EVALUATION OF STATISTICAL RETRIEVAL ERRORS FOR GROUND BASED MICROWAVE RADIOMETER MEASUREMENTS

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1. INTRODUCTION

Dual frequency ground based microwave radiometers (MWR) are widely used to measure precipitable water vapor (PWV) and integrated cloud liquid water (ICL). In the statistical retrieval method, where the relationship between measured brightness temperature (Tb) and opacity (τ) is used, an accurate statistical retrieval algorithm is required. These algorithms include a set of input parameters whose values vary according to location, season, and weather conditions, [1]. One of these input parameters, the mean radiating temperature of the atmosphere (Tmr), is assumed to be known, [2, 3]. The importance of the reduction of the MWR measurement error has increased because are often used as references for other instruments, such as the Global Position Systems (GPS). Consequently different methods of specifying Tmr have been established [2]. The quality of the radiometer retrievals is usually established by comparing it with radiosonde measurements, while the most frequently used estimation of the Tmr value is a monthly mean value calculated from the climatological data.

For different MWR sites and seasons the contribution of the Tmr errors in the statistical retrievals will be different. The main objective of this study is to exam the PWV and ICL MWR retrieval errors due to Tmr uncertainty across Canada during the year. The results should give us awareness on when it is necessary to consider an alternative way of estimating Tmr besides the common climatological approach. This is especially the case when the MWR site is not close enough to one of the climatological radiosonde locations. Also the results can be used to estimate how much the MWR measurements could be improved with a different substitution of Tmr.

2. THEORETICAL APPROACH

If a symbol R represents the MWR retrievals of PWV or ICL, then the statistical retrieval equation can be written as:

$$R = a_0 + \sum_{f=1}^{2} a_f \tau_f \ , \tag{1}$$

where a_0 and a_f are site-specific coefficients for two radiometer frequencies obtained from multi-linear regression and τ_f is the opacity of the atmosphere at a given frequency f:

$$\tau_f = \ln \frac{T_{mr,f} - T_c}{T_{mr,f} - T_{b,f}}, \tag{2}$$

where $T_{mr,f}$ and $T_{b,f}$ are the mean radiating temperature and the brightness temperature of the atmosphere, respectively, at a given frequency f. The constant background cosmic radiation of 2.75K is noted as T_c .

After differentiation of equation (1), we can arrange the elements into two groups:

$$dR = \delta a_0 + \sum_{f=1}^{2} \delta a_f \tau_f \quad + \quad \sum_{f=1}^{2} a_f \delta \tau_f \ . \tag{3}$$

The first two terms on the right side represent error due to the uncertainty of the statistical retrieval coefficients. The third term represents error due to opacity uncertainty and it's explicate form is obtained from differentiation of opacity equation (2):

$$\delta\tau_f = \delta T_{mr,f} \frac{T_c - T_{b,f}}{(T_{mr,f} - T_c)(T_{mr,f} - T_{b,f})} + \frac{\delta T_{b,f}}{T_{mr,f} - T_{b,f}} \ . \tag{4}$$

Equation (4) includes errors due to Tmr uncertainty (first part) and due to the instrumental error (second part).

The discrete expended form of equation (3) is summarized in the following four equations for MWR statistical retrieval errors:

$$\Delta R = \Delta Rs + \Delta Rm + \Delta Ri \,, \tag{5}$$

$$\Delta Rs = \Delta a_0 + \sum_{f=1}^{2} \left(\tau_f \Delta a_f \right), \tag{5a}$$

$$\Delta Rm = \left| \sum_{f=1}^{2} a_f \Delta T_{mr,f} \frac{T_c - T_{b,f}}{(T_{mr,f} - T_c)(T_{mr,f} - T_{b,f})} \right|, \tag{5b}$$

$$\Delta Ri = \sum_{f=1}^{2} \frac{a_f \Delta T_{b,f}}{T_{mr,f} - T_{b,f}} \quad . \tag{5c}$$

ΔRs and ΔRi can be calculated directly because all of the terms in equations (5a) and (5c) are known. The error due to the statistical retrieval coefficients uncertainty (ΔRs) is calculated from the multi-linear regression while the instrumental error (ΔRi) is provided by the manufacturer.

Analyzing the error due to Tmr uncertainty (ΔRm), equation (5b), is the object of this study. Particularly, the variation of PWV and ICL retrievals with $\Delta T_{mr,f}$ calculated from radiosonde observations (RAOB).

3. RADIOSONDE DATA PROCESSING

Values of Tmr and Tb for the 23.8 and 31.4 GHz frequencies and values of PWV and ICL were calculated using algorithms based on the radiative transfer theory for non-scattering atmosphere [4] to a large database of 10 years of RAOB profiles from 1999 to 2008 for 30 locations across Canada and one from US location (Buffalo).

The set of retrieval coefficients a_i ,i=0,1,2 in equation (1) and there uncertainties were calculated using multi-linear regression between PWV or ICL and opacities (2) for monthly subsets of RAOB data for each location. In the opacity equation (2) the Tmr values were approximated as monthly constant values equal to the monthly averaged Tmr value. Since the averaged Tmr value was used instead of the current Tmr value, the Tmr error is estimated as the standard deviation of Tmr which was substituted in (5b).

4. RESULTS AND DISCUSION

The monthly variation of the MWR retrieval errors of ICL and PWV due to the uncertainty of Tmr are shown in Figures 1a, and 1b, respectively. In both graphs the blue star symbols represent monthly averaged errors for each site (31 points for each month) while the red line connects monthly averaged values from all 31 sites. For both retrievals it is evident that generally across Canada the biggest averaged error is in the period between June and October, while during the winter it is the smallest. Closer inspection of (5b) shows that this yearly cycle is caused by the yearly cycle of Tb and Tmr.

The presented monthly averaged retrieval errors for 31 sites have significant variation depending on the RAOB's location. During the period with more liquid precipitation, May-November, this variation is bigger and for some locations it could be up to 35μm for ICL and 0.05cm for PWV. The intensity of variation of the ICL and PWV errors is much more widespread, as shown in the example for the month of September in Figures 2a. and 2b., respectively. The errors could go up to 100μm for ICL and almost 1cm for PWV.

5. CONCLUSION

The study shows that for different sites across Canada and seasons the contribution of the Tmr errors in the statistical retrievals for typical ICL is about 0.005mm, while for PWV it is about 0.005cm, and it may go up to 0.1mm (2%) and 0.8cm (12%), respectively. Those errors could be much bigger if a MWR site is not close enough to one of the climatological radiosonde locations.

For the practical use of the obtained results as guidance as to when it is necessary to consider an alternative way of estimating Tmr besides the common climatological approach, a study with more details should be published.

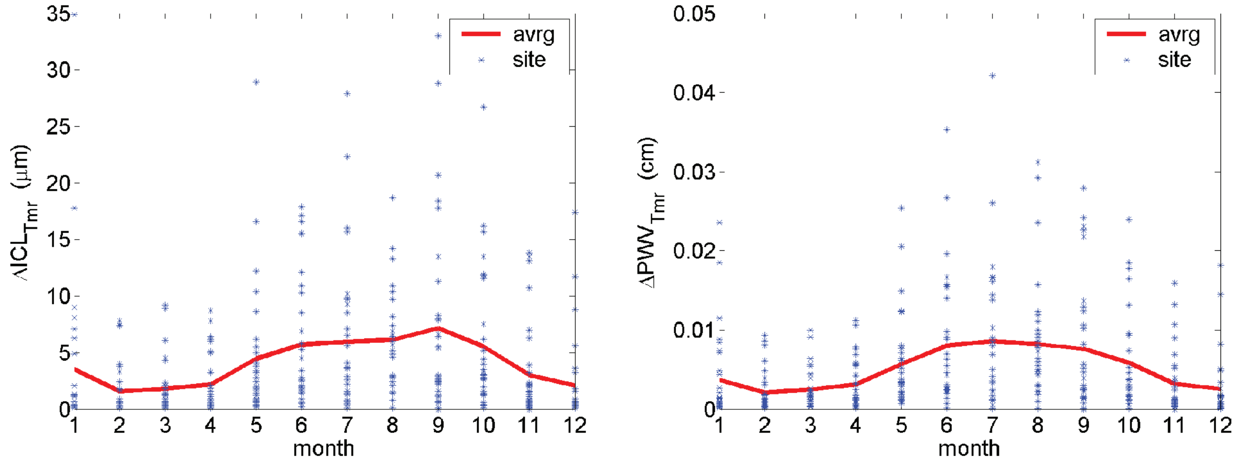

Figure 1. Monthly variation of the site averaged ICL (a) and PWV (b) errors due to the uncertainty of Tmr. The blue star symbols represent monthly averaged errors for a site; the red line connects site and monthly averaged values.

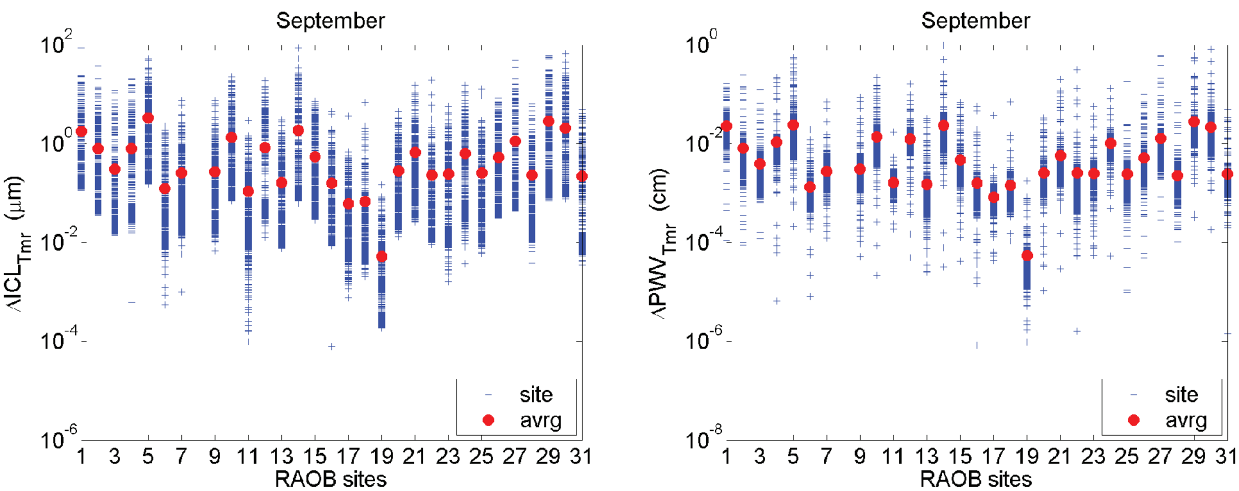

Figure 2. Sites variation for September for ICL (a) and PWV (b) errors due to the uncertainty of Tmr. The blue star symbols errors for a site; the red line connects site averaged values.

6. REFERENCES

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