The Kinematic and Microphysical Control of Storm Integrated Lightning Flash Extent

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Objectives

To investigate the kinematic and microphysical control of lightning properties, particularly those that may govern the production of nitrogen oxides (NOx) in thunderstorms, such as flash rate, type (intracloud [IC] vs. cloud-to-ground [CG] ) and extent.

Data and Methodology

- NASA MSFC Lightning Nitrogen Oxides Model (LNOM) is applied to North Alabama Lightning Mapping Array (NALMA) and Vaisala National Lightning Detection Network® (NLDN) observations following ordinary convective cells through their lifecycle.
- LNOM provides estimates of flash type, channel length distributions, lightning segment altitude distributions (SADs) and lightning NOx production profiles (Koshak et al. 2012).
- LNOM lightning characteristics are compared to the evolution of updraft and precipitation properties inferred from dual-Doppler (DD) and polarimetric radar analyses of UAHuntsville Advanced Radar for Meteorological and Operational Research (ARMOR, C-band, polarimetric) and KHTX (S-band, Doppler).

3 April 2007: Ordinary Convective Cell

- LNOM is applied in a Lagrangian sense (i.e., storm following) to well isolated thunderstorm cell on 3 April 2007 over Northern Alabama. Pulse severe (“1” hail) at 1637 UTC.
- LNOM Analysis Cylinders (LAC’s), ARMOR Reflectivity (4 km), NALMA Flash Origins

Time Evolution of Flash Properties

All Flashes

- Note decrease in flash rate from 1603 to 1608 UTC, but with return to pre-flash rate levels after 1612 UTC.

Cloud Flashes

- Cloud flashes preceded by a strong updraft (zh dBZ) column in developing updraft on west flank of cell on 3 April 2007 over Northern Alabama.

Ground Flashes

- Peak in CG flash rate and extent at 1610-1613 UTC, associated with descent of precipitation volume. Muted CG peak at 1634-1642 with coincident hail descent.

LNOM Analysis Cylinders (LAC’s), ARMOR Reflectivity (4 km), NALMA Flash Origins

Storm Integrated SAD and NOx Production over 1-Hour Lifecycle

SAD

- Cloud flashes dominate SAD aloft (>6 km) because of greater cloud flash numbers and differences in vertical extent by type.
- Differences in vertical extent of flashes over time (1615 to 1620 UTC). Note likely airshift around 1645.

NOx production

- Ground flashes dominate NOx production < 6 km height. For 6-8 km, NOx per CG flash >> NOx per IC flash because of greater cloud flash numbers and differences in vertical extent by type.

Summary and Discussion

- LNOM successfully run in Lagrangian mode for isolated, ordinary (pulse severe) thunderstorm.
- Vertical SAD and NOx production similar to long term means.
- Like flash rate, flash extent is generally correlated with production of precipitation ice and updraft at T < -10°C when measured well by Doppler network.
- Decrease in precipitation ice mass (grain and small hail) associated with peak in CG rate and extent (1610-1615 UTC).
- Inverse aspect of hail core associated with lower NOx flash rate and extent, especially at low levels (1634-1642 UTC).
- Updraft volume, precipitation type and processes (coalescence-freezing) at T < -10°C modulates flash (and likely charging) vertical extent.
- Lifiting of supersaturated drops to -10°C and colder common even when > 5 m s⁻¹ updrafts less widespread (e.g., 1627 UTC).
- Entrainment with typically lightning parameters.
- Large reflectivity gradient at heights above -10°C (indicated vertical extent of precipitation ice) resulted in narrow (jet-like) charging and lightning between 1603-1608 UTC.
- “1” hail reported at 1637 UTC with weak CG activity and limited vertical extent. Efficient wet growth of frozen drops?