The Intracloud to Cloud-to-Ground Lightning Ratio Associated with Extreme Weather over the Contiguous United States

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Objective

• To estimate the intracloud (IC) to cloud-to-ground (CG) ratio (Z = IC/CG) of a large sample of extreme (i.e., severe) weather events over the contiguous United States (CONUS) using coincident Optical Transient Detector (OTD) and Lightning Image Sensor (LIS) and National Lightning Detection Network (NLDN) observations.

• Application: NOAA GOES-R Geostationary Lightning Mapper (GLM) – do statistically significant differences exist in Z among extreme weather type and intensity?

• Basic Science: Boccippio et al. (2001) identified positive anomalies in Z over the north-central and south-central CONUS (see below left). Large Z is associated with intense updrafts (elevated dipole hypothesis) and severe weather.

Annual Climatology of Z=IC/CG

• Regional behavior in Z persists in all severe categories

• Regional differences in LIS Z persists in all categories

• Similar to OTD, regional differences in LIS Z persist in all categories.

• Regional differences in mean severe weather magnitude are fairly minor and not always statistically significant or of expected sign.

• Z is not particularly sensitive to choice of Ip threshold.

• OTD/LIS flash detection efficiency estimated to be 73% to 93% (Cummins et al. 1998, Biagi et al. 2007). Spatially invariant DE correction made (Boccippio et al. 2001).

Data

• NASA Optical Transient Detector (OTD), 1995-1999

• Optical total lightning detection (day and night)

• Coverage up to 37°N over CONUS

• Spatial resolution at nadir 240 seconds used

• Spatial accuracy 20-40 km

• View time data composited to 0.5° × 0.5° grid (20-100 seconds used)

• Z can range from -1 (no OTD/LIS flashes) to 240 (no NLDN flashes)

• OTD has better 3- to 10-minute errors not uncommon

Methodology

• If for each severe storm report, temporal (seconds) and spatial (degrees) coincidence with OTD (or LIS) and NLDN flashes were assessed

• Flash coincidence sensitivity testing (within 300 - 1800 s (1800 shown) and 0.25° - 0.5° shown) of each report

• Order 10° severe storms reported over CONUS in each of the LIS and OTD domains

• Coincidence with LIS/OTD is between 1% and 10%, yielding 10° to 100 samples of total lightning activity around severe storms

• LIS (20-100 s) and OTD (20-240 s) view times composited as area-weighted averages of 0.5° × 0.5° grid box times within the analysis area. Used for flash rate calculations.

• Events with view times < 10 seconds discarded.

• Within 0.5° circle centered on extreme weather event during view time (that occurred within 1800 s (extreme weather event)).

• - DE-connected OTD (or LIS) events provide best lightning (IC/CG) count

• - CIS confirms NLDN and/or GLM counts

• - Z can range from -1 (no OTD/LIS flashes) to 240 (no NLDN flashes)

OTD Results

Table of OTD Z = IC/CG by region and severe weather type for both 10kA and 15kA NLDN Ip thresholds (1995-2001).

• CDF of OTD Z = IC/CG (1800s, 0.5°) by

LIS Results

Table of LIS Z = IC/CG by region and severe weather type for both 10kA and 15kA NLDN Ip thresholds (1995-2001).

• Mean LIS Z > Mean OTD Z in the south

• Similar to OTD, regional differences in LIS Z persist in all categories.

Conclusions

• Regional differences in Z associated with severe weather are apparent. North-central Z > South-central Z > South-east Z (North-east Z).

• Z is not particularly sensitive to choice of Ip threshold.

• Anomaly is still apparent in severe weather events.

• Z is not particularly sensitive to choice of Ip threshold.