# Investigation of the Sources of High Ozone in California's San Joaquin Valley Using Lidar, Aircraft, and Balloon-borne Observations from the 2016 California Baseline Ozone Transport Study (CABOTS)

C. J. Senff, A. O. Langford, R. J. Alvarez II, G. Kirgis, A. M. Weickmann, Wm. A. Brewer, T. Bonin, R. D. Marchbanks, S. P. Sandberg, M. Holloway, S. Chiao, I. C. Faloona, L. T. Iraci

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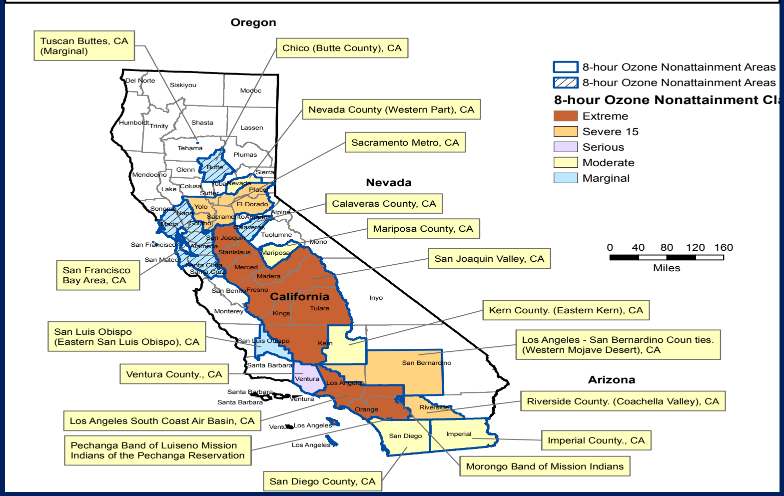
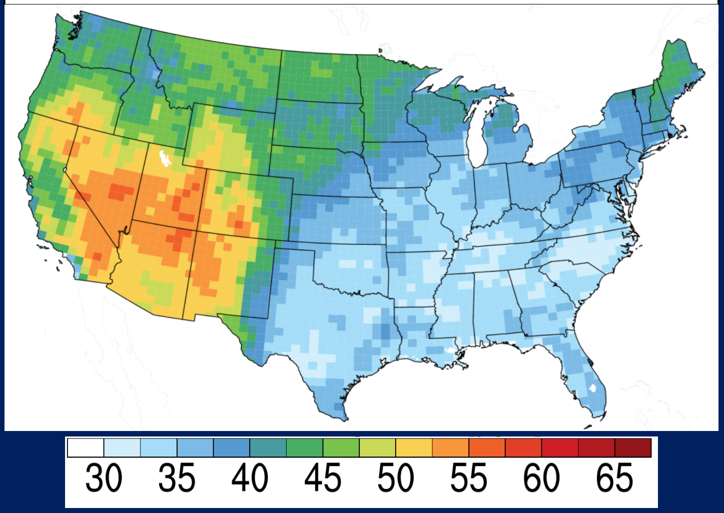
# Challenges for Western US air quality management

- Many areas in California do not meet the $O_3$ NAAQS.
- Springtime background $O_3$ is high in western US and is increasing.
- $O_3$ NAAQS has been lowered to 70 ppbv: slimmer margin to add locally produced $O_3$.

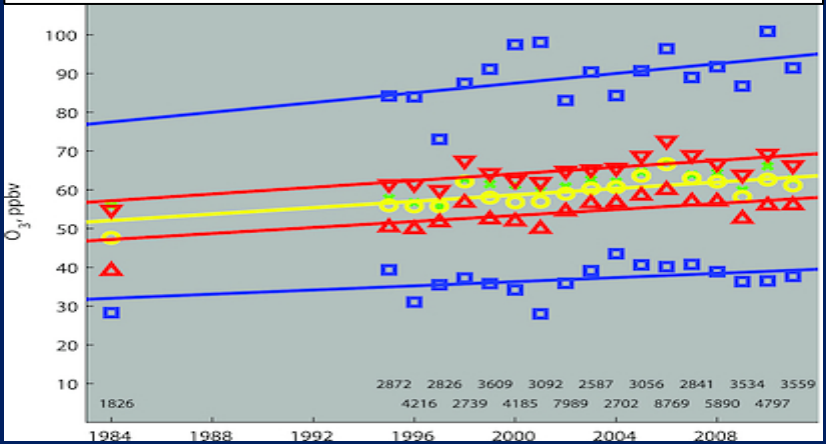
Ozone non-attainment areas in California




Mean background $O_3$ (ppbv), Apr-Jun
(AM3 model, M. Lin)




Apr - May $O_3$ trends, western N. America, 3-8 km MSL
(O. Cooper et al., 2012)



# CABOTS = CAlifornia Baseline Ozone Transport Study

## Objectives

1. Improve knowledge of vertical structure and daily variability of ozone entering California from the Pacific.
2. Understand to what extent trans-Pacific long-range transported ozone mixes down to the surface and affects air quality in the San Joaquin Valley.

## Timeline

- May – August 2016
- 2 IOPs: 29 May – 18 Jun<br>18 Jul – 7 Aug

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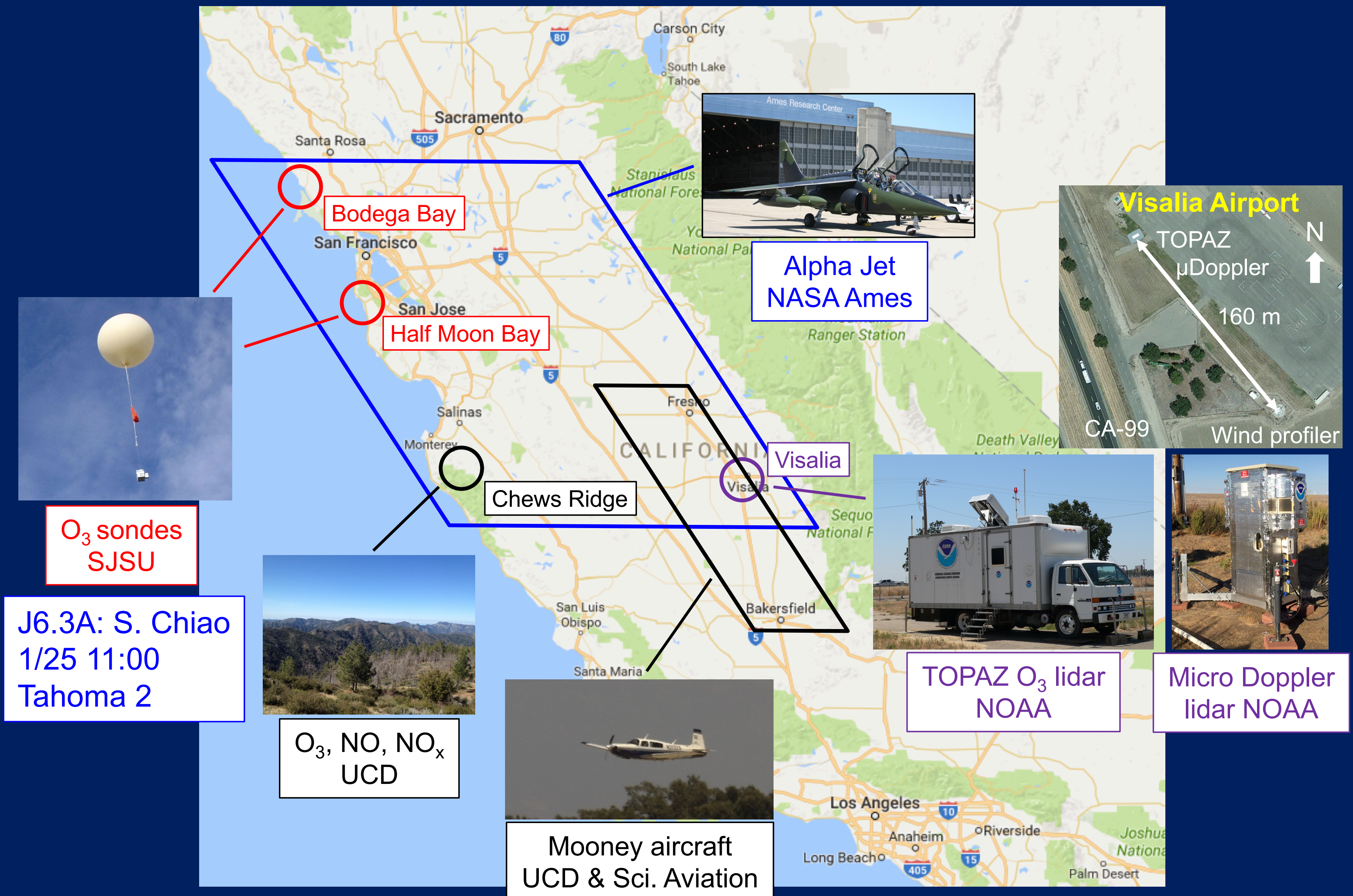
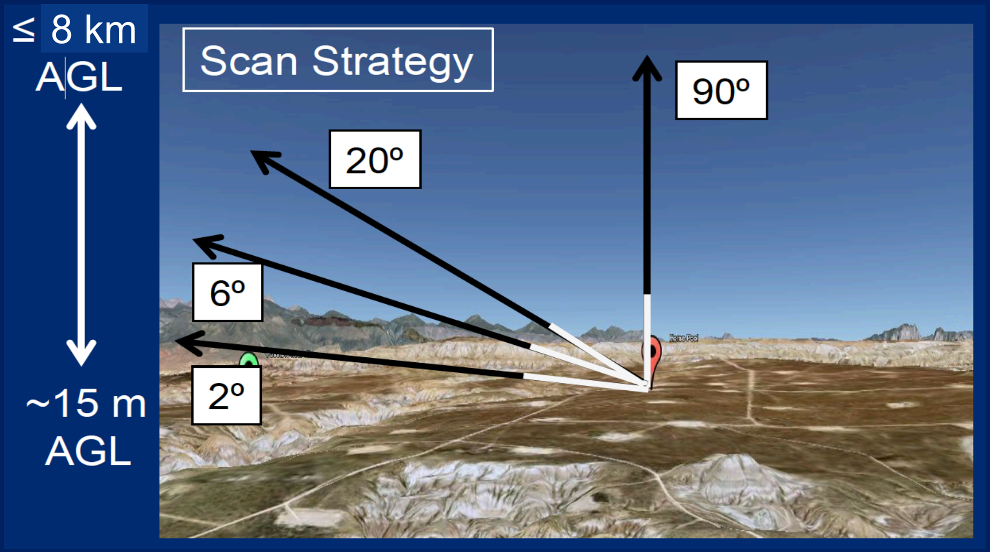
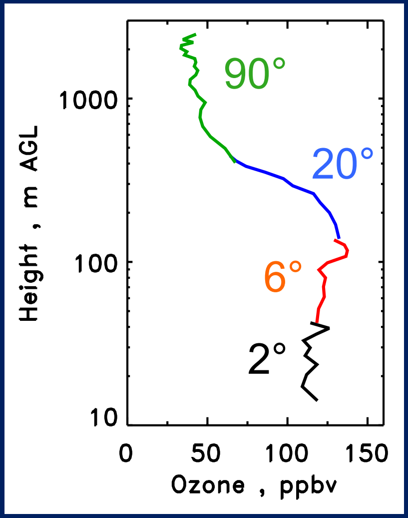


# NOAA TOPAZ Ozone Lidar

(TOPAZ = Tunable Optical Profiler for Aerosol and oZone)

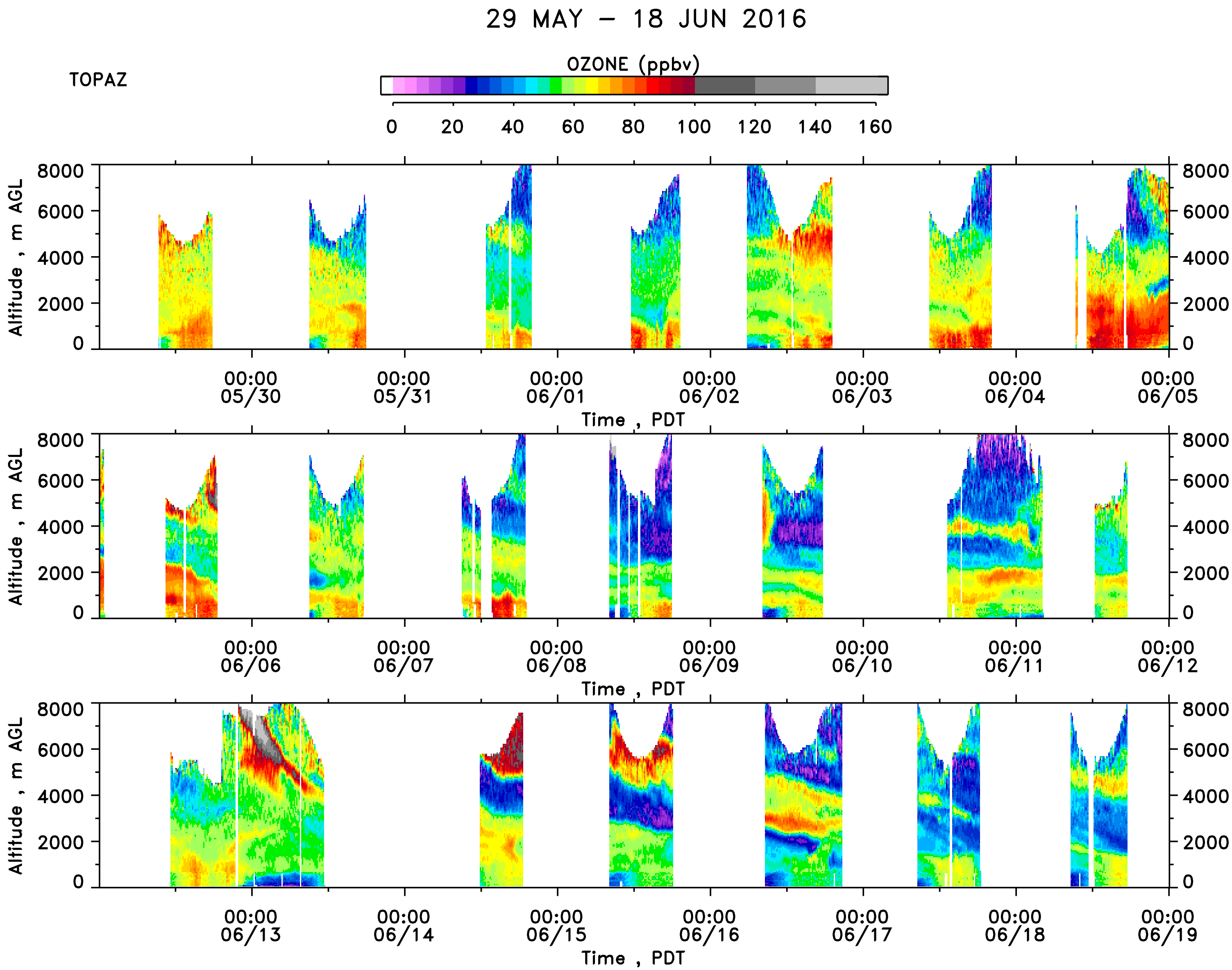
- Tunable UV ozone DIAL
- Based on solid-state Ce:LiCAF laser
- Measures ozone and aerosol backscatter profiles



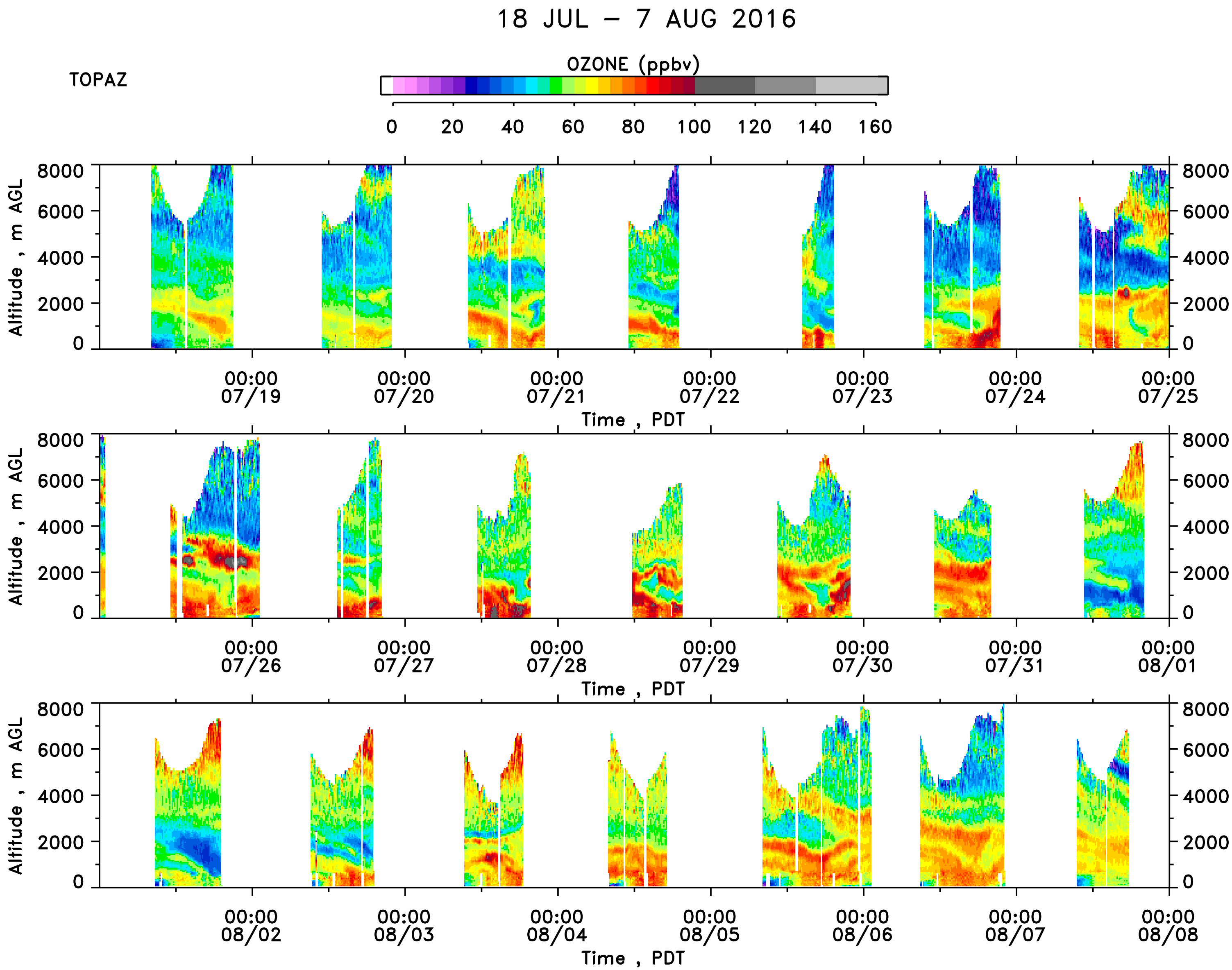




Composite vertical $O_3$ and aerosol profiles every 8 min

# CABOTS: TOPAZ ozone data for IOP1 (212 hours)



# CABOTS: TOPAZ ozone data for IOP2 (223 hours)

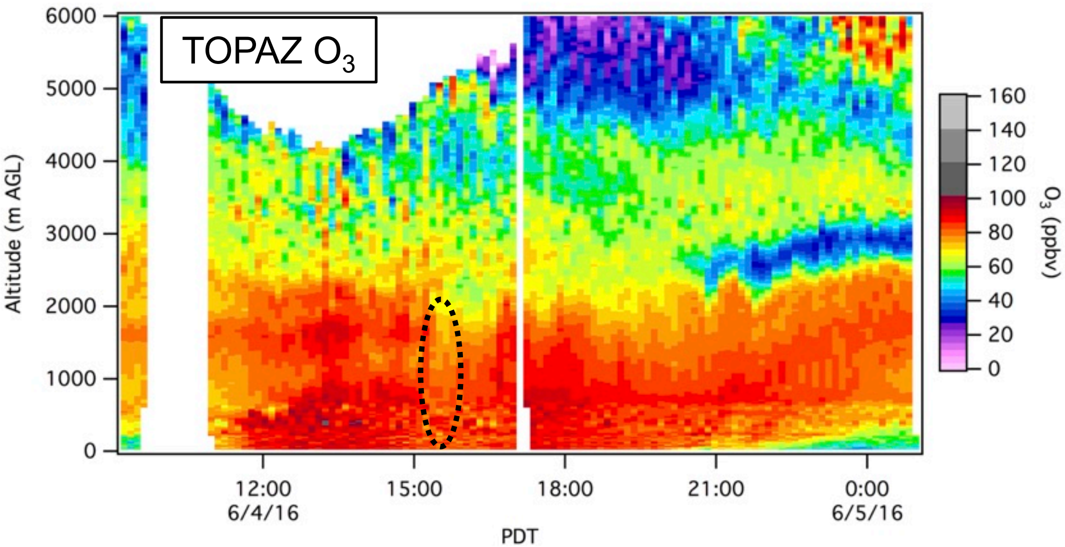


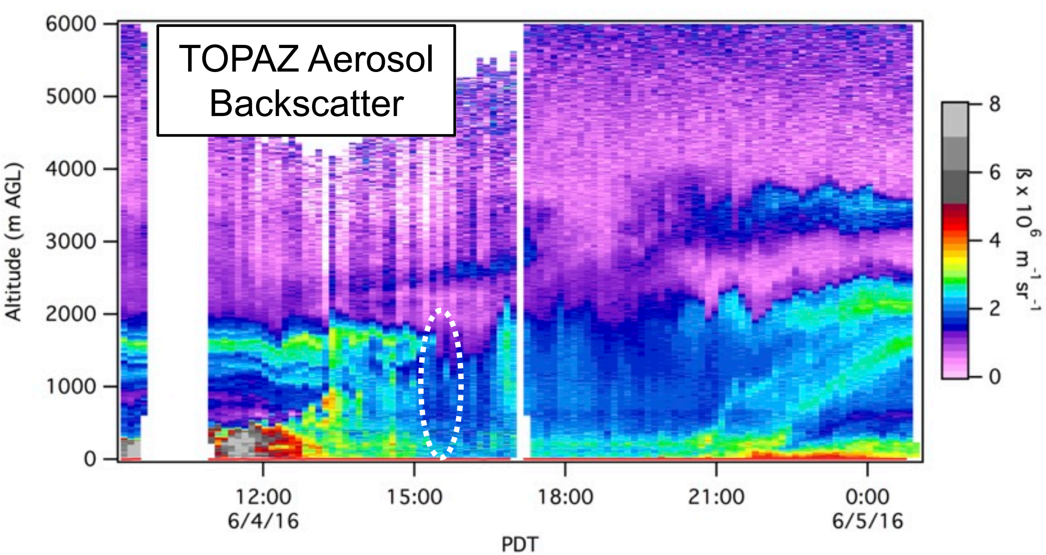
## CABOTS Objective 2:

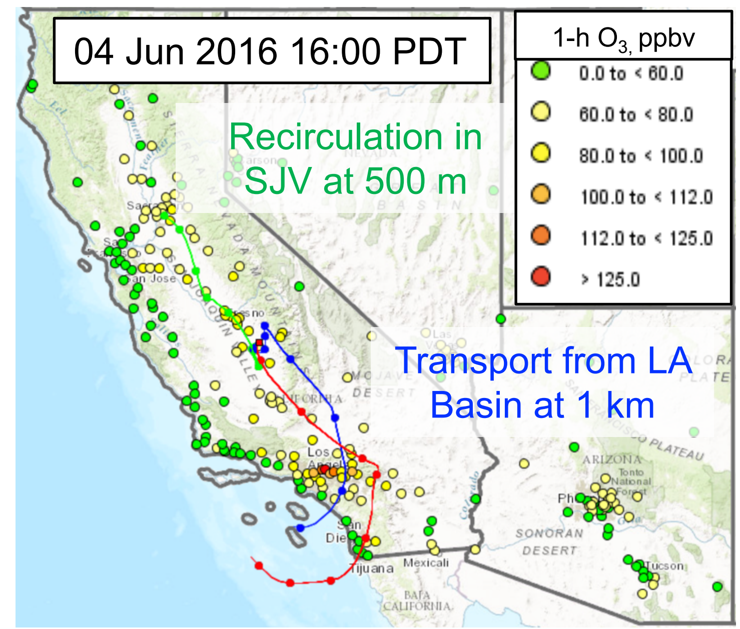
How much does transport contribute to surface ozone in the San Joaquin Valley?

1. **Intrastate transport (e.g. from LA Basin)**
2. Trans-boundary transport (e.g. from Asia)
3. Stratospheric intrusions

# June 4, 2016: High ozone and aerosol above Visalia




48-hour HYSPLIT back trajectories at 500, 1000, and 1500 m AGL

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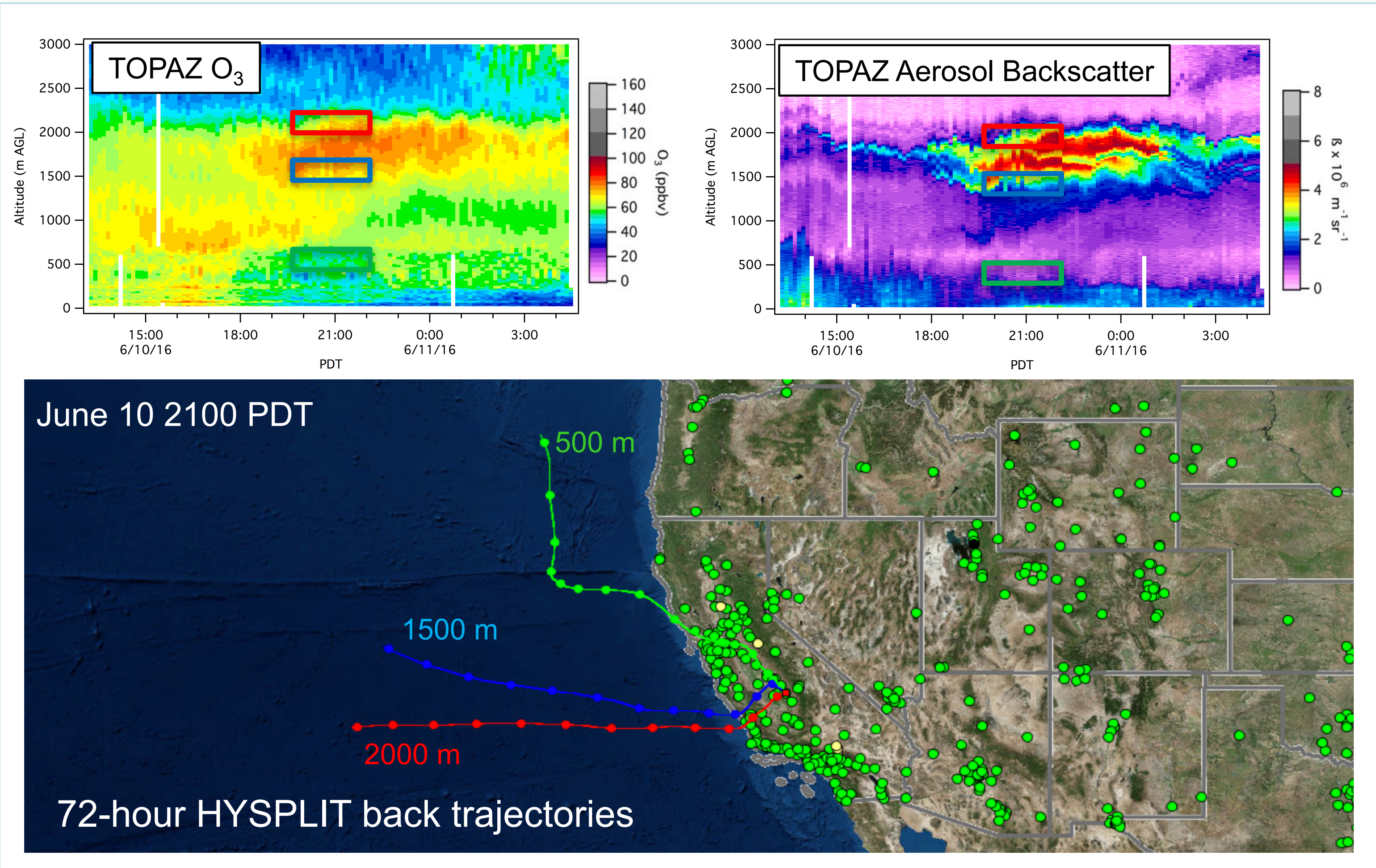
# June 10-11, 2016: Ozone transport from the Pacific



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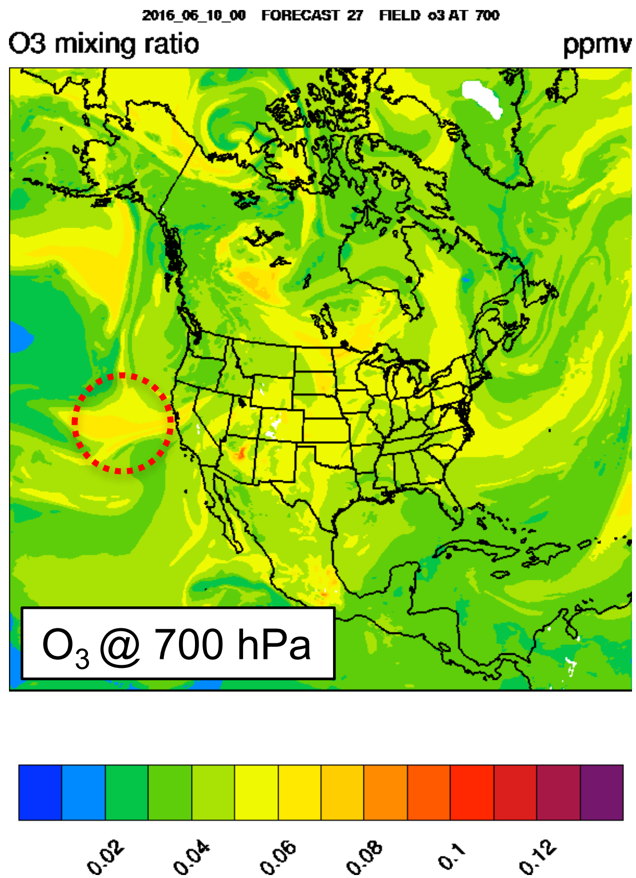
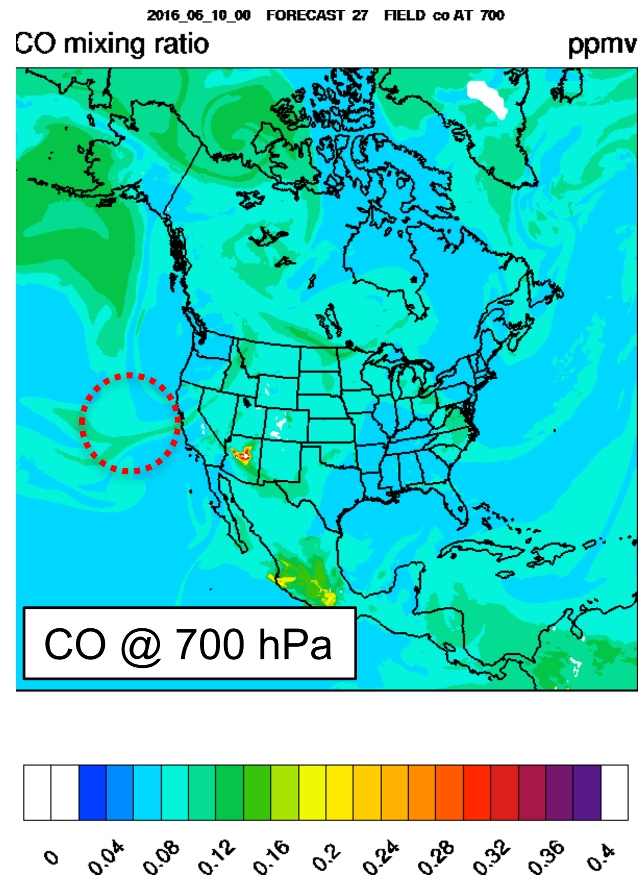
Transported ozone may have originated from Siberian or Alaskan wildfires




NOAA PSD RR-Chem model

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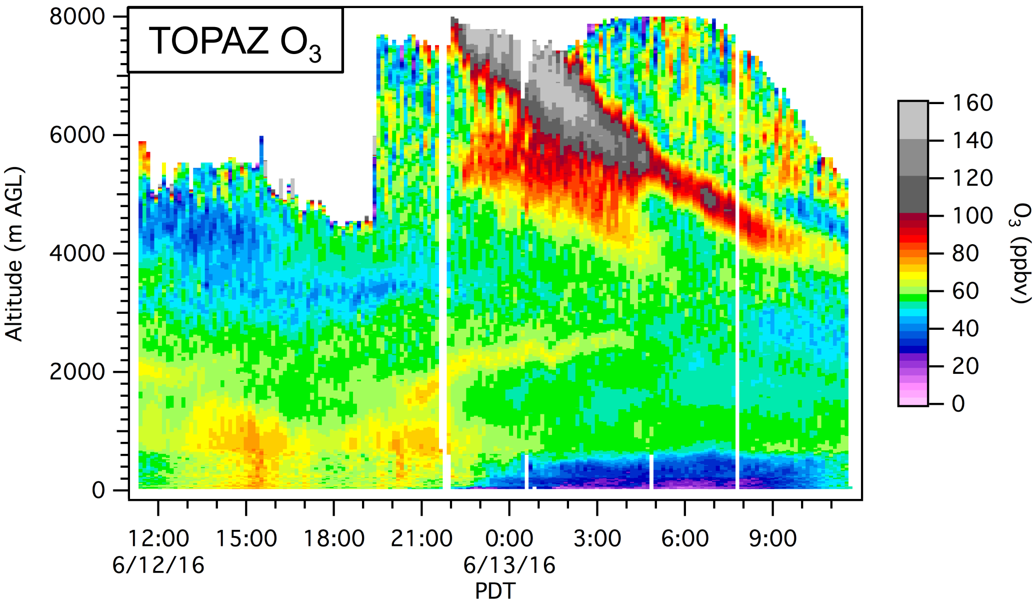
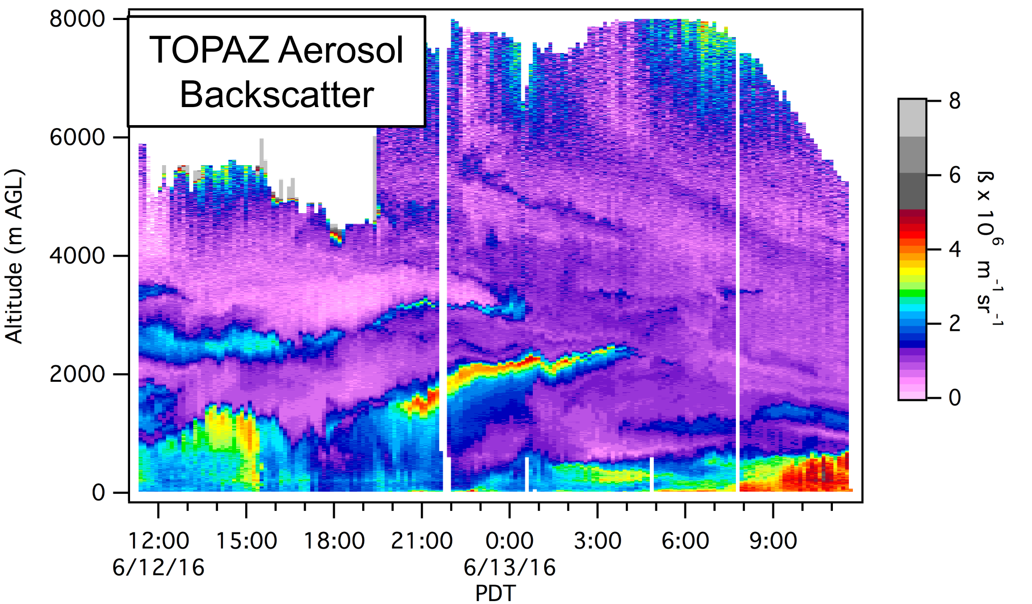
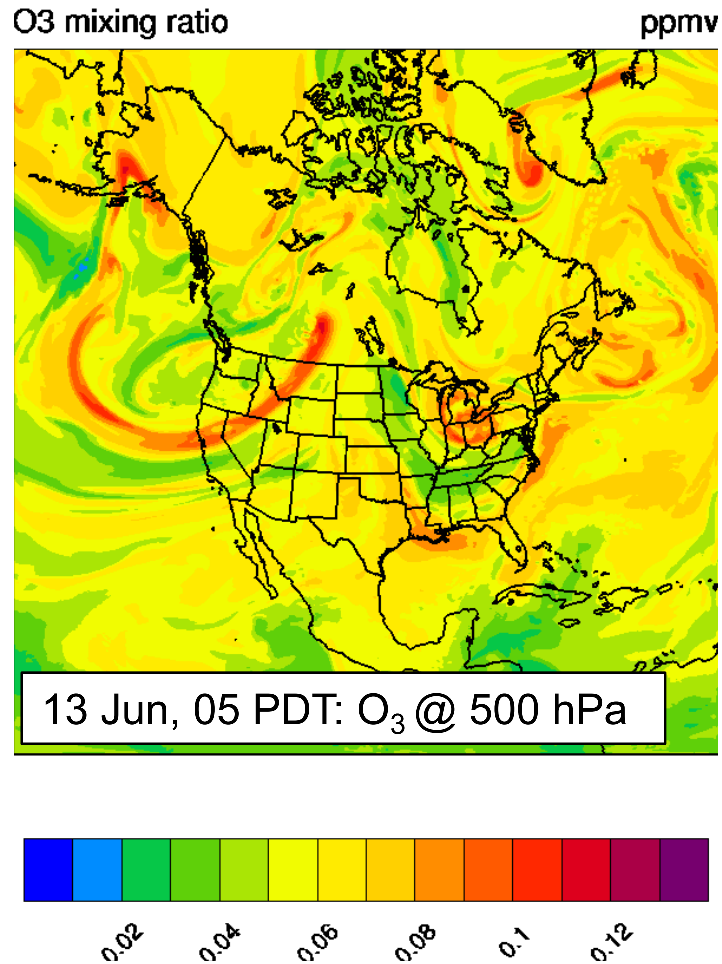
# June 12-13, 2016: Stratospheric intrusion



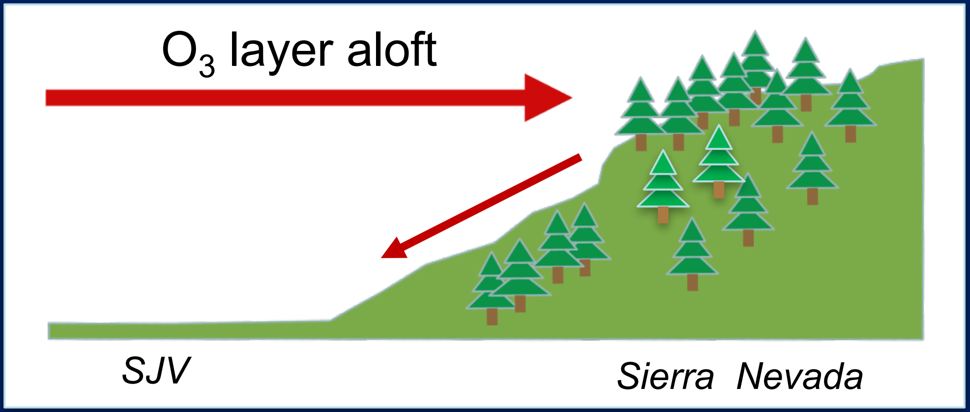



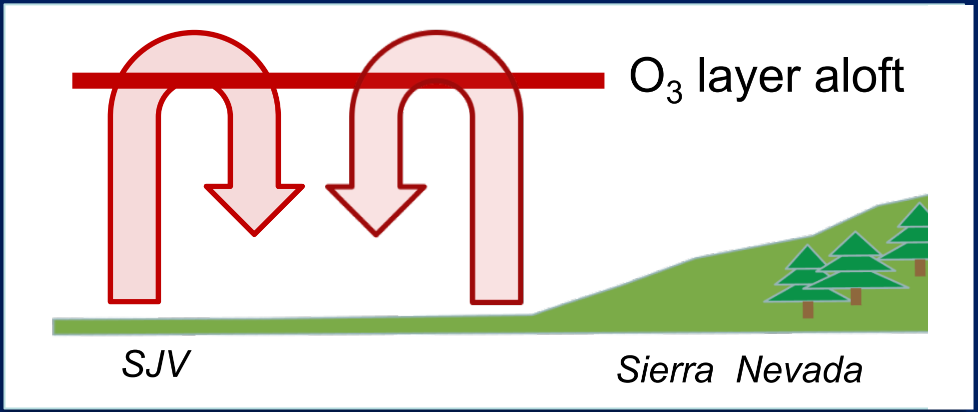

NOAA PSD RR-Chem model

## TOPAZ frequently observed ozone layers above the San Joaquin Valley, but do they get transported to the valley floor?

- Interaction with Sierra Nevada Mountains and subsequent downslope flow?

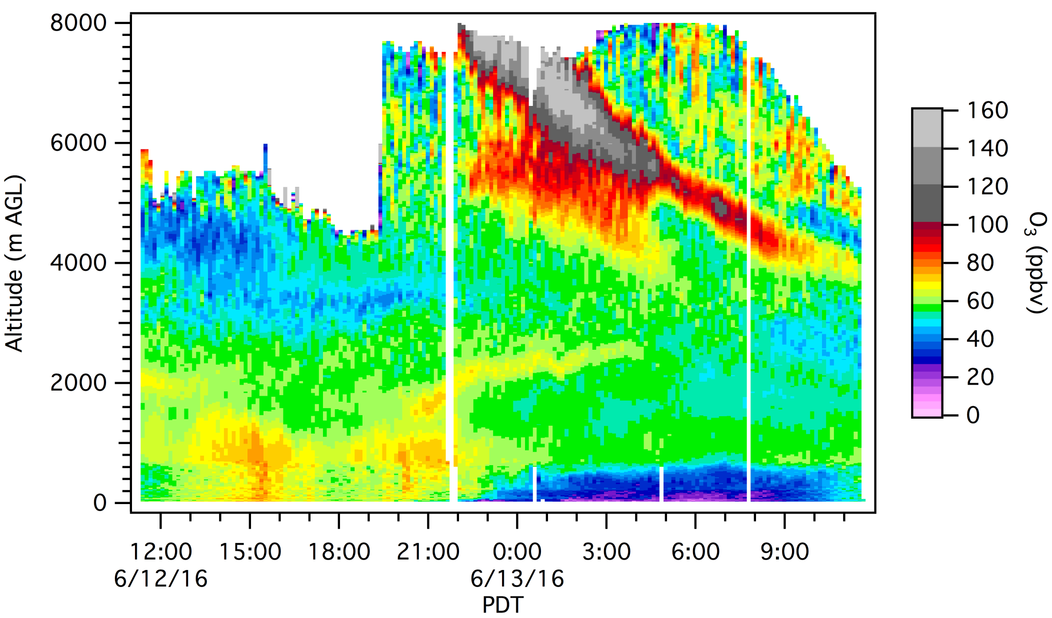


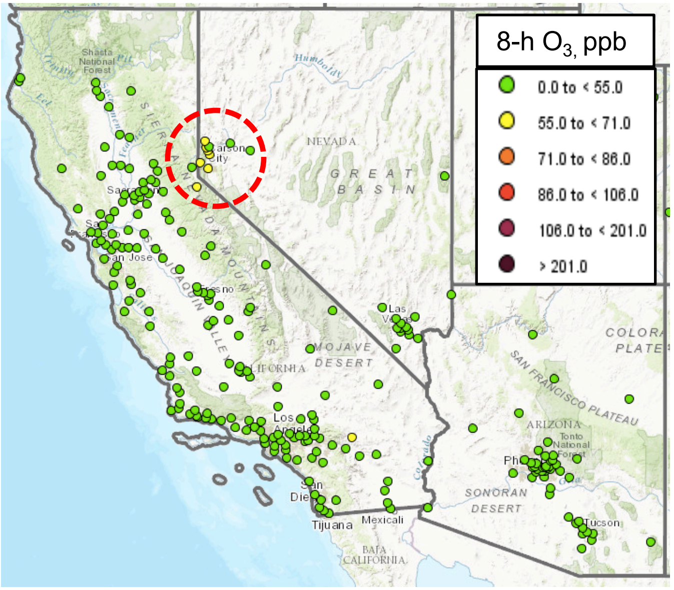

- Entrainment into the boundary layer and mixing to the surface?



# Transport of ozone layers aloft to the valley floor: Interaction with the Sierra Nevada Mountains?

13 June: Stratospheric Intrusion



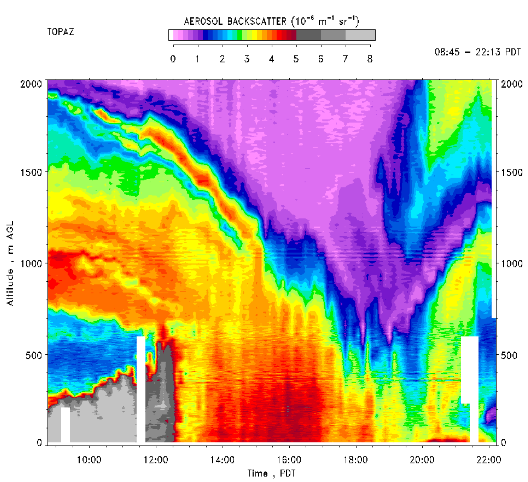




Possible surface impact near Lake Tahoe

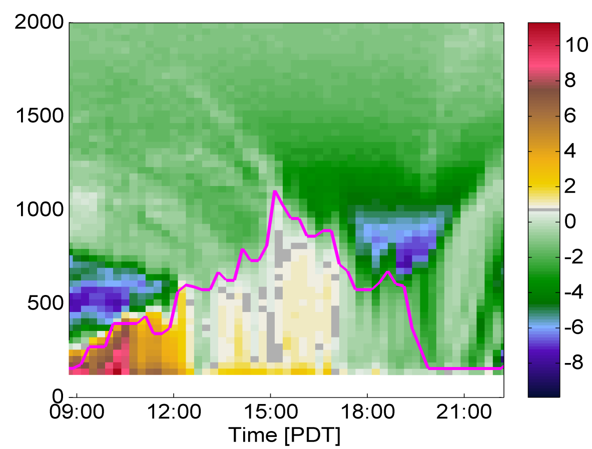
# Transport of ozone layers aloft to the valley floor: Boundary layer entrainment & mixing?

- Boundary layers in the San Joaquin Valley are very shallow: < 1.5 km in late spring, < 1 km in summer
- Only low-altitude $O_3$ layers were entrained and mixed to the surface.

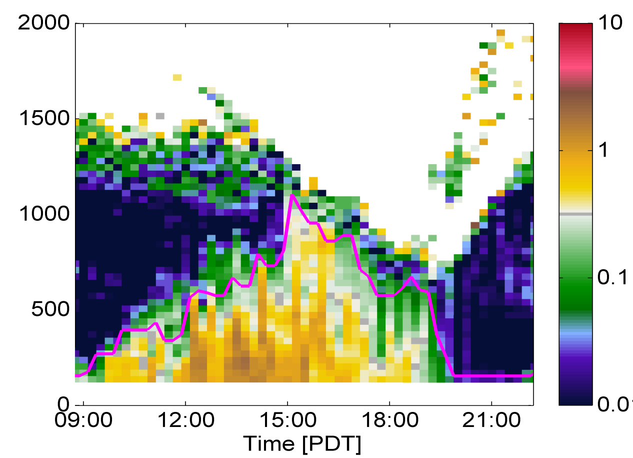
**TOPAZ backscatter**




**Micro Doppler: Range corr. intensity**




**Micro Doppler: w variance, $m^2 s^{-2}$**




August 6, 2016

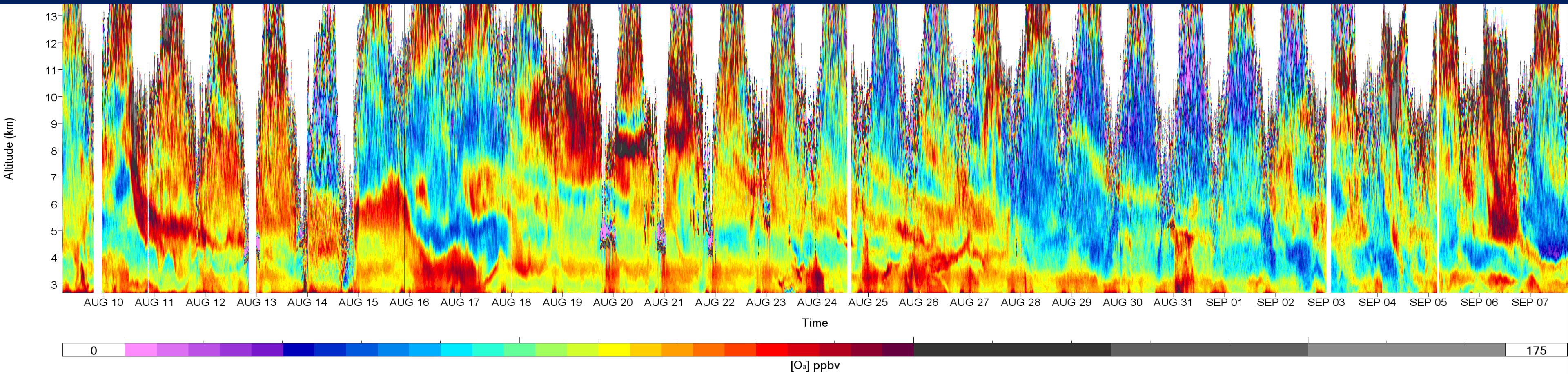
# Summary

- Complex ozone and aerosol layers above the SJV on most days.
- Ozone layers aloft created by regional, trans-Pacific, and stratosphere-to-troposphere transport.
- Entrainment and mixing to the surface usually limited by shallow boundary layers.
- More in-depth analysis underway, making use of the synergy of all instruments deployed at CABOTS.

# Unmet observational needs in Air Quality Research & Forecasting

- Nationwide network of instruments providing continuous profiles of $O_3$ from near the surface to the UTLS.
- Great benefit to AQ model validation and forecast improvement.
- $O_3$ lidars have proven track record and TOLNET is a great start, but …
- $O_3$ lidars are still too expensive and mostly need operators to run them.

**Need robust, autonomous, cost-effective $O_3$ lidars**




ECCC AMOLITE: 31 days of continuous $O_3$ profile observations (K. Strawbridge et al.)