AQUARIUS - Air QUALity Research In the western US

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Photo: Erik Crosman
Wintertime PM\textsubscript{2.5}
Wintertime PM$_{2.5}$

[Map showing locations of Fresno, Salt Lake City, Bakersfield, and Riverside in the western United States.]

[Graph showing PM$_{2.5}$ levels in Bakersfield for 2000-2004 (red line) and 2013-2017 (blue line).]
Coupling between meteorology and wintertime PM

Lareau et al. (2013); Utah
Valleys and basins are particularly prone to stagnation events that favor poor air quality.

Emissions accumulate in persistent cold-air pool (PCAP)

\[ \text{NO}_x, \text{PM}_{2.5}, \text{NH}_4, \text{VOCs} \]

“Neutral” Well mixed

“Inversion” “stable” Mixing is inhibited!

From Sebastian Hoch
Evolution of the vertical structure of the atmosphere

Prabhakar et al. (2017); San Joaquin Valley - Fresno
Science Question: How do meteorological “cold-air pool” conditions contribute to poor wintertime basin air quality, and how can meteorological observations and modeling efforts be designed to most effectively inform emissions and chemistry research?
PM$_{2.5}$ Composition

Chen et al. (2018)
San Joaquin Valley

Young et al. (2017)
Ge et al. (2012)
San Joaquin Valley

Lu et al. (2019): Beijing

McDuffie et al. (2019)
Salt Lake Valley, UT

Bressi et al. (2016)
Po Valley

OA, NO$_3^-$, SO$_4^{2-}$, NH$_4^+$, Cl$^-$
Particle Composition: Relationship with total PM

Based on Franchin et al. (2018); Utah

Young et al. (2016); San Joaquin Valley
Spatial Distribution

- Homogeneous?
- Cities versus rural?
- Altitude?

Pusede et al. (2016): San Joaquin Valley

Chow et al. (2006): San Joaquin Valley

Womack et al. (2019): Utah
Nitrate gas-particle partitioning

Franchin et al. (2018); Utah

Parworth et al. (2017): San Joaquin Valley
Vertical structure: Chemistry + Meteorology Coupling

McDuffie et al. (2019); Utah

Prabhakar et al. (2017); Fresno
Diel Variability and Process Understanding

Young et al. (2016): San Joaquin Valley
Science Question: What are the relevant physical (including meteorological), chemical and thermodynamic processes that govern winter particulate matter formation and loss, what are the uncertainties, and how can these be addressed through measurements and modeling?
Sources of PM Pollution

- Primary organic aerosol
- Secondary organic aerosol
- Secondary inorganic aerosol

Young et al. (2017)
Ge et al. (2012)
San Joaquin Valley
NO\textsubscript{x} \rightarrow \text{Nitrate}

- \textbf{NO\textsubscript{2} column, summer}
  - Weekday
  - Weekend

- \textbf{Ag NO\textsubscript{x} emissions}
  - Russell et al. (2010)
  - Almaraz et al. (2018)

- \textbf{Seasonality}
  - ARB Data (Fresno)
**VOC’s → SOA → Nitrate**

Howard et al. (2010)

Livestock feed

CAFO’s

Yuan et al. (2017)

Volatile Chemical Products & Transport

McDonald et al. (2018)
Science Question: What are the relevant emissions of short-lived pollutants that are most relevant to winter air quality in the western U.S. and what are the major uncertainties in quantifying them? What approaches are required to reduce these uncertainties?
Particulate Nitrate Formation

**Daytime**

\[
\begin{align*}
O_3 + h\nu &\rightarrow O(^1D) + O_2 \\
H_2O + O(^1D) &\rightarrow 2 OH \\
HONO + h\nu &\rightarrow OH + NO \\
CH_2O + h\nu &\rightarrow OH + CH \\
OH + NO_2 &\rightarrow HNO_3 \\
\end{align*}
\]

**Nighttime**

\[
\begin{align*}
O_3 + NO_2 &\rightarrow NO_3 + O_2 \\
NO_3 + NO_2 &\leftrightarrow N_2O_5 \\
NO_3 + VOC &\rightarrow \text{products} \\
N_2O_5 + \text{particles}_{(aq)} &\rightarrow 2 \text{HNO}_3 \\
&\rightarrow \text{HNO}_3 + \text{ClNO}_2 \\
\end{align*}
\]
[Based on Prabhakar et al. (2017); McDuffie et al. (2019); Womack et al. (2019)]
Chemistry + Meteorology Coupling

Winter 2019

Production + Entrainment
Dilution + Deposition

Zhang/Cappa, Unpublished

McDuffie et al. (2019)
Implications for Control Strategies

Pusede et al. (2016); SJV

Lu et al. (2019); Beijing

Womack et al. (2019); Utah
Secondary Organic Aerosol

- Local vs. Regional
- Daytime vs. Nighttime
- Dry vs. Wet (fog/clouds/aerosol)

Source of VOC’s?

Chen et al. (2018); Fresno

Young et al. (2016); Fresno
Science Question: How do winter oxidation cycles impact winter air quality, and how should these oxidation cycles be approached from a measurement and modeling standpoint?
Air pollution – Climate co-benefits

Bares et al. (2018); Salt Lake City
Science Question: How are urban GHG emissions changing in the western U.S., which sectors are responsible for the changes, and how are shifts in GHG emissions associated with changes in short-lived pollutants?
Science Questions Summary

1. Meteorology-Chemistry Coupling and PCAPS
2. Physical, chemical and thermodynamic processes that govern PM formation and loss
3. Emissions of short-lived pollutants
4. Air pollution—Climate co-benefits
5. Winter oxidation cycles
Acknowledgements

The AQUARIUS Organizing Committee

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