Location accuracy ellipse

Context

Estimating the location of cloud-to-ground and intra-cloud discharges is subject to a location error depending on sensor measurement errors made of:

- a systematic error, related to the accuracy of angle (rotation of the antenna in respect to the North) and time measurements (orography and conductivity on the propagation path),
- a random error that depends on interference with radio transmitters, the intensity of the current in the discharge, the shape of the flash and and sensor electronics.

A statistical analysis on archived data determines correction parameters that are used by the lightning location processor to correct every sensor measurement before processing.

The systematic error being corrected, the location error depends on the random errors only. The sensor measurement random errors cannot be corrected, but they can be estimated with a standard deviation.

Based on these data and the residual deviation of the sensor measurements in respect to the discharge location (for angle measurements) and time (for time of arrival measurements), the processor computes a confidence ellipse centered on the discharge position and oriented to the direction of the maximum error.

The semi-major and semi-minor axes of the ellipse respectively indicate the maximum and the minimum estimated location error in meters.

The confidence ellipse is important for certain applications, including incident correlations.

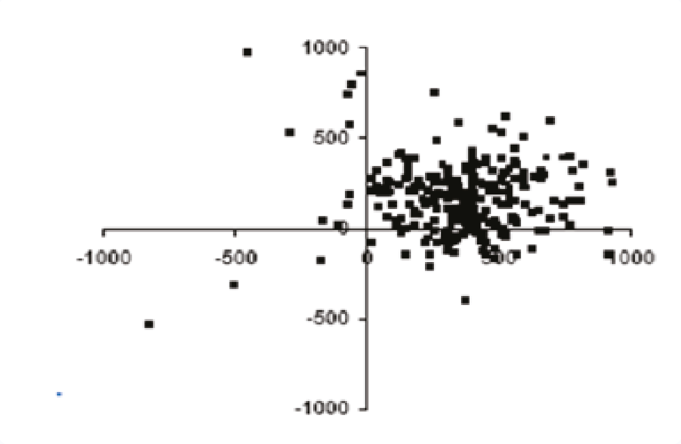


Figure 1. This graph shows the locations of the discharges as calculated by a lightning locator network. In reality, the discharges all have the same position (the centre of the axes), namely the top of a communication tower. As can be seen, the barycentre of the cluster of points is displaced to the right: this is the **systematic error**.
The dispersal of the points with respect to the cluster's barycentre represents the r**andom error**. The distance from a given point to the centre of the axes represents its absolute location error de localisation. It can be seen that each point has a different **absolute error**.

Figure 1.

Principle

The ellipse is derived from the use of the **least squares method**, which allows the calculator to process sensor measurements and locate the discharges. This method minimises measurement errors and leads to an optimized location estimate. Residual measurement errors determine theoretical random errors used to calculate the ellipse.

According to the work of Standsfield (1947), the random error of a lightning location can be estimated with a given probability by an ellipse of which:
- the semi-major axis represents the theoretical maximum error,
- the semi-minor axis represents the theoretical minimum error,
- the orientation represents the direction of the maximum error.

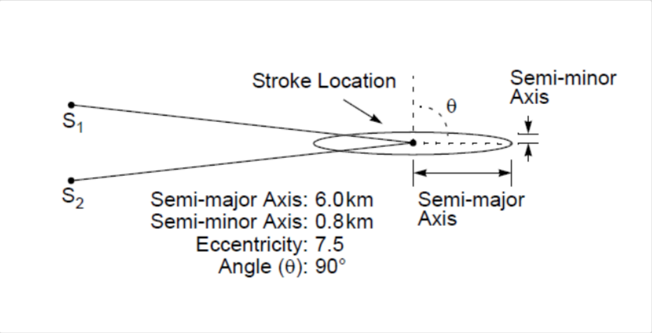
For this to apply:
- the measurement errors must follow a Gaussian law,
- the systematic errors must be eliminated.

How it works

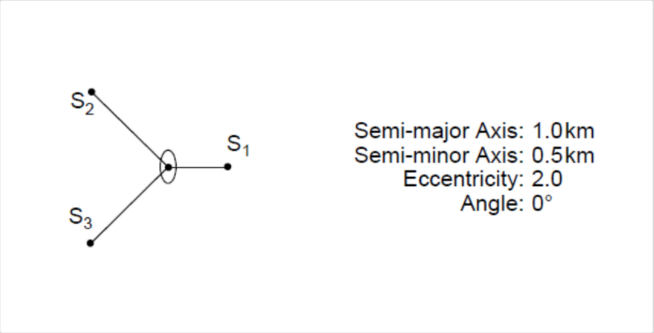
Each calculated location is accompanied by the values of its estimated accuracy ellipse for a probability of 50%. The probability can be changed by simply multiplying the values at 50% by a factor given in the following table:

Scaling Constant	Probability
1	50 %
1,82	90 %
2,57	99 %

Thus, if the semi-major axis is 1 km at a probability of 50%, it will increase to 1.82 km at 90% and 2.57 km at 99%.



Ellipse of a poor location estimate



Ellipse of a good location estimate

IMPORTANT!

The ellipse is a statistical indicator based on the measurement errors made by the sensors. The position reported by METEORAGE remains the most likely based on the measurement data. The ellipse thus serves as a confidence index for discharge positional data; it does not represent an absolute and real measure of the error made.

Systematic errors are considered to be almost zero in the METEORAGE network. This is confirmed by regularly checking the data against 'field' data. The absolute error can therefore be considered to consist of the random error.