Fires, Asian, and Stratospheric Transport Las Vegas Ozone Study (FAST-LVOS)

A study sponsored by the Clark County Department of Air Quality

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Chemical Sciences Division

Cooperative Institute for Environmental Science (CIRES)
University of Colorado, Boulder

Updated January 10, 2017
Ozone concentrations in Desert SW approach 2015 NAAQS in late spring

Mean MDA8 O₃ in May >60 ppbv in remote areas

Where does this O₃ come from?
Los Angeles? Asia? Wildfires? Stratosphere?

Langford NOAA/ESRL/CSD  ENVI-VISION May 10, 2016
Highest ozone in May and June before peak in photochemical production-why?
Where is Clark County?

Clark County encompasses the Las Vegas-Henderson-Paradise, NV Metropolitan Statistical Area (pop. ≈2 million or 70% of Nevada)

Ozone monitors: (pink=state, green=NPS, red=Clark County, blue=NVROI)
The Jean monitor (circle) lies between Los Angeles and Las Vegas
The Joe Neal monitor (square) typically measures the highest $O_3$ in Clark County
Mean contribution of STT to surface $O_3$ during CalNex (May-June 2010)

Descending stratospheric intrusions entrain transported pollution
AM3 model Meiyun Lin (NOAA/GFDL/Princeton)

Stratospheric influx is 4x Asian transport
This question motivated the first LVOS campaign in May-June 2013

LVOS Primary Objectives

• Determine if stratosphere-to-troposphere (STT) and long-range transport from Asia contribute to the springtime O₃ maximum in Clark County.

• Estimate the importance of these processes relative to local O₃ production and regional transport from LA or wildfires.
Las Vegas Ozone Study (LVOS)

May 19- June 29, 2013

NOAA TOPAZ Lidar and in situ measurements on Angel Peak

(36.32° N, -115.57° E, 2.68 km ASL)
Las Vegas Ozone Study (LVOS)

May 19- June 29, 2013

Las Vegas
High ozone days in the Las Vegas Valley coincided with STT events and high ozone at and above Angel Peak

2008 ozone NAAQS (75 ppbv) exceeded on May 21 and 25
3 of 6 NAAQS exceedance days in 2013 occurred during LVOS and coincided with STT/transport events.

Las Vegas Ozone Study (LVOS)

2013: black = CC mean MDA8, red=CC highest MDA8

66 ppbv

May 19
June 29
Clark County was also affected by fires in Arizona, California, and Nevada.

Remaining 3 exceedance days coincided with wildland fires in CA or NV.
An overview of the 2013 Las Vegas Ozone Study (LVOS): Impact of stratospheric intrusions and long-range transport on surface air quality


- NOAA Earth System Research Laboratory, Chemical Sciences Division, Boulder, CO 80305, USA
- Cooperative Institute for Research in the Environmental Sciences, University of Colorado, Boulder, CO 80309, USA
- Laboratoire de l’Atmosphère et des Cyclones (LACy), UMR 8105, Saint-Denis, La Réunion, France
- Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ, USA
- NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA
- NOAA/NESDIS Center for Satellite Applications and Research, Cooperative Institute for Meteorological Satellite Studies, Madison, WI 53706, USA

HIGHLIGHTS

- Stratosphere-to-troposphere transport (STT) significantly impacts surface O₃ in the intermountain west.
- STT can directly lead to exceedances of the 2008 ozone NAAQS during springtime.
- STT influences background surface O₃ more than long-range transport from Asia.
- With a 65 ppbv standard, exceedances may be too frequent to treat as "exceptional events" in the intermountain west during springtime.
Entrainment of stratospheric air and Asian pollution by the convective boundary layer in the Southwestern U.S.


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Outstanding questions to be addressed in FAST-LVOS

• How much of the transported ozone aloft reaches the LVV and how does it get there? (ML entrainment vs orographic flows)

• How much ozone is transported into the LVV from Southern California? (boundary layer vs free trop. transport)

• How much do wildland fires contribute to late spring ozone in the LVV???
**Fires, Asian, and Stratospheric Transport Las Vegas Ozone Study**  
*(FAST-LVOS)*

*(May 20-June 30, 2017)*

- TOPAZ lidar (NLVA) (NOAA/CSD)
- micro-Doppler lidar (NLVA) (NOAA/CSD)
- Mobile sampling lab (Angel Peak) (NOAA/CSD)
- Ozonesonodes* (Joe Neal?) (NOAA/GMD)
- Mooney aircraft* (NLVA) (Scientific Aviation)
- NASA Alpha Jet (AJAX)** (NASA)
- AM4 modeling (NOAA/GFDL)

*Intensives only  **TBD*
Fires, Asian, and Stratospheric Transport
Las Vegas Ozone Study (FAST-LVOS)

(May 20-June 30, 2017)

Intensive Operating Periods (IOPS) to capture transport events

- Reinforce TOPAZ crews for 24 h runs (2 additional people)
- Ozonesonde crew arrives (2 launches/day, 30 total)
- SA Mooney transits to NLVA for daily flights (6h/day, 90 h total)
- CSD mobile lab on standby for mobile operations

(≈15 out of 42 days)
Las Vegas Ozone Study (LVOS)
May 19-26, 2013

STT events most likely near the beginning of the campaign

7 straight days with STT influence!
Las Vegas Ozone Study (LVOS)
May 19-26, 2013

STT events most likely near the beginning of the campaign

First major event on May 20-22, 2013
Las Vegas Ozone Study (LVOS)

RAQMS ozone forecasts during LVOS (Pierce)


00 hours out
Las Vegas Ozone Study (LVOS)

RAQMS ozone forecasts during LVOS (Pierce)

Analysis: 12 UT May 18, 2013  
Forecast: 12 UT May 20, 2013  
48 hours out
Las Vegas Ozone Study (LVOS)

RAQMS ozone forecasts during LVOS (Pierce)

Analysis: 12 UT May 16, 2013
Forecast: 12 UT May 20, 2013
96 hours out
Las Vegas Ozone Study (LVOS)

RAQMS ozone forecasts during LVOS (Pierce)


120 hours out
Fires, Asian, and Stratospheric Transport
Las Vegas Ozone Study (FAST-LVOS)

(May 20-June 30, 2017)

• Deploy improved TOPAZ lidar to NLVA
  ✓ Co-locate with radar wind profiler

• Deploy micro-Doppler lidar to NLVA
  ✓ Mixed layer depth and entrainment

• Base mobile sampling lab at Angel Peak
  ✓ CO, N₂O, H₂O, NO, NO₂, NOy, O₃

• Base Scientific Aviation aircraft at NLVA
  ✓ Horizontal and vertical variability of O₃

• Launch GMD ozonesondes from Joe Neal
  ✓ Vertical profiles into the stratosphere
1. TOPAZ lidar with extended vertical range at NLVA

TOPAZ can now track high ozone layers from the free troposphere into the LVV

Stratospheric intrusion during CABOTS (California Baseline Ozone Transport Study)

Typical TOPAZ performance during LVOS
1. TOPAZ lidar with extended vertical range at NLVA

TOPAZ can now track high ozone layers from the free troposphere into the LVV

Stratospheric intrusion during CABOTS (California Baseline Ozone Transport Study)
North Las Vegas Airport (NLVA)

Vaisala radar wind profiler, ASC sodar, and Radiometrics profiling radiometer provide effective rawinsonde soundings every hour with wind profiles from the surface to 3 kilometers AGL and temperature and humidity profiles to 10 kilometers AGL.
1. TOPAZ lidar with extended vertical range at NLVA

Better understanding of transport through collocation with radar wind profiler

Example: Advection of ozone during CABOTS (California Baseline Ozone Transport Study)

TOPAZ co-located with wind profiler at Visalia, CA Airport
Fires, Asian, and Stratospheric Transport
Las Vegas Ozone Study (FAST-LVOS)

(May 20-June 30, 2017)

- **Deploy improved TOPAZ lidar to NLVA**
  - Co-locate with radar wind profiler

- **Deploy micro-Doppler lidar to NLVA**
  - Mixed layer depth and entrainment

- **Base mobile sampling lab at Angel Peak**
  - CO, N$_2$O, H$_2$O, NO, NO$_2$, NOy, O$_3$

- **Base Scientific Aviation aircraft at NLVA**
  - Horizontal and vertical variability of O$_3$

- **Launch GMD ozonesondes from Joe Neal**
  - Vertical profiles into the stratosphere
NOAA micro-pulse Doppler Lidar: microDop

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse Length</td>
<td>30, 60, 90 m</td>
</tr>
<tr>
<td>Pulse Rep Freq</td>
<td>20,000 Hz</td>
</tr>
<tr>
<td>Beam Rate</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Pulse Energy</td>
<td>50 µJ</td>
</tr>
<tr>
<td>Wavelength</td>
<td>1.553 µm</td>
</tr>
<tr>
<td>Beam Diameter</td>
<td>7.62 cm</td>
</tr>
<tr>
<td>Orientation</td>
<td>Vertical</td>
</tr>
<tr>
<td>Max Range</td>
<td>7 km</td>
</tr>
<tr>
<td>Electrical Power</td>
<td>120V 30A</td>
</tr>
</tbody>
</table>
2. Vertically-staring Micro Doppler lidar at NLVA to characterize mixed layer

Better understanding of vertical entrainment

- microDop range corrected intensity
- microDop w variance, m² s⁻²
- TOPAZ aerosol
- TOPAZ ozone

Visalia, CA Airport
Fires, Asian, and Stratospheric Transport
Las Vegas Ozone Study (FAST-LVOS)

(May 20-June 30, 2017)

- Deploy improved TOPAZ lidar to NLVA
  - Co-locate with radar wind profiler

- Deploy micro-Doppler lidar to NLVA
  - Mixed layer depth and entrainment

- Base mobile sampling lab at Angel Peak
  - \(CO, N_2O, H_2O, NO, NO_2, NOy, O_3\)

- Base Scientific Aviation aircraft at NLVA
  - Horizontal and vertical variability of \(O_3\)

- Launch GMD ozonesondes from Joe Neal
  - Vertical profiles into the stratosphere
LVOS in situ measurements at Angel Peak

$O_3$-CO-$H_2O$ relationships help identify airmass origin
3. Mobile lab for rapid *in situ* measurements

### NOAA CSD mobile lab Instrumentation

<table>
<thead>
<tr>
<th>Gas</th>
<th>Primary Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O_3$</td>
<td>Photochemistry, stratosphere</td>
</tr>
<tr>
<td>$N_2O$</td>
<td>Soils</td>
</tr>
<tr>
<td>NO, NO$_2$, NO$_y$</td>
<td>Combustion, lightning, soils</td>
</tr>
<tr>
<td>CO, CO$_2$</td>
<td>Combustion, vegetation</td>
</tr>
<tr>
<td>CH$_4$</td>
<td>Agriculture, oil and gas, landfills</td>
</tr>
</tbody>
</table>

Mobile lab to be based at Angel Peak
3. Mobile lab for rapid *in situ* measurements

Can measure while in motion at 1 s resolution

**Permanent infrastructure:**
- up to 5 shock-mounted electronics racks
- configurable roof-top inlet plates
- dedicated data system and real-time display
- 2 kW AC or 12 V power from dedicated alternator
- 2 hr battery backup, and plug-in capability
- meteorology sensors

Mobile lab will be based at Angel Peak. Requires two 20 A circuits and internet while parked.
### 3. Mobile lab for rapid *in situ* measurements

#### NOAA CSD mobile lab Instrumentation

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Gases</th>
<th>Time</th>
<th>Detection Limit</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRDS</td>
<td>NO, NO$_2$, NO$_x$, O$_3$</td>
<td>1s</td>
<td>0.1 - 0.001 ppbv</td>
<td><em>Dubé/Brown</em></td>
</tr>
<tr>
<td>WS-CRDS</td>
<td>CO$_2$ and CH$_4$</td>
<td>1s</td>
<td>0.2 ppmv for CO$_2$</td>
<td><em>Peischl/Ryerson</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.2 ppmv for CH$_4$</td>
<td></td>
</tr>
<tr>
<td>ICOS</td>
<td>CO, N$_2$O, and H$_2$O</td>
<td>1s</td>
<td>0.2 ppbv for N$_2$O</td>
<td><em>Peischl/Ryerson</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.2 ppbv for CO</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100 ppmv for H$_2$O</td>
<td></td>
</tr>
</tbody>
</table>
Station CSD Mobile Lab on Angel Peak

TOPAZ truck during LVOS
Drive from AP to LVV profile trace gas distribution during intensives

860 to 2700 m ASL

S. Brown
Fires, Asian, and Stratospheric Transport
Las Vegas Ozone Study (FAST-LVOS)

(May 20-June 30, 2017)

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  ✓ Mixed layer depth and entrainment

• Base mobile sampling lab at Angel Peak
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• Base Scientific Aviation aircraft at NLVA
  ✓ Horizontal and vertical variability of O₃

• Launch GMD ozonesondes from Joe Neal
  ✓ Vertical profiles into the stratosphere
4. Scientific Aviation research aircraft

**Single-engine fixed-wing Mooney**

Measurements of CO$_2$, CH$_4$, O$_3$, and NOx, in addition to horizontal wind, temperature and humidity.
4. Scientific Aviation research aircraft

3 intensives of 4 days each with 6 hours flight time per day

**Potential Flight Plan (6 h flight)**

1. Spiral to 6 km over NLVA
2. Fly to AP at 6km
3. Spiral to 3 km over AP
4. Fly to Jean at 3 km
5. Fly to Barstow at 3 km
6. Descend to 1 km
7. Fly to Jean at 1 km
8. Spiral to 6 km at Jean
9. Fly to NLVA at 6 km
10. Repeat Jean-NLVA legs at 1 km intervals to end

Aircraft will transit from Boulder or Davis for intensives
Fires, Asian, and Stratospheric Transport
Las Vegas Ozone Study
(FAST-LVOS)

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- Launch GMD ozonesondes from Joe Neal
  ✓ Vertical profiles into the stratosphere
5. **GMD ozonesondes at Joe Neal**

Launch ozonesondes at 0900 and 1300 MST during IOPS

GMD ozonesonde crew will transit from Boulder for intensives

*launches are tentatively planned for the Joe Neal monitoring site*
# FAST-LVOS Work Plan (routine)

<table>
<thead>
<tr>
<th>Component</th>
<th>(POC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NLVA lidars</strong></td>
<td>(Alvarez/Senff)</td>
</tr>
<tr>
<td>✓ TOPAZ (&gt;8 h of daily operation)</td>
<td></td>
</tr>
<tr>
<td>✓ micro-Doppler lidar (continuous)</td>
<td></td>
</tr>
<tr>
<td><strong>Mobile van</strong></td>
<td>(Brown/Peischl)</td>
</tr>
<tr>
<td>✓ Continuous sampling at AP</td>
<td></td>
</tr>
<tr>
<td><strong>Mooney Aircraft</strong></td>
<td>(Conley/Pifer)</td>
</tr>
<tr>
<td>✓ Standby mode in Boulder or Davis</td>
<td></td>
</tr>
<tr>
<td><strong>Ozonesondes</strong></td>
<td>(Johnson/Cullis)</td>
</tr>
<tr>
<td>✓ Standby mode in Boulder</td>
<td></td>
</tr>
<tr>
<td><strong>Event forecasting</strong></td>
<td>(Langford/Lin)</td>
</tr>
<tr>
<td>✓ NASA AIRS</td>
<td></td>
</tr>
<tr>
<td>✓ NOAA/NESDIS/NASA RAQMS model</td>
<td></td>
</tr>
<tr>
<td>✓ NOAA Rapid-Refresh model</td>
<td></td>
</tr>
</tbody>
</table>
FAST-LVOS Work Plan (event)

**Forecasted STT, Fire, or Transport Event**

- Activate 2nd TOPAZ team for continuous measurements
- Activate GMD ozonesonde team for intensives
- Transit Scientific Aviation aircraft to NLVA for intensives
- Begin mobile van profiling if ozone reaches Angel Peak
FAST-LVOS
Fires, Asian, and Stratospheric Transport
Las Vegas Ozone Study