Koninklijk Meteorologisch Instituut

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ELDW, Oct 02, 2024

Lightning jumps from geostationary observations for nowcasting severe weather - an update

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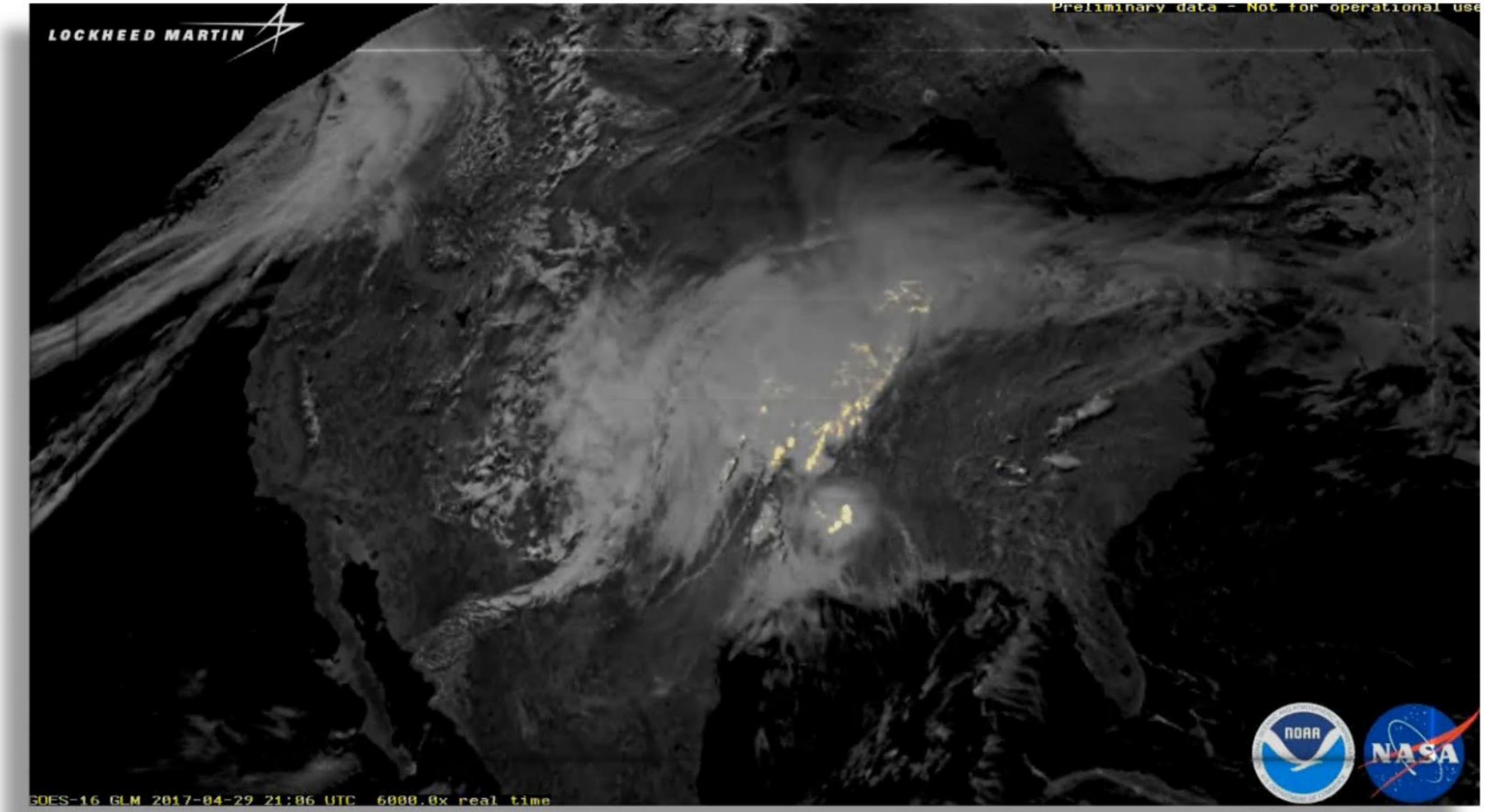
Lightning optical pulses from space

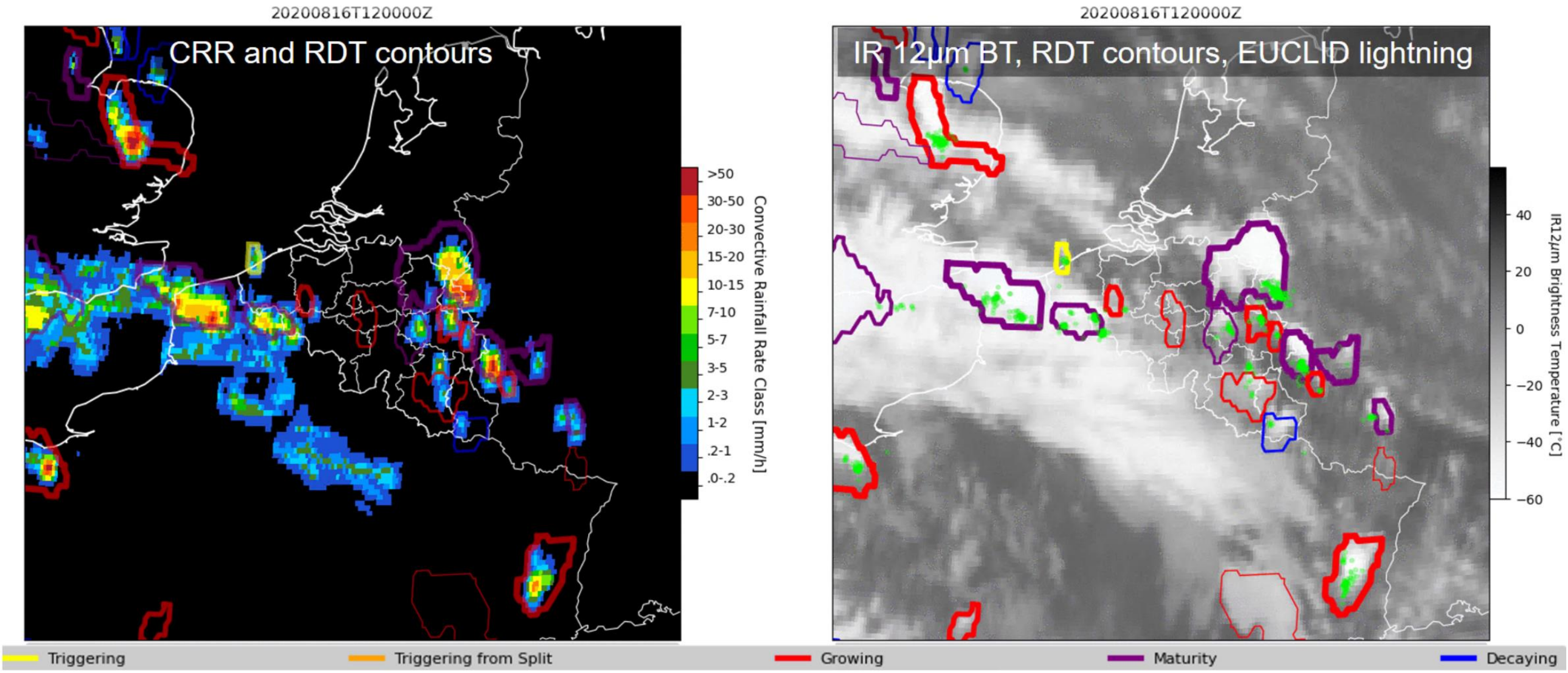
GOES-16 GLM lightning superimposed on GLM background

- Cloud tops illuminated by lightning
- High frequency cameras onboard satellites: **GLM on GOES-R** and **MTG-LI**
- Day and night
- All types of total lightning observed



NWCSAF: Cell tracking Belgium

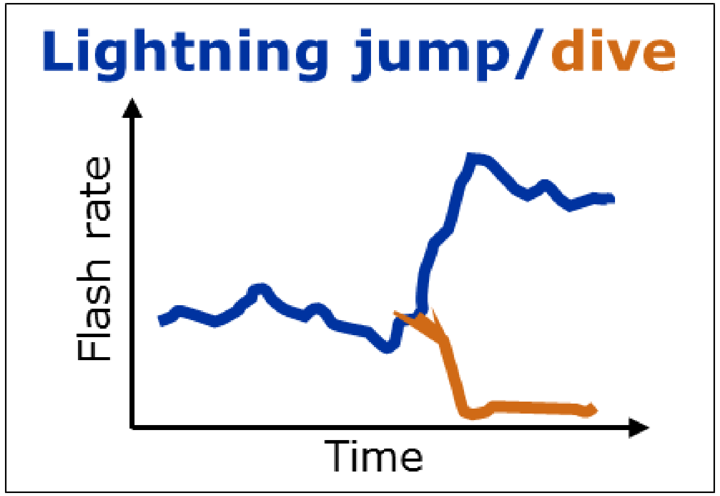
Convective rain rate (CRR) and NWCSAF RDT cell tracking: 16 Aug 2020 – 24 hour loop



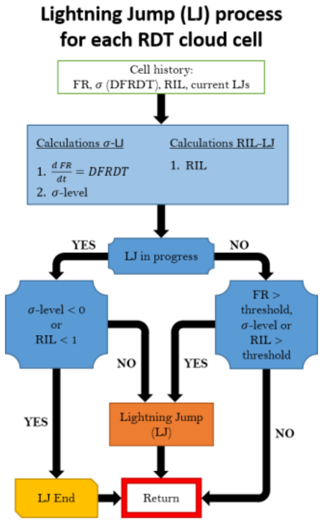
Automated Lightning Jump (LJ) detection

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

Lightning Dive (LD): An abrupt decrease in the total lightning flash rate (flashes per time) observed within a storm cell.



Time series of the GLM lightning flash rate for one tracked RDT storm cell



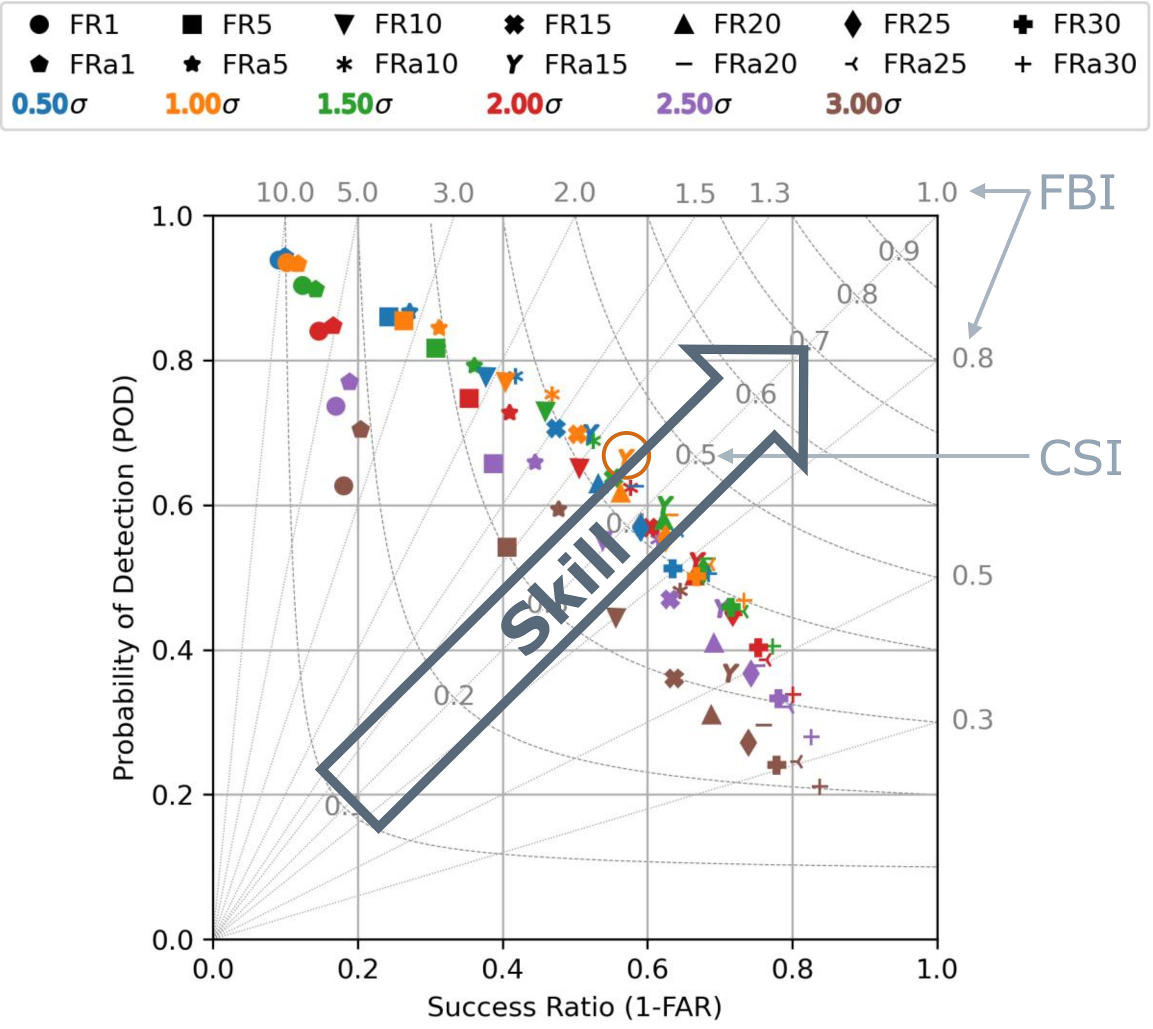
Erdmann and Poelman, 2023, doi: 10.1175/JAMC-D-22-0144.1

Automated detection: Algorithm with a flash rate threshold and a rate-of-change (σ) threshold

→ Test various thresholds to **optimize the algorithm** performance for GLM data

GLM LJs as severe weather predictors (1/3)

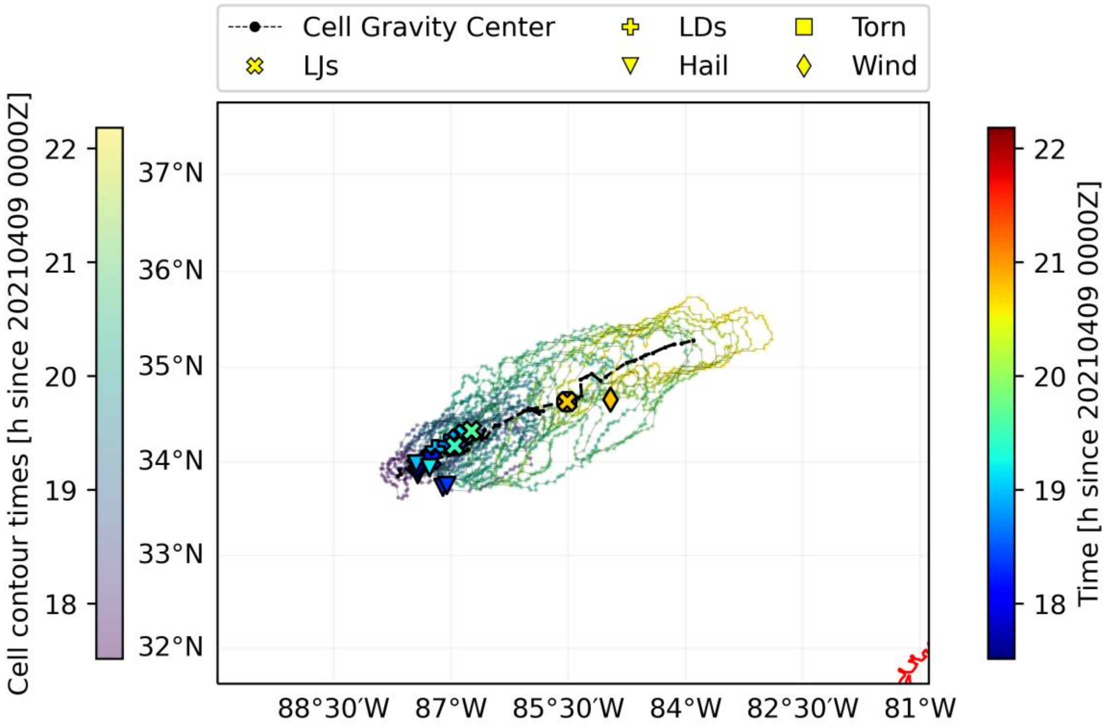
LJs	Severe weather report (Tornado, Hail, Wind)	
	yes	**no**
yes	A -hit-	B -false alarm-
no	C -miss-	D -correct no-

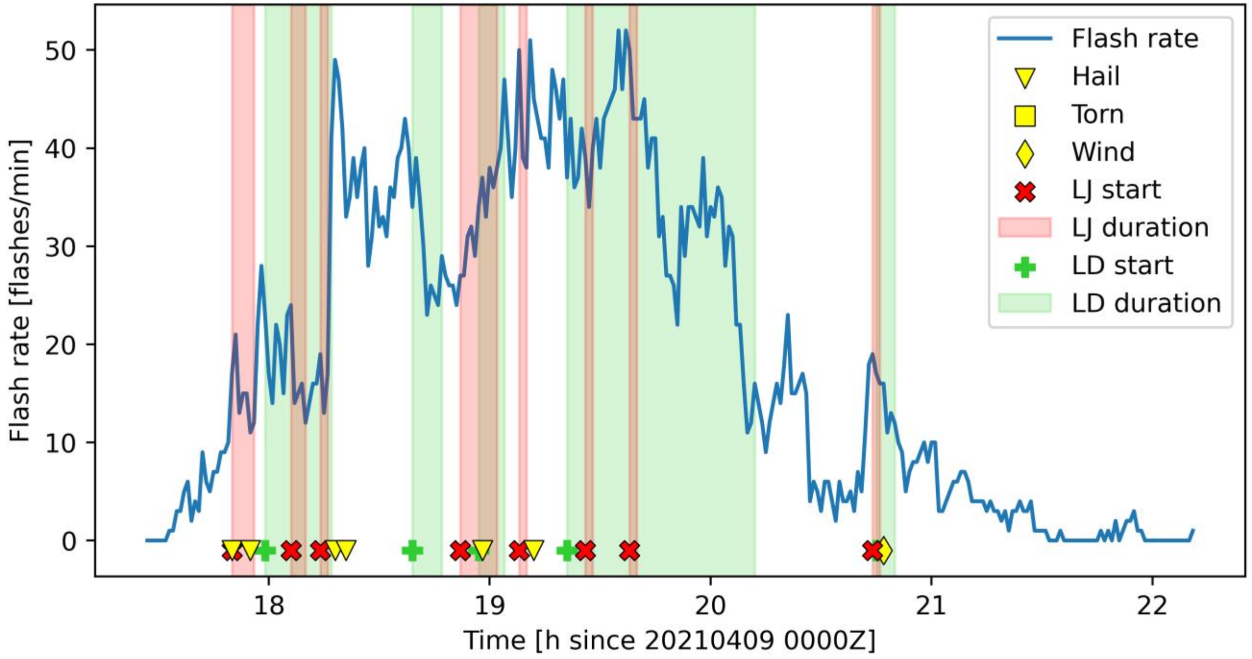


- Results for various LJ algorithm configurations
- **FR | FRa (markers)** and **σ (color)** as variable algorithm thresholds

GLM LJs as severe weather predictors (2/3)

LJ detection: flash rate ≥15 $\mathrm{flashes/min}$, σ-level ≥1.0
LD detection: flash rate ≥10 $\mathrm{flashes/min}$, σ-level ≤-1.0





[figures adapted from the work of Zoe Pelletier]

GLM LJs as severe weather predictors (3/3)

- NCEI severe weather report database → correlate GLM LJs and reports
- Hits, misses, false alarms → statistics and skill scores
- New: **NWCSAF software update** from v2018 to v2021*
  GOES Conus scan (5min update) vs. fulldisk scan (10min update)*

[Credit: Zoe Pelletier]

(WED approach)	Fulldisk 2018	Fulldisk 2021	Conus 2021
POD	0.65	0.83	0.81
FAR	0.18	0.14	0.15
FBI	0.79	0.97	0.94
CSI	0.57	0.73	0.71

POD : Probability of detection

FAR : False alarm ratio

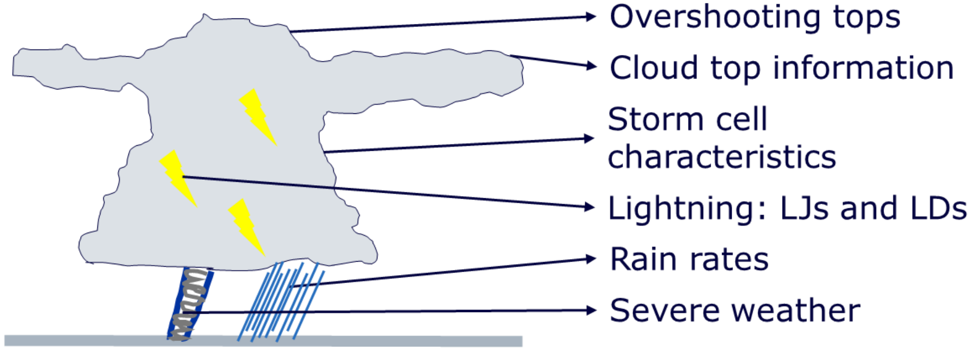
FBI : Frequency bias index

CSI : Critical success index

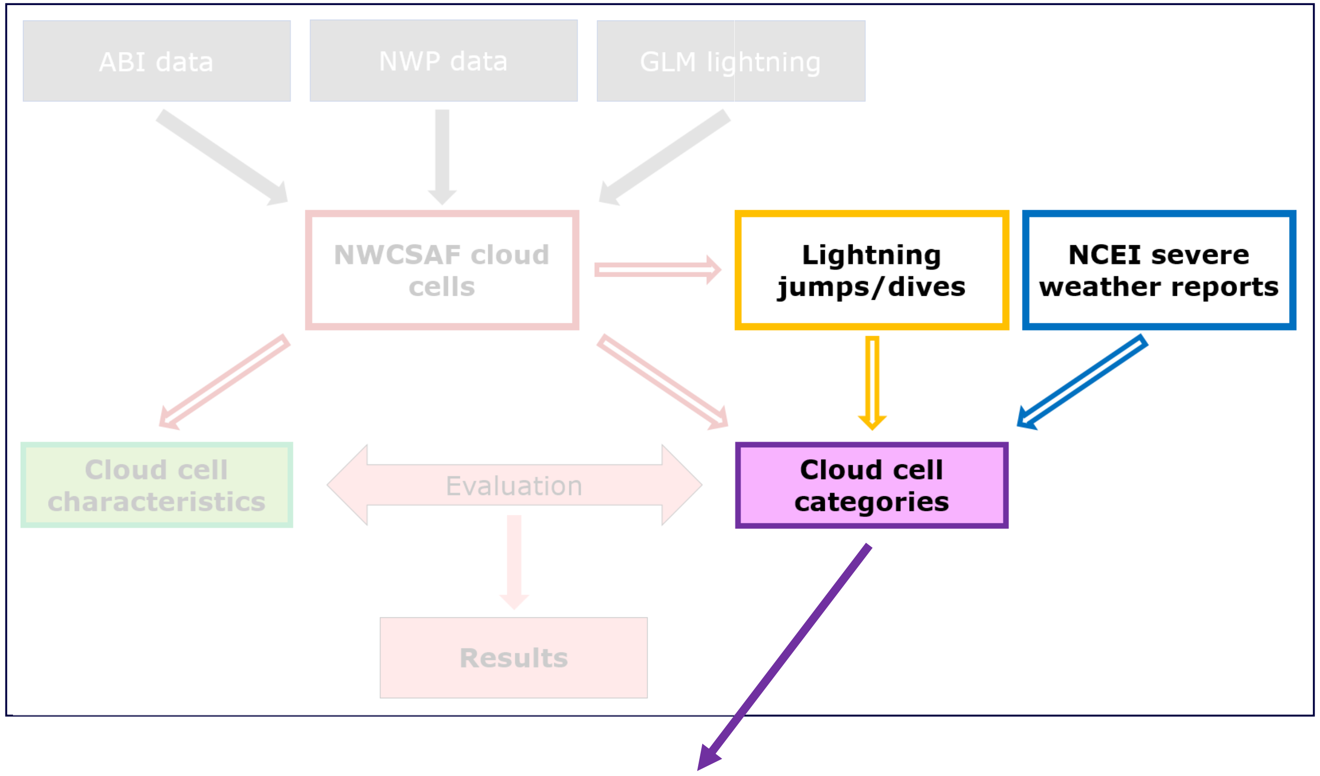
*results for 3 days in April 2021, more cases soon

GOES-based thunderstorm characteristics

- Analysis of almost 25,000 thunderstorms over the US
- NWCSAF cell detection + tracking
- GOES-16 + GLM data
- Storm characteristics



Methods *[Erdmann and Poelman, preprint: egusphere-2024-174]*

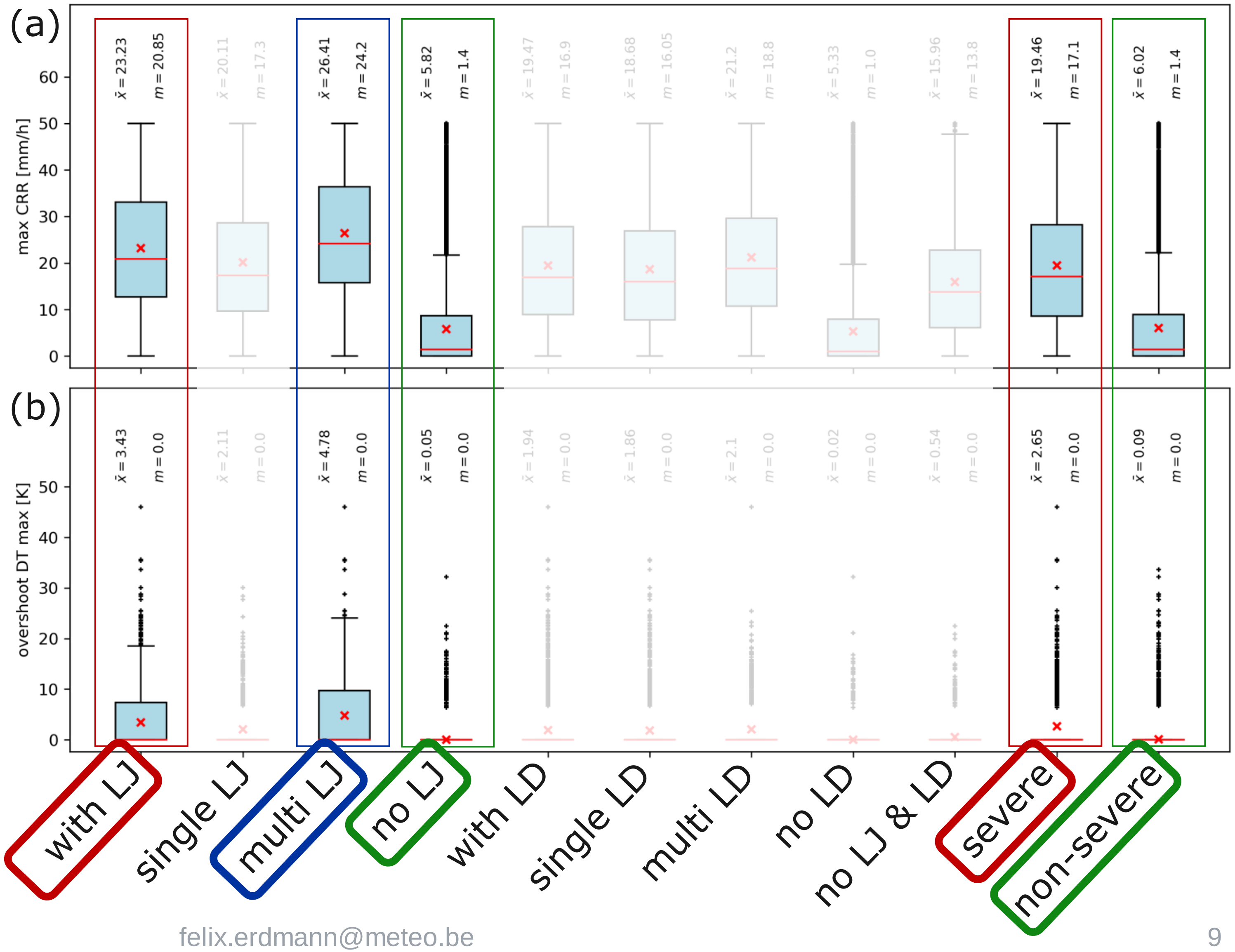


Storms w/ or w/o LJ, LD, severe weather

Thunderstorm categories

- **Categorize** thunderstorms based on LJs, LDs, and severe weather reports (x-axis)

- Compare these storm categories for
  (a) max rain rates
  (b) overshooting tops



LJ-storms vs. severe storms

- Characteristics of storms with LJs similar to those of severe thunderstorms
- Storms with multiple LJs favorable of overshooting tops (~strong updrafts) and high convective rain rates

Characteristic (mean)	With LJ	Multiple LJs	Without LJ	Severe	Non-severe
Cloud top Temp. [K]	215	213	235	218	234
Cloud ice fraction	0.94	0.97	0.79	0.93	0.79
OT* count	0.34	**0.47**	0.0	0.27	0.01
OT* d(Temp.) to anvil [K]	3.4	**4.8**	0.0	2.6	0.1
Max rain rate [mm/h]	23.2	**26.4**	5.8	19.5	6.0
WV7.3 Brightness Temp. [K]	212	211	230	216	230
WV6.2-IR11.2 BTD** [K]	-1.2	-0.6	-8.0	-2.3	-8.0

* overshooting top
** brightness temperature difference

Summary

What do GLM LJs tell us about the storm structure from a satellite point of view?

- Deep convective clouds with cold tops and **high precipitation** potential
- Prone to overshooting tops as a result of **strong convective updrafts**

Are GLM LJs useful to assess thunderstorm severity?

- Strong updrafts correlate to both GLM LJs and severe weather reports.
- Thermal, cloud top, moisture, and precipitation characteristics of thunderstorms with GLM LJs were remarkably similar to those of severe thunderstorms.
- **Storms with multiple GLM LJs** must be monitored (closely) – strongest updrafts, highest rain rates, and share common characteristics associated with tornado and hail storms.
- Not all severe storms have LJs and not all storms with LJs were reported as severe.

Do GLM LDs provide additional information about the storms?

- In general, the LJs are more useful as some LDs also occurred in shallow convection.
- LDs may indicate tornadogenesis in some cases but still more research is needed.

THANK YOU

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A1: Full comparison of storm categories

Characteristic (mean)	withLJ	singleLJ	multiLJ	noLJ	withLD	withNCEI	noNCEI
cell area [km2]	15,780	10,373	21,262	1,911	10,460	12,812	2,066
IR12.3(min_BT) avg [K]	213	215	211	235	217	218	234
min T avg [K]	215	217	213	237	218	219	236
min pressure (top) [hPa]	128.5	136.9	120.1	221.9	138.6	152.7	220.8
vertical grad(T) [K/km]	11.8	13.9	9.6	21.8	14.4	13.2	21.7
cloud ice fraction [-]	0.94	0.92	0.97	0.79	0.92	0.93	0.79
IR3.9(min_BT) avg [K]	234	236	232	252	237	241	252
overshoot count max [-]	0.34	0.21	0.47	0.0	0.20	0.27	0.01
overshoot DT max [K]	3.4	2.1	4.8	0.0	1.9	2.6	0.1
max CRR [mm/h]	23.2	20.1	26.4	5.8	19.5	19.5	6.0
WV6.2(min_BT) avg [K]	211	213	210	225	214	215	225
WV7.3(min_BT) avg [K]	212	214	211	230	215	216	230
WV6.2-WV7.3(p90) max [K]	0.1	-0.2	0.3	-3.3	0.3	-0.5	-3.2
WV6.2-IR11.2(p90) max [K]	-1.2	-1.8	-0.6	-8.0	-2.0	-2.3	-8.0

[Erdmann and Poelman, Table 4, preprint: egusphere-2024-174]