

Interactive comment on “A 4D-Var inversion system based on the icosahedral grid model (NICAM-TM 4D-Var v1.0): 1. Off-line forward and adjoint transport models” by Yosuke Niwa et al.

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RC

The manuscript describes the implementation of the offline forward and adjoint transport for the NICAM-TM 4D-Var system with two different approaches: A linear forward mode with an exact adjoint and a non-linear forward mode with flux limiter using an approximate adjoint.

The manuscript is well written, relevant and well-suited for GMD. The validation methods are well-chosen and the tradeoffs in both modes are explained.

C1

AC

We are grateful for your time to review our paper and for giving us fruitful comments and suggestions. Our replies to the comments are described below with line numbers/pages of the supplementary manuscript. The modifications we made are colored in red in the supplementary manuscript.

RC

As a minor revision I would suggest adding a comparison between the magnitude of the error introduced by data-thinning and the error introduced by using the approximated adjoint (with the non-linear forward equations) on page 10, subsection 3.4 (validation of the adjoint model) to complement the estimate in the companion paper (Niwa et al., 2016). By eye Figure 6 seems to show deviations with a magnitudes up to 10%.

AC

Thank you for your suggestion. We contemplated whether to add the comparison between the data-thinning error and the non-linear effects as suggested. However, we have decided not to add that comparison, for simplicity. In fact, the non-linear effect can be translated to that of the flux limiter, which is already compared with the data-thinning errors in the previous sections (3.2 and 3.3). Furthermore, in the inversion experiment of the accompanying paper, we used the same temporal resolution of the input meteorological data for the forward and adjoint simulations. Therefore, the data-thinning error does not affect the forward-adjoint relationship.

C2

RC

Improving the reproducibility would require providing the source code of the described model versions (offline and online) and the required data which is not yet common practice for weather models and would likely face institutional hurdles.

AC

At this stage, the source code of NICAM(-TM) cannot be available through a web-page, but we can provide it upon request as stated in Code availability. We are happy to share our model code and the dataset with researchers who are interested.

Line-notes:

RC

page 2 line 13: Chevallier et al. (2010) used 21 years of data but note that at this scale “modeling and representativeness errors exceed the measurement errors by an order of magnitude”, therefore the reference does not support the argument. Babenhauserheide et al. (2015) show that a 10 to 15 weeks assimilation window suffices to represent remote fluxes, i.e. in the antarctic (sorry for the self-reference here).

C3

AC

We agree in that a 20-year-long assimilation is very difficult. Here, we wanted to mention the need for an analysis on interannual variations (IAVs), which does not necessarily require one 20-year-long assimilation window. Consecutive several-months-long assimilation windows could be one way to estimate GHG IAV fluxes, but it still requires a number of forward/adjoint simulations. To clarify this, we have modified the text as

“Moreover, a global inversion calculation of an atmospheric greenhouse gas requires a long time analysis (~20 years; e.g. Chevallier et al., 2010) to figure out interannual variations of surface fluxes, resulting in at least hundreds of years of model simulations in total.”

[Page 2, line 13-15]

RC

*page 2 line 14: resulting **in** at least . . .*

*page 2 line 15: of making **the** computation . . .*

*page 2 line 28: loses → **losses***

*page 3 line 34: This avoids the pole problem **inherent in latitude-longitude grids** and . . .*

AC

We have modified the text according to the above comments.

C4

[Page 2, line 15], [Page 2, line 16], [Page 2, line 29], [Page 4, line 5]

RC

page 3 line 34: simulations. **Therefore** ← seems not to follow from the previous sentence. Maybe **The** instead?

AC

We have modified the text as “Owing to the feasibility of high-resolution simulations, the dynamical core...”, because the high-resolution and the non-hydrostatic are linked.

[Page 4, line 6]

RC

page 4 line11:"240km...comparable or finer than previous inversion studies" Carbon-Tracker CTE2016-FT used in the Global Carbon Budget 2016 (Le Quéré et al., 2016) uses 1x1 degree resolution over Europe and North America¹, which is approximately 100x100km resolution.

AC

Thank you for your information. We have modified the text and added Le Quéré et al. (2016) in the reference.

C5

[Page 4, line 17-18]

RC

page 5 line 20: can be easily shown → can **easily be shown**

page 6 line 16: second approach **a** continuous

page 6 line 19: is no longer inexact → **exact**

page 6 line 23: detail derivation → **a detailed** derivation . . .

page 6 line 30: to readily make **create** the adjoint model, but it sometimes makes **this carries the risk of making** the model . . .

page 12 line 13: coefficient, while → coefficient **and**

AC

Thank you for the above corrections. Accordingly, we have modified the text.

[Page 5, line 27], [Page 6, line 24], [Page 6, line 27], [Page 6, line 31], [Page 7, line 7], [Page 13, line 15]

Please also note the supplement to this comment:
<http://www.geosci-model-dev-discuss.net/gmd-2016-231/gmd-2016-231-AC2-supplement.pdf>

Interactive comment on Geosci. Model Dev. Discuss., doi:10.5194/gmd-2016-231, 2016.

C6