Evaluating interactive CH_4 in the Canadian Earth System Model 4 using NDACC FTIR measurements

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and NDACC IRWG PIs and teams

Background

- Increased wetland emissions, more intense wildfires and permafrost thaw are all increasing CH_4 concentrations. Varying rates of increase in recent decades.
- Environment and Climate Change Canada wants to parametrize these impacts through their Canadian Earth System Model (CanESM), which currently uses prescribed surface CH_4 concentrations.
- Recent efforts to make CanESM CH_4 “interactive” (added via prescribed anthropogenic emissions, wetlands and fire emissions, lost via reaction with OH in model chemistry).
- Building on previous work by Victoria Flood, we want to compare the model simulations with NDACC IRWG CH4 tropospheric columns.

CanESM Model Datasets

ESM-repOH

- Interactive CH_4 on
- OH concentrations repeat interannually
- Land, ocean, atmosphere coupled

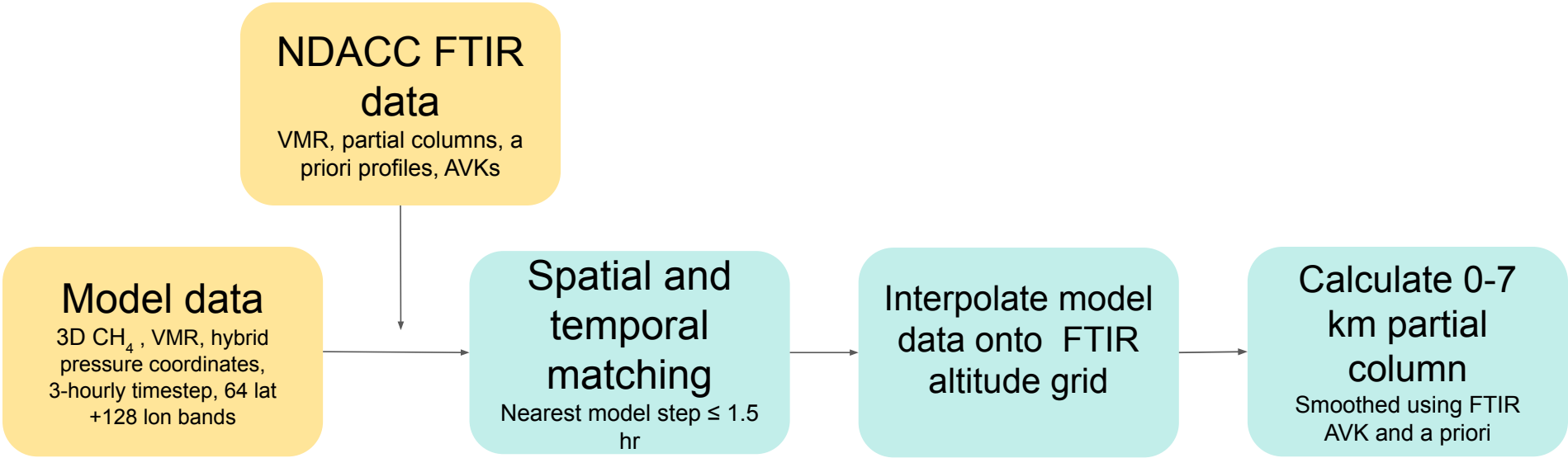
ESM-trOH

- Interactive CH_4 on
- OH concentrations vary (transient)
- Land, ocean, atmosphere coupled

AMIP

- Interactive CH_4 off
- OH concentrations prescribed
- Land and atmosphere coupled
- No ocean coupling (sea surface temperature prescribed)

Processing Workflow



Comparison Metrics (Flood *et. al.,* 2024)

Model–measurement monthly mean percent difference

$$\Delta_{\text{monthly},j} = \frac{1}{N_j}\sum_{i=1}^{N_j}\Delta_i \,.$$

Overall mean percent difference

$$\Delta_{\text{O}} = \frac{1}{N_{\text{months}}}\sum_{j=1}^{N_{\text{months}}}\Delta_{\text{monthly},j} \,.$$

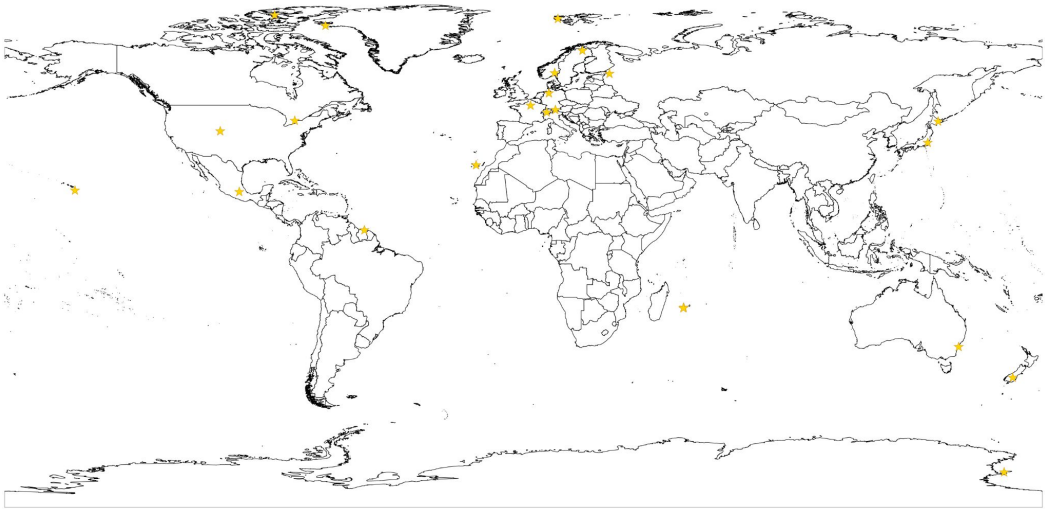
Normalized Root Mean Square Error (not monthly mean)

$$\text{NRMSE} = \frac{1}{\sigma_{\text{F}}}\sqrt{\left[\sum_{i=1}^{N}\left(\text{PC}_{\text{M},i} - \text{PC}_{\text{F},i}\right)^2\right]} \,.$$

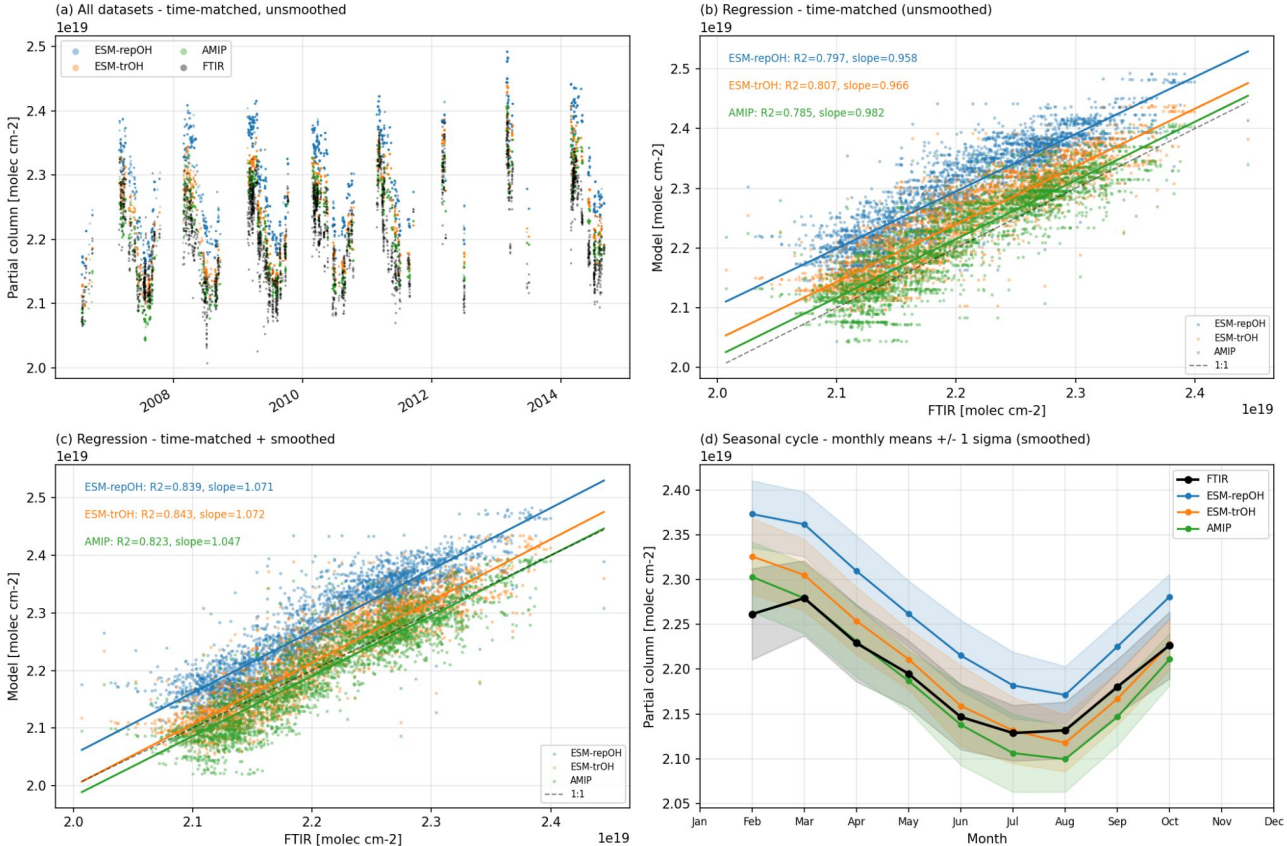
i = model-measurement pair
J = a calendar month
PC = 0-7 km Partial Column
F = FTIR
M = Model
σ_F = standard deviation of FTIR data

Comparison Sites

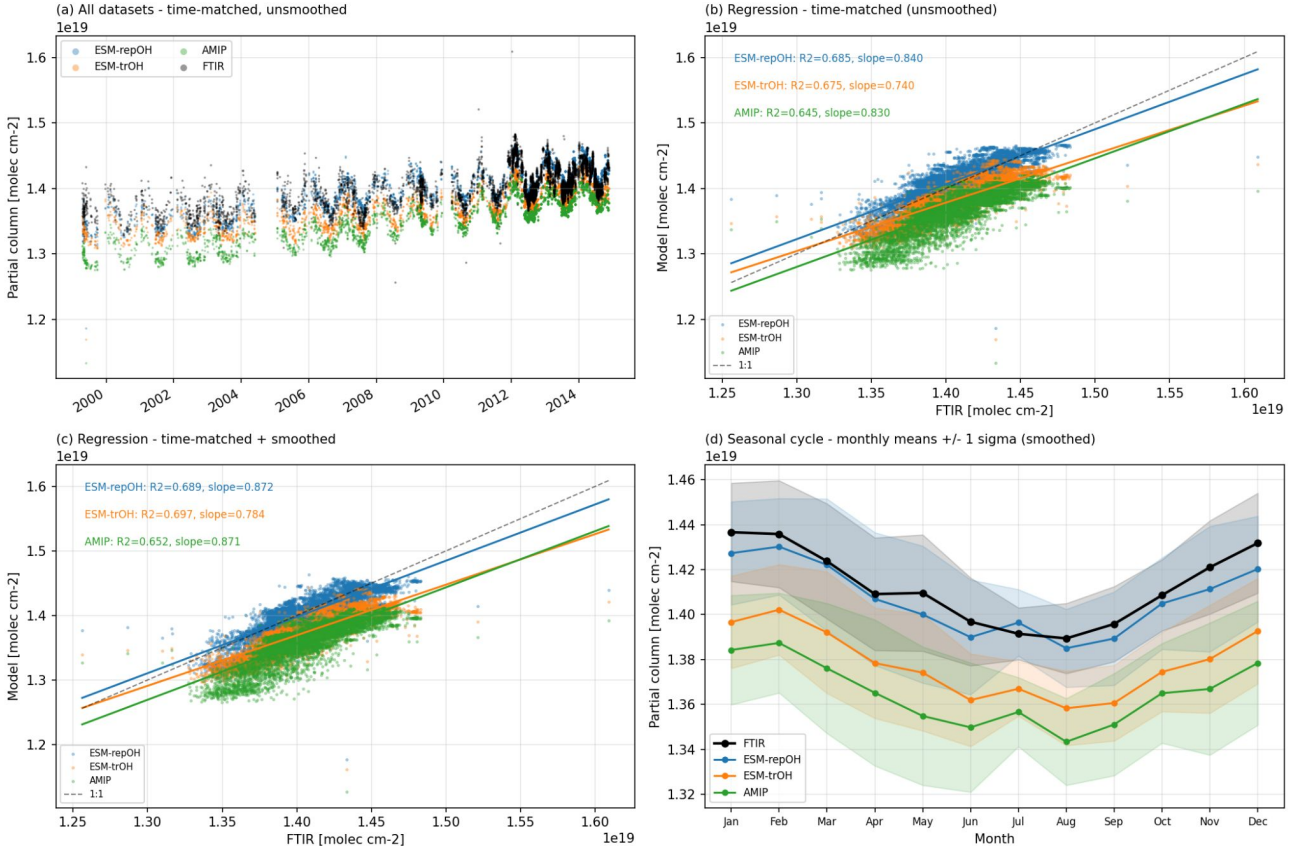
- 23 NDACC sites:
  - Eureka, Ny Ålesund, Thule, Kiruna, Harestua, St. Petersburg, Bremen, Paris, Zugspitze, Jungfraujoch, Toronto, Rikubetsu, Boulder, Tsukuba, Izana, Mauna Loa, Altzomoni, Paramaribo, St. Denis, Maïdo, Wollongong, Lauder, Arrival Heights
- Model data time period:
  - AMIP data 1989-2014
  - ESM-repOH 1982-2014
  - ESM-trOH 1982-2014
- Time periods for the FTIR data vary by start date but all end in 2014



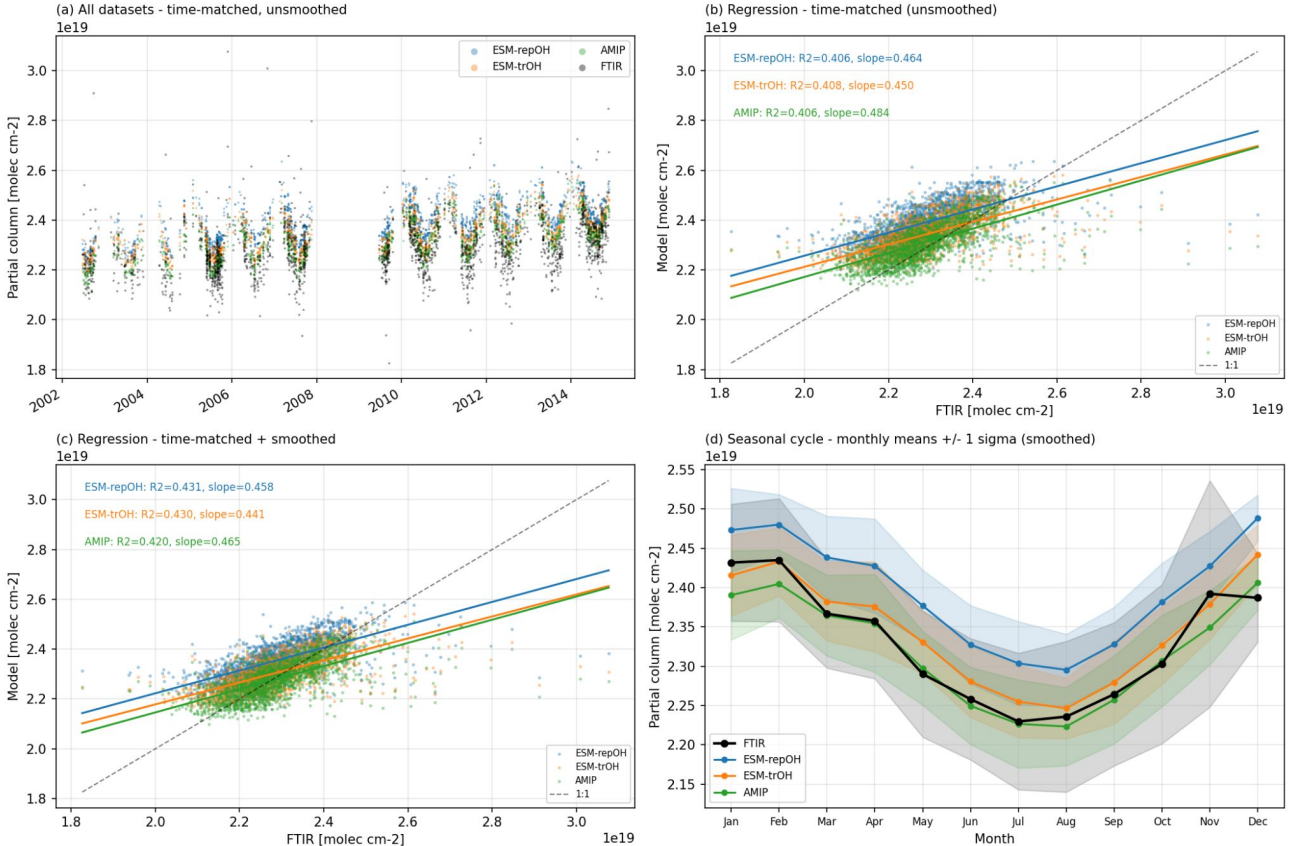
Example 1 (high latitude)- Eureka (80.05, -86.42)



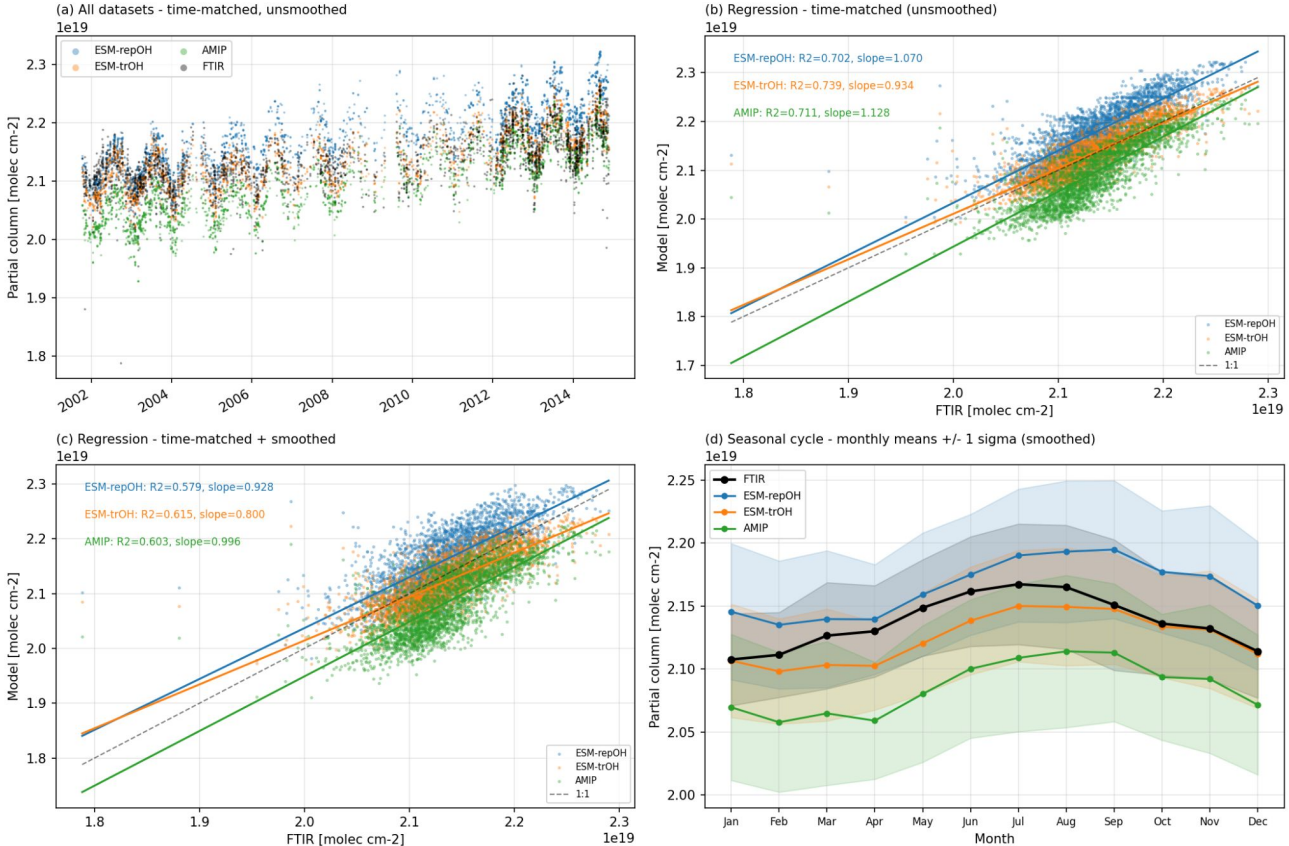
Example 2 (subtropical, ocean, high-altitude)- Izaña (28.30, -16.48)



Example 3 (mid-latitude, NH, urban)- Toronto (43.66, -79.40)

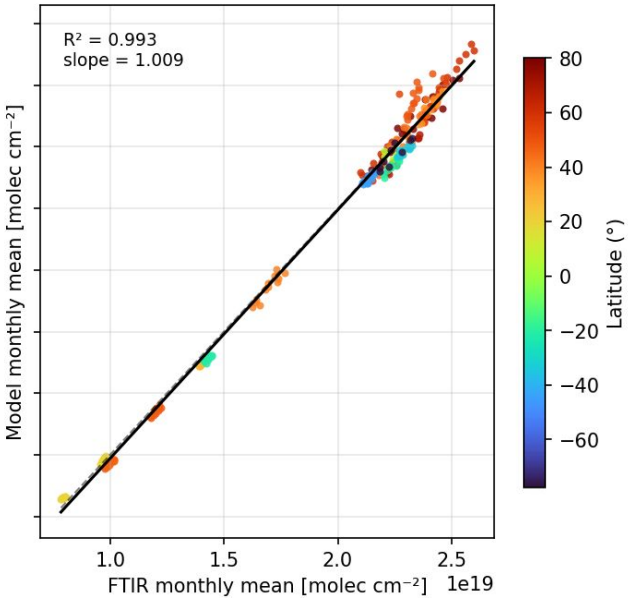


Example 4 (SH, background)- Lauder (-45.04, 169.68)

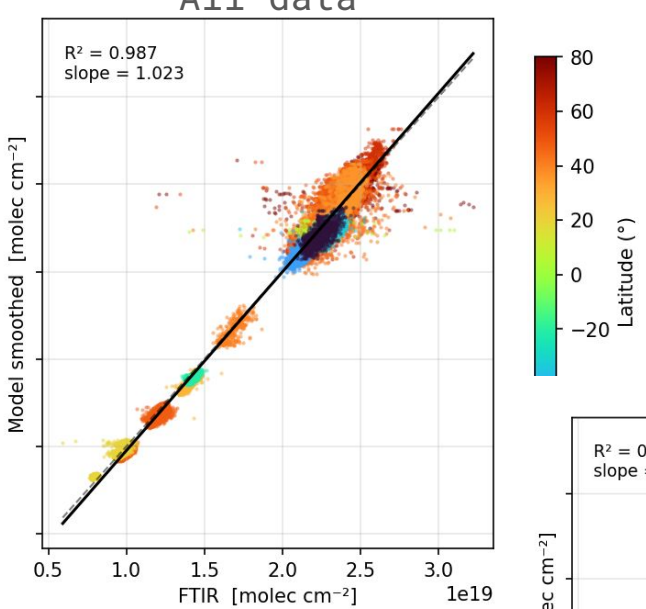


Correlations for all matched pairs from ESM-trOH

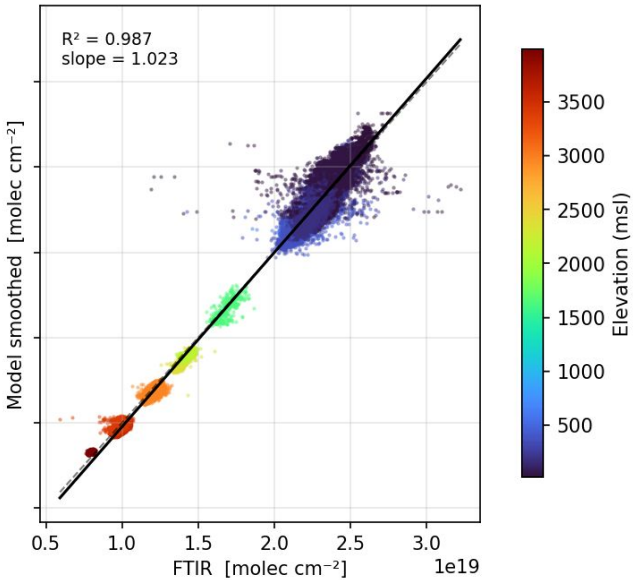
Monthly means



All data

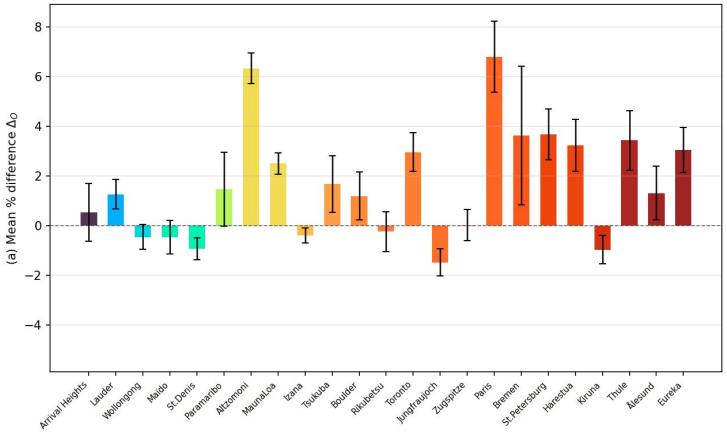


All data

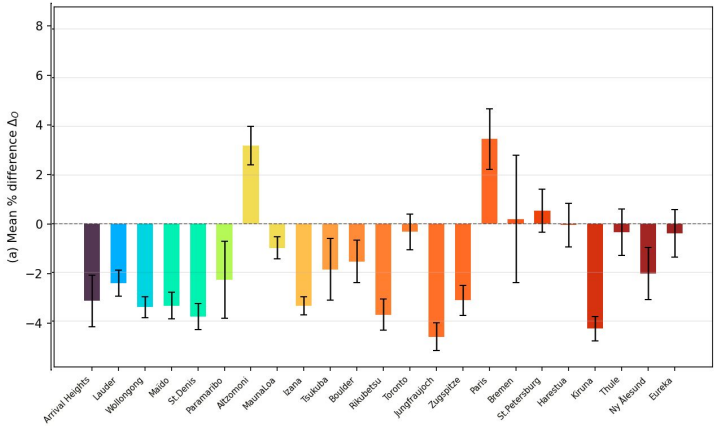


Mean Percent Difference (of monthly means)

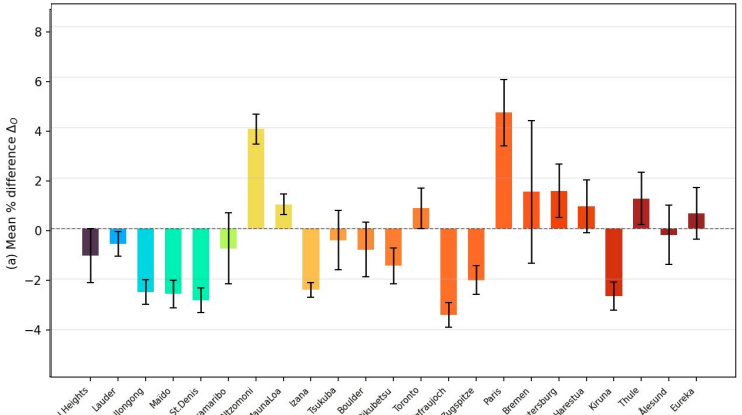
ESM-repOH



AMIP



ESM-trOH

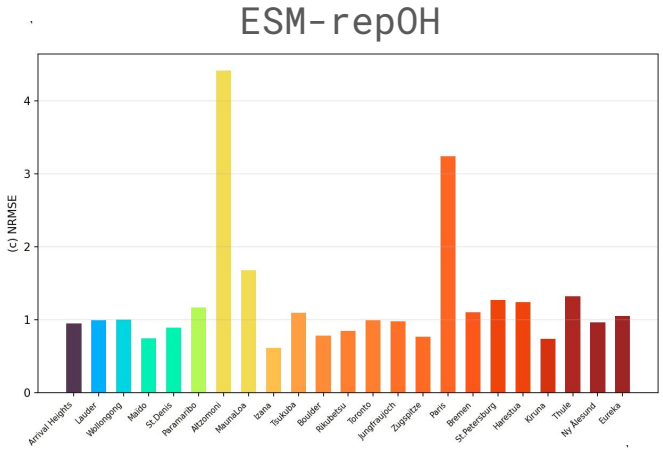


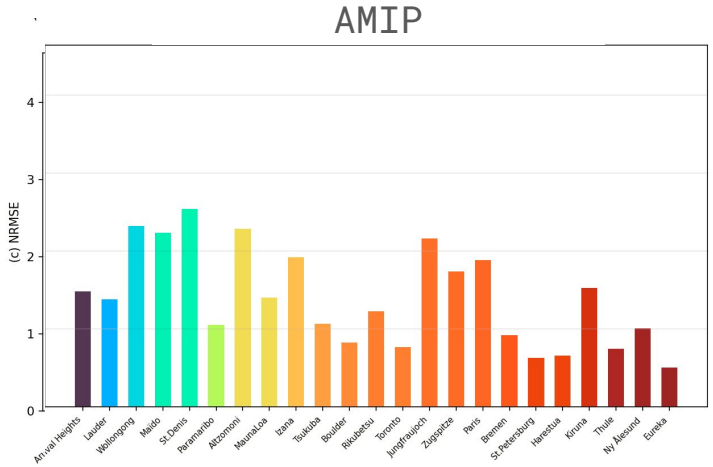
repOH- interannually repeating OH

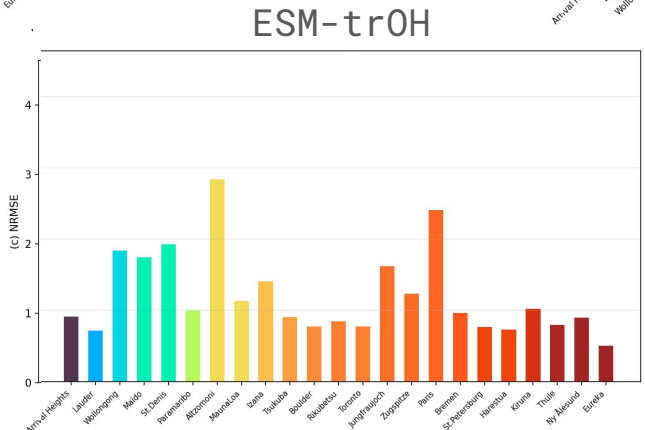
trOH- interannually varying OH

AMIP- non-interactive + no coupling to ocean

Normalized Root Mean Square Error (all data)







repOH- interannually repeating OH

trOH- interannually varying OH

AMIP- non-interactive + no coupling to ocean

Summary and Next Steps

- All three versions of CanESM have strong correlations with the FTIR 0-7 km CH4 partial columns.
- Monthly multi-model mean shows ESM-trOH (with interactive CH4, varying OH, and coupling of land, ocean, and atmosphere) has best agreement with FTIR:
    - ESM-repOH: (+1.7 ± 0.41)%
    - ESM-trOH: (-0.3 ± 0.44)%
    - AMIP: (-1.6 ± 0.50)%
- Lower monthly mean model-measurement percent difference and NRMSE across most sites for trOH relative to other two models, with no clear latitudinal dependence.
- More scatter in model-measurement correlations at lower altitude locations.
- Will be investigating these new results in more detail, including the site-to-site sensitivity to the different model versions.
- Another comparison to be done on whether similar results can be achieved with lower temporal resolution model sampling (monthly vs 3-hourly) to decrease data volume and processing time.

Thanks to Environment and Climate Change Canada, and the Natural Sciences and Engineering Research Council of Canada, as well as all staff at the 23 NDACC stations who contributed data to this project.

We will be reaching out to you soon! ☺