



Comparison of reported Provincial-level emissions of methane in Alberta and Saskatchewan with estimates based on atmospheric observations

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Outline:

- Premise/Goal
- Sources of methane in Alberta & Saskatchewan
- The ECCC GHG Observational Network
- Inverse Methodology
- Approach
- Results
- Conclusions & Next Steps



Premise:

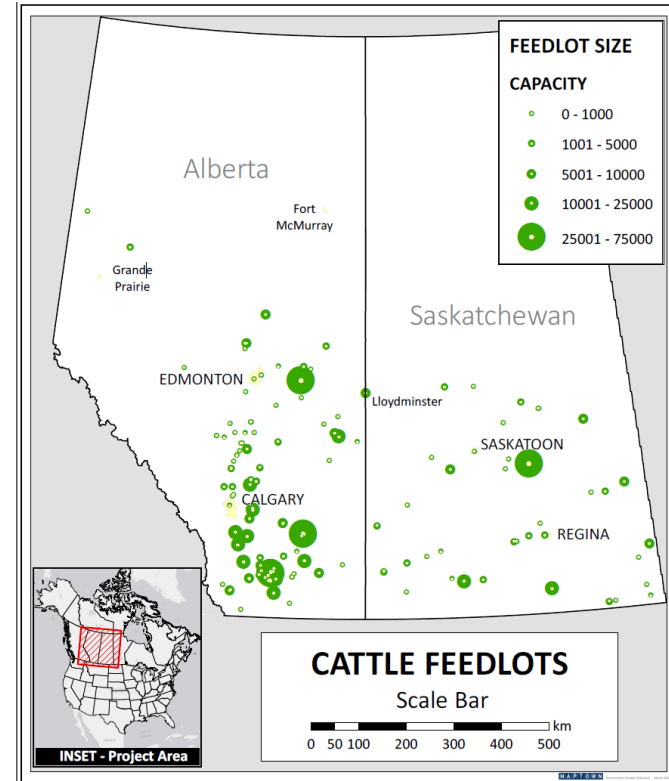
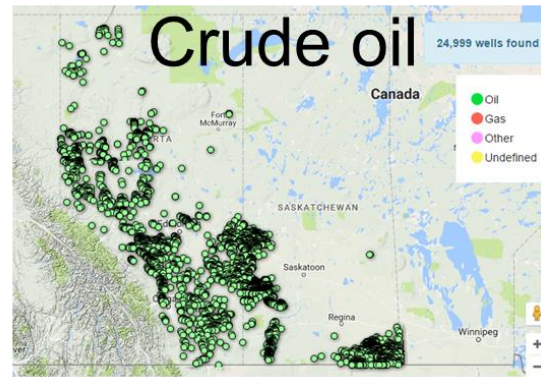
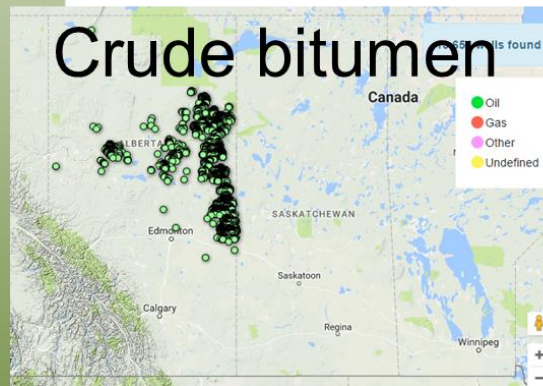
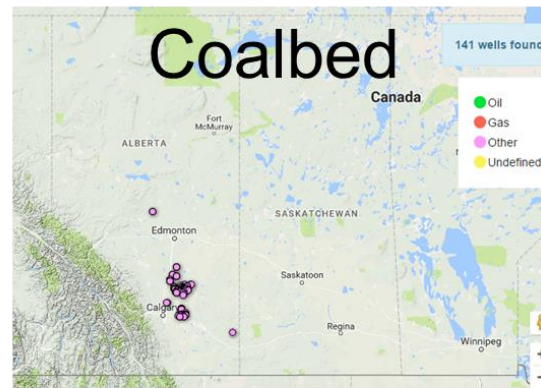
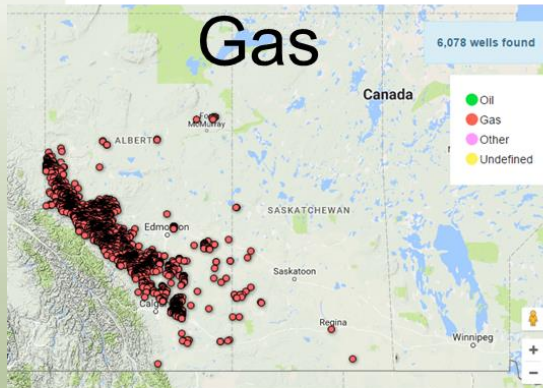
- Atmospheric GHG observations provide an important, large-scale perspective to the understanding of carbon sources.
- Though long lived species, the increase of GHG concentrations in the lower atmosphere over timescales of 2 to 5 days mirror the emissions of GHGs over regions of several hundred kilometers.
- A sufficiently spatially dense surface monitoring network and atmospheric modelling tools can thus characterize regional scale sources.

Goal:

- To develop and test methods integrating atmosphere models and GHG observations to **quantify and track** natural (forest, wetland, Arctic) and anthropogenic (industrial, urban) emissions at regional scales in Canada.



Primary locations of energy (well types) and agricultural (cattle) sources in AB and SK.



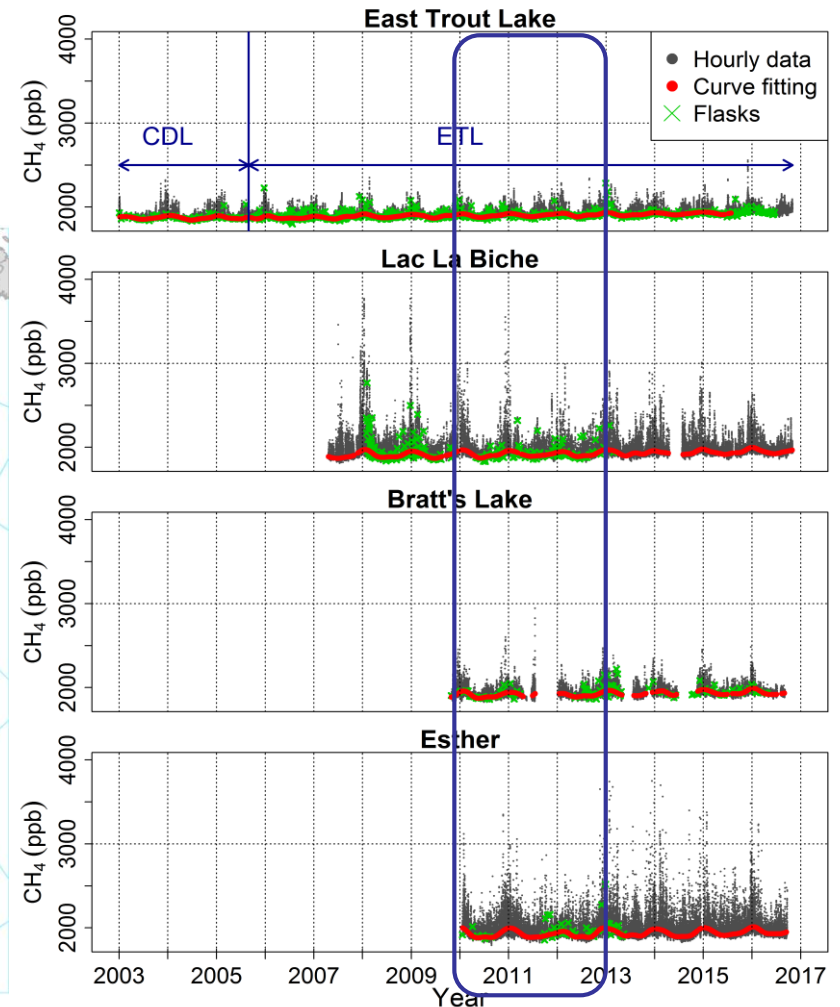
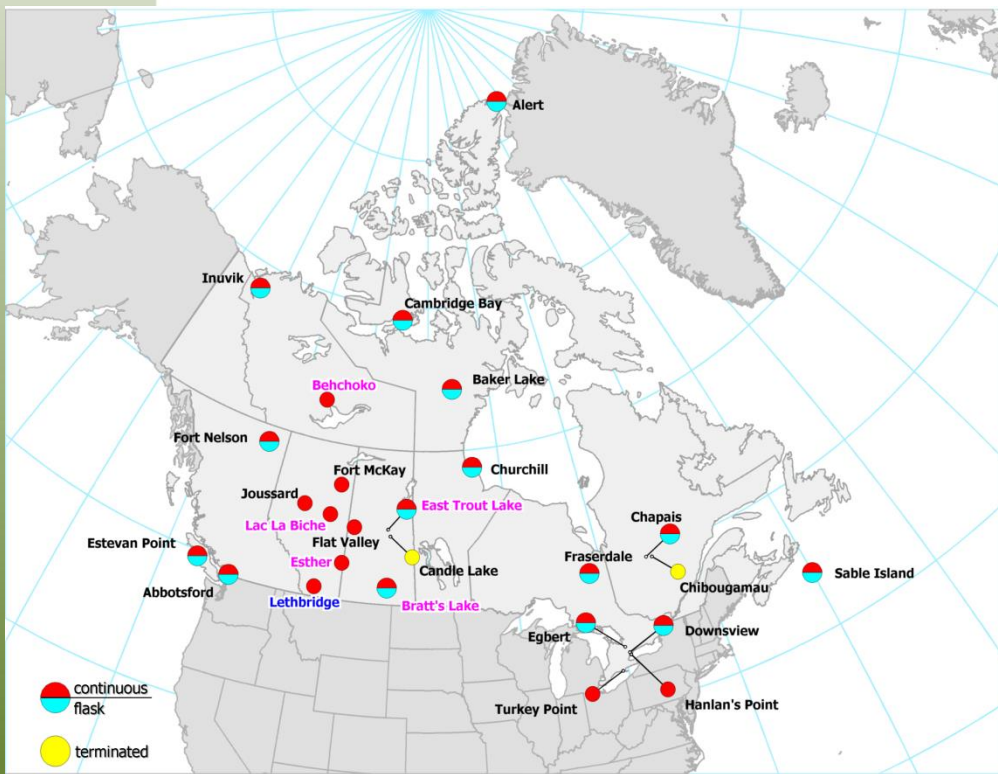
Energy and Agricultural sources represent ~ 97% of AB and SK's total inventory. Can we estimate the contribution of these source sectors using observations and modelling?



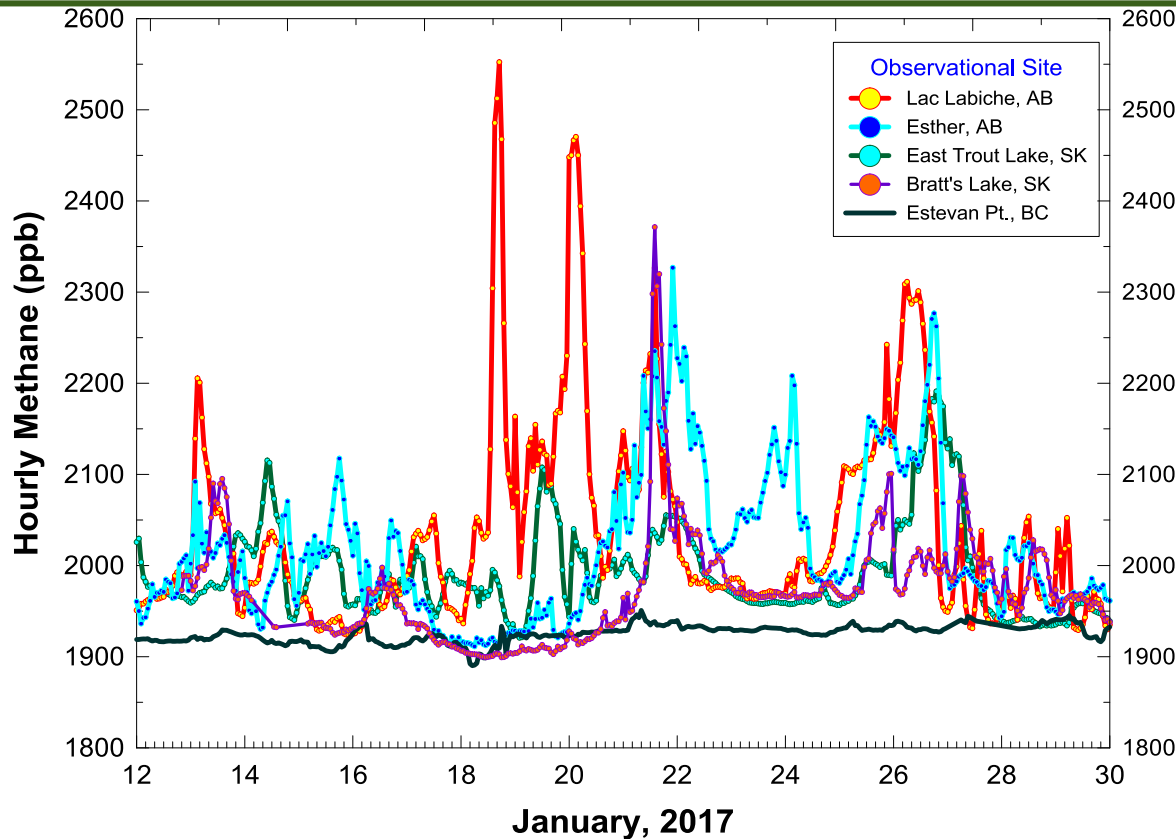
Hourly and weekly methane observations inform estimates of anthropogenic methane emissions in Alberta and Saskatchewan



3 year (2010-2012) study time period using atmospheric methane observations from sites in AB/SK shown below (in pink).



Meteorological conditions in winter allow for a focus on anthropogenic sources, without natural source influences.

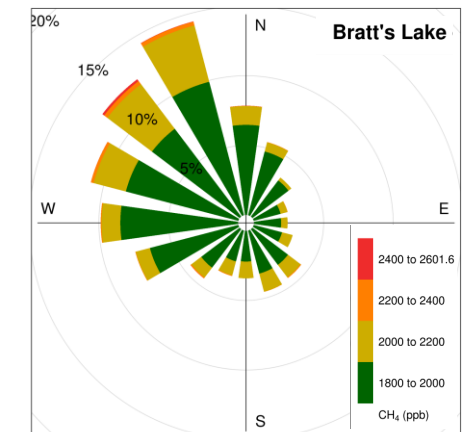
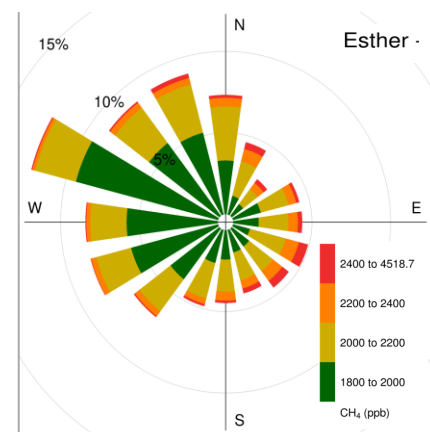
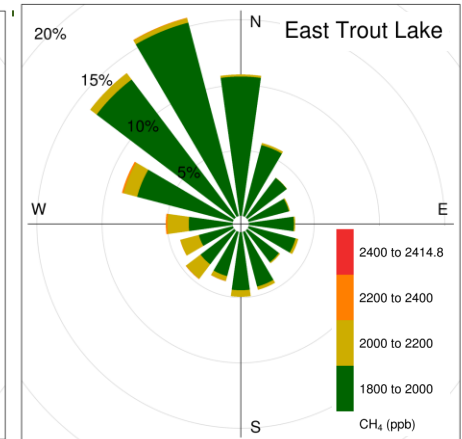
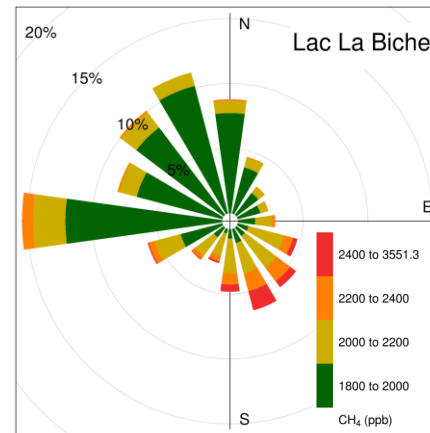
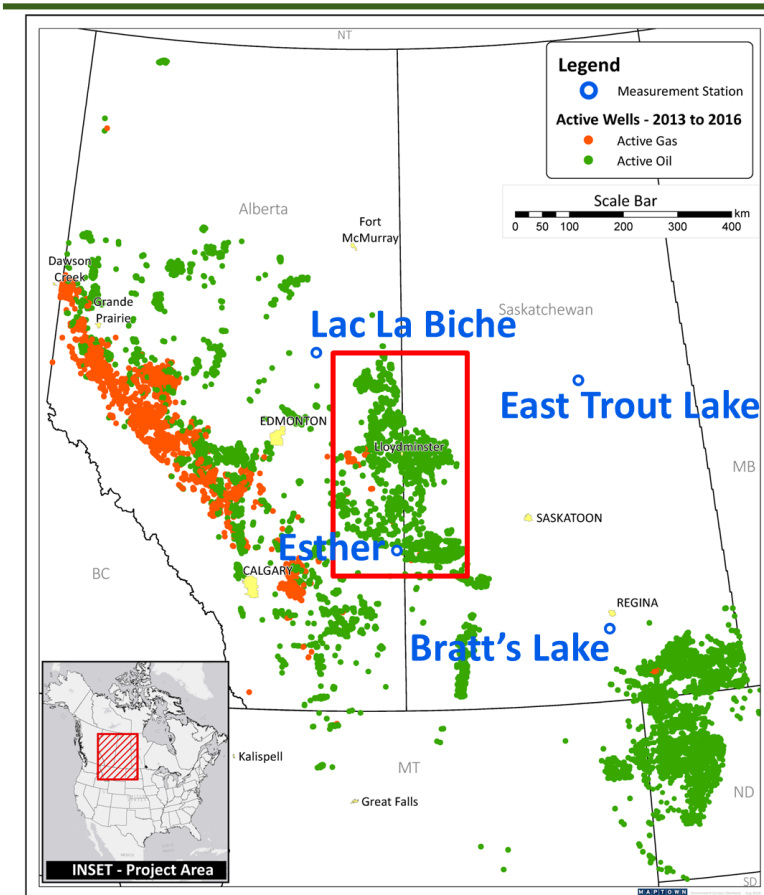


- Results presented today are based on “winter” (October-March) observations only.
- Larger synoptic variability in winter
- Large wetland and other biogenic methane signals in summer are dormant in winter.

Example: Estevan Point shows the typical background signals in the absence of anthropogenic sources in AB and SK.



Over a 6-year period (2010-2016), the influential sources regions at the long-term monitoring sites are clearly evident.



Some sites are influenced by sources from multiple directions where others are influenced by sources in a particular direction.

Page 7 – May-1-18



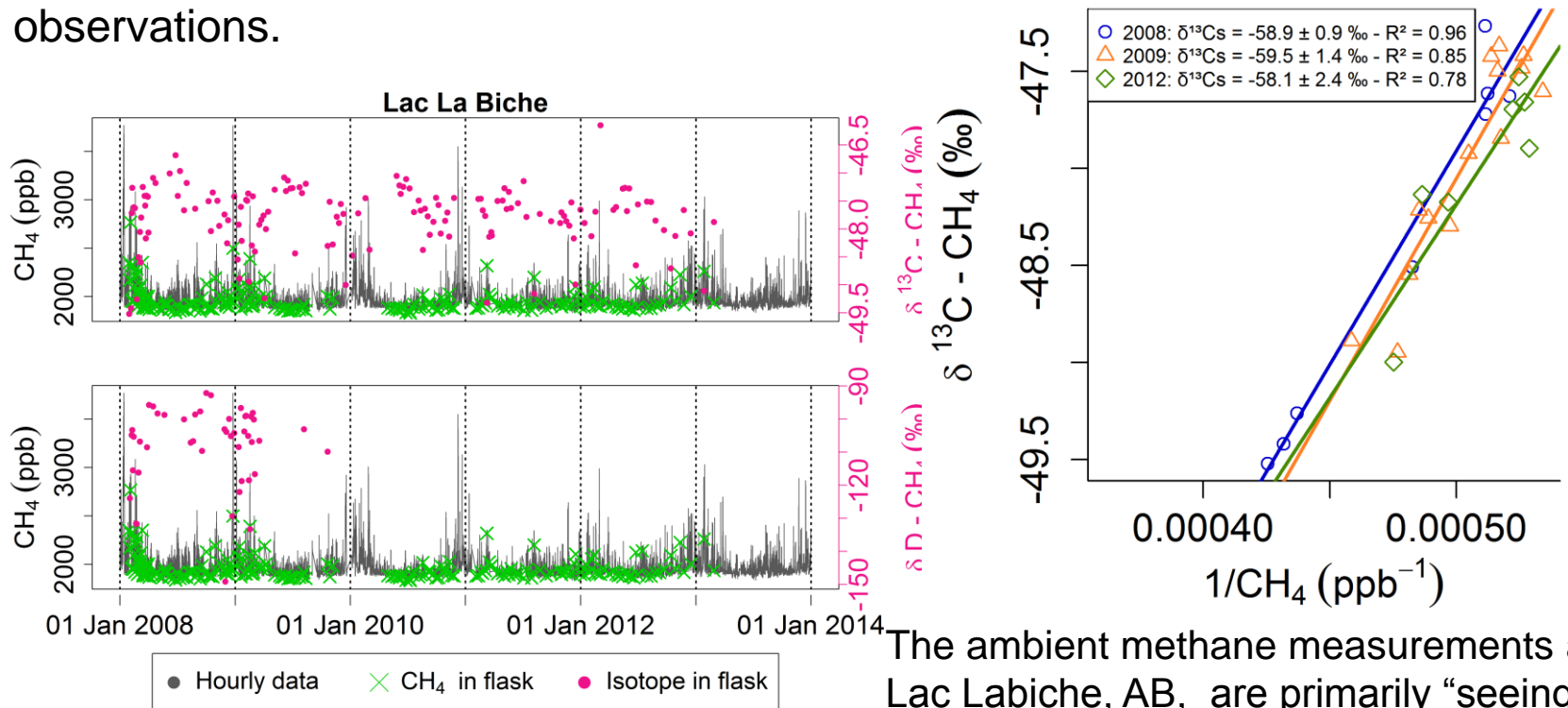
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Canada

Ambient isotopic methane measurements identify oil sources as the major source type

Knowing the source signatures, we can use atmospheric methane isotope measurements to identify methane sources types impacting the methane observations.

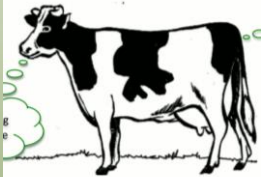


The ambient methane measurements at Lac Labiche, AB, are primarily “seeing” methane from oil sources and not natural gas – Lopez et al (2017), ACP



Inverse modelling framework

(1) Emissions

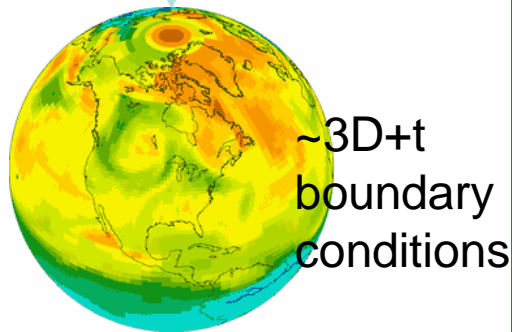


~space+time

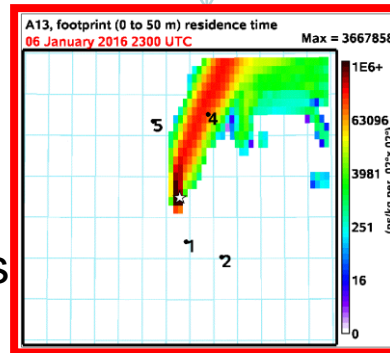
(2) Atmospheric transport modelling

~Meteorology A

~Meteorology B



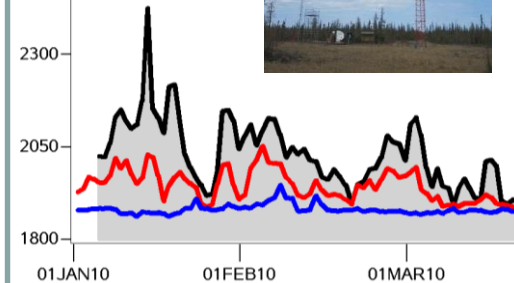
~3D+t
boundary
conditions



(3) Measurements



CH₄ (ppb)



(4) Inverse modelling

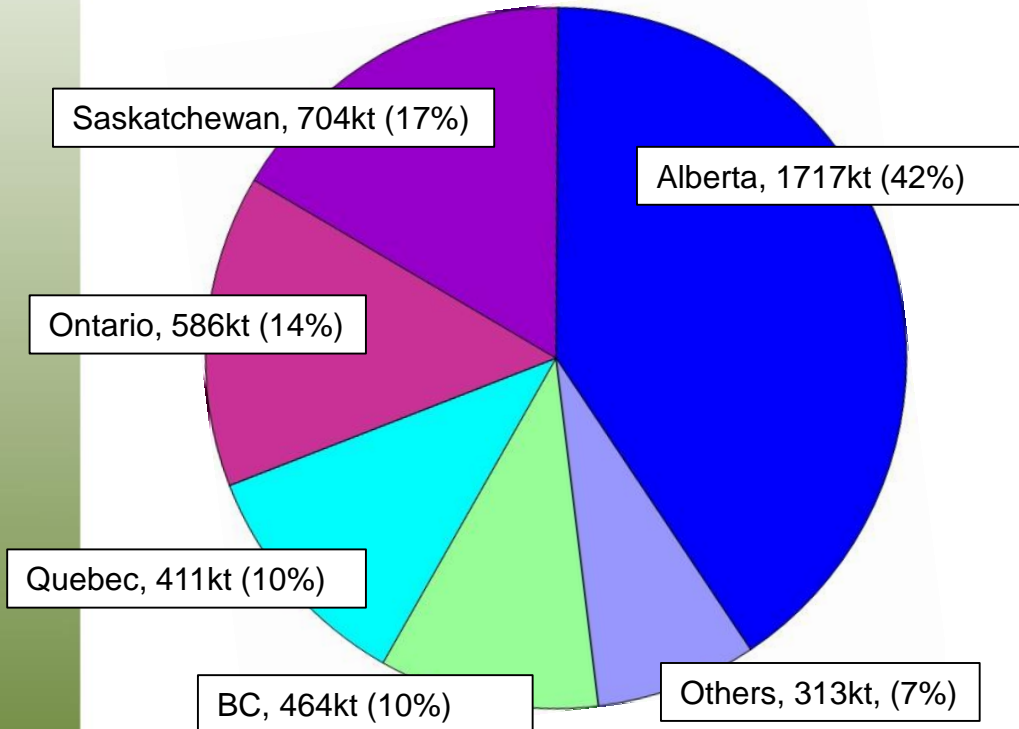
~minimize (optimize) differences between
observations and model results



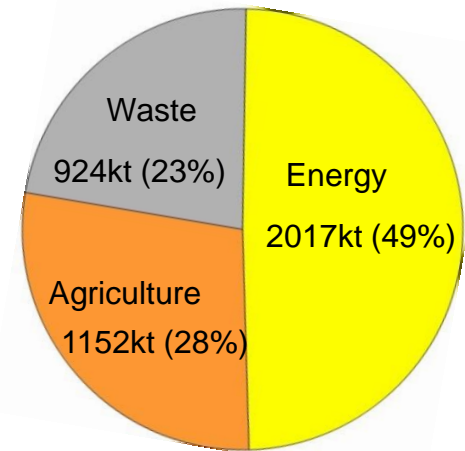
Reported Methane Emissions (NIR 2015 - 4096 kt CH₄ yr⁻¹)

Provincial Contributions to National Emissions

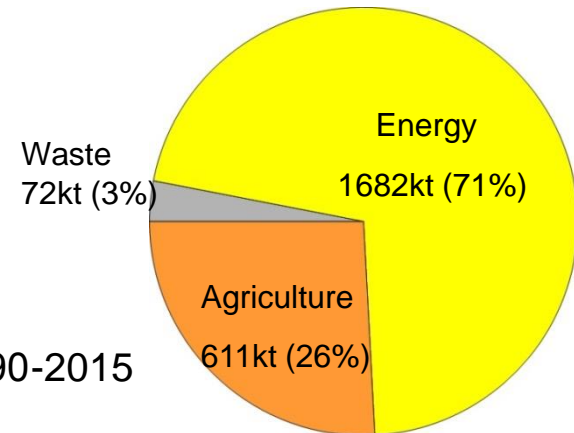
AB & SK contribute ~ 60%



Sector Contributions-CDN Total



Sector Contributions (SK & AB)



Source: Canada's National Inventory Report (NIR): 1990-2015

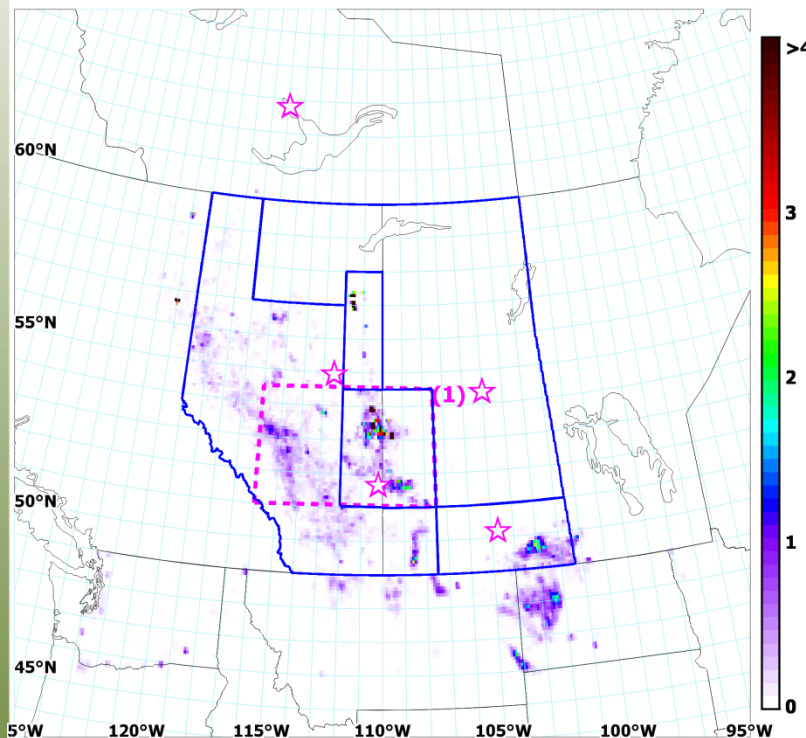
Page 10 – May-1-18



The first step is to spatially distribute the location and magnitude of the emissions (known as a 'prior' – but sometimes referred to as the 'first guess')

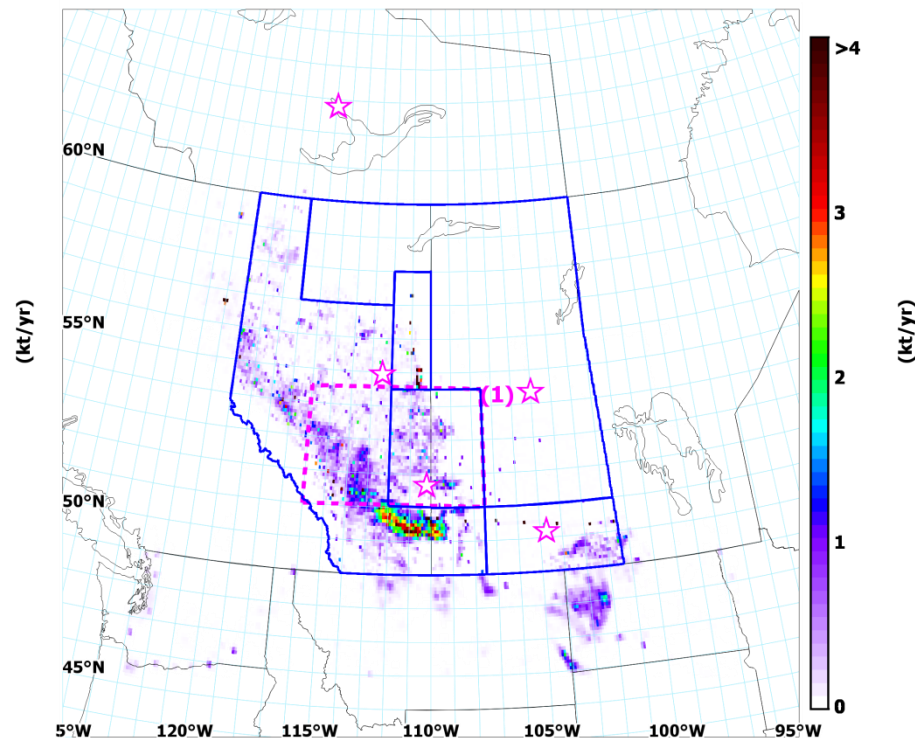
ECCC/AQRD (Normalized to NIR)

Max: 173.9 kt/yr
Total: 1471 kt/yr
(1) 1028.3 kt/yr



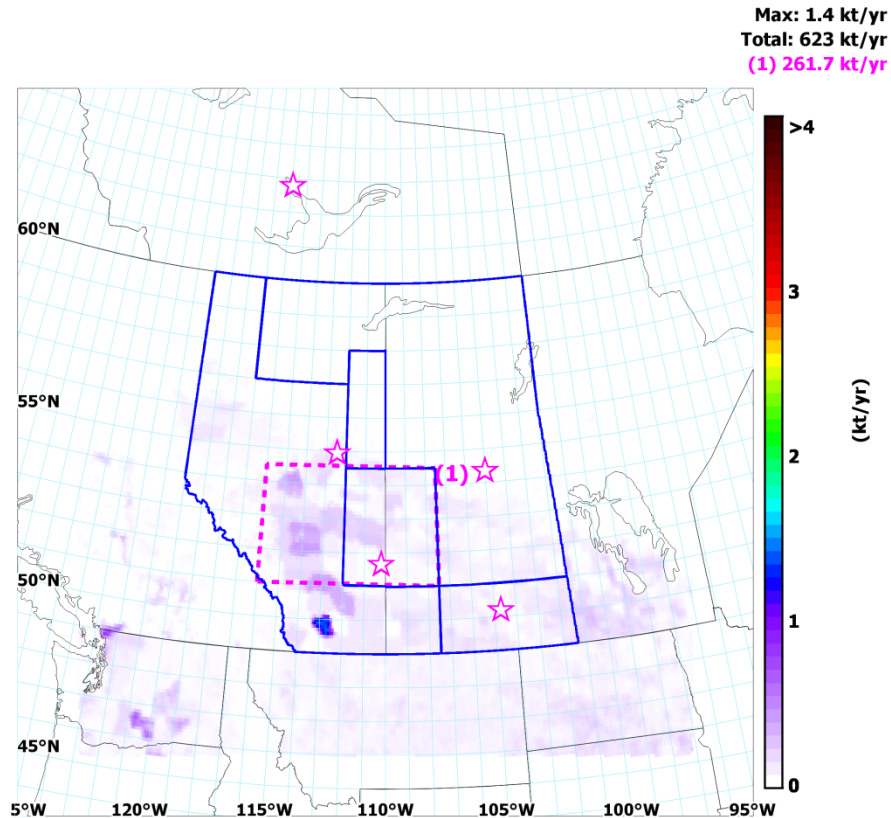
Sheng et al., 2017 (*Atmos. Env.*)

Max: 57.1 kt/yr
Total: 1986.3 kt/yr
(1) 698 kt/yr



Spatial distribution of agricultural sources - 87% of agriculture sources in AB & SK is enteric fermentation (burping cows)

ECCC/AQRD (normalized to NIR)



It is difficult in a modelling framework to isolate the Agriculture and Anthropogenic sources because both sources often overlap spatially, more so in some regions than others...

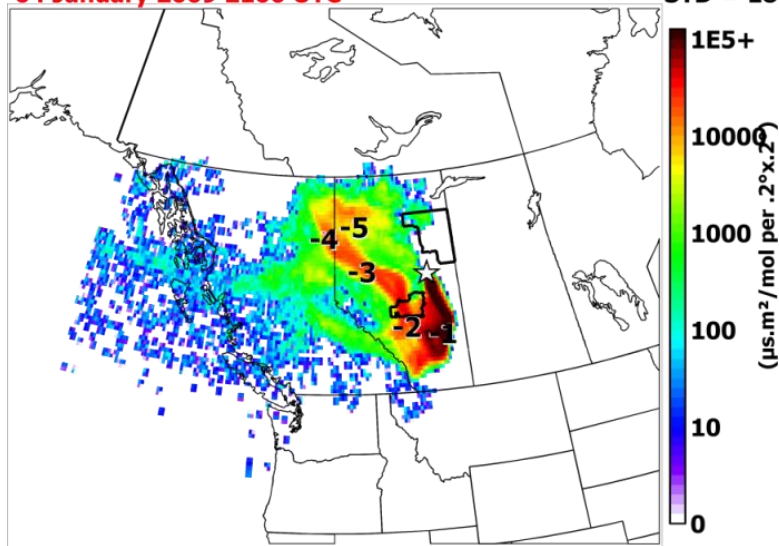


Atmospheric transport models enable methane observations at a site to be linked back to sources

ECMWF-FLEXPART

LLB, footprint (0 to 100 m)
04 January 2009 2100 UTC

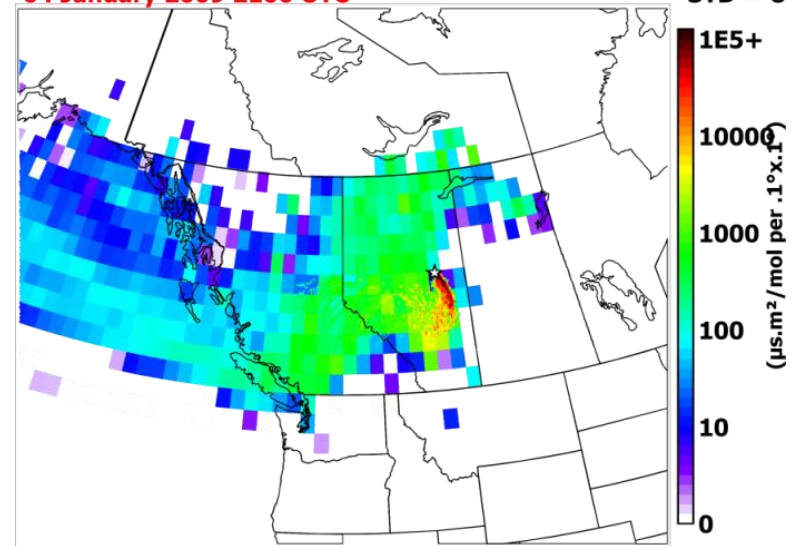
Max = 562738
STD = 18



WRF-STILT

LLB, footprint (50% BLH)
04 January 2009 2100 UTC

Max = 507292
STD = 8



Different atmospheric transport models provide similar understanding of the source footprints. These are examples of two different transport models' hourly footprints for January 4th, 2009 at 2100 UTC.

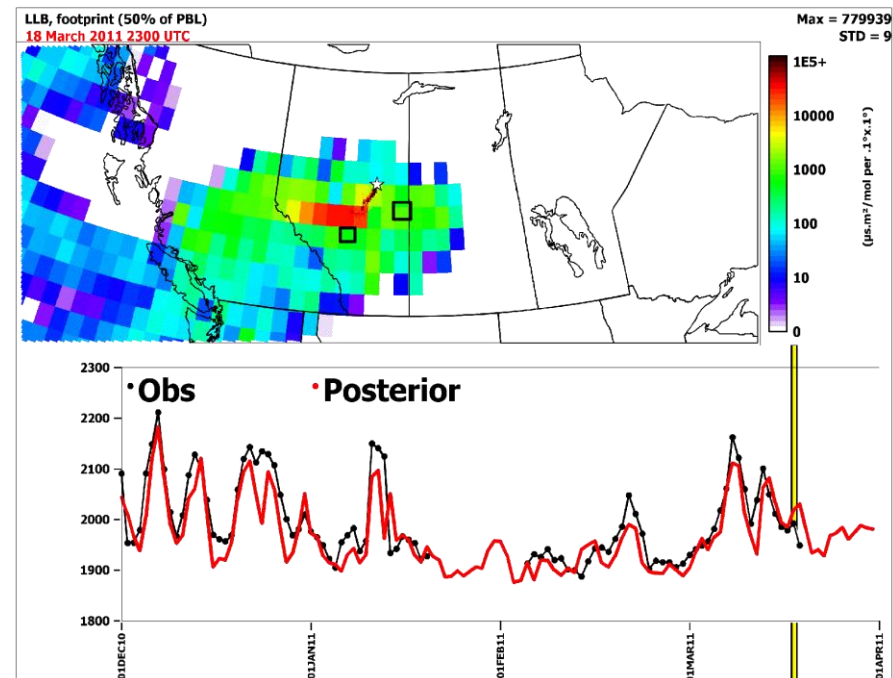
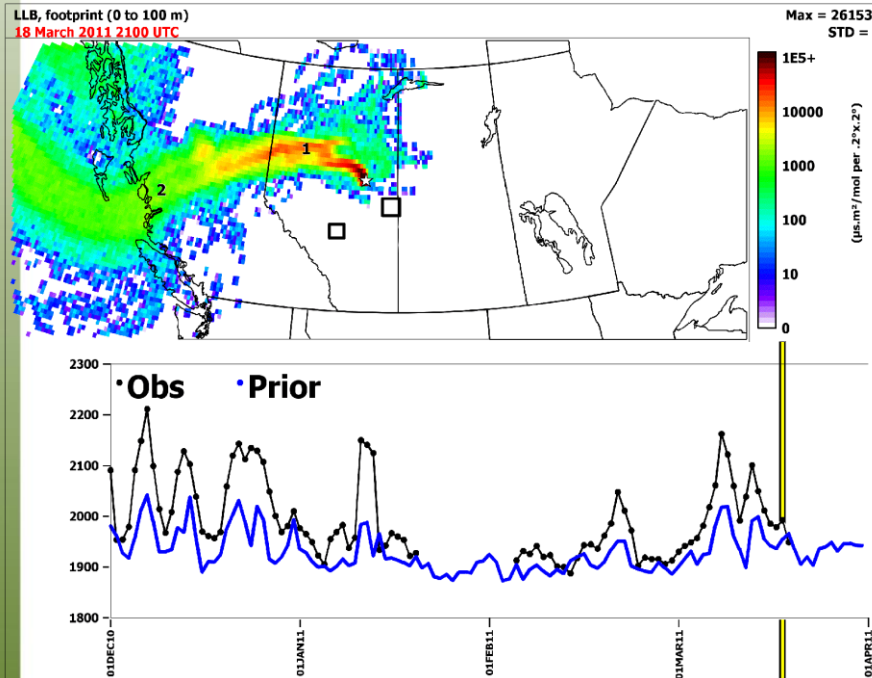


Case study - results using multi-prior and multi-transport means. The 'prior' (blue) and 'posterior' (red) mixing ratios (2010-2011)

From the difference between the 'prior' and the 'posterior' estimates, it is clear that an increase in the 'prior' emissions is required to match the observations.

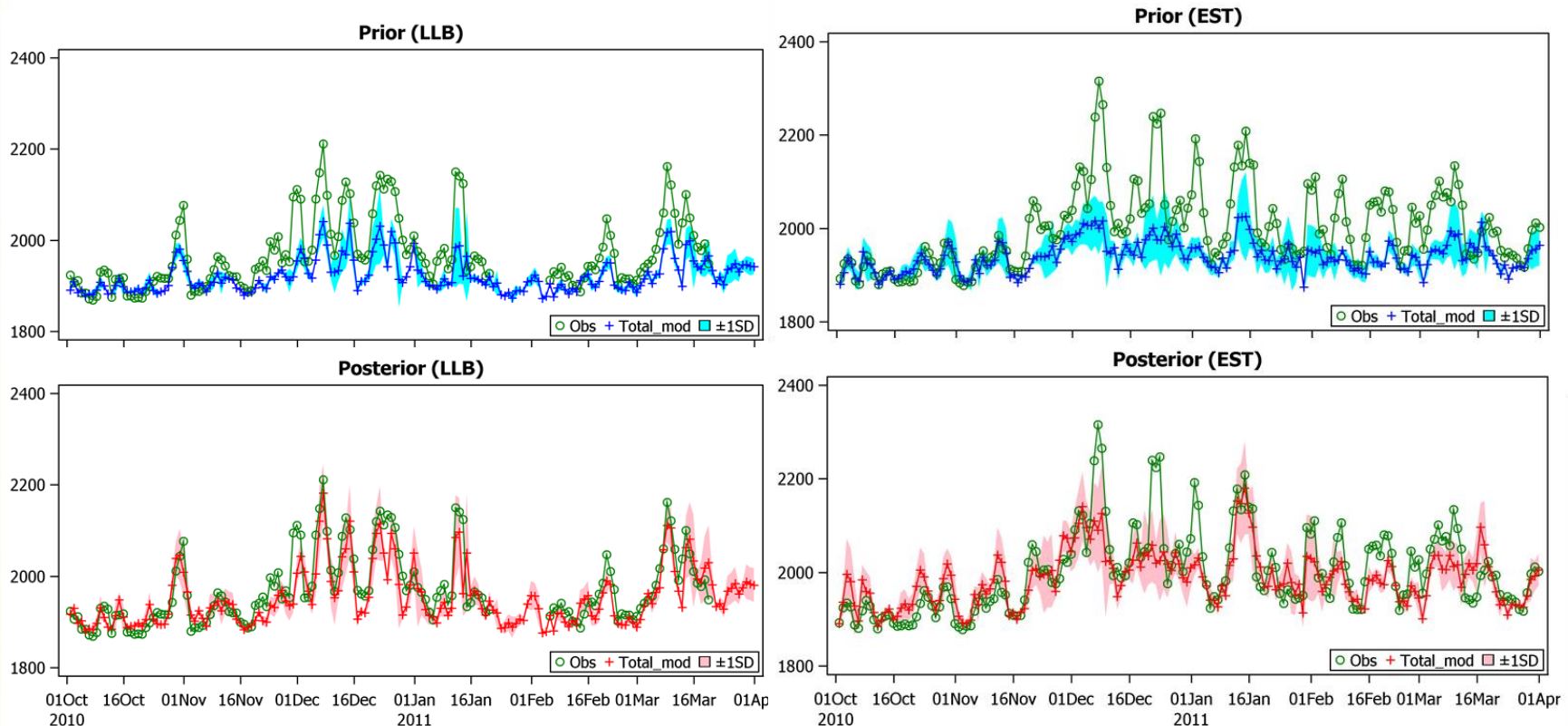
ECMWF-Flexpart

WRF-STILT

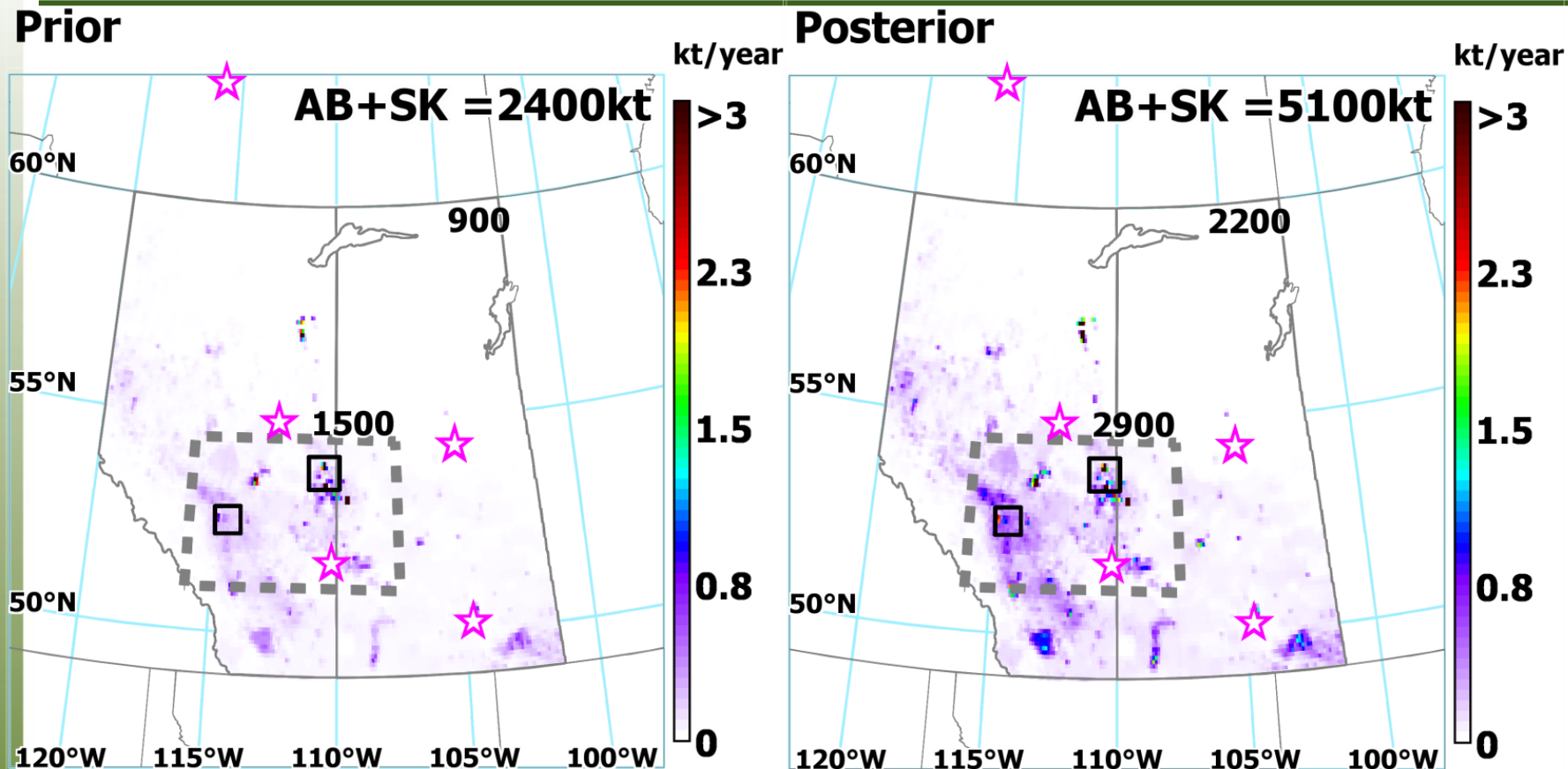


Results: observation and model comparisons at Lac Labiche (LLB) and Esther (EST), AB for winter 2010-11

The uncertainties in the model outputs using two transport models and two priors are shown in the shaded areas. Overall, the uncertainties are smaller than the increase in emissions that is required to match the model output with the observations.



Average (2010-2012) anthropogenic observations-based emissions for Alberta and Saskatchewan



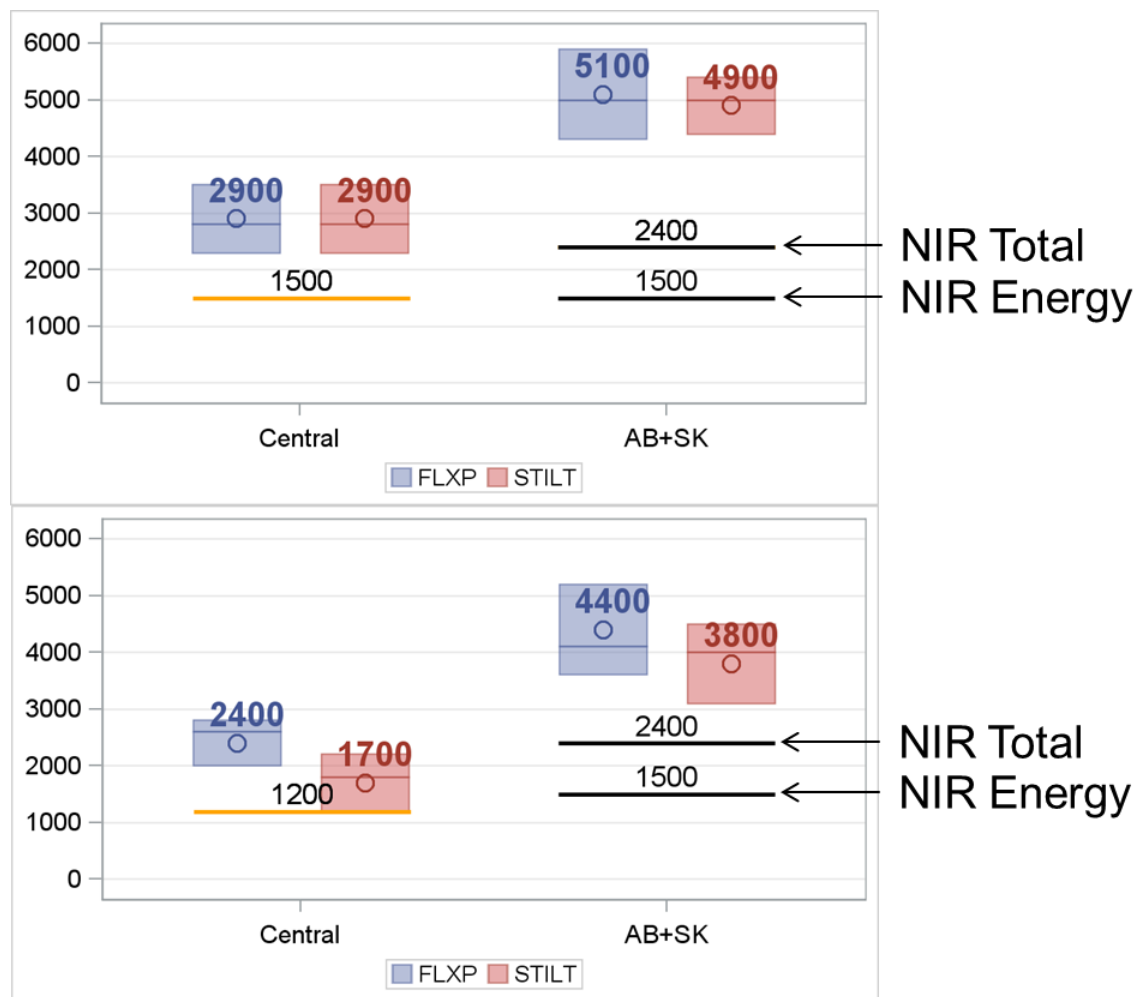
Using the ECCC/AQRD 'Prior' and the Flexpart transport model, a two-fold increase in the combined Agriculture and Oil and Gas sources is required to match the model output with the observations at four sites.

The average (2010-2012) observation-based emissions estimates for AB and SK show that:

ECCE/AQRD

In all 4 model run scenarios, the total NIR values for Alberta and Saskatchewan are under-reported by a range between 40 and 130%.

Sheng et al.,
2017 (Harvard)



Conclusions

- Using atmospheric observations and two atmospheric transport models and two 'prior' spatial emission distributions, results indicate that AB/SK provincial totals **likely** under-reported by 40-130%.
- If agricultural sources (611 Kt) are assumed to be correct, then emissions from the oil and gas sector are **higher** by approximately 2000 Kt; under-reported by 2 to 3 fold.
- These results are consistent with emerging literature.
- 2000 Kt methane is equivalent to 50 Mt GHG (CO₂ Eq.).
- In 2015, **Canada's** total reported **GHG emissions** were 720 Mt. The oil and gas sector was the largest contributor, accounting for 185 Mt.

