Location of campaign
Radars and Tethersonde
TRMM-LBA aircraft
Scenes from TRMM-LBA
Easterly flow turns to westerly flow due to the Andes mountains. When trough moves to the south the region is under easterly flow.

Location of South Atlantic High is key to forcing east vs. west regimes.
Similar to DUNDEE findings

Modulation of CAPE and lightning flash rates by the ITCZ

Petersen el al. (2002)
Cifelli et al. (2002)

**Dual-Doppler polarimetric study of an east phase MCS and a west phase MCS**

**Figure 3.** Time series of 850 mbar smoothed wind direction (black solid line) and 500 mbar dew point temperature (dashed line) from the Abracost Hill sounding site near the TOGA radar. The convective index (gray solid line) represents a ratio of total 40 dBZ area coverage/10 dBZ area coverage using the TOGA radar data (time series courtesy of Dennis Bocci). The convective index values range from ~ 0.03 to 0.02. A running mean has been applied to the time series. The time periods corresponding to the 26 January (990126) and 25 February (990225) MCSs are indicated.

**Figure 6.** (a) North-south vertical cross section for the 26 January easterly MCS through a vigorous convective cell at 2100 UTC. Radar reflectivity is shaded as indicated, $Z_{DR}$ is contoured in blue from 1 dB at an interval of 1 dB. LDR is contoured in red for values of -23, -21, and -19 dB. Velocity vectors are plotted in a storm-relative framework (scale indicated in each figure). (b) As in Figure 6a except an east-west cross section for 25 February 1999, 2340 UTC (note strong LDR signals absent in this case). Approximate location of cross sections are indicated in Figure 4. The cross sections were constructed by superimposing dual-Doppler winds (interpolated onto a 1 km horizontal by 0.5 km vertical grid) with radar $Z_{DR}$, $Z_{H}$, and LDR (interpolated to a 0.5 km horizontal by 0.5 km vertical grid).
East event

Strong mixed phase,
Significant ice contents aloft
Large rain water contents

West event

Weak mixed phase
Low ice water contents aloft
Large rain water contents

Zdp method used to determine Zrain and Z ice, them M-Z relationships used to estimate mixing ratios
Cifelli et al. 2002

East-west microphysical contrast

Evidence of warm rain in west phase convection

Reduced cloud bases, low CCN environment characteristic of west phase. East has higher cloud bases and increased CCN, and larger CAPE

Significant water contents but smaller raindrop mean diameters

Do we expect differences in cloud entrainment between the east and west phases?
Contrasting convective regimes over the Amazon: Implications for cloud electrification

Rosenfeld hypothesis

Large CCN concentrations shut off warm rain and invigorate ice phase

Figure 2. Illustration of the aerosol hypothesis for control of cloud precipitation and electrification.
Pre-monsoon polluted and pre-monsoon clean have similar lightning flash rates? Challenges CCN hypothesis and suggests CAPE controls convective vigor to the first degree.
Figure 9. Distributions of CAPE values based on thermodynamic soundings at the ABRACOS site for the easterly and westerly wind regimes during the wet season January–February 1999.
Fast forward to 2017, 18 years after TRMM LBA...

SPURS-2017 cruise
CSU SEA-POL
5 cm
Doppler, polarimetric
Lightning flashes from **GOES-16 Geostationary Lightning Mapper**

Flashes are per 15 minute intervals

Generally lightning is co-located with cold cloud; some spurious flashes in areas with no cold cloud; appear to be confined to daylight hours (sun glint off ocean)

Satellite based lightning observations useful for locating intense oceanic convection
CAPE computed from 4 per day soundings from R/V Roger Revelle

GLM lightning for 5x5 deg box centered on the Revelle

Lightning for CAPE exceeding 1500 J/kg

Radar observations (shown later)
Lightning is probable when 35 dBZ extends to -10°C or colder (6 km from 0300 Z sounding; 2500 J/kg CAPE); mixed phase microphysics

Non-lightning example
CAPE < 750 J/kg

Evidently higher CAPE values lead to sufficient vertical motions to loft raindrops into mixed phase region and drive mixed phase microphysics

But does CAPE explain lightning flash rates to first order?
Land-based convection with shallow WCD’s: high flash rates achievable for high CCN even with modest CAPE; when CCN concentrations are low, higher CAPE must be present to promote significant flash rates.

Land-based convection with deep WCD’s: high flash rates only apparent when CCN concentrations are high and CAPE is high.

Ocean flash rates restricted due to reduced CAPE (shape of CAPE) and low CCN—deep WCD does its thing and makes warm rain, robbing the mixed phase of condensate.

Updraft width scales with cloud base height: low cloud base heights correspond to narrow updrafts which are subject to more entrainment compared to broad updrafts.

So full variability of lightning in tropical convection needs interplay of CAPE, CCN, WCD and updraft width.
Enhanced lightning over shipping lanes

Direct evidence of CCN Invigoration

Suggests sufficient background CAPE

Thorton et al. 2017 GRL