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.

*This paper presents an unbiased daytime cloud detection algorithm for the FY-3A/VIRR. Progresses have been made to identify the cloud over snow-covered and desert areas. This work is very important and interesting since accurate cloud masking is a very difficult problem over snow/desert area. It is well written and organized, and worth to be published. I only have few comments required the paper to be revised accordingly.*

*1. On page 2 line 15, recommend to change “variable” to “various”. There are several other places need to make changes, such as page 5 line 78.*

The word “variable” has been changed to “various” (see P.2 L.2, P.3 L.11, and P.4 L.15).

*2. On page 5 line 85, “NDSII” should be “NDSI”?*

Thank you for your attention. The NDSII represents the Normalized Difference Snow/Ice Index. The corresponding information has been complemented in the revised paper (see P.4 L.22).

*3. Section 4.1 Comparison with official cloud mask product and MOD35. The authors use MODIS cloud mask product (MOD35) as a high-quality cloud mask product to validate the proposal algorithm through two indices: POD and FAR. However, the paper provides very little information about how do the MODIS and VIRR collocated, what are the collocated criteria? If there is time difference between MODIS and VIRR observations at the same place, how it will change the two parameters?*

For comparisons, the time difference between the data from MODIS and VIRR should be controlled to the minimum in order to eliminate the errors caused by the quick changes of clouds. In order to

collocate MODIS and VIRR data, the time difference was limited within 5 minutes. For the different spatial resolutions between these two observations, the distances between the pixels from VIRR and MODIS were calculated by the haversine formula presented in the revised paper (see P.15 L.9-11). The minimum distance was then applied to collocate MODIS with VIRR. However, the distance should not exceed 1km. The details have been added in the revision (see P.15 L.5-14).

*4. On page 16, lines 327 to 329: "Focused on the cloudy pixels for the case over desert, the values of POD for the new cloud mask scheme and the VIRR official cloud mask product are 53.261% and 67.217%, respectively". If it is the case, the new cloud mask should be worse than the VIRR official cloud mask product.*

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. 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 desert 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 (%) |
|---|---|---|---|---|---|---|
| desert | 12~02 | 21.66 | 8.78 | 98.00 | 43.37 | 60.65 |
| | (7 scenes) | (30.57) | (24.68) | (90.40) | (42.39) | (61.12) |
| | 03~05 | 41.29 | 6.99 | 97.28 | 34.55 | 71.16 |
| | (7 scenes) | (47.75) | (23.22) | (87.36) | (34.34) | (68.88) |
| | 06~08 | 71.49 | 2.40 | 95.73 | 41.94 | 78.57 |
| | (5 scenes) | (80.08) | (4.88) | (90.02) | (34.92) | (82.98) |
| | 09~11 | 73.52 | 6.36 | 86.85 | 44.49 | 77.19 |
| | (3 scenes) | (69.64) | (5.32) | (89.71) | (47.08) | (75.17) |

For the scenes over desert regions, the values of FAR for cloudy pixels had been improved by the proposed cloud mask algorithm. However, the values of POD for cloudy pixels provided by the proposed scheme were mostly lower than those of the official product. When focusing on the cloud-free pixels, the proposed algorithm had significantly increased the values of POD for most

seasons, but the scores of FAR were not as low as expected. A case over deserts 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 case over deserts was obtained on 24 August 2011(VIRR at 05:00:00 UTC, MODIS at 05:05:00 UTC). Figure 1e was the true-color VIRR image composed of channel 1 (red), channel 9 (green), and channel 7 (blue); Figure 1f–1h represented the cloud detection results from MODIS, the proposed algorithm, and the official VIRR product. For the region in the upper left part of the image, both of the MODIS and VIRR official cloud detection products provided practically identical estimations that uncertain clouds existed in this area. The poor identifications of the cirrus clouds by the proposed algorithm resulted in low POD scores of clouds and high FAR scores for clear pixels over deserts. In addition, the false identifications of the special terrain in the bottom right corner of the image by MODIS could be another reason for the poor detection of the proposed algorithm.

*5. On page 17, lines 345 to 347: "Focused on the clear-sky pixels for the case over snow, the values of FAR for the new cloud mask scheme and the VIRR official cloud mask product are 43.345% and 32.485%, respectively,…". Same conclusion can be draw that the new cloud mask is worse than the VIRR official cloud mask product. Please correct the obvious errors which are not consistent with the paper's conclusion.*

The defined validation scores (refer to reply 4) were also calculated based on the total matchup dataset over snow-covered regions. The accumulated results over snow regions were shown as Table 6 in the revised paper (shown as Table 3 here):

Table 3. 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 (4 scenes) | 59.04 (94.11) | 18.63 (32.70) | 73.32 (9.78) | 52.42 (54.32) | 63.84 (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.

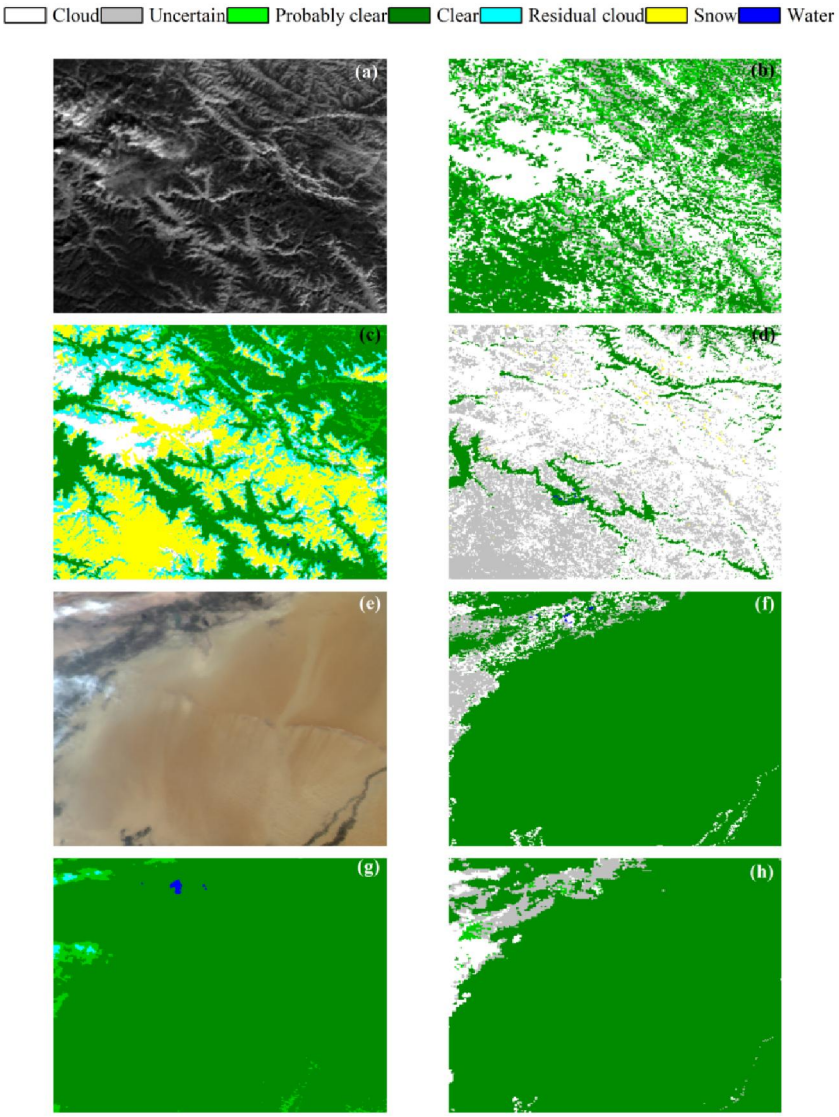


Figure 1. Two cases during the seasons with poor HR scores compared with MODIS. (a)–(d) the snow-covered case on 12 December 2011 (VIRR at 05:25:00 UTC, MODIS at 05:20:00 UTC). (a) the VIRR gray-scale image of channel 6 (1.55–1.64μm); (b)–(d) the cloud detection results from MODIS, the proposed algorithm, and the official VIRR product, respectively.(e)–(h) the case over deserts on 24 August 2011(VIRR at 05:00:00 UTC, MODIS at 05:05:00 UTC). (e) the true-color VIRR image composed of channel 1 (red), channel 9 (green), and channel 7 (blue); (f)–(h) 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, 285 pp., 2006.