MAC-MAQ 2019

Preliminary Assessment of Micro-Pulse LiDAR Measurements of the Mixed Layer Height in the San Joaquin Valley

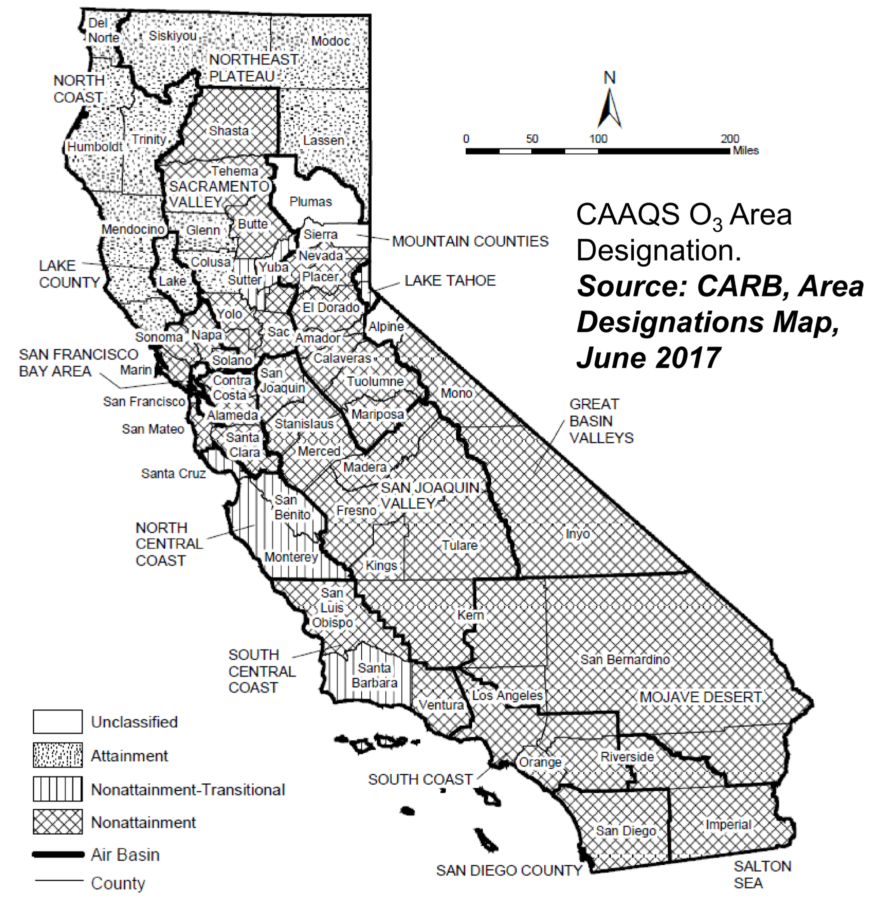
William Vance[1*], Toshihiro Kuwayama[1], Scott Scheller[1], Mac McDougall[1], Reggie Smith[1], Ken Stroud[1], and Michael FitzGibbon[1]

[1] California Air Resources Board, 1001 I Street, Sacramento, CA 95812, United States

I. Introduction

California's $PM_{2.5}$ Challenges

- **Eight counties** in the San Joaquin Valley (**SJV**) were designated as **nonattainment areas** for fine particulate matter (**$PM_{2.5}$**) National Ambient Air Quality Standard (**NAAQS**) in 2012.
- Currently, SJV $PM_{2.5}$ is mostly composed of **ammonium nitrate** (AN) and **organic aerosols** (OA).
- Despite significant reductions of overall ambient $PM_{2.5}$ levels, in recent years the **$PM_{2.5}$ trend has remained flat**, especially in the SJV.
- Characterization, prediction, and control of ambient aerosols in the SJV are complicated by the complex interactions between geography, meteorology, climate, and spatially non-homogeneous mixture of natural and anthropogenic air pollution emissions.



Knowledge Gaps in Addressing SJV $PM_{2.5}$ Problem

- Existing surface measurements alone are insufficient to achieve full understanding of atmospheric processes that contribute to PM production:
  - *Pusede et al. (2016)* – Large decreases in future NO_x emissions will cause a **transition in the dominant AN source from nighttime to daytime chemistry**.
  - *Prabhkar et al. (2017)* – vertical mixing from the residual layer and the shape of the **vertical profile of air pollutants controls the evolution of the surface aerosols**.
- *Kelly et al. (2014)* – Mixing during evening boundary layer transition may be underestimated in certain regional air quality models, which may be leading to excessive nitrate formation.

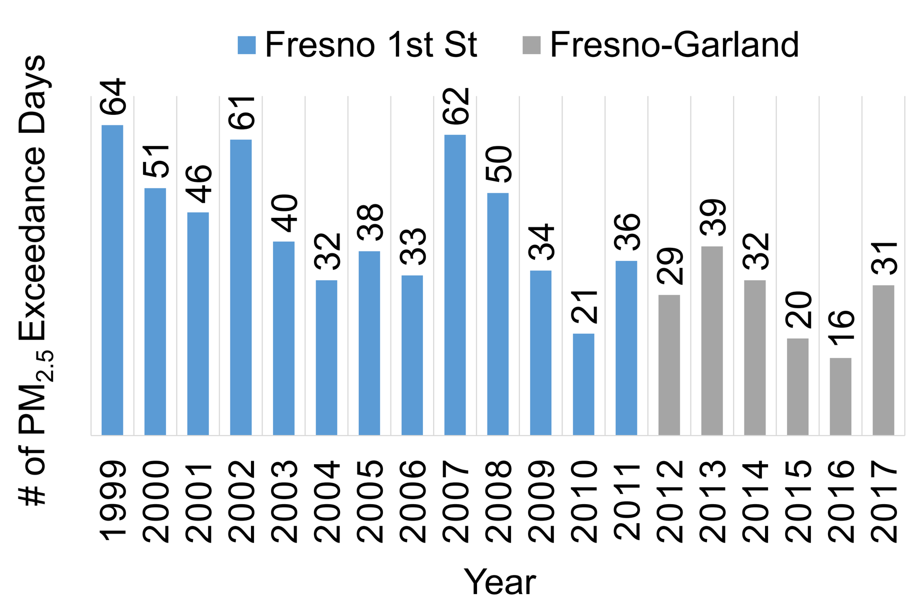


Figure: Historical $PM_{2.5}$ NAAQS exceedances at Fresno, California

Need for More Mixed Layer Height (MLH) Information

- The MLH is a critical meteorological variable, serving as a diagnostic parameter to evaluate the performance of aerosol dispersion and turbulent mixing mechanisms in regional air quality models.

II. Objective

- Study the seasonal changes in MLH using high-frequency normalized relative backscatter (NRB) measurements.
- Gain insight into the influences meteorology has on production mechanisms of PM.

III. Methods

- Deploy Mini Micropulse LiDAR (MiniMPL) at Fresno-Garland Quality Assurance Air Monitoring Site (AQS# 060190011)
- Utilize Haar wavelet covariance transform of MiniMPL NRB to estimate hourly MLH between **October 2018 to May 2019**.
- Use Cyclostationary Empirical Orthogonal Eigenfunction (CEOE) Model on NRB data to identify components of diurnal vertical aerosol distributions that affect surface PM levels.

Haar Wavelet Covariance for MLH Determination

- Haar wavelet, ***h***, is defined by sharp gradient in NRB closest to the surface; boundaries between high and low aerosol density:

$$h\left(\frac{y-b}{a}\right)=\begin{cases}-1: & b-\frac{a}{2}\le y<b\\ +1: & b\le y\le b+\frac{a}{2}\\ 0: & elsewhere\end{cases}$$

where ***y*** is the vertical altitude, ***a*** is the dilation factor and ***b*** is the center of the wavelet function.

- Wavelet covariance, ***w***, at given height ***y*** is described by the integrated product of NRB and ***h***:

$$w_f(a,b)=a^{-1}\int_{y_b}^{y_t}NRB(y)h\left(\frac{y-b}{a}\right)dy$$

III. Methods (cont.)

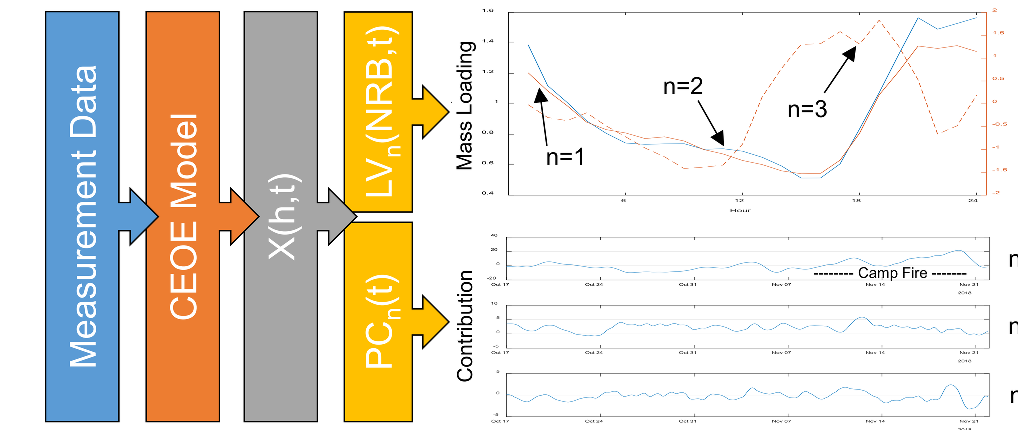
CEOE Modeling of MiniMPL NRB

- The CEOE decomposition of space-time NRB data is:

$$X(\mathbf{s},t)=\sum_n LV_n(\mathbf{s},t)PC_n(t),$$

where X **is composed of the product** of Loading Vectors (LV), which are systematically repeatable patterns in the dataset, and Principle Components (PC) that describe slow random modulation of these patterns.

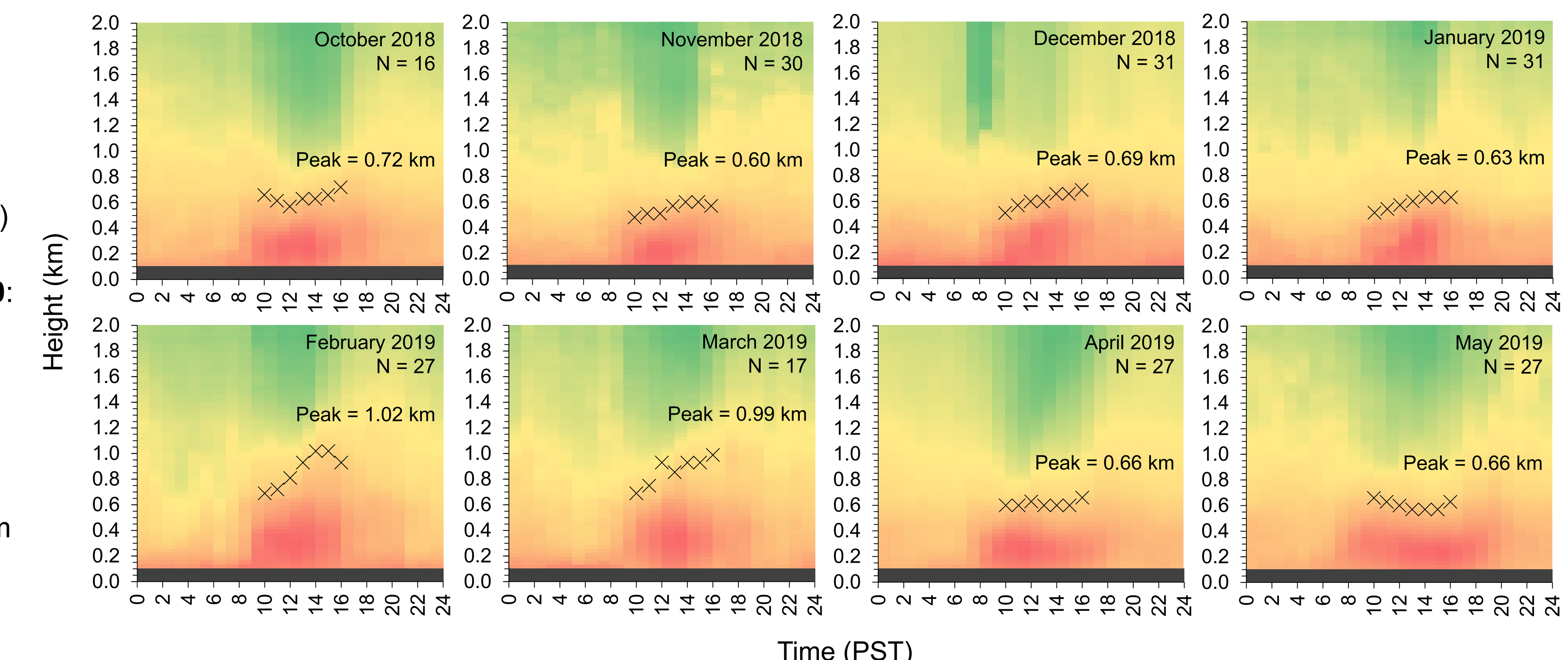
- Representativeness of each function relies on the size of the input data and its systematic repetitiveness within a user defined time period, t; 24-hr.
- NRB dataset was truncated to 0.7 km above the surface to reduce pattern recognition of cloud formations above estimated MLH.



IV. Preliminary Results

MLH Over Fresno Supersite

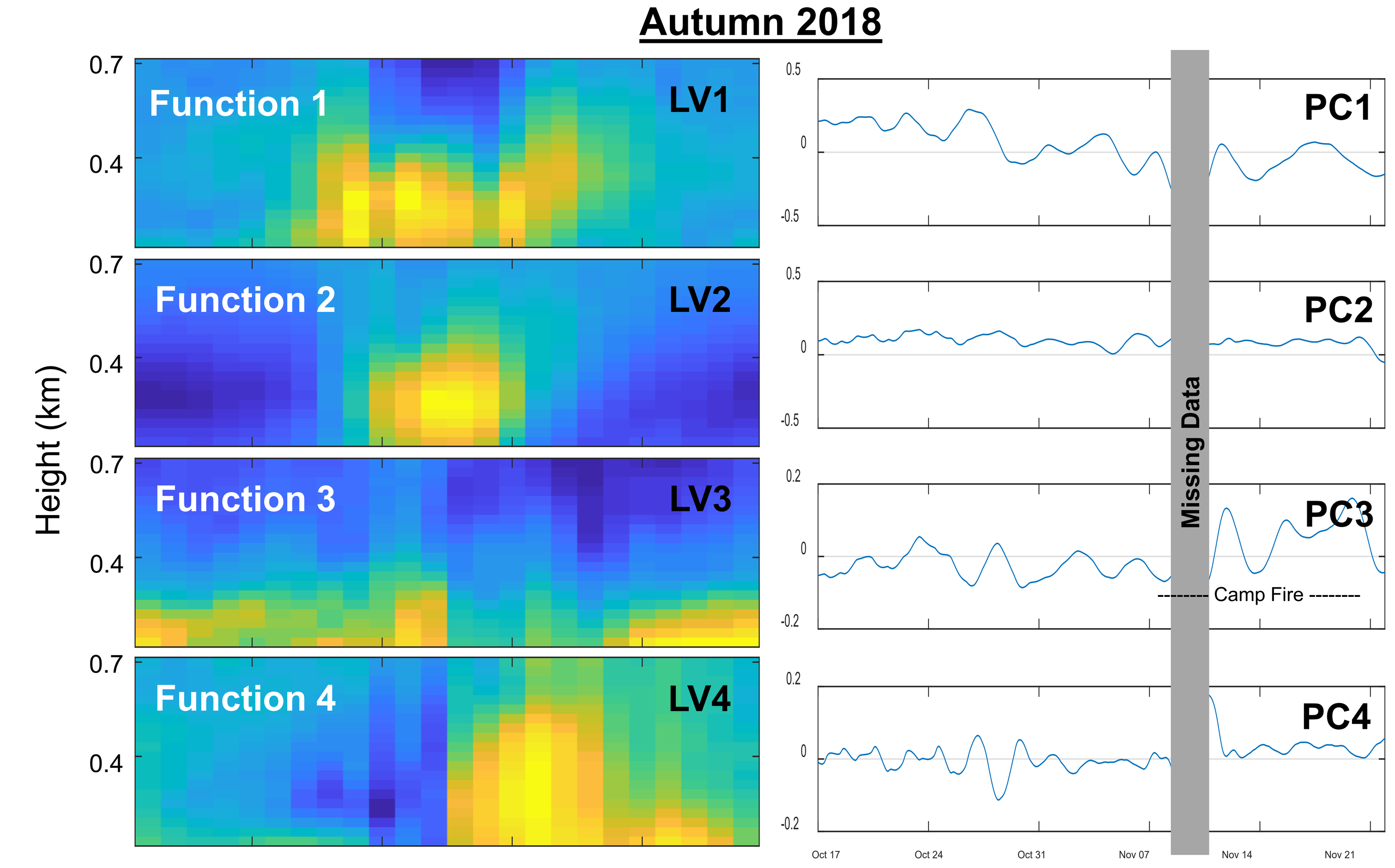
- **2-hr moving median** was used to reduce the noise in MLH calculated every 2 minutes.
- Preliminary data was limited to QA/QC on system diagnostics; influences of fog, heavy rain, and low-lying clouds within 2 km (vertical) will be evaluated in future data analyses.
- **Average monthly MLH between 10:00-16:00**:
  - $\overline{MLH}_{Autumn}$ = 0.59 ± 0.07 km
  - $\overline{MLH}_{Winter}$ = 0.60 ± 0.06 km
  - $\overline{MLH}_{Spring}$ = 0.74 ± 0.16 km



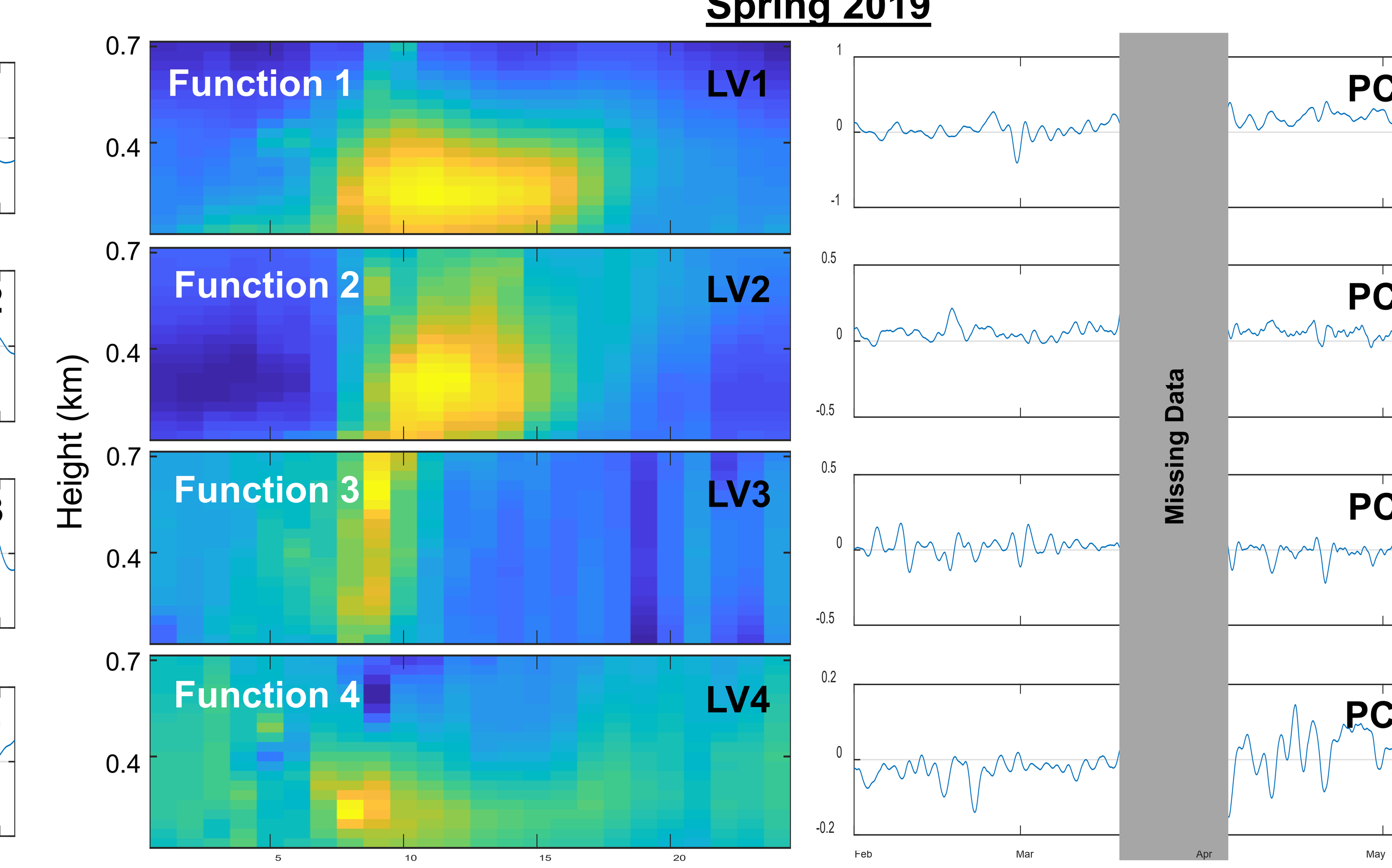
Cyclostationary Analysis

- Four diurnal LV and long-term PC outputs from CEOEM account for ***90%*** and ***83%*** of the total contribution in Autumn 2018 and Spring 2019, respectively.

Autumn 2018



Spring 2019



- Atmospheric processes that are potentially driving the LVs in each function were user defined.

Autumn
Function 1 – Broad average aerosol day (residual layer + surface aerosol)
Function 2 – Low aerosol day (little aloft carry over)
Function 3 – Nocturnal low-level carry over
Function 4 – Broad evening mid to lower level aerosol
} 10.5% contribution

Spring
Function 1 – Broad average aerosol day (residual layer + surface aerosol)
Function 2 – Low aerosol day (little aloft carry over)
Function 3 – Morning upper to low level aerosol influence
Function 4 – Morning to early afternoon mid-level aerosol influence
} 7.0% contribution

V. Summary

- Peak mid-day MLH over Fresno Supersite ranged between 0.60 and 1.02 km with highest peak observed in February 2019 and shows similar seasonal trend as Bianco et al. (2011) where highest MLH was observed during spring months in the SJV.
- CEOE Model resulted in dominant NRB functions that show important differences between seasons, indicating emission and meteorology influences on aerosol profiles.
- Further evaluation of this dataset provides important constraints to check and refine regional air quality modeling performance.

VI. Acknowledgement

CARB thanks staff for helping to organize MAC-MAQ, Dr. Shang Liu and Dr. Seyedmorteza Amini, for providing maintenance and operational support at Fresno Supersite, and Ying-Kuang Hsu for helpful comments. CARB also thanks U.S. EPA Grant Reference #00T41301 for MiniMPL procurement. CARB thanks Dr. Christopher Cappa and Dr. Qi Zhang for their insights, including the operation of Aerosol Chemical Speciation Monitor operating in tandem with MiniMPL under CARB Contract #17RD008.