Doppler lidar telescope focus correction to obtain reliable attenuated backscatter profiles

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Why focus the DL beam?

- Benefits
  - Velocity uncertainty depends on SNR
    - Improve sensitivity in the BL
    - Improve Doppler velocity accuracy
    - Improve data availability in the BL
- Issue
  - Instrument provides profile of signal, not attenuated backscatter

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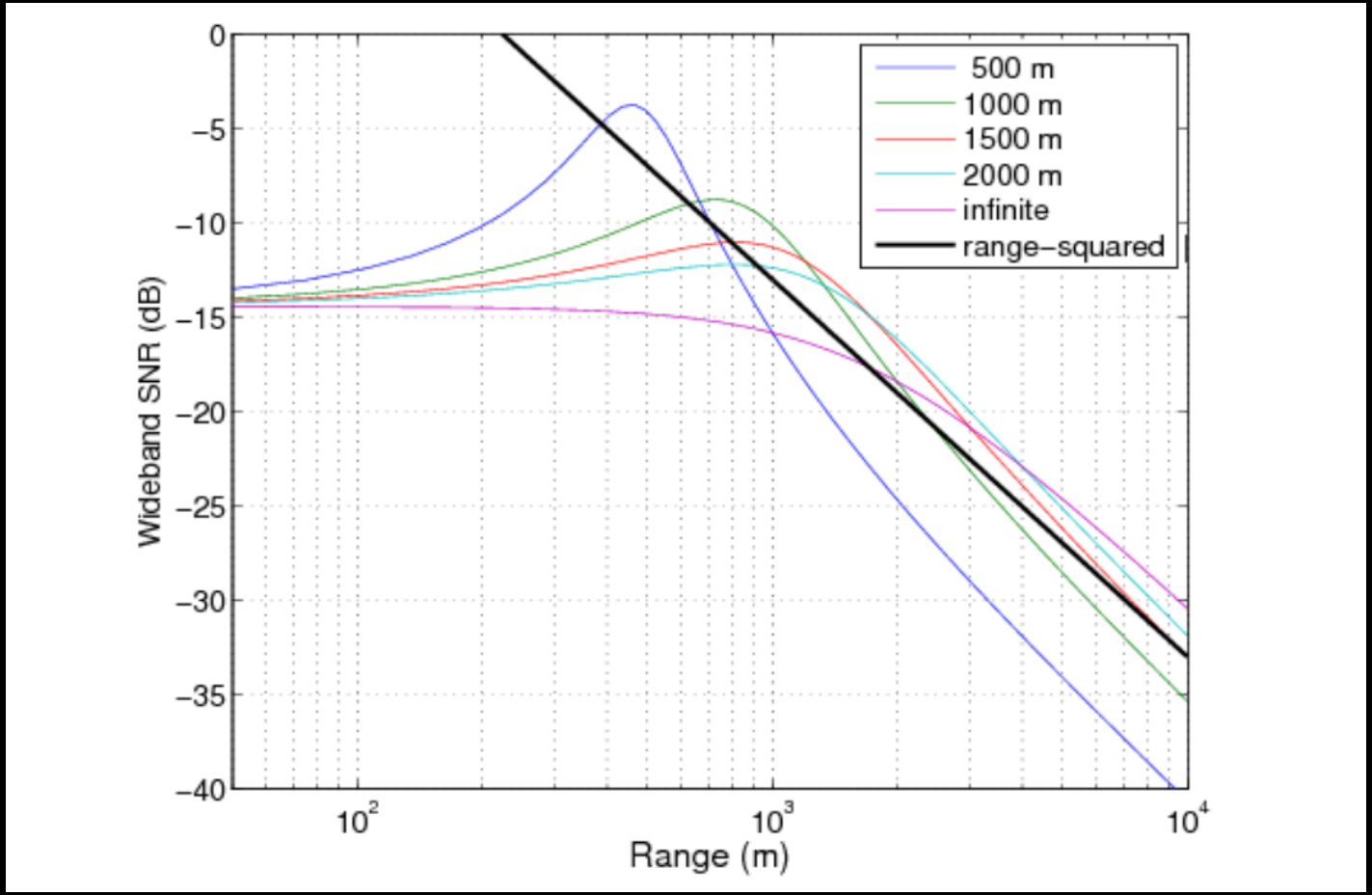
Telescope function - SNR



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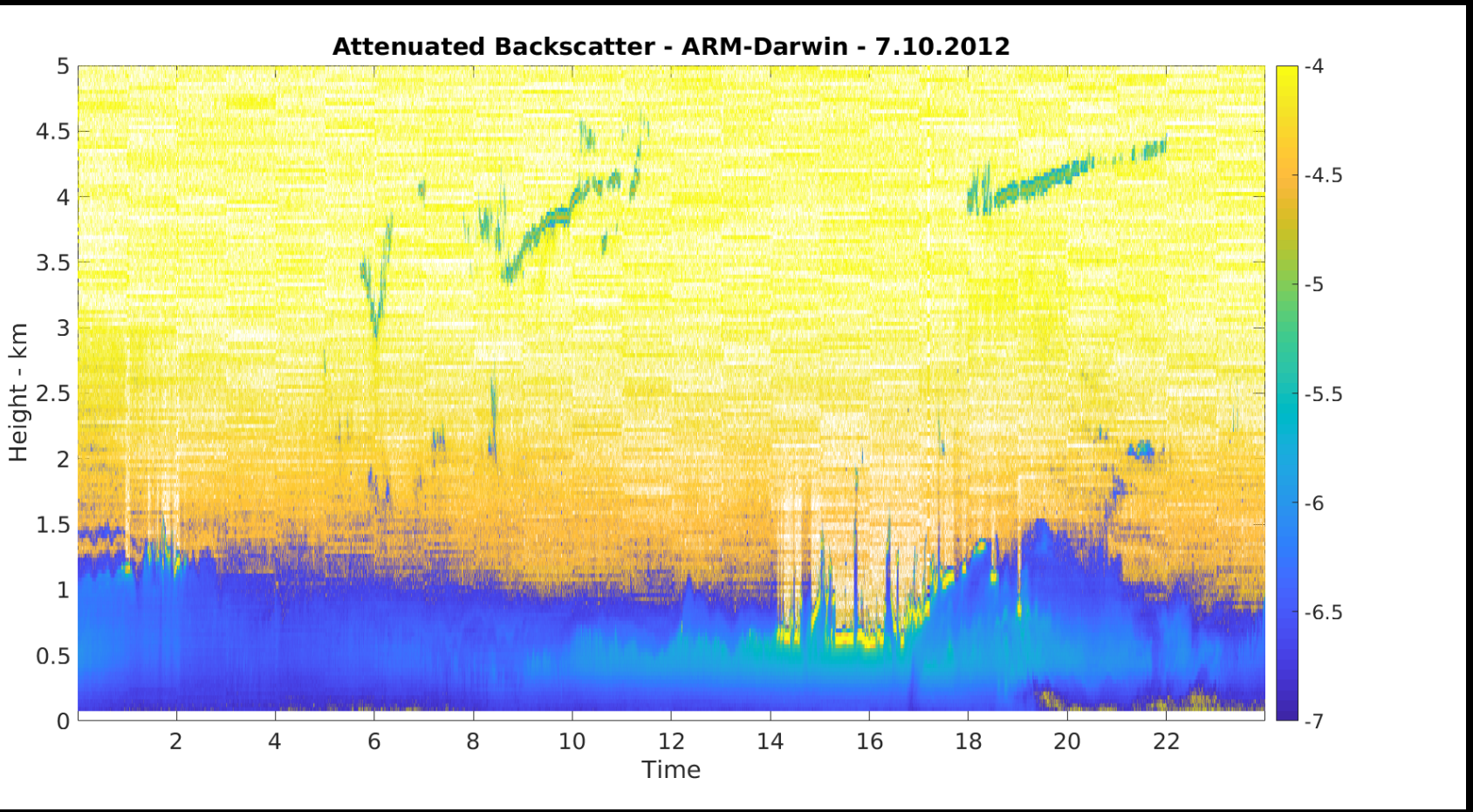
Impact of focus



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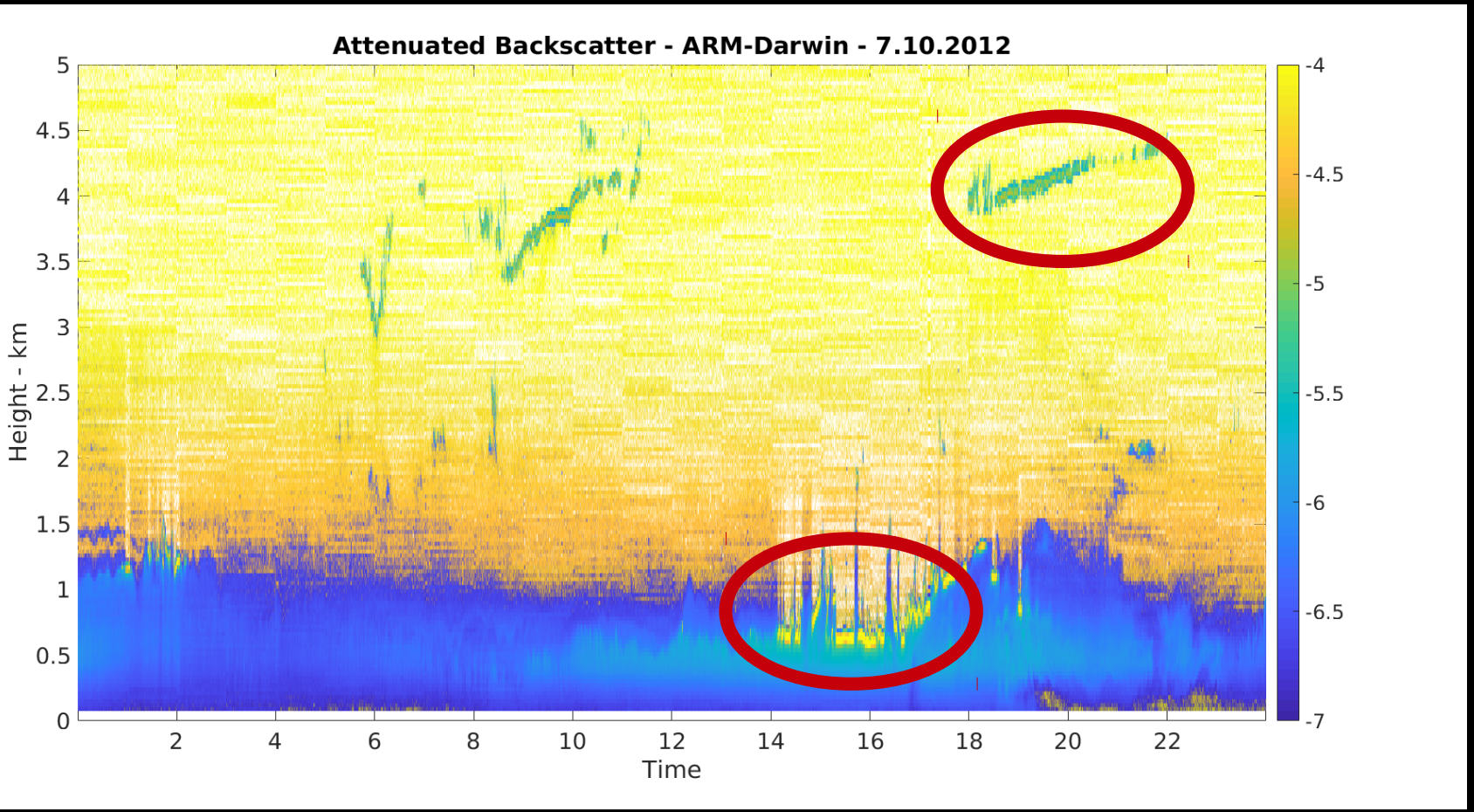
Impact of focus



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Telescope focus function

- The telescope focus can be modified
  - From infinity to 200 m
- We have an analytical expression for the function
- Two important variables – Focus and lens diameter
  - Note that the apparent focus differs from the actual telescope focus
    - Estimation by eye can be inaccurate

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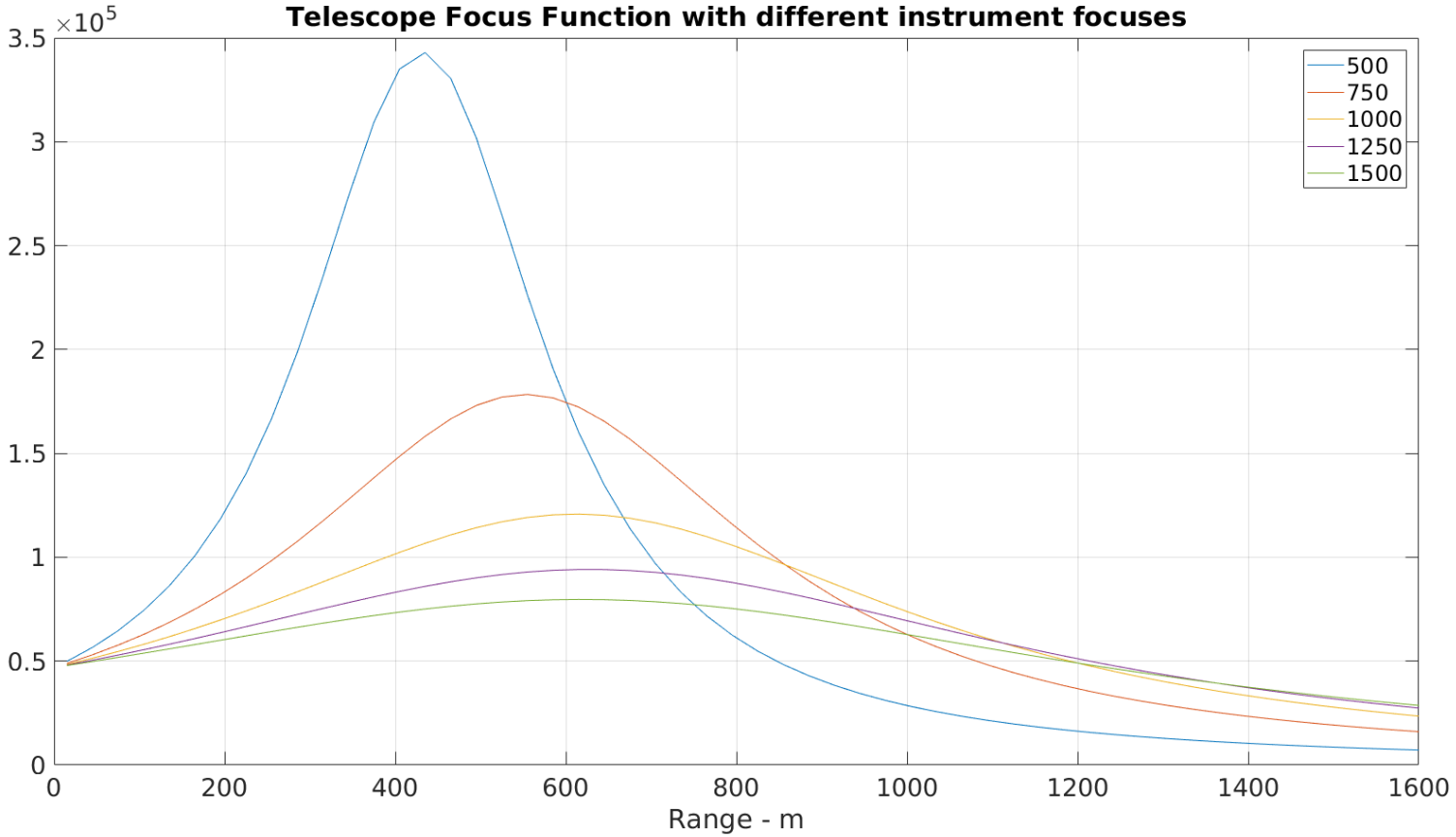
Same lens diameter – 7 cm



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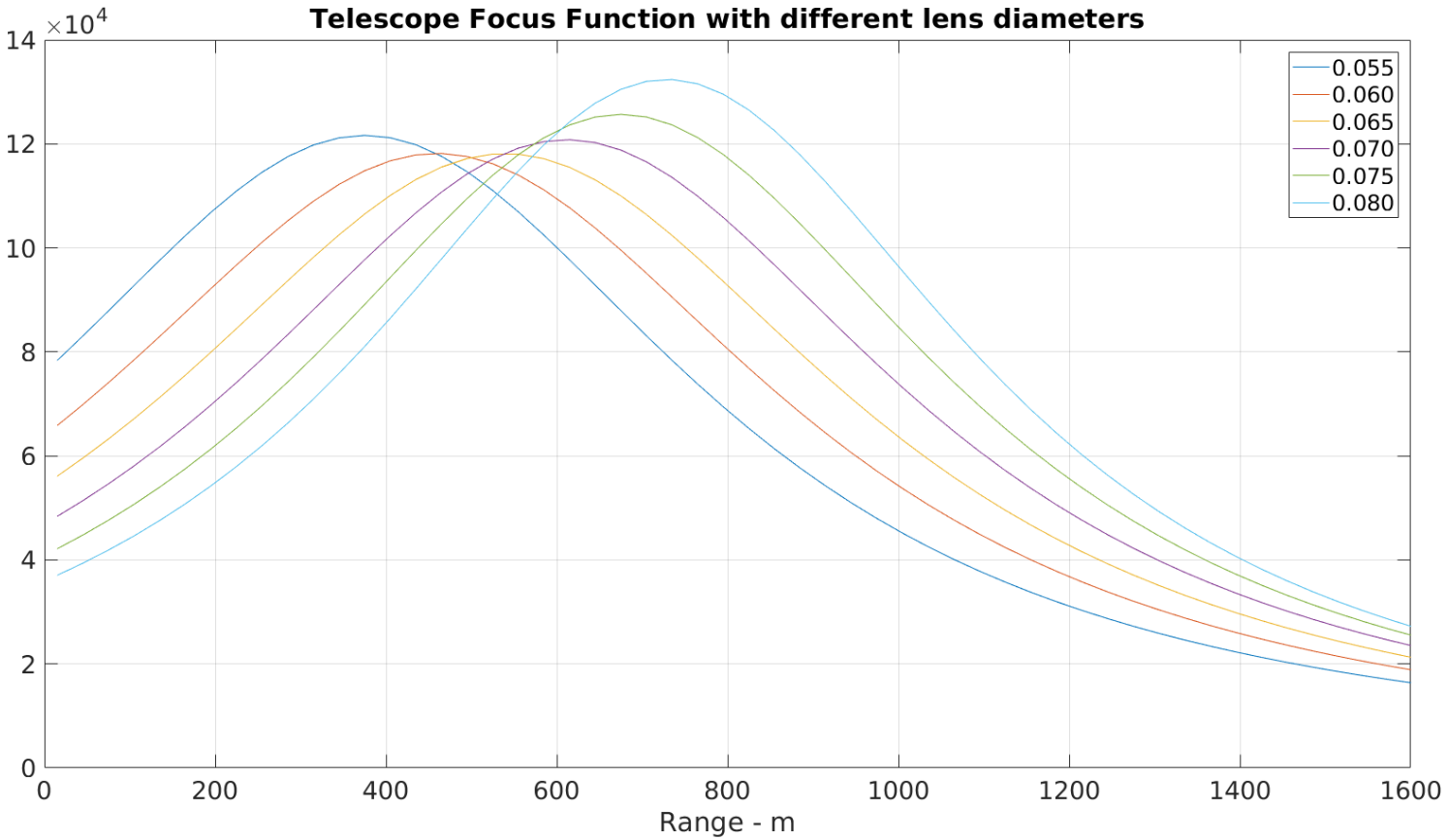
Same focus – 1 km



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Motivation

- We want to estimate the two parameters of the function
  - Obtain telescope function $T_f(r)$
  - Obtain attenuated backscatter profile
    - $\beta'(r) = C\, S(r)\, T_f(r)$
- Understand how variable these parameters are
  - Uncertainty in telescope function
    - Uncertainty in attenuated backscatter profile

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Method for deriving $T_f(r)$

- Compare DL to a collocated Ceilometer
  - Profile shape, not absolute values
  - Don’t require absolutely calibrated ceilometer
- Filter out all profiles not suitable for comparison
  - Profiles with precipitation, clouds, layered situations
  - Profiles without enough signal
- Iteratively correct the DL profile with all possible parameter combinations in our search space
- Select the parameters that create the best fit

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Why not just the ceilometer?

- Obtain uncertainties
- Correct scanning data
- Possibility to remove the ceilometer after $T_f(r)$ is known
- Dual wavelength data on precipitation and clouds

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Longer timeseries

- More reliable estimation of uncertainties
- Observe how much do $T_f(r)$ parameters vary
- Detect changes in the instrument settings, instrument swap, or instrument issues

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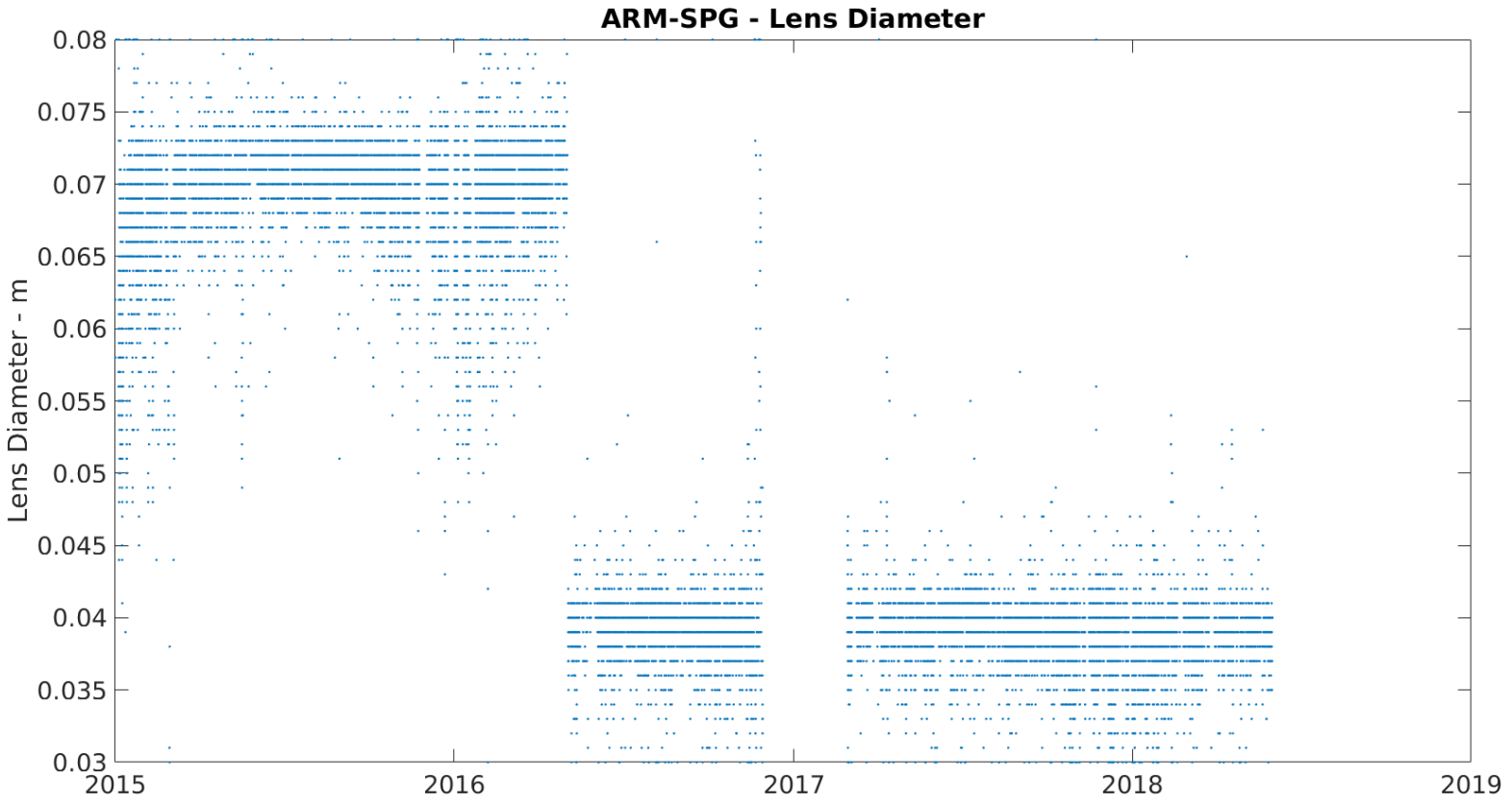
Longer timeseries



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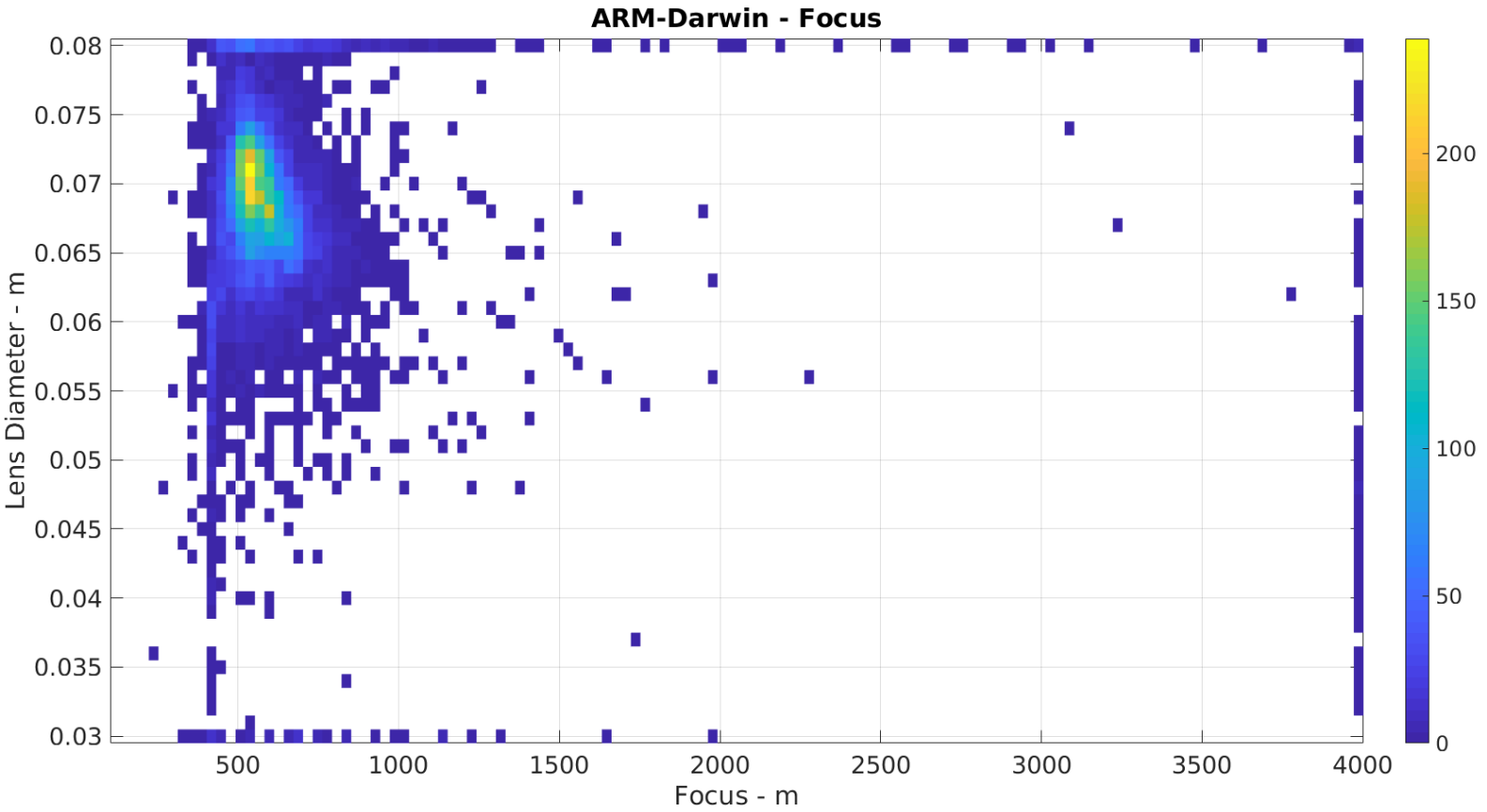
Generate 2-D histograms



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Uncertainty estimates

- Parameter variance from histograms
  - Explain parameter uncertainty
  - Assume Gaussian and orthogonal
- Uncertainty in telescope function
  - Propagate uncertainty
- Caution
  - Distribution not exactly Gaussian - slightly asymmetric
  - Not quite orthogonal

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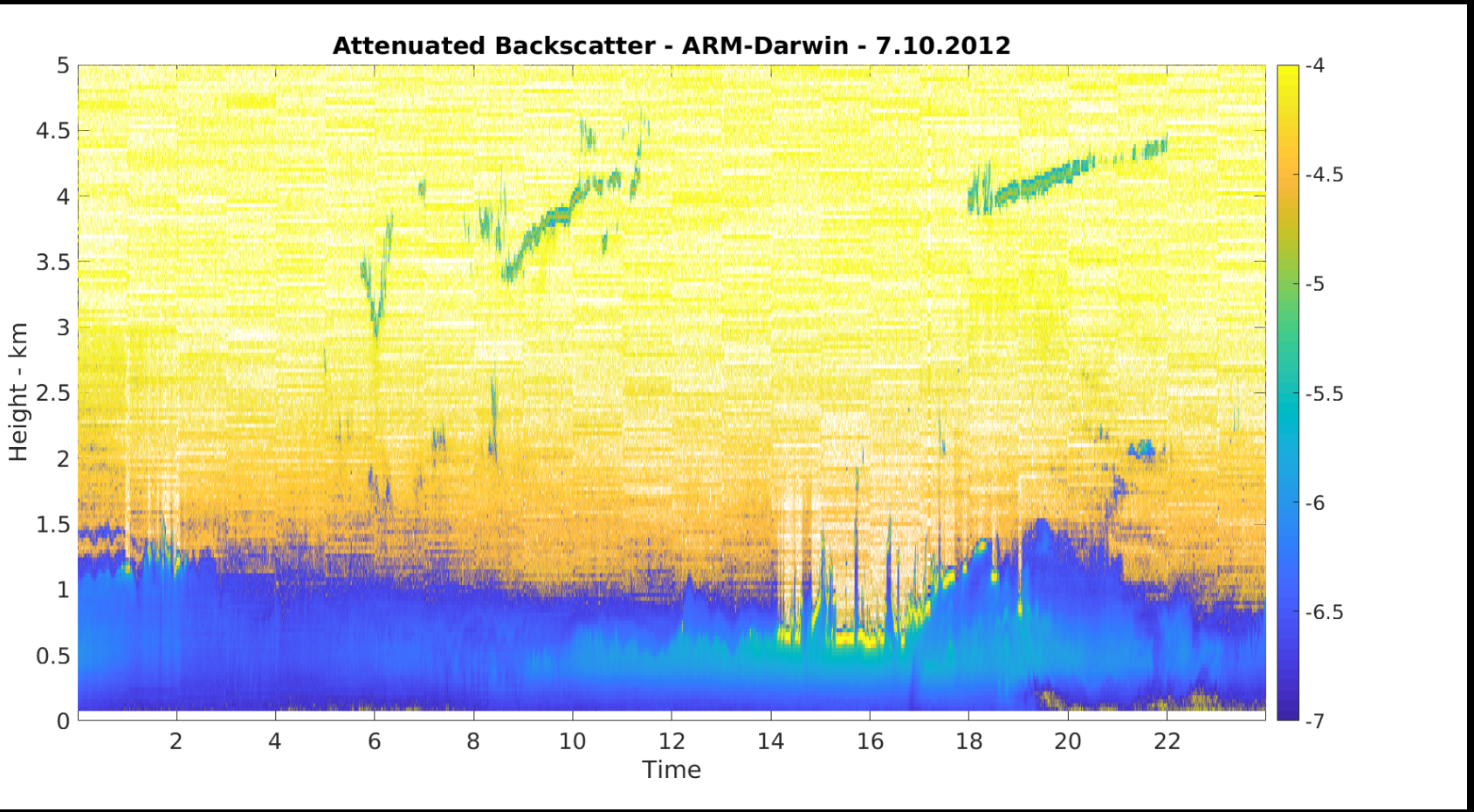
Before focus correction



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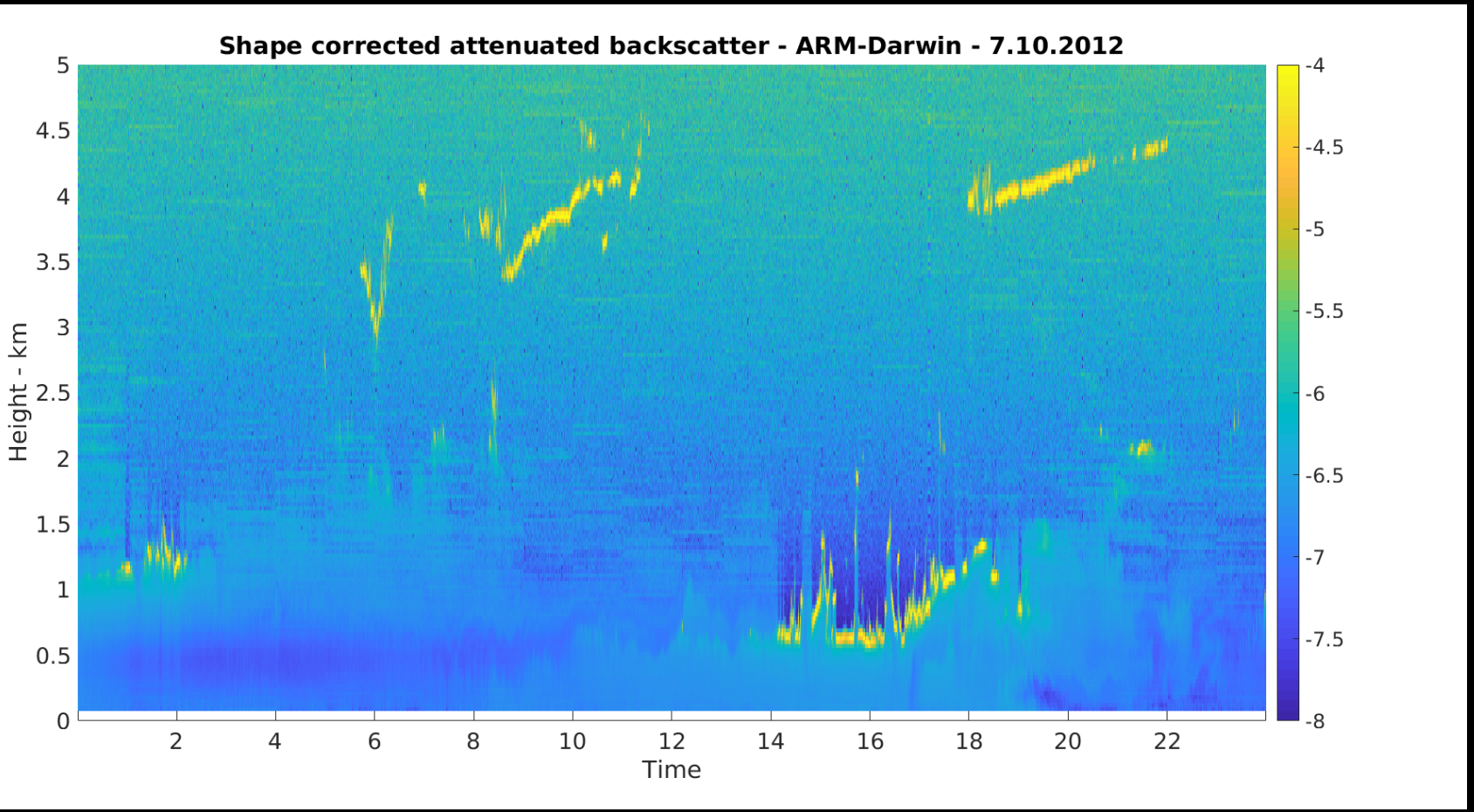
After focus correction



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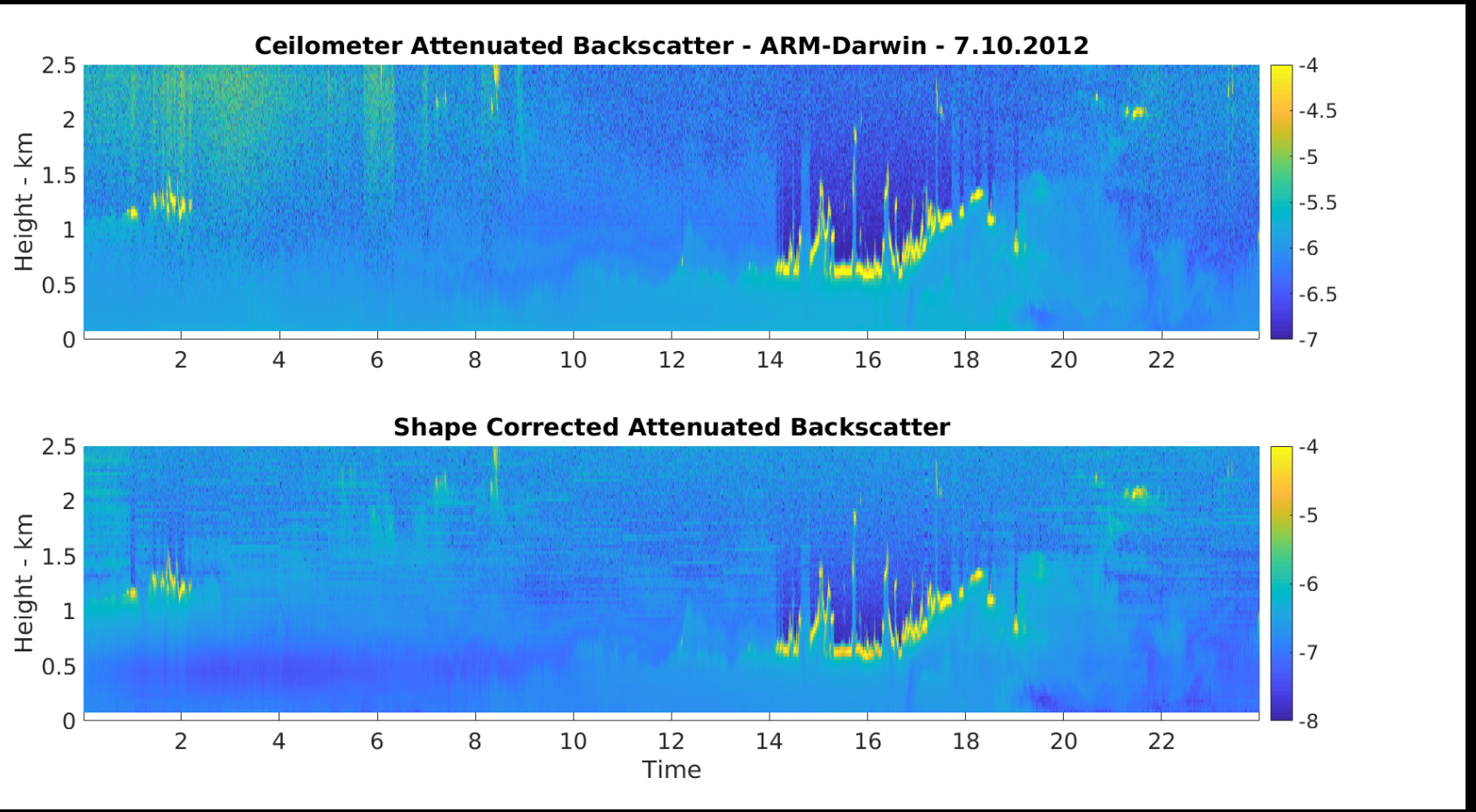

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Summary

- Method for estimating telescope focus function parameters from data
  - Provide reliable attenuated backscatter profiles
  - Provides uncertainties in $T_f(r)$
  - Detection of instrument issues or changes in settings

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