COE CST Eleventh Annual Technical Meeting

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

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Team Members

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

Agenda

- Team Members
- Goals
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- Results
- Conclusions and Summary

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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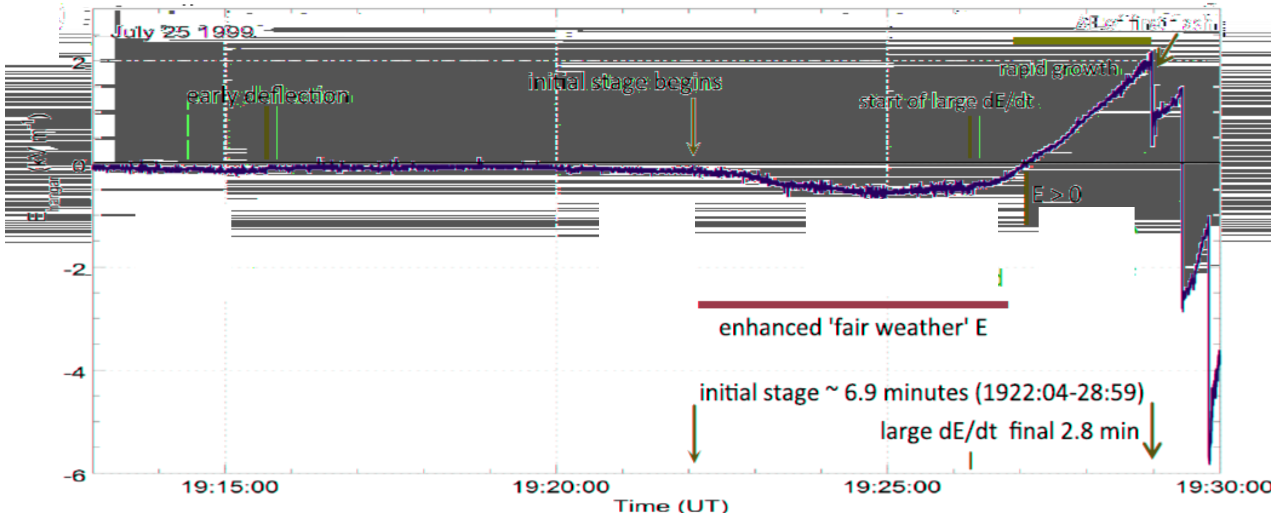
Task Description

- 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 ($\mathbf{J}_E = \sigma\mathbf{E}$).

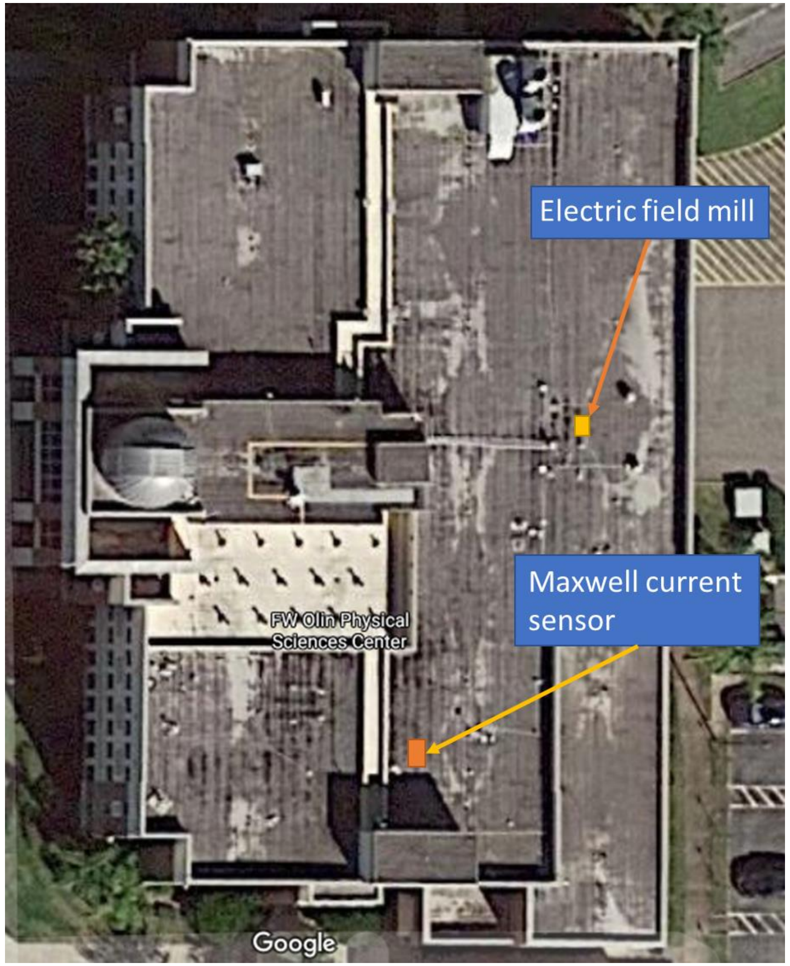


Adapted from Stolzenburg et al. [2015]

- In this **two-year** project we designed, constructed, tested, and deployed a Maxwell current ($\mathbf{J}_M$) and an air conductivity measurement system, as well as deployed an electrostatic field (**E**) measurement system.

- We then acquired data from fair and foul weather in order to examine if a combination of $\mathbf{J}_M$ and **E** measurements provide enhanced insights into charge separation inside clouds.

Results



Electric Field Mill (EFM)

Maxwell Current Measurement

- Our electric field measurement system was operated at 1 Hz.

- Our Maxwell current measurement system has the following characteristics:
  - Sensing plate area of 0.542 m^2.
  - Nominal system vertical dynamic range of ~10 pA/m^2 to 185 nA/m^2.
  - Nominal system bandwidth from ~DC to about 1.4 KHz.
  - Fair weather values were observed to be near zero or slightly positive (few tens of pA/m^2).

Summary of Findings

- For a limited number (two) of observations of initial electrification in nearby thunderstorms, we did not see a clear indication of non-fair-weather values of Maxwell currents significantly preceding the foul weather electric fields.

- For close-by anvil region of thunderstorms, the Maxwell current measurement appears to show significant variations from its fair-weather level. This may or may not be accompanied by foul weather electric fields reported by the EFM.

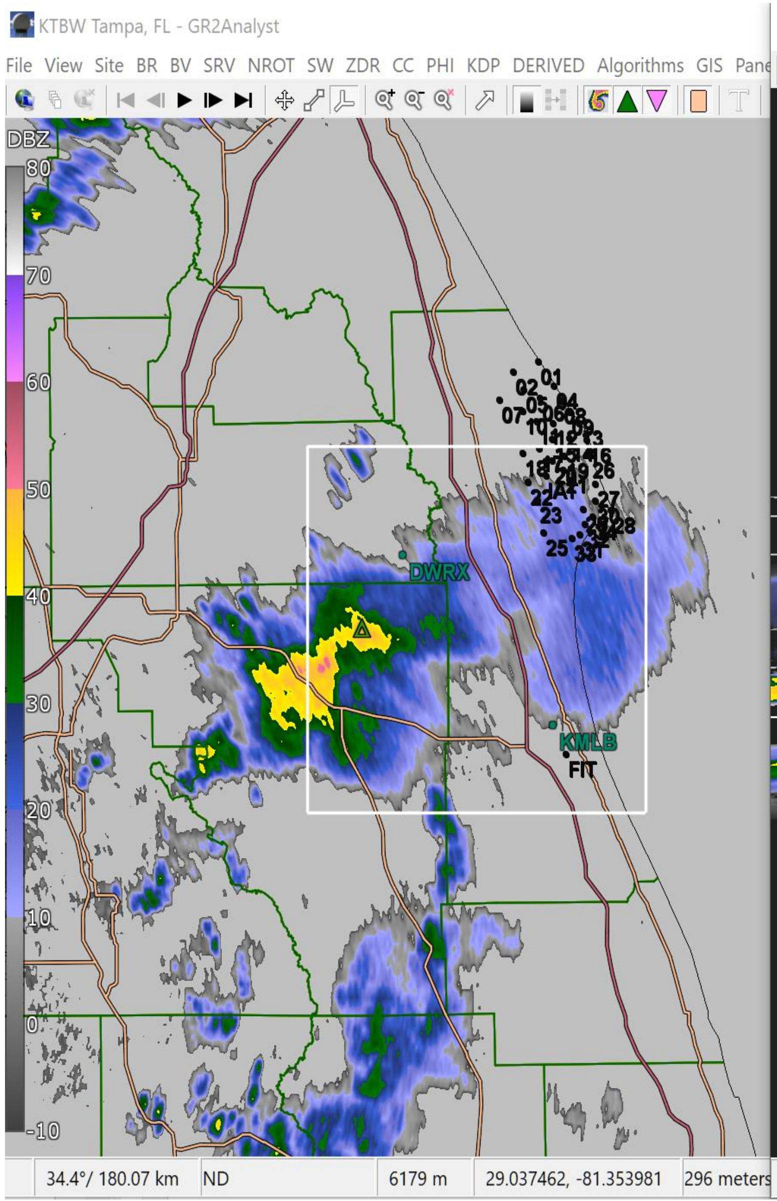
- During large synoptic-scale disturbed weather approaching the measurement site, significantly elevated Maxwell currents were observed. This was not accompanied by elevated (foul weather) electric fields.

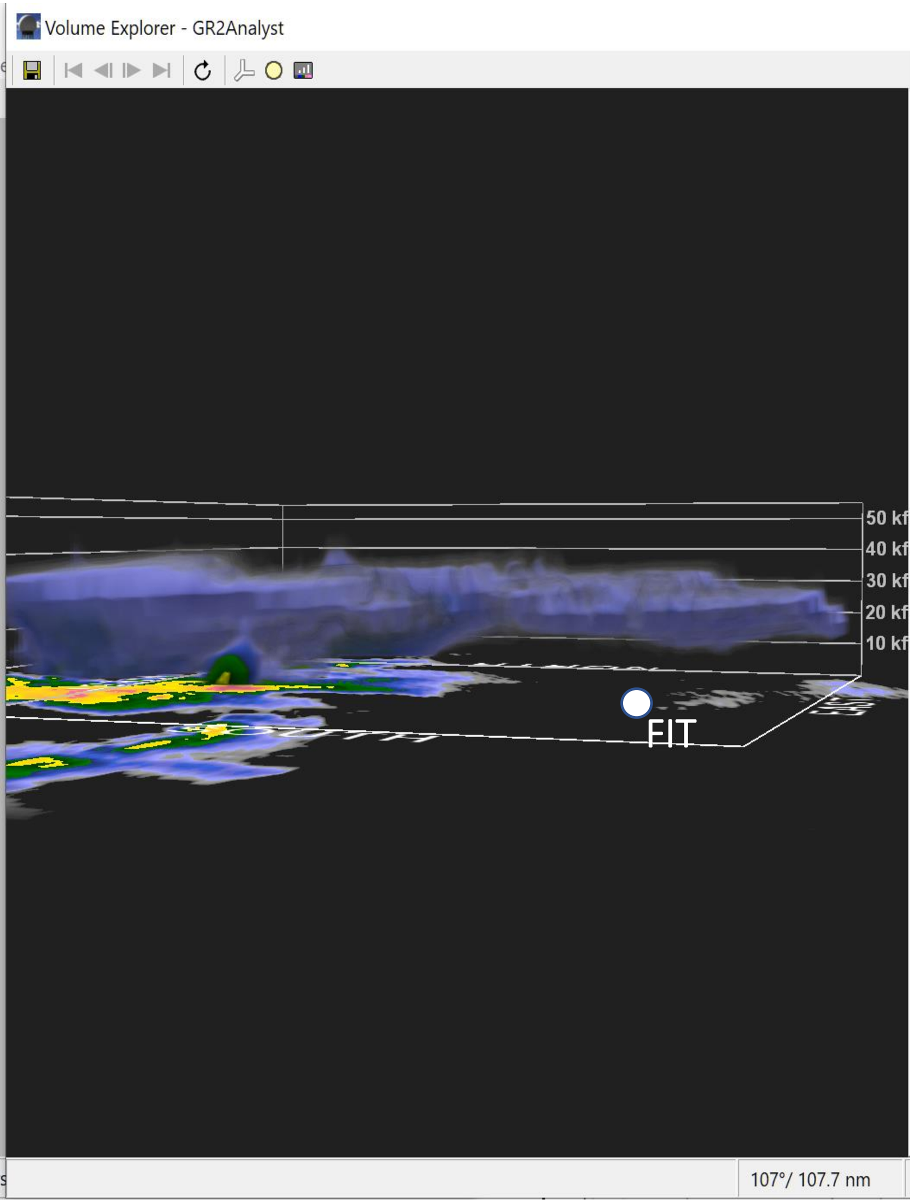
- For a seemingly slightly electrified precipitating cloud developing nearby, Maxwell currents seemed to provide an earlier indication of charge aloft than electric field.

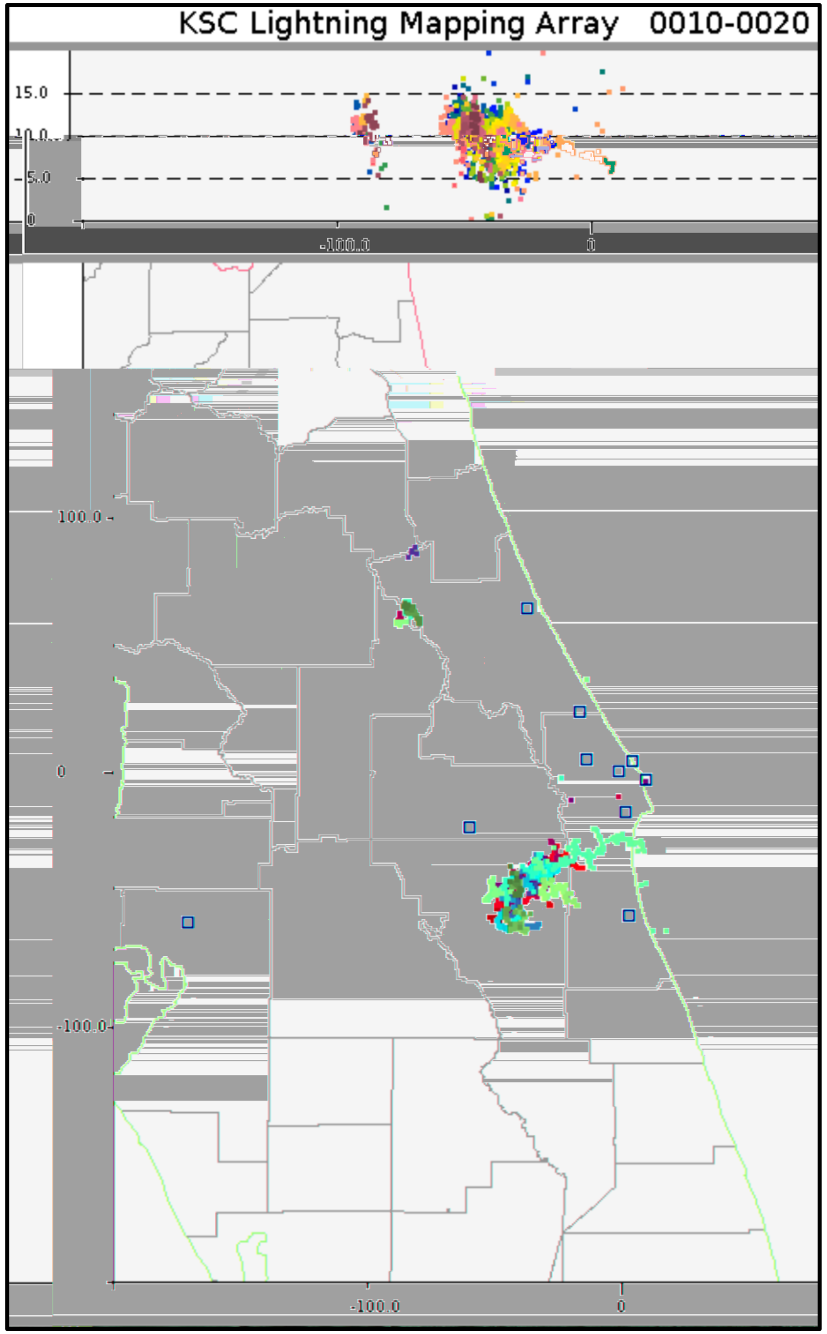
Results: Attached Anvil

March 8-9, 2022 00:10 to 00:20 UTC

(left) KTBW 1.4° tilt (4-6 km); (center) Volume View; (right) LMA Anvil flash







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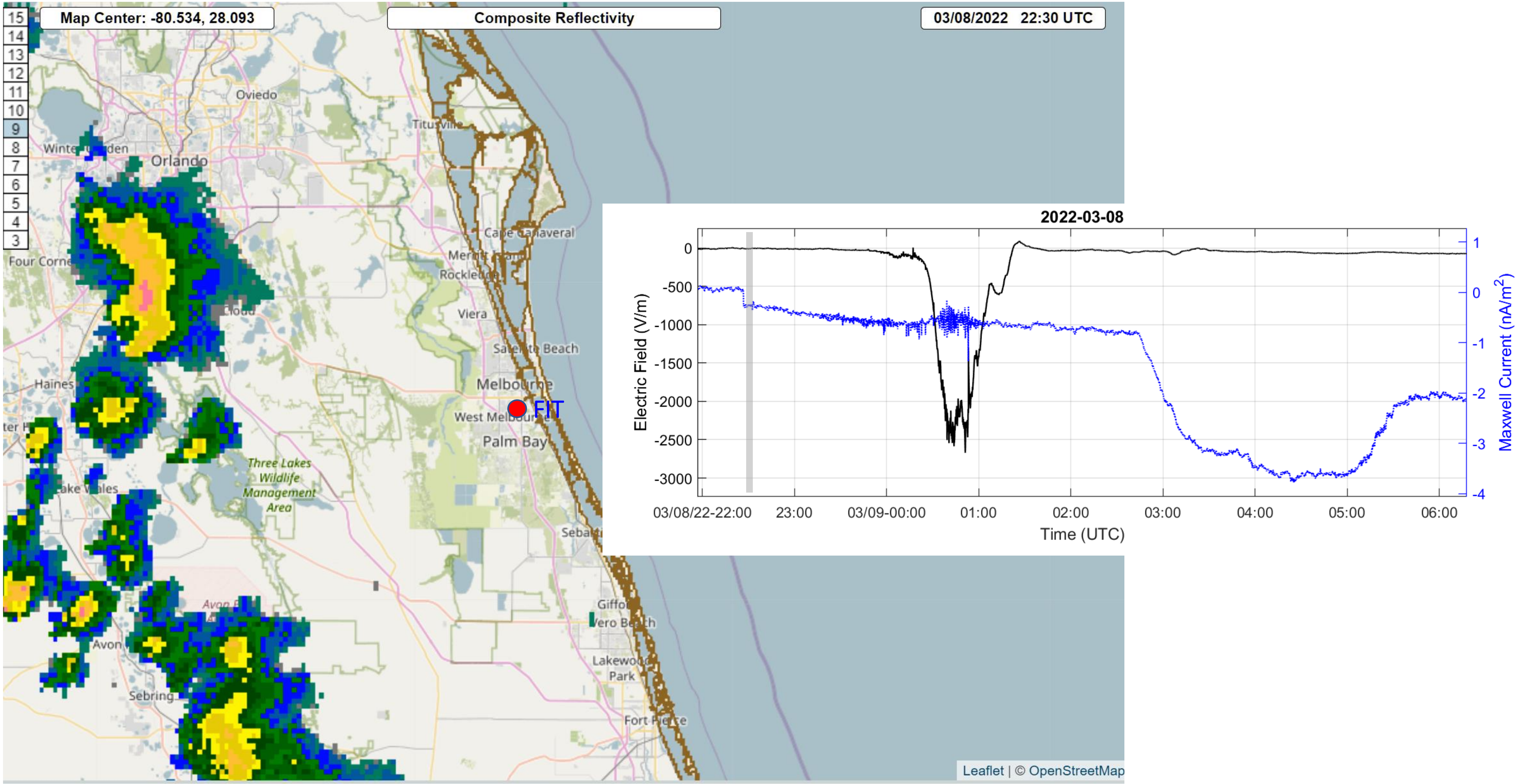

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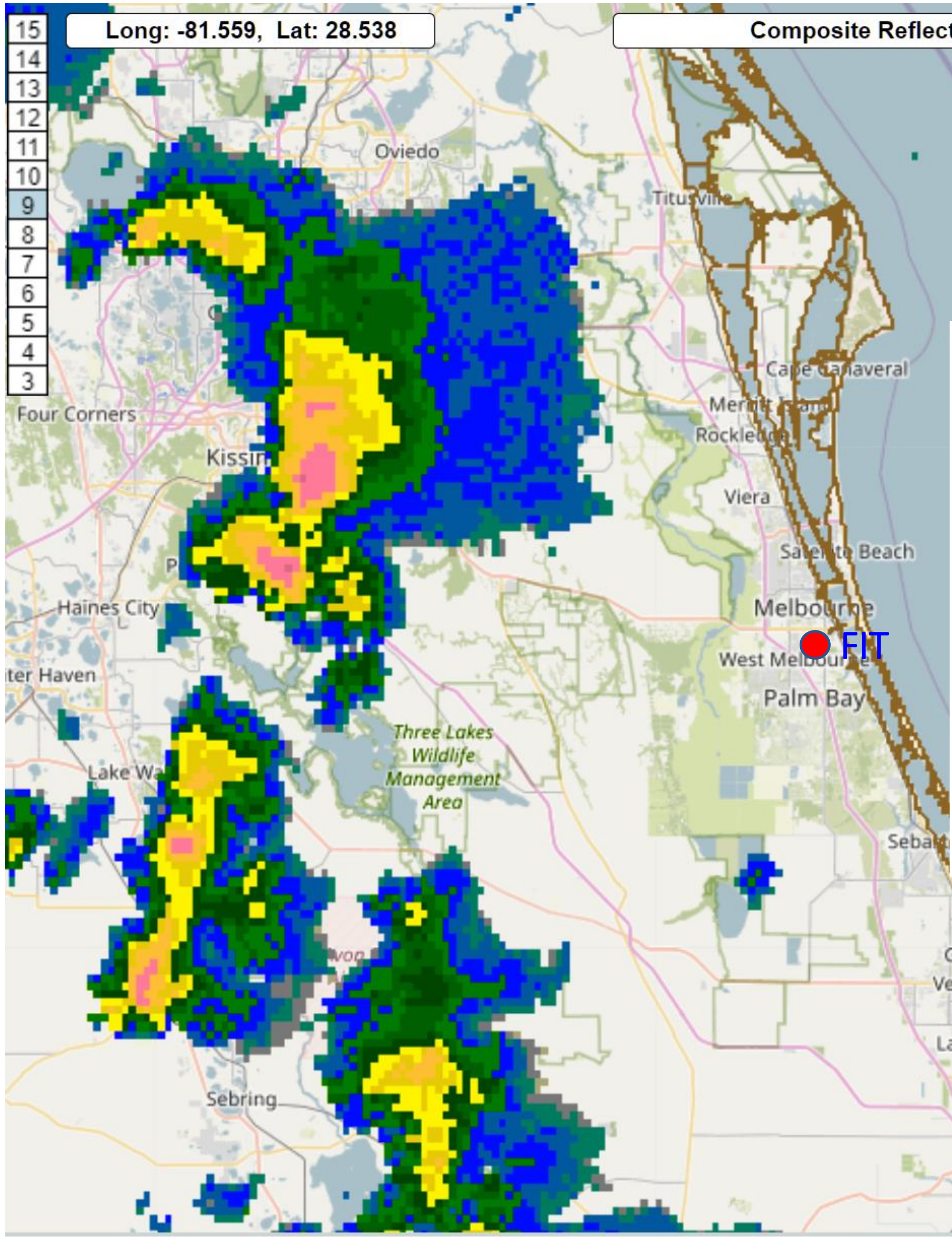

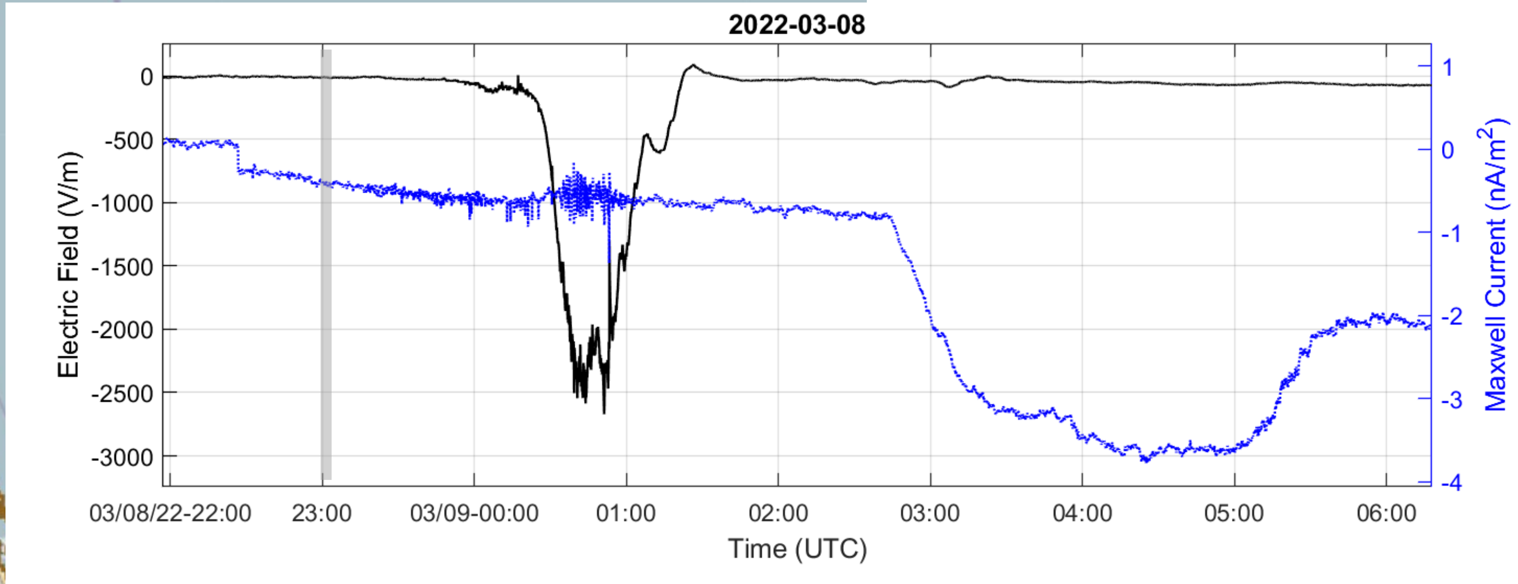

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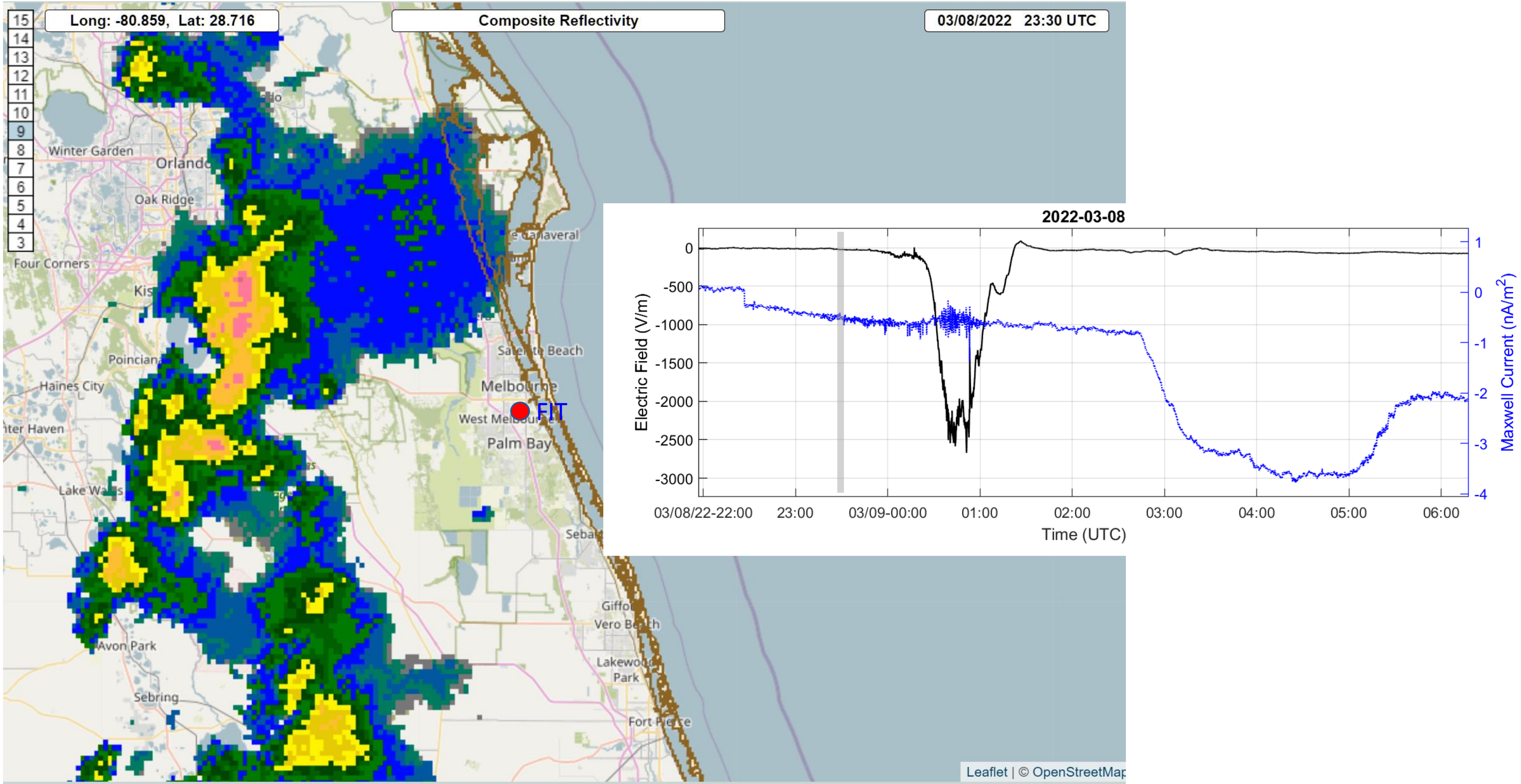

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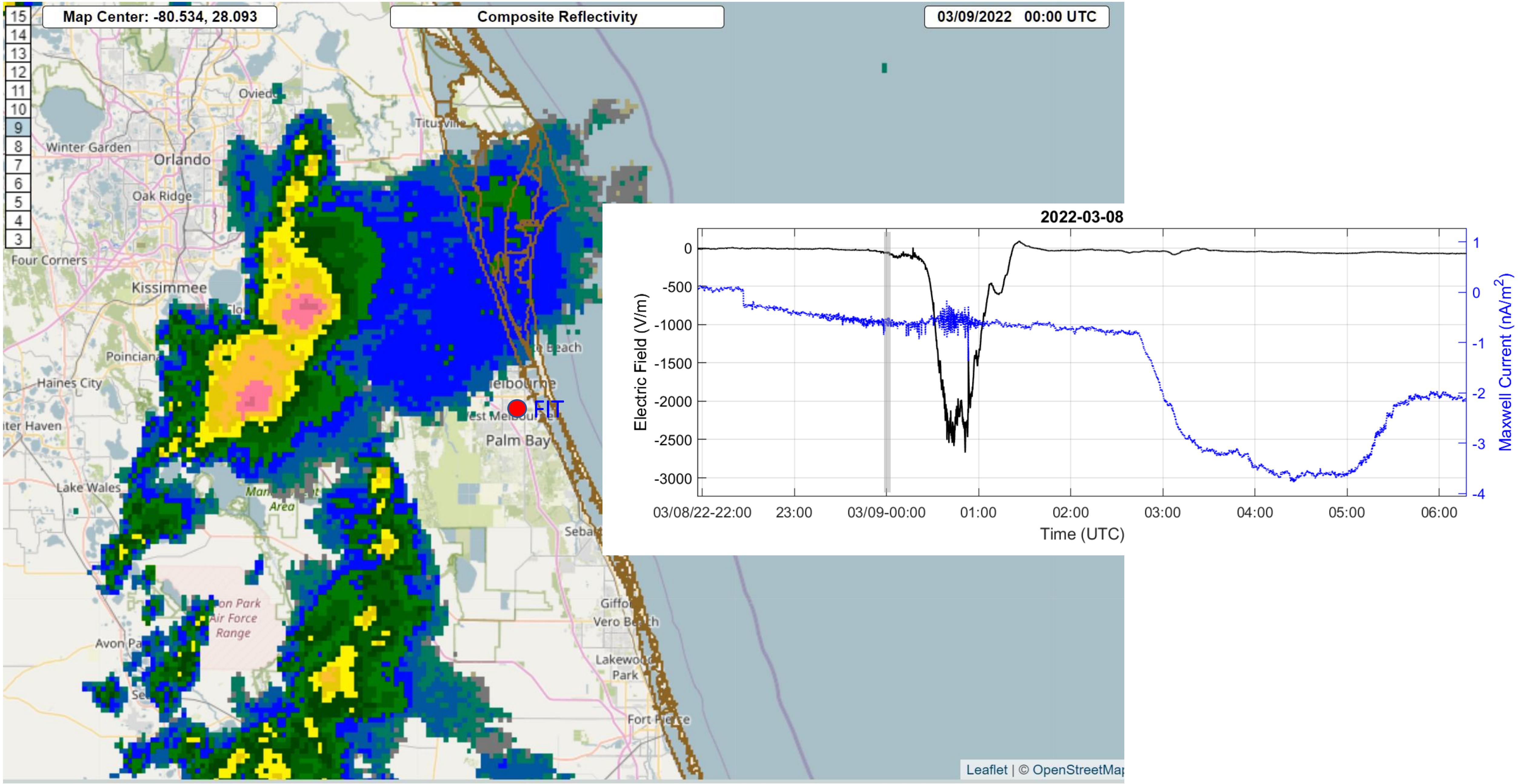

Conclusions and Summary

- In this two-year project we designed, constructed, tested, and deployed a Maxwell current and electric field measurement system. An air conductivity sensor was also developed.

- We analyzed the Maxwell current data in conjunction with measured electric field as well as data from lightning locating systems and weather radars for tens of thunderstorms.

- We found that under certain circumstances such as attached anvils and approaching large-scale synoptic systems, the Maxwell current measurement provided information that was complementary to and augmenting that provided by the electric field measurement.
    - Both of these conditions are a challenge for forecasting elevated electric fields within clouds that might lead to lightning triggering during launch.

- More observations of thunderstorm systems are needed to clearly establish the conditions for which Maxwell current measurements can be used to refine/augment the cloud constraints in the LLCC.

Publications, Presentations, Awards, & Recognitions

After analysis of the data collected using instruments developed and deployed during this two-year project, an abstract and presentation will be prepared for submission/presentation during the 2022 American Geophysical Union Fall Meeting.