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## ***Interactive comment on “Carbon monoxide (CO) and ethane (C<sub>2</sub>H<sub>6</sub>) trends from ground-based solar FTIR measurements at six European stations, comparison and sensitivity analysis with the EMEP model” by J. Angelbratt et al.***

**Anonymous Referee #2**

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### General Comments

This paper presents measurements of the tropospheric partial columns of CO and C<sub>2</sub>H<sub>6</sub> made by FTIR spectrometers at six European stations. Trends from 1996 to 2006 are presented for four of the stations, and are negative for both gases, at about -1% per year. Simulations by the EMEP chemical transport model are compared with the measurements, revealing generally reasonable agreement in the average amplitudes, the seasonal cycle, and the differences between stations. However, there are some discrepancies for CO during periods of large-scale biomass burning in North

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America and Russia. EMEP tends to overestimate the seasonal cycle and underestimate the columns for CO, while overestimating both the seasonal cycle and columns for C<sub>2</sub>H<sub>6</sub>. The model was also used to perform a sensitivity analysis to examine possible causes of the observed CO trends. Reductions in European CO emissions were found to largely explain the trends, while the decrease and increase in North American and East Asian CO emissions, respectively, also had an impact on the measured columns. This paper is a useful contribution to the field, providing a ten-year time series of tropospheric measurements in Europe, and using a chemical transport model to interpret the results. I recommend publication in ACP after the comments below are addressed.

### Specific Comments

Page 13725, line 2: The title mentions six FTIR stations, while this first sentence refers to four. This causes some confusion until the reader realizes that data from six stations are presented and compared with the model, but that measurements from only four of the stations are used to derive trends. Nowhere is it explained why trends are not derived for Bremen and Ny Alesund. This should be explained somewhere near the start of the paper.

Page 13725, line 2: Define FTIR. Acronyms are poorly defined throughout the paper. Define all acronyms once on first use in the Abstract, and again once on first use in the main body of the paper. Also EMEP MSC-W on line 8.

Page 13725, line 5: State what the +/-% terms in the trends represent.

Page 13730, lines 4-6: This appears to be the only place in the paper where errors on the FTIR measurements are discussed. No error bars are included in the plots of the FTIR data. This is unsatisfactory. Ideally, a full error budget would be calculated for each of the six sites, following the formalism of Rodgers (2000). Failing that, perhaps a representative error budget could be presented for one or two of the sites. As NDACC stations, this information should be available. If this task is too difficult, then at least

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some discussion of the applicability of the Zhao et al. (2002) errors to this work should be added. e.g., What terms were included in the error budget calculated by Zhao et al.? How appropriate are those low-altitude, mid-latitude errors to the variety of sites used in this work, which include high altitudes and high latitudes?

Page 13733, line 24: Add a brief discussion about the differences between the meteorological drivers, and the implications of these differences for the results shown in this study.

Page 13734, line 9: Line 1 of the Abstract mentions partial columns of  $\sim 0$ -15 km. Here, it appears that 100 hPa is used as the upper boundary for the partial columns for compatibility with the EMEP lid. Explain why the FTIR tropospheric partial columns are calculated by subtracting the stratospheric component derived from just two sites from the total columns at each site, rather than just integrating the retrieved VMR profiles up to 100 hPa. How do the stratospheric partial columns compare for the other sites?

Page 13734, Section 5.1: Have the model data been smoothed by the FTIR averaging kernels and a priori profiles? It appears not. Ideally this should be done when comparing measurement and model data.

Page 13738: It is not entirely clear why Sections 5.3 and 5.4 are separate. Clarify the difference between the sensitivity analysis and the uncertainty analysis. Table 3 lists all of the runs as sensitivity scenarios.

Page 13738, line 14-17: The two tests Gc-high and Gc-low are not listed in Table 3. Neither are the FTIR-high and FTIR-low tests. Why not? Results are shown in Figure 5 and discussed briefly in Section 6.2.3.

Page 13739, line 16: Clarify whether this refers to the horizontal or vertical model boundary.

Page 13741, line 12-13: It is not clear what is meant by the sentence starting with "Except the trends given in Rinsland ...". Clarify. Can the trends from this paper be

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compared with those in Rinsland et al. and in Mahieu et al.? If not, why not? If so, include them.

Page 13742, line 12-16: Clarify what was done here, e.g., 1996-2006 versus 2006, definition of the baseline scenario.

Page 13745, Section 7: The Conclusions section is rather short. It could be expanded with some discussion of quantitative results and their significance.

#### Technical Corrections

There are many distracting typographical errors. The manuscript should be carefully proof-read to correct these. Some are identified below. There are also numerous places where a comma would help clarify the flow.

Page 13725, line 5: estimated to BE

Page 13725, line 14: modelS have been

Page 13725, line 17-18: is bias more appropriate than deviation?

Page 13725, line 22: year is unnecessary, just 2006 (similarly, elsewhere in the paper time period is redundant as in “time period 1996-2006”)

Page 13725, line 23: 2006 ARE shown . . . 37-50% OF THE MEASUREMENTS for k

Page 13725, line 25: assumptions MADE in this paper

Page 13726, line 25-26: Define FTIR and EMEP MSC-W

Page 13727, line 1: datasetS

Page 13727, line 4: mid-infrared . . . high-resolution (also change throughout the paper)

Page 13727, line 11: especially FOR the spring maximum

Page 13727, line 10: delete earlier, or replace with previously

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Page 13727, line 24: 2/3 of THOSE FROM biomass burning

Page 13728, line 8: photodissociation

Page 13728, line 9: and REACTION WITH water VAPOUR (or H<sub>2</sub>O)

Page 13728, line 11: intra-annual (also change throughout the paper)

Page 13728, line 16-17: remove italics from O(1D), O<sub>2</sub>, and O<sub>3</sub>

Page 13728, line 19: biofuel

Page 13728, line 20: also estimate the

Page 13728, line 21: To BE 2.1

Page 13728, line 22: located IN the Northern Hemisphere

Page 13729, line 4-5: partial column data for CO

Page 13729, line 17: ill-posed

Page 13729, line 18: is a weightED COMBINATION of an

Page 13729, line 19: delete method – M in OEM stands for method

Page 13729, line 22: sumMING

Page 13729, line 24: which useS PROFFIT

Page 13729, line 25: microwindows or micro-windows

Page 13729, line 26: ARE in the region

Page 13729, line 27: For CO, the species

Page 13730, line 1: and H<sub>2</sub>O interfere in the C<sub>2</sub>H<sub>6</sub> microwindow

Page 13730, line 2: define UFTIR

Page 13730, line 11: EMEP should be defined on first use, on Page 13726, line 26,

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not here

Page 13730, line 19: Chemical Transport Model or chemical transport model

Page 13730, line 22: define EQSAM

Page 13731, line 3: delete “of EMEP model”

Page 13731, line 24: concentrationS

Page 13731, line 27: change period after Eq. (2) to comma

Page 13732, line 1: where h . . . height, with

Page 13732, line 4: no indent

Page 13732, line 12: delete hyphen: global scales

Page 13732, line 13: define HTAP

Page 13733, line 1: databases

Page 13733, line 5: compoundS

Page 13733, line 5: define SNAP

Page 13735, line 9: above-mentioned

Page 13735, line 27: model; the

Page 13736, line 1: baseline

Page 13736, line 5: the mass balance IS

Page 13736, line 6: representS

Page 13736, line 9 and 14: inconsistent formatting of subscripts (biomass burning, CH<sub>4</sub> oxidation)

Page 13736, line 17: 11-year period

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Page 13736, line 19: have BEEN shown

Page 13736, line 20: have BEEN shown to

Page 13737, line 10: reduced by 20%

Page 13737, line 17-18: Clarify whether the 0.2 degree C increase is per year.

Page 13737, line 20: “last sensitivity scenario” – Table 3 lists another scenario after this one, Gcnobvoc, discussed in Section 5.4.

Page 13737, line 22: have BEEN shown to

Page 13737, line 25: 2009; Angelbratt et al., 2011)

Page 13737, line 27: and calculate the

Page 13738, line 2: with the global model, which explore the

Page 13738, line 10: baseLINE case

Page 13738, line 11: Sect. 5.1

Page 13739, line 6: delete further

Page 13739, line 7: change ; to comma

Page 13739, line 13: BICs has already been defined

Page 13739, line 27: and so WERE omitted

Page 13740, line 1: FurtherMORE,

Page 13740, line 6: add period after column

Page 13740, line 8: and deviates FROM THE FTIR DATA BY as much as

Page 13740, line 9: inter-station

Page 13740, line 21: the reasons FOR the strong

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Page 13741, line 26: delete year; Figs. 3 and 4

Page 13742, line 4: overestimate

Page 13742, line 9: for some BY as much as ... The European model also underestimates

Page 13742, line 14: baseline scenario

Page 13742, line 17: reduction by 20%

Page 13742, line 22: emission by 20%

Page 13742, line 23: add semicolon after yr-1

Page 13742, line 25: Is 0.4%/year correct? The text and Table 3 say 1.2%/year for CH4.

Page 13742, line 26: 11-year period

Page 13742, line 27: theSE last two

Page 13743, line 3: delete will

Page 13743, line 4: deviateS BY a factor

Page 13743, line 10: delete layer

Page 13743, line 14: explanation FOR the

Page 13743, line 18: on the other HAND

Page 13744, line 7: contribute

Page 13744, line 16: reproduceS

Page 13744, line 18: illustrateS ... decreaseS

Page 13744, line 20: It is also SEEN that

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Page 13744, line 25: emissions Page 13745, line 3: ground-based

Page 13745, line 12: was only working for 2006, the analysis

Page 13745, line 13: the effect of

Page 137456, line 3: Is J. Geophys. Res.-Ocean Atmos. correct?

Page 13754, Table 1 caption: Global sources of CO and C<sub>2</sub>H<sub>6</sub> (Tg yr<sup>-1</sup> and % of total).

Page 13756, Table 3: For GcEAll20, shouldn't it be a 20% increase rather than a 20% reduction? See page 13737, line 14. Make clear the time periods for each reduction (1996-2006 or 2006) and that they are per year. Add Gc-high, Gc-low, FTIR-high, and FTIR-low?

Page 13760, Table 7 caption: Swap the order in the caption to match that in the table (FTIR, Gc, E). "... because of the strong influence from the initial conditions ..."

Page 13761, Table 8: Use the same order for the sensitivity cases by column as they are listed in Table 3. Here or in the text, explain why N/A for Bremen and Ny Alesund.

Page 13763, Figure 1 caption: "The difference between measurements and the model IS marked. . ." Why show the differences as lines rather than points?

Page 13765, Figure 3: Difficult to distinguish the blue and black points. Caption: (red triangles) (blue? squares) (black? diamonds) ... data are also shown. Delete "in the figures". ... the model initial conditions. What decreases (line 3)? The amount or the influence? Delete "given in the literature" – the citation is sufficient.

Page 13766, Figure 4 caption: As in Figure 3. . .

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