Range Oversampling

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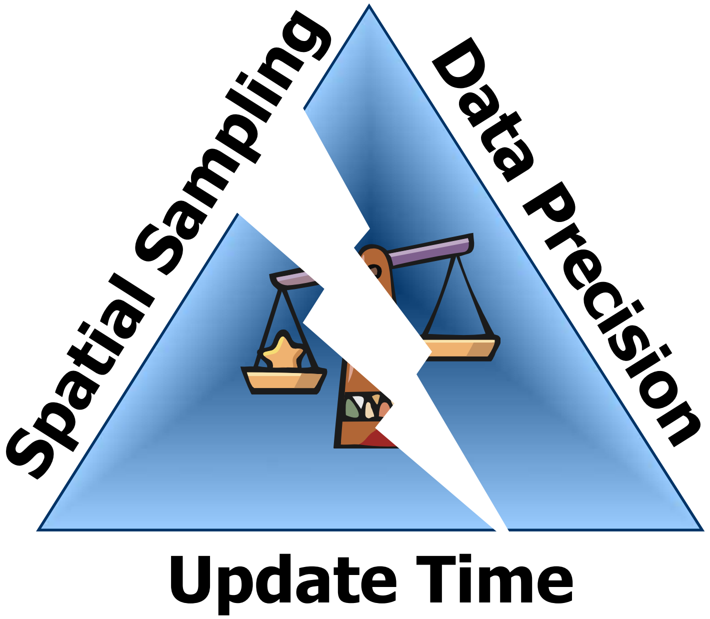
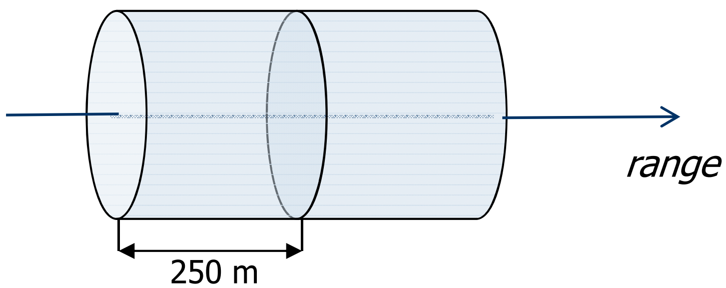
Why range oversampling?

- **Range oversampling** processing leads to
  - **more precise** radar-variable estimates with **same scan times**, or
  - **reduced scan times** with **same precision** of radar-variable estimates, or
  - a combination of both

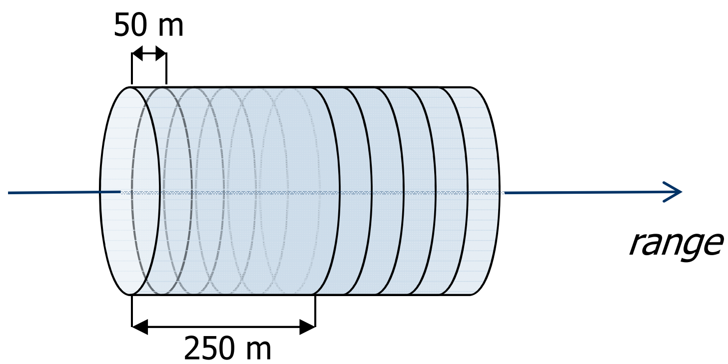


Range Oversampling (I)

- Range oversampling adds more samples without increasing the dwell time



Conventional Sampling (250 m)

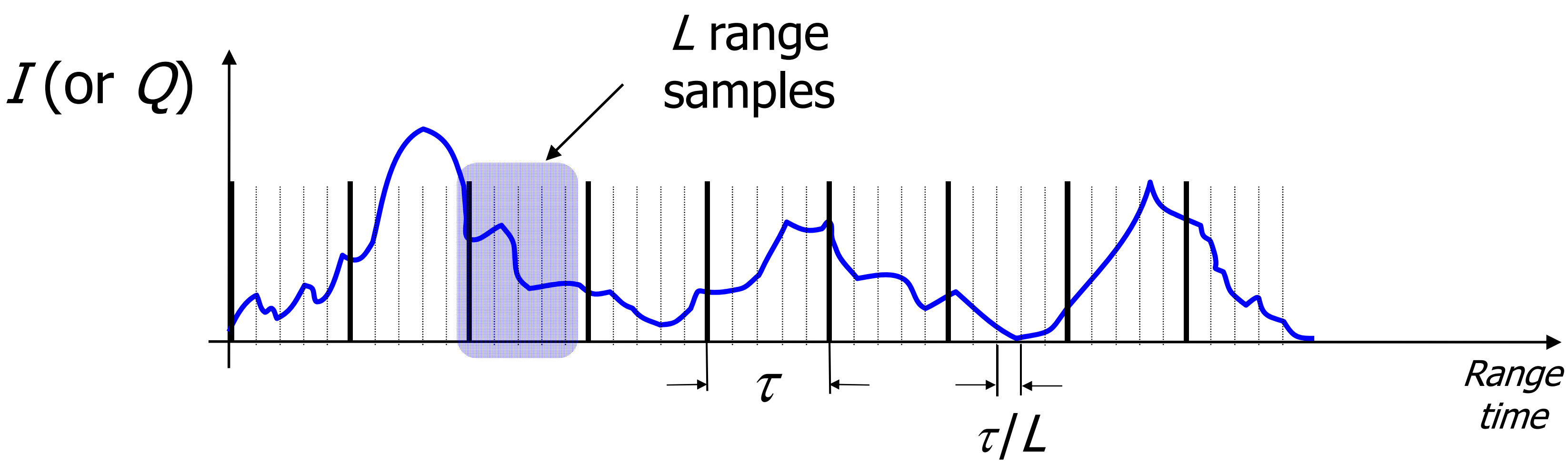


Oversampling (50 m with *L*=5)

- Range oversampling results in overlapping radar volumes
  - Each set of *L* oversampled range samples can be cleverly combined to reduce the variance of radar estimates

Range Oversampling (II)

- Conventional sampling period is given by τ (250 m)
- Oversampling period is given by τ / L (50 m for L = 5)



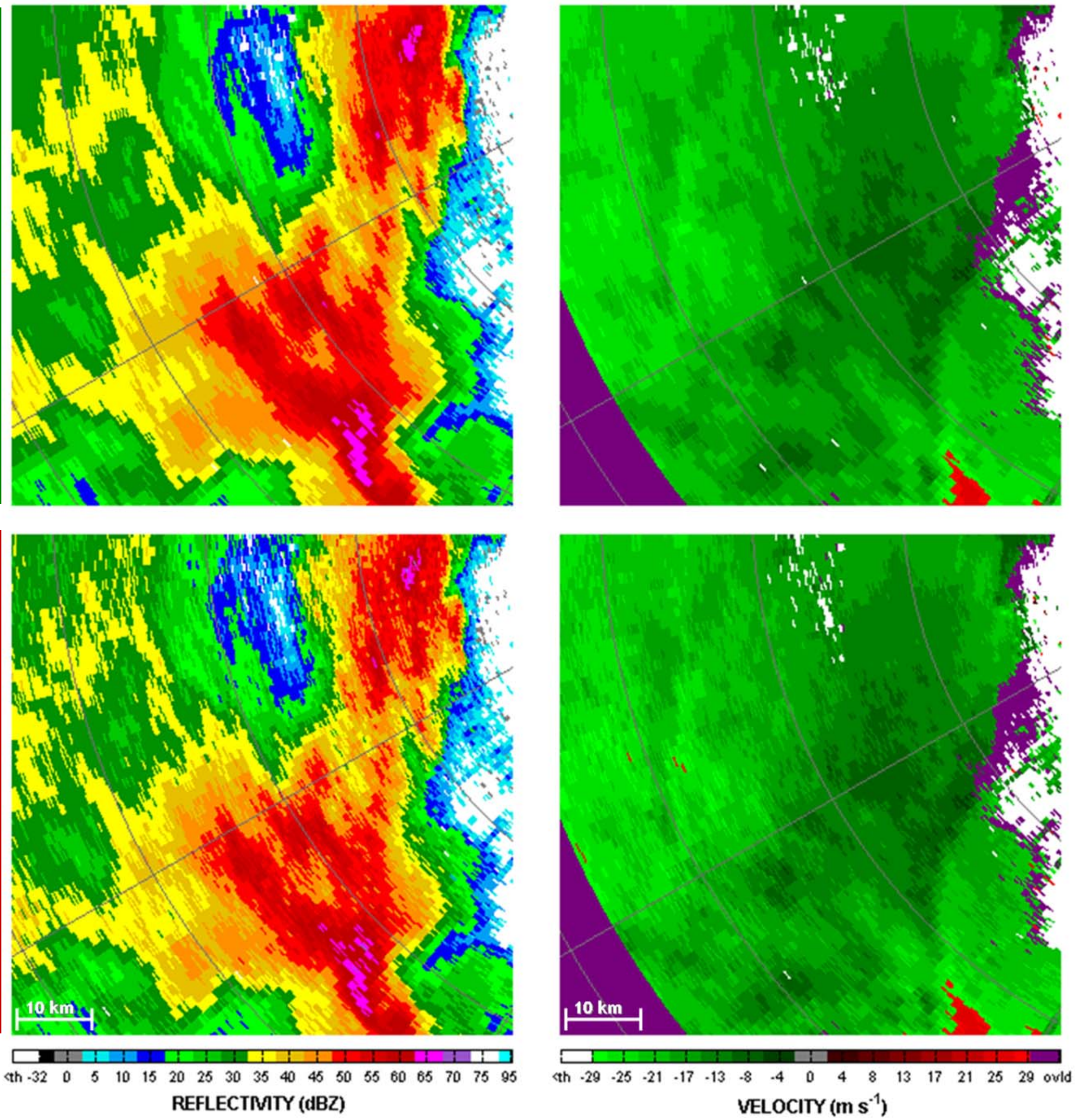
- Dwell time does not change
- Transmitter pulse & receiver filter do not change
- Receiver sampling & computational complexity change

Performance Demonstration

L = 4
2 Apr 2010
10:54 UTC

Range Oversampling Processing
Same observation time

Conventional Processing



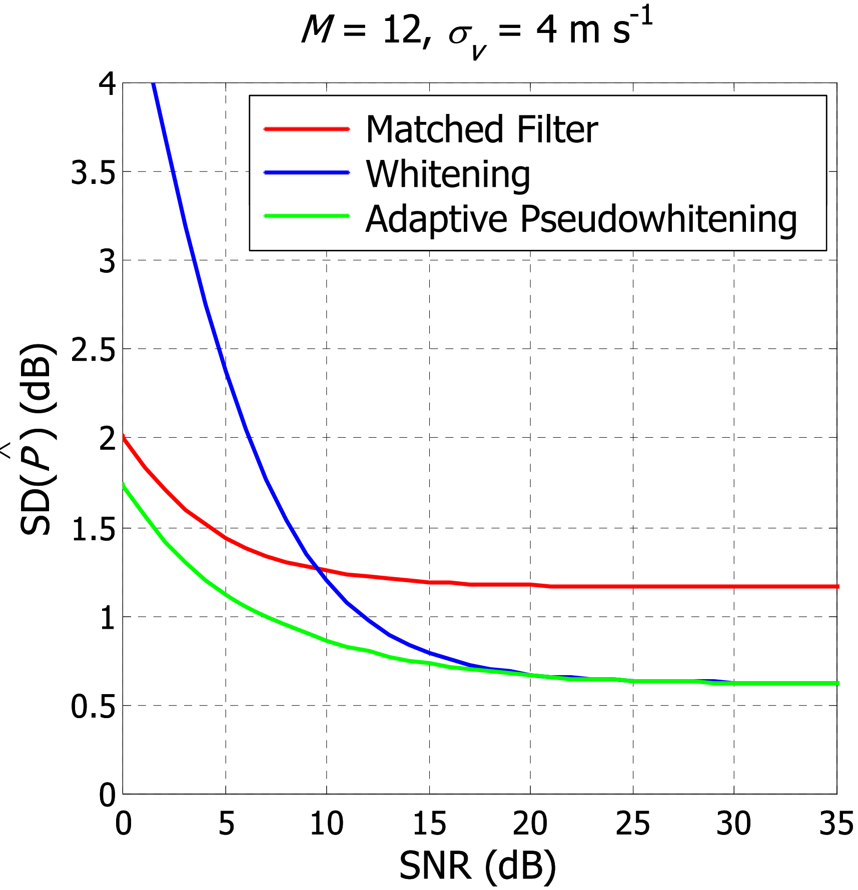
A smoother field with no loss of spatial resolution is an indication of more precise data

Program Milestones (I)

- **Developed technique** (1997-2009)
  - Oversampling and whitening
  - Adaptive pseudowhitening

Adaptive Pseudowhitening

- A **whitening transformation** ignores the effects of noise and leads to optimal performance at high SNR
- The conventional **matched filter** maximizes the SNR and leads to optimal performance at low SNR
- **Adaptive pseudowhitening** includes the effects of noise and leads to optimal performance at all SNRs
  - Uses a different transformation for each radar variable
  - Transformations depend on estimates of SNR, σ_v, Z_{DR}, and ρ_{HV}



Efficient Implementation

- **Adaptive pseudowhitening** uses a different transformation for each radar variable
  - Brute-force approach:
    - six sets of transformed IQ data
    - ground clutter filter applied six times
  - Efficient implementation:
    - one set of partially transformed IQ data
    - ground clutter filter applied once

- The **efficient implementation** of adaptive pseudowhitening ran on the NWRT from 2009 until its decommission in 2016

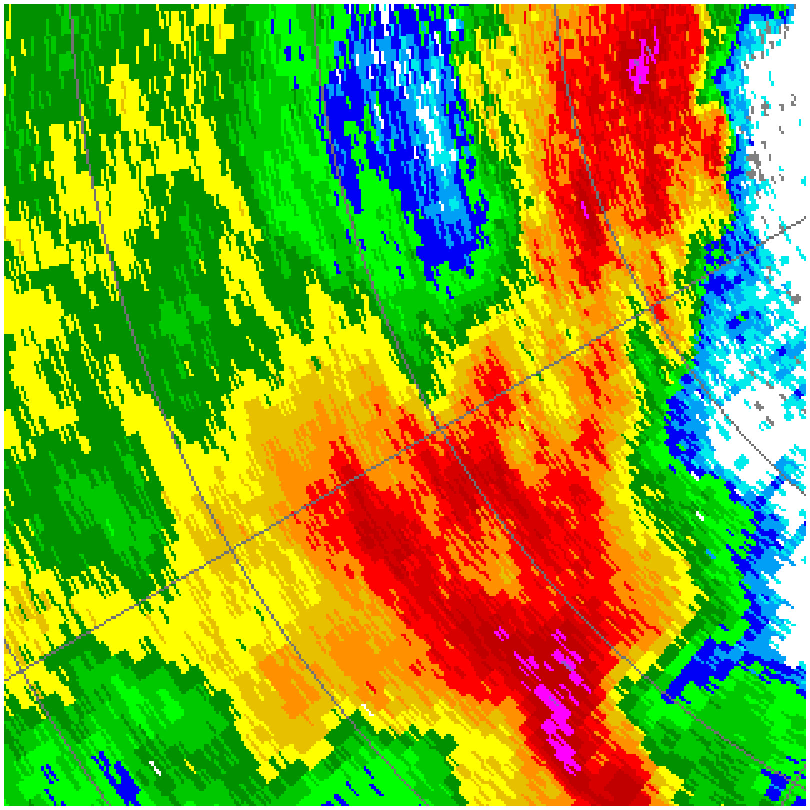
Program Milestones (II)

- **Developed technique** (1997-2009)
- **Implemented in real time on the NWRT PAR** (2009)
  - Exploited for faster updates and improved data quality
    - 50% scan time reduction
  - Integrated with RBRN, CLEAN-AP, and traditional single-pol estimators

NWRT Implementation

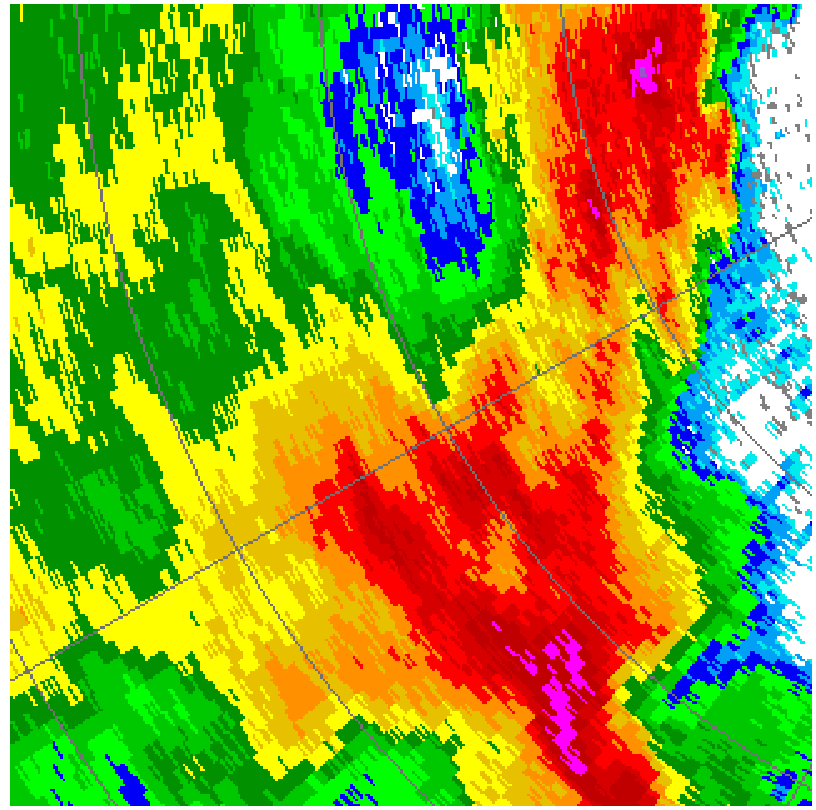
Reflectivity (10:54 UTC 2 Apr 2010)

Conventional Processing



99.2 ms dwell time

Adaptive Pseudowhitening

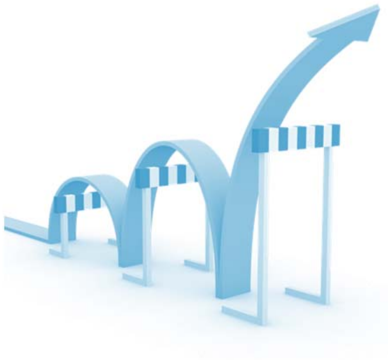


56.8 ms dwell time

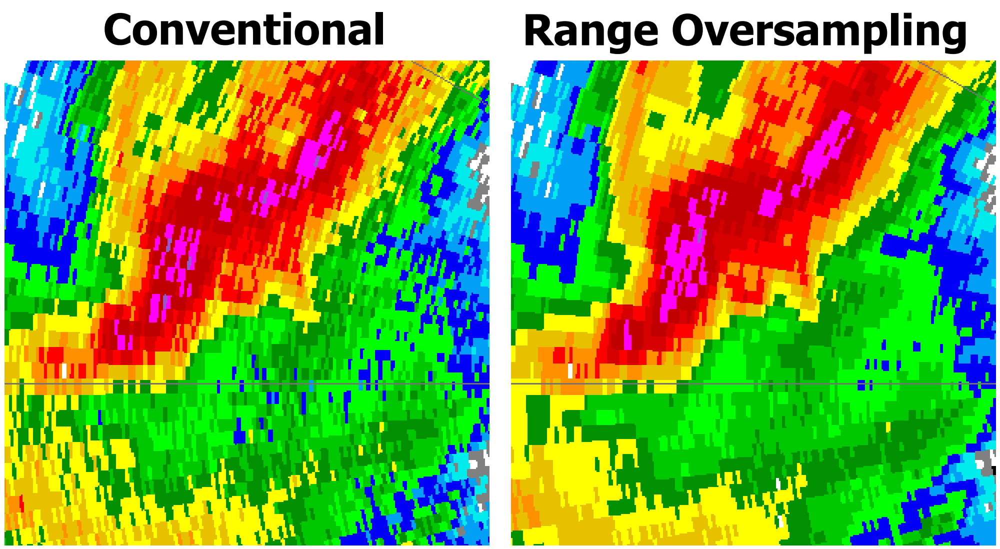
43% faster scans with same or better data quality!

Program Milestones (III)

- **Developed technique** (1997-2009)
- **Implemented in real time on the NWRT PAR** (2009)
- **Addressed practical implementation issues** (2013-2019)
  - Developed range-correlation measurement technique
  - Developed dual-pol extension
    - Integrated with traditional dual-pol estimators
    - Tested with KOUN (RRDA) archived data cases
  - Quantified effects on the range weighting function
  - Developed extension for nontraditional estimators
    - Hybrid spectrum-width estimator
    - New CC estimator
  - Integrated with other techniques/modes
    - Current: RBRN, SZ-2
    - Future: CLEAN-AP/WET, SPRT, HSE
  - Investigated impact of receiver filter bandwidth
    - Tested with KOUN (off-line processing)



The Importance of Accurately Measuring the Range Correlation

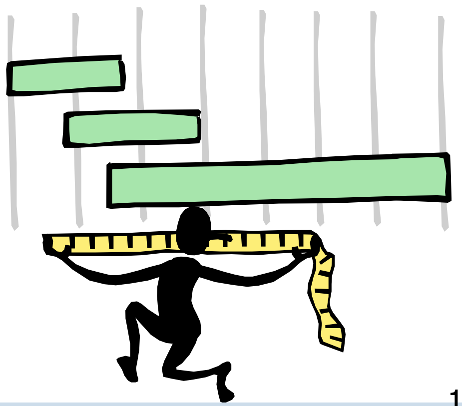


Accurately Measured
Range Correlation

Range Correlation Measurement

- The **range correlation** may change due to
  - environmental changes (temperature)
  - hardware drift from wear-and-tear
  - hardware changes (replaced parts)

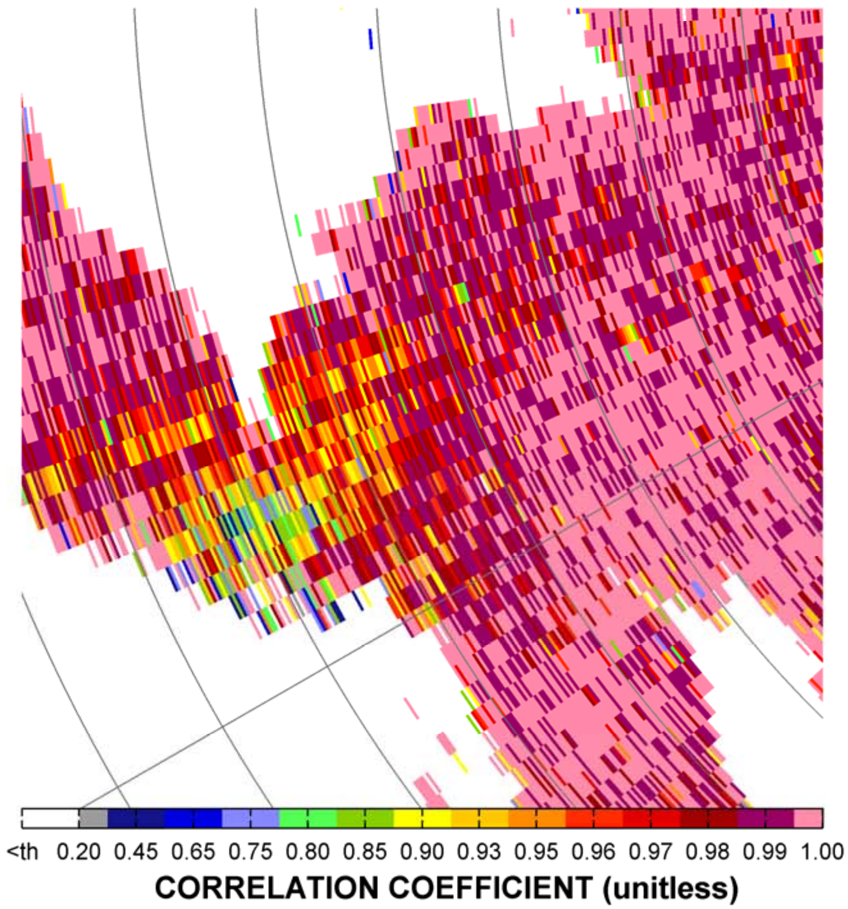
- The range correlation is **measured in real time** from data (no separate measurement)
  - Estimates from multiple radials are combined to make a better estimate
  - Estimate from previous scan is applied to current scan



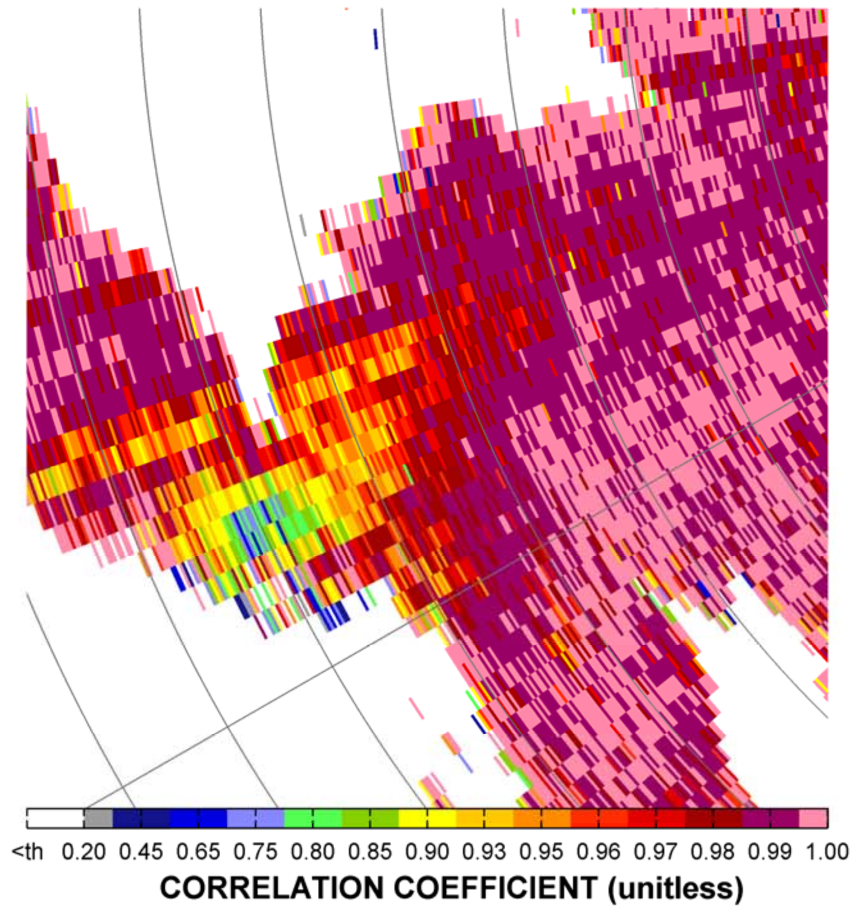
Dual-Pol Extension

Correlation Coefficient (KOUN, 23:37 UTC 12 Aug 2004)

Conventional Processing



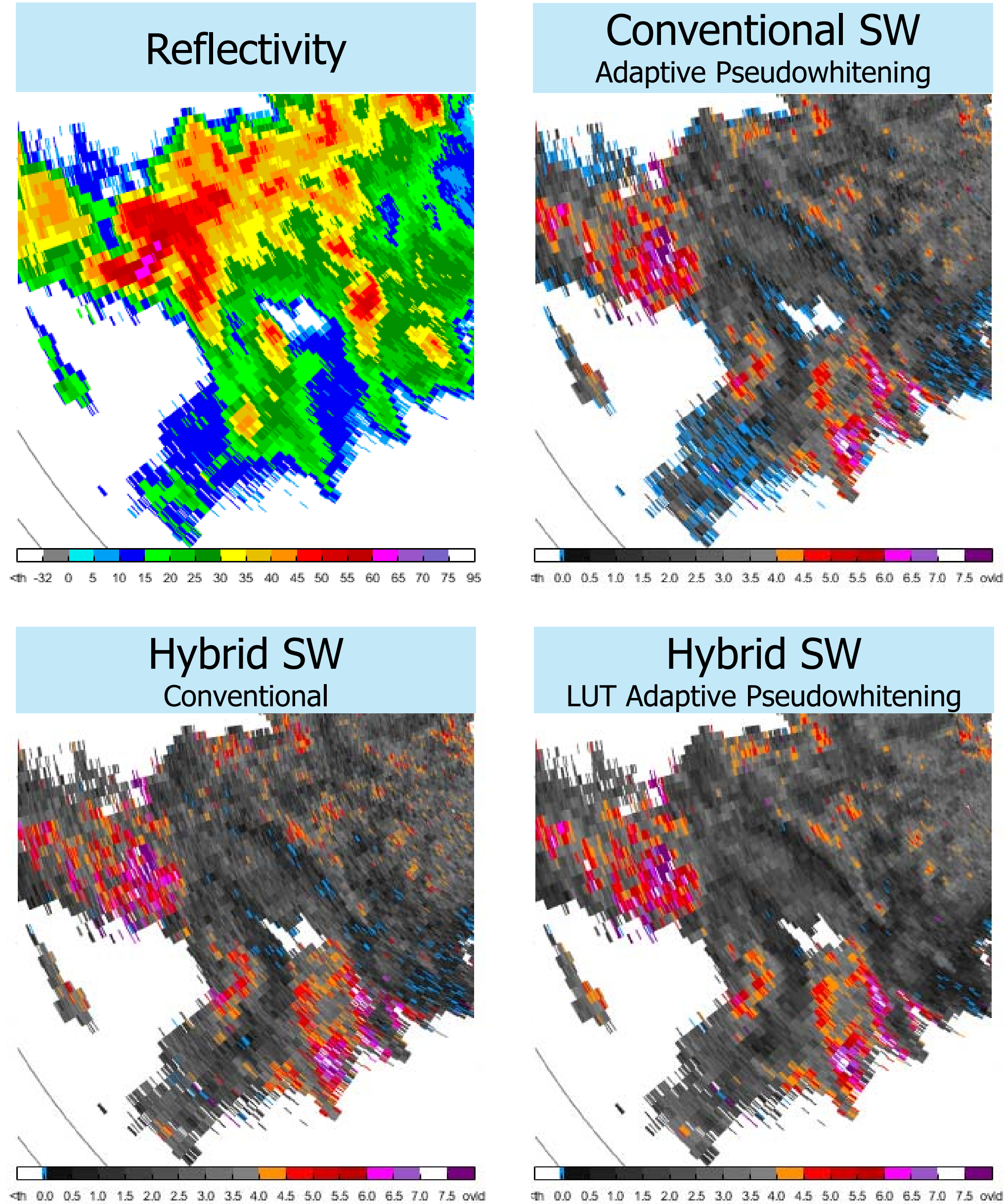
Adaptive Pseudowhitening



better data quality with the same scan time!

LUT Adaptive Pseudowhitening

- **Adaptive pseudowhitening** requires theoretical variance expressions
- **Lookup-table (LUT) adaptive pseudowhitening** works with non-traditional estimators without theoretical expressions



Program Milestones (IV)

- **Developed technique** (1997-2009)
- **Implemented in real time on the NWRT PAR** (2009)
- **Addressed practical implementation issues** (2013-2019)
- **Algorithm description delivered to ROC** (2018)
  - Held TIM to discussed implementation on the ORDA

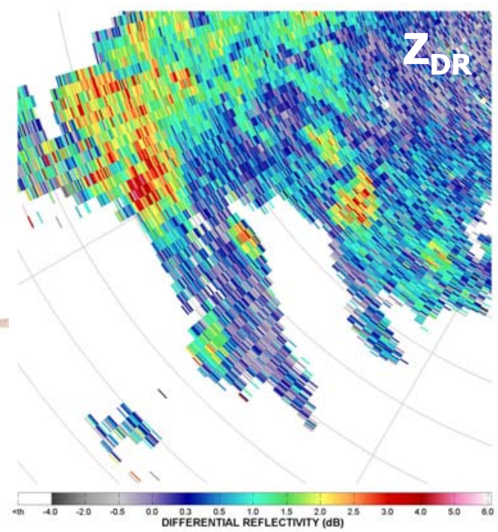
Implementation on the WSR-88D

- Implementation requires
  - producing IQ data with *L*-times faster sampling
    - RVP-900 IF detector has a documented limit of 4200 bins per pulse
    - Vaisala provided mod to support up to 8168 bins per pulse
    - The system would need to support 1884 x *L* bins per pulse
      - for *L* = 5, 9420 bins per pulse
      - for *L* = 4, 7536 bins per pulse
  - increased IQ data throughput by a factor of *L*
  - increased computational complexity by a factor of *L*
- Initial implementation would be aimed at improving quality of all radar variables
  - no VCP changes
  - oversampling factor (*L*) of 4

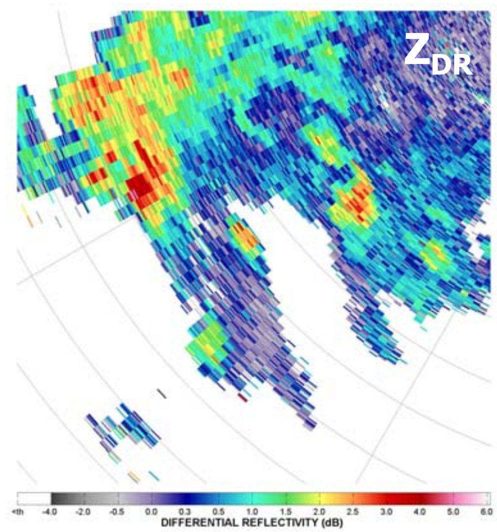
Summary

- **Range oversampling** processing leads to
  - **more precise** radar-variable estimates with **same scan times**, or
  - **reduced scan times** with **same precision** of radar-variable estimates, or
  - a combination of both
- Technique is **mature** and **ready** to transition to the WSR-88D
  - 20+ years in the making
  - 7 years running on the NWRT
  - addressed integration on the WSR-88D

Conventional



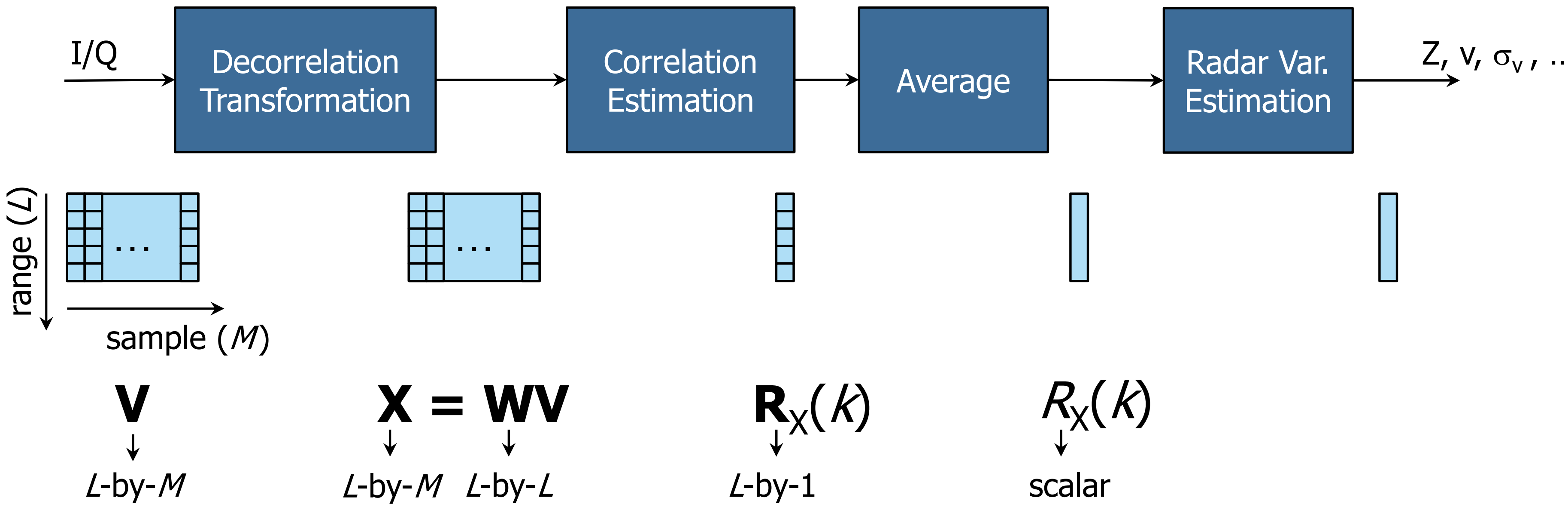
Range Oversampling



Backup Slides

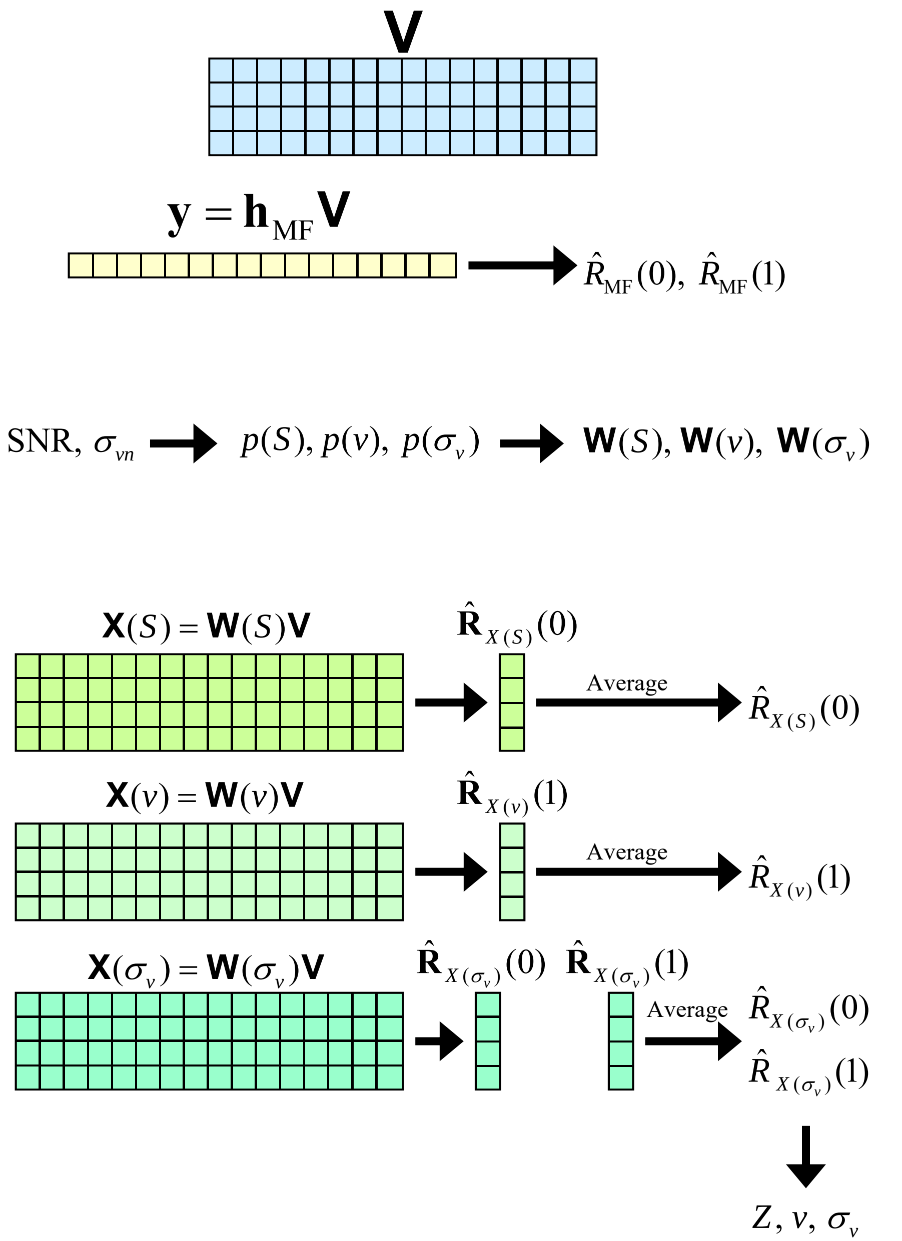
Range Oversampling Processing

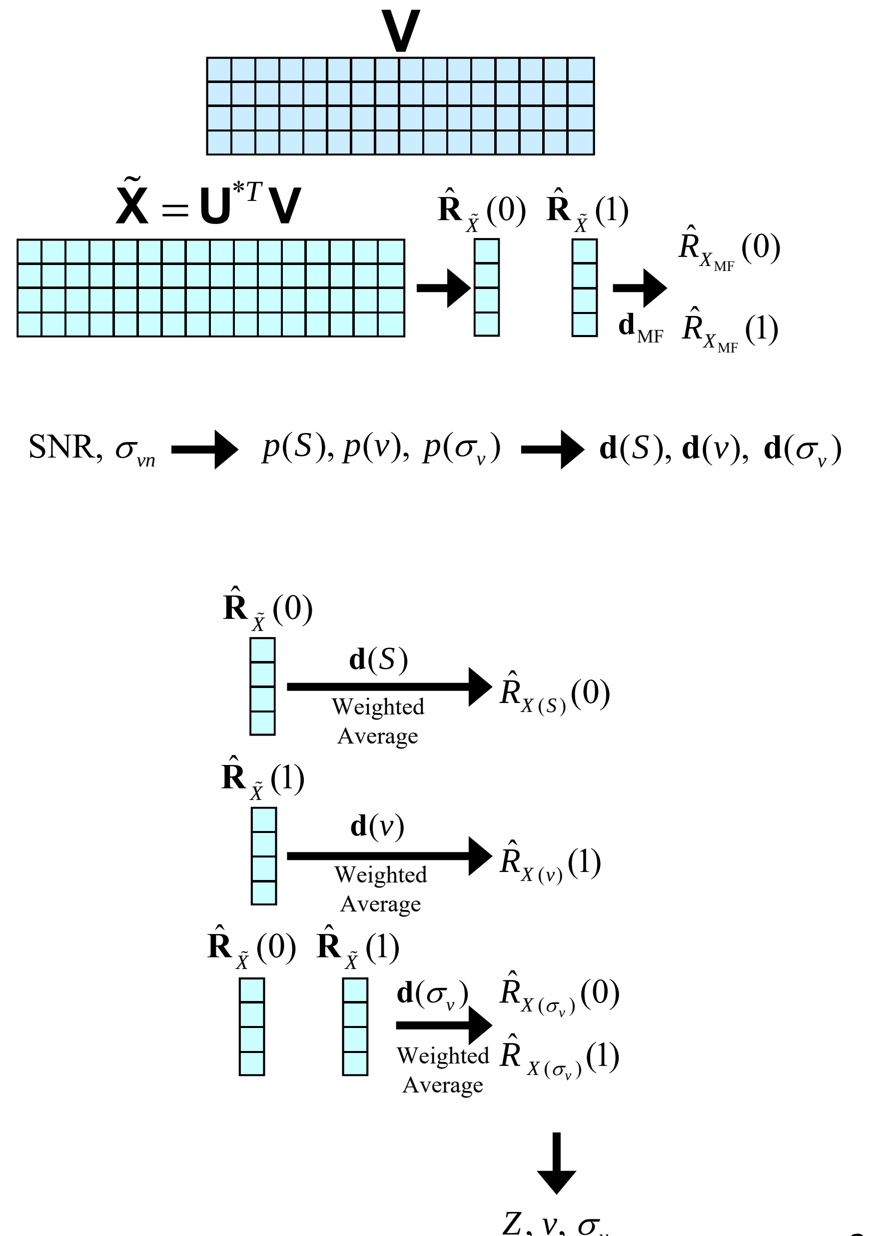
- Basic steps to obtain radar variables for one 250-m range gate



  - If needed, ground clutter filtering occurs after the transformation and before estimating correlations

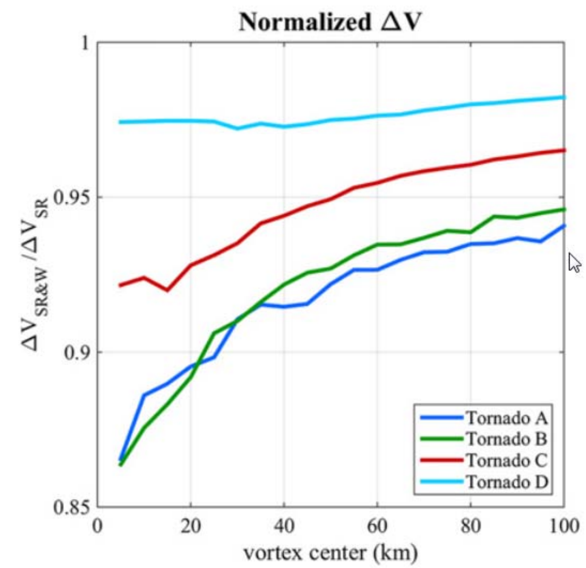
Brute-Force vs. Efficient (single pol)

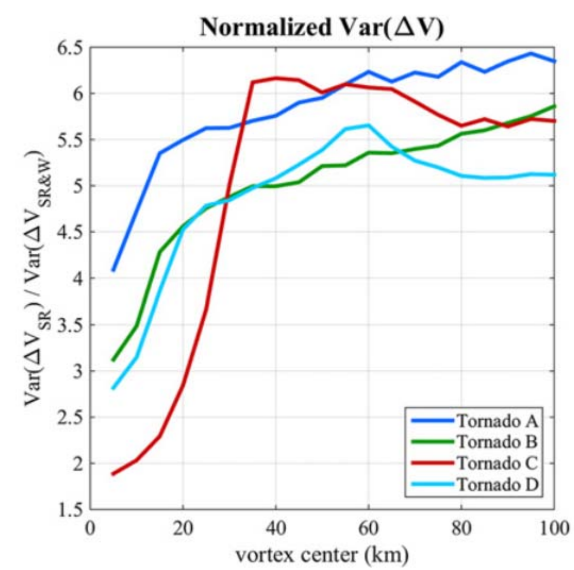




Impacts on TVS

- Super-res enhances the TVS, but results in base data with larger variance
- Range oversampling can be used to reduce the variance of super-res data
  - Range oversampling introduces some degradation in the range resolution
    - This affects the TVS
  - Impact is larger at closer ranges and with smaller tornadoes (50-m core)
    - <50 km: max degradation is 14% (VRF > 1.8)
    - >50 km: max degradation < 8% (VRF > 5)





TVS example: 20 May 2013 (NWRT)