City-scale top-down verification of NO$_X$ emissions in South Korea using satellite observations

Lee, Jae-Hyeong, Sang-Hyun Lee*

Department of Atmospheric Science, Kongju National University, Gongju, South Korea
Email: ljh0226@kongju.ac.kr, sanghyun@kongju.ac.kr

1. Introduction

Anthropogenic NO$_X$ (=NO+NO$_2$) emissions play an important role as a precursor of forming atmospheric ozone (O$_3$) and inorganic particulate matters (PMs). In South Korea, the emissions are attributed to both local anthropogenic sources and the remote sources from adjacent countries of China and Japan. In this study, national NO$_X$ emissions in South Korea of 2010 are top-down verified using satellite-derived NO$_2$ column measurements and the modelled atmospheric concentrations at a city scale.
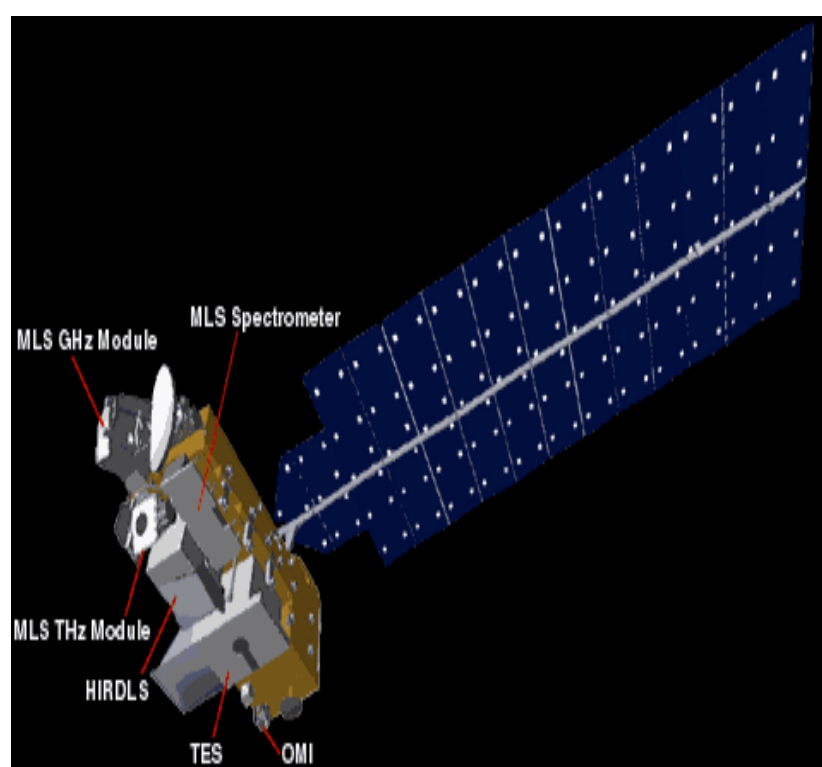
2. Method and data
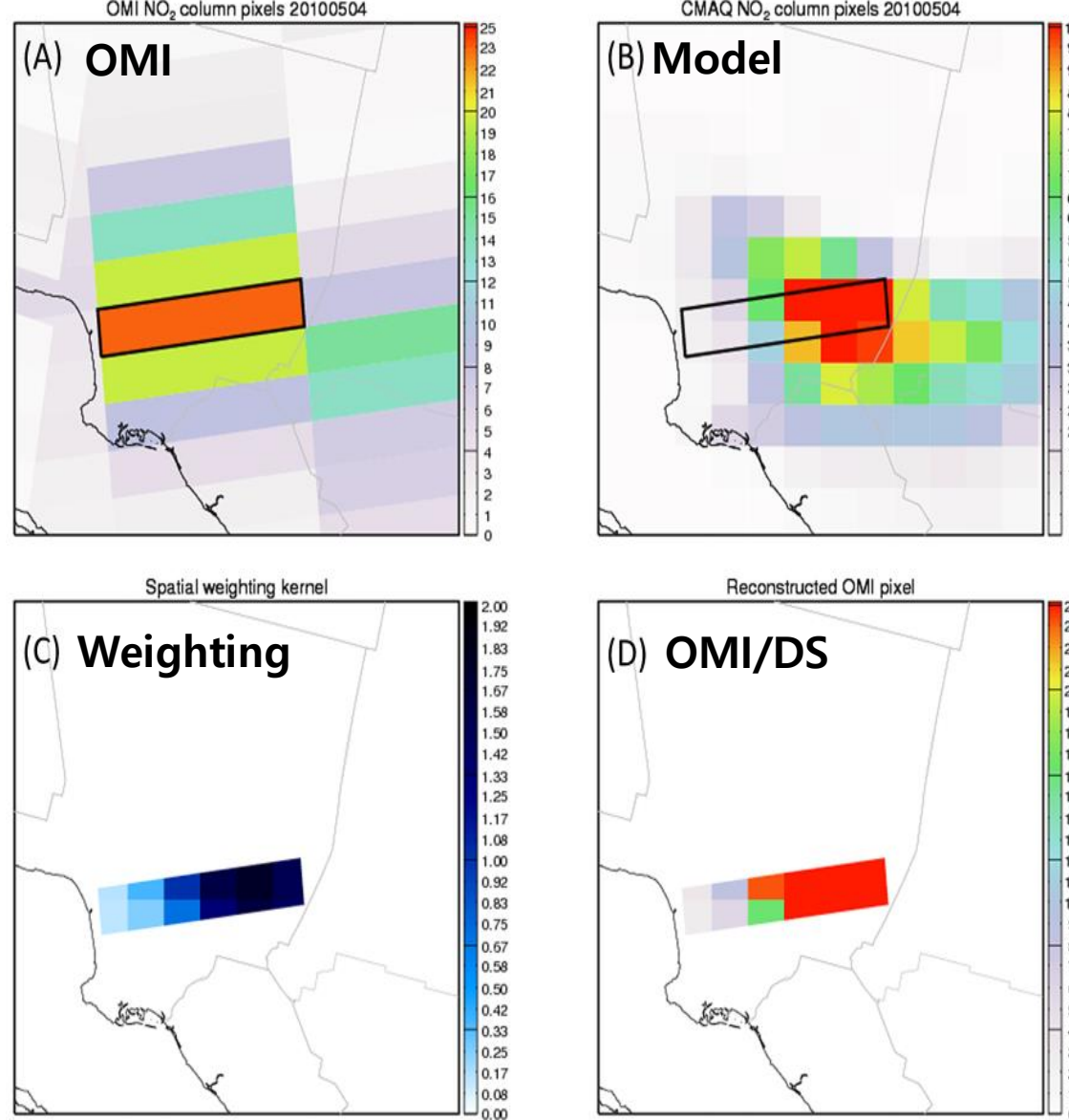
2.1 WRF-Chem model
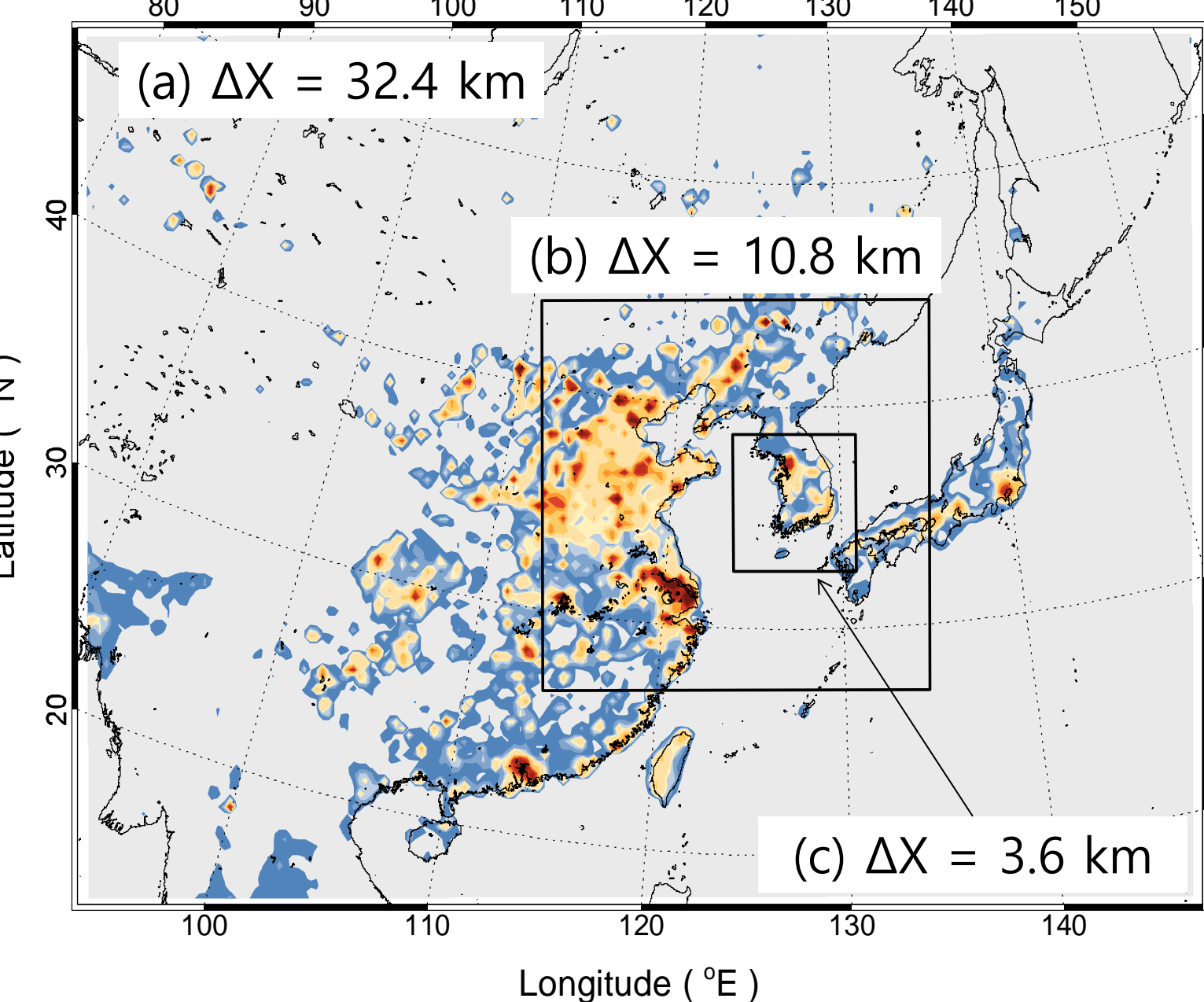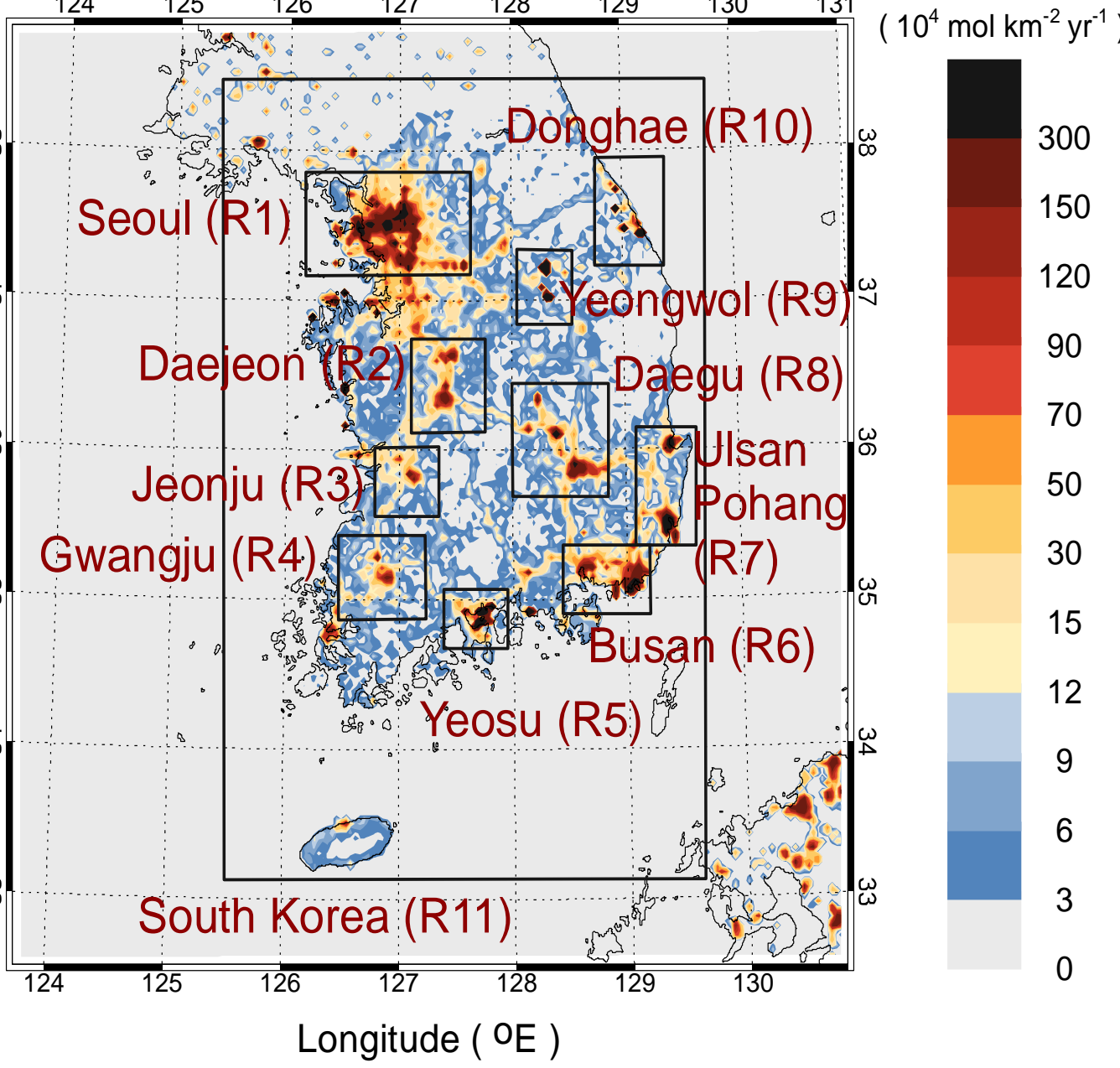
> Configuration of WRF-Chem (Grell et al., 2005)
> → Nested domains: 32.4/10.8/3.6 km
> → Meteorological forcing: NCEP FNL reanalysis data (FDDA grid nudging)
> → RACM (gas) MADE/SORGAM (aerosol)
> → MOZART-4 chemical IC/BCs
> → Anthropogenic emissions: MICS-Asia 2010
> → Biogenic emissions: MEGAN V2
> Simulation: April-September 2010 (6 months)

2.2 NOx emissions

> 10 urbanized areas (rectangles) are defined based on the NO$_X$ emission intensity (R1-R10).
> Total emission amount of the urbanized areas accounts for 68% of the South Korea emissions.
> Each box has at least 50×43 km^2.

2.3 Aura/OMI column NO2 measurements

❖ UV/Vis nadir spectrometer onboard NASA EOS-Aura satellite
❖ KNMI DOMINO v2.0 data

| KNMI/DOMINO v2.0 (Level 2)			
Information	Observation period	Overpass time	Pixel size (nadir)
	2004/07-present	13:45 LST	13×24 km^2
Condition	Cloud Fraction	Pixel size	Surface albedo
	< 0.4	< 1000 km^2	< 0.3

> KNMI OMI NO$_2$ vertical column data (NO$_2$ VCD) are processed following
> Retrieval uncertainties of OMI NO$_2$ (Boersma et al., 2011)
> → AMF (Air Mass Factor) calc.: ~1.0×10^{15} molec. cm^{-2}
> → Spectral fitting: ~0.7×10^{15} molec. cm^{-2}
> → Stratospheric slant columns: ~0.25×10^{15} molec. cm^{-2}

Downscaled (DS) column NO2

Kim et al., (2016)

> Data period: April-September 2010
> Overpass OMI NO$_2$ columns over the South Korea (R11) during the period: 63% (April) ~ 84% (August).
> Downscaled OMI NO$_2$ columns are "mass conservative" (Kim et al., 2013).
❖ Short lifetime of NO$_X$ make the relationship between anthropogenic NO$_X$ emissions and atmospheric NO$_2$ columns directly.

3. Results

### Modelled and observed NO2 columns over South Korea

[Comparison of modelled and observed NO2 VCD]

[WRF-Chem − OMI]
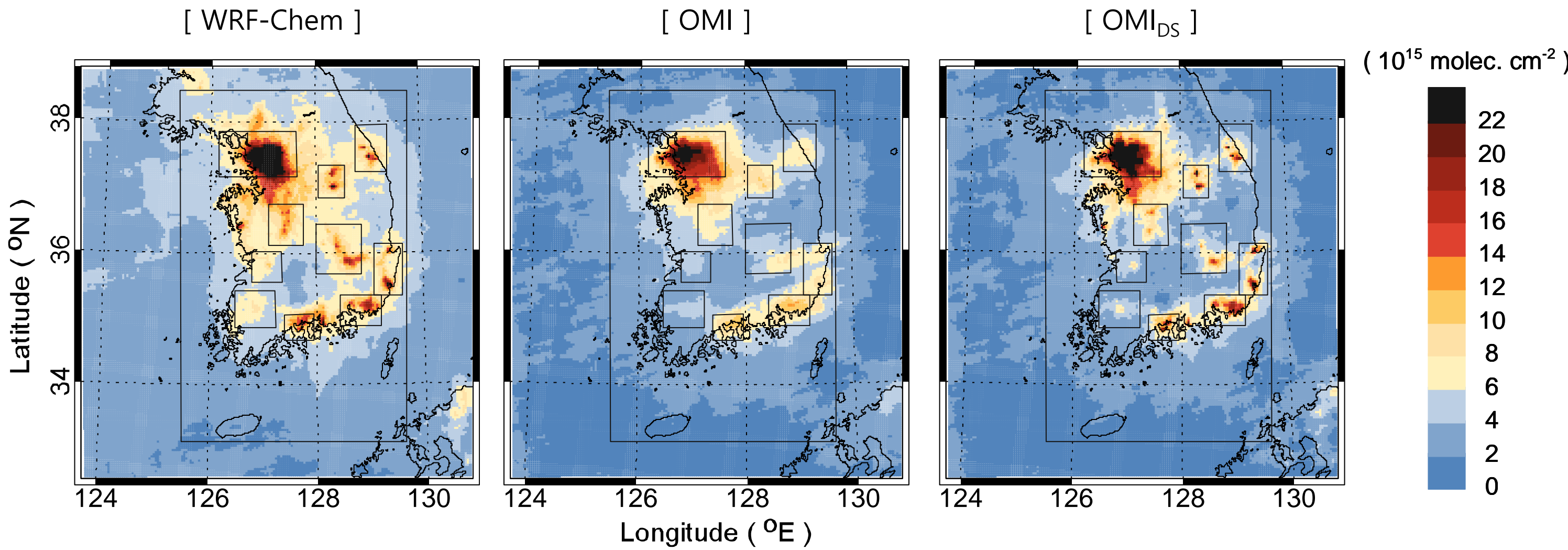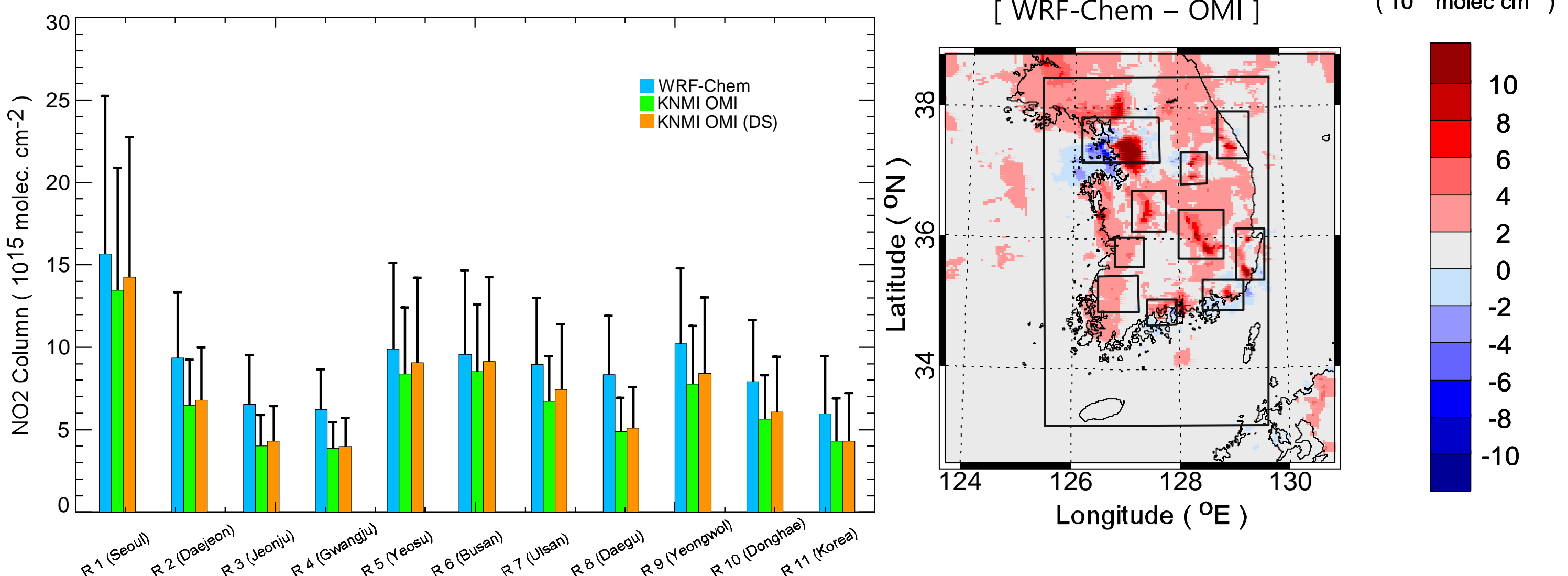
> High NO$_2$ VCD values are apparent in major urbanized areas (rectangles) over South Korea.
> The WRF-Chem modelled NO$_2$ columns are higher at all the urbanized area with a range of 13-69% (40% in the whole South Korea) than those in the observations, indicating that the national emission inventory may slightly overestimates the city-scale NO$_X$ emissions.
> Downscaled NO$_2$ columns reduce the model-observation differences from 4% at region R4 to 14% at region R7, but the overestimation of the modelled emissions remains.

[City-scale comparison of modelled and observed NO2 VCD]
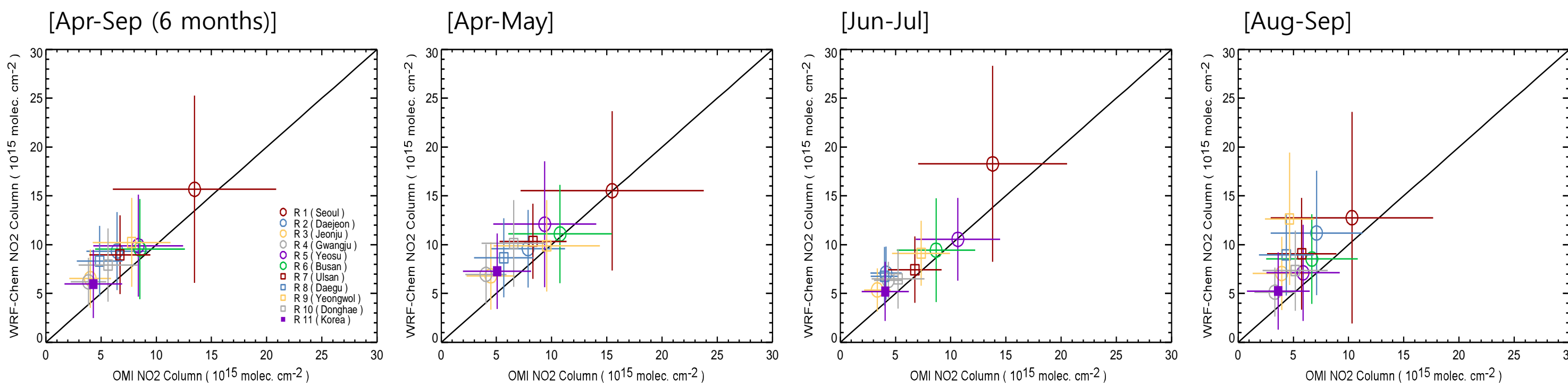
4. Summary and conclusions

> The national anthropogenic NOx emissions over South Korea in 2010 (MICS-Asia 2010) are top-down verified using OMI NO$_2$ column measurements and the WRF-Chem simulated concentrations at 10 urbanized areas.
> The modelled NO$_2$ columns with MICS-Asia 2010 emissions overestimated the observed atmospheric concentrations by 13-69% at the urbanized area (40% in South Korea), which is also valid at different seasons.
> The downscaling approach has a little difference of 4-14% in the interpretation of the results due to increased uncertainties.

References

Boersma, K. F., H. J. Eskes, R. J. Dirksen, R. J. van der A, J. P. Veefkind, P. Stammes, V. Huijnen, Q. L. Kleipool, M. Sneep, J. Claas, J. Leitao, A. Richter, Y. Zhou, and D. Brunner, 2011, An improved tropospheric NO2 column retrieval algorithm for the Ozone Monitoring Instrument. Atmospheric Measurement Techniques, 4, 1905-1928.

Grell, G. A., S. E. Peckham, R. Schmitz, S. A. McKeen, G. Frost, W. C. Skamarock, and B. Eder, 2005, Fully coupled "online" chemistry within the WRF model. Atmospheric Environment, 39, 6957-6975.

Kim, H. C., F. Ngan, P. Lee, and D. Tong, 2013, Development of an IDL-based geospatial data processing framework for meteorology and air quality modeling. Available at: http://aqrp.ceer.utexas.edu/projectinfoFY12_135C12-TN25C12-TN2FinalReport.pdf.

Kim, H. C., P. Lee, L. Judd, L. Pan, and B. Lefer, 2016, OMI NO2 column densities over North American urban cities: the effect of satellite footprint resolution. Geoscientific Model Development, 9, 1111-1123.