# 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

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- Developed tools to bring human observers into the loop on making this distinction
- Produced webaccessible tables with both lightning and fire hot spot counts for each incident

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# **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	А
Polarity	Positive or ne	gative Ip
Туре	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 <sup>2</sup> )						
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						



#### **Detailed Lightning Maps**

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# **Detailed Fire Spread Animations**

- Helps locate fire origination
- Fire hot spot detections from both geostationary and lowearth 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



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# **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**

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

lull	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

gnitions	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
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	Positive	2.1	0.4	1.7	30.7		0.052	56 (59.6%)	38 (40.4%)	94



### **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	gy Max Group Energy						
duration	Duration						
polydist	Distance between flash and fire polygons						
dist	Distance between flash and fire ignition locations						
NLDN Cha	racteristics (strokes/pulses)						
lp	Estimated Peak Current						
sens	Number of sensors observed by						
type	IC or CG						
pol polarity							

#### **Other Parameters...**

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

1000-h Fuel Moisture       Anstrom Index       % Crops         Burning Index       Baumgartner Index       % Developed         Energy Release       Canadian Fire Weather Index (FWI)       % Water/Nonflammable         Component/Build Up Index       Fosberg Fire Weather Index (FFWI)       % Trees         Palmer Drought Severity       Munger Index       % Shrubs         Max T2m       Nesterov Ignition Index       % Herbs         Max wind speed       Sharples Fire Danger Rating       % of each of the 13 Anderson Fire Behavior Fuel Models *** (13 variables)***         Max Td2m       Sharples Fire Joanger Rating       % being fire weather Index (FFWI)         Max surface pressure       Clambra wind speed       % of each of the 13 Anderson Fire Behavior Fuel Models *** (13 variables)***         RH       Wind Speed       Sharples Fire Danger Rating       Sharples fire Weather Index (FFWI)         Wind Speed       Sharples fire Danger Rating       Sharples fire Danger Rating         Wind Speed       Sharples fire Danger Rating       Sharples fire Models winter         States from C3 lightning to nearest GLM grid cell with lightning mine and space       Herbase         RH       Wind Speed       Sharples fire Load       Sharples fire Danger Rating         Wind Speed       Wind State (State Internet Index Internet Index Interes) State Internet Index Internet Index Intern	100-h Fuel Moisture	Vapor pressure	deficit	% Vegetation		
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Duration of nearest GLM flash	Wind Speed			Consecutive frames of nearest GLM flash		
VOIUMETTIC SOIL MOISTURE (STC) Fraction of nearby flashes with XYZ	Volumetric soil moisture (sfc)			Fraction of nearby flashes with XYZ		

STAR brings the power of satellite remote sensing science to all NOAA missions.

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# **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