LOW-COST SENSORS PILOTS

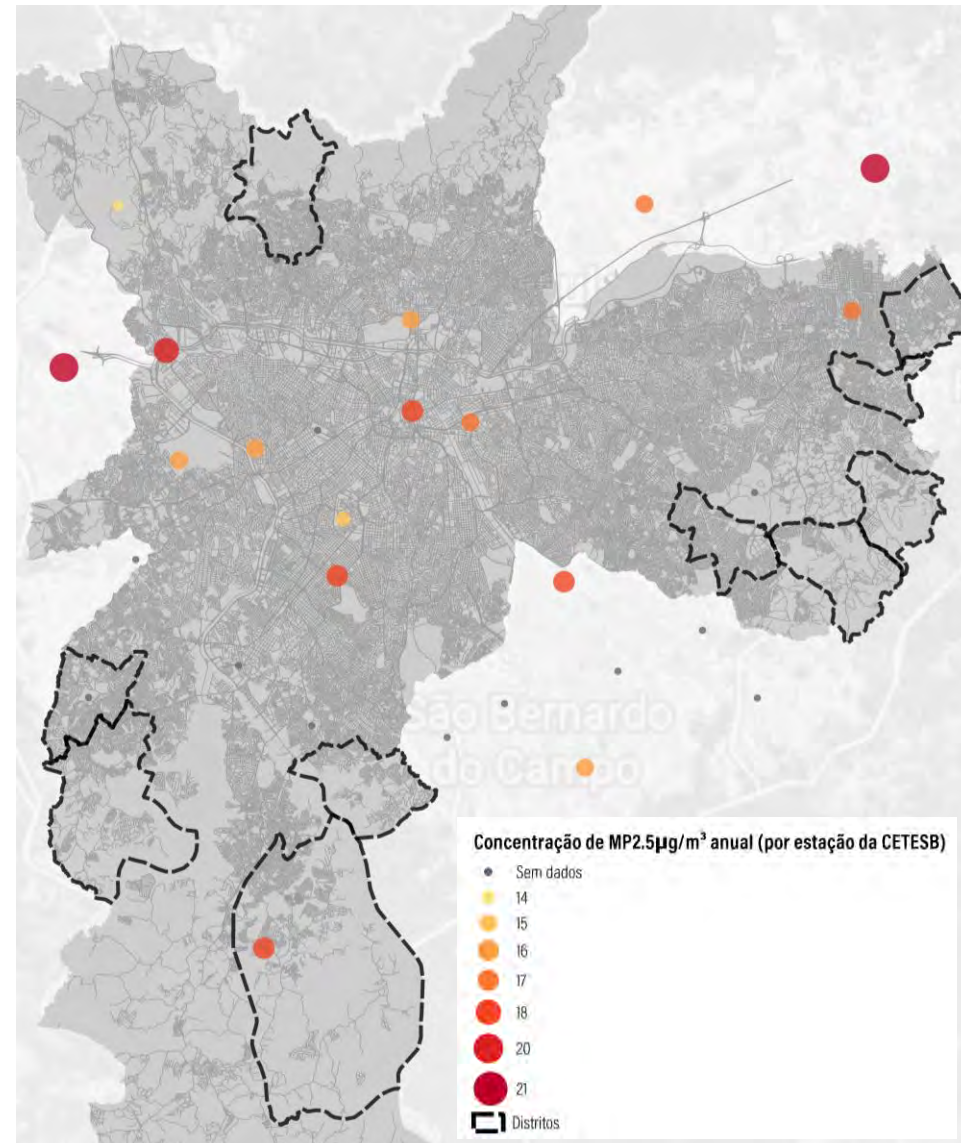CRISTINA ALBUQUERQUE, URBAN MOBILITY MANAGER

AIR POLLUTION IN BRAZIL

- Outdoor air pollution kills over 50,000 people a year in Brazil (WHO, 2018)

- Of a total of 27 Brazilian states, 20 (74%) do not have air quality monitoring data (ISS, 2019)

- Brazilian air quality standards (established by CONAMA) are highly outdated from WHO standards

AIR POLLUTION IN SÃO PAULO

- Although São Paulo is the city with the largest number of monitoring stations in Brazil, peripheral regions still lack information.

- It is estimated that mortality and morbidity caused by air pollution generate an economic cost of up to US$208 millions per year in São Paulo from 2005 to 2009 (VERONEZ et al., 2012)


Concentração de MP2.5µg/m³ anual (por estação da CETESB)
- Sem dados
- 14
- 15
- 16
- 17
- 18
- 20
- 21
- Distritos

PM2.5 monitoring stations in São Paulo

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AIR QUALITY SENSORS

SENSORS USED

- Airbeam2

  - Can be battery operated or using mains power

  - Operate in a mobile environment or fixed location

  - Multiple communication methods (WiFi and cellular)

  - online platform for real-time viewing of data

0.50"

1.10"

5.21"

3.87"

WRI BRASIL
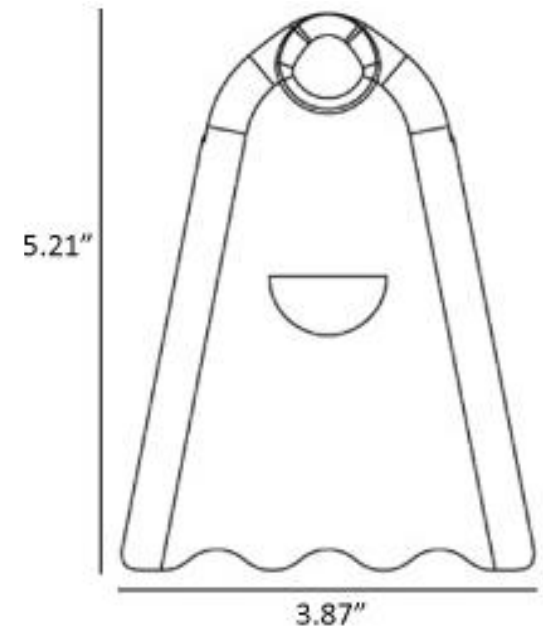
FIXED SENSORS

- Fixed sensors streaming real-time data on aircasting.org. When in fixed mode, sensors generate data every **one minute**

Source: http://aircasting.org/

WRI BRASIL
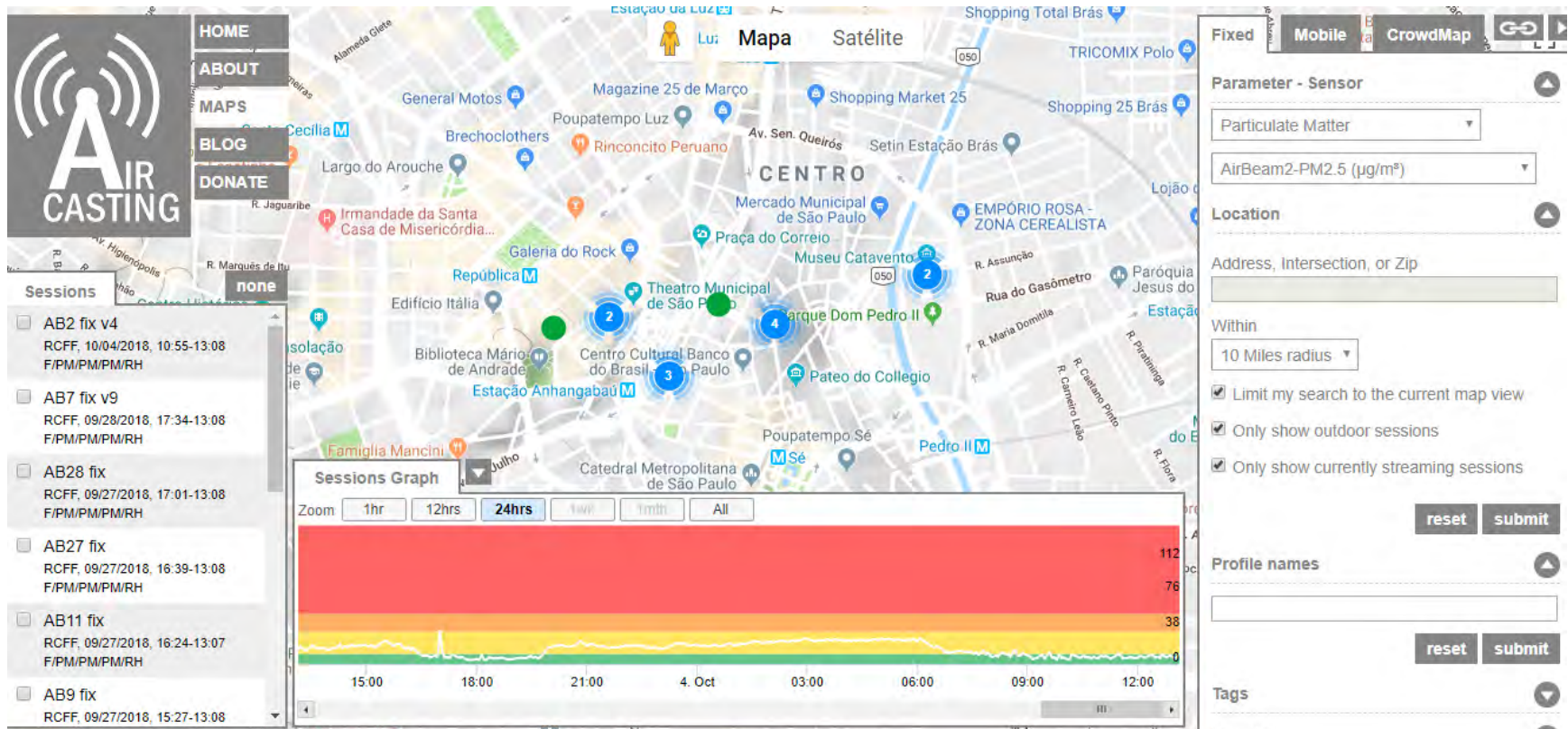
MOBILE SESSIONS

- Mobile sessions showing GPS coordinates. When in mobile mode, sensors generate data every **one second**

Source: https://kepler.gl/#/
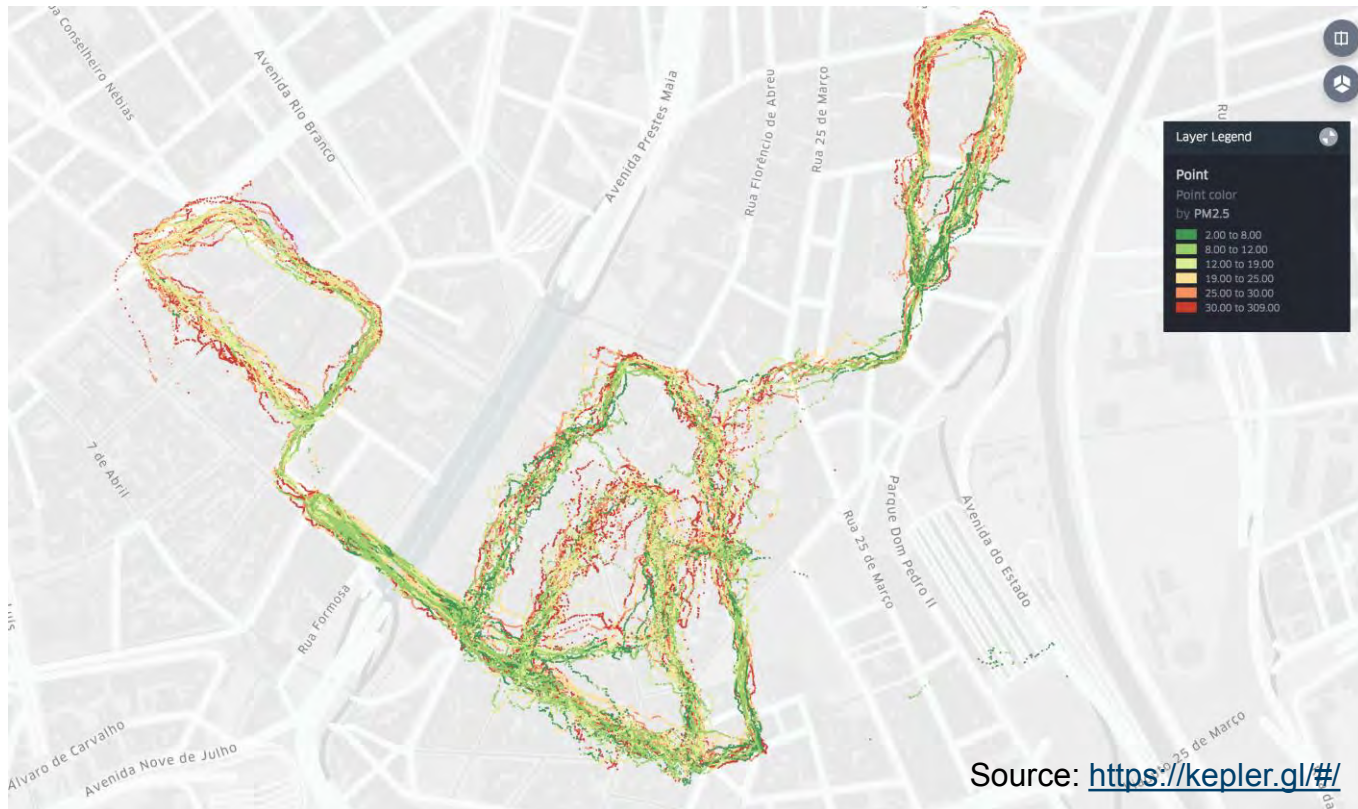
*Analysis of mobile sessions are still in progress

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SENSORS

- **30** AirBeam2 sensors imported from the US to Brazil
  - 1 battery broke before the first study and another after the first study finished
- **18** sensors used in the first study
  - 11 treated as <u>FIXED</u> sensors, located outside public buildings near and within the historic city center
  - 2 "golden" sensors were placed near a ground reference monitor owned by CETESB (Public agency responsible for measuring air pollution)
  - 5 sensors allocated for 5 different <u>MOBILE</u> routes
- **12** sensors used in the second study
  - 2 sensors installed on CETESB monitoring station
  - 6 fixed sensors, located on public schools
 - 4 sensors allocated in <u>MOBILE</u> routes

PROJECT 2018 – CAR FREE FRIDAY

INTRODUCTION

- "Car-Free Friday" (CFF) restricts access to a set of pre-determined streets in the historic city center of São Paulo to **single-occupant vehicles**, **heavy-duty trucks** and **motorcycles** on the last Friday of every month.

- Buses, taxis, bicycles and school vans however are still granted full access to these streets.
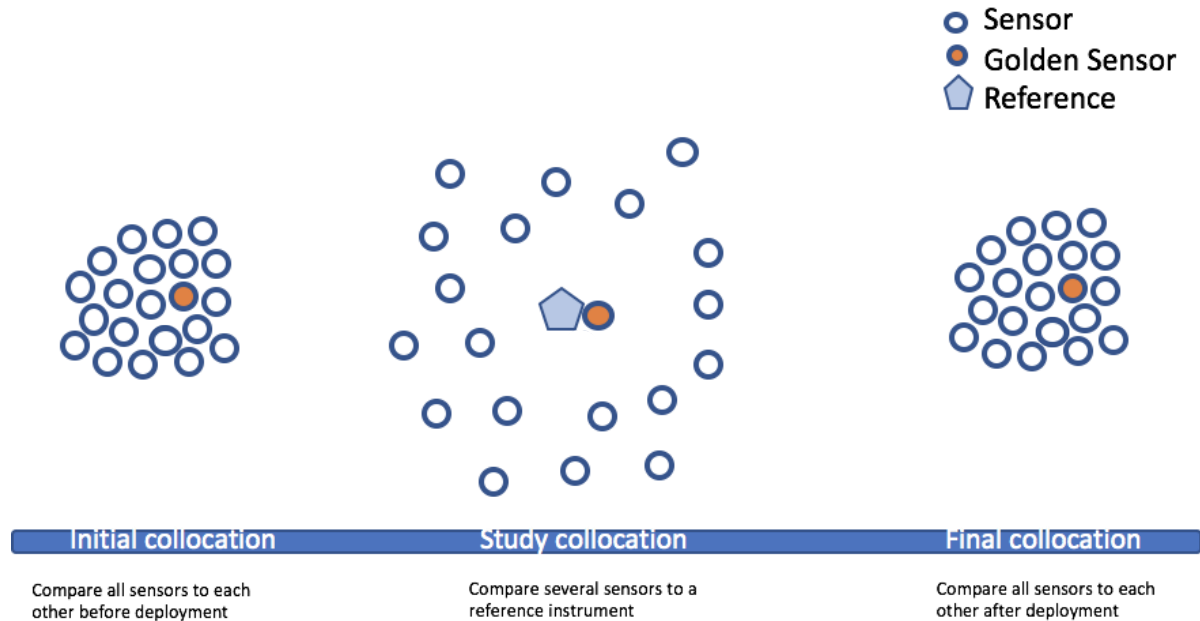
CAR-FREE FRIDAY ZONE IN SÃO PAULO

- Red lines are the limited-access streets during Car-Free Fridays
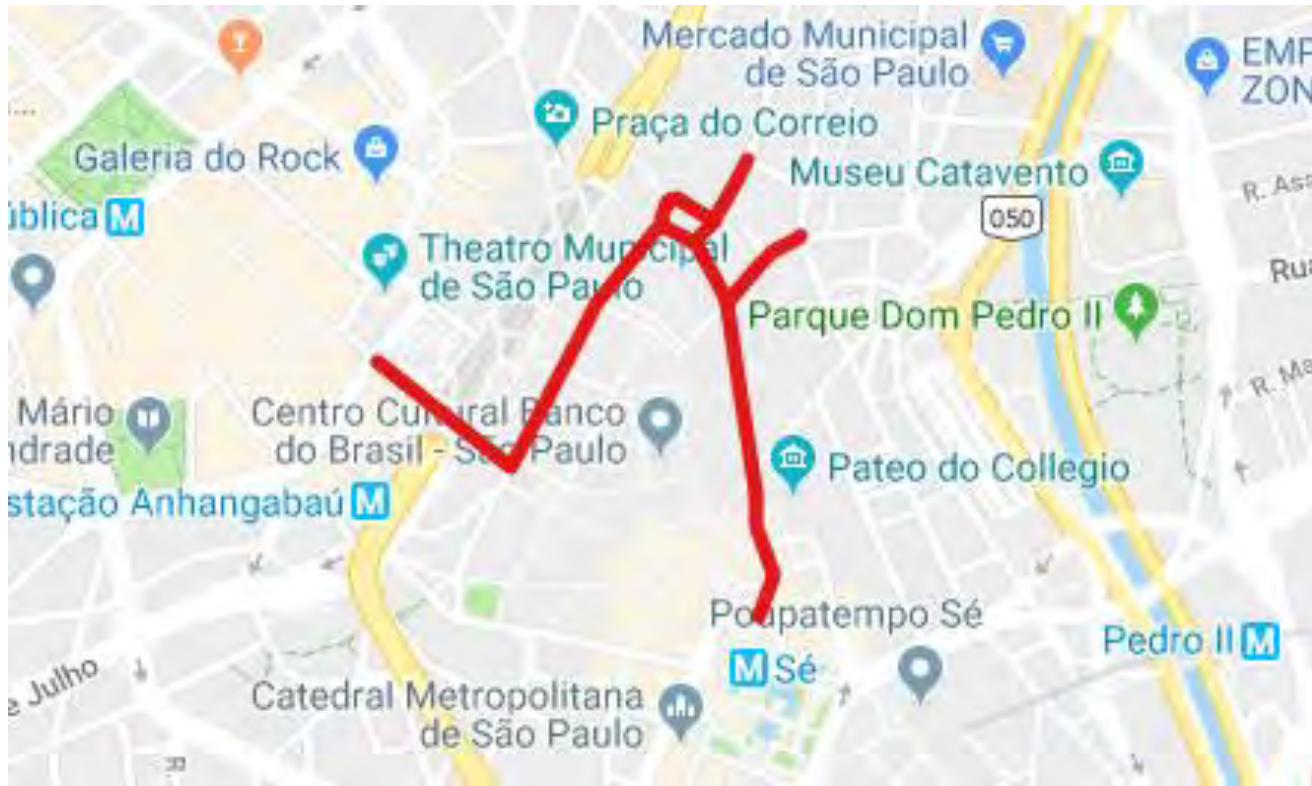
Historic City Center of São Paulo, Brazil

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THREE TIME PERIODS OF STUDY

1. **Pre-collocation**
2. **Field deployment**
3. **Post-collocation**

○ Sensor
● Golden Sensor
⬠ Reference

Initial collocation	Study collocation	Final collocation
Compare all sensors to each other before deployment	Compare several sensors to a reference instrument	Compare all sensors to each other after deployment

Image by Tim Dye of TD Env Services, Inc.
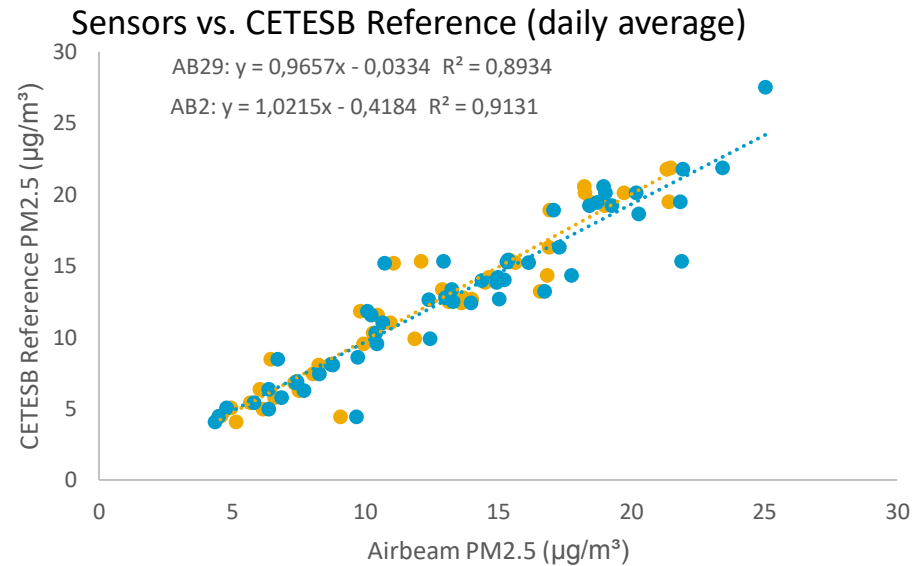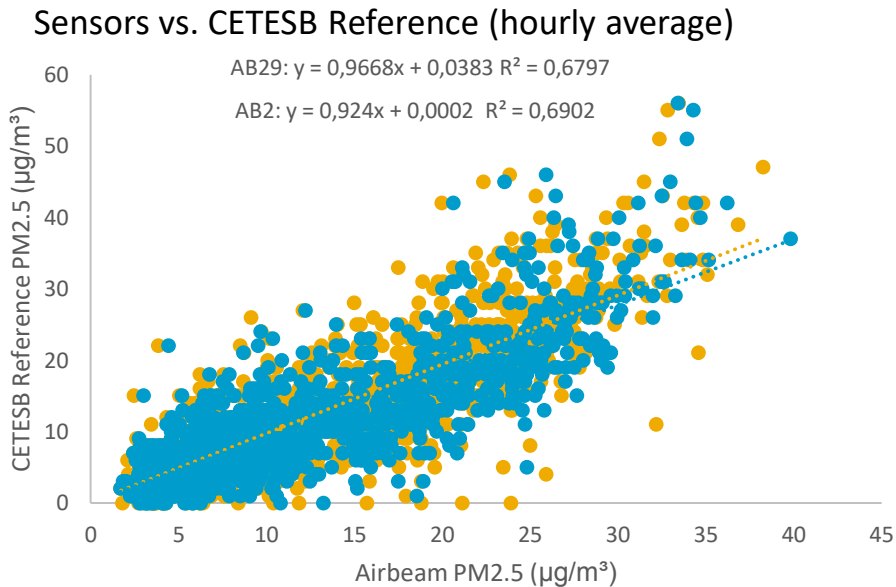
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COLLOCATION

- Process of locating all sensors in the same environment to compare if measurements are consistent

- One sensor is chosen as the "Golden" sensor to serve as reference for the others

- Collocations were made before & after the field study, to check if sensors' performance changed over time

- All 30 sensors were found to be well correlated between one another ($R^2 \geq$ **0.94** when compared to Golden sensor)

- Regression equations resulting from the collocation studies were used to adjust the final data values for the

Image: Photo of pre-collocation study for all 30 sensors

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RESPONSE TO REFERENCE INSTRUMENT

- 2 "golden" sensors were located next to Cetesb ground monitoring station (AB2 and AB29)

- A satisfactory response (Hourly average $R^2 \approx 0{,}68$ / Daily average $R^2 \approx 0{,}9$) shows that sensors results are reliable

Sensors vs. CETESB Reference (hourly average)

AB29: $y = 0{,}9668x + 0{,}0383$ $R^2 = 0{,}6797$

AB2: $y = 0{,}924x + 0{,}0002$ $R^2 = 0{,}6902$

Sensors vs. CETESB Reference (daily average)

AB29: $y = 0{,}9657x - 0{,}0334$ $R^2 = 0{,}8934$

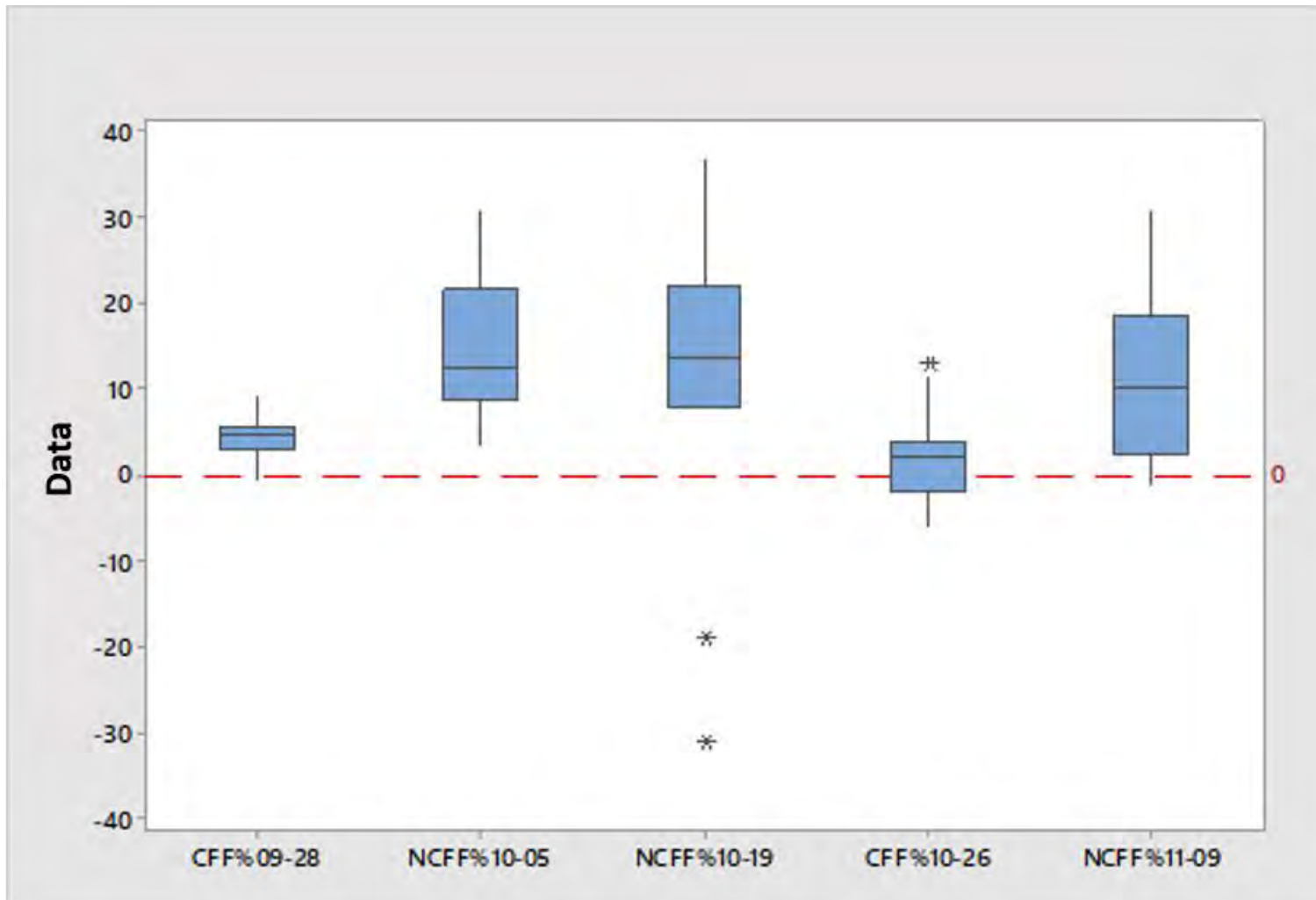AB2: $y = 1{,}0215x - 0{,}4184$ $R^2 = 0{,}9131$
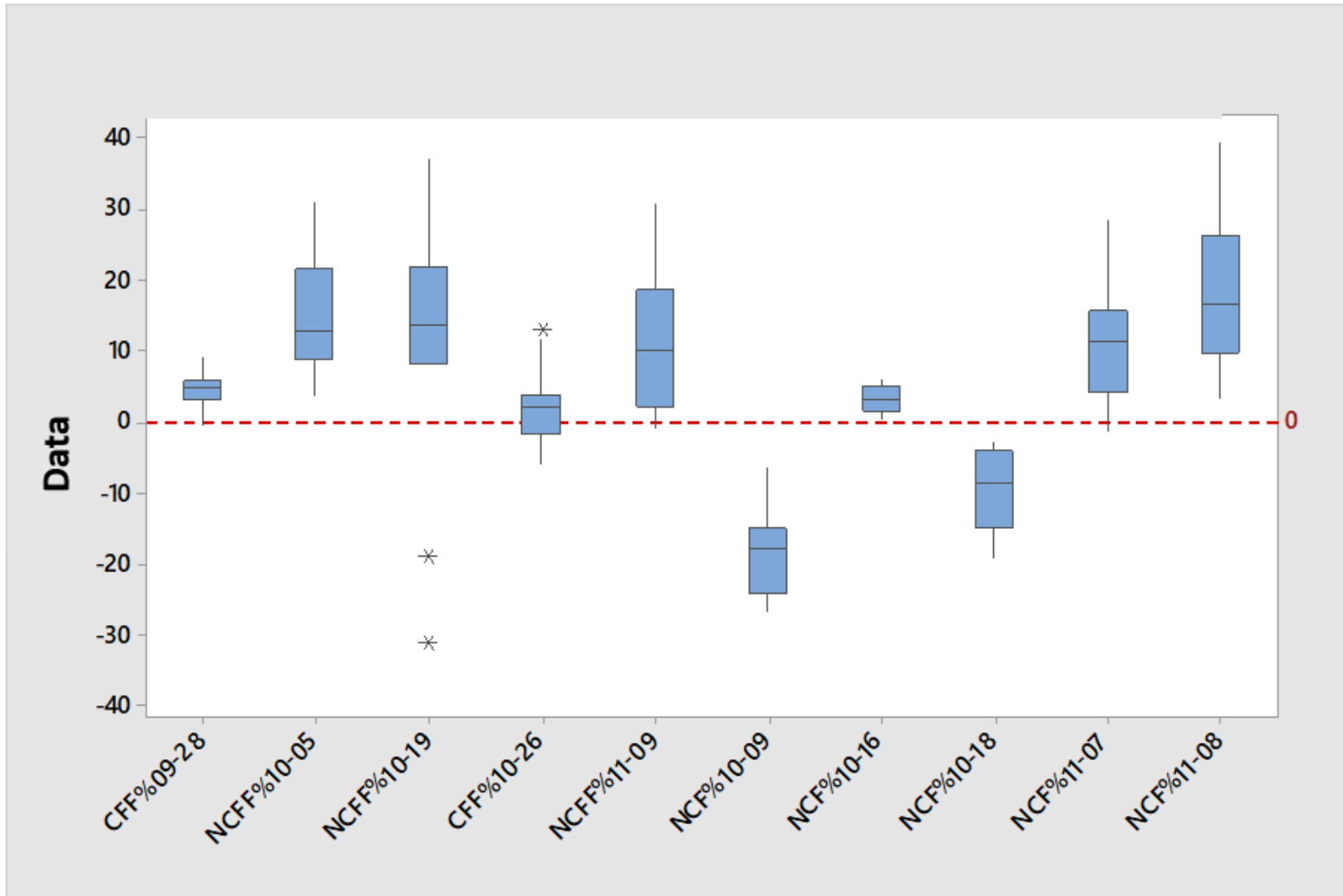
• AB2 to CETESB • AB29 to CETESB

DATA ANALYSIS

- Differences in average PM 2.5 concentrations between the CFF zone (inside) and Non-CFF zone (also inside the zone) were compared to evaluate the impact of the Car-Free Friday initiative on local air quality.
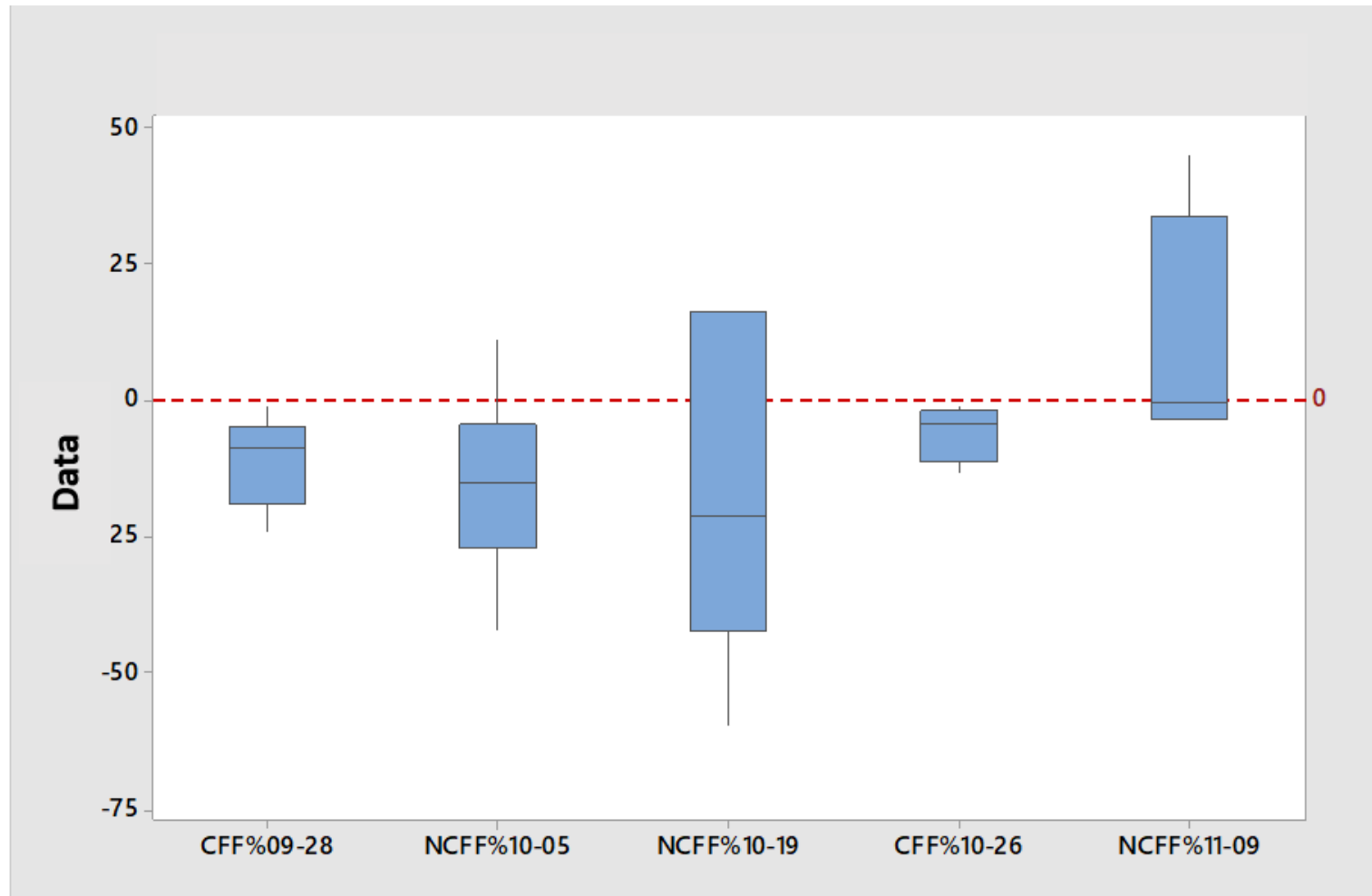

← CFF Zone

Non-CFF Zone

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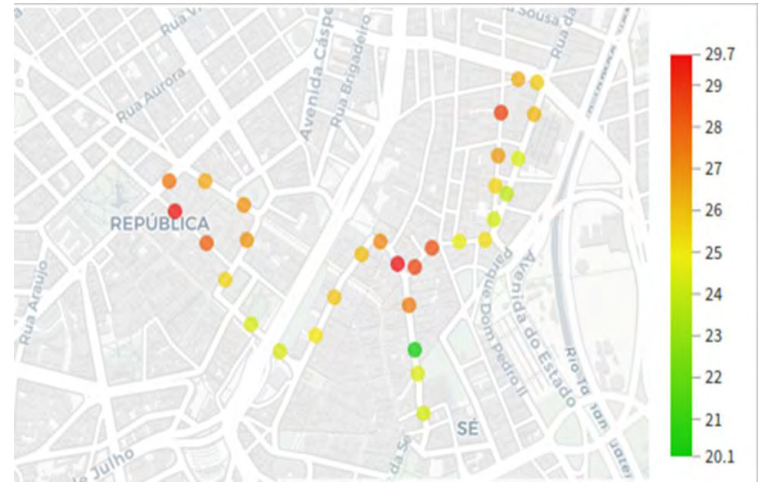# DATA ANALYSIS – FRIDAYS WITH FIXED SENSORS

DATA ANALYSIS – FIXED SENSORS

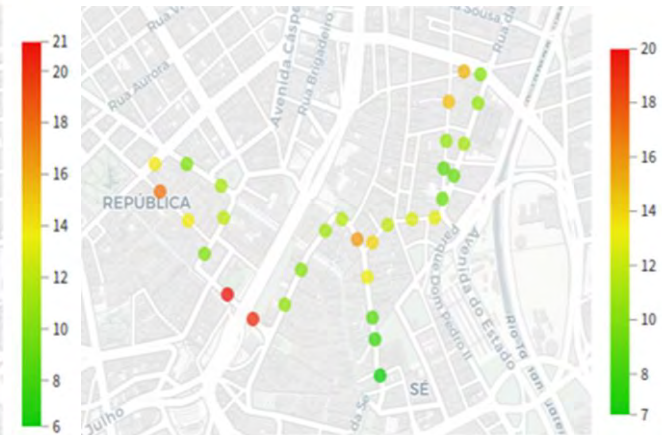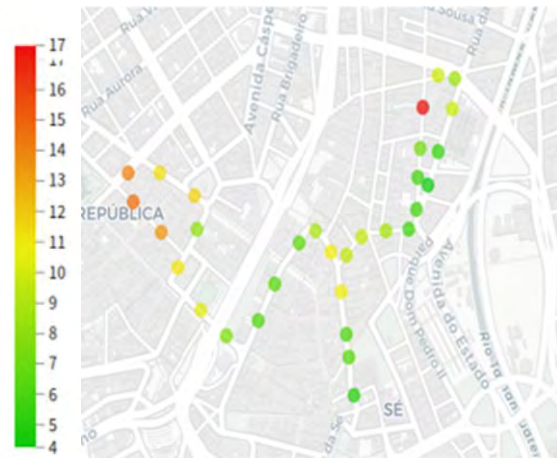# DATA ANALYSIS – FRIDAYS WITH MOBILE SENSORS

DATA ANALYSIS – MOBILE SENSORS
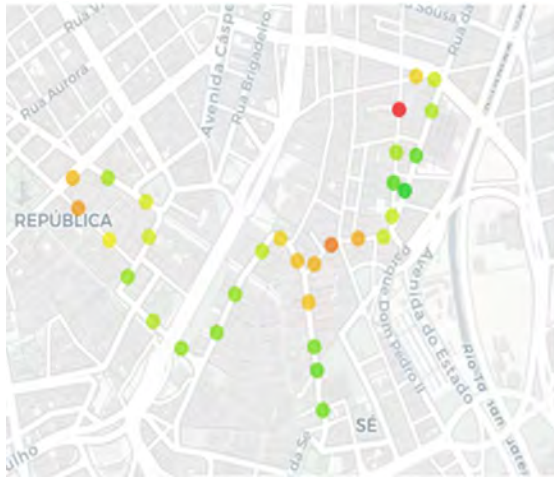
C
F
F

N
C
F
F

DATA ANALYSIS – MOBILE SENSORS

- Relatively higher PM2.5 conditions outside the Car Free Zone (left dots) on Car-free Fridays may indicate more pollutions from another source

- Persistent higher PM2.5 concentrations at a fixed spot occurred on all days and may indicate a very local "hot spot", which could be investigated by looking for local sources of PM2.5 in that area.

CONCLUSIONS

- Inconclusive if the Car-Free Fridays had impact on the local air quality
  - Mobile sensors: we couldn't notice improvements in the local air quality.
  - Fixed sensors: considering only the Fridays measured during the study, we can see a significant statistical difference between the PM2.5 concentrations
  - Lack of secondary data regarding the traffic counting to confirm if the traffic behavior of a Friday is different from other days

PERCEPTION SURVEY

- **78%** of respondents approve of the CFF initiative
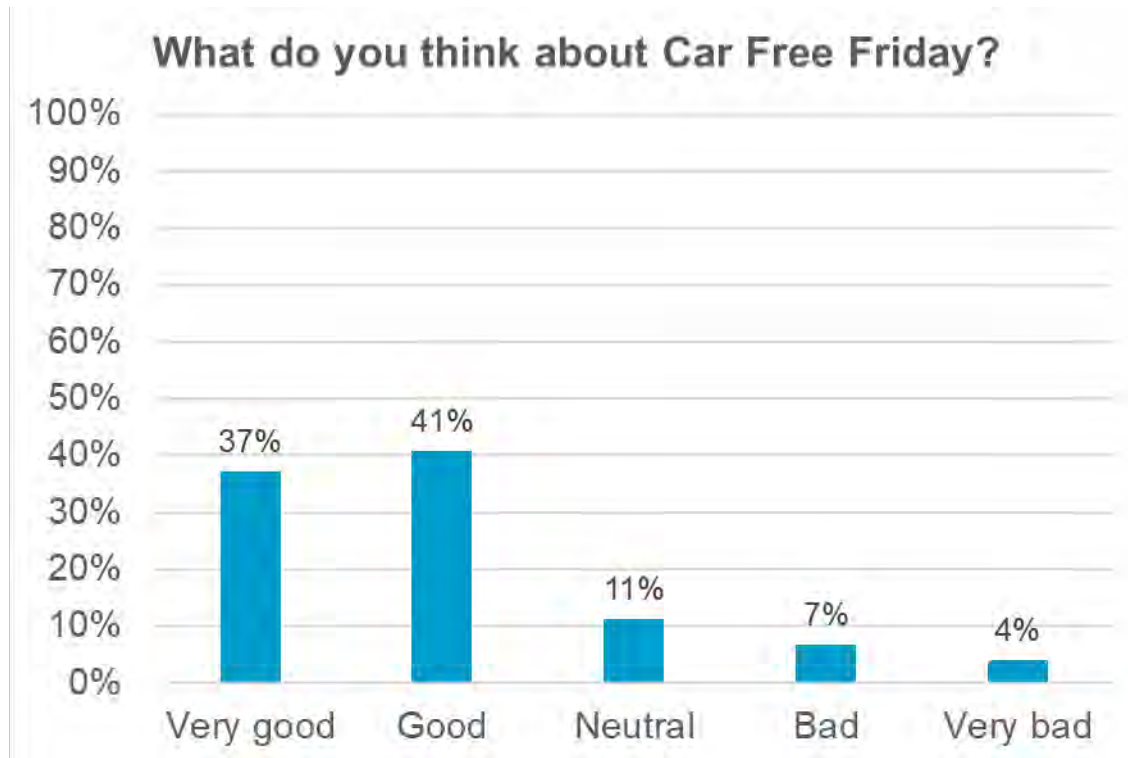
What do you think about Car Free Friday?

| Category	Percentage
Very good	37%
Good	41%
Neutral	11%
Bad	7%
Very bad	4%

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PERCEPTION SURVEY

- The three aspects that were shown to improve the most, according to the perception of respondents, were:
  - Ease of crossing the street
  - Improved walking experience (noise and comfort)
  - Feeling of well-being in the area (quality of life)

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PERCEPTION SURVEY

- The aspects that people disliked the most included:

  1. Lack of information on CFF times and dates
  2. Difficulty using the car
  3. Accessibility
  4. Traffic worsens
  5. Less trade/purchasing
  6. Fewer people walking
  7. Difficulty parking car

What do you dislike about CFF?
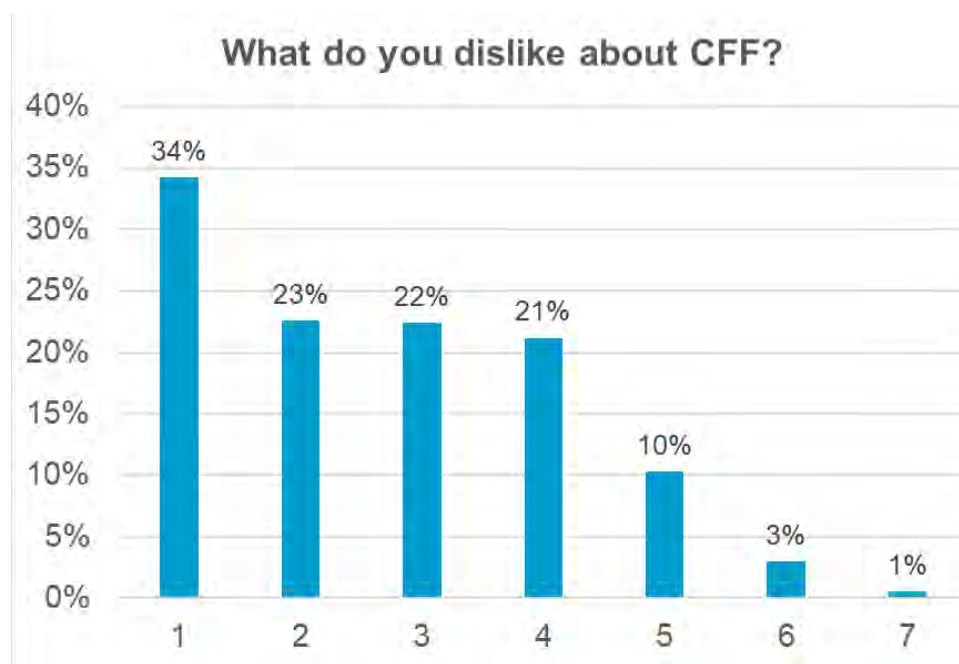
PERCEPTION SURVEY

- The aspects that people liked the most include:
    1. Improved walking
    2. **Clean air**
    3. Silence / tranquility
    4. Encourages public transportation
    5. Safer traffic
    6. Encourages active transport (walking + cycling)
    7. Favors the taxi driver
    8. Best for riding a bike

What do you like most about CFF?

1	52%
2	43%
3	39%
4	22%
5	19%
6	15%
7	9%
8	9%

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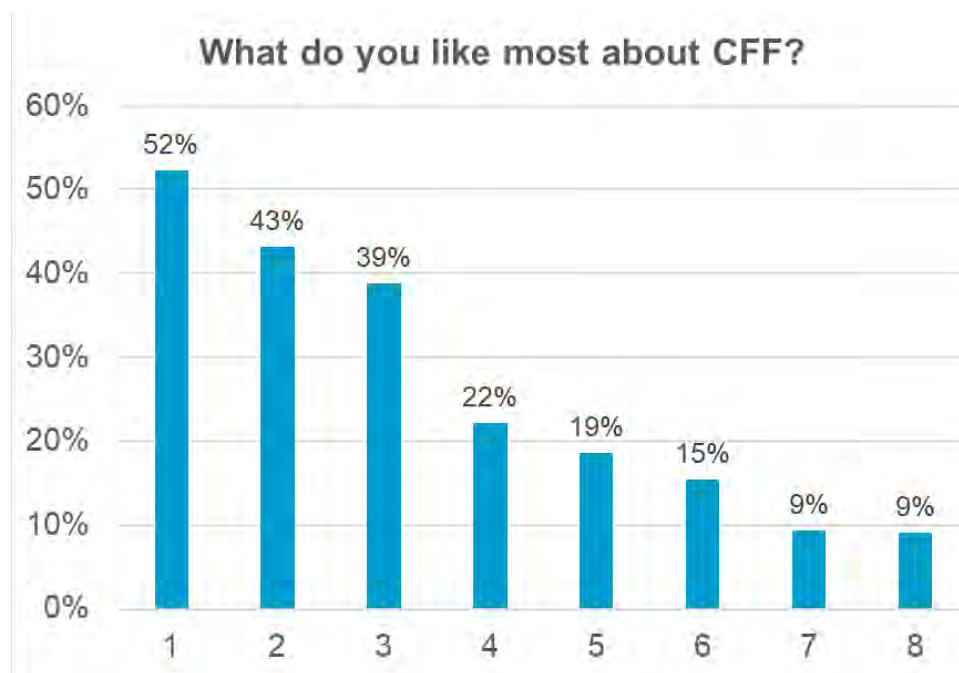
PERCEPTION SURVEY

would you like the program to be expanded to more days of the month?

77%   23%

PERCEPTION SURVEY

Would you like this initiative to be expanded to more parts of the city?

👍 **77%**　　👎 **23%**

PROJECT 2019 – AIR QUALITY AROUND SCHOOLS

WRI BRASIL

OPPORTUNITY: EDUCATIONAL TERRITORIES PROJECT

A municipal project for the creation of spaces which stimulate children cognitive abilities, logical reasoning and motor coordination, provide sensory experiences and coexistence with the community.

OPPORTUNITY: EDUCATIONAL TERRITORIES PROJECT

WRI Brasil's road safety team is supporting 4 Educational Territories in 2019. The air quality team worked together in two territories: Brasilândia and Cidade Tiradentes, aggregating the activities planned in the project and contributing to the urban design from the air quality perspective.

The city aims to implement 10 Educational Territorial projects until the end of 2020.
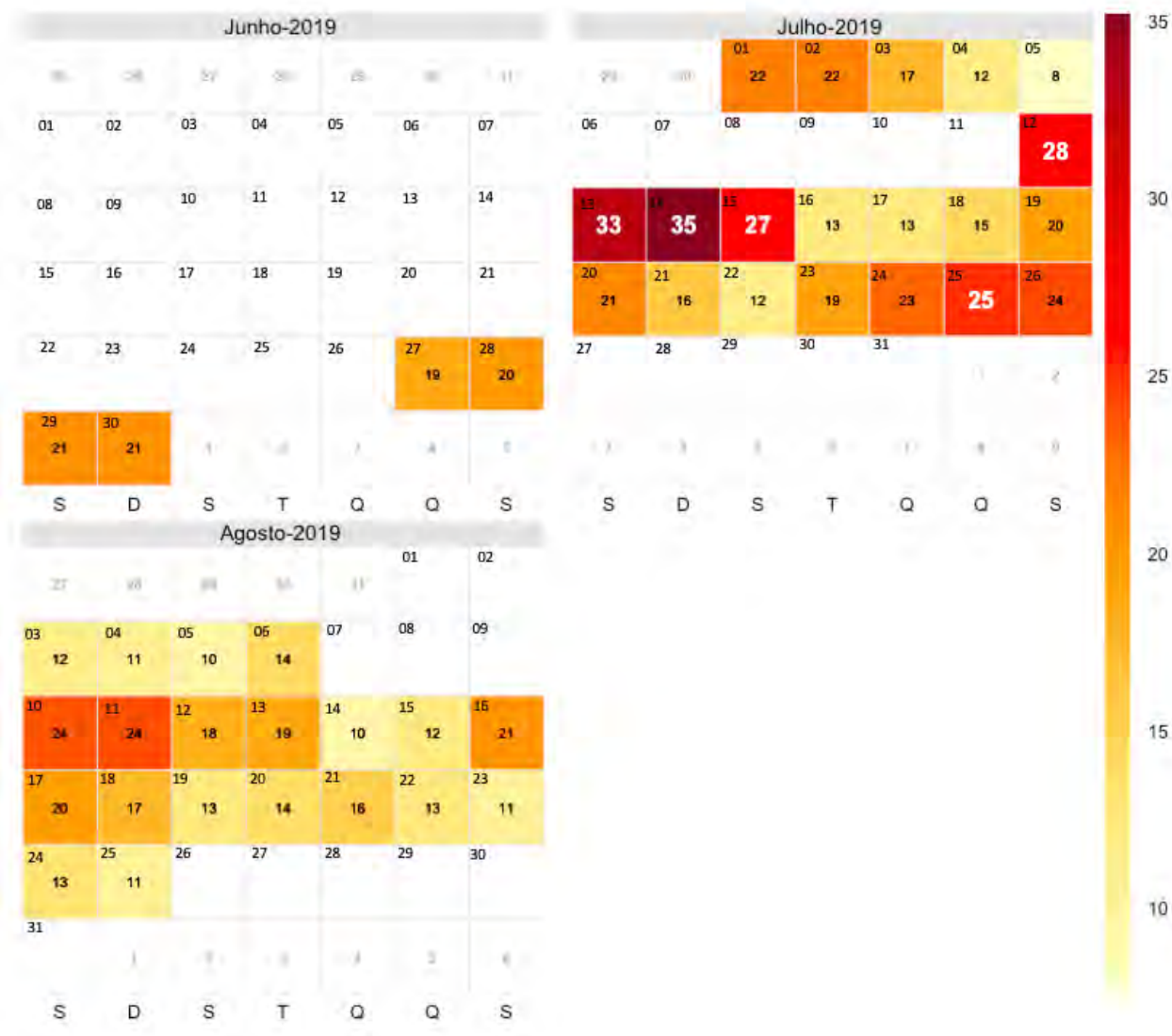
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PM 2.5 MEASUREMENT AROUND SCHOOLS

RESPONSE TO REFERENCE INSTRUMENT:

- 2 sensors located next to Cetesb monitoring station
- Hourly average R² ~ 0,60.
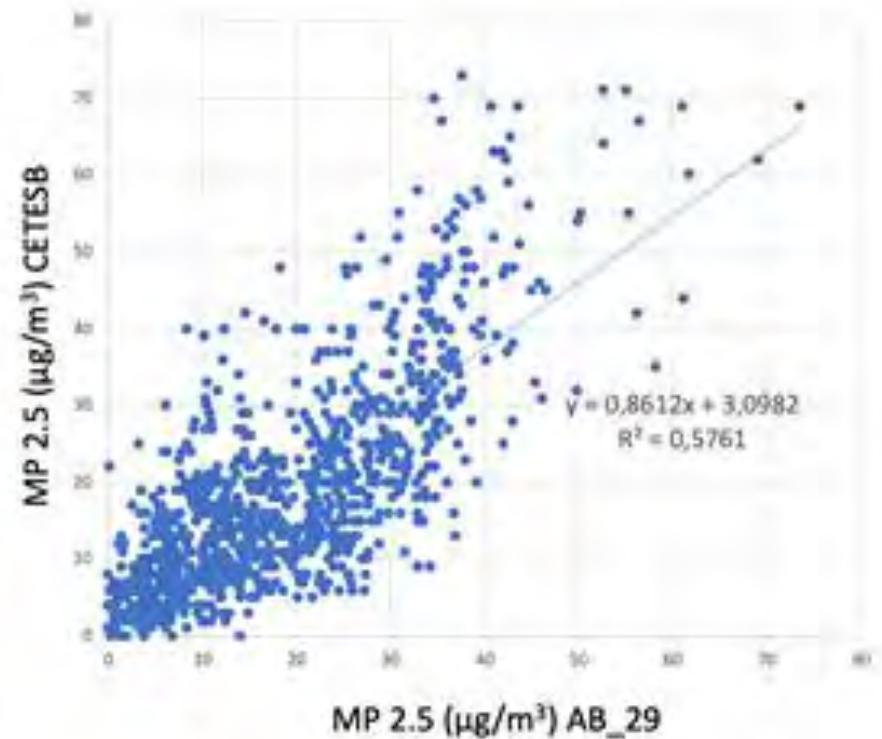
PM 2.5 MEASUREMENT – RESULTS IN BRASILÂNDIA

- 3 fixed sensors

- 44 monitored days

- 5 days exceeded the daily average classified as safe by WHO (25 mg/m3)

- Analysis of daily and weekly cycles

PM 2.5 MEASUREMENT – RESULTS IN BRASILÂNDIA

- During the afternoon, a reduction in PM2.5 is observed, possibly associated with turbulent mixing caused by elevation of the convective boundary layer, concomitant with a probable reduction of important sources such as vehicular.

- On weekdays, maximums are observed at 6am and 7pm, which may be associated with **traffic peaks in the region**.

- The mixing ratio of MP2.5 at weekends is slightly higher than peak weekdays and may be associated with other likely sources such as residential **firewood burning or urban waste burning**

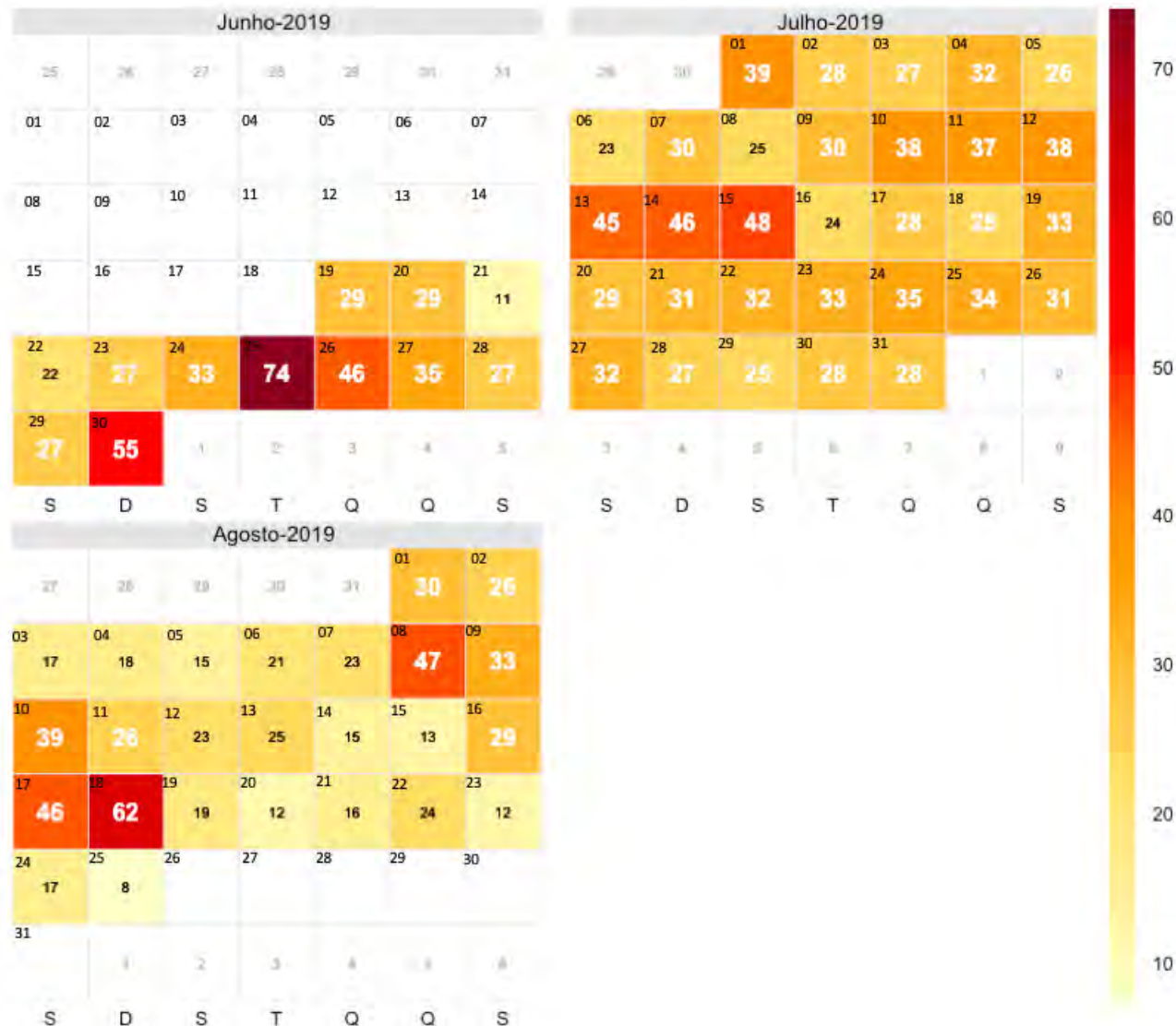Gasoline vehicles   Diesel vehicles   Combustion of biological material and waste

PM 2.5 MEASUREMENT – RESULTS IN CID. TIRADENTES

- 3 fixed sensors

- 68 monitored days

- 47 days exceeded the daily average classified as safe by WHO (70%)

- Analysis of daily and weekly cycles

PM 2.5 MEASUREMENT – RESULTS IN CID. TIRADENTES

- Cid. Tiradentes has well-defined daytime cycles with two peaks located in the morning and evening, respectively, without much change between weekdays and weekends.

- Daytime variability, associated with high MP2.5 concentrations in practically the entire series, suggest vehicular activity as the dominant source in this region. However, it does not rule out the influence of industrial activities in the surroundings.

- Community representatives reported that on June 25, where the daily average was 74mg/m³, there was a large burn on the grounds next to the school.

Gasoline vehicles   Diesel vehicles   Combustion of biological material and waste

MOBILIZATION

- Engagement sessions on air quality with both schools

- Workshop with Plant-for-the-planet
  - Lecture on climate change, air pollution and urban afforestation
  - Training climate leaders
  - Planting seedlings around schools

- Workshop to develop an action plan on mobility, waste management and urban afforestation

LESSONS LEARNED

CHALLENGES

- Import sensors

- Logistical issues with great number of sensors

- Lack of secondary data that could verify possible differences in traffic conditions from Fridays and other weekdays

- The pollutant analyzed for the type of urban intervention chosen.

- Sensors have worsen their reliability with time (comparing correlation with reference instrument in 2018 and 2019) – 1 year guarantee

SUCESSES

- Collocation with reference instrument

- Partnership with local communities and municipality

- Awareness building: more interest on air quality

TIPS TO USE

- Update sensor's firmware on the first use (about 5 minutes per sensor)

- Fixed can be used on Wifi or cellular mode- To use cellular, unscrew the sensor and insert the chip into it.

- In fixed sessions, a cell phone is only necessary to set up the session. After configured, you do not need to keep it close to the sensors (in mobile sessions you do, as it works via bluetooth)

- If it takes too long to set up the session, the sensor does not collect the data (mainly when configuring session using WIFI)
  - To solve this problem you can re-synchronize the session, without having to repeat all the configuration steps, which ends up being faster

- Low battery sensors may have difficulty synchronizing

- When turned on, sensors do not increase the battery level even when plugged in a power source. If it is 50% charged, it will stay with 50% while connected to power source

THANK YOU!

CRISTINA ALBUQUERQUE, URBAN MOBILITY MANAGER