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Geoscientific Model Development Discussions
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Interactive comment on "Description and evaluation of REFIST v1.0: a regional greenhouse gas flux inversion system in Canada" *by* Elton Chan et al.

Anonymous Referee #2

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The manuscript describes a regional inverse modeling system that uses atmospheric observations to estimate GHG fluxes. Synthetic experiments are performed to evaluate the system. A number of specific aspects need to be addressed before I can recommend accepting the manuscript for publication.

Main comments:

Regarding the number of regions: I fully agree with referee #1 in that a prior error of 100% for different regions with a changing number of regions will result in a decrease of the uncertainty of the spatially integrated fluxes, as the errors are assumed uncorrelated. One possible method would be to inflate the variance accordingly such that the prior error of the spatially aggregated flux does not change with the number of re-

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gions. However this has an impact on the comparisons between flux estimates using a different number of regions to be solved for. This might also be part of the reason that posterior estimates shown in Figure 7 are closer to the prior when the number of regions is larger.

The method to calculate the baseline is a bit problematic: Using CT2011 predicted fossil fuel CO2 extracted at locations 5 days before arrival at the observation site does not separate the outside-domain influence from inside-domain influence, where domain means the regional domain of interest. A better method would be to sample the 3d CO2 field at the locations when trajectories first leave that regional domain. To assess the impact, at least a map showing a distribution of the locations of the trajectories at the time step 5 days prior to the measurement should be provided (may be included in an appendix).

Flux error is referred to in the manuscript as the difference between the posterior flux and the target flux (true flux). However, in inverse modeling, usually the statistical uncertainty in the posterior flux estimate is used as an estimate of the expected error in the retrieved flux. In a synthetic experiment, the actual difference between retrieved and true fluxes can be regarded as a realization of this posterior uncertainty. Note that the flux error as referred to in this manuscript is thus expected to be within the 1-sigma uncertainty range for 68% of the cases, i.e. 32% on average are expected outside the range. I suggest also assessing the statistical posterior uncertainty, and including these as error bars in the respective figures.

The appendix appears as another version of the explanation of the simulations, rather than only providing information that is additional to the main manuscript content. For example, eq. A1 and A2 of the appendix are identical to eq. 1 and eq. A2 of the main text.

Contradicting description of the MCMC method: In line 209 it is mentioned that the MCM method is applied without prior constraint (no regularization), then in line 225 it is

mentioned that assumed distributions of lambda_prior are used, which indicates that a prior constraint is used.

Detailed comments:

L45: “different atmospheric transports” -> “different atmospheric transport models”

L75: “CarbonTracker fossil fuel CO2” here a reference should be given

L83: add “Also” at the beginning of the sentence starting with “Other . . .”

L94-95: This is not a typical use of estimation error and uncertainty. If these terms are to be used to refer to synthetic and real data inversion, this should at least be made very clear. However I would not recommend using the terms that way.

L181: Note that CFM approaches can also involve simulations, at least when the number of unknowns is large (e.g. pixel-based inversions).

L189: add “The” before “Inversion”; also check throughout the manuscript for missing articles.

L233: the variance should have units corresponding to the square of the synthetic observations, i.e. if the observations are in ppm (for dry air mole fractions), the variance should have units ppmˆ2.

L289: Note that Gerbig et al. (2003) used temporal and spatial correlation in the measurement uncertainty related to transport error, thus their “D_epsilon” was not diagonal.

Fig. 5 caption: The numbers next to the symbols and the two rows of numbers in brackets below the x-axis should be mentioned/explained in the figure caption. Also the error bars shown in Fig. 5 (b) should be explained. Why are there no error bars in Fig. 5 (a)? What exactly is shown as the y-axis, is it the difference between posterior and target (truth) after spatial aggregation to the respective region (AB+SK and ON) and after temporally aggregated from monthly to annual? Why then are the error bars based on the standard deviation of the monthly errors, and not on the annual errors?

L384: “large degrees of freedoms” -> “large number of degrees of freedoms”

L396: “Bielgers” -> “Bieglers”

L444: “transport errors are in our experiments are” remove the first “are”

Figure 6: it should be mentioned which transport model is used in the pseudo observations. Either in the caption or in the text near line 460. I assume that CT2011 transport was used, corresponding to the case with prior flux and transport error.

L501, also L610-614: 32% of the estimates are expected to not include the truth within the 1-sigma uncertainty range, thus it is not required that all estimates include the truth within their uncertainty range.

L568: The sensitivity experiments should be added to table 3 so that it is clear which station was omitted in which experiment.

L669: The fact that aggregation error does not play an important role is due to the fact that target fluxes and prior fluxes are very close to each other in terms of spatial pattern. It should be clearly discussed as to how far this difference is expected to really represent differences between prior flux and true flux.

L693-696: this general statement on the nature of regional flux inversion should be backed up by references. Note that this statement is quite in contradiction to typical regional inversion results (see e.g. Lauvaux et al.2016).

L698-707: This discussion should include a discussion of pixel-based inversions (solving for spatially resolved fluxes at high resolution but using spatial (or temporal) correlation in the prior uncertainty) as it is state of the art nowadays.

Technical note: it would be much easier for reviewers if the captions for figures and tables were not separated from the figures and tables.

References:

Lauvaux, T., Miles, N. L. and Deng, A.: HighâĂŘresolution atmospheric inversion of urban CO2 emissions during the dormant season of the Indianapolis Flux Experiment (INFLUX), J. Geophys. Res., 121, doi:10.1002/2015JD024473, 2016.

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