RETRIEVAL METHOD OF PATH-INTEGRATED LWC FOR AIRBORNE UPWARD-LOOKING MICROWAVE RADIOMETER USING CLOUD MODEL

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1. INTRODUCTION

Cloud liquid water content is always one of the most important quantities in many subjects and operations, particularly in modification weather. In order to detect the path-integrated cloud liquid water content (L), the Institute of Atmospheric Physics, Chinese Academy of Science develops the airborne up-looking microwave radiometer.

1.1 FORMER METHOD (METHOD 1) [1]

In lower and middle troposphere the relationship between bright temperature (Tb) and L is as follow:

$$L(h)=a_1(h)+a_2(h)\times(Tb(h)-a_0(h))+a_3(h)\times((Tb(h)-a_0(h))^2 \quad (1)$$

h is the height of the radiometer; $a_1(h)$, $a_2(h)$, $a_3(h)$ are the coefficients of the equation; $a_0(h)$ is the average value of Tb at the height h. The a_0, a_1, a_2, a_3 are obtained as the function of height.

$$a_j(h)=\sum_{i=0}^{5}a_{ji}(h-h_0)^i,(j=1,2,3) \quad (2)$$

$$a_0(h)=\sum_{i=0}^{3}a_{0i}(h-h_0)^i \quad (3)$$

h_0 is the average value of height and a_{ji}、a_{0i} are the fitting coefficients.

The coefficients of retrieval equation are obtained through statistic regression method. In the former method (method 1), the statistical samples (sample 1) are produced by historic radiosonde data which are employed to determine the vertical distribution of cloud liquid water content by testing for relative humidity above some threshold value. But such method has some shortages: ①As the dynamic and microphysical processes of stratiform cloud are not considered, the statistical samples are not consistent with the synoptic observations very well; ②As the background atmospheric conditions (i.e. the vertical distribution of vapor and oxygen) of the radiosonde data which are from many years have very large differences, the relationship between Tb and L is not quite accurate; ③ It's not very convenient to pick up radiosonde data from many years for a certain place and a certain month especially during dry season.

1.2 NEW METHOD (METHOD 2 AND 3)

In order to solve the above-mentioned problems, we develop a new retrieval method (method 2) in this paper. The coefficients of retrieval equation are obtained through statistic regression method like former but the statistical samples (sample 2) are produced by the one-dimensional stratiform cloud model [2]. The input of the model include the radiosonde data which is most close to the time when the microwave radiometer works and the actual profile of vertical updraft velocity. The output is the temporal and spatial distributions of cloud liquid water content. As the actual profile of vertical updraft velocity is unknown, we assume several typical profiles [3] (fig. 1) to simulate the possible processes in the stratiform cloud.

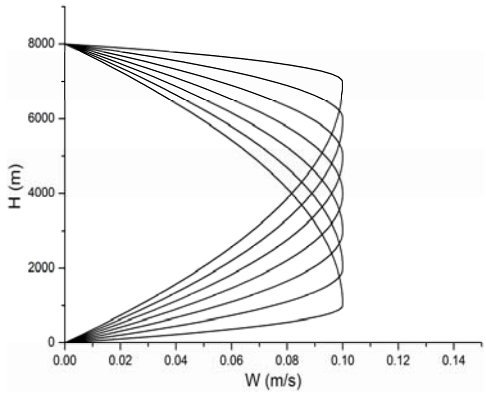

Fig. 1 Profiles of vertical updraft velocity *w*
(every line represents a type of profile)

The factor analysis indicates that the errors caused by the uncertainty of the vertical distribution of cloud liquid water content can not be ignored when compared with the errors caused by the background and the instrument drift errors. In order to improve the retrieval accuracy, we use selected cloud samples (sample 3) which are supplied by cloud model to regress retrieval coefficients according to the synoptic observation (method 3).

2 THE CASE OF 8 JULY 2001 IN JILIN

The flight record and the radiosonde date at 8:00 (CST) that day showed that there were large area of Sc and As on the route and the top of the cloud was above 4km.

2.1 METHOD 2

The samples which have two-layer structure in sample 2 is 35.6% while in sample 1 is 12.5%; the samples whose top of cloud exceeding 4km in sample 2 is 100% while in sample 1 is 40.8%. It's obvious that sample 2 is consistent with synoptic observations much better than sample1.

The fig. 2 compares sample 2 and sample 1 at 0.239km (i.e. the altitude of the station) and 4.039km (i.e. the altitude of the flight). We can see that: ① When L is small sample 2 is concentrated in the middle of sample 1. That's because method 2 decreases the uncertainty of backgrounds of the samples. ② When L is large most of the samples in sample 2 are below sample 1 which makes the fitting line of method 2 migrating downward. That's because the tops of clouds in sample 2 are higher and the temperatures of the clouds are lower, so for the same value of L, the corresponding Tb is higher.

The fig. 3 and 4 show the numerical simulation tests [1] for the fitting coefficients obtained from method 1 and 2. The independent test result indicates that the retrieval accuracy of method 2 is better than method 1 at all altitudes and the statistical relative errors has decreased by 0.15%～7.28% .

The fig. 5 show retrieval results of the radiometric data. When we compare this figure with fig. 4 and correlated contents in literature [4], we can see that: ① The two retrieval results have a positive correlationship. ② The retrieval result is correlated with the PPI of radar qualitatively. ③ The improvement is meaningful when compared with the instrument drift errors.

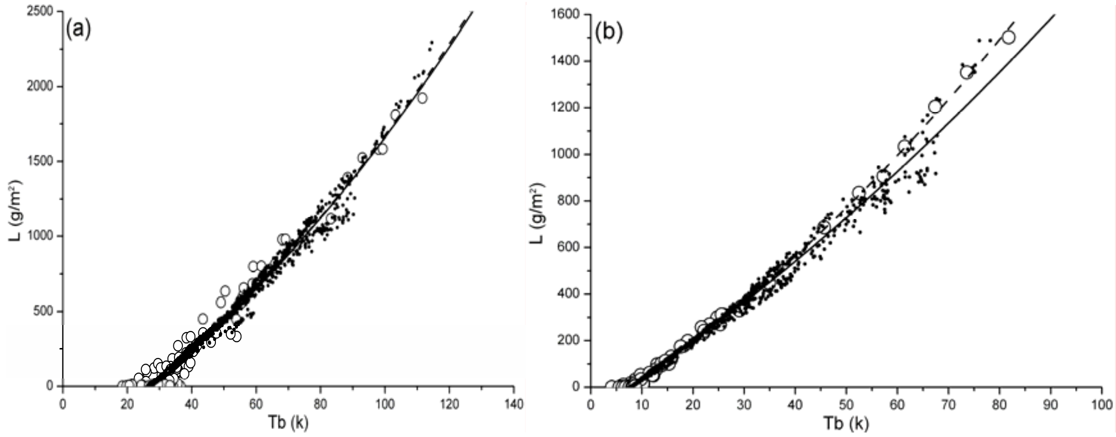

Fig. 2 The comparison of statistical samples at 0.239 km (a) and at 4.039 km (b) produced by method 1 and 2. Open points for fitting sample 1 and dashed line for its fitting line; solid points for fitting sample 2 and solid line for its fitting line

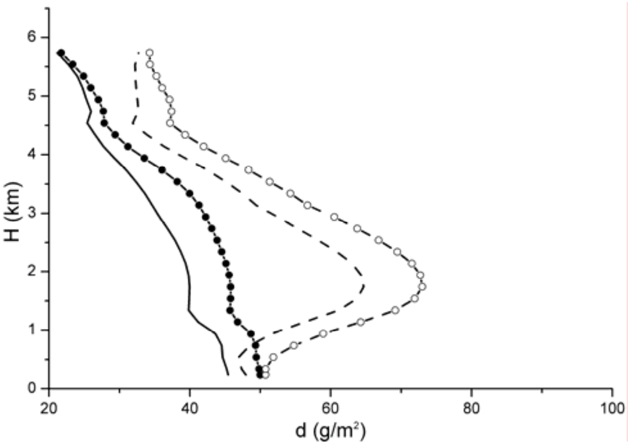

Fig. 3 RMS-errors of retrieved integrated liquid water content with its simulated 'true'
Solid line for self-test results of coefficient 2; dashed line for self-test results of coefficient 1. Solid points for independent test results of coefficient 2; open points for independent test results of coefficient 1

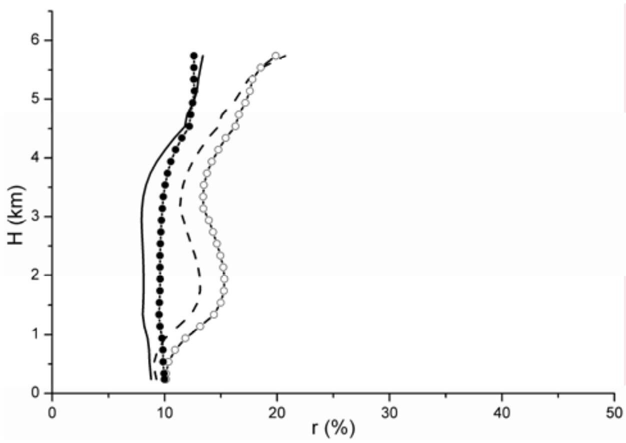

Fig. 4 The same as fig. 3, but for relative errors

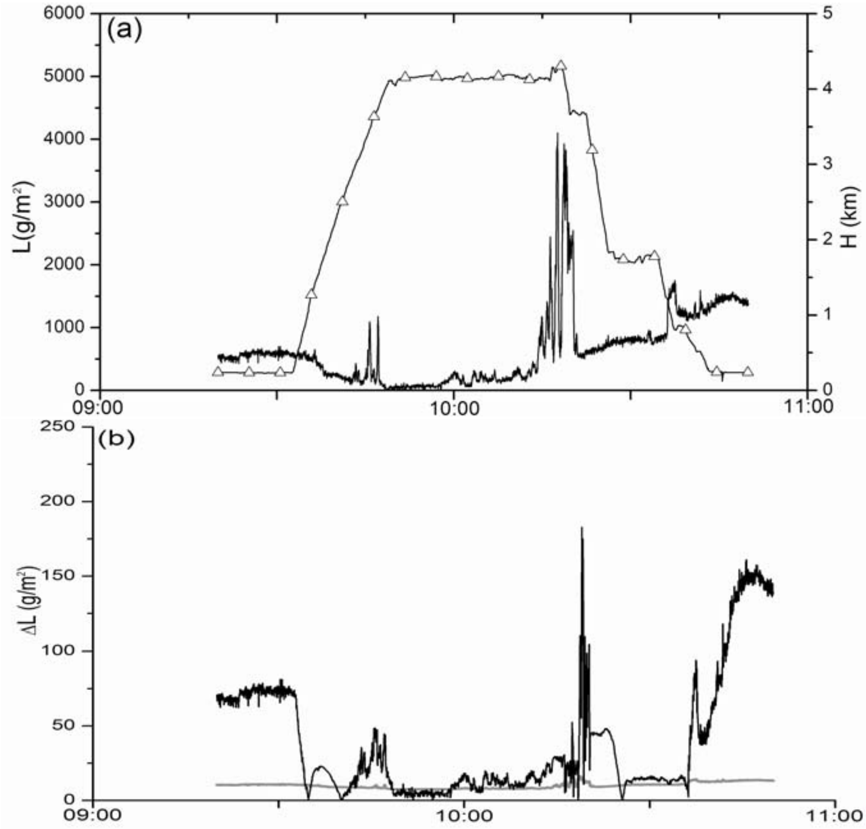

Fig. 5 Retrieval results of the radiometric data in 8 July 2001 with method 1 and 2: (a)Method 2, solid line for temporal series of L, open triangle for flight height measured by a GPS system; (b) Black line for absolute difference between retrieval results of method 1 and 2, gray line for maximum absolute errors caused by instrument drift errors

2.2 METHOD 3

In this method, we select the samples which have two-layer structure and whose tops of clouds exceeding 4km according to the synoptic observation.

The independent test results in fig. 6 and 7 indicate that RMS-errors and relative errors decrease at all altitudes and the relative errors decrease by 0.9%～15.9% when compared with method 1 and 0.5%～4.6% when compared with method 2. In conclusion, method 3 makes a further improvement of retrieval accuracy.

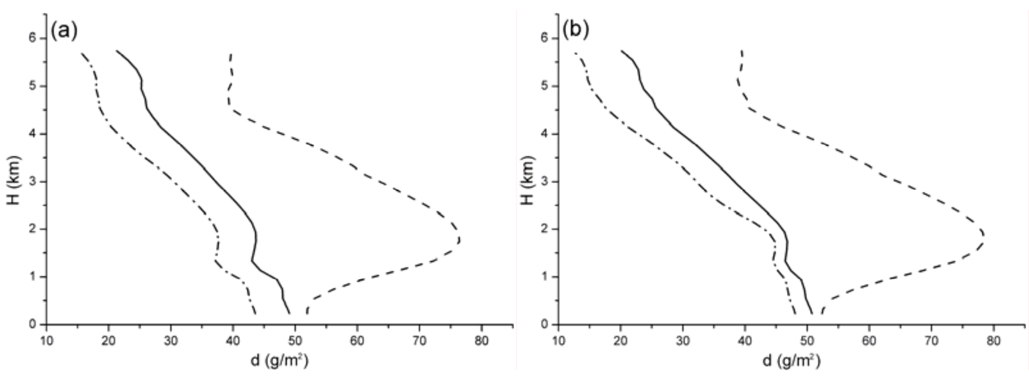

Fig. 6 RMS-errors of retrieved column liquid water content with its simulated 'true'

(a)Self-test; (b)Independent test

Dashed line for method 1; solid line for method 2; dot-dashed line for method 3

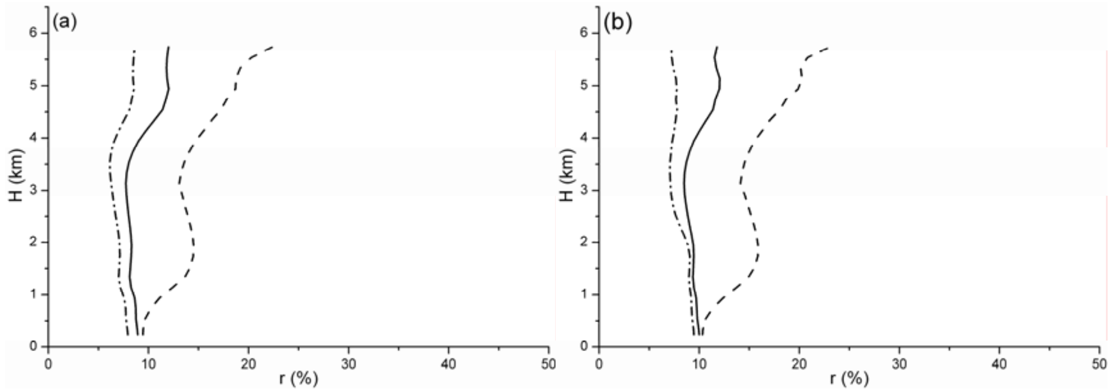

Fig. 7 The same as fig. 6 but for relative errors

3 CONCLUSIONS

Besides the case of 8 July 2001, we have made experiments on more cases, such as 9 July 2001 and 22 April 2002 in Jilin. They all show some similar results:

①The statistical samples of new method are consistent with the synoptic observations much better than the samples of former method.

②The uncertainty of the background field decreases obviously.

③The retrieval accuracy of method 3 increases by 0.9% ～ 37.2% when compared with method 1. This improvement is meaningful when compared with the instrument drift errors.

④The horizontal distributions of L are correlated with the distributions of PPI echo intensity of surface weather radar very well.

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