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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Importance of fossil fuel emission uncertainties over Europe for CO_2 modeling: model intercomparison" *by* P. Peylin et al.

P. Peylin et al.

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Please find below detailed responses to reviewer's comments. The long delay between this response and the initial comments is due to a change of laboratory, excess work load, and personal complications. Thank you for you patience and for considering these responses.

Philippe

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General comments:

A useful contribution to the literature on the subject and carefully completed with adequate explanation and graphics. The only general comment I have is the proportions in the paper are weighted more towards the forward modeling when it seems to me that the inverse sensitivity to the fossil inventories is the crucial scientific advance. The forward modeling is not particularly new, at least insofar as what it says about varying model transport. The critical results are what this all means for the estimate net bioflux. That portion of the paper seems unnecessarily short and probably could incorpo-rate more detail while shortening the portion on the forward modeling (other reviewers may disagree as this is more of a "personal" preference).

Response:

We only partly agree with the reviewer. The forward modelling, although not particularly new in its concept (the transport of several fossil fuel emission inventories), brings however new results in the sense that: * It uses for the first time a relatively large ensemble of transport models including meso-scale models. * The fossil fuel emissions inventories include a new highly resolved estimate (in space and time) for Europe. * The resulting concentration fields are analysed simultaneously at all temporal scales (annual, seasonal, synoptic and diurnal). * The concentration differences induced by varying "transport model" or "fossil fuel emissions" are compared and quantified in a rigorous way. * 14C derived fossil fuel CO2 data are compared to the results of several transport models.

The impact on the estimated net bioflux from an atmospheric inversion is indeed crucial. However the goal of this paper is only to give few insights on the impact of fossil-fuel emission uncertainties on large scale global inversions. We believe that the major next step is to investigate the same impact with a meso-scale inversion system focussing on Europe, using for example nested transport model, such as in Trusilova et al. 2010. However, such work is beyond the scope of this paper. We nevertheless agree that the "inversion section" could discuss more in detail the implication of fossil fuel emissions uncertainties and suggest new studies.

Given these remarks, we thus have substantially shortened the forward modelling section and increased (slightly) the discussion on the inverse results and their implications. For the forward modelling section we have: * decreased the number of figures in the main text: we removed figure 4b, while keeping fig4a and adding it to figure 3 as a third panel. We moved figures 6 and 8 to the supplementary material. * shortened the text (over 30 %) in order to keep only the main messages: this concern sections: 3.1 "FFCO2 Concentration time series" and 3.2 "Surface concentration fields". (see text attached at the end of these responses)

For the "inverse modelling section" we have: * Restructured the text into two subsections "Monthly Fbio fluxes" and "Annual Fbio fluxes" * Added a new figure showing the annual Fbio flux distribution over Europe (extending the limits on the east and west sides) for the reference inversion and for the differences between using IER_hourly and Edgar_annual and between using Edgar_hourly and Edgar_annual: See figure attached to this response. * Discussed more carefully the impact of the temporal variations in fossil fuel emissions (Edgar_hourly – Edgar_annual) versus the impact of temporal plus spatial distribution (IER_hourly – Edgar_annual) * Added a little paragraph on the needs for further studies with inversions at higher spatial resolution: "...Overall these sensitivity tests highlight the increasing impact of uncertainties (mainly biases) in fossil fuel emission inventories on the estimated biosphere fluxes from the continental to the regional scale. However, further investigation need to be carried out with inverse systems at higher spatial resolution (at least 0.5 degre) in order to use all the information contained in the new high resolution FFCO2 emission inventories (i.e., IER_hourly). These systems will be more adapted to investigate separately the effect of diurnal, day to day, and seasonal variations in fossil fuel emissions on the estimated Fbio fluxes." * Overall this section has increased by 50 % (see full new text for that section added at the end of the responses).

K. Trusilova, C. Rödenbeck, C. Gerbig, and M. Heimann: Technical Note: A new coupled system for global-to-regional downscaling of CO2 concentration estimation, At-

mos. Chem. Phys. 10, 3205-3213 (2010).

For example, the "smearing" or "blurring" of the high res fossil in the forward modelling portion of the paper may have inversion implications? This speaks to the spatial resolution of the inventory, something that wasn't discussed in the inverse portion of the paper. What would a flat country inventory look like compare to the higher-res treatments? Since the UN reporting is country-level, this would appear to be an important item to test in the inverse framework. You might do this by taking the IER_hourly and spreading it evenly over bigger cells than its current. So, in addition to different spatial patterns in the fossil inventories and different resolution of transport, you can more directly test the spatial resolution of the fossil inventory in the inverse result.

Response:

We agree that the "smearing" of the high resolution fossil in the forward modelling may have inversion implications. However, we did not perform the test proposed by the reviewer because of the following reasons: * First the differences between the IER_hourly emission inventory at 10 km x 10 km resolution and the Transcom inventory at more than 100 km x 100 km resolution could constitute already a first indication of the impact of the spatial resolution of the fossil inventory in the inverse results. However given the low spatial resolution of the LMDZ and TM3 models (around 300 km resolution for LMDZ and 400 km for TM3), we can not test such impact with the two inversion approaches. * Given these low resolutions, the proposed test would also imply to smooth the spatial resolution close to the country-size level; it would become an extreme and probably unrealistic case of the potential differences in spatial resolution of fossil fuel inventories. Such test needs to be performed with a finer transport model resolution (at least 50 km). * We thus believe that that a "meso-scale inverse approach" would be needed to properly investigate the impact of the spatial resolution of the fossil inventory for Europe. These systems are not yet fully operational but we are currently working with CHIMERE model in that direction and the proposed tests will be performed in a follow up study. * Overall, the results from the existing comparison provide already enough information on the possible spatial resolution of the fossil inventory. We have thus only improved the discussion in the inversion section to highlight the results from the different inversions that were performed: see more details associated to the above comment.

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The study might benefit from one additional tracer: a purely seasonal tracer built off of the EDG_hourly for example. Then the reader could see if it is the diurnal or seasonal cycle that has the impact on the temporal domain. Clearly, the spatial patterns are important but I think that when you discuss the impact of the temporal structure on page 7477 you are comparing the fossil difference to the "full" seasonality of the biosphere when I think this is more relevant when compared to the "residual" flux – the non neutral portion. This is what is essentially solved for and that might be a more pertinent comparison rather than the complete seasonal peak to peak gross flux.

Response:

The first suggestion of the reviewer, i.e. to build a purely seasonal tracer without any diurnal variations, is indeed a good suggestion to distinguish the impact on the inverse results of the diurnal and seasonal cycles, separately. However, the inverse systems that were used in this study still rely on a coarse temporal resolution and do not allow to properly test this effect. LMDZ inversion rely on the use of pre-calculated "retro-plumes" to compute the impact of the fossil fuel emissions at the atmospheric stations (equivalent to the adjoint of the model; see Peylin et al. 2005) and these "retro-plumes" do not resolve the diurnal cycle. Only the day to day variations of the fluxes are accounted for. For TM3, such constraint does not directly apply, but given the required time to perform an inversion with a variational scheme, we thought that such inversion is not worth to carry with such coarse resolution model (4°x5°). Again, such test will

be worth investigating with the new upcoming high resolution atmospheric inversions (based on meso-scale models). We changed the "inversion section" to highlight the need for higher inversion resolution to perform the proposed tests (as a perspective). See above for the added text.

As for the second point, we do not agree with the reviewer. First, table 5 in the paper compares the impact of the fossil fuel differences to the non neutral portion of the biosphere flux, i.e. the annual sink or so called "residual" flux. We choose not to discuss the spatial distribution of such "residual" flux as our current inverse systems, with a limited number of atmospheric stations, can not resolve the annual carbon sink at fine spatial resolution, but only for large regions like those two discussed in Table 5. Finally, we believe that the comparison of the fossil fuel differences to the "full" seasonality of the biosphere is important. Indeed the inversion not only solves for the "residual" flux assuming perfect a priori biosphere seasonal flux patterns, but also corrects for potentially large errors in these seasonal variations (used a priori). The impact on the seasonal scale of the retrieved fluxes is thus an important outcome, especially if we want to validate the seasonal flux pattern of a terrestrial ecosystem model.

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Specific comments

Page 7463, line 18-19: why use SO_2 for residential? Residential heating typically uses liquids or gas and sulfur is primarily an issue for coal.

We chose SO_2 temporal variations mainly for industrial sources and power supply. Given that there is no specific proxy for temporal profile of residential heating in the EMEP database we have used (i.e. more directly related to liquids or gas consumption), we have used the same SO_2 profile as a first approximation.

Page 7482: The Vulcan project can be cited: Gurney, K.R., D. Mendoza, Y. Zhou, M

Fischer, S. de la Rue du Can, S. Geethakumar, C. Miller (2009) High resolution fossil fuel combustion CO2 emissions fluxes for the United States, accepted to Env. Sci. & Tech.

We included this citation.

Table 5: The flux using edgar annual shows a tremendous difference in West Europe for LMDZ v TM3: : :. Can this be right? I also note that the flux diff in the 3rd numerical column for the LMDZ West Europe would represent greater than 100% adjustment (thought absolute is small). Similarly for the 4th column on this inversion. Is that correct?

There is no mistake is the flux numbers of Table 5. If you consider the recent web-site comparing inverse estimates from different models (http://www.carboscope.eu/?q=flux_map) you can see that TM3 places a maximum annual carbon uptake on the western part of Europe while in the LMDz inversion (corresponding to LSCE_an_v2.1) the sink is shifted eastward and northward. We are facing the limits of current inverse systems to estimate accurately regional net carbon fluxes. The differences for the "western Europe" region considered in this paper illustrate current inversion limits. The flux adjustment for each cases should not be compared in percentage to the mean flux (column 1) as we might get a zero mean flux for a given region but still non zero differences (and thus infinite percentage adjustment). The adjustments that are obtained should be compared to the uncertainties associated to the prior/posterior fluxes. These uncertainties, not reported initially, are now included in the paper (see comments on Table-5, below). Around 0.3 GtC/yr for total Europe, these uncertainties are significantly larger than the obtained differences. The obtained adjustments are thus compatible with the uncertainty retrieved by the inversions systems. We have changed the text to mention these two points. In particular, we added, together with a new figure (attached below) showing the annual distribution of the Fbio estimated fluxes, the following text: "First, the mean flux with the Edgar_annual FFCO2 emission (figure 8) presents much larger regional variations in the LMDZ inversion

(than in TM3) that are related to the strong influence of the prior flux distribution in this system (taken from a biogeochemical model, see section 2.3). A detailed analysis of the differences between the two systems is beyond the scope of this paper."

Figure 11: so, is the standard deviation build off of 7 model values and 4 inventory values? If so, can that really be considered adequate to calculate a standard deviation? A similar question applies to table 6.

We agree with the reviewer that a standard deviation computed out of 7 or 4 values suffers from a poor statistical significance. However, the numbers displayed in figure 11 and Table 6 correspond to the mean of several standard deviations. Indeed for the computation of the "tracer Stdev" we first compute for each tracer (i.e., the 4 fossil fuel inventories) the standard deviation of the 7 values obtained from the 7 transport model simulations; we then average the 4 standard deviations (i.e., corresponding to each tracer) in order to obtain a mean Tracer-induced variability (Tracer Stdev). A similar approach is performed to compute the mean transport model standard deviation. The averaging step of several standard deviations thus increases the robustness and statistical significance of the results. Nevertheless, we checked that a different metric based on the range of the different estimates produce similar results. The ratios between the transport-induced variability and the tracer-induced variability calculated with the "standard deviation metric" or the "range metric" are very close. We thus chose to keep the standard deviation metric as the resulting maps are slightly less scattered in space (than with the range metric) and are directly comparable to the estimated errors from the inversions. We have nevertheless modified the text to justify our choice and highlight the robustness of the results obtained with the standard deviation metric. We added in the first paragraph of section 5: ". . ..The computation involves two steps. In the first one, we compute the std-dev of the concentrations obtained with a given transport-model (FFCO2-tracer) and all FFCO2-tracers (transport-models). In the second one, we average the different standard deviations to obtain a mean value. We verified that the ratios between the two std-devs (transport vs emissions, as discussed below) are robust and not sensitive to the small sample sizes (7 transport models and 4 emissions), using the spread of the concentration fields as a metric.".

Page 7464, line 1: so the inventory is based on roughly 3 km x 3 km cells? Or do you mean 10 km x 10 km cells which would be 100 km2?

The resolution is 10 km x 10 km. We corrected the confusion introduced with "km2".

Page 7477, line 24: which fossil inventories are you referring to here when you say, "Differences between fossil fuel maps induces: : :"?

We refer to the differences between all inventories and the reference case ("EDG_annual"). We have improved the text.

Page 7478, line 19: I calculate percentage of 26-40%. Also, this really does imply a range and technically, this is really only two points – you probably should be explicity by saying something like: ": : :corresponds to 26% difference and 40% difference in the two inversions complete in this study, respectively."

There was a little mistake in the computation of the percentage and we change to 26-40%. We also agree with the reviewer that the sentence was somehow misleading as we only use two different inverse systems. We now follow his suggestion.

Table 5: The posterior uncertainty of the 1st column fluxes would be useful and would allow the reader to quickly ascertain to what extent the sensitivities are within the 1sigma on the base fluxes.

We agree that the posterior uncertainties would be useful to the reader and we thus added those numbers for the total of Europe in Table 5. Given the technical difficulties to properly calculate the annual uncertainty with a variational system (i.e., TM3 inversion) accounting for all covariance terms between the weekly flux-error estimates, we did not compute them for the West-Europe region. The posterior uncertainty for total Europe, around 0.3 GtC/year, indicates that the two different estimates are compatible with the associated errors and that the differences induced by different fossil fuel

inventories are also within 1 sigma of the posterior error. We changed the text of section 4 to include this point and added: "The posterior Bayesian uncertainties on Fbio fluxes estimated by the two inversion systems (only calculated for total Europe, Table 5) indicate that i) the two different estimates are statistically compatible (i.e. within the 0.3∼GtC/yr estimated uncertainty) and ii) the differences induced by using different fossil fuel inventories are also within 1 sigma of the posterior error." .

I cannot get the Pregger et al reference. I don't know what the policy is for ths journal, but perhaps a download link could be supplied so readers can access all cited material.

We added the reference to a web site where the paper is accessible: http://www.bgc-jena.mpg.de/bgc-processes/ceip/products/files/Pregger_IER_Final_Report_Feb2007.pdf

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Technical comments

Please use the word "inventories" instead of "maps" as the fossil fuel numbers are really more than what the word map implies (a simple representation of something in space). I would recommend changing throughout

We have changed throughout the manuscript

Page 7464, line 26: Large emissions associated "with" industrial: : :..

Corrected

Page 7466, line 3: what is "double counting: : :.."?

The sentence was misleading as we wanted to refer to possible sources that are not accounted in a particular product.

We changed the sentence by ".....inconsistencies arising from unaccounted sources,..."

Page 7467, line 24: ": : : that COMET was primarily designed to observational points: : :". Do you mean to say "observe"?

The sentence was not correct and we mean to say the COMET was designed to simulate observational points in the PBL. We changed the sentence.

Page 7468, line 1: "The models were: : :. " add 's' to 'model'

Corrected

Page 7469, line 6: remove "successively"

Corrected

Line 15: "will also 'be' spread"

Corrected

Line 17: try "in order to" instead of "with the aim"

Corrected

Page 7472, line5: remove 'by' between 'contributes' and 'about'

Corrected

Page 7473, line 10: do you mean figure 1?

In fact we mean figure 5

Page 7474, line 18: "Eulerian"

Corrected

Page 7476, line 11: at both sites – add 's' to 'site'

Corrected

Line 14: ": : :land) as a background: : :"

Corrected

Page 7477, lines 16-17: the sentence introducing figure 10 appears out of place since figure 10 is discussed more thoroughly on page 7478, line 22 and on. Perhaps delete the sentence here referring to figure 10?

We have deleted such sentence

Line 23: instead of 'in the order of' try "roughly"

Corrected

Line 26: use "on" instead of "in"

Corrected

Page 7478, lines 3-6: remove "the differences remain similar" and connect sentences as ": : : of Europe, the impact of the temporal: : :" also note space between "part" and "of"

Corrected

Line 12: "using the "IER_hourly" emission : : :."

Corrected

Line 14-15: try "These number are slightly smaller than the annual total European differences in fossil fuel emissions themselves (0.23 Gt C/yr for Europe,.."

Corrected

Line 18: strike "it should be realized that"

Corrected

Line 22: focus is mispelled.

Corrected

Page 7481, line 5: “Although fossil-fuel emissions are often considered as a “well: : :.”

Corrected

Line 14: “: : : which also addresses the question of whether: : :. “

Corrected

Line 16: “: : : or if atmospheric CO2 inversions can be used to evaluate fossil fuel: : : “

Corrected

Table 1: Continuous mispelled

Corrected

Table 1: title could be a bit more explicit – perhaps: “Fossil fuel CO2 emissions inventory descriptions”

Corrected

Table 5: title could be: “Annual inverse-estimated biological net fluxes (Gt C/yr) based on the ‘Edgar_ann’ fossil fuel CO2 emissions inventory and inverse-estimated net biological flux differences resulting from use of the other three inventories.

Corrected

Figure 1: have you considered taking the log base 10 for these values – gives a bit more coverage.

We have checked several options including a log base approach, but we found that the standard linear range highlights more clearly/directly the large differences between cities and urban areas with high emissions and the countryside with much lower values. We thus prefer to keep such scale given that in the supplementary material, two figures for the differences between flux inventories highlight the dynamic over non urban areas.

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REVISED VERSION OF SECTION 3.1 and 3.2 (in latex)

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\subsection{FFCO$_2$ Concentration time series}\label{sect:resfor:timeseries}

CO$_2$ concentration time series were simulated for all European measurements sites (see site location at http://www.carboeurope.org/). For the sake of brevity, the discussion is illustrated with the results for one station, the Hegyhatsal tall tower (115m) in Hungary (referred to as “HUN”). Additional figures for HUN and for a second site Schauinsland (SCH, a mountain station in Germany that is usually incorporated in inversions) can be found in the supplementary material. We restricted ourself to these two sites as they can be considered representative of several European stations. To deal with the large number of factorial simulations, 7 transport models x 4 FFCO$_2$ emission inventories, we reduce the number of time series by displaying means across models and means across emissions, in order to compare the effect of emission pattern differences versus transport model differences on the simulated concentrations.

\vspace{0.3cm} {\it Seasonal cycle}

Figure∼\ref{fig:conc_mean} (top) displays the daily mean FFCO$_2$ concentrations averaged across all models for each emission inventory at HUN. Like in most inversion set-ups, we selected daytime values (average over 10h to 17h LT), because existing transport models are known to have difficulties in simulating the stability of the nocturnal planetary boundary layer (PBL) \citep{geels:07}. The simulated time series show large synoptic variations, up to 5 ppm, superimposed on a seasonal cycle of roughly the same size and a trend of few ppm/yr due to the accumulation of emitted FFCO$_2$. These features are common to all stations (fig.∼\figsupConcMean, supplementary material), but the amplitude of the synoptic events and the seasonal cycle varies depending on the location of the site to major industrialized regions. All tracers show a seasonal cycle, which in the case of constant emissions reflects seasonal changes in the atmospheric transport, especially stronger mixing during summer than during winter over Europe. At HUN, the phase and amplitude of the synoptic events are rather similar for all tracers, which indicates that the variation of atmospheric transport is the dominant factor causing day to day variations of FFCO$_2$ at this site. Note that the observed amplitude of the synoptic CO$_2$ variations at HUN is roughly two times larger than the one obtained using FFCO$_2$ only.

Time series for the average across all emission inventories for each transport model (Figure~\ref{fig:conc_mean}, middle), show similar seasonal and synoptic patterns but with much less agreement for the amplitude and the timing of the synoptic events. On average the amplitude of the synoptic events is larger for the mesoscale models (REMO, DEHM, CHIMERE and COMET) and TM5 (zoomed model) than for the coarse global models (TM3 and LMDZ) and the differences between models are largest in winter. Overall, the transport model spread dominates over the spread induced by the four different fossil fuel emissions. Similar results are found at all European stations, (supplementary material).

The effect of neglecting temporal variations in fossil fuel emission, is illustrated with the differences in simulated concentration between \edgh\ and \edga\ emissions at HUN (figure~\ref{fig:conc_mean} bottom). We observe a marked seasonality for all transport models with positive values in winter (up to 3 ppm) and slightly negative values in summer (up to -1 ppm). This difference combines (i) the seasonality of the \edgh\ source with (larger emissions in winter due to larger heating sources ($\sim$50\%) compared to the constant \edga\ source; section \ref{sect:method:emis}), and (ii) the seasonality of the atmospheric vertical mixing with the strongest mixing during summer time. Both effects act in the same direction and the amplitude of the resulting seasonal variation ranges from $\pm$0.5 ppm at remote stations like Pallas in Finland up to $\pm$5 ppm at stations close to industrial areas (i.e., the Cabauw tower in the Netherlands). Note that the covariance between seasonal variations in emissions and transport contributes about 1 ppm to the “seasonal rectifier effect” described for CO$_2$ by \cite{kee-89a}. The concentration differences between \ierh\ and \edga\

emissions (not shown) show more complicated temporal patterns, indicating that spatial differences are as important as the effect of neglecting the temporal variations in the emissions.

\vspace{0.3cm} {\it Diurnal cycle}

Figure~\ref{fig:conc_jul} (top) displays the hourly concentrations averaged across all transport models for each tracer at HUN for one week in July. A large diurnal cycle of up to 2 ppm is observed, with larger concentrations during nighttime than during daytime. For the constant emission fields (\trc\ and \edga), the simulated diurnal variations are fully explained by diurnal variations in the PBL height. For the time varying fluxes, increased fossil emissions during daytime oppose this effect and reduce the diurnal cycle in the simulated summer concentrations by up to 1-2 ppm depending on the station. Similar results are ssupleen at all stations close to source regions. At remote stations or mountain stations (SCH, figure~\figsupConcJul, supplementary material) the time series display almost no diurnal cycle in summer. In winter, no clear diurnal cycle is observed at HUN and SCH (see supplementary material): synoptic events appear to be the dominant source of FFCO$_2$ short term variability, and both spatial and temporal differences between the emission inventories cause significant concentration differences (up to 4 ppm at HUN).

Figure~\ref{fig:conc_jul} (bottom) shows similar time series but now for the average across all tracers for each transport model. The scatter between the different transport models is much larger at all stations, with model to model differences up to 6 ppm, and complicated temporal patterns. For example, TM5 and partly COMET have a large diurnal cycle in summer with elevated FFCO$_2$ concentrations at night compared to daytime (amplitude of nearly 5 ppm), unlike TM3 and LMDZ. In winter (see figures in supplementary material), no clear coherent variations can be discerned between the models at the daily time scale: synoptic events are clearly visible but their amplitudes strongly differ between models (from 2 ppm in TM3/LMDZ to 10 ppm in the other models).

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REVISED VERSION OF SECTION 4 (in latex)

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\section{Impact on inversion of ecosystem fluxes}\label{sect:resinv}

In this section, we investigate the significance of the differences between the fossil fuel emission inventories by quantifying their impact on the optimized biosphere fluxes. We compare the inverted ecosystem fluxes (Fbio) from different inversions for 2001, using the four different fossil fuel emission inventories. We use the \edga\ constant FFCO$_2$ inversion as the “reference” case since this represents the commonly applied assumption in global inverse modelling. We then investigate the differences obtained when using the other inventories. We first discuss the annual mean of Fbio over Europe and then spatial differences (Figure \ref{fig:inv_maps}).

\vspace{0.3cm} {\it Monthly Fbio fluxes}

For all inversions, the monthly European Fbio flux shows a large seasonal cycle (as expected) with a maximum carbon uptake in June (see supplementary material). The amplitude of the seasonal cycle is roughly 1 \gtcm\ integrated over Europe ($12.10ˆ6$ km$ˆ2$). Differences between fossil fuel inventories (each case versus the reference) induce Fbio differences of less than 0.04 \gtcm, which is very small compared to the seasonal cycle and much lower than the estimated Bayesian uncertainty returned by the inversions (in the order of 0.1 \gtcm). Logically, accounting for temporal variations on the fossil fuel emissions (\edgh\ versus \edga) decreases the estimated biosphere flux in winter and increases it during summer, as a compensation for the seasonality imposed on the fossil fuel emissions (\edgh). If we consider smaller regions, like the “western part” of Europe, the impact of the temporal variations of fossil fuel emissions on the derived monthly Fbio fluxes becomes slightly larger when compared to the amplitude of the seasonal cycle but remains below 5\%. These results are consistent

across the two inverse set ups (LMDZ and TM3).

Figure \ref{fig:inv_maps} now illustrates for July the spatial distribution of the impact of fossil fuel emission inventories on Fbio. We compare the results using \edga\ (reference case, bottom panel) to the differences between using \ierh\ and \edga\ (top panel). For this particular month, the differences obtained with the “LMDZ” or “TM3” inversions appear to be on the order of 2 to 6 gC/m2/month across a large part of Europe (with maximum values close to 10 gC/m$ˆ2$/month) while the reference Fbio shows carbon uptake between 20 and 100 gC/m$ˆ2$/month in the same area. On a country scale, a change of fossil fuel emission inventory could thus significantly affect the Fbio flux: for each country the averaged impact can reach in our case 20\% in July. The same calculation obtained between using \edgh\ and \edga\ (not shown) show smaller differences in LMDZ but similar differences in TM3. The TM3 result indicates that temporal variations in fossil fuel emissions can induce regionally significant differences in the estimated monthly Fbio. The smaller difference with LMDZ comes from the fact that this inversion system did not account for the diurnal variations in FFCO$_2$ emissions (see section \ref{sect:method:inversion}). These Fbio differences can directly be compared to the differences between the emission maps themselves. The differences between \ierh\ and \edga\ fossil fuel sources for July (fig.∼\figsupMapIerEdg, supplementary material) can reach $\pm$ 100 gC/m$ˆ2$/month over industrial areas (i.e., Western Germany). This result confirms that the inversions tend to smooth these large FFCO$_2$ emission differences and distribute them spatially over adjacent regions. These results hold for all months and reflect the under-constrained nature of current inversions.

\vspace{0.3cm} {\it Annual Fbio fluxes}

Integrated over the year, the differences in estimated Fbio become much more significant than at the monthly time scale (Table \ref{tab:inv_res}). The effect of accounting for temporal variations in fossil fuel emissions (\edgh\ versus \edga) on the Fbio estimates is limited to less than 5\% (integrated over Europe or its “Western part”), but the effect of switching emission patterns and magnitudes lead to much larger differences. For instance, using the \ierh\ emission inventory changes the mean value of Fbio by $\sim$0.15 GtC/yr for the whole Europe and by $\sim$0.05 GtC/yr for the Western part. These numbers are slightly smaller than the annual total European differences in fossil fuel emissions themselves (0.23~GtC/yr for Europe, Table~\ref{tab:emis}) because part of the fossil fuel difference is compensated by Fbio (and Focean) flux adjustments outside Europe (see figure \ref{fig:inv_mapsbis}). The use of the \trc\ emissions induces smaller changes (less than 20\% integrated over Europe). Overall, the largest fossil difference corresponds to 26\% difference and 40\% difference of the annual Fbio for Europe estimated for that particular year (2001) in the two inversions completed in this study, respectively. The posterior Bayesian uncertainties on Fbio fluxes estimated by the two inversion systems (only calculated for total Europe, Table \ref{tab:inv_res}) indicate that i) the two different estimates are statistically compatible (i.e. within the 0.3~GtC/yr estimated uncertainty) and ii) the differences induced by using different fossil fuel inventories are also within 1 sigma of the posterior error. Note that the two inversion-derived annual Fbio fluxes for Europe are of the same magnitudes than the mean fluxes estimated by \cite{janssens:03}.

If we now consider the spatial distribution of the annual Fbio fluxes (figure \ref{fig:inv_mapsbis}), larger differences than for July are found. First, the mean flux with the \edga\ FFCO$_2$ emission (figure \ref{fig:inv_mapsbis}-bottom) presents much larger regional variations in the LMDZ inversion (than in TM3) that are related to the strong influence of the prior flux distribution in this system (taken from a biogeochemical model, see \ref{sect:method:inversion}). A detailed analysis of the differences between the two systems is beyond the scope of this paper. The Fbio differences between using \ierh\ and \edga\ FFCO$_2$ emissions are significant, and up to 50 gC/m2/yr over specific regions like the Netherlands while the original flux FFCO$_2$ flux difference is around 250 gC/m2/yr (i.e., 0.01 GtC/yr, Table~\ref{tab:emis}). However, the difference between using \edgh\ and \edga\ is proportionally much smaller (unlike for July fluxes), which indicates that the temporal variations in FFCO$_2$ emis-

sions have a negligible impact on the annual Fbio flux, at least given the resolution of transport models used in the two inversions.

Overall these sensitivity tests highlight the increasing impact of uncertainties (mainly biases) in fossil fuel emission inventories on the estimated biosphere fluxes from the continental to the regional scale. However, further investigation need to be carried out with inverse systems at higher spatial resolution (at least 0.5 degree) in order to use all the information contained in the new high resolution FFCO$_2$ emission inventories (i.e., \ierh). These systems will be more adapted to investigate separately the effect of diurnal, day to day, and seasonal variations in fossil fuel emissions on the estimated Fbio fluxes.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 7457, 2009.

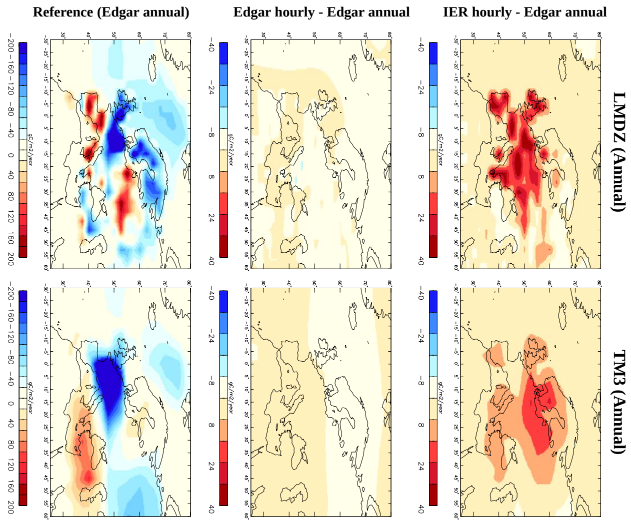

Fig. 1. ADDED FIGURE (short caption): Annual Fbio fluxes estimated with the 2 inversions with Edgar_annual FFCO2 emissions (lower panel) and the differences between IER_hourly or Edgar_hourly and Edgar_annual