Baseline Contributions to Surface Ozone in California’s Central Valley

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Today - 2 heuristic model analyses:

• Review correlation analysis of surface O₃ in North Sacramento Valley with that measured by sondes over Pacific

• Examine historical trends of O₃ in some of California’s air basins

Not limited to Transported Anthropogenic Ozone!
North Sacramento Valley

O$_3$ non-attainment area

Sparsely populated

Inland from Trinidad Head – ozone sonde launch site

Coastal mountain ranges separate valley from Pacific

Examine how surface O$_3$ in the valley depends on that measured by sondes

Focus on summertime (June, July, August)

Parrish et al., ACP, 2010
Over Pacific near surface $O_3$ is at a minimum during summer.

This is background transported ashore to coastal air basins.

Parrish et al., *ACP*, 2010
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Sondes show large vertical gradient, with broad spring-summer maximum at 2 km ~25 ppbv higher than at surface.

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Parrish et al., ACP, 2010
North Sacramento Valley

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This is background transported ashore over Coastal mountains.

One standard deviation above 2 km average approaches NAAQS.

What altitude inflow accounts for background O$_3$ in North Sacramento Valley?

Parrish et al., *ACP*, 2010
North Sacramento Valley

Examine correlation of surface \(O_3\) at Tuscan Butte with that measured by sondes

Parrish et al., *ACP*, 2010
Examine correlation of surface \( \text{O}_3 \) at Tuscan Butte with that measured by sondes

Use interpolated max 8-hr \( \text{O}_3 \) average for all correlations

Diurnal cycle clear in 1-hr data

Daily maximum 8-hr \( \text{O}_3 \) averages capture regional variation

Parrish et al., *ACP*, 2010
North Sacramento Valley

Examine correlation of surface O$_3$ at Tuscan Butte with that measured by sondes

Use interpolated max 8-hr O$_3$ average for all correlations

Sonde data do appear to correlate with surface O$_3$

Parrish et al., *ACP*, 2010
Examine correlation of surface $O_3$ at Tuscan Butte with that measured by sondes

Use interpolated max 8-hr $O_3$ average for all correlations

Correlate surface and sonde data as a function of time offset between data sets

208 summertime sondes: 1997-2008

Parrish et al., ACP, 2010
Examine correlation of surface O$_3$ at Tuscan Butte with that measured by sondes

Use interpolated max 8-hr O$_3$ average for all correlations

Maximum 8-hr average at Tuscan Butte correlates with sonde, but about 1 day later

3.4 days convolution of all time scales involved

Parrish et al., ACP, 2010
Examine correlation of surface $O_3$ at Tuscan Butte with that measured by sondes.

Use interpolated max 8-hr $O_3$ average for all correlations

Correlate surface and sonde data as a function of sonde altitude

Parrish et al., *ACP*, 2010
North Sacramento Valley

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Correlate surface and sonde data as a function of sonde altitude

4 sites:
• Redding, Tuscan Butte in valley
• Lassen at 1.8 km on far side
• Yreka outside valley to north

Parrish et al., ACP, 2010
Examine correlation of surface $O_3$ at Tuscan Butte with that measured by sondes.

Use interpolated max 8-hr $O_3$ average for all correlations.

Significant correlation between sonde (1.0 – 2.5 km) and all surface sites.
Examine correlation of surface O$_3$ at Tuscan Butte with that measured by sondes

Use interpolated max 8-hr O$_3$ average for all correlations

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15 to 30 hour delay between sonde (1 – 2.5 km) and surface sites

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Examine correlation of surface O$_3$ at Tuscan Butte with that measured by sondes.

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Significant correlation between sonde (1.0 – 2.5 km) and all surface sites.

15 to 30 hour delay between sonde (1 – 2.5 km) and surface sites.

Cause of correlation: On-shore flow aloft transported inland over Coastal Range and mixed down to all surface sites.

Parrish et al., ACP, 2010
North Sacramento Valley

Bottom line: On average:

On non-exceedance days, 
(79% of days)
- total $O_3 = 61$ ppbv
- background $O_3 = 48$ ppbv,
- net photo. prod. = 13 ppbv

On exceedance days, 
(21% of days)
- total $O_3 = 81$ ppbv
- background $O_3 = 59$ ppbv,
- net photo. prod. = 22 ppbv

Background $O_3$ alone can exceed NAAQS

Parrish et al., *ACP*, 2010
North Sacramento Valley

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Summary: Exceedance days average 20 ppbv more $O_3$ than non-exceedance days. Difference in transported background $O_3$ accounts for > half (11 ppbv)

Parrish et al., ACP, 2010
North Sacramento Valley

Thoughts & Implications:

- Achieving NAAQS may not be possible with only local and regional control efforts
- Accurate modeling of California O$_3$ requires global model to reproduce background, plus mesoscale model for transport in complex terrain
- Similar transport patterns likely operate in other regions of complex terrain; i.e. San Joaquin Valley

Parrish et al., ACP, 2010
How has \( O_3 \) evolved in response to emission controls in these different air basins?

\( O_3 \) has been measured in nearly all 15 since 1980

6 coastal, 2 in Central Valley (San Joaquin Valley and Sacramento Valley), deserts, mountains, etc.

South Coast has one of the most populous urban areas in the U.S.

San Joaquin Valley is one of the richest agricultural regions of the country

Geology and land-use spectrum gives a wide spectrum of ozone precursor emission sources.
California’s Air Basins

Daily Maximum 8-hour average $\text{O}_3$

May – September $\text{O}_3$ season

Calculate maximum, 90$^{th}$ %, 50$^{th}$ and 25$^{th}$ percentiles

Plot time evolution

Least-squares regression fit to:

$$\text{O}_3 = y_0 + A \exp \left( \frac{t - t_0}{\tau} \right).$$

$y_0 = \text{baseline $\text{O}_3$ contribution}$

$A = 1980 \text{ $\text{O}_3$ enhancement above } y_0$

$t = \text{year}; t_0 = 1980$

$\tau = \text{response time of emission controls}$

How has $\text{O}_3$ evolved in response to emission controls in these different air basins?
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- \( t \) = year; \( t_0 = 1980 \)
- \( \tau \) = response time of emission controls

San Diego:
\[ \tau = 23.5 \text{ years}; \ y_0 = 48 \text{ ppbv} \]

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California’s Air Basins

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How has O$_3$ evolved in response to emission controls in these different air basins?

North Coast:

$\tau$ = 23.5 years

$y_0$ increasing to 44 ppbv
California’s Air Basins

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May – September O₃ season

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California’s Air Basins

Daily Maximum 8-hour average O\textsubscript{3}

May – September O\textsubscript{3} season

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\(y_0\) = baseline O\textsubscript{3} contribution

\(A\) = 1980 O\textsubscript{3} enhancement above \(y_0\)

\(t\) = year; \(t_0 = 1980\)

\(\tau\) = response time of emission controls

How has O\textsubscript{3} evolved in response to emission controls in these different air basins?

San Joaquin Valley:

\(\tau = 23.5\) years; \(y_0 = 84\) ppbv
How has O₃ evolved in response to emission controls in these different air basins?

Compare recent years in South Coast and San Joaquin Valley

- SoCAB decreasing much more rapidly
- SJV seems to be plateauing at higher O₃
- SJV now has higher O₃ than SoCAB (except for maximum)
California’s Air Basins

Why?

• Large differences in evolution of on-road vehicle NOx emissions [McDonald et al., 2012]

• An unknown, temperature-dependent source of reactive VOCs in SJV [Pusede and Cohen, 2012]

• SJV (and Mojave Desert) baseline O$_3$ enhanced due to descent of air from higher altitudes into these basins.

How has O$_3$ evolved in response to emission controls in these different air basins?
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Conclusions:

- Surface $O_3$ in North Sacramento Valley enhanced due to inflow of higher altitude air
- San Joaquin Valley surface $O_3$ evolution consistent with similar inflow into that valley as well

Implication:

- Higher $O_3$ in San Joaquin Valley than South Coast Air Basin means that the Nation’s $O_3$ pollution problem is no longer predominately a large city problem; it now can be worse in rural areas!
A chemist’s schematic view of transport that drives correlations:

North Sacramento Valley

- On-shore flow
- Mountain-Valley Flow
- CBL
- Sierra Mountain Range
- Coastal Range
- MBL
- Pacific Ocean
- Sacramento Valley