Total Lightning Measurements of Tropical Precipitating Systems

CAMEX Workshop
13-15 March 2002

Principal Investigator: Richard Blakeslee, NASA/MSFC/NSSTC
Co-Investigators: Douglas Mach, Univ. of Alabama in Huntsville
Monte Bateman, USRA/NSSTC
CAMEX-4 Electrical Measurements
Research Objectives

*Support overarching science objective*

Observe and explain the structure of convection in tropical cyclones and hurricanes and how the strength and structure changes immediately before and after landfall.
CAMEX-4 Electrical Measurements

Research Objectives

Specific questions pertaining to electrical conditions

- Can lightning provide cues for intensification and storm track forecast (presence of lightning may indicate changes underway)?
- Can lightning serve as useful aid in identifying flood producing rainfall following landfall?
- How are kinematic/microphysical properties of electrically active clouds different from less active clouds (also land vs. ocean convection)?
- What are the electrical properties of precipitating bands in tropical convection and how do they relate to storm microphysics?
- Why are some rainbands more electrically active than others?
Lightning Instrument Package (LIP)
NASA High Altitude ER-2

Instrumentation
- Electric Field Mills (8)
- Conductivity Probe

Measurements
- Vector components of electric field \((E_x, E_y, E_z)\)
- Aircraft Charge
- Air conductivity
- Lightning statistics (derived using field changes)
- Storm electric currents
- Storm charge structure

Measurement Range / Accuracy
- Electric Field: few V/m to hundreds’s of kV/m 5 - 10%
- Conductivity: \(10^{-13} \text{ to } 10^{-11} \text{ mhos/m}\) 5 - 10%
Lightning Instrument Package (LIP)  
NASA Medium Altitude DC-8

*Instrumentation*
- Electric Field Mills (6)
- High voltage “Stinger” (calibration of enhancement factors)

*Measurements*
- Vector components of electric field \((E_x, E_y, E_z)\)
- Aircraft Charge
- Lightning statistics (from field changes, optical transients)
- Storm electric currents (when used with ER-2 measurements)
- Storm charge structure

*Measurement Range / Accuracy*
- Electric Field: \(<1 \text{ V/m} \text{ to } 10^6 \text{ V/m}\)  
  10 - 20\%
LIP Campaign Summary

• Instrument performed well entire program.

• Several interesting thunderstorm flights acquired.

• Most Hurricane overflights showed only weakly electrified conditions.

• Preliminary electric field calibration done; will continue refining.

• Plan to integrate LIP electrical measurements with other sensors.
### Summary of electrical activity

<table>
<thead>
<tr>
<th>Date</th>
<th>Sortie</th>
<th>Description</th>
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<tbody>
<tr>
<td>18 Aug 2001</td>
<td>01-131, 10406</td>
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<td>Storms throughout (2000-2300)</td>
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<td>Buoy overflight (central FL coast)</td>
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<td>Weak (distant?) cells (1830-1915)</td>
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<td>3 Sept 2001</td>
<td>01-134, 10409</td>
<td>Gulf storms</td>
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<td>6 Sept 2001</td>
<td>10410</td>
<td>Overflight FL and GA east coast</td>
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<td>7 Sept 2001</td>
<td>01-135, 10411</td>
<td>Stratiform precipitation over Gulf</td>
<td>Storms throughout (1700-2000)</td>
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<td>01-136, 10412</td>
<td>KAMP</td>
<td>Three storms 1645-1700, 1710-1740, and 1820-1850</td>
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<td>01-137, 10413</td>
<td>Hurricane Erin</td>
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Example of thunderstorm observations

ER-2 electric field observation of embedded convection on 7 Sept. 2001 (i.e., 9-10 electrified storms overflown)
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ER-2 LIP Data Plots

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Calibration of an Airborne Field Mill Array

- Each field mill output can be considered as a linear sum of the external electric field and field due to charge on the aircraft:
  \[ m_i = M_{xi}E_x + M_{yi}E_y + M_{zi}E_z + M_{qi}Q \]  
  (a)
- The set of equations (a) for all mills on an aircraft can be represented as a matrix equation:
  \[ m = M\mathbf{E} \]  
  (b)
  where \( m \) (mill outputs) & \( \mathbf{E} \) (vector electric field and field due to charge on the aircraft) are vectors, and \( M \) is a 6x4 matrix
- To determine the electric field \( \mathbf{E} \) from the mill outputs \( m \), we need the 4x6 matrix \( C \) which satisfies the equations:
  \[ \mathbf{E} = C^T m \]  
  (c)
  \[ C^T M = I \]  
  (d)
  where \( I \) is the 4x4 identity matrix
- Although we need \( C \) to determine \( \mathbf{E} \) from the mill outputs, \( m \), the unique properties of the \( M \) matrix drive our method
  - There is only one \( M \), that satisfies (b) for all possible values of \( \mathbf{E} \) and \( m \)
  - In the process of determining \( C \) from \( M \), we can manipulate the inverse to emphasize or de-emphasize individual mills in the determination of \( \mathbf{E} \)
- To determine \( M \), we follow a “cookbook” type procedure:
  1) Estimate \( M \)
  2) Determine \( C \) from \( M \)
  3) Calculate the estimated \( \mathbf{E} \) from \( C \) and \( m \)
  4) “Fix” \( \mathbf{E} \) based on knowledge of flight conditions
  5) Use “fixed” \( \mathbf{E} \) and \( m \) to determine new \( M \)
  6) Repeat
  7) Final \( M \) scaling
  8) Invert final \( M \) to produce \( C \)
  9) Use equation (c) to determine \( \mathbf{E} \) from \( C \)
Priority Days (first tier)
ER-2 Electric Fields

Sortie: 132  Day: 232 = 20 Aug 2001  (High Gain; prelim. cal. applied)
ER-2 Electric Fields

Sortie: 135  Day: 250 = 07 Sep 2001  (High Gain; prelim. cal. applied)
ER-2 Electric Fields

Sortie: 136  Day: 252 = 09 Sep 2001  (High Gain; prelim. cal. applied)
Priority Days (second tier)
ER-2 Electric Fields

Sortie: 131    Day: 230 = 18 Aug 2001    (High Gain; prelim. cal. applied)
ER-2 Electric Fields

Sortie: 134  Day: 246 = 03 Sep 2001  (High Gain; prelim. cal. applied)
ER-2 Electric Fields

Sortie: 138    Day: 259 = 16 Sep 2001    (High Gain; prelim. cal. applied)
Un- or weakly electrified cases
ER-2 Electric Fields

Sortie: 133  Day: 238 = 26 Aug 2001  (High Gain; prelim. cal. applied)
ER-2 Electric Fields

Sortie: 137  Day: 253 = 10 Sep 2001  (High Gain; prelim. cal. applied)
ER-2 Electric Fields

Sortie: 141  Day: 266 = 23 Sep 2001  (High Gain; prelim. cal. applied)
ER-2 Electric Fields

Sortie: 142  Day: 267 = 24 Sep 2001  (High Gain; prelim. cal. applied)