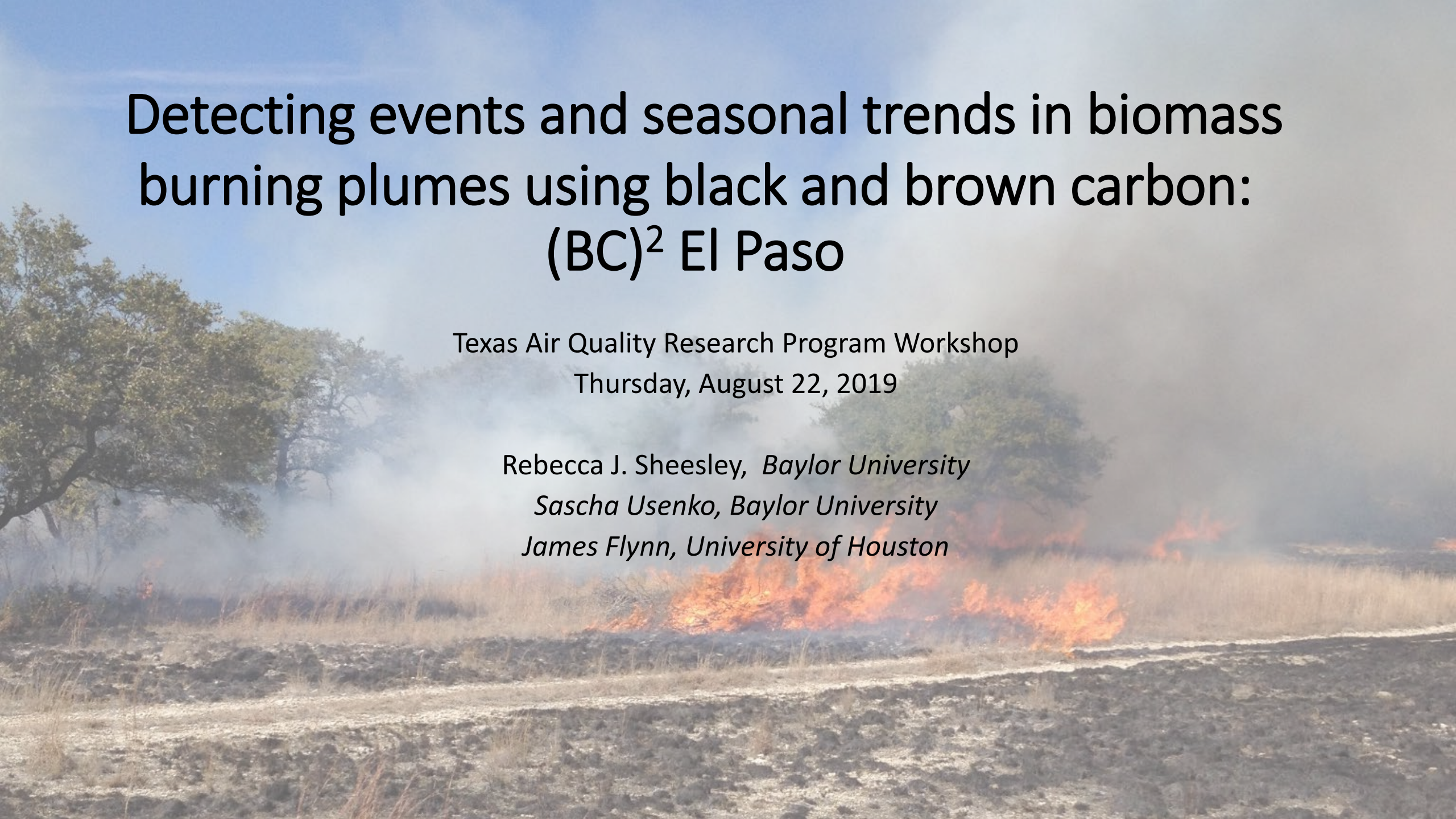

Detecting events and seasonal trends in biomass burning plumes using black and brown carbon: $(BC)^2$ El Paso

Texas Air Quality Research Program Workshop
Thursday, August 22, 2019

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Acknowledgements

- Funding – AQRP (19-031) and TCEQ
- Graduate Students and Postdocs
  - Sujan Shrestha - Baylor
  - Meghan Guagenti - Baylor
  - Subin Yoon - University of Houston
- UTEP – Luis Morales and Facility Management Staff
- Dr. Rosa Fitzgerald's Research Group at UTEP
  - Pam Lara
  - Nakul Karle
  - Suhail Mahmud

Background and motivation

Texas AQRP Priority Research Areas for 2018-19

- El Paso projects to improve understanding of high ozone and particulate matter
  - Unique conditions in El Paso: meteorology, topography, emissions and transport
- Deploy new monitoring technologies for quantifying particulate matter composition on a continuous or frequent basis (i.e. quicker than current filter methods). Instrumentation that could quantify elemental (black) and organic (brown) carbon would be particularly useful, so that researchers can determine when wildfires are playing an important role in El Paso pollutant concentrations. This project would be a proof-of concept study.

Hypothesis:

Biomass burning is influencing air quality in El Paso, TX. The tricolor absorption photometer (TAP) instrument will provide a cost-effective, sensitive means of identifying biomass burning plumes in El Paso through the real-time characterization of black carbon and brown carbon.

Aerosol optical properties and sources

- Atmospheric aerosols can both absorb and scatter light depending upon their composition, size, shape, and source.
- Light absorption from vehicle exhaust is dominated by black carbon (BC).
- Light absorption from biomass burning includes both black carbon and brown carbon (BrC, or light absorbing organic carbon).
- BrC exhibits strong light absorption in the near-UV and UV bands while BC strongly absorbs in the whole solar spectrum with a weak wavelength dependence.
- Utilize unique wavelength dependence of aerosol absorption in biomass burning plumes to identify influence in urban areas.
- Increases in aerosol scattering can be used to indicate dust impacts.

Optical properties, cont.

- The light absorption and scattering coefficients (b_{abs} and b_{scat}) measurements can be determined for aerosols using real-time filter-based or flow path optical measurements.
- Wavelength dependence of these extinction coefficients can be used to calculate the absorption Ångström exponents (AAE) and scattering Ångström exponents (SAE).
  - The AAE and SAE track the wavelength dependence of absorption and scattering at two or more different wavelengths.
  - BC should have a lower AAE value, near 1
  - High AAE values indicate the presence of BrC (>1) due to it's ability to selectively absorb short wavelengths
  - SAE is inversely related to the particle size which indicates that larger particles will have smaller SAE (good indication of dust)

$(BC)^2$ El Paso

- Identify the peak season for local and Mexican biomass burning that impacts El Paso.
- Identify differences in optical properties between biomass burning plumes and “normal” urban pollution in El Paso.
- Compare the new TAP to the older aethalometer
- Determine the annual cost/time investment for the operation of a TAP at a monitoring site
- Compare optical properties to identification of biomass burning from existing TCEQ monitoring (i.e. real-time $PM_{2.5}$, NO_x, and CO)

$(BC)^2$ El Paso Sampling Site – Mar 21 – Jun 30, 2019

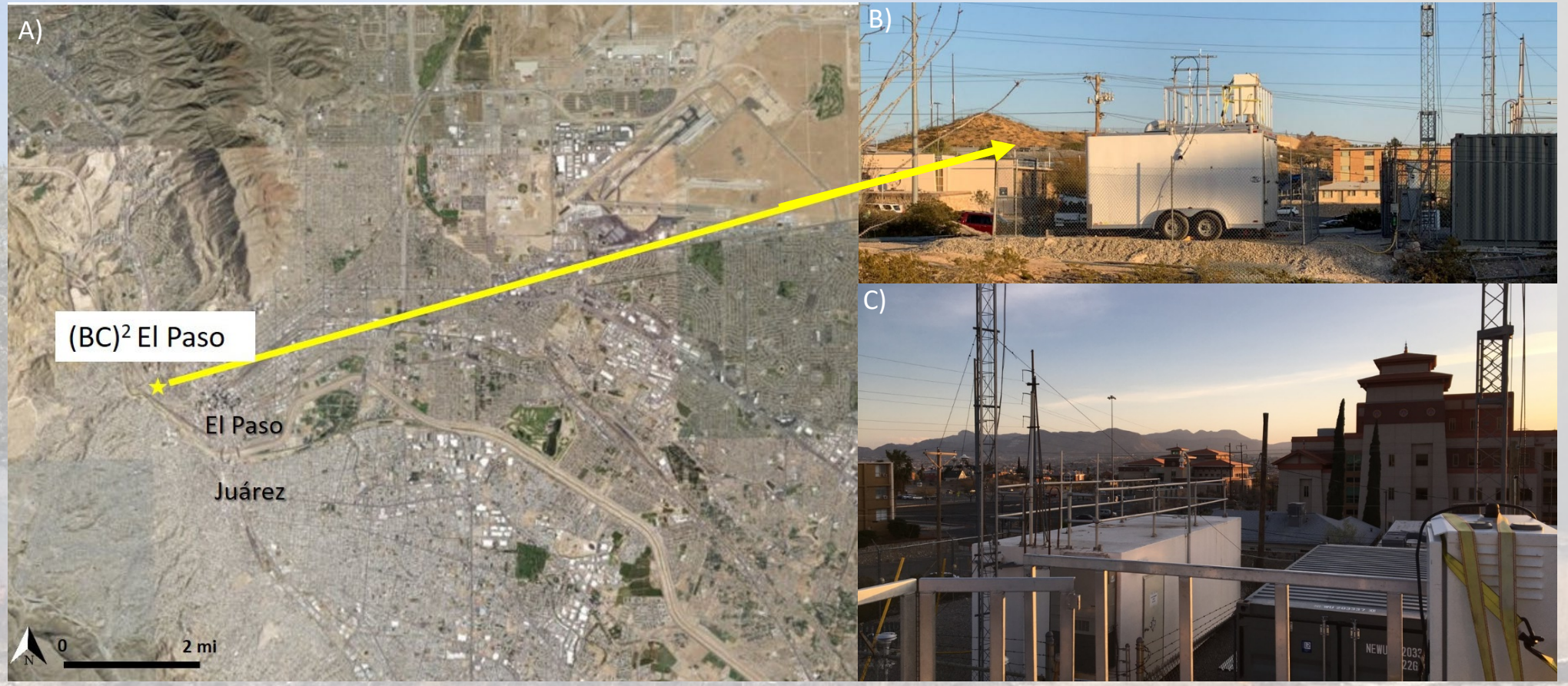
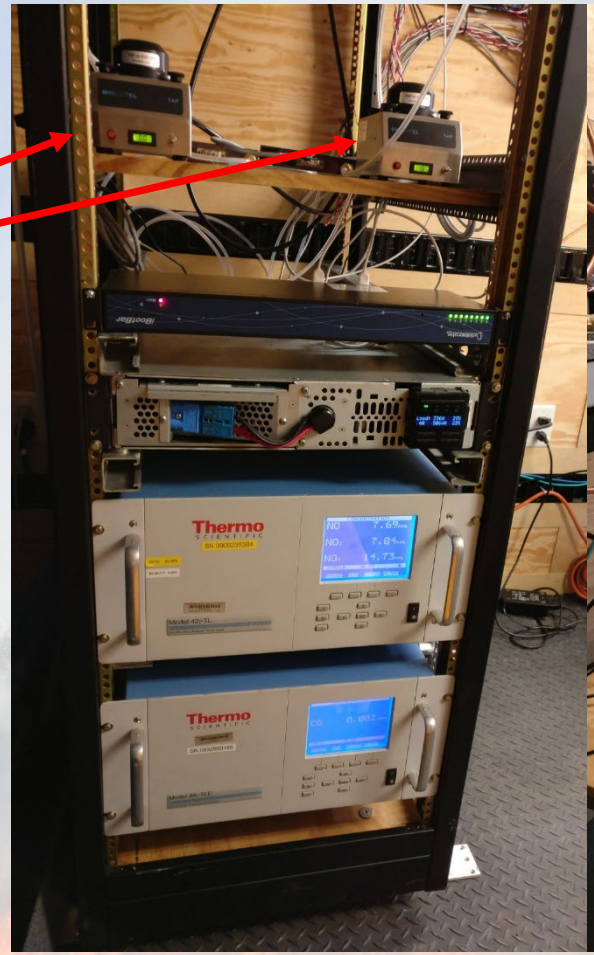


Figure 1. A) Site location for $(BC)^2$ El Paso campaign. B) Baylor Air Monitoring Trailer co-located with the CAMS 12 (UTEP) site. C) View from top of Baylor Air Monitoring Trailer overlooking El Paso and Juárez.

Instrumentation

Optical Measurements

- Aerosol absorption
  - Tricolor Absorption Photometer UV (TAP, Brechtel)
    - Three wavelengths (365, 520, 640 nm)
    - Two instruments, alternating every hour
  - Seven channel Aethalometer (AE42, Magee Scientific)
    - Seven wavelengths (370, 470, 520, 590, 660, 880, 950 nm)
- Aerosol Scattering
  - Nephelometer (TSI):
    - Three wavelengths (450, 550, 700 nm)

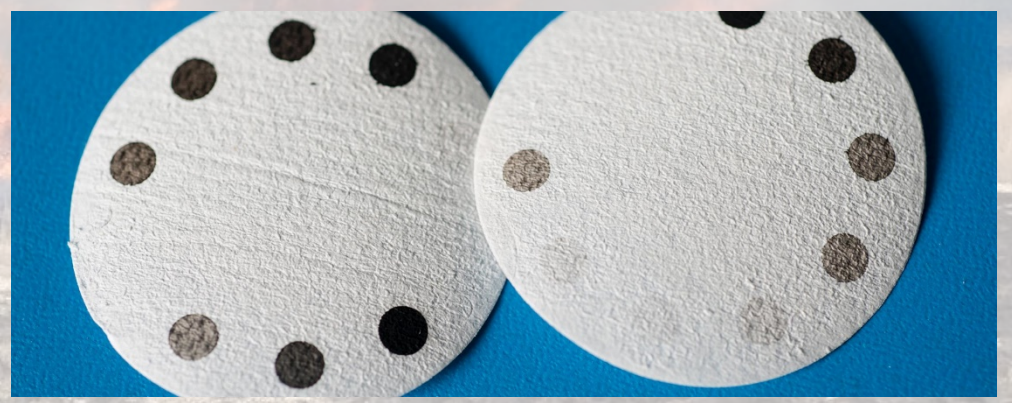


Supporting Measurements

- CO (Thermo, 48*i*-TL)
- NO/NO_2 (Thermo, 42*i*-TLE)
  - Custom Chemiluminescence with UV-LED photolytic converter)
- Event based, PM Filter samples (organic and elemental carbon)
- Remote data: Satellite (ex. NASA MODIS, NOAA Hazard Mapping System)
- NOAA HYSPLIT Model: back trajectories

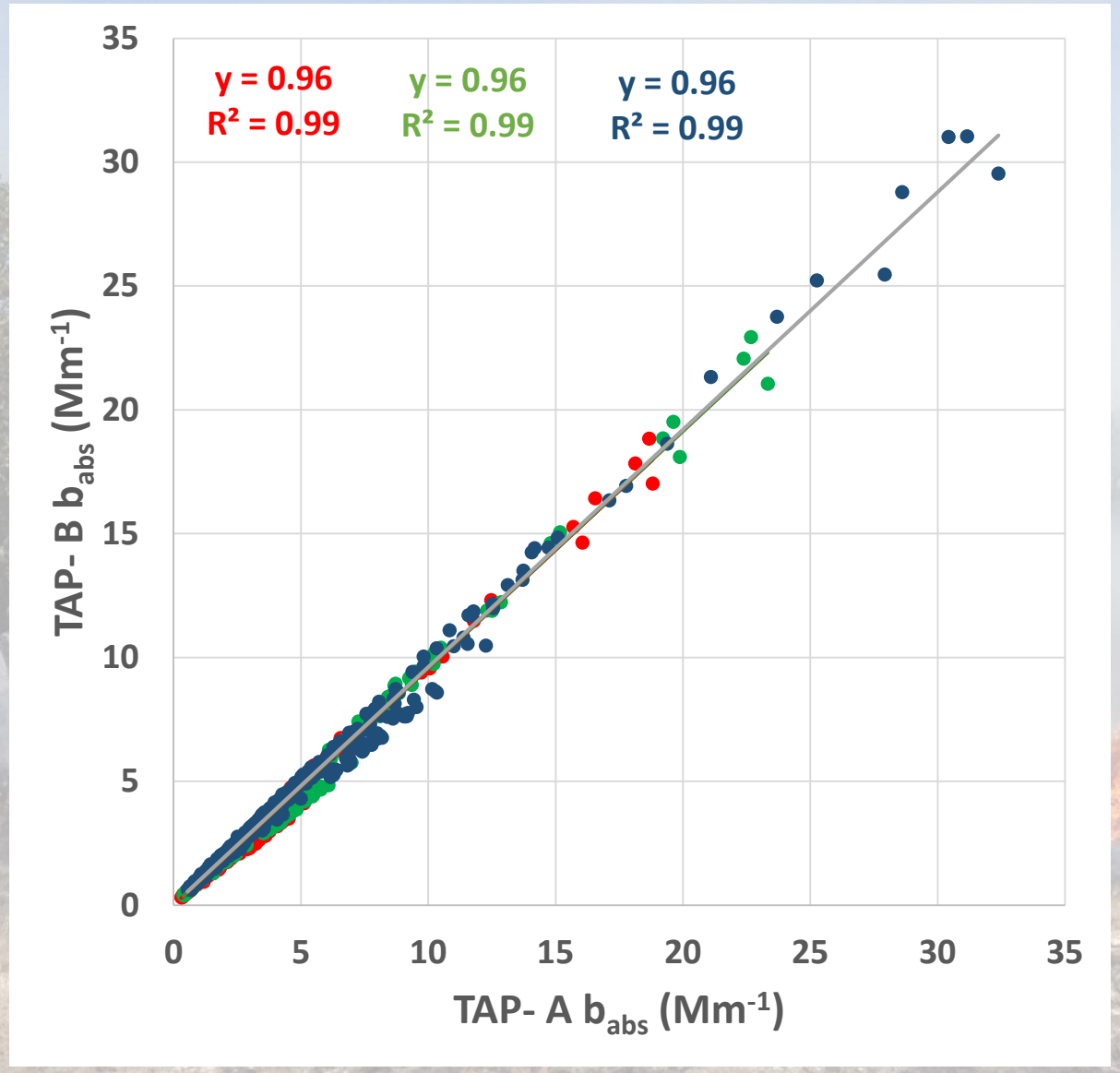
Instrument checks

- Intercomparibility
  - Between two TAPS
  - Between CAMS and UH trace gas

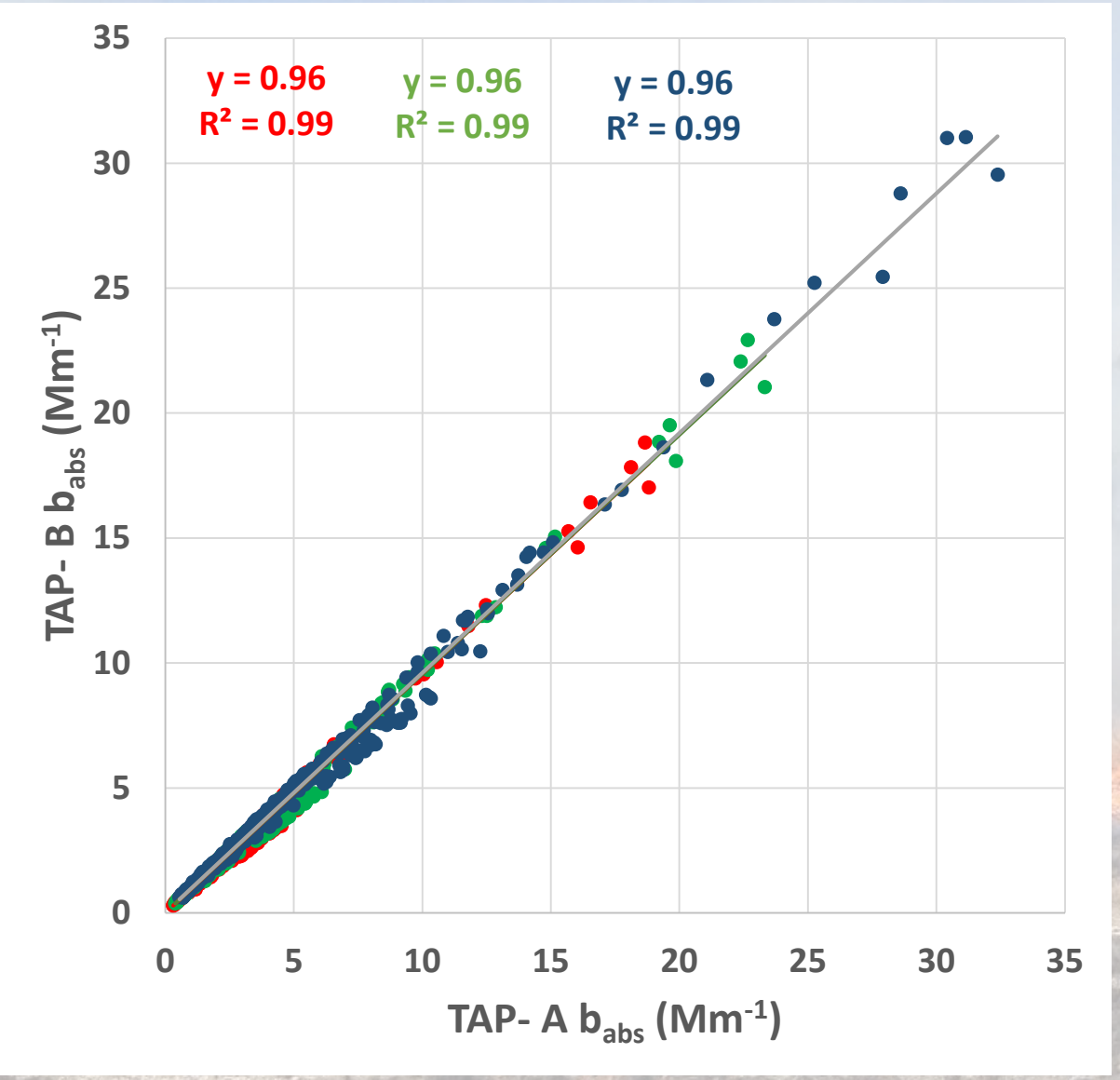


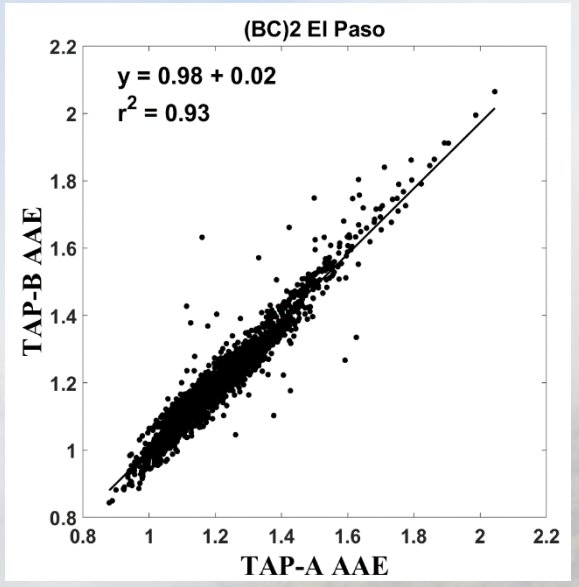
https://www.brechtel.com/products-item/tricolor-absorption-photometer/

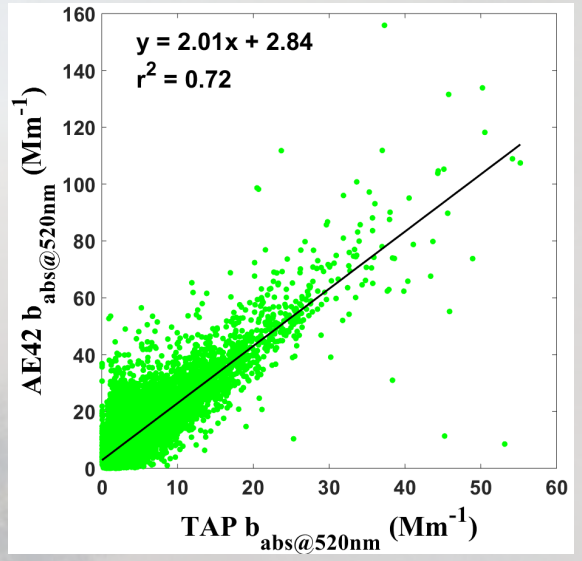
Intercomparison of TAPs – Aerosol absorption

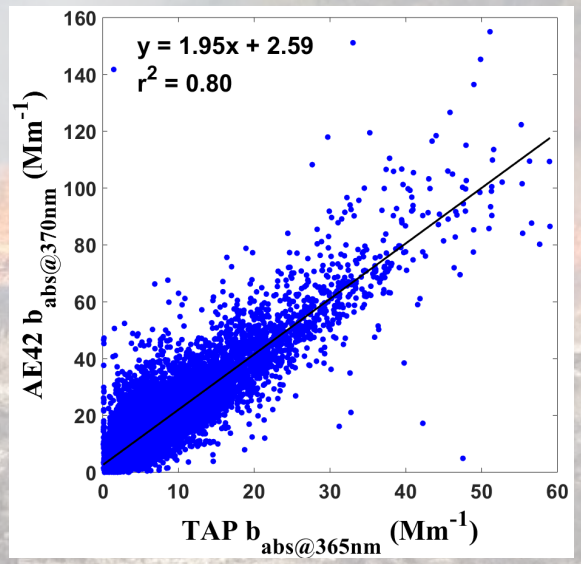


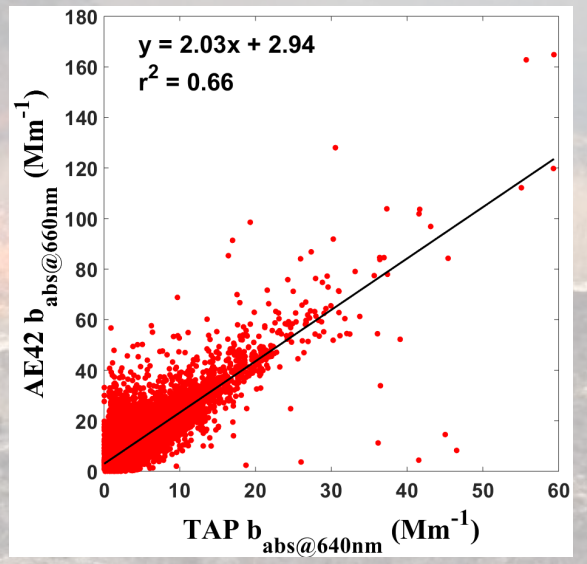
Intercomparison – Aerosol absorption



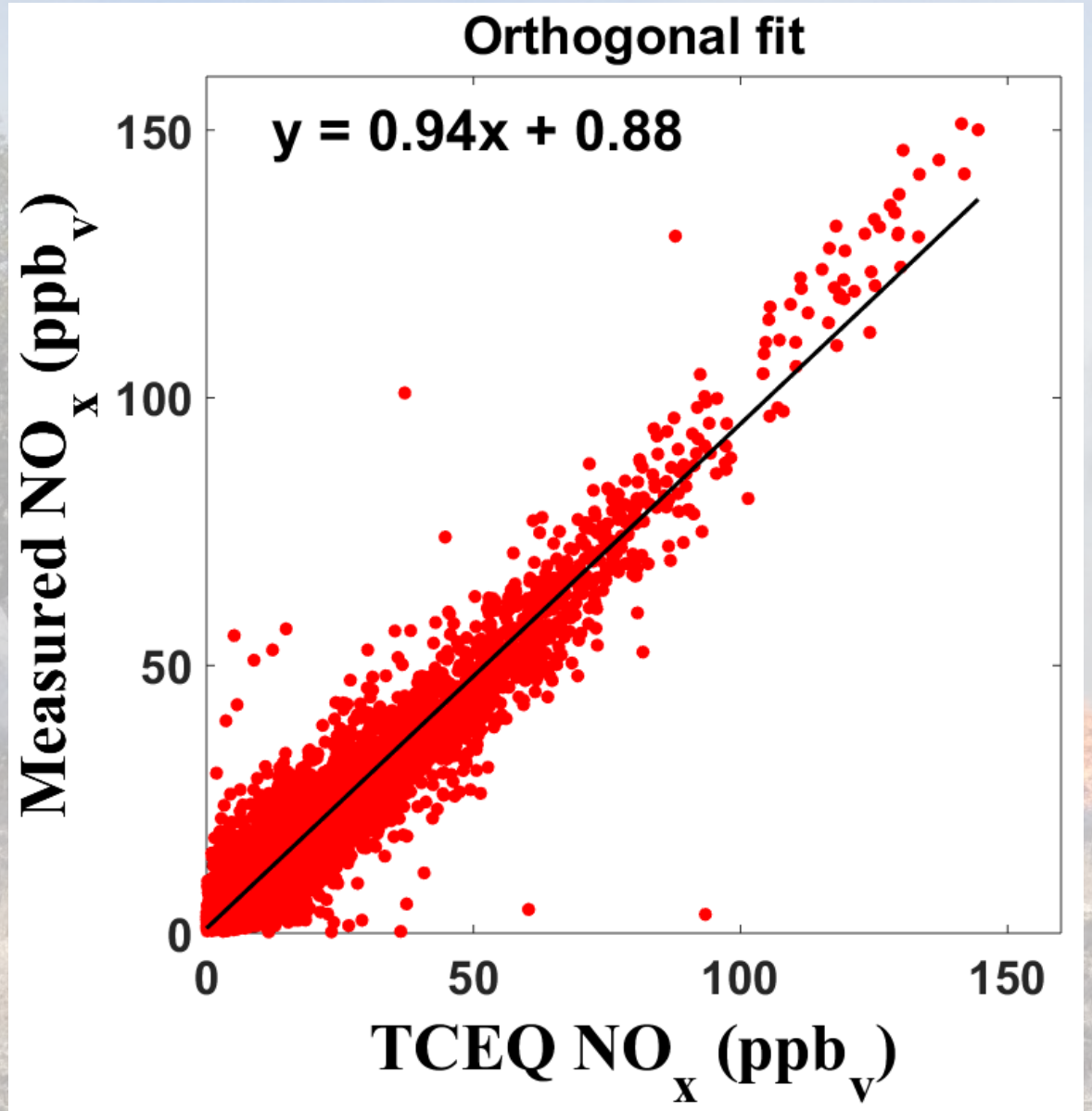


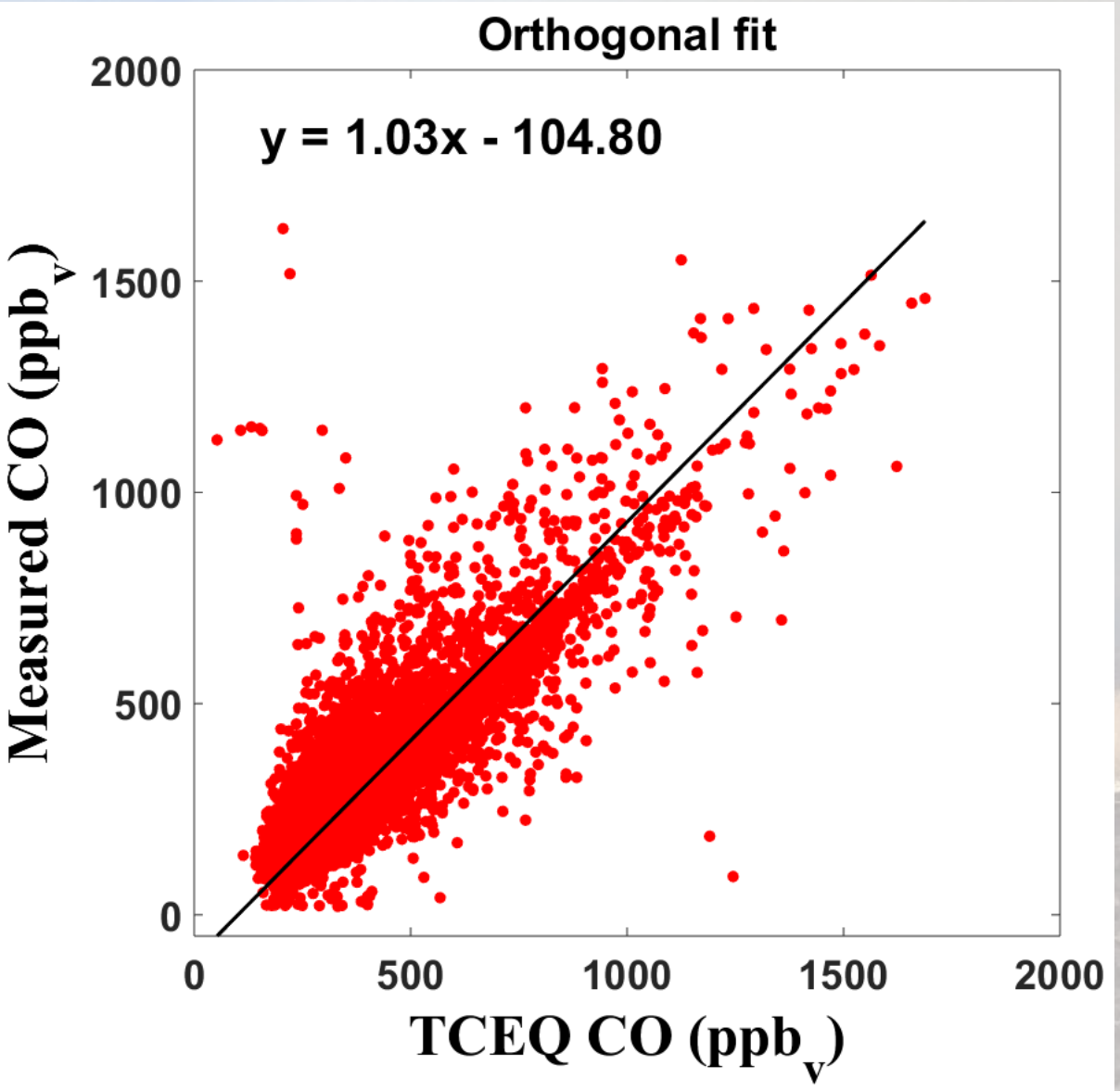






$(BC)^2$ El Paso – TCEQ CAMS 12 Comparison





Optical Properties – Aerosol Absorption

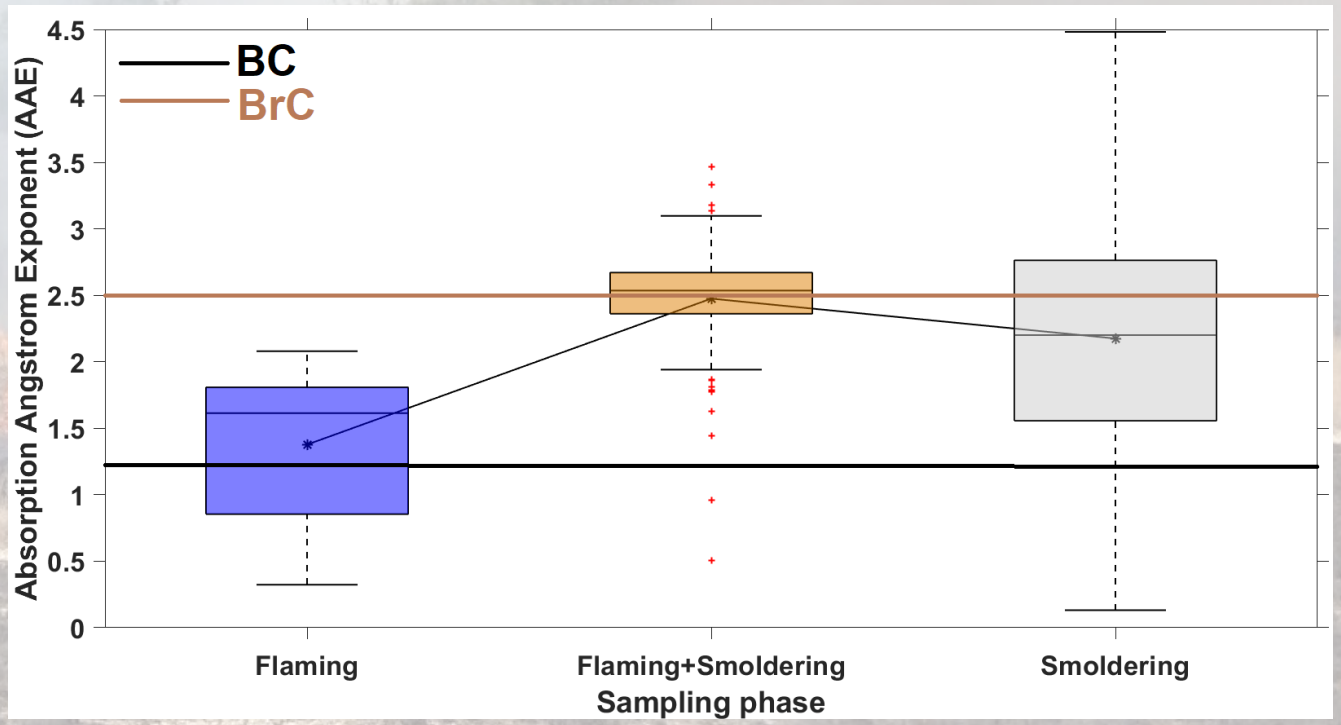
Angstrom exponent is calculated as the negative slope of the linear fit of the optical parameter versus the wavelengths on a log-log plot.

- Absorption Angstrom Exponent (AAE) calculation

$$AAE = -\frac{\ln(b_{abs\lambda_1}, b_{abs\lambda_2}, b_{abs\lambda_3})}{\ln(\lambda_1, \lambda_2, \lambda_3)}$$

where, b_{abs} is the absorption coefficients measured by TAPs at 640, 520 and 365 nm wavelengths (λ_1, λ_2 and λ_3 respectively).

- **AAE ~ 1 is motor vehicle exhaust**
- **AAE >1 biomass burning**



Schmeisser *et al.* 2017

Optical Properties – Aerosol Scattering

- Scattering Angstrom Exponent (SAE) calculation

$$SAE = - \frac{\ln(b_{scat_{\lambda_1}}, b_{scat_{\lambda_2}}, b_{scat_{\lambda_3}})}{\ln(\lambda_1, \lambda_2, \lambda_3)}$$

where, b_{scat} is the scattering coefficients measured by nephelometer at 700, 550, 450 nm wavelengths (λ_1, λ_2 and λ_3) respectively.

  - **High SAE means smaller particles**
  - **Low SAE means larger particles**

- Single scattering albedo (SSA) calculation

$$SSA = \frac{b_{scat}}{b_{scat} + b_{abs}}$$

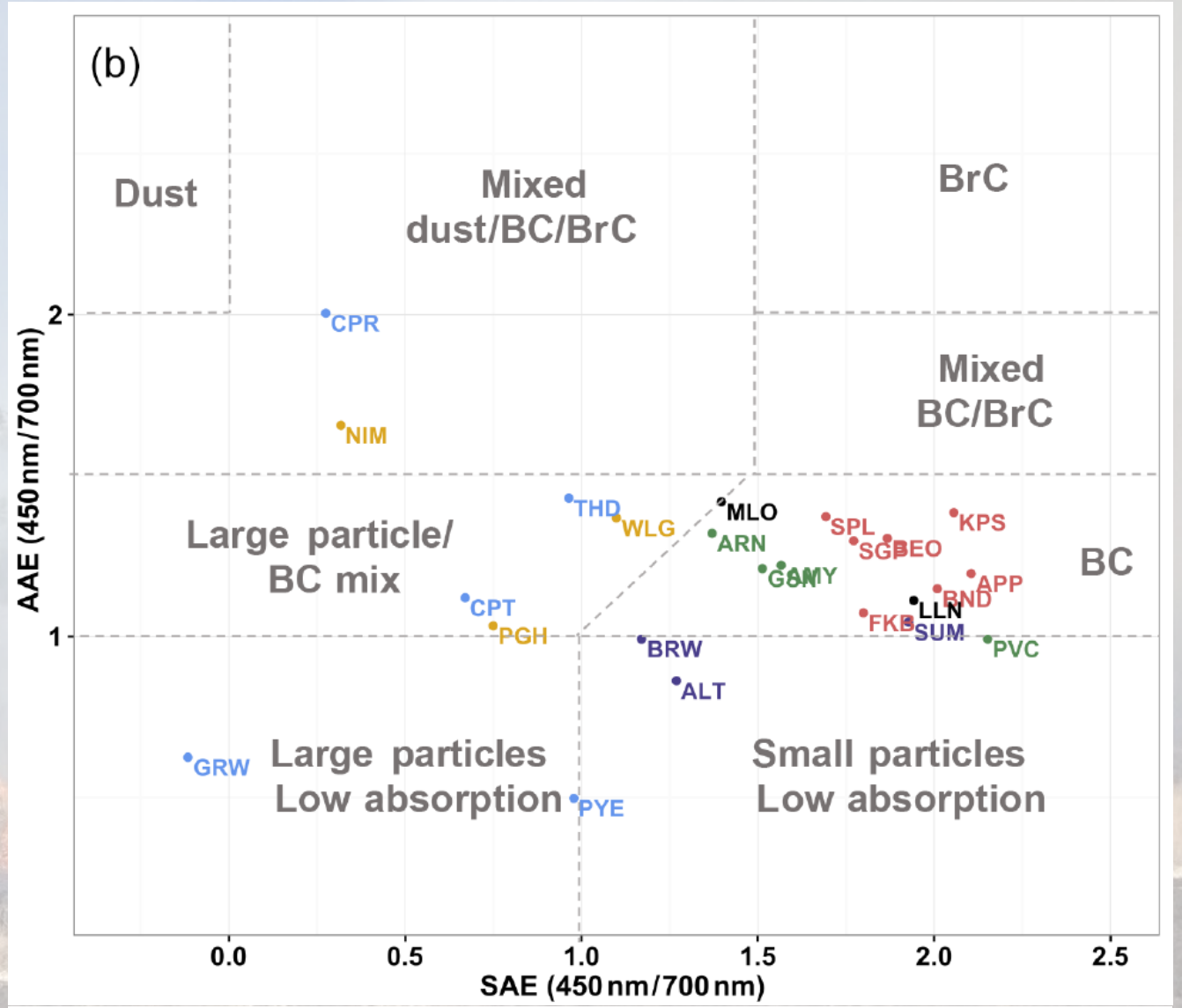
  - High SSA (>0.9)means the atmosphere is dominated by scattering aerosols
  - Low SSA (<0.9) means atmosphere is dominated by absorbing aerosols

Relationships between aerosol optical properties

AAE indicates aerosol composition and SAE indicates aerosol size

AAE vs SAE plot provides

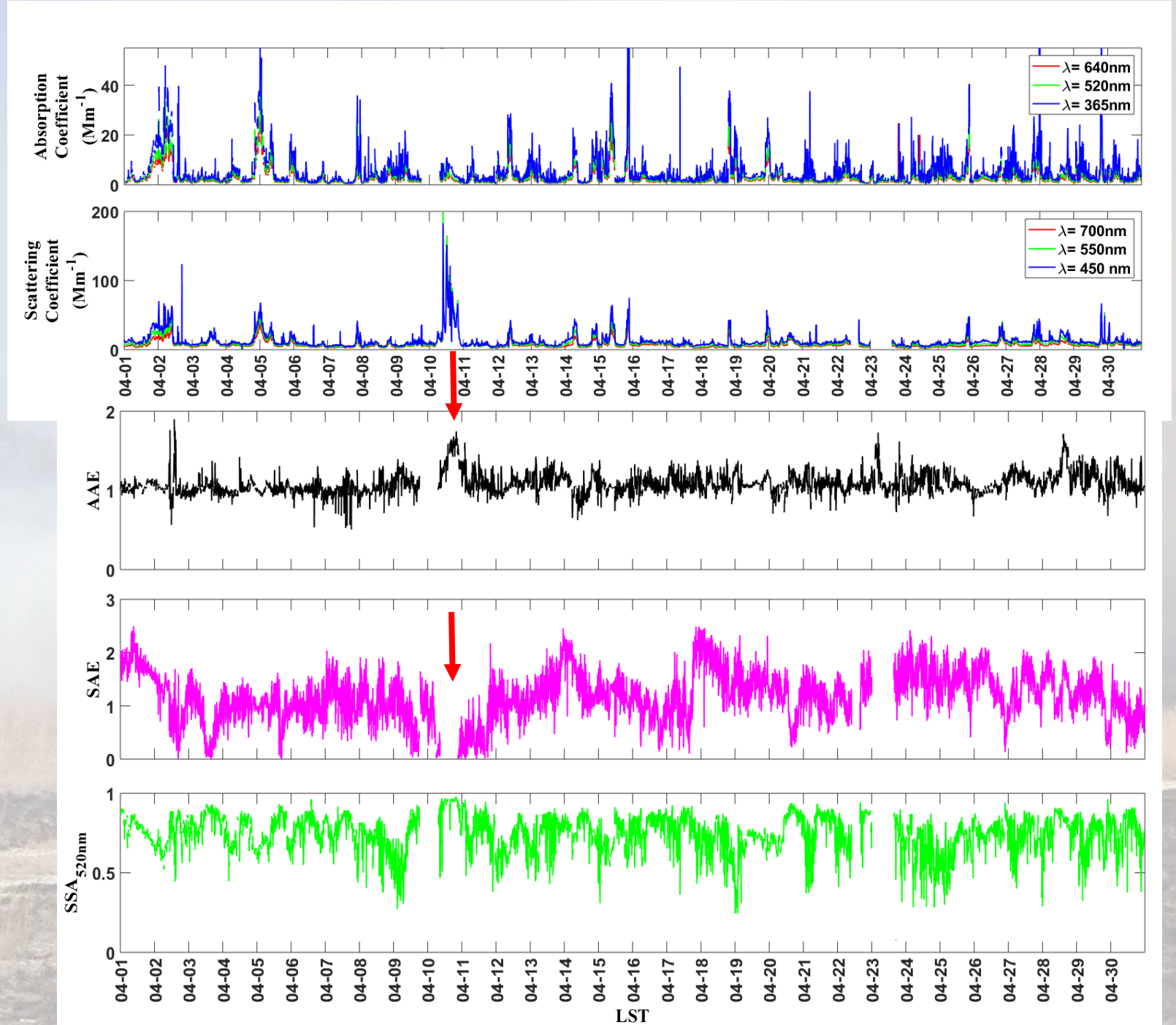
- *visualization of aerosol optical properties*
- *likely aerosol type*



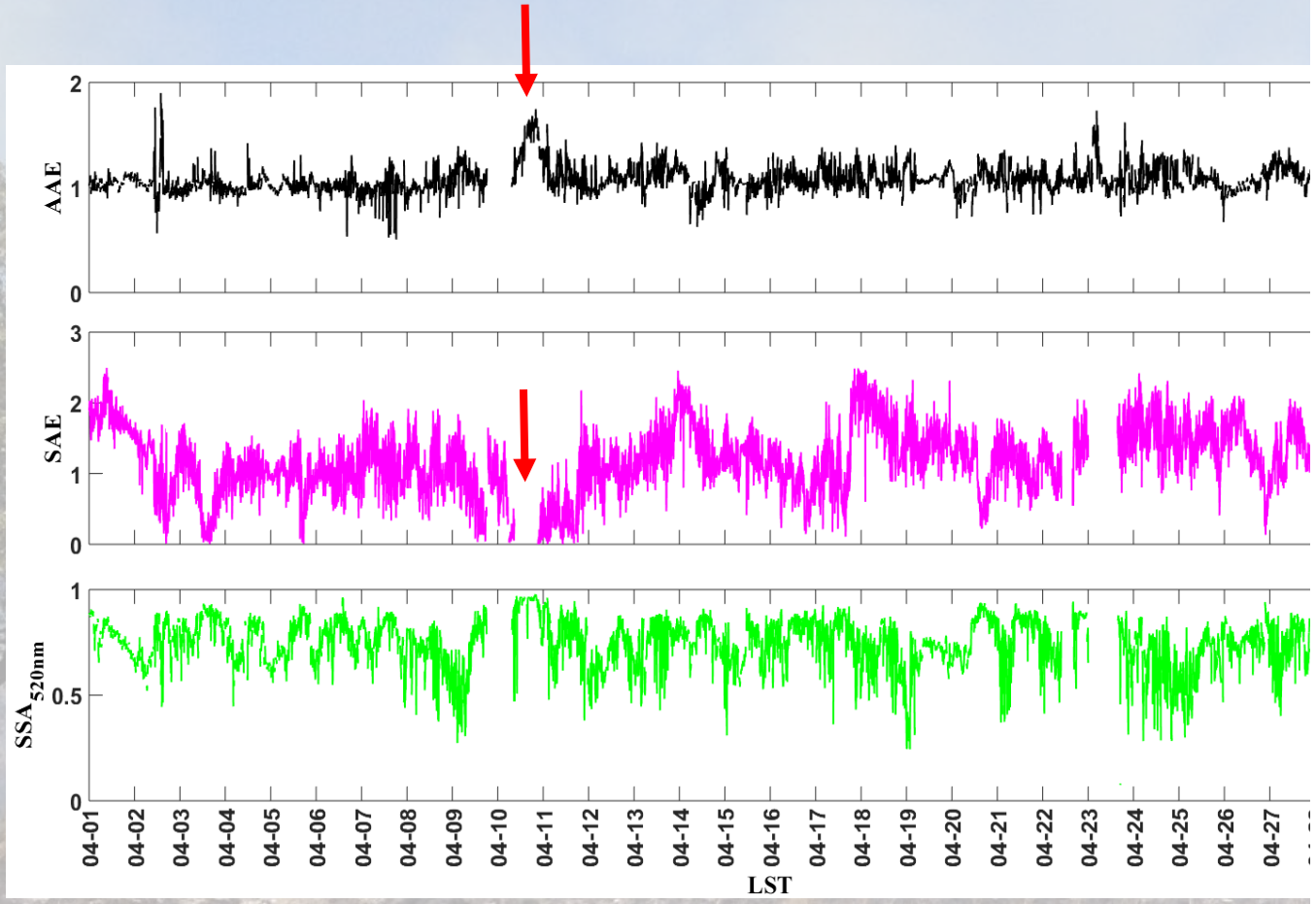
Schmeisser *et al.* 2017

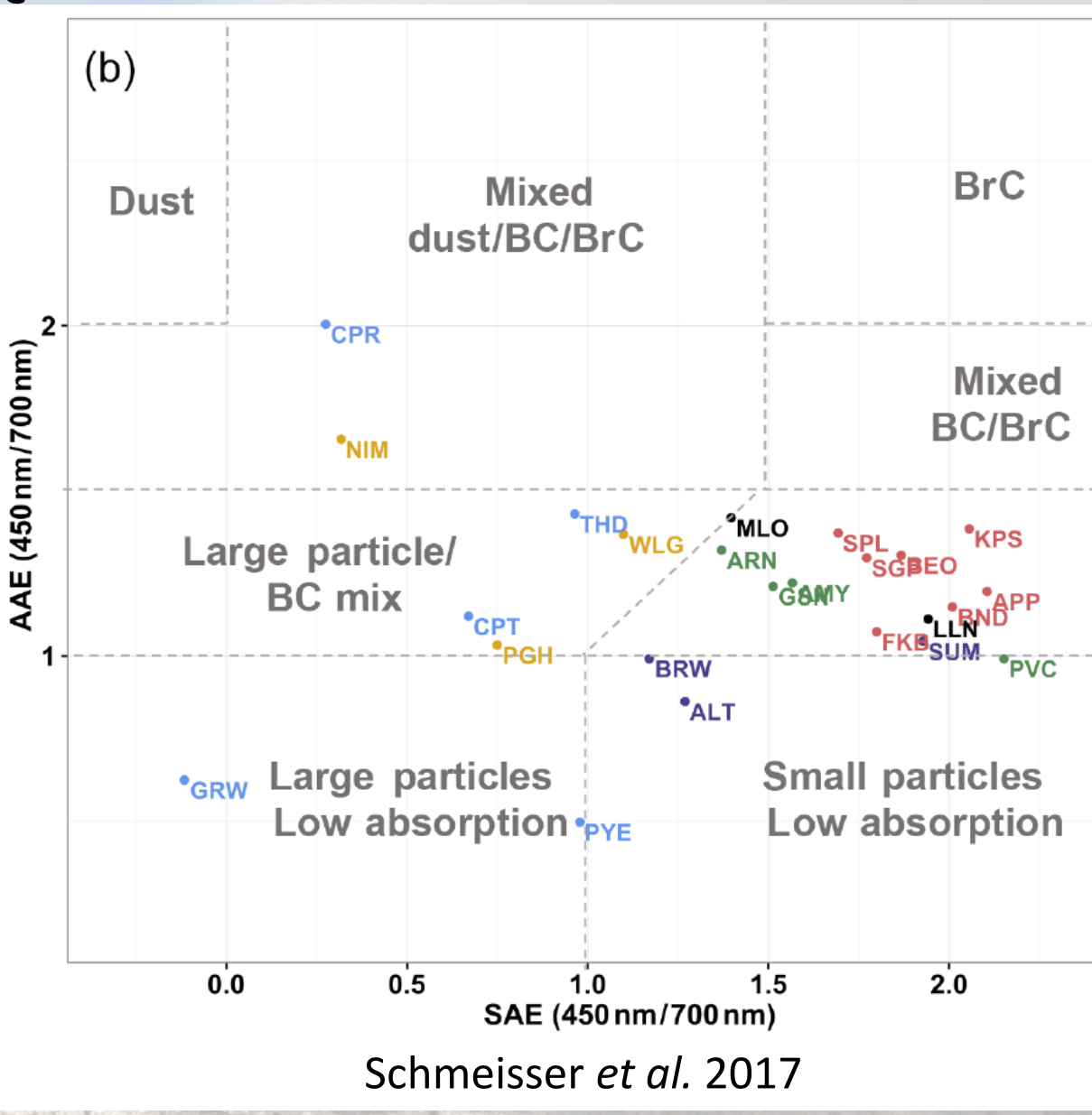
$(BC)^2$ El Paso early results

- April 2019, example of campaign start
- Much more variability in the Absorption Coefficient than in the AAE
- AAE has a relatively stable value near 1, which would be expected for an urban signal dominated by high temperature combustion like motor vehicle exhaust
- SAE has an event April 10, and low values for early April



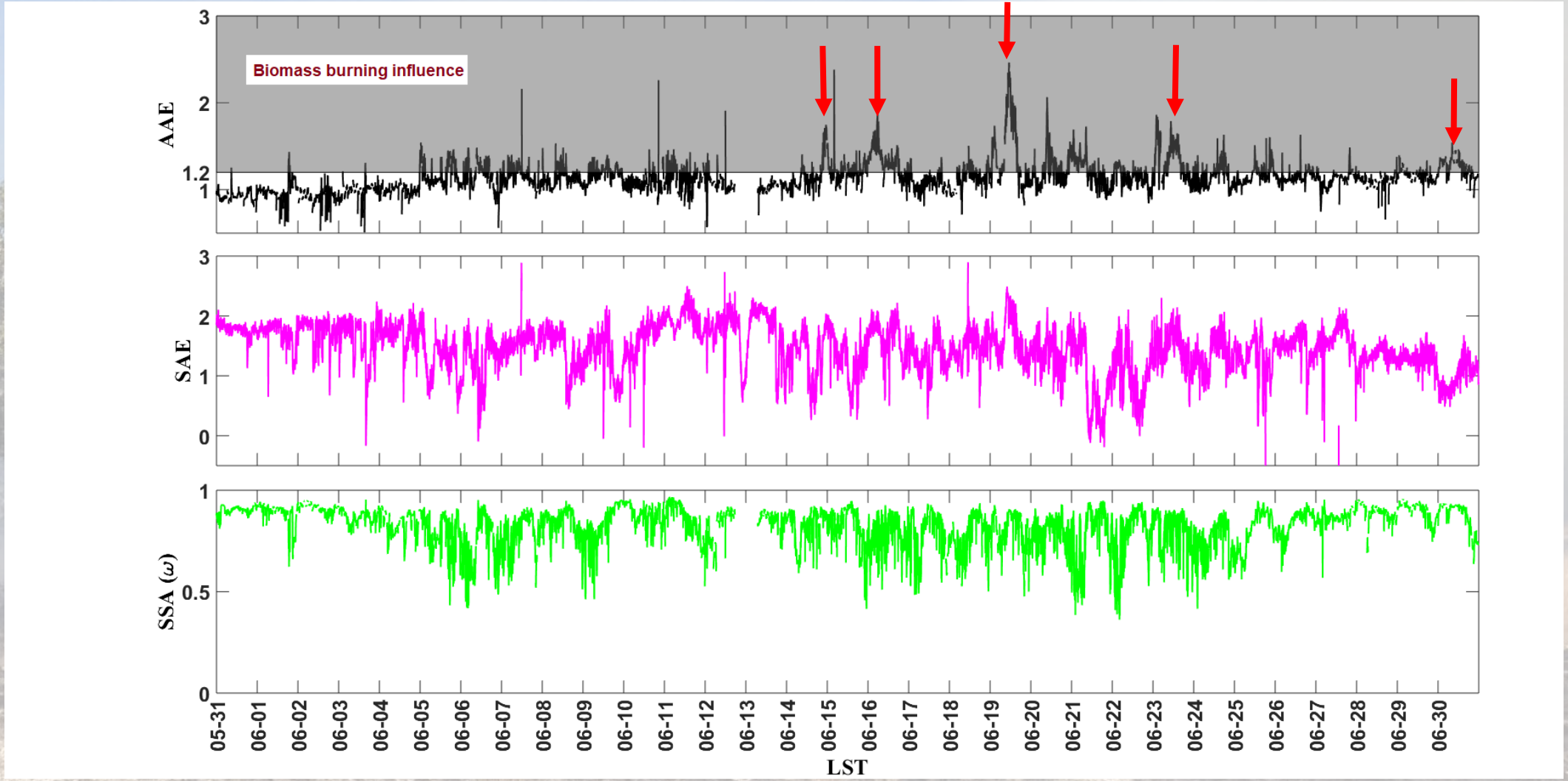
Key findings: April dust event



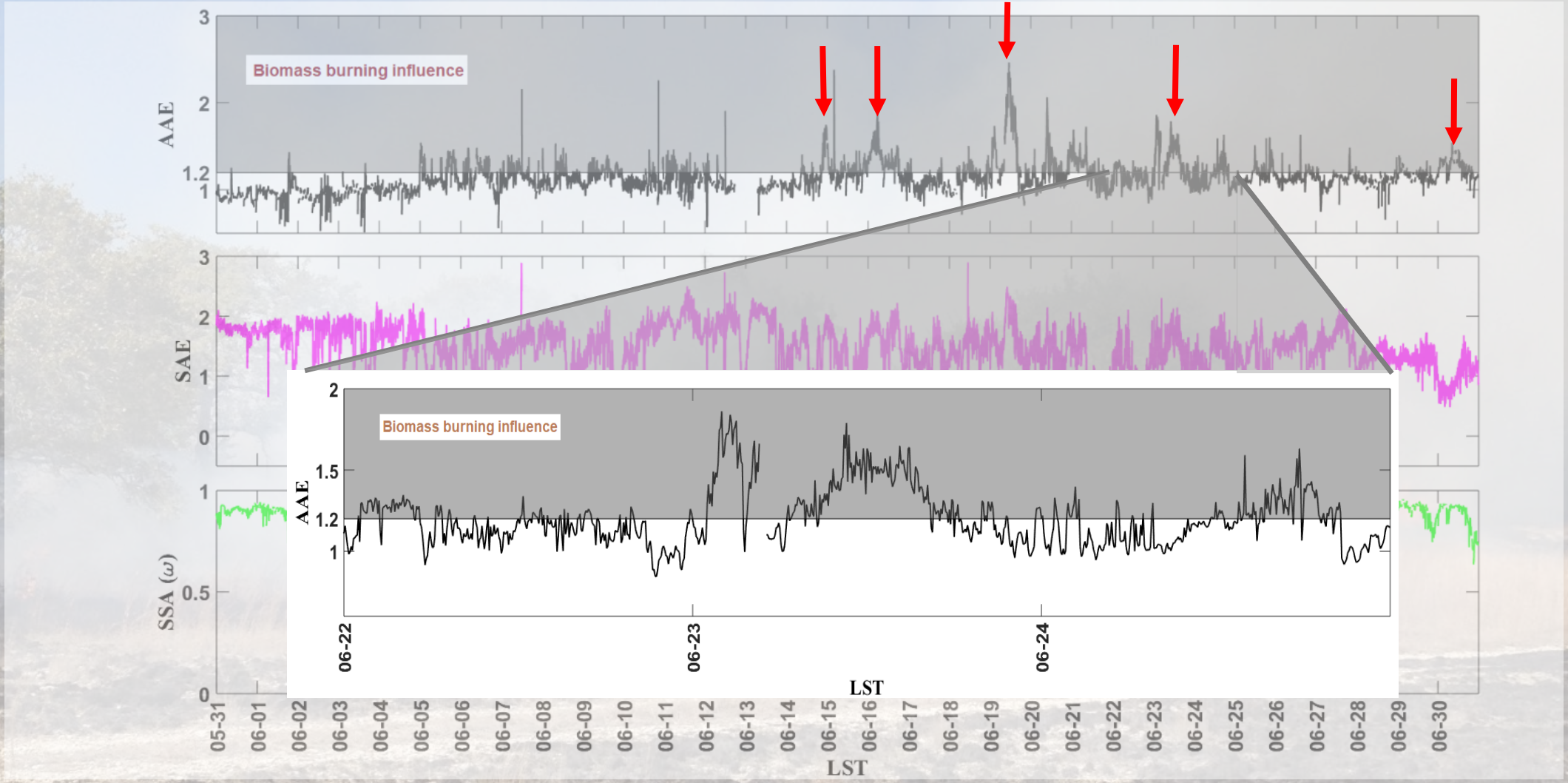


Schmeisser *et al.* 2017

Key Scientific Findings: Biomass Burning Events



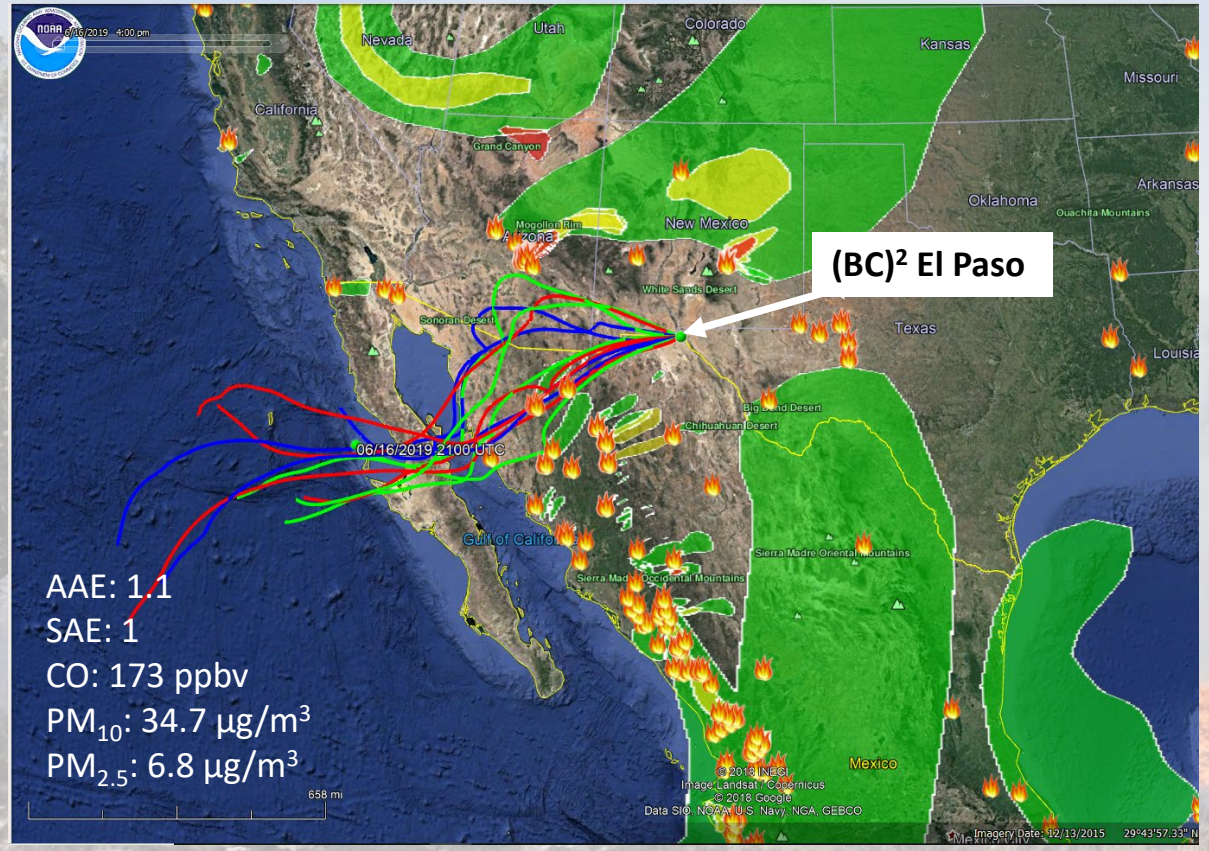
Key Scientific Findings: Biomass Burning Events



BB event day on 6/23

Remote Satellite data and NOAA HYSPLIT Model

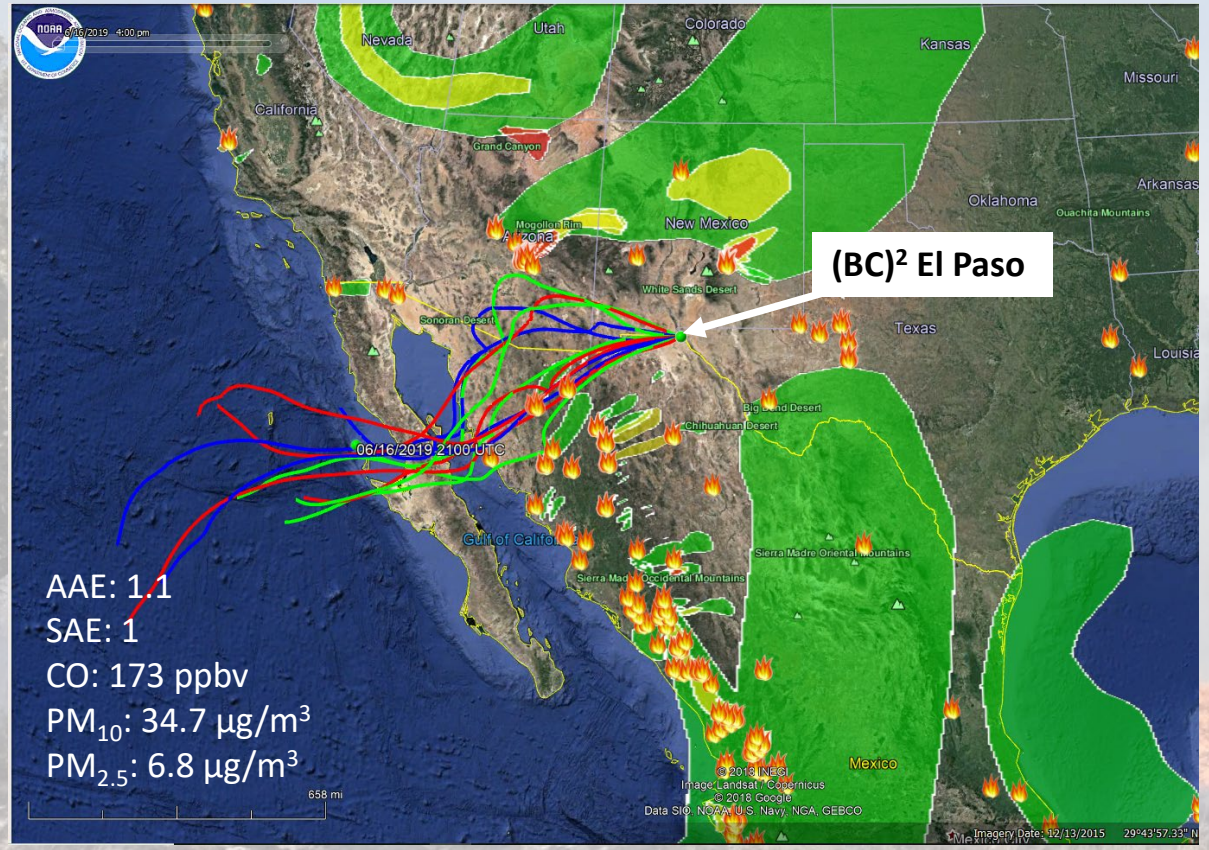
June 22- Non Event day



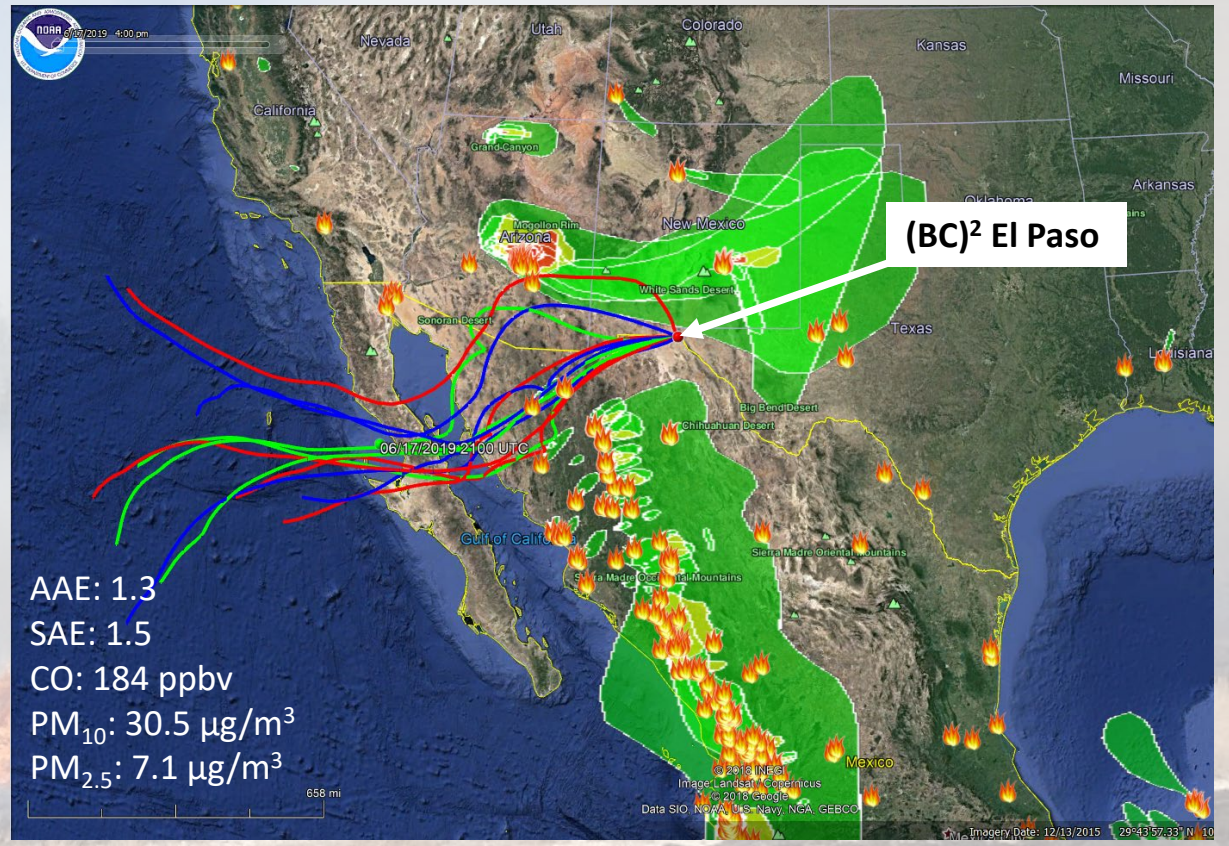
Layers include NASA MODIS Active Fire Data, NOAA Hazard Mapping Smoke Product, and NOAA HYPLIT 72-hr back trajectory

Remote Satellite data and NOAA HYSPLIT Model

June 22- Non Event day



June 23- Event day



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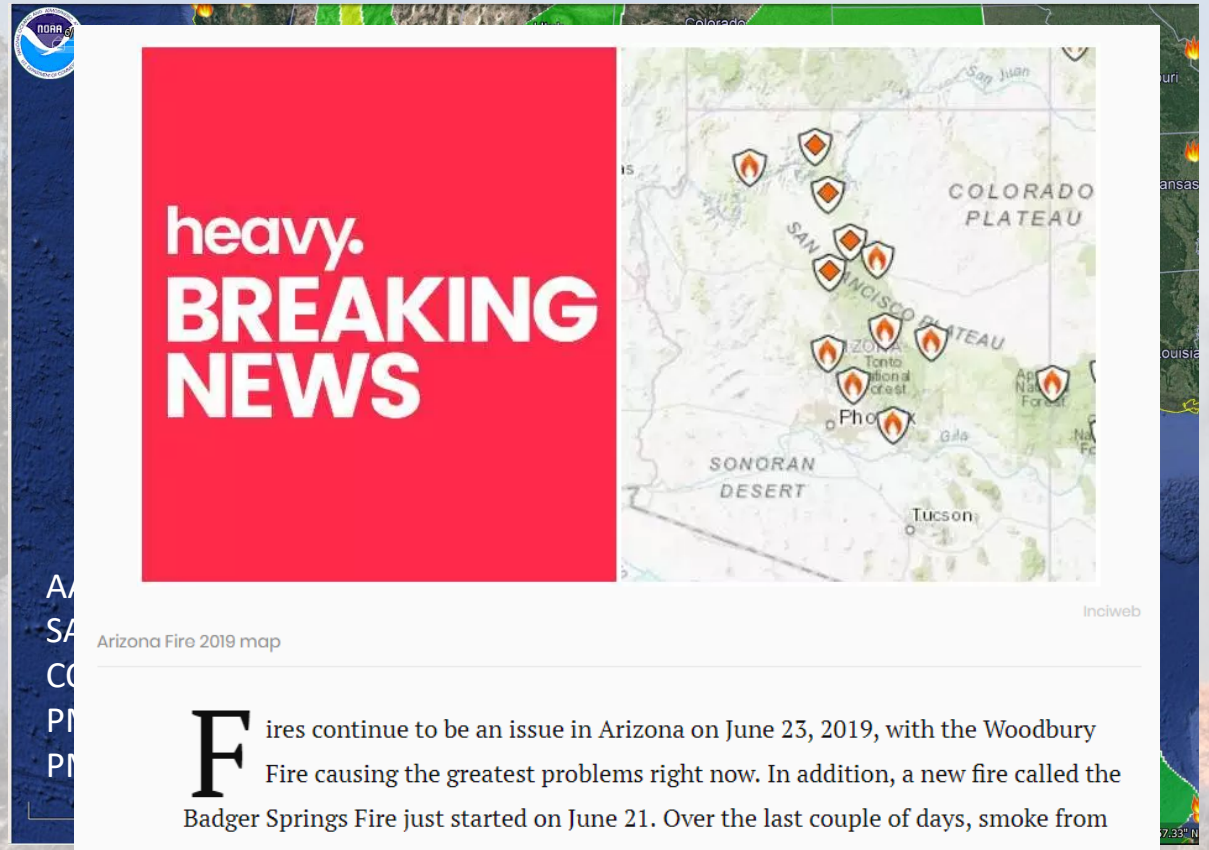
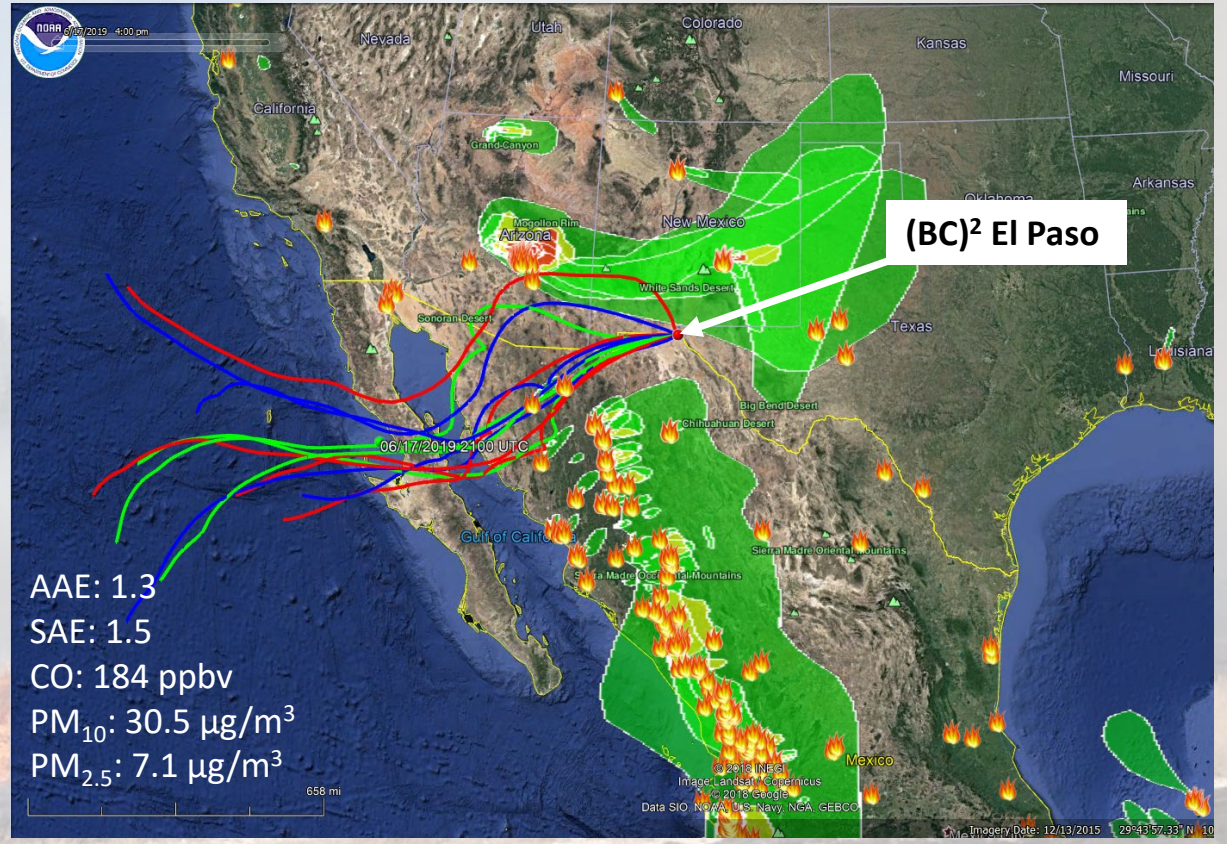
Remote Satellite data and NOAA HYSPLIT Model

June 22- Non Event day



June 23- Event day



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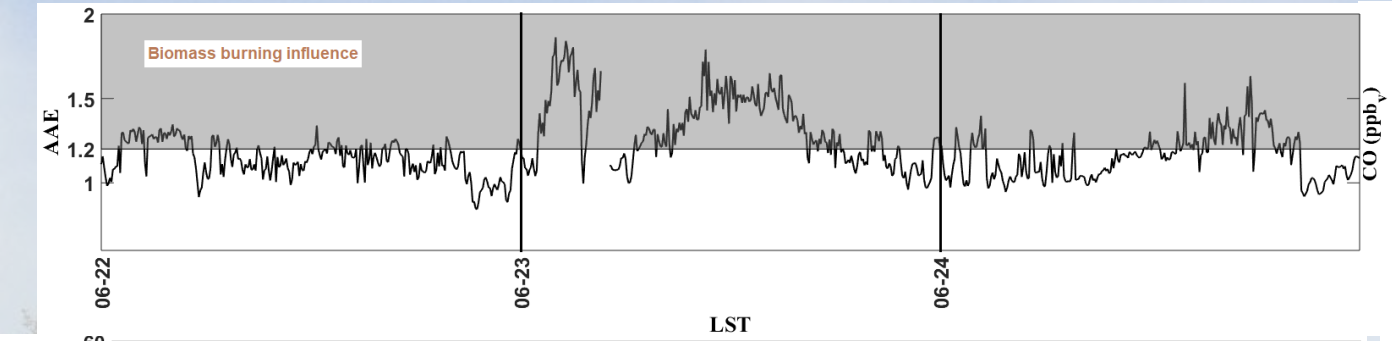
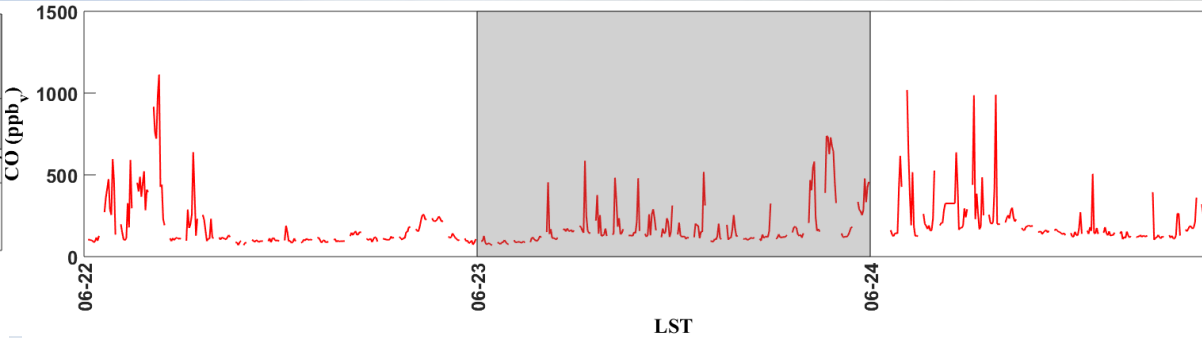
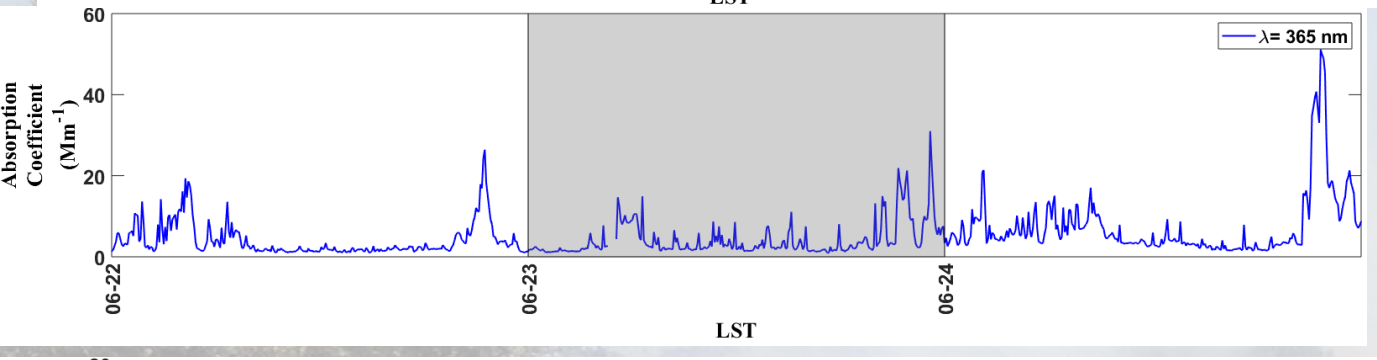
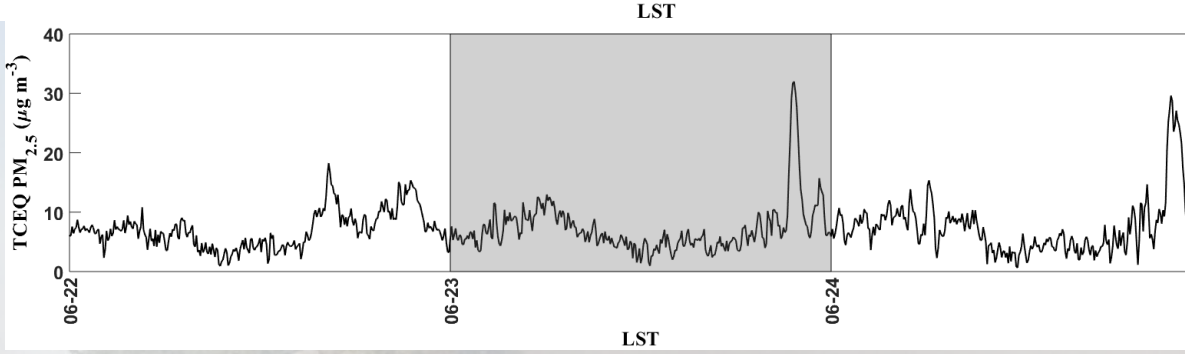
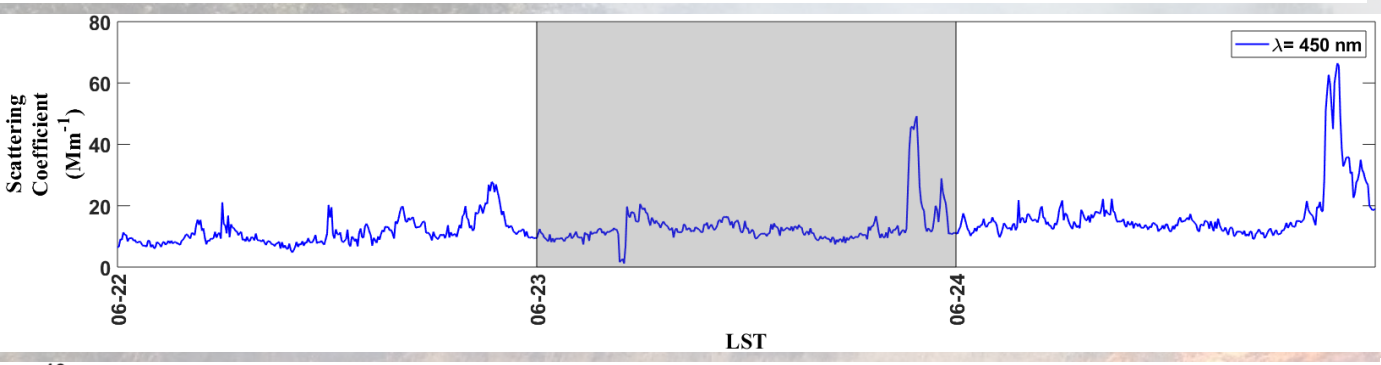
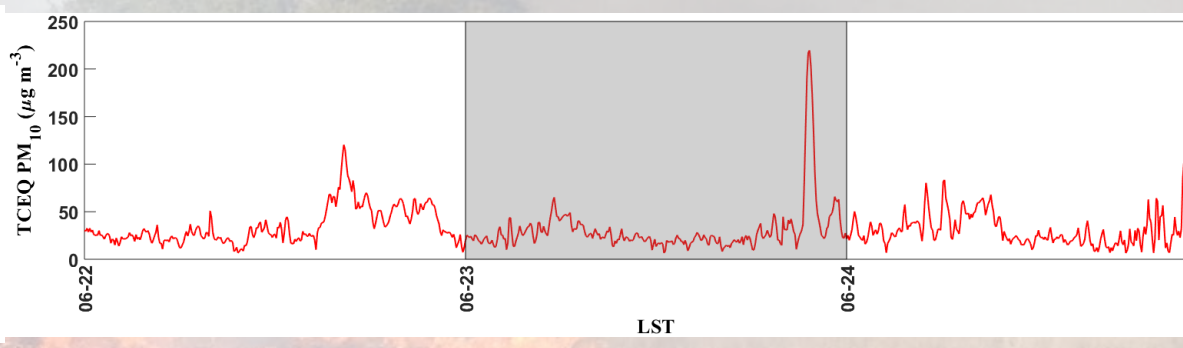

Biomass burning influence
AAE
2
1.5
1.2
1
06-22
06-23
06-24
LST

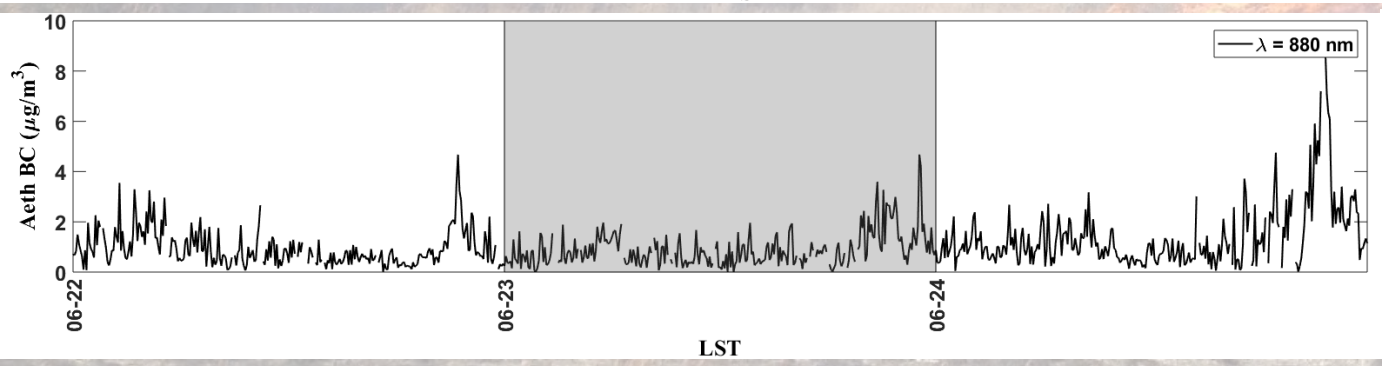

CO (ppb$_v$)
1500
1000
500
0
06-22
06-23
06-24
LST

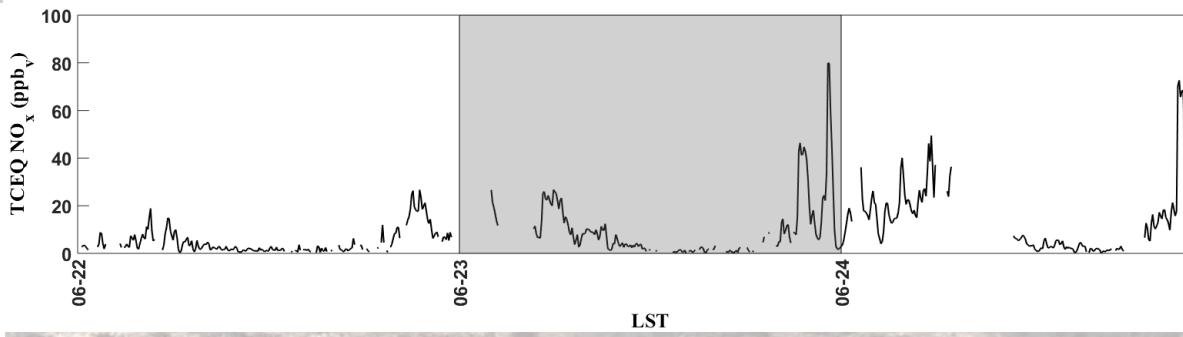

Absorption Coefficient (Mm^{-1})
λ= 365 nm
60
40
20
0
06-22
06-23
06-24
LST


TCEQ PM$_{2.5}$ (μg m^{-3})
40
30
20
10
0
06-22
06-23
06-24
LST

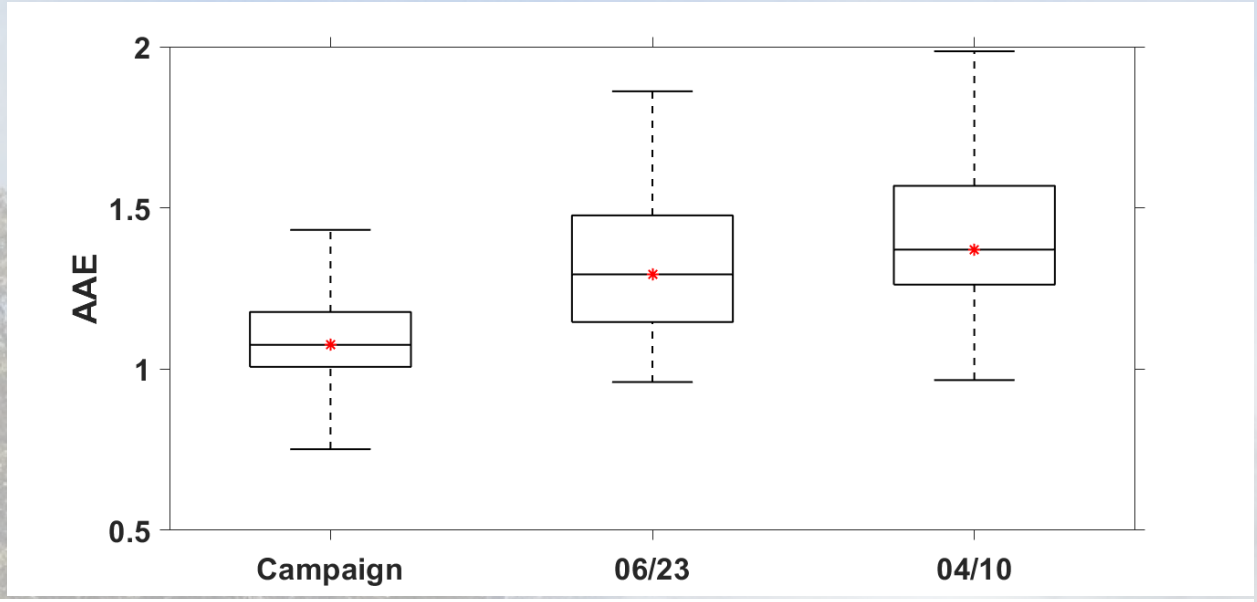

Scattering Coefficient (Mm^{-1})
λ= 450 nm
80
60
40
20
0
06-22
06-23
06-24
LST

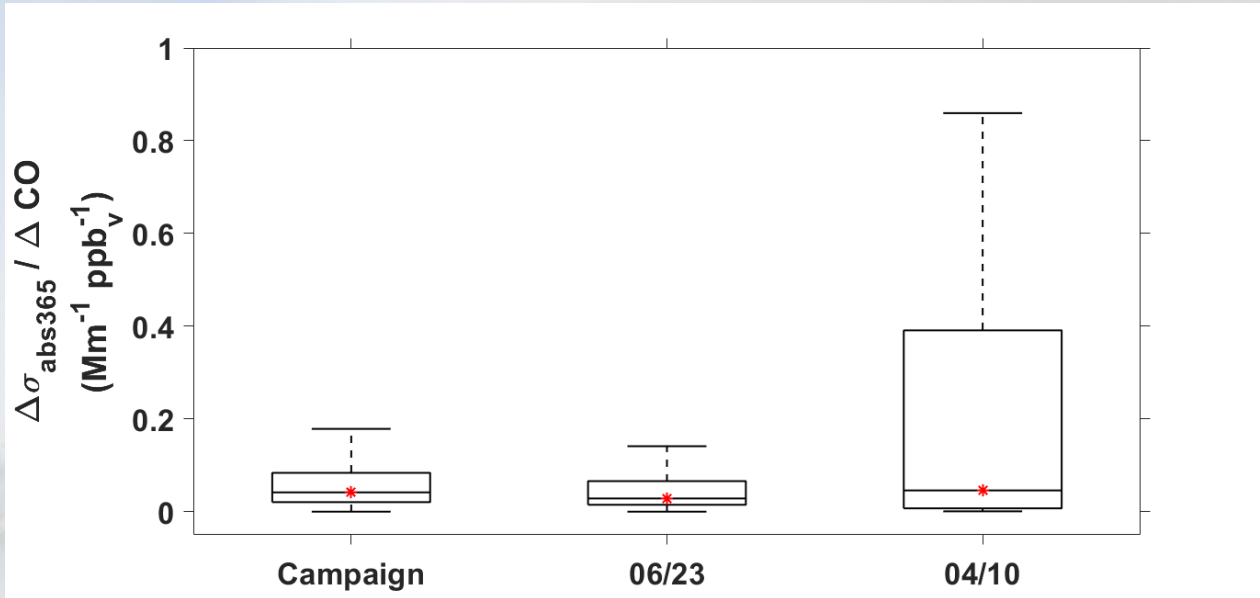

TCEQ PM$_{10}$ (μg m^{-3})
250
200
150
100
50
0
06-22
06-23
06-24
LST

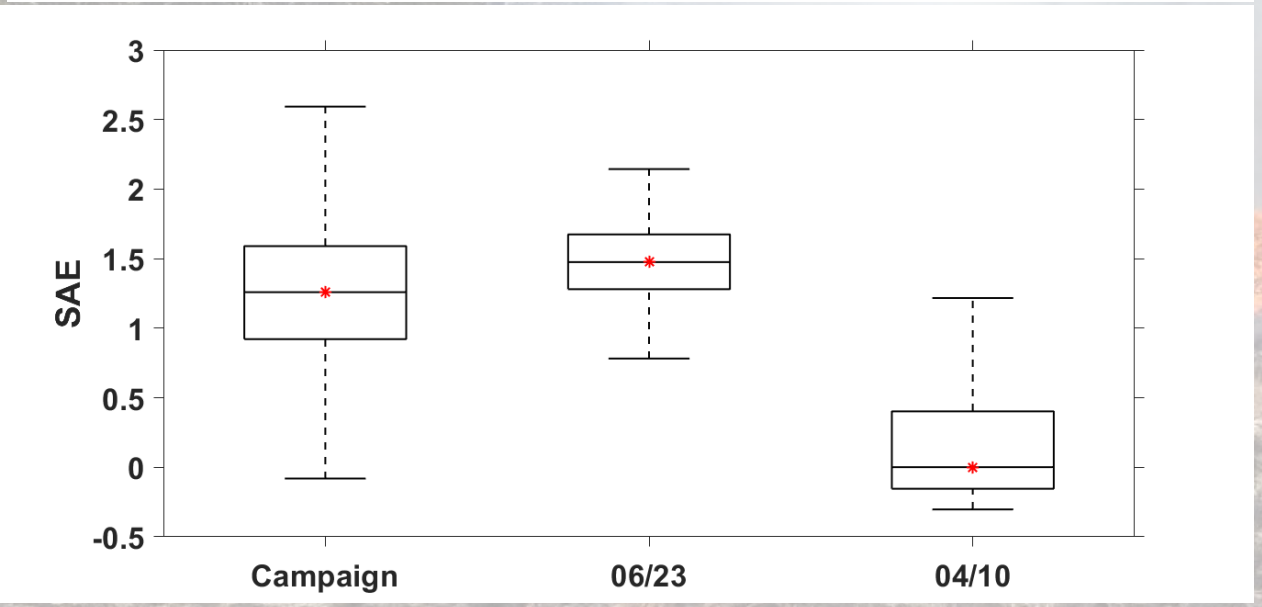

Aeth BC (μg/m^3)
λ = 880 nm
10
8
6
4
2
0
06-22
06-23
06-24
LST

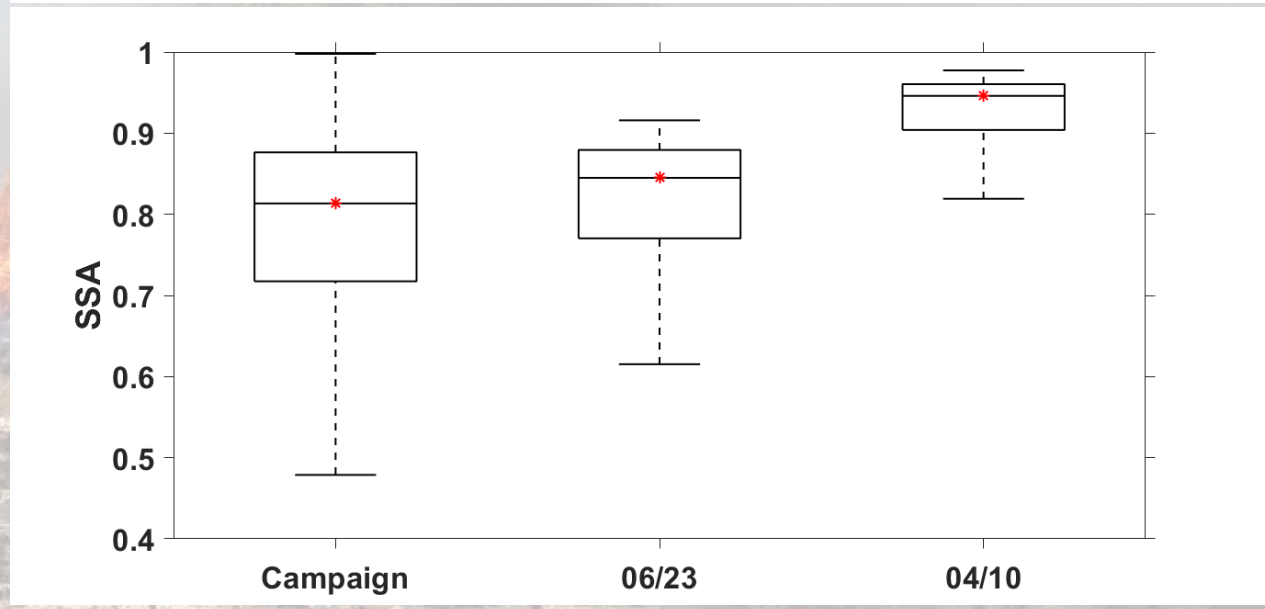

TCEQ NO$_x$ (ppb$_v$)
100
80
60
40
20
0
06-22
06-23
06-24
LST

Key Findings: Aerosol Optical Properties 6/23 and 4/10

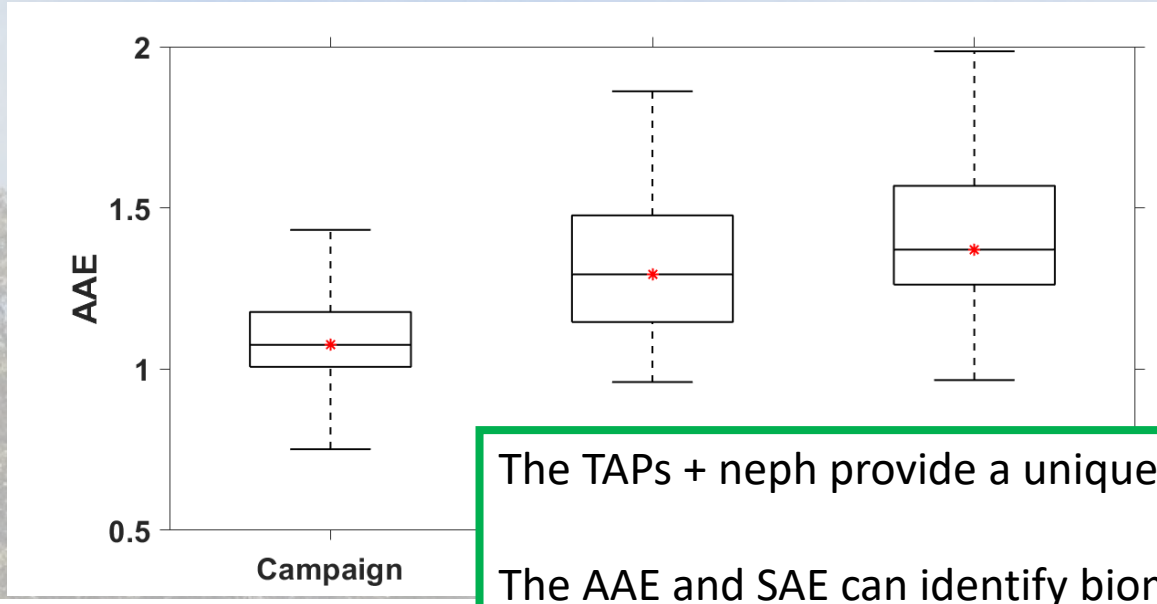


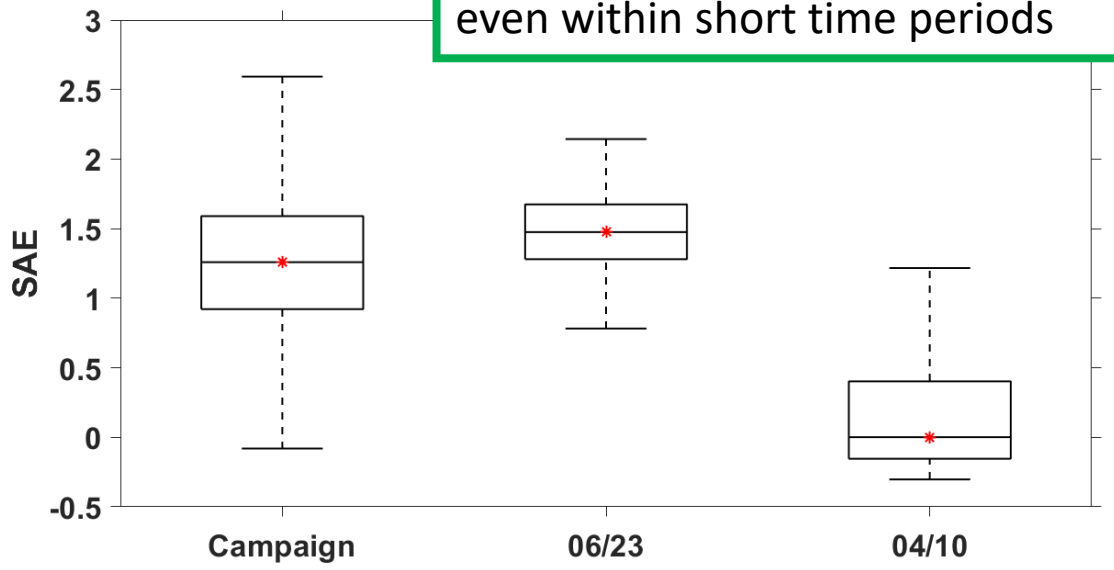






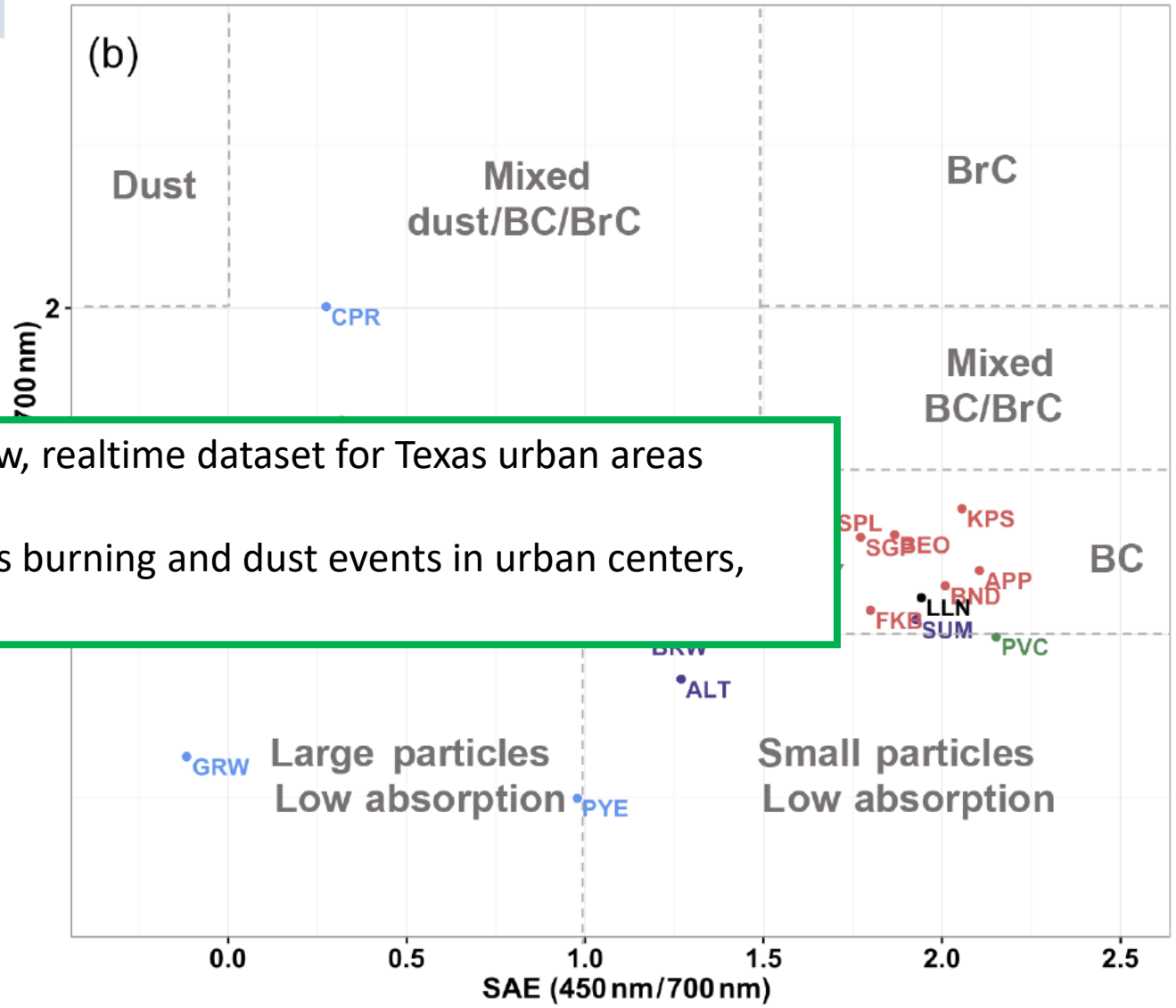
Key Findings: Aerosol Optical Properties





The TAPs + neph provide a unique new, realtime dataset for Texas urban areas

The AAE and SAE can identify biomass burning and dust events in urban centers, even within short time periods



Schmeisser *et al.* 2017

Ease of operation– Time and Effort

- Remote Daily Checks (TAPS and neph)
  - Use of TeamViewer to monitor instrumentation status and data acquisition
  - Daily plotting of real-time data for monitoring aerosol optical properties
  - Data is continuously uploaded to external server for backup of site computer
  - Trailer had internal cameras for additional remote monitoring (NEST)
  - External checks
    - Evaluation of TCEQ CAMS 12 datasets for CO, NO_x, PM_{10} & $PM_{2.5}$ data
    - Use of NASA MODIS & NOAA Hazard Mapping System data and NOAA HYSPLIT
  - AE42 was not online and required weekly, manual data downloading.

Instrument and weekly activities	Filter Changing/Advancement	Time Gap in Data	Hours Required
Tricolor Absorption Photometer (TAP)	7±1 days	1 hour	30 mins
Aethalometer (AE42)	3±1 days	45 mins	15 mins

Conclusions

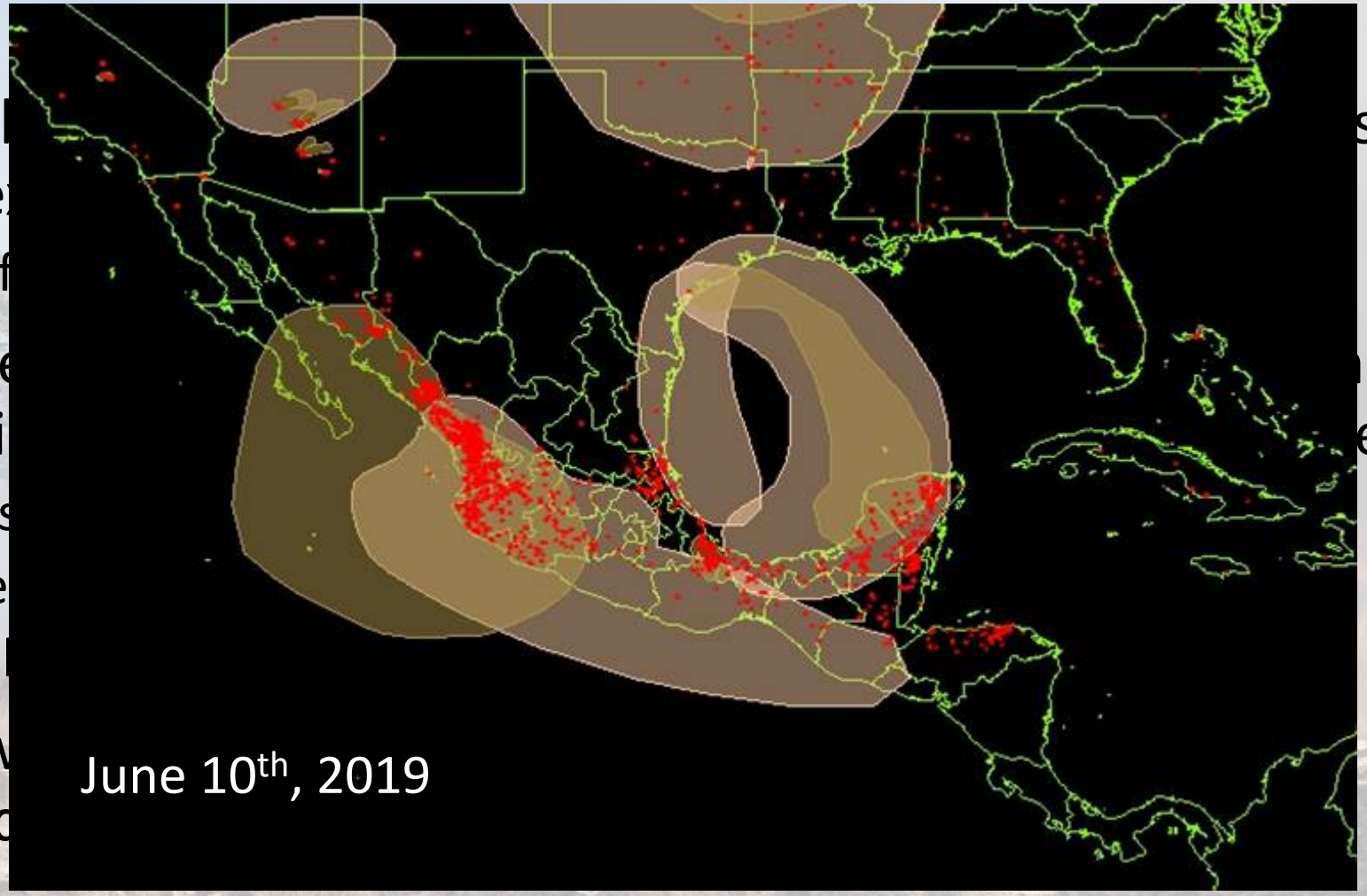
- The TAP was able to identify even relatively short BB events in an urban landscape
- AAE helps reduce variability within the absorption data to improve bb events detection
- BB events identified using the TAP matched up well with remote monitoring datasets (*e.g.,* MODIS)
- SAE calculated from the Neph scattering data helped identify dust events and work well in combination with the TAP
- TAPs had good comparability over the course of the campaign
- TAP has a small footprint (space, power, and volume) that could potential be included at addition TCEQ monitoring sites.
- Constructed a portable air monitoring trailer capable of assessing BB event in urban centers across Texas.

Future work

- Take portable optical suite of measurements for BB and dust studies in other Texas cities (Houston?)
  - Can use for study of events or as a real-time indicator
- Combine results of BB and dust identification through AAE and SAE with additional characterization to understand magnitude of events
  - Filter-based chemical analysis (e.g. potassium ion and radiocarbon)
  - Real-time particle speciation (e.g. HR-TOF-AMS)
  - Chemical transport modeling (e.g. GEOS-Chem)
- Combine with additional gas measurements and modeling to understand interaction of BB events with ozone production

Future work

- Take portal … studies in other Te…
  - Can use f…
- Combine re… d SAE with additi… events
  - Filter-bas…
  - Realtime…
  - Chemical…
- Combine w… understand…



Questions?

Assistant Professor of Climate Change

The Department of Environmental Science at Baylor University invites applications for a tenure-track faculty position at the intersection of climate change and air quality. The successful applicant will join our dynamic faculty in pursuing essential research questions in the area of climate change and air quality. We are interested in candidates who are working to model and understand climate interactions with specific atmospheric processes, including biogeochemical feedback loops, earth-atmosphere interactions, and atmospheric composition. This is one of a series of hires under Baylor University *Illuminate*Initiatives. Candidates with expertise in climate and/or air quality modeling, atmospheric chemistry and high-performance computing are particularly encouraged to apply. The successful candidate will establish a rigorous externally funded research program; mentor doctoral students through the Ph.D. in Environmental Science; engage undergraduate students; and teach environmental science and data modeling courses. Applicants must have a doctoral degree and a proven research record. We encourage applicants who will develop collaborations with faculty in Environmental Science, in allied departments from the College of Arts and Sciences and who can expand existing external collaborations in Texas and beyond. The position is slated to begin in August 2020. Competitive salary, start-up funds and laboratory space are available, and will be commensurate with experience and qualifications.

Electronically submit applications via Interfolio using the followinglink: **apply.interfolio.com/66172**

Application review will begin 10/15/2019 and will continue until the position is filled.

Questions should be directed to Dr. George Cobb (George_Cobb@Baylor.edu), Chair of Environmental Science, or Dr. Rebecca Sheesley (Rebecca_Sheesley@Baylor.edu).

To learn more about the above position, please visit these links: http://www.baylor.edu/environmentalscience;http://www.baylor.edu/artsandsciences/;andhttps://jobs.baylor.edu/ .