## Supporting Information for

# [Description and evaluation of REFIST v1.0: a regional greenhouse gas flux inversion system in Canada]

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## Introduction

Figure S1 shows the annual percentage errors by 1-monthly inversions using the same experimental setups presented in Table 3 in the paper.

Figures S2 to S13 show the year 2009 annual spatial patterns of CT2011 fossil fuel  $CO_2$  target flux (left column), posterior flux (middle column) and relative percentage error (right column). The relative percentage error of the posterior flux and the target flux is defined as [(posterior flux – target flux)/target flux) x 100%]. Seven spatial definitions are used for the regional inversions that include 2, 4, 7, 11, 19, 27, 37 sub-regions for the western region of Alberta+Saskatchewan (AB+SK) and 1, 2, 4, 6, 12, 23, 49 sub-regions for the eastern region of Ontario (ON).

## Interpretation

Figures S2 (MCMC for AB+SK region) vs S4 (CFM for AB+SK region) and S3 (MCMC for ON region) vs S5 (CFM for ON region) show spatially, the annual patterns of the posterior fluxes obtained from the MCMC and the CFM methods. Unrealistic negative fluxes (black) do not exist on the annual time scale for the provinces of AB+SK and ON with any number sub-regions using either MCMC or CFM method. In order words, this suggests that unrealistic features are not introduced by flux error as long as the modelled transport is perfect.

Figures S6 (MCMC for AB+SK region) versus S8 (CFM for AB+SK region) and S7 (MCMC for ON region) versus S9 (CFM for ON region) confirm that the number of unrealistic sub-regions increases as the number of sub-regions to be optimised increases particularly in the eastern region of ON.

Spatially, unrealistic annual negative fluxes appear as the number of sub-regions increased with either MCMC (Figure S7) or CFM (Figure S9) method.

Figures S10 and S11 show spatially the annual errors for the seven spatial definitions over the provinces of AB+SK and ON respectively using the MCMC method. Blue and red areas represent under- and over-estimations compared to the target. Unrealistic negative posterior fluxes (black sub-regions) appear for the province of ON when six or more sub-regions (E18 to E21) are used which are consistent with previous sets of experiments. We note also that the estimation errors around the stations can be much larger than the percentage differences of the prior and the target fluxes, and there is no improvement with increasing sub-region resolution. This means that the accuracy of the inversion results is not simply determined by the sensitivity of the station's footprints, that high sensitivity does not guarantee reliable flux estimates. Large estimation errors around stations are particularly noticeable using the CFM method that will be discussed.

Figures S12 and S13 show that the annual spatial patterns obtained from the CFM method are quite consistent with those obtained from the MCMC method, but the errors tend to be more positive. Similar to the MCMC results, unrealistic negative posterior fluxes (black sub-regions) appear as shown in Fig. S13 for the province of ON when six or more sub-regions are used (E39 to E42). These unrealistic sub-regional fluxes are

consistent between the two inversion methods and are similar to the transport error only case. It is important to point out again that the spatial patterns of the annual errors increase in similarity using the MCMC and CFM methods as the number of sub-regions decreases. This means that the flux estimates are stable and robust when only a few sub-regions are estimated. The posterior fluxes of the two optimisation methods in fact become nearly identical when the least number of sub-regions are used.











**Figure S2.** Annual estimation errors (relative percentage difference of the posterior flux estimates from the target flux) using the MCMC method with flux error for the 7 spatial definitions for the provinces of AB+SK for the year 2009. Negative fluxes are shown in black.





Figure S3. Same as Fig. S2 but for the province of ON





**Figure S4.** Annual estimation errors (relative percentage difference of the posterior estimates from the target flux) using the CFM method with flux error for the 7 spatial definitions for the provinces of AB+SK for the year 2009. Negative fluxes are shown in black.





Figure S5. Same as Fig. S4 but for the province of ON.





**Figure S6.** Annual estimation errors using the MCMC method with transport error for the 7 spatial definitions for the provinces of AB+SK for the year 2009. Negative fluxes are shown in black.





Figure S7. Same as Fig. S6 but for the province of ON.





**Figure S8**. Annual estimation errors using the CFM method with transport error for the 7 spatial definitions for the provinces of AB+SK for the year 2009. Negative fluxes are shown in black.





Figure S9. Same as Fig. S8 but for the province of ON.





**Figure S10**. Annual estimation errors using the MCMC method with flux and transport errors for the 7 spatial definitions for the provinces of AB+SK for the year 2009. Negative fluxes are shown in black.





Figure S11. Same as Fig. S10 but for the province of ON.





**Figure S12**. Annual estimation errors using the CFM method with flux and transport errors for the 7 spatial definitions for the provinces of AB+SK for the year 2009. Negative fluxes are shown in black.





Figure S13. Same as Fig. S12 but for the province of ON.