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Application of Allan Deviation to Assessing Uncertainties of Continuous-measurement Instruments, and Optimizing Calibration Schemes

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Technological advancement of instrumentation in atmospheric and other geoscience disciplines over the past decade has lead to a shift from discrete sample analysis to continuous, in-situ monitoring. Standard error analysis used for discrete measurements is not sufficient to assess and compare the error contribution of noise and drift from continuous-measurement instruments, and a different statistical analysis approach should be applied. The Allan standard deviation analysis technique developed for atomic clock stability assessment by David W. Allan [1] can be effectively and gainfully applied to continuous measurement instruments. As an example, P. Werle et al has applied these techniques to look at signal averaging for atmospheric monitoring by Tunable Diode-Laser Absorption Spectroscopy (TDLAS) [2]. This presentation will build on, and translate prior foundational publications to provide contextual definitions and guidelines for the practical application of this analysis technique to continuous scientific measurements. The specific example of a Picarro G2401 Cavity Ringdown Spectroscopy (CRDS) analyzer used for continuous, atmospheric monitoring of CO_2, CH4 and CO will be used to define the basics features the Allan deviation, assess factors affecting the analysis, and explore the time-series to Allan deviation plot translation for different types of instrument noise (white noise, linear drift, and interpolated data). In addition, the useful application of using an Allan deviation to optimize and predict the performance of different calibration schemes will be presented. Even though this presentation will use the specific example of the Picarro G2401 CRDS Analyzer for atmospheric monitoring, the objective is to present the information such that it can be successfully applied to other instrument sets and disciplines.

[1] D.W. Allan, “Statistics of Atomic Frequency Standards,” Proc, IEEE, vol. 54, pp 221-230, Feb 1966
[2] P. Werle, R. Miicke, F. Slemr, “The Limits of Signal Averaging in Atmospheric Trace-Gas Monitoring by Tunable Diode-Laser Absorption Spectroscopy (TDLAS),” Applied Physics, B57, pp 131-139, April 1993