



Current Peak Estimates provided by Lightning Location Systems for Lightning Return Strokes to Tall Towers

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Outline

- Introduction
- Experimental results - Toronto 2005
- Far-field peak - current peak relationship
- Tall-tower 'correction' factor
- Validation of NALDN current estimation
- Conclusions



Introduction

- Tall structures are often struck by lightning
- Excellent means to record lightning currents
- Data from instrumented towers can be used to calibrate LLS (Lightning Location Systems)
- Transient processes may occur along the tower
- EM environment is influenced by the presence of the tower



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
- NALDN current estimation

Introduction

Toronto 2005

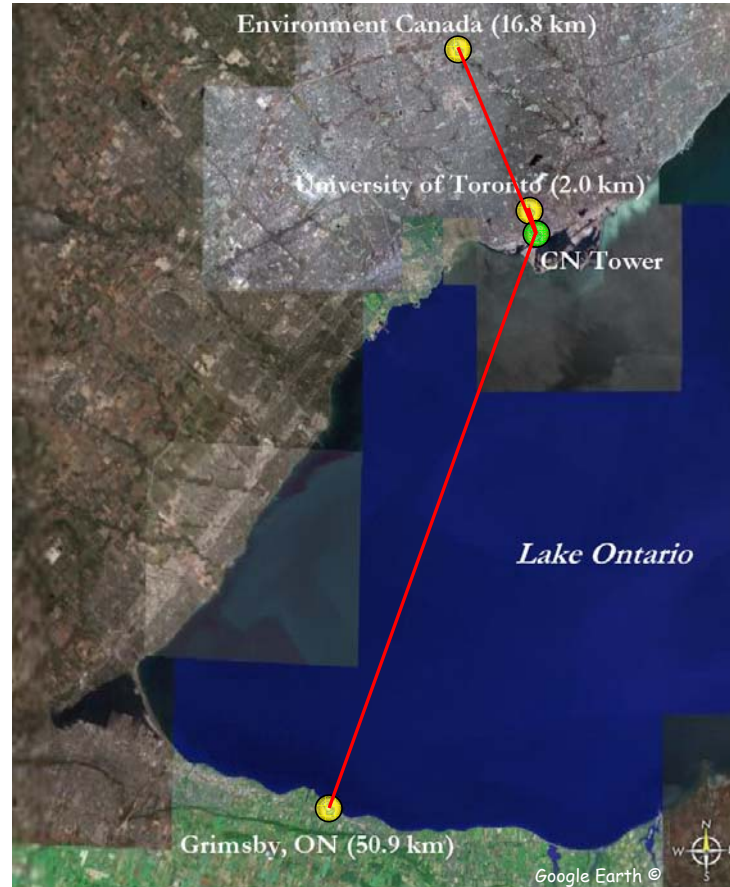
Factor k'_{tall}

NALDN

Conclusions



Location of CN Tower and EM field sensors



Introduction

Toronto 2005

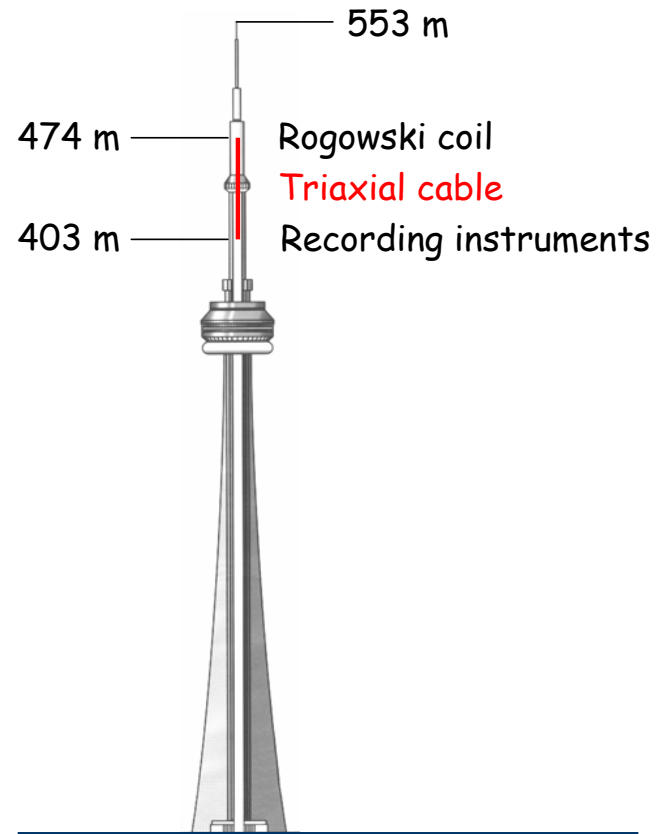
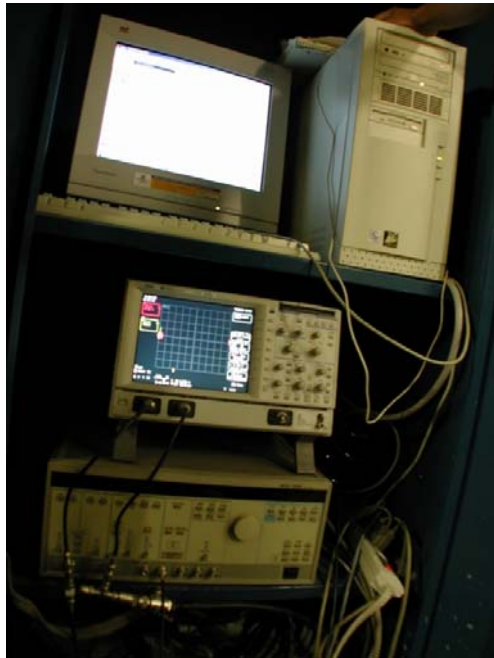
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CN Tower current measurement system



Introduction

Toronto 2005

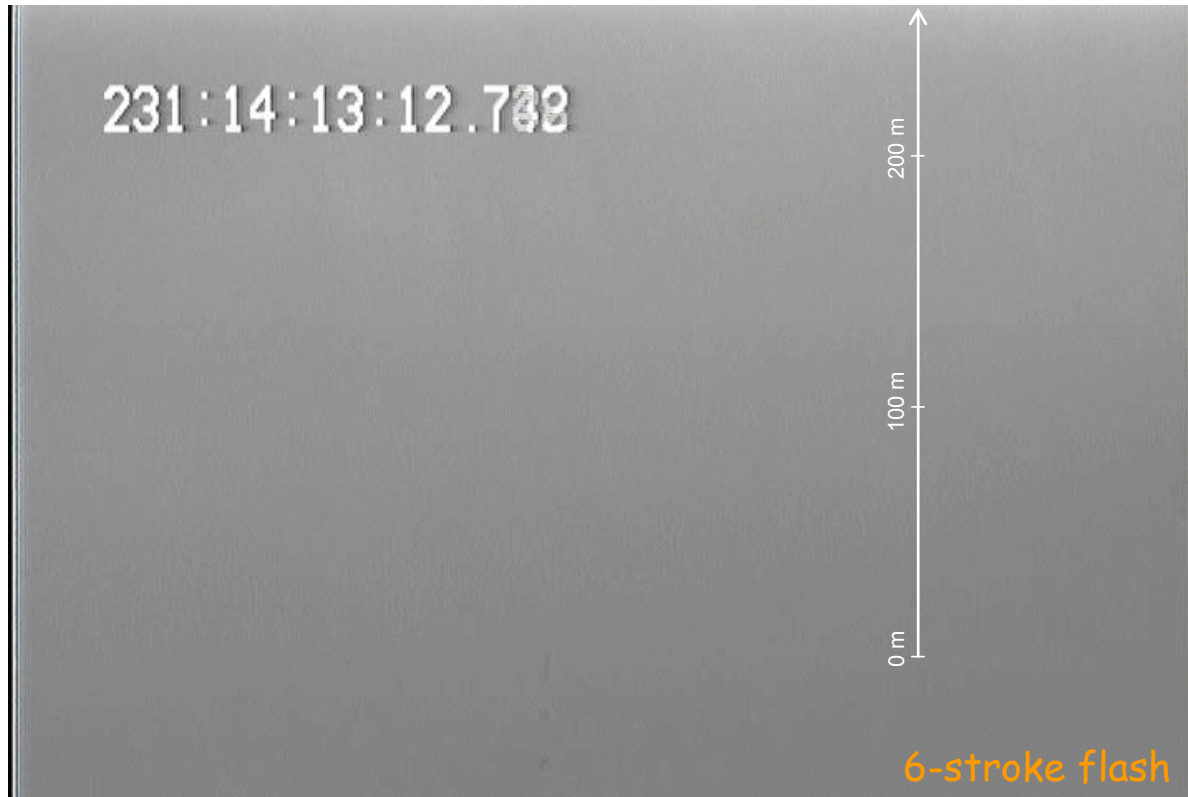
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A representative video capture



Introduction

Toronto 2005

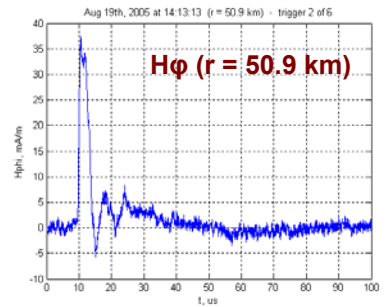
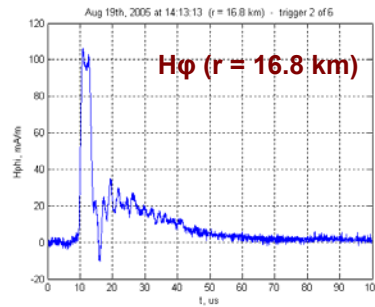
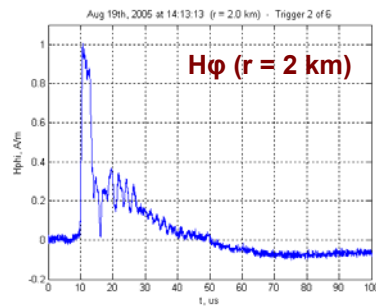
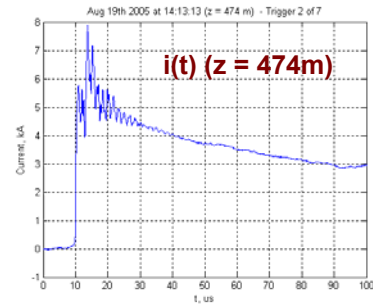
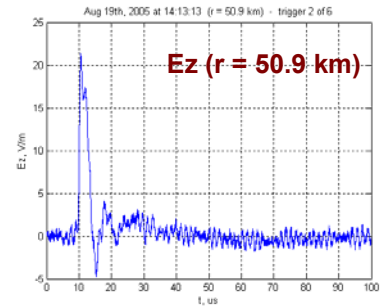
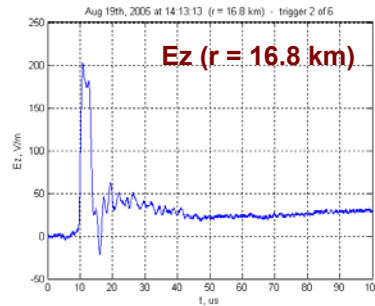
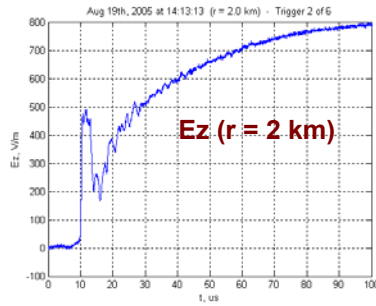
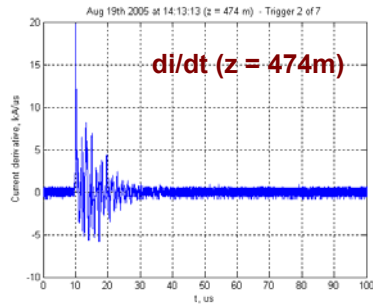
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A representative set of simultaneous data



Introduction

Toronto 2005

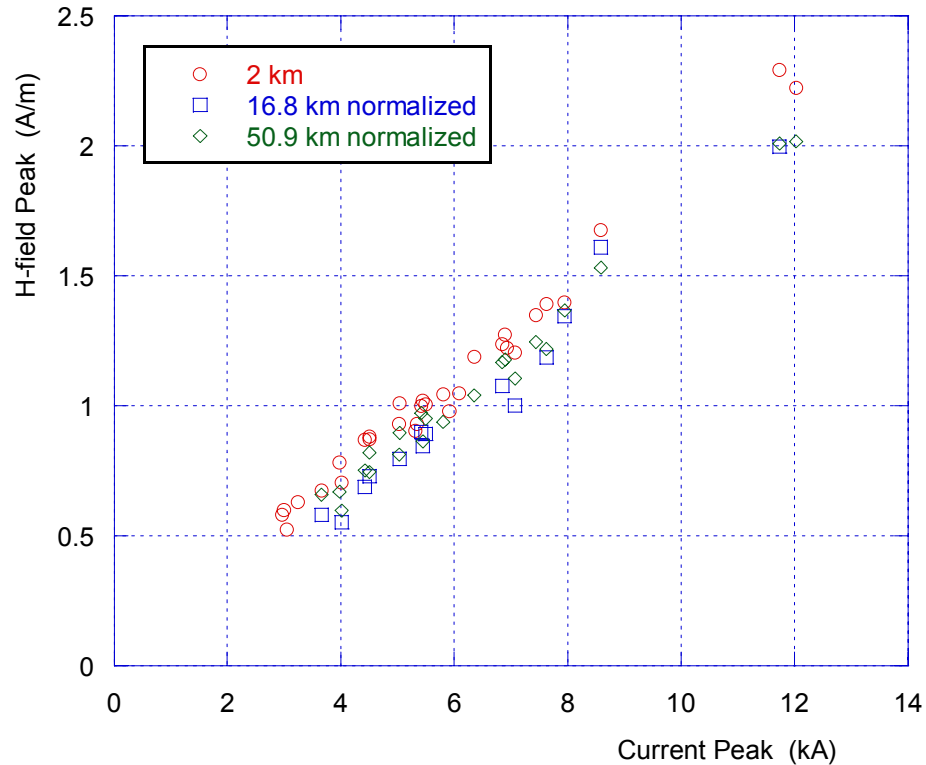
Factor k'_{tall}

NALDN

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H-field peak distribution of recorded data





Far-field – Current relationship

Ground-initiated strike:

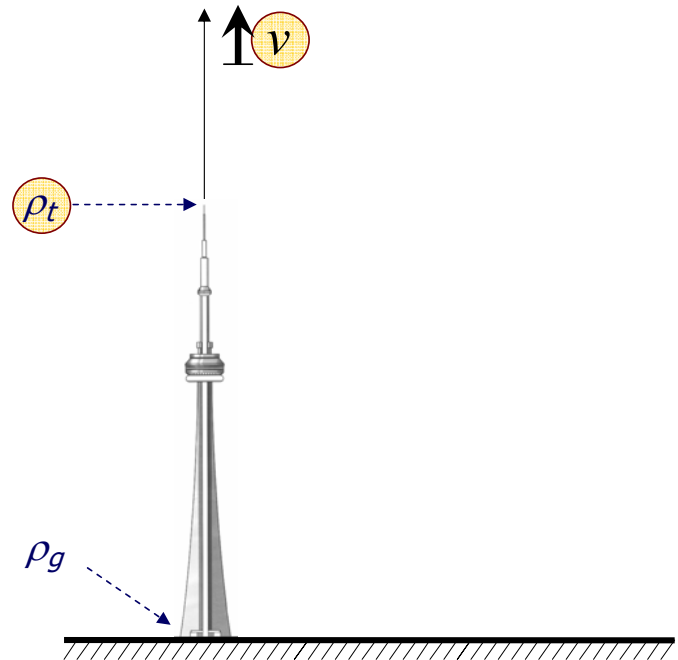
$$H_{\varphi peak} = \frac{v}{2\pi cr} I_{peak}$$

Tower-initiated strike:

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

[Bermudez et al., 2005]

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



Much less sensitive to the value of the return-stroke speed



Tall-tower correction factor k'_{tall}

[Bermudez et al., 2005]

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

$v = 120 \text{ m}/\mu\text{s}$

[Wang et al., 1995]

ρ_t
= -0.366

[Janischewskyj et al., 1996]

ρ_g



Tall-tower correction factor k'_{tall}

[Bermudez et al., 2005]

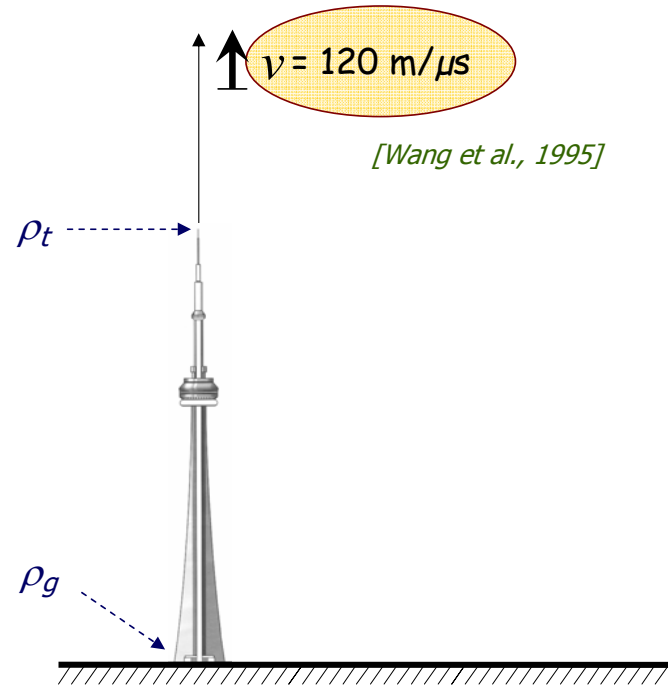
$$k'_{tall-1} = \frac{1 + (1 - 2\rho_t) c/v}{1 - \rho_t} = 3.9$$

- Distributed-source approach
- Engineering TL model
- Current reflections traveling at speed c

[Baba & Rakov, 2007]

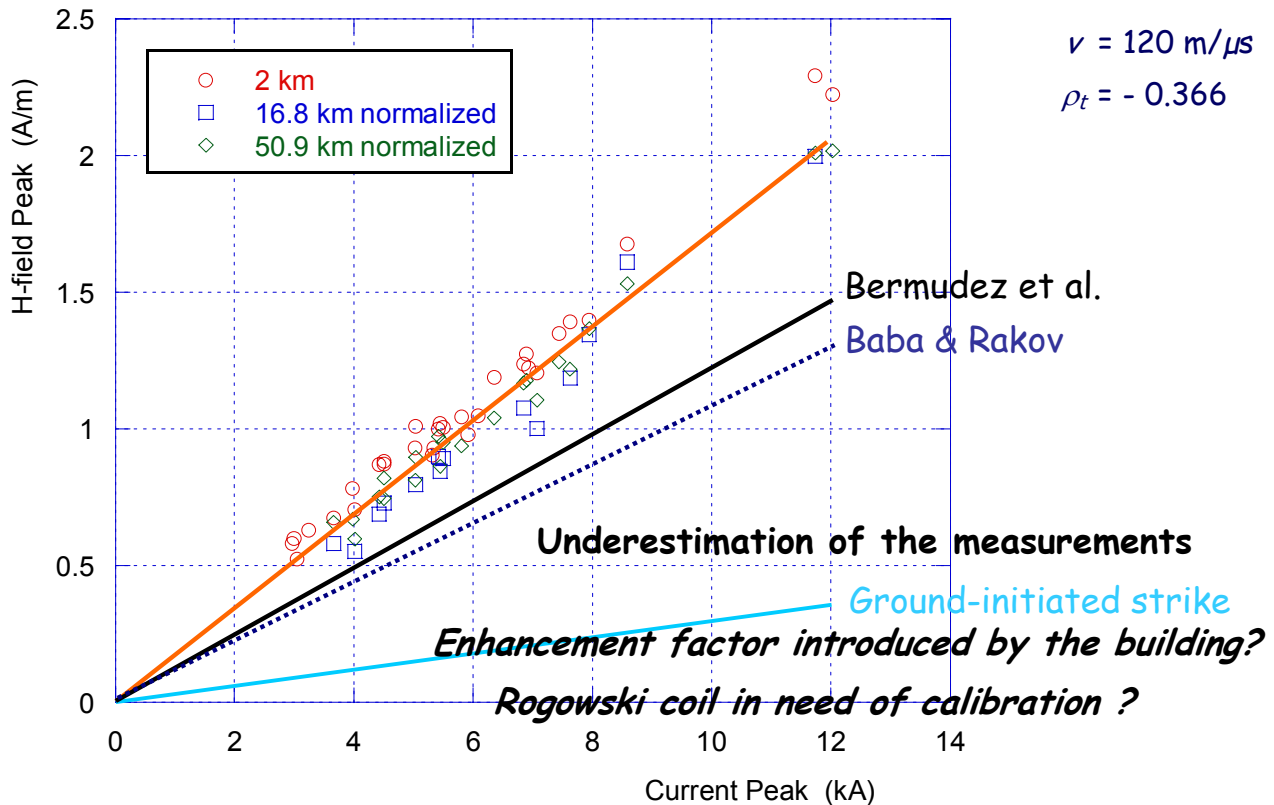
$$k'_{tall-2} = 1 + c/v = 3.5$$

- Lumped-voltage-source approach
- Engineering TL model
- Current reflections traveling at speed v



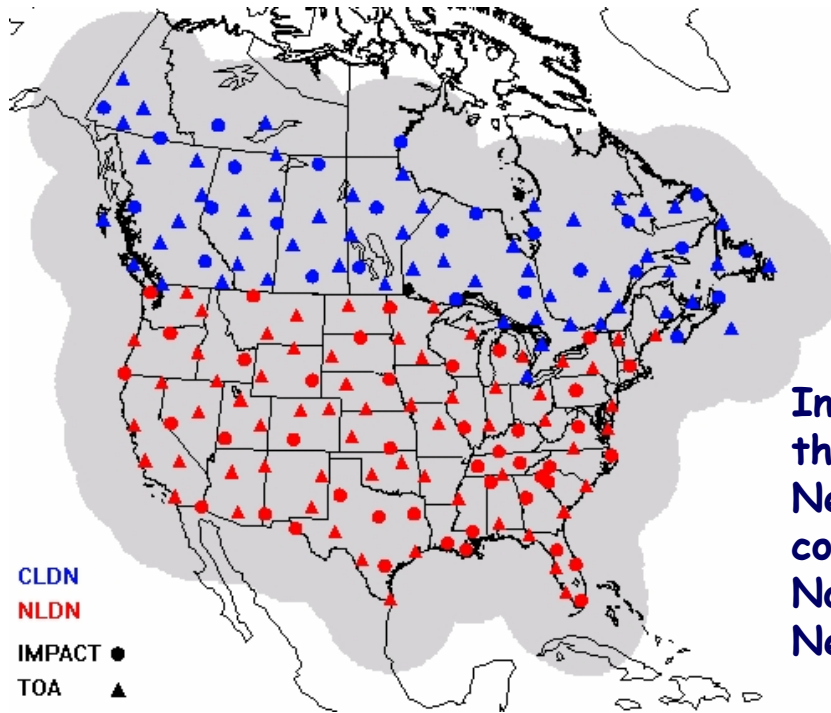


Tall-tower correction factor k'_{tall}





North American Lightning Detection Network



In 1998, Environment Canada set up the Canadian Lightning Detection Network (CLDN), which runs in conjunction with the NALDN as the North American Lightning Detection Network (NALDN).

(Courtesy of Kerry Anderson -
Canadian Forest Service Edmonton, Alberta)

Introduction

Toronto 2005

Factor k'_{tall}

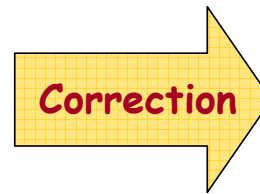
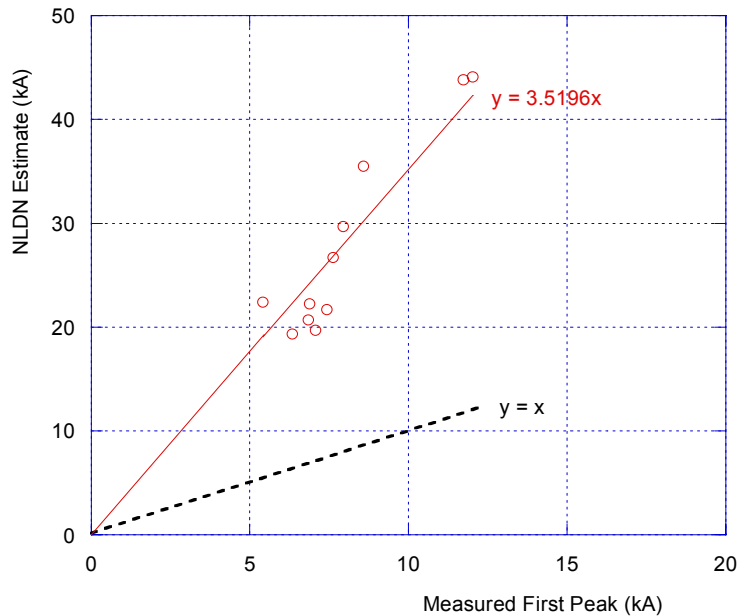
NALDN

Conclusions



Comparison with NALDN data

NALDN current estimates



[Bermudez et al., 2005]

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

[Baba & Rakov, 2007]

$$k'_{tall-2} = 1 + c/v = 3.5$$

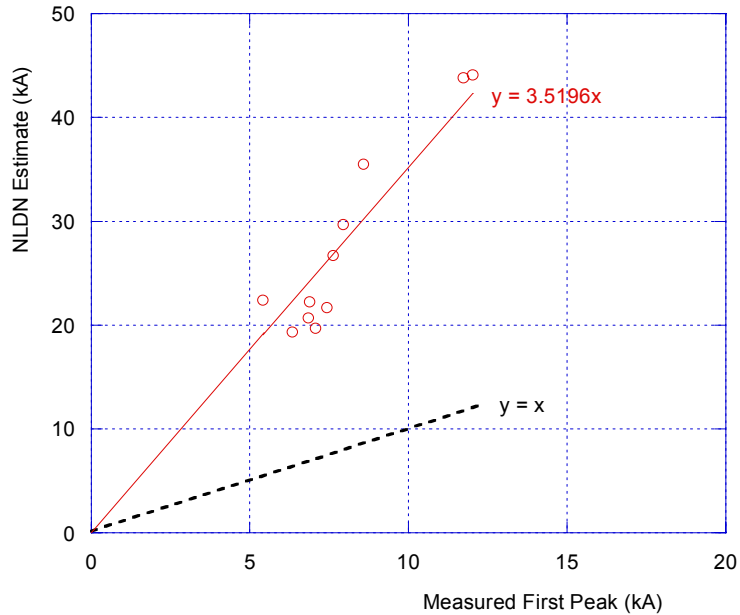
$$v = 120 \text{ m}/\mu\text{s}$$

$$\rho_t = -0.366$$

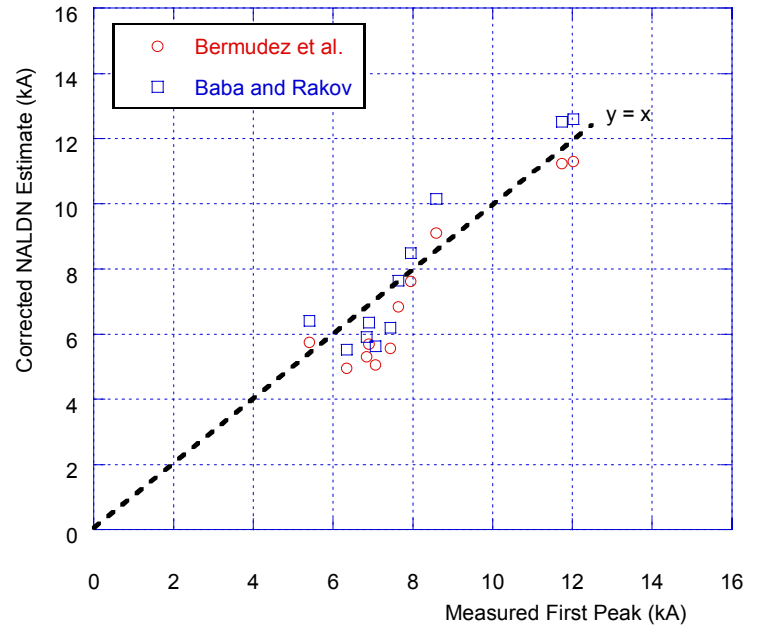


Comparison with NALDN data

NALDN current estimates



After correction



[Bermudez et al., 2005] $k'_{tall-1} = \frac{1 + (1 - 2\rho_t) c/v}{1 - \rho_t} = 3.9$

[Baba & Rakov, 2007] $k'_{tall-2} = 1 + c/v = 3.5$



Conclusions

- The presence of an elevated strike object enhances the radiated electromagnetic field peaks.
- As a result, NALDN overestimates the actual lightning current peaks.
- The presence of an elevated strike object should therefore be taken into account (factor k'_{tall}).
- As opposed to lightning strikes to ground, the far-field - current relationship for strikes to a tall structure is not sensitive to the value of the return-stroke speed.
- The NALDN estimates can be successfully corrected through the factor k'_{tall} , for which two different formulations have been presented.