Phoenix ozone variation due to urbanization and regional transport

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Motivation

Lower tropospheric ozone adversely affects human health, reduces crop yields, and damages natural ecosystems. Therefore, ozone (O_3) is one of the six criteria pollutants regulated by the US Environmental Protection Agency (EPA) through National Ambient Air Quality Standards (NAAQS). The Phoenix metropolitan area is classified as an O_3 nonattainment area under the 2008 NAAQS primary O_3 standard (i.e., 75ppbv). The US EPA has already proposed to lower the standard to 65-70 ppbv (EPA 2014) and may also redefine the national O_3 secondary standard for protecting sensitive vegetation and ecosystems.

Improved understanding and attribution of [O_3] sources in Phoenix is necessary to develop effective air quality management strategies to achieve ever more stringent US air quality standards.

High Resolution WRF-Chem setup

WRF-Chem model System:

WRF-Chem is the Weather Research and Forecasting (WRF) model online coupled with Chemistry (Figure 1. http://wrf-model.org/WG11). This model includes multiple options on the parameterization schemes of atmospheric dynamics, physics, dispersion, and chemistry processes based on users' requirements.

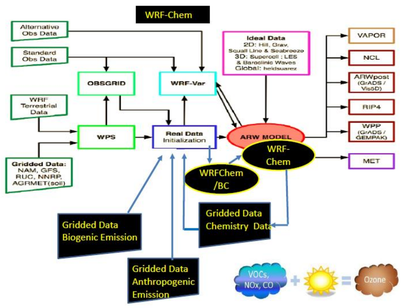

Figure 1: WRF-Chem system

The model simulates the emissions, transport, mixing, and chemical transformation of trace gases and aerosols simultaneously with meteorology.

Model setup in this study

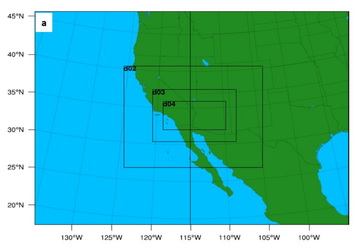

Figure 2: Model domains

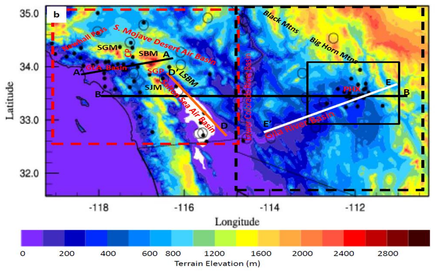

Figure 3: Terrain (m) in Domain 4 and others

Model physics and chemistry

RADM2 chemistry; MDAE/SORGAM aerosol; MAGAN biogenic emissions; NEI05 anthropogenic emissions; and Wesely dry deposition.

We have developed a new method to downscale the 4-km resolution NEI05 data to 1-km resolution. In comparison with the default method provided by WRF-Chem developers, our method made great improvement in simulating pollutant concentrations (Li et al. 2014), as shown in Figure 5.

We use the episode of May 14, 2012 as example presenting here. On this day, there were 12 observation sites where daily maximum 8-hr average (DMA8) ozone concentrations ([O_3]) were over 80ppb in Phoenix area.

We employ WRF-Chem to investigate the possible sources attributing to this high [O_3] through a series of sensitivity studies.

Results: Model Validations

Wind comparison between observations and simulations

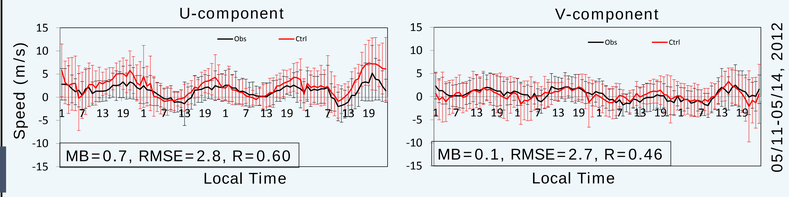

Figure 4: Surface wind comparisons between simulations (red) and observations (black). The time period is May 11 to 14, 2012. There are total 20 sites, including those in CA and AZ with locations shown in Figure 3 as circles. The error bars represent the standard deviations. Mean Biases (MB), RMSE and correlation coefficient R are labeled also. Ctrl represent WRF-Chem CTRL run (running WRF-Chem as usual).

Pollutant comparisons between observations and simulations

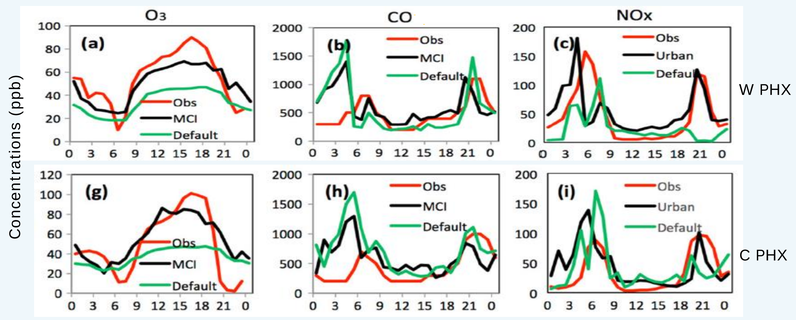

Figure 5: Comparisons of ground-level O3, CO and NOx concentrations from observations and simulations at West Phoenix and Central Phoenix site. MCI represents model simulations with anthropogenic emissions downscaled using MCI method. Default represents model simulations with anthropogenic emissions downscaled using the default method. More on ozone comparison can be found in our ERL paper (Li et al. 2014).

Results: Impact of urbanization on ozone concentrations

To do this research, we have conducted another run: everything is the same as control(MCI) run, but remove the urban land cover in WRF-Chem. The differences of [O_3] are shown in Figure 6:

This figure shows that urbanization results in the nighttime [O_3] increase for about 10-20 ppb(Fig. 6c) while causes no change during daytime(Fig.6a).

The DMA8 [O_3] differences show that urbanization increases about 2-4 ppb in the NE and SE region(not shown).

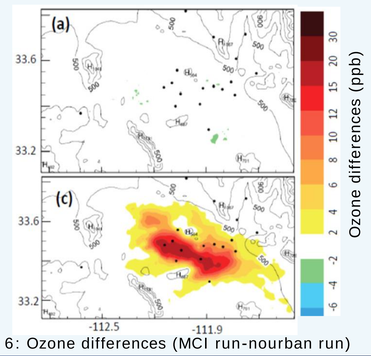

Figure 6: Ozone differences (MCI run-nourban run)

Results: Impact of pollutant regional transport on PHX [O_3]

To do this research, besides control run (CTRL), other three extra runs are conducted: Everything is the same as CTRL, but close anthropogenic emissions in southern California (noCA); Everything is the same as CTRL, but close Arizona anthropogenic emissions (noAZ); Everything is the same as CTRL, but close all anthropogenic emission in Domain 4 (as shown in Figure 3), keeping biogenic emissions only (BEO).

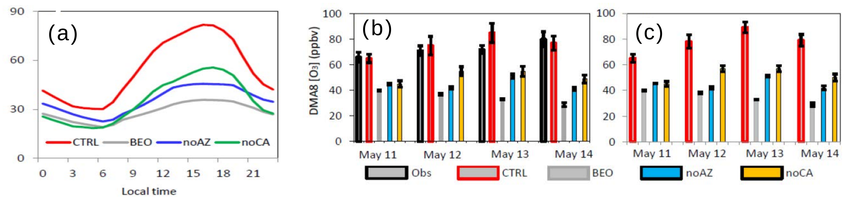

Figure 7: (a)simulated mean diurnal variation of [O_3] at Phoenix urban setting for different emission scenarios averaged from May 11-14, 2012; (b)DMA8 [O_3] in Phoenix area from observations (Obs), simulations from CTRL, noAZ, noCA and BEO simulations, respectively, averaged from observation sites; and (c) the same as (b) but for all metropolitan urban area grid cells.

Figure 7 indicate that AZ emissions are the main sources for Phoenix [O_3] variations. Assuming that the contribution of SoCal to DMA8 [O_3] in the Phoenix area is the difference between the CTRL and noCA experiments. So SoCal emissions contribute to PHX ranges between 20 – 30 ppbv (Relative to the CTRL run, the percentage contributions of 26% - 36%). The DMA8 [O_3] from the BEO experiment are in excess of 30 ppbv.

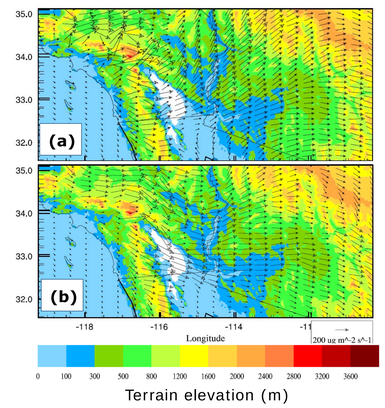

Figure 8: Integrated ozone transport flux differences (CTRL-noCA) from surface to 1400 m above ground-level: (a) average from 18Z to 02Z, May 11 to May 14, 2012, and (b) average from 03Z to 17Z, May 11 to 14,2012.

Transport pathway is clear to be presented.

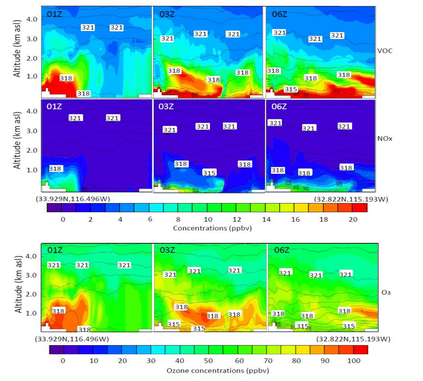

Figure 9:The vertical distribution of VOC (top), NOx (middle), and O_3 (bottom) along the cross-section D'D (shown in Figure 1b) in Salton Sea Basin at 01Z, 03Z, and 06Z, May 13, 2012. Contours are potential temperature with 1-K interval.

Vertically presents the transport processes.

References

Li, J. Georgescu, M, Hyde P, Mahalov A, and Moustaoui M, 2014: Achieving accurate simulations of urban impacts on ozone at high resolution. *Environ. Res. Lett.* **9**(2014),114019.

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