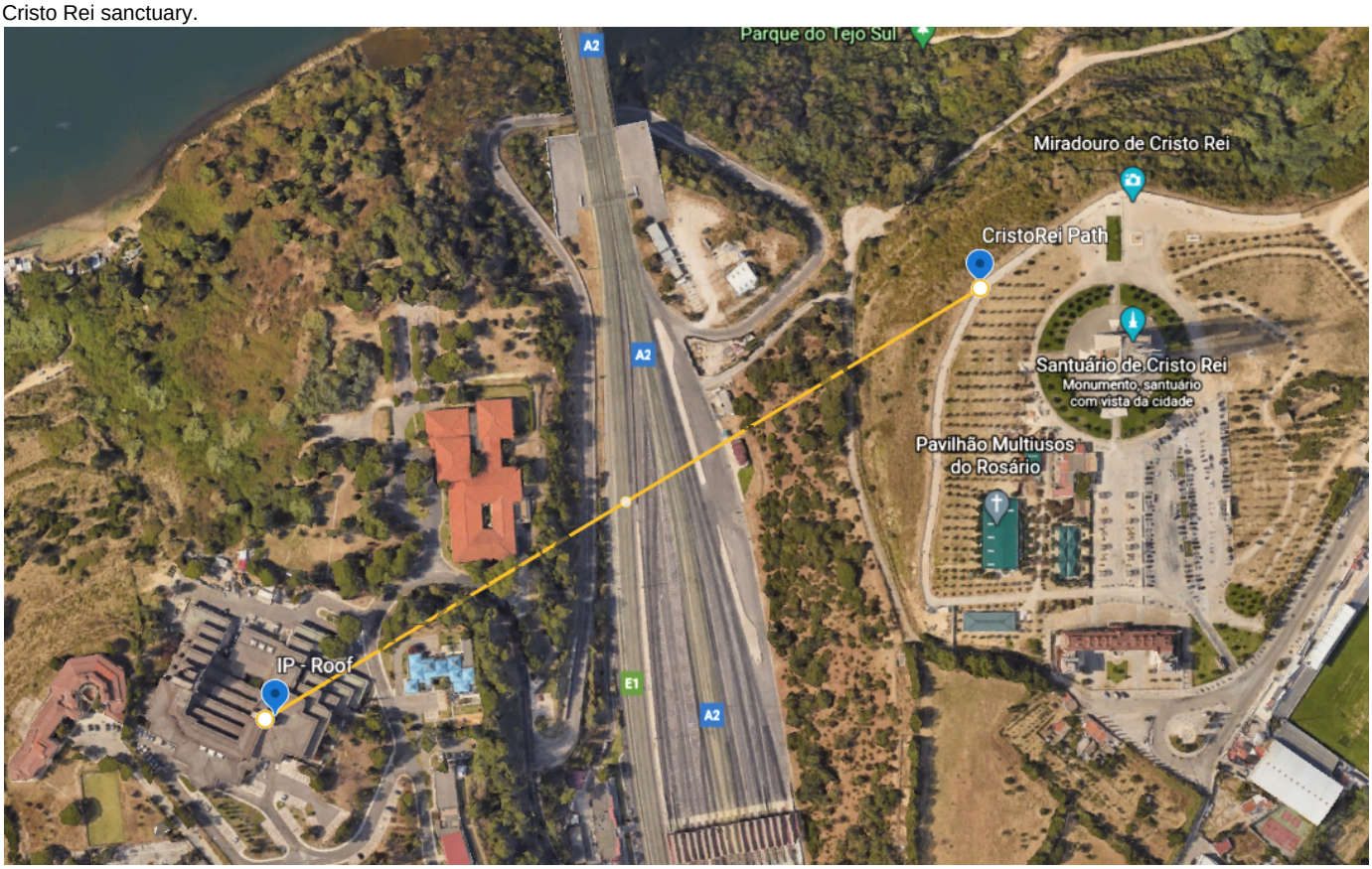
Testing Lambertian Absorption

Experiment plan and results	This experiment is designed to prove that we can use the lambertian notion that light absorption depends on the optical path and that we can use this to determine a projection in a tomographic imaging system.
Experiment owner	@ Rui Almeida
Jira ticket(s)	https://rfa123c.atlassian.net/browse/PHD-3
Status	DONE
On this page	

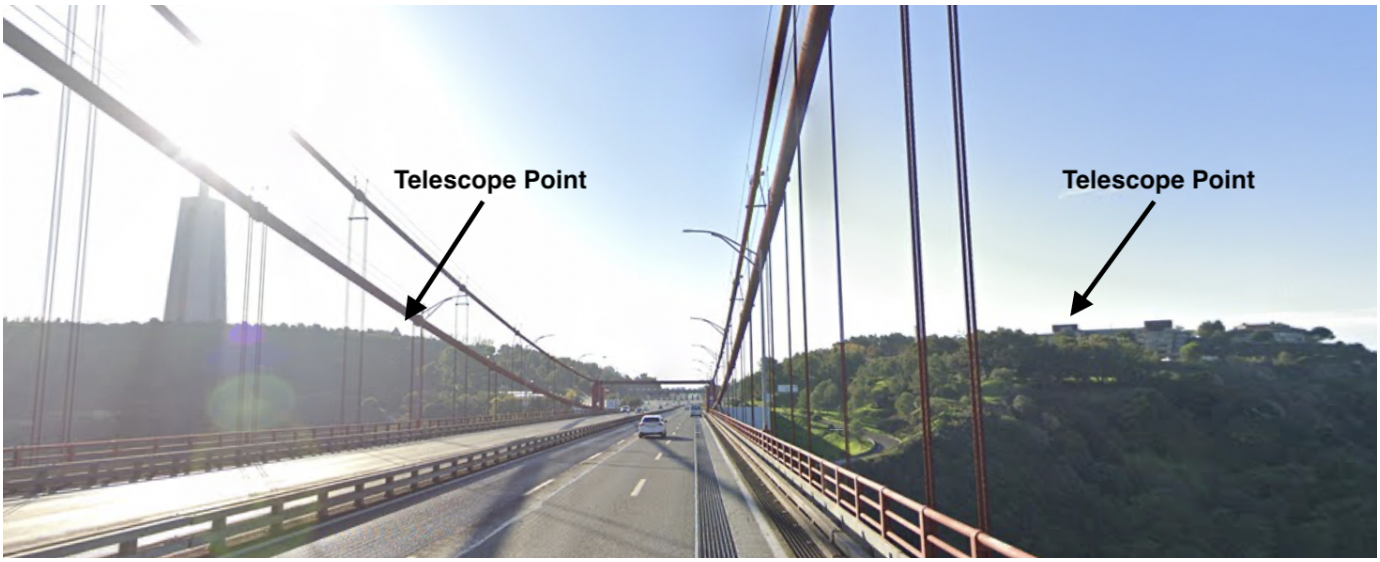
📋 Experiment planning

Overview

The experiment was designed to validate that we are able to measure trace gas concentrations with our current instruments and using passive DOAS for an optical path of around 1km. We will assemble a telescope on the roof of the IEP building and another one in a specific point of the Cristo Rei sanctuary.

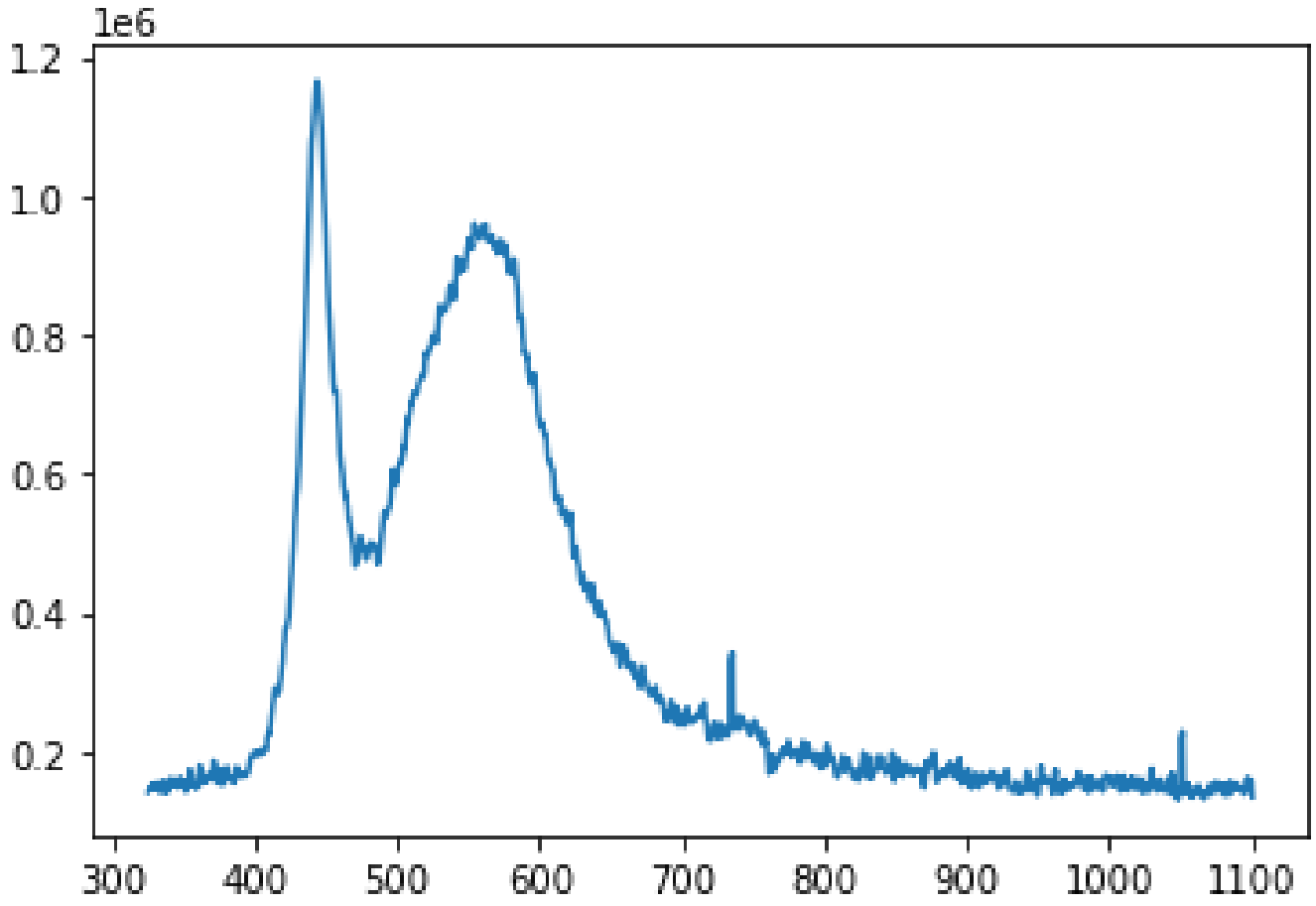


Both points are located in Pragal - Almada, Portugal. They are, however, on opposite banks of the valley created by the A2 motorway, which is one of the country's busiest roads, especially during rush hour.



In addition to the telescopes, we will use a collimated light source pointing from one telescope to the other. An artificial light source will give us a baseline with which to compare our target data, the passive DOAS trace gas concentrations.

The selected light source is a bright 20W XP50.2 LED lamp collimated through the telescope located at the sanctuary. The relative spectrum of this white lamp is presented in the figure below.



Hypothesis

We hypothesize that light absorption between points A and B will *be equal to the difference in absorptions* in A and B and we can measure this difference with our equipment.

Actions

Action ID	Action	Description
A	Active trace gas concentration determination	With the two telescopes facing each other, we collect spectra for two minutes with the light source turned off and another 2 min with the light source turned on.
B	Passive trace gas concentration determination	With the two telescopes aligned and approximately facing East, we collect spectra for 2 minutes.
C	Passive reference collection	With the two telescopes pointed upwards, we collect spectra for 2 minutes.

Experiment day

When we get to the sites of the experiment, we must start by preparing the equipment for operation. This will entail:

1. Mount the tripods and the telescope on it;
2. Point the telescope in the general direction of the other experiment site;
3. Connect all fiber optics to the spectrometer and the optical adapter on the telescope;
4. Connect the spectrometer to the USB port and check AVASOFT detects it;
5. Finish pointing the device and focus telescope and take note of its geographical position (LAT LON).

Additional Material

The experiment starts in the dead of the night and goes on for 6 hours. Bring:

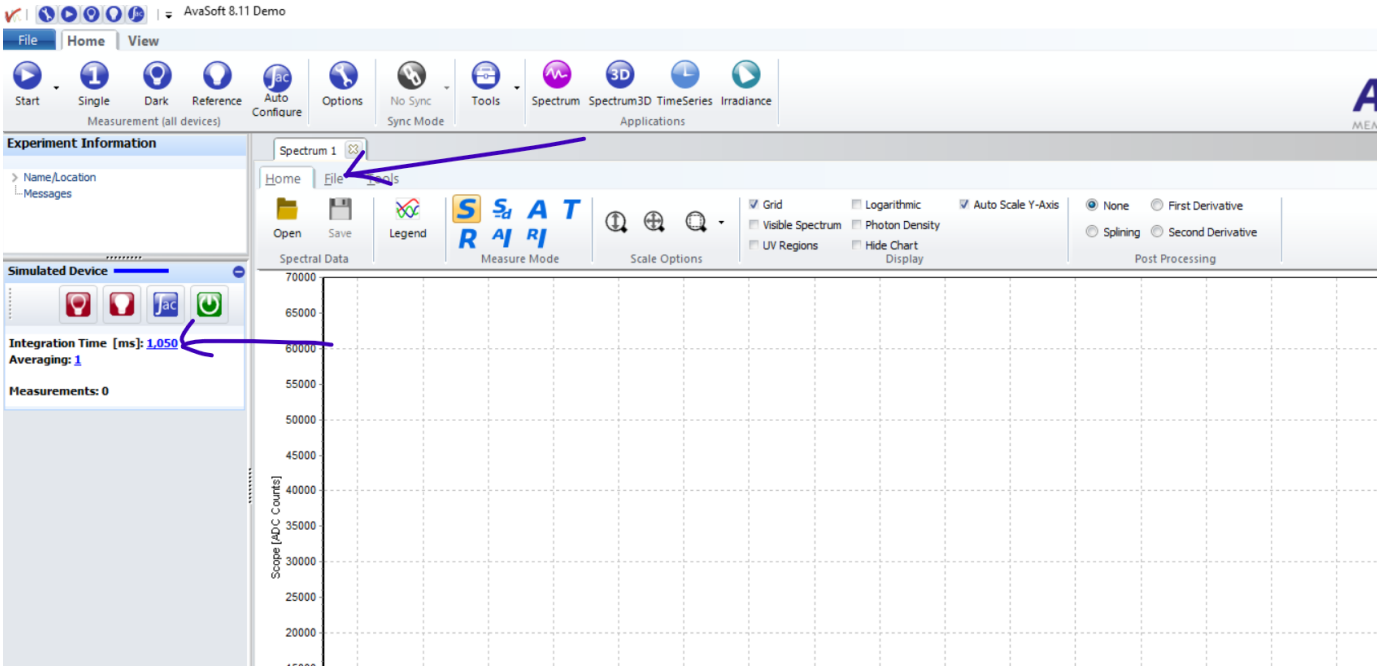
- warm clothes;
- food;
- water;
- something to pass the time (most of the time there will be nothing to do for the experiment);

The following table presents the list of prescribed actions and their periodicity. Note that only the IEP telescope moves (natural light exclusive).

Time Frame	Period	Action
05:00 - Sunrise	15 minutes	A
Sunrise	Once	C
Sunrise - 11:00	15 min	A and B

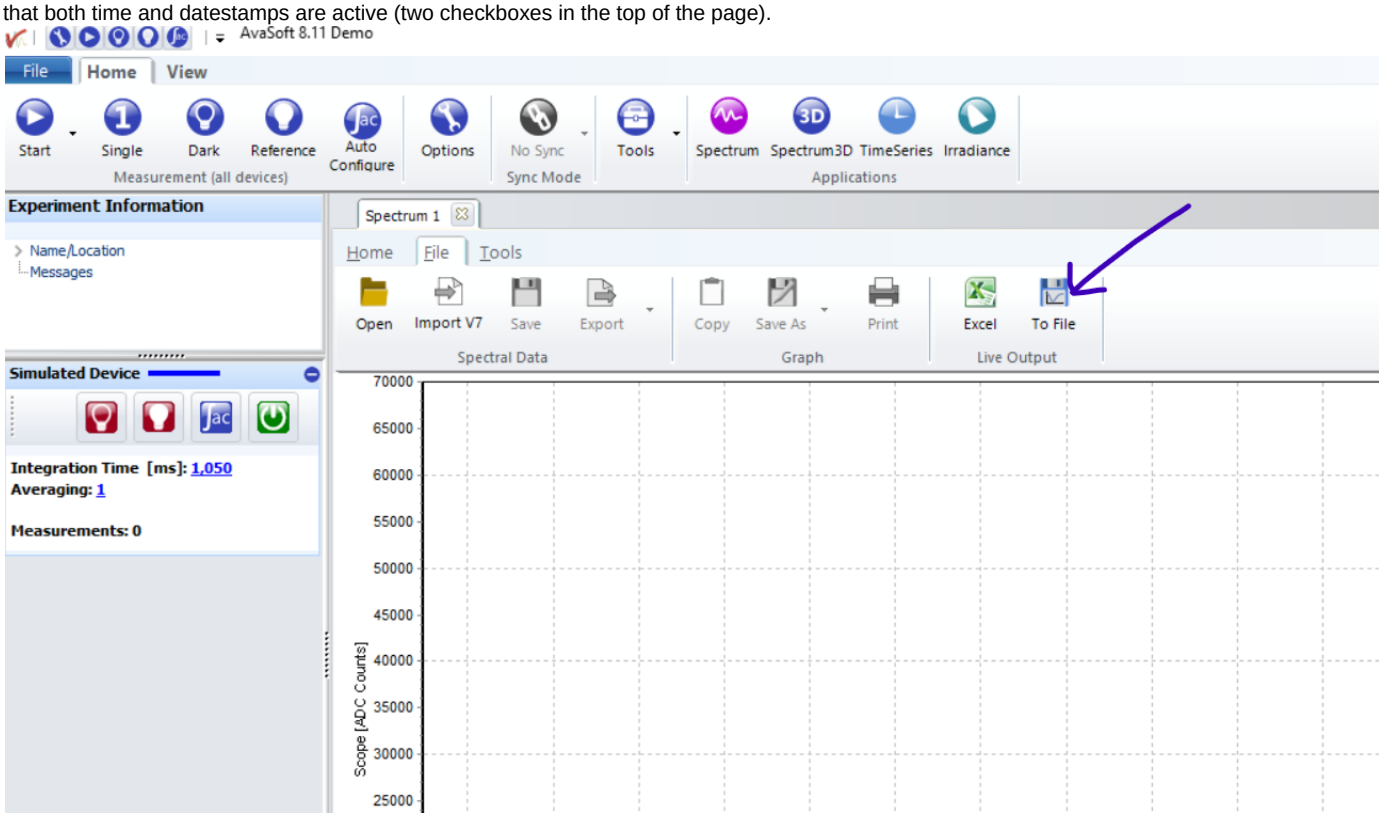
Spectrometer Software Settings

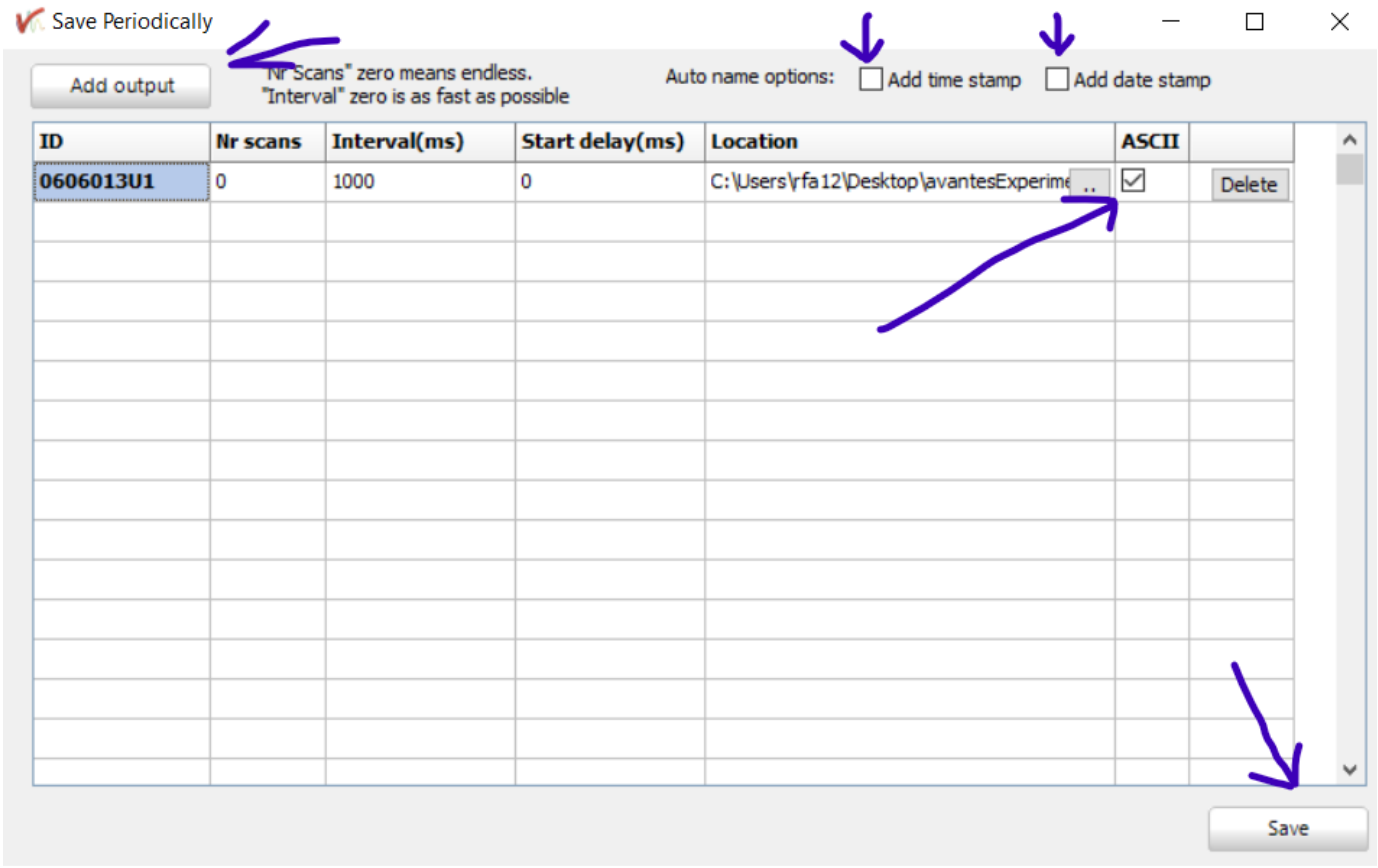
Calibration Coefficients	From spectrometer’s memory (no action required)
Integration Time	500 ms
Number of measurements	-1 (non stop)
Reference Spectrum	None



File saving settings

At the start of the experiment, setup file saving in the AvaSoft software to save a file to disk each second from the spectrometer output. Check that both time and datestamps are active (two checkboxes in the top of the page).





Results

1st experiment run

Experiment start	07 Jun 2021
Conclusion	**INCONCLUSIVE**

The first attempt at the experiment was run on Jun 7 2021. All weather conditions were optimal for the kind of data acquisition we were conducting. The experiment started with a small delay, caused by last minute conditions due to not having a laptop battery charger (on the sanctuary side). This lack of a charger came to not influence the results, since it was the other laptop (on IEP's roof) that failed first, closing the experiment for this day.

The acquisition table follows:

#	Passive meas.	Passive ref.	Active mean.	Active ref.
1	06:20	06:23	06:15	--
2	06:46	06:50	06:41	--
3	07:04	07:07	07:00	--
4	07:25	07:27	07:21	--
5	07:48	07:50	07:45	--
6	08:10	08:12	08:06	08:08

On the one hand, it is clear from this table that we do not have data on the active reference spectra (likely due to some operation error on my part); on the other hand, we have too few data points to make any claim of validation or refutation of the principle we were to measure.

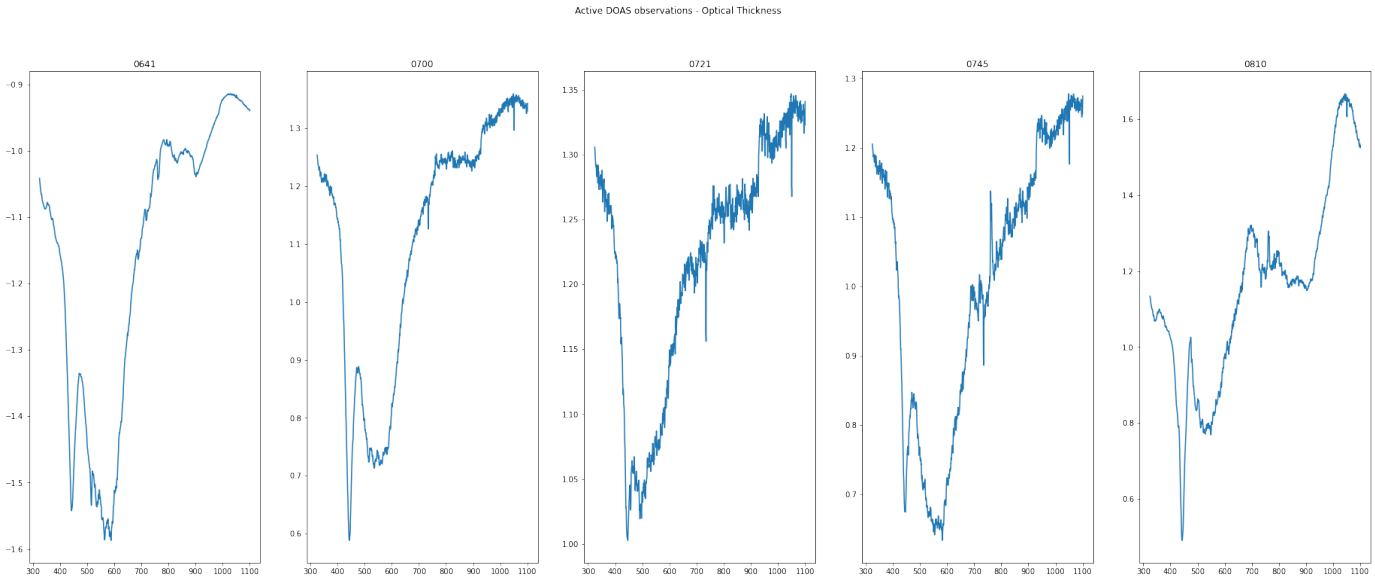
The acquired data makes it clear that we need to take another go at the experiment, from the top. Logistically, this is already being prepared (UPS and authorizations).

Preliminary results - data analysis

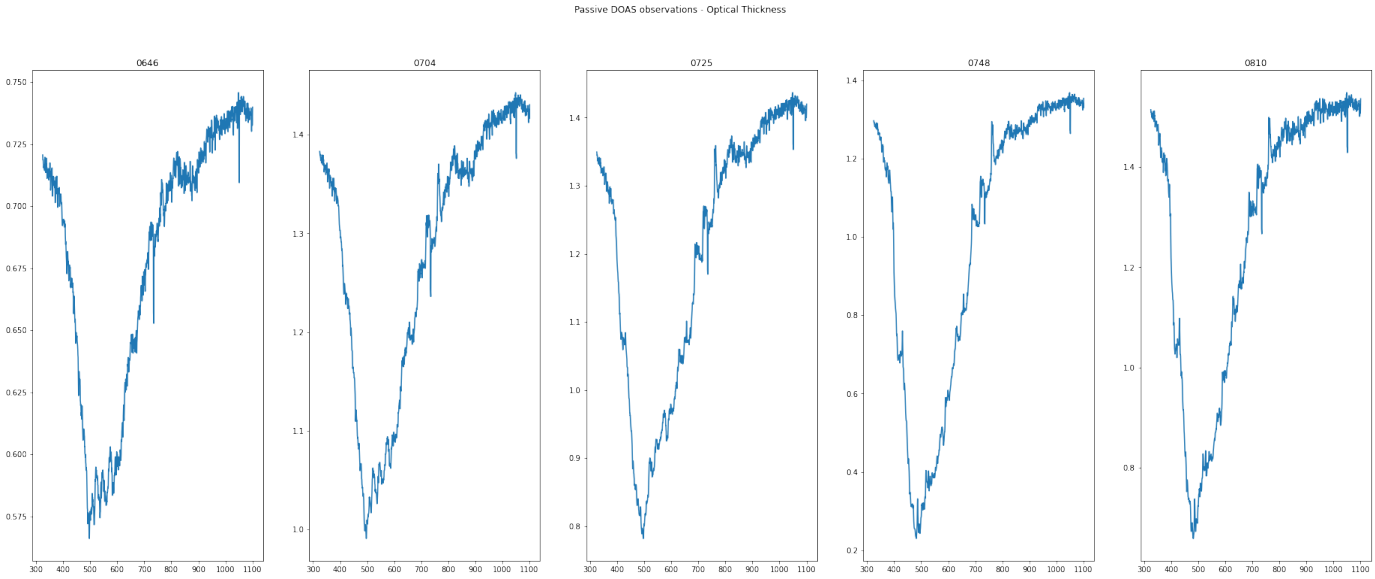
Although there is insufficient data to produce a convincing conclusion at this point, the data that was collected was of good quality and allowed some interesting analysis.

The collected spectra were correctly displayed, having the expected shape. In terms of optical density, here are the charts for the produced signals:

Active DOAS



Passive DOAS

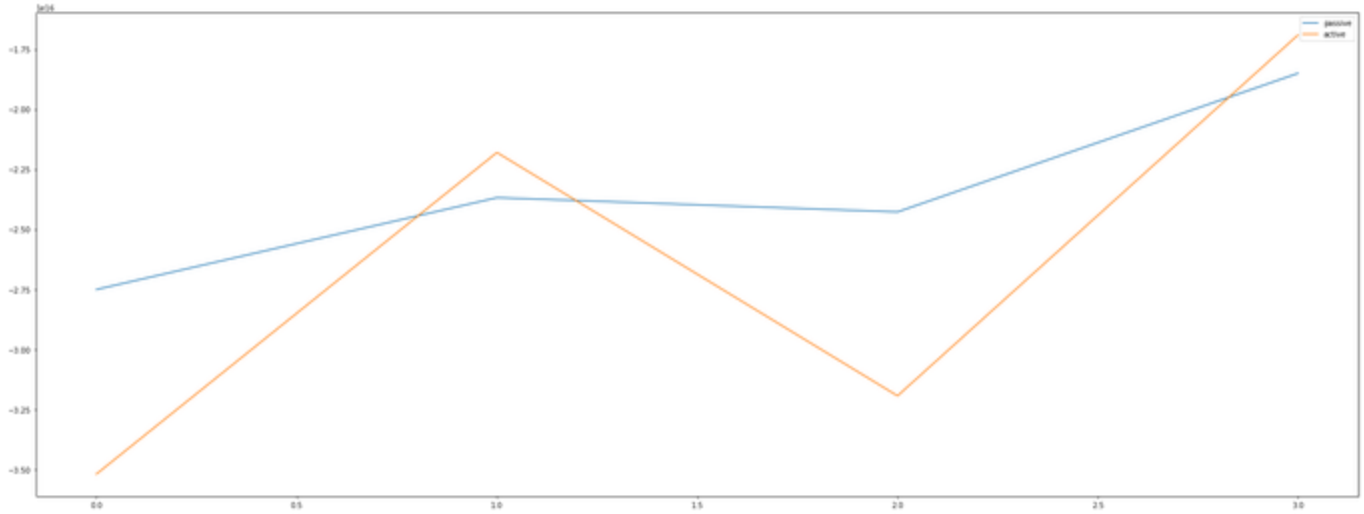


NO2 Concentration

NO2 concentration results were a bit surprising, but this is probably due to a lack of reference or some contamination in the spectra, so it's not a definitive conclusion.

The first datapoint, at around 0620, is decisively the highest. This is quite surprising, given that the number of cars that were on the road at that time was minute, compared with what came next. To add to the confusion, the second datapoint is the lowest of the dataset, and after this, measurements behave as they should (rising).

A good result was that in any case, both passive and active measurements seem to have a good agreement, indicating that our premise is valid, as it should. The following chart demonstrates this point.



2nd experiment run

Experiment start	22 Jun 2021
Conclusion	**PLAUSIBLE**

The second run of the experiment took place on the 23rd of June. The weather was not as good as during the first run, namely because of the wind. The East Bank assembly was moved behind a few meters. This improved the measurements but made them more difficult. The figure shows how the East Bank was relocated.

We were able to make many more measurements, that are presented in the following table.

#	Active	Active Reference	Passive
1	06:07	05:57	06:14
2	06:35	06:30	06:40
3	06:50		06:50
4	07:10	07:15	07:00
5	07:50	07:40	07:10
6	08:08	08:03	07:25
7	08:18	08:21	07:53
8	08:35	08:30	08:35
9	09:00	08:53	09:02
10	09:45	09:50	09:24

11	10:00	10:05	09:53

DOAS analysis of the collected spectra produced the following charts:

These density values were obtained from the following fits:

✨ Conclusions

- Good quality measurements produced coherent results (passive vs active) that disagree with the official numbers.

- In the field, we did see an increase in the number of cars that were passing the bridge, but we don’t know if that would be enough to produce these changes.
- The fits are good, particularly the ones obtained in the West Bank, indicating that we were in fact measuring what we thought we were measuring, thus confirming the densities in the previous plots.
- The fact that this is a manual procedure makes it very difficult to ensure proper alignments, so it is possible that this error played some part in the disagreement between the two sources.
- The wind also played a role in destroying alignments.

Results do disagree with the official concentrations, but are quite coherent within themselves. The hypothesis in test can be considered plausible, but without improving the acquisition process (at least making it automatic) it is difficult to assert that it is verified.