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Construction and Analysis of an Ozone Profile Climatology Over Houston, Texas

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Abstract

Since the summer of 2004, over 200 ozonesondes have been launched from the campuses of Rice University or the University of Houston (29.7 N, 95.3 W), each about 3 miles from downtown Houston. These sounding launches have been sponsored by NASA, the Shell Center for Sustainability of Rice University, and the Texas Commissions for Environmental Quality as part of a large effort to understand Houston's ozone problem. Data from these soundings have provided valuable insight into the seasonal and diurnal variations of the vertical ozone distribution and their relationship to changes in atmospheric conditions. In this presentation, we show annual and seasonal variability in the ozone profile, evidence for the impact of meteorological factors on the ozone profile, and comparisons of the ozonesonde data with TES and OMI retrievals.

Project Background

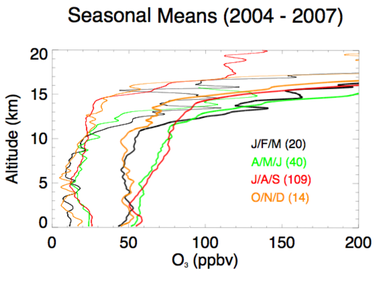
Figure 1. Rice Univ. students prepare an ozonesonde for launch during the Summer 2005.

Since the project's inception in July 2004, more than 20 undergraduate students from Rice, the Univ. of Houston, and Valparaiso Univ. have launched over 200 ozonesondes in Houston. Students are responsible for instrument preparation, calibration, and launches, and participate in data reduction and analysis.

Each launch includes a 2Z-ECC ozonesonde from En-Sci Corporation (Komhyr, 1986) and an RS80-15N radiosonde for measurements of temperature, pressure, and humidity. Since 2006, most launches also have included a GPS that provides wind speed and direction data. Profiles extend from the surface to 20-35 km altitude, depending on the balloon size (300 - 1200 g). Most launches occur around 13:00 local solar time to coincide with Aura satellite overpasses.

Seasonal Variability

Figure 2 (right). Means (thick) and standard deviations (thin) of ozonesonde profiles over Houston separated by season. **Summer (JAS)** shows enhanced ozone in the surface layer, indicative of local production. **Spring (AMJ)** shows a nearly constant profile in the first 5 km, with a secondary peak in surface ozone pollution this time of year. **Fall (OND)** and **winter (JFM)** means show lower ozone levels from the surface to 10 km.



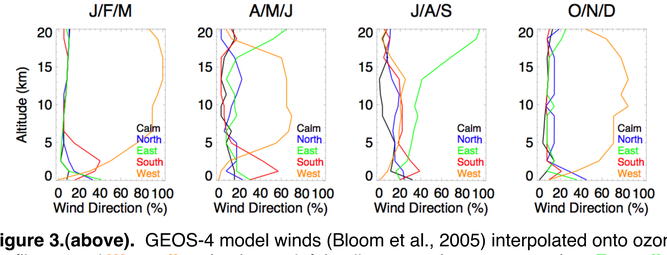
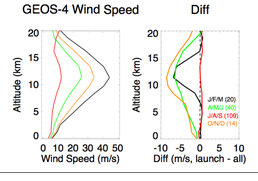


Figure 3.(above). GEOS-4 model winds (Bloom et al., 2005) interpolated onto ozonesonde profiles reveal **Westerlies** dominate aloft in all seasons but summer, when **Easterlies** are frequent. Near the surface, **Southerly** winds dominate in spring, while **Northerly** and **Easterly** winds dominate in fall and winter. During summer, surface winds from the **North**, **East**, and **South** occur regularly.

Figure 4 (right). Seasonal, mean GEOS-4 wind speeds for all days (left plot) and differences with means on launch days only. During **Summer**, launch days are representative of general conditions. In other seasons, launch days favor weaker winds, when launching is far easier.



Interannual Summertime Variability

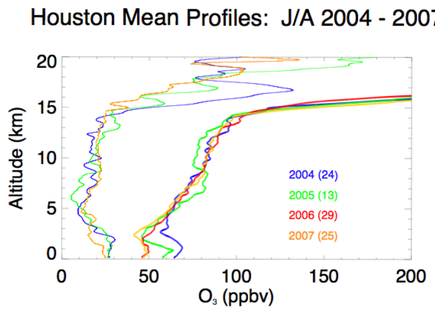


Figure 5 (above). July and August ozone means (thick) and standard deviations (thin). **2004** surface pollution was the worst of the 4 years, in part due to the impact on two days of Alaskan forest fire smoke (Morris et al., 2006), but mainly due to meteorological differences (see below). During TexAQS II (**2006**), ozone levels were unusually low from the surface to ~5 km.

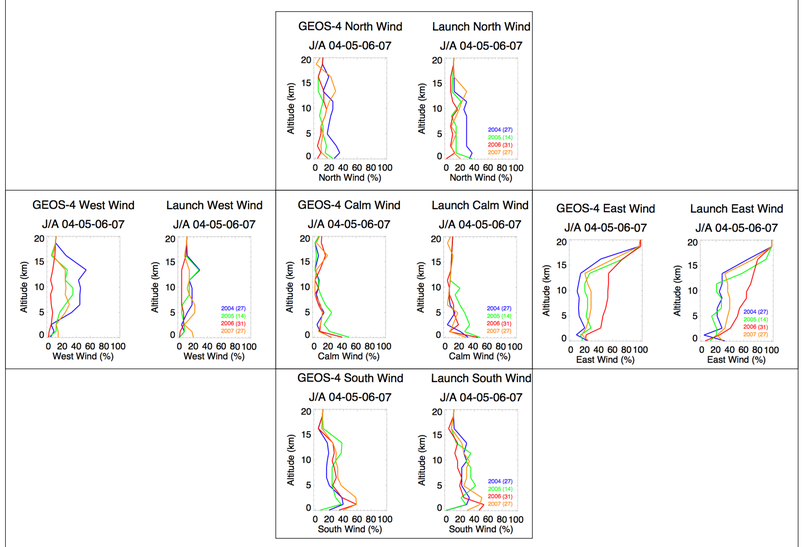
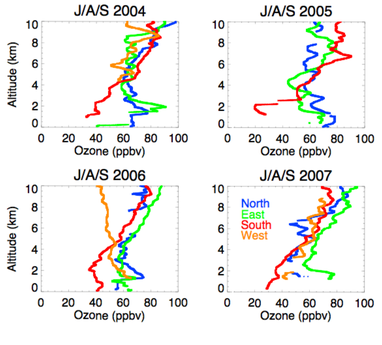


Figure 6 (above). Using GEOS-4 analyses, we investigated annual differences of numerous meteorological factors, including potential vorticity, potential temperature, and winds, in an attempt to explain the year-to-year ozone differences. Of these factors, only the wind direction varied significantly. Above are plotted the frequency of winds from each direction and of calm winds (< 2.5 m/s) each year. The left panel in each pair shows means from all J/A days each year while the right panel shows the means only on launch days. During **2004**, launch days were dominated by more frequent east and north surface winds, brining elevated background levels off the continental U.S. and pollution from the industrial sector east of the launch site. During **2006** and **2007**, southerly winds prevailed, bringing relative clean air from the Gulf of Mexico into the Houston area, suppressing pollution levels.

Figure 7 (right). Annual ozone profile means during the July-August-September period, separated by wind direction at each level, as indicated by interpolated GEOS-4 analyses. Below 4 km, winds from the **East** and **North** tend to bring higher ozone amounts to Houston, while winds form the **South** tend to bring in lower levels of ozone. Again, **Northerly** winds during summer can bring elevated background ozone levels to Houston from the continental US. **Easterly** winds bring pollution from the industrial ship channel into the city. **Southerly** winds bring in clean air off the Gulf of Mexico. Mixing ratios below 4 km are consistent year-to-year. The impact of forest fires is seen in the 2004 data (~2km).

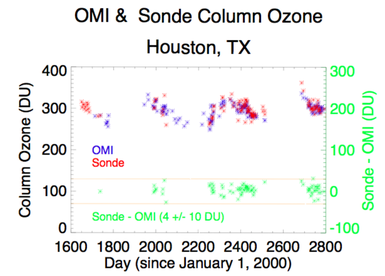


Aura Satellite Comparisons

OMI

The Ozone Monitoring Instrument (OMI) is a nadir-viewing, hyperspectral imager that produces daily, global maps of total column ozone with a 3 km field of view. Binning results in an effective 13 × 24 km horizontal resolution. The data shown here employ the TOMS Version 8 retrieval (Bhartia, 2007).

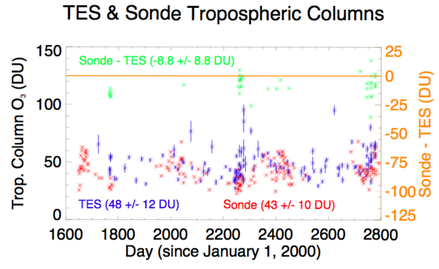
Figure 8 (right). OMI and **Sonde** ozone columns over Houston for the period July 2004 through August 2007 show similar magnitudes and seasonal variability. The **Sonde - OMI data** show column differences for the 88 close coincidences. **Sondes** that fail to reach 30 mb are not used in this study. The McPeters et al. (1997) balloon burst climatology is added to **Sonde** columns above the burst altitude.



TES

The Tropospheric Emission Spectrometer (TES) was designed to measure the global, vertical distribution of tropospheric ozone and ozone precursors. TES is a nadir and limb viewing infrared Fourier transform spectrometer (FTS). The data here are TES nadir measurements of ozone (footprint of 5km × 8 km) taken while in the standard measurement mode (called a "Global Survey") and have been screened on the TES "master" quality flag. The tropospheric column is calculated using a tropopause height (pressure) from the GMAO GEOS-5 analyses. TES ozone measurements have been thoroughly validated, and biases relative to other ozone measurements characterized (Nassar et al., 2007, Osterman et al., 2007, Richards et al., 2007). TES has been seen to have a high bias relative to sondes (as seen also in this study, particularly in the upper troposphere; however, data users should feel confident in using the data in scientific analyses.

Figure 9 (right). Tropospheric ozone columns over Houston for the period July 2004 through August 2007 show similar magnitudes and variability. The **Sonde - TES data** are coincidences that have been integrated to the same vertical level in the atmosphere. **TES** shows a high bias relative to the **Sondes**, as has been seen in other studies.



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All data can be found at http://www.rice.edu/ozone.

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