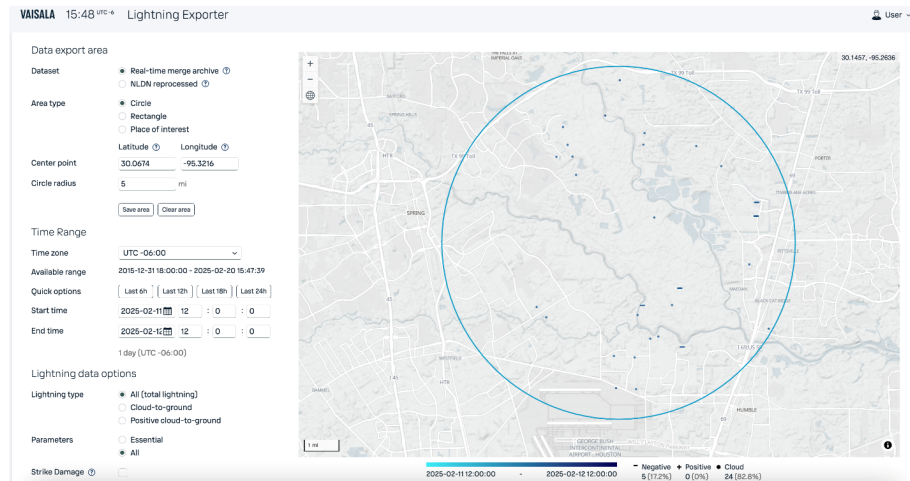


Understanding and interpreting lightning data

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The U.S. National Lightning Detection Network™ (NLDN™) has provided lightning data over the entire continental United States for more than 35 years. The initial nationwide build-out of the NLDN was driven by interest from the electric utility industry and supported by the Electric Power Research Institute (EPRI). Background information about the NLDN, the data that it provides, and some examples of its uses in the electric utility industry are given in Cummins et al. (1998a,b), Cummins and Murphy (2009), Cummins and Chisholm (2015), and Murphy et al. (2021). In this paper, we summarize the essential components of lightning data and highlight some of the capabilities that are available now, given the most recent improvements in the performance of the NLDN.



Report Preview

Time (UTC -06:00) ↓	Latitude	Longitude	Cloud?	Signal strength (kA)	Ellipse angle (deg)	Ellipse semi-major (m)	Ellipse semi-minor (m)	Chi²	Number of sensors	Degrees of freedom	Max rate of rise (kA/ps)	Sub-millisecond portion (ns)	Peak-to-zero (ns)	R (I)
2025-02-12 02:53:29.877	30.0074	-95.3133	true	4	83	1845	271	0.8405353	3	3	2.24	3264	4000	
2025-02-12 02:55:40.628	30.021	-95.3238	true	7.9	178	223	200	0.76520324	4	5	2.8	500224	4800	
2025-02-12 02:55:55.353	30.0247	-95.2914	false	-10	0	200	200	0.4181907	5	7	-3.6	895168	26850	
2025-02-12 02:56:40.728	30.029	-95.3028	true	-4.8	82	1884	243	0.8816118	3	3	-1.99	541440	1950	
2025-02-12 02:57:00.567	30.0204	-95.314	true	-10.4	8	200	200	0.45622286	8	13	-2.7	538432	2850	
2025-02-12 02:57:00.567	30.0281	-95.3066	true	-7	9	400	400	1.174859	5	7		784448		
2025-02-12 02:57:35.098	30.0586	-95.2977	true	-7.4	172	208	200	0.8903721	4	5	-2.92	257162	10000	
2025-02-12 02:58:03.745	30.0378	-95.3126	true	-6.4	81	1726	217	0.5879997	3	3	-2.59	767936	3700	
2025-02-12 02:58:03.780	30.0418	-95.3102	false	-8.7	174	200	200	0.81015134	6	9	-3.96	726016	24550	
2025-02-12 02:58:03.821	30.0488	-95.2926	false	-13	176	200	200	0.41740802	12	17	-4.68	775872	25550	
2025-02-12 02:58:06.632	30.0369	-95.3558	true	1.8	81	2656	260	0.2063777	2	1	0.78	807680	8700	
2025-02-12 02:58:33.320	30.0411	-95.3604	true	-2.7	79	1987	210	0.16033779	2	1	-1.3	206384	2600	
2025-02-12 02:58:33.621	30.0419	-95.2963	true	-7.8	173	200	200	0.23427327	4	5	-3.55	3776	9150	
2025-02-12 03:00:28.276	30.0784	-95.2564	false	-3.9	81	2441	248	0.6696486	2	1	-1.95	296704	19850	
2025-02-12 03:01:33.970	30.0953	-95.3417	true	-10.1	163	200	200	0.29446194	7	11	-4.7	533888	8550	
2025-02-12 03:02:13.404	30.084	-95.2562	false	-9	164	200	200	0.5720594	7	11	-3.96	673696	25250	
2025-02-12 03:03:28.189	30.1071	-95.2848	true	3.1	78	2455	340	0.61328965	2	1	1.08	522176	4850	
2025-02-12 03:03:42.153	30.1076	-95.3457	true	-5.8	78	1323	200	0.33242747	3	3	-2.58	731472	2750	

Report Preview

Time (UTC -06:00) ↓	Latitude	Longitude	Cloud?	Signal strength (kA)
2025-02-12 02:53:29.877	30.0074	-95.3133	true	4
2025-02-12 02:55:40.628	30.021	-95.3238	true	7.9
2025-02-12 02:55:55.353	30.0247	-95.2914	false	-10
2025-02-12 02:56:40.728	30.029	-95.3028	true	-4.8

Figure 1 shows NLDN data from a query around a specific location and over a specific time period, together with a zoomed-in view of the essential data fields.

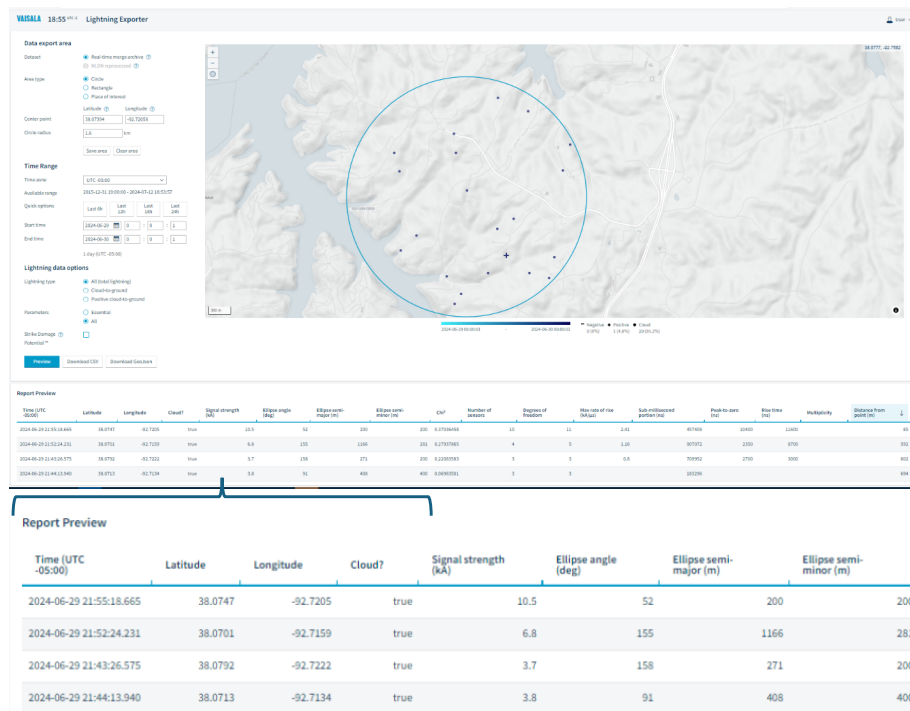


Figure 1. Sample NLDN data from a query to the Vaisala Lightning Exporter™, with a zoomed view of the essential data fields below.

The basic function of the NLDN is to determine the precise times and positions of lightning events. It does this by way of a network of remote sensors that measure the time of arrival of radio-frequency signals generated by lightning, with GPS timing, as well as the angle of arrival of those signals, their peak amplitudes, and various information about the features of those signals. These measurements are sent from the sensors to a central processing system, whose first job is to determine which of the many signals, coming from many widely distributed sensors, belong to a particular lightning event. Following that determination, the central processor then proceeds to combine the various time and angle measurements to determine the time and position of each lightning event. That critical information can now be determined with sub-microsecond accuracy in time (separated into the millisecond level and the sub-millisecond component in the example query above) and median location accuracy better than 100 meters.

The peak amplitudes (including sign – positive or negative) reported by the sensors are used to estimate the peak current of the lightning event, shown in the above example as the “signal strength” field and reported in

Commented [HL1]: @Martin Murphy I have provided some higher resolution screenshots above with Lightning exporter showing the query + map, report details, and zoom in on the Essential fields.

Commented [MM2R1]: Excellent! I figured that either you or Brooke had higher quality examples than I do. Somehow or other I lost my login to Exporter, so I'm always digging around to find old stuff that I still have sitting around 😊

kA. In the case of return strokes in cloud-to-ground (CG) lightning, this is literally an estimate of the maximum current of the stroke at the point where it contacted ground. All cloud lightning (IC) events are also assigned an equivalent peak current. The same signal amplitude measurements from the sensors can also be used to estimate the maximum time derivative of the current in CG return strokes. This parameter is shown as “Max rate of rise” in the above example, in units of kA/ μ s. The maximum rate of rise of CG return stroke current is important in the case of objects that have significant inductive impedance, as described in Rakov (2012).

As described in Cummins and Murphy (2009), the shapes of the signals received by the sensors (known as “waveforms”) can be used to differentiate between the return strokes in CG lightning and other signals generated by IC events. In the example shown above, the “Cloud?” field indicates whether or not each event was classified as an IC pulse or a CG stroke. Over the years, as the information provided by the sensors has improved, the lightning type classification algorithms in the central processing system have improved in tandem, as discussed in detail in Murphy et al. (2021). Validation studies such as Zhu et al. (2016) indicate classification accuracy better than 90%, and work is ongoing to improve upon this.

The central processing system further utilizes the information supplied by the sensors to determine a number of quality metrics about every lightning position. Many of these quality parameters are used within Vaisala to monitor the performance of the network on a continuous basis. Of particular interest to many users of NLDN data is the position confidence region, which takes the form of an ellipse. Details about the ellipse calculation are given in Cummins et al. (1998b). The size (at any desired confidence level) and orientation of the ellipse can be used to assess the likelihood that any particular CG stroke made contact with a particular structure on the ground.

With the median location accuracy now better than 100 m, the NLDN is capable of distinguishing between the different ground strike points within a single CG flash. This provides very useful information given that somewhere between a third and half of CG flashes contact the ground in multiple locations. Figure 2 shows NLDN data from a CG flash with 13 strokes together with their confidence regions (scaled up to the 99% confidence level). Two of the strokes in this flash were 2.8 km to the northeast of the main cluster and clearly formed a separate ground strike point. Two other strokes were separated from the main cluster by about 0.8 and 1.1 km and are probably also separate ground strike points. Ground strike point information was recently made available in an enhanced NLDN data product called Strike Damage Potential.

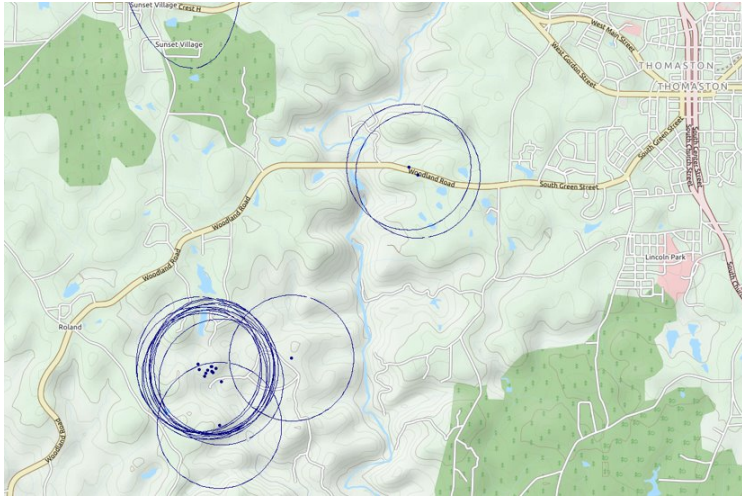


Figure 2. A 13-stroke CG flash with the position confidence regions around all stroke positions.

Thanks to steady progress in sensing technology and central processing algorithms over the more than 35 years that the NLDN has provided nationwide data over the US, the data available today give highly detailed information that is valuable in many application areas, including the electric power industry. In this short overview, we have described the key data fields of most direct usefulness.

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