LAX Air Quality and Source Apportionment Study

Welcome

Robert Freeman
Los Angeles World Airports

Los Angeles World Airports
Facilities Management Group

Public Symposium

September 28, 2013

Phase III Study – Consultant Team Organization Chart

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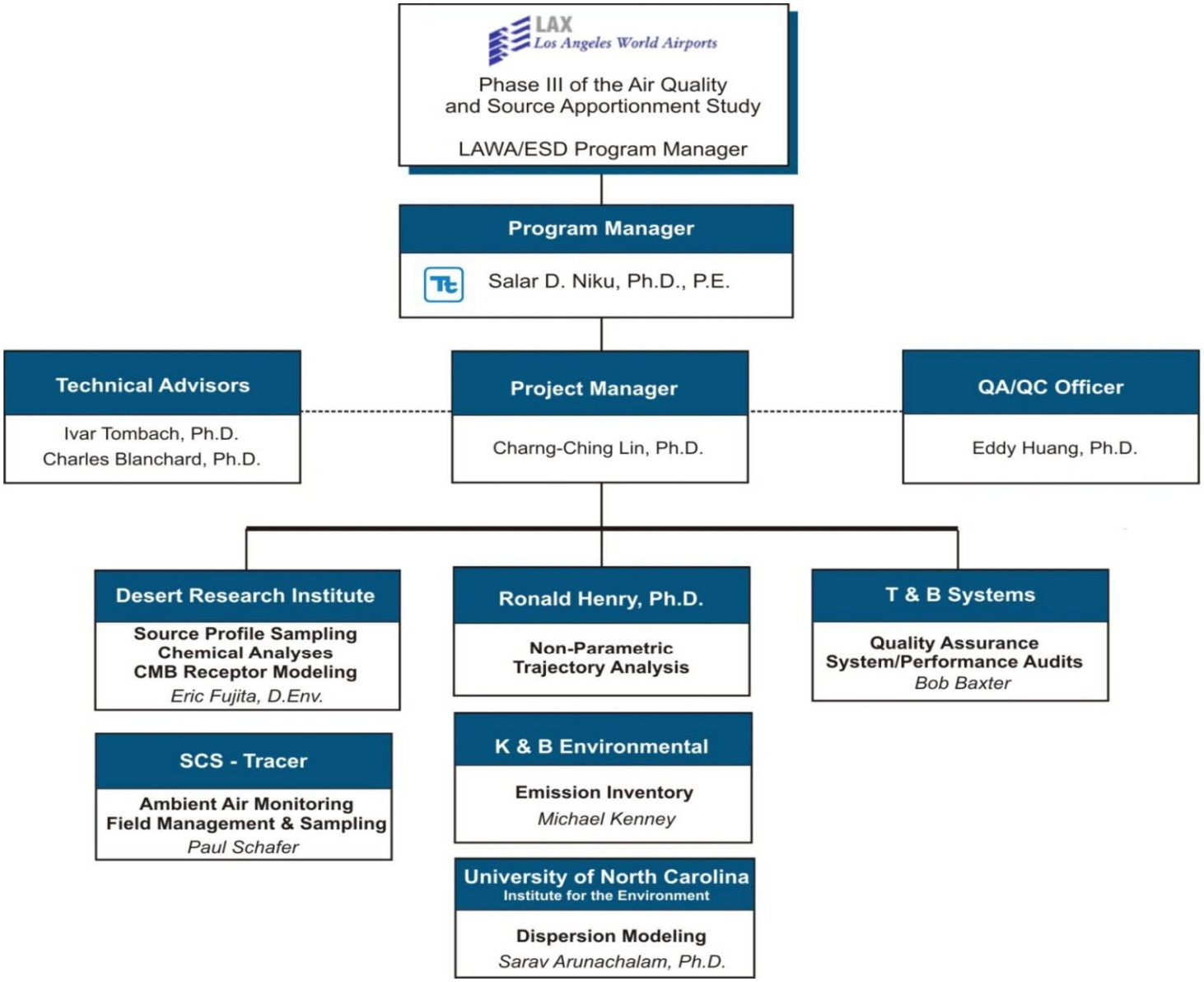

LAX Air Quality and Source Apportionment Study

Overview

John R. Pehrson, P.E.
CDM Smith

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LAX Air Quality & Source Apportionment Study

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- First apportionment study of its kind at a major airport
- Study was conducted by internationally recognized team of independent experts in the field of air quality and source apportionment
- Met the objective of apportioning emissions
- Supplemental study was performed to further investigate ultrafine particle (UFP) sources
- Produced valuable new information that will support future research by the scientific community

Study was Conducted in 3 Phases

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- Phase I - Preparation
- Phase II - Demonstration Project
  - Evaluated measurement techniques
  - Recommended pollutants for further study
- Phase III - Core Study
  - Two 6-week measurement periods
  - Source Apportionment (4 approaches)
  - Supplemental Study

Conducted by Jacobs Consultancy, Inc., now known as LeighFisher

Conducted by Tetra Tech, Inc.

Monitoring Locations

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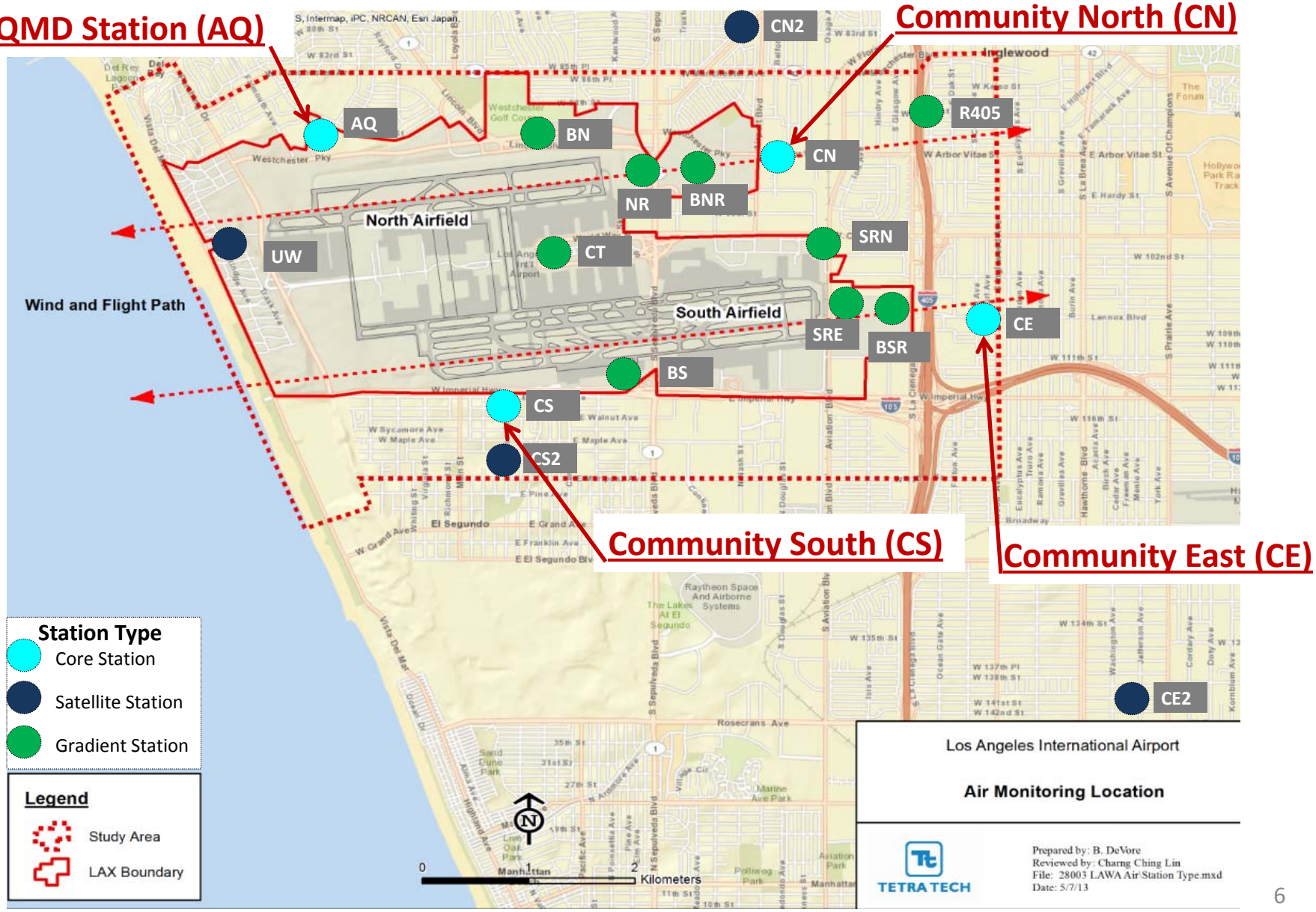

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LAX Area AQ vs Standards & Regional AQ

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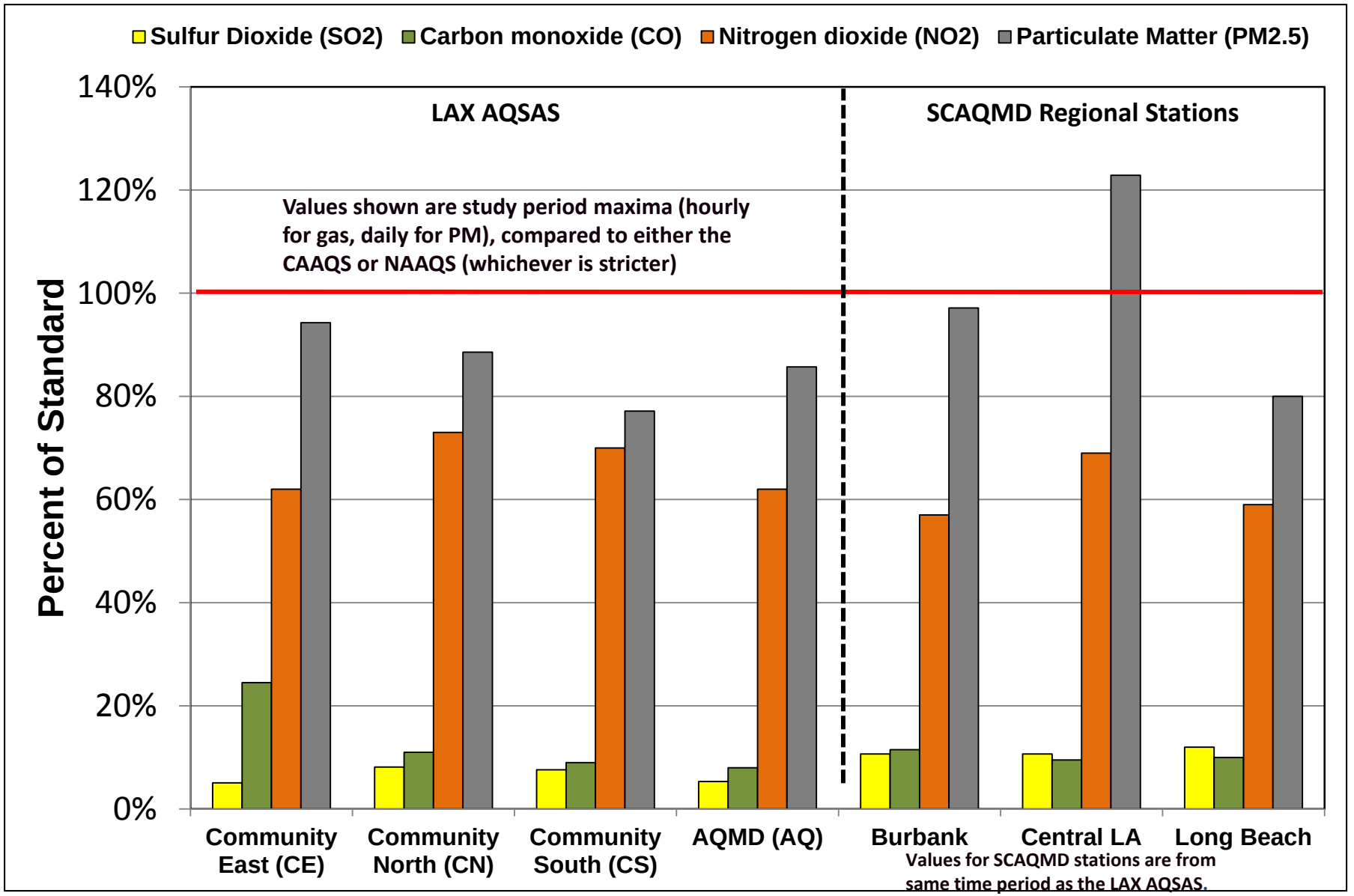

Air Toxics: LAX Area vs Regional

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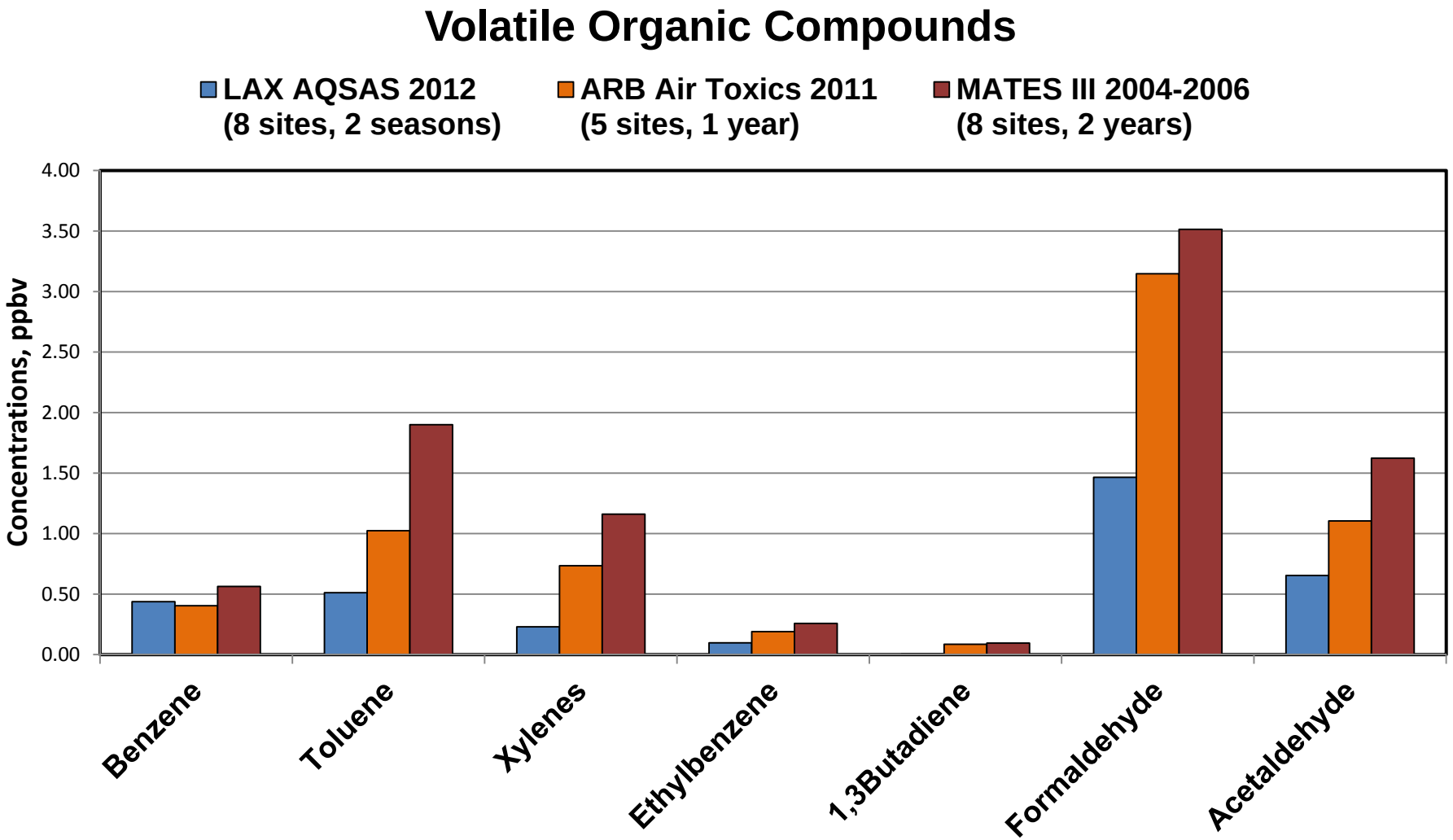

Source Apportionment Findings

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- CO: 11 to 51 percent on-airport contribution
- NO_x: 16 to 76 percent on-airport contribution
- BC: 17 to 70 percent on-airport contribution
- SO_2: 9 to 84 percent on-airport contribution
- UFP: 52 to 94 percent on-airport contribution
- $PM_{2.5}$: 5 to 20 percent airport-related contribution

AQSAS UFP Supplemental Study

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- Based on data analysis from 1st Season sampling, a supplemental study was conducted to further investigate UFP sources
- Larger UFPs appear to be associated with motor vehicle emissions
- Smaller UFPs appear to be associated with jet engine exhaust
- Currently, no regulatory standards for UFP

LAX Air Quality and Source Apportionment Study

Air Quality Monitoring

David Campbell
Desert Research Institute

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Acknowledgments

- LAWA: Environmental Services Division (Norene Hastings, Nancy Price, Amylou Canonizado); Airports Development Group (Bob Werner)
- Tetra Tech: Charng Ching Lin, Erica Alvarado, Jay Sandoval
- SCS Tracer Environmental: Paul Schafer
- South Coast Air Quality Management District: Los Angeles-LAX air quality monitoring station (AQ), Sumner Wilson
- Community Volunteers
  - La Feria Restaurant
  - El Segundo Unified School District
  - Crislyn McKerron
  - Sally Lokey
  - F. Michael Lewis
  - Trinity Lutheran Church School: Rev. Lawrence Becker, Fran Sanders
- DRI Organic Analysis Laboratory: Barbara Zielinska, Ph.D., Anna Cunningham and Mark McDaniel
- DRI Environmental Analysis Facility: Judith Chow, Ph.D., Steven Kohl, Ed Hackett, Dana Trimble and Brenda Cristani

What air pollutants were measured and why?

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- Criteria Pollutants
  - Pollutants for which air quality standards have been established by EPA and CARB
  - Routinely monitored at many locations throughout the U.S.
  - CO, NO_2, SO_2, $PM_{2.5}$
  - Standards are in terms of maximum allowable peak hourly or daily values, so continuous monitoring is required
    - Federally approved methods were used for monitoring these pollutants
  - Ozone was not measured as it is a secondary pollutant (formed by photo-chemical reaction of other pollutants) so high levels occur miles downwind from pollution sources

What air pollutants were measured and why?

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- Criteria Pollutants
- Air Toxics
  - Chemical compounds (e.g. benzene, formaldehyde) and metals (e.g. cadmium, mercury) that *"are known or suspected to cause cancer or other serious health effects"*
  - Produced by mobile sources (autos, trucks, ships), industrial processes, consumer products (paint, cleaning solvents), and fuel combustion (wood fires, natural gas)
  - No standards for these pollutants, but relationships between ambient concentrations and health impacts may have been established
  - These are routinely monitored at a few locations in L.A. and other major urban areas
  - LAX AQSAS measured weekly and daily average concentrations of a subset of the 187 air toxics currently listed by EPA
    - Excluded compounds from indoor sources and industries not operating in the LAX area

What air pollutants were measured and why?

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- Criteria Pollutants
- Air Toxics
- Surrogate Measurements

  Measurements related to pollutants of concern that cannot be directly measured

  – Black Carbon (BC) or Elemental Carbon (EC); surrogate for diesel particulate matter (DPM), a known carcinogen

  – Ultra-fine Particles (UFP); indicator of freshly formed aerosol particles

- Meteorology; provides information about pollutant transport and dispersion

What are BC and EC?

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- Black Carbon or Elemental Carbon (aka *soot*)
  - Highly visible particulate air pollutant that occurs throughout urbanized areas and near roads with significant heavy-duty diesel vehicle traffic
  - Not a specific chemical compound; defined by the measurement method used
    - No standards or health-based threshold levels have been established
  - Often associated with toxic organic compounds such as Polycyclic Aromatic Hydrocarbons (PAH)
  - Used as a surrogate for diesel engine exhaust, *but also produced by other combustion sources*

What is UFP?

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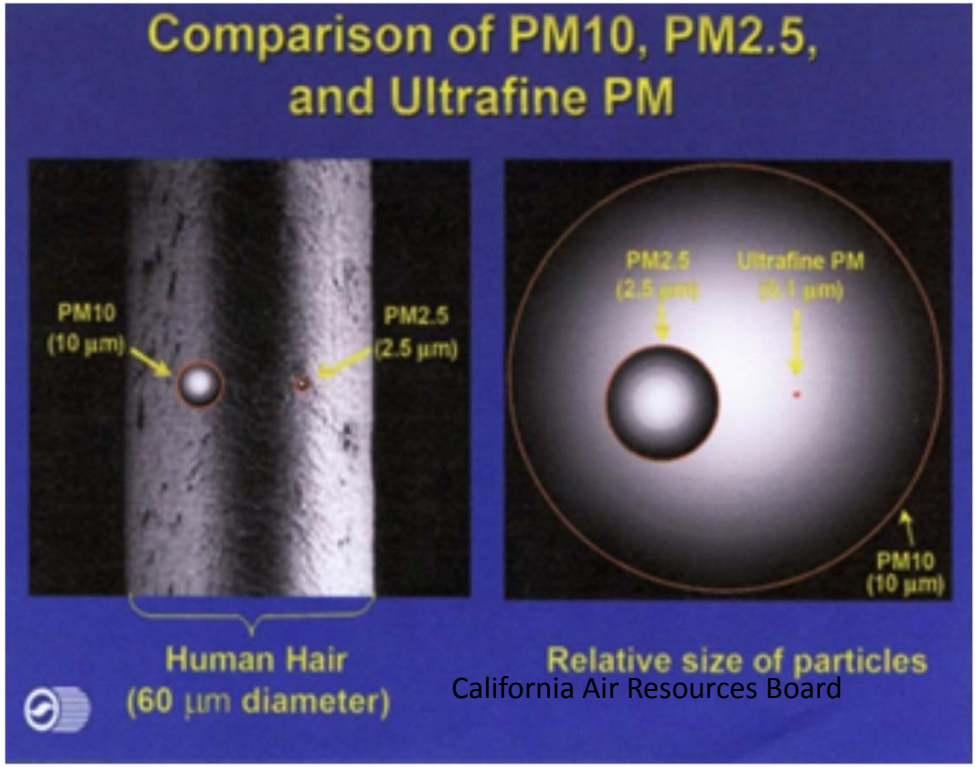
- Ultra-Fine Particles (UFP) < 100 nm in diameter
  - Ultra-Fine Particles are created by combustion (cars, trucks, power plants, cooking, smoking) and also formed by chemical reactions of gaseous pollutants (NO_x, SO_2, VOC) in the air



California Air Resources Board

Why did we measure UFP?

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- Ultra-Fine Particles (UFP)
  - Prior research indicated that UFP are an important component of jet aircraft exhaust
  - Number of UFP decrease rapidly with distance from source
    - Therefore, UFP counts may be used as an indicator of proximity to fresh emissions
  - Statistical links between high numbers of UFP and health effects have been reported, but overall evidence is not conclusive (*HEI 2013*)
    - No AQ standards or threshold levels have been established for UFP in the U.S. (and none are anticipated in the near future)

How were the measurement locations chosen?

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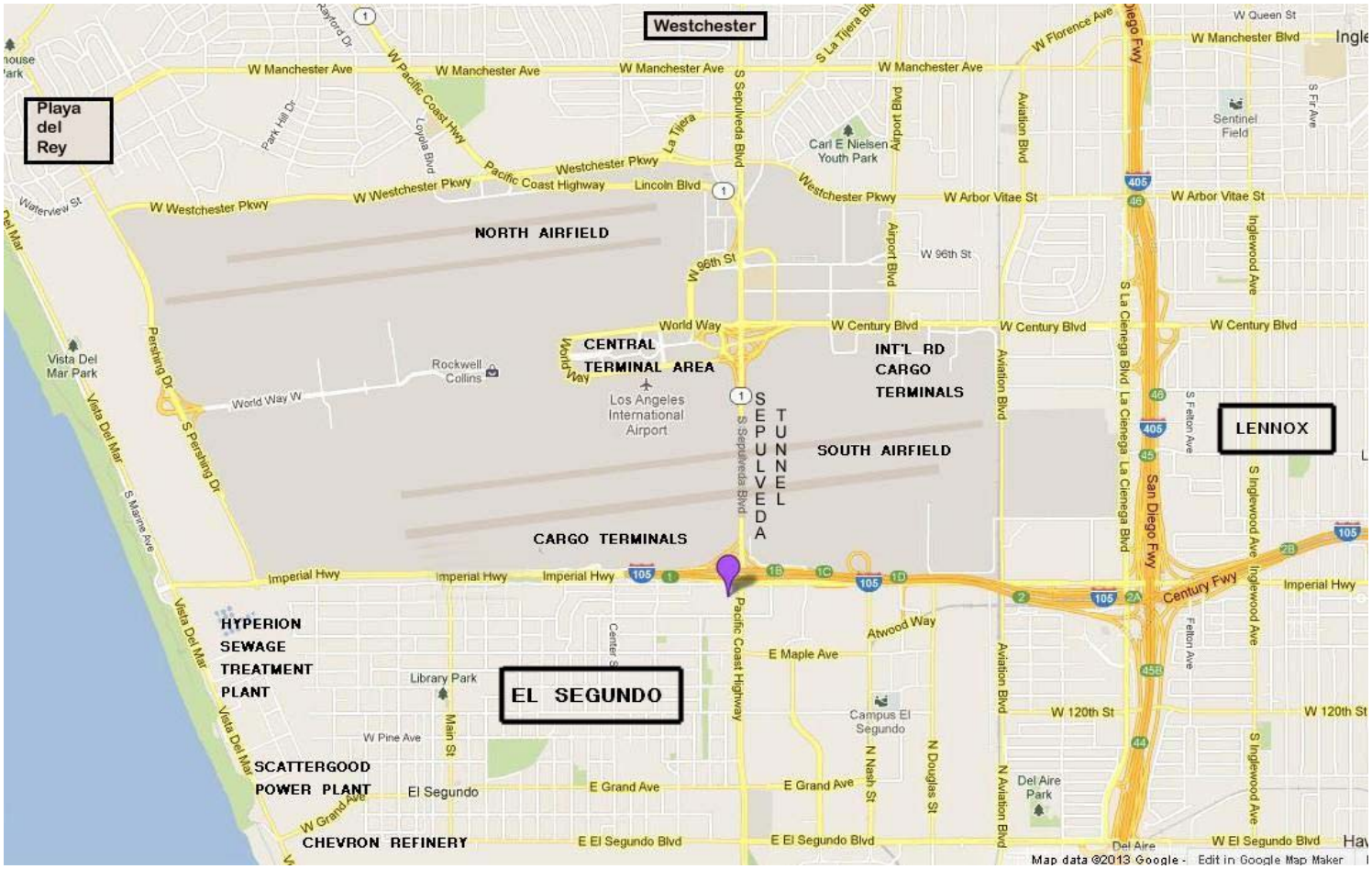
Monitoring was **design**ed to represent adjacent communities that may be impacted by airport emissions, as well as characterizing gradients between airport and residential areas



How were the measurement locations chosen?

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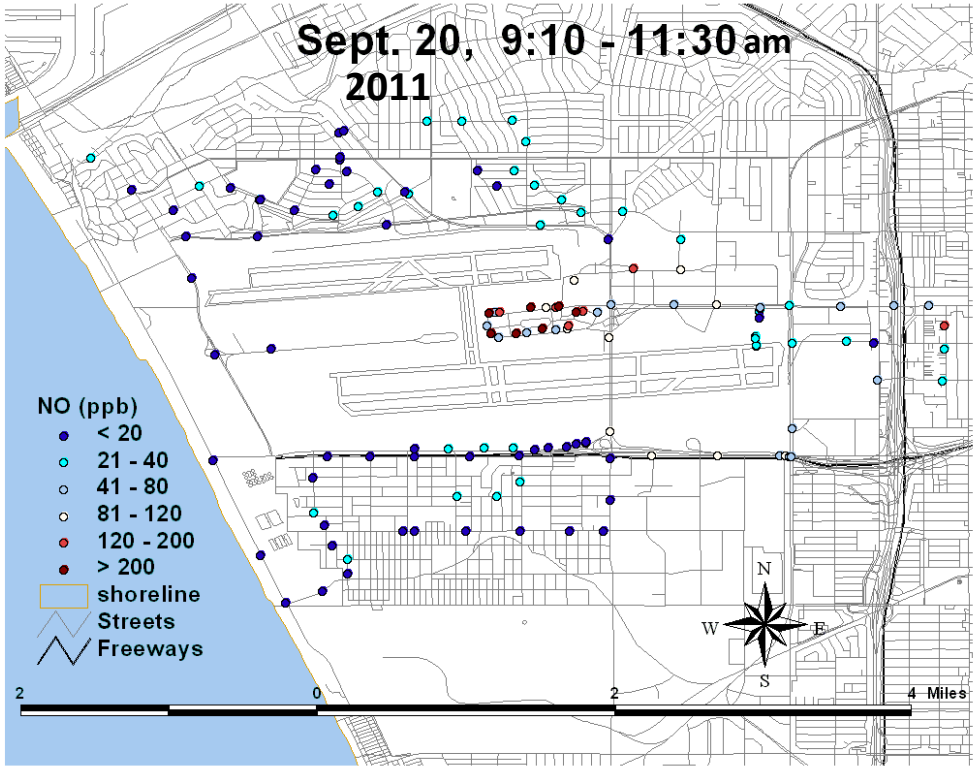
Surveys were done using mobile monitoring equipment to determine if hotspots or large spatial variability existed within target areas



How were the measurement locations chosen?

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- Approximate locations were identified as being in the target area but not too close to other local sources

- Specific locations that provided the necessary **access** and **clearance** from obstructions were selected for core site stations

- Homes with suitable conditions for monitoring were selected for secondary community sites

Sampling Locations Map

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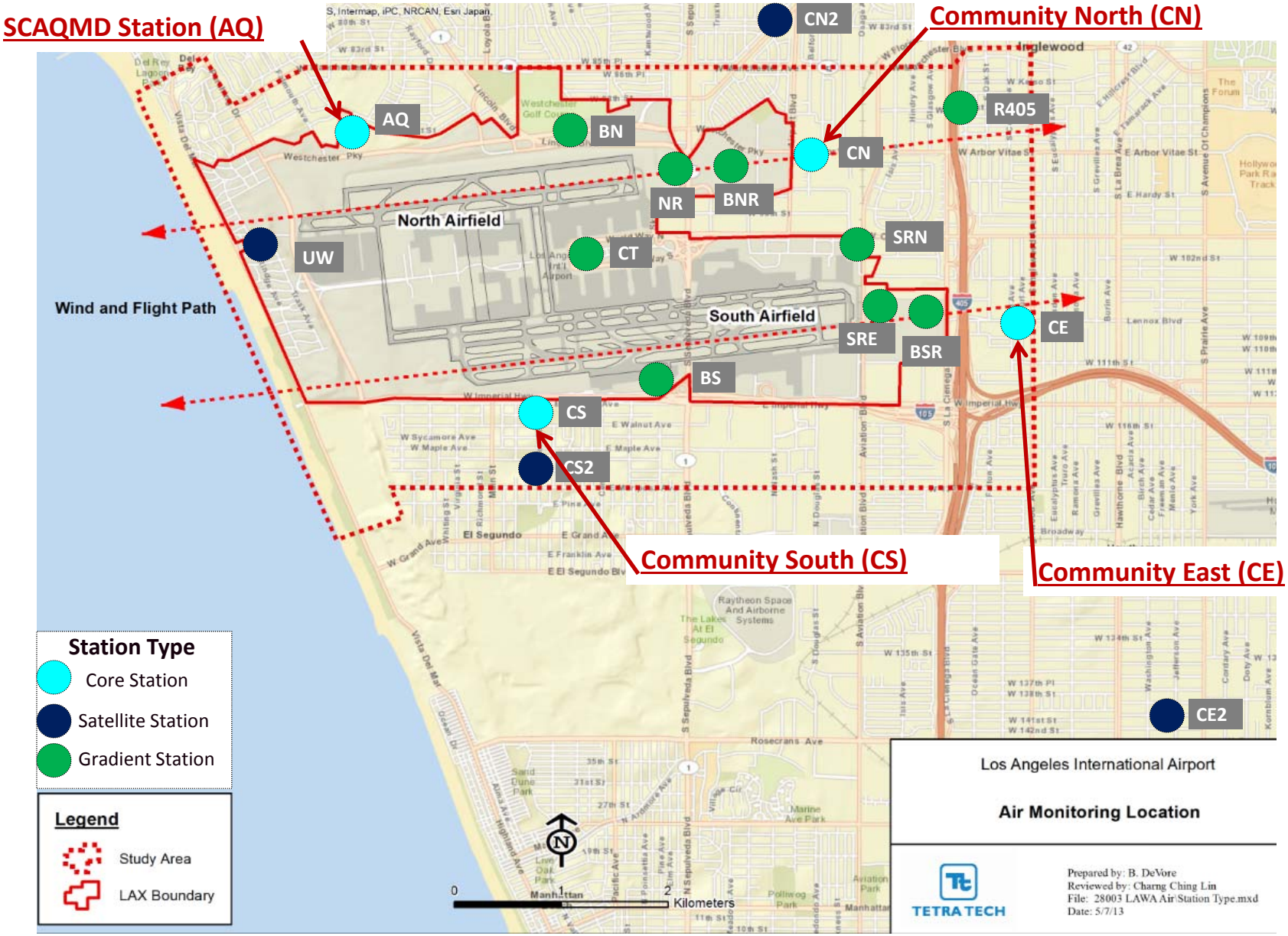

What factors influence local air quality?

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- Proximity to sources of pollutants
- Meteorology
  - Wind speed – affects dispersion of pollutants
  - Wind direction – determines transport from sources
  - Temperature – warmer air increases mixing volume
  - Humidity/precipitation – may increase or reduce particles
  - Cloud cover – sunlight promotes photochemistry
- Source Activity
  - Vehicle traffic patterns – commute periods vs. weekends
  - Flight schedules - affect level of airport activity
  - Holidays – reduce commuter and truck traffic
  - Seasonal variations – increase or decrease energy use

How do these factors influence local air quality?

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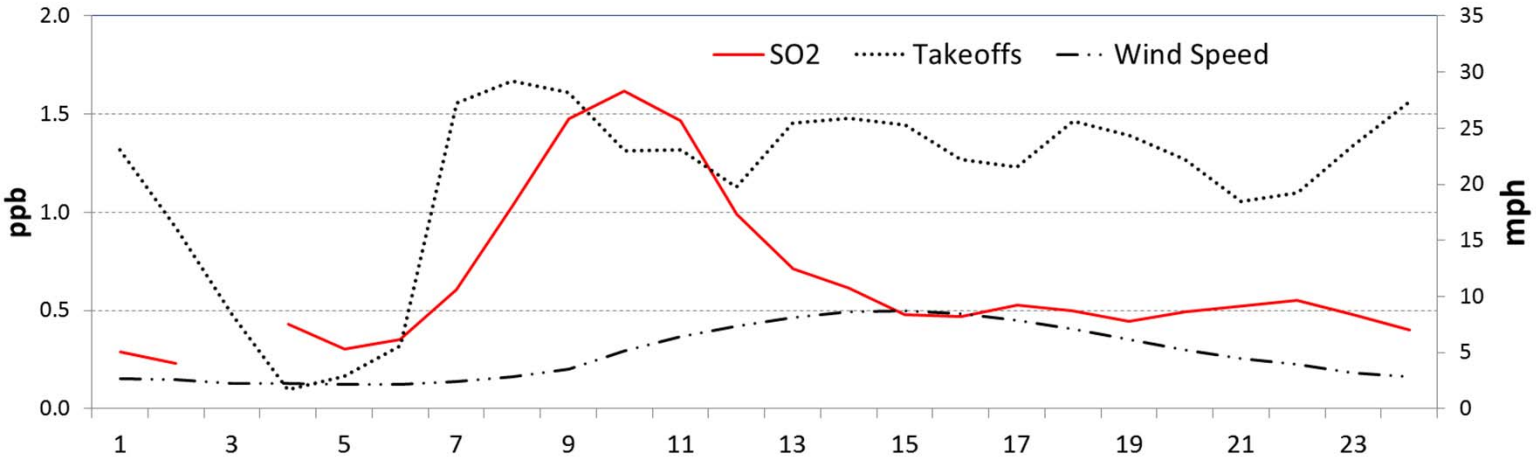
- SO_2 is a major component of aircraft exhaust but very little is emitted by on-road vehicles. It increases with runway activity, but is also affected by meteorology



Summer season data from Community East (CE) site, located east of South Runway and 405 Freeway

How do these factors influence local air quality?

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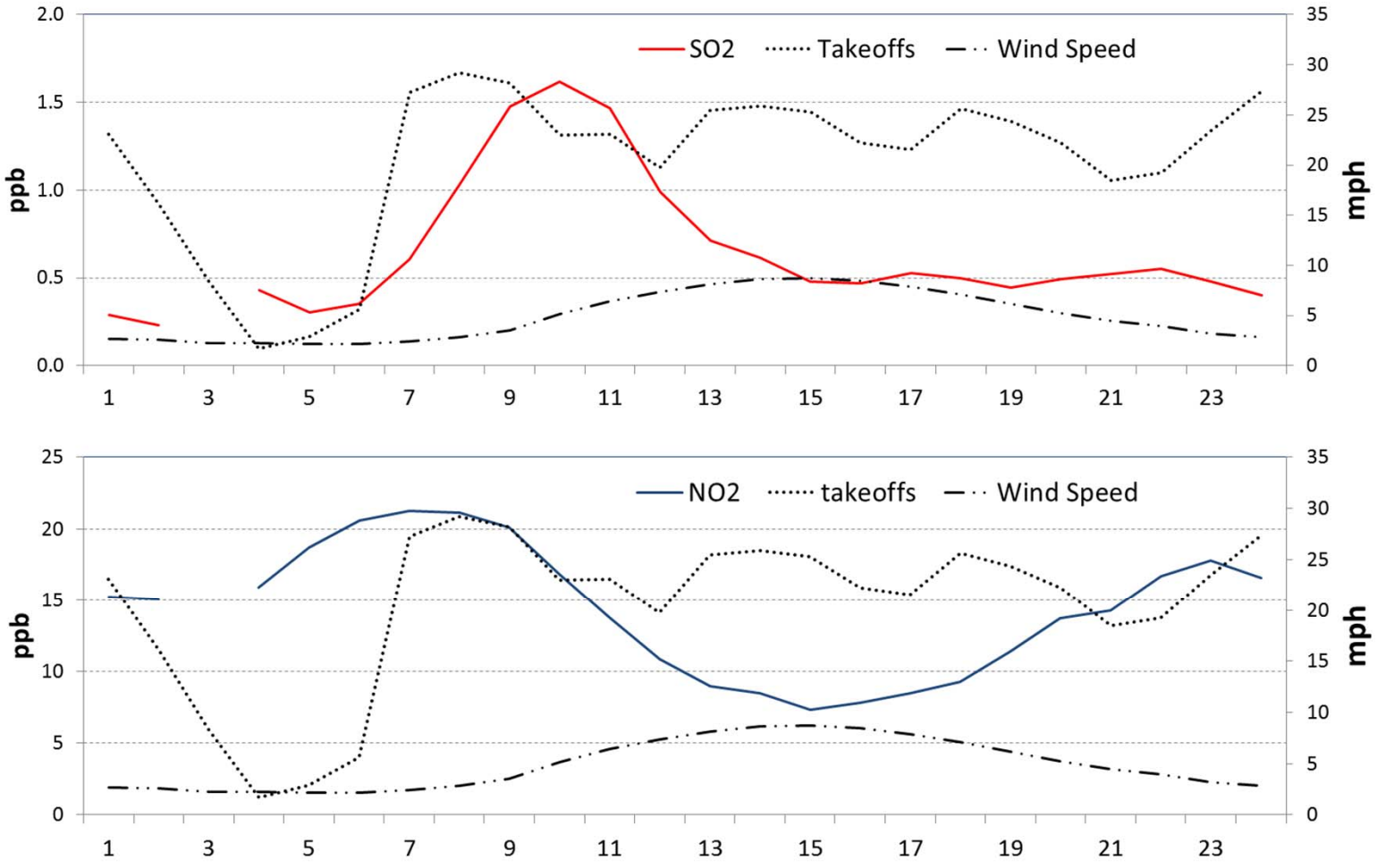
- In contrast, NO_2 is emitted by all types of engines, so it more strongly reflects on-road traffic patterns



Summer season data from CE site, located East of S. runway and 405 freeway

How were these influences taken into account?

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- Air quality measurements were made for 6-week periods to allow us to “average out” meteorology and diurnal activity patterns
- Measurements were repeated in summer and winter to investigate seasonal effects on air pollution concentrations
- Monitoring sites were set up at varying distance from sources
- Continuous monitoring of criteria pollutants and chemical analysis of daily air samples were used in conjunction with meteorology data to relate variations in pollutant concentrations to source activity patterns

Were high levels of pollution measured in my community?

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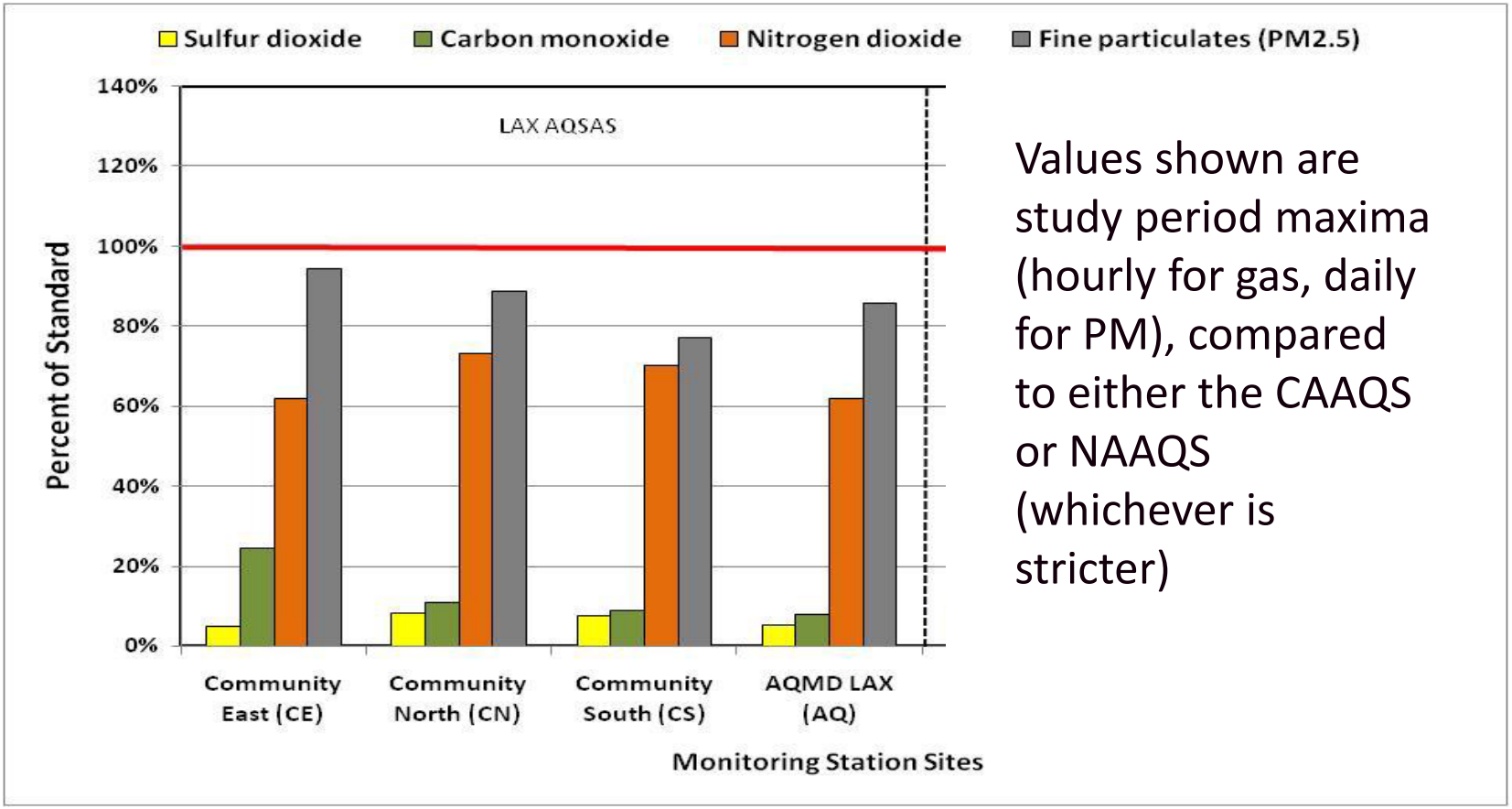
- The maximum concentrations of regulated pollutants measured at the community sites were all below existing hourly and daily Air Quality standards



Values shown are study period maxima (hourly for gas, daily for PM), compared to either the CAAQS or NAAQS (whichever is stricter)

How is the air quality in my community relative to other locations?

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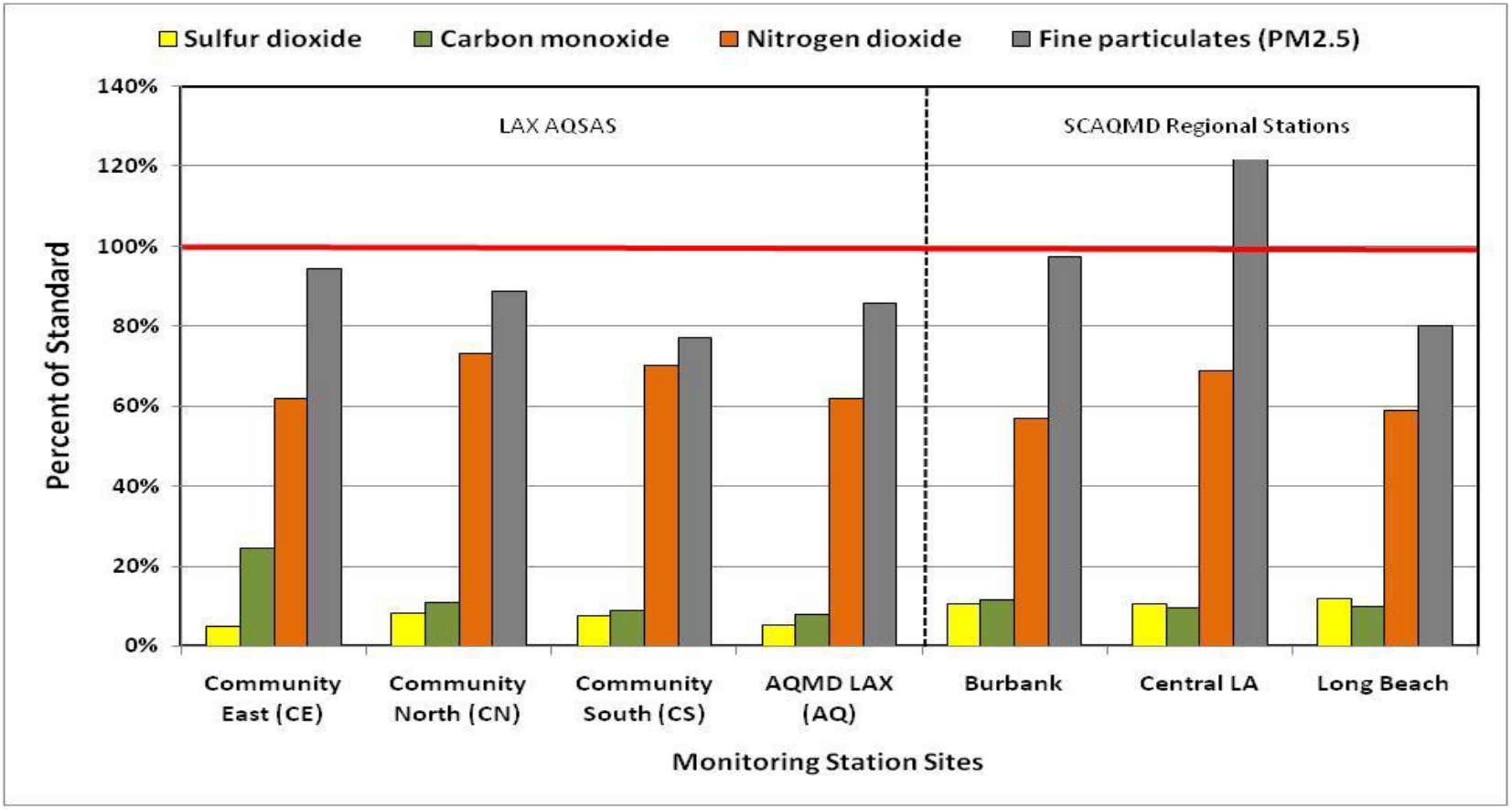
- $PM_{2.5}$ approached the level of the standard, but was not higher than at other urban monitoring sites in the region



Values for SCAQMD stations are from same time period as LAX study.

What about the “Air Toxics”?

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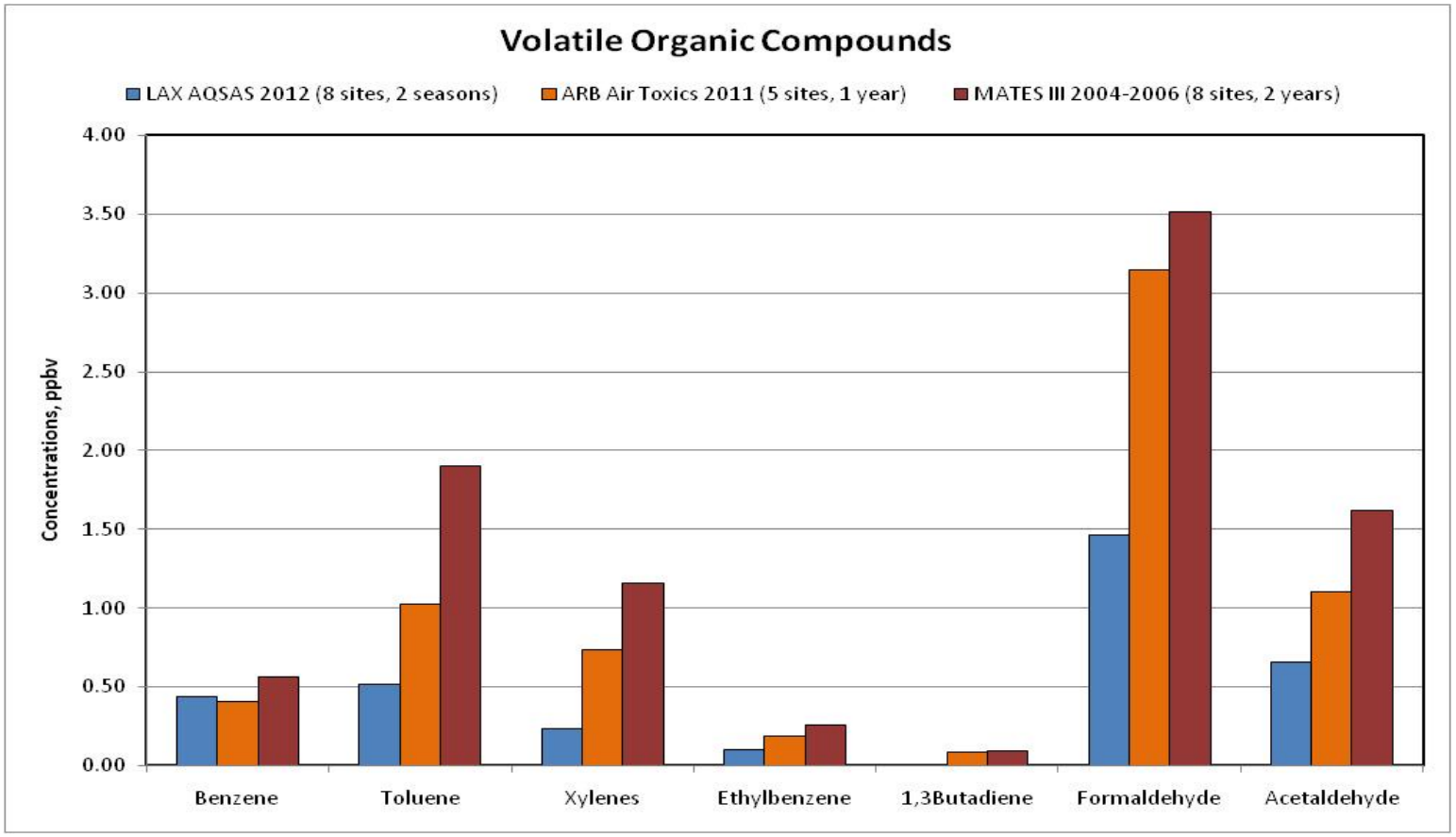
- Pollution levels measured during the study were similar to or lower than at other urban monitoring sites in the region



What about the "Air Toxics"?

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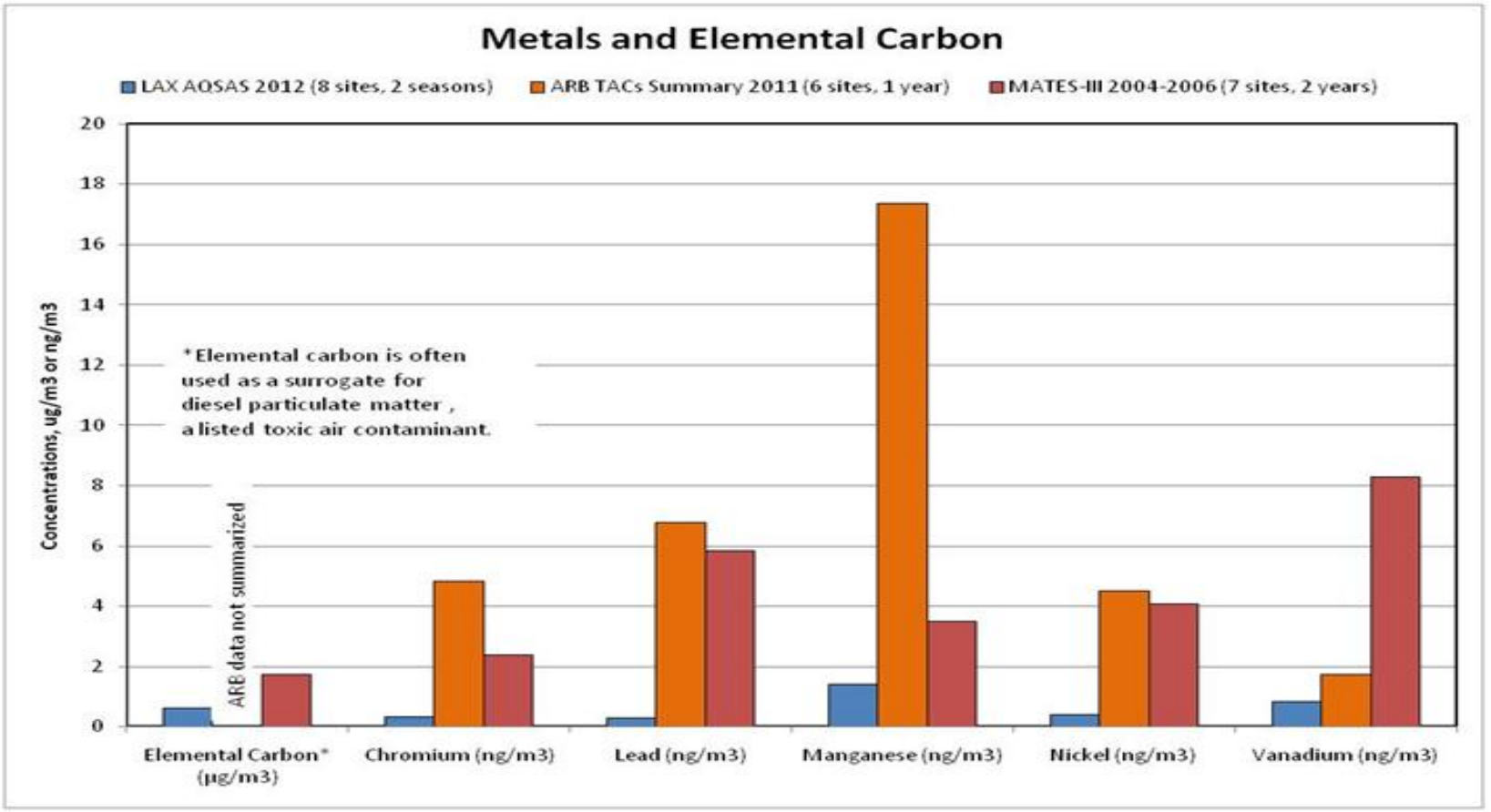
- Pollution levels measured during the study were lower than at other urban monitoring sites in the region



Are you saying there's no pollution from the airport?

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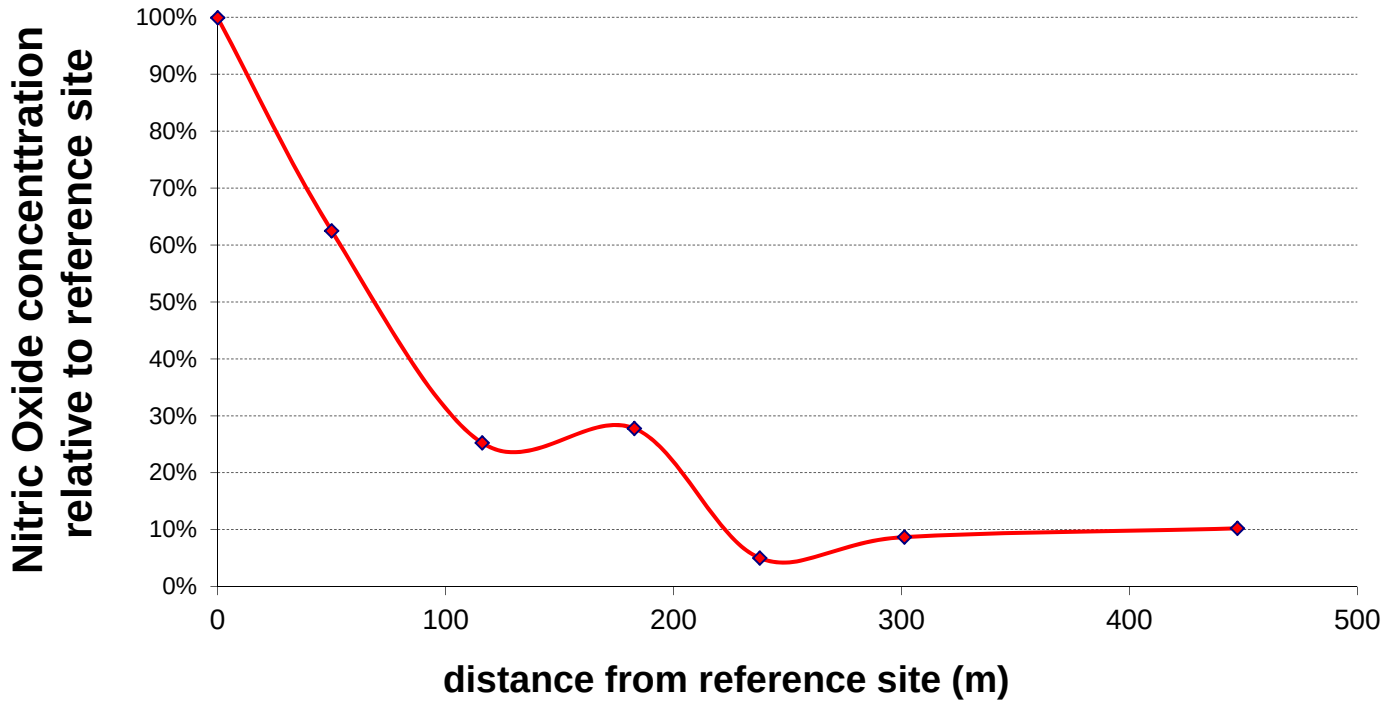
- No, higher pollutant levels were measured close to sources (busy roads and runways), but decrease rapidly downwind



Are you saying there's no pollution from the airport?

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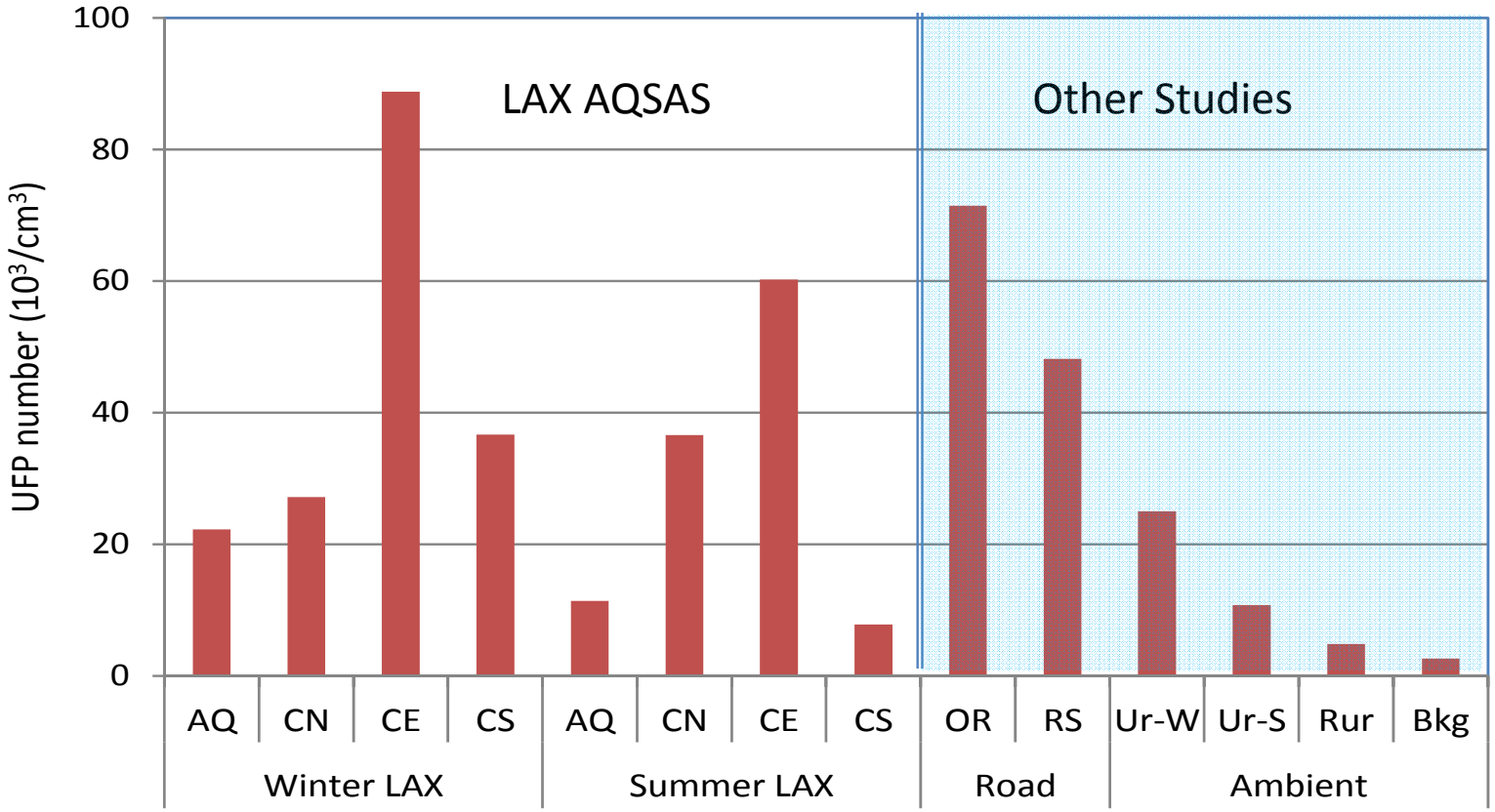
- Also, average UFP number concentrations were higher at the Community East (CE) site (downwind of the South Airfield) than typically measured at urban locations



Data from Morawska, et al. 2008, Atmos. Environ. v42(35); Hudda, et al. 2010, Atmos. Chem. Phys. Discuss., v10.

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Source Apportionment Tools and LAX AQSAS Source Apportionment Findings

Charng-Ching Lin, Ph.D.
Tetra Tech, Inc.

What is “Source Apportionment”?

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- Receptor-based models utilize chemical measurements at an individual monitoring site (**the receptor**) to calculate the relative contributions from **major sources** to the pollution at that site. Receptor-based modeling is also referred to as **source apportionment.**
- Receptor-based models are most commonly used to investigate the sources of particulate air pollution, using **speciated chemical data** of the sampled particulate matter. However, more advanced techniques that incorporate **wind trajectory data** can be applied to the gaseous pollutants.
- The main output from these models is **an estimate of the contributions from each source to the air pollution at that site**. (http://www.epa.gov/oaqps001/aqmportal/management/modeling/receptor.htm)
- In our study, a broader definition of “Source Apportionment” was used, which included **receptor modeling** and **source-based modeling**. These will be discussed in more detail in the following presentation.

What is “Source Apportionment”?

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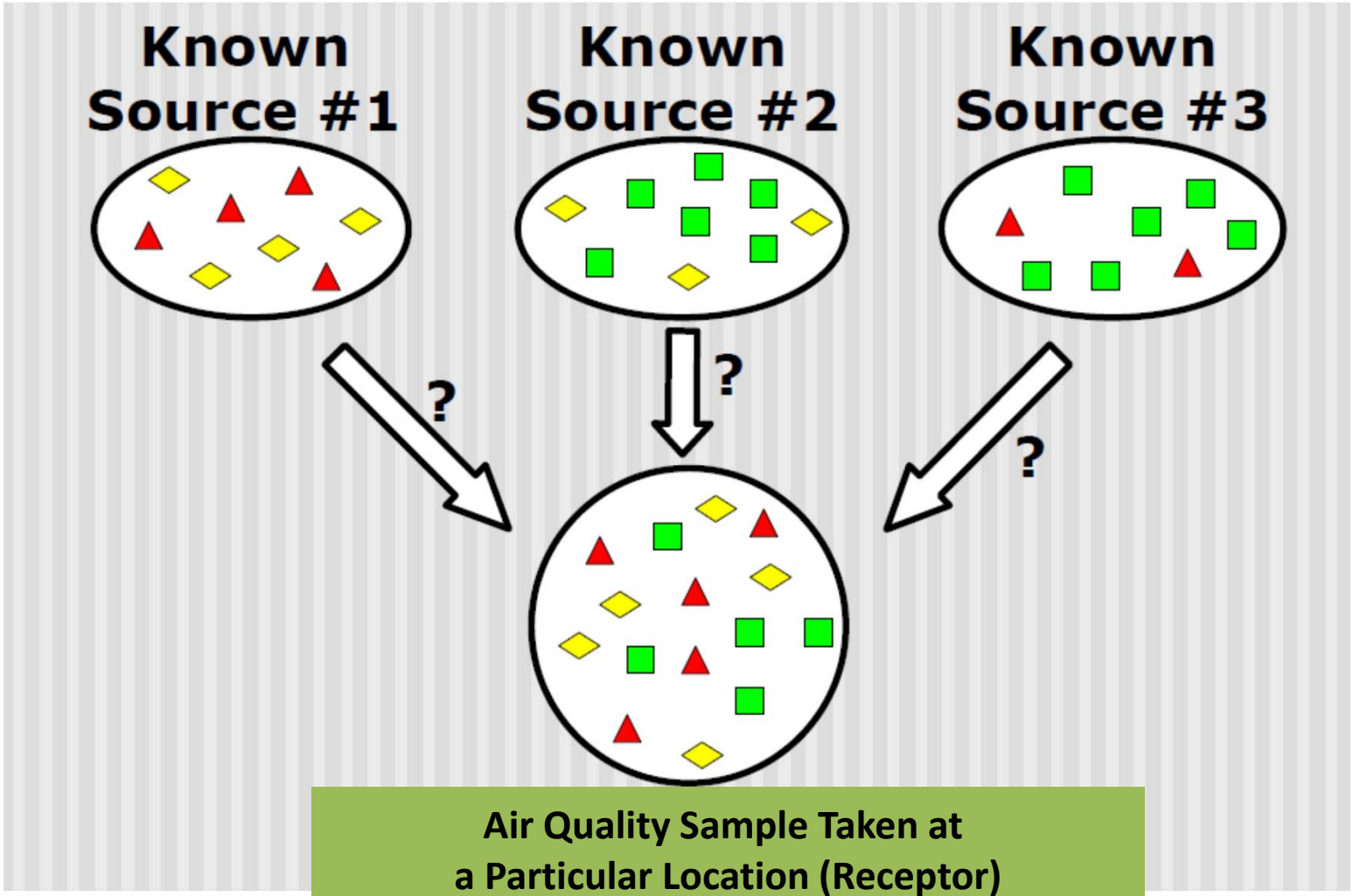

(From: Lynn Hildemann, 2002,. “Introduction to Source Apportionment”. Stanford Univ.

Source Apportionment in LAX AQSAS

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Community North

Community East

Community South

Source Apportionment Tools

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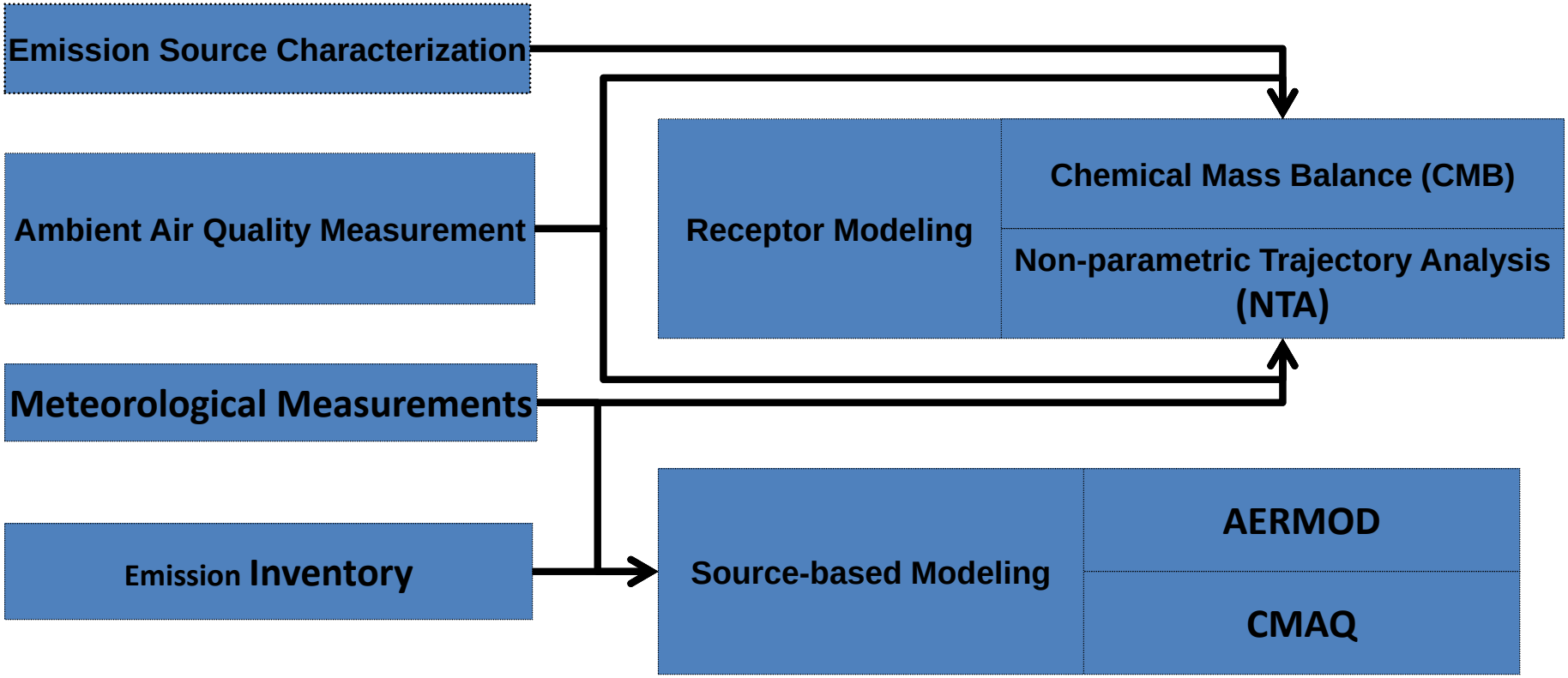

AERMOD: American Meteorological Society/U.S. EPA Regulatory Model
CMAQ: Community Multi-scale Air Quality Model

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Emissions Inventory and Source-Based Modeling

Michael Ratte
KB Environmental Sciences

Los Angeles World Airports
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Emissions Inventory and Source-Based Modeling

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- *What is an emission inventory?*

The quantity of air pollutants emitted by various sources such as aircraft, power plants, and motor vehicles. In this case, the pollutants included carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), particulate matter (PM_{10} and $PM_{2.5}$), and volatile organic compounds (VOC); all of which are commonly associated with fuel-burning sources. Fugitive emissions (roadway dust) are also included.

- *What is source-based dispersion modeling?*

A modeling approach focused on the emission source; while accounting for its release characteristics, and the influence of meteorological, terrain, and surface conditions within time and location to estimate/predict an ambient concentration at nearby community sites. Allows for the determination of contribution by source (apportionment of Airport vs. Non-Airport) for CO, NO_x, SO_x, and $PM_{2.5}$.

Source-based Modeling Methods

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- *What source-based modeling methods are used in this study?*

AERMOD (USEPA preferred/recommended dispersion model) is a steady-state dispersion model designed for short-range dispersion of pollutants from emission sources. Widely used for permitting and CEQA/NEPA.

CMAQ (Community Multi-scale Air Quality) is a dispersion model that provides regional background concentrations to allow for an estimate of airport concentrations, which may not be accounted for in AERMOD, and to account for pollutants where atmospheric formation, air toxics, and urban scale are important. Used in SCAQMD 2012 Air Quality Management Plan.

Each method has its own strengths and limitations which provide complementary results. Used to estimate concentrations (1-hour, daily, and period average) at the Community North (CN), Community East (CE), Community South (CS), and Air Quality (AQ) monitoring sites for CO, NO_x, SO_x, and $PM_{2.5}$.

Emission Sources

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- *What Study Area emission sources are included in the emissions inventory and source-based modeling?*
- Airport Emission Sources
  - ✓ Aircraft (approach, taxi in, startup, taxi out, takeoff, and climbout)
  - ✓ Auxiliary Power Units
  - ✓ Ground Support Equipment (belt loaders, aircraft tugs, etc.)
  - ✓ Airport Stationary Sources such as generators, cogen, boilers, and cooling towers
  - ✓ Parking Facilities
  - ✓ On-airport Roadways and Off-airport Roadways/Freeways
  - ✓ Aggregate Stationary Sources and Area-wide Sources
- Non-Airport Emission Sources
  - ✓ Off-airport Stationary Sources such as refineries and power plants (Chevron, Scattergood, and El Segundo facilities)
  - ✓ Off-airport Roadways/Freeways
  - ✓ Marine Vessels
  - ✓ Off-road Equipment (construction equipment, trains, etc.)
  - ✓ Aggregate Stationary Sources and Area-wide Sources

Off-Airport Roadway Apportionment

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- *How are airport emission sources apportioned especially associated with off-airport roadways?*
  - All sources on the Airport are assigned as Airport sources (aircraft, GSE, on-airport roadways/parking). Most sources off the Airport are assigned as Non-Airport sources (power plants, refineries, marine).
  - However, off-airport motor vehicles are apportioned as either Airport-related or Non-Airport-related, based on available traffic surveys. In general, roadways closer to the Airport were assigned a greater percentage of Airport-related traffic.

Off-Airport Roadway Apportionment

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Values represent estimated percentage of total traffic related to Airport.

Data Used for Emissions Inventory

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- *What type of data is used to estimate Airport and Non-Airport emissions?*
  - Models, information, data, and guidance (FAA, USEPA, CARB, SCAQMD, CalTrans, etc.) available from:
    - Aircraft operations (time/date, arrival/departure, aircraft type, aircraft weight, runway/gate assignment, taxiway path)
    - Equipment surveys
    - Permits/continuous emission monitoring equipment
    - Traffic counts (volume, speed, type of vehicles)
    - Along with approved emission factors provide an understanding of how much pollutants were emitted.
  - Data was representative of the conditions during the two 6-week monitoring seasons.

Emission Inventory Results

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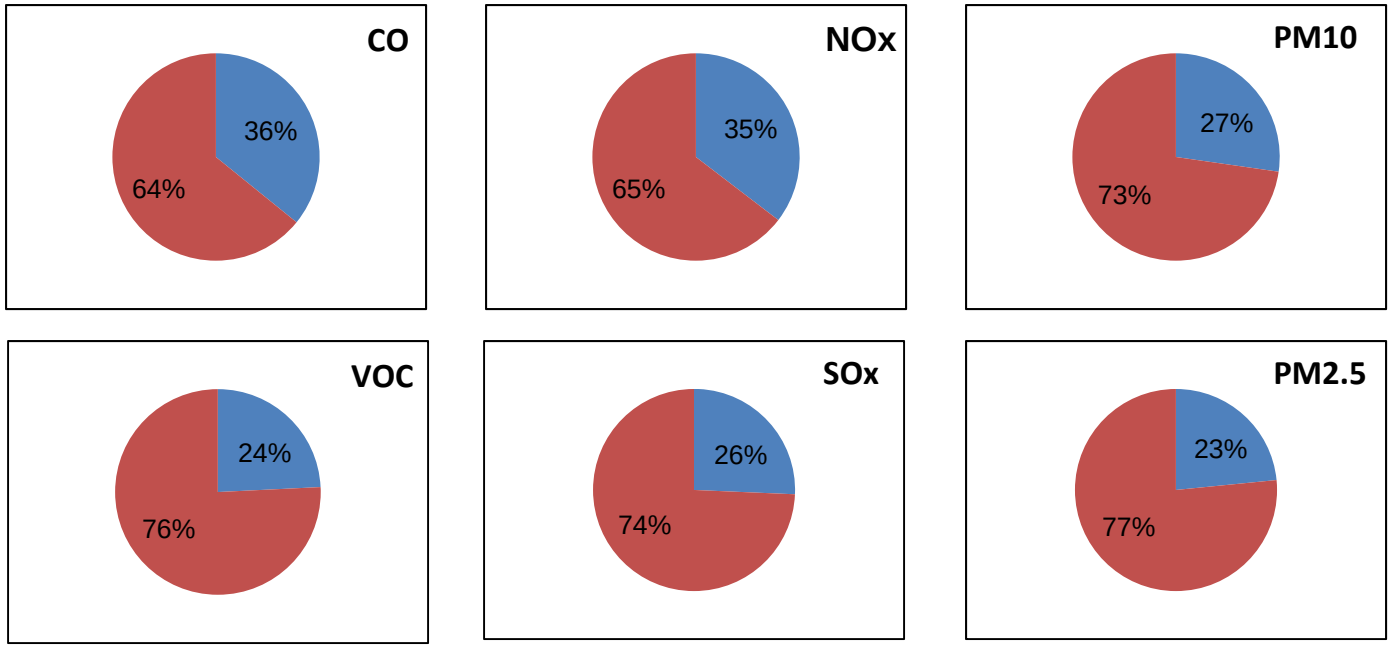
- *What are the results of the emissions inventory?*
  - It depends on the pollutant; however, approximately 23 to 36 percent of the emissions within the Study Area are related to the **Airport**: CO (36 percent), VOC (24 percent), NO_x (35 percent), SO_x (26 percent), PM_{10} (27 percent) and $PM_{2.5}$ (23 percent) versus related to **Non-Airport** sources.



Airport Emissions of VOC, NO_x, SO_x and $PM_{2.5}$

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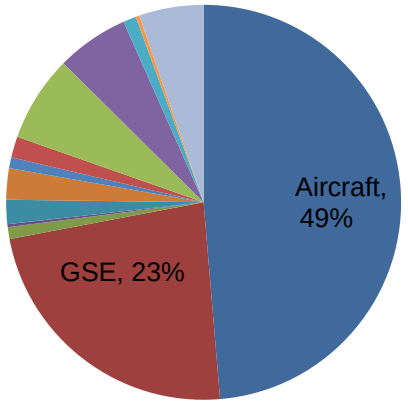
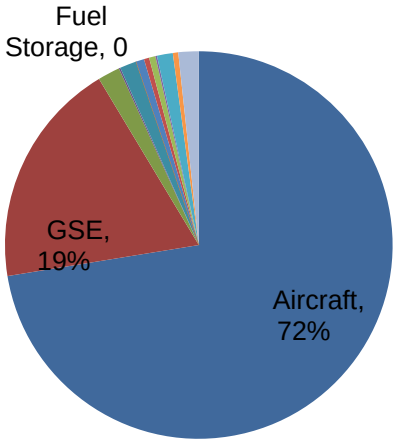
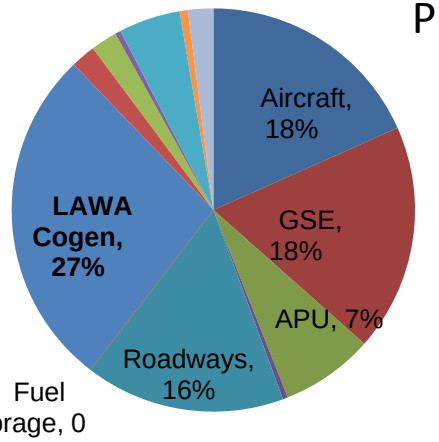


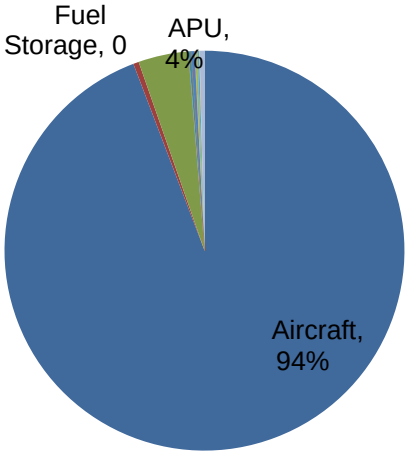
VOC



NOx



PM2.5



SOx

Aircraft and **GSE** dominate CO, VOC, and NOx. **Aircraft** dominate SOx. PM2.5 is from many sources.

Emission Inventory Results

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- *How do Airport sources contribute to traffic emissions?*
  - The Airport-related traffic emissions (both on and off-airport) are approximately 12 percent (i.e., 88 percent is related to Non-Airport activities) of the total traffic-related emissions within the Study Area for CO, VOC, NO_x, and SO_x.
  - The Airport-related traffic emissions are approximately 36 percent (i.e., 64 percent is related to Non-Airport activities) of the total traffic-related emissions within the Study Area for PM_{10} and $PM_{2.5}$.

Emission Inventory Relationship to Source-Based Modeling

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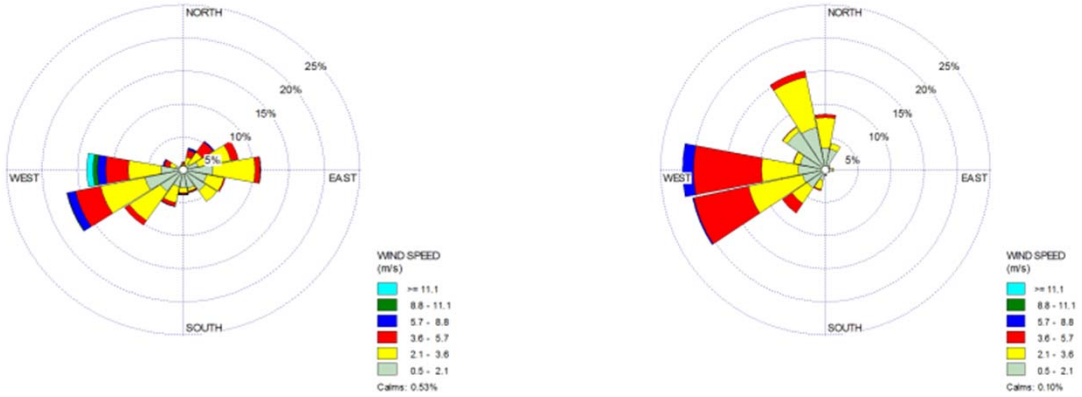
- *How does an emission inventory relate to source-based modeling results?*
  - The emissions inventory alone cannot determine the Airport contribution to ambient concentrations at the community sites. The pollutant concentrations at receptors are a function of amount of emissions as well as location, release characteristics, how its emissions vary with time, surface conditions, meteorological (wind, turbulence), and terrain data.



Winter and Summer monitoring season wind roses.

Data Used for Source-Based Modeling

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- *What type of data was used to conduct the source-based modeling?*
  - In addition to the estimated emissions, where the emission occur, and when (time of day, day of week) the emissions occur.
  - 1-minute and hourly surface (NWS) and upper air (SODAR) meteorological data, terrain data, and source emission characteristics (stack height, exhaust velocity and temperature), provide a means to estimate where the pollutants end up and the concentration at the receptors.
  - Data is representative of the conditions during the two 6-week monitoring seasons.

AERMOD Results

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- *What were the AERMOD results?*
  - Although the emissions inventory showed Airport contribution of 23 to 36 percent, the Airport contribution to concentrations is different depending on circumstances (meteorological and other conditions).
  - Of all the Airport-related sources, motor vehicles account for the highest contribution at AQ and CS. Aircraft takeoff dominate at CE while GSE emissions dominate at CN.
  - Of all the Non-Airport related sources, off-road equipment dominate at AQ, CN, and CS, motor vehicles dominate at CE, but also play a major role at AQ and CN.
  - Short-term impacts (one-hour maxima) driven by airport-related sources at the AQ, CE, and CN sites during both the Summer and Winter Seasons, while non-airport sources dominate the long-term impacts (six week averages).
  - Pollutant concentrations aloft were often higher than those at the surface. The highest concentrations for aircraft takeoff and landing, power plants, and marine sources were found aloft and not at the surface.

Airport vs. Non-Airport Contributions during Winter

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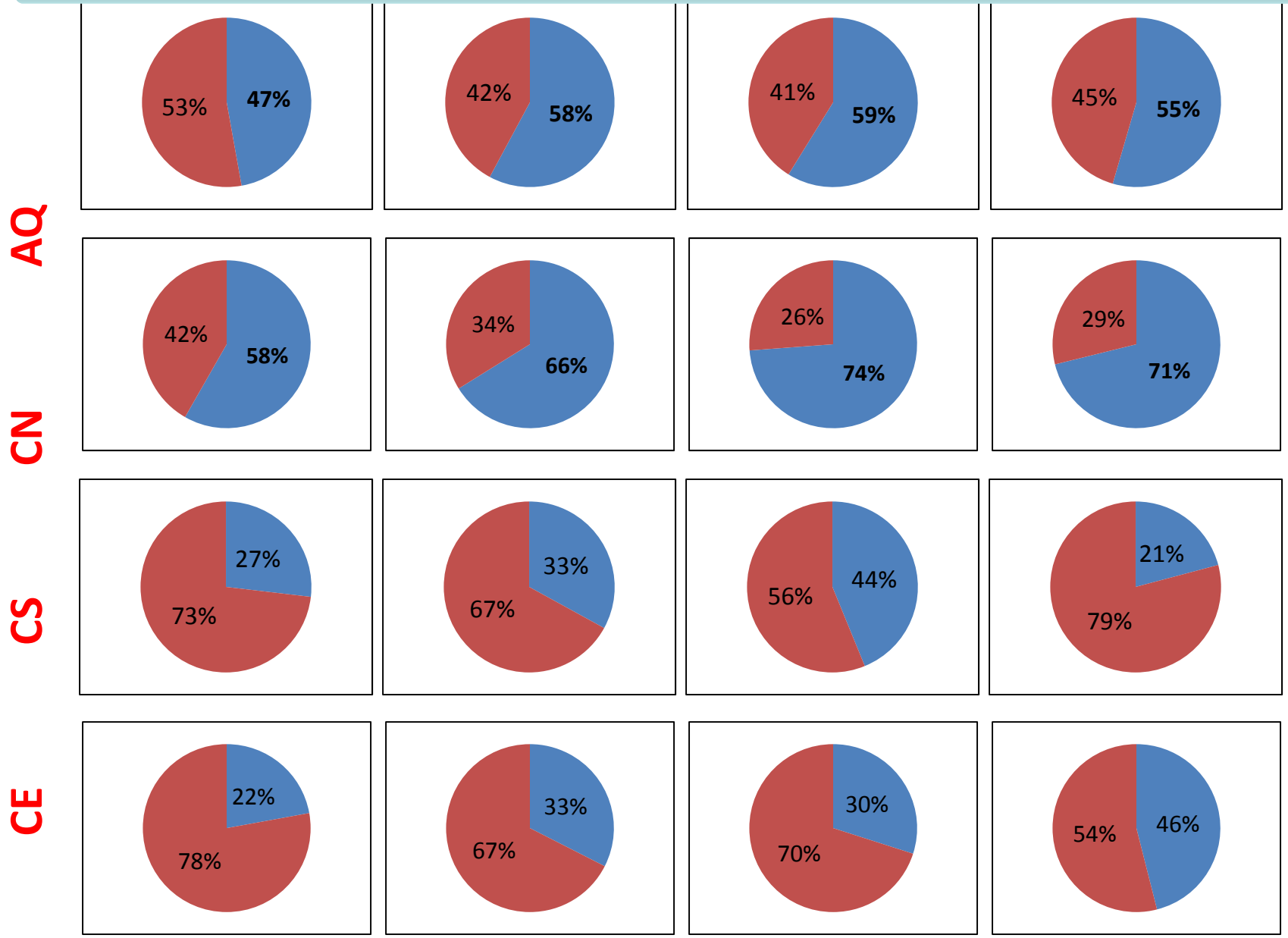

Airport vs. Non-Airport Contributions during Summer

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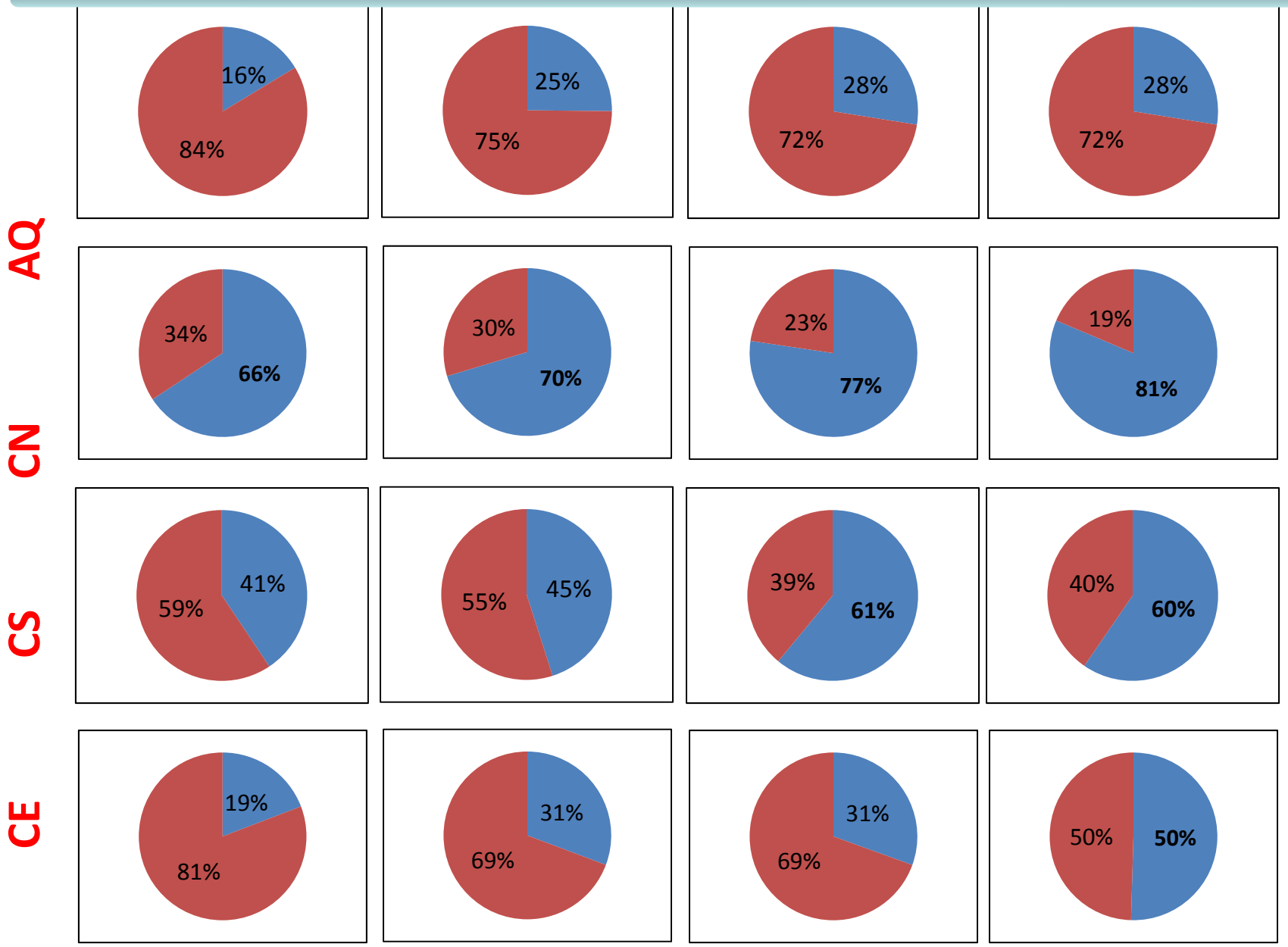

CMAQ Modeling

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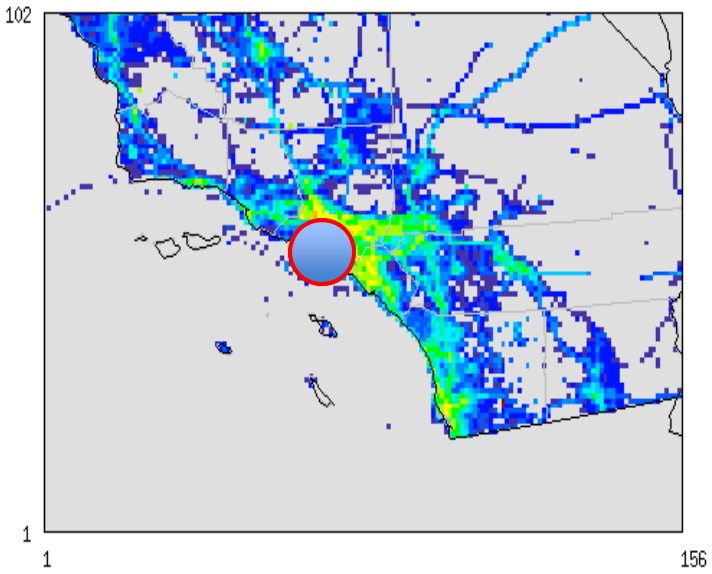
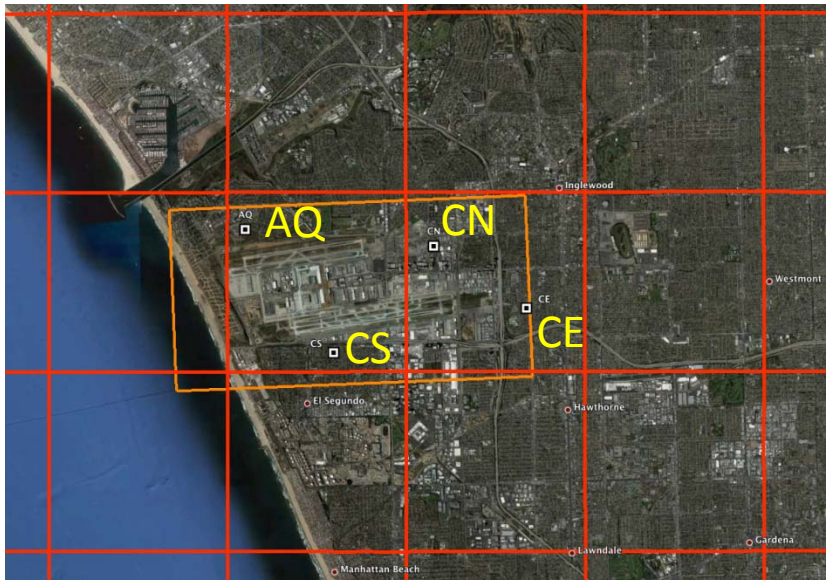


AQMD 4-km
Modeling Domain



Zoomed-in region around
LAX

CMAQ Results

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Facilities Management Group

- *What were the CMAQ results?*
  - CO Impacts
    - ✓ Airport sources contribute 10 to 26 percent during Summer and 5 to 16 percent during Winter.
  - SO_x Impacts
    - ✓ Airport sources contribute 16 to 30 percent during Summer and 14 to 31 percent during Winter
  - NO_x Impacts
    - ✓ Airport sources contribute 27 to 49 percent during Summer and 16 to 35 percent during Winter
  - $PM_{2.5}$ Impacts
    - ✓ Airport sources contribute 11 to 20 percent during Summer and 5 to 15 percent during Winter.

CMAQ Findings

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Facilities Management Group

- *What were the CMAQ findings?*
  - Generally lower contribution during the winter season than summer season.
  - There are sources outside the Study Area which substantially contribute to the impacts at the community sites.
  - Chemical transformations are an important consideration.
  - Study Area emissions have impacts much beyond the immediate Study Area, sometimes at downwind distances up to 100 to 150 kilometers (approximately 60 to 90 miles) from the Airport. This was observed specifically for NO_x and SO_x during both seasons.

LAX Air Quality and Source Apportionment Study

Receptor Modeling

Professor Ronald C. Henry
Sony Astani Department of Civil & Environmental Engineering
University of Southern California

Receptor Modeling Methods

Los Angeles World Airports
Facilities Management Group

- Chemical Mass Balance (CMB)
  - Uses chemical “fingerprints” for source apportionment
  - Supported by the U. S. EPA for over 20 years
  - Used to determine contribution of jet exhaust to fine particles and hydrocarbon gasses
- Nonparametric Trajectory Analysis (NTA).
  - Uses 1-minute wind and pollutant data for source apportionment.
  - Developed for the U. S. EPA over the last 5 years
  - Used to apportion CO, NO_x, SO_2, and Black Carbon

CMB Source Contributions to $PM_{2.5}$ at CN Site

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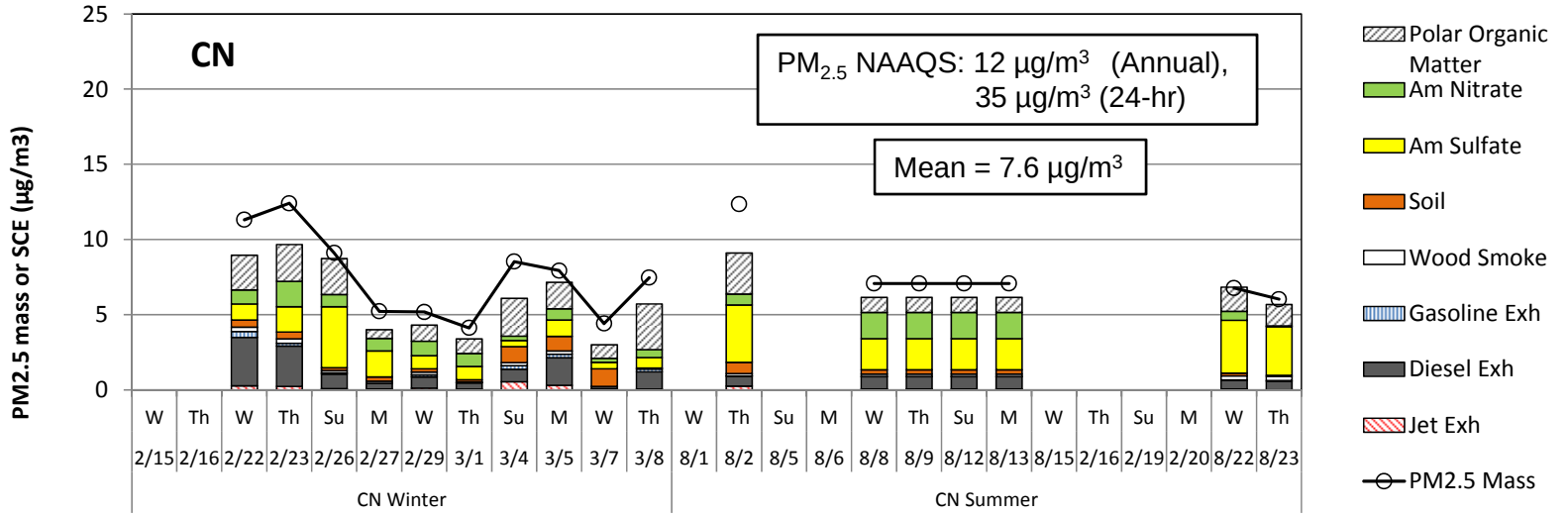

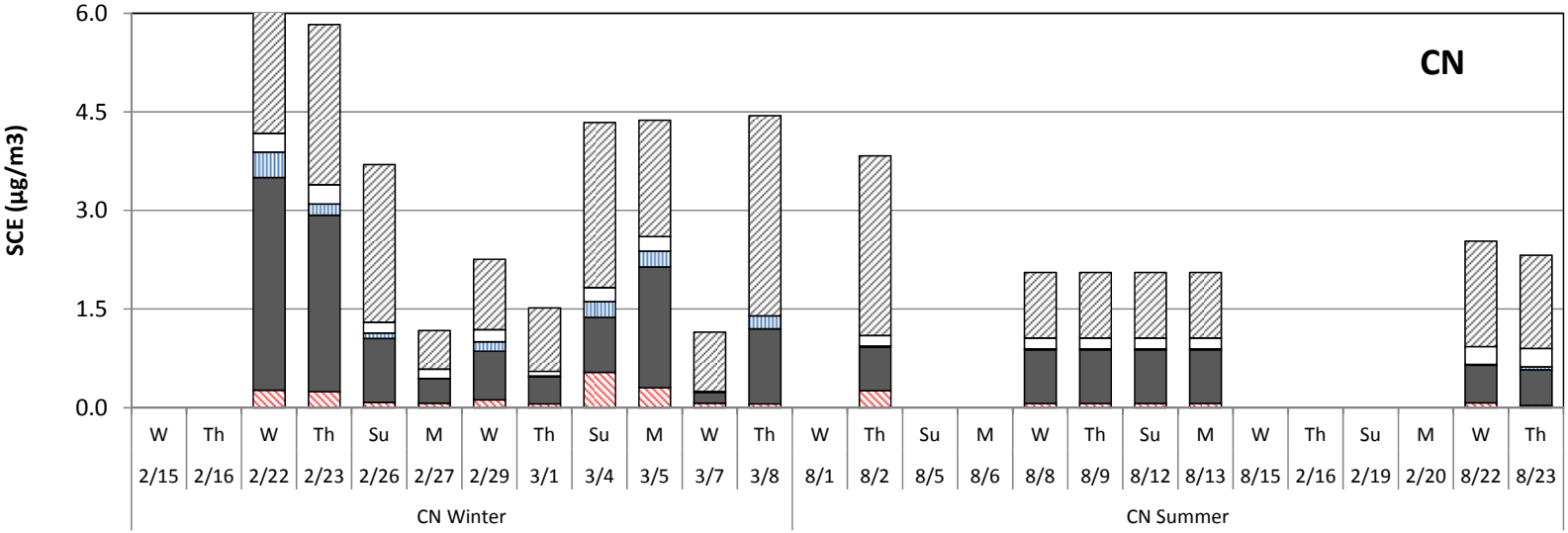

Total VOC by CMB

Benzene by CMB

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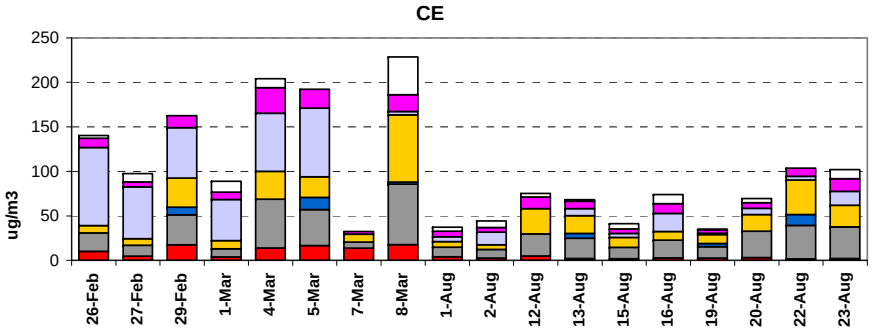

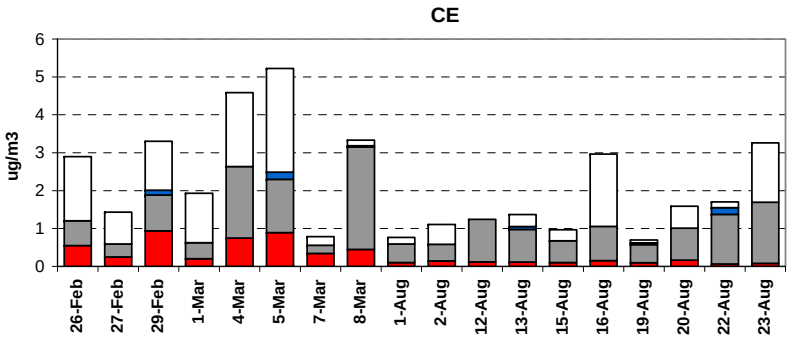

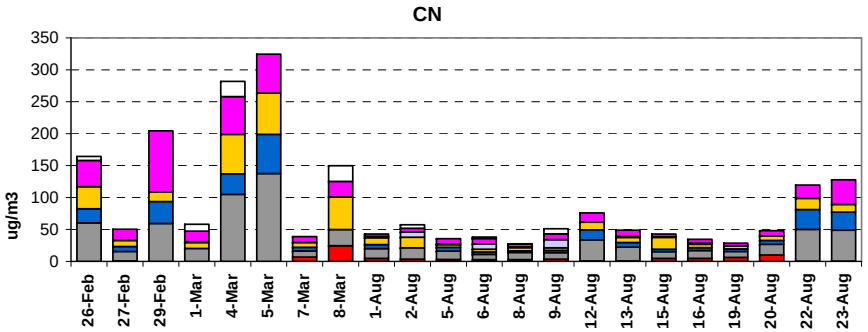

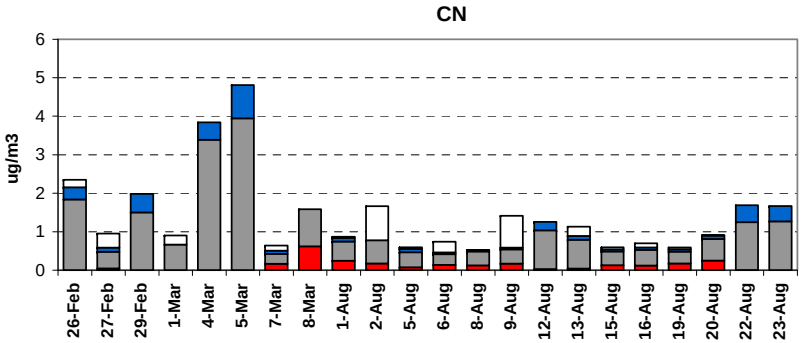

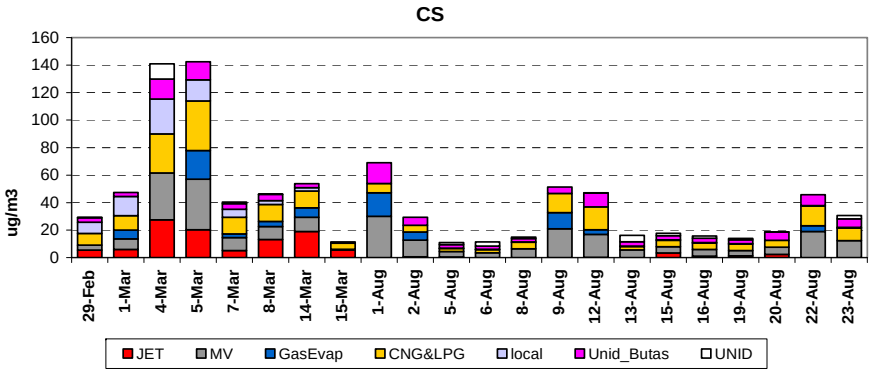

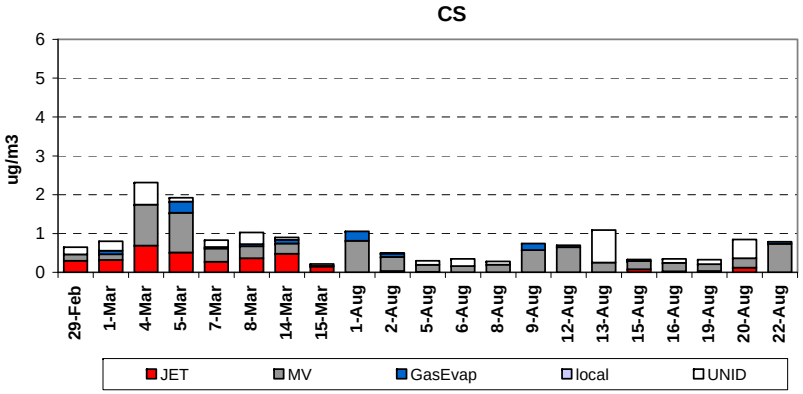

NTA Summer

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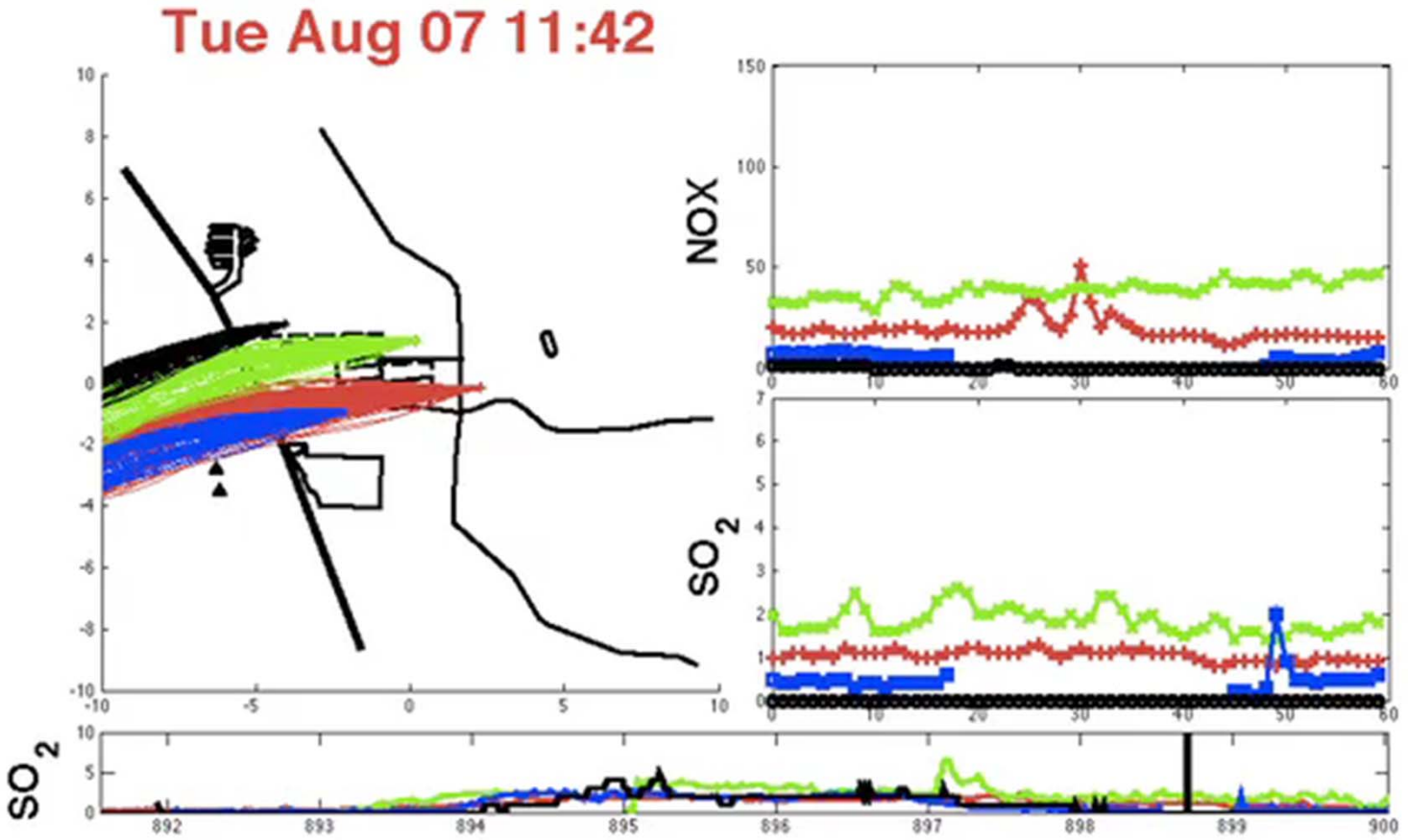

Winter NTA Source Apportionment

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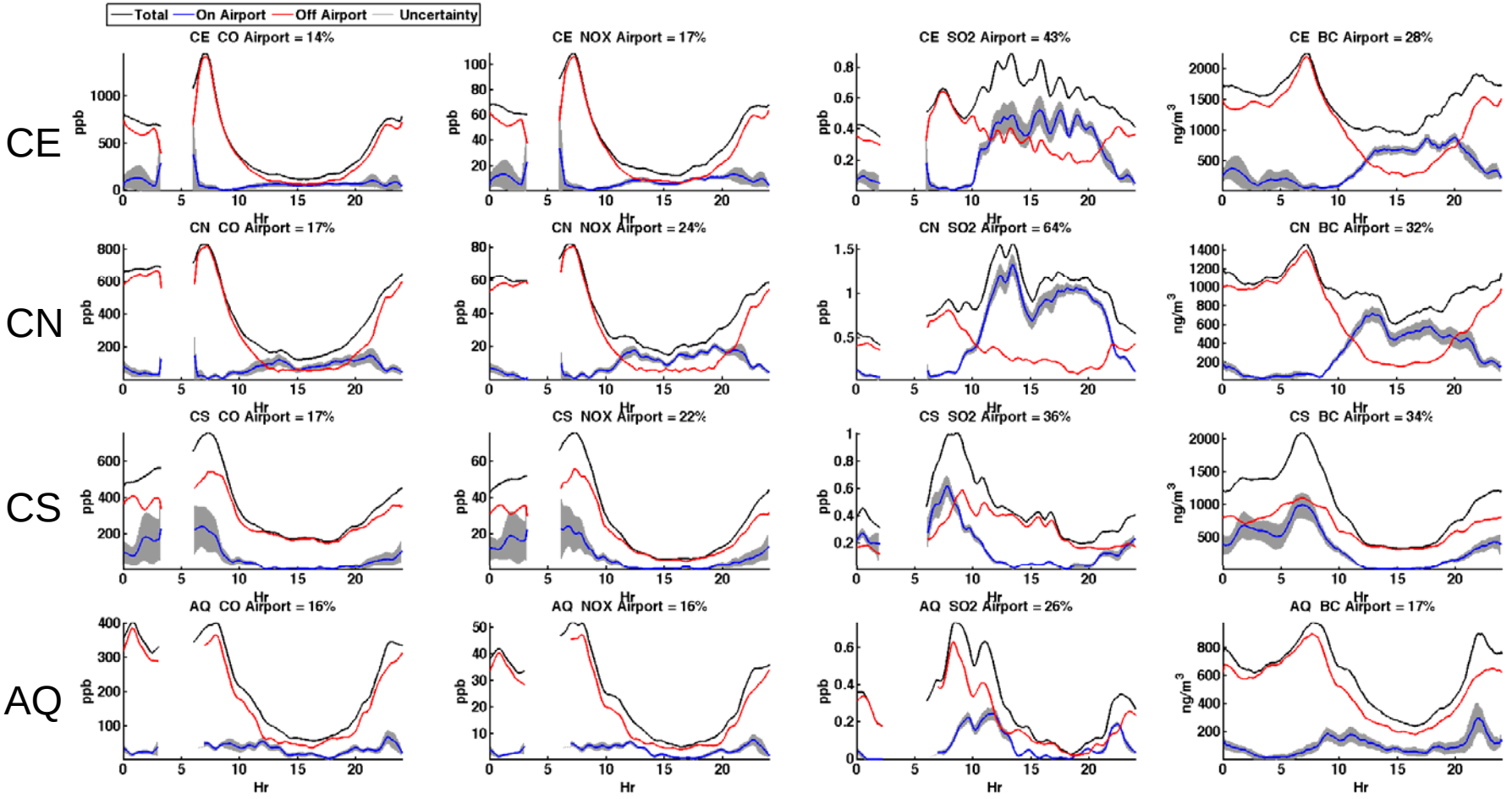

Season Average Source Apportionment

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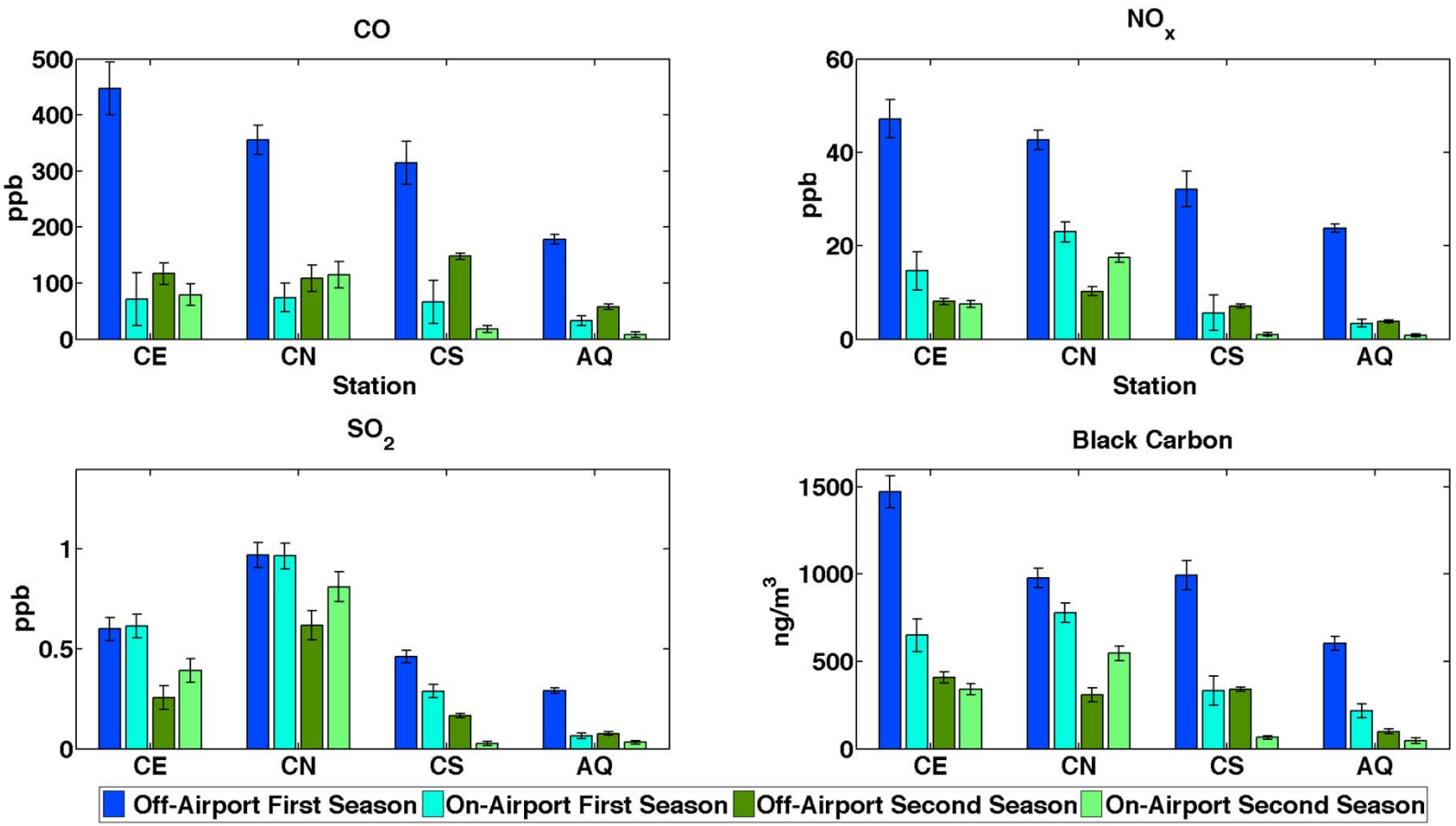

Receptor Modeling Key Findings

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- The contribution of jet exhaust to airborne fine particle mass is very small.
- The contribution of jet exhaust to benzene and total hydrocarbon gases is small.
- At the Community South (CS) and Air Quality (AQ) stations, off-airport sources are greater than on-airport for all species modeled by NTA.
- The airport is a major contributor to sulfur dioxide and, to a lesser extent, particulate black carbon at the Community East (CE) and Community North (CN) stations.

Nonparametric Trajectory Analysis

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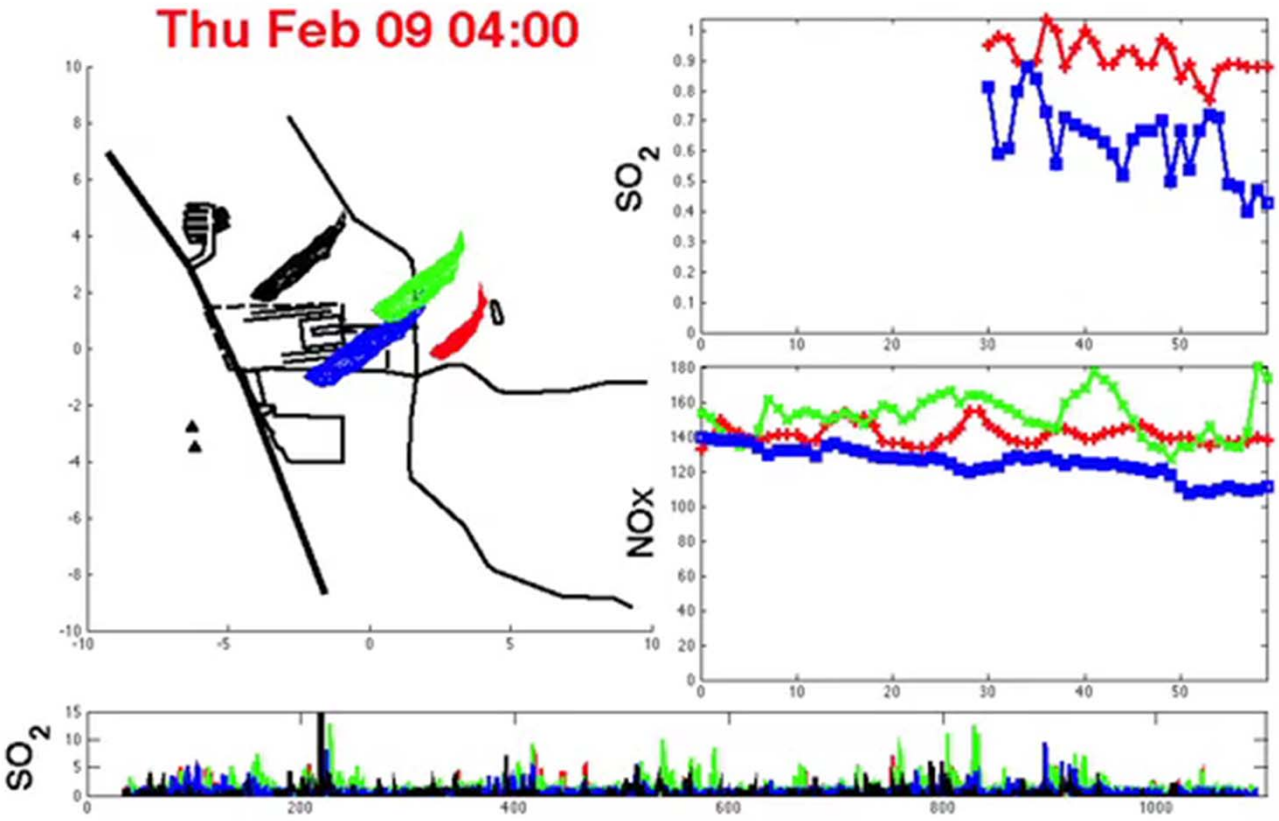

Winter BC, SO_2, UFP at CN, CE

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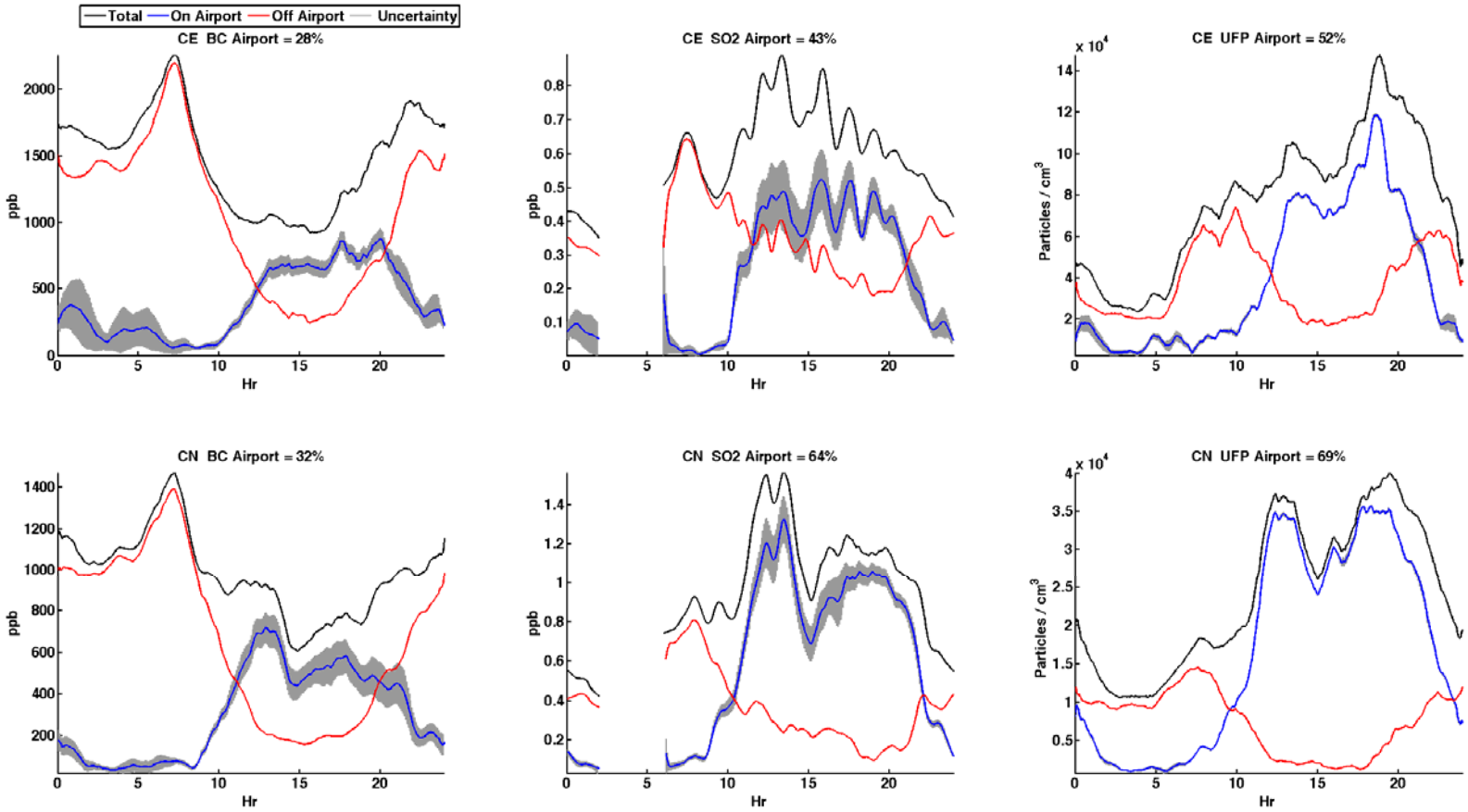
Facilities Management Group



15 Minute Break

Please submit any Question Cards to the FEEDBACK Station at the back of the room or raise your hand and someone will pick up your card. Thank you.