JPL Table Mountain NDACC/TOLNet Lidar

The JPL Table Mountain Facility (TMF) tropospheric ozone (O_3) lidar is located near Wrightwood, CA (34.3N, 117.7W) at the high elevation of 2285 meters, between the Los Angeles Basin and the Mojave Desert. The system is part of the Network for the Detection of Atmospheric Composition Change (NDACC) and has produced O_3 profiles from ~3.5 km up to > 20 km with a temporal resolution of 5-10 minutes since 1999. The lidar data have been used to study seasonal and inter-annual variability and long-term trends of tropospheric O_3. Together with the co-located NDACC water vapor Raman lidar, the TOLNet lidar provides unique data for the study of stratosphere-troposphere exchange (STE). This lidar, together with the other co-located lidars, have been used to support satellite validation (e.g., Aura-MLS) and measurement campaigns such as the Measurements of Humidity in the Atmosphere and Validation Experiments (MOHAVE) (http://tmf.jpl.nasa.gov/tmf-lidar/campaigns/mohave2009.htm).

Please contact Dr. Thierry Leblanc (thierry.leblanc@jpl.nasa.gov) for further information regarding these research topics. For more information about JPL's Table Mountain Facility lidars please visit: http://tmf.jpl.nasa.gov/tmf-lidar/

1. Evaluation of Multi-year Vertical Ozone Profiles

The TMF tropospheric O_3 lidar measurements have been used to produce a 15-year climatology, and to assess seasonal and interannual variability and long-term trends. No significant signature of inter-annual variability could be observed in the 2000-2015 lidar time-series, with only a statistically non-significant positive anomaly in 2003-2007 in the lower troposphere. Trend analysis reveals however a statistically significant positive trend of 0.31 ppbv yr^{-1} in the free troposphere (7-10 km) for the period 2000-2015.

In the upper troposphere and lower stratosphere (UTLS), frequent tropopause folds found in the vicinity of TMF (27% of the time, mostly in winter and spring) produce a dual vertical structure in O_3 within the fold layer, characterized by higher-than-average values in the bottom half of the fold (12-14 km), and lower-than-average values in the top half of the fold (14-18 km). This structure is consistent with the expected origin of the air parcels within the fold, i.e., mid-latitude stratospheric air folding below the upper tropospheric sub-tropical air.

Details on this work can be found in a study, currently under review at the ACPD website: Granados-Muñoz, M. J. and Leblanc, T.: Tropospheric Ozone Seasonal and Long-term Variability as seen by lidar and surface measurements at the JPL-Table Mountain Facility, California, Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-70, in review, 2016.

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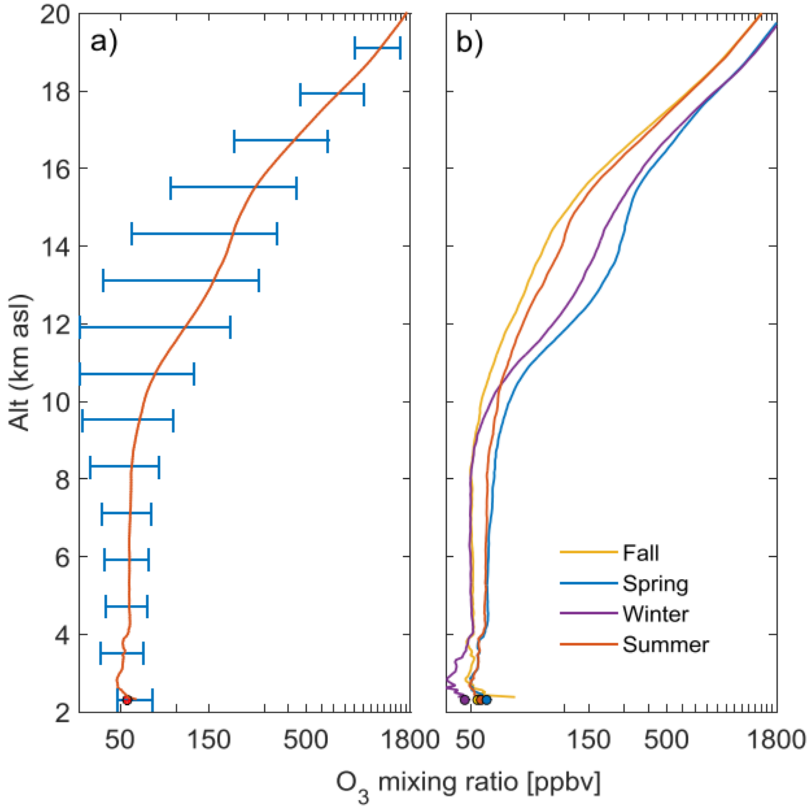
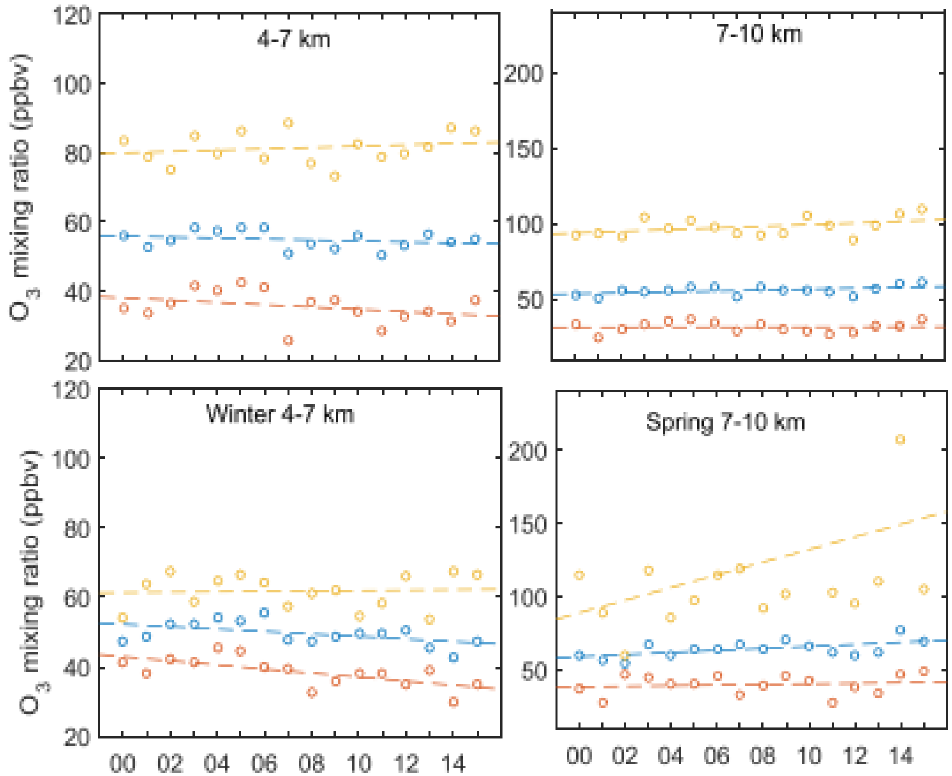
1. Evaluation of Multi-year Vertical Ozone Profiles



Climatology (a) and seasonal (b) O_3 at TMF between 2000 and 2015



Time-series of annual (top) and season (bottom) averaged O_3 from 2000 – 2015.

- **TMF lidar observations from 2 to >20 km were evaluated from 2000 – 2015.**
- **O_3 seasonality is evident from TMF observations with largest values occurring in the troposphere during the spring/summer and in the stratosphere during winter/spring.**
- **Long-term trends of O_3 in the troposphere (4-10 km) were observed, with statistically significant decreasing trends during the winter months (4-10 km) and increasing trends during the spring and summer months (7-10 km).**

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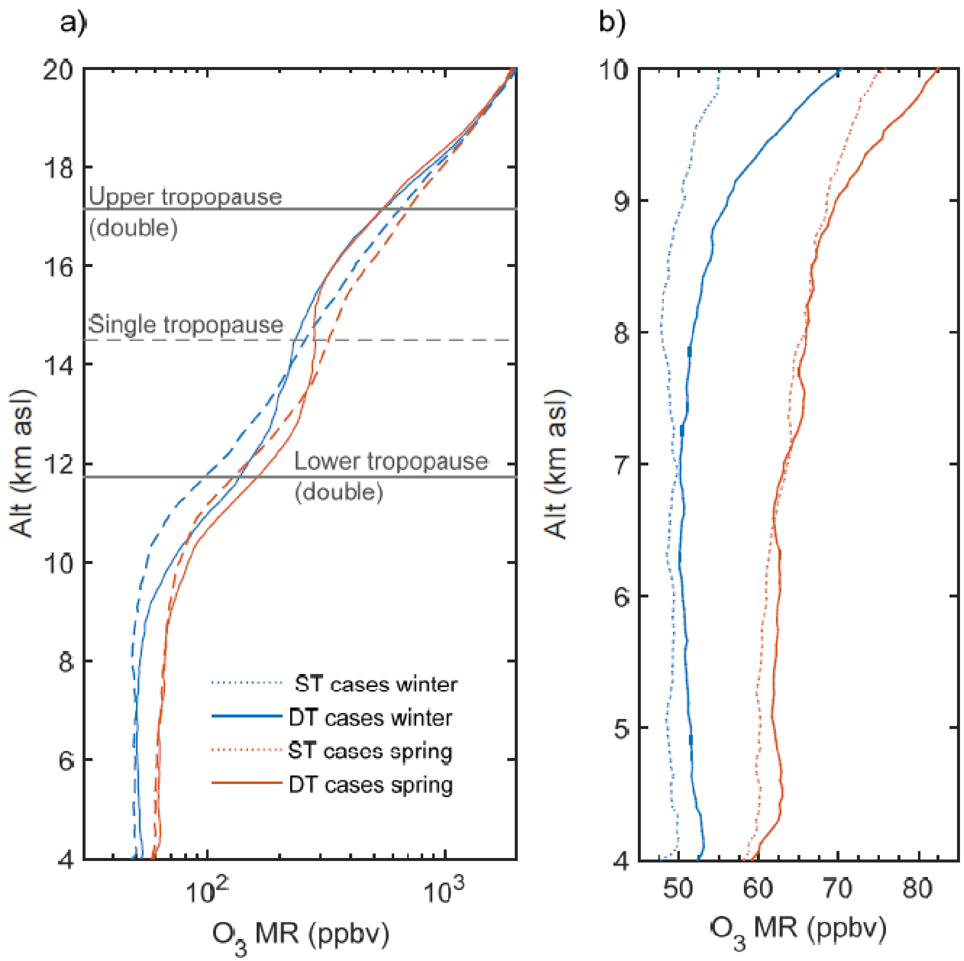

(a) Winter and spring averaged O_3 mixing ratio profiles computed in the presence of a double tropopause (DT) and single tropopause (ST). (b) Same as (a) but zoomed in on the tropospheric part of the profiles

- **Frequent tropopause folds found in the vicinity of TMF (27% of the time, mostly in winter and spring).**
- **A dual vertical structure in O_3 is observed, with higher-than-average values in the bottom half of the fold (12-14 km), and lower-than-averaged values in the top half of the fold (14-18 km).**
- **Increased O_3 values (+2 ppbv) observed in the lower part of the troposphere (4-7 km).**

2. Air Parcel Classification at TMF

A classification of the air parcels sampled by the TMF lidar was made at 1-km intervals between 5 km and 14 km altitude, using 8-days backward trajectories from the HYSPLIT4 model. This classification revealed large influence of the Pacific Ocean, with air parcels of low ozone content (50 ppbv), and significant influence of the stratosphere leading to O_3 values of 65-80 ppbv down to 8-9 km. In the summer, enhanced O_3 values (70 ppbv) were found in air parcels originating from Central America, probably due to the enhanced thunderstorm activity during the North American Monsoon. During this study no outstanding influence from the Asian boundary layer was identified.

Details on this work can be found in a study, currently under review at the ACPD website: Granados-Muñoz, M. J. and Leblanc, T.: Tropospheric Ozone Seasonal and Long-term Variability as seen by lidar and surface measurements at the JPL-Table Mountain Facility, California, Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-70, in review, 2016.

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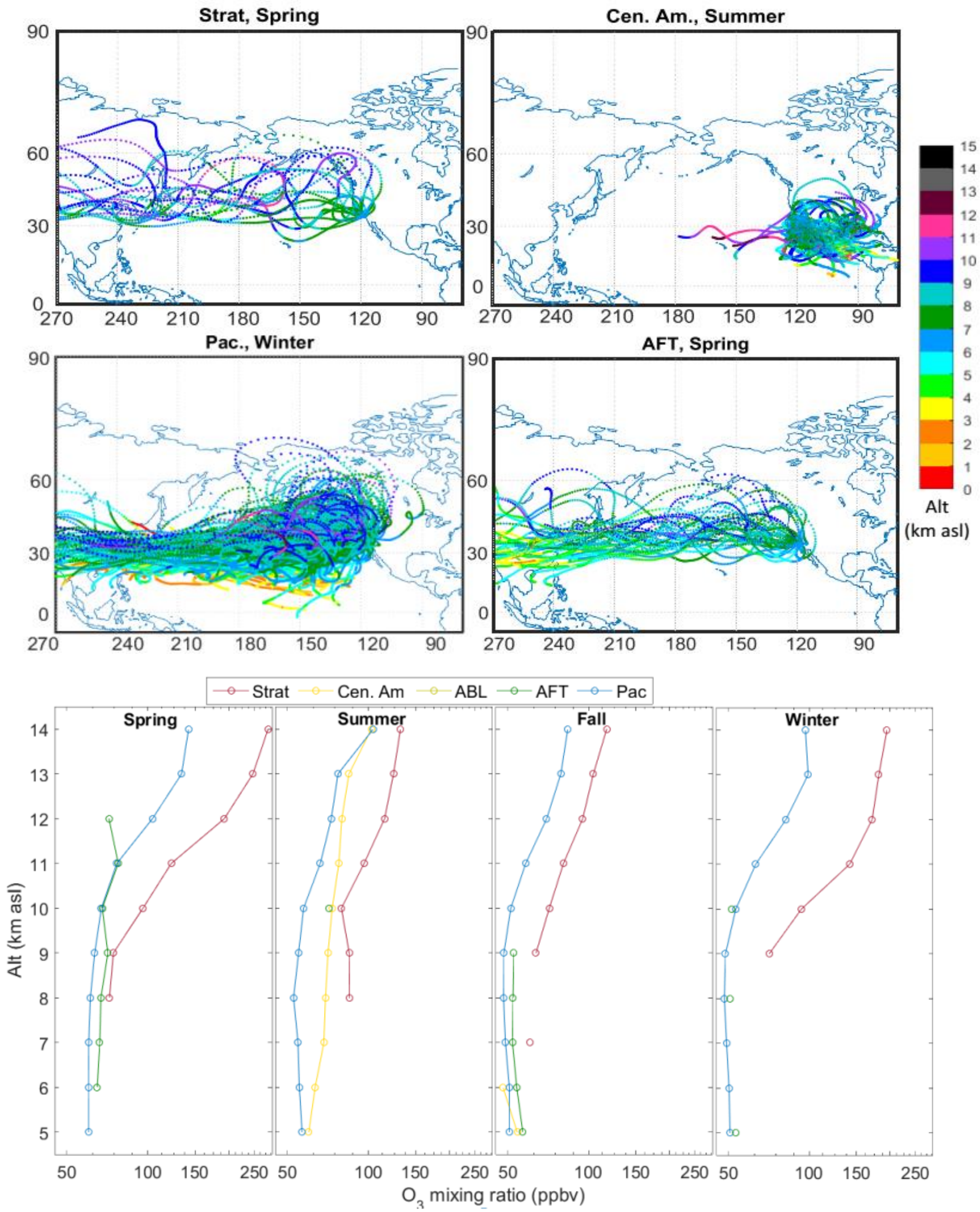

HYSPLIT4 8-day back-trajectories arriving at TMF at 7 km (top) and O_3 profiles associated with different source regions during each season (bottom).

- HYSPLIT 8-day back-trajectories were grouped based on ending altitude/location to identify air parcel source regions.
- 5 main regions were identified to be impacting TMF O_3 profiles: stratosphere, Asian boundary layer, the free-troposphere above Asia, Central America, and the Pacific Ocean.
- Larger O_3 mixing ratio values were observed when the air masses were classified as stratospheric regardless of altitude and season.
- During the summer, TMF O_3 profiles are impacted by Central American air masses with lightning-induced enhancements of O_3 occurring during the North American summer monsoon.

3. Water Vapor and Ozone During MOHAVE

The Measurements of Humidity in the Atmosphere and Validation Experiment (MOHAVE) 2009 campaign took place on 11–27 October 2009 at the JPL TMF in California. Besides the validation of several lidar and non-lidar water vapor instruments, one objective of the campaign was to study upper tropospheric humidity variability at timescales varying from a few minutes to several days, and correlate this variability with O_3 measured by the NDACC/TOLNet lidar.

The water vapor and O_3 lidar measurements, together with the advected potential vorticity outputs from the high-resolution transport model MIMOSA, allowed for the identification and the study of a deep stratospheric intrusion over TMF during MOHAVE-2009. These observations demonstrated the lidar had a strong potential for future long-term monitoring of water vapor in the UTLS.

More details on this work can be found in: Leblanc, T., et al.: Measurements of Humidity in the Atmosphere and Validation Experiments (MOHAVE)-2009: overview of campaign operations and results, Atmos. Meas. Tech., 4, 2579-2605, doi:10.5194/amt-4-2579-2011, 2011

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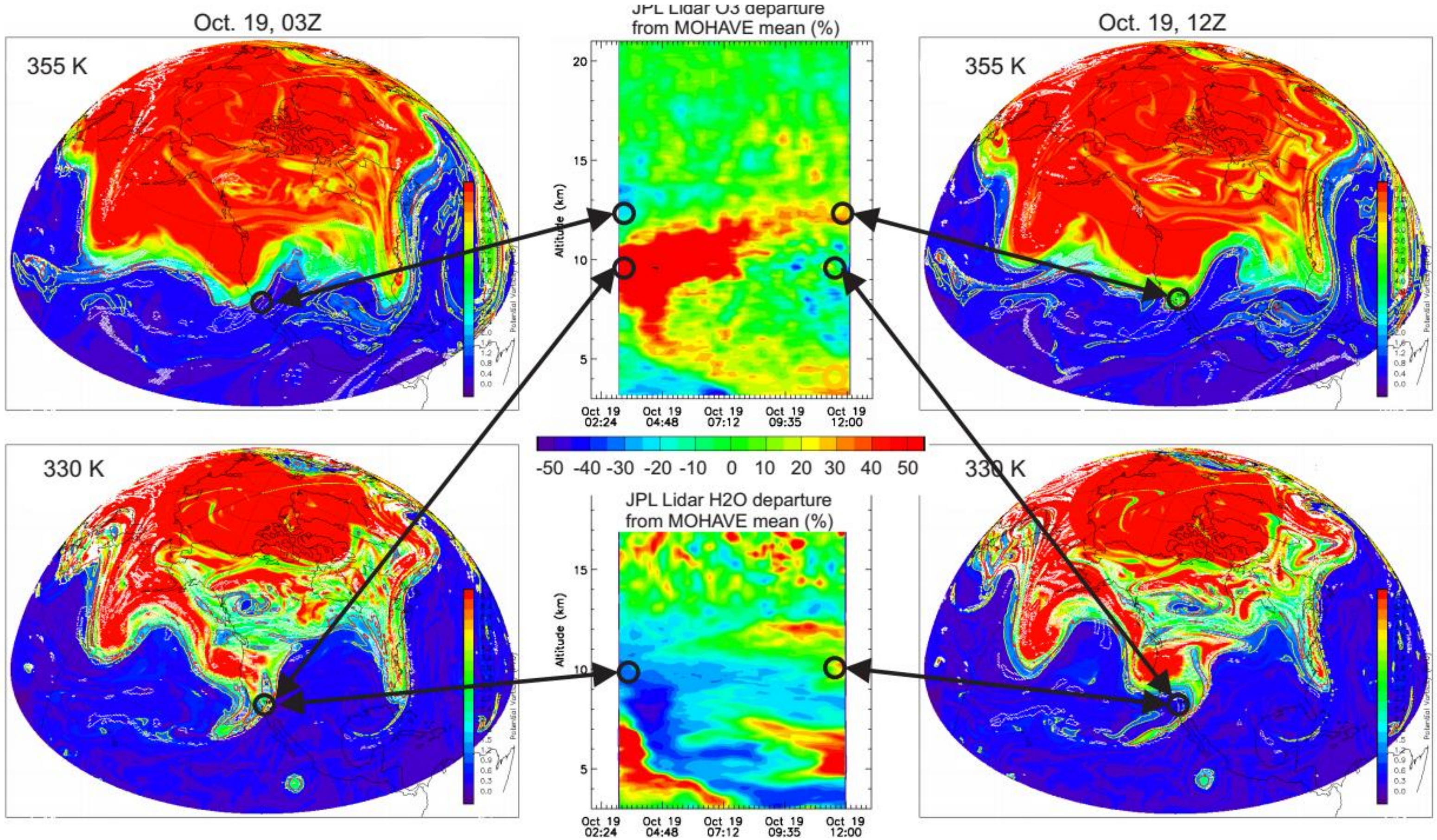
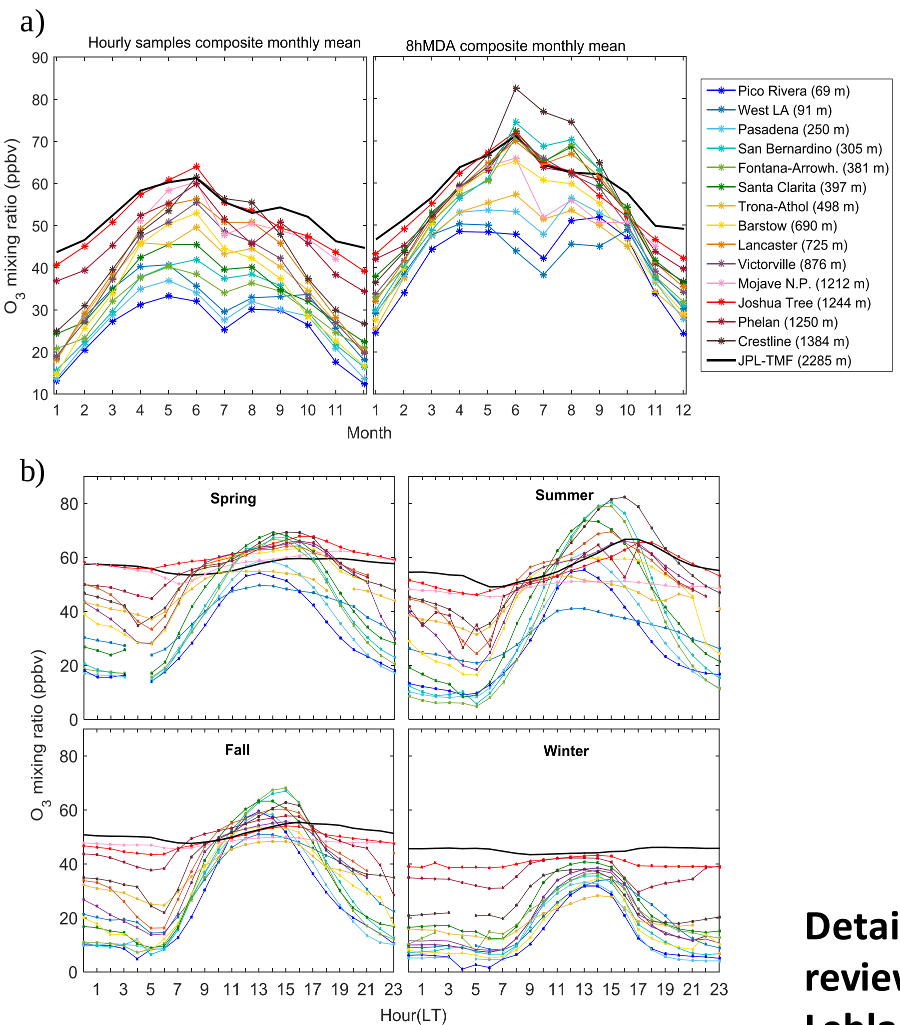


- **Stratospheric intrusions were clearly observed to coincide with dry layers by the TMF system during MOHAVE in October 2009.**
- **Intrusions tend to occur along the subtropical jet-stream in a region of a tropopause fold.**
- **TMF lidar observations were compared with high-resolution MIMOSA modeled PV fields further indicating the influence of UTLS water vaper and O_3 over the TMF location.**

4. TMF Surface Ozone Observations



(a) Composite monthly mean surface O_3 obtained from hourly samples and 8h MDA values and (b) composite mean O_3 daily cycle at TMF and nearby ARB stations for the period 2013-2015.

Since 2013, the TMF tropospheric O_3 lidar measurements are complemented by surface O_3 ozone measurements. Surface O_3 at TMF is typical of high elevation remote-sites, with small amplitude in the seasonal and diurnal cycles, and high O_3 values, compared to neighboring lower altitude stations representative of urban boundary layer conditions. O_3 values range from 45 ppbv in the winter morning hours to 65 ppbv in the spring and summer afternoon hours. The seasonal cycle at the surface is similar to that observed by lidar between 3.5 km and 9 km because of the low influence of the boundary layer.

Details on this work can be found in a study, currently under review at the ACPD website: Granados-Muñoz, M. J. and Leblanc, T.: Tropospheric Ozone Seasonal and Long-term Variability as seen by lidar and surface measurements at the JPL-Table Mountain Facility, California, Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-70, in review, 2016.

Supporting Information and Publications

Instrument Description

McDermid, I. S., Haner, D. A., Kleiman, M. M., Walsh, T. D., and White, M. L.: Differential absorption lidar systems for tropospheric and stratospheric ozone measurements, Opt. Engin., 30, 22-30, 10.1117/12.55768, 1991.

McDermid, S., Beyerle, G., Haner, D. a and Leblanc, T.: Redesign and improved performance of the tropospheric ozone lidar at the Jet Propulsion Laboratory Table Mountain Facility., Appl. Opt., 41(36), 7550–7555, 2002.