Snowfall Microphysics with Surface-Based Observations in Southern Finland

Dmitri Moisseev[1], Annakaisa von Lerber[2], Jussi Tiira[1], and Walter Petersen[3]

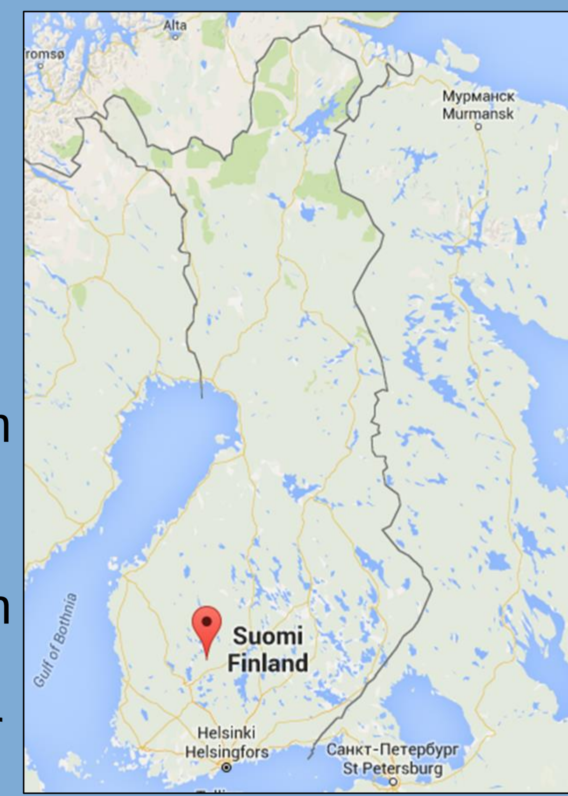
[1]University of Helsinki, [2]Finnish Meteorological Institute and [3]NASA-MSFC Earth Science Office

Summary

- Focus is on studying microphysical properties of snowfall and how these change with different microphysical processes
- Goal is to build a link between the ground observations and remote sensing retrievals and to provide verification for numerical weather prediction models
- Idea is to investigate snowfall microphysical properties with resolution of few minutes
- Mass-dimensional *m(D)* and fall velocity-dimensional *v(D)* relations and particle size distributions (PSD) are retrieved with combined observations of video-disdrometer (PIP) and precipitation gauge

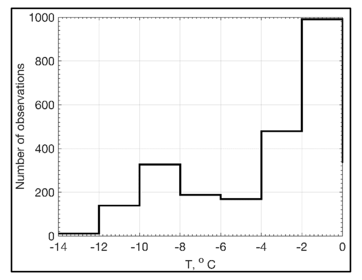
Hyytiälä precipitation measurement field in 2017 with surface instrumentation and radars operating at C-, K_u- and K_a-bands (W-band will be installed in October 2017).

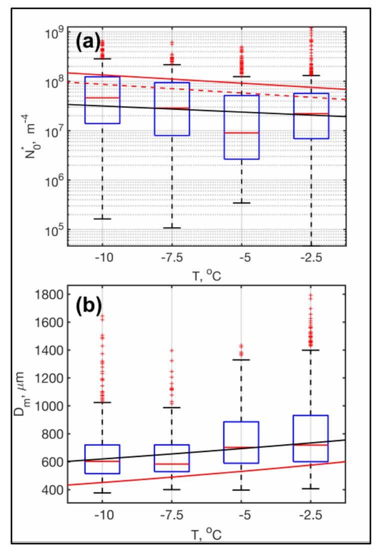
UH Research Station



- Locates circa 200 km North from Helsinki
- Clouds/Precipitation measurements started in 2014 with BAECC (Biogenic Aerosols Effects on Clouds and Climate)-campaign
- Operating as part of the GPM GV program since 2013
- Instrumentation and implementation designed especially for winter precipitation measurements
- FMI operational dual-polarization Doppler radar locates 64 km from the station

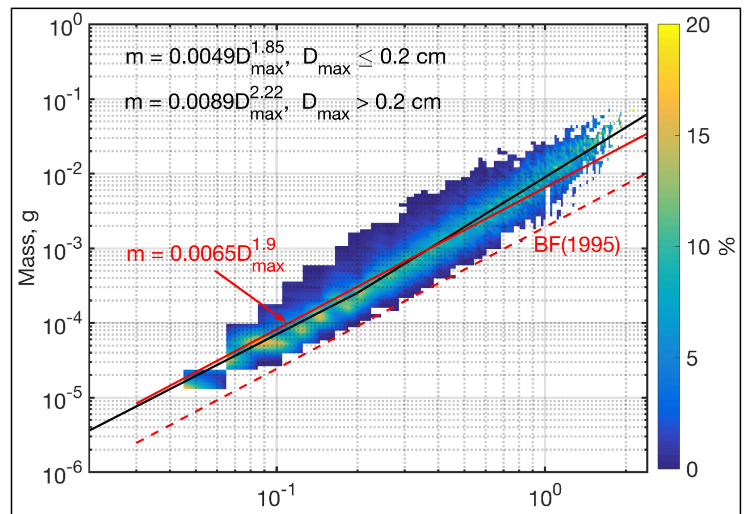
How representative airborne observations of PSD and the retrieved m(D) relations are for surface snowfall?



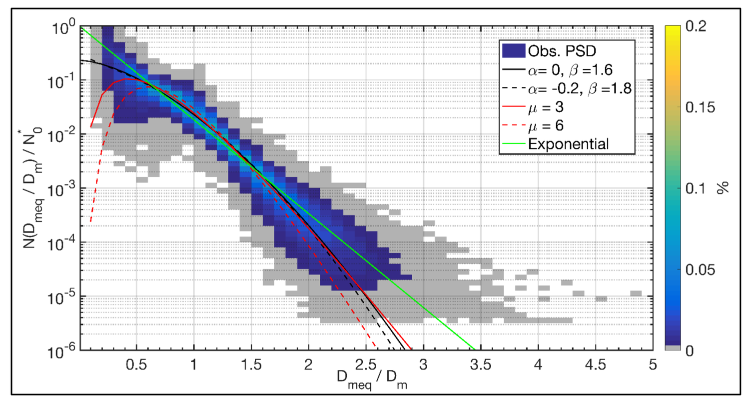


The analysis is based on 24 snowfall events during winters 2013 - 2015 with surface air temperature varying between -14°C – 0°C.

The box plots present temperature dependence of N_0* and D_m. As expected D_m increases with temperature*T*. The retrieved dependences differ from the existing parametrization (red lines). At least a big part of this difference can be explained by the heavier ice particles that we observe in the snowfall.



For every 5-minute *m(D)* and *N(D)* are retrieved from PIP (Particle Imaging Package) and gauge observations. Reasonable agreement with the parametrizations presented in the literature are found, but the observed snowflakes on the ground are typically larger and denser than reported parametrization.



Normalized PSD parametrization is described as a function of melted equivalent diameter D_{meq} [Delanoë et al. 2005, 2014, Testud et al. 2001]

$$N(D_{meq}) = N_0^* F(D_{meq}/D_m)$$

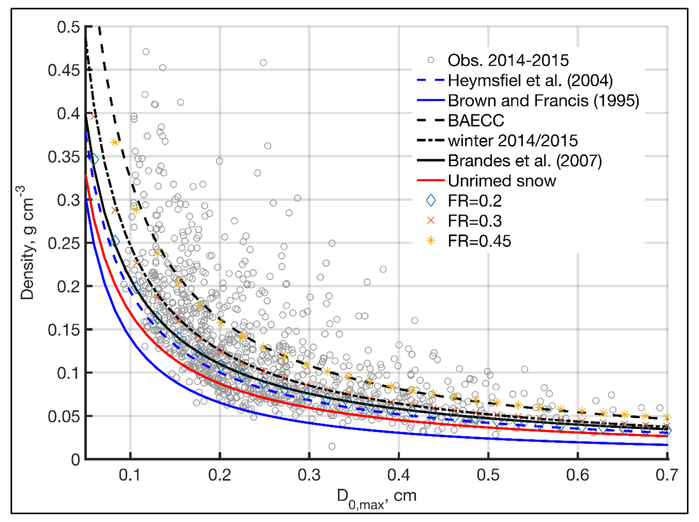
Normalization factor N_0* and mass-weighted mean diameter D_m are calculated from the PIP measurements. The normalized PSD can be approximated either by the gamma or generalized gamma functions, and its shape is rather stable. PSD shape is found to be similar to shown in [Delanoë et al. 2014], which implies that the PSD shape does not change much as we go from ice clouds to surface snowfall.

$$F(D_{meq}/D_m) = \frac{\Gamma(4)}{4^4}\frac{(4+\mu)^{4+\mu}}{\Gamma(4+\mu)}\left(\frac{D_{meq}}{D_m}\right)^{\mu} exp\left(-(4+\mu)\frac{D_{meq}}{D_m}\right)$$

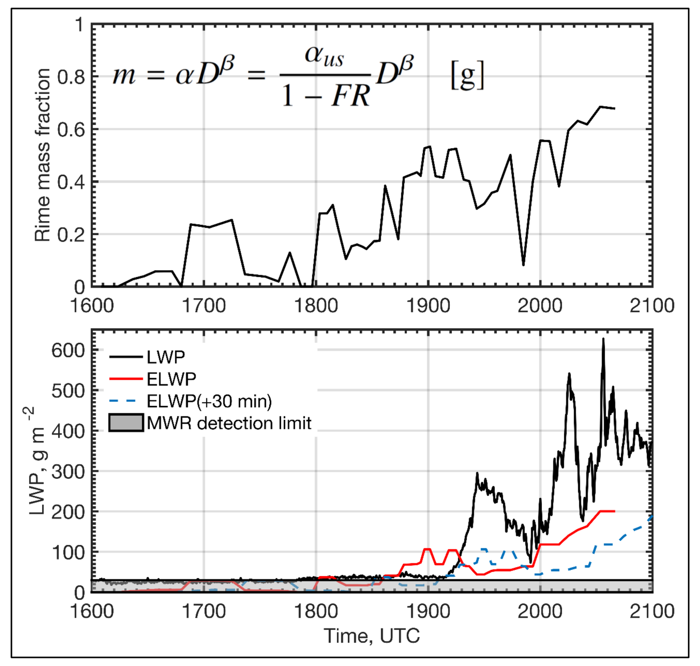
$$F(D_{meq}/D_m, \alpha, \beta) = \beta\frac{\Gamma(4)}{4^4}\frac{\Gamma(\frac{\alpha+5}{\beta})^{4+\alpha}}{\Gamma(\frac{\alpha+4}{\beta})^{5+\alpha}}\left(\frac{D_{meq}}{D_m}\right)^{\alpha} exp\left(-\left[\frac{D_{meq}}{D_m}\frac{\Gamma(\frac{\alpha+5}{\beta})}{\Gamma(\frac{\alpha+4}{\beta})}\right]^{\beta}\right)$$

How important riming is for surface precipitation?

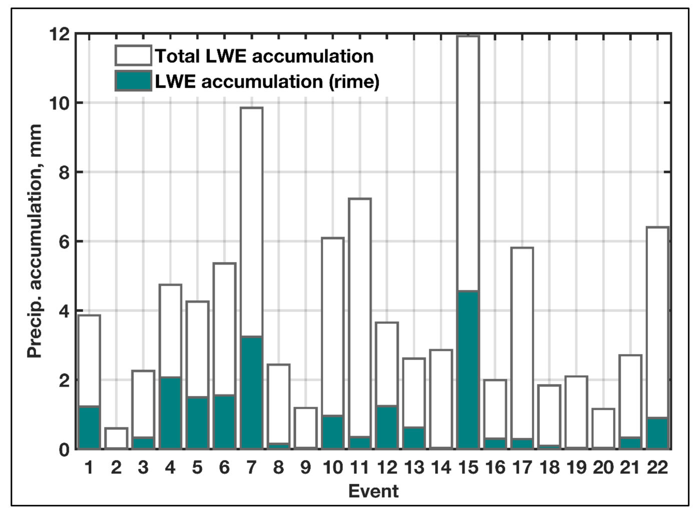
The study covers 22 snowfall events observed during two consecutive winters, 2013/2014 and 2014/2015. The ensemble mean density is retrieved using particle volume flux computed from PIP and liquid water equivalent (LWE) precipitation rate measured by a weighing gauge [Tiira et al. 2016]. Firstly a mass-dimensional relation of unrimed snow is derived.



Following the approach used in a single ice-phase category microphysical scheme in numerical weather prediction models [Morrison and Grabowski, 2008, Morrison and Mildbrandt, 2015], it is assumed that prefactor of *m(D)* relation is determined by the rime mass fraction, while the exponent does not change.

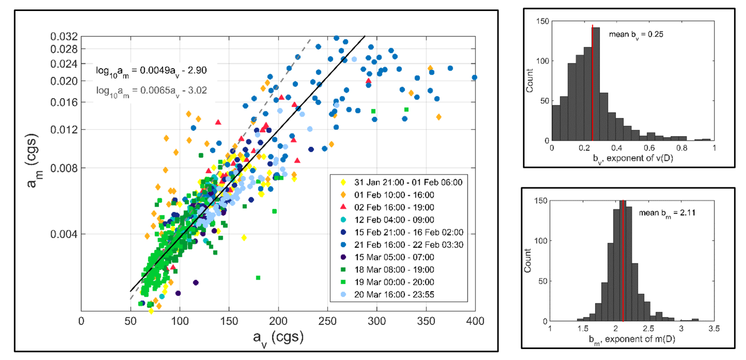


The validity of the proposed retrieval method is checked by estimating particle effective liquid water paths (ELWP) that correspond to the computed rime mass fractions and these are compared to microwave radiometer observations (LWP). It is showed that LWP and ELWP react to the same processes that take place in the observed precipitation systems.

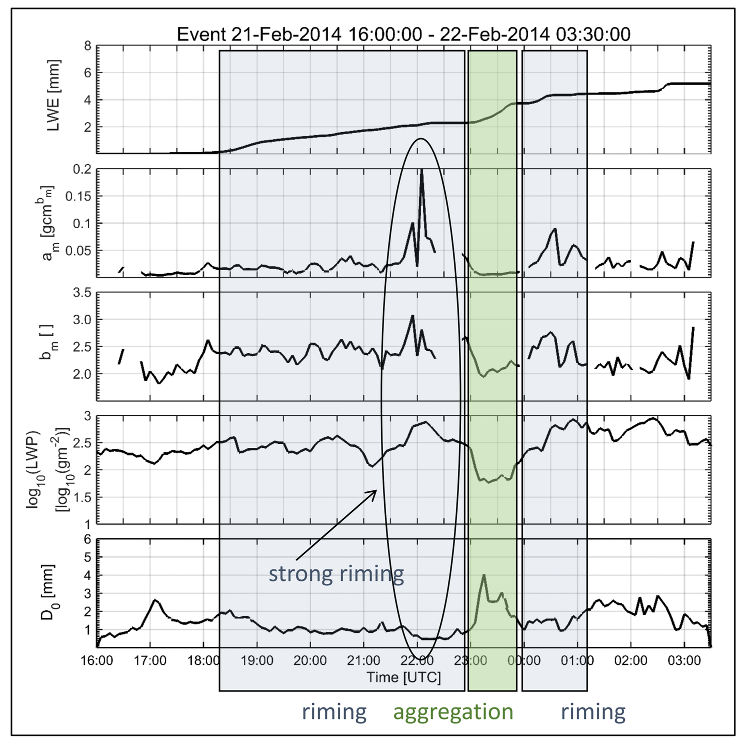


The importance of riming for surface snow accumulation is investigated. [Mitchell et al.1990] and [Harimaya and Sato, 1989] have shown that riming could explain 30% to 100% of surface snowfall mass. Here it is found that riming is responsible for 5% to 40% of precipitation mass. Based on few case studies, it seems that there is a correlation between rime fraction and precipitation accumulation.

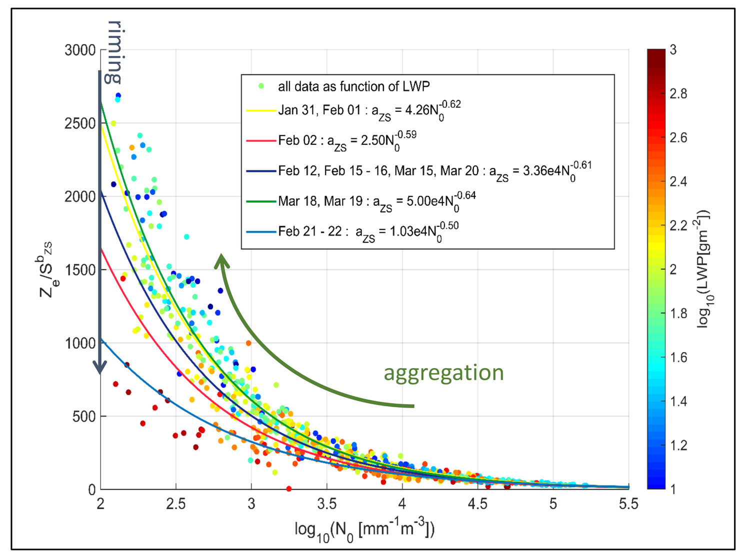
How riming and aggregation change parameters of Z_e -S relation?



Here ten snowfall events in winter 2014 are studied. The *m(D)* relation is computed for 5-minute observations based on hydrodynamic theory [Mitchell and Heymsfield, 2005, von Lerber et al. 2017]. The retrieved values are well aligned with other literature values.



Changes in *m(D)* relation are found to correspond to transitions of microphysical processes. For example on February 21- 22, both riming and aggregation processes are present. The strongest accumulation is occurring between 23:00 - 00:00 UTC, when large aggregates are observed. This can be seen as both factors of *m(D)* relation and LWP decrease, while median volume diameter increases. During this period the exponent of *m(D)* ranged between 1.9 - 2.16, while during the rest of the event it is closer to 2.5, with maximum values occurring at 22:00 UTC coinciding with the peak in LWP.



Dependence of Z_e-S relation on *m(D)* relation and PSD is shown. The changes in prefactor of Z_e-S for a given intercept parameter N_0 are shown to be linked to changes in liquid water path, which can be considered to be a proxy for the degree of riming. The prefactor is strongly driven by N_0. Especially during periods with low precipitation rate, aggregation decreases N_0 and increases prefactor values. Whereas riming decreases the prefactor.