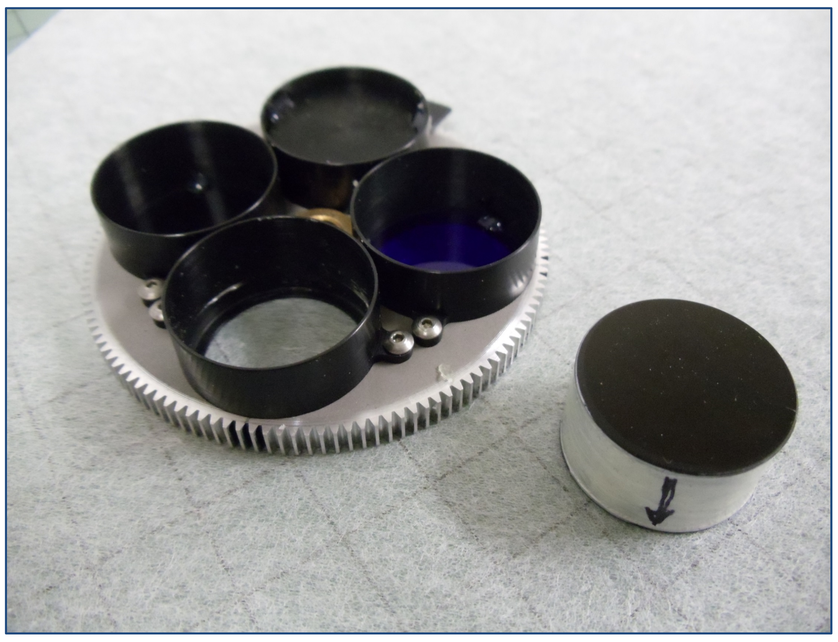
Update on the calibration and system upgrades of the NOAA-GRAD UV Monitoring Networks

Improvements in the uncertainty of the NEUBrew Brewer Mark IV spectral UV and total column ozone measurements with a replacement new type ammonium nickel-sulfate hexahydrate UV filter



A new Inrad Optics UVC-7 combination filter ready for installation in a Brewer Mark IV spectrophotometer's filter wheel #3

During the direct-sun ozone measurements, near simultaneous measurements of five wavelengths are made. Four of the wavelengths are sensitive to ozone absorption and the fifth is sensitive to ozone and sulfur dioxide absorption. In Brewer language, the individual signals are referred to as F_i. The F_i's are the log (base 10) of the raw signals and are corrected and compensated for deadtime, temperature, and Rayleigh scattering.

Four sets of single ratios are formed:

$MS_4 = F_5 - F_2$ $(includes\ effects\ of\ O_3\ and\ SO_2)$
$MS_5 = F_5 - F_3$
$MS_6 = F_5 - F_4$ $(affected\ predominantly\ by\ O_3)$
$MS_7 = F_6 - F_5$

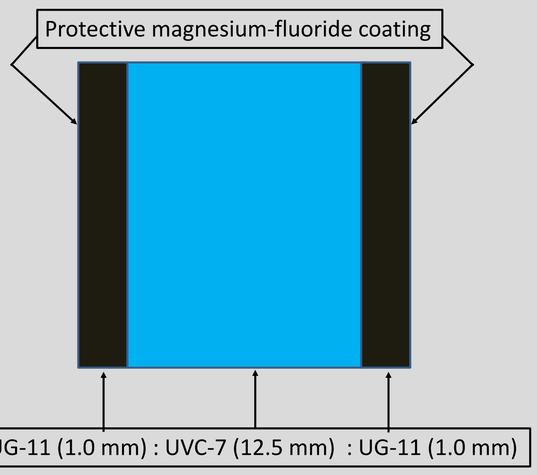
MS_5, MS_6, and MS_7 are mostly independent of SO_2 effects. MS_4 is largely affected by SO_2 column amounts.
From the single ratios two weighted higher-order ratios are formed:

$MS_9 = MS_5 - 0.5 * MS_6 - 1.7 * MS_7$
$MS_{11} = \frac{MS_9 - B1}{A1 * M2}$

The weightings were calculated to minimize the effects of absorption which are linear in wavelength. MS_9 is also weighted to remove SO_2 absorption effects. From the two weighted double-ratios total column ozone and SO_2 can be determined. However, if the input optic is directed to the internal quartz-halogen lamp instead of the sun MS_8 and MS_9 can be calculated. In this case, MS_8 and MS_9 are referred to as R5 and R6 respectively. If the internal lamp is measured daily then R5 and R6 can be used to track the ozone and SO_2 calibration stability. Each day a new B1 (ozone calibration constant) is determined using the following equation. This is accomplished by adjusting the original B1 value that was established during the WMO-traceable ozone calibration with the change in R6 value from the reference value. The reference R6 value was also determined at the same time as the original B1 value.

$$B1_{current} = B1_{reference} + (R6_{current} - R6_{reference})$$

Inrad's new UVC-7 combination filter



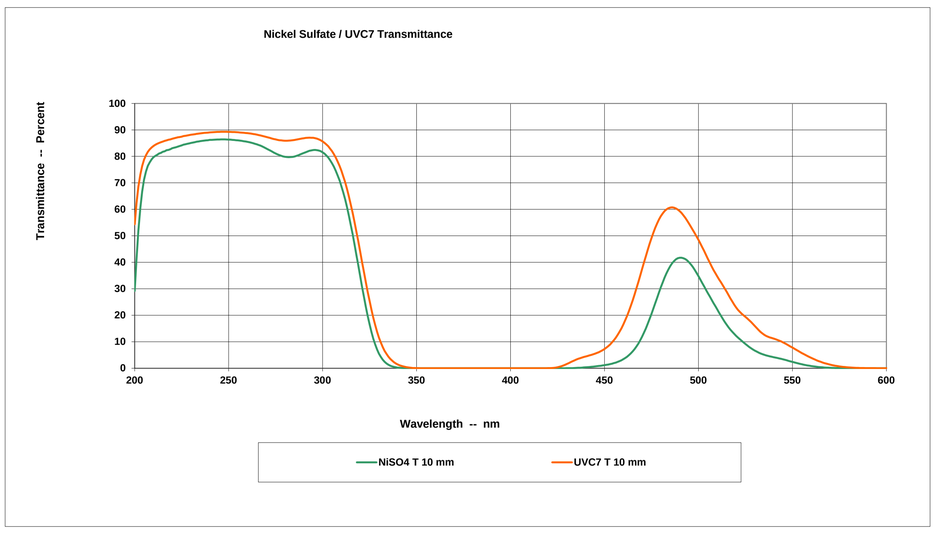
The UVC7 filter is a modified nickel-sulfate crystal by replacing half of the nickel ions with ammonium. The new filter is claimed to be thermally stable to 125 degrees Celsius. The original NiSO4 filter was hygroscopic, taking on and giving off water molecules as a function of temperature and Humidity. This behavior produces change in the spectral transmittance of the crystal, thereby changing the calibration of both the UV and ozone Measurements. The new crystal shows great promise in eliminating this unwanted behavior with its greatly improved thermal stability.

Characteristics of Inrad's new UVC7 ultraviolet filter

Like its nickel-sulfate cousin the new UVC7 is birefringent, but it is in all three planes instead of one for nickel-sulfate. Since the Brewer spectrophotometer has polarization sensitive components such as its ruled grating monochromator and slanted quartz input window, special care should be used when installing the new filter. The orientation should be considered when making polarization sensitive measurements such as the Brewer's Umkehr and NO2 routines. The crystal's three principal polarization directions were measured by its manufacturer, Inrad at 546.1 nm to be:

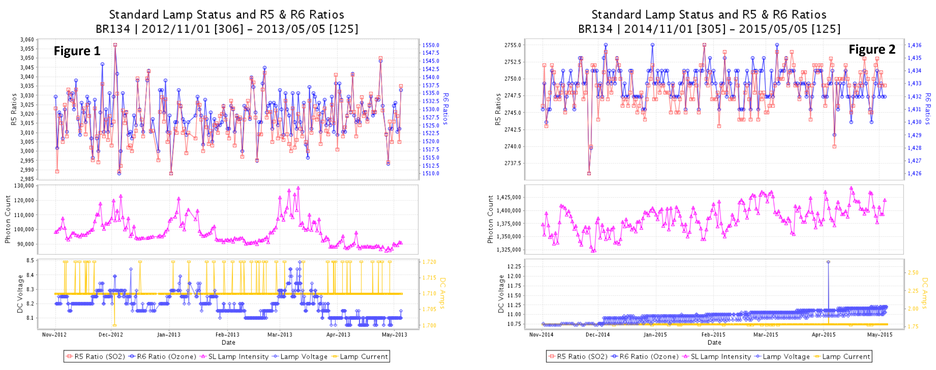
n(x) = 1.5018
n(y) = 1.5097
n(z) = 1.5092

Inrad has chosen the optic axis to be the "darkest", but not the least polarization sensitive. They chose [n(x) – n(y)] = 0.008 as the optic axis, which is similar to quartz , which is quite tenable for our purposes.

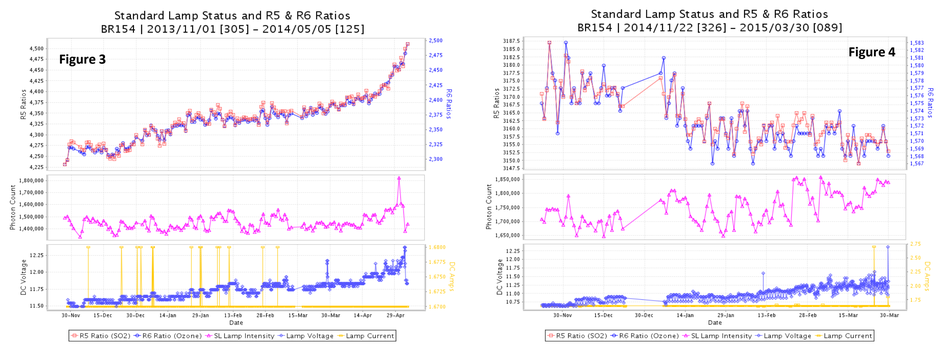


Modeled comparison of the transmittance of the original $NiSO_4$ to the new UVC7 crystals. The new UVC7 crystal, with half the nickel ions that those of the $NiSO_4$ is "brighter" and has a slightly broader bandpass. The unwanted transmittance from 450-550 nm is suppressed with the addition of the UG-11 filters.

Initial results of the UVC7 filter



Brewer 134 has historically been the most stable of the NEUBrew network instruments. Even so, installing the new UVC7 combination filter has improved its spectral stability from +/- 19 units with the old $NiSO_4$ filter to +/- 4 units over the same time period.



Brewer 154, Houston, TX had the most unstable $NiSO_4$ of the NEUBrew network instruments. The R6 values for that filter, shown in the Figure 3 change from approximately 2325 to 2500 (+/- 90 units) over a 5 month period. While the new UVC7 filter, after Brewer 154's installation at the site in mid-November changes approximately +/- 6 units.

Antarctic Spectral UV Calibration Train

Improving traceability to the NIST 1990 irradiance scale

CUCF maintains laboratory standards 200WN011, 200WN002, and 200W039 All three lamps are calibrated to the historical BSI scale used for the Antarctic UV monitoring program

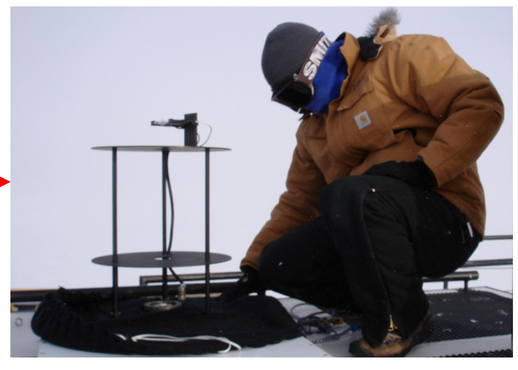
→ Traveling standard 200WN004 is used during site visits to calibrate station working standards. Its calibration is checked before and after site visits

→ Station triad of working standards

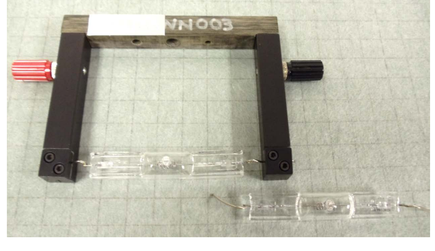
Two onsite reference lamps at each station operated infrequently

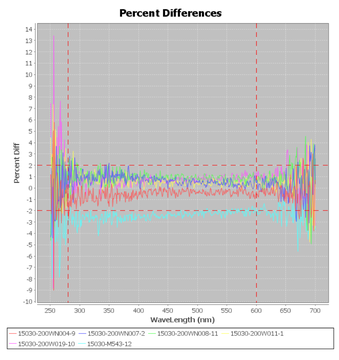
NPX: 200WN005 (annually)
200WN006 (biennially)
MCM: 200WN007 (annually)
200WN008 (biennially)
PAL: 200WN009 (annually)
200WN010 (biennially)

The CUCF maintains three 200 watt lamps as laboratory reference standards. They have been calibrated by BSI to their historical scale. The BSI scale is tied to the 1990 NIST irradiance scale through their NIST reference standard F-616. The scale from the CUCF triad is used to calibrate the AntUV traveling standard, 200WN004. The traveling standard is used during site visits at all three Antarctic UV monitoring stations to transfer the BSI scale to the station working standards. Additionally, there have been six new standards produced, two for each station. The six new standards will be operated infrequently, with one of them operated once per year and the second operated once biennially. This allows us to more closely track the stability of the three working standards at each station. Employing lamps that are used infrequently takes a lot of the guess work out of which lamps are drifting.



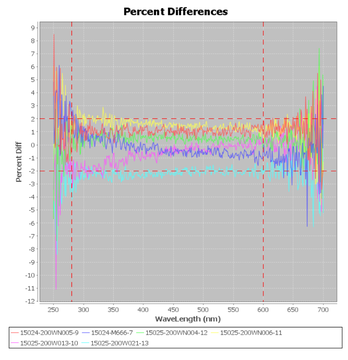
200 Watt calibration of the SUV-100 UV spectroradiometer at the South pole station





McMurdo opening calibrations
January 30, 2015

Using the described procedure, lamps that are our of Calibration can easily be identified and re-calibrated. In the plot, lamp M-543 is determined to have drifted from its calibration certificate.



South Pole station opening calibrations
January 25, 2015

Here, lamp 200W021 is easily observed to have drifted from its calibration.

1. Genbo Su, et.al., Ammonium nickel sulfate hexahydrate crystal: a new ultraviolet light filter, J. Phys. D: Appl. Phys. 35 (2002) 2652-2655

2. http://inradoptics.com/products/uv-filter-crystals/uvc7