Investigating the impact of COVID-19 public health actions on NO_2 levels

Yayne-abeba Aklilu, Ryan Duruisseau-Kuntz, Alexander Salm, Casandra Brown, Greg Wentworth, Travis Tokarek

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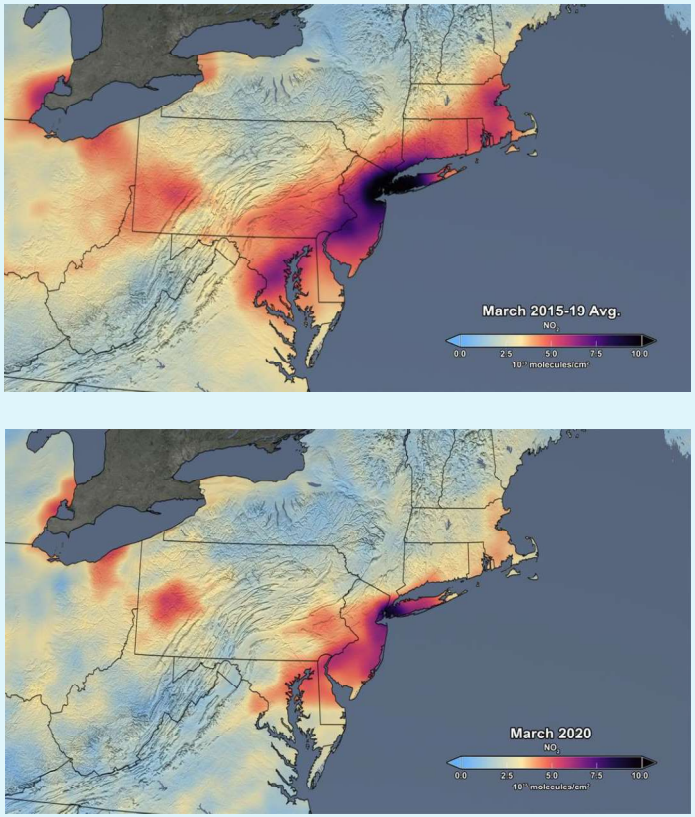
Alberta

Nitrogen dioxide

Public health action and changes in NO_2

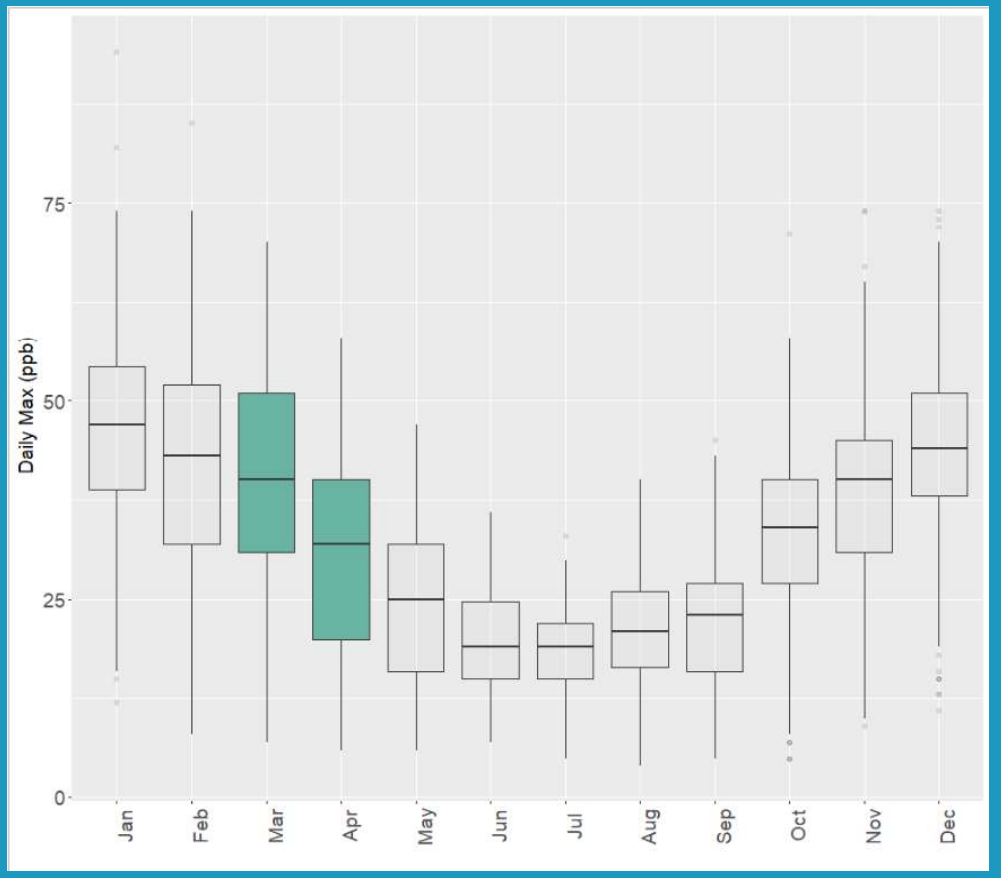
- Worldwide public health actions to limit the spread of COVID-19
  - included actions to reduce mobility
  - One secondary effect of these measures was a reduction in air pollution
    - Most notably NO_2
- Satellite measurements of NO_2
  - One of the first to illustrate observed changes



NO_2 Troposphere column density NE USA
Adopted from https://svs.gsfc.nasa.gov/

Challenges in identifying changes in NO_2

- Ambient concentration is affected by
  - Emissions
  - Atmospheric processes
    - Transport, dispersion
    - Chemistry/transformation
    - Deposition
- Spring is a period of transition
  - *Higher NO_2 in winter → lower NO_2 in summer*
- Comparisons to historical data
  - needs careful design due to year-to-year variability



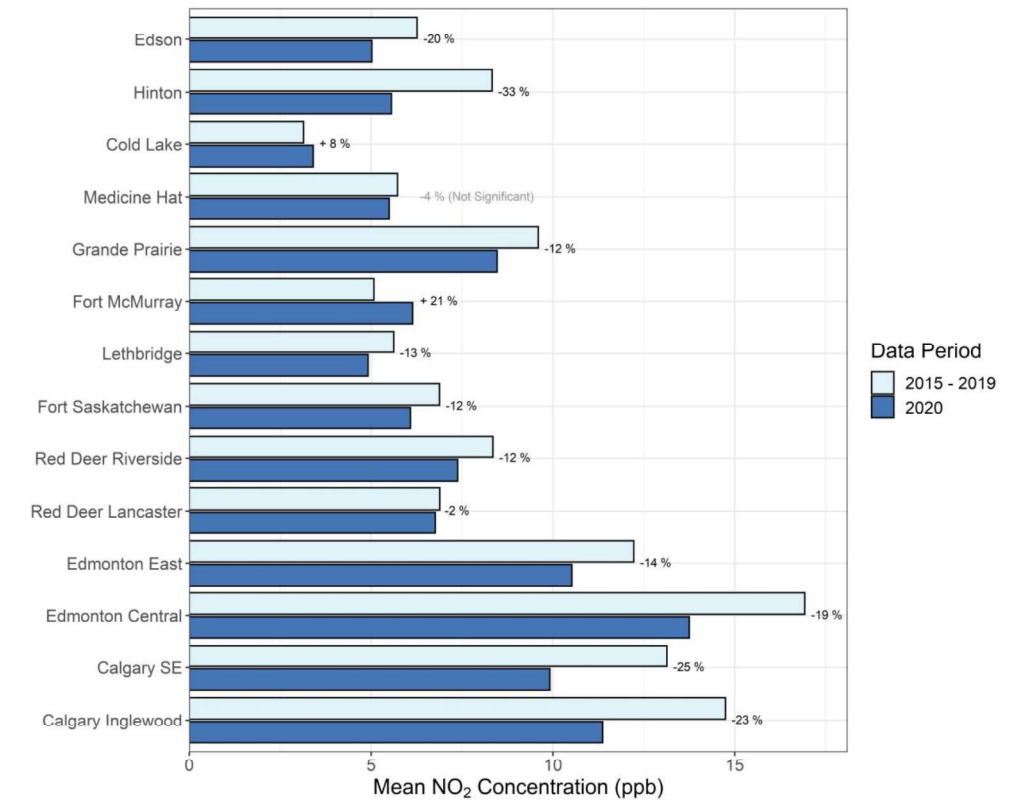
Seasonal variability of daily maximum NO_2 at Calgary Inglewood

Methods used

Comparison to Historical

- Input data
  - Five years of historical data (2015-2019)
    - To account for variability due to meteorology
  - Excluded weekends and holidays
    - Measures were thought to predominantly affect weekday traffic patterns and volume
  - Removed samples known to have been impacted by exceptional events
  - Examined two periods
    - A: March 16-April 24 *Focus of presentation*
    - B: April 27 – June 12

Bulk comparison



Mean NO_2 concentrations for March 16 - April 24

- Observed differences* were variable
- NO_2 Decrease in 2020
  - Observed at most sites
  - Ranged from 2 to 33% (1-4 ppb)
- Increase in 2020
  - Fort McMurray (Patricia McInnes) and Cold Lake
- No significant change
  - Medicine Hat

*Mann Whitney U test used to test significance ($p<0.05$)

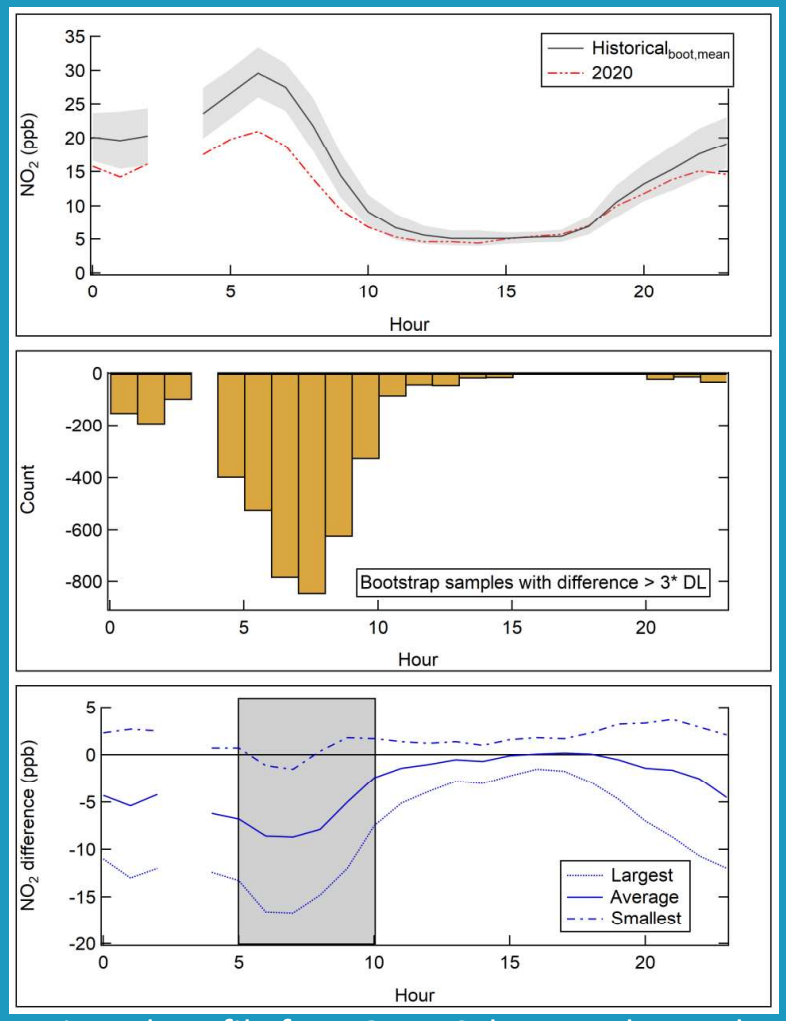
Were observed changes limited to select hours of the day?

Thus, could the observed difference be muted for bulk comparisons?

Diurnal comparison

- Bootstrapping* to determine
  - Mean historical concentration ($\bar{X}^*_{hr}$) and 95% confidence intervals for each hour of the day

  *1000 samples with replacement
- NO_2 difference $\overline{X}^{2020}_{hr} - \bar{X}^*_{hr}$
  - Most prominent in the morning
  - e.g., Inglewood (hour 5 to 10)
    - Mean difference: 7-9 ppb



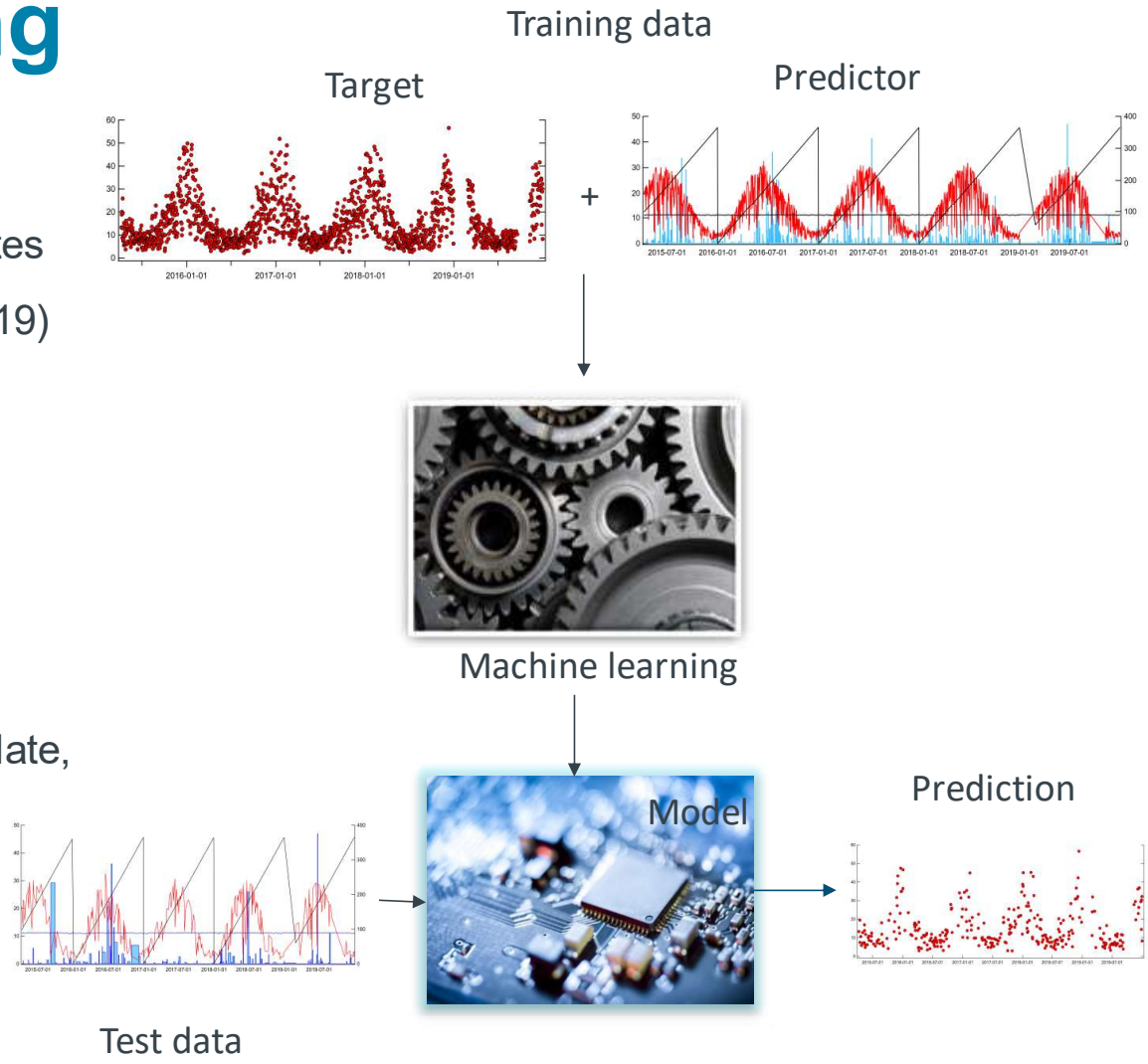
Diurnal profile for NO_2 at Calgary Inglewood

Could business as usual machine learning predictions of 2020 concentrations provide an improved measure of changes in NO_2?

Predicting business-as-usual

Supervised learning

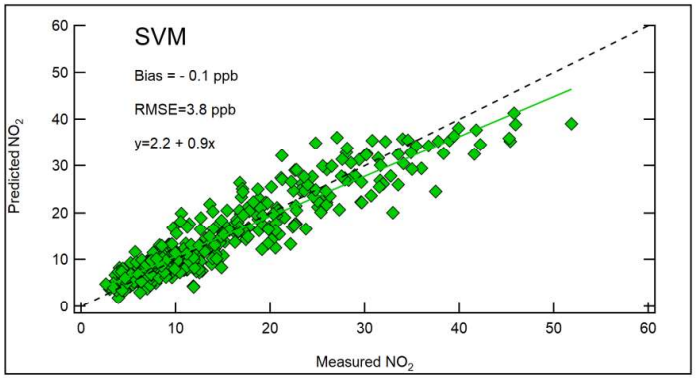
- Training data
  - Calgary Inglewood and supporting sites
    - 80% (April 2015 - December 2019)
  - Target variable (NO_2)
  - Predictor variables
    - Meteorology (Wind, RH, Temp, Pressure, Solar Radiation, Precipitation)
    - Temporal (Day of week, Julian date, Month, Day of study)

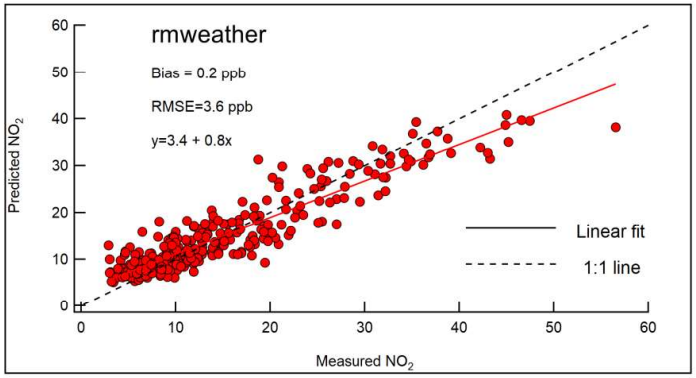


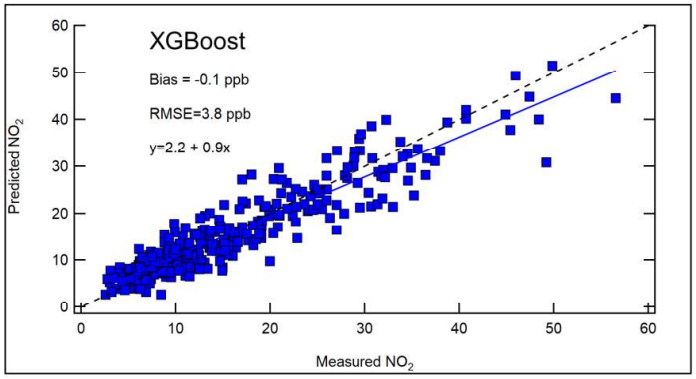
Model Performance

- Test data
  - Model selected
  - 20% of 2015 - 2019 data
- Test runs
  - Conducted independently
- Results
  - SVM ~ XGBoost ~ rmweather
    - Negligible bias
    - RMSE ~ 4ppb
    - Underpredict elevated values*
  - rmweather and XGBoost overpredict low values

*XGBoost does a little better

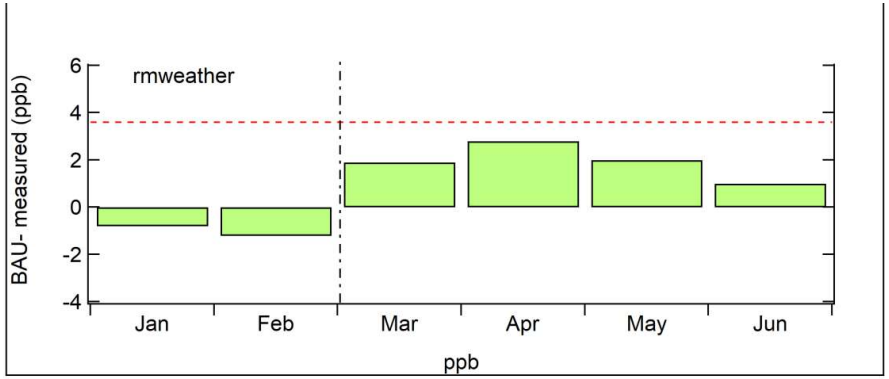


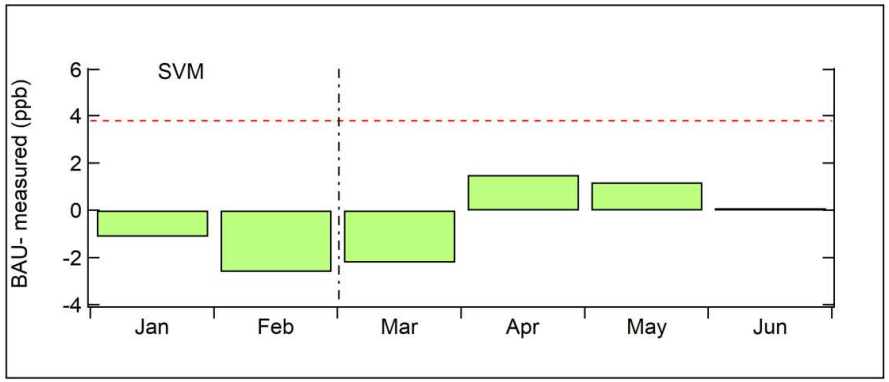


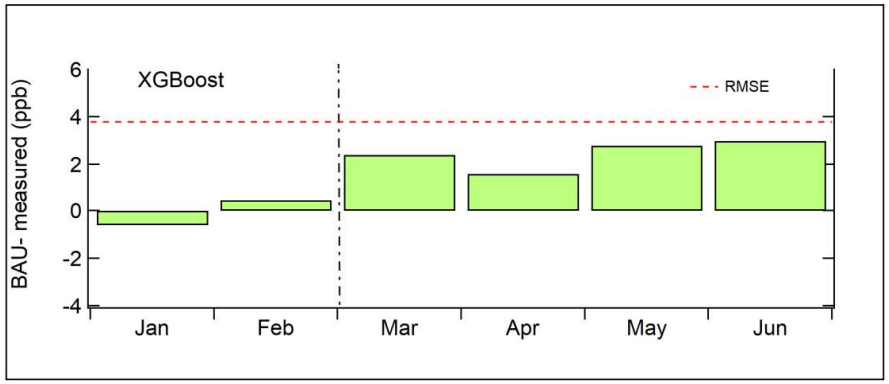


Business as usual predictions

- Prediction period
  - January - June 2020 (inclusive)
- Difference calculation
  - [BAU] – [Measured]
- Results
  - Unaffected period Jan to Feb 2020
    - diff low or negative (BAU < measured)
    - Models underpredicted higher values typically observed in the winter
  - March to April 2020
    - Difference 2-3 ppb (except for March -SVM)
    - ~ bulk comparison to historical data
    - Observed difference < RMSE







Conclusion

- Comparison to historical NO_2 data
  - Bulk comparison
    - Resulted in a marginal difference for most monitoring sites
  - Diurnal evaluation illustrated
    - Differences between 2020 and historical data varied by time of day
      - Notable changes in NO_2 during the morning hours
      - Minimal difference for the remainder of the day
      - Likely resulting in the marginal difference observed in the bulk comparison

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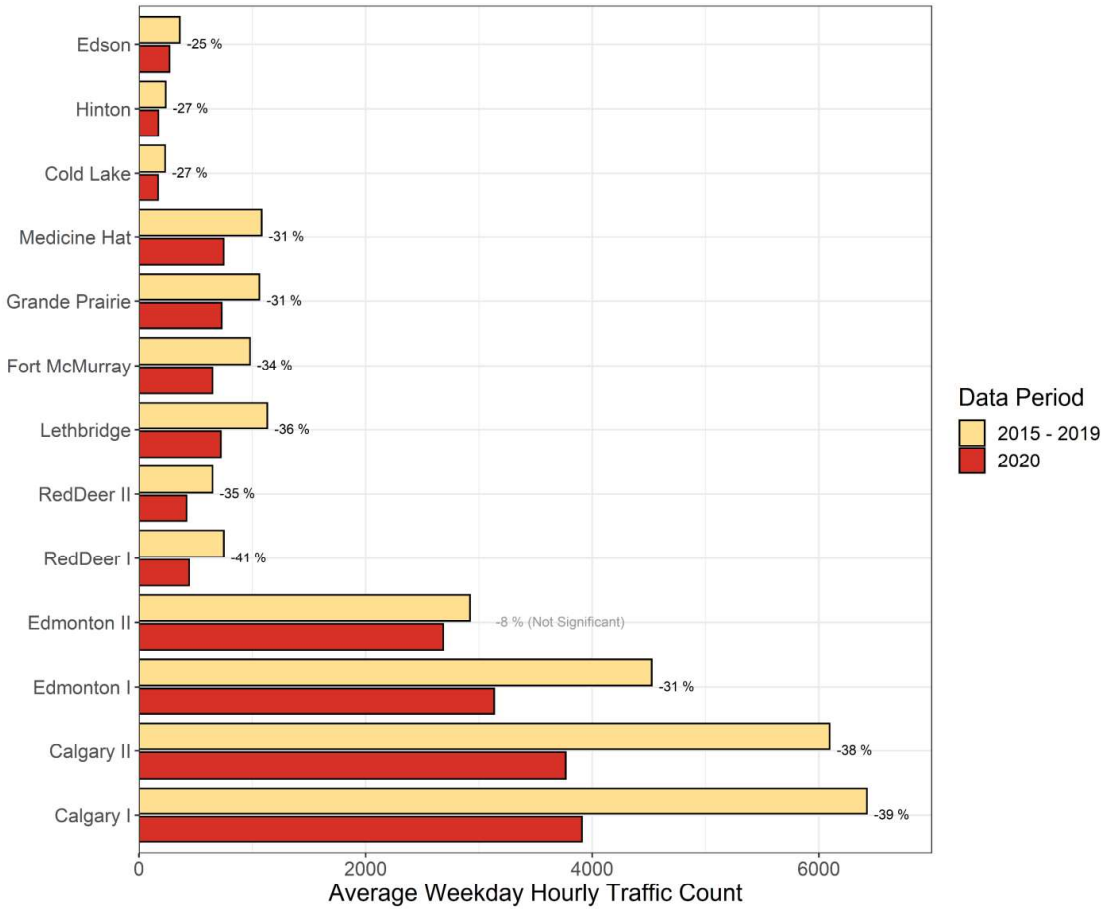
Conclusion

- Comparison to Machine Learning predicted BAU
  - Model performance
    - The three different algorithms had comparable test results
    - RMSE ~ 4ppb
    - All models underestimated elevated concentration → underpredicted wintertime concentrations
  - Measure of changes March and April 2020
    - The observed difference (BAU – Measured) ≤ to prediction error (RMSE) of a model
    - The three models selected did not provide *an improved measure* of changes in NO_2

Questions?



Change in weekday traffic. Data from Alberta Transportation. Data include sample period between March 16 – April 24 (excluding weekends and holidays). Significance was tested using Mann Whitney u test (p value ≤ 0.05). This test compares the distribution of the two data sets.