

Interactive comment on “Validation of OCO-2 error analysis using simulated retrievals” by Susan S. Kulawik et al.

Susan S. Kulawik et al.

susan.s.kulawik@nasa.gov

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Thank you to reviewer 1 for the helpful comments. We have responded to all comments.

Reviewer 1 major comment: p6 l5, Eq 6: This is not the χ^2 of an optimal estimate because the constraint term is missing. Without the additional term $(\hat{x} - x_a)^T S^{-1} a$ ($\hat{x} - x_a$) I think the expectation value will not be the number of degrees of freedom of the retrieval system (See Rodgers book Eq. 2.43).

Response: Thank you for pointing this out. As the reviewer notes, the (retrieved minus prior) contributes to the χ^2 used for the goodness-of-fit in an optimal estimate. For oco-2 fits, there four "bands" contributing to the χ^2 , the O2A, the weak, the strong, and the state deviation from the prior. However, the purpose of Eq. 6, is to see how

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well each spectral band is fit for different categories. e.g. see Section 4.2 dP, where the spectral fit is checked for different surface pressure error ranges. This diagnostic was also renamed, "rad_chi²" so as to avoid confusion with the χ^2 used in the retrieval. This section was reworded to explain better the purpose of this diagnostic, "One useful diagnostic is an estimate of how well the modeled radiances match the observed radiances for each of the three OCO-2 spectral bands."

The same terminology was updated in 2.3 (quality flags) and 4.2 (dP) to be consistent.

p1 l14: what about adding "... larger than predicted by linear error estimation,..." Response: Updated as suggested.

p1 l25: shouldn't it read "was launched" Response: Updated as suggested.

p2 l1: either "analysis follows" or "analyses follow" Response: Wording changed to, "OCO-2 error analysis uses Rodgers (2000)..."

p3 l16: "...linearity of the retrieval system in the vicinity of the result..." Actually it is not assumed that the retrieval system is linear but that it is only moderately nonlinear (in Rodgers' language). That is to say, that the system behaves approximately linear in 1 around the result. Response: Thank you for noting this. Updating to "1) Linear estimates of errors, which assumes moderate linearity of the retrieval system"

p3 l18: I thought you talk about error estimation but here you talk about the retrieval. Please clarify. Perhaps "Error estimation based on retrievals using a..."? Response: Updated 2), 3), and 4) as suggested, e.g. "2) Error estimates from non-linear retrievals of simulated radiances using a fast, simplified radiative transfer, called the surrogate model (Hobbs et al., 2017)."

p4 l10 "...the a priori covariance matrix for CO₂ has the dimension..." Response: Updated the wording as suggested.

p4 l12 I might have missed something but it is not clear to me what "aircraft variability" is. I am not sure if the term "error" is adequate in the context of a priori uncertainty.

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Response: The variability of the aircraft is outside the scope of this paper. Wording updated to, "The larger variability near the surface allows more variability in the retrieved CO₂ profile near the surface."

p4 l14 I suggest to add the term "assumed" somewhere. Either "The assumed a priori errors" or, "are all assumed uncorrelated". Response: Wording updated as suggested, to "The a priori errors for other parameters are all uncorrelated in the a priori covariance... "

p4 l35 "Sainv" have you pasted a LaTeX macro into a word document here? Response: It looks like the word file got mangled in transit between co-authors, and have updated many similar issues in the text.

p5 l 33 and throughout: I suggest to avoid these technical abbreviations like "CO₂_grad_delta" in the text as far as possible and to use common language instead. If you do not want to use common language for these terms, then please replace the variable name of the computer code by a variable in mathematical notation. Response: Updated this to a mathematical notation which I cannot paste into this text box, but first introduced near the end of the abstract.

p6 l1 this should read 2; there are numerous errors of this type. I do not mention each single one. Response: This notation was updated in response to the major comment, above. The notation was also fixed.

p6 l5 try to avoid computer language type variable names, replace by mathematical notation. Response: Updated to r , for radiance, in Eq. 6.

p7 l20 "errors due to physics that is perfectly described by the retrieval forward model" not quite clear what is meant. Please reword. Response: This was worded confusingly. Updated wording to, "This error analysis ideally would use the exact same forward model in both the L1b simulations and the L2 retrieval algorithm, as our analysis assumes that Eq. 1 should be valid, without errors from forward model differences."

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p11 l17. I do not think that the smoothing error describes the error introduced by the "imperfect sensitivity". Imperfect sensitivity will cause retrieval noise. The cause of the smoothing error is that $x_{true} \neq x_a$. Response: I see how imperfect sensitivity results in noise which is not smoothing error. Updated wording to, "Smoothing error occurs when the averaging kernel deviates from the identity matrix..."

p8 l19 should this read, "second moment"? Response: Yes, thank you.

Subsection headers 4.1 and 4.2: please avoid variable names in the subsection headers. Response: Updated names to "The retrieved profile gradient" and "The retrieved surface pressure".

p14 l13: Not sure if abbreviation "LMT" has been defined. I might have missed the definition but please check. Response: Yes they were defined earlier, but now are re-referenced Section 2.1 and the paper Kulawik et al. (2017) here.

p15 l9: There is something wrong after "...contribute." Response: Cleaned up extra punctuation, line now reads, "Although it is typically assumed that the surface pressure is determined solely from the O₂A band, the strong and weak CO₂ bands also contribute information."

p15 l22: I thought that the reduced 2 means 2 divided by the degrees of freedom. Isn't normalization with the related inverse covariance matrix inherent in the 2 by definition? Response: This notation and definition was cleaned up when Eq. 6 was tidied. It is no longer called "reduced" but uses Eq. 6 directly.

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