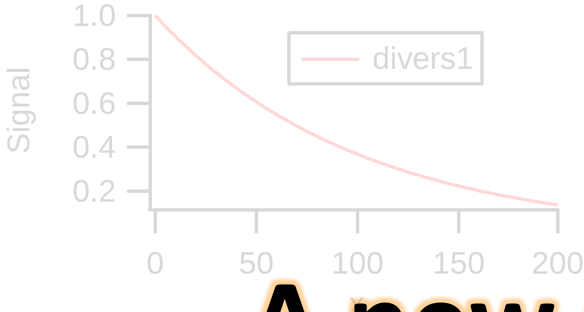
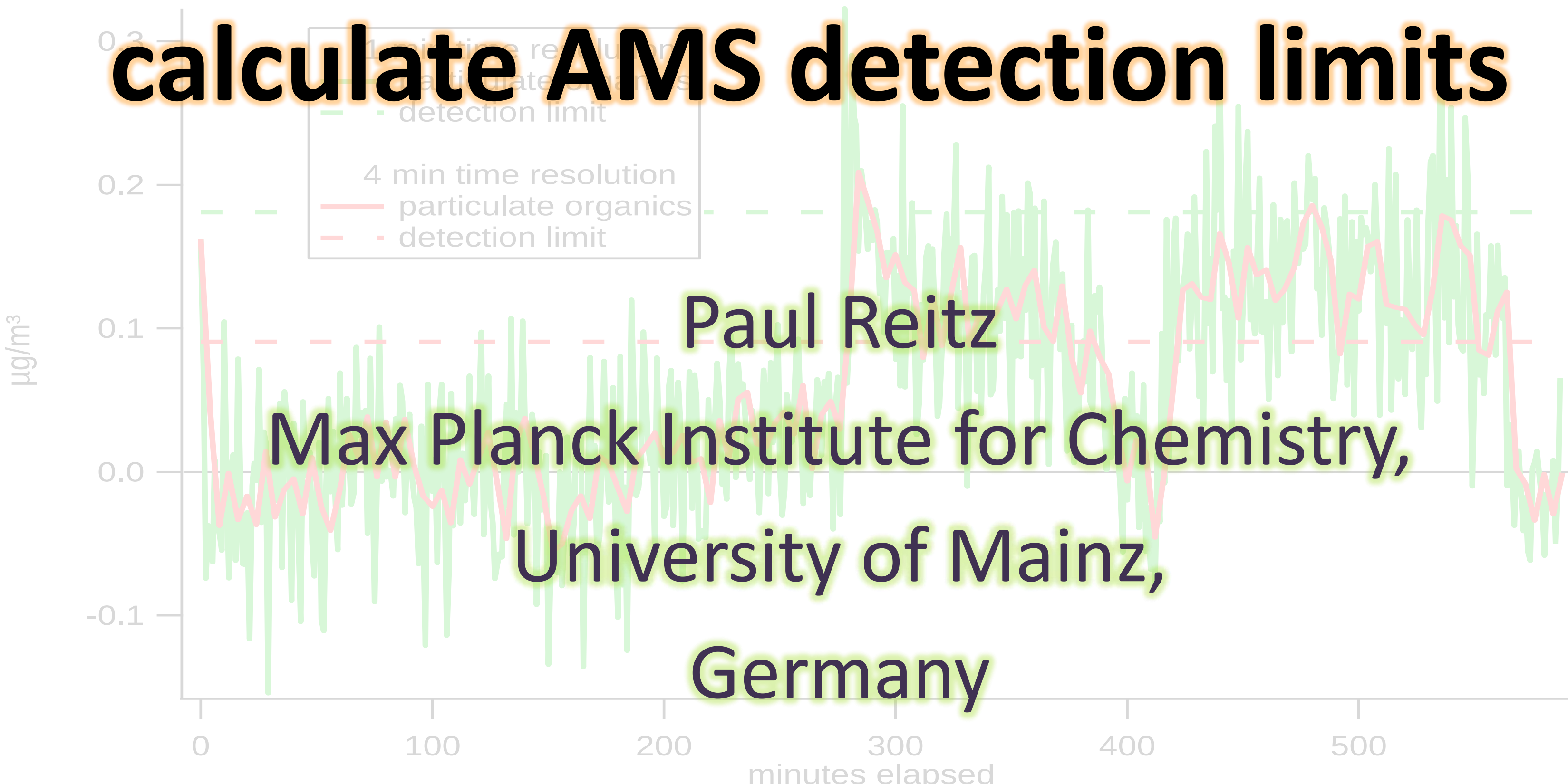


$$\sigma = \sqrt{\frac{18}{35}\frac{1}{N-5}\sum_{i=2}^{N-3}\left(F_i - \frac{2}{3}F_{i-1} + \frac{1}{6}F_{i-2} - \frac{2}{3}F_{i+1} + \frac{1}{6}F_{i+2}\right)^2}$$

A new and easy method to calculate AMS detection limits



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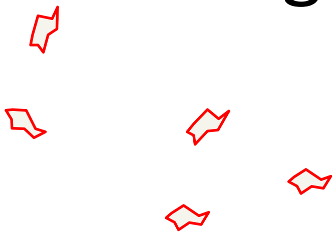
Overview

- Motivation
- Principle of work
- Test results

Motivation

- Detection limits are important when measuring:
  - in remote areas
  - thin coatings in the lab

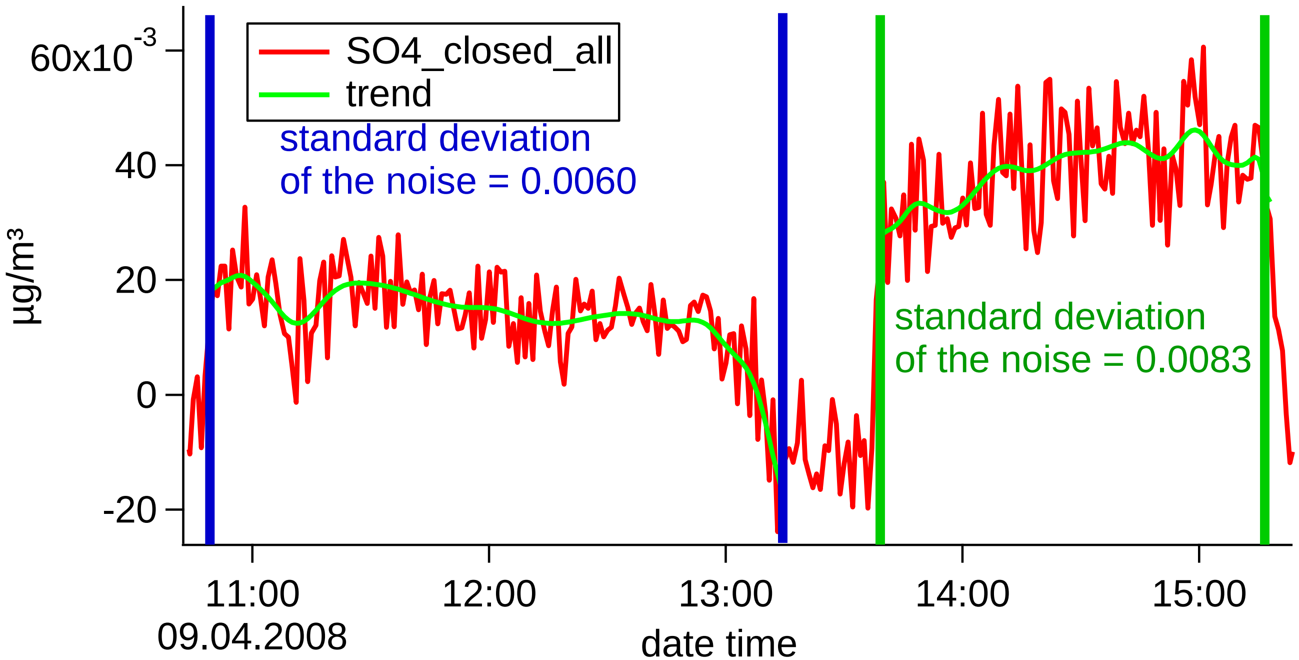


- Classic (e.g.: Allan et al, Bahreini et al.): estimation via counting statistics
  or:
  3 x standard deviation of filter measurement
- New: From the noise of the closed signal during regular measurements (Drewnick et al. AMT 2009):

$$3 \times \sqrt{2} \times standard\ deviation\ of\ closed\ signal\ noise$$

Motivation

- Detection limits are dependent on instrument history => detection limit during the filter period is often different from the one during a certain measurement. => the new method is preferable



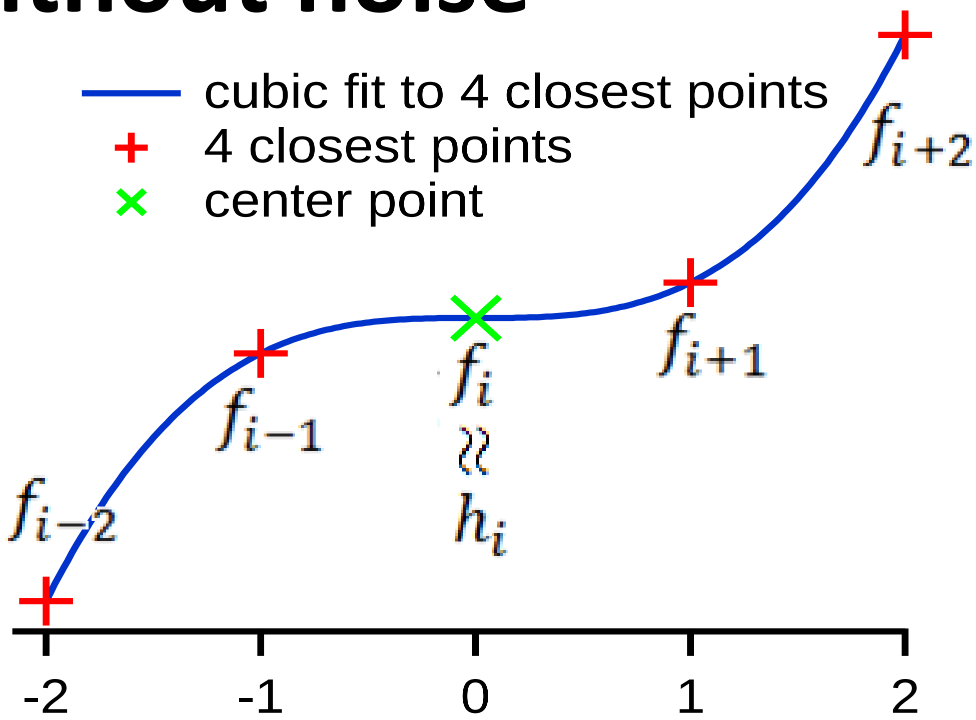
Problem: long scale variations in closed signal

=> <u>Standard deviation cannot be calculated directly</u>

Principle of work

- Requirements:
  - Noise varies on a much shorter time scale than the closed signal without noise ✔
  - Closed signal is reasonably smooth (✔)
  - Time series has equidistant time steps (✔)
- Step 1: Combine adjacent points to an expression which is only constituted of the noise.
- Step2: Combine these terms to an expression that is proportional to the standard deviation of the noise.

Ideal case without noise



f_i: Ideal closed signal

Interpolated point

$$h_i = \frac{2}{3} f_{i-1} - \frac{1}{6} f_{i-2} + \frac{2}{3} f_{i+1} - \frac{1}{6} f_{i+2}$$

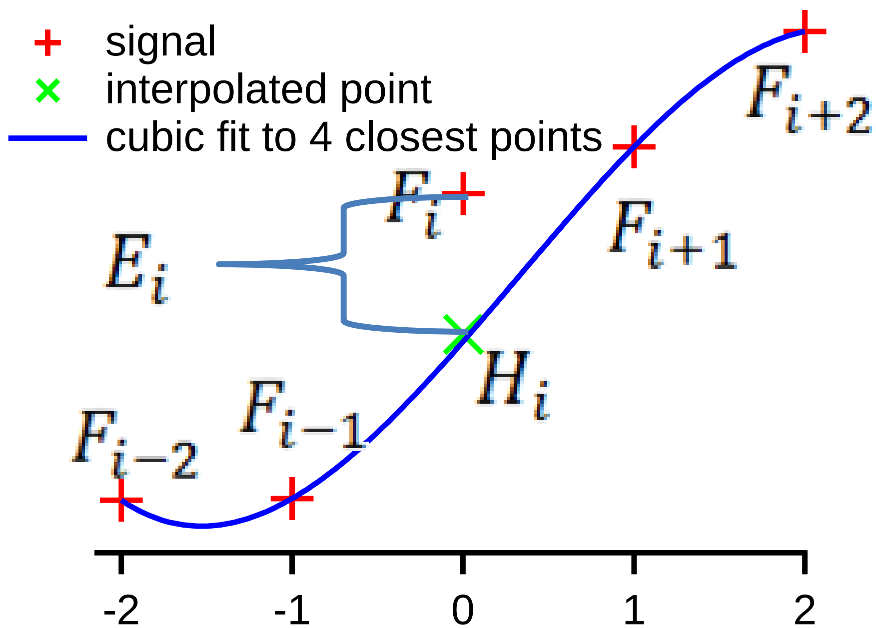
$$f_i - h_i \approx 0$$

Step 1

Realistic case with noise

Real closed signal → F_i ; **noise** → ε_i

$$F_i = f_i + \varepsilon_i$$



$$E_i = F_i - H_i$$

$$E_i \approx \varepsilon_i - \frac{2}{3}\varepsilon_{i-1} + \frac{1}{6}\varepsilon_{i-2} - \frac{2}{3}\varepsilon_{i+1} + \frac{1}{6}\varepsilon_{i+2}$$

E_i depends only on the noise

Step 2

Standard deviation: $\sigma = \sqrt{\frac{1}{n-1}\sum_{i=0}^{n-1}\varepsilon_i^2}$

Similar sum with E_i^2: $R := \sqrt{\frac{1}{(N-4)-1}\sum_{i=2}^{N-3}E_i^2}$

After some calculation: $R \approx \sqrt{\frac{35}{18}}\sigma$

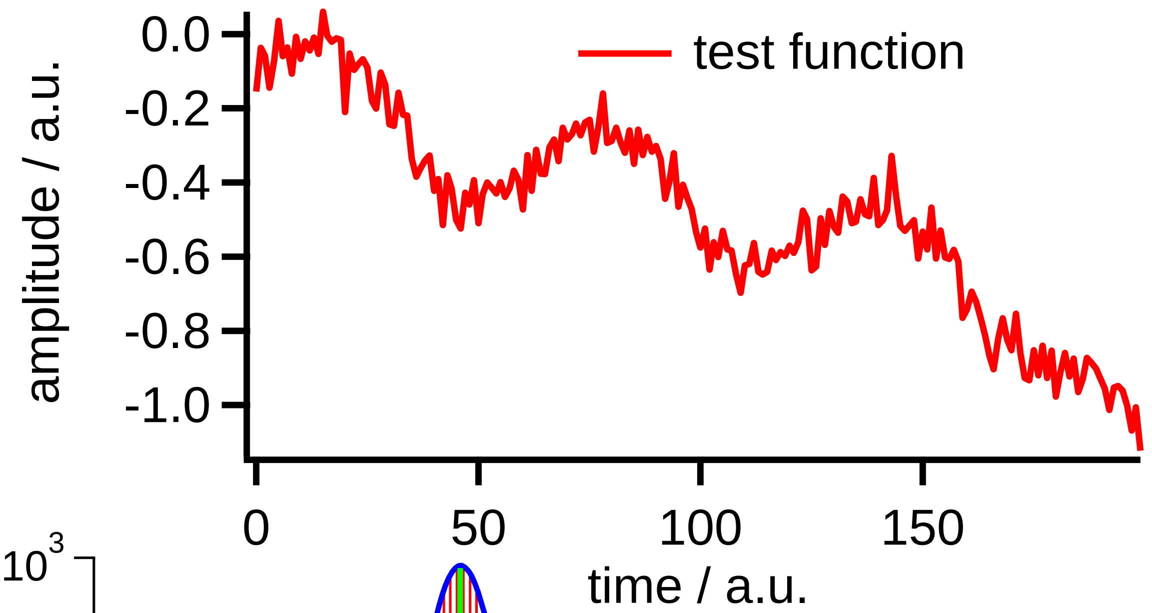
The formula

After replacing E_i in R,
inserting F_i and H_i in E_i
and inserting F_i in H_i,
we finally get the standard deviation
as a function of the measured values F_i

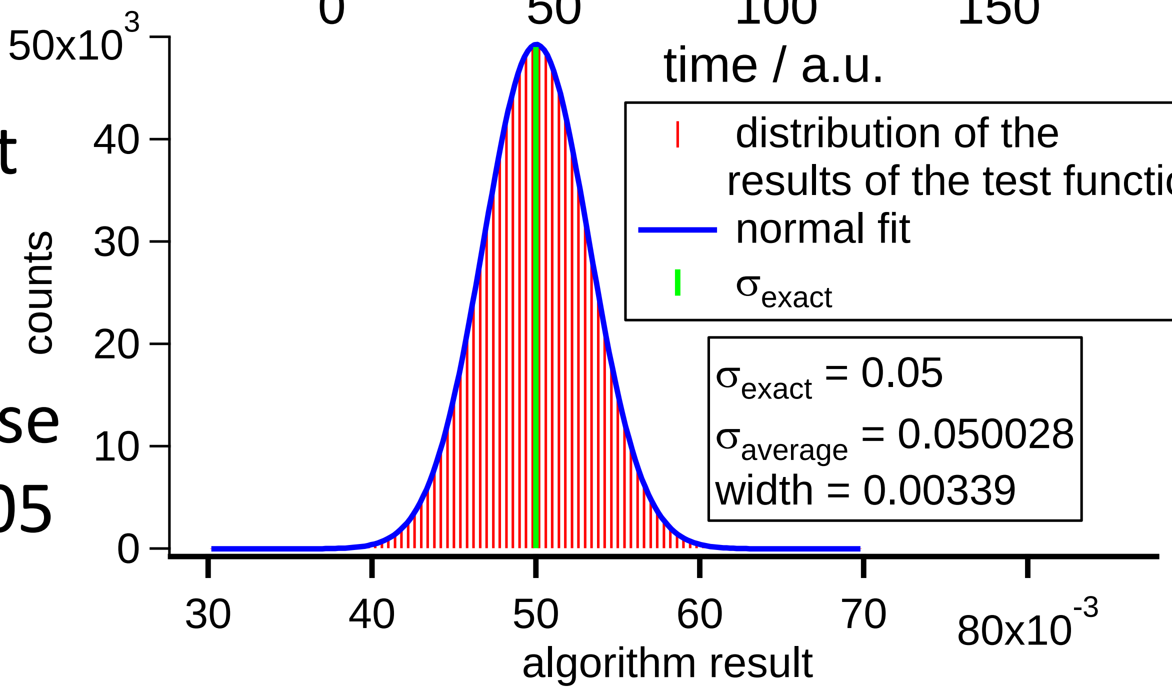
$$\sigma = \sqrt{\frac{18}{35}\frac{1}{N-5}\sum_{i=2}^{N-3}\left(F_i - \frac{2}{3}F_{i-1} + \frac{1}{6}F_{i-2} - \frac{2}{3}F_{i+1} + \frac{1}{6}F_{i+2}\right)^2}$$

Test

Test:
Add random noise of known standard deviation (0.05) on different signals and use the algorithm on it.



Result of 100,000 test runs:
Same signal wave
100,000 different noise waves with sdev = 0.05



Conclusion

- With this new algorithm now it is possible to get experimental detection limits during regular measurement:
  - With sufficient precision (if period has more than 50 points)
  - Without loosing measurement time for filter periods
  - Without falsification of the detection limit due to changed background during filter measurement

Igor procedure will be available!

Paper with detailed description in preparation for Atmospheric Measurement Techniques

Thank You For Your Attention