A Study of Tropospheric Ozone Column Enhancements over North America using a Regional Model and Satellite Data

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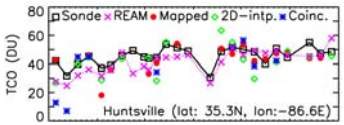
1. Introduction

Tropospheric ozone columns (TCOs) have already proved valuable for the study of ozone enhancement associated with dynamical and chemical processes such as biomass burning and El Nino events. The purpose of this study is to examine the variability of TCOs using satellite and model data over North America, and to study one spring TCO enhancement event.

REAM is a 2-D **R**egional ch**E**mical tr**A**nsport **M**odel. Its chemistry and deposition modules are based on the same modules used in the GEOS-CHEM with improvements in the lightning schemes, mixing depth estimation, and so on. Over the U.S, the model is driven by meteorology from the MM5 mesoscale model.

Using residual methods three types of TCOs have been derived by subtracting Microwave Limb Sounder (MLS) stratospheric columns from Ozone Monitoring Instrument (OMI) total columns. They are called OMI/MLS mapped, OMI/MLS 2-D interpolated, and OMI/MLS coincident columns. In the derivation of the first two types of TCOs, PV-ozone mapping and 2-D spatial interpolation have been performed on MLS data to improve the MLS data spatial resolutions.

2. Comparisons with ozonesondes



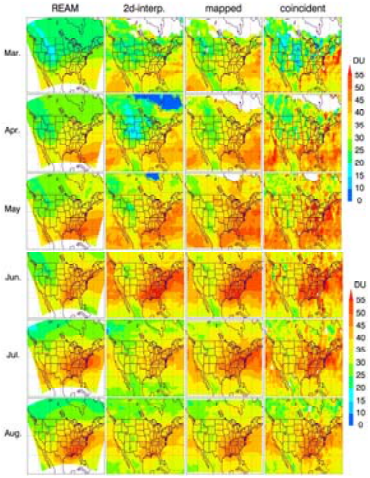
Based on the comparisons at four ozonesonde station over U.S. between 35º-42ºN during spring & summer 2005:

OMI-MLS vs. sonde: **-5±11DU (corr:0.7)**

REAM vs. sonde: **-7±6DU (corr:0.7)**

TCOs from ozonesonde, REAM, OMI/MLS mapped, OMI/MLS 2D-interpolated, and OMI/MLS coincident at Huntsville for spring and summer 2005.

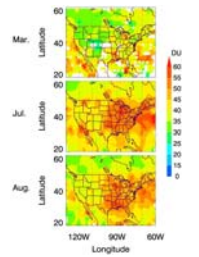
3. Monthly mean distributions in spring and summer 2005



Good agreements have been found between model and satellite TCO data in spring. During the spring months, the band of enhancement over the extra-tropical region divides into one TCO high over the Eastern Pacific near the Baja peninsula and the other over the Gulf of Mexico, Eastern United States and the adjacent North Atlantic. The TCO enhancements increased from March to May.

In summer, the area of TCO enhancements shift northward compared to the spring, and OMI-MLS and REAM agree well in the locations of enhancements although there is disagreement in the enhancement intensity in June.

Monthly mean TCO distributions based on REAM, OMI-MLS 2D-interpolated, OMI-MLS mapped, and OMI-MLS coincident (left to right) for March to August (top down) 2005.



OMI-MLS vs. TES: **-6±10DU (corr:0.5)**

REAM vs. TES: **-10.5±8.9DU (corr:0.6)**

Despite the relatively high bias, in March, TES also indicate small patchy high TCOs in the high TCO regions indicated by the REAM and OMI/MLS such as around the Baja peninsula and near the West Coast of California.

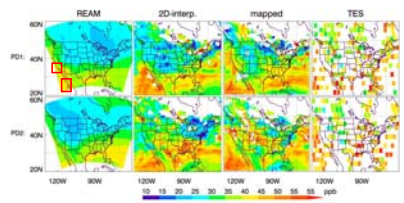
In July and August, TES monthly mean data agree well with OMI-MLS and REAM in the locations of enhancements and the monthly variations.

Monthly mean TES tropospheric ozone columns over North America for March (top), July (middle), and August (bottom). A Barnes smoothing routine with the influencing distance of 250 km has been used

4. A spring case study

Purpose: identifying the mechanisms associated with the TCO enhancements.

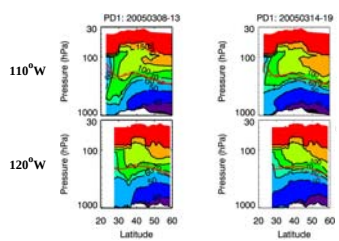
Periods selection: A six-day period (PD1: March 8-13, 2005) has been chosen for the spring case study due to its association with the strongest TCO enhancement event in spring 2005 in REAM. The following six-day period (PD2: Mar. 14-19) has been chosen for comparison purposes. Data from several days are required to obtain a complete OMI/MLS TCO maps over North America due to the clear sky constraint.



REAM and satellite data show TCO enhancements over the south of Baja peninsula and over the West Coast of California.

Tropospheric ozone columns during period 1 (PD1: 20050308-20050313, top) and period 2 (PD2: 20050314-20050319, bottom), using REAM, OMI-MLS 2-D interpolated, OMI-MLS mapped, and TES (left to right).

4.1 REAM vertical cross-sections

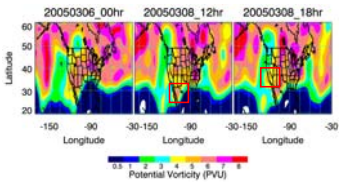


On 110ºW, in period 1, a tongue of ozone-rich air extends from stratosphere down to ~700 mb causing the TCO elevation over the BAJA peninsula region. The same cross section map for period 2 doesn't indicate a strong stratospheric intrusion feature.

Along the 120ºW meridian crossing the West Coast of California, the figures on the left show some indication of stratospheric influence near the tropopause in both periods.

Meridional pressure by latitude cross-sections of ozone (in ppb) at 110W (top, cross the Baja peninsula) and 120W(bottom, cross the West Coast of California) based on REAM during period 1 (20050308-20050313, left) and period 2 (20050314-20050319, right).

4.2 Wave breaking diagnostics



There is steepening of the wave crest in PV a couple of days before period 1. On May 08 at 12 UTC a high PV cutoff with PV values as high as 6 PV units appears beside the wave crest. At 18hr, March 08, a relatively weak cutoff high shows up over the West Coast of California. The wave breaking events correspond to the time and locations of the TCO maxima in REAM simulations.

PV contours on the 350 K isentropic surface. PV data are calculated using the six-hourly NCEP reanalysis data.

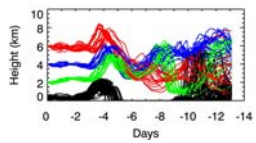
4.3 Study of Tran-Pacific influence – back trajectories & GEOS-CHEM

In order to estimate the influence of cross-Pacific transport, back trajectories have been initialized around the West Coast every six hours for periods 1 and 2, respectively, using the HY-SPLIT model.

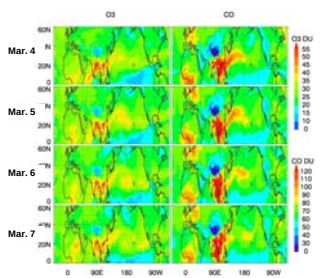
The statistics of the trajectories originating from East Asia based on 540 trajectories with initial heights of 2, 4, and 6 km for each period, are shown below.

	Period 1	Period 2
%	33%	15%
Average heights* (km)	2.5	5.0
# within mixed layer	92/180	17/93

* The average heights of the trajectories at the end of the trajectory period over East Asia.



The time height cross-section of the back trajectories associated with TCOs > 45 DU in REAM initialized around the West Coast of the U. S. Green, blue, and red lines correspond to trajectories initialized at the heights of 2, 4, and 6 km, respectively.



A few days before the event, there is a TCO maximum which propagates across the Pacific; the corresponding CO maps from GEOS-CHEM indicate some similar transport activities. However, the CO high dissipated before it reached the continental U.S., though there is a slight elevation of CO at the end over the West Coast.

GEOS-CHEM daily mean ozone and CO columns for March 4 - 7, 2005. The CO columns can be converted from Dobson units to molecules/cm2 by multiplying a constant (2.687E16).

5. Summary

- Monthly mean TCOs from REAM, OMI-MLS, and TES show two areas of high ozone columns in spring: one around the Eastern Pacific near the Baja peninsula and the other around the Eastern States and the adjacent oceans. The TCO elevation increases from March to May. The areas of TCO elevations shift northward in summer.
- Based on the spring case study, in period 1, the high TCOs over the Baja peninsula are concluded to be mainly due to the stratospheric air intrusion through a wave breaking event.
- At the same time, high TCOs over the West Coast of California result from the enhancement due to the same stratospheric intrusion at the upper troposphere and perhaps the influence of cross-Pacific transport. High ozone values at the surface are also indicated (but not shown).