Measurement and Modeling of Air Quality for Bangkok, Thailand

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INTRODUCTION:

Thailand has experienced rapid industrialization and urbanization in the past 3 decades which has led to an adverse impact on urban air quality. Majority of the country's development has occurred within and around Bangkok (BKK), the capital city of Thailand; and Bangkok Metropolitan Region (BMR). The increase in emissions is due to accelerated growth in automotive and industrial activities. Since 1995, BMR has begun to experience air quality degradation, in particular, enhanced ozone (O_3) due to elevated O_3 precursor emissions, strong solar radiation, high temperature and high humidity.

OBJECTIVES:

1) Perform observational and modeling-based analyses to characterize air quality in BMR.
2) Analyze the relationship between O_3 and its precursors (NO and NO_2) in BMR.
3) Analyze effects of local and regional contribution on O_3 in the BMR.

METHODOLOGY:

Observational-Based Analysis:

1) Analyze hourly observations from 15 monitoring stations located in BMR in 2010 to 2014 (collected by the Pollution Control Department, Thailand).
2) Classify the monitoring stations into 3 groups including BKK sites, roadside sites, and BKK suburban sites.
3) Investigate O_3 concentrations and the interplay between pollutants and meteorology in BMR.

Modeling-Based Analysis:

1) The Weather Research and Forecasting with Chemistry (WRF-Chem) model version 3.9.1 is used.
2) A three month simulation during Thailand's "dry" (i.e., Northeast Monsoon) season in 2010 is simulated.
3) Assess the model performance compared to observed meteorology and O_3 in BMR.

STUDY AREA:

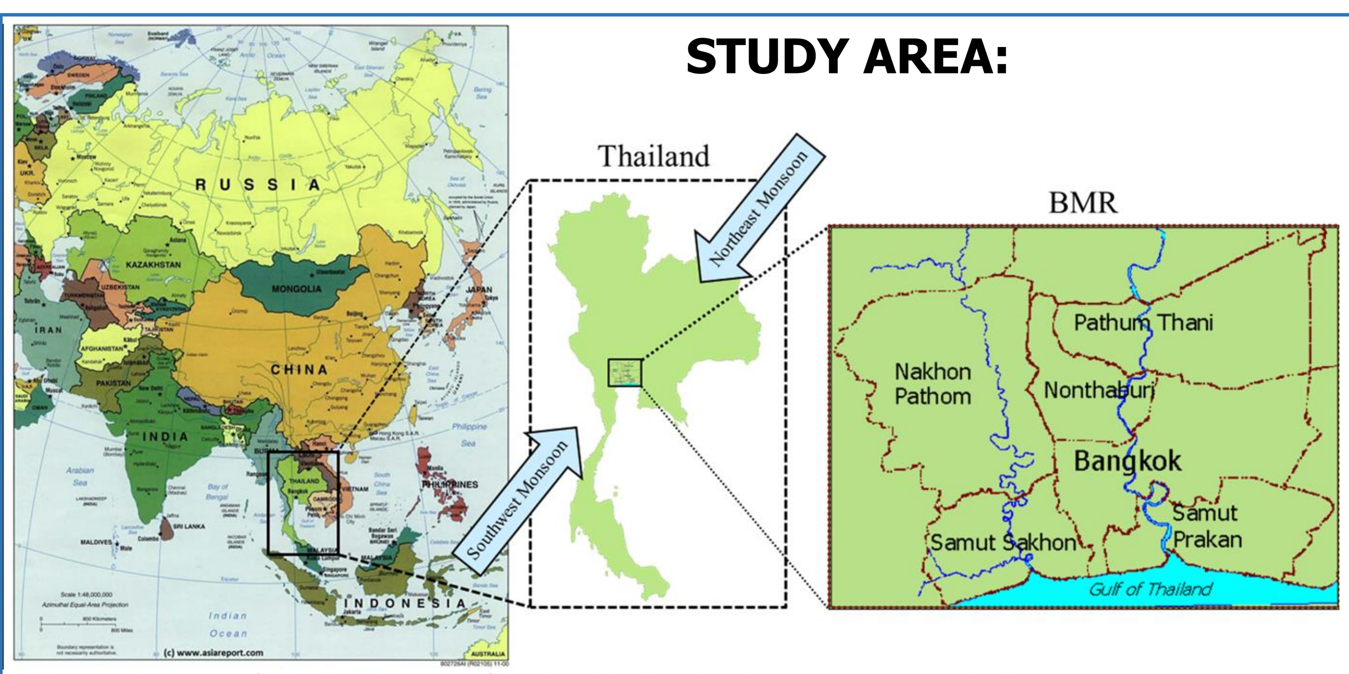


Figure 1: map of Thailand, map of BMR with the dominant monsoon winds

RESULTS:

Observational-Based Analysis

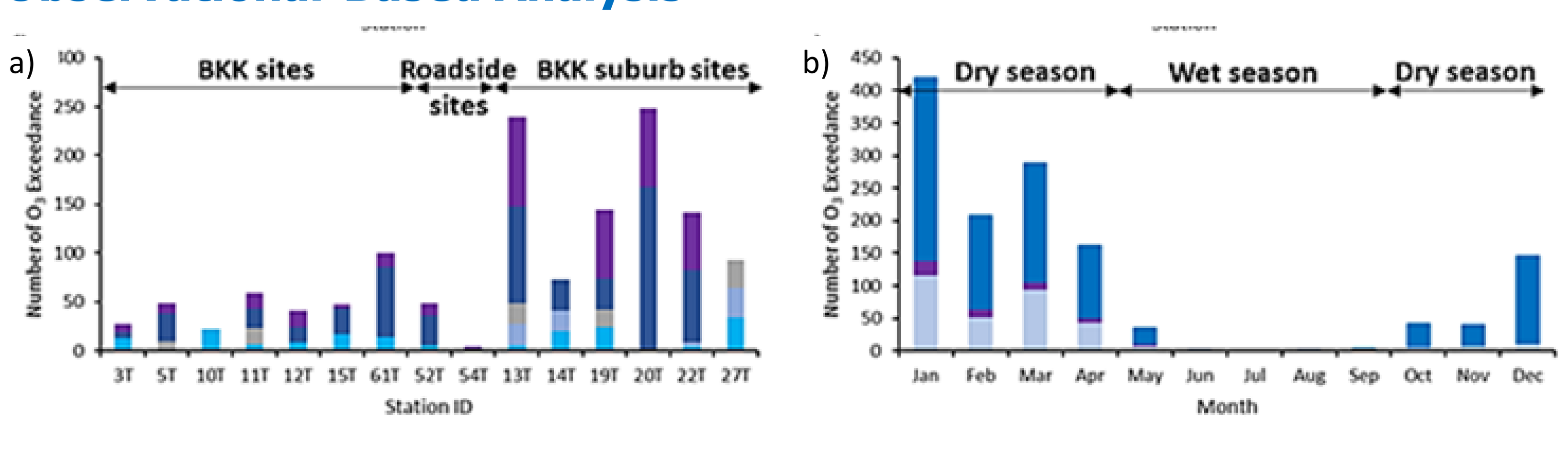


Figure 2: number of hourly O_3 exceedances is shown by a) locations and b) seasons.

1) O_3 concentrations ($[O_3]$) exceeded the National Ambient Air Quality Standard of Thailand (100 ppb), especially during the dry seasons and occurred at BKK suburb sites more frequently than other sites.

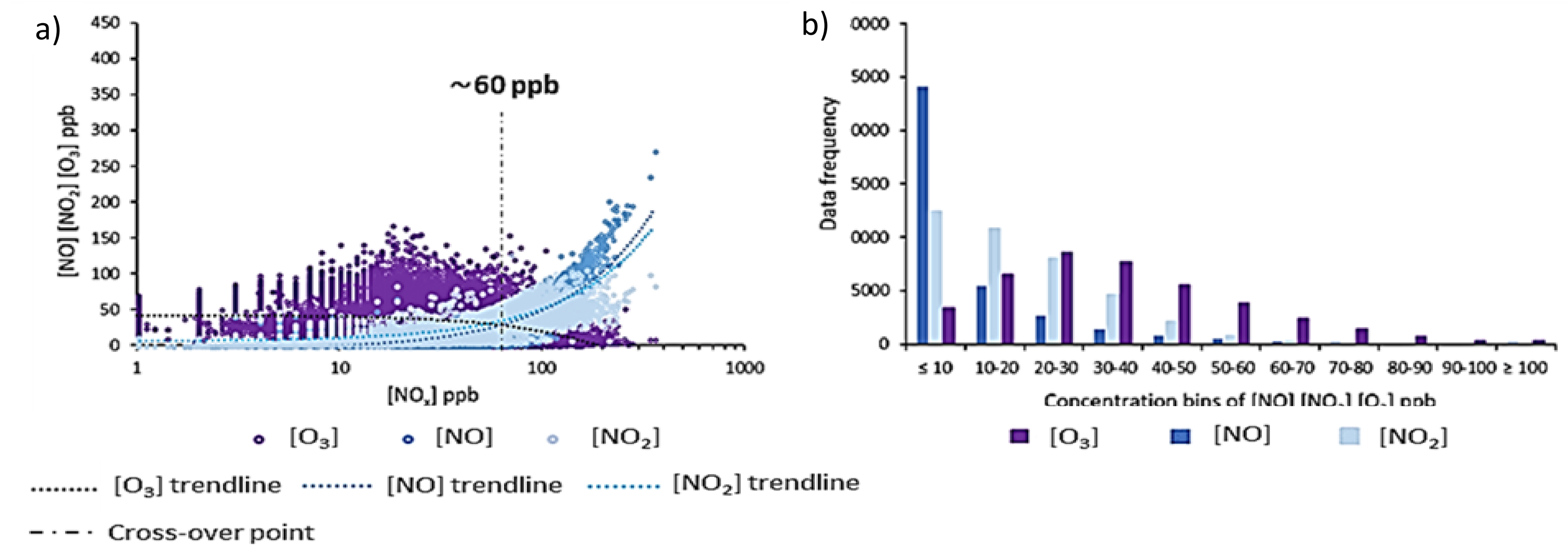


Figure 3: (a) Relationships and crossover points of NO, NO_2 and O_3 (only at BKK sites is shown), (b) distribution of data

2) Interconversion between O_3, NO and NO_2 indicates crossover points between the species occur when $[NO_x]$ (NO + NO_2) is ~60 ppb. O_3 dominates when $[NO_x]$ < 60 ppb, but NO dominates when $[NO_x]$ > 60 ppb.

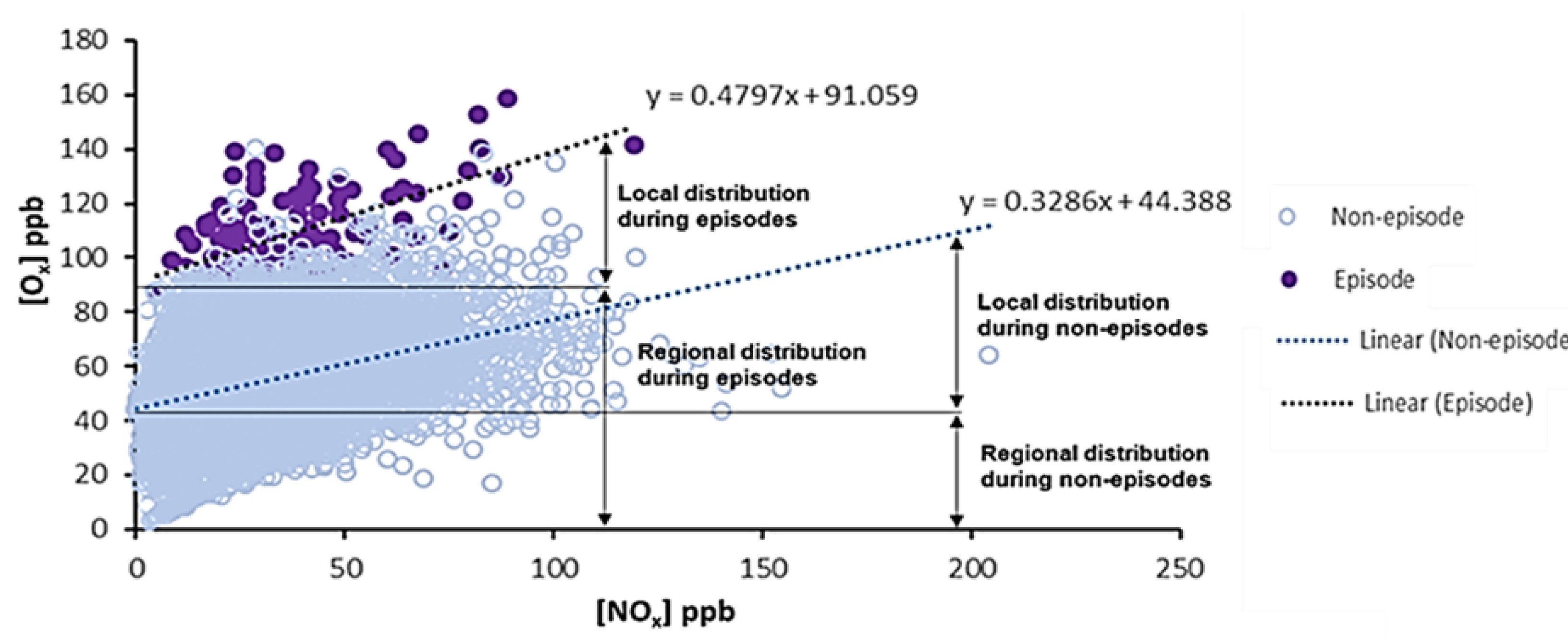


Figure 4: Effects of local and regional contributions on O_x during non-episode and episode days (only at BKK sites is shown)

3) O_3 episodes (hourly $[O_3]$ > 100 ppb) in BMR were due to (1) atmospheric stagnant conditions (WS < 4 ms^{-1}), (2) origin of the air masses, and (3) local and regional contributions of O_x (O_3 + NO_2).

RESULTS:

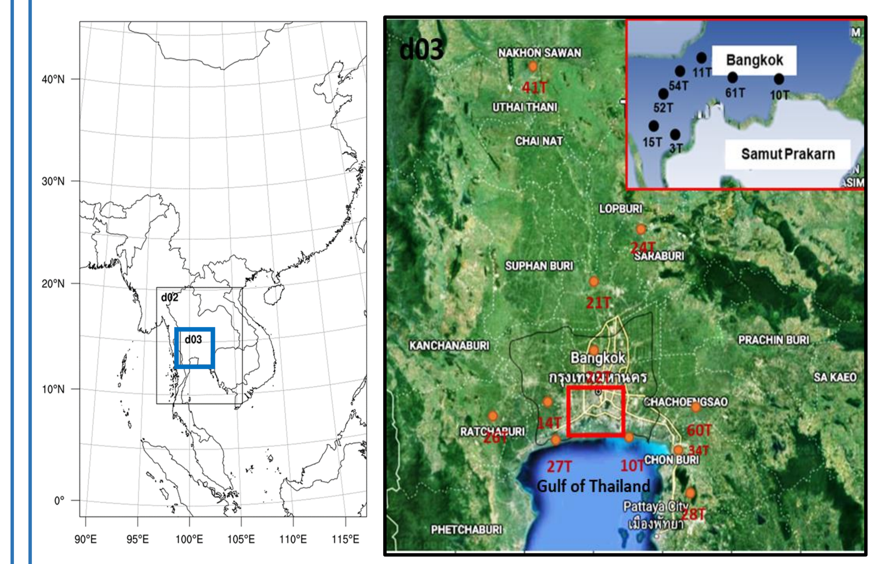
Model-Based Analysis (WRF-Chem)

Model Configurations

Table 1: Model configurations listed for WRF-Chem

Setting	Selection
Domain setting	Triple-nested domain (36-, 12- and 4-km horizontal resolutions)
Emissions:	Anthropogenic emissions: EDGAR-HTAP Biogenic emissions: online MEGAN
Meteorological data	NCEP-FNL
Initial/Boundary conditions	MOZART
Physics	
Microphysics	Thompson
Long wave radiation	A new version of Rapid Radiative Transfer Model (RRTMG)
Short wave radiation	RRTMG
Planetary boundary layer	Yonsei University
Cumulus physics	Grell-Freitas (only domain 1 and 2)
Chemistry	
Chemical mechanism	RADM2-MADE/SORGAM
Biogenic emission	Online MEGAN
Photolysis	Madronich F-TUV photolysis
Dry deposition of gas/aerosol species	Turned on
Subgrid convective	Turned on (only domain 1 and 2)
Aerosol effect in radiation	Turned on
Chemical mechanism	RADM2-MADE/SORGAM
Study period	January 1 to March 31, 2010
Spin-up time	December 18 to 31, 2009

Model Evaluation protocol

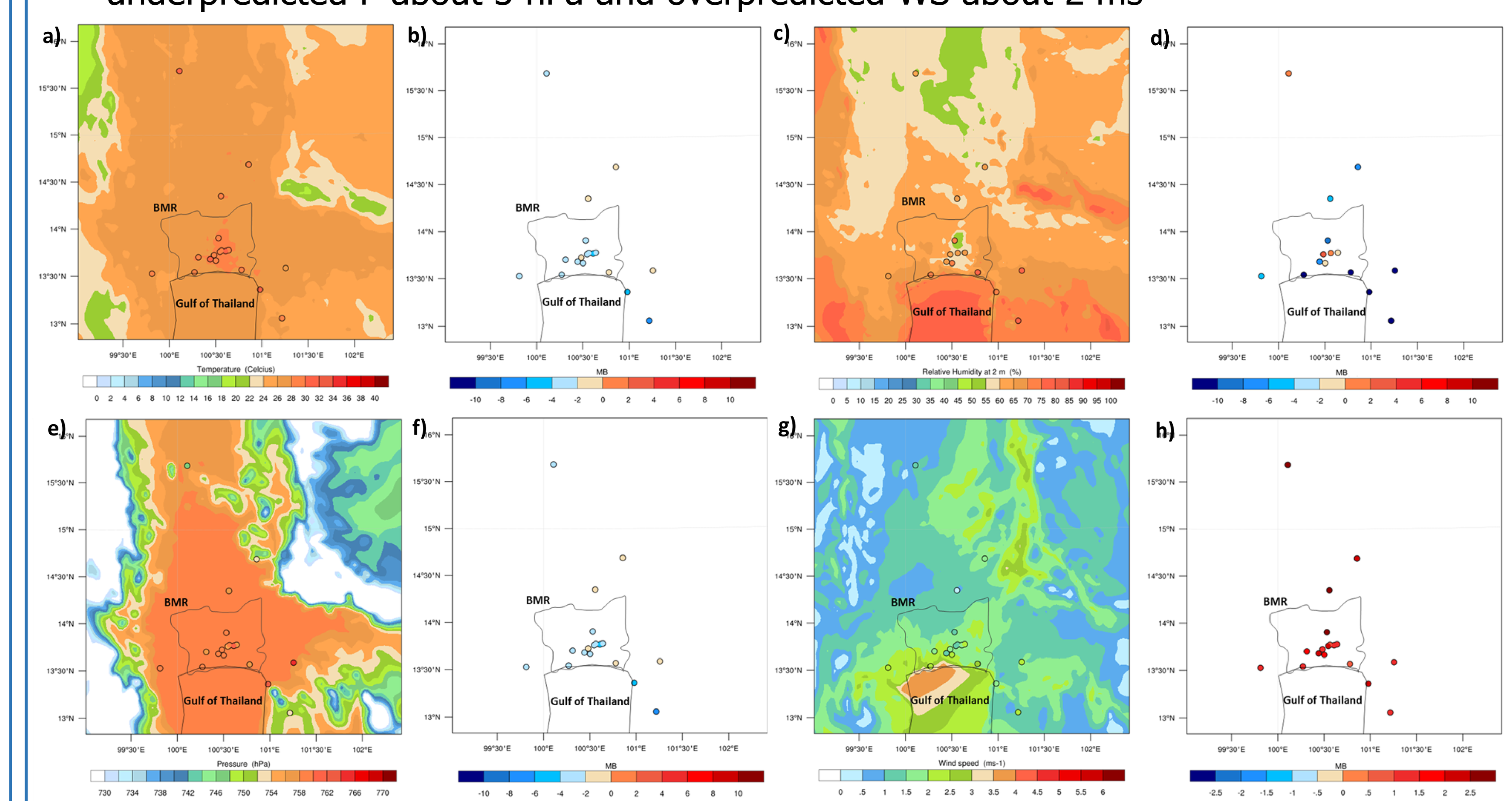


1) Compared model results from innermost 4 km domain against 18 observation sites in the innermost domain
2) Statistics: correlation coefficient (*r*) and mean bias (MB)

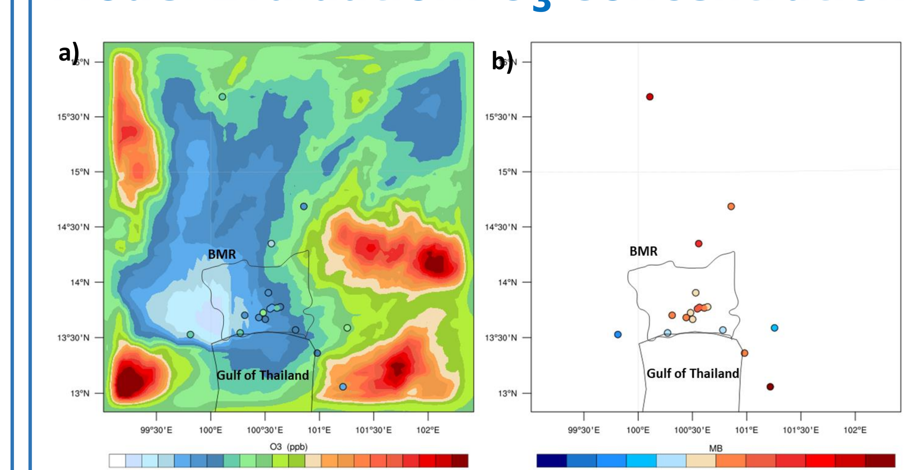
Figure 5: Model domains including outermost domain (d01), the 2nd domain (d02), the innermost domain (d03) and monitoring sites

Model Evaluation: Meteorology and O_3 Concentrations

1) The model demonstrated high correlation (r) for temperature at 2 m (T2) (*r*~0.8), relative humidity (RH) (*r*~0.7), pressure (P) (*r*~0.7) and wind speed (WS) (*r*~0.1)
2) The model underpredicted T2 about 3 °C, underpredicted RH about 7%, underpredicted P about 3 hPa and overpredicted WS about 2 ms^{-1}



Model Evaluation: O_3 Concentrations



Overall, the model overpredicted average daytime $[O_3]$ (mean obs: 31.6±8.3 ppb, mean sim: 35.2±17.2 ppb, averaged MB: 3.6 ppb)

Figure 7: Comparison between simulations and observations of (a) average of daytime $[O_3]$, (b) average MB of daytime $[O_3]$

CONCLUSION:

1) Observational-based analysis shows the relationship between $[O_3]$ and $[NO_x]$ in BMR.
2) $[O_3]$ episodes in BMR were due to atmospheric stagnant conditions, origin of the air masses, and local and regional contributions of O_x .
3) Overall good model performance of WRF-Chem in simulating meteorology and O_3 in BMR.

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