Cloud-height mapping from all-sky camera network

C. Herrero del Barrio[1,2], R. Román[1,2], S. Herrero-Anta[1,2], D. González-Fernández[1,2], R. Carracedo[1,2], R. González[1,2] B. Longarela[1,2], J. Gatón[1,2], D. Mateos[1,2], A. Calle[1,2], C. Toledano[1,2], V.E. Cachorro[1,2] and Á. de Frutos[1,2] celia@goa.uva.es

[1]Group of Atmospheric Optics (GOA-UVa), Universidad de Valladolid, Spain
[2]Laboratory of disruptive interdisciplinary science (LADIS), Universidad de Valladolid, Spain

PRESENTE All-Sky Camera Network

- **20 cameras** distributed in public buildings (17 in the city + 3 more than 30 km away)
- 4 Pyranometers + 2 Ceilometers + 3 Photometers

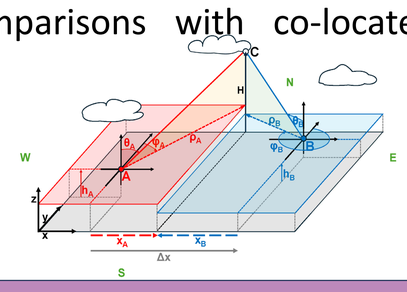
Instrument management & Data Acquisition (GOA-SCAN Protocol)

- **OMEA-3C-TF + Triband Filter** (*Alcor System*): SONY CMOS + fisheye lens + triband filter
- Geometrical calibration using start positions: **ORION** (*Antuña-Sanchez et al.*, 2022).
- Automated **GOA OMEA-Capture software** + continuous monitoring and maintenace of the cameras (*Román et al.*, 2025)
- **High Dinamic Range Images** (Multi-exposure sequences) every 5 min (daytime) 2 min (night-time).

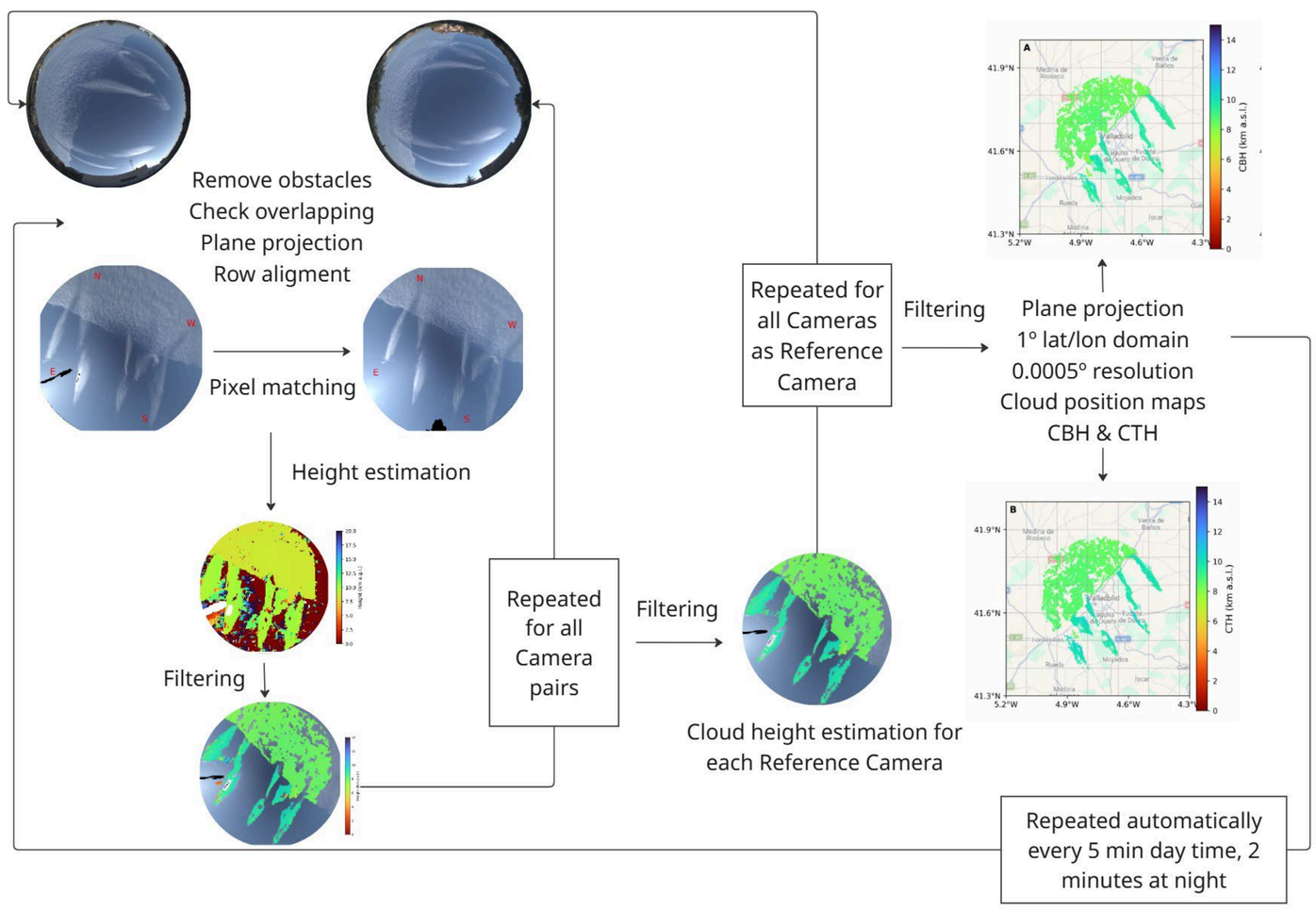
Introduction

This work presents an all-sky camera network for automated cloud detection and height retrieval in Valladolid, Spain. The methodology is based on stereoscopic reconstruction (Eq.1) derived from camera pairs. It is systematically applied across the entire network trough an automated pipeline operating in near real-time. Wide camera distribution enables the retrieval of diverse cloud heights, using optimized camera pairs for specific height ranges. Multi-filtering criteria is applied, effectively discarding artifacts to provide reliable cloud base height (**CBH)** and cloud top height (**CTH)** values. The accuracy of the system has been independently validated through comparisons with co-located ceilometer data and satellite observations.

$$H = \frac{h_B \sin\phi_B \tan\theta_B - h_A \sin\phi_A \cos\theta_A - \Delta x}{\sin\theta_B \tan o_B - \sin\phi_A \tan\theta_A} \qquad \text{(Eq.1)}$$



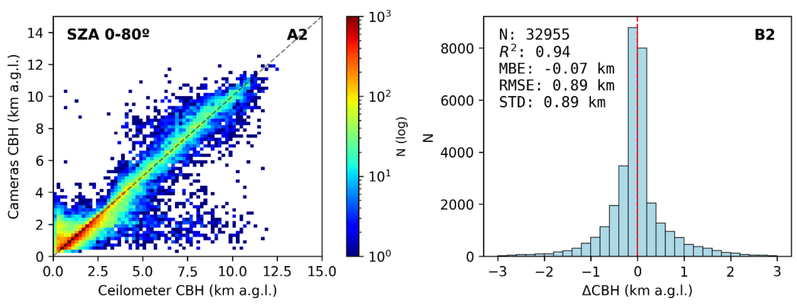
Methodology



Ceilometer Comparison (Jun 2023-Feb 2026)

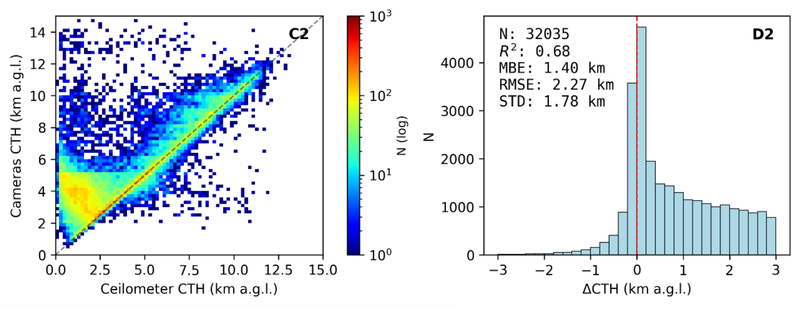
Overall cloud detection agreement for daytime: **86%** (97% cloud-free).

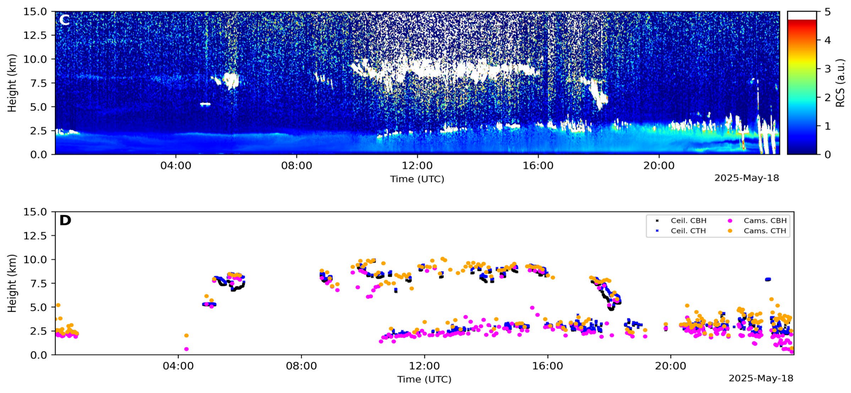
Performance degradates when including night-time (66%) due to low ilumination conditions affecting pixel matching and cloud segmentation, especially for high and transparent clouds.



Overestimation in CTH is observed compared to the ceilometer; this is attributed to signal saturation in optically thick clouds, where the ceilometer fails to detect the real cloud top. Filtering these cases improves correlation (R^2 = 0.8).

High accuracy for CBH. Underestimation cases revealed discrepancies in broken cloud scenarios or multi-layer scenes; when the ceilometer's point measurement targeted high-level clouds, while the cameras' spatially aggregated data captured lower layers present in the wider scene.



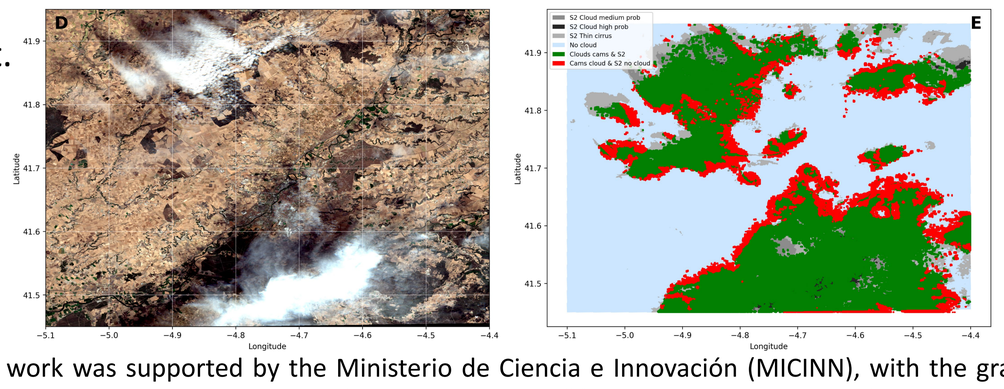


Overall, the all-sky camera networks is capable of retrieving different cloud layers in the same scene, maintaining high consistency with the ceilometer.

Satellite Comparison

Cloud spatial distribution compared against **Sentinel-2 scene classification product (60 m)** shows significant agreement.

Discrepancies are found for high transparent clouds and cloud edges.



Conclusions & Outcomes

- Cost-Effective & Scalable all-sky camera network.
- Automated and computational efficient near real-time methodology for cloud height mapping (less than 5s in average for processing each time-stamp).
- Consistency when comparing with ceilometer and satellite meassurements.
- Potential use for 3D cloud reconstruction and satellite validation.

ACKNOWLEDGEMENTS: This work was supported by the Ministerio de Ciencia e Innovación (MICINN), with the grant no. PID2024-157697OB-I00. This work is part of the project TED2021-131211B-I00375 funded by MCIN/AEI/10.13039/501100011033 and European Union, "NextGenerationEU"/PRTR, is based on work from COST Action CA21119 HARMONIA and the Marie Sklodowska-Curie Staff Exchange Actions with the project GRASP-SYNERGY (grant no. 10 101131631). Financial support of the Department of Education, Junta de Castilla y León, and FEDER Funds is gratefully acknowledged (Reference: CLU-2023-1-05). This work was funded by European Comision through the EUBURN-RISK project (INTERREG-SUDOE; S2/2.4/F0327). The authors acknowledge the support of the Spanish Ministry for Science and Innovation to ACTRIS ERIC.**REFERENCES:** Antuña-Sánchez et al., 2022, Orion software tool for the geometrical calibration of all-sky cameras PlosOne; Román et al., 2025, Star photometry with all-sky cameras to retrieve aerosol optical depth at nighttime, AMT.