45TH WS ELECTRIC FIELD MILL LIGHTNING PREDICTION THRESHOLD ANALYSIS

Maj Charles A. Skrovan

Thesis Advisor: Lt Col Geyer
Reader: Dr. Hill

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Abstract

The AFIT of Today is the Air Force of Tomorrow.

This study seeks to determine a single electric field mill reading threshold for lightning onset and a separate single EFM reading threshold for lightning cessation. A regression model analysis and threshold analysis of time series data is planned to be used to determine thresholds for 20 minutes to 30 minutes, using 5-minute increments before the first total lightning detection and 15 minutes after the last total lightning detection in the vicinity of an EFM. Threshold values for each EFM voltage reading will also be considered from 100 volts/meter to 4000 volts/meter in 100 volts/meter increments for each detection time.

Purpose

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- Determine a threshold Electric Field Mill reading value to predict lightning onset (30 minutes prior to first lightning strike) and succession (15 minutes after last lightning strike)
  - Lightning strikes can have potential negative affect on space vehicles and hardware
  - Stop work for certain processing operations when lightning detected w/in 5NM of CCAFS leads to loss of production

Data Preparation

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- Convert RAW data to R data frame combined 20,000+ separate files
- Reduce & filter noise EFM data from 50 Hz readings to 1-minute averages for 31 sensors
  - 50 Hz * 60 Seconds * 60 Minutes * 24 Hours * 30 Days * 5 Months * 4 Years = ~2.6 billion rows
    - Converting to minute data and missing reduced to less than 741,000 rows by 31 sensor columns
- Convert LDAR distances from meters to lat/long then to 5 NM radius for each of 31 sensors
  - (consider total lightning: cloud-to-ground and cloud-to-cloud)
- Combine EFM and LDAR data sets into single data frame
- Create additional statistical columns
  - Absolute values of EFM readings
  - Absolute mean of EFM readings
  - Geometric mean of EFM readings
  - Binary lightning strike/storm windows
  - Determine storm length and time-to-end

EFM Locations

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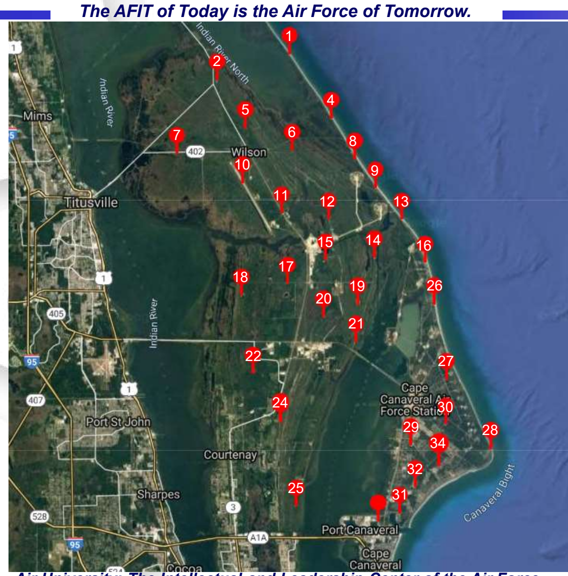

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EFM Mean Voltage

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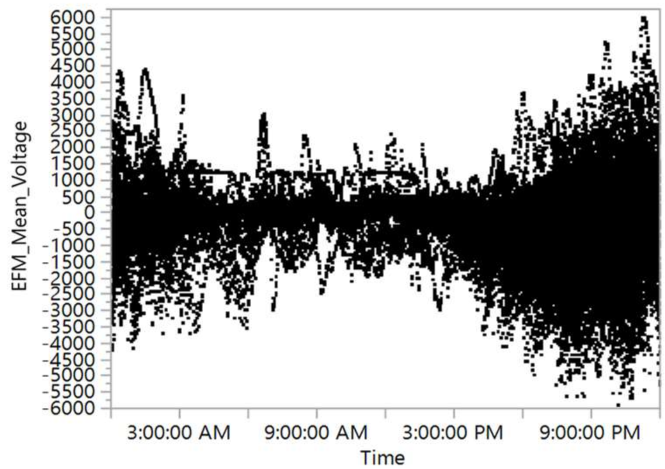
Bivariate Fit of EFM Mean Voltage By Time



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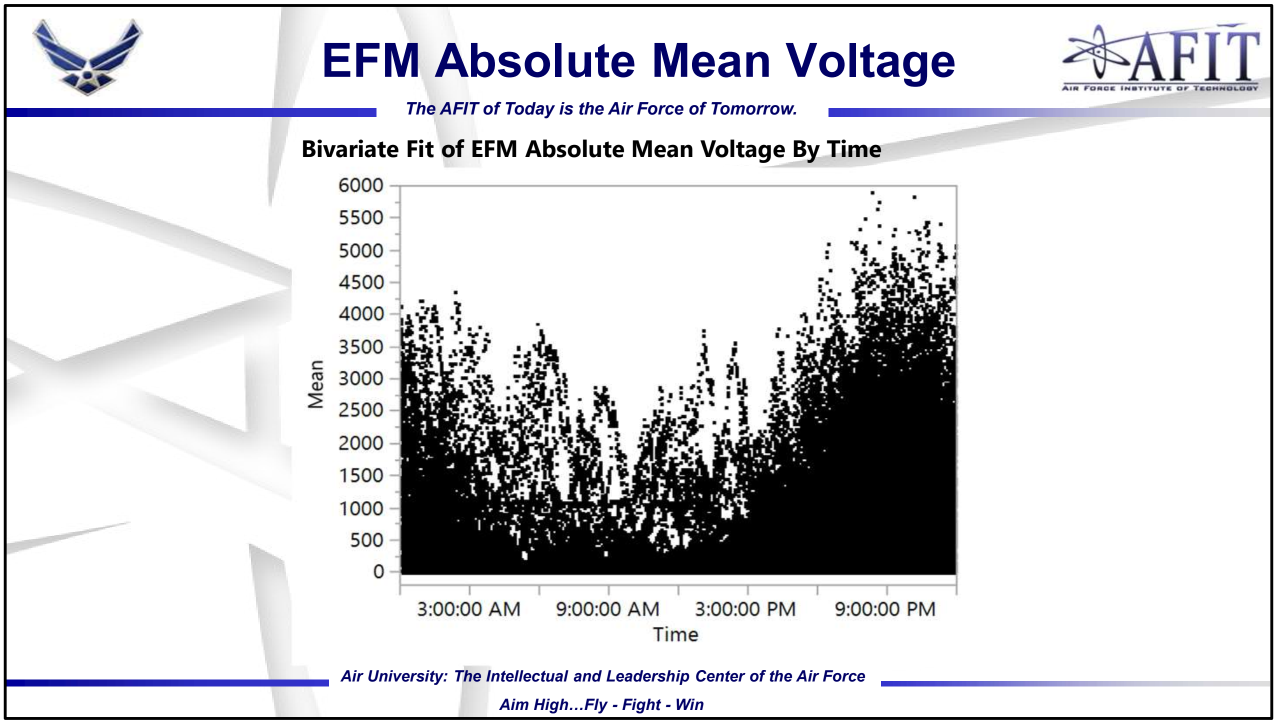
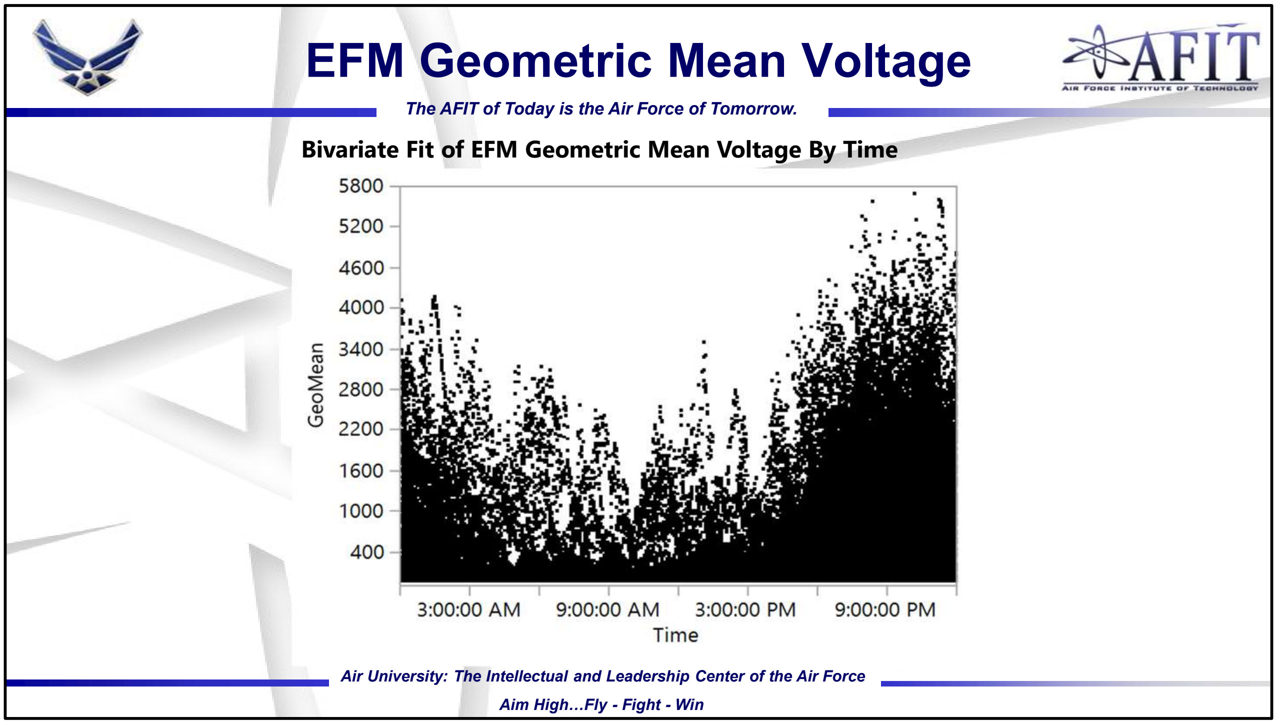
The scatter plot shows that there is potentially some correlation for EFM voltages to time of day, however further analysis proves otherwise. This is due to the huge amount of data close to the origin. Diurnal variation.



This is a scatter plot of all the EFM readings measured as the difference between the EFM volt/m and the non-storm average volt/m for that sensor.



Geometric mean just shows tighter bands as extremely large values aren't as heavily weighted

EFM vs. Lightning Issues

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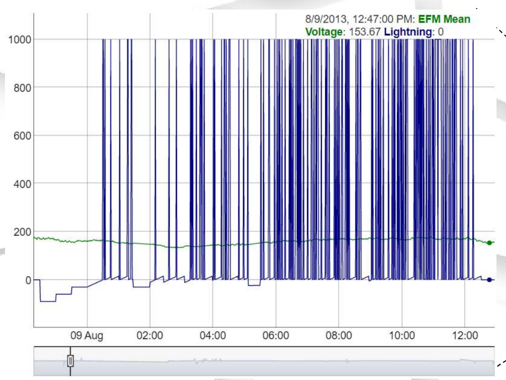
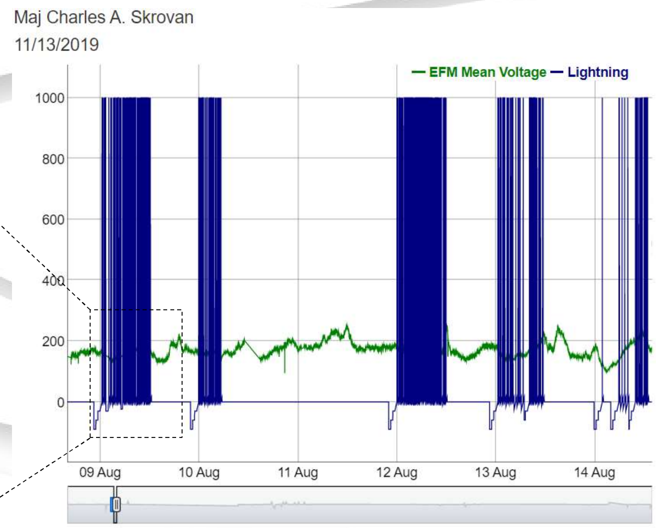
- **9 – 14 Aug 2013**
- **Issue: relatively flat EFM response during known storms**





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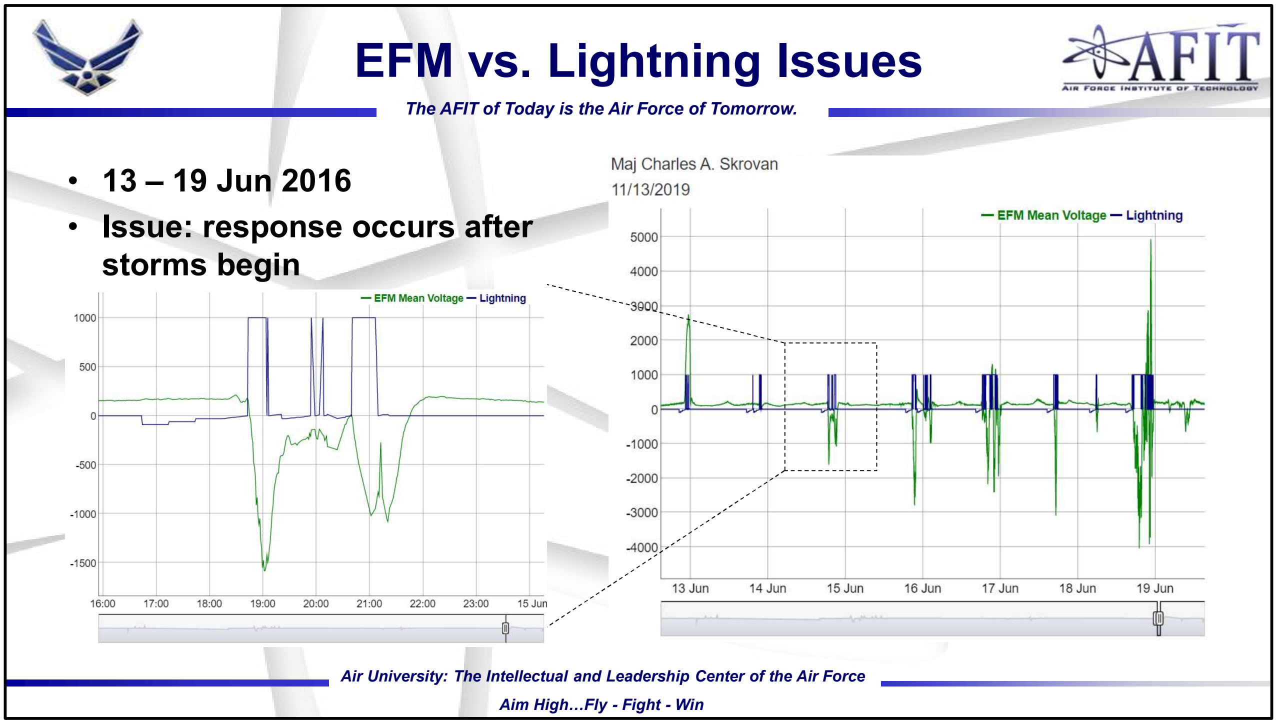
EFM readings stay near average when lightning storms are occurring.



EFM readings spike AFTER first lightning strike occurs/storm begins.

EFM vs. Lightning Issues

The AFIT of Today is the Air Force of Tomorrow.

- **14 – 17 Jun, 3 – 7 Jul 2013, 17 – 19 Jun 2015**
- **Issue: EFM spikes when no lightning storms occur**

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EFM spikes but no storms are reported based on LDAR data.

Multivariate Comparisons

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- **Multivariate Comparisons with RAW EFM Voltage Readings**

	Time	KSC1	KSC2	KSC4	KSC5	KSC6	KSC7	KSC8	KSC9	KSC10	KSC11	KSC12	KSC13	KSC14	KSC15
Time	1	-0.0404	-0.0531	-0.0325	-0.0577	-0.0697	-0.0751	-0.047	-0.0405	-0.0702	-0.0704	-0.0533	-0.0335	-0.0517	-0.0233
KSC1	-0.0404	1	0.6211	0.6664	0.6011	0.574	0.426	0.54	0.4528	0.4582	0.4253	0.3991	0.3509	0.3409	0.0903
KSC2	-0.0531	0.6211	1	0.51	0.769	0.5869	0.6844	0.4445	0.378	0.607	0.4836	0.4041	0.2974	0.3315	0.1086
KSC4	-0.0325	0.6664	0.51	1	0.6187	0.7464	0.4244	0.8062	0.6732	0.5449	0.5594	0.582	0.5318	0.505	0.1402
KSC5	-0.0577	0.6011	0.769	0.6187	1	0.7721	0.6803	0.5483	0.463	0.7727	0.6341	0.5228	0.3675	0.4087	0.1335
KSC6	-0.0697	0.574	0.5869	0.7464	0.7721	1	0.5564	0.715	0.6061	0.7558	0.7429	0.6728	0.4848	0.5236	0.1614
KSC7	-0.0751	0.426	0.6844	0.4244	0.6803	0.5564	1	0.395	0.3417	0.6955	0.5386	0.4105	0.2867	0.3486	0.1156
KSC8	-0.047	0.54	0.4445	0.8062	0.5483	0.715	0.395	1	0.8406	0.5387	0.6171	0.7211	0.6592	0.6282	0.1759
KSC9	-0.0405	0.4528	0.378	0.6732	0.463	0.6061	0.3417	0.8406	1	0.4864	0.5884	0.7408	0.8055	0.7182	0.1822
KSC10	-0.0702	0.4582	0.607	0.5449	0.7727	0.7558	0.6955	0.5387	0.4864	1	0.7858	0.6105	0.4044	0.4749	0.1643
KSC11	-0.0704	0.4253	0.4836	0.5594	0.6341	0.7429	0.5386	0.6171	0.5884	0.7858	1	0.7902	0.5092	0.595	0.2048
KSC12	-0.0533	0.3991	0.4041	0.582	0.5228	0.6728	0.4105	0.7211	0.7408	0.6105	0.7902	1	0.6443	0.7578	0.2197
KSC13	-0.0335	0.3509	0.2974	0.5318	0.3675	0.4848	0.2867	0.6592	0.8055	0.4044	0.5092	0.6443	1	0.775	0.2795
KSC14	-0.0517	0.3409	0.3315	0.505	0.4087	0.5236	0.3486	0.6282	0.7182	0.4749	0.595	0.7578	0.775	1	0.2192
KSC15	-0.0233	0.0903	0.1086	0.1402	0.1335	0.1614	0.1156	0.1759	0.1822	0.1643	0.2048	0.2197	0.2795	0.2192	1
KSC16	-0.0351	0.2833	0.2496	0.4415	0.3043	0.3998	0.2621	0.548	0.6492	0.3593	0.4486	0.5568	0.7824	0.7781	0.1624
KSC17	-0.0653	0.3171	0.357	0.4368	0.4519	0.5212	0.4256	0.4907	0.5061	0.5783	0.6879	0.6574	0.4766	0.6327	0.2324
KSC18	-0.0728	0.2899	0.3786	0.3811	0.4545	0.4936	0.4804	0.421	0.4239	0.584	0.6441	0.5507	0.3994	0.5184	0.1792
KSC19	-0.0565	0.2856	0.2885	0.4144	0.3605	0.4415	0.3371	0.5072	0.5711	0.4425	0.5483	0.6298	0.6043	0.8033	0.2109
KSC20	-0.0583	0.2893	0.295	0.4013	0.3757	0.4462	0.3528	0.4761	0.5171	0.4632	0.5679	0.6057	0.5227	0.6961	0.2068
KSC21	-0.0448	0.2437	0.2364	0.3429	0.293	0.363	0.3029	0.4226	0.4845	0.3851	0.4755	0.5229	0.5292	0.664	0.1928
KSC22	-0.0597	0.2223	0.2525	0.2948	0.3204	0.3576	0.3261	0.3371	0.3562	0.4057	0.4672	0.4278	0.3556	0.4647	0.1481
KSC24	-0.0647	0.1793	0.191	0.2519	0.2579	0.2935	0.2629	0.2911	0.3092	0.3214	0.3676	0.345	0.3236	0.4174	0.1245
KSC25	-0.0588	0.1215	0.155	0.1785	0.1773	0.213	0.1928	0.2364	0.251	0.229	0.2776	0.2741	0.257	0.3284	0.0881
KSC26	-0.0326	0.2394	0.2045	0.3651	0.2562	0.3332	0.2345	0.4473	0.5322	0.3168	0.4041	0.474	0.6412	0.6789	0.4835
KSC27	-0.0294	0.1662	0.1673	0.2454	0.2022	0.239	0.1803	0.3152	0.3704	0.2381	0.306	0.3359	0.4455	0.479	0.1083
KSC28	-0.0255	0.1246	0.1188	0.164	0.1499	0.1676	0.1218	0.2141	0.2578	0.1601	0.2046	0.2224	0.3093	0.3122	0.0675
KSC29	-0.0451	0.1465	0.1443	0.1969	0.1754	0.2102	0.1729	0.2514	0.2998	0.2252	0.2728	0.2818	0.3468	0.4017	0.0951
KSC30	-0.0388	0.1412	0.1484	0.2001	0.182	0.2079	0.1607	0.2546	0.3102	0.2077	0.2568	0.2749	0.3723	0.3978	0.0885
KSC31	-0.0303	0.1211	0.125	0.1499	0.1391	0.1532	0.1425	0.1937	0.2203	0.1703	0.2011	0.2054	0.2505	0.2802	0.0684
KSC32	-0.0287	0.1322	0.1355	0.1721	0.1571	0.1798	0.1492	0.2164	0.2487	0.1846	0.2236	0.232	0.2817	0.3214	0.0794
KSC34	-0.0373	0.1268	0.1332	0.1777	0.1633	0.1877	0.1522	0.2271	0.2644	0.1887	0.2358	0.2466	0.307	0.3424	0.0787

	KSC16	KSC17	KSC18	KSC19	KSC20	KSC21	KSC22	KSC24	KSC25	KSC26	KSC27	KSC28	KSC29	KSC30	KSC31	KSC32	KSC34
Time	-0.0351	-0.0653	-0.0728	-0.0565	-0.0583	-0.0448	-0.0597	-0.0647	-0.0588	-0.0326	-0.0294	-0.0255	-0.0451	-0.0388	-0.0303	-0.0287	-0.0373
KSC1	0.2833	0.3171	0.2899	0.2856	0.2893	0.2437	0.2223	0.1793	0.1215	0.2394	0.1662	0.1246	0.1465	0.1412	0.1211	0.1322	0.1268
KSC2	0.2496	0.357	0.3786	0.2885	0.295	0.2364	0.2525	0.191	0.155	0.2045	0.1673	0.1188	0.1443	0.1484	0.125	0.1355	0.1332
KSC4	0.4415	0.4368	0.3811	0.4144	0.4013	0.3429	0.2948	0.2519	0.1785	0.3651	0.2454	0.164	0.1969	0.2001	0.1499	0.1721	0.1777
KSC5	0.3043	0.4519	0.4545	0.3605	0.3757	0.293	0.3204	0.2579	0.1773	0.2562	0.2022	0.1499	0.1754	0.182	0.1391	0.1571	0.1633
KSC6	0.3998	0.5212	0.4936	0.4415	0.4462	0.363	0.3576	0.2935	0.213	0.3332	0.239	0.1676	0.2102	0.2079	0.1532	0.1798	0.1877
KSC7	0.2621	0.4256	0.4804	0.3371	0.3528	0.3029	0.3261	0.2629	0.1928	0.2345	0.1803	0.1218	0.1729	0.1607	0.1425	0.1492	0.1522
KSC8	0.548	0.4907	0.421	0.5072	0.4761	0.4226	0.3371	0.2911	0.2364	0.4473	0.3152	0.2141	0.2514	0.2546	0.1937	0.2164	0.2271
KSC9	0.6492	0.5061	0.4239	0.5711	0.5171	0.4845	0.3562	0.3092	0.251	0.5322	0.3704	0.2578	0.2998	0.3102	0.2203	0.2487	0.2644
KSC10	0.3593	0.5783	0.584	0.4425	0.4632	0.3851	0.4057	0.3214	0.229	0.3168	0.2381	0.1601	0.2252	0.2077	0.1703	0.1846	0.1887
KSC11	0.4486	0.6879	0.6441	0.5483	0.5679	0.4755	0.4672	0.3676	0.2776	0.4041	0.306	0.2046	0.2728	0.2568	0.2011	0.2236	0.2358
KSC12	0.5568	0.6574	0.5507	0.6298	0.6057	0.5229	0.4278	0.345	0.2741	0.474	0.3359	0.2224	0.2818	0.2749	0.2054	0.232	0.2466
KSC13	0.7824	0.4766	0.3994	0.6043	0.5227	0.5292	0.3556	0.3236	0.257	0.6412	0.4455	0.3093	0.3468	0.3723	0.2505	0.2817	0.307
KSC14	0.7781	0.6327	0.5184	0.8033	0.6961	0.664	0.4647	0.4174	0.3284	0.6789	0.479	0.3122	0.4017	0.3978	0.2802	0.3214	0.3424
KSC15	0.1624	0.2324	0.1792	0.2109	0.2068	0.1928	0.1481	0.1245	0.0881	0.4835	0.1083	0.0675	0.0951	0.0885	0.0684	0.0794	0.0787
KSC16	1	0.4651	0.3897	0.6807	0.5598	0.6082	0.3687	0.3544	0.3036	0.841	0.5585	0.3893	0.4295	0.4536	0.3015	0.3423	0.3763
KSC17	0.4651	1	0.7921	0.6723	0.7605	0.6066	0.6254	0.4905	0.349	0.4371	0.3515	0.2379	0.3376	0.3044	0.2477	0.2838	0.2779
KSC18	0.3897	0.7921	1	0.5626	0.6592	0.5335	0.6968	0.5336	0.374	0.3707	0.31	0.2238	0.3275	0.2864	0.2575	0.2744	0.2687
KSC19	0.6807	0.6723	0.5626	1	0.8402	0.8361	0.5553	0.5204	0.4074	0.6784	0.5482	0.3493	0.4765	0.4601	0.3435	0.3851	0.3963
KSC20	0.5598	0.7605	0.6592	0.8402	1	0.8024	0.6553	0.5843	0.4292	0.5614	0.4812	0.3234	0.4549	0.4212	0.337	0.3704	0.3748
KSC21	0.6082	0.6066	0.5335	0.8361	0.8024	1	0.5857	0.5927	0.4653	0.6578	0.5984	0.401	0.5519	0.5183	0.4035	0.4501	0.4528
KSC22	0.3687	0.6254	0.6968	0.5553	0.6553	0.5857	1	0.7752	0.5187	0.3895	0.375	0.2639	0.4061	0.3506	0.3366	0.3449	0.33
KSC24	0.3544	0.4905	0.5336	0.5204	0.5843	0.5927	0.7752	1	0.66	0.3902	0.4183	0.3251	0.4964	0.4168	0.4343	0.442	0.4181
KSC25	0.3036	0.349	0.374	0.4074	0.4292	0.4653	0.5187	0.66	1	0.3464	0.4009	0.3713	0.5309	0.4417	0.5692	0.531	0.4699
KSC26	0.841	0.4371	0.3707	0.6784	0.5614	0.6578	0.3895	0.3902	0.3464	1	0.6867	0.4753	0.5252	0.5546	0.3667	0.4267	0.4654
KSC27	0.5585	0.3515	0.31	0.5482	0.4812	0.5984	0.375	0.4183	0.4009	0.6867	1	0.6339	0.6997	0.7962	0.4964	0.5766	0.6428
KSC28	0.3893	0.2379	0.2238	0.3493	0.3234	0.401	0.2639	0.3251	0.3713	0.4753	0.6339	1	0.6279	0.7476	0.5443	0.6245	0.7192
KSC29	0.4295	0.3376	0.3275	0.4765	0.4549	0.5519	0.4061	0.4964	0.5309	0.5252	0.6997	0.6279	1	0.8199	0.7095	0.8127	0.8234
KSC30	0.4536	0.3044	0.2864	0.4601	0.4212	0.5183	0.3506	0.4168	0.4417	0.5546	0.7962	0.7476	0.8199	1	0.6038	0.7146	0.8053
KSC31	0.3015	0.2477	0.2575	0.3435	0.337	0.4035	0.3366	0.4343	0.5692	0.3667	0.4964	0.5443	0.7095	0.6038	1	0.8323	0.7211
KSC32	0.3423	0.2838	0.2744	0.3851	0.3704	0.4501	0.3449	0.442	0.531	0.4267	0.5766	0.6245	0.8127	0.7146	0.8323	1	0.8277
KSC34	0.3763	0.2779	0.2687	0.3963	0.3748	0.4528	0.33	0.4181	0.4699	0.4654	0.6428	0.7192	0.8234	0.8053	0.7211	0.8277	1

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Multivariate correlations show sensors located near each other have some correlation. Some sort of inconsistency is presenting in KSC15

EFM Mean Voltage Least Squares Fit

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EFM Mean Voltage/Time vs. Lightning Prediction

Summary of Fit

RSquare	0.141512
RSquare Adj	0.14151
Root Mean Square Error	211.1348
Mean of Response	49.37997
Observations (or Sum Wgts)	735811

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	5406842121	2.7034e+9	60644.86
Error	735808	3.2801e+10	44577.906	**Prob > F**
C. Total	735810	3.8208e+10		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	45.217513	0.504074	89.70	<.0001*
EFM_Mean_Voltage	-0.217787	0.00065	-335.2	<.0001*
Time	0.0006772	9.885e-6	68.50	<.0001*

Prediction Expression

45.21751263 + -0.217786895 • EFM_Mean_Voltage + 0.0006771592 • Time

EFM Abs Mean V./Time vs. Lightning Prediction

Summary of Fit

RSquare	0.211176
RSquare Adj	0.211174
Root Mean Square Error	202.3867
Mean of Response	49.37967
Observations (or Sum Wgts)	735814

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	8068539637	4.0343e+9	98492.00
Error	735811	3.0139e+10	40960.383	**Prob > F**
C. Total	735813	3.8208e+10		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.8571723	0.472209	8.17	<.0001*
AbsMean	0.2464774	0.00057	432.78	<.0001*
Time	0.0001819	9.605e-6	18.94	<.0001*

Prediction Expression

3.8571722573 + 0.2464773585 • AbsMean + 0.0001819149 • Time

EFM Geo Mean V./Time vs. Lightning Prediction

Summary of Fit

RSquare	0.192712
RSquare Adj	0.19271
Root Mean Square Error	204.7416
Mean of Response	49.37967
Observations (or Sum Wgts)	735814

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	7363080395	3.6815e+9	87824.82
Error	735811	3.0845e+10	41919.133	**Prob > F**
C. Total	735813	3.8208e+10		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	6.50769	0.477587	13.63	<.0001*
GeoMean	0.2901371	0.000712	407.66	<.0001*
Time	0.0002731	9.693e-6	28.17	<.0001*

Prediction Expression

6.5076899928 + 0.2901370729 • GeoMean + 0.0002730918 • Time

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Least Squares Linear Regression models comparing the Mean Voltage and Time, Absolute Mean Voltage from Sensor Mean and Time, and Geometric Mean Voltage from Sensor Mean, with Lightning as the response show how each input explains the amount of variance in the dataset. The best method is Absolute Mean Voltage from the Sensor Mean with Time, however, this only accounts for just over 20% of variation in the dataset.

EFM All Sensors Least Squares Fit

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Effect Summary

Source	LogWorth	PValue
KSC12	1167.053	0.00000
KSC7	1055.954	0.00000
KSC25	900.665	0.00000
KSC17	479.796	0.00000
KSC24	354.208	0.00000
KSC18	296.113	0.00000
KSC21	247.384	0.00000
KSC13	156.992	0.00000
KSC14	147.887	0.00000
KSC28	135.421	0.00000
KSC31	125.632	0.00000
KSC32	84.588	0.00000
KSC8	56.456	0.00000
KSC16	43.849	0.00000
KSC11	40.731	0.00000
KSC30	34.434	0.00000
KSC34	22.304	0.00000
KSC22	20.770	0.00000
Time	20.650	0.00000
KSC4	20.517	0.00000
KSC10	11.977	0.00000
KSC6	11.785	0.00000
KSC1	8.815	0.00000
KSC15	6.078	0.00000
KSC19	5.159	0.00001
KSC29	3.647	0.00023
KSC5	3.457	0.00035
KSC9	2.952	0.00112
KSC26	2.193	0.00641
KSC27	1.402	0.03964
KSC20	0.961	0.10931
KSC2	0.808	0.15548

Summary of Fit

RSquare	0.24433
RSquare Adj	0.244297
Root Mean Square Error	198.0919
Mean of Response	49.37967
Observations (or Sum Wgts)	735814

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	32	9335284932	291727654	7434.366
Error	735781	2.8872e+10	39240.419	**Prob > F**
C. Total	735813	3.8208e+10		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.8686377	0.464281	8.33	<.0001*
KSC1	0.0036001	0.000596	6.04	<.0001*
KSC2	-0.001285	0.000905	-1.42	0.1555
KSC4	0.008185	0.000865	9.46	<.0001*
KSC5	-0.004645	0.001299	-3.58	0.0003*
KSC6	0.0086125	0.00122	7.06	<.0001*
KSC7	0.0601687	0.000862	69.79	<.0001*
KSC8	0.0191534	0.001202	15.94	<.0001*
KSC9	-0.004007	0.00123	-3.26	0.0011*
KSC10	0.005815	0.000816	7.12	<.0001*
KSC11	0.0137313	0.001018	13.49	<.0001*
KSC12	-0.057067	0.000778	-73.38	<.0001*
KSC13	0.0257522	0.000962	26.76	<.0001*
KSC14	0.026971	0.001039	25.97	<.0001*
KSC15	-0.000983	0.000199	-4.93	<.0001*
KSC16	-0.011221	0.000801	-14.01	<.0001*
KSC17	0.0488653	0.001041	46.95	<.0001*
KSC18	0.0363352	0.000986	36.84	<.0001*
KSC19	0.005309	0.001181	4.50	<.0001*
KSC20	-0.001797	0.001122	-1.60	0.1093
KSC21	-0.029905	0.000889	-33.65	<.0001*
KSC22	-0.009189	0.000965	-9.52	<.0001*
KSC24	0.0368672	0.000915	40.31	<.0001*
KSC25	0.048271	0.000749	64.43	<.0001*
KSC26	0.002195	0.000805	2.73	0.0064*
KSC27	0.0021873	0.001063	2.06	0.0396*
KSC28	0.0232719	0.000937	24.84	<.0001*
KSC29	-0.003823	0.001036	-3.69	0.0002*
KSC30	0.0130781	0.001057	12.37	<.0001*
KSC31	-0.019096	0.000798	-23.92	<.0001*
KSC32	0.0259393	0.001325	19.58	<.0001*
KSC34	-0.009525	0.000964	-9.88	<.0001*
Time	8.9468e-5	9.424e-6	9.49	<.0001*

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A Least Squares Fit regression model using individual sensor readings and time offer the most explanation of variation in data, but still only accounts for up to 25% of the variation. This is NOT a good fit for the data.

Threshold Confusion Matrix for Individual Sensors

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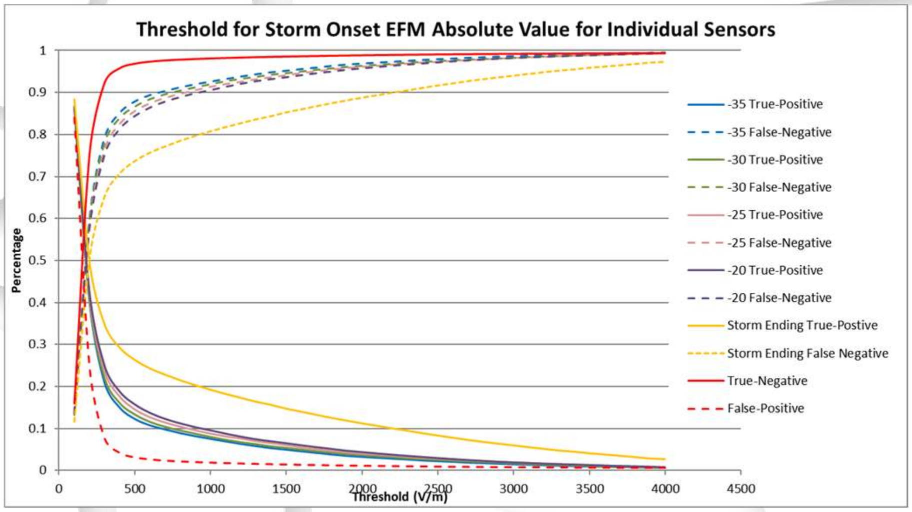

- **Inversely proportional: As True-Negative predictions get better, True-Positive predictions get worse**

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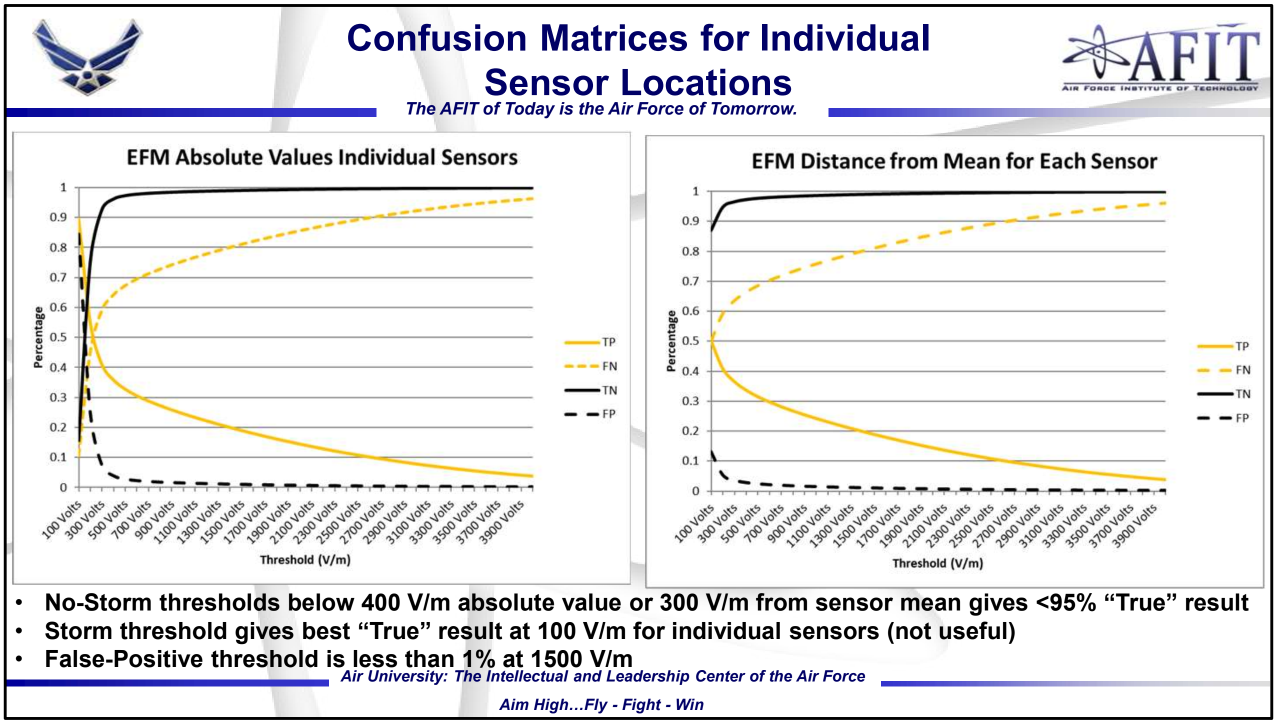
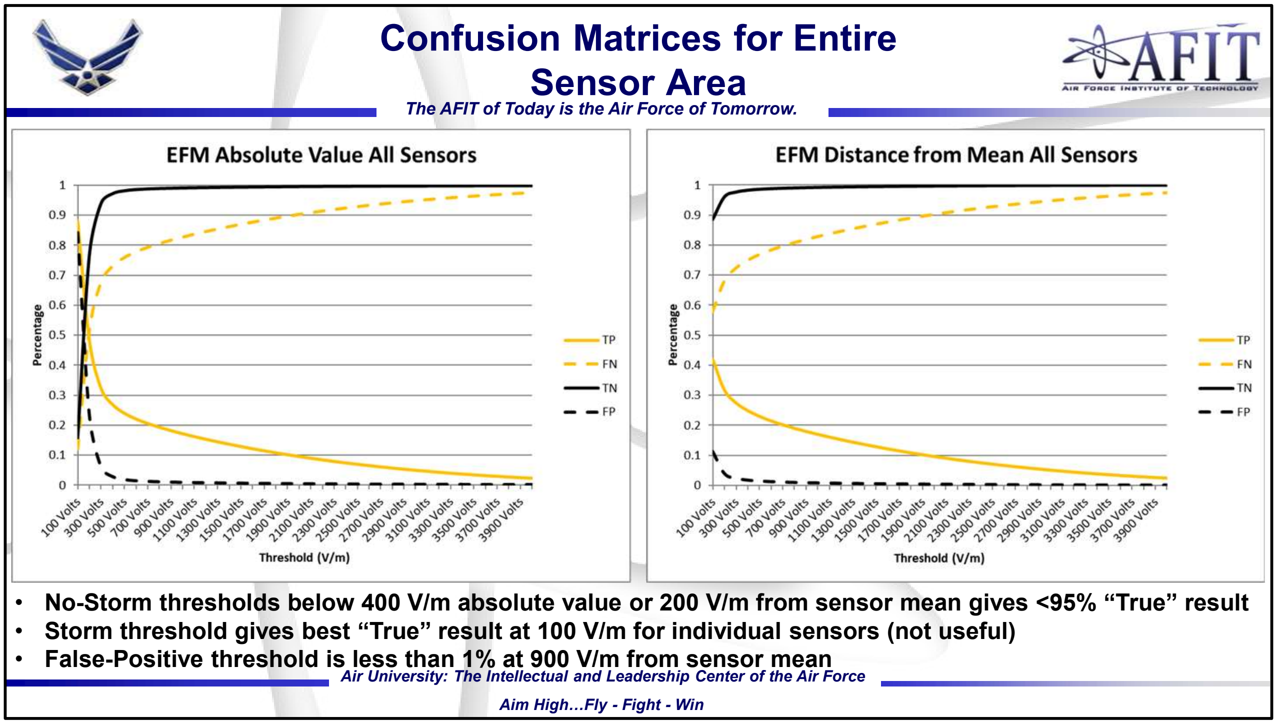
True-Negative measures voltage below threshold when there are no lightning storms presenting.
True-Positive measures voltage above threshold when lightning storms are occurring.
False-Positive measure voltage above threshold when there are no lightning storms presenting.
False-Negative measure voltage below threshold when lighting storms are occurring.



Each individual sensor is tested to determine if the voltage reading exceeds the threshold value from 100 V/m to 4000 V/m.
True Positive is considered when a storm is occurring within 5 NM of the sensor and EFM voltage exceeds threshold.
False Positive is considered when no-storm is occurring within 5 NM of the sensor, but EFM voltage exceeds threshold.
True Negative is considered when no-storm is occurring within 5 NM of the sensor and EFM voltage is below threshold.
False Negative is considered when a storm is occurring within 5 NM of the sensor, but EFM voltage is below threshold.



Each individual sensor is tested to determine if the voltage reading exceeds the threshold value from 100 V/m to 4000 V/m.
True Positive is considered when a storm is occurring anywhere in the vicinity of CCAFS and EFM voltage exceeds threshold.
False Positive is considered when no-storm is occurring anywhere in the vicinity of CCAFS, but EFM voltage exceeds threshold.
True Negative is considered when no-storm is occurring anywhere in the vicinity of CCAFS and EFM voltage is below threshold.
False Negative is considered when a storm is occurring anywhere in the vicinity of CCAFS, but EFM voltage is below threshold.

Confusion Matrices for Means Over Entire Sensor Area

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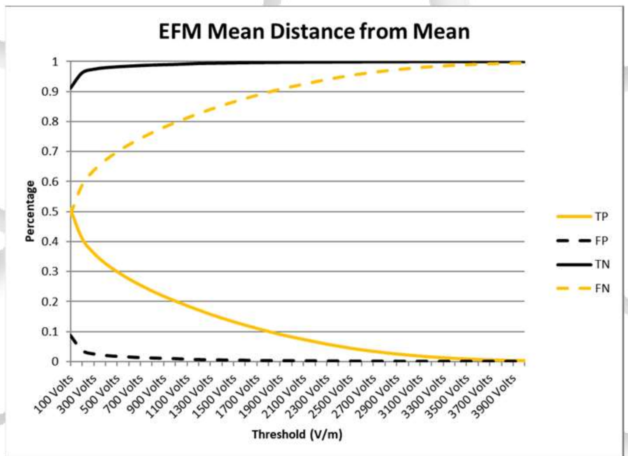

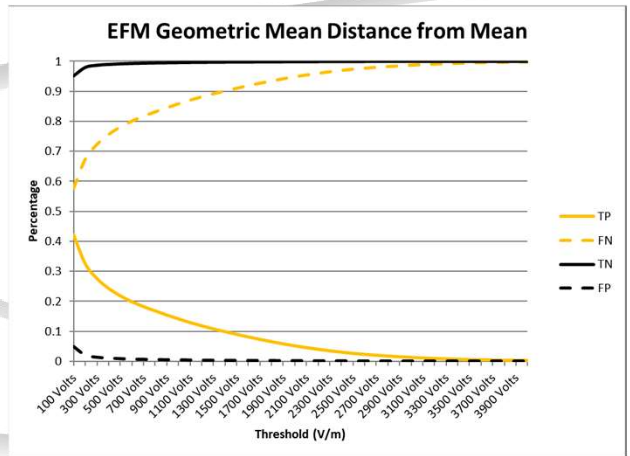

- **No-Storm thresholds below 200 V/m mean from sensor mean or 100 V/m geometric mean from sensor mean gives <95% "True" result**
- **Storm threshold gives best "True" result at 100 V/m for individual sensors (not useful)**
- **False-Positive threshold is less than 1% at 1500 V/m**

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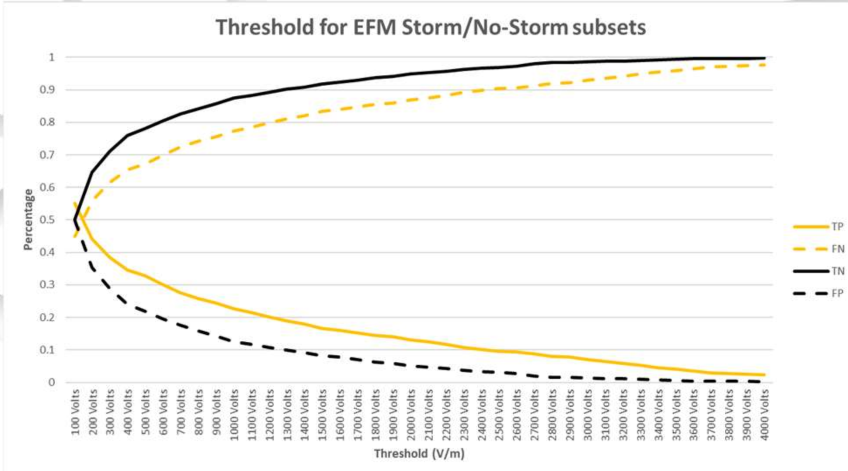
The mean voltage and geometric mean voltage of all sensors are tested to determine if the voltage reading exceeds the threshold value from 100 V/m to 4000 V/m.
True Positive is considered when a storm is occurring anywhere in the vicinity of CCAFS and EFM mean/geometric mean voltage exceeds threshold.
False Positive is considered when no-storm is occurring anywhere in the vicinity of CCAFS, but EFM mean/geometric mean voltage exceeds threshold.
True Negative is considered when no-storm is occurring anywhere in the vicinity of CCAFS and EFM mean/geometric mean voltage is below threshold.
False Negative is considered when a storm is occurring anywhere in the vicinity of CCAFS, but EFM mean/geometric mean voltage is below threshold.

Storm/No-Storm Threshold Confusion Matrix for Entire Sensor Area



- **No-Storm threshold below 2100 V/m mean from sensor mean gives <95% "True" result**
- **Storm threshold gives best "True" result at 100 V/m, just over 55% of all storms above threshold**

Slope Threshold Confusion Matrix for Individual Sensors

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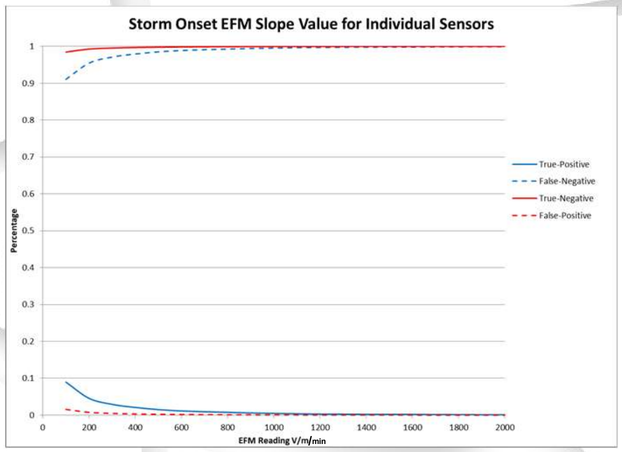

- **Change in voltage from minute to minute is also not a good indicator for lightning onset**
- **99% confidence that change in voltages below 500 V/m/min indicate no-storms**

Preliminary Results

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- This is still largely a work in progress
  - Large timeseries data set reduced and noise-filtered using mean values
  - Least Squares Fit of EFM data only accounts for up to 25% of variance
    - Not a good fit to predict if lightning will or is occurring
  - Threshold analysis shows inverse relation w/True-Positive & True-Negative outcomes with increasing threshold voltages
  - EFM readings alone are NOT a useful tool for predicting lightning
    - Appear to be reactive, not predictive

Next phase: predict time to end of storm

Next Steps

- **Setup lightning-ending prediction columns (complete)**
- **Subset data frame into storm-only datasets for individual storms**
- **Perform negative binomial regression analysis for each sensor on each storm**
  - **EFM readings vs. storm ending time**
  - **Lightning strikes vs. storm ending time**
- **Develop negative binomial regression model to compute time to storm end**

Questions?

XTS Plot

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- **EFM Mean Voltage and Lightning w/in 5 nm of any sensor**

dygraphmeanall.html

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Times of interest:
9 – 14 Aug 2013 – EFM reading close to average while lightning occurring
13 – 19 Jun 2016 – EFM readings spike after lightning has started
14 – 17 Jun 2013, 3 Jul – 7 Jul 2013 – EFM readings spike but no lightning occurring

Multivariate Comparisons

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- **Multivariate Comparisons with Absolute EFM Voltage Readings**

	Time	KSC1	KSC2	KSC4	KSC5	KSC6	KSC7	KSC8	KSC9	KSC10	KSC11	KSC12	KSC13	KSC14	KSC15
Time	1	0.1567	0.1601	0.1809	0.162	0.1543	0.1547	0.1674	0.1599	0.1589	0.1582	0.1399	0.1722	0.1544	0.0346
KSC1	0.1567	1	0.7347	0.763	0.7319	0.7196	0.6305	0.7009	0.635	0.656	0.6501	0.6314	0.5576	0.5872	0.1276
KSC2	0.1601	0.7347	1	0.6838	0.8437	0.7476	0.7884	0.6509	0.593	0.7577	0.6898	0.6428	0.537	0.5793	0.1426
KSC4	0.1809	0.763	0.6838	1	0.7468	0.8064	0.6185	0.8516	0.771	0.707	0.7138	0.7384	0.686	0.6949	0.1603
KSC5	0.162	0.7319	0.8437	0.7468	1	0.8418	0.7891	0.7144	0.656	0.8451	0.7718	0.7086	0.5956	0.6323	0.1545
KSC6	0.1543	0.7196	0.7476	0.8064	0.8418	1	0.7101	0.8014	0.7291	0.8306	0.8245	0.7831	0.6649	0.6953	0.1653
KSC7	0.1547	0.6305	0.7884	0.6185	0.7891	0.7101	1	0.6118	0.5652	0.7892	0.7113	0.6435	0.5194	0.5792	0.1425
KSC8	0.1674	0.7009	0.6509	0.8516	0.7144	0.8014	0.6118	1	0.8761	0.7089	0.7496	0.8167	0.7721	0.7751	0.1817
KSC9	0.1599	0.635	0.593	0.771	0.656	0.7291	0.5652	0.8761	1	0.6607	0.72	0.8181	0.844	0.8089	0.1808
KSC10	0.1589	0.656	0.7577	0.707	0.8451	0.8306	0.7892	0.7089	0.6607	1	0.847	0.7562	0.6066	0.665	0.1727
KSC11	0.1582	0.6501	0.6898	0.7138	0.7718	0.8245	0.7113	0.7496	0.72	0.847	1	0.8518	0.6766	0.7364	0.1925
KSC12	0.1399	0.6314	0.6428	0.7384	0.7086	0.7831	0.6435	0.8167	0.8181	0.7562	0.8518	1	0.7666	0.8388	0.197
KSC13	0.1722	0.5576	0.537	0.686	0.5956	0.6649	0.5194	0.7721	0.844	0.6066	0.6766	0.7666	1	0.8242	0.3005
KSC14	0.1544	0.5872	0.5793	0.6949	0.6323	0.6953	0.5792	0.7751	0.8089	0.665	0.7364	0.8388	0.8242	1	0.1992
KSC15	0.0346	0.1276	0.1426	0.1603	0.1545	0.1653	0.1425	0.1817	0.1808	0.1727	0.1925	0.197	0.3005	0.1992	1
KSC16	0.1554	0.5508	0.5256	0.6541	0.5713	0.6148	0.515	0.7194	0.768	0.589	0.6456	0.7265	0.8363	0.8429	0.1719
KSC17	0.1661	0.5837	0.5969	0.6574	0.6536	0.6878	0.6401	0.6744	0.6656	0.7302	0.7787	0.7724	0.6367	0.7476	0.2107
KSC18	0.1635	0.567	0.6192	0.6187	0.6689	0.6939	0.6762	0.6457	0.6333	0.7451	0.7772	0.7315	0.6097	0.697	0.1816
KSC19	0.1537	0.5539	0.5611	0.6409	0.6097	0.66	0.5767	0.7069	0.7265	0.654	0.7155	0.779	0.7348	0.865	0.195
KSC20	0.1579	0.5588	0.571	0.6349	0.6252	0.6651	0.5985	0.684	0.6908	0.6715	0.7362	0.7732	0.6886	0.805	0.1915
KSC21	0.1437	0.5275	0.5399	0.5957	0.577	0.6178	0.5525	0.6653	0.679	0.6219	0.6751	0.7269	0.6905	0.7914	0.1999
KSC22	0.1567	0.5145	0.5438	0.5619	0.5856	0.6142	0.5891	0.6042	0.5962	0.6403	0.6805	0.6753	0.5873	0.6781	0.1673
KSC24	0.1511	0.4781	0.5087	0.5339	0.5427	0.573	0.5411	0.5764	0.5681	0.5809	0.6243	0.6313	0.5697	0.6541	0.1547
KSC25	0.1531	0.4432	0.4687	0.4921	0.5027	0.5246	0.5004	0.5406	0.543	0.5301	0.5628	0.5797	0.5406	0.6095	0.1283
KSC26	0.1554	0.5233	0.4927	0.5949	0.5364	0.5677	0.4894	0.6541	0.6912	0.553	0.6068	0.6667	0.7415	0.7745	0.6029
KSC27	0.1645	0.4635	0.461	0.513	0.4925	0.5168	0.4579	0.5795	0.5981	0.5005	0.5507	0.5963	0.6346	0.6658	0.14
KSC28	0.1461	0.4199	0.4201	0.4634	0.4452	0.461	0.4238	0.5109	0.5203	0.459	0.4907	0.5229	0.5398	0.5713	0.1241
KSC29	0.1446	0.4564	0.4574	0.5022	0.4912	0.5176	0.4703	0.5551	0.5697	0.5087	0.5563	0.5903	0.5967	0.6399	0.1391
KSC30	0.1495	0.4538	0.4486	0.4919	0.4811	0.5013	0.4543	0.5476	0.5652	0.492	0.5377	0.5756	0.5964	0.6316	0.1344
KSC31	0.1395	0.4127	0.4174	0.4537	0.4472	0.4675	0.4361	0.5021	0.5059	0.4639	0.4962	0.5281	0.5288	0.5628	0.1219
KSC32	0.1459	0.4209	0.4279	0.464	0.4581	0.4749	0.4364	0.5128	0.5241	0.4717	0.5043	0.5406	0.5456	0.5844	0.1283
KSC34	0.1457	0.4319	0.4347	0.4733	0.4643	0.481	0.4517	0.5208	0.5333	0.4765	0.5175	0.5518	0.5547	0.5946	0.1276

	KSC16	KSC17	KSC18	KSC19	KSC20	KSC21	KSC22	KSC24	KSC25	KSC26	KSC27	KSC28	KSC29	KSC30	KSC31	KSC32	KSC34
Time	0.1554	0.1661	0.1635	0.1537	0.1579	0.1437	0.1567	0.1511	0.1531	0.1554	0.1645	0.1461	0.1446	0.1495	0.1395	0.1459	0.1457
KSC1	0.5508	0.5837	0.567	0.5539	0.5588	0.5275	0.5145	0.4781	0.4432	0.5233	0.4635	0.4199	0.4564	0.4538	0.4127	0.4209	0.4319
KSC2	0.5256	0.5969	0.6192	0.5611	0.571	0.5399	0.5438	0.5087	0.4687	0.4927	0.461	0.4201	0.4574	0.4486	0.4174	0.4279	0.4347
KSC4	0.6541	0.6574	0.6187	0.6409	0.6349	0.5957	0.5619	0.5339	0.4921	0.5949	0.513	0.4634	0.5022	0.4919	0.4537	0.464	0.4733
KSC5	0.5713	0.6536	0.6689	0.6097	0.6252	0.577	0.5856	0.5427	0.5027	0.5364	0.4925	0.4452	0.4912	0.4811	0.4472	0.4581	0.4643
KSC6	0.6148	0.6878	0.6939	0.66	0.6651	0.6178	0.6142	0.573	0.5246	0.5677	0.5168	0.461	0.5176	0.5013	0.4675	0.4749	0.481
KSC7	0.515	0.6401	0.6762	0.5767	0.5985	0.5525	0.5891	0.5411	0.5004	0.4894	0.4579	0.4238	0.4703	0.4543	0.4361	0.4364	0.4517
KSC8	0.7194	0.6744	0.6457	0.7069	0.684	0.6653	0.6042	0.5764	0.5406	0.6541	0.5795	0.5109	0.5551	0.5476	0.5021	0.5128	0.5208
KSC9	0.768	0.6656	0.6333	0.7265	0.6908	0.679	0.5962	0.5681	0.543	0.6912	0.5981	0.5203	0.5697	0.5652	0.5059	0.5241	0.5333
KSC10	0.589	0.7302	0.7451	0.654	0.6715	0.6219	0.6403	0.5809	0.5301	0.553	0.5005	0.459	0.5087	0.492	0.4639	0.4717	0.4765
KSC11	0.6456	0.7787	0.7772	0.7155	0.7362	0.6751	0.6805	0.6243	0.5628	0.6068	0.5507	0.4907	0.5563	0.5377	0.4962	0.5043	0.5175
KSC12	0.7265	0.7724	0.7315	0.779	0.7732	0.7269	0.6753	0.6313	0.5797	0.6667	0.5963	0.5229	0.5903	0.5756	0.5281	0.5406	0.5518
KSC13	0.8363	0.6367	0.6097	0.7348	0.6886	0.6905	0.5873	0.5697	0.5406	0.7415	0.6346	0.5398	0.5967	0.5964	0.5288	0.5456	0.5547
KSC14	0.8429	0.7476	0.697	0.865	0.805	0.7914	0.6781	0.6541	0.6095	0.7745	0.6658	0.5713	0.6399	0.6316	0.5628	0.5844	0.5946
KSC15	0.1719	0.2107	0.1816	0.195	0.1915	0.1999	0.1673	0.1547	0.1283	0.6029	0.14	0.1241	0.1391	0.1344	0.1219	0.1283	0.1276
KSC16	1	0.6416	0.6041	0.7873	0.7194	0.7521	0.6129	0.6059	0.5769	0.8755	0.7119	0.617	0.6504	0.662	0.5712	0.5956	0.6162
KSC17	0.6416	1	0.846	0.7678	0.8188	0.7384	0.7511	0.6735	0.5922	0.6125	0.5674	0.5054	0.5786	0.5538	0.5182	0.5312	0.5313
KSC18	0.6041	0.846	1	0.7194	0.7733	0.6954	0.7973	0.7038	0.6126	0.5813	0.5464	0.5017	0.5733	0.548	0.5236	0.5255	0.5321
KSC19	0.7873	0.7678	0.7194	1	0.8885	0.8832	0.7301	0.7103	0.6483	0.7738	0.7009	0.599	0.6872	0.6733	0.6056	0.6182	0.6346
KSC20	0.7194	0.8188	0.7733	0.8885	1	0.8575	0.7825	0.746	0.6591	0.7054	0.6624	0.5759	0.6737	0.6489	0.6011	0.6062	0.6201
KSC21	0.7521	0.7384	0.6954	0.8832	0.8575	1	0.7437	0.7455	0.6792	0.7695	0.735	0.6319	0.726	0.7054	0.6342	0.656	0.6618
KSC22	0.6129	0.7511	0.7973	0.7301	0.7825	0.7437	1	0.8403	0.7061	0.6142	0.6037	0.5451	0.6402	0.6046	0.5955	0.5875	0.5921
KSC24	0.6059	0.6735	0.7038	0.7103	0.746	0.7455	0.8403	1	0.7843	0.6158	0.6325	0.5773	0.6952	0.6419	0.6542	0.6371	0.6349
KSC25	0.5769	0.5922	0.6126	0.6483	0.6591	0.6792	0.7061	0.7843	1	0.5973	0.6255	0.615	0.7193	0.665	0.7337	0.6973	0.6748
KSC26	0.8755	0.6125	0.5813	0.7738	0.7054	0.7695	0.6142	0.6158	0.5973	1	0.7755	0.6569	0.6974	0.714	0.6007	0.637	0.6562
KSC27	0.7119	0.5674	0.5464	0.7009	0.6624	0.735	0.6037	0.6325	0.6255	0.7755	1	0.7486	0.7996	0.8538	0.6827	0.7222	0.7652
KSC28	0.617	0.5054	0.5017	0.599	0.5759	0.6319	0.5451	0.5773	0.615	0.6569	0.7486	1	0.7491	0.8113	0.7102	0.7543	0.8046
KSC29	0.6504	0.5786	0.5733	0.6872	0.6737	0.726	0.6402	0.6952	0.7193	0.6974	0.7996	0.7491	1	0.8717	0.8034	0.8507	0.8633
KSC30	0.662	0.5538	0.548	0.6733	0.6489	0.7054	0.6046	0.6419	0.665	0.714	0.8538	0.8113	0.8717	1	0.7451	0.7958	0.8526
KSC31	0.5712	0.5182	0.5236	0.6056	0.6011	0.6342	0.5955	0.6542	0.7337	0.6007	0.6827	0.7102	0.8034	0.7451	1	0.8539	0.8014
KSC32	0.5956	0.5312	0.5255	0.6182	0.6062	0.656	0.5875	0.6371	0.6973	0.637	0.7222	0.7543	0.8507	0.7958	0.8539	1	0.856
KSC34	0.6162	0.5313	0.5321	0.6346	0.6201	0.6618	0.5921	0.6349	0.6748	0.6562	0.7652	0.8046	0.8633	0.8526	0.8014	0.856	1

Multivariate Comparisons

The AFIT of Today is the Air Force of Tomorrow.

- **Multivariate Comparisons with EFM Voltage Readings Folded on Mean Voltage**

	Time	KSC1	KSC2	KSC4	KSC5	KSC6	KSC7	KSC8	KSC9	KSC10	KSC11	KSC12	KSC13	KSC14	KSC15	KSC16
Time	1	0.128	0.1525	0.1437	0.1552	0.1515	0.1527	0.1487	0.1409	0.1546	0.1578	0.132	0.1435	0.1449	0.0344	0.1379
KSC1	0.128	1	0.6595	0.707	0.6583	0.6128	0.5684	0.6483	0.5827	0.5832	0.5917	0.5107	0.5152	0.5413	0.1458	0.5039
KSC2	0.1525	0.6595	1	0.6267	0.8167	0.7305	0.7689	0.6553	0.6035	0.7426	0.6925	0.585	0.5481	0.5721	0.151	0.5245
KSC4	0.1437	0.707	0.6267	1	0.6848	0.6988	0.5675	0.7731	0.703	0.6474	0.6619	0.5943	0.6399	0.641	0.1761	0.5981
KSC5	0.1552	0.6583	0.8167	0.6848	1	0.808	0.7587	0.7082	0.6541	0.8143	0.7636	0.6282	0.6011	0.6178	0.1631	0.5661
KSC6	0.1515	0.6128	0.7305	0.6988	0.808	1	0.6845	0.7707	0.714	0.7892	0.8048	0.6817	0.6667	0.6687	0.172	0.602
KSC7	0.1527	0.5684	0.7689	0.5675	0.7587	0.6845	1	0.6193	0.5743	0.7655	0.7186	0.5841	0.5292	0.5727	0.1511	0.5149
KSC8	0.1487	0.6483	0.6553	0.7731	0.7082	0.7707	0.6193	1	0.8866	0.706	0.7636	0.7329	0.7921	0.7829	0.1898	0.7198
KSC9	0.1409	0.5827	0.6035	0.703	0.6541	0.714	0.5743	0.8866	1	0.665	0.7367	0.7347	0.8566	0.812	0.1915	0.7648
KSC10	0.1546	0.5832	0.7426	0.6474	0.8143	0.7892	0.7655	0.706	0.665	1	0.839	0.68	0.6123	0.657	0.1832	0.5857
KSC11	0.1578	0.5917	0.6925	0.6619	0.7636	0.8048	0.7186	0.7636	0.7367	0.839	1	0.7709	0.6949	0.7378	0.2026	0.6609
KSC12	0.132	0.5107	0.585	0.5943	0.6282	0.6817	0.5841	0.7329	0.7347	0.68	0.7709	1	0.6907	0.7359	0.1949	0.6557
KSC13	0.1435	0.5152	0.5481	0.6399	0.6011	0.6667	0.5292	0.7921	0.8566	0.6123	0.6949	0.6907	1	0.8222	0.1831	0.827
KSC14	0.1449	0.5413	0.5721	0.641	0.6178	0.6687	0.5727	0.7829	0.812	0.657	0.7378	0.7359	0.8222	1	0.206	0.8192
KSC15	0.0344	0.1458	0.151	0.1761	0.1631	0.172	0.1511	0.1898	0.1915	0.1832	0.2026	0.1949	0.1831	0.206	1	0.1829
KSC16	0.1379	0.5039	0.5245	0.5981	0.5661	0.602	0.5149	0.7198	0.7648	0.5857	0.6609	0.6557	0.827	0.8192	0.1829	1
KSC17	0.1607	0.5379	0.5959	0.6316	0.6422	0.6742	0.6321	0.6894	0.6835	0.7236	0.7899	0.6761	0.6553	0.7456	0.2191	0.6518
KSC18	0.1637	0.5192	0.6229	0.5892	0.6664	0.6877	0.676	0.662	0.6515	0.7421	0.7923	0.6639	0.6269	0.6982	0.1942	0.6163
KSC19	0.1491	0.508	0.56	0.5968	0.5997	0.6381	0.5702	0.7231	0.7431	0.6487	0.7223	0.7012	0.7518	0.8623	0.2031	0.7795
KSC20	0.1497	0.5007	0.5572	0.5775	0.6074	0.641	0.5819	0.6789	0.6835	0.6523	0.7392	0.6719	0.6842	0.7801	0.1983	0.7075
KSC21	0.1339	0.4815	0.5138	0.5409	0.5379	0.5702	0.5217	0.6511	0.6648	0.5816	0.6465	0.6313	0.6759	0.7567	0.1821	0.708
KSC22	0.1539	0.466	0.5425	0.5258	0.5721	0.5947	0.5855	0.6084	0.6016	0.6327	0.6856	0.6128	0.5929	0.6698	0.1777	0.6121
KSC24	0.1537	0.4428	0.5128	0.5069	0.5417	0.5675	0.5473	0.5905	0.584	0.5881	0.6442	0.5842	0.5857	0.6568	0.1683	0.6173
KSC25	0.1467	0.4002	0.4447	0.447	0.4893	0.4931	0.4695	0.5256	0.5303	0.5031	0.5506	0.5215	0.5251	0.5839	0.1388	0.5518
KSC26	0.135	0.4829	0.4947	0.5469	0.5328	0.5611	0.4924	0.661	0.6941	0.5538	0.6217	0.5954	0.7392	0.7786	0.1653	0.8513
KSC27	0.1439	0.4355	0.4658	0.4885	0.4954	0.5155	0.4608	0.5956	0.6137	0.5069	0.5727	0.5511	0.6505	0.6697	0.1531	0.709
KSC28	0.1306	0.3932	0.4232	0.4435	0.4464	0.4555	0.4231	0.5248	0.536	0.4643	0.5089	0.4883	0.5578	0.5774	0.1375	0.625
KSC29	0.1401	0.417	0.4598	0.4735	0.4881	0.5116	0.4714	0.5686	0.5839	0.5114	0.5723	0.543	0.609	0.6396	0.1514	0.6516
KSC30	0.1413	0.4223	0.4548	0.4701	0.4845	0.4998	0.4566	0.5643	0.5831	0.4984	0.5585	0.533	0.6138	0.6379	0.1472	0.6628
KSC31	0.1294	0.3837	0.42	0.4309	0.4461	0.4618	0.4353	0.5149	0.5202	0.4631	0.5128	0.4865	0.5419	0.5681	0.1343	0.5752
KSC32	0.1351	0.3961	0.4352	0.4505	0.4644	0.476	0.4452	0.5313	0.5427	0.4842	0.5274	0.5087	0.565	0.5891	0.1407	0.6032
KSC34	0.1343	0.3862	0.429	0.4416	0.4528	0.4583	0.4365	0.5253	0.5409	0.4721	0.5261	0.4974	0.5642	0.5856	0.1445	0.6074

	KSC17	KSC18	KSC19	KSC20	KSC21	KSC22	KSC24	KSC25	KSC26	KSC27	KSC28	KSC29	KSC30	KSC31	KSC32	KSC34
Time	0.1607	0.1637	0.1491	0.1497	0.1339	0.1539	0.1537	0.1467	0.135	0.1439	0.1306	0.1401	0.1413	0.1294	0.1351	0.1343
KSC1	0.5379	0.5192	0.508	0.5007	0.4815	0.466	0.4428	0.4002	0.4829	0.4355	0.3932	0.417	0.4223	0.3837	0.3961	0.3862
KSC2	0.5959	0.6229	0.56	0.5572	0.5138	0.5425	0.5128	0.4447	0.4947	0.4658	0.4232	0.4598	0.4548	0.42	0.4352	0.429
KSC4	0.6316	0.5892	0.5968	0.5775	0.5409	0.5258	0.5069	0.447	0.5469	0.4885	0.4435	0.4735	0.4701	0.4309	0.4505	0.4416
KSC5	0.6422	0.6664	0.5997	0.6074	0.5379	0.5721	0.5417	0.4893	0.5328	0.4954	0.4464	0.4881	0.4845	0.4461	0.4644	0.4528
KSC6	0.6742	0.6877	0.6381	0.641	0.5702	0.5947	0.5675	0.4931	0.5611	0.5155	0.4555	0.5116	0.4998	0.4618	0.476	0.4583
KSC7	0.6321	0.676	0.5702	0.5819	0.5217	0.5855	0.5473	0.4695	0.4924	0.4608	0.4231	0.4714	0.4566	0.4353	0.4452	0.4365
KSC8	0.6894	0.662	0.7231	0.6789	0.6511	0.6084	0.5905	0.5256	0.661	0.5956	0.5248	0.5686	0.5643	0.5149	0.5313	0.5253
KSC9	0.6835	0.6515	0.7431	0.6835	0.6648	0.6016	0.584	0.5303	0.6941	0.6137	0.536	0.5839	0.5831	0.5202	0.5427	0.5409
KSC10	0.7236	0.7421	0.6487	0.6523	0.5816	0.6327	0.5881	0.5031	0.5538	0.5069	0.4643	0.5114	0.4984	0.4631	0.4842	0.4721
KSC11	0.7899	0.7923	0.7223	0.7392	0.6465	0.6856	0.6442	0.5506	0.6217	0.5727	0.5089	0.5723	0.5585	0.5128	0.5274	0.5261
KSC12	0.6761	0.6639	0.7012	0.6719	0.6313	0.6128	0.5842	0.5215	0.5954	0.5511	0.4883	0.543	0.533	0.4865	0.5087	0.4974
KSC13	0.6553	0.6269	0.7518	0.6842	0.6759	0.5929	0.5857	0.5251	0.7392	0.6505	0.5578	0.609	0.6138	0.5419	0.565	0.5642
KSC14	0.7456	0.6982	0.8623	0.7801	0.7567	0.6698	0.6568	0.5839	0.7786	0.6697	0.5774	0.6396	0.6379	0.5681	0.5891	0.5856
KSC15	0.2191	0.1942	0.2031	0.1983	0.1821	0.1777	0.1683	0.1388	0.1653	0.1531	0.1375	0.1514	0.1472	0.1343	0.1407	0.1445
KSC16	0.6518	0.6163	0.7795	0.7075	0.708	0.6121	0.6173	0.5518	0.8513	0.709	0.625	0.6516	0.6628	0.5752	0.6032	0.6074
KSC17	1	0.8494	0.7681	0.7996	0.6919	0.7477	0.6897	0.5706	0.6254	0.587	0.521	0.5939	0.5717	0.5323	0.5529	0.5347
KSC18	0.8494	1	0.724	0.7668	0.6649	0.7945	0.7205	0.5939	0.5958	0.5666	0.517	0.5879	0.5663	0.5387	0.5478	0.5368
KSC19	0.7681	0.724	1	0.8593	0.8428	0.7251	0.7152	0.6233	0.7698	0.7096	0.6093	0.6913	0.68	0.6126	0.6306	0.6256
KSC20	0.7996	0.7668	0.8593	1	0.7831	0.767	0.7501	0.6278	0.7013	0.6731	0.5836	0.6784	0.6594	0.608	0.6211	0.6087
KSC21	0.6919	0.6649	0.8428	0.7831	1	0.7033	0.7123	0.616	0.7285	0.7035	0.6144	0.6929	0.6782	0.612	0.6371	0.6217
KSC22	0.7477	0.7945	0.7251	0.767	0.7033	1	0.8361	0.6677	0.6151	0.6128	0.5541	0.6452	0.6122	0.6039	0.601	0.5876
KSC24	0.6897	0.7205	0.7152	0.7501	0.7123	0.8361	1	0.7607	0.6264	0.6502	0.5956	0.7084	0.6589	0.6683	0.6608	0.6382
KSC25	0.5706	0.5939	0.6233	0.6278	0.616	0.6677	0.7607	1	0.5773	0.6152	0.5983	0.6991	0.6505	0.7117	0.6835	0.6403
KSC26	0.6254	0.5958	0.7698	0.7013	0.7285	0.6151	0.6264	0.5773	1	0.7753	0.665	0.7004	0.7217	0.6088	0.6438	0.6515
KSC27	0.587	0.5666	0.7096	0.6731	0.7035	0.6128	0.6502	0.6152	0.7753	1	0.7621	0.808	0.8621	0.6952	0.7387	0.7606
KSC28	0.521	0.517	0.6093	0.5836	0.6144	0.5541	0.5956	0.5983	0.665	0.7621	1	0.7624	0.8204	0.7263	0.7706	0.7946
KSC29	0.5939	0.5879	0.6913	0.6784	0.6929	0.6452	0.7084	0.6991	0.7004	0.808	0.7624	1	0.875	0.8096	0.8589	0.8419
KSC30	0.5717	0.5663	0.68	0.6594	0.6782	0.6122	0.6589	0.6505	0.7217	0.8621	0.8204	0.875	1	0.7562	0.8094	0.8396
KSC31	0.5323	0.5387	0.6126	0.608	0.612	0.6039	0.6683	0.7117	0.6088	0.6952	0.7263	0.8096	0.7562	1	0.8575	0.7877
KSC32	0.5529	0.5478	0.6306	0.6211	0.6371	0.601	0.6608	0.6835	0.6438	0.7387	0.7706	0.8589	0.8094	0.8575	1	0.8364
KSC34	0.5347	0.5368	0.6256	0.6087	0.6217	0.5876	0.6382	0.6403	0.6515	0.7606	0.7946	0.8419	0.8396	0.7877	0.8364	1

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