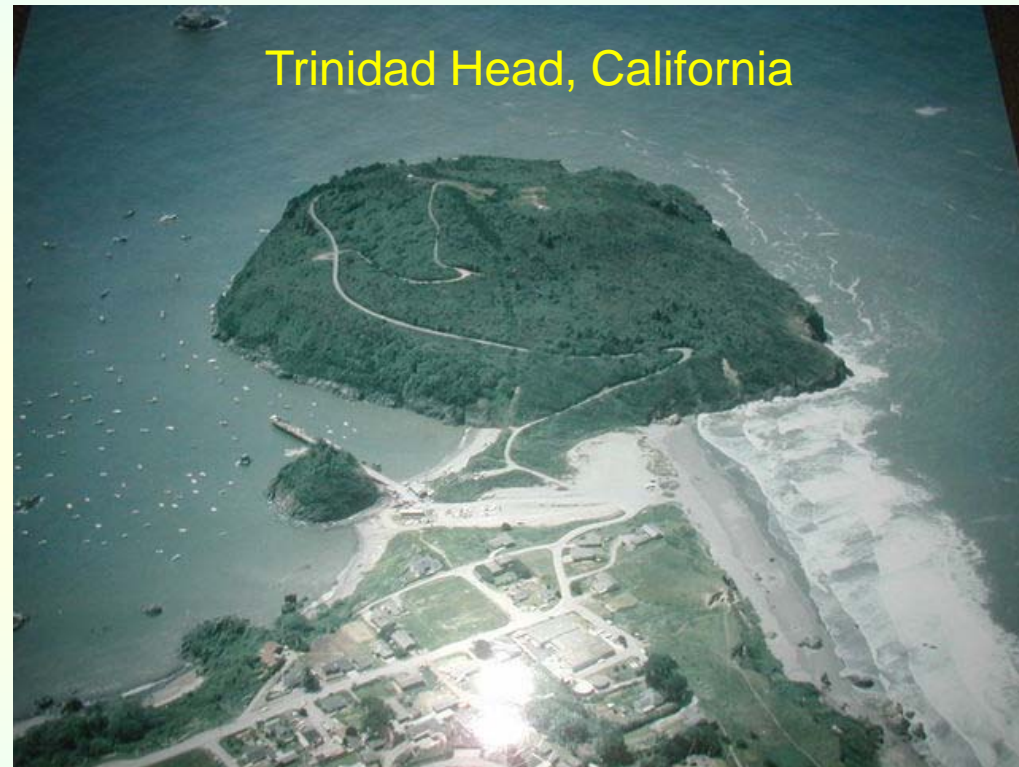# Air Quality Implications of Ozone in Air Entering the West Coast of North America

Today:

Ask: What effect does transported background O_3 have on air quality in California?

Answer: Correlate GMD surface and sonde O_3 data from Trinidad Head with California air quality monitoring data.

Discuss implications.

Trinidad Head, California

David Parrish, **Ken Aikin, Sam Oltmans, Bryan Johnson**
ESRL Global Monitoring Division 2009 Annual Conference
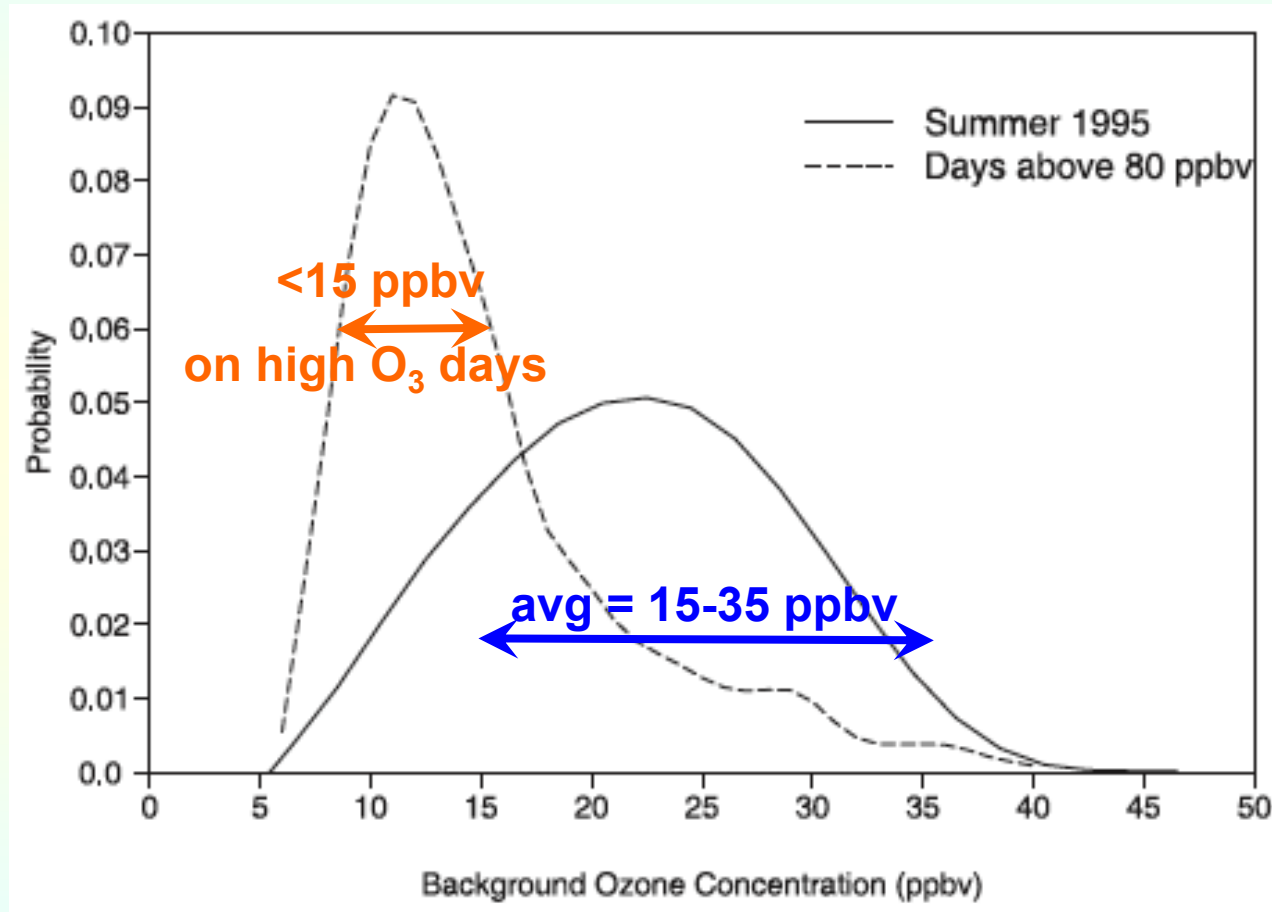
Policy Relevant O$_3$ background:
Concentrations that would exist in the US in the absence of anthropogenic emissions from North America

NAAQS = 75 ppbv for 8-hr average

Policy relevant back-ground evaluated by models

GEOS-CHEM: 2° x 2.5°, 20 layers (5 < 2km)

Model results suggest NAAQS is achievable

Fiore, A.M., D.J. Jacob, et al., Background ozone over the United States in summer: Origin, trend, and contribution to pollution episodes (2002) *J. Geophys. Res., 107*, 10.1029/2001JD000982.

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

O$_3$ non-attainment area in North Sacramento Valley lies inland from Trinidad Head

Coastal mountain ranges separate valley from Pacific
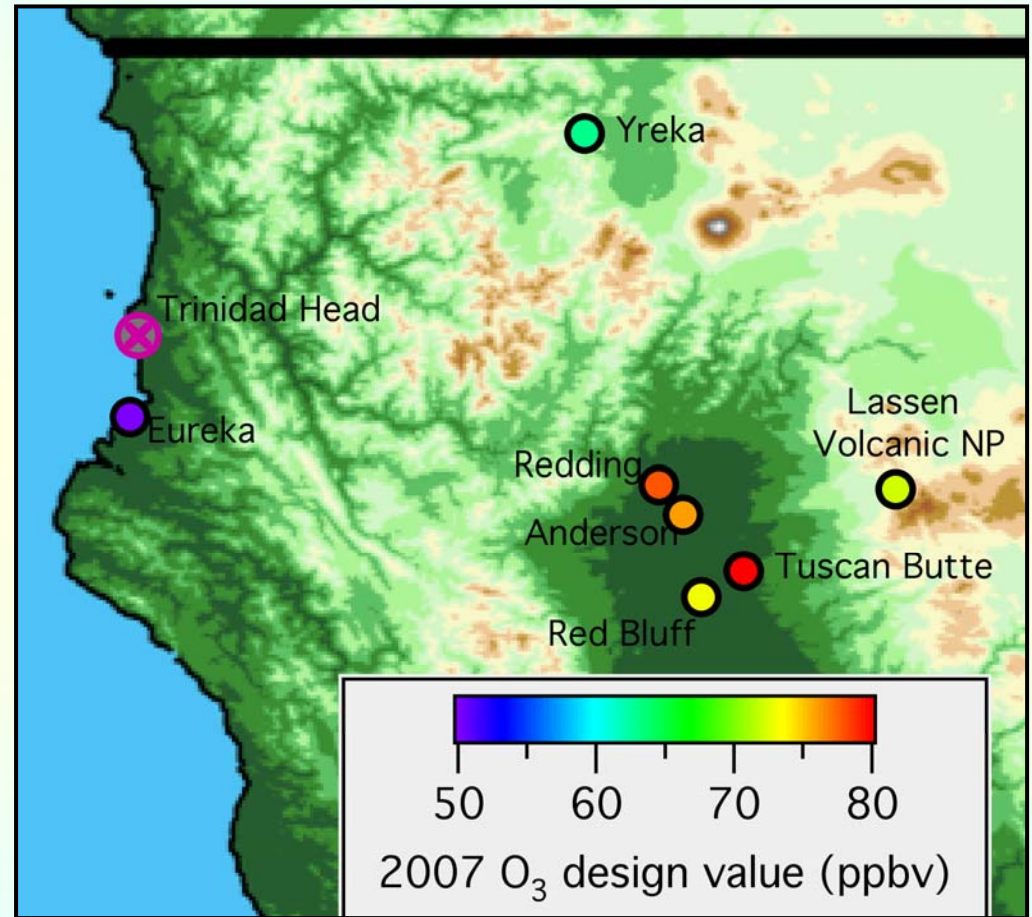
O$_3$ design value: 3 year average of 4th highest daily maximum 8-hr O3 average
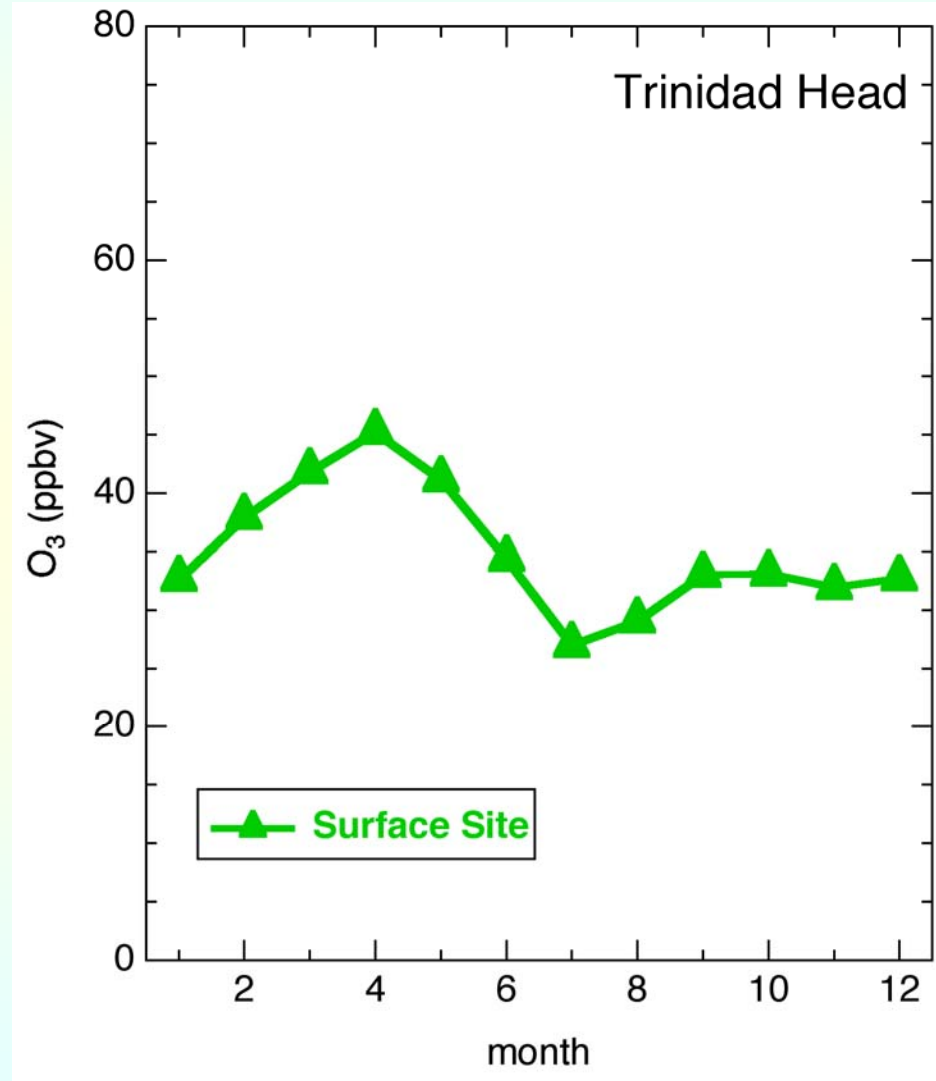
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Summertime O$_3$ minimum in Pacific marine boundary layer (MBL)

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Strong vertical gradient, with broad spring-summer maximum at 2 km
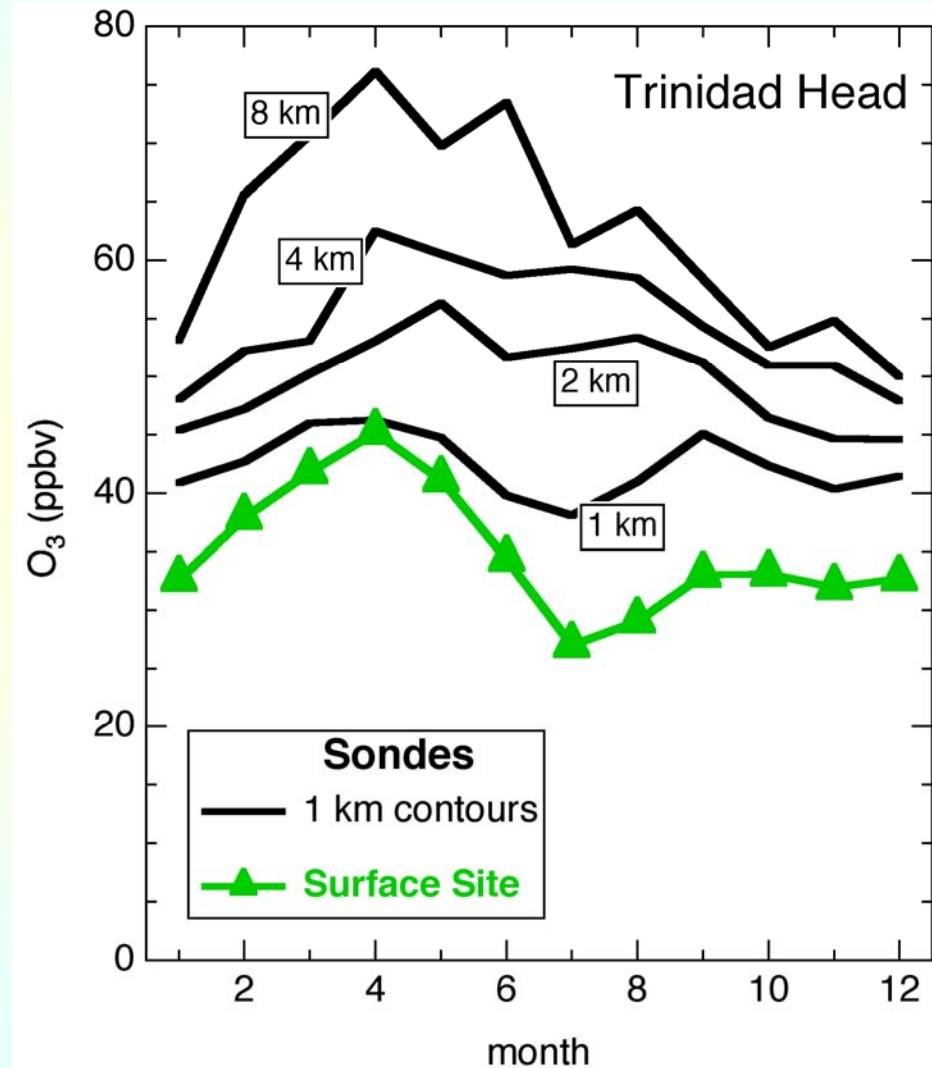
Policy Relevant O$_3$ background:
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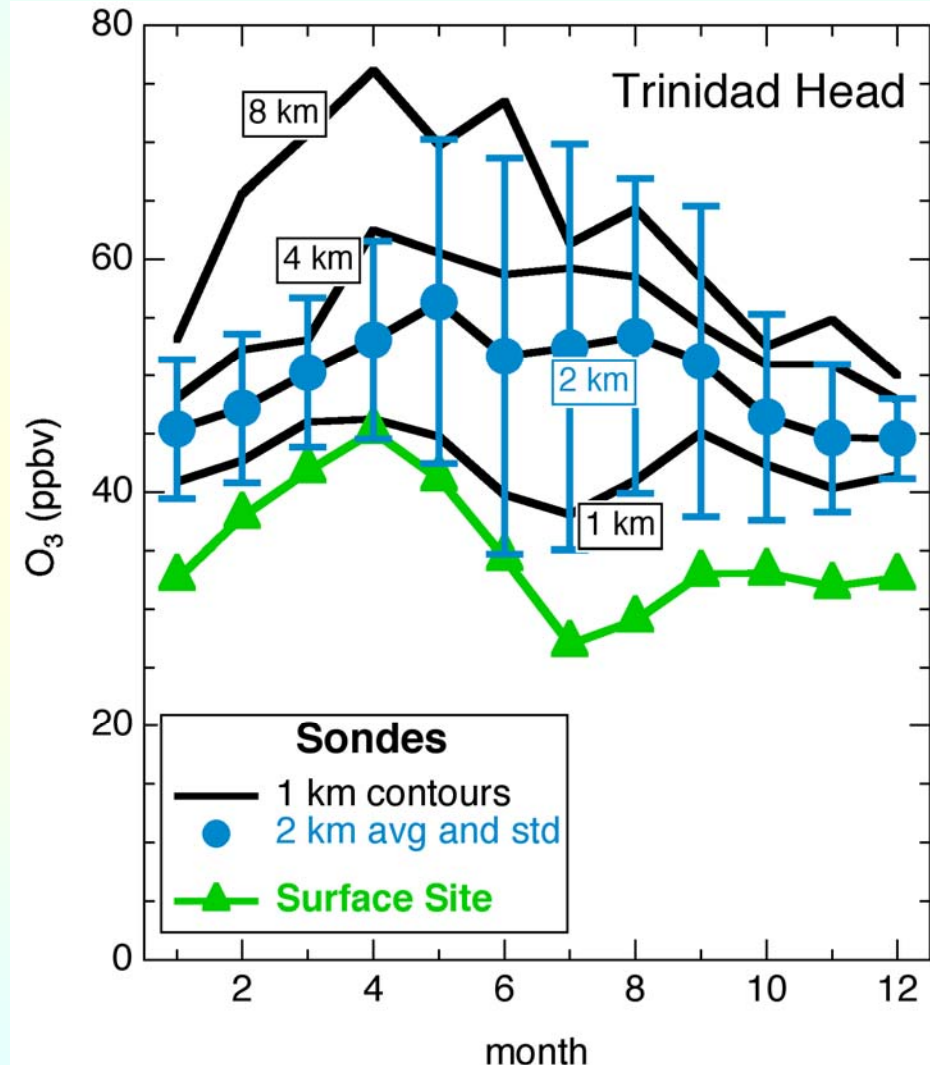
Coastal mountain ranges separate valley from Pacific

Summertime O$_3$ minimum in Pacific marine boundary layer (MBL)

Strong vertical gradient, with broad spring-summer maximum at 2 km

One standard deviation above 2 km average approaches NAAQS

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

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

Introduce some tools!

What altitude inflow accounts for background O$_3$ in North Sacramento Valley?
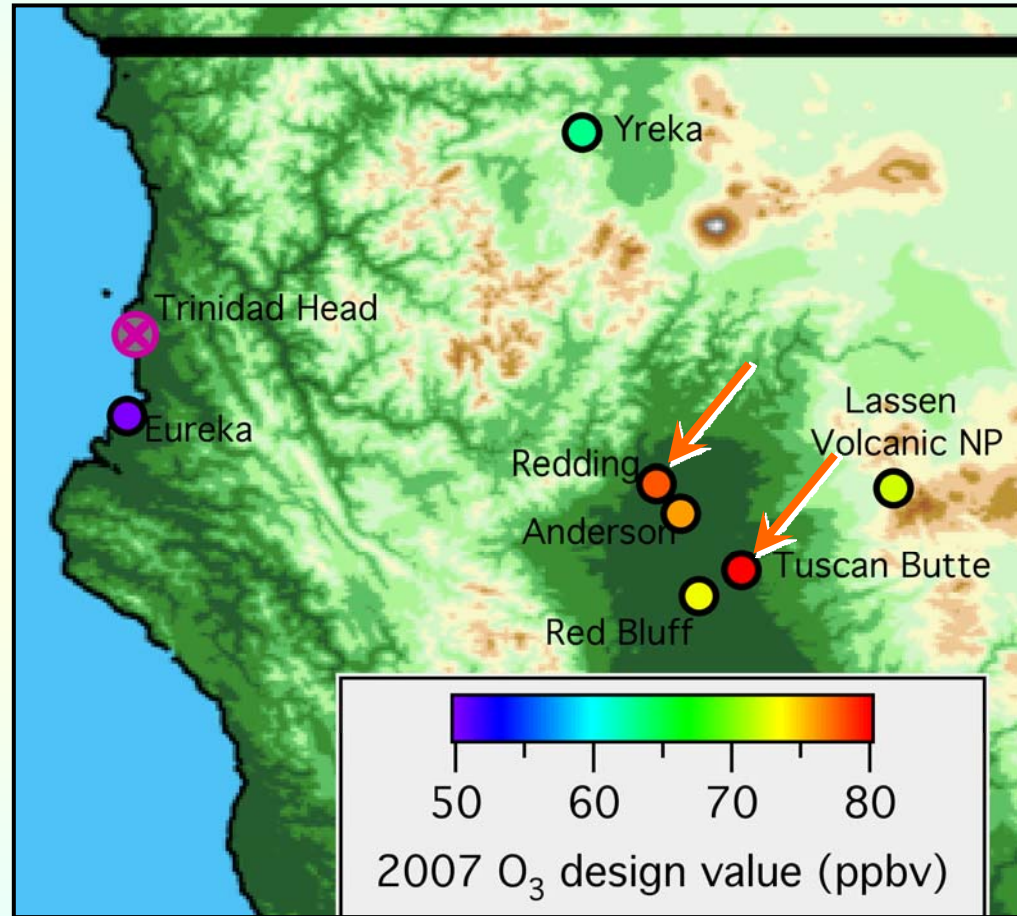
Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

Daytime O$_3$ correlates at all valley sites

Lower nighttime O$_3$ at urban site

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

- 20 days of example data
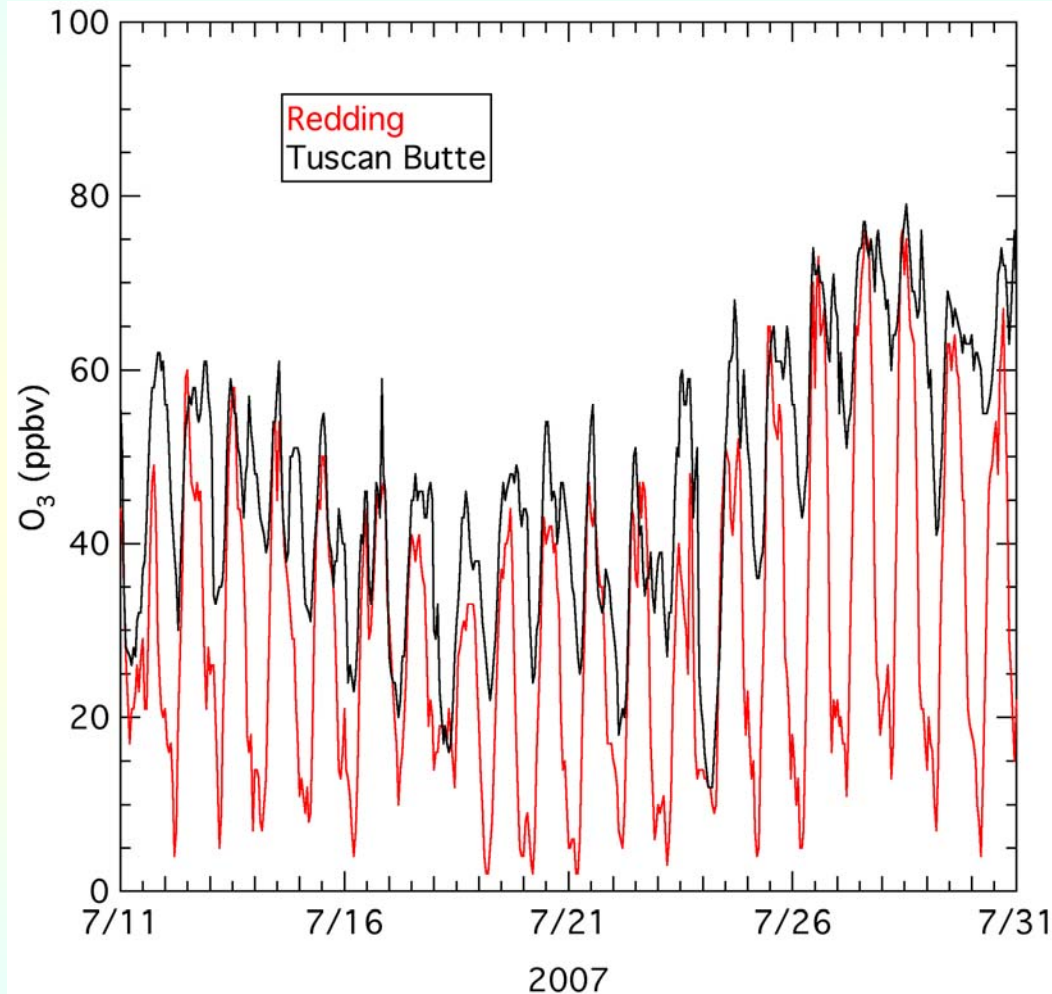- Diurnal cycle clear in 1-hr data

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

Daytime O$_3$ correlates at all valley sites

Lower nighttime O$_3$ at urban site

Daily maximum 8-hr O$_3$ averages capture regional variation

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

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

- 20 days of example data
- Diurnal cycle clear in 1-hr data

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

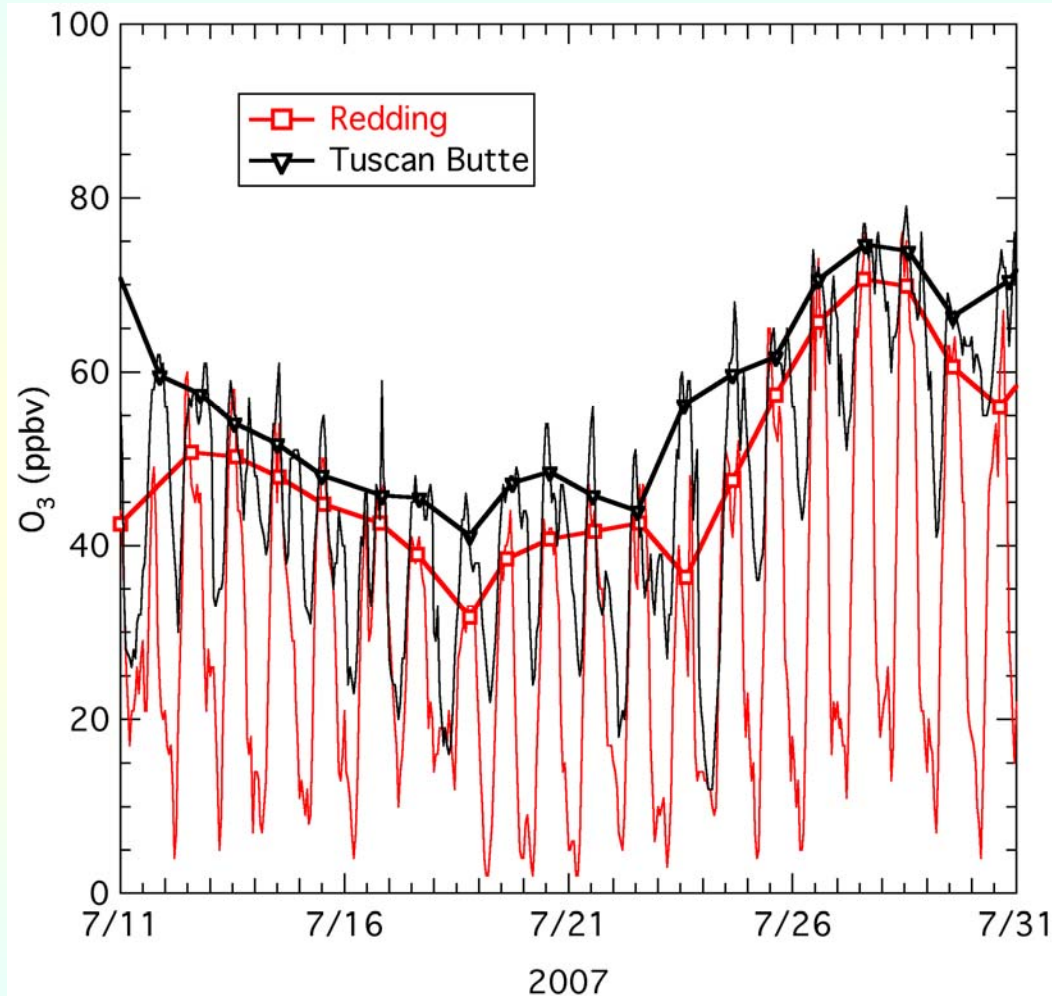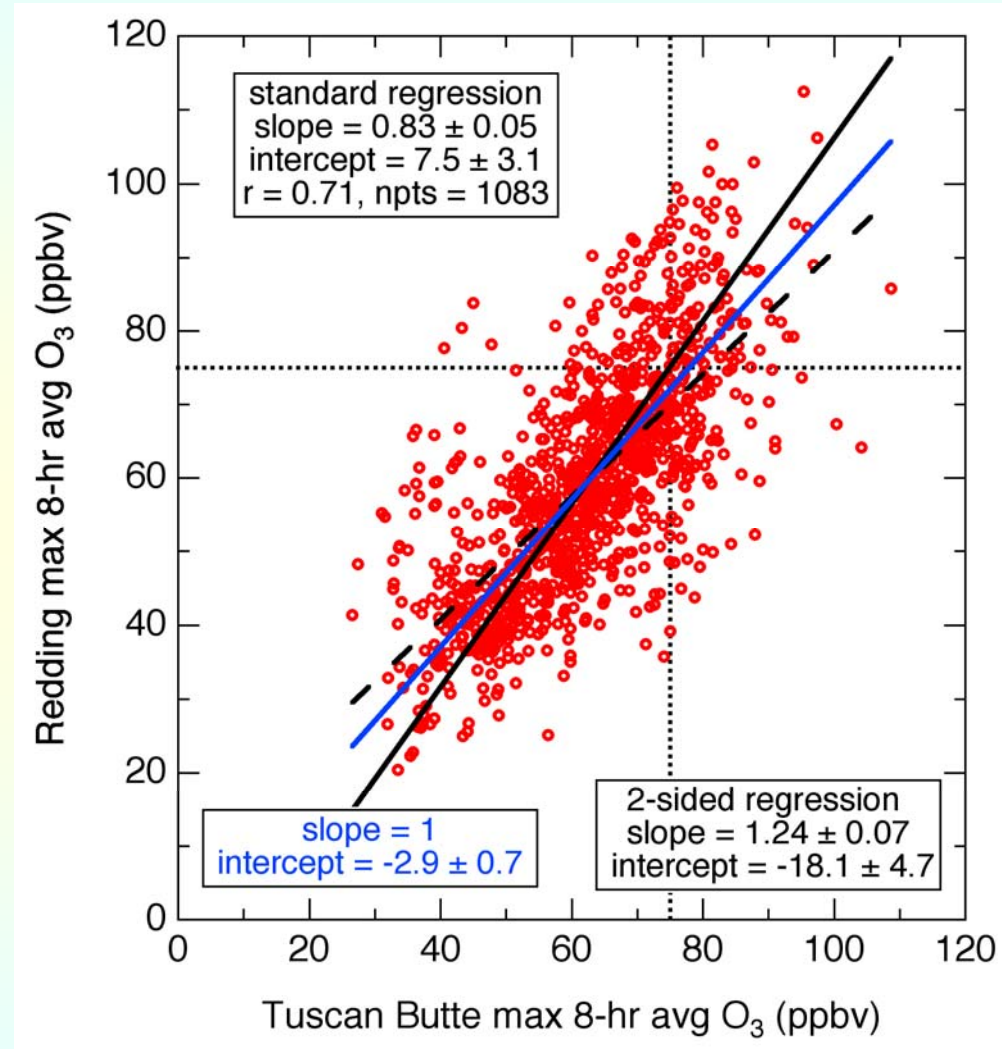**Use correlations between O$_3$ measured at different sites and by sondes to help answer question below**

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

Linear regression, slope = 1: intercept = Δ averages

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

standard regression
slope = 0.83 ± 0.05
intercept = 7.5 ± 3.1
r = 0.71, npts = 1083

slope = 1
intercept = -2.9 ± 0.7

2-sided regression
slope = 1.24 ± 0.07
intercept = -18.1 ± 4.7

Redding max 8-hr avg O$_3$ (ppbv)

Tuscan Butte max 8-hr avg O$_3$ (ppbv)

- Summer (June, July, Aug) only
- 1995 - 2008

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

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

Linear regression, slope = 1: intercept = $\triangle$ averages

Correlate as a function of time offset between data sets

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

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

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

Linear regression, slope = 1: intercept = Δ averages

Correlate as a function of time offset between data sets

Tuscan Butte peaks 2 hr earlier

O$_3$ turnover time about 2.7 days

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

- Summer (June, July, Aug) only
- 1995 - 2008

Policy Relevant O₃ background:
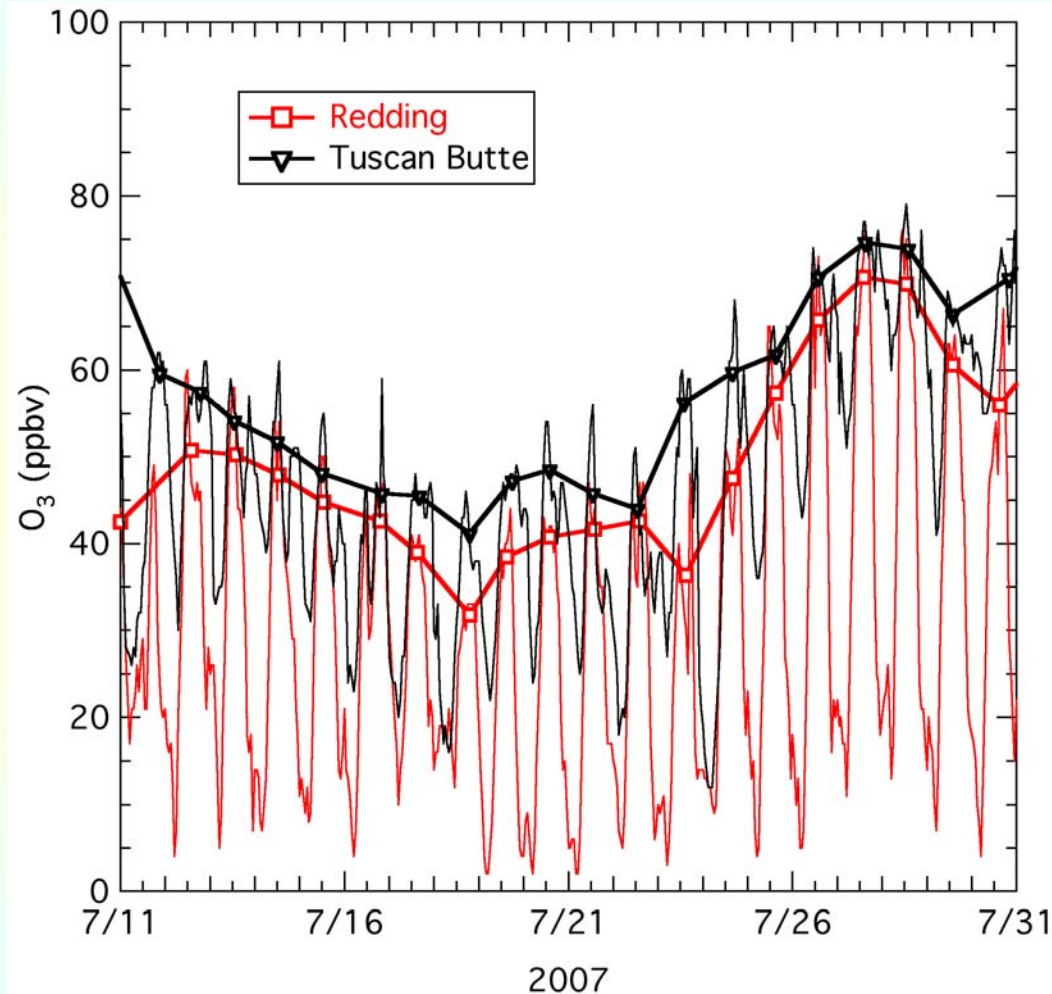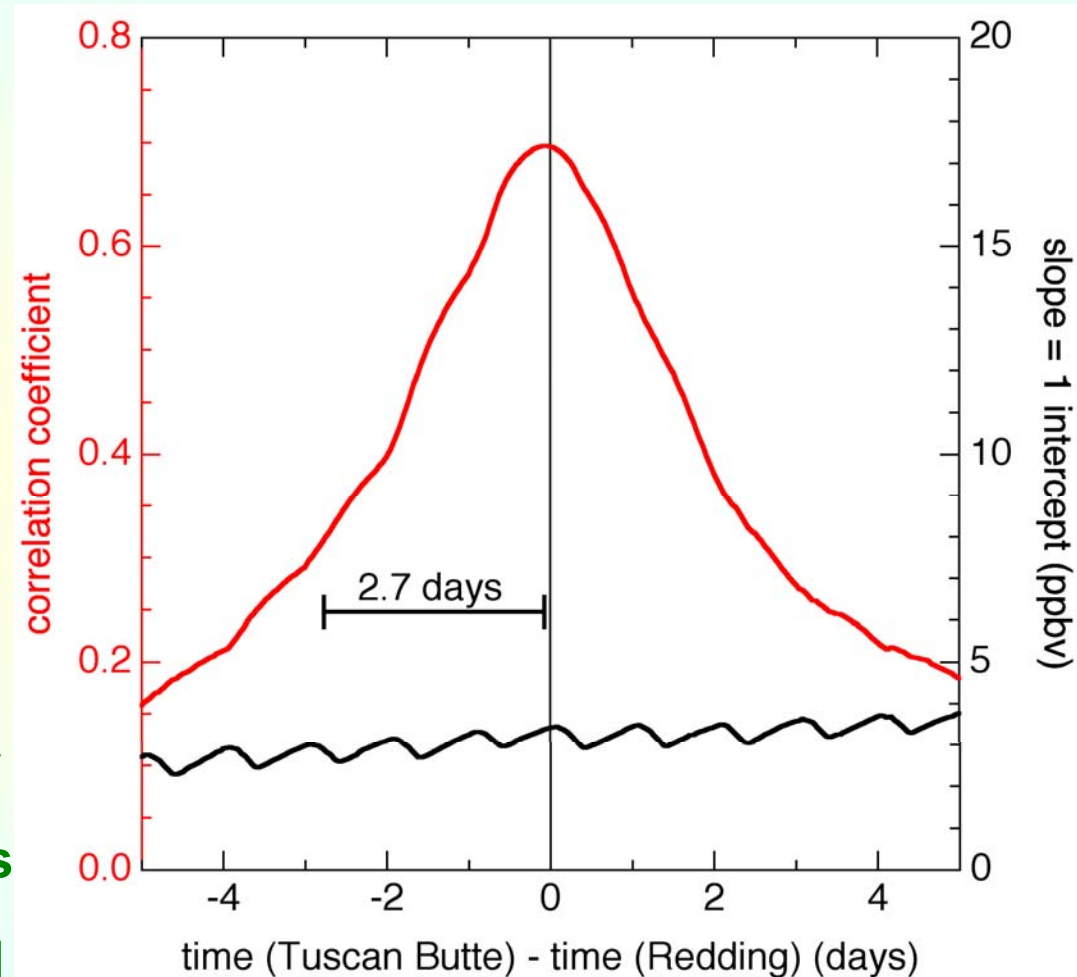## Can we estimate from experimental data?

Use correlations between O_3 measured at different sites and by sondes to help answer question below
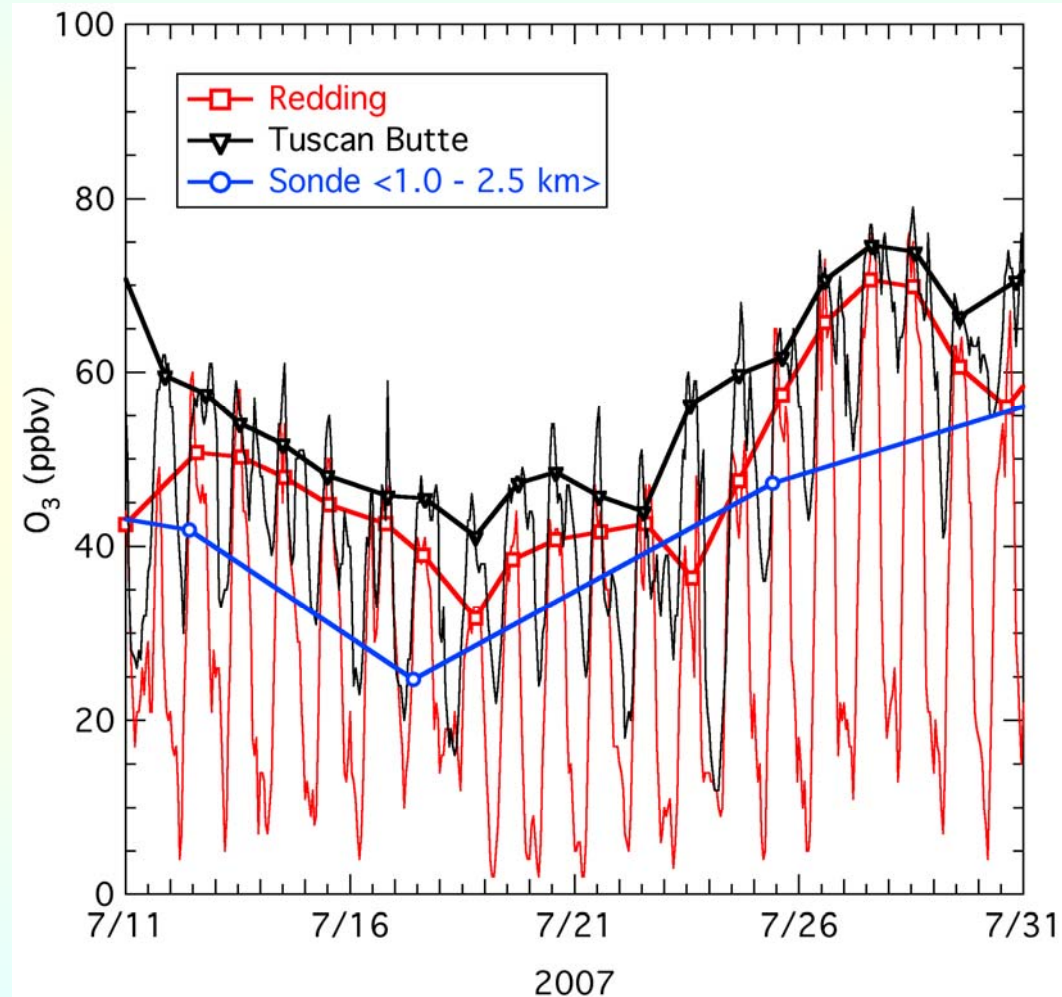
Use interpolated max 8-hr O_3 average for all correlations

Correlate as a function of time offset between data sets

Correlate surface data with sonde as a function of altitude

≈ 700 sondes 1997-2008, 208 in summer

What altitude inflow accounts for background O_3 in North Sacramento Valley?

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

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

Tuscan Butte O$_3$ about 13-15 ppbv higher than sonde O$_3$

3.4 days convolution of all time scales involved

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

Sonde average 1 - 2.5 km

3.4 days

- Summer (June, July, Aug) only
- 1997 - 2008

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

Apply these tools!

4 sites:

- Redding, Tuscan Butte in valley
- Lassen at 1.8 km on far side
- Yreka outside valley to north

2007 O$_3$ design value (ppbv)

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

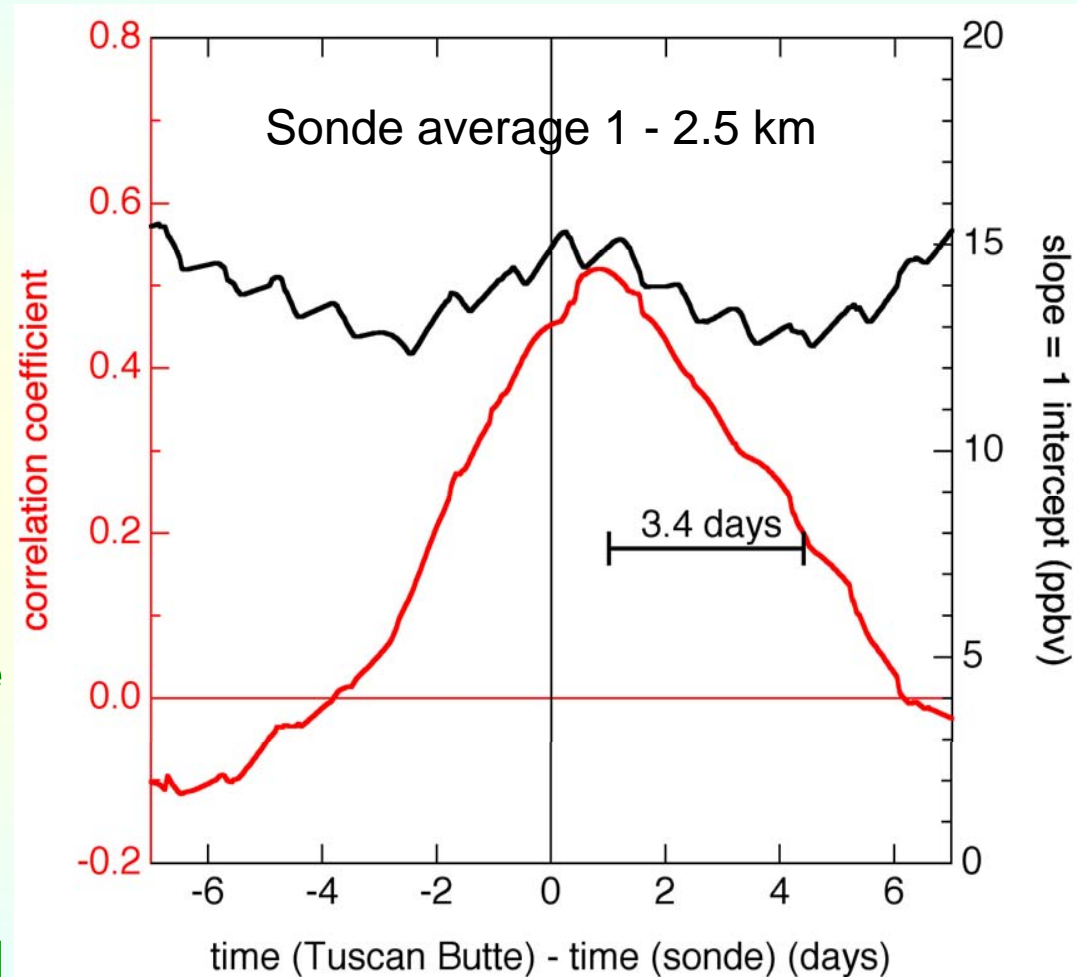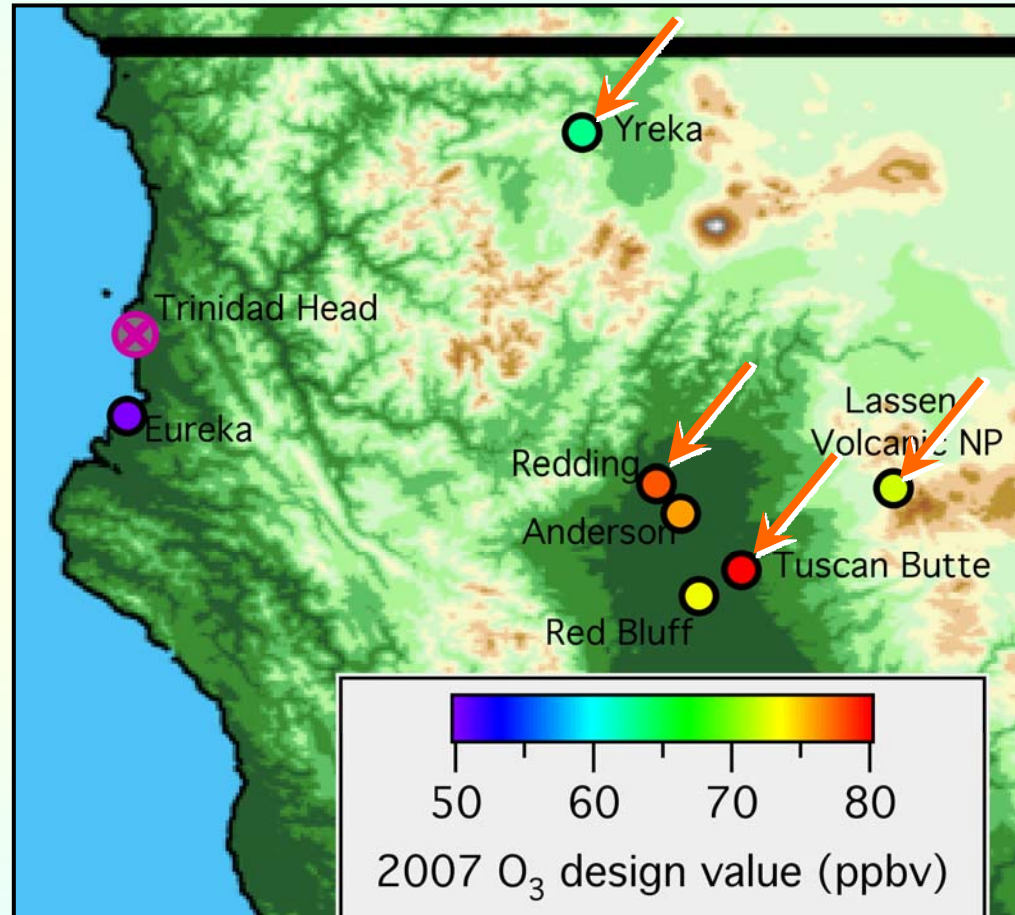# Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

Significant correlation between sonde (1 – 2.5 km) and all surface sites.

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

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

Significant correlation between sonde (1 – 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 and mixed down to all surface sites.

What altitude inflow accounts for background O$_3$ in North Sacramento Valley?
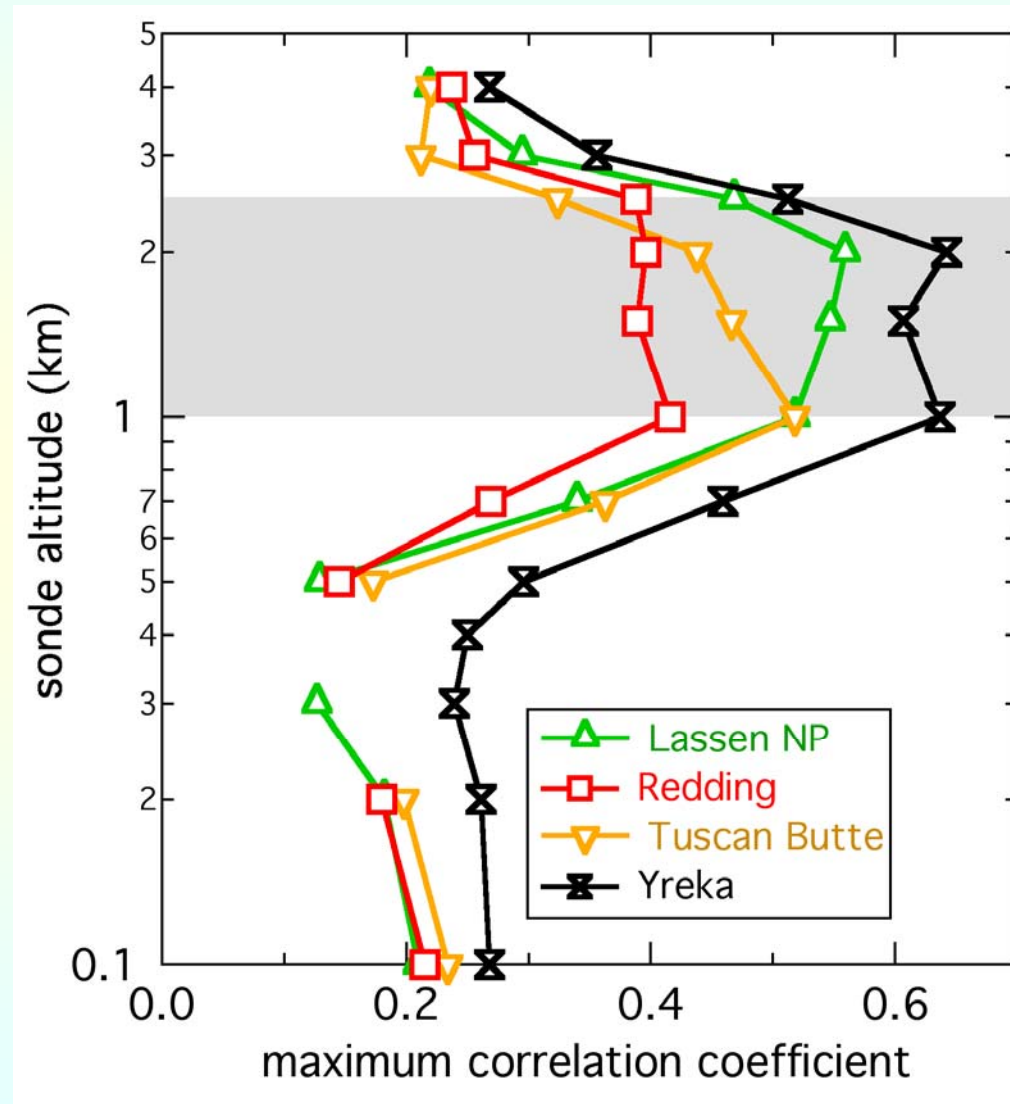
Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

A chemist's schematic view of transport that drives correlations:

Sonde samples on-shore flow at 1 – 2.5 km, which mixes down to inland sites 15-30 hrs later

On-shore flow

Mountain-Valley Flow

Sierra Mountain Range

CBL

Coastal Range

MBL

Sacramento Valley

Pacific Ocean

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

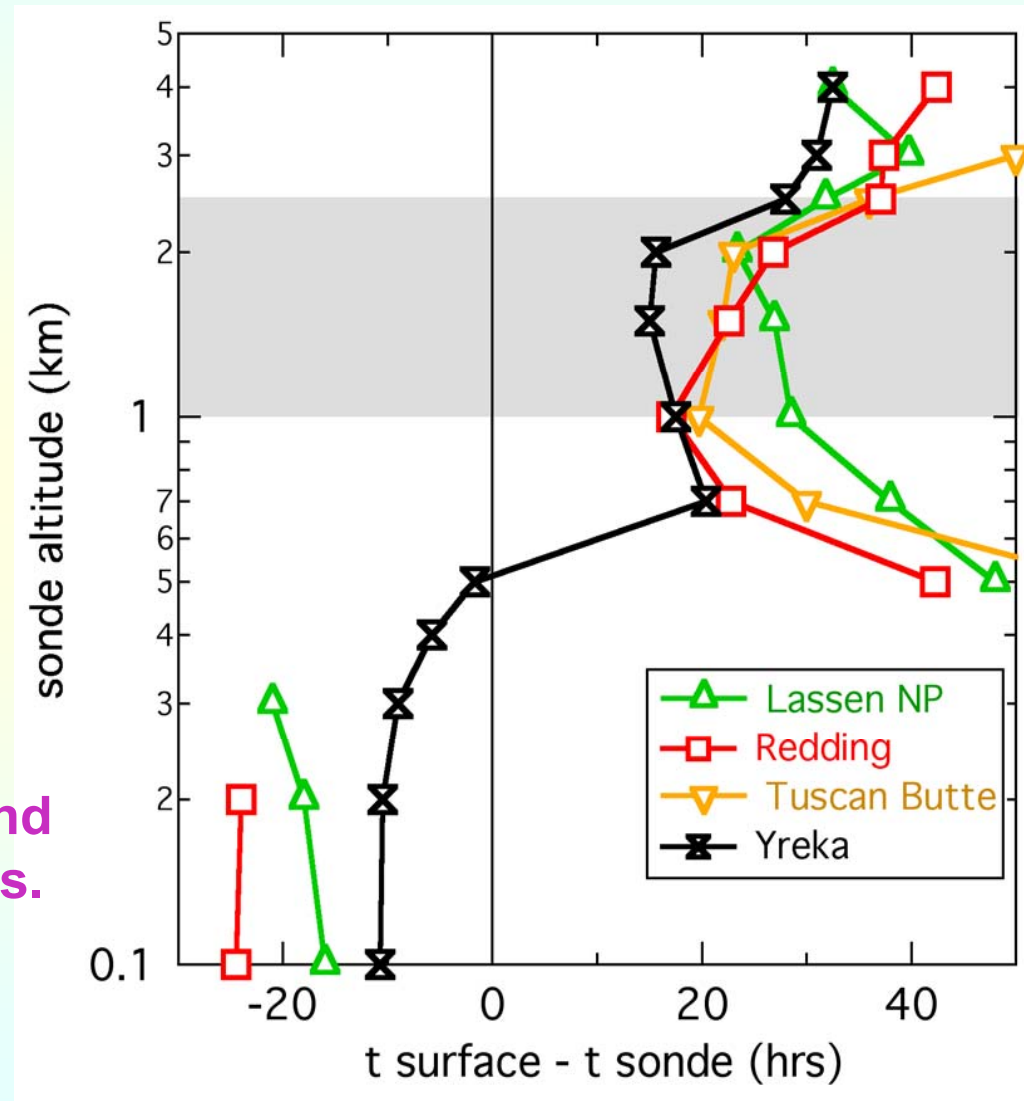# Policy Relevant O$_3$ background:
Can we estimate from experimental data?

What is the bottom line?
Northern Sacramento Valley:

On average, O$_3$ in background air = 50 ppbv, net photo. prod. = 15 ppbv total = 65 ppbv

On exceedance days, background O$_3$ = 59 ppbv, net photo. prod. = 22 ppbv total = 81 ppbv

Unit slope suggests that surface maximum O$_3$ is directly proportional to background

Background O$_3$ alone can exceed NAAQS

Tuscan Butte - Summer

NAAQS

slope held at 1
intercept = 15 ± 2

2-sided regression
slope = 0.92 ± 0.26

standard regression
slope = 0.50 ± 0.11
intercept = 40 ± 6
r = 0.52, npts = 209

Maximum 8-hr average O$_3$ (ppbv)

sonde O$_3$ (ppbv)

Policy Relevant O$_3$ background:
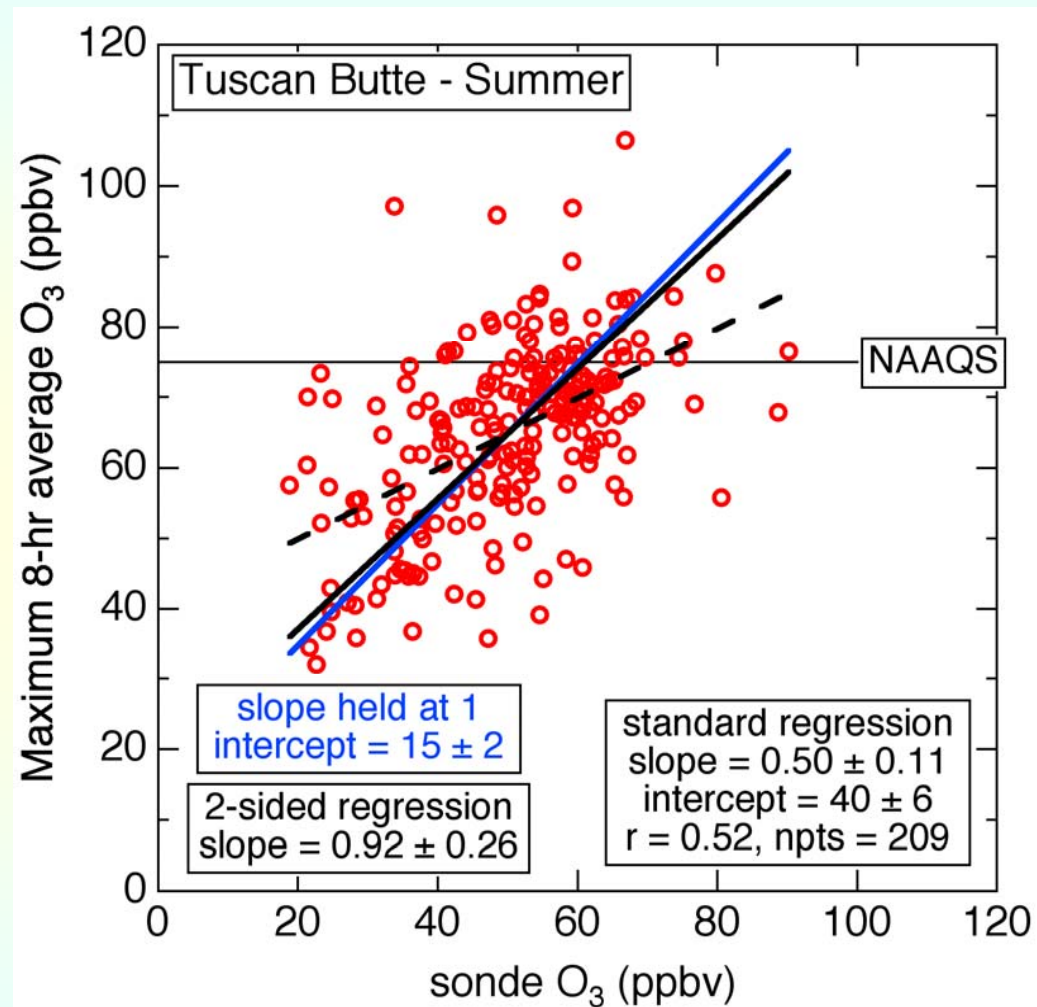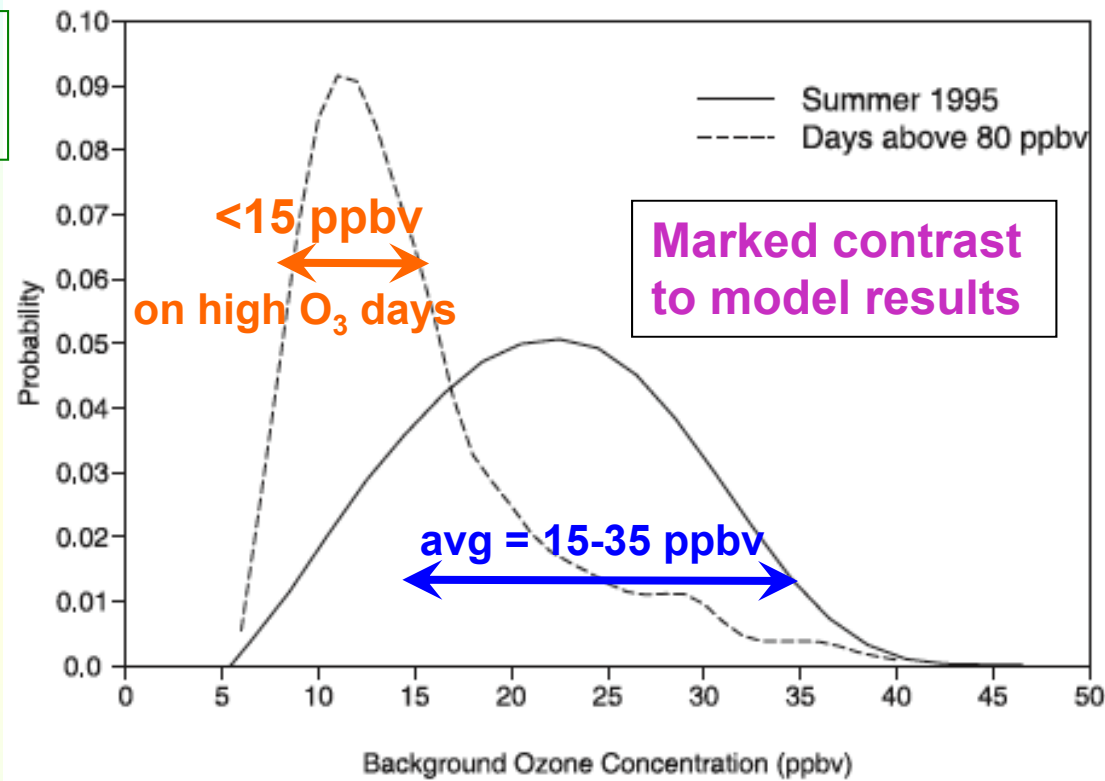## Can we estimate from experimental data?

What is the bottom line?
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  background air = 50 ppbv,
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Unit slope suggests that
  surface maximum O$_3$ is
  directly proportional to
  background

Background O$_3$ alone can
  exceed NAAQS

<15 ppbv
on high O$_3$ days

Marked contrast
to model results

avg = 15-35 ppbv

Summer 1995
Days above 80 ppbv

Probability

Background Ozone Concentration (ppbv)

**Caveat: Background O$_3$ transported into
Sacramento Valley does not equal O$_3$
that would exist in the absence of North
American anthropogenic emissions –
Overestimate due to deposition?**
Not likely to explain large difference

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Thoughts & Implications:

- **GMD data sets from Northern California provide very useful resource to investigate effects of background O$_3$**

- **Chemical measurements provide useful tracer for transport study**

- **Achieving NAAQS may not be possible with only local and regional control efforts**

- **California Central Valley is less responsive to control strategies than LA Basin; background O$_3$ is higher – less room for reduction**
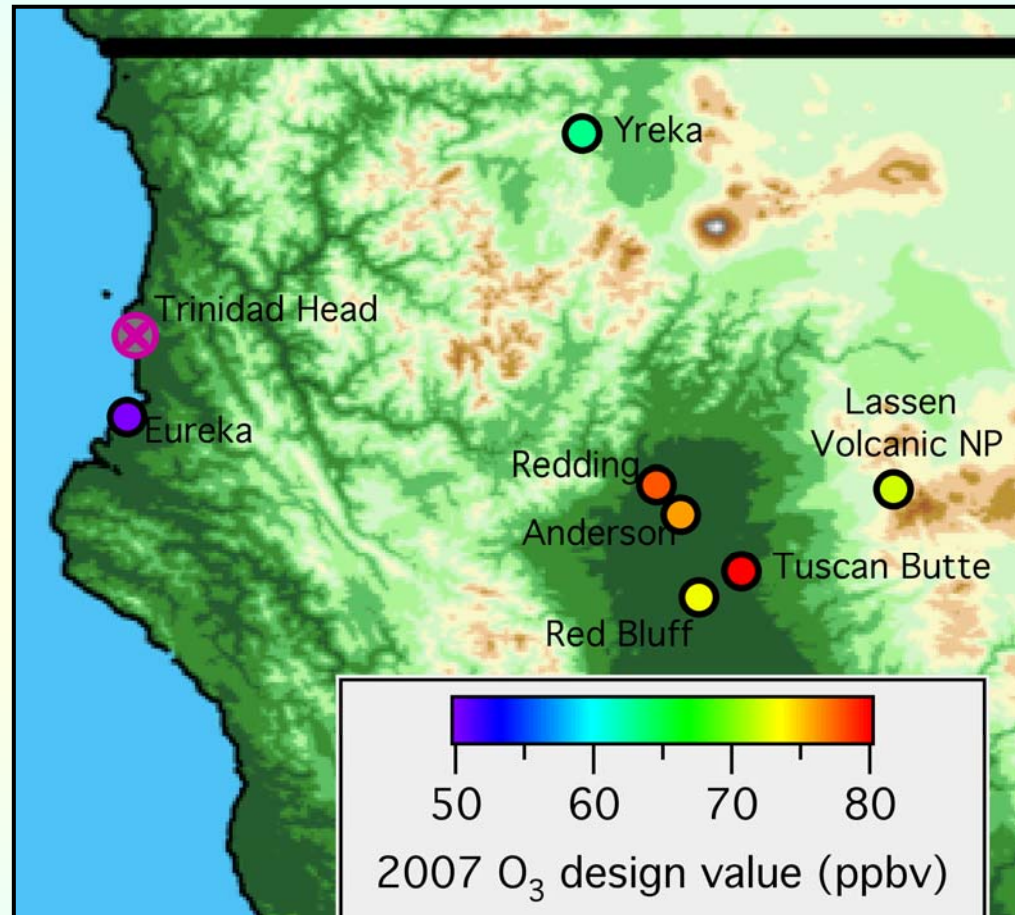
- **Accurate modeling of California O$_3$ requires global model to reproduce background plus mesoscale model for transport in complex terrain**

Extra Slides

Policy Relevant O₃ background:
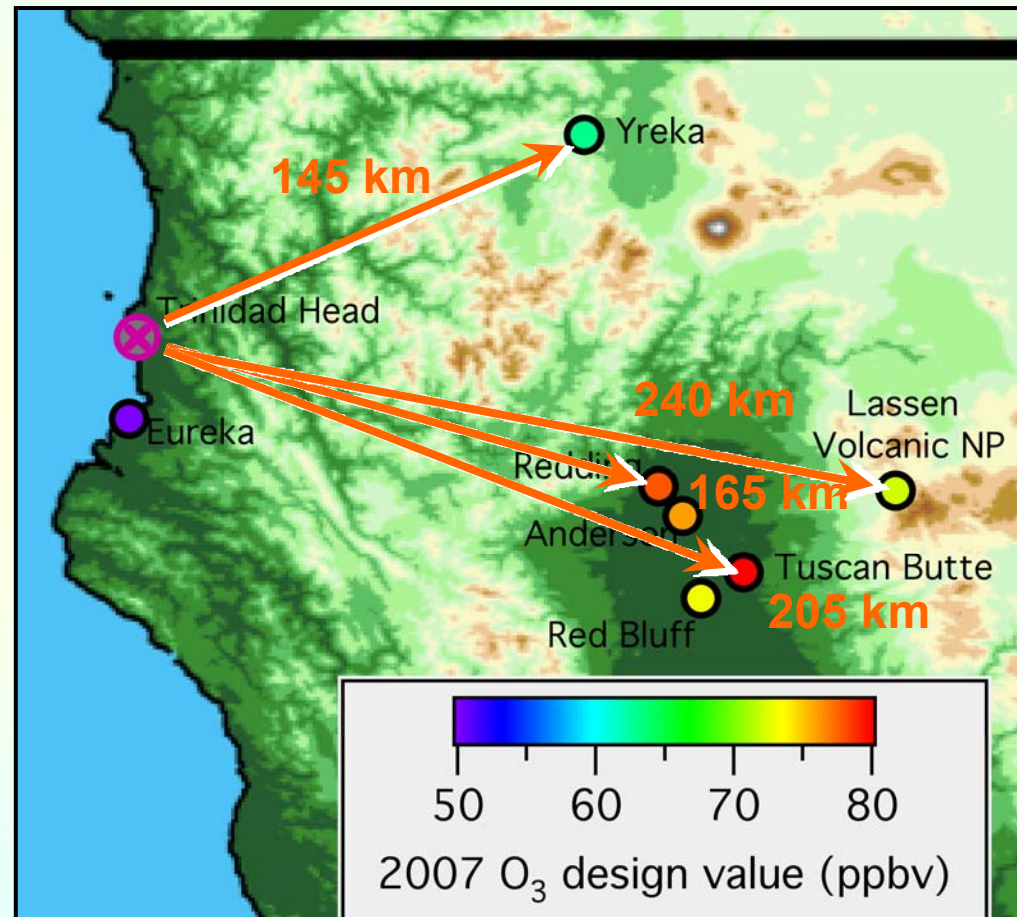## Can we estimate from experimental data?

Use correlations between O_3 measured at different sites and by sondes to help answer question below

Correlating one snapshot of O_3 aloft with interpolated daily max 8-hr average at surface sites 145 to 240 km distant in directions from NE to SE, and from 0.15 to 2.8 km elevation

Variation expected in vertical and spatial dist'bn of O_3 in onshore flow, transport times, mixing to surface, etc., etc.

What altitude inflow accounts for background O_3 in North Sacramento Valley?

Why are correlations so poor?

145 km

240 km

165 km

205 km

Yreka

Trinidad Head

Eureka

Redding

Anderson

Lassen Volcanic NP

Tuscan Butte

Red Bluff

50   60   70   80

2007 O₃ design value (ppbv)

Correlations are remarkably strong!

Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

A chemist's schematic view of transport that drives correlations:

Sonde samples on-shore flow at 1 – 2.5 km, which mixes down to inland sites 15-30 hrs later

Land-sea breeze circulation brings some inland air back to coast for sonde to sample ≈ 15 hr *later*

On-shore flow

Mountain-Valley Flow

Sierra Mountain Range

Land-Sea Breeze

Coastal Range

CBL

MBL

Pacific Ocean

Sacramento Valley

What altitude inflow accounts for background O$_3$ in North Sacramento Valley?
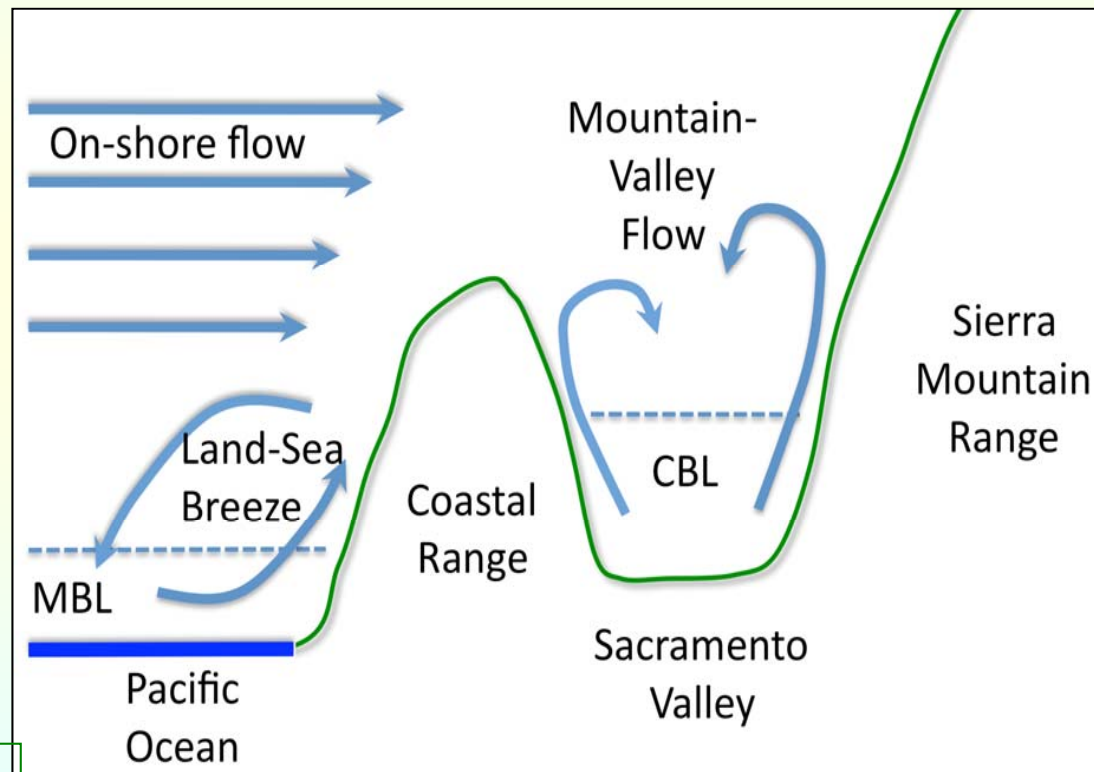
Policy Relevant O$_3$ background:
Can we estimate from experimental data?

Use correlations between O$_3$ measured at different sites and by sondes to help answer question below

Surface site O$_3$ is 0 to 20 ppbv greater than sonde O$_3$ avg (1 – 2.5 km) – difference represents net photochemical production at inland sites.

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