Evaluation of Lightning Flash Rate Parameterizations for Colorado Storms Observed During DC3

AE33B-0341
Poster Hall (Moscone South)
11 December 2013, 1:40pm-6:00pm

Brett Basarab, Brody Fuchs, and Steven Rutledge

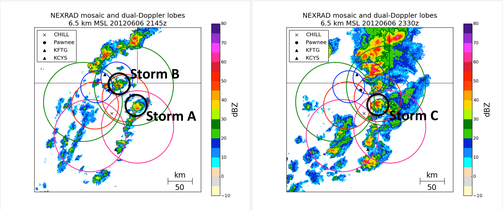
Department of Atmospheric Science, Colorado State University, Fort Collins, CO USA

Background

Accurate prediction of lightning activity in thunderstorms is important in order to quantify the amount of nitrogen oxides ($NO + NO_2 = NO_x$) produced by lightning (LNO_x). Many cloud-resolving model studies rely on flash rate parameterizations to predict lightning activity and LNO_x since the processes leading to charge separation and lightning discharge are difficult to explicitly represent in models. This study evaluates several flash rate parameterizations by comparison to observations for three Colorado storms during the Deep Convective Clouds and Chemistry Experiment (DC3). Observed flash rates were inferred from Lightning Mapping Array (LMA) detected sources using a flash counting algorithm. Some parameterizations are modified and retested by combining DC3 data with previous storm-total lightning datasets. We also present preliminary tests of new flash rate-storm parameter relationships calculated from DC3 data.

Data and Methods

- Three storms observed on 6 June 2012 in northeastern CO:
  Storm A: 21:05z – 21:55z
  Storm B: 21:30z – 23:30z
  Storm C: 23:06z – 00:18z
- Tracked storms based on NEXRAD mosaic composite reflectivity; computed flash rates using flash counting algorithm under development at CSU (Brody Fuchs) and Texas Tech University (Eric Bruning)



Tested six parameterizations:

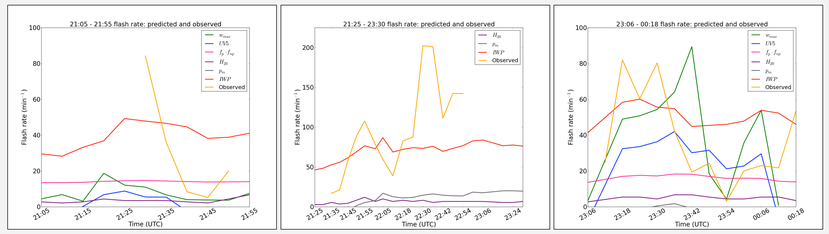
1. Maximum Vertical Velocity (m/s):	$f = (5.0\times10^{-6})\times w_{max}^{4.5}$	**Price and Rind (1992)**
2. Updraft volume > 5 m/s (m³):	$f = (6.75\times10^{-11})\times UV5 - 13.9$	**Deierling and Petersen (2008)**
3. Max height of 20-dBZ echo (km):	$f = (3.44\times10^{-5})\times H_{20}^{4.9}$	**Price and Rind (1992)**
4. Precipitation ice mass (kg):	$f = (3.4\times10^{-8})\times p_m - 18.1$	**Deierling et al. (2008)**
5. Ice mass flux product (kg m s⁻²):	$f = (9.0\times10^{-15})\times(f_p \cdot f_{np}) + 13.4$	**Deierling et al. (2008)**
6. Ice water path (kg m⁻²):	$f = 33.33\times IWP - 0.17$	**Petersen et al. (2005)**

- **Modified existing parameterizations:** Combined data from STEPS, STERAO-A, and northern Alabama (Deierling and Petersen (2008) and Deierling et al. (2008)) with DC3 data to modify existing UV5, P_m, and ice mass flux product parameterizations
- **Tested new parameterizations:** Used only DC3 data to develop new relationships between IWP, graupel echo volume (GEV) and 30-dBZ echo volume (30-dBZ EV)

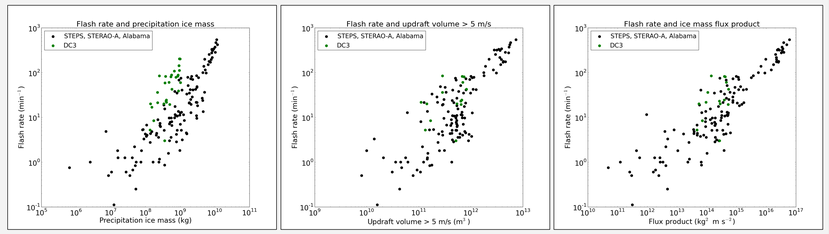
Results

- **Existing parameterizations:** Poorly predict flash rate for storm A and storm B. W_{max} slightly over-predicts the magnitude of the peak flash rate for storm C and lags this observed flash rate peak.

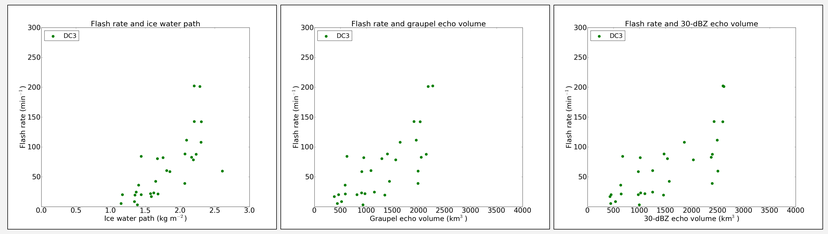
Storm A **Storm B** **Storm C**



- **Modified parameterizations:** For linear flash rate-storm parameter relationships (UV5, P_{flux}, P_m) investigated how trends were affected by Colorado DC3 data.



- **New parameterizations:** For DC3 data only, observed correlations between flash rate and IWP, GEV, and 30-dBZ EV.



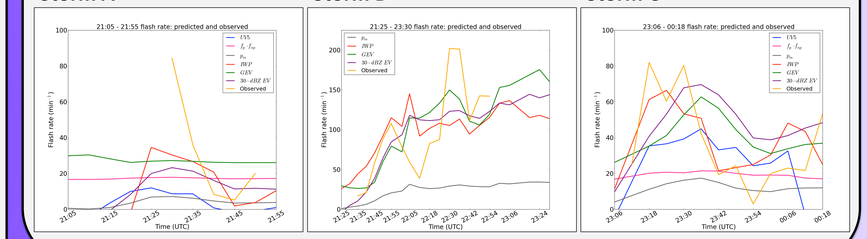
- **Trends:** The following trends were calculated using data plotted above

Storm parameters	Equation	r-value
1. Precipitation ice mass (kg):	$f = (3.12\times10^{-8})\times p_m - 0.8$	0.88
2. Updraft volume > 5 m/s (m³):	$f = (6.69\times10^{-11})\times UV5 - 10.5$	0.93
3. Ice mass flux product (kg m s⁻²):	$f = (8.93\times10^{-15})\times(f_p \cdot f_{np}) + 16.6$	0.96
4. Ice water path (kg m⁻²):	$f = 98.19\times IWP - 111.1$	0.73
5. Graupel echo volume (km³):	$f = (3.72\times10^{-5})\times GEV^2 - 0.0335\times GEV + 33.6$	0.77
6. 30-dBZ echo volume (km³):	$f = 0.0518\times(30\text{-}dBZ\ EV) - 11.8$	0.74

Discussion

The modified IWP parameterization better predicts the first flash rate peak, but not the second, for storm B; it predicts flash rate reasonably well for storm C (plots below). GEV and 30-dBZ EV predict the general flash rate trend for storm C. In all storms, the observed flash rate tends to fluctuate more strongly than predicted. This behavior is most evident for storms A and B and suggests that simple flash rate parameterizations may not adequately predict lightning behavior in all storms. The generally good agreement between the Deierling et al. (2008) data and DC3 data suggests that our flash counting algorithm is accurately identifying flashes.

Storm A **Storm B** **Storm C**



Summary

Lightning flash rate parameterizations were tested against observations for three Colorado storms during DC3. While these existing parameterizations did not predict flash rates well in general, modified parameterizations that included DC3 data yielded some improvement (although these results are preliminary and limited to three storms). Additional DC3 cases will be considered in order to develop more robust relationships between flash rates and storm parameters. We plan to continue to refine the flash counting algorithm described above for more accurate determination of flash rates. This work merits further investigation into the relationship between LNO_x and the spatial and size distribution of flashes within storms.

References:

1. Deierling et al. (2008), The relationship between lightning activity and ice fluxes in thunderstorms, *J. Geophys. Res.*, **113**, D15210, doi:10.1029/2007JD009700.
2. Deierling, W., and W. A. Petersen (2008), Total lightning activity as an indicator of updraft characteristics, *J. Geophys. Res.*, **113**, D16210, doi:10.1029/2007JD009598.
3. Petersen et al (2005), TRMM observations of the global relationship between ice water content and lightning, *Geophys. Res. Lett.*, **32**, L14819, doi:10.1029/2005GL023236.
4. Price, C., and D. Rind (1992), A simple lightning parameterization for calculating global lightning distributions, *J. Geophys. Res.*, **97**(D9), 9919–9933, doi:10.1029/92JD00719.

This work is supported by NSF grant AGS-1010657.