

The AMSU Observation Bias Correction and Its Application Retrieval Scheme, and Typhoon Analysis

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Abstract

Since most of AMSU channels have a beam position-dependent bias, it is crucial to remove such a bias for providing useful profiles of the atmosphere. Measurement errors are estimated from the differences between satellite observations and the simulated satellite observations, which were obtained from a radiative transfer operator with 12-hours forecast of their input. The measurement errors estimated in this way will contain the forecast error of a 12 hour forecast. The NMC method assumes that the statistics of differences between forecasts at different ranges valid at the same time are the representative of forecast error statistics. The differences used in the NMC method have been transferred to brightness temperature in each AMSU channel with the radiation transfer operator. These data can then be used to obtain the value of 12 hours forecast error in brightness temperature for each AMSU channel. Thus, the 12 hour forecast error in each AMSU channels can be removed when the measurement errors are estimated as mentioned above.

In this study, we carefully examine the AMSU beam near Taiwan. A bias correction method, which concerns the beam position-dependent bias and the effect of 12 hours forecast error used on the regression equations, has been built. A data retrieval method based on one-dimensional variational scheme has also been developed. Through the comparison of the retrieved profiles and the background fields, we found that the method worked well near the Taiwan area. Even with quite accurate background fields, the retrieved profiles have shown positive impact to improve the fields. The results show that the improvement made in the retrieval scheme over the background error is about 0.45K in the temperature profiles, above 780 hPa. The study used corrected AMSU data to identify thermal anomalies and estimate tangent winds that successfully analyzed typhoon structure.

Introduction

In the past few years much research has involved variational retrieval schemes. Variational retrieval methods are examined that under a precise background field provide better retrieval results (Eyre, 1989). A variational iteration method was applied in this research. One important issue in variational retrieval is to correct the satellite observation bias and to estimate random errors. Observation bias is estimated from the difference between observed brightness temperature and simulated brightness temperature. Simulated brightness

temperature is calculated based on a forecast model through a RTE model. So the observation bias is included in the numerical forecast model's error. In order to make the data correct for retrieval, a statistical correct scheme is needed.

Variational Methodology

The solution of the variational retrieval scheme is to get the minimum value of the cost function. Then it gets the best atmosphere parameter: x . The cost function is written as follows.

$$J(x) = (x - x^b)^T C^{-1} (x - x^b) + \{y^m - y(x)\}^T E^{-1} \{y^m - y(x)\} \quad (1)$$

x^b is background (or initial guess). C is covariance of background error. y^m is observation values. $y(x)$ is simulation values from RTE while atmosphere parameters are x .

The cost function is the sum of the deviation between x and the background and the deviation between the observed value and calculated value under x situation. So we should find a proper x that lets the calculated value correspond to the observation value relevantly. The methodology is using Newtonian iteration method (Eyre 1989).

$$x_{n+1} = x^b + W_n \{y^m - y(x_n) - K_n (x^b - x_n)\} \\ W_n = CK_n^T (K_n CK_n^T + E)^{-1} \quad (2)$$

When the value $x_{n+1} - x_n$ is smaller than a threshold, then above function converges.

The covariance error of the background field may be obtained by statistical calculation from the error of 12 hour forecast field (Parrish and Derber 1992). Errors of other parameters are set as follows, surface air temperature is 2.34K, surface air humidity is 0.3 ln(g/kg), surface temperature is 1.67K, surface pressure is 3.42hPa, the content of ozone is 40 Dobson, cloud height is 200hPa, cloud fraction is 0.5 and cloud liquid water content is 0.5mm. (Eyre 1990).

Surface emissivity is described as in (Grody 1988)

$$\varepsilon(\nu) = \frac{\varepsilon_\nu + \varepsilon_x (\nu / \nu_0)^k}{1 + (\nu / \nu_0)^k} \quad (3)$$

During the retrieval procedure the corrected magnitude of background error depends on the ratio of observation error and background error, which is presented by matrix E and matrix C . The calculation of the observation covariance error is a little complicated. The estimated satellite observation error includes instrument error, satellite data procedure error, radiation transfer model error and error of radiation model input parameters. In summary, above items could be classified into two items, that is systematic error and random error. Systematic error is possibly corrected. Random error is the diagonal elements in matrix E . Because the limb

effect of AMSU is asymmetrical, limb adjustment procedure is also necessary.

AMSU Bias Correct and retrieval result

The merit of variational retrieval can be applied directly to satellite observation data; it may avoid some errors which were caused during preprocessing (Eyre 1989). AMSU limb effects along the viewing angle are due to asymmetry, we must adjust for this. First, we plot the scatter diagrams of AMSU for each channel to each FOV. Before doing the adjustment, the difference between observation data and calculated data are chosen. This data should be estimated for its mean and standard deviation. If any channel differences between observation and calculated are larger than 3 times of the standard deviation, these data are treated as bad data. Channel 7, for four different scan angles, are shown in Fig. 1.

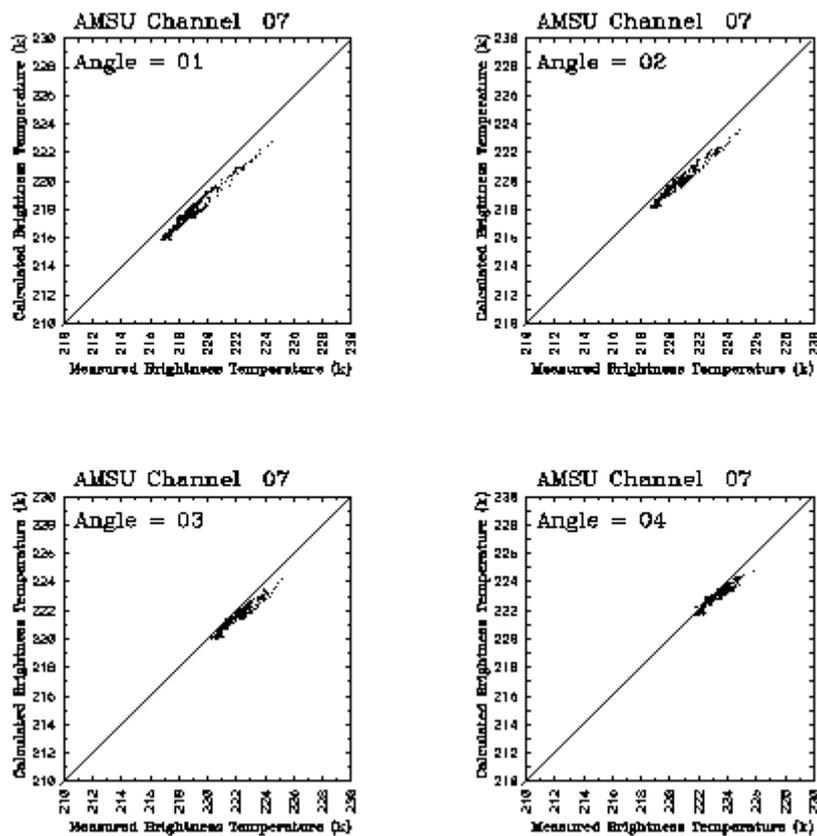


Fig.1: Scattering diagram of AMSU channel 7 for simulated Tb and measured Tb from FOV of 1 to 4. The scan angle biases are a little difference.

After proper data are selected, regression coefficients are calculated for each channel in each viewing angle to correct the observation. Then adjusted brightness $T^* = aT_B + b$ will be found, where T_B is the observed satellite brightness temperature, a is slope and b is intercept.

About 900,000 data were used to get these coefficients. Because estimated observation systematic error and random error are included in the background (forecast) error, the 12 hours forecast statistic error has been transferred to radiance. Then the background error can be removed. AMSU channel 2 is used as a parameter to adjust surface emissivity, this adjustment will be done when calculated T_b are equivalence to observed T_b . In reality it is not a proper procedure, but it is more reasonable when no observations of surface emissivity exist. Real data on 22 June 2002 were tested, and the improvement of vertical temperature is significant, as shown on Fig. 2.

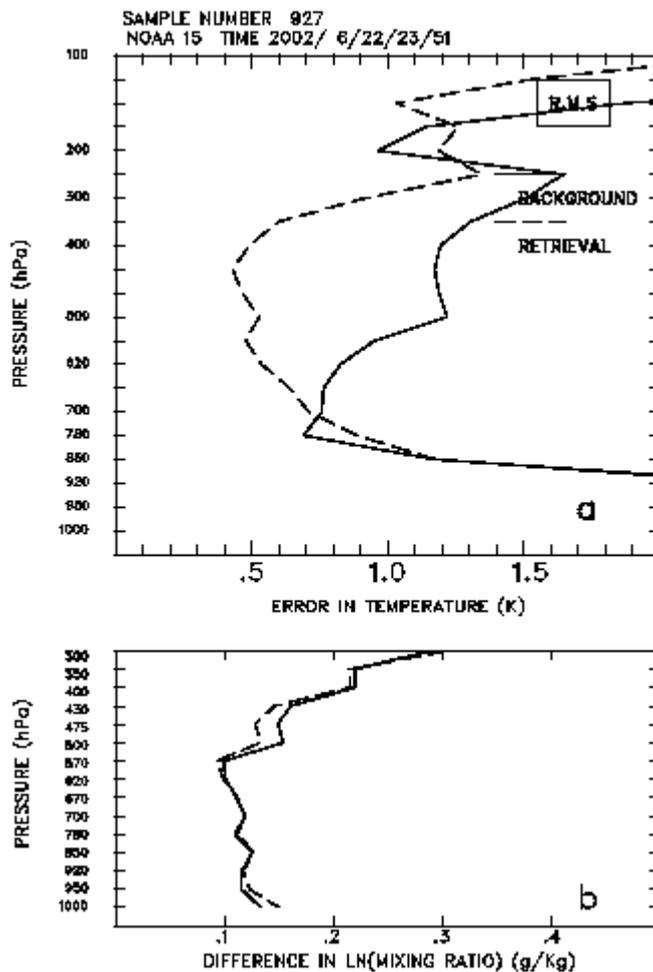


Figure 2. Real data on 22/Jun/2002 23Z. Total 927 corrected satellite observation were retrieved. (a)temperature (b)maxing ratio mean error covariance. Solid line is background error and dash line is error of retrieval.

Limb Adjustment on AMSU

For the asymmetry of AMSU limb bias, statistical methods were considered. We tried to use the algorithm from Goldberg(2001). Because of misinterpretation of the physical

coefficient, some channels of AMSU were not corrected. The results are shown on Fig 3. Surface channel 1,2 are correct, but others channels are failed to be correct. Further investigation is needed.

Typhoon Monitoring - methodology

Understanding the thermal structure of typhoons is helpful to weather forecasting. It has been examined that a relationship exists between temperature anomalies and the maximum wind and central pressure of tropical cyclones.(Kidder 2000) Whether to make a limb correction to each FOV before

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 Comparison for Limb Correction

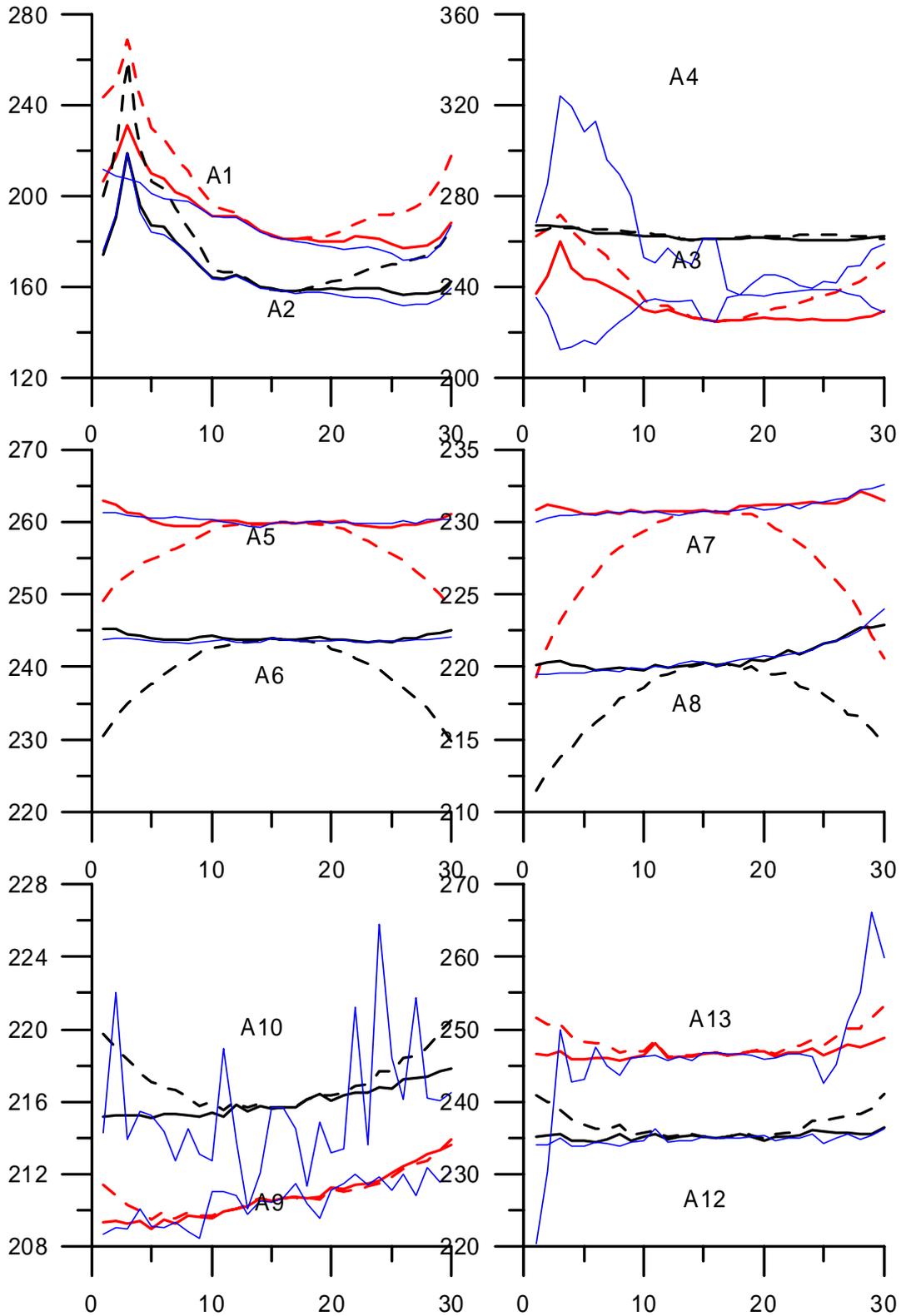


Figure 3. AMSU limb adjustment results for NOAA 16 channel 1-13. Dash line means raw data, red solid line means applied by NESDIS coefficients, blue line means results in this study.

retrieval or make a different set of coefficients for each FOV is a controversial problem. Zhu and Kidder (2002) show that the RMS error is less than 1.75K for the above two schemes. So here, the latter scheme was chosen for further processing.

AMSU has the capability to penetrate cloud, but the AMSU observation still can be interfered by raindrops. It may cause the temperature too cool under 700hPa in retrieval temperature profiles near the typhoon center. So under heavy rainfall situation channel 3-5 are not recommended be use in retrieval. Only channels 6-11 were used to retrieve temperature profile. When temperature profiles are retrieved from AMSU, the 2 or 3 dimension gradient wind vectors can be estimated using the gradient balance equation. The algorithm to estimate the 2-dimension gradient wind is from the paper of Kidder (2000). In order to study the center of a typhoon, the 250hPa highest temperature anomaly is located. The method used to drive the 3-dimension wind vector has been described in Zhu et al. (2002).

Typhoon Monitoring - result.

The above techniques was applied on the typhoon of 16/Oct/2001 23Z. As shown in Fig 4, AMSU channels 6-11 of NOAA-15 was used for the case study. The anomaly of temperature near the center of the typhoon is obviously identified. Anomaly warming extends from level 250hPa with anomaly of 7K to level 620hPa with a 4K anomaly. The warm core is a little inclined to the north. The gradient wind is changing with the radius of typhoon and pressure variance as shown in Fig 5. Maximum wind speed is located at a radius about 100km. Mean maximum wind speed is about 25m/s. From the pattern of the wind fields, positive vorticity exists in the lower layer of the typhoon. Weak negative vorticity is located on upper layers of the typhoon. The structure of the typhoon is reasonable, given general acknowledge. The core of maximum wind speed inclines to the outside, this is characteristic of a strong typhoon. According to the empirical function (Kidder 2000) , the temperature anomaly is used to estimate the maximum wind speed and radius of maximum wind speed. This typhoon has a maximum temperature anomaly of about 10.5K, so the maximum wind speed should be 46m/s, and radius of maximum wind speed is 125Km. From Fig. 5 mean maximum wind speed is about 25m/s, which is the value of the mean azimuth angle. So the estimated wind speed is reasonable. Others cases were studied and provided a reasonable analysis.

Conclusion

AMSU data is a widely used in NWP and weather analysis. We applied proper adjustment to correct the observation error, allowing AMSU data to be used more precisely. When the observation error is corrected, the 1D variational retrieval test shows that the correcting process is needed.. Temperature anomalies can be obtained from retrieved temperature profiles. Based on these temperature profiles, the 2 and 3dimension wind vectors are

successfully driven. A local typhoon statistical analysis database is necessary for further utilization. Typhoons often make a severe disaster in the northwest Pacific Ocean area. AMSU may provide more precise information on typhoon analysis.

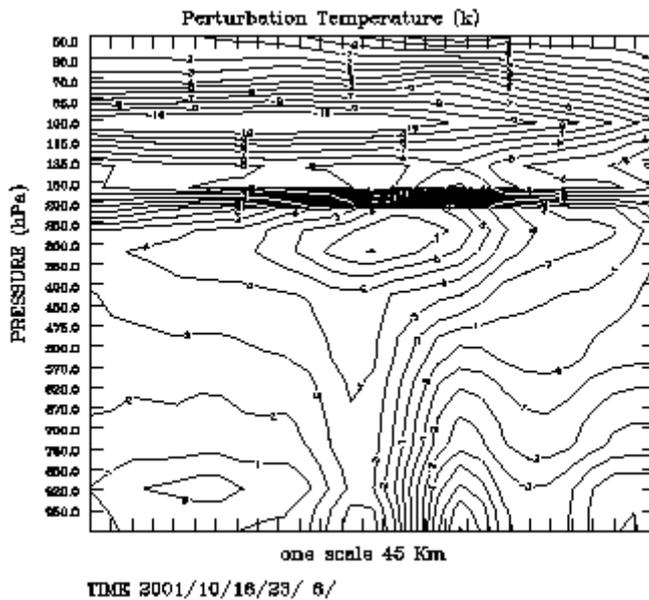


Figure 4. Temperature anomaly analysis profile obtained from south to north (right) on Typhoon HaiYen

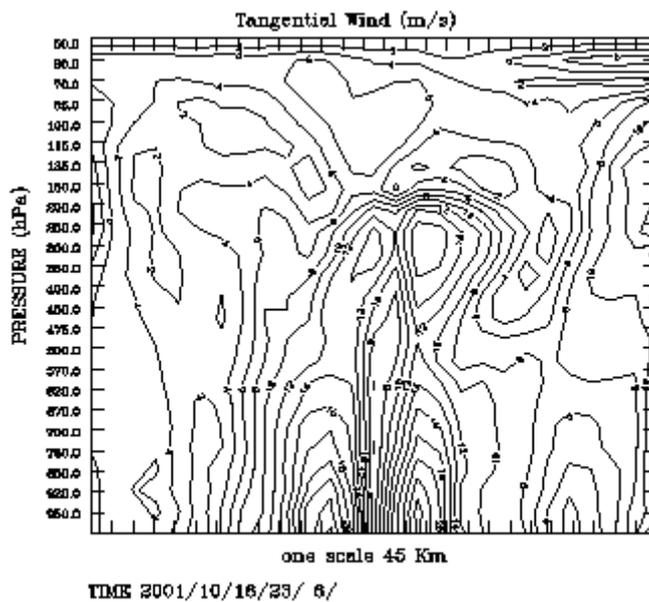


Figure 5. Gradient wind profile (Mean azimuth) on typhoon HaiYen.

The effect of ice particles on AMSU is needed for further study. Precipitation and water vapor content were not considered in this research. That will be the future task.

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