Characterizing the Relation between Lightning and Wildfires in the Western United States

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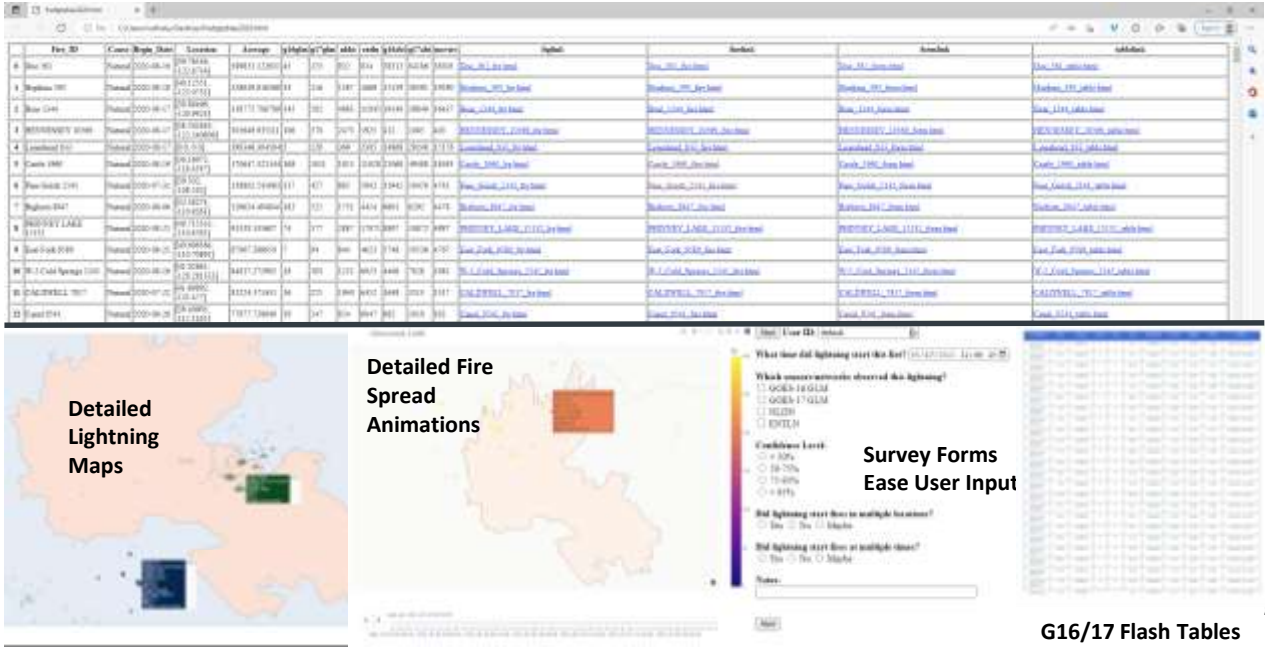
Overview

- Lightning ignited wildfires often smolder for some time before being discovered, so there can be a lag between lightning outbreaks and wildfire outbreaks
- Working to combine satellite- and ground-based lightning data to better characterize the lightning that ignites wildfires
- Near-term Goal: Develop a training dataset of all lightning flashes known to have ignited a wildfire
- Long-term Goal: Apply machine learning to determine when and where lightning is most likely to ignite wildfires
- Long-term Goal: Leverage any delay between lightning strike and fire ignition to suppress some fires before they grow out of control

Identifying Lightning that Ignites Fires

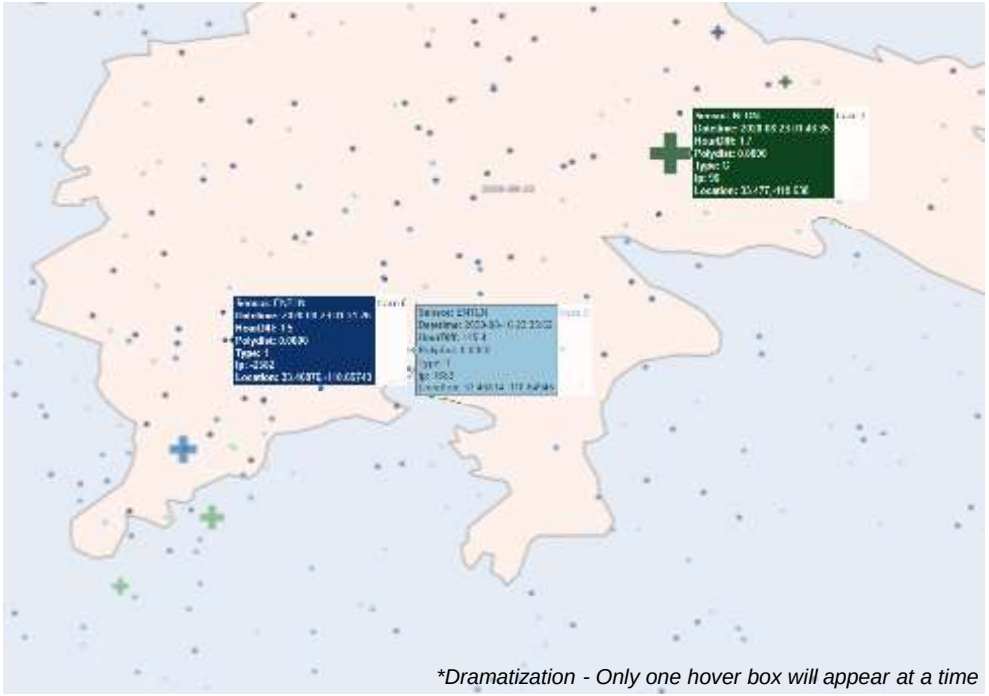
- Automated identification of lightning that ignites wildfires leaves more uncertainty than desired
- Developed tools to bring human observers into the loop on making this distinction
- Produced web-accessible tables with both lightning and fire hot spot counts for each incident



Detailed Lightning Maps

- Symbols are color coded by time to fire start (darker shades are nearer 0Z on the official start date)
- Symbol sizes are scaled by the estimated peak current (NLDN/ENTLN) and area (GLM)

NLDN/ENTLN Characteristics (strokes/pulses)	NLDN	ENTLN
Estimated Peak Current (Ip)	kA	A
Polarity	Positive or negative Ip	
Type	C (cloud) G (ground)	1 (cloud) 0 (ground)

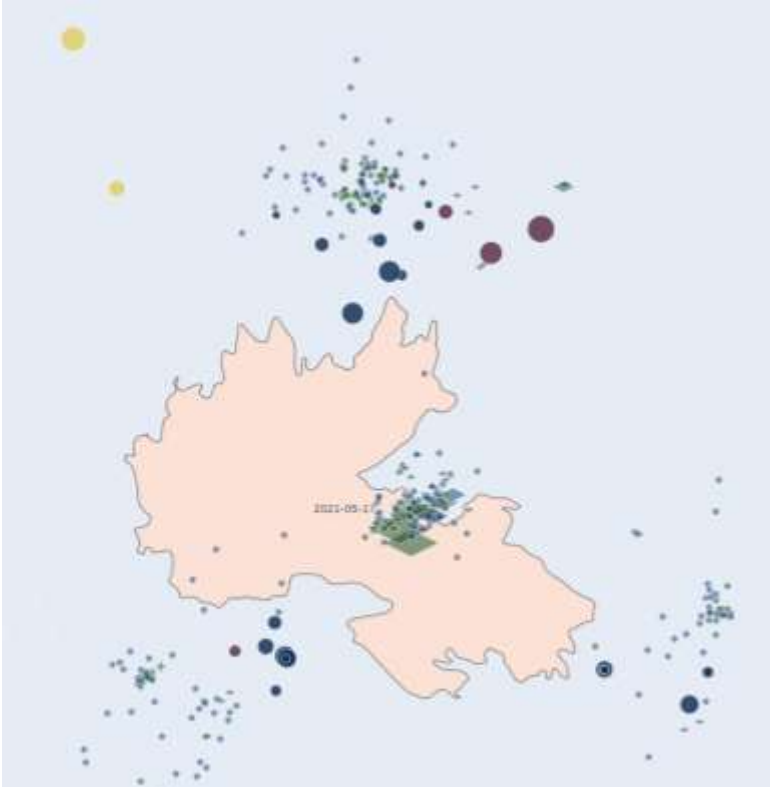


NLDN (blue shades) and ENTLN (green shades) include all cloud-to-ground strokes (diamond = negative polarity, plus = positive polarity) and intra-cloud pulses (hexagons)

Detailed Lightning Maps

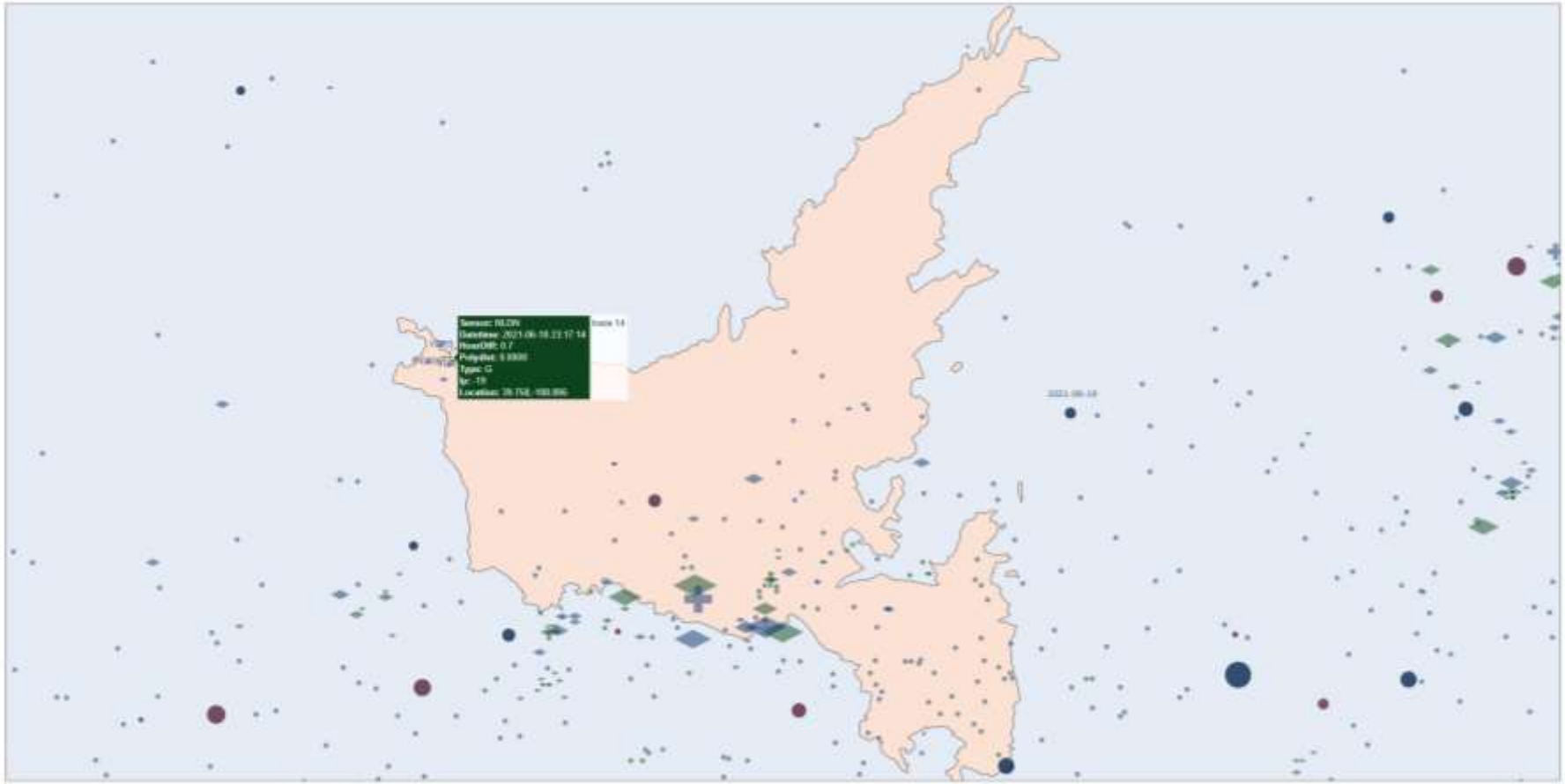
- GLM flashes are displayed as circles scaled by their area at their centroid location (include parallax offset)
- maxcon is a proxy for continuing current, and mneg and mga are suggestive of IC/CG

GLM Characteristics (flashes)	
farea	Flash Area (km^2)
fenergy	Flash Energy (fJ)
maxcon	Max Consecutive Frames
mneg	Maximum Number of Events per Group
mga	Maximum Group Area
maxenergy	Maximum Group Energy (fJ)
duration	Duration (sec)
polydist	Distance between flash and fire polygon



GOES-East = yellow (oldest) to blue (most recent)
GOES-West = beige (oldest) to red (most recent)

Detailed Lightning Maps

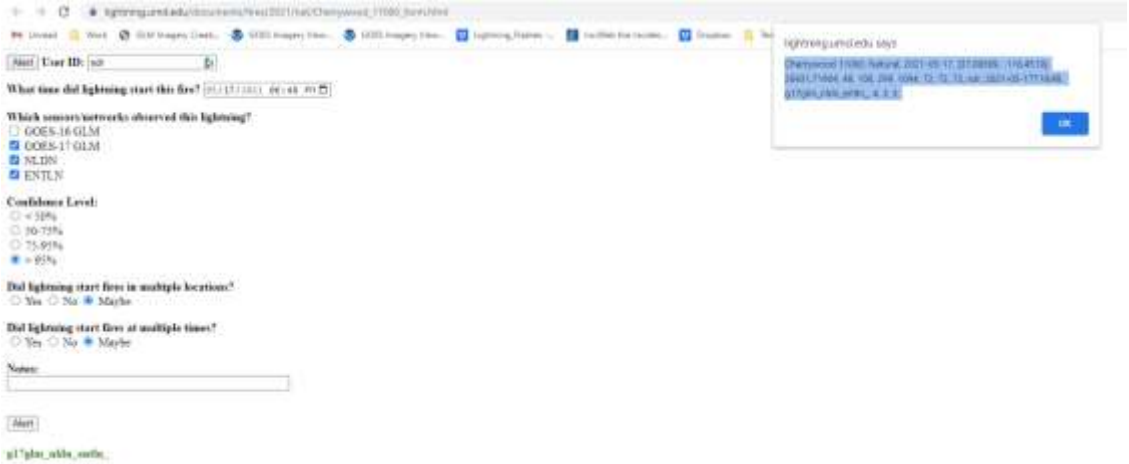


Detailed Fire Spread Animations

- Helps locate fire origination
- Fire hot spot detections from both geostationary and low-earth orbiting sensors
- GOES-East and West ABI, MODIS, and VIIRS are combined into 15-min bins
- Symbol color and size both correspond to the estimated fire radiative power (frp)

Survey Form Eases User Input

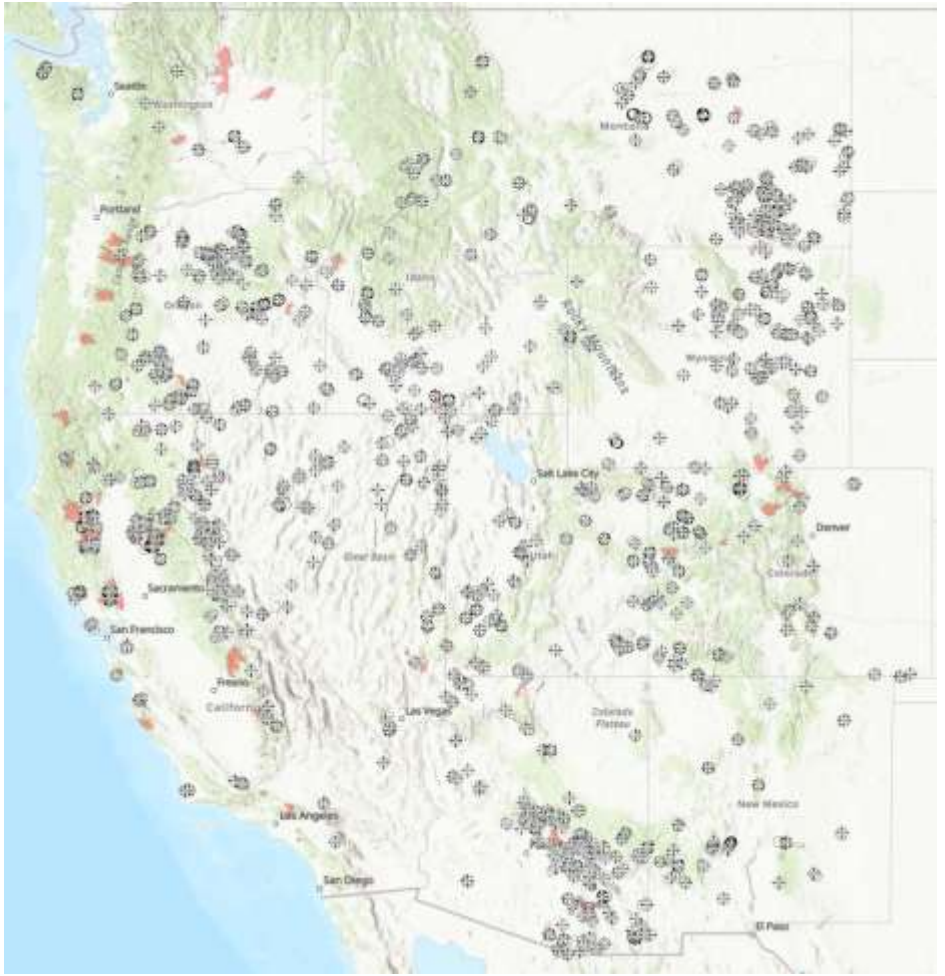
- Prefilled forms for each incident require minimal input from the human observer
- Select the time and day of the fire ignition (one minute accuracy)
- Indicate which networks observed the lightning
- Indicate confidence level
- Potential multiple starts?
- Any additional notes?
- “Alert” produces comma delimited alert box to copy and paste into spreadsheet



2020 Lightning Ignitions

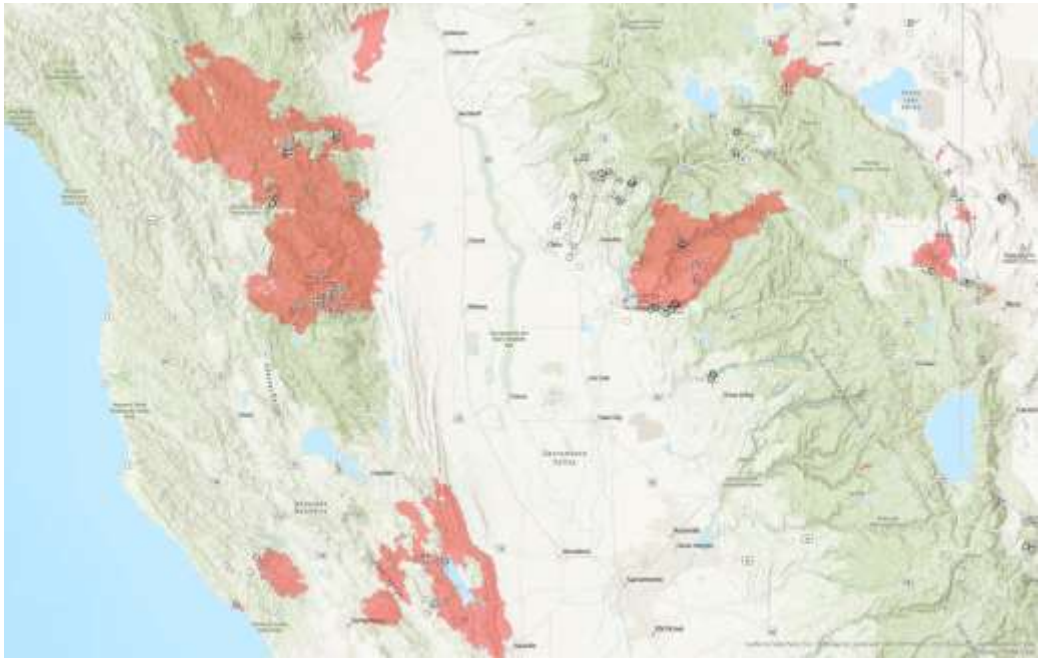
1648 Strokes	
1502 CG (91.2%)	145 IC (8.8%)
1447 –CG, 96.3% 55 +CG, 3.7%	52 –IC, 35.9% 93 +IC, 64.1%

- Identified 1648 strokes likely to have ignited wildfires
- Most were classified as negative polarity cloud-to-ground (CG)
- Most intracloud (IC) strokes were classified as positive polarity



2020 Lightning Ignitions

- Reconstituted 841 fire-igniting flashes to include both ignition and non-ignition strokes
- ~10% had only IC components, most were positive polarity
- Durations comparable between networks



Polarity	Strokes	CG Strokes	IC Strokes	Max Ip	Min Ip	Duration	IC Flashes	CG Flashes	Total Flashes
Bipolar	6.0	3.1	2.9	13.9	-31.5	0.302	11 (6.5%)	157 (93.5%)	168
Negative	3.7	2.9	0.8	---	-27.0	0.167	21 (3.6%)	558 (96.4%)	579
Positive	2.1	0.4	1.7	30.7	---	0.052	56 (59.6%)	38 (40.4%)	94

2020 Lightning Ignitions

- Compiled a null stroke then flash dataset to look for any obvious differences

Null

Polarity	Strokes	CG Strokes	IC Strokes	Max Ip	Min Ip	Duration	IC Flashes	CG Flashes	Total Flashes
Bipolar	7.4	4.5	2.8	12.0	-33.8	0.341	5 (1.9%)	253 (98.1%)	258
Negative	5.5	4.6	0.9	---	-26.8	0.255	11 (1.4%)	803 (98.6%)	814
Positive	2.2	0.5	1.8	16.9	---	0.077	61 (55.5%)	49 (44.5%)	110

Ignitions

Polarity	Strokes	CG Strokes	IC Strokes	Max Ip	Min Ip	Duration	IC Flashes	CG Flashes	Total Flashes
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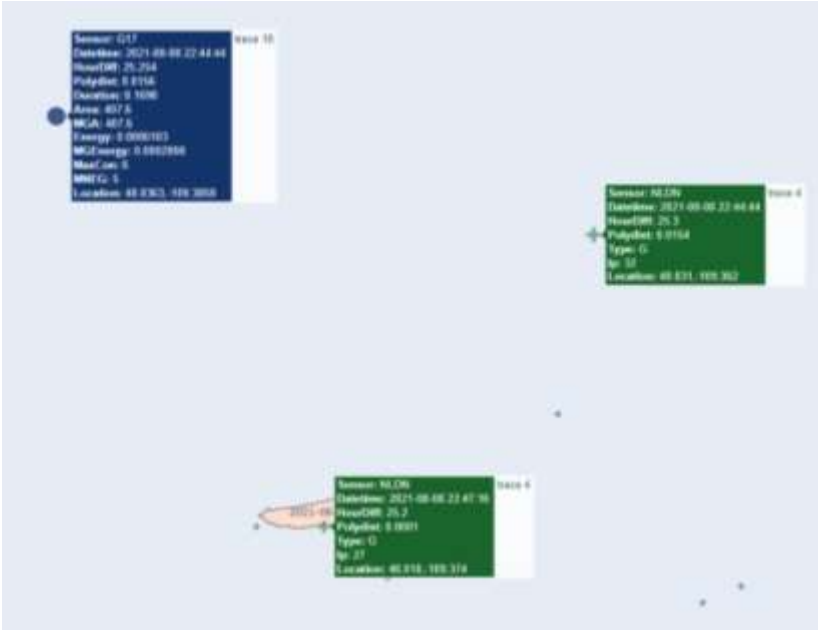
Ground-Based Network Performance

- ENTLN location accuracy precludes its use for this application
- Only used NLDN stroke locations to designate fire ignitions
- Lightning very often located within the fire footprint, strokes outside the footprint were relocated to the nearest boundary

GLM Performance

- GOES-East and GOES-West GLMs only observed 76 (9%) and 159 (19%) of these flashes, respectively
- Nearly always observe nearby lightning, despite missing ignition flashes
- Is some physical process confounding known detection efficiency issues?



Sensor	farea	fenergy	maxcon	mneg	mga	maxenergy	duration	Stroke Count	CG Count	IC Count	NLDN Duration
G16	372.7	0.000478	1.9	5.1	371.4	0.000229	0.203	5.2	3.2	2.0	0.243
G17	441.4	0.000543	4.3	6.5	472.6	0.000264	0.218	4.9	3.2	1.7	0.242

Next Steps

- Properly classify as many fire ignitions as possible
- Determine how many fires dwelled before growing and for how long
- Characterize lightning environments where fires dwell versus those with growth quickly after ignition
- Begin developing the LILI Model

GLM Characteristics (flashes)	
farea	Flash Area
fenergy	Flash Energy
maxcon	Max Consecutive Frames
mneg	Maximum Number of Events per Group
mga	Maximum Group Area
maxenergy	Max Group Energy
duration	Duration
polydist	Distance between flash and fire polygons
dist	Distance between flash and fire ignition locations
NLDN Characteristics (strokes/pulses)	
lp	Estimated Peak Current
sens	Number of sensors observed by
type	IC or CG
pol	polarity

Other Parameters…

- Working to combine data on the land surface, meteorology, and lightning for both the ignitions and null datasets

100-h Fuel Moisture	Vapor pressure deficit	% Vegetation
1000-h Fuel Moisture	Anstrom Index	% Crops
Burning Index	Baumgartner Index	% Developed
Energy Release Component/Build Up Index	Canadian Fire Weather Index (FWI)	% Water/Nonflammable
Palmer Drought Severity	Fosberg Fire Weather Index (FFWI)	% Trees
Max T2m	Munger Index	% Shrubs
Max wind speed	Nesterov Ignition Index	% Herbs
Min RH	Sharples Fire Danger Rating	% of each of the 13 Anderson Fire Behavior Fuel Models ***(13 variables)***
Max Td2m		
Max surface pressure		
Temp		
RH		
Wind Speed		
Volumetric soil moisture (sfc)		

Maximum_6-hour_temperature_change
Maximum_6-hour_wind_speed_change
Maximum_6-hour_wind_gust_potential
Maximum_6-hour_wind_direction_change
Maximum_6-hour_dewpoint_depression
Minimum_6-hour_surface_pressure
Maximum_6-hour_surface_pressure_change
Precipitable_Water
Multi-Sensor_QPE_Pass 1, 6-hourly
Multi-Sensor_QPE_Pass 1, 12-hourly
Multi-Sensor_QPE_Pass 1, 24-hourly
LCL height
CAPE
1 km to 6 km wind shear
Surface to 1 km wind shear
500mb_wind_speed

CG lightning flash peak current
CG lightning stroke peak current
CG lightning flash polarity
CG lightning stroke polarity
CG lightning multiplicity
Flash type
Stroke type
Distance from CG lightning to nearest radar echo > 25 dBZ
Distance from CG lightning to nearest 6-hour precip > 0.1 inch
Distance from CG lightning to nearest radar echo > 15 dBZ
Distance from CG lightning to nearest 6-hour precip > 0.05 inch

Distance from CG lightning to nearest GLM grid cell with lightning
Area of nearest GLM grid cell with lightning in time and space
Average area of GLM grid cells with lightning within 25 km
Largest area of GLM flash within 25 km
Energy of nearest GLM grid cell with lightning in time and space
Flash Extent Density (FED) of nearest GLM grid cell with lightning
Maximum Group Area (MGA) of nearest GLM flash
Maximum Number of Events per Group (MNEG) of nearest GLM flash
Consecutive frames of nearest GLM flash
Duration of nearest GLM flash
Fraction of nearby flashes with XYZ…

Developing the LILI (or LIROI) Model

- Once lightning data are properly classified, join with additional data
- Integrate findings with parallel effort applying blended lightning grids (Zhang et al. 2022)
- Determine the best AI for this application
- Train model on subset sample, then evaluate performance on independent sample
- Tune/refine model as needed
- Develop training resources
- Incorporate into NESDIS fire product information storefront