Characterization of Metop-A GOME-2 and Aura OMI NO_2 Data for Regional and Global Air Quality Modeling Applications

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Goal of this study: . This study aims at understanding how satellite data from multiple platforms can be beneficial to improving air quality model forecasts.

The need for routine data to monitor and forecast air quality over high temporal and spatial scales has resulted in the development of a host of air quality products from research and operational satellite sensors. Among the trace gases, satellite-derived NO_2 is one of the key species that is being used to monitor air quality. NO_2 is a key precursor for ozone and nitrate aerosol formation in photochemical smog that results in deteriorated air quality. Aura Ozone Monitoring Instrument (OMI) launched in 2004 and Metop-A Global Ozone Monitoring Experiment (GOME-2) instrument launched in 2006 are providing daily global snapshots of NO_2. Plans are underway to utilize the data in operational air quality forecasting models as soon as the data become operational. While applications such as the use of satellite derived NO_2 data to constrain emissions in the model to improve air quality predictions are evolving, there is a need to first understand and characterize satellite derived NO_2 data on different spatial and temporal scales. Prior to GOME-2 and OMI, ESA GOME instrument and Envisat SCIAMACHY instrument provided NO_2 data for over a decade. These data were, however, at a much coarser resolution compared to OMI and GOME-2 and required spatial and temporal averaging in order to use them in air quality studies. Although OMI data are available at 13 km X 24 km and GOME-2 data at 40 km X 80 km, there are no known studies to date that analyzed the data on sub-daily time scales.

NO_x ($NO + NO_2$) concentrations vary during the day and this variability is often not well represented in air quality forecast models due to lack of timely observations. This diurnal variability is different in different parts of the globe depending on the source of emissions, whether they are anthropogenic or natural (e.g., wildfires) and photochemistry. GOME-2 and OMI instruments observe the same location on the Earth at different times because of their different equator crossing times (GOME-2 is flying in the morning orbit with 9:30 AM equator crossing time and OMI is flying in the afternoon orbit with 1:10 PM equator crossing time). This study proposes to analyze GOME-2 and OMI data for diurnal variation in NO_2 and how that information can be used in operational air quality forecast models. For demonstration purposes, the operational Community Multiscale Air Quality (CMAQ) model used by the U.S. NOAA National Weather Service (NWS) for air quality forecast guidance will be used in the study. Other independent global chemistry and transport models (potentially in collaboration with European counterparts) will play a role as well. This study proposes to test the use of bringing in the model predicted NO_2 vertical profiles as *a priori* to improve satellite retrievals, similar to the work being done at KNMI.

Six months of 2007 NO_2 data corresponding to summer (June, July, and August) and winter (December, January, and February) from GOME-2, OMI, and operational CMAQ simulations will be used to analyze spatio-temporal patterns in NO_2 over the U.S. First, the differences in observed tropospheric amounts of NO_2 between GOME-2 and OMI have to be reconciled for algorithm/instrument differences. To minimize these differences, NOAA GOME-2 NO_2 algorithm will be run using same *a priori* NO_2 vertical profile and similar approaches as OMI algorithm for converting slant column amounts to vertical column amounts and extracting tropospheric NO_2 amount from total NO_2 column amount.

A second set of GOME-2 and OMI NO_2 retrievals will be obtained using model predicted NO_2 vertical profiles as *a priori* in the algorithm. Once the algorithm differences are minimized, data will be analyzed for diurnal and seasonal patterns and compared to CMAQ simulations. *Note that a priori information for satellite retrievals is not coming from CMAQ.*

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Satellite and model data will also be compared to available ground-based observations from well calibrated Brewer spectrometers to establish a reference point for bias and noise in satellite data. In addition to conducting analysis of specific episodes to see the performance of satellite retrievals under different scenarios, time series analysis of satellite and ground-based measurements will be carried out to study seasonal variations and analyze the performance of satellite retrievals when column NO_2 amounts are small. Analysis of biases in satellite retrievals as a function of NO_2 amounts may identify sources of errors in satellite retrievals.

Spatio-temporal patterns observed in satellite data will be compared to CMAQ predictions to assess the accuracy of model predictions. Because the CMAQ model provides hourly forecasts, analysis will be carried out to evaluate the model on similar time scales (~ daily). Although there can be many sources of errors in model predictions, errors in CMAQ ozone (observed – predicted) will be correlated to errors in CMAQ NO_2 amounts (observed – predicted) to diagnose the effect of uncertainties in NO_x emissions on model predicted ozone. If the analysis shows that the CMAQ model is not accurately prescribing NO_x emissions, a recommendation will be made to the NWS to incorporate satellite data to constrain the emissions and improve model performance.

The key outcome of this project will be a demonstrated capability in using data from a constellation of satellites and models to enhance our understanding of the atmospheric physics and chemistry and help incorporate the new science into air quality forecast models. Deteriorated air quality is not confined to any one region. With atmosphere knowing no political boundaries, long-range transport of pollutants impacting local air quality elsewhere is a common phenomenon and must be addressed using both satellites *to monitor* and models *to forecast*.