CABOTS Observations from Chews Ridge & Aircraft

California Baseline Ozone Transport Study (CABOTS)
Science Meeting 19 April 2017
Satellite data confirms growth of Asian NO\textsubscript{x} \& O\textsubscript{3}; Coarse transport model shows influence on US West Coast

**source:** Verstraeten et al., 2015
Chemical transport models are imprecise in capturing the details of O$_3$ violations even aloft: Huang et al., 2013

Mt. Happo (1.85 km): Lin et al., 2010

source: Jonson et al., 2010
Study focus: Southern San Joaquin Valley

- Bodega Bay
- Half Moon Bay
- Pinnacles NP
- Chews Ridge
- Fresno-Skypark
- Lower Kaweah
- Visalia
- Arvin-Ni Giorgio
Long term quantile trends in $O_3$ at Chews Ridge (nighttime onshore data only)

- 2.1 ppb/yr (95%)
- 0.5 ppb/yr (75%)
- Statistically insignificant (50%)
- -0.7 ppb/yr (25%)
- -1.1 ppb/yr (5%)
Airflow & Geography of CABOTS

- Bodega Bay
- Half Moon Bay
- San Joaquin Valley
- Fresno
- Visalia
- Chews Ridge

Low-level flow
700 hPa flow

Pacific High
Cartoon Schematic of Transport to SJV

- O₃ Lamina
- Subsidence
- Chews Ridge
- Santa Lucia Range
- Diablo Range
- Sierra Nevada
- NW
- ENTRAINMENT
- NW
SJSU \( \text{O}_3 \)-sonde correlations BBY-HMB-Chews Ridge

Cross Correlation Between Sondes at Bodega Bay & Half Moon Bay

\[ \text{Correlation Coefficient} \]

\[ \text{Altitude (km)} \]

\( \text{O}_3 \) Sondes' Correlation to Chews Ridge

\[ \text{Correlation Coefficient} \]

\[ \text{Altitude (km)} \]
BBY O₃-sonde correlation to SJV

Bodega Bay O₃ Sondes' Correlation to SJV (N=13)

Altitude (m)

Correlation Coefficient

-0.5 0 0.5 1
Chews O$_3$ correlated to O$_3$ observed above the SJV boundary layer by ARB APOB profiles

Source: from 200 daily a.m. aircraft profiles over Fresno during summers of 2012/13. Data courtesy of Dartanion Mims, CARB.
Average Profiles from EPA/BAAQMD Flights 27-29 July & 4-6 August, 2016

- **Mean ± s.d.**
- **Median**

**EPA Afternoon Flight Profiles**

- **Free Troposphere**
- **Intermediate “Buffer Layer”**
- **Atmospheric Boundary Layer**
Ozone from fumigation by the residual layer (08:00) strongly correlated to the afternoon’s MDA8 value.
Overnight Evolution of $O_x$ can Determine Nocturnal Mixing Rate, Eddy Diffusivity: $K_z$

$K_z = 2.9 \text{ m}^2\text{s}^{-1}$
Overnight mixing modulated by the nocturnal jet strength
Simple parameterization of eddy diffusivity from Richardson

Bulk Richardson Number vs. Eddy Diffusivity

\[ y = -1.5965x + 13.505 \]
\[ R^2 = 0.8367 \]
\[ p = 0.001 \]
WRF modeling by S. Chen’s Group helps to constrain our estimates of entrainment velocity: 4.3 +/- 0.9 cm/s.
WRF modeling by S. Chen’s Group helps to interpret “subsidence” in TOPAZ figures

Fig. (Above) Here is an example of estimated subsidence from TOPAZ ozone layers on 08/04/2016. The black line is the estimated height change while the white line is an estimated error in that measurement.

Fig. (left) Shows the poor correlation we have found between the WRF predicted subsidence and that which was determined from what appear to be subsiding ozone layers in the TOPAZ data. WRF data is selected right above Visalia in the range of 800 to 1500m and then averaged. Clearly we need some way to account for advection of ozone at height to really determine what the ozone at height is doing. Presumably these layers are not simply laminar and have some structure or tilt.
Chews Ridge Data During Soberanes Fire
July 22 – October 15, 2016: 85 days, 535 km²

Photo Credit: Chris Reed
Chews Ridge Data During Soberanes Fire
July 22 – October 15, 2016

MODIS True Color: 29-July
Landsat OLI: 16-Sept
Soberanes Fire Influence on SJV surface AQ
NO\textsubscript{x} Emission Estimates from Afternoon EPA Airborne Budgets

Estimates of NO emissions from California soils (natural and cropland) generated by using stable isotopic modelling and IMAGE model.

[from Almaraz et al., to be submitted to PNAS]

\[
\begin{align*}
\frac{\partial [NO_x]}{\partial t} &+ U \frac{\partial [NO_x]}{\partial x} - k_{OH+NO_2}[OH][NO_x] = 0 \\
\frac{\partial [NO_x]}{\partial x} &+ \frac{w_e \Delta [NO_x]}{z_i} = [NO_x] \quad \text{Emissions (tons/d)}
\end{align*}
\]

<table>
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<tr>
<th>Date</th>
<th>( \frac{\partial [NO_x]}{\partial t} )</th>
<th>( \frac{\partial [NO_x]}{\partial x} )</th>
<th>( \frac{w_e \Delta [NO_x]}{z_i} )</th>
<th>( [NO_x] )</th>
<th>Emissions (tons/d)</th>
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<td>0.12</td>
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<td>0.8</td>
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Estimated Soil NO\textsubscript{x} = 530 tons/d

CARB NO\textsubscript{x} Emissions:
Kings+Tulare+Fresno+Madera = 138 tons/d
Current Lines of Research

**Topic:**

- Estimating vertical mixing from midnight to sunrise flight data. *Caputi et al., in preparation.*
- Careful budgeting of NO$_x$ in the ABL between Fresno/Visalia to regional emissions of NO$_x$, indicative of strong ag soils source in SJV *Almaraz et al., in preparation*.
- Chews Ridge data set being finalized for submission to CABOTS. O$_3$/NO$_x$ in wildfires. *Asher in support of AJAX team*.
- Budgets of O$_3$ and CH$_4$ and boundary layer height to improve understanding of local production & ABL dynamics. *Trousdell et al., in preparation*.
- Modeling residence times of 3 layer system (ABL, Buffer Layer, FT) and how nocturnal transport affects the Residual layer.

**Preliminary Results:**

- Overnight *eddy diffusivity values, $K_z$*, range from 1.5-7.5 m$^2$/s. *Parameterization with overnight bulk Ri #*
- Preliminary $E_{NOx}$ range 280 – 920 tons/d. *CARB inventory <140 tons/d*  
  *ag soil NOx ~ 500 tons/d*

- CABOTS data is a very unique time series of varying (Soberanes) wildfire influence. *Hypothesis: net P$_{O3}$ in effluent?*
- Preliminary P(O3) range 3.5 – 16 ppb/hr  
  *Brune et al. (2016): 3– 15 ppb/hr*  
  *Pusede et al. (2014): 10 – 26 ppb/hr*

- Preliminary residence time of ‘buffer layer’ is ~36 hours.
Diurnal pattern of SJV surface $O_3$

![Graph showing diurnal pattern of SJV surface $O_3$](image)

- **MDA8 interval**
- **PST (hour)**

Legend:
- Shafter
- BFL Mean
- Fresno
- Arvin