Biral
Visibly Better

White Paper
February 2015

The importance of including the natural variability of lightning strength in assessment of thunderstorm range uncertainty

Dr Alec Bennett PhD MInstP FRMetS CMet

A method of estimating lightning distance from a single-site lightning detector is to measure the change in electrostatic field produced by the lightning strike. This can be measured directly using slow-response antennas or indirectly by identifying features of the electromagnetic (radio) signal. Other techniques are used, but tend to suffer from increased range uncertainty due to increased assumptions about the expected signal or variability in signal propagation. The two unknowns are usually distance to lightning and lightning strength (called "charge moment" in the case of electrostatics). To estimate distance, the lightning strength must be assumed. In reality, the lightning charge moment typically varies by an order of magnitude between individual flashes during a storm. This variability in lightning strength is normally the main source of uncertainty in lightning range estimation using a single-site lightning detector.

Acceptable levels of uncertainty

The FAA[1] requires a thunderstorm reporting range of 30 nautical miles (56km) with the range and bearing of thunderstorms (the latter in octants) available between 10-30 nautical miles (19-56km). Range resolution is required to be 1 nautical mile (~1.8km).

With regards to range accuracy, the FAA requires a RMSE (root mean squared error) of 5.5 km in ranges between 0-19km and 11.1km between ranges 19-56km. Note it is a RMSE requirement so individual range errors exceeding these requirements would be acceptable.

Errors in range estimation

The error in range estimation if a fixed value for the lightning charge moment is chosen is shown in Figure 1. The range error was calculated by determining the theoretical electric field change with distance for a typical lightning flash with a charge moment of 70 Ckm, compared to a flash with 20 and 160 Ckm. These limits encompass the majority of charge moments found during a typical thunderstorm. The FAA RMSE limits are included in the figure as a reference. It can be seen that the maximum error associated with assuming 70 Ckm when the actual value was between 20-160 Ckm lies mostly within the FAA RMSE limit until the range exceeds ~32km. Although the 20-160Ckm variability will produce errors which exceed FAA limits at ranges beyond 32 km, it must be remembered that the regulations are for RMSE, so some exceedance from individual flashes is acceptable and the RMSE value is still likely to be within acceptable levels for ranges between 32-56 km.

Natural variability

Given the natural variability of lightning

[1]US Federal Aviation Administration Advisory Circular 150-5220-16D "AUTOMATED WEATHER OBSERVING SYSTEMS (AWOS) FOR NON-FEDERAL APPLICATIONS", April 2011.

Biral

strength during a typical thunderstorm, which is usually unknown to the sensor, it is simply not possible to provide lightning range accuracies approaching 1 km or less, even if the instrument and site permitted precise measurements of the electrostatic field change. For example, a 1 km range uncertainty at 30 km corresponds to only a 10% uncertainty in charge moment, which is over 7 times lower than that expected from natural variability alone.

Laboratory conditions

It is therefore apparent that 1 km range accuracy for a standalone lightning detector with no accurate, independent information on lightning charge moment is only applicable to laboratory conditions. Under these conditions the detector is provided with input from an idealised lightning signal of known intensity. A reported "range accuracy" derived using such a technique is more appropriately described as measurement repeatability than an accuracy value which can be usefully associated with range uncertainty of lightning flashes from real thunderstorms.

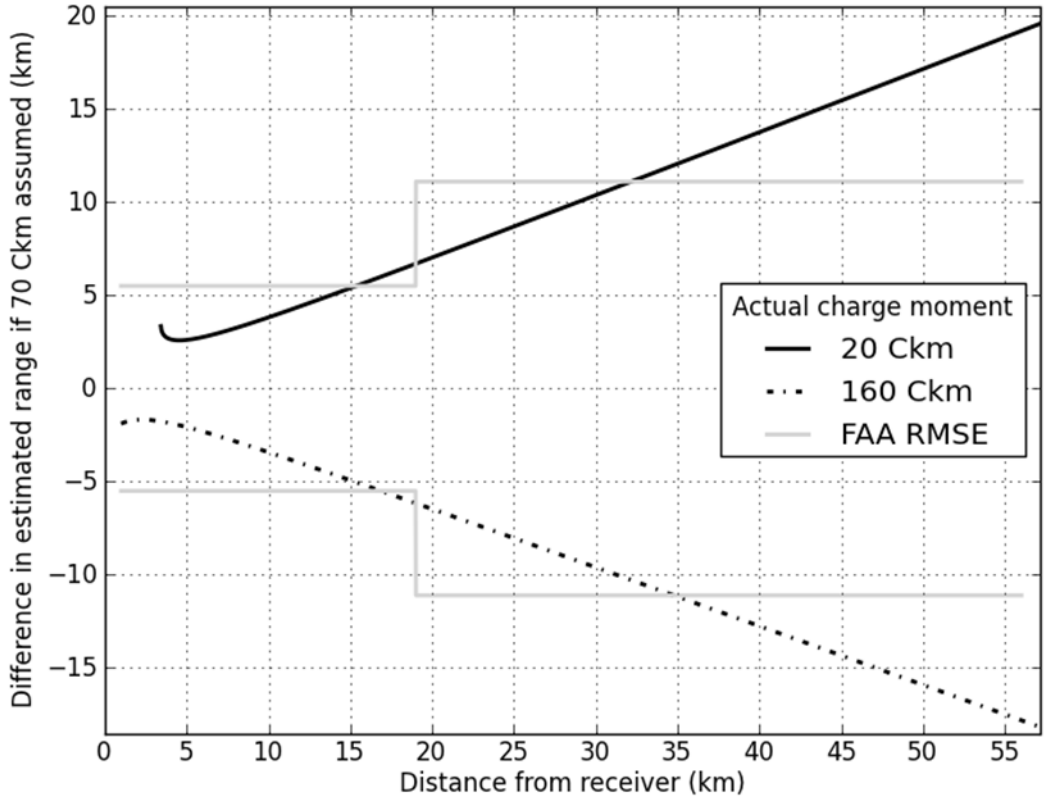

Figure 1: *Difference in range estimation if a lightning charge moment of 70 Ckm is assumed compared to an actual value between 20 and 160 Ckm, for a lightning channel length of 3km. Grey lines identify FAA RMSE location accuracy requirements.*

About the Author

Dr Bennett is the Meteorological Products Manager for Biral, UK. He has a PhD in Atmospheric Electricity and 10 years' experience in research and development of lightning detection systems, including working at the UK Metrological Office and being a visiting Research Fellow at the University of Bath. He has written over 20 papers in atmospheric electricity, which have been published in peer-reviewed international journals.