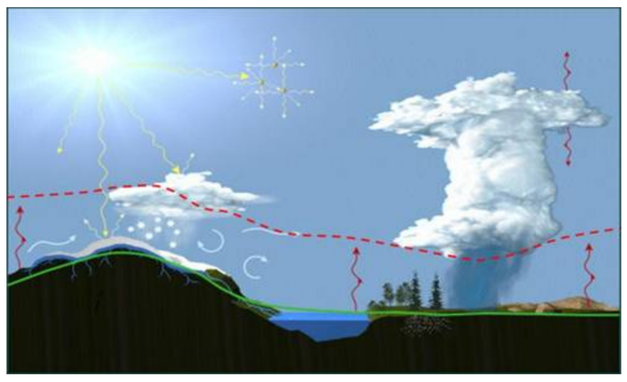
Estimating cloud base height from all-sky imagery using artificial neural networks

Mikhail Borisov, Mikhail Krinitskiy
borisov.ma@phystech.edu and krinitsky@sail.msk.ru
Moscow Institute of Physics and Technology
Shirshov Institute of Oceanology, Russian Academy of Sciences

Overview

Cloud Base Height(CBH) is important meteorological parameter of atmosphere.



CBH demonstrates strong correlation with thickness Planetary Boundary Layer in cases with cumulus clouds.
CBH is important condition for building routes of aircrafts and conditions of take- off and landing planes.

CBH estimation methods

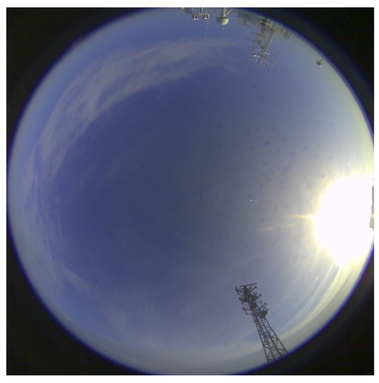
The most well-known methods for calculating the height of the CBH:

- Lidar
- Aircrafts and weather balloons
- Visual – expert classified cloud types
- Parameterizations

These methods are of little use in conditions of a small amount of cloud cover or sea rolling

Data

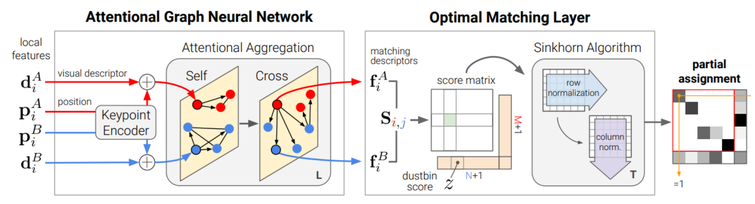
Dataset of All-Sky Images over the Ocean (DASIO) contains more than 2.5 million photographs.



Features of all-sky images:

- Strong distortion of the image at the edges of the visible area. Distortion results in strong variation of angle distance between pixels
- Viewing angle 180°(π radians) in vertical planes
- Image size is 1920*1920 px.

Algorithm

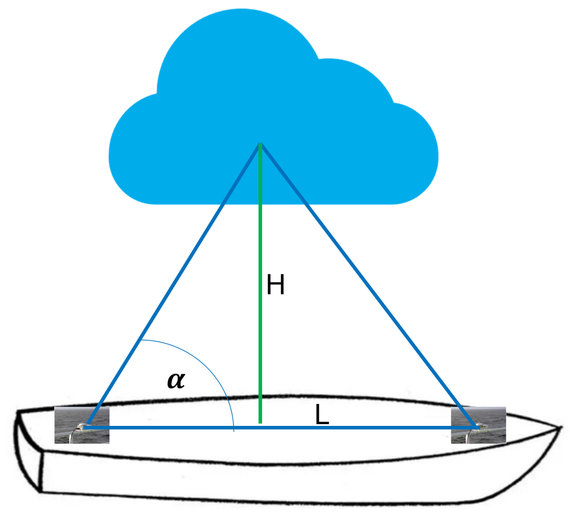


SuperGlue[1] is an artificial neural network architecture designed for keypoint matching. It involves keypoint embedding to generate descriptors for keypoints, capturing their visual features. These descriptors are used to compute pairwise matching scores between keypoints, considering both their visual similarity and spatial relationships. A graph is constructed, where nodes represent keypoints and edges connect potentially matching keypoints, with edge weights determined by the matching scores. Finally, an optimization algorithm is applied to find the optimal set of matching correspondences within the graph, improving the accuracy and robustness of keypoint matching.

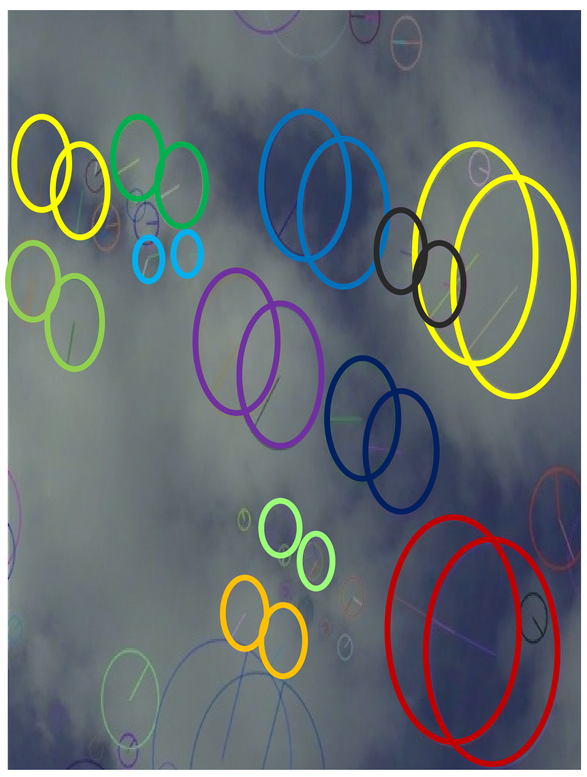
Exploiting parallax effect

$$H = \frac{L}{2\sin\frac{\alpha}{2}} \sim \frac{L}{\alpha} = \frac{1920L}{S\pi}$$

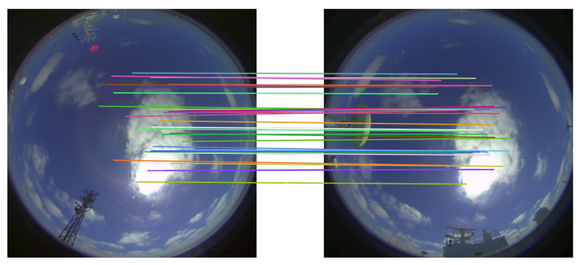
The angle α is calculated from the ratio $\frac{\alpha}{\pi} = \frac{S}{1920}$ (due to π radians of viewing angle per 1920 px.)
S – the distance in pixels between the key points after conversion.
L - the distance between cameras .

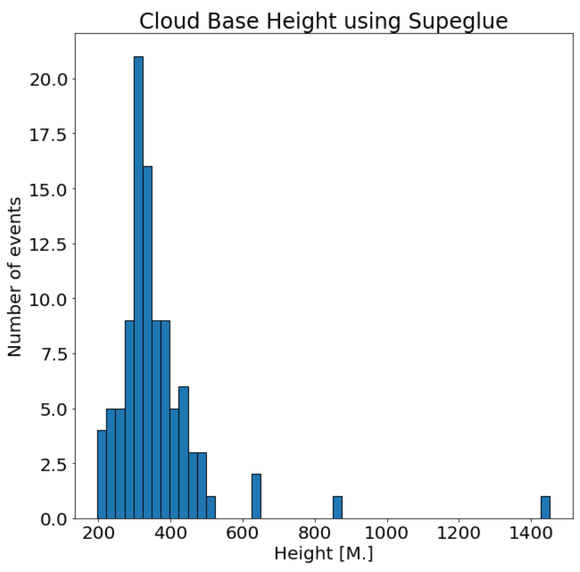


Example of combined photos with detected key-points.



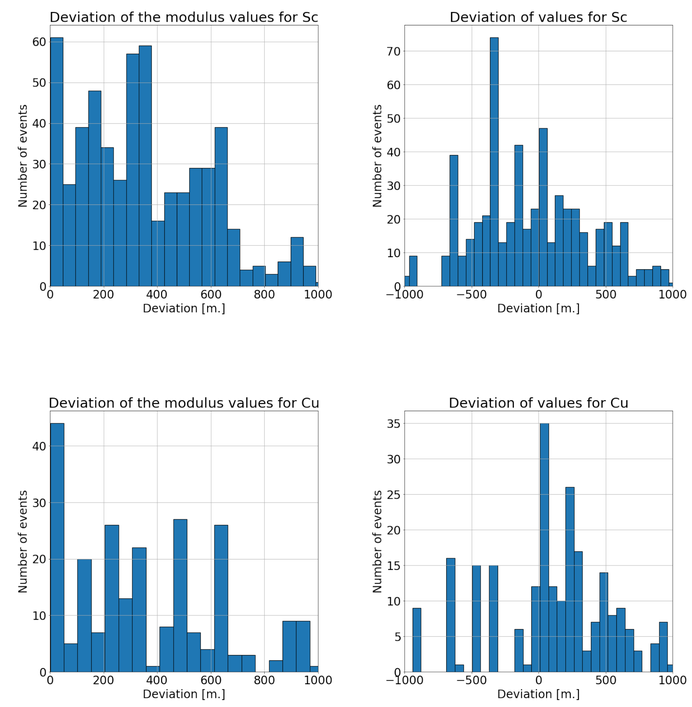
Applying network





ERA-5

Based on AI-58, we validated CBH with ERA-5 reanalysis data.



Conclusion

- We present an approach exploiting parallax effect and keypoints detection and matching for estimating cloud base height using all-sky images acquired by our low-cost optical package Sail Cloud v.2
- We demonstrate the results using expeditions AI-58 and AI-61 as an example
- The most close correspondence is observed for Cu and Sc clouds

Bibliography

[1] e. a. Paul-Edouard Sarlin, "SuperGlue: Learning Feature Matching with Graph Neural Networks," 2020. [Online]. Available: http://arxiv.org/abs/1911.11763