Hovering a Microscope on a Drone: Development of UAV Based Systems for High-resolution Imaging of Falling Snow



Koen Muller, Mario Camenzind, Ilja Shesterikov, Simone Morandi, and Filippo Coletti



Institute of Fluid Dynamics, D-MAVT, ETH Zurich







Motivation: Availability of Flexibly Deployable Snow Characterization Instruments for Fieldwork

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Snow Falling in Action by Koen Muller, ETH, Zurich, Switzerland

DJI Mavic 3E Tele-lens and Spotlight



Commercial off-the-shelf drone:

- weight: 915 1050 gram
- focal length 29.85mm (162mm equiv.)

Spotlight angle ~12.5°

Camera angle 9 – 12°

- aperture: f/4.4
- sensor: ½ inch, 4:3, 12MP.

Spotlight (CZZI):

Object-distance

3 meters

- operating power: 30W
- light output: 1830 lumens.



Snow Identification and Extraction of Metrics ETHzürich

Image gradient segmentation scheme to identify snowflakes and extract metrics of:

- maximum diameter D_{max}
- minimum diameter D_{min}

- aspect ration AR = $\frac{D_{min}}{D_{max}}$

- orientation angle heta
- equivalent radius $r_{eq} = \sqrt{\frac{A}{\pi}}$
- simplified complexity $X = \frac{P}{2\pi r_{eq}} (1 + \sigma)$





following Garrett et al. (2014), even though a considerably lower resolution of 160μm vs 14 – 34μm.

Quantitative Snowflake Comparison



Sortation of snowflake images by complexity...

in comparison with Garrett et al. (2014).



Quantitative Snowfall Characterization



Strong resembles when reproducing statistical distributions like the Marshall-Palmer size distribution.



Snowflake Orientation in Freefall



Differences in freefall orientation: Horizontal predominance over ground-based measurements.





First Validation Study – Visible Motion Blur

Test flight and ground-based proofing.





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Latest Developments – First Snowflake Image ETHzürich

Boosting the illumination,

TriSonica anemometer & automated imaging.



Take Home Messages



We have presented two novel drone-based platforms for imaging natural snowfall.

- A smaller commercially available DJI Mavic 3E drone equipped with a tele-lens and spot-light provides a flexible platform for snowflake imaging and statistical characterization.
- Reproducing different snowflake metrics, we observe that elongated snowflakes have a strong tendency to fall in horizontal orientation.
- We demonstrated the feasibility of mounting a long-range microscopy platform on a much larger DJI Matrice 600 Pro to boost the image resolution.

In future work, we aim to collocate the two systems side-by-side for simultaneous statistical characterization and harvesting of high-resolution snowflake imagery.



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[Extra] How about the Induced Flow?

L. Bauersfeld, K. Muller, D. Ziegler, F. Coletti and D. Scaramuzza, *Robotics Meets Fluid Dynamics: A Characterization of the Induced Airflow Below a Quadrotor as a Turbulent Jet*, IEEE RAL, vol. 10, no. 2, pp. 1241-1248, 2025

doi: 10.1109/LRA.2024.3518835.



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