Validating Short-Lived Climate Forcer Modelling in the High Arctic with TCCON

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TCCON — total carbon column observing network

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Background

- The Arctic Monitoring and Assessment Programme (AMAP) is a working group of the Arctic Council that consolidates evidence on various factors impacting the Arctic environment and the health of people who live there in order to inform policy.
- AMAP uses a suite of models to model species of interest. AMAP is currently particularly interested in short-lived climate forcers (SLCFs)
- SLCFs are species with climate impacts and lifetimes shorter than that of CO_2
- Due to their short lifetimes, the effects policy changes impacting SLCFs can be seen much quicker than policies targeting CO_2
- TCCON species of interest that are SLCFs are CH_4 and CO

Methods

- We use TCCON data products to validate the outputs of various models used by AMAP at the three Arctic TCCON sites: Eureka, Ny Ålesund , and Sodankylä for 2014-2015
  - Eureka and Ny Ålesund retrievals used the recently released GGG2020
  - Sodankylä retrievals used GGG2014
  - Not all models provided by AMAP model CH_4
  - GEM-MACH model output was only provided for 2015
- Model predictions were extracted at the grid cell containing the station in question
- To convert model profiles to column-averaged dry air mole fractions, we applied a pressure-weighting function:

$$X_{gas} = \sum_{i=1}^{n} \frac{1}{p_{surf}} \left| \left(-p_i + \frac{p_{i+1} - p_i}{\ln(\frac{p_{i+1}}{p_i})} \right) + \left(p_i + \frac{p_i + p_{i-1}}{\ln(\frac{p_i}{p_{i-1}})} \right) \right| u_i$$

  - p_i is the pressure at level i
  - p_{surf} is the surface pressure
  - u_i is the volume mixing ratio of the gas in question at level i
- We are in the process of applying smoothing and dry air corrections (see Future Work)
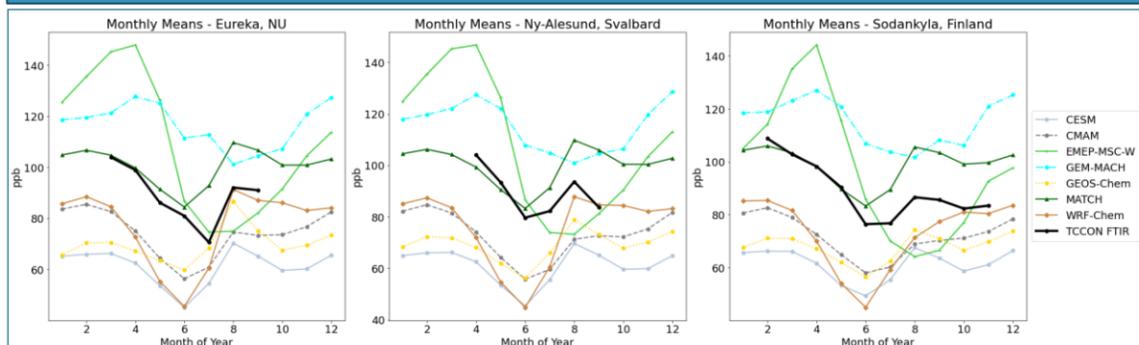
Time series - XCO
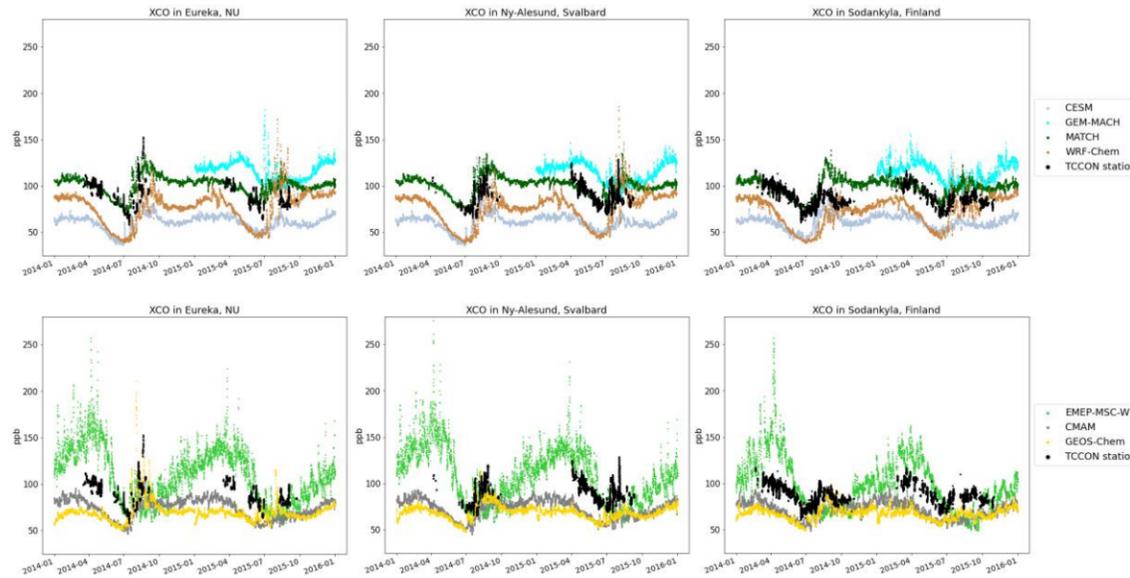
- The top and bottom row of plots in this section differ only in the models shown – these plots are separated in order to improve legibility. Axis scales have been standardized across stations and models portrayed for ease of comparison.
- For XCO, we can see that the differences between different sites are small in terms of model performance
- We can also see that many models perform similarly, with a few slightly outperforming or underperforming the others
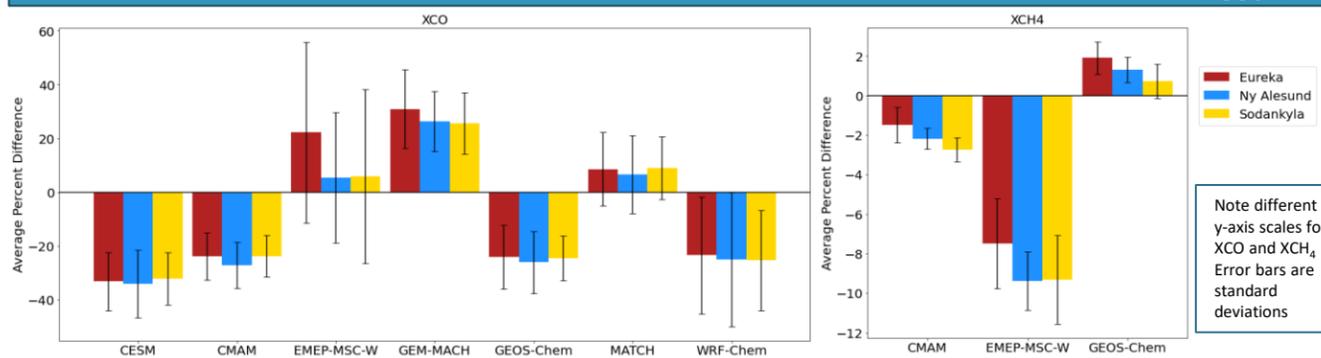
Time series – XCH$_4$
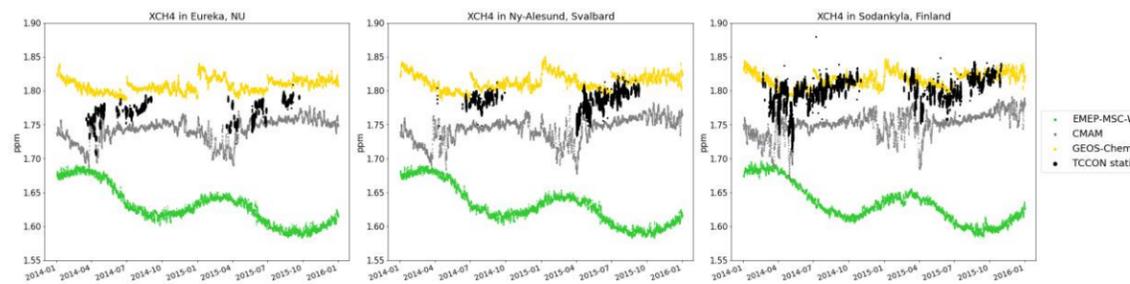
- For XCH$_4$, we see that GEOS-Chem and CMAM do a relatively good job of modelling both the approximate amount of methane as well as seasonal trends, while EMEP-MSC-W performs more poorly at these stations.
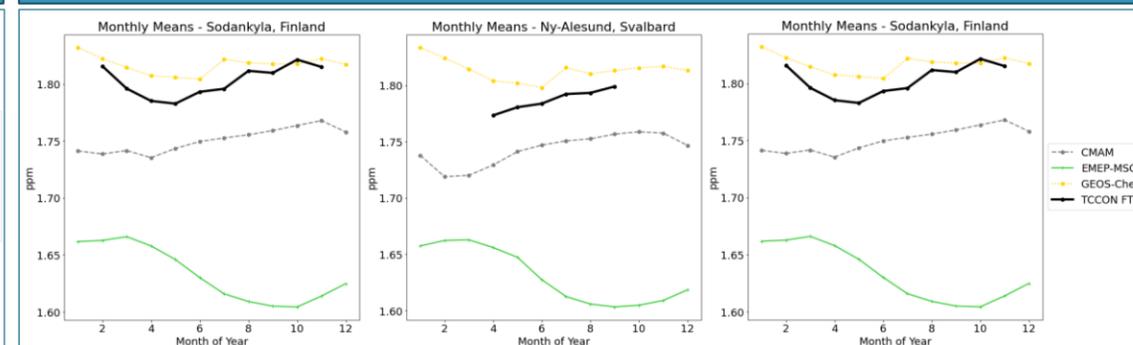
% Differences

$$\%\text{diff} = \frac{\text{Model} - \text{TCCON}}{\text{TCCON}} \times 100\%$$

Note different y-axis scales for XCO and XCH4 Error bars are standard deviations

Coincidences were found by matching TCCON measurements to the closest temporal model prediction; here we present the means of the percent differences between coincidences

Monthly Means - XCO

Monthly Means – XCH$_4$

Conclusions

- While further work is necessary to make sure comparisons between the produced model column-averaged mole fractions and TCCON data products are accurate and valid, these preliminary results appear to be somewhat consistent with other validations of AMAP models (e.g. surface CO, Whaley et al., 2022, in review)
- All models struggle more with modelling CO than CH_4 when looking at percent differences (note: CH_4 is more abundant; absolute differences do not follow this trend)
- MATCH tentatively appears to outperform other models when modelling CO

Future Work

- Immediate future work includes applying smoothing with TCCON averaging kernels and dry air corrections – these are currently in progress
- We also intend to incorporate more models into the comparisons including MRI-ESM-2 and MATCH-SALSA
- We would also like to compare model differences in design that may be driving differences in performance, with a goal of ultimately improving our understanding of the Arctic carbon cycle

References

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