Validation of GMI snowfall observations by using a combination of weather radar and surface measurements

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Research

- Surface measurements of snow microphysics are combined with large-scale weather radar observations
- Event-specific Z_e –S relations with the defined uncertainties are applied to weather radar observations
- Feasibility of dataset is demonstrated with NASA GPM Microwave Imager (GMI) snowfall product with GPROF-algorithm versions V04 and V05

University of Helsinki Research Site

- Observations are carried out at the Hyytiälä Forestry Field Station of University of Helsinki, in Finland.
- The region is hilly, forest-covered land with marshland and ridges, and typically in Finland circa 10% of the surface area is covered by lakes.
- The measurement site is also sheltered by the forest, the local wind conditions are moderate.
- Cloud/precipitation measurements started
  - GPM GV program 2013
  - US DOE ARM BAECC (01.02-12.09. 2014)
  - ACTRIS 2015 –
  - HyIce 2018 –

Instrumentation in Hyytiälä

Gauges

Disdrometers
- Parsivels
- 2DVD
- PIP

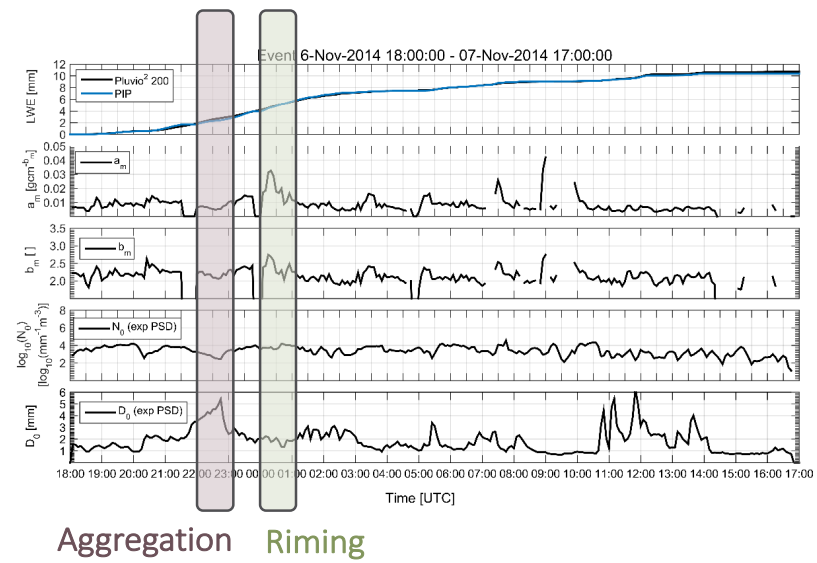
Snow depth sensor

Radars C, Ku, Ka, and W(coming October 2017

FMI C-band weather radar

Surface Measurements

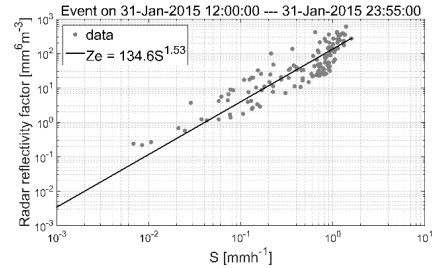
- Z_e-S relations are obtained by combining observations of PIP with a co-located precipitation weighing gauge.
- Mass of falling snow particles can be estimated with hydrodynamic theory [Böhm,1989,Mitchell and Heymsfield, 2005].
- Value of the diameter correction factor is determined by comparing the LWE accumulation of the event estimated by PIP with accumulation measured by the gauge.
- Equivalent reflectivity factor Z_e and precipitation rate S are defined every 5-minutes with the observed and averaged PSD, the fitted *v(D)* relation and the retrieved *m(D)* relation.

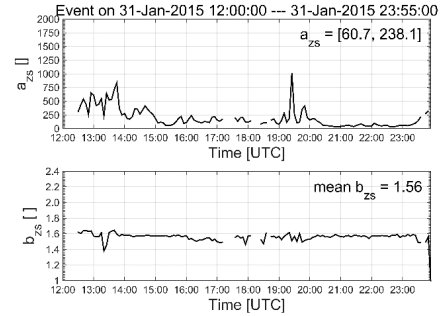


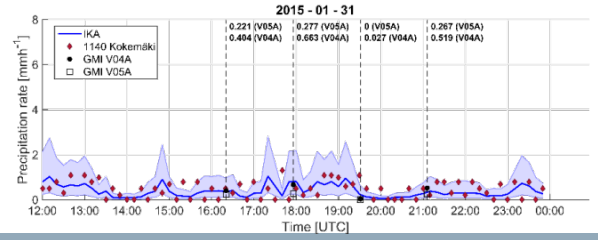
Event-specific and instantaneous Z_e-S relations

Two types of Z_e-S relations are computed ($Z_e = aS^b$)

- Event-specific Z_e-S relation:
  - single prefactor and exponent describe the event
  - total least-squares fit in log-log-space to 5-minute observations
- Instantaneous Z_e-S relation:
  - used to compute the uncertainty of the radar-based snowfall estimate
  - PSD assumed gamma-distributed
  - prefactor is dependent on N_0 and on both prefactors of *m(D)* and *v(D)* relations.
  - error limits of prefactor are determined from CDF at percentiles of 25% and 75%, when keeping exponent to its fixed value (mean).

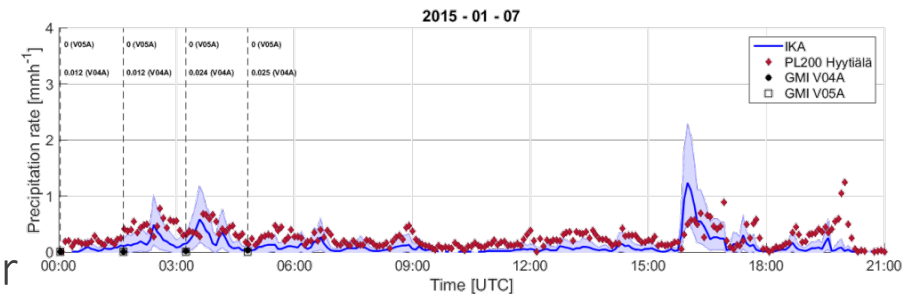


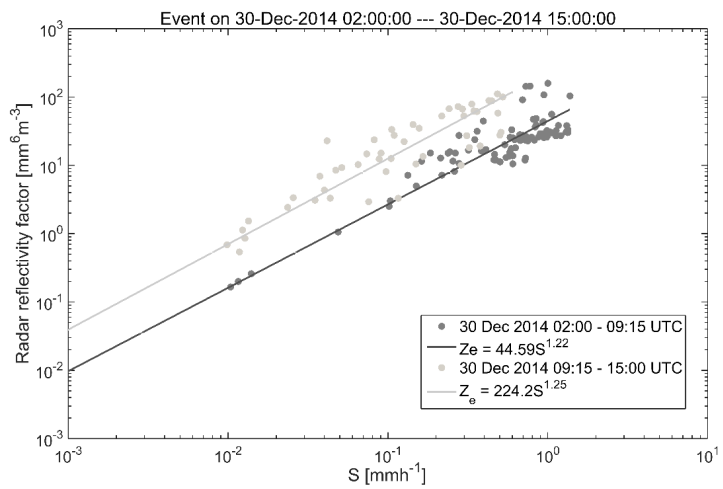




Event-specific and instantaneous Z_e-S relations

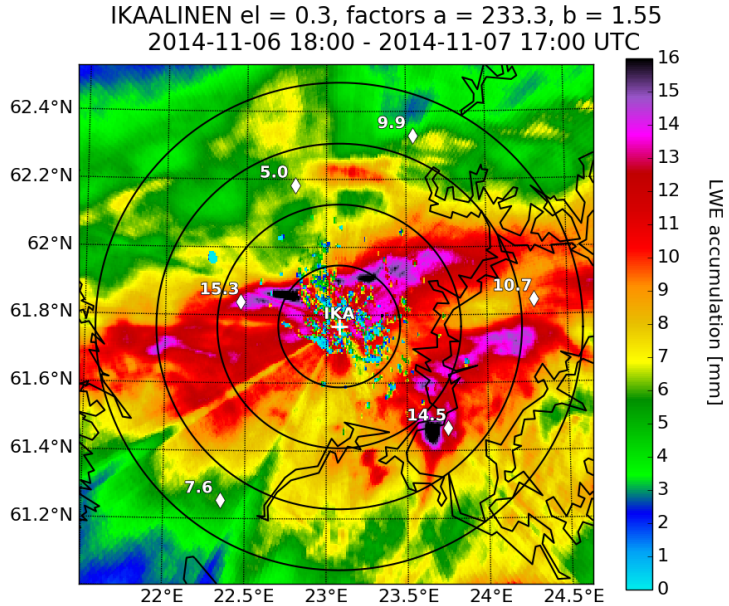
- An average relation computed from long-term observations is applied, if the main part of the snowstorm (the highest accumulation) does not move over the measurement site
- The presented method has uncertainties estimating the snowfall rate
  - With shallow clouds with small particles
  - With clearly two different snow types





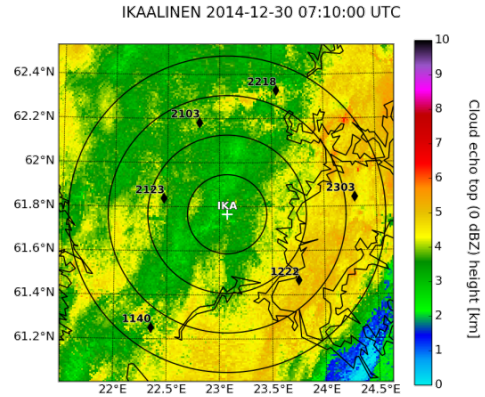
Radar Measurements

- The event-specific Z_e-S relation is applied to PPI-scans with lowest elevation (0.3°) and the accumulated precipitation of the snow event is computed and compared with gauge observations.
  - Clutter removal with a stationary statistical ground clutter map

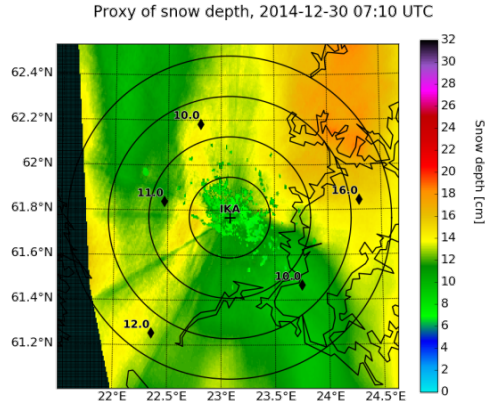


Radar-based products

- **Cloud echo top** is computed from the volume scans of Ikaalinen radar (elevation angles between 0.3° – 45°) using 0 dBZ as the reflectivity factor threshold

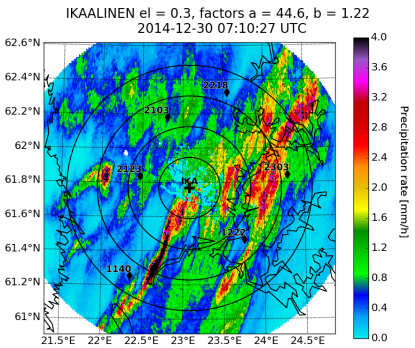


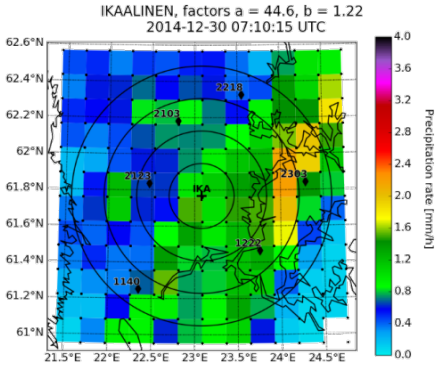
- **Snow depth proxy** is estimated with the radar-based snowfall LWE accumulation adjusted by the AWS snow depth measurements.



Comparison with GMI Snowfall Rate

- Eight snowfall events with 26 GMI overpasses
- Radar-estimated snowfall rates are averaged over four elevation angles (0.3°, 0.7°, 1.0°, 1.5°), temporarily over 20 minutes, and to a larger sampling grid of 15 km X 15 km
- Snowfall rate is retrieved with the GPROF versions V04 and V05
- Compared products are:
  - surface precipitation
  - column water vapor index
  - probability of precipitation
  - surface class





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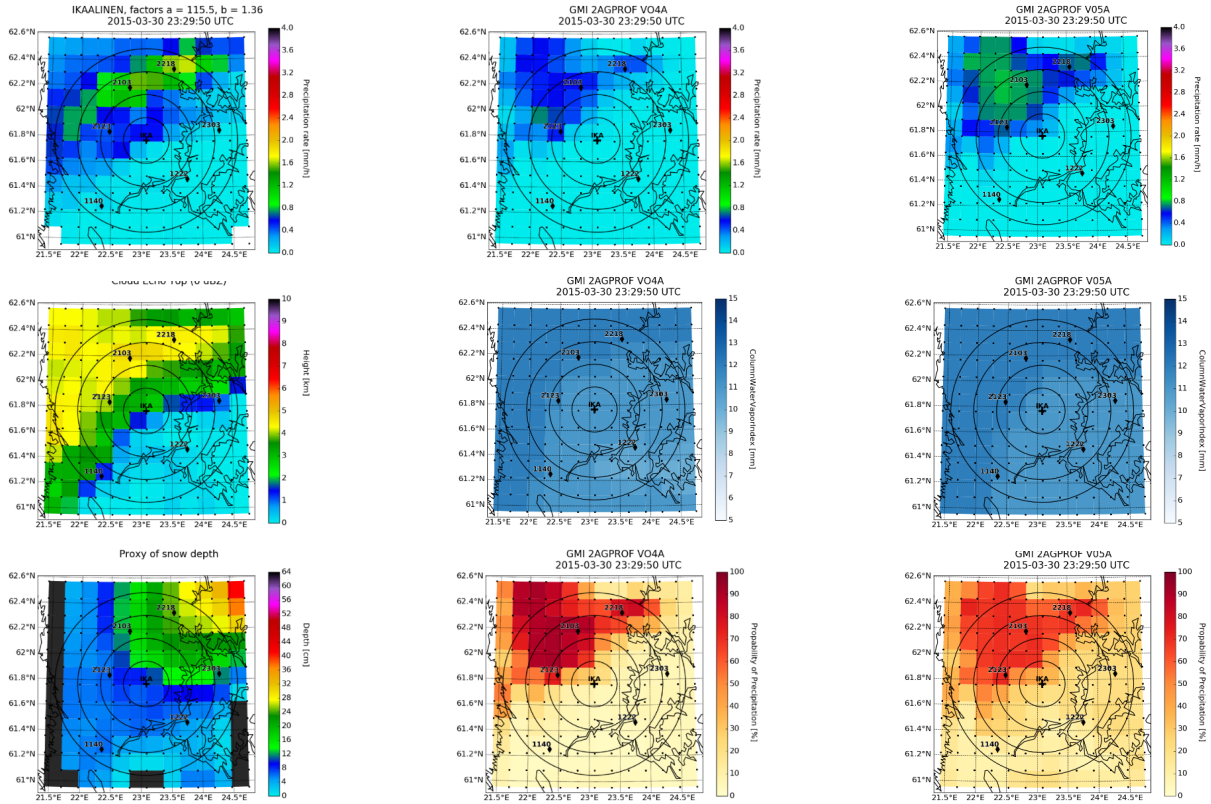

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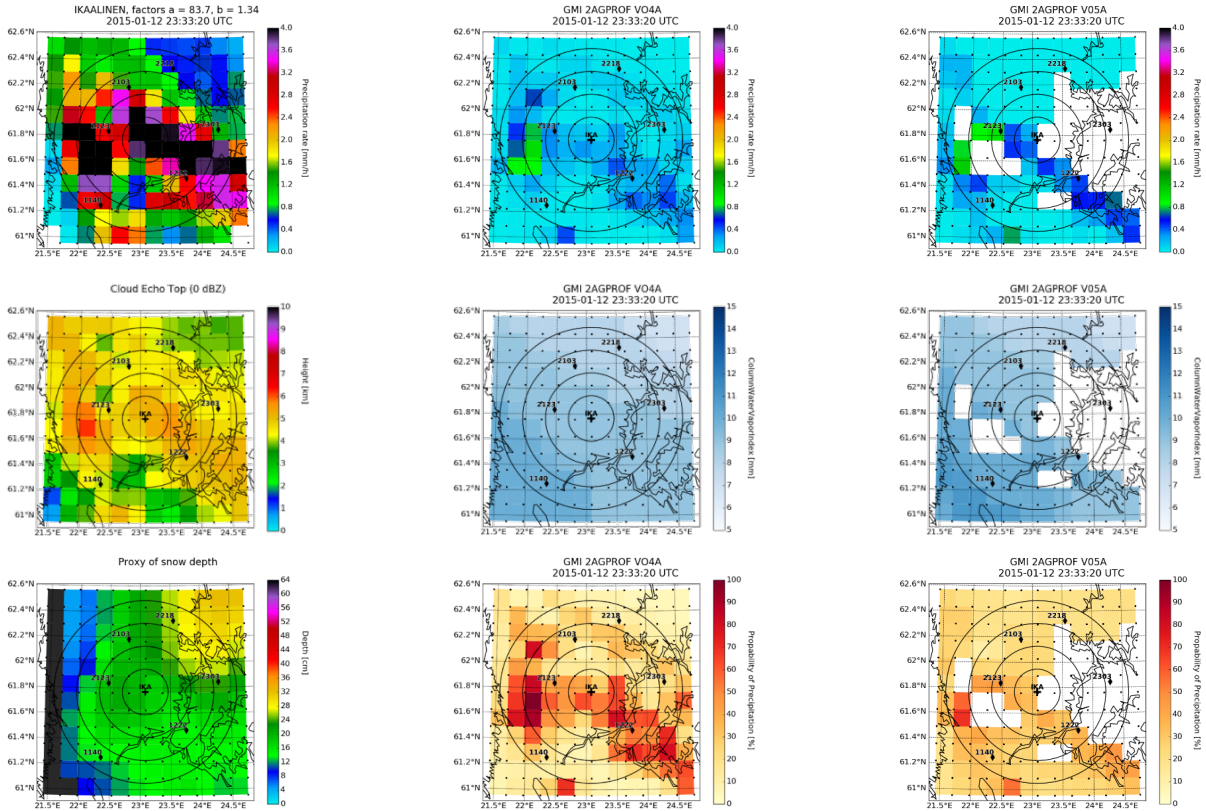

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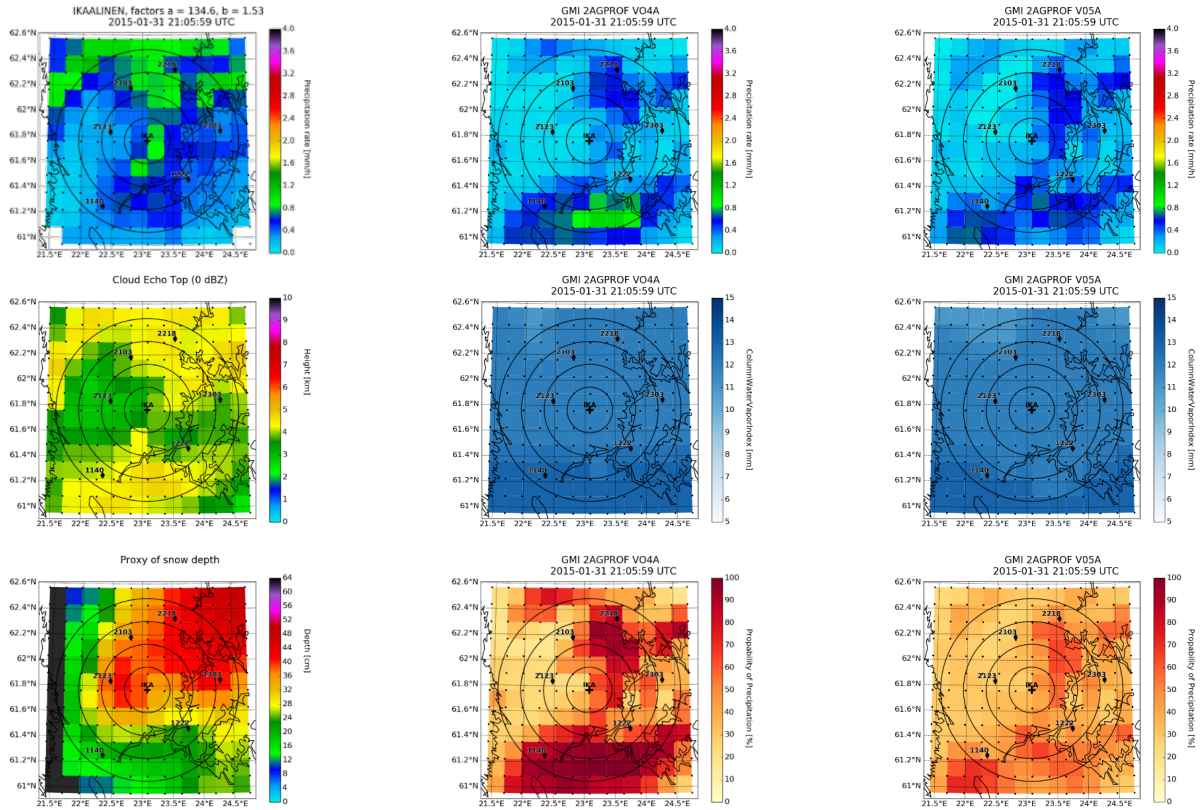
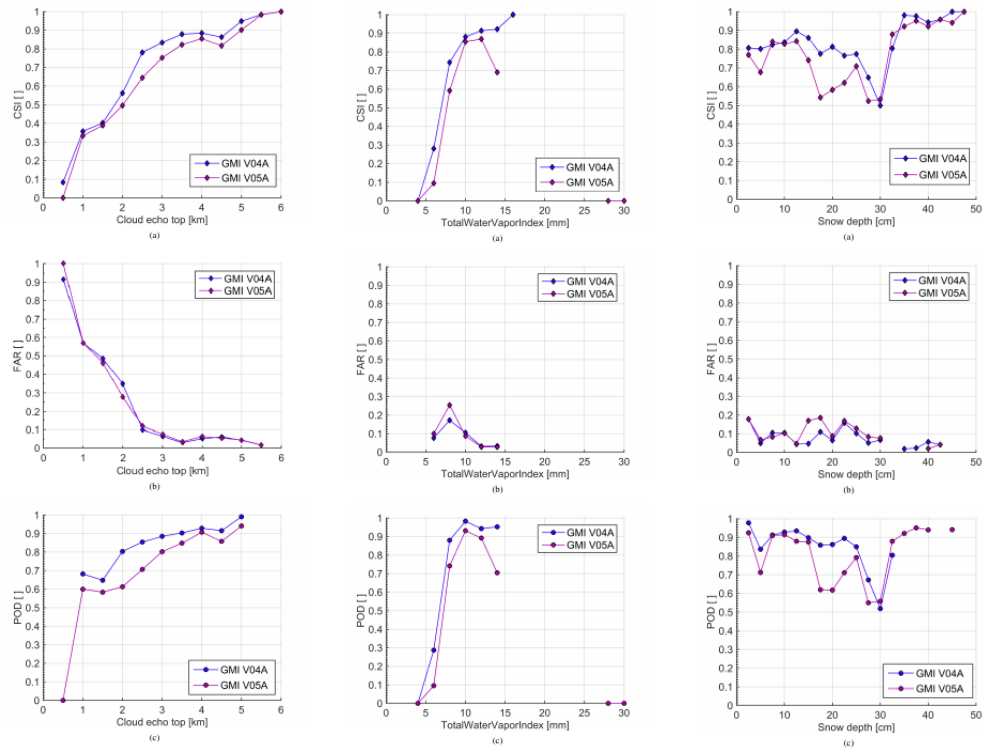


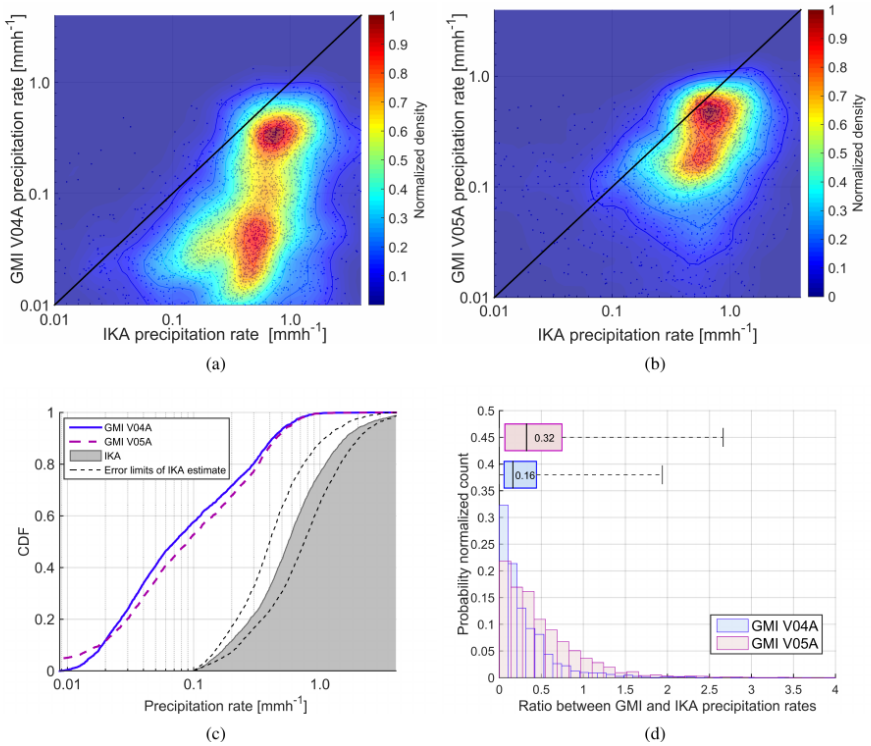
Detection skill of GMI GPROF in snowfall

- Critical Success Index (CSI)
  - 0.83 (V04)
  - 0.79 (V05)
- False Alarm Rates (FAR)
  - 0.09 (V04)
  - 0.10 (V05)
- Probability of Detection (POD)
  - 0.90 (V04)
  - 0.84 (V05)
- Dependence of detection skill on cloud echo top height



Quantitative Snowfall Estimate

- Bias between the GMI- and radar-estimated snowfall rate
- Both versions underestimate the snowfall rate, by factor of 6 (V04) and 3 (V05)



Summary

- Demonstrated the feasibility of radar-based surface snowfall rate
- Introduced a method to define uncertainties of Z_e –S relations for weather radar observations
- Generated datasets for GV of space-based snowfall products
- Compared NASA GPM Microwave Imager (GMI) snowfall product with GPROF-algorithm versions V04 and V05 with ground observations