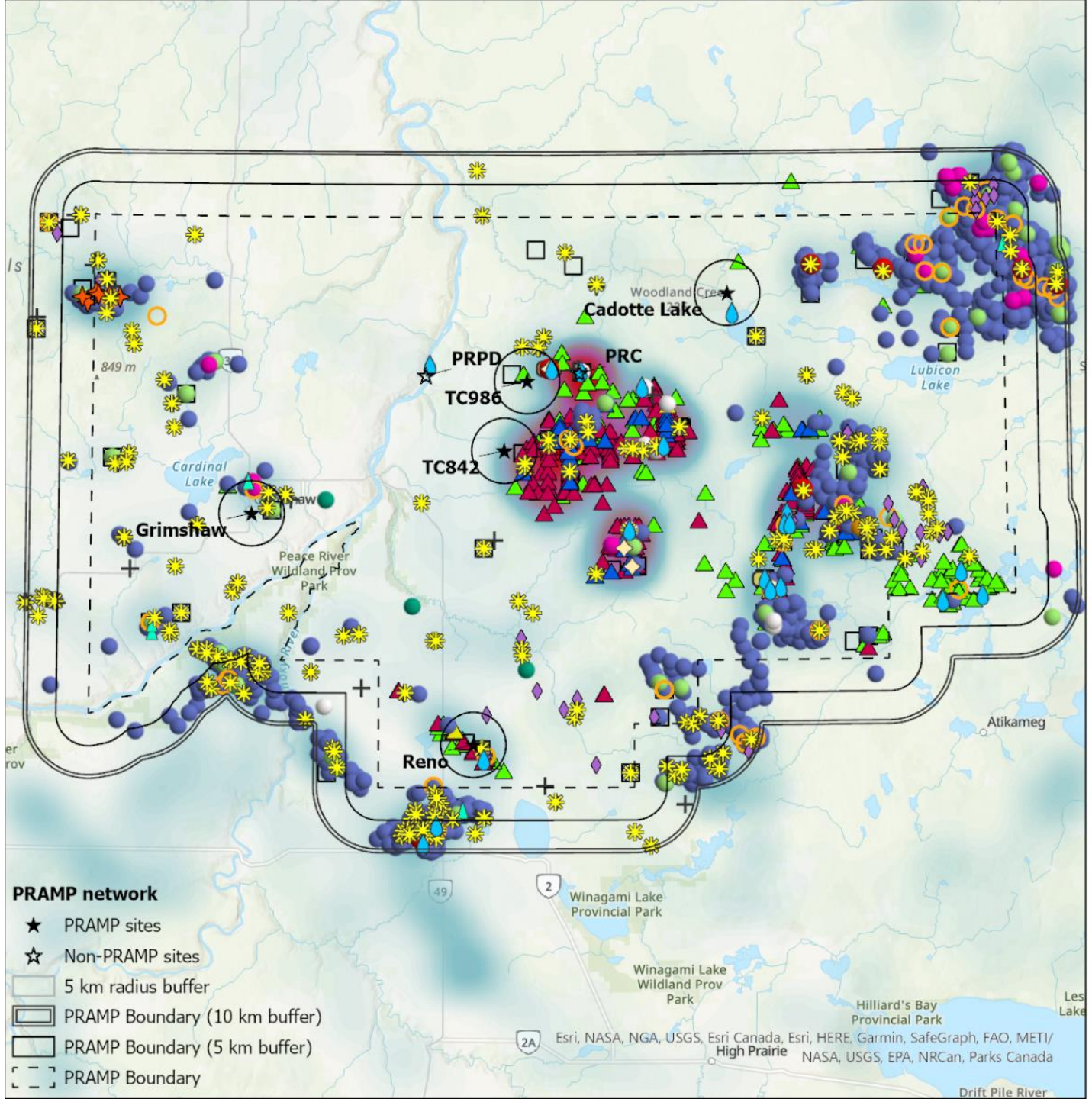
Peace River Area Monitoring Program (PRAMP) - Air Quality Monitoring Network Evaluation

Priority 1 Tier One Emerging Issues

April 14, 2022

Peace River Monitoring Area Program (PRAMP)

- Current and potentially new continuous air monitoring stations (including a 5 km radius buffer)
  - Three Creeks (TC 986 & TC 842)
  - Reno
  - Cadotte Lake
  - Grimshaw
  - Peace River Complex (PRC)
  - Peace River Pulp Division (PRPD/Mercer Plant)
- Stations are not in the heart of emission sources
- Symbols show the locations of emissions facilities
- Base map shows the area density of surface wells locations.



Facilities in the PRAMP area (Data: AER)

Oil & Bitumen Facilities
- Oil Sands
- Rail Car Oil Load-/Unloading
- Oil Pipeline
- Enhanced Recovery
- Crude Oil Multi-Well
- Crude Oil Proration
- Crude Oil Single-Well
- Oil Tank Farm
- Crude Bitumen Heavy Oil
- Crude Bitumen Multi-Level Pro.
- Crude Bitumen Multi-Level
- Crude Bitumen Single-Well

Gas Facilities
- Underground Gas Storage
- Gas wells, plants & pipelines
- Field Gas Meter Station

Other Facilities
- Drilling & Completing
- Custom Treatment
- Brine Production
- Compressor Stations
- Surface Waste Facility
- Disposal
- Water Source

Wells area density

Sparse

Dense

m

Basis for Evaluation – Emerging Issues

- **Priority One**
  - Hydrocarbon context: emissions reduction, regional air quality improvement, a regulatory framework for CHOP is in place (Directive 84) and mitigation measures have been implemented. How do these changes inform the optimization of PRAMP's monitoring program?

- **Priority Two**
  - The air monitoring station and 12 passive monitors at the Peace River Complex are anticipated to be added to the PRAMP network soon. If or how can the overall monitoring network be optimized?
  - PRAMP has been asked to consider incorporating the two Mercer air quality monitoring stations, Mercer Plant (PRPD) and Mercer Town. If or how can the network be optimized?

- **Priority Three**
  - There is a large monitoring-deficient area adjacent to PRAMP. Are there any emerging air quality issues in this area that PRAMP should consider in its monitoring program?
  - How can lower-cost technologies best be incorporated into the PRAMP program (e.g., Purple Air sensors).

Priority 1 Approach

❖ Potential Outcomes

- Reconsider number of stations and/or parameters
- Reconsider location, duration, frequency, methodology, technology, etc.

❖ Assessment using continuous, intermittent and historical AQ/emissions data:

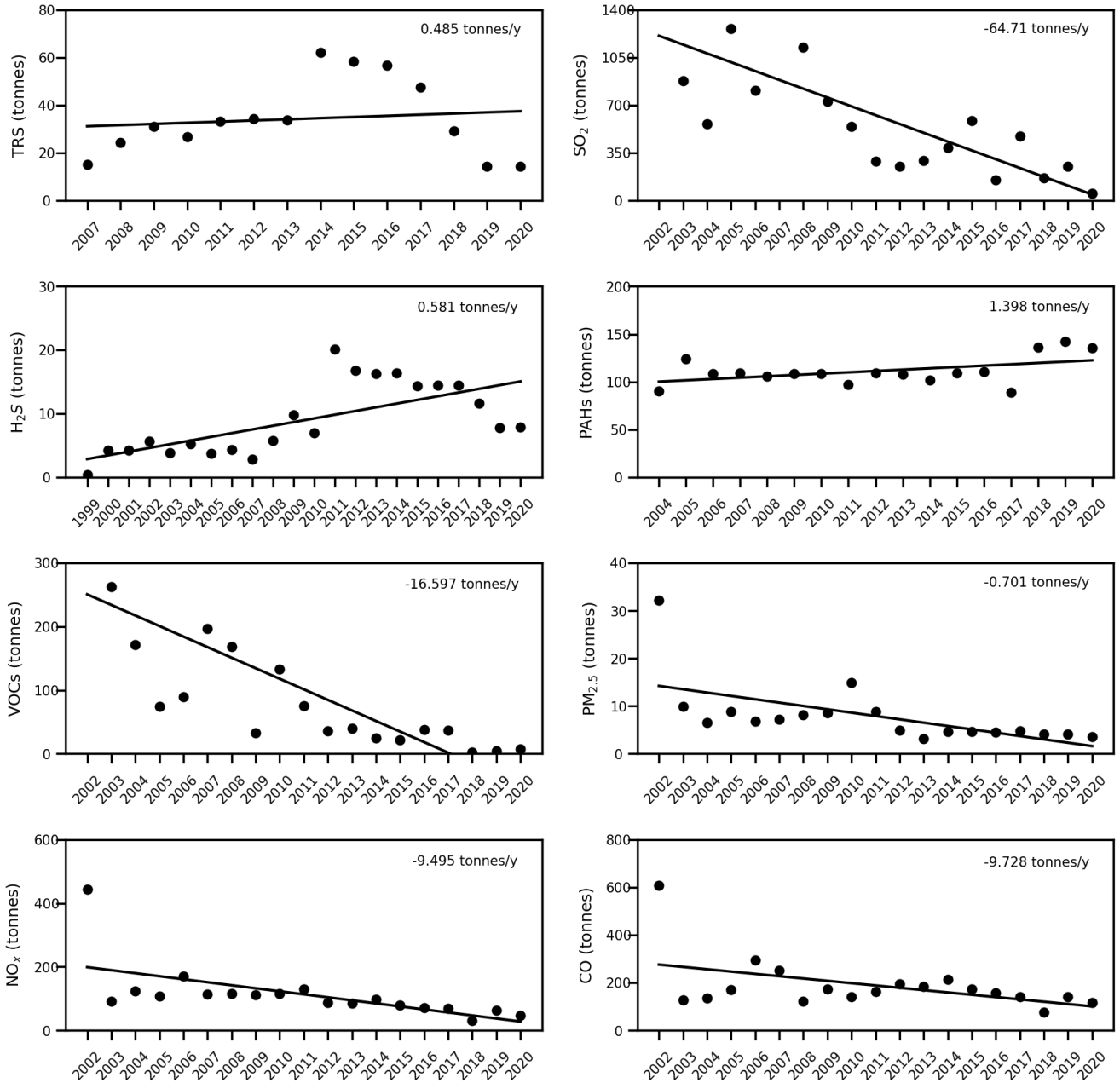
- Temporal trends of emissions as reported to NPRI from facilities within PRAMP
- Time series, temporal trends and compliance of pollutants levels measured by the PRAMP network
- Correlations of pollutants among PRAMP stations for optimization purposes
- Diurnal variations of pollutants at each PRAMP station and comparison between stations
- Meteorological controls on pollutants at each PRAMP station: wind and pollution roses
- Changes in canister-based VOCs concentrations over time and their compliance

NPRI Emission Trends

- Linear trends of annual emissions increase or decrease over the entire period of reporting:
  - However:
    - Since 2011, all decrease except PAHs
    - Near-zero VOC emissions since 2018

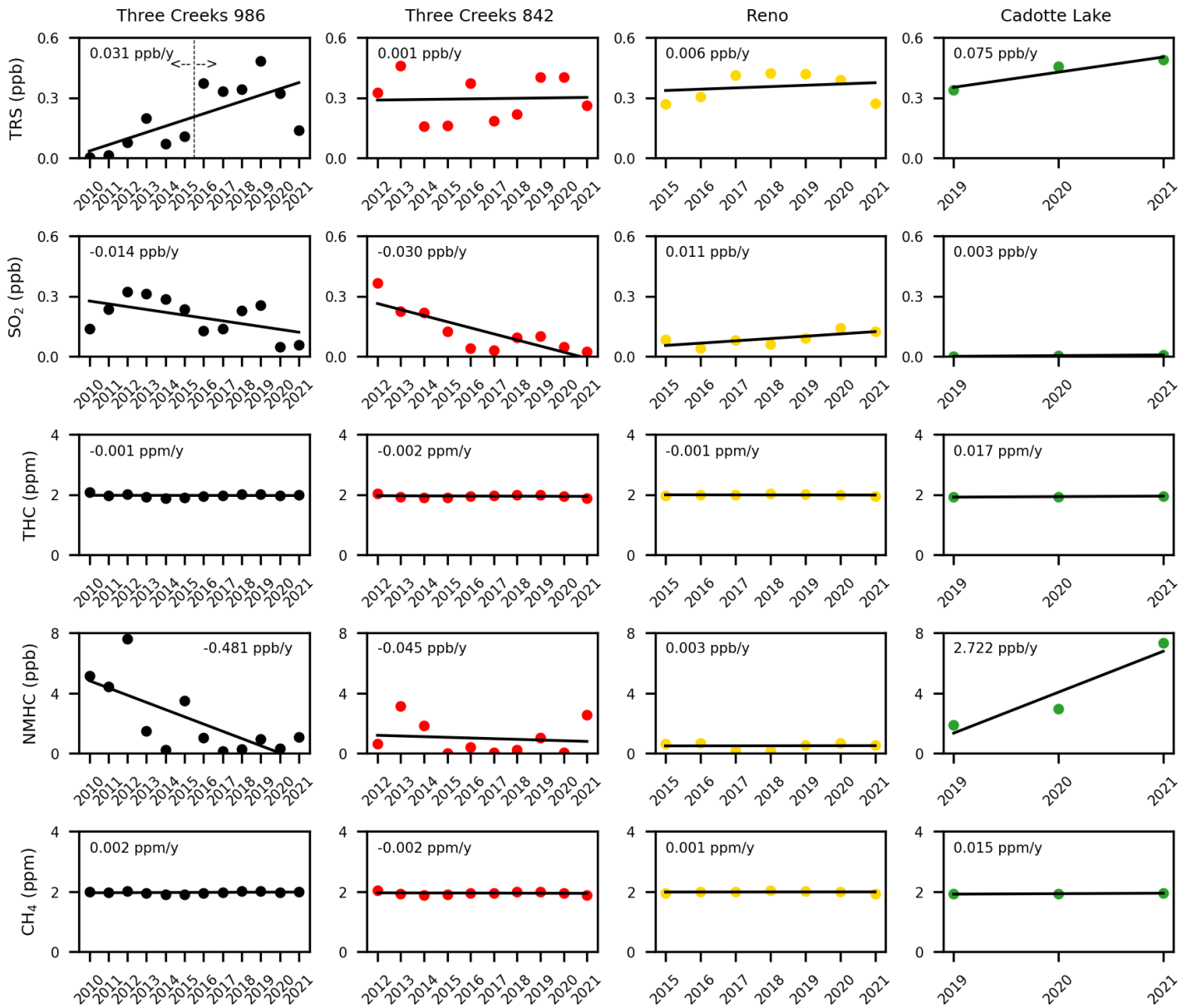
- Are decreased reported emissions the result of market trends, or improvements in emission control?

- If the latter, can VOC monitoring be eliminated, given the relatively large decrease?



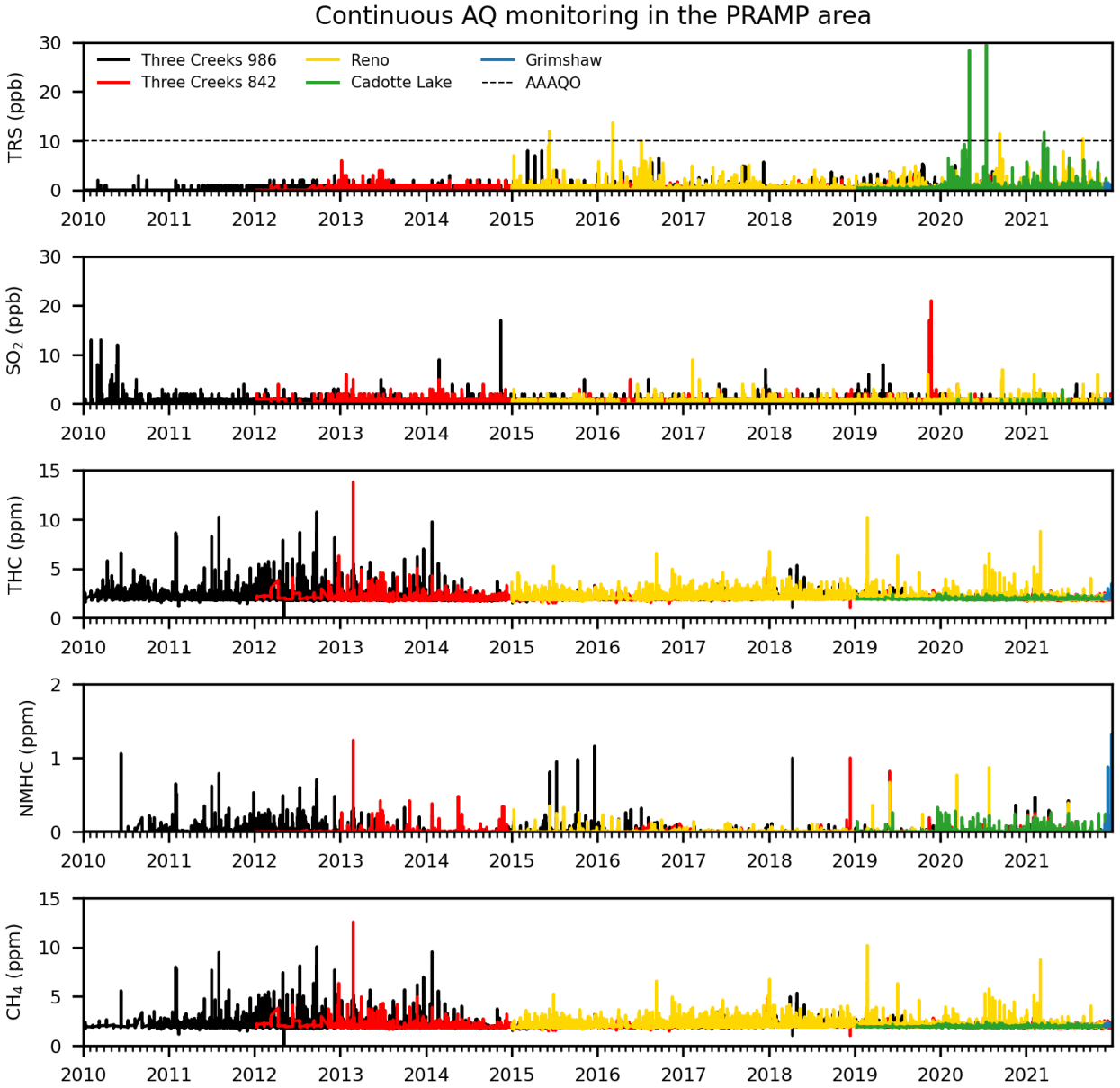
PRAMP Concentration Trends

- Linear trends of annual concentrations increase/decrease over the entire period of reporting
- Trends statistically not significant at Cadotte Lake due to short record
  - However:
    - Since 2011, all stations decrease TRS
    - TRS trend at 986 different before/after 2015 due to different analytical settings
    - SO_2 decreases at Three Creeks
    - No change in THC or CH_4 concentrations
    - Reductions in NMHC at 986
- Annual averages don't tell the full story on trends, but it is not evident that low VOC emissions are reflected in sustained reductions at all stations (e.g., 2021 NMHC at 842)



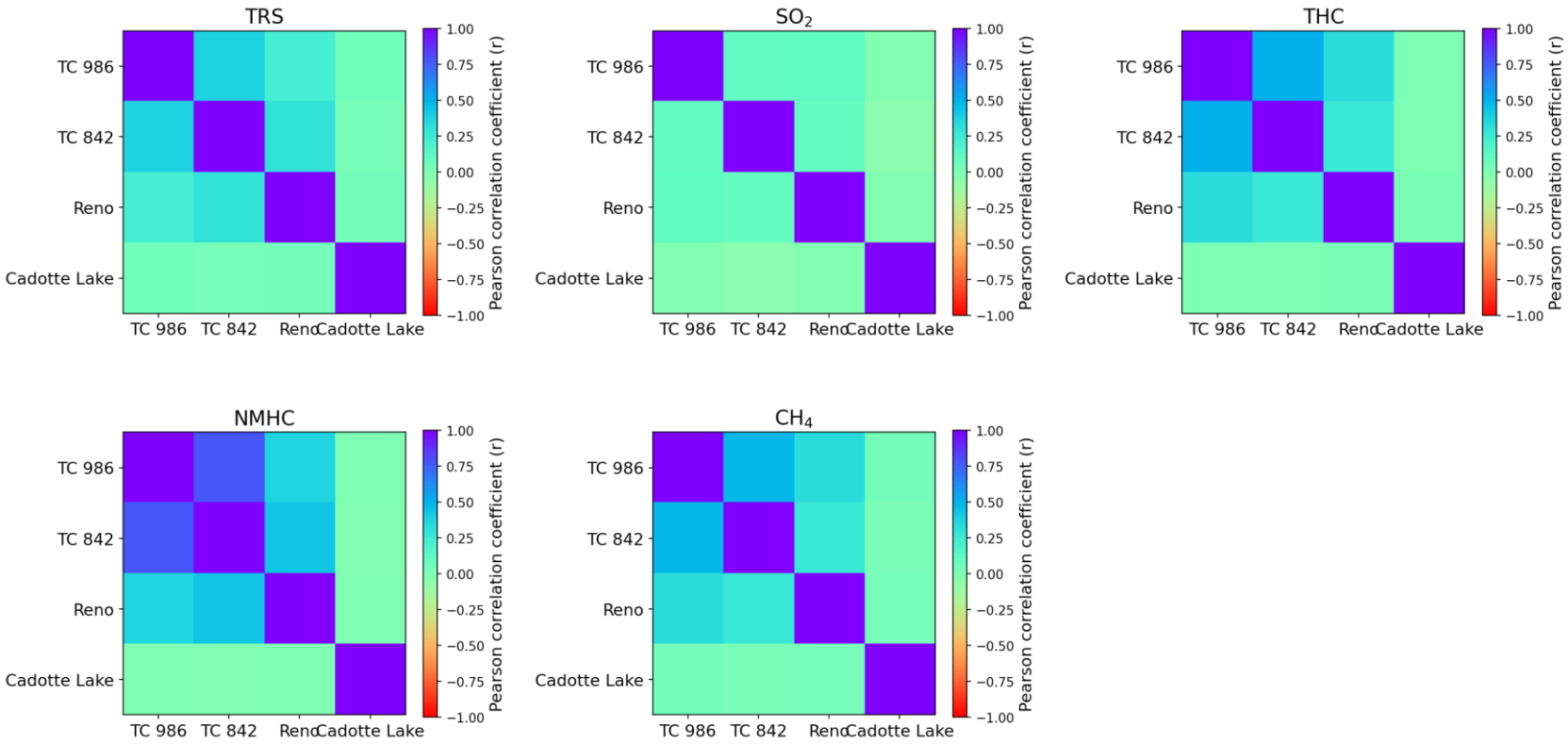
Compliance of 1-h average concentrations

- Historical and recent exceedances of 1-hour TRS threshold at Cadotte Lake and Reno, suggesting an ongoing potential for occasional odour detection
- No exceedances of 1-hour SO_2 (1-h AAAQO = 172 ppb)
- No exceedances of 1-hour CH_4 (ESL = 20-512 ppb for both short and long terms)
- No thresholds for THC and NMHC
- Grimshaw is a new station that started operating in December 2021 (here only data from December 2021 is presented)



PRAMP Station Correlations: Three Creeks 986 & 842, Reno and Cadotte Lake (2019-2021 data)

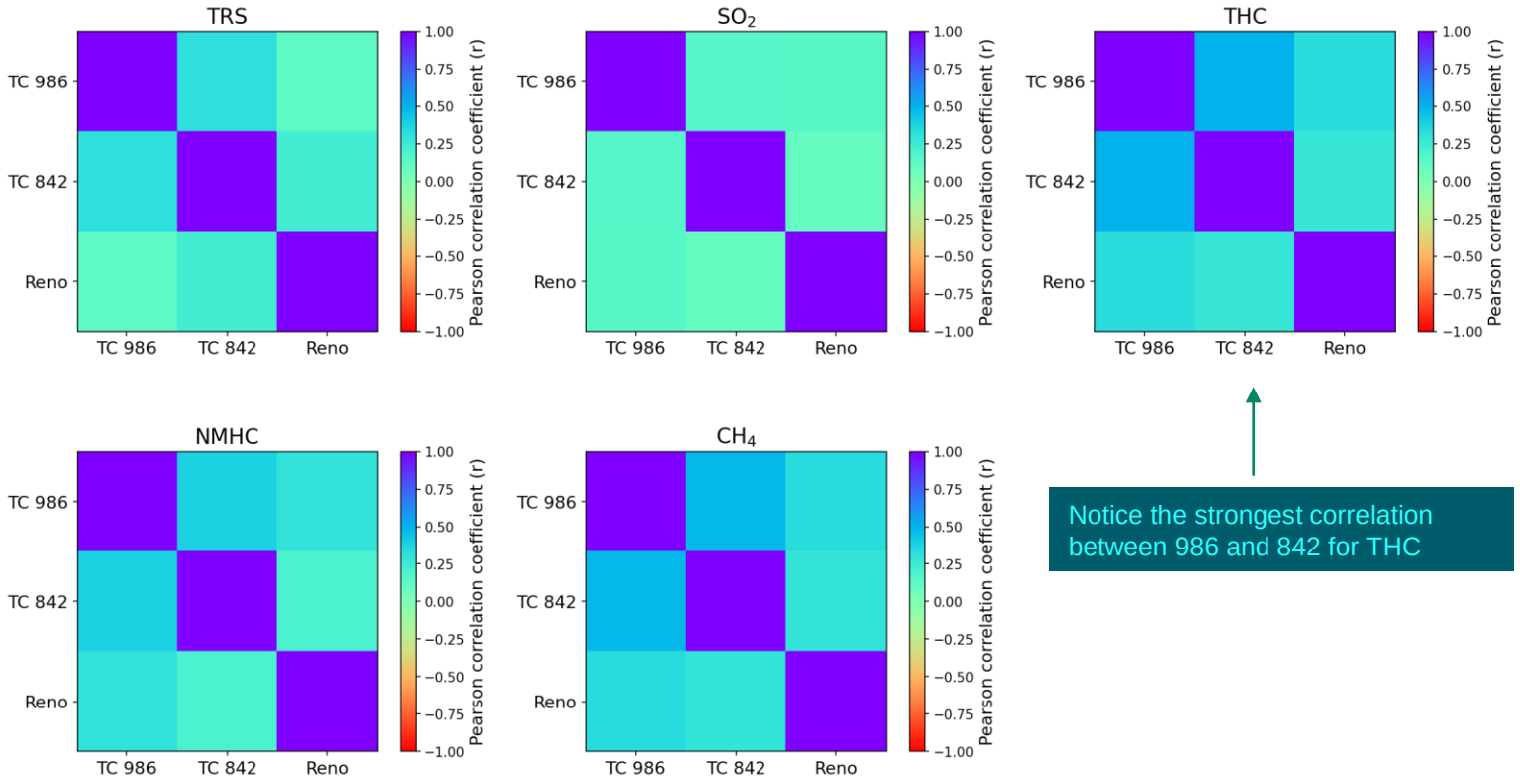
- Are the stations highly correlated for all pollutants? If yes, then one of the stations can be removed from the network.
- Pearson *r* varied from -0.003 to +0.78→ stations are spatially and temporally related, especially in terms of NMHC (0.78) and THC (0.5)
  - However, the correlations for other pollutants are weak → different controls at each station (e.g., wind direction, emissions) may prevent stronger correlations → stations are not so similar.



Notice the strongest correlation between 986 and 842 for NMHC

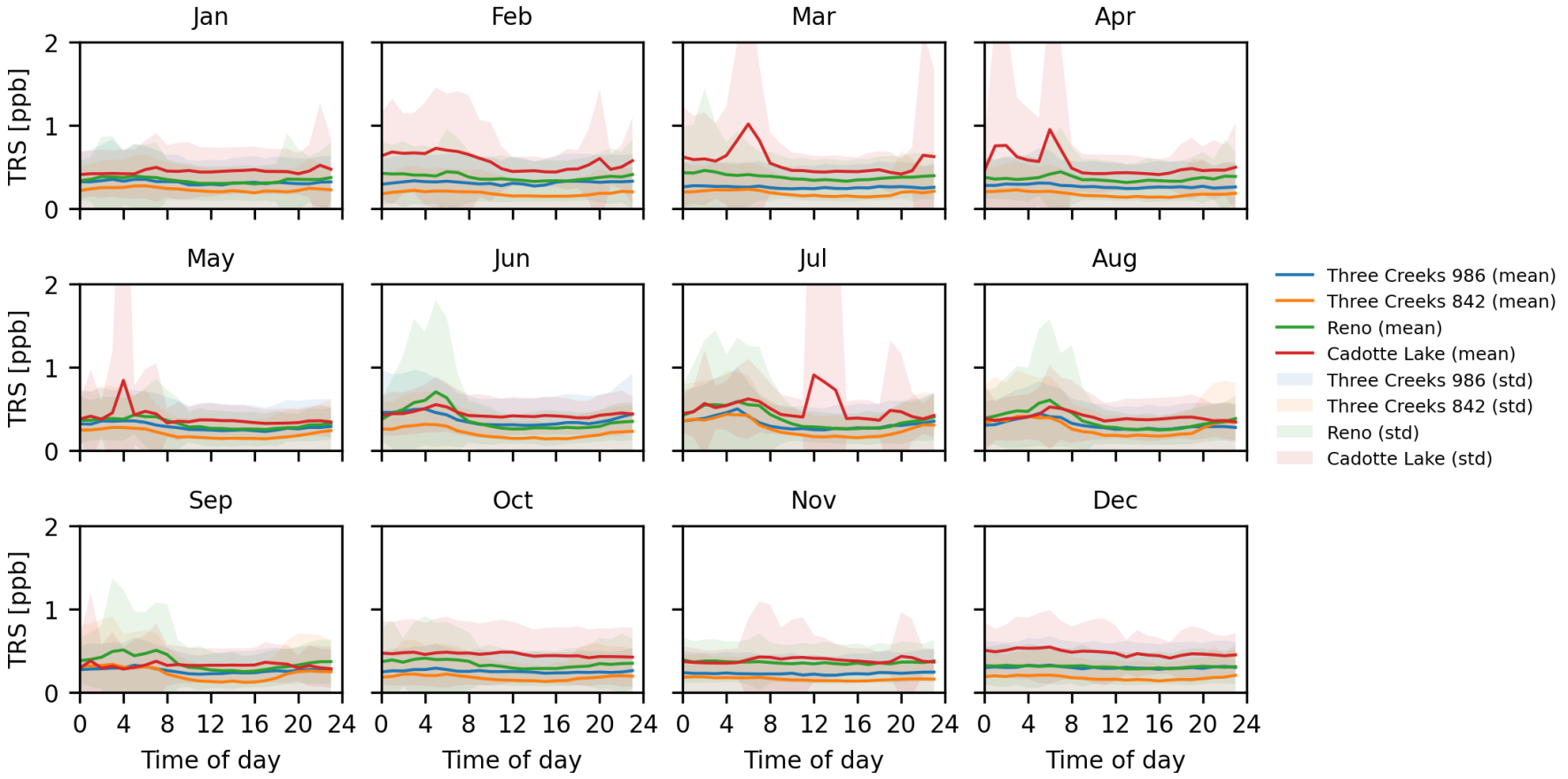
PRAMP Station Correlations: Three Creeks 986 & 842 and Reno (2015-2021 data)

- Are the stations highly correlated for all pollutants? If yes, then one of the stations can be removed from the network.
- Pearson *r* varied from +0.1 to +0.5→ stations are spatially and temporally related, especially in terms of THC
  - However, the correlations are weak → different controls at each station (e.g., wind direction, emissions) may prevent stronger correlations → stations are not so similar.



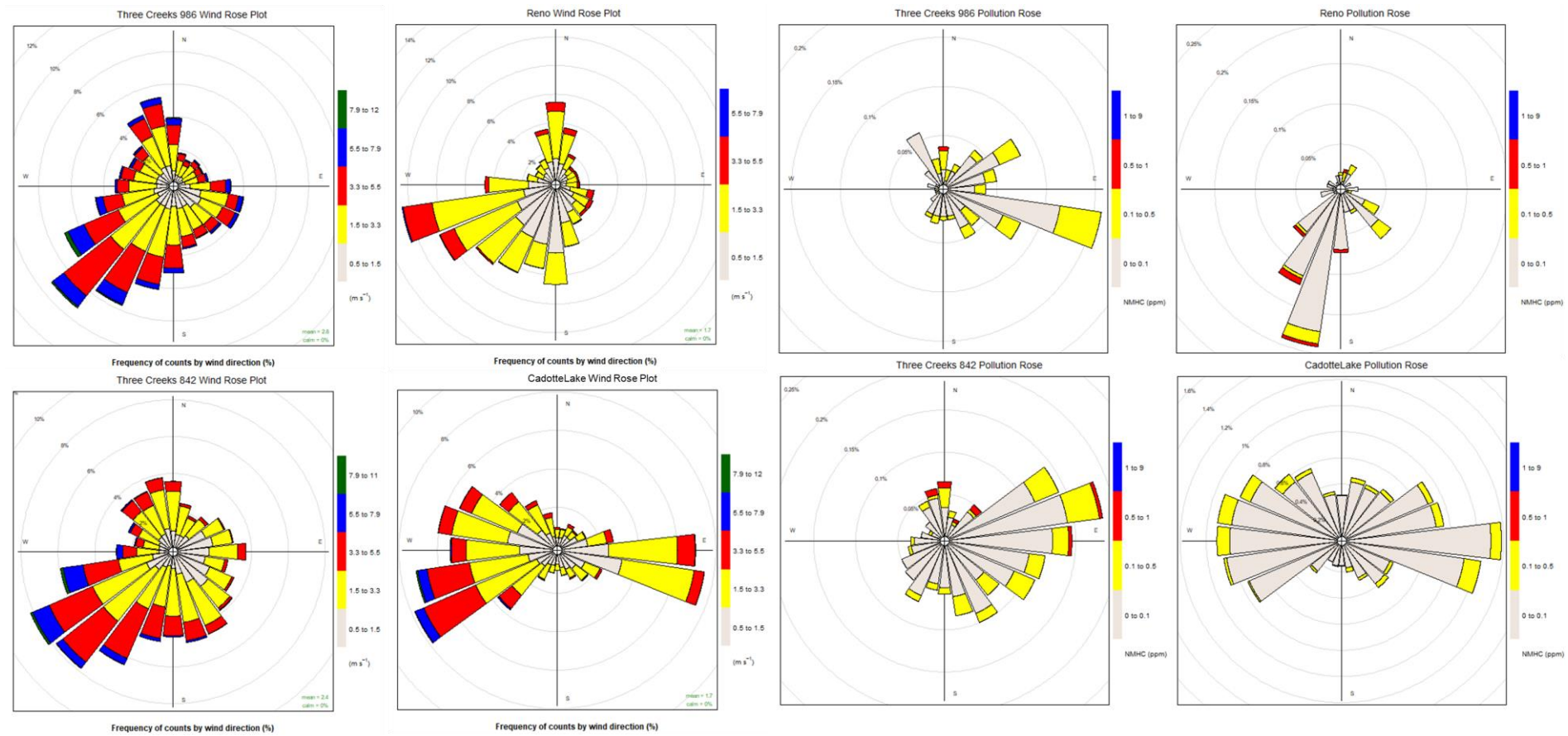
Diurnal Variations – TRS example

- Diurnal variations in mean concentration, and in the standard deviations of concentration can support network rationalization.
- In this TRS example, Cadotte Lake has a unique profile, and so is not a candidate for elimination. It was also unique for NMHC.
- Overall, average diurnal profile is not the best differentiator. But considering the diurnal variation of all gases, either station 986 or station 842 are considered potentially redundant.



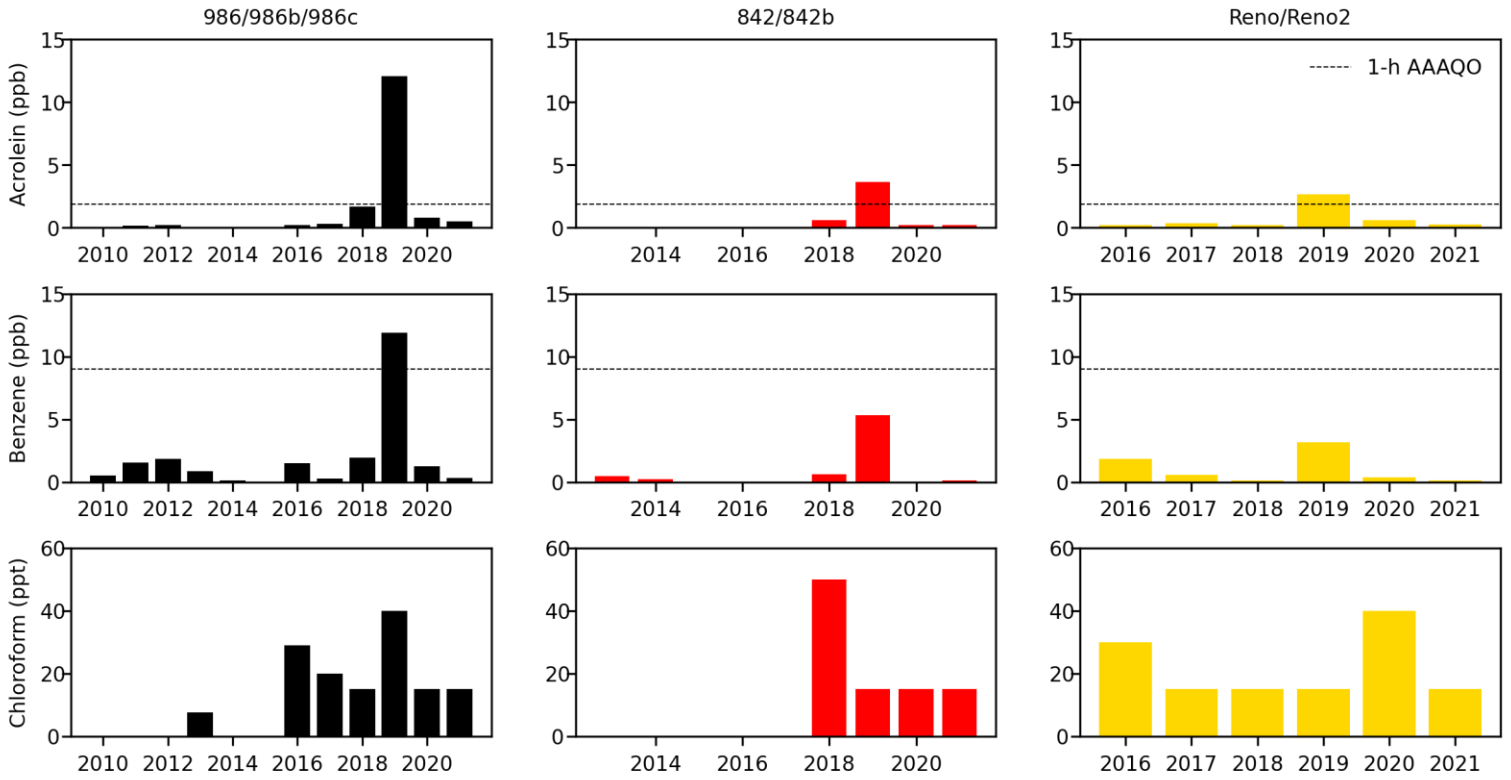
Meteorological Effects – Wind & Pollution Roses

- Are any pollution roses different than the wind rose? If yes, the station might be uniquely situated.
- In this NMHC example, pollution roses for all except possibly Cadotte Lake are different than the wind rose and reflect the influence of nearby sources.
- To understand if one is potentially redundant, would need to better understand local sources near each. Without that, we would say none can be eliminated.



Changes and compliance of canister-based VOCs concentrations at or nearby PRAMP stations between 2010 and 2020 (e.g., acrolein, benzene and chloroform)

- Each station has different timeline
- Data compare well between stations, but 986 recorded a higher exceedance of the AAAQO for acrolein in 2019 compared to 842 and Reno
- 986 also recorded an exceedance for benzene in 2019
- No odour exceedances for chloroform were found at any site
- The VOCs decrease over the past 3 years at all stations, except for chloroform at Reno
- With one exception, the Three Creaks stations show similar VOCs ranges, suggesting possible redundancy.



- The number of samples used to derive the average concentration represented by each bar varied largely, from 1 to 51 samples, depending on the VOC.
- The exceedances in acrolein and benzene during 2019 were based on 1 sample (at 986), 2 samples (at 842) and 5 samples (at Reno).

Priority 1 Summary

❖ What the assessment says:

- Since 2011, emissions of all NPRI reported compounds, except PAHs, have decreased. This supports reduced monitoring for VOCs (NMHC), of which emissions are near zero when summed over all NPRI reports. However:
  - Are reductions the result of decreased production, and might increase again?
  - Are many smaller facilities emitting below reportable levels? Yes.
- Trends in annual average concentrations of pollutants in the PRAMP network. Since 2011, TRS decreased at all stations. SO_2 decreased at Three Creeks stations. There were reductions in NMHC at 986.
  - However, low reported VOC emissions are not reflected in sustained NMHC reductions at all stations (e.g., 2021 NMHC at 842)
  - It is likely that low levels of VOC emissions from many facilities and well sites contribute to elevated baseline concentrations
  - Similar trends and concentrations at both Three Creeks stations, suggesting one is redundant
- Time series of extreme concentrations of pollutants in the PRAMP network, and AAAQO compliance.
  - Historical and recent exceedances of 1-hour TRS threshold at Cadotte Lake and Reno, suggesting an ongoing potential for occasional odour detection
  - 1-hour SO_2 concentrations are much less than AAAQOs
- Changes in canister-based VOC concentrations suggest a weak decreasing trend over the past 3 years

Priority 1 Summary

❖ What the assessment says:

- Correlations of pollutants among PRAMP stations for optimization purposes:
  - The largest correlations were found between Three Creeks stations for NMHC (r = 0.78) and THC (r = 0.5) over the past 3 years → the stations might be marginally redundant but only with respect to hydrocarbons
  - Overall, the low correlations do not support a reduction in the number of stations
- Diurnal variations of pollutants at each PRAMP station
  - Unique profiles for Cadotte Lake for TRS and NMHC
  - Considering all gases, 986 is potentially redundant
- Meteorological controls on pollutants at each PRAMP station (pollutant roses)
  - For all pollutants but NMHC, the pollutant roses are similar to the wind rose for each station, suggesting unique sources are not contributing and therefore that some stations are redundant
  - Differences for NMHC suggest the stations are uniquely situated and not redundant. Further work looking at emissions from nearest facilities contributing to concentrations would be needed to reverse this (i.e., a dispersion model study).

Priority 1 Draft Recommendations

- Remove stations?
  - The assessment weakly supports elimination of one of the Three Creeks stations with the 986 being the potential candidate based on temporal trends, diurnal profiles and correlation. However, the support is too weak for this recommendation to be made.

- Reduce parameters?
  - Can VOC/NMHC be eliminated given D84? No, given apparent non-reportable sources.
  - Can SO_2 or TRS be eliminated? No, because SO_2 is relevant and TRS still shows exceedances at two stations.
  - What about meteorology? No, given differences in windroses at sites.
  - Eliminate THC or CH_4? Yes, possible

		Station Name									
Monitoring Method	Parameter	986c	842b	Reno	AQHI (Grimshaw)	CNRL (PRC)	Mercer (Townsite)	Mercer (Plantsite)	Peace River (above valley)	Peace River (in valley)	Nampa
Continuous	Sulphur Dioxide	√	√	√	√	√	√				
	Total Reduced Sulphurs	√	√	√	√	√	√	√			
	Hydrogen Sulphide					√					
	Hydrocarbons *Total, Methane, & Non-Methane*	√	√	√	√	√					
	Oxides of Nitrogen *Total, Nitric Oxide, Nitrogen Dioxide*				√						
	Ozone				√						
	Fine Particulate Matter *Particles ≤ 2.5 Microns in Diameter*				√		√				
	Wind *Speed & Direction*	√	√	√	√	√	√	√			
	Precipitation	√	√	√							
	Climate Variables *Temperature, Relative Humidity, Barometric Pressure*	√	√	√	√	√	√	√			
	Air Quality Health Index (AQHI) *Third-Party Calculated Multi-Parameter Index*				√						
Intermittent	Non-Methane Hydrocarbon Canister	√	√	√							
	Methane Canister	√	√	√							
Passive	Polycyclic Aromatic Compounds	√									
Small Sensor	Fine Particulate Matter *Particles ≤ 2.5 Microns in Diameter*	√	√	√	√				√	√	√
	Climate Variables *Temperature, Relative Humidity*	√	√	√	√				√	√	√
	Air Quality Health Index Plus (AQHI+) *Third-Party Calculated Single-Parameter Index*	√	√	√	√				√	√	√

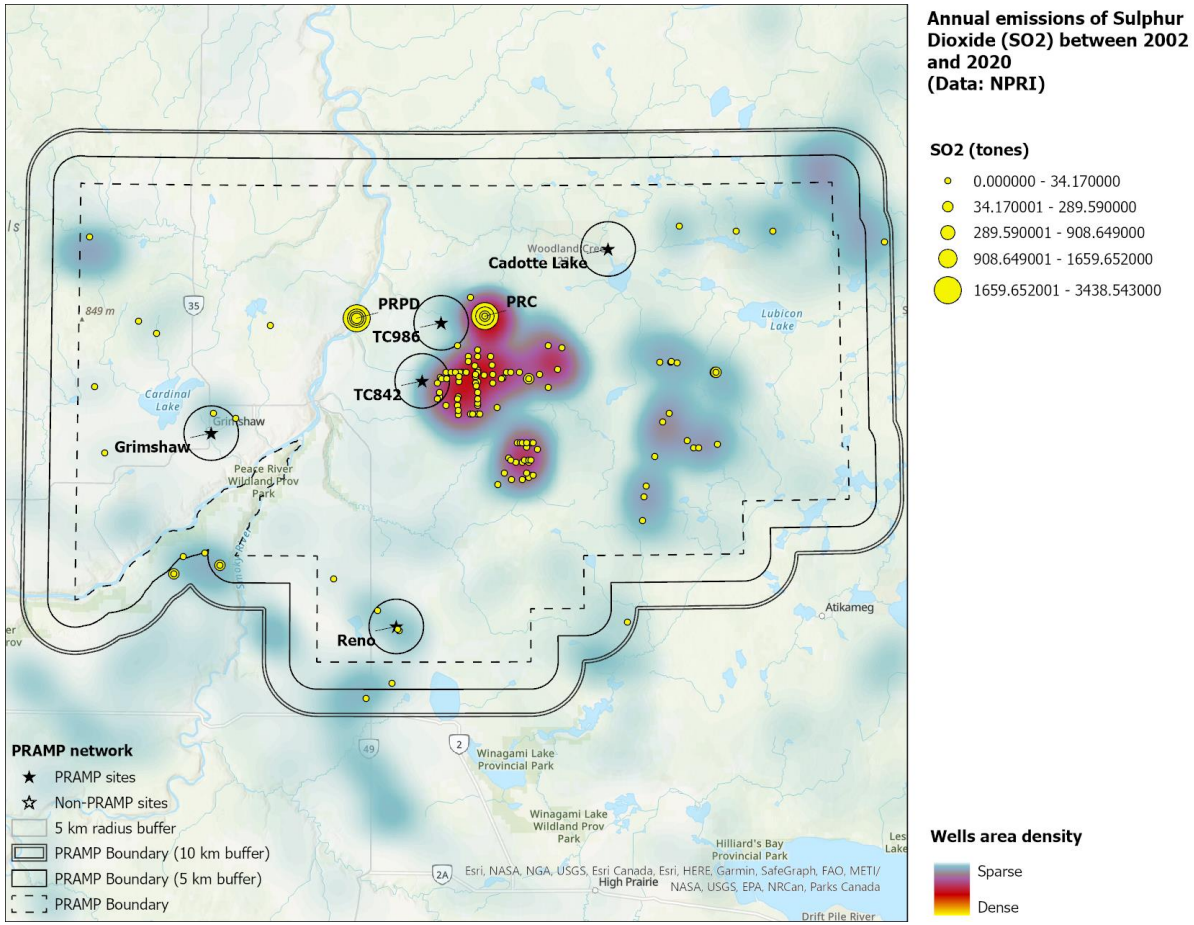
Priority 1 Draft Recommendations

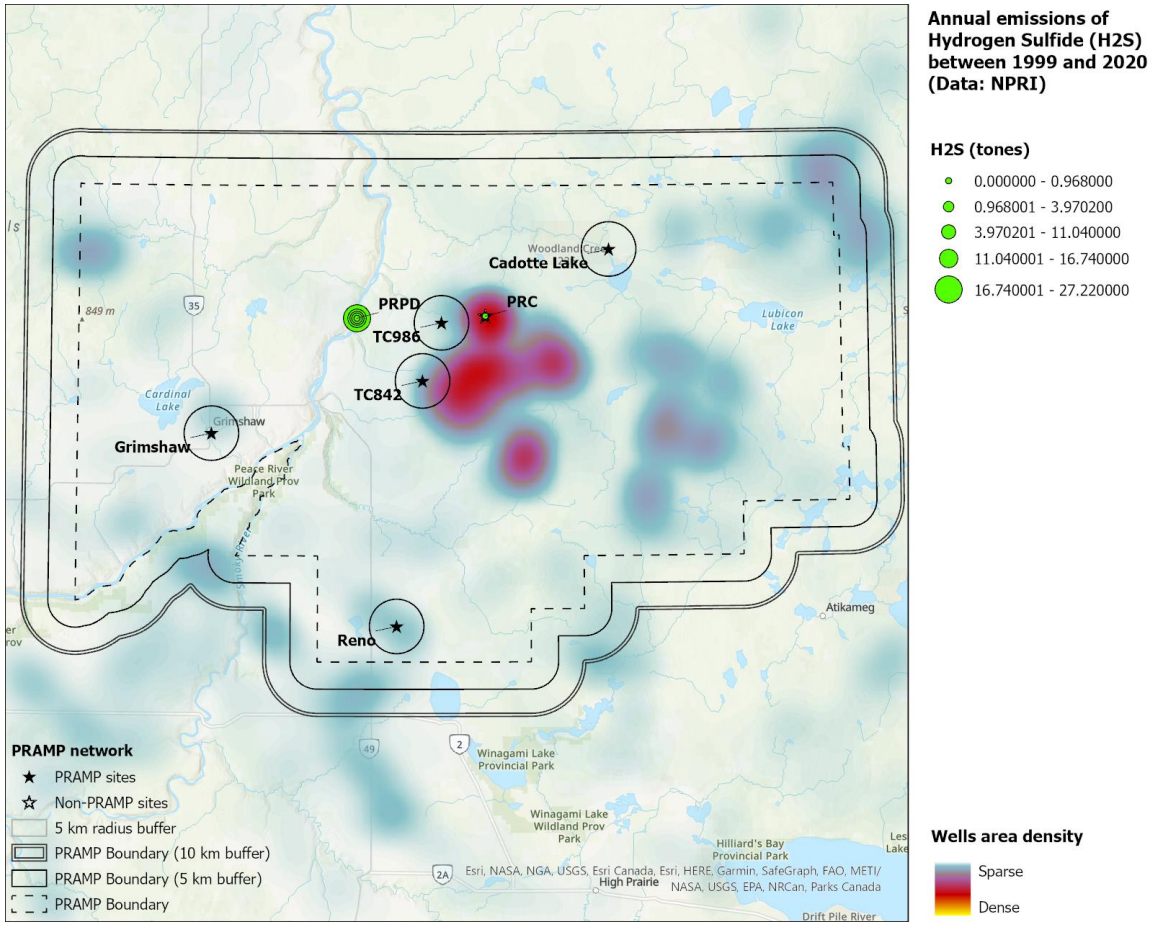
- Move stations?
  - No, unless we want to move into more dense emission areas
- Change technology?
  - Passive SO_2? Possible
  - Passive or gas-sensitive semiconductor technology VOC? Possible

Monitoring Method	Parameter	Station Name: 986c	842b	Reno	AQHI (Grimshaw)	CNRL (PRC)	Mercer (Townsite)	Mercer (Plantsite)	Peace River (above valley)	Peace River (in valley)	Nampa
Continuous	Sulphur Dioxide	√	√	√	√	√	√				
	Total Reduced Sulphurs	√	√	√	√	√	√	√			
	Hydrogen Sulphide					√					
	Hydrocarbons *Total, Methane, & Non-Methane*	√	√	√	√	√					
	Oxides of Nitrogen *Total, Nitric Oxide, Nitrogen Dioxide*				√						
	Ozone				√						
	Fine Particulate Matter *Particles ≤ 2.5 Microns in Diameter*				√		√				
	Wind *Speed & Direction*	√	√	√	√	√	√	√			
	Precipitation	√	√	√							
	Climate Variables *Temperature, Relative Humidity, Barometric Pressure*	√	√	√	√	√	√	√			
	Air Quality Health Index (AQHI) *Third-Party Calculated Multi-Parameter Index*				√						
Intermittent	Non-Methane Hydrocarbon Canister	√	√	√							
	Methane Canister	√	√	√							
Passive	Polycyclic Aromatic Compounds	√									
Small Sensor	Fine Particulate Matter *Particles ≤ 2.5 Microns in Diameter*	√	√	√	√				√	√	√
	Climate Variables *Temperature, Relative Humidity*	√	√	√	√				√	√	√
	Air Quality Health Index Plus (AQHI+) *Third-Party Calculated Single-Parameter Index*	√	√	√	√				√	√	√

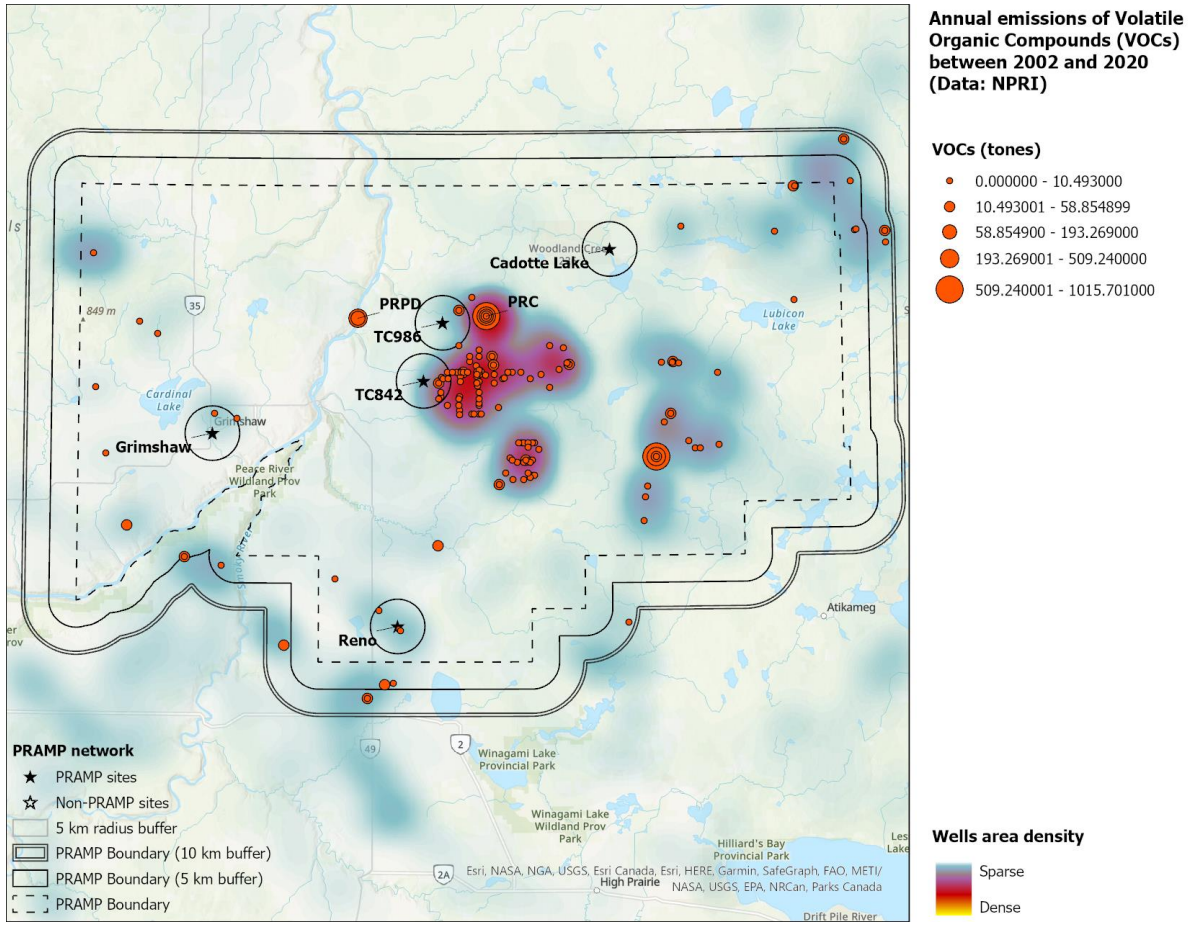
Thank you.

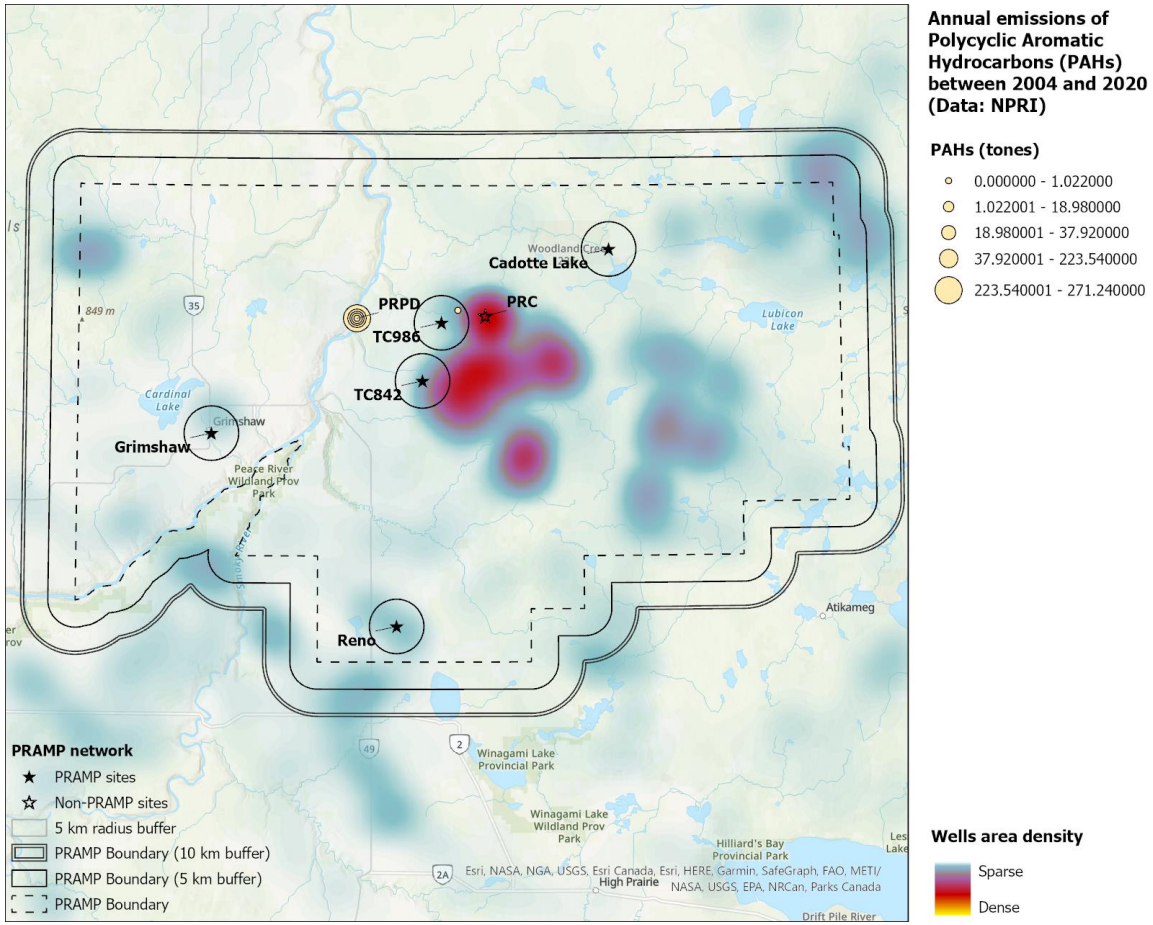
Historical air emissions from facilities within PRAMP boundaries
Locations of SO_2 and H_2S sources along with annual emissions (NPRI data)



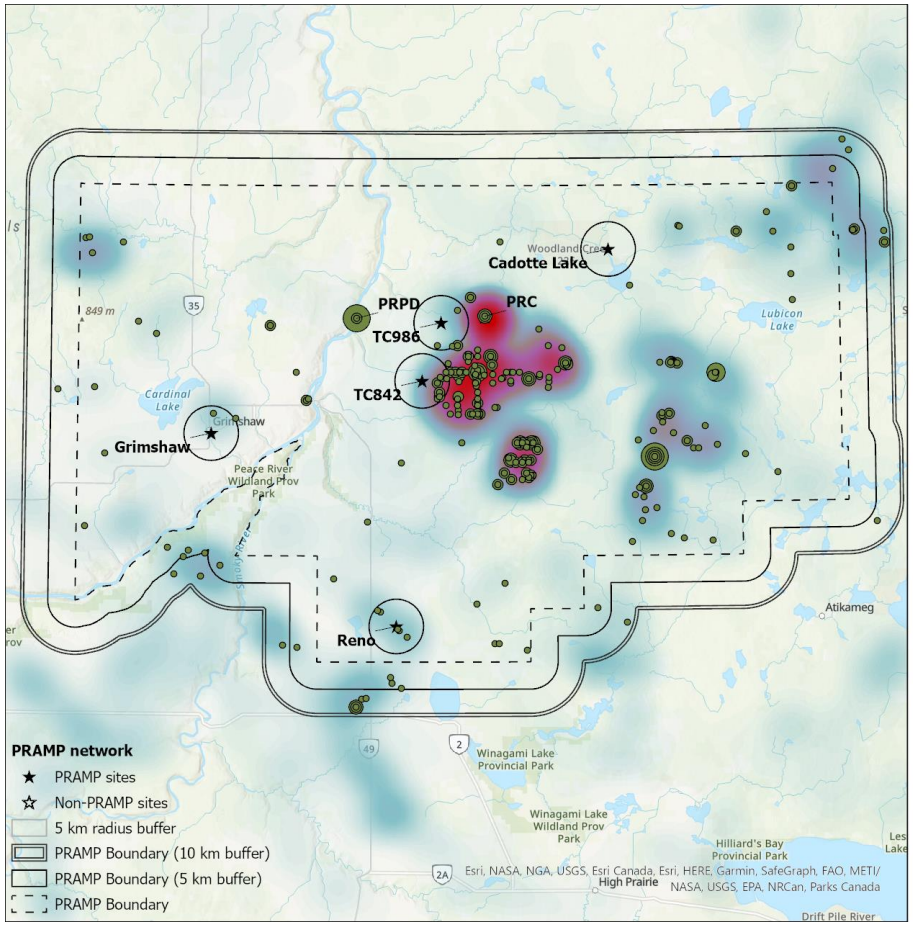


Historical air emissions from facilities within PRAMP boundaries
Locations of VOCs and PAHs sources along with annual emissions (NPRI data)





Historical air emissions from facilities within PRAMP boundaries
Locations of $PM_{2.5}$ and NO_x sources along with annual emissions (NPRI data)



Annual emissions of fine particulate matter (PM2.5) between 2002 and 2020 (Data: NPRI)

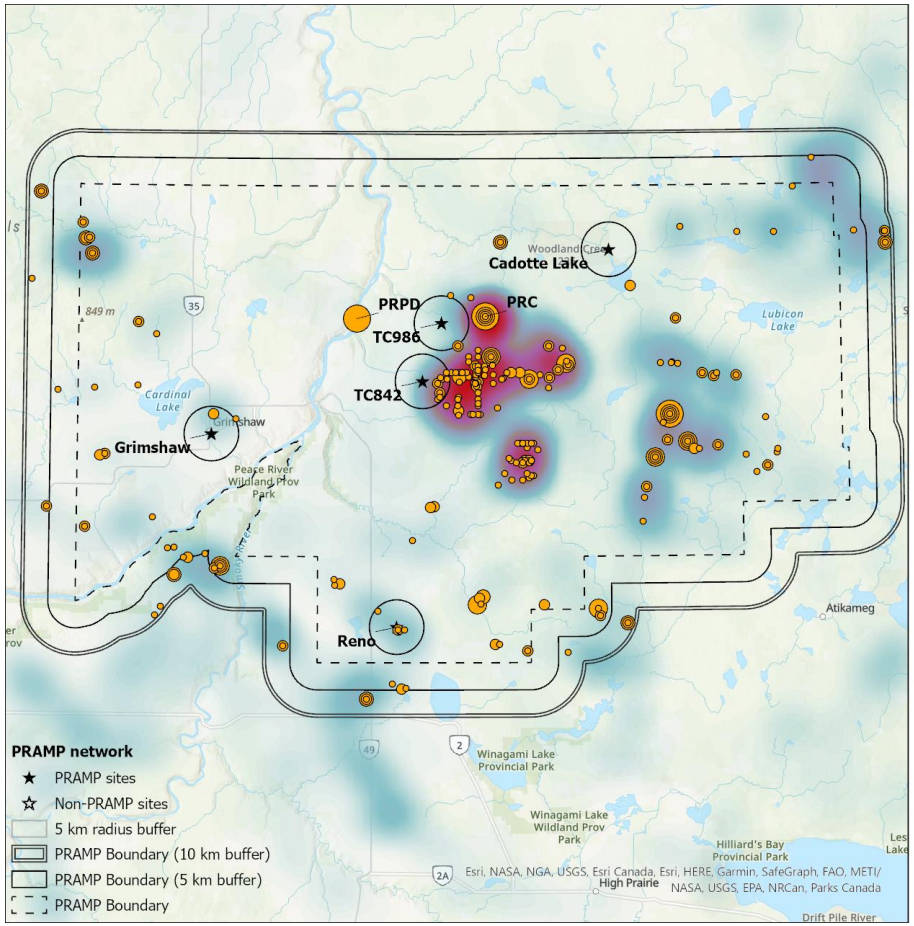
PM2.5 (tones)

- 0.000000 - 3.460000
- 3.460001 - 10.253200
- 10.253201 - 28.600000
- 28.600001 - 87.430500
- 87.430501 - 190.802900

Wells area density

Sparse

Dense



Annual emissions of Oxides of Nitrogen (NOx) between 2002 and 2020 (Data: NPRI)

NOx (tones)

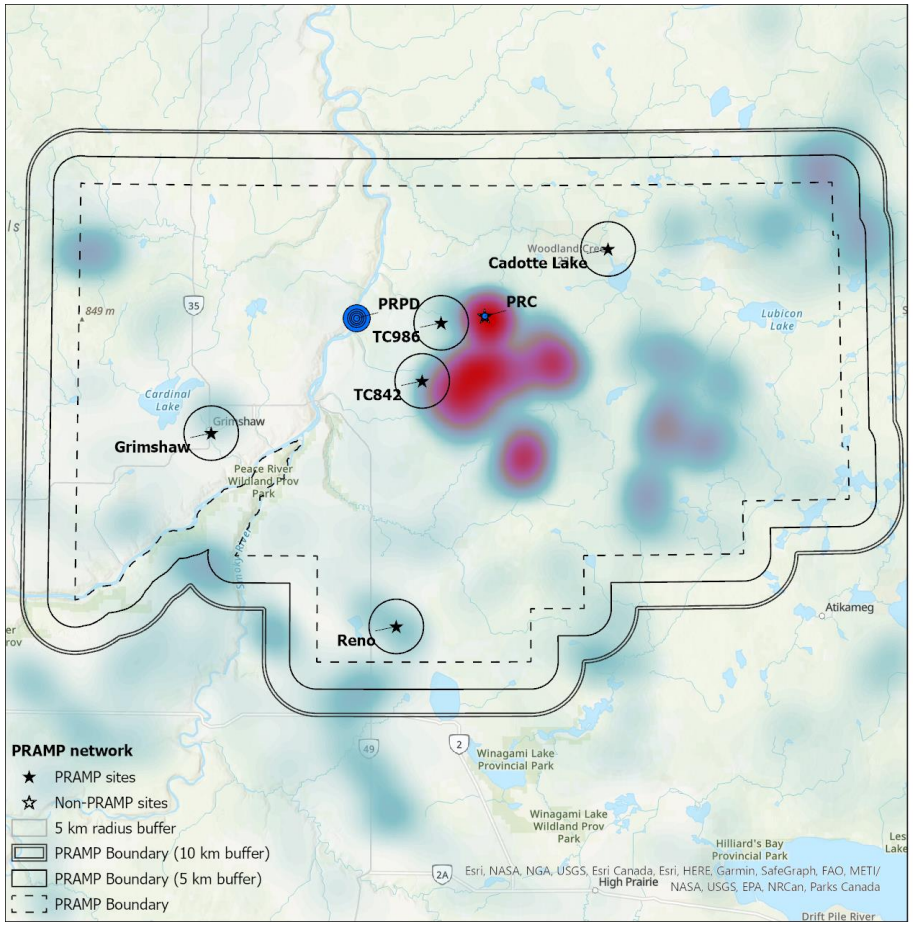
- 0.000000 - 47.017000
- 47.017001 - 117.326000
- 117.326001 - 226.160000
- 226.160001 - 445.799000
- 445.799001 - 1059.980000

Wells area density

Sparse

Dense

Historical air emissions from facilities within PRAMP boundaries
Locations of TRS and CO sources along with annual emissions (NPR data)



Annual emissions of Total Reduced Sulphur (TRS) between 2007 and 2020 (Data: NPRI)

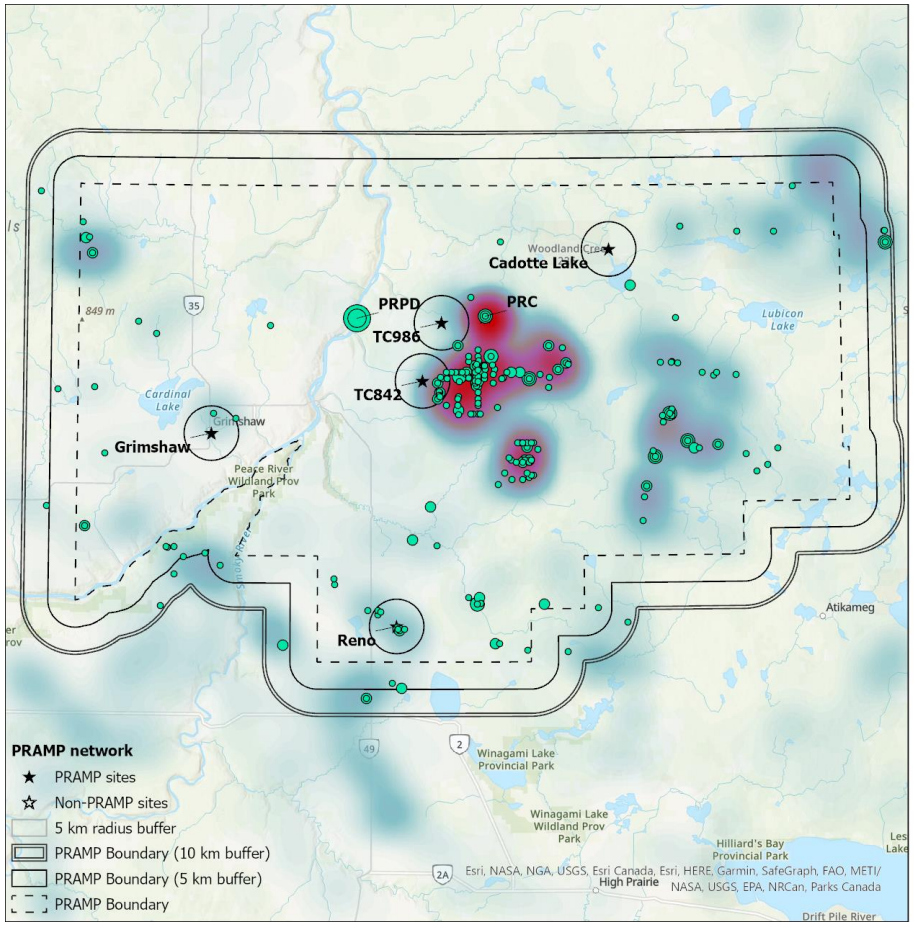
TRS (tones)

- 0.000000 - 6.817700
- 6.817701 - 18.389200
- 18.389201 - 35.468000
- 35.468001 - 51.847000
- 51.847001 - 61.973700

Wells area density

Sparse

Dense



Annual emissions of Carbon Monoxide (CO) between 2002 and 2020 (Data: NPRI)

CO (tones)

- 0.000000 - 71.210000
- 71.210001 - 189.959000
- 189.959001 - 630.092300
- 630.092301 - 2638.970200
- 2638.970201 - 4661.207500

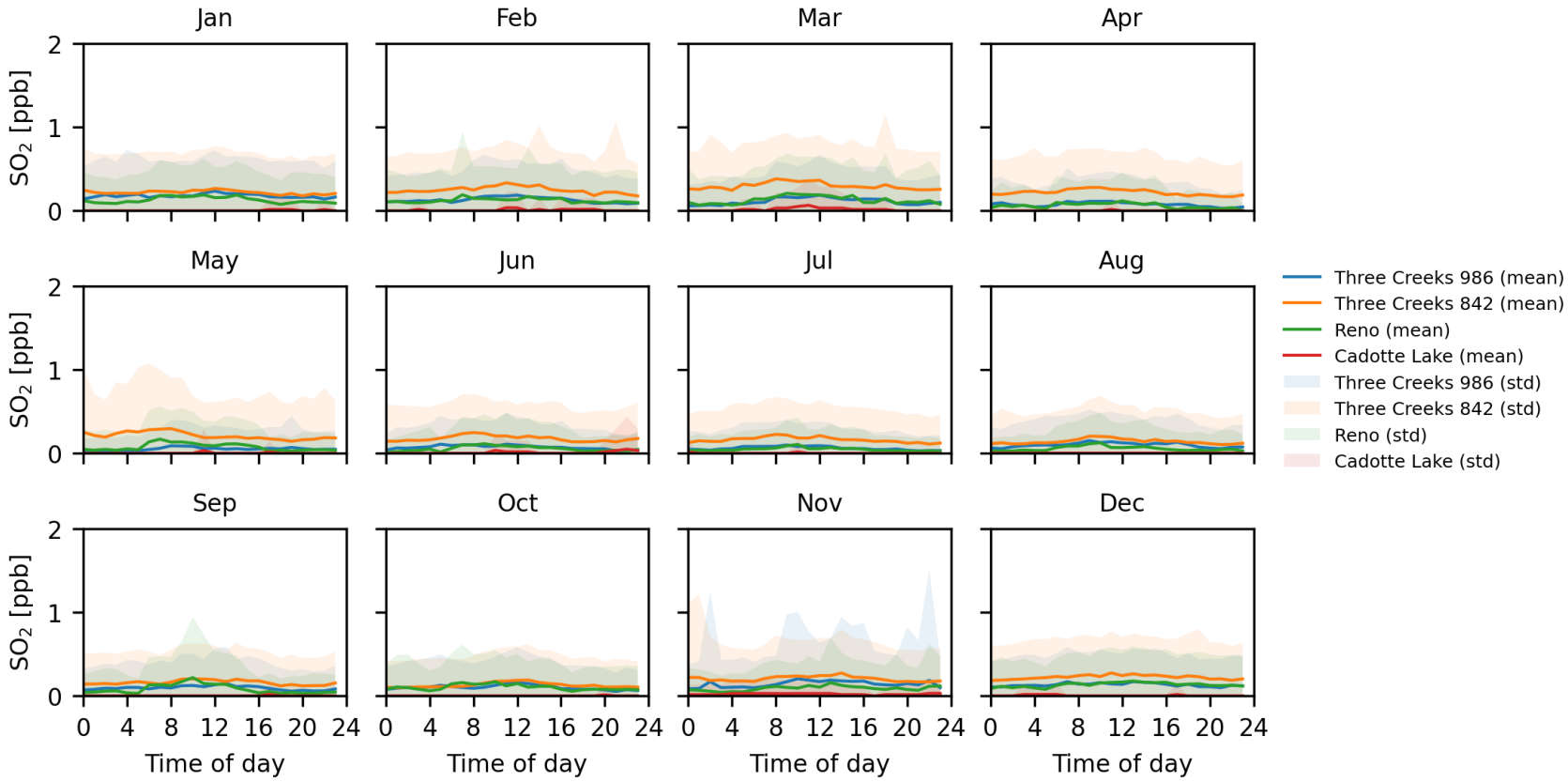
Wells area density

Sparse

Dense

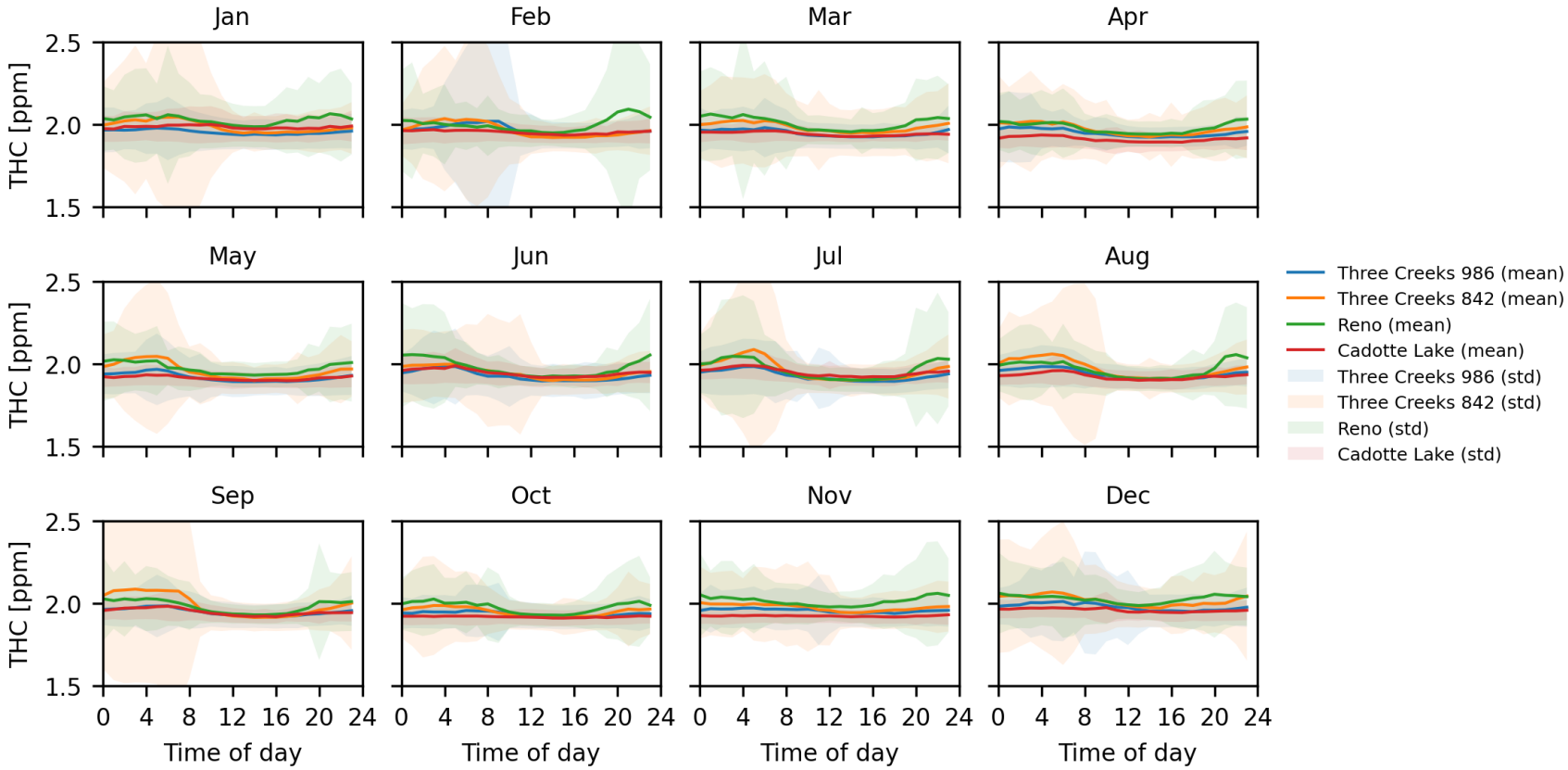
Diurnal Variations – SO_2 example

- No significant difference in the average diurnal profiles of SO_2 between stations
- 842 shows slightly higher concentration throughout the 24-h span, especially during spring (March and April).



Diurnal Variations – THC example

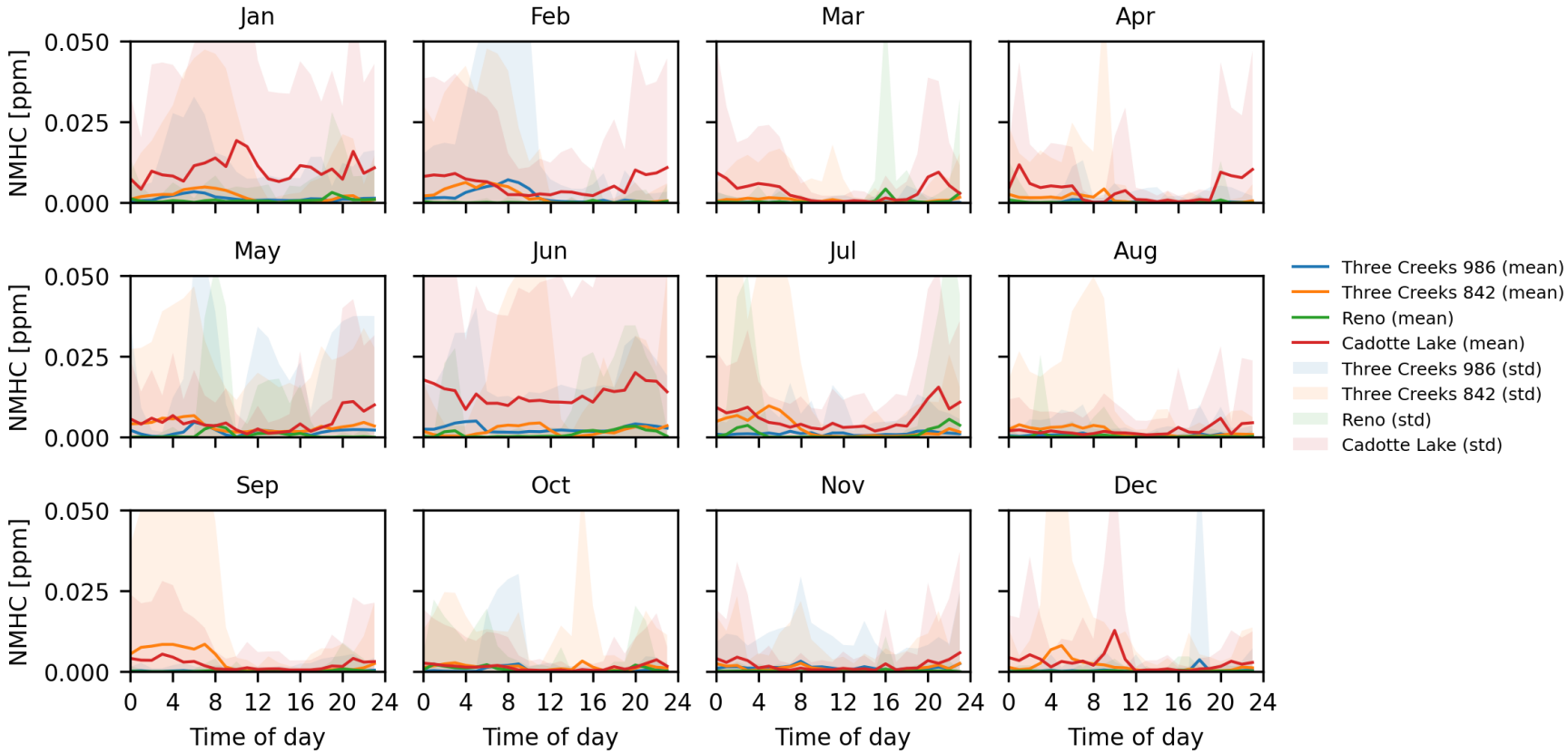
- Significant difference between sites are not obvious in any month
- U-shape like diurnal profiles suggest active photochemistry of hydrocarbons and possibly a stronger vertical mixing, particularly during summer.



Diurnal Variations – NMHC example

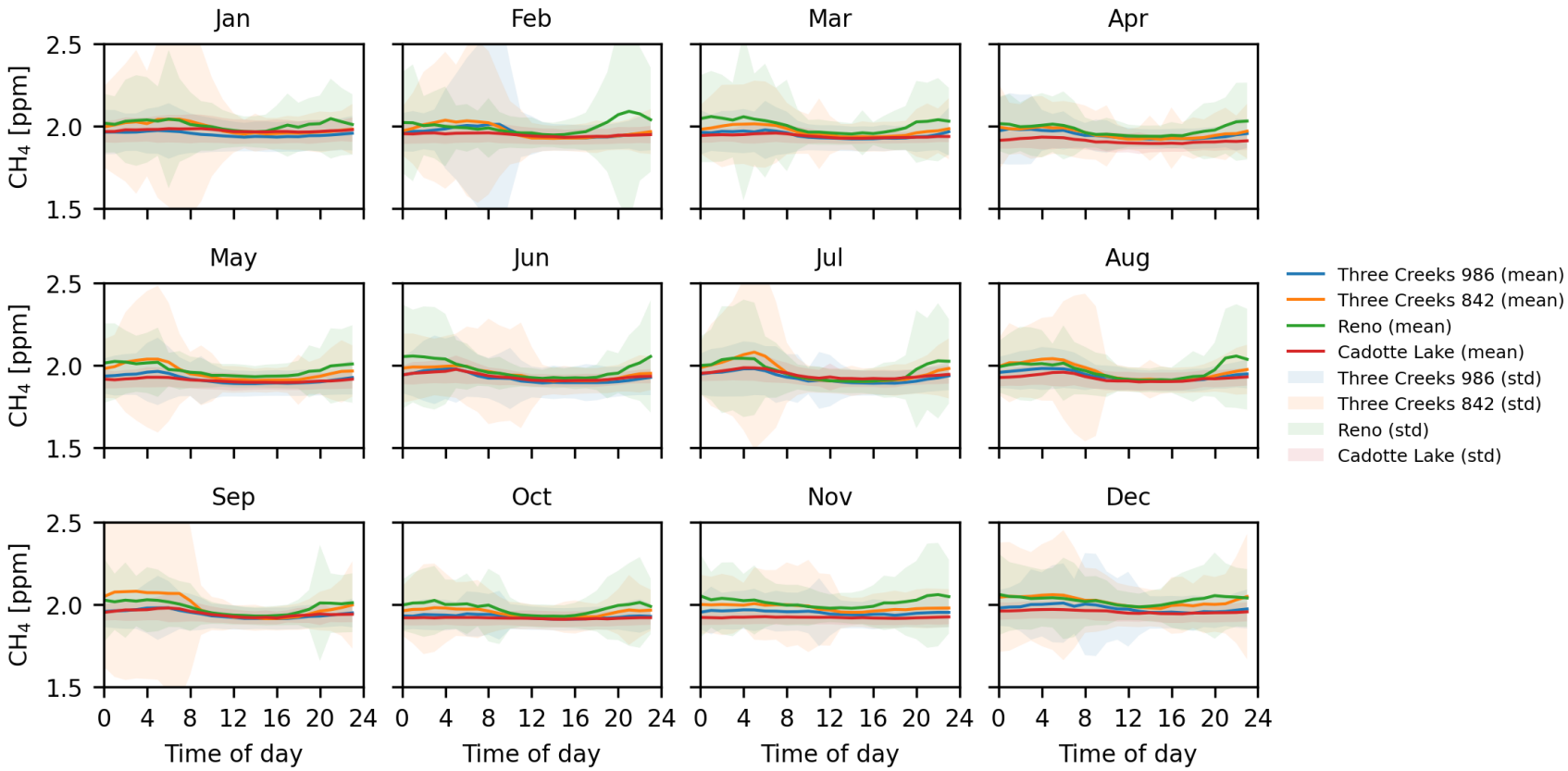
- Diurnal profiles of NMHC at Cadotte Lake are clearly distinct from those at other stations regardless the season

- Variability is large at all stations (larger standard deviations) in several months.

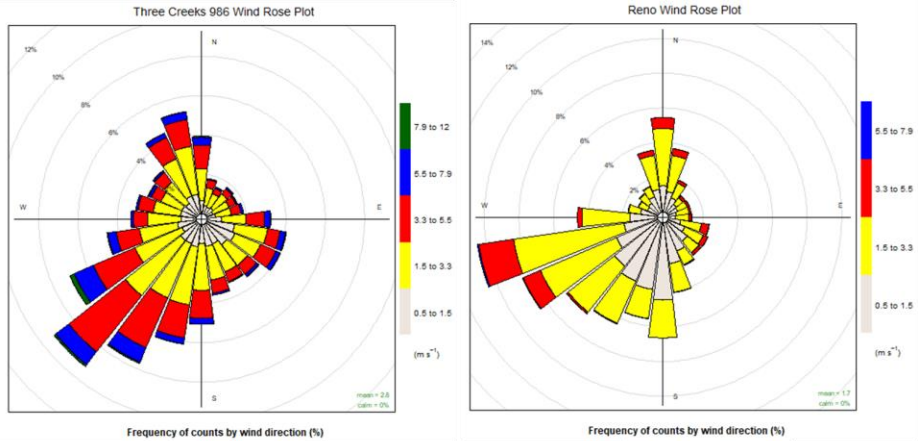


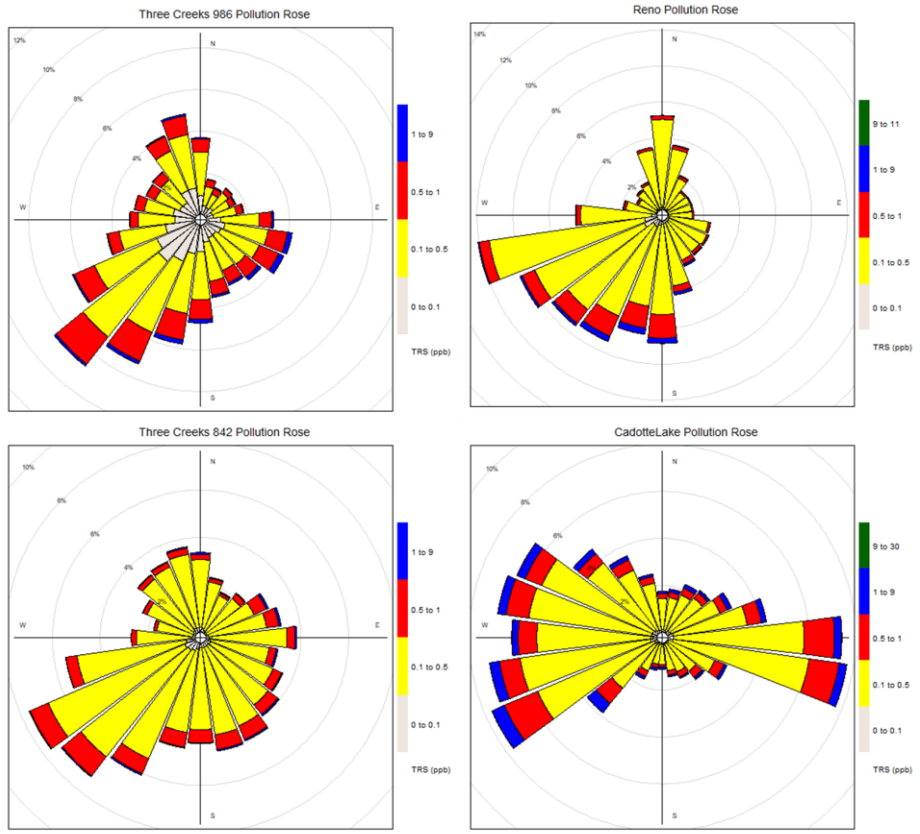
Diurnal Variations – CH_4 example

- Methane's diurnal profiles are consistent with those of THC due to CH_4 being the dominant hydrocarbon in the THC sum.

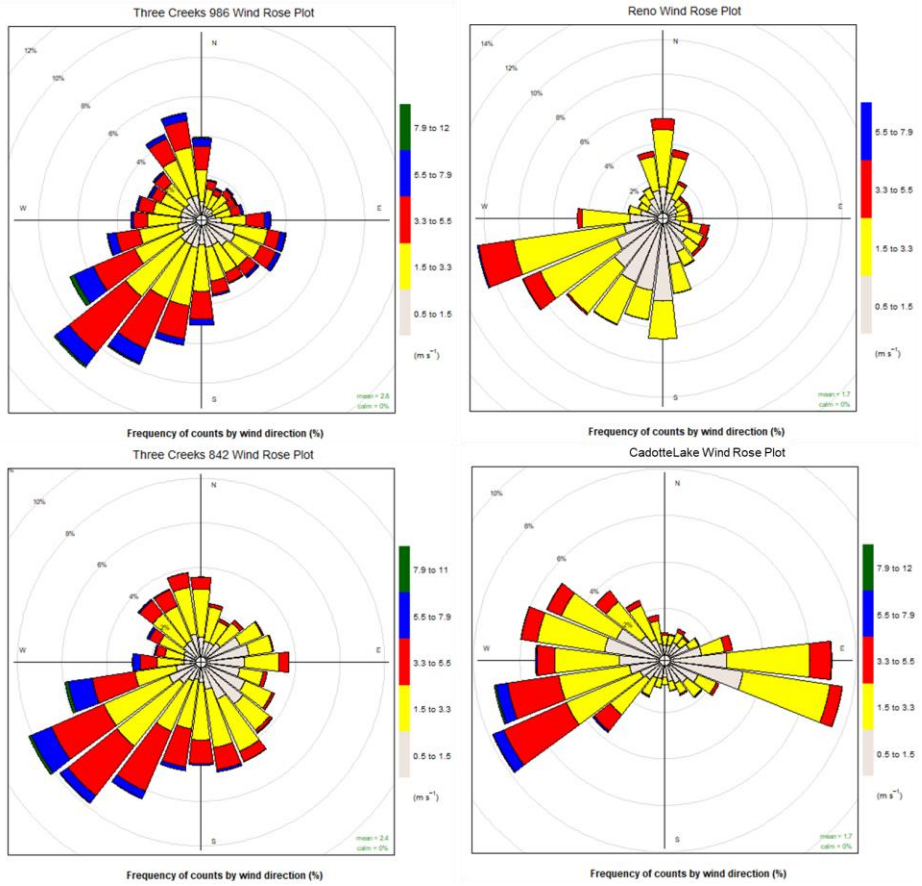


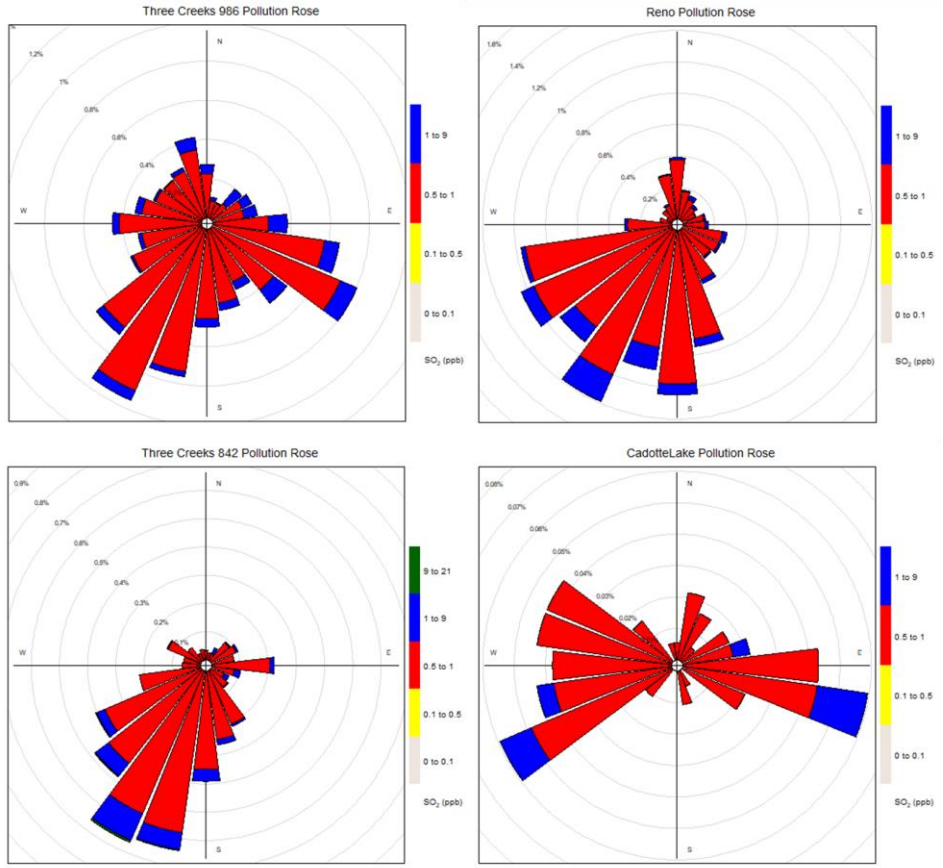
Meteorological Effects – Pollution Roses for TRS are not different than the related wind roses → stations not uniquely situated



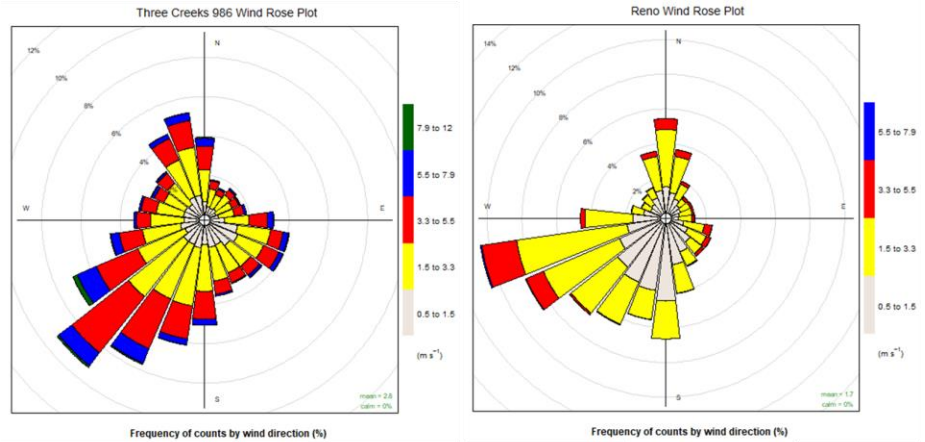


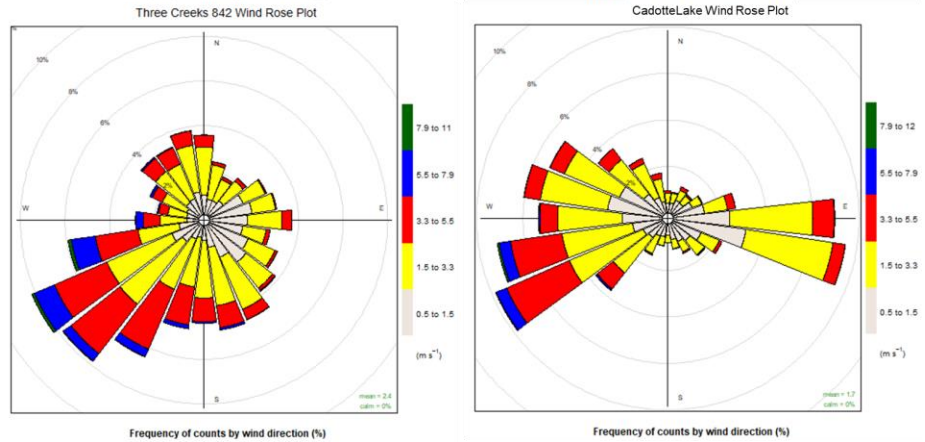
Meteorological Effects – Pollution Roses for SO_2 are not different than the related wind roses → stations not unique

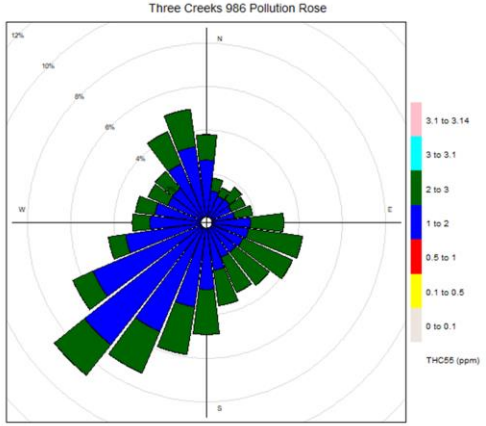


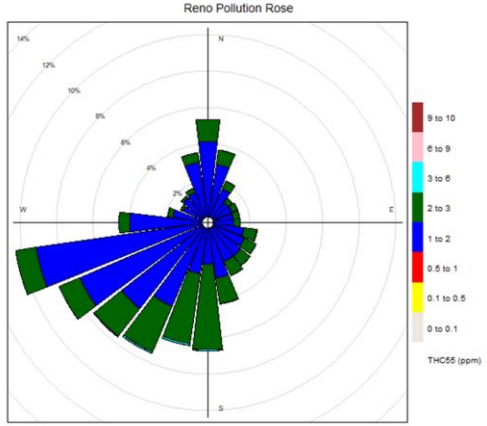


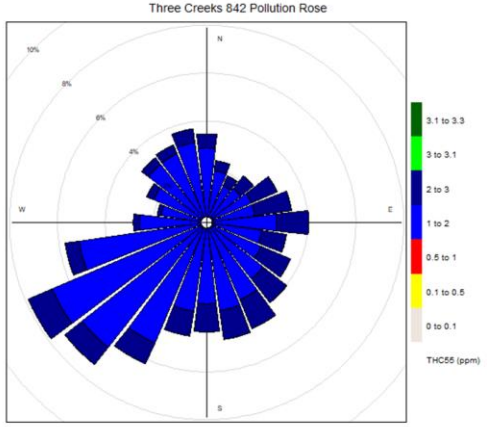
Meteorological Effects – Pollution Roses for THC are not different than the related wind roses → stations not unique

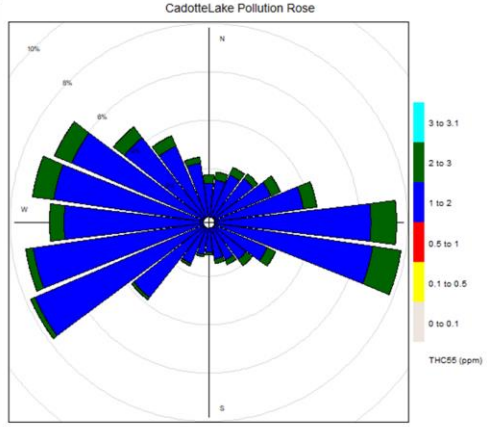




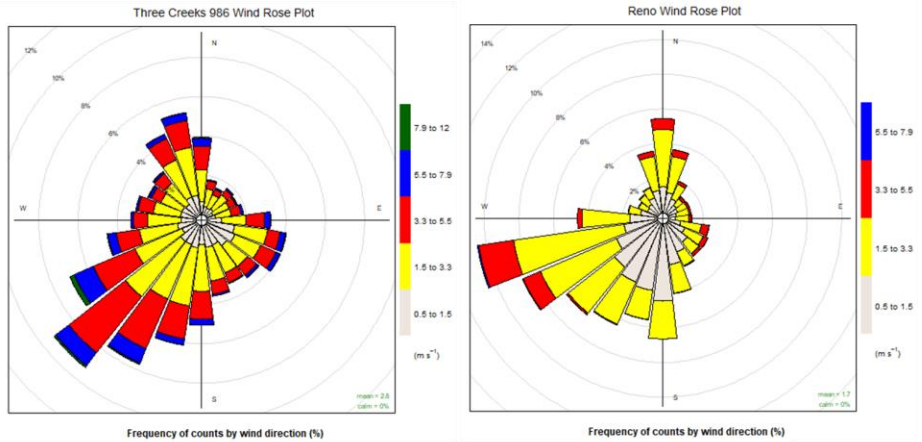


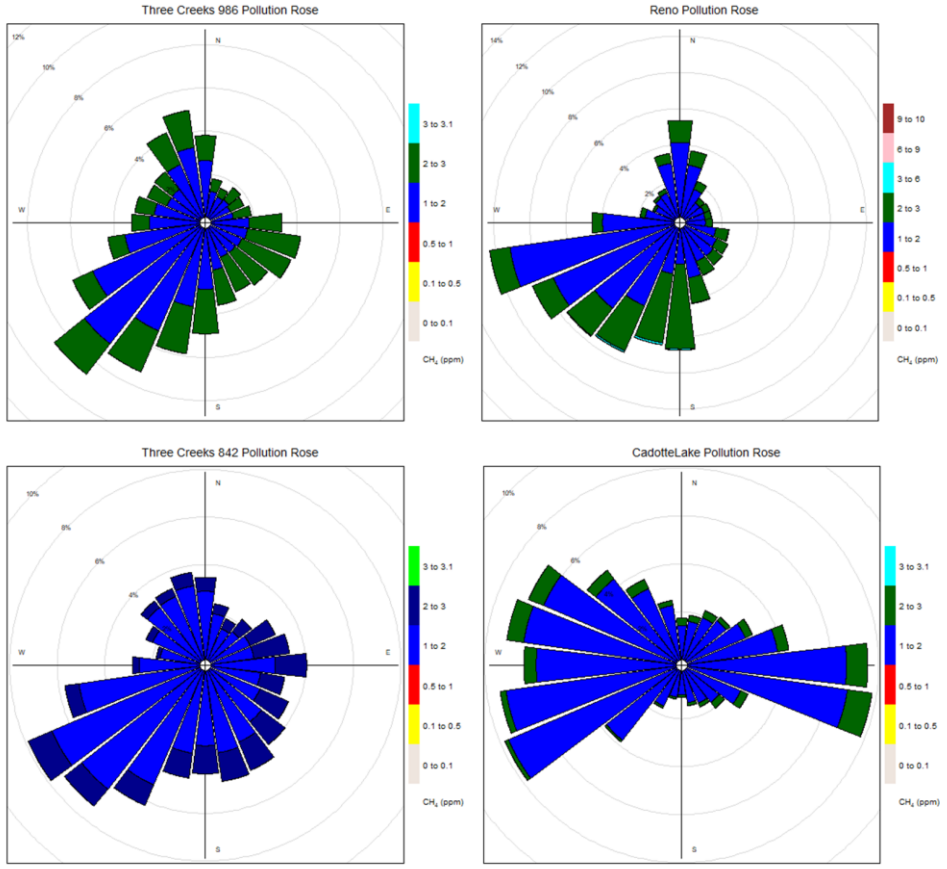






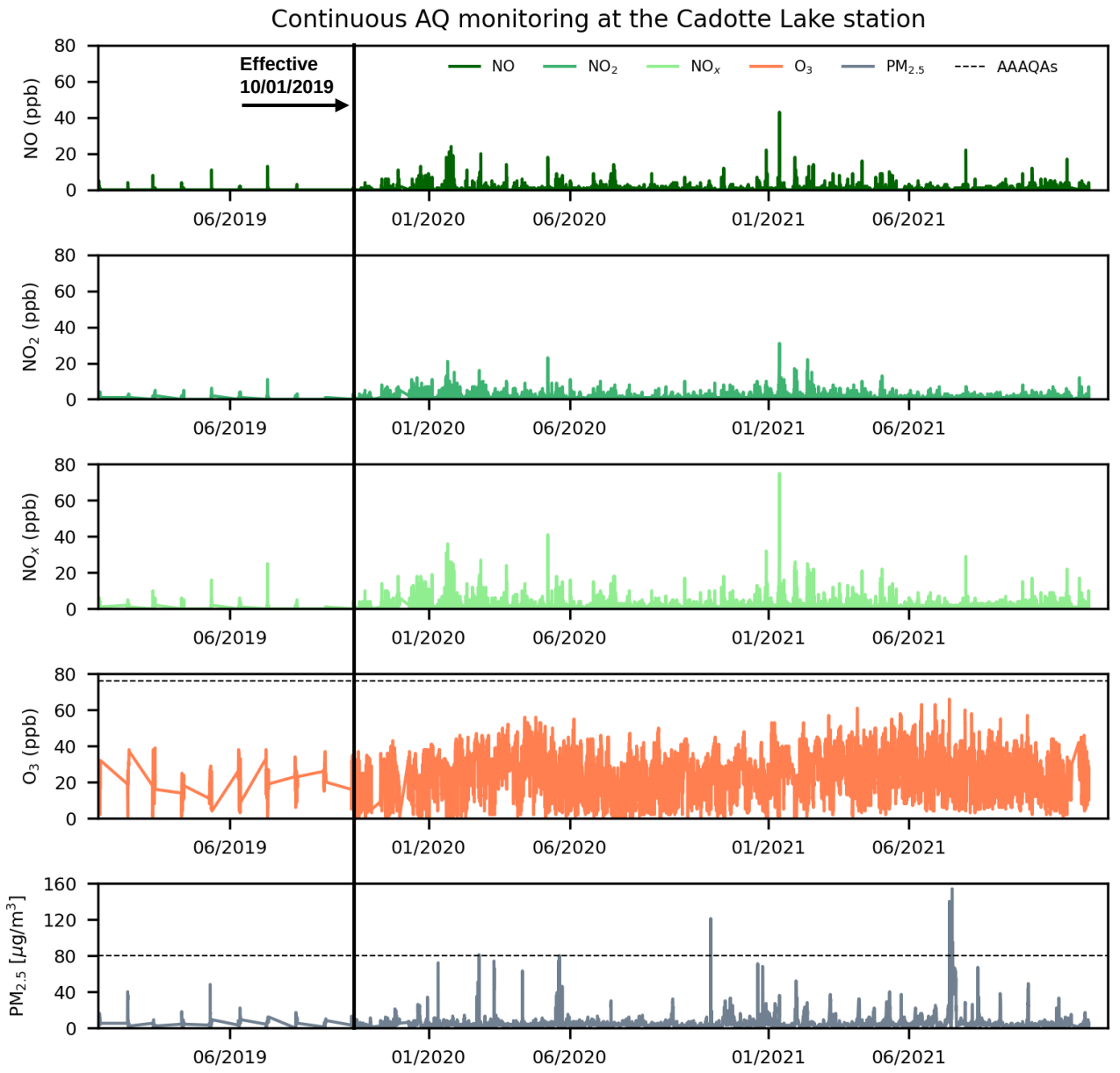
Meteorological Effects – Pollution Roses for CH_4 are not different than the related wind roses → stations not unique





Compliance of 1-h average concentrations at Cadotte Lake

- Complementary air monitoring at Cadotte Lake started on October 1st, 2020
  - Data records however started a bit earlier, but measurements were taken at a much lower temporal resolution
- No exceedances of 1-hour NO_2 (AAAQO = 159 ppb); NO and NO_x do not have AAAQO for comparison
- No exceedances of 1-hour O_3 (AAAQO = 76 ppb)
- A few high $PM_{2.5}$ concentration events were recorded in late 2020 and throughout 2021 and they exceeded the 1-h AAAQO of 80 µg/m^3



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