



## RMD Expedition

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### SO<sub>2</sub>/NO<sub>2</sub> Calibration Guide

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## Description

The RMD Expedition is calibrated at Resonance Ltd. to provide the most accurate readings possible for SO<sub>2</sub>/NO<sub>2</sub> detection. Calibration coefficients should never need to be adjusted, and should never be changed without first consulting Resonance Ltd. The calibration gas cells are used primarily to provide a known reference signal at every measurement site. Changing the core coefficients is not recommended because SO<sub>2</sub>/NO<sub>2</sub> readings vary due to numerous environmental variables that can't be precisely known. Scientifically, it is better to keep the core coefficients intact and post-adjust the data according to what the calibration cells read at the time of measurement as opposed to changing the under-the-hood settings themselves.

The following guide walks through the measurement process and should clarify the required steps and highlight factors that affect the measurement accuracy. This guide is written to complement the Resonance RMD Expedition software package.

## Spectrometer Settings & Preview Window

Before any useful data can be collected, the first step is to make sure the PACA mirror is pointed towards the open sky and adjust the spectrometer to allow the appropriate amount of light into the system. Refer to the spectrometer preview window within the **Recorder Tab**. If the preview is hidden, you can enable it by right-clicking anywhere on the graph and selecting **Show Spectrometer Preview**. You should see a spectrum of skylight displayed. The spectrometer's integration time must be adjusted such that the light at 400nm is roughly 40,000 counts. Increase the integration time if the spectrum is too low and vice versa. Once the integration time has been set, you can now specify the number of averages the spectrometer should perform. This sets the acquisition period. For example, if the integration time was set to 100ms, and the averages 10, a spectrum would be received every  $10 \times 100\text{ms}$  (1s). Note that the software will refresh its display no faster than a period of 500ms, regardless of the acquisition period. Therefore a setting of 100ms and 1 average would result in an acquisition period of 100ms, however the software will only request a spectrum every 500ms. The recommended approach for this situation is to set the averages to 5, therefore using the otherwise wasted 400ms left in the update interval to average data.

## Dark Spectrum

With the spectrometer integration time set, a **dark** spectrum can now be acquired. The **dark** provides a measure of the intrinsic offset signal in the spectrometer when there is no light. This offset signal can then be subtracted from acquired spectra (which is done automatically). The PACA has a built-in shutter to perform this operation. Simply press the **Store Dark** button. The process includes a 30 second delay to allow the spectrometer to settle. The total time is therefore 30s + the integration time. It is important to note here that the dark spectrum is tied to the integration time.

**Note:** Whenever the integration time is changed, a new dark must be taken.

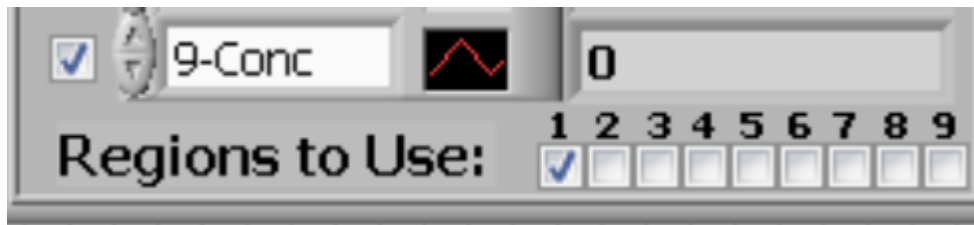
## Reference Spectrum

The **reference** spectrum provides a measure of the background skylight to be used in the correlation algorithm. The PACA must be oriented such that the mirror sees the open sky. **There must be no SO<sub>2</sub>/NO<sub>2</sub> in the optical path when taking a reference!** The PACA should also not point directly at the sun. The integration time should be the same as the dark. With the PACA mirror oriented at the open sky, simply press the **Store Reference** button. The software will store the latest received spectra and define it as the **reference**.

Remote measurement that relies on scattered skylight is prone to varying light levels. Clouds, time of day, and the position of the sun all affect the reference. Taking a **reference** spectrum often is recommended for any changing skylight conditions. The position of the sun itself does not matter when taking a **reference** due to UV scattering, but a good rule of thumb is to point the PACA to an open region of sky with similar characteristics of the SO<sub>2</sub>/NO<sub>2</sub> region. For example, if the SO<sub>2</sub>/NO<sub>2</sub> region is completely clear, do not take a reference in a cloudy area of sky. Try to find a clear region away from the SO<sub>2</sub>/NO<sub>2</sub> source. Again, be very careful to avoid accidentally pointing towards a region that may have trace amounts of SO<sub>2</sub>/NO<sub>2</sub> – this will decrease the instrument's accuracy. Once a dark and reference have been taken, the instrument will start plotting the concentration of SO<sub>2</sub>/NO<sub>2</sub> in its optical path. Move on to the next section to verify the reported concentration is accurate.

## Averaged Concentration and Available Wavelength Regions

The RMD Expedition software uses multiple wavelength regions in its correlation algorithm. Selected regions are averaged together to give the final concentration reading (the white plot on the chart recorder). There are 9 regions available for configuration in the software but only 6 are used by default for NO<sub>2</sub>, and 3 for SO<sub>2</sub>. Each region can be graphed and monitored simultaneously, which provides useful feedback and may indicate that a region may require tweaking. Ideally, all regions should directly overlap with themselves and the average, but depending on the concentration of SO<sub>2</sub>/NO<sub>2</sub> being observed, one region may be slightly more accurate at low concentrations, and the other more accurate for higher concentrations. This is why they are averaged. The regions are selected in the bottom-left corner of the main **Recorder** tab:



## NO<sub>2</sub> Calibration Cells

The system's accuracy can now be checked against the included gas calibration cells. Cells can be placed in the PACA while pointing at a clear part of the sky. The SO<sub>2</sub>/NO<sub>2</sub> concentration should be plotting in the chart recorder (white plot). The **running averages** setting can be very helpful to smooth some the noise, but also delays display of the latest data. If the acquisition time was 1s, for example, and the averaging routine takes the last 5 data points and averages them together and presents it as the last point.

With a calibration cell in place, check to see that the reported concentration agrees with cell's value. The value will fluctuate normally about +/- 10ppm-m on a bright day. This is a very rough figure and depends on many variables intrinsic to remote measurement.

If the reported concentration is not agreeing with the gas cell, there are a number of things to note before attempting to tweak the absorption and wavelength coefficients. Look at the plots for the SO<sub>2</sub>/NO<sub>2</sub> regions. Remember that the final reported concentration is an average of these regions. The closer the plots are to each other, but where plot 1 was below plot 2 for the first cell, the opposite may be true for the second. This happens because each region has its own relationship with the SO<sub>2</sub>/NO<sub>2</sub> concentration, and one region may be optimized for higher concentrations, and the other lower.

## Adjusting SO<sub>2</sub>/NO<sub>2</sub> Coefficients

If you still feel the need to recalibrate the system, seek advice directly from Resonance Ltd. first. This process relies greatly on an experienced DOAS user and is hard to reduce to simple instructions.

## Contact

Resonance Ltd. stands behind every product we sell. We welcome feedback and encourage any of our customers to contact us with questions, or concerns. You may contact us through e-mail, our website, telephone, or fax!

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