Lightning Instrument Package (LIP): Performance and Status of Data Processing

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Genesis and Rapid Intensification Processes (GRIP)
Science Team Meeting

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GRIP Lightning Instrument Package (LIP) Support Team Members

Name	*Organization*	*Role*
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Doug Mach	UAHuntsville	Co-I, LIP Software Lead, Field and Operations support, Calibration Lead
John Hall	UAHuntsville	Software, Networking, and Web Development and Support
Jeff Bailey	UAHuntsville	Conductivity Probe Lead, Field and Operations Support
Chris Schultz	UAHuntsville	Field and Operations Support
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Dennis Buechler	UAHuntsville	Field and Operations Support

GRIP Science Relevance

- Several GRIP science questions will benefit from a detailed knowledge of the electrical conditions of the storms observed.
  - o What environmental and inner core factors govern rapid intensification?
  - o Do hot towers and convective bursts play a major role or are they merely an indicator of energy conversion processes?
  - o What is the predictability of rapid intensification and what observations are most critical to its prediction?
  - o What is the role of internal structure changes, including rainbands, eyewall replacement cycles and storm asymmetries on tropical cyclone intensity change?
- Periods of strong convection, indicated by lightning bursts, may be precursors to storm intensity changes … but the lightning bursts themselves are not sufficient to indicate strengthening or weakening in a storm

What LIP Observations Provide

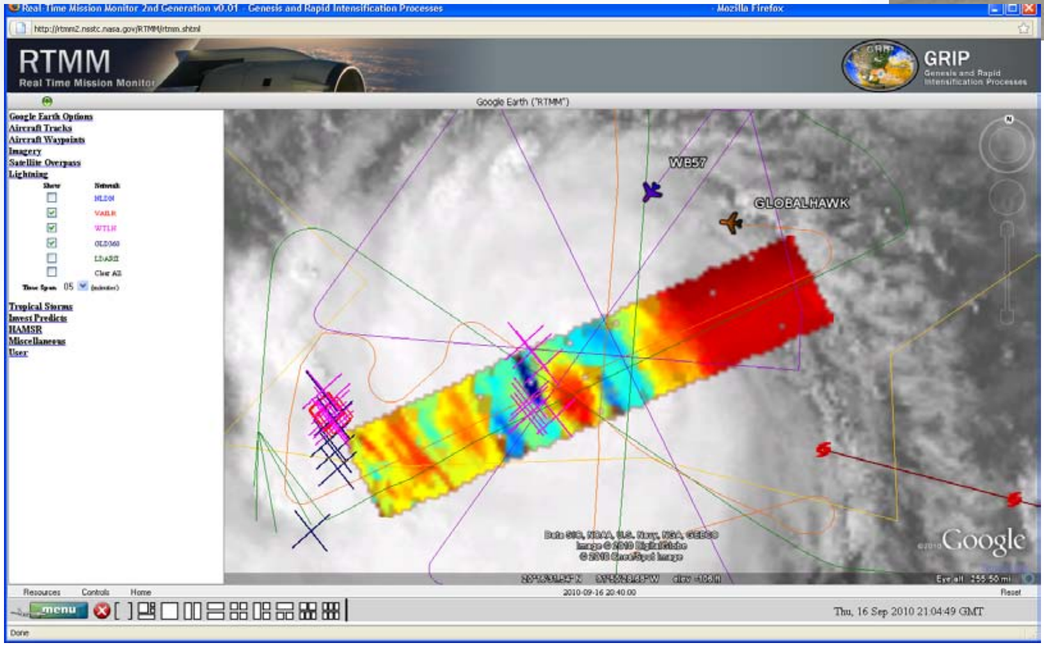
- Provide a detailed close-up view of the electric fields and total lightning (IC and CG) in and around storms investigated by the Global Hawk (*note: network lightning measurements at long range detect primarily Cloud-to-Ground lightning at low, variable DE – hence may miss significant lightning signal*).
- In some cases, the LIP may provide the only lightning and electrical measurements available for a sampled storm.
- LIP measurements will help locate the strong convection within large cloud systems, and as previously noted, monitoring flash rate may provide clues on intensity changes.
- LIP data, with other measurements, will be used to better understand the development, structure and evolution of tropical cloud systems.
- Real-time monitoring of electric fields and lightning supported mission operations and aircraft safety

Lightning and Electric Field Data Sets

Aircraft Observations

Provide detailed close-up "snapshots" of electric fields and total lightning in and around the storms flown.

- Data will help "calibrate" surface networks



Screen Capture of Real Time Mission Monitor 16 September 2010 showing lightning from long-ranged networks

Surface Networks

Offer continuous monitoring of convection with lightning (mostly cloud-to-ground).

- National Lightning Detection Network (NLDN)
- WeatherBug Total Lightning Network (WTLN)
- Vaisala GLD360 & Long Range
- World Wide Lightning Location Network (WWLLN)

Global Hawk LIP Observations

Instrumentation

- **Electric Field Mills (*6*)**
- **Conductivity Probe (*integration not completed for GRIP*)**

Measurements

- **Vector components of electric field (E_x, E_y, E_z)**
- **Aircraft Charge (E_Q)**
- **Air conductivity (*use estimate for GRIP*)**
- **Lightning statistics (*derive using field changes*)**
- **Storm electric currents**
- **Storm charge structure**

Embedded Linux System (ELS) and Electric Field Mill flown on Global Hawk

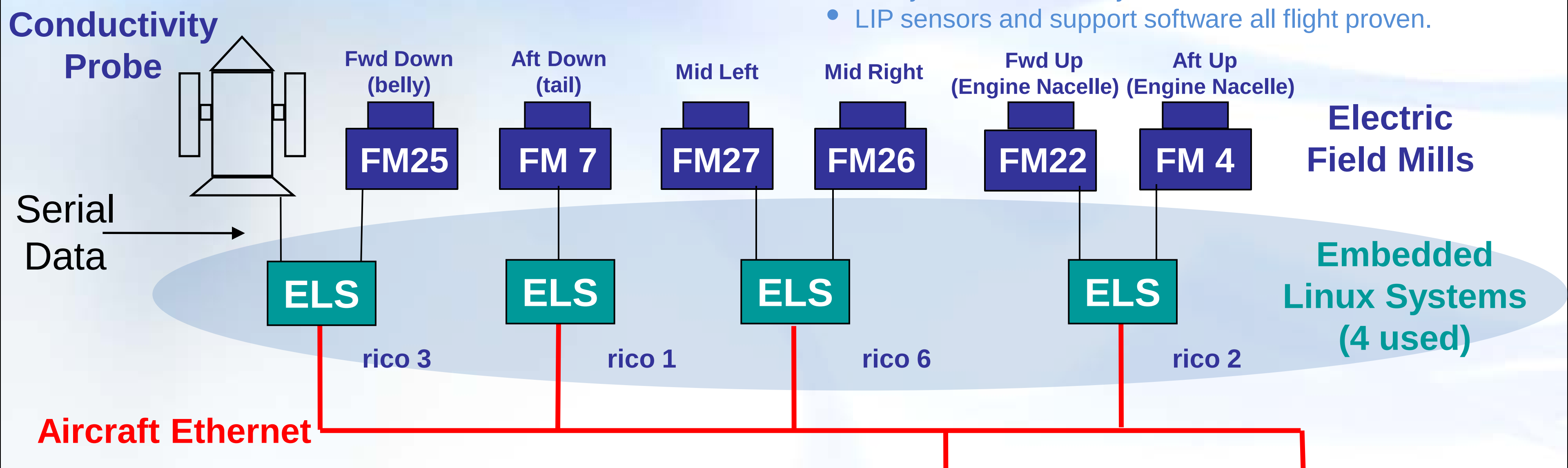
Measurement Range / Accuracy

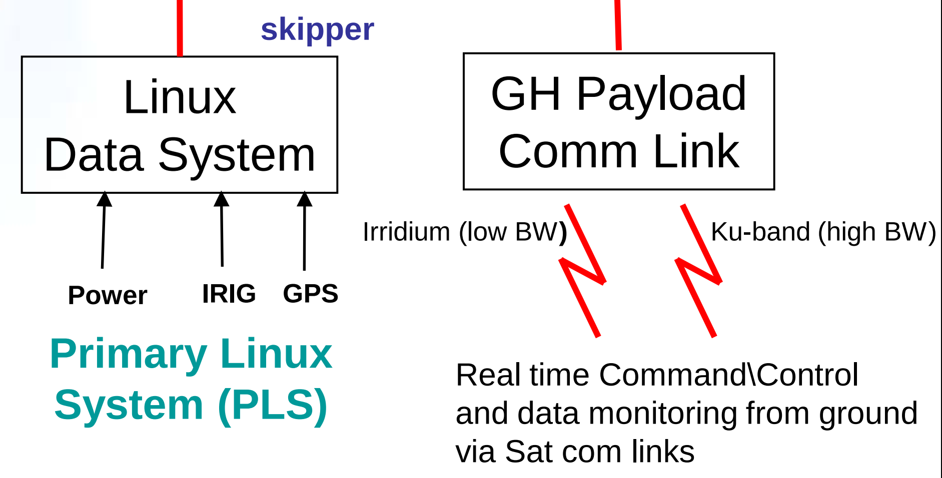
- **Electric Field : few V/m to hundreds's of kV/m 5 - 10%**
- **Conductivity : 10^{-13} to 10^{-11} mhos/m 5 - 10%**

- A LIP has flown in various configurations on several aircraft including ER-2, DC-8, UND Citation, WB-57, and Altus UAS.
- Global Hawk offers new long-duration, observational paradigm (hours versus minutes on-station).
- Present sensors built in 1998.

LIP "Sensor Web Enabled" Configuration on Global Hawk

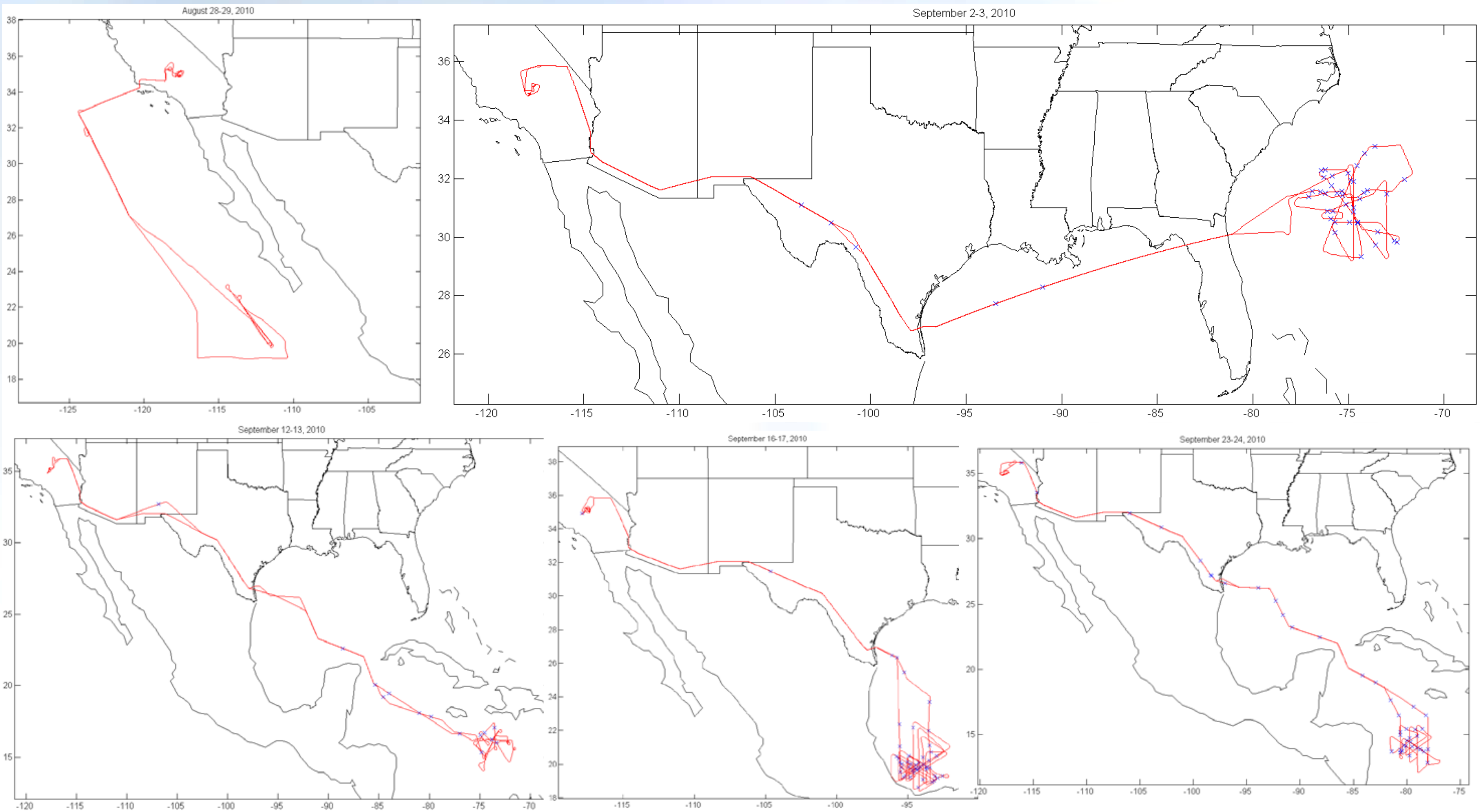
- ELS makes all sensors fully sensor-web enabled.
- All systems are time-synchronized via NTP.
- LIP sensors and support software all flight proven.





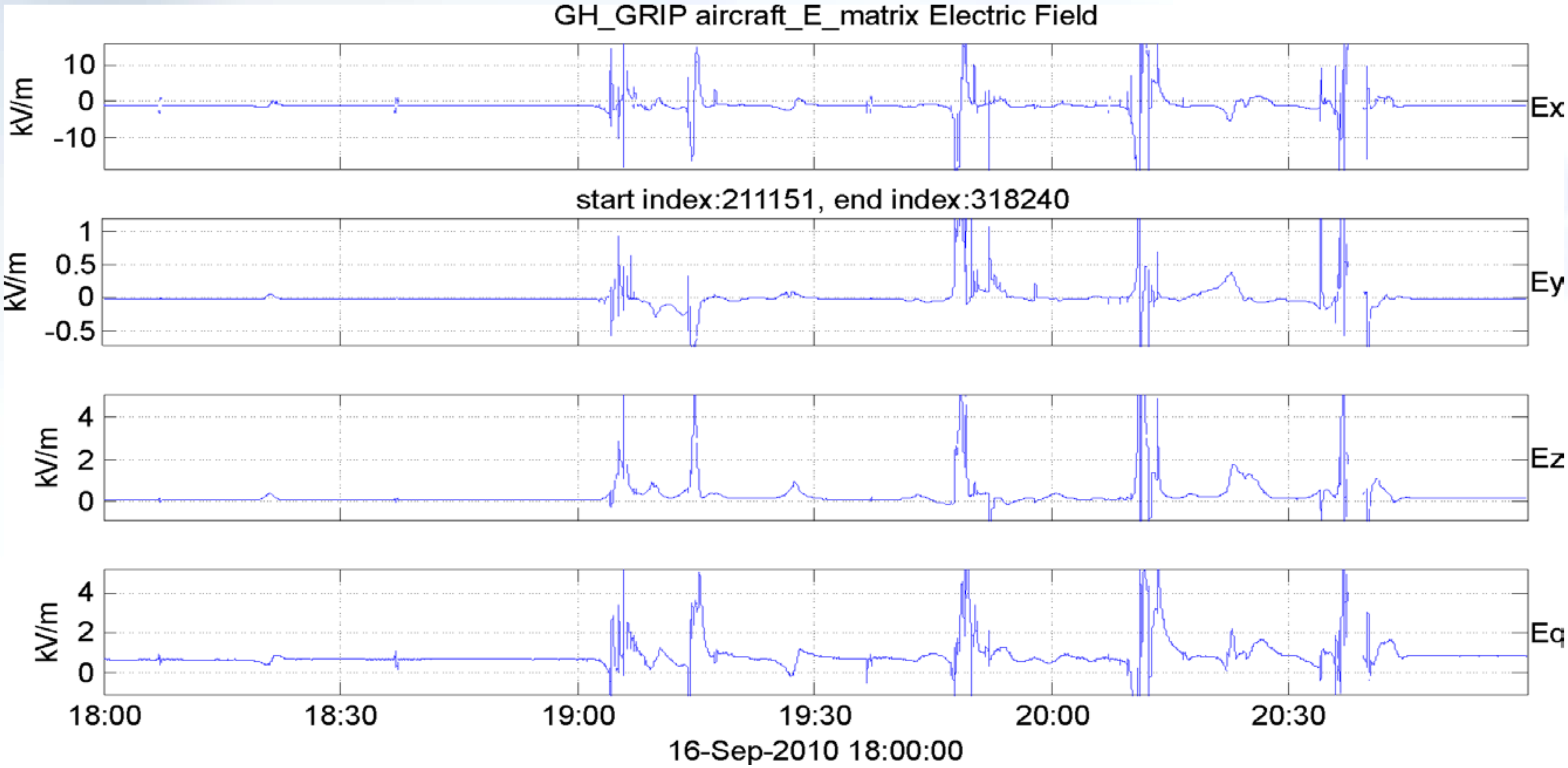
Flight Paths and Electrified Overpasses

Global Hawk flight tracks. X's mark where electrified clouds were overflown.



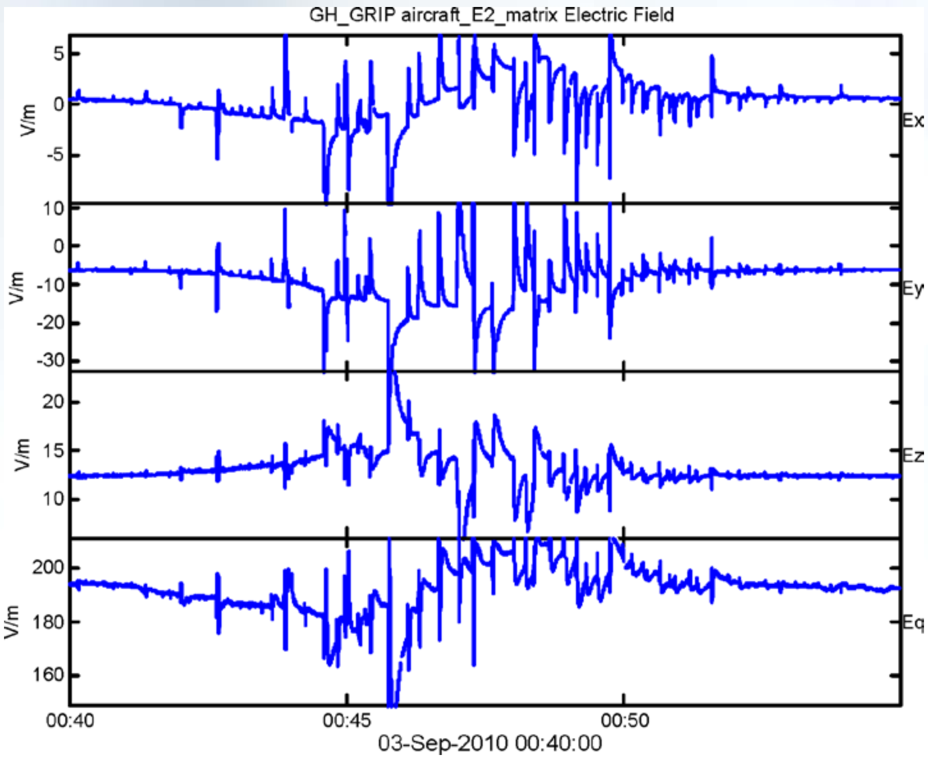
Quick Look LIP Example of Electric Field Observations

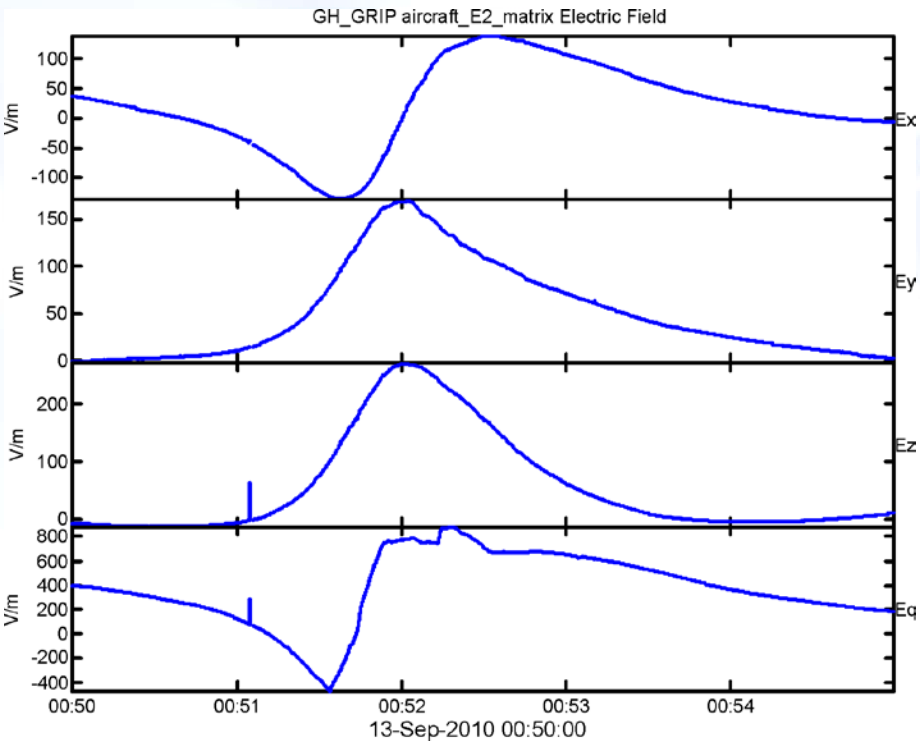
Global Hawk electric field observation of multiple passes of the inner core of Hurricane Karl on 16 Sept. 2010 during periods with convective burst activity (*note: over 70 electrified storm clouds overflown during this 26 hour mission*)



Quick Look Example of Clouds with and without lightning

Global Hawk LIP electric field observations of a single pass near a storm with lightning (left) and without lightning (*note: the small field values and the E_y component indicate that we passed to the side of these electrified clouds rather that passing directly over the storm core*)





LIP Data Summary

Preliminary LIP Statistics from Global Hawk overflights

Flight Date	Start Time (UTC)	End Time (UTC)	Total Data Collection Time (Hours)	Total Electrified Overpasses	Overpasses With Lightning (% of total)	Total Lightning Flashes	Max Flash Rate	Max Peak E	Min Peak E	Mean Peak E
28-Aug-10	28-Aug-10 1223	29-Aug-10 0327	15.2	0	0	0	0	-	-	-
2-Sep-10	02-Sep-10 0311	03-Sep-10 0402	24.9	49	9 (18%) GH avoided TS	223	6.5 fl/min	80 V/m	-26 V/m	15 V/m
12-Sep-10	12-Sep-10 1109	13-Sep-10 1152	24.7	20	7 (35%)	88	5.3 fl/min	218 V/m	-40 V/m	35 V/m
16-Sep-10	16-Sep-10 1208	17-Sep-10 1428	26.3	73	24 (33%)	177	2.6 fl/min	1500 V/m	-25 V/m	153 V/m
23-Sep-10	23-Sep-10 1452	23-Sep-10 1704	26.2	48	25 (52%)	91	2.1 fl/min	900 V/m	0 V/m	105 V/m
Totals	-	-	117.3	190	65 (34%)	579	6.5 fl/min	1500 V/m	-40 V/m	93 V/m

LIP Status

Global Hawk with GRIP payload conducts successful check out flight on Aug15, 2010.

- LIP performed well during GRIP.
- Calibration of FM on aircraft complete.
  - Despite limitations with maneuvers (altitude, aircraft control), calibration was straight forward due to mill placement and electrically quiet aircraft
  - See backup slides for details on calibration procedures.
- Initial LIP processing (quick look data) complete.
  - Quick look data just provided to the GRIP archive
- Detailed analysis about 30% complete.
  - An order of magnitude more data acquired per flight than past missions (i.e., 26 hours versus 2-3 hours).

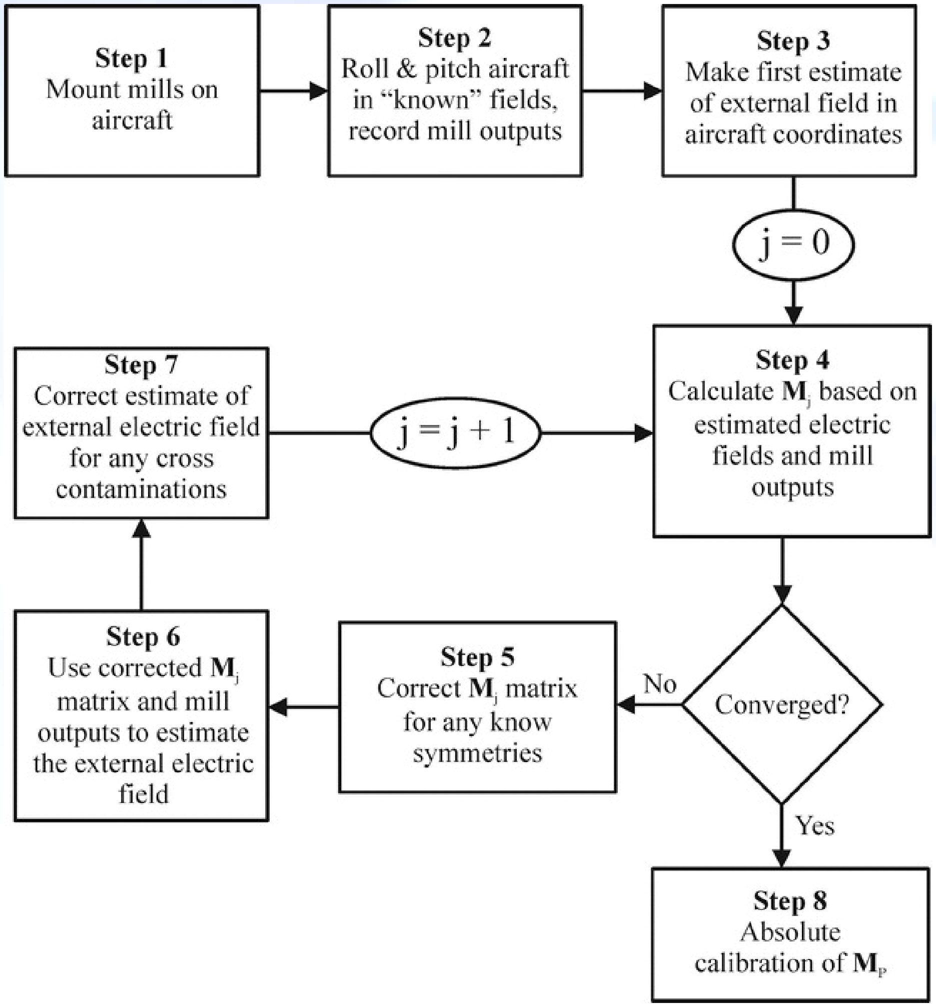
Future Work

- Complete the detailed LIP data analysis and provide results to the GRIP archive.
- Collaborate with other GRIP teams engaged in hurricane-lightning studies.
  - Plans for collaborations are underway.
  - Provide electric field and lightning data to other GRIP research groups (and as noted above to the GRIP archive)
- Determine storm current output in support of global electric circuit studies.
  - The Global Hawk GRIP flights will increase by more than 20% the existing database of storm current output observations.

Backup Slides on Calibration

Calibration Procedure

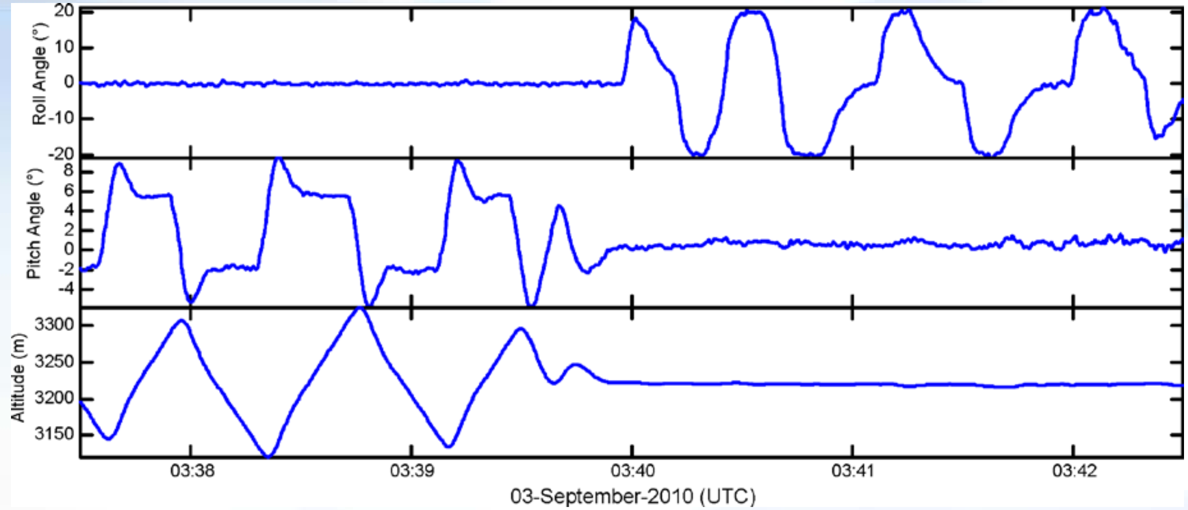
- Calibration of LIP sensors on aircraft follows procedure in Mach, D. M., W. J. Koshak, 2007: General Matrix Inversion Technique for the Calibration of Electric Field Sensor Arrays on Aircraft Platforms. *J. Atmos. Oceanic Technol.*, **24**, 1576–1587.
- The procedure uses a "cookbook" method
  - Fly aircraft roll & pitch maneuvers in "known" field conditions (use ground-based field observations and the Gish model for fair weather electric field with altitude)
  - Estimate the "true" fields in the aircraft reference frame
  - Use a matrix inversion technique to determine the "calibration matrix"
  - Iterate the estimated fields and calibration matrix until the system converges



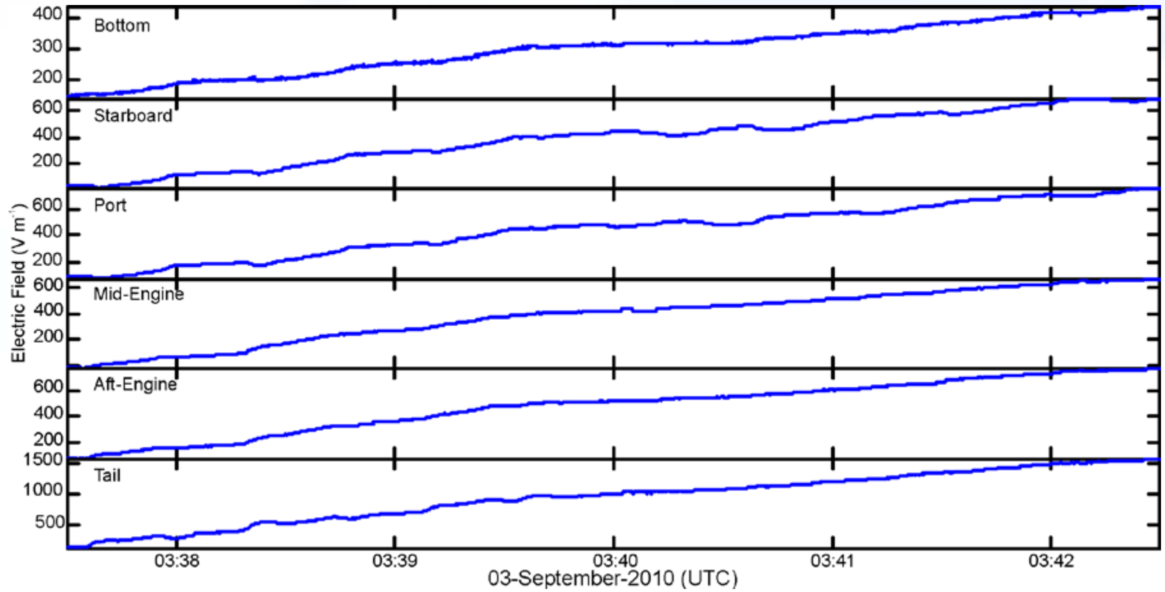
LIP Calibration Data – part 1

Calibration data was collected at 3000 m (very high but still works because the Global Hawk is an electrically quiet aircraft, enabling very small signals to be observed)

Aircraft Nav Data



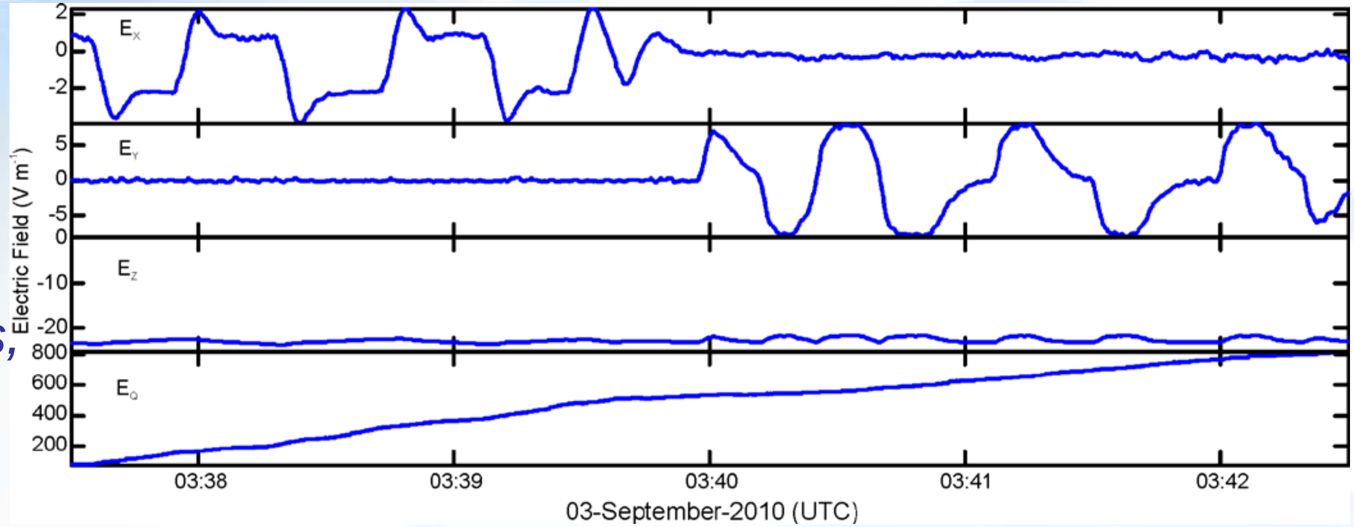
Raw Mill Electric Field Data



LIP Calibration Data – part 2

Excellent results obtained from the calibration procedures, leading to a "well calibrated" airborne field mill system

Ideal Aircraft Frame Electric Field Data



Final (Real) Aircraft Frame Electric Field Data