An unprecedented coincidence of microwave images obtained by the RadarSAT-1 synthetic aperture radar (SAR) and SeaWinds/QuikSCAT scatterometer, depicting the state of the sea surface, and NOAA/HRD aircraft reconnaissance including a Stepped Frequency Microwave Radiometer (SFMR) and on-board radars, occurred in Hurricane Katrina (2005) near the time of her peak intensity on August 28th, south of New Orleans. This unique collection of imagery and in situ measurements above, within and below the cloud enables quantitative analysis of internal dynamics and surface interactions in a category 5 hurricane, including its inner core which governs storm intensity on short time scales. Activity in the eye, a region mostly devoid of precipitation and containing the highest values of isobaric moist entropy, is noteworthy. It is shown that one day before landfall, strong surface winds occurred in certain regions of the eye in association with mesovortices originating in the eyewall, and solid-body rotation of the eye itself. A self-consistent interpretation of the eye’s enhanced capillary-wave roughness is obtained, confirming the magnitude and spatial variation of satellite-retrieved surface winds and the orientation of eye mesovortices. Implications for the eye’s moist entropy balance are noted.