Probability of Detection of SPLASH* Using Polarimetric Radar

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*SPLASH = Storms Producing Large Amounts of Small Hail

SPLASH Background

- Recent spike in interest concerning storms that produce large accumulations of small hail:
  - Kalina et al. 2016
  - Ward et al. 2018
  - Kumjian et al. 2019
  - Wallace et al. 2019
  - Friedrich et al. 2019
- Case data have been limited when considering SPLASH radar signatures.
- More data are needed for statistical analysis.

Photo/Video Credits: Aaron Ward

SPLASH Signature Review

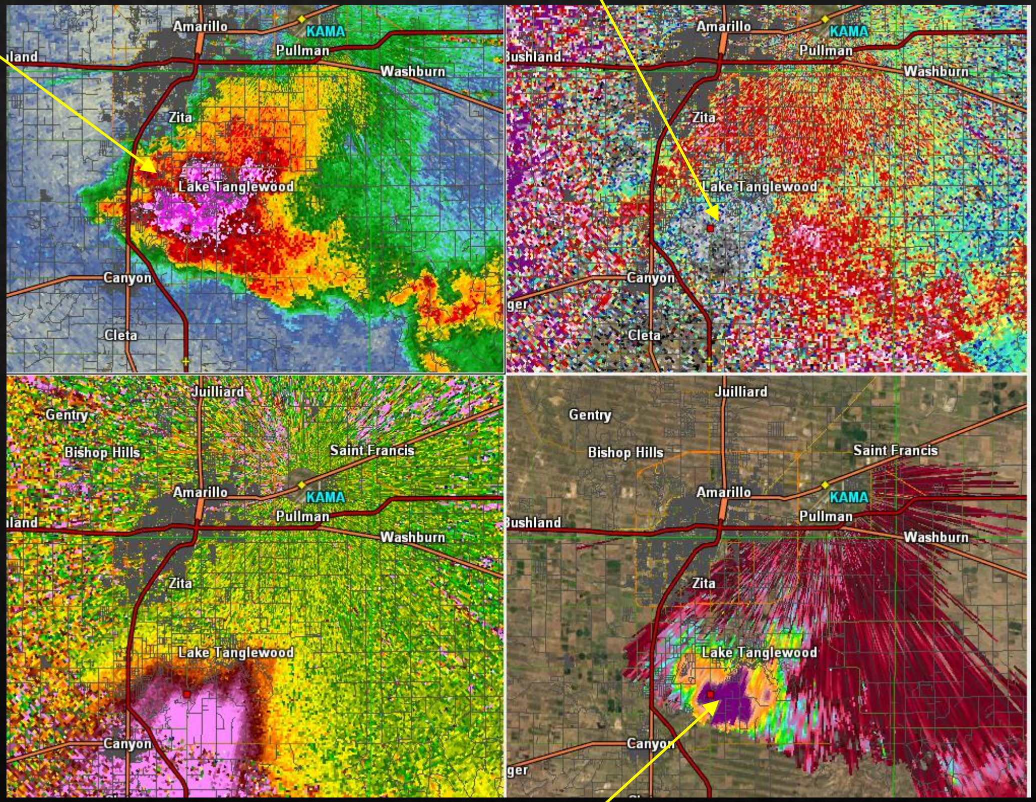
- ◇ Large Reflectivity (Z)
- ◇ Large Specific Differential Attenuation (ADP)
- ◇ Anomalously large Specific Differential Phase (KDP)

Kumjian et al. 2019

Reduced Z_{DR} values down radial

>= 50 dBZ

Z_H (dBz) Z_{DR} (dB)

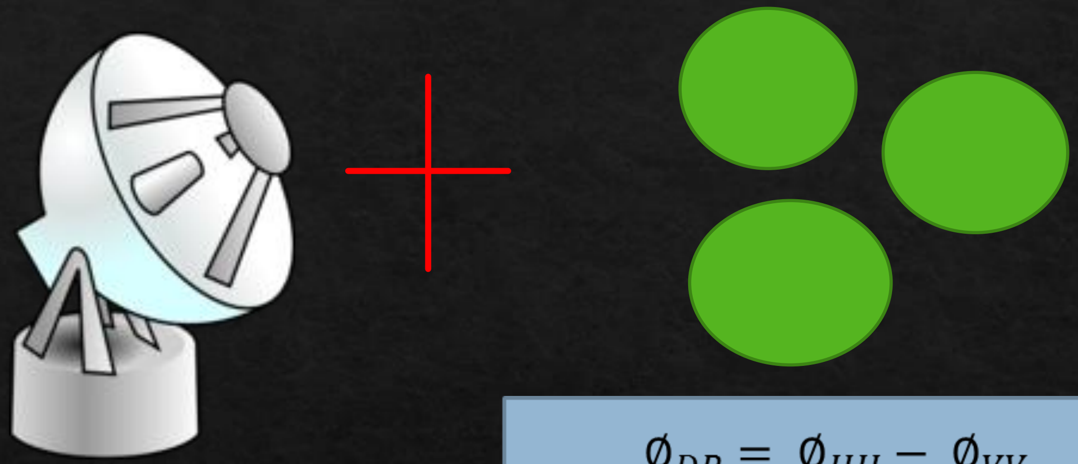


Phi_{DP} (°) K_{DP} (°/km)

>= 7.5 °/km

Specific Differential Phase (KDP)

Large Hail



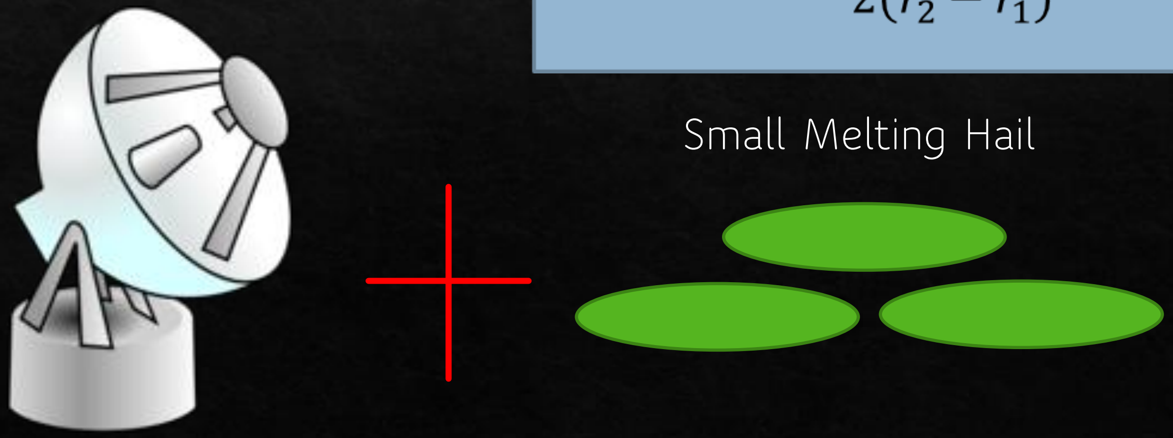
$$\phi_{DP} = \phi_{HH} - \phi_{VV}$$

$$KDP = \frac{\phi_{DP}(r_2) - \phi_{DP}(r_1)}{2(r_2 - r_1)}$$

Small Melting Hail

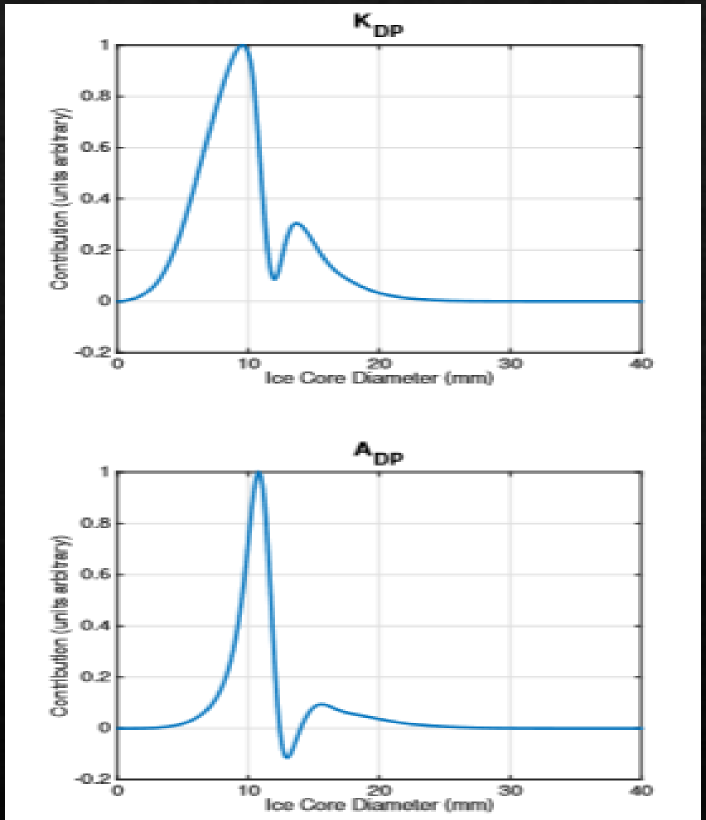
Slower

Faster

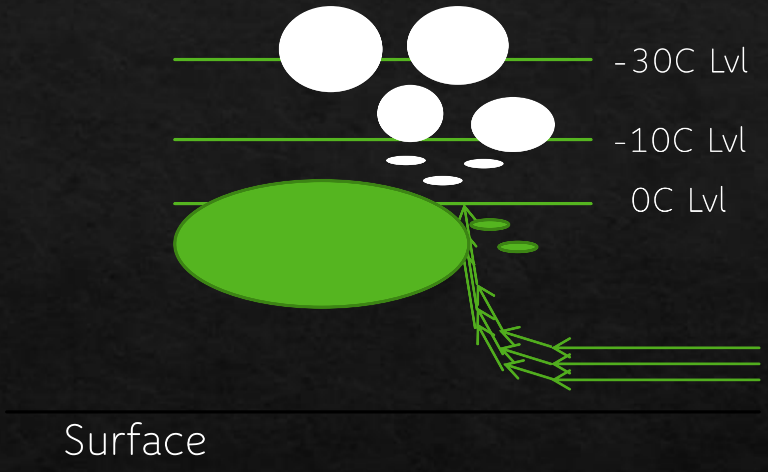


Melting Hail Microphysics

- Amount of melting will depend on wet bulb zero height (WBZ).
- S-band Scattering calculations From Bringi & Seliga (1977a,b).
- Regardless of the particle size distribution selected, smaller melting stones dominate contributions to K_{DP} and A_{DP}.



From Kumjian et al. 2019

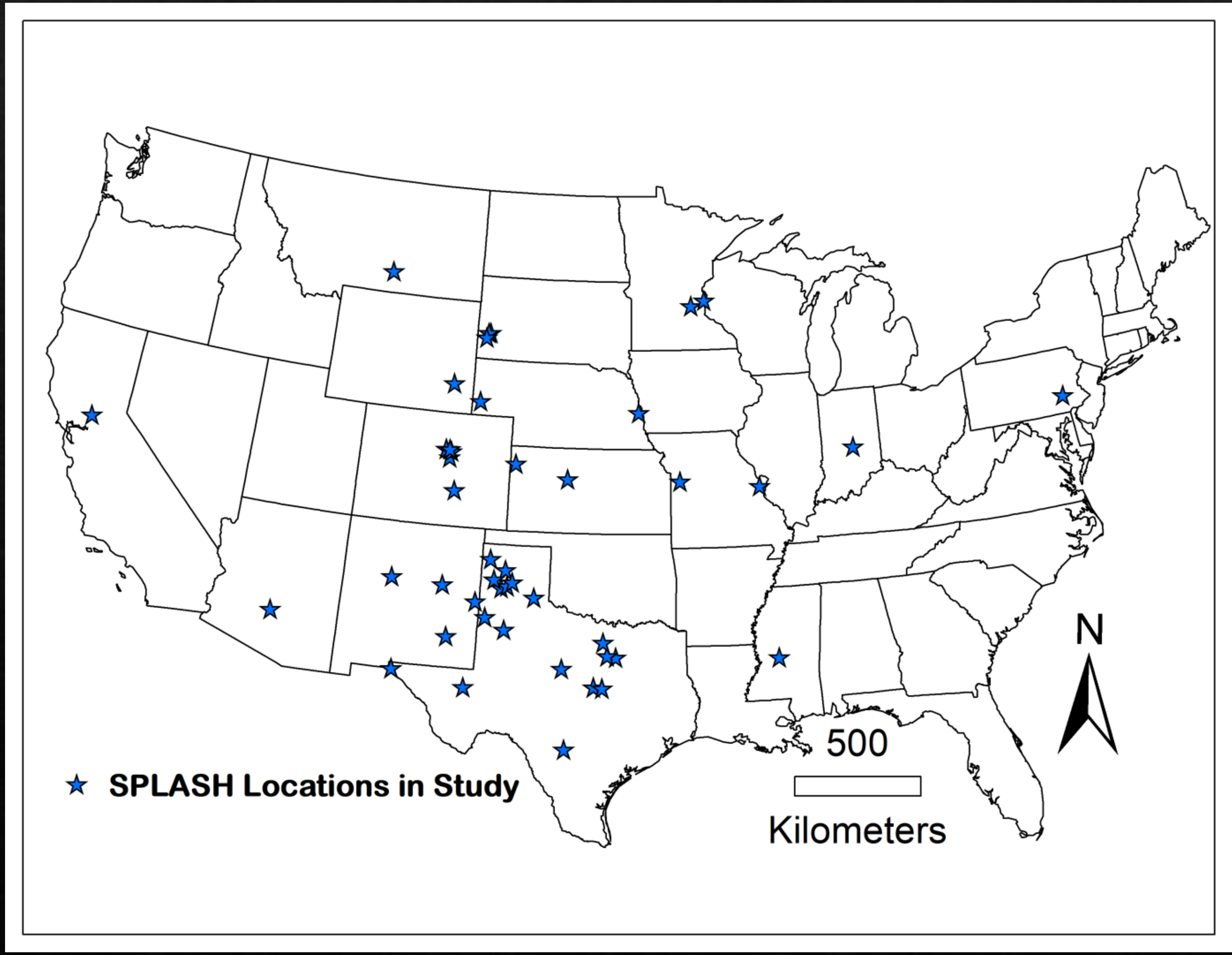


- Two-layer spheroids w/max allowable liquid water mass based on Rasmussen & Heymsfield (1987), Ryzhkov et al. (2013a,b), and Kumjian et al. 2018.

Hypothesis

- SPLASH POD using polarimetric signatures will be high near the radar, but may not be detectable at long range (> 40km).
- SPLASH POD using polarimetric signatures will be high when the wet bulb zero height (WBZ) is high, but may not be detectable when the WBZ is low (< 2500 m).

Case Selection and Examples



April 11, 2012 – Amarillo, TX
Credit: NWS Amarillo

June 8th, 2017 – Canyon, TX
Credit: NWS Amarillo

March 31, 2016 – Gluckstadt, MS

July 14, 2015 – Rapid City, SD

March 8, 2015 – Jonesboro, TX

May 18, 2015 – Pecos, TX

Methods: Calculating KDP & ADP

Specific Differential Phase (KDP)

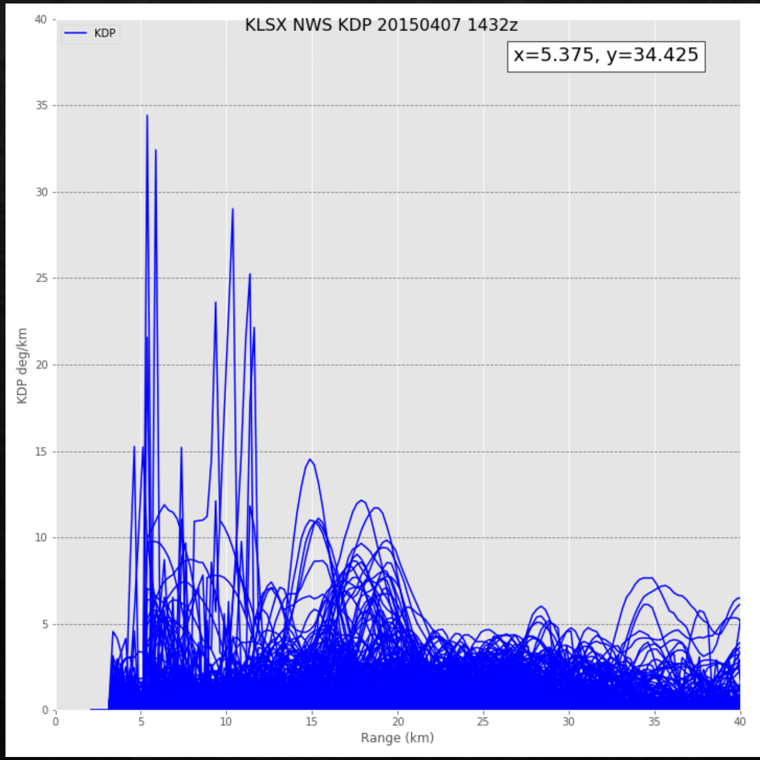
- Used WSR-88D archived radar data.
- Only considered the 0.5° slice for simplicity.
- Calculated based on Ryzhkov et al. 2005 (method used operationally).
- With help of Py-ART, gate filters were used to isolate true max KDP value.

Specific Differential Attenuation (ADP)

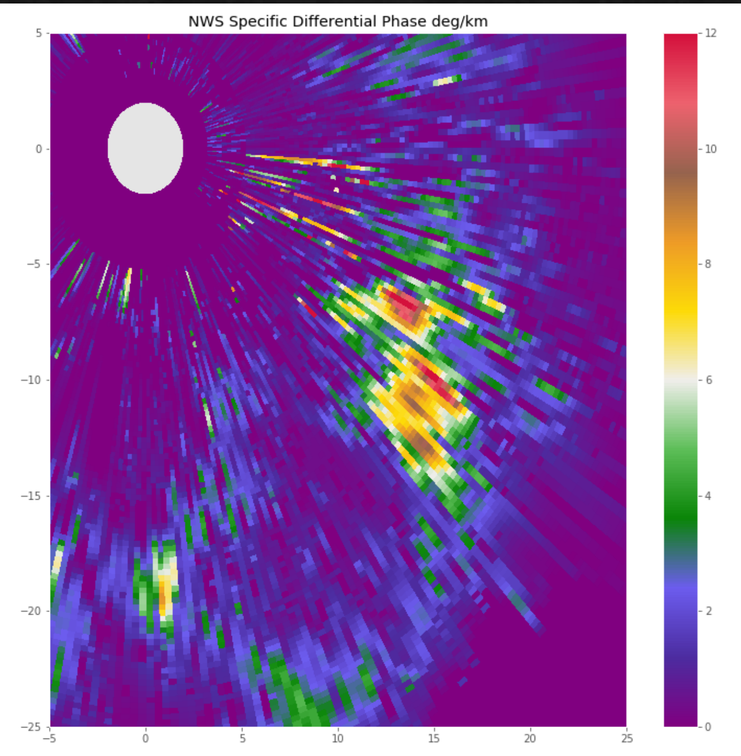
- Used WSR-88D archived radar data.
- Only considered the 0.5° slice for simplicity.
- Calculation based on linear dependence with PhiDP (Ryzhkov et al. 2013).
- Attenuation was computed up to WBZ from most valid RAOB.
- With help of Py-ART, gate filters were used to isolate true max KDP value.

Methods: Adding Gate Filters

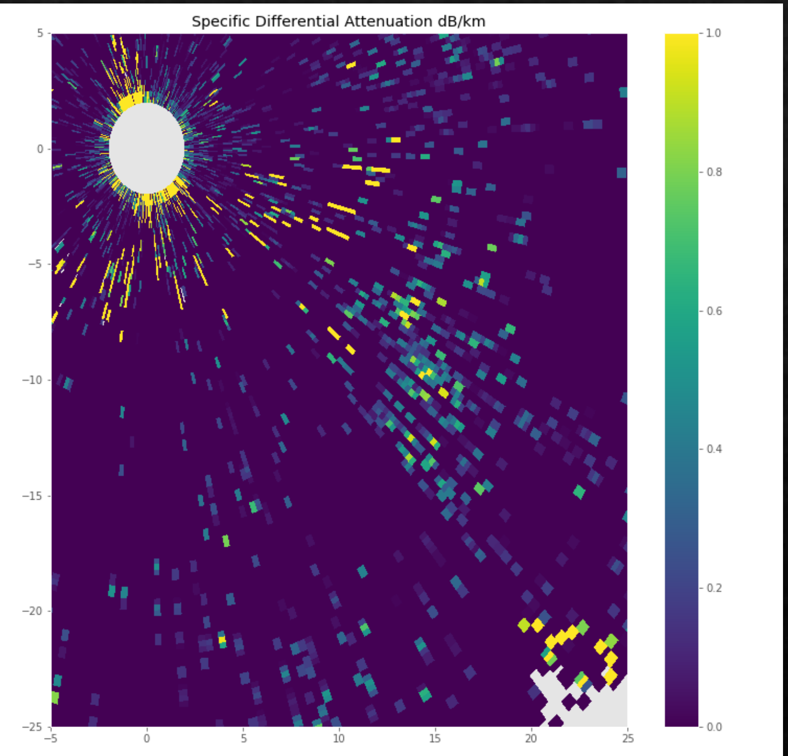
Specific Differential Phase (°/km)



Specific Differential Phase (°/km)



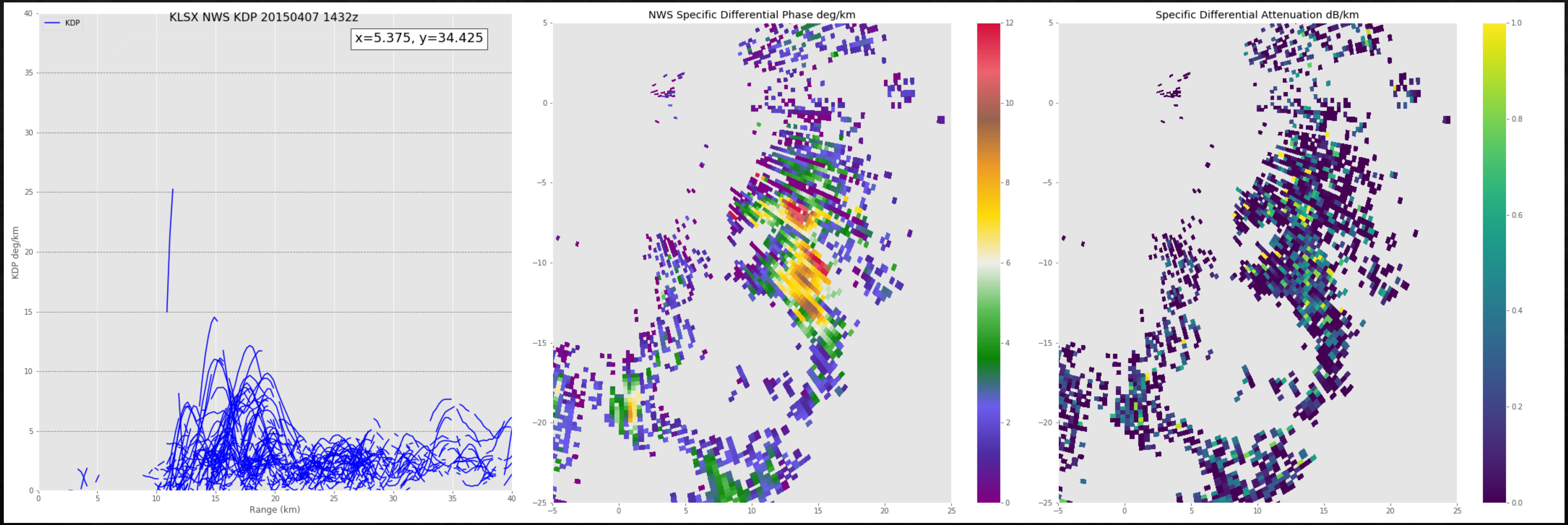
Specific Differential Attenuation(dB/km)



Methods: Moment Based Gate Filter (Z & CC)

pyart.filters.moment_based_gate_filter

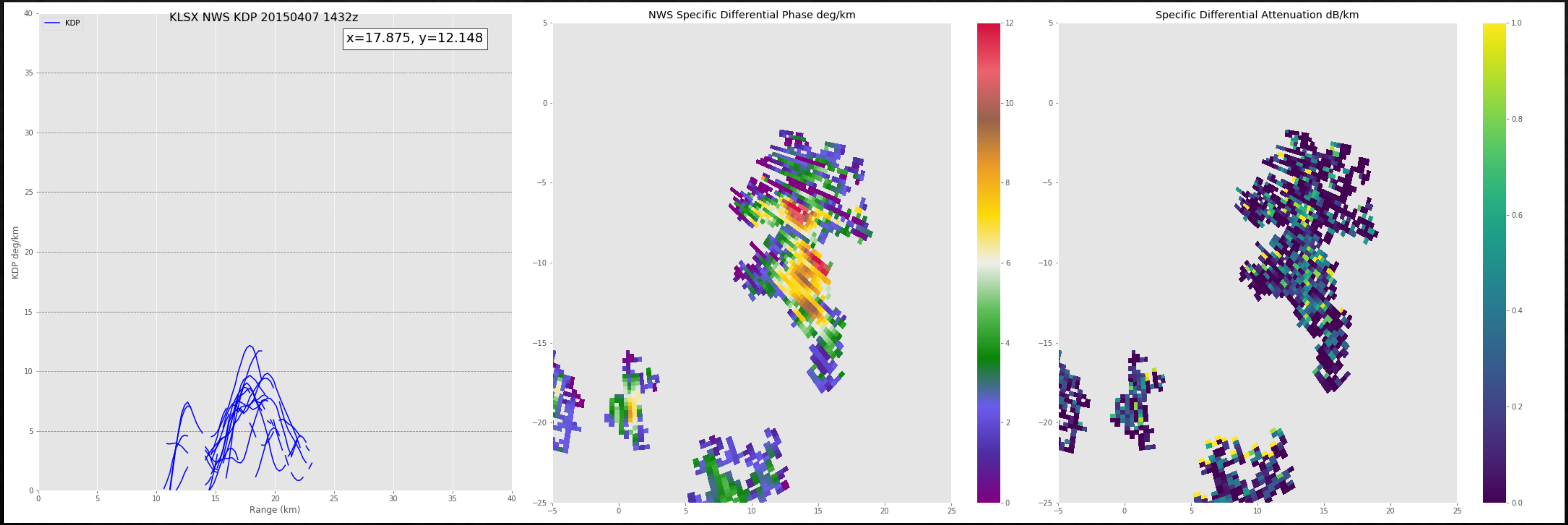
Specific Differential Phase (°/km) | Specific Differential Phase (°/km) | Specific Differential Attenuation(dB/km)



Methods: Remove Insignificant Features

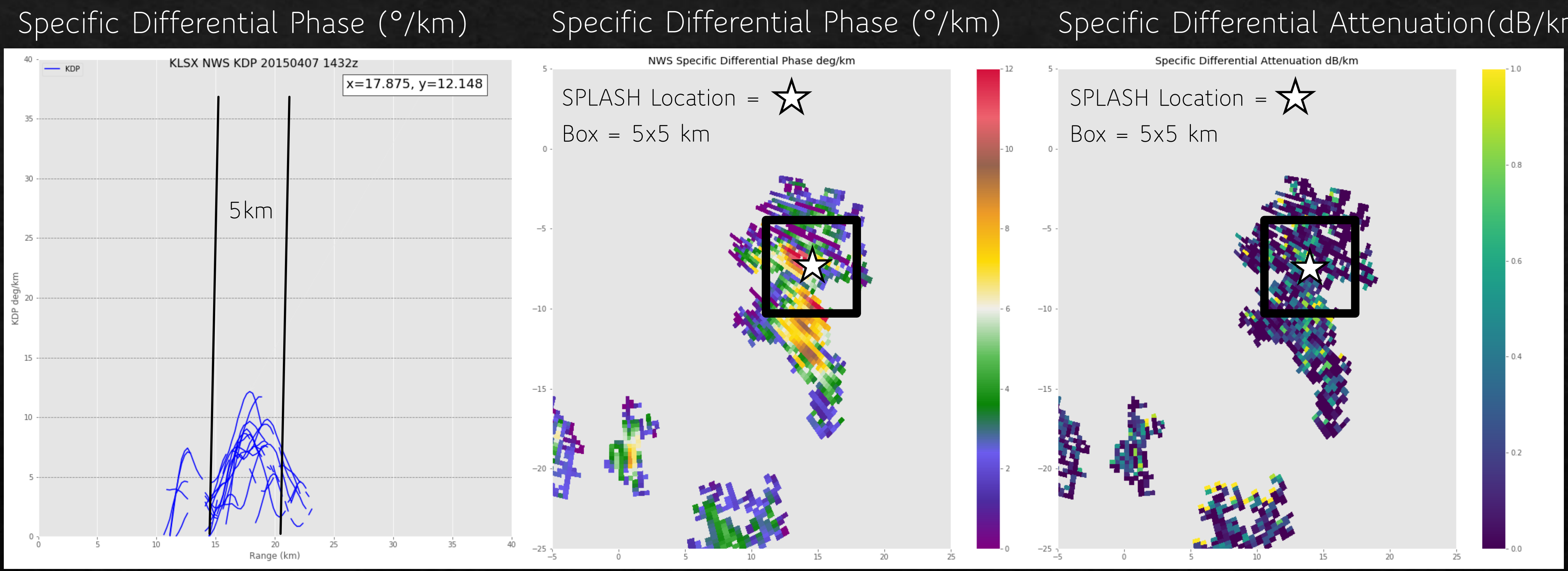
pyart.filters.moment_based_gate_filter + echo.correct.noise.significant_detection

Specific Differential Phase (°/km) | Specific Differential Phase (°/km) | Specific Differential Attenuation(dB/km)



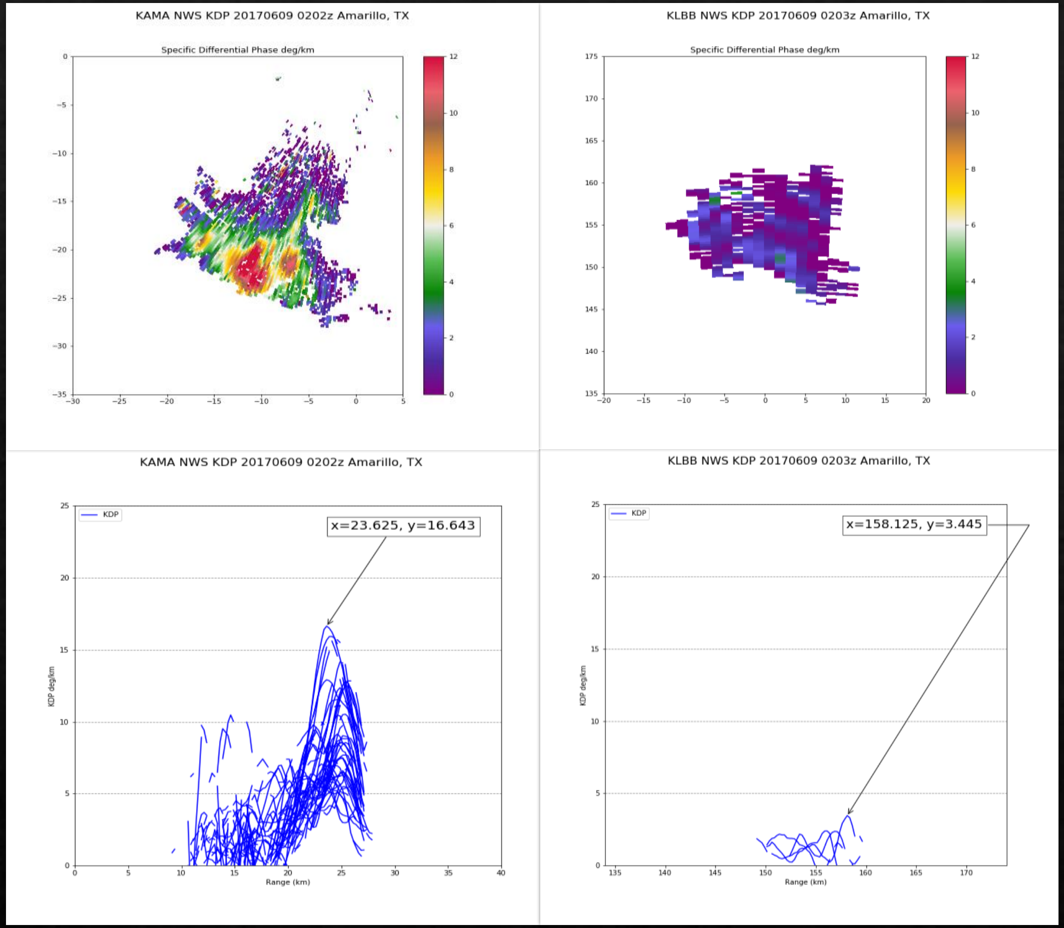
Methods: Haversine Formula

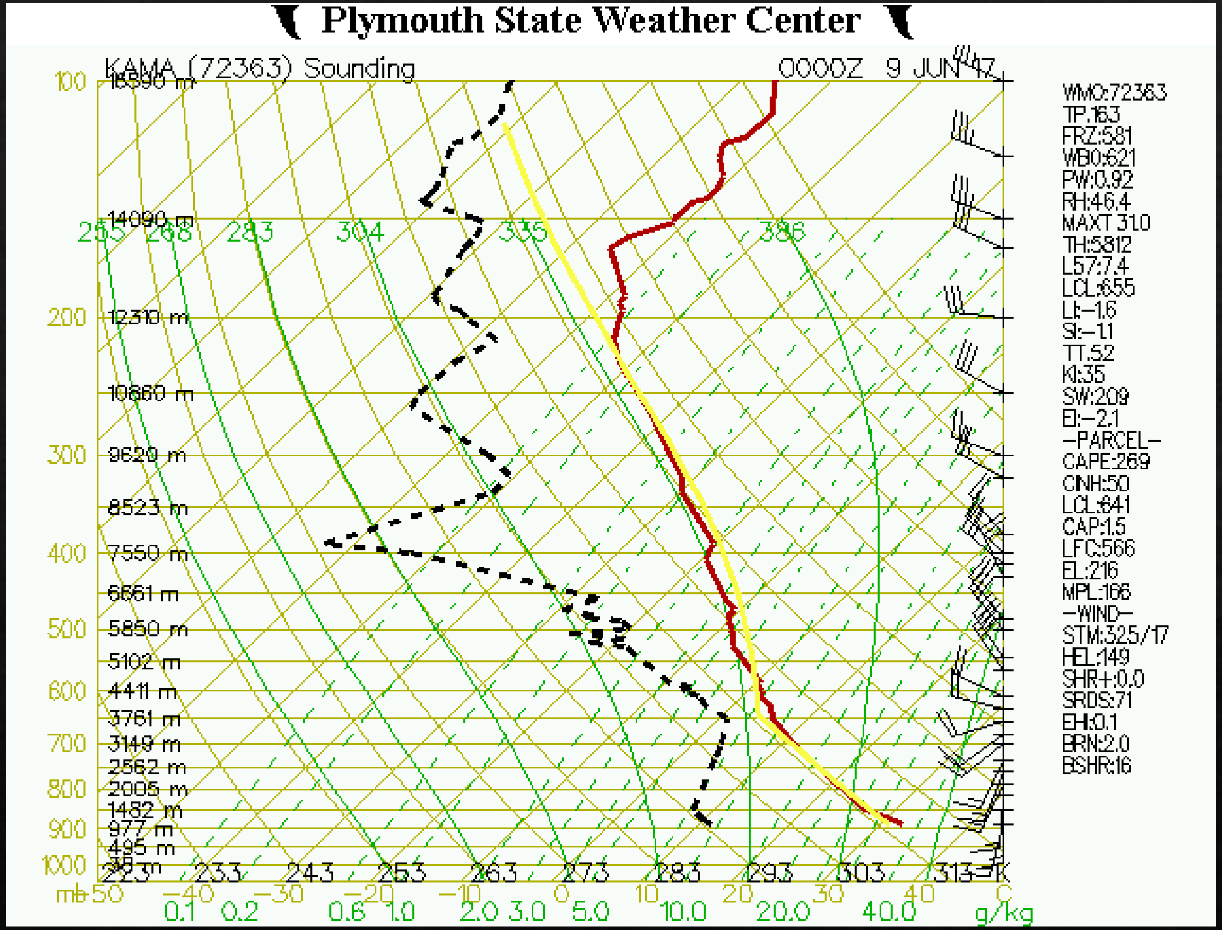
pyart.filters.moment_based_gate_filter + echo.correct.noise.significant_detection + Haversine



Methods: Radar Range and Wet Bulb Zero Height

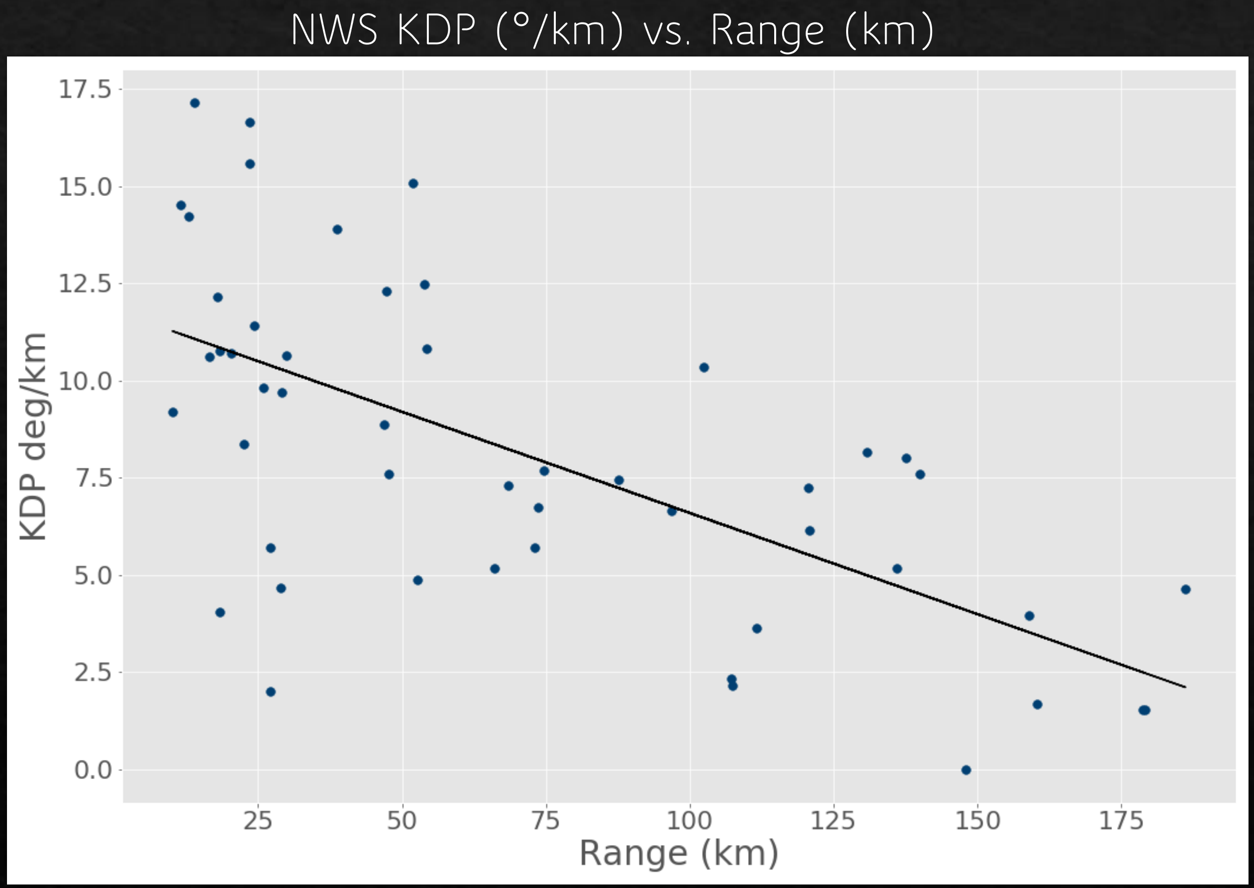
Short Range KDP (KAMA) Long Range KDP (KLBB)



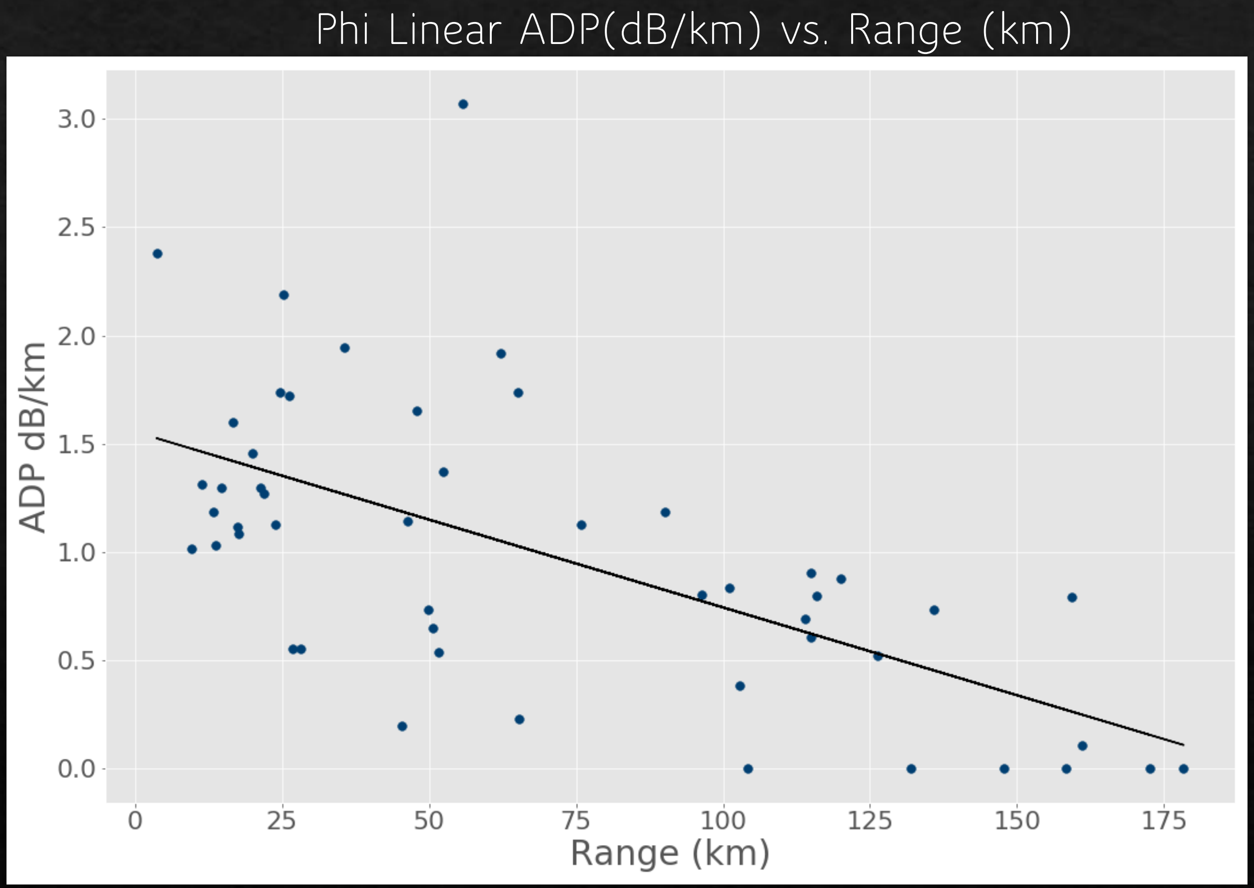


- In cases where one WSR-88D was within 50km of the SPLASH point, and a second was within 150km, data from both radars were used (true for six cases).
- Wet bulb zero heights from the Plymouth State Weather Center Text Listings were used for the nearest RAOB in space and time.

Results: Max KDP/ADP vs. Radar Range

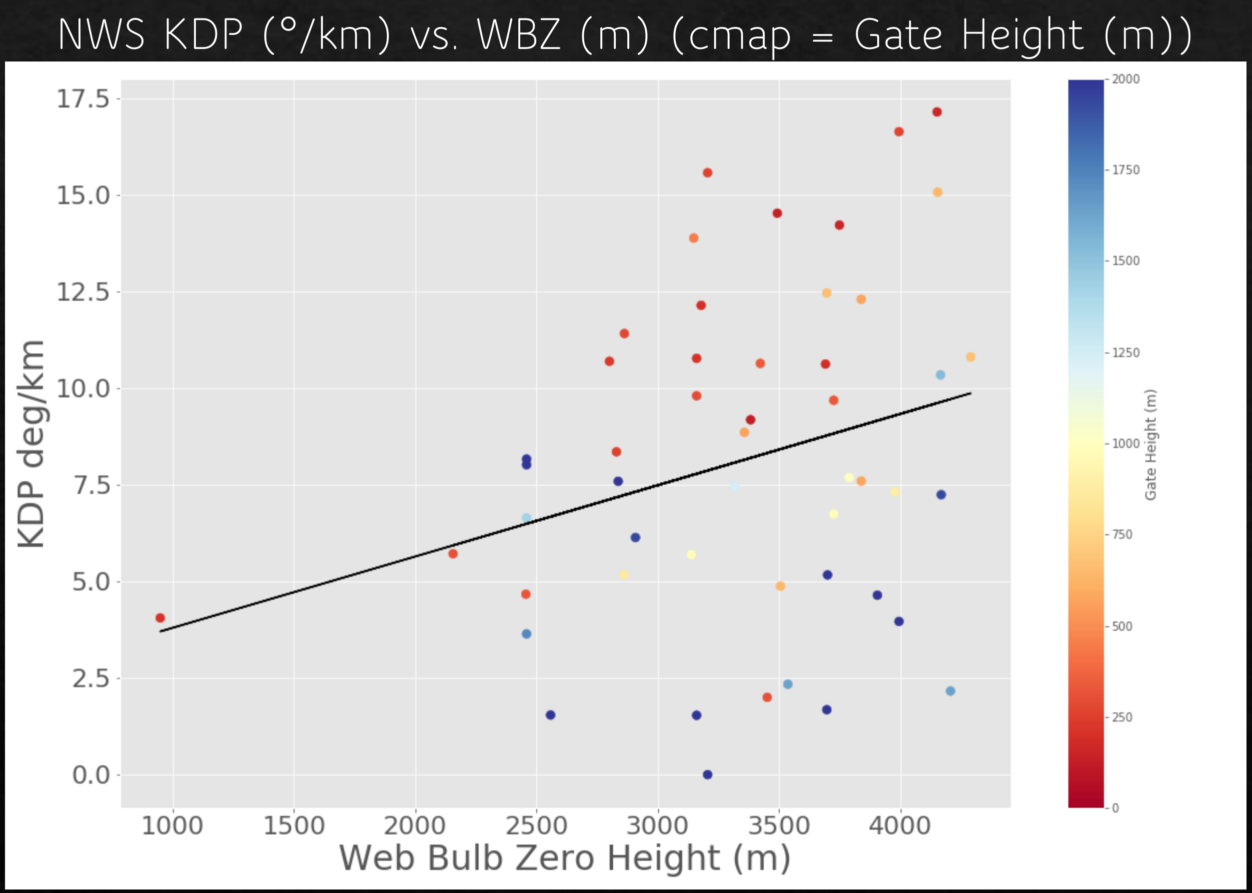


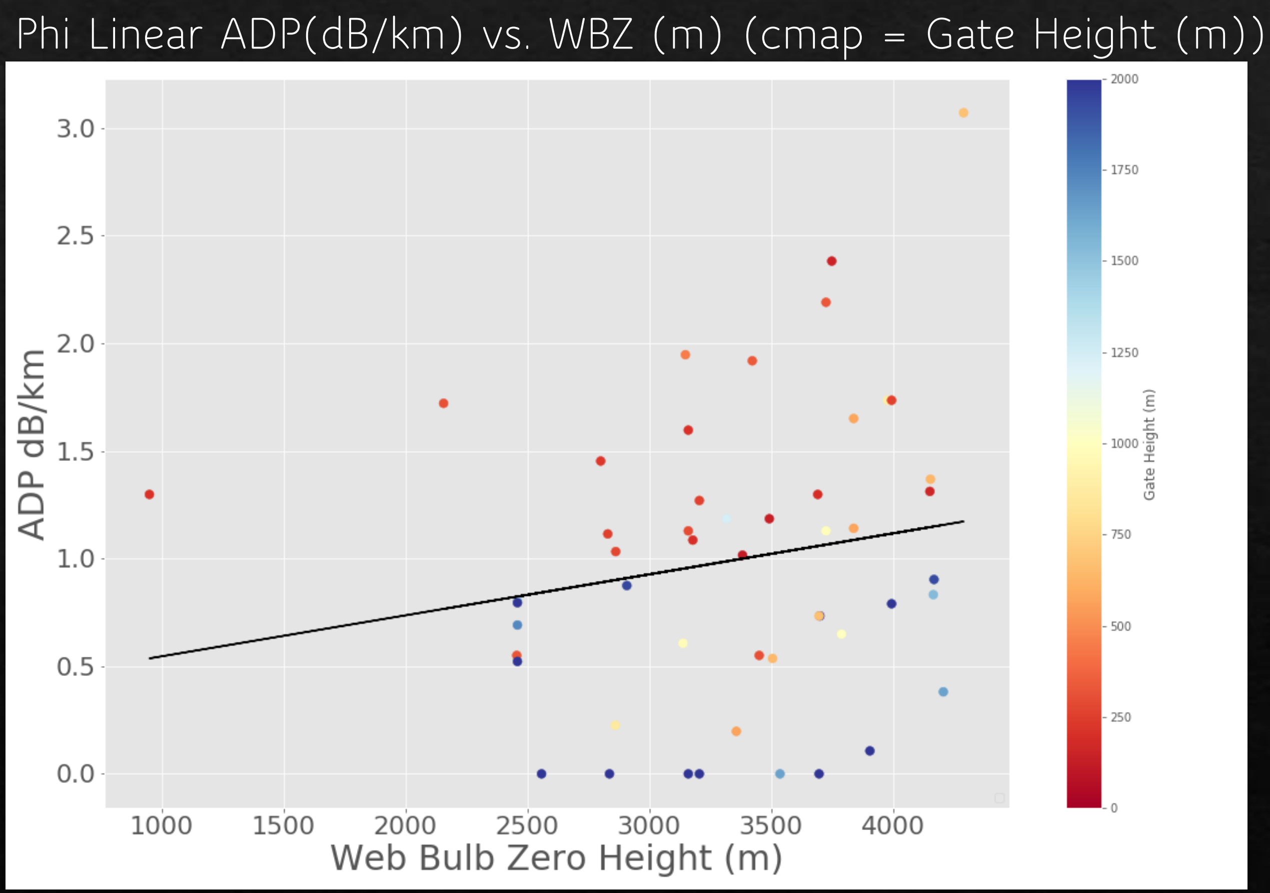
$R^2 = 0.412792184$



$R^2 = 0.384511954$

Results: Max KDP/ADP vs. WBZ





$R^2 = 0.078864361$

$R^2 = 0.033771512$

Final Numbers: SPLASH POD

Criteria:
ADP > 1.0 dB/km
KDP > 7.5 °/km

Results:
KDP all (50): 0.54
ADP all (50): 0.50

KDP r <= 40km (20): 0.80
ADP r <= 40km (20): 0.90

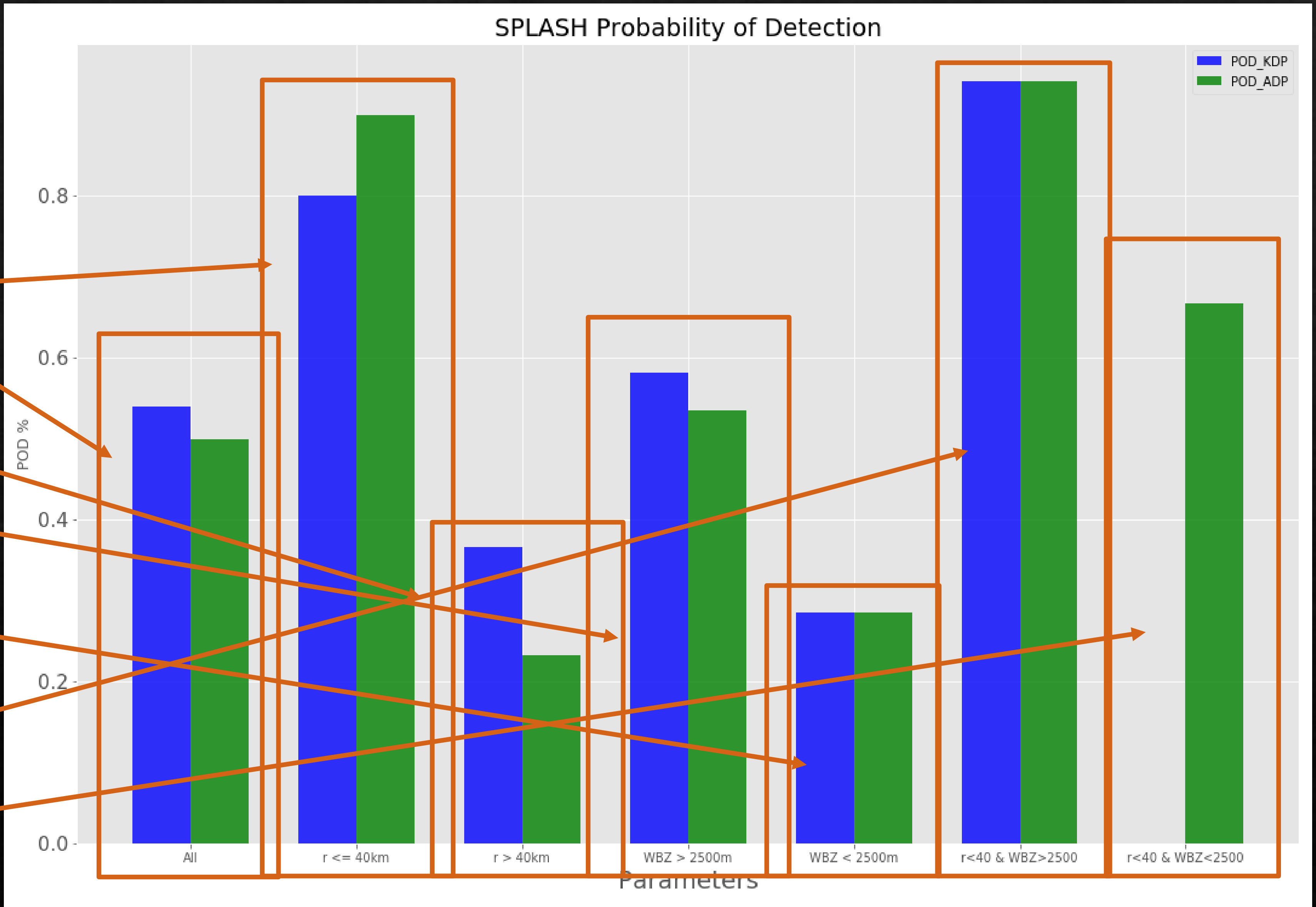
KDP r > 40km (30): 0.37
ADP r > 40km (30): 0.23

KDP WBZ => 2500m (43): 0.58
ADP WBZ => 2500m (43): 0.54

KDP WBZ < 2500m (7): 0.29
ADP WBZ < 2500m (7): 0.18

KDP r < 40km & WBZ => 2500m (17): 0.94
ADP r < 40km & WBZ => 2500m (17): 0.94

KDP r < 40km & WBZ < 2500m (3): 0.00
ADP r < 40km & WBZ < 2500m (3): 0.67



SPLASH False Alarm & Lead Time

- The lack of a dedicated reporting method for SPLASH cases results in unreliable statistics for FAR and lead time.
- One goal of this research is to prove that SPLASH cases are worthy of National Weather Service warnings and verification, similar to that of a severe thunderstorm.
- Once verification occurs across NWS offices on a regular basis, FAR and lead time statistics will become more reliable.

Potential Use in Decision Support Services Regime

- The high POD values using KDP and ADP suggest SPLASH radar signatures provide unique information that can provide operational meteorologists “just in time” information about potentially hazardous accumulations of hail.
- This information can be passed on to public safety personel (e.g. Dept. of Transportation for snow plow deployment) to help protect life and property.
- A few offices (e.g. KAMA & KUNR) are issuing warnings and advisories to warn the public.

Conclusion

- Scatter plots revealed notable trends with range, but the trends with WBZ were not as easy to determine because of differences in gate height. More data is needed to get better R^2 values.
- SPLASH POD was very high (94%) for KDP & ADP when both r < 40 km and WBZ => 2500 m, but POD values drop off at ranges > 40 km (KDP = 37%, ADP = 23%) and WBZ < 2500 m (KDP = 29%, ADP = %18).
- POD values suggest polarimetric radar SPLASH signatures can be used for life saving decision support services.
- False alarm and lead time statistics are unreliable due to limitations in reporting and verification procedures (or lack thereof).
- Verification procedures for SPLASH cases should be employed across the NWS.
- More work is needed to better identify the environments that are favorable for SPLASH cases, with utilization of model proximity soundings and additional SPLASH cases.