A WRF-Chem Flash Rate Parameterization Scheme & LNO_x Analysis of the 29-30 May 2012 Convective Event in Oklahoma During DC3

Kristin Cummings[1, 2], Kenneth Pickering[1,3], Mary Barth[4], Megan Bela[5], Yunyao Li[1], Dale Allen[1], Eric Bruning[6], Don MacGorman[7], Steven Rutledge[8], Brody Fuchs[8], Andrew Weinheimer[4], Ilana Pollack[9], Thomas Ryerson[9], Heidi Huntrieser[10]

(1) University of Maryland, College Park, MD, (2) NASA/KSC, Kennedy Space Center, FL, (3) NASA/GSFC, Greenbelt, MD, (4) NCAR, Boulder, CO, (5) University of Colorado, Boulder, CO, (6) Texas Tech University, Lubbock, TX, (7) NOAA/NSSL, Norman, OK, (8) Colorado State University, Fort Collins, CO, (9) NOAA CSD, Boulder, CO, (10) Institut für Physik der Atmosphäre, Deutsches Zentrum für Luft-und Raumfahrt, Oberpfaffenhofen, Germany

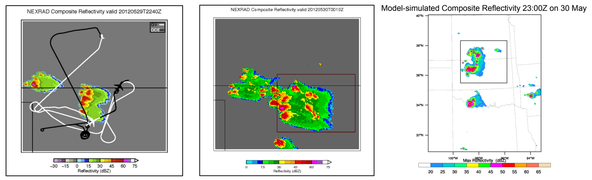
Objectives

To study the 29-30 May 2012 deep convective storm observed during the Deep Convective Clouds and Chemistry (DC3) experiment over Oklahoma, its convective transport of trace gases, and associated lightning occurrence and production of nitrogen oxides (NO_x). The key objectives include:

- Simulate the observed storm using WRF-Chem
- Compare the physical features of the simulated storm against aircraft and ground-based observations
- Add flash rate parameterization schemes (FRPSs) to the model and identify the best match to observations
- Determine NO production scenario for IC and CG flashes following a lightning-NO_x (LNO_x) scheme

Background

The storm system developed around 21Z on 29 May along the Kansas/Oklahoma border and continued until 04Z on 30 May. The aircraft (DC8, GV, and Falcon) sampled the storm and its environment from ~20Z on 29 May to ~01Z on 30 May. The DC8 focused on storm inflow and outflow, while the GV concentrated on outflow.



FRPSs are based on a simulated thunderstorm's physical features. Six types of FRPSs have previously been used in cloud-resolving models:

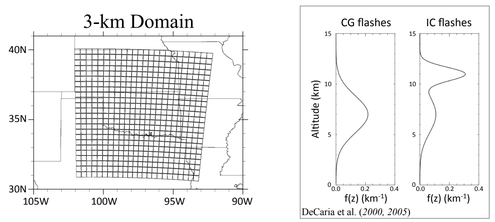
- Ice water path (*Petersen et al., 2005*)
- Cloud top height (*Price & Rind, 1992*)
- Maximum vertical velocity (*Price & Rind, 1992*)
- Updraft volume (*Deierling & Petersen, 2008*)
- Ice mass flux product (*Deierling, 2006; Deierling et al., 2008*)
- Precipitation ice mass (*Deierling et al., 2008*)

In model-simulated storms, LNO_x is placed in the:

- Vertical along typical IC and CG lightning flash channel Gaussian distributions
- Horizontal based on reflectivity ≥ 20 dBZ

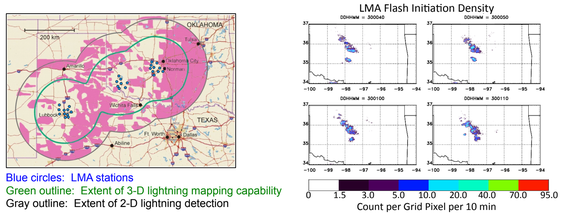
WRF-Chem

- Nested domains: 15-km and 3-km
- Initialize with DART and GFS for boundary conditions
- Morrison microphysics scheme, YSU PBL scheme, RRTMG radiation scheme
- Coarsely prescribed IC:CG ratios (*Boccippio et al. 2001*)
- FRPS based on maximum vertical velocity (*Wmax*)
- DeCaria et al. (*2000, 2005*) LNO_x scheme



Observations

- National Lightning Detection Network (NLDN): Used CG flash data
- Oklahoma Lightning Mapping Array (LMA): Flash initiation density data at 3-km horizontal and 5-min temporal resolution
- NEXRAD level II regional 5-min data (*C. Homeyer*)



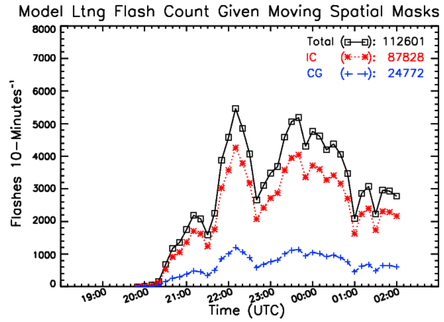
Methodology

- Created moving spatial masks at 10-min intervals for comparison of observed and model-simulated storms
- Used offline calculations, with adjustment factors, to analyze the six FRPS trends
- Calculated NLDN total flashes given NLDN CG flashes and mean IC:CG ratio for the storm region (3.9 ± 0.49), which is based on Boccippio et al. (*2001*)

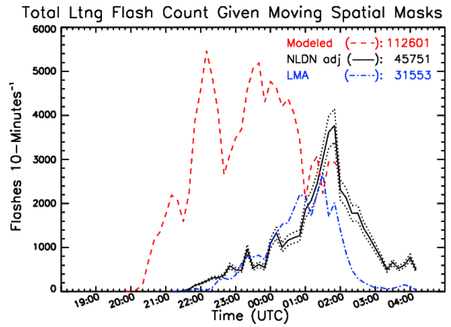
$$Total\ flashes = CG\ flashes \times [1/0.93]\ NLDN\ DE \times [IC{:}CG\ ratio + 1]$$

- Compared flash rate trends over the observed and model-simulated storm's lifetime

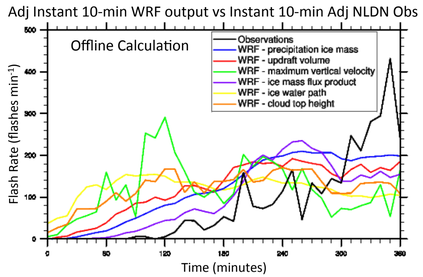
Results



- Model-simulated flashes, based on *Wmax*, appear to start one hour before the initial flashes observed by the NLDN and LMA



- *Wmax* FRPS overestimates both lightning detection networks



- Observed trend is most similar to *flux product*, *precipitation ice mass*, and *updraft volume*
- Primary peaks in *Wmax* and *ice water path* occur before the observed peak
- Magnitude of primary peak in observations does not match any of the FRPSs

Conclusions

	CG Flashes	Total Flashes	Time Period (UTC)	Model Overestimates by
NLDN	8,679	44,406	21:10-04:10	~2.5
LMA	---	31,553	21:10-04:10	~3.5
Model-Simulated	24,772	112,601	19:50-02:00	---

- Model overestimate of observed flashes may be due to:
  - Area of model-simulated storm exceeding the area of the observed storm by roughly a factor of 2
  - Observed storm passes over northern edge of LMA

Flash Rate Parameterization Scheme	Total Flashes Prior to Scaling	Scaling Factor
Maximum Vertical Velocity	3,951	1.1310
Cloud Top Height	708	6.3138
Updraft Volume	21,118	0.2116
Ice Water Path	4,452	1.0035
Precipitation Ice Mass	164,749	0.0271
Ice Mass Flux Product	36,745,336	0.0001

Observations: 4,468 adjusted NLDN total flashes over storm lifetime (21:10Z to 04:10Z)
Model: Time period is 19:50Z to 02:00Z

- Offline calculations indicate the *Wmax* FRPS:
  - Needs the least adjustment to match observed NLDN total flashes at each 10-min time step
  - Seems to coincide with observed peaks, if model-simulated trend begins 80 min later
  - Needs to be scaled up, but scaled down when used online in the model. This may partly be due to the first minute of observed total flashes at each 10-min interval being used to coincide with the instantaneous storm parameter data generated at each 10-min model time step.

Future Work

- Perform a trace gas simulation and analysis of NO_x, CO, and O_3 using WRF-Chem
- Compare model-simulated LNO_x against aircraft measured NO_x
- Determine NO production scenario per IC and CG flash that best matches aircraft observed NO_x mixing ratios
- Investigate O_3 changes downwind of flight