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EUCLID – TECHNICAL STRUCTURE AND PERFORMANCE OF THE EUROPEAN WIDE LIGHTNING LOCATION SYSTEM

Gerhard DIENDORFER
OVE – ALDIS

EUCLID – the EUropean Cooperation for LIghtning Detection was formally founded in 2001 as a cooperation among operators of lightning location networks in several countries in Europe. Currently the EUCLID network is a composite network utilizing about 100 Vaisala-GAI sensors. Data exchange between the countries is on a cooperation basis. It is also an objective to have a common European forum for discussion, maintenance, technical solutions, and network optimization. The EUCLID network provides lightning data for Europe with homogenous quality in terms of detection efficiency and location accuracy.

1 - INTRODUCTION

EUCLID (**EU**ropean **C**ooperation for **LI**ghtning **D**etection) is a collaboration among operators of national lightning detecting networks with the aim to identify and detect lightning all over the European continent.

The countries involved are Germany, Austria, Hungary, Czech Republic, Slovenia, Holland, Belgium, Luxembourg, Italy, Poland, Slovakia, Norway, Denmark, Switzerland, Sweden and France. At the moment the complete network consists of about 100 sensors of various types (IMPACT 141T, IMPACT ES, IMPACT ESP, LPATS III and LPATS IV) in these 13 countries, contributing to the detection of lightning (Fig.1).

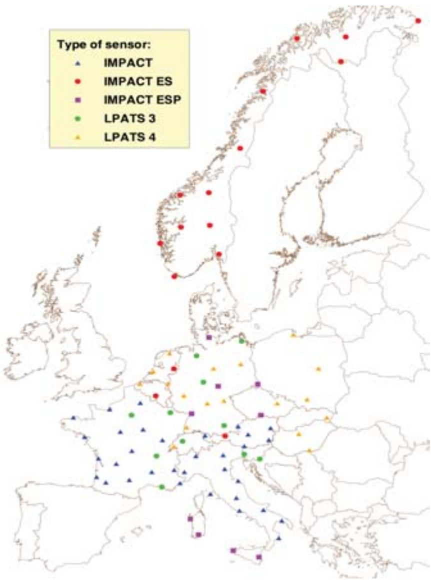

Figure 1 –European Map showing sensors participating in the EUCLID network

Each sensor detects the electromagnetic signal emitted by the lightning return stroke. This technology uses GPS Satellite signals for time information. For each lightning stroke the main parameters are recorded, namely the time of event, the impact point (Latitude and longitude), the Current intensity and polarity, and the number of subsequent strokes.

The sensors transmit the raw data to two identically configured LP2000 central analyzers - one in Karlsruhe, Germany and the other in Vienna, Austria (see Fig.2). These two LP2000 are processing the data received from all the connected sensors independently and one is assumed to be a standby backup for the other LP2000. This leads to a complete picture of lightning activity in real time of high accuracy and reliability. The output data stream is forwarded to Meteorage, the LLS operator in France, and all lightning data collected is archived as well for post-storm analysis and for providing services to the EUCLID data customers.

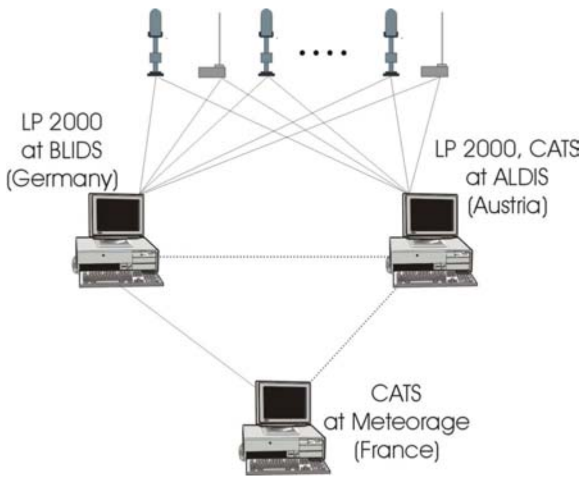

Figure 2 – technical concept of EUCLID

High reliability of the EUCLID network is achieved by a direct and independent access of each of the LP2000 to most of the sensors.

2 – TECHNICAL STRUCTURE

Over the last decade national lightning location systems were installed in most of the European countries employing different types of sensors (LPATS or IMPACT). Introduction of the LP2000 by Vaisala-GAI allowed the first time to merge a mix of LPATS and IMPACT type sensors to a single LLS. Real time processing of lightning data requires a permanent data communication with all sensors. High costs for permanent international communication (e.g. X.25) restricted the interconnection of national networks in the mid 90's. Today the enormous development of the Internet allows a very cost effective communication between a LP2000 and sensors installed in different countries. Various tests of the Internet communication (time delays, data rate, etc.) provided evidence for a satisfactory use of this stat of the art communication.

3 – BENEFITS TO THE EUCLID MEMBERS

Different analysis of data from the individual national networks with the integrated EUCLID network showed the advantages of a large integrated LLS. A successful location of a lightning discharge requires a minimum of two to four sensors reporting a stroke, depending on the type of sensors contributing to the solution. Two IMPACT sensors reporting angle and time or four LPATS sensors reporting only time are necessary for the calculation of an unambiguous striking point.

The overall performance of a lightning location network is basically defined by the baseline between sensors, the configured threshold values and the type of sensors (LPATS versus IMPACT) utilized. In addition to these predefined parameters local operating conditions (background noise at the sensor site, attenuation of propagating fields over poor conducting ground, etc.) may cause some reduction in the performance of a system. As a general rule we can state, that the more sensors are available in a given area the higher is the probability to detect a stroke. Integration of sensors in a neighboring country will therefore help to increase the detection efficiency and to improve location accuracy in a national network.

An example for the performance changes due to the network interconnection is given in Fig.3. In this figure the average number of sensors reporting (ANSR) is shown for the year 1997 (Fig.3a), when the Austrian network was a national network based on 8 IMPACT sensors only and for the year 2002 (Fig.3b), when Austria was integrated in the large EUCLID network. The ANSR is a good primary indicator for the performance of a lightning location network. The higher the value of ANSR the higher is the probability to detect lightning accurate and to detect discharges with smaller amplitudes.

Obviously the ANSR values have increased significantly due to the interconnection with the neighboring LLS. In 1997 large areas of Austria exhibit an ANSR from 2 to 4, whereas in 2002 the ANSR is greater than 8 for most of the Austrian territory.

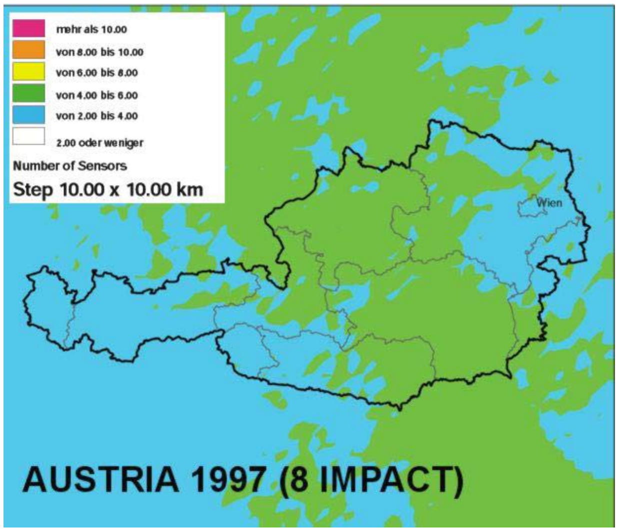

Figure 3a –Average Number of Sensors Reporting (ANSR) in Austria in 1997

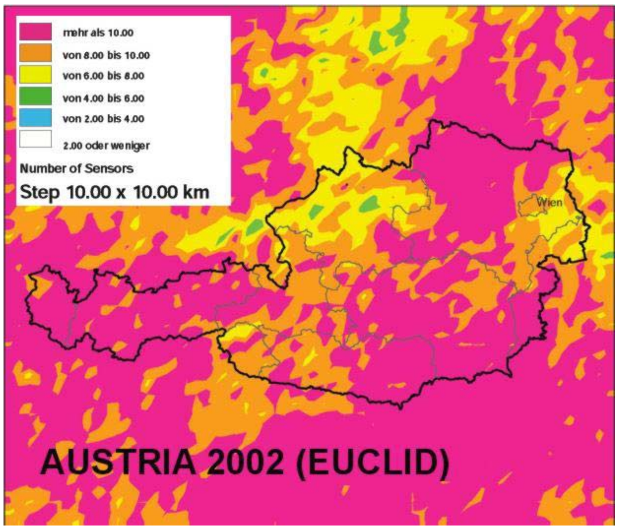

Figure 3b –Average Number of Sensors Reporting (ANSR) in Austria in 2002

4. EUCLID PERFORMANCE

Detection Efficiency (DE), Location Accuracy (LA) and Peak current Estimate are the three major performance parameters of LLS. Projections provided by the system manufacturer GAI for the DE and the LA are shown in Fig.4 and Fig.5. These projections are based on reasonable assumptions for the performance of each sensor type.

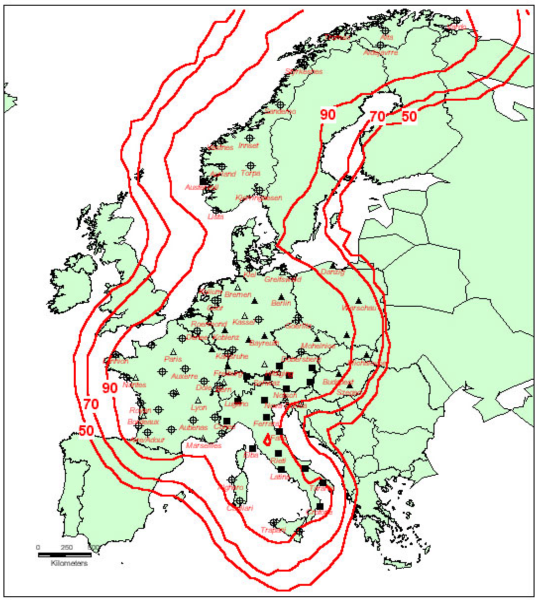

Figure 4 – Detection Efficiency Projection Ground Flashes Equivalent peak current > 10kA (provided by GAI)

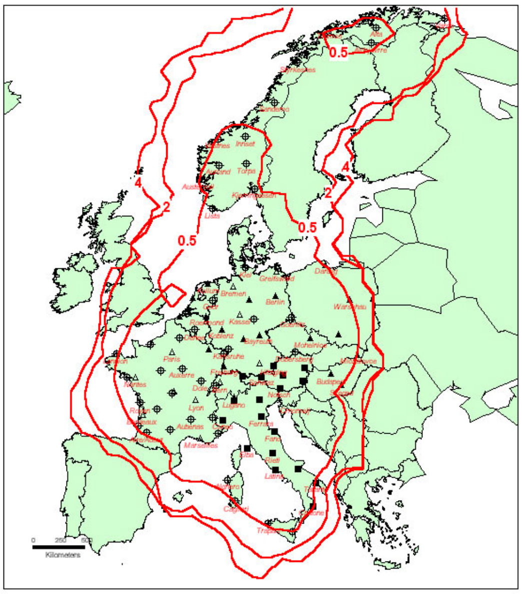

Figure 5 –Location Accuracy Projection -Contours of the 50% Confidence Ellipse in km (provided by GAI)

4.1 DETECTION EFFICIENCY

Analysis of correlated measurements of lightning strikes to an instrumented radio tower [1] results in a flash detection efficiency of 98% for flashes with at least one stroke exceeding a peak amplitude of 10 kA and 86% for flashes with at least one stoke exceeding a peak amplitude of 2 kA (see Table 1). Stroke detection efficiency ranges from 64% for strokes greater than 2 kA to 93% for strokes greater than 10kA.

	Gaisberg Tower		EUCLID			
I_{min} [kA]	Number of Flashes	Number of Strokes	Number of Flashes	Number of Strokes	**Flash DE**	**Stroke DE**
10	47	147	46	137	**98%**	**93%**
8	51	206	50	187	**98%**	**91%**
6	62	272	58	234	**94%**	**86%**
4	68	365	63	282	**93%**	**77%**
2	77	463	66	296	**86%**	**64%**

Table 1 – Detection Efficiency of the EUCLID network for direct strikes to an instrumented tower

4.2 LOCATION ACCURACY

The directly measured lightning strikes to the radio tower provide also a unique source of ground truth data to evaluate the location accuracy of the EUCLID network at this location in Austria. A median distance of 450m between the tower site and the GPS time correlated EUCLID locations was determined for a set of 285 strokes to the tower in the year 2000 and 2001 (see Fig. 6). This location accuracy is well within the projected value of 500 m given in Fig.5.

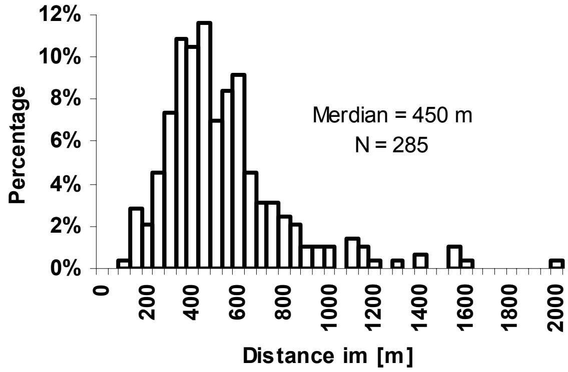

Figure 6 – Distribution of distances between EUCLID locations and the tower site

It is interesting to note, that there exists a systematic shift of the locations to the north-east by about 400 m as shown in Fig.7

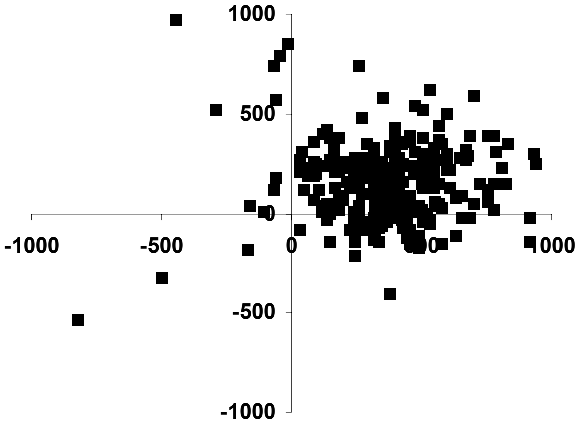

Figure 7 – Plot of EUCLID locations for correlated strokes - tower is located in the origin

In case of a successful elimination of this systematic location error in the future, the location accuracy could be improved to about 200m.

4.3 PEAK CURRENT ESTIMATE

Lightning location systems provide a peak current estimate inferred from the remotely measured peak electromagnetic fields. In the EUCLID data the relation

$$|i_p| = 0,23.|S_n|$$

is used, where i_p is the lightning peak current in kA and S_n is the mean of the signal strengths from the DF's participating in the location in LLP-units and range-normalized to 100 km. Different to the NLDN in the US in the EUCLID network no attenuation model is applied to the range normalized peak signals.

The results in Fig.8 show, that on average EUCLID underestimates the lightning peak current amplitudes by about 5% compared to the directly measured current amplitudes at the instrumented tower. This is within the range of estimated accuracy of +/- 10% of the current measurement system installed at the tower.

In the examination given in Fig.8 no distinction was made between current pulses superimposed on the initial continuing current (ICC) of the most frequently occurring upward initiated flashes to the tower and the return stroke type pulses following the ICC after a short time period of no current flow in the lightning channel.

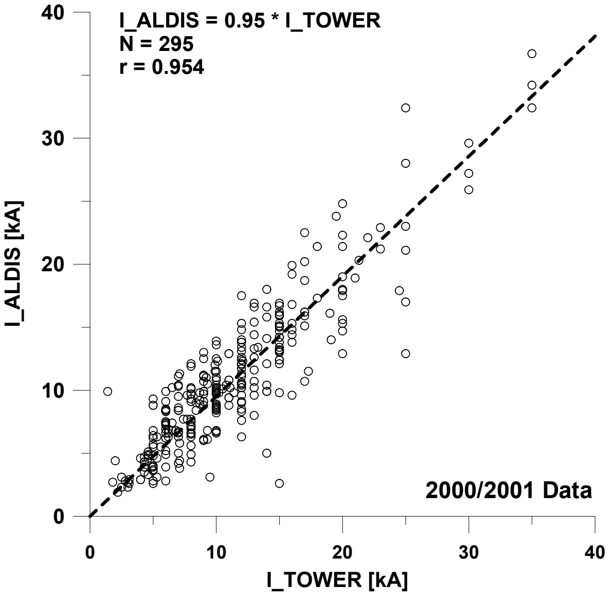

Figure 8 – Comparison of directly measured currents I_TOWER with the current estimates from EUCLID

NOTE: Absolute values of negative stroke peak currents are plotted and I_ALDIS is equal to I_EUCLID

5 - CONCLUSIONS

Two years of experience and extensive evaluation of the integrated lightning location system EUCLID allows us to conclude, that this network interconnection provides benefits to all the participating national networks and helped to improve the quality of lightning detection in Europe. The data from the tower experiment in Austria proofed the validity of the model based projections for detection efficiency and location accuracy of the EUCLID network.

7 - REFERENCES

[1] DIENDORFER G., W. HADRIAN, F. HOFBAUER, M. MAIR, W. SCHULZ „Evaluation of Lightning Location Data Employing Measurements of Direct Strikes to a Radio Tower". *Proceedings of the CIGRE Session 2002, Paris.*

Main author
Dr. Gerhard DIENDORFER
OVE-ALDIS
Kahlenberger Str. 2A
A-1190 Vienna, Austria
Phone: +43-1-3705806 - 212
E-mail: g.diendorfer@ove.at