



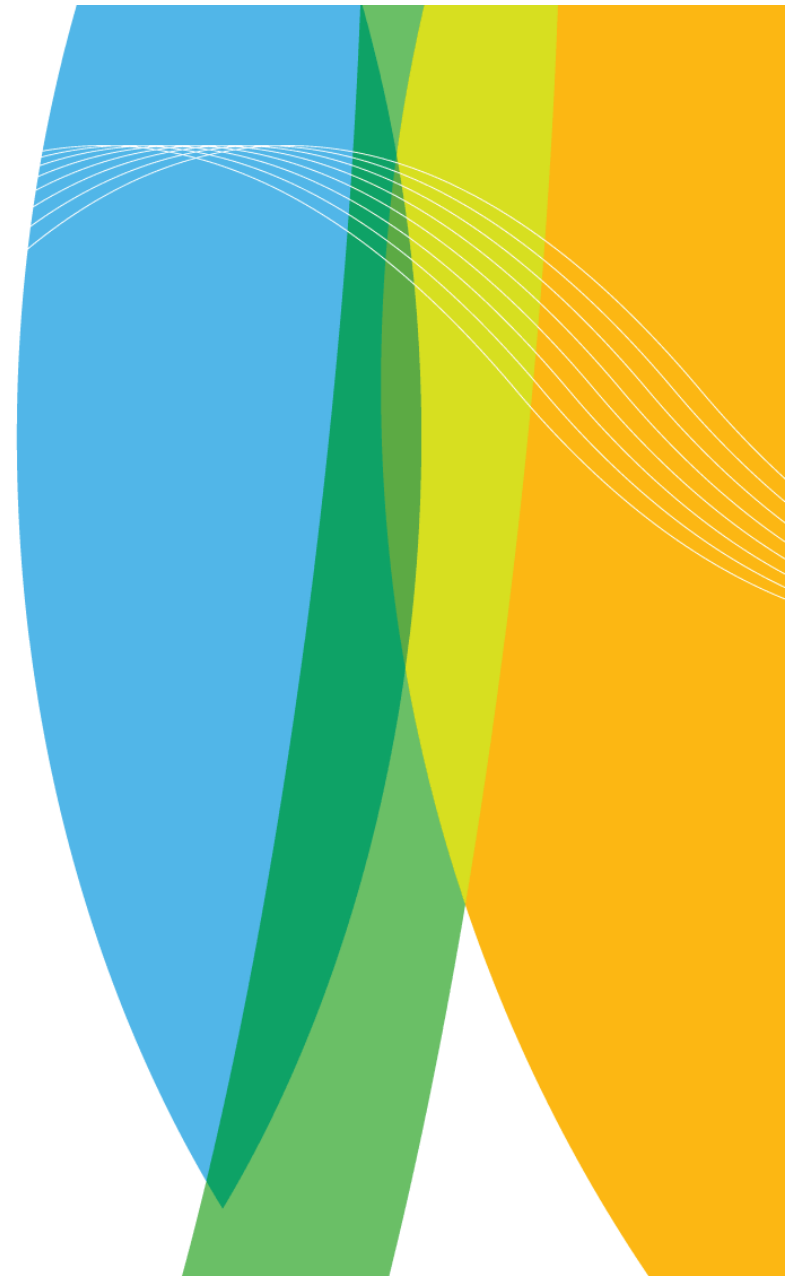
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A case study update of LF/VHF relations of located lightning

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Introduction - 1

Finland is covered by about 30 IMPACT-type LF sensors (NORDLIS network) for ground strokes,

and 3 SAFIR LF+VHF sensors in SW Finland:

- interferometric VHF antennas for cloud discharges (“events” or “points”)

- LF antennas for time-of-arrival data to the IMPACT network

LF data: LFG classified as ground stroke, LFC cloud discharge

In 2008, VHF sensitivity has been increased: significantly more points detected – virtually all LF flashes now accompanied by VHF points in SW Finland



Introduction - 2

Purposes of this study:

- how temporally coincident/correlated LF and VHF give different views to a flash
- e.g. VHF points give estimates to flash duration and extent
- outliers may be better identified

Data set: one hour 00-01 UTC Aug 18, 2008

- temporal groups (“flashes”) selected manually from a time-ordered file – about 600 flashes
- large spatial scatter was allowed to reveal data quality and nature of outliers

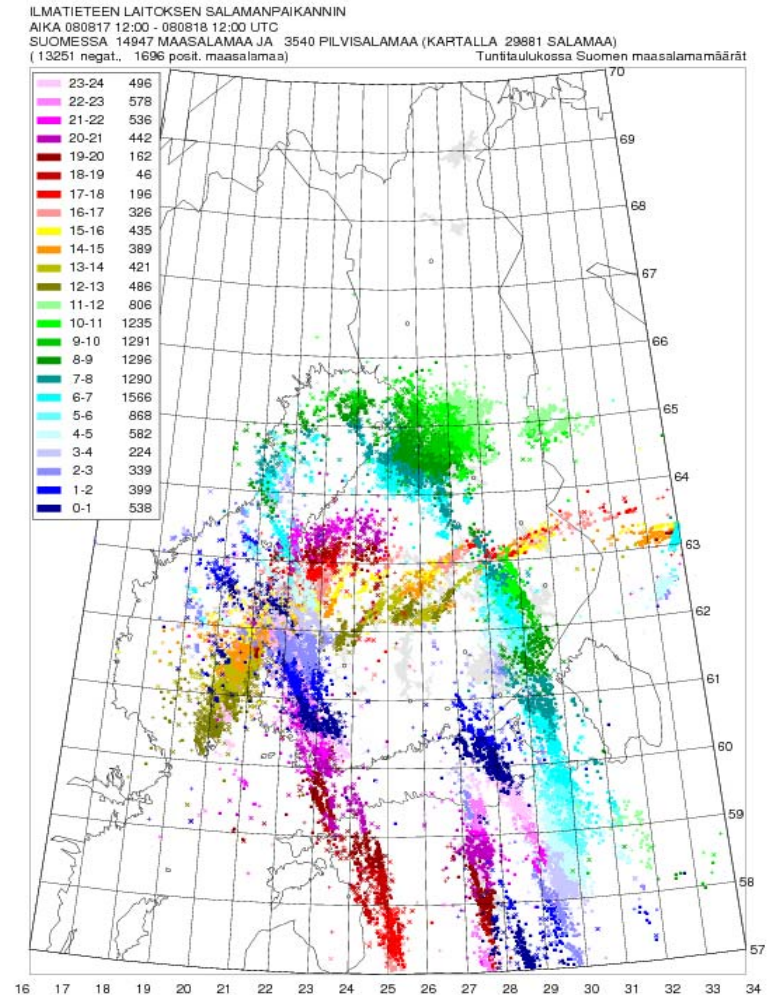


Episode: map shows located LF ground flashes (first strokes) during Aug 17-18, 2008.

Time development obscured by overlap of two days

Dense clusters and stray flashes – generally, all stray flashes are not outliers

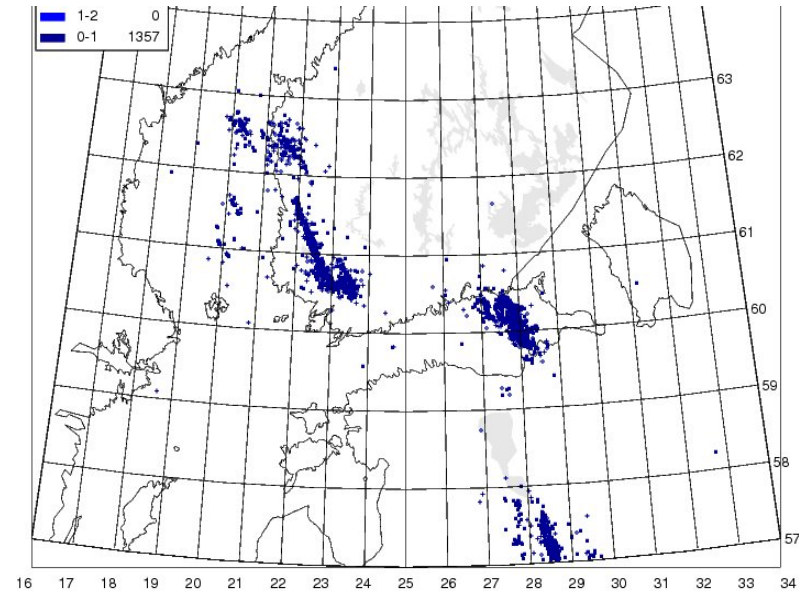
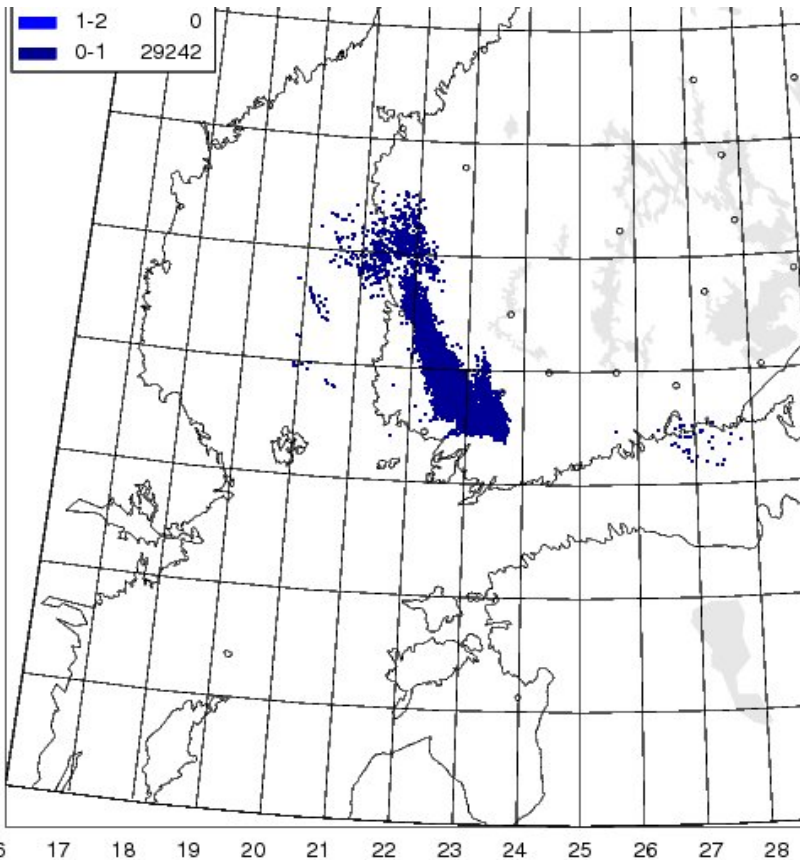
The case-study period (Aug 18, 00-01 UTC) is shown in dark blue





VHF points (left); LF strokes (right)

00-01 UTC; area around 62N not used (far from VHF sensors)





Example of LF-VHF flash (problematic):

9 LF strokes and 56 VHF
points during 0.13 s

LF1 (-30 kA C) coinc with VHF
LF2 (+28 G), LF3 (-13 C) coinc, 0.4
ms after LF1

LF4 (-142 G)

LF5 (+30 G)

LF6 (-20 G)

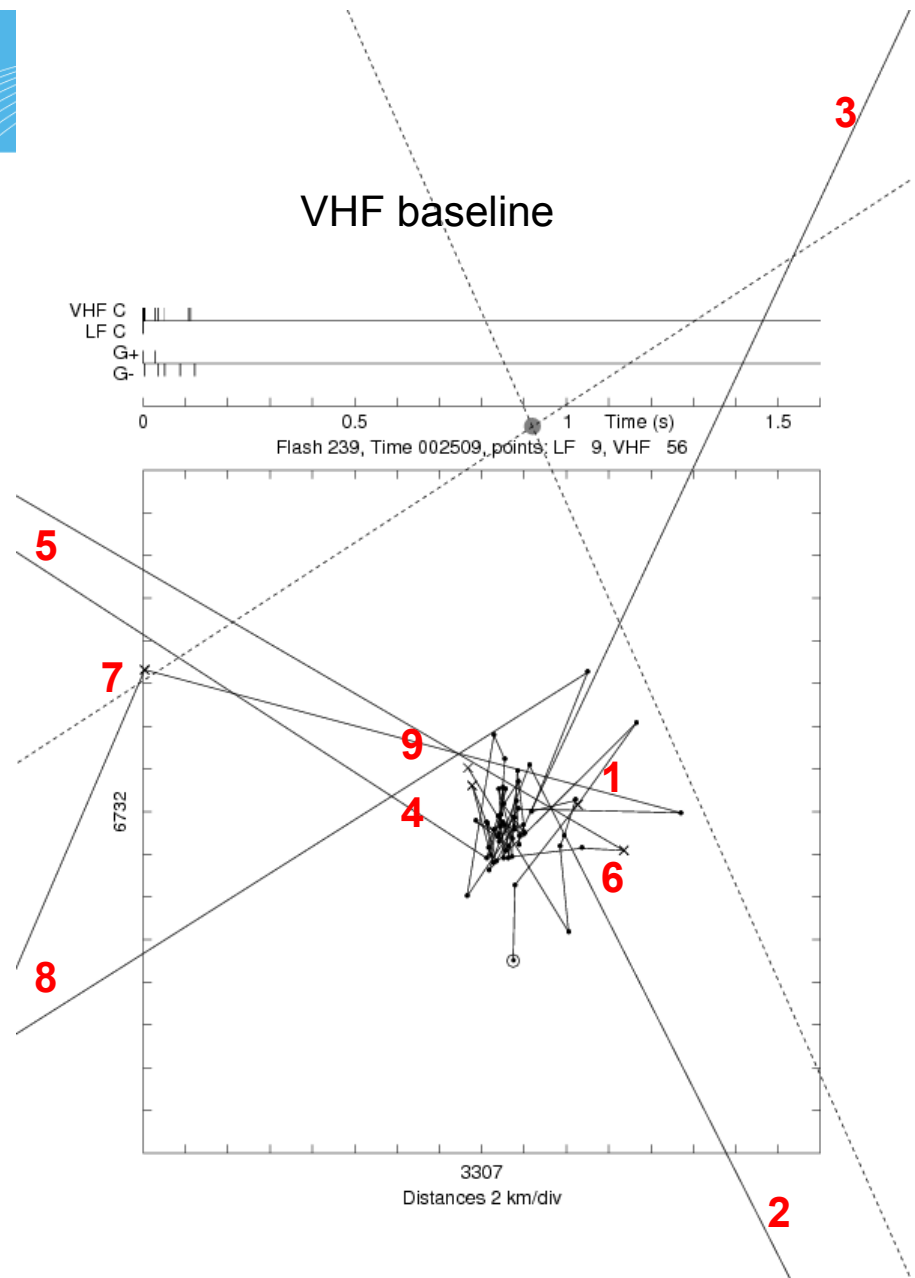
LF7 (-30 G)

LF8 (-29 G)

LF9 (-12 G)

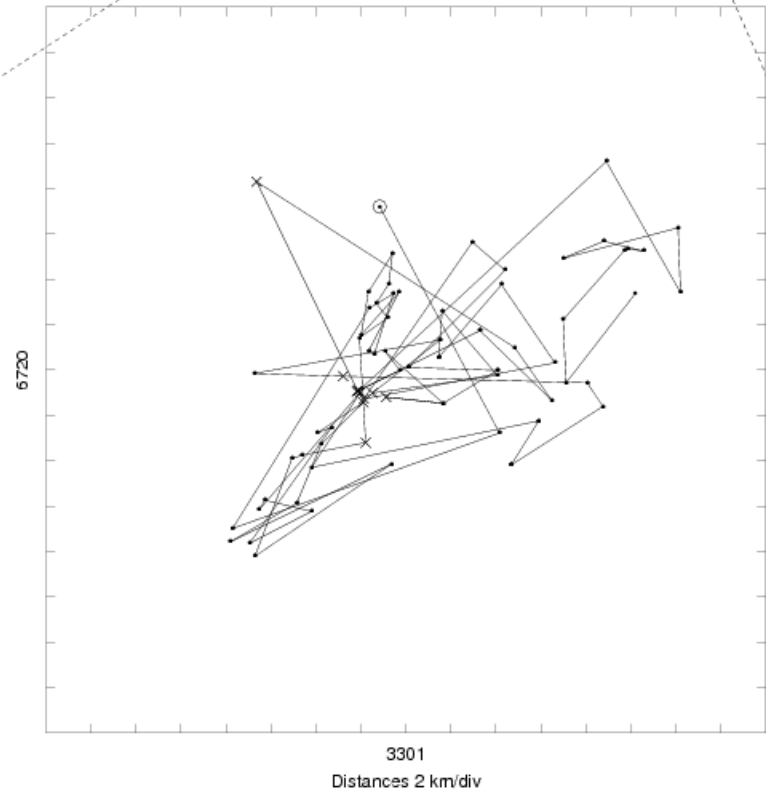
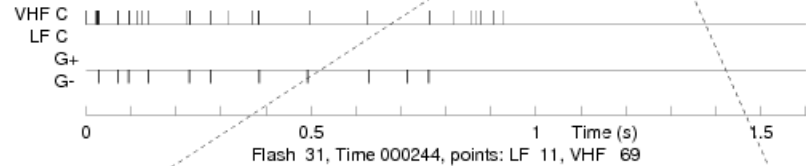
Physically: 5-stroke neg. flash and
4 strokes cloud/outlier

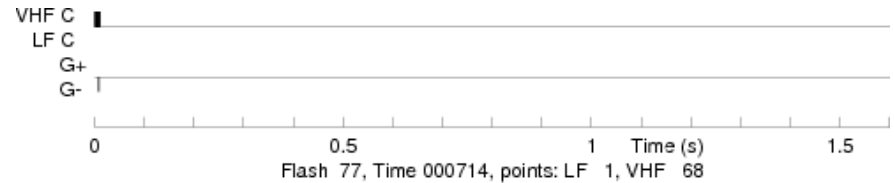
Reported: 3-stroke flash (4,6,9) +
six single-stroke: apparent increase
of detection efficiency (7 vs 1 gnd)!



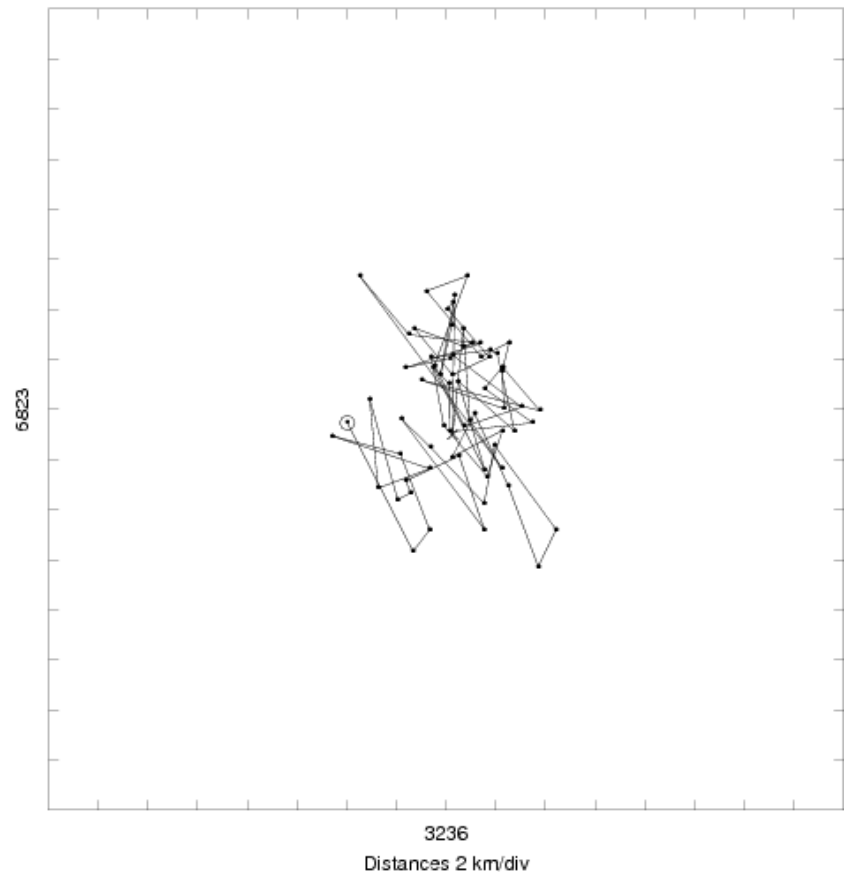


- In some cases, the flashes are long, abundant with LF strokes and VHF points, and fairly coherent spatially
- Extent is defined as the smaller VHF diameter to avoid the effect of stray points (here, about 12 km)





- In some cases, the VHF burst is tight and short
- here 60 VHF points precede the LF stroke, followed by 8 VHF
- spatial VHF extent is typical, about 10 km





Statistics – cloud flashes

VHF-only cloud flashes (< 10 p. ignored) 227

- 39 points / flash
- duration 0.42 s
- extent 9.7 km

VHF + 1 LFC cloud flashes 44

- 42 VHF/flash
- duration 0.40 s
- extent 9.9 km
- LFC stroke position 11
- LF is first point in 27 % (almost solely positive)



Statistics – ground flashes

VHF + one LFG, or LF > 1: 334

- LF-multiplicity 3.05
- 51 VHF/flash (single-stroke: 42)
- duration 0.47 s (single-stroke: 0.40 s)
- extent 9.1 km
- first LF stroke position 23
- LF is first point in 27 %
- LF occurs only after the VHF points: 8 %



Conclusions

- Cloud/ground flash ratio around 1
- VHF-based duration 0.4-0.5 s (range 0.01 – 1.0 s)
- VHF-based horizontal extent about 10 km
- Temporally dense clusters of cloud points: often stepped leader (tens of VHF, 10 ms); LF is first point in $\frac{1}{4}$ of ground flashes: VHF is also inter-stroke and post-stroke activity
- Temporally coincident (0.0-0.1 ms) outliers are often tens of km astray; about 10 % of strokes are spurious and may be reported as separate flashes due to spatial distance
- No easy method to automatically identify and remove all kinds of outliers