Using dual-polarization radar and crowdsourced mPING reports to investigate hydrometeor refreezing

Dana M. Tobin and Matthew R. Kumjian

Department of Meteorology, Penn State University, University Park, Pennsylvania, USA

Signature of Refreezing:

A unique and persistent signature in polarimetric radar observables during winter storms producing ice pellets is indicative of hydrometer refreezing (Kumjian et al. 2013). The signature is notably characterized by an enhancement in Z_{DR} and K_{DP}, and a reduction in ρ_{hv} within a region of decreasing Z_H beneath the melting layer "brightband".

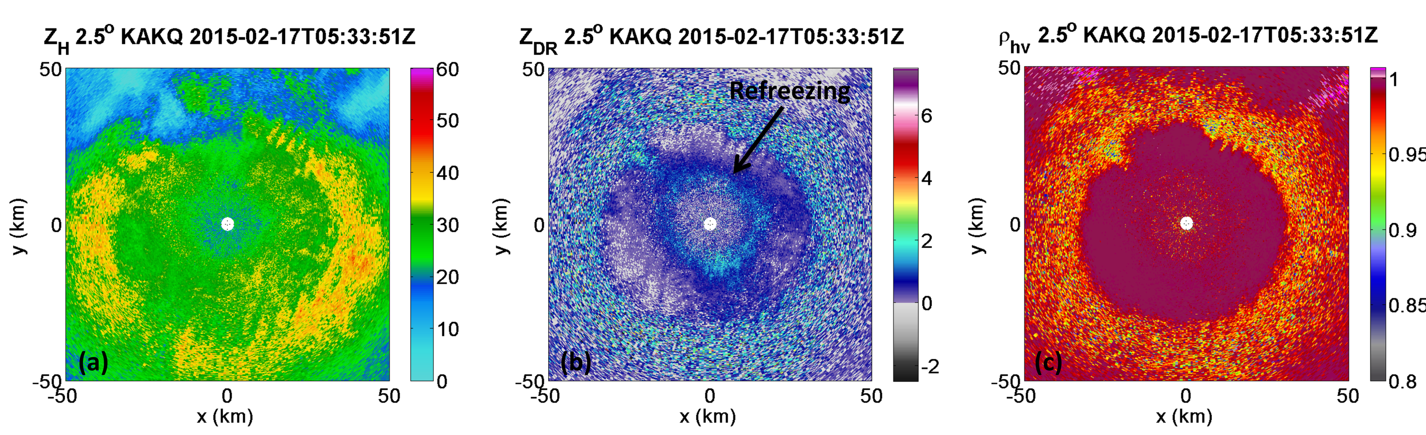


Fig. 1: Example refreezing signature in PPIs of the polarimetric radar variables (a) Z_H, (b) Z_{DR}, and (c) ρ_{hv} at 2.5° elevation collected at 0533 UTC 17 February 2015 by the S-band KAKQ radar. Refreezing indicated by arrow in (b). Colorbars adapted from traditional AWIPS color schemes.

Analysis Methods:

Polarimetric radar data are presented in the form of a time series of quasi-vertical profiles (QVPs) where a single QVP is the azimuthal mean of a PPI (Kumjian et al. 2013; Ryzhkov et al. 2015). The 2.4° elevation angle is chosen to better capture low levels (< 1 km). The AWIPS inspired color scheme in *Fig. 1* is modified for Z_H and Z_{DR} to enhance contrast and better visualize polarimetric refreezing.

Crowdsourced precipitation reports from the Meteorological Phenomena Identification Near the Ground (mPING; Elmore et al. 2014; www.nssl.noaa.gov/projects/ping) within a 100 x 100 km^2 grid space centered on the radar are selected to represent precipitation types associated with QVP signatures.

Precipitation reports are abbreviated and symbolized as follows: HAIL (magenta squares) are hail, RA (green circles) are rain, NONE (brown squares) are reports of no precipitation, FZDZ (blue diamonds) are freezing drizzle, RA/SN (blue asterisks) are rain/snow mixtures, FZRA (blue circles) are freezing rain, RA/IP (cyan circles with blue outline) are rain/ice pellet mixtures, IP (cyan circles) are ice pellets, IP/SN (cyan asterisks) are ice pellet/snow mixtures, and SN (black asterisks) are snow reports.

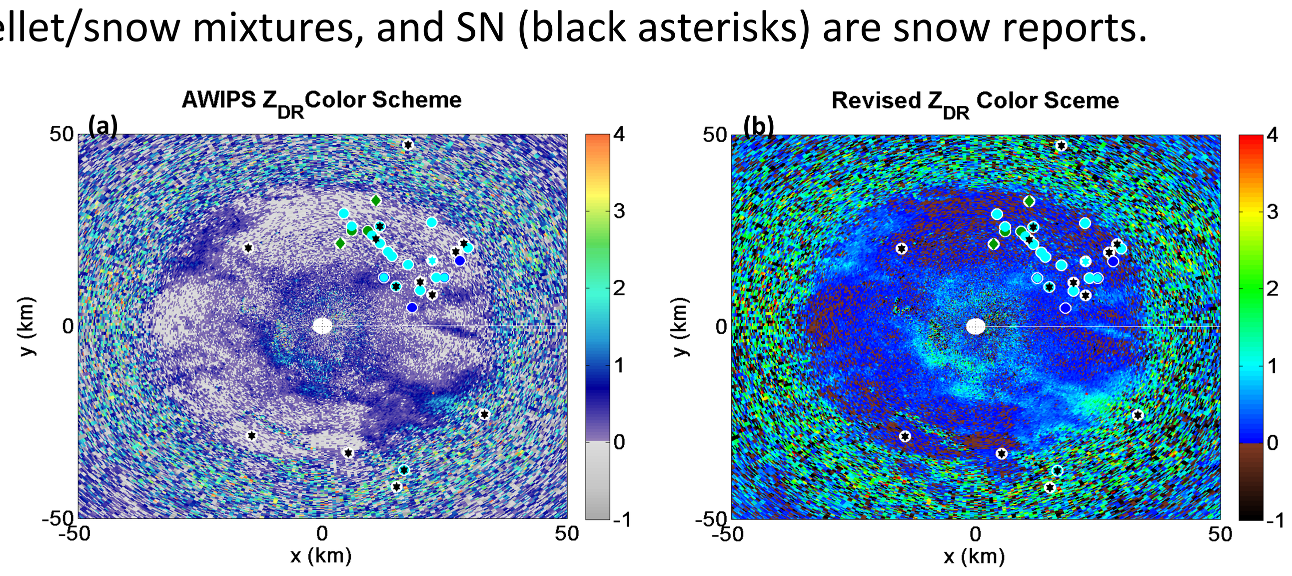


Fig. 2 : PPIs of Z_{DR} with (a) AWIPS color and (b) a revised color scheme at 2.46° elevation collected at 0001 UTC 4 January 2015 by the S-band KENX radar.

Thermodynamic profiles of temperature and relative humidity are obtained from hourly Rapid Refresh (RAP) model output. Stull (2011) provides an equation for computing wet bulb temperature (T_w) from values of T and RH. Contours of T_w overlaid on QVPs are referred to as isopsychrotherms, derived from the Greek terms: *Isos* meaning "equal"; *psukhros* meaning "cold"; and *thermē* meaning "heat."

Precipitation Transition Events:

Examination of the evolution of QVPs during winter precipitation type transition events from IP to FZRA reveals a descent of the polarimetric signature of refreezing that appears to intersect the ground at the time of the changeover as indicated by mPING reports. More easily identifiable in Z_{DR}, the enhancement associated with refreezing descends nearly linearly in time.

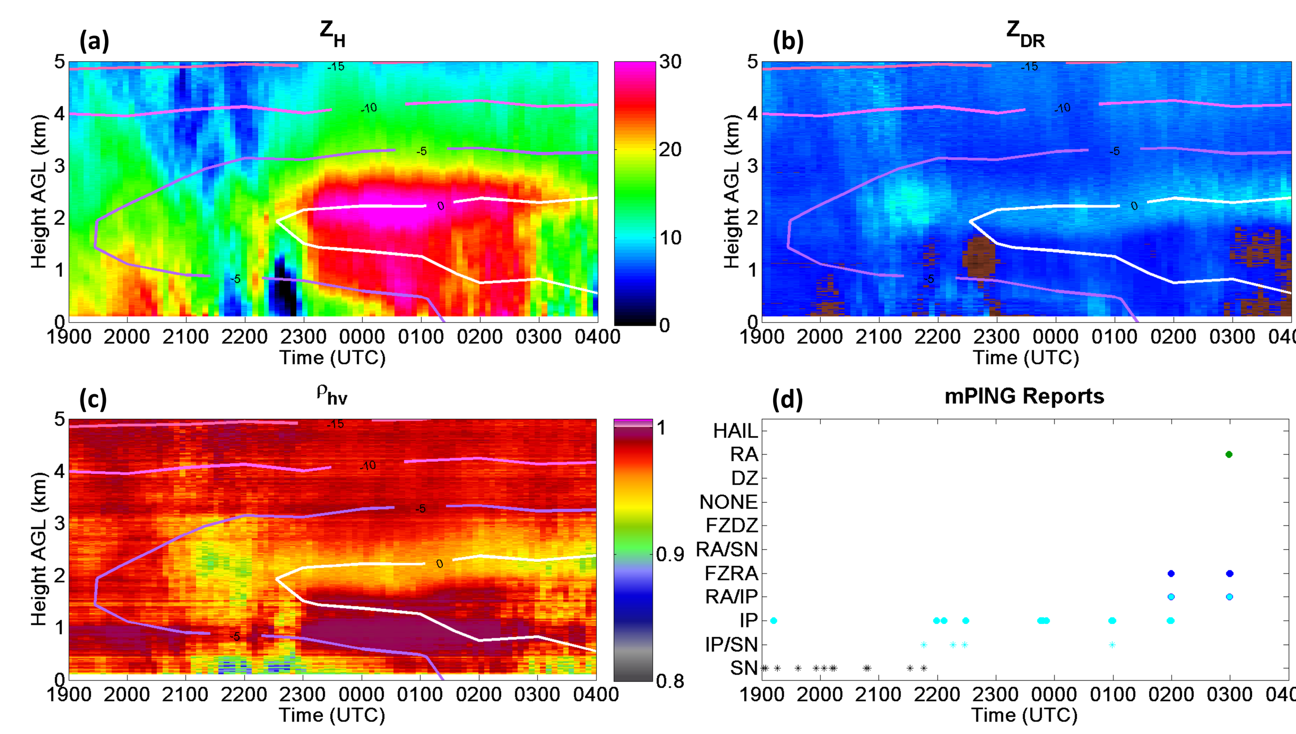


Fig. 3: QVP evolutions of (a) Z_H, (b) Z_{DR}, and (c) ρ_{hv} at 2.4° elevation collected on 3-4 January 2015 by the S-band KENX radar with (d) accompanying mPING reports. Labeled contours indicate isopsychrotherms in °C derived from hourly RAP analyses.

Forecasting Applications:

The linear descent of the refreezing signature in time prompts an investigation into its ability to forecast an IP to FZRA precipitation changeover event. A linear extrapolation through the enhancement of Z_{DR} associated with refreezing in QVPs prior to 0000 UTC at KENX forward in time reveals an intersection with the ground at approximately 0200 UTC. Precipitation reports confirm this changeover occurs at this time.

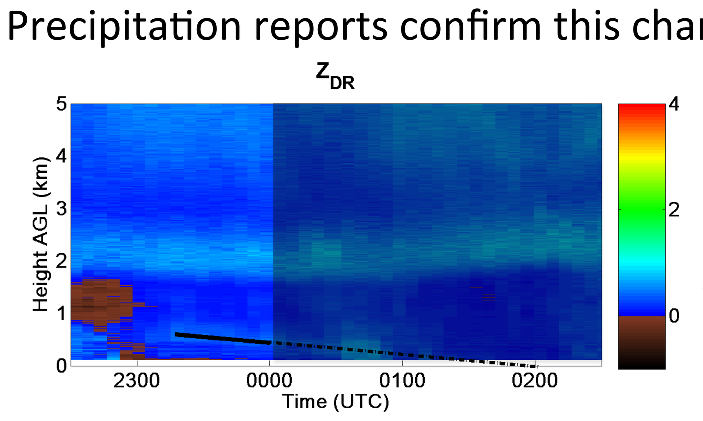
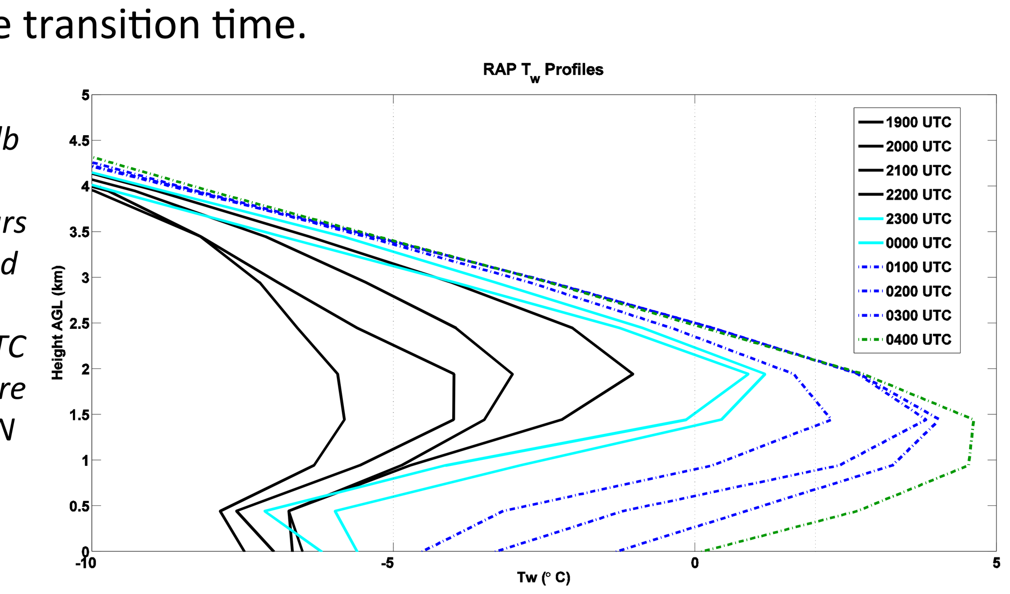


Fig. 4: Schematic of linear extrapolation to approximate precipitation changeover time. Dashed line indicates projection of Z_{DR} enhancement prior to 0000 UTC forward in time through greyed out QVPs.

Schuur et al. (2012) provide a simple algorithm to identify precipitation types from T_w profiles. Profiles with a single warm layer (T_w > 0°C) aloft are classified as IP if T_{w_max} < 2°C and T_{w_min} < -5°C, and FZRA if T_{w_max} > 2°C and T_{w_min} ≥ -5°C. Utilizing this algorithm, the 0000 UTC 4 January RAP cycle forecasts a transition from IP to FZRA occurring prior to 0100 UTC. The RAP shows little skill in accurately predicting the transition, whereas a simple linear extrapolation of the refreezing signature from QVPs provides an accurate transition time.

Fig. 5: RAP-derived wet bulb temperatures from 3-4 January 2015. Solid contours are hourly analyses. Dashed contours are hourly forecasts from the 0000 UTC cycle. Precipitation types are indicated by color where SN is black, IP is cyan, FZRA is blue, and RA is green.



Mixed Precipitation Events:

The variability of the refreezing signature is examined during an event which produced a mix of both ice pellets and snow. An enhancement of Z_H located above the enhancement in Z_{DR} associated with refreezing is present when IP is the dominant precipitation type. When reports are more evenly mixed among IP, IP/SN, and SN, there is no enhancement in Z_H but, rather, a pronounced decrease. Radar variables above the refreezing layer in both instances are nearly identical, indicating potentially significant differences in the underlying microphysics that produce the refreezing signature in the presence of additional precipitation types.

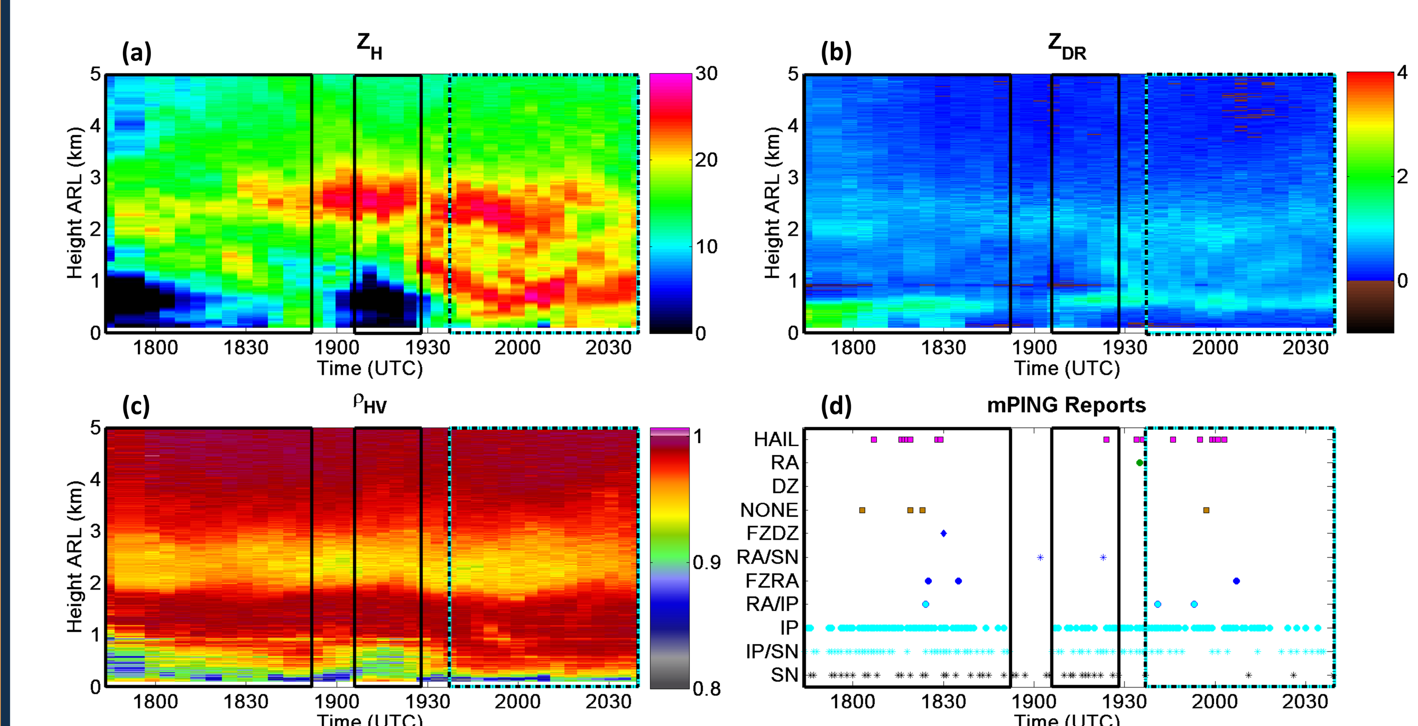


Fig. 6: QVP evolutions of (a) Z_H, (b) Z_{DR}, and (c) ρ_{hv} at 2.4° elevation collected on 2 March 2014 by the S-band KTLX radar with (d) accompanying mPING reports. Solid black rectangle outlines indicate time periods of IP, IP/SN, and SN mixed precipitation reports. Dashed black and cyan rectangle outlines indicate a time period of mostly IP precipitation reports.*

*HAIL reports at this time are presumed to be reports of IP incorrectly identified by users

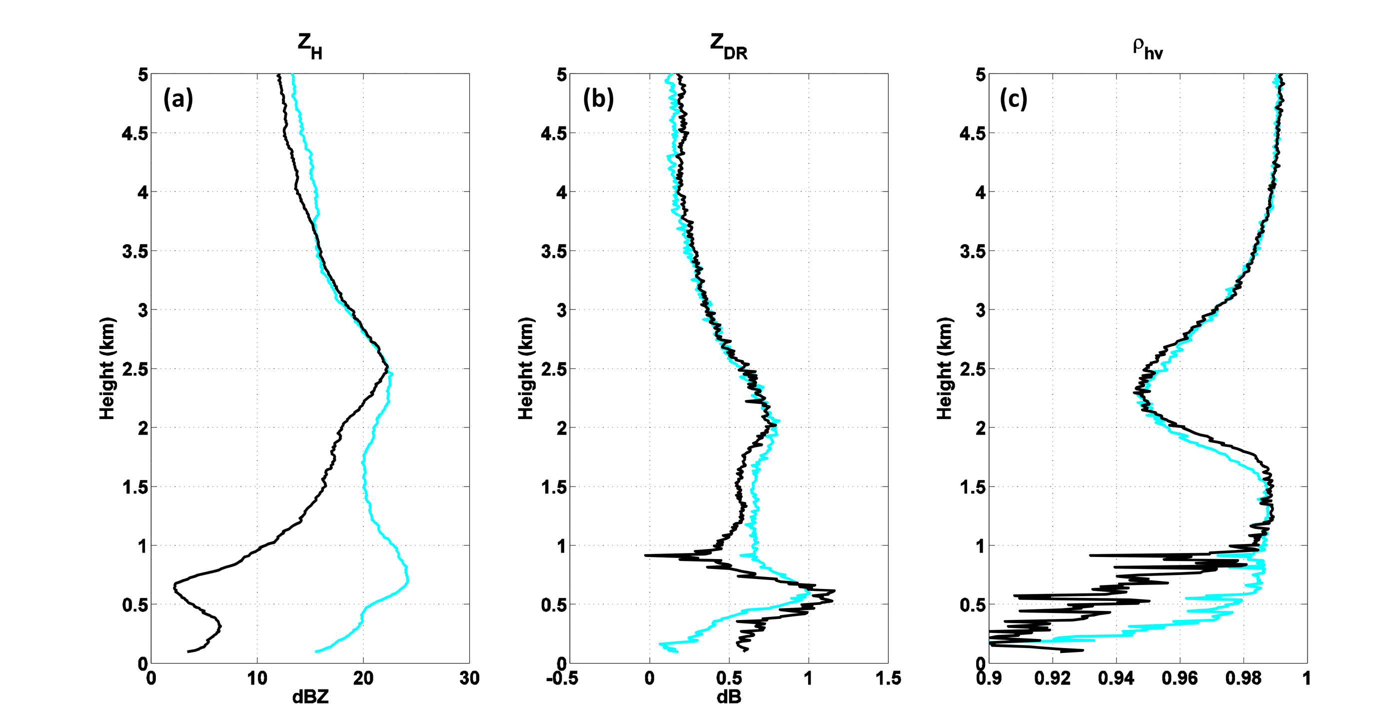


Fig. 7: Time-averaged QVPs of (a) Z_H, (b) Z_{DR}, and (c) ρ_{hv} from time periods indicated by rectangles in Fig. 5. Black QVP indicates time periods of IP, IP/SN, and SN mixed precipitation reports. Cyan QVP indicates a time period of mostly IP precipitation reports.

References:

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