Solar absorption spectroscopy at the Dalhousie Atmospheric Observatory

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1. Site and instrument description

The Dalhousie Atmospheric Observatory (DAO) is located in Halifax, Nova Scotia, Canada, (44.64N, 63.59W). The primary DAO instrument is a newly refurbished version of an ABB Bomem DA8 Fourier Transform Spectrometer (FTS) and has been making solar absorption measurements since June 2011. The spectrometer is owned by the Canadian Space Agency and the electronics and software modifications have been performed at Dalhousie University. Physical changes include the replacement of the original 16-bit digitizer with a new 18-bit model, thus avoiding the need for an undesirable gain switch during scans.

The spectrometer is supported by a custom built solar tracker enclosed in a small commercial dome. The entire system can be largely operated remotely, save for liquid nitrogen supply to the detectors.

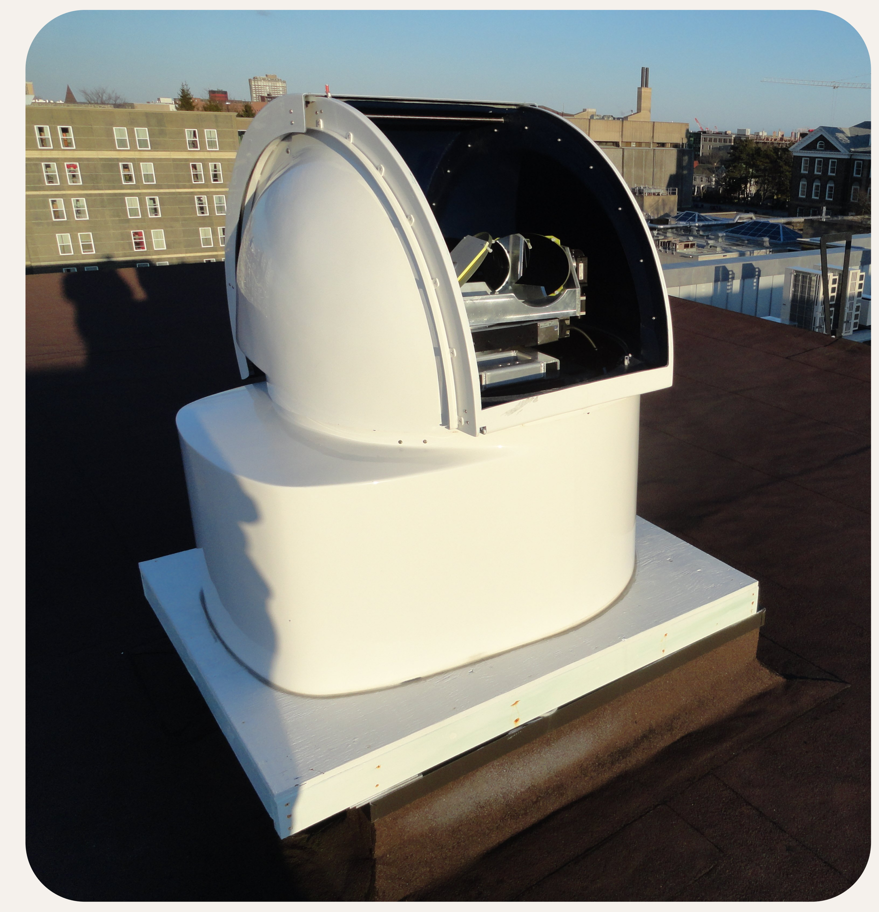
OPD
250 cm

Resolution
0.004 cm^{-1}

750-4300 cm^{-1} every 50 min. through 6 filters

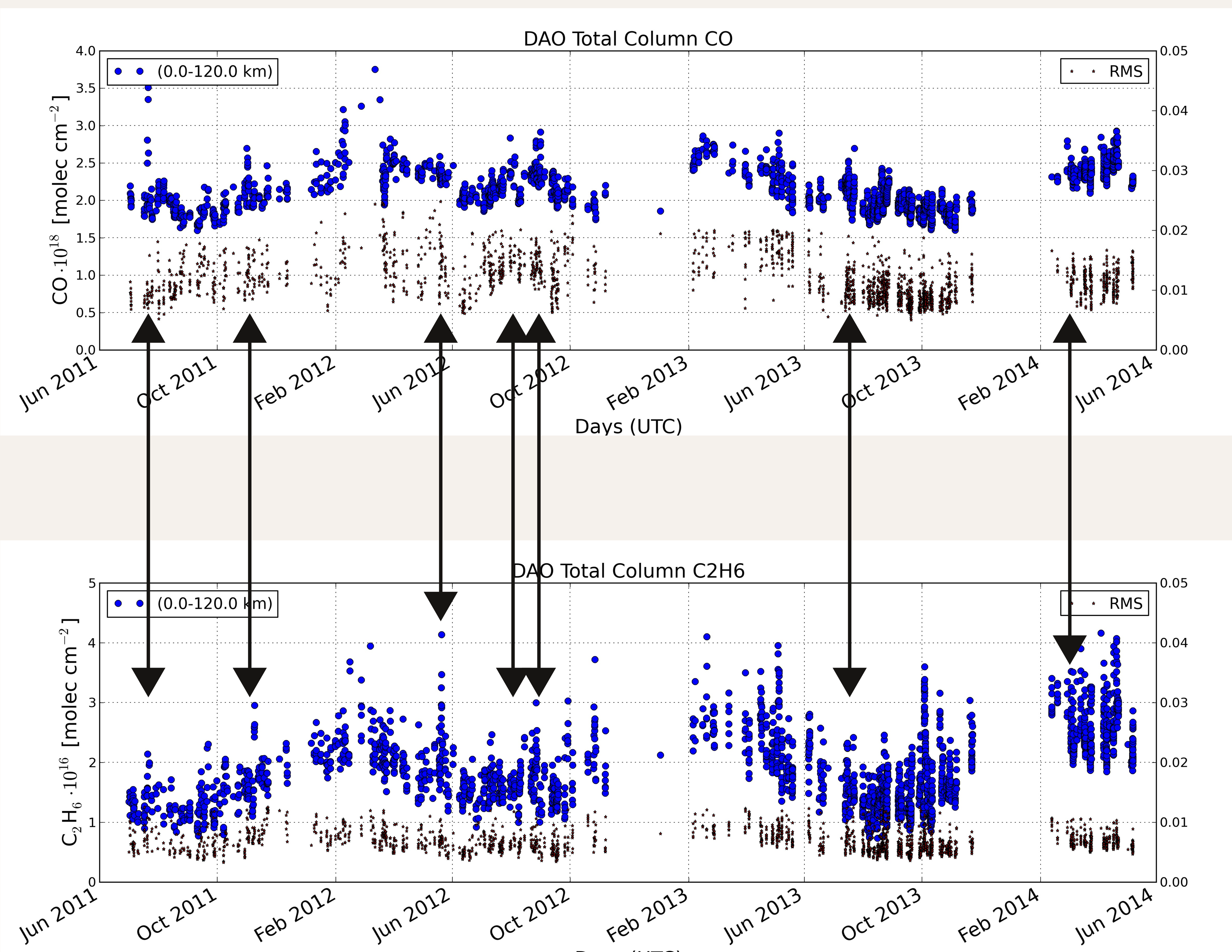
InSb and MCT detectors

KBr Beamsplitter



2. Time series of CO and C_2H_6

The measurement record from the DAO-DA8 began in June 2011 and has continued with only a few interuptions. Shown below are the total column measurements of carbon monoxide (CO) and ethane (C_2H_6) spanning three years. Both species clearly show the expected seasonal cycle for an observing site in the Northern hemisphere.

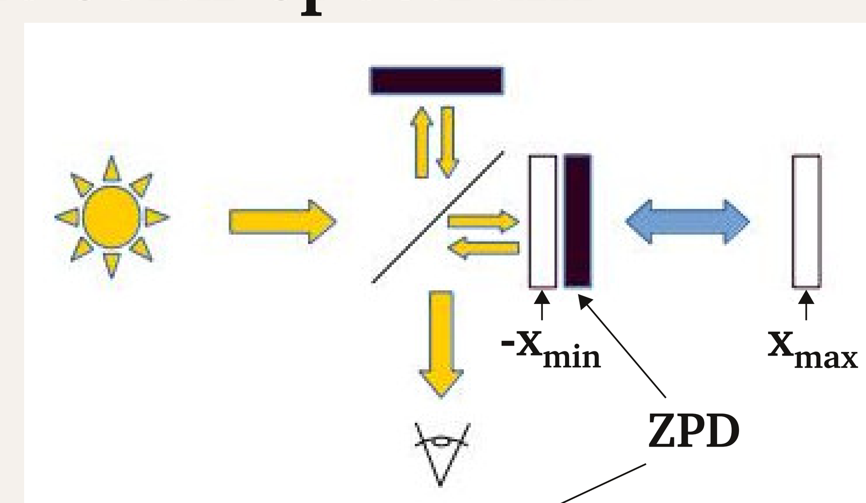


The DAO-DA8 is co-located with a CIMEL sun photometer that is part of the AEROCAN network. The marked points above correspond to enhancements in the CO record that are associated with elevated levels of fine-mode aerosol optical depth.

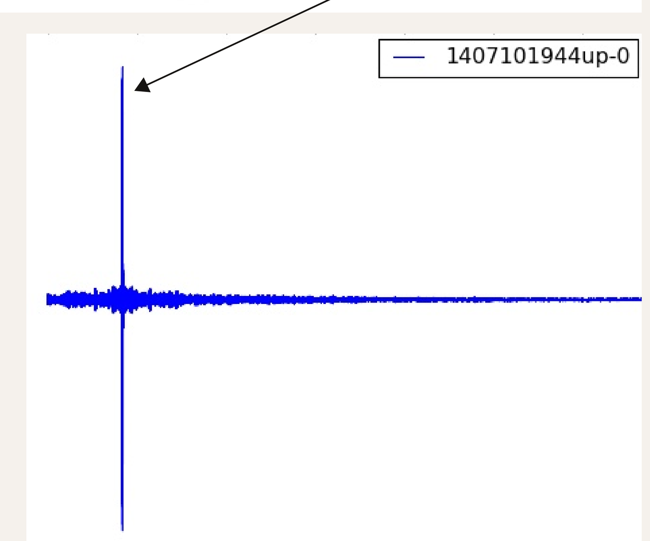
Halifax is ideally situated to monitor the pollution outflow from northeast North America. We have detected events associated with biomass burning in the Canadian boreal forest, as well as events associated with anthropogenic pollution from the industrial regions surrounding the Great Lakes.

3. Phase correcting the solar spectrum

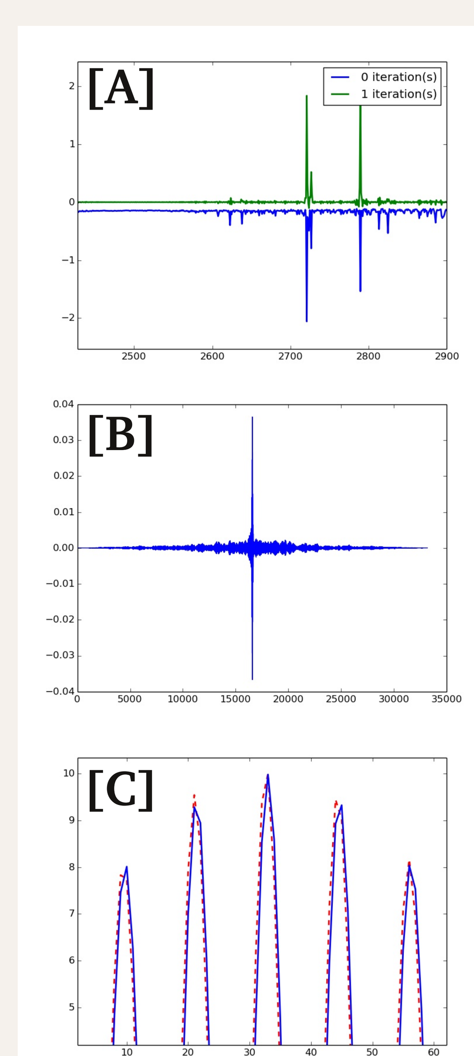
An ideal FTS system will provide an AC output that is symmetric about the Zero Path Difference point (ZPD), and can thus be transformed using only a simple cosine Fourier transform of the interferogram (IGM) from ZPD to X_{max}



In reality, optical components and sampling electronics can introduce wavelength-dependent phase shifts that will result in asymmetries in the IGM. If the ZPD falls between two digital sample points, this will introduce an additional linear phase shift. In this case a complex Fourier transform will produce both real and imaginary components.



The solution is to use information within the short double sided portion of the spectrum from $-X_{min}$ to $+X_{min}$ to shift all of the information into the real part of the spectrum. At DAO we use a modified version of the method developed by Forman, Steel, and Vanasse [1].



1. Take FFT of short double sided IGM.

$$m_s(\sigma) = \int M_s(x) e^{2\pi i \sigma x} dx$$

2. Derive phase curve. [A - blue]

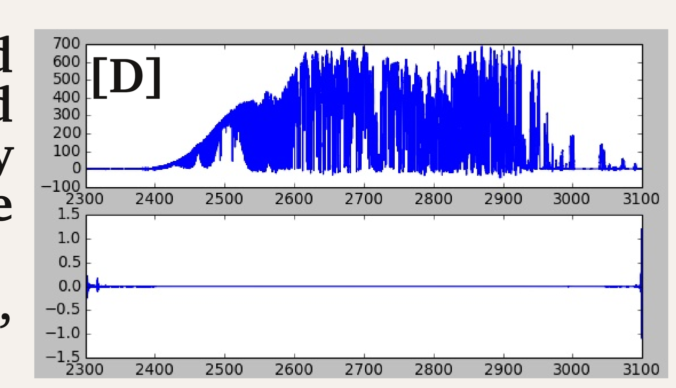
$$\epsilon(\sigma) = -\arctan \frac{\Im(m_s(\sigma))}{\Re(m_s(\sigma))}$$

3. IFFT to create phase interferogram. [B]

$$F(x) = \int_{-\infty}^{\infty} e^{i\epsilon(\sigma)} e^{-2\pi i x \sigma} d\sigma$$

4. Convolve F(x) with original IGM to produce a phase corrected IGM. [C - blue, compared to red original]. Repeating steps 1 and 2 shows improved phase curve. [A - green]

5. FFT corrected IGM and discard residual imaginary portion of the complex spectrum. [D - top shows real, bottom imaginary]



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References

[1] Forman, Steel, & Vanasse, J. Opt. Soc. Am. 56, 59-63, 1966
[2] D. Wunch, Ph.D. Thesis University of Toronto, 2007