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Deep learning for Chinese NOx emission inversion and the integration of in situ observations: a case study on the COVID-19 pandemic

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The COVID-19 pandemic led to the lockdown of over one-third of Chinese cities in early 2020. Observations have shown significant reductions of atmospheric abundances of NO_2 over China during this period. This change in atmospheric NO_2 implies a dramatic change in emission of NO_x, which provides a unique opportunity to study the response of the chemistry of the atmospheric to large reductions in anthropogenic emissions. We use a deep learning (DL) model to quantify the change in surface emissions of NO_x in China that are associated with the observed changes in atmospheric NO_2 during the lockdown period. Compared to conventional data assimilation systems, deep neural networks are free of the potential errors associated with parameterized subgrid-scale processes. Furthermore, they are not susceptible to the chemical errors typically found in atmospheric chemical transport models. The neural-network-based approach also offers a more computationally efficient means of inverse modeling of NO_x emissions at high spatial resolutions. Our DL model is trained using meteorological predictors and reanalysis data of surface NO_2 from 2005 to 2017. The evaluation is conducted using in-situ measurements of NO_2 in 2019 and 2020. The Baidu 'Qianxi' migration data sets are used to evaluate the model's performance in capturing the typical variation in Chinese NOx emissions during the Chinese New Year holidays. The TROPOMI-derived TCR-2 chemical reanalysis is used to evaluate the DL analysis in 2020. We show that the DL-based approach is able to better reproduce the variation in anthropogenic NO_x emissions and capture the reduction in Chinese NO_x emissions during the period of the COVID-19 pandemic.