A new particle – by – particle hot plate technique for measurement of precipitation rate, snow density and visibility

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A breakthrough in measurement of precipitation mass and density

Accurate characterization of precipitation particle mass and density is critical for quantifying the hydrologic budget, validating remote sensing measurement, weather modeling, climate prediction, and snow safety applications.

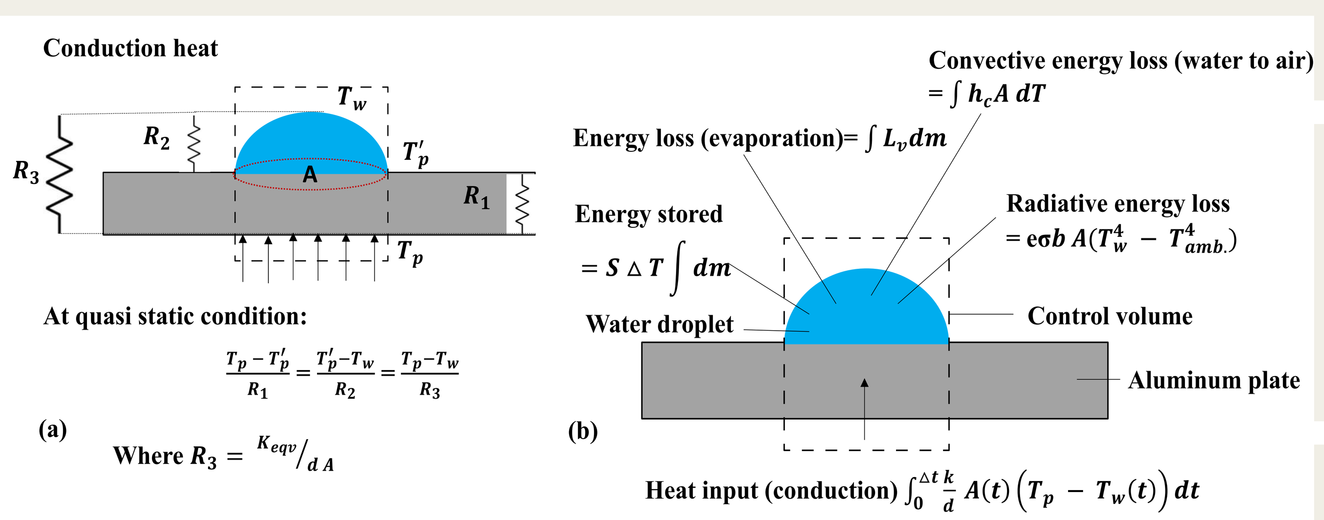
We have developed a new device for accurate measurement of rainfall rate, snowfall rate, visibility, and precipitation size and mass distributions.

Most of the time snowflakes are non-spherical and spherical assumption creates a significant error in the quantification of density, size distribution, precipitation rate, etc.

Atmospheric turbulence effects on falling hydrometeors is dependent on the properties of individual particles including size, physical cross-sectional area, density, and mass.

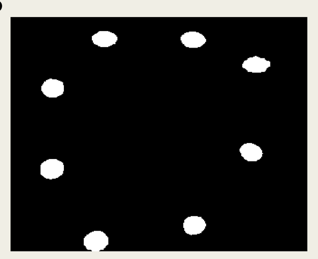
A particle-by-particle hot plate method

Schematic of the energy balance of control volume across a water droplet

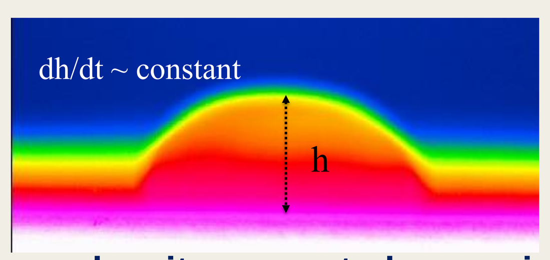


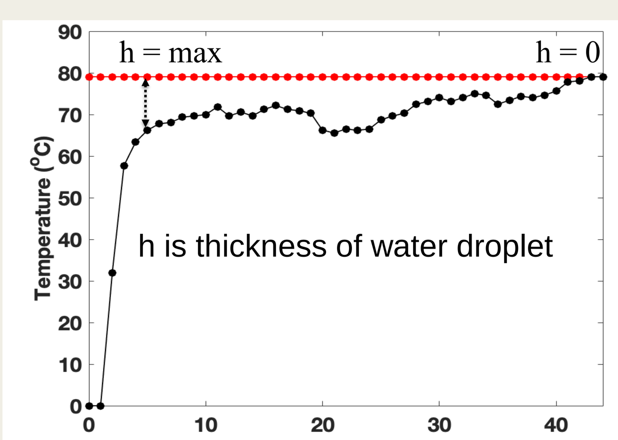
Method validation

Plan view of water droplets on the hot plate derived from thermal images

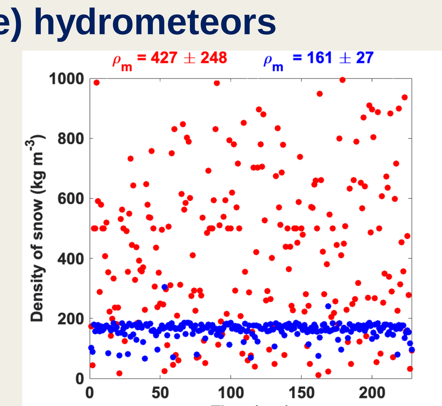


Thermal image of the side view of water droplet



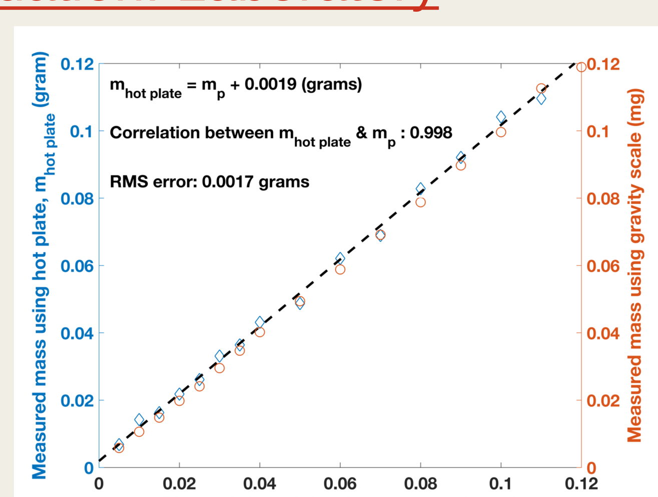


Snow density computed assuming spherical (red) and non-spherical (blue) hydrometeors



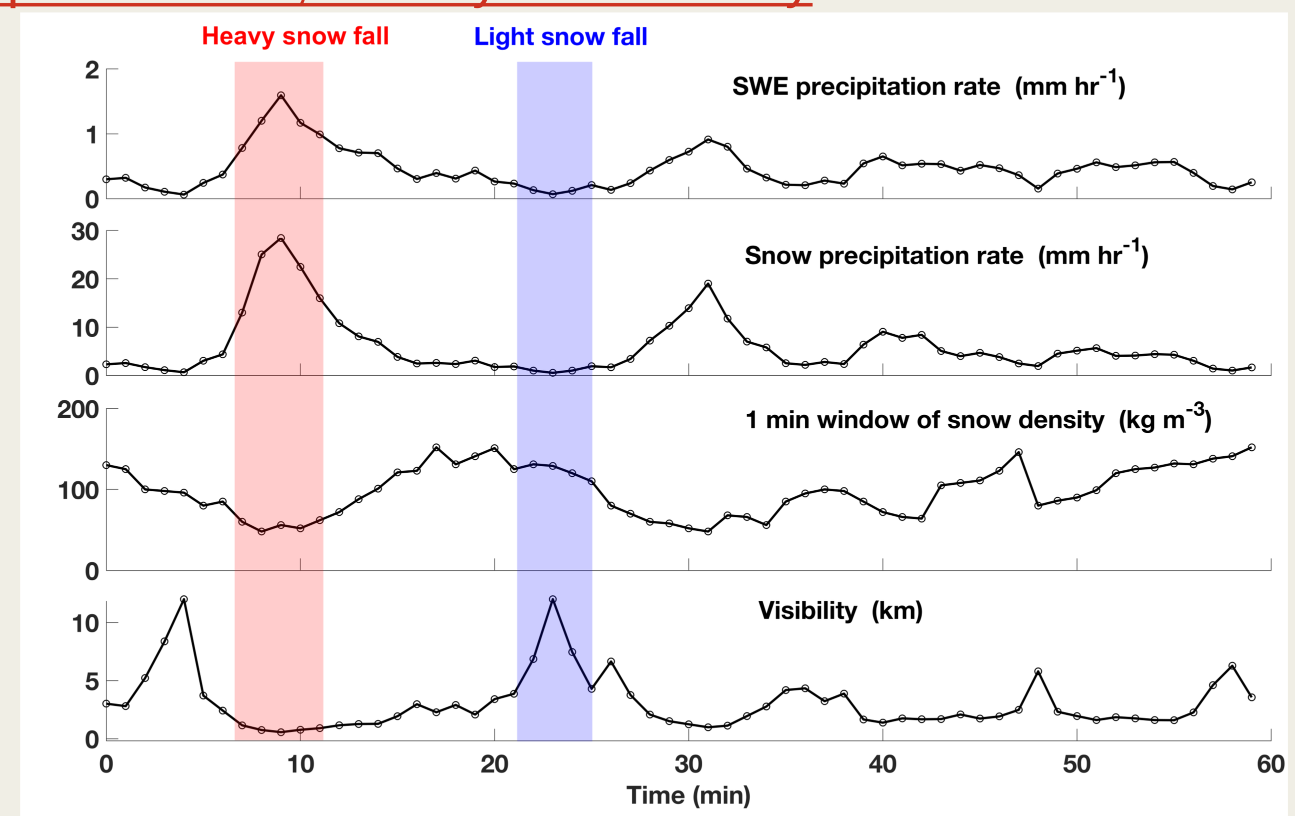
Mass validation: Laboratory

Correlation between water droplet mass measured using a pipette and particle-by particle hot plate method shown with a linear fit (R^2 = 0.998).



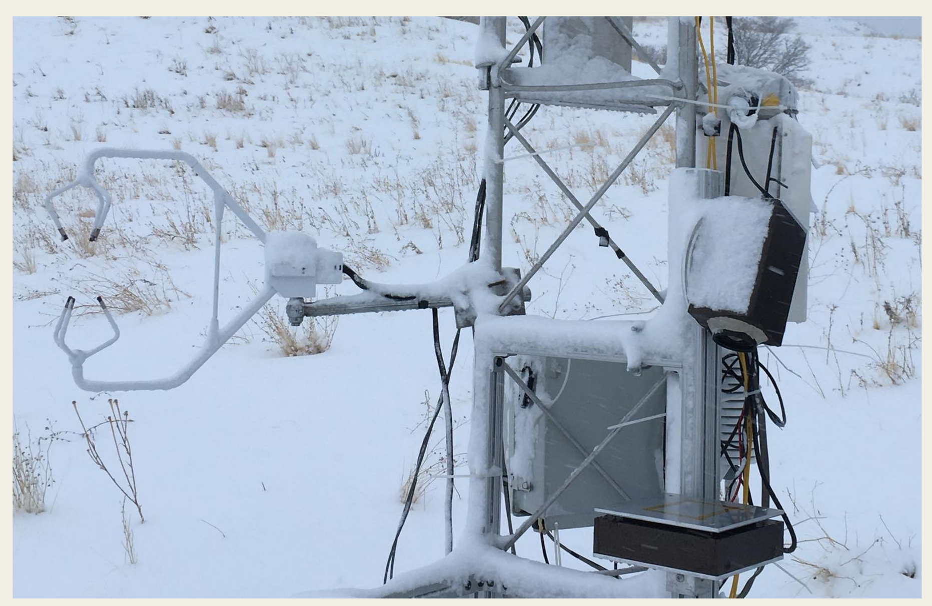
Precipitation rate, density and visibility

The melted snow water equivalent precipitation rate (SWE), snowfall precipitation rate, mean snow density, and visibility (10 Feb 2019)

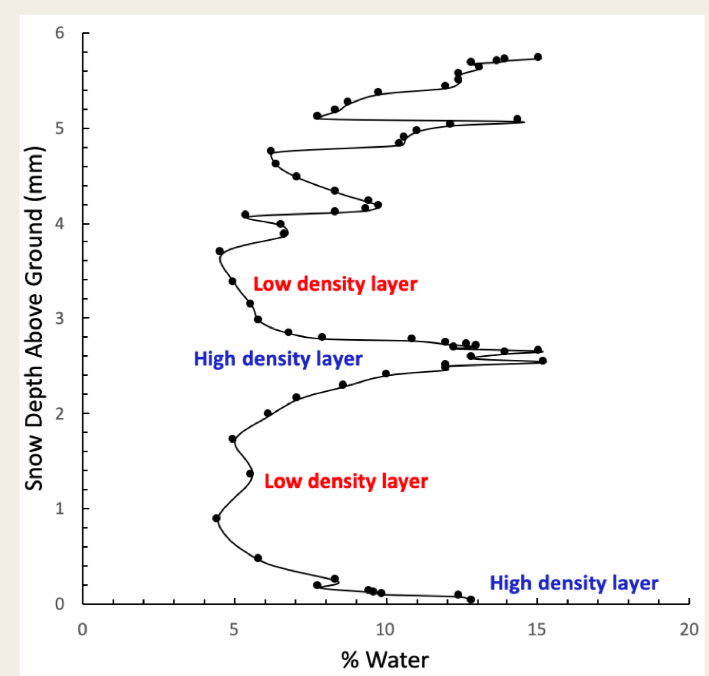


Realtime snow-density profiles

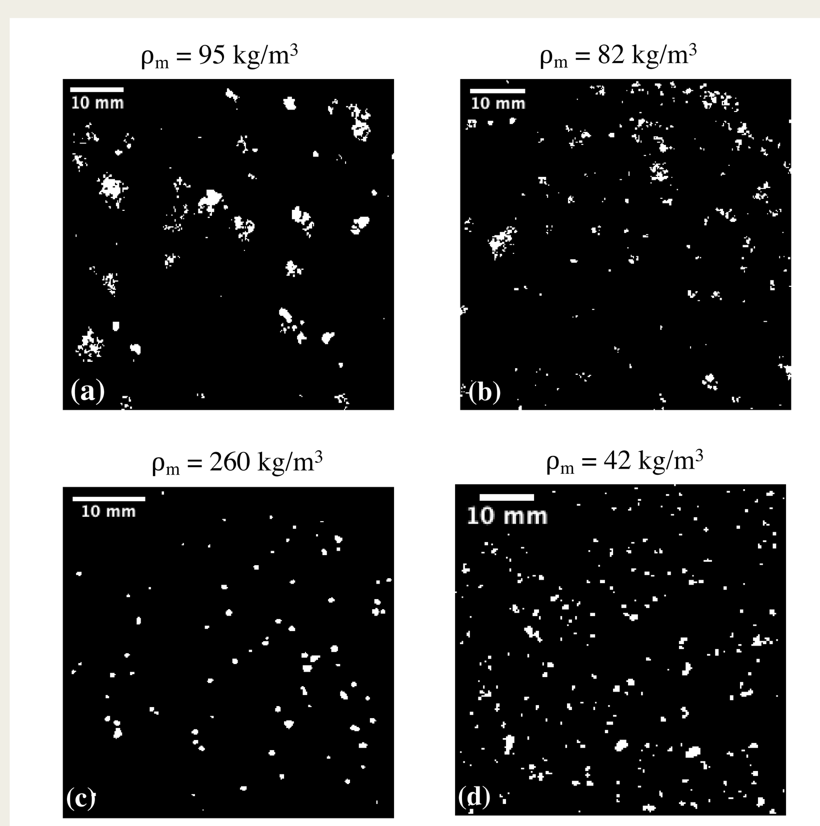
Illustration of a deployment of the hot plate and thermal camera system



Accumulation of snow above the ground is quantified using the fall rate and density of snow measured using

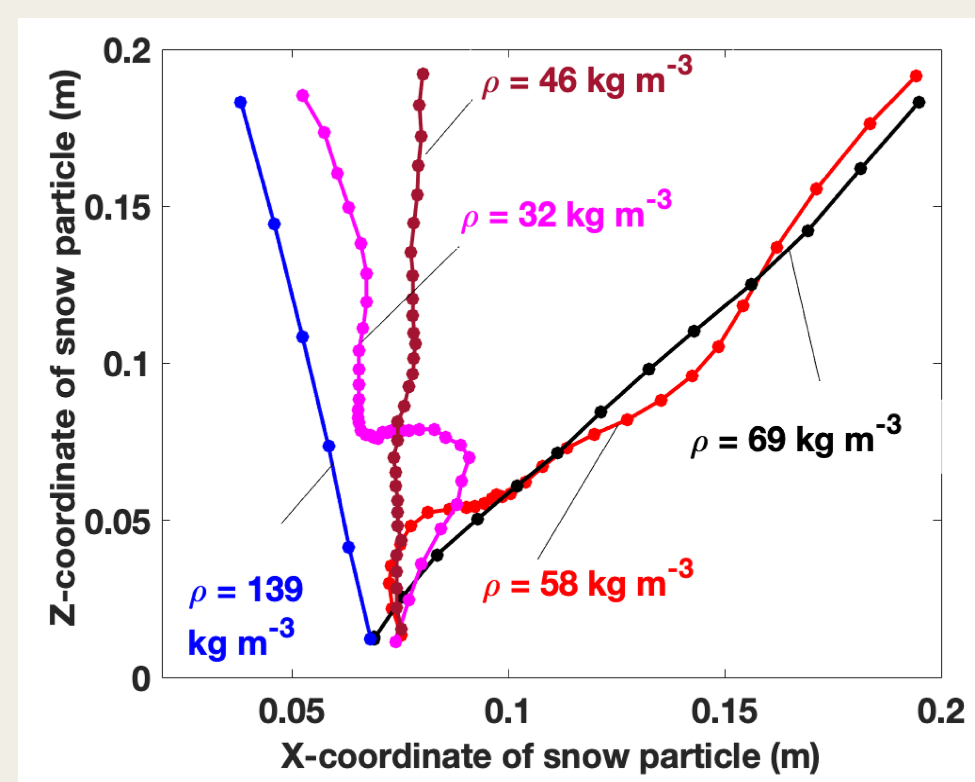


Infrared Imagery of frozen hydrometeors on the hot plate



	(a)	(b)	(c)	(d)
SWE fall rate (mm hr^{-1}):	2.5	1.4	1.5	6.28
Snow fall rate (mm hr^{-1}):	26.3	17.06	5.76	14

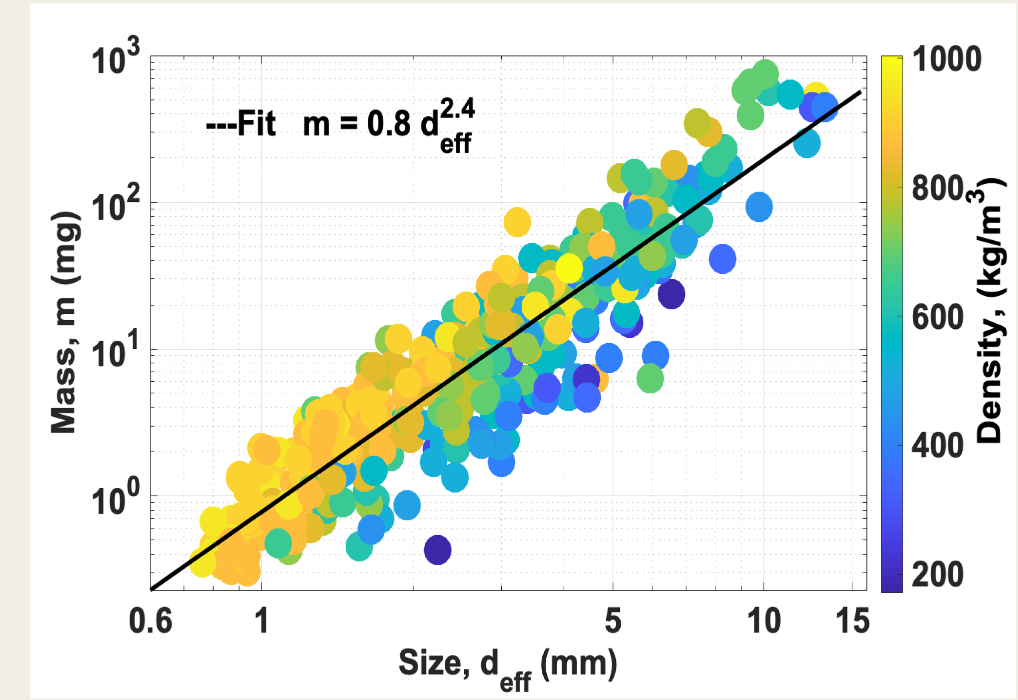
Effect of turbulence on frozen hydrometeors

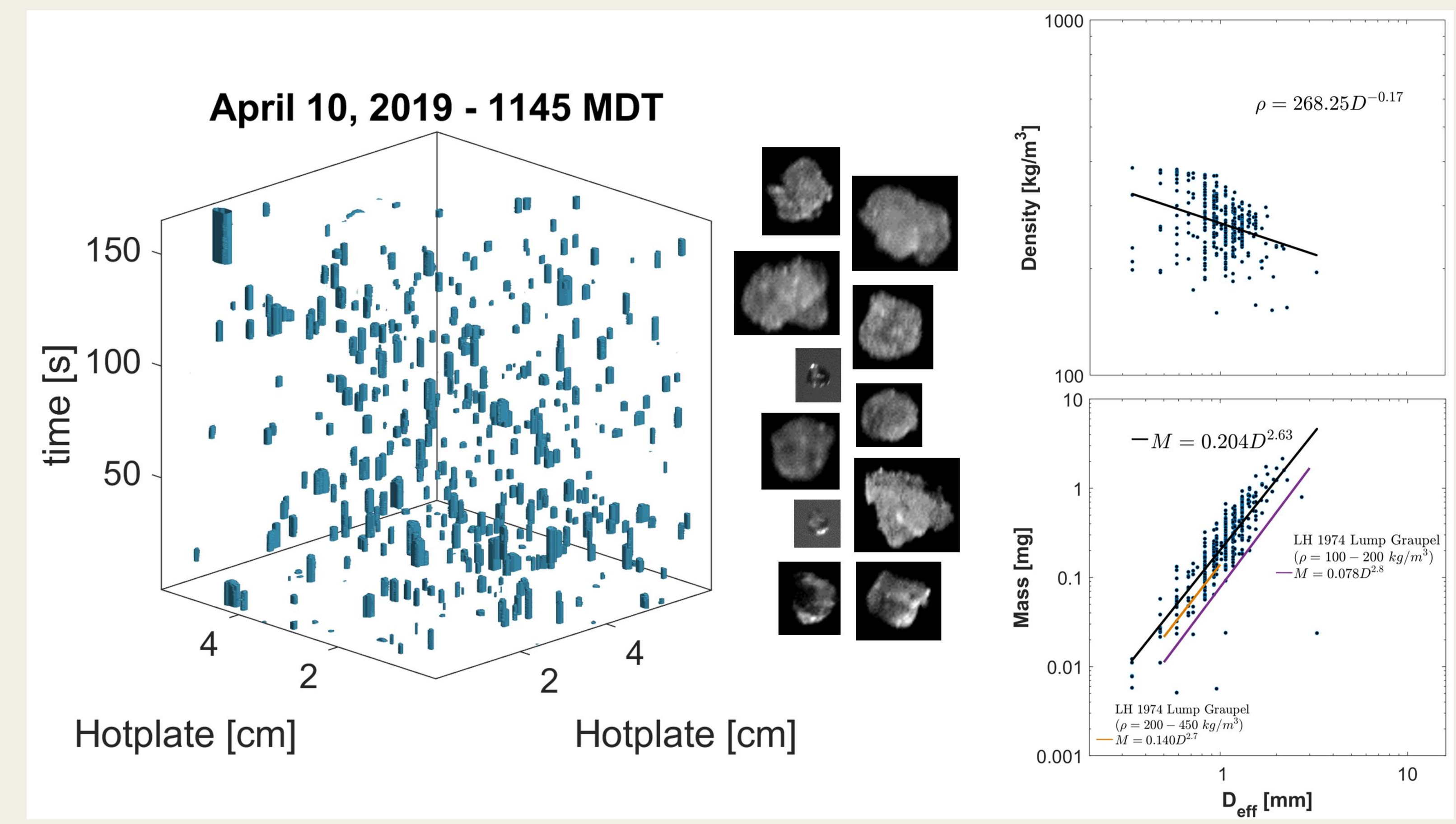


Visual tracking of frozen hydrometeors using a light sheet and digital camera. Note the relation between measured density and trajectory

Mass, diameter and density of hydrometeors

Rain/Snow mix event: 30 April 2019





Size distributions of rain and snow

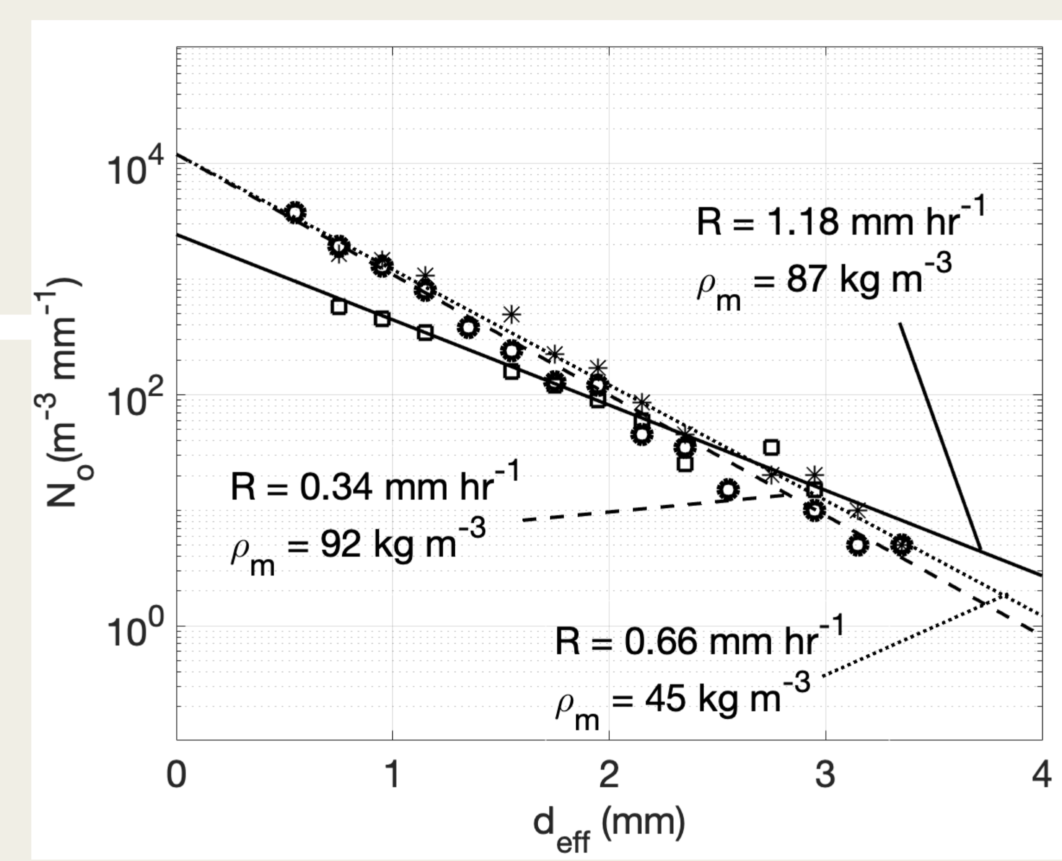
For size $d_{eff} > 0.75\ mm$, experimental observation can be fitted by relation:

$$N(d_{eff}) = N_0\, e^{-\nu d_{eff}}$$

Where, d_{eff} is equivalent circular diameter and bin size: 0.2 mm

$N_0 = 0.089\ cm^{-4}$ for all intensity of rainfall.
($N_0 = 0.08\ cm^{-4}$ Gunn and Marshall, 1957)

$N_0 = 2.98\ X\ 10^3\ R^{-1.1}\ m^{-3} mm^{-1}$ for snow
($N_0 = 3.8\ X\ 10^3\ R^{-0.87}\ m^{-3}$ Gunn and Marshall, 1957)



References & Acknowledgements

K. L. S. Gunn and J. S. Marshall, The distribution with size of aggregate snowflakes, Journal of Meteorology, vol. 15, pp. 452-461, 1957

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