

General, specific and minor comments of the reviewer in *Italic* characters.
Replies of the authors in Normal characters.

Reviewer #2

Authors apply newly developed data fusion methods to MARSCHALS and MIPAS_STR colocated observations as an example of the synergy in microwave and infrared limb sounding techniques. Unfortunately, no comparison was made using a "standard" direct L1 to L2 joint microwave/IR retrieval. I think this would have provided a better context for the work presented. Also there are other a posteriori methods of combining L2 data (some mentioned in the paper) which would have formed an interesting comparison. Instead a less ambitious comparison is made using a retrieval of the microwave measurements with the independently retrieved infrared data as a priori. The MMS data fusion involves combining the individual MSS retrievals from both instruments. This is done in this paper by using Tikhonov-Phillips regularization. Unsigned systematic errors are included in the analysis. I recommend the paper for publication in AMT.

We agree with the reviewer #2, see answer to reviewer #1 on this issue.

Regarding "a posteriori methods of combining L2 data (some mentioned in the paper) which would have formed an interesting comparison", it is not clear to which methods the reviewer is referring to. If the reference is made to the method used in Aires et al. (2012), this is a simple weighted mean of the profiles retrieved from the single measurements and this is not expected to provide better results than the retrieval of the microwave measurements with the independently retrieved infrared data as a priori.

Comments and typos etc:

Please define better what you are calling "measurement space" (I know it says rows of Jacobian matrix etc on next line, but I passed over that at first). Really most would expect this terminology to be associated with the y-vector (observations, or radiance measurements in the Rodgers terminology) and not the x (retrieved quantities). Also, in the (L1+L2) method the Fisher information matrix is referred to as being associated with the "inverse problem of measurements of vertical atmospheric profiles". This is poorly worded. If we were dealing with "measurements of vertical atmospheric profiles" we would not have an inverse problem to worry about.

The measurement space is correctly defined at page 11686 L21 as "the space generated by the rows of the Jacobian matrix of the FM". In order to avoid that the reader passes over this definition (as the reviewer did) in the revised version of the paper we added "defined as" before the definitions of the measurement and null spaces (page 11686 L21 and L22).

We used the terminology used in Ceccherini et al. (2009), where the MSS was presented.

Regarding the observation relative to the Fisher information matrix in the revised version of the paper we have modified the sentence reported by the reviewer (page 11692 L14) in "...associated to the inverse problem of indirect measurements of vertical atmospheric profiles"

P11674,L4 : is focusing => focuses
Done

P11675,L6 : land surface [such] as
Done

P11675,L13 : synergetic => synergistic
Done

P11675,L18 : same => similar
Done

P11675,L22 : to => involving

Done

P11676,L6 : use[s]

Done

P11676,L14 : in => of

P11676,L15: the small temperature ... (stronger temperature ...) not sure what you mean here..

The statement referred to the different Temperature dependence of emission in the microwave (linear) and in the infrared (non-linear) and to the associated complementary pros and cons.

However, following the suggestion of another reviewer (see Specific Comments of reviewer #3), we removed this statement in the revised version of the paper.

P11676,L19 : temperature[s]

Done

P11676,L25 : work in => penetrate through

Done

P11677,L1 : one => unity in the mid-infrared

Done

P11677,L7 : microwave [frequencies]

Done

P11677,L24 : moment [and therefore]

Changed "... while CO₂ and CH₄ that have no permanent dipole moment cannot be observed" with "... while CO₂ and CH₄ have no permanent dipole moment and cannot be observed"

P11678,L2 : study, [but] was not

Done

P11678,L5 : launch [such] as

Done

P11678,L6 : ESA Call

Done

P11678,L7 : proposed [PREMIER] mission [was] aimed

Done

P11678,L13 : in this paper => on

Done

P11679,L1 : embarking??

Changed "embarking" to "carrying on board"

P11679,L4 : composed by => comprised of

Done

P11679,L4 : to => with

Done

P11679,L5 : instrument[s]

Done

P11680,L2 : can satisfactorily meet ... so why need ir limb sounding as well??

An improvement of the quality of the products obtained with the fusion of millimeter-wave and infrared limb sounding measurements could change the requirements with the purpose of an always more detailed description of the atmospheric processes in UTLS.

P11680,L12 : an => a

Done

P11680,L12 : there are also strong gradients in the stratosphere e.g. across polar vortex, Rossby wave breaking and fine filaments etc

We fully agree with Reviewer #2 on the fact that strong gradients might occur in the stratosphere. In fact, according to our statement the approximation [of weak horizontal gradients] “is QUITE ACCEPTABLE in the stratosphere, where a uniform composition is OFTEN PRESENT”. We believe that it is not strictly necessary in this context to enter into more details specifying a list of cases where the approximation is not valid in the stratosphere.

P11680,L21 : an => a

Done

P11681,L13 : delete /you can/

Done

P11681,L27 : spectroscopic continuum profile ... or in other words a baseline fudge-factor/junk collector ... and what about the molecular continua for H₂O, N₂?

The molecular continua for H₂O and N₂ are taken into account in the forward model. As specified in the paper, more details are given in Castelli et al. (2013).

P11682,L7 : radiometric gain and offset ... are you actually retrieving these? if so some more detail needed here

The details are given in the reference (Castelli et al. 2013) quoted at the end of the sentence. We prefer not to extend further the paper repeating information included in references that is not relevant for the subject of the paper.

P11682,L24 : [a] few blocks e.g. correlations ... (it may not be clear to some what you mean by blocks)

In order to avoid any possible misunderstanding, in the revised version of the paper we removed “but only few blocks”.

P11683,L13 : allows [one] to

Done

P11684,L9 : could use nW here, also ... cm => cm⁻¹

We would prefer using the indicated unit for consistency with Woiwode et al. (2014).

P11684,L9 : /includes [its] own

Done

P11684,L12 : Is 0.8 arcmin how well the mirror can be controlled? Is the actual pointing knowledge any better?

The value of 0.8 arcmin is the estimated total 1 σ pointing error, including uncertainties of the attitude information (from the AHRS), the accuracy of the scan-mirror control and uncertainties of the line-of-sight retrieval to correct systematic uncertainties.

Replaced: ‘The pointing accuracy is estimated to be within 0.8 arcmin.’

With: ‘The total pointing accuracy is estimated to be within 0.8 arcmin (1 σ) and includes uncertainties of the attitude information from the AHRS, the accuracy of the scan-mirror control and uncertainties of the line

of sight retrieval to correct systematic uncertainties. This corresponds to about 100 m at the lowest tangent altitude of 5 km (for details see (Woiwode, 2012)).’

P11684,L19 : 196.1 [cm⁻¹]

Done

P11685,L7 : The retrieval temperature was inverted.... you mean the radiances (observations) were inverted

Replaced: ‘temperature was inverted,’

With: ‘temperature was retrieved’

P11685,L11 : 5% error in CO2 seems overly large

The 5% uncertainty was adopted as an estimate to account for both, errors in the spectral line data and the CO₂ profile.

Replaced: ‘was considered to estimate the effect of errors in the spectral line data and CO₂ profile.’

With: ‘was considered as an estimate to account for both, errors in the spectral line data and the CO₂ profile profile applied.’

P11686,L20 : see general comment on terminology

Already answered in the general comments

P11687,L18 : suited => suitable

Done

P11688,L12 : influent??

Replaced “influent” with “influential”

P11688,L22 : Differently to = In contrast to

Done

P11690,L21 : was OE previously defined?

Yes, in subsection 2.1.2

P11691,L22-26 : I could not understand why $DOF \geq 1$

The Tikhonov-Phillips method applied in the paper provides a constraint on the derivative of the VMR with respect to altitude. Therefore, also if we apply a very strong constraint fixing completely the derivative of the VMR the absolute position of the profile remains a free degree of freedom.

P11692,Equation 9: should be $f_i =$ and not f_l ?

Yes, changed “ $f_i =$ ” to “ $f_i =$ ”

P11693,L1 : independent [of]

Done

P11693,Equation 10: should be $f_i x_i^2 =$ and not $f_l x_l^2$?

Yes, changed “ $f_l x_l^2$ ” to “ $f_i x_i^2 =$ ”

P11693,L6 : as [a] quantifier

Done

P11693,L7 : as [an] alternative

Done

P11693,L24 : allows [one] to

Done

P11694,L11 : consisted => consists

Done

P11694,L26 : above Scandinavia

Done

P11696,L5 : O3 not o3

Done

P11700,L27 : while [it] increases

Done

P11701,L14 : was TIR previously defined?

Yes, in section 1 (Introduction)

P11701,L17 : was SF previously defined?

No, definition added here

P11701,L23 : infrared hardly lead[s] to

Done

P11703,L8 : used => chosen

Done

P11703,L16 : directly incomparable => which are not directly comparable

Done

P11703,L17 : analysis => analyses

Done

P11703,L24 and L26 L1+L2 => (L1+L2)

Done

P11706,L25 : Identity => identity

Done

P11707,L15 : option as an alternative

Done

P11708,L10 : three-year ... part => some ?

Done

Table 1: delete Band A heading in first column

Done

Why degree symbol after N? Number of channels used.

Done

Table 2: spectral bias and ... (delete spectra at the end)

Done

CH3CL => CH3Cl

Done

Figure 7: H3O => H2O

Done.