OPTICAL PULSE CHARACTERISTICS IN AN INHOMOGENEOUS ATMOSPHERE

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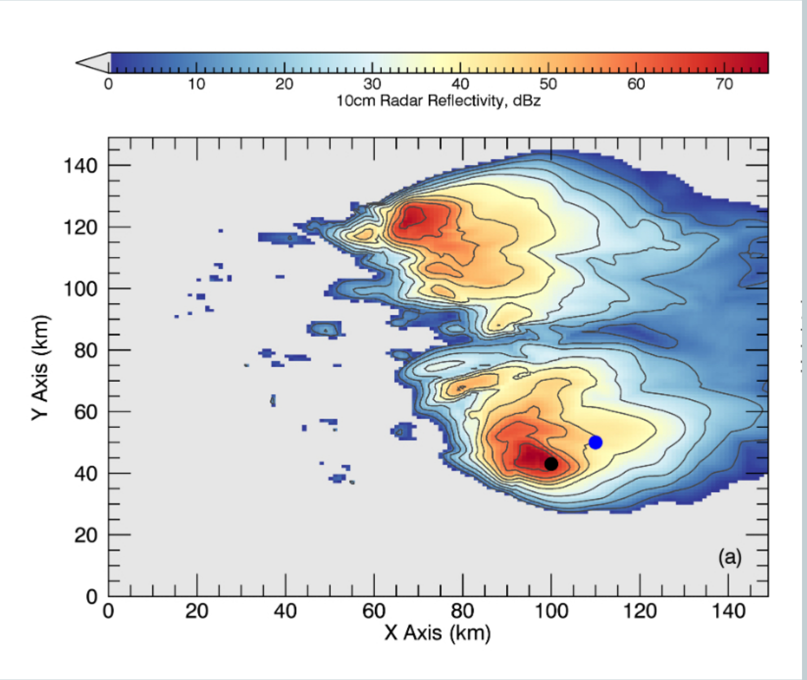
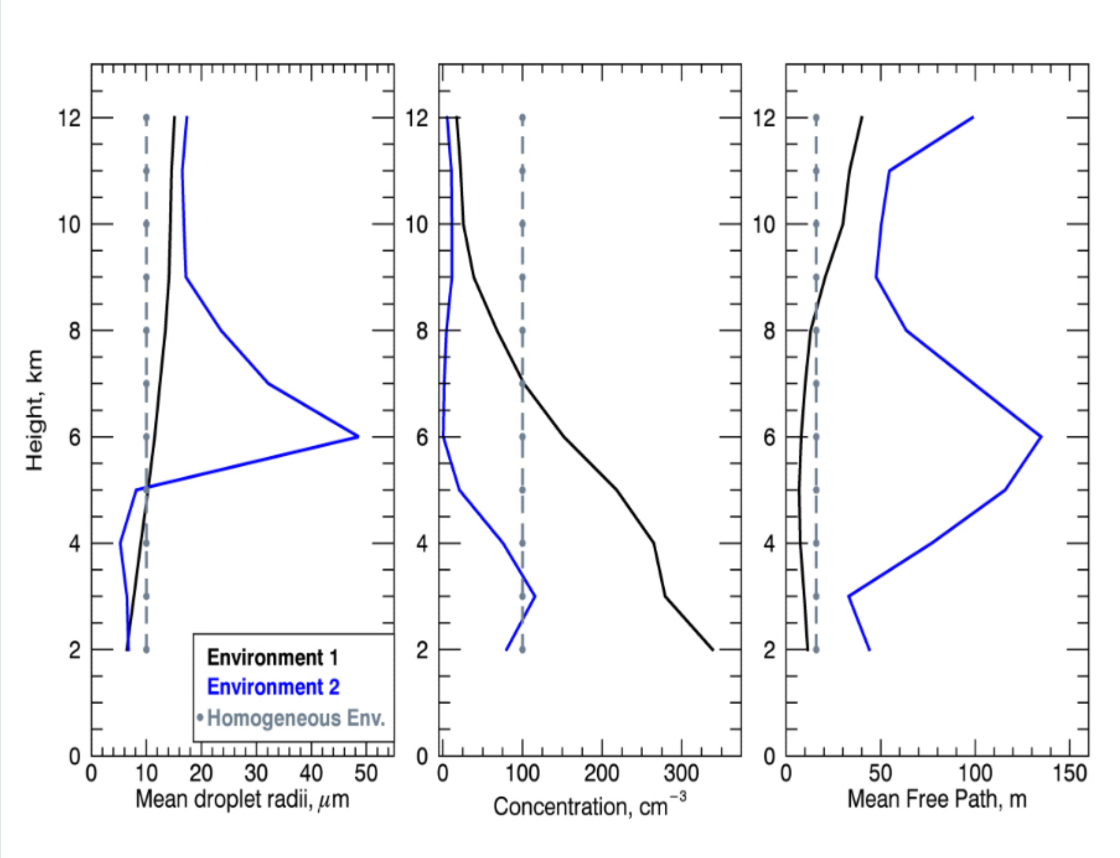
OPTICAL SCATTERING: OVERVIEW

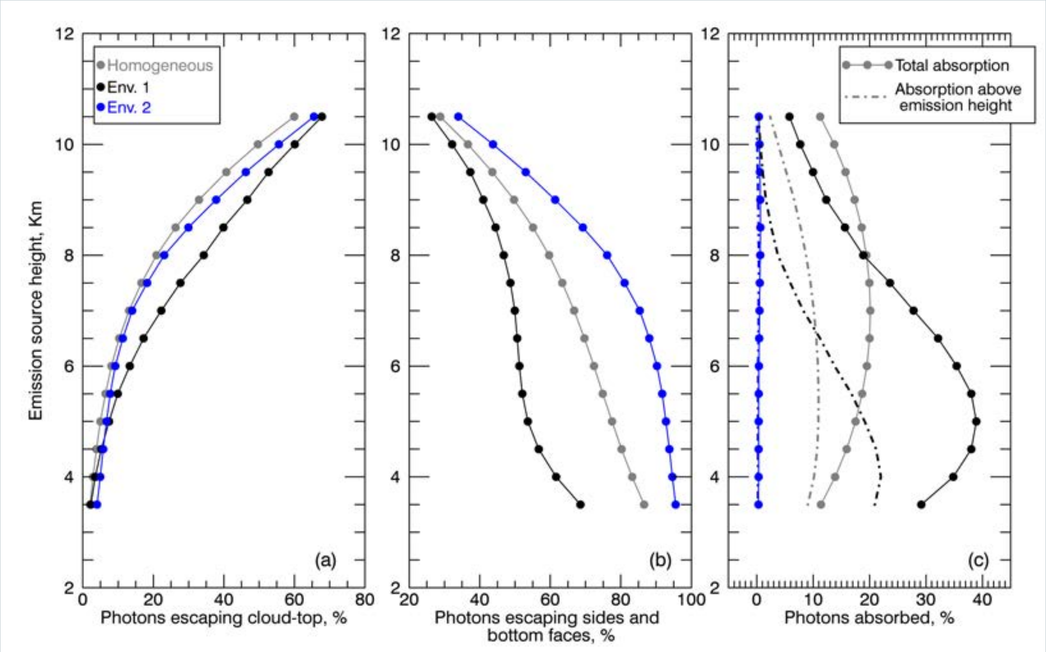
I. Understanding what modulates the light reaching GLM

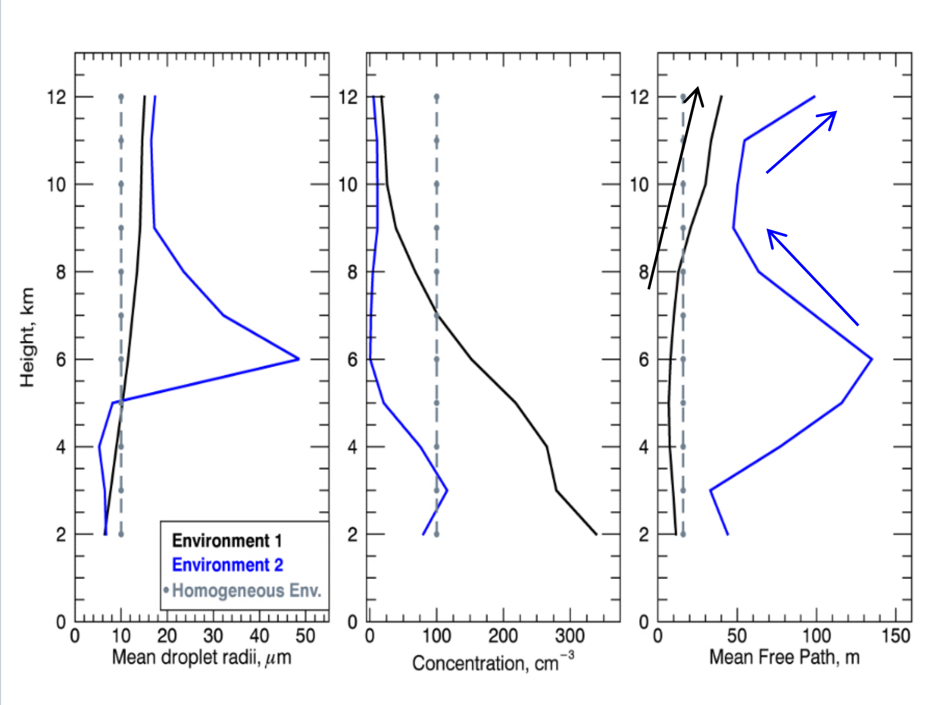
- Developing a Monte Carlo scattering model within an inhomogeneous microphysical environment
- Recreating GLM optical emission using ground-based lightning data





IDEALIZED/PNT-SRC SIMULATIONS





The MFP profile gradient indicates the direction where light will be brightest.

- For increasing MFP, this is the top/upper half
- For decreasing MFP, this is the bottom/lower half

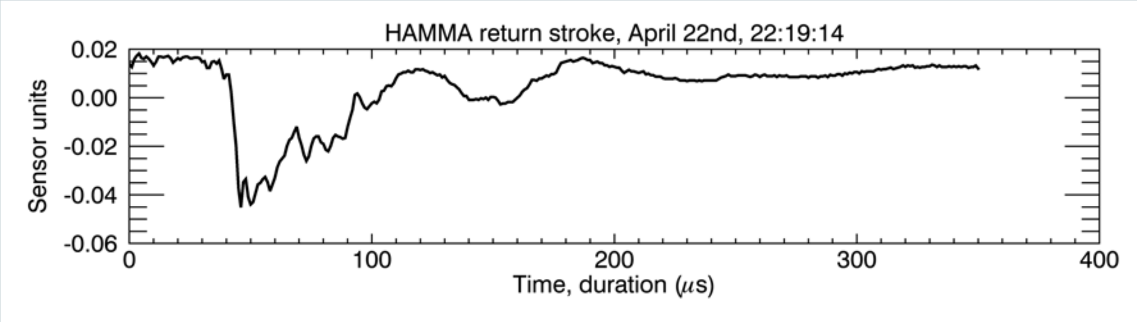
1. In an inhomogeneous atmosphere we found
   - The height of the source, and overall scatterer concentration were two important controlling mechanisms – not specifically ice concentration.
   - Light reaching cloud-top is highest in Env. 1, in area of highest reflectivity and concentration
   - Env 2. has less light reaching cloud-top, but more light escaping horizontal faces
     Vertical attenuation is greatest in Env. 1
2. An important control is the *gradient* of the microphysical profile.

PULSE BROADENING IN AN INHOMOGENEOUS CLOUD

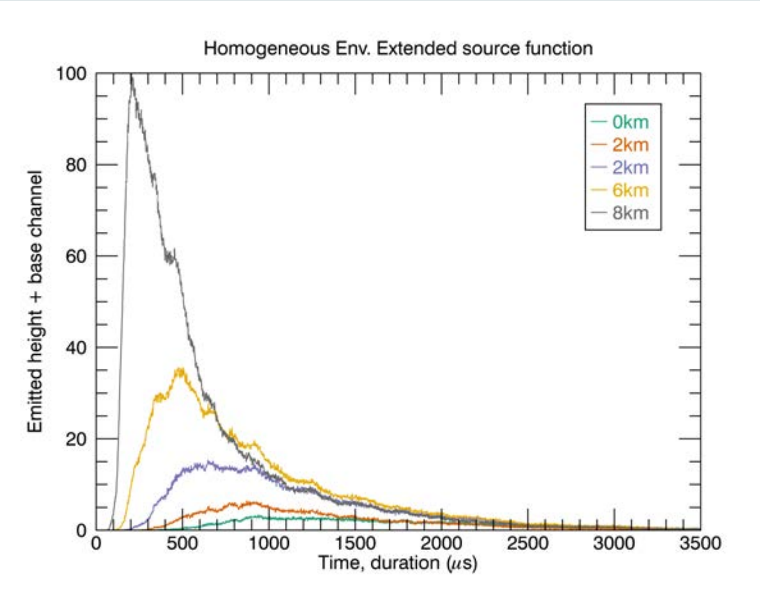
Results: source function

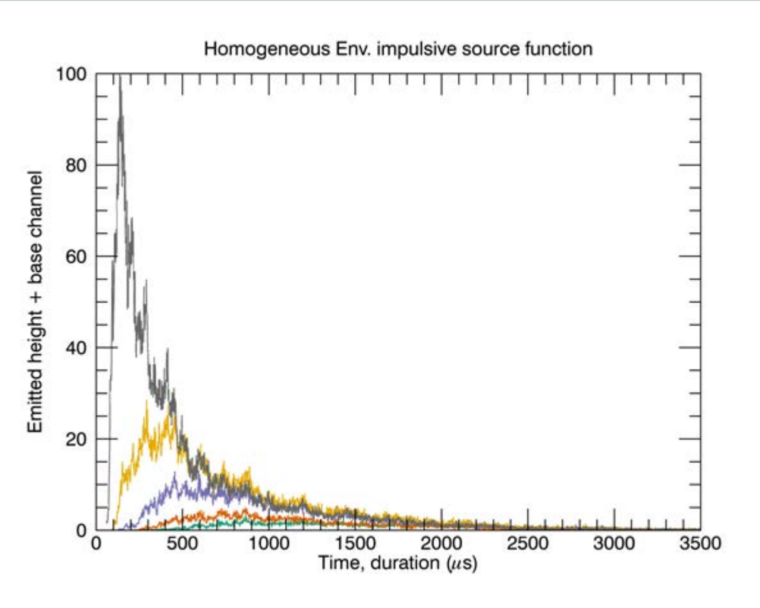
- Light is binned in 2 μs increments
- Cloud-top density is normalized to each function
  - The extended function simulates a larger amount of light

- The extended function produces a marginally larger pulse at cloud-top (for sources deep in the cloud) with a longer decay.



- The waveform is normalized to the same peak as the impulsive function,
  - ancillary pulses are included in the simulation. RS pulse width ~60 μs , 10 μs 0-peak risetime
  - The original channel is 1.5-2.5km with a horizontal component





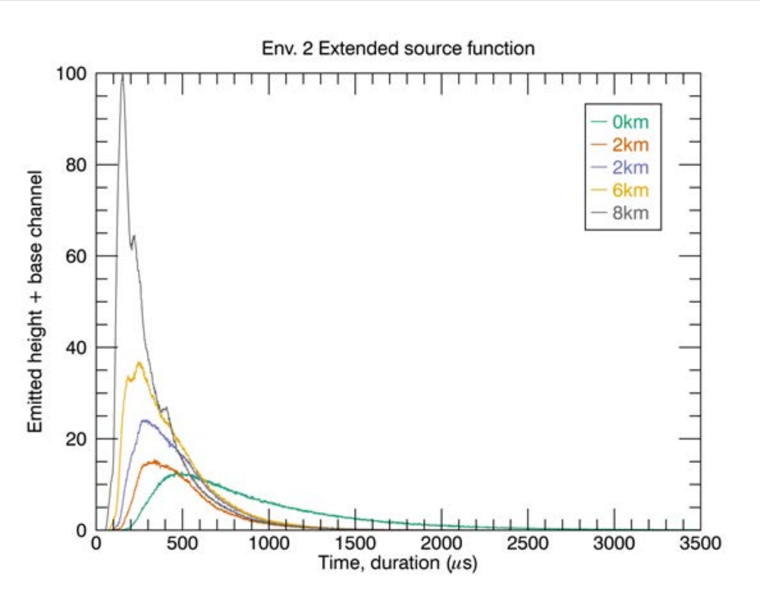
PULSE BROADENING IN AN INHOMOGENEOUS CLOUD

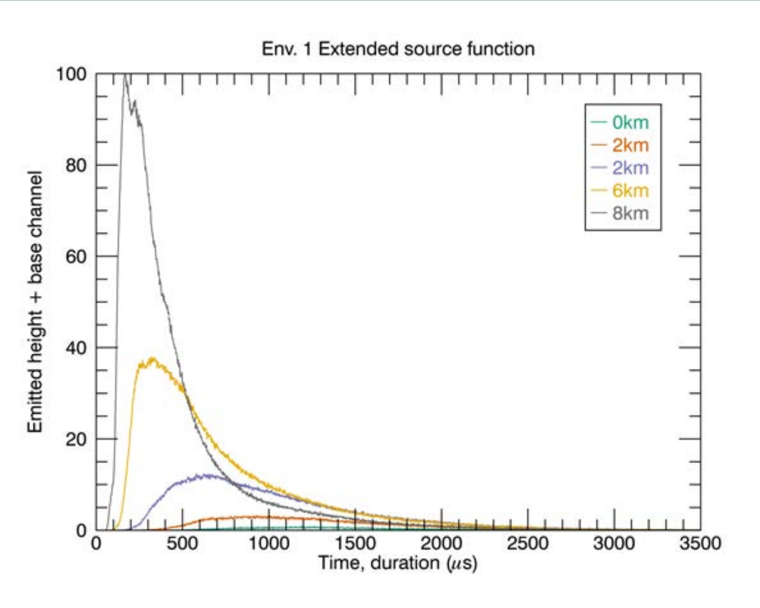
- The cloud-top pulse width and rise times are attributed to the MFP magnitude in Env. 1 vs. Env. 2

- Where the vertical gradient of the MFP indicated where the largest amount of optical emission would exit the cloud, here the MFP indicates pulse shape.

- Env. 2 has a shorter optical path length due to the larger MFP
  - A larger MFP indicates fewer scattering interactions and less absorption
  - Light escapes the sides of clouds rather than cloud-top

- The aircraft measured optical pulses averaged a rise time and duration of 235±130 μs and 880±362 μs respectively.
  - At the original channel height the simulated pulses have a longer duration.
  - The simulation agreed with measurements with a source height of 7km, with a 5km scattering depth.
  - The source height is undetermined in the U2 measurements

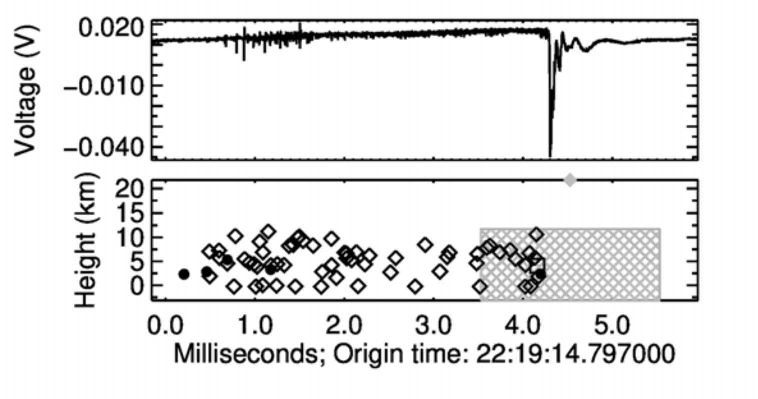


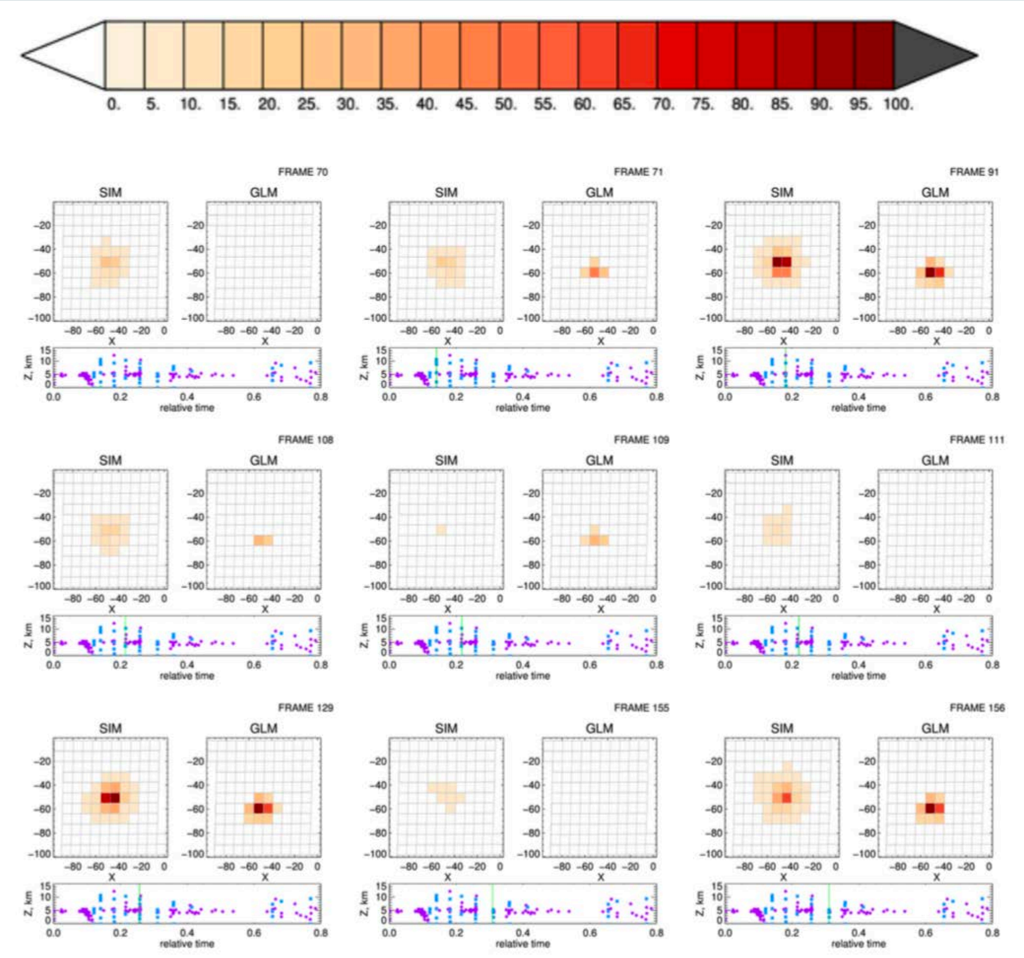


SIMULATED CLOUD-TOP FOOTPRINT AND GLM

Results: Cloud-top footprint

- Cloud-to-ground lightning
  - The peak pixels are matched in the simulation
    - Note, not consecutive groups
  - The first frame is either absent due to the coherency filter or below threshold (observed in the flashes with preliminary breakdown)
  - The source amplitude for return strokes GLM did not detect were large, but occurred deep in the cloud (10km scattering depth)

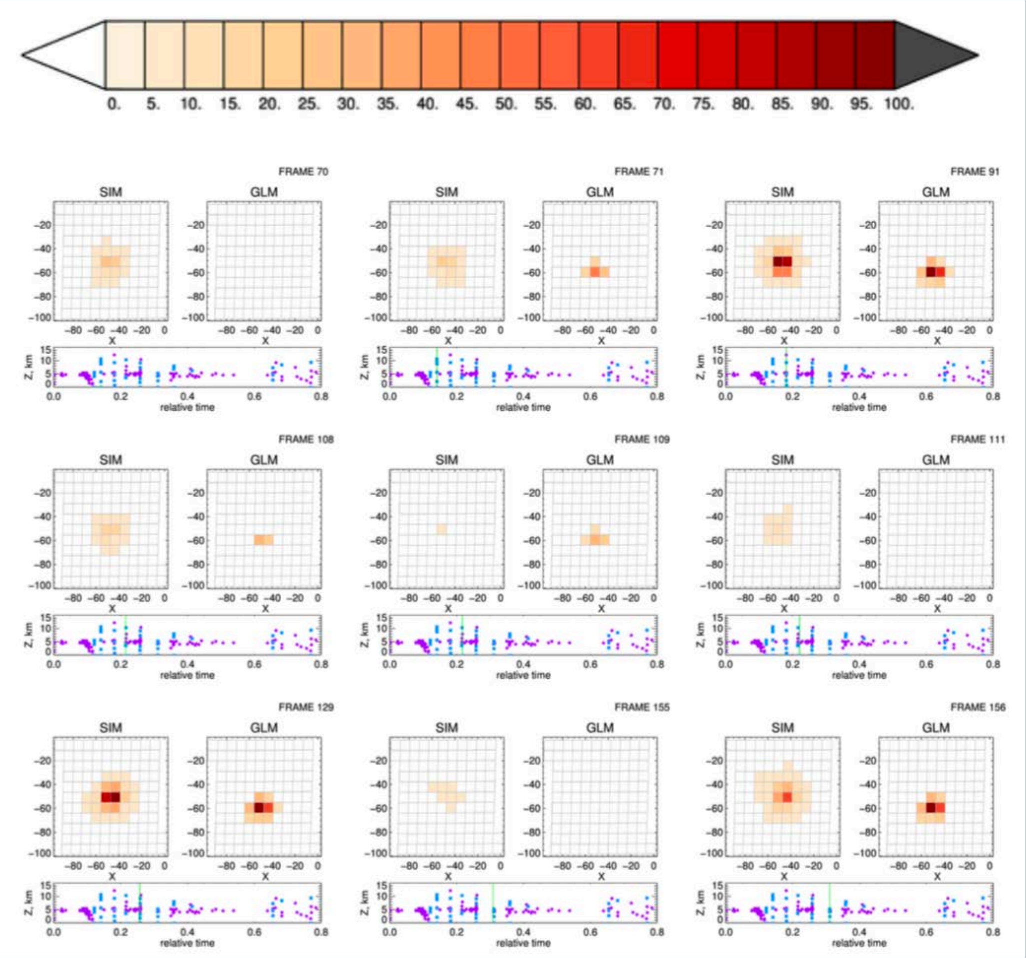


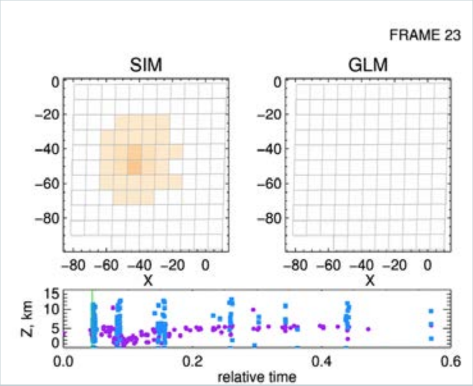


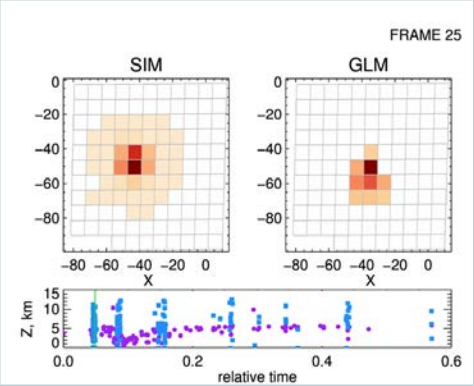
SIMULATED CLOUD-TOP FOOTPRINT AND GLM

Results: Cloud-top footprint

- Cloud-to-ground lightning is particularly affected by presumed frame-splitting
  - GLM had low detection for early return strokes, preliminary breakdown
  - GLM missed all but the final discharge (K-change) in a flash.
  - Results were similar for all three microphysical environments, the source altitude is the largest control on light reaching cloud-top







SUMMARY AND QUESTIONS

1. Scattering depth is the most important model control on light reaching cloud-top
   - The amount of light reaching cloud-top is similar across the three profiles below 7km

2. WHERE and HOW your scattering concentration exists matters: they both factor into the MFP
   - Ice concentration has the largest impact on absorption in Profile 2 – away from the reflectivity maximum of a storm

3. These simulations address a <u>percentage</u> of light reaching cloud-top: amplitude is king
   - 13% (Profile 2) or 22% (Profile 1) of a small flash can be below GLM threshold, for a mid-level discharge