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25 Years of Solar Spectral UV Measurements at Lauder

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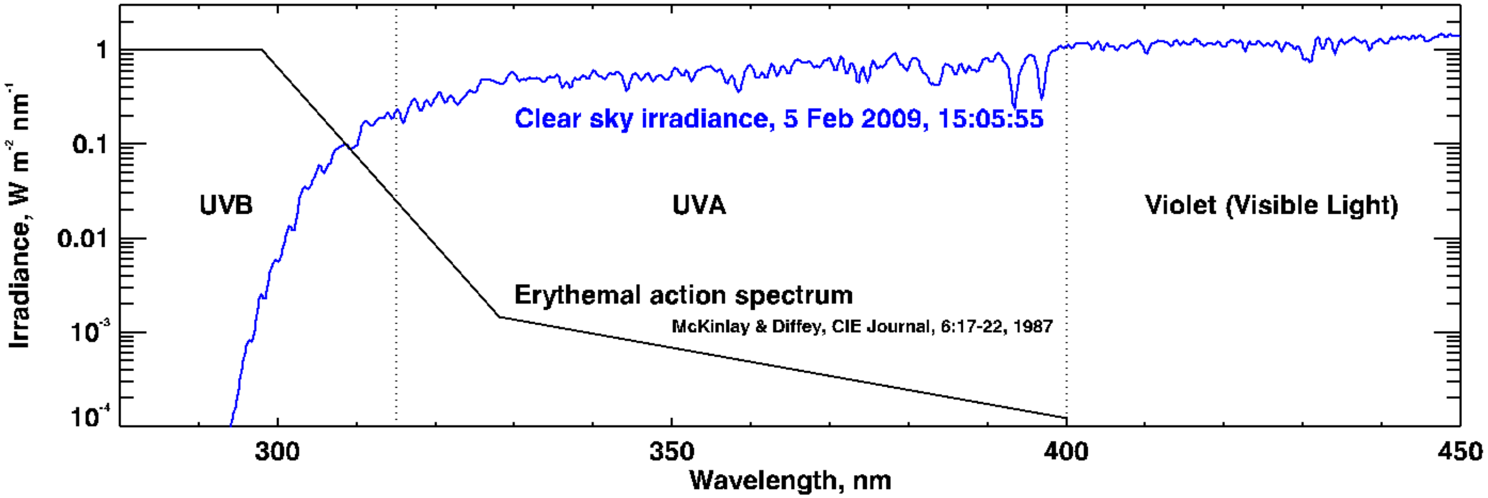
Background

In the 1970s, a possible threat to the ozone layer from NO_2 emissions by supersonic aircraft led the Lauder auroral research station to measure stratospheric NO_2 by twilight zenith-sky spectroscopy.

When the real threat to stratospheric ozone appeared in the 1980s, NO_2 proved to be very important in mitigating ozone destruction. Lauder began to measure ozone by Dobson and sondes, and ozone-depleting substances (ODS) by FTIR.

New Zealand already had the highest rates of skin cancer in the world, along with Australia. Ozone depletion prompted concern about any increase.



Useful measurement of UV is challenging, because the intensity falls by more than three orders of magnitude just as the erythemal tendency of human skin increases by the same amount with decreasing wavelength.

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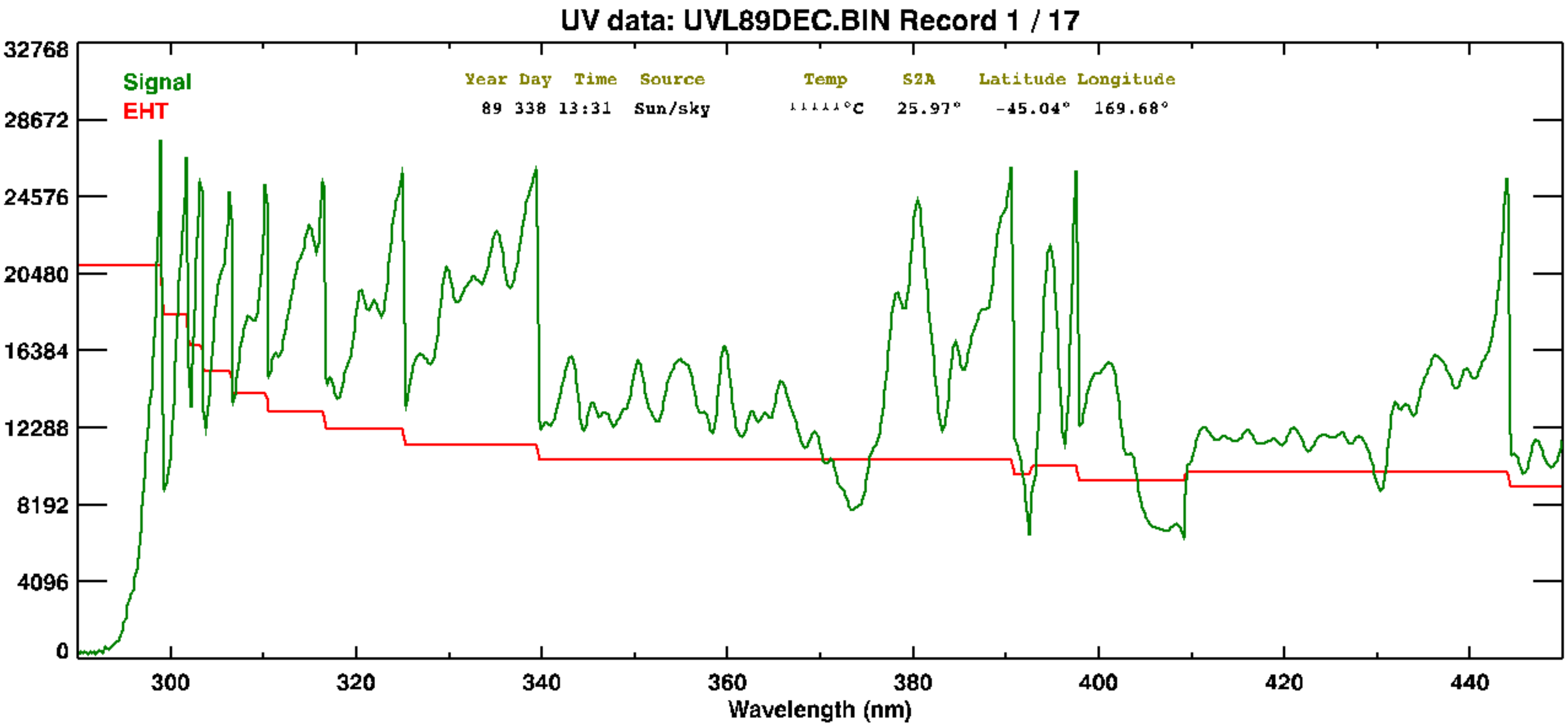

The UV-vis spectrometers for stratospheric NO_2 provided a basis for a new UV spectroradiometer, with a double monochromator to reduce stray light. ‘UVL’ scans 290-450 nm at ~1 nm bandwidth, oversampled to 0.2 nm steps for accurate spectral alignment. The required wide dynamic range is achieved by stepping the PMT voltage.

Measurements in New Zealand and Germany showed erythemal UV to be 50% higher, and 40% at equivalent latitude.
(Seckmeyer & McKenzie, Nature 359, *135*, 1992)

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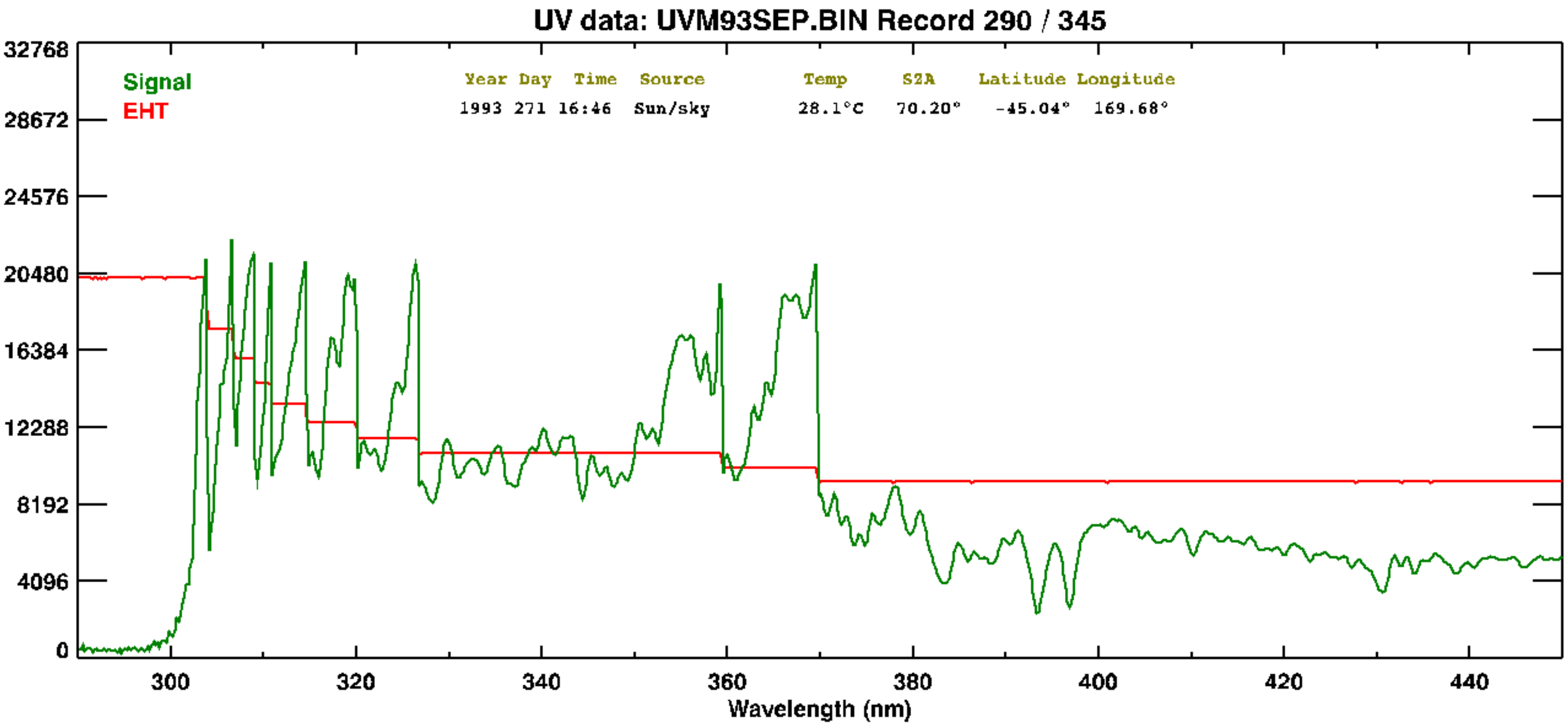
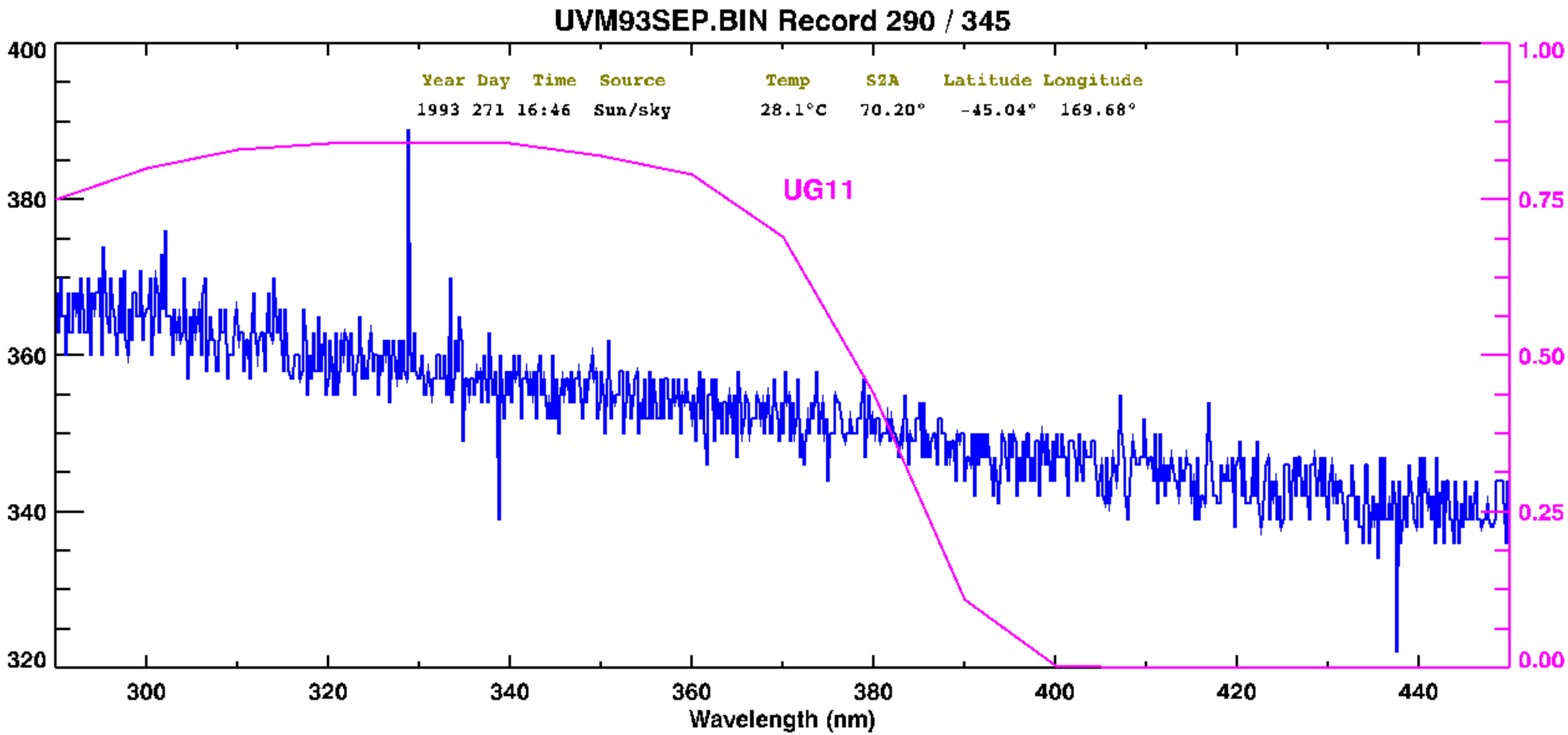


A second system, 'UVM' was built in 1993.

It again recorded data as 16-bit integers, with gain-switching.

Data are time-stamped at 370 nm, the centre of the scan, but this is sub-optimal near twilight when light level is changing rapidly.



UVM introduced a third channel, recording the variation in UV intensity over the scan as measured by a photodiode at the aperture behind a UG11 filter.

The diode signal is used in post-processing to detect cloud-affected data.

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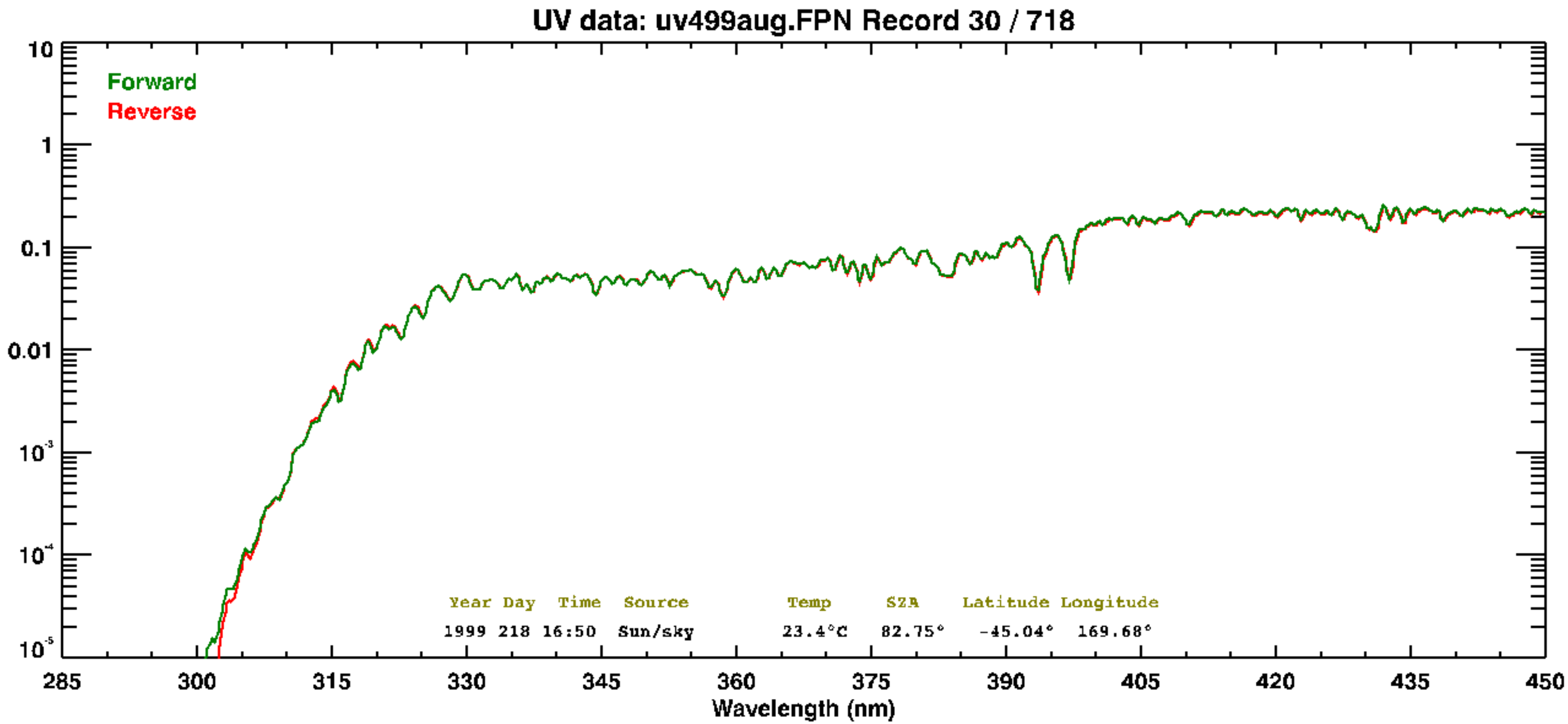

When spectral UV was added to the NDSC suite of measurements, Lauder instruments were developed for several other locations, now including:

UV3 (Mauna Loa) & UV5 (Boulder) for NOAA;

UV6 (Melbourne) & UV7 (Alice Springs) for the Bureau of Meteorology;

UV8 (last known address, Tokyo);

UV2, UV4, & UV9 at Lauder.

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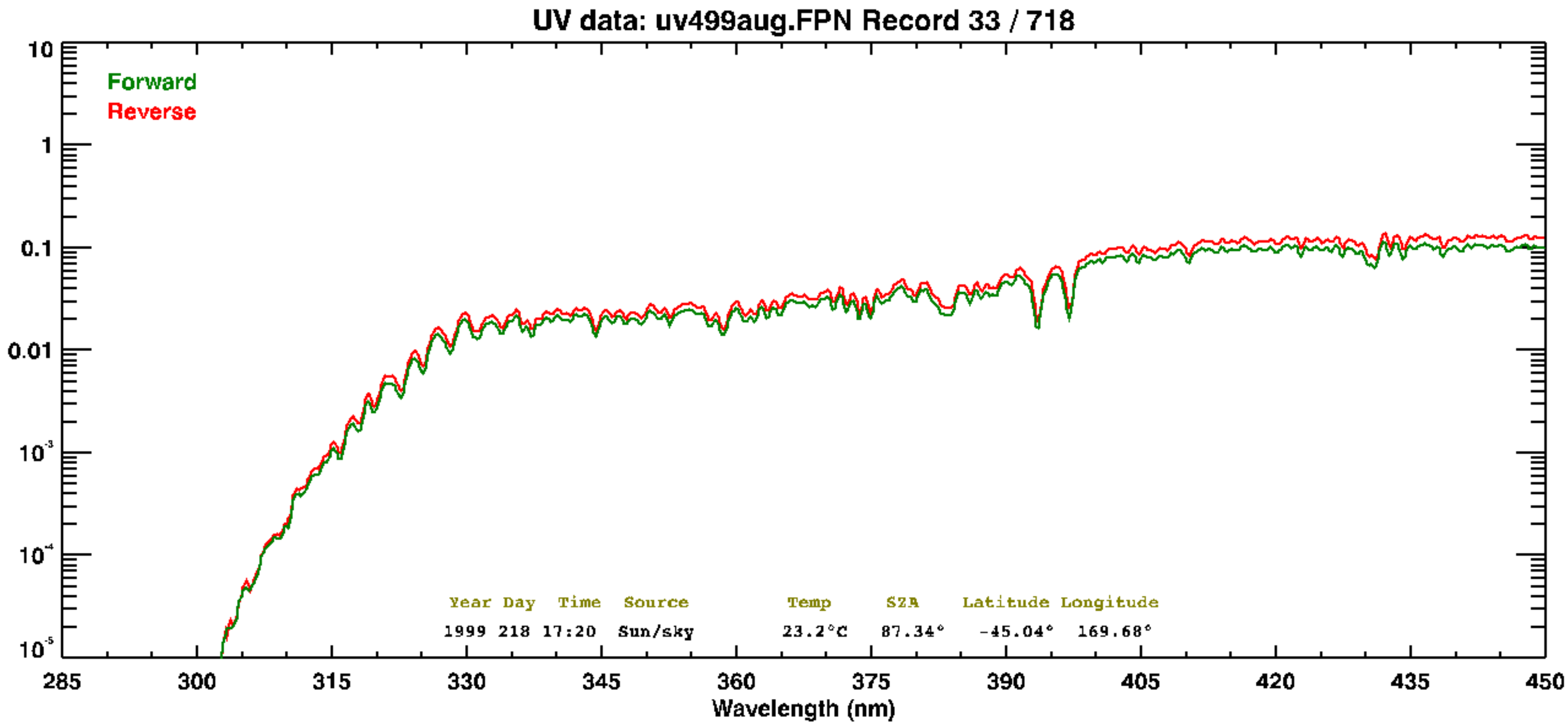

With improved electronics, the new systems eliminated the gain changes, but maintain resolution at the shortest wavelengths by slower scanning.

They also measure during both backward and forward scans.

UV9 is used to maintain consistency with the NOAA and Bureau of Meteorology systems.

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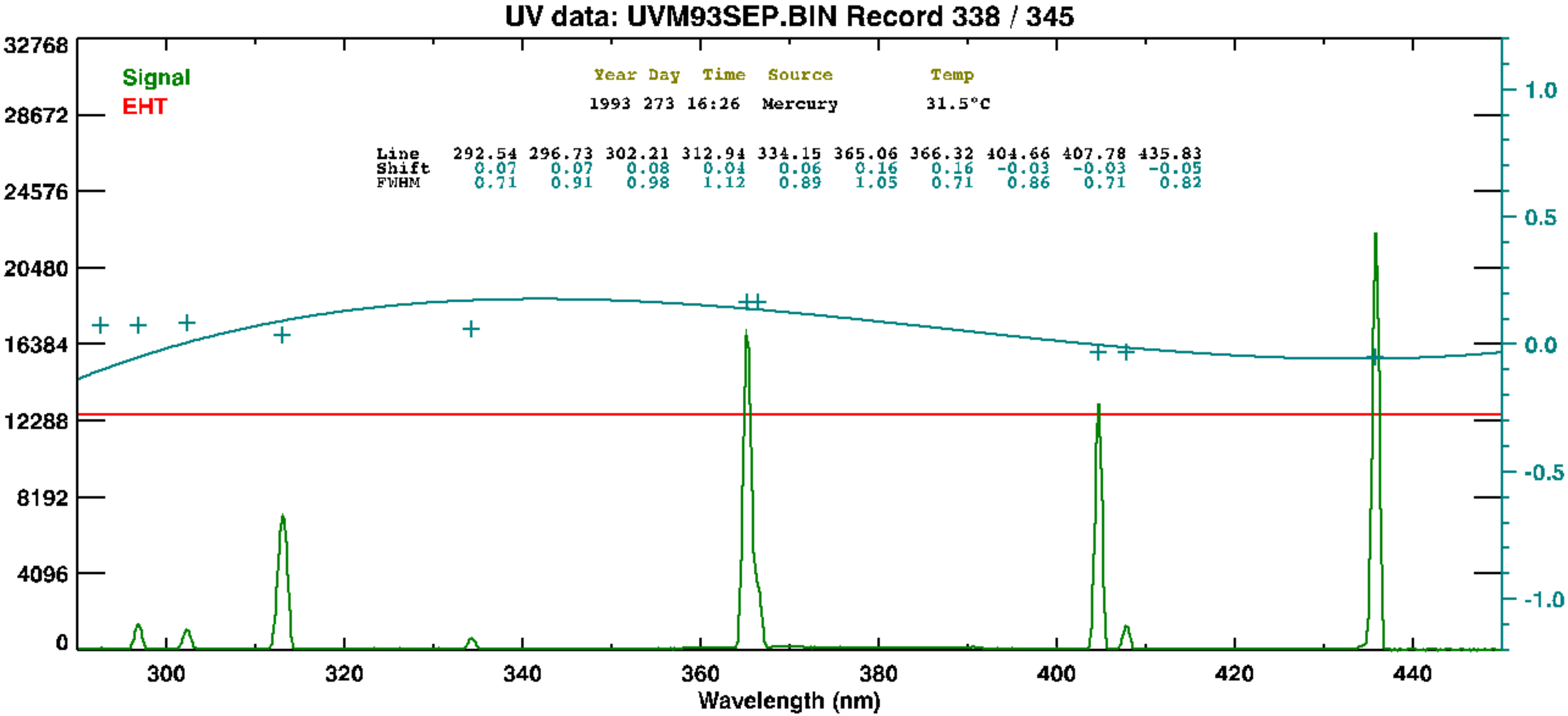

All systems are checked weekly with a 45 W lamp for stability, and with a Mercury lamp for spectral alignment. The latter determines a pattern and overall stretch that is applied to the raw measured spectra, referenced to the 296.73 nm line.

Final alignment of solar measurements uses the calcium doublet.

Following the recent QASUME intercomparison, we will explore use of the 'SHIC' algorithm to align directly on the solar spectrum.

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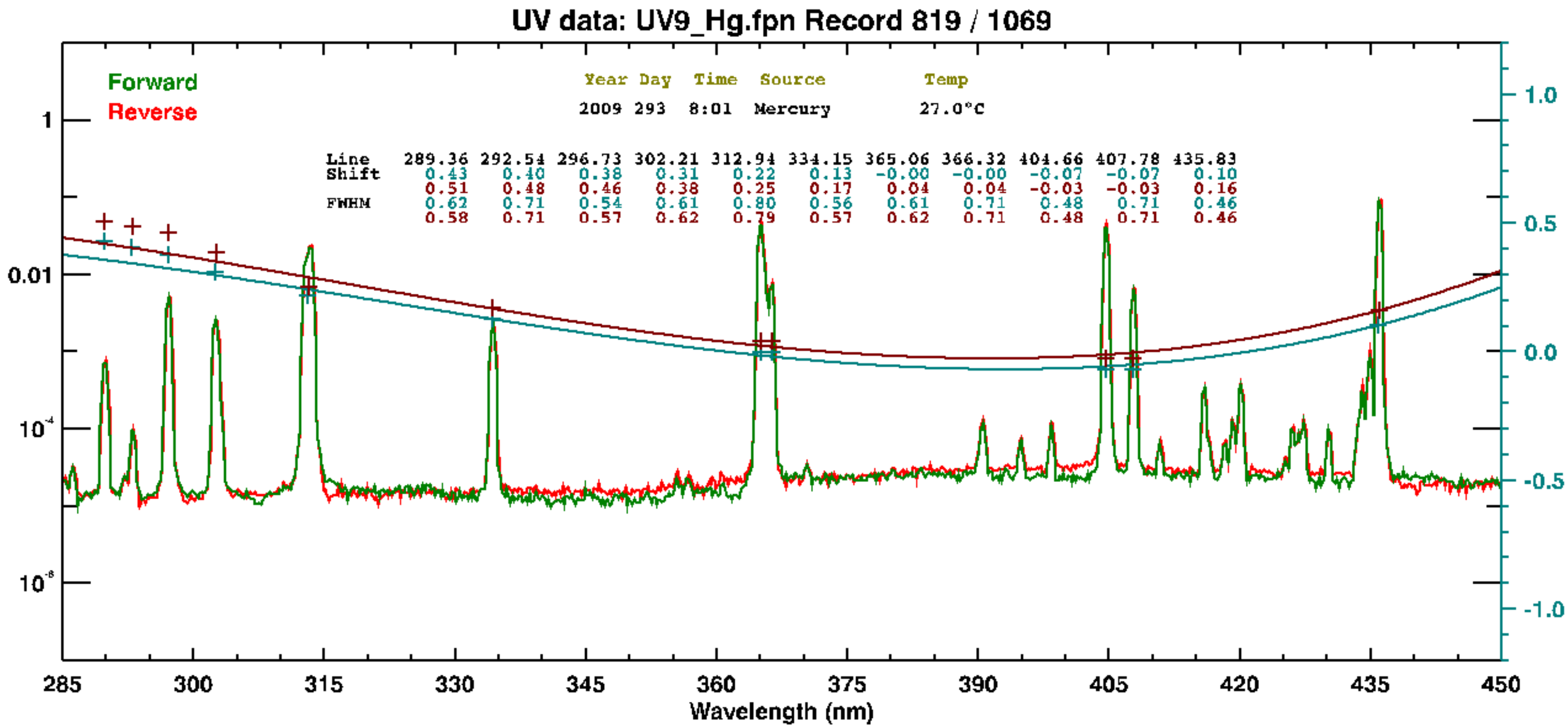

Each instrument has its own shift pattern, dependent on system geometry. Mercury lines are fitted to determine a smooth shift function.

If the required shift exceeds 0.5 nm then the alignment is shifted by fixed steps to bring the shifts back into the range of adjustment allowed in processing.

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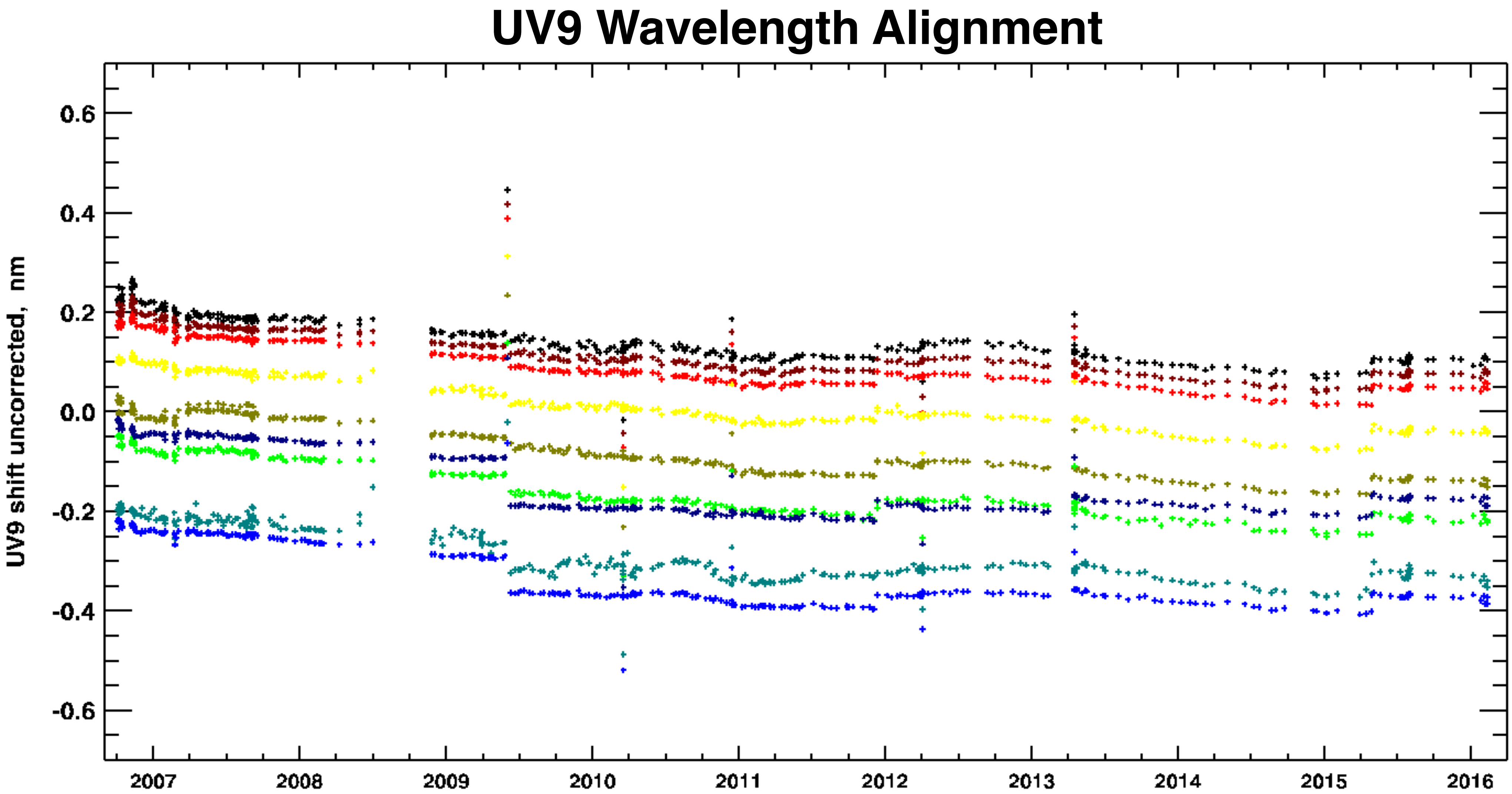

The fitted shifts suggest substantial drift in alignment, suggesting wear in the drive.

In retrospect, it is much less than first appears, as some shifts seem to have been premature.

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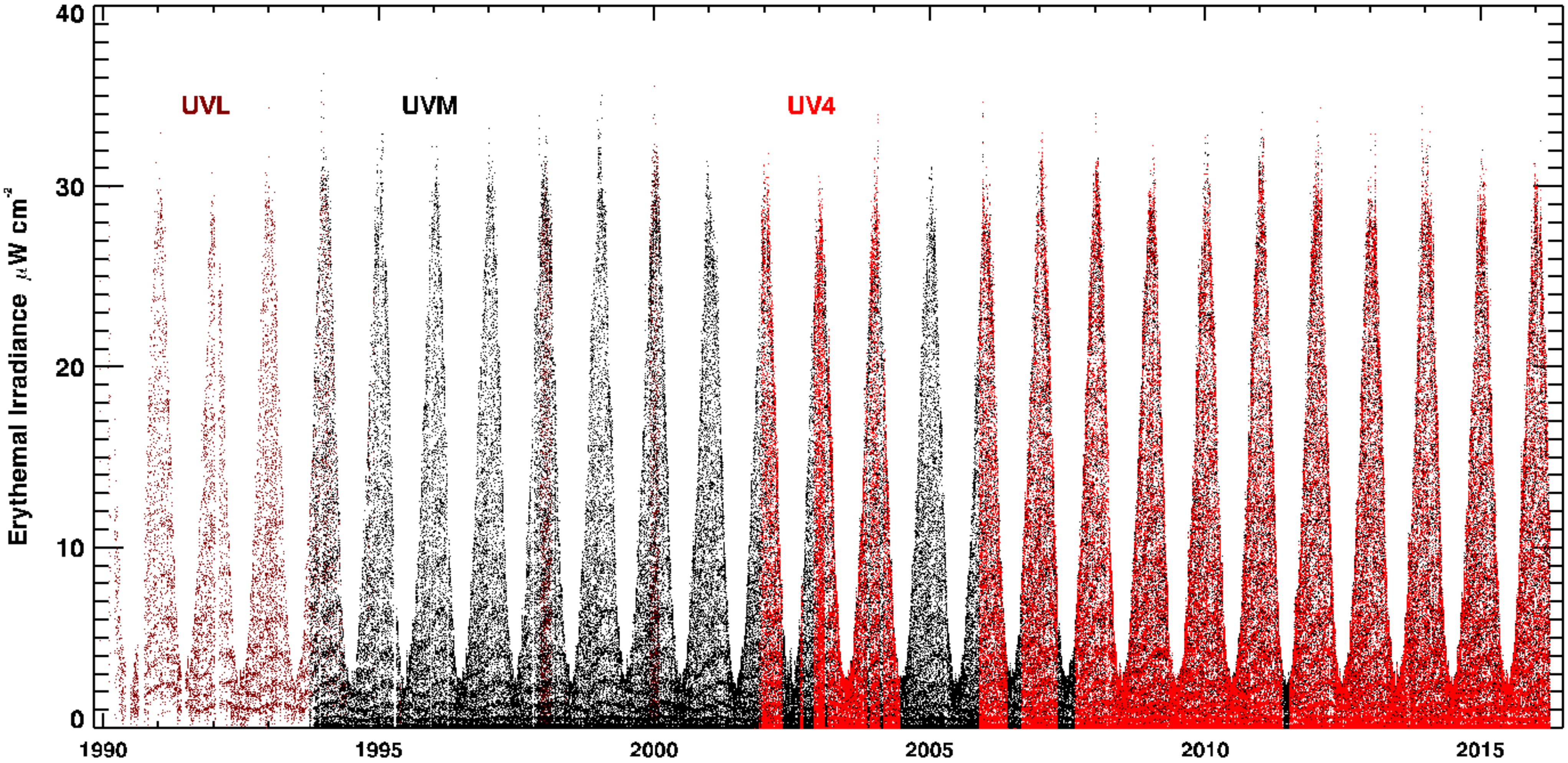
UVL, UVM, UV4 – Erythemal UV



Careful reconsideration along these lines, and comparison of spectrometers where they overlap, can be used to build a consistent time series, as here for erythemal UV.

Solar elevation dominates, followed by cloud. The annual ozone cycle can be seen in the bands for fixed solar zenith angle and nearly clear sky.

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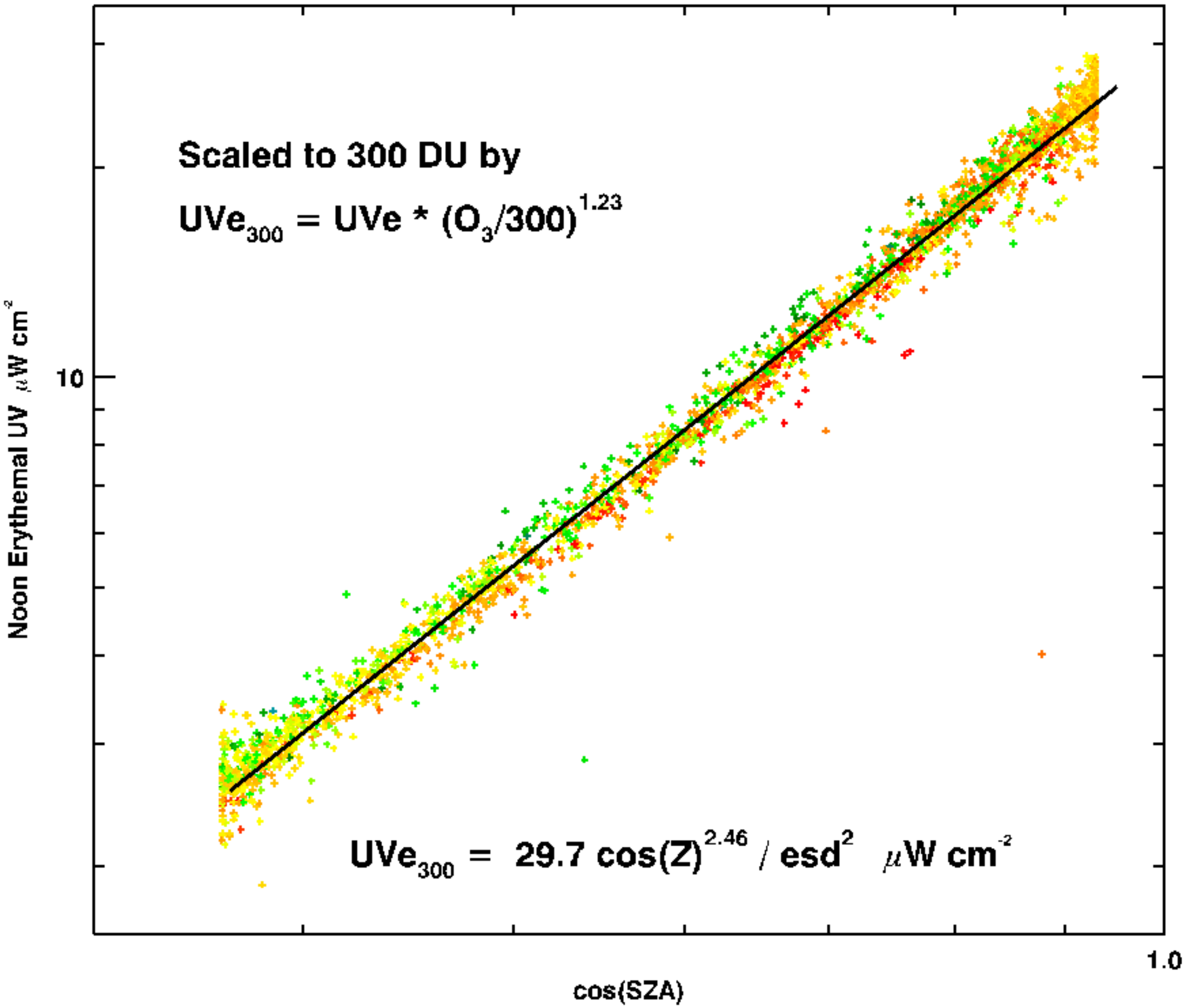
UV around Solar Noon on Clear Days



The two largest factors for clear-sky days are accurately represented in Radiative Transfer models.

To a precision sufficient for many purposes, erythemal UV allows a simple functional description, for low aerosol absorption.

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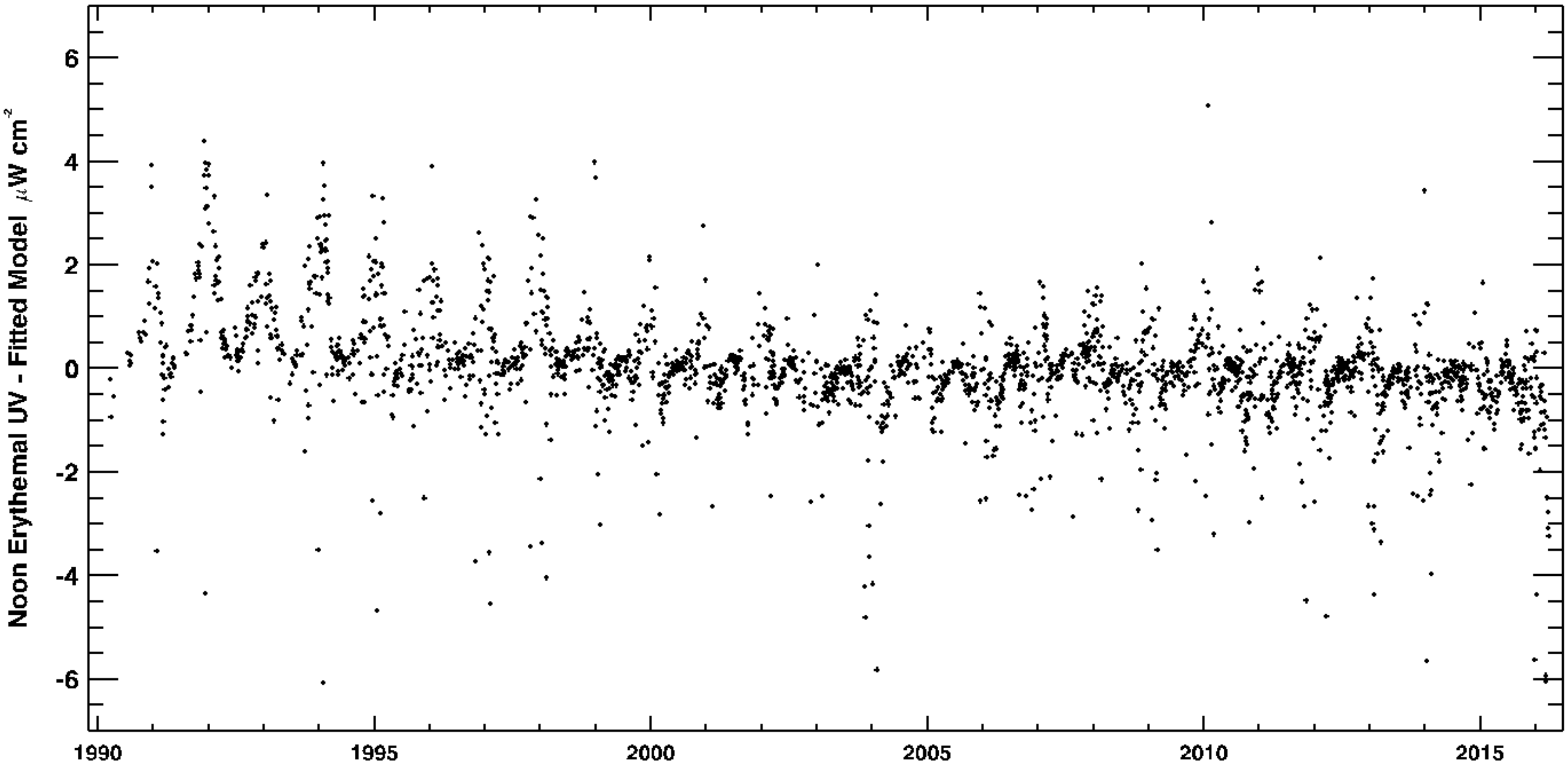
Noon Erythemal UV – Fitted Model



Mean values around noon on clear days, minus the simple model, provide a measure of longer term UV change. Instrument changes still seem to dominate.

There is no useful correlation with geophysical (SOI, QBO, Solar flux) time series, and even the effect of Pinatubo in 1992 is not apparent.

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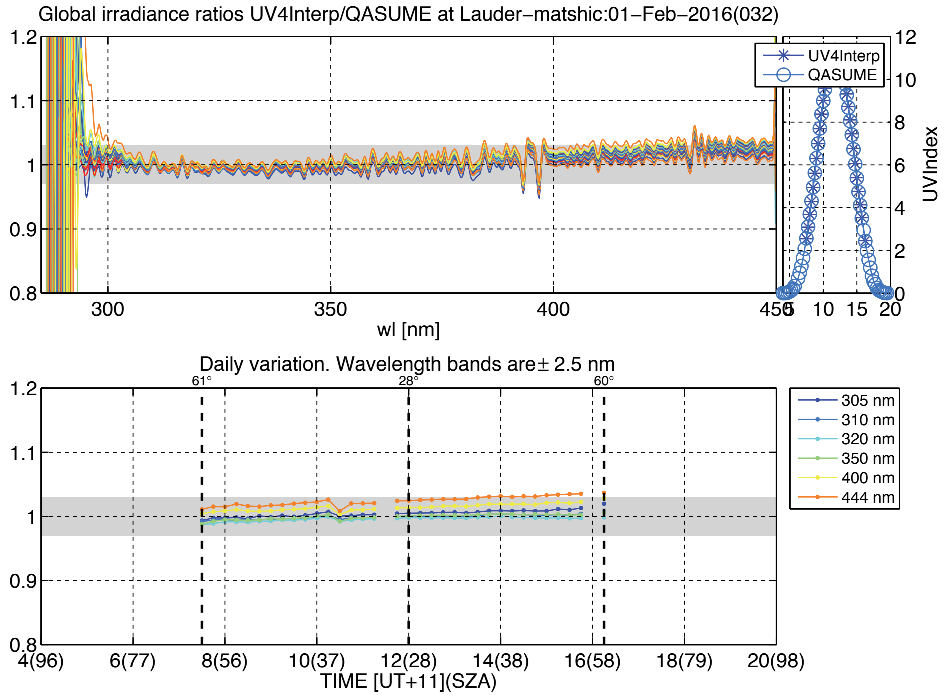
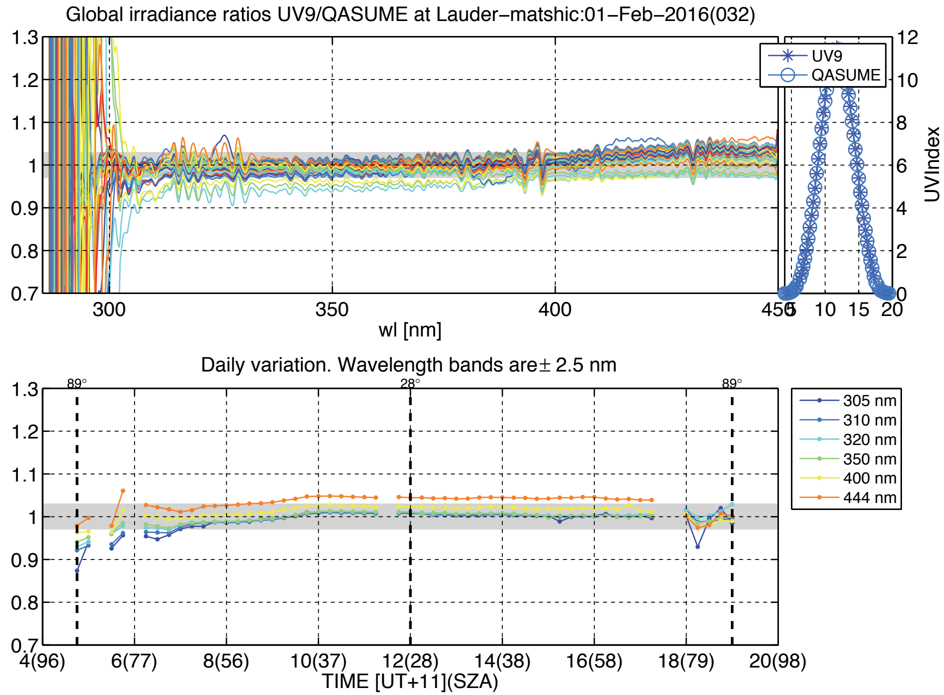




The fault is not with the spectrometers, as shown in the recent intercomparison with the QASUME travelling reference. Agreement was excellent, after adjustment for the different sampling regimes.

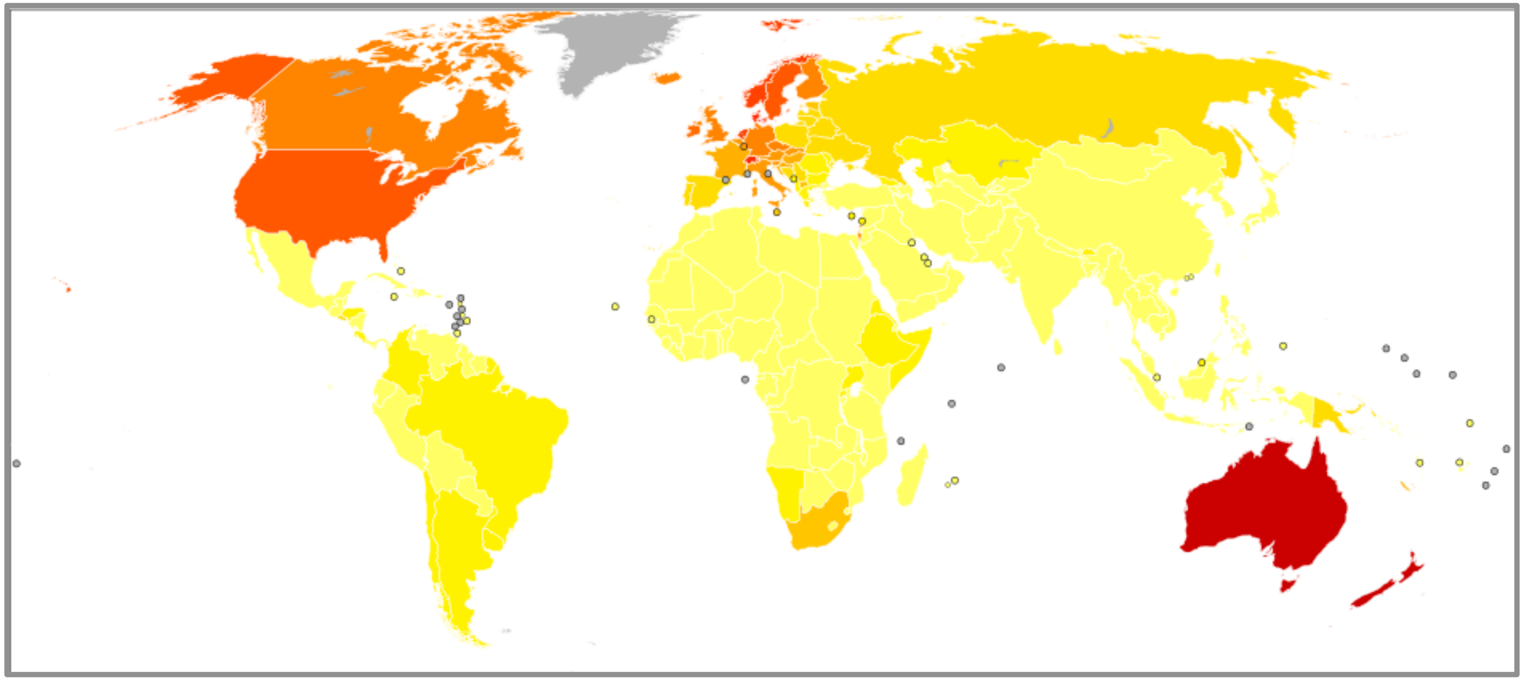
The intercomparison did unearth some errors in processing, particularly an inverted cosine correction for UV4. That had much less effect on erythemal UV than at longer wavelengths, and anyway the data used here are corrected values.

It is probably a misplaced hope to expect to see any long-term change in UV except through change in ozone or cloud. Both are better discerned by other measures.

Discussion

This might prompt the question of what is the ongoing purpose in the UV time series, and is there a need to continue it?

New Zealand's death rate from skin cancer (predominantly melanoma) has now surpassed Australia's, and the road toll in either country.



Age-standardized *incidence* rate of melanoma of the skin per 100,000 inhabitants in 2008.[83] no data; less than 1.75; 1.76–3.50; 3.51–5.25; 5.26–7.00; 7.01–8.75; 8.76–10.50; 10.51–12.25; 12.26–14.00; 14.01–15.75; 15.76–17.50; 17.76–19.25; more than 19.25

The UV research programme has been justified, in part, by the importance of the risk. What has 25 years of UV research done to reduce it?

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We certainly understand it better.

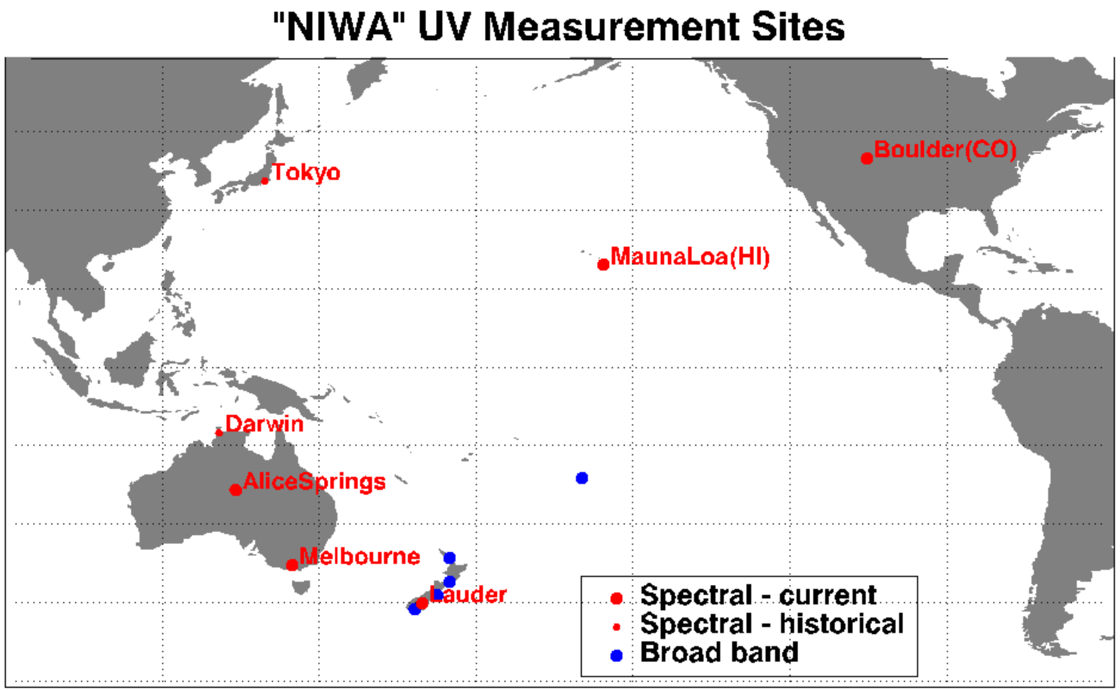
The high prevalence of melanoma is not caused by the annual Antarctic ozone hole, during which ozone is high and UV relatively low over New Zealand, though UV can be greater because of less ozone at mid-latitudes when the hole breaks up.

High skin cancer in New Zealand is caused by:

- ~40% more erythemal UV than at similar northern latitudes;
- pale-skinned immigrant population (melanoma 10 x lower for Māori);
- cooler temperatures.

Half of the 40% difference can be explained by ozone differences, ellipticity of Earth's orbit, and known AOD differences. The remainder awaits explanation, possibly through higher UV absorption by northern hemisphere aerosol.

The NIWA research programme contributes UV spectra to NDACC for 5 sites.



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UVI: Spectral Measurements Summary

Location	Year Start	Year End	Number of Scans	SZA_{min} (Deg)	Oz_{min} (DU)	Mean CMF	UVI Stats			SED Dose Stats	
							Max	% days UVI>3	% days UVI>10	Max	% days SED>3
New Zealand											
Lauder (45°S)	1994	2006	106,826	21.6	220	**0.74**	**14.4**	**37**	**15**	**77**	**95**
Lauder (45°S)	2006	2015.5	90,818	21.6	225	**0.74**	**13.7**	**40**	**16**	**76**	**95**
Australia											
Melbourne (38°S)	2009.4	2015.4	63,478	14.3	236	**0.67**	**13.7**	**42**	**19**	**77**	**99**
Alice Springs (24°S)	2006.5	2015.3	97,754	0.5	219	**0.82**	**19.1**	**79**	**48**	**85**	**100**
Darwin (12°S)	2003.5	2006.0	26,961	0.1	229	**0.77**	**18.1**	**99**	**61**	**78**	**100**
USA											
MLO Hawaii (20°N)	1997.9	2015.2	212,302	0.3	215	**0.88**	**19.6**	**99**	**79**	**95**	**100**
Boulder CO (40°N)	2001.4	2015.6	164,833	16.6	221	**0.73**	**13.3**	**48**	**11**	**67**	**99**

2 to 3 SED = 1 MED (i.e., 1 Minimum Erythemal Dose, or 1 "Sunburn")
Need for protection!

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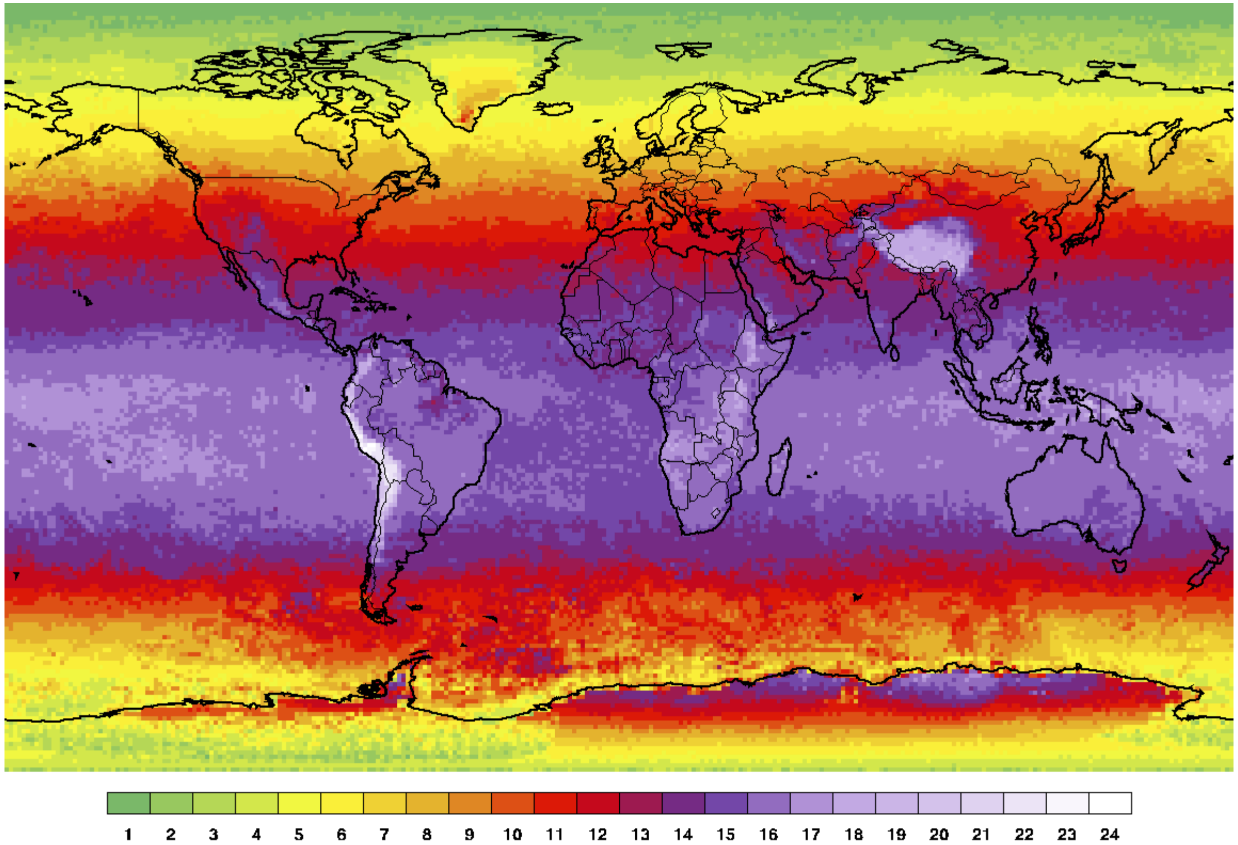
Global Peak UV from TOMS 8



Peak UVI

UV intensity in New Zealand is not extreme by world standards. About 90% of the world's people live in areas where peak UVI is 'extreme' (> 10).

Over 20 million people live where UVI exceeds 20.

Population (year 2000, global 6.056 billion) living where the peak UVI exceeds values given in column 1

UVI>	Area (%)	Land (%)	Pop (%)	Pop. (M)
10	78.4	70.4	89.1	5390
11	74.1	66.6	85.0	5150
12	66.9	60.6	74.8	4530
13	61.5	55.2	62.4	3780
14	51.2	44.8	37.7	2290
15	41.2	36.0	27.1	1640
16	21.3	18.5	12.8	770
17	5.5	6.3	4.80	290
18	0.64	2.0	1.39	84
19	0.36	1.1	0.78	47
20	0.22	0.68	0.35	21
21	0.19	0.59	0.28	17
22	0.078	0.250	0.135	8
23	0.029	0.094	0.085	5
24	0.003	0.010	0.011	0.7

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The 25-year record of solar spectral UV measurements to NDACC standards at Lauder and overseas sites has been invaluable for:

- **demonstrating the dependence on solar zenith angle and ozone;**
- **determining hemispheric differences in mean intensity;**
- **quantifying the effects of clouds, elevation, albedo, bush fires, volcanoes;**
- **evaluating the relative risks and benefits of environmental UV radiation.**

We have participated in behavioural and health studies of UV exposure with electronic dosimeters. People typically receive at most 5%, and often less than 1%, of environmental UV.

With behaviour the single biggest factor, we have worked with health groups (Cancer Society, Health Promotion Agency) to develop guidelines for safe exposure, and to provide UV information via media, the web, and now with smartphone apps.

Do we need to continue?

The value of the spectral record is in its applicability to new questions.

These include increasing interest in the health effects of vitamin D, and the possible carcinogenicity of UV-A.