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EUBREW NET

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Measurement principle, Calibration & Basic evaluation

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EuBrewNet Training School,Tuesday 6, 18:15 -19:00

Quadrennial Ozone Symposium 2016 4–9 September 2016 Edinburgh, United Kingdom

Outline

Measurement principle

Brewer calibration

Steps to make the reponsivity time series

pmod wrc

The Brewer spectrophotometer

Modified Ebert Grating Spectrometer with photon counting detection and six exit slits

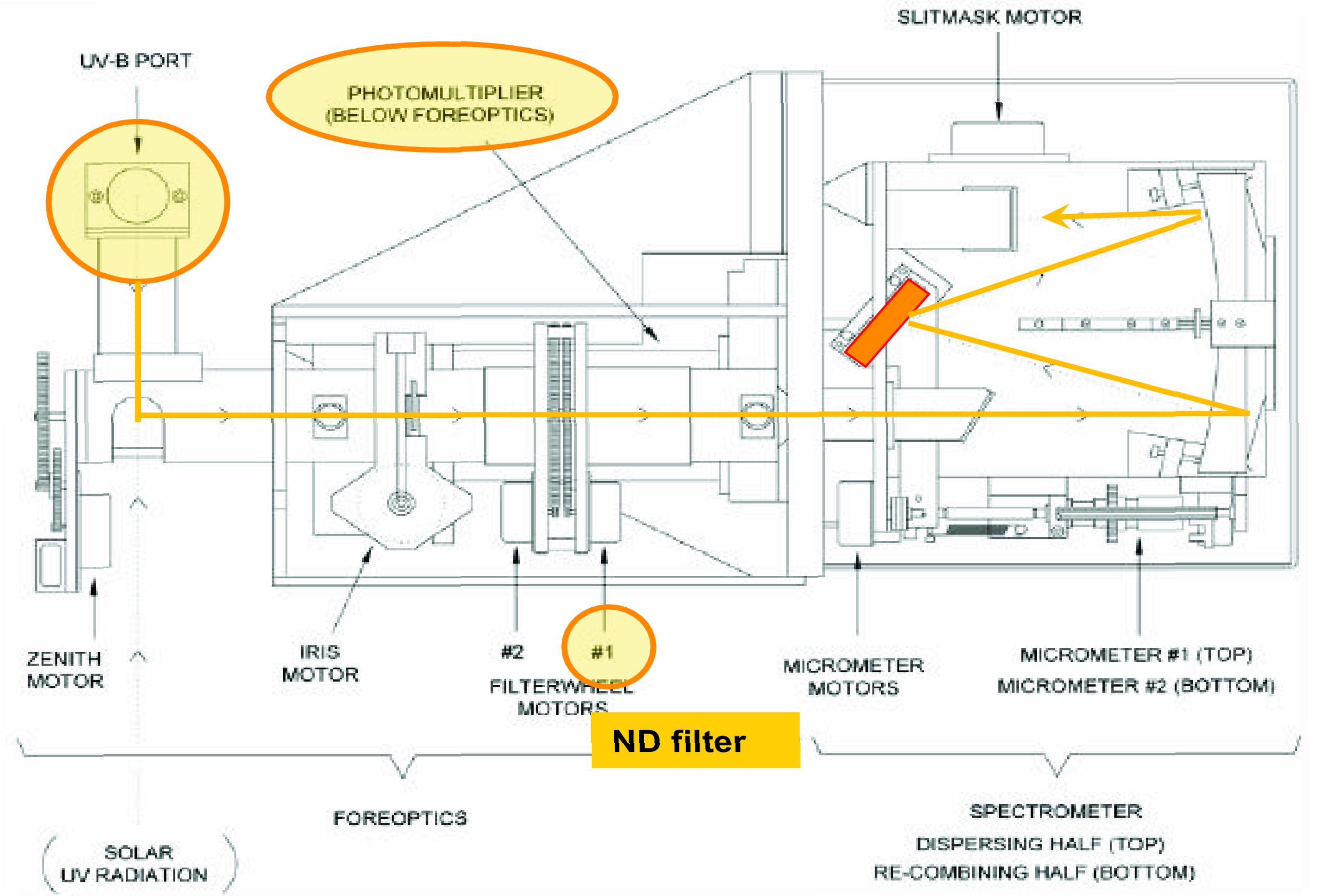


Figure 2.5: Top View of Spectrophotometer

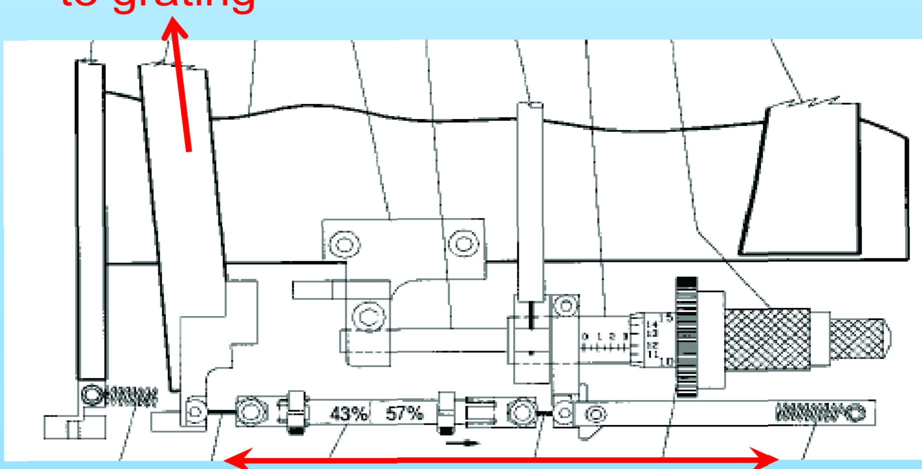
Basic design features:

- Spectral purity
- Wavelength step 0.0075 nm/step
- Passive temperature compensation
- High wavelength stability

Wavelength scale calibration

Goal: find a relationship between the grating rotation and wavelength.

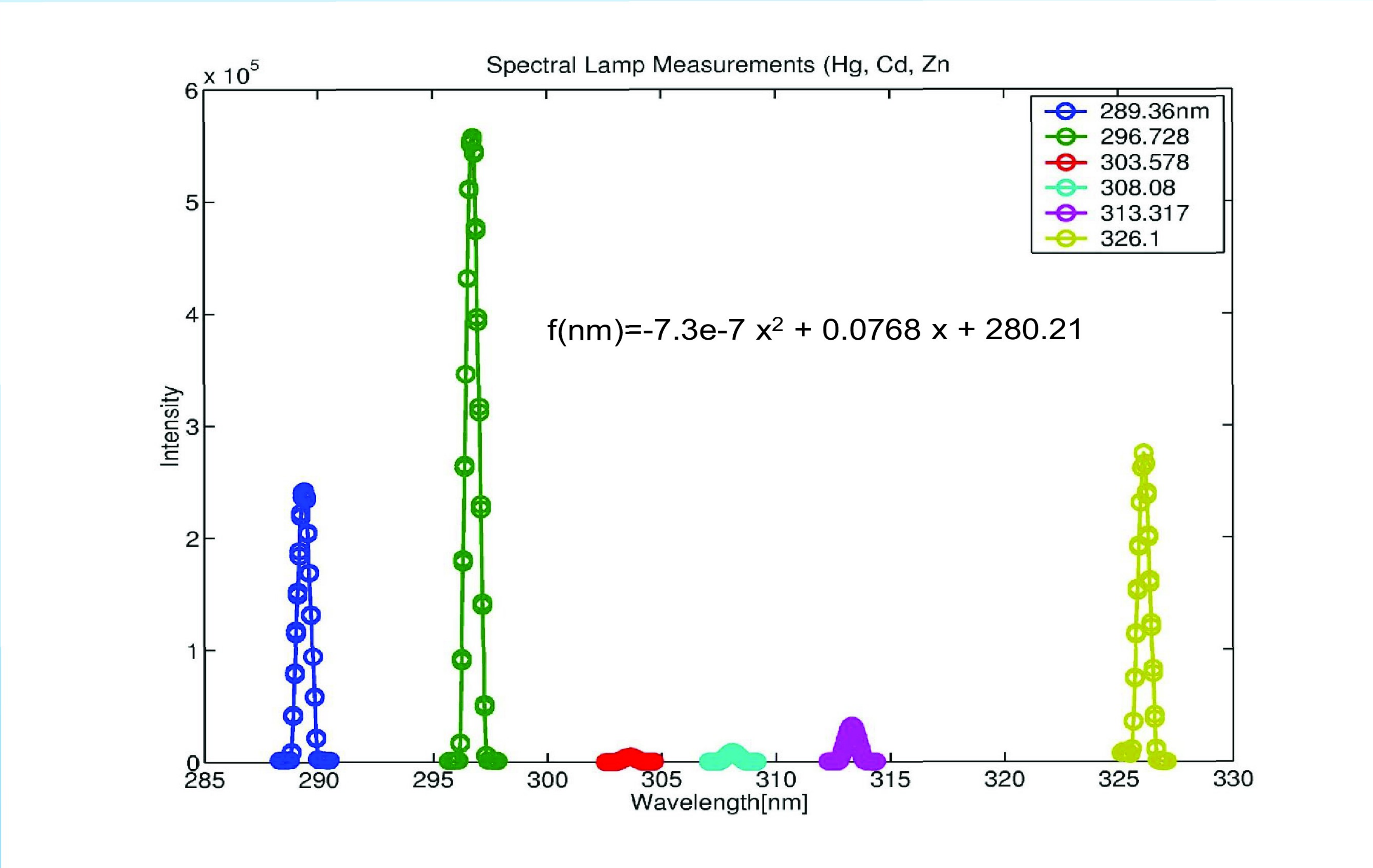
- The wavelength scale is determined from measurements of discrete spectral lines from spectral discharge lamps (Mercury, Cadmium, Zinc, Indium)
- A smooth function (polynomial) describes the relation between the grating angle (micrometer steps) and the wavelength of each spectral line.



Emission lines:

Mercury	289.360 nm
	296.728 nm
	334.148
Cadmium	313.317
	326.105
	340.365
	349.995
Indium	293.263
	303.936
Zinc	310.836
	303.578
	328.233

Example of dispersion measurement on slit 1

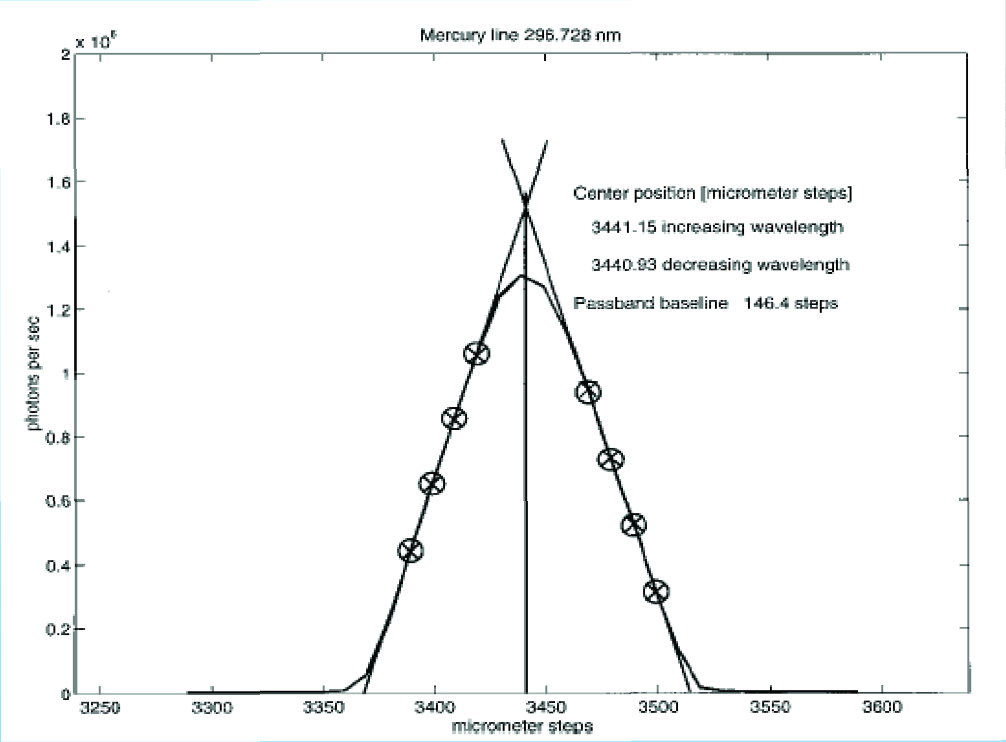


Slit function

The slit function represents the response of the spectroradiometer to monochromatic light.

It is obtained by scanning though the output of a monochromatic source i.e. laser line or spectral discharge lamp.

The slit function is necessary for determining the spectral resolution of the spectroradiometer (stray light, Full width at half maximum)



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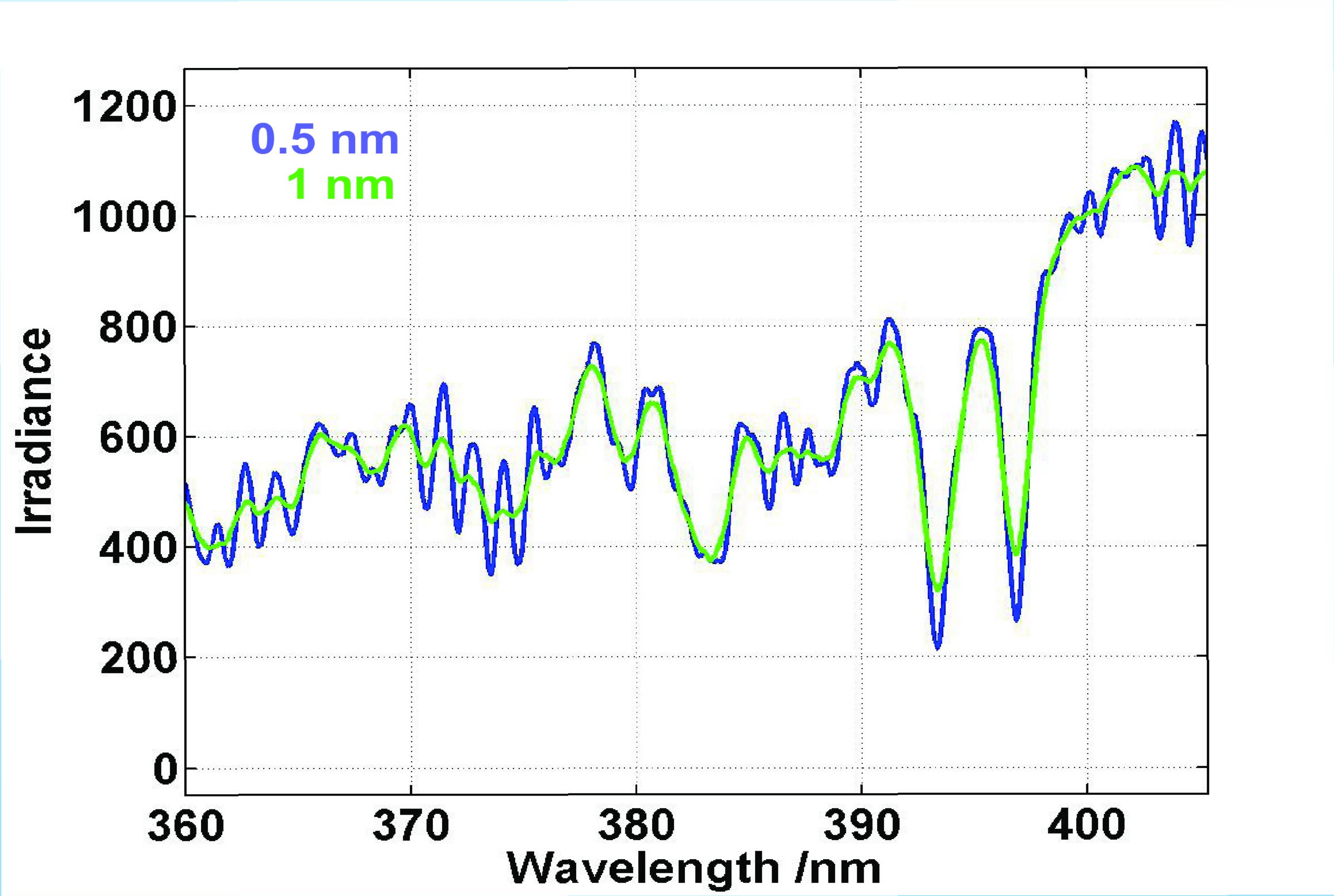
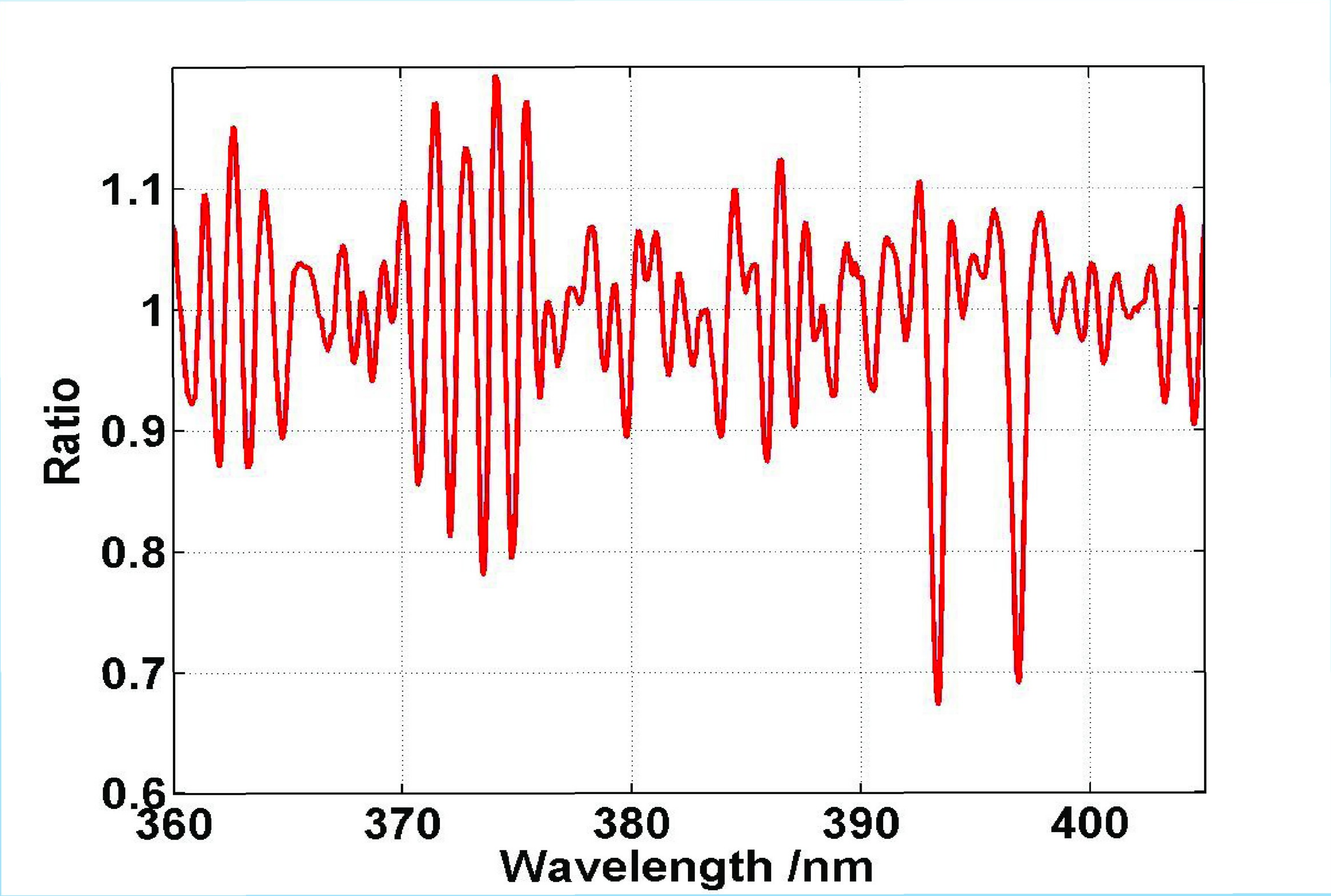
Resolution of Solar Spectra



Resolution of solar spectra



Linearity and Neutral Density choice for global UV measurements

The radiation from lamps used for the calibration is 10-100 times weaker than the solar radiation. It is necessary to check the linearity of the spectroradiometer to be able to convert from counts to irradiance:

$$I\,[Wm^{-2}nm^{-1}] = \frac{signal_{SUN}}{signal_{LAMP}} \cdot Lamp\ Irradiance\ [Wm^{-2}nm^{-1}]$$

Deadtime correction algorithm:

$$N = N_0 e^{-\tau N_0}$$

Brewer uses up to 80000 counts/cycle (for ds).
This corresponds to ~1.5 10^6 photons/sec
→ Deadtime correction of about 6%

The UV scans (ul, ux) use a fixed ND-Filter which needs to be selected based on the maximum expected irradiance at each measuring site.

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Measurement principle for spectral solar UV irradiance

$$I[Wm^{-2}nm^{-1}] = \frac{signal_{SUN}\ [photons \cdot s^{-1}]}{Responsivity\ [photons \cdot s^{-1} \cdot W^{-1} \cdot m^{2} \cdot nm]}$$

The Instrument responsivity is obtained by measuring the response of the instrument to a source with known radiation.

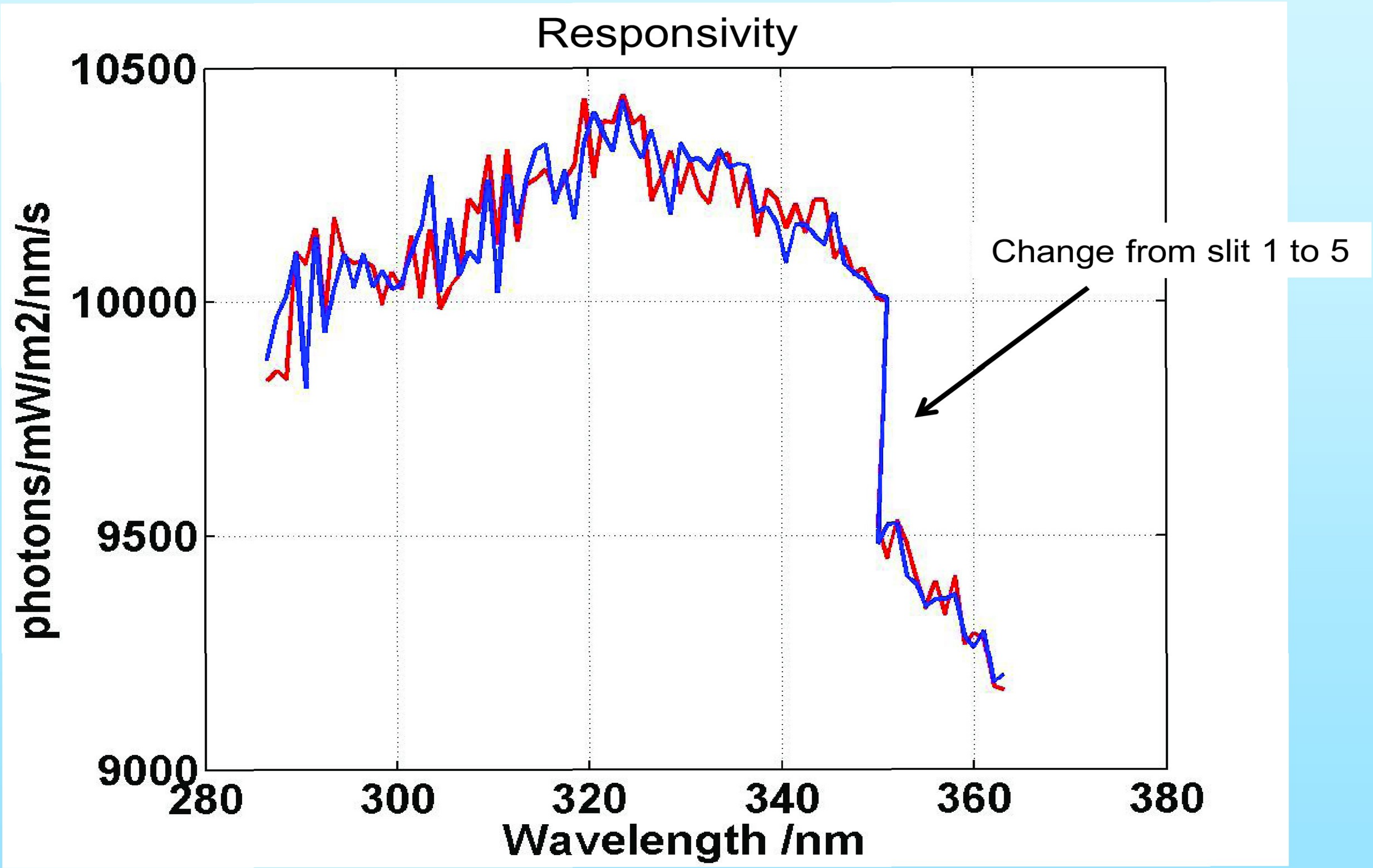
Typically a tungsten-halogen lamp with a calibration certificate

$$Responsivity\ [photons \cdot s^{-1} \cdot W^{-1} \cdot m^{2} \cdot nm] = \frac{signal_{LAMP}\ [photons \cdot s^{-1}]}{Lamp\ Irradiance[W \cdot m^{-2} \cdot nm^{-1}]}$$

$$\boxed{I[Wm^{-2}nm^{-1}] = \frac{signal_{SUN}}{signal_{LAMP}} \cdot Lamp\ Irradiance\ [Wm^{-2}nm^{-1}]}$$

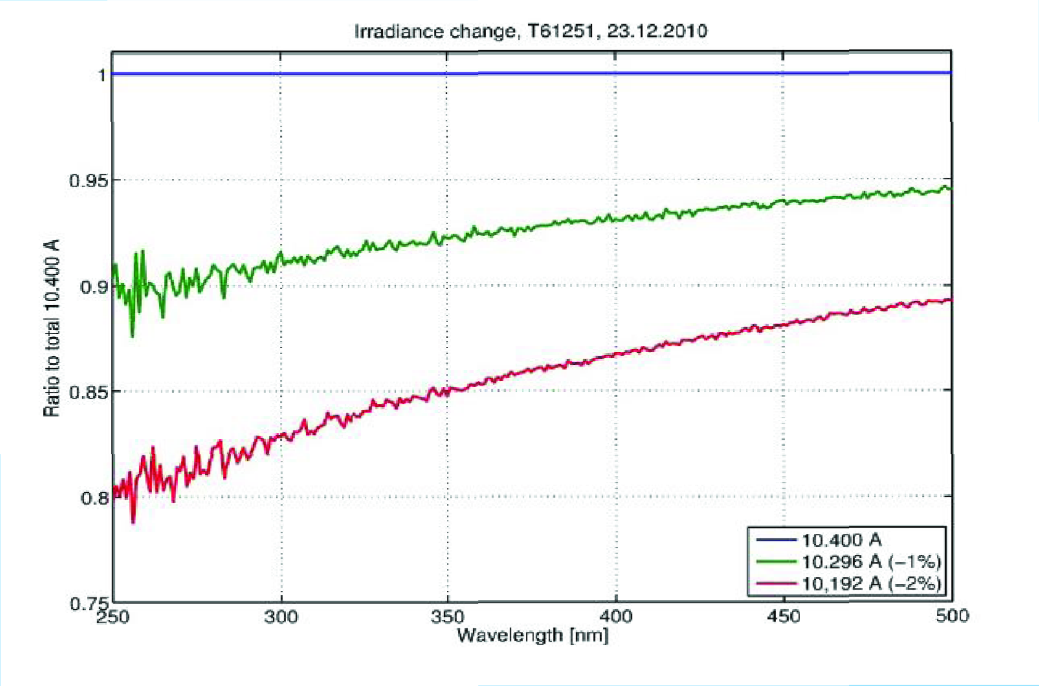
We assume that the relationship is independent on the level of radiation e.g. the instrument is linear...

Example Brewer #163



Lamp Current

Spectral Irradiance standards operate at a stable nominal current, typically, 1000W and 8.0 A. The voltage is monitored to check for drifts and changes of the lamp.



Wavelength (±2nm)	Relative Irradiance change for a 1% Current change
255	10%
280	9.1%
300	8.7%
350	7.6%
400	6.8%
500	5.4%

Summary of a lamp calibration

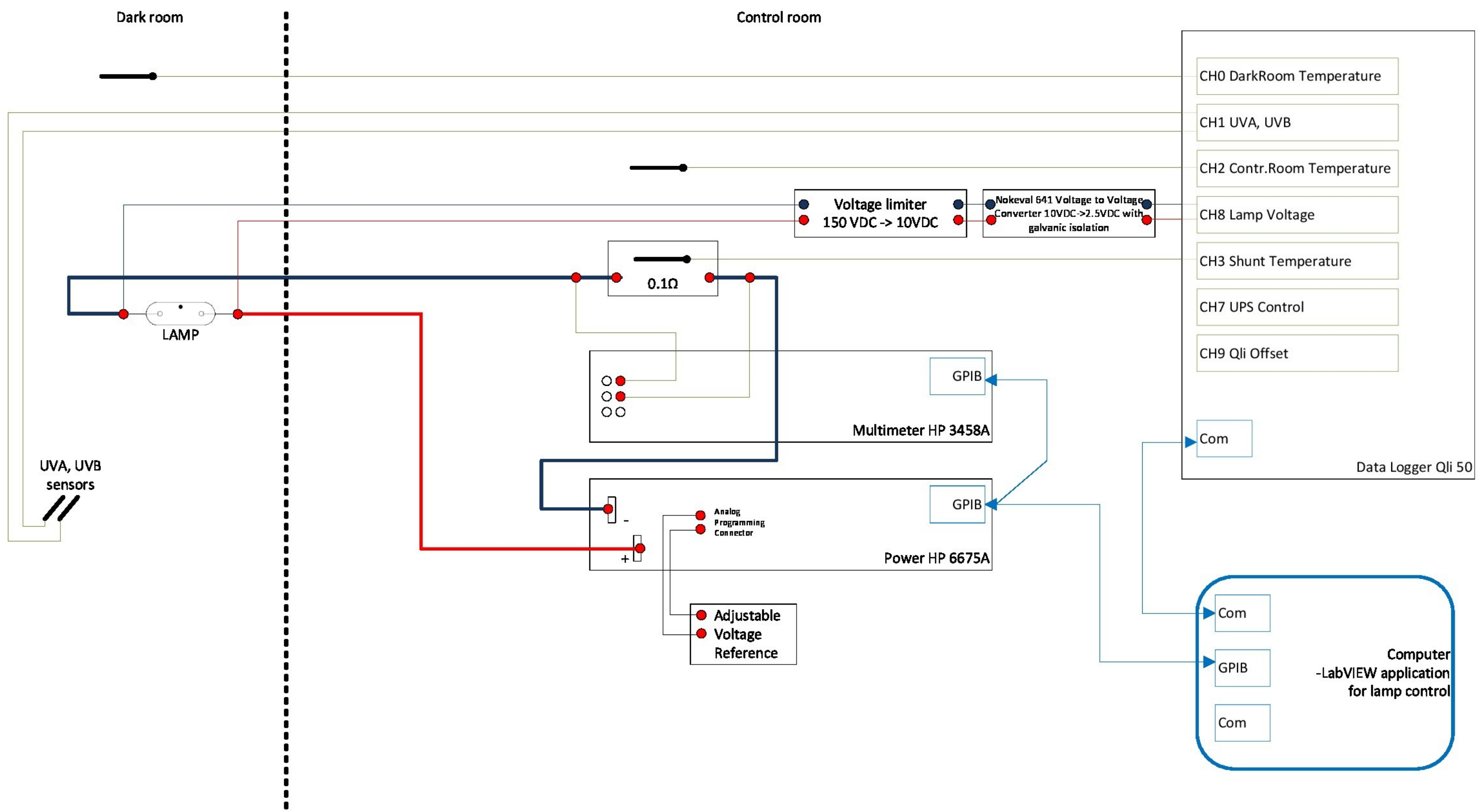
1000 W Calibration:

- Lamp current should be stabilised to within 0.1% of the nominal value (for example 8.0 A) for an irradiance stability of 1%.
  - In the UV, 1% change in current corresponds to 10% change in lamp radiation output.
- Distance between spectroradiometer reference plane and lamp reference plane should be well known (square law).
  - Error = 2Δd/d,
    i.e. ±1 mm uncertainty in 500 mm produces uncertainty in calibration of ±0.4%.
- Calibration frequency ~ 1/month.

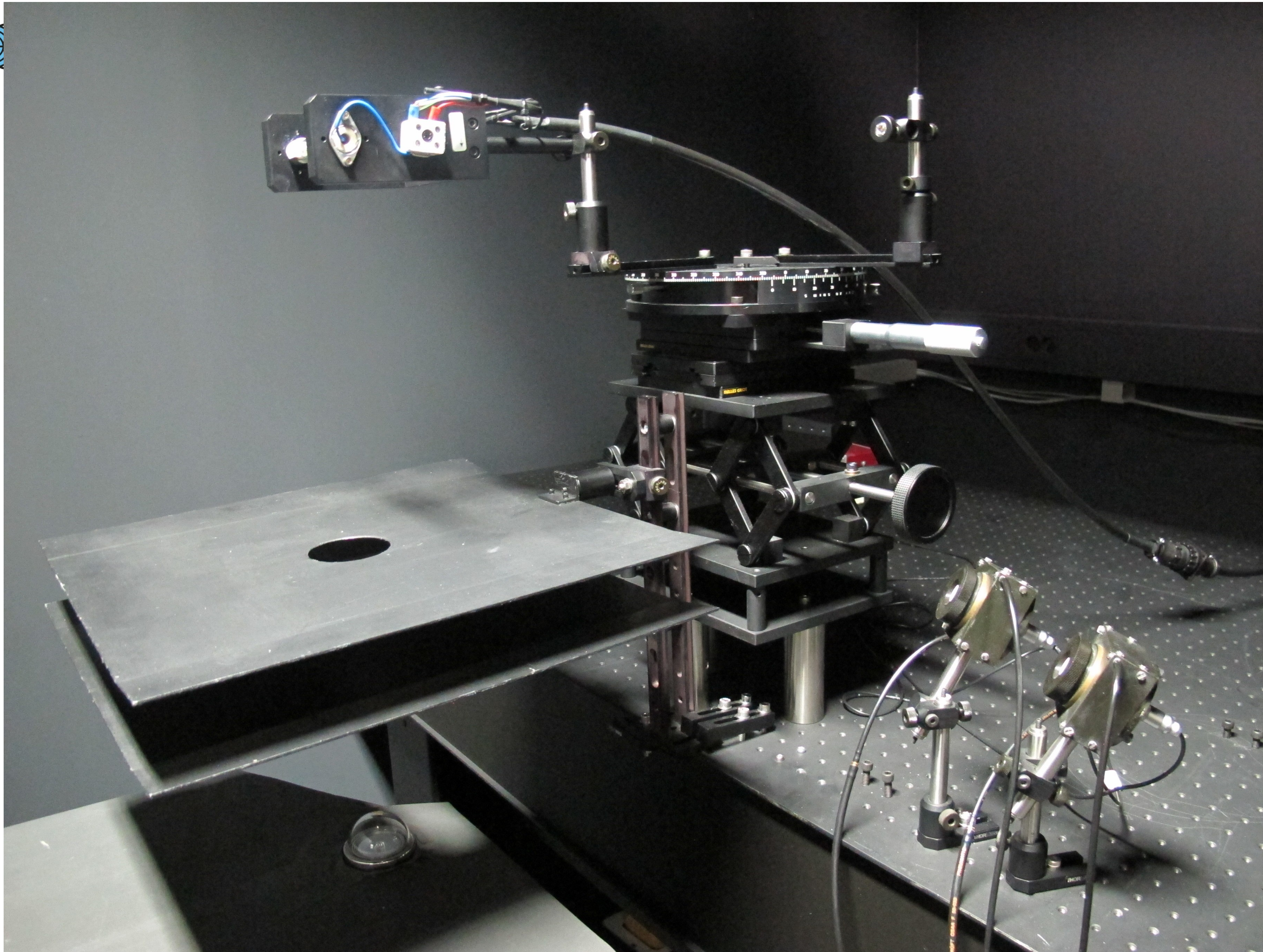
Portable calibration (50 W lamps):

- Portable calibrator should be calibrated relative to 1000 W calibration.
- Calibration frequency ~ 1/week.

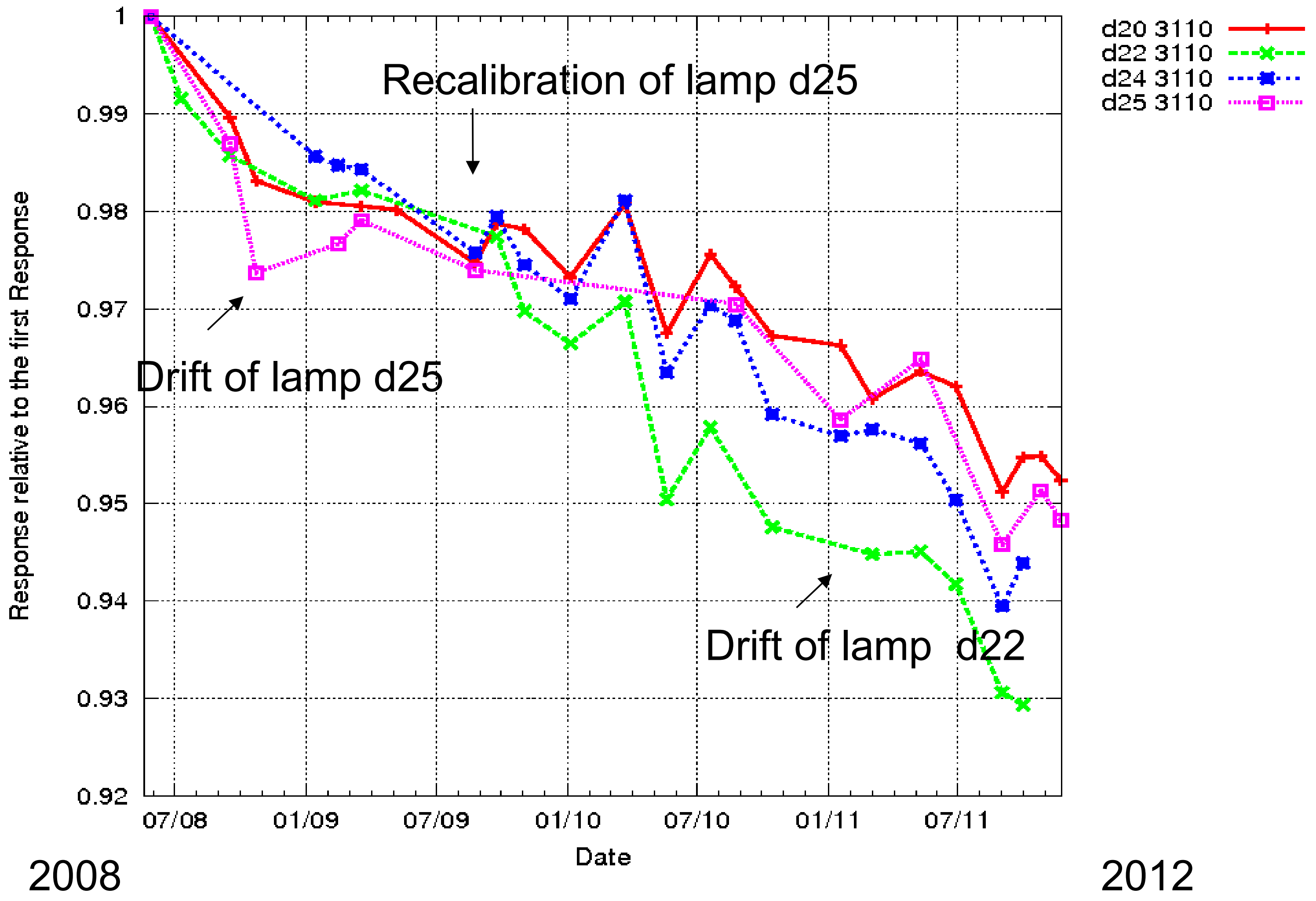
Each calibration should consist of the average of several lamps (i.e. at least three) to detect drifts and fluctuations of individual lamps.

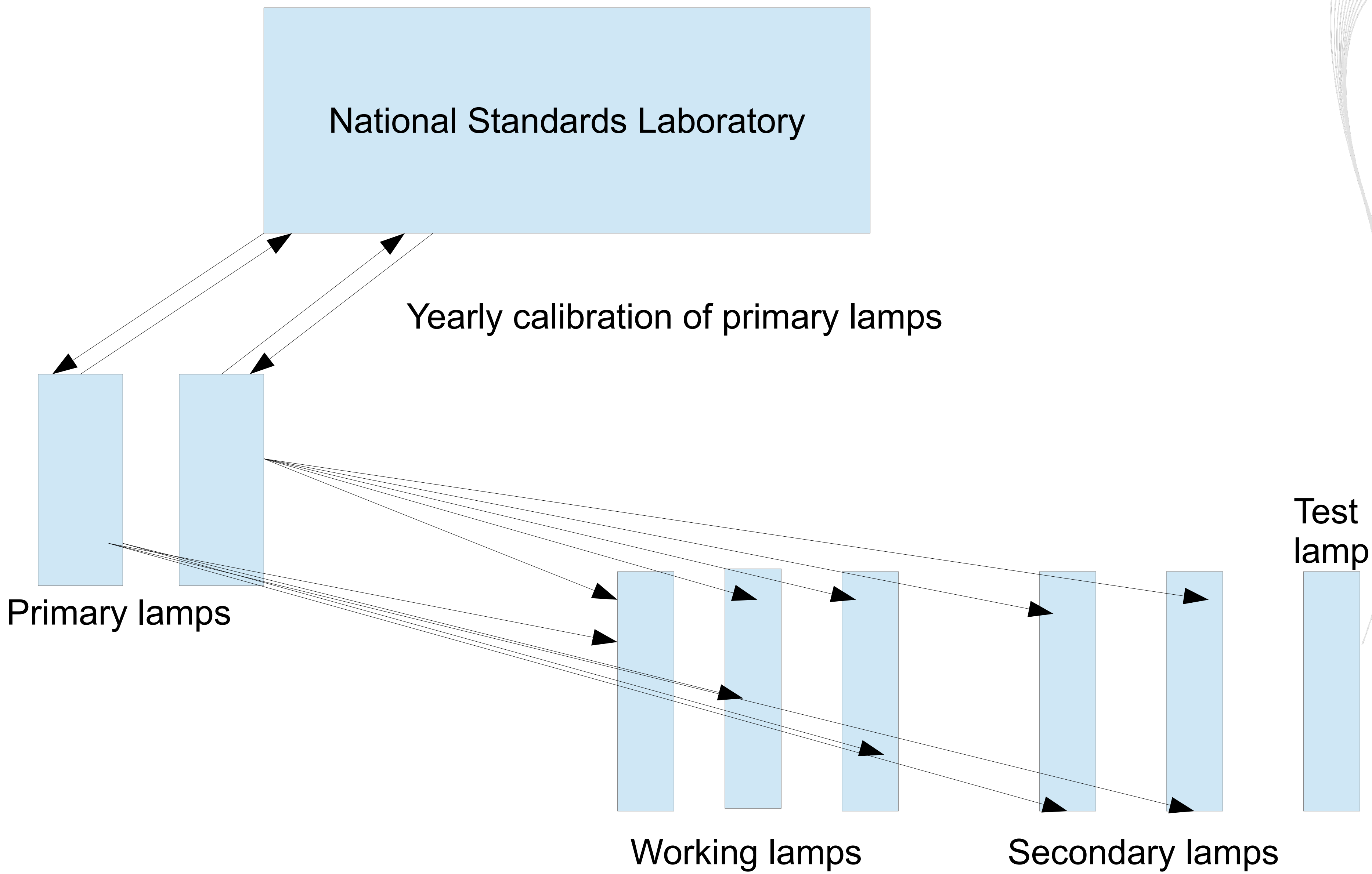


Dark room
Control room
CH0 DarkRoom Temperature
CH1 UVA, UVB
CH2 Contr.Room Temperature
CH8 Lamp Voltage
CH3 Shunt Temperature
CH7 UPS Control
CH9 Qli Offset
Com
Data Logger Qli 50
Voltage limiter
150 VDC -> 10VDC
Nokeval 641 Voltage to Voltage Converter 10VDC->2.5VDC with galvanic isolation
0.1Ω
LAMP
GPIB
Multimeter HP 3458A
UVA, UVB sensors
GPIB
Analog Programming Connector
Power HP 6675A
Adjustable Voltage Reference
Com
GPIB
Com
Computer -LabVIEW application for lamp control



Several lamps are needed in order to detect the possible drift of a lamp




National Standards Laboratory
Yearly calibration of primary lamps
Primary lamps
Test
lamp
Working lamps
Secondary lamps

Frequency of UV calibration

In WMO-GAW report No. 126: Guidelines for Site Quality Control of UV Monitoring:

page 9-10: "Frequency of the instrument calibration: in situ against 200W working standard every 2 weeks, laboratory calibration of 200 W and/or instrument to 1000W reference every 6 months or more frequently or more frequently if so indicated by in situ calibrations."

In Sodankylä:

1000 W lamp tests every six week in the laboratory
Calibration of the irradiance scale

50 W lamp tests every three weeks on the roof
Check the stability of the instrument: detection of changes in the spectral response → need for laboratory calibration

In addition to lamp tests in the laboratory:
- -Check of the humidity of the Brewer: drying of desicants
- -Cleaning of the tracker wheel

Example of a lamp test schedule

Brewer #037: Primary standards D24 and D62

Year 2015,
vk 5 lab: 800, 802, 850, D20, D66, D25
vk 8 roof: 800, 802, 850
vk 11 lab: 800, 802, 850, D20, D25, D63
vk 14 roof: 800, 802, 850,
vk 17 lab: 800, 802, 850, D20, **D24**, **D62**
vk 20 roof: 800, 802, 850 Calibration at the National Standards Lab of D24 and D62
vk 23 lab: 800, 802, 850, D20, **D24**, D25, D61, D63, **D62**, D64, D66
vk 26 roof: 800, 802, 850
vk 29 lab: 800, 802, 850, D20, D25, D61
vk 32 roof: 800, 802, 850
vk 35 lab: 800, 802, 850, D20, D61, D63
vk 38 roof: 800, 802, 850
vk 41 lab: 800, 802, 850, D20, D63,D64
vk 44 roof: 800, 802, 850
vk 47 lab: 800, 802, 850, D20, D64, D66

Steps for processing the response time series

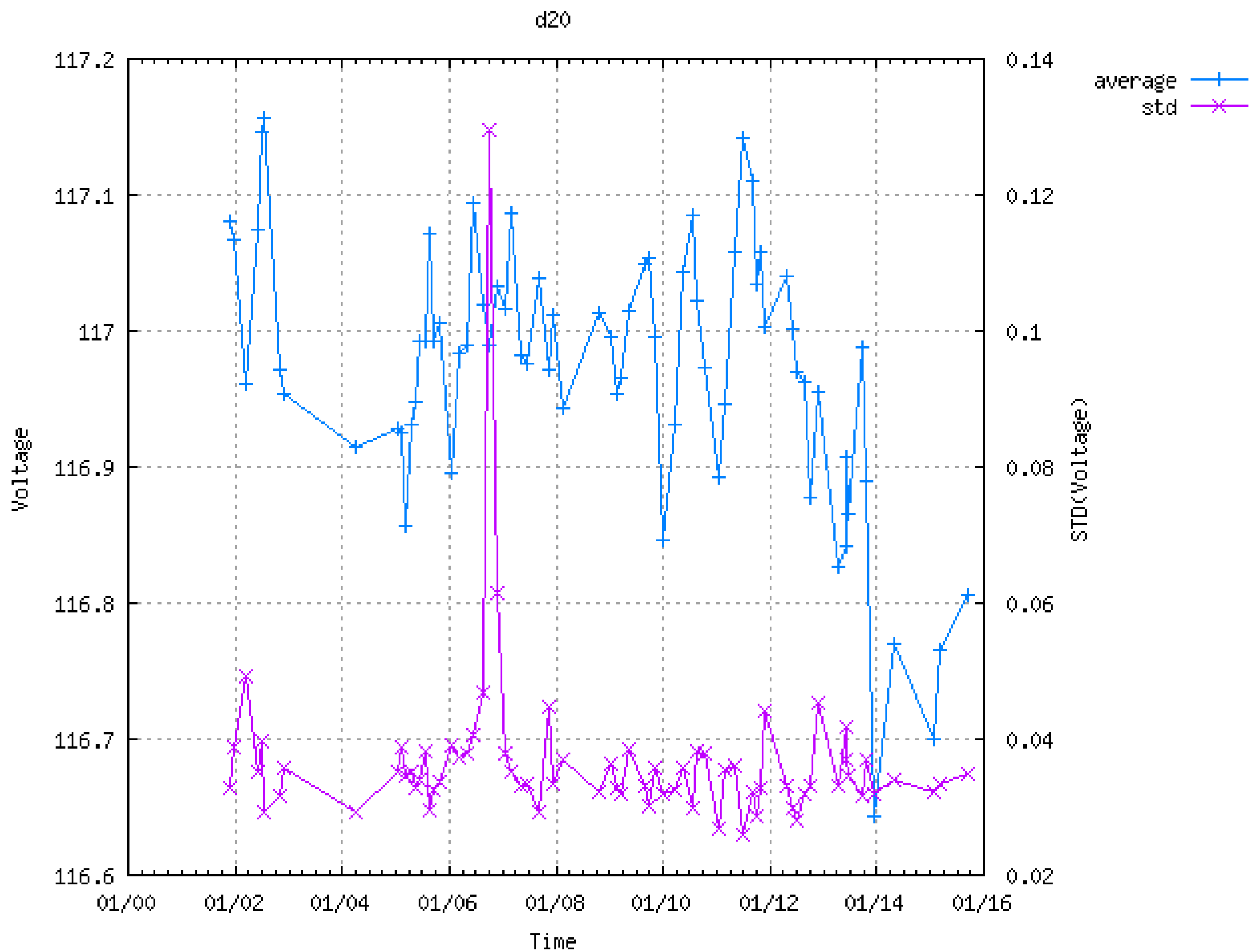
Keep a log book of burning time of your lamps:

e.g. for the work lamp D20 in Sodankylä:

Total burn time 37:20:18 (134418 seconds)
27.11.2001 33101 11:51:04 12:27:59, 2215 seconds
28.12.2001 36201 12:23:48 12:58:59, 2111 seconds
11.03.2002 07002 08:43:53 09:17:44, 2031 seconds
06.06.2002 15702 00:13:58 00:48:36, 2078 seconds
03.07.2002 18402 16:25:23 17:11:29, 2766 seconds
13.07.2002 19402 15:35:25 16:01:37, 1572 seconds
29.10.2002 30202 08:51:35 09:20:04, 1709 seconds
....

! It is very important to use some lamps less frequently than the others, as then the lamps age in a different rhythm and you can notice when a lamp start to drift!

1. Check the voltages of the lamps during the calibration



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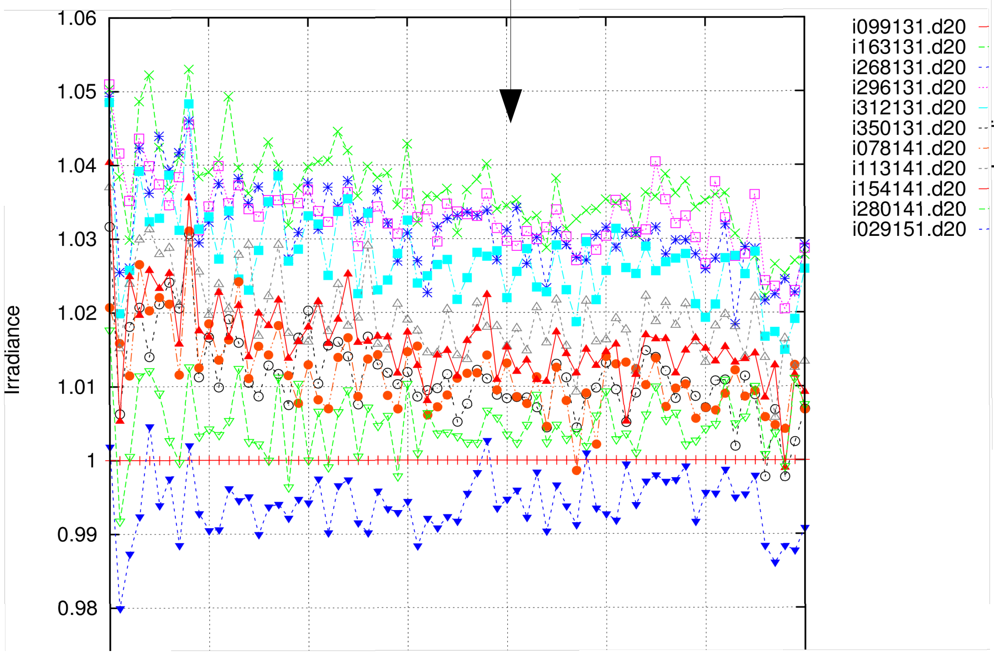
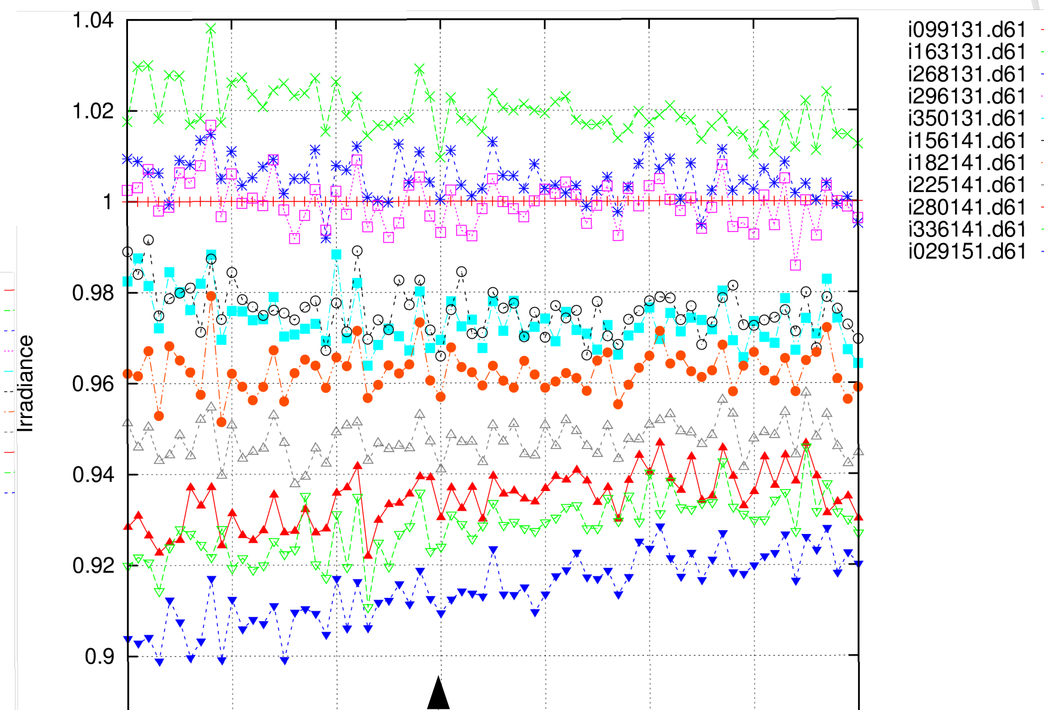
2. Get a general idea of what is going on:

Check the spectral irradiances of each lamp using one unchanged spectral responsivity.

Nothing very strange





Possible drift of lamp

3. Transfer of the irradiance scale from the primary lamps to working lamps

a) Calculation of responsivity with primary lamps D24 and D62 on days 13014 and 16214 (before and after the calibration at NSL)

→ resp13014.d24 and resp13014.D62
and resp16214.d24 and resp16214.D62

If the lamps have not changed during the travel to the NSL, the responsivities should be within 1% from each other.

→Calculate the average of resp16214.d24 and resp16214.D62 and use it to determine the irradiances of the working lamps.

->After the primary lamps return from calibration, its good to measure them and all working lamps during the same day/days.

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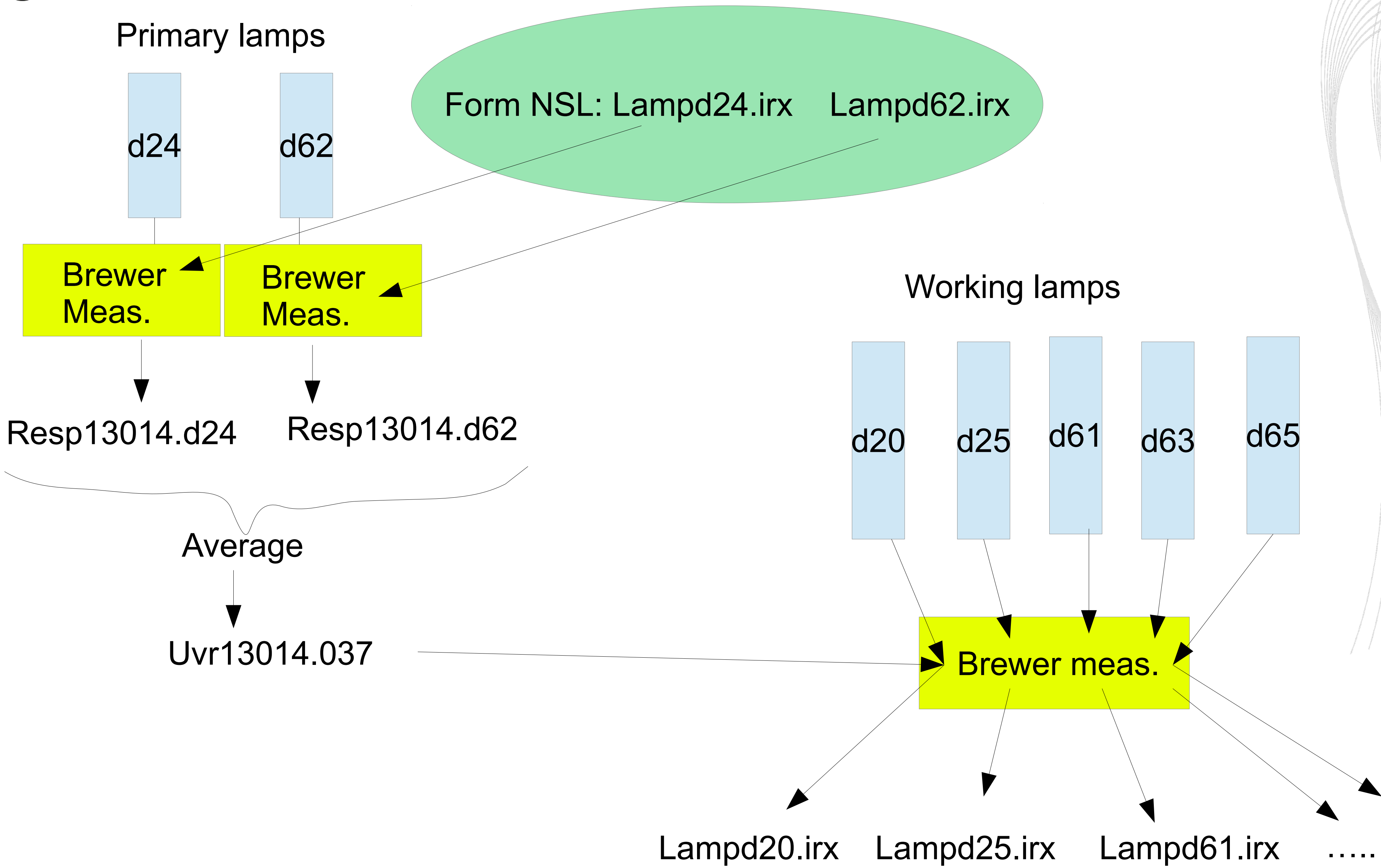

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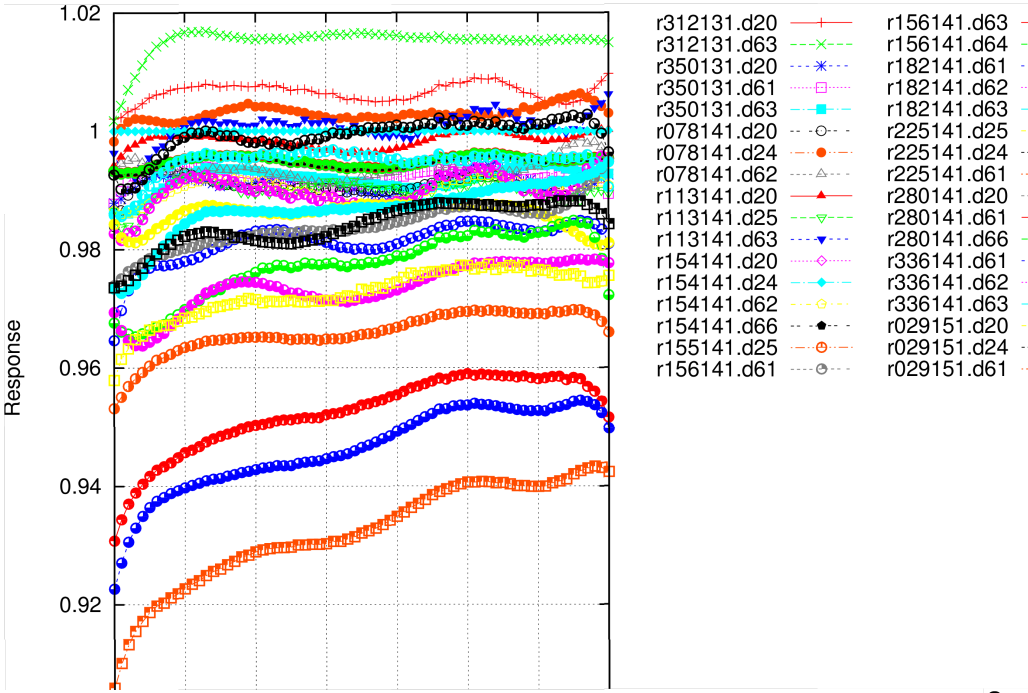
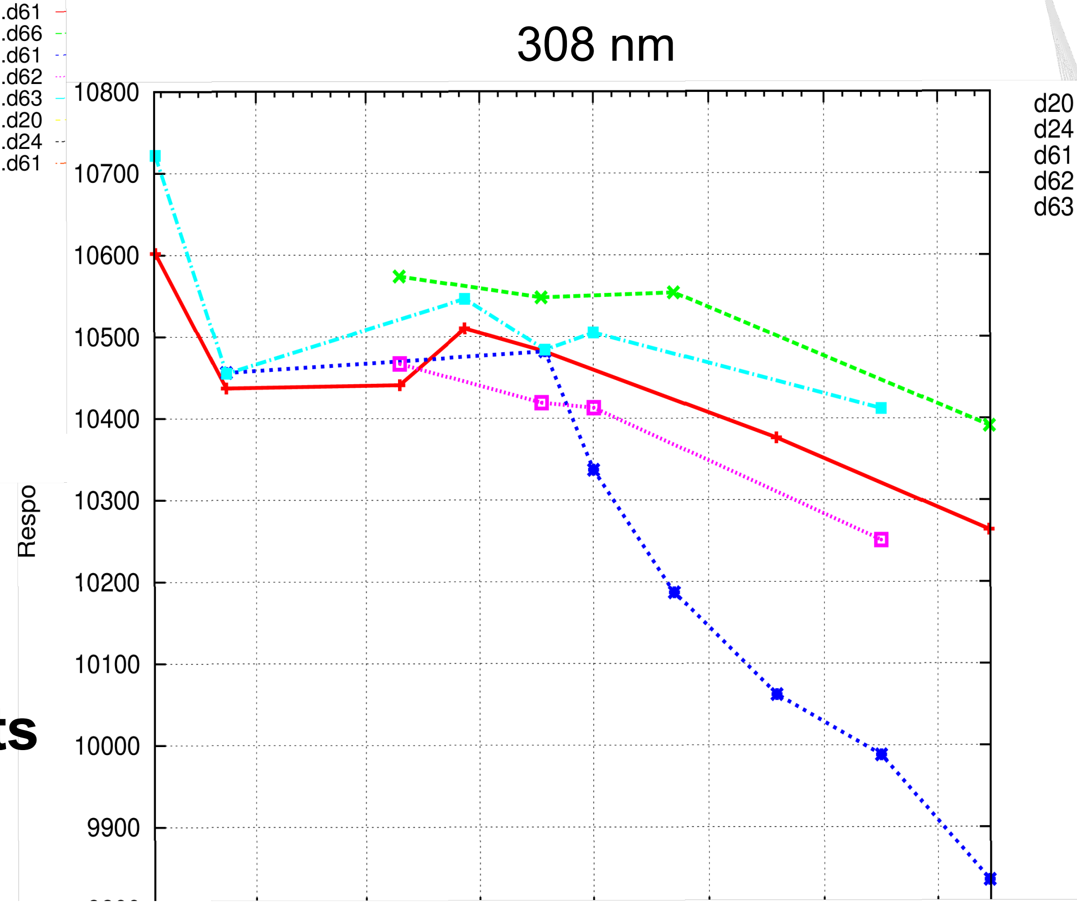
Responsivity time series

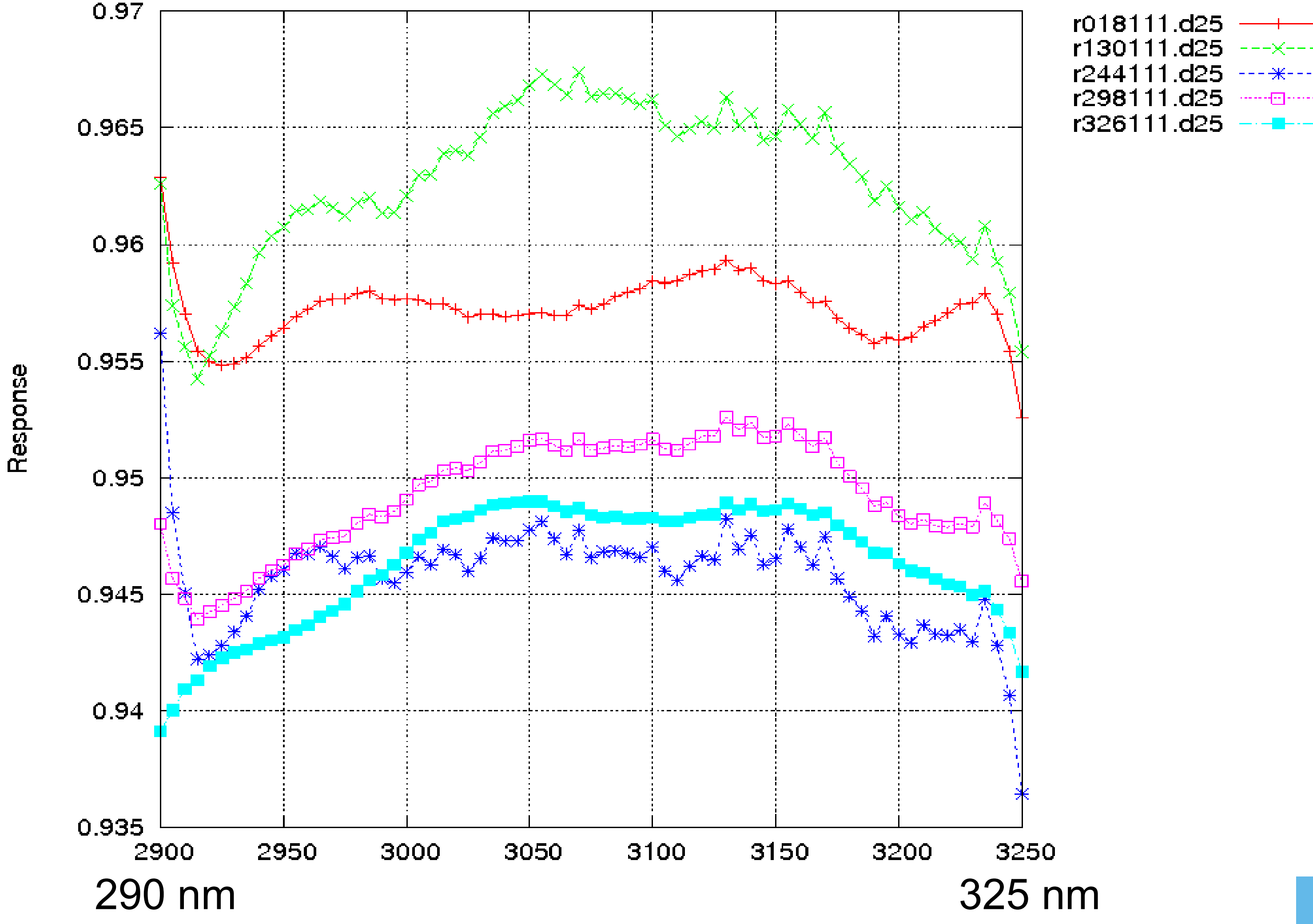
1. Calculate the individual responses with each lamp.





2. Choose good measurements

Spectral responsivity of the Brewer #037 measured with lamp d25 in 2011, compared to the spectral responsivity in 2008

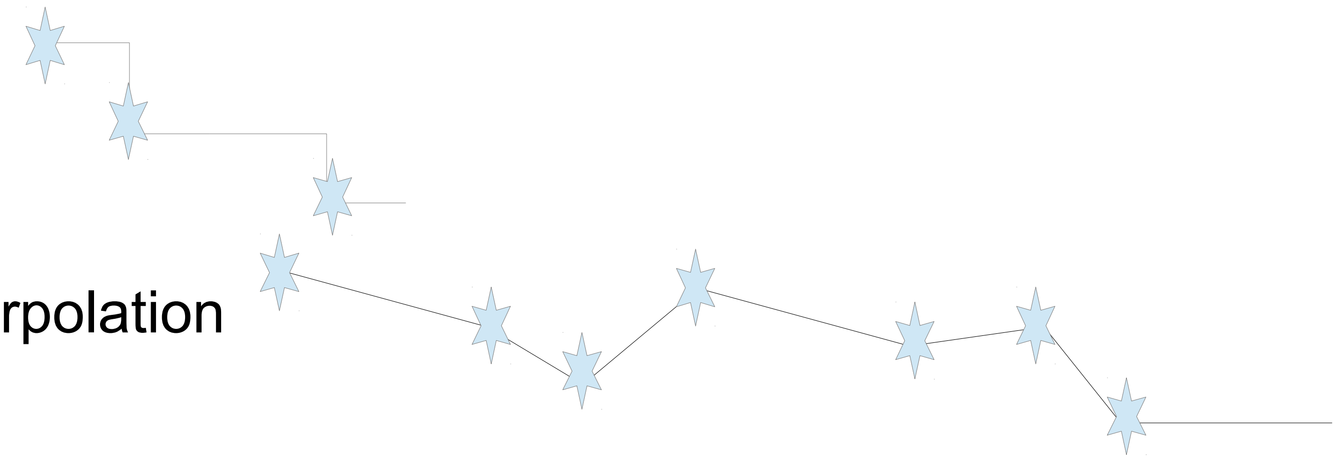


Daily responsivity

1. Stepwise

Or

2. Linear interpolation



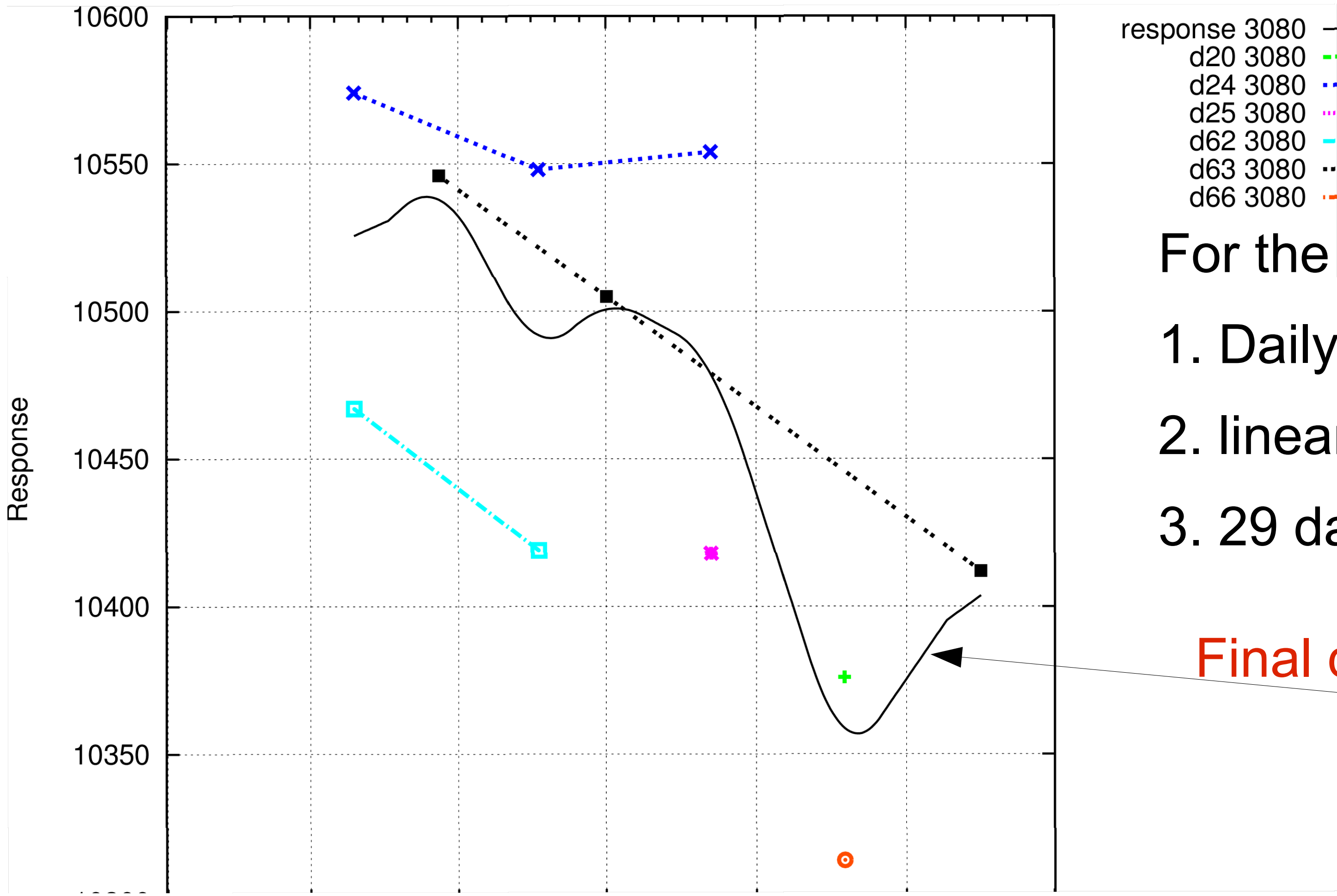
If you choose the linear interpolation:

Once you have only the good measurements left, you have to either

a) make daily average first and then a linear interpolation

Or

b) Make a linear interpolation and then calculate the daily average



For the Brewer#037:

1. Daily average
2. linear interpolation
3. 29 day moving average

Final daily responsivity

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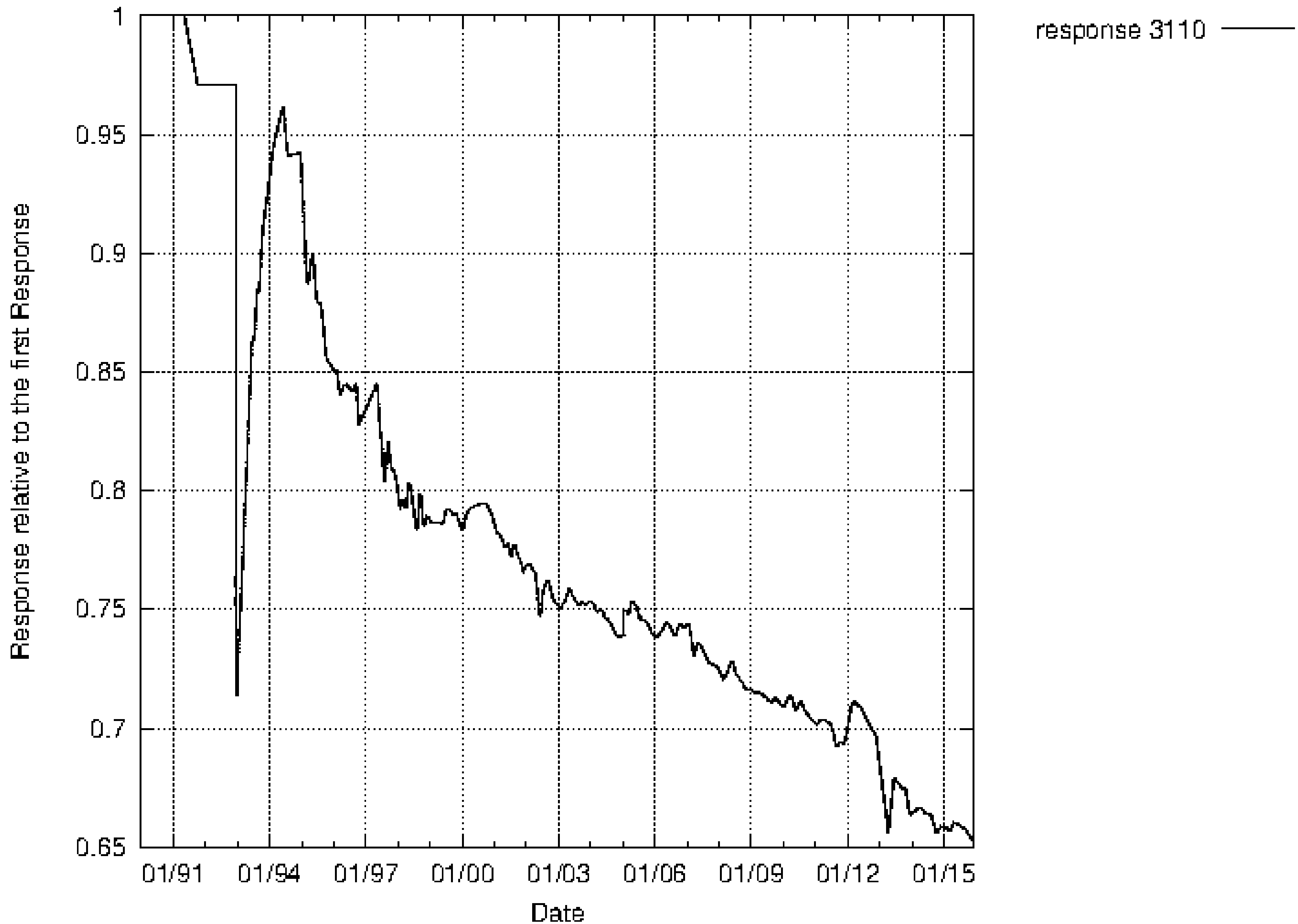
Response time series of the Brewer#037 at 311 nm 1990-2015



Litterature

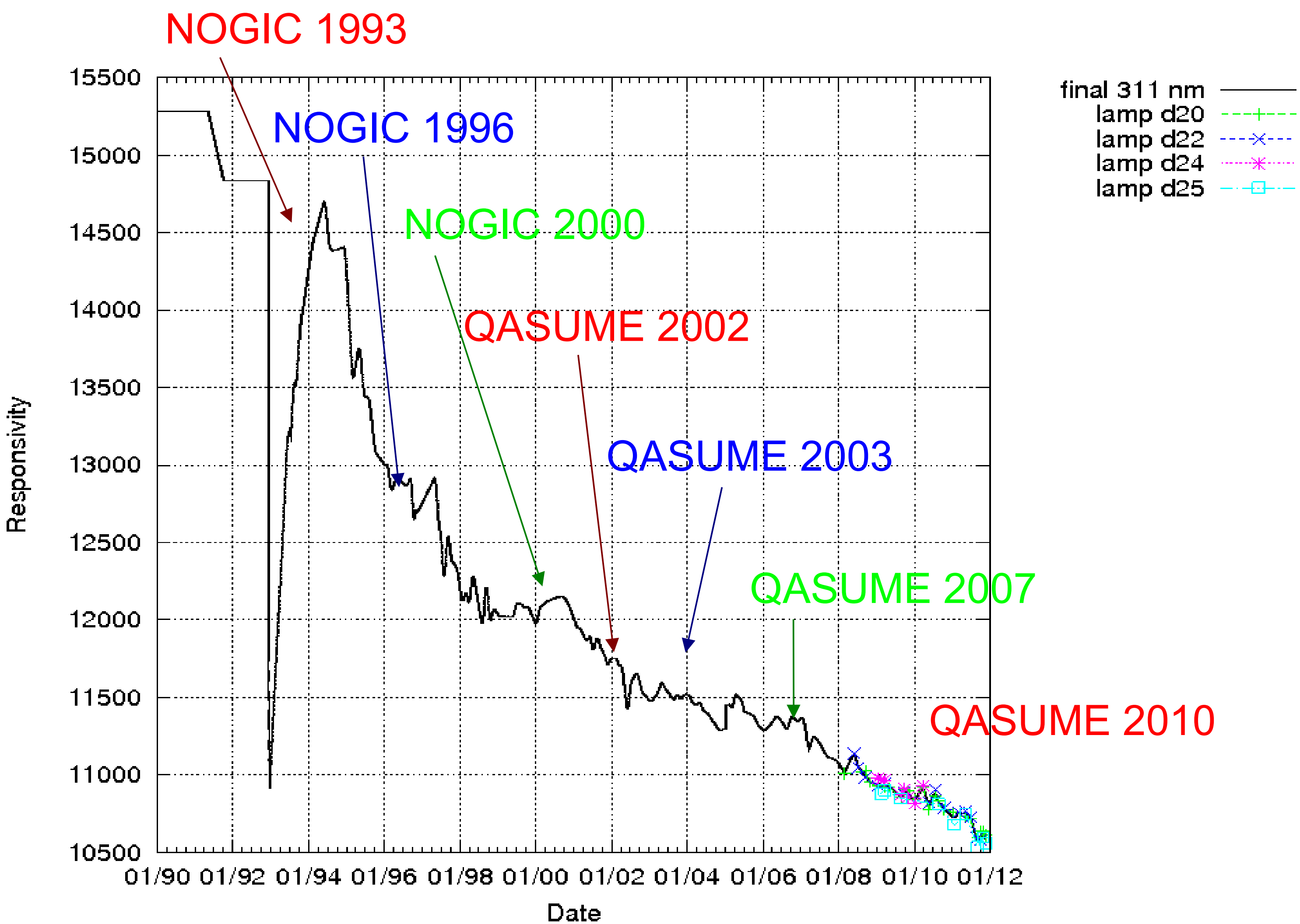
Heikkilä, A., Lakkala, K., Mäkelä, J.S., Meinander, O., Kaurola, J., Koskela, T., Karhu, J. M., Karppinen, T., Kyrö, E., de Leeuw, G: In search of traceability: two decades of calibrated Brewer UV measurements in Sodankylä and Jokioinen, Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-40, in review, 2016.

Lakkala, K., Suokanerva, H., Karhu, J. M., Aarva, A., Poikonen, A., Karppinen, T., Ahponen, M., Hannula, H.-R., Kontu, A., and Kyrö, E.: Optical laboratory facilities at the Finnish Meteorological Institute – Arctic Research Centre, Geosci. Instrum. Method. Data Syst., 5, 315-320, doi:10.5194/gi-5-315-2016, 2016.

Webb, A., Gardiner, B., Martin, T., Leszcynski, K., Metzdorf, J.,and Mohnen, V.: Guidelines for Site Quality Control of UV Mon-itoring, Global Atmosphere Watch Report No. 126, World Meteorological Organization (WMO), Geneva, 39 pp., 1998.

Webb, A., Gardiner, B., Leszczynski, K., Mohnen, V., Johnston, P.,Harrison, N., and Bigelow, D.: Quality Assurance in Monitoring Solar Ultraviolet Radiation: the State of the Art, Global Atmosphere Watch Report No. 146, World Meteorological Organiza-tion (WMO), Geneva, 45 pp., 2003.

QA using independent solar UV comparisons



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