COE CST Tenth Annual Technical Meeting

Measurements of Thunderstorm Electrical Parameters For Improvement of the Lightning Flight Commit Criteria

PI: Amitabh Nag

Co-PIs: Kenneth Cummins, Hamid Rassoul

Student: Mathieu Plaisir

Agenda

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- Goals
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Team Members

Prof. Amitabh Nag
Principal Investigator

Prof. Ken Cummins
Co-Principal Investigator

Prof. Hamid Rassoul
Co-Principal Investigator

Mr. Mathieu Plaisir
Graduate Student

- Organizations providing matching funds
  - Florida Institute of Technology FLORIDA TECH
  - Vaisala Inc. VAISALA
- Collaborators: NASA Kennedy Space Center

Goals

- Beyond vehicle and payload issues, weather has been the single largest source of launch delays and scrubs on the Eastern Range [e.g., Roeder and McNamara, 2006; Maier, 2015].
- One way to minimize launch costs is to reduce the uncertainty associated with the cloud rules that protect a launch vehicle by preventing its interaction with natural lightning or a lightning strike triggered by the vehicle during a launch.
- These cloud rules on the Eastern and Western Federal Ranges are known as the Lightning Launch Commit Criteria (LLCC) and are referred to as the Lightning Flight Commit Criteria (LFCC) in the FAA's Code of Federal Regulations.
- The LLCC/LFCC have caused nearly 5% of the launches from CCAFS/KSC to scrub and delayed 35% of the launches [Hazen et al., 1995].
- By better understanding the environmental conditions that indicate initiation and cessation of thundercloud electrical activity, a more refined electric field threshold could be introduced leading to a relaxation of the cloud constraints.
- Ultimately, this will lessen the percentage of launch delays and scrubs associated with the LLCC/LFCC thus promoting the commercial launch sector.

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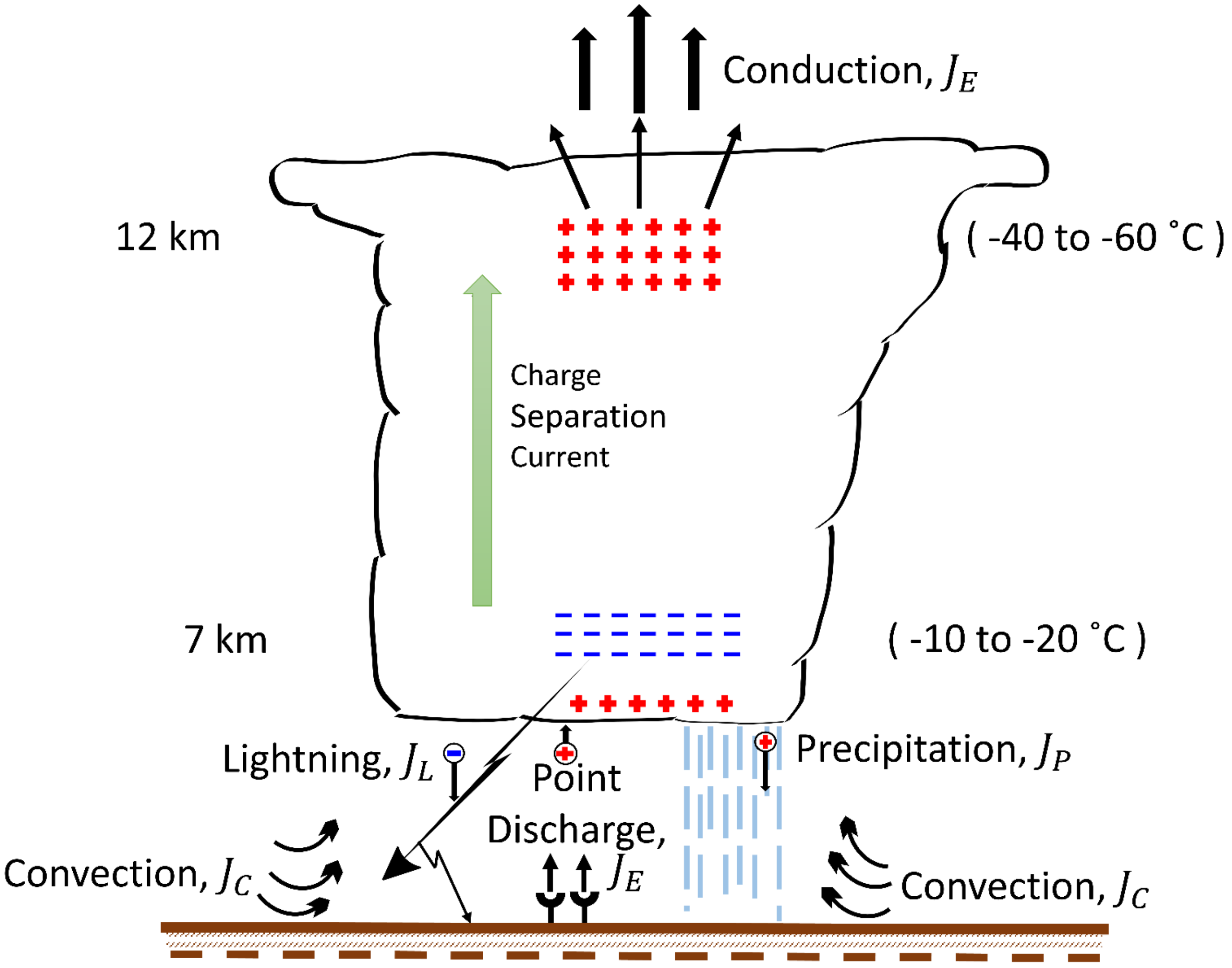
Task Description

- Maxwell currents below electrified clouds are the sum of the conduction current (J_E), the convection current (J_C), the lightning current (J_L), the precipitation current (J_P) and the displacement current ($\frac{\partial(\varepsilon_0 \boldsymbol{E})}{\partial t}$) and is given by the following equation:

$$\boldsymbol{J}_M = \boldsymbol{J}_E + \boldsymbol{J}_C + \boldsymbol{J}_L + \boldsymbol{J}_P + \frac{\partial(\varepsilon_0 \boldsymbol{E})}{\partial t}$$

- The exact relationship between the commencement of separation of charges within clouds and Maxwell currents below them is not known.



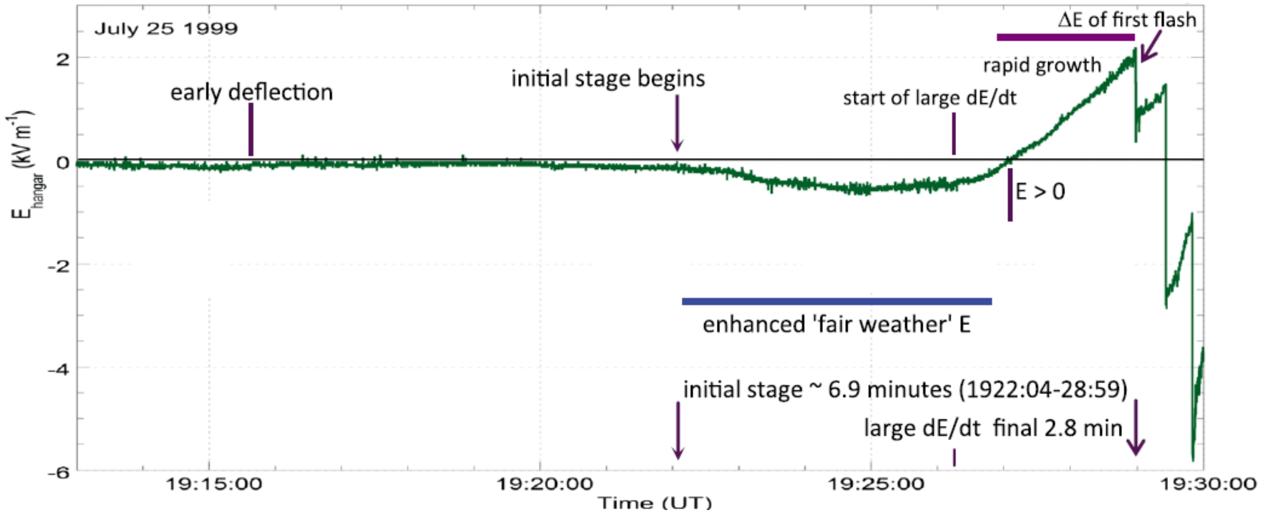
Components of Maxwell current associated with thunderclouds

Task Description

- At early stages of cloud-charge separation when the charge separation in a cloud is just starting, and late in the life-cycle of previously electrified clouds the Maxwell current can be approximated as

$$\boldsymbol{J}_M = \boldsymbol{J}_E + \frac{\partial(\varepsilon_0 \boldsymbol{E})}{\partial t}$$

- At early phases of cloud electrification, for relatively low values of electric field, $\mathbf{J_E}$ can be expressed as the product of the air conductivity and electrostatic field ($\mathbf{J}_E$ = σ**E**).



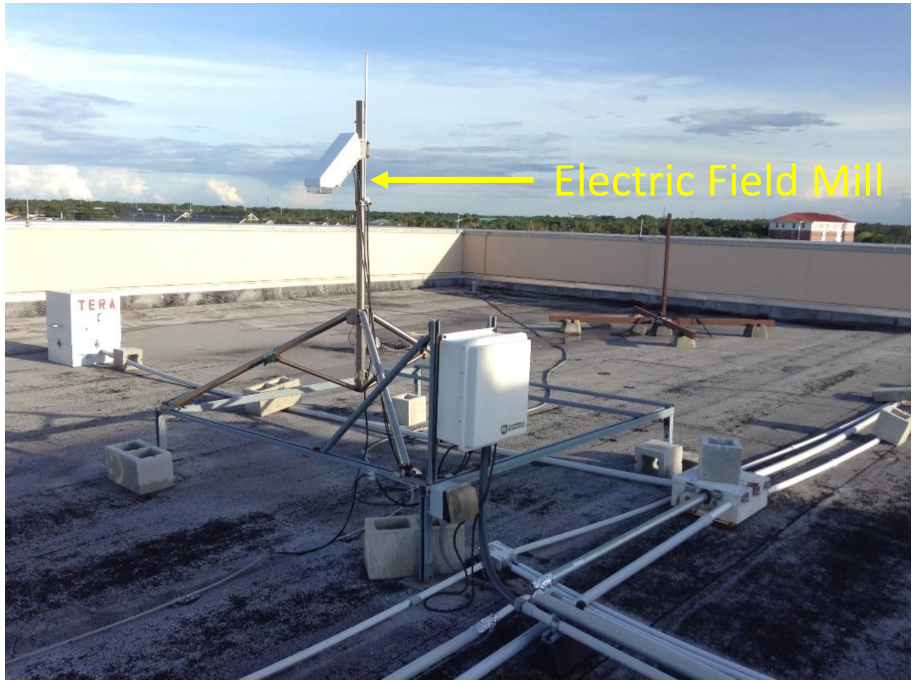
Adapted from Stolzenburg et al. [2015]

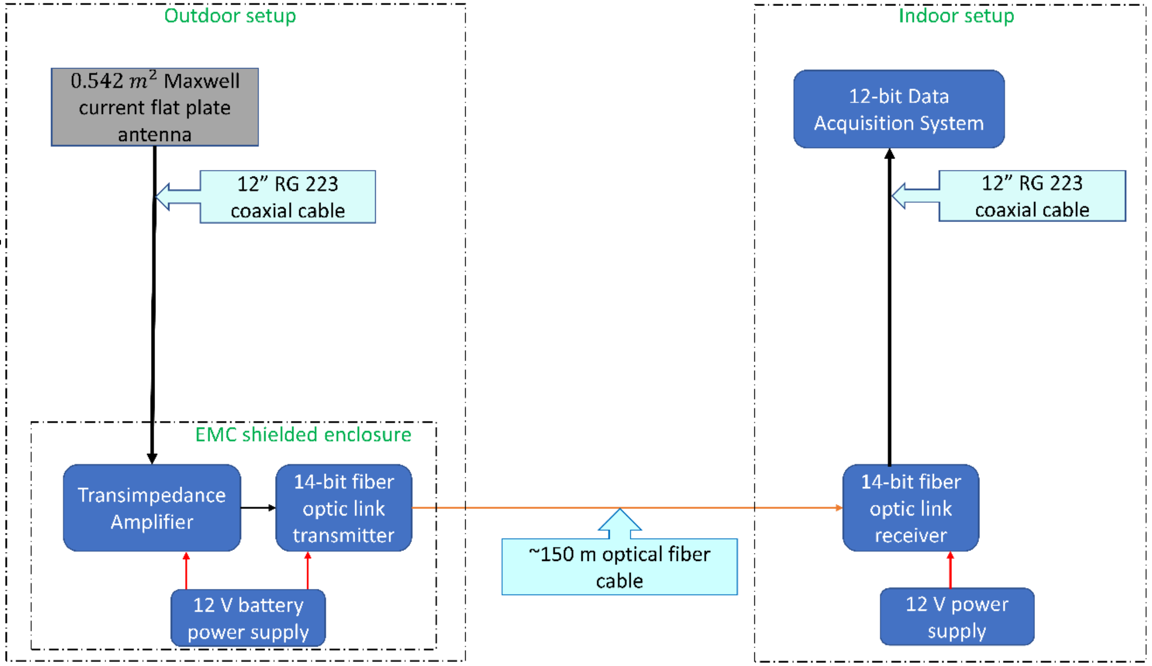
- In this project we measure:
  - Electrostatic field (**E**)
  - Air conductivity (σ)
  - Maxwell current ($\mathbf{J}_M$)

- This will enable us to extract signatures of the conduction and displacement currents at early times after inception of cloud charge separation.

Results: Progress to date

- Our Maxwell current measurement system will have the following characteristics:
  - Sensing plate area of 0.542 m^2.
  - Nominal system vertical dynamic range of 4 pA/m^2 to 70 nA/m^2.
  - Nominal system bandwidth from DC to about 2 KHz.





- These characteristics will allow us to extract Maxwell current measurements at early stages of cloud electrification with suitable dynamic range at various frequency ranges of interest using digital processing techniques.

Schedule

May – July, 2020	Instrumentation development ○ Select, order, and purchase parts for Maxwell current, and air conductivity measurements ○ Deploy electric field measurement ○ Fabricate Maxwell current sensor
August – November, 2020	End-to-end testing of Maxwell current measurement system ○ Laboratory testing and calibration ○ Fair-weather field testing and calibration
November, 2020 – February, 2021	• Fabricate and test air conductivity measurement • Deploy measurements • In-situ testing of measurement setup
March – September, 2021	• Data collection
October, 2021 – April, 2022	• Analysis of Maxwell current data in conjunction with electrostatic field and air conductivity measurements as well as weather radar and lightning locating system (NLDN and LMA) datasets • Interpretation of analysis results and conclusions on the efficacy of Maxwell current measurements for improvement of lightning flight commit criteria

Publications, Presentations, Awards, & Recognitions

We are at the start of this project, so we have no publications yet.

Summary and Future Work

- Examine correlated signatures of the conduction and displacement components of the Maxwell current.
- Examine correlated weather radar and lightning locating system data.
- Provide new insights into improved detection of cloud electrification onset.
- Goals:
  - Improve the cloud rules in the Lightning Launch/Flight Commit Criteria.
  - Facilitate more efficient decision-making on launch delays and scrubs.
- In the future, understanding obtained from this project will help facilitate balloon-borne electric field and current measurements which will lead to more refined electric field models that employ finite element methods to relate measured and computed electric fields.