Ref.: ACP-2015-884

We would like to thank the co-editor and both anonymous referees for their reviews and very constructive remarks. These were taken into account in the new version of the paper (online revised paper: "CO_Variability3.pdf").

In the following, we answer to the individual comments and have listed other technical corrections to fix some grammatical errors.

Best regards,
Y. Té

Co-editor

Comment#01

A few small changes could help non experts in FTIR retrievals understand the comparability of these data with surface in situ observations.

Answer#01

We have added the following sentence to justify the comparability between FTIR and in situ observations at page 14, lines 384-385:

> "The comparability between FTIR retrievals and surface in situ observations is thus assured."

Referee#1

Comment#01

First. The use the phrase ‘seasonal variation’ throughout when ‘seasonal cycle’ may be more appropriate. The former suggests variation within a season, while the ‘season cycle’ indicates the annual changes in weather, daylight …, due to yearly variations of the Earth's orbit..

Answer#01

As proposed, we have replaced ‘seasonal cycle’ by ‘seasonal variation’ 5 times:

- Page 1, line 4
- Page 1, line 14
- Page 16, line 417
- Page 18, line 464
- Page 20, line 484

Comment#02

Second. I would like to see more discussion of the measurements. Not the already detailed technical information, but how differences in instruments effect the results. Comparability (the closeness of agreement between measurements made at the same time and location) of the surface FTR retrievals should be mentioned. Possible biases among instrument results

should be noted. In particular, is there bias resulting from potentially interfering atmospheric constituents with location or seasonality, such a the presence of clouds or aerosols?

Answer#02

We have modified and added some sentences to explain the comparability of the data at page 7, lines 200-207:

"The following precautions have been taken in order to improve comparability between satellite and ground based measurements:

- Only clear sky data from ground-based FTIR and satellites has been used.
- The CO abundance is retrieved from the same spectral domain (4.7 µm for both the ground-based FTIR and the satellite instruments), allowing to minimize possible biases related to spectroscopic parameters and interfering atmospheric constituents (gaseous species, aerosols).
- Satellite data were selected within a 30 km × 30 km square centered at the site location: corresponding to a range of ±0.15° for the latitude and ±0.23° for the longitude."

Referee#2

Technical Corrections

Page 2, line 49 – From THE end of 1980 until 1997, CO decreased.

- Done at page 2, line 33.

Page 2, line 50 – Since then, a few

- Done at page 2, line 34.

Page 2, line 51 – unusualLY

- Done at page 2, line 35.

Page 3, line 64 – give the Bruker model, as done for the other two sites immediately below

- Done at page 2, lines 47-48: "Bruker IFS 125HR".

Page 7, line 209 – should be “degrees of freedom for signal (DOFS)” here, and DOFS should replace DOF throughout the paper

- Done at different locations:
  - Page 4, lines 108-109: "degrees of freedom for signal (DOFS)".
  - Page 5, line 142: "DOFS"
  - Page 6, line 181: "DOFS"
  - Page 7, line 196: "DOFS"

Page 8, line 240 – which version of WACCM?

- Done at page 5, line 135: "version 4 WACCM".

Page 9, line 209 – fix this sentence

- Done at page 6, line 178: "IASI L2" was removed.

Page 10, line 296 – on-board NASA's Terra …

- Done at page 6, line 186.

Page 15, line 449 – delete colour

- Done at page 10, line 325: we have kept "the".

Page 15, line 456 – interpolated the lower pressure levels ONTO thinner

- Done at page 11, line 335.

Page 17, line 507 – Figure/Fig. 5

- Done at page 14, line 382 and page 15, line 393.

Page 17, line 508 – delete points and point

- Done at page 14, lines 383-384: "two independent measurements of tropospheric CO: the first supplies maximal information".

Page 18, line 2 of caption – comeS

- Done at page 14, line 2 of caption.

Page 19, line 526 – downwind

- Done at page 15, line 399.

Page 20, line 566 – low-altitude

- Done at page 16, line 429.

Page 21, line 1 of caption – Monthly averaged CO in situ …
Page 21, line 2 of caption – green squares for the means of the four urban sites
Page 21, line 3 of caption – is applied to the 5-year monthly means for urban (green line) and mountain (red line) sites.
Page 21, line 4 of caption – The two lowermost datasets show …

- Done at page 17, the caption is now: "Monthly averaged CO in situ measurements at the surface in Switzerland using Swiss NABEL data from 2009 to 2013 (green squares are the means of the four urban sites and red diamonds are for Jungfraujoch). The sine function fit is applied to the 5 years monthly means of urban (green line) and mountain (red line) sites. The two lowermost datasets show the residuals of the fit (green open squares for urban sites and

red small diamonds for Jungfraujoch). Monthly averaged CO surface VMR from GEOS-Chem located at Jungfraujoch is shown in red open circles".

Page 21, line 583 – change close-by to nearby

- Done at page 16, line 440.

Page 24, line 650 – timescale THAN complete

- Done at page 20, line 497.

Page 24, line 640 – state explicitly whether this time lag is seen in the measurements, or in the measurements and GEOS-Chem

- Done at page 20, lines 488-490: "Interestingly, a time-lag of about 2 months between upper altitude and surface CO has been found in the measurements and GEOS-Chem in both Paris and Jungfraujoch".

Page 25, line 655 – instruments are capable of SAMPLING the …

- Done at page 20, line 502.

Page 33, Table 5 caption – Ground-based FTIR instrument parameters for the three measurement stations.

- Done at page 29, the caption is now: "Ground-based FTIR instrument parameters for the three measurement stations".

Below, there are other technical corrections to fix some grammatical errors (mentioned by referee #02): 'The manuscript still has many distracting grammatical errors that should be corrected'

- Page 1, line 1: The → This

- Page 1, line 11: in Paris and at Jungfraujoch → at Paris and Jungfraujoch

- Page 1, line 14: allow identification of → identify

- Page 1, line 15: In Paris and at Jungfraujoch → At both Paris and Jungfraujoch

- Page 1, line 17: In → At

- Page 2, line 24: terpene), which are emitted by plants → terpene, which are emitted by plants)

- Page 2, line 31: Before 1980, there were only few measurements, which → The limited measurements before 1980

- Page 2, line 34: CO has decreased → atmospheric CO decreased

- Page 2, line 39: CO were initiated through → CO began with

- Page 3, lines 66-67: at the East coast of Australia and about 80 km from the South of Sydney. Here, we present NDACC analysis data on → on the East coast of Australia, about 80 km from the south of Sydney. Here, we analyse NDACC data for

- Page 3, lines 72-73: data which → information which

- Page 3, lines 80-81: from the remote sensing data and the one from the surface → from both the remote sensing data and the surface

- Page 4, line 86: on → for

- Page 4, line 88: Using appropriate → Appropriate

- Page 4, line 90: But for the present CO study → For this CO study

- Page 4, lines 106-107: wings of that line → wings of the P(8) line

- Page 5, line 118: thanks to the → due to the

- Page 5, line 128: fitting → fit

- Page 5, line 134: for the → for

- Page 8, lines 226-227: For the paper, we have focussed on the urban sites Bern, Lausanne, Lugano and Zürich as → In this paper, we have focussed on the urban sites Bern, Lausanne, Lugano and Zürich, as

- Page 8, line 230: Results of surface CO at Wollongong were obtained from → Surface CO at Wollongong is measured using

- Page 8, line 244: In situ data was monthly → For this paper, in situ data is monthly

- Page 9, line 258: CO is emitted from anthropogenic, biomass burning and biofuel burning sources → CO is sourced from anthropogenic, biomass burning and biofuel burning emissions

- Page 10, lines 299-301: The CO mean value of $1.1\times10^{18}$, molecules/cm$^2$ at Jungfraujoch is quite low due to the → The CO column mean value of $1.1\times10^{18}$, molecules/cm$^2$ at Jungfraujoch is quite low and is attributed to the

- Page 10, lines 302-303: For its characterisation, we have used a sine function → We have used a sine function to characterize seasonality

- Page 10, line 307: Here y represents → Where y represents

- Page 10, line 314-315: but not significantly higher, → but not significantly, higher than at Jungfraujoch

- Page 12, line 347: over the → for the

- Page 12, line 5 of the Figure 2 caption: by full circles in black colour → black full circles

- Page 13, line 3 of the Figure 3 caption: blue one are → blue dotted line are

- Pages 12-13, lines 353-355: as compared to the ground-based FTIR stations in the Southern Hemisphere ranging from -19.2% to -27.5% and depending on → when compared to the ground-based FTIR stations in the Southern Hemisphere ranging from -19.2% to -27.5% and concluded differences depend on

- Page 13, line 356: events unaccounted → events are unaccounted

- Page 13, line 361: and not at reproducing → rather than reproducing

- Page 13, line 363: Northern Hemispheric → Northern Hemisphere

- Page 13, line 369: hilly → mountainous

- Page 15, line 412: a maximum → a surface maximum

- Page 16, lines 424-425: Quite differently, in situ surface CO at Jungfraujoch shows the same seasonal variability as the whole atmosphere (characterized by the total column seasonality) being shifted → In contrast, in situ surface CO at Jungfraujoch shows the same seasonal variability as the whole atmosphere (characterized by the total column seasonality) and is shifted

- Page 16, lines 426-428: modeling at Jungfraujoch. Unlike the modeling for Paris where the underestimation is much stronger, the GEOS-Chem underestimates the CO surface VMR by about 23% → model at Jungfraujoch. Unlike the model at Paris, where the underestimation is much stronger, GEOS-Chem underestimates the CO surface VMR by about 23% at Jungfraujoch

- Page 16, lines 434-435: Hemispheric spring (Edwards et al., 2006). Unlike the two Northern Hemispheric sites, there seems to be no → Hemisphere spring (Edwards et al., 2006). Unlike the two Northern Hemisphere sites, there is no

- Page 17, lines 448-449: another three GEOS-Chem simulations have been run → we perform three GEOS-Chem sensitivity simulations

- Page 17, line 450: these runs → these simulations

- Pages 18-19, lines 468-469: Inversely, shutting off either biomass burning or biogenic emissions, only weakly affect the seasonal variation and the maximum peaks. → In comparison, shutting off either biomass burning or biogenic emissions, only weakly affects the seasonal variation and the maximum peaks.

- Page 19, lines 469-470: As compared to the standard run, CO columns are just a little bit lower due to some emissions missing. → Compared to the standard run, CO columns are marginally lower due to some missing emissions.

- Page 19, line 475: Northern. → Northern Hemisphere.

- Page 20, line 490: lag is likely linked to → lag is likely due to

- Page 20, lines 498-500: study more closely the link between local and non-local emission sources and the magnitude of the time shift between surface and total column CO by extending the present study on more sites and to improve the analysis → study the link between local and non-local emission sources and the magnitude of the time shift between surface and total column CO by extending the present study to more sites and improving the analysis

We hope that we have answered clearly and in a satisfying manner each of the comments from the co-editor and both referees.