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# Analyzing automatically detected lightning jumps from optical Geostationary Lightning Mapper (GLM) lightning observations

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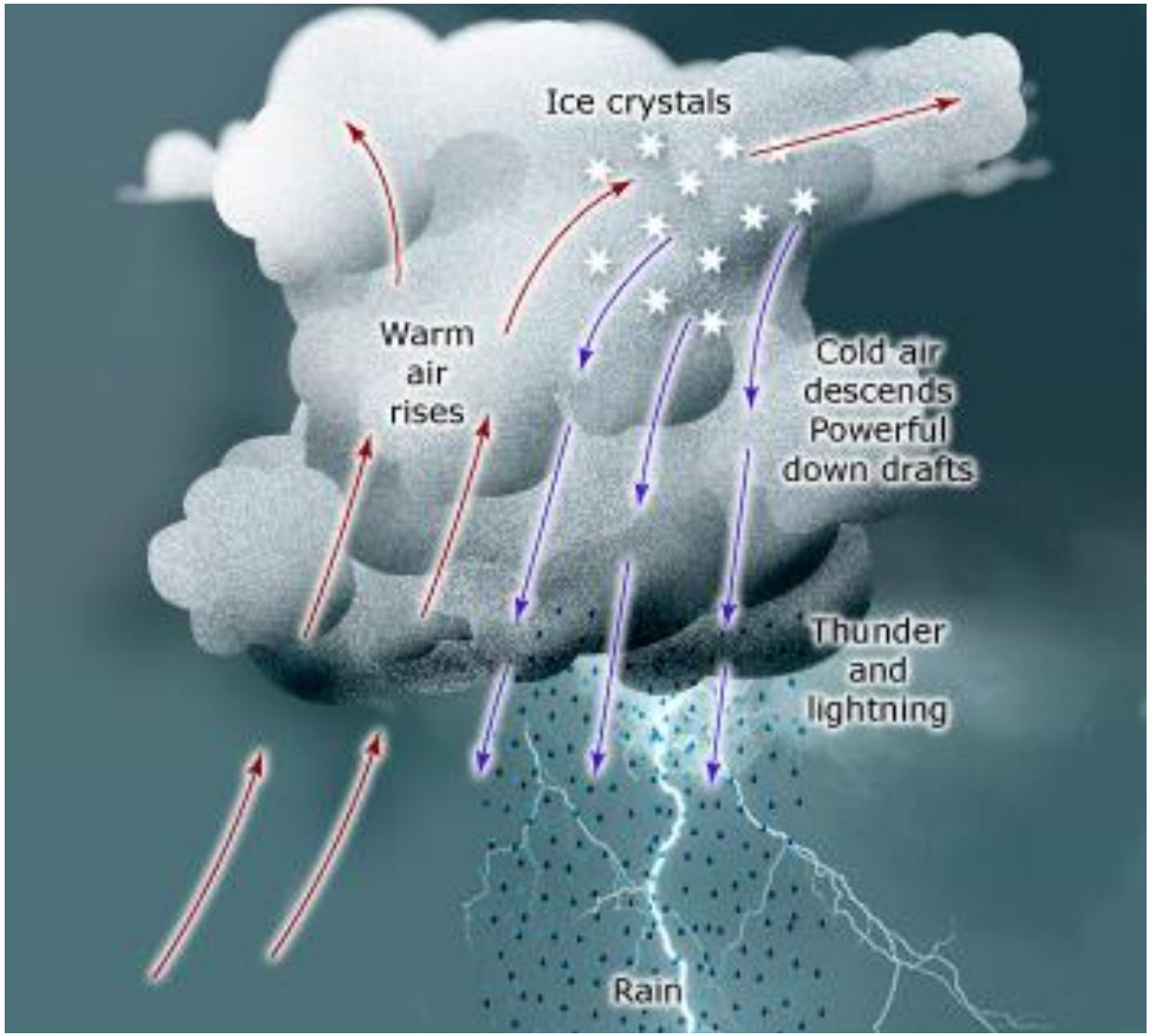
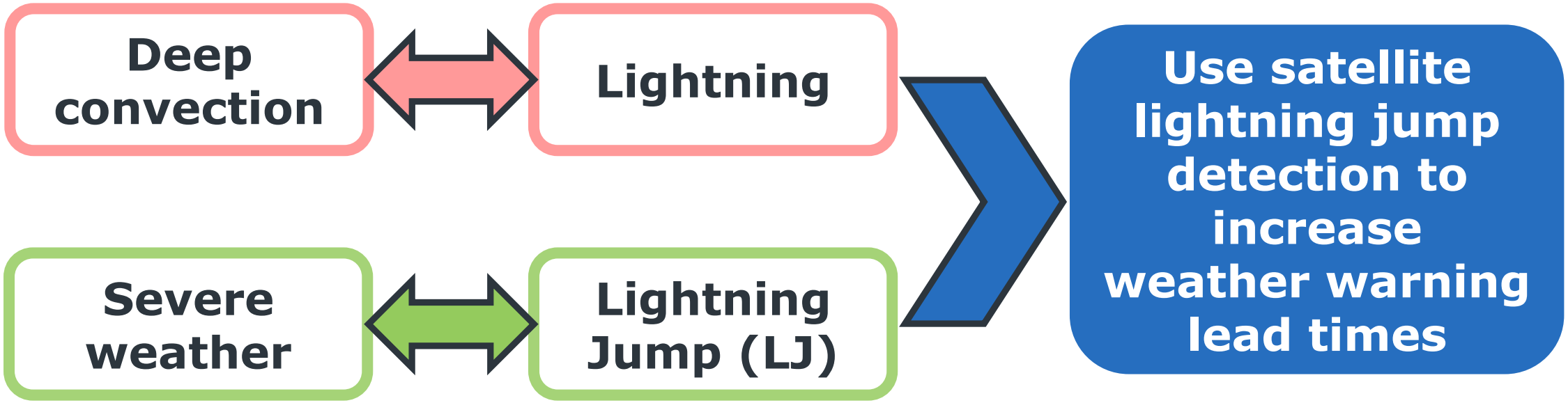
# Introduction




*Adapted from Erick Brenstrum, 'Weather - Thunderstorms', Te Ara - the Encyclopedia of New Zealand, http://www.TeAra.govt.nz/en/interactive/7767/how-a-thunderstorm-forms (accessed 25 November 2020)*

# Motivation

- Thunderstorms with **dangerous weather phenomena**
- **New generation satellites** (GOES-R series, Meteosat Third Generation [MTG]) carry new **lightning locating sensors**




e.g., Williams et al., 1999, Goodman et al., 2005,
Gatlin and Goodman, 2010, Schultz et al., 2009, 2016

# GOES-GLM lightning observations

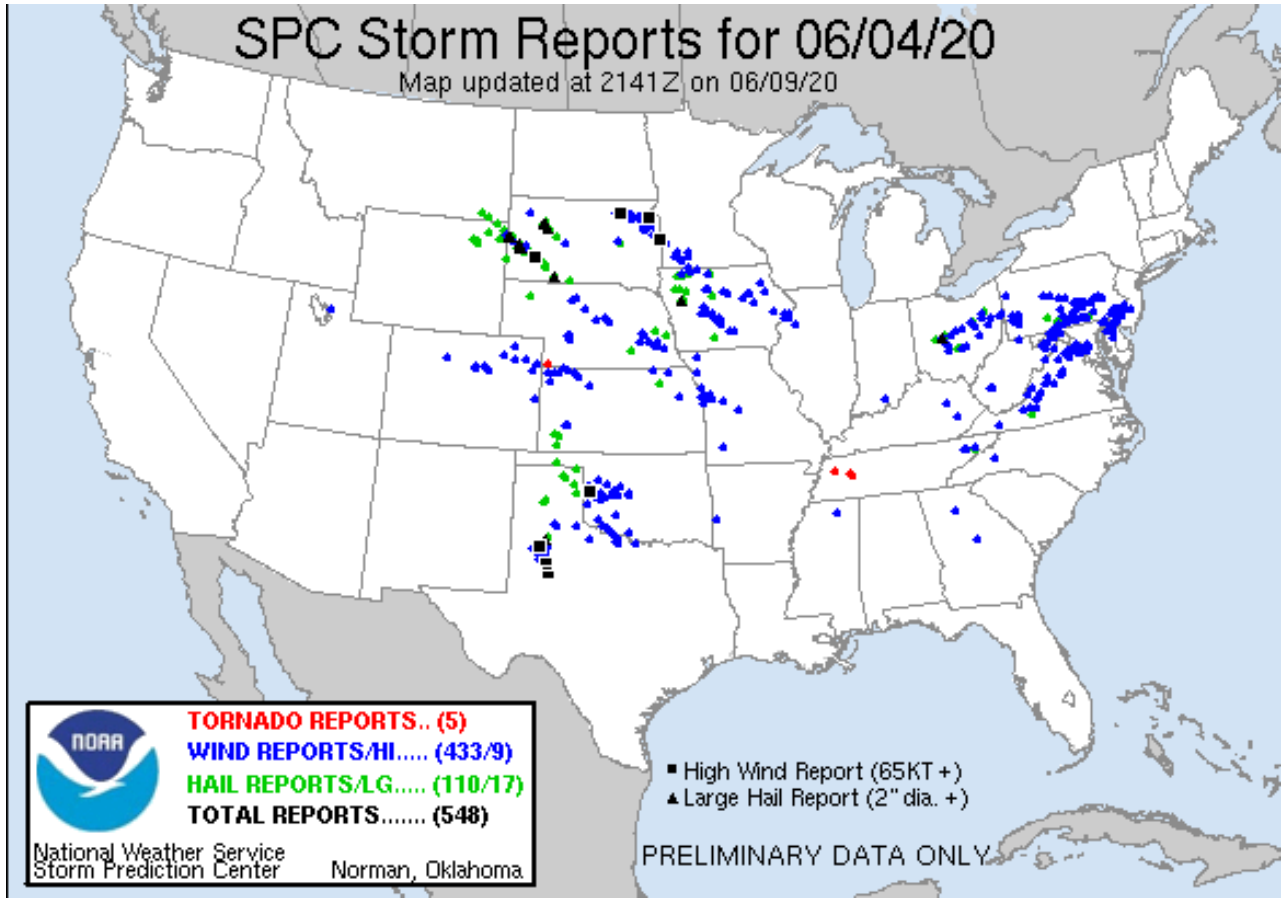
- **Total lightning** (CG+IC)
- Day- and nighttime
- Cloud top illumination
- **Optical lightning** observation at 777.4nm
- Narrow band of 1nm
- Platform: GOES-16 and 17*
  *GOES-17 GLM not used here

(e.g., Goodman et al. 2003, Mach 2020)

**GLM observations over southeastern United States**

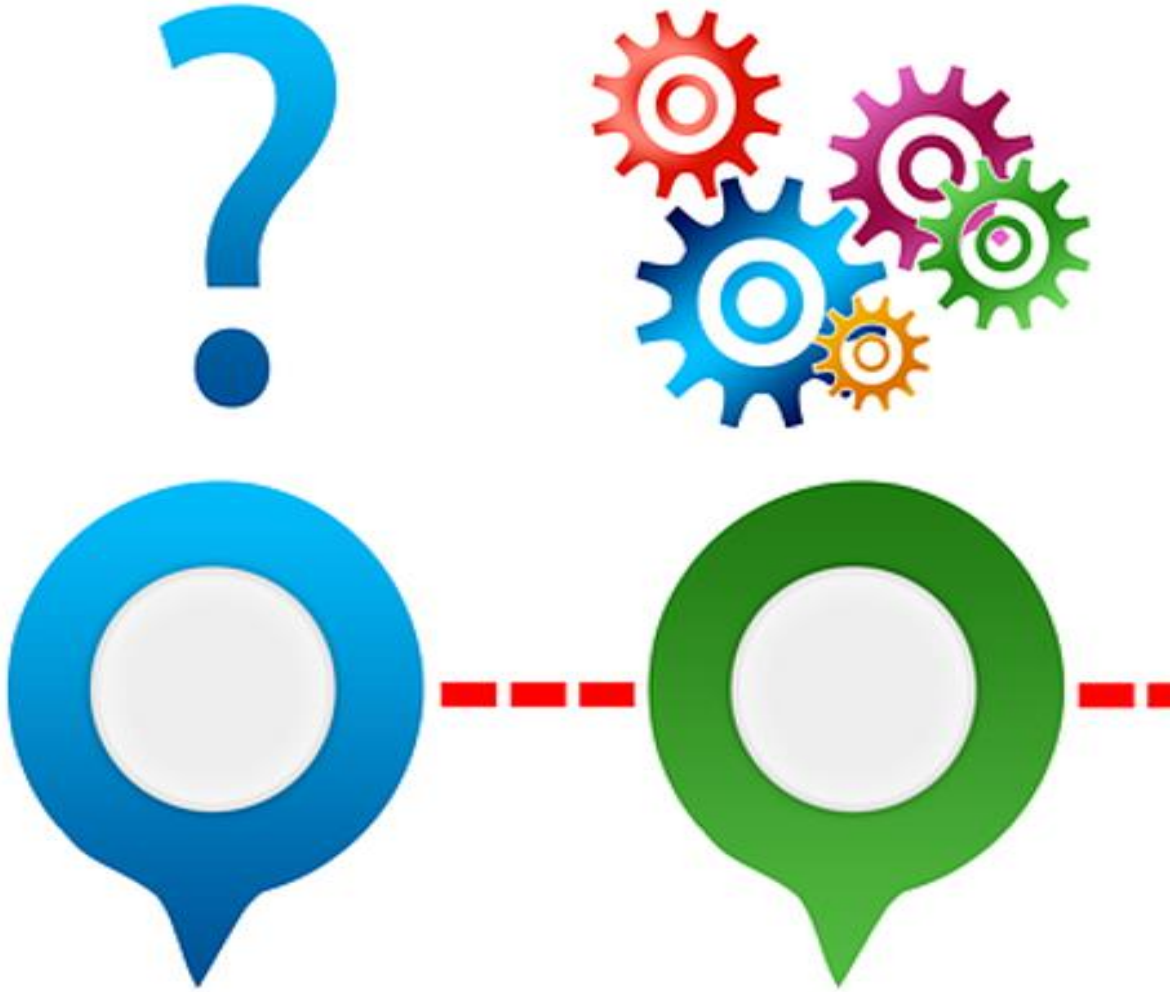
# Storm Prediction Center (SPC) reports

- SPC's **severe weather event** archive https://www.spc.noaa.gov/exper/archive/
- Reports: Tornadoes, Large hail (>1inch~2.54cm), Severe winds (damaging or >50kn)
- Time of occurrence, latitude, longitude (and location, county, state, comments)
- Here: grouped by 6min | 10km




(2020-06-04 1200 UTC – 2020-06-05 1159 UTC)

# Methodology

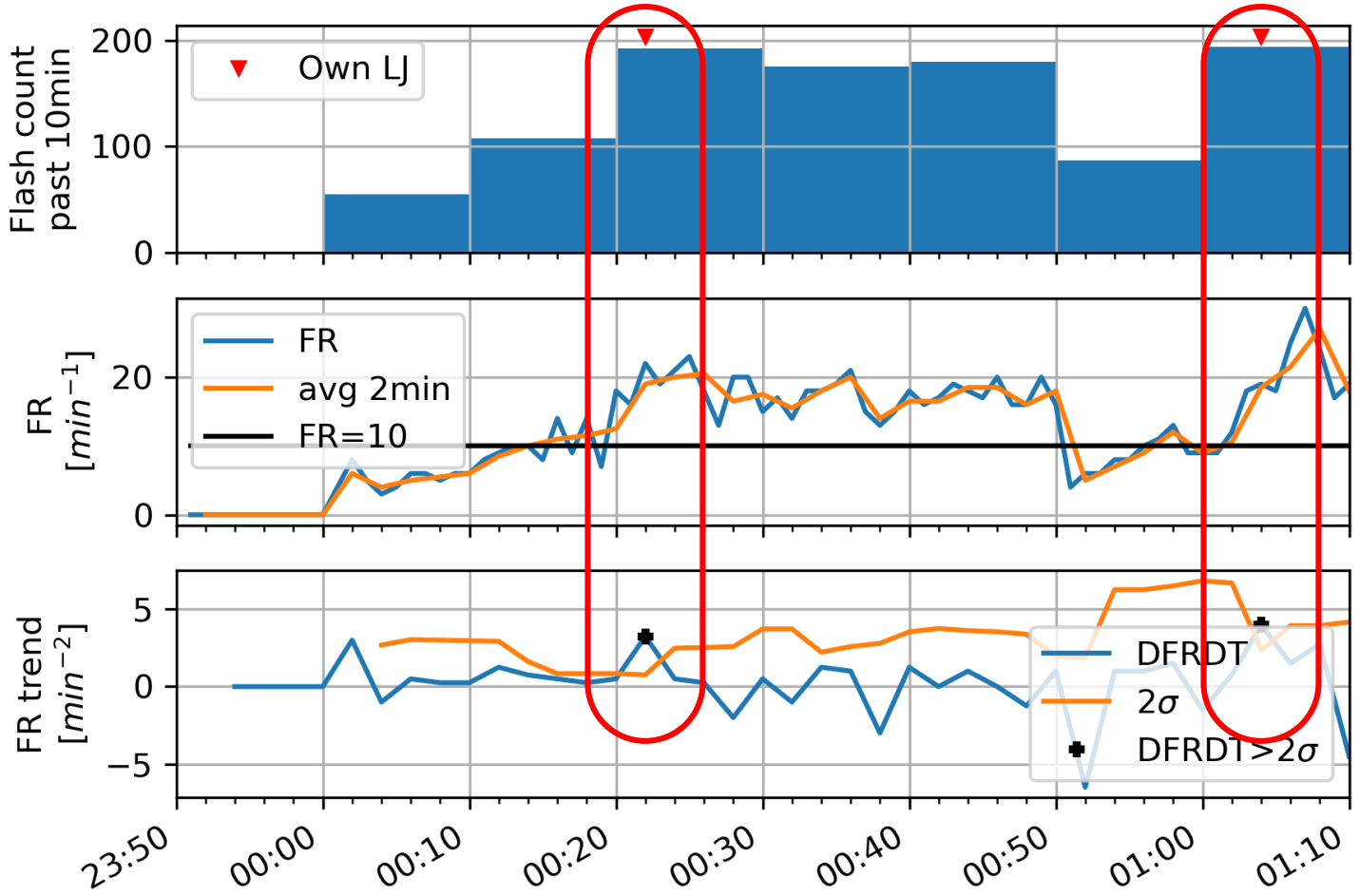


# Automated Lightning Jump (LJ) detection

**Lightning Jump (LJ):** An abrupt increase in the total lightning flash rate (flashes per time) observed within a storm cell.

- Test **LJ algorithms**
  - 2$\sigma$ LJ algorithm (Schultz et al., 2009)
    - Flash rate (FR) threshold: 10 flashes per minute
    - $\sigma$-level threshold: 2
  - **Modification**: FR per cell area in $\sigma$-calculation
  - **New:** FR/area relative increase

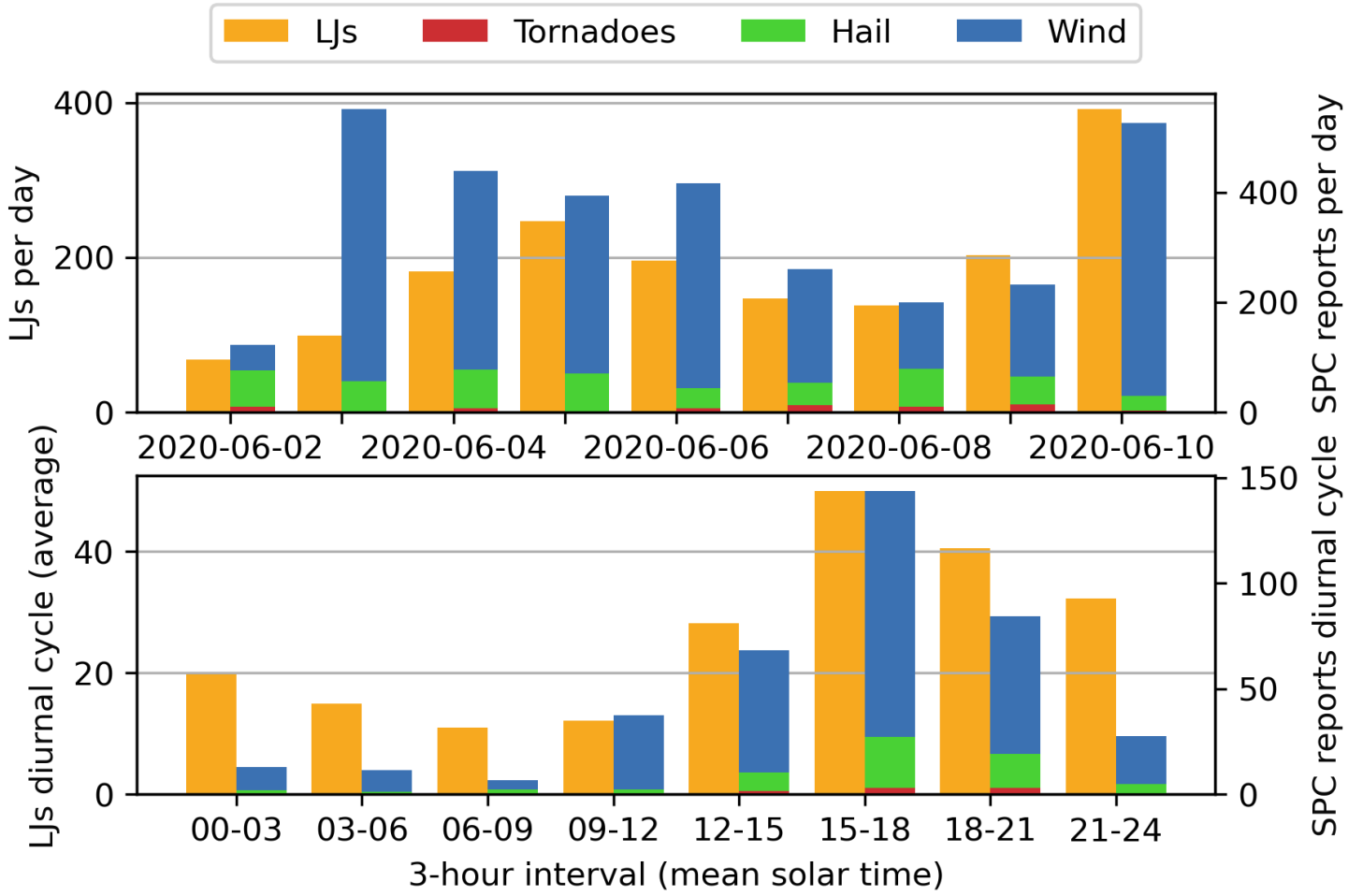
**Cell trajectory with 2 LJs (2020-06-02 00:00Z-01:10Z)**



# LJ and severe weather occurrences

## CONUS 2020-06-02 to 2020-06-10 LJs and SPC reports

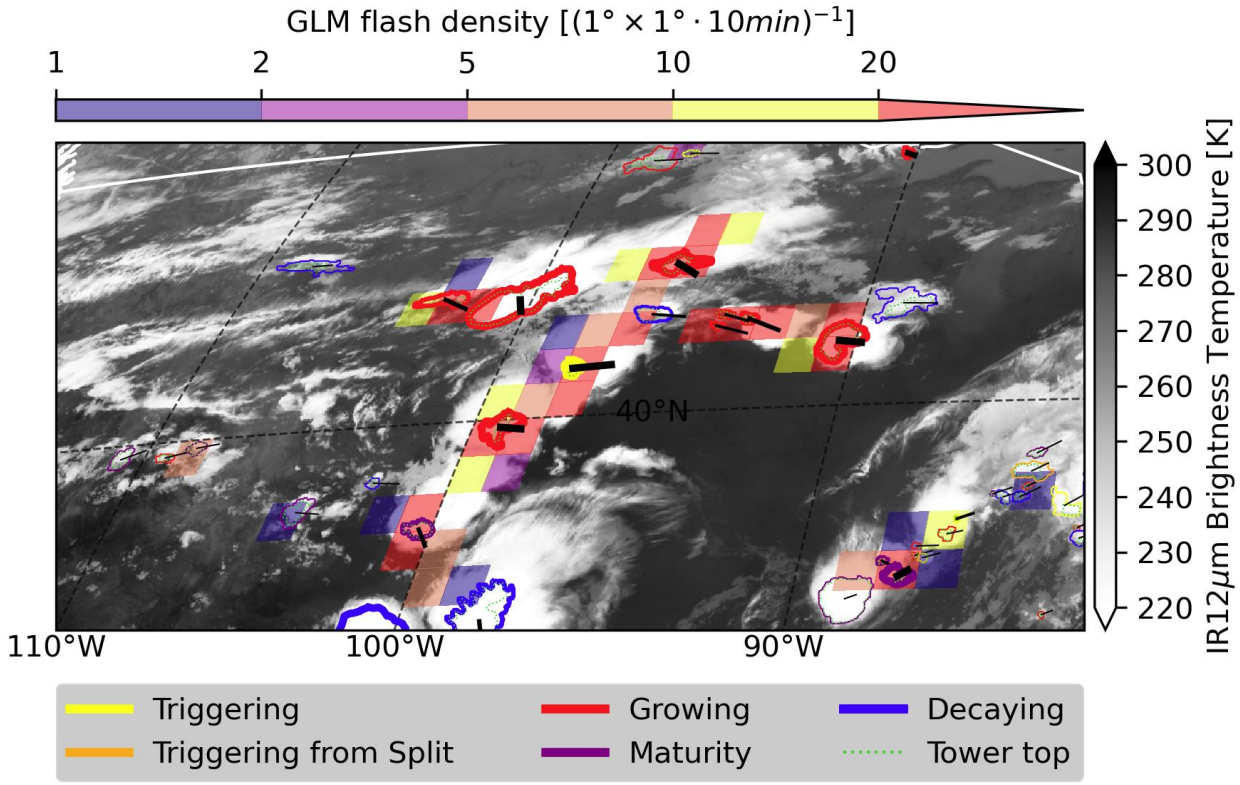
- Total LJs: 1672
- LJs on all 9 days observed
- LJs mostly in local afternoon and evening
- Total SPC reports: 3152 (Tornado: 74, Hail: 487, Wind: 2591)
  with available GLM-16 data: 2917 (68, 452, 2397)



# SAFNWC nowcasting software

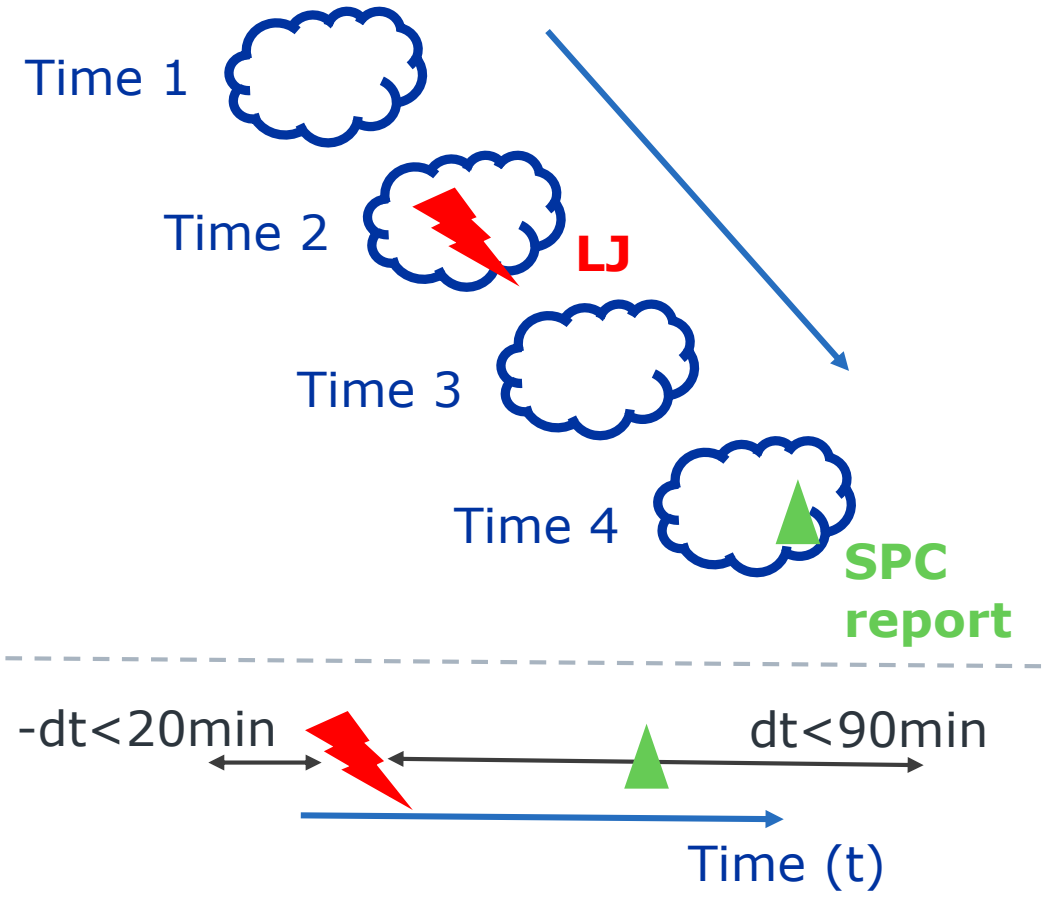
- **Nowcasting** based on satellite imagery (here GOES-16)
  - NWP data and observations, e.g., lightning records, as optional import
- Identification of (convective) cloud cells
- **Automated storm tracking**: Rapid Developing Thunderstorm Convective Warning (RDT-CW) package
- Other products, e.g., convective rain rates, convective initiation

**RDT-CW significant cells on top IR12 background image and GLM flash density (2020-06-05 03:10Z-03:20Z, zoom)**



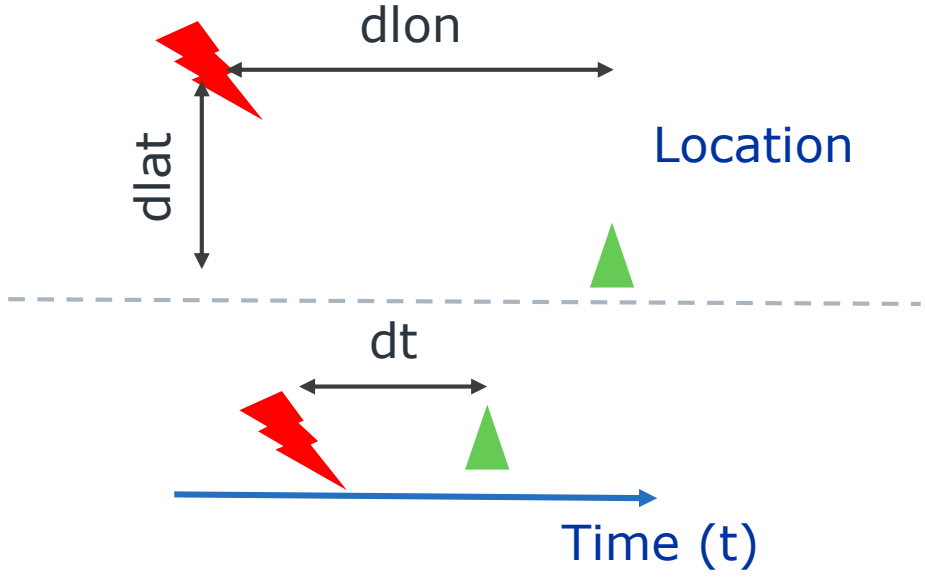
# Matching of LJs and SPC reports

## 1) Cell trajectory based matching

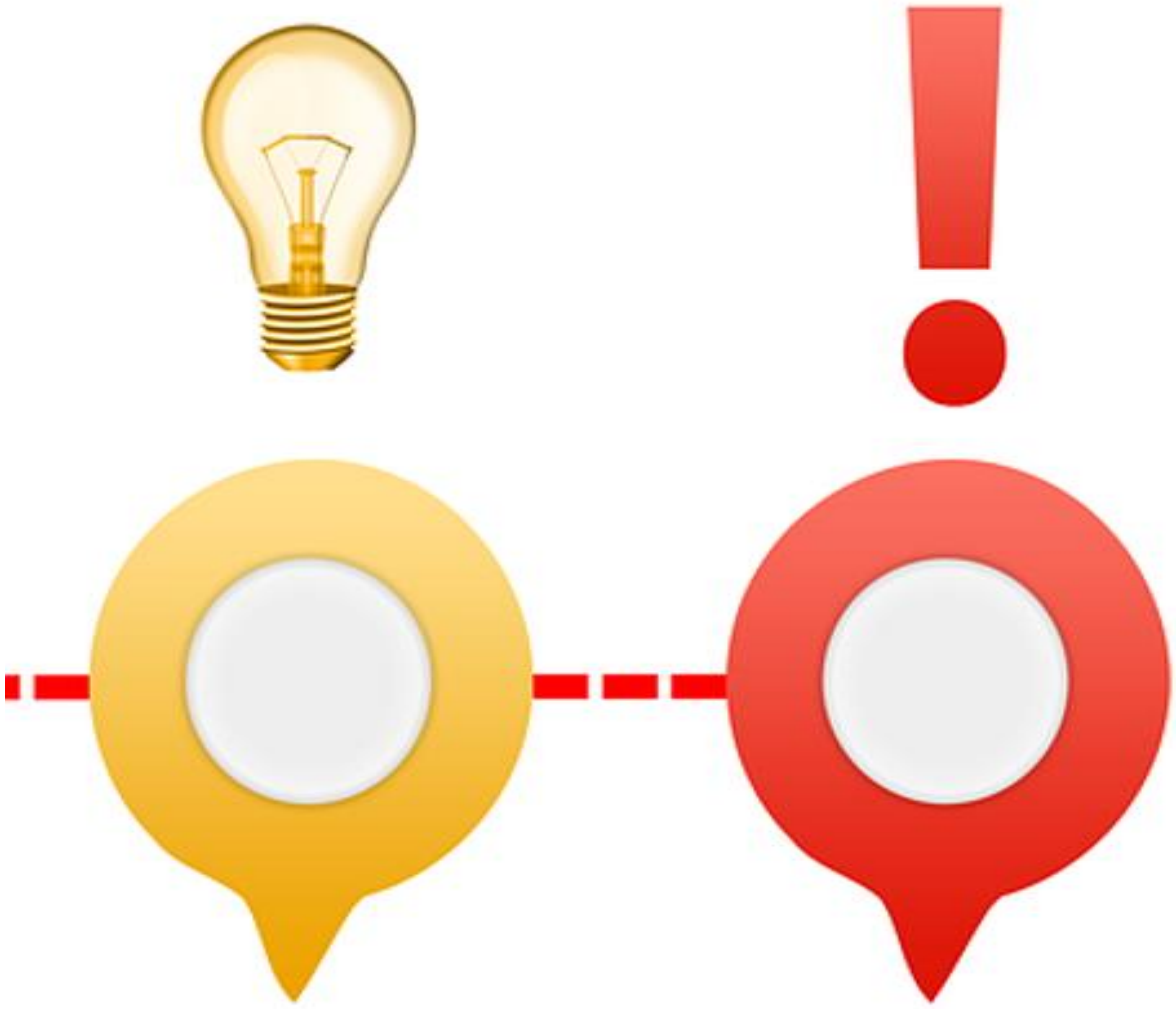



## 2) Weighted Euclidean Distance (WED) based matching

$$WED = \frac{dlat}{50km + R_{cell}} + \frac{dlon}{50km + R_{cell}} + \frac{dt}{5400s|_{\text{LJ before SPC}} \text{ or } 1200s|_{\text{LJ after SPC}}} < 1$$



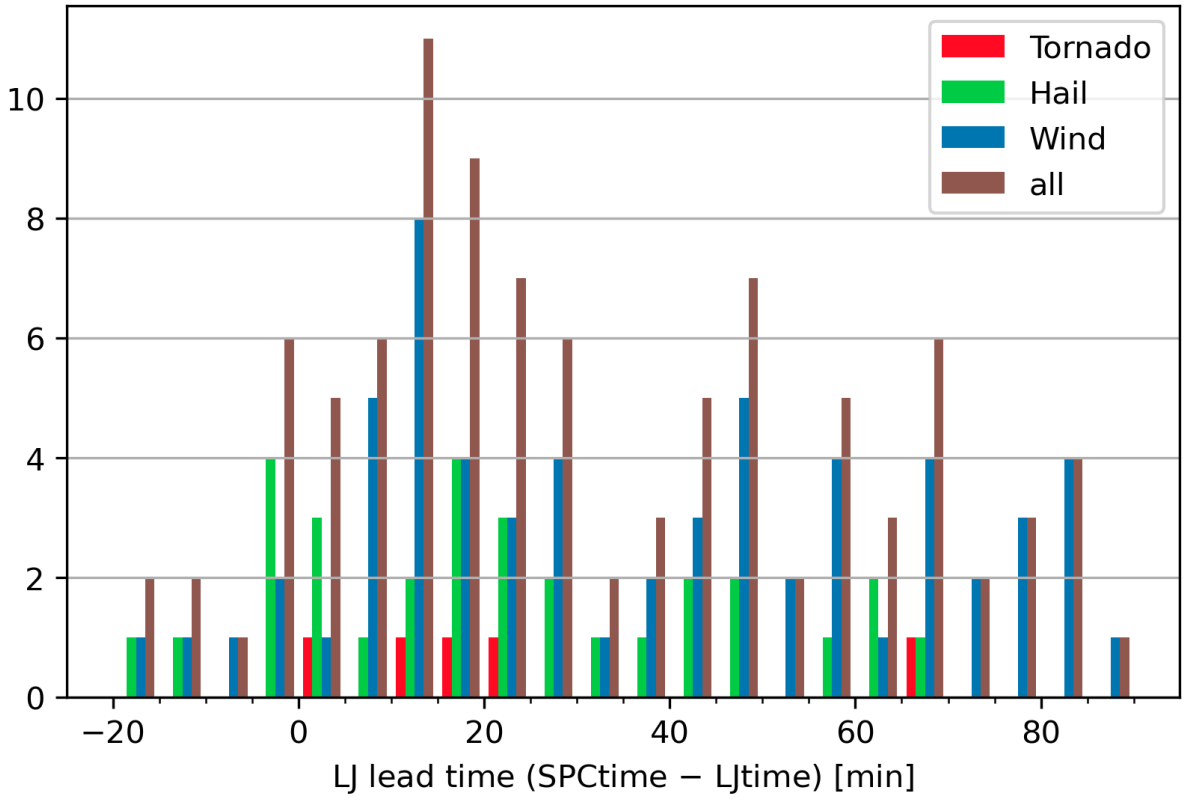
# Results



# Lead times of LJ and SPC report matches

Example:

- **Max. lead times** of LJ to SPC reports (positive = LJ before SPC report)
- Period: 07 Jun 2020, 1900 UTC to 08 Jun 2020, 0250 UTC
- Trajectory-based matching
- **Trajectories**: 946; **29 with LJs**
- LJ algorithm: Sigma-algorithm with 15 flashes/minute and sigma of 1.50



# LJs to predict SPC reports (Tornado, Hail, Wind)

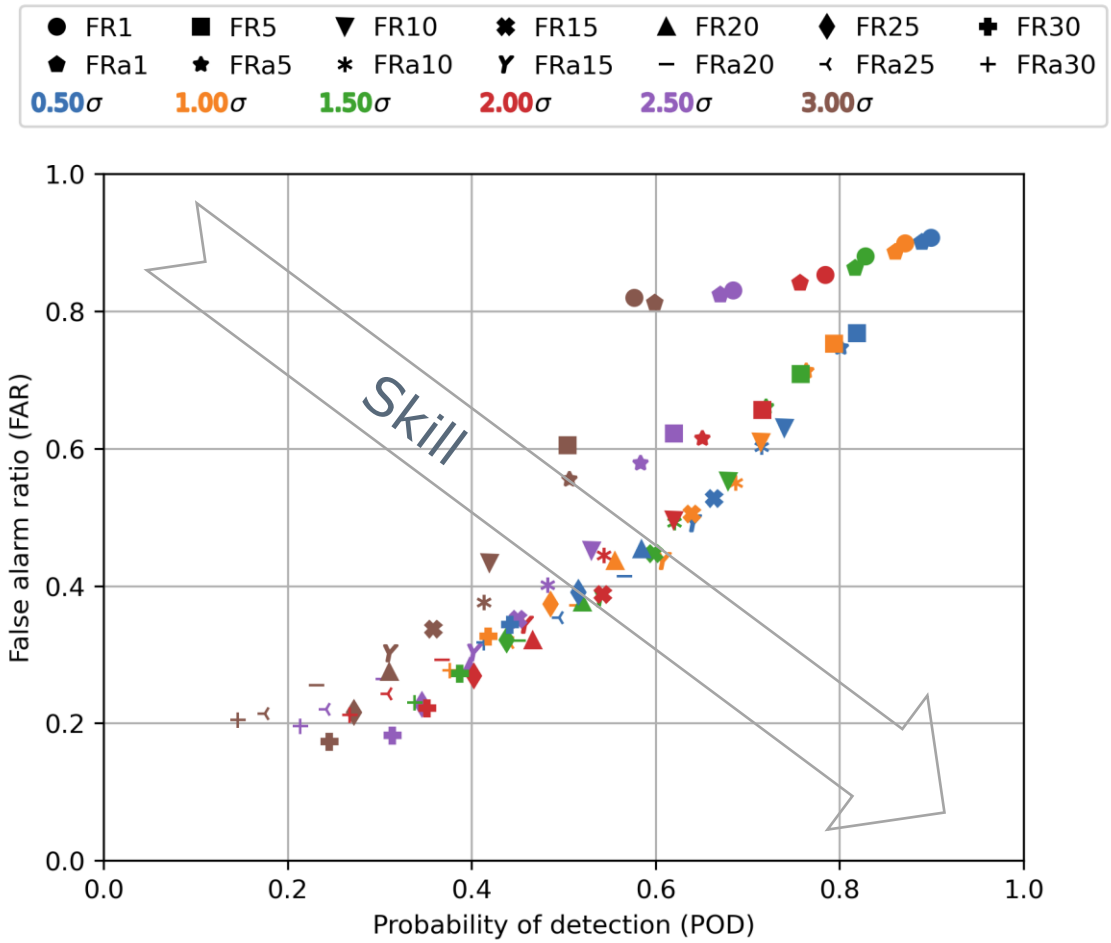
## Quantitative measures (scores)

- Probability of Detection (POD):
  $$\mathrm{POD} = \frac{hits}{hits+misses}$$
- False Alarm Ratio (FAR):
  $$\mathrm{FAR} = \frac{false\ alarms}{false\ alarms+hits}$$
- Frequency Bias Index (FBI)
- Critical Success Index (CSI)
- Different LJ algorithms and SPC-LJ matching (trajectory vs WED)

| LJs | SPC reports (Tornado, Hail, Wind) | |
|---|---|---|
| | yes | no |
| yes | -hit- | -false alarm- |
| no | -miss- | -correct no- |

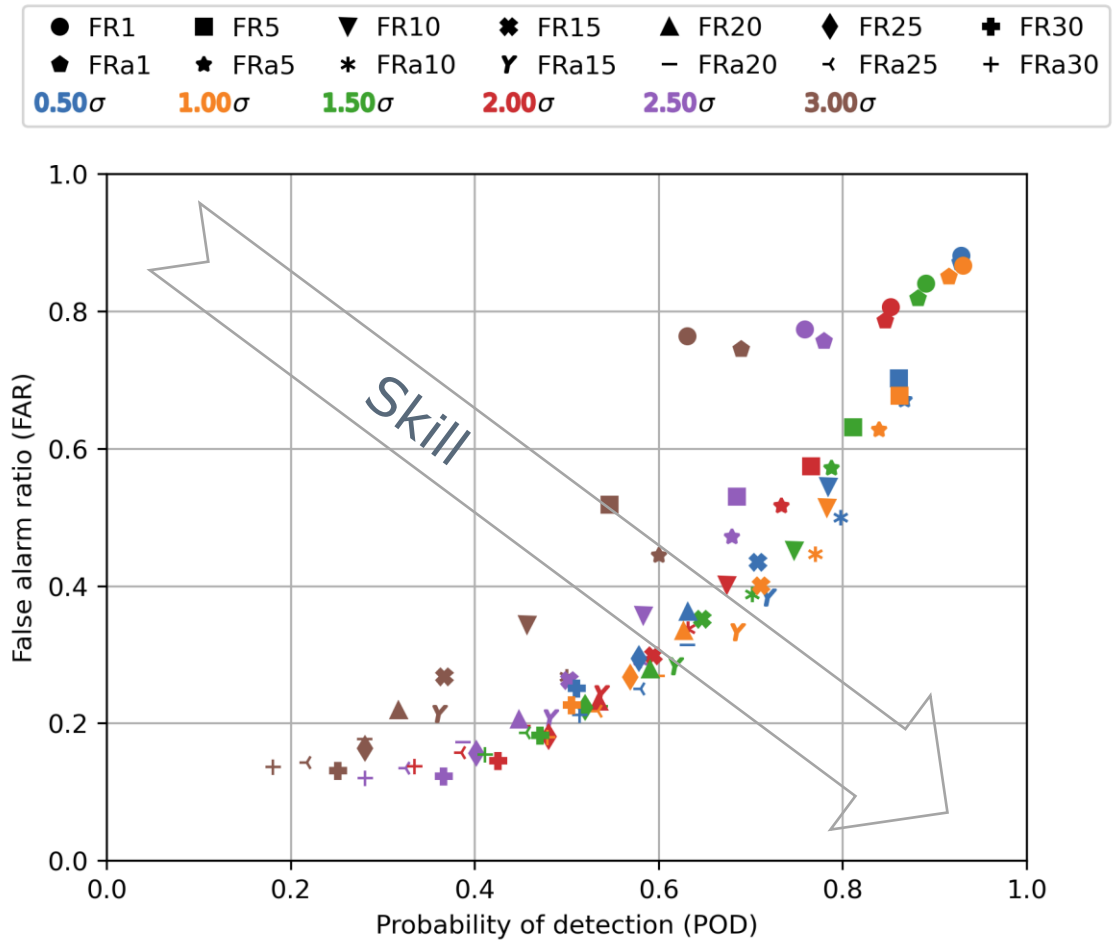
# LJ algorithms for trajectory matching

- FR and $\sigma$ as algorithm thresholds (variated here)
- FR – original $\sigma$-algorithm
- FRa – flashes per cell area based $\sigma$-calculation
- Slight advantage – higher POD with lower FAR – for flashes per cell area based $\sigma$-calculation
- Other LJ algorithms in testing

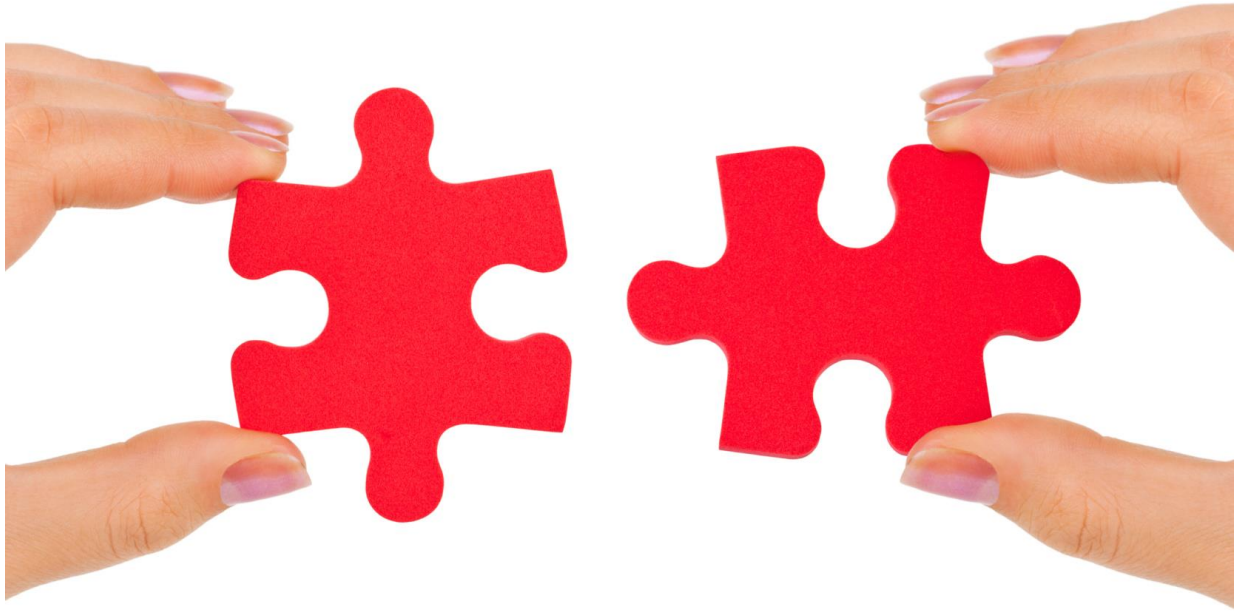


# LJ algorithms for WED matching

- FR and $\sigma$ as algorithm thresholds (variated here)
- Slight advantage – higher POD with lower FAR – for flashes per cell area based $\sigma$-calculation (FRa) over original $\sigma$-calculation (FR)
- Other LJ algorithms in testing
- Higher POD + lower FAR than trajectory matching



# Conclusions



# Summary

- **Automated** storm-tracking and detection of **GLM lightning jumps (LJs)**
- Most LJs in local afternoon and evening
- **LJ-SPC report lead times** from a few minutes to more than an hour
- **Flashes per cell area** improve the original $\sigma$**-algorithm**
- Trajectory approach with physically related matches
- WED-based matching of LJs and SPC events with better POD and FAR than trajectory approach
- **Objective: Optimize LJ algorithms** for satellite lightning observations with respect to severe weather warning lead times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# THANK YOU

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# Backup slides

# Matching of RDT cells and SPC reports

- Study case: June 02-10, 2020, CONUS, GOES-16
- SPC report within satellite scan interval (**10 minutes** for GOES-16) and **less than 50 km** from the cell contour matched to that cell
- 1 SPC report only matched to the closest cell at report time (often within the cell contour)

**Map SPC reports and RDT-CW cells (cells with SPC report pink) for 2020-06-02**