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Atmospheric Chemistry and Physics Discussions

# *Interactive comment on* "Cloud Photogrammetry with Dense Stereo for Fisheye Cameras" *by* C. Beekmans et al.

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We thank the referee for the important and valuable comments on the paper. We will use them to correct the paper for the final version. Our response to the referees comments are as follows:

-> Referee Comment:

"In many parts of the manuscript, rectification is referred as the method that allows dense stereo matching. I find this misleading, because rectification is merely a transformation to translate the epipoles to infinity so that the epipolar lines are parallel in both images, hence matching algorithm is less time consuming and more straightforward to design."



Authors Response:

We agree with the referee. Our intention was to emphasize that epipolar rectification is usually a prerequisite to efficient out-of-the-box dense stereo matching techniques, like the mentioned Semi-Global-Matching approach. Also other approaches like for example the Graph-Cut technique usually require rectified images. On the other hand the plane-sweep algorithm does not and works on the original (or undistorted) images.

-> Referee Comment:

"Page 3, Line 3, Romps and Oktem also studied convective clouds in the following two references Romps and Oktem, Stereo photogrammetry reveals substantial drag on cloud thermals, GRL, 2015 Oktem and Romps, Observing atmospheric clouds through stereo reconstruction, Proceedings of SPIE - The International Society for Optical Engineering, March 2015"

Authors Response:

Our focus lies on the feasibility of the proposed method to reconstruct the cloud morphology in its full extent, while the referenced paper uses the stereo technique with the aim to answer a specific question that can also be answered with a feature-based method. Therefore, the main difference is the use of a dense versus a sparse stereo reconstruction. Further, we use automated matching, while the referenced paper mentions that the features are matching manually across the images. However, the paper needs to be added to the related work section.

-> Referee Comment:

"In Section 3, the parameters such as theta and phi angles are only displayed in figures but are not introduced in the text nor in the captions. There are many parameters used in the equations, it maybe a good idea to list and define them in a separate table or introduce/explain them in the text."

Authors Response:

We agree with the referee. In the text it says 'r(theta)' instead of 'theta'. The angle phi is not introduced. We will correct this.

-> Referee Comment:

"In Section 3.3, it is claimed that rectification allows to use the complete image content of a fisheye image. It is not clear to me why the whole content of rectified image can be used but the whole content of the non-rectified image cannot. Besides, the distortion (stretching) introduced by the rectification is likely to severely limit the use of data beyond a certain theta."

Authors Response:

Although the whole image content can be used theoretically, the rectification, but also the geometric conditioning of parts of the images limit its use. The first lines in this section are a bit misleading in this regard. We therefore agree with the referee and will correct this in the final version. Of course the image content of a non-rectified image can also be used, e.g. for feature-based matching. However, the matching algorithm we use requires epipolar rectified images and non-rectified images are therefore not an option. As is shown in Fig.11 a large negative impact is due to the geometric conditioning along the baseline as is also stated in Öktem et al. (2014). Since the stretching occurs mostly at the left and right sides of the image, the impact is largest in these regions. We did not experience a larger negative effect along the central meridian (top, zenith, bottom).

-> Referee Comment:

"Section 4, Line 14, "Dense stereo is advantageous when dealing with complex geometries but also effectively delivers reasonable results for image regions with low-contrast". I believe that this statement needs revision to clarify the point being made. I understand the clouds are considered as complex geometries but it is not clear to me how dense stereo is advantageous for these cases."



Authors Response:

Matching errors during a sparse feature-based reconstruction are likely to result in a quite different cloud shape because every feature is comparatively important due to their small amount. Also, features are generally matched independently across the image, without any corrective term like in a globally optimized matching. Hence, not only the likelihood of error occurrences, but also their respective impact on the final reconstruction is larger, than with global matching. Another issue is that we can simply expect more 3D information about the object, which is preferable for a later visualization, but also for processing, e.g. segmentation and tracking, since a larger data basis is provided for these tasks.

Technical Corrections: If not directly responded to, comment will be taken into account for correction.

-> Referee Comment:

"Page 4, equations with phi uses lowercase phi in one equation, and uppercase phi in another, do they refer to different parameters?"

Authors Response:

No. This is an error and will be corrected.

-> Referee Comment:

"Page 6, the last equation which is below Line 30, Is this the intended notation for e.g. "atan2(z_v,y_v)"? I believe that the notation should be revised to clearly state the formula."

Authors Response:

Yes. The full notation will be inserted in the final version.

-> Referee Comment:

"Page 9, the first equation on the top, what is “sin(delta)”?"

Authors Response:

This is an error. ’delta’ should be ’theta’.

-> Referee Comment:

"Page 13, Line 26, is “..0.15 seconds...” supposed to be “... 15 seconds ...”?"

Authors Response:

This refers to the averaging time of a single range resolved scan (a single elevation value / beam), which takes 0.15 seconds. The whole scan (elevation angle from 15 degrees to 165 degrees) takes almost 1 minute.

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