VAMP:

Part 1: requirements, constraints and construction of range bin definitions

Part 2: Mie Quality Control

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Overview

- Part 1:
  - List requirements and constraints as used for this study, which are in turn used to compose range bin definitions
  - present constructed range bin definitions
  - as is detailed in TN1
- Part 2:
  - study Mie quality control
  - based on Mie Core QC output parameters
  - as is detailed in TN3, part 1 (section 3, task 4a)

Part 1: requirements, constraints and construction of range bin definitions

Mission requirements

- wind HLOS component accuracy for the instrument itself:
  - 1 m/s below 2 km (PBL)
  - 2 m/s between 2 and 16 km (free troposphere)
  - 3 m/s above 16 km (UTLS)
- accuracy including representativeness error:
  - 2 m/s below 2 km (PBL)
  - 3 m/s between 2 and 16 km (free troposphere)
  - 5 m/s above 16 km (UTLS)
- zero wind bias:
  - below 0.4 m/s
  - slope error below 0.7 %

Characteristics/constraints:

- Laser:
  - 355 nm, 100 Hz pulsed, 120 mJ pulses, Burst mode, 7 s on, 21 s off, corresponding to 50 km of data and 150 km gap, off-nadir 37.5 degree pointing
- Instrument:
  - 2 spectrometer channels named Mie (Fizeau) and Rayleigh (FP)
  - 24 atmospheric vertical rangebins, programmable during the mission
  - max. altitude of 31.7 km, max. separation between sampling top of both channels 16 km, bin size between 250 m and 2 km (in steps of 250 m)
  - range bin definition may change 8 times per orbit (pre-programmed, can only be updated once a week)

Calibration:

- spectrometer calibration (MRC, RRC)
  - assumed perfect (these have no consequence for rangebin definitions in wind mode)
- zero wind calibration (ZWC)
  - seems mainly possible above ice/snow and deserts
  - quality largely depends on stability of pointing of the system, accumulation of several orbits gives more precise results
  - several rangebins at and below the surface need to be reserved for this type of calibration
  - idea: don't try to get ground echos in cases with low albedo (above oceans!)
  - Mie ZWC has better quality than Rayleigh ZWC, so no ground echos needed for Rayleigh channel

Spectrometer constraints:

- Mie channel:
  - large rangebins give large height assignment errors
  - overlap with Rayleigh channel needed to allow correction and detection of cross-talk and extinction
  - lowest Mie bin needs to be at least 1 bin below lowest Rayleigh bin
- Rayleigh channel:
  - rangebin size needs to be at least 1 km (below 16 km), 1.5 km (between 16 and 28 km), and 2 km (above 28 km) to obtain sufficient signal levels in clean atmospheres
  - overlap with Mie needed to easier detect cross-talk and extinction
  - oversampling with Mie desired to get better height assignment

Atmosphere characteristics/constraints:

- the altitude of the highest common cloud type (cirrus) varies with climate zone and season
- the altitude of the tropopause, and the jets vary as well
- PSCs occur only in polar regions
- range bin definitions may be modified to adapt to these atmospheric properties

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Range bin definitions:

- reference range bin definitions (available before start of VAMP)
  - Default (provided by the E2S), WVM1, WVM2 (provided by ESA)
- alternative definitions oversampling the PBL
  - WVM_tr_zwc, WVM_et_zwc, WVM_tr_nozwc, WVM_et_nozwc
- alternative definitions oversampling the jet level
  - WVM_tr_zwc2, WVM_et_zwc2, WVM_tr_nozwc2, WVM_et_nozwc2
- modified versions of PBL and jet level oversampled definitions
  - needed because it was found that minimum Rayleigh rangebin size should be 1 km to yield sufficient signal
  - same names, but appended with "_1km"
- a stratosphere scenario
  - WVM_stratos (reaching upto 36.5 km)

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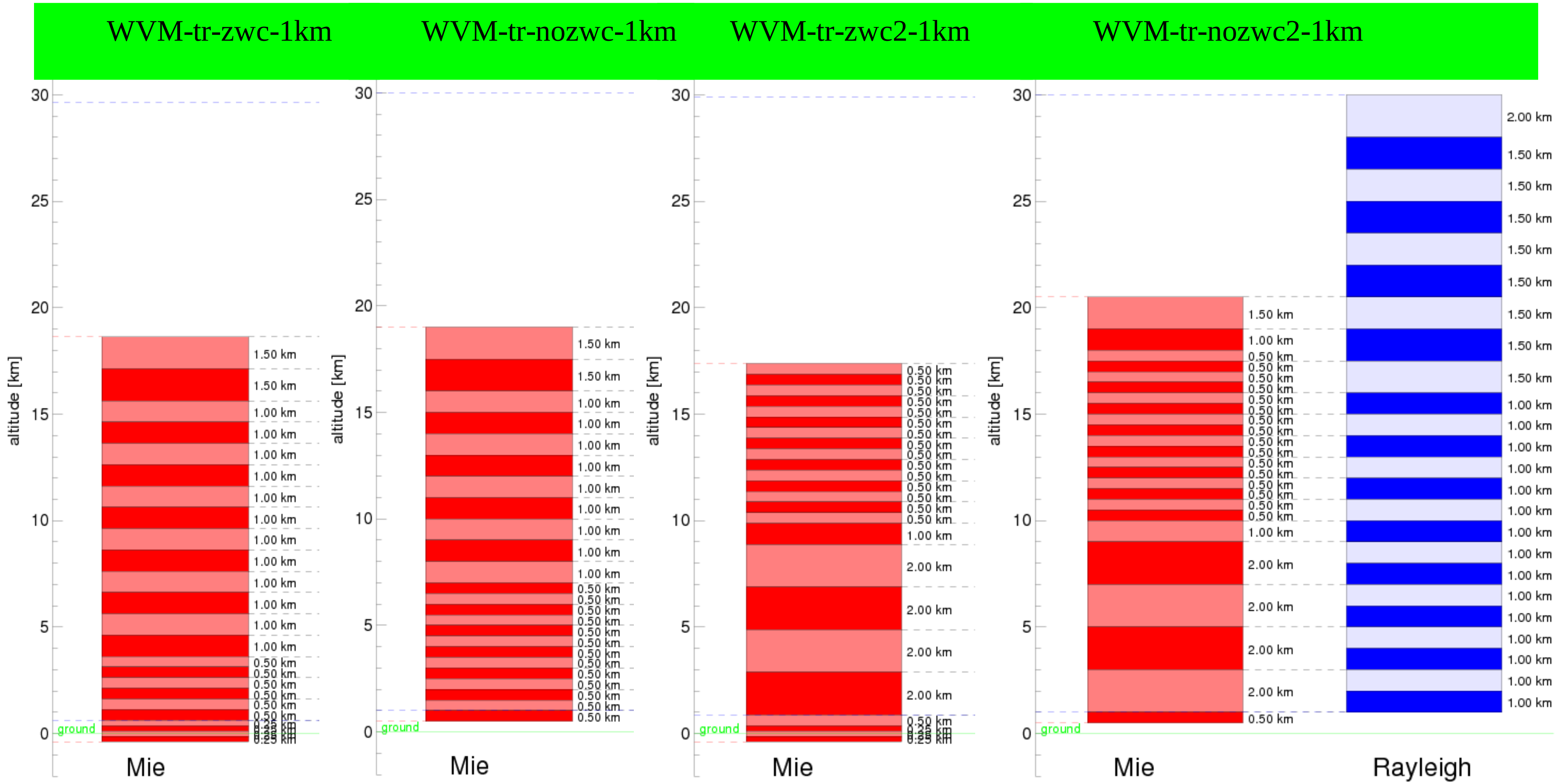
Range bin definition: tropics



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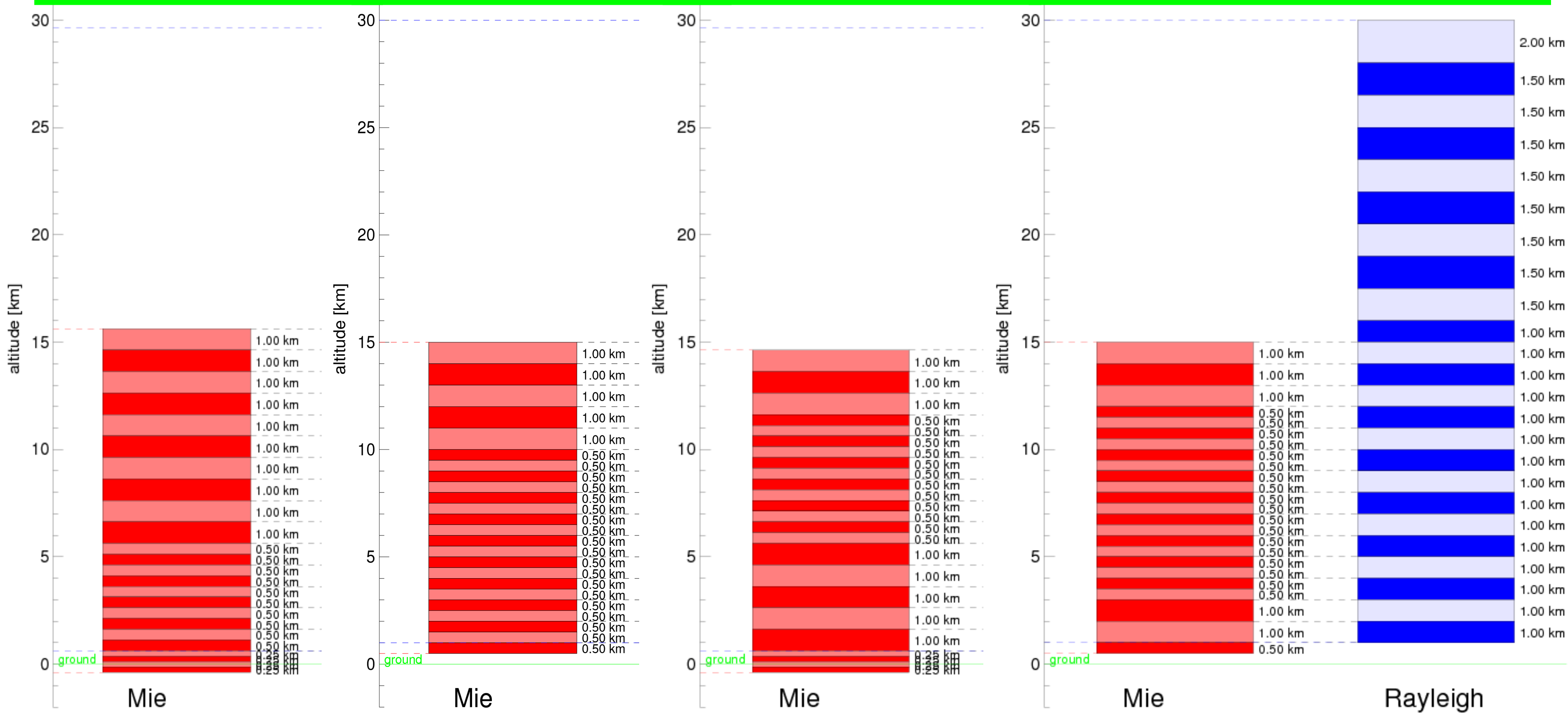
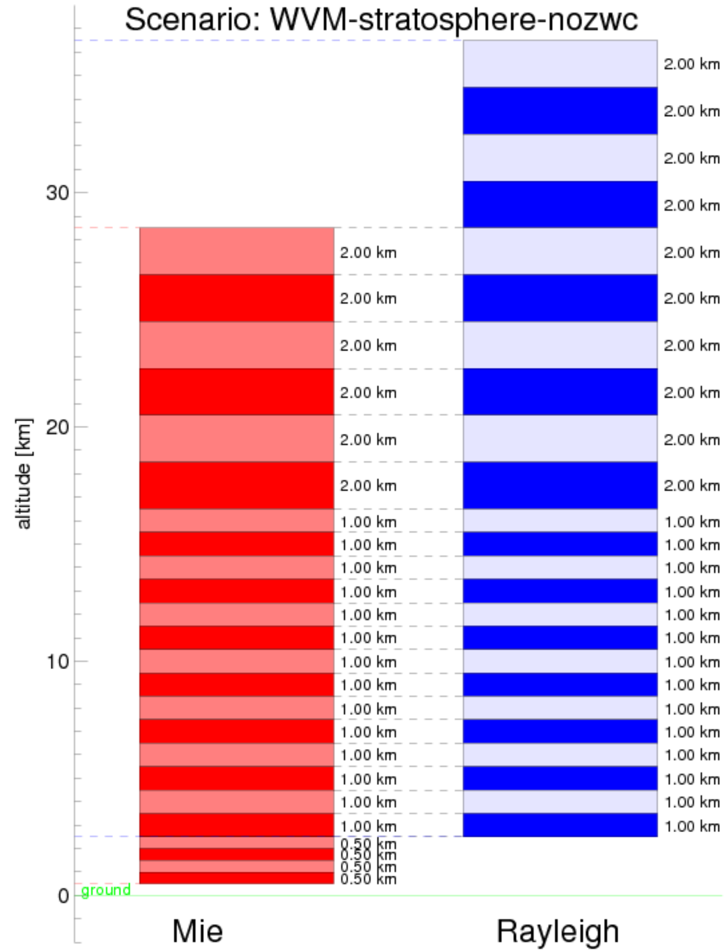
Range bin definition: extra-tropics

WVM-et-zwc-1km	WVM-et-nozwc-1km	WVM-et-zwc2-1km	WVM-et-nozwc2-1km



Range bin definition: stratospheric



Main question:

- So now we have a nice set of different range bin definitions for our mission, but the question still is which ones to use in which conditions?
- the remaining work packages focus on answering this question

Recommendations:

- In future missions range bin definitions should be more flexible:
  - remove artificial limitations on maximum altitude (31.7 km) and channel separation (16 km) and investigate what the requirement should be in that region (possibly 3 m/s is too strict here)
  - allow larger rangebins. This would allow use of Rayleigh bins at higher altitudes (stratosphere). Also it would allow to check the upper Rayleigh bins for cross-talk
  - allow for more Mie range bins (125 m bins upto 20 km, then 1 or 2 bins of 6 km or so to cover the remaining Rayleigh bins, so about 162 range bins in total). This would improve height assignment significantly.
  - don't implement limitations like "lowest Mie bin needs to be at least 1 bin below lowest Rayleigh bin" in future missions

Part 2: Mie Quality Control

Mie channel quality control

- wind retrieval on the Mie channel spectrometer results is done by curve-fitting:
  - spectral peak should have a Gaussian shape but needs to be convoluted with the Airy shaped transmission function of the spectrometer
  - in stead the spectrum is fitted to a simple Lorenzian curve using downhill-simplex method
  - this yields some fitting parameters that can be used for quality control (residual error, FWHM, number of iterations)
  - in addition a signal to noise ratio (SNR) is calculated which is considered for quality control as well
  - these parameters can then be used to apply data selection to improve the data quality in a statistical way, it will not fix any systematic problems (biases)

Simulation setup

- A dedicated tool in Fortran was written to study the Mie Core retrieval algorithm by taking all essential algorithms from the E2S simulator software and converting them to Fortran
- As input data we used 10 half orbits (night time) of CALIPSO backscatter data collocated with ECMWF model winds
- The error multiplier method as described later by K. Houchi was used to add more variability to the smooth model wind profiles
- poisson noise and realistic signal levels have been added, but issues like mispointing and spectrometer calibration have been ignored (assumed perfect)
- vertical sub-bin sampling was applied to simulate effects of height assignment and wind shear

Observations (1)

- Several issues where found during construction of the simulation
  - a preliminary test using LITE data clearly showed that the algorithm can produce wrong results if signals levels are too high (this causes an integer overflow and deformes the spectral shape). This issue was reported as a bug to the L1B team
  - in the final simulations the signal levels where carefully tuned to not have this issue
  - without data selection cases with very low signal dominate the results (for these cases a noise peak is fitted which can result in arbitrary wind)
  - so for all following cases a SNR threshold of 10 was applied, and only data for which the fitting algorithm reports success (Validity flag set to true) is taken into consideration

Observations (2)

- Iterations:
  - it was found that for a large fraction of the data (72%) the Mie Core algorithm does not converge, but reaches the maximum allowed number of outer loop iterations (30)
  - this is mainly caused by noise, which makes the residual error larger than the threshold, even for the best possible fit
  - after about 12 iterations no improvement is seen any more, so the iteration threshold may be set tighter without loss of quality (this may make execution of the algorithm a bit faster on average)
  - the inner loop seems properly tuned, and no improvement can be expected by tuning its thresholds

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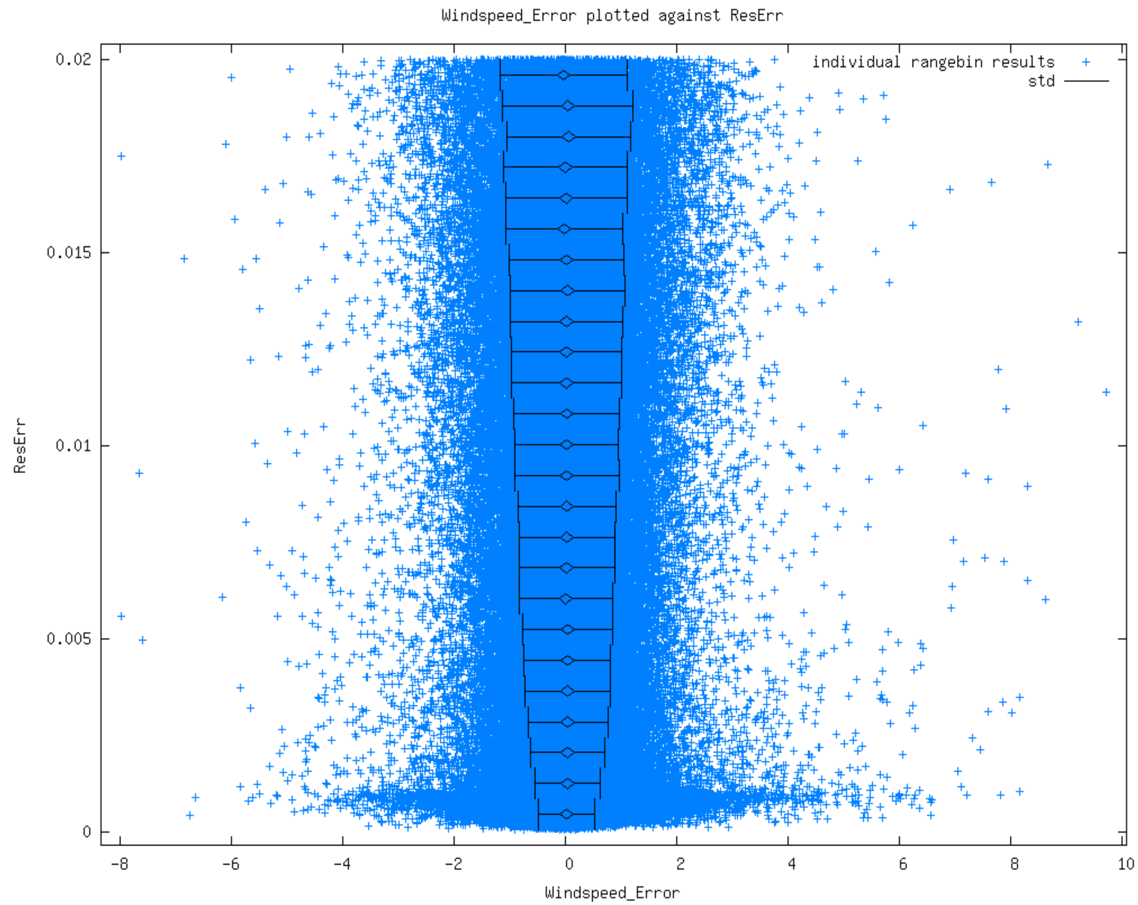
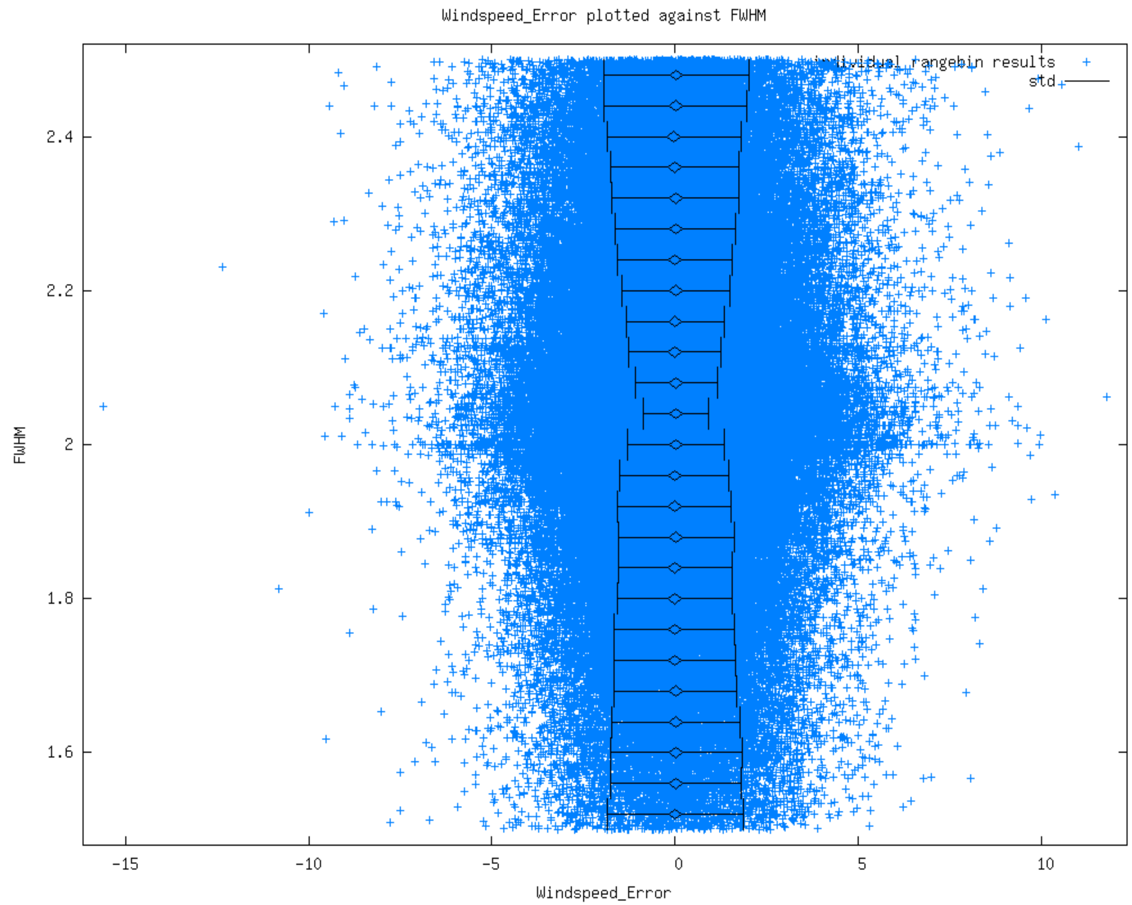
Residual error

- a clear relation between residual error and LOS wind quality was observed
- selecting data with a residual error below a certain threshold will clearly decrease the overall LOS wind error



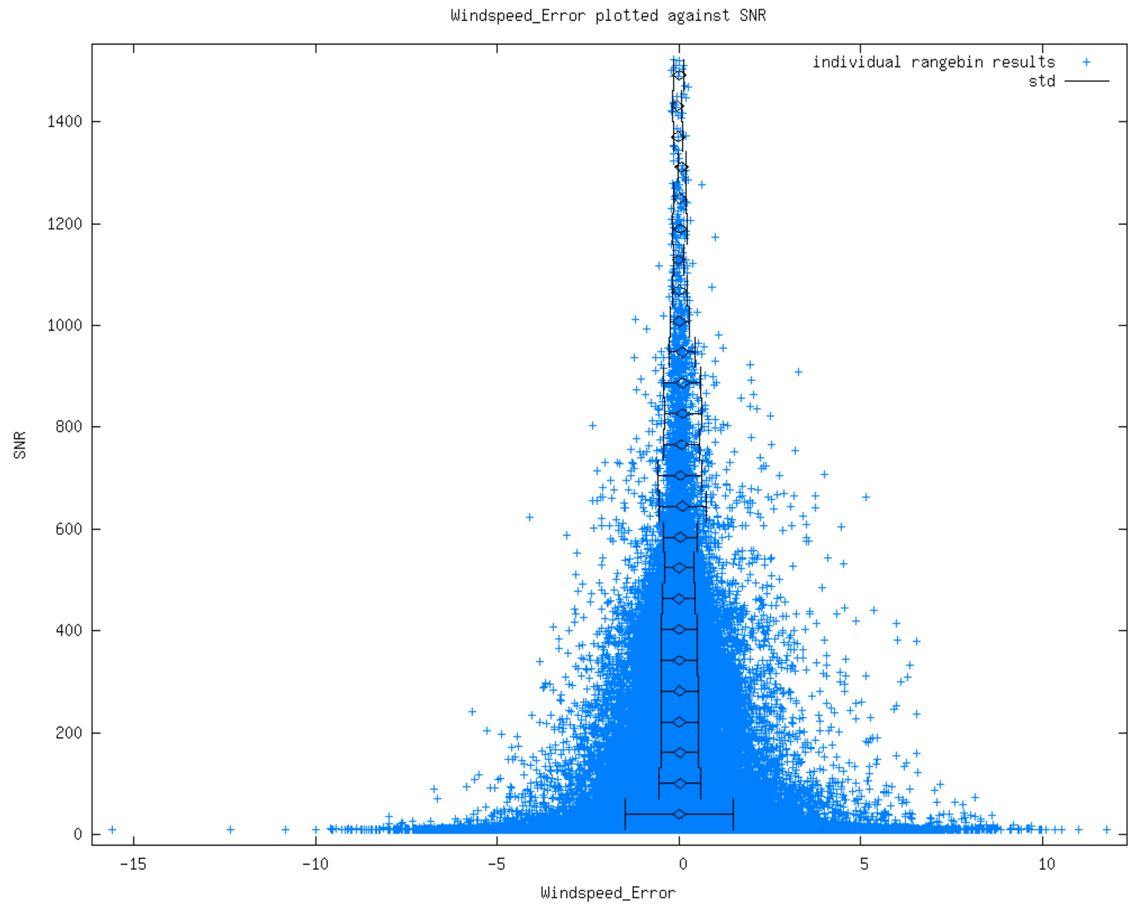
FWHM

- also a clear relation between FWHM and LOS wind quality was observed
- an optimum quality occurs close to FWHM=2.05
- selecting data now takes 2 thresholds



SNR

- finally also a strong relation between SNR and LOS wind quality is present in the data



Threshold example

Applied thresholds	nr of datapoints left	percentage	std in wind velocity error
SNR>10, ValFlag set	468781	100%	1.266 m/s
SNR>10, ValFlag set, ResErr<0.013	239624	51%	0.651 m/s
SNR>10, ValFlag set, 1.78<FWHM<2.34	433926	93%	1.215 m/s
SNR>10, ValFlag set, 2.026<FWHM<2.051	111360	24%	0.842 m/s
SNR>10, ValFlag set, 1.78<FWHM<2.34, ResErr<0.013	238117	51%	0.648 m/s
SNR>10, ValFlag set, 2.026<FWHM<2.051, ResErr<0.013	91240	19.5%	0.547 m/s

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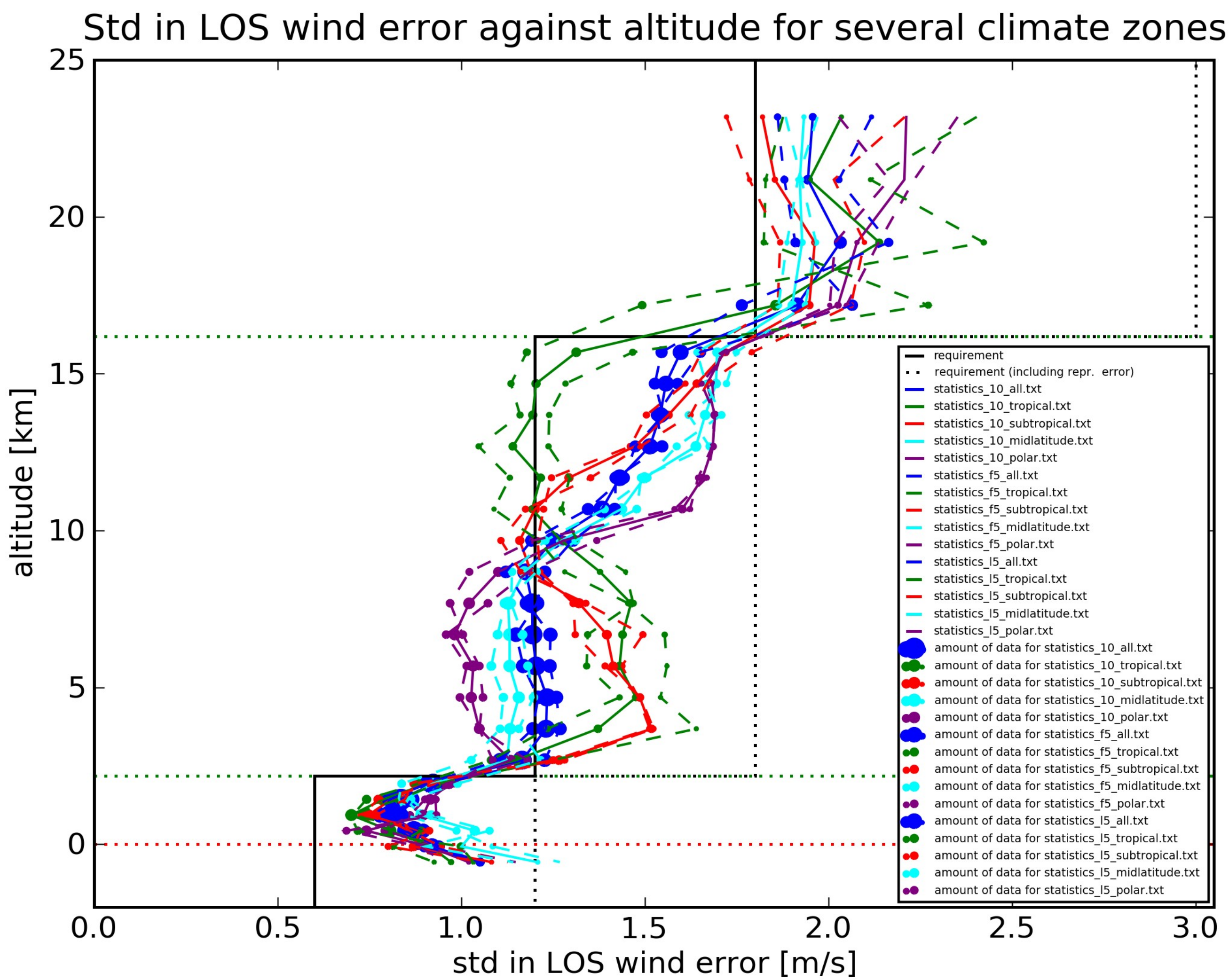
Altitude variation of quality



Which parameter to use for data selection?

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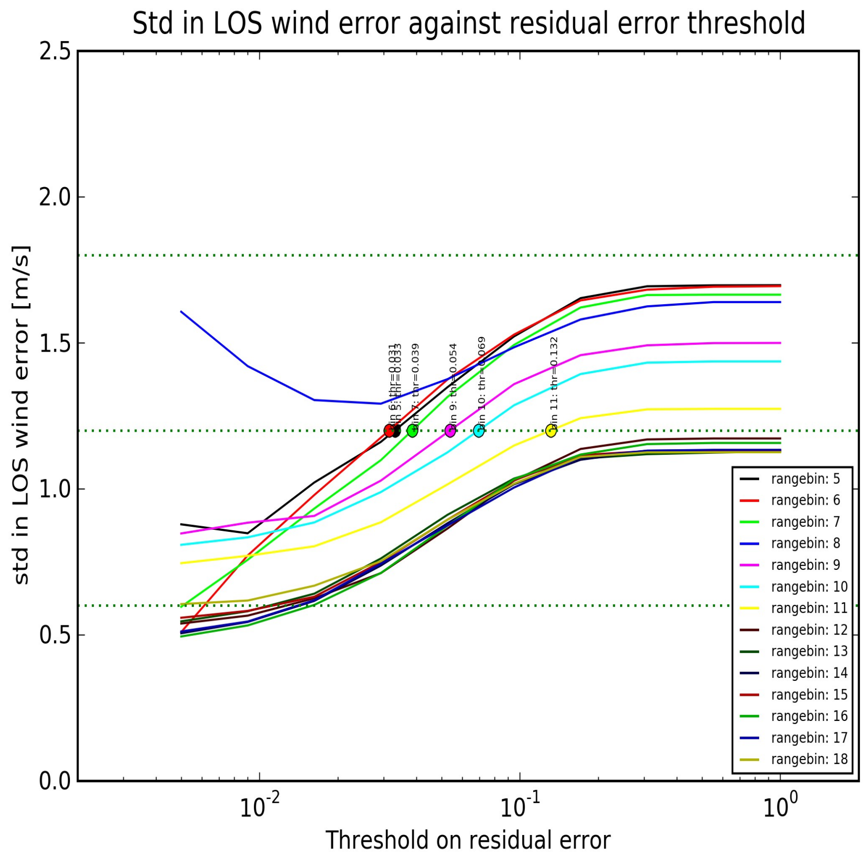
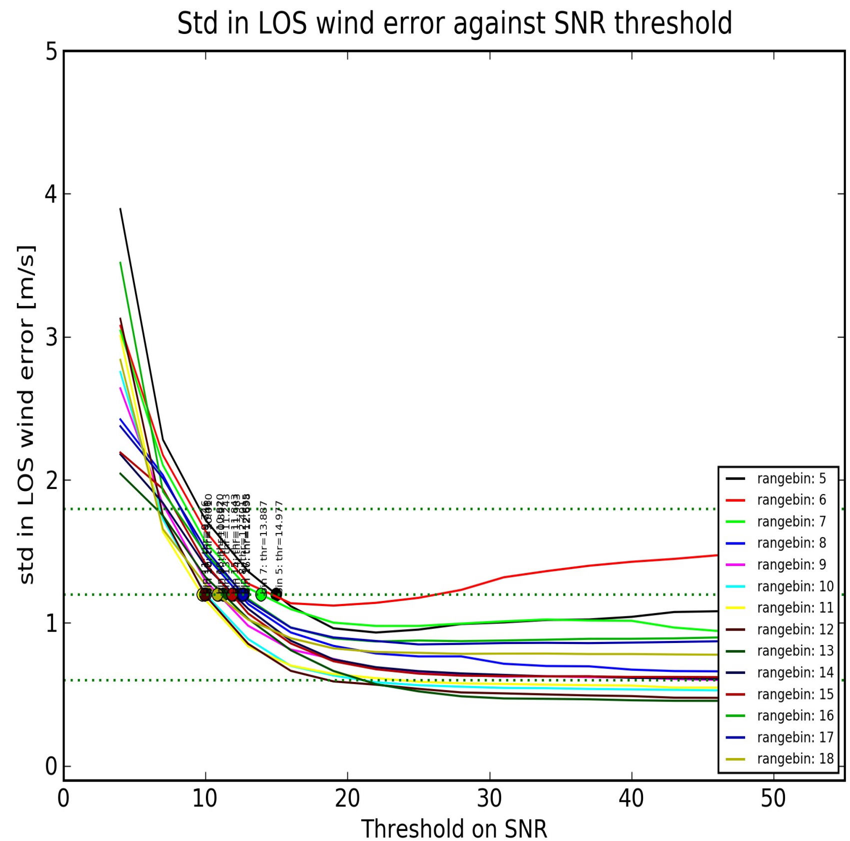
- SNR most suitable thanks to its exponential relation to std.dev





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Conclusions/Recommendations (1)

- placing a threshold on SNR seems most suitable to select data to reach a desired quality, and in any case to block nonsense results only SNR values above 10 should be used
- only data with Validity Flag set (so successful fits) should be used
- thresholds for data selection may vary with altitude, and the requirements imposed for that altitude. Therefore it is recommended to use at least 3 different values (this has been communicated to the L2B team)
- the maximum number of outer loop iterations can safely be lowered to about 12
- inner loop thresholds need no threshold tuning

Conclusions/Recommendations (2)

- the SNR and fit results should be made available in the product file to allow the user to choose a non-nominal quality level
- the effort to determine suitable thresholds should be continued on actual measurements during the Cal-Val and operational phase of the mission

- finally it should be investigated whether it is possible to derive the Rayleigh peak width from the background signal in the Mie channel, combined with both Rayleigh channels
  - this would allow for more QC options (checks on Rayleigh peak broadening would become possible)

The end