The initiation of thunderstorms along radar fine-lines

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It is becoming increasingly apparent that thunderstorms tend to break out in the afternoon along mesoscale convergence lines (e.g. Wilson et al. 1994). These lines are often visible as radar fine-lines, due to an elevated concentration of insects in the convective boundary-later (CBL). In the absence of significant topography, the fine-scale convergence along radar fine-lines is generally due to a density contrast in CBL airmasses across the fine-line. Sometimes this density difference is partly due to a humidity difference. In order to develop a sharp transition of a conserved property, such as water vapor, sustained convergence needs to occur with the CBL. These humidity boundaries (known as drylines) are common in the southwestern Great Plains of North America, but similar boundaries occur in Europe.

On the scale of 1-20 km, the definition of a dryline appears to be driven by density current dynamics. This conclusion arises from several case studies collected during the International H_2O Project (IHOP_2002). Of particular use is the Wyoming Cloud Radar (WCR) aboard the University of Wyoming King Air aircraft (WKA). The UWKA conducted several traverses perpendicular to drylines as they became more defined, sometimes prior to convective initiation (CI). The WCR mainly operated in profiling mode, with beams both below and above the aircraft. In situ thermodynamic data were interpreted in the context of the vertical structure of the radar 'fine-line'.

In each case we find that the virtual potential temperature (θ_v) gradient within the CBL is consistent with the slope of the echo plume, the solenoidal circulation (retrieved from dual-Doppler synthesis below the aircraft), and the direction and speed of propagation of the dryline. In one case the dryline alters course (from progressive to retrogressive), an event marked by a change in echo slope and a change in sign of the θ_v gradient. As such drylines are very similar to other mesoscale boundaries propagating in the CBL, such as outflow boundaries, sea breezes, and fronts. In fact it is quite possible that all fine-lines seen by radar in the CBL are associated with some θ_v gradient, whose origin may be hard to determine.

Overall, drylines and radar inferred fine-lines must be due to sustained convergence (Wilson et al. 1994, Geerts and Miao 2005), but it is often not clear what drives the mesoscale boundary-layer convergence (Wilson and Schreiber 1986, Droegemeier 1990, Brooks et al. 1992, Bluestein and Parker 1993). Without the full knowledge and understanding of dynamical processes prior to and at CI (Koch and McCarthy 1982), forecasters are only able to guess if a dryline, for example, will result in an outcome of convective storms.