Review of

"On the efficient treatment of temperature profiles for the estimation of atmospheric transmittance under scattering conditions"

by Lindstrot and Preusker

This paper aims to replace a sometimes-made approximation in atmospheric remote sensing retrievals, in which a globally constant temperature profile is assumed, so that atmospheric optical depths or transmittances can be precalculated. In this way, labor-intensive calculations can be avoided in operational retrievals, which can speed up these retrievals by a substantial amount. The authors show that, at least for the application of surface pressure retrievals from the near-infrared observations in the Oxygen A band near 760 nm, the use of a single mean temperature profile leads to large errors. The authors further show that these errors can be greatly reduced by using a handful of temperature profile eigenvectors, and that the pre-calculation approach can still be used with minimal errors due to temperature profile assumptions.

General Comments

Overall I found this paper very readable, however the paper suffers from a couple structural problems that need to be addressed before publication.

1) The paper seems to have fairly limited scope. The authors state that it can be applied under scattering conditions, and can be applied to any problem including gaseous absorption or emission. However, the authors do not discuss which problems it would be most useful for. Their application, that of surface pressure retrieval from non-hyperspectral NIR measurements, is a fairly specialized one, and its not clear that it would apply to many other actual problems. For instance, in retrievals in which there are more than one or two retrieved quantities (ie a higher dimensional state vector), typically the RT cannot be done as an offline lookup table, so this technique would not be applicable to those problems. It is likely only applicable to problems in which a look-up table is already used, and further in which a mean temperature profile is assumed, or to problems which lend themselves to such an approach. Could the authors name any other specific retrieval algorithms (operational or otherwise) for which this is the case? Do they only intend this technique to be used for radiometers, as opposed to spectrometers? If the latter, then the paper will require some simulations for actual spectrometers (such as SCIAMACHY or GOSAT).

2) The authors do not go through any mathematics to prove the hypothesis given by equations (3) and (4); rather they are empirically demonstrated to be effectively true for their specific application. These hypotheses may break down in certain situations (such as very high optical depth, and/or high

spectral resolution situations). It would be more illuminating to go through some mathematics (at least in an appendix) to go from temperature space to optical depth or transmittance space, and further to radiance space. For instance, why do the authors work in transmittance rather than optical depth? Given that t = exp(-tau * airmass), you can eliminate the airmass dependence by precalculating tau instead of t. Further, because optical depths add and transmittances multiply, equation (3) could be rewritten more accurately as

$$t = t_{mean} \cdot \Delta t_0 \cdot \Delta t_2 \cdots \cdot \Delta t_{ncomp}$$

where $\Delta t_i = e^{-m\, c_i \Delta\tau_i}$, with m being the airmass, and $\Delta\tau_i$ being the difference in the total column gas optical depth induced by using the i^{th} temperature eigenvector, relative to just using the mean temperature profile. Under the assumption of small optical depths, this will reduce to the author's equation (3), but not in general. This point needs to be addressed, because it questions the generality of the authors' assumptions.

Specific Comments

* It would be very helpful to see a plot of the actual eigenvectors (just the first few), plus the mean profile. Please consider adding such a plot.

* Page 4476 – please state if using a different day at a different time of year (say February or July) change the eigenvectors at all.

* Page 4480 – It would be useful to state the surface pressure error when only two eigenvectors are used. This is relevant because this is apparently what the authors adopt for their specific surface pressure retrieval application.

* Fig 7 – why do the RMS errors not approach zero with higher numbers of eigenvectors?

* Figure 8 is not particularly useful because the colors change so little within a given plot. Perhaps a 1D plot would be better for a nadir instrument, and over plot an instrument viewing at e.g. 50 or 60 degrees zenith angle? I think this would be clearer.

* Section 3.2 – Again their hypothesis is only demonstrated for a single (relatively wide) channel of a single instrument. Even in the O2 A band, questions arise: would it work for the somewhat narrower channels of SCIAMACHY? How about the very narrow channels of GOSAT? How about different gases, that may have somewhat different temperature dependencies and vertical distributions (such as ozone or water vapor)? The authors should state that they are only speculating that the

technique will generalize; they have not proven it for any other cases. (again let me re-iterate that backing up the speculation with some real mathematical derivations would let one see under which conditions the hypothesis may be expected to hold).

* Section 3.2 – the authors state that ΔL_2 is “spectrally almost constant”. This does not look to be the case to me (at all) – it is just that ΔL_2 is much smaller than ΔL_{mean}. Please check this statement and revise if necessary. Furthermore, consider that some applications might require accuracies significantly better than 1%, especially spectrometers where the relative ratios between different channels is what matters. If these temperature-induced errors have a significant impact on those ratios, significantly more eigenvectors might be required, and at large optical depths (i.e. high spectral resolution), the whole technique might even break down.

* Conclusions, page 4482, line 22. State “from MERIS”.

* Page 4482, line 25 – Regarding water vapor, again this is pure speculation, and is likely to only work as the authors think it will for spectrally course instruments such as MERIS or MODIS. The authors should remove this sentence, or add a caveat along these lines.

* Page 4483, lines 1-3 ending with “using one or two eigenvectors is sufficient.” Again this is speculation – it all depends if equations (3) and (4) hold up or break down for high spectral resolution instruments.

* Page 4483, line 5: add “for which these temperature approximations hold”. Again this statement may not be true in general.

Technical Comments

The authors should state that equation (2) is a definition.

The authors should state that equations (3) and (4) are hypotheses only; the way they are talked about, it’s like they are provable which they are not.

Line 10, page 4478 – please state that the calculation is for some reference surface pressure.