# Methane observations in Alberta and Saskatchewan (Canada): Distinct signals from oil and gas activities.


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## Introduction:

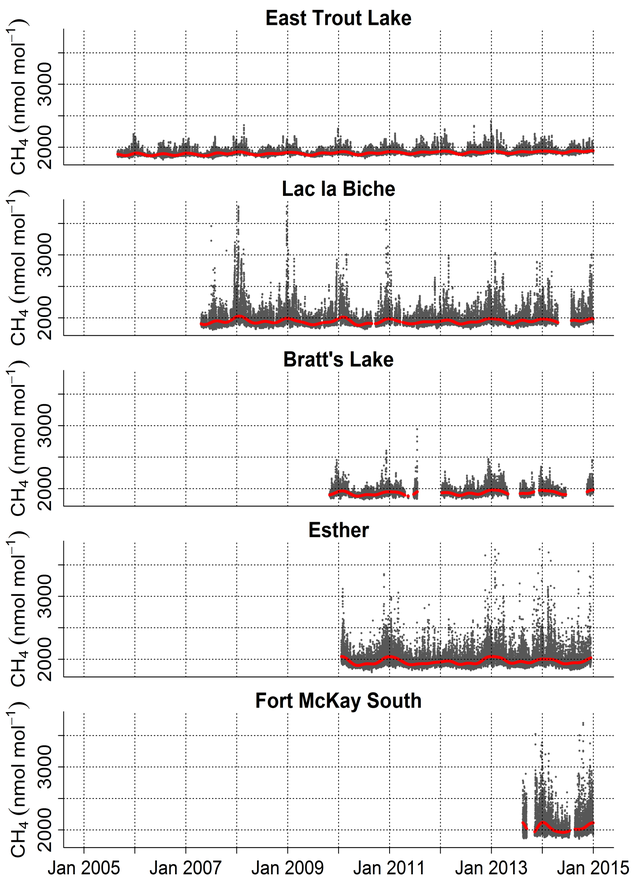
Environment Canada's (EC) atmospheric greenhouse gas (GHG) measurement program currently conducts on-going accurate atmospheric measurements of $CO_2$, $CH_4$ and other GHGs from 22 coastal, interior and high Arctic regions in Canada. This work focuses on describing the observational patterns of methane observed at 3 sites in Alberta (AB) and at 2 sites in Saskatchewan (SK). These sites are of particular interest as:

- 85 % of the national production of oil and natural gas are extracted in AB and SK
- methane emissions from fossil fuel activities in AB and SK account for ≈ 70 % of the total Canadian $CH_4$ emissions

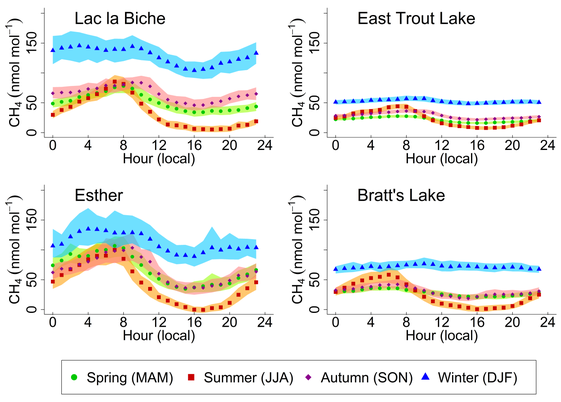
## Continuous measurements:


**Figure top**: location of the 5 measurement stations + Edmonton (capital of AB).

**Figure right**: hourly measurements at the 5 stations. The red lines are the mean afternoon mole fractions. The large observed peaks are due to regional contaminations, $CH_4$ being transported from the source to the stations: LLB, EST and FMS are closer to the main $CH_4$ sources in AB and SK, compared to ETL and BRA stations.



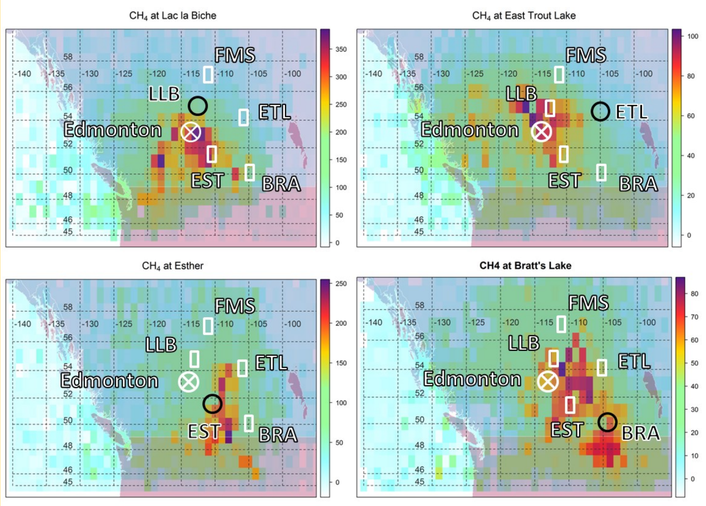

## Diurnal cycle:




Mean diurnal cycle of $CH_4$ per season. Data have been detrended relative to Alert station (Nunavut, Canada, 82.45°N, 62.51°W).

- the diurnal cycles are mainly driven by the planetary boundary layer (PBL) height
- the mole fractions are larger in winter due to weak OH reaction, and shallow and stable condition of the PBL, leading to an accumulation of $CH_4$ close to the surface
- the winter $CH_4$ values at LLB and EST stations are much larger and noisier than at ETL and BRA stations pointing out the strong contribution of air masses transported from polluted area to LLB and EST stations

## Concentration weighted back-trajectory model in winter:




$$C_{ij} = \frac{1}{\sum_{l=1}^{M} \tau_{ijl}} \sum_{l=1}^{M} C_l \tau_{ijl}$$

- $C_{ij}$: average weighted concentration in the grid cell (i,j),
- l: index of the back-trajectory,
- M: total number of back-trajectories used in the analysis,
- $C_l$ detrended $CH_4$ mole fraction upon arrival of the trajectory l,
- $\tau_{ijl}$: residence time of trajectory l in grid cell (i, j).

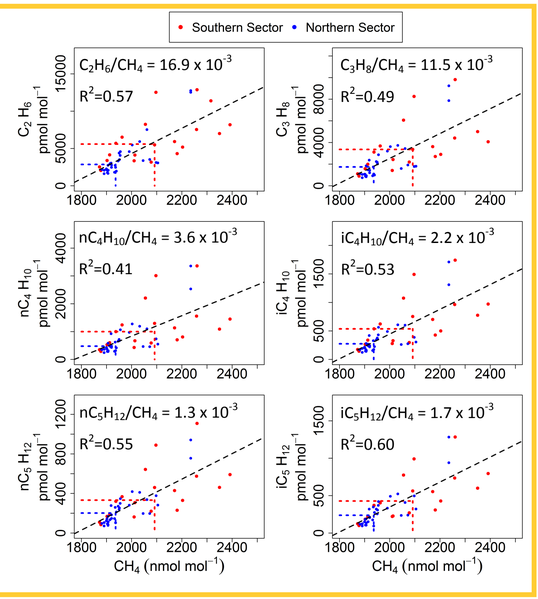
- Air masses coming from Edmonton area and arriving at LLB and ETL are charged with high $CH_4$ mole fractions. $CH_4$ emissions in this area are likely due to leaks from the distribution system of natural gas (compressors, storage tanks and refineries) and from oil and gas extraction.
- The large $CH_4$ mole fractions measured at FMS station do not influence LLB and ETL stations: $CH_4$ emissions are much larger in Edmonton area than in the northern part of AB.
- Air masses coming from the southern part of AB and SK, and from the northern part of North Dakota and Montana (US) bring high $CH_4$ mole fraction to EST and BRA stations and are attributed to:
  - oil and gas production located in the Bakken basin
  - beef cattle located in the southern part of AB and SK

## Non-Methane Hydrocarbon at LLB:

NMHC have been measured from 2008 to 2012 on a weekly basis at LLB.

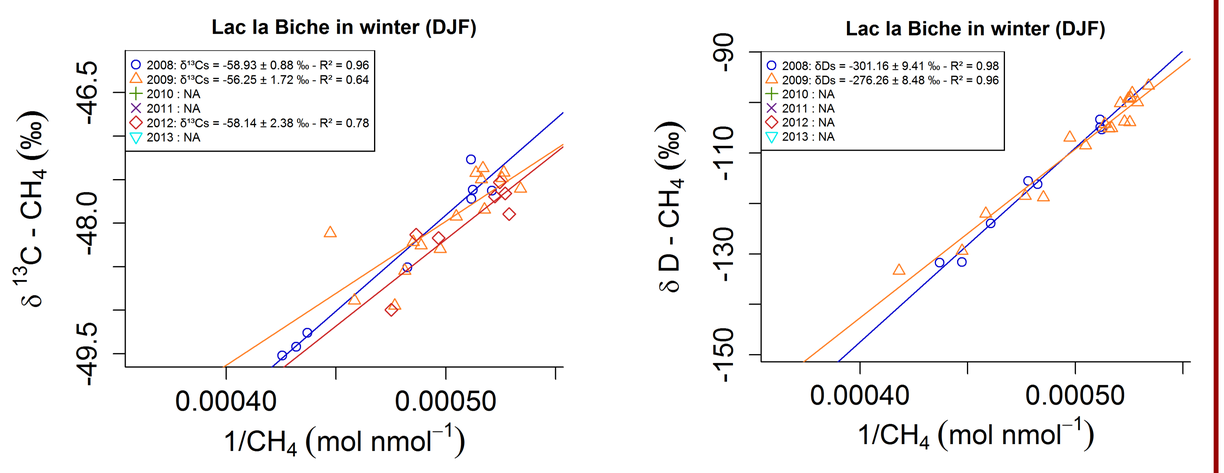
**Figure:** scatter plot of $CH_4$ measurements in function of the $C_2$-$C_5$ alkanes measurements in winter at LLB. The measurements have been classified in function of air masses origin:

- median mole fractions are higher when air masses are from the south (Edmonton area)
- slopes $C_2$-$C_5$/$CH_4$ are not significantly different between the two air masses regimes.




## Isotopic $CH_4$ measurements at LLB:

$\delta^{13}$C-$CH_4$ and δD-$CH_4$ have been measured on a bi-weekly basis at LLB from 2008 to 2013.




**Figures**: winter atmospheric $CH_4$ signatures (δCs) calculated from the Keeling plots: $\delta^{13}$Cs are in the left panel and δDs are in the right panel.

- wetlands are frozen in winter
- atmospheric $\delta^{13}$Cs in winter are between –58.93 ‰ and –56.25 ‰
- atmospheric δDs in winter are between –301.16 ‰ and –276.26 ‰

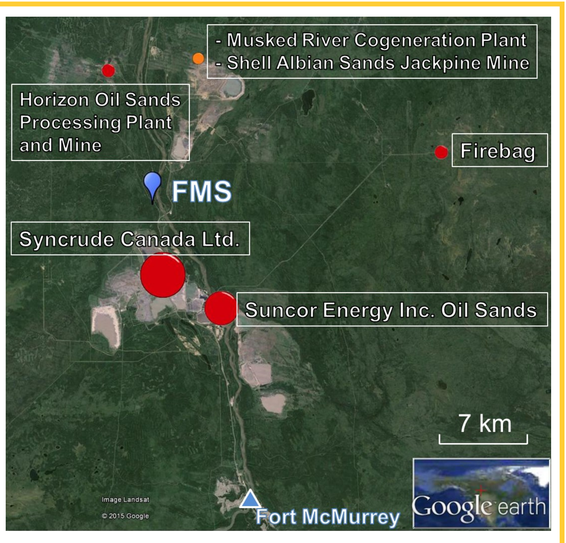
→ the atmospheric $\delta^{13}$C-$CH_4$ and δD-$CH_4$ signatures suggest that the natural gas extracted in AB has a biogenic origin

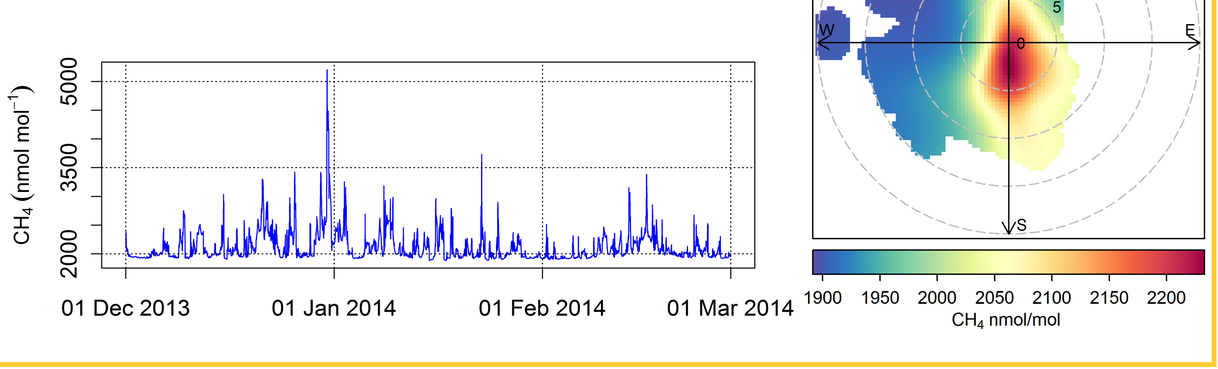
## Fort McKay South (FMS) station:

**Figure left**: the station is located in the Athabasca oil sands area and is surrounded by 5 non-conventional oil extraction facilities having annual emissions larger than 1000 kt $CO_2$eq. Diameter of the red dots is proportional to the emissions. Together, these 5 industries emit 5 % of the total $CH_4$ emissions of Alberta.

**Figure bottom left**: time series of $CH_4$ in winter at FMS station

**Figure bottom right:** PolarPlot of $CH_4$ in winter at FMS. The $CH_4$ measurements are presented in function of wind direction and wind speed. The highest mole fractions are from the south and are measured during low wind speed conditions.




## Conclusions:

- Edmonton area and Bakken basin are two high potential sources of $CH_4$ contributing to the largest mole fractions measured at LLB and ETL, and at EST and BRA, respectively.
- The natural gas extracted in Alberta has biogenic origin
- The high $CH_4$ mole fractions measured at FMS station are from the two main non-conventional oil industries located 10 km south of the station but the total emissions are significantly lower than those from Edmonton area.