A Comprehensive Study of Superstorms from 1957 to present

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We present a comprehensive study of all 39 superstorms (minimum Dst ≤ −250 nT) occurring from 1957 to present including analyzing their main phase developments, seasonal and solar cycle dependences, as well as their solar and interplanetary causes. We find that 87% of the superstorms have a multistep main phase development or are built upon preceding geomagnetic activities, and 90% of the superstorms occurred either near solar maximum or during the declining phase. For the superstorm association with solar activities, 54% of the superstorms were associated with X-class solar flares, 36% were associated with M-class flares, and 5% with C-class flares. All solar flares related to superstorms occurred in active regions, indicating the importance of active regions to superstorms. Most flares were located in the central meridian or slightly west of it as expected. For the interplanetary conditions leading to the development of the superstorm main phase, 95% of the 19 superstorms with available solar wind data are solely caused or partially caused by the sheath anti-sunward of an interplanetary coronal mass ejection (ICME), indicating the importance of the sheath structure in driving superstorms. For eight superstorms that have identifiable interplanetary shocks preceding the ICMEs, the shock normal angles were almost all quasi‐perpendicular. Larger shock normal angles statistically corresponded to greater superstorm intensities.