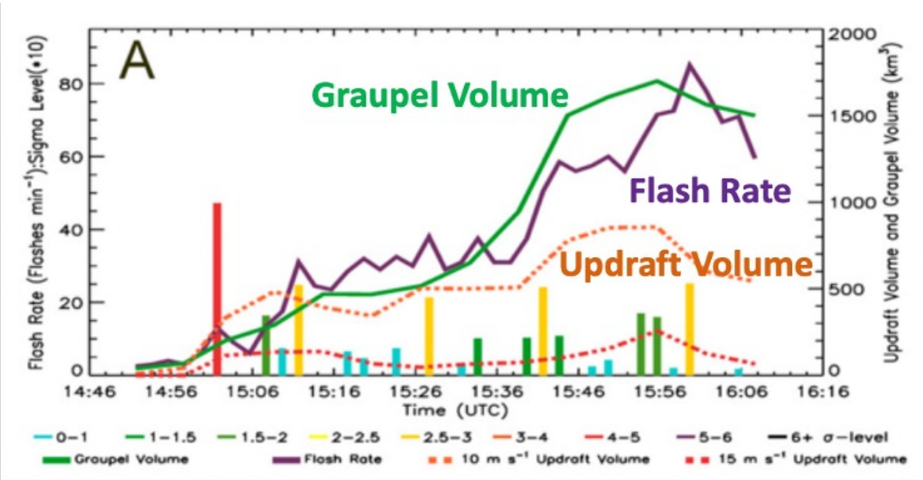
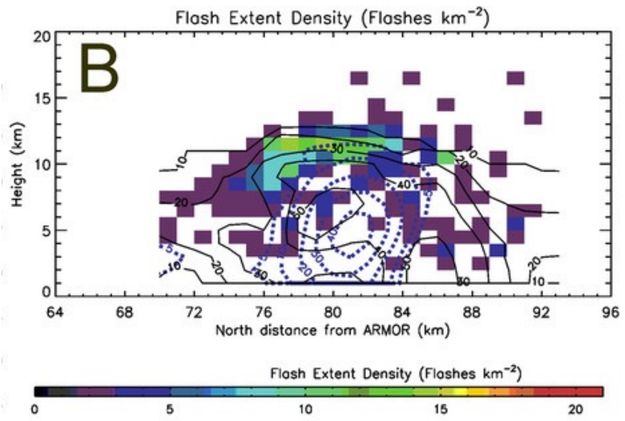
Convective updrafts, microphysical signals, and LIGHTNING

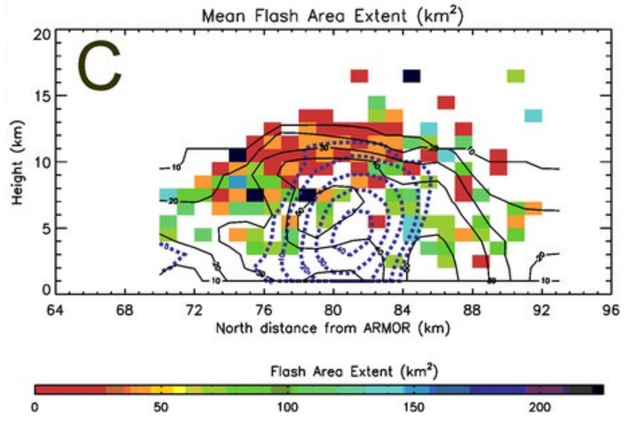
Drs. Kelcy N. Brunner[1], Eric C. Bruning[1],
Marcus van Lier-Walqui[2]
Toshihisa Matsui[3], and Taka Iguchi[4]

1. Texas Tech University Geosciences Dept.
2. CSSR Columbia University; NASA Goddard Institute of Space Studies
3. NASA Goddard Space Flight Center
4. University of Maryland

Lightning Signals in Thunderstorms



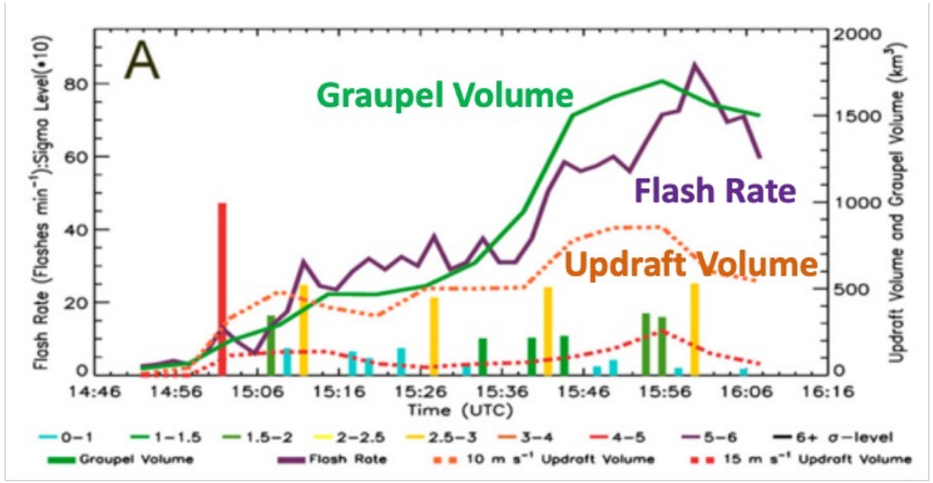


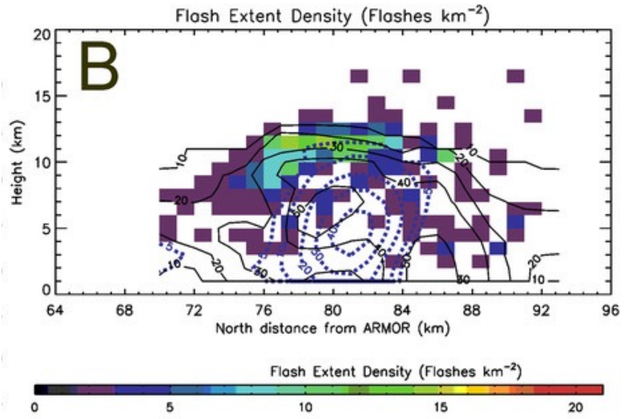


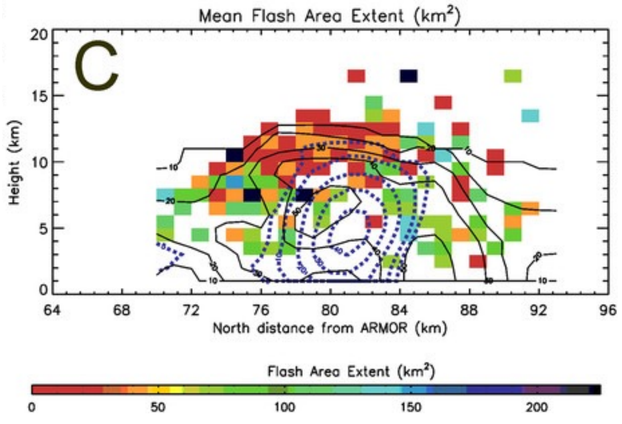
- Lightning flash rates vary with:
  - Updraft speed/volume
  - Graupel mass/volume
- Why?
  - Updraft lofts particles, more NIC, pockets of charge form
- Small flashes are located near the updraft

Schultz, et al., 2015 (A), 2017 (B, C)

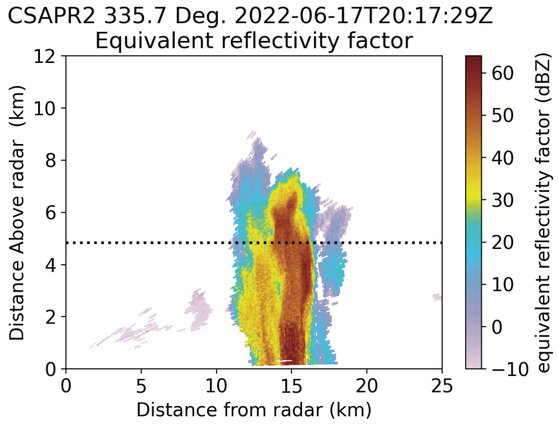
Lightning Signals in Thunderstorms

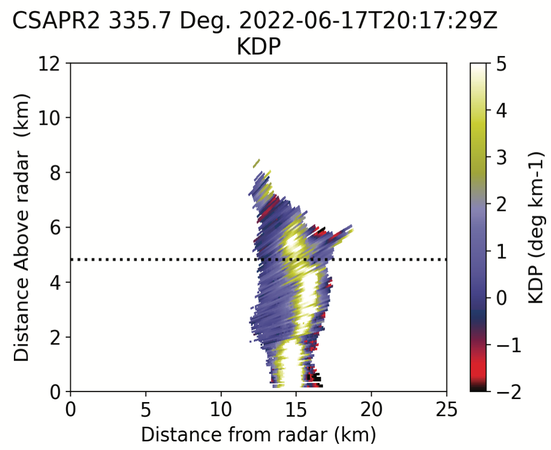


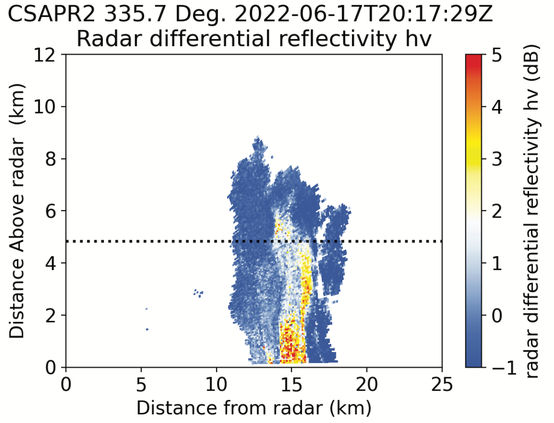


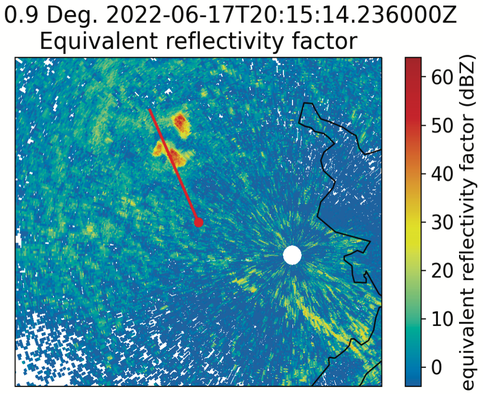


Schultz, et al., 2015 (A), 2017 (B, C)





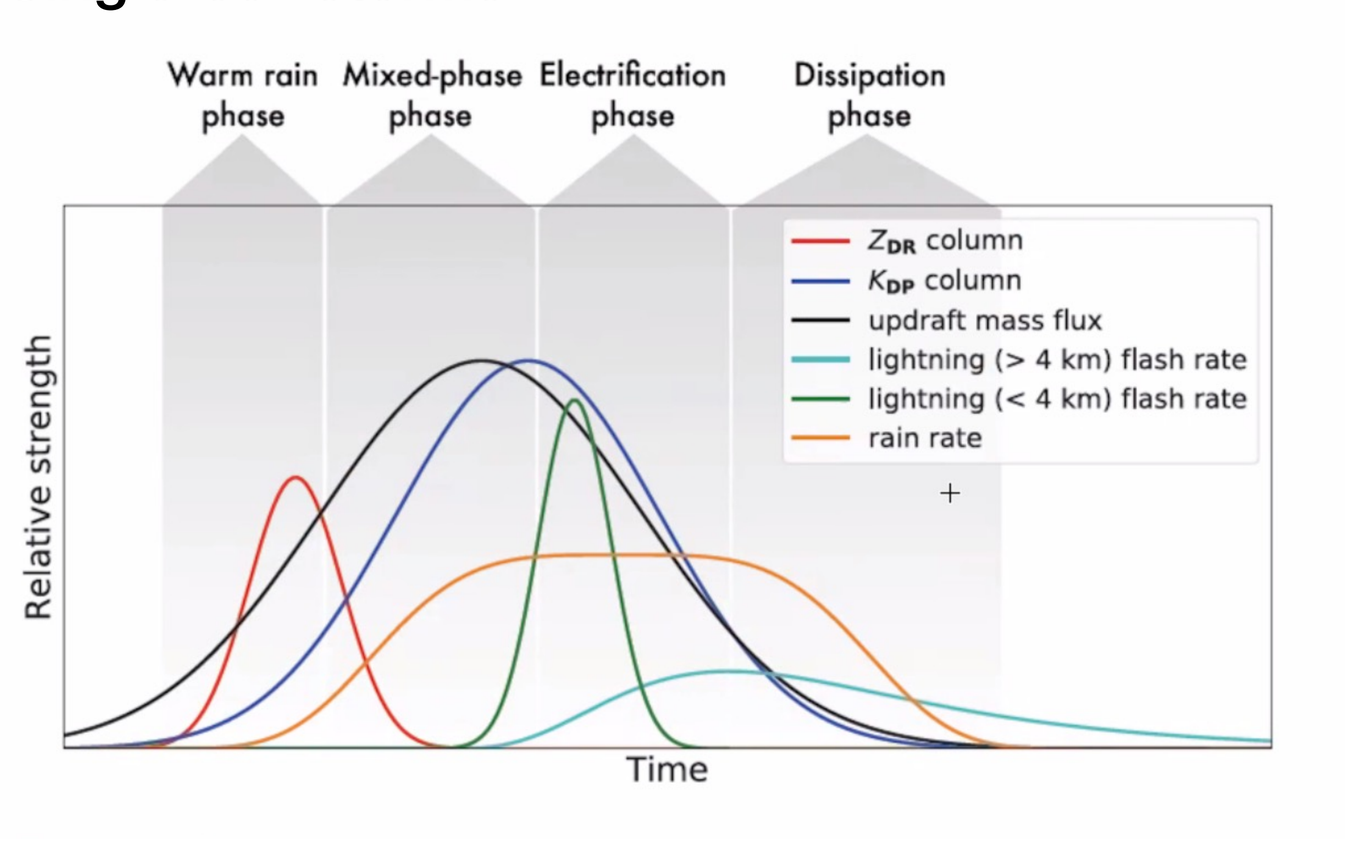




Bruning, ARM/ASR 2022

Lightning Signals in Thunderstorms

Single-cell storms

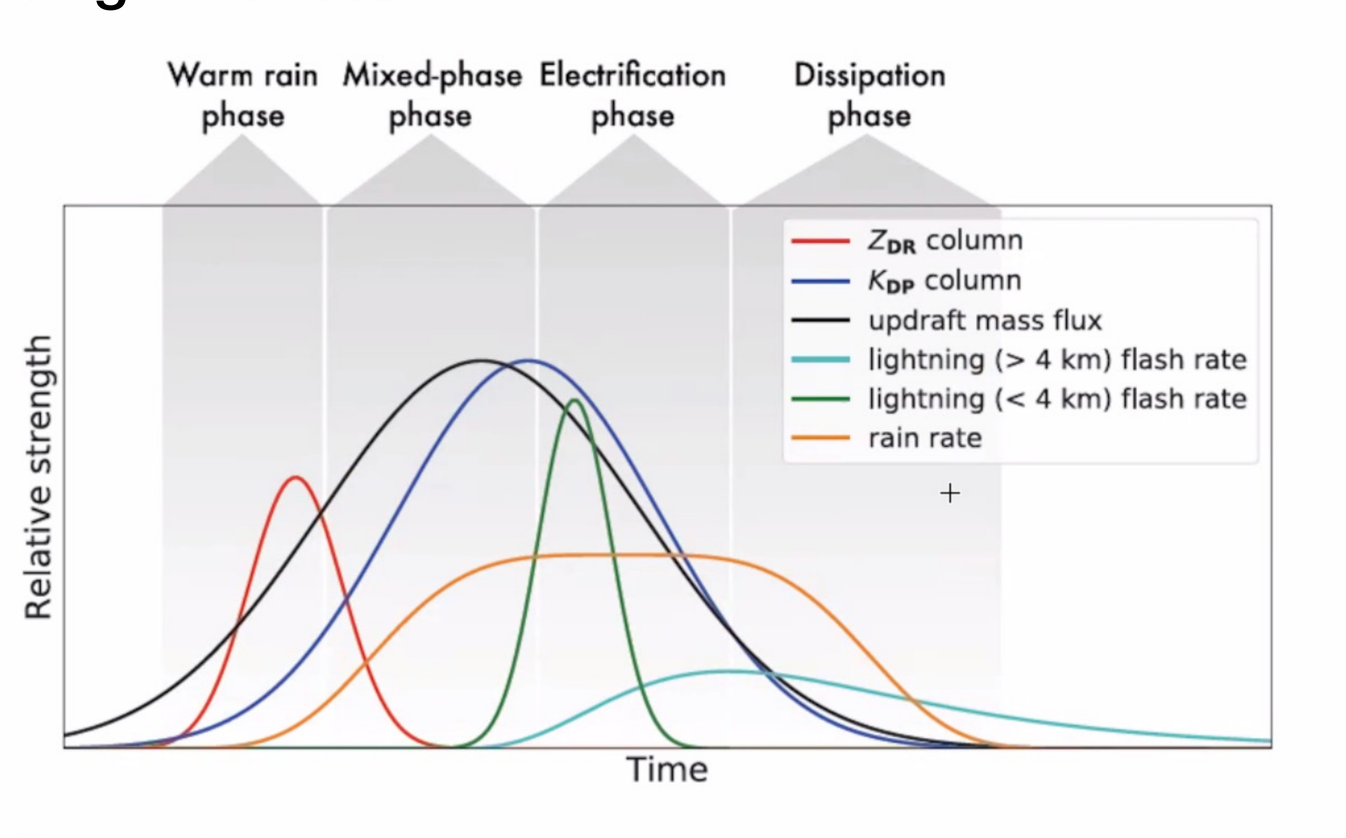


Fridlind et al. (2019, AMT)

- Single cell storms follow a conceptual model:
  - Updraft lofts supercooled water in the mixed phase region,
    - we have glaciation, graupel grows in the mixed phase region,
    - charging occurs as graupel and ice collide,
    - charge regions form and lightning begins
  - Small flashes peak first, larger flashes occur more slowly through dissipation
- How are more complex, multi-cell thunderstorms different?

Lightning Signals in Thunderstorms

Single-cell storms

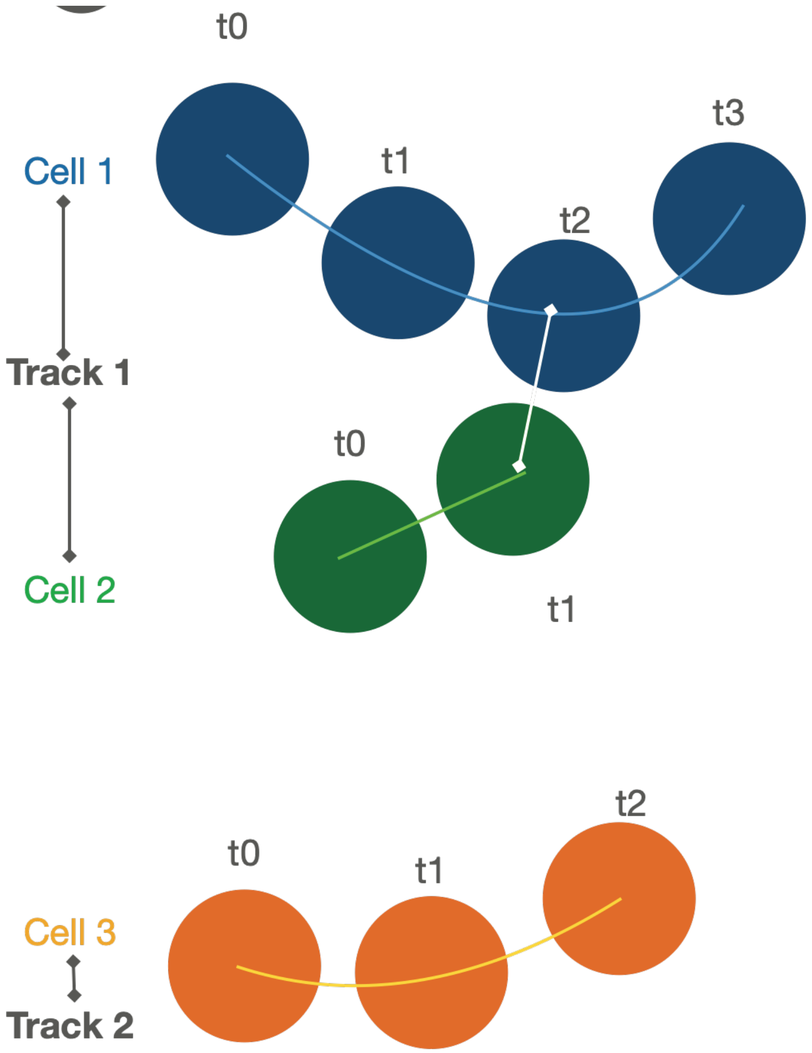


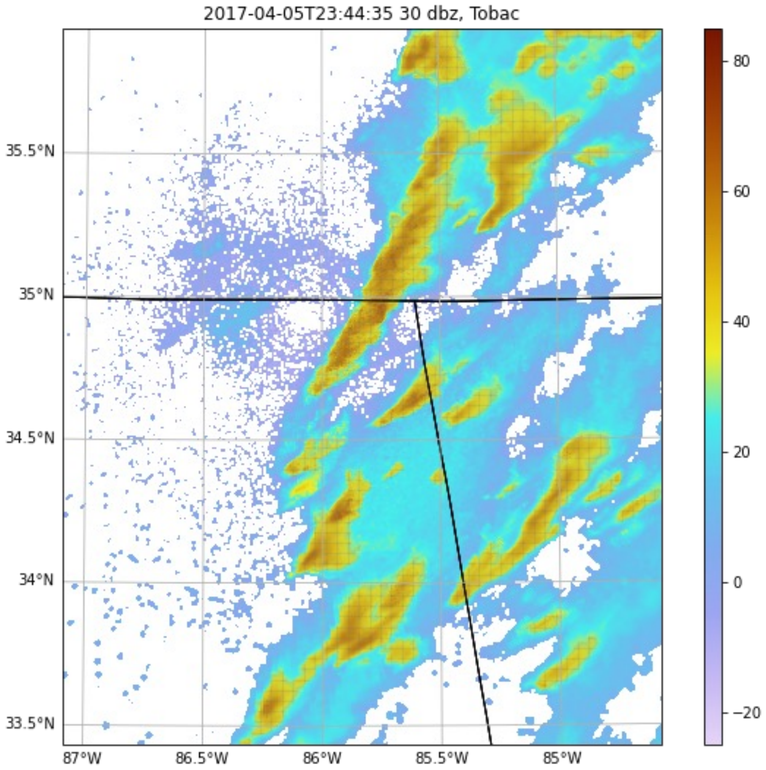
Fridlind et al. (2019, AMT)

- **What separates buoyant deep convection from warm rain cells?**
  - Do lightning measurements capture these differences?
- **How prevalent is the conceptual model?**
  - Are we seeing Kdp/Zdr columns frequently in relatively benign cells?
- **How do we identify a consistent signal of electrification in a complex microphysical and kinematic field?**
  - First focusing on glaciation signals

tobac - Tracking and Object-Based Analysis of Clouds

Tracking methods



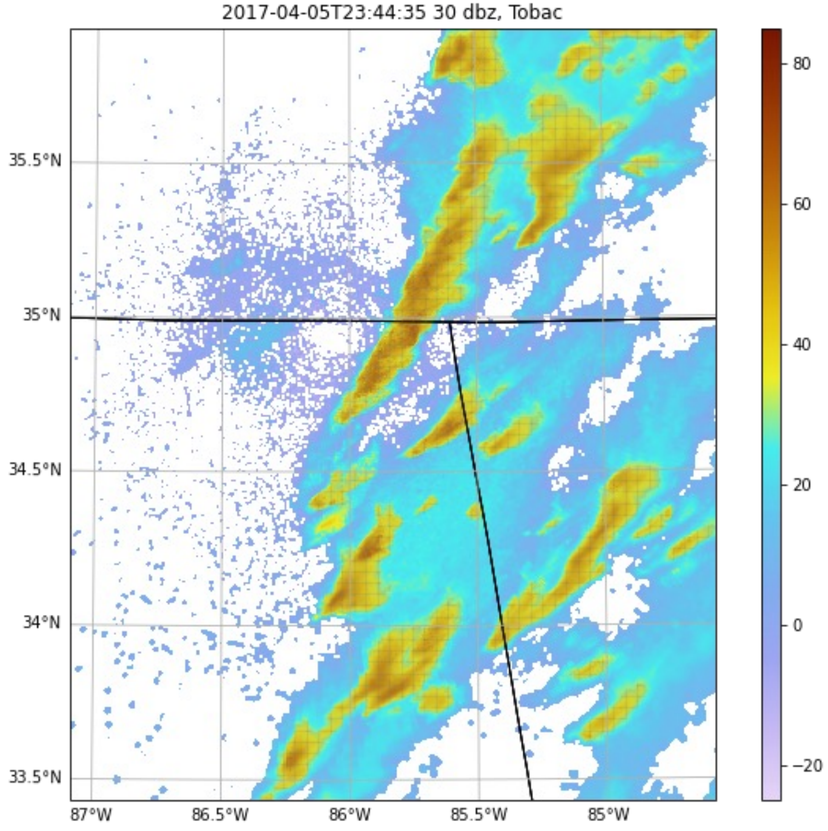


- Tracking using the open source package tobac:
  - https://github.com/tobac-project/tobac
  - Heikenfeld, et al., 2019
  - Based on watershed + TrackPy linking, including merge/split
  - Creates Features, 2d id mask, cells, and Tracks
- Radar: composite reflectivity at 30dBz

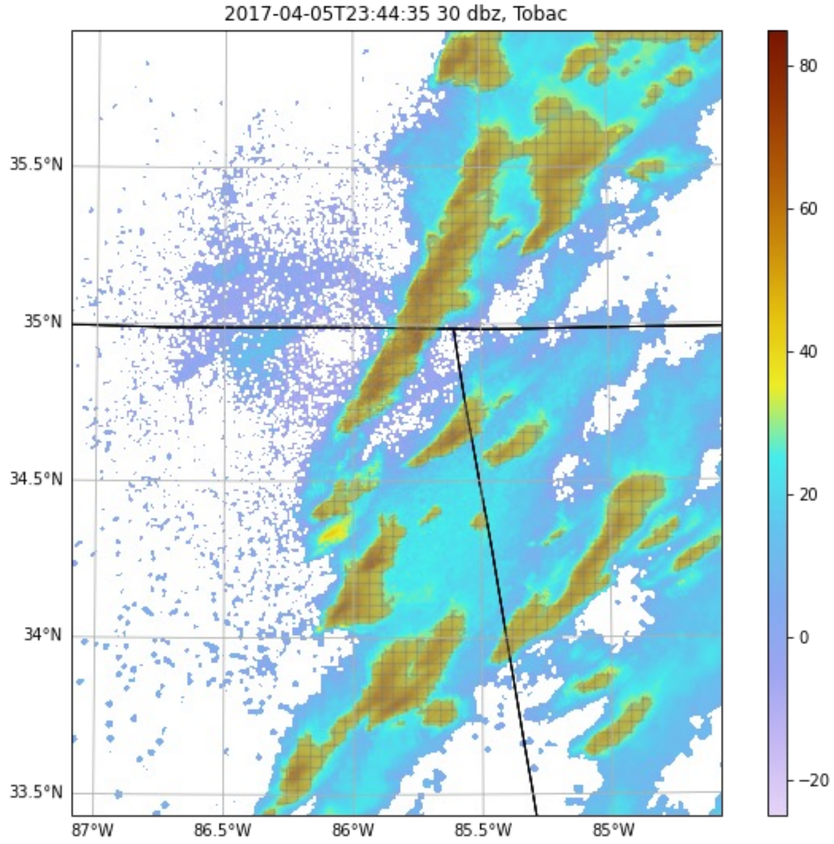
tobac - Tracking and Object-Based Analysis of Clouds

Tracking methods

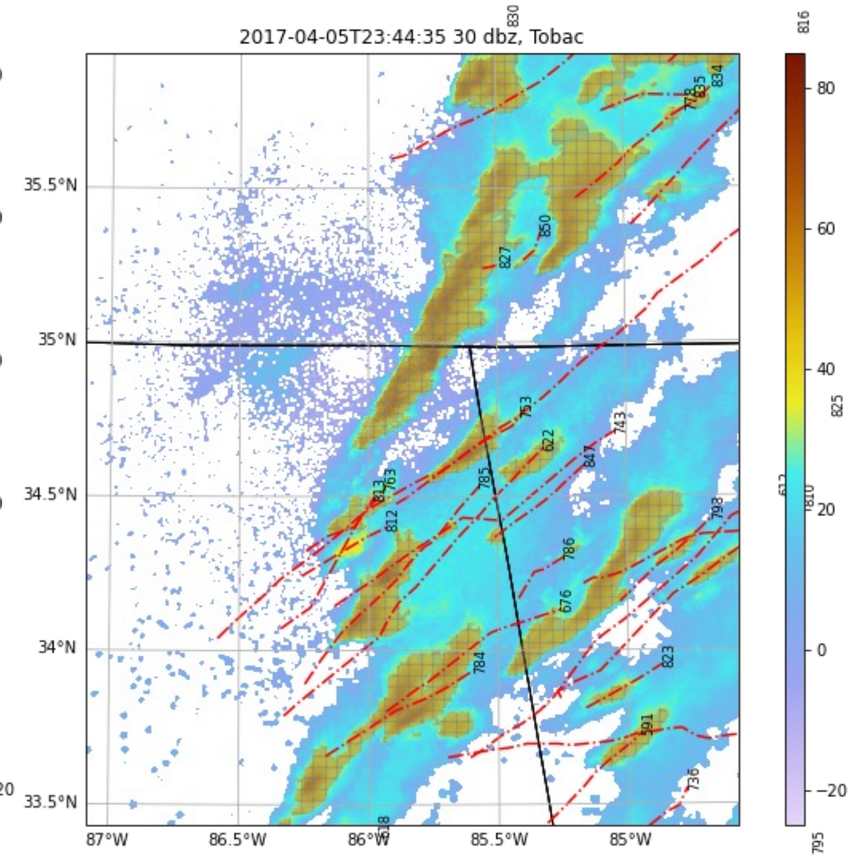
Identify Features



Feature Mask



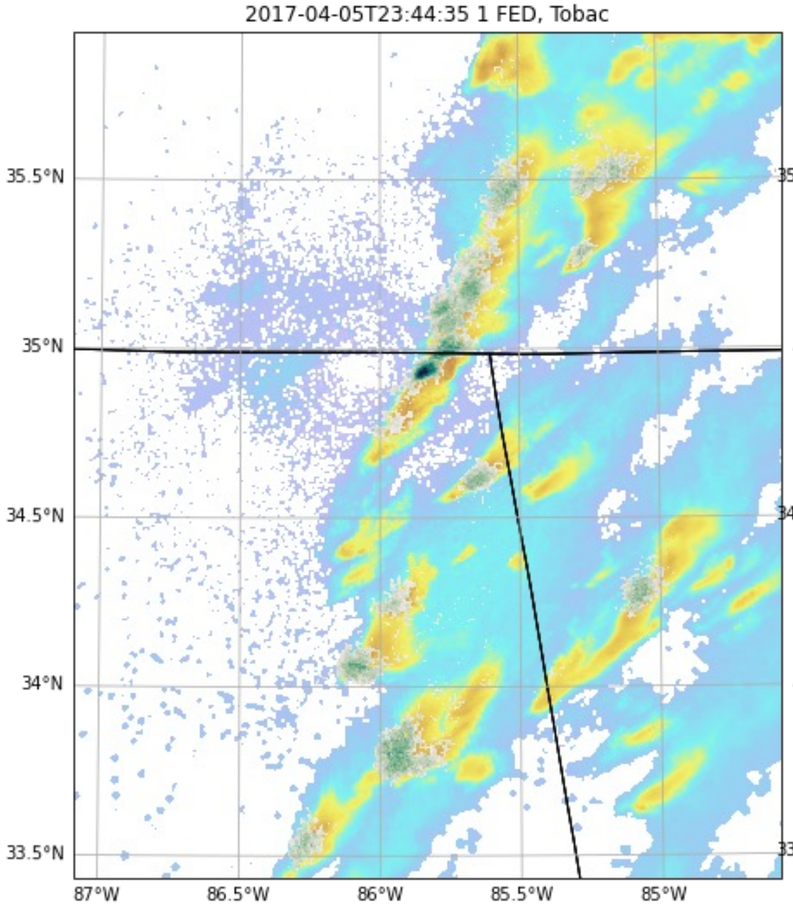
Link Features



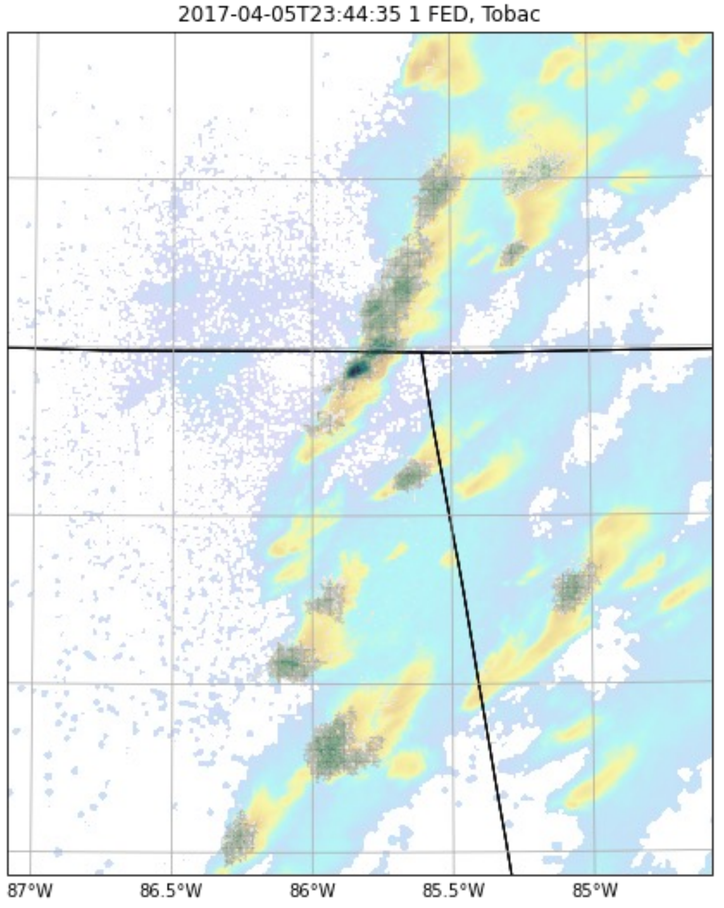
tobac - Tracking and Object-Based Analysis of Clouds

Tracking methods

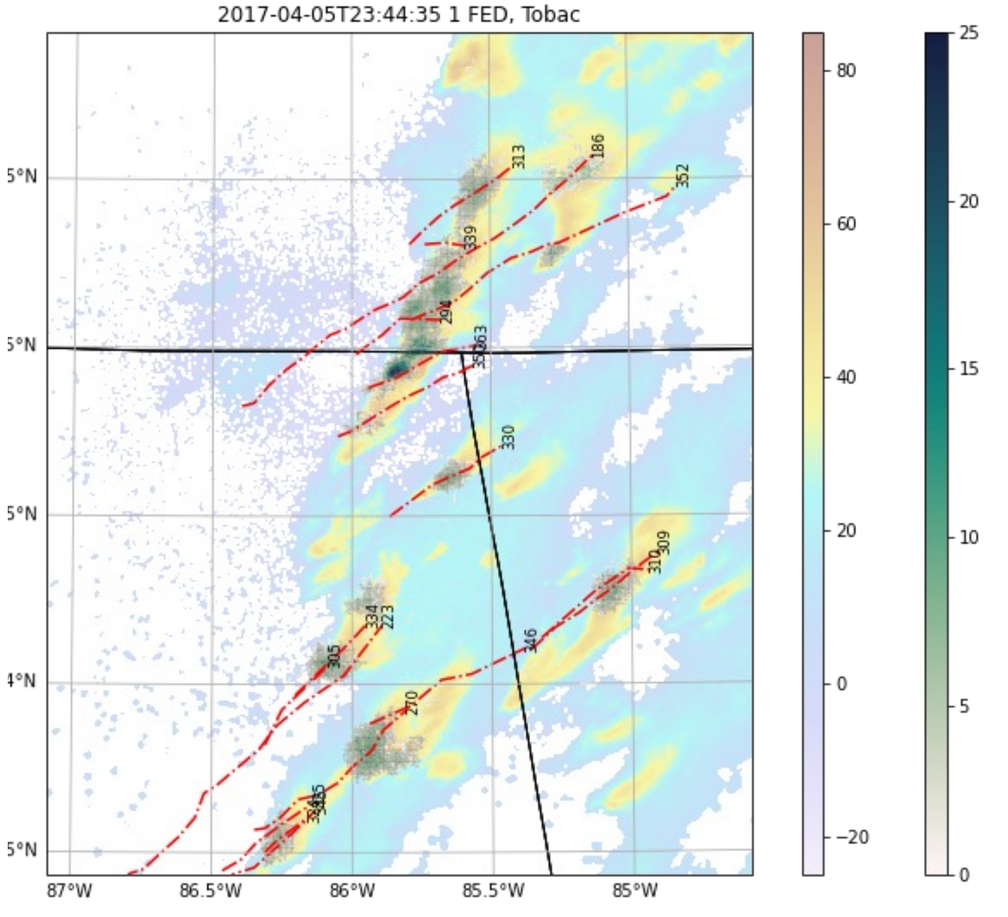
Identify Features



Feature Mask



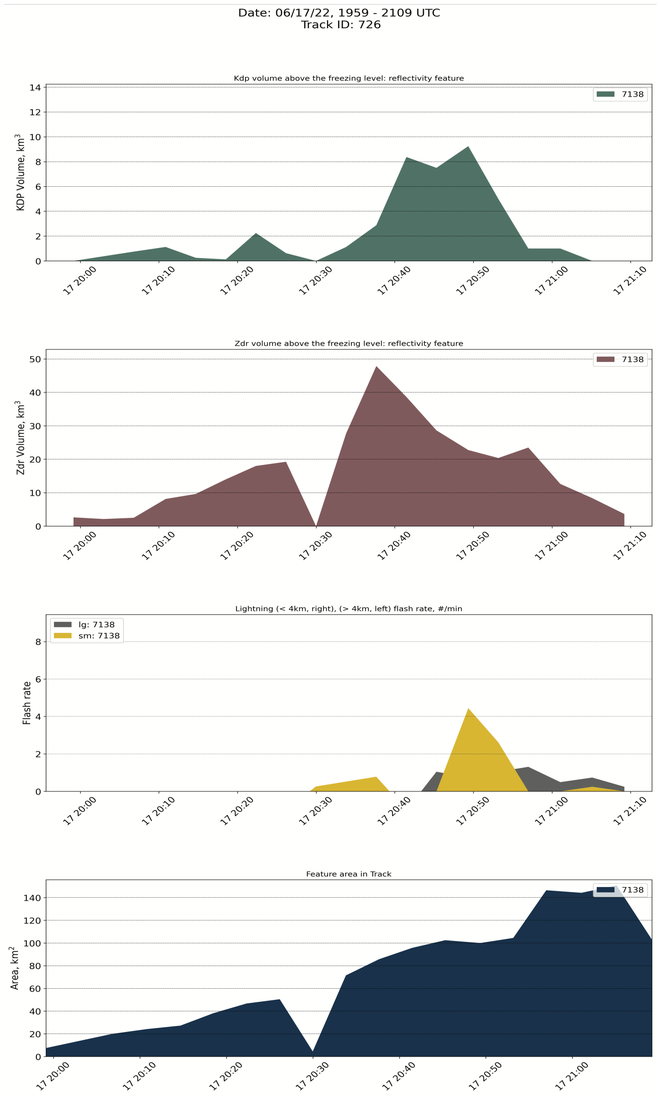
Link Features

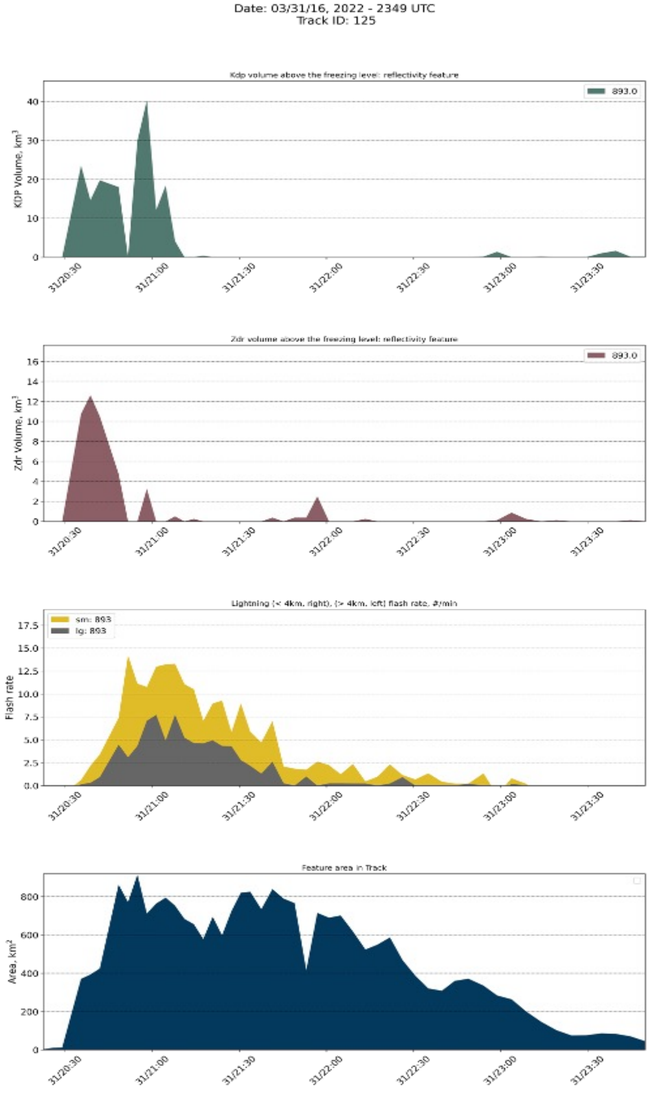


Methods: microphysical signals

Radar and dual-polarimetry methods

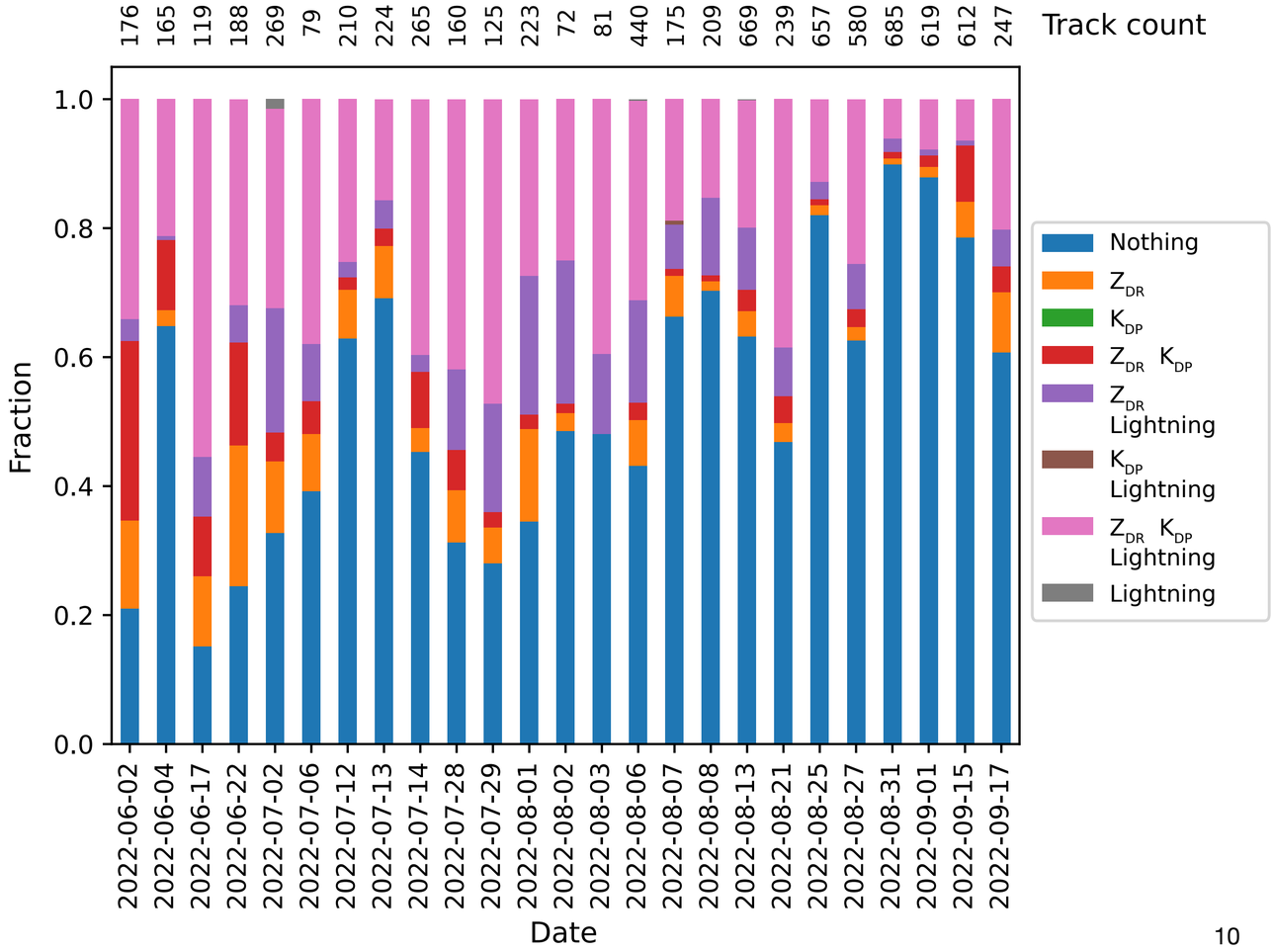
- Zdr/Kdp column:
  - Volume in 3km above the melting level
  - Column Strength – vertically integrated in same 3km slab
- Cell area/max reflectivity
- Flash rate by size:
  - Small flashes with area < 4km
  - Large flashes with area > 4km



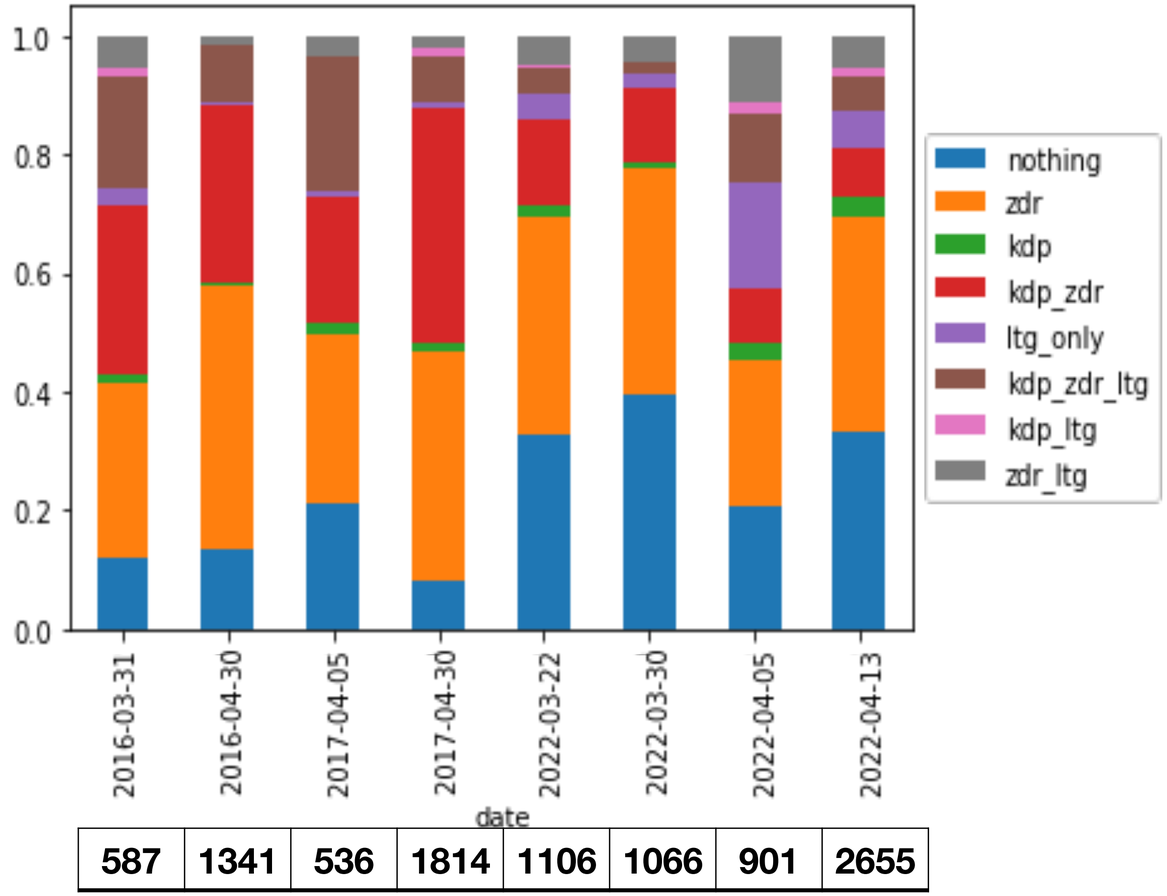


Results - Isolated vs. Complex/multi cells

Single/Isolated Dominant



Complex/Multicell Dominant



587	1341	536	1814	1106	1066	901	2655

Results: Histograms

- How do KDP and ZDR line up?
- Where Lightning aligns with KDP/ZDR
- Where Lightning doesn't align with KDP/ZI

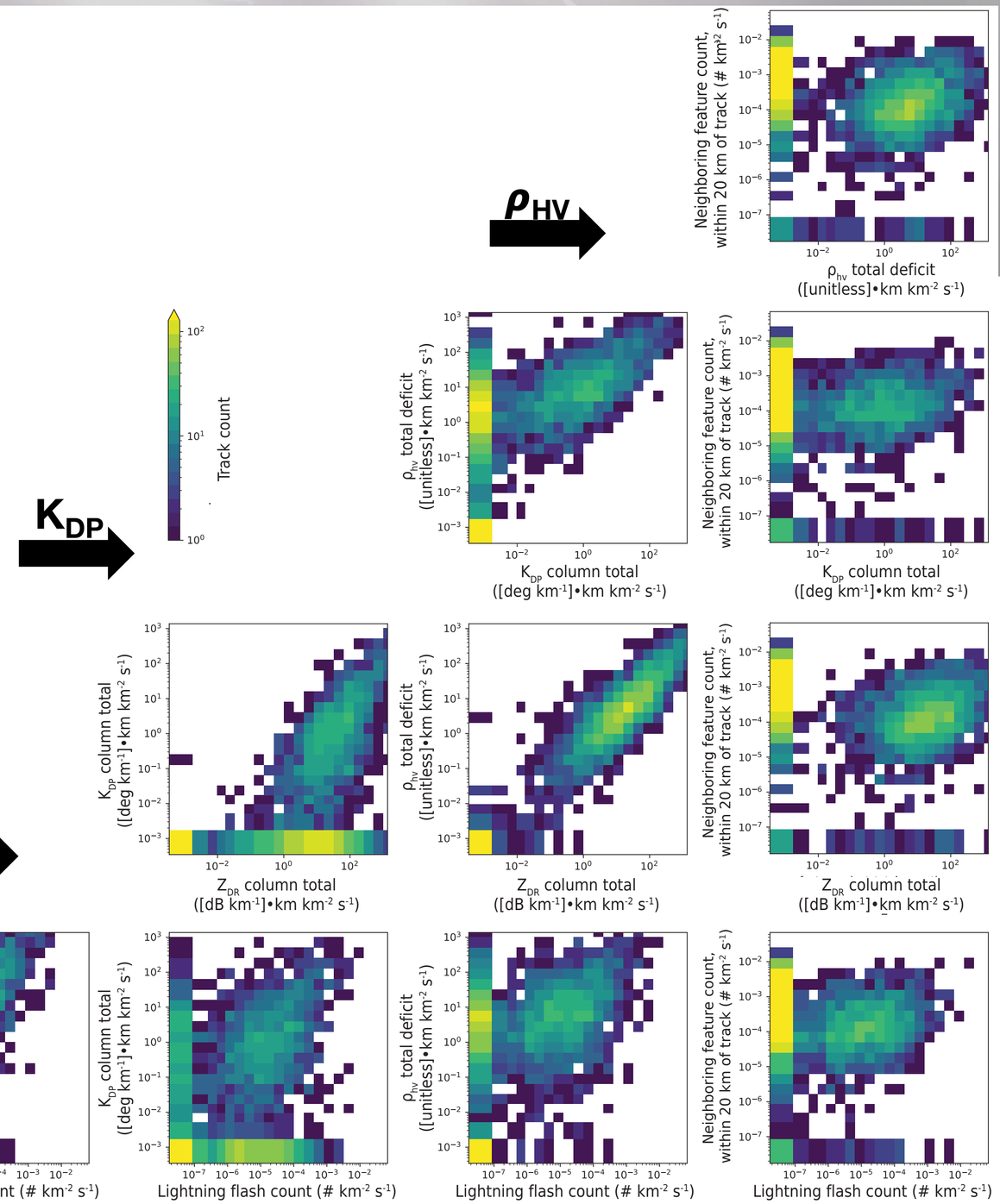
K_{DP} column total ([deg km^{-1}]•km km^{-2} s^{-1})

Z_{DR} column total ([dB km^{-1}]•km km^{-2} s^{-1})

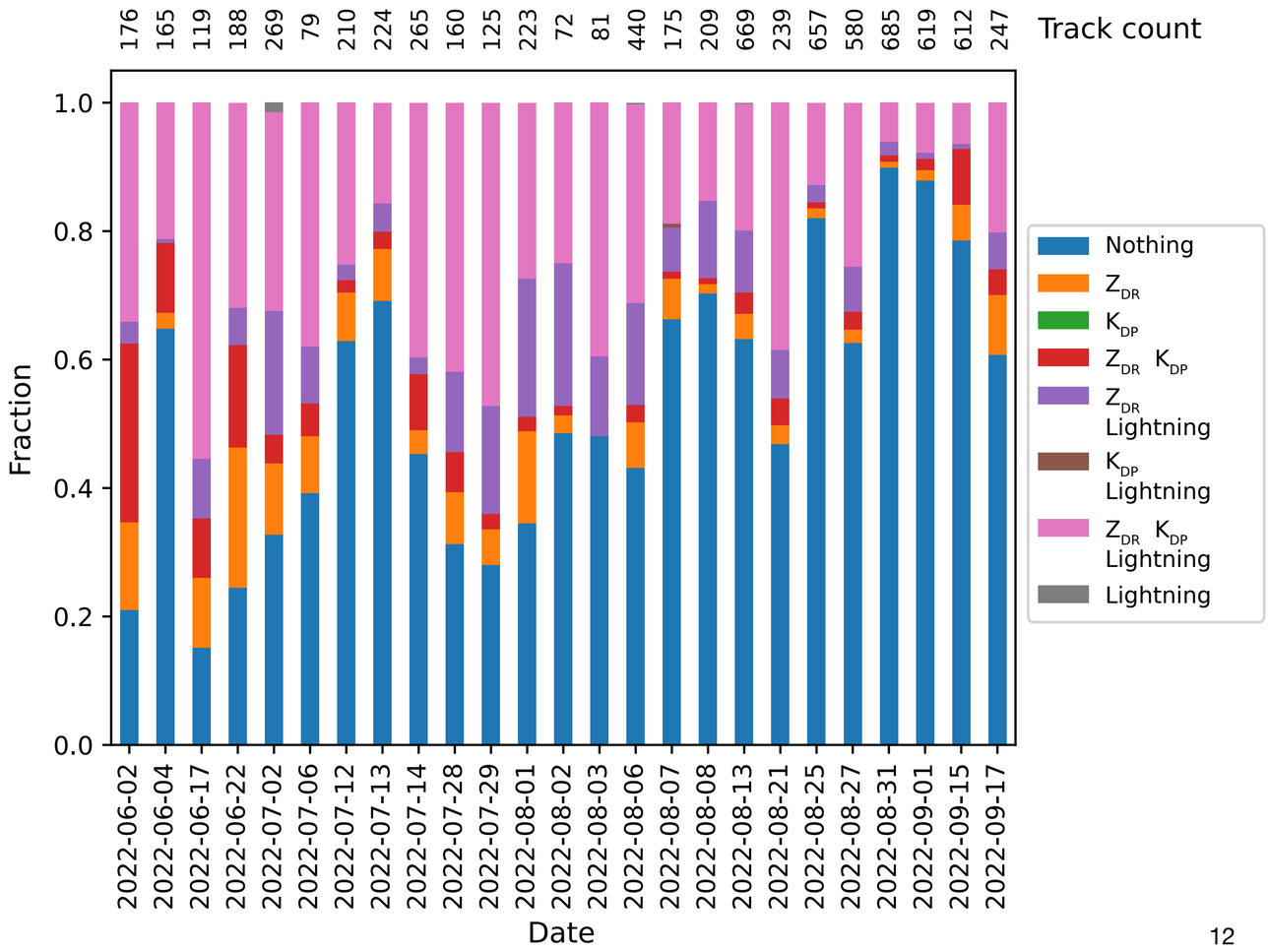
ρ_{hv} total deficit ([unitless]•km km^{-2} s^{-1})

Lightning flash count (# km^{-2} s^{-1})

Neighboring feature count, within 20 km of track (# km^{-2} s^{-1})



Ongoing Discussion



- **Where do environmental variables play a part?**
- **Aerosols and Lightning**
- **Convective feedbacks in air quality**
- **Lightning with and without polarimetric signals**
- **Cell populations without a glaciation signal (KDP column)**

Convective updrafts, microphysical signals, and LIGHTNING

Drs. Kelcy N. Brunner[1], Eric C. Bruning[1],
Marcus van Lier-Walqui[2]
Toshihisa Matsui[3], and Taka Iguchi[4]

1. Texas Tech University Geosciences Dept.
2. CSSR Columbia University; NASA Goddard Institute of Space Studies
3. NASA Goddard Space Flight Center
4. University of Maryland