Dear Referee:

Thank you for your comments concerning our manuscript entitled “Improved cloud mask algorithm for FY-3A/VIRR data over the northwest region of China”. Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our research. We have made great efforts to make corresponding changes according to the comments. The main corrections in the paper and the responses to the referee’s comments are as following; the original comments are in italic and our answers are in normal font.

General comments

This paper aims at developing a new cloud mask algorithm for FY-3A/VIRR in order to improve the current cloud mask products of FY-3A/VIRR. The new algorithm are designed to perform unbiased cloud identification with estimating a value, "final confidence flag", which results in between 0 and 1 for ambiguous pixels. The threshold values for the individual threshold tests are statistically determined. The new algorithm are validated by comparing the cloud mask results for several satellite images to those of MODIS as well as ground observations. The comparisons suggest that the new algorithm can improve the cloud mask results, especially over snow. This paper is well written, but there are some points to be improved. I think it is better to show more examples of cloud mask results and its validation, even only the FAR and POD. In particular, examples over ocean and forest may be informative, and perhaps support the advantage of the new algorithm.

Thank you for your suggestions. We have added 47 scenes collocated with the MODIS cloud mask products and 96 individual matchups between VIRR and the ground-based observations from two weather stations in 2011 to improve the validation of the proposed algorithm. The accumulated validation scores of POD (probability of detection), FAR (false-alarm ratio), and HR (hit rate) for four seasons have been also complemented in the revision (see Table 6). This study is mainly focused on the improvement of the cloud detection results over the varied surface types in the northwest region of China. The surfaces include desert and mountainous regions with snow cover during the winter that are generally difficult scenes for cloud detection. The ocean and forest scenes are also significant surfaces in cloud detection areas. However, these scenes are not included in our research

region and not the main points for our study.

Specific comments

1. *p10 l197 and Figure 1, Figure 2 Define what "land" in Fig. 1 and Fig. 2 means. Is it land part except to desert and snow areas?*

   It is true that “land” includes the land part except desert and snow areas. The corresponding description has been added in the text (see P.8 L.2).

2. *p14 l276 Please briefly explain the meaning and efficiency of the calculation of Q values by the presented equations (even if details of the meaning is explained in the reference of CLAUDIA).*

   As the referee’s suggestion, the corresponding description has been added in the revision (see P.12 L.1-10).

3. *p14 l288 Why are NDSI and NDVI excluded from calculation Q and are independently used? Explain the advantage.*

   The tests of NDSI and NDVI, which were excluded from the calculation of the final confidence level, were designed on the basis of the characteristics of the special surfaces. Based on the classifications of the unbiased algorithm, it would be more accurate to apply these tests independently to separate clear-sky special surfaces into distinct categories. In addition, it could provide flags for the special surfaces instead of the overall clear-sky classification, which could be convenient for users of the cloud detection results to select proper regions for their research purposes and targets. The advantages have been also complemented in the revised paper (see P.13 L.1-6).

4. *p16l326 For estimating POD and FAR, the pixels of both MODIS and VIRR are categorized into only two groups, "cloud" and "clear". However, MOD35 and the new algorithm identifies the pixels to several types, (e.g., "cloud", "uncertain", "probably clear", "residual cloud", etc.). What types of pixels are included in the "cloud" (or "clear") category?*

   The official cloud mask products from MODIS and VIRR contained four confidence levels: high confidence of clouds (cloudy), low confidence of clouds (uncertain), low confidence of clear sky (probably clear), and high confidence of clear sky (clear). For these two official products, the cloudy pixels included high confidence of clouds (cloudy) and low confidence of clouds (uncertain); the

clear-sky ones contained low confidence of clear sky (probably clear) and high confidence of clear sky (clear). For the proposed algorithm, the pixels with the confidence level between 0 and 0.5 and the residual cloudy pixels over deserts were classified as clouds for quantitative analysis, while the remaining pixels belonged to the cloud-free category. The corresponding description has been added in the revised paper (see P.16 L.8-14).

5. *p17 l346 Do you have a inference for reasons why FAR by the new cloud mask scheme is larger than that of the VIRR official cloud mask product for the case over snow?*

To provide quantitative validation, the MODIS cloud mask product (MOD35), as a high-quality cloud mask product, was taken as "truth" for the evaluation of the proposed cloud mask algorithm. For the revised paper, we have added overall 47 scenes collocated with the MODIS cloud mask products for four seasons in 2011. Five validation scores (POD_{cloudy}, POD_{clear}, FAR_{cloudy}, FAR_{clear}, and HR) were defined as below:

$$POD_{clear} = d/(c+d),$$

$$FAR_{clear} = b/(b+d),$$

$$POD_{cloudy} = a/(a+b),$$

$$FAR_{cloudy} = c/(a+c),$$

$$HR = (a+d)/(a+b+c+d),$$

where a represented the number of pixels identified as cloudy by both VIRR and MODIS. d represented the number of pixels identified as cloud-free by both VIRR and MODIS. b and c were the numbers of pixels showing different classifications between VIRR and MODIS. The notations used in the equations were shown as Table 5 in the revised paper (shown as Table 1 here):

Table 1. The notations used for the definitions of POD, FAR, and HR scores.

Scenario	VIRR cloudy	VIRR clear
MODIS cloudy	*a*	*b*
MODIS clear	*c*	*d*

The defined validation scores were calculated based on the total matchup dataset for the evaluation of the proposed algorithm. The accumulated results over snow regions were shown as Table 6 in the revised paper (shown as Table 2 here):

Table 2. Accumulated results of the proposed algorithm for POD, FAR, and HR validation scores for four seasons. Corresponding values are given for the VIRR official products in brackets.

Scenario	Month (2011)	POD cloudy (%)	FAR cloudy (%)	POD clear (%)	FAR clear (%)	HR (%)
snow	12~02	59.04	18.63	73.32	52.42	63.84
	(4 scenes)	(94.11)	(32.70)	(9.78)	(54.32)	(65.74)
	03~05	55.21	32.18	77.76	32.82	67.41
	(9 scenes)	(94.86)	(51.99)	(12.82)	(25.38)	(50.48)
	06~08	77.72	20.23	67.52	35.22	73.86
	(7 scenes)	(93.59)	(30.18)	(33.33)	(24.05)	(70.83)
	09~11	77.64	15.65	68.56	41.57	74.79
	(5 scenes)	(95.86)	(25.68)	(27.72)	(24.56)	(74.45)

For the scenes over snow-covered regions, the values of FAR for cloudy pixels had been greatly improved by the proposed cloud mask algorithm. However, the values of POD for cloudy pixels provided by the proposed scheme were lower than those of the official product. When focusing on the cloud-free pixels, the proposed algorithm had significantly increased the values of POD, but the scores of FAR were not as low as expected. A case over snow with poor HR score was illustrated as Fig. 8 for the reasons of this result in the revised paper (shown as Fig.1 here). The snow-covered scene was obtained on 12 December 2011(VIRR at 05:25:00 UTC, MODIS at 05:20:00 UTC). Figure 1a was the VIRR gray-scale image of channel 6 (1.55–1.64μm); Figure 1b–1d represented the cloud detection results from MODIS, the proposed algorithm, and the official VIRR product. Considering the difference between the reflectance of snow cover and clouds at wavelengths between about 1.55 and 1.75μm(Gareth, 2006), the dark-colored areas in Fig. 1a could probably be identified as snow-covered regions. Apparently, the snow-covered regions had been identified as

clouds by the official product of VIRR. For MODIS cloud detection product, the snow-covered regions in the bottom left corner of the image had been correctly classified as clear-sky pixels. However, there were still some snow-covered pixels in the bottom right part of the image that were identified as cloudy ones. For the proposed algorithm, the low POD for clouds and the high FAR for clear pixels were probably caused by the underestimation of clear-sky areas over snow-covered surfaces for MODIS.

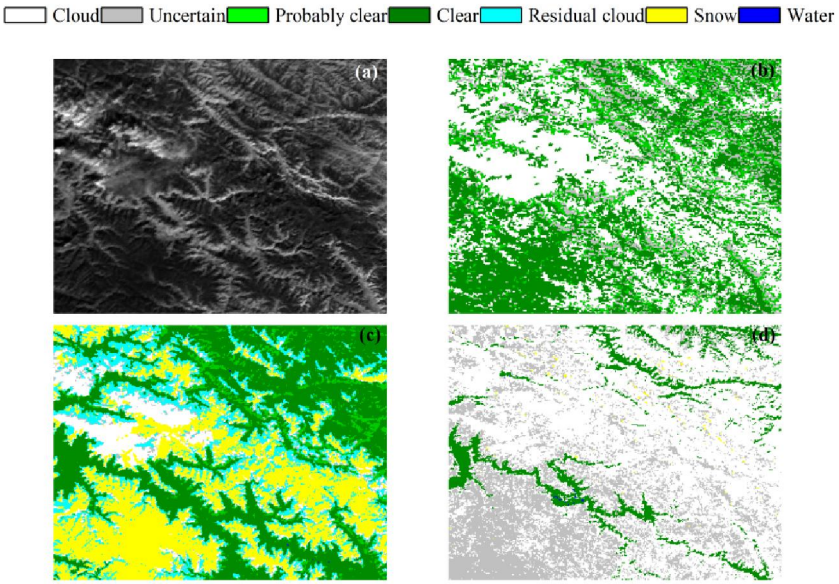

Figure 1. The snow-covered case on 12 December 2011 (VIRR at 05:25:00 UTC, MODIS at 05:20:00 UTC) (a) the VIRR gray-scale image of channel 6 (1.55–1.64μm); (b)–(d) the cloud detection results from MODIS, the proposed algorithm, and the official VIRR product, respectively.

Reference

Gareth, R. W.: Remote sensing of snow and ice, CRC Press, Boca Raton, 285pp, 2006.