Response to the referee #1

June 22, 2016

We are very grateful to referee #1 for the careful reading of our manuscript and for providing constructive comments which helped to improve the manuscript. This document includes all the referee's comments as well as our replies to every one of them.

Specific comments

1. **Comments from the referee:** Introduction: The authors mention the use of AMDAR and MODE-S as in-situ techniques for measuring temperature. The main disadvantage is according to the authors the high cost and very low temporal resolution. They do so without providing any reference or numbers. Since the mention of these techniques isn't relevant for the paper, either skip this remark or present some references and/or numbers on which the statement is based.

   Author's response:
   According to the referee's suggestion we have added a new reference about these techniques in the manuscript.

   Author's changes in the manuscript: p. 2, line 3
   The aircraft use sensors or the emerging MODE-S method to retrieve the temperature **(De Haan, 2011)**.

2. **Comments from the referee:** (Experimental site and instrumentation) local set-up: was the pointing direction of both radiometers the same?

   Author's response:
   The pointing direction of both radiometers has been specified in the manuscript.

   Author's changes in the manuscript: p. 3, lines 7-11
   In addition, the performance of TEMPERA are compared with another microwave radiometer (HATPRO), which has some different instrumental characteristics and also uses a different inversion algorithm. **The pointing directions for TEMPERA and HATPRO radiometers during the campaign are Northwest (320°) and North (350°), respectively.** Next a technical description of the different instruments used in this study is presented.

3. **Comments from the referee:** (Experimental site and instrumentation) time resolution of TEMPERA retrievals is 15 minutes (pg 4.), what is the time resolution of the HATPRO retrievals?

Author's response:

The time resolution of HATPRO retrievals is higher than for TEMPERA. In order to compare both radiometers the HATPRO temperature profiles have been averaged to obtain a profile every 15 minutes. This point has been clarified in the manuscript.

Author's changes in the manuscript: p. 5, lines 5-7

The lower four channels have a bandwidths of 230 MHz while for the optically thick channels (56.66-58 GHz) wider bandwidths (2 GHz) are used. **The temperature profiles from HATPRO are averaged in order to get the same temporal resolution than for TEMPERA radiometer (15 minutes).**

4. **Comments from the referee:** (Experimental site and instrumentation) not any numbers are presented on the estimated accuracy of the measured Tb's (specification?), are these unknown?

Author's response:

According to Stähli et al. (2013) the Tb accuracy for TEMPERA radiometer is 0.5 K and the radiometric resolution is between 0.03 and 0.05 K for 1.0 s integration time. This information has been included in the manuscript.

Author's changes in the manuscript: p. 3, lines 17-20

The calibration of the detected signal in the two backends is performed by means of an ambient hot load in combination with a noise diode. **The brightness temperature accuracy for this radiometer is 0.5 K and the radiometric resolution is between 0.03 and 0.05 K for 1.0 s integration time (Stahli et al., 2013).**

5. **Comments from the referee:** (Brightness temperature comparison) What is the effect of the fixed LWC assumption of 0.28 g/m^2 on the forward model results, e.g. compared to a quasi-adiabatic assumption?

Author's response:

The incorporation of a constant LWC profile with a value of 0.28 g/m^2 in the forward model to characterize clouds has a positive impact on the temperature retrievals from TEMPERA radiometer as it has been shown in Navas-Guzmán et al. (2014). This value is characteristics of stratus, which are the most typical clouds found in our area.

We have performed a statistical analysis with one year of data (2014) where clouds have been characterized using different LWC profiles (triangular, rectangular, adiabatic). Figure 1 shows the mean deviations between the temperature profiles from TEMPERA radiometer and from radiosondes at Payerne. This plot evidences a better agreement when clouds are considered in the retrievals than when there are not included (gray and black line). The deviations are not very different when rectangular, triangular or adiabatic LWC profiles are considered in the forward model. Rectangular (red line) and triangular (green line) LWC profiles show the lower bias with radiosondes. So by simplicity we have considered in our study the rectangular (constant) LWC profile to characterize clouds.

Since this paper is not focus on cloud characterization we have just added the reference of Navas-Guzmán et al. (2014) in the corresponding sentence in the manuscript where this approximation was used to characterize the clouds.

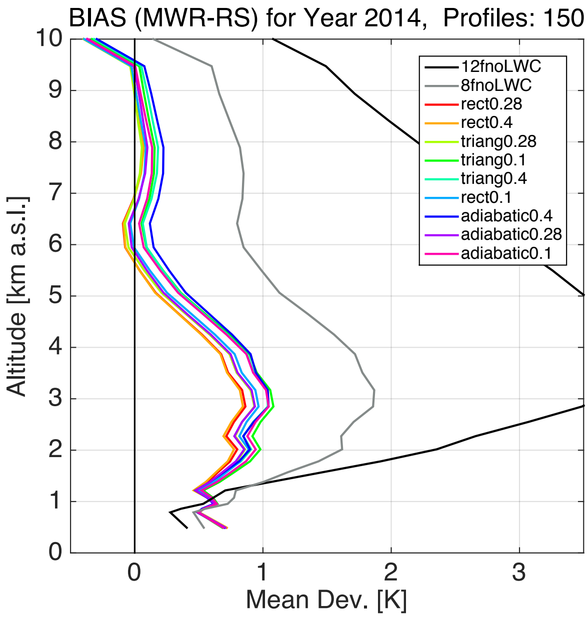

Figure 1: Mean temperature deviation between TEMPERA retrievals and radiosondes. Different LWC profiles have been considered to characterize clouds on TEMPERA retrievals.

Author's changes in the manuscript: p. 7, lines 18-19

In this study we have assumed a constant LWC value of 0.28 g/m^2 for those altitudes with a relative humidity larger than 97% and a temperature larger than -20°C **(Navas-Guzmán et al., 2014)**.

6. **Comments from the referee:** (Brightness temperature comparison) The radiosonde takes about half an hour to reach 10 km height. Are the data of the radiometers averaged over this period? Or is any other processing applied?

Author's response:

The microwave radiometer retrievals have been averaged over 15 minutes. We consider that this time resolution is good enough to compare with radiosondes since it is the average time that a radiosonde can reach altitudes around 4-5 km, which is the range where microwave radiometers have their maximum response (higher measurement response). In addition any change in the atmospheric conditions during this time interval would be much more pronounced in the lower part of the troposphere than in the upper part. For all these reasons we consider that the 15-minute averaged profiles are suited to compare with the radiosondes.

7. **Comments from the referee:** (HATPRO radiometer versus RS) Loehnert and Maier (2012) did find that LN calibrations might not always be properly executed. Did the authors check that for the analysis period 2014 the relevant LN calibrations were of sufficient quality?

Author's response:

We have analyzed the HATPRO time series and such discontinuities as in the 2012 publication are not present in the analyzed data set. This is due to the fact that the calibration procedure has been significantly improved. We perform now a series of checks before a new calibration is accepted. For example, we measure the scene at 5° elevation angle and the cold load before and after the calibrations. One can expect to find brightness temperatures close to ambient air temperature (for the most opaque channels) and the boiling point of liquid nitrogen, respectively. If this is not the case, the calibration is rejected. Comparison with radiosondes using a forward model is also performed after calibration.

8. **Comments from the referee:** (HATPRO radiometer versus RS) The bias dependence of the HATPRO 52.25 GHz channel on the elevation in clear-sky is quite different for this study than in Loehnert and Maier (2012) (both table 3). Since it concerns the same radiometer, have the authors an explanation for this difference?

   Author's response:

   The largest negative bias of up to 6K compared to the radiosonde has been observed in the 52.28 GHz channel. This is consistent with Löhnert and Maier 2012. The large negative bias reported for some periods in Löhnert and Maier 2012 in the 51.26 GHz channel was not found in the present study. While we do not have a precise explanation for this behavior, it should be noted that the instrument underwent a revision by the manufacturer where important radiometric components like amplifiers have been exchanged.

9. **Comments from the referee:** Intercomparison of retrieved temperature profiles: a-priori profile for OEM. The authors claim one of the advantages of the OEM is that it doesn't need radiosondes profiles to train either the neural network or to retrieve the linear regression coefficients. But the authors use radiosonde profiles to calculate mean monthly a-priori temperature profiles. How does that relate to their statement that OEM doesn't need radiosonde profiles?

   Author's response:

   Using Optimal Estimation Method (OEM) an a-priory information is needed in order to constraint the space of solution of any atmospheric parameter to realistic one. In the case of our temperature retrievals we have used monthly mean temperature profiles from radiosondes launched at Payerne since it was an available database. However, any other source (models, satellites measurements, ...) could have been used as a-priory information.

   When the measurement response of the retrieval is high (>80%), as it is in our case for the range used for the comparison, more than 80% of the information comes from the measurements and not from the a-priory profile, therefore the influence in our results of this a-priory information is very small. In fact, any other reasonable profile would lead to the same solution. For this reason we state that this method does not need radiosonde profiles to train itself and get good results as other methods.

Technical corrections

1. **Comments from the referee:** pg 1 line 15 "neuronal networks": the common used name is "neural networks"

Author's response:
Done (page 1 line 15).

2. **Comments from the referee:** pg 1 line 23 "spatial resolution": for radiosonde "vertical resolution" is a more appropriate term

   Author's response:
   Done (page 1 line 23).

3. **Comments from the referee:** pg 2 line 8 "atmospheric dynamics", since the radiometer provides temperature profiles, "atmospheric thermodynamics" is characterized

   Author's response:
   Done (page 2 line 8).

4. **Comments from the referee:** pg 5 fig. 2 in caption: "for HATPRO" change to "for TEMPERA"

   Author's response:
   Done.

5. **Comments from the referee:** pg 5 line 6 "radiometric resolution": should this be "radiometric accuracy" instead?

   Author's response:
   Yes, we apologize for the mistake, it is radiometric accuracy. It has been corrected in the manuscript (page 4 line 11).

6. **Comments from the referee:** pg 5 line 15 "first seconds of the flight" change to "first part of the flight"

   Author's response:
   Done (page 6 line 1).

7. **Comments from the referee:** pg 9 line 20 "temporal variations of" change to "standard deviations of"

   Author's response:
   Done (page 9 line 2).

8. **Comments from the referee:** pg 11 line 3 "the mean and the standard Tb deviation" although what is meant is clear, but more proper would be "the mean and the standard deviation of the Tb differences"

   Author's response:
   Done (page 11 line 9).

9. **Comments from the referee:** pg 13 line 15 "first kilometer there" change to "first kilometer, there"

   Author's response:
   Done (page 14 line 9).

10. **Comments from the referee:** pg 14 line 13 "any temporal dependence" is "any diurnal dependence" meant here?

Author's response:
Done (page 15 line 3).

11. **Comments from the referee:** pg 16 line 3 "patter"change to "pattern"

    Author's response:
    Done (page 15 line 30).

12. **Comments from the referee:** pg 21 add DOI's to the references where applicable

    Author's response:
    Done.