An Assessment of Land Surface and Lightning Characteristics Associated with Lightning-Initiated Wildfires

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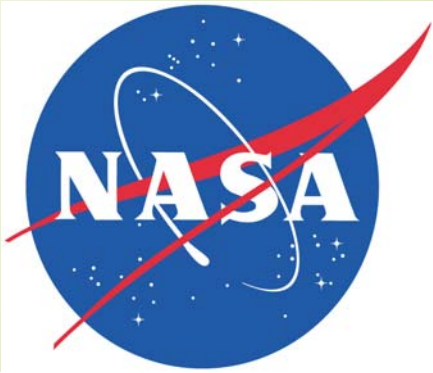
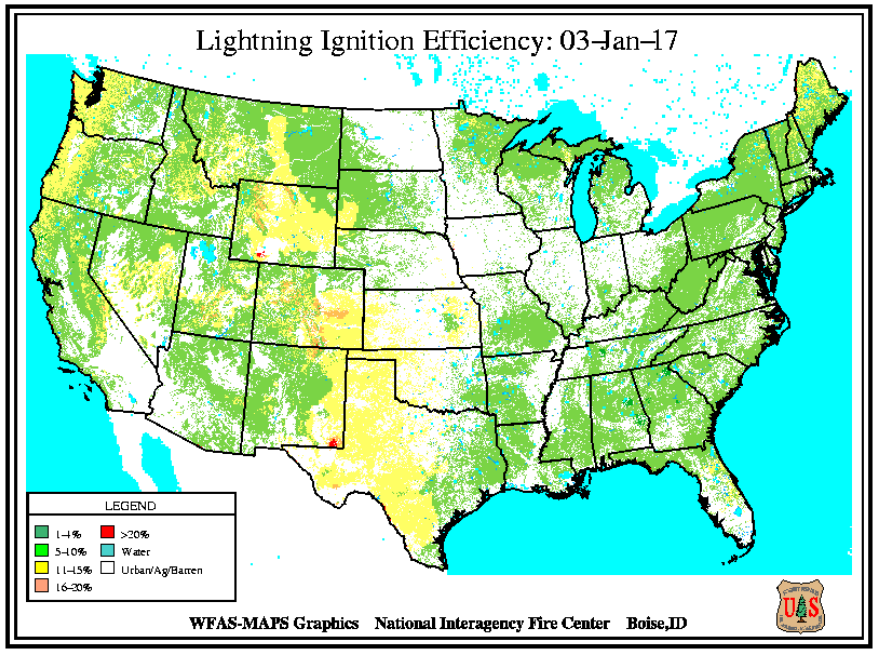


Purpose and Goals

- Can we use modeled information of the land surface and characteristics of lightning beyond flash occurrence to increase the identification and prediction of wildfires?

- The goals of this study are to:
  - Combine observed cloud-to-ground (CG) flashes with real-time land surface model output, and
  - Compare data with areas where lightning did not start a wildfire to determine what land surface conditions and lightning characteristics were responsible for causing wildfires.

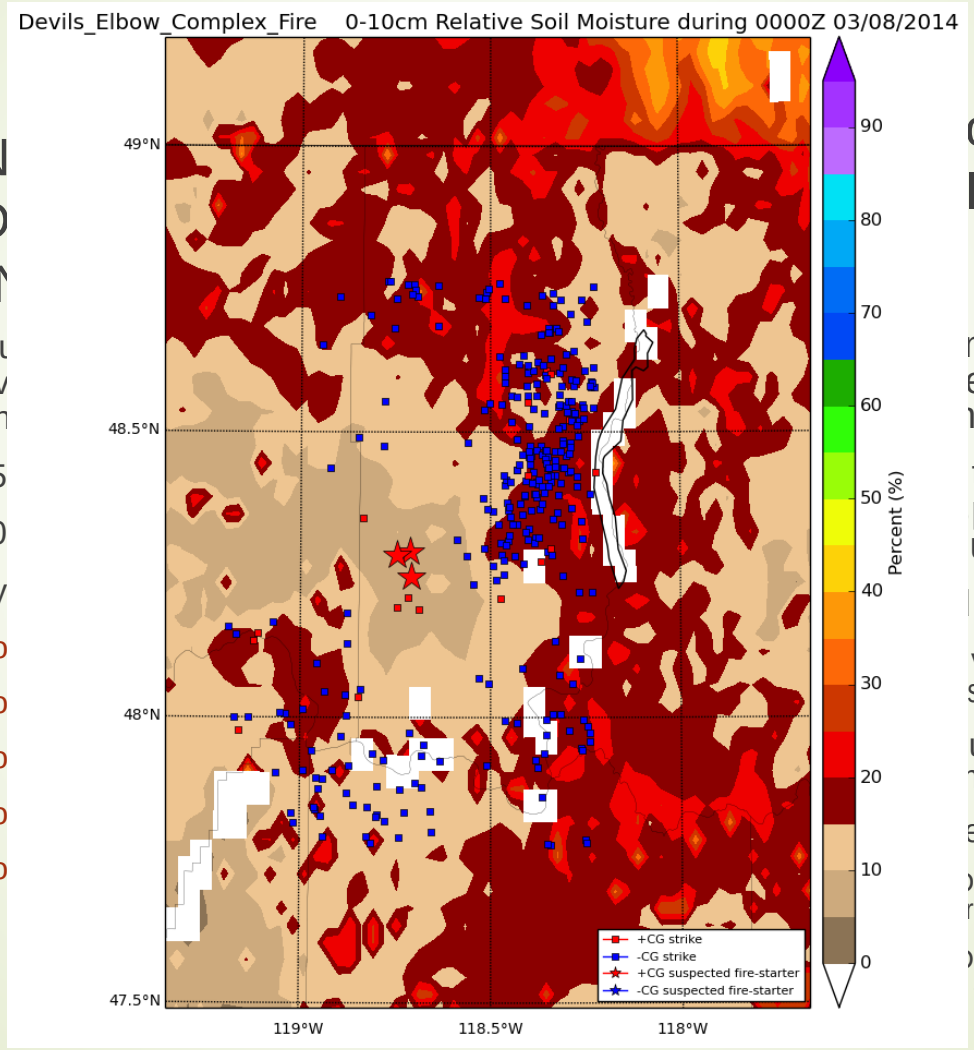
Current Methods



https://www.wfas.net/images/firedanger/ltng_pi.png

- Currently the U.S. Forest Service utilizes flash density, Normalized Difference Vegetation Index (NDVI), and fuel density/type to assess lightning ignition efficiency for the day.
- Based on this efficiency, a lightning density threshold is applied to compute the probability that a wildfire has started.
  - If the Ignition Efficiency is high (salmon color), the density required for ignition is 9 flashes km^{-2}.
  - If the Ignition Efficiency is Extreme (red), the density required for ignition is 5 flashes km^{-2}.
  - These are empirically derived metrics from Latham and Schleitter (1989).

Data Sources



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DIS monthly climatology for
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DIS/VIIRS real-time daily GVF;
– present

Methods

1. 87 lightning initiated wildfires were analyzed between 2008 and 2015
   - Majority of cases from 2012-2015 time frame to take advantage of VIIRS GVF.
   - Information were obtained from InciWeb: Incident Information System Website.
   - Date/time and estimated latitude/longitude coordinates of the origin of each case were recorded.
2. Lightning data obtained from the NLDN; only CG flash designation were used.
3. Land surface data obtained from the Land Information System (SPoRT-LIS).
4. Each lightning flash within a 100-km radius of the wildfire start point was used to extract land surface model information to compare fire-starting flashes with non-fire-starting flashes.
5. Wilcoxon-Mann-Whitney Rank Sum test performed to determine degree of independence between the fire starting and non-fire starting flashes for each lightning and land surface parameter examined.
   1. A p-value of 0.05 was used for significance testing.

Results

- 84 of 87 wildfires identified to be lightning initiated contained at least 1 flash at the initiation point within +/- 3 hours of the fire start time.
  - The 3 fires reported as lightning initiated may not necessarily falsely identified because smoldering can occur for days (e.g., Lang et al. 2015).
- Over 7,000 km^2 were consumed by these fires, with the largest fire analyzed burning 1,223 km^2 of land [Approximately the size of Delaware].

Lightning

Red: Fire-starter	Green: Non-fire starter	
	Peak Amplitude (kA)	
-CG 25th Percentile	-13.475	-7.0
-CG Median	-22.25	-12.9
-CG 75th Percentile	-39.5	-23.1
+CG 25th Percentile	+25.25	+19.7
+CG Median	+36.0	+27.2
+CG 75th Percentile	+51.15	+41.5
-CG Mean	-30.9	-18.92
+CG Mean	+47.19	+35.09
-CG Rank-sum p-value	2.48×10^{-11}	
+CG Rank-sum p-value	0.139	

- A total of 5,382 CJ(I7 ations where a cloud-to-ground flash occurred were analyzed
  - 4,822 negative CG
  - 560 positive CG flashes
- 110 flashes could be associated with a wildfire initiation point
  - 100 of these were negative CG; 10 were positive CG
  - 26 ignition locations had multiple flashes
- 61 of 100 negative fire-starting flashes were single-stroke negative flashes.
- All 10 fire-starting positives were single-stroke flashes.
- The null hypothesis was rejected for magnitude of –CG flashes between FS and NFS (meaning the populations are statistically different); it was supported for +CG flashes (meaning no statistical difference between FS and NFS)

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CJ(I7 should this be 5,382?

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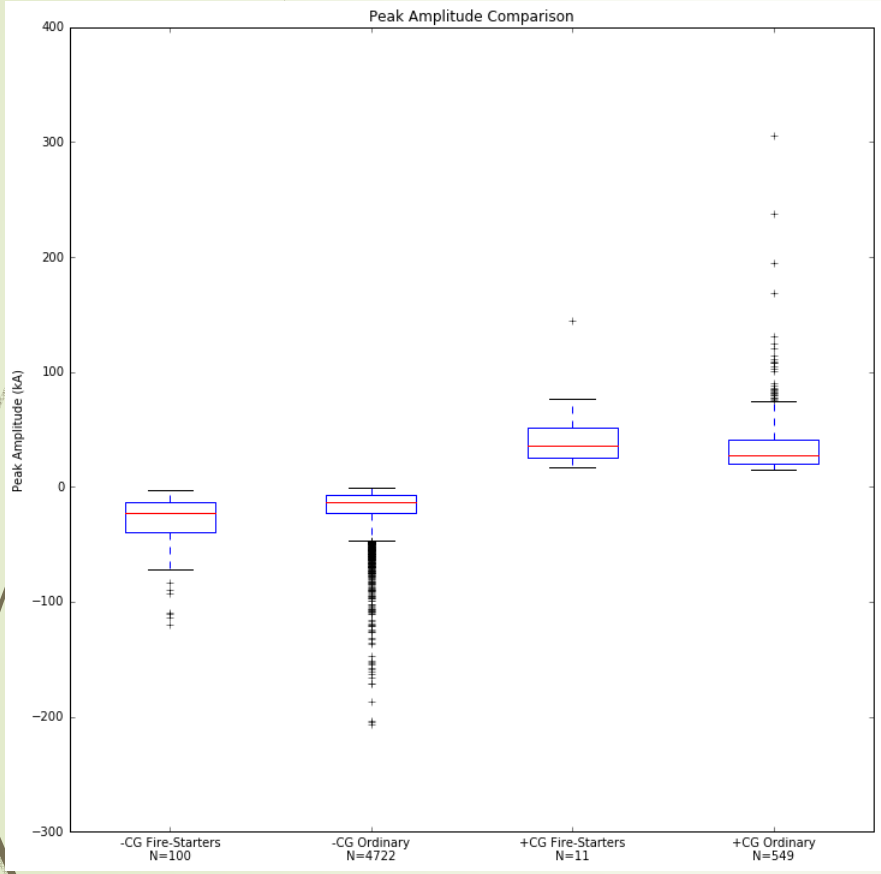
Peak Amplitude



Red: Fire-starter	Green: Non-fire starter	
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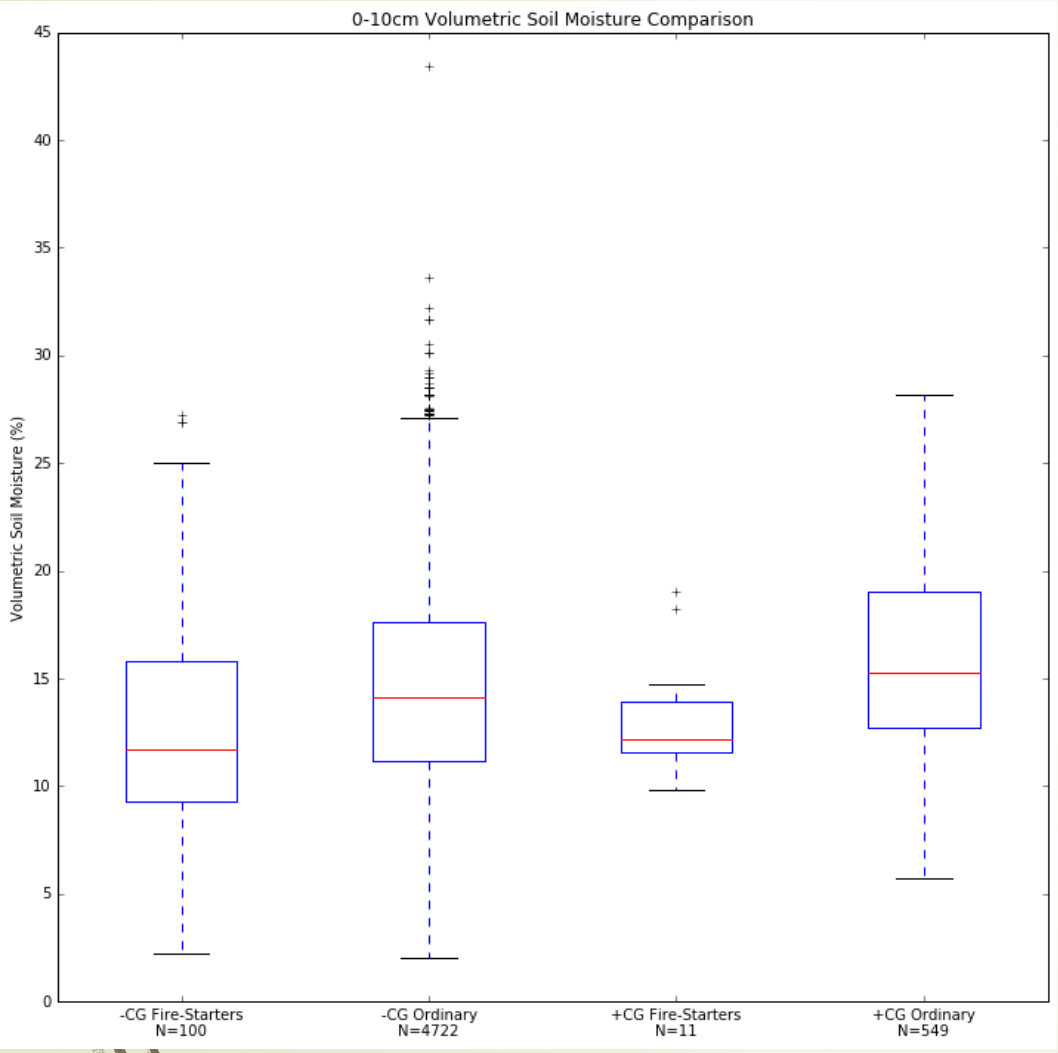
Negative CG Peak Amplitude was statistically different for fire starters than non-fire starters

+CG Peak amplitude was not statistically significant, meaning that the characteristics of the flash are similar (i.e., powerful flashes), but other land surface or meteorological factors influence fire start potential.

0-10 cm Volumetric Soil Moisture CJ(I8



Red: Fire-starter	Green: Non-fire starter	
	0-10 cm Volumetric Soil Moisture (%)	
-CG 25th Percentile	9.3%	11.2%
-CG Median	11.7%	14.1%
-CG 75th Percentile	15.8%	17.6%
+CG 25th Percentile	11.55%	12.7%
+CG Median	12.2%	15.3%
+CG 75th Percentile	13.9%	19.0%
-CG Mean	13.07%	14.88%
+CG Mean	13.21%	15.89%
-CG Rank-sum p-value	2.53×10^{-4}	
+CG Rank-sum p-value	2.61×10^{-2}	

- Suspected fire-starters occurred over areas of lower volumetric soil moisture on average.
- P-values for both polarities less than 0.05 indicating that the medians and distributions are shifted toward slightly drier values.

Slide 9

CJ(I8 These distributions are only shifted slightly, and both have very broad ranges. I don't really see how anything could be concluded from this, except that the means/distributions are shifted toward slightly drier values.
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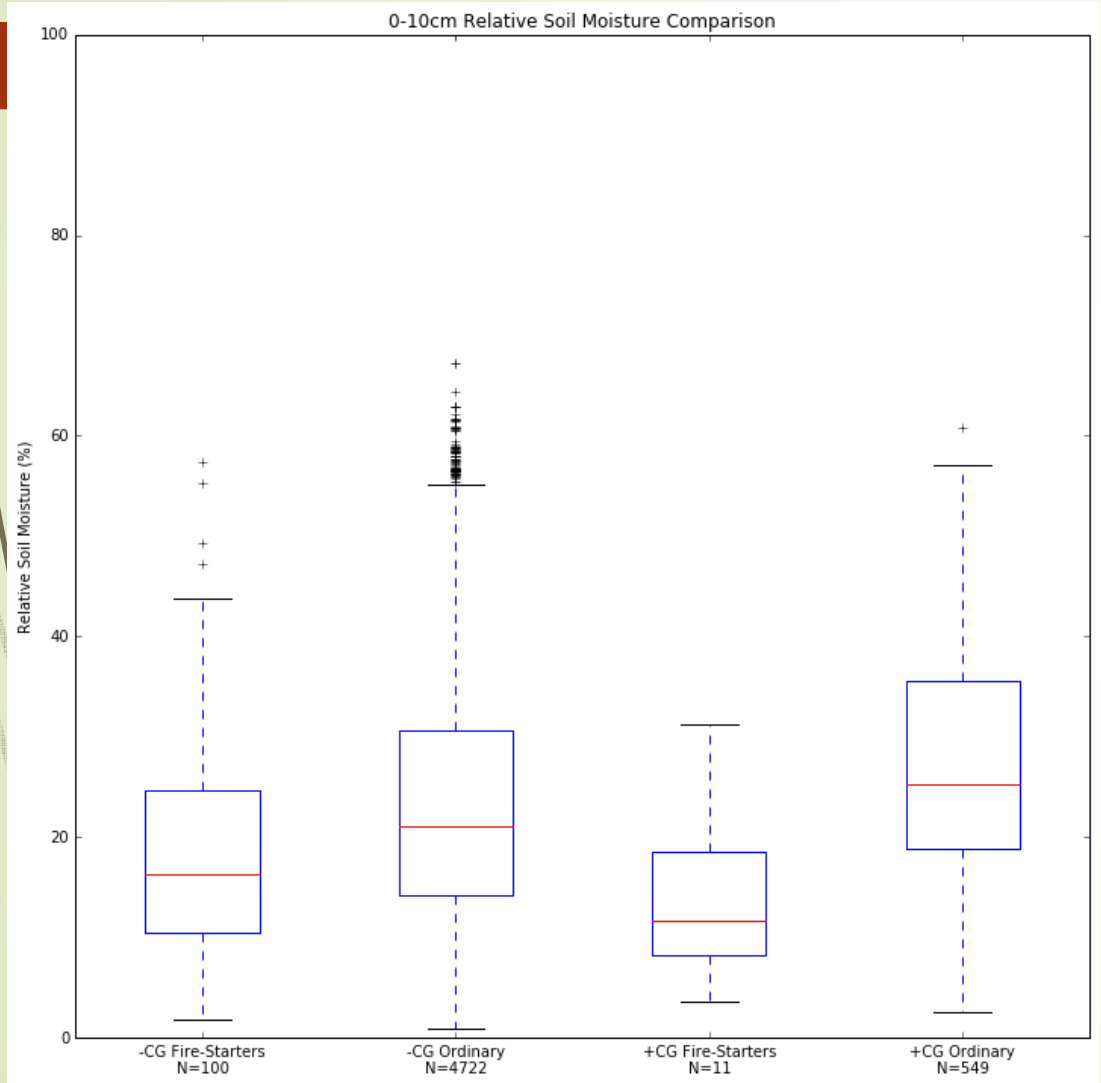
0-10 cm Relative Soil Moisture



Red: Fire-starter	Green: Non-fire starter	
	0-10 cm Relative Soil Moisture (%)	
-CG 25th Percentile	10.52%	14.18%
-CG Median	16.27%	21.13%
-CG 75th Percentile	24.65%	17.6%
+CG 25th Percentile	8.21%	18.83%
+CG Median	11.61%	25.32%
+CG 75th Percentile	18.52%	35.54%
-CG Mean	18.89%	23.82%
+CG Mean	14.24%	26.93%
-CG Rank-sum p-value	2.57×10^{-5}	
+CG Rank-sum p-value	4.78×10^{-4}	

- Boxplot shows significant difference between distributions of suspected fire-starters and ordinary strikes of both polarities.
  - P-values less than 0.05 indicating separation of distributions are most prevalent with the +CG flashes
  - Suspected fire-starters were primarily in areas of lower relative soil moisture.

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CJ(I9 I have the same comment on the distributions. However, the +CG here seem to have more distinctly different distributions.

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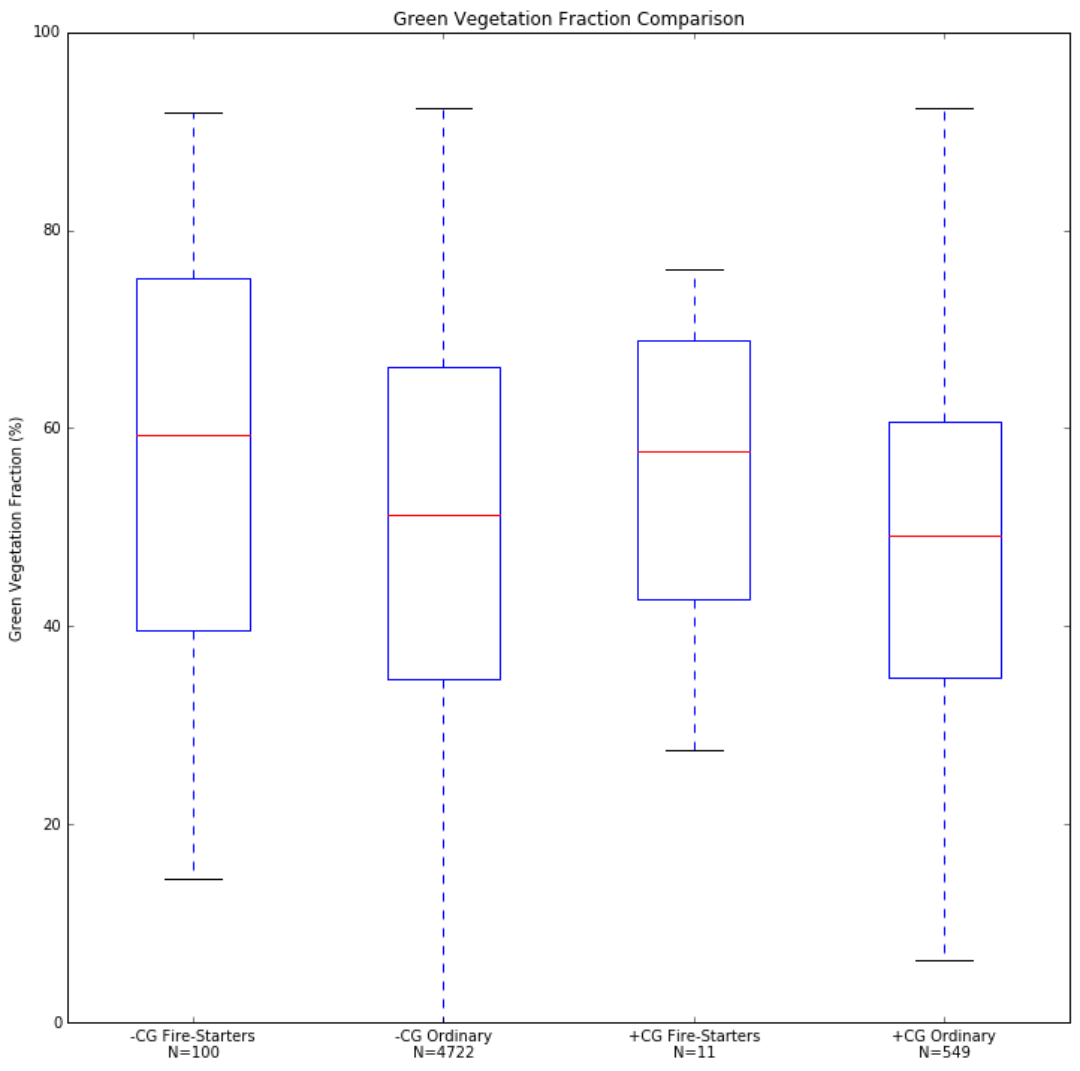
Green Vegetation Fraction



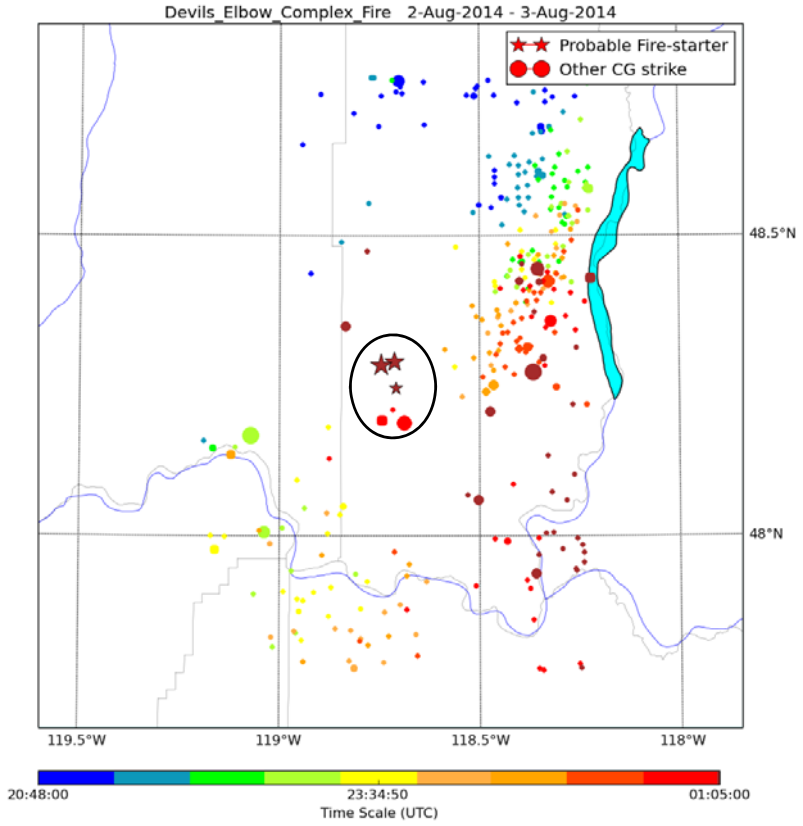
Red: Fire-starter	**Green**: Non-fire starter	
	Green Vegetation Fraction (%)	
-CG 25th Percentile	39.67%	34.69%
-CG Median	59.29%	51.2%
-CG 75th Percentile	75.08%	66.24%
+CG 25th Percentile	42.81%	34.76%
+CG Median	57.63%	49.11%
+CG 75th Percentile	68.95%	60.63%
-CG Mean	56.49%	50.97%
+CG Mean	55.63%	49.24%
-CG Rank-sum p-value	9.15×10^{-3}	
+CG Rank-sum p-value	0.179	

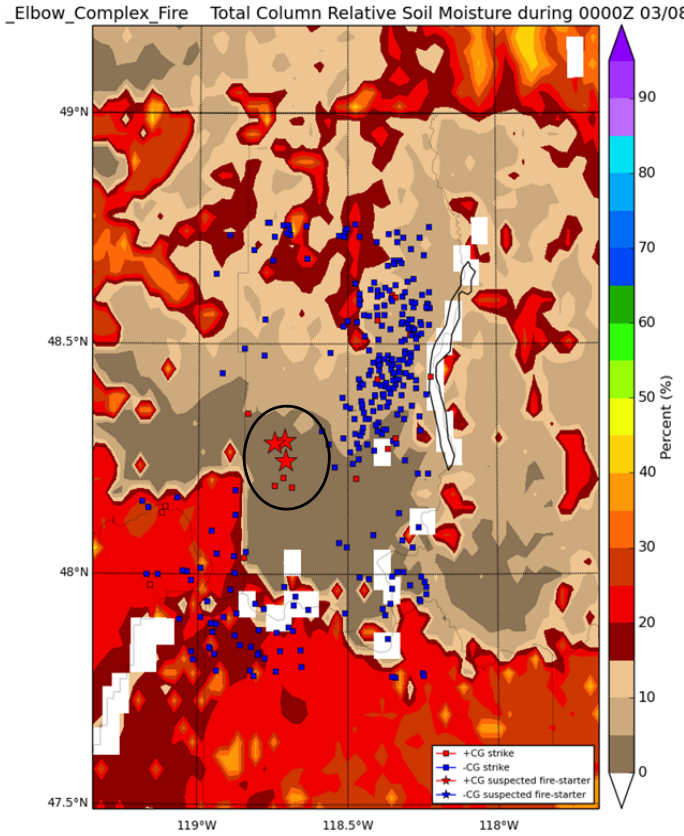
- Boxplot shows suspected fire-starters typically occurred over relatively well-vegetated areas.
  - True for –CG strikes due to low p-value.
  - Not necessarily true for +CG strikes due to p-value > 0.05.
    - Affected by low sample size compared to –CGs recorded.

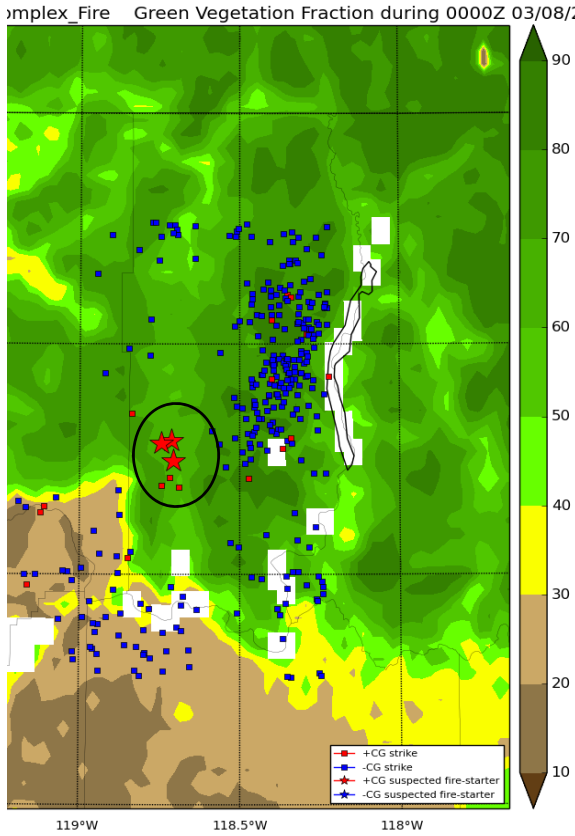
Random Sampling to test hypotheses

Parameter	Overall	Random sample
Magnitude	**-CG: reject** **+CG: accept**	**-CG: reject (30/30)** **+CG: accept (26/30)**
Multiplicity	**-CG: accept** **+CG: accept**	**-CG: accept (28/30)** **+CG: accept (30/30)**
0-10 cm soil moisture content	**-CG: reject** **+CG: reject**	**-CG: reject (30/30)** **+CG: reject (30/30)**
0-10 cm relative soil moisture	**-CG: reject** **+CG: reject**	**-CG: reject (30/30)** **+CG: reject (30/30)**
GVF	**-CG: reject** **+CG: accept**	**-CG: accept (18/30)** **+CG: accept (26/30)**
0-200 cm relative soil moisture	**-CG: accept** **+CG: reject**	**-CG: accept (30/30)** **+CG: accept (21/30)**

- 10 different random samples were computed for the positive and negative polarity non-fire-starting populations for each parameter and then compared to the fire- starting population.
- GVF for –CGs and 0-200 cm relative soil moisture for +CG occurrence from rejecting the null hypothesis of different distributions to accepting that the distributions were the same the majority of the random samples.



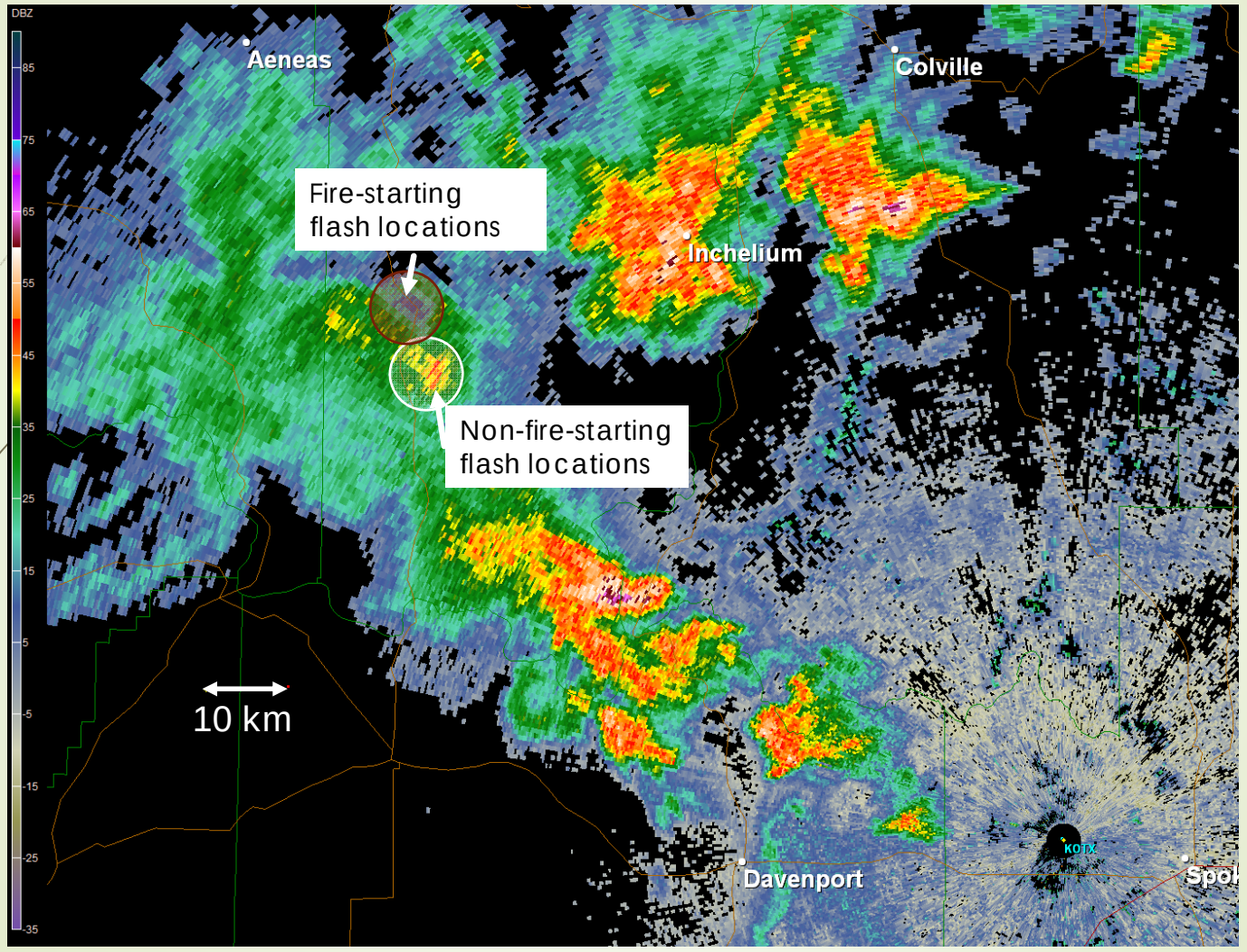




Very similar characteristics of 3 fire-starting and 3 non-fire starting positive flashes

What was different?

The flash location relative to precipitation cores...



Conclusions

- Statistical differences between suspected fire-starters and non-fire-starters were peak-current dependent.
  - More intense strikes typically were suspected fire-starters.
  - Majority of flashes (71 of 110) were single-stroke flashes.
  - -CG p-value = 2.48×10^{-11} (distributions were significantly different).
  - +CG p-value = 0.14 (distributions were similar).
- 0-10 cm Volumetric and Relative Soil Moisture comparisons were statistically dependent to at least the p = 0.05 independence level for both polarity flash types.
  - Suspected fire-starters typically occurred in areas of lower soil moisture than non-fire-starters.
- GVF value comparisons were only found to be statistically dependent for -CG flashes.
  - However, random sampling of the –CG non-fire starter dataset revealed that this relationship may not always hold.

CJ(I14

CJ(I15

Slide 15

CJ(I14 Shouldn't this read "statistically significant" (not statistically dependent)?
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CJ(I15 again, statistically significant?
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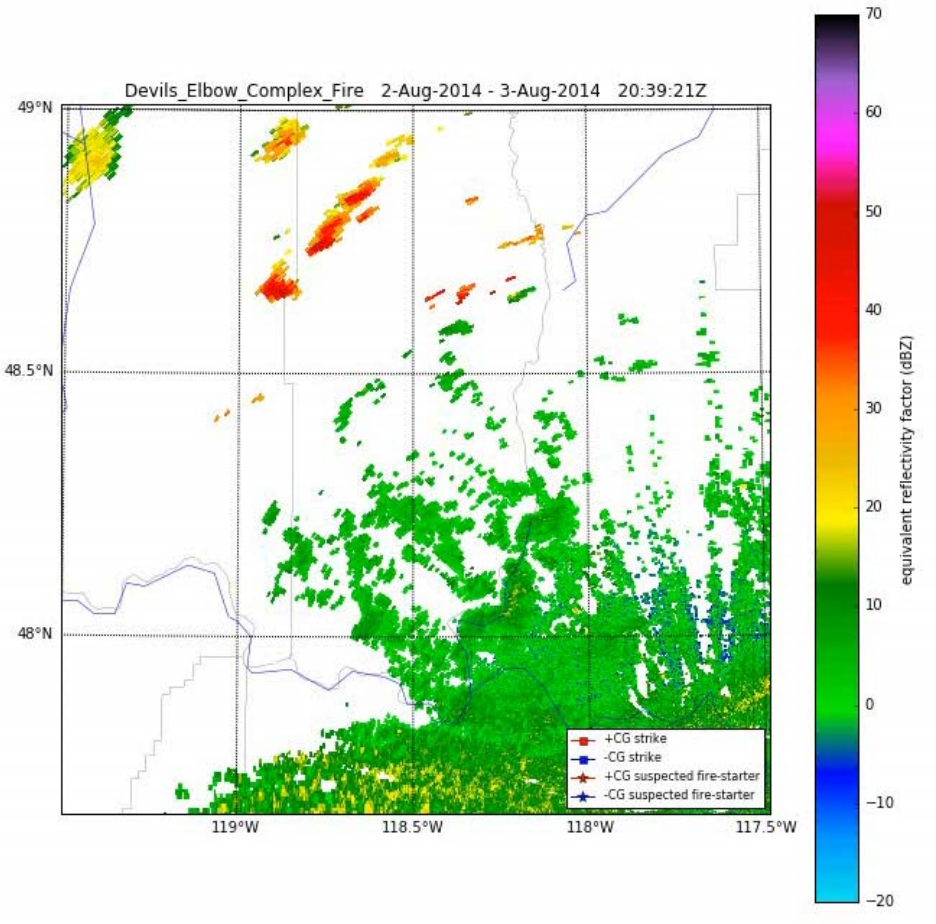
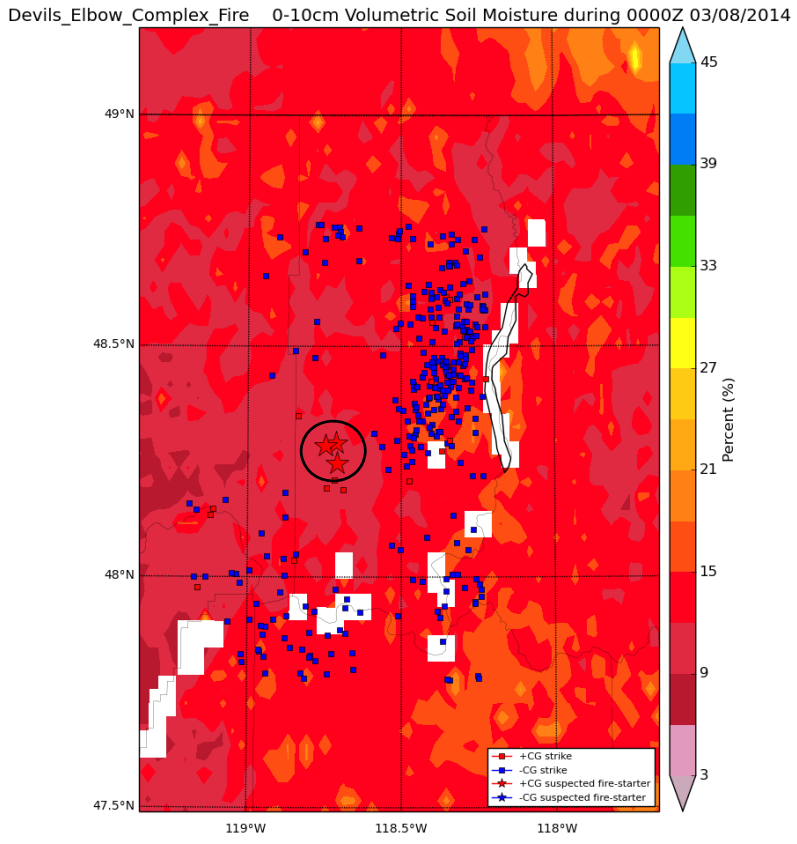
Future Work

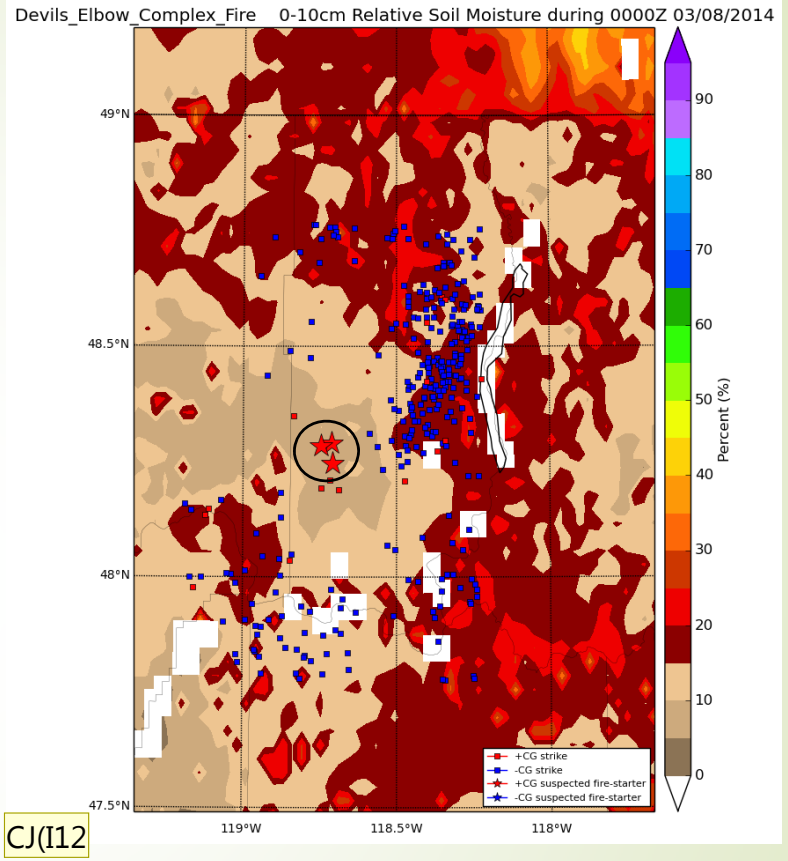


- Introduce more lightning-initiated wildfire cases throughout the United States.
  - Most cases analyzed were concentrated in the Intermountain West.
  - See if different conditions are required for lightning to ignite wildfires in other regions.
- Obtain near-surface meteorological data present at the time of wildfire occurrence.
  - E.G., relative humidity and wind speed are known to be contributing factors.
- Query radar imagery for precipitation features in lightning-initiated wildfire cases.
  - Look where flash occurred relative to storm features.

Thank you!

- Funding for this work was supported by the NASA Internship Program and the NASA Short-term Prediction and Research Transition Center (NASA-SPoRT).





CJ(I12

Date	Time (UTC)	Peak Amplitude (kA)	Multiplicity (# Return Strokes)	0-10cm Volumetric Soil Moisture	0-10cm Relative Soil Moisture	Total Column Relative Soil Moisture	Green Vegetation Fraction
03/08/2014	00:19:36	+39.4	13	11.6 %	8.3 %	3.2 %	66.4 %
03/08/2014	00:21:35	+22	22	11.6 %	8.1 %	3.0 %	67.8 %
03/08/2014	00:22:55	+23.6	19	11.5 %	7.9 %	2.6 %	70.8 %

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CJ(I12 Be consistent with number of decimal places. Why 1 vs. 2 vs. 3 decimal places for different land surface variables?

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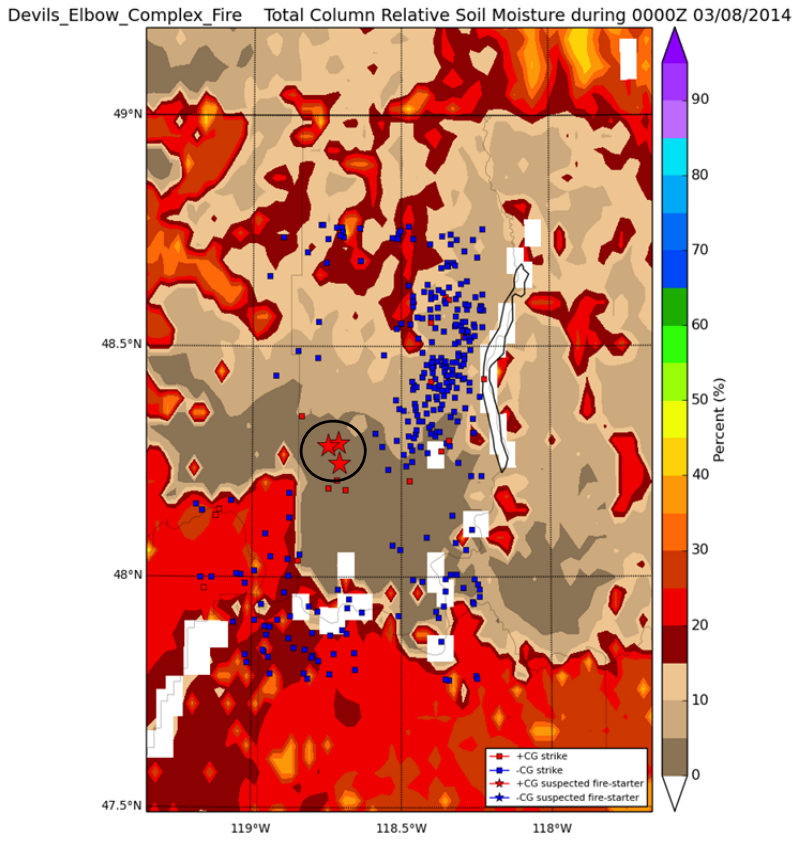

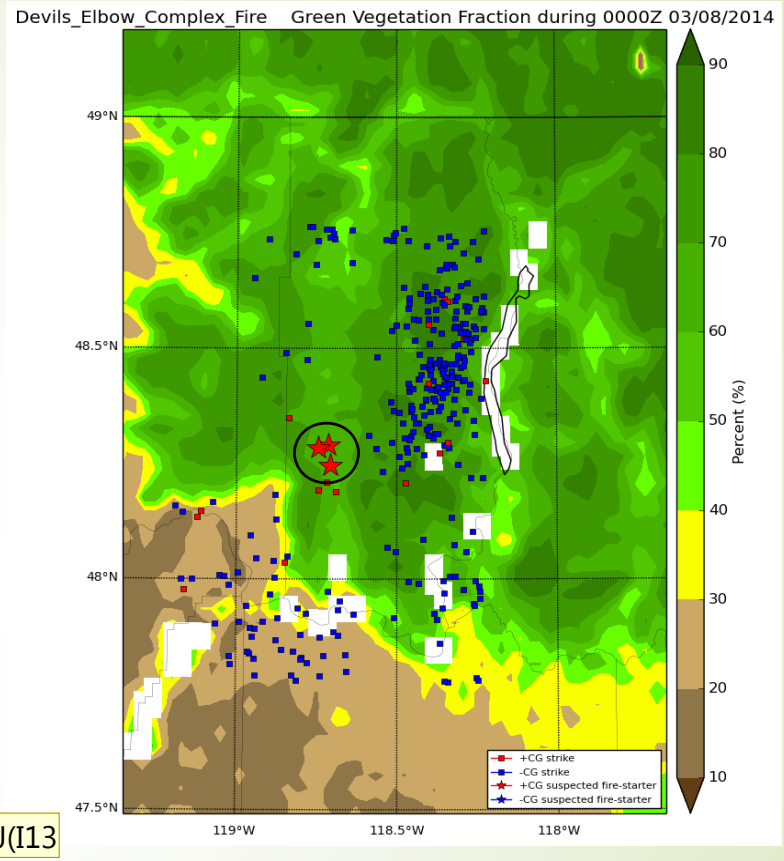

CJ(I13

Date	Time (UTC)	Peak Amplitude (kA)	Multiplicity (# Return Strokes)	0-10cm Volumetric Soil Moisture	0-10cm Relative Soil Moisture	Total Column Relative Soil Moisture	Green Vegetation Fraction
03/08/2014	00:19:36	+39.4	13	11.6 %	8.282 %	3.19 %	66.43 %
03/08/2014	00:21:35	+22	22	11.6 %	8.129 %	2.98 %	67.76 %
03/08/2014	00:22:55	+23.6	19	11.5 %	7.921 %	2.58 %	70.77 %

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CJ(I13 Ditto on consistent decimal places

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