Ground-based in-situ snowfall speed measurements: Microphysical properties of snowflakes

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ABSTRACT

In this work, we present new measurements of snowflakes' microphysical properties using our ground-based **D**ual - **I**ce **C**rystal **I**mager (**D-ICI**) instrument that takes high-resolution side- and top-view images of snowflakes. Size, area, and fall speed of the snow particles are determined from the images. Their shapes are classified in needles, columns and bullets, plates, stellars, bullet rosettes, graupel, irregular, and also ice and water droplets. In addition, we analyze the relationships between these microphysical properties. We show results from several snowfall events in Kiruna, Sweden from 2014 to the present.

INTRODUCTION AND STUDY AREA

Accurate knowledge of atmospheric snow particles' (ice crystals and snowflakes) microphysical properties (size, particle size distribution (PSD), area, area ratio, shape and fall speed) is required for meteorological forecast and climate models. For instance, they can help improve parameterizations of snow particles in atmospheric models. In order to measure these properties, in our study case we use ground-based in-situ optical instruments.

METHODOLOGY

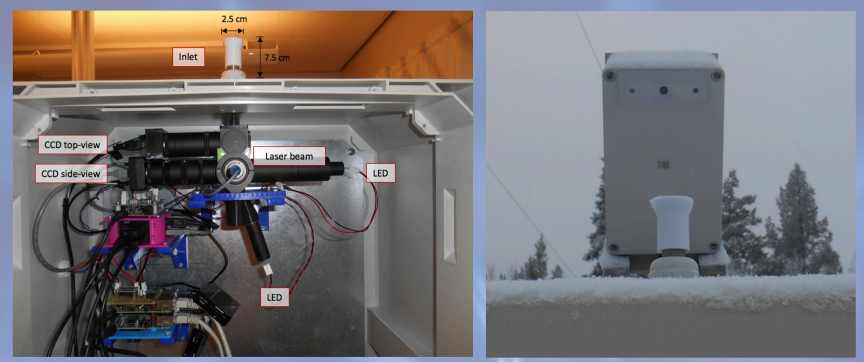

FIG. 2: Dual-imager instrument. *Left*: In lab-set. *Right*: In field-test.

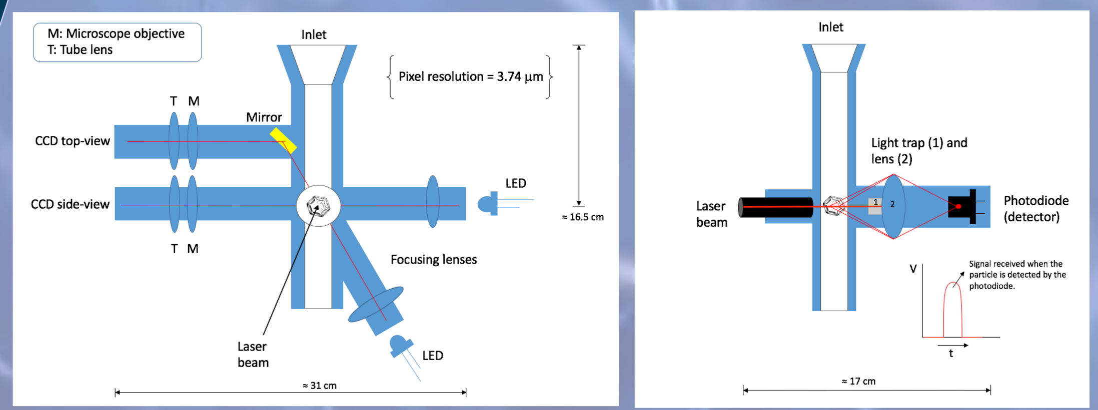

FIG.3: Set-up of dual-imager instrument. *Left*: Front view. *Right*: Perpendicular view.

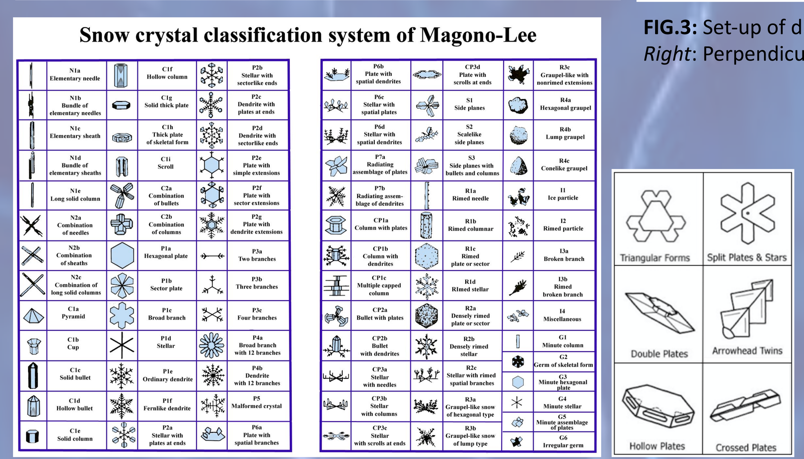

FIG.4: For shape classification use shapes from Magono-Lee [1] (*left*) and from Libbrecht [2] (*right*).

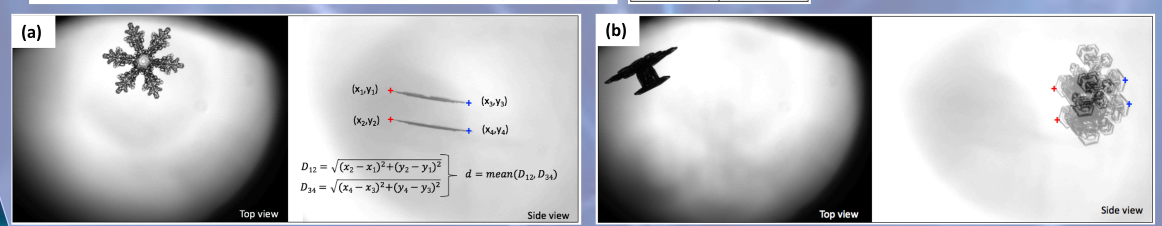

FIG.5: Shape determination and fall speed analysis. Two examples **(a)** and **(b)** with two different particles are shown. Two images (side- and top-view help with better shape determination. *Left*: Top-view images. *Right*: Side-view images. They are exposed twice to enable fall speed measurements.

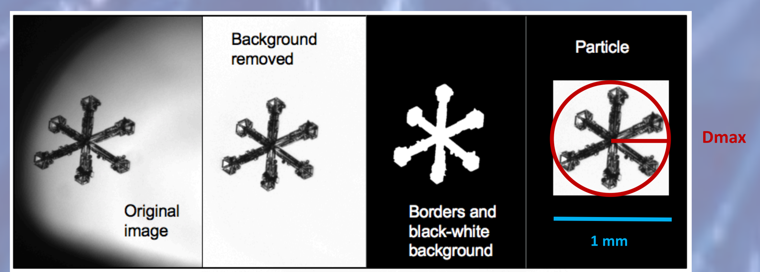

FIG.6: Automated image analysis process: background is removed; then particle and its boundary are detected; size and area are determined from black-white image. As size we use maximum dimension (Dmax), which is the diameter of the smallest circle that completely encloses the particle.

DATA AND RESULTS

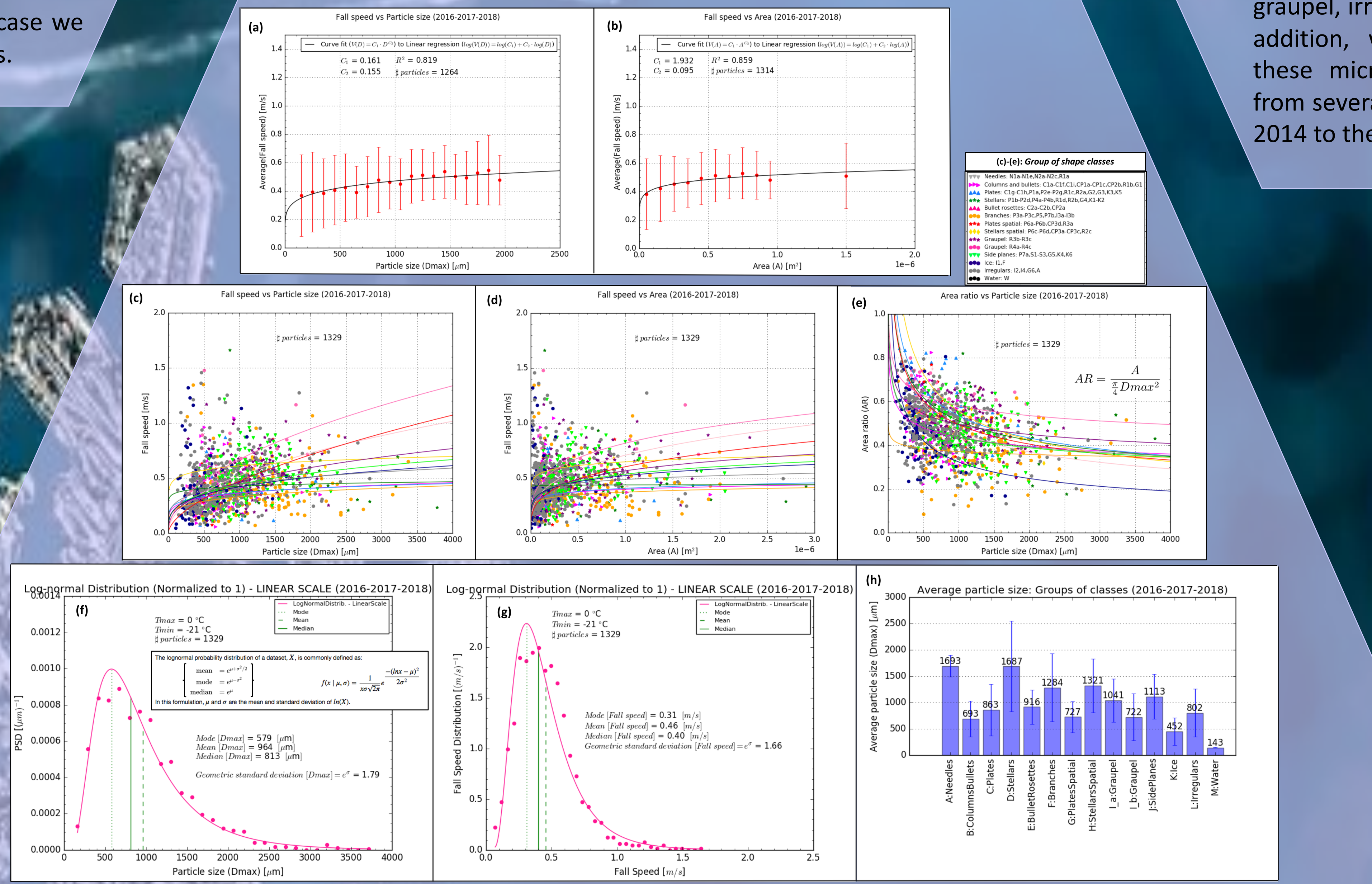

FIG.7: **(a)** Fall speed averaged over size ranges vs. Particle size. Error bars represent the std(Fall speed); **(b)** Fall speed averaged over area ranges vs. Particle area. Error bars represent the std(Fall speed); **(c)** Fall speed vs. Particle size for individual particles (different groups of shape classes marked according to legend *Group of shape classes*); **(d)** Fall speed vs. Particle area for individual particles; **(e)** Area ratio vs. Particle size for individual particles; **(f)** Particle size distribution (normalized to 1) and log-normal fit; **(g)** Fall speed distribution (normalized to 1) and log-normal fit; **(h)** Average particle size for different groups of shape classes.

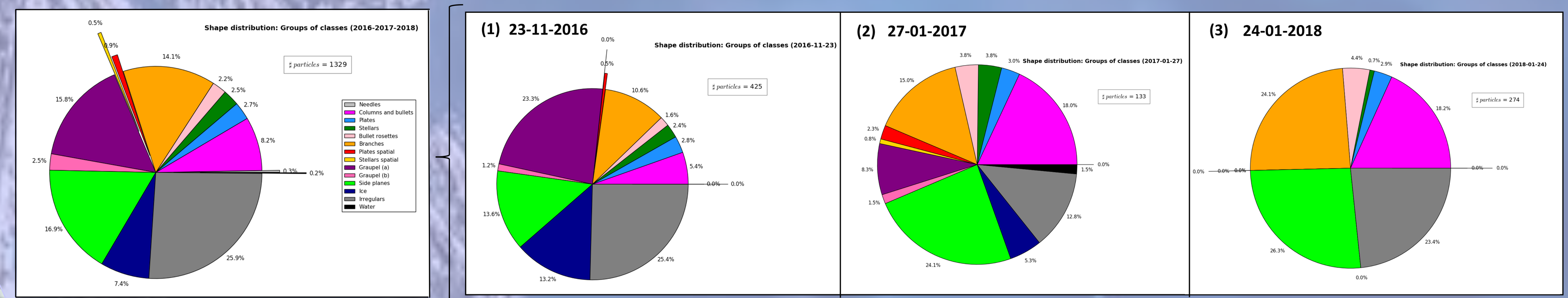

FIG.8: Shape distribution of snowflakes for some snow events taken during 2016-2017-2018. *Left*: Average. *Right*: Individual events.

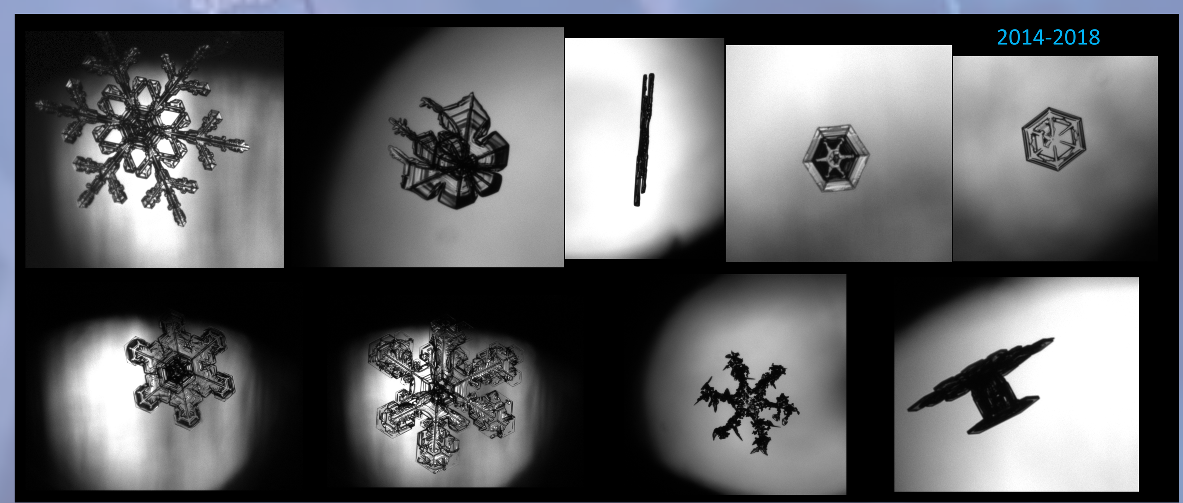

FIG.9: Top-view images of different snowflakes (stellar, plate, needle, plate, rimed stellar crystal, capped column shapes). These images were taken by our instrument in several snow events in Kiruna from 2014 to the present.

HOW SNOWFLAKES GET THEIR SHAPE?

During early growth, local conditions may favor columnar or plate growth. As a snowflake grows and precipitates it encounters always changing temperature and humidity resulting in a variety of growth habits. Under certain conditions, branching instabilities may cause corners to grow out as branches. Changing conditions could then favor, for example, growth of new plates, the formation of new arms/branches on the new plates, and so on. The final result is a great variety of shapes of snowflakes, such as, needles, stellars, plates, graupel and so on.

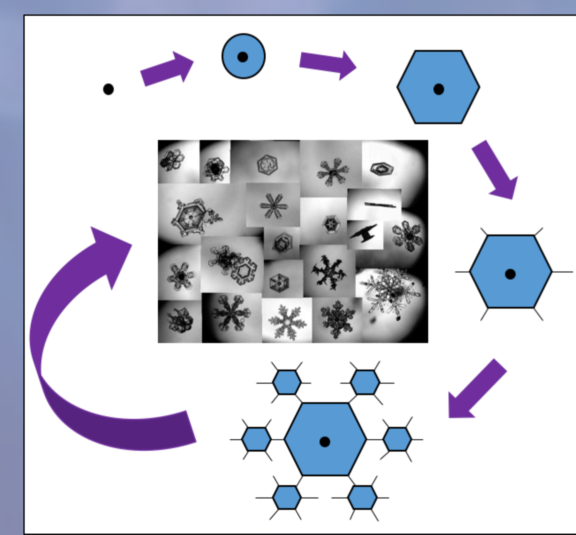

FIG.1: Simplified diagram that shows the formation and growth of a snowflake.

CONCLUSIONS

- Our instrument collects all kind of snow particles in Kiruna covering a sizes from 50 μm to 4 mm.
- Our instrument measures size, area and fall speed of individual snowflakes.
- Our data is useful for identification and classification of particle shape.
- Our data is useful for improving our understanding of precipitation in cold climate.
- Our data is useful for improving parameterizations for climate and forecast models.

FUTURE WORK

- Continue measurements and compare our data (from 2018) with other ground-based in-situ instruments located in Kiruna.
- Autonomous shape determination and fall speed analysis.
- Update our shape classification system with new snowflakes.
- More data analysis of fall speed and shape.
- Comparison with radar snowfall measurements.

FIG.10: Other ground-based in-situ instruments currently located in Kiruna. *Left*: PIP (Particle Imaging Package) instrument. *Right*: MASC (Multi-Angle Snowflake camera) instrument. One photo shows the instrument as viewed from above and the other one from the side.

REFERENCES:

[1] C. Magono, C. W. Lee., Meteorological classification of natural snow crystals, J. Fac. Sci. Hokkaido Univ. Vol. II (4) (1966) 321–335.

[2] K. Libbrecht, Ken Libbrecht's Field Guide to Snowflakes, 2006.

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