Evaluating and Improving the Performance of the FTIR Spectrometer at the Toronto Atmospheric Observatory

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1. Background
The Fourier Transform Infrared (FTIR) spectrometer installed at the Toronto Atmospheric Observatory (TAO) is an ABB Bomem DA8 model. Six filters are installed to optimize the signal in specific spectral regions. The DA8 has an optical path difference of 250 cm resulting in a maximum spectral resolution of 0.004 cm⁻¹.

In June 2007 at the Toronto Atmospheric Observatory, MCT filter 6, which is mainly used for retrievals of O₂ but also for CINO₂, HNO₂, N₂O, CH₄ and C₂H₆, was moved into the sample compartment of the spectrometer from the external filter wheel location in order to increase the accuracy of aperture centering by having an empty slot in the filter wheel. However, this was found to have introduced channeling into the signal. This discovery led to an assessment of the signal-to-noise ratio (SNR) of eleven years of data taken with all six filters, to evaluate the quality of the data over the years. A variety of mirror scan speed and scan co-add tests were also performed in order to decrease noise levels in future measurements.

2. Signal-to-Noise Ratio (SNR) Assessment
2.1 Method
Firstly, the ranges used for the evaluation of the signal-to-noise ratios for each filter were determined. Areas of the spectrum with linear trends and no absorption lines were chosen for the purposes of doing a linear approximation later on. A MATLAB code was generated with the purpose of performing the simple calculation:

\[ \text{SNR} = \frac{P_{\text{signal}}}{P_{\text{noise}}} \]

Then, the SNR values for each measurement from the past 12 years were plotted to observe any useful trends.

2.2 Results

2.3 Discussion
From the plot of filter 6, the decrease of the signal-to-noise ratios around July 2007 can be seen. That is when channeling was introduced into the signal by moving filter 6 into the sample compartment.

The increase in the range of SNR values for filter 2 around 2011 is also evident. That change is due to a change in settings used for that filter. At that time %ADC values were systematically too low even on sunny days so the external aperture was increased from 0.5 mm to 1.0 mm with the option of varying the gain, low to high.

Since filter 2 used the same settings as filters 1 and 5, but experienced an increase in SNR values after an increase in the external aperture. Some testing will be done with filter 1 and 5 to see if the same increase can be replicated with them by increasing the aperture size from 0.5 to 1.0 mm.

There is also a general downward trend for all filters towards lower SNR values and that can be only attributed towards aging of the TAO DA8 setup given that settings and measurement procedure remained constant over the years.

3. Co-Add/Scan Speed Testing
3.1 Method
For each filter, 4 runs of 1 scan, 2 runs of 2 scans and a regular run of 4 scans at a scan speed of 0.5 cm/s were performed. Then the spectrums of the 4 single runs were averaged, and 2 double runs were averaged as well. SNR values were found for all 3 cases for each of the 6 filters. The process was then repeated at 1.0 cm/s. The values were then compared to see if any additional noise was being introduced.

During scan-speed testing, runs at 0.5 cm/s, 1.0 cm/s, 1.5 cm/s and 2.0 cm/s with 4 scans each were conducted and SNR values were measured. Then a comparison was made to see how much noise was being introduced by the quicker scan-speeds.

3.2 Results

3.3 Discussion
The testing revealed that the regular run with 4 scans yields the same SNR values as 4 averaged single scan runs. However, 4 averaged single scan runs have the advantage of manually excluding one or two runs if they were spoiled by a cloud coming in or another unforeseen circumstance.

As for scan speed tests, there is an expected decrease in signal-to-noise ratios. Retrievals are yet to be performed on all the runs to see if 1x4 and 4x1 runs are truly equal.

If an automated system were to be set up in the future, there would be a trade-off between SNR values of the scans and the number of scans. However, overall much more data could be gathered because the entire 20-minute run could no longer be spoiled by a 20-second passing cloud.

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