Developing a method to adjust CO emissions in North Korea using DMZ ground observations, satellite observations and simulations

Eunhye Kim[1,2], Yang Liu[2], Soontae Kim[1,2]

[1]Department of Environmental & Safety Engineering, Ajou University, South Korea

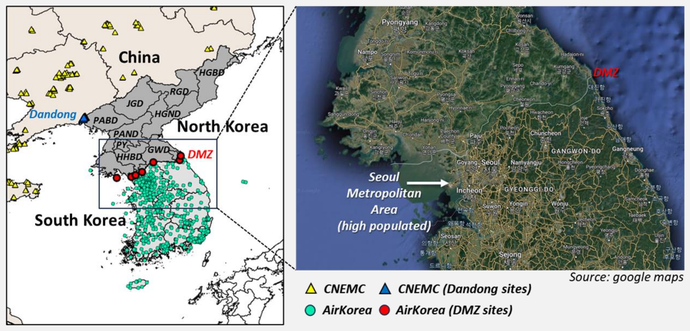
[2]Gangarosa Department of Environmental Health, Rollins School of Public Health, Emory University, GA, USA

Background

- Since North Korea does not release an official emissions inventory (EI), emissions in North Korea are roughly estimated using the limited data.
- Uncertainties in emissions from North Korea can result in errors in studies conducted in neighboring countries based on simulated concentrations with the emissions.
- Therefore, it is essential to use realistic emissions from North Korea for modeling-based air quality research is necessary in Northeast Asia.
- We adjusted North Korean CO emissions by using EI-based simulations, DMZ ground observations, and satellite observations.

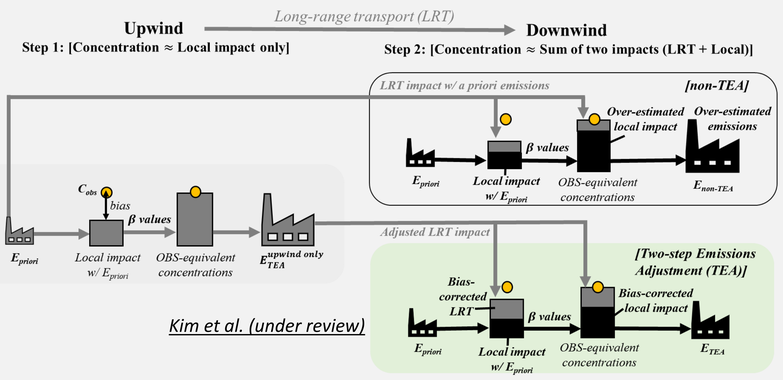
Methodology

Target domain & period



- CMAQ v5.3.2 was utilized for the simulations. The modeling domain covers part of China, North Korea, and South Korea with a 9-km grid resolution.
- The study was conducted from December 2020 to March 2021. During the period, northwesterly winds become predominant; thus, emissions in North Korea may significantly affect the air quality in South Korea.

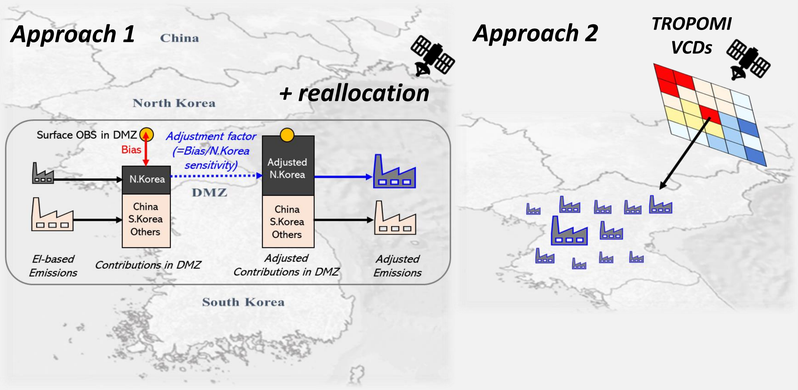
STEP1: Upwind emissions adjustment using TEA



Kim et al. (under review)

- CO emissions in China and South Korea were adjusted prior to adjust North Korean CO emissions using the Two-step Emissions Adjustment (TEA) approach. This approach adjusts downwind emissions of air pollutants with ground observations and EI-based simulations while considering their long-range transported emission impacts from upwind areas.

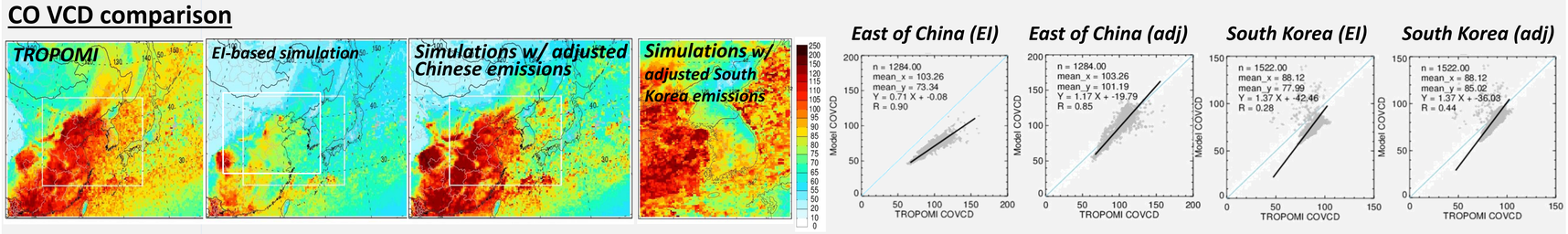
STEP2: North Korea emissions adjustment



- In approach 1, the emissions adjustment factor that minimizes the difference in CO concentrations between ground observations and simulations at the DMZ monitoring stations was estimated and applied to the EI to adjust CO emissions in North Korea. In addition, the adjusted emissions were reallocated using spatial distributions of the EI and satellite-based Vertical Column Densities (VCDs).
- In approach 2, the emissions were adjusted by using the ratio of VCDs from satellite and EI-based simulation.
- To verify the adjusted emissions, the CO concentrations simulated with the adjusted emissions were compared with the ground observations at Dandong stations, which is located at the China-North Korea border as well as DMZ stations.

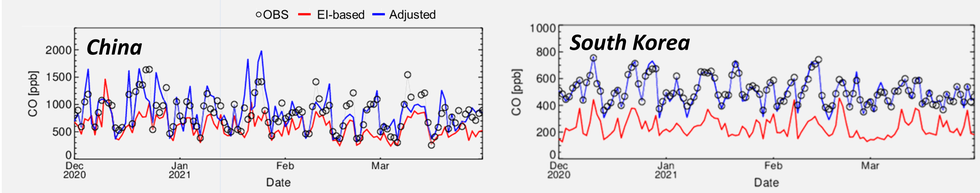
Upwind emissions adjustment

CO VCD comparison



- The simulated CO VCD based on EI was underestimated compared to the TROPOMI VCD in Northeast Asia.
- After adjusting emissions using TEA, the simulated CO VCD showed good agreement with the TROPOMI VCD in both China and South Korea.

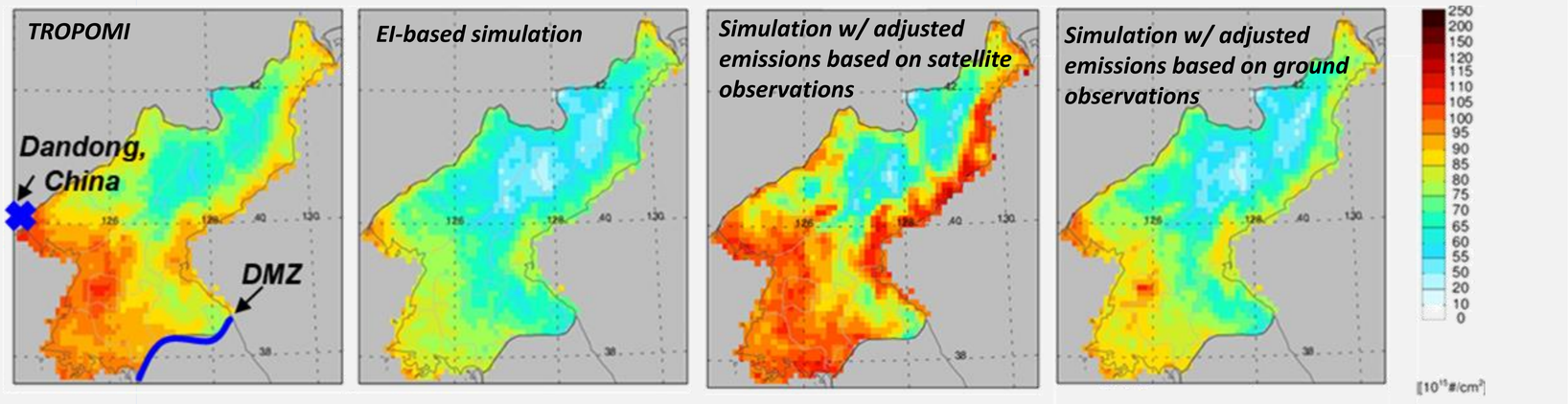
Comparison of surface CO concentrations



- The CO concentrations simulated with the adjusted emissions showed a good agreement with observed concentrations in both China and South Korea.

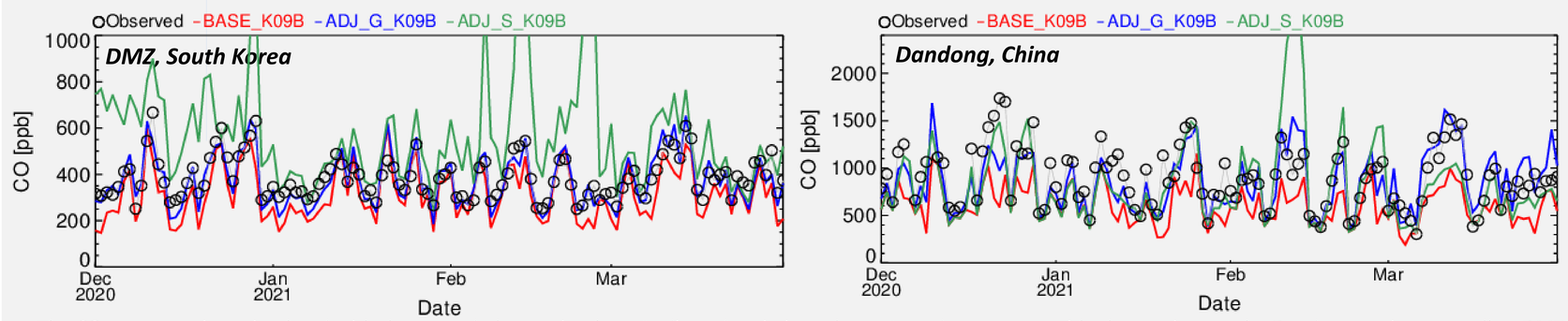
North Korea emissions adjustment

CO VCD comparison



- After the emissions adjustment with ground observations and satellite observations, CO emissions in North Korea were 10 times and 38 times higher than the EI, respectively.
- The adjusted CO emissions with ground observations were reallocated through a hybrid of the spatial distribution of the satellite VCD and EI, which include information on major emission sources.
- The spatial distribution of simulated VCDs with reallocated emissions were similar with the TROPOMI VCDs.

Comparison of surface CO concentrations



- The CO concentrations simulated with the ground observation-based adjusted emissions showed good agreement with observations at the Dandong stations as well as DMZ stations.
- Those with the satellite observation-based adjusted emissions were overestimated. It may be because the emissions were adjusted without considering long-range transport.

Conclusion

- North Korean CO emissions were adjusted and reallocated using an EI-based simulation, ground observations at DMZ stations, and the satellite observation.
- The CO emissions are 10 times higher for ground observation-based adjustment and 38 times higher for satellite observation-based adjustment compared to the EI.
- Simulated CO concentrations with the ground observation-based adjusted and reallocated emissions showed good agreement with observations in both the DMZ and China while those with satellite-based adjusted emissions were overestimated compared to observations.
- In the future, it will be necessary to estimate local CO emissions in North Korea by utilizing the ratio between the observed VCD and re-simulated VCD while excluding the impact of long-range transport using a chemical transport model.

Acknowledgement

- This work was supported by the National Air Emission Inventory and Research Center (NAIR) in South Korea and the Samsung Advanced Institute of Technology.

Developing a method to adjust CO emissions in North Korea using DMZ ground observations, satellite observations and simulations

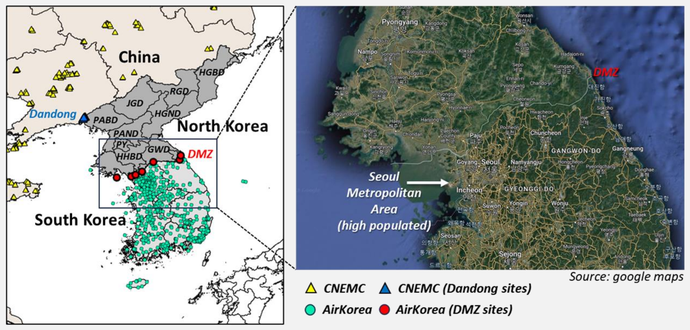
Eunhye Kim, Soontae Kim
Department of Environmental & Safety Engineering, Ajou University, South Korea

Background

- Since North Korea does not release an official emissions inventory (EI), emissions in North Korea are roughly estimated using the limited data.
- Uncertainties in emissions from North Korea can result in errors in studies conducted in neighboring countries based on simulated concentrations with the emissions.
- Therefore, it is essential to use realistic emissions from North Korea for modeling-based air quality research is necessary in Northeast Asia.
- We adjusted North Korean CO emissions by using EI-based simulations, DMZ ground observations, and satellite observations.

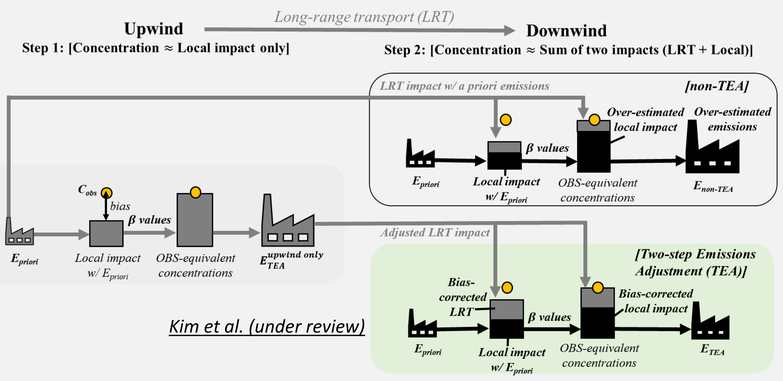
Methodology

Target domain & period



- CMAQ v5.3.2 was utilized for the simulations. The modeling domain covers part of China, North Korea, and South Korea with a 9-km grid resolution.
- The study was conducted from December 2020 to March 2021. During the period, northwesterly winds become predominant; thus, emissions in North Korea may significantly affect the air quality in South Korea.

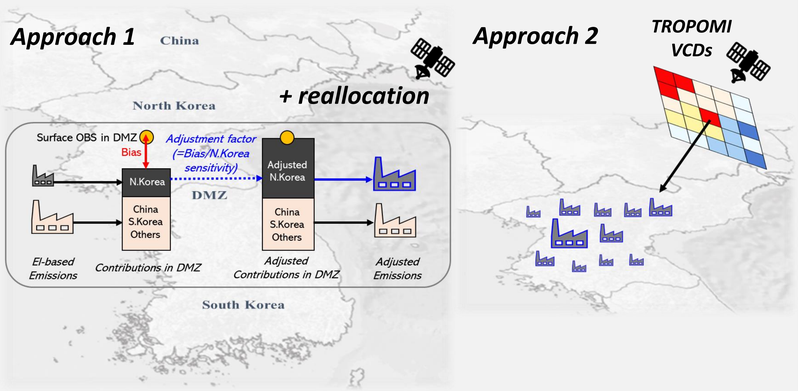
STEP1: Upwind emissions adjustment using TEA



Kim et al. (under review)

- CO emissions in China and South Korea were adjusted prior to adjust North Korean CO emissions using the Two-step Emissions Adjustment (TEA) approach. This approach adjusts downwind emissions of air pollutants with ground observations and EI-based simulations while considering their long-range transported emission impacts from upwind areas.

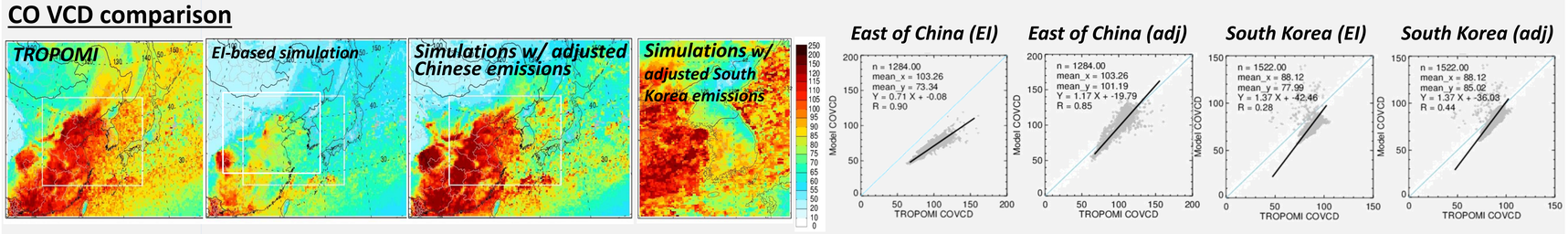
STEP2: North Korea emissions adjustment



- In approach 1, the emissions adjustment factor that minimizes the difference in CO concentrations between ground observations and simulations at the DMZ monitoring stations was estimated and applied to the EI to adjust CO emissions in North Korea. In addition, the adjusted emissions were reallocated using spatial distributions of the EI and satellite-based Vertical Column Densities (VCDs).
- In approach 2, the emissions were adjusted by using the ratio of VCDs from satellite and EI-based simulation.
- To verify the adjusted emissions, the CO concentrations simulated with the adjusted emissions were compared with the ground observations at Dandong stations, which is located at the China-North Korea border as well as DMZ stations.

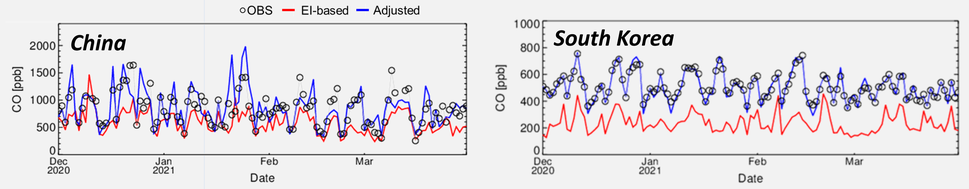
Upwind emissions adjustment

CO VCD comparison



- The simulated CO VCD based on EI was underestimated compared to the TROPOMI VCD in Northeast Asia.
- After adjusting emissions using TEA, the simulated CO VCD showed good agreement with the TROPOMI VCD in both China and South Korea.

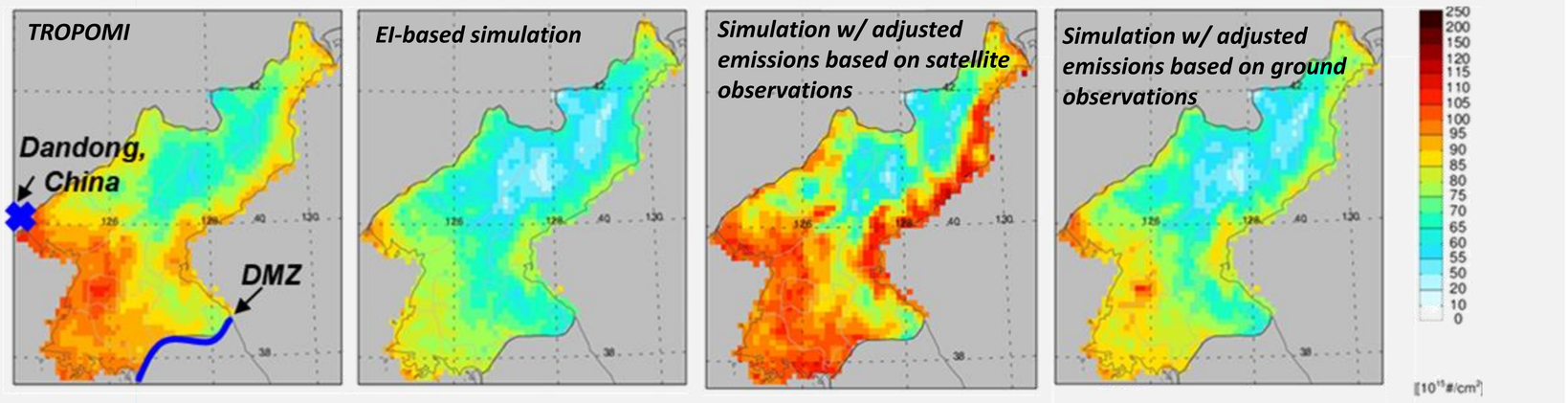
Comparison of surface CO concentrations



- The CO concentrations simulated with the adjusted emissions showed a good agreement with observed concentrations in both China and South Korea.

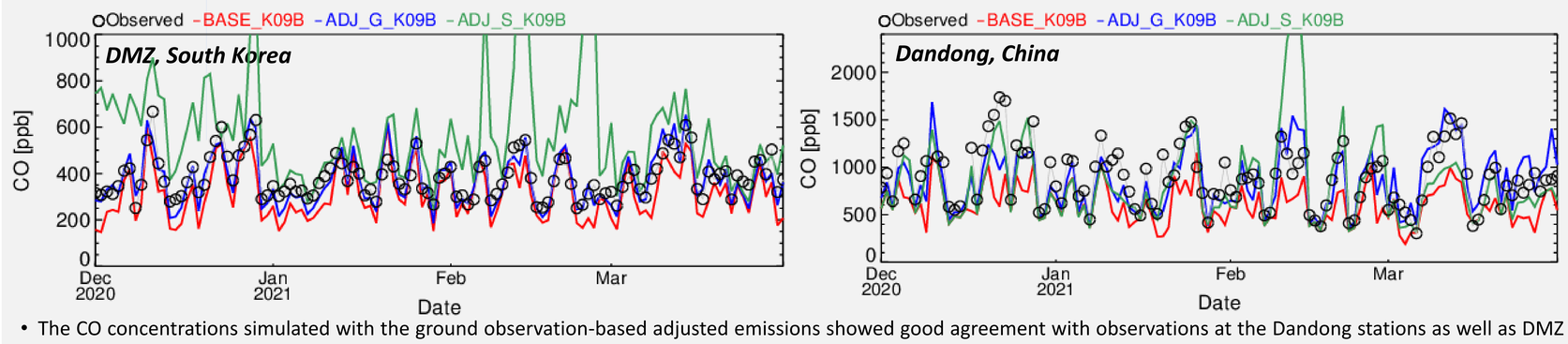
North Korea emissions adjustment

CO VCD comparison



- After the emissions adjustment with ground observations and satellite observations, CO emissions in North Korea were 10 times and 38 times higher than the EI, respectively.
- The adjusted CO emissions with ground observations were reallocated through a hybrid of the spatial distribution of the satellite VCD and EI, which include information on major emission sources.
- The spatial distribution of simulated VCDs with reallocated emissions were similar with the TROPOMI VCDs.

Comparison of surface CO concentrations



- The CO concentrations simulated with the ground observation-based adjusted emissions showed good agreement with observations at the Dandong stations as well as DMZ stations.
- Those with the satellite observation-based adjusted emissions were overestimated. It may be because the emissions were adjusted without considering long-range transport.

Conclusion

- North Korean CO emissions were adjusted and reallocated using an EI-based simulation, ground observations at DMZ stations, and the satellite observation.
- The CO emissions are 10 times higher for ground observation-based adjustment and 38 times higher for satellite observation-based adjustment compared to the EI.
- Simulated CO concentrations with the ground observation-based adjusted and reallocated emissions showed good agreement with observations in both the DMZ and China while those with satellite-based adjusted emissions were overestimated compared to observations.
- In the future, it will be necessary to estimate local CO emissions in North Korea by utilizing the ratio between the observed VCD and re-simulated VCD while excluding the impact of long-range transport using a chemical transport model.

Acknowledgement

- This work was supported by the National Air Emission Inventory and Research Center (NAIR) in South Korea and the Samsung Advanced Institute of Technology.