NSF NCAR | EARTH OBSERVING LABORATORY

Processing of Doppler spectra collected by an airborne cloud radar

Ulrike Romatschke, Paul Romatschke, Matthew Hayman, Michael Dixon

PrePEP, March 2025

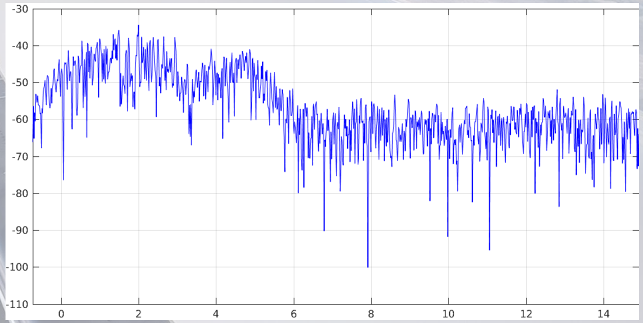
HIAPER Cloud Radar (HCR)

- Deployed on NSF/NCAR HIAPER aircraft in an under-wing pod
- W-band (3 mm, 94 GHz)
- Beam stabilization when staring at zenith or nadir

Ulrike Romatschke romatsch@ucar.edu

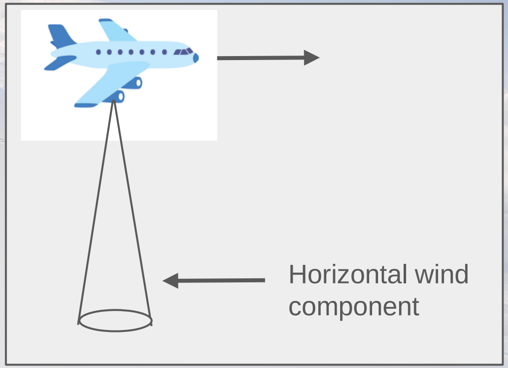
Doppler spectra

- Doppler spectra from vertical pointing radars can provide additional information to moments processed with the pulse-pair technique.
- Doppler spectra provide the opportunity to calculate higher-order moments, such as skewness, kurtosis, and other spectral parameters.
- Higher-order moments are under-utilized.
  - Difficult to obtain high-quality estimates.
  - Large data volume.

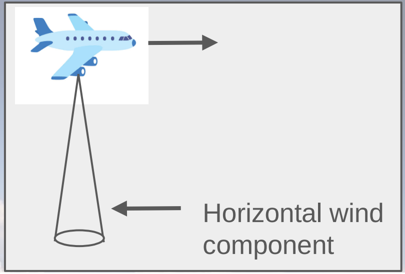


Objectives

- Develop processing technique that produces high-quality Doppler spectra
  - Correct spectra for broadening caused by aircraft motion due to non-zero beam width
- Calculate higher order moments
  - Improved spectrum width
  - Skewness, kurtosis
- Calculate other spectral parameters
- Distribute to data users



Correct for broadening caused by aircraft motion



Theoretical beam broadening spectrum (BBS)

Beam broadening effect on Doppler spectral width of wind profiler

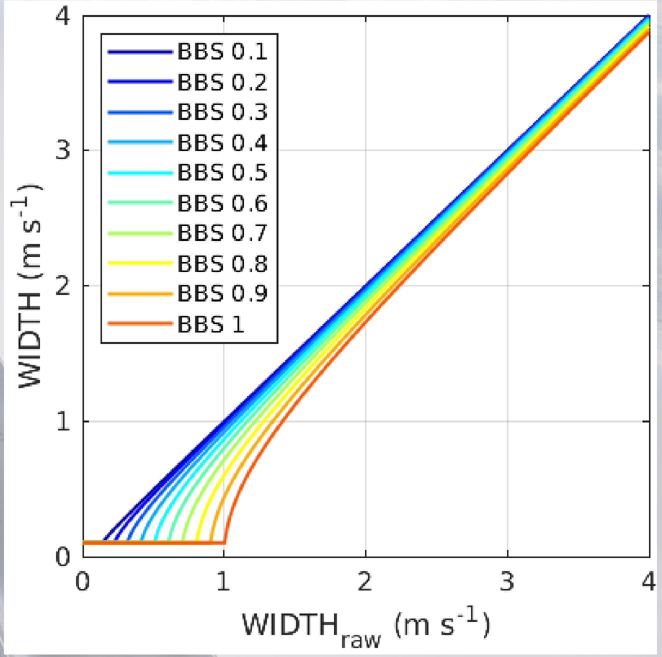
Meng-Yuan Chen[1] and Yen-Hsyang Chu[1,2]

Received 9 March 2011; revised 18 May 2011; accepted 30 June 2011; published 30 September 2011.

$$BBS = 0.3 vel_{aircraft} \sin(el)\ beamWidth$$

Legacy method

$$WIDTH = \sqrt{WIDTH_{raw}^2 - BBS^2}$$

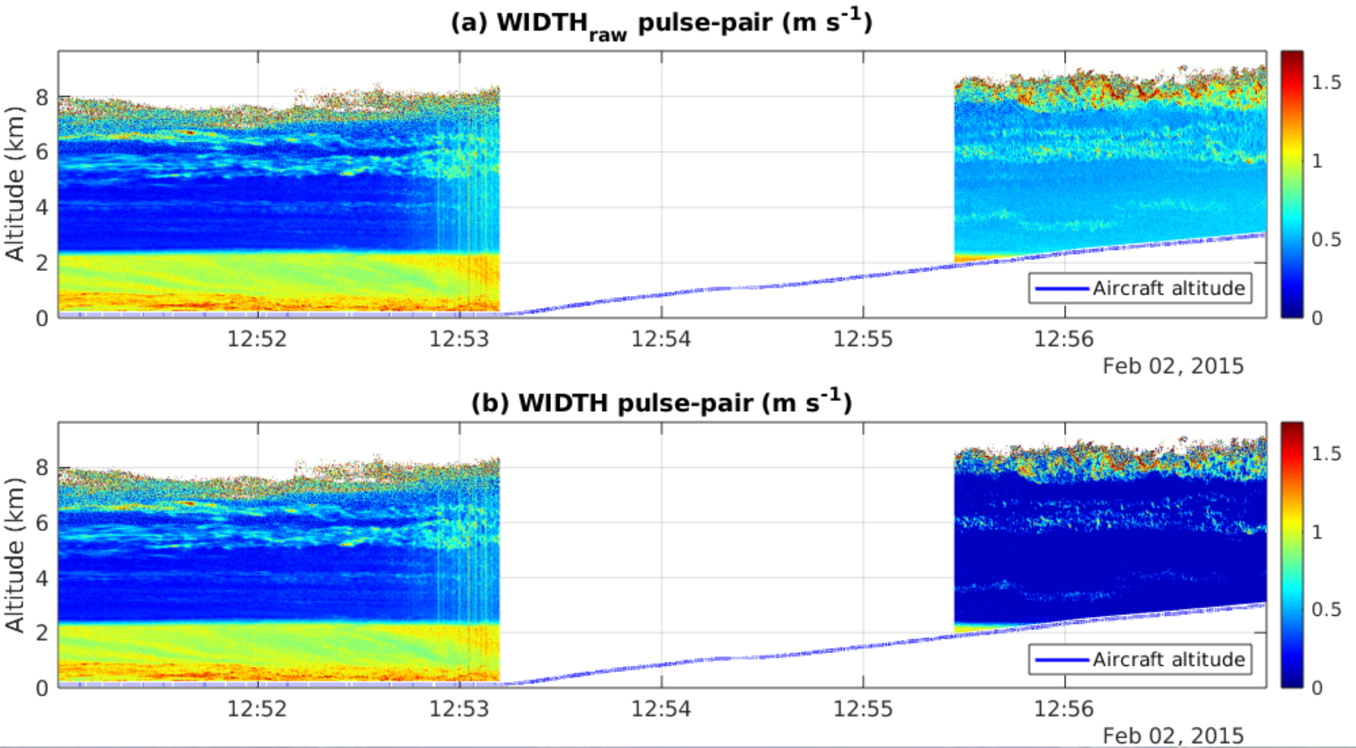


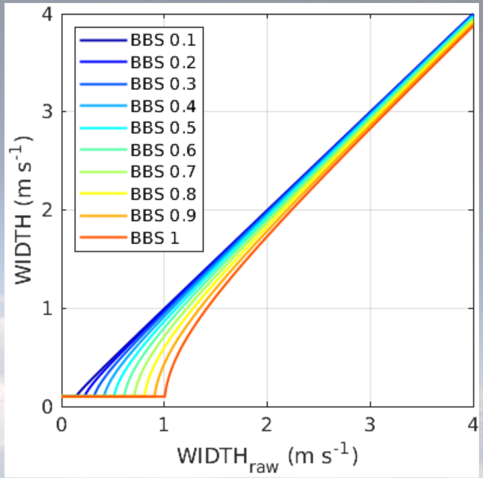
Issues

- Artificial lower bound
- Tendency to over-correct
- Does not correct spectra

Ulrike Romatschke romatsch@ucar.edu

Correct for broadening caused by aircraft motion – Legacy method

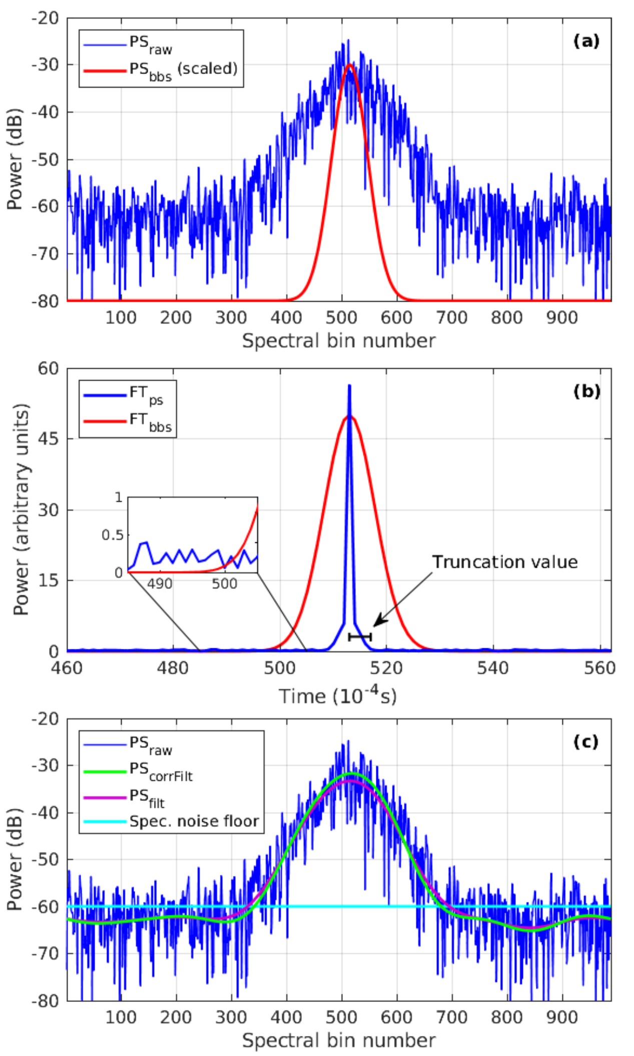




Ulrike Romatschke romatsch@ucar.edu

Correct for broadening caused by aircraft motion – New method

1. Use BBS to create a correction Gaussian
2. Fourier transform the Doppler spectrum and the correction Gaussian
3. Divide the Doppler spectrum by the Gaussian
4. Filter corrected spectrum with a low-pass filter (truncation of the autocovariance function)
5. Inverse Fourier transform the corrected Doppler spectrum
6. Scale to the original power
7. Find spectral noise floor (Hildebrand and Sekhon, 1974) and remove noise

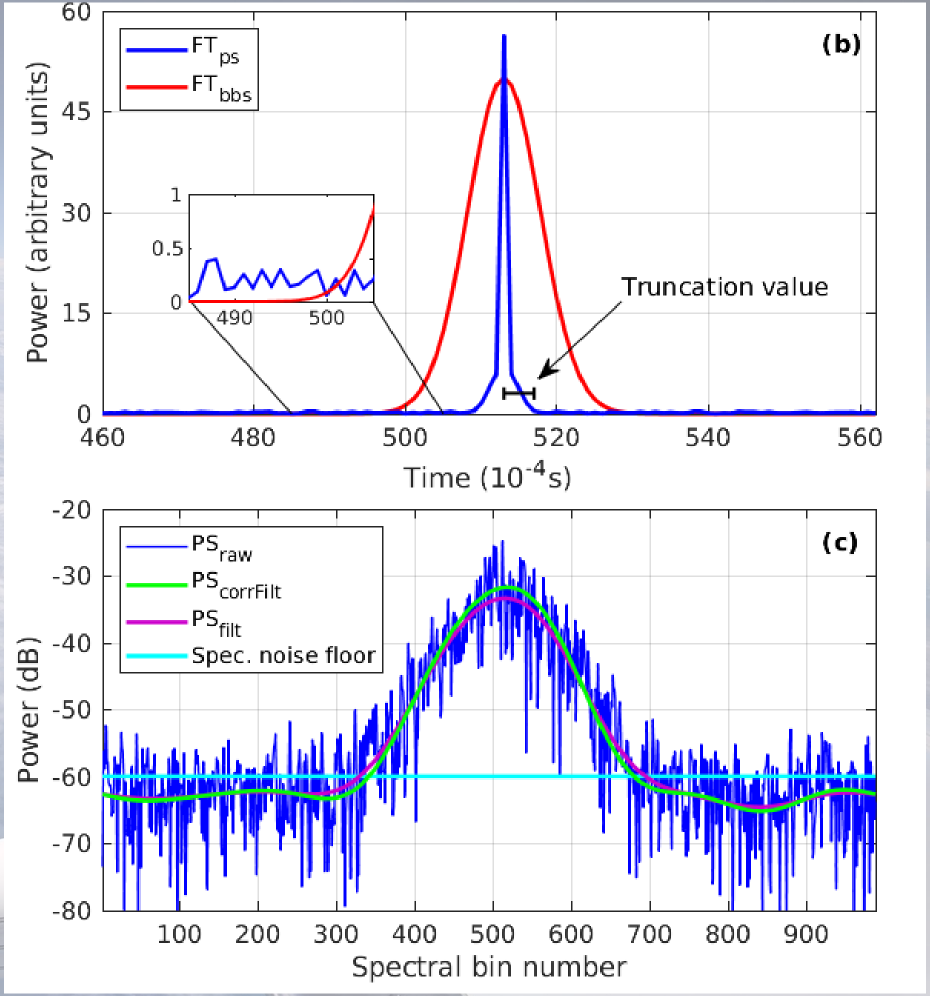


Ulrike Romatschke romatsch@ucar.edu

Filter optimization

How much filtering is justified?

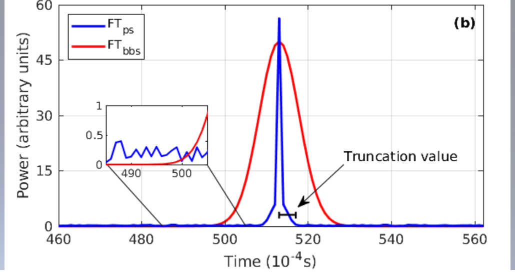
What is the optimum truncation value?

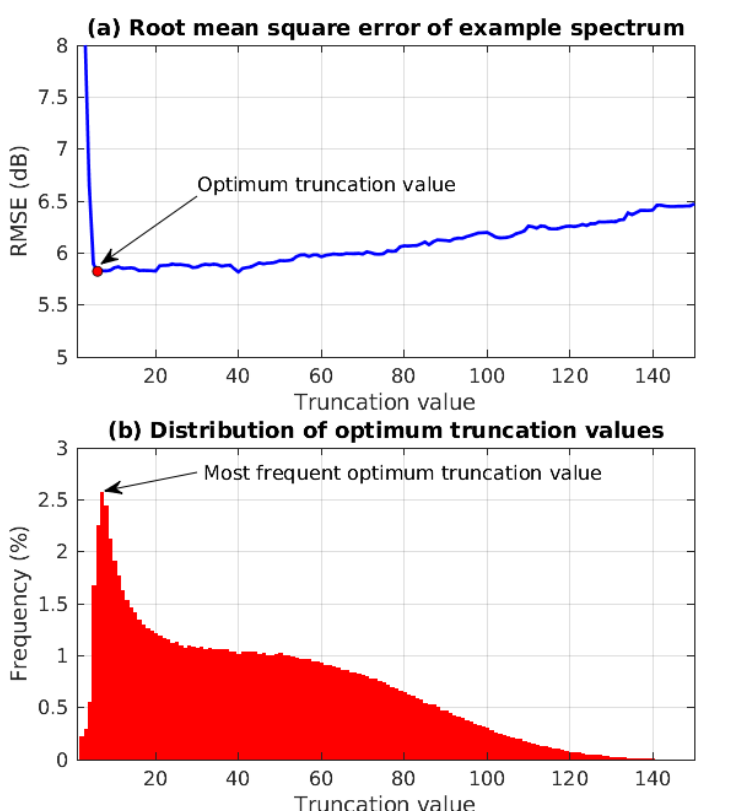


Ulrike Romatschke romatsch@ucar.edu

Filter optimization using holdout cross-validation

1. Split spectrum into two (Spectrum A and B) by taking every other data point.
2. Filter Spectrum A with a range of truncation values.
3. Calculate root mean square error (RMSE) between filtered Spectra A and unfiltered Spectrum B.
4. Repeat for many spectra.
5. Find most frequent optimum truncation value.

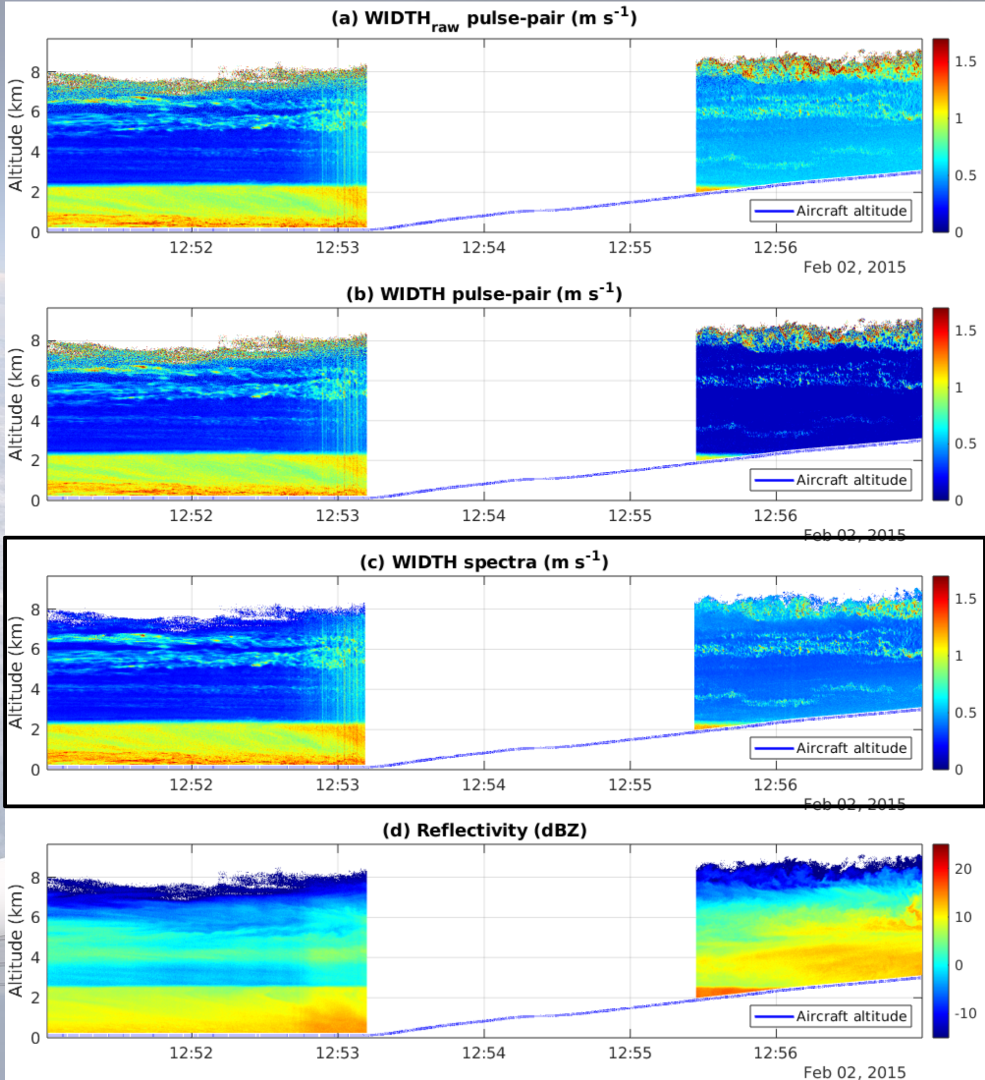




Ulrike Romatschke romatsch@ucar.edu

Correct for broadening caused by aircraft motion

New method →

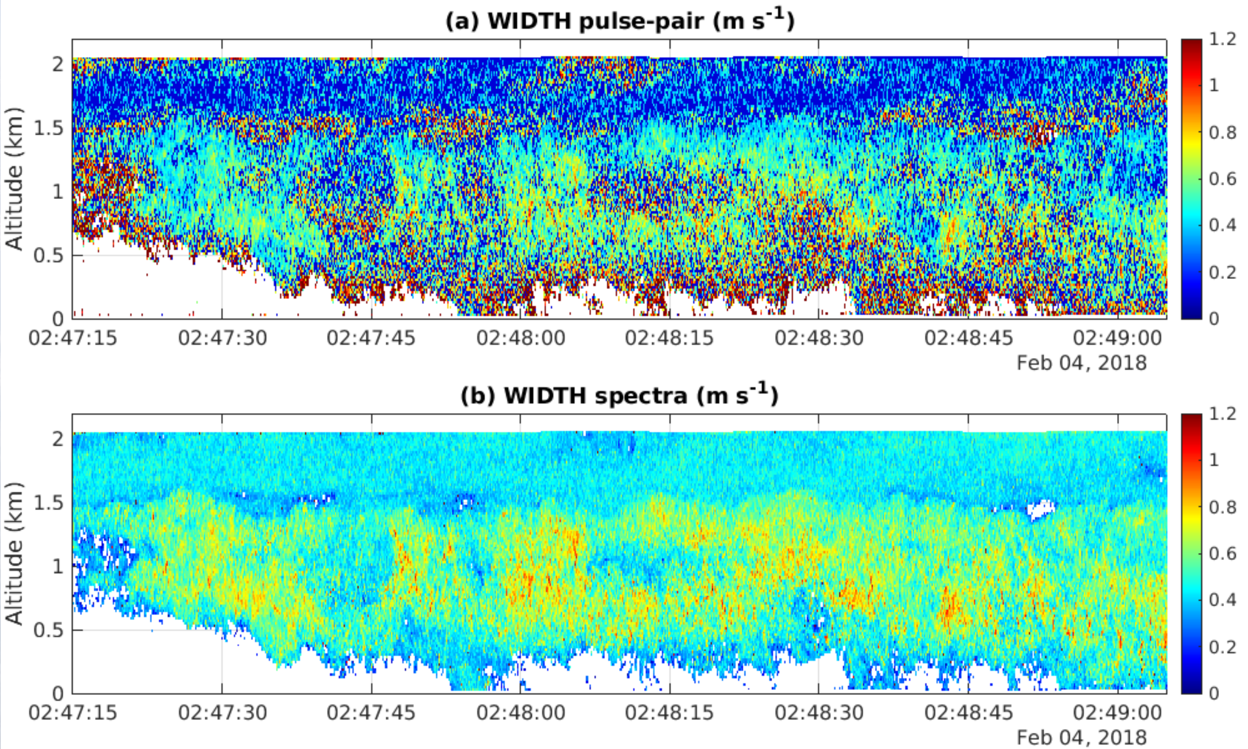


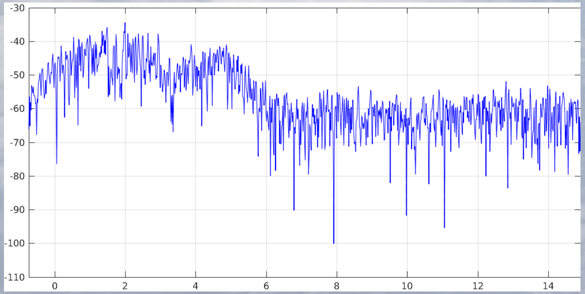
Ulrike Romatschke romatsch@ucar.edu

Improved spectrum width

New correction method

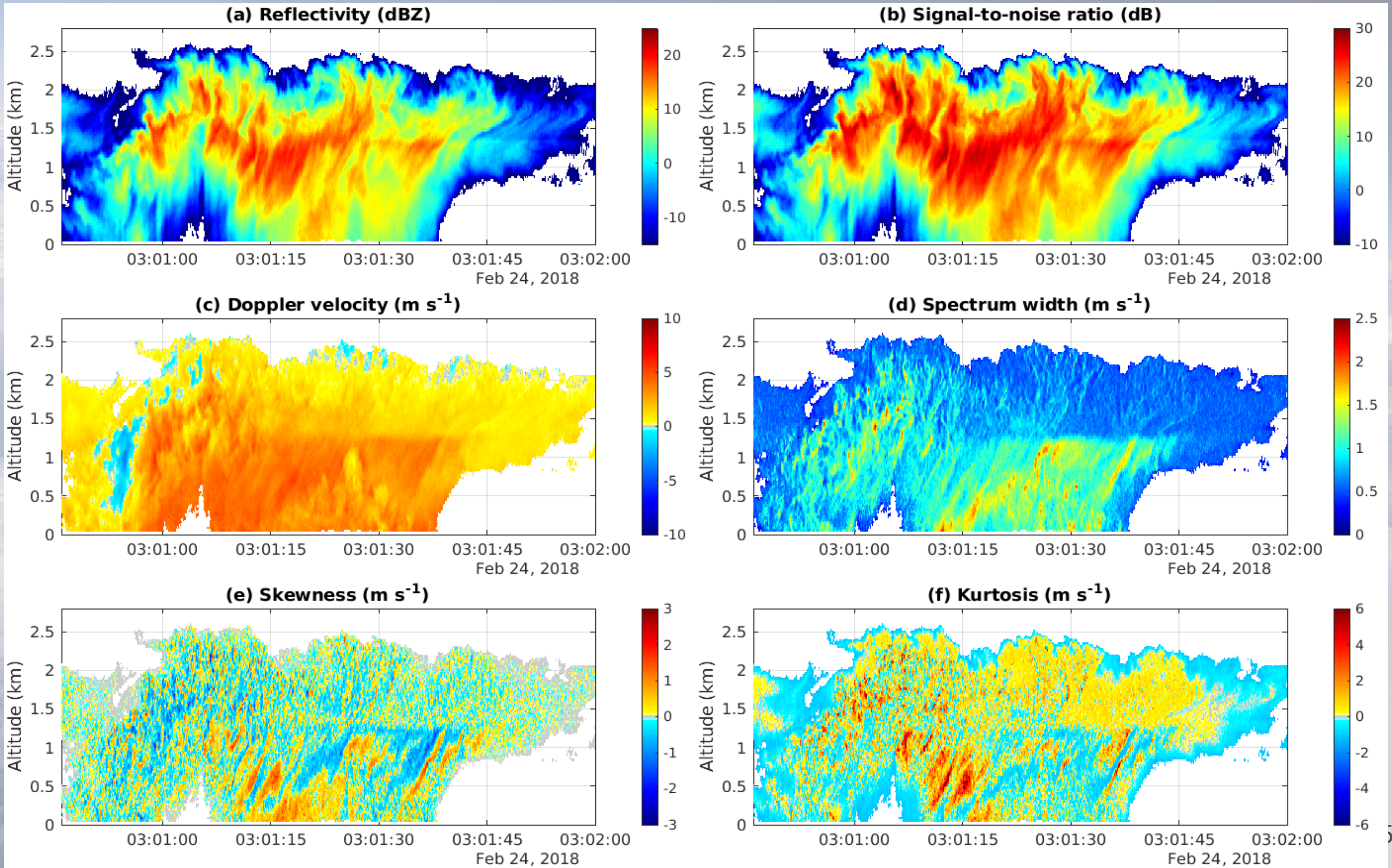
- De-noised.
- Spectral processing does not assume Gaussian shape of spectrum.



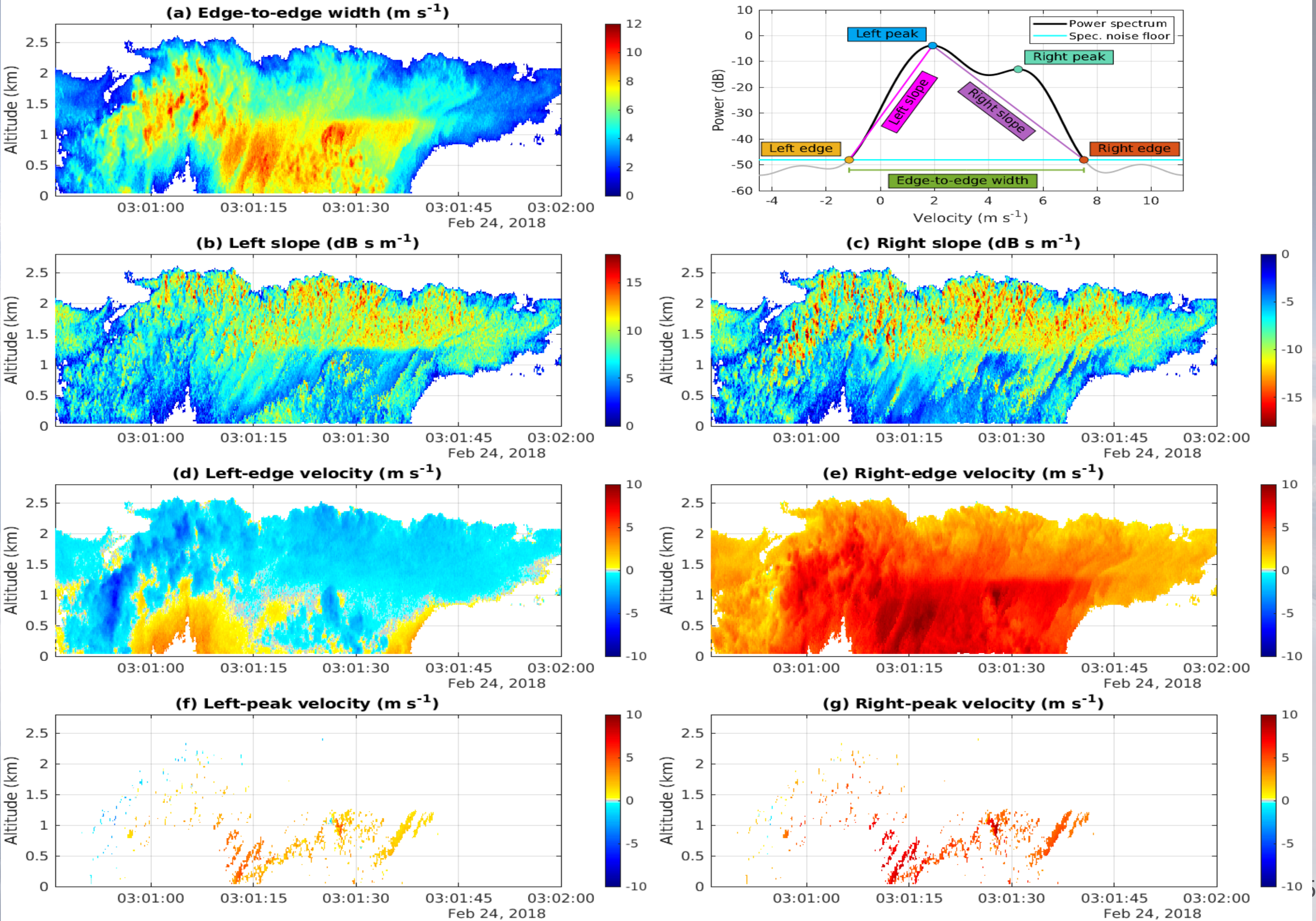


Ulrike Romatschke romatsch@ucar.edu

Higher-order moments



Spectral parameters



Ulrike Romatschke

Provide higher-order moments and spectral parameters for all HCR field campaigns

- NOR’EASTER - 1 research flight over the **US East Coast**
- CSET - 16 research flights **between California and Hawaii**
- SOCRATES - 15 research flights over the **Southern Ocean** south of Australia
- OTREC - 22 research flights over the **East Pacific and SW Caribbean Ocean**
- SPICULE - 10 research flights over the **US Great Plains**

Data is freely available in the EOL Field Data Archive https://data.eol.ucar.edu/

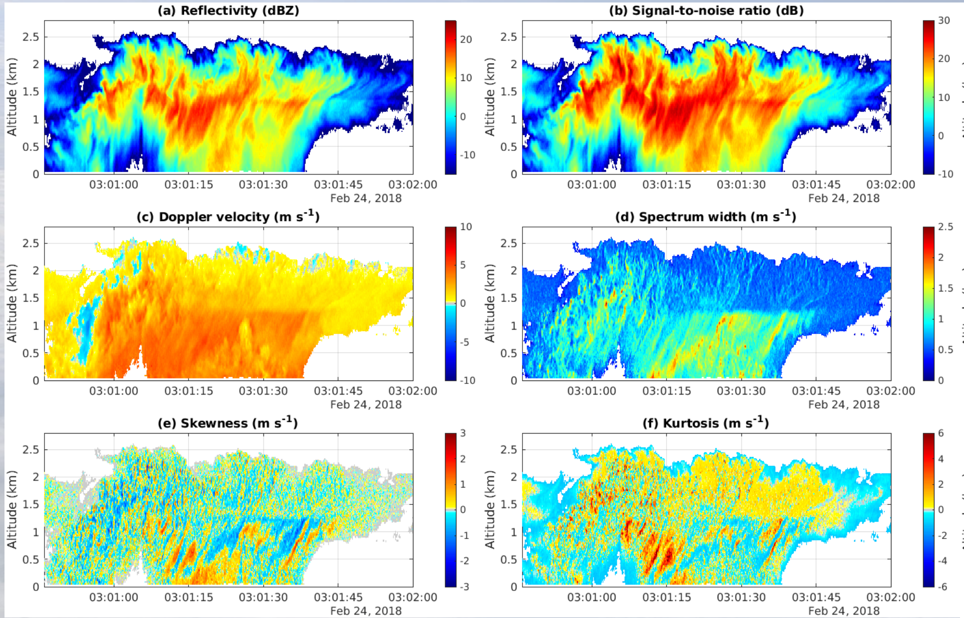
Conclusions

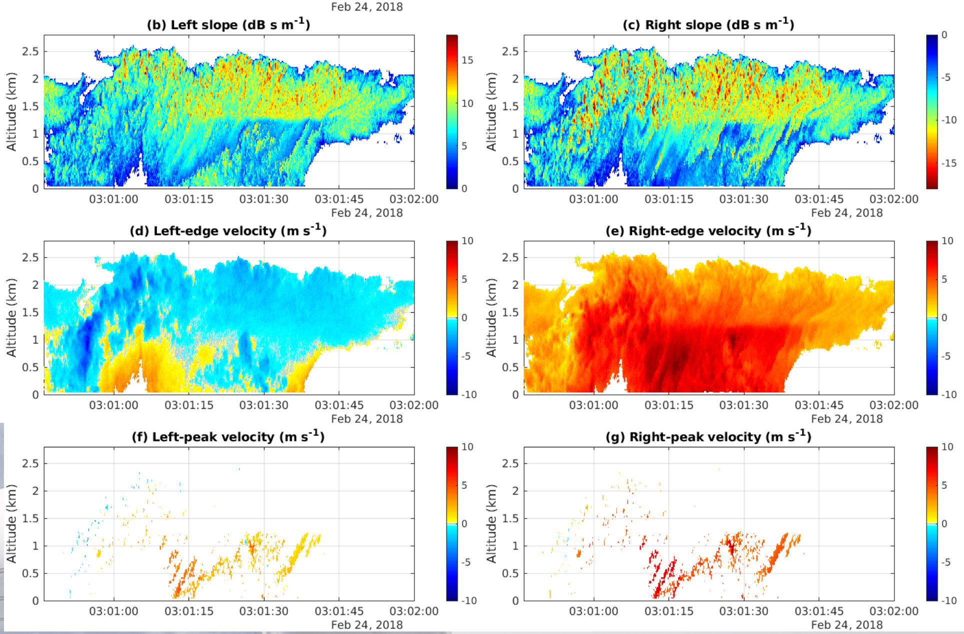
- We developed a processing technique for airborne radar Doppler spectra
  - Corrects spectra for aircraft motion broadening
- Processed Doppler spectra are used to calculate
  - Improved spectrum width
  - Skewness and kurtosis
  - Spectral parameters

Future work

- Provide higher-order moments and spectral parameters to the community
- Derive microphysical and dynamic quantities

Thank you!





Romatschke, U., P. Romatschke, M. Hayman, and M. J. Dixon, 2025: **Processing of Doppler spectra collected by an airborne cloud radar for the calculation of skewness, kurtosis, and other spectral parameters.** Submitted to *Earth and Space Science*.

Ulrike Romatschke romatsch@ucar.edu