We thank the anonymous referee for very thorough and constructive comments. Below are our responses to the comments. The response (in blue) follows each comment.

Anonymous Referee #1

Overview: This article proposes a new method of cloud detection for ground based sky RGB images. It is the latest in a series of algorithms for this purposed proposed by this group. A new element is an approach to estimate the clear-sky values based on multiple channels. Additionally, differencing and threshold methods of cloud detection are combined here to make this a step forward in the evolution of cloud recognition algorithms. The approach merits publication, however, to greatly improve the presentation and accurately convey the algorithm to the public the authors should add several details, for example to the process of estimating clear-sky values, before the article is finalized.
Comments:

The authors need to explain where the coefficients come from for the RAS channel computation (page 4, line 21). Do these apply for any sensor or just this TCI model? What about RAS values less than zero? I don't see values less than zero in Figures 1f, 2g & 2h, for example. How are they handled when performing the cloud detection portion of the algorithm?

Answer: In our manuscript, the variable Y represents the panchromatic channel, which is converted from the RGB channels using the existing color space conversion algorithms. Therefore, these coefficients are general and independent of sensor. We added the following reference to the revised manuscript.

Ford, A. and Roberts, A.: Color Space Conversions, technical report, 1-31, 1998. Available at http://www.poynton.com/PDFs/coloureq.pdf.

All images appearing in the manuscript are in the unsigned 8-bit format (the intensity range is 0-255 for each channel). By analyzing the brightness distribution of pixels in the Figures 1f, 2g and 2h, we can find that all pixels equal to or less than zero are the sky background. So, for those negative RAS values, we directly assign them to zero.

Fig. 3 doesn't add much information for understanding the algorithm. If you wish to keep it, then the steps in the CSBD box should be listed, as well as the solar position box.

Answer: Thanks for the reviewer's suggestion. We will delete this Fig. 3 and add some explanations about CSBD and solar positioning algorithm in the revised manuscript.

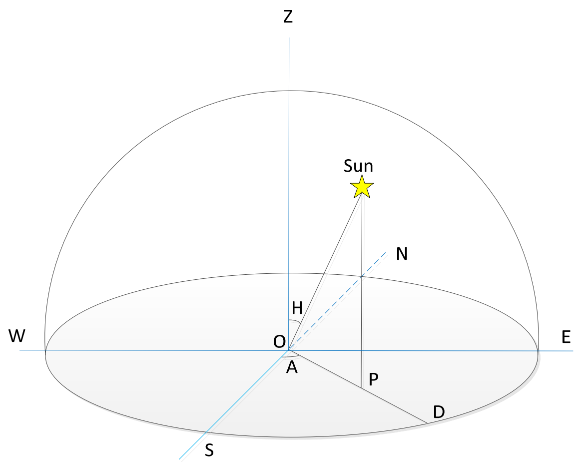
First paragraph of section 3.2 leaves me confused about what 'sun positioning algorithm' was used. The Yang et al. (2015) article mentions at least 4 methods. If you are using the steps given specifically in Yang et al. (2015), then please state that. If not, then state what is different. Does a special calibration of the fish-eye lens need to be done in order to map the image pixel to a particular sky elevation-azimuth direction?

Answer: We applied the same steps to determine sun positions in the TCI images as mentioned in Yang et al. (2015). We revised the manuscript to make it clearly.

Calculating the solar position requires two basic steps, one is to compute the solar zenith angle and azimuth, and the other is to determine the specific coordinates of the sun in the image. Actually, the solar zenith angle and azimuth can be obtained using any existing solar positioning algorithm. In our study, the Plataforma Solar de Almería (PSA, Blanco-Muriel et al., 2001) algorithm was adopted.

Blanco-Muriel, M., Alarcon-Padilla, D. C., Lopea-Moratalla, T., Lara-Coira, M.: Computing the solar vector, Sol. Energy, 70, 431–441, 2001.

The fisheye lens in our device adopts an angular projection (also called a f-theta lens), which means the distance from the center of the image is proportional to the angle around the projection sphere. According to the imaging principle of f-theta lens, the following schematic and equations are applied to calculate the specific position of the sun in the TCI image (Yang et al. (2015)), and no special calibration for the fisheye lens is necessary.



$$X = C_x - OD \times sinA \times H/\alpha$$
$$Y = C_Y + OD \times cosA \times H/\alpha$$

Where H and A represent solar zenith angle and azimuth, X and Y are the central coordinate of the sun in the image, C_x and C_Y represent the central point of the image, α is the half of the angle of view of fisheye lens.

How were the thresholds used in the article determined? Are they universal or do they change with instrument or location? Examples are page 6, line 16 & page 7, line 12-13. This is an essential element of a successful cloud identification scheme. So, details must be included.

Answer: We agree with the comment of the referee. We have mentioned some details in Page 6, Line 19-21 in the original manuscript. To better explain the details, we modified this sentence as

"A suitable threshold is the key of a successful cloud detection algorithm. An exact threshold should be higher than the sky background brightness and lower than the cloud brightness. That means the accurate threshold is depend on local climatic conditions. Since the sky background is mainly related to the aerosol/molecules scattering intensity in the RAS channels and the aerosol concentration above the Tibetan Plateau is very low in most cases, a fixed threshold of 10 is set for the binarization of the RAS channels in our experiments."

The text at the end of section 3.2 (page 6, line 22-page 7, line 3) is not clear in explaining the use of the CSBL. Essentially, is an image from the CSBL used for the clear-sky image? If so, then how is the RAS of the original sky image used? Likewise, how is the 'empirical coefficient' on page 6, line 29 derived? Does the CSBL need to be created using the same instrument which collects the original sky image to which the cloud detection algorithm is being applied?

Answer: In the CSBD and DTCA algorithms, the CSBL is crucial, which needs to be built before the differential processing using the same device and in the same geographic position. When the sun is visible in the original TCI image, the clear sky image, which has the same solar zenith angel as the TCI image, is picked out from the CSBL, then the RAS channels are extracted from the two images to perform differential processing. To better reduce the detection errors in the circumsolar region, we enhanced the brightness values of the circumsolar region in clear sky image by multiplying a factor, which is an empirical coefficient. Our sensitivity tests show that a coefficient of 2 would result in a satisfactory cloud detection.

To better explain our algorithm, we revised the last paragraph of section 3.2 as

"We have built a real clear sky background library (CSBL) in the previous CSBD algorithm (Yang et al., 2016). The CSBL library includes the initial creation phase and the subsequent update phase. At the initial stage, the brightness histogram of each TCI image is analyzed. When the histogram shows significant unimodal distribution and the peak of the histogram is on the low brightness side, the image can be considered as clear sky (Yang et al., 2015). Then the image is rotated by an angle equal to its solar azimuth angle. The rotated image is one of background images in the CSBL library, which consists of series of real clear sky images with a solar zenith angle interval of 1°. At the update stage, the results of cloud detection and brightness histogram analysis are combined to determine whether the image is clear sky. Considering the aerosols and climate seriously affect the brightness distribution of the clear sky background, the CSBL library is updated

on each clear sky day to ensure that the clear sky background image with the closest date as the TCI image is available for cloud detection. Figure 4 shows an example of cloud detection using CSBD algorithm. Fig. 4a is the image after rotation from the image of the third row of Fig. 3a, which was taken on 21 June 2013. Fig. 4b shows the RAS channel image of Fig. 4a. The clear sky image, shown in Fig. 4c, which was shot on 11 June 2013 and had the same solar zenith angle as Fig. 4a, is picked out from the CSBL. Fig. 4d shows the RAS channel image of Fig. 4c. When the sun is shining on the hemispherical shield of the TCI device, it produces significant noise in the circumsolar region. To better reduce the detection errors in the circumsolar region, we enhanced the brightness values in the circumsolar region by multiplying an empirical coefficient. Here, we set the coefficient to be 2. Fig. 4e represents the new RAS channel of Fig. 4d after brightness enhancement for the circumsolar region, and Fig. 4f denotes the difference of Fig. 4d and Fig. 4e. The background brightness is very small in the differencing image (Fig. 4f) because of their close dates (Fig. 4a and Fig. 4c) and low aerosol concentration in the Tibetan Plateau. Due to the potential difference in aerosol loading in two different images (days), the clear sky backgrounds in the reference image and in the processing image may not be the same. We assume that the difference or the noise level in the clear sky background is small. Therefore, we set a threshold of 10 for the differencing algorithm. Fig. 4g shows the result of binarization processing for Fig. 4f, and Fig. 4h is the ultimate result obtained by reversing rotation an angel of solar azimuth. Comparing the result of CSBD with that of threshold method (Fig. 4h and the last row of Fig. 3c), it is clear that the CSBD algorithm obtained satisfactory cloud identification results in the whole image.”

The comparison presented in section 4 should clarify if the images used are separate from the CSBL. Results from the CSBD should also be listed in table 1 to make the case that this latest algorithm is superior to others. Additionally, is the recognition error rate an over or under estimate by the algorithm compared to the standard? The standard deviation in the mean error for the different cases should be also given in table 1.

Answer: Thanks for the suggestions. In the previous manuscript, we simply took the absolute value for the error rate in Table 1. In order to show whether the algorithms are over or under estimate the results, we recalculated the error rate and the standard deviation for each algorithm. Since the GBSAT and CSBD algorithms are aimed at partly cloudy images, they are not suitable for the clear sky and overcast images. Here we only compared the results of R/B, multicolor and DTCA, which are shown in the new Table 1.

Table 1. The recognition errors rate of different cloud detection algorithms

	Clear sky		Cirriform		Cumuliform		Stratiform		Mixed cloud		Total	
	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std
R/B	3.7	1.3	-24.5	16.7	-4.1	13.0	-2.9	9.3	-10.4	13.8	-7.7	15.3
Multicolor	43.5	15.0	-18.6	42.0	-4.6	40.6	-63.1	30.7	-26.9	38.3	-13.9	48.9
DTCA	2.5	2.5	-19.6	15.6	-0.4	9.3	-2.2	5.0	-6.5	11.5	-5.2	12.5

Here, negative values denote underestimation, and positive values mean overestimation. The conclusions are similar to the qualitative assessment: the multicolor algorithm is poor for all types of TCI images, the identification precision is low for the cirriforms in the R/B algorithm, and DTCA algorithm has the best identification effectiveness for all test images. The average recognition error rate of DTCA algorithm is -5.2%, but the error rate is -19.6 for the cirriforms, which means it still underestimate some thin clouds.

In addition to evaluate the error rate for each cloud type as Table 1, we also compared the errors rate under different sun conditions. We randomly selected 100 total sky images (50 visible sun cases and 50 blocked sun cases) from the mixed cloud type for quantitative evaluation of cloud detection algorithms. The results are shown in Table 2. The CSBD algorithm performs well under visible sun conditions, but poor under fully blocked sun conditions. The DTCA algorithm obtains the best recognition accuracy under both conditions.

Table 2. The recognition errors rate under different sun conditions

	Visible sun		Blocked sun	
	Avg	Std	Avg	Std
R/B	-8.8	13.6	-15.2	13.9
Multicolor	31.8	25.2	-24.3	32.0
CSBD	0.5	14.9	-15.5	25.2
DTCA	-2.2	10.2	-5.9	10.1

Both Table 1 and Table 2 will be added in the revised manuscript.

Details:

Page 1, Line 13: "…identify cloud pixels. If the sun is visible in…"

Answer: We will revise it as suggestion.

Page 2, Line 5: "Recorded downwelling…"

Answer: We will revise it in the revision.

Page 2, Line 7: "…phenomenon in clear sky conditions…"

Answer: We will revise it.

Page 5, line 28: "In the DTCA algorithm…"

Answer: We will revise it.

Page 7, line 9: Need reference for the “automatic white balancing”.

Answer: We will add the following reference in the revision.

“Liu, Y., Chan W., and Chen Y.: Automatic white balance for digital still camera, IEEE Trans. Consumer Electron., 41, 460-466, 1995.”