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Interactive Comment

Interactive comment on "Known and unknown unknowns: the application of ensemble techniques to uncertainty estimation in satellite remote sensing data" *by* A. C. Povey and R. G. Grainger

A. C. Povey and R. G. Grainger

adam.povey@physics.ox.ac.uk

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We thank Dr. Sayer for his extensive thoughts on the paper and his positive recommendations. He raises a number of interesting points that warrant further discussion, though we present our opinion here. We especially appreciated the references provided, being well aware that our knowledge of the literature is finite.

Comments:

- We propose changing the title of this paper to, "Known and unknown unknowns: Uncertainty estimation in satellite remote sensing" to satisfy the comments of both reviewers.

  We agree that sensitivity studies are examples of the first style of ensemble and now mention them at the end of P8517, L17.

  In the near future, we intend to use ensemble techniques to eliminate cloud filtering from the ORAC algorithm by retrieving both aerosol and cloud properties for each pixel. This will hopefully serve as a suitable demonstration.

P8516 The requested change has been made.

P8519–20 These have been defined and we apologise for the oversight.

P8521 "Earth-bound" has been deleted from L20 and L23–24 has been revised to, "…(Smith et al., 2002) or the Moon (Eplee et al., 2011). This can complement pre-launch calibration or may be the only direct calibration possible (Heidinger et al., 2003)."

P8522 This is a subtle point and requires more thorough explanation. The following has been added as Sec. 3.7 — Summary:

> "Measurement and parameter errors are both intrinsic sources of uncertainty in a retrieval. Measurement errors affect the quantities measured and analysed by the retrieval. Parameter errors are propagated from auxiliary inputs, such as meteorological data or empirical constants. Resolution errors result from finite sampling of a constantly varying system. These can be especially important as satellites do not sample the environment randomly but with a systematic bias due to the satellite's orbit and quality control or filtering.

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> Approximation errors represent aspects of the analysis that could have been done more precisely but do not affect the fundamental measurand. A plane parallel atmosphere is a simplification of the real world; it would not be observed. System errors express choices in the analysis that alter the measurand. An assumed aerosol optical model will represent a possible state of particulates in the atmosphere; it may be unlikely but still possible. The system error results from the difference between the assumed system and reality."

The use of Mie or T-matrix theory for aerosols would therefore cause approximation errors as the particles will not be spheroidal.

Sec. 3.4 P8524, L6 has been amended to, "When Level 2 data are aggregated onto a regular grid, the result is Level 3 data," and the following added at the end of the section, "Level 2 data can also be averaged while remaining on the satellite grid (for example, Hsu et al., 2013), which could be referred to as Level 2.5 data."

Your points on the effect of swath are highly relevant and we have included them with a reference to your paper in the end of Sec. 3.4.2,

> "Sampling is also affected by the instrument swath. As examined in Sayer et al. (2015, currently under discussion), there is often a distortion of pixel size, shape, and overlap near the edges of a swath (e.g. the MODIS "bowtie effect"). The local solar time of pixels is variable across any swath. These effects complicate the definition of the measurand and raise important questions for the production of Level 3 data: Should overlapping data from different swaths be combined despite differences in local time? When combining pixels, should they be weighted by their area? Should distorted pixels be excluded from such averages entirely?"

P8524 You are correct. The point has been revised to,

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> "Resolution errors are a function of the pixel size and the variability of the measured quantity. A satellite datum is interpreted as a spatial average over the footprint of the pixel. This presumes that the value retrieved is equal to the average of retrievals from infinitely high spatial resolution data (i.e. the derivative of the product with respect to the measurement is linear for variations within the pixel). While this approximation holds in many circumstances, it is not universally true and certainly breaks down as pixels are aggregated to represent a larger spatial scale."

P8529 We have added "As an illustration," to the start of P8529, L1 and the following has been added on P8530, L1: " All variables retrieved may have a weighting function, such as cloud effective radius (Platnick, 2000)."

P8529–30 This reference has been included on P8530, L1.

Sec. 4.1.2 We have extended the figure as requested (shown below) and split the section into two. Sec. 4.1.2 covers P8531, L1–18; P8532, L7–19; and P8533, L4–9 with the remainder of the original section included in a new Sec. 4.1.3 — Formalism for comparison.

Sec. 4.1.3 Our point is semantic; error envelopes are a validation tool rather than an uncertainty estimate. They provide information about data quality and error, but require external information and the results are not necessarily transferable. The second paragraph has been revised to,

> "This is an efficient means of communicating the results of the validation against AERONET and conveys a quantitative measure of the degree of certainty the data producer has in their product. It is not, strictly, an estimation of uncertainty. Such validation techniques are

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> neither universal (being dependant on the collocation criteria), internally consistent (as external data are used), nor transferable (being representative of only the conditions considered). Though envelopes provide a diagnostic approximation of the uncertainty, additional correction is necessary to use them as prognostic uncertainties (Hyer et al., 2011). Treating envelopes as a transferable uncertainty has led to significant difficulty integrating data from different sensors as global and local sources of error are disconnected (Holzer-Popp et al., 2014)."

It is precisely because satellite errors are predominately systematic that comparison against AERONET provides a limited source of uncertainty information. AERONET observations have lower uncertainties because the measurement more directly observes AOD than satellite sensing, but they are still retrievals with their own uncertainties. When evaluating aerosol retrievals, where the surface is the dominant signal, the envelope is only representative of surfaces similar to those near an AERONET station.

On P8534, L3 "a single uncertainty value for all retrievals" has been replaced with "envelopes". On L6–7, "single number" has been replaced with "simple expression".

P8537 It has been clarified that this refers to Collection 5. Hopefully a few odd turns of phrase can keep the reader engaged through the paper's length.

Sec. 5.3 The section has been renamed as recommended.

Fig. 3 The purpose of the plot is not to demonstrate the details of each curve but to convey that a 2-D model evolves in a 3-D space. We would have plotted continuous surfaces if the reader could interact with the figure. Splitting into five panels would clarify each slice but may distract for the visual analogy we are attempting to convey. However, it is a simple change if other readers find it confusing.

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- These grammatical issues have been revised where identified.

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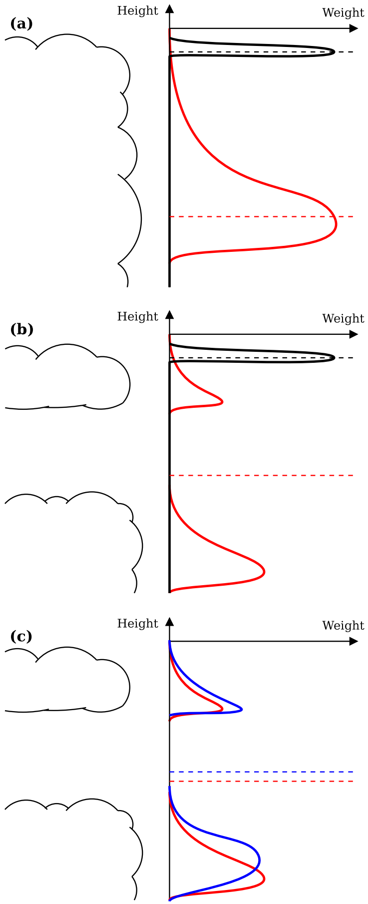

Fig. 1. Revised version of Fig. 6.