Ozone net production rate within the Manaus urban plume, in Central Amazonia

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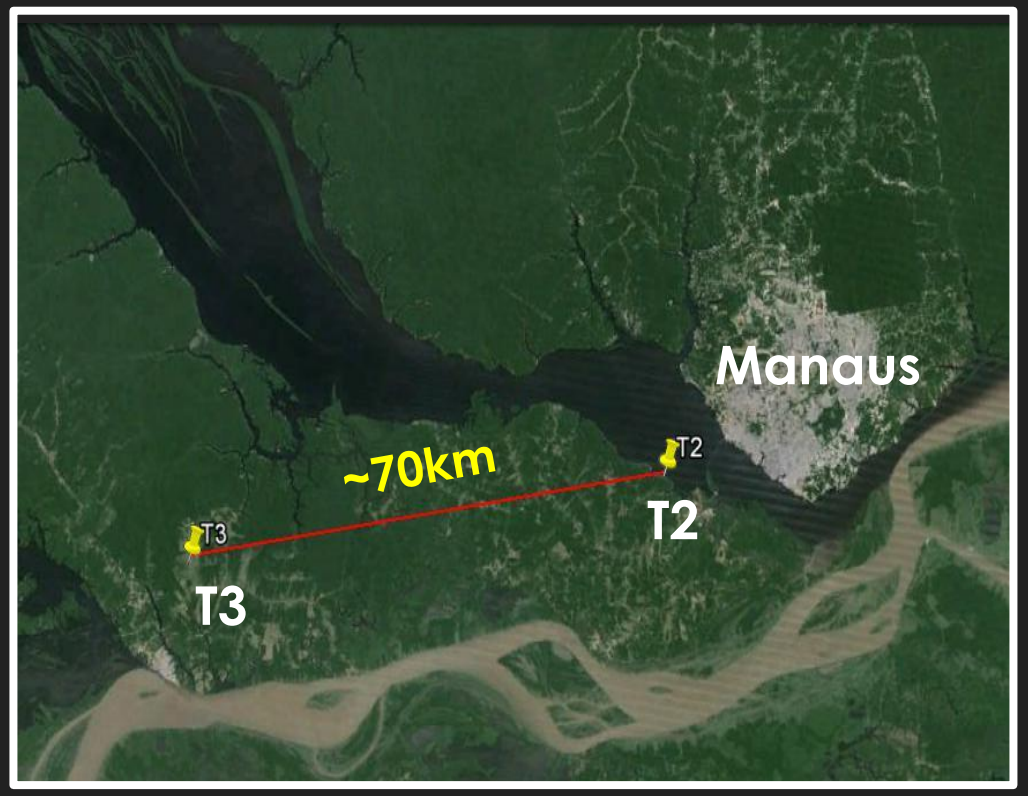
GOAMAZON 2014
U.S. DEPARTMENT OF ENERGY

Introduction

GoAmazon 2014/15 T2 and T3 sites



Manaus emission pattern might have changed over time:

- increase on the vehicle fleet
- moving to cleanner power plant fuels

Does the combination of BVOCs and urban emissions increase O_3 production downwind of Manaus?

Biogenic VOC

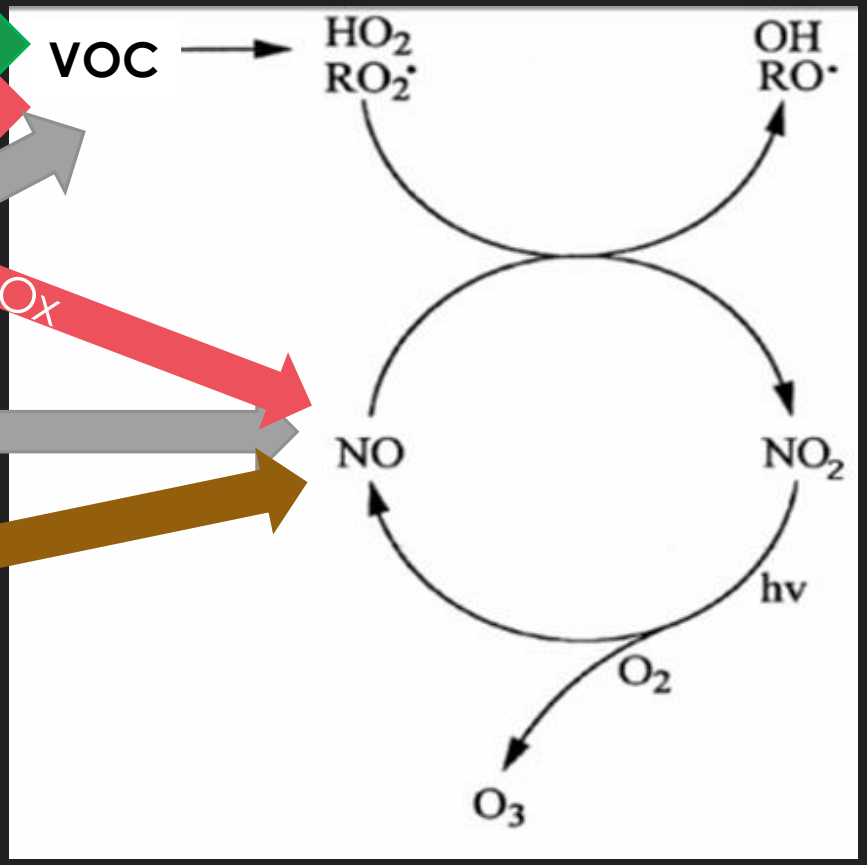
Biom.Burning VOC

Biom.Burning NOx

Traffic VOC

Traffic NOx

Power plant NOx



Net production rate of trace gas species along the transport from Manaus to downwind areas

$$P_{net} = P_{chemistry} + Inputs - Dillution - Deposition \quad (ppb/h)$$

$$P_{net} = \frac{O_3(\vec{r}, t_0 + \Delta t) - O_3(\vec{r_0}, t_0)}{\Delta t}$$

Is there signifficant O_3 photochemical production along the transport of the urban plume, from the source to downwind areas?

$\vec{r_0}$: position of the source (Manaus)

$\vec{r}$: position downwind of Manaus

t_0: when plume leaves Manaus

Δt: transport time from $\vec{r_0}$ to $\vec{r}$

O_3 enhancement factor with respect to background conditions

$$EF_{O3} = \frac{dO_3}{dCO} = \frac{O_3 - O_3(bkg)}{CO - CO(bkg)}$$

Evalute the O_3 enhancement over background conditions accounting for the dillution effect

CO:

- Relatively long chemical life
- Low solubility in water
- Mostly affected by dillution (within the time frame of a day)

Methods

Ground based data

(T2 and T3 GoAmazon sites)

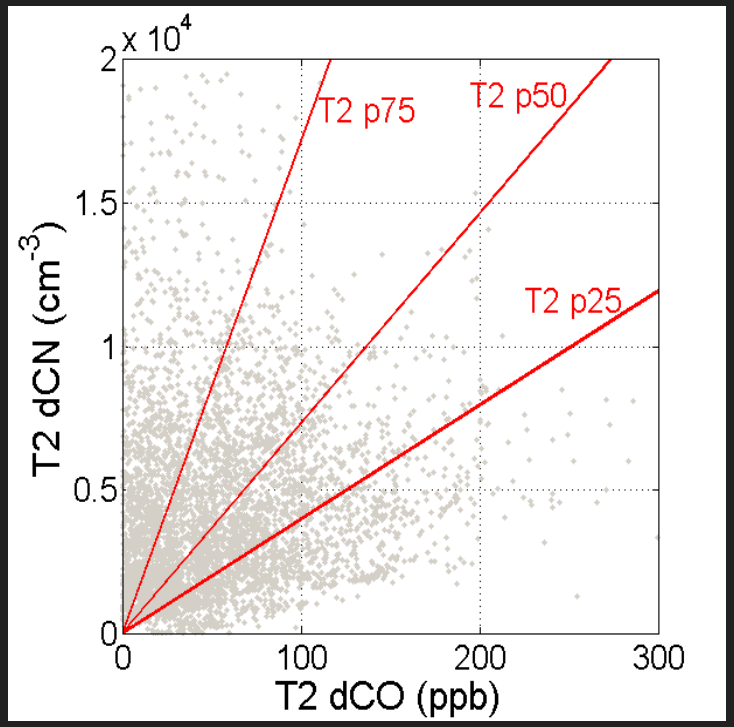
Urban plume detection at T3

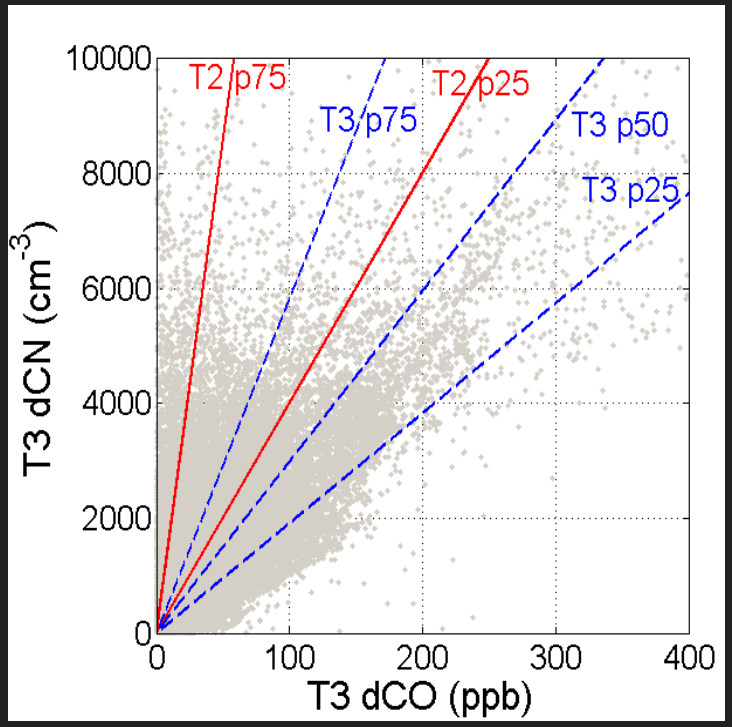
- Criteria 1: urban plume signature

$$\frac{dCN}{dCO} = \frac{CN_i - CN_{background}}{CO_i - CO_{background}}$$

$$CN_{background} = 500\ cm^{-3}$$

$$CO_{background} = 110\ ppb$$

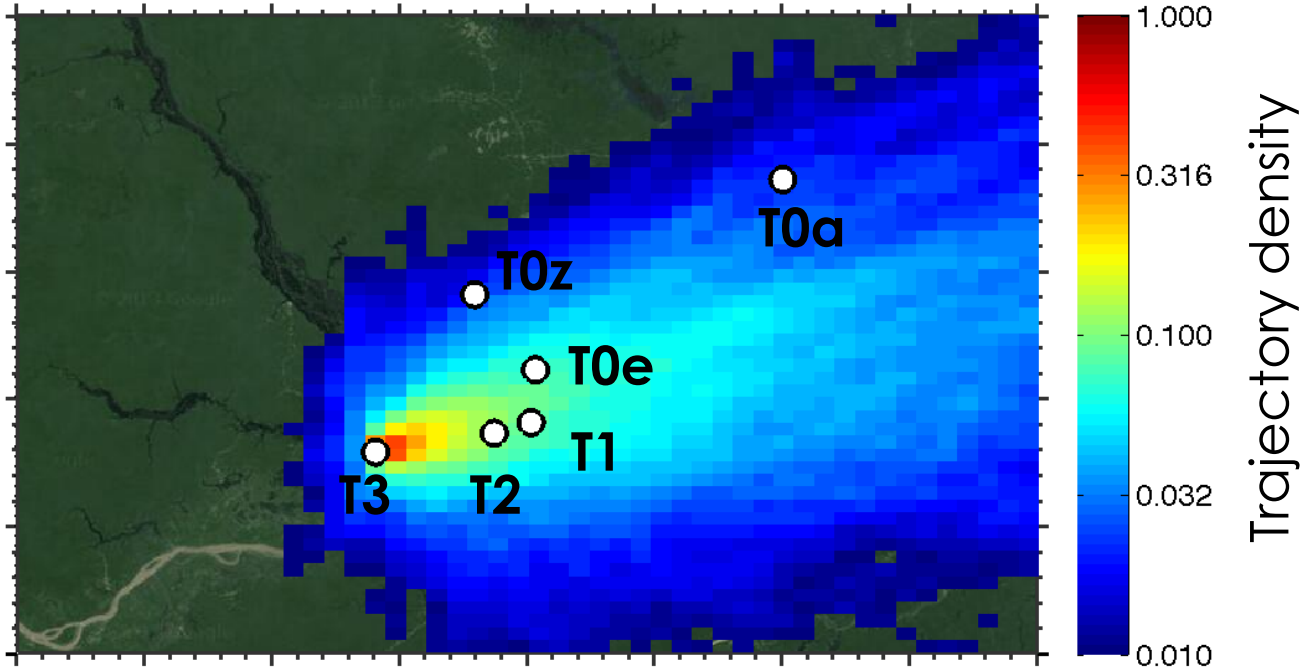




Range was observed in 21% of valid data at the T3 site

Urban plume detection at T3

- Criteria 2: Hysplit backtrajectories



- All points to the east of T3
- Within the boundary layer (height<1000m)

- Typical transport time: 7 hours.
- Requirements matched in 37% of the measurement period

Urban plume detection at T3

- Combination of criteria 1 (plume signature) and criteria 2 (backtrajectories):

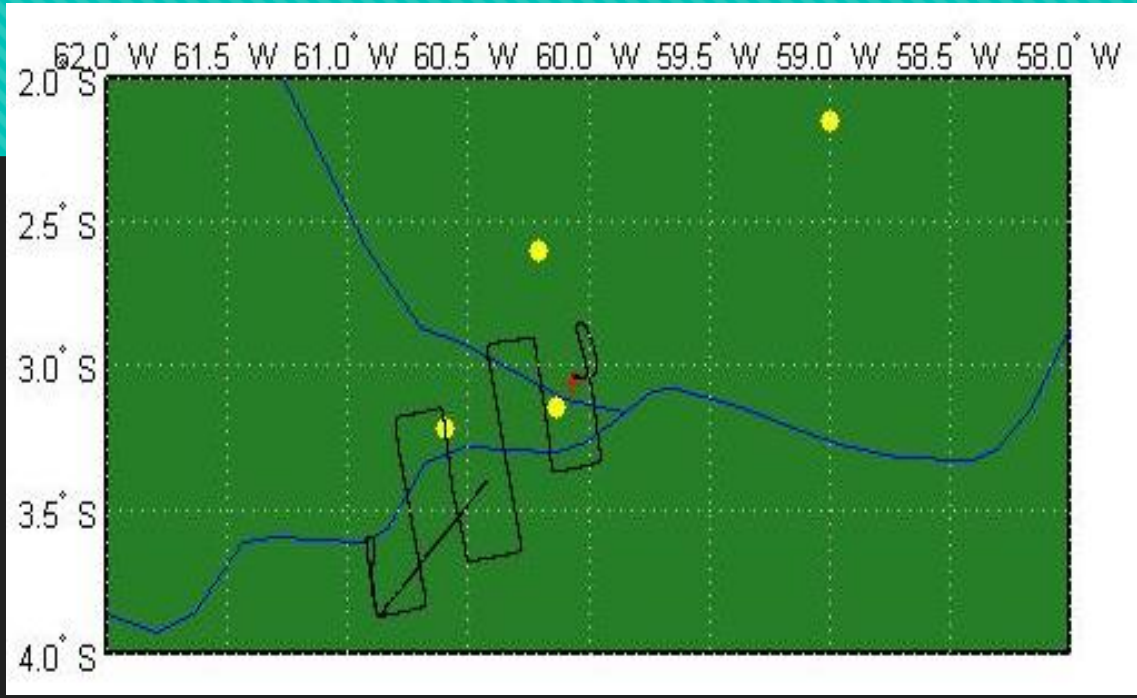
10% of the valid data period at the T3 site

- There is another method proposed to track the urban plume at T3 (Ryan Talman's). Comparison between the two methods is on its way.

Methods

G1 airborne data

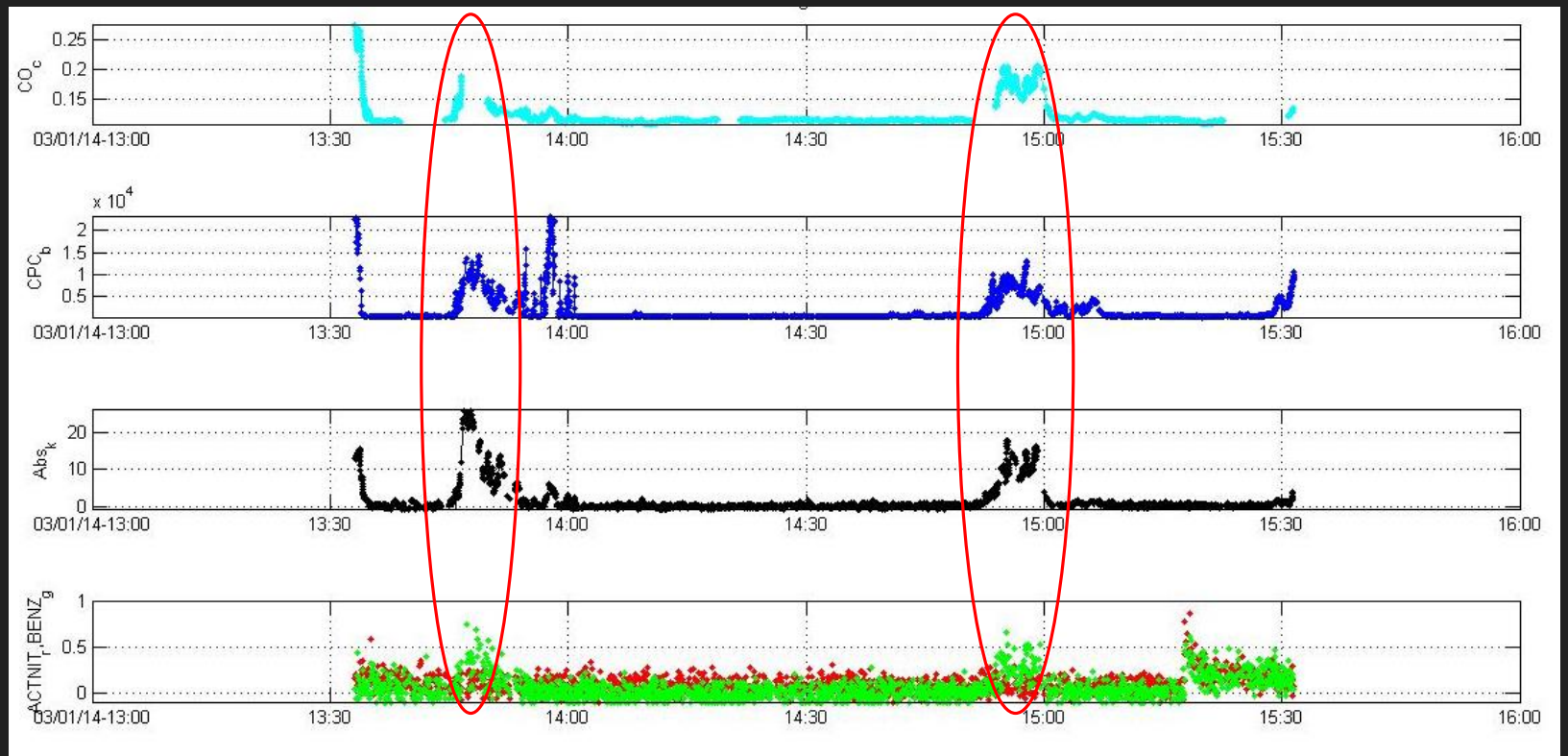
G1 dataset



- 35 flights
  - #1-16 wet season
  - #17-35 dry season
- Plume transects at ~constant altitudes
  - 75% <700 m;
  - 25% 900-1700 m

G1 plume/background detection

- Visual identification of plume transects: CO, CN and absorption peaks
- Acetonitrile used as a tracer for biomass burning plumes

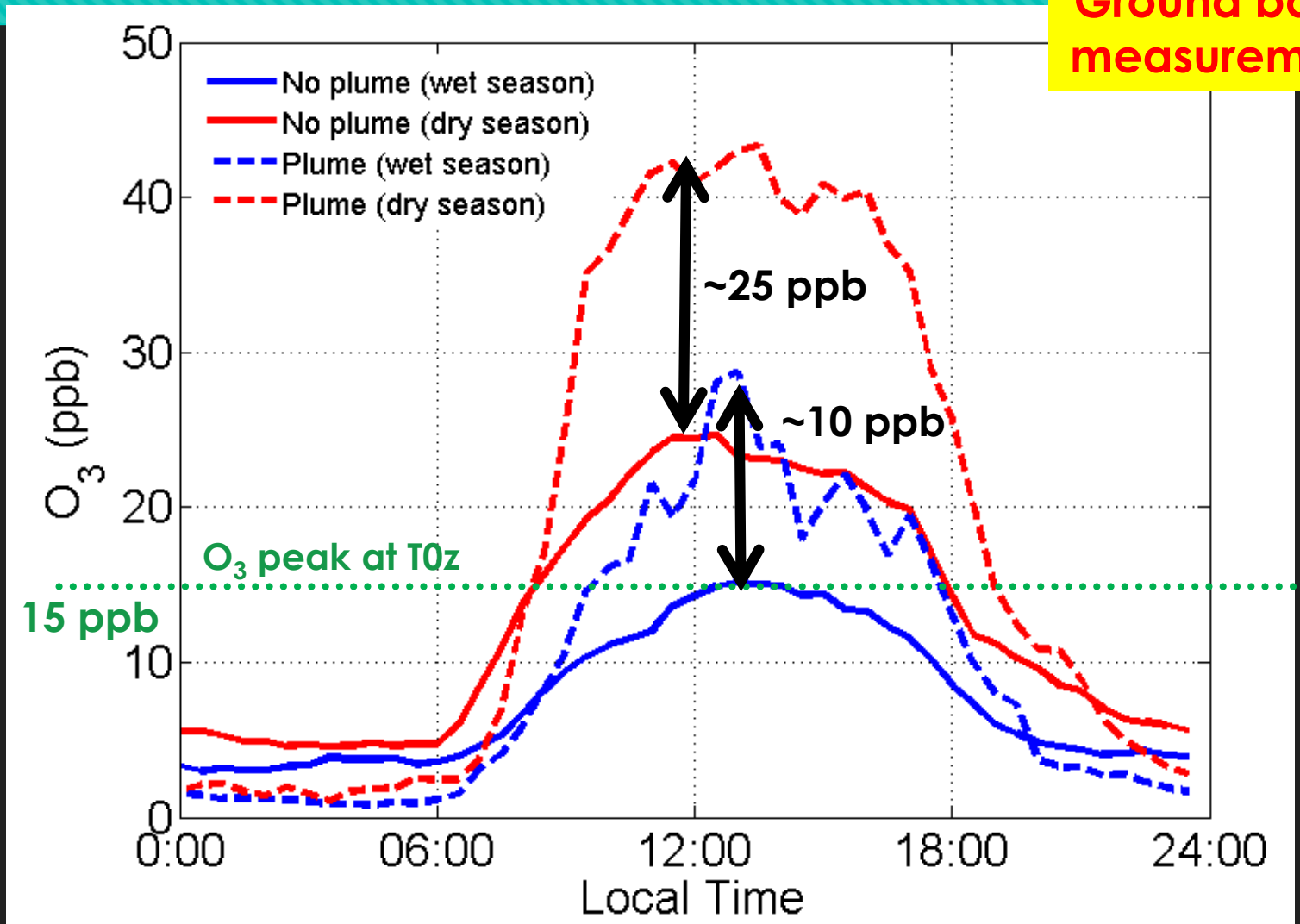


Results

Average impacts of the Manaus urban plume over O_3 concentrations at T3

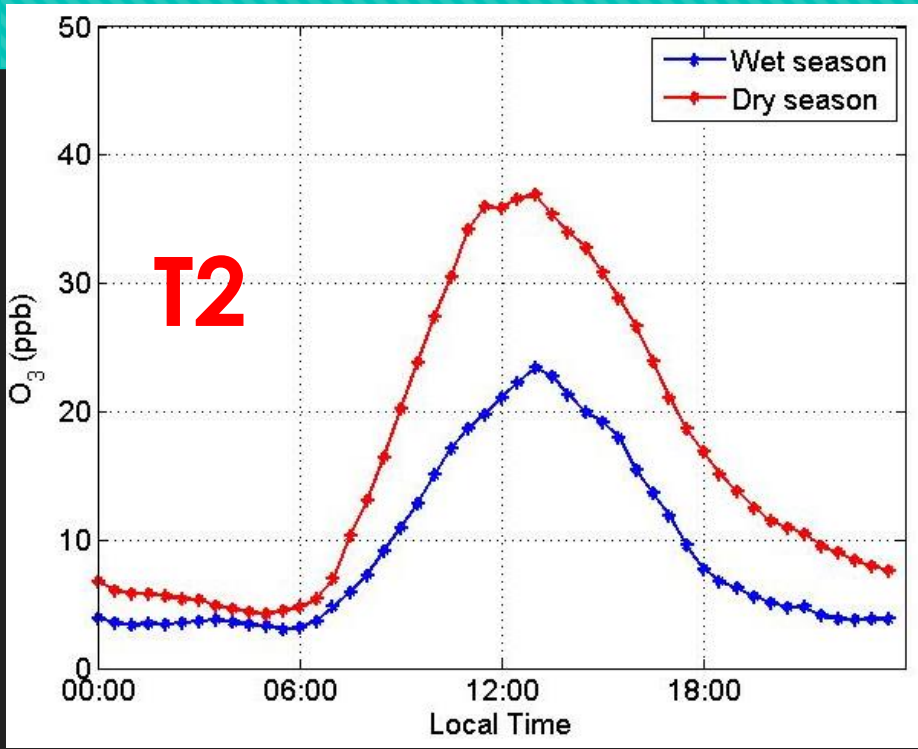
Average impact of the Manaus plume over O_3 concentrations at T3

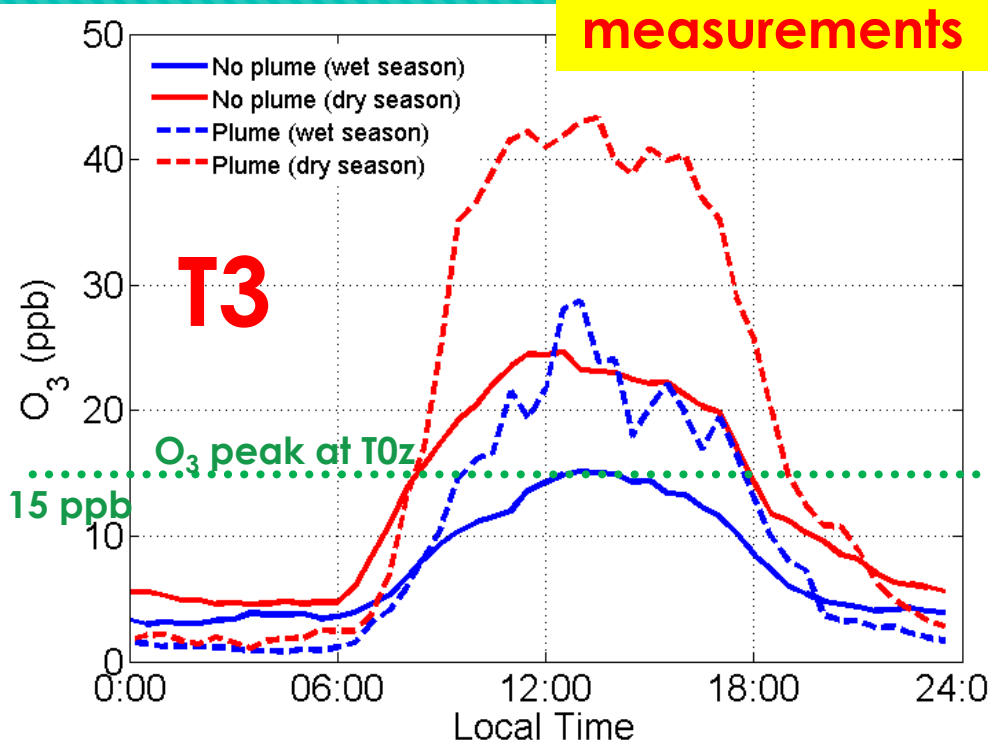
Ground based measurements



O_3 average diurnal cycle at T2 and at T3

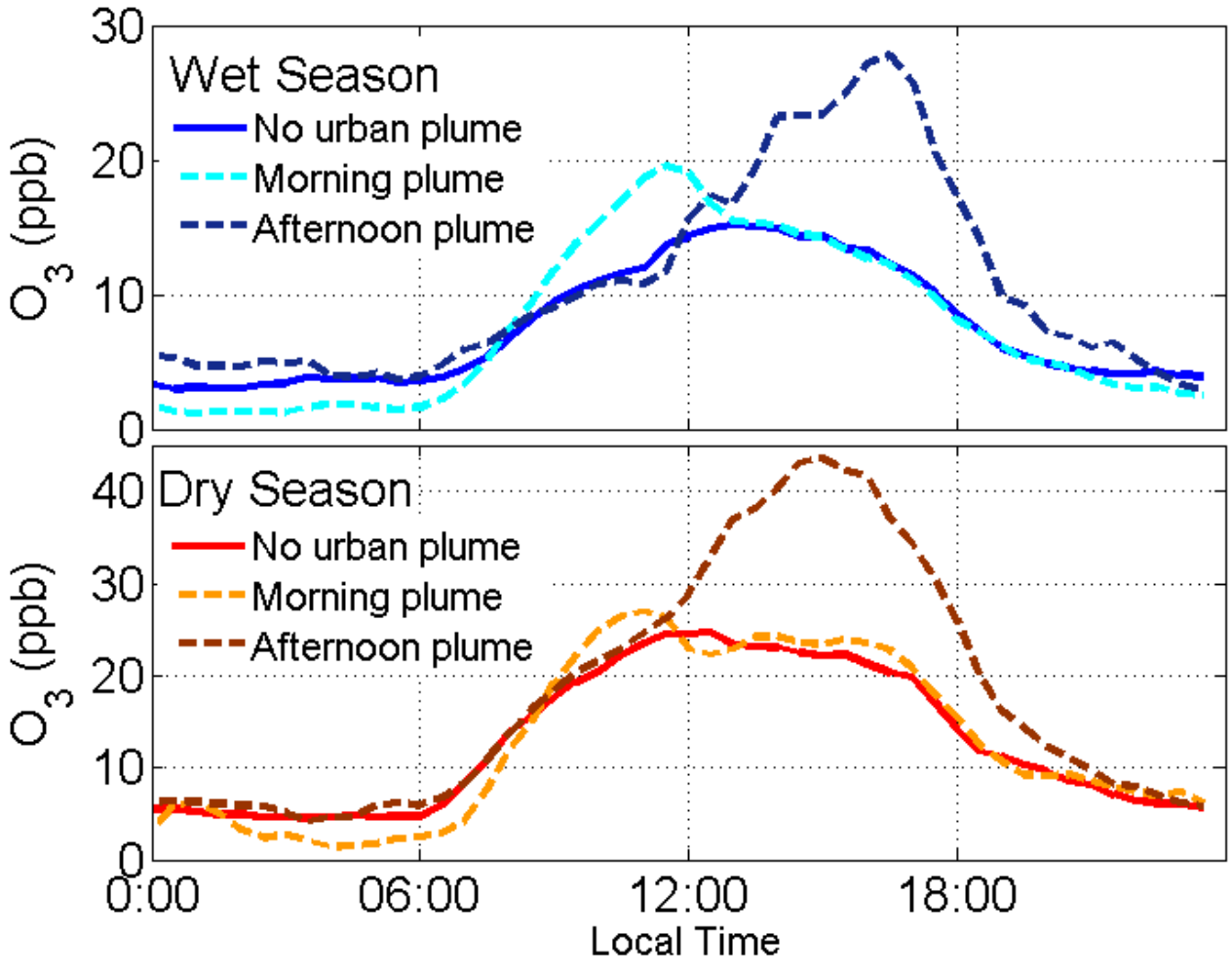
Ground based measurements





Average conditions are very similar at T2 and T3 when impacted by the urban plume

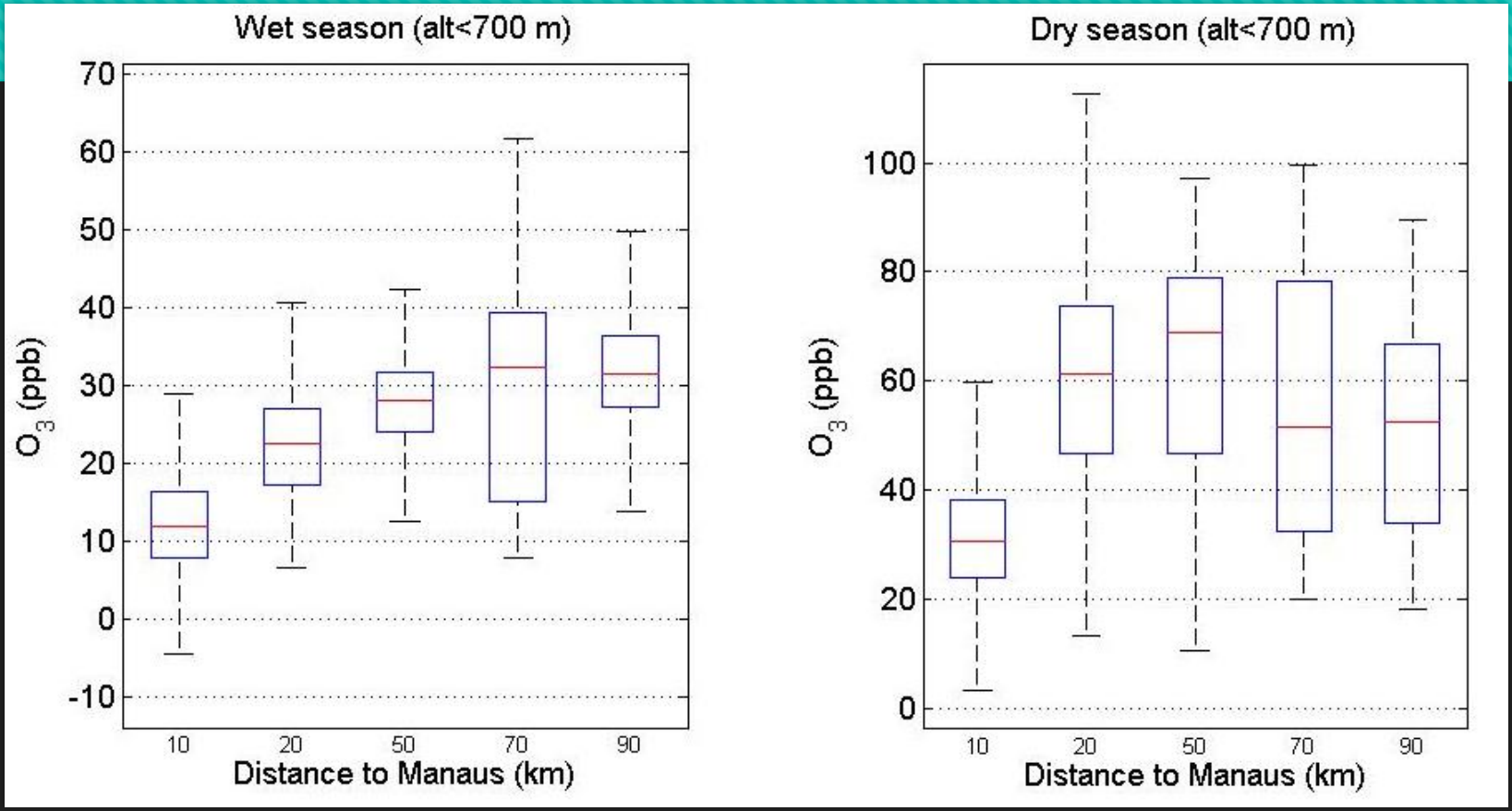
Impact of the Manaus plume at T3 at specific times of the day



Ground based measurements

- Avoided rainny days
- Morning plume only (3:00-9:00 LT, 26 days)
- Afternoon plume only (13:00-18:00 LT, 20 days),

Airborne O_3 X distance from Manaus



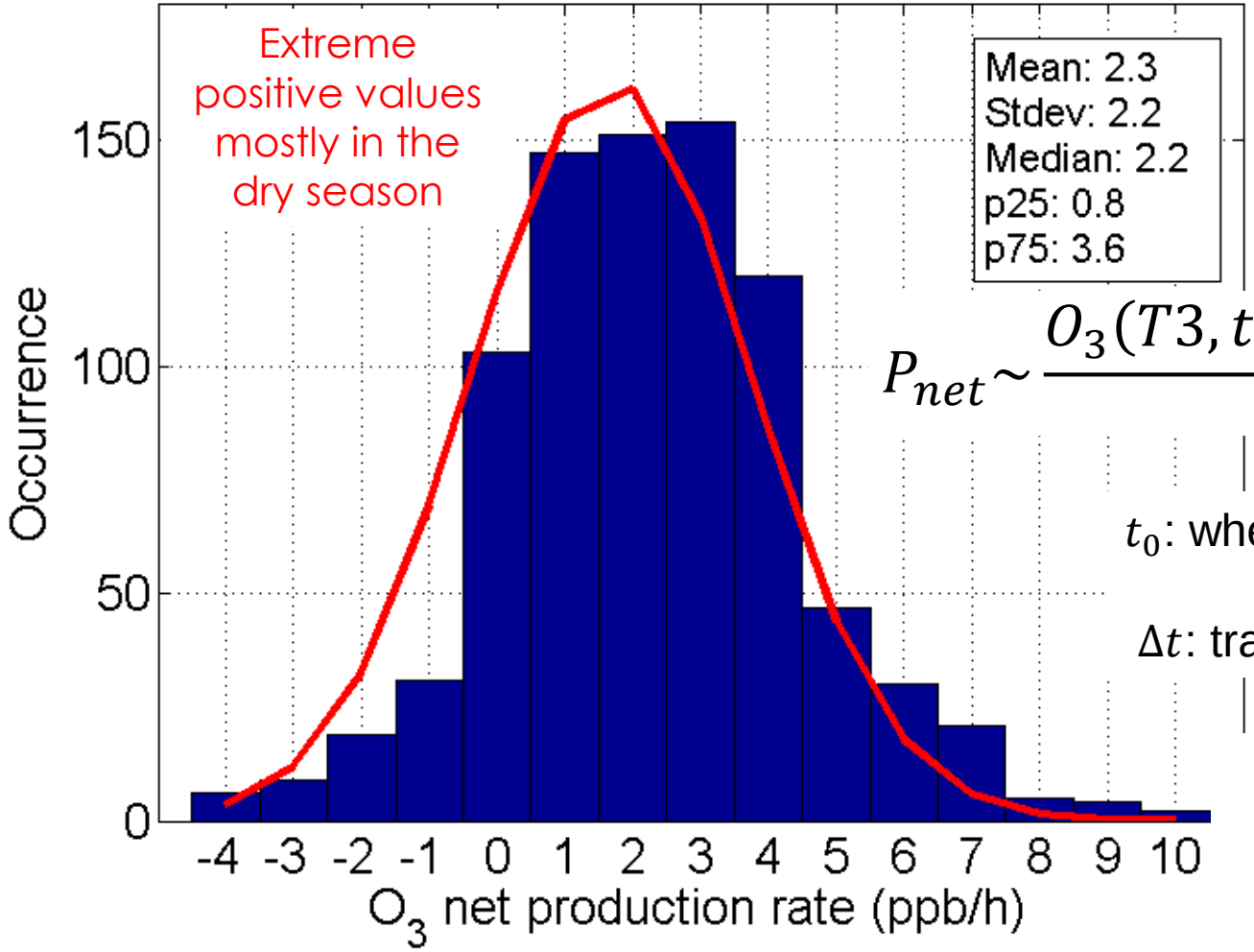
G1 data show an increase on O_3 as soon as the airplane leaves Manaus.

Results

O_3 net production rate within the plume, in reference to the urban plume source

O_3 net production rate along the daytime transport of urban plume

Ground based measurements



$$P_{net} \sim \frac{O_3(T3, t_0 + \Delta t) - O_3(T2, t_0)}{\Delta t}$$

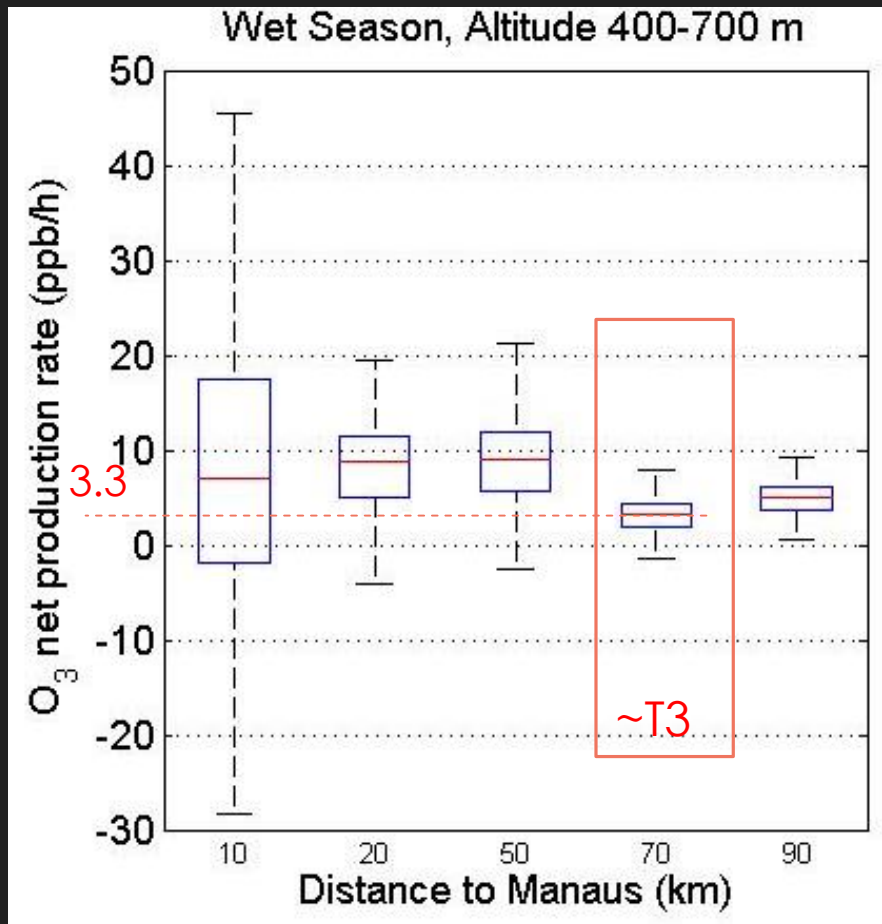
t_0: when plume leaves T2

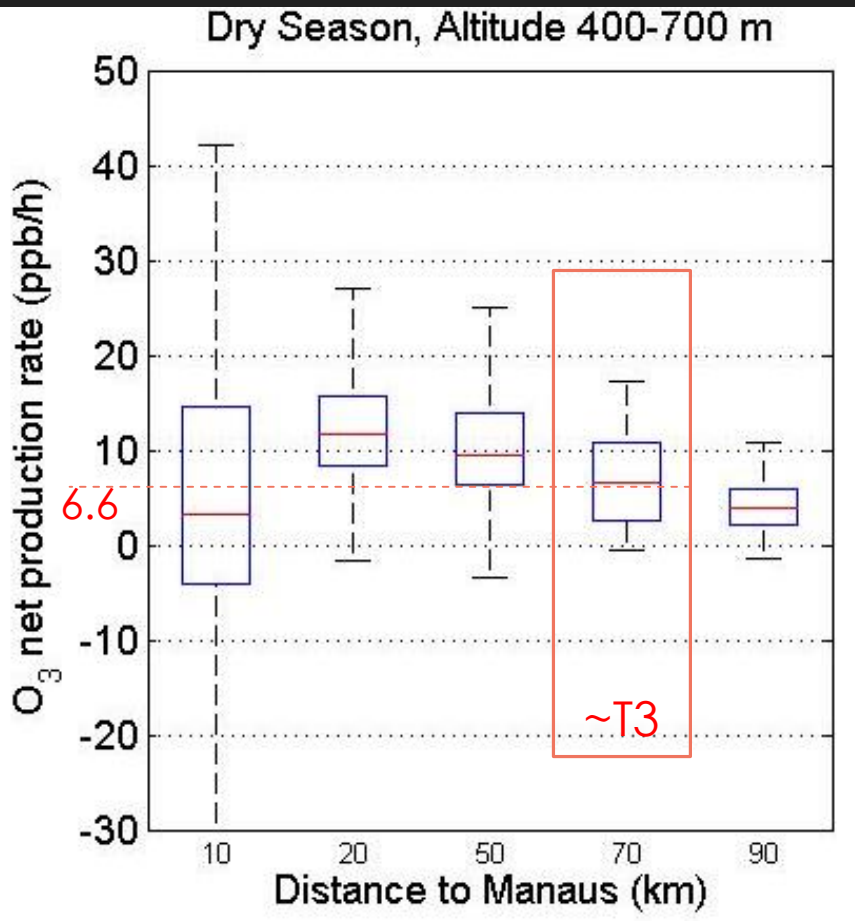
Δt: transport time from T2 toT3

Including O_3 chemical production, dillution, deposition and inputs

O_3 net production rate from G1 data

Airborne measurements





O_3 net production rate comparison

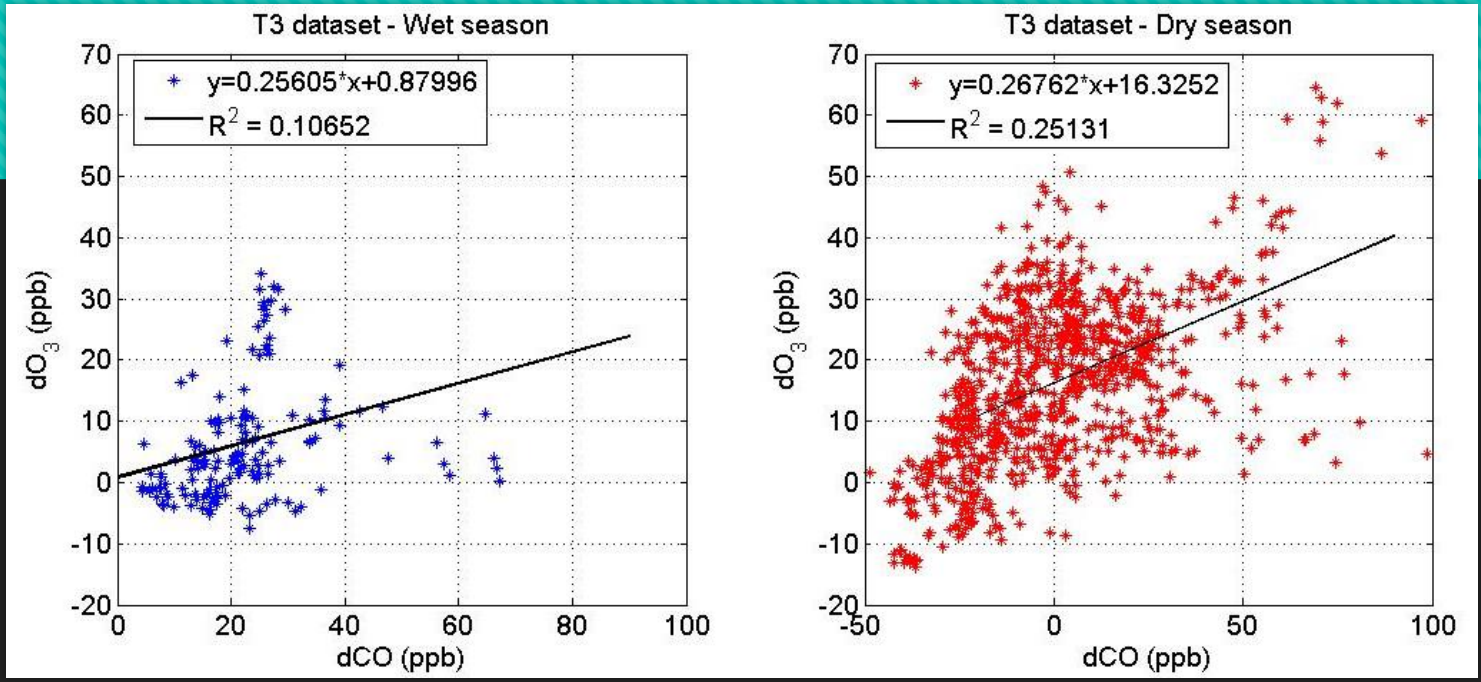
	Median (ppb/h)	p25 (ppb/h)	p75 (ppb/h)	Observation
T3, 2014	2.2	0.8	3.6	Ground based
G1, 2014	3.7	2.0	5.7	Alt<700m; Distance 60-75km
LBA/CLAIRE July 2001	10-15	-	-	Distance 40-70km; Khun et al., 2010
ABLE2B 1985	~4	-	-	Alt~200m; Distance ~100km; Andreae et al., 1988

Nowadays fast O_3 production driven by changes on Manaus emissions patterns (VOC/NOx)?

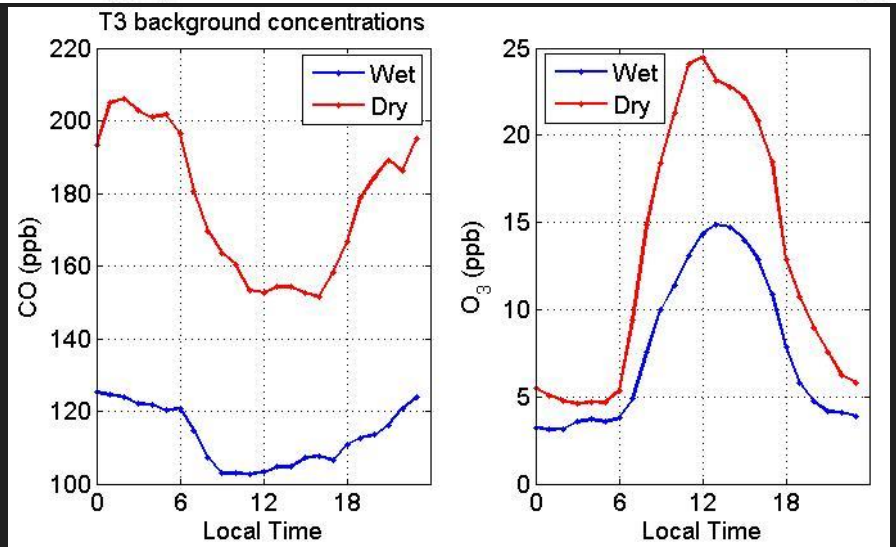
Results

O_3 enhancement factor with respect to background conditions

T3 enhancement factor dO_3/dCO



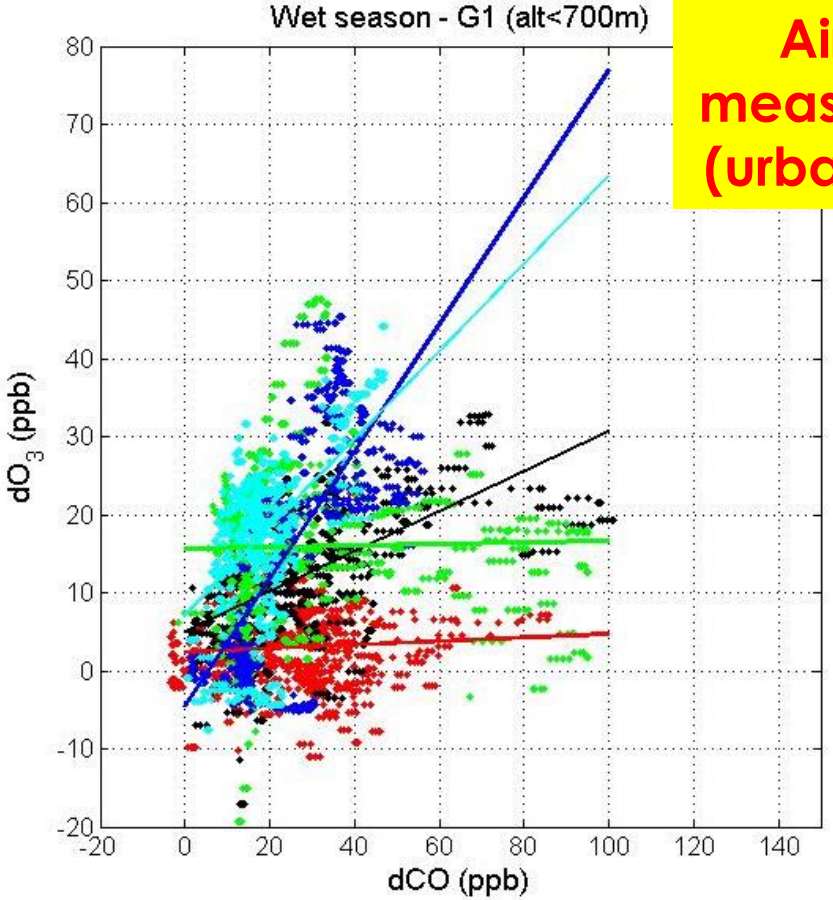
O_3 and CO subtracted by background concentrations from average diurnal cycles at T3

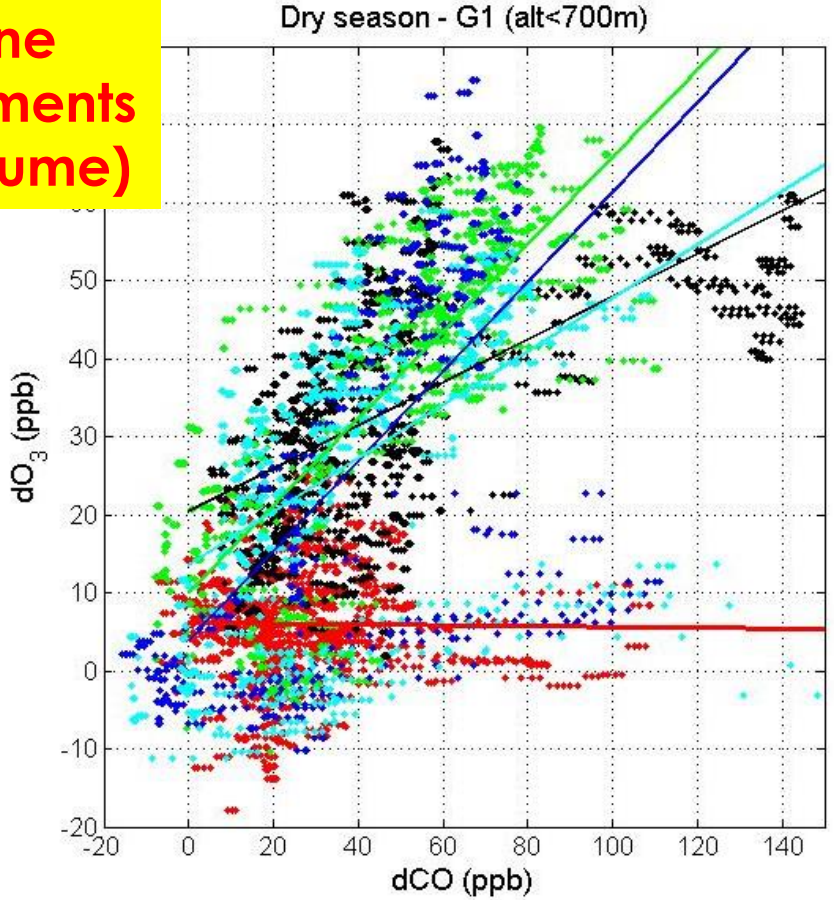


Ground based measurements (afernoon plumes)

G1 enhancement factor dO_3/dCO

Airborne measurements (urban plume)





10km: y=0.02 + 2.4 (r^2=0.01)

20km: y=0.25 + 5.0 (r^2=0.34)

50km: y=0.09 + 16 (r^2=0.00)

70km: y=0.82 – 4.6 (r^2=0.56)

90km: y=0.56 + 7.2 (r^2=0.30)

10km: y=-0.01 + 6.1 (r^2=0.00)

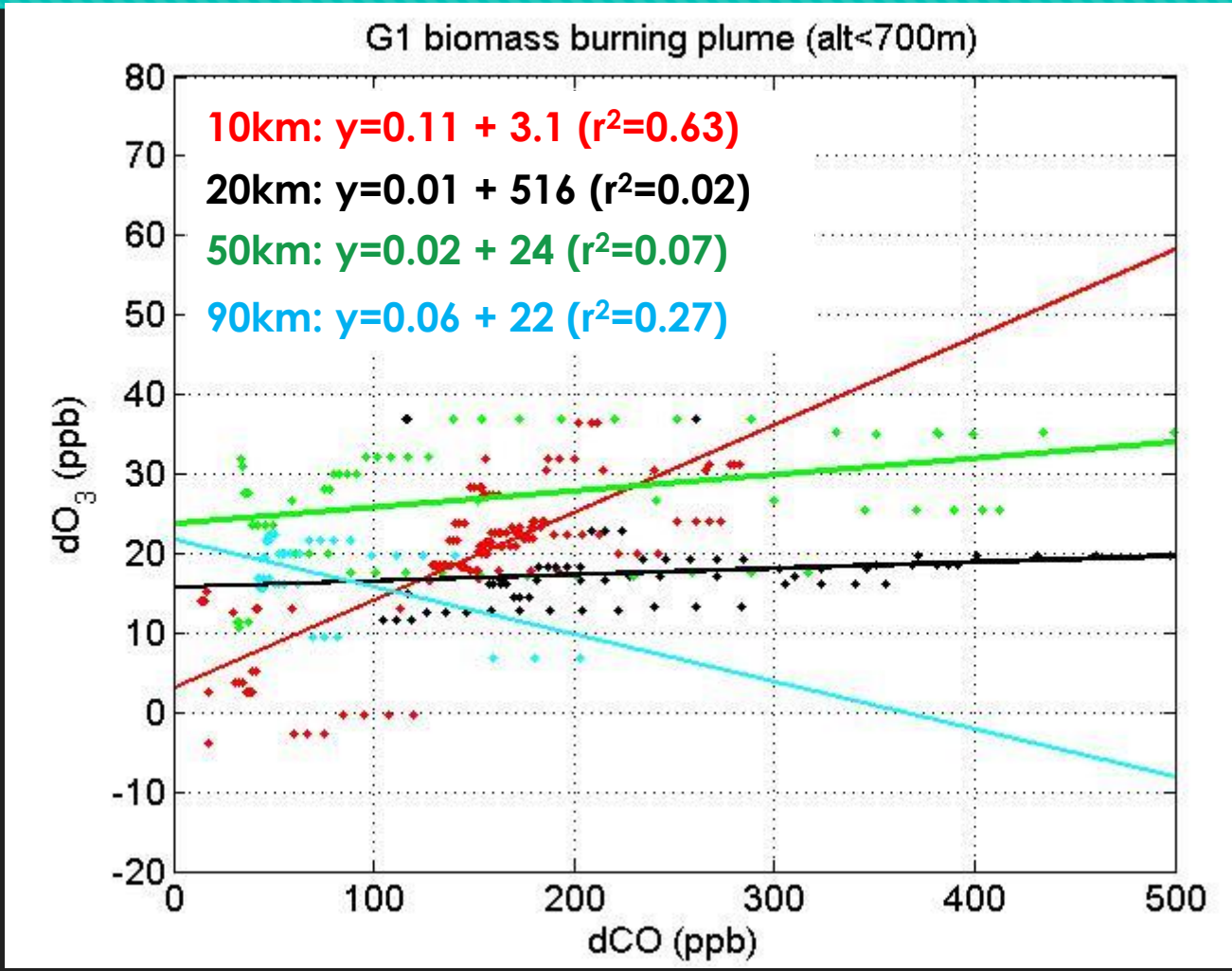
20km: y=0.28 + 20 (r^2=0.35)

50km: y=0.56 + 10 (r^2=0.61)

70km: y=0.57 +3.8 (r^2=0.42)

90km: y=0.34 + 13 (r^2=0.27)

G1 enhancement factor dO_3/dCO



Airborne measurements (biomass burning plume)

Enhancements from biomass burning plumes are much smaller in comparison to urban plumes

Khun et al. (2010)
O_3 EF for a single flight in the dry season of 2001

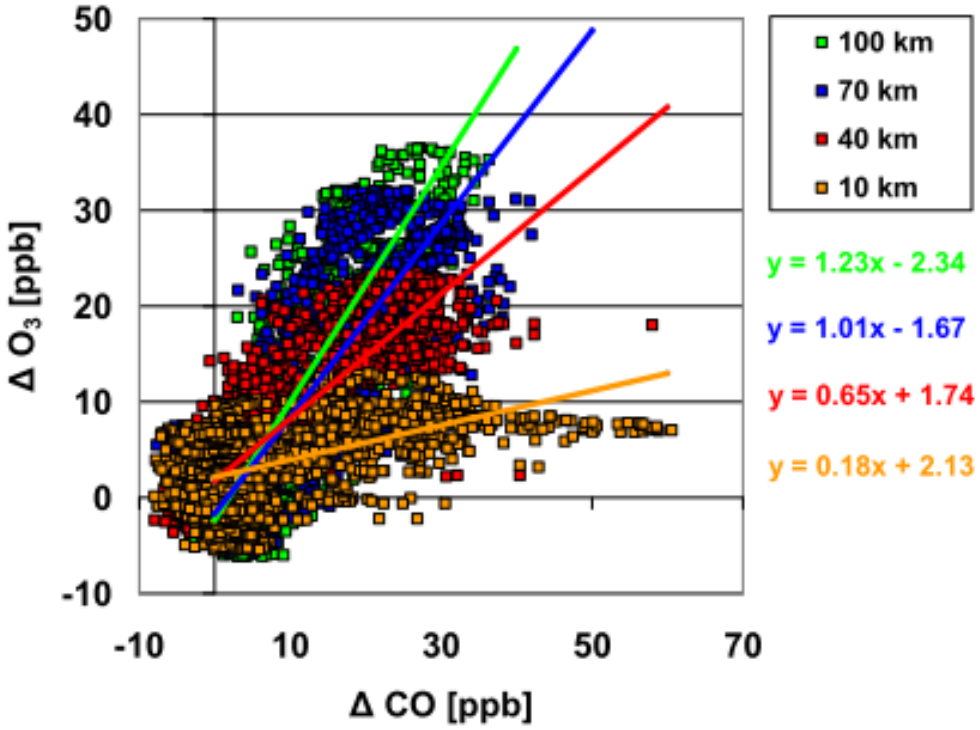


Fig. 7. ΔO_3 to ΔCO enhancement factors as a function of downwind distance from Manaus City during Flight #18 on 19 July 2001, 10:00–14:00 LT. Data from all transects of each vertical profile are binned. Slopes of a linear regression using the reduced-major-axis (RMA) regression method are given.

Khun et al., ACP, 2010

- G1: slope dO_3/dCO = 0.57 in the dry season at 70km distance
- T3: slope dO_3/dCO = 0.27 in the dry season

Summary

- On average, the O_3 peak is similar at T2 (source region) and T3 (when impacted by the urban plume).
- Airborne data shows that most of O_3 is formed within 20 km from Manaus.
- Relatively low O_3 net production rates, suggesting that the plume is oxidized within ~20 km from Manaus.
- Greater O_3 enhancement factors in urban plumes in comparison to biomass burning plumes.
- O_3 enhancements with respect to background in 2014 are smaller that observations from 2001.

Thanks for the attention!

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