Low-cost air quality monitors

Peter Jackson
(with thanks to Brayden Nilson)

Presented at: KAQR meeting May 11, 2020

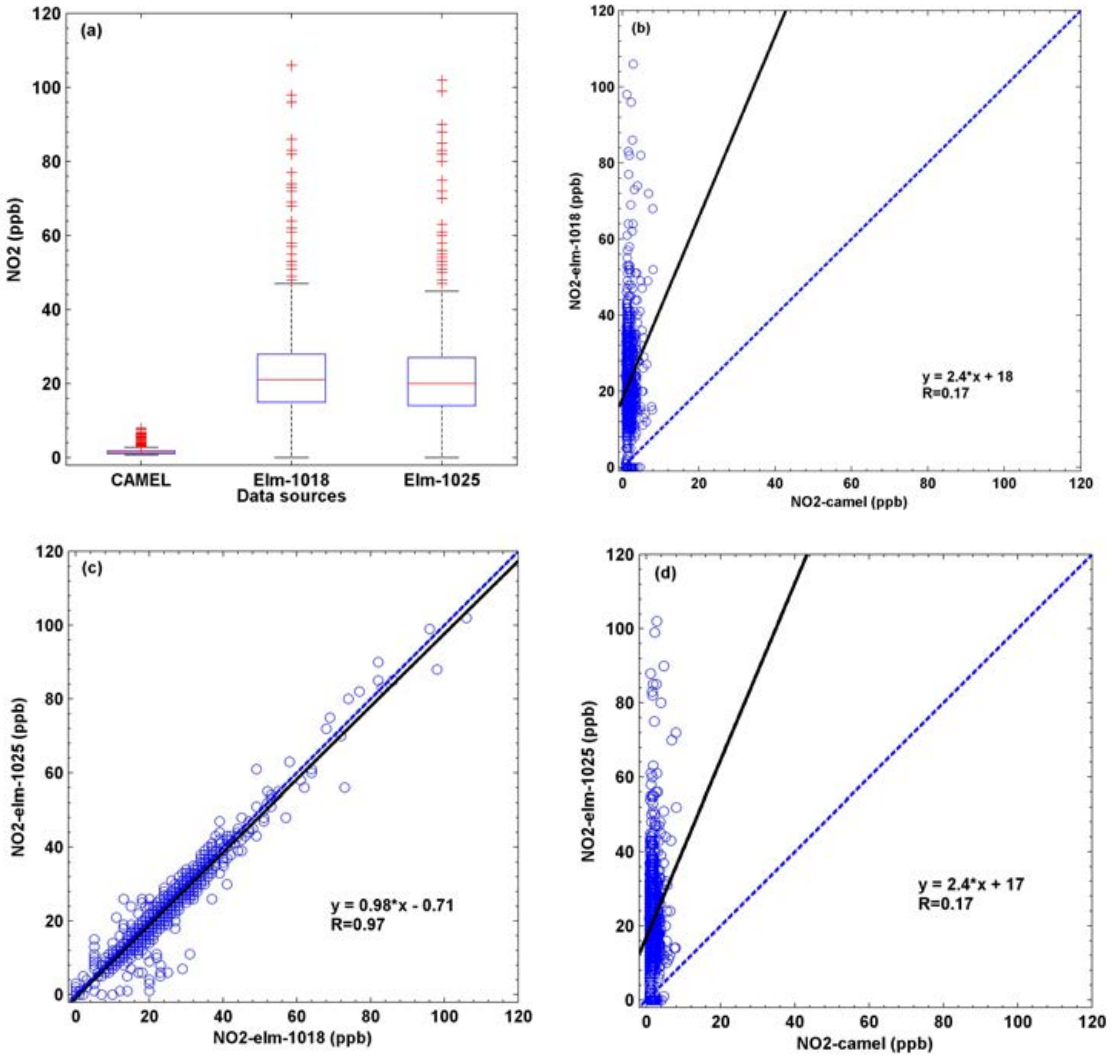
Air Quality Monitoring

- Until recently, due to cost, AQ monitoring has been in the realm of governmental and professional research agencies
- Regulatory “gold standard” monitors are designated as Federal Equivalent Method (FEM) or Federal Reference Method (FRM) through rigorous testing by the US EPA
- Single FEM monitors typically cost $15-40K and require periodic calibrations and maintenance by qualified technicians to generate reliable and accurate data, as well as data quality control / quality assurance procedures
- Consequently there are relatively few FEM AQ monitors in most cities
- However we know that air pollution levels vary a lot over short distances…

“Small Sensors” for AQ

- The past decade has seen development of many low-cost sensors for gases and particulates
- Gas sensors are typically electro-chemical or metal oxide semi-conductors
- PM sensors usually use light scattering by particles to measure particle counts by size and calculate mass concentration
- Cost and size offer ability to densely monitor areas, and to mount monitors on mobile platforms (e.g. drones) to better understand AQ patterns, validate models, assess exposure, etc.
- Potential to monitor smaller centres, FN communities, etc

Cautions with low-cost monitors



- A collocation study in NEBC between a FEM NO_2 monitor (CAMEL) and two low-cost multi-sensor monitors
- They correlate well with each other, but not with FEM monitor
- What do their numbers mean?

Source: Islam and Jackson, 2015

Interpretation of low-cost monitor data

- Low-cost monitors will give different values compared with FEM monitors but this does not mean they are not useful
- If they have a high correlation, then at least they go up and down together, and the low-cost monitor can be used to detect when AQ levels are changing – this can be helpful for people to make decisions regarding their activities
- If they have a high correlation but biases or large RMSEs, they can also be corrected with site-specific calibrations, so that their values are closer to FEM values

Implications for AQ management

- There will be a proliferation of small sensors that will improve over time
- The allow monitoring at the neighbourhood level, better exposure assessment and optimization of FEM networks
- However, if their accuracy characteristics are not understood, their “numbers” are difficult to interpret for both the public and professionals
- Other issues include correct siting, servicing and replacement as the sensors age and degrade

Some small sensors work better…

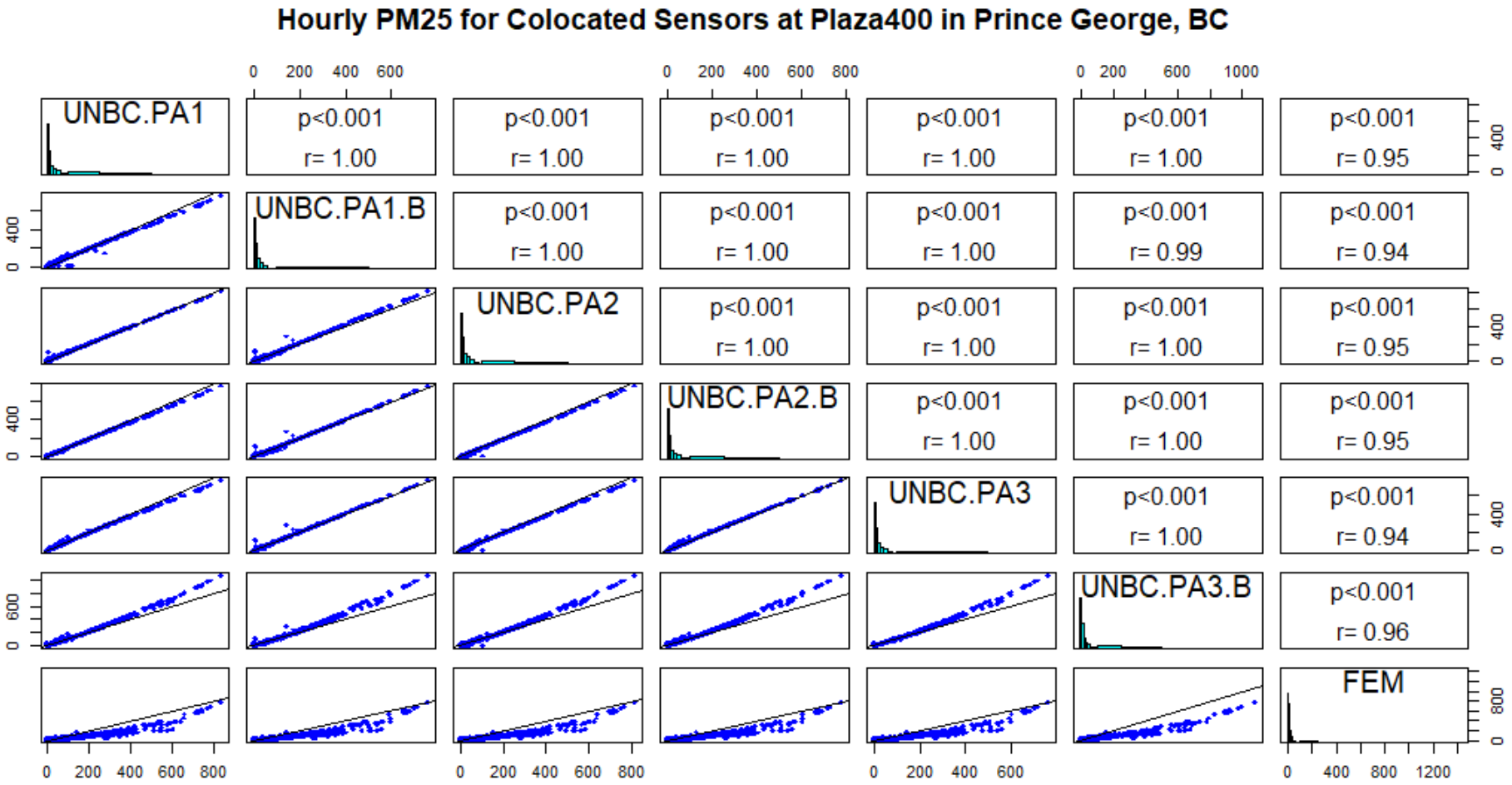
- We (and many others) have become interested in PurpleAir PAII monitors (PA) for $PM_{2.5}$
- PAs have dual Plantower light scattering sensors (mini nephelometers), and connect to a home WIFI network enabling them to upload data in realtime to a central server (https://www.purpleair.com/map) and http://weather.unbc.ca/aqmap for BC
- They cost $US230-260

UNBC PurpleAir project

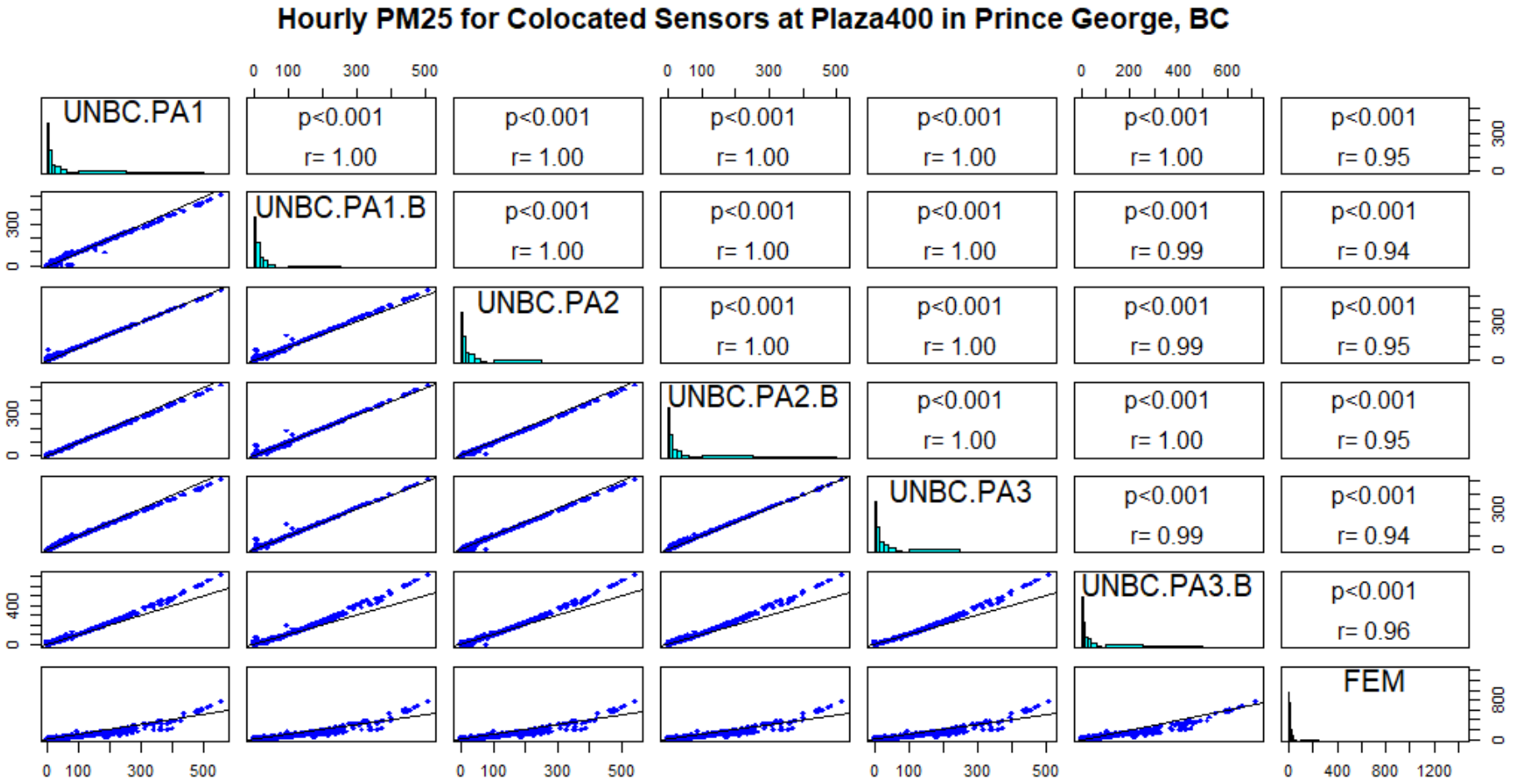
- Interpretation of “numbers” important for scientists and the public
- We need to know more about the characteristics of these monitors
  - Inter-sensor reliability
  - Calibrations/corrections – sensor specific? Airshed specific?
  - Modes of failure and calibration changes over time
- We are interested in calibrating/correcting PA data, and displaying corrected values on a map
- Brayden Nilson internship project funded by MITACS/BCME&CCS and currently ECCC

Evaluation of PurpleAir PA II

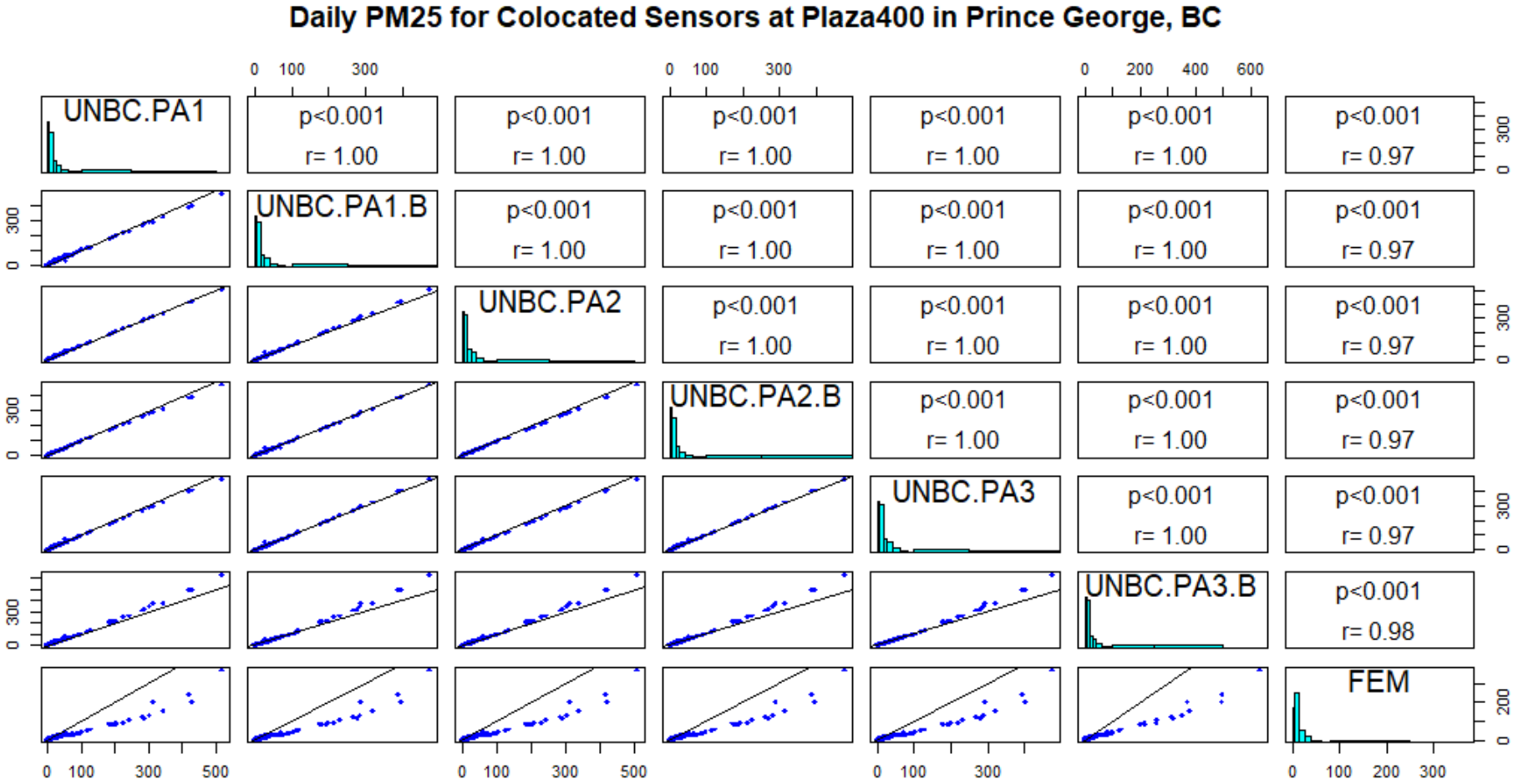
- Collocation of three PA monitors (6 sensors) with the BCME&CCS (NAPS) PG Plaza SHARP (FEM) monitor from February 2017 until the present (except August-December 2017) and an additional 14 PA II's from December 2017-April 2018 show very promising results



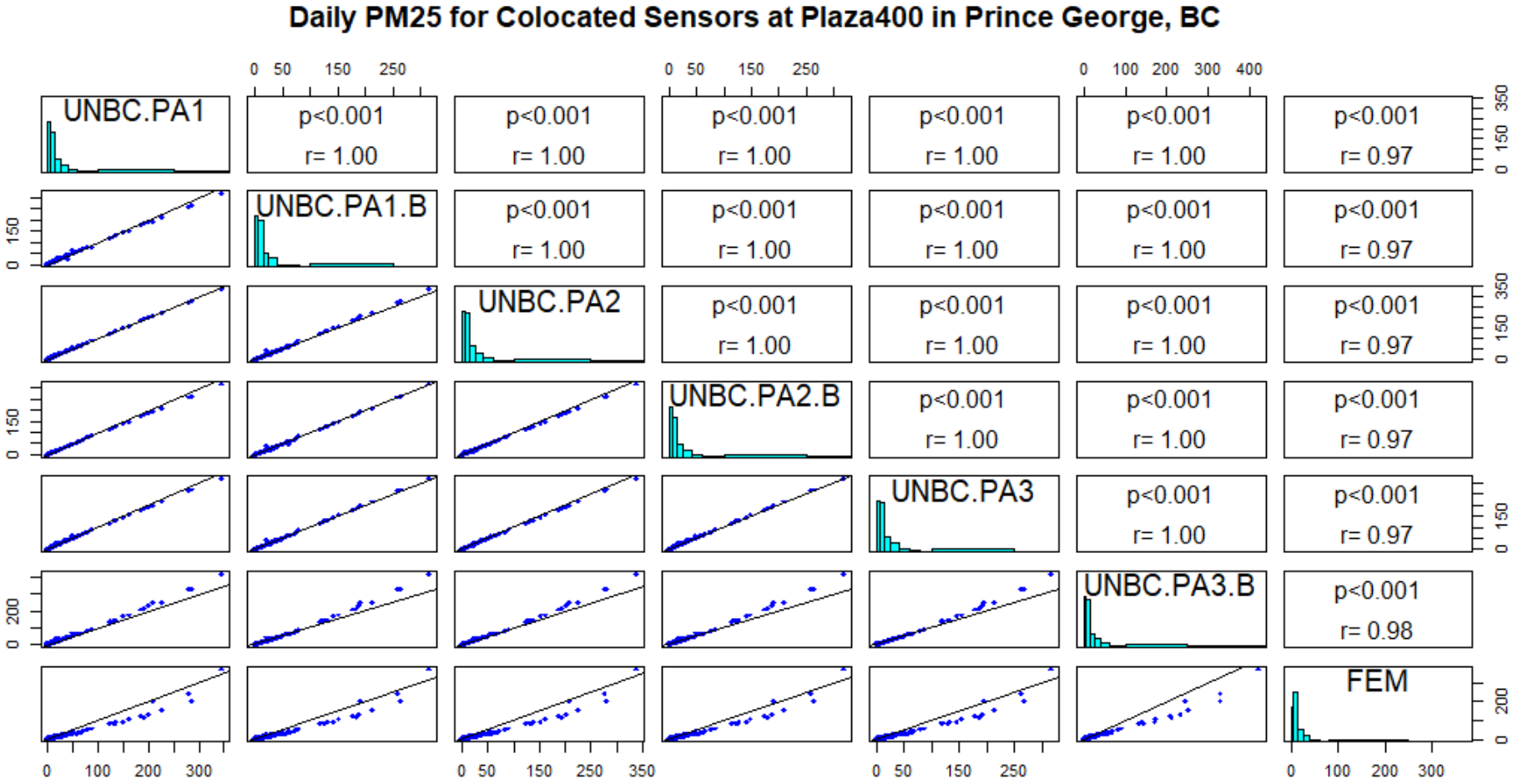
Hourly PM2.5 = ATM



Hourly PM2.5 = CF_1

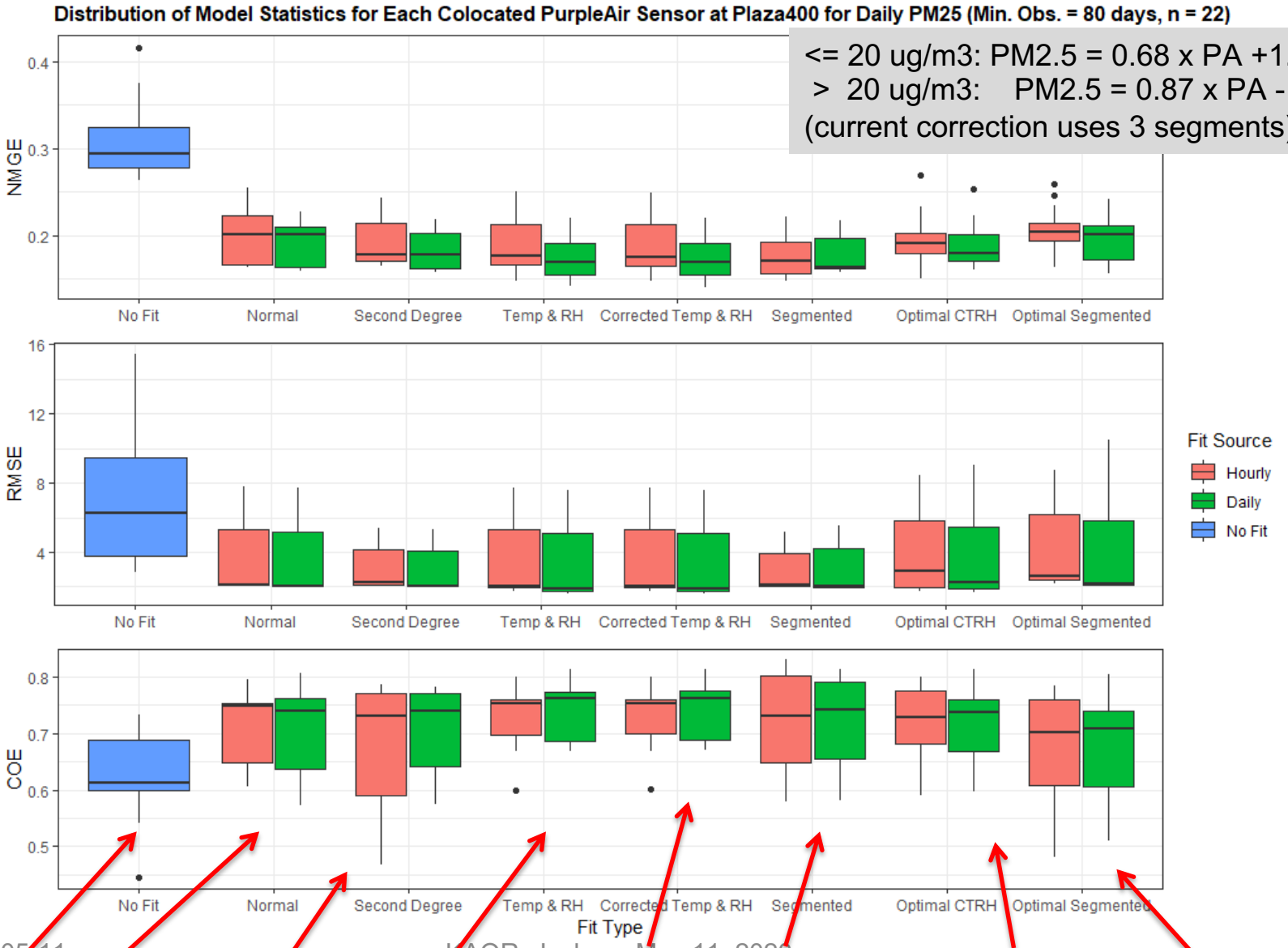


Daily PM2.5 = ATM



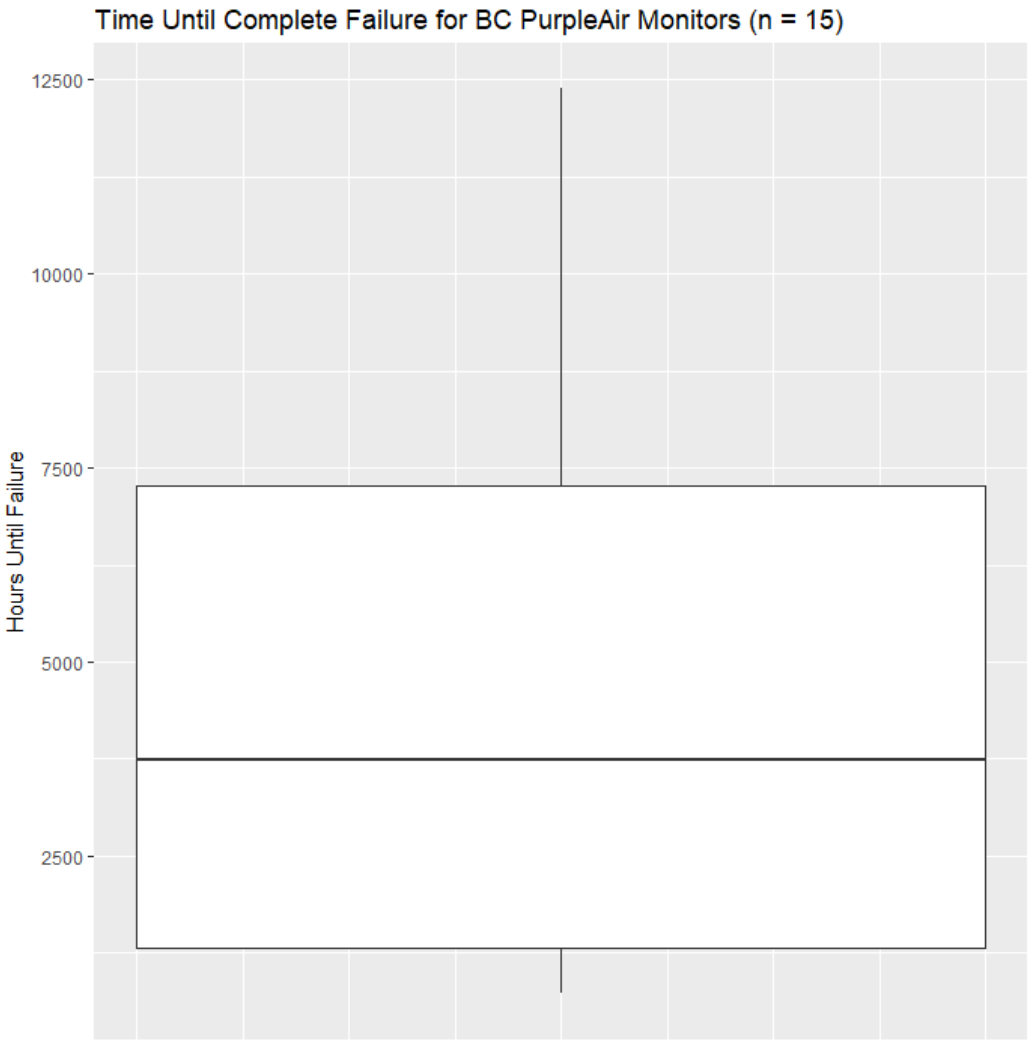
Daily PM2.5 = CF_1

Calibration models



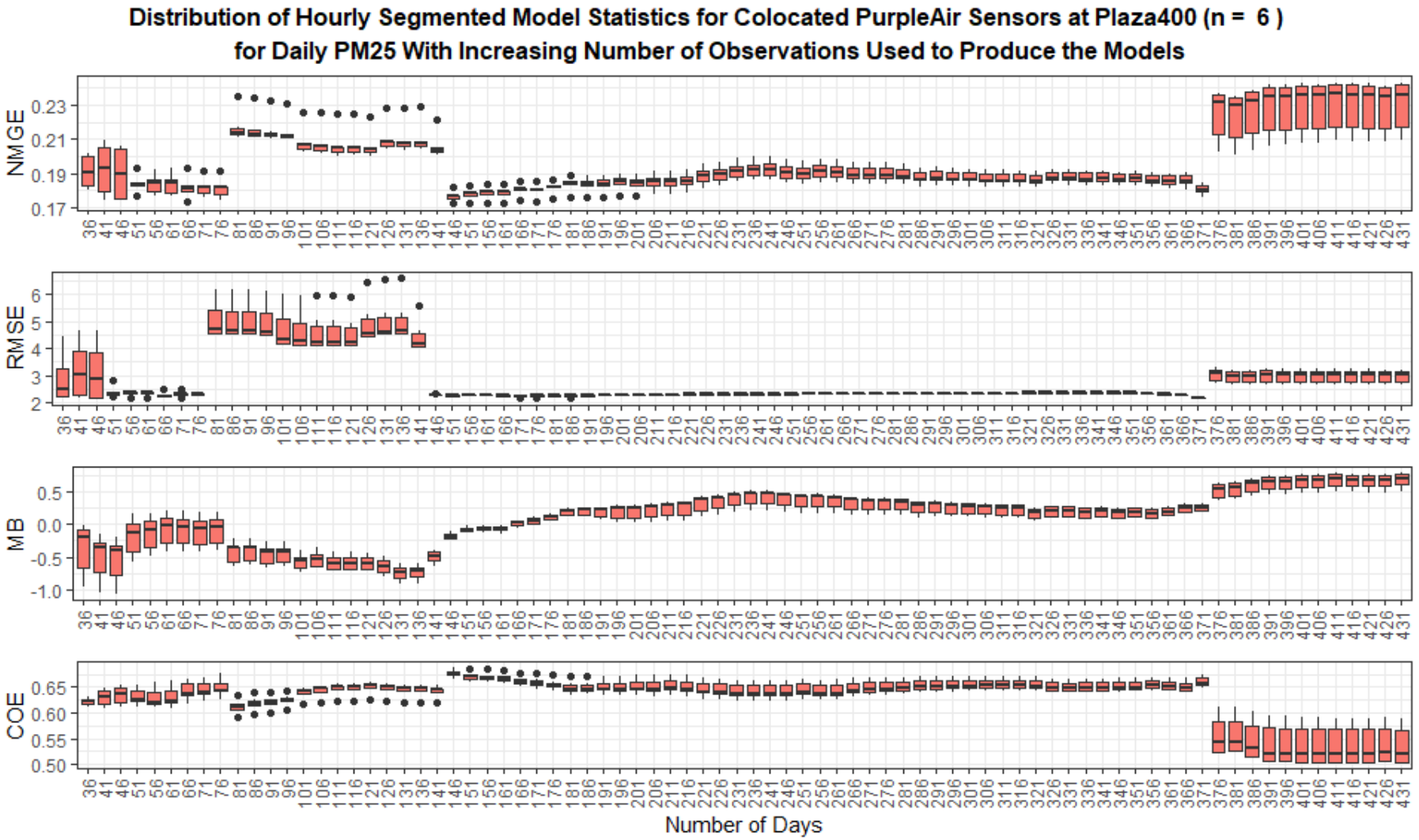
<= 20 ug/m3: PM2.5 = 0.68 x PA +1.91
> 20 ug/m3: PM2.5 = 0.87 x PA - 6.62
(current correction uses 3 segments)

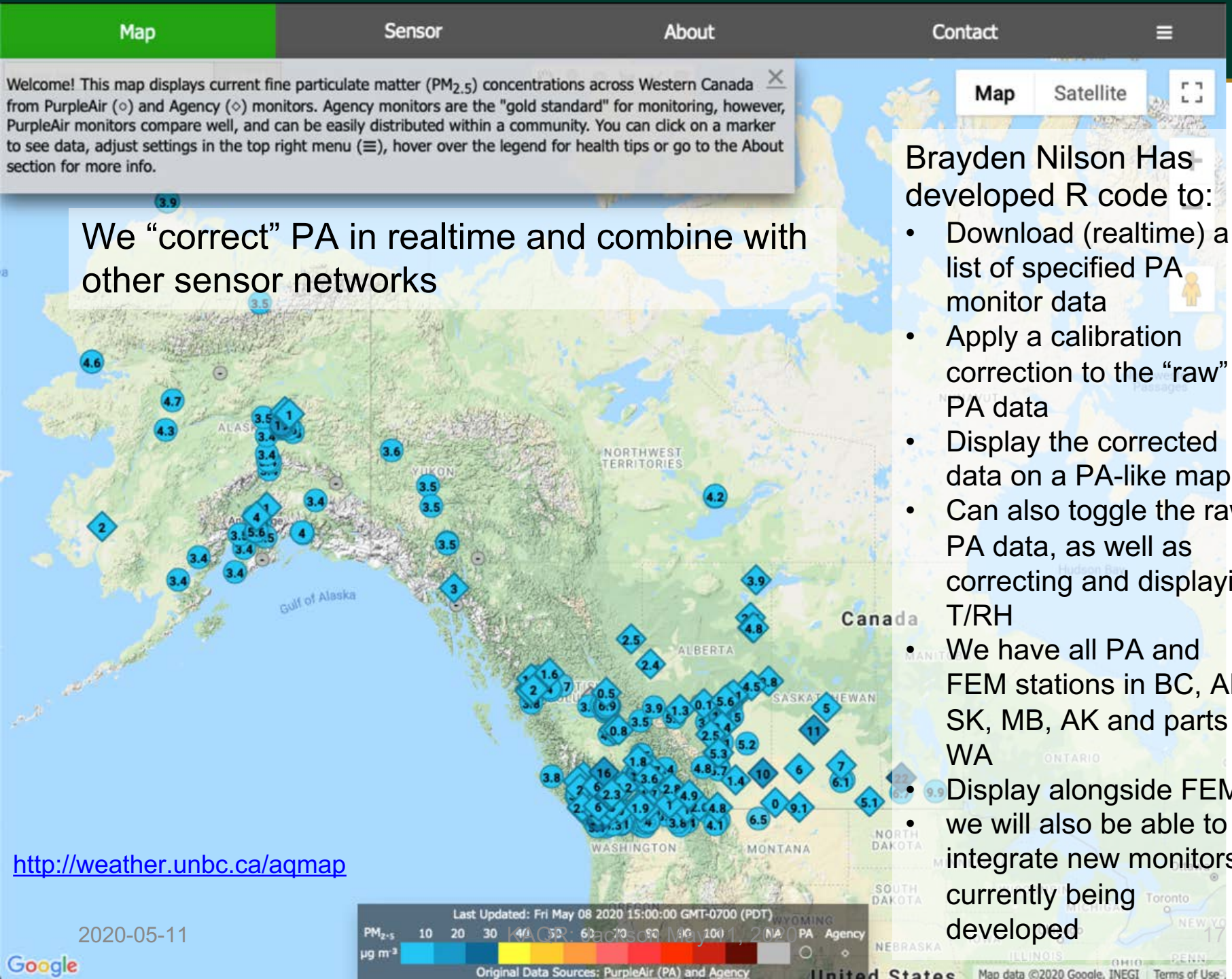
Raw data | linear reg | 2nd deg poly | multivar | multivar | segmented lin | single model T/RH | single model seg.



- Time until failure for PurpleAir monitors that have completely failed in BC.
- Failures were determined by calculating model statistics between the A and B sensors within each PA2 monitor for increasing periods of data.
- An abrupt shift in the Pearson's correlation coefficient signifies either the A sensor or B sensor failed.

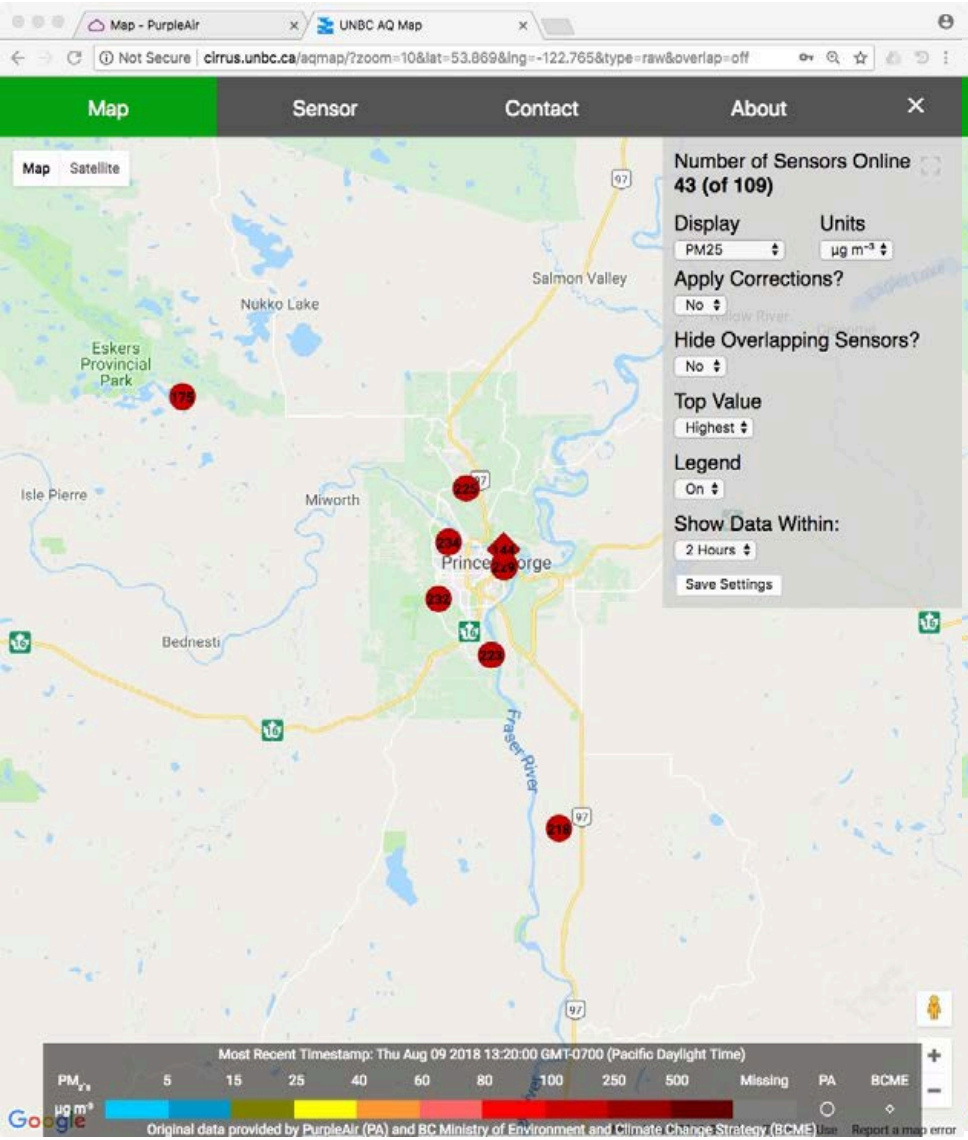
Total Number of Monitors	**112**
Number Failed	15
Mean Days to Failure	194
Median Days to Failure	155
Min Days to Failure	30
Max Days to Failure	516

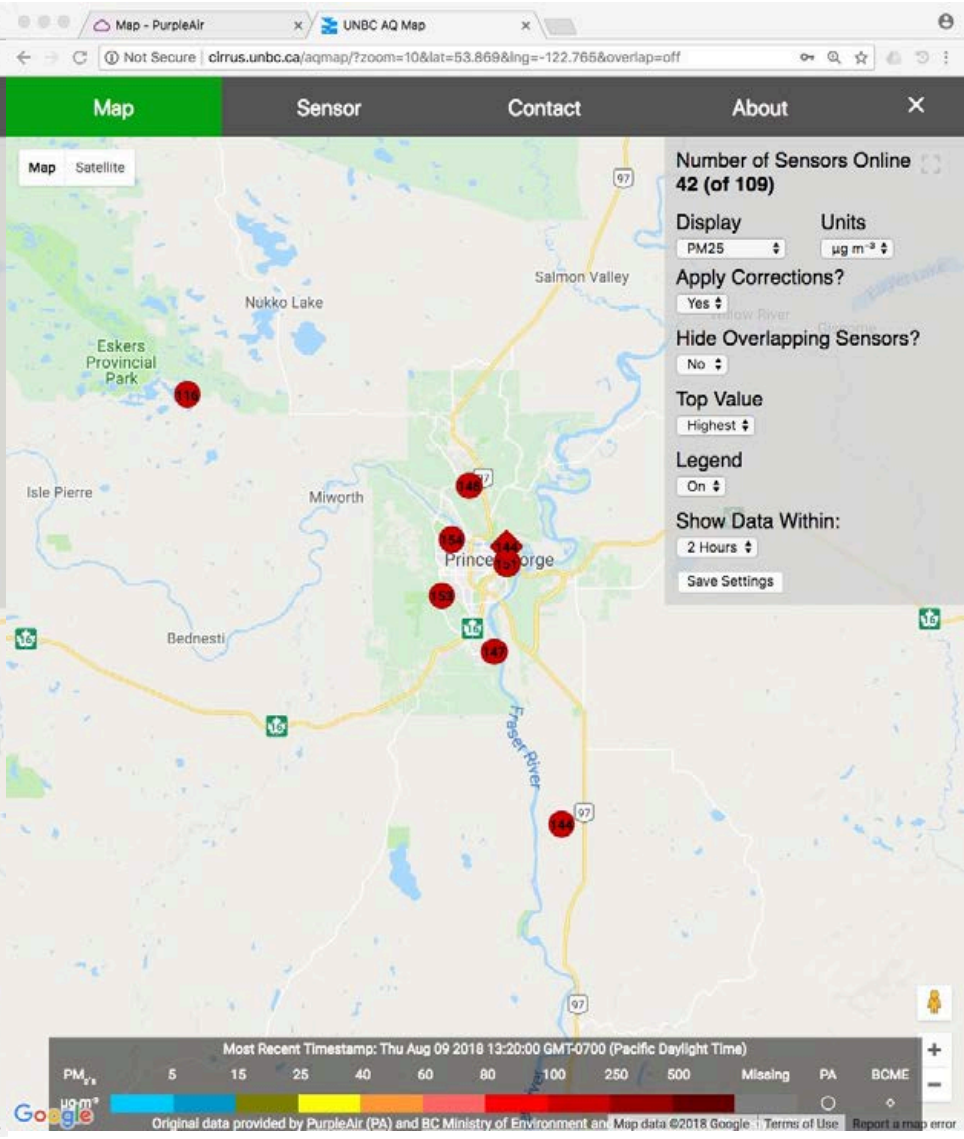

Distribution of Hourly Segmented Model Statistics for Colocated PurpleAir Sensors at Plaza400 (n = 6)
for Daily PM25 With Increasing Number of Observations Used to Produce the Models
NMGE
RMSE
MB
COE
Number of Days


Map
Sensor
About
Contact
Welcome! This map displays current fine particulate matter ($PM_{2.5}$) concentrations across Western Canada from PurpleAir (○) and Agency (◇) monitors. Agency monitors are the "gold standard" for monitoring, however, PurpleAir monitors compare well, and can be easily distributed within a community. You can click on a marker to see data, adjust settings in the top right menu (≡), hover over the legend for health tips or go to the About section for more info.
Map
Satellite
We “correct” PA in realtime and combine with other sensor networks
Brayden Nilson Has developed R code to:
• Download (realtime) a list of specified PA monitor data
• Apply a calibration correction to the “raw” PA data
• Display the corrected data on a PA-like map
• Can also toggle the raw PA data, as well as correcting and displaying T/RH
• We have all PA and FEM stations in BC, AB, SK, MB, AK and parts of WA
• Display alongside FEM
• we will also be able to integrate new monitors currently being developed
http://weather.unbc.ca/aqmap
Last Updated: Fri May 08 2020 15:00:00 GMT-0700 (PDT)
PM2.5 10 20 30 40 50 60 70 80 90 100 NA PA Agency
µg m-3
Original Data Sources: PurpleAir (PA) and Agency
Gulf of Alaska
Canada
ALBERTA
NORTHWEST TERRITORIES
YUKON
WASHINGTON
MONTANA
Google
Map data ©2020 Google, INEGI
Terms of Use

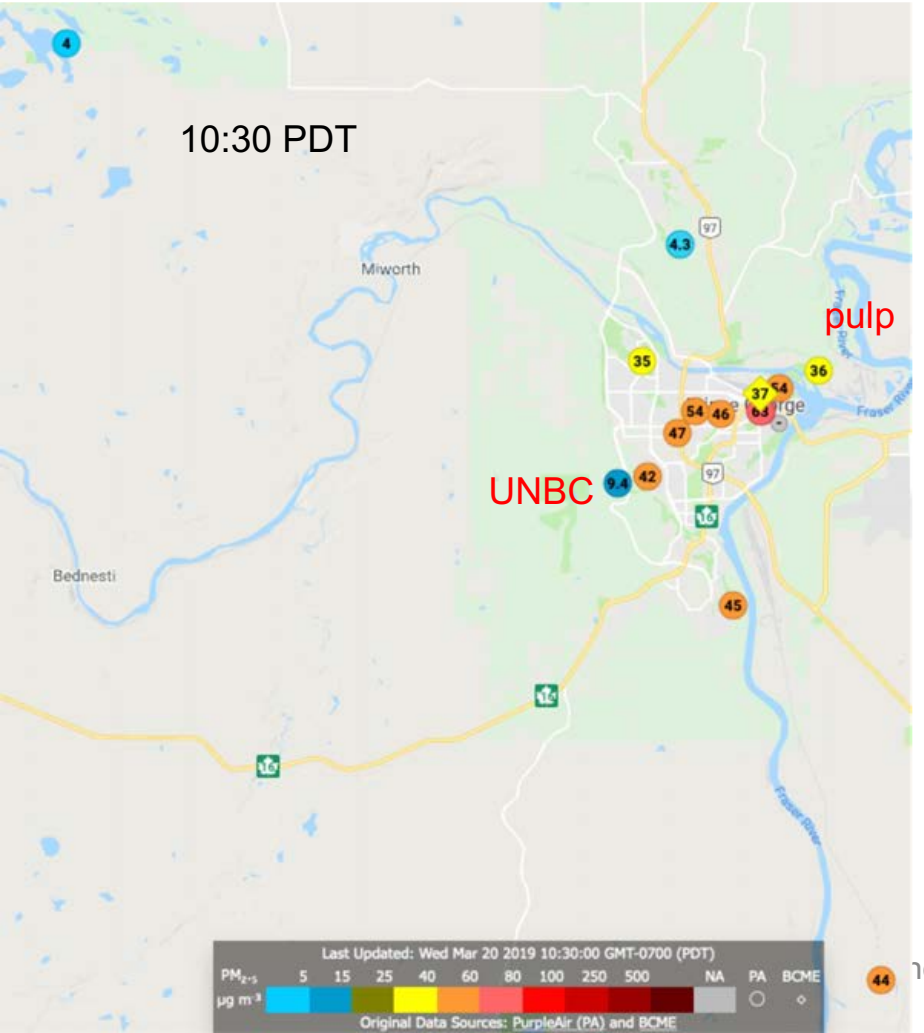
2018-08-09 uncalibrated wildfire smoke

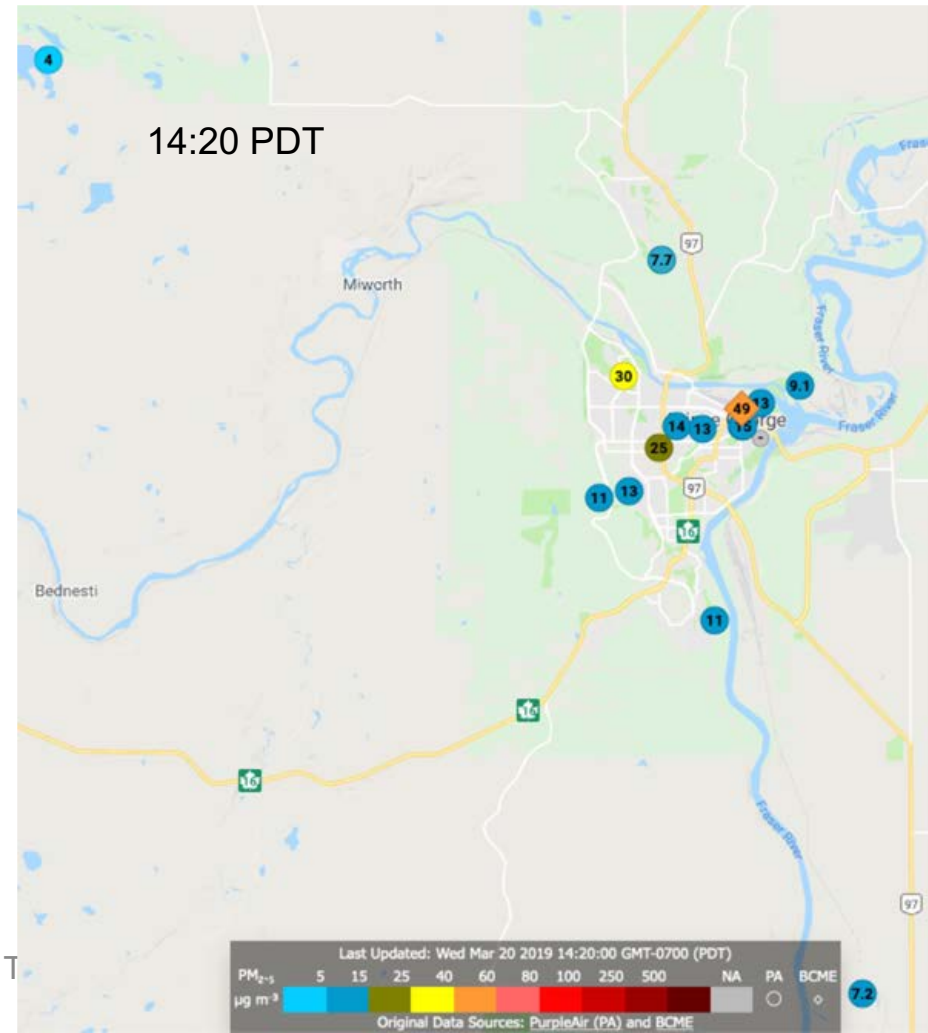
2018-08-09 calibrated



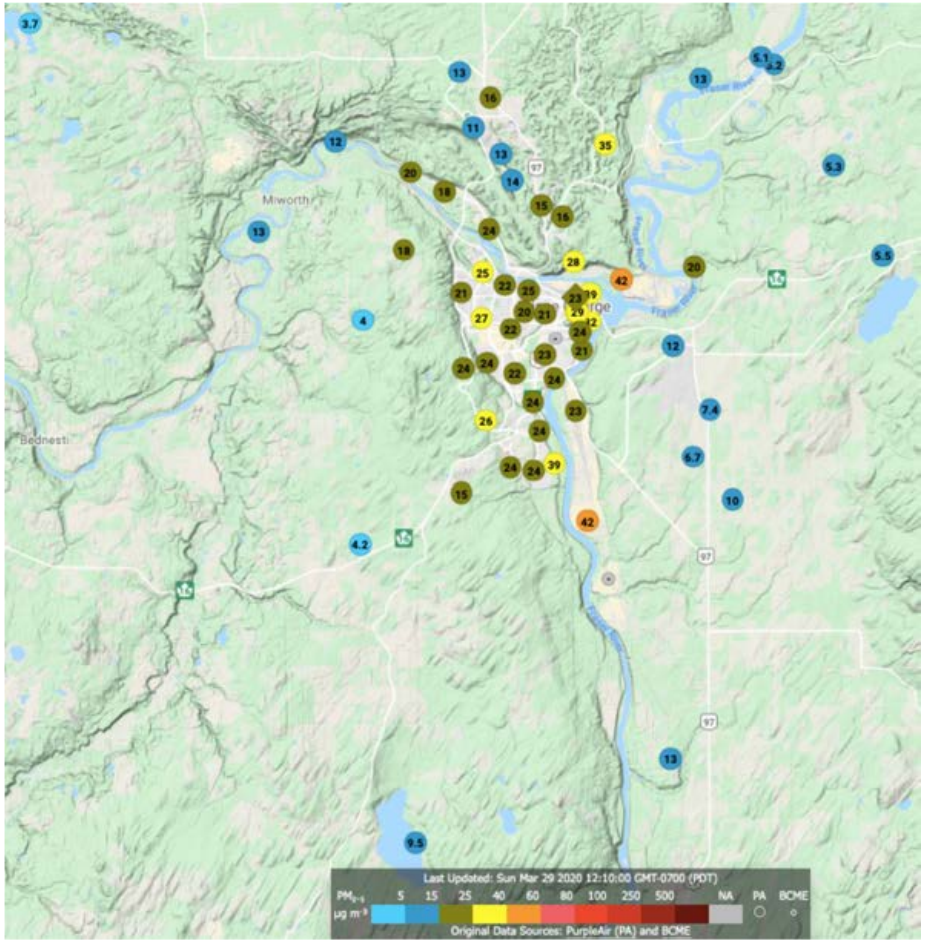


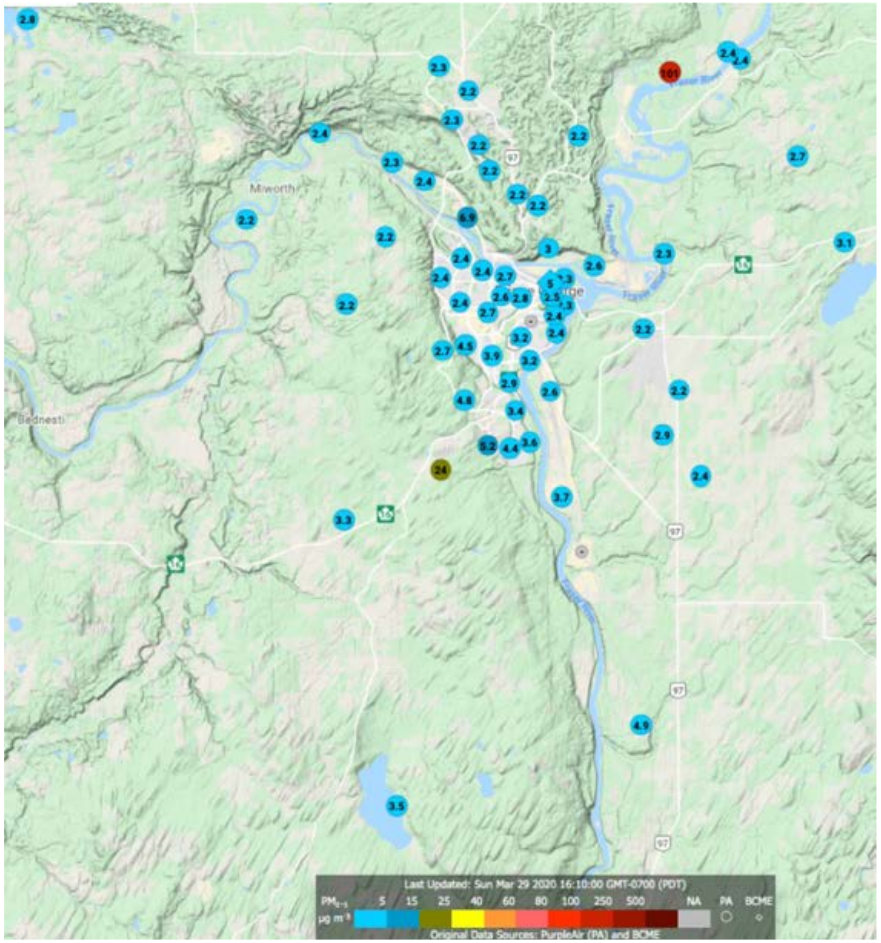
March 20, 2019 Dust Episode





Prince George Example – High levels in Valley, rapidly changing





EPA United States Environmental Protection Agency

Environmental Topics | Laws & Regulations | About EPA | Search EPA.gov

CONTACT US

SHARE

Air Sensor Toolbox for Citizen Scientists, Researchers and Developers

- What's New

AIR SENSOR TOOLBOX

ts and others on how to select and use low-cost, portable air sensor technology and formation can help the public learn more about air quality in their communities.

South Coast Air Quality Management District

South Coast AQMD

Home
Conference 2017
Sensors
Evaluations
Research Projects
Resources
Workshops
Sensor News
About Us
Contact AQ-SPEC
FAQs
Advisory Board
About SCAQMD

Select Language

Sign-Up

AQ-SPEC

Air Quality Sensor Performance Evaluation Center

Recently added/updated:

- NEW! Purple Air PA-I Indoor - Field Evaluation (posted, 5/30/18)
- NEW! AQ-SPEC in the news (posted, 5/25/18)
- Article by Hagler et al. in Environmental Science & Technology
- Article by Papapostolou et al. in Atmospheric Environment

Background