

Impact of Transported Background Ozone on Air Quality in California

David Parrish, NOAA/ESRL/Chemical Sciences Division

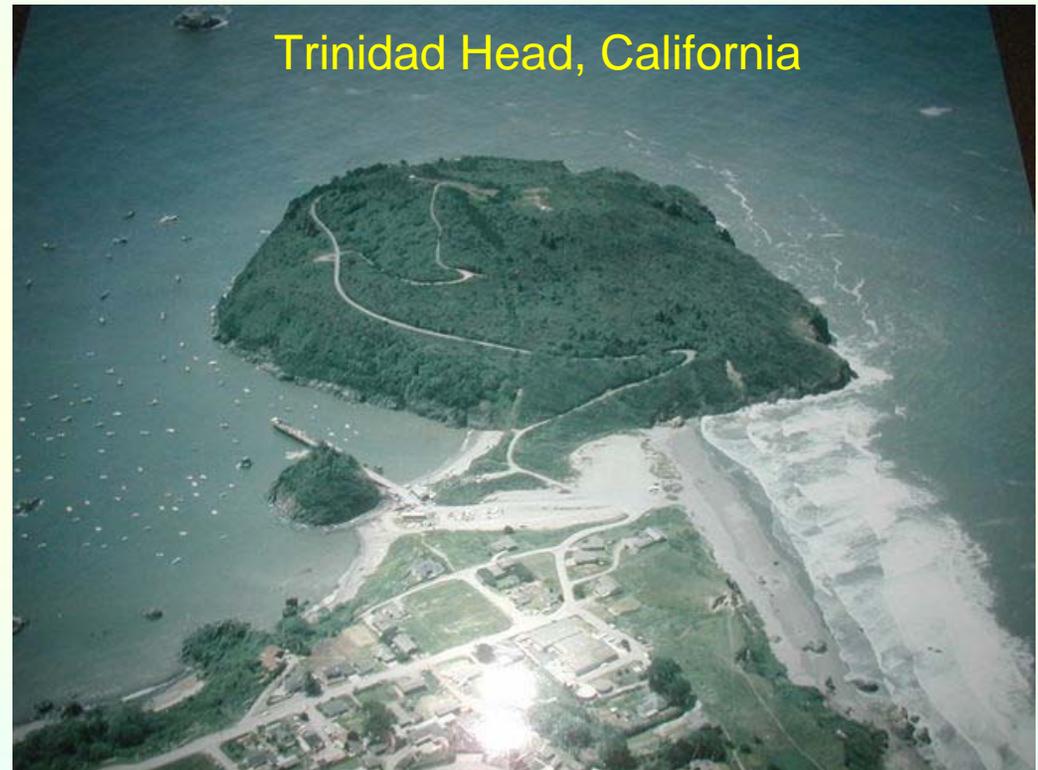
Ken Aikin, Sam Oltmans, Bryan Johnson, Mike Ives

Today

: Quick look at background O_3 and CO from 22 June 2008 flight

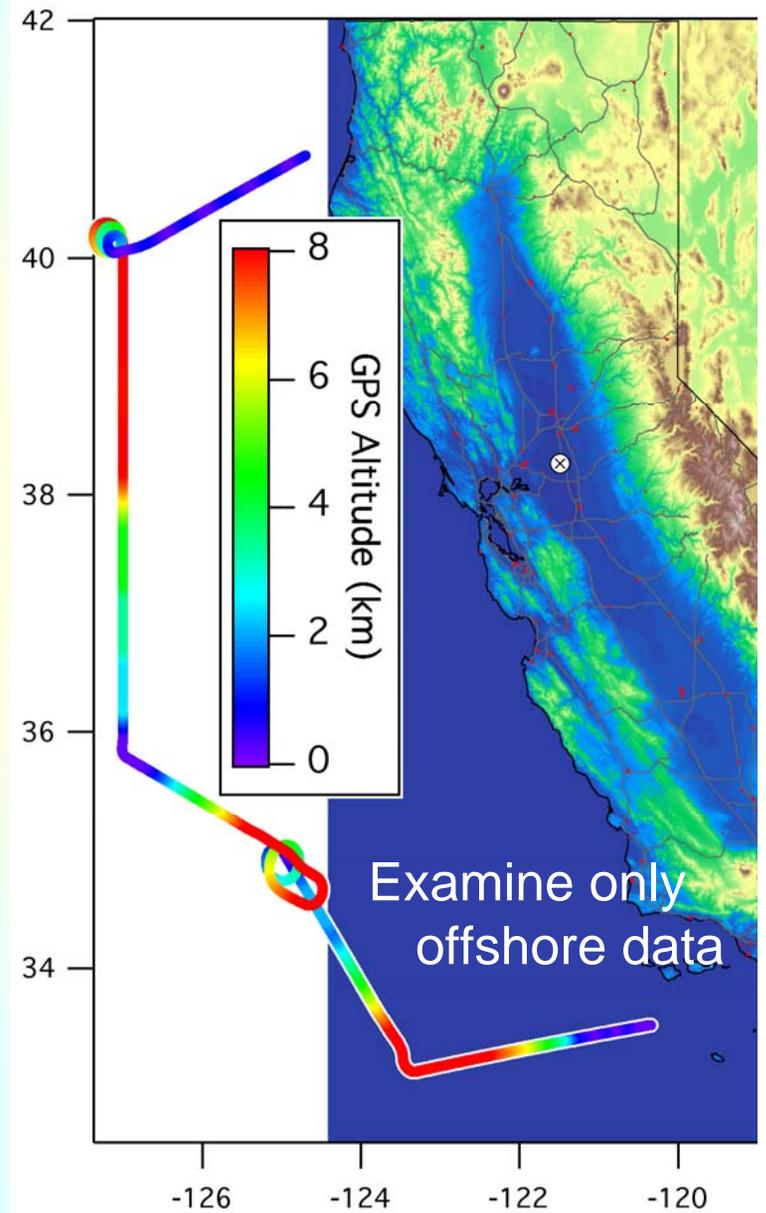
Compare to other data sets

Show that transported background O_3 plays a major role in air quality in California

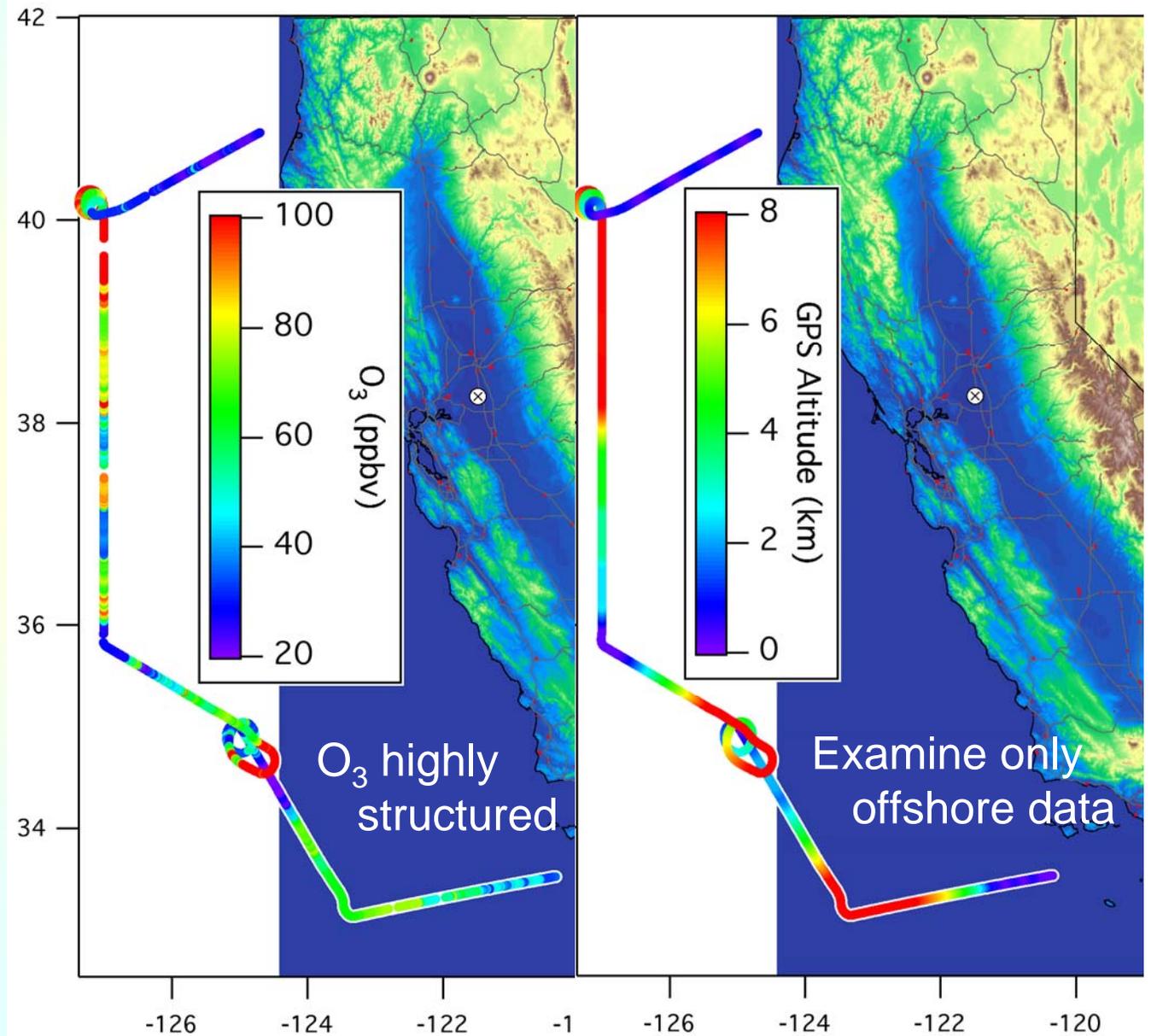


ARCTAS California Workshop
Preliminary Data Analysis
30 June 2009 – 1 July 2009

Quick look at background O₃ and CO from 22 June 2008 flight

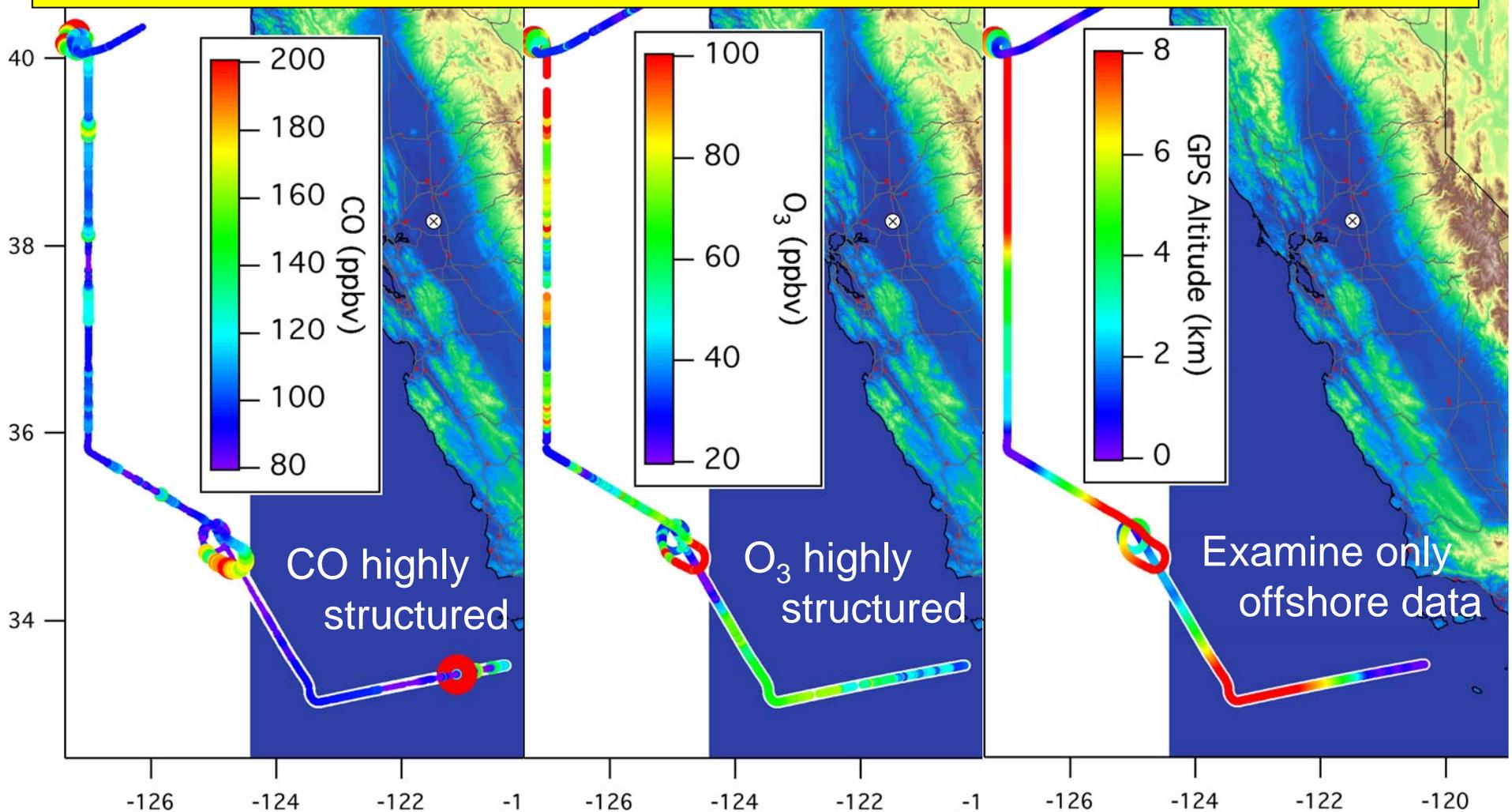


Quick look at background O_3 and CO from 22 June 2008 flight



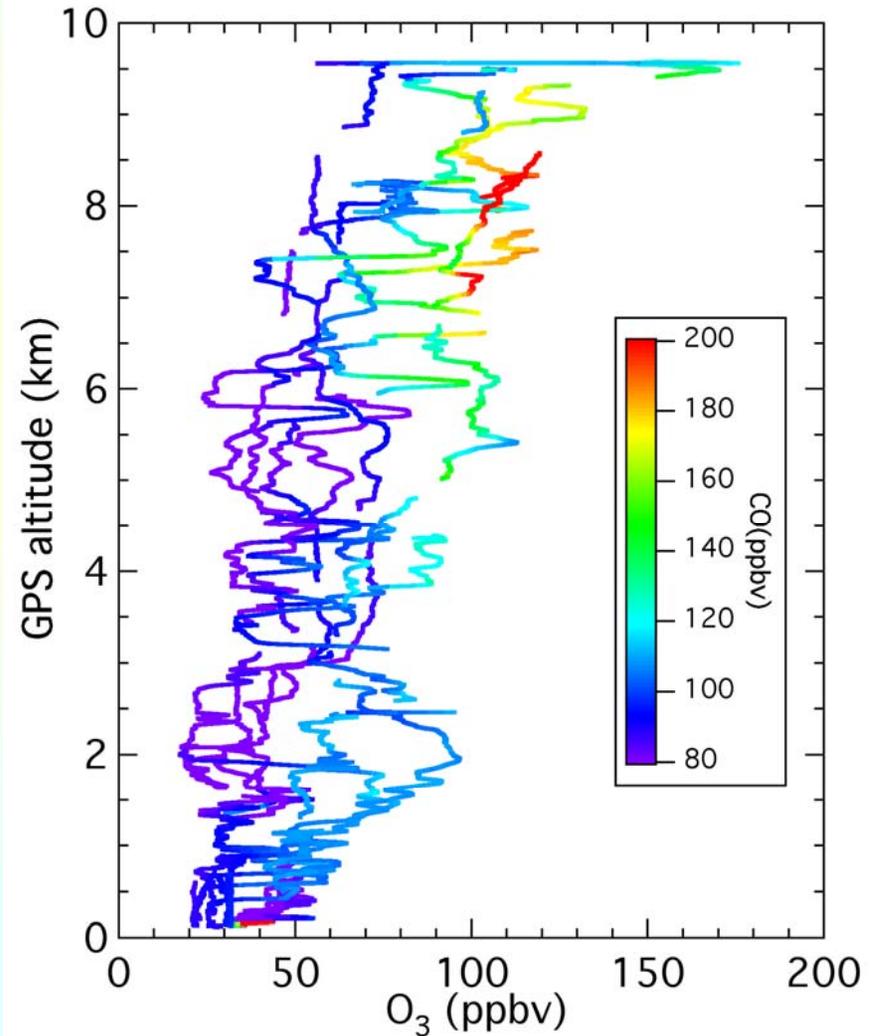
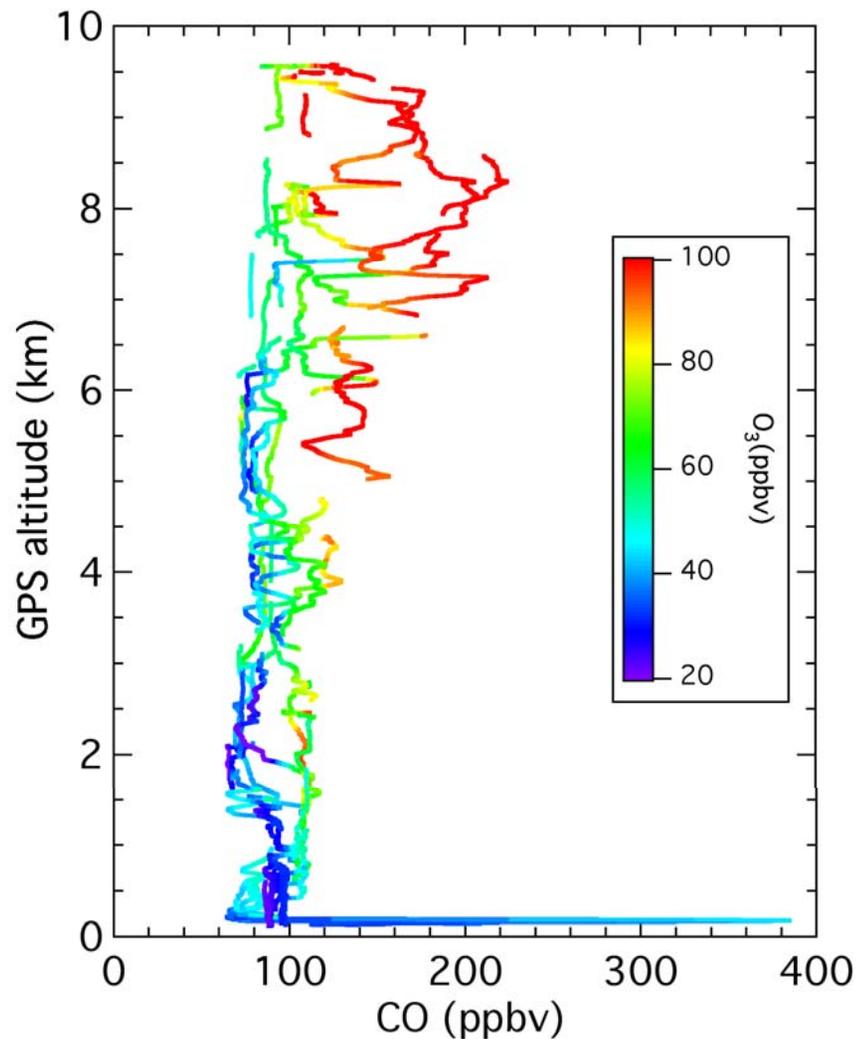
Quick look at background O_3 and CO from 22 June 2008 flight

Background concentrations of O_3 and CO are poorly defined concepts. Background air over the Pacific is really a large number of plumes of varying history in the process of intermixing and dispersing.



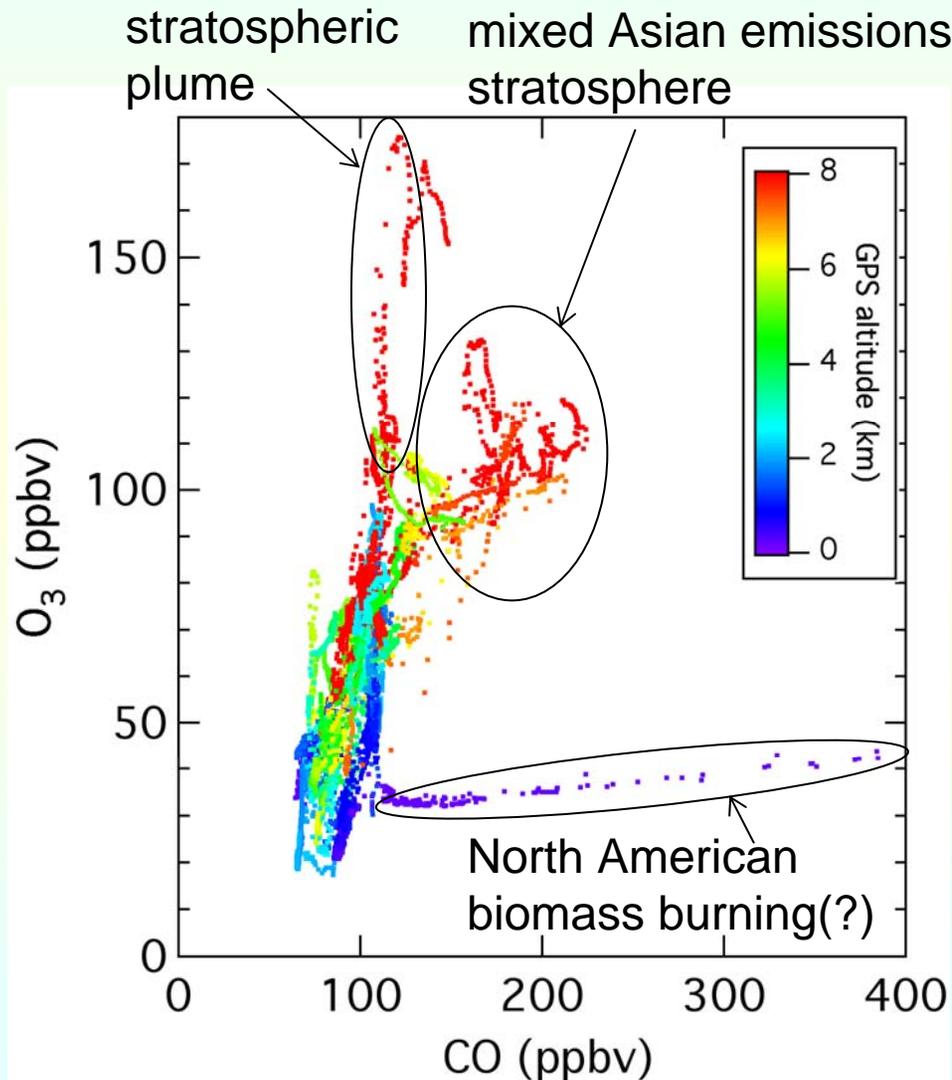
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Quick look at background O₃ and CO from 22 June 2008 flight

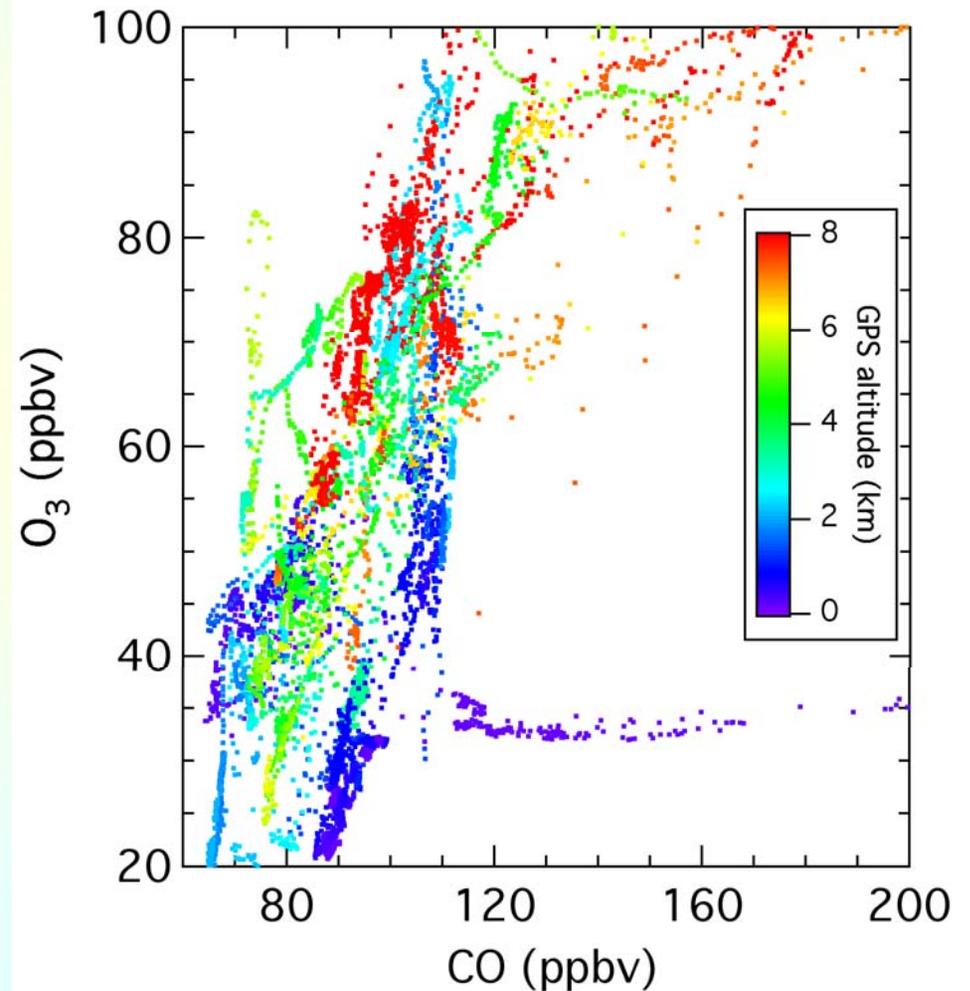
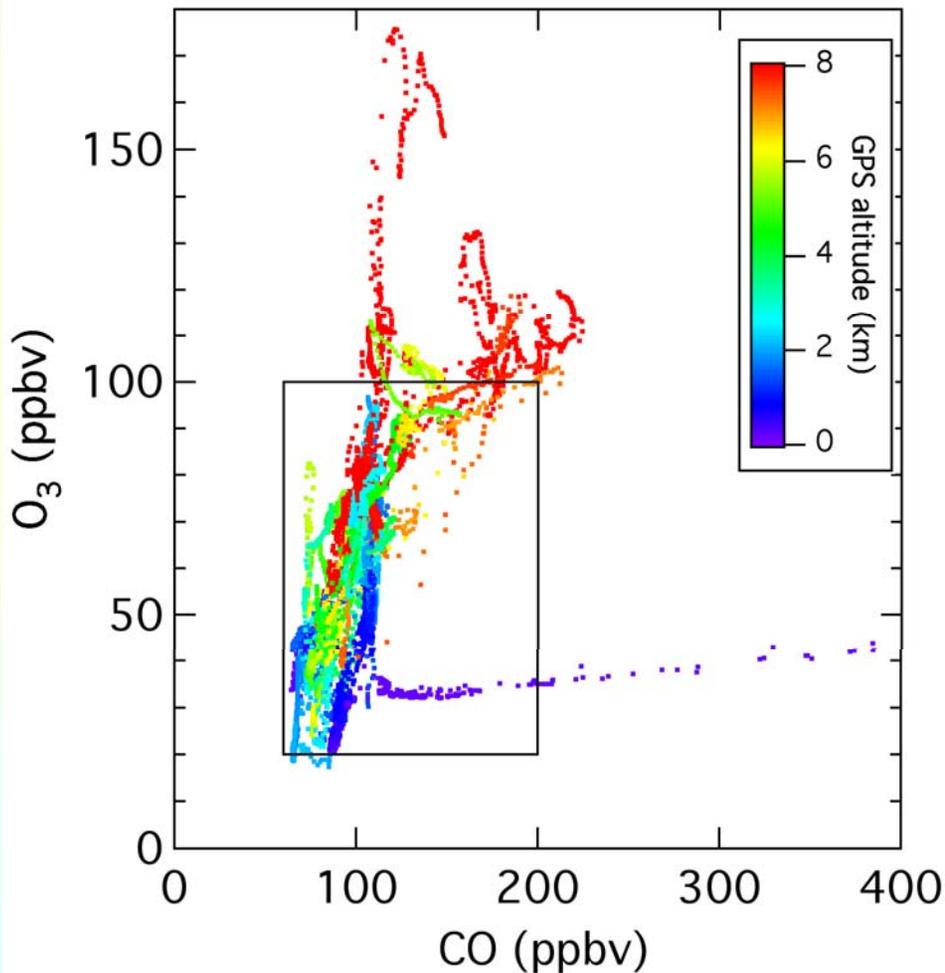
O₃ versus CO relationships provide indication of plume histories.



Quick look at background O_3 and CO from 22 June 2008 flight

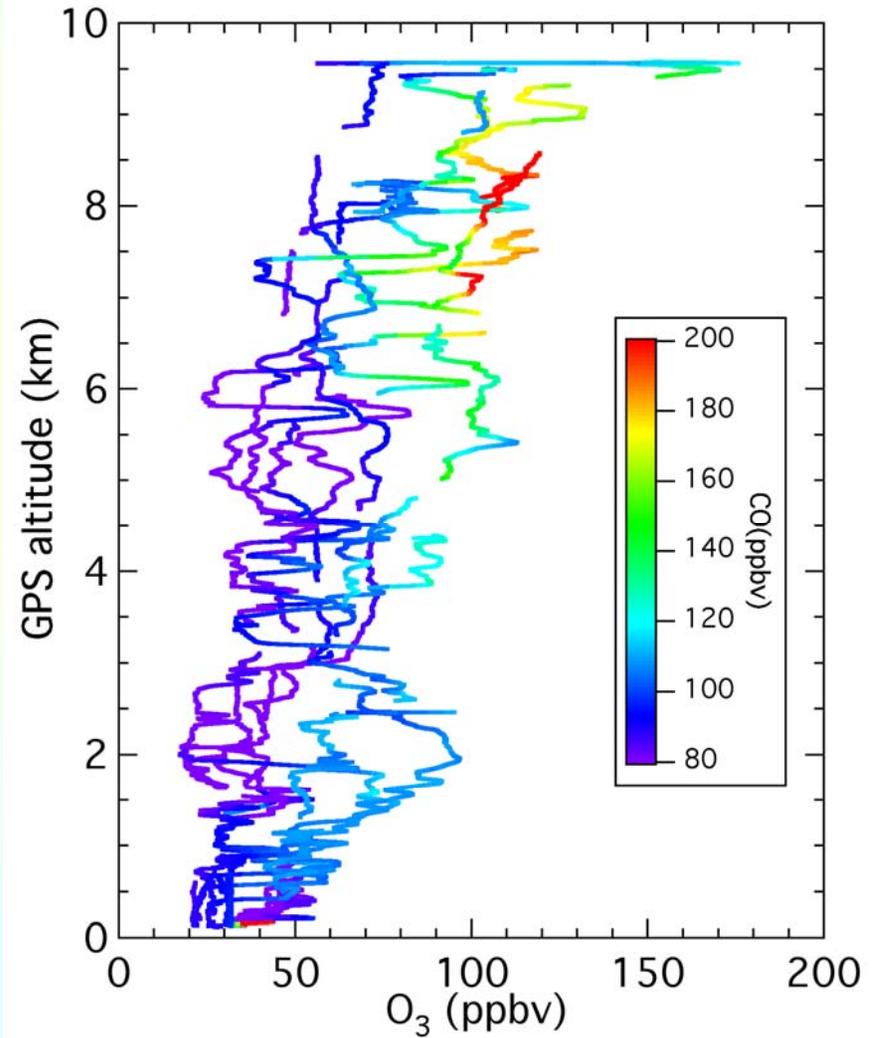
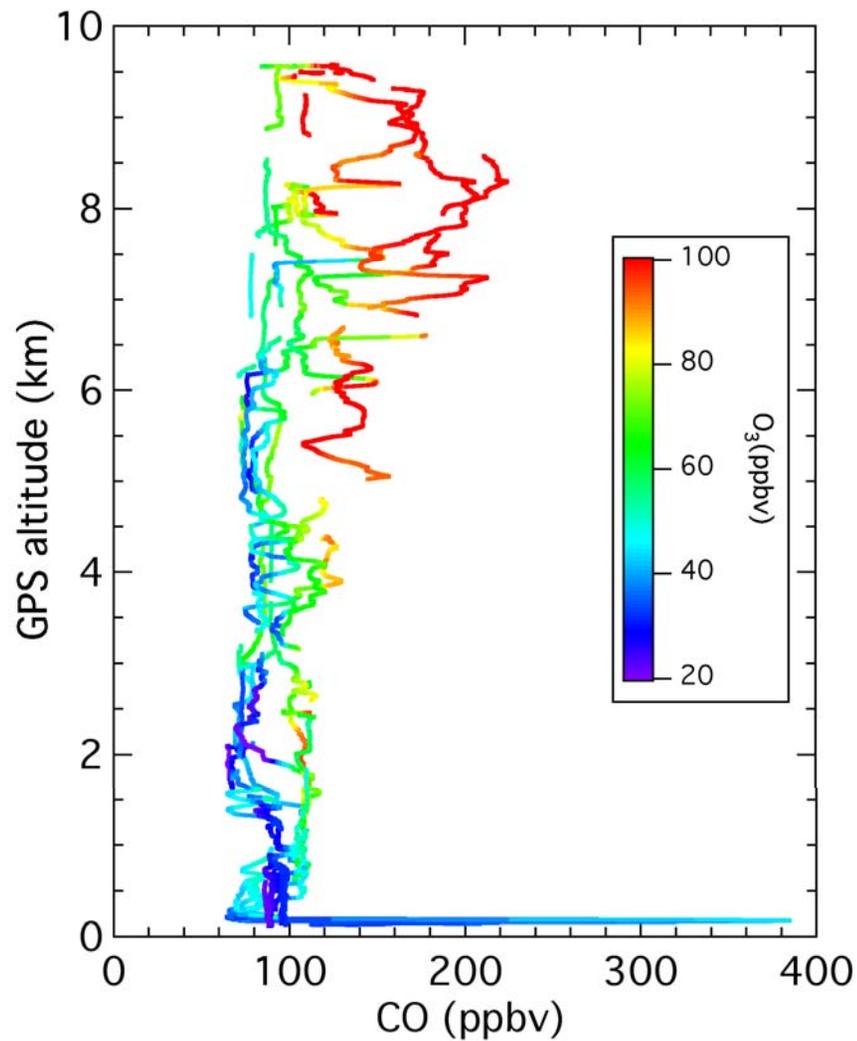
O_3 versus CO relationships provide indication of plume histories.

Diverse menagerie of plumes!



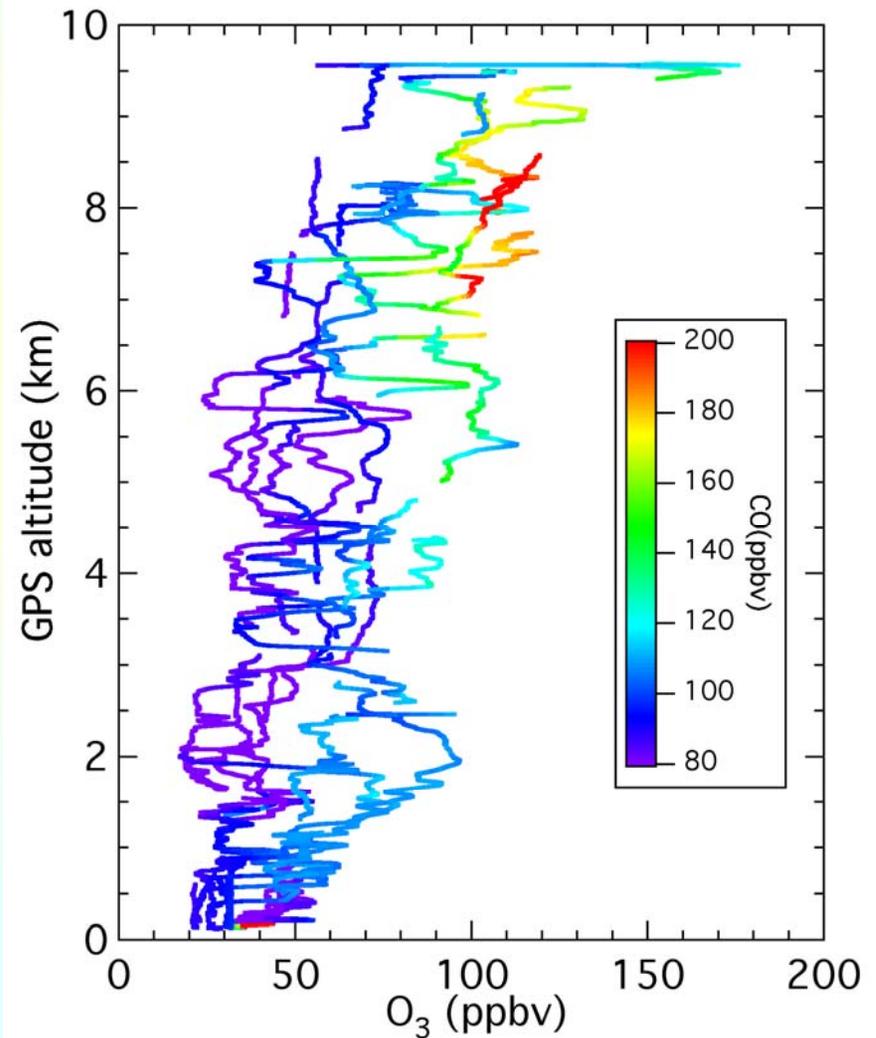
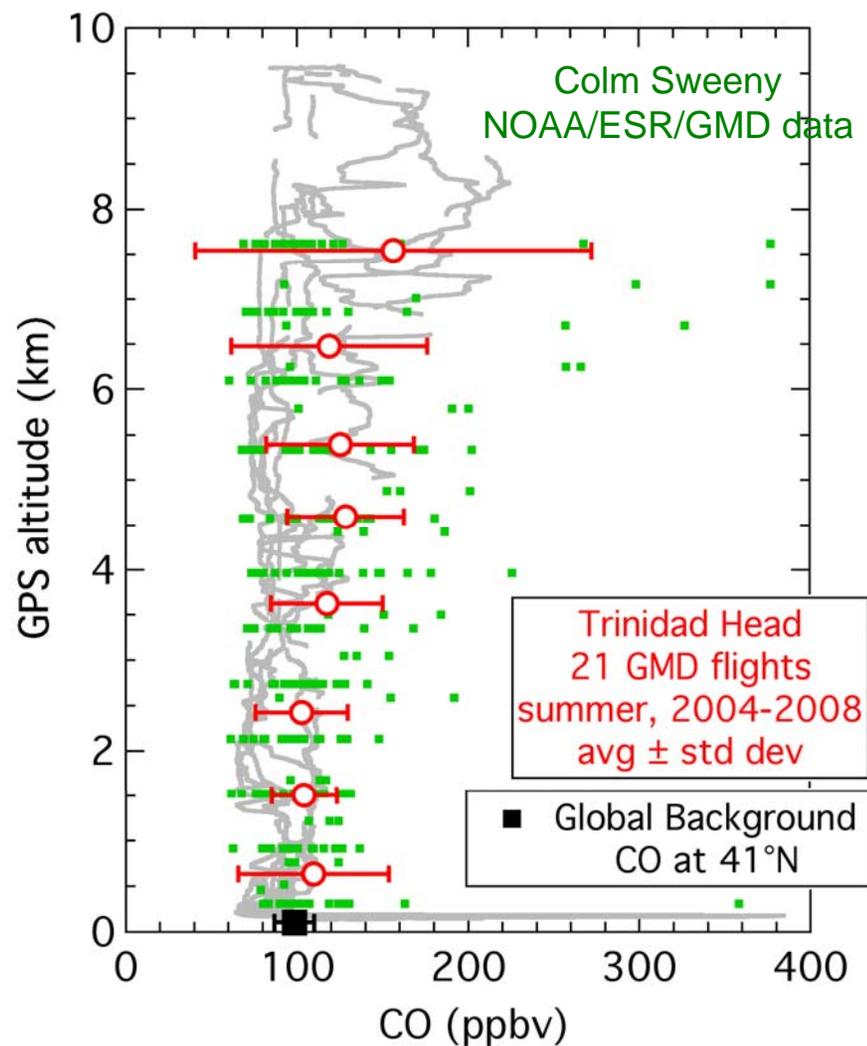
Compare to other data sets

Background air over the Pacific is better thought of as a large number of plumes of varying history in the process of intermixing and dispersing.



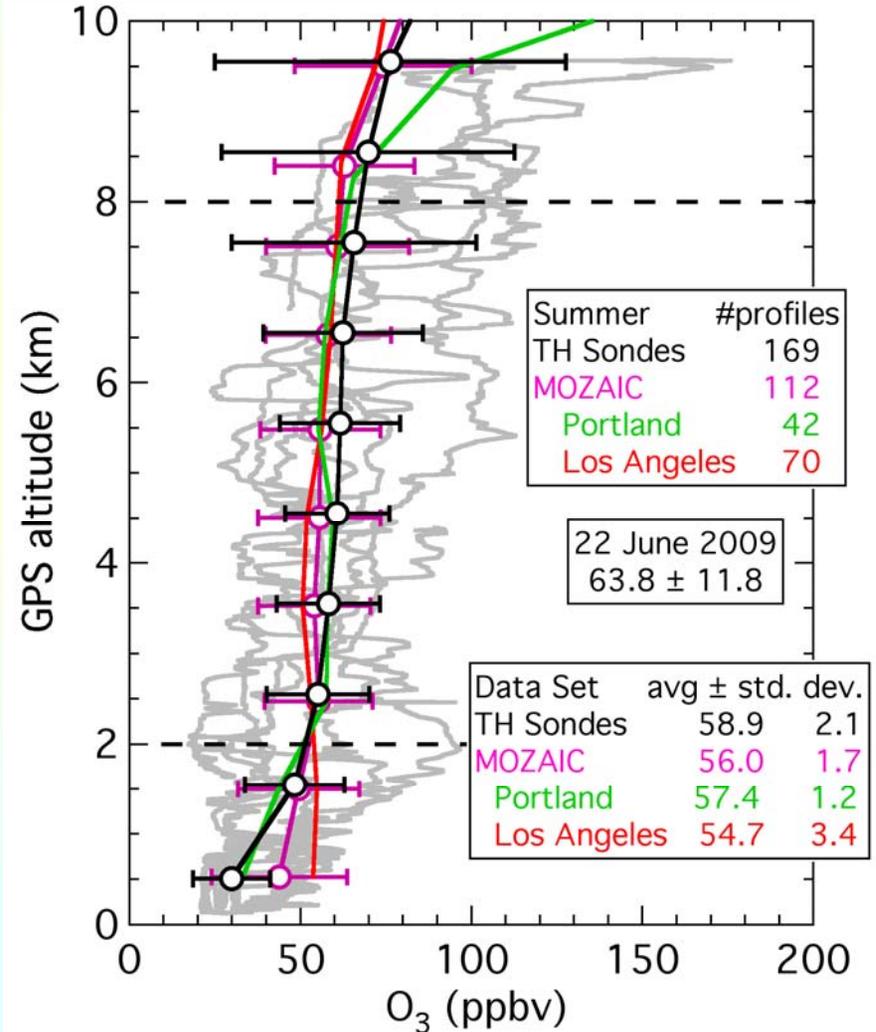
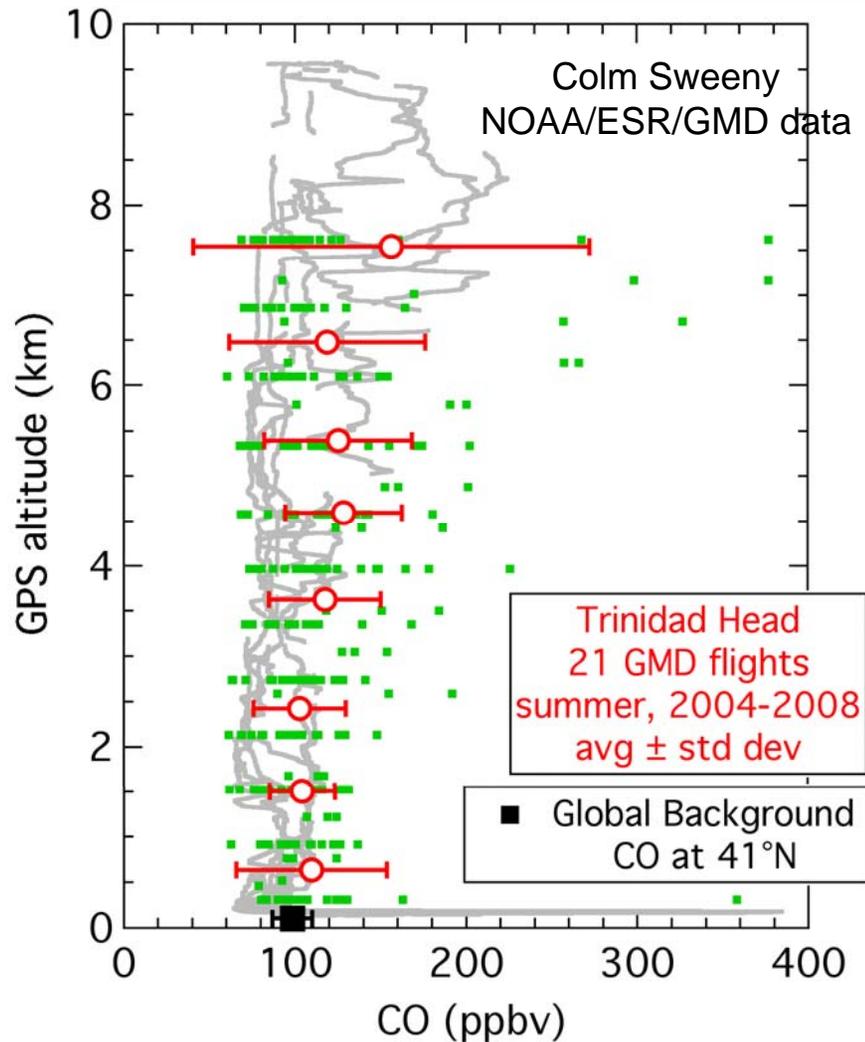
Compare to other data sets

CO plumes frequently observed aloft, often more concentrated than 22 June flight – Asian biomass source?



Compare to other data sets

CO plumes frequently observed aloft, often more concentrated than 22 June flight – Asian biomass source?
No evidence for latitudinal gradient in average O₃
22 June 2008 data are generally consistent with other data sets

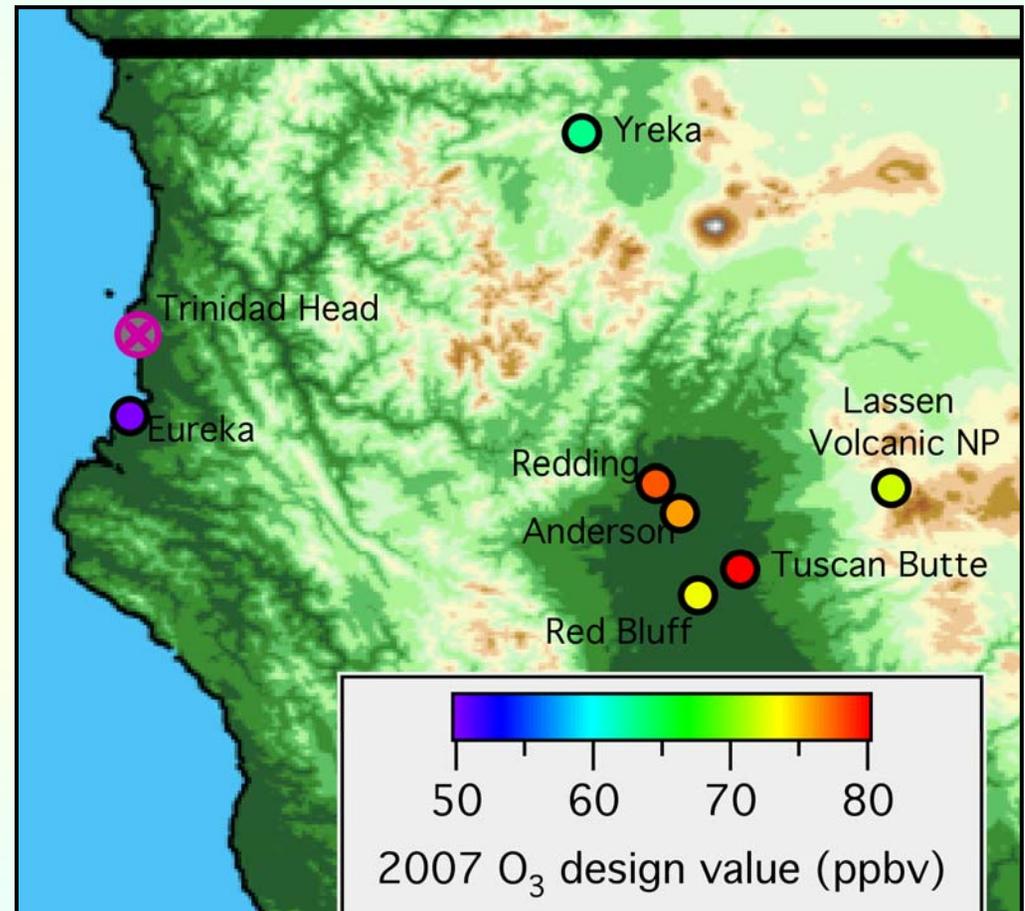


Impact of Transported Background Ozone on Air Quality in California

O₃ non-attainment area in North Sacramento Valley lies inland from Trinidad Head

Coastal mountain ranges separate valley from Pacific

Focus on summertime
(June, July, August)



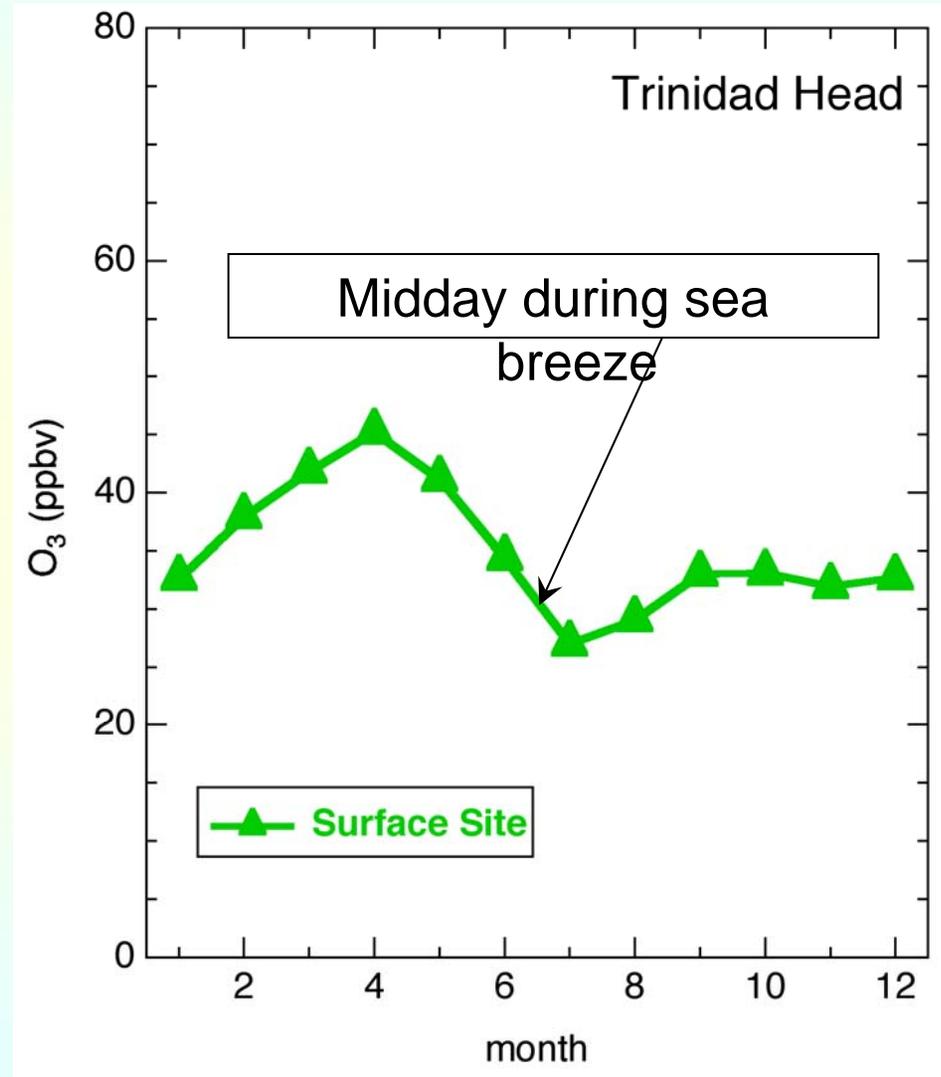
O₃ design value: 3 year average of 4th highest daily maximum 8-hr O₃ average

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Coastal mountain ranges separate valley from Pacific

Summertime O₃ minimum in Pacific marine boundary layer (MBL)



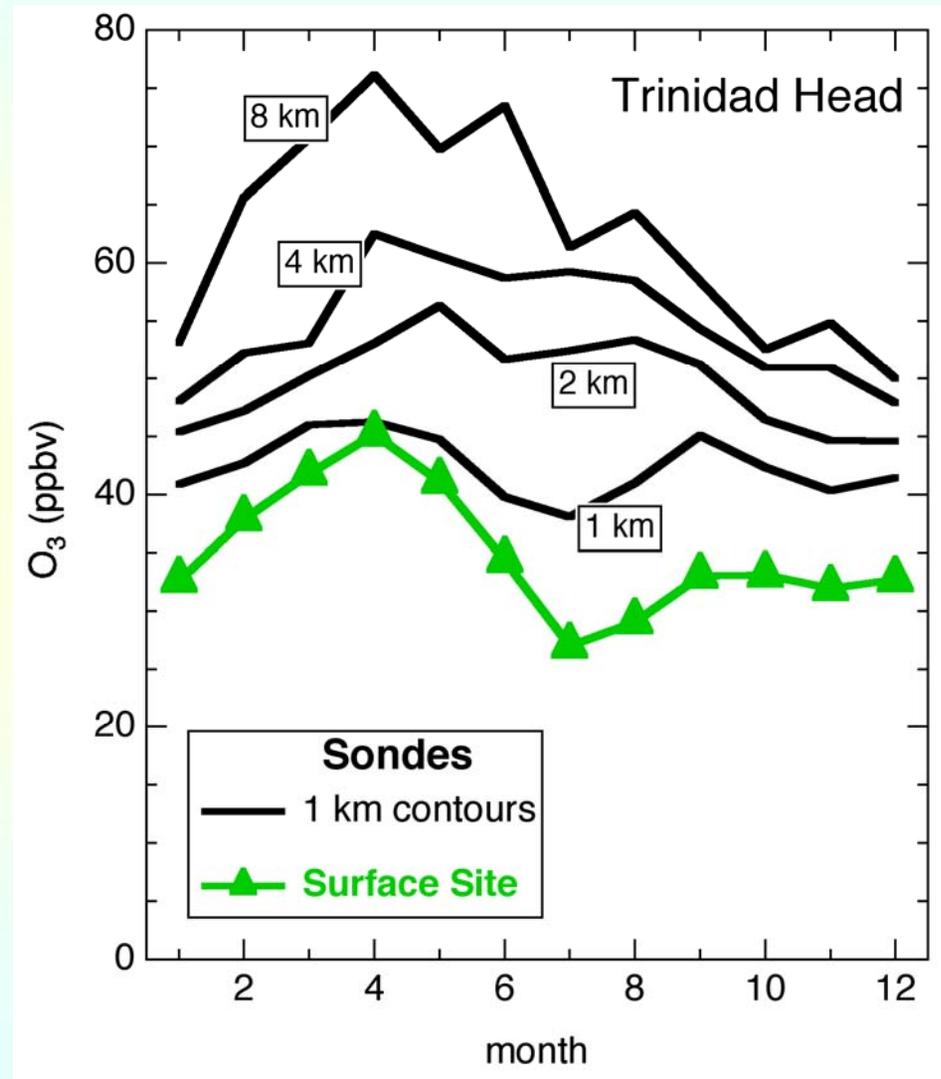
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Strong vertical gradient, with broad spring-summer maximum at 2 km



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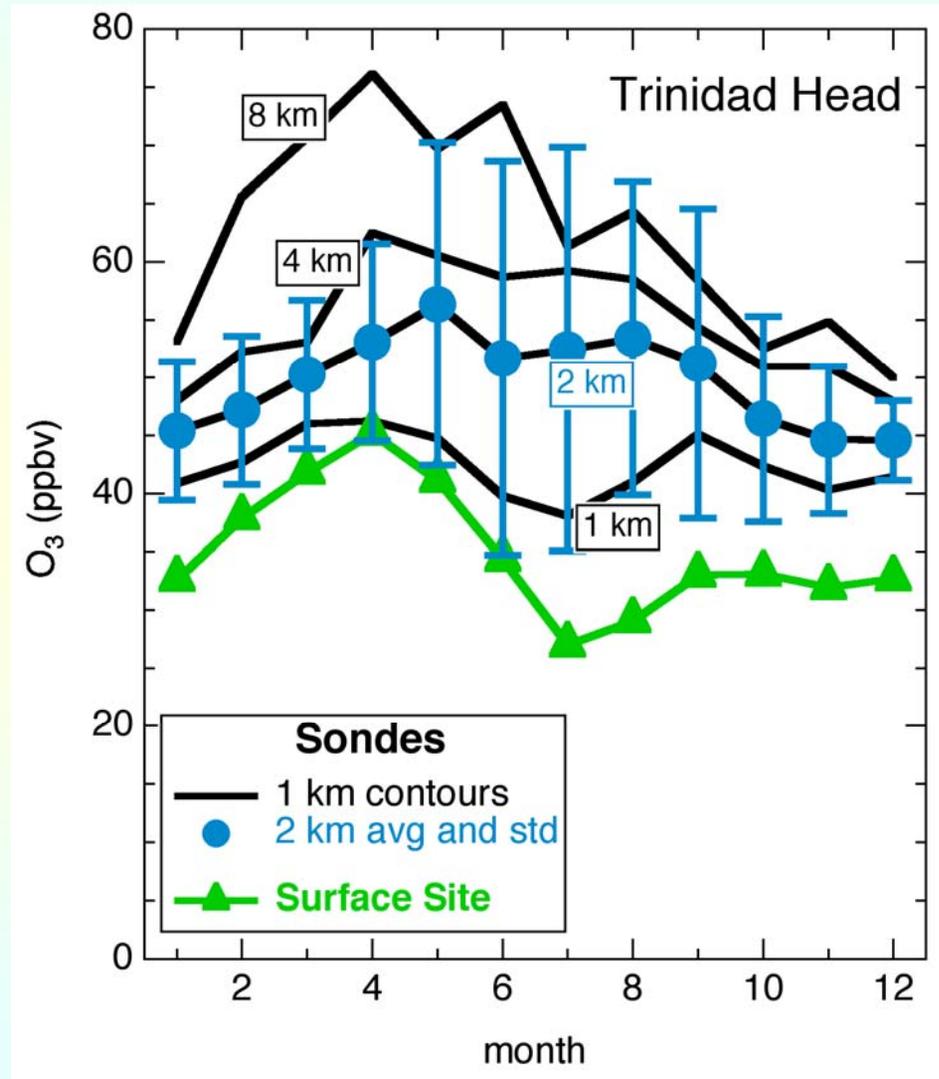
Coastal mountain ranges separate valley from Pacific

Summertime O₃ 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 O₃ in North Sacramento Valley?



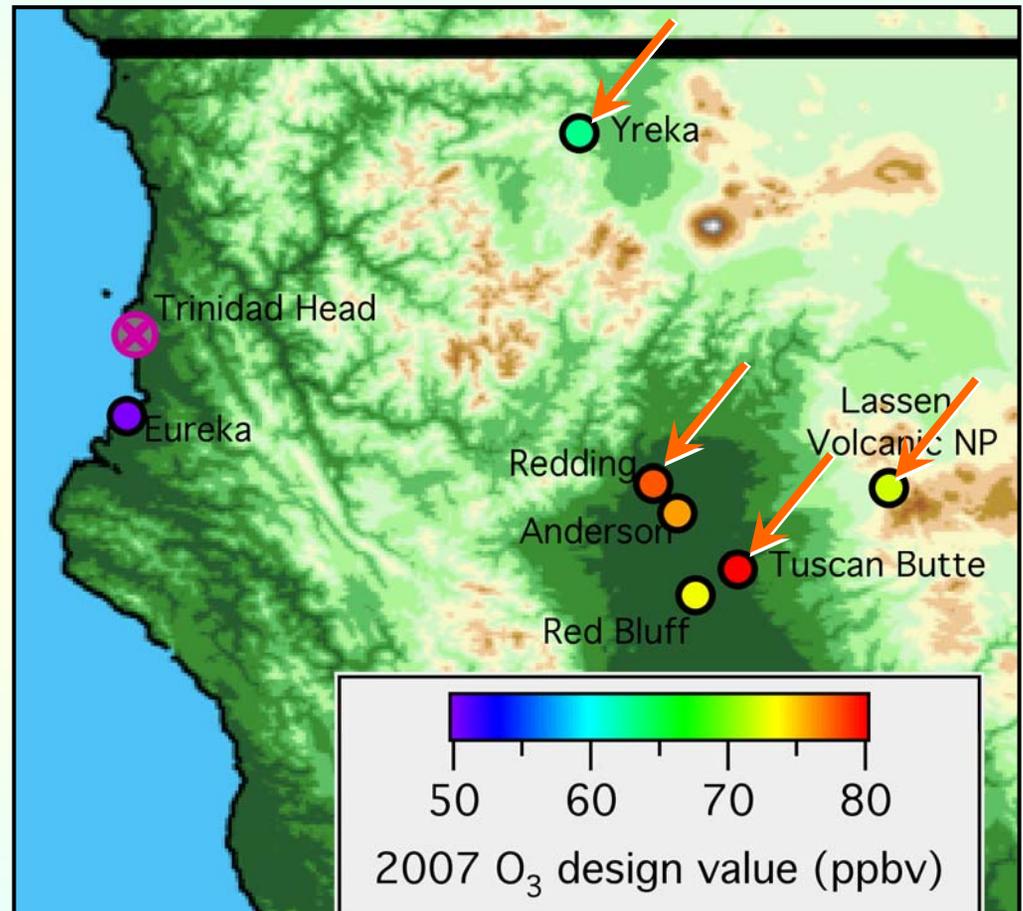
Impact of Transported Background Ozone on Air Quality in California

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

4 sites:

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

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

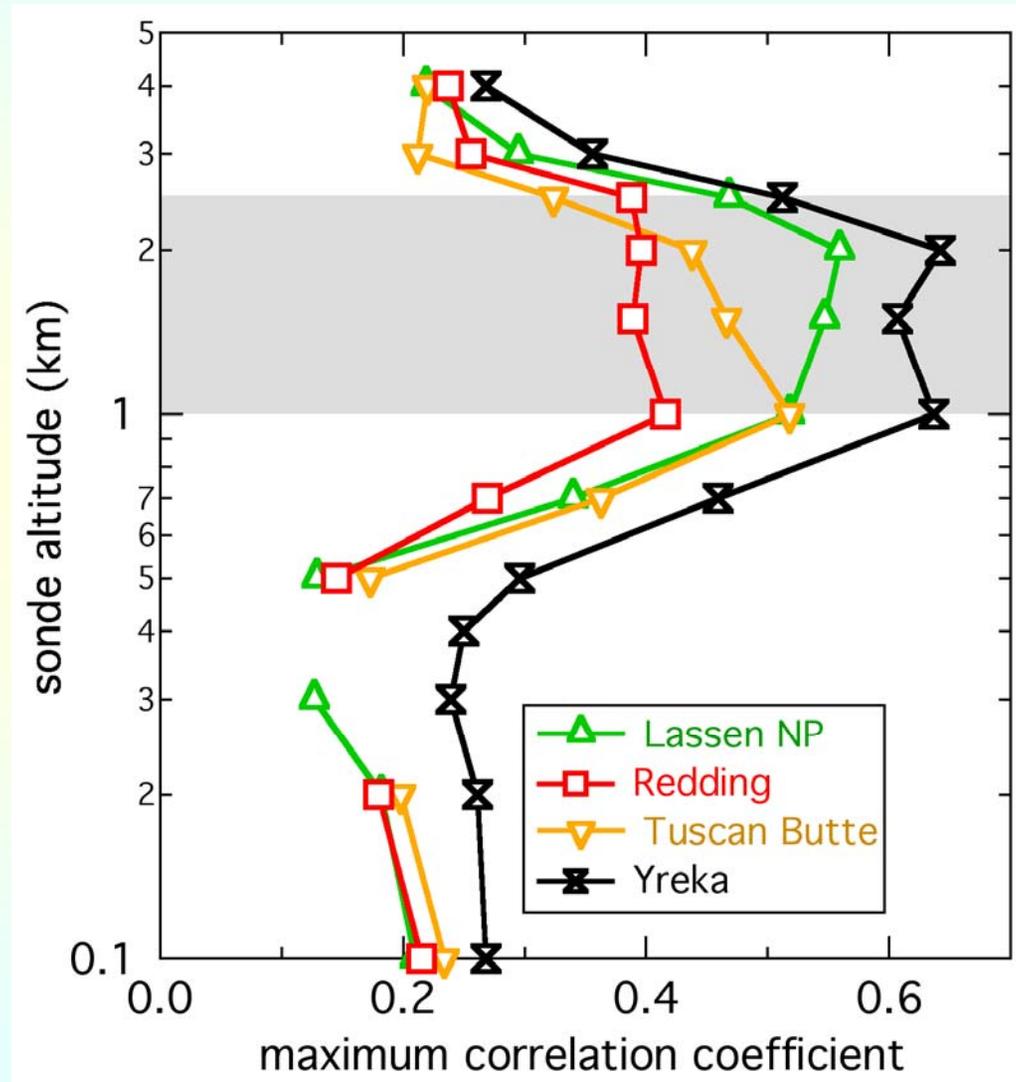


Impact of Transported Background Ozone on Air Quality in California

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?



Impact of Transported Background Ozone on Air Quality in California

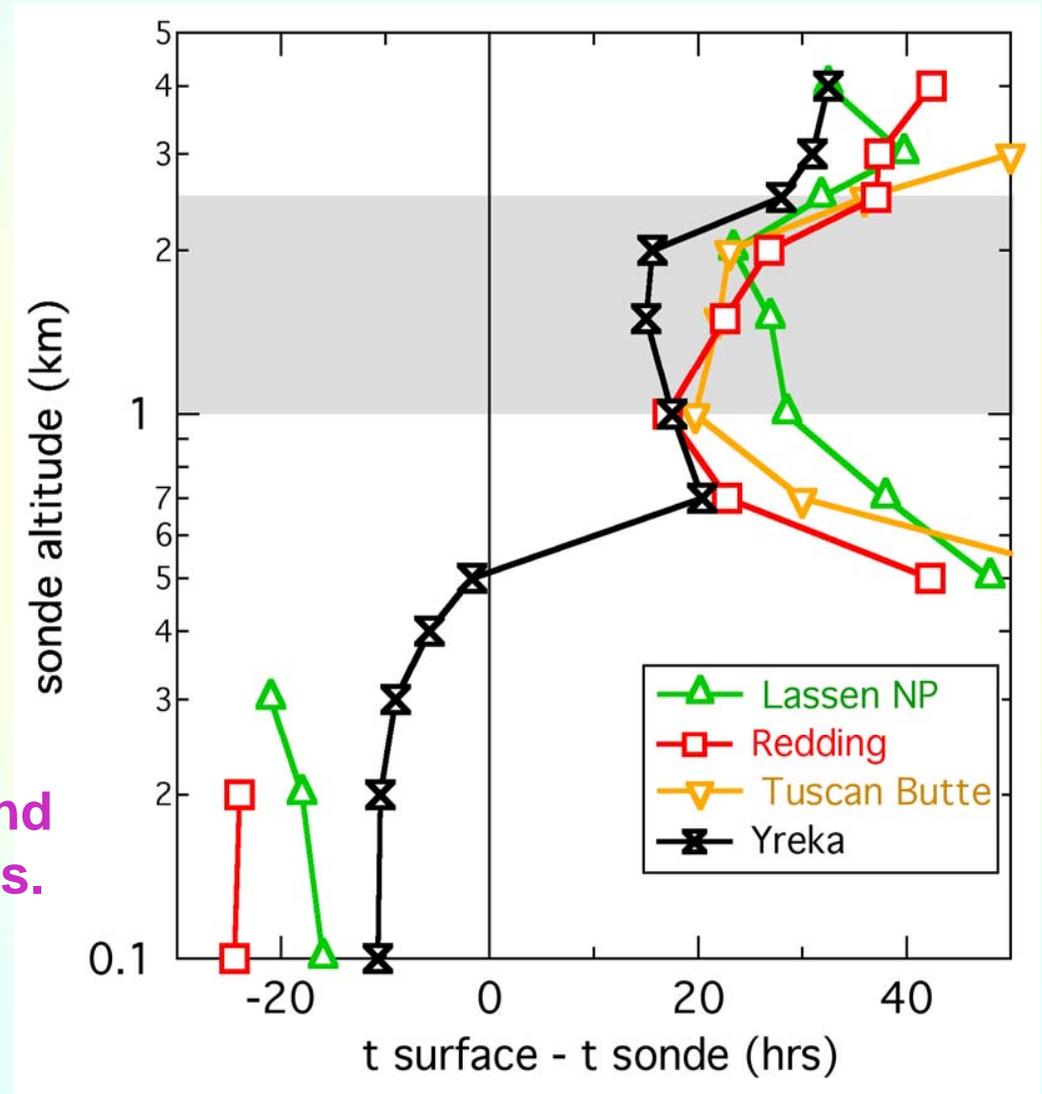
Use correlations between O_3 measured at different sites and by sondes to help answer question below

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?



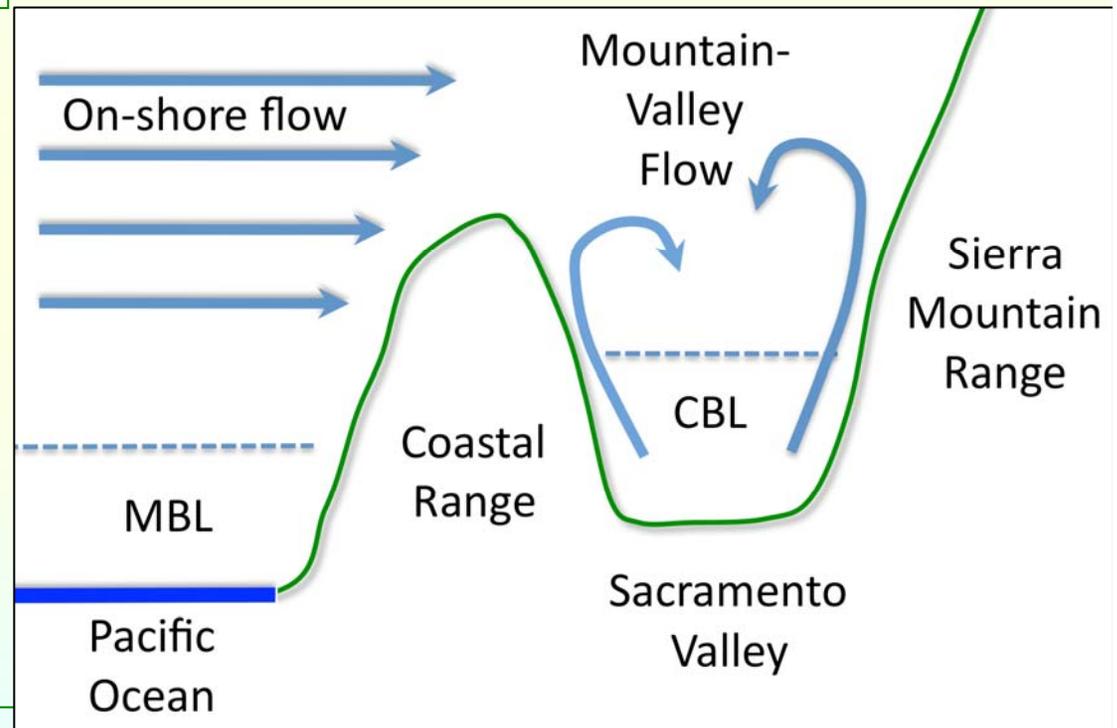
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Use correlations between O_3 measured at different sites and by sondes to help answer question below

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

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

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



Impact of Transported Background Ozone on Air Quality in California

What is the bottom line here?
Tuscan Butte in Northern
Sacramento Valley:

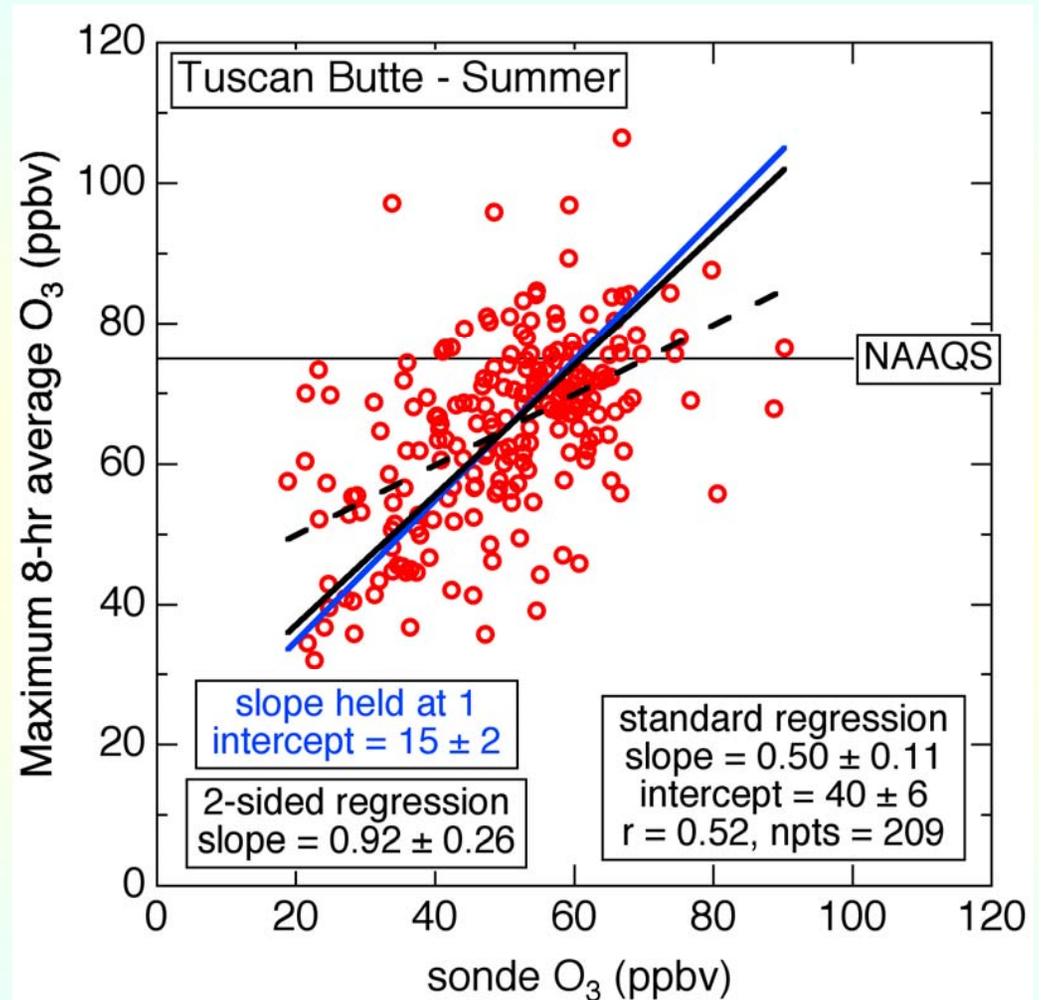
On average:

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

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

Background O_3 alone
can exceed NAAQS

Take Home Message:



Transported background O_3 plays a
major role in air quality in California

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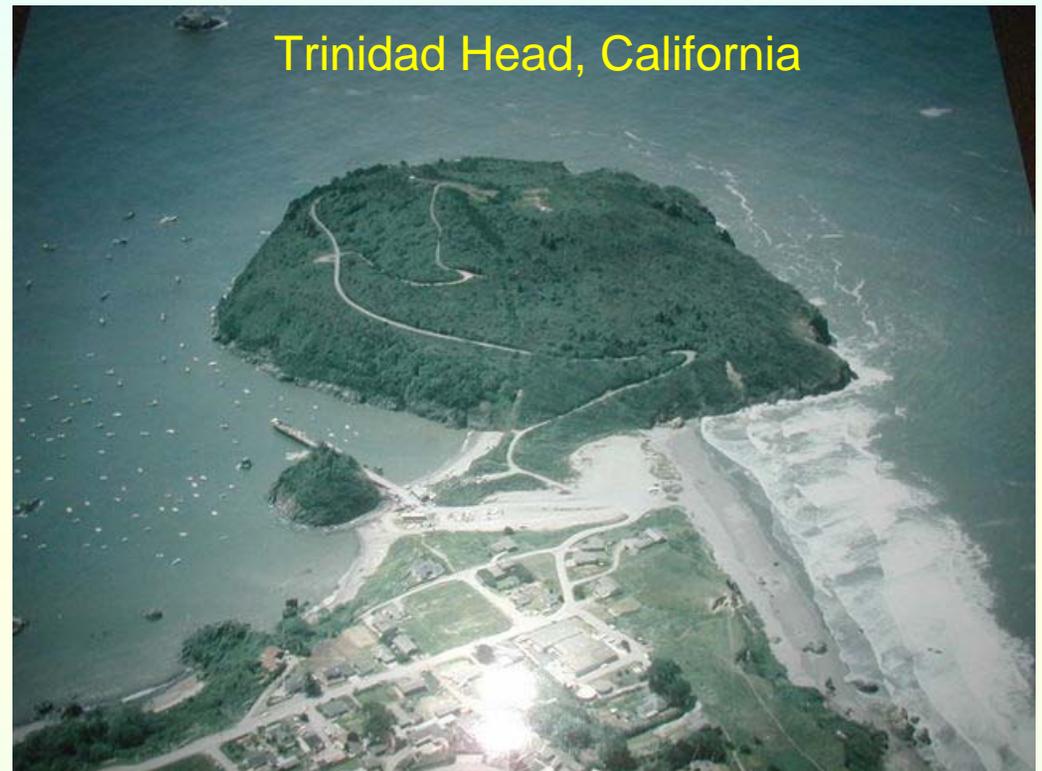
Today

- Quick look at background O₃ and CO from 22 June 2008 flight – myriad intermixing and dispersing plumes.

Consistent with other data sets

Transported background O₃ plays a major role in air quality in the Northern Sacramento Valley - Similar transport patterns likely operate in other regions of complex terrain – e.g. San Joaquin Valley

Accurate modeling of California O₃ requires global model to reproduce background plus mesoscale model for transport in complex terrain



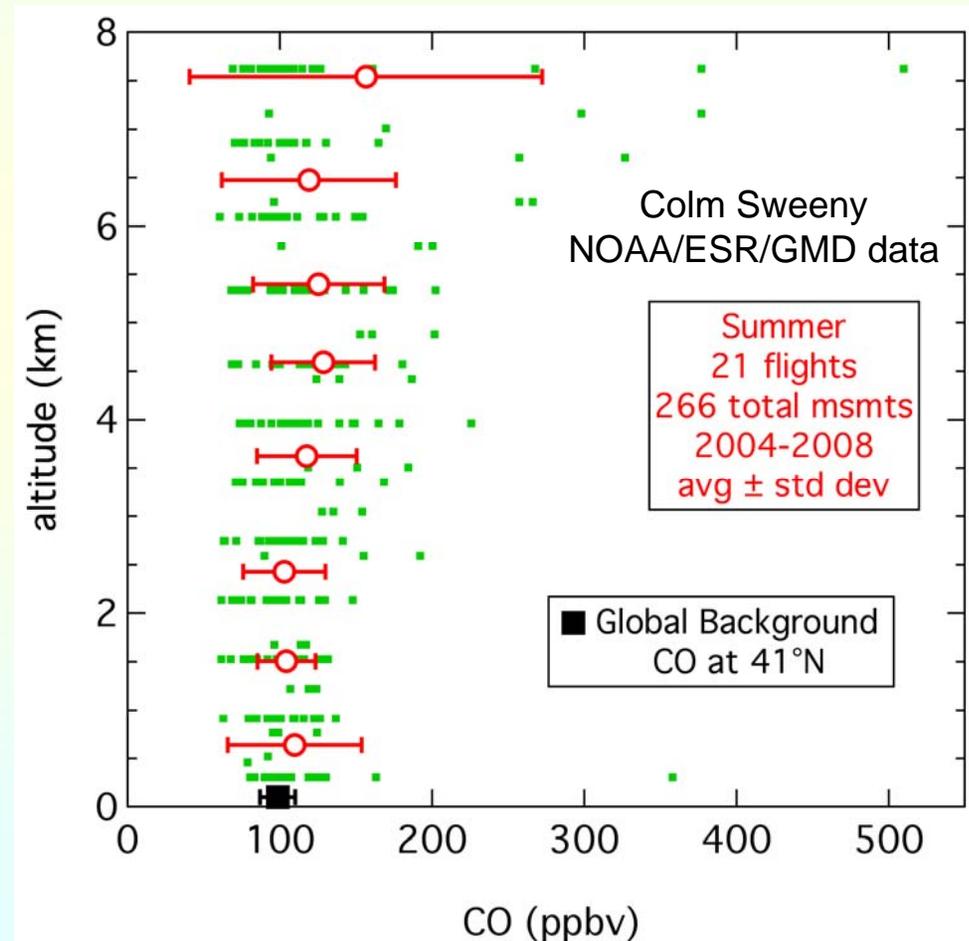
Question:

What about direct transport from central to northern California, or recirculation (anti-cyclonic flow) of air from southern California?

Northwesterly prevailing winds suggest such transport not common.

Measurements of CO over Trinidad Head show no recent North American plumes present.

Very difficult to propose mechanism for moving California emissions out of BL to free troposphere over Trinidad Head.



Policy Relevant O₃ background:

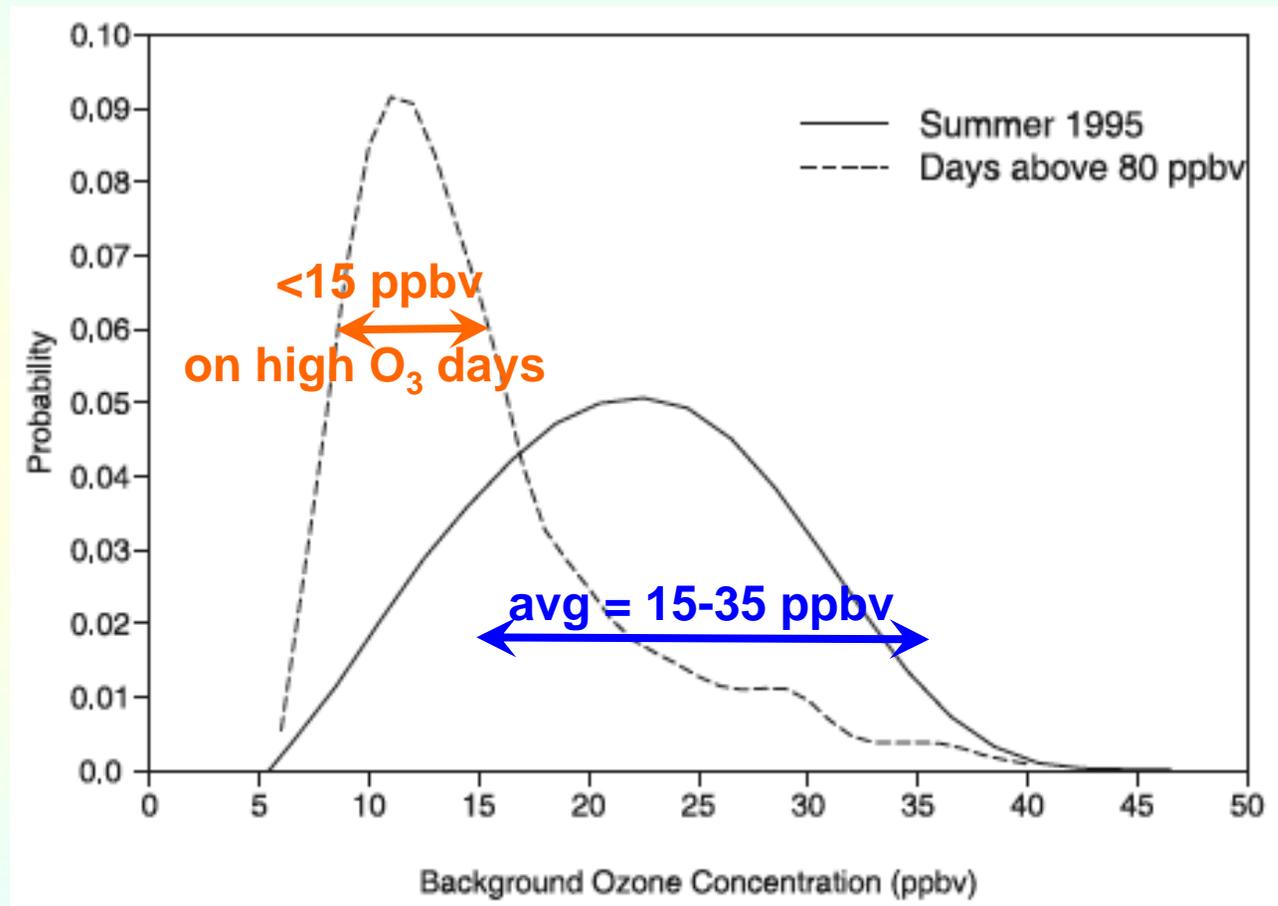
Concentrations that would exist in the US in the absence of anthropogenic emissions from North America

NAAQS = 75 ppbv for 8-hr average

Policy relevant background evaluated by models

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

Model results suggest NAAQS is achievable



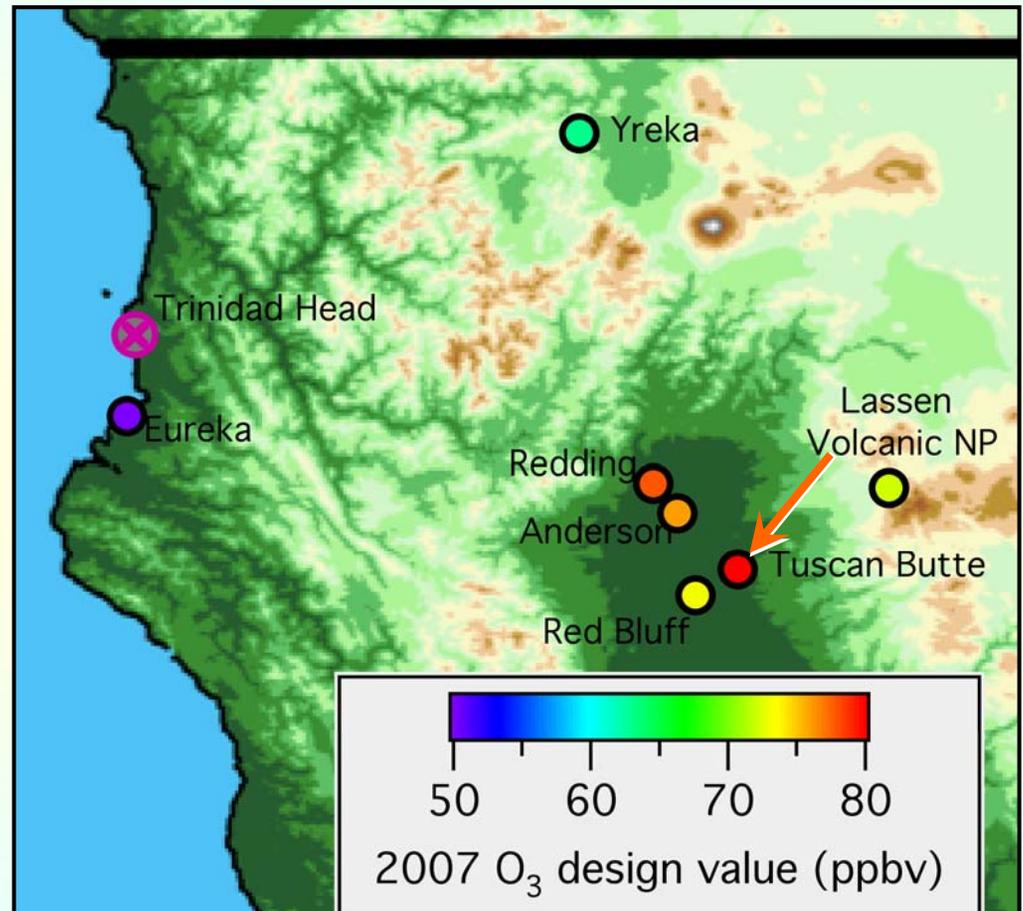
Fiore, A.M., D.J. Jacob, et al., Background ozone over the United States in summer: Origin, trend, and contribution to pollution episodes (2002) *J. Geophys. Res.*, 107, 10.1029/2001JD000982.

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

Look at Tuscan Butte site in Sacramento Valley

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

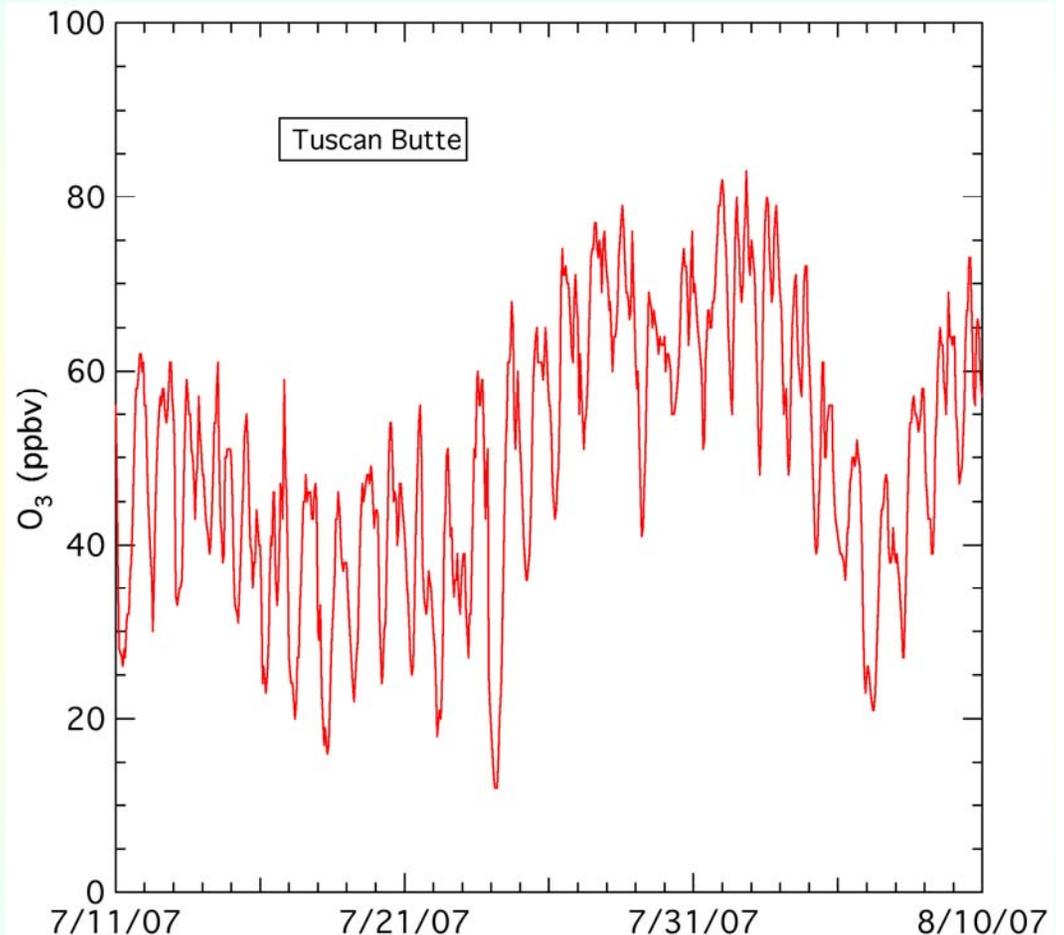


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Use correlations between O_3 measured at different sites and by sondes to help answer question below

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

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



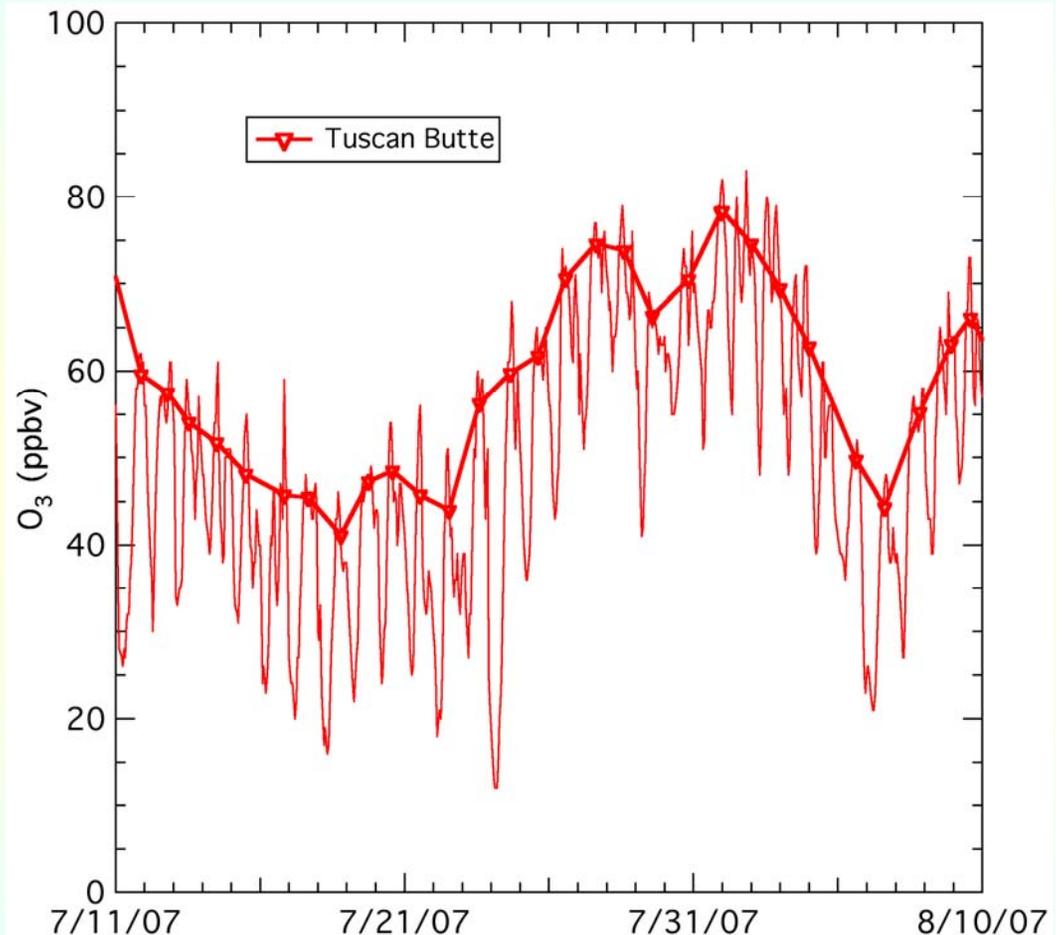
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Use correlations between O_3 measured at different sites and by sondes to help answer question below

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?



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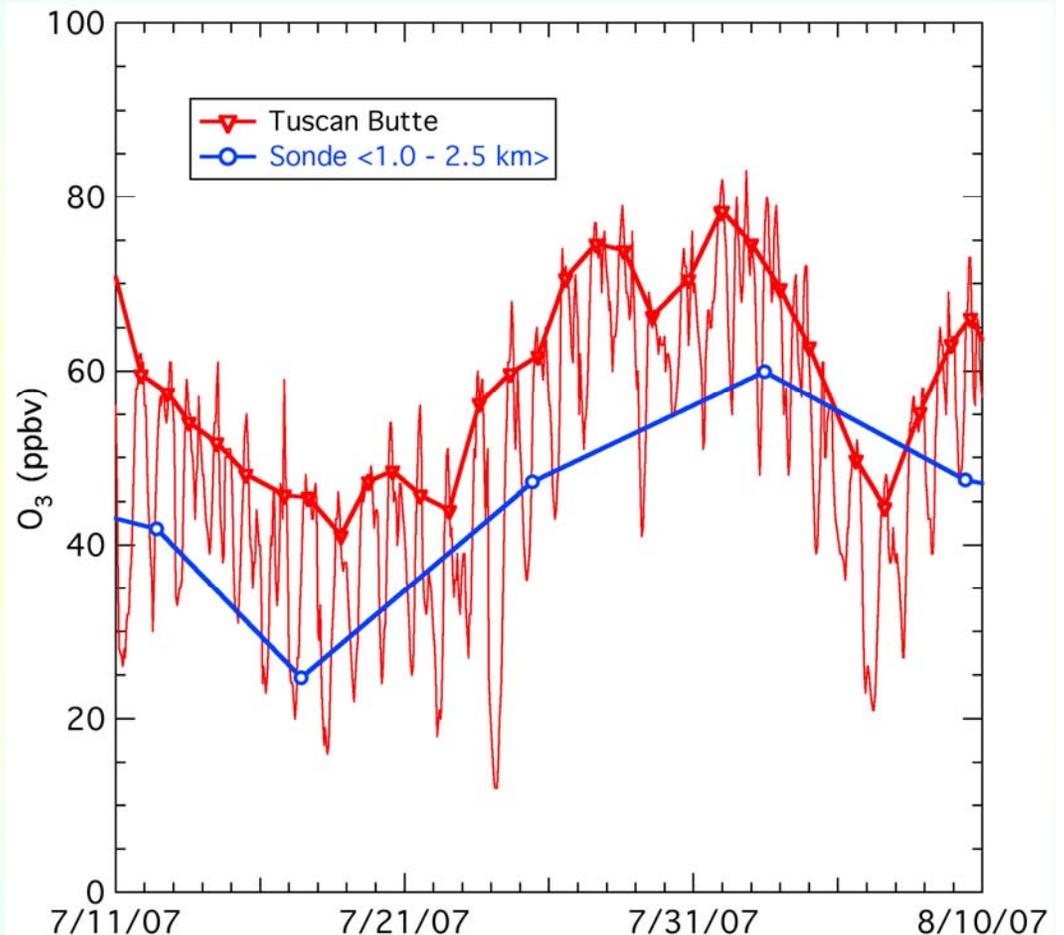
Daily maximum 8-hr O_3 averages capture regional variation

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

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



208 summertime sondes
1997-2008

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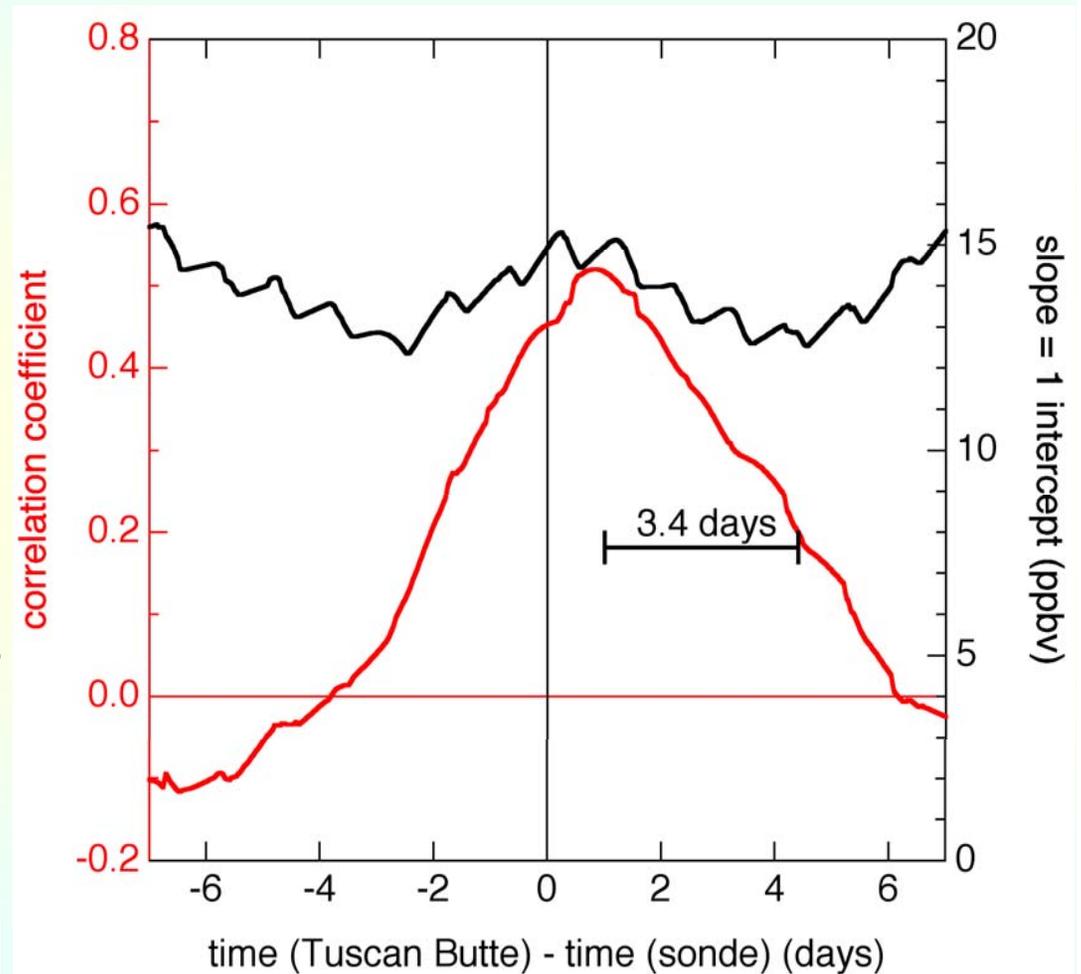
Maximum 8-hr average at Tuscan Butte correlates with sonde, but about 1 day later

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



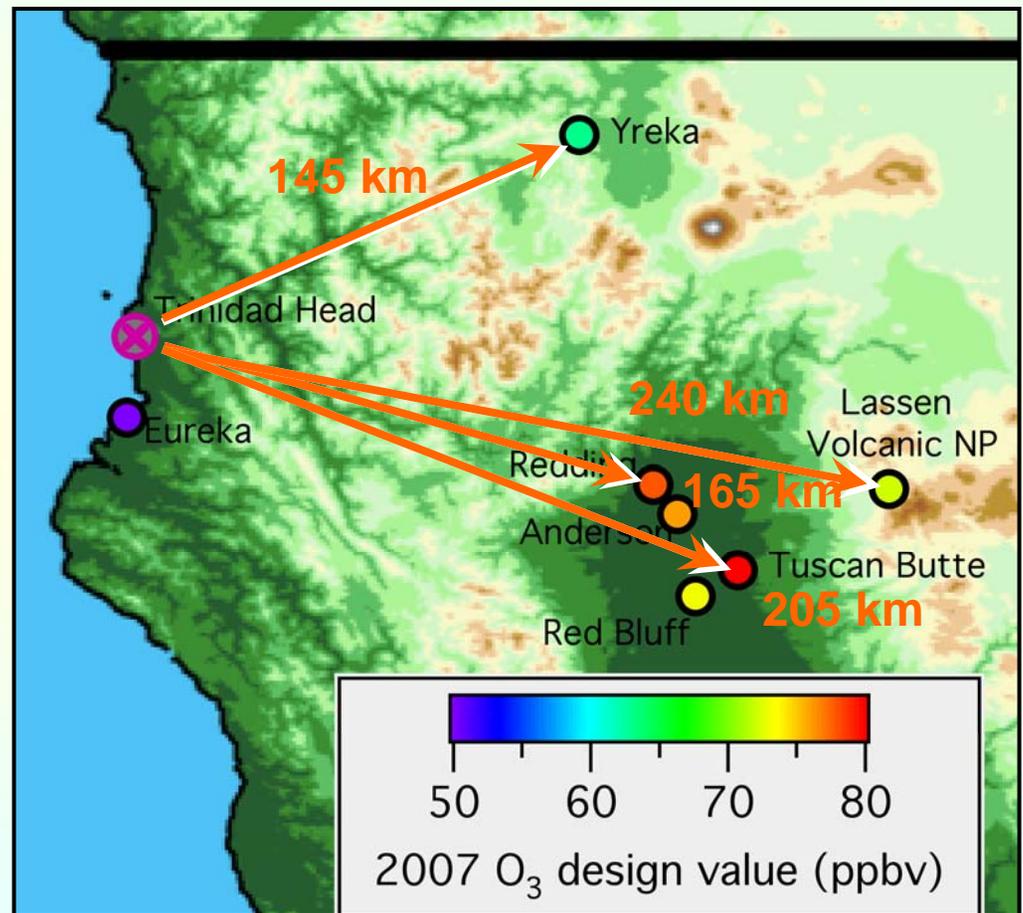
208 summertime sondes
1997-2008

Question:

Why are correlations so poor?

Analysis correlates one snapshot of O_3 aloft with interpolated daily max 8-hr average O_3 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 distribution of O_3 in onshore flow, speed and direction of onshore wind, times for transport, mixing to surface, etc., etc.

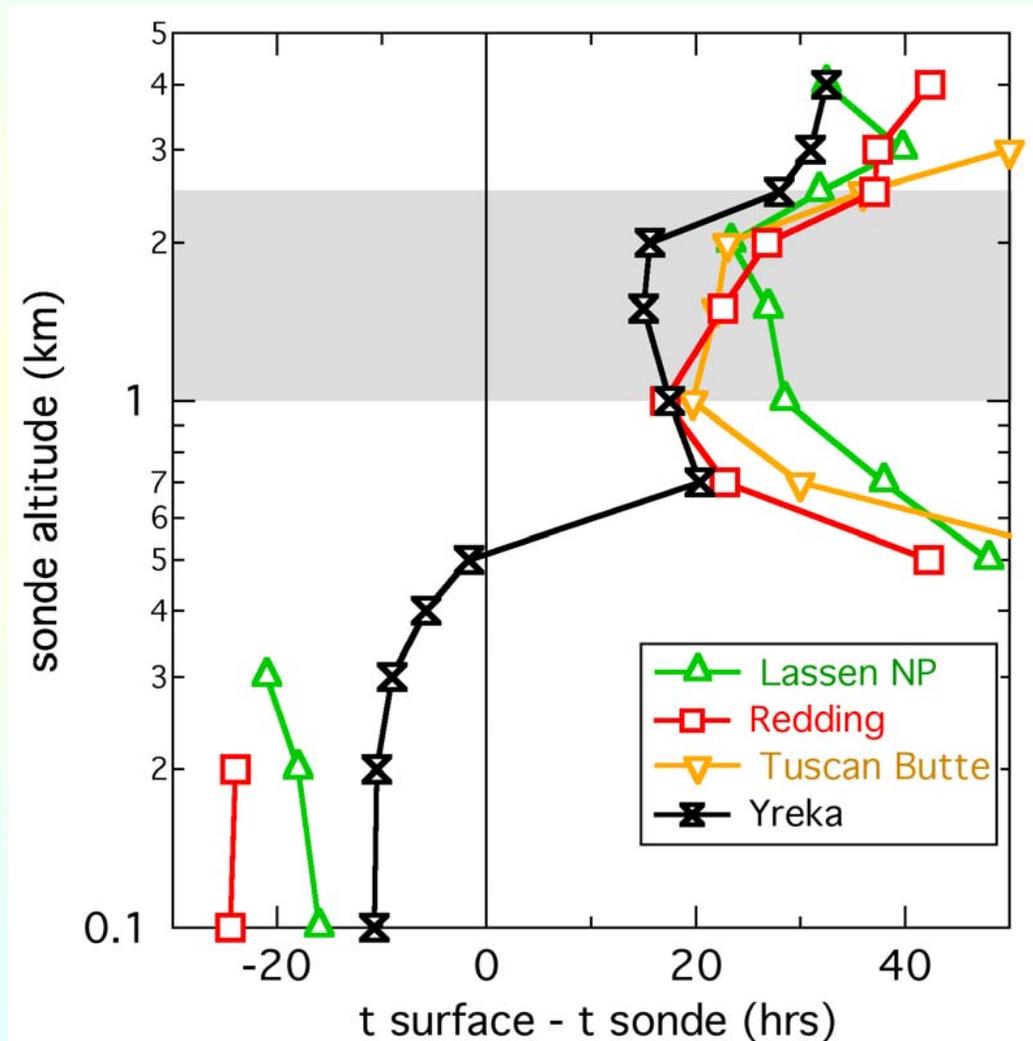


Correlations are remarkably strong!

Question:

You have fallen into a classic pit..... Correlation does not show causation!

Very true, but there are no other contenders for the cause, especially that can explain why today's sonde O_3 correlates with tomorrow's maximum O_3 in the valley!



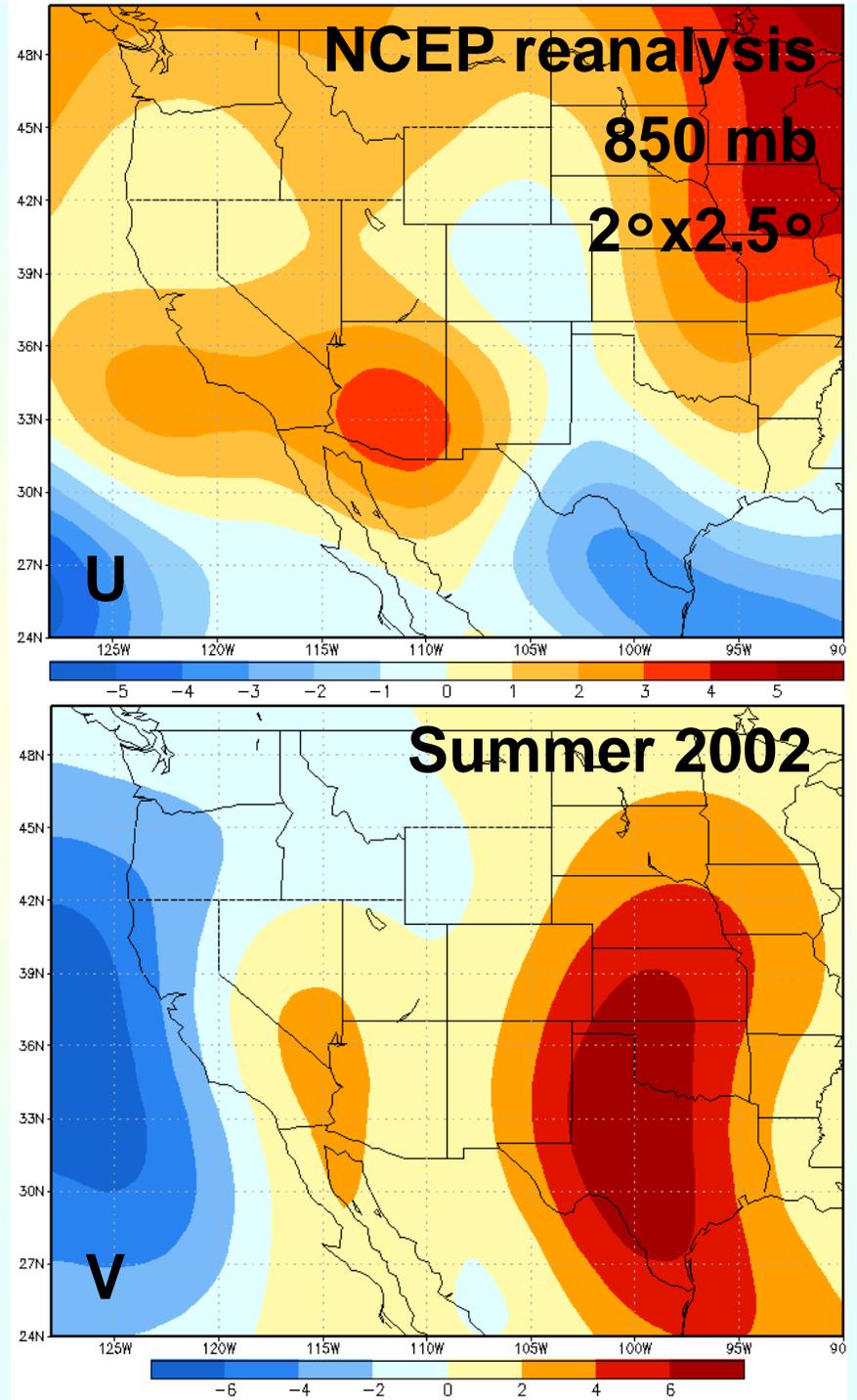
Question:

Why is there no meteorological analysis?

Good question! What do you have in mind?

Northwesterly prevailing winds at 850 mb, but resolution is not adequate to tell us much about the mesoscale mountain-valley and land-sea breeze circulations.

We plan to work with fine scale WRF modelers to more clearly define these transport mechanisms.



Question:

Doesn't MBL air flow through SF Bay, Carquinez Strait and into Central Valley?

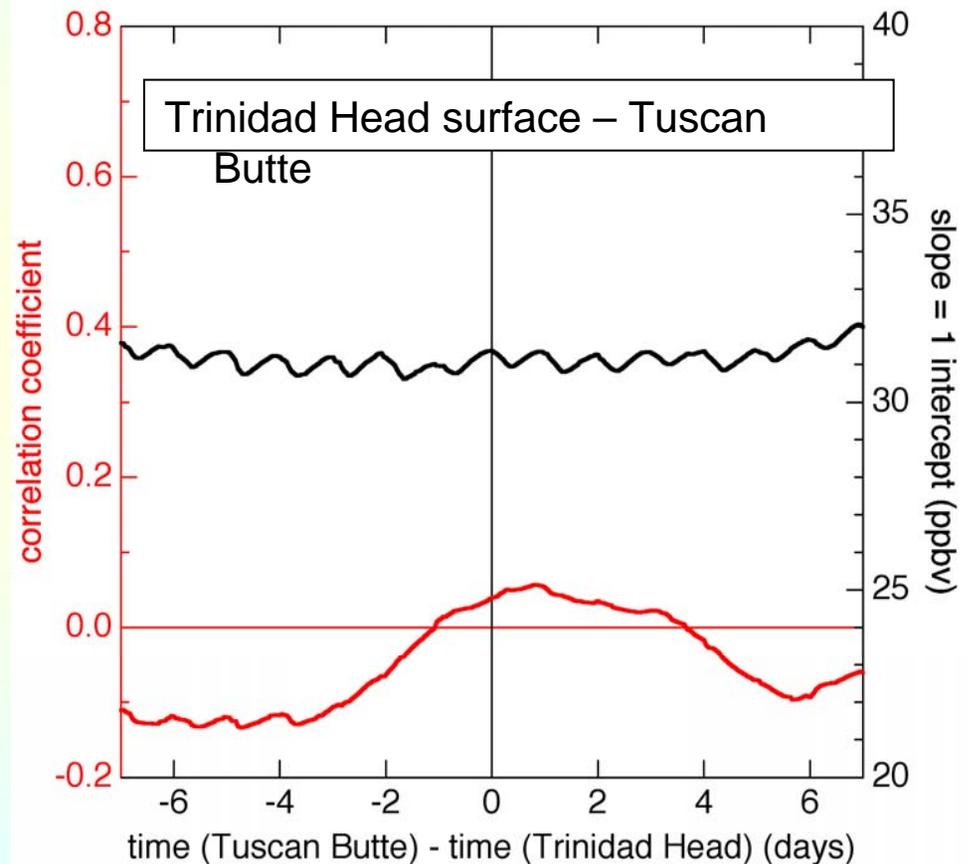


The California Almanac Of Emissions And Air Quality 2009 Edition – Fig. 3.6

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Certainly ..., however there is no significant correlation between surface O₃ at Trinidad Head and in Northern Sacramento Valley.



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Doesn't MBL air flow through SF Bay, Carquinez Strait and into Central Valley?

Certainly ..., however there is no significant correlation between surface O₃ at Trinidad Head and in Northern Sacramento Valley.

Downward transport from above MBL dominates background contribution to surface O₃ in Northern Sacramento Valley.

