Linking Satellite based Lightning Initiation Nowcasts with WRF Lightning Threat Forecasts to produce a combined Nowcast of Lightning Onset and Extent

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Objective

Create an algorithm that blends convective and lightning initiation forecasts from the SATellite Convection AnalySis and Tracking system (SATCAST) with forecasts of lightning density from the Weather Research and Forecasting (WRF) model Lightning Forecast Algorithm (LFA).

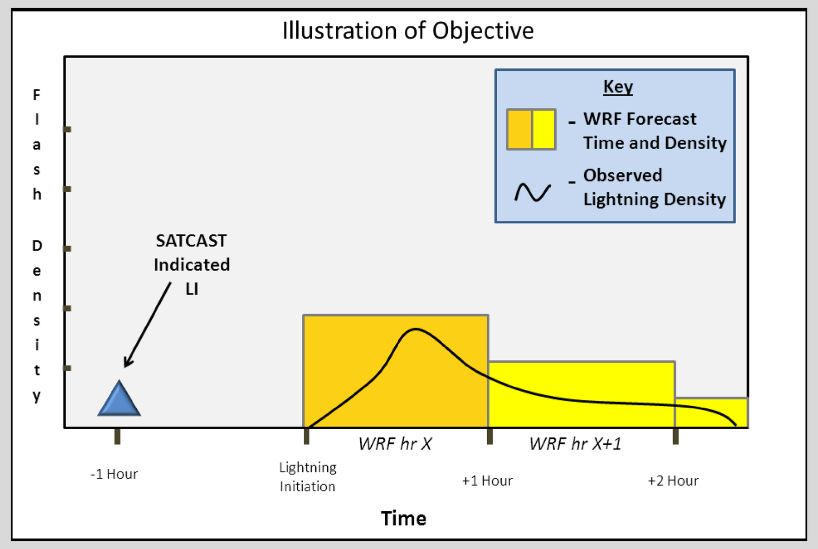

Figure 1: An illustration of the objective of this research. This is a plot of Time vs. Flash Density. The timeline starts with SATCAST detection of cumuli capable of producing convection/lightning. Following the detection is a plot of actual lightning density on top of the forecasted lightning density from the WRF.

Methodology

- Compile a list of possible case days across LMA domains
- Acquire WRF model output data for each day
- Identify individual convective cells and attain lightning flash data from the LMA for each individual storm
- Calculate "true" lightning origin density for each convective cell
- Plot observed lightning flash data relative to forecasted WRF LFA to find spatial and temporal accuracy of WRF
- Create a range and time weighted approach to link observed flash density to forecasted flash density
- Collect/compute the satellite interest fields from SATCAST to find possible relationships between those fields and lightning density
- Produce an operational algorithm to connect the WRF and SATCAST to nowcast lightning onset and extent

References

Harris, Ryan J., John R. Mecikalski, Wayne M. MacKenzie, Philip A. Durkee, Kurt E. Nielsen, 2010: The Definition of GOES Infrared Lightning Initiation Interest Fields. *J. Appl. Meteor. Climatol.*, 49, 2527–2543.

McCaul, Eugene W., Steven J. Goodman, Katherine M. LaCasse, Daniel J. Cecil, 2009: Forecasting Lightning Threat Using Cloud-Resolving Model Simulations. *Wea. Forecasting*, 24, 709–729.

This research is funded by the 2009 NASA ROSES Gulf of Mexico Initiative Project.

Data

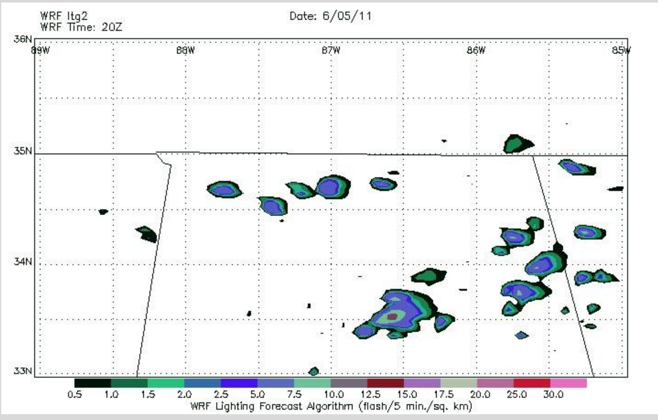

Figure 2: Plot of WRF Lightning Threat 2 over N. Alabama for 20Z on 5 June 2011.

WRF Lightning Threat from LFA

- Hourly forecast of lightning origin density (flashes/5 min/km^2)
- Threats based on Graupel Flux, Vertically Integrated Ice, and a combination of the two

(McCaul et al. 2009)

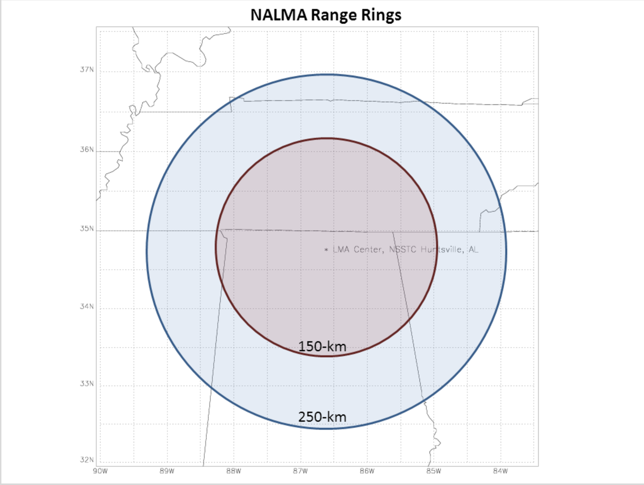

Figure 3: Image depicting the 250-km and 150-km range of the North Alabama Lightning Mapping Array surrounding the centroid at the National Space Science and Technology Center in Huntsville, AL.

True Lightning Flash Data from NALMA

- Used as Ground Truth
- Can calculate actual lightning origin density from individual storms
- Focus more on storms within 150-km of centroid

Interest Field	Threshold
10.7-µm T_b	<0°C
10.7-µm T_b time trend	<-6°C (15 min)$^{-1}$
6.5-10.7-µm T_b difference	>-30°C
13.3-10.7-µm T_b difference	>-13°C
6.5-10.7-µm T_b time trend	>5°C (15 min)$^{-1}$
13.3-10.7-µm T_b time trend	>4°C (15 min)$^{-1}$

Table 1: Satellite interest fields and thresholds for lightning initiation from Harris et al. (2010)

Satellite Interest Fields used by SATCAST

- Satellite thresholds that indicate potential for lightning initiation (LI)
- Can provide an average lead time of ~35 minutes prior to LI
- Look for possible correlation between these fields and lightning density

(Harris et al. 2010)

Preliminary Results/Progress

Currently building a data base with LMA Flash Origin Density, WRF output flash origin density (from all three threats), and SATCAST convection/lightning initiation fields.

WRF Distance/Time Weighting Approach

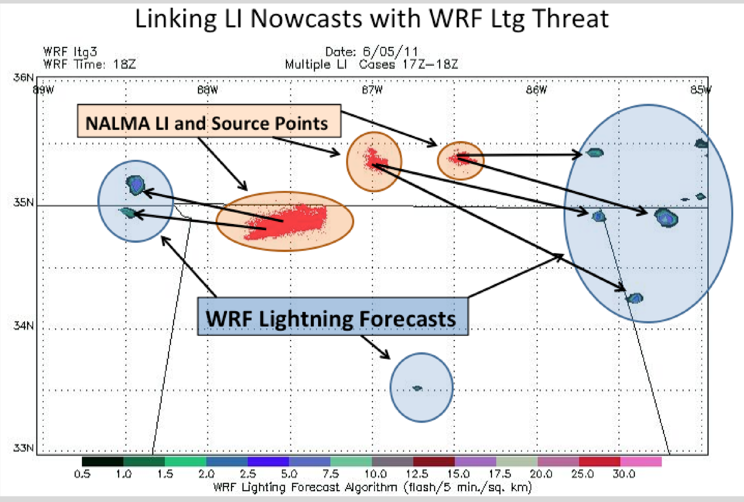

Figure 4: Plot of both lightning source points from the North Alabama LMA and WRF lightning density forecasts using threat 3 from 17Z-18Z on 5 June 2011. Arrows signify the linking of observed lightning with forecasted lightning density, however a time and distance weighted approach will apply all forecasted lightning to each cell.

Example Equation for Distance/Time Weighted Average

$$\frac{\sum_{n=1}^{10}\frac{D_n}{d}}{\sum_{n=1}^{10}\frac{1}{d}}\, M\cdot\tau\cdot c$$

n=forecasted cell #

D_n=maximum forecast density for that cell

d=distance from LMA flash sources to forecast cell

M=maximum flash density across domain

t=time weight

c=scalar

LTG Threat #	HR										
3	18										
WRF FOD	Lat	Lon	Lat Dif	Lon Dif	Lat Distance (km)	Lon Difference Adjusted	Lon degrees to km conversion	Lon Distance (km)	Actual Dist to Storm	Flash Weight	Dist Weight
6	35.172506	-88.435577	0.024618	1.479629	2.732597699	0.817545145	0.007365272	200.892638	200.9112219	0.029863937	0.004977323
2.25	34.958902	-88.49854	0.188986	1.542592	20.97744369	0.818617163	0.00737493	209.1669965	210.2162828	0.010703262	0.004757005
1.25	33.515102	-86.722985	1.632786	0.232963	181.2392261	0.825788405	0.007439536	31.31418413	183.9245367	0.006796266	0.005437012
2.25	35.426457	-85.646318	0.278569	1.30963	30.9211556	0.816266942	0.007353757	178.0899195	180.7543562	0.012447833	0.00553237
7	34.91776	-85.627429	0.230128	1.328519	25.54420519	0.818823316	0.007376787	180.0945209	181.8970667	0.038483303	0.005497615
6.5	34.256691	-85.394466	0.891197	1.561482	98.92285612	0.822121293	0.007406499	210.8259261	232.880447	0.027911317	0.004294049
9	34.884831	-85.224466	0.263057	1.731482	29.19932379	0.81898824	0.007378273	234.6730656	236.4826594	0.038057759	0.00422864
0.7	35.057558	-85.09854	0.09033	1.857408	10.0266289	0.81812239	0.007370473	252.0066288	252.2060155	0.002775509	0.003965012
1.5	35.082203	-84.997799	0.065685	1.958149	7.291034198	0.817998697	0.007369358	265.7149894	265.815001	0.005643022	0.003762015
1.7	35.500036	-84.997799	0.352148	1.958149	39.0884237	0.81589585	0.007350414	266.3998292	269.2522495	0.006313782	0.003713989
										Total Dist Wgt	0.046165031
										Total Flash Wgt	0.17899599
										Weighted Flash	3.877306818

Table 2: This table depicts the process of distance weighting of WRF model output for Lightning Threat 3 for 18Z on 5 June 2011. The location and values of maximums in flash origin density output from the model are located and compared, distance-wise, to the actual observed location of lightning. Then a weighted average (in blue) of lightning density can be calculated using the equation shown above.

LI Time (UTC)	Model Hour Forecast	WRF 3	LMA Density	Scalar	Average Scalar with > 1 WRF Cells
	15Z	0	12.25761	NA	
	16Z	0		NA	
	17Z	1.7		7.210361	
1826	18Z	3.927087		3.121299	
	19Z	4.413791		2.777117	
	20Z	3.941622		3.109789	
	21Z	5.32704		2.301018	
	22Z	5.003932		2.449596	2.751764

Table 3: The distance weighted values of Lightning Threat 3 obtained by the process depicted in Table 2 are then compared to the actual observed lightning density based on LMA data. A scalar comparing the two is then calculated and an average scalar (in red) for that case is obtained.

LMA Density	Ave Scalar
13.39586	3.5138516
12.257614	2.75176399
11.001283	2.30965089
6.1322264	1.41161493
6.0593811	1.40317592
4.8932481	1.04304811
2.4287304	0.55017403
1.2283683	0.2862025

Table 4: This shows the average scalar (in red) alongside each respective case's flash density.

Once a lot of cases are documented, these scalars can be better "trained" and applied in the above equation* to determine the max flash density possible for a convective storm based on its location relative to the WRF forecasted flash density.

*This equation will most likely be edited based upon what works/what doesn't. Also, other methods of weighting are being explored.

SATCAST Interest Fields Approach

Date	Case #	Lightning Start Time (UTC)	Lightning End Time (UTC)			Cell Latitude	Cell Longitude		
6/5/2011	5	1826	1959			35.30368	-86.60336		
Time (UTC)	Cloud Top Temp (10.7 Tb)	Cloud Top Cooling (10.7 temporal diff)	6.5-10.7 spec diff	6.5-10.7 temporal diff	13.3-10.7 spec diff	13.3-10.7 temporal diff		LI Time (UTC)	LMA Density
1715	281.176	-0.026	-40.588	0.026	-20	0.032			12.25761
1732	270	-9.862	-29.412	9.862	-10	8.824			
1745	282.353	14.253	-42.353	-14.932	-21.176	-12.896			
1815	264.118	-5	-28.824	2.647	-15.882	-1.471		1826	

Table 5: This shows the documentation of 6 observed satellite interest field values (in green) leading up to lightning initiation for a case from 5 June 2011.

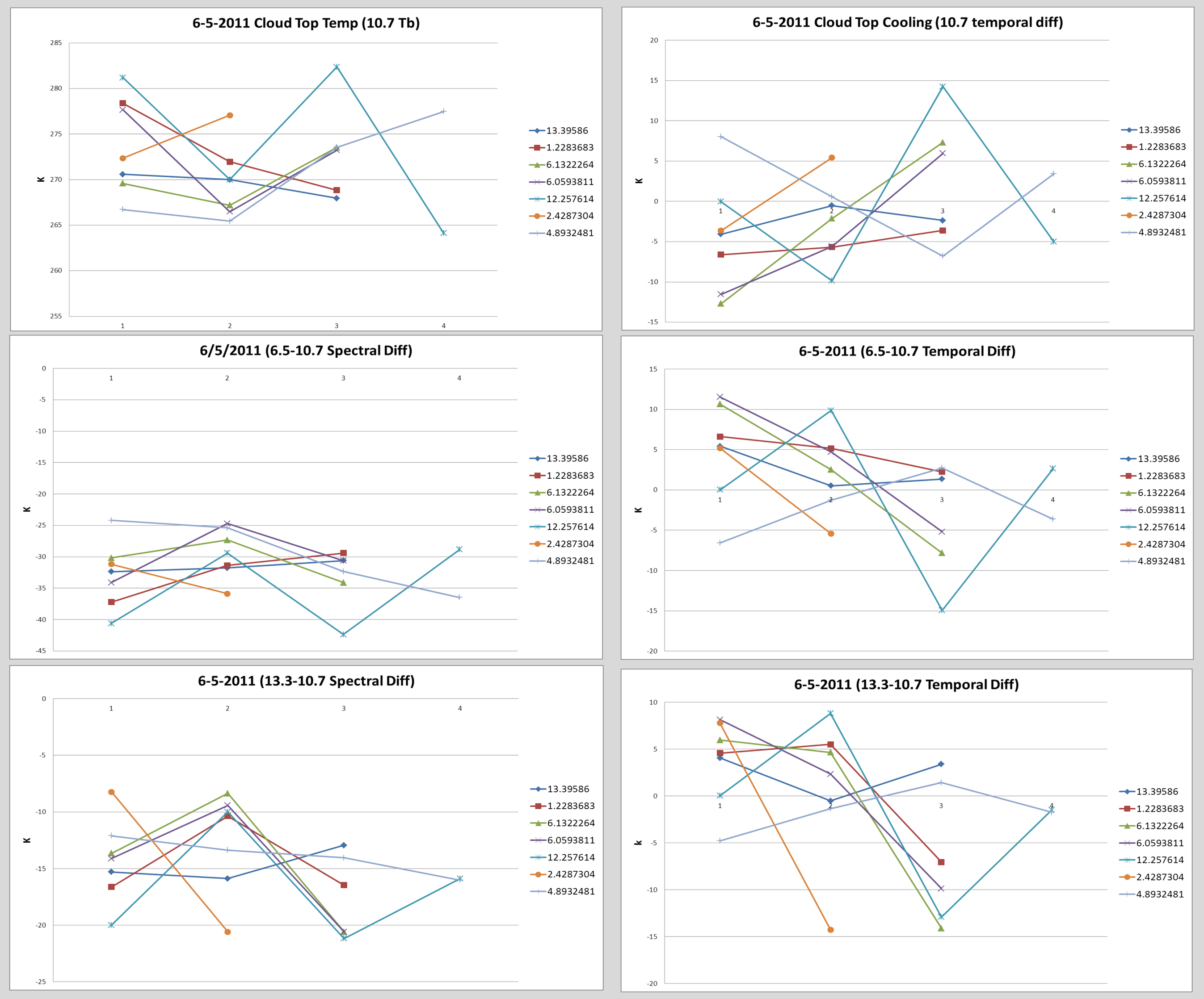

Figure 5: These six plots correspond to the 6 satellite interest fields documented in Table 5, but include data from all 7 cases from 5 June 2011. Each interest field plot includes data from seven different flash density cases on that day.

Future/Ongoing Work

- Keep adding to current data set (~50 cases to be analyzed)
  - Goal is to have ~200 total cases
- Perfect distance/time-weighted approach to WRF output
  - Look to include other parameters from WRF to aid in this (CAPE, updraft speed, ect.)
- Repeat methodology on each case to get better results
- Expand to include other LMA site regions
  - Kennedy Space Center (KSC LDAR), Washington D.C. (DCLMA)
- Include/compute 3.9-µm interest fields
- Look into correlations between flash density and satellite fields

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Poster #723

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