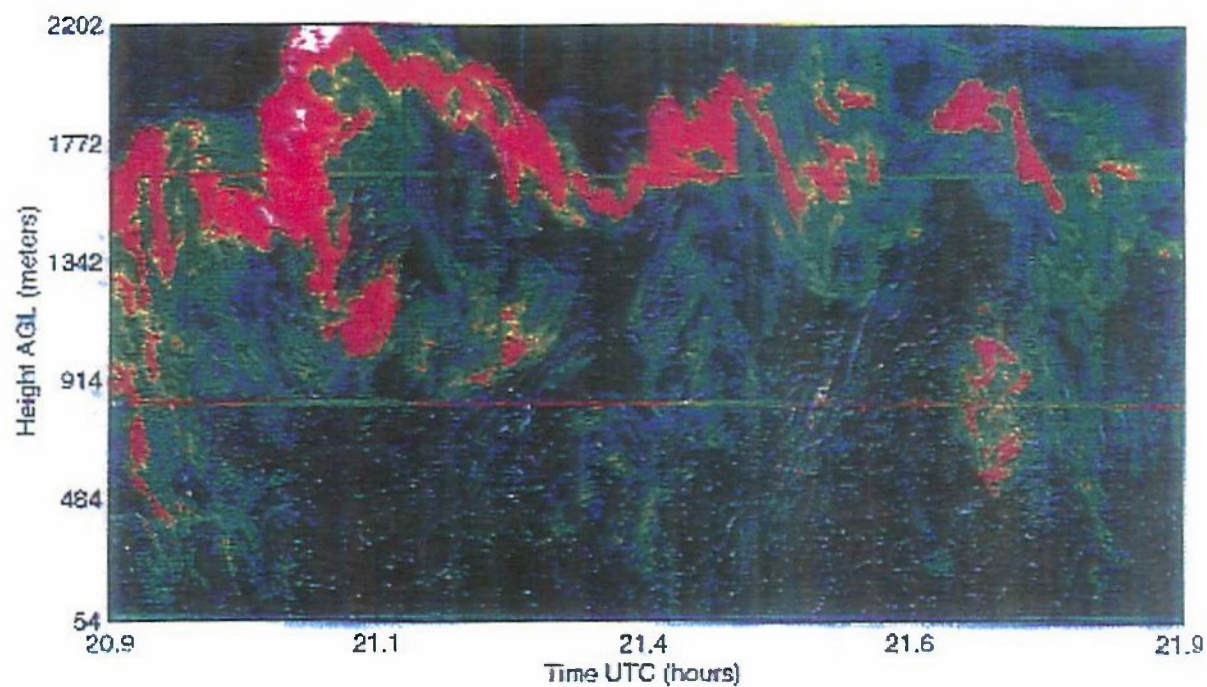


Plate 8. Midday boundary layer convection sensed by the FMCW radar on August 26, 1992. Insects act as tracers delineating the cell boundaries and providing flow visualization.

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