Why Models Overpredict Summertime Boundary Layer Ozone in Central East China?
-The Role of East Asia Summer Monsoon-

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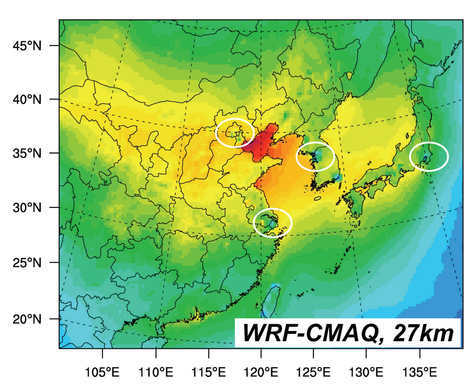
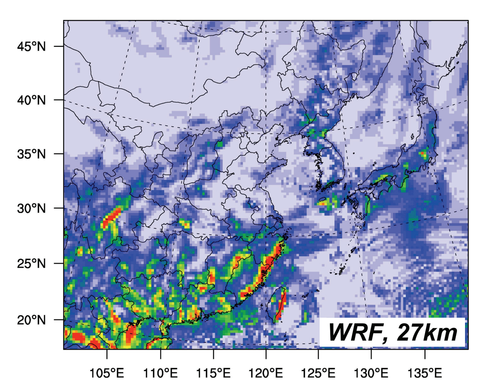
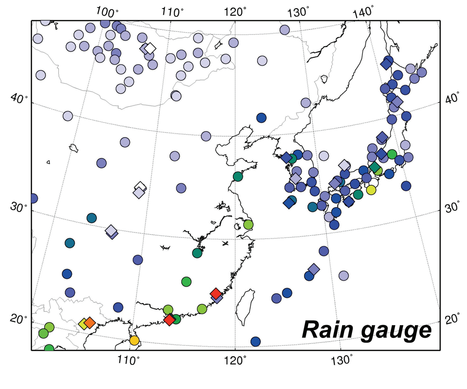
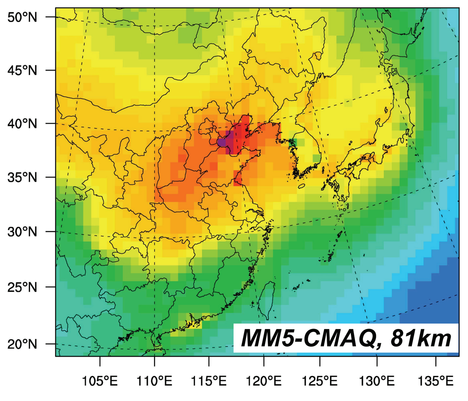
Overview: This study employs the Community Multi-scale Air Quality (CMAQ) model driven with both MM5 and WRF regional climate models to examine mechanisms controlling boundary layer (BL) ozone (O_3) over East Asia. We find that the BL O_3 budget shows complex interactions among photochemical production, vertical mixing, Asian monsoon circulation, and global pollution inflows. For example, East Asia summer monsoon (EASM) plays a key role controlling the simulated and observed summer minimum of BL O_3. We have evaluated MM5 and WRF precipitation fields against satellite observation, and find that MM5 underestimates rainfall over many areas, which partly explains why MM5-CMAQ overpredicts summertime O_3 at Beijing and two mountain sites in North China Plain. Inter-annual variability of EASM and its potential impact on O_3 concentrations are also discussed.

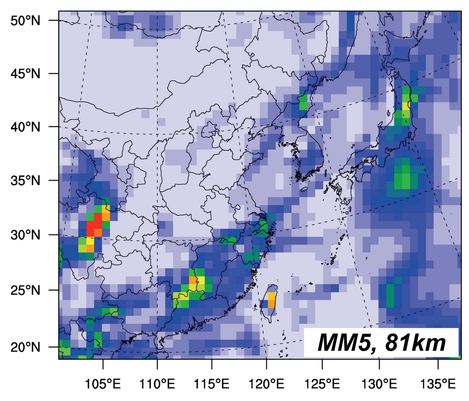
Regional Climate Model Performance in Simulating East Asia Summer Monsoon and Associated Impacts on Near Surface Ozone

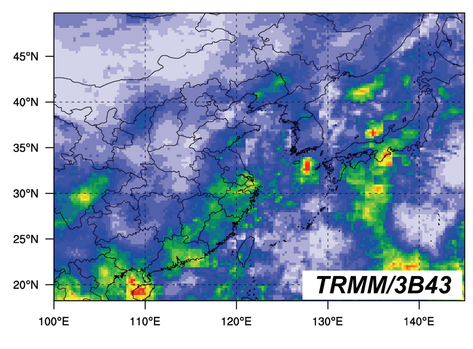






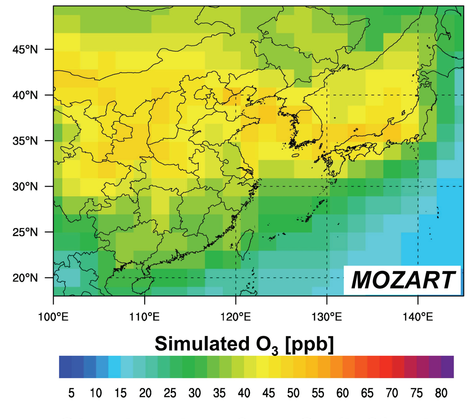






Simulated Precipitation [mm/day]
0 2 4 6 8 10 12 14 16 18 20

Observed Precipitation [mm/day]
0 2 4 6 8 10 12 14 16 18 20



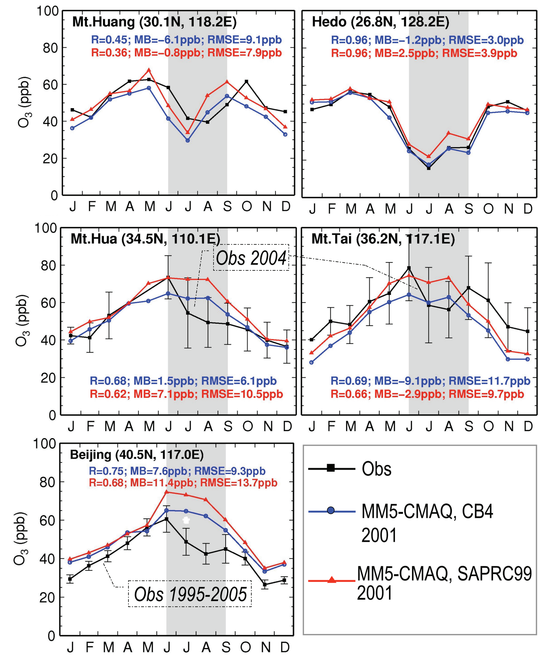
Simulated O_3 [ppb]
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

Physics	MM5	WRF
Land Surface	Noah	Noah
Reanalysis	NCEP/NCAR (2.5x2.5°, 6hr)	FNL (1x1°, 6hr)
Boundary layer	MRF	YSU
Microphysics	REISNER1	WSM-6
Longwave radiation	Cloud	RRTM
Cumulus parameterization	Grell	Kain-Fritsch
Depth of first model layer	~73 m	~20 m
Analysis nudging	Yes	Yes
Initialization	Annual continuous run	re-initialize every 5.5 days, first 12 hr data not used

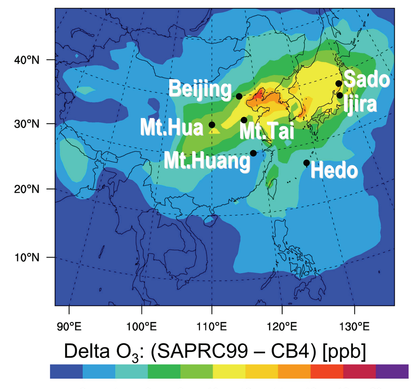
Simulated surface O_3 (left), simulated precipitation (middle) , and observed precipitation (right) in Aug. 2001

- Both MM5-CMAQ and WRF-CMAQ are driven with chemical boundary conditions from the MOZART global model.
- Clear benefit of high resolution model in capturing fine scale regional processes, i.e., NO_x titration of O_3 in mega-cities
- MM5 generally underestimates rainfall as compared with both TRMM satellite data and ground-based rain gauge [2], which partly explains why CMAQ overpredicts surface ozone in central east China and Japan.
- Increasing rainfall in WRF leads to ~10 ppb decrease of surface O_3 in CMAQ.
- The WRF re-initialization every 5.5 days using reanalysis data and Single-Moment 6-Class Microphysics (WSM6) scheme are likely main reasons for the improving predictions of rainfall in WRF.

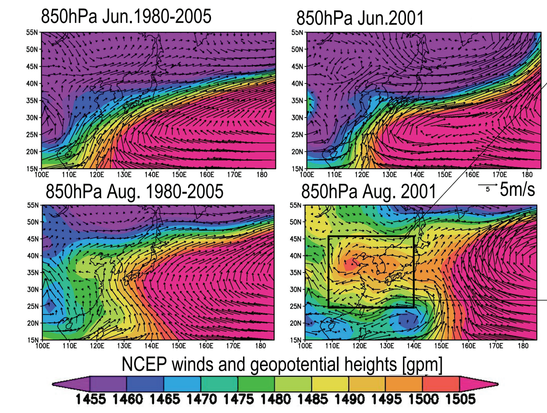
Seasonal Cycle of Boundary Layer Ozone: Impacts of Monsoon Circulation and Photochemistry

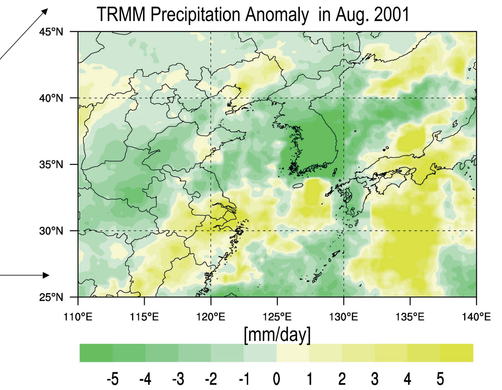


Seasonal cycle of surface ozone [3]

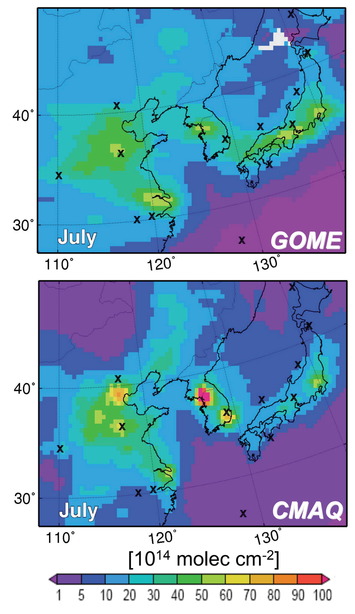


Photochemical sensitivity





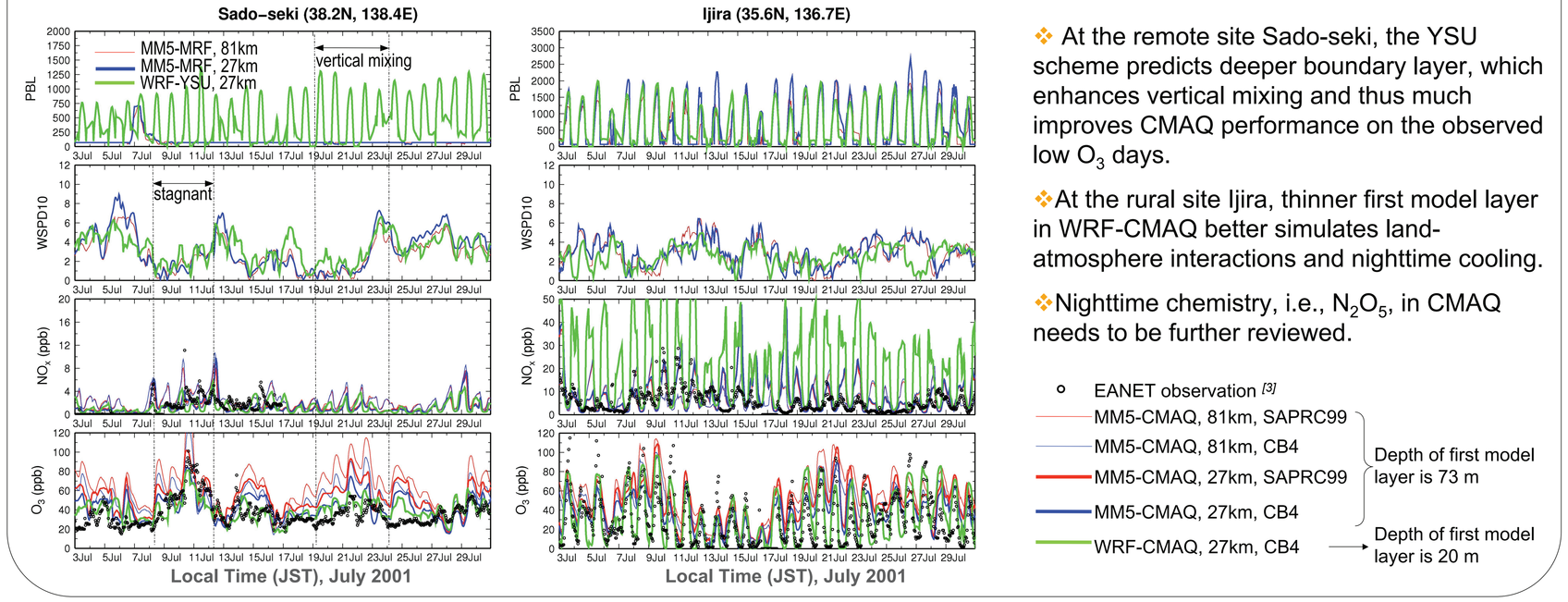
Seasonal and inter-annual variability of East Asia summer monsoon



Tropospheric NO_2 columns from GOME satellite data [4] ***and CMAQ***

- Surface O_3 at lower latitude exhibits a summer minimum due to monsoonal intrusion of low-O_3 marine air masses fro tropical Pacific.
- The monsoon band shifts to northwest in August, resulting in more frequent cloudy and rainy weather in central east China as contrast to June and explains the sharp drop in observed O_3 during July and August.
- EASM over North China Plain is weaken in August 2001 (weak La Nina year) , which might increase surface O_3 as simulated by the model.
- CMAQ well reproduces the satellite-derived NO_2 columns, suggesting overprediction of summertime O_3 is not due to the errors of NO_x emissions.
- Pronounced photochemistry sensitivity over central east China and downwind areas also contributes to the overprediction of summertime O_3.

Day-to-day and Diurnal Variations of Near Surface Ozone: the Role of Boundary Layer Mixing



- At the remote site Sado-seki, the YSU scheme predicts deeper boundary layer, which enhances vertical mixing and thus much improves CMAQ performance on the observed low O_3 days.
- At the rural site Ijira, thinner first model layer in WRF-CMAQ better simulates land-atmosphere interactions and nighttime cooling.
- Nighttime chemistry, i.e., N_2O_5, in CMAQ needs to be further reviewed.

[1] This work was supported by NASA Grant NNX07AL36G.

[2] The TRMM (Tropical Rainfall Measuring Mission) data were provided by the NASA/GSFC's Laboratory for Atmospheres and TSDIS. Ground-based rain gauge data were obtained from NOAA/Climate Data Online System and EANET.

[3] Ozone measurement data in China and Japan was obtained from EANET, Ding A. et al. (2008), and Li J. et al. (2007).

[4] The GOME (Global Ozone Monitoring Experiment) data were based on Richter A. et al. (2005)