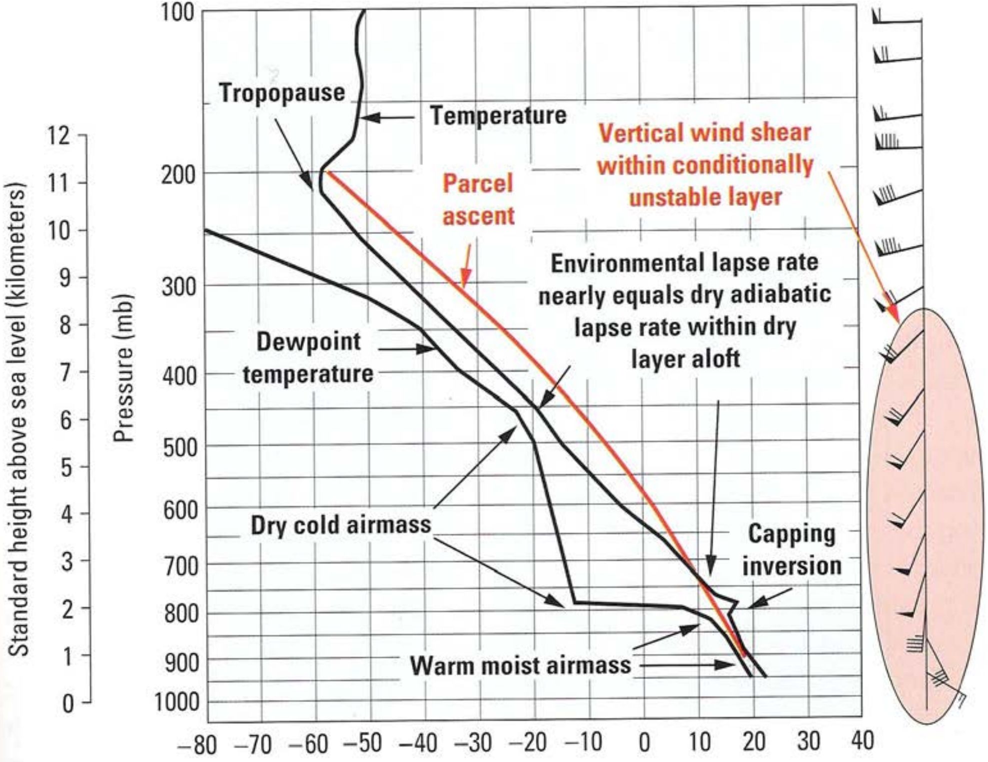


FIGURE 18.16
A typical sounding in the supercell environment showing a conditionally unstable atmosphere with warm, moist air in the lower troposphere, dry air in the middle troposphere, a capping inversion, and strong shear. The path of an unstable parcel ascending through this environment is shown in red.

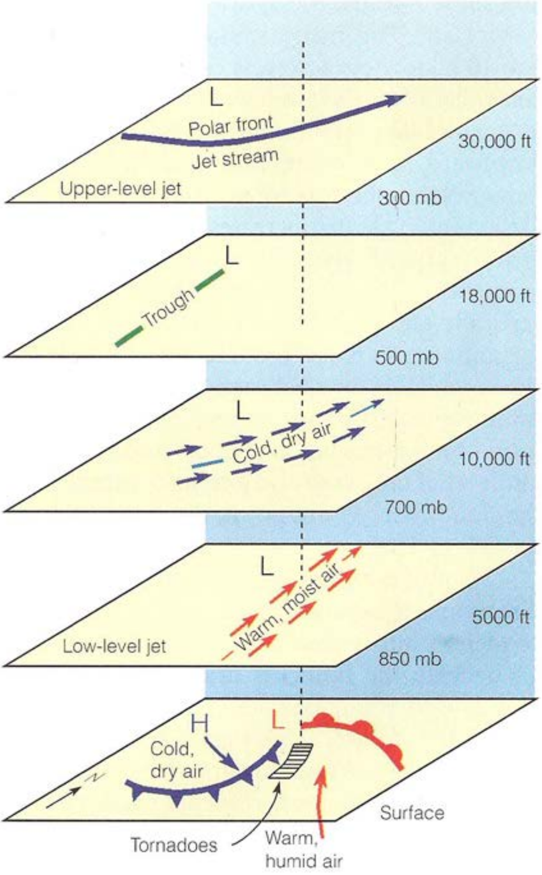


FIGURE 15.32
Conditions leading to the formation of severe thunderstorms that can spawn tornadoes.

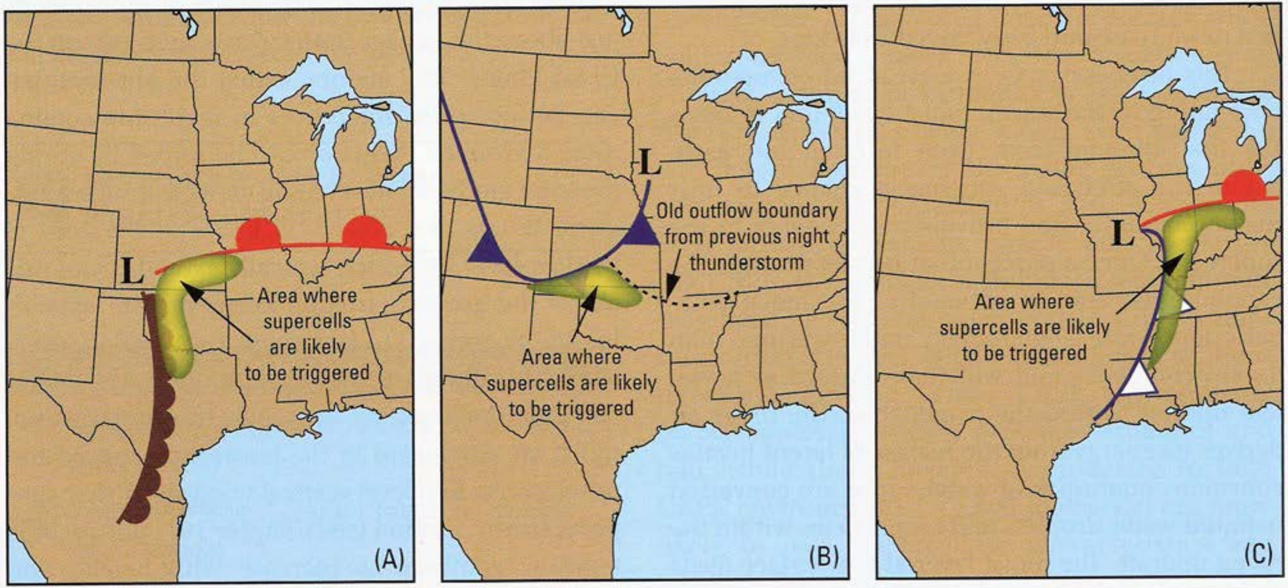


FIGURE 18.17 Examples of weather patterns favorable to supercell development. Supercells typically develop on warm side of boundaries, particularly near boundary intersections.

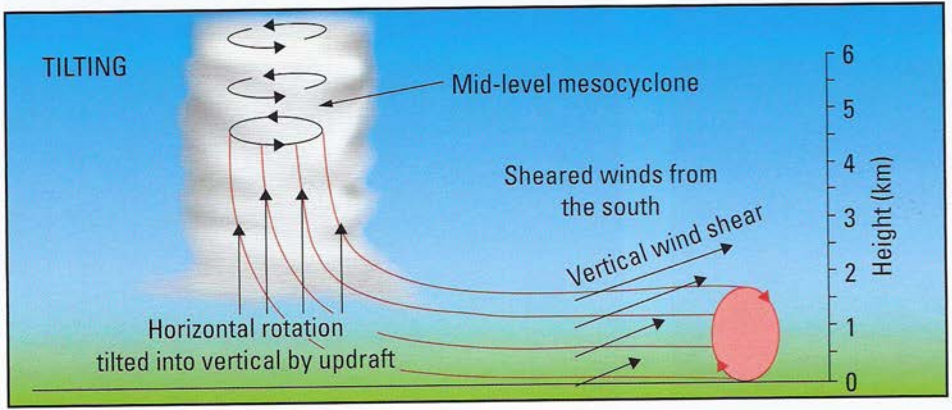


FIGURE 19.2 Supercell rotation requires the presence of vertical wind shear in the layer where air is buoyant. Vertical wind shear creates rotation with the axis of rotation parallel to the ground. The horizontal rotation associated with the vertical wind shear is tilted into the vertical by the developing updraft.

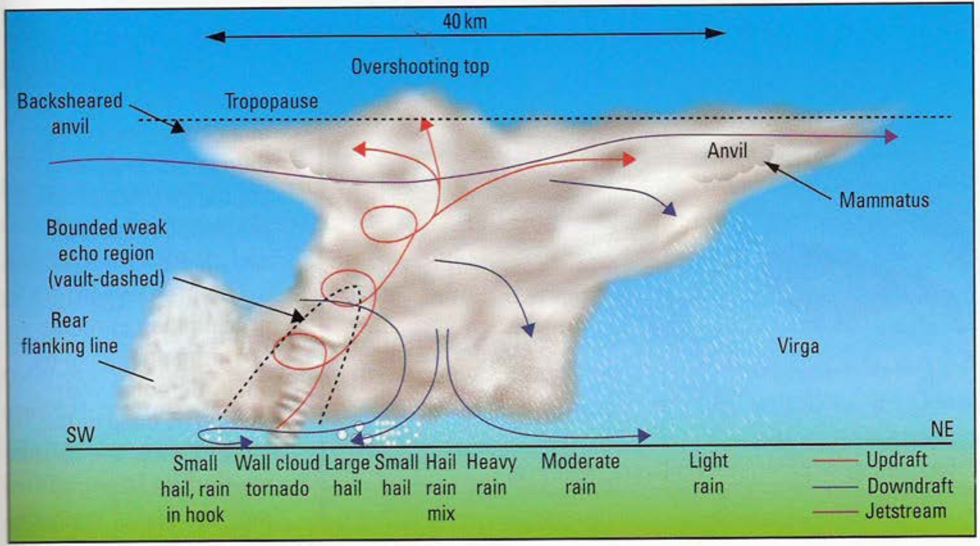


FIGURE 18.19 Cross section of a classic supercell thunderstorm from southwest to northeast showing structural features and the typical precipitation pattern. Red arrows indicate the rotating updraft (mesocyclone), and blue arrows show the downdraft. The purple arrow near the top denotes the jetstream flow at high altitudes.

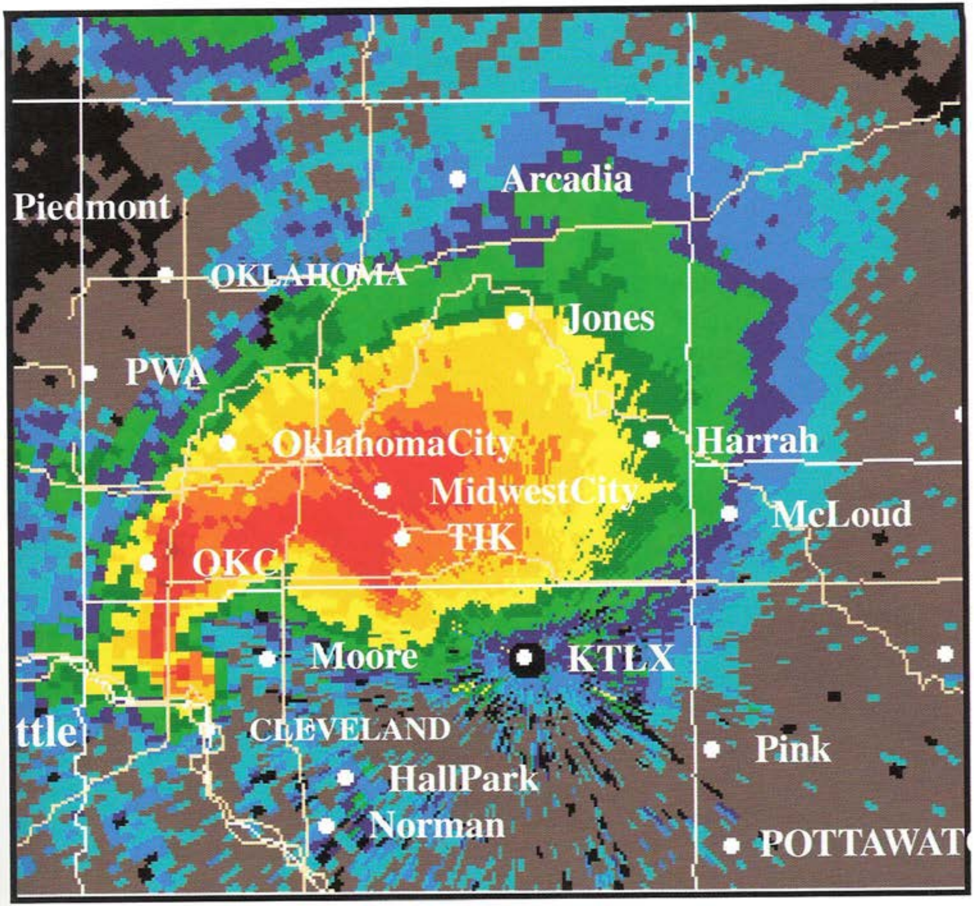


FIGURE 18.22 Radar reflectivity image of the supercell thunderstorm that devastated portions of the Oklahoma City, Oklahoma, metropolitan area on 3 May 1999. Note that the hook-shaped echo and debris signature are similar to the schematic in Figure 18.21.

FIGURE 18.20 A wall cloud.

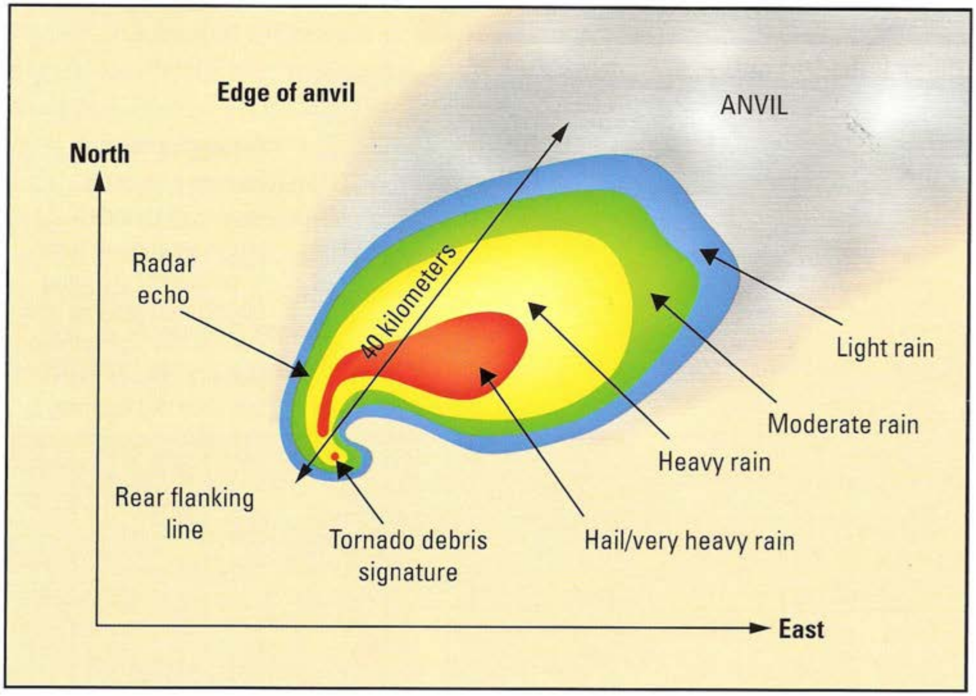


FIGURE 18.21 Plan view of a classic supercell thunderstorm showing the distribution of precipitation (colors) and clouds (gray). Within the colored region, precipitation particles are large enough to be easily detected with radar. The cusp of the hook denotes the updraft region. The strong echo near the end of the hook, called a "debris ball," is caused by flying debris created by the tornado.

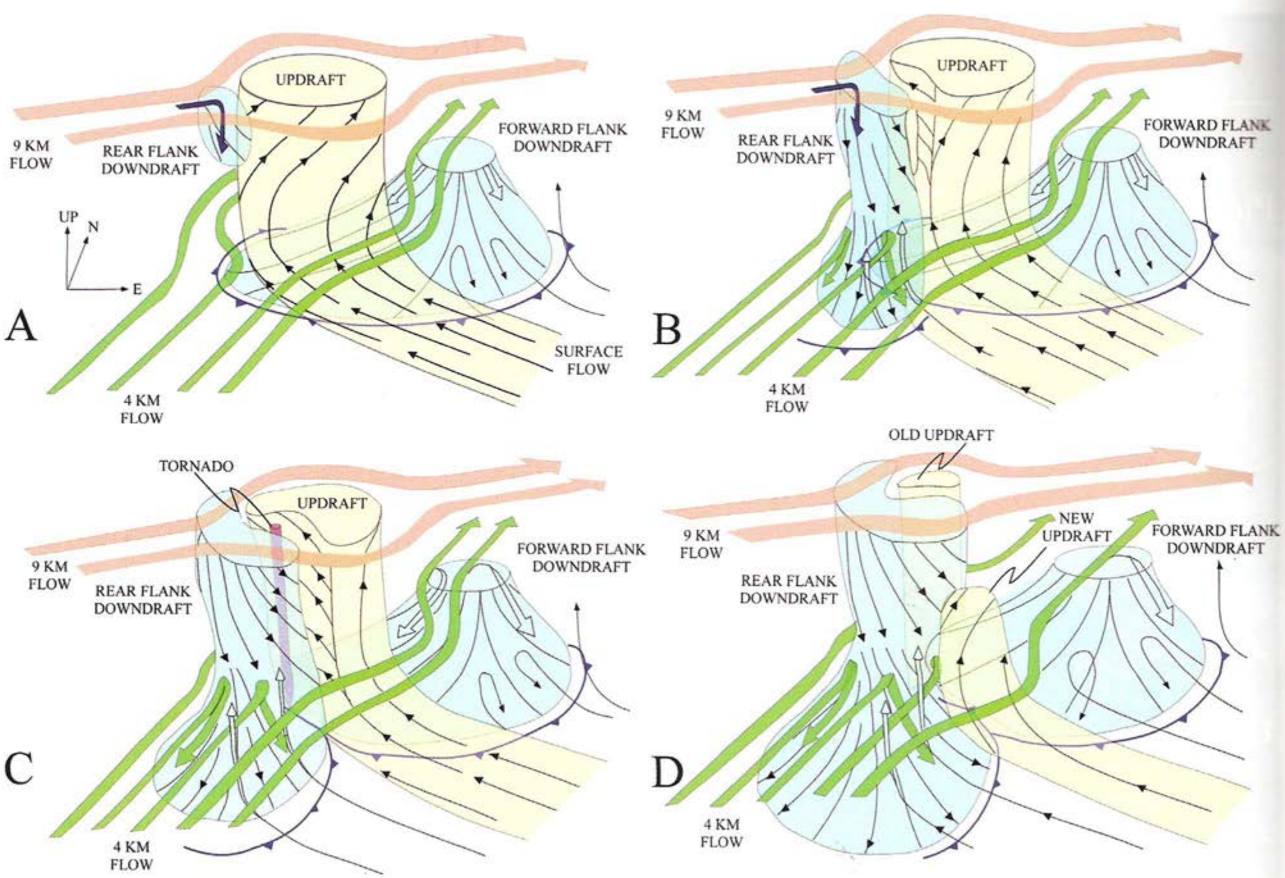
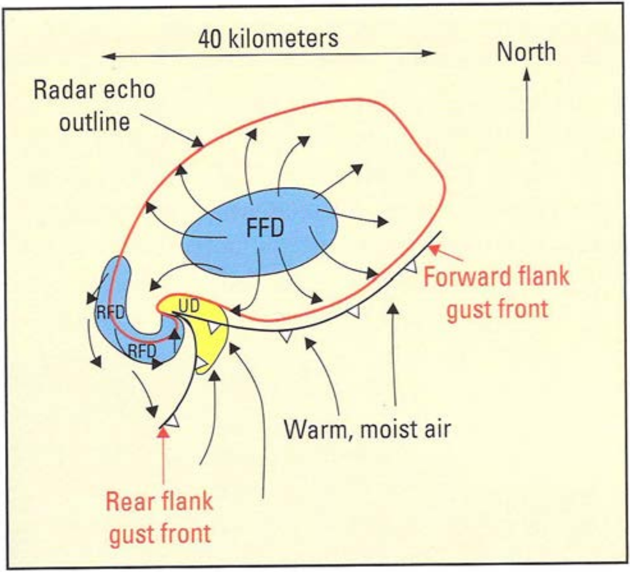


FIGURE 18.23 Schematic, three-dimensional depiction of evolution of a supercell thunderstorm. Updrafts/downdrafts and the tornado location are identified. Conventional frontal symbols are used to denote outflow boundaries (gust fronts) at the surface. Lines with arrows denote the flow relative to the storm. Blue regions denote downdrafts and yellow regions updraft. The orange and green arrows denote the flow at 9 km and 4 km, respectively. (A) shows the initial formation stage of the supercell with the forward flank downdraft formed and the rear flank downdraft developing. (B) shows the full formation of both forward and rear flank downdrafts. (C) models the mature supercell with a strong rotating updraft and tornado (red) located at the coupling of the updraft and rear flank downdraft. (D) depicts the decaying supercell storm—the rear flank downdraft wrapping around the updraft and cutting off the supply of warm, moist air. A new updraft is forming to the southeast of the previous updraft.


40 kilometers
North
Radar echo outline
FFD
RFD
RFD
UD
Forward flank gust front
Warm, moist air
Rear flank gust front

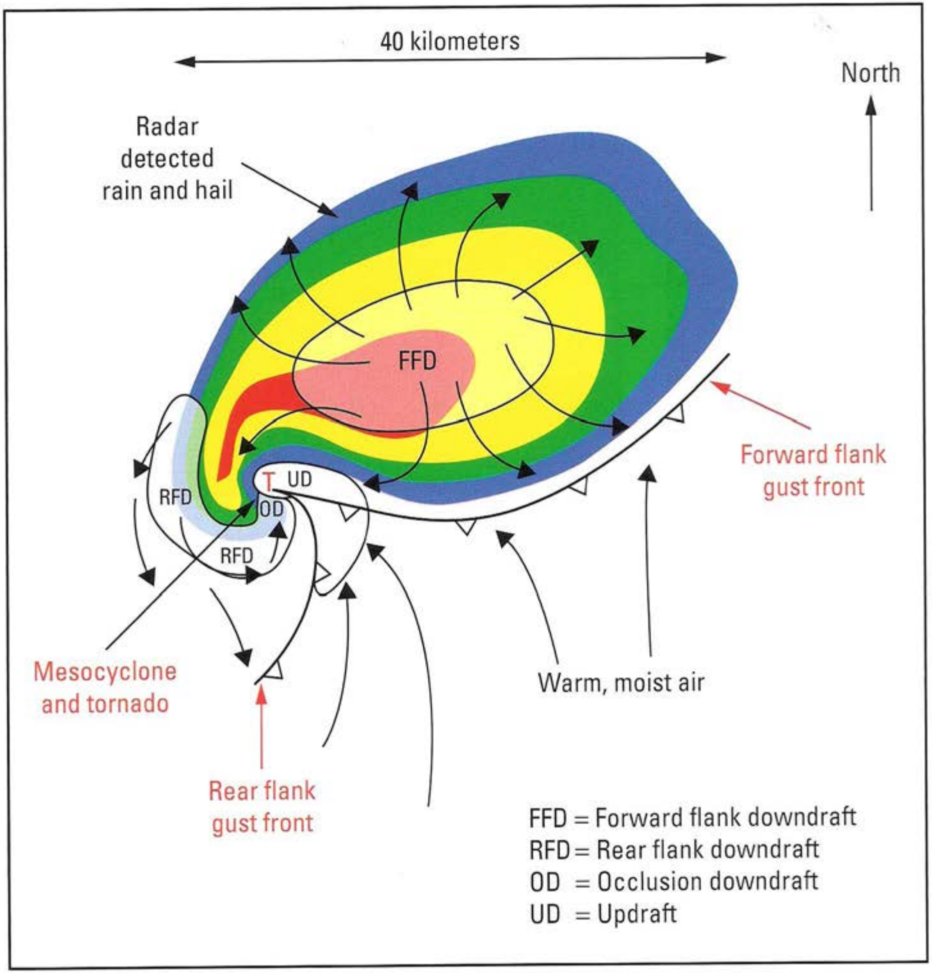


FIGURE 19.3 A plan view of a supercell thunderstorm. Color-coded areas denote precipitation (blue, light rain; green, moderate rain; yellow, heavy rain; red, very heavy rain and hail). The positions of the updraft, downdrafts, gust fronts, mesocyclone, and tornado (if present) are noted. The rear-flank downdraft (RFD) and updraft (UD) are shaded gray.

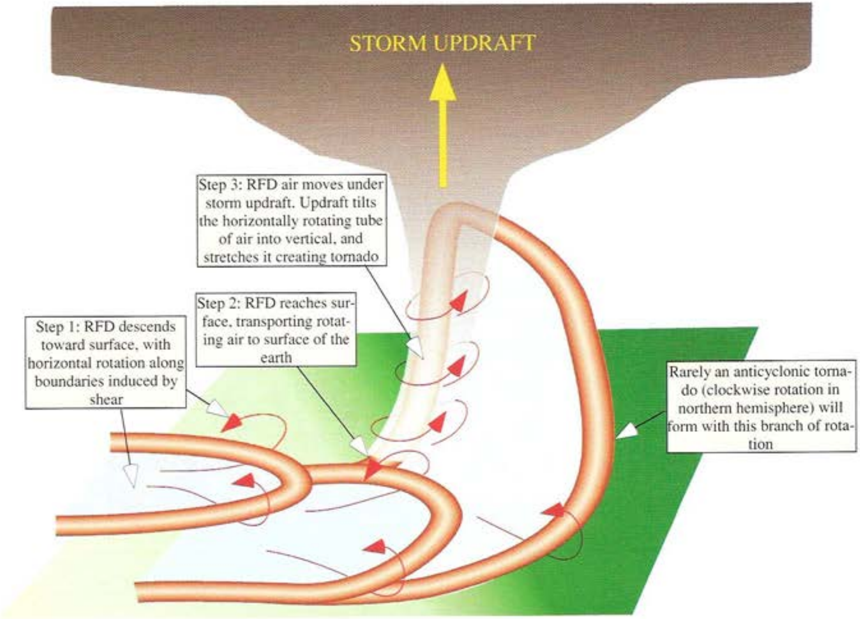


FIGURE 19.6 Illustration of how descending air within the rear-flank downdraft (represented by the light blue shading) generates rotation along its periphery (represented by the brown tubes) with the axis of rotation in the horizontal. After the descending air reaches the ground, the surface-based rotation at the gust front periphery moves under the updraft. Here the rotation is tilted upward as the forward region of the rear-flank downdraft is stretched upward into the updraft creating the tornado. On rare occasions, the clockwise-rotating branch of rotation on the opposite side of the rear-flank downdraft may be stretched upward into the updraft to form an anticyclonic tornado.

FIGURE 19.1 The life cycle of the Cordell, Oklahoma, tornado of 22 May 1981, viewed from the south. (A) Dust became airborne underneath the wall cloud at 5:20 PM. (B) A rotating dust column formed under the wall cloud and obscured any existent condensation funnel at 5:22 PM. (C) At 5:26 PM., a narrow condensation funnel became well developed and visible as the rotating dust column disappeared, perhaps because the tornado had moved away from a recently plowed field. (D) The tornado picked up a dust sheath again, surrounding the condensation funnel at 5:26 PM. (E) At 5:28 PM., the tornado roped out. (F) the tornado dissipated at 5:28 PM.

The VORTEX Experiments

Potential mechanisms that trigger rotation at the ground and the formation of a tornado have been difficult to establish because few observations have been available. To make scientific advances, researchers routinely chase supercell thunderstorms every year as they move across the plains, deploying suites of instrumentation in the path of tornadoes. The largest campaigns ever assembled to study tornadoes were the first and second "Verification of the Origins of Rotation in Tornadoes Experiments" called VORTEX (the spring tornado seasons of 1994 and 1995) and VORTEX2 (the spring tornado seasons of 2009 and 2010). VORTEX deployed mobile ground-based radars, meteorological instruments on chaser cars, and a special dual Doppler radar called ELDORA on a research aircraft operated by the National Center for Atmospheric Research. Eight tornadoes were examined at close range. Unprecedented data,

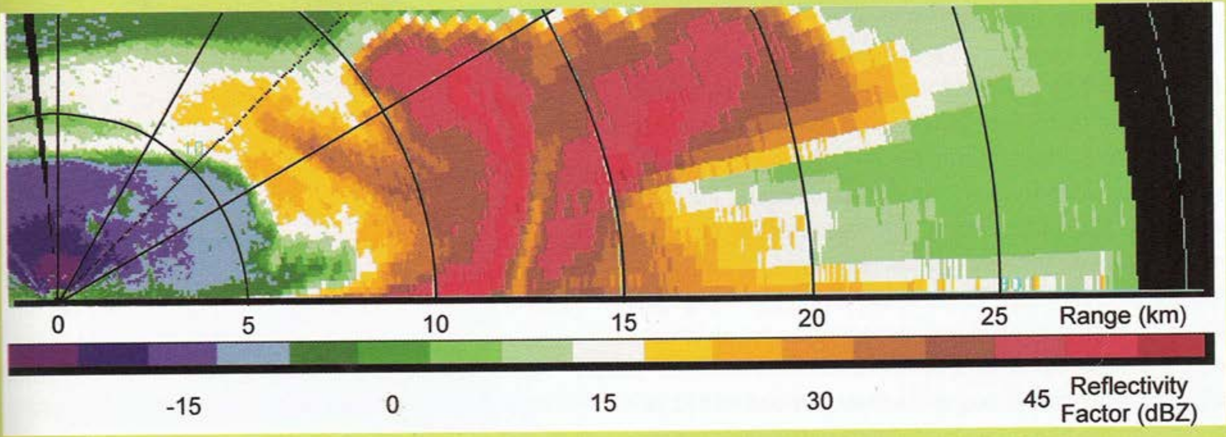


FIGURE 19A Vertical cross section of the radar reflectivity through a supercell thunderstorm and tornado near Friona, Texas, on 2 June 1995 measured by the ELDORA radar onboard the National Center for Atmospheric Research Electra aircraft. The data were collected during VORTEX, the Verification of the Origins of Rotation in Tornadoes Experiment.