Ozone Flux and Production Downwind of Houston and Dallas

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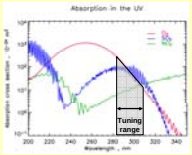
Introduction

Large urban areas in eastern Texas, such as Houston and Dallas/Fort Worth, often experience high ozone pollution events during the summer months. Under the right meteorological conditions, ozone produced locally in these urban areas is transported into other areas of eastern Texas, where it increases the regional ozone background and may push smaller urban areas into ozone non-compliance. To quantify this export of ozone from Houston and Dallas/Fort Worth, we use airborne ozone lidar data collected during the Texas Air Quality Study (TexAQS) 2000 and TexAQS 2006. We selected six flights (four from 2006 and two from 2000) during which we mapped out the Houston/Ship Channel and Dallas/Fort Worth ozone plumes by flying multiple downwind transects across the plumes. From the lidar data we compute horizontal fluxes of ozone as well as ozone production rates in these plumes.

Instrumentation: TOPAZ Ozone Differential Absorption Lidar

For the TexAQS 2006 study, NOAA/ESRL developed TOPAZ (**T**unable **O**ptical **P**rofiler for **A**erosol and **O**zone), a new-generation airborne ozone and aerosol lidar. This new lidar is light-weight and compact, so it can be flown on a rather small research aircraft, such as the NOAA Twin Otter. It incorporates the latest solid-state laser technology and its transmitter is tunable in the UV spectral region.



TOPAZ lidar mounted in NOAA Twin Otter

NOAA Twin Otter N46RF

TOPAZ specs:

- 3 channels (285 – 310 nm, tunable)
- Pulse energy: 0.2 to 0.4 mJ
- Rep rate: 1 kHz
- Nadir-looking

TOPAZ measurements:

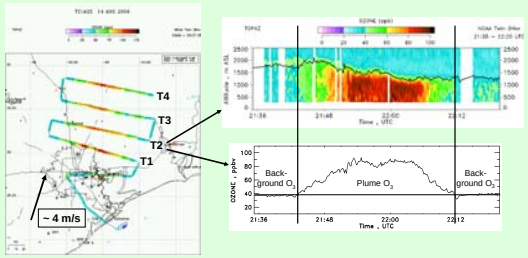
- Ozone & aerosol backscatter profiles
- Altitude coverage: surface up to 3.5 km
- Resolution: 10 s or 650 m horizontal, 100 m vertical (O3), 6 m (aerosol)
- Precision: 3 – 15 ppb

Methodology

Objective:
Compute total horizontal flux of ozone produced by Houston and Dallas/Fort Worth metro areas.

Approach:
Use airborne lidar data from flight transects downwind of metro areas and calculate plume fluxes for each transect and ozone production rates between adjacent transects.

Meteorological Conditions:
Steady synoptic flow at speeds of several m/s.



Flux calculation:

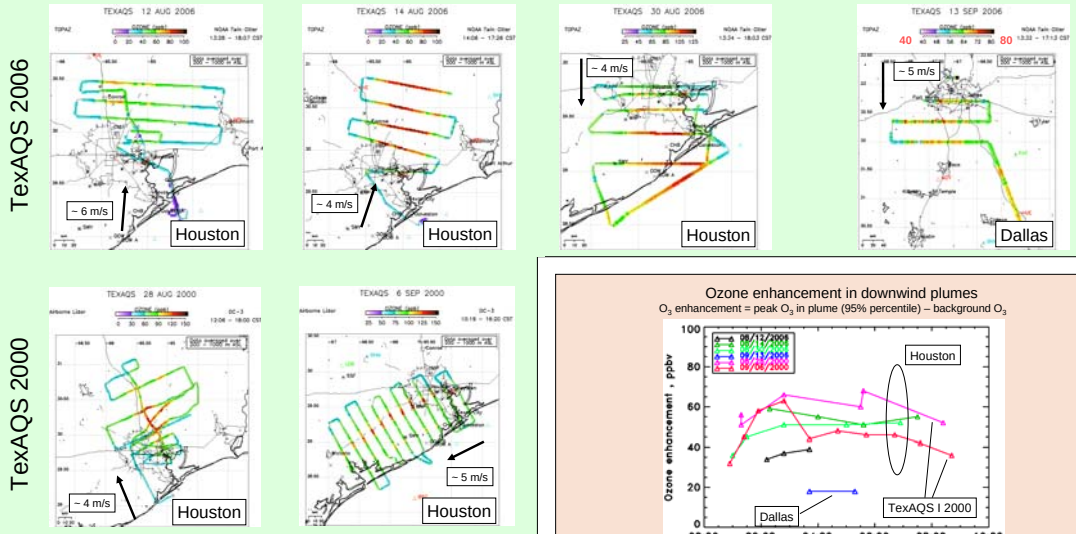
- Integrate excess ozone in plume (plume O_3 – background O_3) between surface and top of boundary layer and between horizontal plume edges.
- Multiply with horizontal wind speed (from wind profiler network) to yield flux in molecules O_3 / sec for each transect.
- Angle between flight transect and plume is taken into account.

Ozone production rate retrieval:

- Take difference in integrated excess plume ozone between adjacent transects and divide by plume area.
- Divide by plume travel time between adjacent transects to compute ozone production rate in ppbv/h.

Errors in ozone flux and production rate calculation	
O_3 cross section	< 3%
O_3 RMS error	< 0.2%
Plume boundaries	~ 5%
Background O_3 determination	~ 5%
Wind speed	~ 1 m/s or < 25%
Total	< 30%

Houston and Dallas plumes sampled during TexAQS 2000 & TexAQS 2006

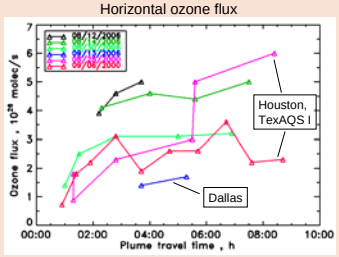


Ozone enhancement in downwind plumes

O_3 enhancement = peak O_3 in plume (95% percentile) – background O_3

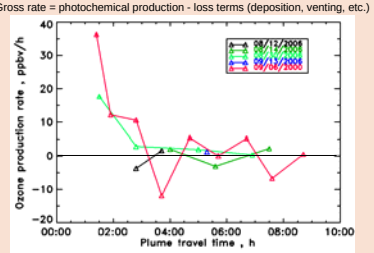
Ozone fluxes and production rates

Horizontal ozone flux



Ozone production rate

(Gross rate = photochemical production - loss terms (deposition, venting, etc.)



Metro area	Date	Wind direction	Wind speed , m s^{-1}	Time, CST	Background O_3, ppb	O_3 enhancement, ppb	Flux, molec O_3 s^{-1}
Houston	8/12/2006	S	7.3	16:57 – 17:34	29	39	$5.0*10^{26}$
Houston	8/14/2006	S	4.5	16:58 – 17:26	34	55	$5.0*10^{26}$
Houston	8/30/2006	N	3.8	17:10 – 17:43	59	52	$3.2*10^{26}$
Houston	8/28/2000	S	4.2	16:11 – 16:40	53	52	$6.0*10^{26}$
Houston	9/06/2000	NE	5.2	14:13 – 14:43	69	46	$3.6*10^{26}$
DFW	9/13/2006	N	4.6	15:49 – 16:34	57	18	$1.7*10^{26}$

Flux results for transects with highest flux

Summary

- Above-background ozone flux produced in Houston metro area ranges from 3.2 to 6.0 * 10^{26} molec/s.
- Export of ozone from DFW metro area is about a factor of 2 to 3 less than from Houston (based on 1 Dallas case only).
- Ozone enhancements in Houston plume of up to ~70 ppbv.
- A flux of 4.6* 10^{26} molec O_3 / s (average of all Houston cases) emitted over a day (8 hours) is equivalent to a 10-ppb increase in ozone over an approx. 10,000 square mile area, assuming a 2-km deep mixed layer.
- Houston ozone flux and production rates are similar for 2000 and 2006.