

* Cross-comparison tools for LIS, LMA, and VLF/LF Ground-based Network Data

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with help from:

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GLM Stakeholders Workshop 2014

* Context

* Requirement

Ground-base lightning observations are needed to help create GLM proxy and ground-validation datasets over large continental and oceanic regions

* Some Approaches

* “bulk statistical analysis of datasets at the cell flash-rate level

* Detailed stroke/pulse inter-comparisons to understand what is seen uniquely and in-common by various data sources (*this work*)

* Issue

* LLS performance for CG strokes and cloud pulses must be characterized before it can be intelligently applied

* Location accuracy

* Detection efficiency

* Type classification (CLD/CG)

* Sub-context: CHUVA LLS inter-comparisons

* What sorts of tools?

* Exploration Tools

- * Described in CHUVA Workshop abstract ([Cummins et al.](#))
- * Similar to DLR tools
- * Detailed flash-level visual exploration
 - * LIS groups
 - * LMA sources
 - * VLF/LF strokes and cloud pulses

* Statistical LLS Inter-comparison Tools

- * Stroke/pulse level
- * Flash level
- * Available for community use (supported by NASA)
 - * Fully documented

* LLS Inter-comparison Tool

- * Coded in Matlab
- * Stand-alone executables can run on Unix, Linux, and Windows
- * Can specify datasets and related parameters in a "cfg" file using a text editor...

```
# sample Spec file for LLS comparison
# written by Ken Cummins, July 2011

# Definition of possible fields in each data file
#   Date (D): date yyyy-mm-dd
#   Time (O): Occurrence time (hh:mm:ss.mmmmmm)
#   Lat (L): decimal degrees
#   Lon (G): decimal degrees
#   Ip (I): Peak Current (kA)
#   LocErr (E): position error (km)
#   ChiSq (C): Chi-square or consistency parameter
#   NSR (N): integer number of sensors reports
#   Type (T): G or C
#   Skip (S): field to skip
#

Ref_file: data/sampleRef.asc
Ref_fmt: DOLGIECTN

Test_file: data/sampleTest.asc
Ref_fmt: DOLGIECTN

# DT is the nominal correlation time in microseconds
DT: 100.

# DD is the nominal spatial correlation distance in km
# (should be at least DT*c = DT(sec) * 3*10^8(m/sec) =
DT(uS)*0.3(km/uS)
DD: 30.0

# MATCH is a true/false requirement for type-matching
MATCH: false

# START is the start data/time
# If not defined, starts at the beginnig of the later-start file
START: 2011-07-01@00:00:00

# STOP is the stop date/time
# If not defined, stops at the end of the earlier-stop file
STOP: 2011-07-30@23:59:59

# LATLON is the lat-lon rectangular boundry for analysis region
# in decimal degrees ( LL_lat LL_lon UR_lat UR_lon )
# If not defined, the whole region is used
LATLON: 36.,137.,41.,142.
```

* Tool “Outputs”

* Analysis “Sheets”

* Sheet 1:

- * Requires date, time, lat, lon, and (optionally) type (CG/CLD pulse)

* Sheet 2:

- * Requires peak current estimates

* Sheet 3:

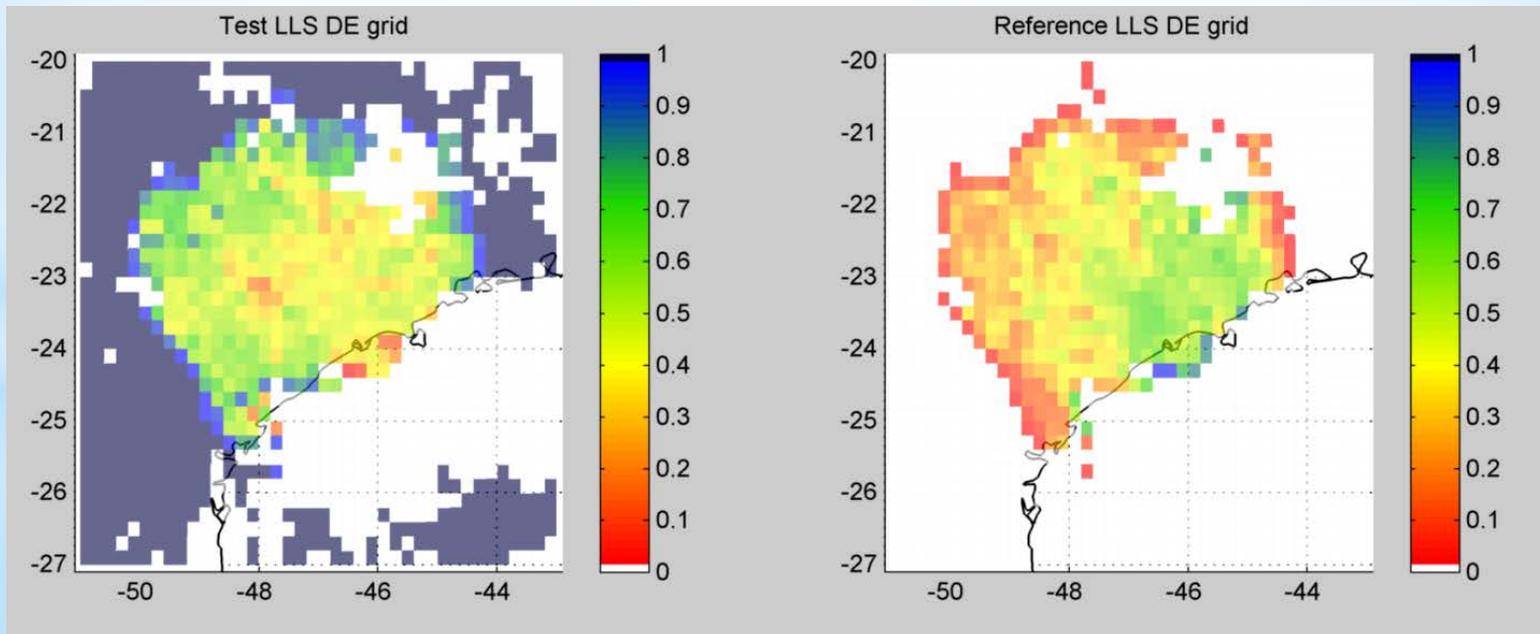
- * Requires quality-related parameters
 - * location error estimate
 - * # sensors reporting the stroke/pulse

* Spatial Detection Efficiency

* Flash Analysis

* Spatial Detection Efficiency

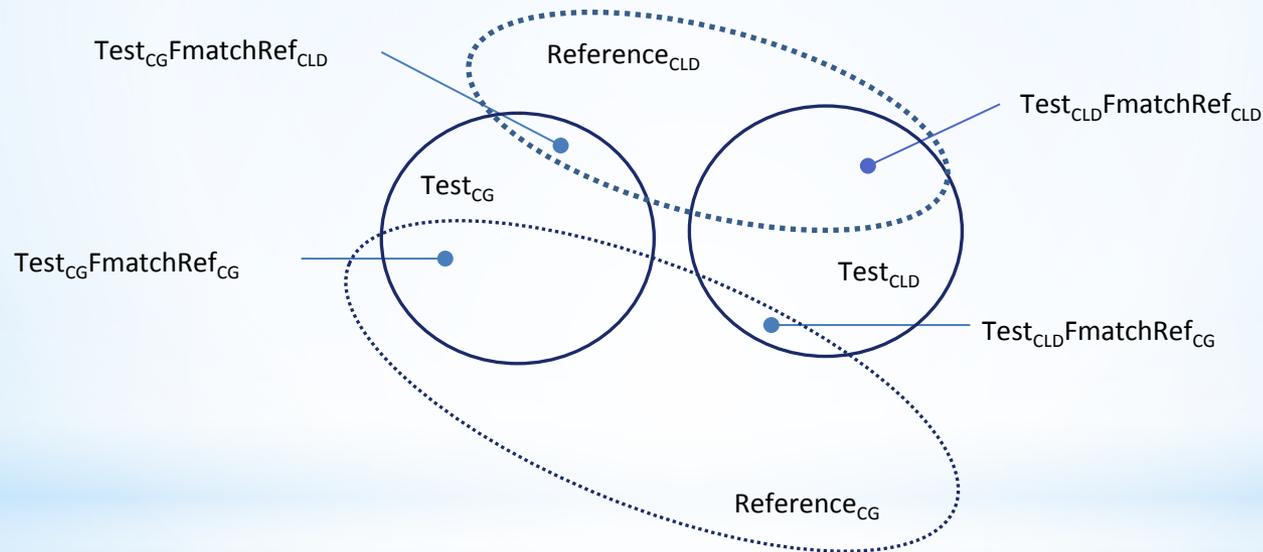
- * Observe spatial variation in DE
 - * Combined for cloud pulses and CG strokes
- * Helpful for selecting LLS comparison regions
- * Automatic global country/coastline
- * Example: CHUVA TLS200cg (ref) and GLD360 (test)



* Flash Analysis Overview

* Definition of flash DE

- * This is complicated by the fact that LLS's frequently disagree about the discharge type (cloud vs. CG)



Examples:

$$DE_TestCGF = 100. * (Test_{CG} FmatchRef_{CG} + Test_{CLD} FmatchRef_{CG}) / (Ref_{CG} F);$$

$$DE_TestAll = 100. * allMatchTest / (Ref_{CG} F + Ref_{CLD} F);$$

[Details](#)

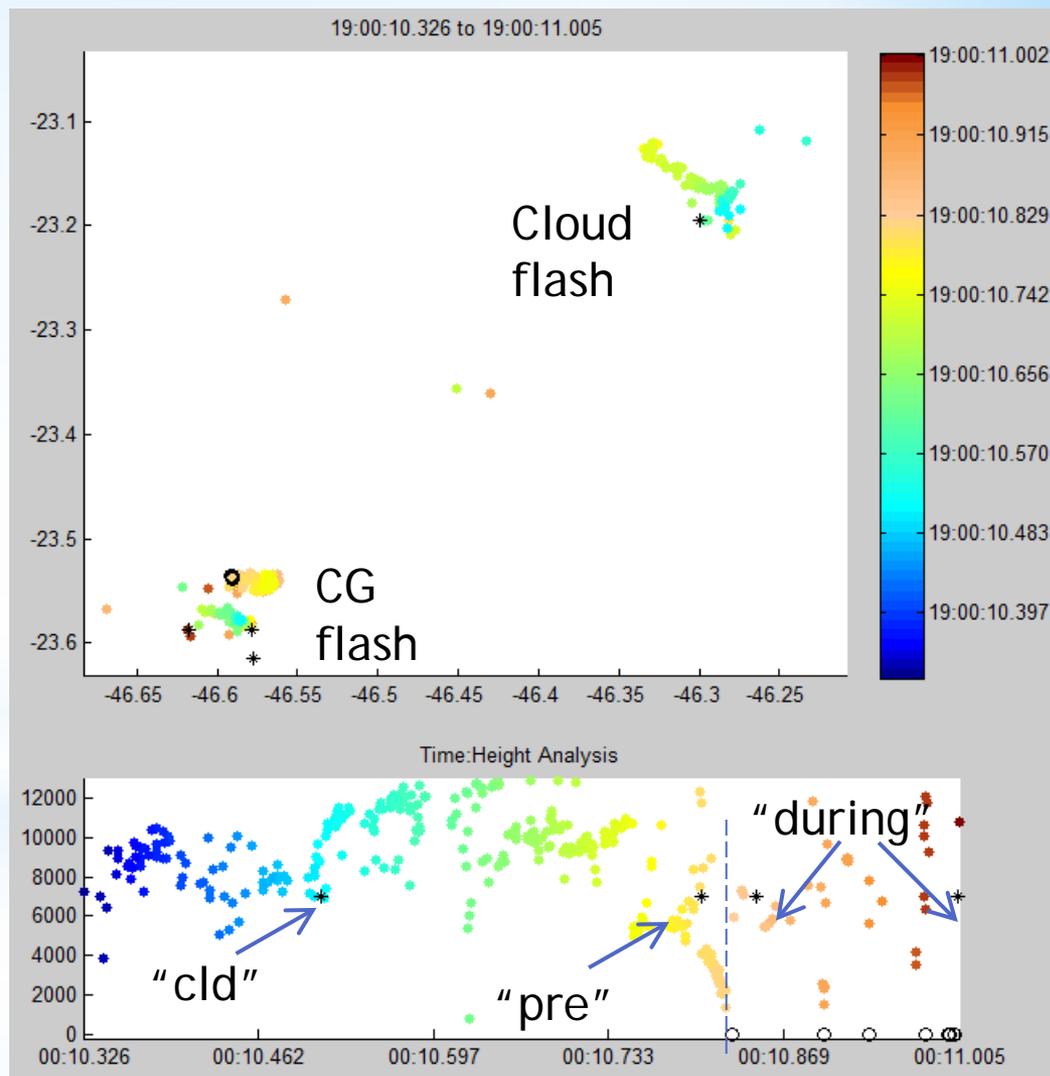
* Additional Flash Analysis: where (*in time*) are the LLS cloud pulses detected?

* The Flash Analysis includes a temporal analysis for each network

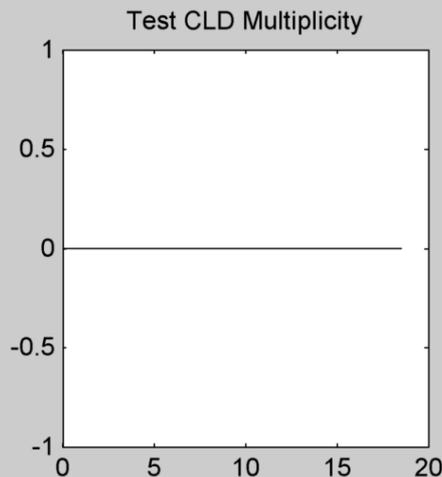
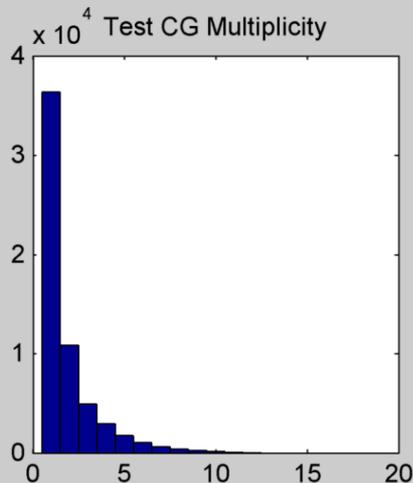
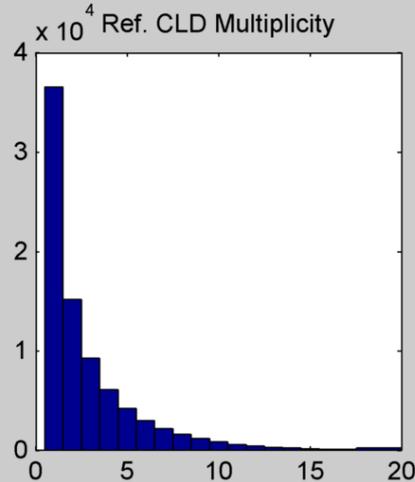
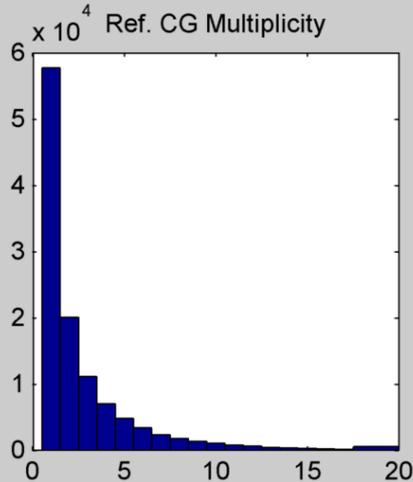
* Are they part of a cloud flash?

* Are they part of a CG flash?

* What part of a CG flash?



* Flash - CHUVA LINET vs. GLD360



Flash Analysis

max. ISI: 3.000000e-01 max. Rng: 30.0

----- Reference Network -----
 ---Type--- Flashes Mult PctFI
 CG 114774 2.73 58.2
 CLD 082542 2.87 41.8

*** IC:CG Flash Ratio 0.72

---Type--- Events Mult PctCLD
 CLD-in-CG 210471 1.83 37.2
 PreCG 118640 1.03 21.0

Flash Detection Efficiency
 refCG testCG refCLD testCLD refAll testAll
 82.9 31.2 NaN 14.9 82.9 24.4

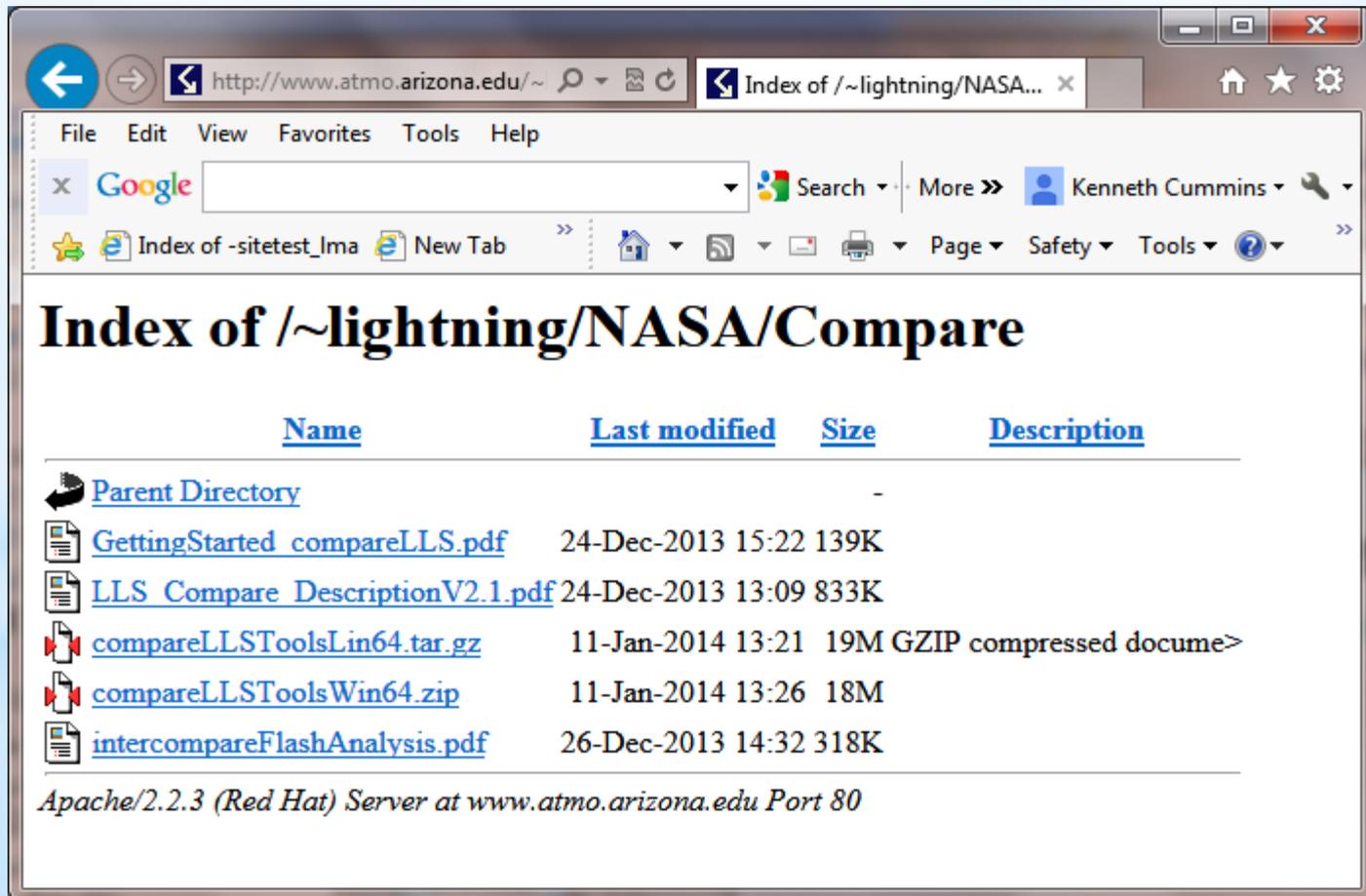
----- Test Network -----
 ---Type--- Flashes Mult PctFI
 CG 060043 1.95 100.0
 CLD 000000 NaN 0.0

*** IC:CG Flash Ratio 0.00

---Type--- Events Mult PctCLD
 CLD-in-CG 000000 0.00 NaN
 PreCG 000000 0.00 NaN

* How to get the stuff...

<http://Atmo.Arizona.edu/~lightning/NASA/Compare/>



The screenshot shows a web browser window with the address bar displaying `http://www.atmo.arizona.edu/~lightning/NASA/Compare/`. The browser's menu bar includes File, Edit, View, Favorites, Tools, and Help. A search bar with the Google logo is visible. The main content area displays the title "Index of /~lightning/NASA/Compare" and a table of files. The table has columns for Name, Last modified, Size, and Description. The files listed are:

<u>Name</u>	<u>Last modified</u>	<u>Size</u>	<u>Description</u>
Parent Directory	-	-	-
GettingStarted compareLLS.pdf	24-Dec-2013 15:22	139K	
LLS Compare DescriptionV2.1.pdf	24-Dec-2013 13:09	833K	
compareLLSToolsLin64.tar.gz	11-Jan-2014 13:21	19M	GZIP compressed docume>
compareLLSToolsWin64.zip	11-Jan-2014 13:26	18M	
intercompareFlashAnalysis.pdf	26-Dec-2013 14:32	318K	

At the bottom of the page, it says: *Apache/2.2.3 (Red Hat) Server at www.atmo.arizona.edu Port 80*

* Example Use: LIS-referenced DE

* Simple question: When LIS saw something, did others see it?

* METHOD:

- * Selected a “common” (small) region and time period

- * Region determined by LINET

- * Time period limit defined by TLS200

- * January 1 through March 27, 2012

- * Note: LINET is compromised during these times

- * Total Groups/Flashes were ~2900/300 in 13 overpasses

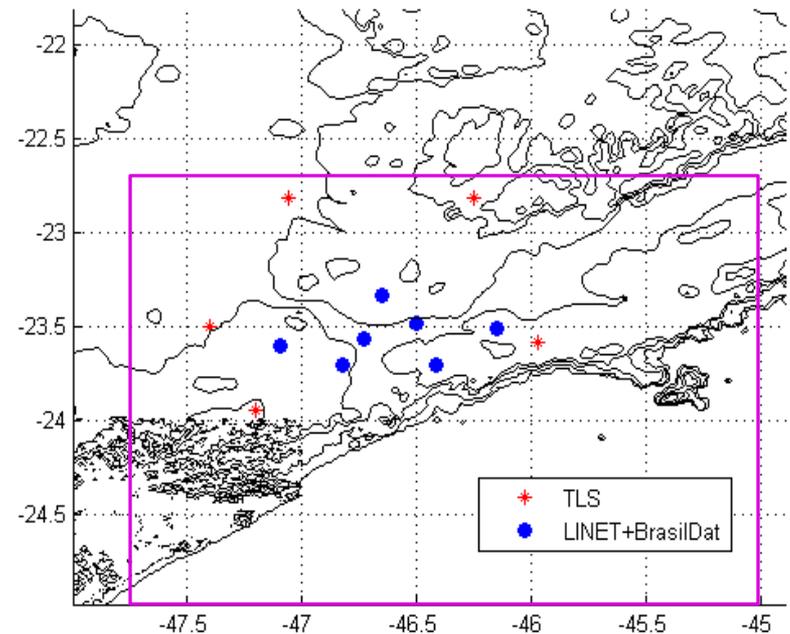
- * Use tools to compute group-referenced and Flash-referenced DE

- * Produce flashes from LIS Groups and LLS “events”

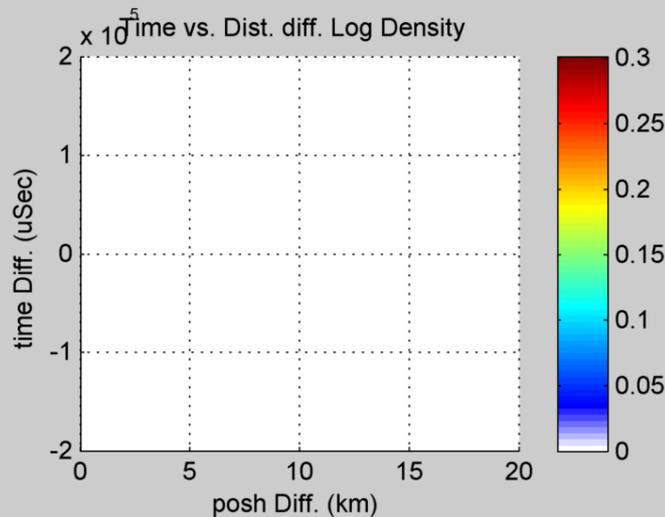
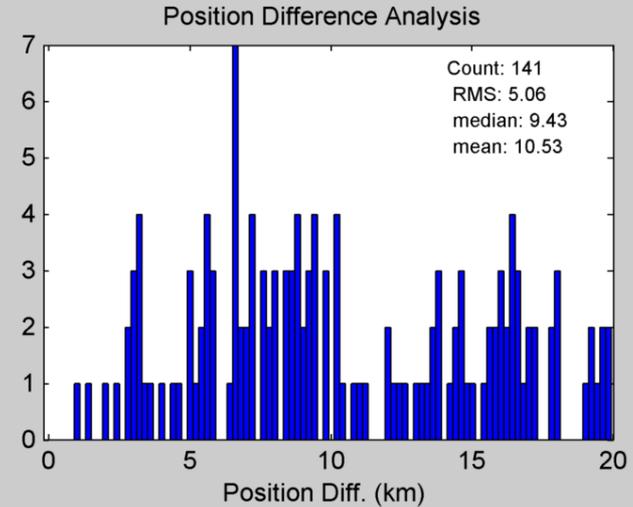
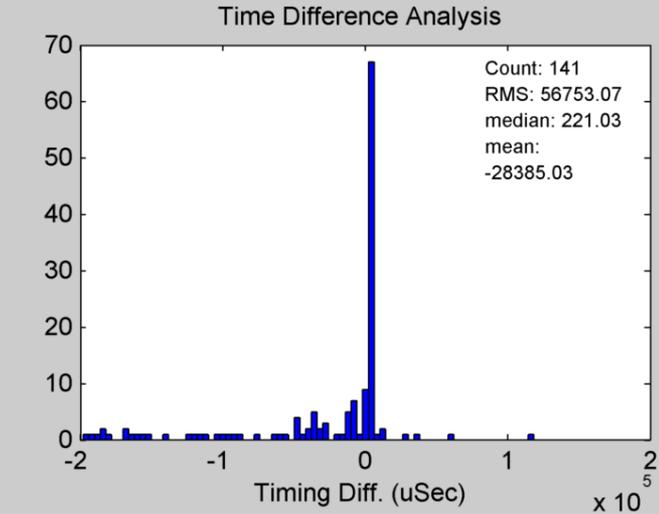
- * Multiple IPI/Distance Criteria for flash grouping: (200 ms/20 km; 500 ms/30 km; 500 ms /50 km for some long-range networks)

* Selection of the Analysis Domain

- * Smaller domain would not have enough LIS flashes (< 300)
- * The domain is quite large for LINET
- * confirmed that the LINET pulse/stroke DE, relative to TLS-LF-all, was not compromised over this domain



* Sheet 1 - LIS Groups vs. GLD360



LIS_GLD.cfg -- accum -- 09-May-2014 14:52:03
Reference File: LIS-LMA-2012-03-27_19_01_11_03152_LIS.txt
Test File: 2012.03.27.gld360.txt

Network	#CG / DE	#CLD / DE	#Corr / DE
Ref:	2707 / (0.5)	0 / (NaN)	141 / (0.5)
Test:	28890 / (5.2)	0 / (NaN)	141 / (5.2)

Classification Table: Test

	CG	CLD
Ref. CG	000141	000000
Ref. CLD	000000	000000

8898 rej. for separation distance 0 rej. for Type mis-match

* Flash Summary Statistics

Flash Grouping (IPI/Dist)	LLS Network	Relative Group DE	Relative Flash DE	Mean Groups/fl	Mean Mult. (G/C)	Nominal Sensor Baseline in test region
200/20	LINET	32.0	61	8.4	3.3/3.2	22-45 km
200/20	TLS-LF "all"	23	56	8.4	2.9/2.5	55-125 km
200/20	BrasilDat	15	45	8.4	1.8/3.3	~100 km
200/20	GLD360	5	17	8.4	2.4/0.0	>big
200/20	TLS-LF CG	6	13	8.4	3.3/0.0	55-125 km
200/20	StarNet	2	8	8.4	1.6/0.0	>big
200/20	WWLLN	1	2	8.4	1.7/0.0	>big
(estimated uncertainty of about +/-2%)						
500/30	LINET	32	67	9.2	3.5/3.4	22-45 km
500/30	TLS-LF "all"	23	67	9.2	3.0/2.8	55-125 km
500/30	BrasilDat	15	53	9.2	1.8/3.6	~100 km
500/30	GLD360	5	24	9.2	2.8/0.0	>big
500/30	TLS-LF CG	6	19	9.2	3.5/0.0	55-125 km
500/50	StarNet	2	14	10.3	2.0/0.0	>big
500/50	WWLLN	1	5	10.4	2.0/0.0	>big

* Comments from data contributors

* WWLLN

- * The small domain and small number of flashes result in uncertainty in the WWLLN findings. Analysis over a larger domain should be done

* LINET

- * During much of this time, only 5 of the 7 sensors were operational.
- * Leap-second issue with LIS data?

* BrasilDat

- * Typically, only 1-2 of the 7 “special” sites were operational, and the network was just being calibrated. The network is now working much better than it was during the CHUVA campaign. (the ~100 km baseline in the previous slide reflected the “functional” baseline during this study)

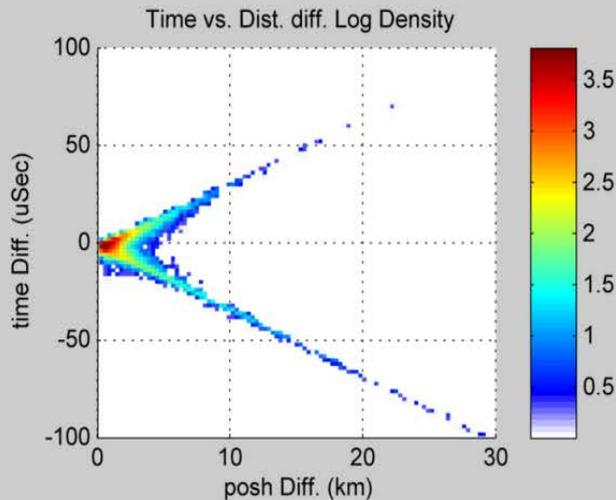
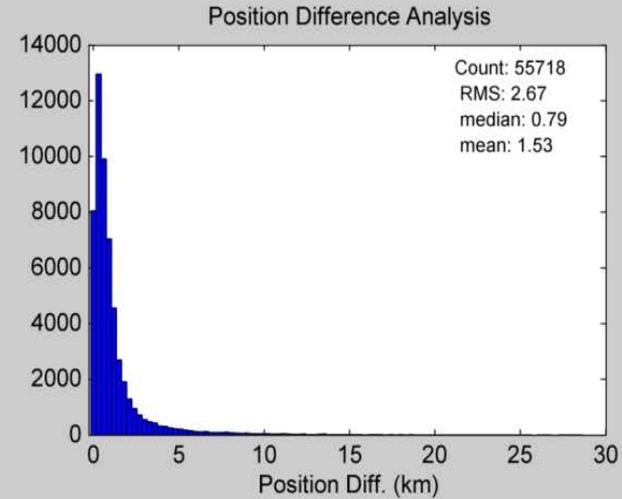
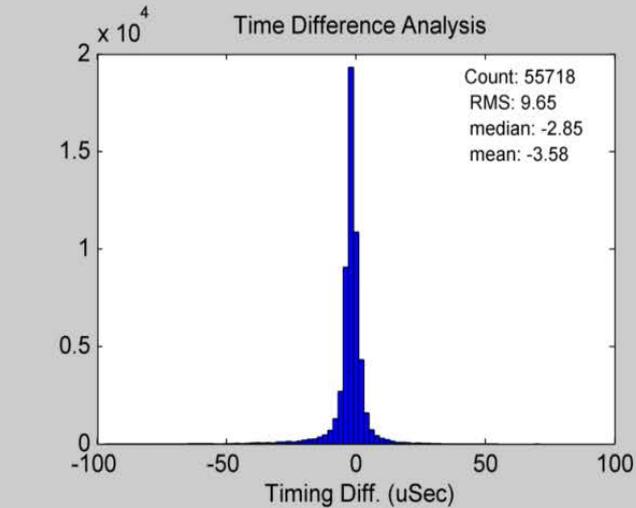
* Summary / Comments

- * LLS Relative Performance vs. LIS Total Lightning
 - * Wide variation in TL flash DE (few percent => ~70%)
 - * Short-baseline VLF/LF networks CAN detect a majority of TL flashes (but do not represent the spatial extent of big flashes)
 - * Note: Hartmut indicates that for days with all LINET sensors working, they would detect almost all LIS flashes that were within the network, as well as some flashes not reported by LIS
 - * Some long-range LF networks MIGHT be sufficiently good to allow statistical up-scaling of the data for mid-oceanic LIS proxy and validation activities

*End of talk...

*Thanks!

* Sheet 1 - two networks in Japan



SampleSpec.cfg 03-Nov-2013 15:09:11
 Reference File: data/sampleRef.asc
 Test File: data/sampleTest.asc

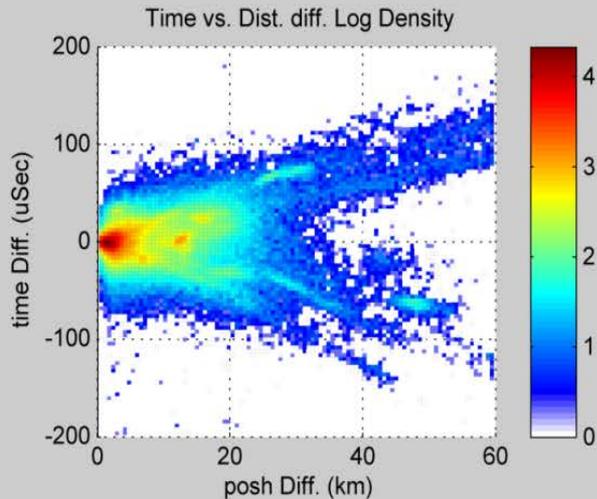
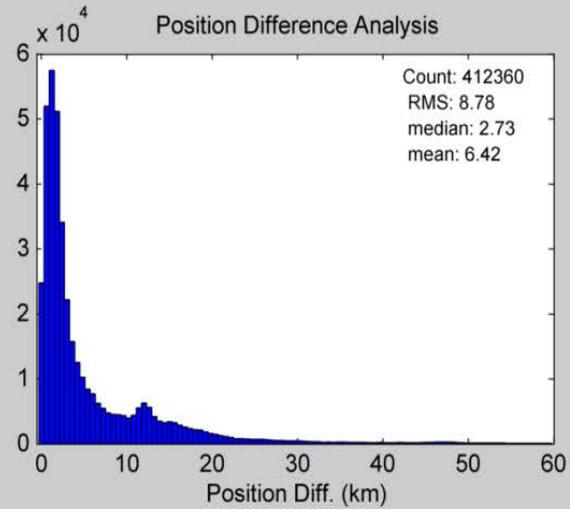
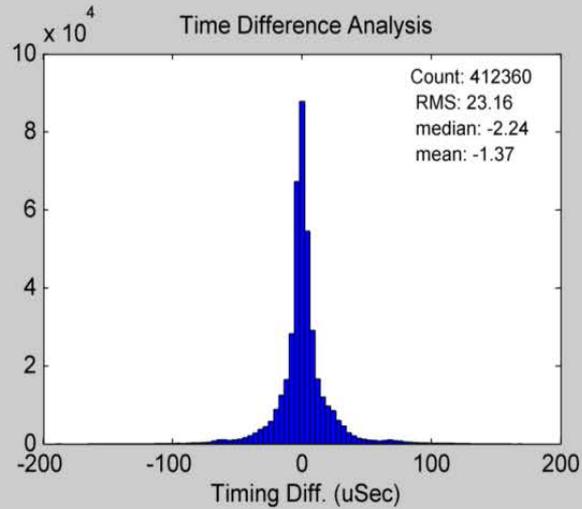
Network	#CG / DE	#CLD / DE	#Corr / DE
Ref:	62594 / (72.7)	2102 / (0.6)	55718 / (70.8)
Test:	74902 / (87.0)	3841 / (1.1)	55718 / (86.1)

Classification Table:

	Test	
	CG	CLD
Ref. CG	054461	000006
Ref. CLD	001228	000023

57 rej. for separation distance 0 rej. for Type mis-match

* Sheet 1 - GLD360 vs. NALDN



NLDN_GLDrepNew.cfg 04-Nov-2013 07:03:18
 Reference File: data/2011-08-04_NALDN.txt
 Test File: data/2011_08_04_gldCluster

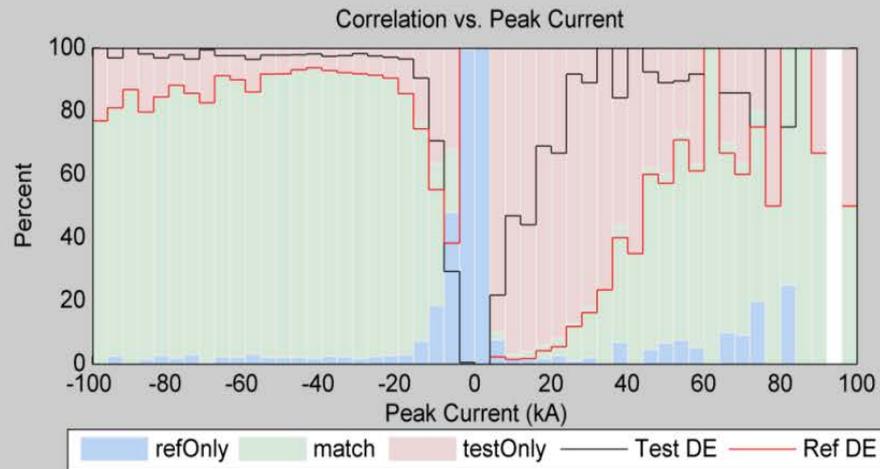
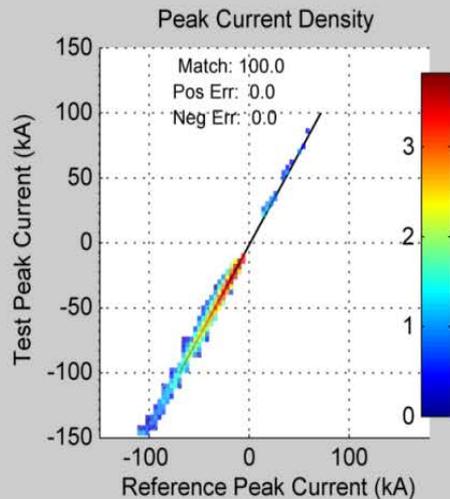
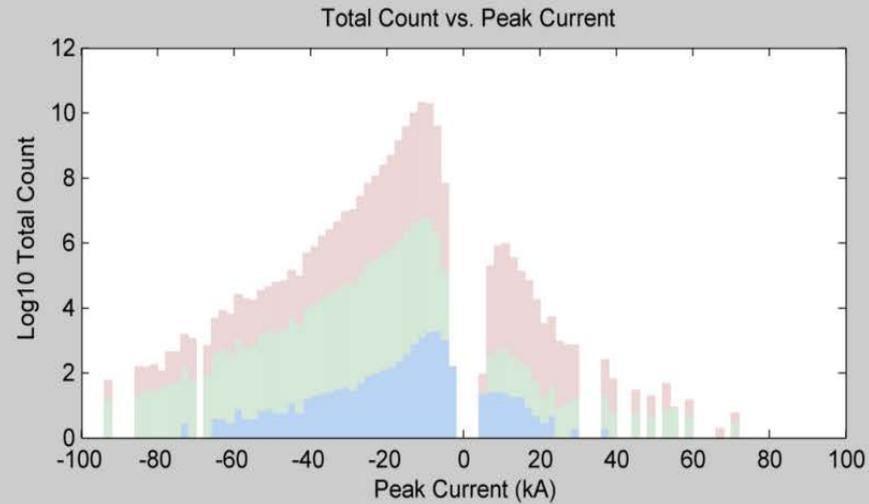
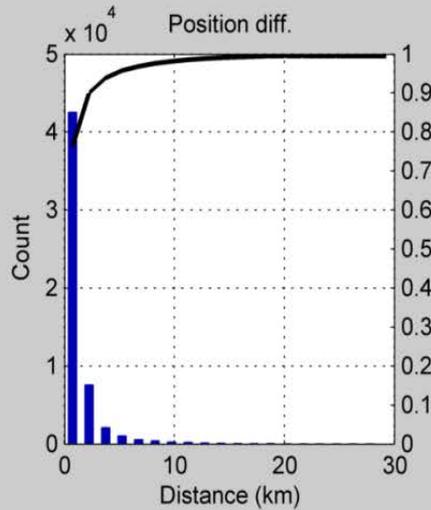
Network	#CG / DE	#CLD / DE	#Corr / DE
Ref:	820524 / (47.6)	639464 / (NaN)	412360 / (61.9)
Test:	665845 / (38.6)	0 / (0.0)	412360 / (28.2)

Classification Table:

	Test	
	CG	CLD
Ref. CG	316817	000000
Ref. CLD	095543	000000

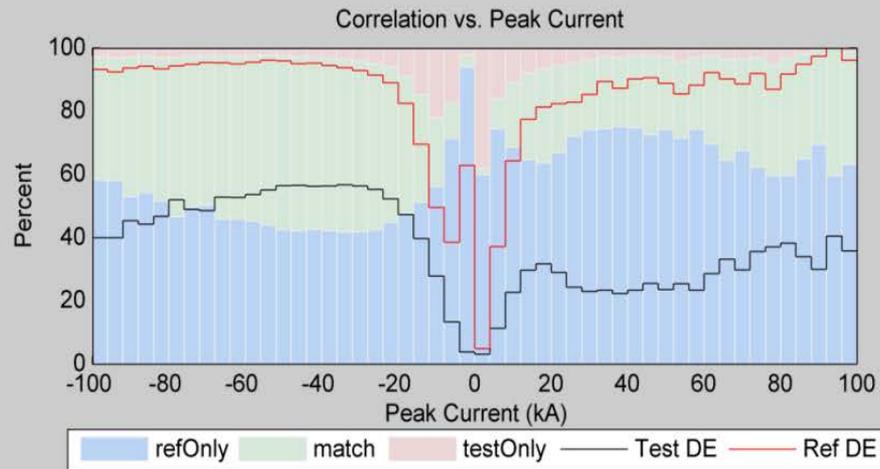
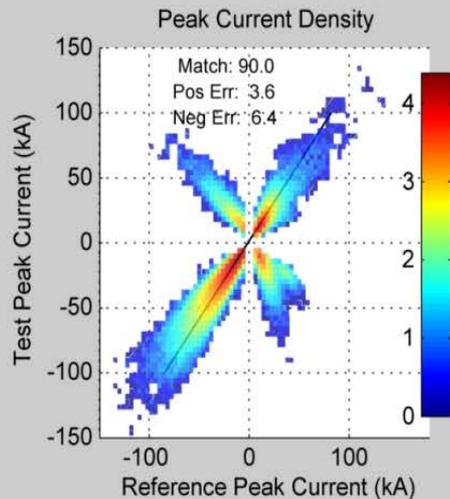
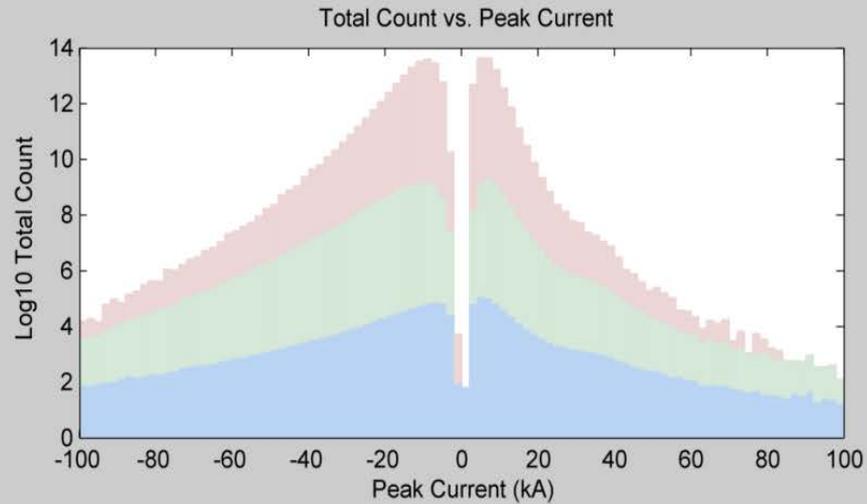
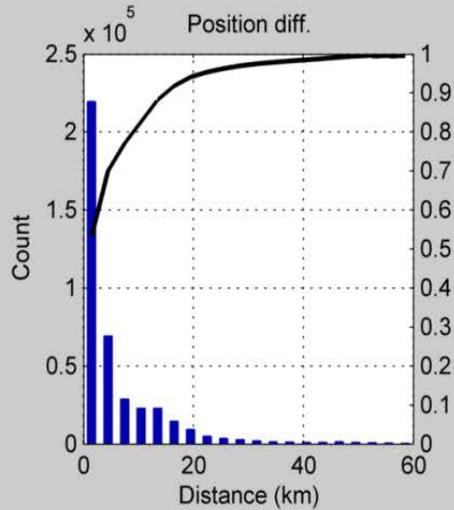
13334 rej. for separation distance 0 rej. for Type mis-match

* Sheet 2 - two networks in Japan



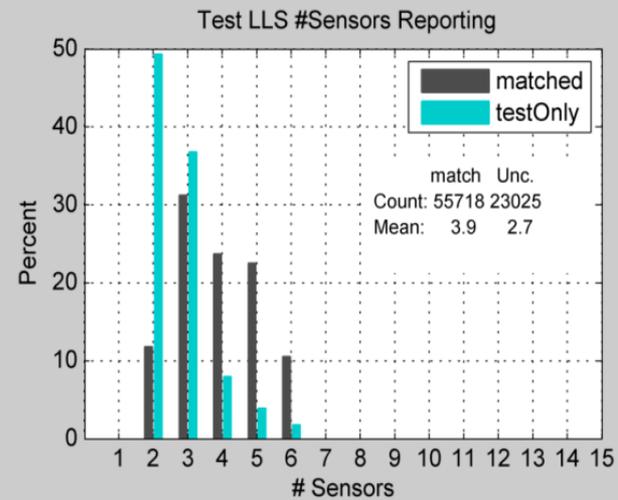
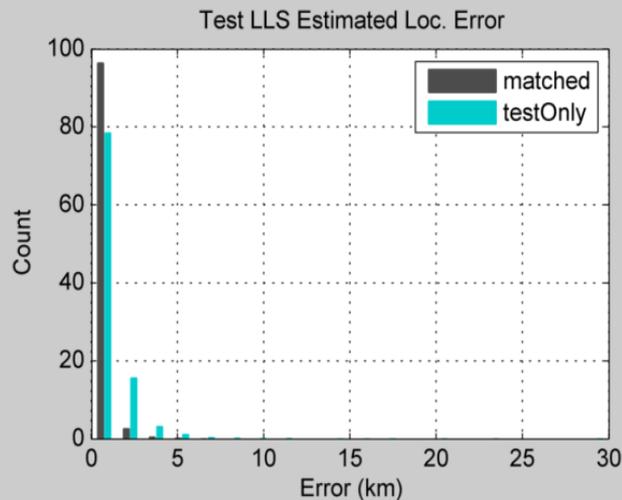
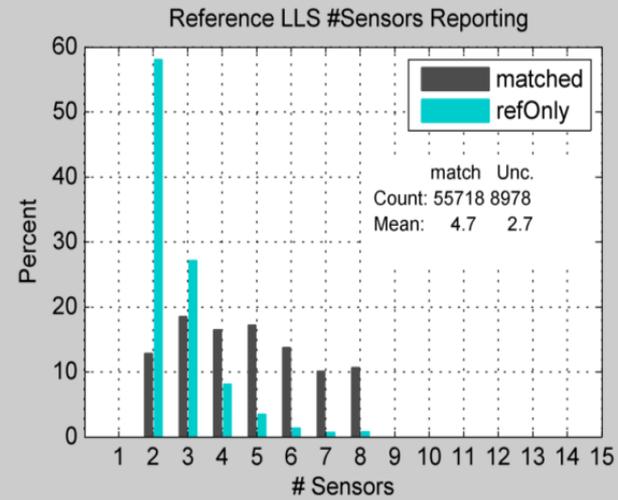
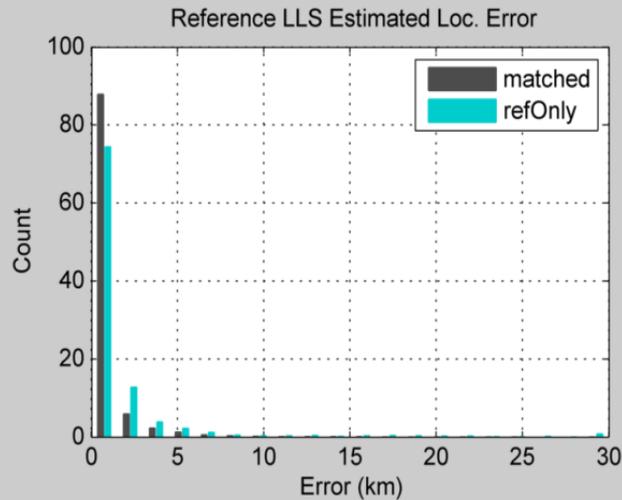
SampleSpec.cfg 03-Nov-2013 11:25:49 -- sampleRef.asc sampleTest.asc

* Sheet 2 - GLD360 vs. NALDN



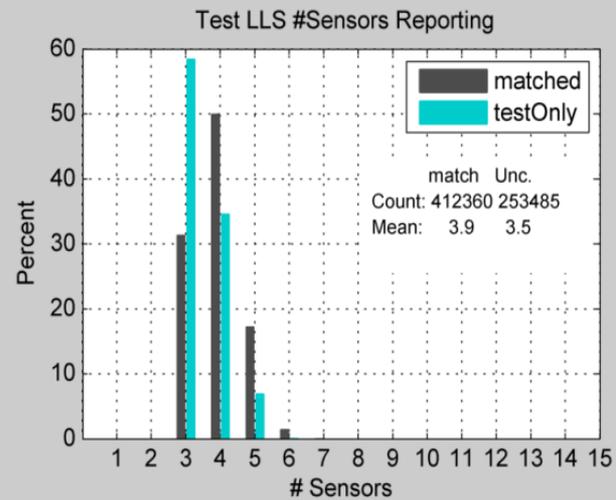
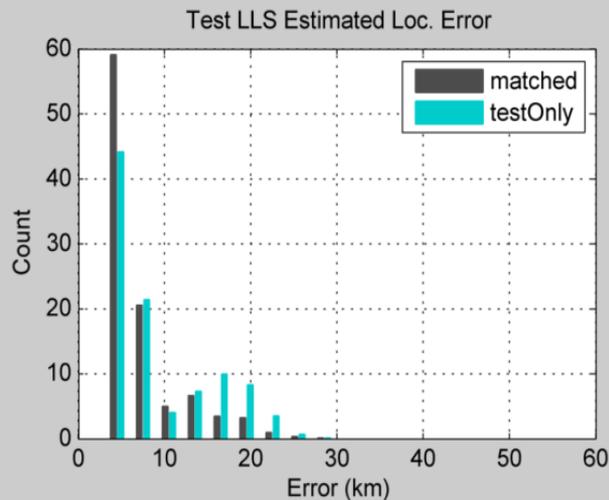
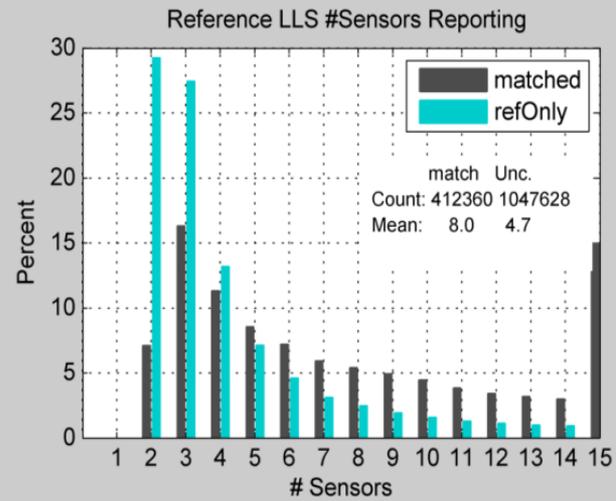
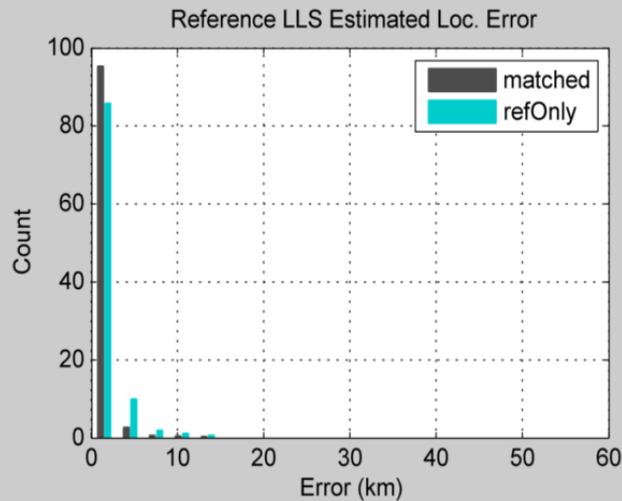
NLDN_GLDrepNew.cfg 04-Nov-2013 07:03:18 -- 2011-08-04_NALDN.txt 2011_08_04_gldCluster

* Sheet 3 - two networks in Japan



SampleSpec.cfg 03-Nov-2013 11:25:49 -- sampleRef.asc sampleTest.asc

* Sheet 3 - GLD360 vs. NALDN



* Flash Analysis Overview

- * Flash Grouping (within an individual LLS dataset)
 - * **New flash** is initiated if there are no “**active**” flashes within the max inter-pulse interval (IPI) and within the max separation distance (*typically 200 mS and 10 km for “accurate” LLS’s*)
 - * If there is a match with more than one active flash, then the new pulse is added to the flash with the spatially-closest pulse
 - * A flash is “closed” if the time between the most-recent pulse and the first pulse in the flash is greater than the max flash duration (*typically 1 second*)

* Flash Analysis Overview

* Flash / Pulse “Typing”

- * Pulses within a CG flash are categorized as one of three types:
 - * “pre” cloud: likely preliminary breakdown or leader pulse
 - * “during” cloud: k-changes etc.
 - * “CG” stroke: we think we knew what this is...
- * Any flash containing a CG stroke is a CG flash

* A flash is detected in-common by two LLS’s if:

- * Any pulse in the flash is matched using the tight requirements employed by the Inter-comparison Tool
- * Any “unmatched” pulses in the flash meet the max IPI/Distance requirements when compared to any pulse from the other LLS

* Time-height Analysis of LIS, LMA, and LINET

