Data Quality Determination of Radio Occultation in moist troposphere

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ABSTRACT

How to observe the atmosphere is a subject of atmospheric research. The meteorological satellites and the ground states are used to do observation. However, both ways do not satisfy the requirement of scientists, especially the profiles of atmosphere on the ocean and the data for global atmosphere. Radio occultation (RO) technique, which has been used in planet science, is a method to solve the problem. In RO technique, the low Earth orbit (LEO) satellite receives the two frequency signal of Global Positioning System (GPS) satellite. The excess phase of the signal is calculated to retrieve the profiles of atmosphere parameters. In moist troposphere, the fluctuations appear in the phase of the signal and open loop (OL) is used to resolve it. The quality of the GPS signal generally deteriorates as the altitude decreases. In the procedure, the SNR of the GPS signal is used as the criterion. However, the SNR decreases with fluctuation which makes it difficult to locate the data of poor quality. In this paper, the phase of the signal will be used as part of the criterion.

KEY WORDS: Radio Occultation, Open Loop

1. INTRODUCTION

The atmospheric phenomena at low altitude (generally below 10 km) are of great interest for climatic modeling and weather prediction. When the GPS signal is transmitted through the low-altitude atmosphere, the multi-path and strong fluctuation caused by moist troposphere could deteriorate the quality of data. In FORMOSAT-3 data, open loop (OL) technique is used to replace the traditional phase lock loop (PLL) technique to track the GPS signal at low altitude. Basically, OL technique uses a frequency filter with pre-defined bandwidth to ensure signal receiving. However, with OL, the phase of the GPS signals are affected by navigation codes. It needs a follow-up algorithm to correct the phase. The quality of GPS data deteriorates as the altitude decreases. And eventually, the GPS signal becomes too weak for the algorithm to proceed. The data quality is the main factor which decides the lowest altitude of the retrieved parameter profiles. In the paper, a criterion of the quality of the GPS signal will be set up.

2. OPEN LOOP

Generally, PLL is applied to tracks the frequency of the signal using negative feedback. When the signal is transmitted through the atmosphere at low altitude, the multi-path and strong fluctuation caused by moist troposphere could deteriorate the quality of data. Thus PLL often fails in this situation. In order to circumvent this problem, OL, which had been used in planetary studies, is used to replace PLL at low altitude. OL use calculated phase model replace feedback received signal phase model to track received signal. PLL use feedback received signal phase model to track signal and it can modulate the influence of code. In OL, there is no information of code in calculated phase model, so it will affect the retrieval results by using excess phase. But the advantage of OL is that it can re-trace the lost signal when the frequency of the signal is in the trace range of OL phase model. The intermittent received signal will make the determination of data quality difficult.

3. CRITERIA OF DATA QUALITY

The quality of the GPS signal generally deteriorates as the altitude decreases. It is importance to find criteria with which the NCURO procedure can determine which portion of the data should be discarded due to the poor quality. In the algorithm, the SNR of the GPS signal is use as one of the criteria. The excess phases and the corresponding SNRs of the L1 and L2 signals are shown in Figure 1 and 2, respectively. Nevertheless, the SNR decreases with fluctuation which makes it difficult to locate the data of poor quality. In addition to SNR, the phase of the signal will be used as part of the criterion.

The quality of the phase can not be easily examined in the data of the excess phase. However, it can be examined in the data of Doppler. Figure 3(a) shows the Doppler of a L1 data. In the Doppler, the three line situation due to the activation of OL gradually become more indistinct and the data points distribute randomly at the end. The degree of clearness of the line in the plot of Doppler is defined as the quality of phase data. It is calculated by the process given below:

1. Use OL correction methods mentioned previously to correct Doppler without the consideration of the SNR. The result is shown in Figure 3(b).
2. Remove the Doppler effect by using partial line fitting, as shown in Figure 4(a). Use the function $b = \cos(2\pi a)$ to transfer the data, where a and b are the value of the points in Figure 4(a) and (b), respectively.
3. Get the standard deviation of each data point in Figure 4(b). The standard deviation of each data point is defined as the standard deviation

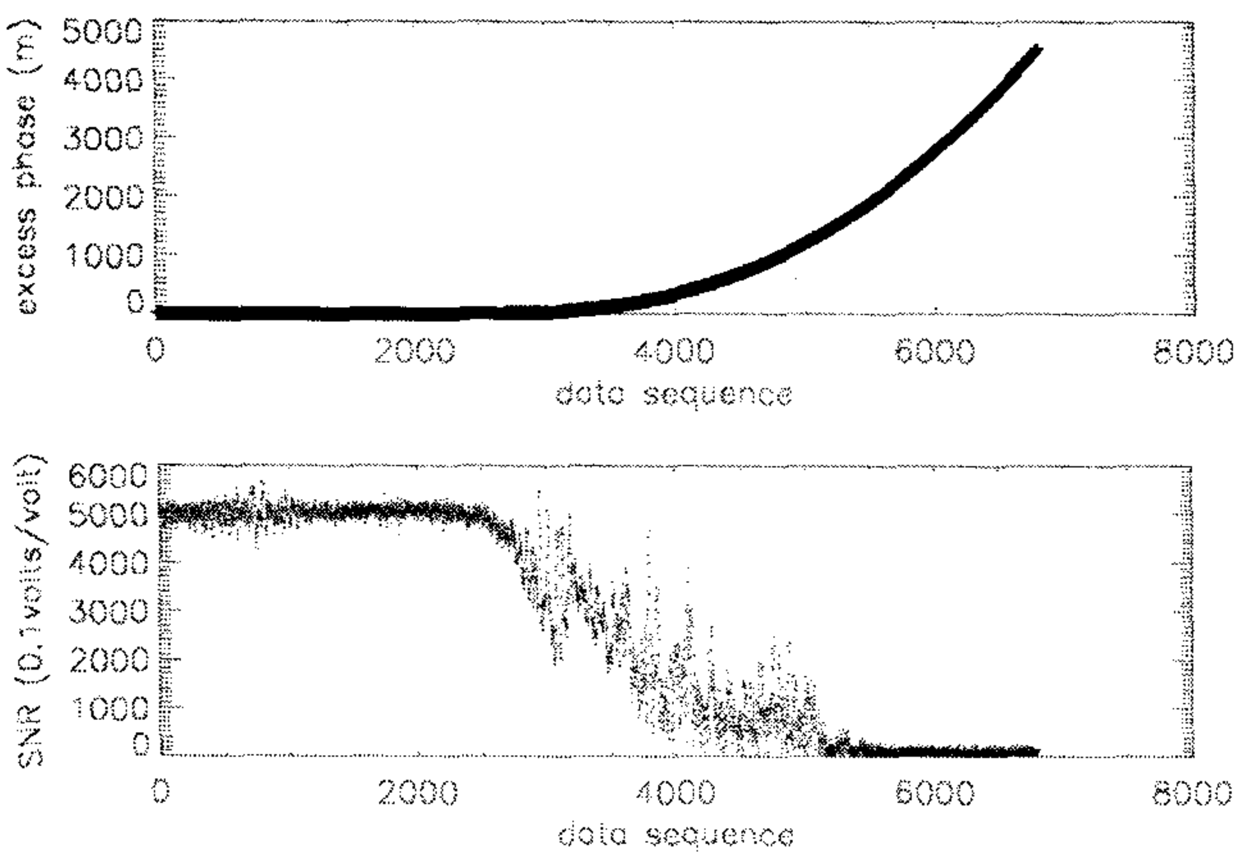


Figure 1. The excess phase of the L1 RO data (up), and its corresponding SNR (down). The data is from atmPhs_C001.2007.055.00.18.G14_0001.0001_nc.

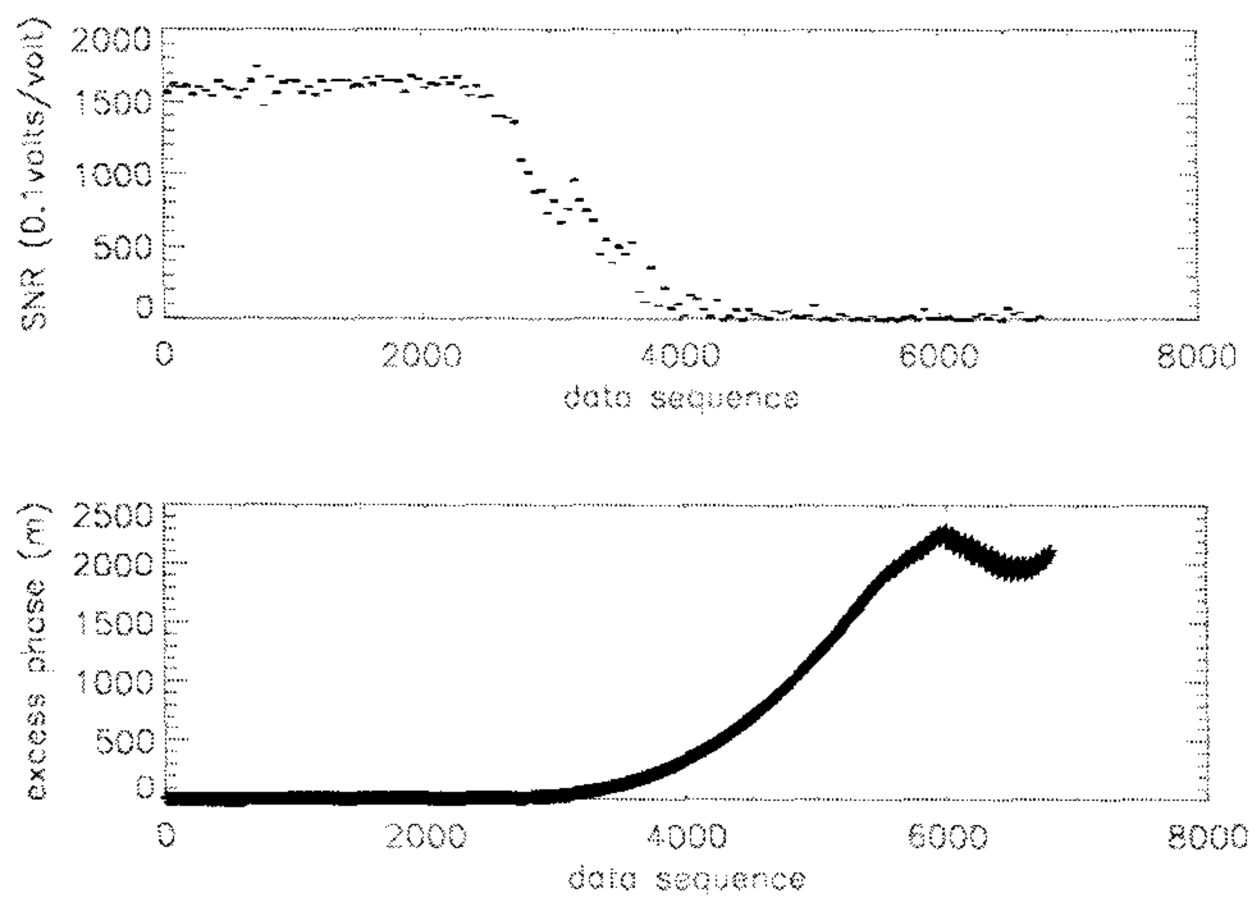


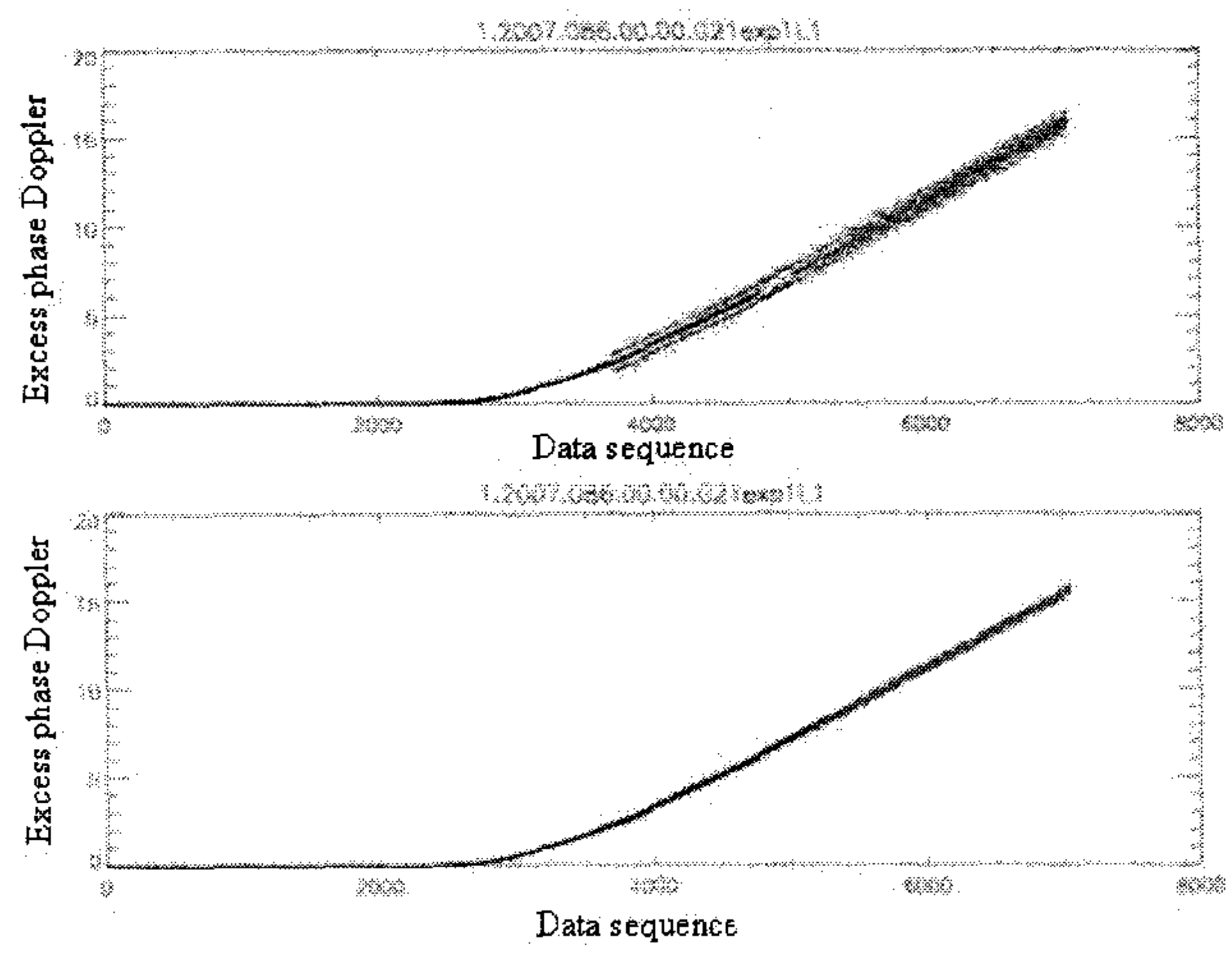
Figure 2. The excess phase of the L2 RO data (up), and its corresponding SNR (down). The data is from atmPhs_C001.2007.055.00.18.G14_0001.0001_nc.

of the nearest 50 points from each side of the data point. The result is shown in Figure14(c).

4. Regress the data at the back in Figure 4(c) which is larger than 0.1 by line fitting. The result is shown in Figure 4(d).

Figure 4(d) shows the degree of clearness, which is obtained by line fitting of the data in Figure 4(c). The main point of the criterion using SNR and the degree of clearness is to reject the data at the end of Doppler in Figure 3(a) where the data points distribute randomly and spread in ordinate. When the quality of the data fails the criterion, it is considered the receiver does not receive the GPS signal and this portion of data has to be rejected. After consider several tens of data, the degree of clearness is set to be 0.3 of ordinate.

Unlike the L1 signal, the quality of the phase of the L2 signal can be examined in Doppler easily. As shown in the Figure 5(up), the variation of the Doppler of the L2 signal at the end of sequence is much larger than



that of the Doppler of the L1 signal. To decide the cut-off point

Figure 3. The uncorrected (up) and corrected (down) Doppler of the RO data atmPhs_ C001.2007.055.00.18.G14_0001.0001_nc. In (b), the correction method is without navigation code.

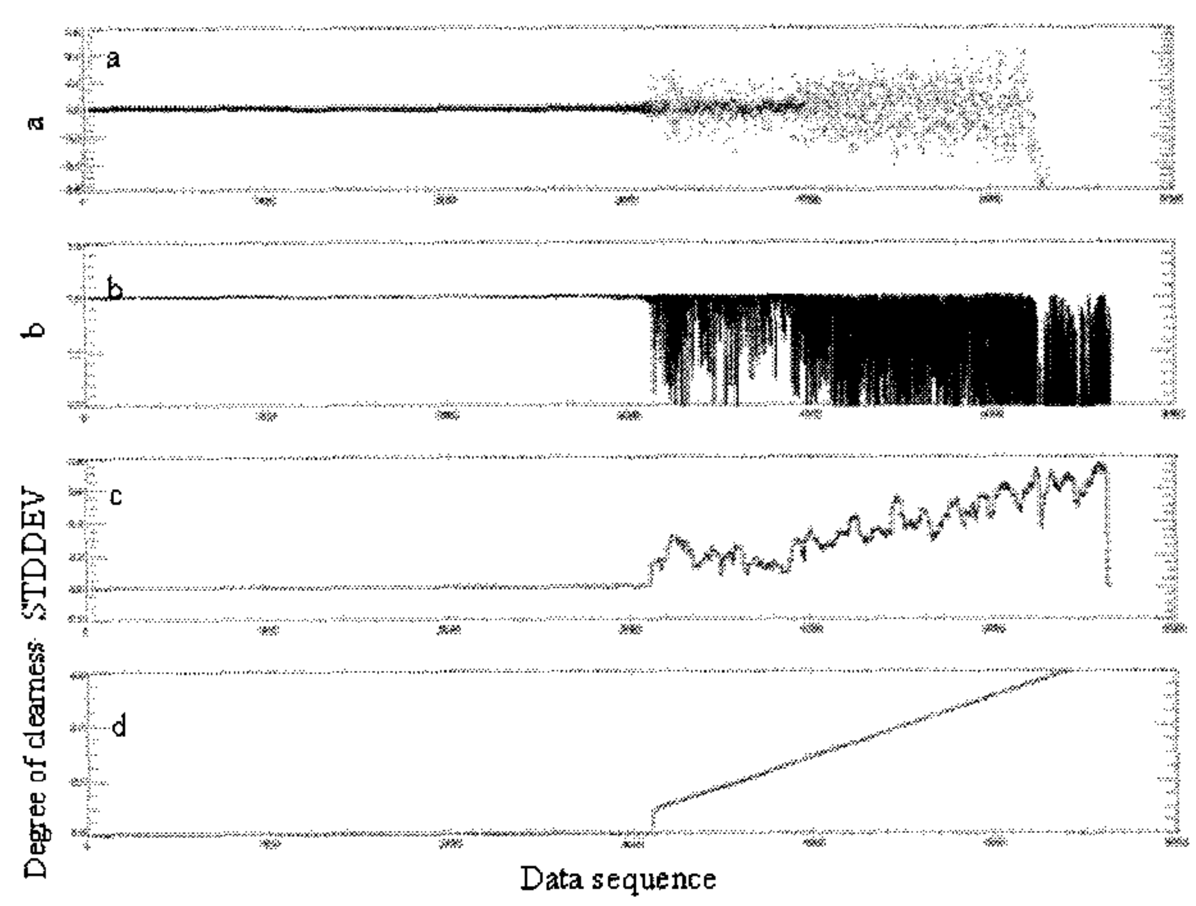


Figure 4. The calculation of the degree of clearness in section 4. (a) and (b) are calculated results corresponding to the steps 1 and 2, (c) is to step 3, and (d) is to step 4.The data is from atmPhs_C001.2007.055.00.18.G14_0001.0001_nc.

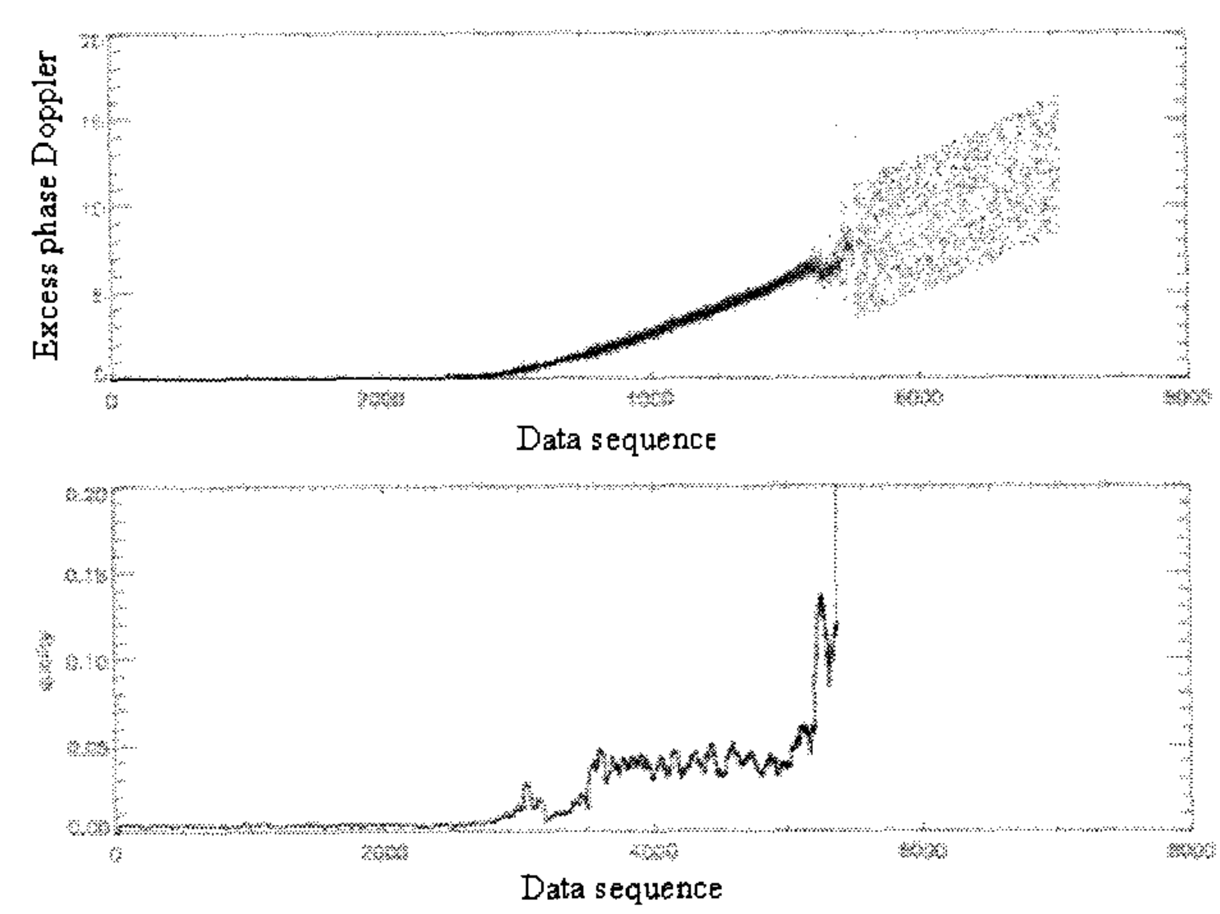


Figure5. The Doppler (up) and the degree of clearness (down) of the L2 RO data atmPhs_C001.2007.055.00.18.G14_0001.0001_nc.

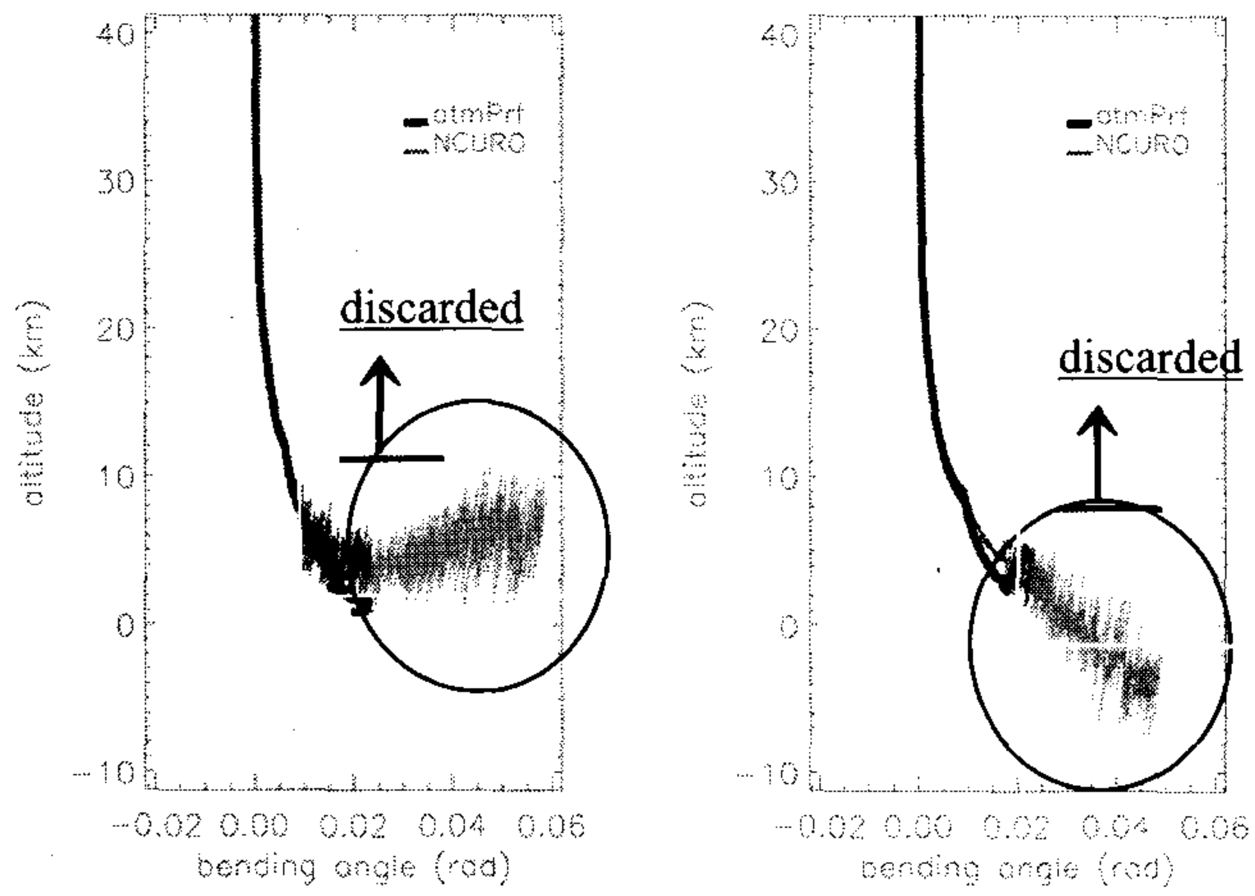


Figure 6. The retrieved profiles of the bending angle of the L1 signal. The results retrieved by NCURO are from (a) atmPhs_C001.2007.041.04.01.G06 _0001.0001_nc and (b) atmPhs_C003.2007.036.01.39.G30 _0001.0001_nc. The results retrieved by TACC are from (a) atmPrf_C001.2007.041.04.01.G06 _0001.0001_nc and (b) atmPrf_C003.2007.036.01.39.G30_0001.0001_nc. The data in the circled region is discarded by the criteria.

of the L2 signal is easier than that of the L1 signal. It is only necessary to run the step 3 in the procedure mentioned above using the Doppler of the L2 signal. The result is shown in Figure 5(down). The value of standard deviation rises abruptly when the data begin to distribute randomly. After consider several tens of data, the cut-off point is set at the point with 0.05 of ordinate.

In Figure6, data in the circled region is the discarded portion discarded by the criteria.

4. CONCLUSION

We have set up an algorithm to consider the degree of clearness. It can determine the quality of the signal based on the phase of the signal. The noise is discarded by the algorithm in the retrieved results.

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