TEMPERATURE AND HUMIDITY PROFILES RETRIEVING OVER LAND USING CLEAR SKY MEASUREMENTS OF MICROWAVE HUMIDITY-TEMPERATURE SOUNDER ON CHINESE FY-3C SATELLITE

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ABSTRACT

An one-dimensional variational retrieval system was developed to retrieve the clear sky atmospheric temperature and humidity profiles over land using the measurements of microwave humidity-temperature sounder (MWHTS) on Chinese FY-3C satellite. The system parameters are configured by analyzing the MWHTS channel properties and the climate condition over land. The retrieval results are evaluated by root mean square error (rmse) with respect to European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis data. The validated results show that the maximum root mean square error of temperature and humidity are 2.59K and 11.87%, respectively. The retrieval results, compared with National Centers for Environmental Prediction (NCEP) 6 hour forecast profiles, show that the background profiles can affect the accuracy of retrieval proflies and FY-3C/MWHTS measurements can improve forecast precision of humidity.

Index Terms— FY-3C/MWHTS, one-dimensional variational retrieval system, clear sky, temperature and humidity profiles, land

1. INTRODUCTION

Temperature and humidity play a very important role in meteorological research. Such parameters may not only be used to assess the atmospheric stability and to assist in nowcasting of convective weather but also to monitor climate[1]. There are a lot of public literature researching on retrieving these two parameters using satellite measurements[2,3]. Physical retrieving is considered to be the basic method which obtain the atmospheric parameters by solving the radiative transfer equation, and to be the most effective way to improve retrieval accuracy. The FY-3C satellites was successfully launched on 23 September 2013 and carries the Microwave humidity-temperature sounder onboard whose measurements can be used to retrieve the atmospheric temperature and humidity profiles simultaneously[4].

In this paper, we first analyze the parameters of an one-dimensional variational retrievial system which affect the retrieval accuracy, and then choose the optimum parameter combinations for MWHTS. The retrieval system of MWHTS use the measurements of China land in clear sky to retrieve the temperature and humidity profiles, and the preliminary results show that this system has higher accuracy.

2. ONE-DIMENSIONAL VARIATIONAL RETRIEVAL SYSTEM

2.1 one-dimensional variational retrieval system mathematical basis

The one-dimensional variational retrieval system employs the RTTOV as the forward radiative transfer model to calculate the simulated brightness temperatures. The iterative process of this system used in this paper aims at minimizing the following cost function[3]:

$$J(X)=[\frac{1}{2}(X-X^B)\times B^{-1}\times(X-X^B)]+$$
$$[\frac{1}{2}(Y^O-Y(X))^T\times E^{-1}\times(Y^O-Y(X))]$$

where X^B and B are the background and error covariance matrix of X, which is the parameter to be retrieved, respectively. E is the measurement error covariance matrix, including the observation error covariance matrix and the modeling error covariance matrix. Y^O and $Y(X)$ are the observations and simulated measurements. The minimization of this cost function is the basis for the variational retrieval. The solution that minimizes this cost function is found by solving for

$$\frac{\partial J(X)}{\partial X}=0$$

This results in the following solution:

$$\Delta X_{n+1}=[BK_n^T(K_nBK_n^T+E)^{-1}]$$
$$\times[(Y^O-Y(X_n))+K_n\Delta X_n]$$

where n is the iteration index. *K*, in this case, is the Jacobian or the derivative of *Y* with respect to *X*.

2.2 one-dimensional variational retrieval system parameters

In this paper, in order to assess the accuracy improvement of NCEP 6 hour forecast profiles by the retrieval, the retrieval system selects the NCEP 6 hour forecast profiles as the background profiles. The background error covariance matrix is generated using ECMWF reanalysis data, the exact formula is given as follows [3]:

$$\sigma_{ij}^2=\frac{1}{N}\sum_{i=1}^{N}\sum_{j=1}^{N}(x_i-\bar{x}_i)\times(x_j-\bar{x}_j)$$

where σ_{ij}^2 is one of the elements of the matrix corresponding to row i and column j. N is the number of profiles, and $\bar{x}$ is the average value along the row or along the column.

For the difference between the observations and the simulated brightness temperatures, a statistic regression method is proposed to correct the bias piexl by piexl. The exact formula is given in the following[5]:

$$T_{ij}^*=a_{ij}T_{ij}+b_{ij}ab$$

where T_{ij}^* are the correct MWHTS brightness temperatures and T_{ij} are the original observed brightness temperatures, i is channel index and j is pixel index. a and b are the slope and intercept coefficients, respectively. The measurement error covariance matrix is generated using the forward model error and the channel noise.

2.3 convergence check

The following quantity is computed to check the convergence

$$\frac{|J_{n+1}-J_n|}{J_n}<0.01$$

That is, if the relative value of the cost function changes within 0.01, and the maximum number of iteration is less than 10, then the iteration is stoped, and the retrieval is set to the background profiles.

3. RETRIEVAL ACCURACY AND ERROR ANALYSIS

In this paper, root mean square error is considered as the standard quantification to validate the retrieval with ECMWF ERA Interim reanalysis data. FY-3C/MWHTS data from April and May 2015 were used in a detailed comparison between MWHTS sounding profiles and ECMWF reanalysis profiles, as well as the background profiles. Only MWHTS data in clear sky over China land within 0.5h of ECMWF reanalysis data and 0.05° latitude/longitude are used in retrieval validation. Fig. 1 shows the vertical distribution of rmse of the retrieval profiles and the background profiles with respect to ECMWF reanalysis data. The accuracy of the retrieval is 2.59K for the temperature and 11.87% for the relative humidity. The validated results show that this retrieval system has higher accuracy. The rmse of the retrieval for humidity profiles is smaller than that of the background profiles, especially from 250 hPa to 750hPa, this suggests that the retrieval for humidity can improve the background profiles, i. e. NCEP 6 hour forecasts profiles.

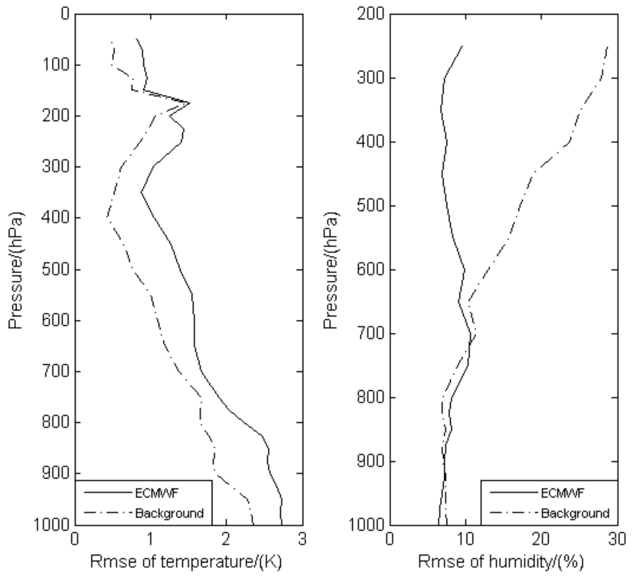

Fig. 1 Retrieval results

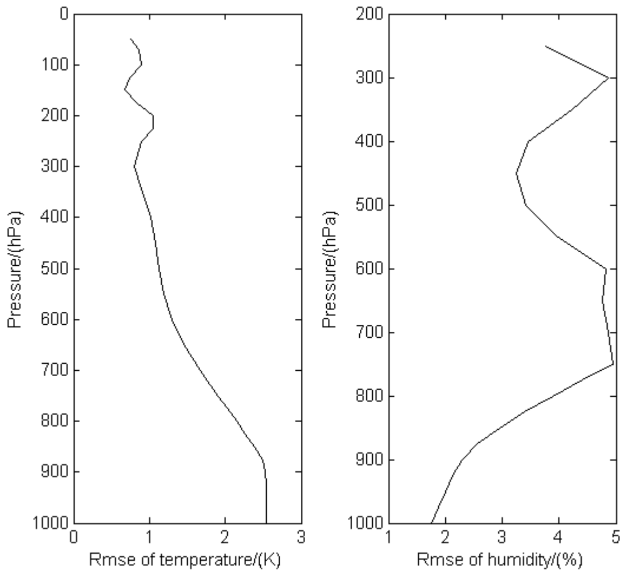

Fig. 2 The effect of background profiles on the retrieval accuracy

In order to assess the effect of the background profiles on the retrieval accuracy, we use the ECMWF reanalysis data as the background profiles to get the retrievals. The validated results are show in Fig. 2. The rmse of the retrieval is decreased compared with that in Fig. 1, especially for humidity profiles, which show that the background profiles which can bring a serious error are important to the retrieval system.

4. CONCLUSION

The paper built an one-dimensional variational retrieval system for FY-3C/MWHTS to retrieve the atmospheric temperature and humidity profiles in clear sky over land. The retrieval has higher accuracy, and can improve the accuracy of NCEP 6 hour forecast profiles, therefore, FY-3C/MWHTS is significant to numerical weather prediction. The background profiles, which are major error sources, can affect retrieval accuracy, we can select another data source which has higher accuracy with respect to the true state of atmosphere as the background profiles to improve the performance of the retrieval system in the further research.

5. REFERENCES

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