Ice Particle Characterization with the VISSS

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Objectives

Research Question: What are the most frequent ice particle shapes at different locations and how often are they rimed?

Why? We see processes as fingerprints on the particles. We need these fingerprints to understand the processes, e.g. aggregation, riming and secondary ice processes.

Where and When? How?

Locations and Campaigns

- Hyytiälä, Finland, November 2021 - June 2022
- Gothic, Colorado, November 2022 - June 2023, embedded in SAIL
- Eriswil, Swiss, December 2023 – February 2024, embedded in CloudLab – PolarCap

- Mountainous vs. "flat" subpolar region
- Complex wind situations due to orography

- same instrument at each location
- ~ 1 billion snowflakes

Fig. 1: Map, showing the measurement locations of VISSS1

Video In-Situ Snowfall Sensor (VISSS1)

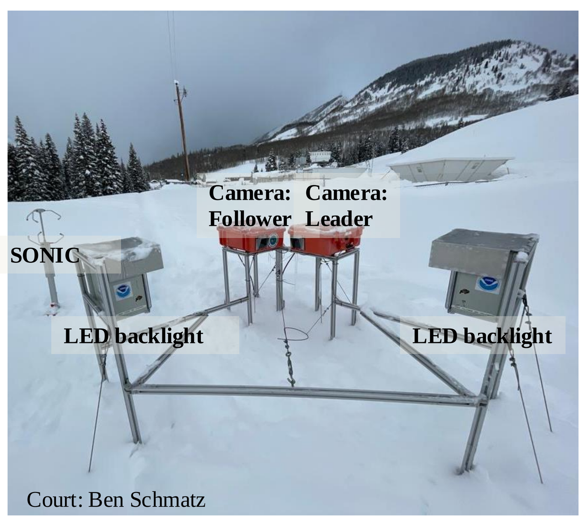

Fig. 2: VISSS at RMBL, two cameras, 90° (orange boxes), two green LED backlights (grey boxes), SONIC

- Two-camera systems, 90°
- Telecentric lenses
- → Sizing distance independent
- Two green backlights
- Snow particle images of two sides
- → Size, Number, Shape, Complexity
- Frame rate: 140 Hz
- Observation volume: ~8x8x6 cm
- Minimum detection size: 200 µm
- Described by Maahn et al. (2024)

Particle Shapes

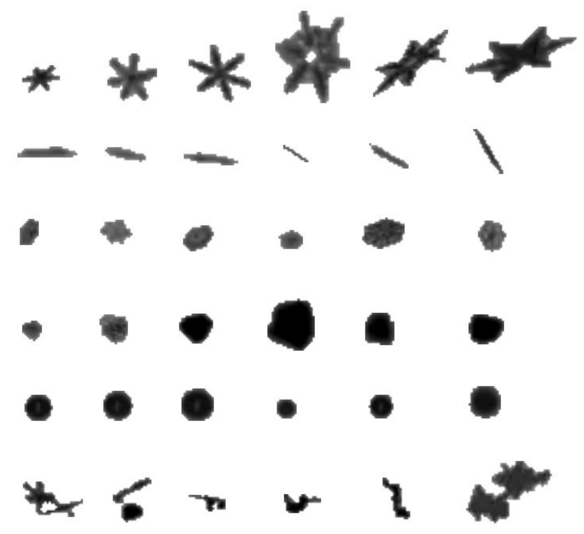

Fig. 3:Different kind of particle shapes

- Stellars / Dendrites
- Needles / Columns
- Plates
- Graupel
- Sphericals
- Aggregates / Irregulars
- / Not classified

Data Processing Algorithm

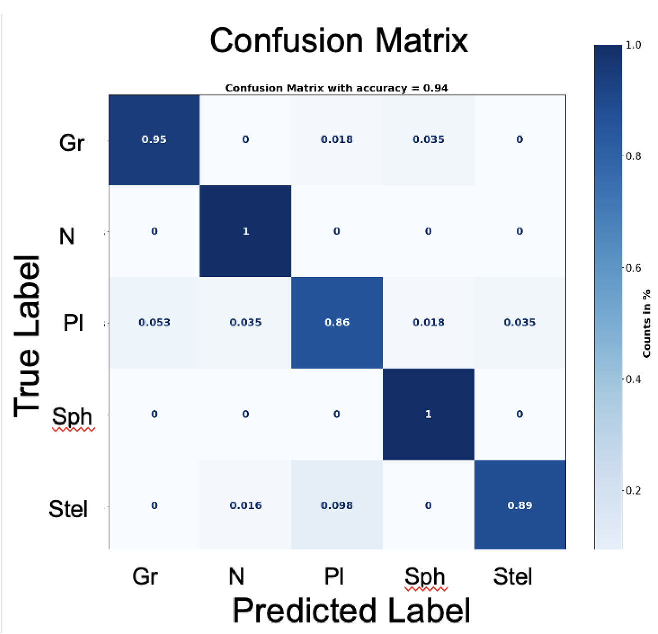

Fig. 4: Confusion Matrix of Shapes Algorithm

- machine learning algorithm
- sklearn.ensemble.HistGradientBoostingClassifier
- Input:
  - 250 labeled unambiguous particles per shape
  - Dfit (3 fits, blue, white, magenta)
  - contourFFT (for the first 16 wave numbers)
  - amplitude ratio (Amp_n/ Amp_sum, for the first 16 wave numbers)
  - difference of the 2 cameras, max or min of cameras
  - Size threshold: DMax > 8 px (0.5 mm)
- Accuracy: 0.94
- Worst True positive = 0.86 (plates)
- some errors by mixing up particle shapes
- aggregates/irregulars/ not classified particles:
  - probability < 0.95
  - same particle but different shapes

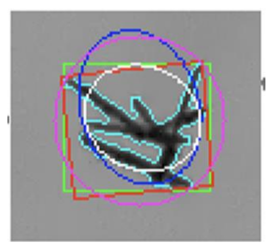

Fig. 5: DFits on particle

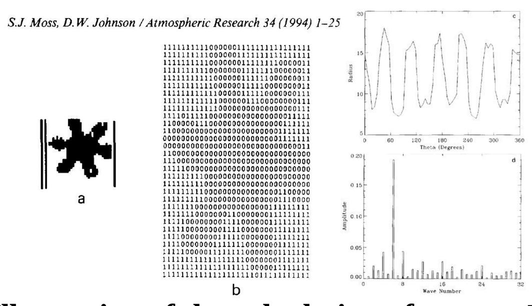

Fig. 6: Illustration of the calculation of contourFFT and wave numbers, and amplitude sum

Rime Mass in-situ method

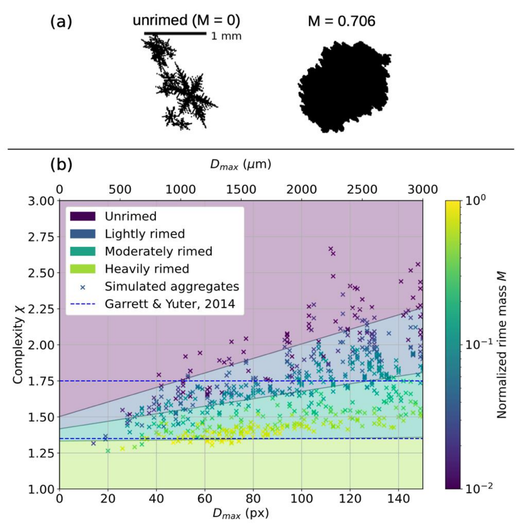

Fig. 7: Fit between rime mass M, DMax and Complexity, by Maherndl et al. 2024

-In-situ method:
Riming changes shape to more spherical particles
Complexity χ: Perimeter/(2√(π*Area)) Gergely et al. (2017)
Sphere: χ=1
Not size independent, larger particles have larger χ
Relation between χ, M and size by Maherndl et al. 2024

- M < 0.01 unrimed
- 0.01-0.1 lightly rimed
- 0.1-1 moderately rimed
- M ≥ 1.0 heavily rimed

Results

Ice Particle Shape Distribution

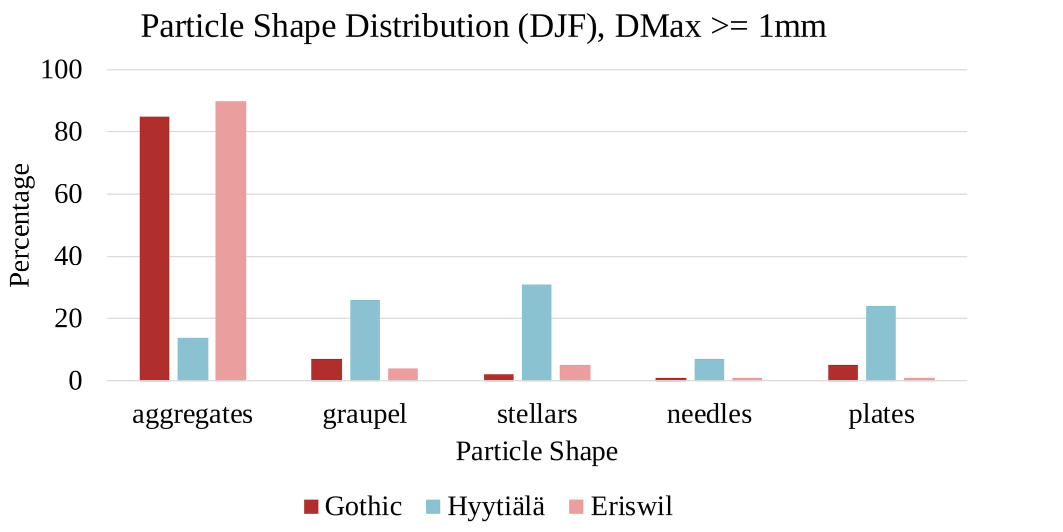

Fig. 8: Particle shape distribution for larger particles during the three winter months at Hyytiälä, Gothic, and Eriswil

- 70 – 80 % of particles < 0.5 mm
- main shape differs for location
- mountainous (Gothic, Eriswil):
  - aggregates most frequent shape
  - different kinds of aggregates
  - often rimed
  - or broken particles
- sub-polar (Hyytiälä):
  - frequently pristine particles
  - pure needle cases

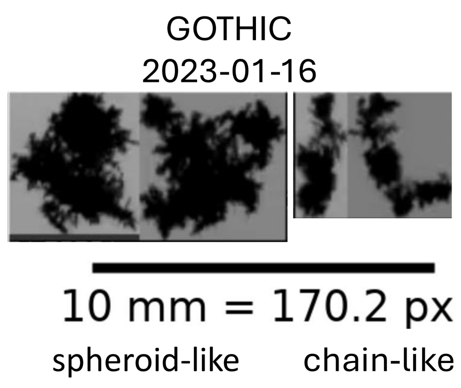

Fig. 9: Samples of aggregates

Special Cases

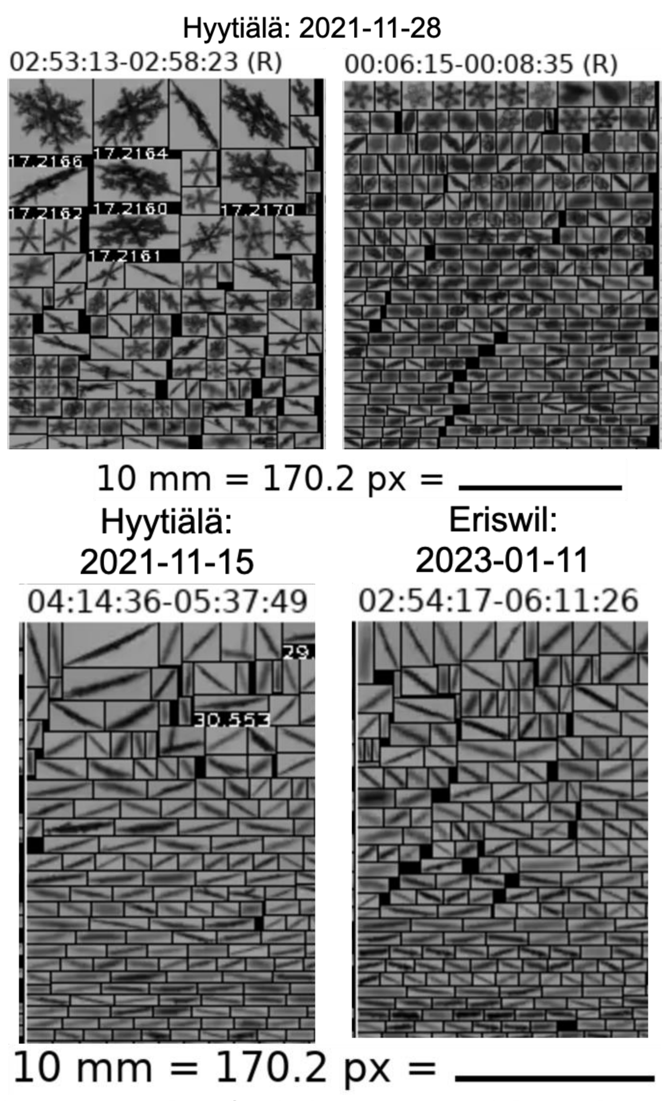

Fig. 10: Samples of pristine snow particles and needles

Degree of Riming

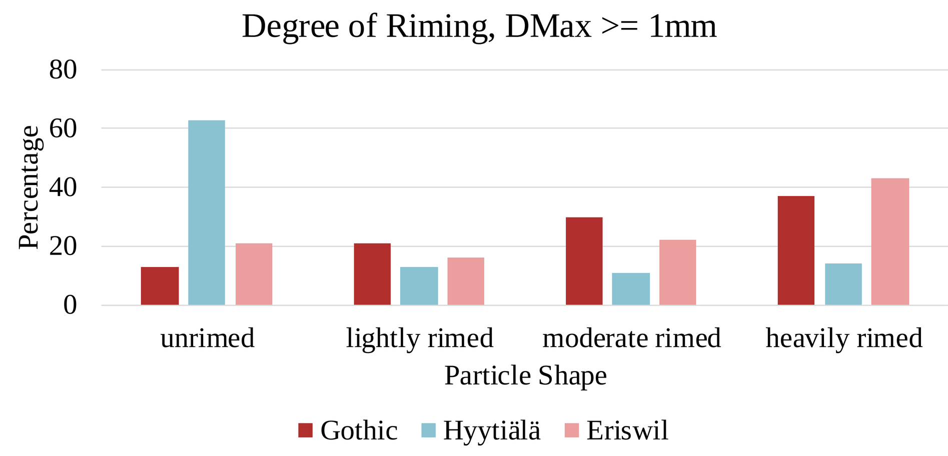

Fig. 10: Distribution of Degree of Riming for larger particles during the three winter months at Hyytiälä, Gothic, and Eriswil

- different stages of riming observed
- heavily rimed caused by graupel
- lightly rimed caused by pristine particles
- mountainous (Gothic, Eriswil):
  - graupel particles most frequent
  - highest percentage of rimed/heavily rimed particles
- sub-polar (Hyytiälä):
  - pristine particles most frequent
  - highest percentage of unrimed particles

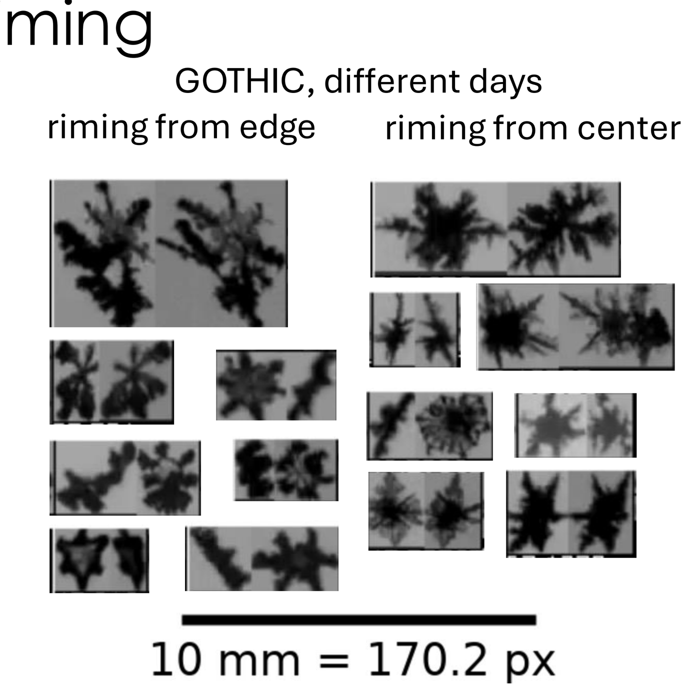

Fig. 11: Samples of rimed snow particles

- two different ways of riming observed
  - riming on outer edges first
  - riming at center first

Summary and Outlook

- unique and very large dataset, different locations (mountainous vs. sub-polar)
- between 20-30 % of particles large enough for classification
- different stages of riming observed, different ways of riming observed
- most common shape graupel and aggregates, pristine particles are rare and more often in Hyytiälä

- ➢ Finding reason how different particle shapes get rimed (e.g. from edge or center)
- ➢ Finding relationships between particle shape and aspect ratio, fall velocity, or IWC
- ➢ Finding relationship between particle shape and polarimetric radar variables
- ➢ Finding reason for different kind of aggregation
- ➢ more measurement campaigns

References

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