

# Speciated Source Apportionment of PM<sub>2.5</sub> at Big Bend National Park using Positive Matrix Factorization

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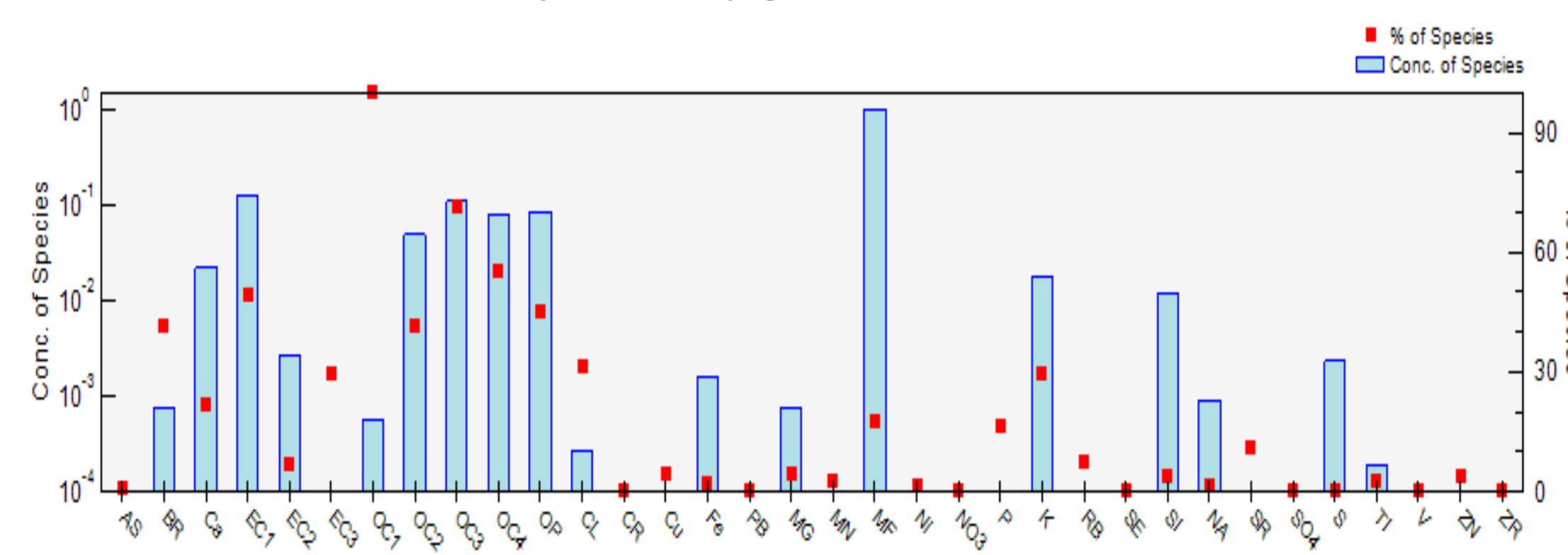
## Introduction and Objectives

We used Positive Matrix Factorization (PMF) to identify the major species source contributions to PM<sub>2.5</sub> concentrations in Big Bend National Park, Texas (BIBE) between 2011 – 2014 from daily average concentrations of speciated aerosol components from the IMPROVE monitoring network. We also investigated the feasibility of including relevant seasonal and meteorological variables into the PMF aerosol source apportionment analysis.

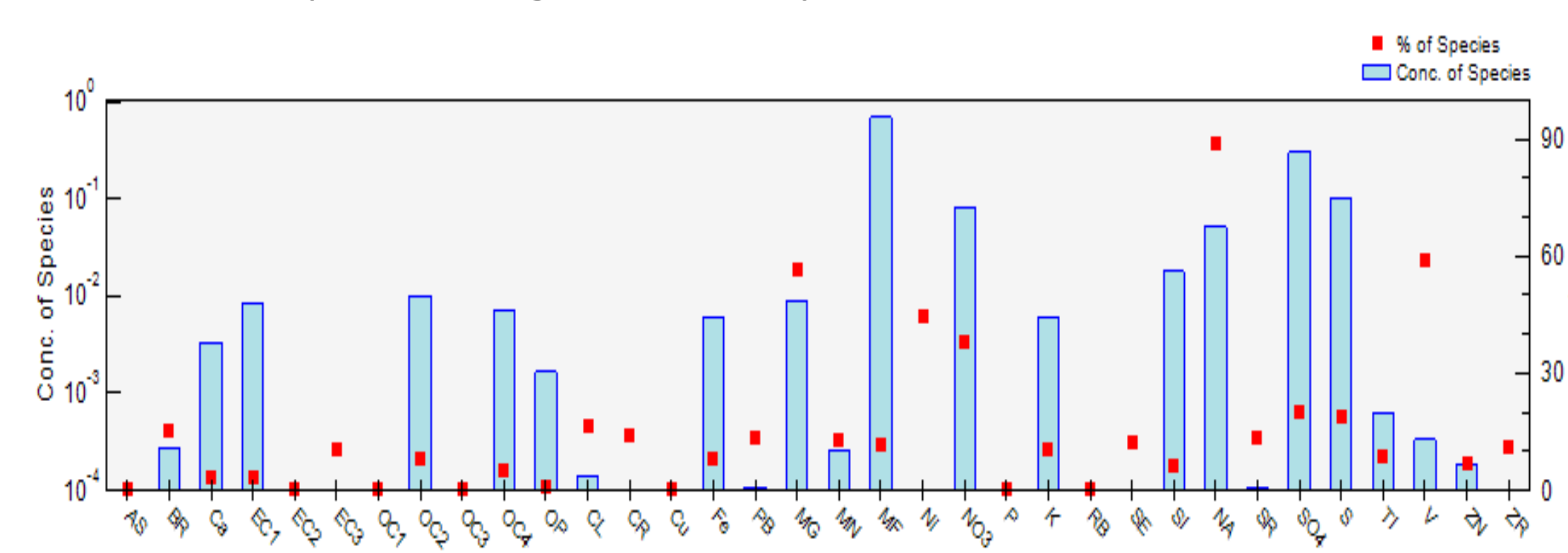
PMF is a statistical method that identifies a user specified number of source factor profiles, comprised of the relative composition of a particle species for each source and source strengths, for each receptor sample period. The source factor percent contributions for the 2011 – 2014 period were compared to corresponding metrics for a previous study conducted by the Causes of Haze Assessment (COHA) program [Green, 2006] during the 2000 – 2004 time frame. In addition, the Stochastic Time Inverted Transport (STILT) model [Lin et al., 2003] was used to calculate surface footprints that indicate the geographical source regions associated with the source factors identified by PMF.

## Baseline PMF Source Factor Analysis

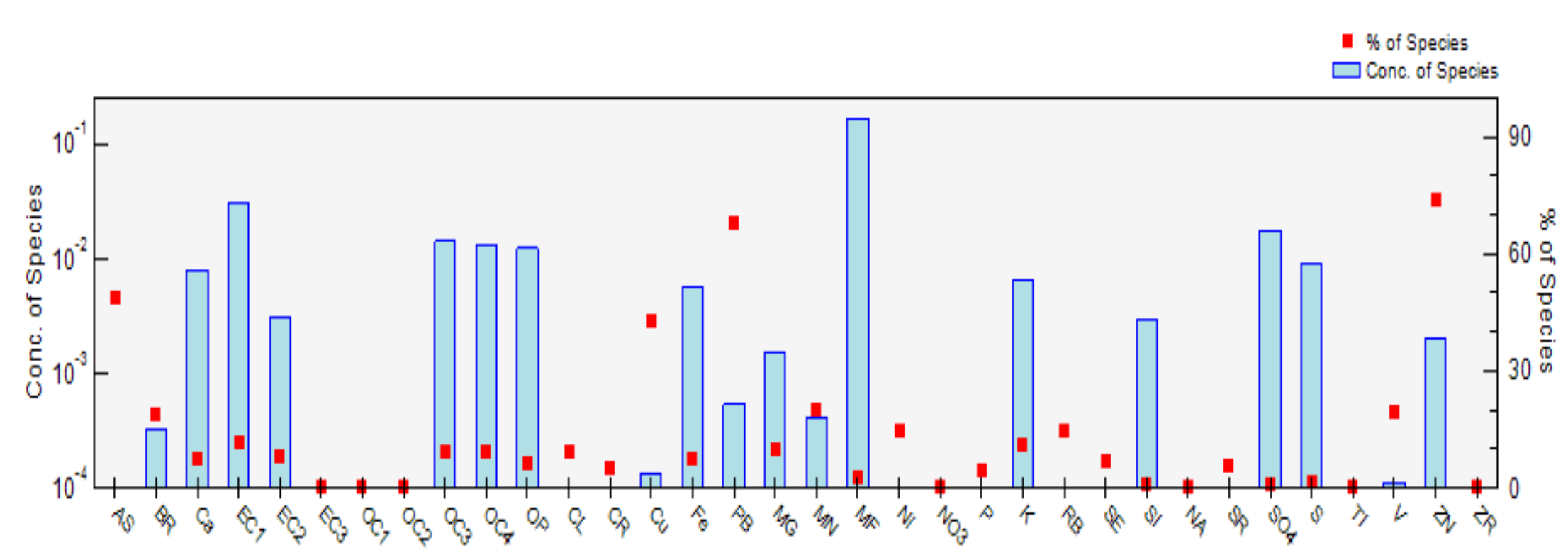
We identified six factors, consistent with the COHA analysis. The source factor profiles are below. Blue bars show the normalized concentration of each species (µg/m<sup>3</sup>) in the factor, while the red dots show the percentage of that species in the factor.



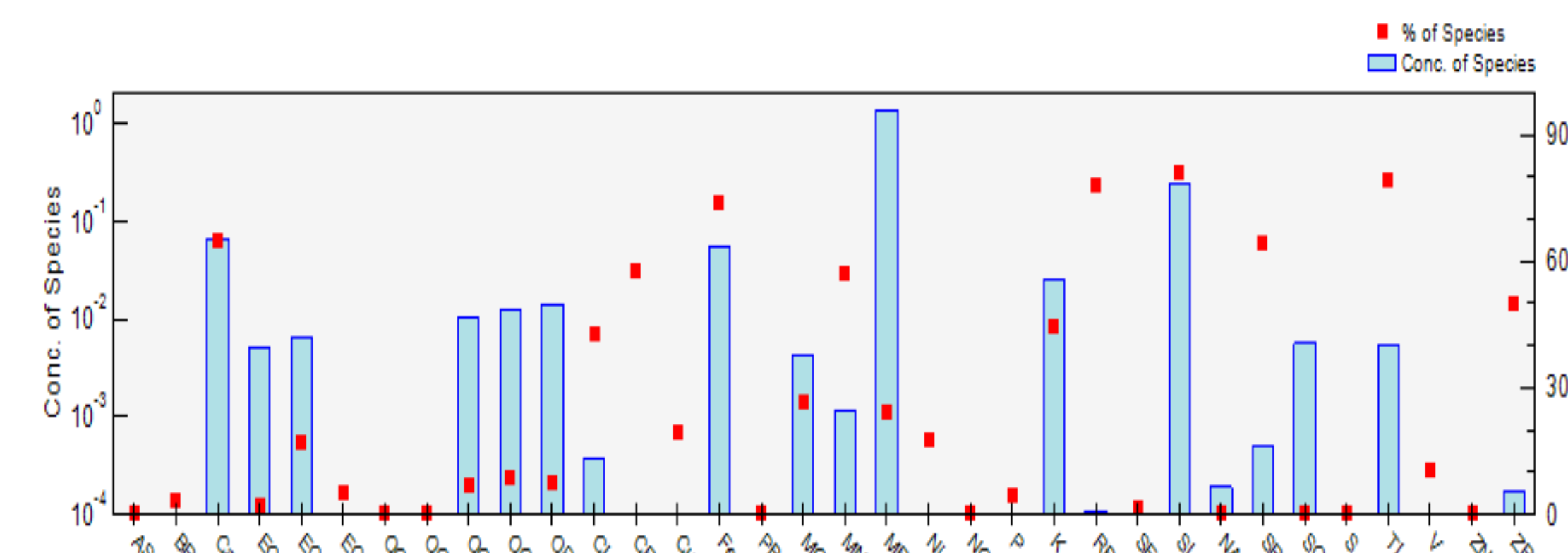
Factor 1 is smoke from biomass burning ("Smoke").



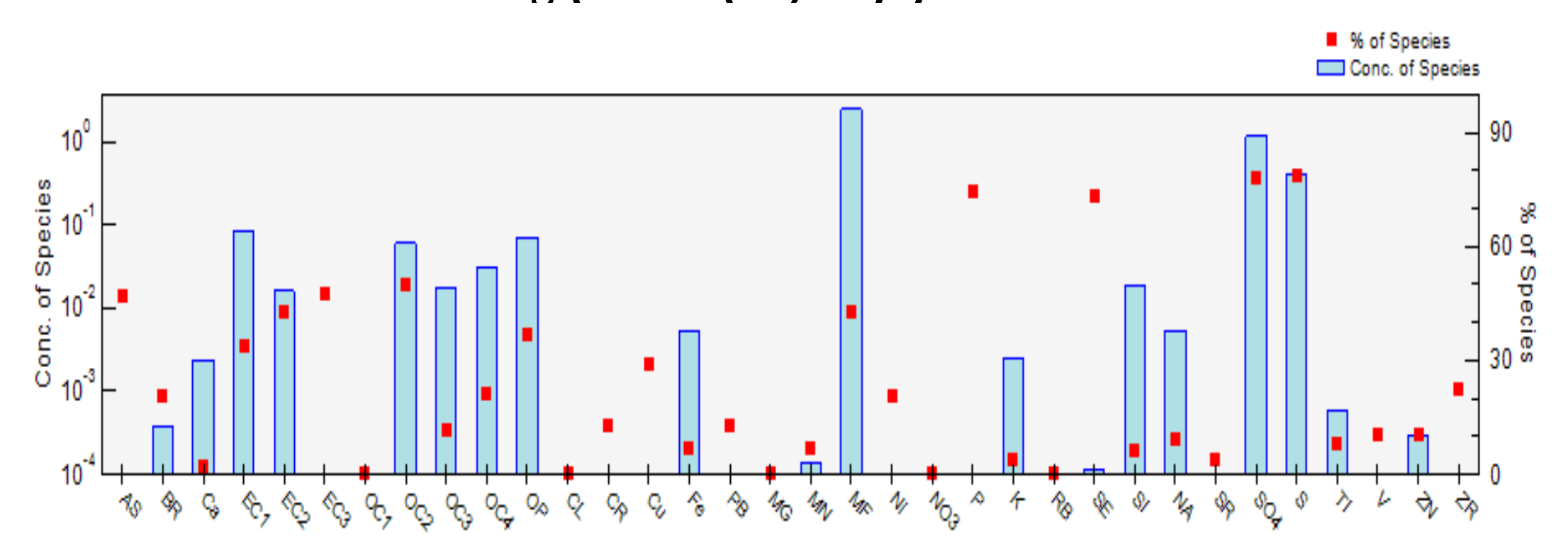
Factor 4 is a mixture of sea salt and nitrate ("Sea salt / Nitrate").



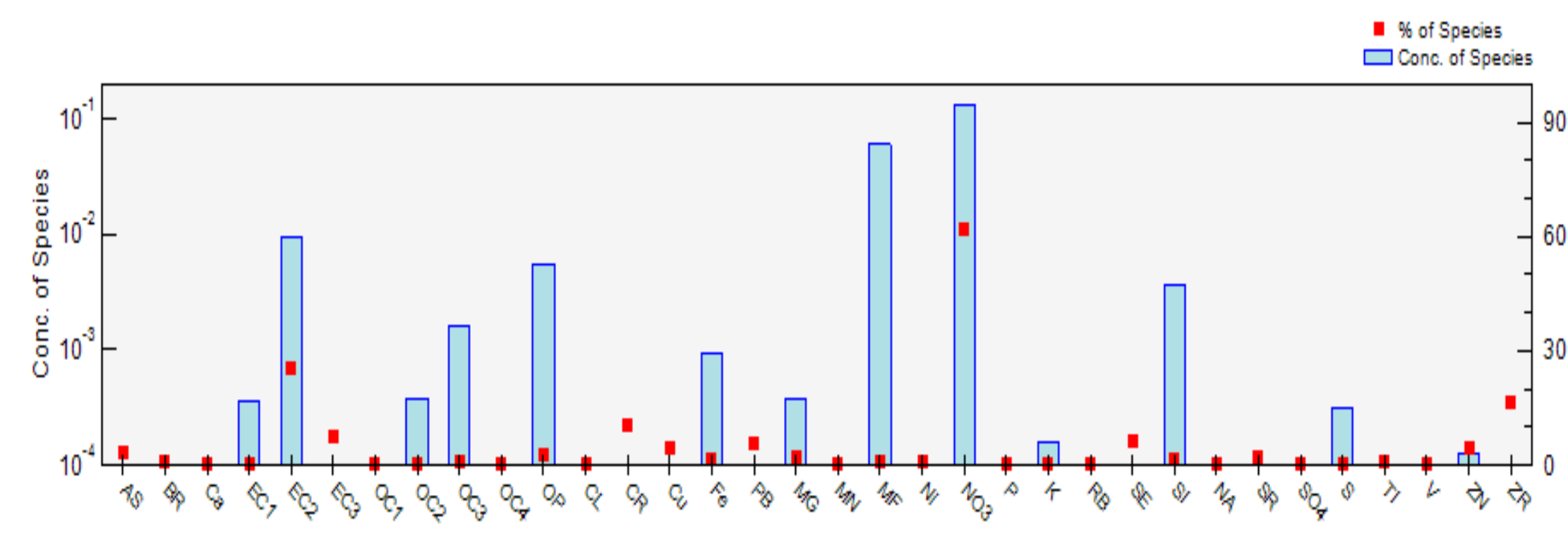
Factor 2 is identified as heavy metal dust with arsenic and lead from biomass burning ("Dust (As, Pb)").



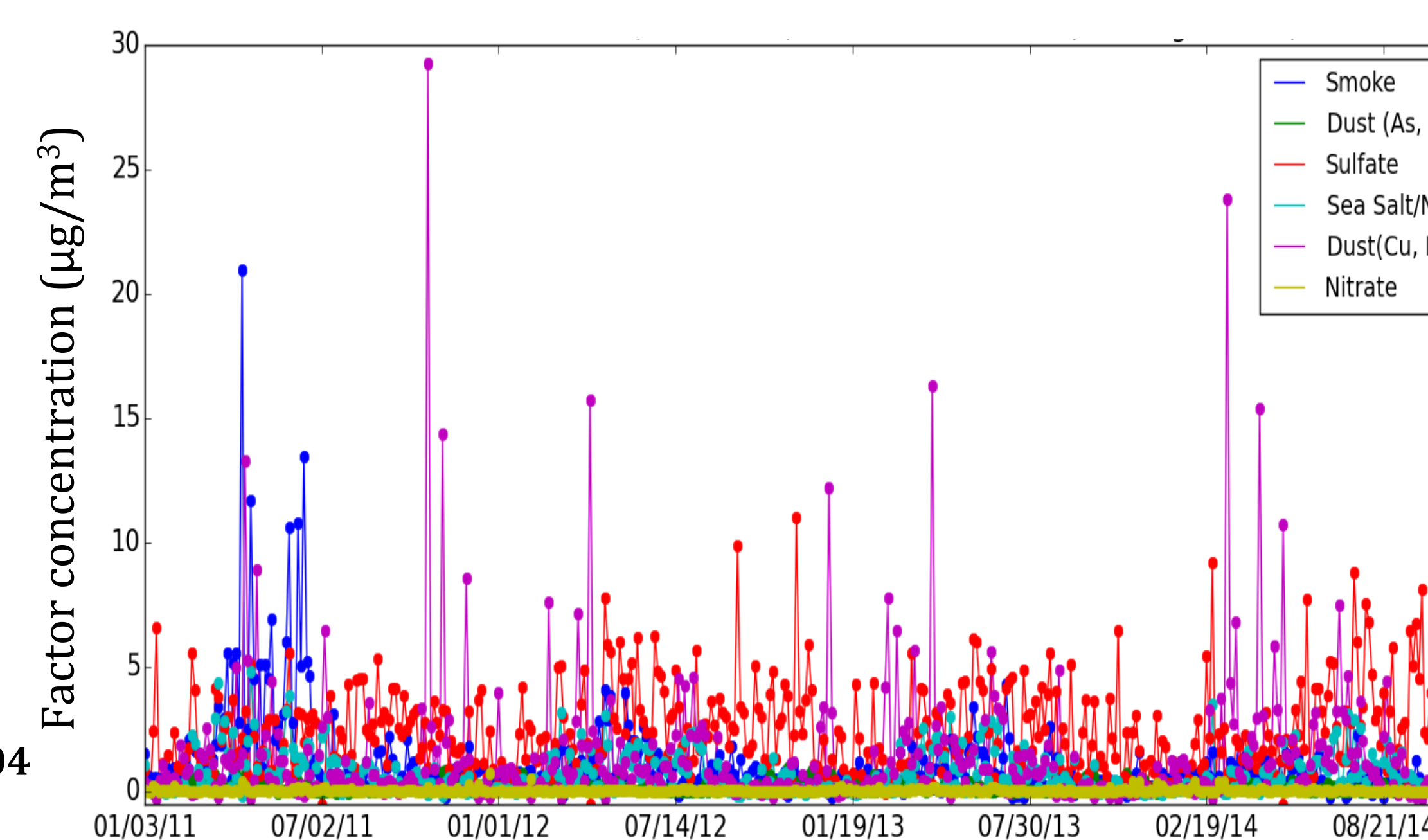
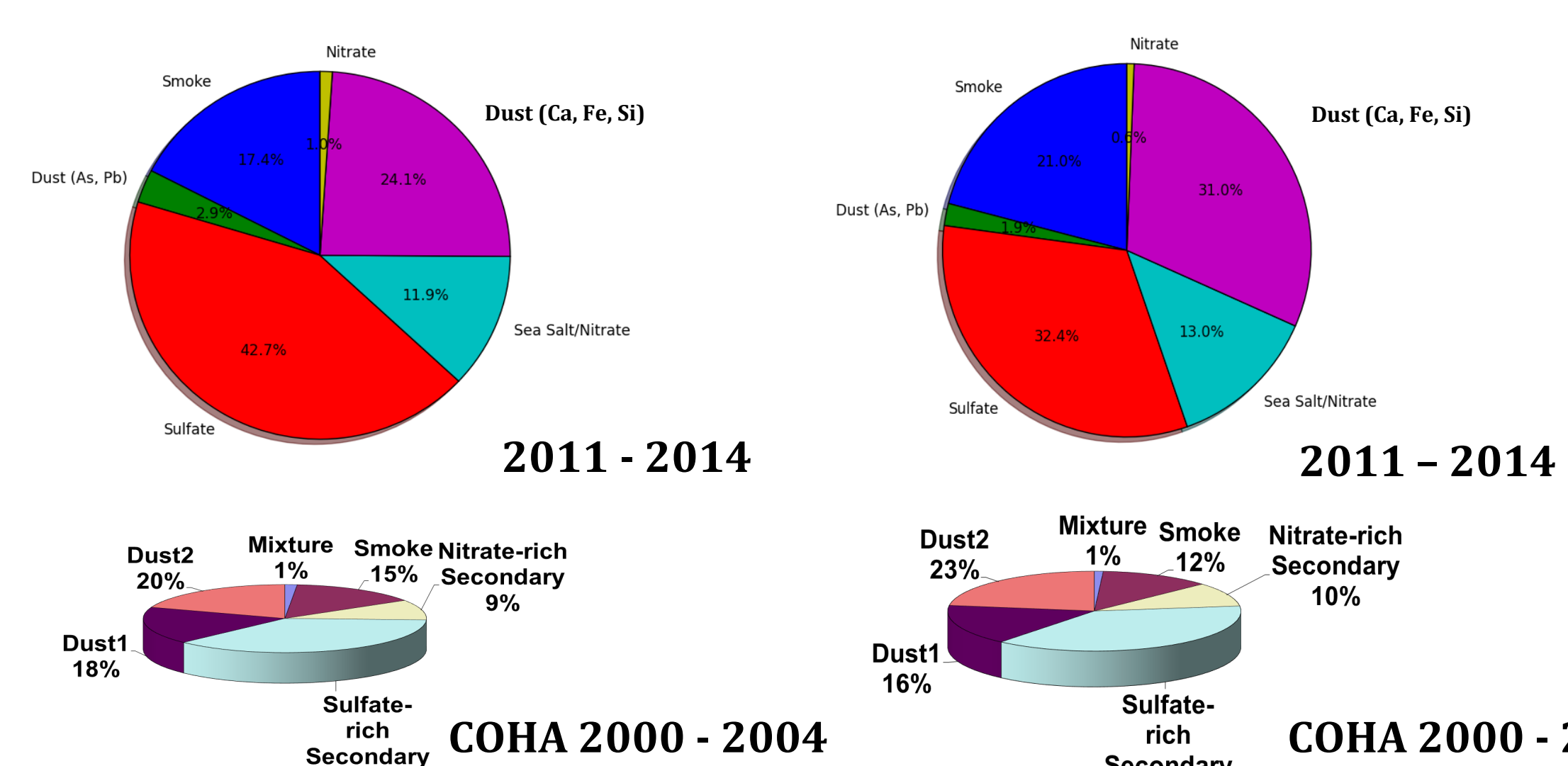
Factor 5 is identified as a mineral dust ("Dust (Ca, Fe, Si)").



Factor 3 is identified as secondary sulfate pollution ("Sulfate").



Factor 6 is identified as secondary nitrate pollution ("Nitrate").

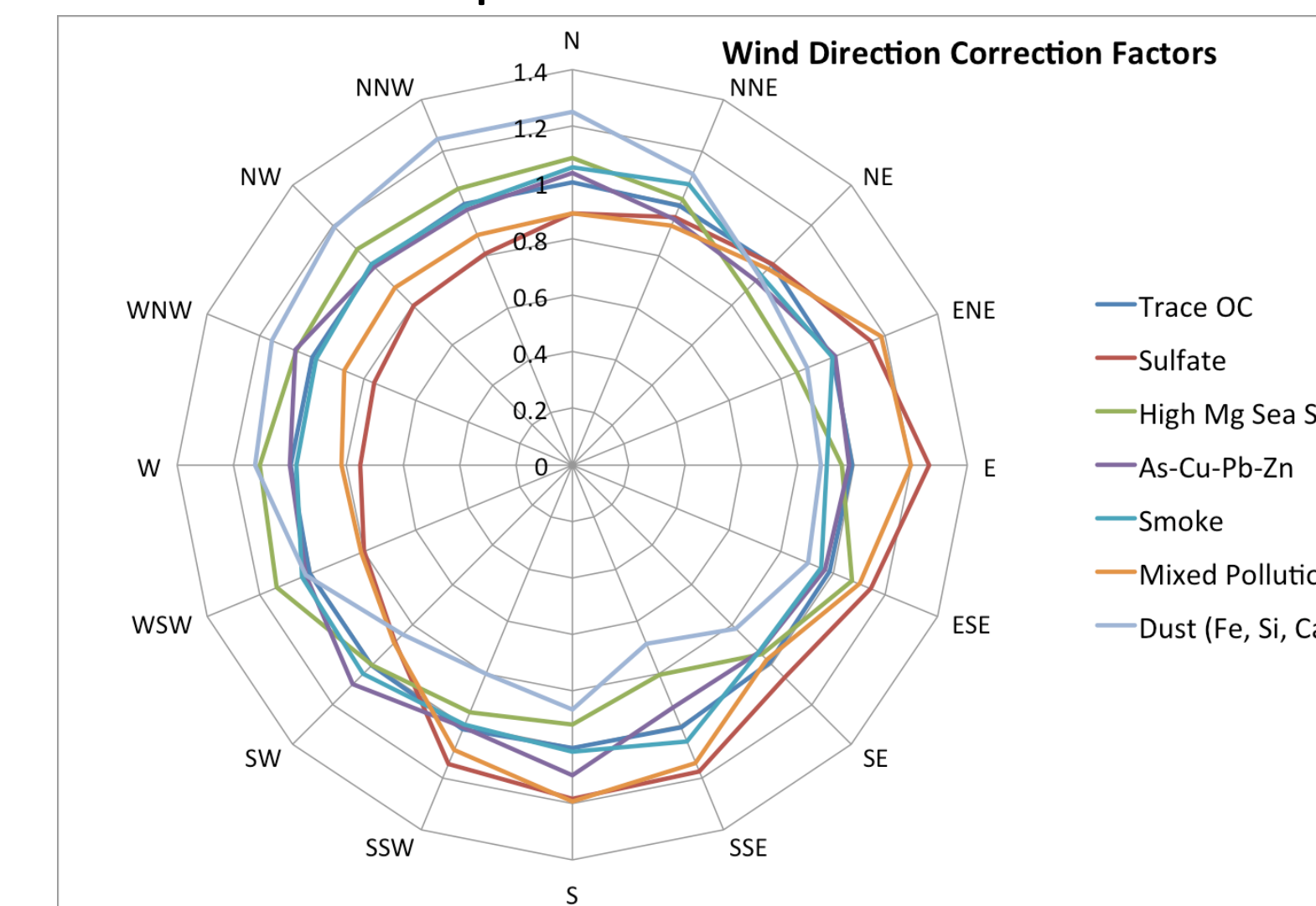


Time series of factor contributions in µg/m<sup>3</sup> to PM<sub>2.5</sub> measured concentrations at BIBE during 2011 – 2014.

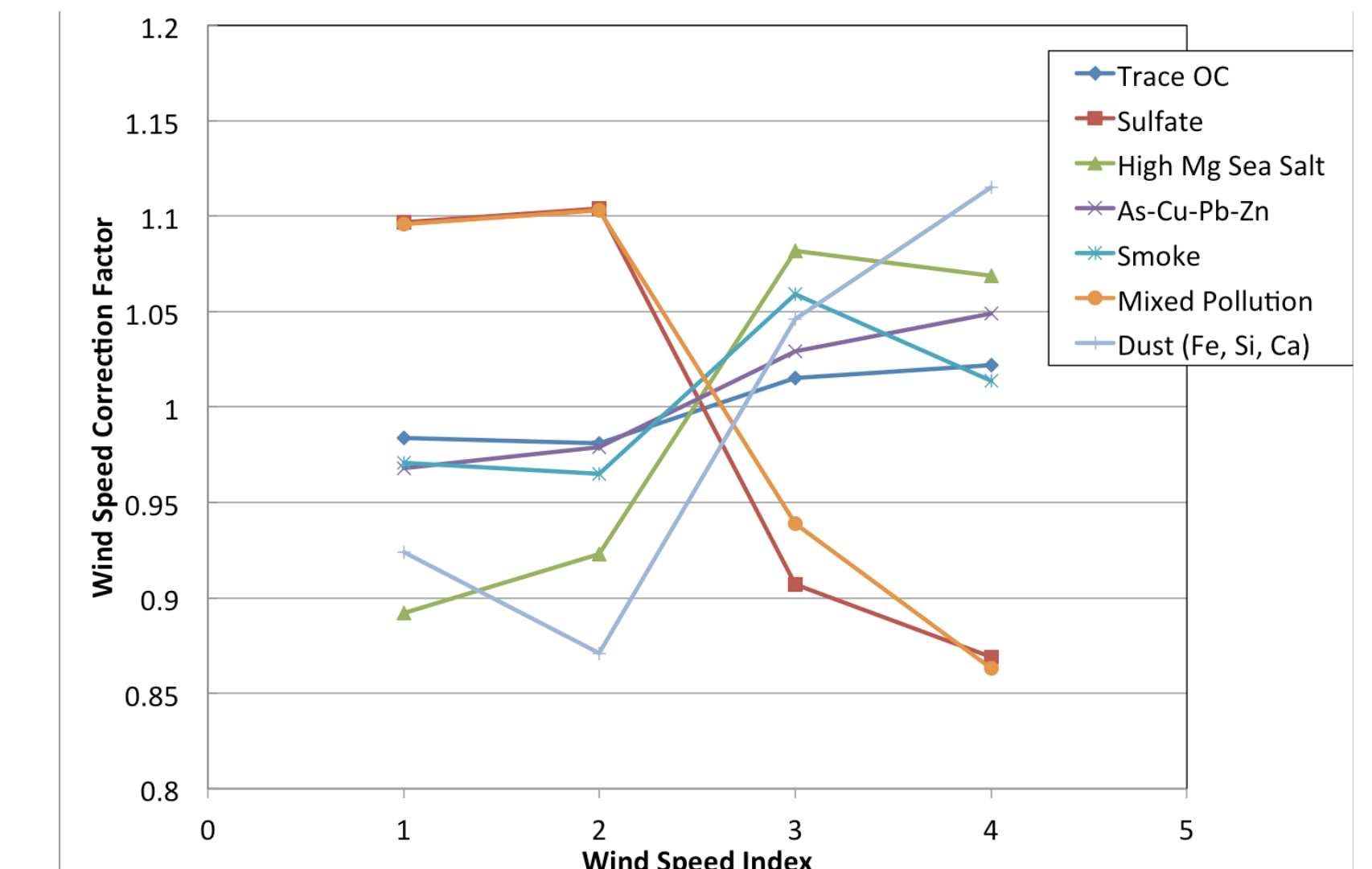
**References**  
 Green, M., 2006: Causes of Haze Assessment, online available report available at <http://coha.dri.edu/index.html>.  
 Lin, J. C., C. Gerbig, S. C. Wolsey, A. E. Andrews, B. C. Daube, K. J. Davis, and A. Grainger, 2003: A near-field tool for simulating the upstream influence of atmospheric observations: The stochastic time-inverted Lagrangian transport model (STILT), *J. Geophys. Res.*, 108(D16), 4493, 10.1029/2002JD003161.  
 Paatero, P., 2009: Extended factor analysis, enhanced with error estimation of composition factors and with different rotational tools, including PMF2-style FPEAK rotations, internal memo prepared for EPA, June 17, 2009, 38 pp.  
 Paatero, P., and P. K. Hopke, 2002: Utilizing wind direction and wind speed as independent variables in multilinear receptor model studies, *Chemom. Intell. Lab. Syst.*, 60, 25-41.

## Expanded Parametric Model

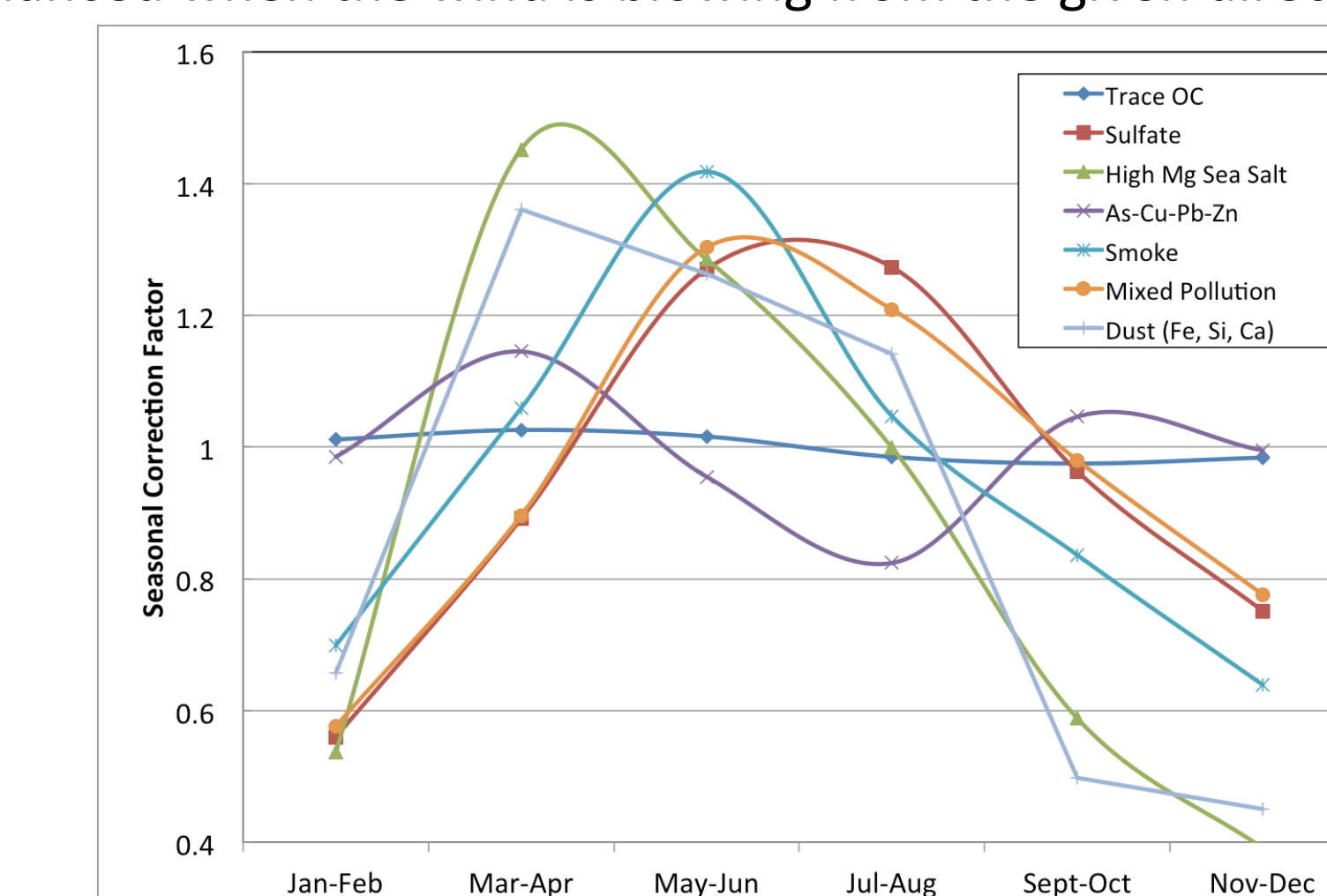
The Expanded Parametric Model [Paatero and Hopke, 2002, Paatero, 2009] is a method to incorporate meteorological and other variables directly into the PMF analysis. In this analysis wind speed, wind direction, day of the week and season were incorporated into a 7-factor PMF analysis.



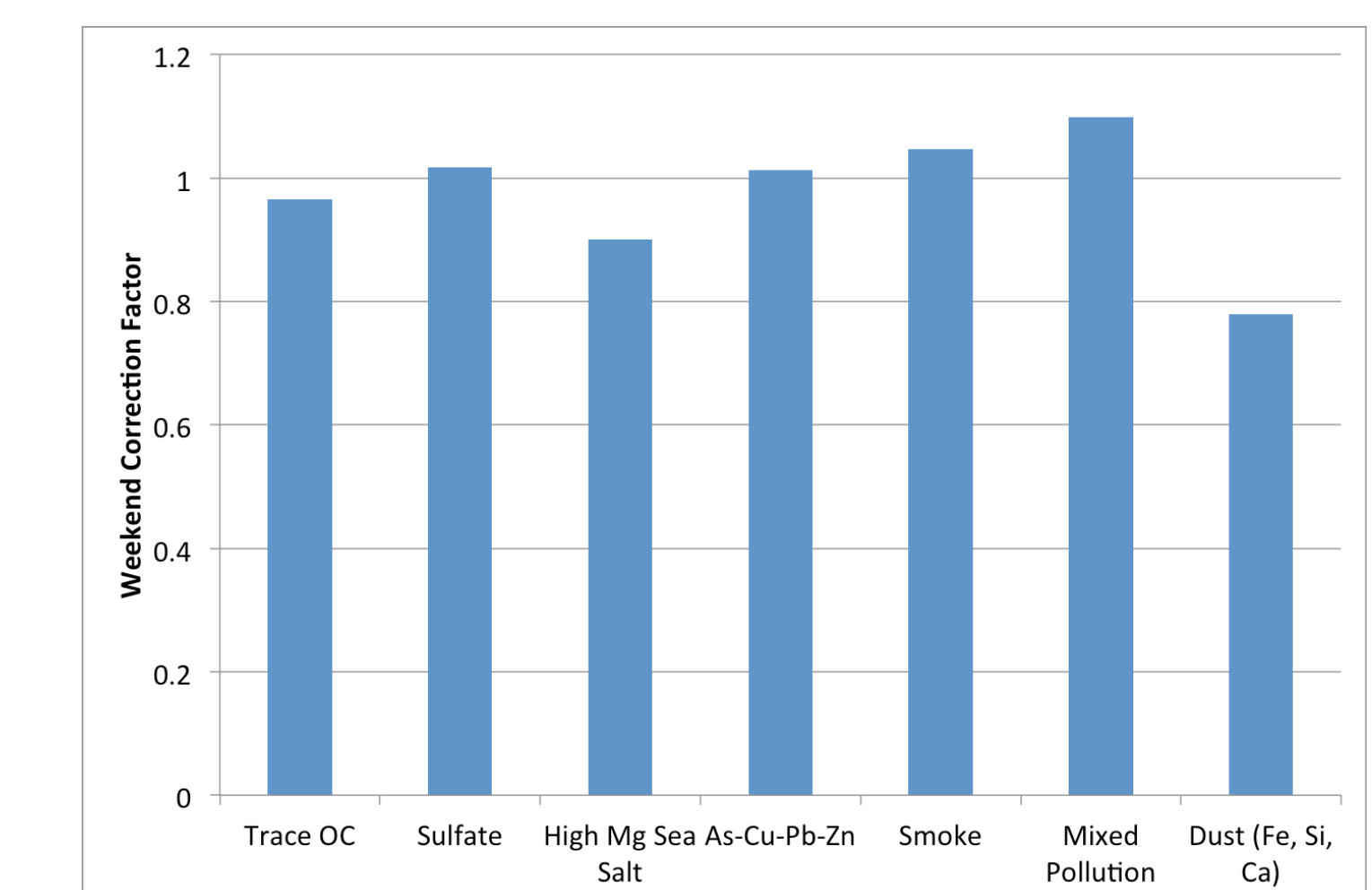
The wind direction correction factors for the 7-factor extended parametric model fit. A value above 1 means that the factor is enhanced when the wind is blowing from the given direction.



The wind speed correction factors for the 7-factor extended parametric model fit. A value above 1 means that the factor is enhanced when the wind is blowing at the given speed.



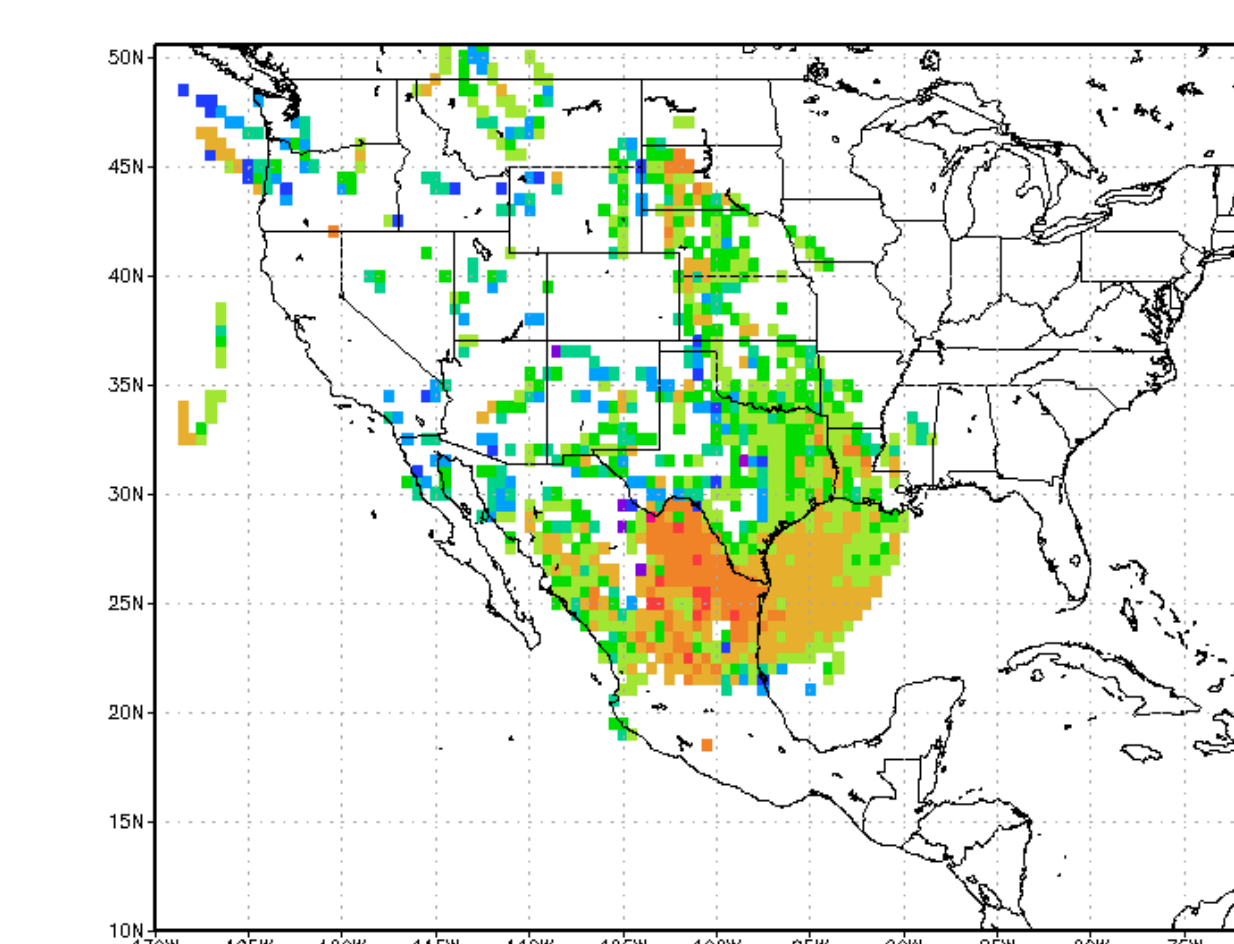
The seasonal correction factors for the 7-factor extended parametric model fit. A value above 1 means that the factor is enhanced during that two-month period.



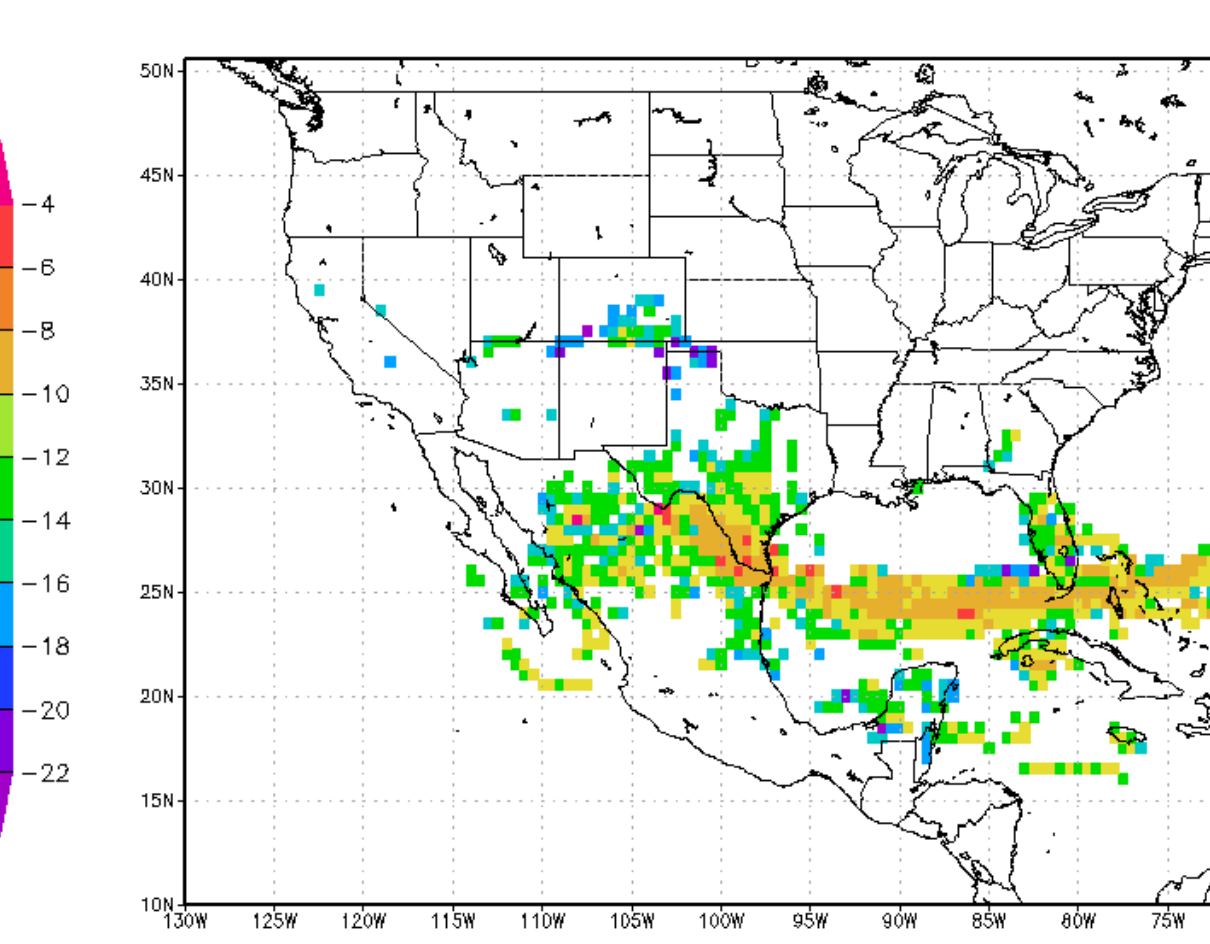
The weekend correction factors for the 7-factor extended parametric model fit. A value above 1 means that the factor is enhanced.

## Footprint Analysis

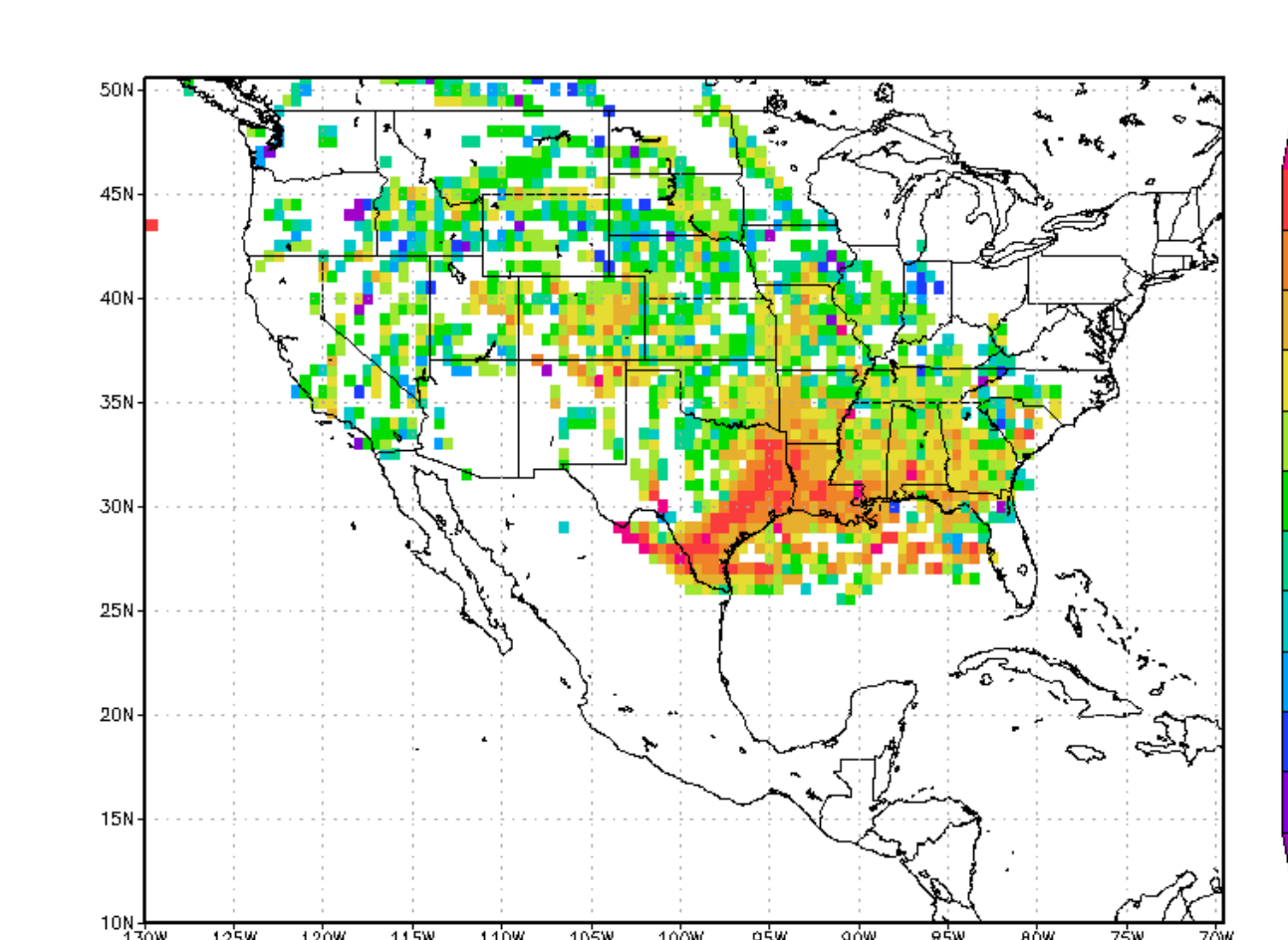
STILT 10-day footprints were calculated using the 32 km North American Regional Reanalysis (NARR) for receptors at BIBE. The footprint represents the influence of upwind surface fluxes on concentrations measured at a receptor. Examining footprints can provide a better understanding of the transport patterns influencing PM<sub>2.5</sub> at BIBE.



Footprints as ln(ppmv/µmol/m<sup>2</sup>/s) for January 15, 2011, a day with a relatively high sulfate source contribution factor.



Footprints for June 2, 2011, a day with a relatively low sulfate factor but with a moderately high smoke factor.



Footprints for August 28, 2011, a day with a high sulfate factor and moderate smoke factor.

Average 2011 – 2014 footprints for all the days with greatest 20% PM<sub>2.5</sub> concentrations (left) and lowest 20% PM<sub>2.5</sub> concentrations (right) measured in BIBE.

## Summary

1. The major contributing factors to the PM<sub>2.5</sub> concentrations in BIBE during 2011 – 2014 were secondary sulfate pollution, dust, and biomass burning smoke.
2. The proportional contribution of sulfate pollution decreased substantially compared to the COHA analysis of 2000 – 2004.
3. The Expanded Parametric Model is a reasonable way to add additional meteorological and other data such as wind speed, wind direction, season, and day of week but provided little additional information.
4. The STILT footprint analysis indicated that the strongest source region for all factors was from south and west of BIBE in north central Mexico.

### Acknowledgements

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The Pie charts show factor contributions to the PM<sub>2.5</sub> concentrations for 2011 – 2014 and COHA PMF runs for 2000 – 2004 from Green [2006]. The charts to the right are segregated by the days with the highest (top) and lowest (bottom) 20 % of PM<sub>2.5</sub> concentrations.

