

# Response to comments of reviewer 1

We thank the anonymous reviewer for the positive comments and the suggestions, which helped to improve the manuscript. In the following we provide a point-to-point response to all reviewer comments. The reviewer's comments are printed in italic and our response in roman font type. We indicate the line numbers of the revised manuscript where larger revisions have been made. For the reviewer's convenience we also copied larger changes we made to the manuscript to this response and enclosed them with quotation marks.

*The manuscript presents improvements in a retrieval algorithm for ground-based thermodynamic profiles in the boundary layer. It is well structured and clear in the goals of the study as well as in the presentation of the results. I found the explanations and the illustration of the methodology well referenced and convincingly justified. I recommend the publication of the manuscript with just few minor/technical corrections.*

**Response:** Thank you for this positive evaluation.

## 1.1 *Minor comments*

1. *L61-63. I find this part a bit confusing as you just mentioned the need to inflate the noise and you apply a noise-reduction technique. Maybe to make the sentence clearer, I would reformulate it in this way: "The usage of the radiance uncertainty before noise filtering for the error covariance matrix together with the noise-filtered radiance in the measurement vector is intended to compensate for the missing forward model uncertainty".*

**Response:** Thank you for this suggestion. We changed the text accordingly.

2. *L181-182. Can you clarify the usage of cloudy-contaminated data for the analysis? In particular, in the last paragraph of Sect. 2 it is not clear to me whether you use only cloud-free profiles for the IRS analysis or, as you said before in the manuscript, you keep cloud-free data only for the radiosonde comparison.*

**Response:** For the statistical analysis in Figures 9, 11, 15, we completely excluded samples with cloud contamination for the IRS (all samples with LWP > 8 g m<sup>-2</sup>). When analyzing profiles, we allowed profiles with LWP > 8 g m<sup>-2</sup>, but did not use any data above cloud base height. This is

why the number of available data points decreases with height in Fig. 10. We rewrote this sentence to clarify (l. 191-193):

“This is why we excluded any profiles with  $LWP > 8 \text{ g m}^{-2}$  in our statistical analysis for the IRS-based TROPoe experiments (Sects. 4.1 and 4.3). In our height-resolved analysis related to temporal consistency (Sect. 4.2.1), we excluded data above cloud base only instead of excluding the cloudy profiles completely.”

3. *Two questions about the WVBAND experiment. Is the information about near-surface water vapor coming from Ymet? I understand that you use the information from the additional band according to the WV content in a linear fashion, but could this usage introduce an overall bias between dry air profiles and high-humidity profiles? Is this additional band used for all retrievals in Fig. 3 panel (c)? I notice that almost all values are changing in panel (c) with respect to panel (b), and I assume that the only change between the two is the additional band.*

**Response:** Yes, the information about near-surface water vapor is coming from Ymet (we added this information to the text). In the example in Fig. 3, the additional band in WVBAND is used in all samples, because the near-surface water vapor was above the threshold of  $12 \text{ g kg}^{-1}$ . This is the reason for the different values between NOISE (b) and WVBAND (c). The additional band is also used in TROPOEIN (see Table 2 for an overview of the configurations). We added this information to the text (l. 237-238):

“Since near-surface water vapor mixing ratio was above the threshold of  $12 \text{ g kg}^{-1}$  throughout the day, the additional band is used in all profiles leading to slightly different values between NOISE and WVBAND.”

To investigate if the additional band introduces a bias between dry and moist profiles, we searched for a period with a mix between dry (i.e., noise in the additional band largely inflated and thus not used) and moist conditions (i.e., noise not inflated and thus used). We were hoping to see if there is a jump between neighboring profiles that either used or did not use the additional band. However, the challenge is to find a day where moisture values spanned such a large range, i.e. below  $7$  and above  $12 \text{ g kg}^{-1}$  in neighboring profiles. The best period we could find was at SGP with a rapid change in humidity related to a frontal passage (Fig. 1 in this response). Before the frontal passage on April 17, near-surface mixing ratio was close to  $12 \text{ g kg}^{-1}$  (Fig. 1a), i.e. noise in the additional band was inflated only slightly (Fig. 1b). After the frontal passage shortly after midnight on April 18, humidity dropped and reached values of less than  $7 \text{ g kg}^{-1}$ , i.e. noise

in the additional band was strongly inflated. By comparing the time-height sections of NOISE (Fig. 1c) and WVBAND (1d), we were not able to identify more striping or biases between dry and moist profiles in WVBAND compared to NOISE, and therefore we do not believe that the inclusion of the additional WV band leads to a bias.

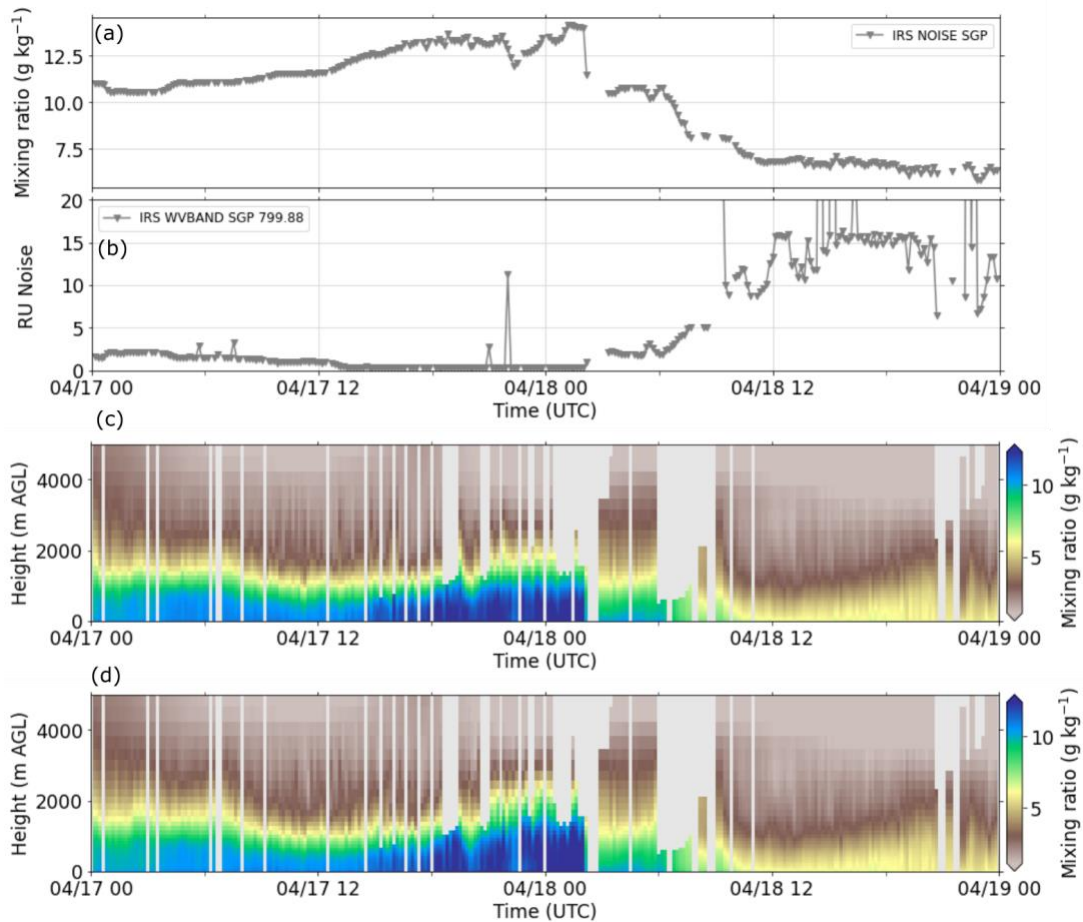


Fig. 1: (a) Near-surface mixing ratio used for inflating the noise in the band between 793 and 804  $\text{cm}^{-1}$ , (b) noise at 800  $\text{cm}^{-1}$ , (c) water vapor mixing ratio profiles in NOISE, and (d) water vapor mixing ratio profiles in WVBAND on April 17-18 2019 at SGP.

4. *Regarding the TROPOEIN experiment: is the usage of the additional information at a previous step in the measurement vector equivalent to using as a-priori information the retrieved profile at a previous time step? Or would this make the retrieval too tight to the previous state?*

**Response:** Using the retrieved profile as prior, could be an alternative way of including it in the retrieval. However, we prefer not to do this for two reasons. The first is as you suggest: it would be too restrictive to the previous state, especially in a covariance between levels perspective. The

second is philosophical: observations belong in the observation vector, and the prior should be only the climatology. We prefer this approach because then the denominator in the information content calculation stays the same, and thus we can more easily assess the improvement in the information content (i.e., the increase in the degrees of freedom for signal) when we use the TROPOEIN vs not.

## 1.2 Technical comments

L7: *is crucial* → *are crucial*

**Response:** Changed.

L6-10: *I suggest to move the sentence “The characterization of the uncertainty ... for retrieval performance” right before “Since each profile...” and start here a new sentence “We present methods...”*

**Response:** Changed.

L14: *spectrometers, radiometers* → *spectrometer, radiometer*

**Response:** Changed.

L16-17: *I would reformulate as: “Observations of the continuous temporal evolution and the diurnal cycle of thermodynamic profiles are essential for the analysis of physical processes....”*

**Response:** Changed.

L30: *Shall you also spell AERIOe out?*

**Response:** AERIOe is essentially modeled after AERIprof – AERI being the instrument, and “oe” being the method used for the retrieval. We added the following information (l. 30-31):

“Based on the AERIOe optimal-estimation physical retrieval algorithm (Turner and Löhnert, 2014), which was developed for the Atmospheric Emitted Radiance Interferometers (AERI) instruments and only allowed infrared radiances as input, ...”

L46: *I would replace “this process is iteratively repeated” with “the state vector is modified in an iterative process.”*

**Response:** Changed.

*L76: spectral band from → spectral band at*

**Response:** Changed

*L95: are analyzed → is analyzed*

**Response:** Changed.

*L127: I would say “once daily only during intense observation periods”*

**Response:** Radiosondes were launched once daily every day of the campaign. During intensive observation periods, radiosondes were launched in up to 2 hour intervals. We changed the text to (l. 132-133):

‘Radiosondes were launched twice per day at SMT and at least once daily, and more frequently during intensive observation periods, at SAV.’

*L127: numbers → number*

**Response:** Changed.

*L133: I think the detail about the usage of narrow and wide FOVs is possibly too technical, if you don’t explain it further, I think it is better to just say that the detail of the usage of water vapor profiles is described in the papers you mention.*

**Response:** We removed this detail.

*L164. Isn’t the  $1-\sigma$  uncertainty the square root of the diagonal elements of the matrix  $Sop$ ?*

**Response:** Yes. Changed.

*Fig.7 and 8: Since you first describe Fig.8 and then discuss Fig.7 (except for the reminder at L257) I would invert the order of the two figures.*

**Response:** We prefer to keep Fig. 7 before Fig. 8, because we think that the reference to the lines of the additive factor and multiplier in Fig. 7 in the paragraph (l. 254-262) is useful. Hence Fig. 7 is used before Fig. 8.

*End of Sect. 3, I would add a sentence informing that the results of the correlation analysis are presented in the next section.*

**Response:** Added.

L355: on the average → on average

**Response:** Changed.

*Caption of Fig.11: I find the term “probability” confusing; would it be appropriate to say “distribution of”?*

**Response:** Changed.

L383: *linesin* → *lines in*

**Response:** Changed.

L384: *lower* → *less relevant*

**Response:** Changed.

L386: *Like for* → *In the same way as for*

**Response:** Changed.

L387: *Please introduce again Fig.11 here, for example: “As reported in Fig. 11 bottom row, ...”*

**Response:** Changed.

L424: *contain* → *have*

**Response:** Changed.

L424: *an additional spectral band* → *the additional spectral band*

**Response:** Changed.

L425: *add “ratio” to water vapor mixing*

**Response:** Changed.

L427: *I would delete the comma after “water vapor band”*

**Response:** Changed.

L430: *“10-min profile”* → *“10 minutes a profile” ...*

**Response:** Changed.

*In the caption of Fig. A1, replace (Fig. A1)” with “(panel a)”*

**Response:** Changed.