



# Three-station EM field measurements of CN Tower lightning strikes

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# Outline

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- Introduction
- Description of the measurement sites
- Representative set of experimental data
- Preliminary analysis of collected data
- Conclusions

Introduction	Sites description	Data set	Data analysis	Conclusions
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# Measurement campaign in Toronto 2005

Simultaneous *GPS*-stamped measurements of :

- Lightning current on the CN Tower
- EM field at three distances (2 km, 16.8 km and 50.9 km)
- Video imaging with DVD quality
- Hi Speed camera images (No *GPS* time here)

**Introduction**

Sites description

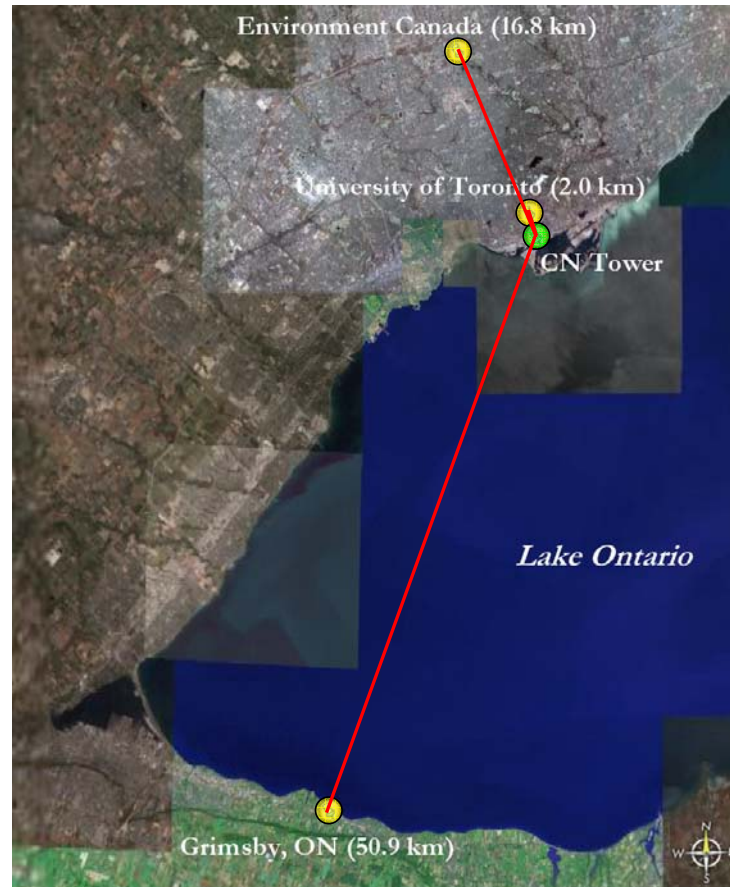
Data set

Data analysis

Conclusions



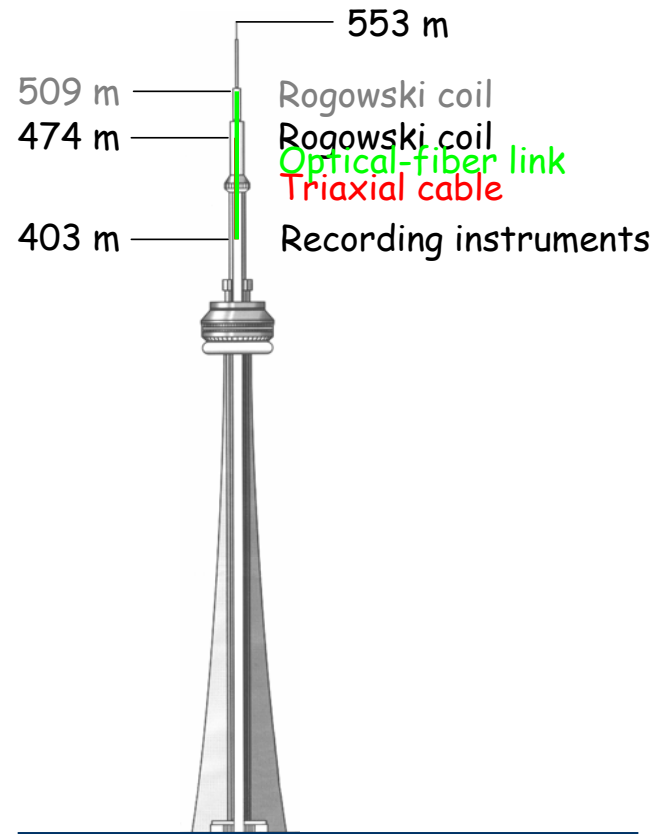
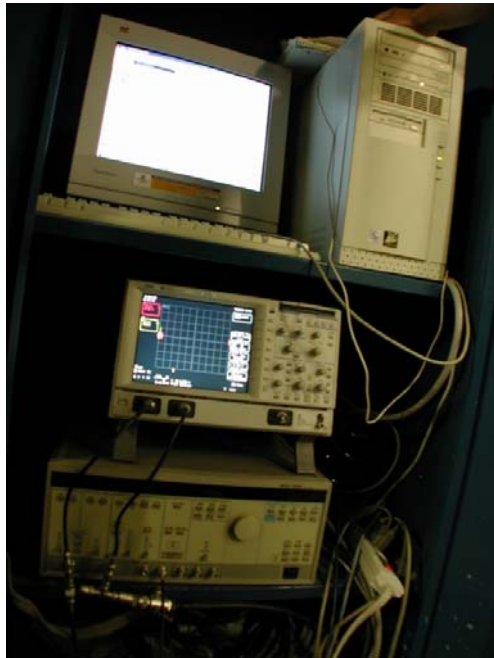
# Location of CN Tower and EM field sensors



Introduction	<b>Sites description</b>	Data set	Data analysis	Conclusions
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# CN Tower current measurement system



Introduction

Sites description

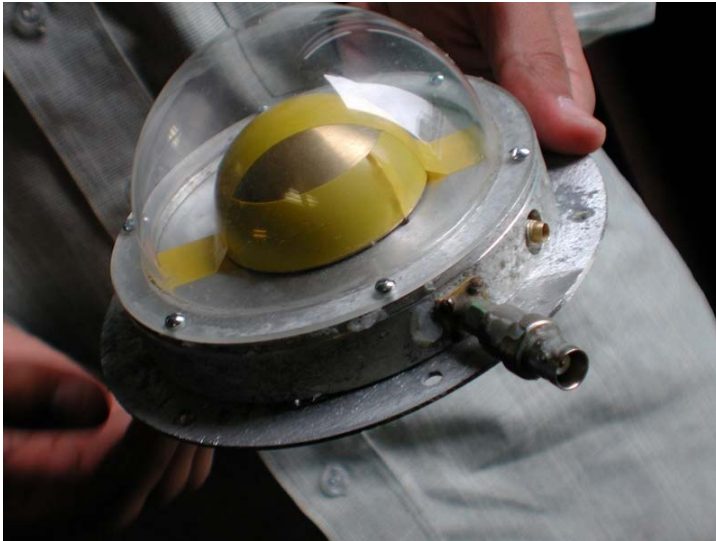
Data set

Data analysis

Conclusions



## EM field sensors installed at the UofT



- Electric field sensor
- Active hemispheric type
- (47 Hz - 100 MHz)



- Magnetic field sensor
- Active single-loop type
- (635 Hz - 134 MHz)

Signals are carried to the digitizer via 50- $\Omega$  triaxial cables

Introduction

Sites description

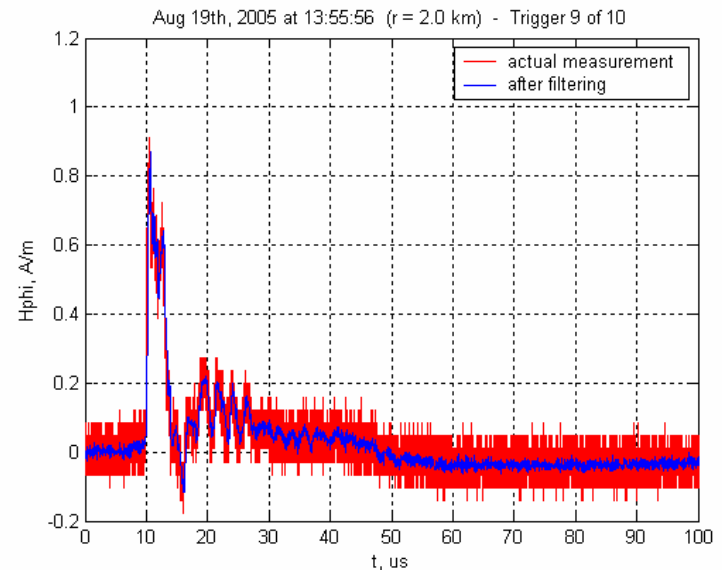
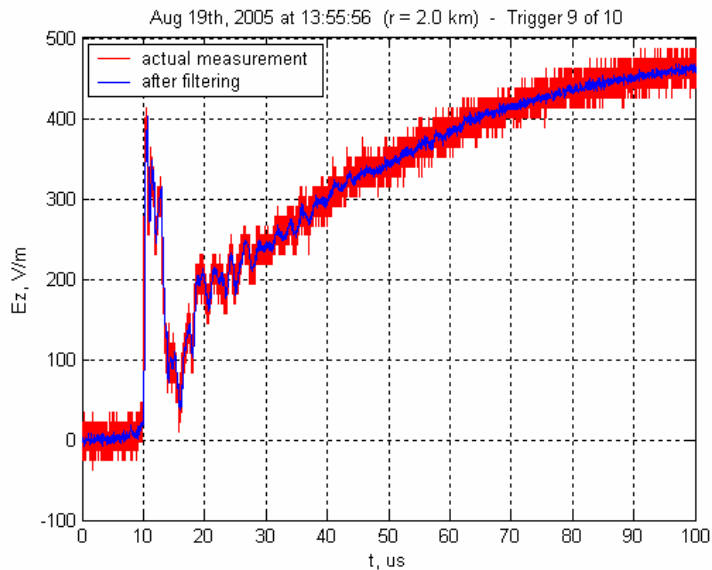
Data set

Data analysis

Conclusions



# EM field sensors installed at the UofT



20-MHz low-pass filtering to improve SNR

Introduction

Sites description

Data set

Data analysis

Conclusions



# EM field sensors installed at the UofT



· Permanent installation

· On the roof of a four-floor building

Introduction

**Sites description**

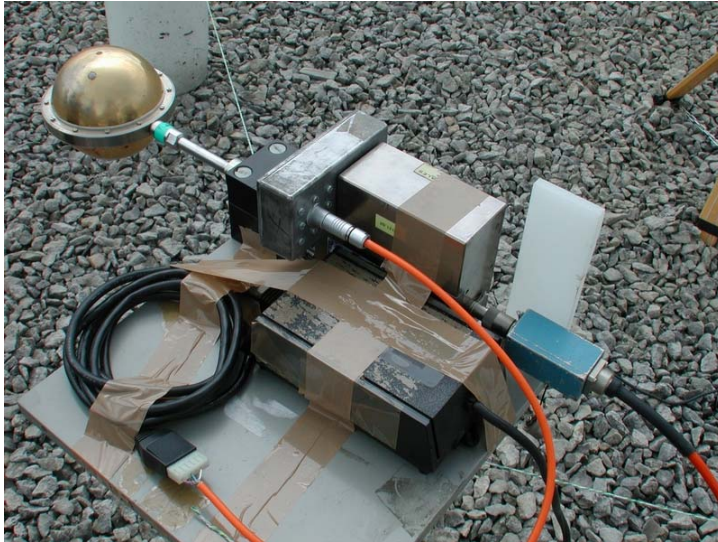
Data set

Data analysis

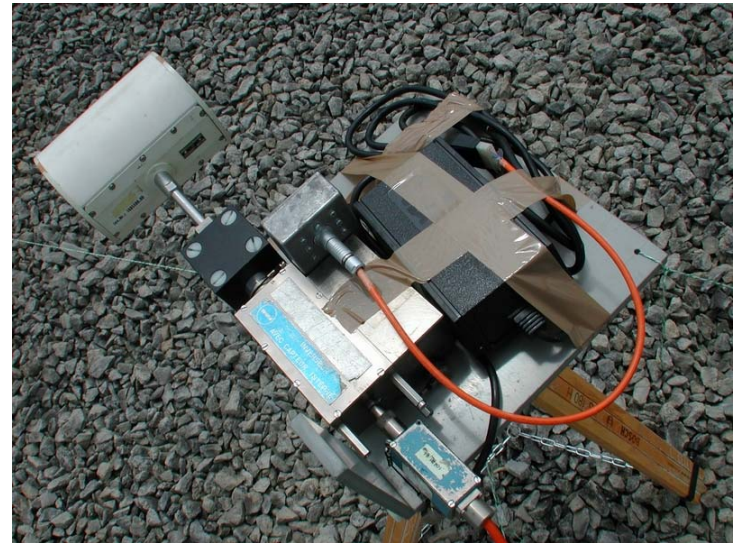
Conclusions



## EM field sensors installed at 16.8 and 50.9 km



- Electric field sensor
- Active spherical type
- (1 kHz - 150 MHz)



- Magnetic field sensor
- Active multi-loop type
- (4 kHz - 150 MHz)

Low-noise, multiple-gain sensors provided with optical-fiber links

Introduction

Sites description

Data set

Data analysis

Conclusions



# EM field sensors installed at 16.8 km



· On-tripod installation



· On the roof of a four-floor building

Introduction

**Sites description**

Data set

Data analysis

Conclusions



## EM field sensors installed at 50.9 km



- On-tripod installation

- On the roof of a two-floor building
- Directly on the lake shore

Introduction

**Sites description**

Data set

Data analysis

Conclusions



## A representative video capture

231:14:13:12.749

Introduction

Sites description

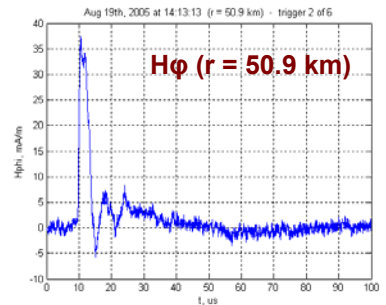
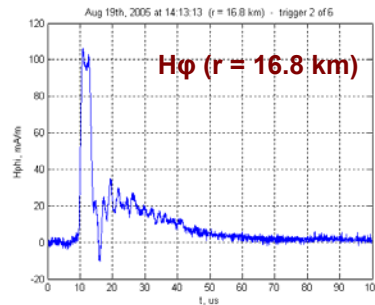
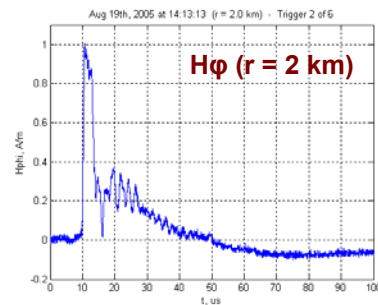
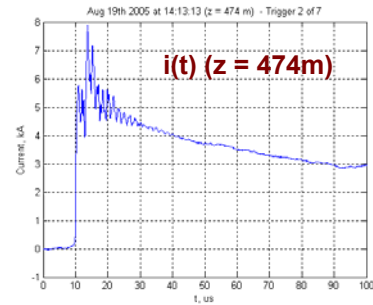
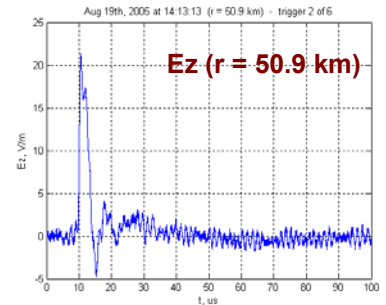
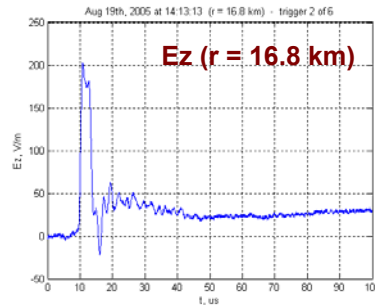
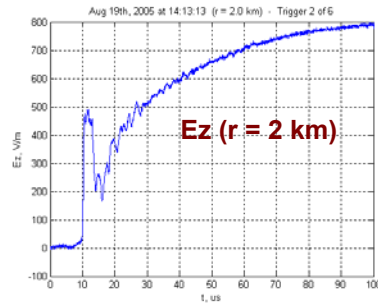
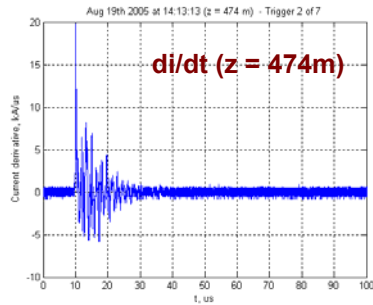
**Data set**

Data analysis

Conclusions



# A representative set of simultaneous data



Introduction

Sites description

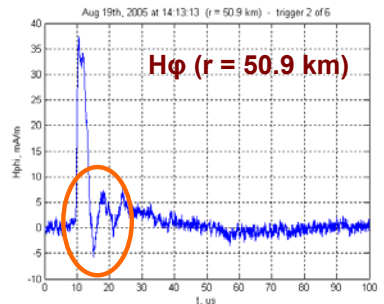
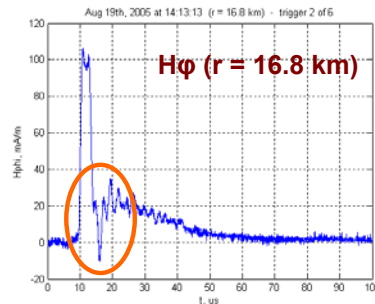
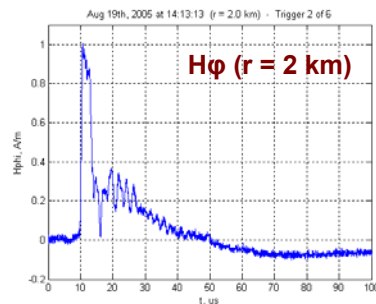
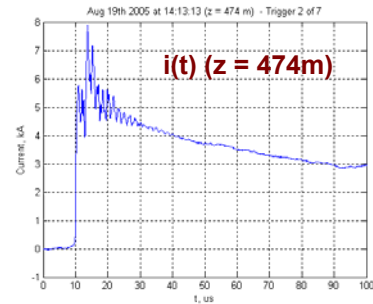
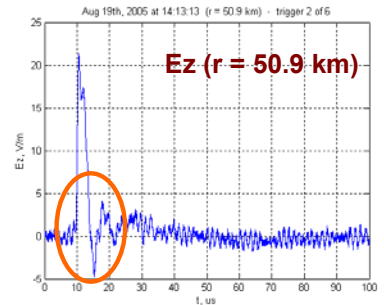
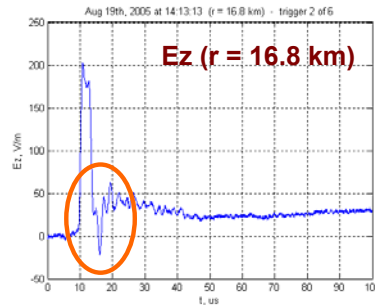
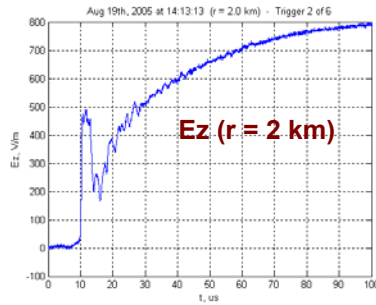
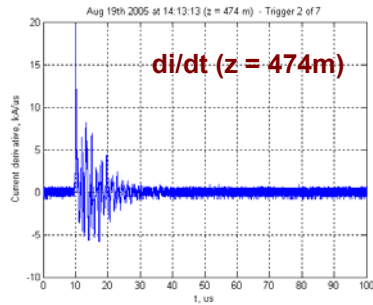
**Data set**

Data analysis

Conclusions



# A representative set of simultaneous data



Narrow zero crossing after the first peak

Transient phenomena along the tower?

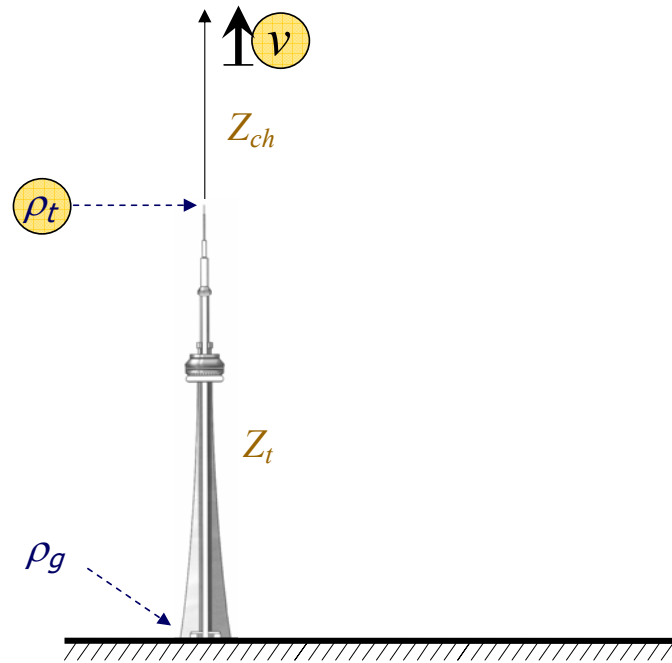
Introduction	Sites description	Data set	<b>Data analysis</b>	Conclusions
--------------	-------------------	----------	----------------------	-------------



# Far-field Enhancement factor $k$

$$H_{\varphi peak} = \frac{v}{2\pi cr} k I_{peak} \quad (1)$$

$$k = \frac{1 + (1 - 2\rho_t) c/v}{1 - \rho_t} \quad (2)$$



Bermudez et al. , "Far-field - current relationship based on the TL model for lightning return strokes to elevated strike objects," *IEEE Transactions on Electromagnetic Compatibility*, vol. 47, pp. 146-159, 2005.

Introduction

Sites description

Data set

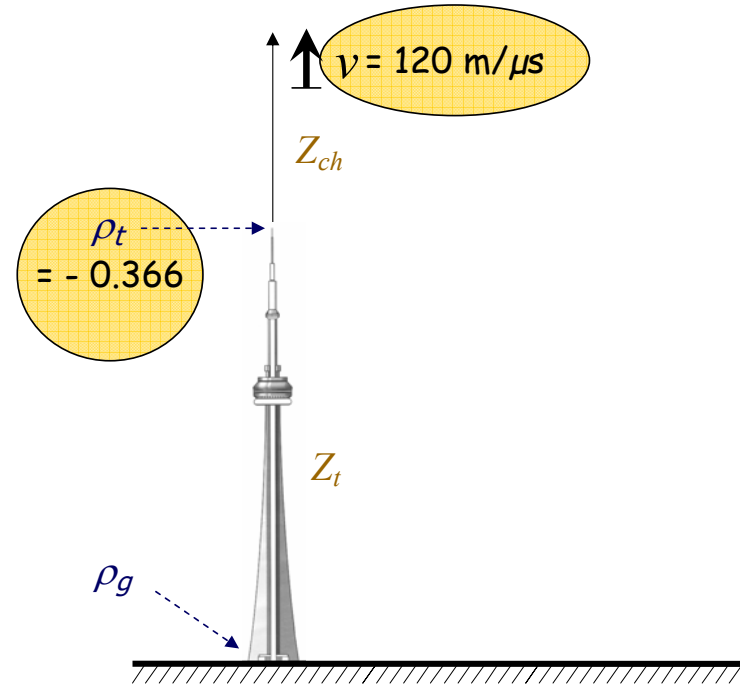
Data analysis

Conclusions



# Far-field Enhancement factor $k$

$$k = \frac{1 + (1 - 2\rho_t) c/v}{1 - \rho_t} = 3.9$$



W. Janischewskyj et al. , "Collection and use of lightning return stroke parameters taking into account characteristics of the struck object," presented at 23rd ICLP, Florence, Italy, 1996.

Introduction

Sites description

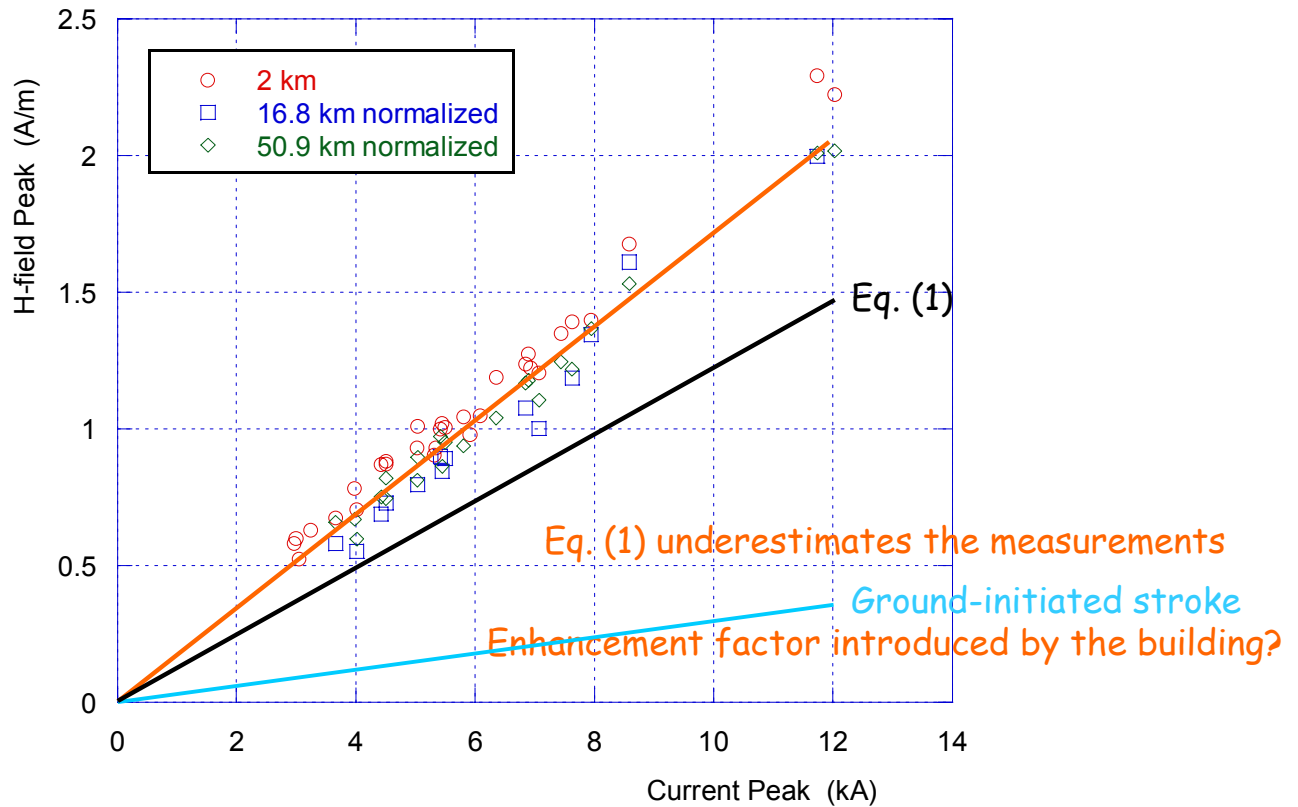
Data set

Data analysis

Conclusions

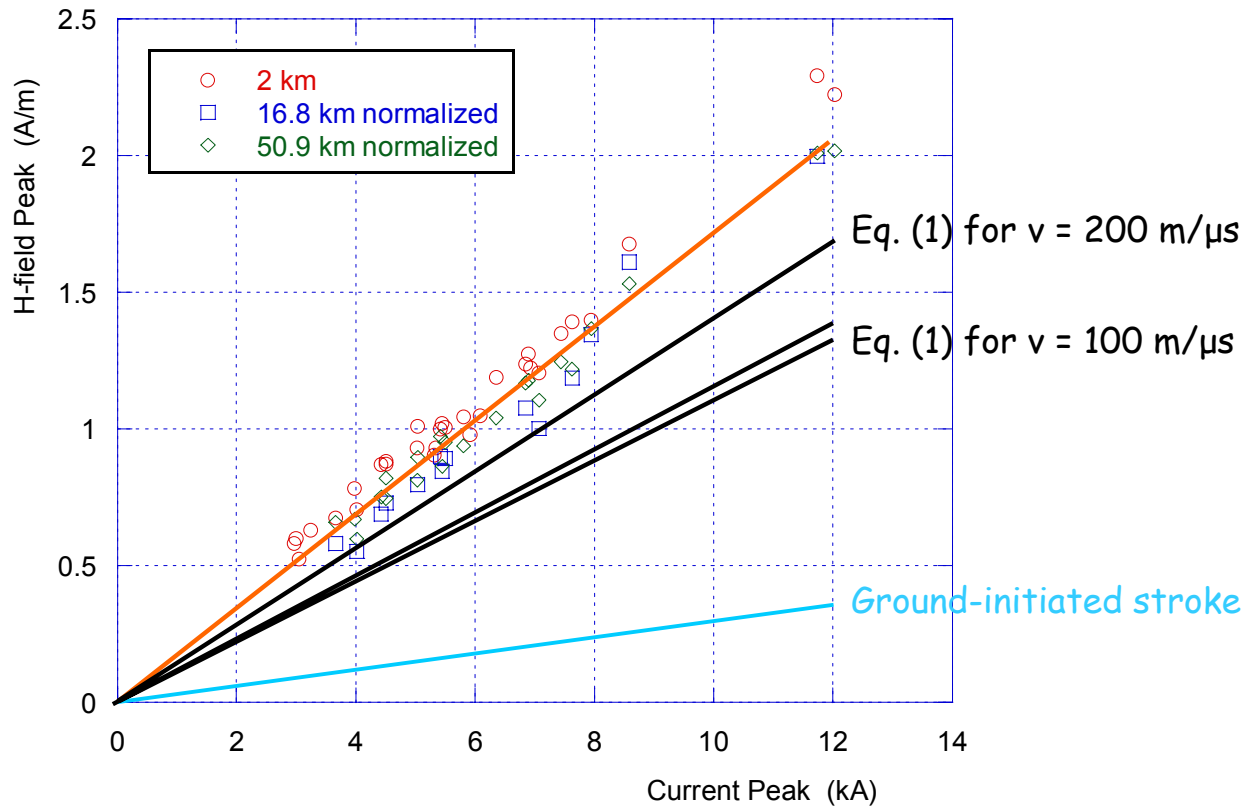


# H-field peak distribution of recorded data





# H-field peak distribution of recorded data



Introduction

Sites description

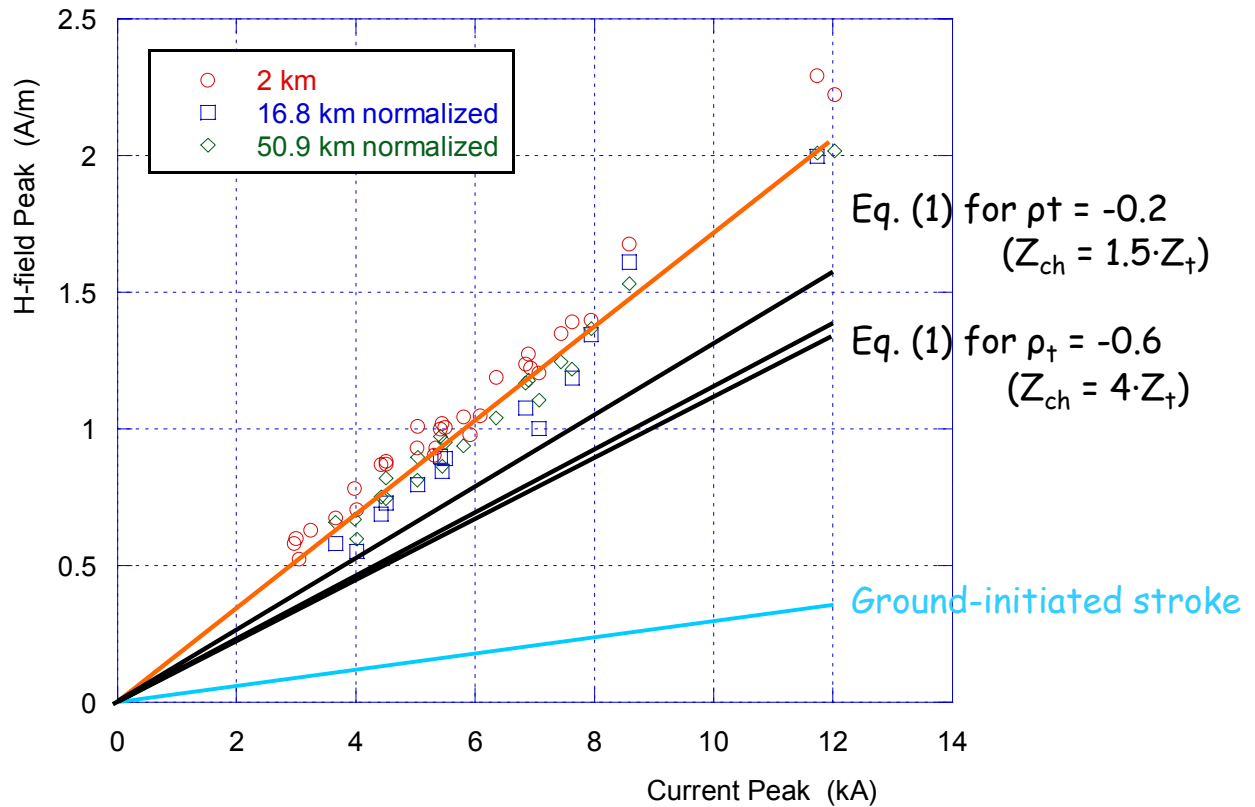
Data set

Data analysis

Conclusions



# H-field peak distribution of recorded data



Introduction

Sites description

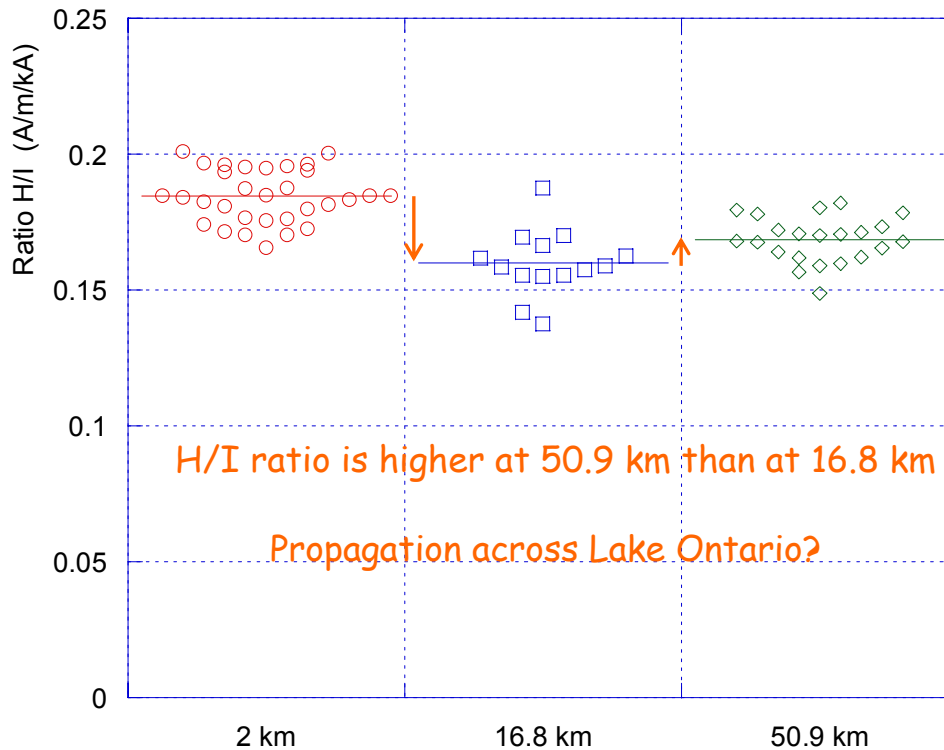
Data set

**Data analysis**

Conclusions



# Distribution of H/I normalized at 2 km



Introduction

Sites description

Data set

Data analysis

Conclusions

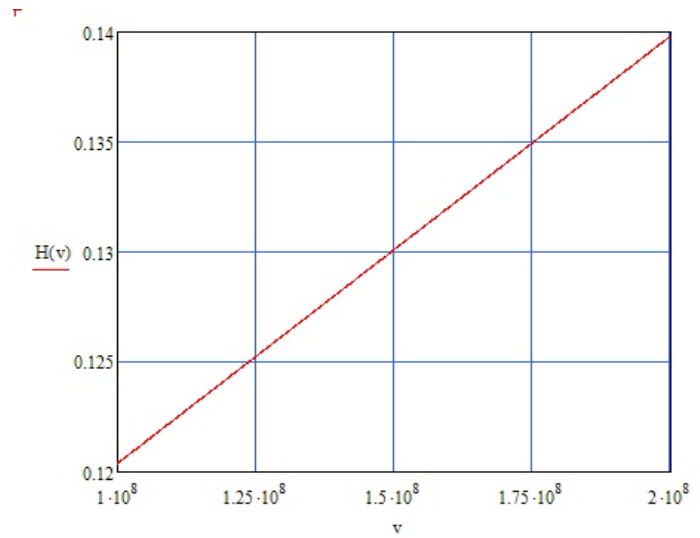
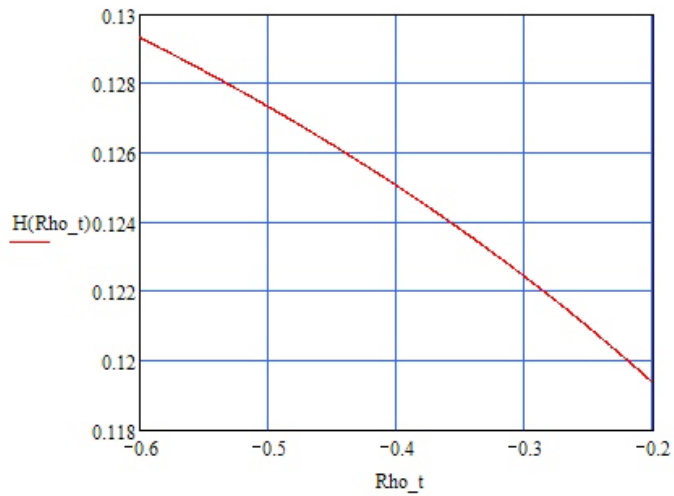


# Conclusions

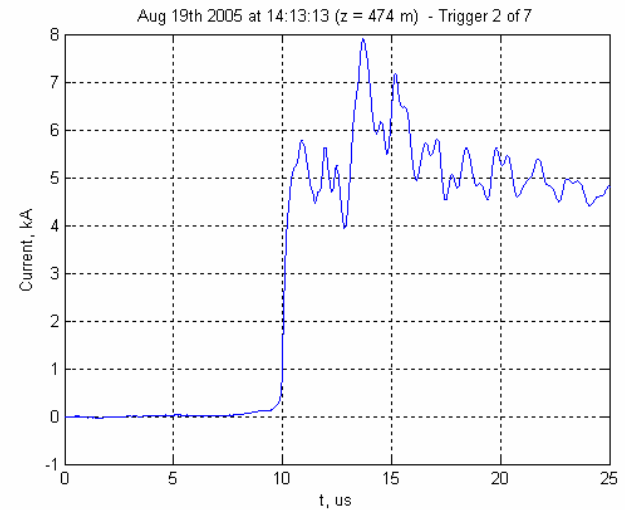
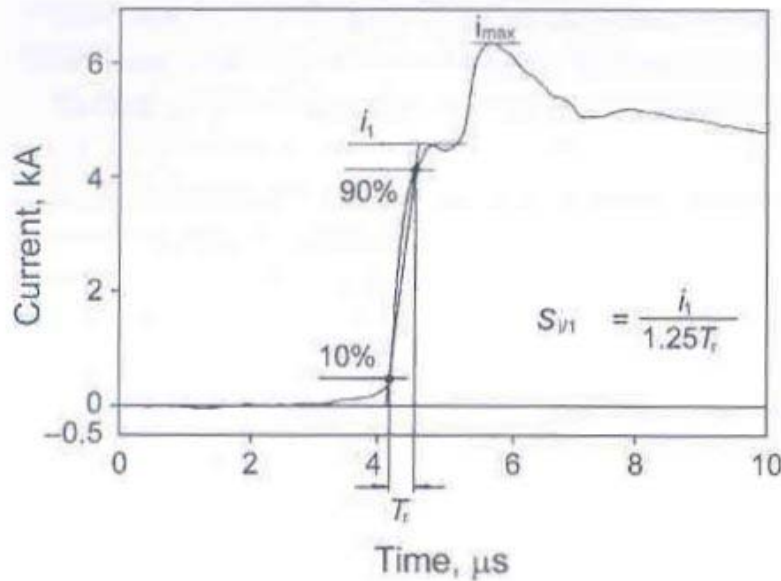
- Preliminary analysis of simultaneous measurements of return-stroke current, electric and magnetic fields at three distances associated with lightning strikes to the CN Tower during 2005
- Electric and magnetic fields measured after propagation paths over land and over Lake Ontario
- Narrow zero crossing due to undershoot after the far-field peak
- Good agreement between the formula proposed by *Bermudez et al.* and the measurements for the far-field peaks (effect of the building should also be considered)
- The EM field appears to suffer less attenuation when propagates across the surface of Lake Ontario than over land.

Introduction	Sites description	Data set	Data analysis	<b>Conclusions</b>
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# Definition of the adopted Current peak



Introduction

Sites description

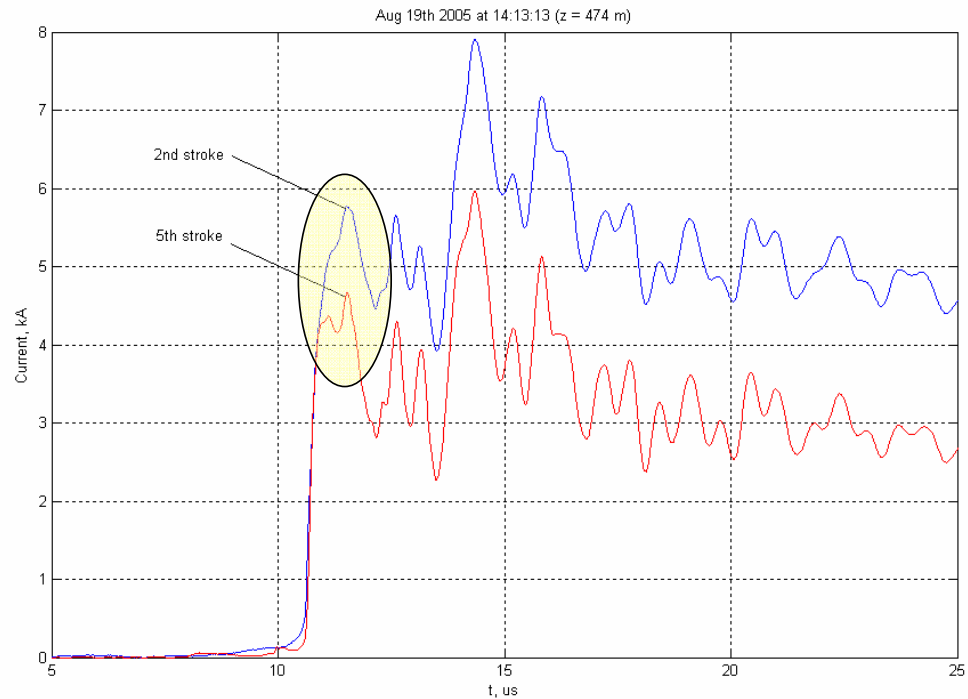
**Data set**

Data analysis

Conclusions



# Definition of the adopted Current peak



Introduction

Sites description

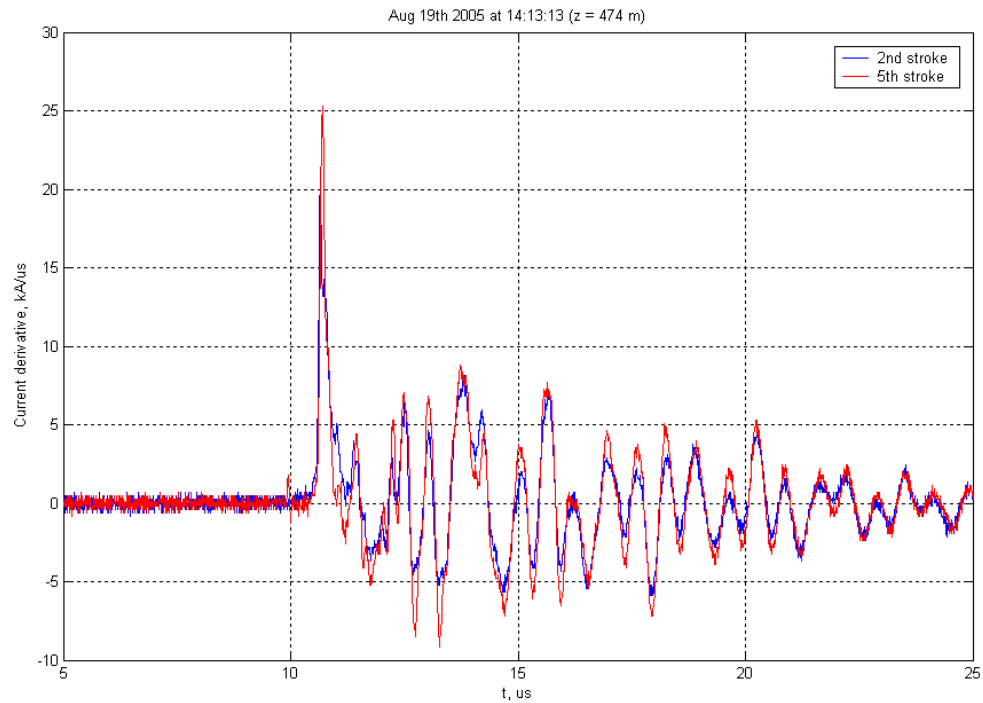
**Data set**

Data analysis

Conclusions



# Definition of the adopted Current peak



Introduction

Sites description

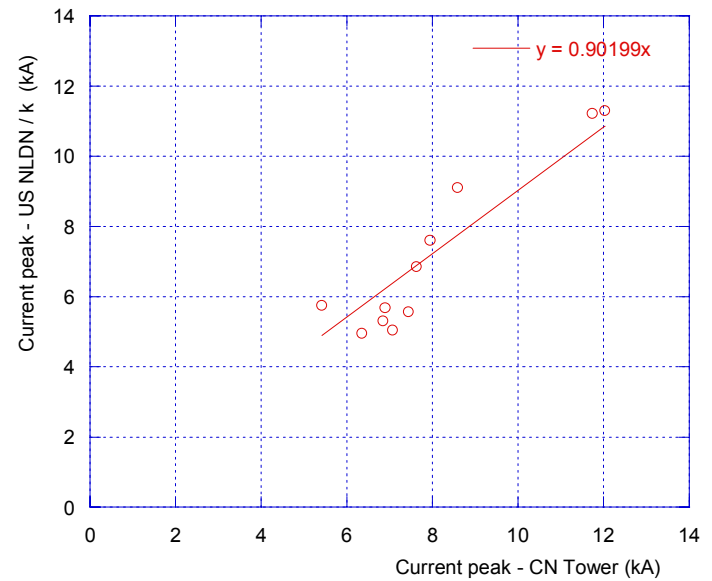
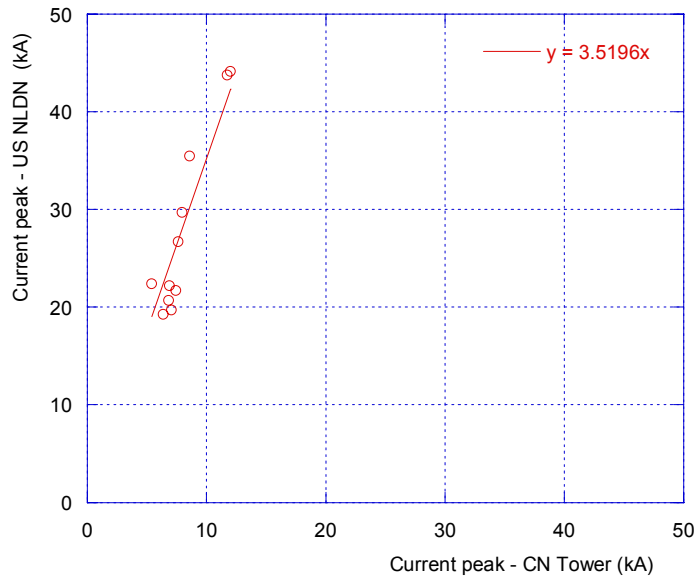
**Data set**

Data analysis

Conclusions



# Comparison with data from US NLDN



Introduction

Sites description

Data set

**Data analysis**

Conclusions