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

A study sponsored by the Clark County Department of Air Quality

Co-PIs: Andrew O. Langford and Christoph J. Senff

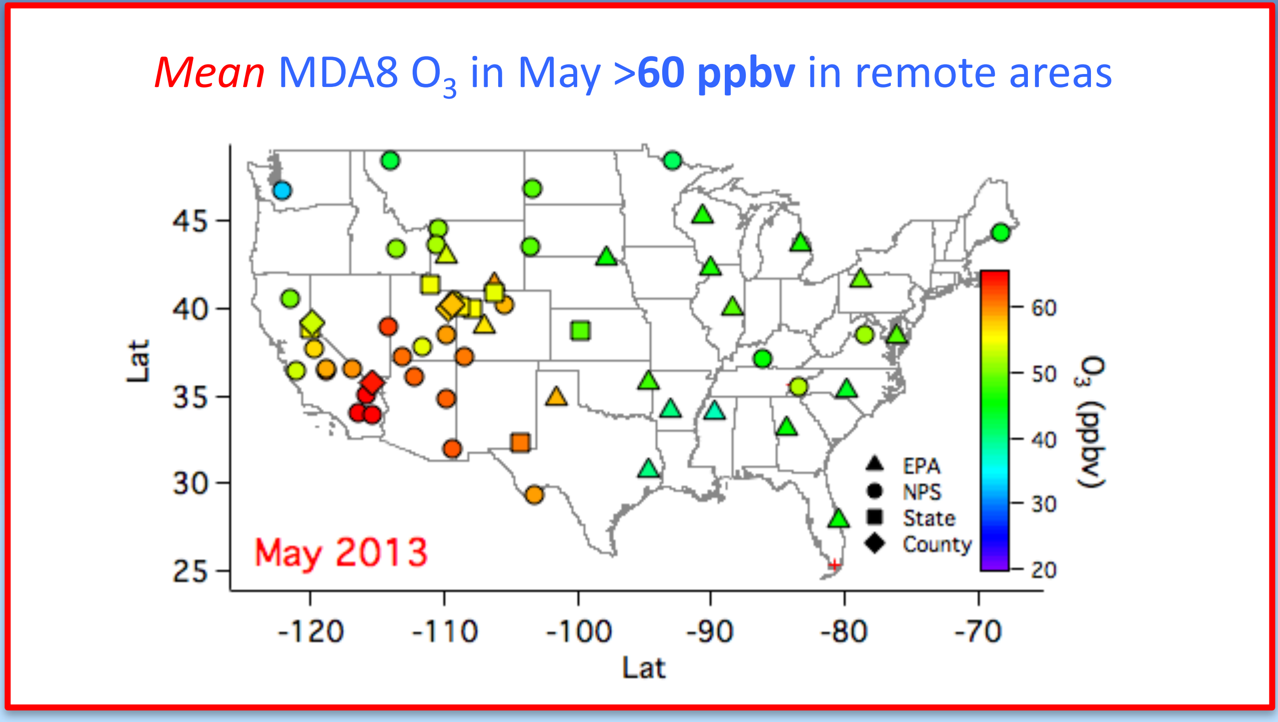
NOAA Earth System Research Laboratory
Chemical Sciences Division

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

Updated January 10, 2017

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE

Ozone concentrations in Desert SW approach 2015 NAAQS in late spring

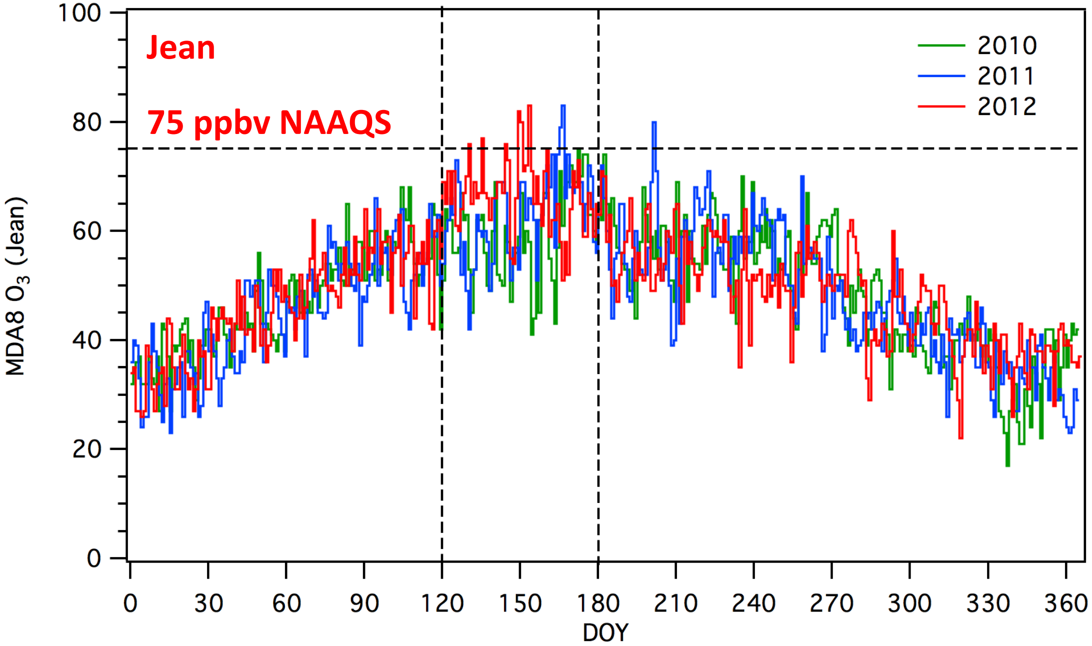


Where does this O_3 come from?

Los Angeles? Asia? Wildfires? Stratosphere?

Motivation

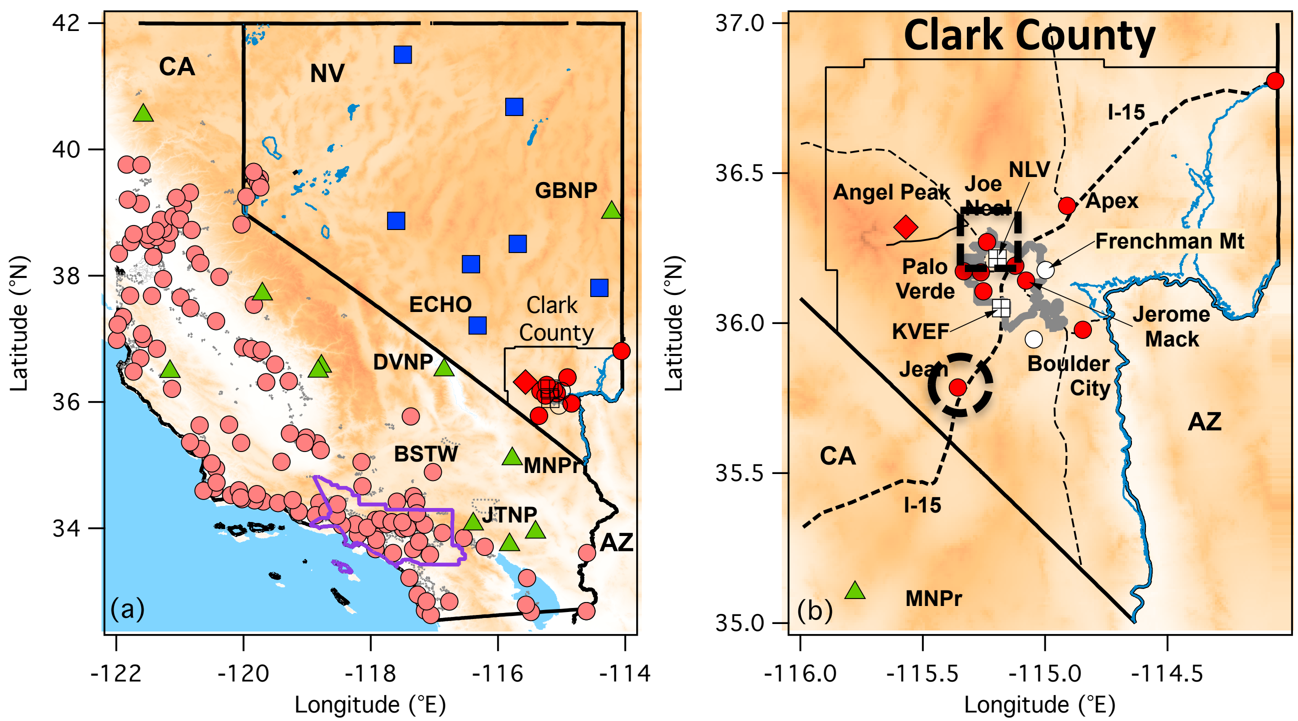
Mean surface ozone in Clark County approaches the NAAQS in late spring and early summer



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)

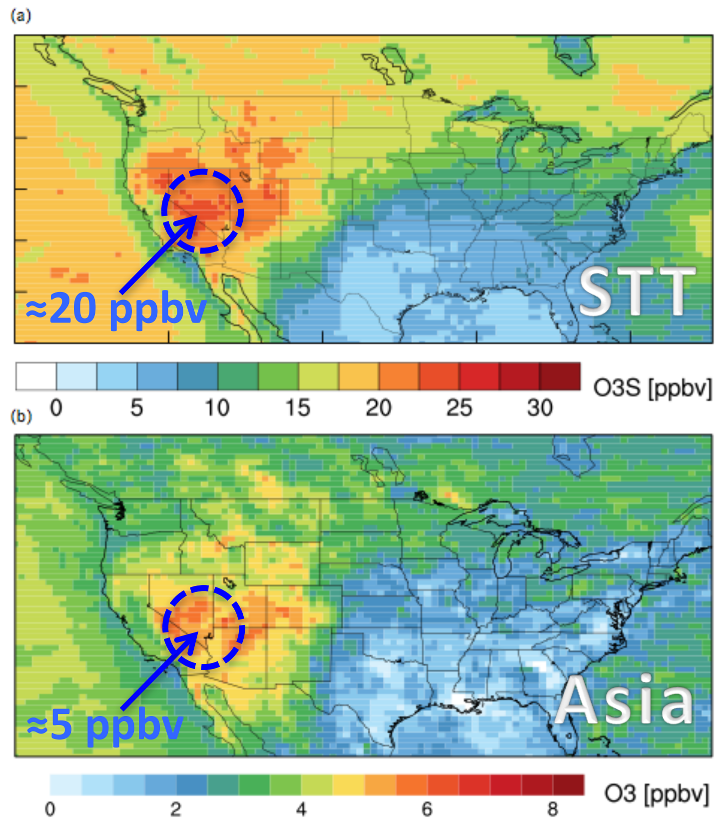


Ozone monitors: (pink=state, green=NPS, red=Clark County, blue=NVROI)

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

Las Vegas Ozone Study (LVOS)

May 19- June 29, 2013

This question motivated the first LVOS campaign in May-June 2013

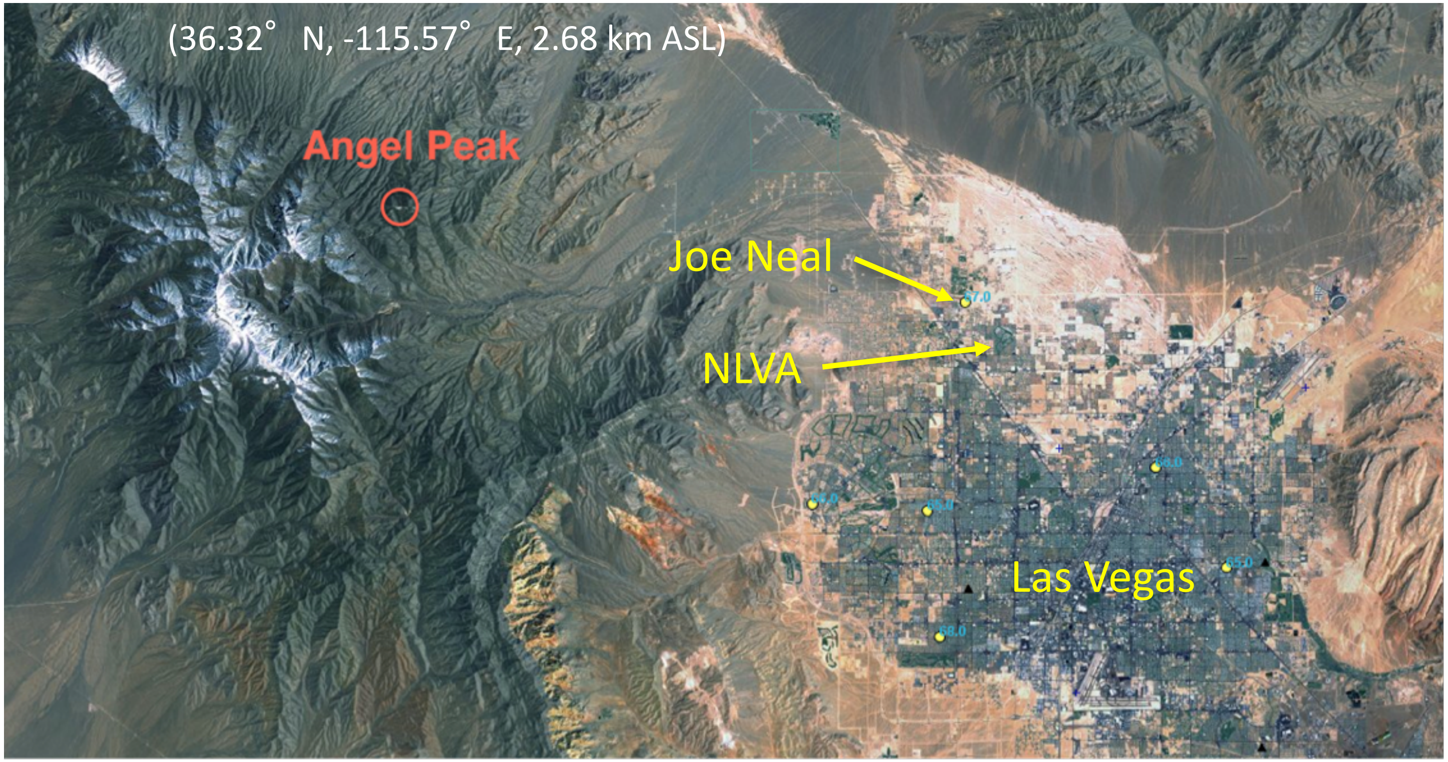
LVOS Primary Objectives

- Determine if stratosphere-to-troposphere (STT) and long-range transport from Asia contribute to the springtime O_3 maximum in Clark County.
- Estimate the importance of these processes relative to local O_3 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

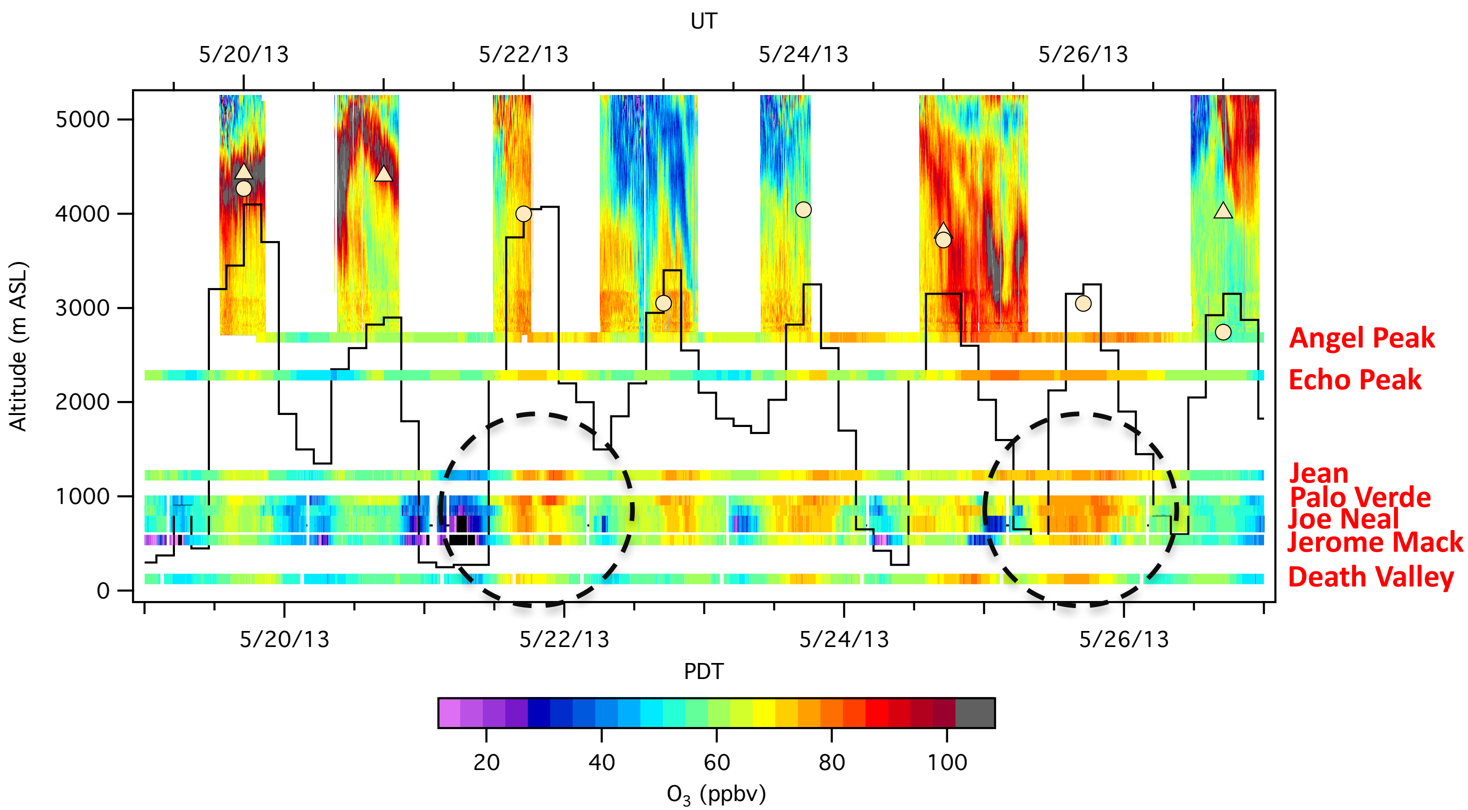


Las Vegas Ozone Study (LVOS)

Las Vegas Ozone Study (LVOS)

May 19- June 29, 2013

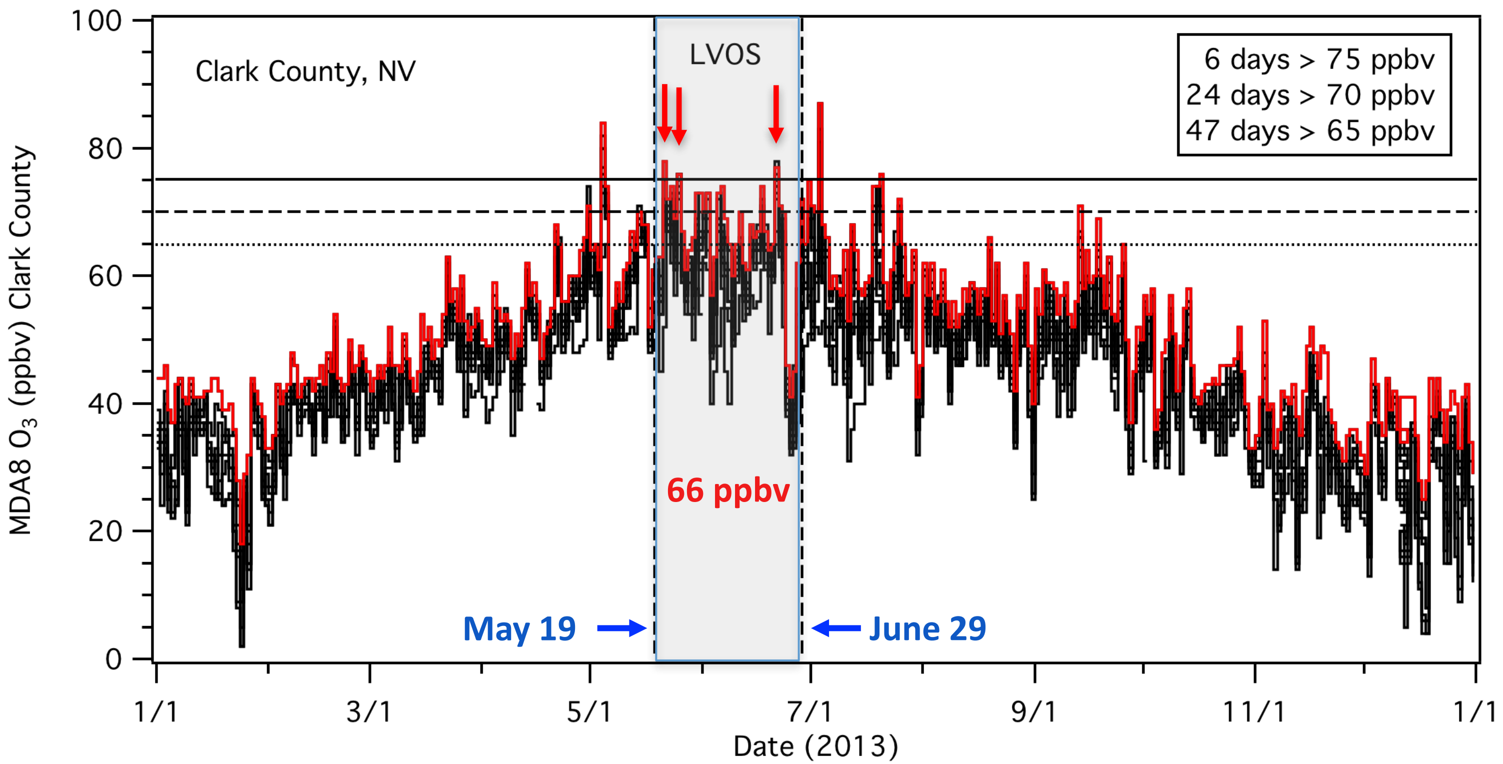
High ozone days in the Las Vegas Valley coincided with STT events and high ozone at and above Angel Peak



2008 ozone NAAQS (75 ppbv) exceeded on May 21 and 25

Las Vegas Ozone Study (LVOS)

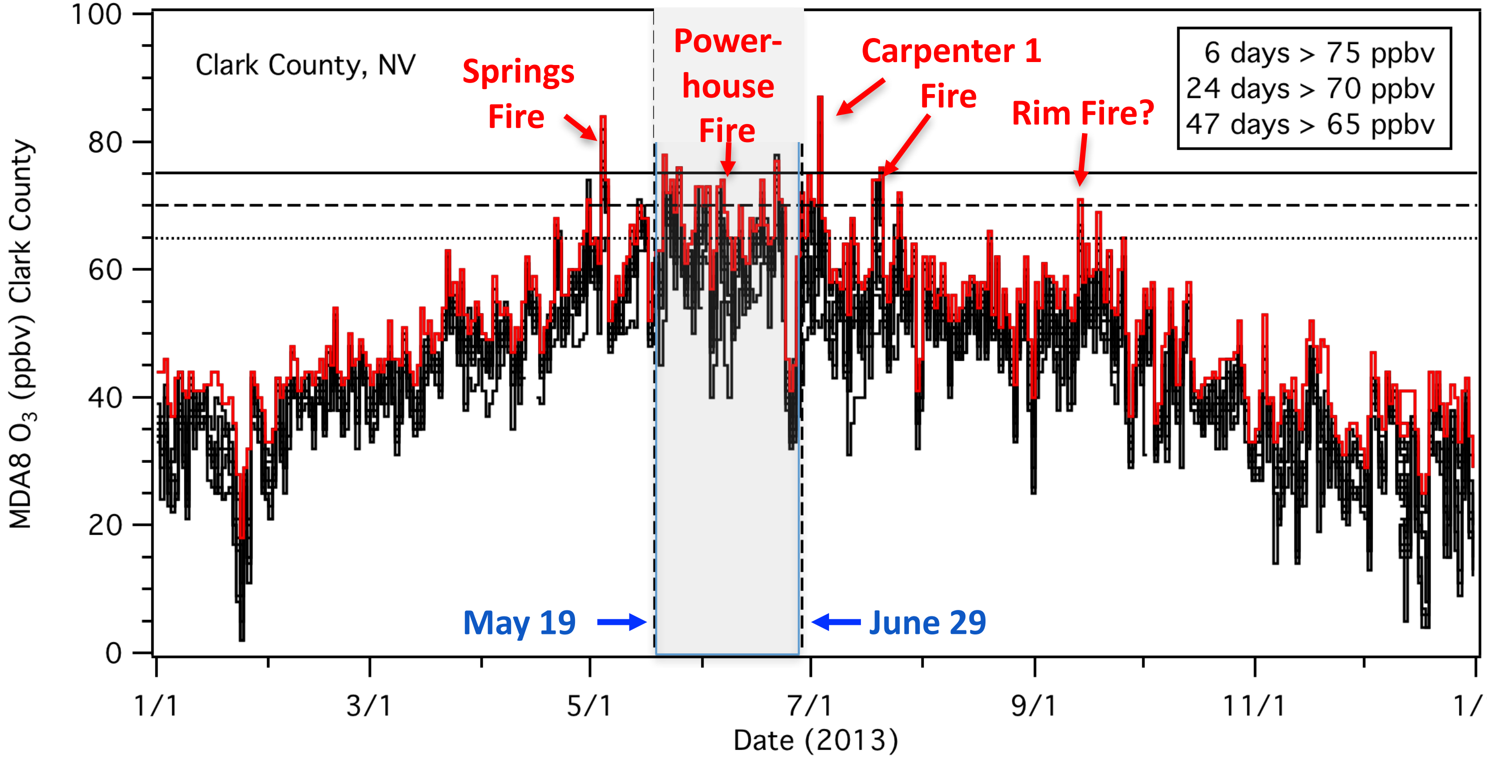
2013: black = CC mean MDA8, red=CC highest MDA8



3 of 6 NAAQS exceedance days in 2013 occurred during LVOS and coincided with STT/transport events

Las Vegas Ozone Study (LVOS)

Clark County was also affected by fires in Arizona, California, and Nevada



Remaining 3 exceedance days coincided with wildland fires in CA or NV

Las Vegas Ozone Study (LVOS)

LVOS
Las Vegas Ozone Study

May 19- June 29, 2013

Atmospheric Environment 109 (2015) 305–322

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

ELSEVIER

ATMOSPHERIC ENVIRONMENT

An overview of the 2013 Las Vegas Ozone Study (LVOS): Impact of stratospheric intrusions and long-range transport on surface air quality

CrossMark

A.O. Langford [a, *], C.J. Senff [a, b], R.J. Alvarez II [a], J. Brioude [a, b, c], O.R. Cooper [a, b], J.S. Holloway [a, b], M.Y. Lin [d, e], R.D. Marchbanks [a, b], R.B. Pierce [f], S.P. Sandberg [a], A.M. Weickmann [a, b], E.J. Williams [a]

[a] *NOAA Earth System Research Laboratory, Chemical Sciences Division, Boulder, CO 80305, USA*
[b] *Cooperative Institute for Research in the Environmental Sciences, University of Colorado, Boulder, CO 80309, USA*
[c] *Laboratoire de l'Atmosphere et des Cyclones (LACy), UMR 8105, Saint-Denis, La Reunion, France*
[d] *Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ, USA*
[e] *NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA*
[f] *NOAA/NESDIS Center for Satellite Applications and Research, Cooperative Institute for Meteorological Satellite Studies, Madison, WI 53706, USA*

H I G H L I G H T S

- Stratosphere-to-troposphere transport (STT) significantly impacts surface O_3 in the intermountain west.
- STT can directly lead to exceedances of the 2008 ozone NAAQS during springtime.
- STT influences background surface O_3 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.

Las Vegas Ozone Study (LVOS)

May 19- June 29, 2013

JOURNAL OF GEOPHYSICAL RESEARCH
Atmospheres
AN AGU JOURNAL

JGR

Explore this journal >

Research Article

Entrainment of stratospheric air and Asian pollution by the convective boundary layer in the Southwestern U.S.

A. O. Langford, R. J. Alvarez II, J. Brioude, R. Fine, M. Gustin, M. Y. Lin, R. D. Marchbanks, R. B. Pierce, S. P. Sandberg, C. J. Senff, A. M. Weickmann, E. J. Williams

Accepted manuscript online: 30 December 2016 Full publication history

DOI: 10.1002/2016JD025987 View/save citation

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/2016JD025987

Accepted Articles

Browse Accepted Articles
Accepted, unedited articles published online and citable. The final edited and typeset version of record will appear in future.

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)
- **Ozonesondes*** **(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

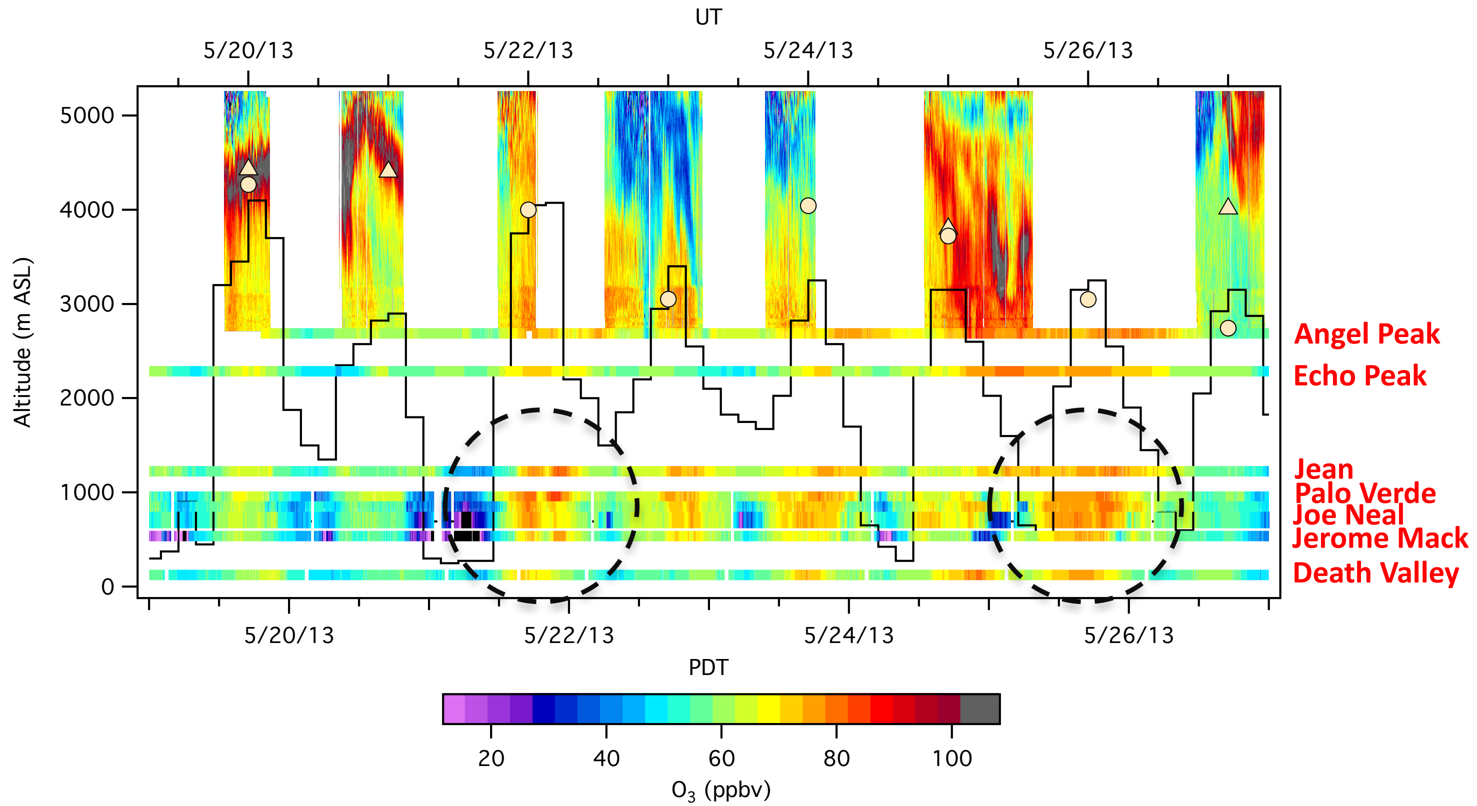
- Reinforce TOPAZ crews for 24 h runs (2 additional people)
- Ozonesonde crew arrives (2 launches/day, 30 total)
- SA Mooney transits to NLVA for daily flights (6h/day, 90 h total)
- CSD mobile lab on standby for mobile operations

(≈15 out of 42 days)

Las Vegas Ozone Study (LVOS)

May 19- 26, 2013

STT events most likely near the beginning of the campaign

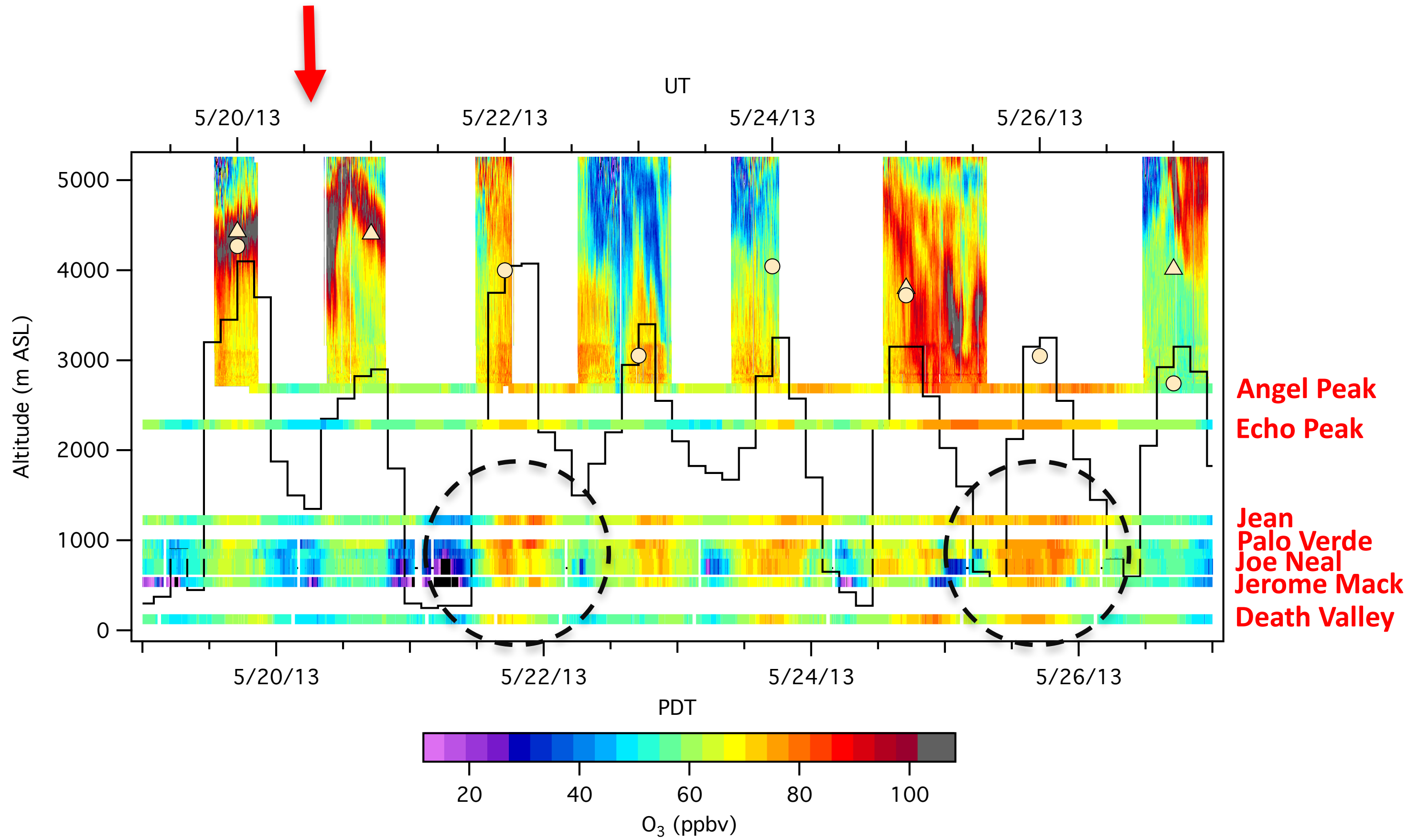


7 straight days with STT influence!

Las Vegas Ozone Study (LVOS)

May 19- 26, 2013

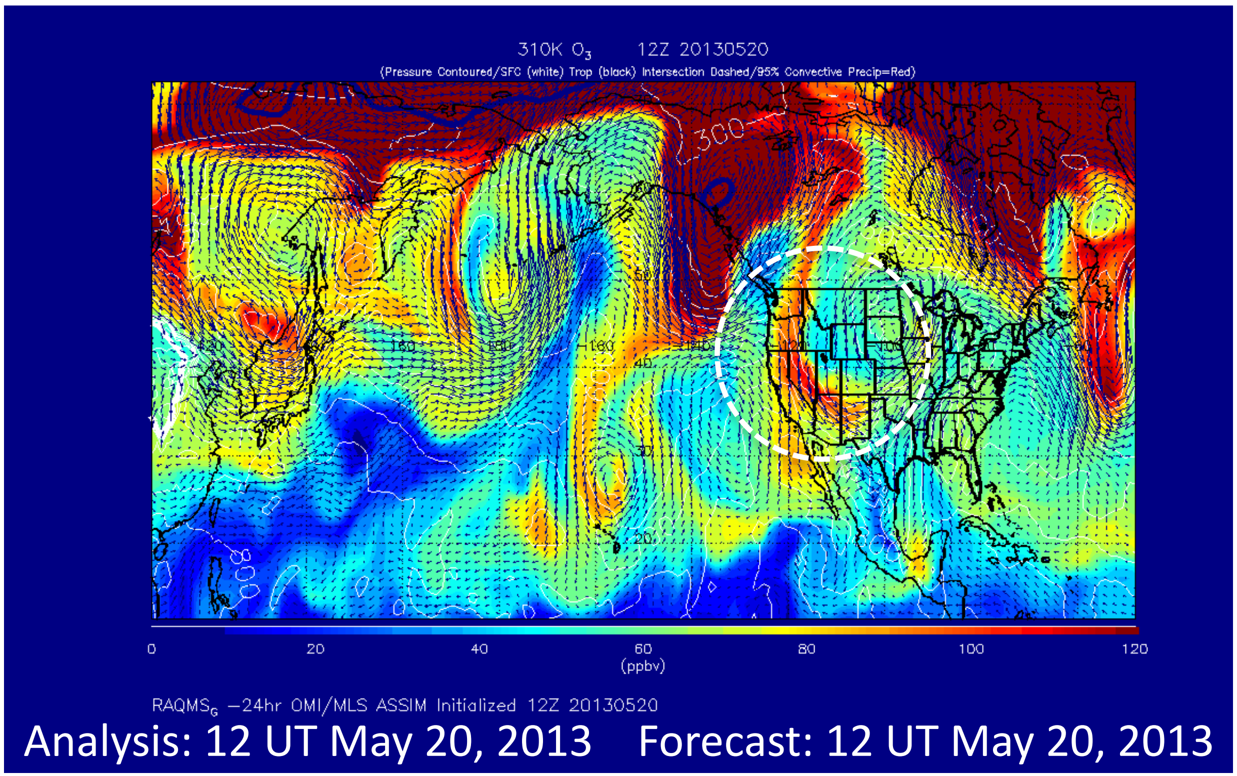
STT events most likely near the beginning of the campaign



First major event on May 20-22, 2013

Las Vegas Ozone Study (LVOS)

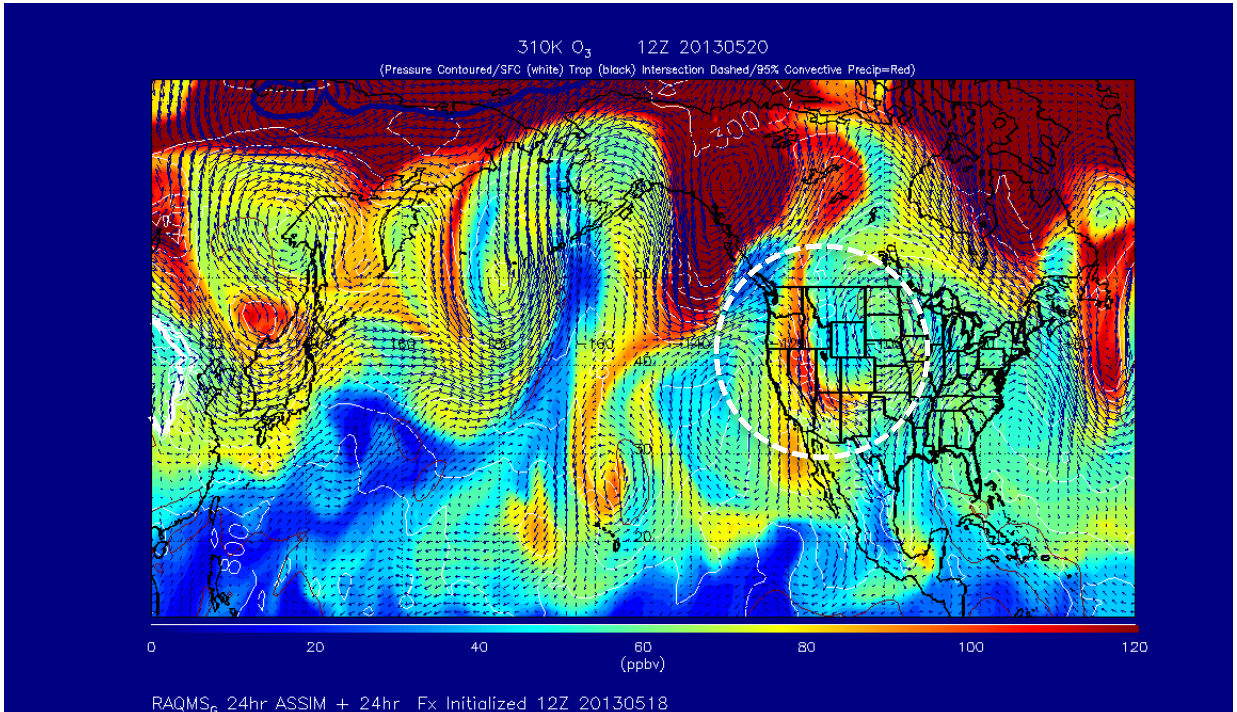
RAQMS ozone forecasts during LVOS (Pierce)



00 hours out

Las Vegas Ozone Study (LVOS)

RAQMS ozone forecasts during LVOS (Pierce)



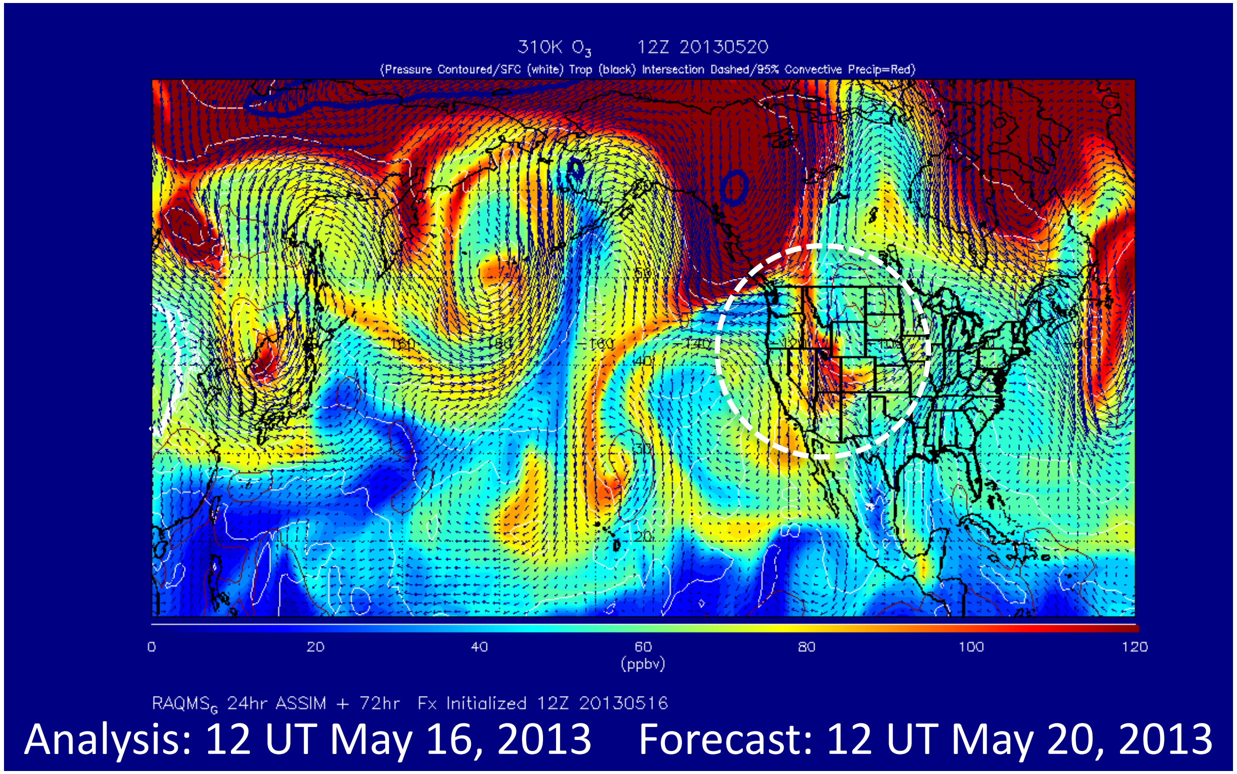
Analysis: 12 UT May 18, 2013 Forecast: 12 UT May 20, 2013

48 hours out

Las Vegas Ozone Study (LVOS)

LVOS Las Vegas Ozone Study

RAQMS ozone forecasts during LVOS (Pierce)

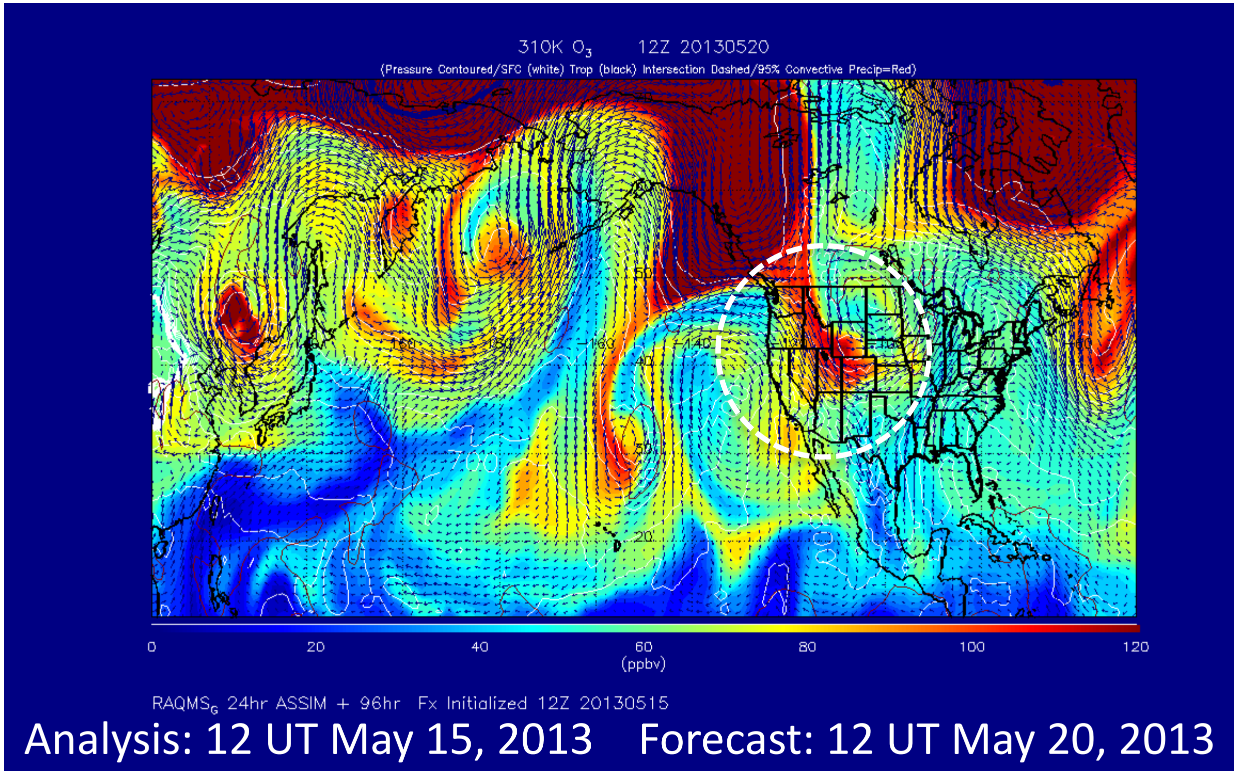


96 hours out

Las Vegas Ozone Study (LVOS)

LVOS
Las Vegas Ozone Study

RAQMS ozone forecasts during LVOS (Pierce)



120 hours out

***F**ires, **A**sian, and **S**tratospheric **T**ransport*
Las **V**egas **O**zone **S**tudy
(***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*

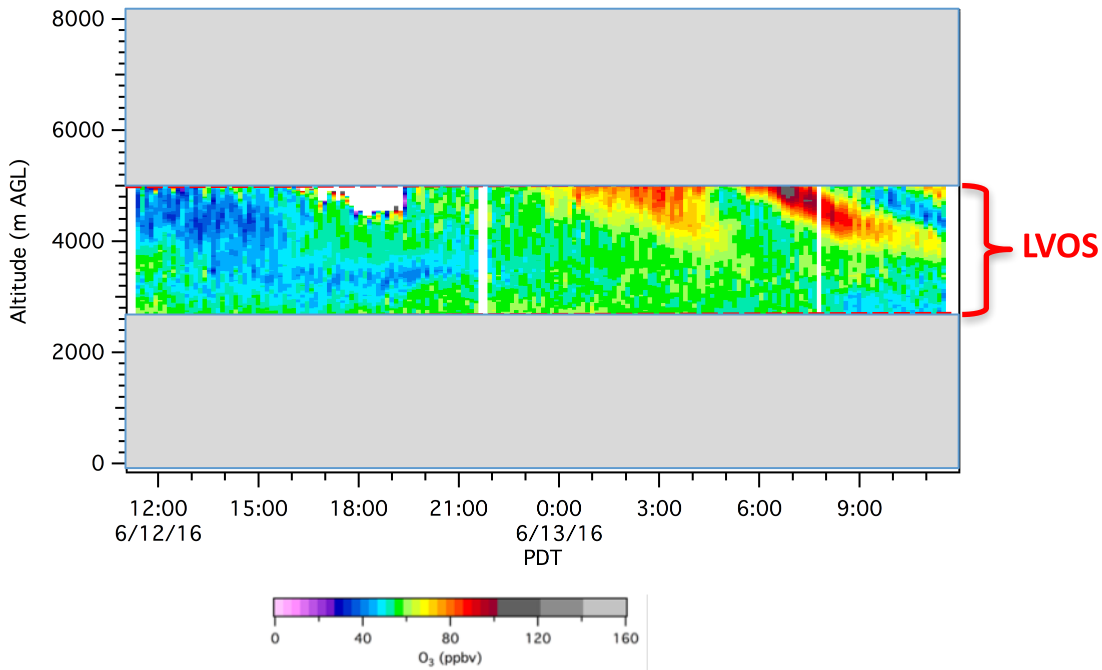
- **Launch GMD ozonesondes from Joe Neal**
  - ✓ *Vertical profiles into the stratosphere*

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)

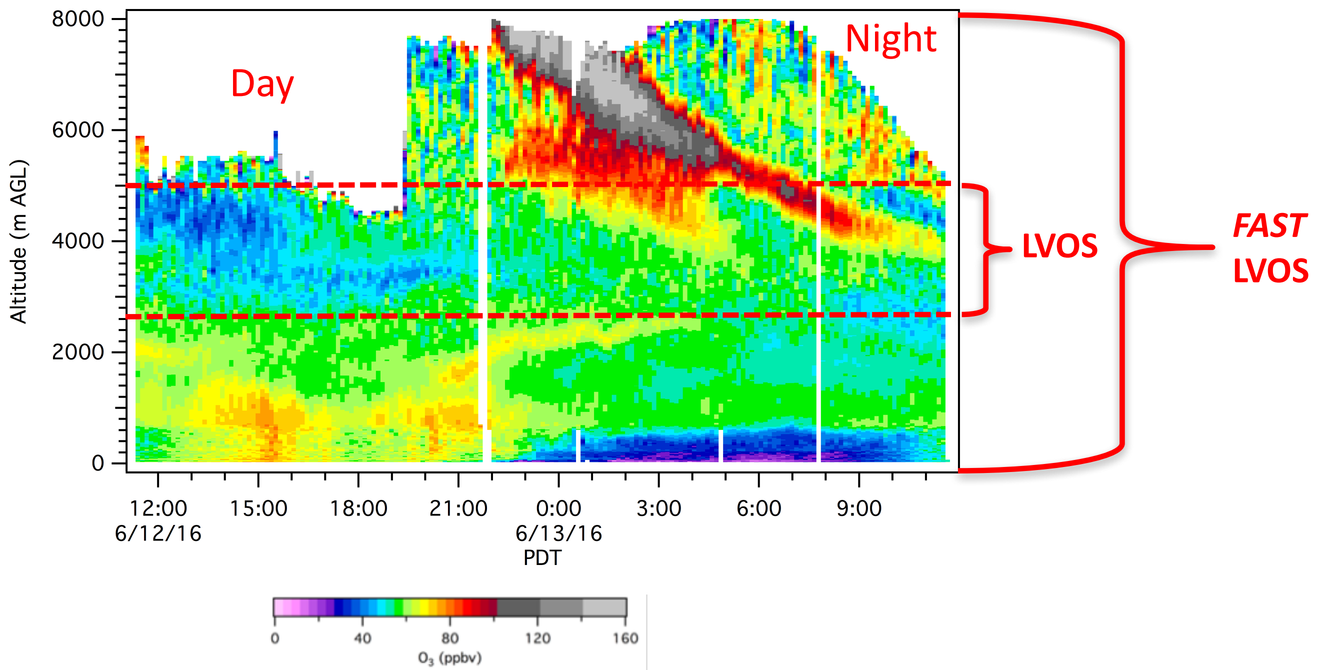
Typical TOPAZ performance during LVOS



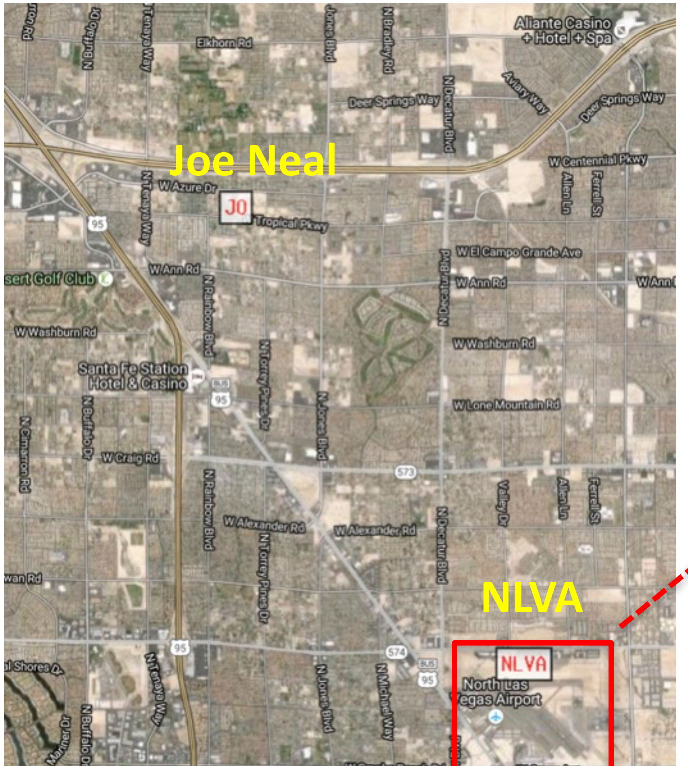
1. TOPAZ lidar with extended vertical range at NLVA

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)

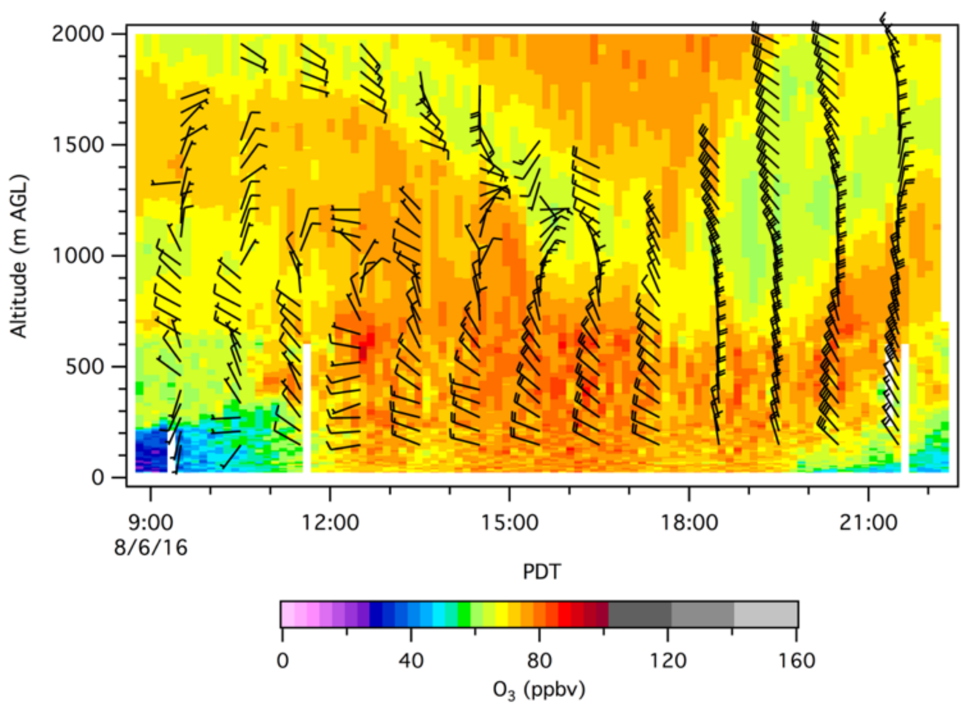


Vaisala radar wind profiler, ASC sodar, and Radiometrics profiling radiometer provide effective rawinsonde soundings every hour with wind profiles from the surface to 3 kilometers AGL and temperature and humidity profiles to 10 kilometers AGL.

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

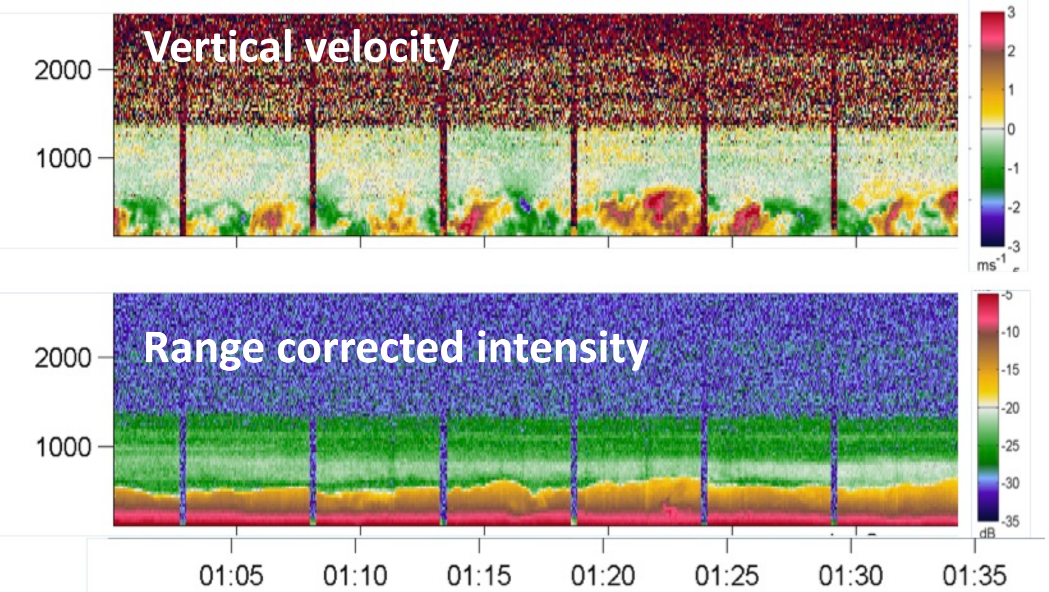
Fires, Asian, and Stratospheric Transport Las Vegas Ozone Study (*FAST-LVOS*)

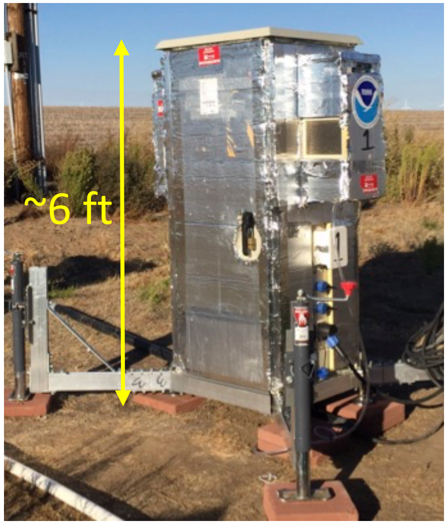
(May 20-June 30, 2017)

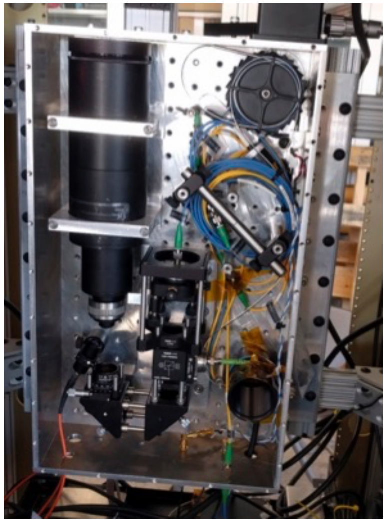
- **Deploy improved TOPAZ lidar to NLVA**
  - ✓ *Co-locate with radar wind profiler*
- **Deploy micro-Doppler lidar to NLVA**
  - ✓ *Mixed layer depth and entrainment*
- **Base mobile sampling lab at Angel Peak**
  - ✓ *CO, N_2O, H_2O, NO, NO_2, NOy, O_3*
- **Base Scientific Aviation aircraft at NLVA**
  - ✓ *Horizontal and vertical variability of O_3*
- **Launch GMD ozonesondes from Joe Neal**
  - ✓ *Vertical profiles into the stratosphere*

NOAA micro-pulse Doppler Lidar : **microDop**

Pulse Length	30,60,90 m
Pulse Rep Freq	20,000 Hz
Beam Rate	2 Hz
Pulse Energy	50 µJ
Wavelength	1.553 µm
Beam Diameter	7.62cm
Orientation	Vertical
Max Range	7km
Electrical Power	120V 30A

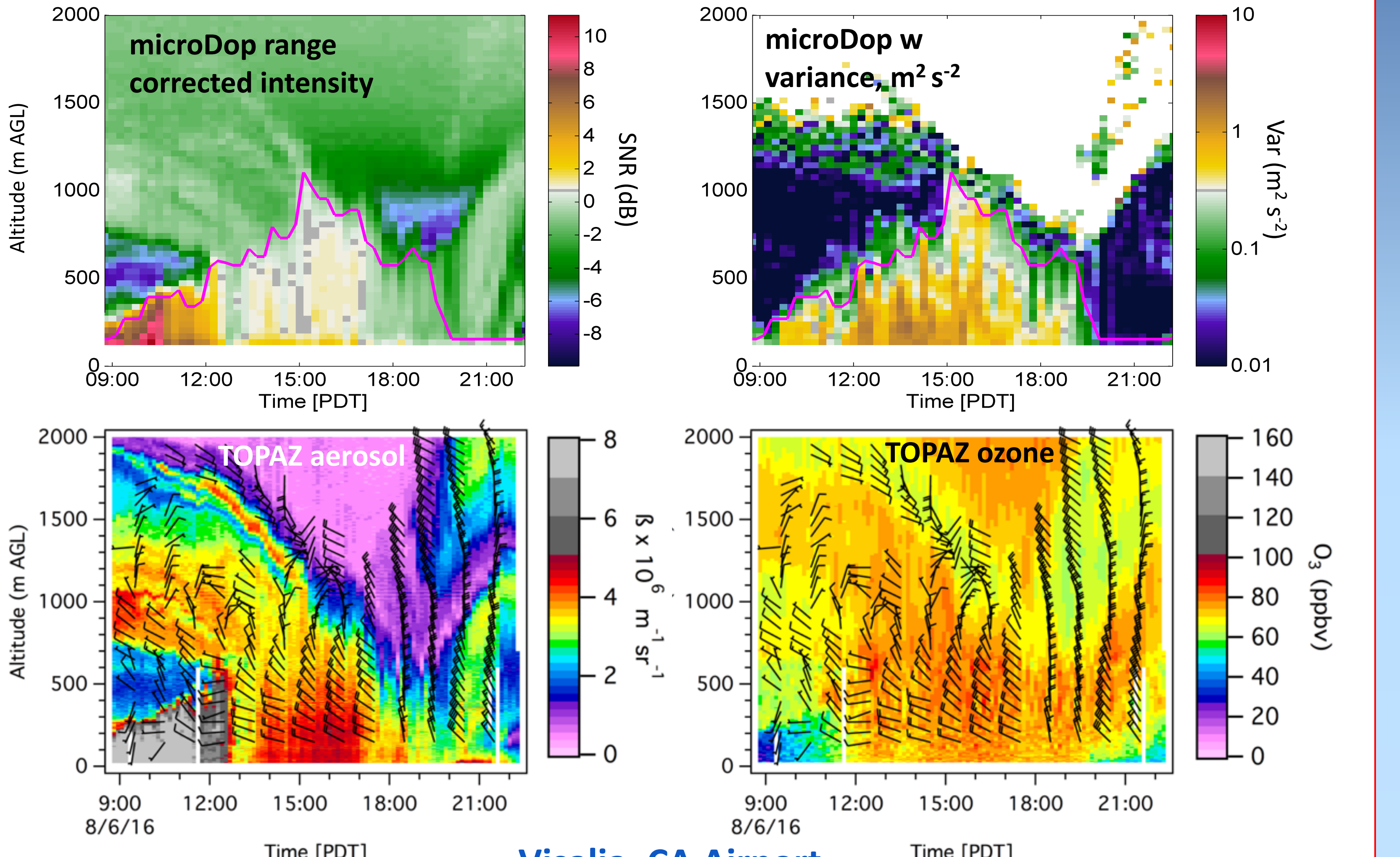






2. Vertically-staring Micro Doppler lidar at NLVA to characterize mixed layer

Better understanding of vertical entrainment



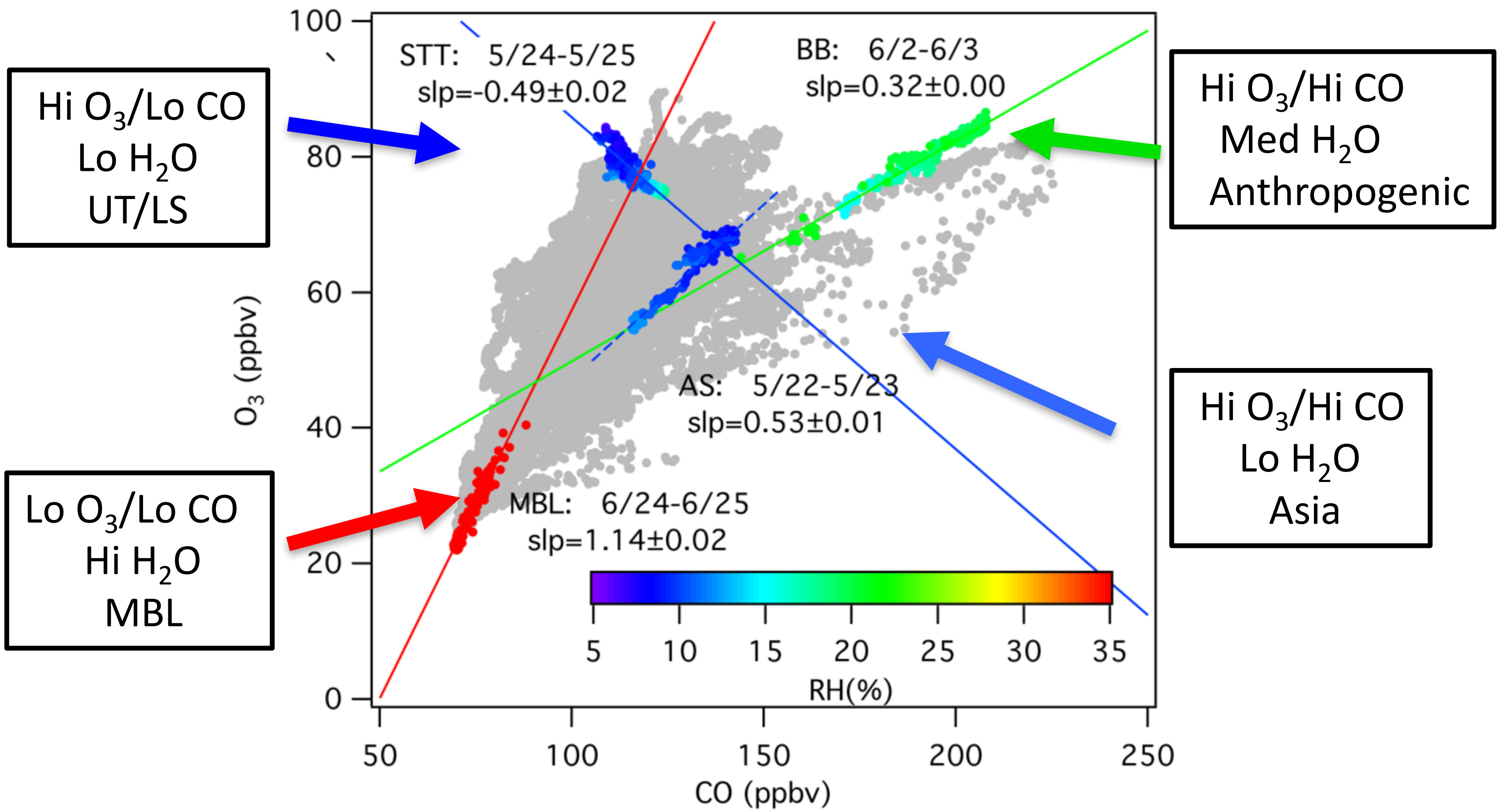
Visalia, CA Airport

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

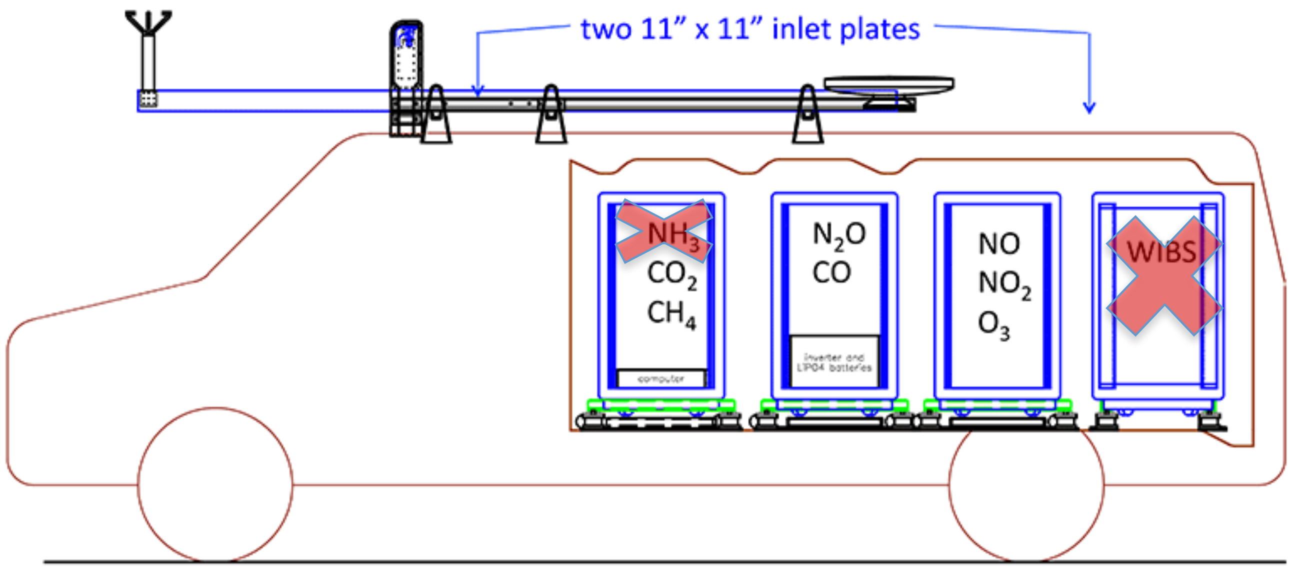
NOAA CSD mobile lab Instrumentation

Gas	Primary Sources
O_3	Photochemistry, stratosphere
N_2O	Soils
NO, NO_2, NOy	Combustion, lightning, soils
CO, CO_2	Combustion, vegetation
CH_4	Agriculture, oil and gas, landfills

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.

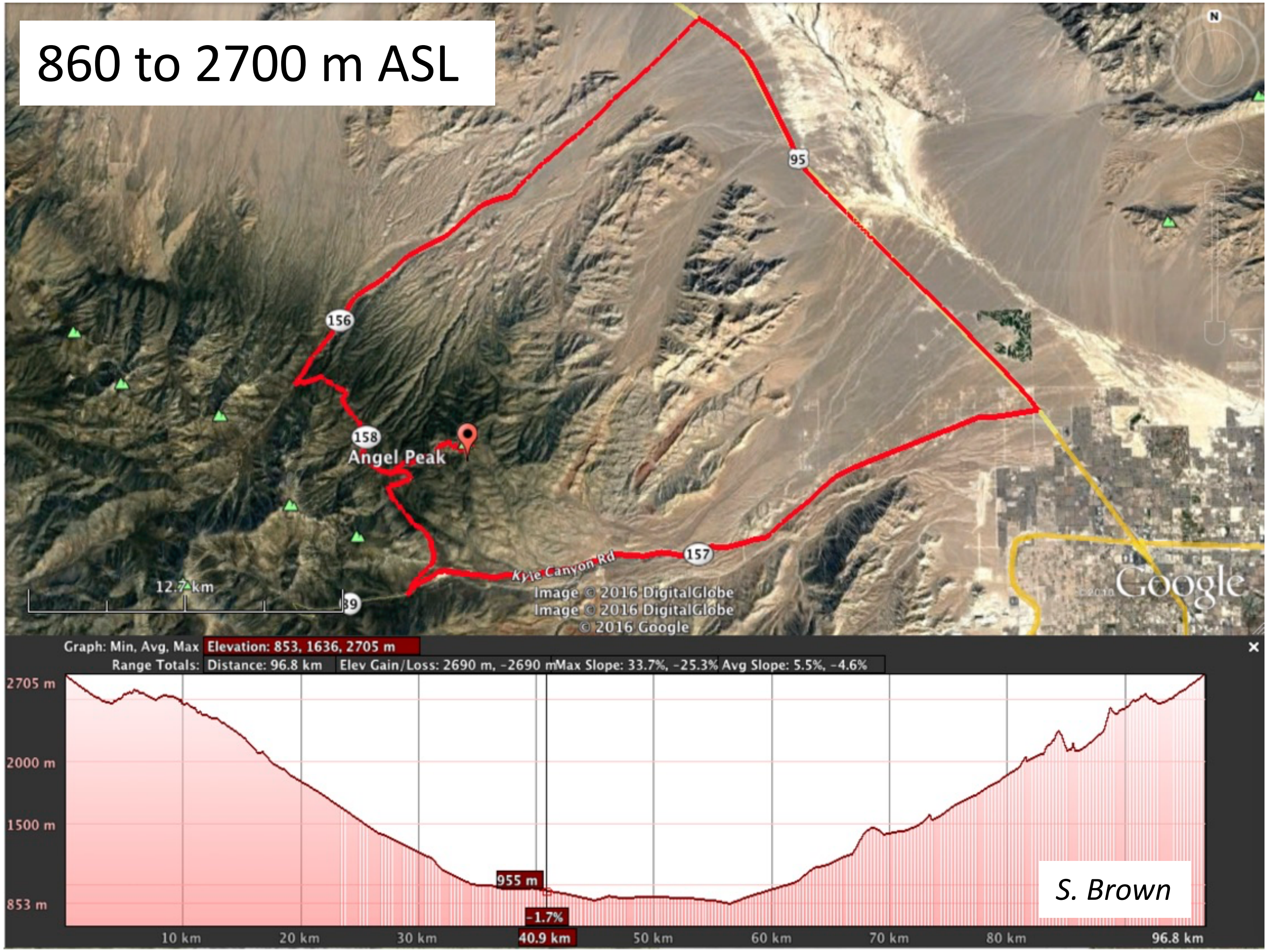
3. Mobile lab for rapid *in situ* measurements

NOAA CSD mobile lab Instrumentation

Instrument	Gases	Time	Detection Limit	PI
CRDS	NO, NO_2, NOy, O_3	1s	0.1 - 0.001 ppbv	*Dubé/Brown*
WS-CRDS	CO_2 and CH_4	1s	0.2 ppmv for CO_2 0.2 ppmv for CH_4	*Peischl/Ryerson*
ICOS	CO, N_2O, and H_2O	1s	0.2 ppbv for N_2O 0.2 ppbv for CO 100 ppmv for H_2O	*Peischl/Ryerson*

Station CSD Mobile Lab on Angel Peak

Drive from AP to LVV profile trace gas distribution during intensives



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*

4. Scientific Aviation research aircraft

SCIENTIFIC AVIATION

Stephen Conley

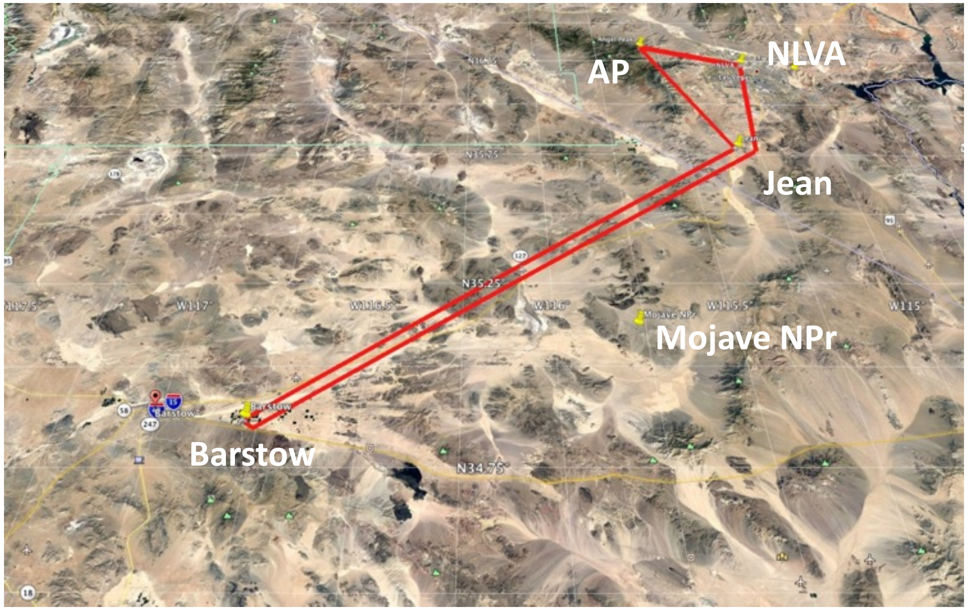
Single-engine fixed-wing Mooney

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

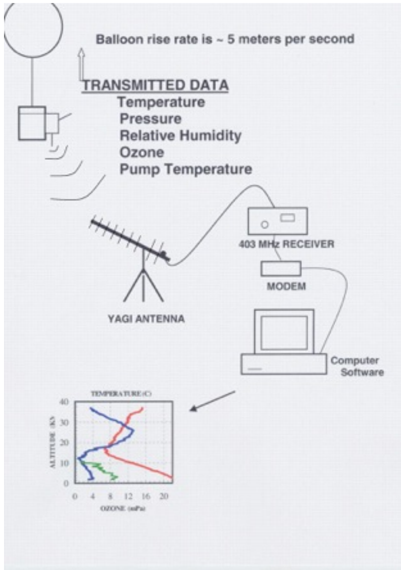
Fires, Asian, and Stratospheric Transport Las Vegas Ozone Study (*FAST-LVOS*)

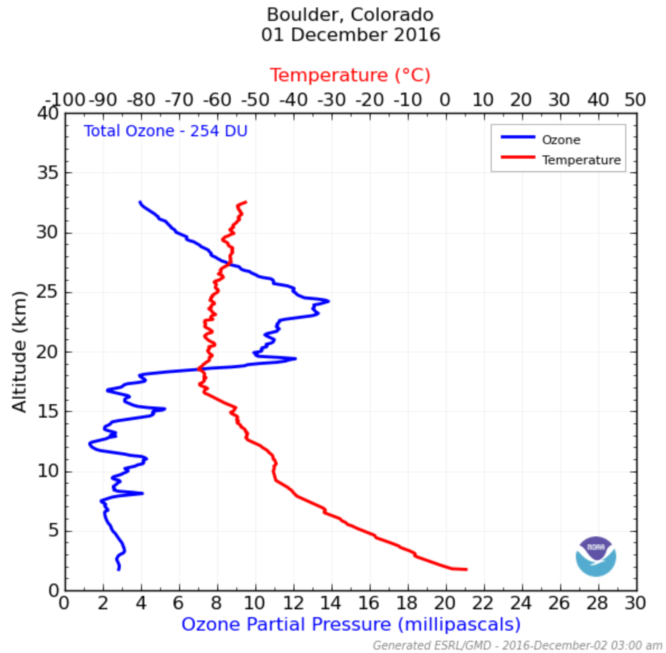
(May 20-June 30, 2017)

- **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*

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)

Component	***(POC)***
• **NLVA lidars**	(Alvarez/Senff)
✓ *TOPAZ (>8 h of daily operation)*	
✓ *micro-Doppler lidar (continuous)*	
• **Mobile van**	(Brown/Peischl)
✓ *Continuous sampling at AP*	
• **Mooney Aircraft**	(Conley/Pifer)
✓ *Standby mode in Boulder or Davis*	
• **Ozonesondes**	*(Johnson/Cullis)*
✓ *Standby mode in Boulder*	
• **Event forecasting**	(*Langford/Lin*)
✓ *NASA AIRS*	
✓ *NOAA/NESDIS/NASA RAQMS model*	
✓ *NOAA Rapid-Refresh model*	

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