Describing the electrical nature of the Amazon thunderstorms during the 2\textsuperscript{nd} GO-Amazon IOP and ACRIDICON-CHUVA Field Campaign

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The most efficient electrical charging mechanisms relies on the collision between ice crystals and graupel:

- It does not require an Electric field to polarize the particles
- The collisions happen in the presence of super cooled water droplets (riming)
- The charge transfer (+ or -) depends on:
  - LWC
  - Temperature during the collision
  - Size of the particles – velocity
  - Growth phase

![Diagram](image)

**Fig. 3.12.** Charge (in fC) gained by rimed graupel colliding with ice particles as a function of temperature and liquid water content. Open circles indicate that rimed graupel gained positive charge, solid circles indicate that it gained negative charge, and x’s indicate that no charge was transferred. (Adapted from Takahashi 1978, with permission.)
Data Set: IOP 2 – Sep-Oct 2014

**Lightning Networks:**
- STARNET - CG
- LINET – IC + CG

**Vertical Electrical Field:**
- Network of Field Mills

**Rain Measurements:**
- Doppler S-Band – SIPAM – Manaus
- Doppler Dual Pol – X Band – T3 – CHUVA
- W Band (95 GHz) ARM Cloud Radar
- MRR (24 GHz)
• Sferics Timing and Ranging Network – STARNET

0.1 x 0.1 degree grid box
Summary of STARNET lightning data

IOP2

GoAmazon IOP2 (2014-09-01 to 2014-10-04)

number of STARNET strokes

150,000 sferics
100,000 sferics
50,000 sferics

20 1 6 11 16
Local Time

Manaus

STORM-T
• 3D total (intracloud + cloud-to-ground) lightning data from DLR Lightning Network (LINET) during part of GoAmazon IOP2: – 29 Aug 2014 – 07 Oct 2014
Summary of LINET lightning data IOP2

GoAmazon IOP2 (2014-09-01 to 2014-10-04)

Number of LINET strokes

Local Time

Manaus
Network of 7 field mills

- 5 Campbels
- 2 Bolteks
Electrical field from Coulomb’s Law

\[
E = \frac{1}{4\pi\varepsilon} \sum_{i=1}^{N\text{charges}} \frac{q_i}{r_i^2}
\]

\[
\vec{E} = \frac{1}{4\pi\varepsilon} \frac{q}{r^2} \hat{a}_r \left[ \frac{V}{m} \right]
\]
Case Study:

*September 8th, 2015*

19-22 UTC
Total Lightning - LINET
3,067 IC + 1,213 CG Neg and 2,167 CG Pos
25 IC+CG per second – Maximum
Sferics – STARNET
2,174 Sferics
10 Sferics per second – Maximum
Field Mill
> 7 kV/m
SIPAM S-Band x LINET Sferics sources
SUMMARY – T3

W-Band

XPOL

MRR

LINET STARNET

IC+CG

-10 & -40°C

Ez
What does LINET measure?
RADIO SIGNAL EMISSIONS

Stepped Leader either from IC and CG – LF and HF

Return Stroke CG – VLF and LF
Dipole Negative

Dipole Positive
Tripole

Quadpole
W band

MRR

5 and 10 km
W band

MRR

5 and 10 km
How does the thunderstorm evolve Temporally and Spatially?
How does the thunderstorm look inside?
19:26 UTC

XPOL Radar

Zh

Doppler Vel

ZDR

Spectral Width

PhiDP

RhoHV
SIPAM Radar

19:36 UTC
20:36 UTC

SIPAM Radar
What did happen to have these lightning spots?
Conclusions

• Lightning activity increases as transition season advances from dry to wet
• Diurnal convection favors lightning activity
  – 16 trough 21 UTZ (12-17 Local Time)
• The river + city circulation play an important role on the convection/lightning enhancement, boosting the vertical shear.
• Vertical Electrical field oscillation points to Negative Di-Tri-Quadipole configuration.
Conclusions

- IC charge density sources point to a Quadipole configuration:
  - Q- at -10/20 & -50°C and Q+ at -30 & -55°C
- CGs are observed over convective cores
- ICs are observed aloft over the turbulent cores
- 35 dBZ (S-Band) reaches as high as 10-12 km
- > 50 dBZ above 10 km over Severe Activity and tilted (shear).
Next Steps

- Correct XPOL for power decay, rain attenuation and radome wetting.
- Apply hydrometeor classification.
- Run the inverse problem of Coulombs Law by combining Ez, LINET and XPOL to infer the charge centers.
- Inspect the role of turbulence and hydrometeor types on the lightning activity through numerical simulations.
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