Measuring Snowfall with a Low-Power K-Band Radar (Micro Rain Radar) in Polar Regions

Maximilian Maahn

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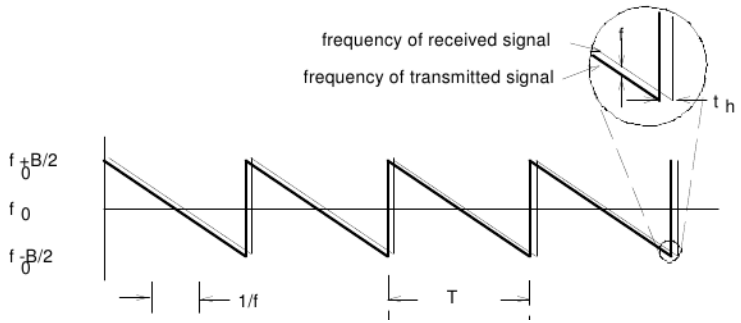
Micro Rain Radar (MRR)

- Vertically pointing
- 24 GHz (12.4 mm)
- 30 range gates
- 30...200 m vertical resolution
- FM-CW
- 50 mW, 25 W, 20 kg

- Developed for *rain*



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Can we use MRRs for snowfall?

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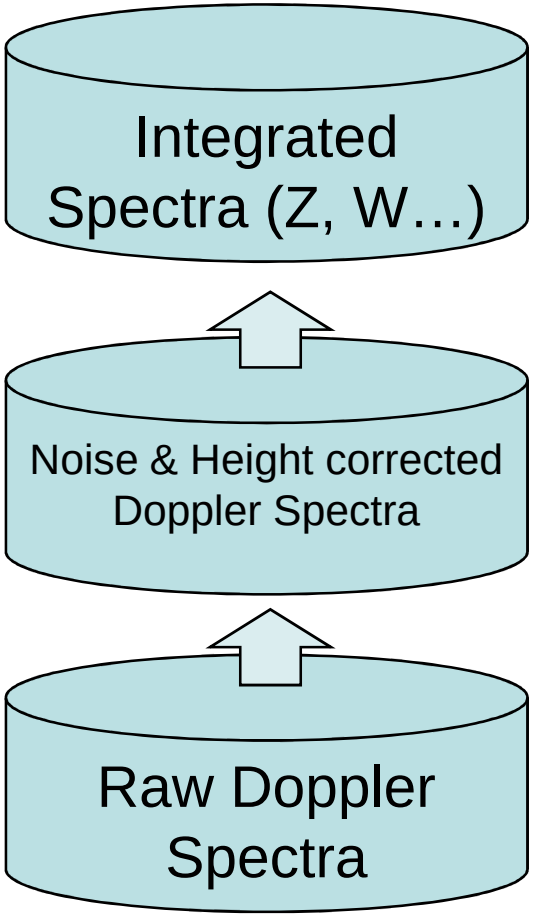
Get Ze from MRR data



Must not be used for snow, because Z is derived from DSD assuming **only rain**

Good performance > 3 dBz
Incomplete noise removal disturbs smaller reflectivities. Correction of aliasing effects needed (Kneifel et al.,2011)

Gives best results for snow with proposed routine
→ Sensitivity ~ -5 dBz

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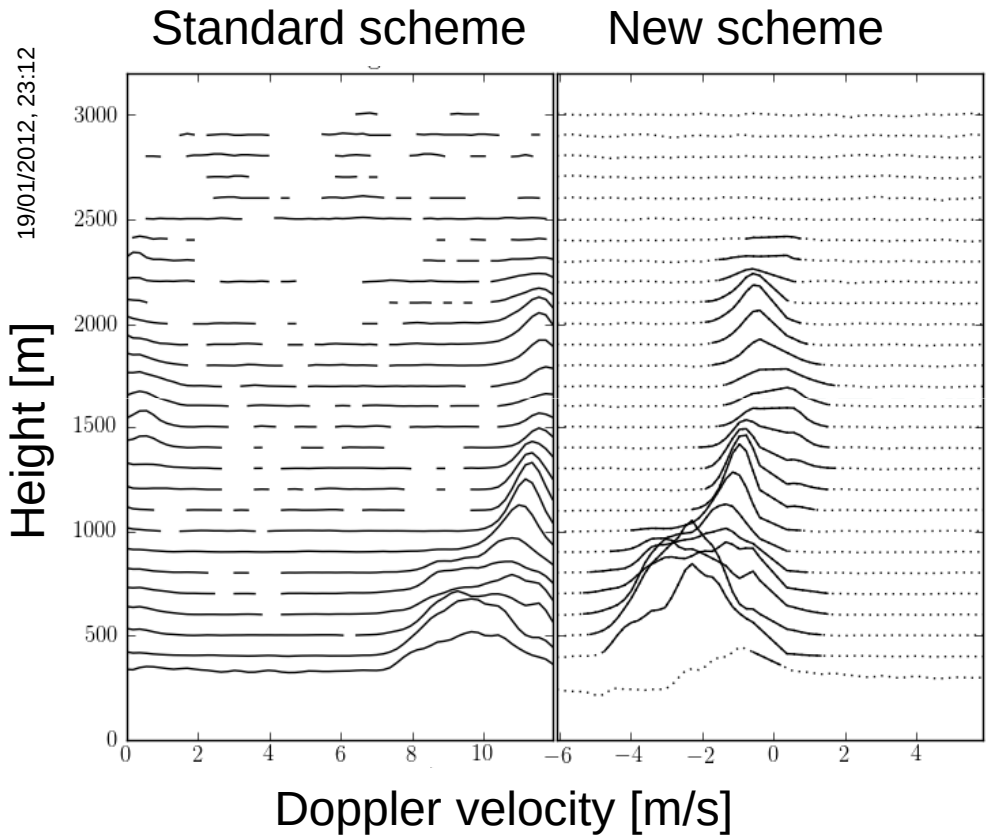
New routine based on Raw Doppler Spectra



1. **Determine the most significant peak including its borders (modified Hildebrand and Sekhon, 1974)**
2. **Define remaining spectrum as noise and remove noise from peak**
3. **Dealiase the spectrum, because Nyquist range is small (using Ze - v relation by Atlas et al., 1973)**
4. **Calculate Z_e, SNR, W**

➢ **Independent on type of hydrometeor!**

New MRR routine is available as open source at
http://gop.meteo.uni-koeln.de/software/

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Comparison with Cloud Radar

- **Reference:** MIRA35 35.2 GHz cloud radar
- Collocated measurements January-April 2012
- at UFS Schneefernerhaus (German Alps, 2650m)
- Δt = 60s

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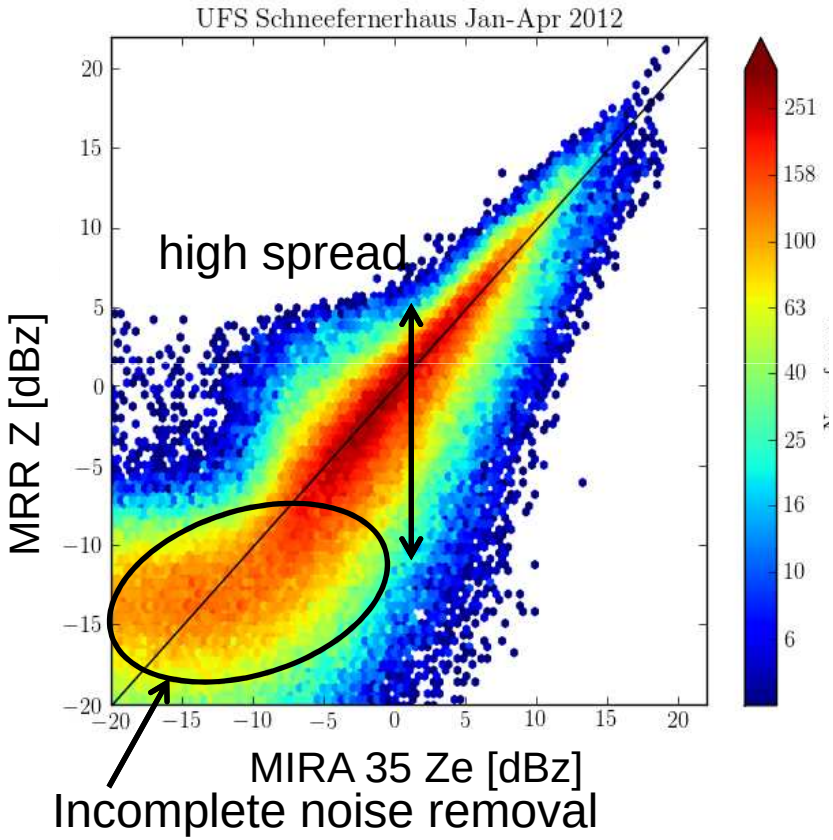
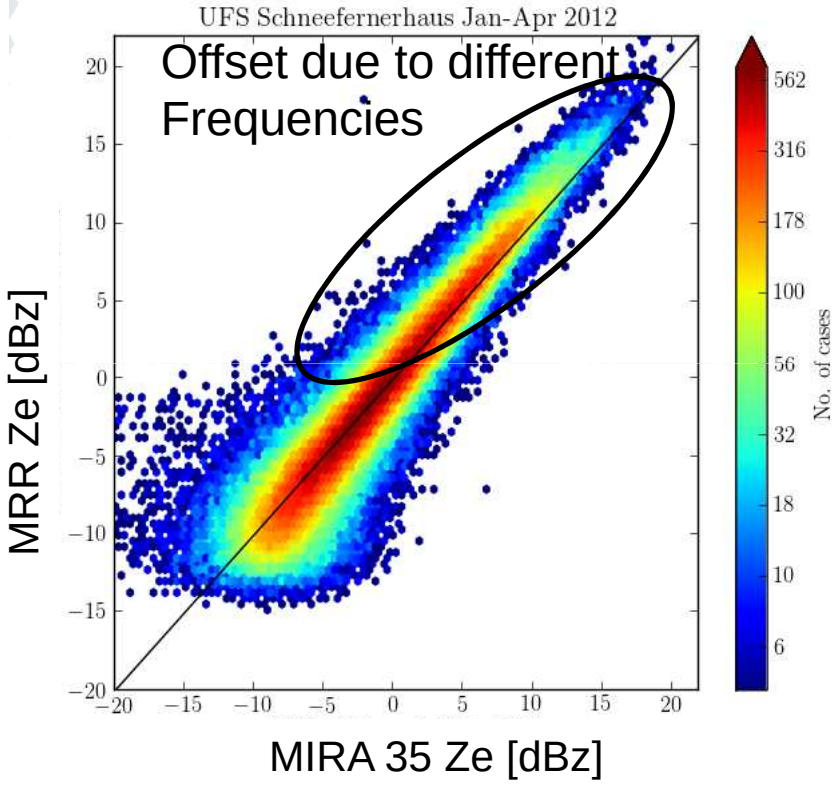
MIRA vs. MRR: Z_e

Standard Product



Proposed Routine



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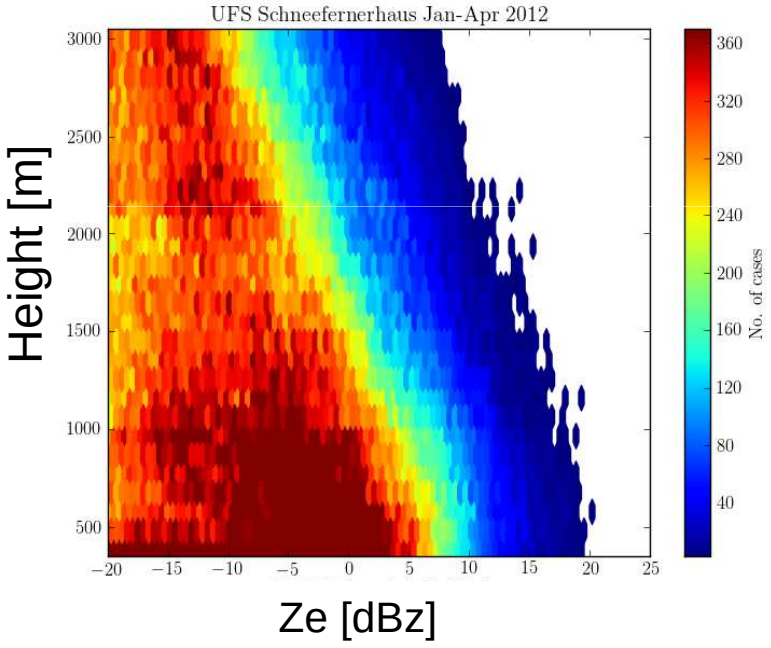
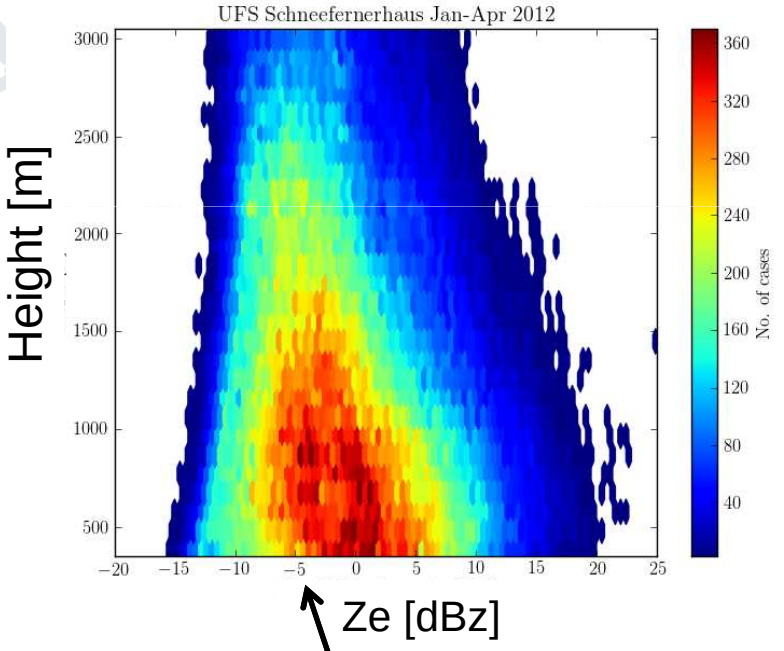
MIRA vs. MRR: Frequency by altitude

MIRA35



MRR (new routine)



-5 dBz ➔ 0.01 - 0.1 mm/h

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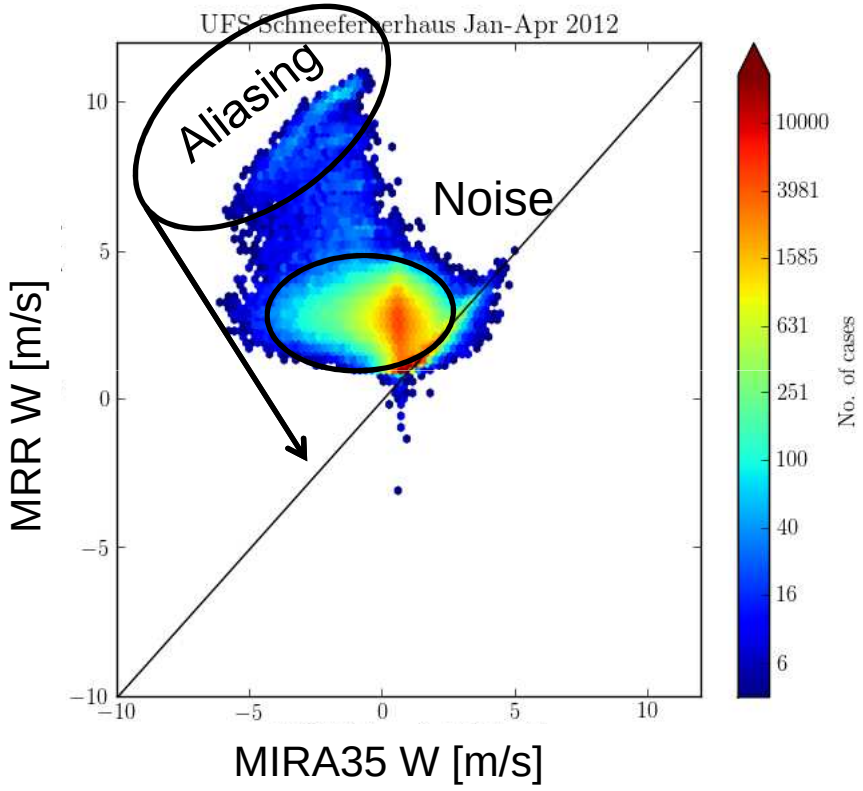
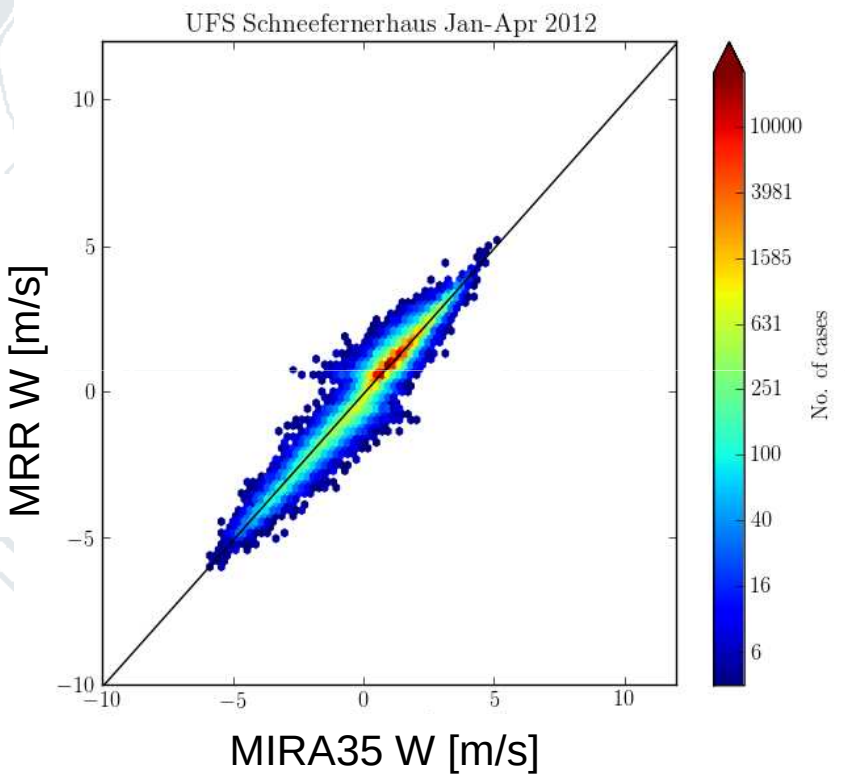
MIRA vs MRR: W

Standard Product



Proposed Routine



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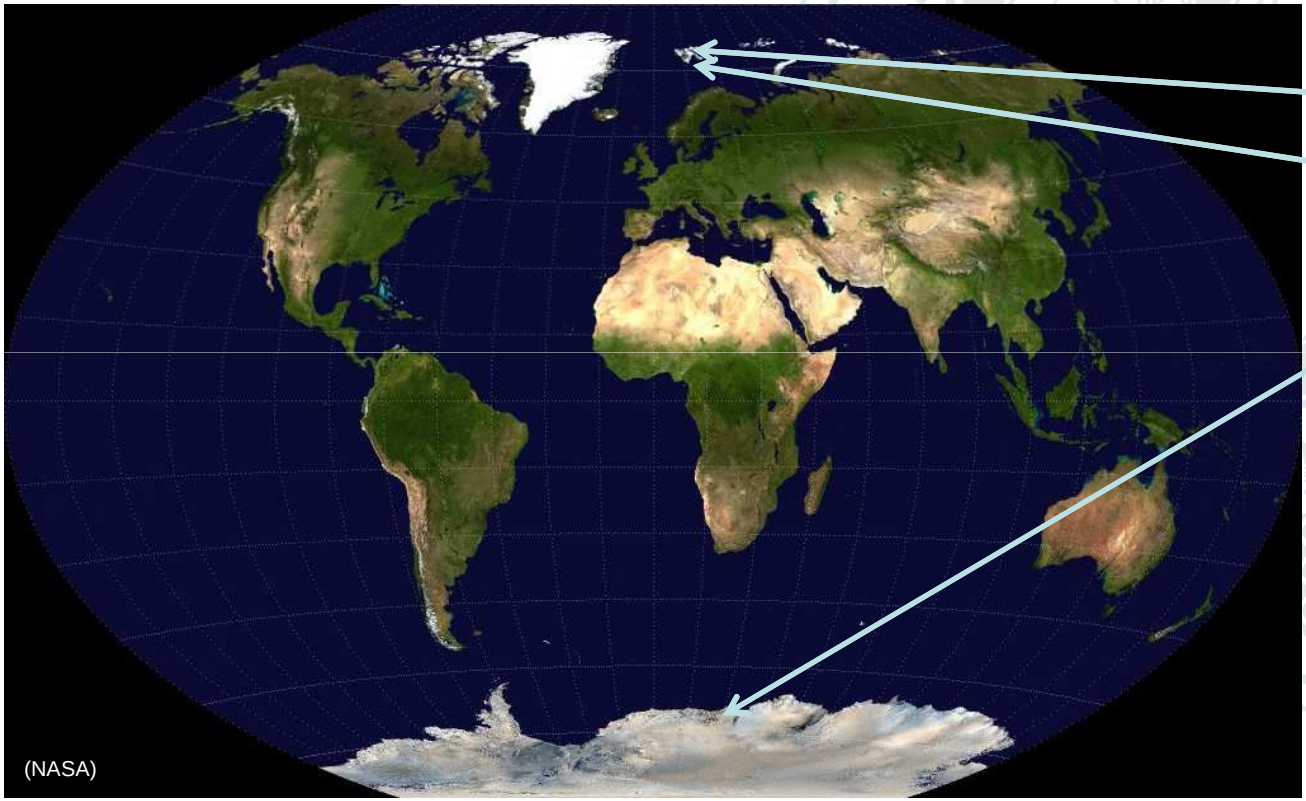
Outlook: Application to MRR measurements



- Ny-Ålesund (79°N): winter 2010/11
- Longyearbyen, (78°N): winter 2010/11
- Princess Elisabeth station (72°S): summer seasons 2010,11 and 12

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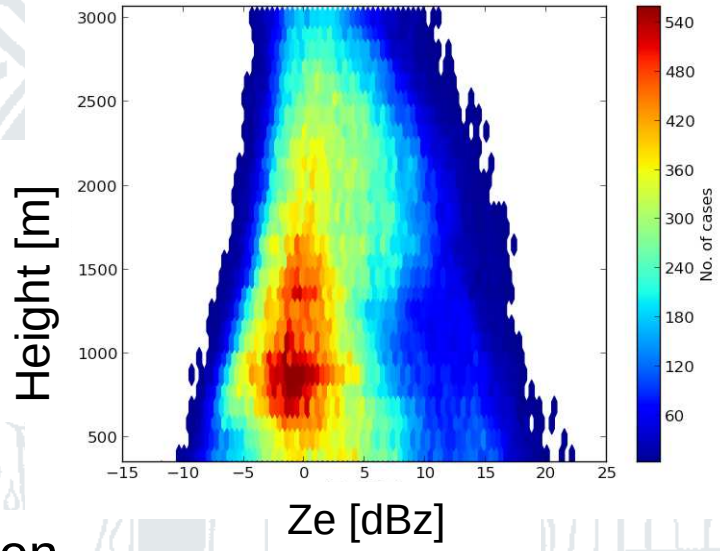
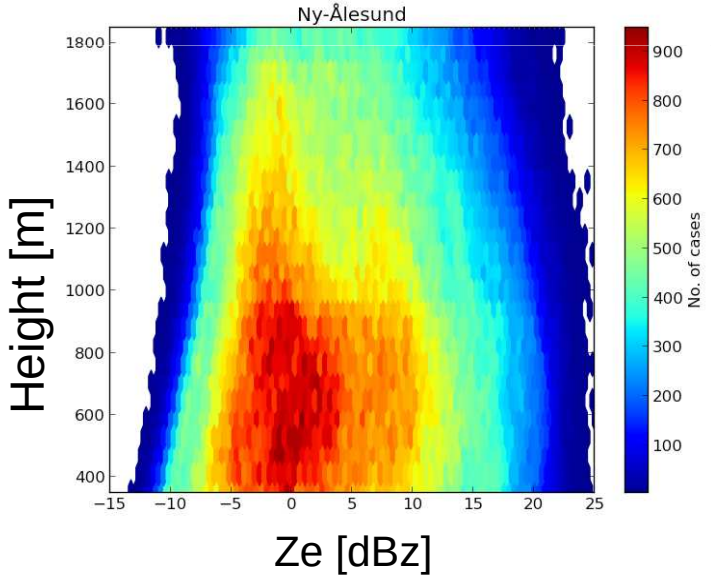
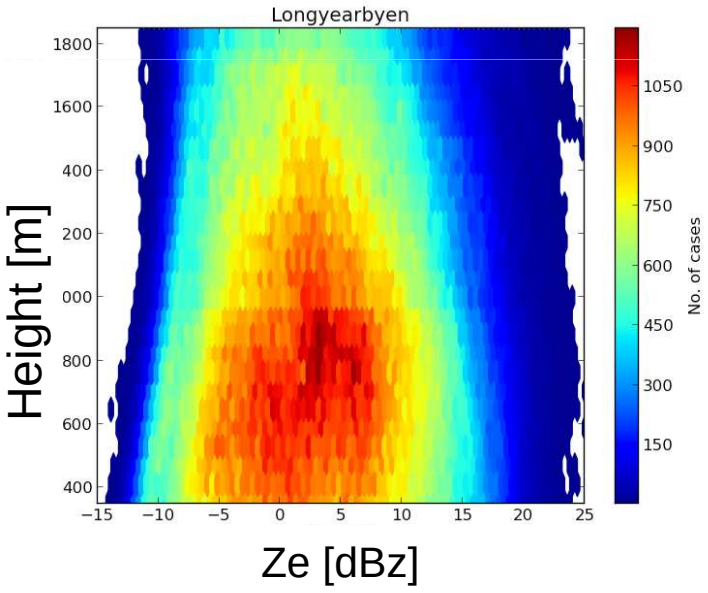
Frequency by altitude diagrams

Antarctica



Spitsbergen





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Conclusion

1) MRR standard products highly biased for snow.
2) But, snow can be observed (> -5 dBz) if the new scheme is used.
3) MRR has potential for snowfall climatologies

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Thank you for your attention

Thanks to ERAD for covering travel expenses!

Maahn and Kollias (2012): Improved Micro Rain Radar Snow Measurements Using Doppler Spectra Post-Processing, *submitted to AMT*

New MRR routine is available at http://gop.meteo.uni-koeln.de/software/

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Back-up slides

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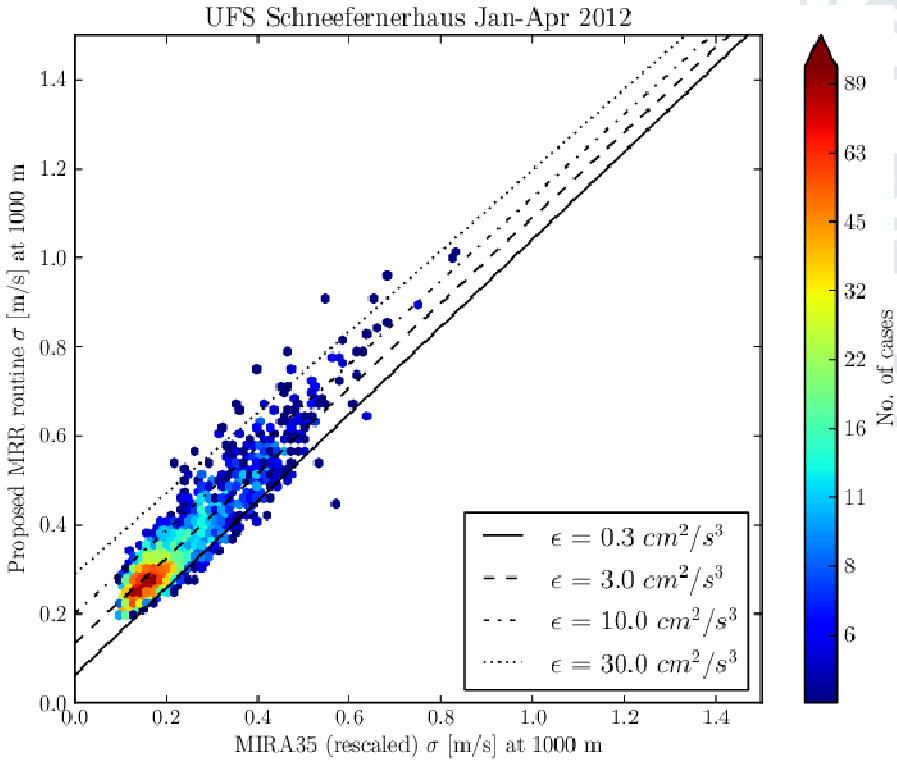
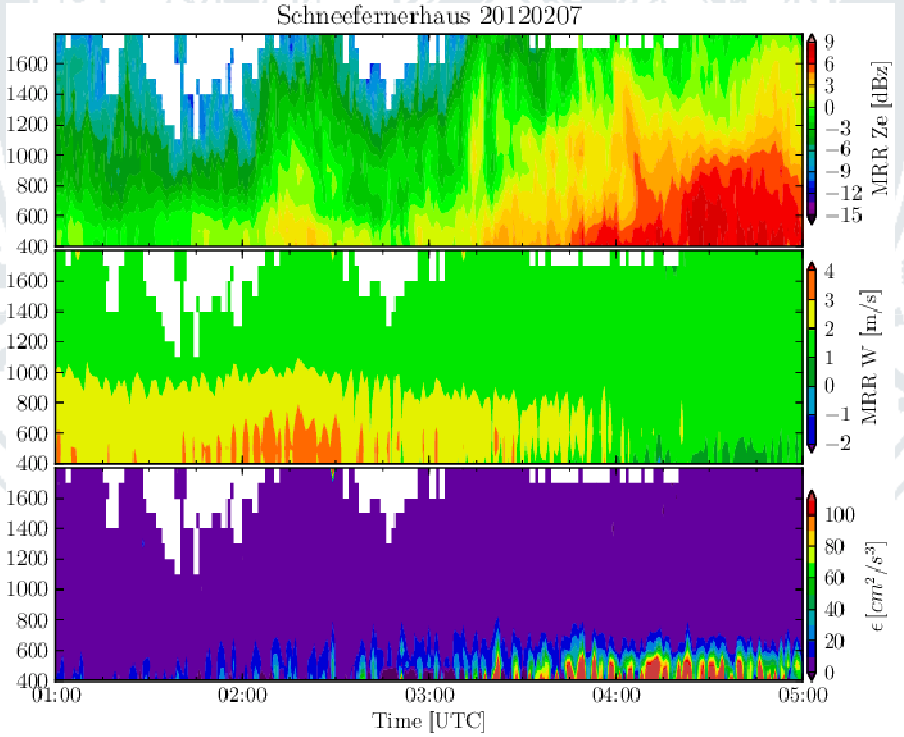
Comparison of sigma





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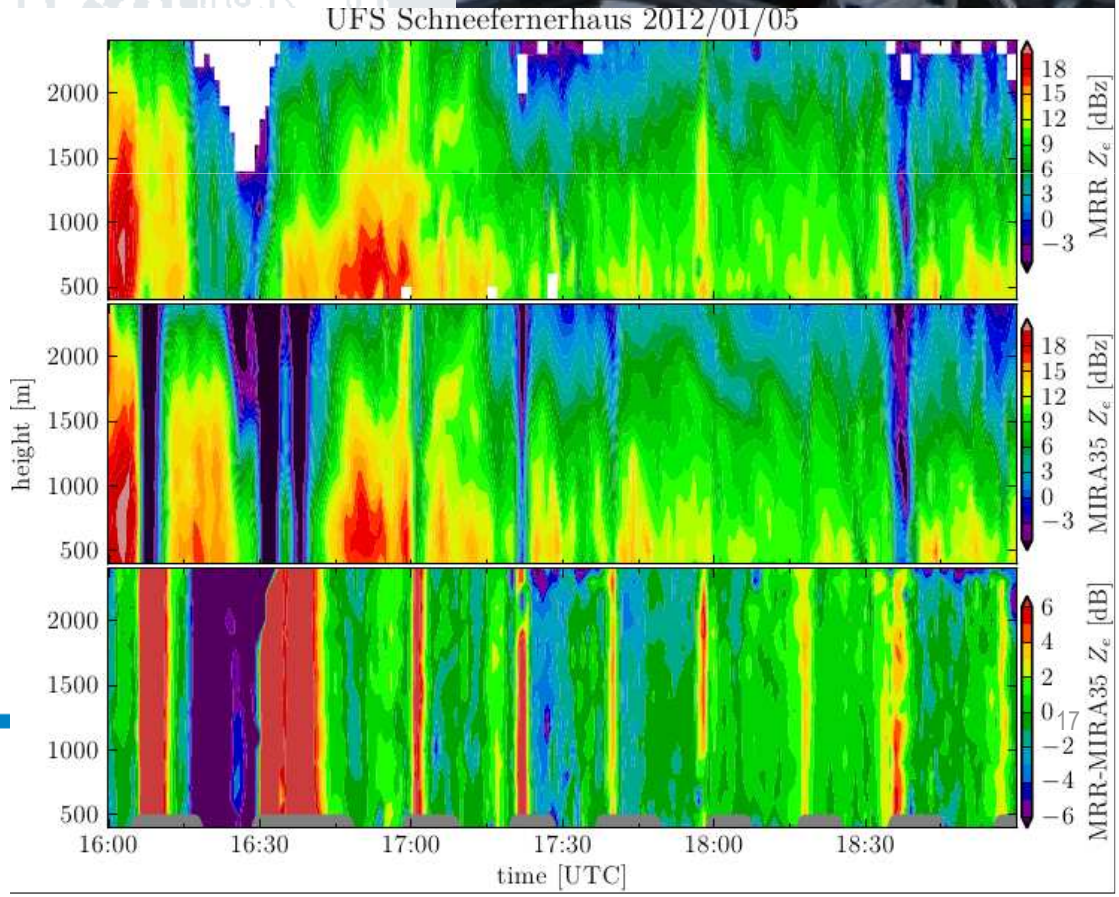
Comparison with Cloud Radar

- **Reference: MIRA35 35.2 GHz cloud radar**
- **January-April 2012 at UFS Schneefernerhaus (German Alps)**
- **>15% of data had to be discarded because of attenuation due to wet snow on dish**



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Metek's (indirect) approach for Z

Recorded Doppler Power Spectrum

Convert to DSD using Mie Theory

$Z \sim D^6$, $R \sim D^3$

$$P(v) \rightarrow P(D) \rightarrow N(D) \rightarrow Z, R$$

Assume Doppler velocity = fall velocity and convert to drop size using Atlas et al. (1973)

- **Works good for rain! Easy to compare with Z from C-band radar, Parsivel etc.**

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Why does it not work for snow?

Size – fall velocity different for snow and has *much* higher uncertainty

$Z \sim D^6$, $R \sim D^3$ not feasible for snow

$$P(v) \rightarrow P(D) \rightarrow N(D) \rightarrow Z, R$$

Backscattering cross section different for snow and depends heavily on particle type

- **Z, R are biased for snow!**
- **Instead: calculate Z_e from Doppler spectrum P(v)**

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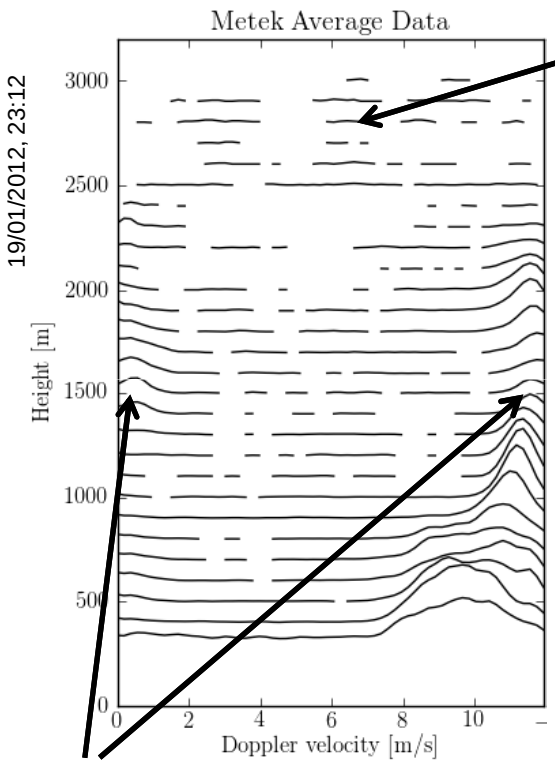
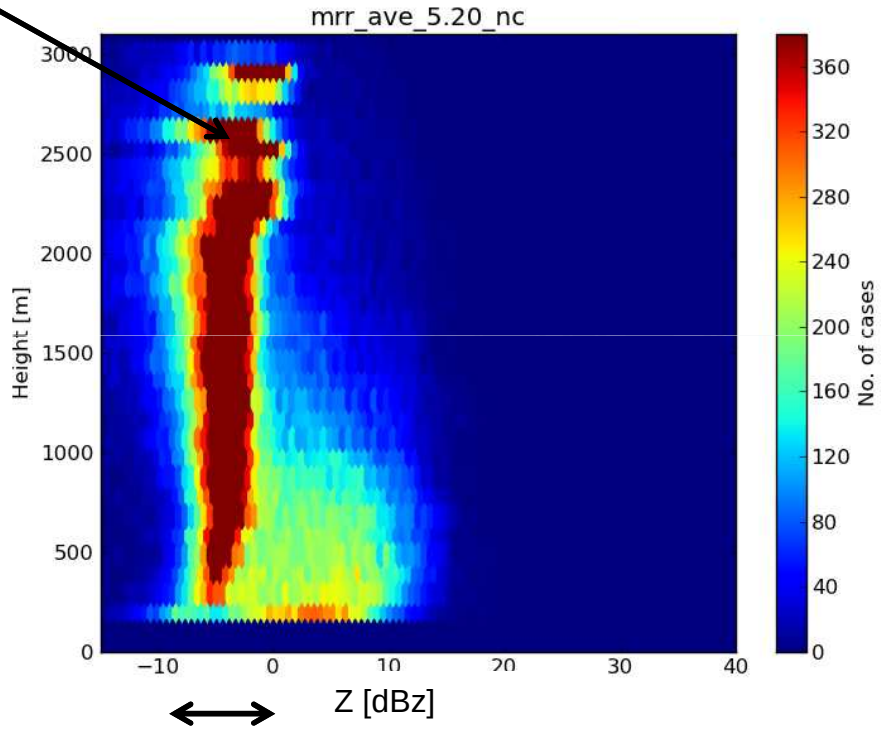
Doppler Spectrum cannot be used

Noise is not properly removed from the spectra





Aliasing due to limited unambiguous Doppler range

Sensitivity is lost due to contamination with noise

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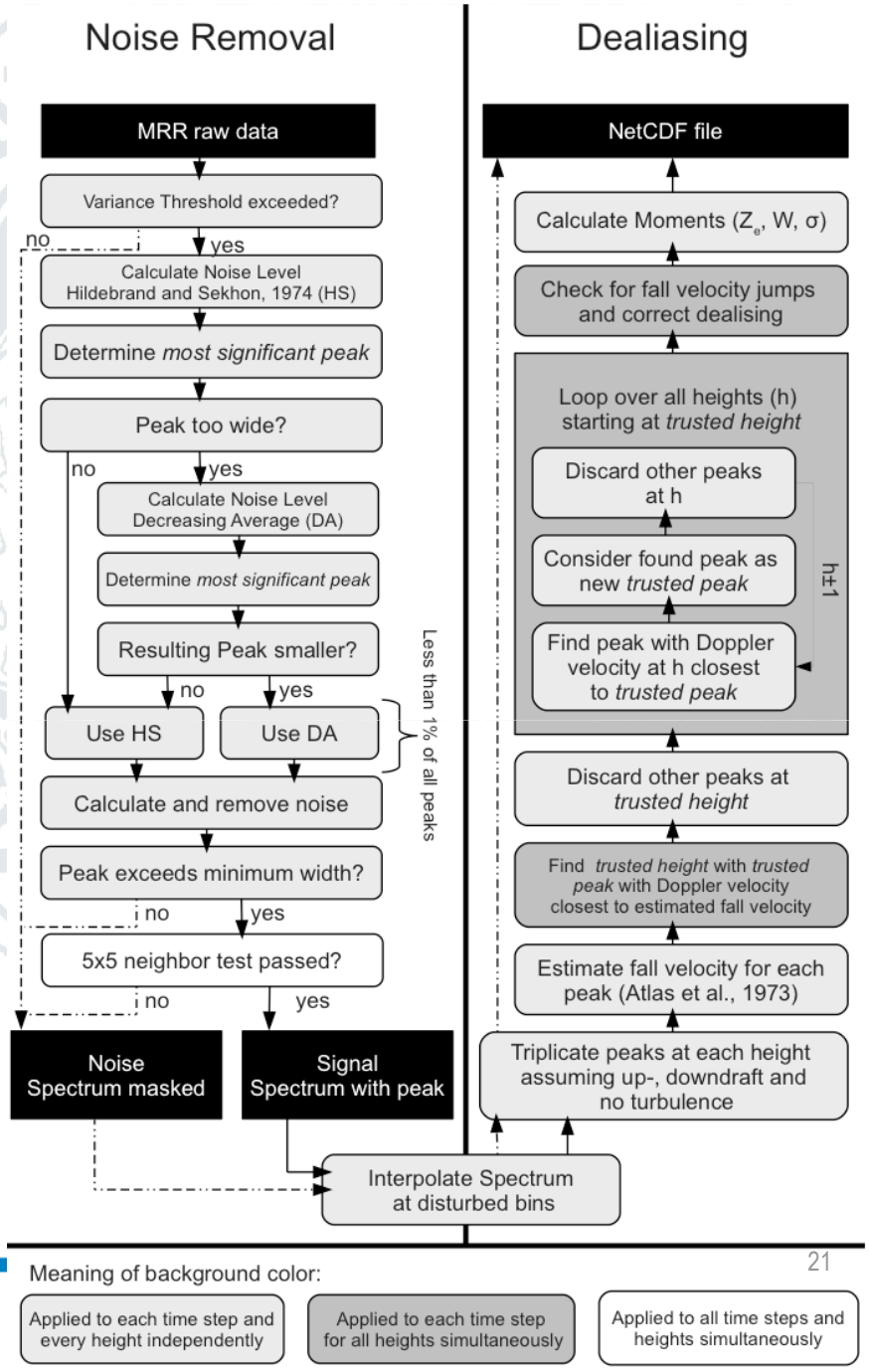
Flow chart diagram



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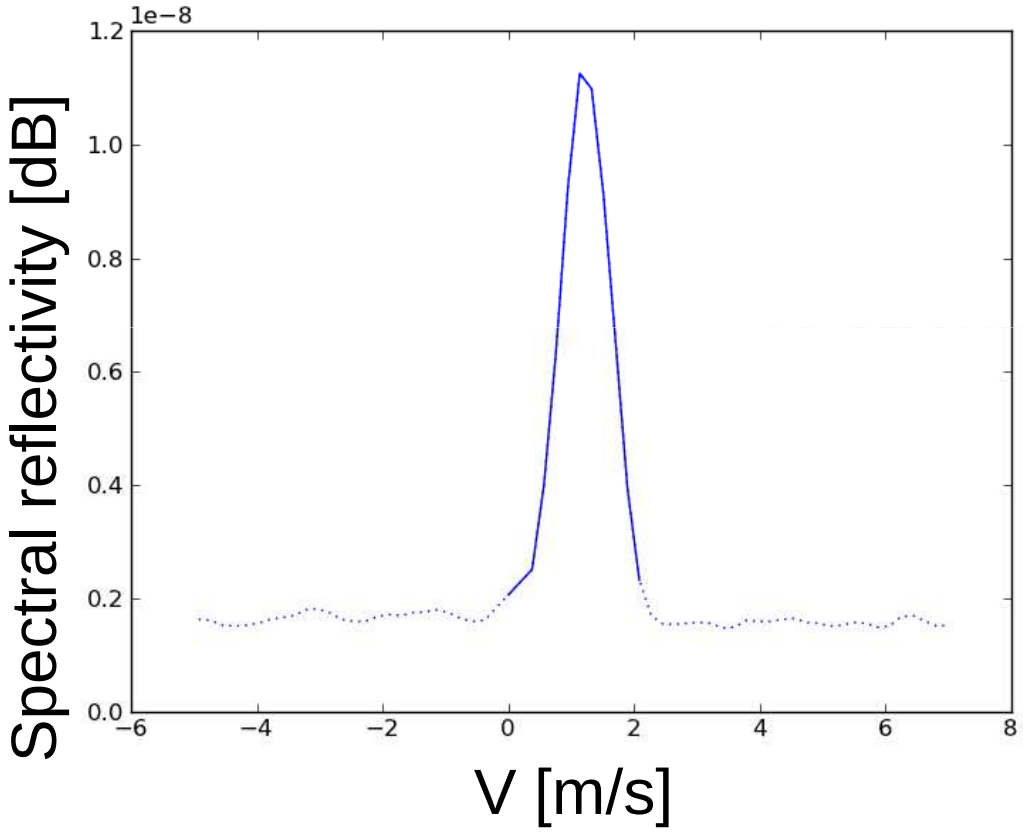
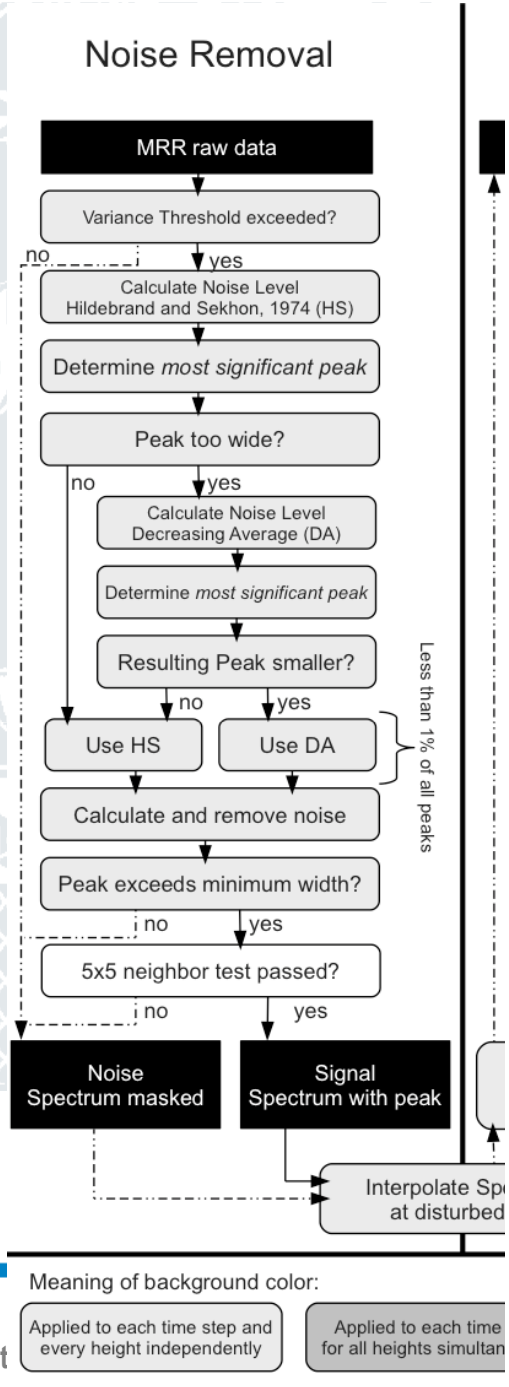
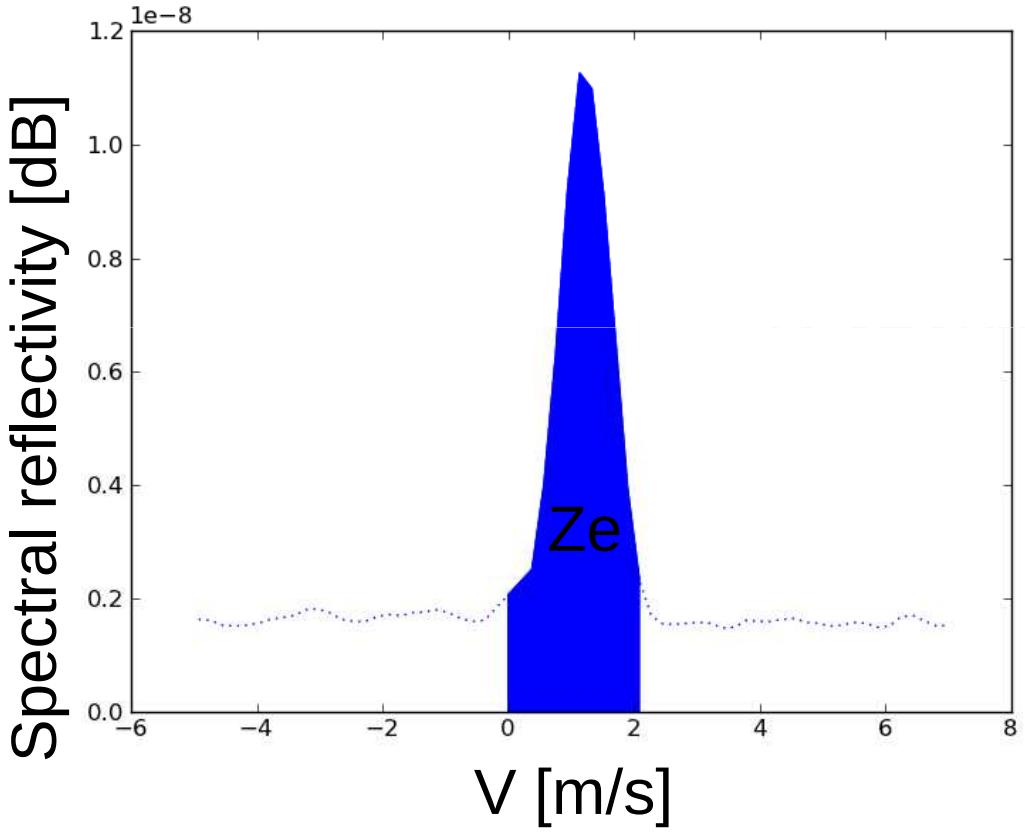
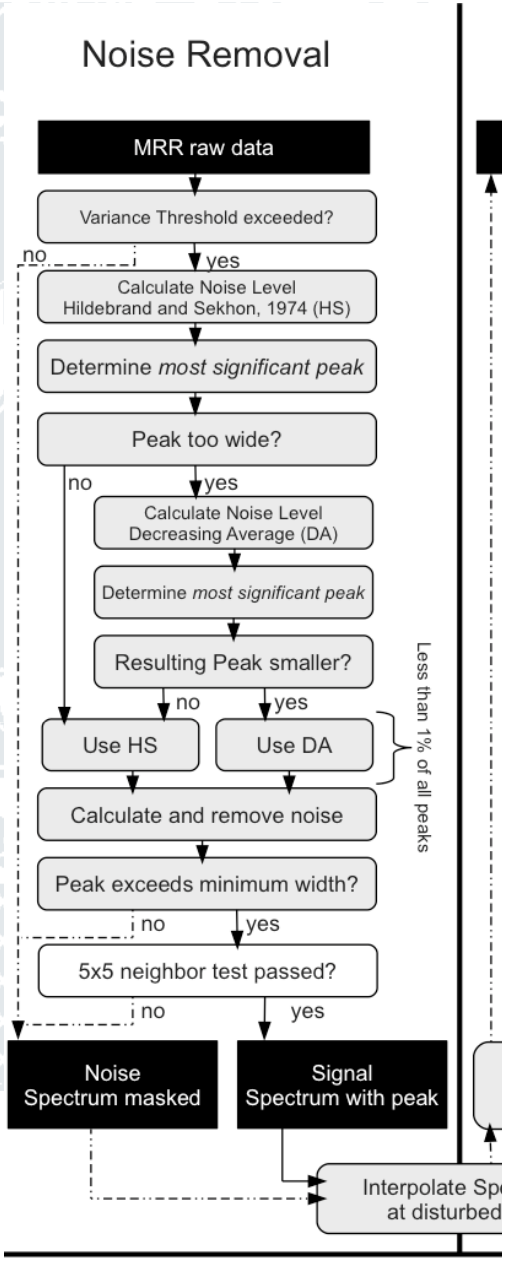
Get Ze


1e−8
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−6
−4
−2
0
2
4
6
8
Spectral reflectivity [dB]
V [m/s]


Noise Removal
MRR raw data
Variance Threshold exceeded?
no
yes
Calculate Noise Level
Hildebrand and Sekhon, 1974 (HS)
Determine most significant peak
Peak too wide?
no
yes
Calculate Noise Level
Decreasing Average (DA)
Determine most significant peak
Resulting Peak smaller?
no
yes
Use HS
Use DA
Less than 1% of all peaks
Calculate and remove noise
Peak exceeds minimum width?
no
yes
5x5 neighbor test passed?
no
yes
Noise
Spectrum masked
Signal
Spectrum with peak
Interpolate Sp
at disturbed
Meaning of background color:
Applied to each time step and
every height independently
Applied to each time
for all heights simultan

Get Ze


1e−8
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Spectral reflectivity [dB]
Ze
−6
−4
−2
0
2
4
6
8
V [m/s]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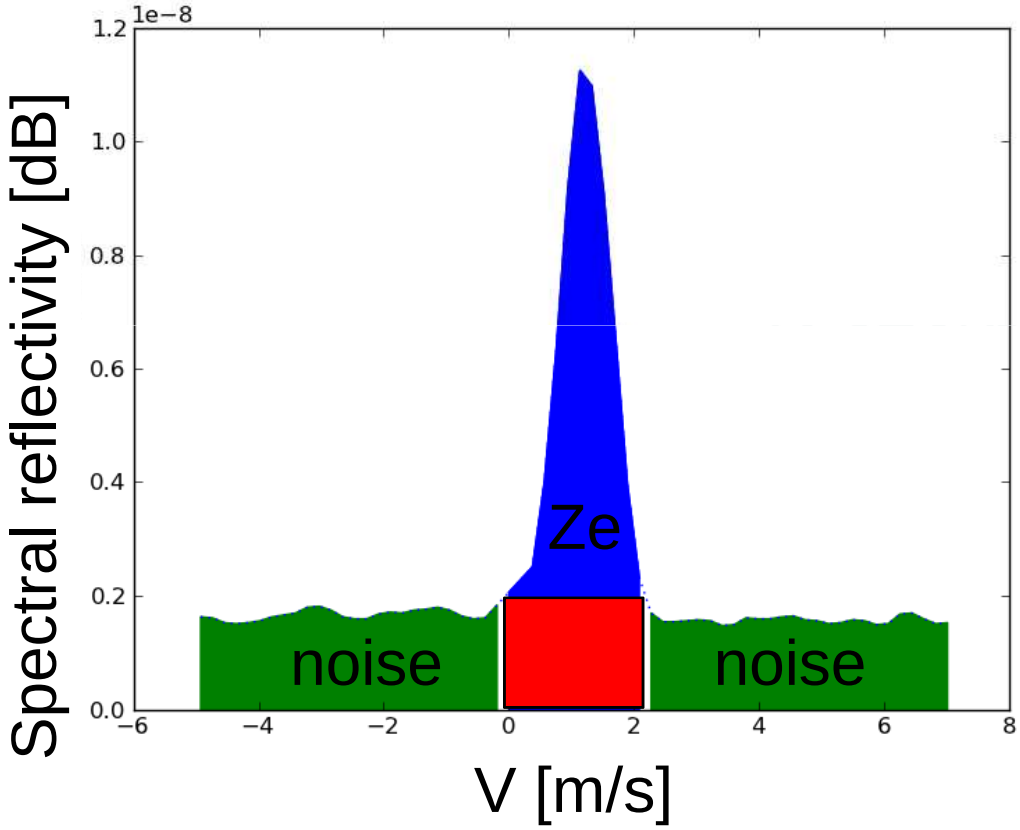
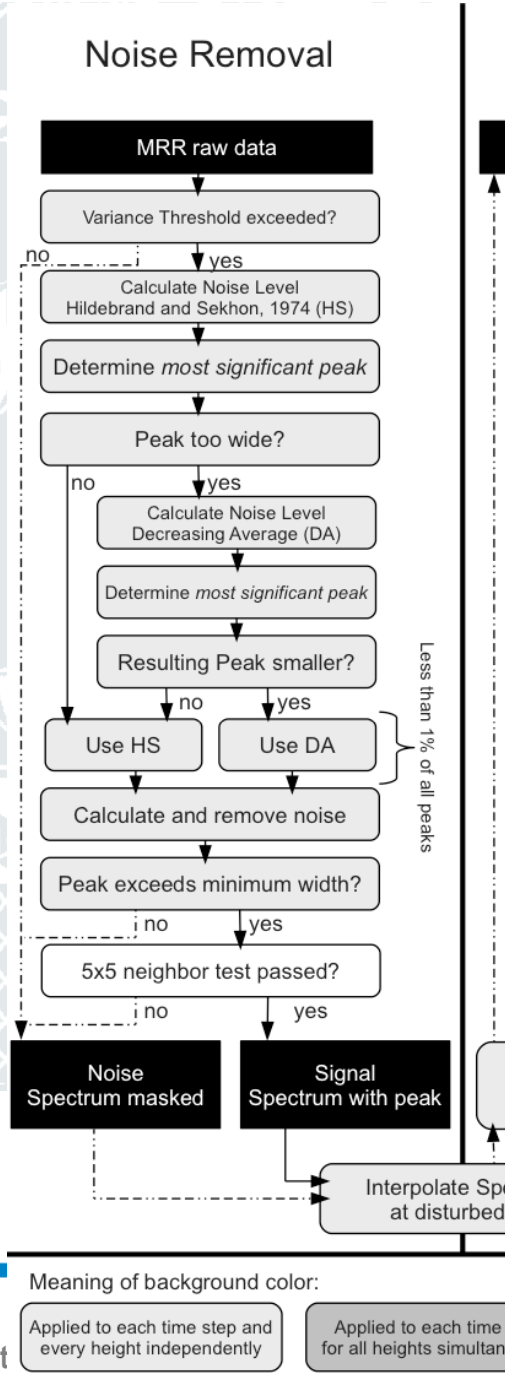
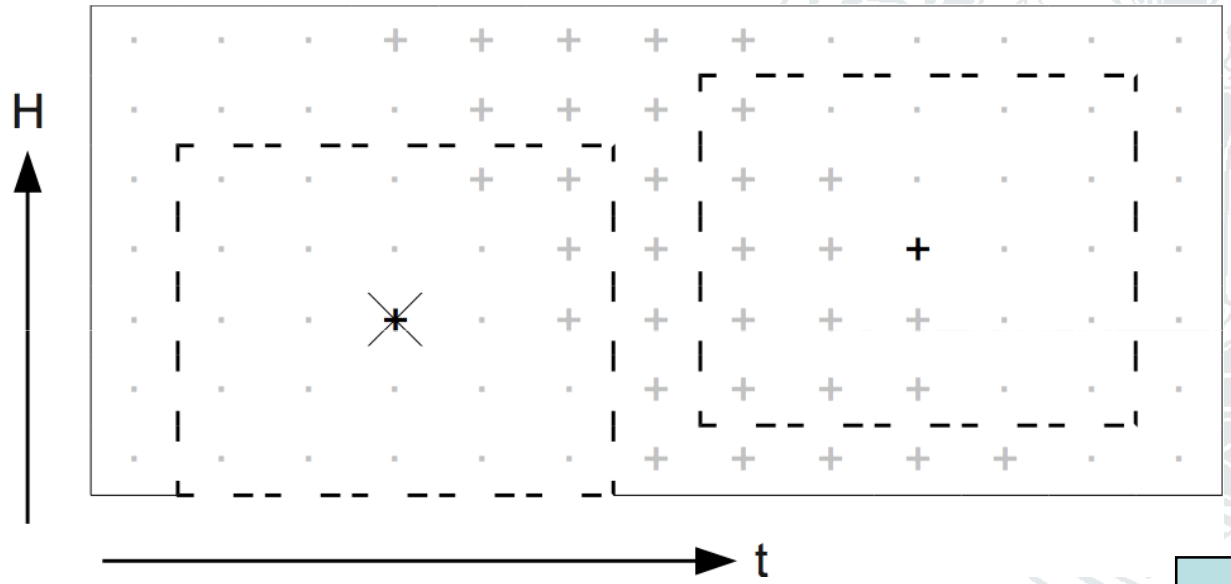
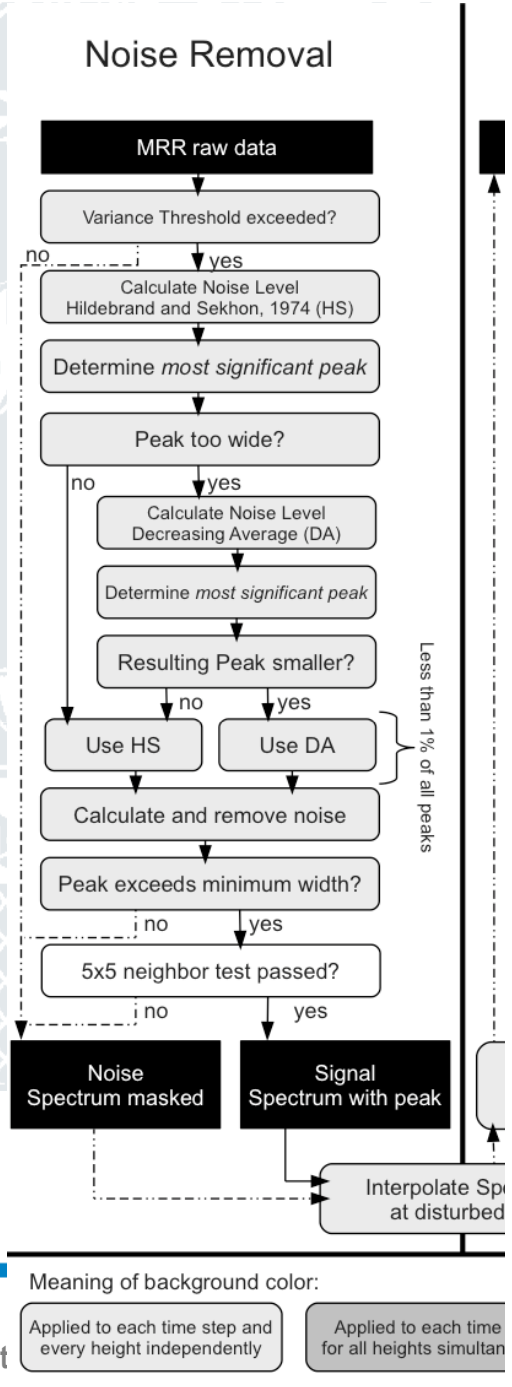
Get Ze


1e−8
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Spectral reflectivity [dB]
Ze
noise
noise
−6
−4
−2
0
2
4
6
8
V [m/s]

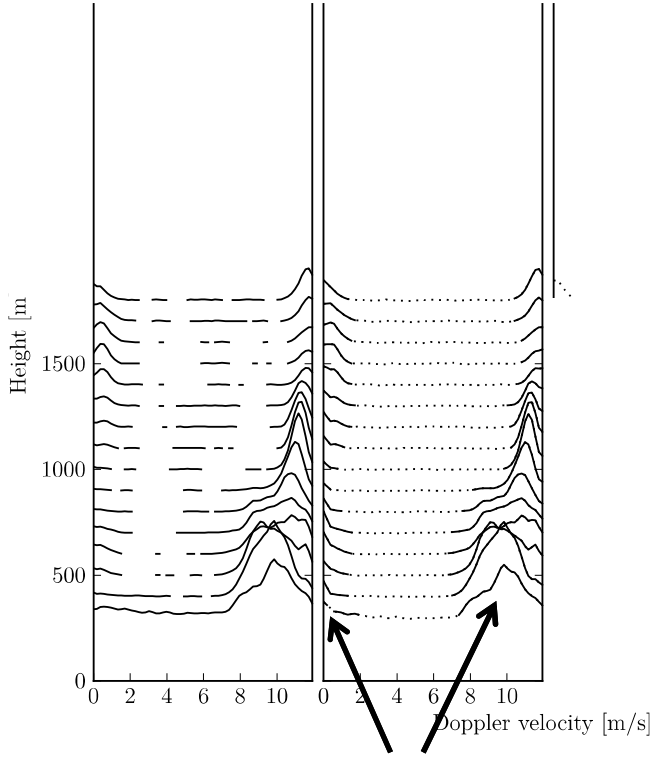

Noise Removal
MRR raw data
Variance Threshold exceeded?
no
yes
Calculate Noise Level
Hildebrand and Sekhon, 1974 (HS)
Determine most significant peak
Peak too wide?
no
yes
Calculate Noise Level
Decreasing Average (DA)
Determine most significant peak
Resulting Peak smaller?
no
yes
Use HS
Use DA
Less than 1% of all peaks
Calculate and remove noise
Peak exceeds minimum width?
no
yes
5x5 neighbor test passed?
no
yes
Noise
Spectrum masked
Signal
Spectrum with peak
Interpolate Sp
at disturbed
Meaning of background color:
Applied to each time step and
every height independently
Applied to each time
for all heights simultan

Remove clutter

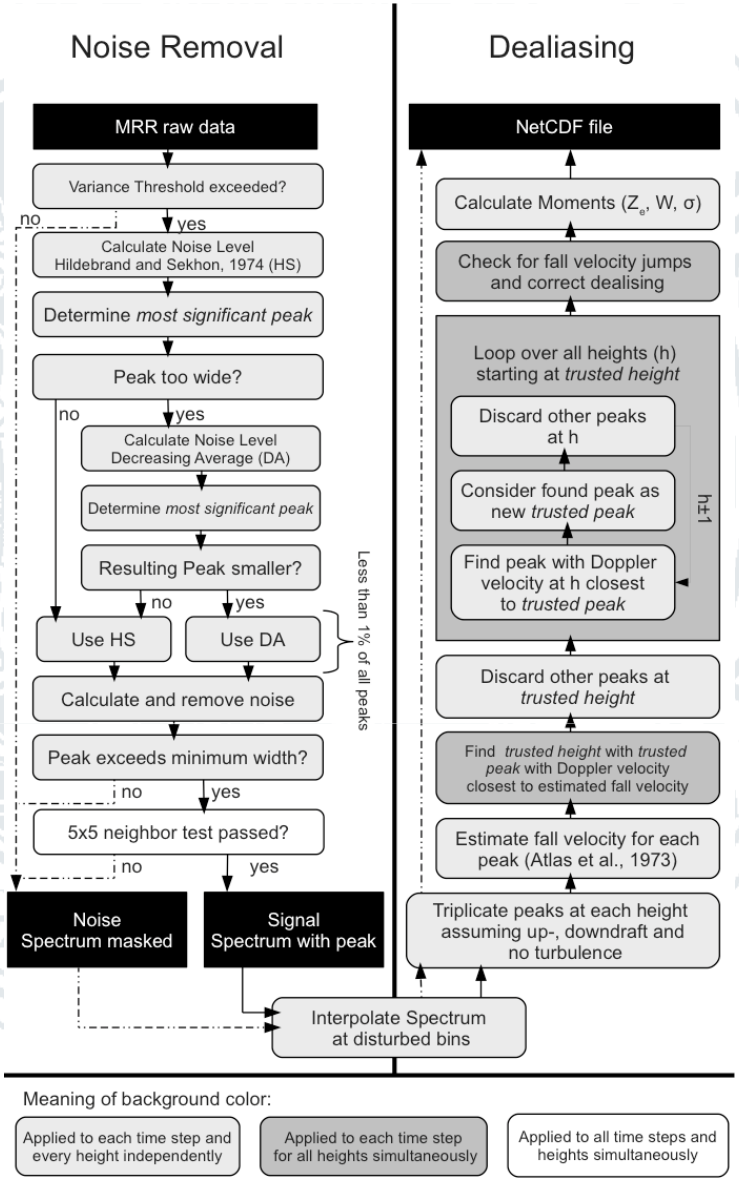




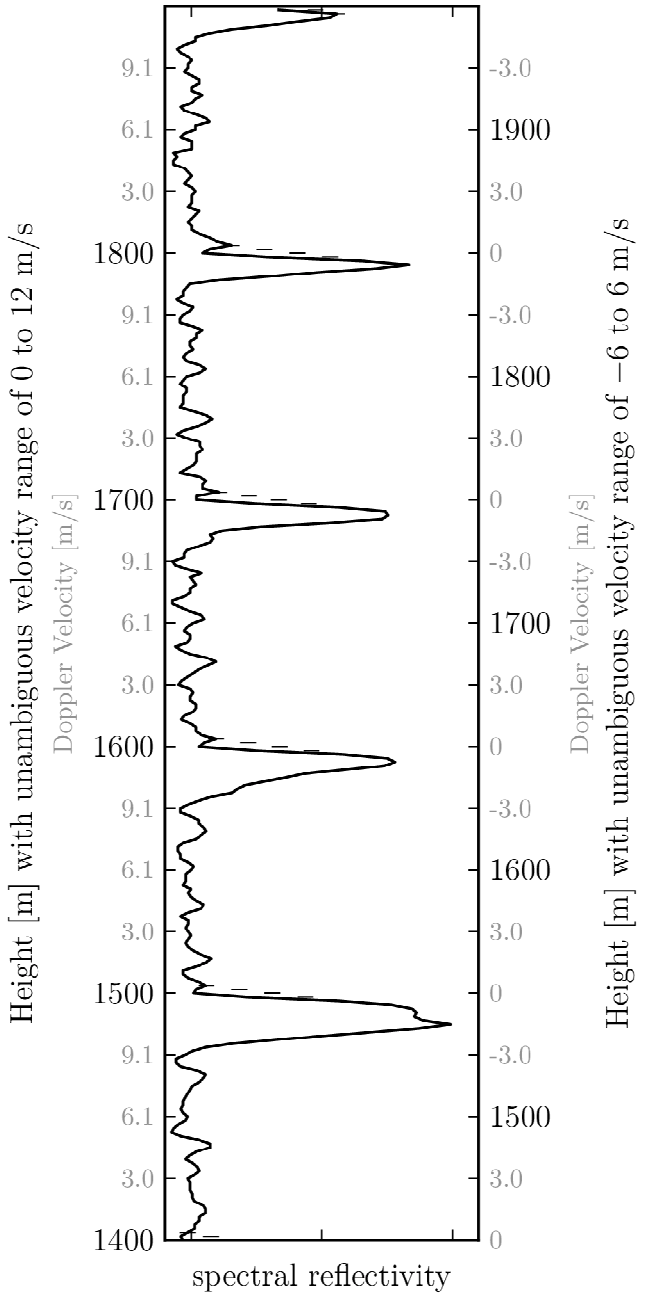
Resulting Spectra



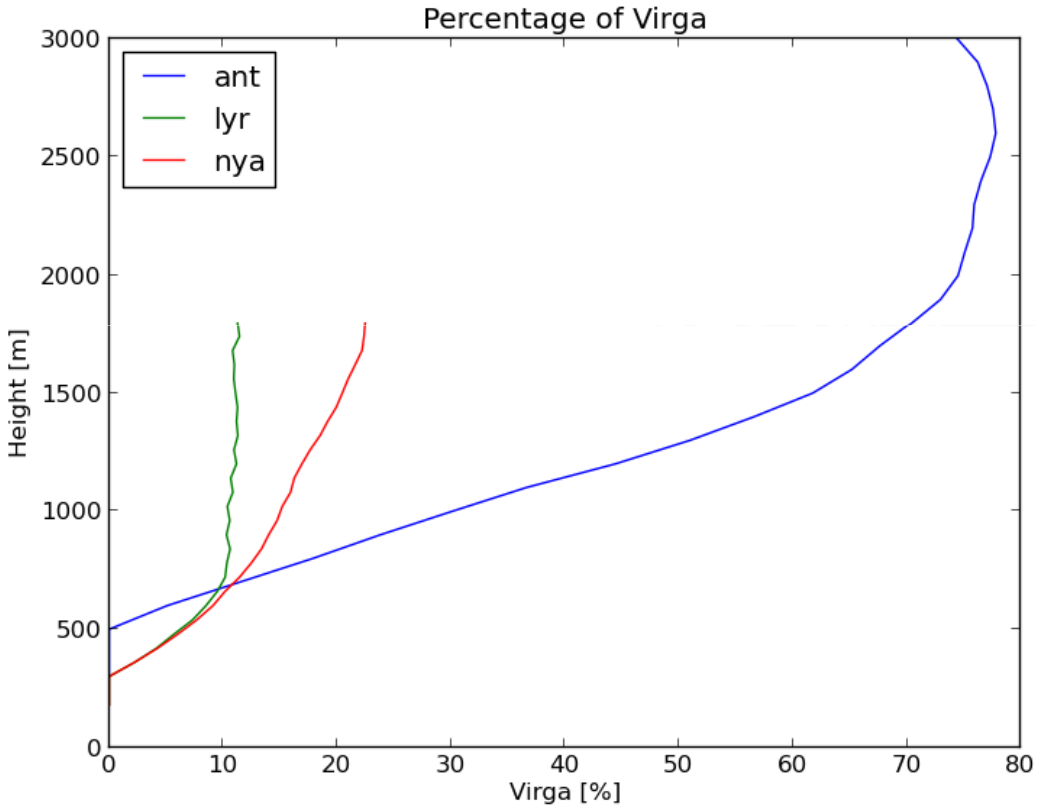
Aliasing



Aliasing


Height [m] with unambiguous velocity range of 0 to 12 m/s
Doppler Velocity [m/s]
Height [m] with unambiguous velocity range of −6 to 6 m/s
Doppler Velocity [m/s]
spectral reflectivity
9.1
6.1
3.0
0
-3.0
1400
1500
1600
1700
1800
1900

Virga



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