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Atmospheric Measurement Techniques Discussions

Interactive comment on "Atmospheric CO_2 and CH_4 abundances on regional scales in boreal areas using CAMS reanalysis, COCCON spectrometers and Sentinel-5 Precursor satellite observations" *by* Qiansi Tu et al.

Anonymous Referee #2

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This paper shows observations of column averaged dry air mole fractions of carbon dioxide and methane (XCO2 and XCH4), which have been made over a multi-year field campaign in two boreal locations, using Bruker EM27/SUN spectrometers. The observations are compared with CAMS (Copernicus Atmosphere Monitoring Service) model data and, in the case of methane, with satellite data from the Sentinel-5 Precursor (S5P) TROPOMI instrument. The authors also compare the regional gradients in XCO2 and XCH4, i.e. the differences between the column observations made at the two sites, with those obtained from CAMS and S5P. Through this, the authors aim

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to demonstrate how these ground-based measurements could potentially be used to investigate regional greenhouse gas (GHG) sources and sinks.

They find that the EM27/SUN observed XCO2 shows similar, very good correlation with CAMS at both sites (with CAMS higher than the observations), whilst for XCH4 they find that the EM27/SUN columns are lower than CAMS but higher than S5P. The correlations between the EM27/SUN XCO2 and XCH4 gradients and those for CAMS and S5P are generally less than those for the individual site GHG columns. There is reasonable agreement between the GHG column gradients obtained by different means, with CAMS predicting higher XCO2 and XCH4 gradients than those observed using the EM27/SUNs. The S5P XCH4 gradients are also in reasonable agreement, though the authors note that the comparison is limited by the small number of S5P XCH4 observations available over the two boreal sites.

The challenges of performing satellite retrievals of atmospheric composition in boreal regions (high airmass, lack of soundings in winter months, poorly understood surface optical properties in snowy conditions) mean that the validation opportunities presented by EM27/SUNs operating in these locations are of particular interest. The performance shown here of the S5P XCH4 retrievals compared with those from the EM27/SUNs is therefore one of the important outcomes of this work. If this is one of the first inter-comparisons between S5P and EM27/SUN data (particularly in a boreal region), then I think this is worth highlighting in the abstract and conclusions.

Overall I think that the work shown here is well presented and suitable for publication, although I have some technical comments, queries and suggestions that I think will improve the paper once they have been addressed. These are listed below, in order of the manuscript line that they relate to.

Line 45: ‘satellite observations at high latitudes have lower confidence due to the high airmass present in the path of the incoming signal’ – is there a reference that can support this statement?

Line 100: typo, should read ‘CH4’, not ‘CO4’.

Line 100: ‘compared with the TCCON official MAP a-priori profiles’ – please explain briefly what these are (this is addressed at Line 165, but it would be better to do this here since this is the first place in the manuscript that the MAP profiles are mentioned).

Line 118: ‘The public S5P CH4 data. . .’ – please provide a reference for the dataset used (e.g. can be webpage and date of access if acquired from a web portal) including the version number.

Line 140: possible typo, should this read ‘6-hourly’ instead of ‘hourly’?

Line 147: Please include in this paragraph how frequently the Aircore was flown during the campaign (or a cross reference to Section 3.1.2, though I think this information would be better placed in the ‘Sites and Data’ Section). Were the AirCore launches always at the same time of day, and were they timed to coincide with S5P overpasses?

Line 161: Is there a reference for the PROFFAST algorithm that you can include here?

Line 170: Clarification: are the daily 1200 UTC CAMS profiles used as a priori information the same as those in the model dataset described in Section 2?

Line 184: I would be wary of using the term ‘underestimated’ here, since both the MAP and the CAMS profiles are model-based estimates whereas this implies that the CAMS profile is the ‘truth’ that you’re comparing MAPS against. Explicitly say that the MAP profiles are underestimated relative to CAMS, or that the MAP profile estimates are lower than the CAMS estimates. The same point applies to Line 190.

Line 209: ‘likely due to the seasonal bias in CAMS’ – please include a reference to back up this statement.

Line 237: It would be useful to include example averaging kernel plots from the Sodankyla observations, if possible.

Line 238: ‘we expect that a more realistic a-priori profile will bring the results in better

agreement' – can you briefly explain why the MAPS profiles are used in TCCON, when more realistic representations of the atmosphere are available? I think TCCON uses the MAPS profiles for operational reasons, i.e. interpolating NCEP is much simpler than generating high resolution model output for every TCCON location, plus even a high resolution atmospheric model can be more realistic in some regions compared with others – possibility of site vs. site biases being introduced.

Line 242: Comparison of TCCON vs COCCON XCO2 – according to Wunch et al (2011), an airmass bias correction is applied to the standard TCCON XCO2 data. Has this airmass bias correction been removed from the TCCON data for this comparison, or has an airmass bias correction been applied to your COCCON data to ensure that the two datasets are being treated in the same way?

Line 257: 'The COCCON data discussed below are using the CAMS profiles as a-priori profiles' – I'm happy with the justification for using CAMS instead of MAPS, based on the impact that the polar vortex has on the profile shape, and the errors that an incorrect profile shape introduces in a profile-scaling retrieval. However, can the columns retrieved using the CAMS profiles still be referred to as 'COCCON data' if a different a priori profile is used from the one used in the standard COCCON retrieval procedure? If as a result the data quality is no longer directly comparable with that obtained by other instruments operating in the COCCON framework (which may refer to this paper when publishing their own work), then it may be necessary to clarify this distinction by referring to this data as 'COCCON-CAMS', for example, when the CAMS (i.e. non COCCON) profile is used in the retrieval.

Line 258: in Section 3.2, can you clarify whether the CAMS reanalysis data you compare against is the same as that used for the a priori profiles in the retrieval?

Line 315: typo, missing ')'

Line 316: typo, missing ')'

Line 334: ‘MAP is more constant and overestimated over the whole year’ – same point as for Lines 184 and 190, clarify that this is an overestimate compared with the CAMS estimate (e.g. ‘the MAP estimated CH4 is more constant, and greater than that estimated by CAMS over the whole year’)

Line 352: ‘In contrast, the S5P satellite generally measures lower atmospheric XCH4 than COCCON’ – is this also seen in other studies comparing S5P with TCCON and/or EM27/SUN data? Is this finding specific to boreal regions? Also, if this is the first comparison to be published between EM27/SUN and S5P then I think this is worth mentioning both here and in the abstract.

Line 385: Please mention which satellite instrument the N2O data comes from in the caption for Figure 3.

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