Cloud geolocation estimation from all-sky-view cameras

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1. Introduction

All-sky-view cameras capture whole sky images at a high temporal resolution and provide continuous ground-based cloud observations. However, geographic positions of clouds are not so obvious if directly observed from the captured whole sky images.

In this study, the clouds on the whole sky images are projected to the real world to achieve geolocation estimation, providing observers an intuitive insight on the cloud distribution over the regional area.

2. Device

- The all-sky-view cameras used in this study, namely ASC-200 (Figure 1), are fabricated by Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences.
- The components of ASC200:

Visible Camera
180° FOV 2000 × 1944 resolution
450–650 nm

Infrared Camera
160° FOV 640 × 512 resolution
8–14 μm

Environmental Regulation
Inner temperature & humidity adjustment

Data Analysis System
Automatic acquisition, processing, and storage whole sky images

Figure 1. ASC200 instrument.

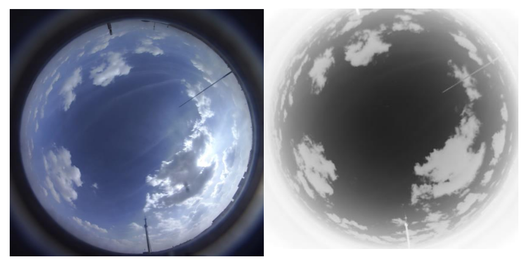


Figure 2. Visible (left) and infrared (right) whole sky images captured by ASC200

- ASC200 can provide cloud observation every 10 minutes via visible and infrared spectrum and achieves cloud cover estimation.

3. Method

Whole sky images
↓
Cloud classification
↓
Zenith and azimuth angles of the classified cloud pixels
↓
The distance of clouds from the observer's location
↓
Projection into map

Figure 3. Flowchart of cloud geolocation estimation.

Cloud classification

cloud pixels are recognized from the captured images

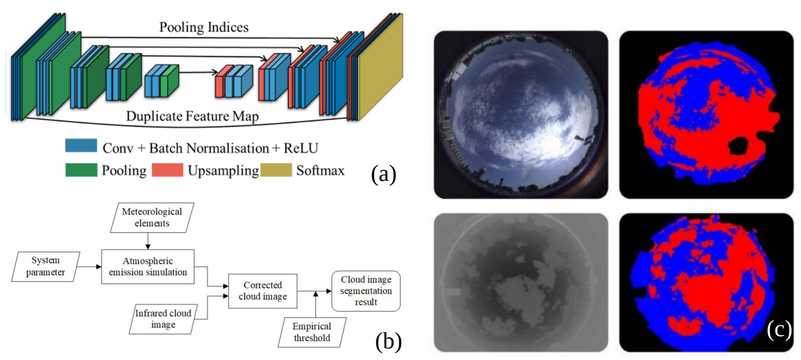
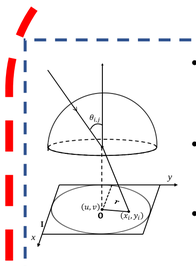


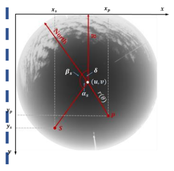
Figure 4. Cloud classification method and results

- The visible images use a trained convolutional neural network [1] to segment clouds from sky (Figure 2a)
- The infrared images use the brightness temperature difference[2] to recognize clouds (Figure 2b)
- Figure 3c presents the segmentation results, in which the clouds and skies are marked as red and blue.

Pixel viewing angle calibration



- Fitting Imaging model:
  $\sqrt{(x_s-u)^2+(y_s-v)^2}=f\cdot\theta_s$
- Obtaining parameters:
  focal length f and zenith point (u, v)
- The zenith angle for any other pixel:
  $\theta=\sqrt{(x-u)^2+(y-v)^2}/f$



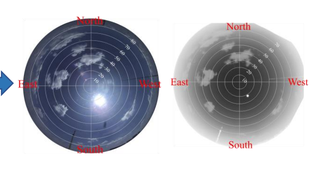
- Setting reference axis R:
  $\delta=\frac{1}{n}\sum_i^n(\beta_{si}-\alpha_{si})$

$$\beta_s=\begin{cases}\arctan\frac{|y_s-v|}{|x_s-u|}*180/\pi, & x_s\le u \text{ 且 } y_s\le v\\ 360-\arctan\frac{|y_s-v|}{|x_s-u|}*180/\pi, & x_s\le u \text{ 且 } y_s>v\\ 180-\arctan\frac{|y_s-v|}{|x_s-u|}*180/\pi, & x_s>u \text{ 且 } y_s\le v\\ 180+\arctan\frac{|y_s-v|}{|x_s-u|}*180/\pi, & x_s>u \text{ 且 } y_s>v\end{cases}$$

- Obtaining parameters δ:
- The azimuth angle for any other pixel:
  $\alpha=\beta-\delta$

Sun's positions in sky $(\theta_s, \alpha_s)$and image (x_s, y_s)

Pixel viewing angle distribution



- The zenith and azimuth angles for all pixels on visible and infrared whole sky images can be computed, including the classified cloud pixels [3].

The distance of clouds from the observer's location

- Utilizing cloud-base-height $\boldsymbol{h}$ provided by ceilometer, above zenith angle $\boldsymbol{\theta}$ and azimuth angle $\boldsymbol{\varphi}$, the distance of clouds from observer's location $(\boldsymbol{X}, \boldsymbol{Y})$ can be performed.

$$\boldsymbol{X = h * tan\theta * cos\varphi}$$
$$\boldsymbol{Y = h * tan\theta * sin\varphi}$$

3. Results

- With known distance from observation site, the clouds can be projected into Google Map (50 m resolution).
- We process a sequence of whole sky images captured in June 25th, 2020 (local time), and the results are presented in Figure 5. As we can see, the cloud distribution can be clearly presented over observation site.

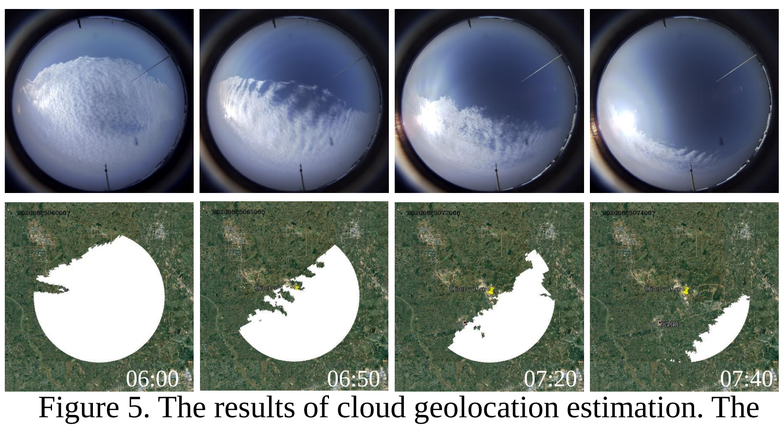


Figure 5. The results of cloud geolocation estimation. The cloud base height provided by ceilometer is 1650 m.

- The cloud variation also can be clearly presented through processing cloud geolocation for successive whole sky images. As shown in Figure 5, the clouds was moving towards southeast, to some extent, indicting wind spend and wind direction

4. Conclusion

- A cloud geolocation estimation method is proposed, which provides observers an intuitive insight on the cloud distribution over the regional area.
- Successive cloud geolocation estimation indicates wind speed and direction, and has significance for solar energy application.
- However, the accuracy of cloud geolocation needs to be further verified, such as comparison with satellite images [4].
- The multi-layer clouds are not considered in this study, which must be improved in future.

5. Reference

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