AQUARIUS - Air QUAlity Research In the western US

Chris Cappa
UC Davis

AQUARIUS Workshop
25 September 2019

Photo: Erik Crosman

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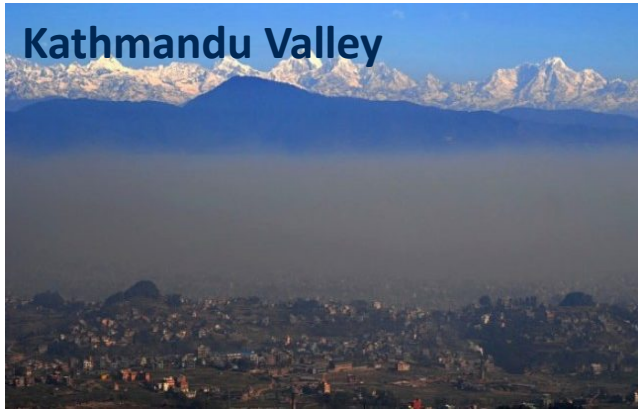
Kathmandu Valley



Central Valley, CA

Salt Lake Valley, UT

Po Valley, Italy

Denver, CO

Los Angeles, CA

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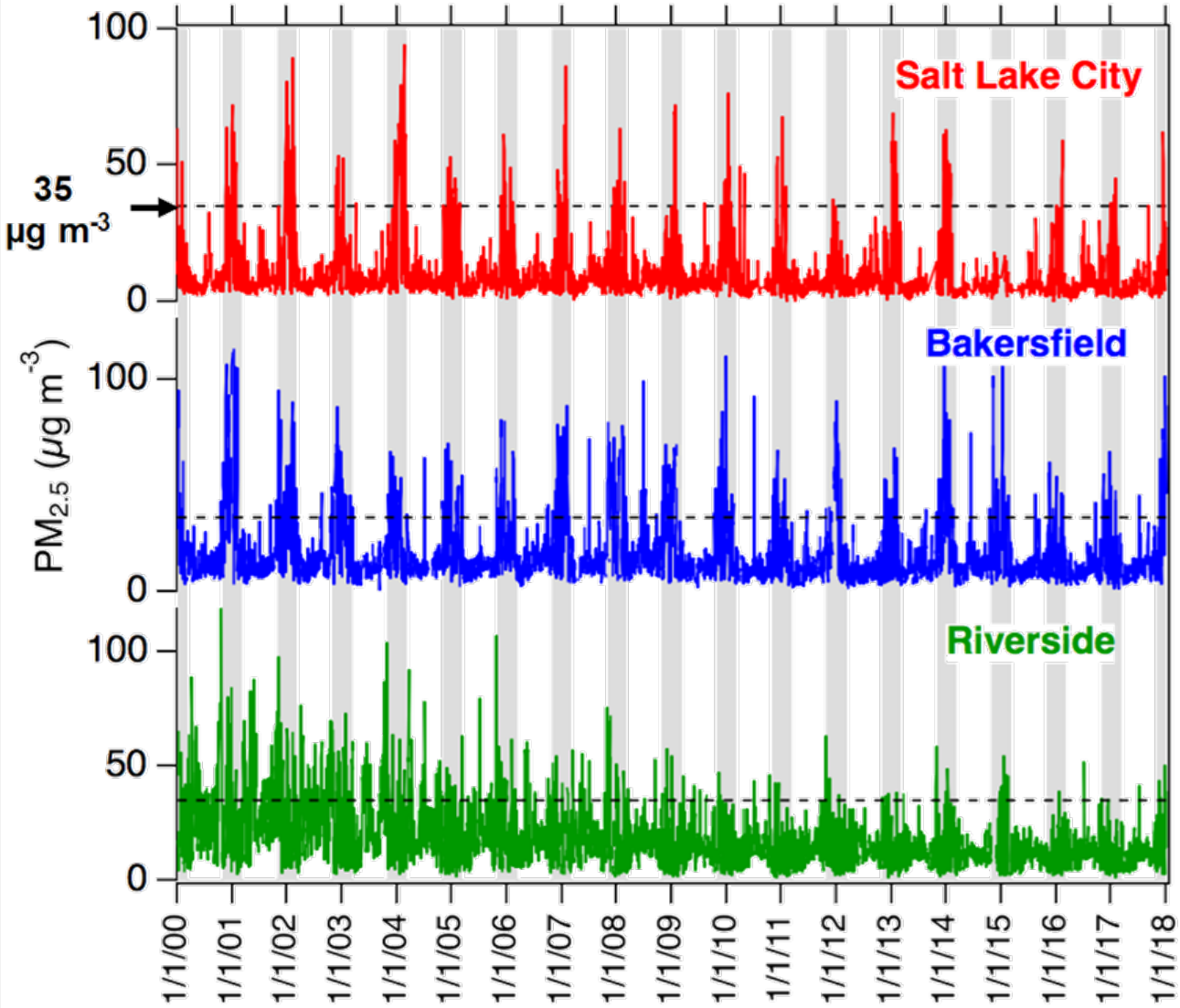
Wintertime $PM_{2.5}$



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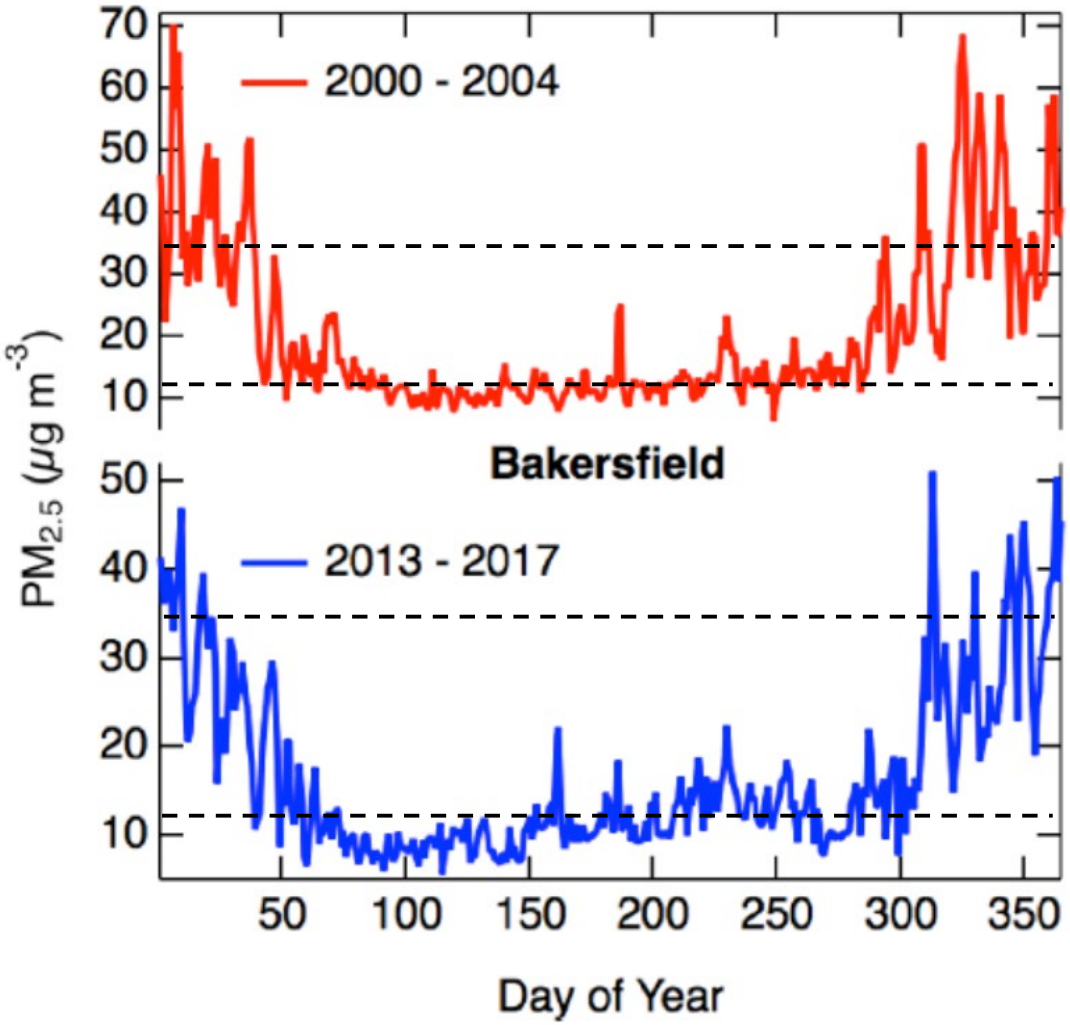
Wintertime $PM_{2.5}$



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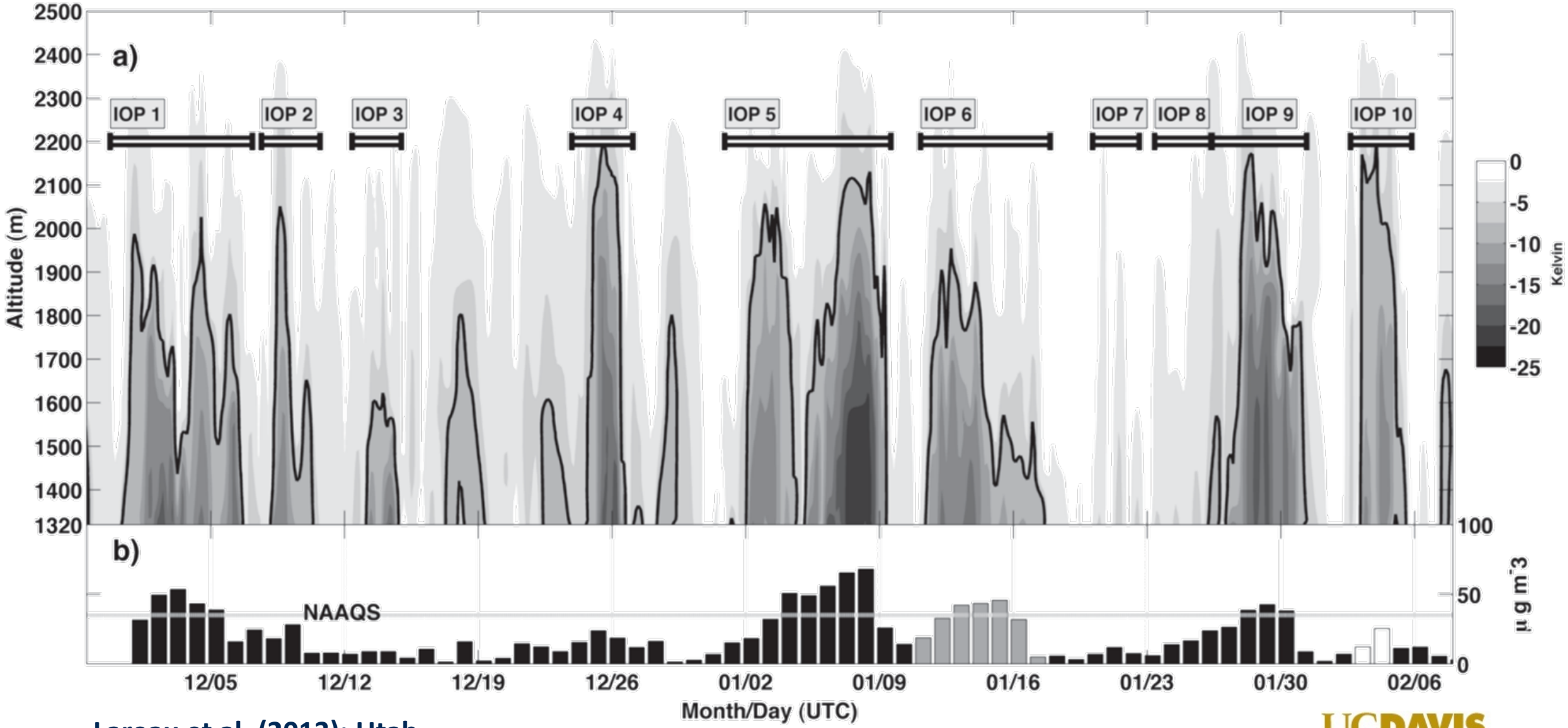
Coupling between meteorology and wintertime PM



Lareau et al. (2013); Utah

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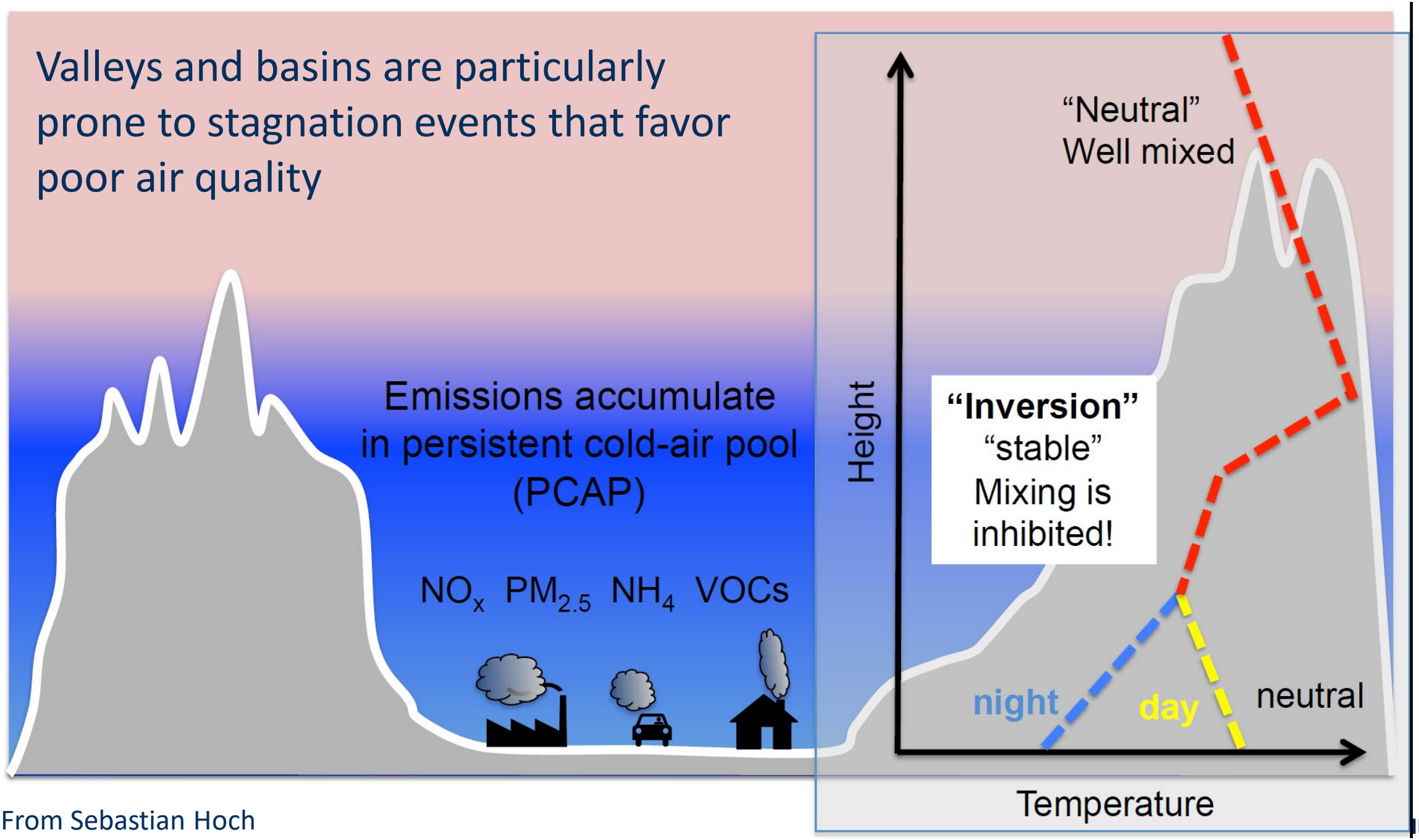
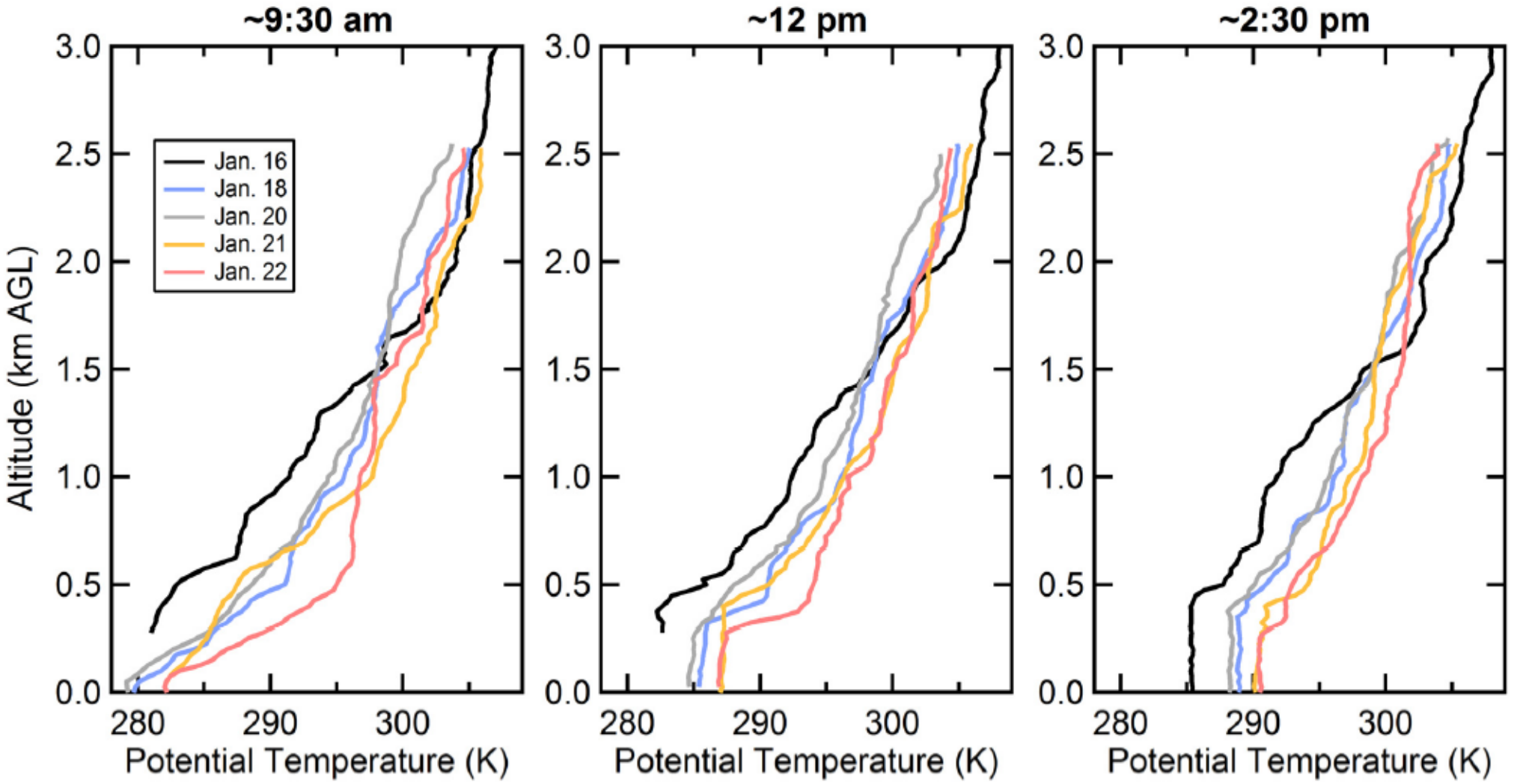
Valleys and basins are particularly prone to stagnation events that favor poor air quality

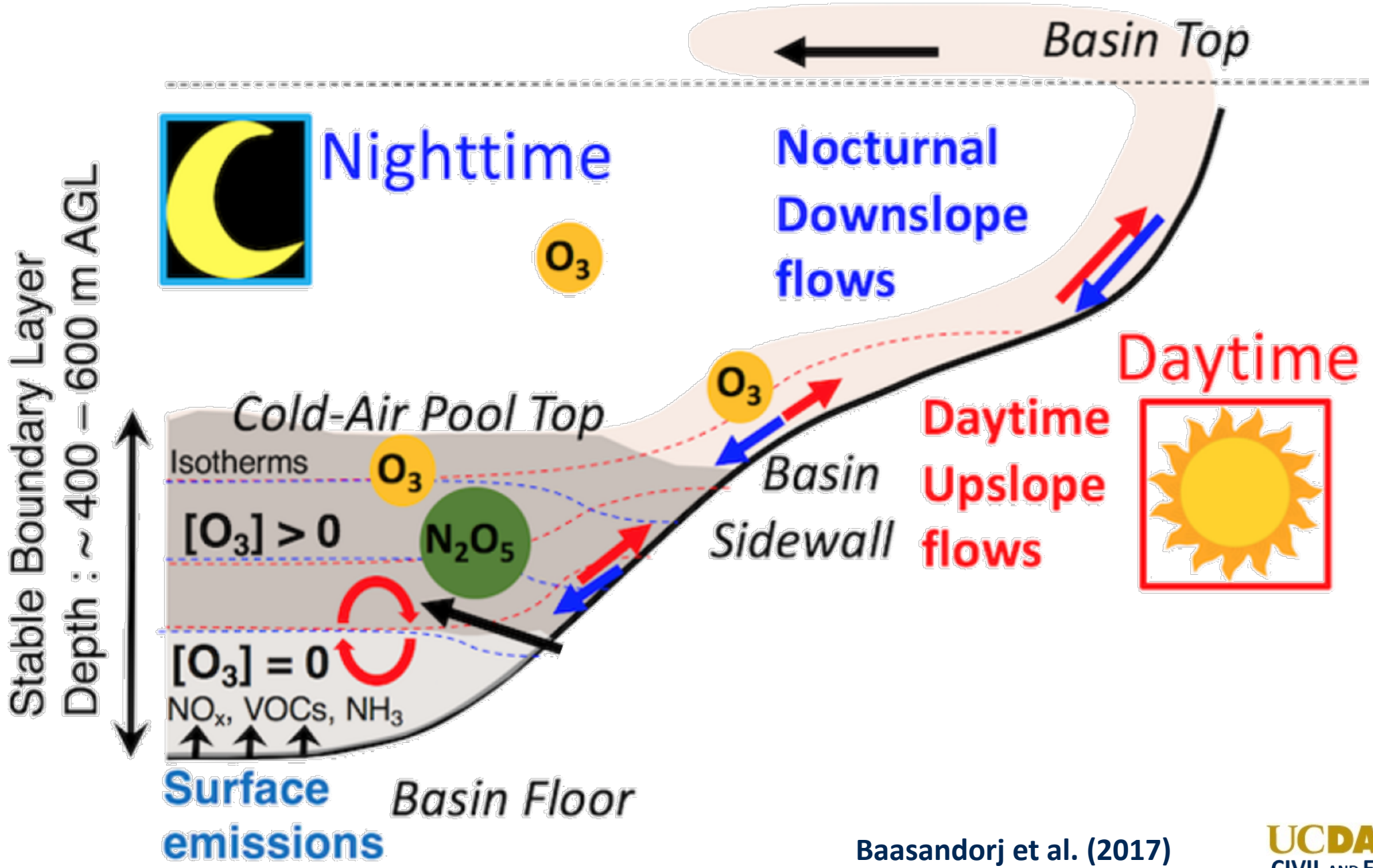


From Sebastian Hoch

Evolution of the vertical structure of the atmosphere



Prabhakar et al. (2017); San Joaquin Valley - Fresno

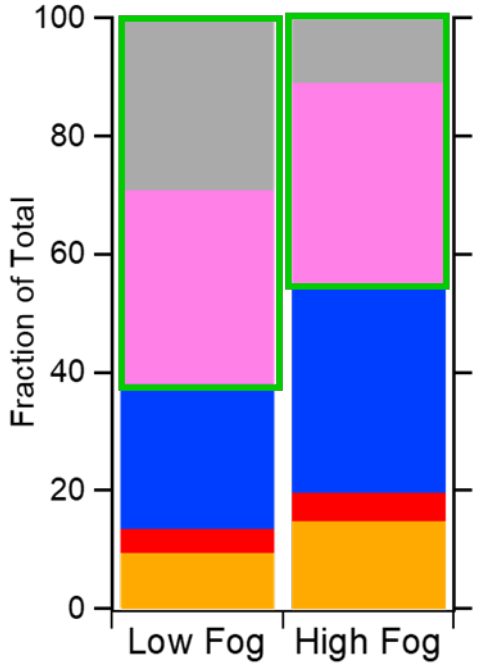


Baasandorj et al. (2017)

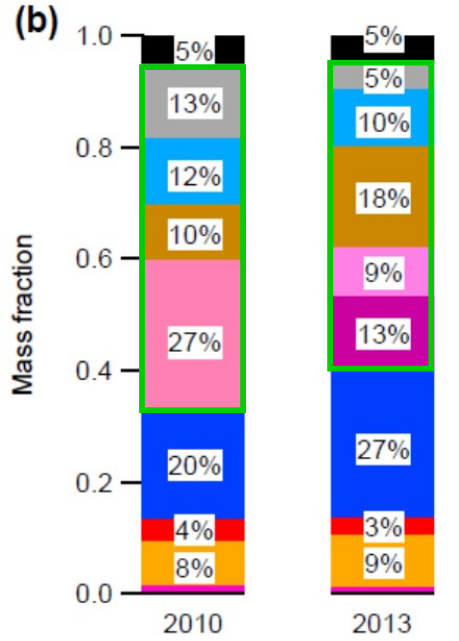
Science Question: How do meteorological “cold-air pool” conditions contribute to poor wintertime basin air quality, and how can meteorological observations and modeling efforts be designed to most effectively inform emissions and chemistry research?

$PM_{2.5}$ Composition

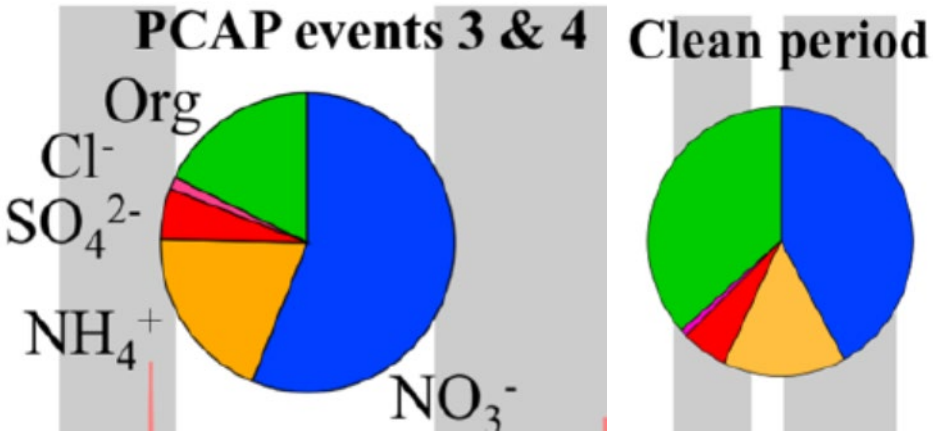
OA, NO_3^-, SO_4^{2-}, NH_4^+, Cl^-



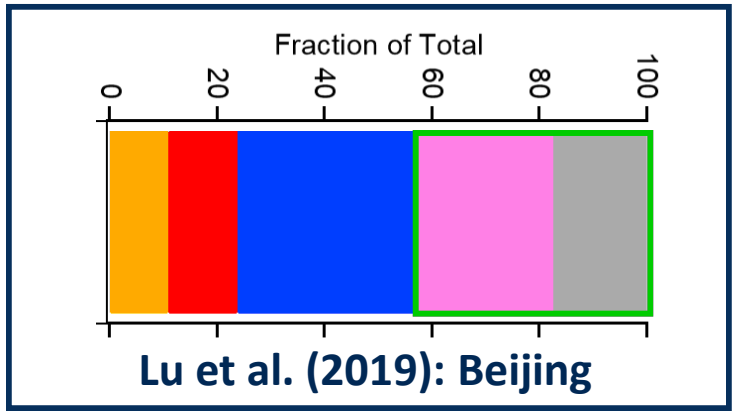
Chen et al. (2018)
San Joaquin Valley



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

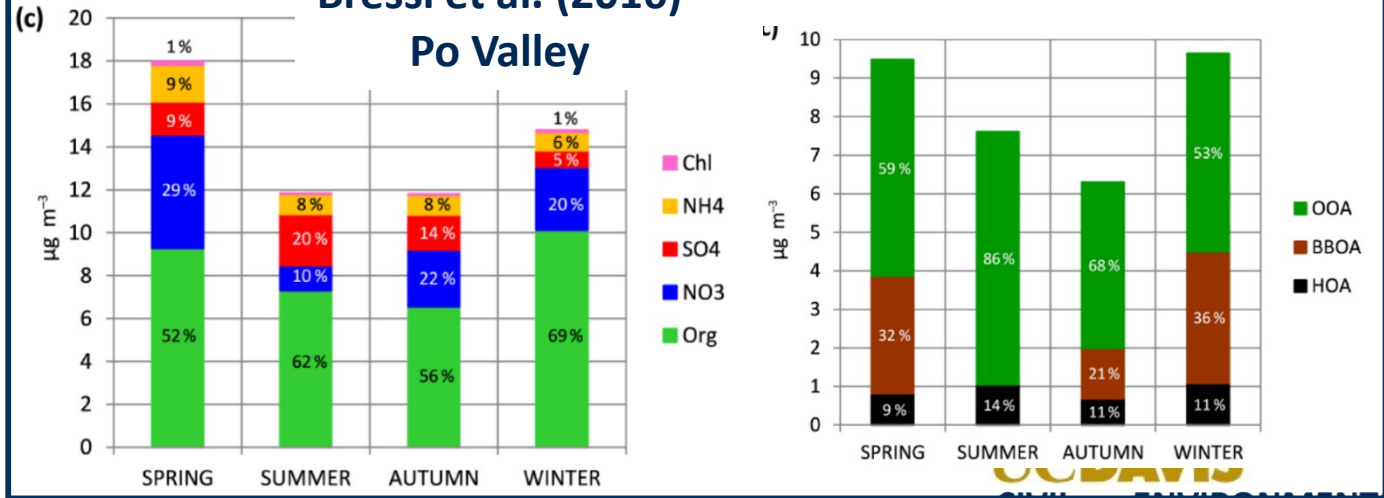


McDuffie et al. (2019)
Salt Lake Valley, UT



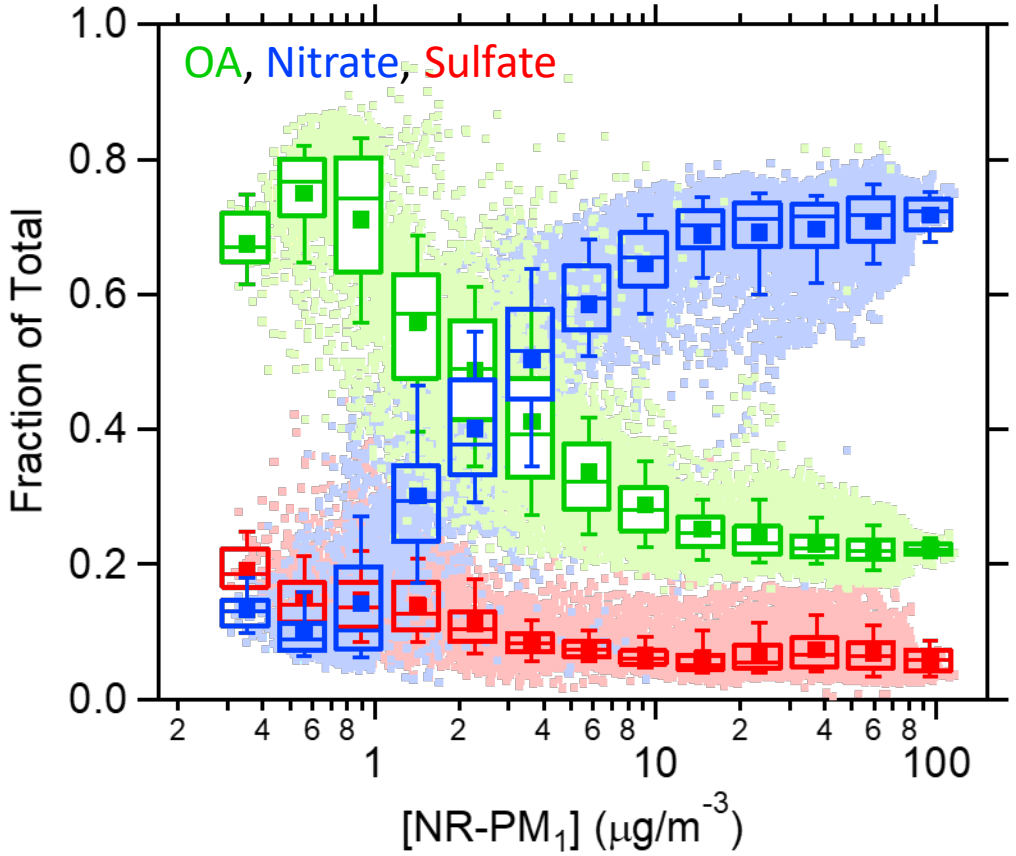
Lu et al. (2019): Beijing

Bressi et al. (2016)
Po Valley



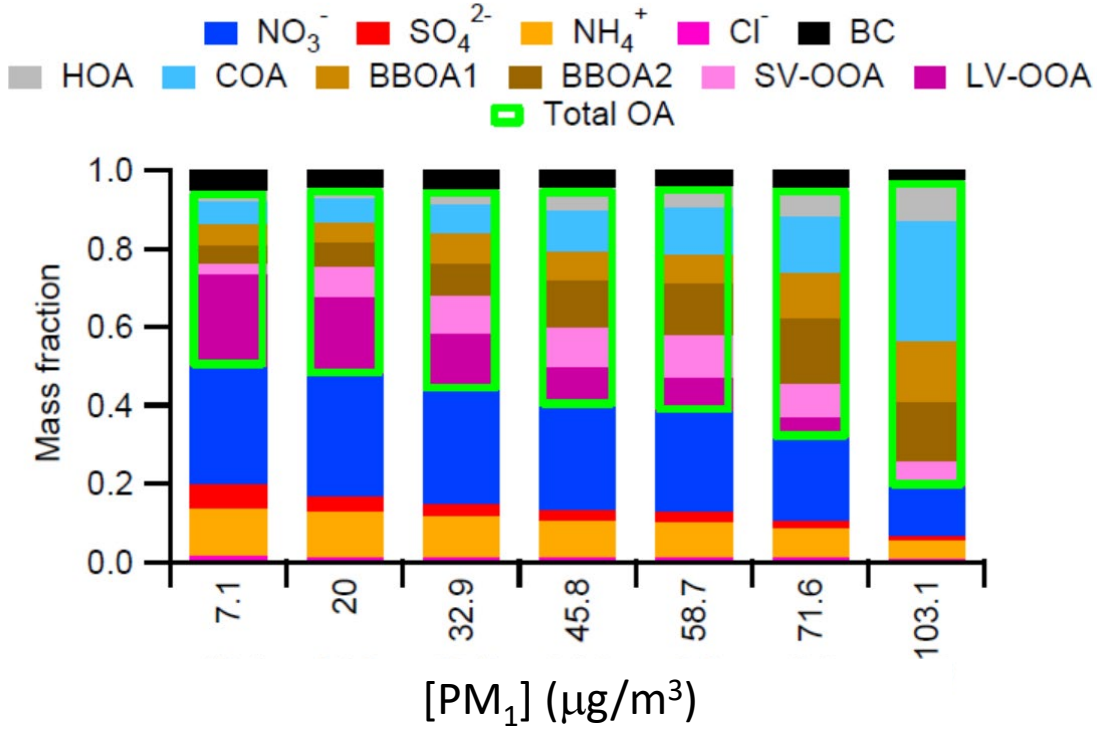
Particle Composition: Relationship with total PM

Aircraft Measurements



Based on Franchin et al. (2018); Utah

Ground Measurements



Young et al. (2016); San Joaquin Valley

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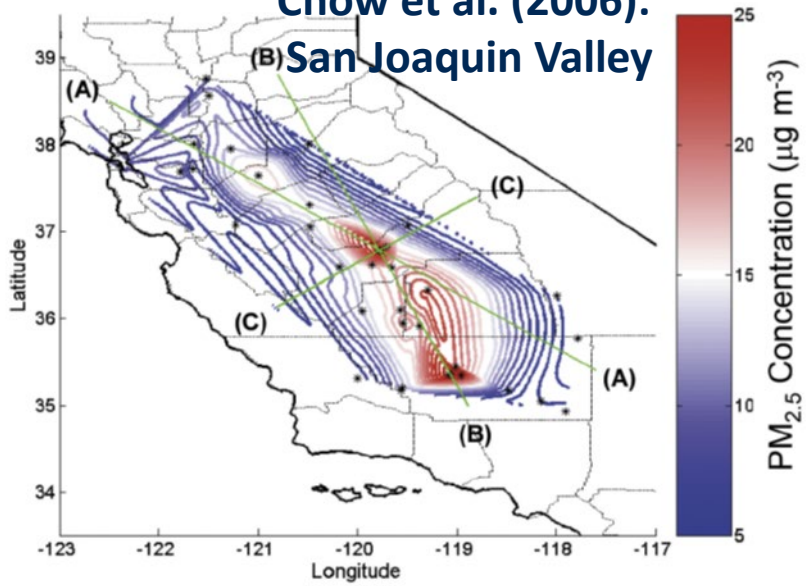
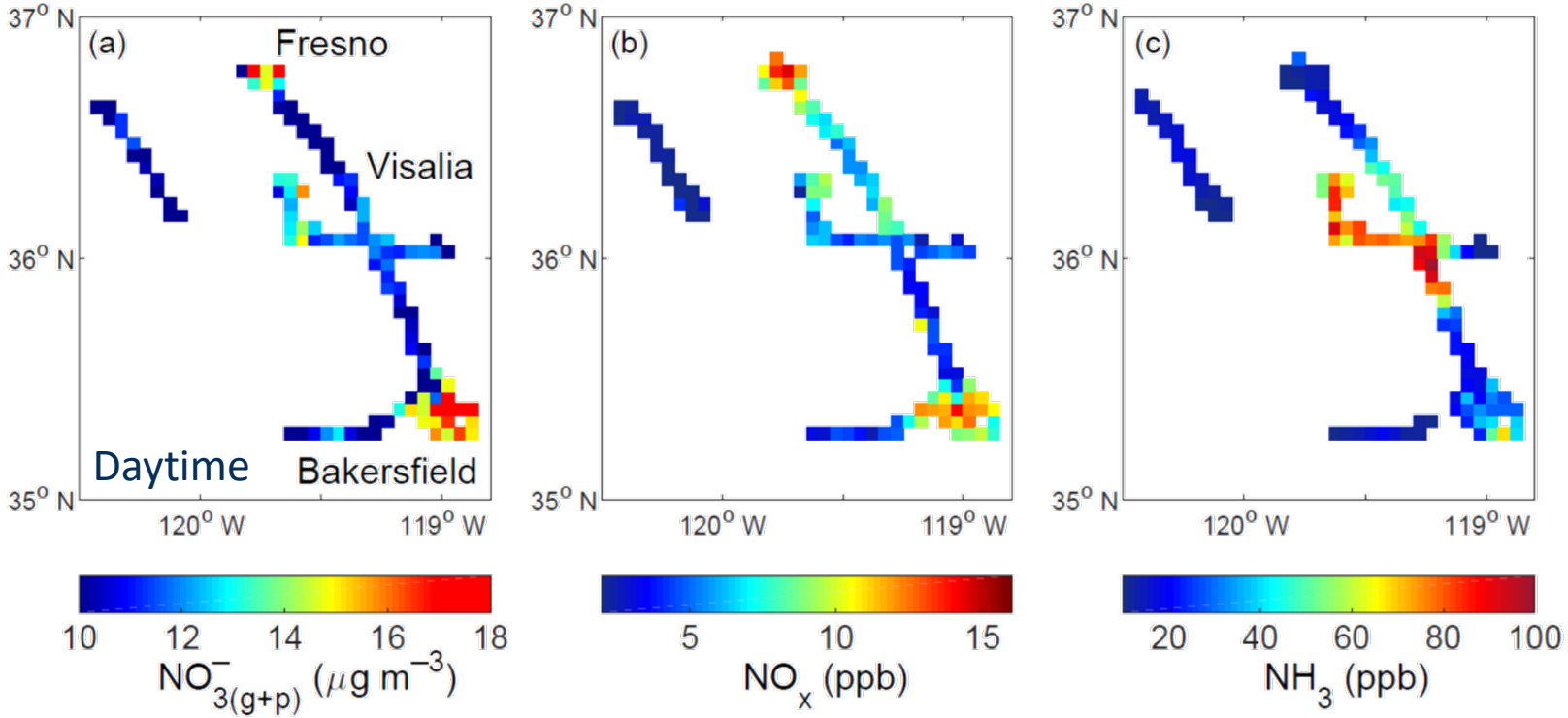
Spatial Distribution

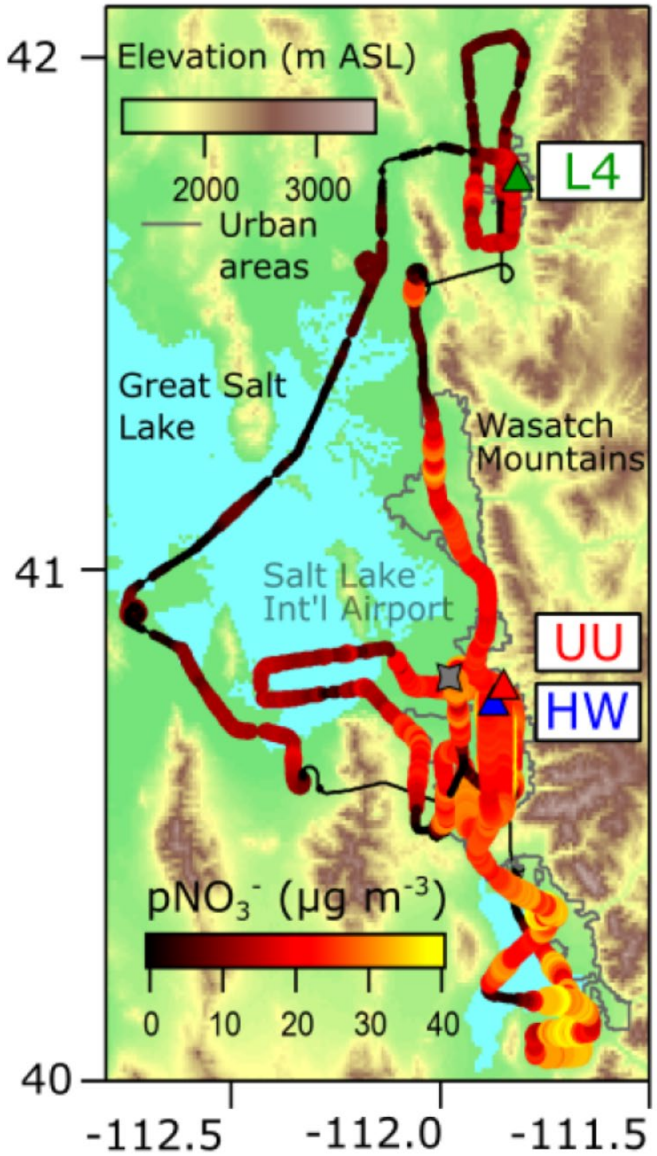
- Homogeneous?
- Cities versus rural?
- Altitude?

Chow et al. (2006): San Joaquin Valley



Pusede et al. (2016): San Joaquin Valley





Womack et al. (2019): Utah

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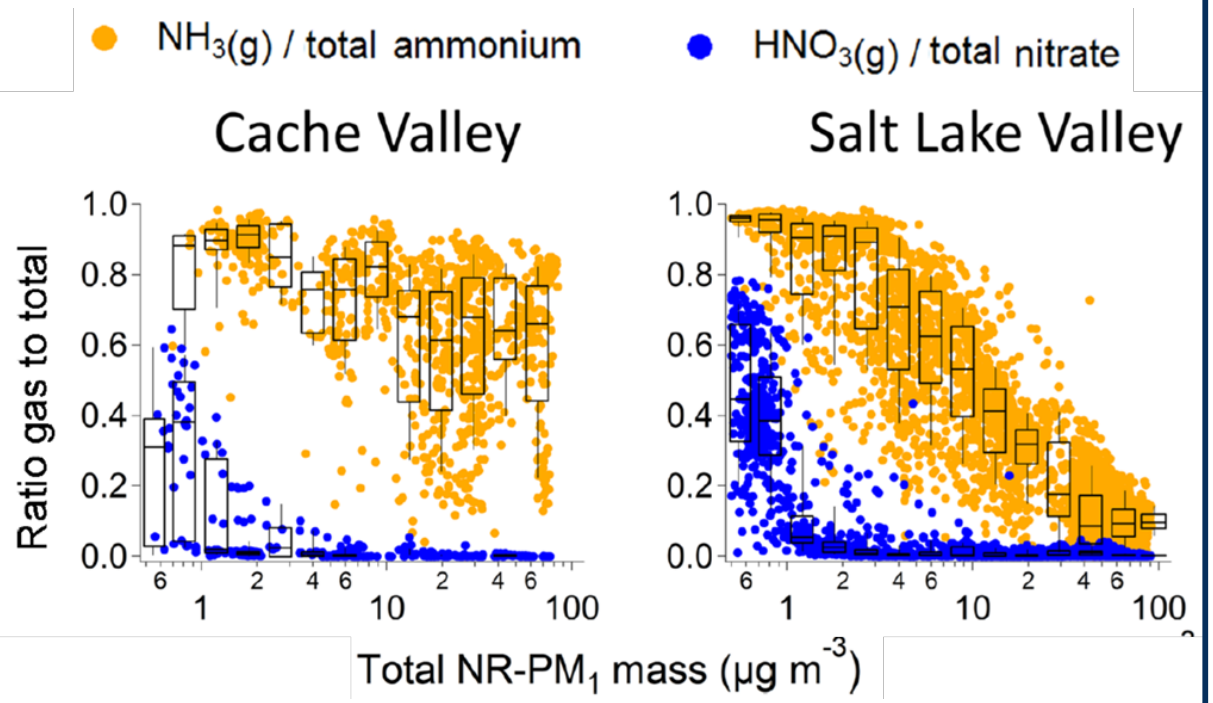
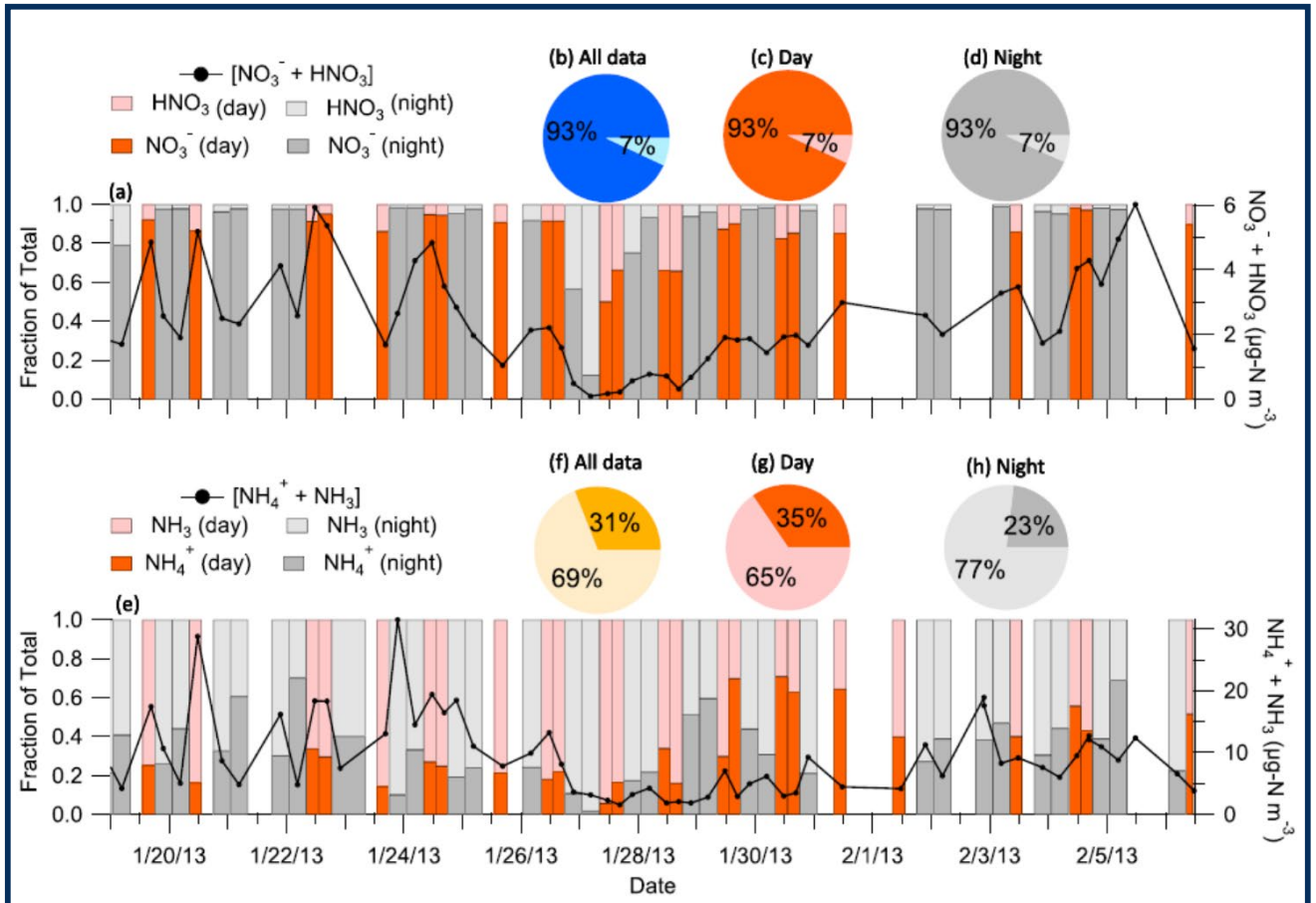
Nitrate gas-particle partitioning



Franchin et al. (2018); Utah



Parworth et al. (2017): San Joaquin Valley

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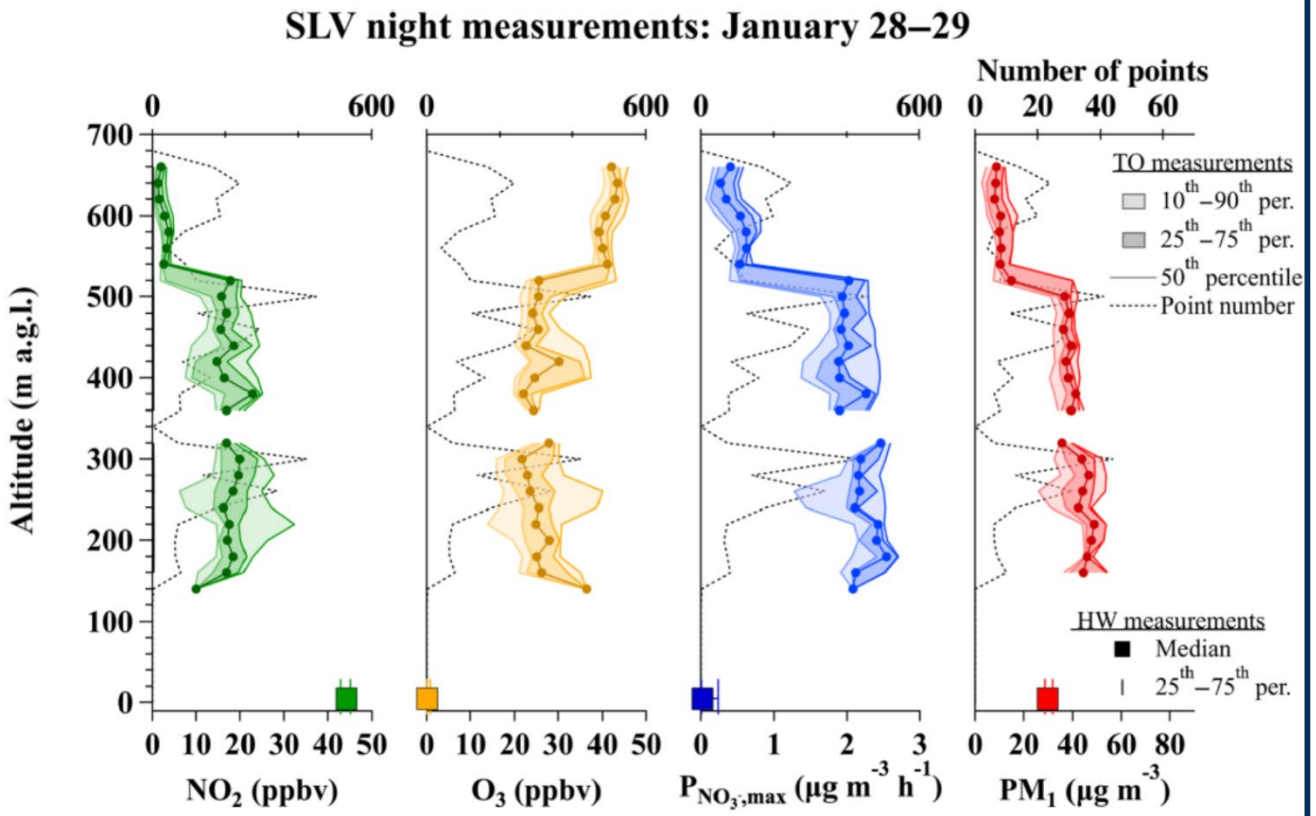
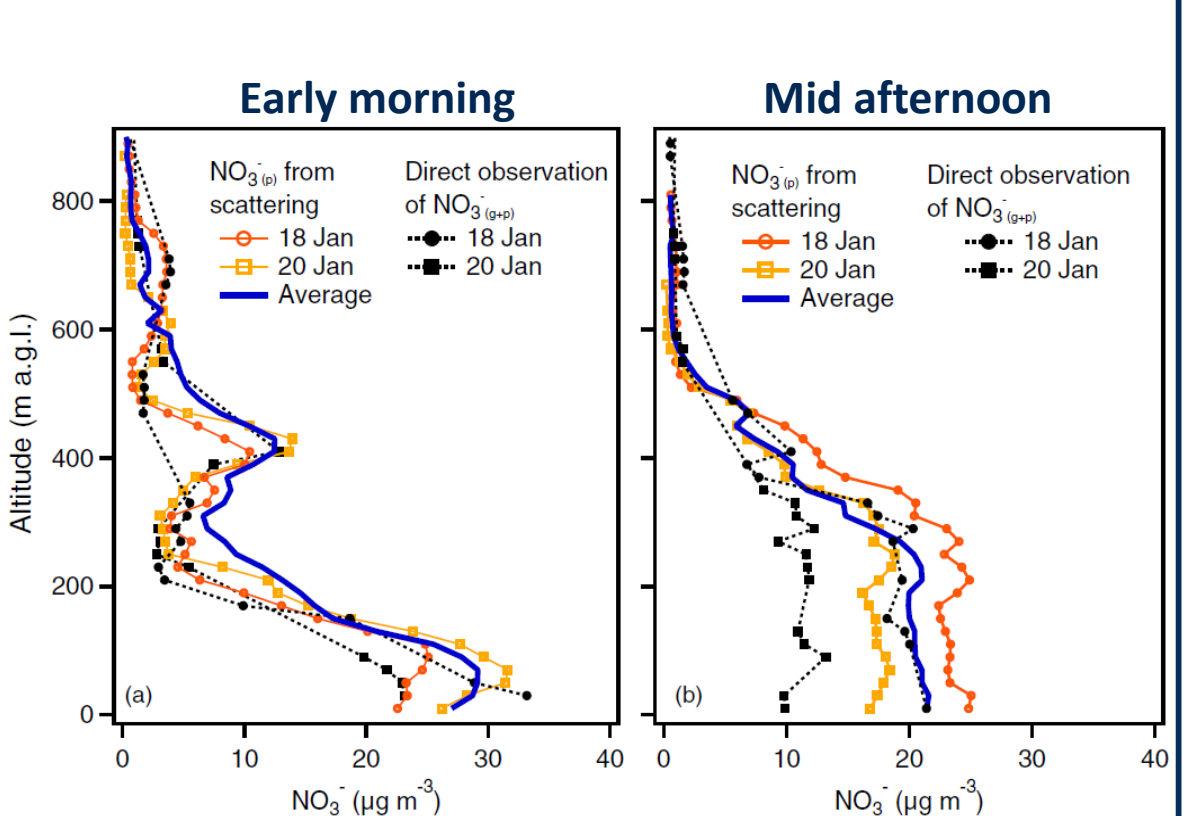
Vertical structure: Chemistry + Meteorology Coupling



McDuffie et al. (2019); Utah



Prabhakar et al. (2017); Fresno

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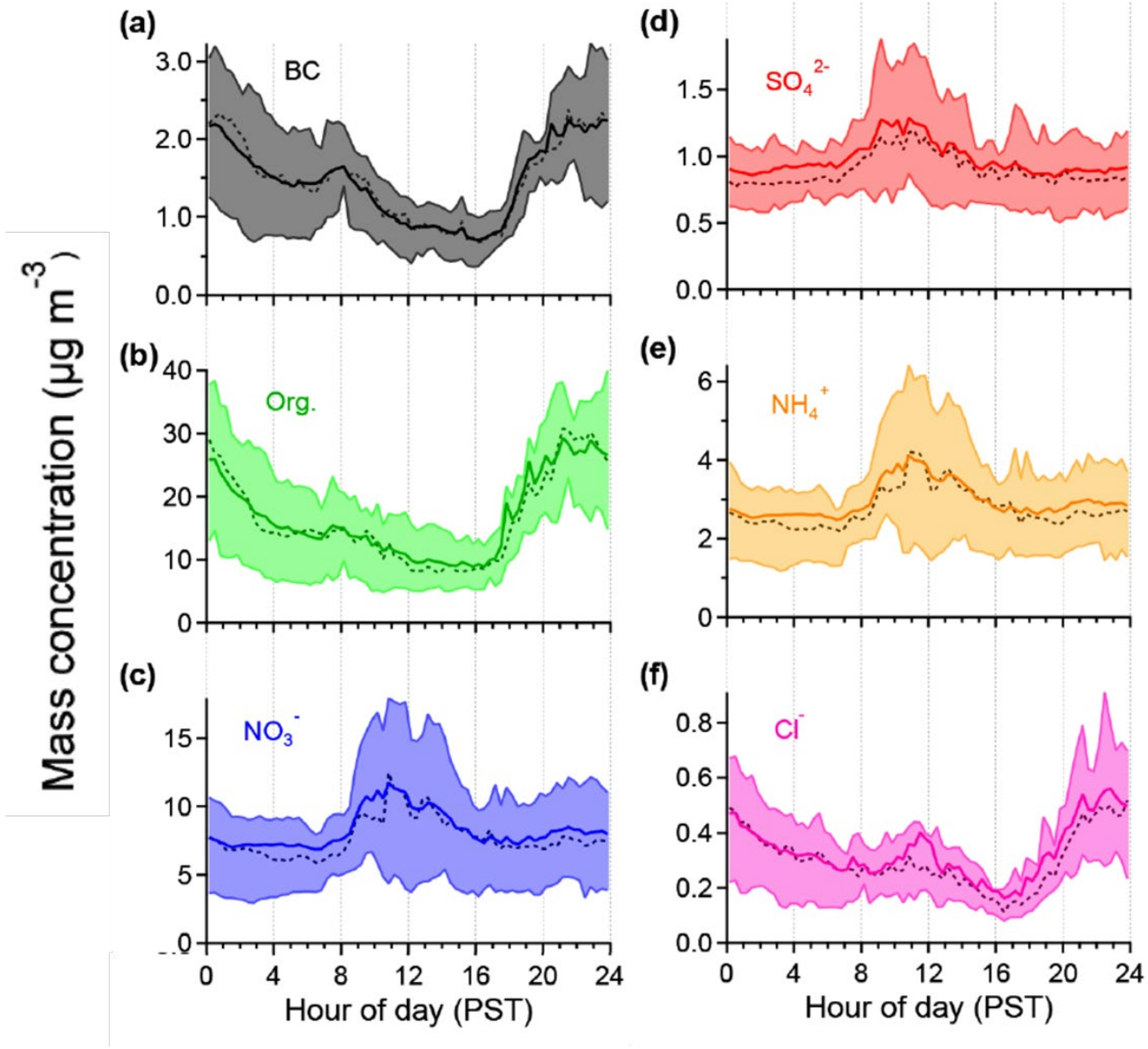
Diel Variability and Process Understanding



Young et al. (2016): San Joaquin Valley

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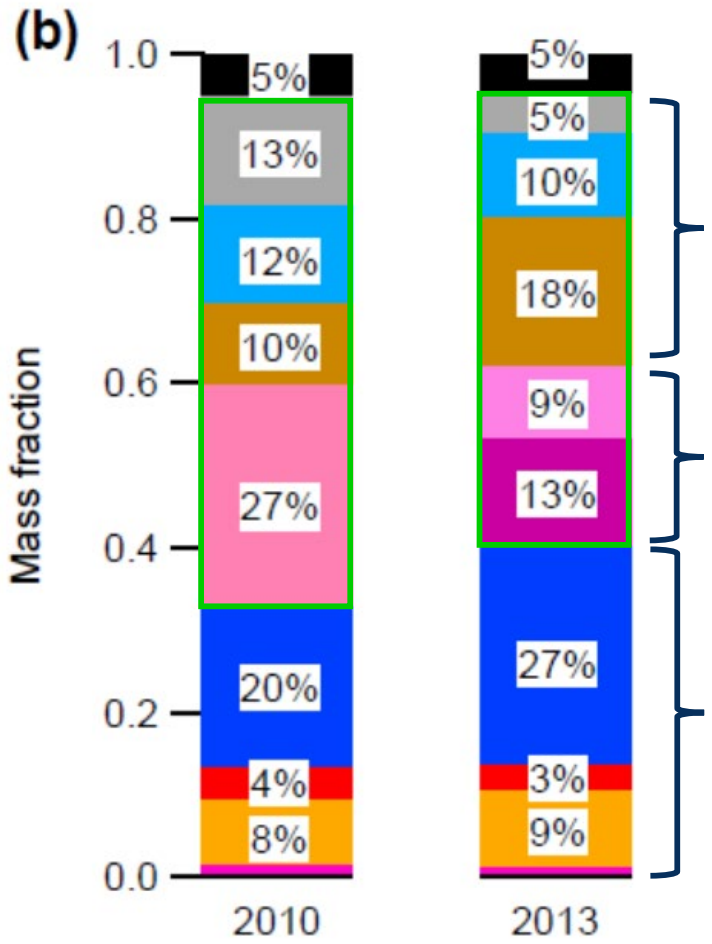
Science Question: What are the relevant physical (including meteorological), chemical and thermodynamic processes that govern winter particulate matter formation and loss, what are the uncertainties, and how can these be addressed through measurements and modeling?

Sources of PM Pollution



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

Primary organic aerosol

Secondary organic aerosol

Secondary inorganic aerosol

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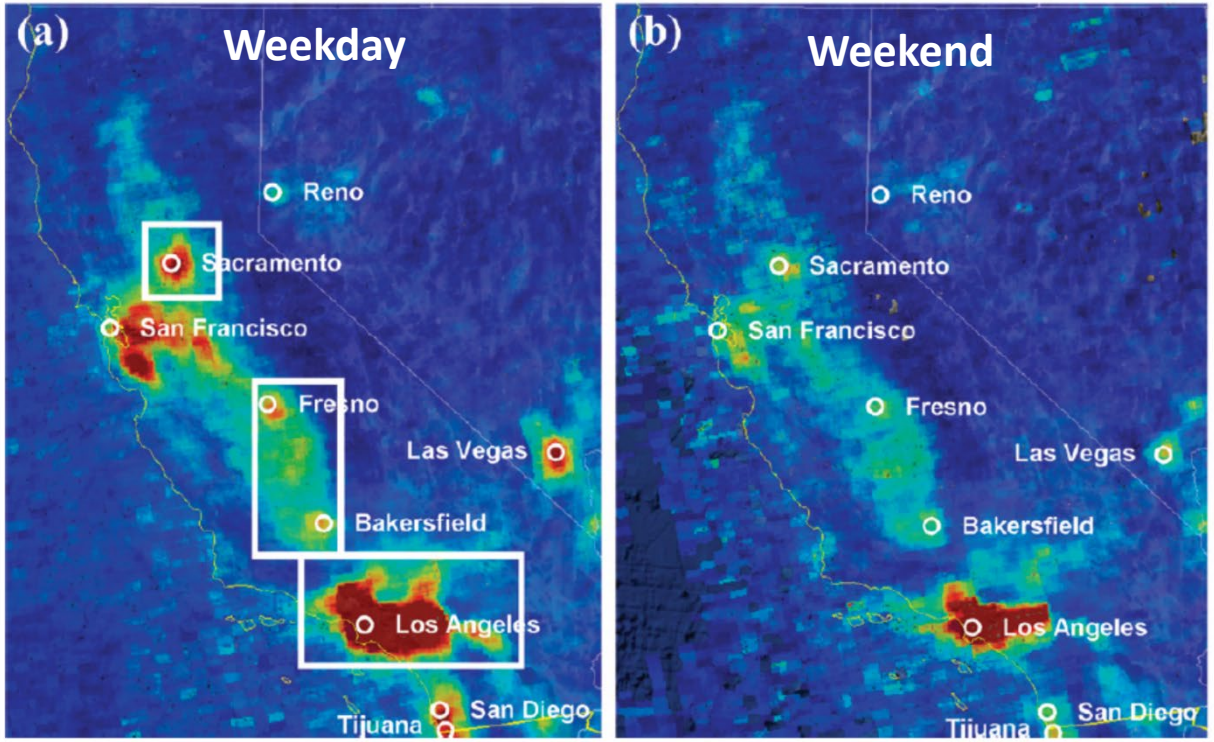
NO_x → Nitrate

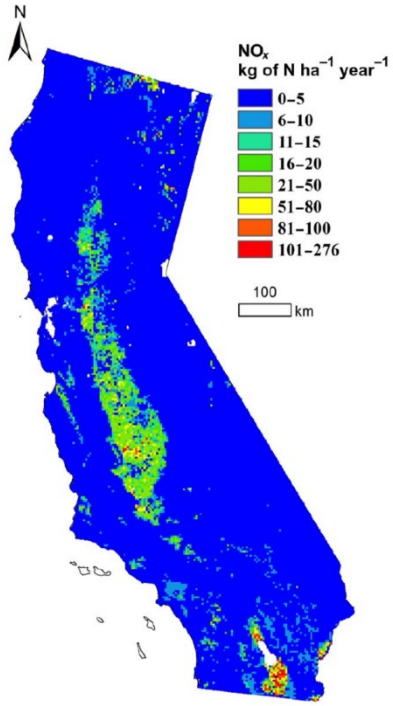
vs.

NO_2 column, summer



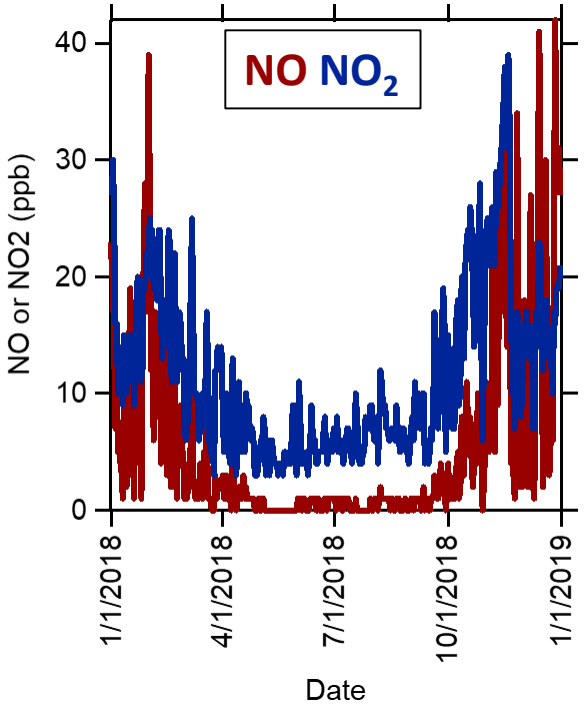
Russell et al. (2010)

Ag NO_x emissions



Almaraz et al. (2018)

Seasonality



ARB Data (Fresno)

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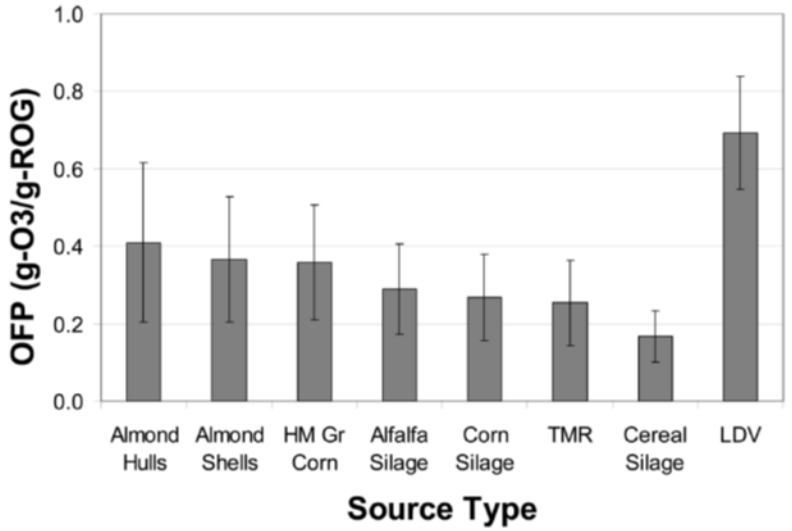
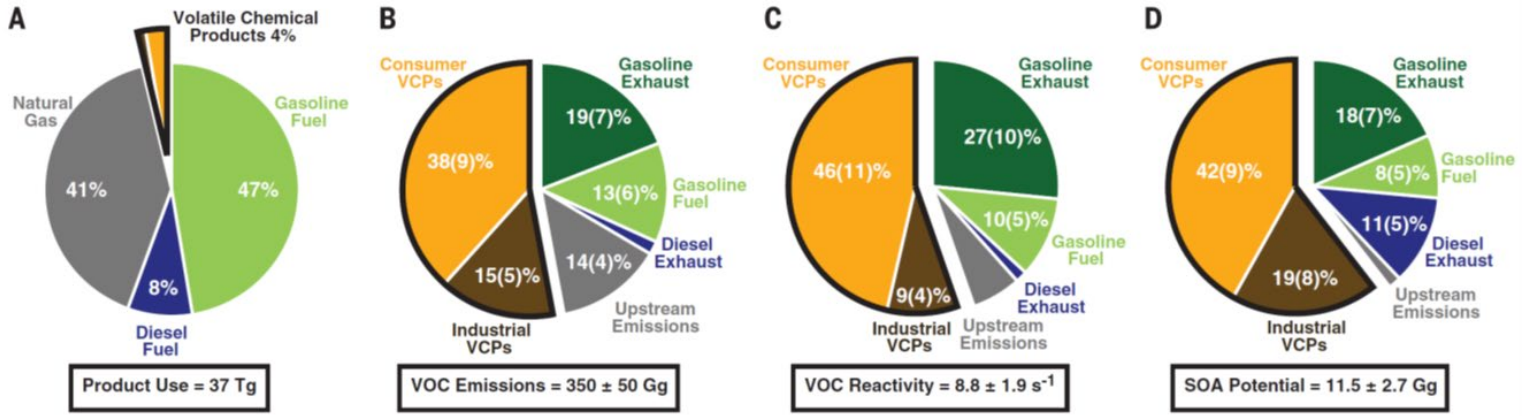
VOC's → SOA → Nitrate

Livestock feed



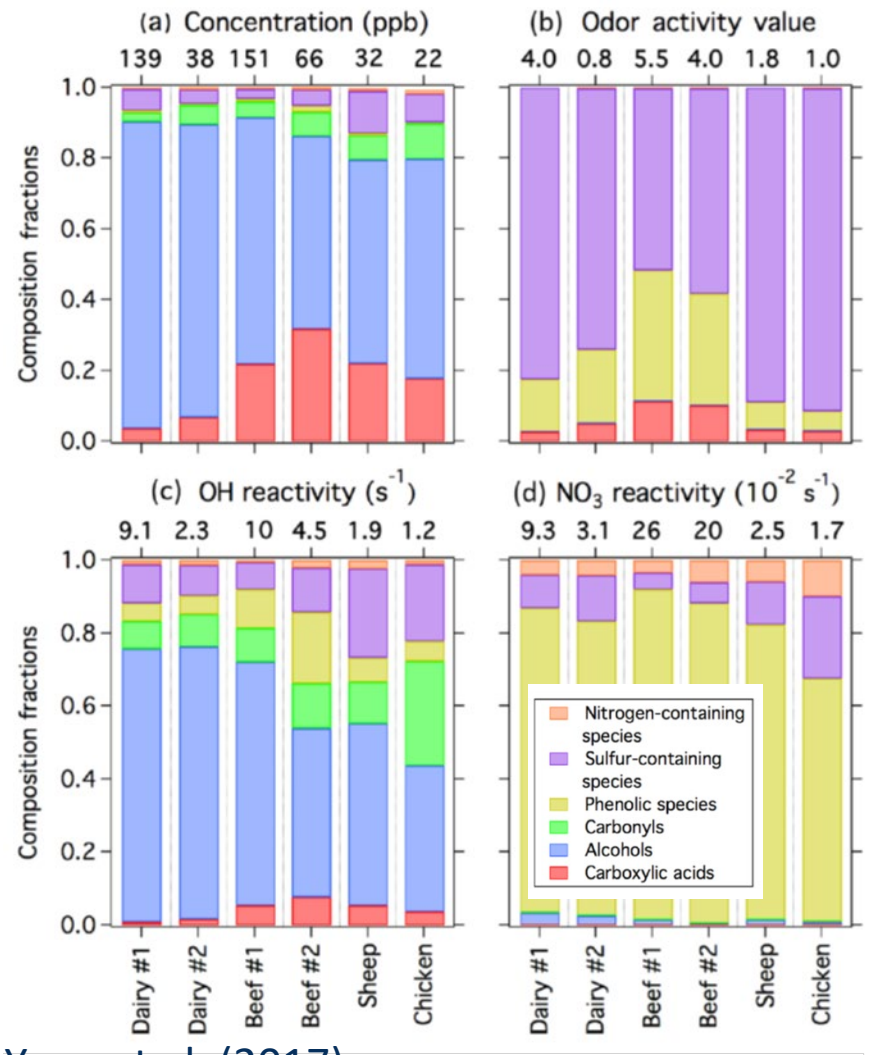
Howard et al. (2010)

Volatile Chemical Products & Transport



McDonald et al. (2018)

CAFO's



Yuan et al. (2017)

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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

$O_3 + h\nu \rightarrow O(^1D) + O_2$

$H_2O + O(^1D) \rightarrow 2\ OH$

$HONO + h\nu \rightarrow OH + NO$

$CH_2O + h\nu \rightarrow OH + CH$

$OH + NO_2 \rightarrow \mathbf{HNO_3}$

$\mathbf{HNO_3} \leftrightarrow \mathbf{NH_3}$

$\mathbf{HNO_3} \leftrightarrow \mathbf{AN}$

Nighttime

$O_3 + NO_2 \rightarrow NO_3 + O_2$

$NO_3 + NO_2 \leftrightarrow N_2O_5$

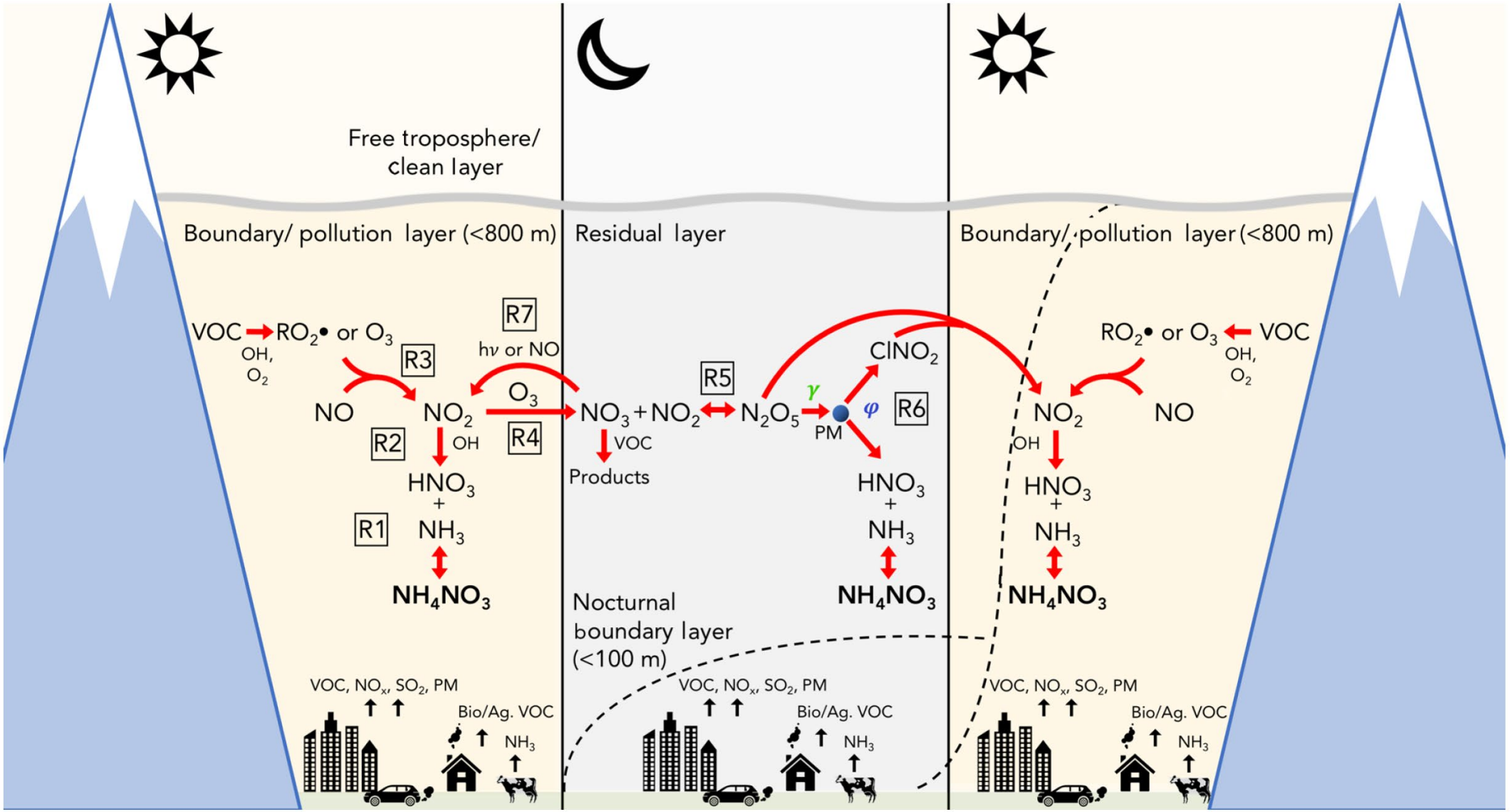
$NO_3 + VOC \rightarrow products$

$N_2O_5 + particles_{(aq)} \rightarrow 2\ \mathbf{HNO_3}$

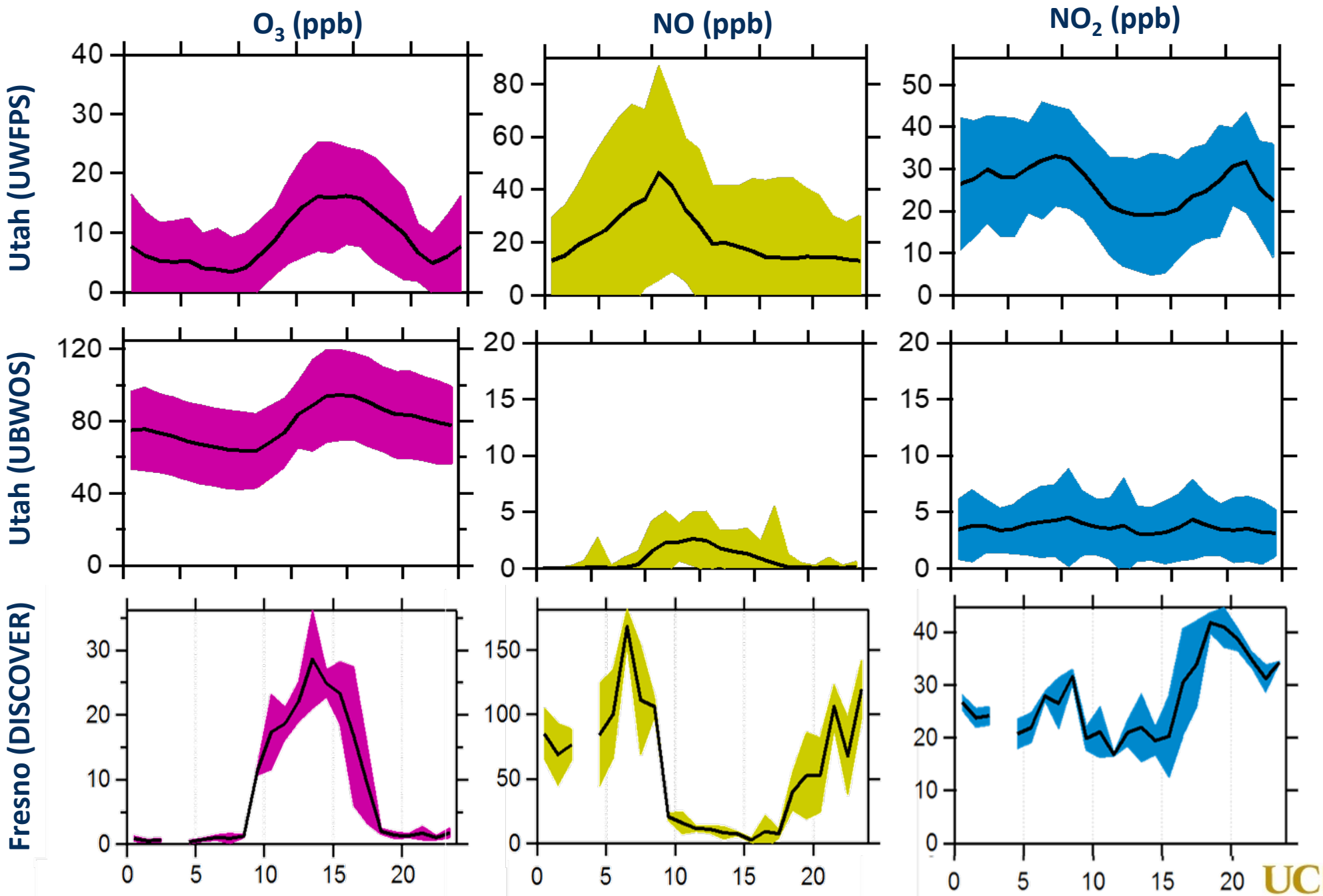
$\rightarrow \mathbf{HNO_3} + ClNO_2$

$\mathbf{HNO_3} \leftrightarrow \mathbf{NH_3}$

$\mathbf{HNO_3} \leftrightarrow \mathbf{AN}$

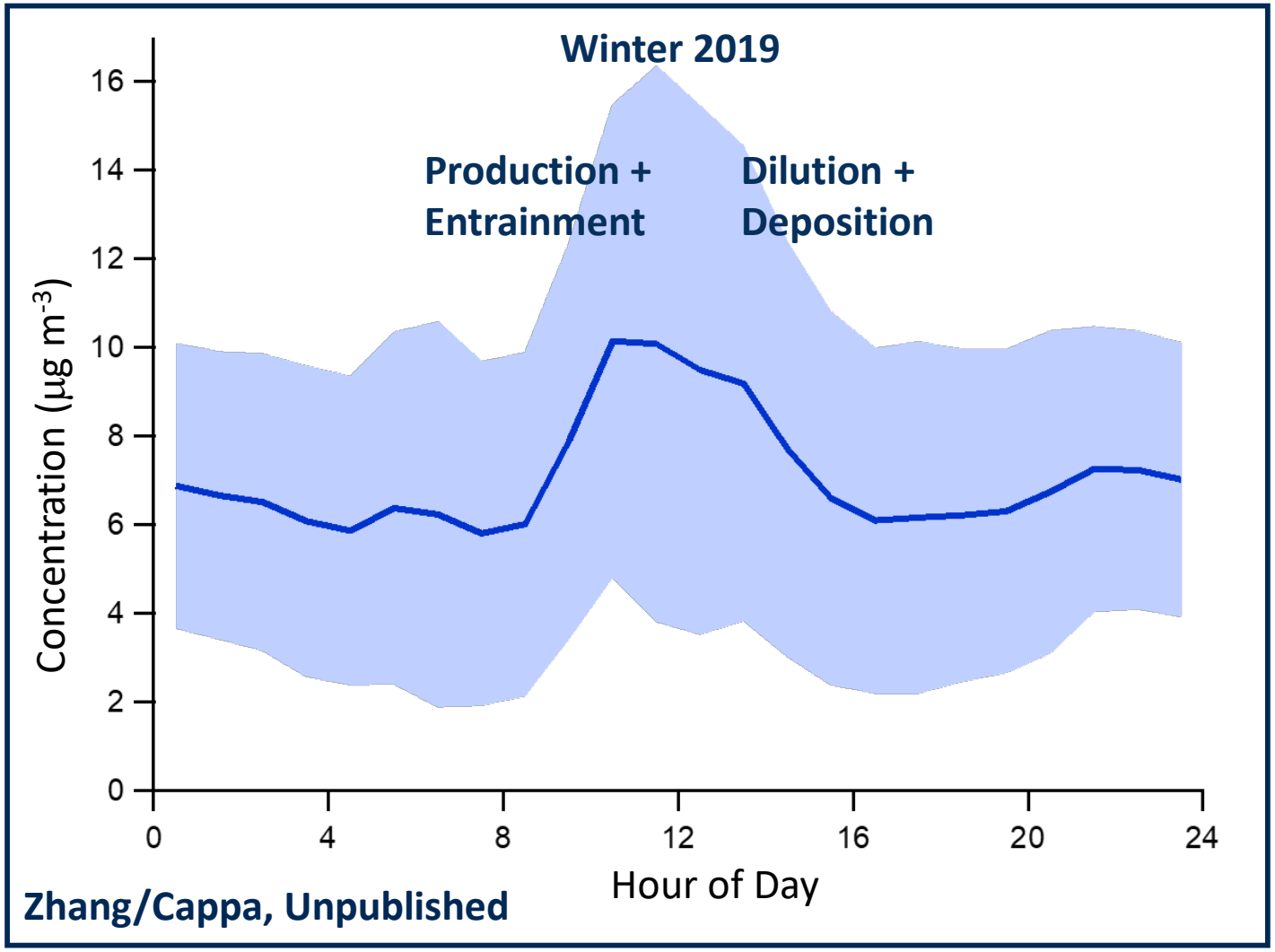


McDuffie et al. (2019)

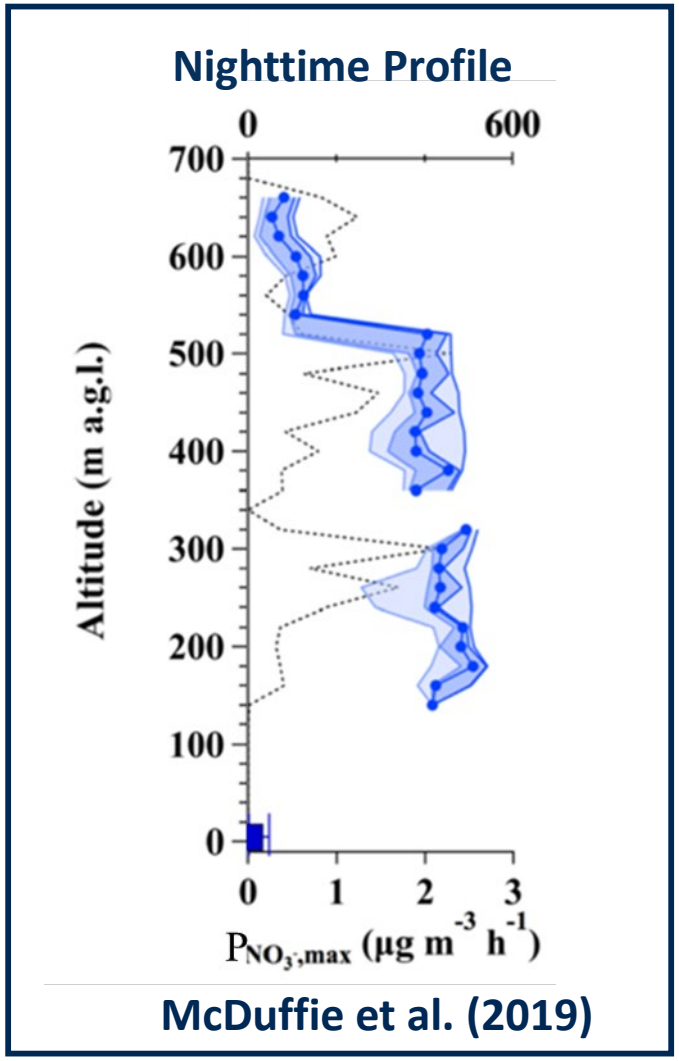


[Based on Prabhakar et al. (2017); McDuffie et al. (2019); Womack et al. (2019)]

Chemistry + Meteorology Coupling

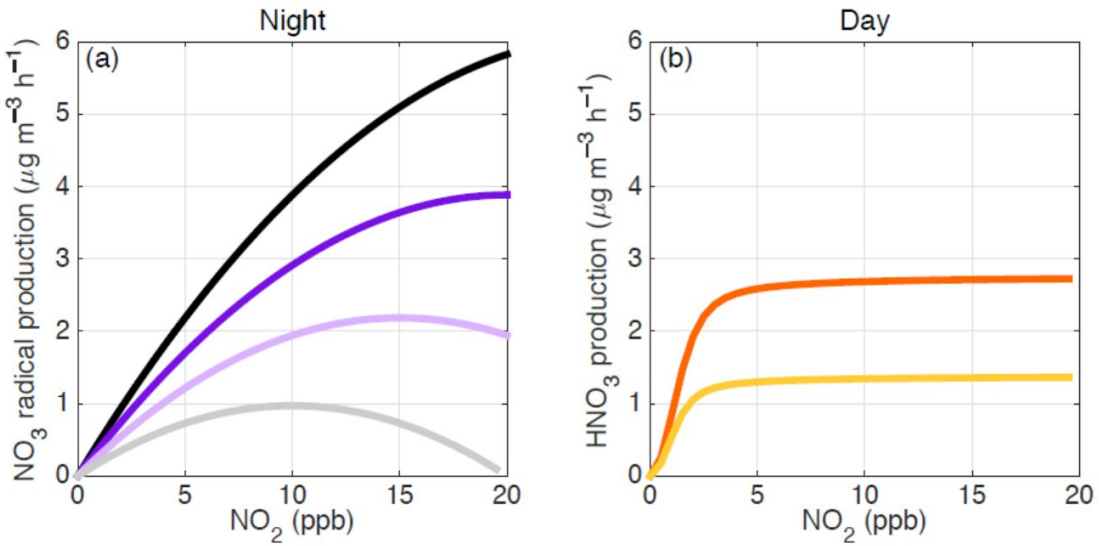


Zhang/Cappa, Unpublished

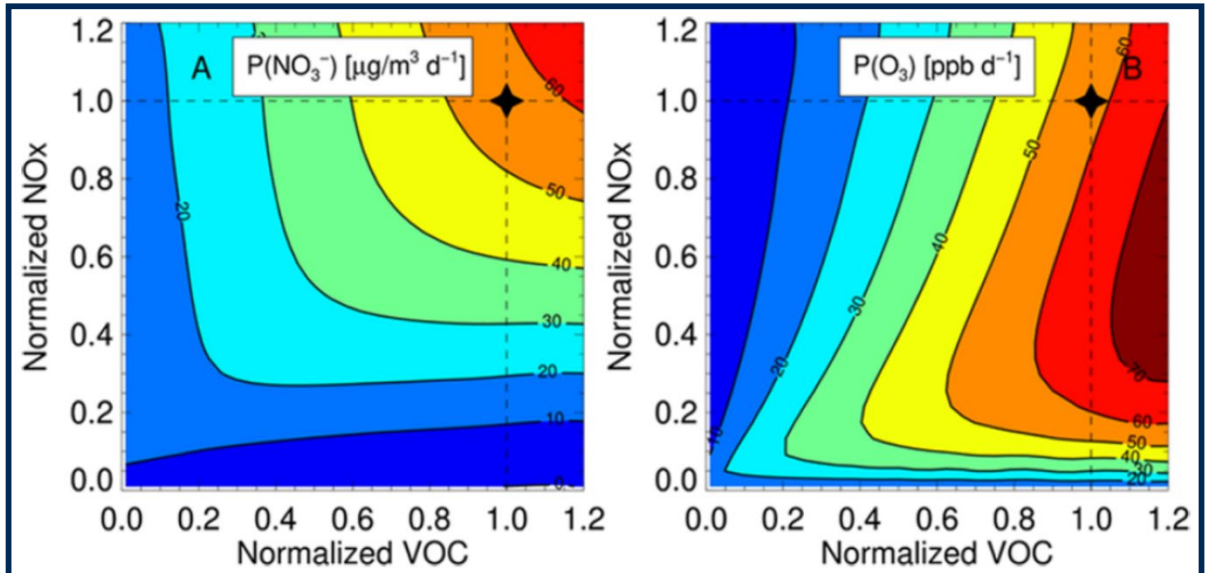


McDuffie et al. (2019)

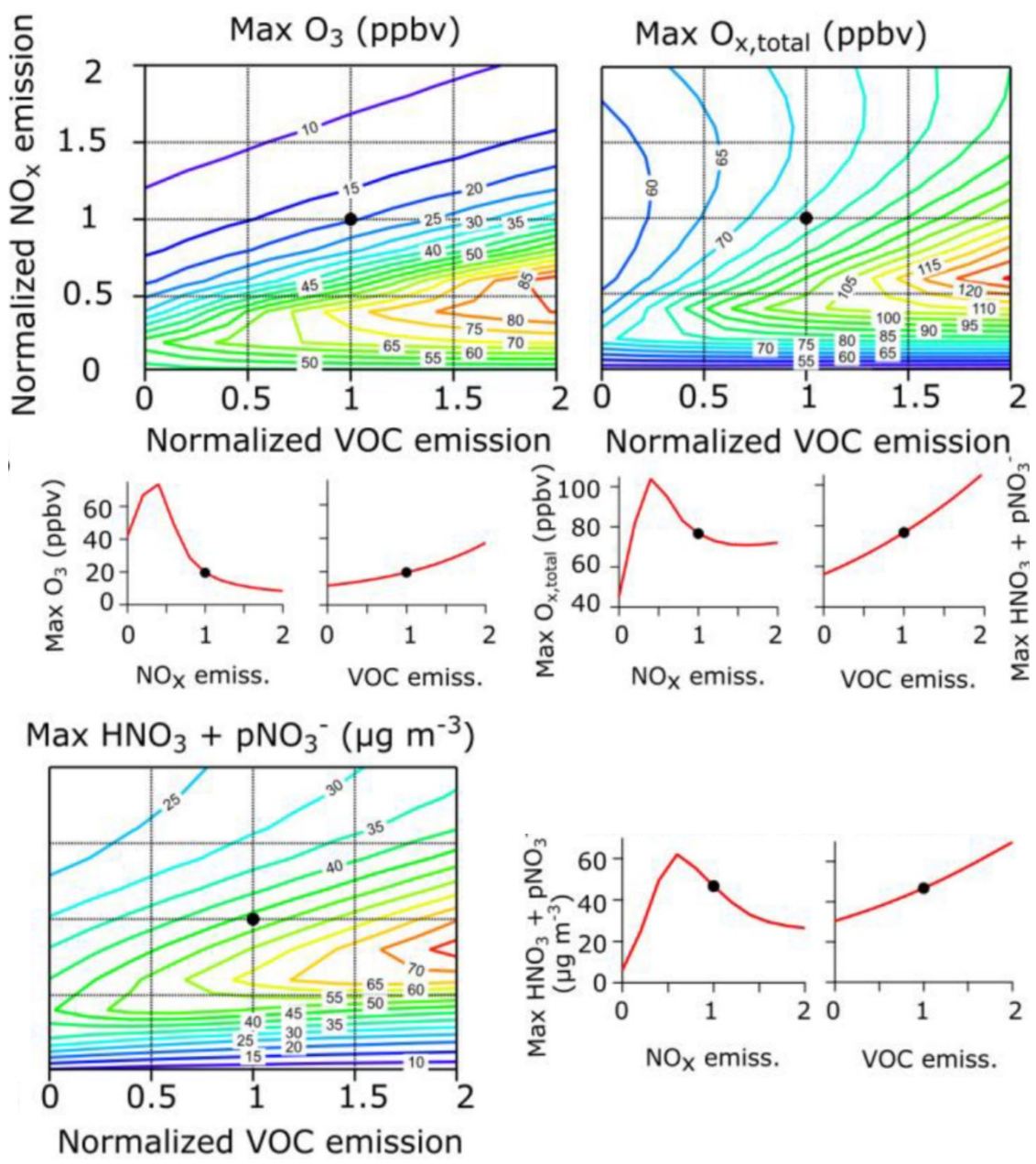
Implications for Control Strategies



Pusede et al. (2016); SJV

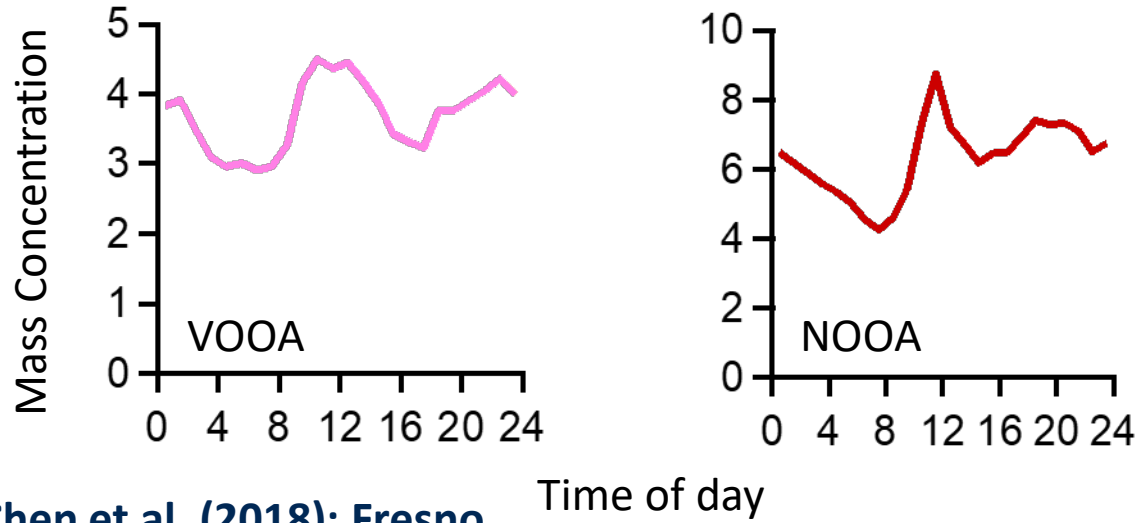


Lu et al. (2019); Beijing

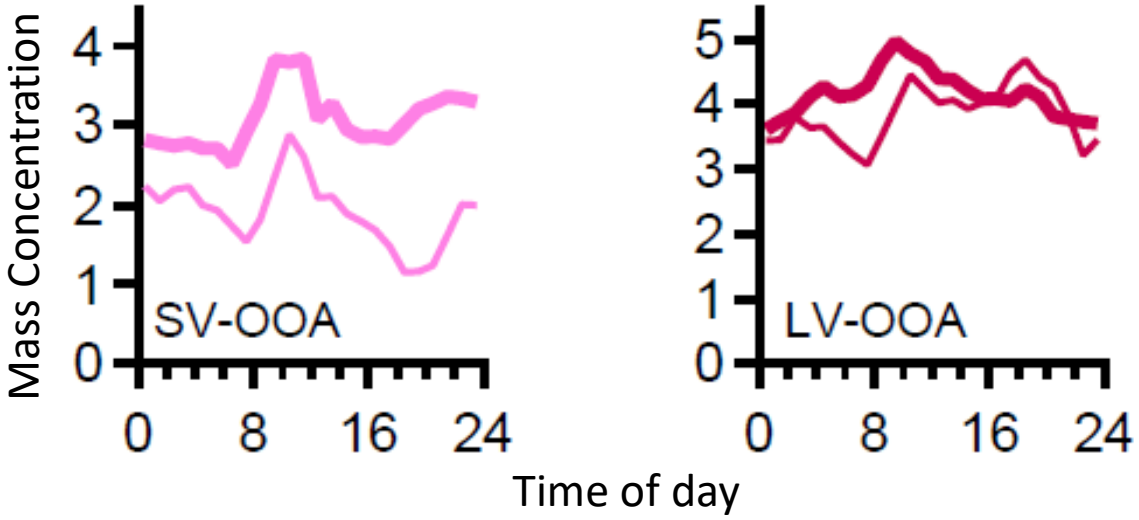


Womack et al. (2019); Utah

Secondary Organic Aerosol



Chen et al. (2018); Fresno



Young et al. (2016); Fresno

Local vs. Regional

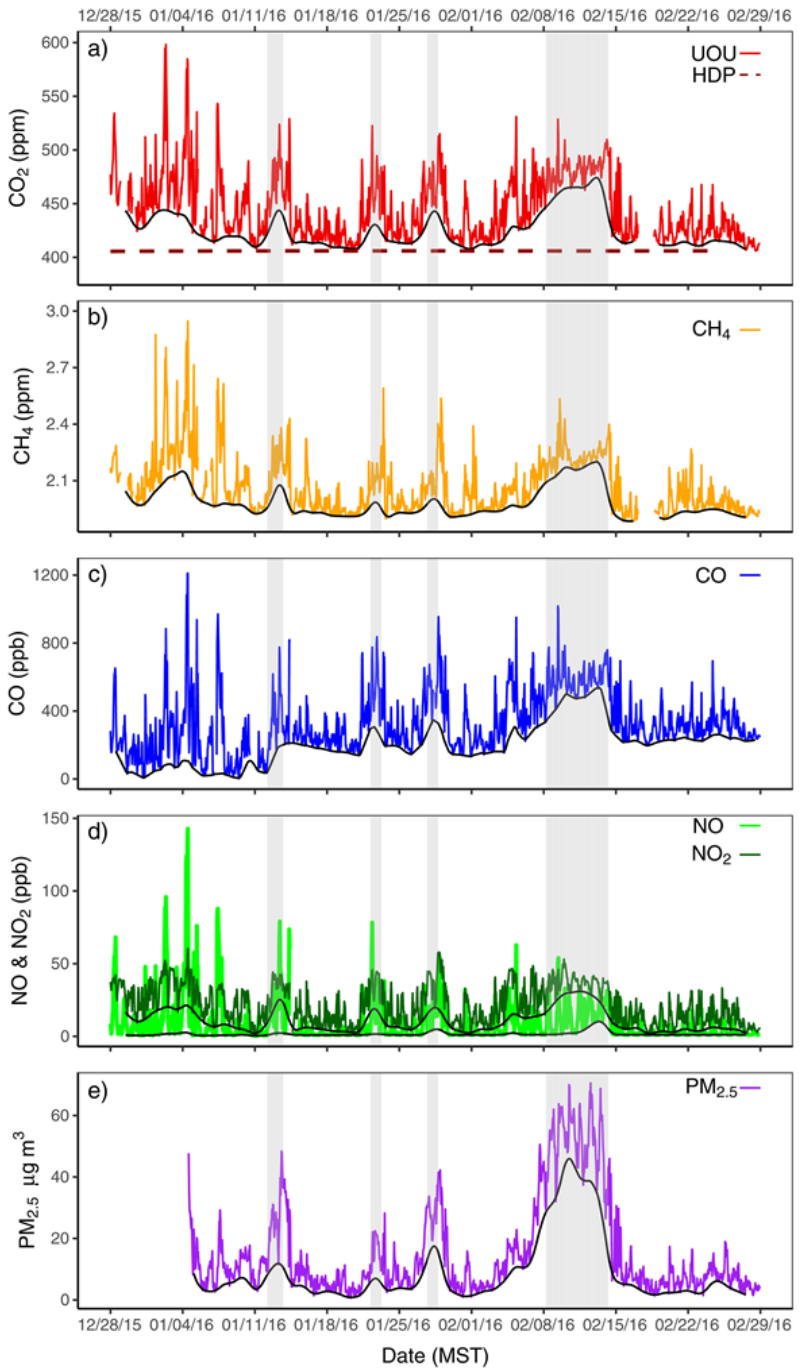
Daytime vs. Nighttime

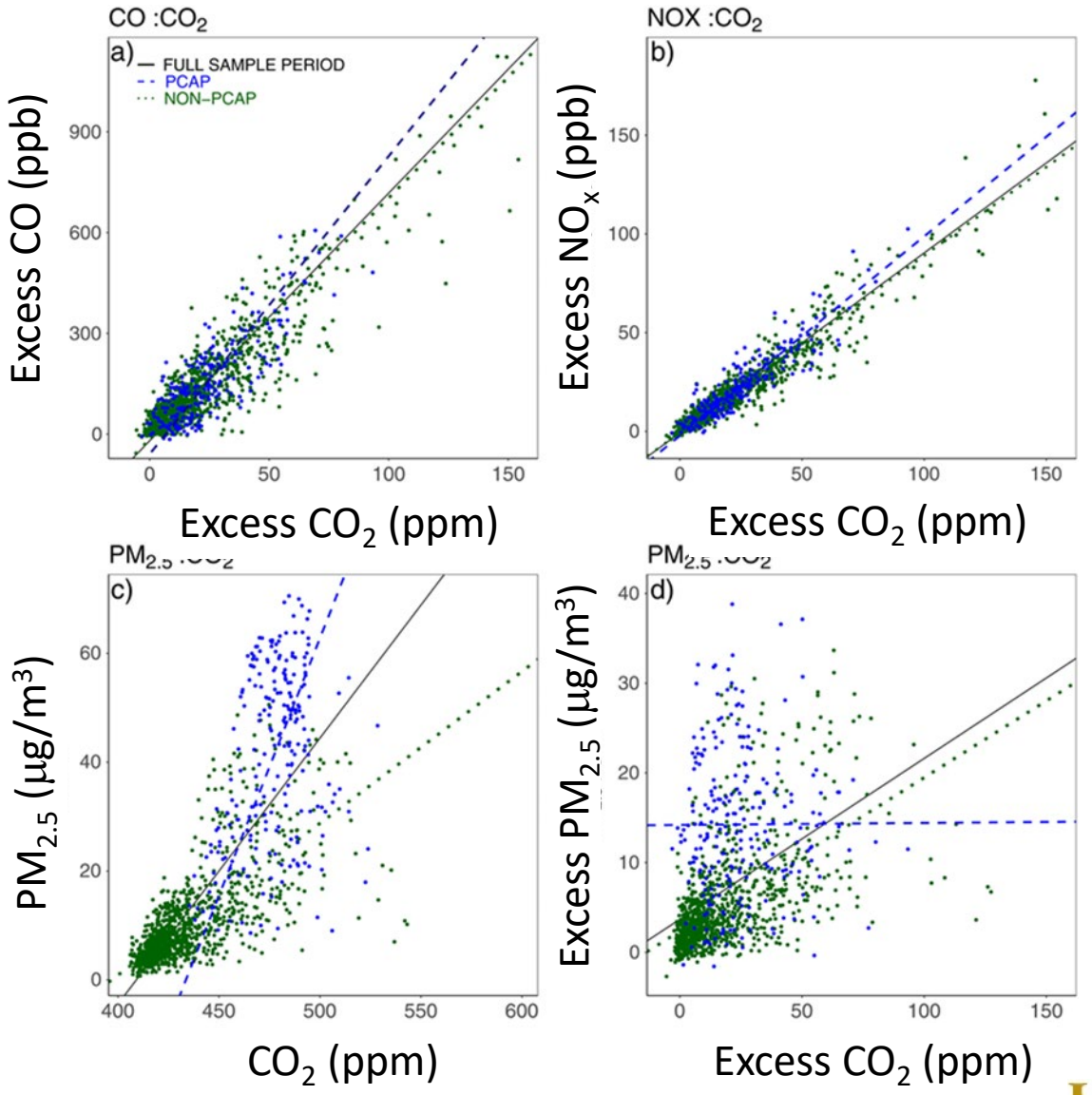
Dry vs. Wet (fog/clouds/aerosol)

Source of VOC's?

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

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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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https://atmos.utah.edu/aquarius/index.php

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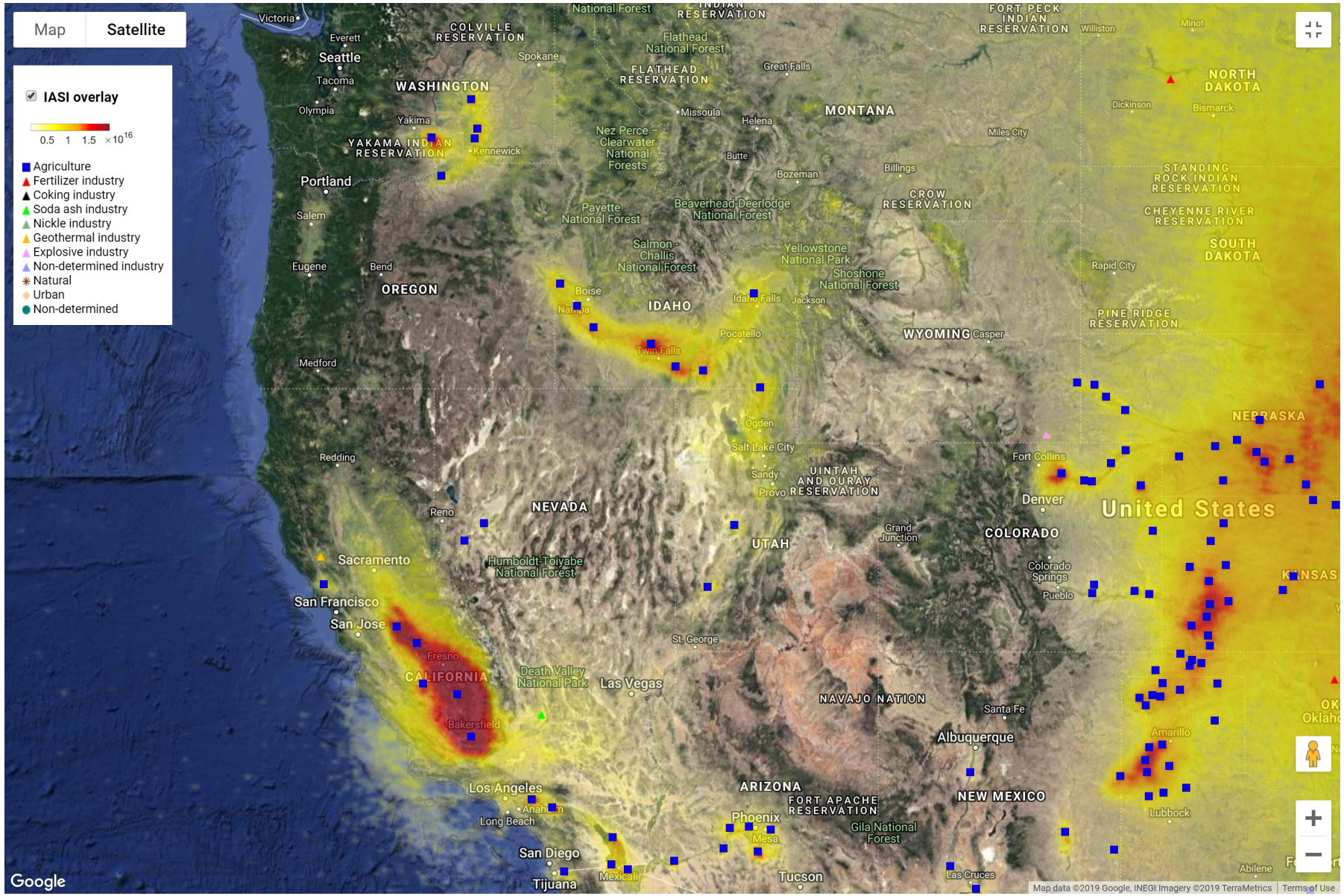

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