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Lightning Outbreak and Convective Evolution within the Inner Core in Super Typhoon Haiyan (2013)

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Data from the World Wide Lightning Location Network (WWLLN), Joint Typhoon Warning Center (JTWC) best-track, the Multifunctional Transport Satellite (MTSAT), and the National Centers for Environmental Prediction (NCEP) global final analysis are used to analyze the environmental conditions, convective evolution and lightning outbreaks of Super Typhoon Haiyan (2013), the strongest storm landed at the Philippines on record. The distinction of lightning activity in Haiyan is the tremendous inner-core lightning production, with almost half (49%) occurred within the inner-core region. The inner-core lightning outbreaks occurred during three stages: the periods of rapid intensification (RI), the time period of maximum intensity (MI), and the weakening stage after it crossed the central Philippines. There was a dramatic preference for inner-core lightning to occur downshear-left of the storm center during the RI and MI outbreaks; while a preference of upshear during the weakening outbreak. High lightning flash rates were associated with low brightness temperatures from satellite observations and all the outbreaks were consistently collocated with the sharp decreases of median brightness temperatures in the inner core.

Haiyan developed under a favorable large-scale environmental conditions with high SST (30 °C), high moisture content (79%) and weak shear (4.5 m s-1). These favorable environment parameters promoted the RI just after Haiyan's formation. Convective bursts during the RI stage were located inside the radius of maximum wind (RMW) and moved gradually closer to the center along with the storm intensification. The favorable environmental conditions, placement of convective bursts and contraction of the eyewall maintained the long period (66 h) of the storm's RI. During the period of eyewall replacement cycle (ERC), there were no obviously extreme values of lightning rate in the inner core in Haiyan, which is in contrast to those previous studies that found eyewall lightning outbreak during ERC. The shear dropped to weak magnitude (<5 m/s) throughout the MI period after the ERC, when the second lightning outbreak occurred. Convective bursts were apparent and lightning flashes were more frequent during the MI stage then that during the RI period. A symmetric distribution of very low cloud top temperatures (< -85°C) expanded around the inner core, suggesting that the coverage and strength of intense convection was more intense after the ERC.

The final convective burst was displaced ∼50 km to the southeast of the center with a upshear orientation compared to the earlier bursts during the RI and MI stages. Due to the great changes of direction of wind shear, the motion vector turned to coincide with the shear direction, causing the deep convection occurred upshear (e.g. right-front quadrant of the storm motion). The asymmetric structure, the placement of deep convection core outside the RMW, and the large magnitude of wind shear led to the weakening of the storm. Haiyan changed its track just after the final inner-core lightning outbreak during the weakening stage.