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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Upper tropospheric CH_4 and CO affected by the South Asian summer monsoon during OMO" *by* Laura Tomsche et al.

Anonymous Referee #1

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Summary

The manuscript by Tomsche et al. presents observations of CH4 and CO obtained during the OMO campaign in 2015 with the TRISTAR instrument on board the German High-Altitude and Long Range Research Aircraft HALO. Transport pathways and origin of trace gases are identified using FLEXPART, an Lagrangian dispersion model. Additionally the in situ data are compared with simulations carried out with the CCM EMAC.

The vertical profiles taken during the campaign show different altitude distributions depending on geographic locations. The authors classify different profiles as NH and SH background and AMA influenced and define an observation-based threshold value for CH4 and CO to distinguish between air masses from in and outside the AMA.

A case study for one flight during OMO (leading from Greece to Oman and back) is presented to demonstrate the interplay between surface emissions, deep convection and transport for the observed CH4 values. The observations showed enhanced values of CH4 and CO in air masses, which could be traced back with trajectory calculations to areas of strong emission in southeastern and eastern Asia. The trajectories showed upward transport via deep convection inside and at the edge of the Asian Monsoon Anticyclone (AMA), indicating strong impact of the dynamics of the AMA, thus making especially CH4 a good AMA tracer. Comparisons with results from EMAC show only a mediocre agreement, in particular the model underestimates the CH4 values and overestimates CO for air from within the AMA, while it overestimates both species in background air. Nevertheless, the large-scale dynamical situation seem to be represented quite good by EMAC (Table 1). Therefor the model is used in the following to identify different AMA modes and outflow events. Various measurement flights are then analyzed with respect to the dynamical situation and the relative position with respect to the AMA.

The paper shows the AMA as a distinct and persistent, although dynamically active feature observable in CH4 and CO. The dependency of the distributions of these tracers from the emission regions and the convective centres, as well as the influence of the relative position of the observations with respect to the AMA is clearly emphasized.

General

The present manuscript is well written and organized, but very extensive and sometimes too descriptive. Nevertheless the content presented is structured methodically and scientifically sound. The paper focuses on the analysis of observations of atmospheric tracers (CH4, CO) obtained during the OMO campaign carried out in 2015.

The tools used in addition to the statistical analysis are primarily two numerical models, namely FLEXPART, a Lagrangian dispersion model, and EMAC, a CCM widely used in the german atmospheric community. The FLEXPART trajectories are driven by

ECMWF operational data used to gain information about the transport pathways of the observed air masses. These data is used in a 1x1 degree horizontal resolution with the full vertical resolution of 137 levels. Vertical motion is calculated using a stochastic approach. Additionally moist convection is parameterized.

The EMAC model, on the other hand, has a much coarser resolution of 2.8x2.8 degrees and 90 levels. Unfortunately the EMAC simulation used is not described in detail, leaving open some important questions: Is EMAC used in an offline CTM mode? If this is the case, what is the model then driven by? Or, in other words: Do both models, the Lagrangian as well as the Eulerian model "see" the same background atmosphere? What kind of vertical velocity was used for the EMAC simulation. Another important point of course would be the initialization of the model, the length of the simulation and whether a certain spin-up time was necessary.

Since during the analysis of the data results from both models were used simultaneously (e.g. footprints and emission data) or observations of tracers obviously transported upward by convection are compared to distributions modified by vertical transport in EMAC, a more detailed description of the model setup would be very helpful. A very interesting diagnostic in this context would e.g. be the vertical transport time of tracers emitted from the surface to reach the 200 hPa level in EMAC.

The derivation of threshold values for CO and CH4 to distinguish between the inside of the monsoon anticyclone and the outside by using vertical profiles for NH and SH background and AMA leads to the question, why profiles over Egypt are considered as influenced by AMA and profiles over Cyprus are not. At least a look at the figures showing the different AMA modes (figures 18 to 21) would lead to a different expectation. But this is just judged by visual measure (and only on 204 hPa), so if there are distinct differences between profiles at these locations, the authors would be well advised to please show them. Since the classification of profiles influences the threshold values, this question may be quite important for the further analyses.

The observations shown for the case study for flight 19 indicate a highly structured CO and CH4 distribution in the vicinity of the AMA boundary region. The distributions simulated by EMAC matches the observations only very roughly. In particular the CH4 values are underestimated significantly. By looking at the horizontal and vertical distributions one gets the impression, that the vertical transport of the model is probably to weak. This may have several reasons: First, the vertical velocity may be to slow, e. g. the processes leading to strong updraft (namely convection) are to weak or insufficiently parameterized, or second, the numerical horizontal diffusion implied by the coarse grid resolution dampens the strong updraft plumes (approximately above 500 K). Adding horizontal wind as contour lines to the cross sections could shed some light on this problem. The included lines of potential temperature already point into this direction.

However, although the EMAC distributions may be consistent within the model, these effects may lead to a too small AMA region, when defined by an observational-based CH4 threshold. A dynamical shape of the AMA could be gained by using geopotential height or stream function. In this context I would suggest to add some contour lines to the figures displaying the horizontal CO and CH4 distribution including the threshold values and lower values to give a better visual feedback of the AMA and its position relatively to the flight tracks. This is meant with reference to figures 7, 8, 18 – 21.

A comparison between footprints of last PBL contact derived from 10 day backward trajectories from FLEXPART and the surface emissions from EMAC could be much more efficient, when footprints would be graphically added to the surface emission charts.

The analysis with respect to the different AMA modes defined by the CH4 distribution of the EMAC simulation leads to very interesting results, which are almost impossible to interpret from the values of table 2 without the knowledge of the flight tracks and the position of the AMA. Probably one could use the distance not to the anticyclonic centers but to the boundaries of the anticyclones. Nevertheless the discussion of the results remains complex, and the authors do a good job here.

The last case study focusing on an outflow event tracked with trajectories and probed twice within 4 days seem to give better agreement with EMAC results (again only judged by visual measure). Maybe an additional figure showing observed and simulated tracer distributions would complement this very interesting manuscript. These plots are already in the supplement.

Summarizing, the paper is well-written and presents an important contribution to our understanding of transport. I recommend to accept the paper after some minor revisions noted in the text above. The most important one would be a more detailed description of the EMAC simulation with respect to the questions raised above.

Specific comments

Important: Please describe the EMAC simulation with respect to the above mentioned questions.

Important: Please be more specific on the reasons for the distinction between Cyprus and Egypt profiles.

Suggestion: Add horizontal wind as contour lines to the cross sections. Refers to figures 9-12.

Suggestion: Add some contour lines to the figures displaying the horizontal CO and CH4 distribution including the threshold values and lower values to give a better visual feedback of the AMA and its position relatively to the flight tracks. This is meant with reference to figures 7, 8, 18 – 21.

Suggestion: Add footprints graphically to the surface emission charts.

Suggestion: Add figures with observed and modeled CO and CH4 along the flight track for the outflow event case study.

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