Air Quality and Acid Deposition Forecast of South Athabasca Oil Sands Development Applying CMAQ Model

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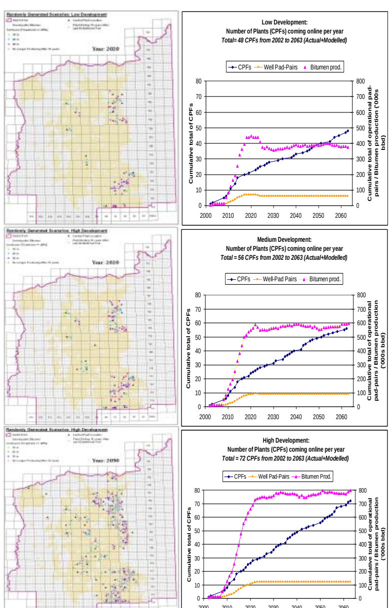
Introduction

The objective of this study is to assess air impact of environmental footprints of oil sands production in the future. Based on baseline simulation (Xu, et al. 2014), developed emission inventories and modelling inputs for forecasted future development scenarios, this study applies CMAQ model to simulate the ground level concentrations of ozone, $PM_{2.5}$, and their precursors, and nitrogen and sulphur acidic deposition in SAOS for future development scenarios. The CMAQ predictions for 2020 low production, 2020 high production and 2050 high production scenarios demonstrate the estimated impacts of future development scenarios on ambient air quality in the SAOS. By comparing air quality forecasts of the future scenarios with baseline year 2010 and the comparisons amongst future scenarios, the model predicts insignificant difference between 2020 scenarios and 2050 high production for O_3, SO_2, NO_2, CO, but increase particularly in the southern part of SAOS for $PM_{2.5}$ and PM_{10}, and locally significant increase of annual total acidic deposition near newly commissioned central processing plants in the 2050 high production scenario.

SOURCE EMISSIONS FORECAST METHODOLOGY

Based on the assumption in the future development scenarios that each township under in-situ development has a central processing plant at its township center, the following pictures show us spatial distribution of the central processing plants to be in operation and facilities to be decommissioned in future production expansion (Environ and Novus, 2014). Pollutant emission rates of the existing in-situ facilities in operation at various production scales were established. Nonlinear relationships of emission rates versus production levels were regressed and applied to estimating emission rates of air pollutants from the to-be-built central processing plants in the future scenarios.



CMAQ MODELING RESULTS of OZONE and $PM_{2.5}$ for YEAR 2020 and 2050 FUTURE SCENARIOS

The three figures in the left column in Figure 1 compare maximum 8-hour average ozone concentrations among the three future scenarios. All the comparisons depict to us that within SAOS area, there is insignificant difference of ozone concentrations in the projected future year scenarios. The three figures in the right column in Figure 1 compares the highest 24-hour average $PM_{2.5}$ concentrations of the future scenarios. For the two 2020 scenarios, the $PM_{2.5}$ concentrations increase in SAOS area and significantly increase in southern portion of SAOS; and for the 2050 high production scenario, the $PM_{2.5}$ concentrations significantly increase in SAOS with larger increase in southern portion of SAOS. Moreover, the figures also indicate insignificant $PM_{2.5}$ difference between 2020 low and high production scenarios, but significant $PM_{2.5}$ increase in 2050 scenario in comparison to 2020 scenarios.

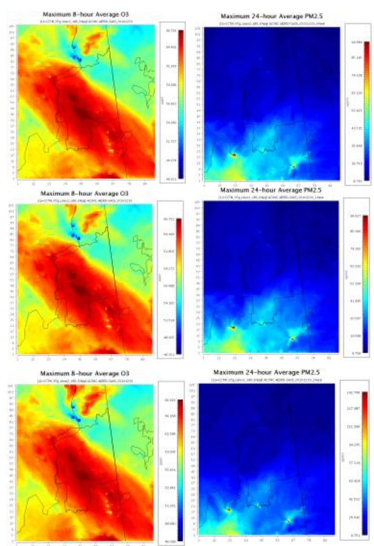


Figure 1. CMAQ-estimated maximum 8-hour ozone concentrations (left) and maximum 24-hour $PM_{2.5}$ concentrations (right) for the 2020 low and high and 2050 high production scenarios, sequentially and respectively.

CMAQ MODELING RESULTS of SO_2 and NO_2, and $PM_{2.5}$ and PM_{10} ANNUAL DIFFERENCE from Baseline for YEAR 2020 and 2050 FUTURE SCENARIOS

Figure 2 and Figure 4 demonstrate SO_2 and NO_2 annual average and maximum 24-hour average concentrations for the development scenarios. The comparison among them shows insignificant difference between 2020 low and high productions, except some locally confined increase nearby the new sources and significant increase in 2050 high production scenario.

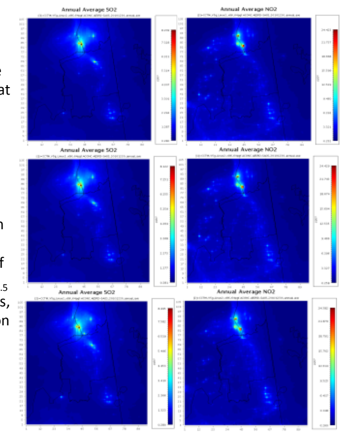


Figure 2. CMAQ-estimated annual average SO_2 (3 figures at left), NO_2 (3 figures at right) concentrations for the 2020 low and high and 2050 high production scenarios, sequentially and respectively.

Figure 3 presents PM_{10} and $PM_{2.5}$ annual average concentrations differences from the baseline for the development scenarios. Similar to 24-hour average $PM_{2.5}$ and PM_{10} concentrations, there are $PM_{2.5}$ increases in SAOS area for all the future scenarios.

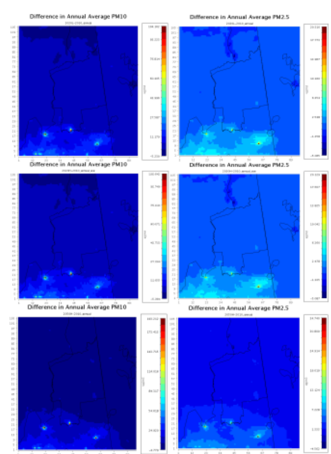


Figure 3. CMAQ-estimated differences of annual average PM_{10} (left) and $PM_{2.5}$ (right) concentrations from baseline year for the 2020 low and high and 2050 high production scenarios, sequentially and respectively.

However, the increase is insignificant between 2020 low and high production scenarios, while there is significant increase for 2050 high production scenarios, particularly in the southern SAOS.

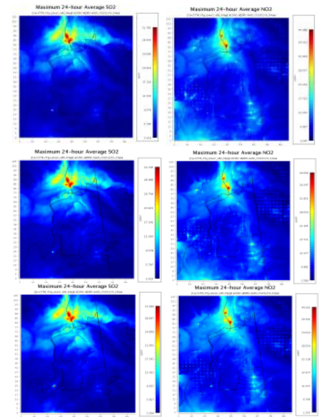


Figure 4. CMAQ-estimated maximum 24-hour average SO_2 (3 figures at left), NO_2 (3 figures at right) for the 2020 low and high and 2050 high production scenarios, sequentially and respectively.

CMAQ MODELLING RESULTS of NITROGEN and SULPHUR TOTAL DEPOSITION for YEAR 2020 and 2050 FUTURE SCENARIOS

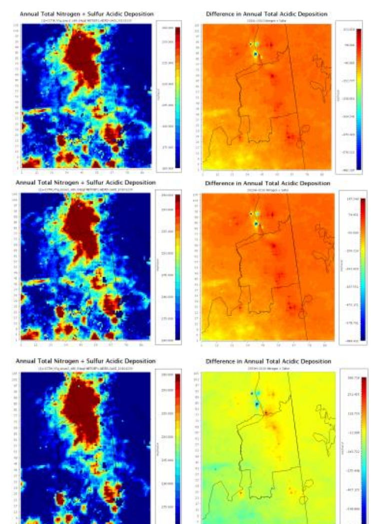


Figure 5. CMAQ-estimated annual total nitrogen and sulphur deposition (left) and acidic deposition differences from baseline year (right) for the 2020 low and high and 2050 high production scenarios, sequentially and respectively (unit in H^+ eq/ha/year).

Figure 5 compares CMAQ-estimated annual total acid deposition (nitrogen and sulphur) across the 4 km resolution domain for future scenarios. The comparison shows insignificant difference between 2020 low and high production scenarios; but in 2050 high production scenario, compared to the 2020 scenarios, particularly in the northern SAOS, there is slightly spatial expansion of areas with acidic deposition exceeding 250 H^+ eq/ha/yr management trigger level of critical load for high sensitivity area.

CONCLUSIONS

In summary, the impacts of future oil sands development were estimated with CMAQ, with comparing baseline year 2010, future scenarios 2020 low production, 2020 high production and 2050 high production.

In conclusion, the model predicts the potential issue caused by future development may be $PM_{2.5}$ and PM_{10} in the 2050 high production scenario. Nonetheless, the issue may mainly exist in the southern part of SAOS area and can be mainly attributable to emissions from the sources outside of the SAOS boundary, including sources in the south of SAOS, such as community, industry and traffic sources in Northern Saskatchewan region, particularly in the Edmonton capital region, and other regional background contributors.

Besides inherent limitation and uncertainty of the model, the modelling results strongly rely on the accuracy of modelling inputs, especially meteorological data and emissions inventories. While emissions inventories for baseline and future year scenarios were investigated to the best knowledge as possible (based on the best available data), the results are also based on forecasted anthropogenic emissions which were not intended to be the definitive representations of emissions in the forecast periods. In addition, the 2010 meteorology was hypothetically applied to future year scenarios. Therefore, this model forecast should be considered as a useful “range-finding” tool in comparing the future-year scenarios with the baseline case. In this study, the modelling results for the 2010 baseline year were used as a benchmark in comparison to future development scenarios. The relative comparison amongst future scenarios and the baseline should be more meaningful.

REFERENCES

Environ and Novus, 2014. Development of Air Emissions Inventories and Inputs to Support Air Quality Modelling of Selected Pollutants using Community Multiscale Air Quality (CMAQ) and Long Range Dispersion CALPUFF Model for the South Athabasca Oil Sands Area (SAOS). Novato, CA; Guelph, Ontario. July.

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