Radar-derived Quantitative Precipitation Estimation Using a Hybrid Rate Estimator Based On Hydrometeor Type

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8B.3
AMS 31st Conference on Hydrology
Seattle, Washington, USA
2017-01-25

NCAR is sponsored by the US National Science Foundation

Dual-polarization RADAR QPE algorithms use relationships such as the following to compute precipitation rate from radar variables.

R(Z) for rain:

$$R(Z) = 0.0274Z^{0.694}$$

which is equivalent to:

$$Z = 178R^{1.44}$$

R(Z) for dry snow (i.e. above the melting layer):

$$R(Z) = 0.0954Z^{0.5}$$

which is equivalent to:

$$Z = 110R^{2.0}$$

R(Z,ZDR) (from Berkowitz 2013):

$$R(Z, ZDR) = 0.0067Z^{0.927}\ Zdr^{-3.43}$$

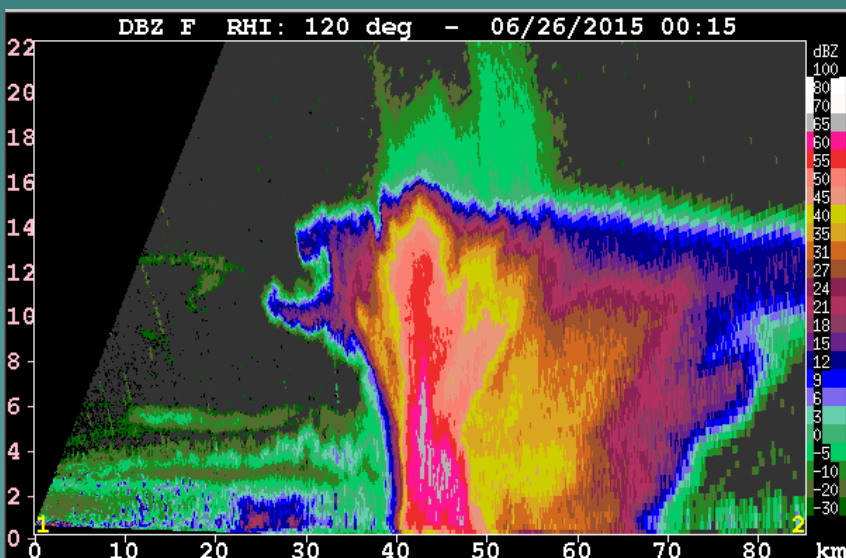
R(KDP) (from Berkowitz 2013):

$$R(KDP) = \mathrm{sign}(Kdp)\ 44.0\ |KDP|^{0.822}$$

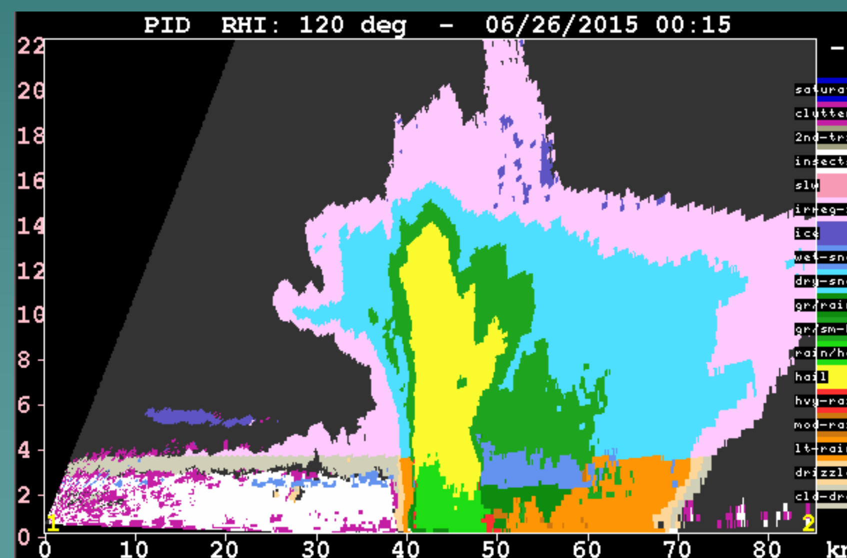
Convective example from S-Pol radar at PECAN project

We can use a hydrometeor classification algorithm to determine which rate relationship is appropriate at each grid point (Giangrande and Ryzhkov 2008; Berkowitz et al. 2013).

We use the NCAR Particle ID (PID) algorithm (Vivek. et al. 1999) to classify each radar gate.

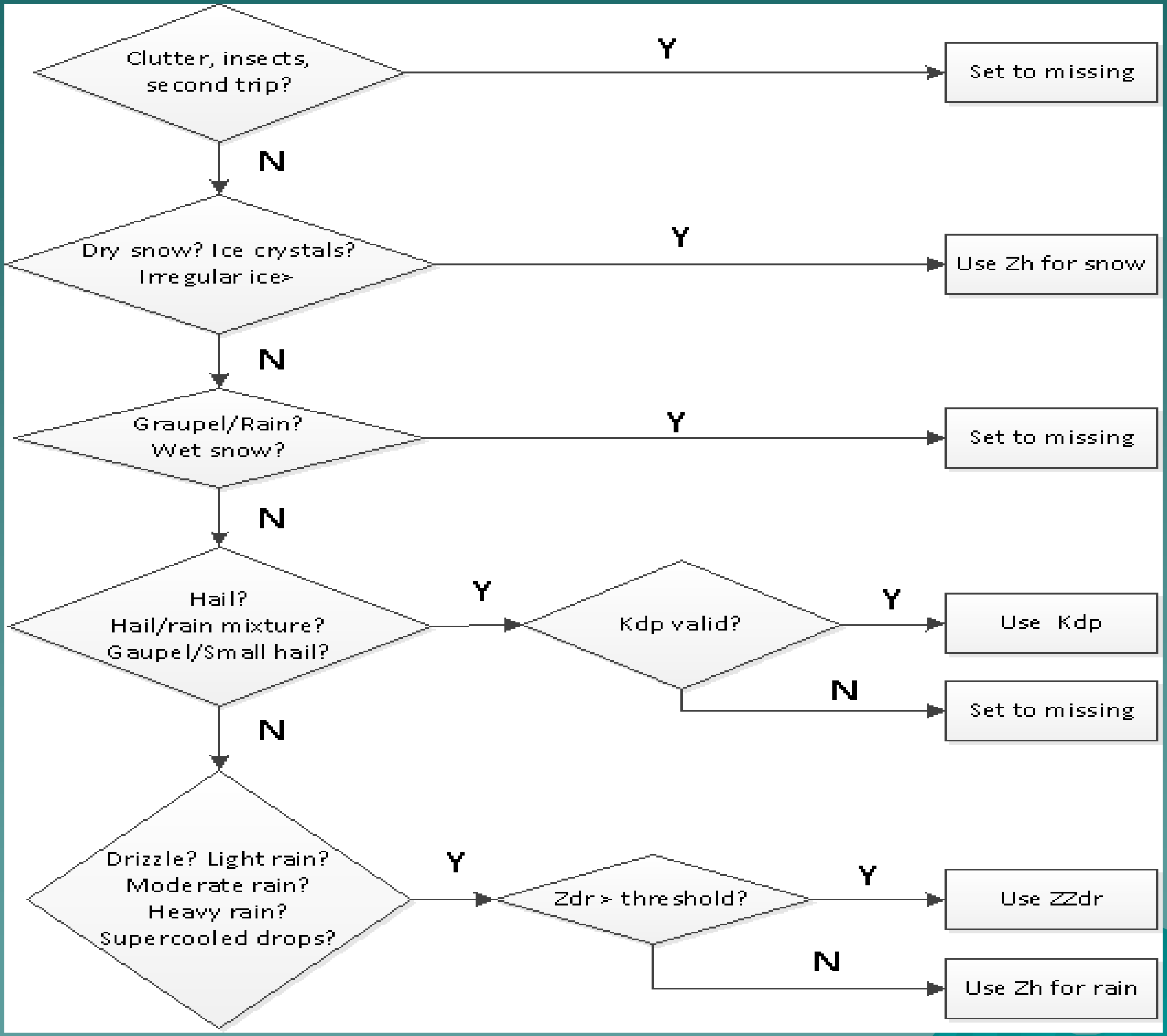


RHI for reflectivity



RHI for NCAR PID

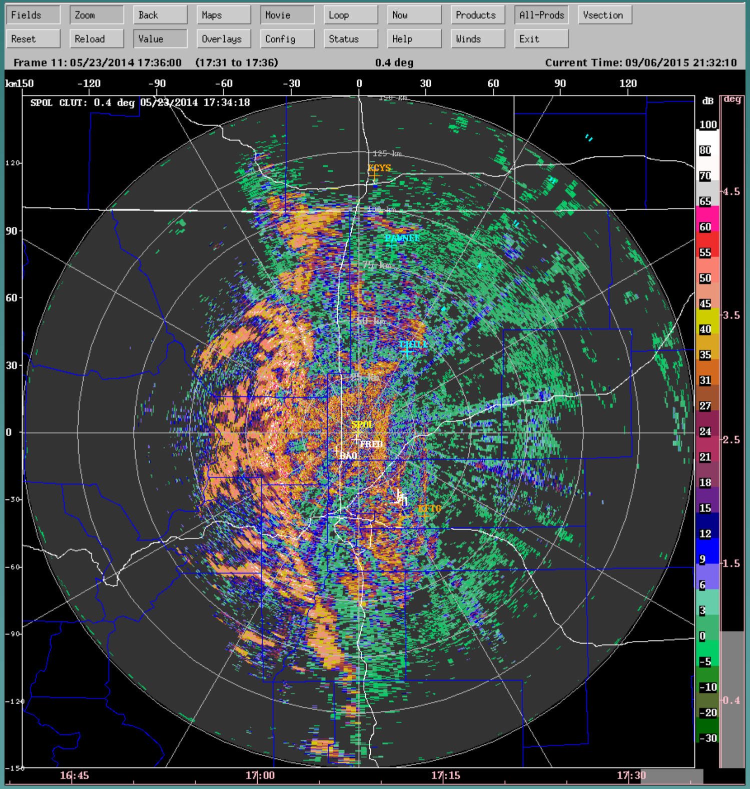
Decision tree for NCAR HYBRID algorithm uses PID to select rate relationship



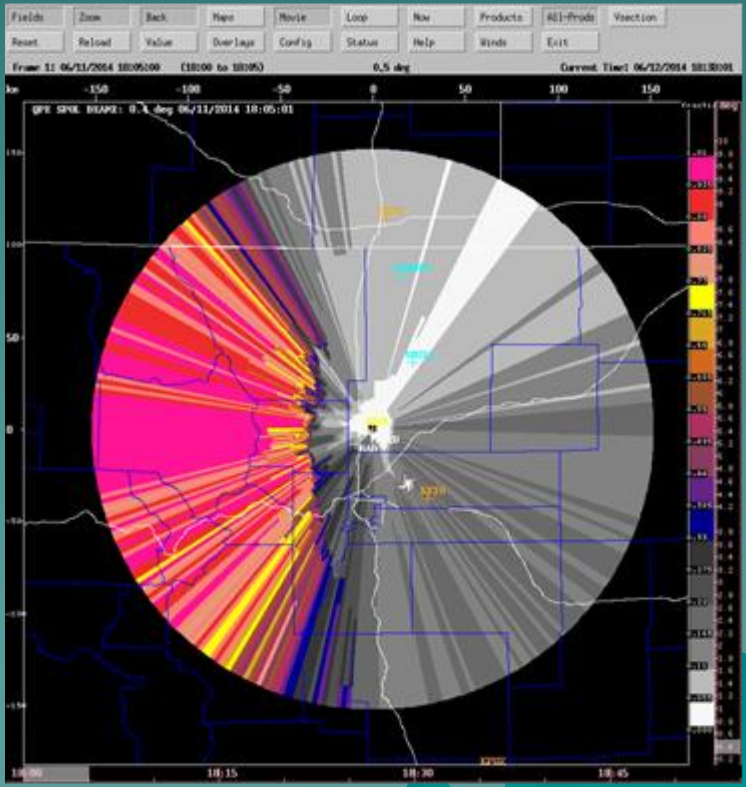
Beam blockage algorithm

Uses the SRTM 30-m resolution digital elevation data from the space shuttle STS-99 mission. Takes account of standard atmospheric propagation effects and the convolution of the beam pattern with the terrain features.

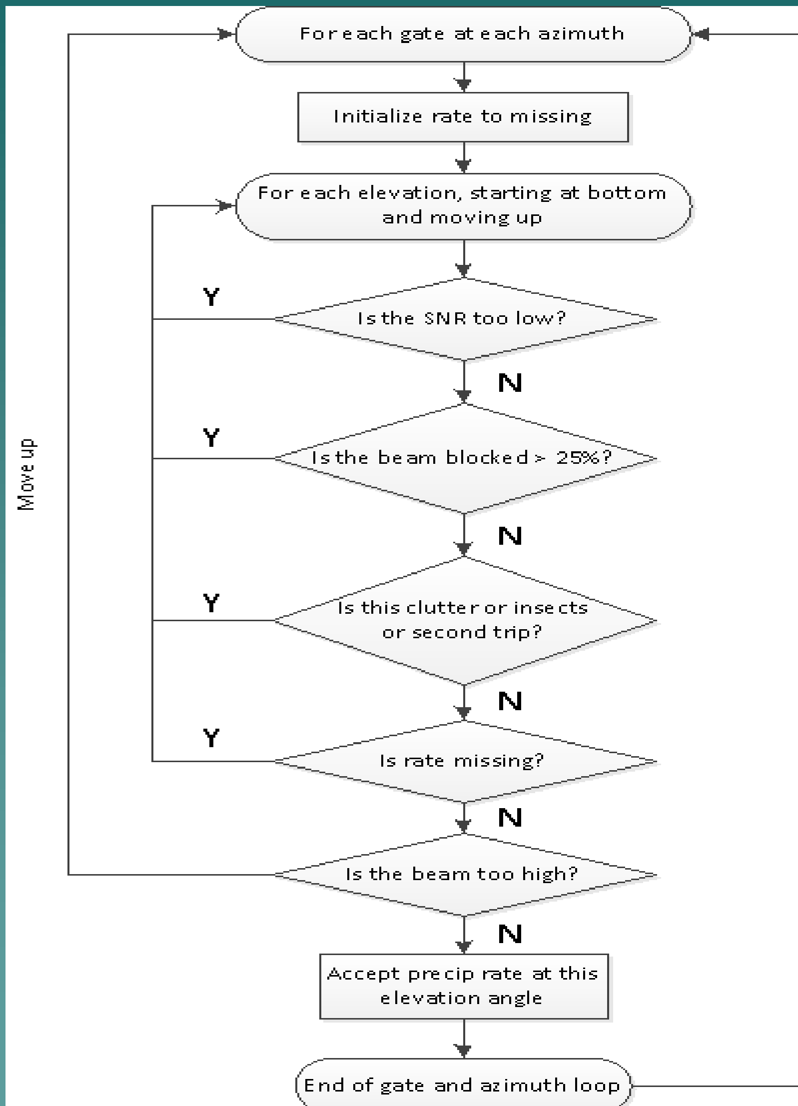
Example – clutter at the S-Pol at the Front range site

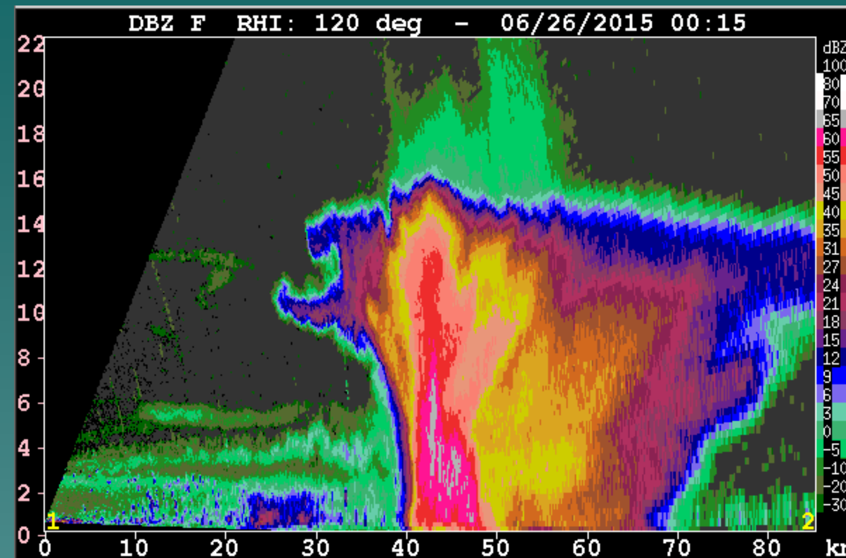


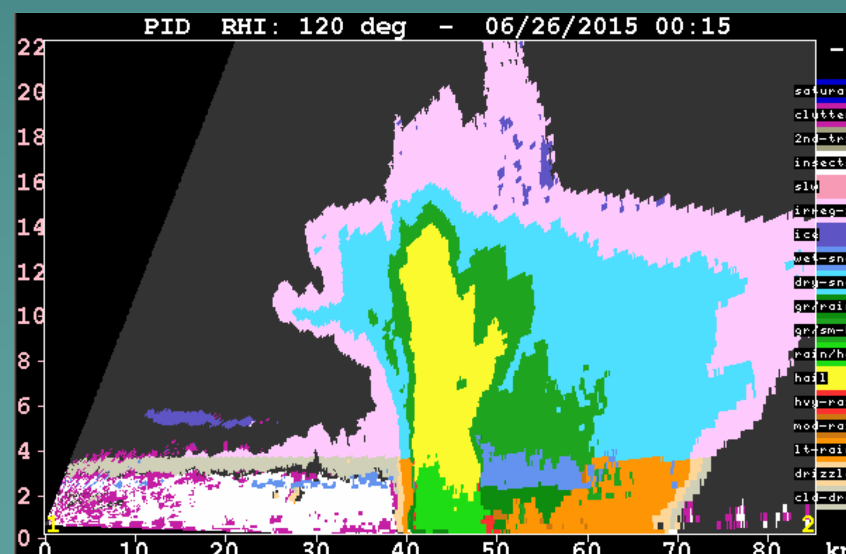
Cumulative beam blockage map S-Pol at the Front range site



Decision tree for mapping QPE from aloft to the surface



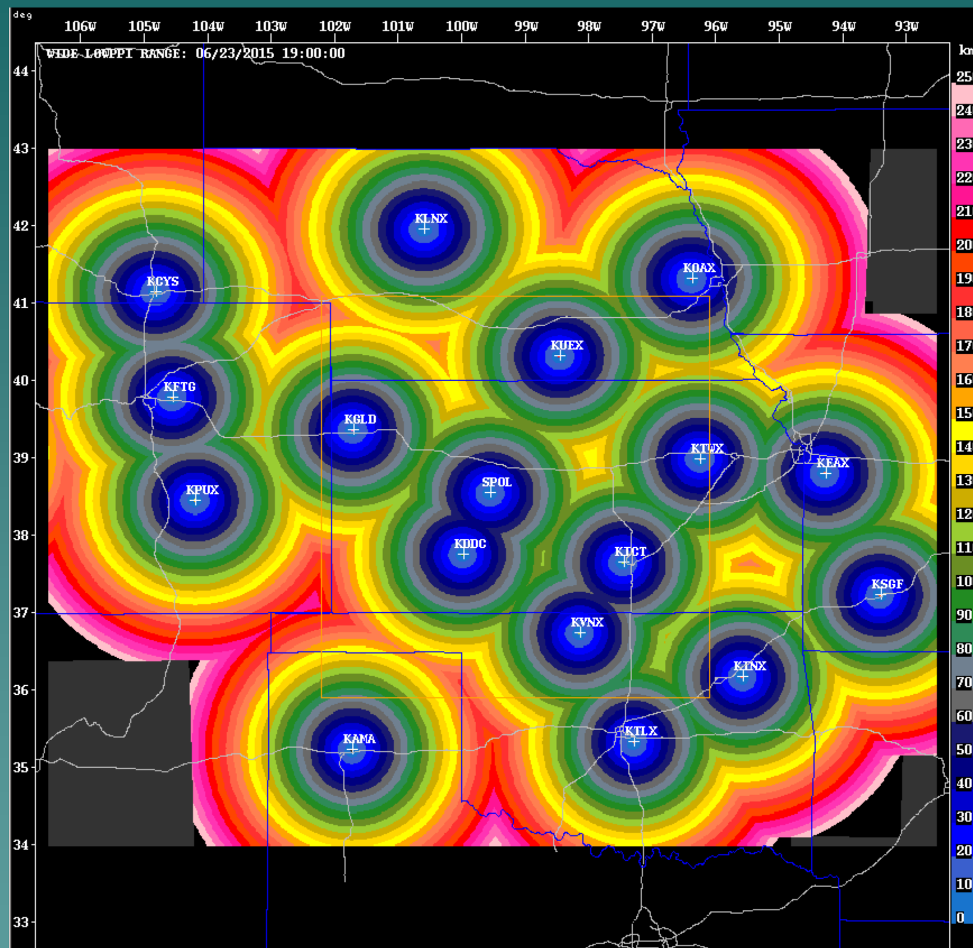




Field Test
Plains Elevated Convection at Night (PECAN)

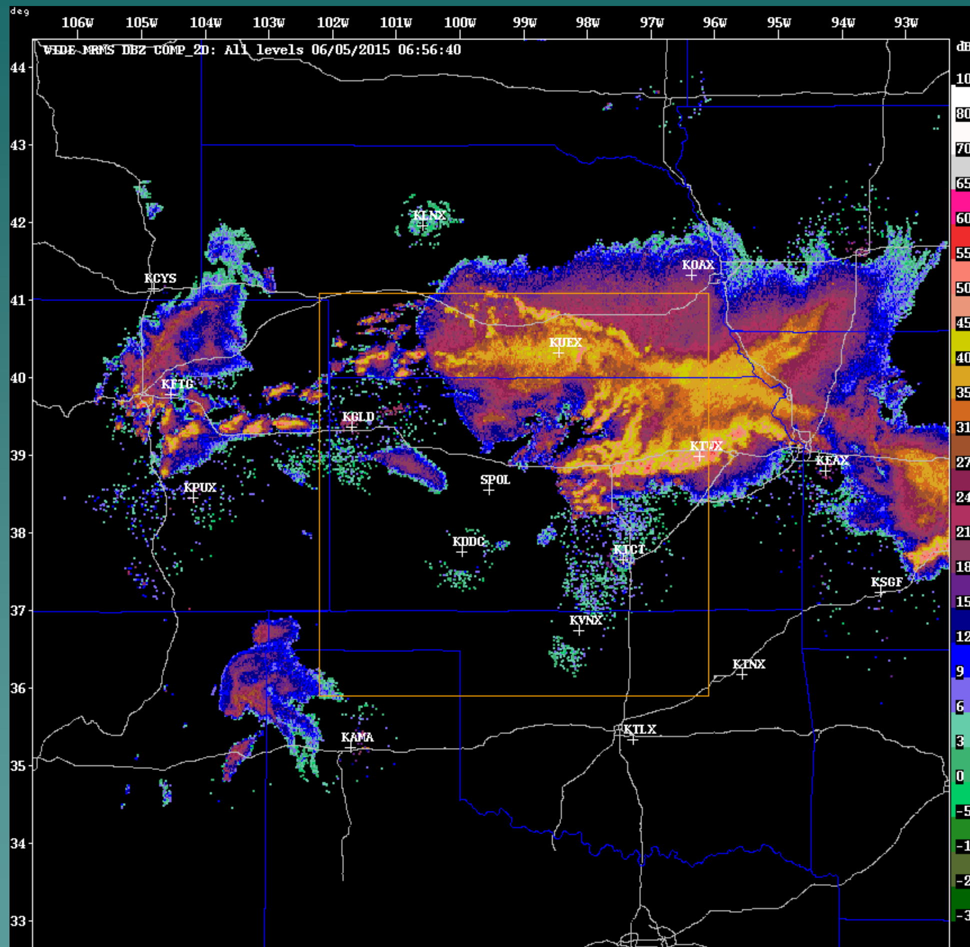
- The PECAN project was centered on Kansas, and ran from the beginning of June to mid-July 2015.
- The QPE system was run on a network of 16 NEXRAD radars, plus the NCAR S-Pol radar.
- The RUC-RAPID model was used to provide temperature profiles for the PID algorithm.
- The system was up and running prior to the start of PECAN, so the time period for this study is 2015/05/17 to 2015/07/16.

17 radars of the S-band network used for the PECAN QPE product



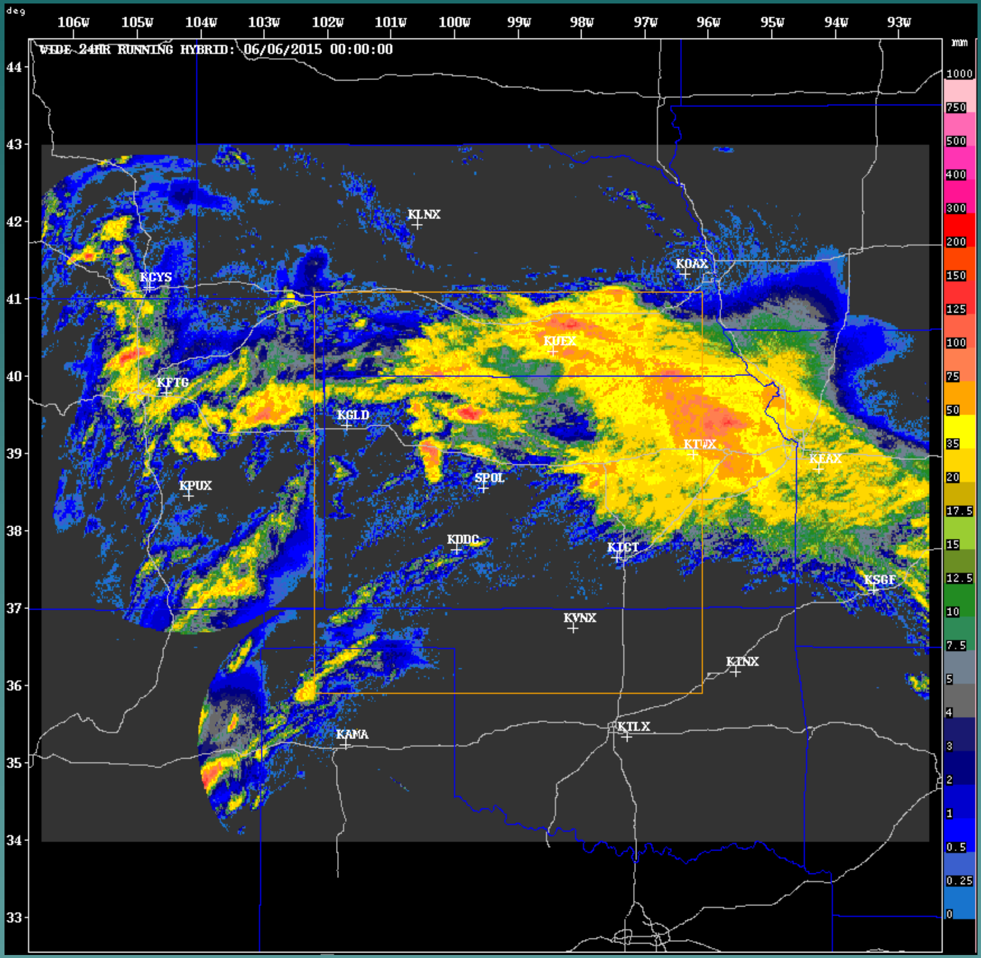
The color scale shows the range from the closest radar

Example of large-scale convective system at PECAN. MRMS column-maximum reflectivity at 07:00 UTC on 2015/06/05.

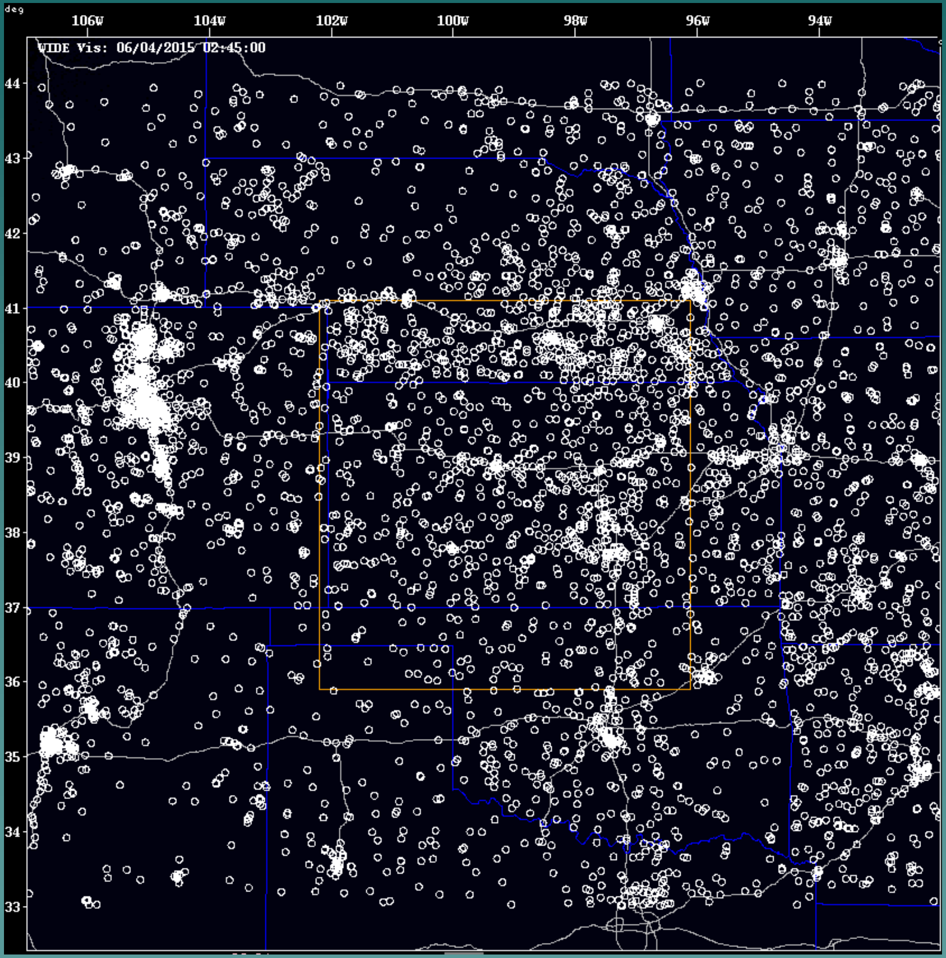


The orange rectangle is the primary PECAN study domain.

Accumulation (mm) from NCAR HYBRID QPE for the 24-hour period ending at 00:00 UTC on 2015/06/06.



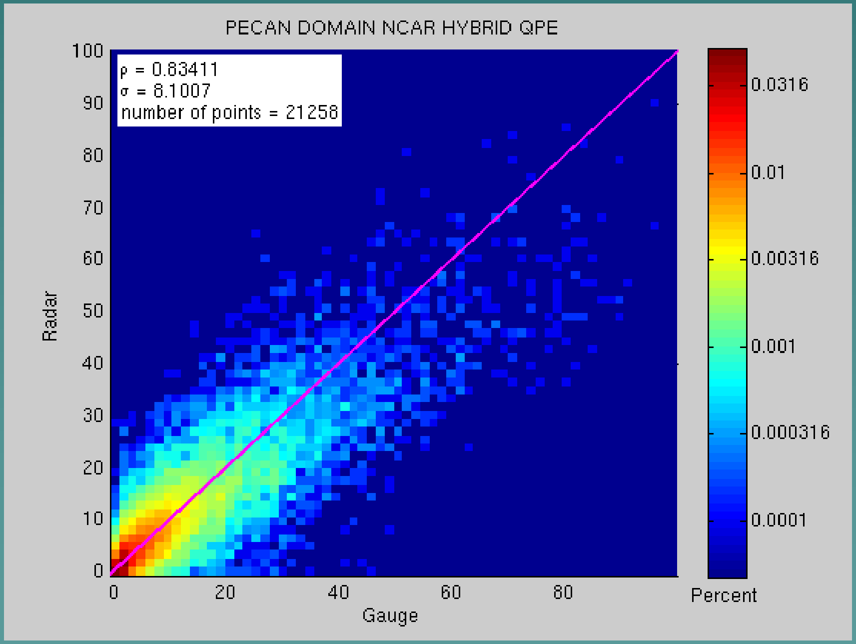
Map of daily precipitation gauge sites for the QPE domain.



Data for these sites is available from NCDC.
For QPE verification, only stations within the orange rectangle are used.

Radar-based 24-hour QPE vs gauge-measured statistics 2015/05/17 – 2015/07/16

Method	N points	Correlation	Bias radar/gauge
NCAR HYBRID	21258	0.834	0.940

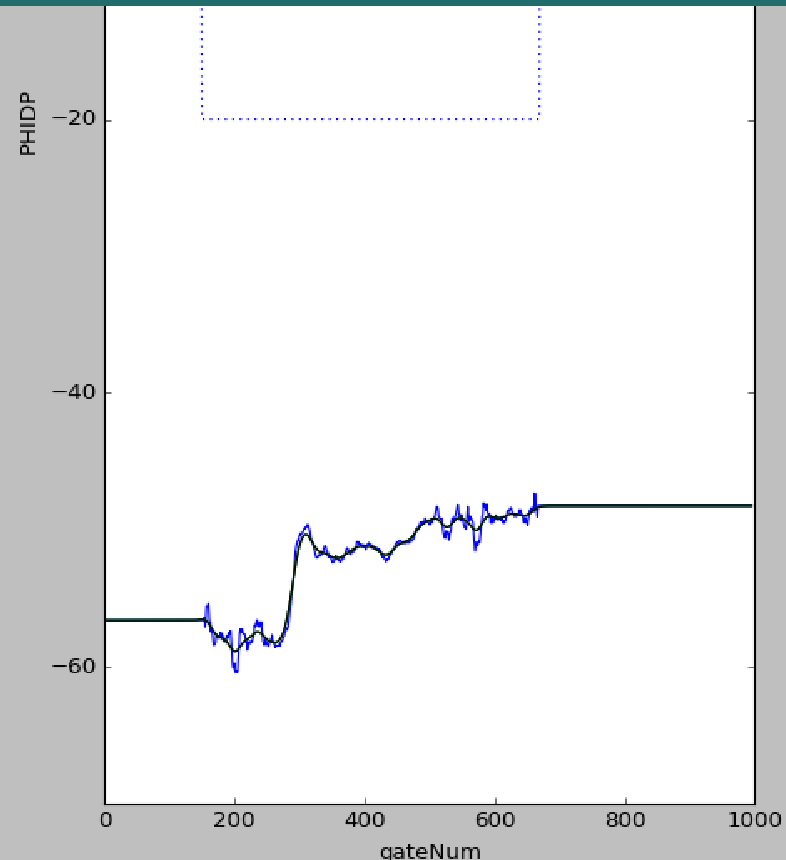


Recent improvements

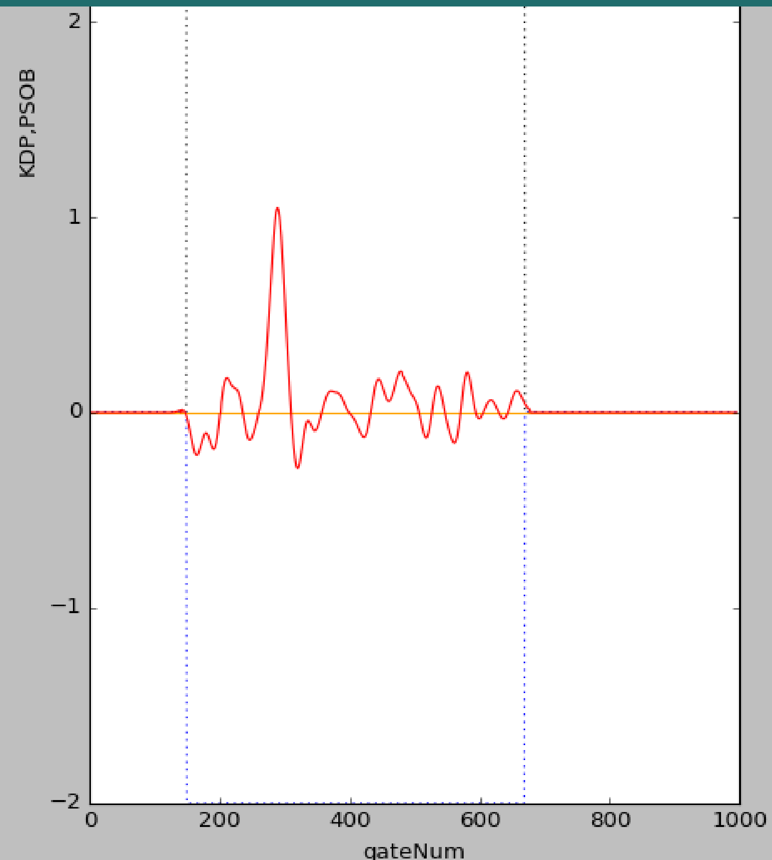
A number of issues have been noted with the existing implementation, and we have been working to mitigate them.

- Improvements to KDP, both in location and value.
- Enhancements to the detection of the melting layer.

To compute KDP we apply a filter because measured PHIDP is noisy. This causes the KDP signature to be smeared in range.

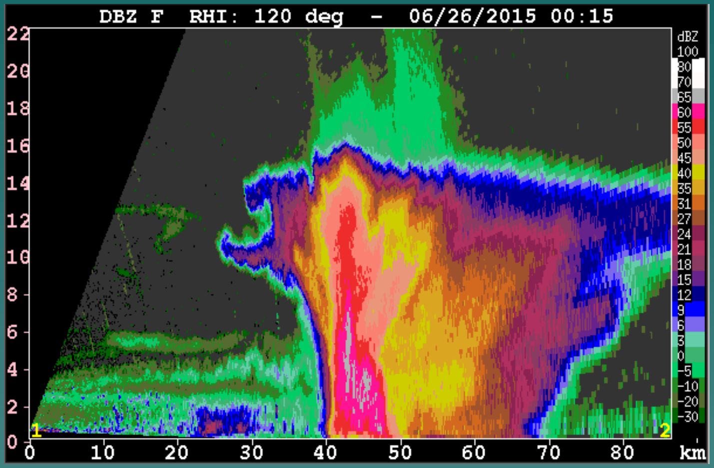


Blue – measured PHIDP
Black – filtered PHIDP

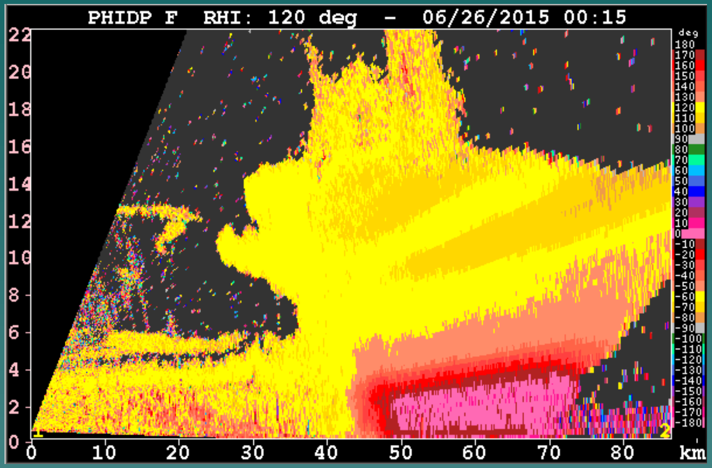


Estimated KDP is smeared in range

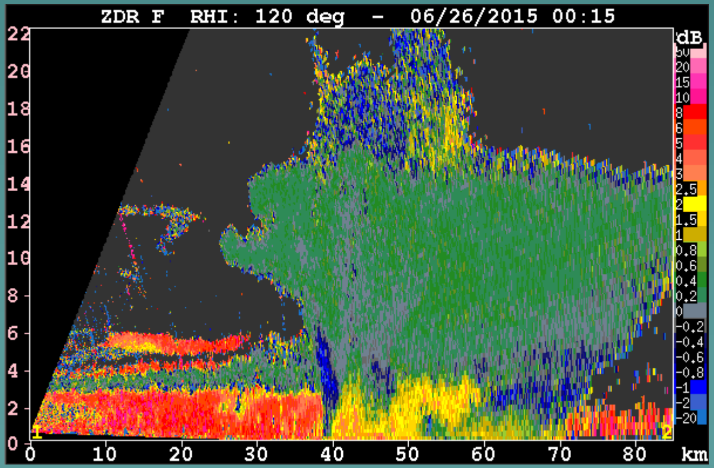
KDP computed as slope of filtered PHIDP



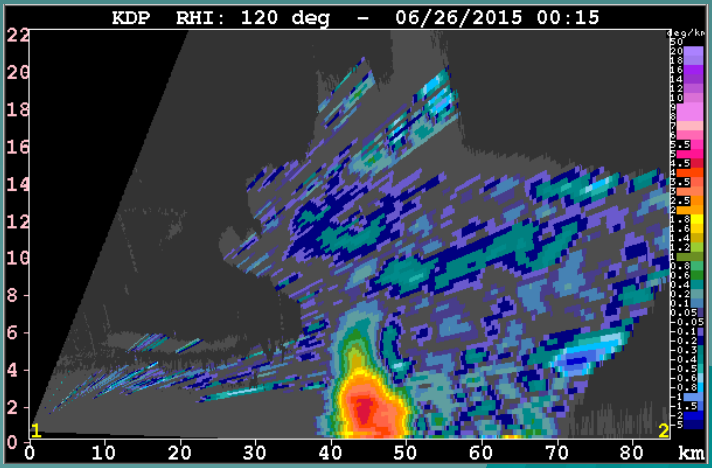
DBZ



PHIDP



ZDR



KDP computed from slope of filtered PHIDP

KDP can be estimated as a function of Z and ZDR

For example, the following is from Vivek et al., 2003:

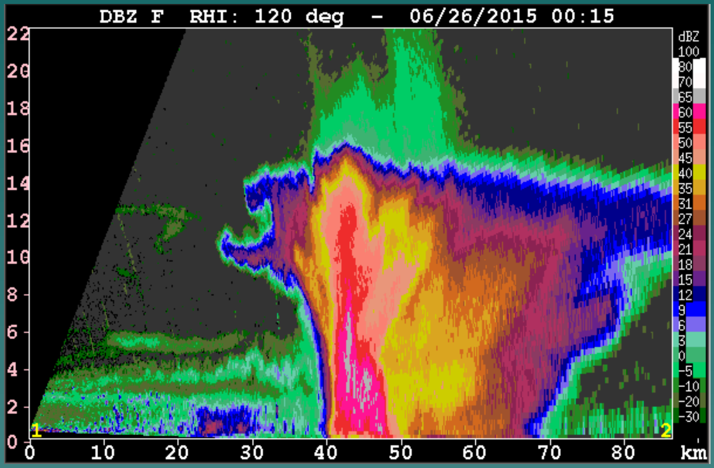
$$KDP = 3.32 \times 10^{-5} \times Z \times ZDR^{-2.05}$$

We can use this relationship to estimate the spatial location and value of KDP, while preserving the measured change in PHIDP (Ryzhkov, personal communication).

We apply the following steps:

- filter PHIDP to smooth out the noise
- divide the ray into segments containing significant PHIDP changes
- for each gate in the segment, estimate KDP from Z and ZDR
- integrate estimated KDP across the segment to estimate PHIDP change
- adjust estimated KDP so that the estimated PHIDP change matches the measured PHIDP change for the segment

Modification to KDP based on Z and ZDR



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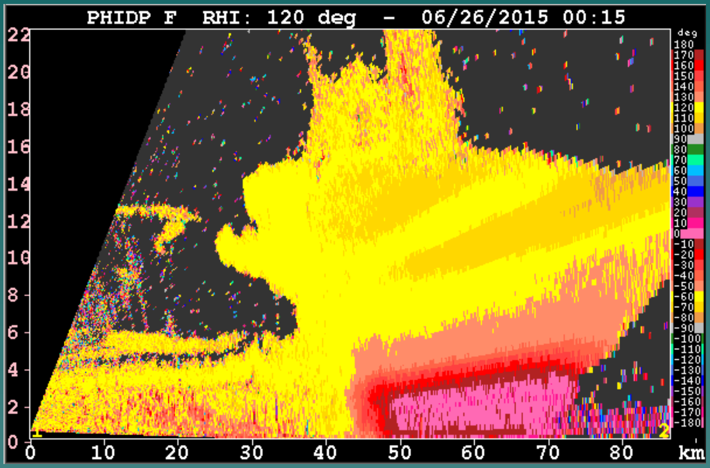
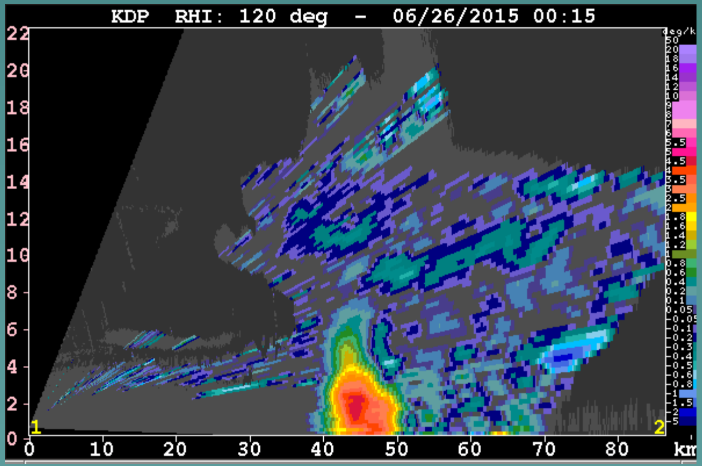
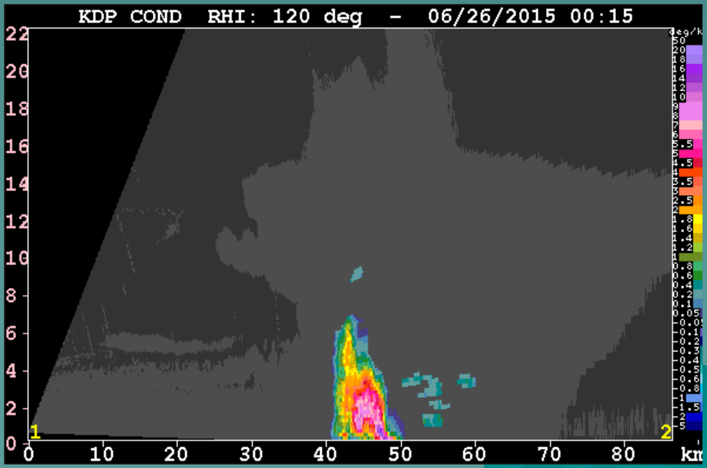


PHIDP



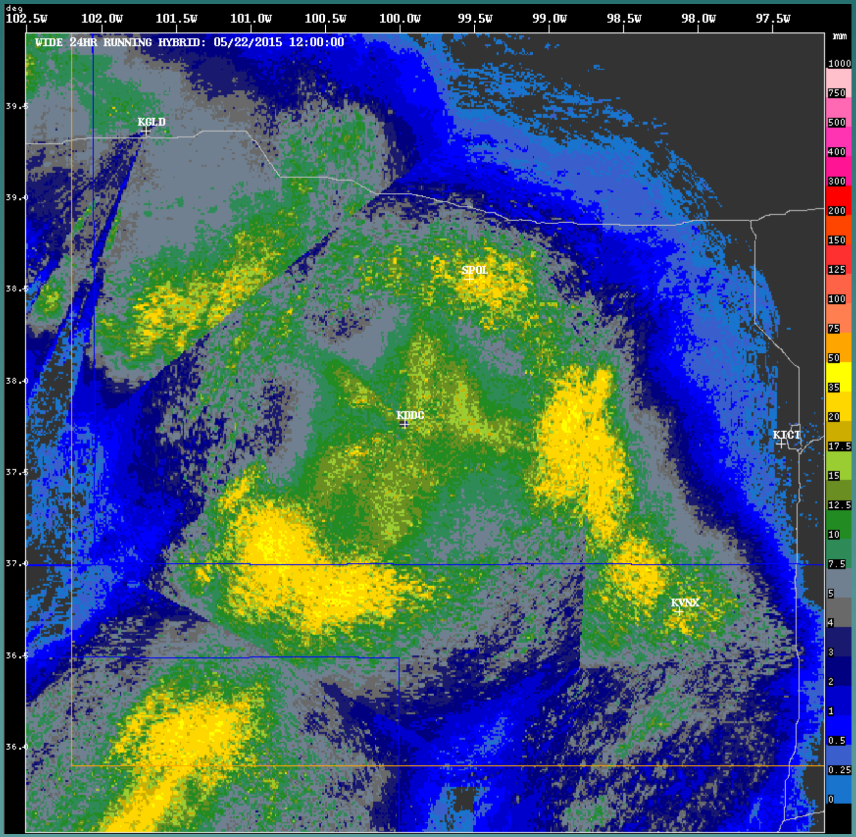
KDP computed from slope of filtered PHIDP



KDP estimated from Z and ZDR normalized by measured PHIDP change

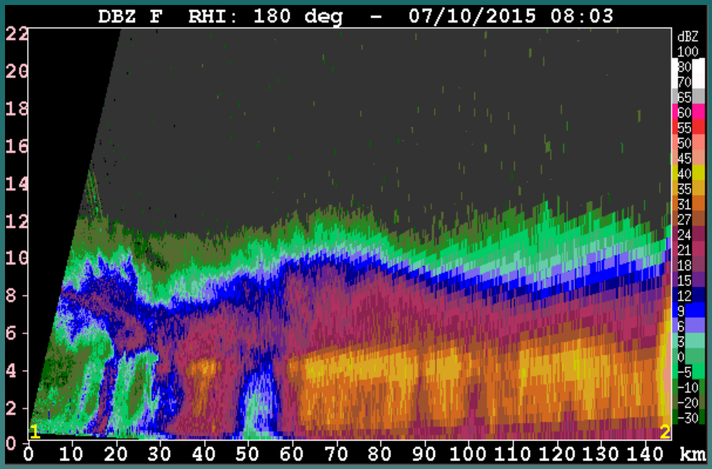
Melting layer artifacts

Accumulation over an event lifetime highlights problems in dealing with the melting layer.



24-hour QPE accumulation for the KDDC radar,
at 12:00 UTC on 2015/05/15, for NCAR Hybrid QPE algorithm

Stratiform RHI example from S-Pol at PECAN project



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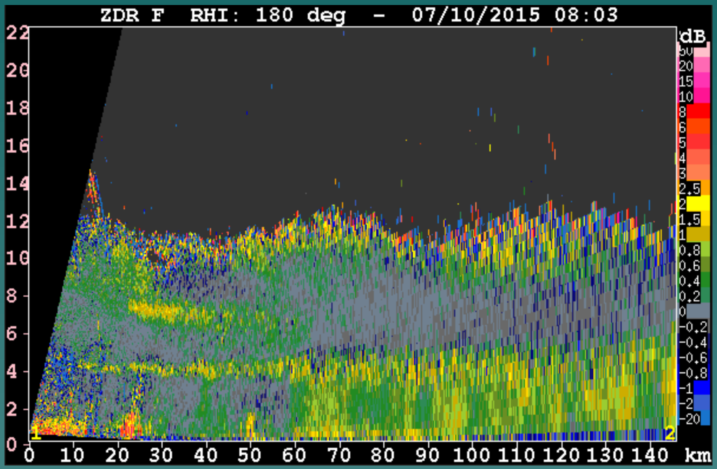
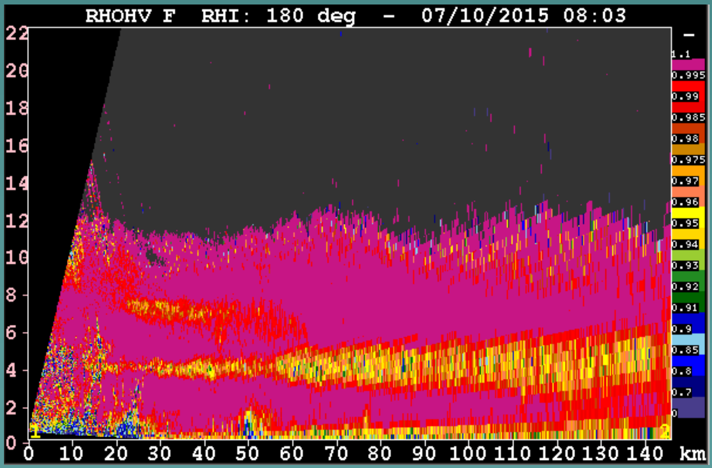
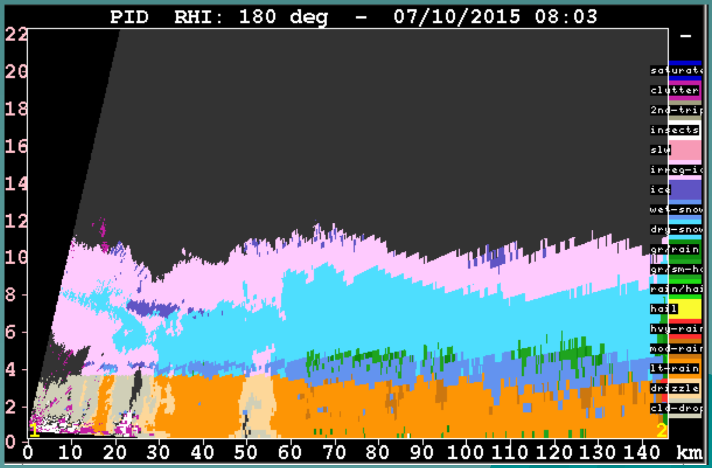


ZDR

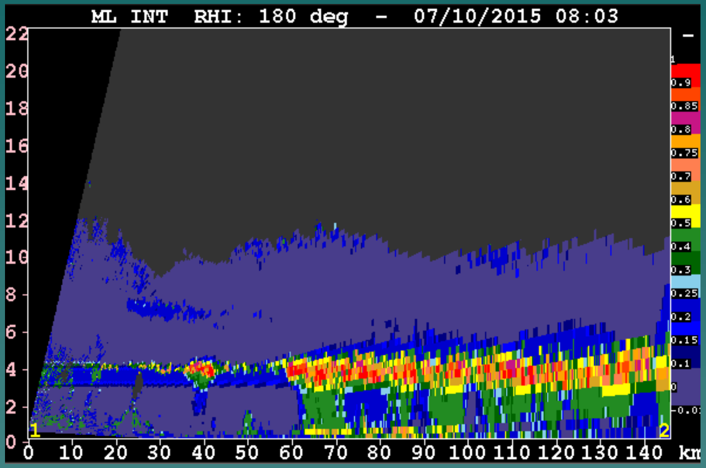


RHOHV

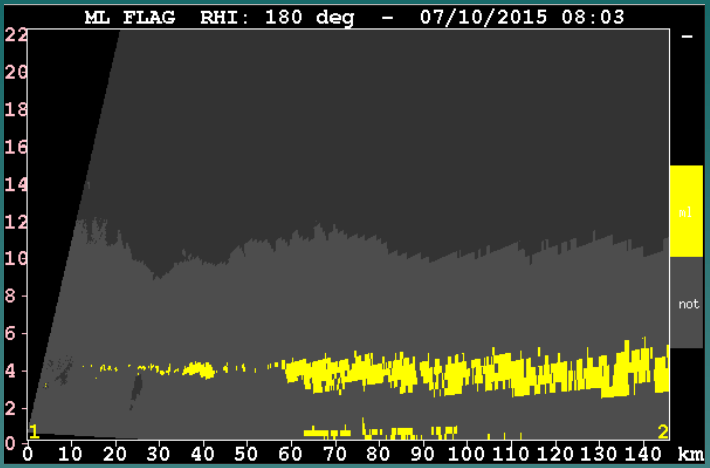


PID

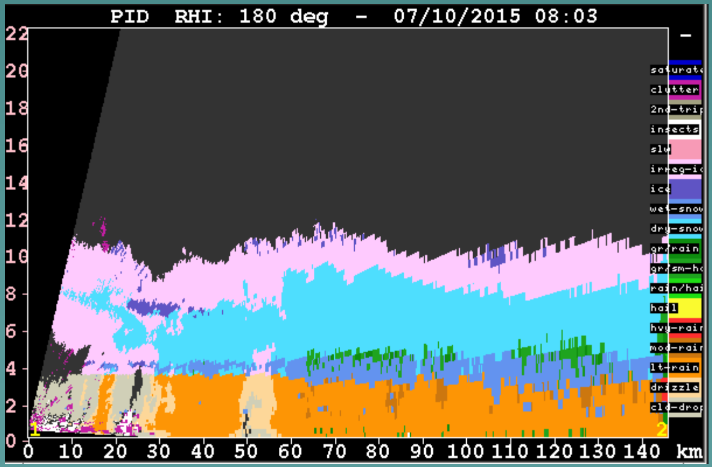
Identification of the melting layer



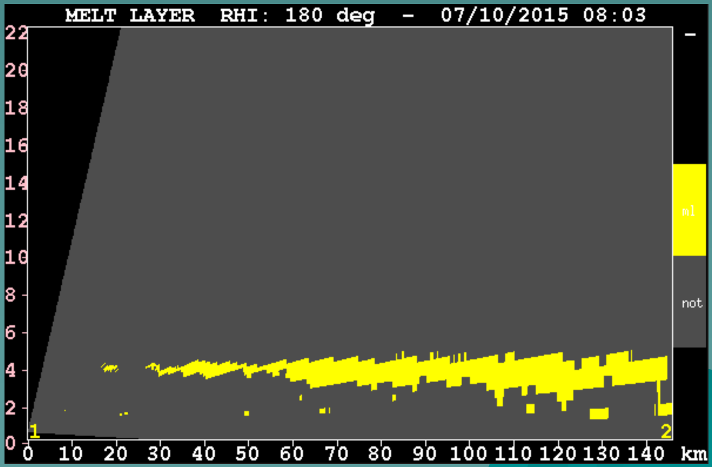
Interest field for melting layer
(Giangrande et al., 2008)



Melting layer flag based on
Giangrande et al., 2008

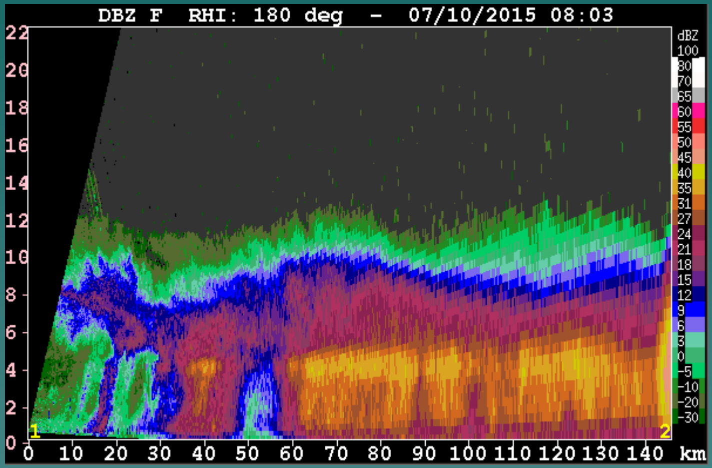


NCAR PID

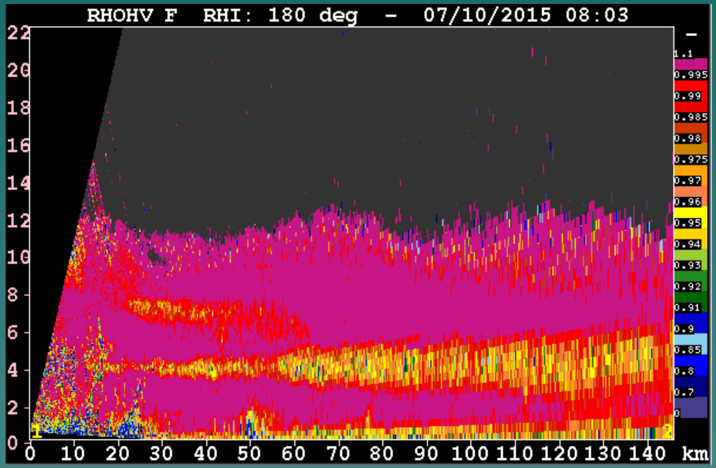


Melting layer flag based on PID

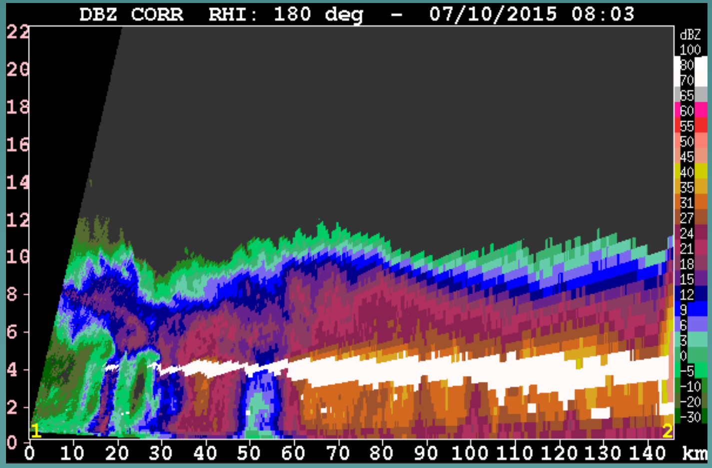
The melting layer algorithm under-estimates the upper limit of the layer.
We can extend it upwards by increasing the RHOHV threshold used above the layer.



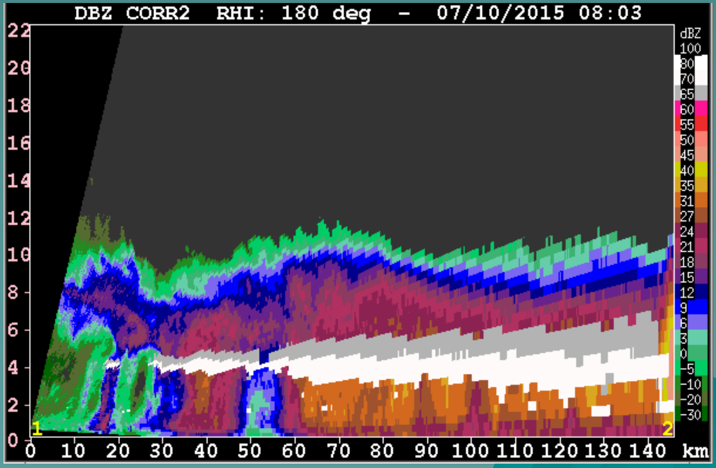
DBZ



RHOV

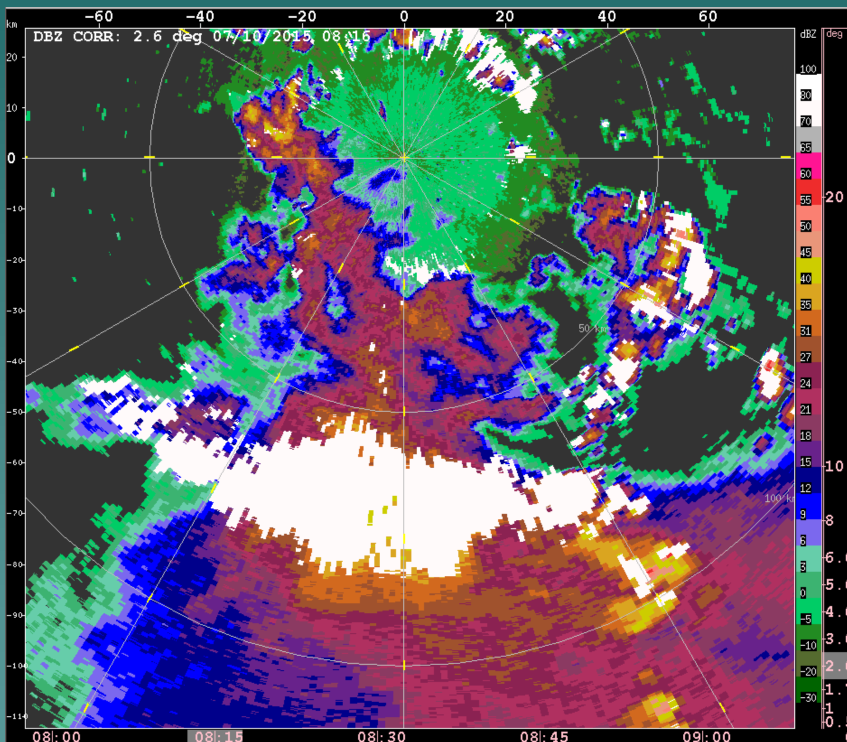


ML (white) using RHOHV threshold of 0.98

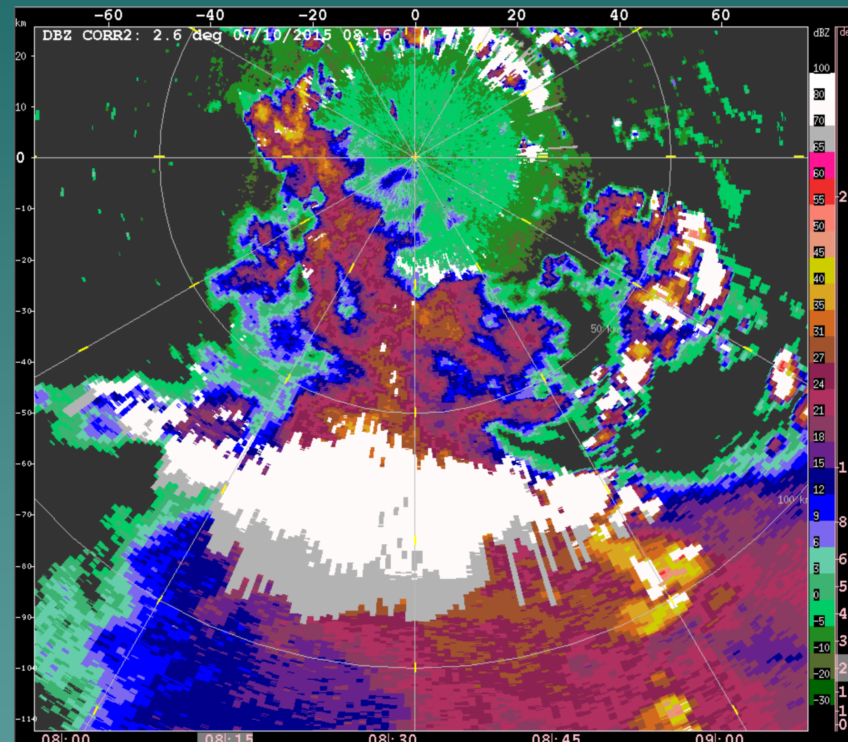


ML (gray) increasing RHOHV threshold to 0.995 above the layer

Extension of melting layer upper limit by increasing the RHOHV threshold above the layer. PPI case.



ML (white) using RHOHV
threshold of 0.98



ML (gray) increasing RHOHV
threshold to 0.995 above the layer

Conclusions

- The QPE algorithm based on the NCAR Particle ID was reviewed.
- When tested using the PECAN data set, the results were encouraging. However, artifacts related to KDP and the melting layer signature were identified.
- A modified KDP estimator, based on Z and ZDR, was tested.
- Identification of the melting layer was modified by extending the upper limit, using a higher RHOHV threshold.

Thank you