The "Eye" of the Hurricane

Courtesy of NOAA

The "eye" is a roughly circular area of comparatively light winds and fair weather found at the center of a severe tropical cyclone. Although the winds are calm at the axis of rotation, strong winds may extend well into the eye. There is little or no precipitation and sometimes blue sky or stars can be seen. The eye is the region of lowest surface pressure and warmest temperatures aloft - the eye temperature may be 10 C [18 F] warmer or more at an altitude of 12 km [8 mi] than the surrounding environment, but only 0-2 C [0-3 F] warmer at the surface (Hawkins and Rubsam 1968) in the tropical cyclone. Eyes range in size from 8 km [5 mi] to over 200 km [120 mi] across, but most are approximately 30-60 km [20-40 mi] in diameter (Weatherford and Gray 1988). The eye is surrounded by the eyewall, the roughly circular area of deep convection which is the area of highest surface winds in the tropical cyclone. The eye is composed of air that is slowly sinking and the eyewall has a net upward flow as a result of many moderate - occasionally strong - updrafts and downdrafts. The eye's warm temperatures are due to compressional warming of the subsiding air. Most soundings taken within the eye show a low-level layer which is relatively moist, with an inversion above - suggesting that the sinking in the eye typically does not reach the ocean surface, but instead only gets to around 1-3 km of the surface.

The general mechanisms by which the eye and eyewall are formed are not fully understood, although observations have shed some light on the problem. The calm eye of the tropical cyclone shares many qualitative characteristics with other vortical systems such as tornadoes, waterspouts, dust devils and whirlpools. Given that many of these lack a change of phase of water (i.e. no clouds and diabatic heating involved), it may be that the eye feature is a fundamental component to all rotating fluids. It has been hypothesized (e.g. Gray and Shea 1973, Gray 1991) that supergradient wind flow (i.e. swirling winds that are stronger than what the local pressure gradient can typically support) present near the radius of maximum winds (RMW) causes air to be centrifuged out of the eye into the eyewall, thus accounting for the subsidence in the eye. However, Willoughby (1990b, 1991) found that the swirling winds within several tropical storms and hurricanes were within 1-4% of gradient balance. It may be though that the amount of supergradient flow needed to cause such centrifuging of air is only on the order of a couple percent and thus difficult to measure.

Another feature of tropical cyclones that probably plays a role in forming and maintaining the eye is the eyewall convection. Convection in tropical cyclones is organized into long, narrow rainbands which are oriented in the same direction as the horizontal wind. Because these bands seem to spiral into the center of a tropical cyclone, they are sometimes called spiral bands. Along these bands, low-level convergence is a maximum, and therefore, upper-level divergence is most pronounced above. A direct circulation develops in which warm, moist air converges at the surface, ascends through these bands, diverges aloft, and descends on both sides of the bands. Subsidence is distributed over a wide area on the outside of the rainband but is concentrated in the small inside area. As the air subsides, adiabatic warming takes place, and the air dries. Because subsidence is concentrated on the inside of the band, the adiabatic warming is stronger inward from the band causing a sharp contrast in pressure falls across the band since warm air is lighter than cold air. Because of the pressure falls on the inside, the tangential winds around the tropical cyclone increase due to increased pressure gradient. Eventually, the band moves toward the center and encircles it and the eye and eyewall form (Willoughby 1979, 1990a, 1995).

Thus the cloud-free eye may be due to a combination of dynamically forced centrifuging of mass out of the eye into the eyewall and to a forced descent caused by the moist convection of the eyewall. This topic is certainly one that can use more research to ascertain which mechanism is primary.

Some of the most intense tropical cyclones exhibit concentric eyewalls, two or more eyewall structures centered at the circulation center of the storm (Willoughby et al. 1982, Willoughby 1990a). Just as the inner eyewall forms, convection surrounding the eyewall can become organized into distinct rings. Eventually, the inner eye begins to feel the effects of the subsidence resulting from the outer eyewall, and the inner eyewall weakens, to be replaced by the outer eyewall. The pressure rises due to the destruction of the inner eyewall are usually more rapid than the pressure falls due to the intensification of the outer eyewall, and the cyclone itself weakens for a short period of time.