ALTERNATIVE APPROACHES FOR LONG TERM AIR QUALITY DATA ANALYSIS SHOW CHANGES NOT DETECTED BY TREND ANALYSIS IN THE FIRST NATION COMMUNITY OF FORT MCKAY LOCATED IN THE CENTRE OF ATHABASCA OIL SANDS, ALBERTA

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OVERVIEW

- Air Quality Change/Trending
- Previous Findings
- Methods
- Findings
- Recommendations

AIR QUALITY CHANGE/TRENDING

- A stated purpose for air quality monitoring in the oil sands regions is "***data trending***".

- Questions are: "***what does data trending mean***?" and "***how should (can) it be done to make it meaningful/useful as an air quality tracking and management tool***?"

AIR QUALITY CHANGE/TRENDING

- The **issue/problem/challenge**[1]:
  - "*Because the concept of a trend in a data set seems clearly self-evident, most data analysts take it for granted and only few bother to examine the essence of it or to define it rigorously for the purpose of data analysis.*"
- The **approach/solution**[1]:
  - "*Because many of the difficulties concerning trend stem from the lack of a proper definition for the trend in nonlinear nonstationary data, a definitive and quantitative study on trend and detrending is needed.*"

- **Our Study**: We evaluated some nonlinear approaches for assessing and evaluating possible air quality changes associated with oil sands emissions.

[1]Wu, Z., Huang, N. E., Long, S. R., & Peng, C.-K. (2007). On the trend, detrending, and variability of nonlinear and nonstationary time series. PNAS, 14889-14894.

PREVIOUS TRENDING/FINDINGS

- Most analyses of changes in air quality assume the type of change i.e. that it is monotonic, linear and directly related to growth of oil sands industry.
- Tools used are different types of linear regression.
- Only clear upward trend signal detected is for NOx species

THE CURRENT OIL SANDS DEVELOPMENT RELATED AIR QUALITY TRENDING CONUNDRUM

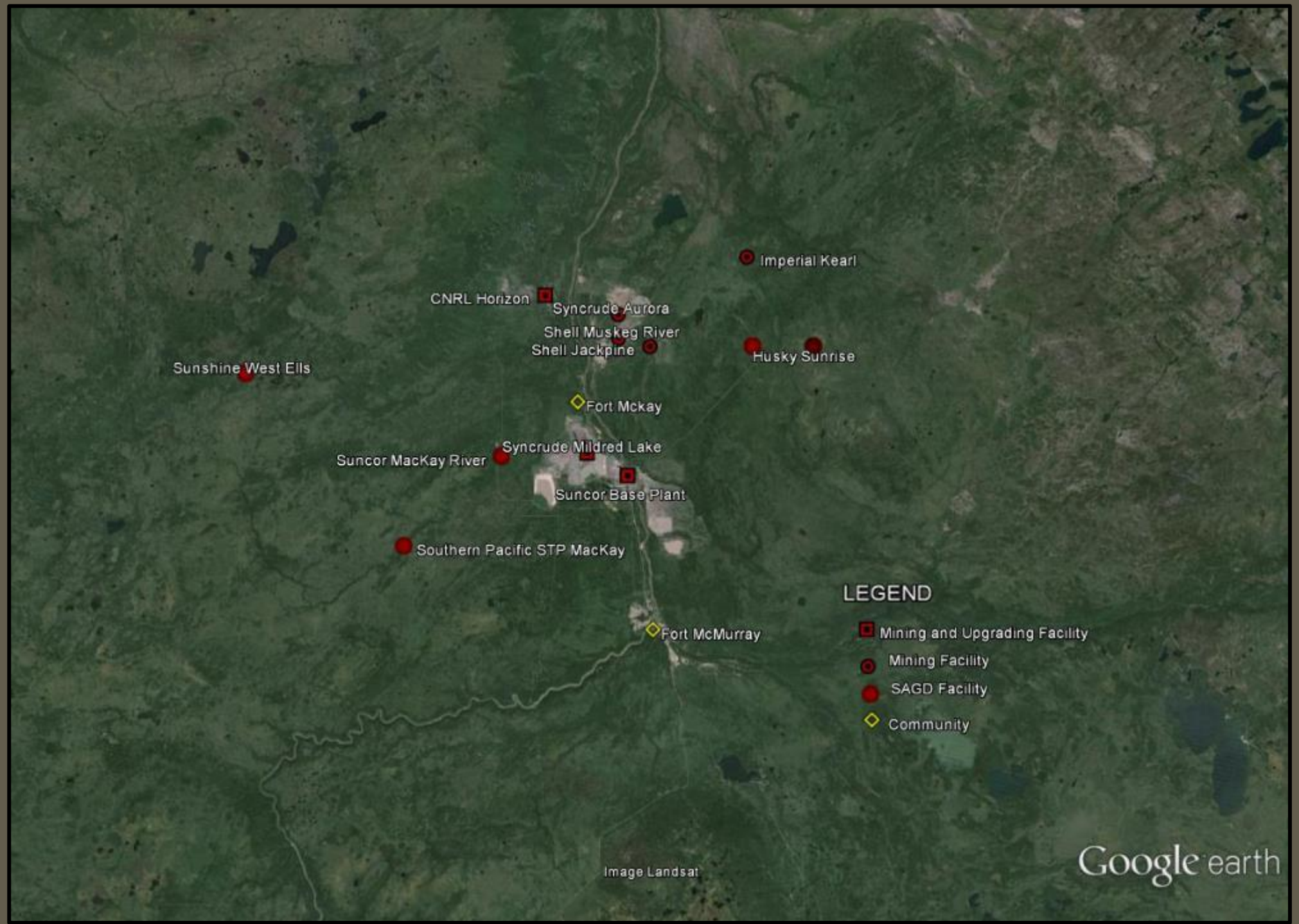
- How can significantly increasing emissions North of Fort McMurray not be detected by the air quality monitoring in Fort McKay?
- Is there really no detectable change or trend or are we not using the right/best tools to detect air quality changes?
- We think we are not using the most appropriate methods to detect and understand air quality trends/changes.

Average Emissions and Percent Change in Emissions of the Noted Parameters for the Noted Periods (tonnes/yr)

Period	SO_2	NOx	$PM_{2.5}$	VOC	RSC (H_2S, CS_2 & COS as H_2S)
1998-2001	97,276	36,573	1,158	26,495	141
2011-2014	78,262	70,562	5,291	54,961	340
% Change	-20%	93%	357%	107%	140%

EXOGENOUS VARIABLES (NOISE) IN AIR QUALITY DATA SETS THAT COMPLICATE/LIMIT LINEAR TRENDING IN OIL SANDS REGION

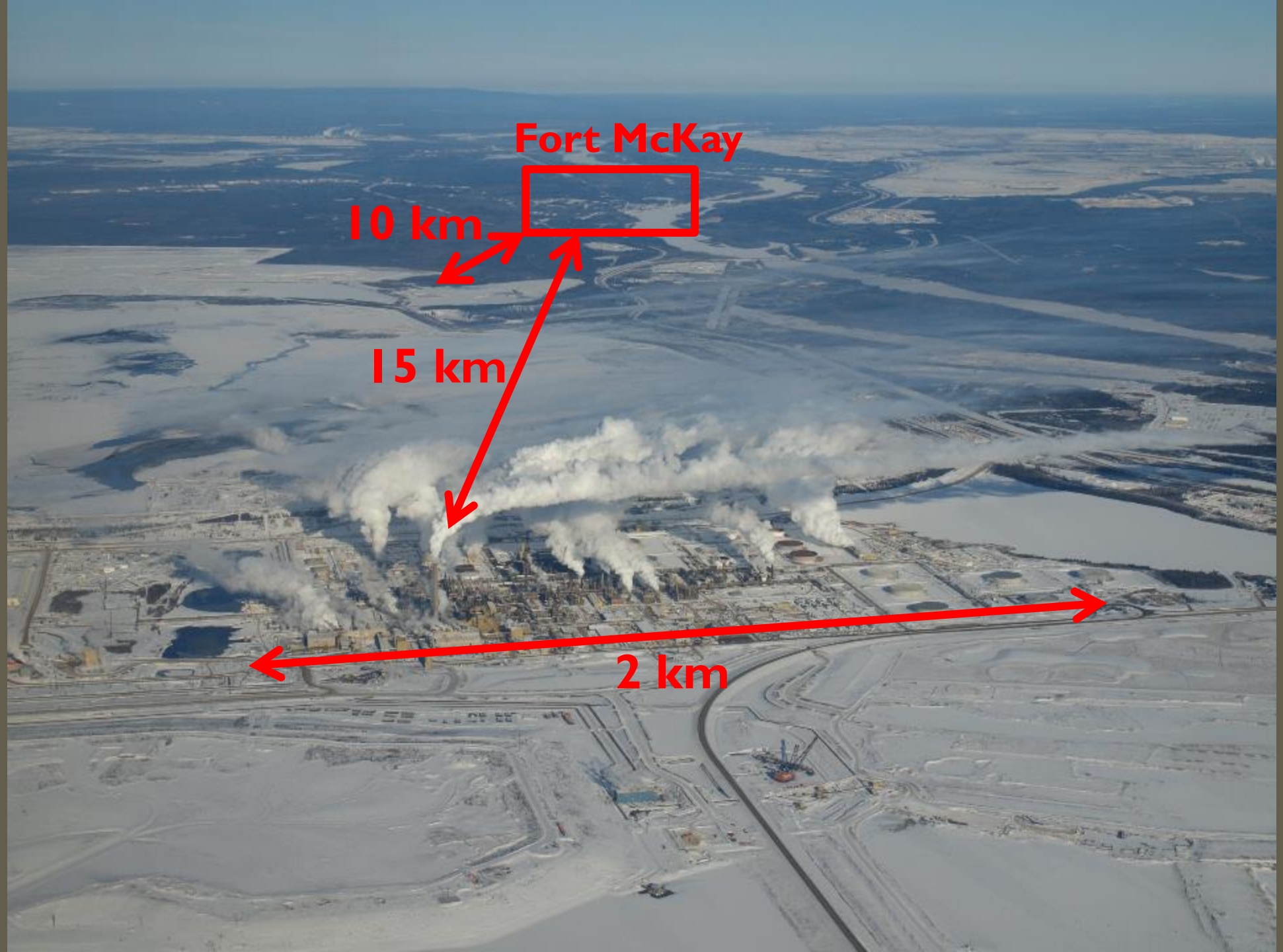
- Instrument noise and measurement methodology, calibration and operational changes (most relevant when concentrations are low and change being measured is small e.g. TRS)
- Short and longer term variability in emissions, i.e. non-steady state conditions (for yearly time series trending this is most relevant when emission change is significant and extended in duration e.g. months or years)
- Inter-annual variability in meteorology (most relevant when there is large variability in wind profiles between major emission sources and monitoring locations)
- Natural (e.g. wildfires) & Global (e.g. methane) influences versus emission related air quality changes Upper level versus ground-level wind patterns
- Nature of emission changes i.e. step versus linear
- Upper level versus ground-level wind patterns


Imperial Kearl
CNRL Horizon
Syncrude Aurora
Shell Muskeg River
Shell Jackpine
Husky Sunrise
Sunshine West Ells
Fort Mckay
Syncrude Mildred Lake
Suncor MacKay River
Suncor Base Plant
Southern Pacific STP MacKay
Fort McMurray
LEGEND
Mining and Upgrading Facility
Mining Facility
SAGD Facility
Community
Image Landsat
Google earth

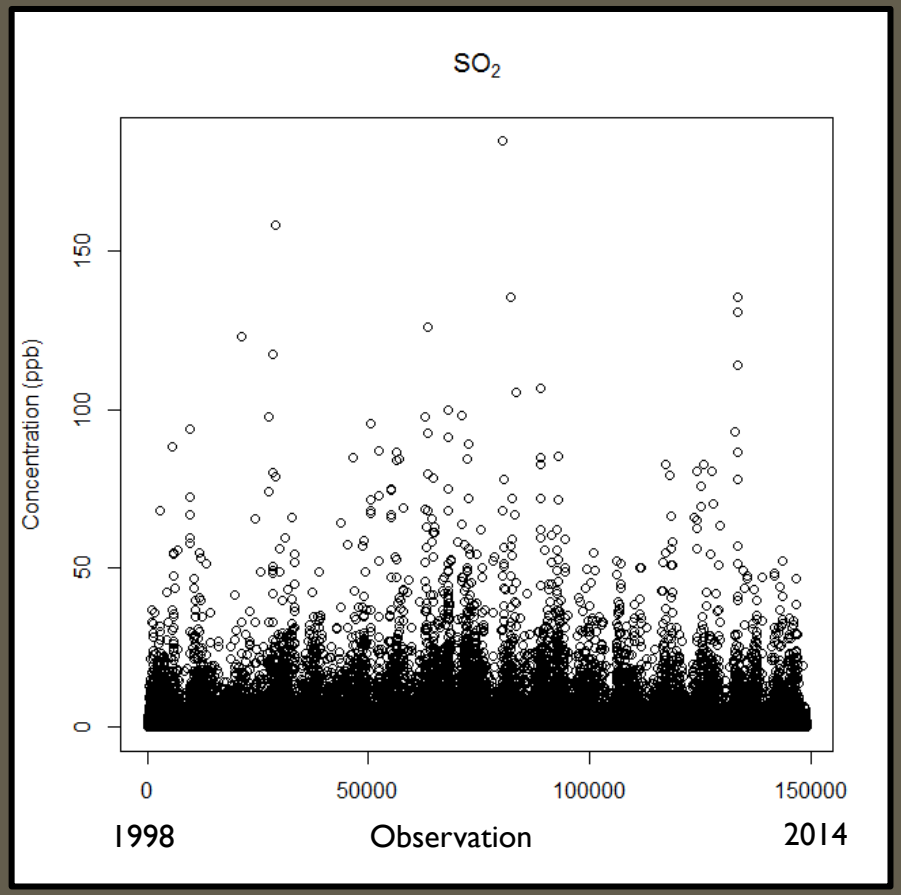
THE DATA

- WBEA AMS 1: Bertha Ganter-Fort McKay
- Parameters: NO_2, NO_X, NO, SO_2, THC, TRS, $PM_{2.5}$, O_3, wind direction, wind speed, temperature, relative humidity at 2m and 10m.
- Continuous data – hourly reads from 1998-2014
- Production Data: AER
- Emissions Data: NPRI, CEMA, AEMERA, Facility Annual Reports
- Some elevated wind level data from the Environment Canada Air Monitoring Station in Fort McKay(Oski-ôtin) to compare ground and elevated wind direction profiles

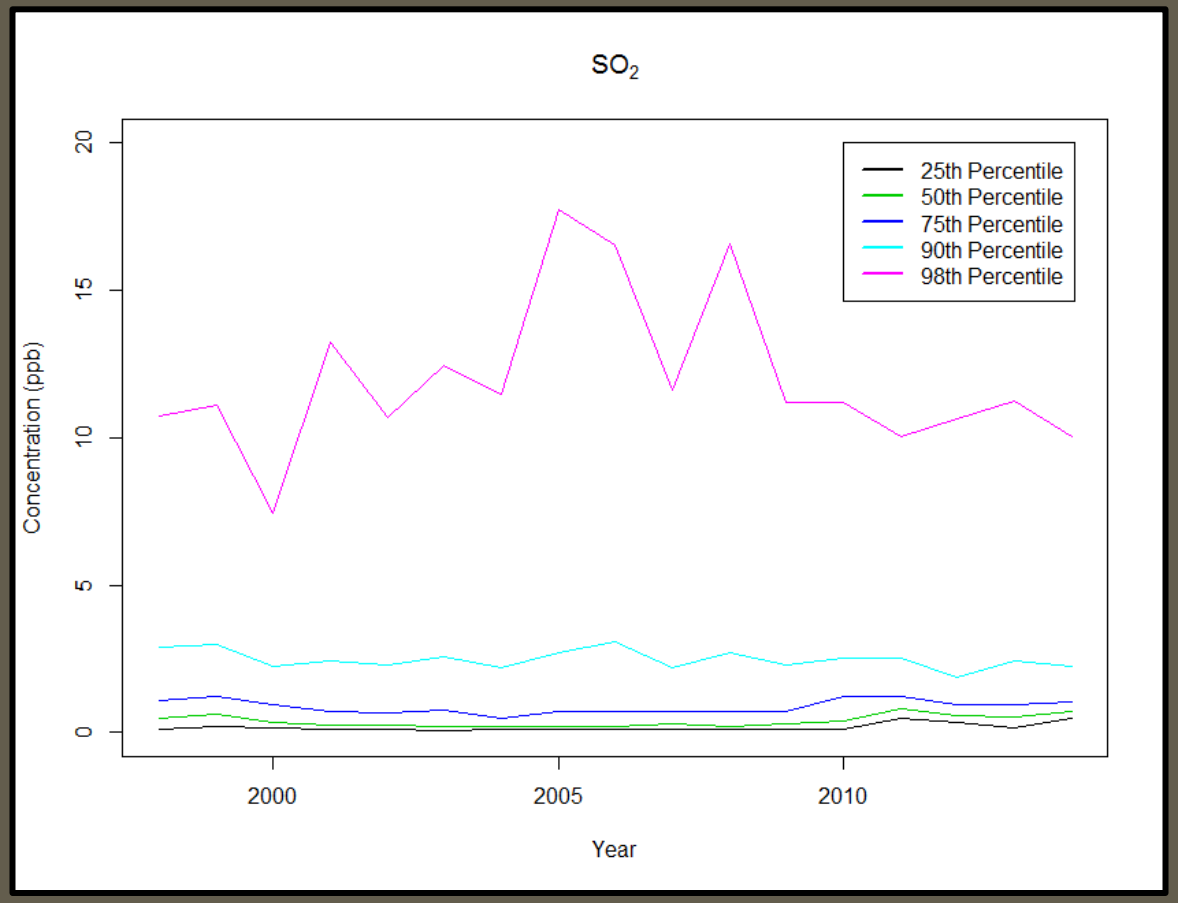
Relating Emissions to Air Quality is Complicated!


Fort McKay
10 km
15 km
2 km

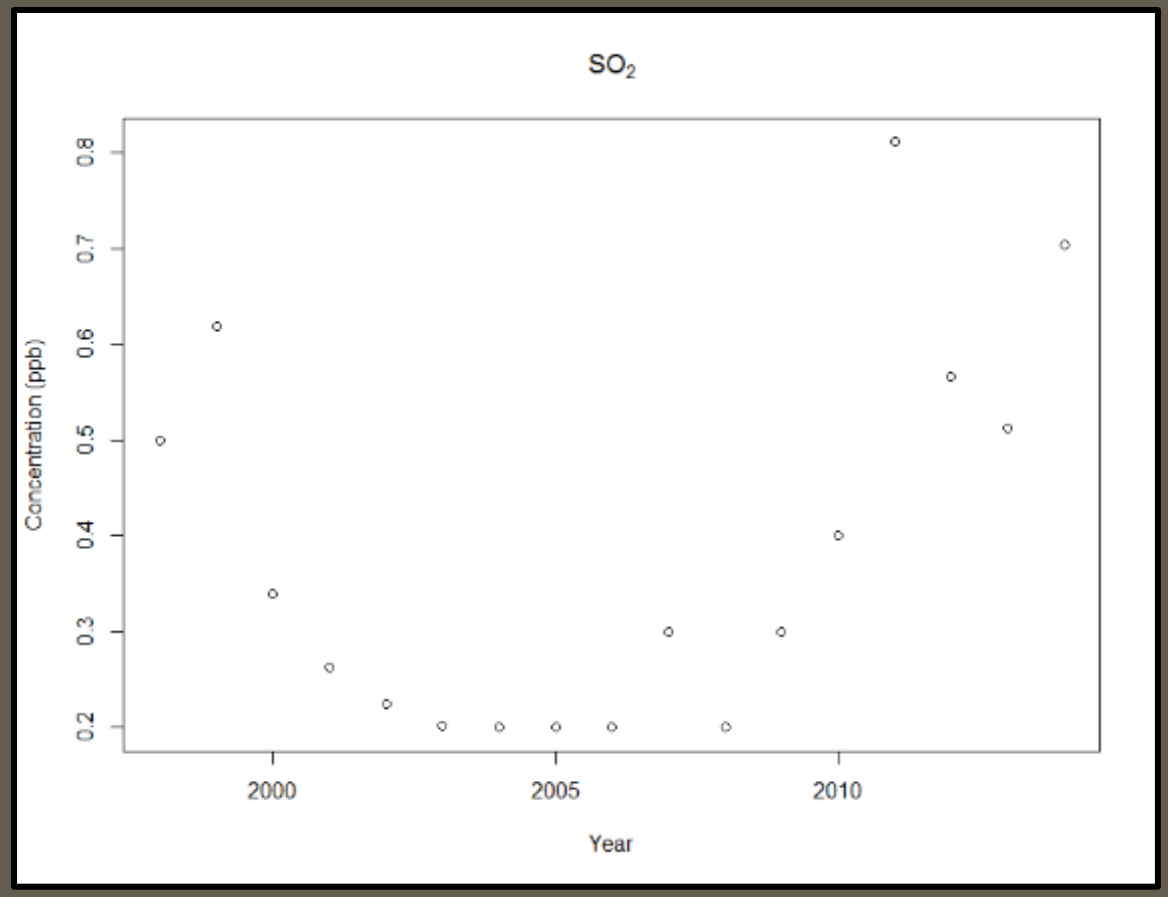
CONSIDER JUST SO_2



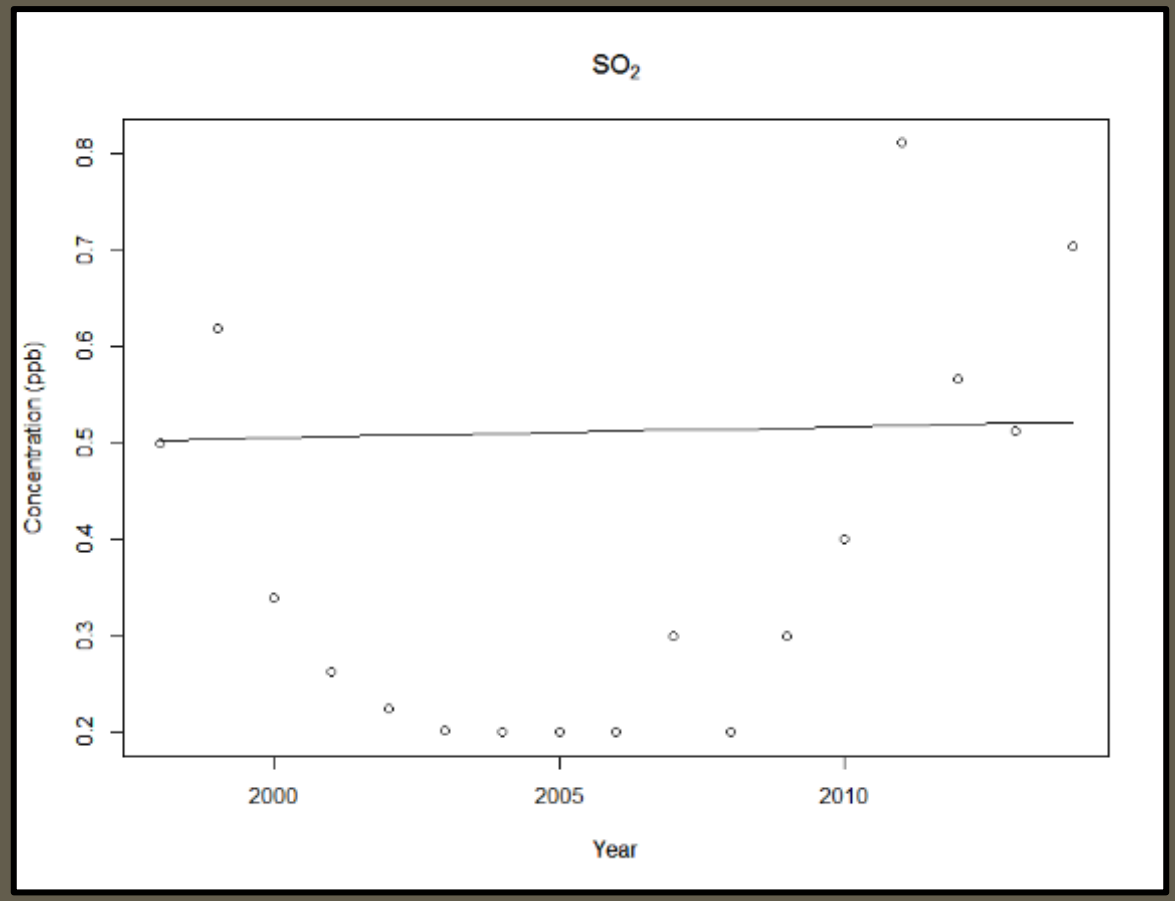
PERCENTILES BY YEAR



MEDIAN YEARLY SO_2



MEDIAN YEARLY SO_2 TREND



TRENDS

- Most analyses of changes in air quality assume the type of change: that it is linear, monotonic, and directly related to growth of oil sands industry.
- Tools used are different types of linear regression.
- What is needed is a way of detecting change that does not assume what form that change will take, and a way of linking this to environmental stressors.

METHODS

Statistical Trends and Tests	Relationship to Industry	Poor Air Quality Events	Detecting Meaningful Change	Influence of Wind Direction
• Non-parametric Theil-Sen • Mann Whitney U: Early Industrial to Late Industrial	• Correlation: Production • Correlation: Emissions	• Assessing frequency, magnitude and duration of poor air quality events • Trends in poor air quality events	• Estimating background variability • Odds Ratios	• Non-parametric regression with modified Gaussian Kernel

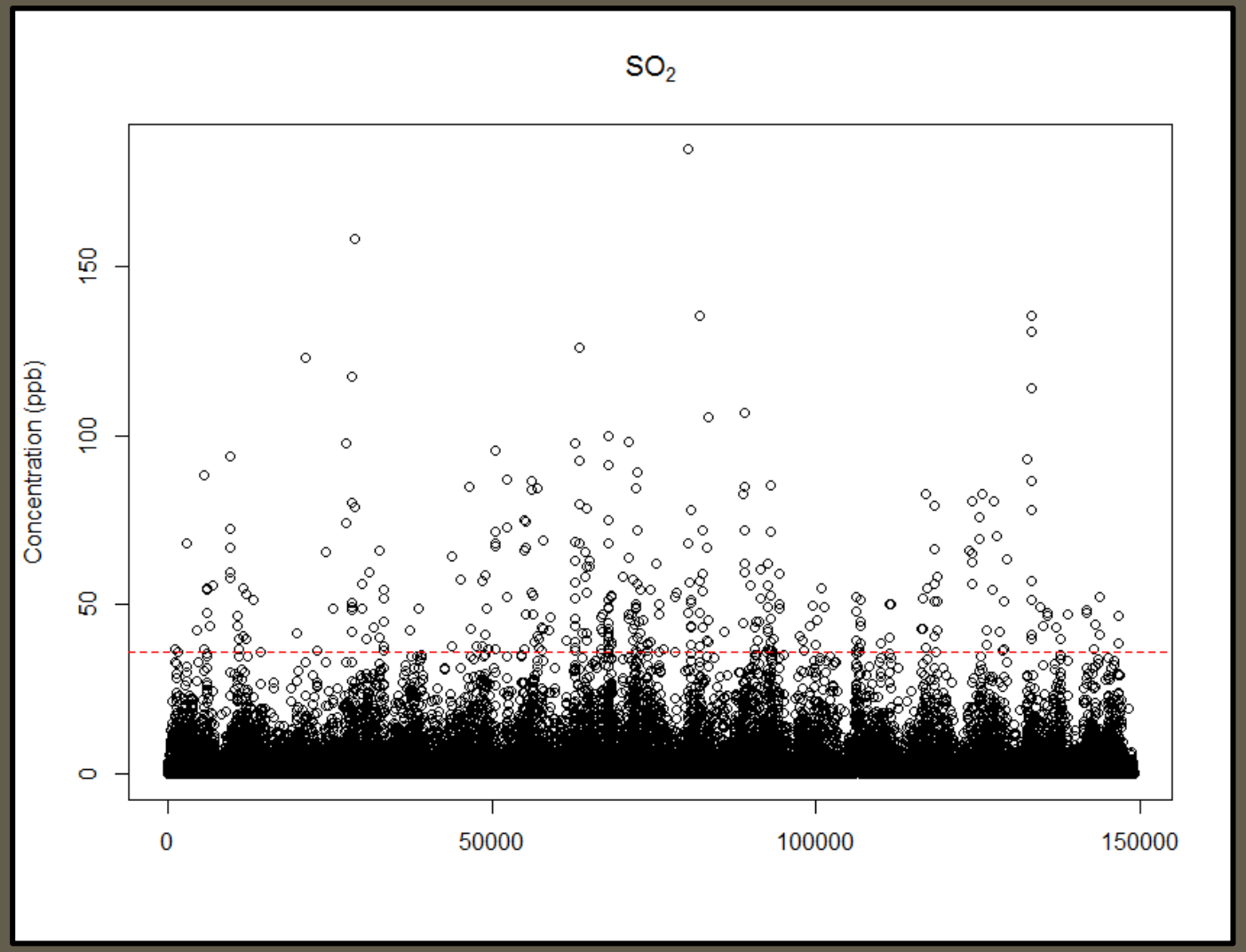
HAS AIR QUALITY CHANGED?

Parameter	N-ENE	E	S-SSE	S-SW	WSW	N-NNW	All
NO_2	**37**	**113**	**263**	**212**	**67**	**87**	**158**
SO_2	**-39**	**-35**	**15**	**15**	**38**	**17**	**10**
TRS	**41**	**21**	**8**	**7**	**37**	**18**	**16**
THC	**8**	**8**	**5**	**6**	**13**	**6**	**8**
O_3	0.4	1.7	**-1.8**	**-14**	**-20.7**	**-6.6**	**-4.2**
$PM_{2.5}$	**39**	**8**	**-4**	**19**	**39**	**26**	**24**

Summary of percent change in parameter of interest, coming from specific air directions, in the early industrial period (1998-2001) to the late industrial period (2011-2014). Orange indicates comparisons that showed a significant increase, while green shows a significant decrease ($p<0.001$) according to Mann-Whitney U tests.

POOR AIR QUALITY EVENTS

- Defining "poor" air quality is difficult
- There are many different management and odour thresholds, some designed to protect from acute injury, some for other reasons
- We tested a number of thresholds. In each case we are interested more in the frequency, duration and trends in poor air quality events than the specific value of the threshold.

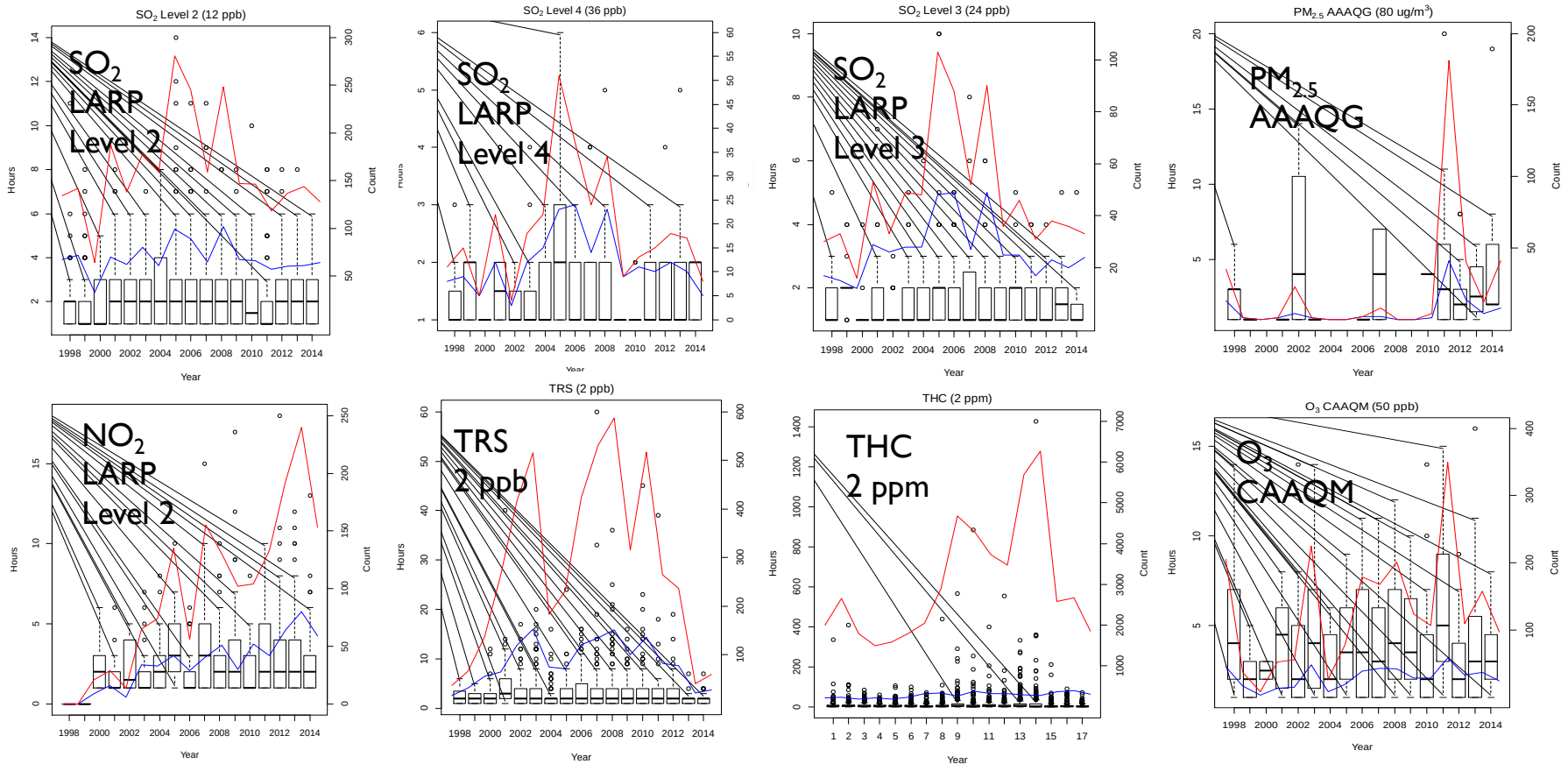


Trends and Tests

Relationship to Industry

Poor Air Quality Events

Detecting Meaningful Change



Boxplots of event duration by year

- Total hours past threshold
- Total number of events

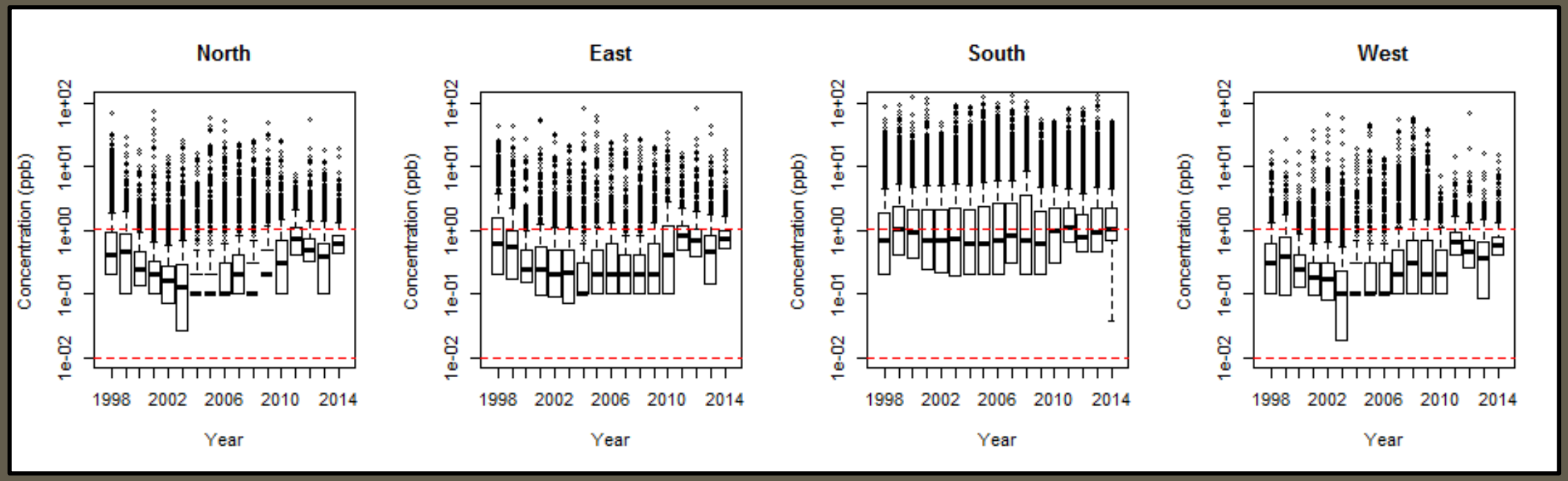
DETECTING MEANINGFUL CHANGE

- There's clearly a great deal of variability in the data set.
- This variability contributes to an inability to detect trends, *but this does not mean that there have not been meaningful changes in air quality.*
- How do you detect change from normal background variation?

ASSUMED NATURAL VARIABILITY

- There are no air quality measurements from before industrial development.
- Fort Chipewyan also has a community station, however, it does not measure the same parameters.
- Between 1998-2001, there is no development west of Fort McKay.
- Assume background is equivalent to the first three years of measurements, when the winds are westerly.

COMPARE DATA TO ESTIMATE OF NATURAL BACKGROUND VARIABILITY



Trends and Tests

Relationship to Industry

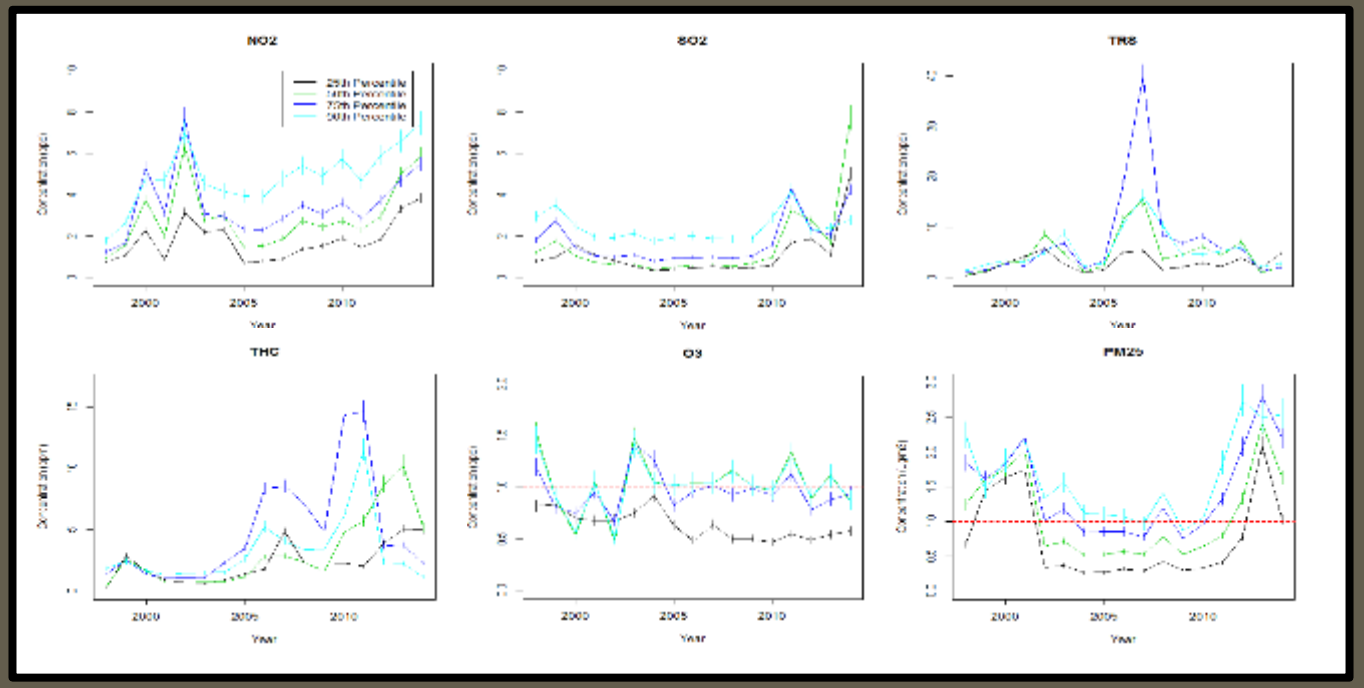
Poor Air Quality Events

Detecting Meaningful Change

Influence of Wind Direction

ODDS RATIOS

This allows you to detect deviation from background variability, but makes no assumptions on the type of change.

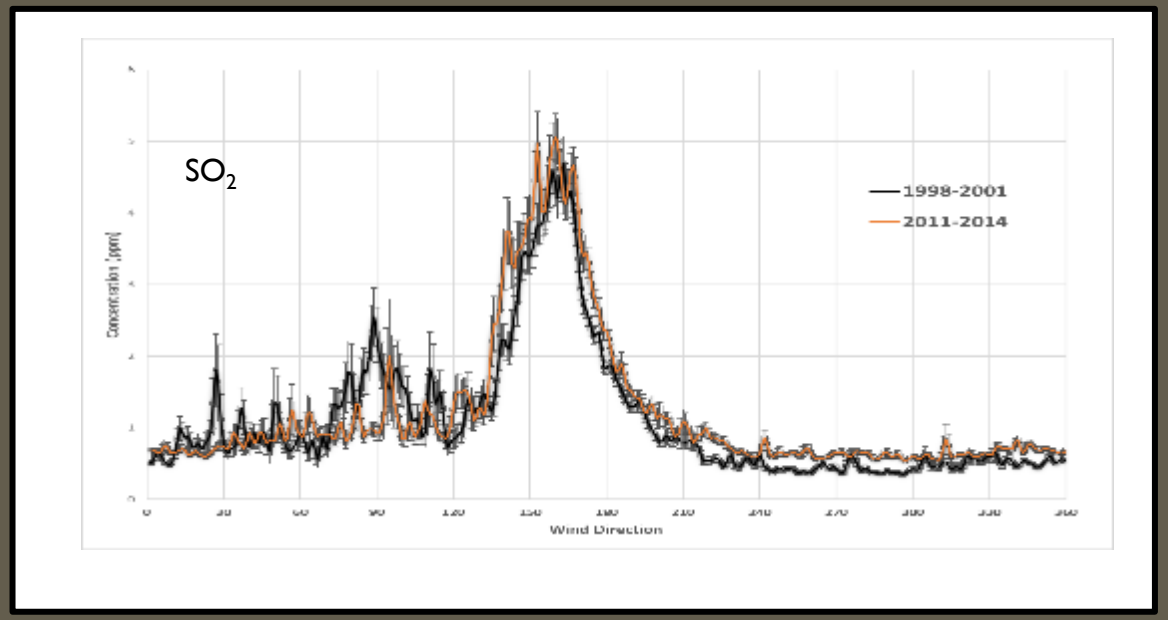


Odds ratios are well used in the medical literature, and confidence interval calculation considers variability in control and experimental population

INFLUENCE OF WIND DIRECTION

- Air quality at any particular point is a complex function of source dynamics, wind direction, wind speed, meteorological parameters, and topography.
- There are a number of facilities around Fort McKay, can plotting compound concentration as a function of wind direction show anything?

HENRY PLOTS



Trends and Tests

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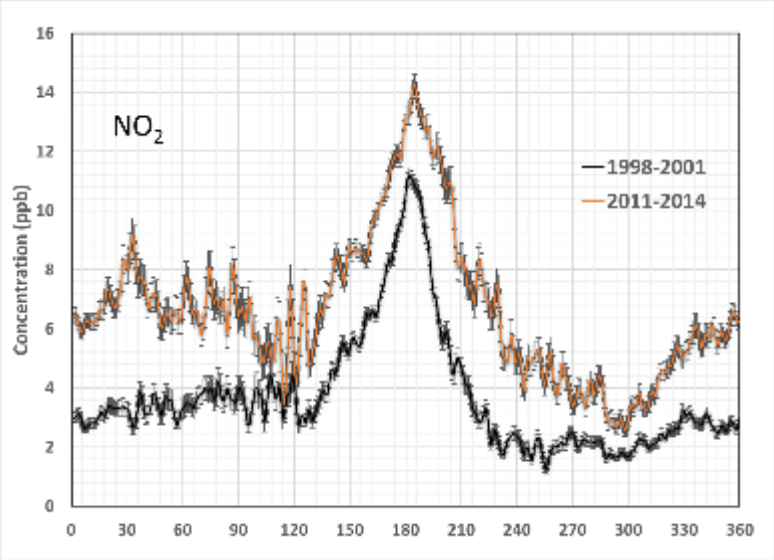
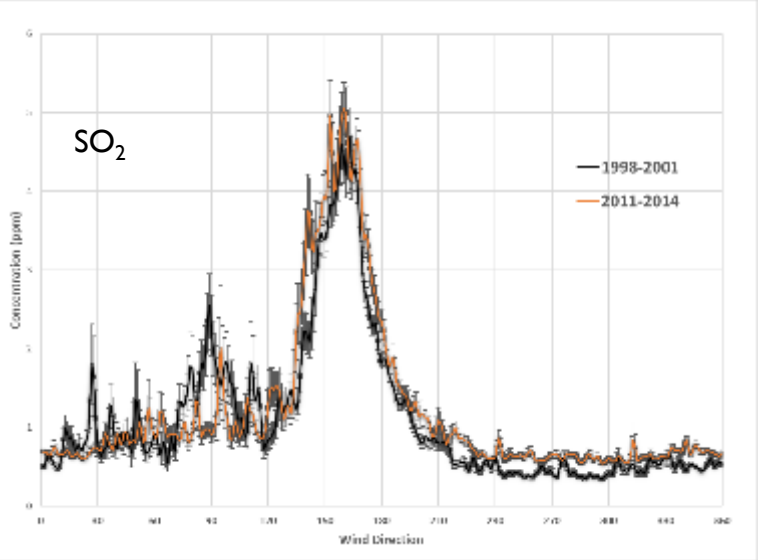
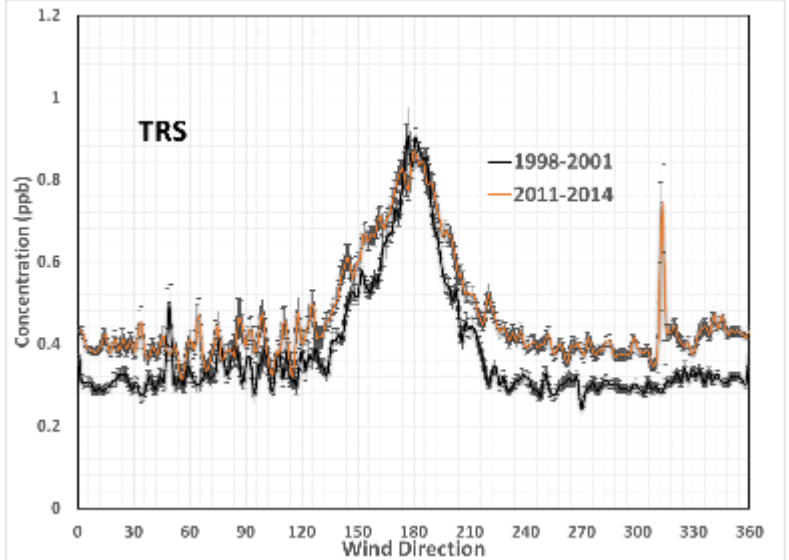
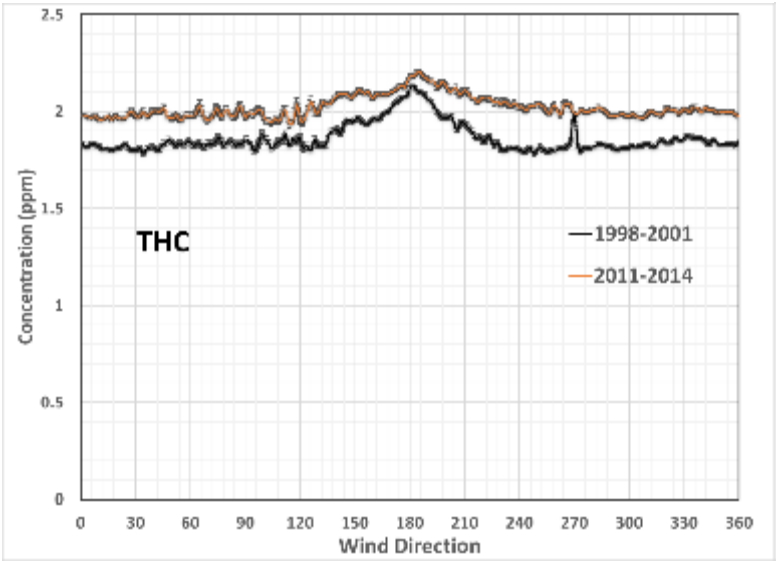


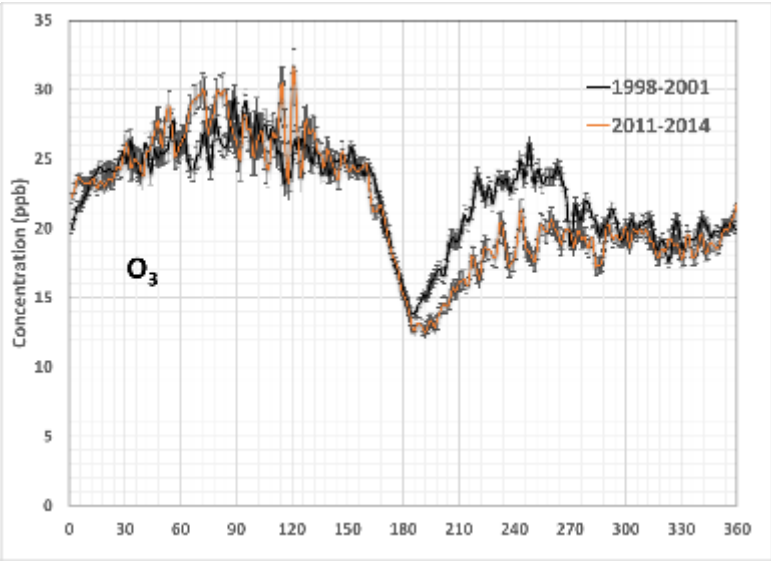


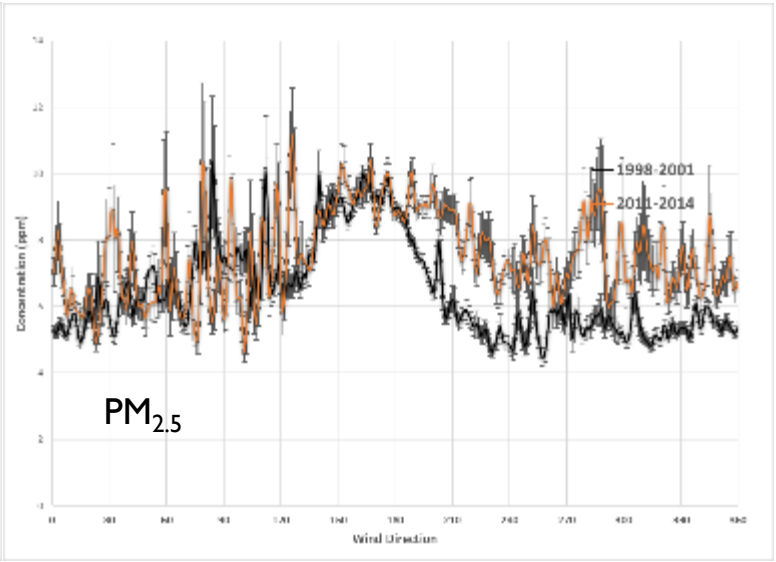


Trends and Tests | Relationship to Industry | Poor Air Quality Events | Detecting Meaningful Change | **Influence of Wind Direction**

HENRY PLOTS







Trends and Tests | Relationship to Industry | Poor Air Quality Events | Detecting Meaningful Change | **Influence of Wind Direction**

CONCLUSIONS

- Rather than being stable and relatively unaffected by industry, Fort McKay's air quality is dynamic, subject to air quality events, and showing evidence of decreasing quality in several important measures.
- These analyses show that air quality dynamics in the community of Fort McKay are complex and non-linear. As such time series trending analysis would appear to have limited value as an air quality assessment and management tool in the oil sands region.

CONCLUSIONS

- An assessment of the frequency and distribution of air events suggested that air quality events are relatively common, and that though most last for an hour or two, some can persist for days.
- The frequency of air quality events due to NO_2, THC and O_3 are increasing.
- Winds from southerly directions are associated with higher ambient concentrations of all compounds but O_3.

MANAGEMENT CHALLENGES

- The comparison of ambient concentrations of compounds to the assumed background showed statistically significant changes to air quality that would not have been detected using simple linear trending, and may be a conceptually simple method of detecting change in monitoring programs.
- The Henry method is a powerful tool for assessing the influence of wind direction, and can help identify the source of chronically high concentrations of specific compounds.
- The AAAQO and LARP Air Management Triggers manage chronic poor air quality, as described by average or median yearly air quality, or manage severe adverse events with hourly triggers, limits, objectives or thresholds. However, there is no consideration of the frequent sub-acute exposures to several compounds.

ACKNOWLEDGEMENTS

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THANK YOU
QUESTIONS?