Latest Results from the

RPG-FMCW-94-SP Cloud Radar

(or, to stay in line with WG-3:
a few slides on a 89 GHz radiometer with some active
94 GHz extensions to give the radiometer-derived LWP
a bit more vertical structure...)

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RPG-FMCW-94-SP Cloud Radar

94 GHz FMCW Doppler Cloud Radar:

- Very High Sensitivity (down to -60 dBz)
- High Dynamic Range (-60 to +20 dBz)
- Complete Rain Mitigation System
- Compact and Low Cost
- Full Networking Capability (TCP/IP)

Includes 89 GHz Channel for Measurement of:

Integrated Liquid Water Path (LWP)

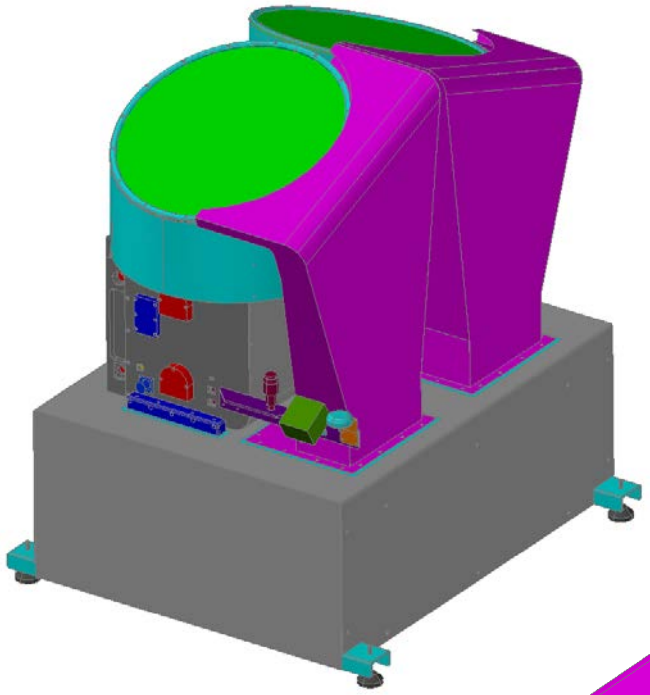
Specs (I)

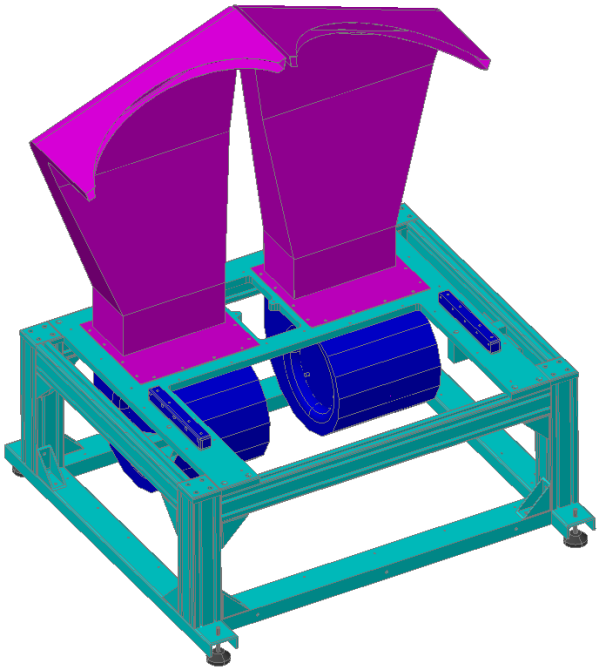
Parameter	Specification
Centre Frequency	94 GHz (λ=3.19 mm) ± 100 MHz typical, (adjustable by software between 92.3 and 95.7 GHz)
IF range	350 kHz to 3 MHz
Transmitter power	2 W typical (solid state amplifier) Lower transmitter powers are available for reduced priced
Antenna type	Bi-static Cassegrain with 500 mm aperture
Antenna gain	51.5 dB
Beam width	0.48° FWHM
Polarisation	V (optional V & H)
Rx System Noise Figure	4 dB (400 K system noise temperature)
Typical Dynamic range (sensitivity) with 2 W transmitter	-60 dBz to +20 dBz (at 500 m height / 5 m resolution) -50 dBz to +20 dBz (at 2 km height / 10 m resolution) -47 dBz to +20 dBz (at 4 km height / 30 m resolution) -36 dBz to +20 dBz (at 10 km height / 30 m resolution)
Ranging	100 m to 12 km typical, 16 km maximum
Maximum vertical resolution	1 m (range: 0.1 km – 0.6 km), 2 m (range: 0.6 km – 1.0 km), 4 m (range: 1.0 km – 2.5 km), 8 m (range: 2.5 km – 5.0 km), 16 m (range: 5.0 km – 12.0 km)
Calibrations (automatic)	Power monitoring of the transmitter, plus receiver Dicke-switch for gain drift compensation (radar and passive channel)
Calibrations (maintenance)	Liquid nitrogen receiver calibration, external reference sphere

Specs (II)

A/D Sampling rate	**8.2 MHz (data processing between 0.35 and 3 MHz)**
Data processing system	High-Performance embedded PC
Sampling rate (full profiles)	Adjustable: ≥1 second
Doppler range	± 9 m/s unambiguous velocity range (0-2500 m), ± 4.2 m/s above
Doppler resolution	± 1.5 cm/s or higher
Chirp variations	3 typical, 10 possible, re-programmable
Passive channels	89 GHz for integral LWP detection
Control connection	TCP/IP connectivity via fibre optics data cable to internal PC
Operation software	Real time visualization, real time data extraction, real time control (adaptive observation modes depending on context)
Data products (available as files)	Reflectivity, Doppler spectra (including calculated moments), LWC profiles. Data levels: L1: calibrated dBZ, L2: retrieved data
Data formats	netCDF (CF convention), proprietary binary, ASCII
Mitigation system for rain/fog/dew	Strong dew blower (approx. 2000 m^3/h), radomes with hydrophobic coating ,optional heater (additional 2-4 kW)
Additional sensors	Automatic weather station with P, T, RH, RR, Snow, WS, WD
Scanning / mounting	Baseline: mounted on a fixed stand of 0.5 m height Optional: scanner unit for full sky scanning capability
Dimensions	115×56×82 cm^3 (with antennas),(80×40×40 cm^3 (box only)
Weight	Approx. 280 kg/80 kg with/without stand & blower (w/o scanner)

FMCW Radar Hardware





Ground based radar requires strong blower / heater:

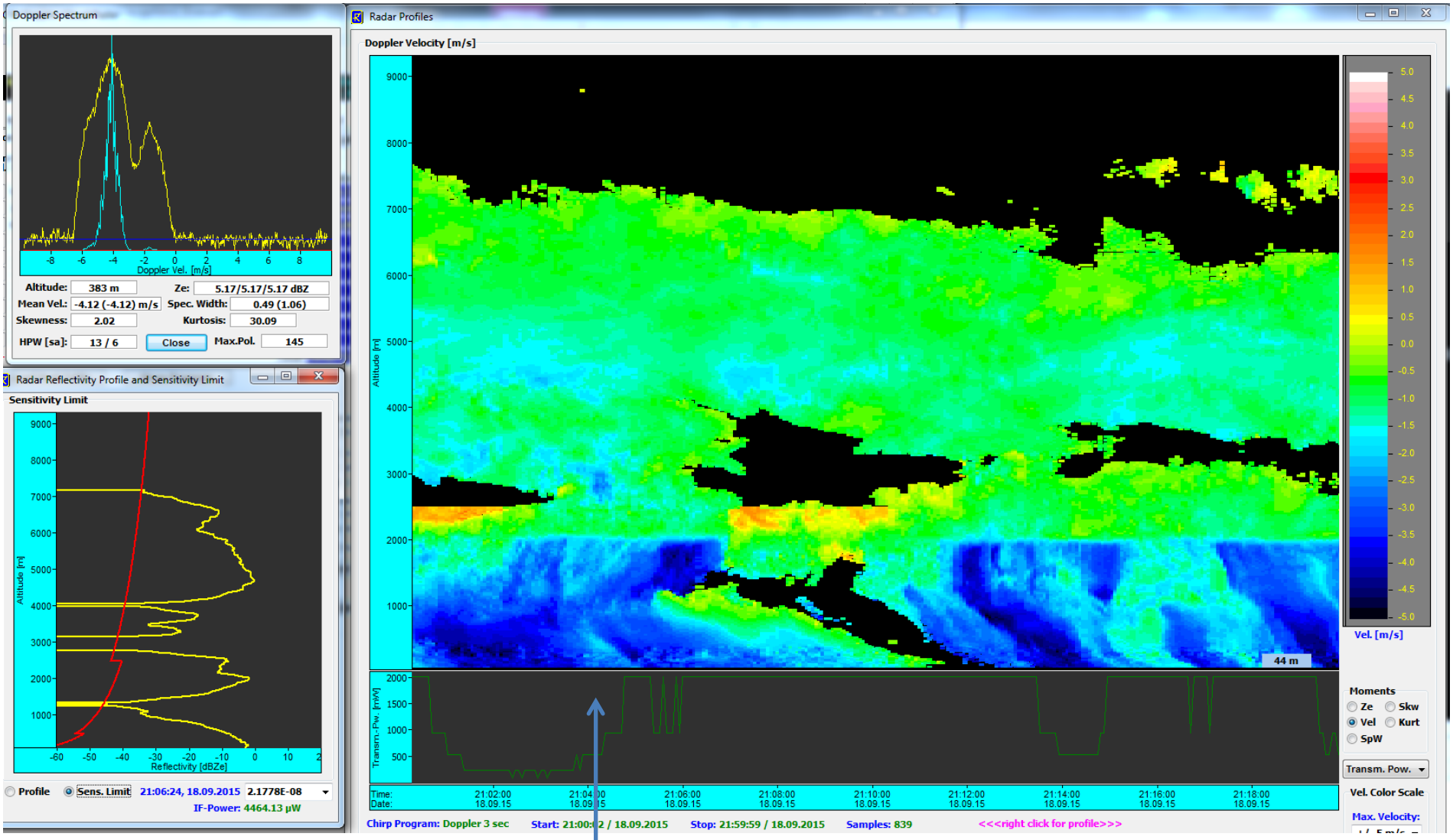
The contamination of the microwave windows by snow, ice, rain leads to unacceptably high reflectivity errors or even ‚blindness' of the instrument

Even small contaminations with rain droplets, condensation or snow are causing big errors in LWP retrievals from the direct detection channel

Solution:

- Strong air flow of 2x2000 m³/h over the windows
- Air can optionally be heated. Power: 2 kW to 4 kW

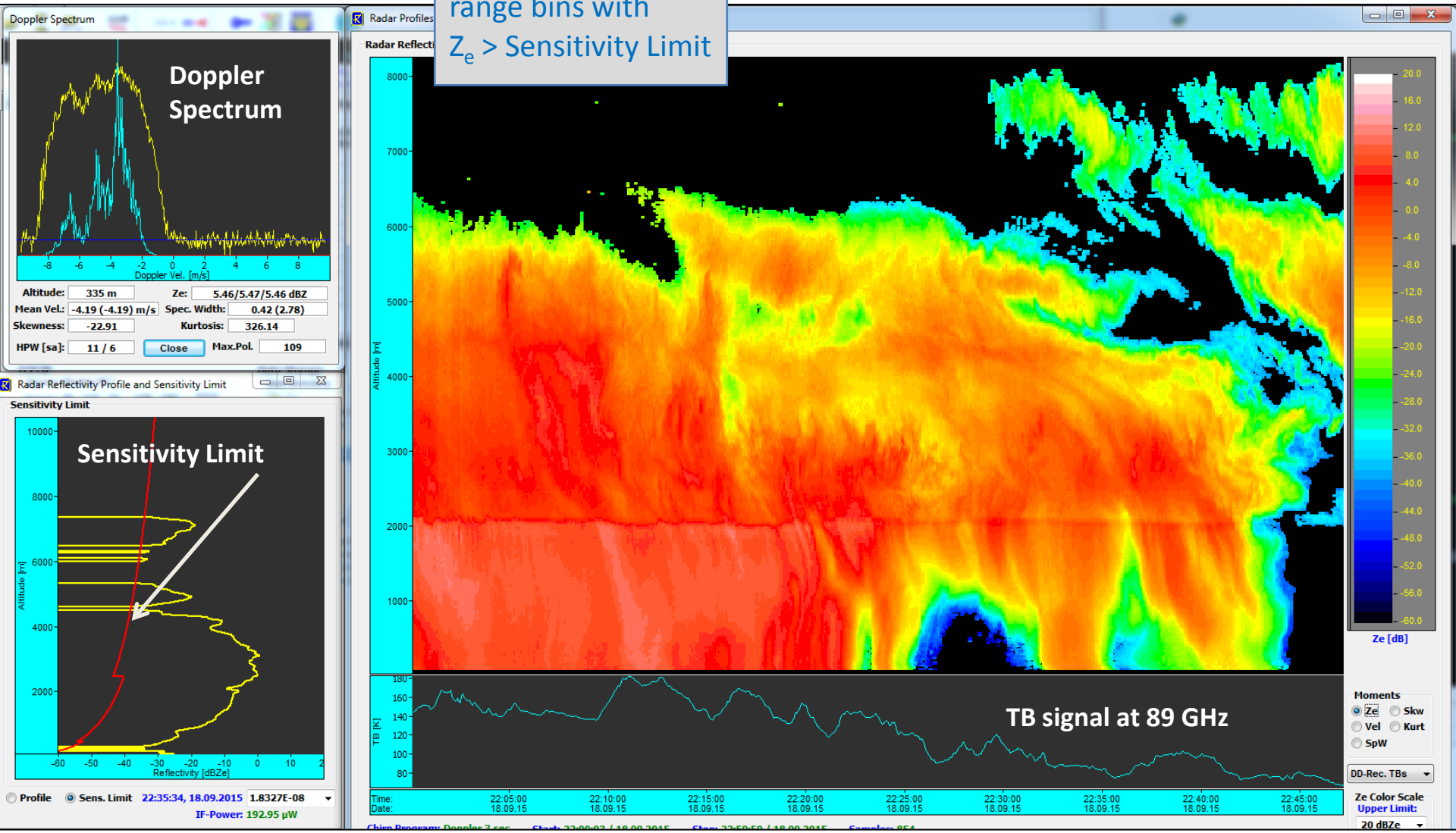
Automatic Transmitter Power Tuning



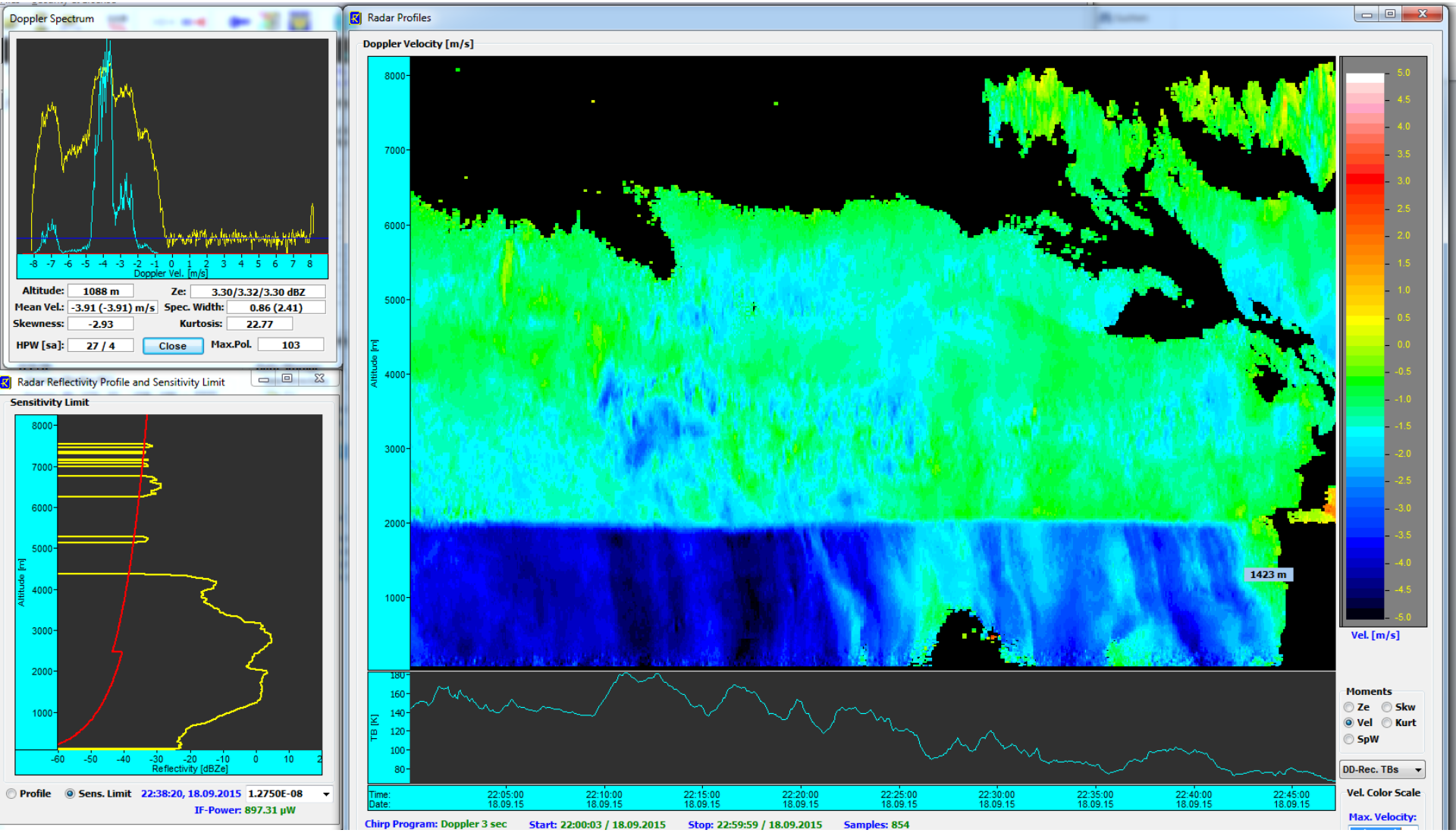
Transmitter Power Adjustments increase dynamic range by 16 dB!

High Radar Reflectivity Sensitivity

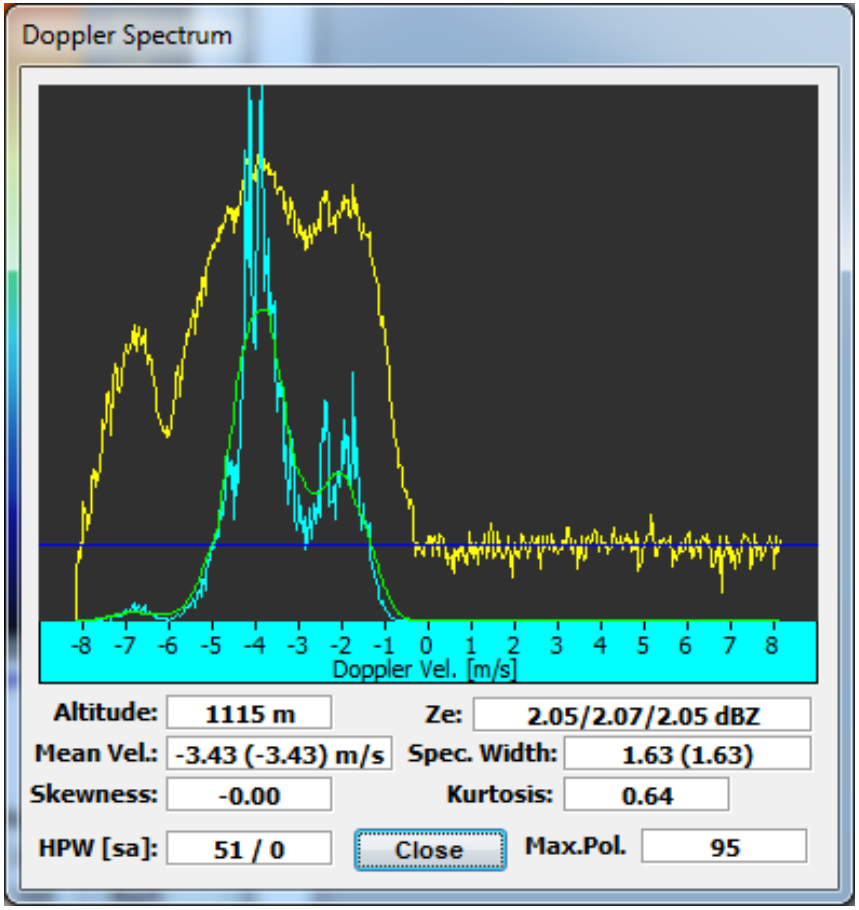
Doppler spectra are only calcuated for range bins with Z_e > Sensitivity Limit

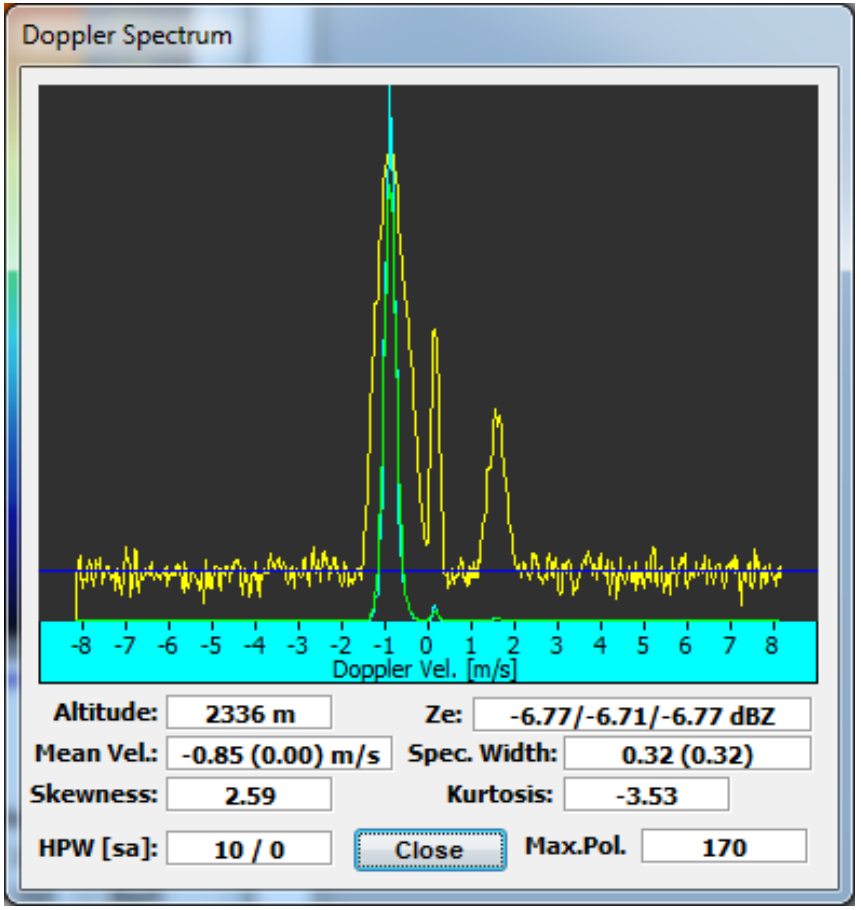


Cloud Dynamics:Doppler Velocity

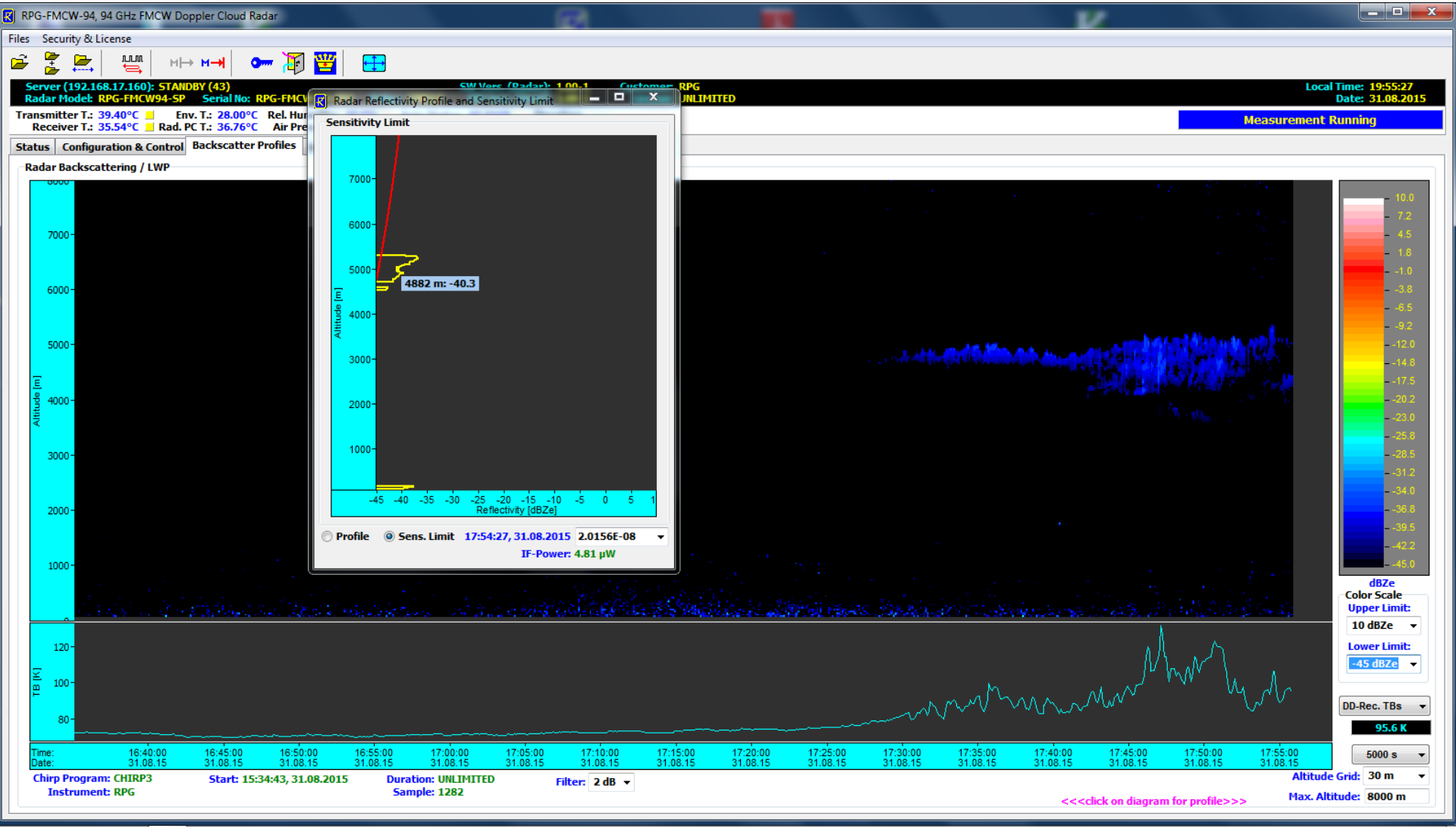


Doppler Spectra Reveal Cloud Physics

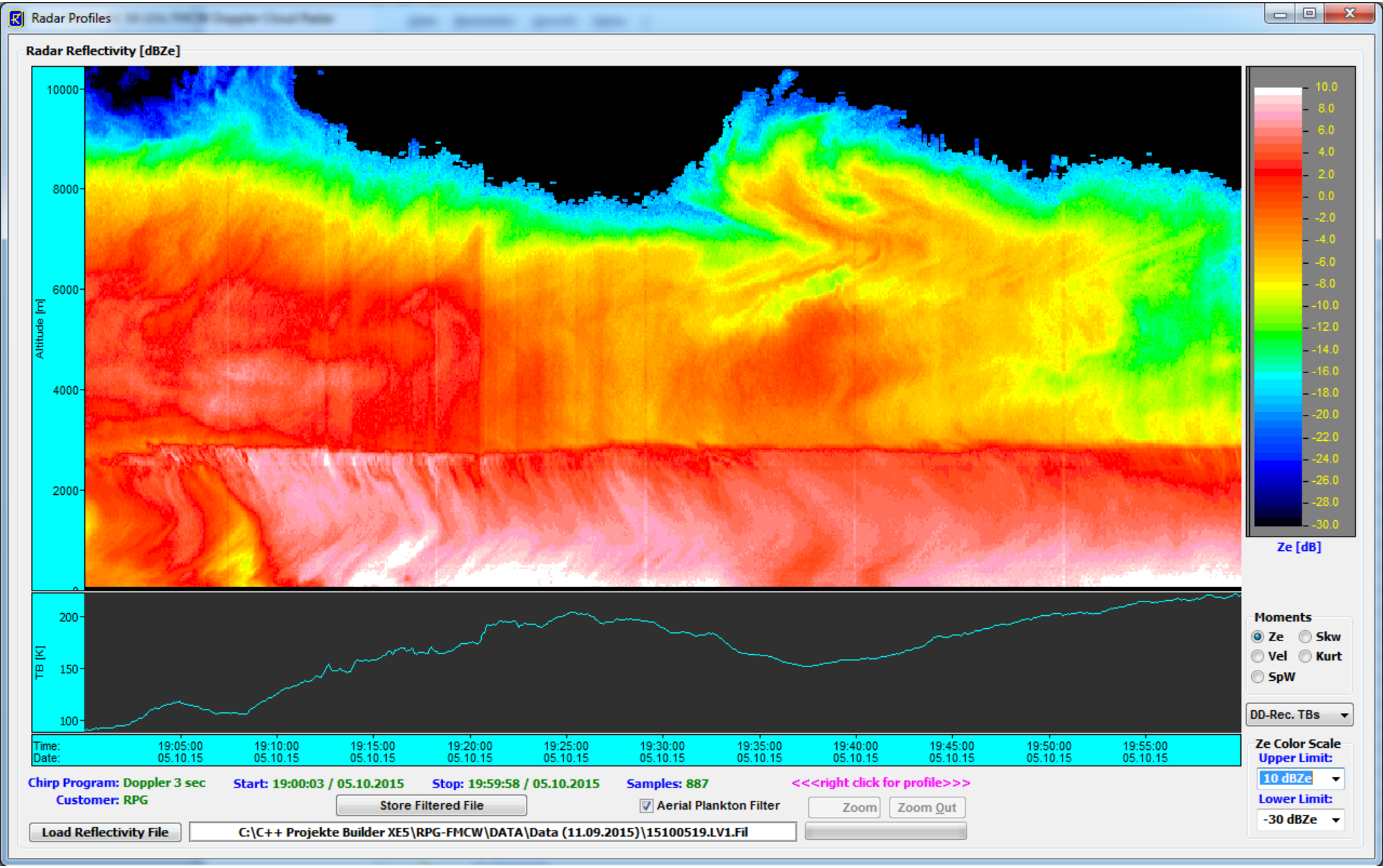




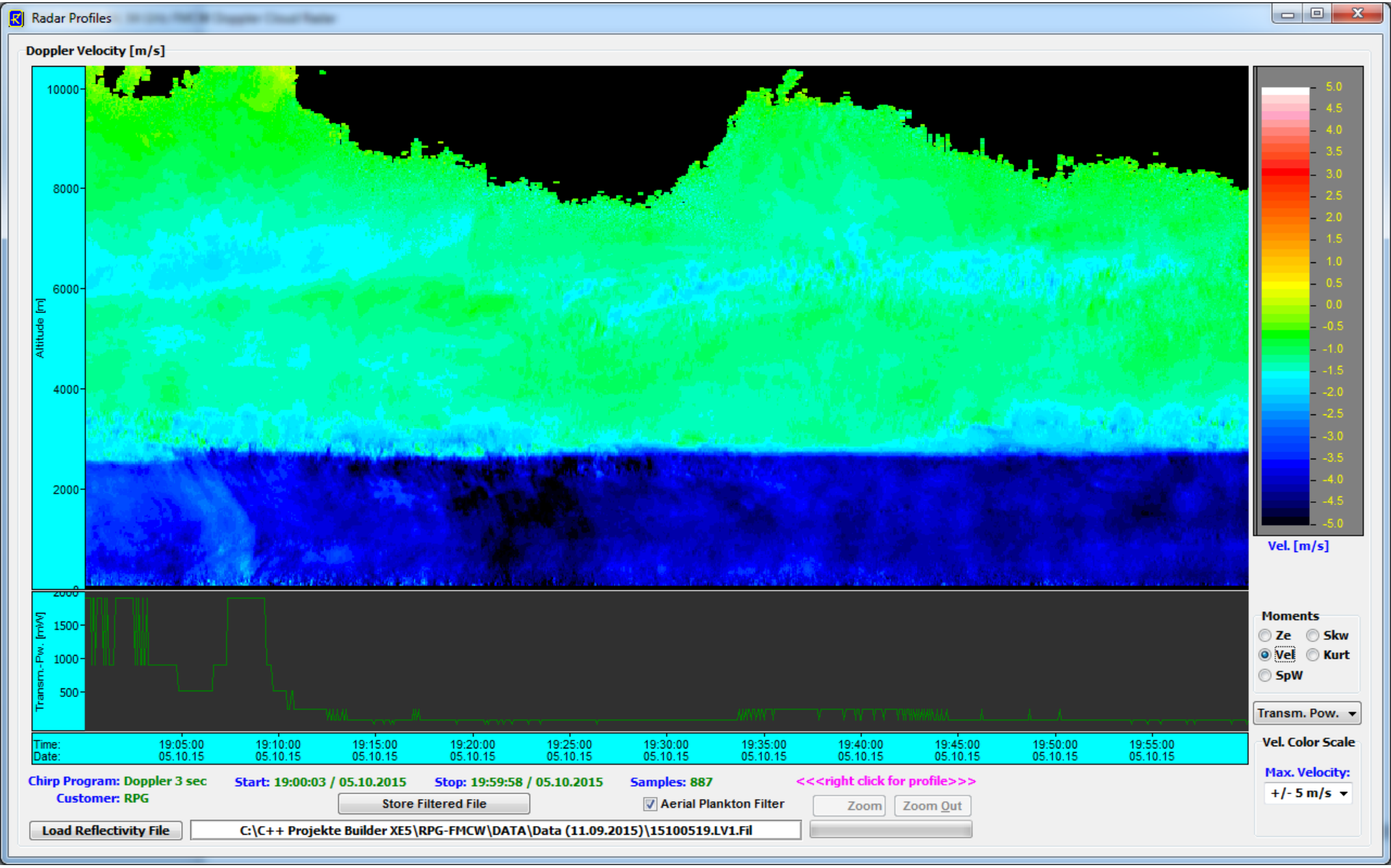
Sensitivity: Liquid Water Cloud at 5 km



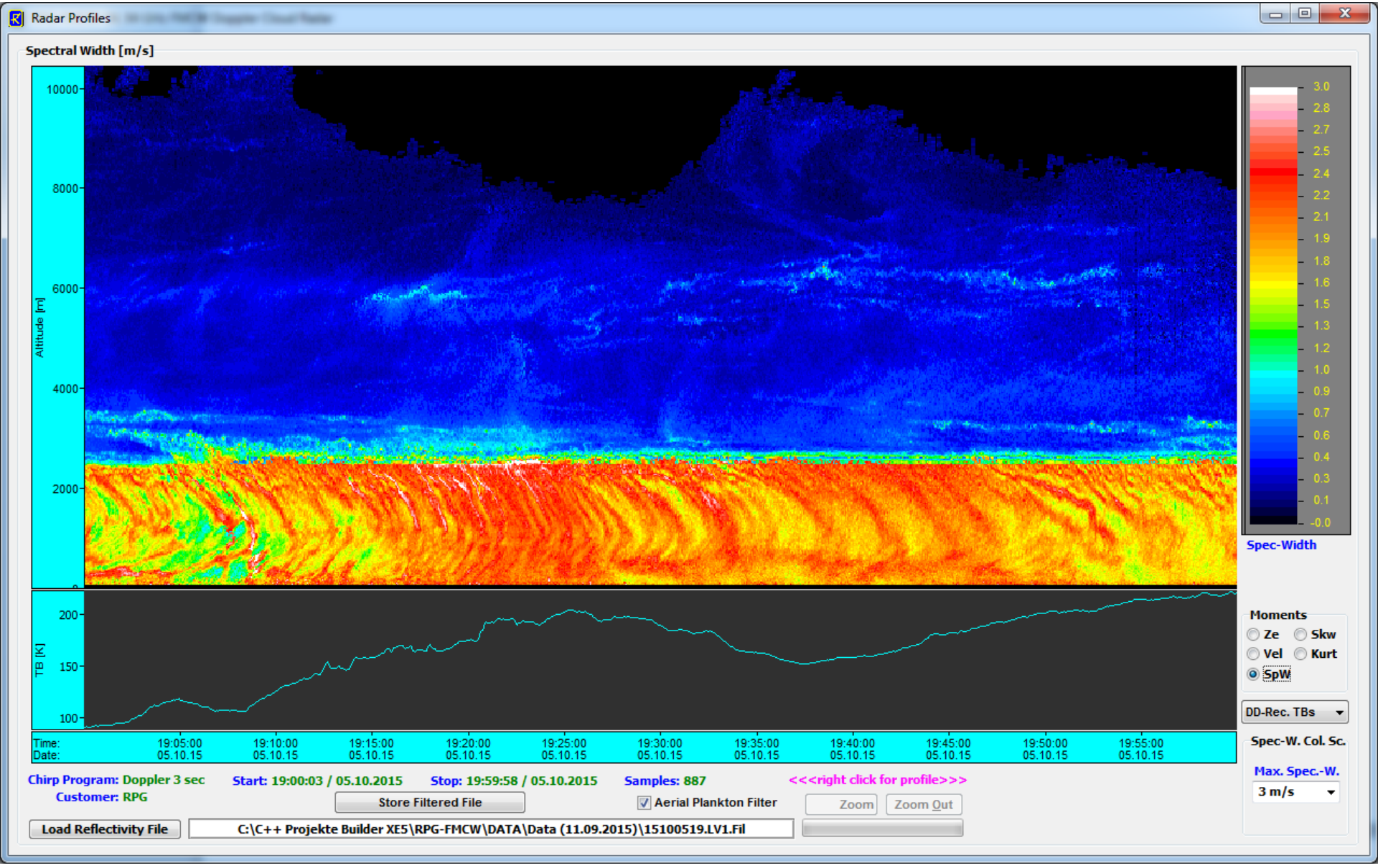
Rain Event: Refelectivity Ze



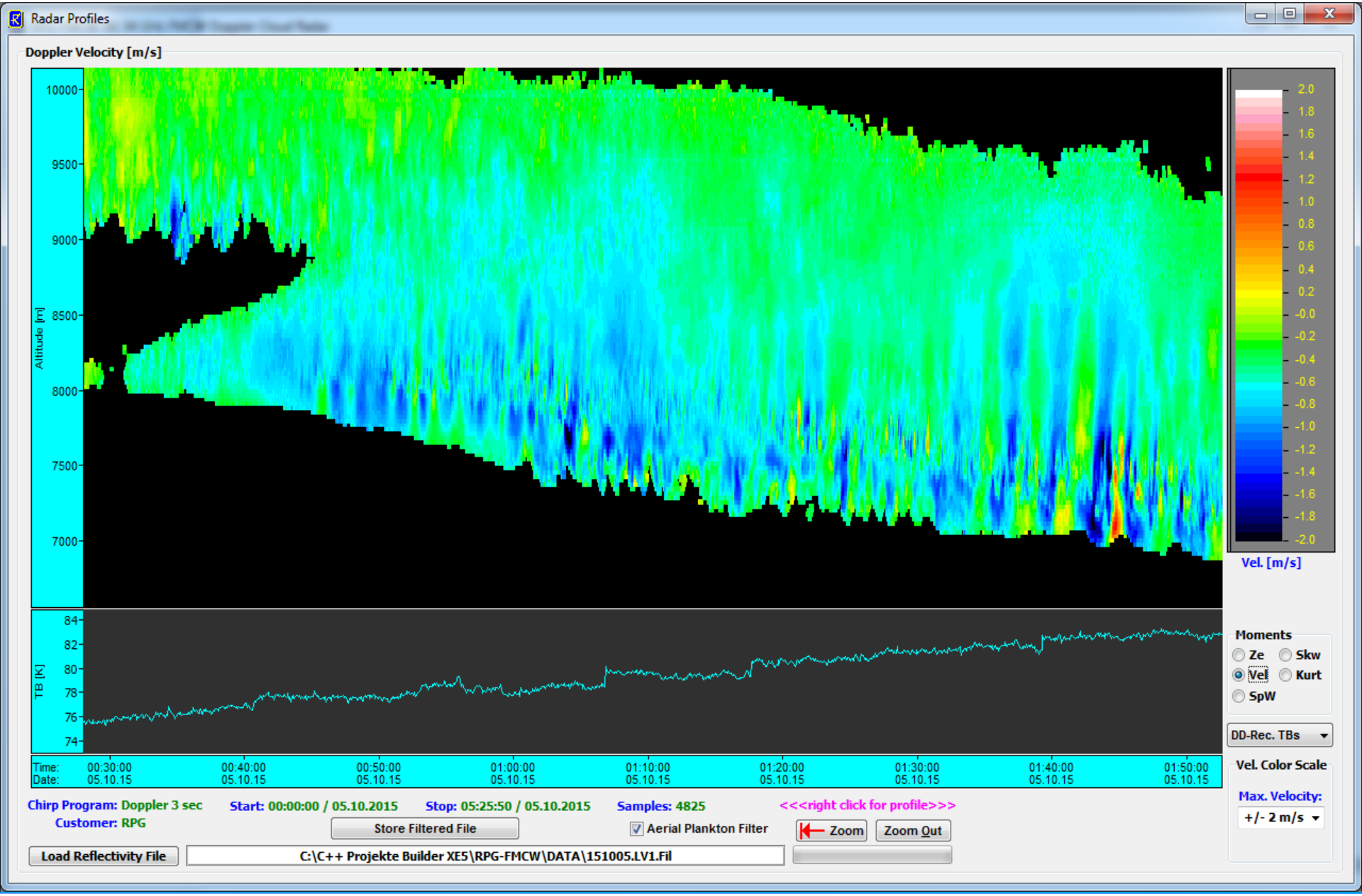
Rain Event: Doppler Velocity



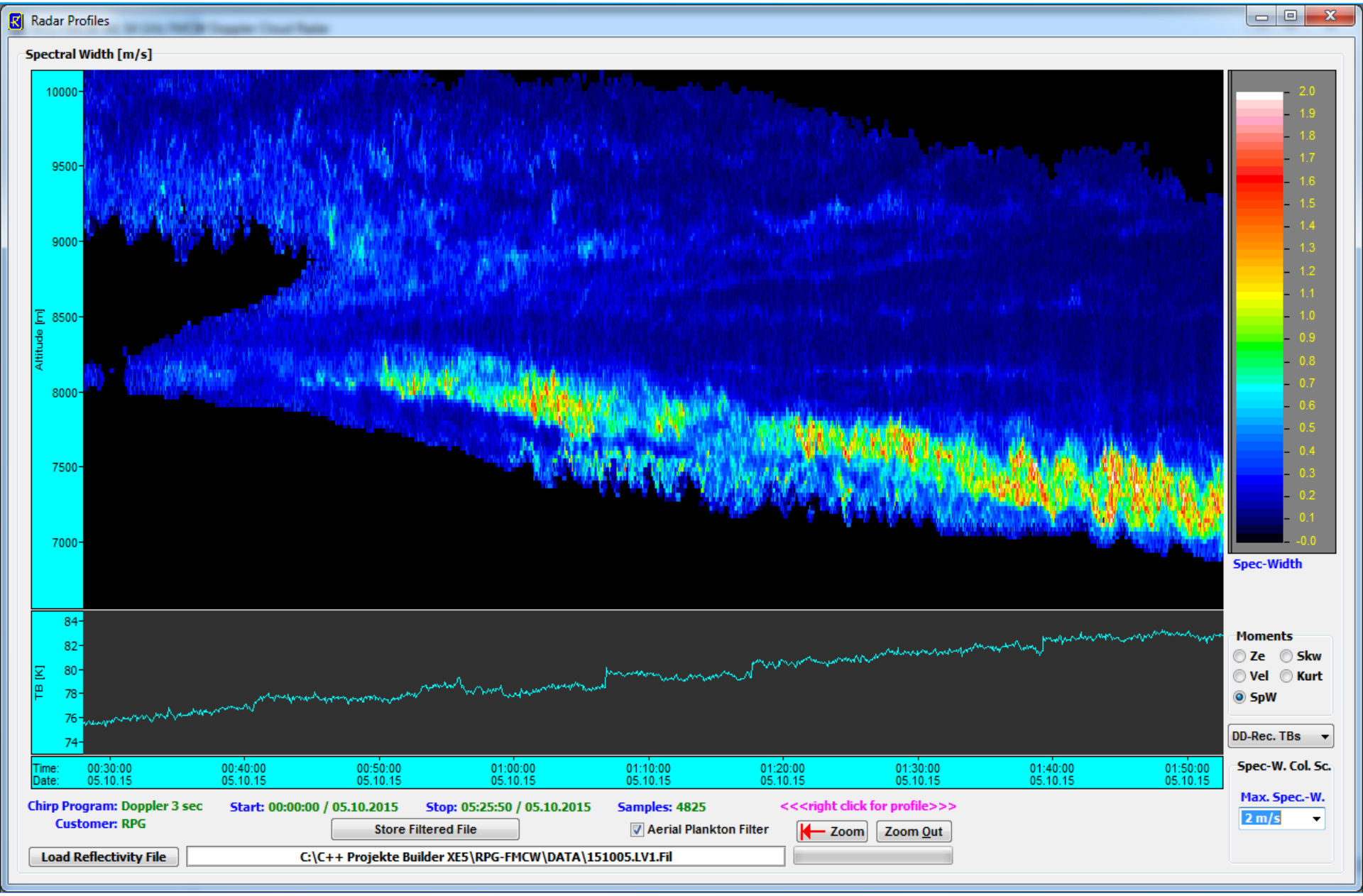
Rain Event: Spectral Width (DSD)



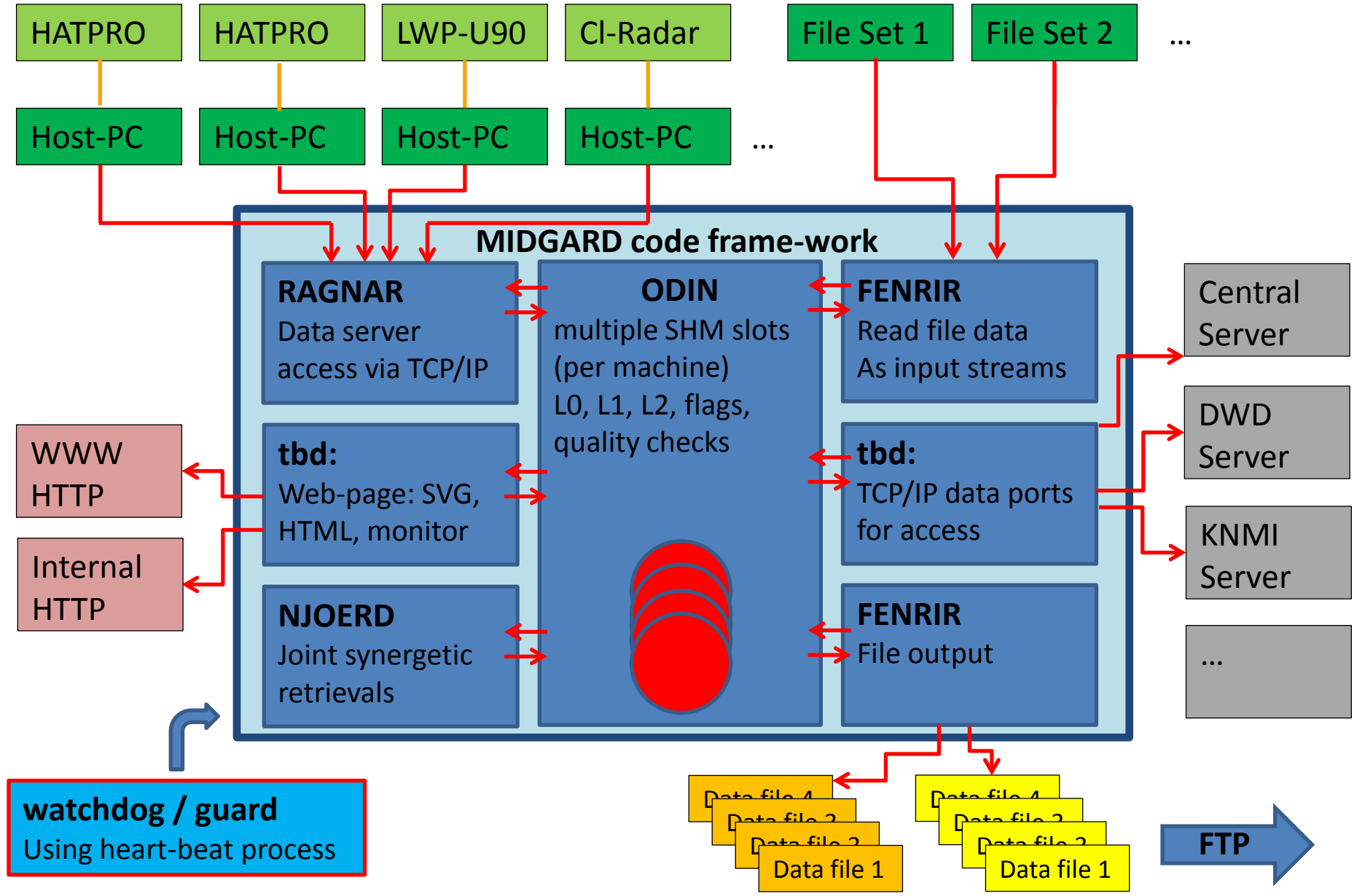
Cirrus: Velocity



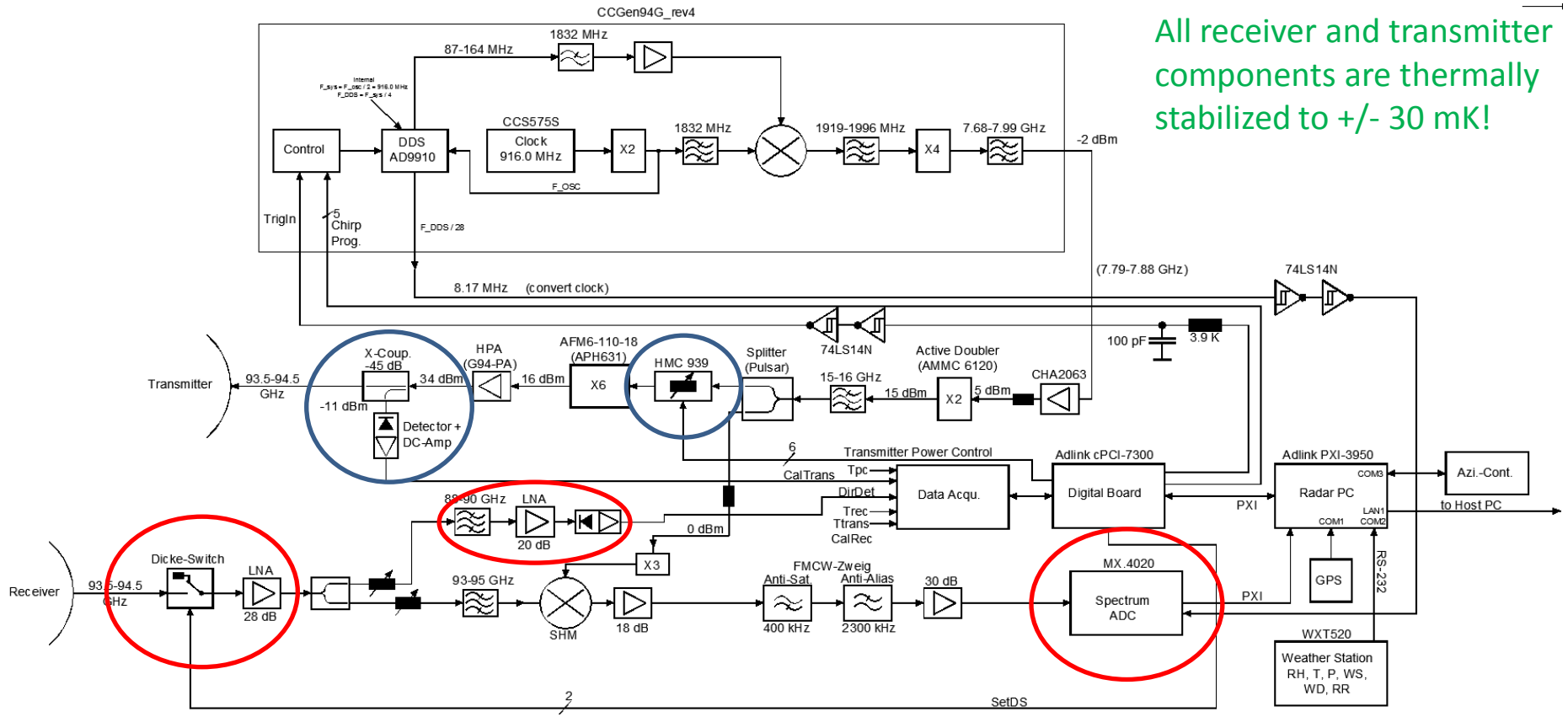
Cirrus: Spectral Width



Synergy with MWR: MIDGARD, ODIN, RAGNAR, …



RPG-FMCW-94-SP Radar Schematic



All receiver and transmitter components are thermally stabilized to +/- 30 mK!

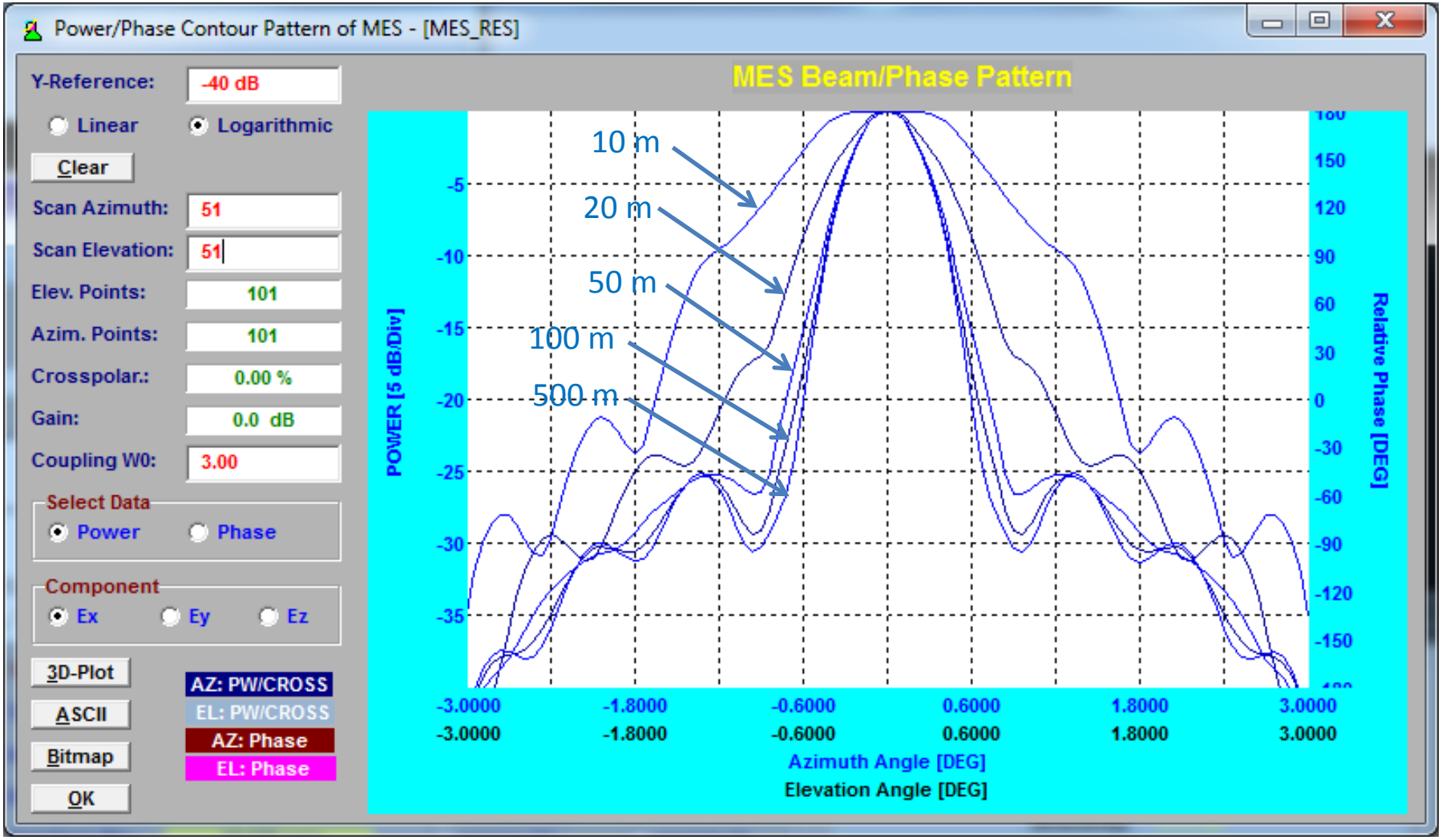
Transmitter calibration issues:

1. Monitoring of output power, detector calibration
2. Power attenuation for dynamic range extension (17 dB)
3. Calibration of optical losses (feedhorns and Cassegr.)

Receiver calibration issues:

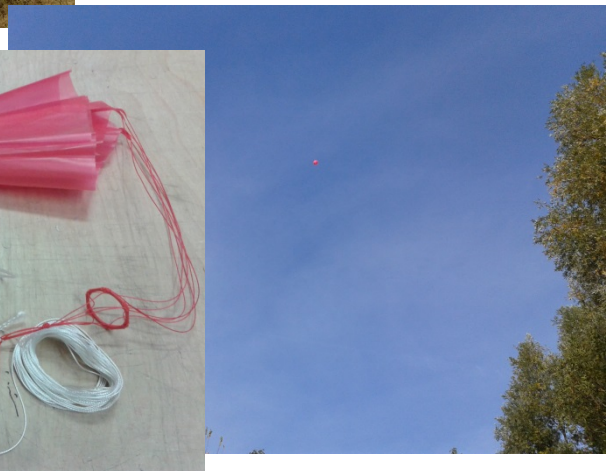
1. Suppression of spurious detection signals from ADC
2. Dicke switch as internal ambient temp. Reference
3. Determination of Gains and Tsys in DD and Radar Ch.
4. Determination of total receiver chain gain
5. Correction of optical losses

Antenna Far Field Determination



Antenna far field can be assumed for distances >100 m

Spherical Reflector Calibration Results



Metal ball diameter: 48 mm
Reflector altitude: approx. 140 m
Reflector distance from radar: 960 m
Atmospheric attenuation: -0.6 dB
(path length 1900 m)

Expected power ratio Pr/Pt: -126.5 dB

Measured power ratio: -127.5
Corrected for attenuation: -126.9 dB

Deviation from theoretical value: 0.4 dB!

Excellent Internal Radar Calibration!!