

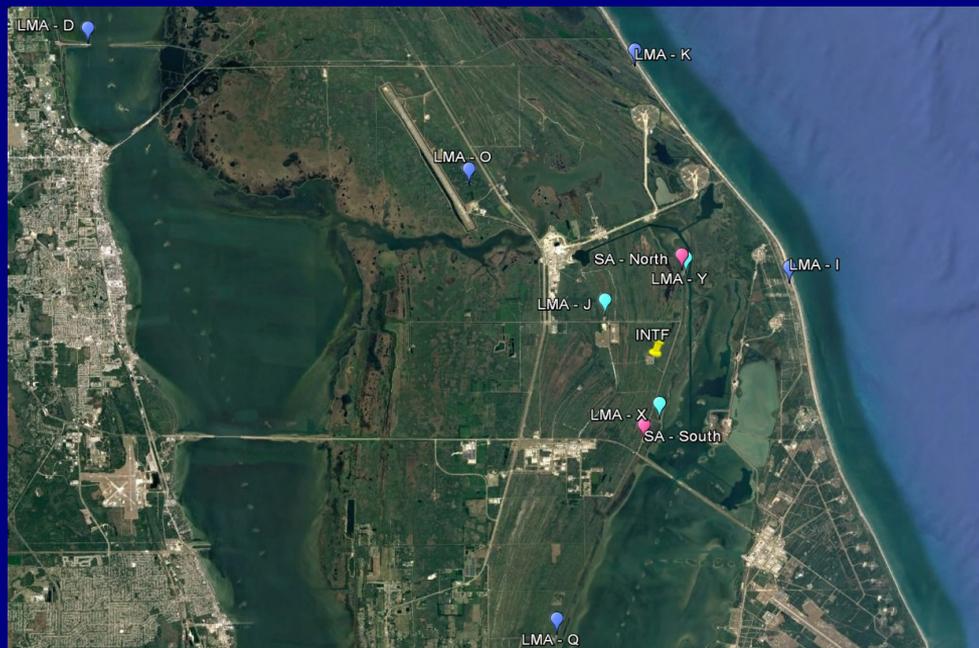
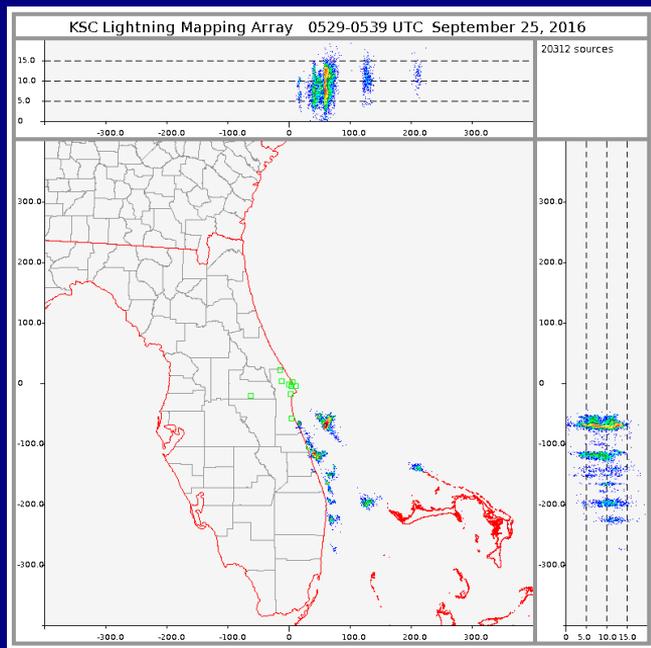
The KSC Interferometer (INTF) and Lightning Mapping Array (LMA)

by

Mark A Stanley, Paul R Krehbiel, Julia N Tilles, William Rison,
Robert Brown, Jennifer Wilson and Ningyu Liu

KSC LMA Layout

URL: http://lightning.nmt.edu/ksclma/current/current_anim.html



NMT Broadband VHF INTF System

- VHF: 20 – 80 MHz (roughly)
- DAQ: 16-bit continuous @ 180 MHz (4 channels)
- Antennas (3): 13" diameter circular disk, dE/dt
- Fast antenna (FA):
 - $\tau = 100 \mu\text{sec}$
 - Simultaneously sampled and stored with VHF
- Slow antenna (SA):
 - $\tau = 10 \text{ sec}$
 - Continuously sampled: 24-bit @ 50 kHz
 - Can be used as INTF trigger source for close flashes



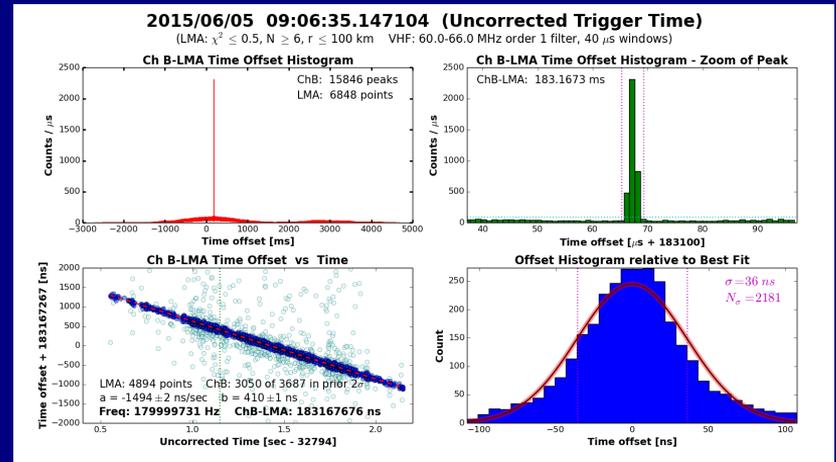
NMT INTF System Layout

Configuration: Equilateral triangle w/ 100 meter baselines



What's New – LMA Relative Timing

- Tight INTF-LMA pairing for flashes
 - Automated 4 step process for raw VHF:
 - Determine LMA bandpass power vs time
 - Locate windowed peak times (thresholded)
 - Histogram of pair-wise time offsets:
 - Peak of histogram is initial time offset estimate
 - Slope & y-intercept of offsets vs time:
 - Slope → Refined sample rate (from 180 MHz)
 - Intercept → Refined time offset (at trigger time)
 - Time offset accurate to several nanoseconds
 - Sample rate accurate to a few Hertz

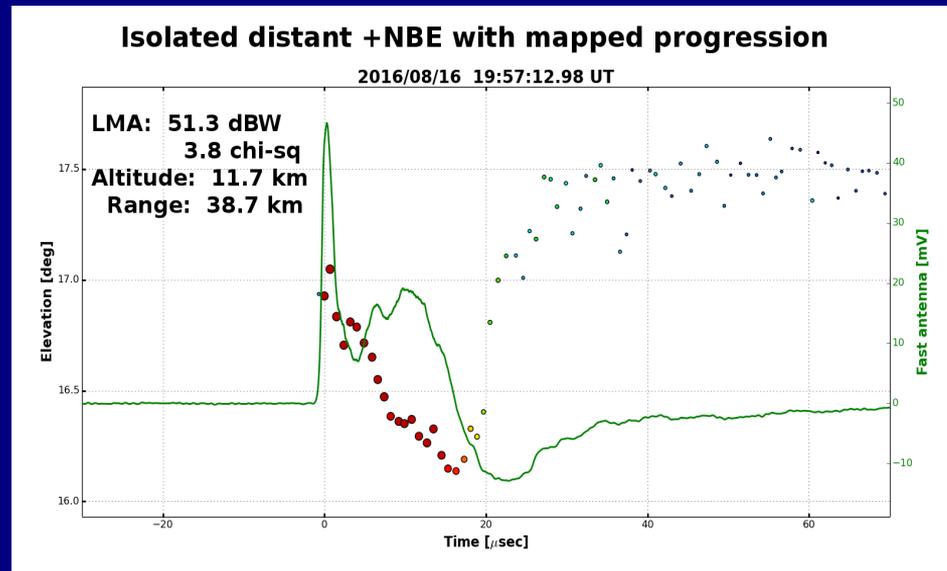
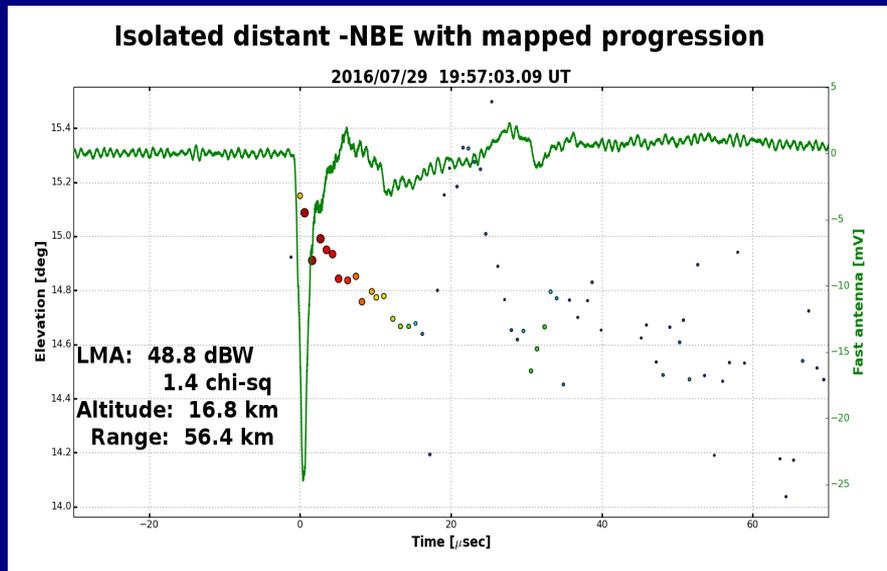


What's New – Hardware & Software

- **New INTF PC:**
 - Fast 3.7 TB RAID buffer
 - CPU: 16 cores
 - GPU: 2048 streaming cores, 3.5 TFLOP (for future calculations)
- **Additional triggering mode: Broadband VHF**
 - Scans continuous VHF data (based on Osaka Univ LIVE)
 - Set to 50/50 ms pre/post trigger for KSC
 - Can capture entire flashes via successive triggers
 - Augments manual triggering (2013-) and SA-AUX triggers (2015-)

“Got NBEs”?

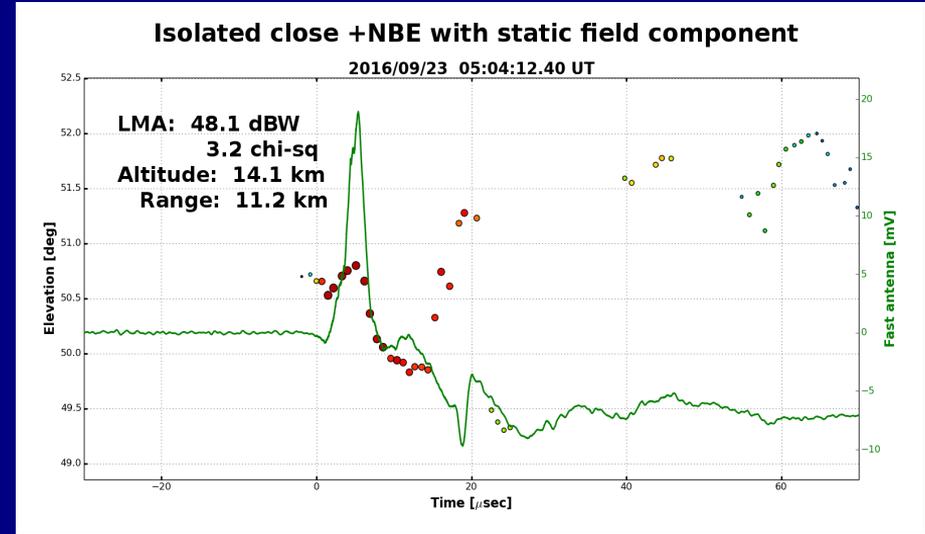
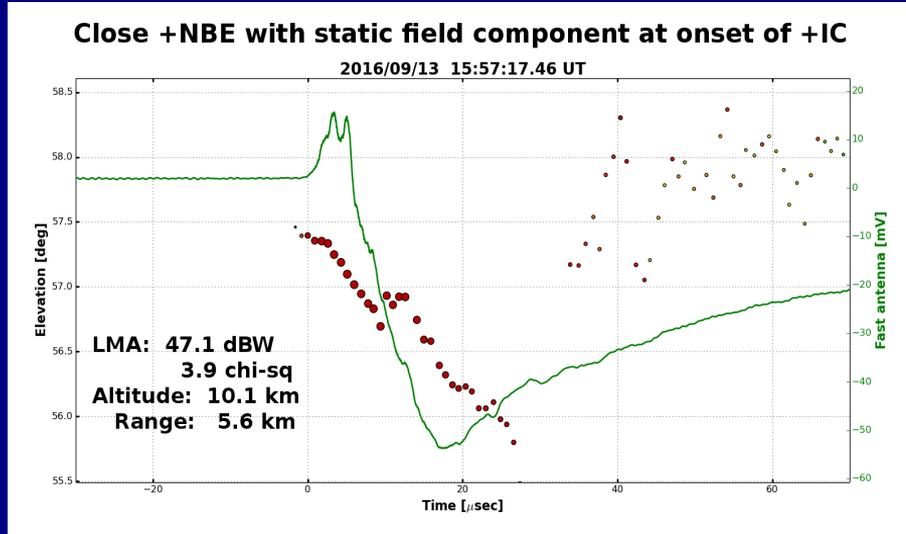
Likely mapped progression of well over 1000 Narrow Bipolar Events so far. Here are just a few:



Note: able to resolve development out to 60 km range because of 100 m baselines

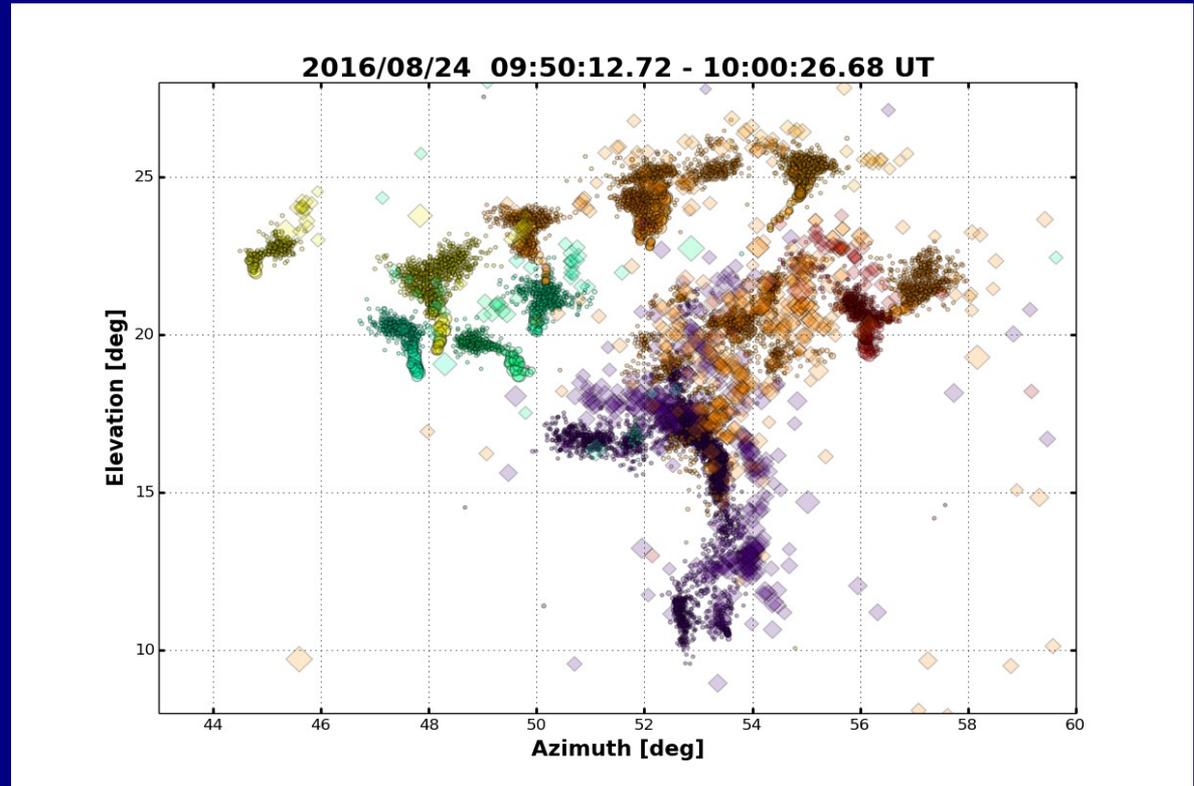
“Got NBEs”?

A couple of examples from many close NBEs captured so far:

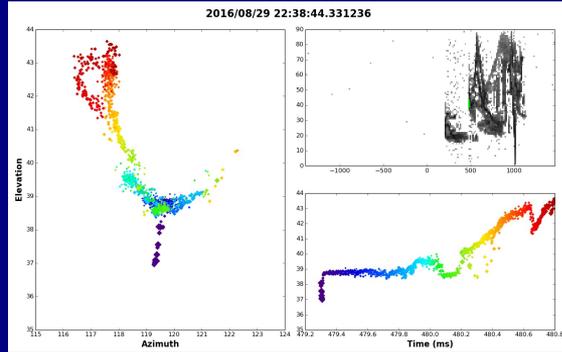


INTF-LMA Comparison: NBEs Near Storm Top

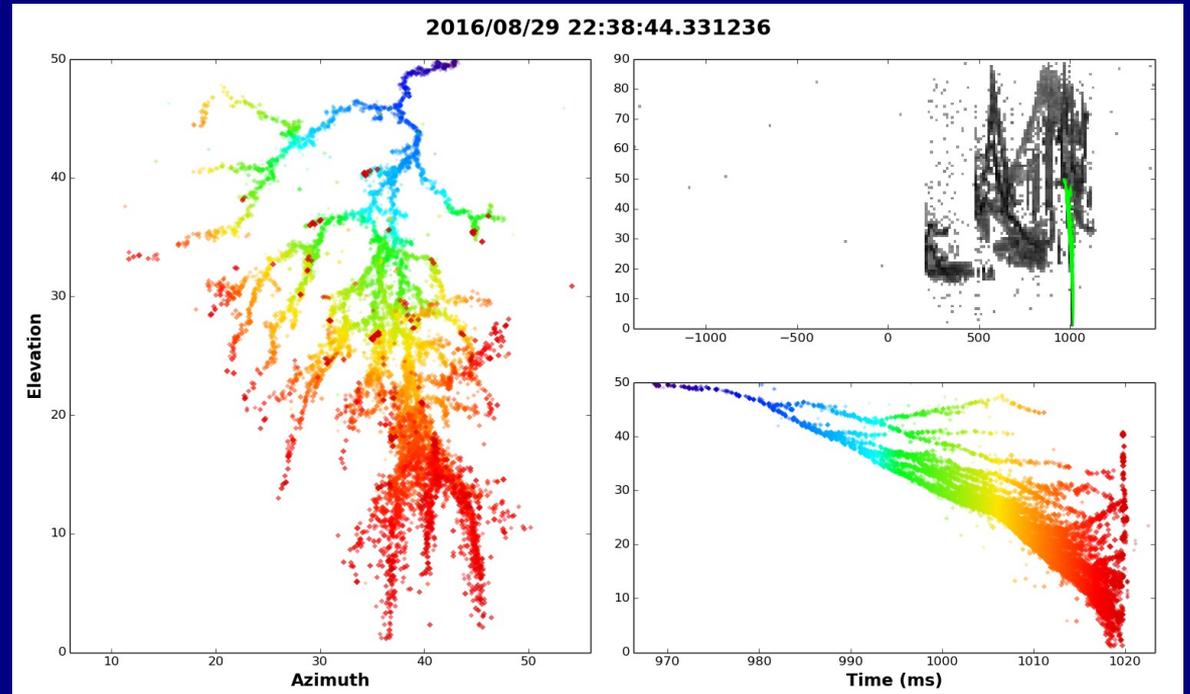
- Storm was ~30 km to ENE
- A few short (seconds) long intervals were processed from longer 10 minute interval
- Events are rainbow-colored according to time with purple the oldest and red the newest
- Symbol sizes are proportional to power
- Circles are INTF located sources while transparent diamonds are from the LMA: a small systematic azimuth & elevation offset on the order of a degree is evident



INTF Detailed Maps: NBE / BFB Example



- Flash started with a high power NBE and associated fast positive breakdown
- IC flash initially developed normally with channels reaching directly above the INTF site
- IC spawned a single stroke Bolt-From-the-Blue (BFB) -CG



Summary

- Increasing the baseline length to 100 meters has extended the useful range of the INTF.
- VHF triggering has significantly enhanced the ability to capture flashes and particularly isolated NBEs.
- A large amount of raw data has been collected so far: roughly 29 TB, which averages out to over 400 GB/day.

Future Work

- **Speed-up processing with GPU (high priority)**
- Improve INTF GUI and data accessibility
- Produce INTF-LMA hybrid 3D maps
- Imaging of simultaneous sources
 - Add 2 or 3 antennas to existing array (3 → 10 or 15 baselines)
 - Use CLEAN or similar algorithm to deconvolute images