CHAPTER 7

(Chapter was not revised since the six edition)

LOCATING THE SOURCES OF ATMOSPHERICS

7.1 General

7.1.1 *Definitions*

Atmospherics, or sferics, may be defined as electromagnetic waves resulting from lightning discharges in the atmosphere. From a practical point of view, one is usually interested in the source of the atmospheric, the lightning flash. Then the atmospherics are considered only as a phenomenon which offers a means of detecting and/or locating flashes. A mere detection of flashes is usually limited to local warning purposes while flash location data can be used for various meteorological and other tasks. Terms such as sferics observations are convenient expressions to cover both kinds of methods.

Cloud flash: A lightning discharge occurring within a cloud or between different clouds. It is usually outside the practical interest when thunderstorms are concerned, but may be useful in local thunderstorm warning systems.

Cloud-to-ground flash: The type of lightning flash of common practical interest. Referred to simply as a flash.

Direction finder (DF): An instrument which determines the direction of arrival of an atmospheric.

Fix: The estimated location of a lightning flash as deduced from atmospherics.

Flash: The total lightning event consisting of one or more return strokes (and of leaders preceding each stroke).

Flash counter: An instrument for counting the number of lightning flashes in the vicinity of a station.

Multiplicity: The number of strokes in a lightning flash. Most positive flashes are one-stroke flashes.

Polarity: Cloud-to-ground lightning flashes are either negative or positive according to the sign of the electric charge lowered from the cloud to the ground. Negative flashes are more common, positive flashes are typical of winter conditions.

Range: The radius of observation of a (sferic) detection device. Local means here a range of a few tens of kilometres, regional means a few hundred kilometres, and a long-range instrument has a range of up to one or a few thousand kilometres.

Sferic: The accepted contraction of the word atmospheric for meteorological purposes.

Source: The place of origin of an atmospheric, normally a lightning flash.

Static: A small-scale electrical discharge in the atmosphere. The use of this word for atmospheric is not recommended.

Stroke or return stroke: The main pulse of strong electric current in the lightning channel. A flash contains one or more strokes.

Time-of-arrival (TOA) receiver: An instrument which determines the time of arrival of an atmospheric to a high degree of accuracy (of the order of a microsecond, μs).

7.1.2 *Units*

Lightning flashes are characterized, in addition to polarity and multiplicity, by their strength. The most frequently used definition of the strength is the peak value of the electric current of a return stroke (usually the first stroke of a flash), measured in units of amperes (A). Typical magnitudes of flash strengths are tens of kiloamperes (kA). The intensity of a thunderstorm may be described in terms of the flash rate in a given area, the average multiplicity, the average strength and the ratio of the number of negative to positive flashes. Present-day techniques for determining the various characteristics of thunderstorms would make it possible to define a useful descriptive and concise measure (“index”) of thunderstorm activity, but no such general index exists yet.

Defining the performance of a lightning detection/location system requires certain parameters. A local warning device, such as a flash counter, involves parameters like the detection radius or range (usually a few tens of kilometres), the fraction of flashes observed within the radius, and the fraction of false alarms. A location system is mainly subject to location errors (normally of the order of kilometres) and the less-than-perfect detection efficiency (the fraction of the number of observed to true flashes in a given region, usually expressed in per cent). Errors in the estimation of flash strength and multiplicity are usually of lesser concern.

7.1.3 *Meteorological requirements*

The location of regions of thundery activity by means of sferics data, especially real-time data, provides the meteorologist with valuable supplementary information. This information is of particular value when it is available for large ocean areas or other regions in which observational stations are sparsely distributed. It can also provide clues about the instability of air masses and the location and movement of fronts, squall lines, tropical storms and tornadoes, and can aid investigation of past events. Examples of the uses of lightning location data are given in Orville, *et al*. (1987) and Holle, Lopez and Watson (1990).

Meteorological services to aviation can also benefit from sferics data since thunderstorms are a major hazard to flying, both because of the vigorous air motions and because the lightning may strike and damage the aircraft. The weather forecasts provided for aircrews and for traffic control can be improved by the inclusion of the latest sferics day and the choice of a storm-free track is greatly assisted by the knowledge of the areas in which thundery activity is taking place. Similar considerations apply to the launching of spacecraft.

Other sectors are concerned with the effect of lightning strikes, for example as a cause of damage to vulnerable installations, such as electric power cables above ground, as a hazard when mining with explosives, and as a cause of forest fires. Sferics observations can be used to provide warnings of such risks, both in regional terms through their interpretation by a forecaster and in local terms through direct use of an automatic warning system. In addition, sferics observations for scientific purposes are made by meteorological and atmospheric research institutes in several countries.

7.1.4 *Methods of observation*

7.1.4.1 DIRECTION FINDERS (DF)

The most widely used sferics observation systems today are based on automatic direction finders (DF). A direction finder uses two orthogonal loop aerials aligned north-south and east-west to resolve the direction of arrival of the sferic in terms of its horizontal magnetic components. A remaining 180° directional ambiguity is resolved by the vertical electric component which is sensed by a horizontal plate antenna.

A wide-band direction finder, detecting sferics at frequencies up to one MH, may be used as a local stand-alone lightning warning system. Its most efficient use is, however, as a basic element in a regional network of three or more direction finders to locate lightning flashes by finding the intersection points of the directions. An operational location system is described in section 7.2.

Long-range direction finders (700–4 500 km) tuned to very low frequencies (5–10 kHz) have been used experimentally with the goal of mapping thunderstorms on continental or even global scale (Heydt and Takeuti, 1977; Grandt and Volland, 1988). The long path of propagation, whose influence on the pulse depends on the frequency, offers a possibility of estimating the distance from a single-station measurement by comparing the sferics components at several frequencies. So far, the questions of accuracy, detection efficiency, and operational feasibility are unclear; hence, these systems will not be discussed here.

7.1.4.2 TIME-OF-ARRIVAL RECEIVERS

The distance of the source of a sferic to an observing station can be determined if the arrival time of a pulse can be measured with an accuracy of the order of 1 μs. This accuracy requirement is associated with the speed of propagation of the sferic which is 300 m in a μs. Because the time of occurrence of the lightning is not known, the time measurement is only relative, and locating the source requires the determination of the arrival-time difference from several stations. A general requirement for synchronizing the stations is the use of an accurate timing item, such as provided by navigation satellites or broadcasting networks. The sferics-signal propagation time is less sensitive to variations in the properties of the terrain than is its direction and hence, in principle, an arrival-time network could determine lightning locations more accurately than a comparable direction-finder network. Comparisons are discussed in section 7.4.

Two types of arrival-time receivers are currently in operational use. One of these is designed for use as a regional system (Bent and Lyons, 1984) and is described in section 7.3. The other type has been developed by Lee (1986*a*, 1986*b*, 1989) to exploit the long-range performance of this technique and has been in operational use in the United Kingdom for more than three years; a description is given in section 7.3.6.

7.1.4.3 LOCAL LIGHTNING DETECTORS

Because local lightning detectors are not used widely by Meteorological Services or other users with scientific purposes, little information is available about their present-day markets and possible investigations of performance. Presumably, progress in this field has been slower than for location systems, and it is assumed that the results of a five-instrument comparison made by Johnson and Janota (1982) still has some validity. The discussion of local detectors is restricted to the short descriptions in this section.

Stand-along direction finders can be used as lightning warning devices. The direction information is clearly the greatest advantage over other local detectors. Also, the average signal strength of a group of flashes may be used to estimate the distance. In the comparison of Johnson and Janota (1982), the high sensitivity together with insufficient rejection of unwanted signals caused a lot of false alarms in the instrument tested. After the comparison, a new instrument, called thunderstorm sensor appeared in the market. It is basically the direction finder used in current DF networks (see section 7.2.1) and has the same capability to reject other than cloud-to-ground flashes. A computer display unit shows the situation in a sector format supplemented by some statistical data. The range has been set to 160 km. The thunderstorm sensor has been applied rather widely by institutes and companies for which the more accurate regional flash location data exceed their needs and/or financial resources for this purpose.

Lightning flash counters are designed to count the discharges occurring within a radius of 20 to 50 km, depending on the adjustment of sensitivity of the instrument. The principle of the counter is based on the detection of a simple rapid electric field change (a static), which increases the sensitivity to false alarms. The false alarm rate can, however, be reduced by a careful choice of the location to avoid nearby sources of disturbance. Local flash counters can be used in synoptic meteorology for issuing storm warnings, especially in connection with weather radars. Their simple construction and operation as well as low price make them also feasible for use as warning devices in any activities which may benefit from short-term knowledge of approaching thunderstorms.

A third type of instrument for warning of a risk is based on the detection of the high static electric field associated with thunderclouds. The rapid decrease of the field strength with distance limits the useful range to 10–20 km. In this case, the advance warning is not based on the distance of an approaching thunderstorm cell but on the build-up time of the electric field of an overhead or nearby thundercloud from the warning threshold value to the lightning breakdown value.

The static vertical electric field at the ground level can be measured by a field mill (a periodically changing capacitor), a radioactive probe (a short vertical antenna with a radioactive preparation to make the surrounding air electrically conducting by ionization), or a corona point (a high sharp point which exhibits a corona discharge when the electric field exceeds a threshold value). According to Johnson and Janota (1982), the corona-point instrument is susceptible to ambient noise which causes false alarms, while the two former are subject to leak currents caused mainly by spiders and insects, and requiring a lot of maintenance.

7.2 The direction finding lightning location system

7.2.1 *The direction finder*

A commercially-available system of this type is described by Krider, Noggle and Uman, 1976, and by Maier, *et al*., 1984. It can be built with an integral structure with both the antennas and the associated electronics within the same unit, making the installation relatively easy.

The most important features are, from the present point of view, its capability of detecting very weak sferic signals while rejecting effectively signals other than those originating from cloud-to-ground lightning flashes. The test is based on an analysis of the pulse form of the signal and only a form resembling the return stroke is accepted. Some local non-lightning disturbances may pass the test, but such false signals are usually so weak that only one direction finder may be close enough to detect them; a false located lightning, which requires coincident signals from at least two direction finders, is virtually always avoided.

The pulse-form criteria imply that the sferic from a genuine but distant cloud-to-ground flash may be too distorted to be accepted. The surface-wave pulse itself is modified during the propagation over the terrain, and a slightly delayed component reflected from the ionosphere is superposed on it. Due to these factors, the nominal range of a direction finder is normally 400 km; attenuation of the signal strength over a distance of this magnitude has a minor effect. Yet many flashes much farther away are accepted, which means that more distant thunderstorms are detected although the information of their locations and flash frequencies is less accurate.

The system provides the following digital information of an accepted flash: the direction of arrival (the bearing angle), signal strength, polarity and multiplicity. These data are sent immediately to the modem, which is normally connected to the central unit of the network.

7.2.2 *Direction finder network configuration*

If there are coincident observations of two direction finders, the lightning location can be calculated as the intersection point of the two bearings. The determination of the location is generally most accurate when the bearings intersect close to perpendicular, while near the baseline joining the two stations, the location errors may increase considerably. As a result, a network should include at least three direction finders.

In order to cover as large an area as possible with a minimum number of direction finders, the direction-finder configuration must fulfil certain conditions. First, in order to minimize the occurrence of near-parallel (baseline) bearings, a small network should form a regular figure (an equilateral triangle for a three-DF system, a square for a four-DF system); for larger networks, stations lying on the same straight line should be avoided. Second, the spacing of the stations should be fairly even. In order to achieve a good performance within the distance dictated by the 400-km range, the spacing between neighbouring stations should be between about 150 and 250 km.

The actual network configuration which can be realized also depends on the availability of sites which are free of screening structures or terrain features, nearby sources of disturbances, and vandalism. The availability of communication lines may also limit the choice, and the presence of some kind of trained personnel may be useful although the direction finder needs very little maintenance.

An important point to be considered is the redundancy of a network, that is, the number of stations compared with the minimum number needed to maintain it operational. Failures in the communications lines between the direction finders and the central unit are not uncommon, and it may be recommended that any region of interest should be covered by at least four direction finders. Redundancy also improves the location accuracy and detection efficiency of the network (see section 7.2.3).

The system employs a central unit position analyser (PA) which receives the direction-finder data and computes the locations. If the communications lines are fixed, the PA determines the coincidences from the arrival times of the DF data; if the communications are packet-switched, which is cheaper, the PA keeps track of the clocks of each direction finder using the coincidence information provided by the observed flashes themselves. When coincident data from more than two direction finders are received by the PA, an optimized location is computed. Optimization can be simply the choice of the most perpendicular pair of bearings, or some statistical procedure like a least-squares fit (see section 7.2.3).

The definition of coincidence between direction finders depends on the noise conditions in the network areas. A safe value is 20 ms, but if a direction finder fails to detect the first stroke of a flash and reports the second flash instead, the coincidence is lost. A coincidence window of 50 ms increases somewhat the number of located flashes, but the window must remain below 100 ms to avoid false coincidences.

A network could use also the DF information from another network. For instance, the performance of a national network can be improved by using some direction finders in a neighbouring country and vice versa. The realization of such a connection is a technical question which cannot be addressed here.

7.2.3 *Location accuracy and detection efficiency of direction finder networks*

The bearings measured by direction finders are subject to so-called site errors, which are angular errors caused by nearby natural and man-made irregularities in the terrain surrounding the direction-finder site. The errors vary with direction, mostly in a systematic way, and once found, they can be loaded into the PA as systematic corrections.

One possibility of finding systematic errors has been described by Mach, MacGorman and Rust (1986). For a three-DF observation, for instance, one can compute the intersection point of one pair of bearings and correct the third bearing toward this point. This is made in the three different ways (for each DF) for this observation, and a great number of observations is collected to cover all directions and distances. After one complete run, the resulting corrections are applied partially to the original data and new runs are iterated until the corrections converge. Systematic errors may be as large as 10° in some directions before correction.

A more sophisticated method has been developed by Orville (1987). It is a kind of least-squares fit which is easy to adapt to a large number of direction finders. It can be used either iteratively to obtain the systematic corrections or as a single-run optimization method.

A problem with both of the above methods is that while the systematic bearing errors in each direction (actually, in sectors of a few degrees) are the average values over a large dataset, there remains a scatter of more random nature which may be several degrees in some sectors. Orville’s method is best suited to adjust, or optimize, after the systematic corrections, the final locations by minimizing such random variations, independent of what method has been used in determining the systematic errors. Note that the systematic errors, once found, are treated as instrumental constants while the final optimization is an operation computed separately for each flash (real time or later). In the determination of systematic errors, the random errors are present and cause bias in the results. In fact, application of Mach’s and Orville’s methods to the same data may lead to different systematic-error estimates.

A solution to the problem of the coupling of the two different types of errors has been described by Passi and Lopez (1989). The idea, which can be justified theoretically, is to represent the systematic-error curves as double-period sinusoidals with unknown coefficients, and in the equations for determining these coefficients the systematic and random errors are decoupled. After the systematic correction curves from a representative historical dataset have been found, Orville’s method is perhaps the easiest to use for optimizing the final locations.

The errors discussed above are caused by external factors. The fact that the direction finder accepts only relatively well-shaped pulses means that the direction can be computed accurately. According to the manufacturer, the bearing errors due to pulse distortion and non-vertical components of the electric field remain below 1°.

Another factor in the performance of a lightning location system is its detection efficiency. Mach, MacGorman and Rust (1986) found that a four-DF system, a typical network for regional use, had a detection efficiency of about 70 per cent. The method was a comparison with ground-truth data. For another four-DF system, Tuomi (1991) determined how the number of located flashes depended on the number of direction finders present. If it is assumed that all cloud-to-ground flashes in the nominal area of coverage have a chance to be accepted by a direction finder; a fraction of 50 to 80 per cent of these are actually detected by it. As a result, a two-DF system detects only about one half of these flashes and a three-DF system 70 to 80 per cent, as has also been suggested by Mach's result. This would imply that a significant fraction, of the order of 10 per cent, of the cloud-to-ground flashes are not detected.

7.2.4 *Maintenance of a direction finder network*

A direction finding network is relatively easy to set up once proper sites have been found and the communication lines established. If properly shielded from overvoltages, it is also technically rather reliable, requiring very little technical maintenance.

The main tasks of maintenance involve the operation of the PA and data quality control. The operation, that is, the arrangement of the data display and the data flow to users and archives, can and should be made automatically, after which the routine operational side reduces to a minimum. A more enduring task, and more interesting, is on the scientific side, which includes not only the physical or meteorological research of the final results but also the determination of the site errors, the establishment of the location optimization and of the resulting accuracy, and the definition of the true area of coverage in terms of the detection efficiency.

7.3 Examples of time-of-arrival location systems

As explained in section 7.1.4.2, two types of time of arrival (TOA) systems are in current operational use, an example of each type is described here.

7.3.1 *A regional time of arrival (TOA)*

Reports of experiences with TOA networks are significantly rarer than those of DF networks, and for this reason the present section is relatively brief compared with the preceding section. Much of the description is made by pointing out similarities and differences of the two systems.

7.3.2 *The time-of-arrival (TOA) receivers*

The antenna of the receiver is a simple whip antenna which is easy to install because there are no special requirements to avoid nearby structures, cables, etc. That is, a receiver which records the time of arrival rather than the direction is immune to site errors. The receiver digitizes the pulse for a period of up to 100 μs with a resolution of 0.2 μs, determines the polarity and the time of occurrence of the peak, and sends all this information to the central unit. The clock of the receiver is continually adjusted by using an external timing signal, typically LORAN-C or GPS. The receiver analyses each stroke of a flash separately.

7.3.3 *Network configuration*

For a regional lightning location system, the receivers are installed into a long-baseline system where they are separated by distances of 150 to 250 km. However, recent information suggests that a much larger separation between stations is possible while still maintaining detection efficiency and locational accuracy adequate for some applications. The recommended number of stations is four to six. Requirements for the choice of the network geometry are similar to those of a direction-finder network. Also, the requirements for the communications between the receiver stations and the central unit are similar.

7.3.4 *Location accuracy and detection efficiency of time-of-arrival (TOA) networks*

The TOA technique of locating lightning is in principle very accurate. The determination of the peak of the pulse can generally be made with an error of one or a few μs, which corresponds to a spatial error of the order of 1 km or less. Errors in travel times caused by differences in propagation paths also cause errors of the order of one μs. However, larger errors may be caused by the effect of the propagation conditions to the rise in time of the main stroke pulse. The strike location corresponds to the initial rise of the pulse, while the pulse peak occurs slightly later (MacGorman and Rust, 1988). The different strokes of a flash, located by the pulse peaks, may show little scatter, but the location of the whole group may be in some error because of pulse rise times.

Still larger errors can be caused by a misinterpretation of the pulse peak, which may be blurred or displaced by the presence of ionospheric reflections or by the distortion of the waveform due to distance. According to one manufacturer, such spurious locations are usually separate and randomly distributed, and their number can be reduced by filtering (by dropping out those cases where there is, for a properly chosen time period, only one location within a map element of given size).

According to a report distributed by the manufacturer, the detection efficiency of a four-to-six station TOA network is about 80–85 per cent in terms of the detected strokes. Because a flash may still be detected even if a stroke is lost (this is also true for DF), the detection efficiency with respect to flashes may be higher, but no estimate is given. Nor is it known how efficient is the rejection of pulses from sources other than cloud-to-ground lightning.

7.3.5 *Time-of-arrival (TOA) system maintenance*

From the point of view of operation and maintenance, a TOA network is quite similar to a DF network, i.e. technical maintenance is probably not a problem while the tasks of data distribution and scientific quality control are long-lasting and interesting.

7.3.6 *The arrival time difference (ATD) system*

The arrival time difference (ATD) network was developed by the United Kingdom Meteorological Office to prove wide area lightning location over Europe and the eastern Atlantic. The TOA technique was chosen for superior location accuracy at long range. Because of the change in shape of sferic waveforms that takes place over long rage due to propagation effects, differences in waveform arrival times between pairs of detectors are computed using a time lag correlation technique involving the entire waveform envelope.

7.3.7 *The arrival time difference (ATD) network*

This consists of five detectors in the United Kingdom at separations varying from 300 to 900 km. In addition, two further detectors in Gibraltar and Cyprus operate at separations from the United Kingdom of 1 700 and 3 300 km, respectively and are particularly vital to the long range performance of this system. One detector (the selector) is set less sensitive than the others, which are then invited to submit data on sferics that they receive within a given time tolerance of the selector. Locations are then computed for those events that pass given quality control criteria; e.g. at least four detectors contributing sufficiently well defined correlations and well behaved variation of sferic amplitude with range.

7.3.8 *Arrival time difference (ATD) location accuracy and detection efficiency*

Current location accuracy is typically 1 to 2 km in the United Kingdom, 2 to 5 km in Europe and 5 to 10 km over the eastern Atlantic. Beyond that, the accuracy lies between 1 and 2 per cent of the range out to 12 000 km. With the loss of the non-United Kingdom detectors the accuracy degrades by about a factor of 10 outside the United Kingdom.

The present system is limited both by communication speed and processor power to a throughput of 450 flashes per hour. As a result, flash detection efficiency is rather low and varies with the overall level of activity in the service area. Variations in Europe are between 25 and 70 per cent.

7.3.9 *Arrival time difference (ATD) maintenance*

The precision oscillators used for keeping time at the detector stations require regular calibration against LORAN-C or GPS. A requirement for a long-range system is an adequate propagation model to correct for diurnal effects and also for land/sea path changes. In the absence of such a model, timing consistency checks are made at intervals using data from all detectors in the network.

7.4 Comparisons of direction finder (DF) and time-of-arrival (TOA) networks

The fact that DF systems have been on the market since the end of the 1970s and TOA systems appeared at least five years later has resulted in a significant difference in the reported experiences with the systems. While results obtained by various lightning location position (LLP) installations are rather abundant, corresponding TOA reports are few, and the number of comparisons between the two systems is still smaller. Hence, the results presented here should not be directly generalized to the conditions met in different countries; another, perhaps more important point is that both systems are developing all the time. Any institute planning to set up a new lightning location system should look at the situation as it stands at that time and should consult as many new reports as possible.

A problem with the comparisons is that they have not been published in generally-available journals, but rather in institute reports which are difficult to obtain. The comparison made by MacGorman and Rust (1988) was presented orally in a conference but the actual results were not given in the proceedings; however, the same results are quoted by Murphy (1988) in an informal report. Another comparison is a study made by Oskarsson (1989) and published as an institute report in Swedish.

According to Murphy (1988), the major DF networks in the United States have a mean location error of about 3 km; in areas with short DF baselines, the error may be below 1 km and in long-baseline regions, about 5 km. A typical value of the detection efficiency is 70 per cent. The false detection rate is very low. It was not reported whether the system uses an optimization procedure in computing the locations. The TOA location errors are of the order of 10 km and the detection efficiency is 35–45 per cent. It is probable, however, that these numbers have now been improved by technical developments.

Oskarsson (1989) made a comparison of TOA and DF systems in Sweden, for a few thunderstorm events. The users of the TOA system estimated an average accuracy of 5 km, a somewhat better performance than the DF system, but the latter was evidently not using an optimization procedure; a striking example of the effect is given by Passi and Lopez (1989). Relating the flash and stroke numbers, it appeared that the TOA flash-detection efficiency was lower than that of the DF system by a factor of between 1 and 1.5. In Finland, it was estimated that a four-station DF network had an average accuracy of 5 km after systematic corrections and optimization (Tuomi, 1991); the real-time accuracy, without optimization, was somewhat worse.

As a conclusion, one may say that the two competing systems offer broadly comparable performance. When planning to purchase one or the other, or either system from competing suppliers, it would be useful to try to find answers to questions using the newest information available, such as:

(*a*) Is the DF central unit capable of using an optimization procedure?
(*b*) Is a qualified person available to control the quality of the data of either system?
(*c*) What are the systems, if any, in neighbouring countries? Could a network connection be useful?
(*d*) Are good timing signals available for TOA?
(*e*) How good is the rejection of false alarms in the TOA system? What is the resulting detection efficiency?
(*f*) For a particular application, is it important to identify flashes rather than strokes?
(*g*) What communications links will be needed? For both systems, the communication between the central unit and the DF/TOA stations is likely to be costly, unless it can be integrated with existing facilities;
(*h*) How many DF or TOA stations would be required to provide useful location accuracy and detection efficiency over the desired coverage area?
(*i*) Are there DF/TOA station siting considerations which would favour the latter?

7.5 A combination of the direction finder (DF) and time-of-arrival (TOA) techniques

The SAFIR lightning location system developed in France represents a very sophisticated but rather expensive means of providing very high detection efficiency with good accuracy over a range of about 150 km using very high frequency detectors.

A typical network consists of three detectors located on 120° sectors between 20 and 70 km from a central station. Each detector uses three antennae positioned between 1 and 2 m from a central point on the assembly also on 120° sectors. This assembly acts as an interferometer to compute both the azimuth and the elevation angles of observed lightning events. The data acquisition rate is high enough to identify sections of the lightning trajectory which provides good distinction between cloud-cloud and cloud-ground discharges. This is a good system for warning of lightning risk at launch sites, airports etc. where cloud-cloud lightning is important. In view of the relatively short range it is less suitable for use in a national location network.

7.6 Presentation and distribution of lightning data

With today's versatile computer facilities, numerous possibilities of data presentation are at hand. One of the most useful methods for weather forecasters is to superimpose the lightning locations on a weather-radar or satellite-picture screen display to identify active clouds.

Computer networks offer almost unlimited possibilities to distribute real-time or historical flash location data to those interested. The problems are common to the distribution of any information and is not specific to lightning location data.

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