# On the Variations of Electric Fields, Lightning and Storm Properties

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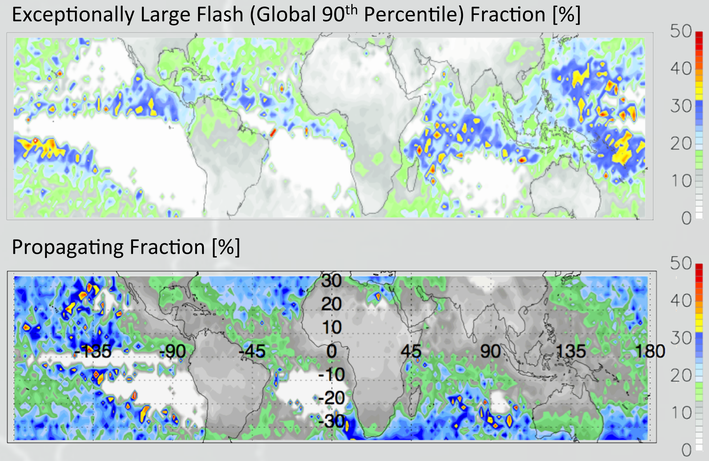
## Motivation

- The Global Electric Circuit (GEC) is typically described in terms of two species of electrified clouds:
  - Thunderstorms - lightning is detected
  - Electrified Shower Clouds (ESCs) – no lightning detected
- Is this simple categorization sufficient to describe the diversity of electrified clouds and how they relate to the larger circuit?

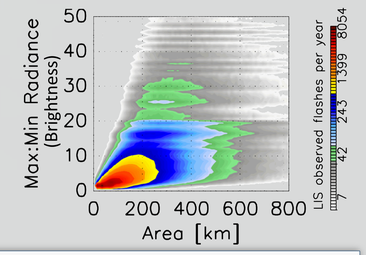
## Optical Flashes and Illuminated Clouds

- Tropical Rainfall Measuring Mission (TRMM)
  - Global snapshots between +/- 36° latitude from late 1997 to 2015
  - Coincident observations from Precipitation Radar (PR), Microwave Imager (TMI), Visible and Infrared Scanner (VIRS), and Lightning Imaging Sensor (LIS)
  - LIS and GOES-R Geostationary Lightning Mapper (GLM) are both optical sensors and can provide similar measurements of lightning

## Optical Lightning Flashes as a Tool to Diagnose Electricity

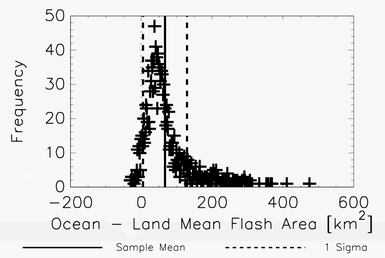



- Optical flash characteristics (brightness, area, pulse count, duration) may yield information about discharges and electrified clouds, but convoluted by other factors:
  - Scattering properties of cloud medium
  - Sensor considerations
- Land / ocean contrasts particularly curious in light of observed differences in electricity

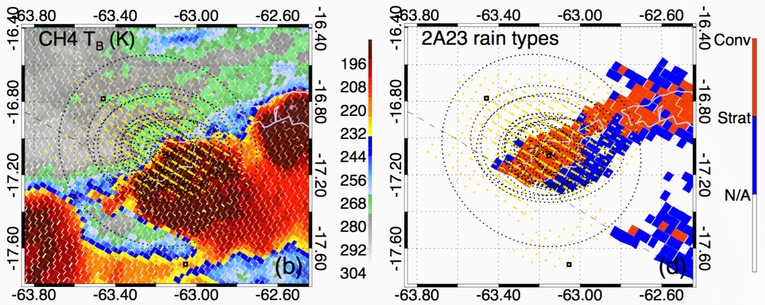



### LIS Flashes in Similar Clouds

- Nearly identical Illuminated Clouds are identified between land and ocean and flash optical characteristics are intercompared
- Even with storm properties and instrument sensitivity held constant, oceanic flashes still different compared to land flashes
- Oceanic propagation inclination may imply a preference for complex electrical structures



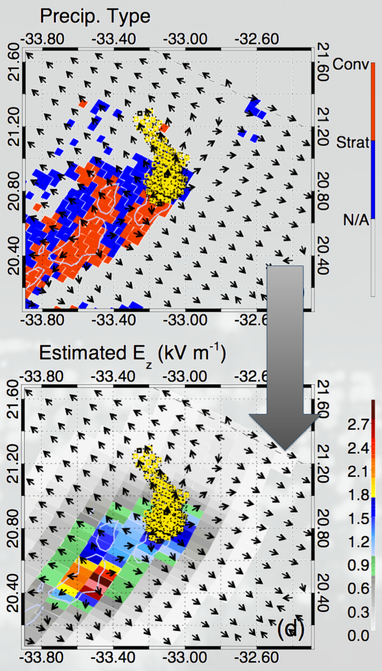

## Typical Optical LIS Lightning Flashes




Illuminated Pixel ▫ Flash Endpoint ····· Group Ellipsoid Fit

- LIS Illuminated Cloud Features (ICFs)
  - Characterize storm regions relevant to each lightning flash by grouping contiguous regions of LIS illuminated (event) pixels
  - Coincident VIRS, PR, and TMI observations summarized for each feature
  - 7 million ICFs observed between 1998 and 2011

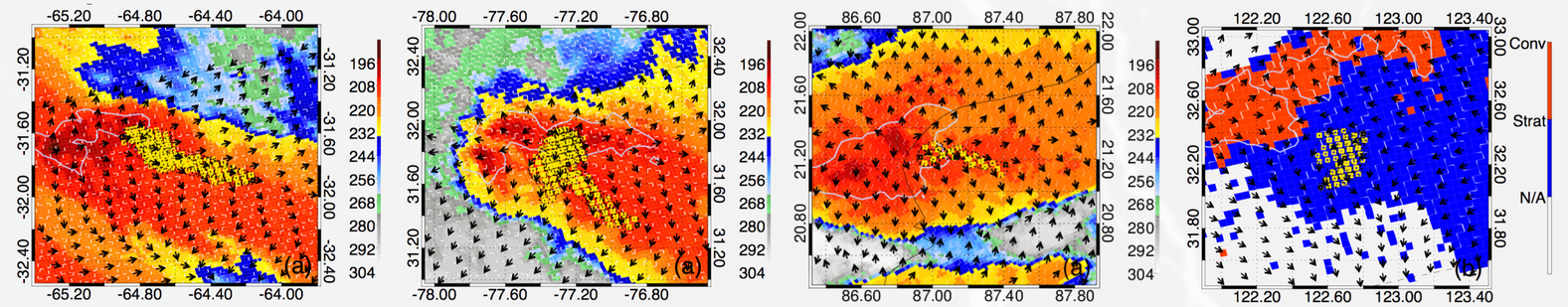
## Satellite Electric Field Retrieval




- Developed using coincident NASA ER-2 aircraft electric field and passive microwave observations
- Represents electrified clouds as a distribution of net charges and approximates electric field vector
- Limited to regions within 1km of sea level to prevent snow artifacts
- INPUTS:
  - TRMM PR-derived charge layer height field
  - TRMM TMI 85 GHz (37 GHz) Polarization Corrected Temperature (PCT) field
- OUTPUTS:
  - Ex, Ey, Ez at prescribed observer altitude (20 km)
- Electrified Cloud Features (ECFs)
  - Extension of TRMM Radar Precipitation Features (RPFs) with nonzero Ez at 20 km
  - 6 million ECFs from 1998 to 2012

VS:

## Propagating Optical LIS Lightning Flashes




## A Global Comparison of Various Types of Electrified Clouds

| | All Electrified Clouds | Electrified Shower Clouds [%] | Mesoscale Systems |
|---|---|---|---|
| LAND | 389844 ECFs (82%)<br>Mean $E_{z\text{-}max}$ = **114 V m$^{-1}$** | | 21020 ECFs (41%)<br>Mean $E_{z\text{-}max}$ = **347 V m$^{-1}$** |
| OCEAN | 5739377 ECFs (98.8%)<br>Mean $E_{z\text{-}max}$ = **41 V m$^{-1}$** | | 461319 ECFs (89%)<br>Mean $E_{z\text{-}max}$ = **124 V m$^{-1}$** |
| LAND | 54532 ECFs (11%)<br>Mean $E_{z\text{-}max}$ = **663 V m$^{-1}$** | Thunderstorms w/o Propagating Flashes [%] | 18090 ECFs (35%)<br>Mean $E_{z\text{-}max}$ = **1141 V m$^{-1}$** |
| OCEAN | 57029 ECFs (1.0%)<br>Mean $E_{z\text{-}max}$ = **730 V m$^{-1}$** | | 46262 ECFs (9%)<br>Mean $E_{z\text{-}max}$ = **790 V m$^{-1}$** |
| LAND | 32136 ECFs (7%)<br>Mean $E_{z\text{-}max}$ = **1430 V m$^{-1}$** | Thunderstorms w/ Propagating Flashes [%] | 12600 ECFs (24%)<br>Mean $E_{z\text{-}max}$ = **2511 V m$^{-1}$** |
| OCEAN | 14778 ECFs (0.2%)<br>Mean $E_{z\text{-}max}$ = **1527 V m$^{-1}$** | | 10042 ECFs (2%)<br>Mean $E_{z\text{-}max}$ = **1841 V m$^{-1}$** |

## Summary

- Electrified clouds and illuminated cloud are examined across the globe from TRMM observations
- Flash properties such as propagation can be observed in optical data
- Land / ocean differences between optical flashes in similar clouds imply fundamental differences in electrified clouds and discharges in each region
- Mean $E_{z\text{-}max}$ values over oceanic thunderstorms slightly stronger than over land
- Thunderstorms with propagating flashes have 2x stronger $E_{z\text{-}max}$ values than typical thunderstorms and may constitute a separate species of electrified cloud
- "Thunderstorm" and "ESC" categories appear to not be sufficient to represent the observed variations in electricity within the same species of electrified cloud

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