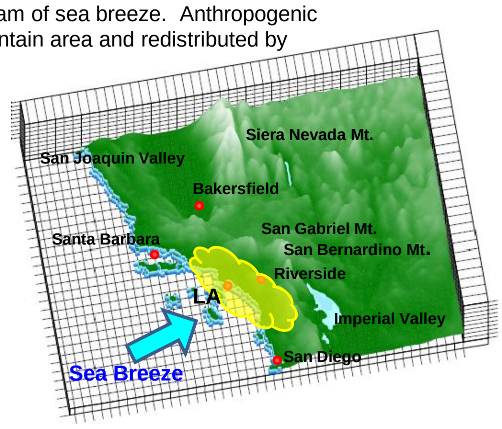
Vertical Circulation of Air Pollutants and Ozone Distribution over Los Angeles

Hiroaki Minoura[1,2], Darko Koracin[3], Joshua S. Fu[4], Xinyi Dong[4], and Cheng-En Yang[4]

[1]Toyota Motor North America, 1555 Woodridge Ave., Ann Arbor, MI, U.S.A.
[2]Toyota Central R&D Labs. Inc., Nagakute, Aichi, Japan
[3]Desert Research Institute, 2215 Raggio Parkway, Reno, NV, U.S.A.
[4]University of Tennessee, 59 Perkins Hall, Knoxville, TN, U.S.A.

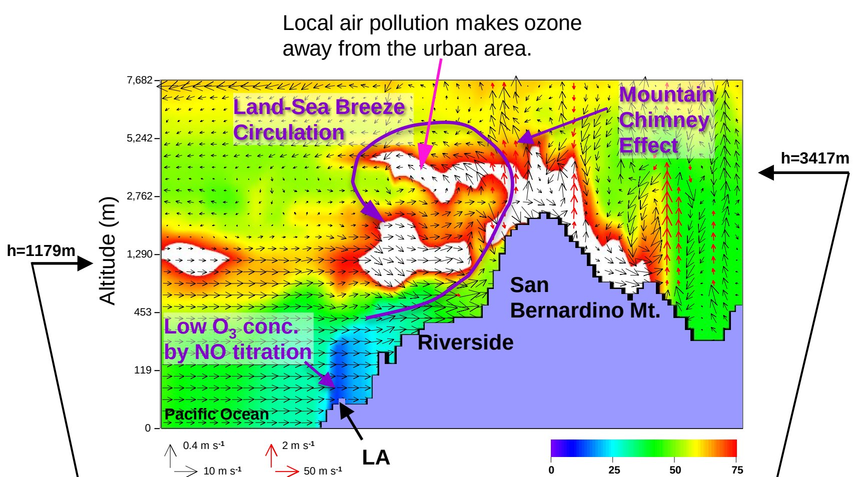
Why vertical analysis necessary?

Los Angeles is in the unique geographical situation surrounded by 2000m class mountains downstream of sea breeze. Anthropogenic air pollutions are gathered at mountain area and redistributed by mountainous complicated flow.



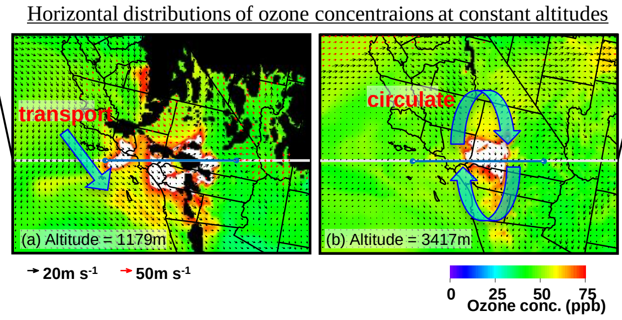
Local vs transported

Mountain chimney effect promotes vertical circulation and ozone formation begins with transported NOx concentration decrease.



A latitude cross-section of ozone distribution at 18:00 July17

Horizontal distributions of ozone concentraions at constant altitudes



Ozone and ozone precursor transported from northwest at the top of the PBL height.

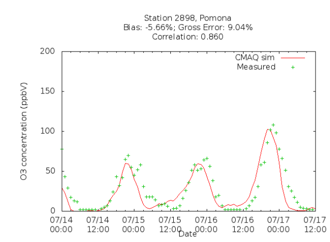
Ozone generated from local air pollution stayed (not transported but rotated) above the PBL.

Summary

1. By using CMAQ ready horizontal wind data, vertical wind velocity was estimated. In a latitude cross-section including Los Angeles (LA), counter clockwise air flow promoted by the mountain chimney effect was revealed in the west side of San Bernardino Mt. (SB-Mt).
2. The vertical circulation transported the urban air pollution between LA and Riverside (RS), and produced a high ozone concentration above the PBL.
3. A high ozone concentration of ozone (hot spot) near the urban area between LA and RS with high HNO_3 concentration suggests ozone formation by fresh air pollutants. A hot spot over the Pacific Ocean with high H_2O_2 suggests ozone formation by aged air pollutants transported from the northwest.
4. The on-road gasoline vehicle emission (anthropogenic emission) contributed ozone formation far away from the source, in contrast, the biogenic emission (natural emission) contributed near the urban area.
5. By the vertical distribution analysis, it is confirmed that the local air pollution contribution can be clearly distinguished with the contribution of transported air pollution.

CMAQ air quality simulation

AQ model	CMAQ 4.7.1
date	July 14 – July 19, 2005
domain	South CA, 229 x 169 @ 4km, 41 vertical layers
emission	EPA 2005NEI + SMOKE with WRF Base case, 7 emission sources (on-road gasoline, on-road diesel, off-road gasoline, off-road diesel, residential, industrial, biogenic)



Example of O_3 concentration comparison

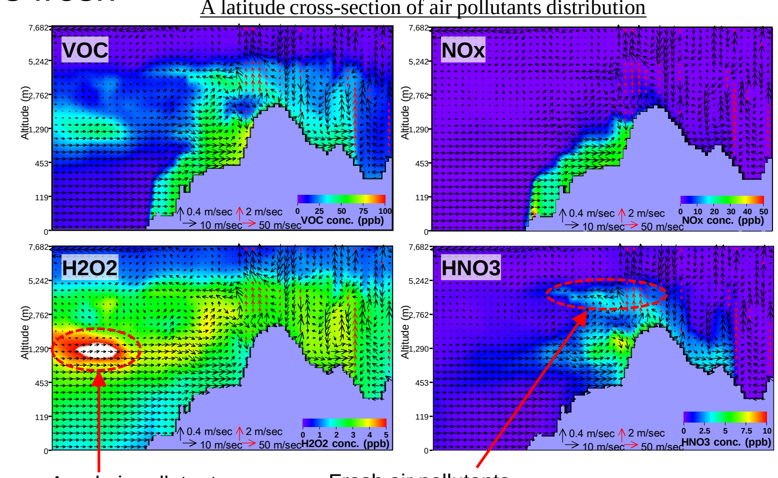
Evaluation results using 43 EPA monitor data

Evaluation items	Evaluation equation	Simulation results	Tolerance of the EPA
Mean Normalized Bias (MNB)	$MNB = \frac{1}{N}\sum_{i=1}^{N}\frac{M_i - O_i}{O_i}$	9.5%	< 15%
Mean Normalized Gross Error (MNGE)	$MNGE = \frac{1}{N}\sum_{i=1}^{N}\frac{\lvert M_i - O_i\rvert}{O_i}$	15.4%	< 30%
Peak Accuracy (PA) ratio	$PA = \left(\frac{MNB}{MNGE}\right)_{max\ conc.}$	16.3%	< 20%

CMAQ simulation showed a good agreement with monitored ozone concentration.

Aged vs fresh

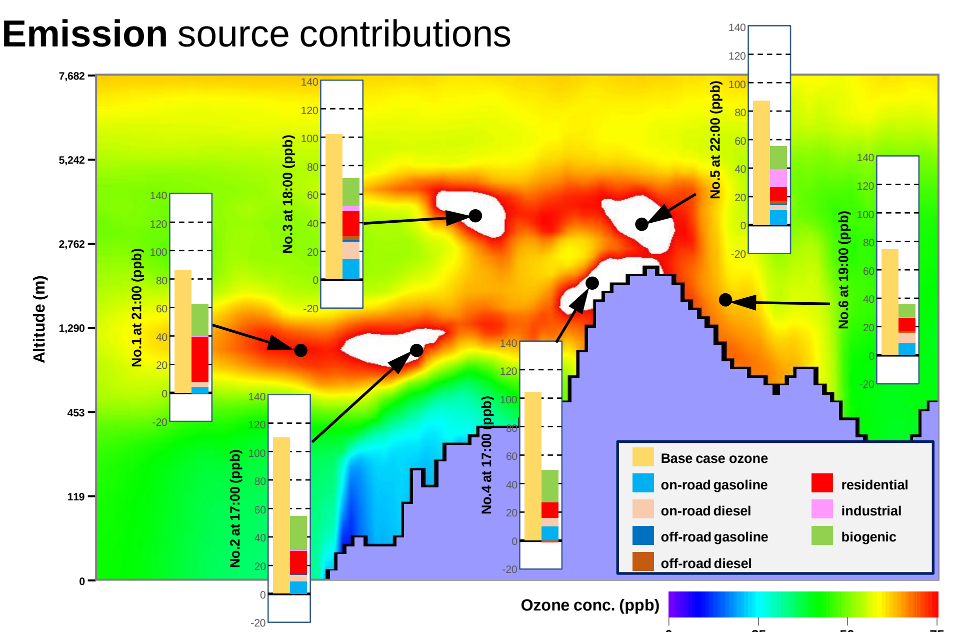
A latitude cross-section of air pollutants distribution



Aged air pollutants

Fresh air pollutants

Emission source contributions



Time averaged hot spot distributions (high ozone concentrations of more than 75ppb) from 13:00 to 23:00 on July 17 and emission source contributions at typical points.

On-road gasoline emission contribution to ozone formation appears to be small (4.8%) near the urban area but large (13.9%) above the PBL outside of the urban areas.
In contrast, the biogenic contribution was large (21.6%) near the urban area and small (19%) at remote places above the PBL.