Thunderstorms characteristics during ACRIDICON-CHUVA and GoAmazon field campaigns

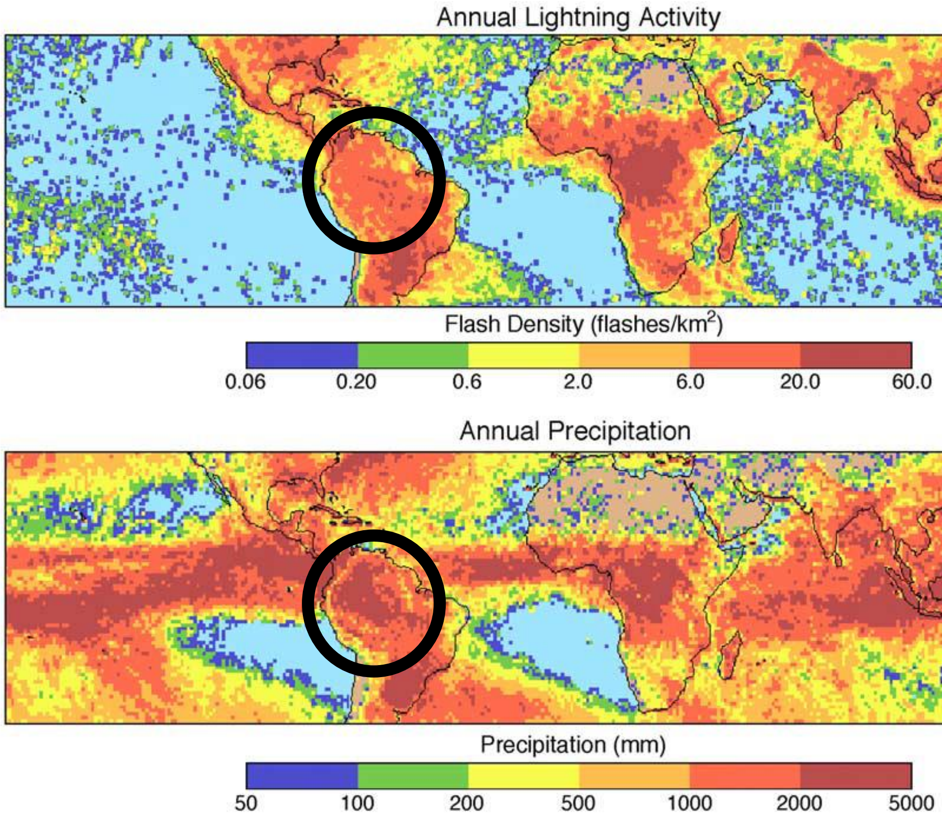
Rachel Albrecht, Ramon Braga, Carlos Morales, Hartmut Höller,

Luiz Machado, Daniel Rosenfeld, Manfred Wendisch, Meinrat Andreae, Ulrich Pöschl, João Neves, Thiago Biscaro, Wagner Lima, Cristiano Eichholz, Romulo Oliveira, Vinicius Sperling, Izabelly Carvalho, Alan Calheiros, Lia Amaral, Micael Cecchini, Jaci Saraiva, Ivan Saraiva, Courtney Schumacher, Aaron Funk

(rachel.albrecht@iag.usp.br)

Motivation

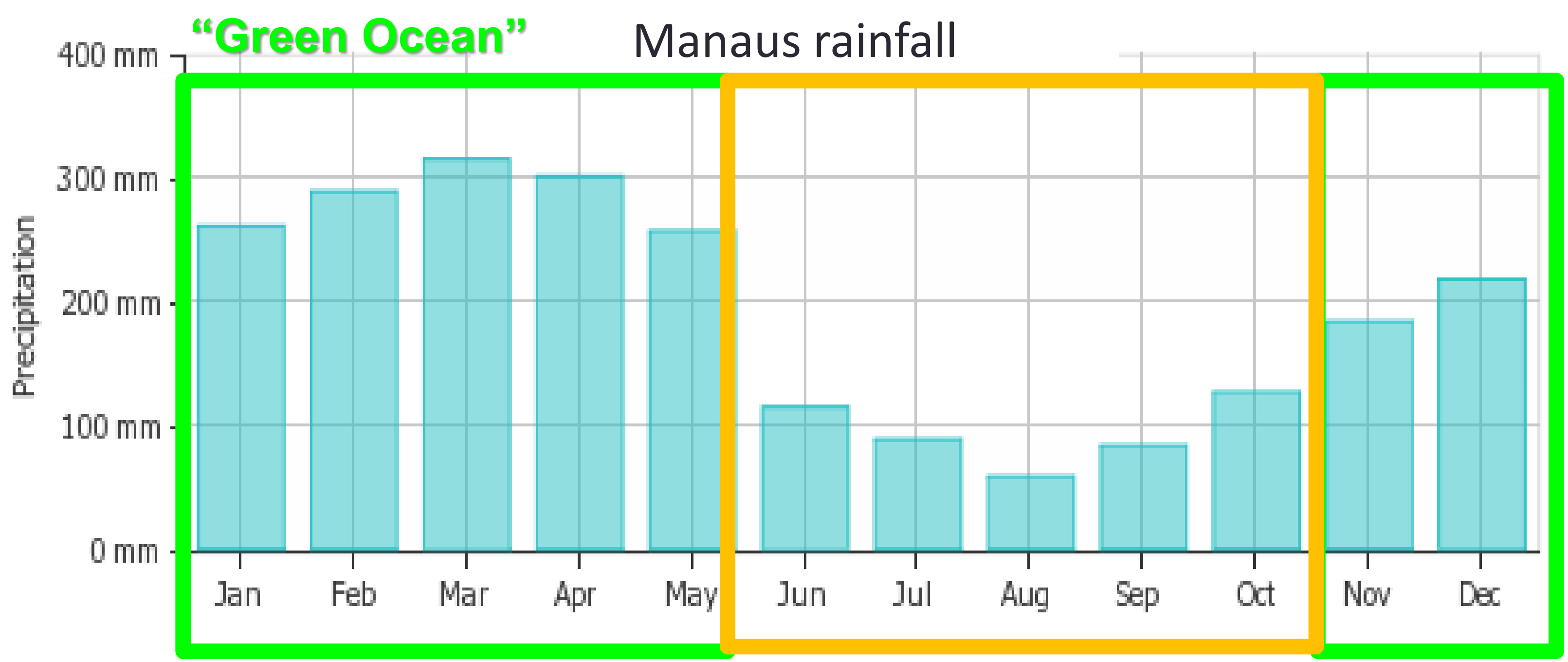
- Lightning and rainfall does not have a linear relationship:
  - Rainfall is produced by modest lifting and moderate updrafts over large areas.
  - ***Lightning*** production is a response from ***deeper lifting*** and ***strong updrafts***.



Williams (2005) Atm. Res.

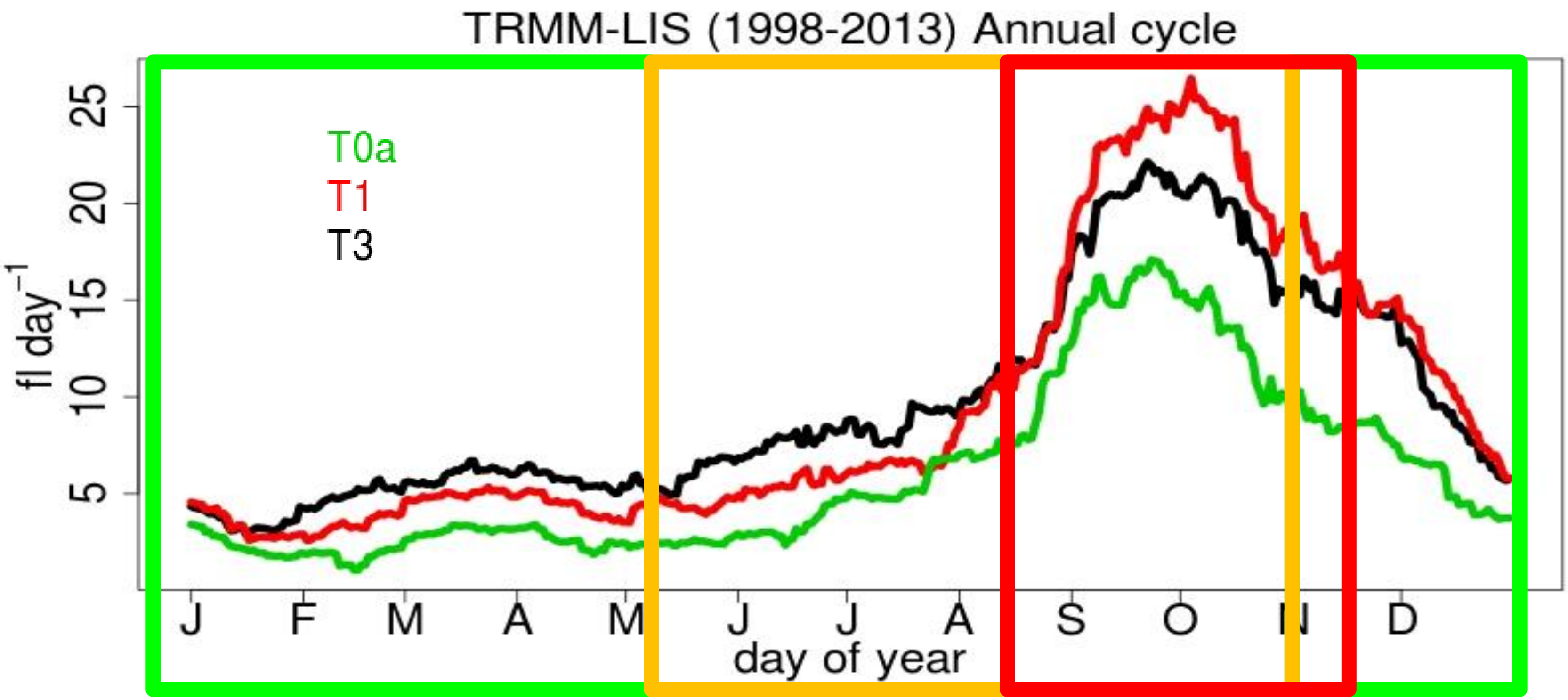
Motivation

- The Amazon basin itself is an example of this “mismatch” on rainfall and lightning along the year:
  - well defined **DRY (Jun-Oct)** and **WET (Nov-May)** seasons



Motivation

- The Amazon basin itself is an example of this “mismatch” on rainfall and lightning along the year:
  - well defined **DRY (Jun-Oct)** and **WET (Nov-May)** seasons
  - well defined **LIGHTNING (Sep-Nov)** season



Objective

- Quantify the factors that control deep convection in the Amazon and the interactions between them:
  - Large-scale circulation – moisture and wet season onset
  - Thermodynamics – diurnal cycle of PBL and instability
  - Cloud microphysics – CCN/IN activation, latent heat

Depth and area of updraft

Modified by land-cover modification

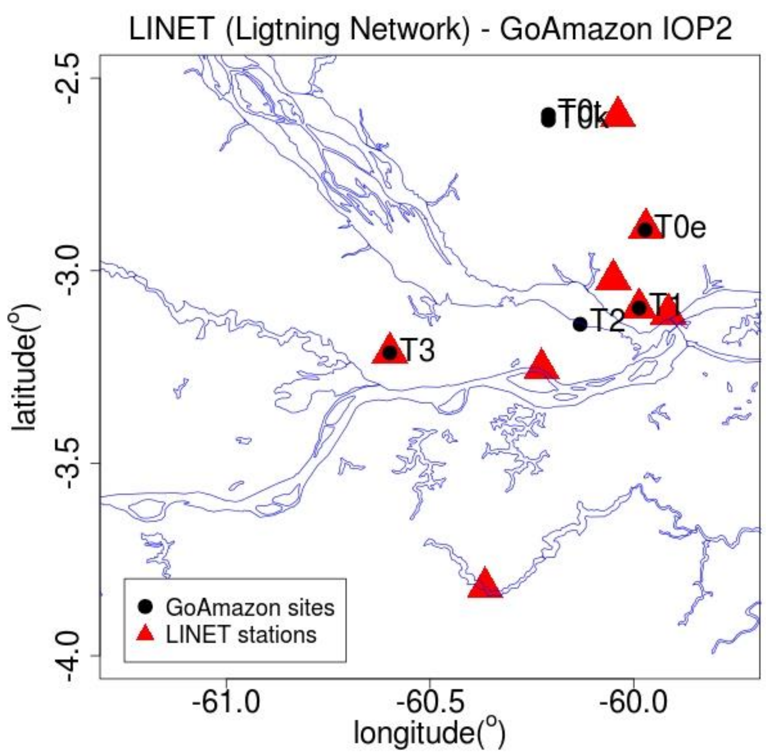
→ Cloud-aerosol-precipitation “intensity” of interactions in deep convection are probably season (wet vs. dry-to-wet) dependent

Data

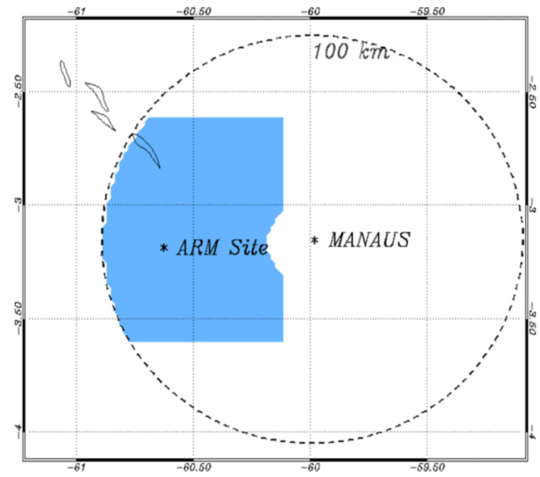
- GoAmazon (T3 site) and ACRIDICON-CHUVA Project field experiments (Feb-Dec 2014):
  - Pollution background – Cloud Condensation Nuclei concentrations.
  - Thermodynamics – Convective Available Potential Energy (CAPE)
    - Four daily radiosonde at ARM T3 (2014-2015) at 00 UTC, 06 UTC, 12 UTC and 18 UTC.
    - Also at 15 UTC during GoAmazon Intensive Operation Periods (IOP1: Feb-Mar 2014; IOP2: Sep 2014)
  - Raining clouds macrophysics – SIPAM S-band radar:
    - volumetric Constant Altitude Plan Position Indicator (CAPPI) of dBZ (quality control from Courtney Schumacher group)

Data

- Lightning data as proxy for deep convection:
  - Vaisala GLD360 network
  - LINET: 3D total (i.e., intracloud e cloud-to-ground) lightning, 29 Aug 2014 to 07 Oct 2014



Methodology – Part I



- Data from February-December 2014

- Identified clusters of convective cells close to T3 site:
  - radar CAPPI at 0.5 km of height
  - minimum threshold of 20 dBZ (~1 mm h^{-1}),

- Calculate
  - Radar liquid water path (LWP) and ice water path (IWP) (Petersen and Rutledge, 2001)

$$LWC = 3.44 \times 10^{-3}\, Z^{4/7}$$

$$LWP = \int_{0.5km}^{6.0km} (0.5 \cdot LWC)\, dz \; [\mathrm{Kg\ m^{-2}}]$$

$$IWC = 1000\, \pi\, \rho\, (N_0^{3/7})\, (5.28 \times 10^{-18}\, Z \;/\; 720\,)^{4/7}$$

$$IWP = \int_{6.5km}^{12km} (500 \cdot IWC)\, dz \, [\mathrm{g\ m^{-2}}]$$

where $N_0 = 4 \times 10^6\ m^{-4}$ and $\rho = 917\ Kg\ m^{-3}$.

Methodology – Part I

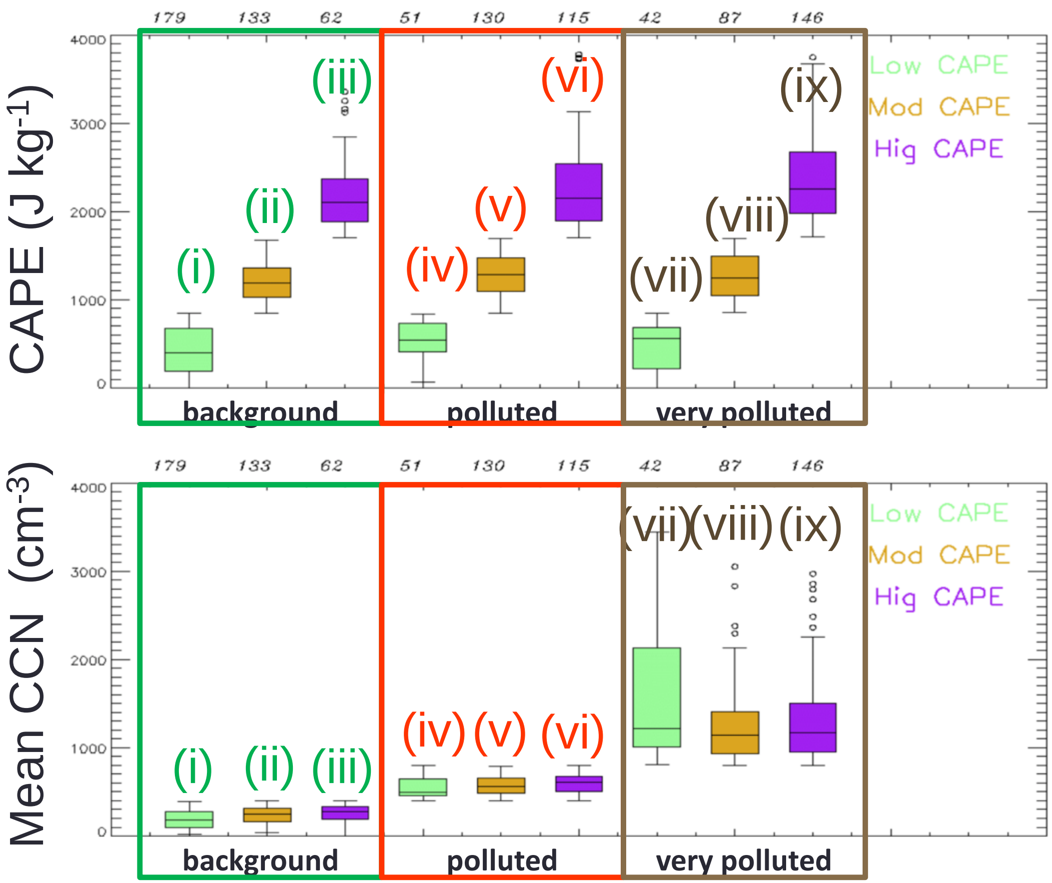
- Classify storms by different "**E**nvironment for **R**ain **D**evelopment' (***ERD***):

  - 3 categories as a function of mean hourly CCN concentrations at T3:
    - Background: mCCN < 400 cm^{-3};
    - Polluted: 400 cm^{-3} < mCCN < 800 cm^{-3} ;
    - Very Polluted: mCCN > 800 cm^{-3}.

  - 3 categories of CAPE (~ the terciles of CAPE distribution) from T3 sondes:
    - Low CAPE: CAPE < 850 J kg^{-1}; (Low Instability)
    - Moderate CAPE: 850 J kg^{-1} < CAPE < 1700 J kg^{-1}; (Moderate Instability)
    - High CAPE: CAPE > 1700 J kg^{-1} (High Instability)

Methodology – Part I

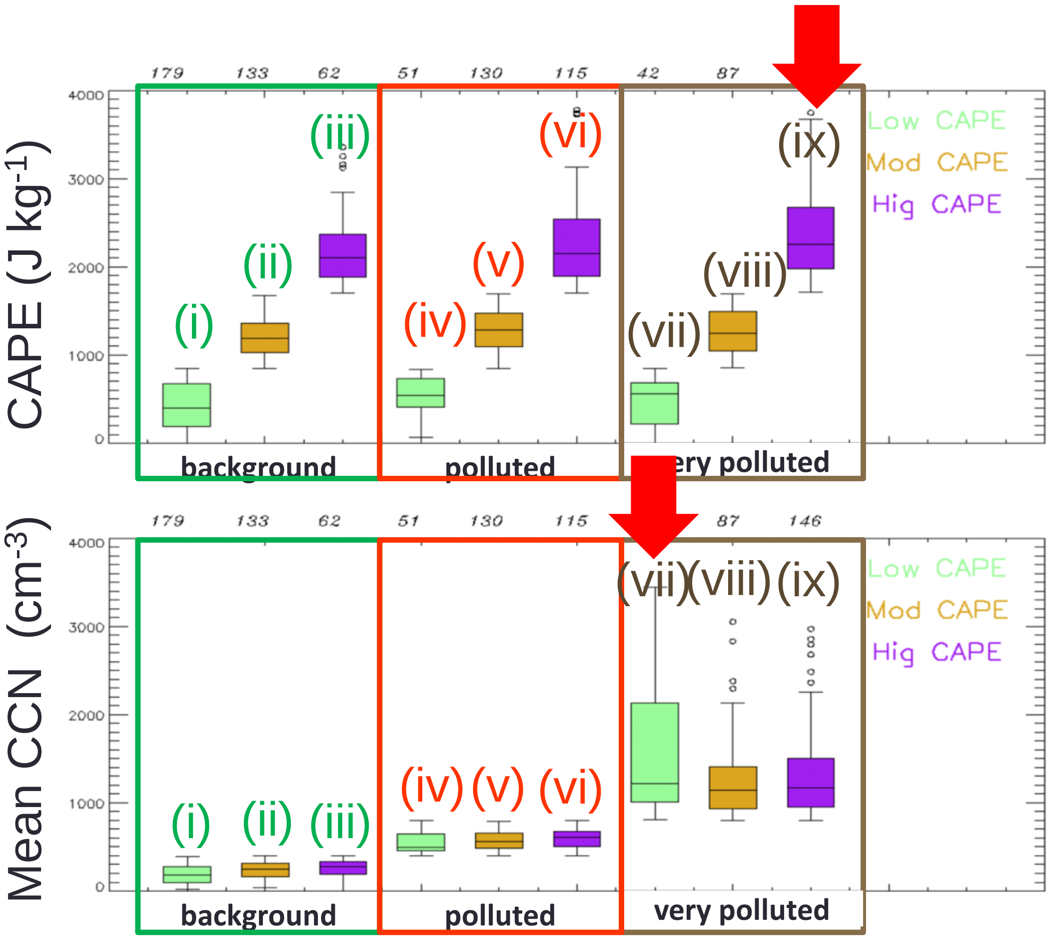
- Therefore, a total of **9 possible ERD** as combinations of mean CCN and CAPE categories, for example:



i. background and low CAPE
ii. background and moderate CAPE
iii. background and high CAPE
iv. polluted and low CAPE
v. etc…

Methodology – Part I

- Therefore, a total of **9 possible ERD** as combinations of mean CCN and CAPE categories, for example:



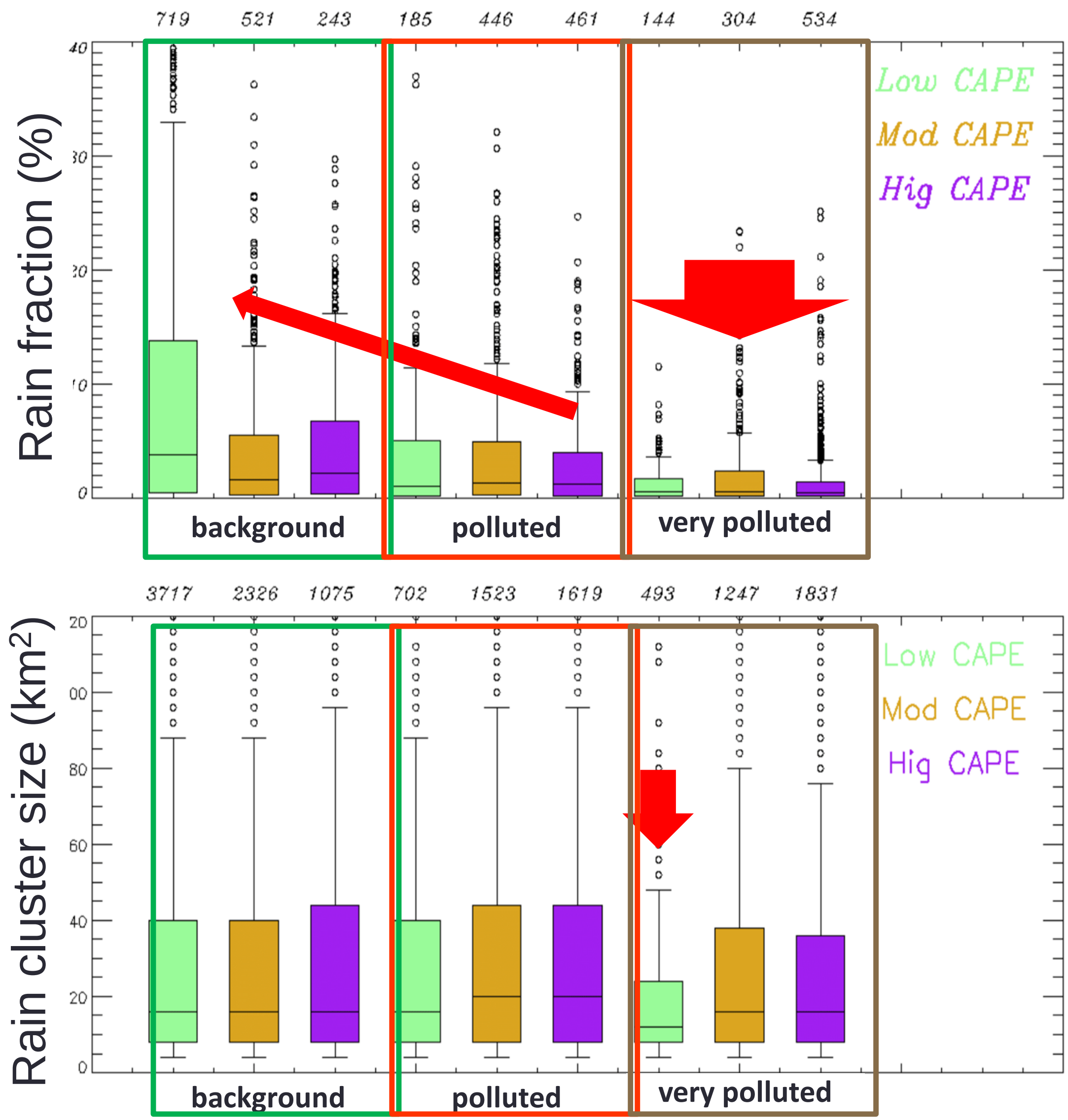
High CAPE :

- Very Polluted is slightly skewed to higher values.

Very Polluted:

- **low CAPE** is skewed to higher pollution values

Preliminary results – Part I



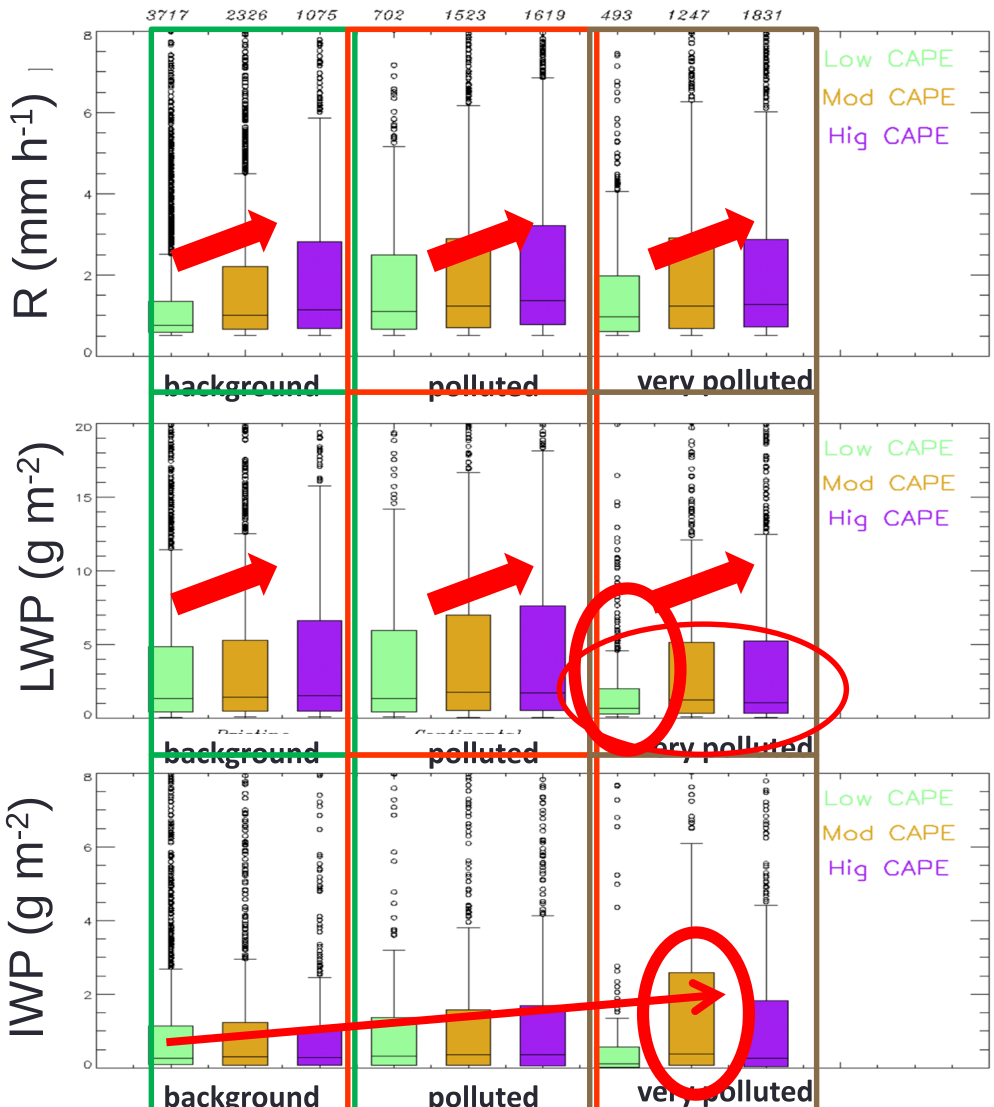
Rain Fraction (% of radar pixels Z >20 dBZ):

- significantly lower during Very Polluted cases, regardless of the thermodynamical instability category.
- gradually increases as cleaner the atmosphere gets

Rain clusters:

- similar sizes among other ERD conditions (→ higher RF values are due to a greater number of cells and not larger cells.)
- Very Polluted and low CAPE ERD, smaller clusters (→ tend to be suppressed in size)

Preliminary results – Part I



Rain Rate:

- Increases with instability, regardless pollution conditions

LWP:

- Skewed to higher values as higher the instability.
- Smaller LWP during Very Polluted conditions
- Very small values of LWP during Very Polluted + Low Instability conditions

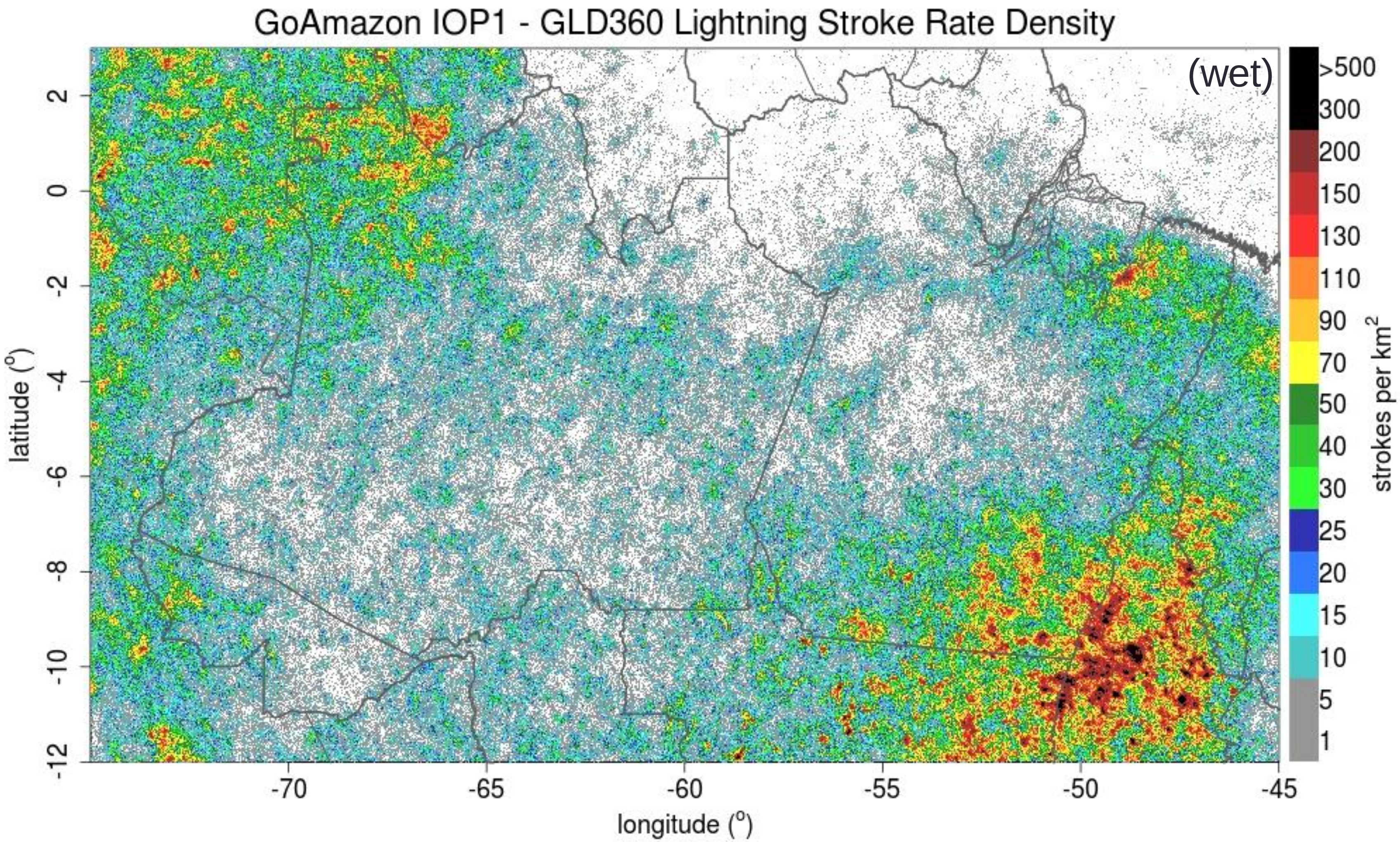
IWP:

- Modest increase with pollution.
- Higher values in Very Polluted +Mod.CAPE conditions

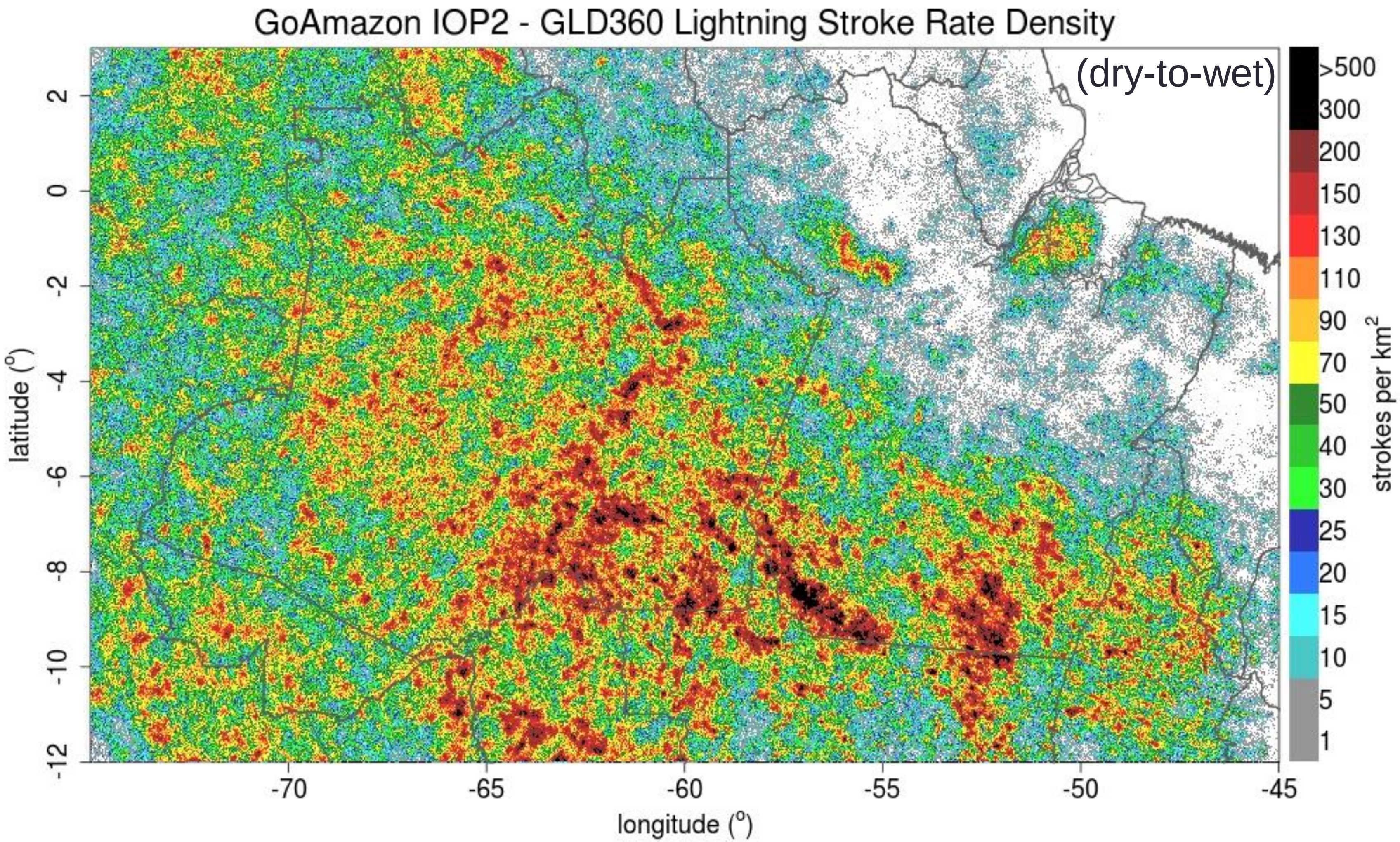
Methodology – Part II

- Overview of lightning activity during IOP1 and IOP2:
    - Spatial and "seasonal" variability of *lightning stroke rate density* (i.e., lighting strokes per km^2 per IOP)
    - Diurnal Cycle

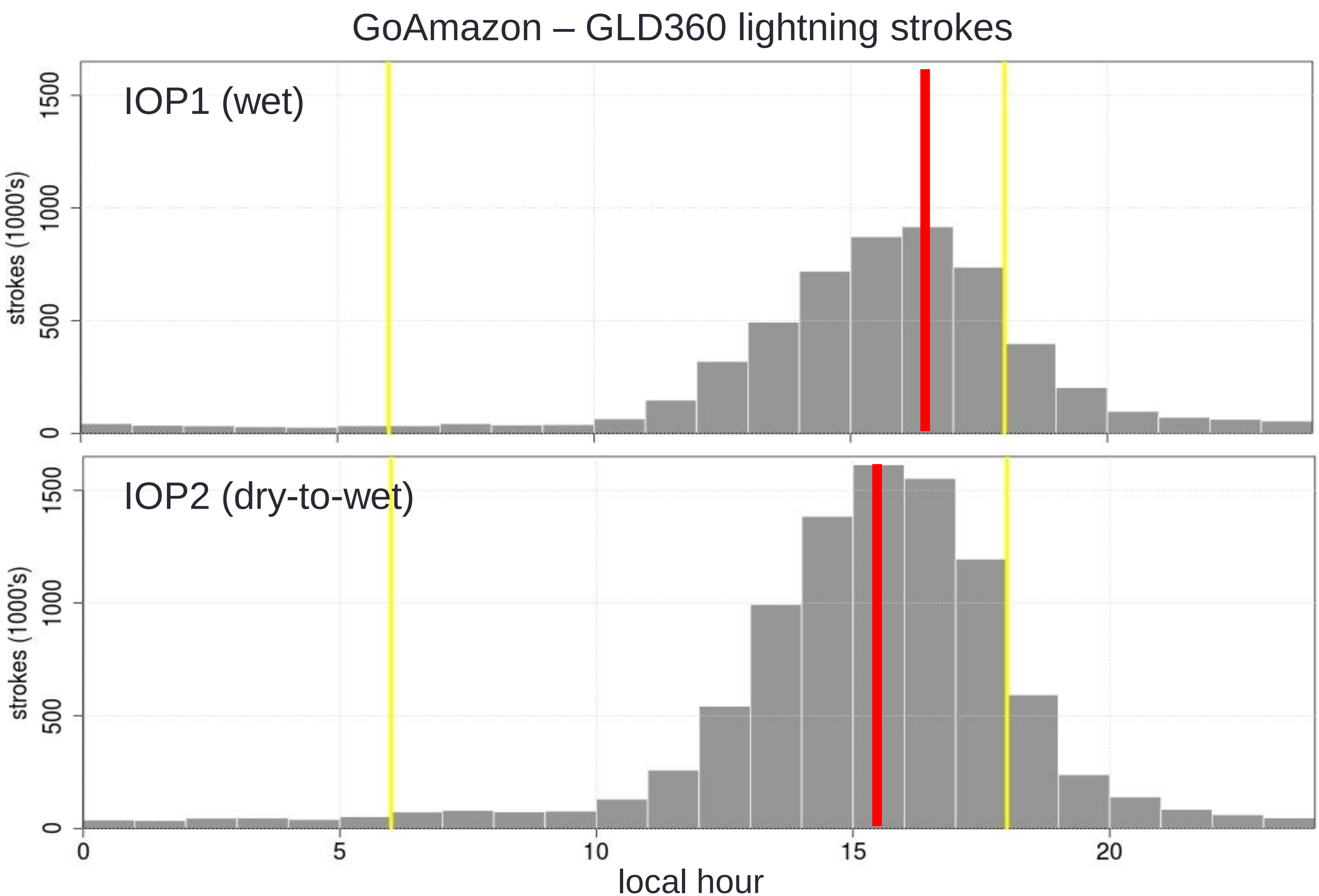
Preliminary results – Part II



Preliminary results – Part II

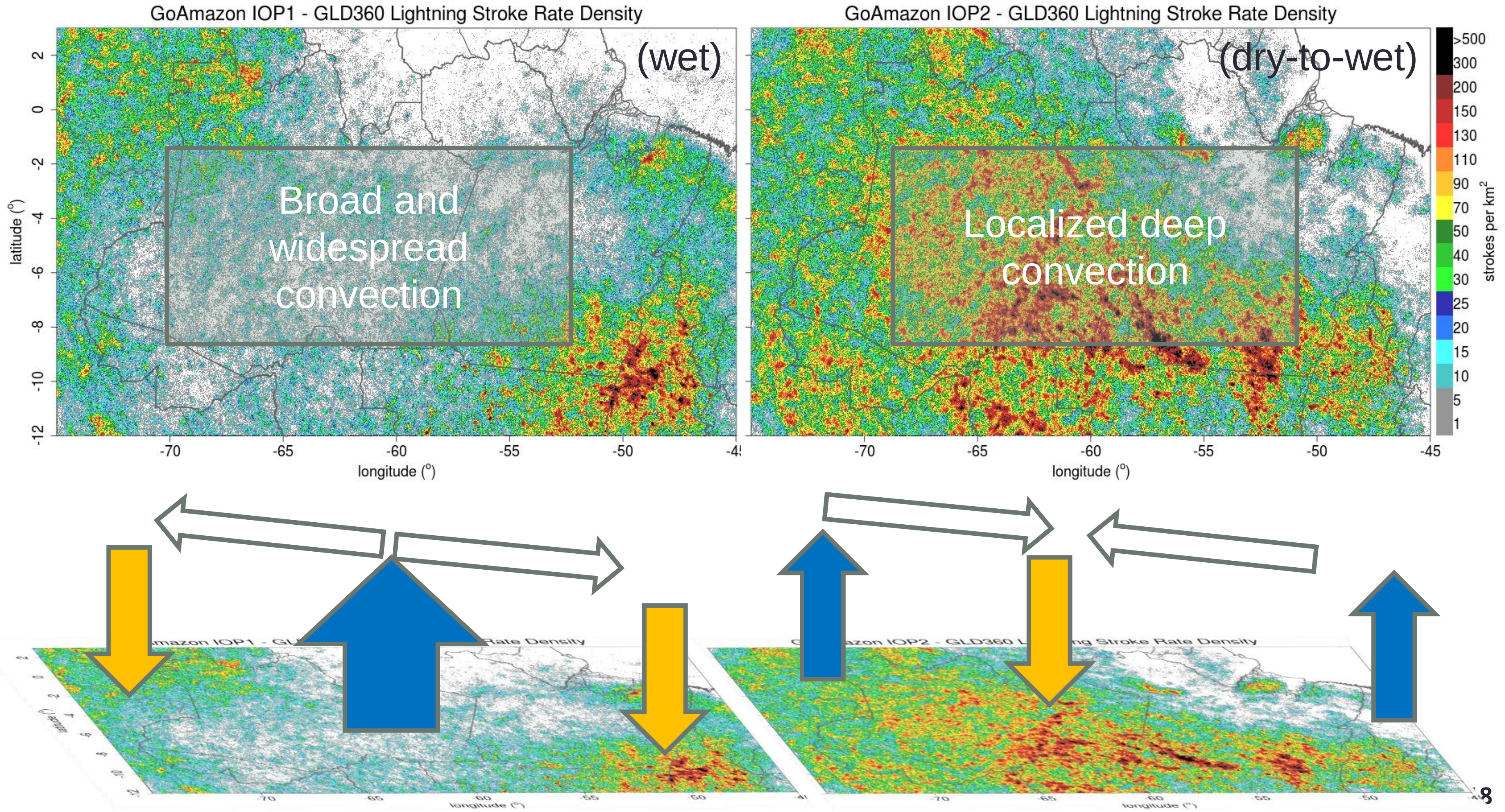


Preliminary results – Part II



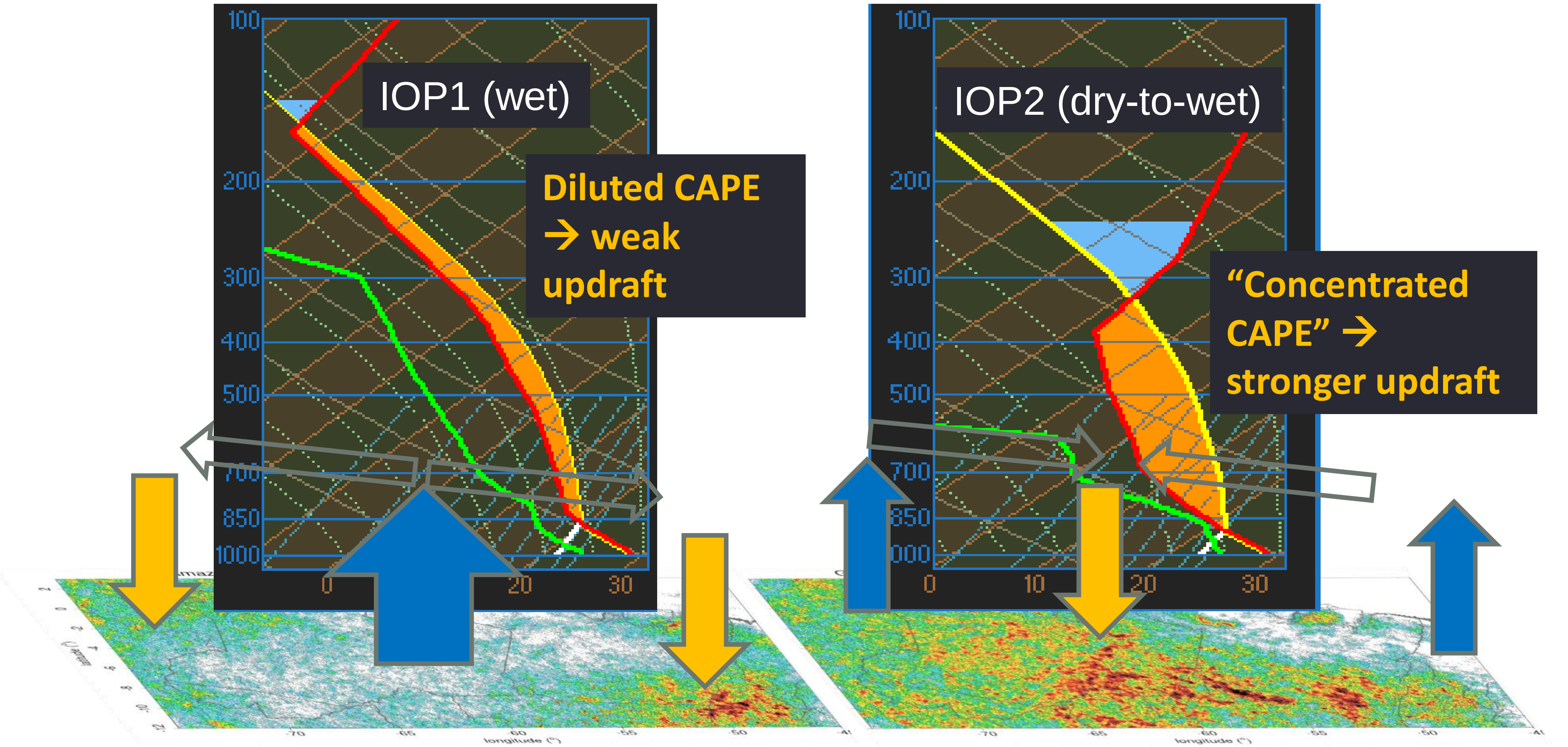
Preliminary results – Part II

- Large-scale:



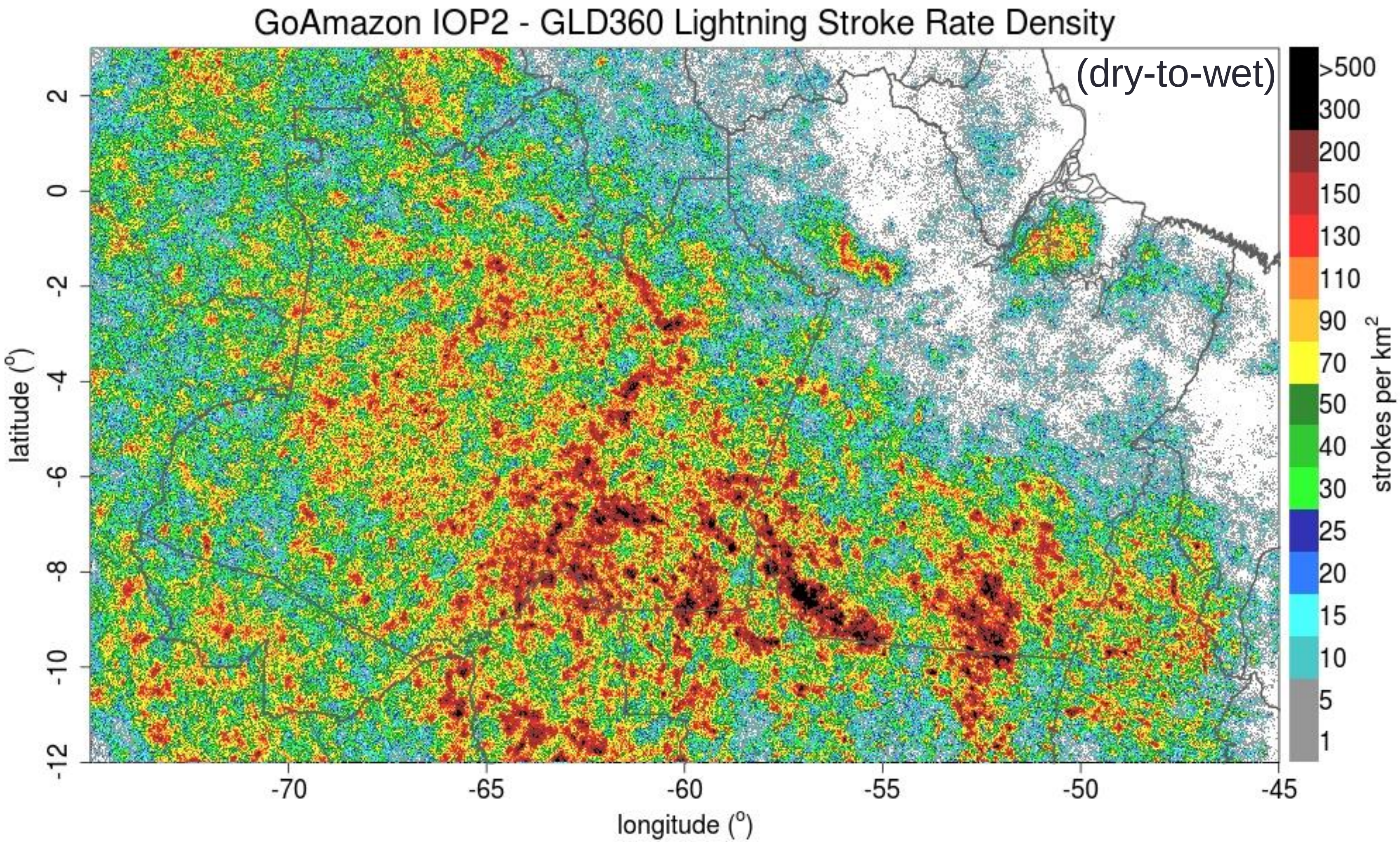
Preliminary results – Part II

- Large-scale + Thermodynamics :
  - Same CAPE value (or a bit higher during IOP2), and “fat” vs. “skinny”



Preliminary results – Part II

- Large-scale + Thermodynamics + Local River Breeze Circulation:



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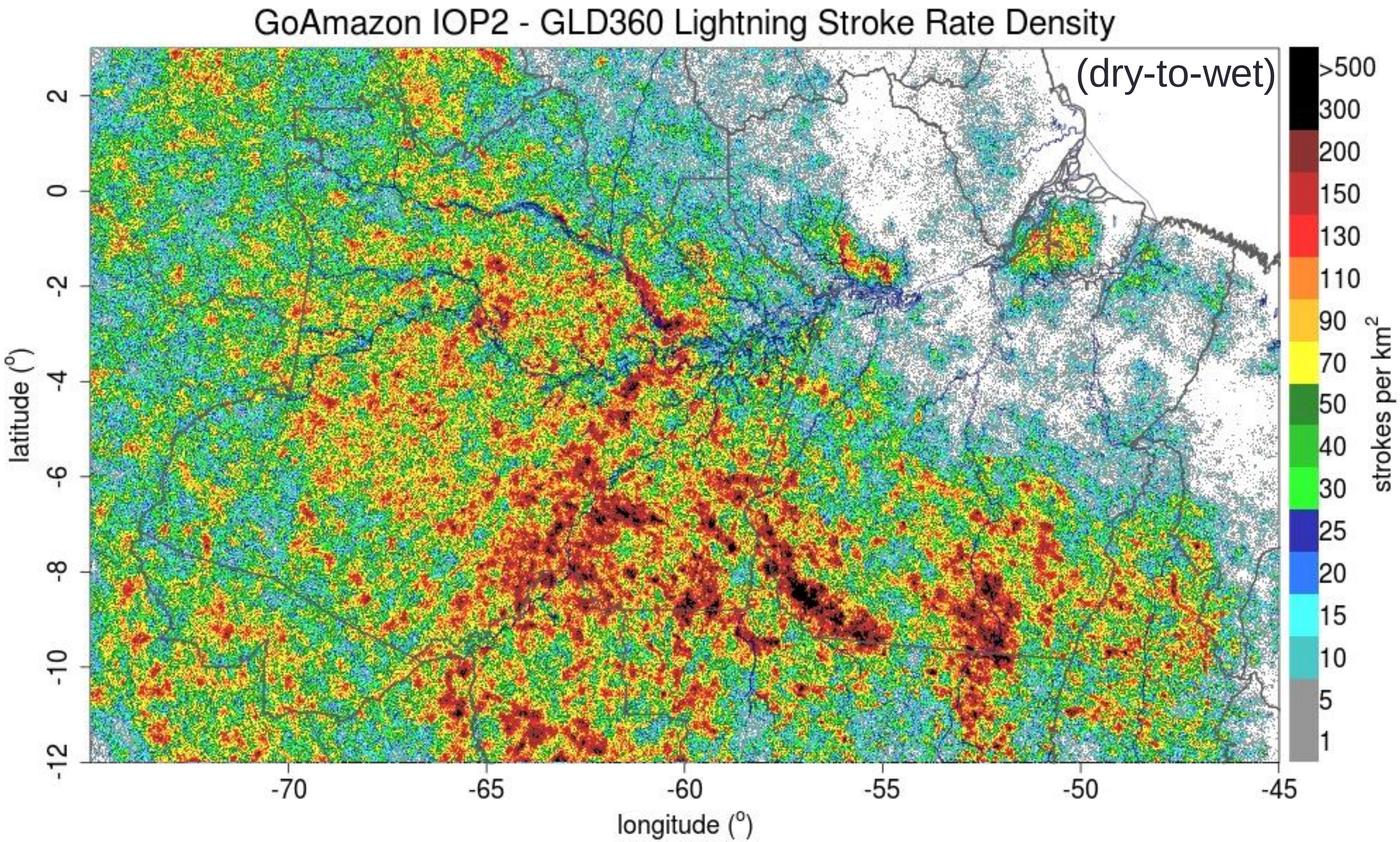

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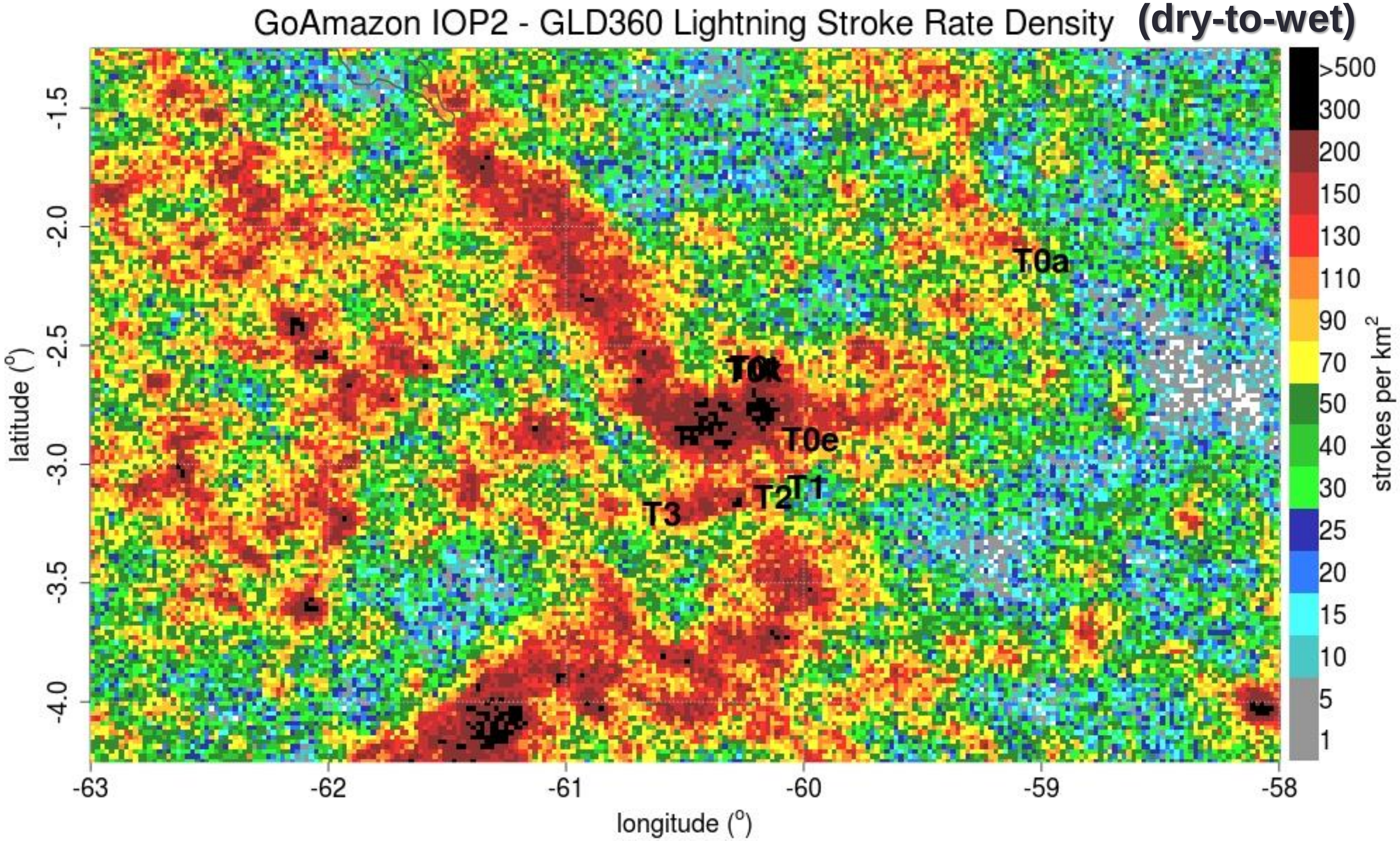

Preliminary results – Part II

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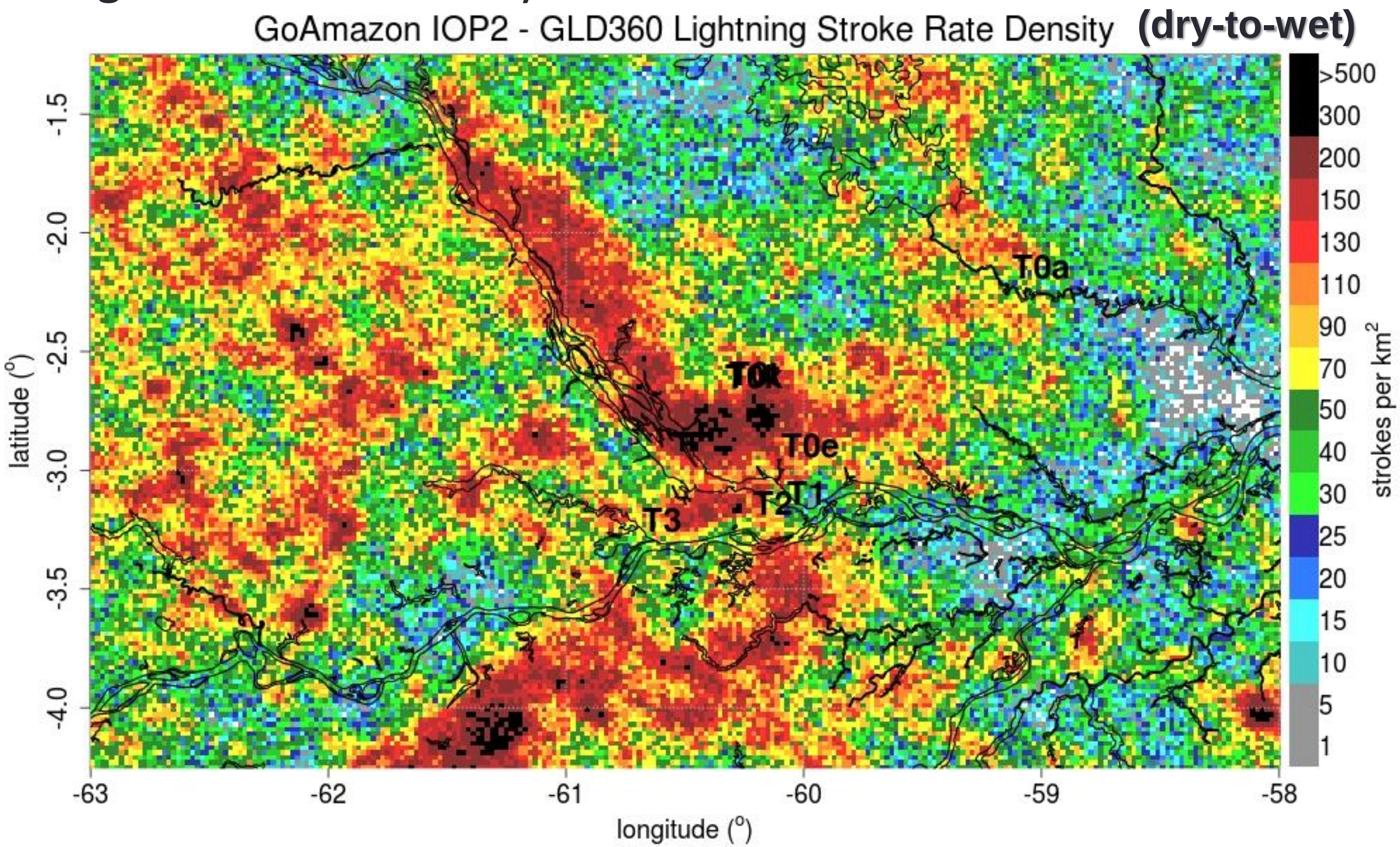
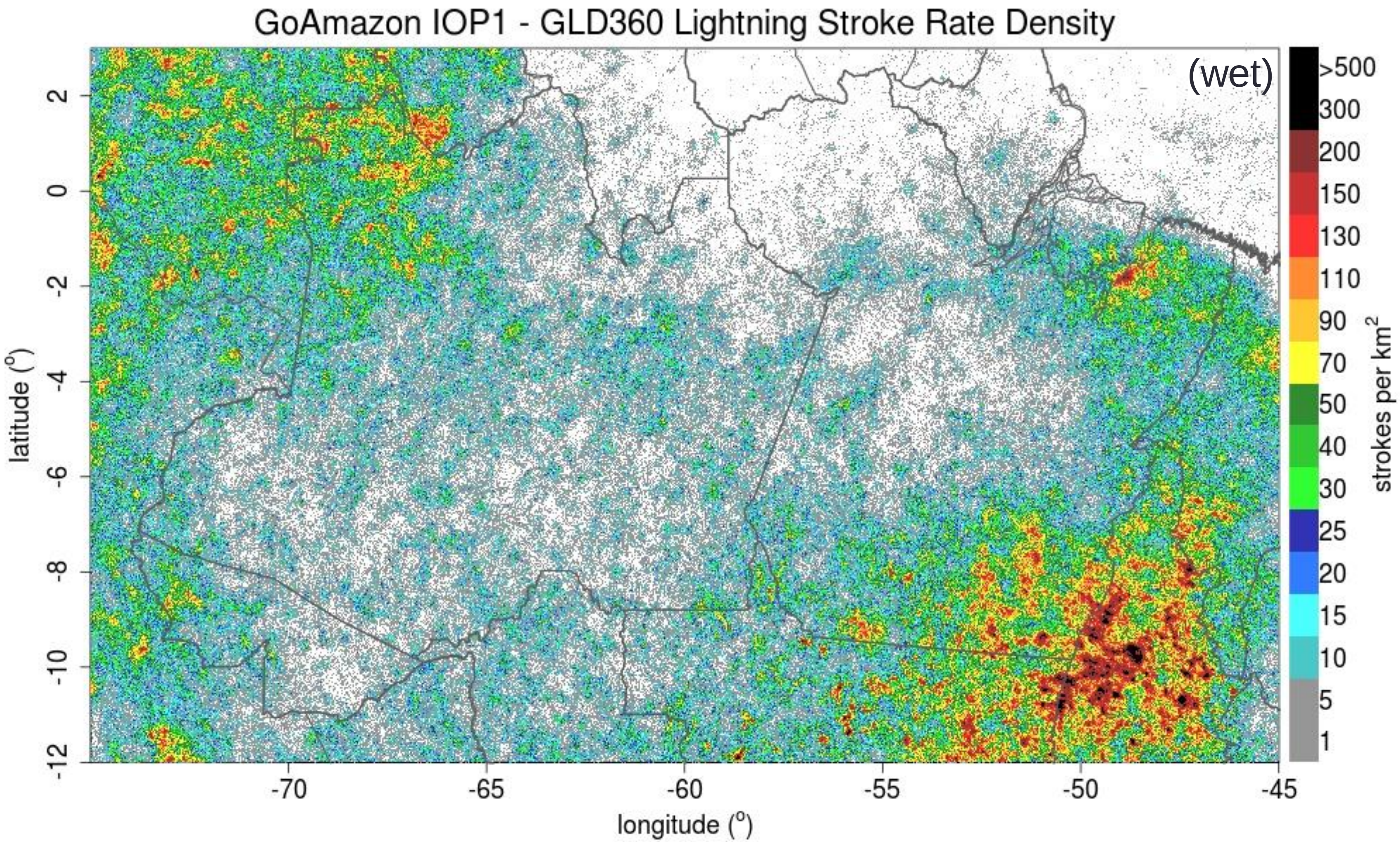


Preliminary results – Part II

- Large-scale + Thermodynamics + ~~Local River Breeze Circulation~~:



Preliminary results – Part II

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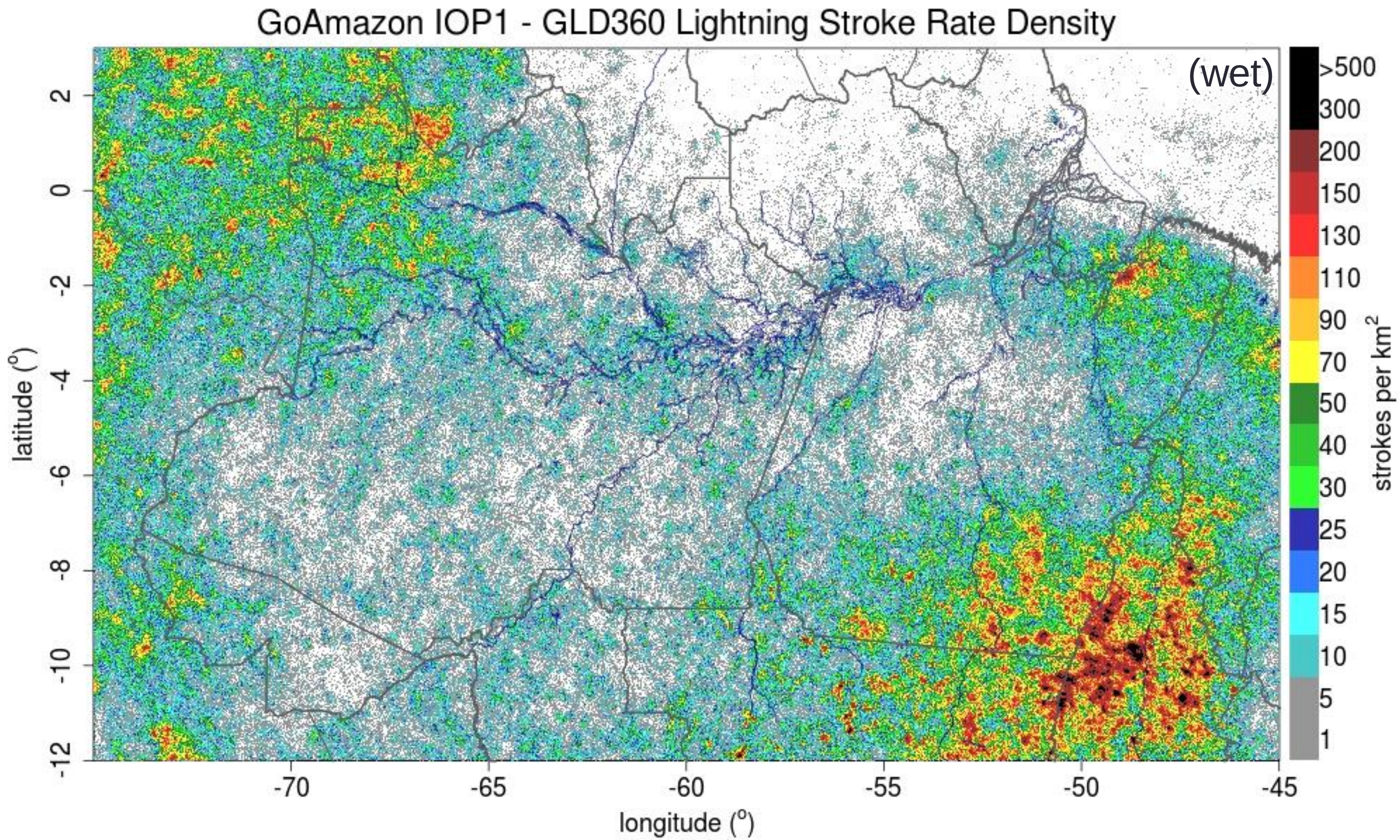

Preliminary results – Part II

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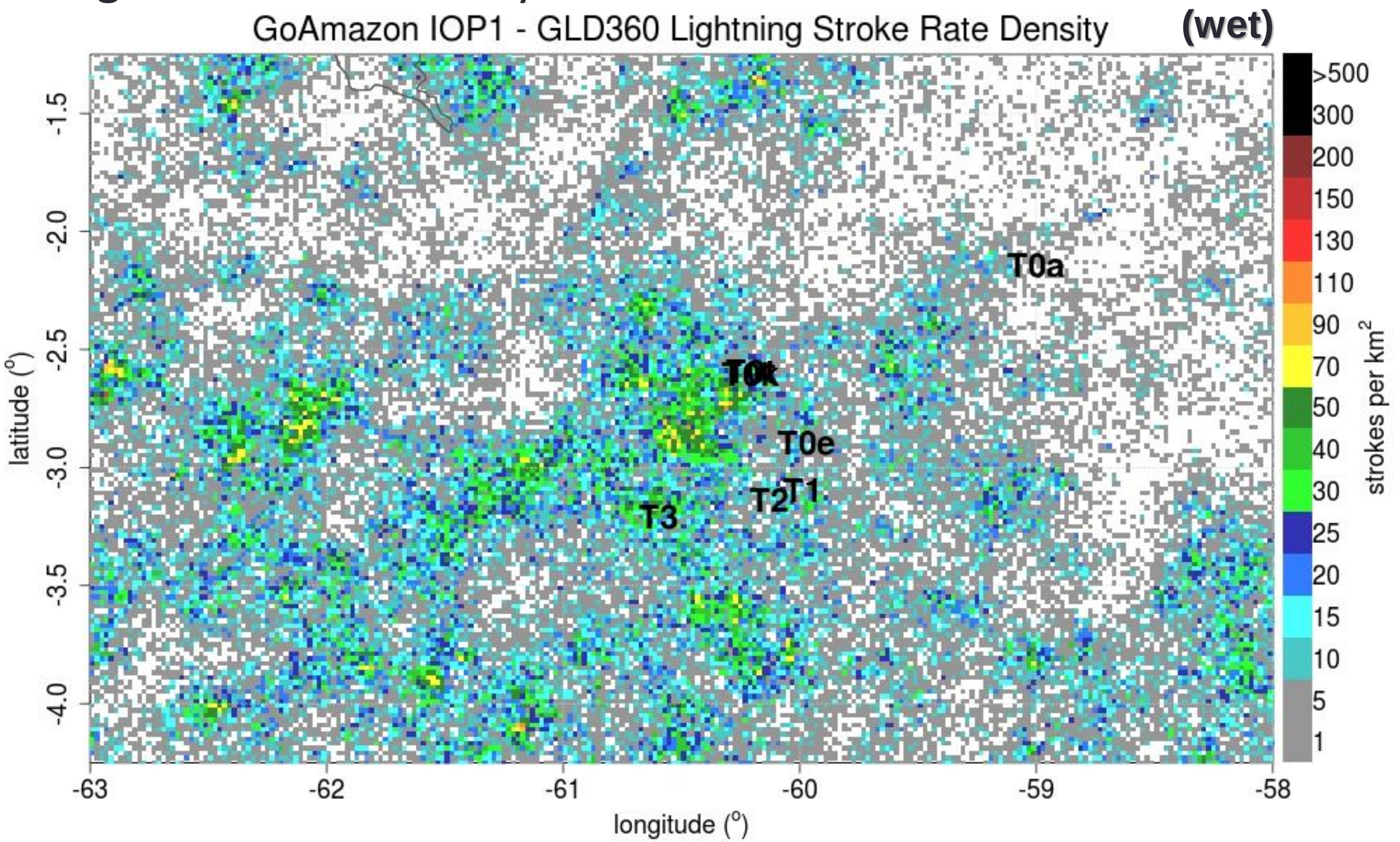

Preliminary results – Part II

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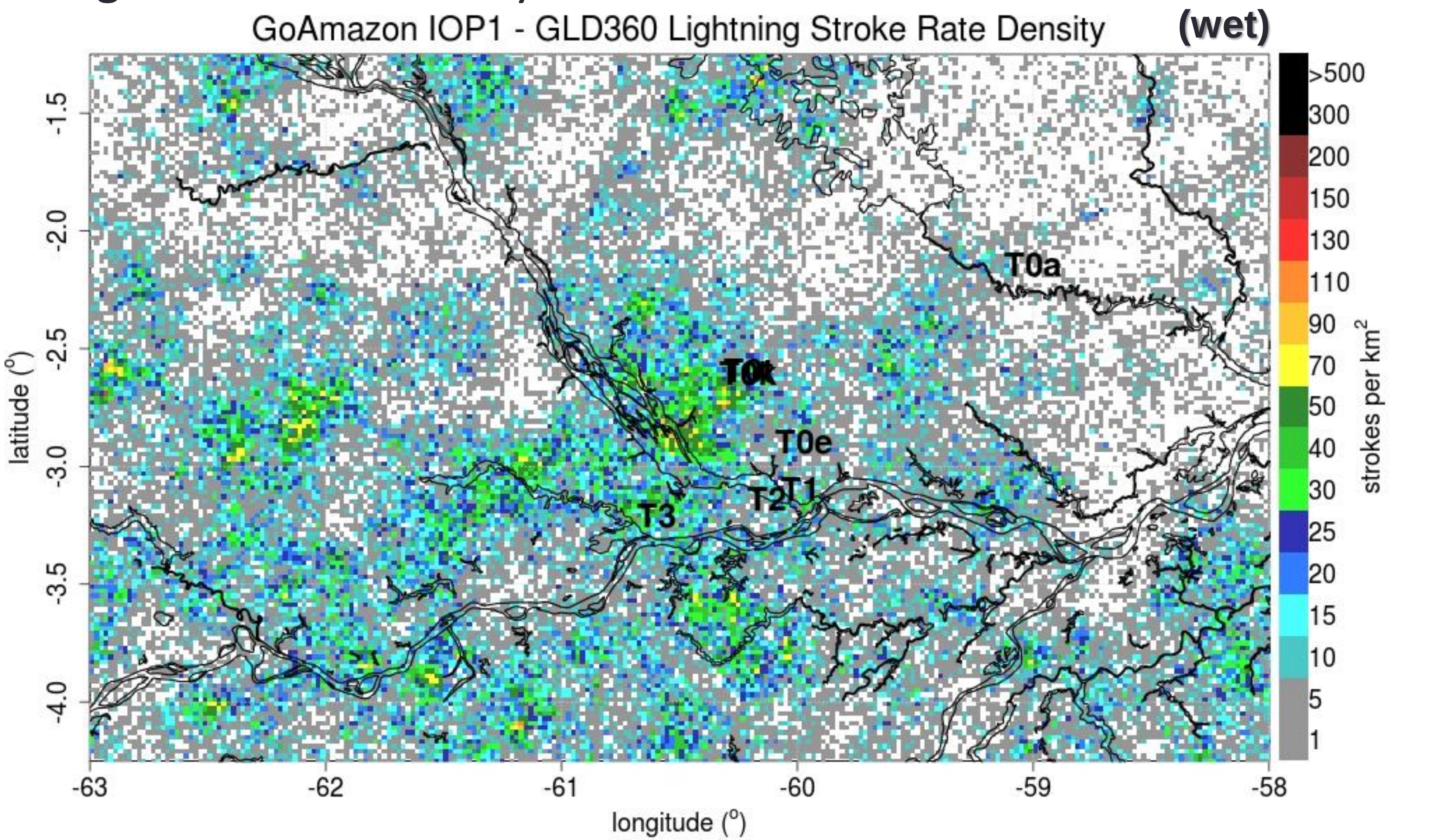

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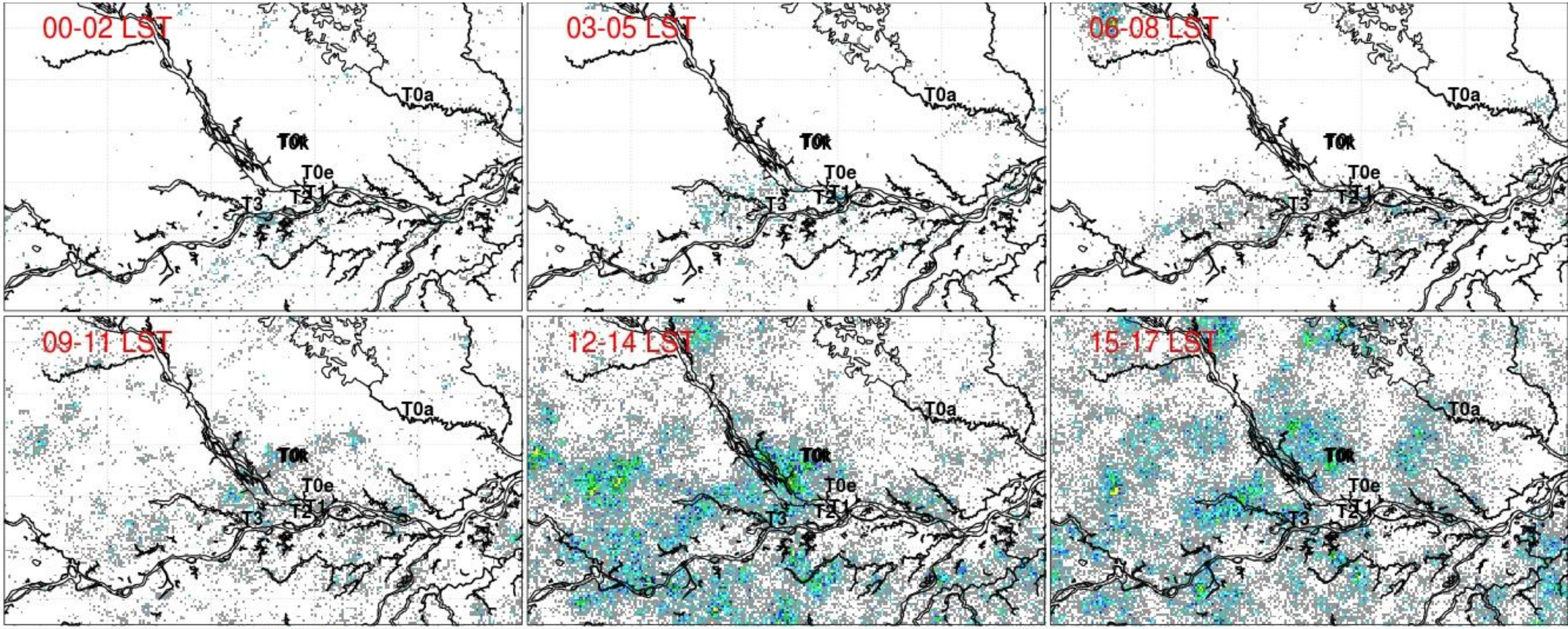
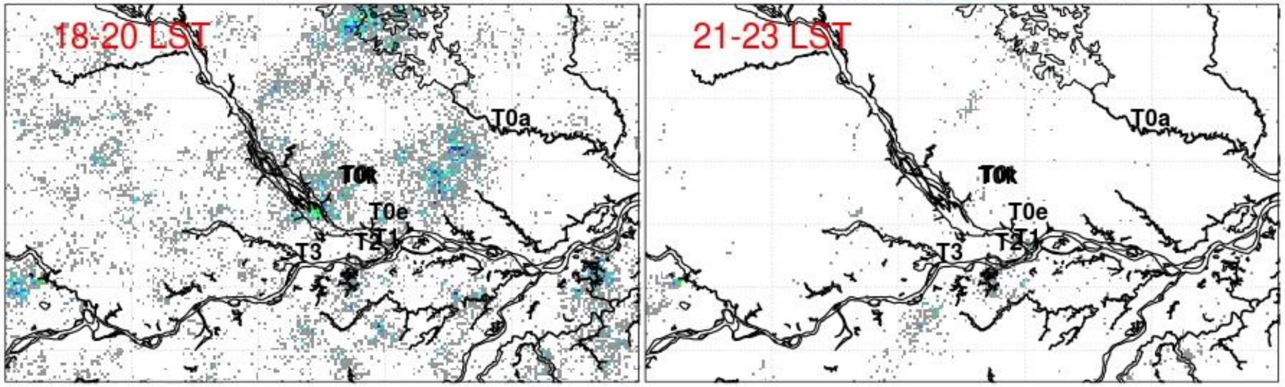
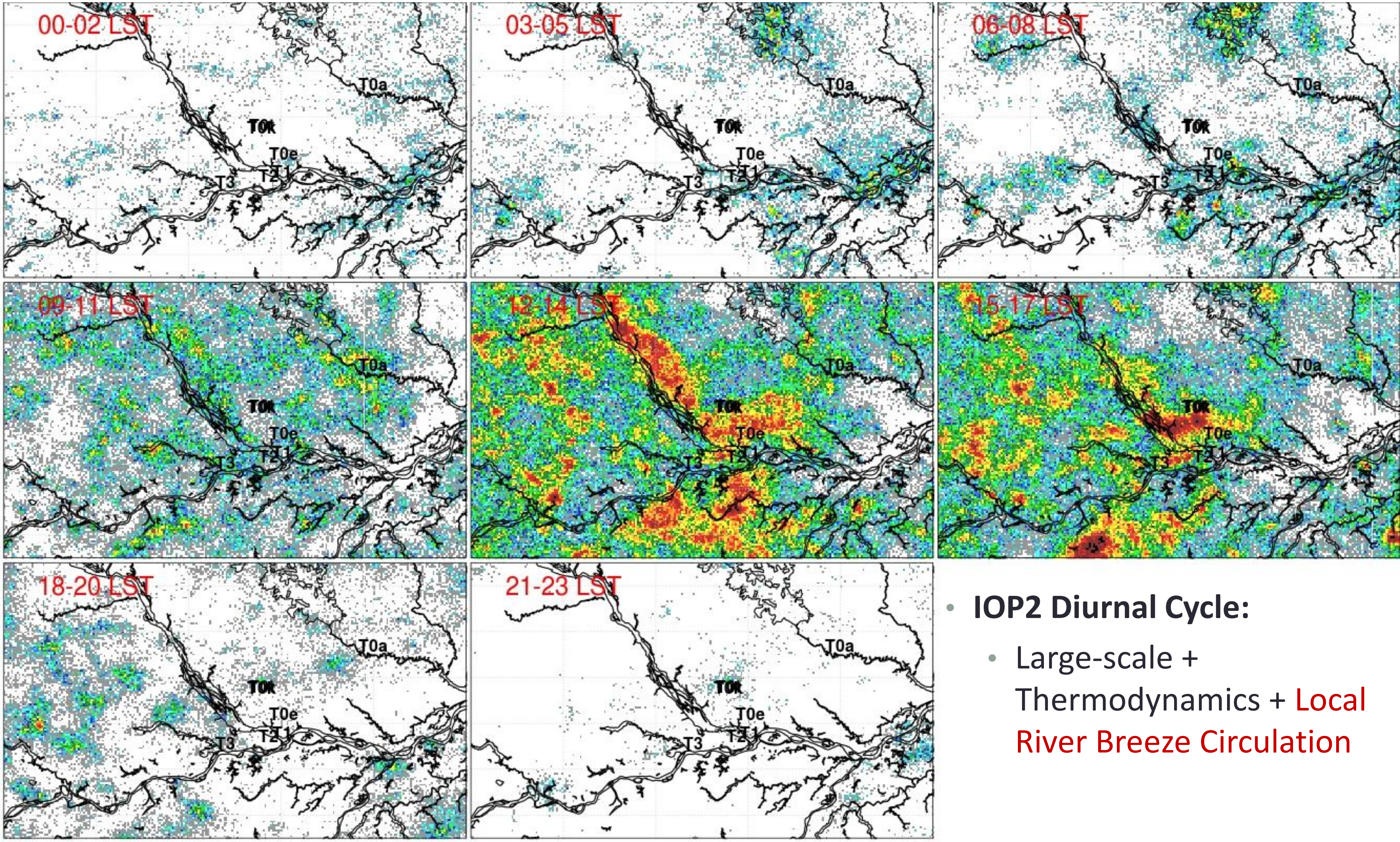




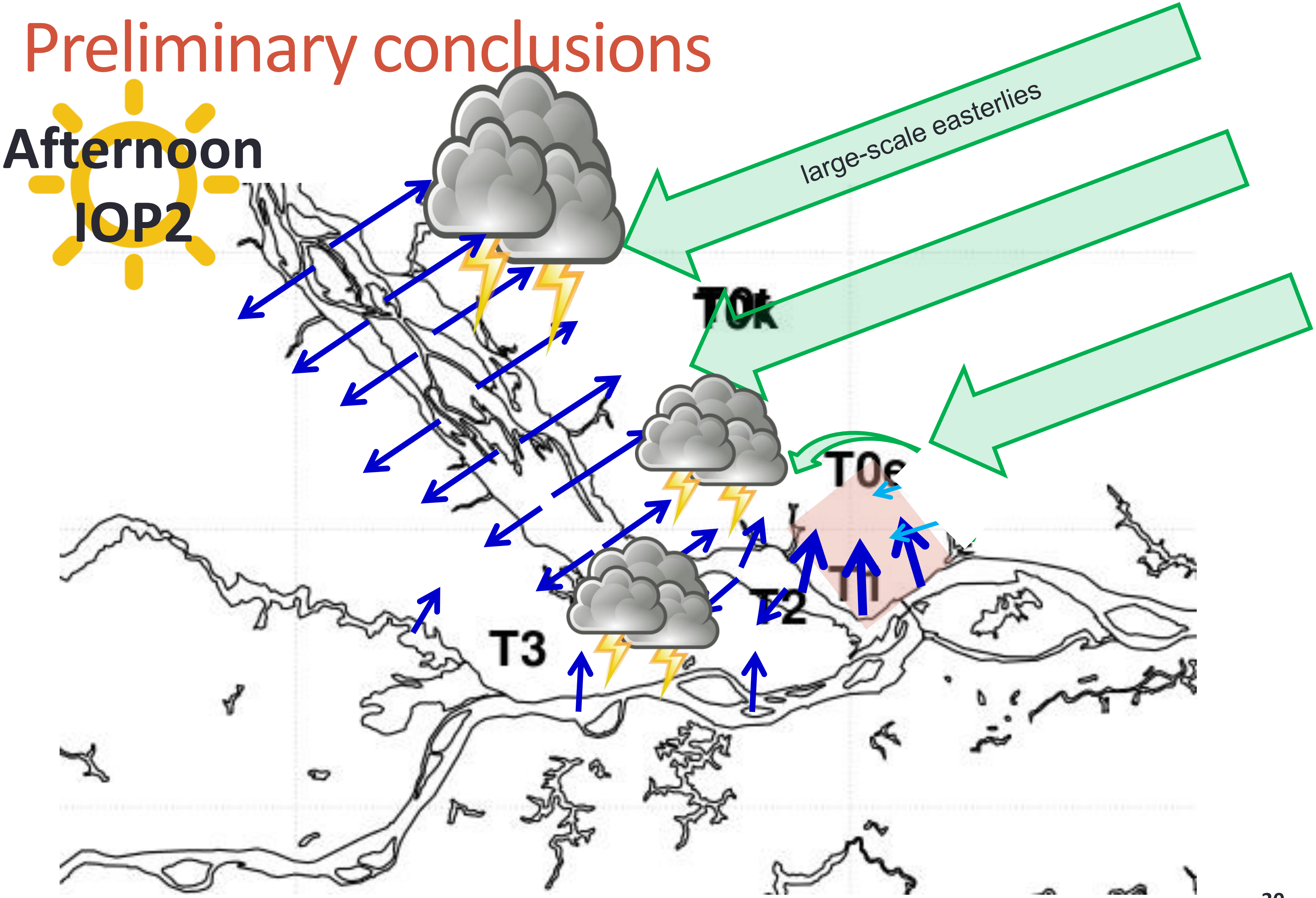
- **IOP1 Diurnal Cycle:**
  - Large-scale + Thermodynamics + ~~Local River Breeze Circulation~~

Preliminary results – Part II

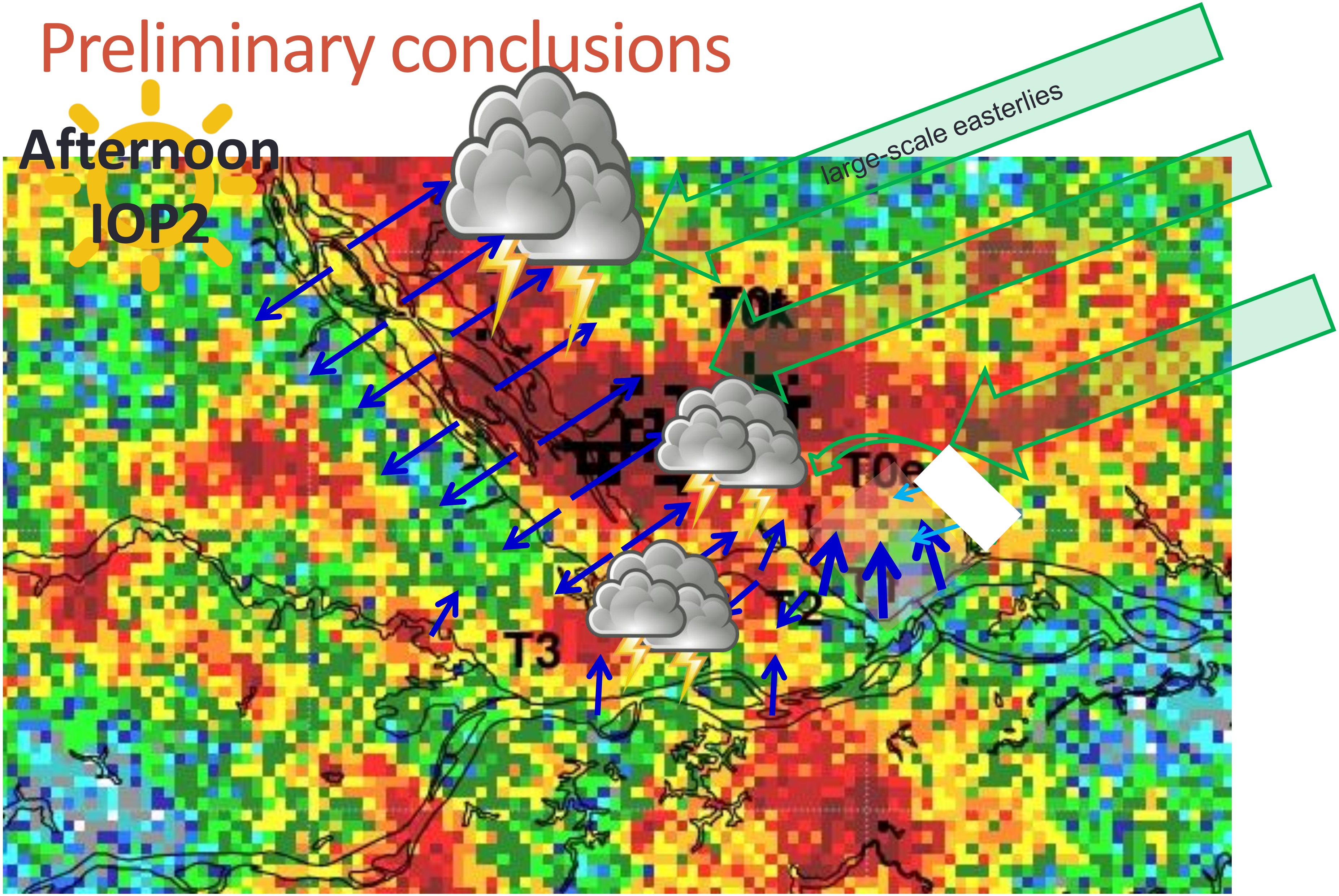


- **IOP2 Diurnal Cycle:**
  - Large-scale + Thermodynamics + Local River Breeze Circulation

Preliminary conclusions

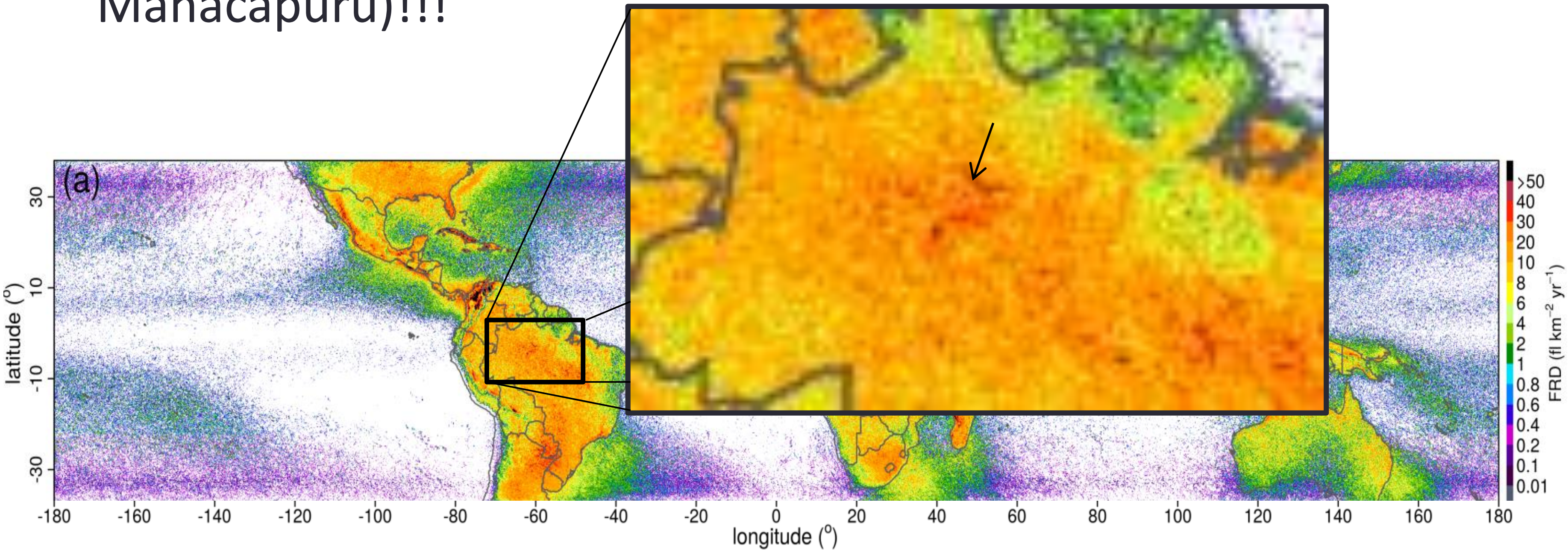


Preliminary conclusions



Preliminary conclusions

- East side of Rio Negro river is the place with most total (i.e., intracloud and cloud-to-ground) lightning density in Brazil (near Manacapuru)!!!



Albrecht et al. (2016): *Where are the lightning hotspots on Earth?* Bulletin of the American Meteorological Society 2016 ; e-View (doi: http://dx.doi.org/10.1175/BAMS-D-14-00193.1)

Preliminary conclusions

- East side of Rio Negro river is the place with most total (i.e., intracloud and cloud-to-ground) lightning density in Brazil (near Manacapuru)!!!

Rank #	FRD (fl km^{-2} yr^{-1})	Grid Latiude (º)	Grid Longiude (º)	Nearst Populated Place Location	Country	Continent
1	232.52	9.75	-71.65	Lake Maracaibo	Venezuela	South America
2	205.31	-1.85	27.75	Kabare	Dem. Rep. Congo	Africa
3	176.71	-3.05	27.65	Kampene	Dem. Rep. Congo	Africa
4	172.29	7.55	-75.35	Cáceres	Colombia	South America
5	143.21	-0.95	27.95	Sake	Dem. Rep. Congo	Africa
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190	68.21	3.65	18.95	Libenge	Dem. Rep. Congo	Africa
191	68.21	-2.35	-60.85	Manacapuru	Brazil	South America
192	68.12	2.65	21.45	Lisala	Dem. Rep. Congo	Africa
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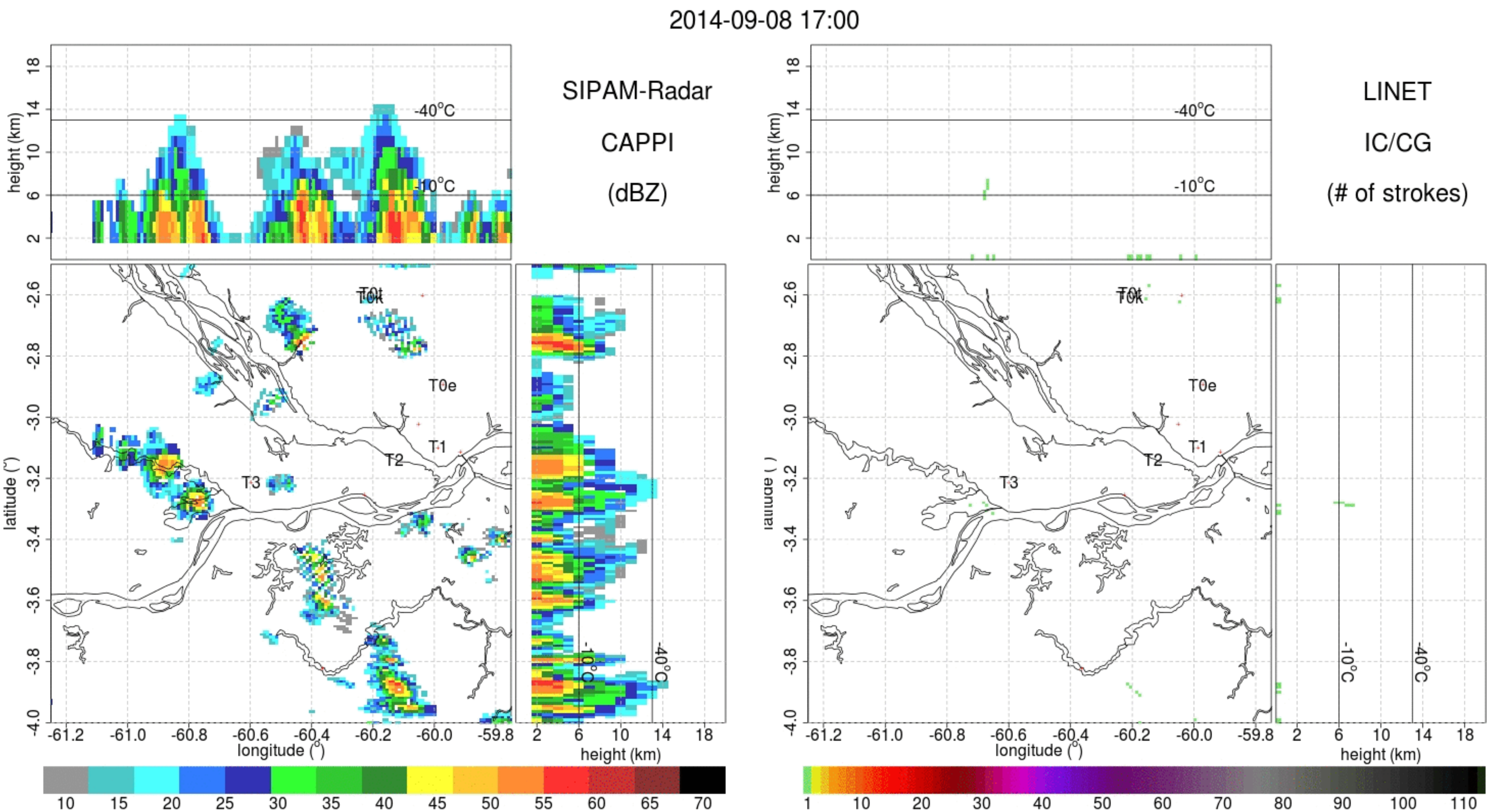
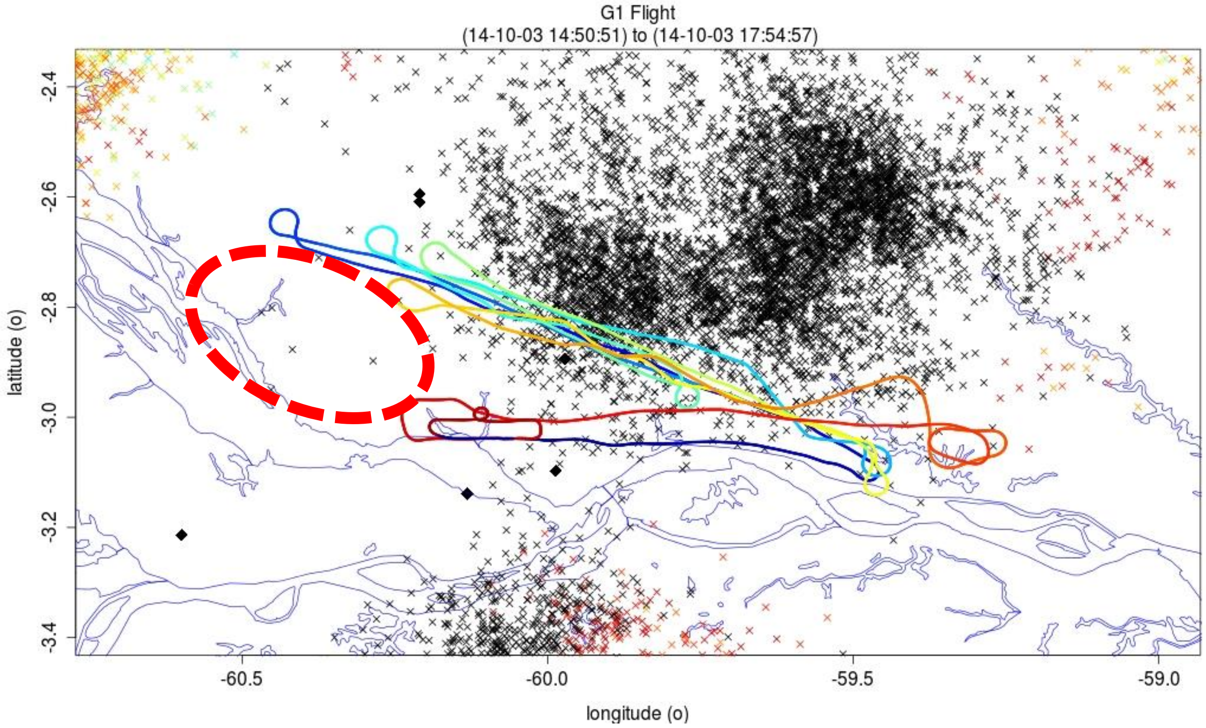
Example of river breeze and/or land cover influence on local deep convection



Future work

- Compare non-thunderstorms vs thunderstorms CCN/cloud particle distribution from G1 and HALO.



Color is time (blue beginning, red end of flight)
X – lightning (**black** is lightning up to 60 min after end of flight)

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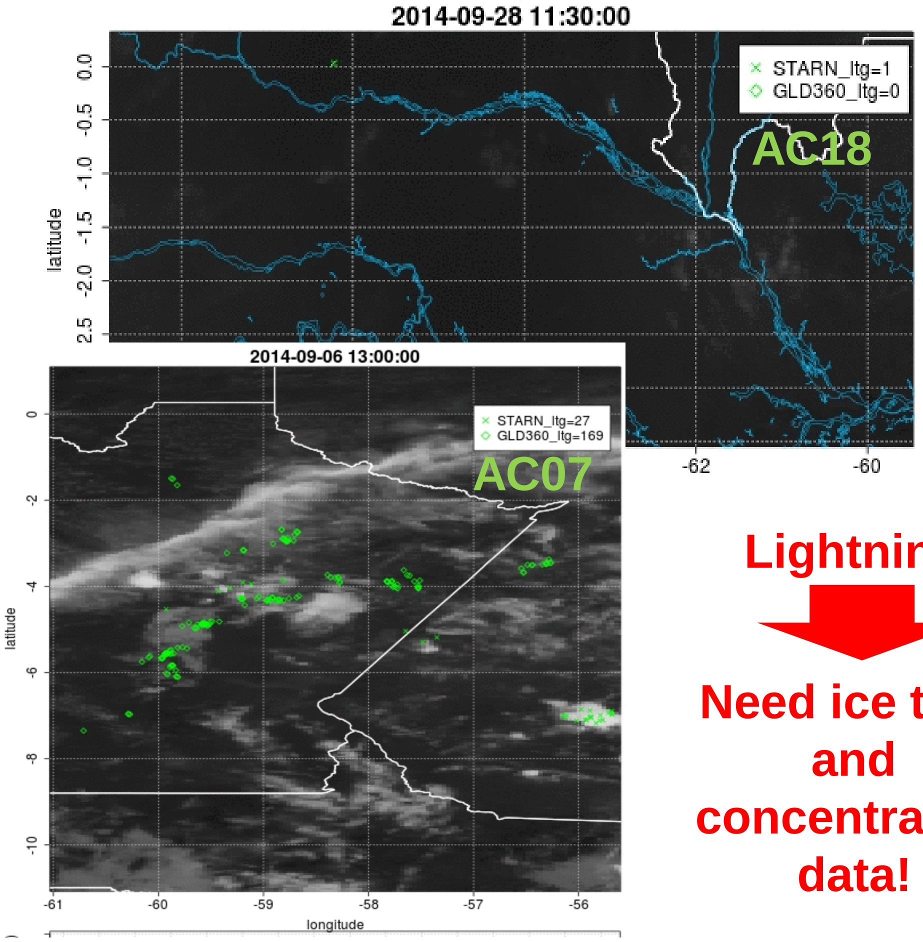
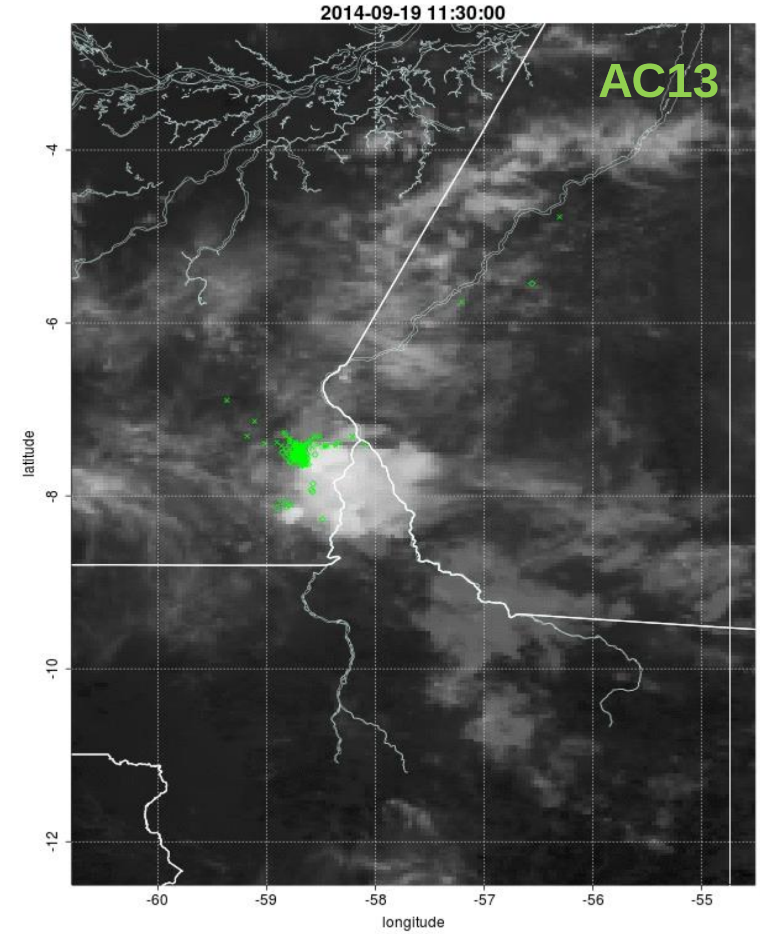


Lightning

Need ice type and concentration data!



Thank you!

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CNPq

Embrapa

FAPESP

CAPES