UV in Europe and New Zealand - results with contributions from Hannover published in the years 2005-2008

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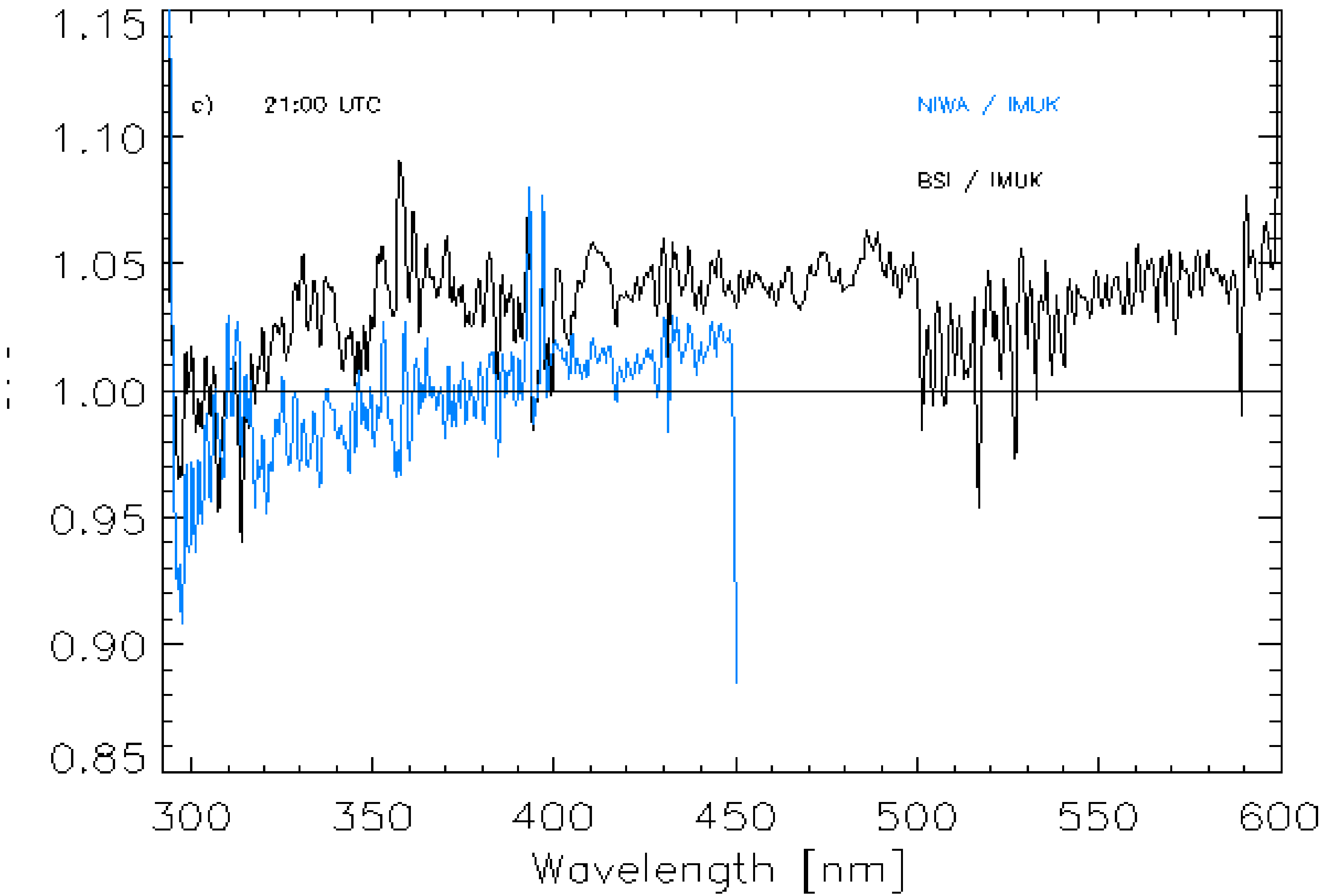
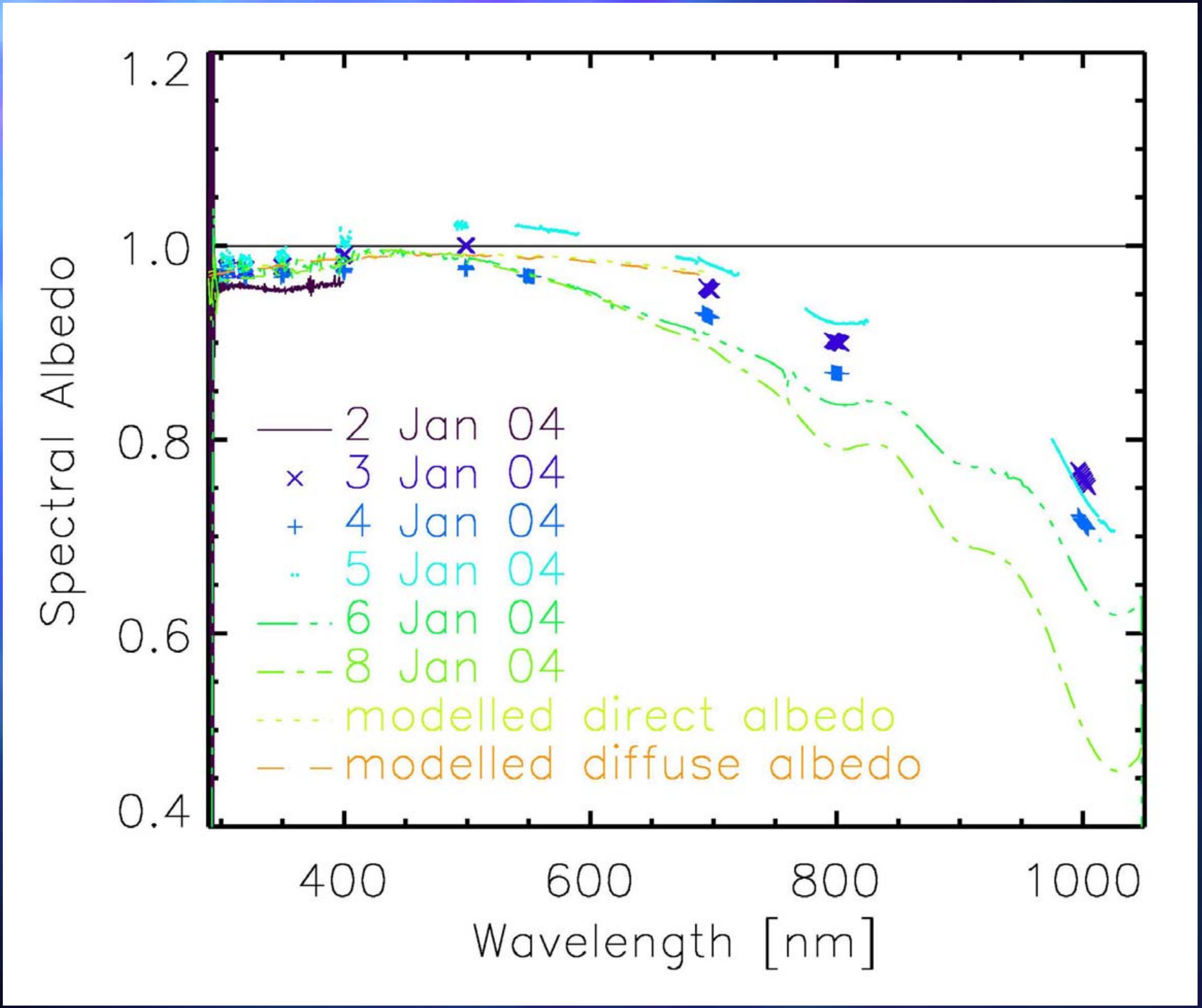
- High quality measurements and QA/QC
- New method to calculate uncertainties
- UV climatology in Europe and New Zealand
- Sky radiance measurements

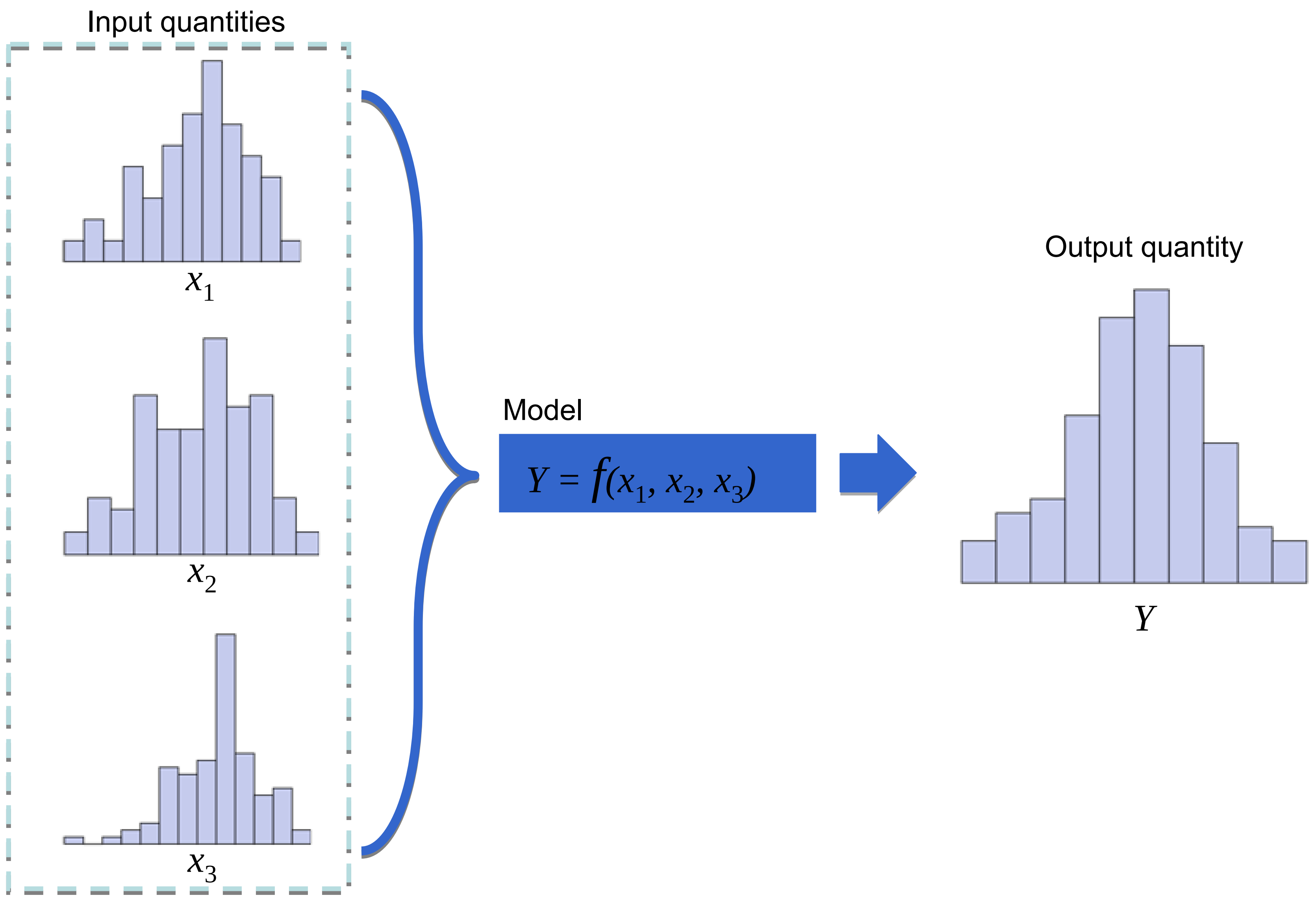
Intercomparison of spectroradiometers at Table Mountain, Boulder 22 June 2003



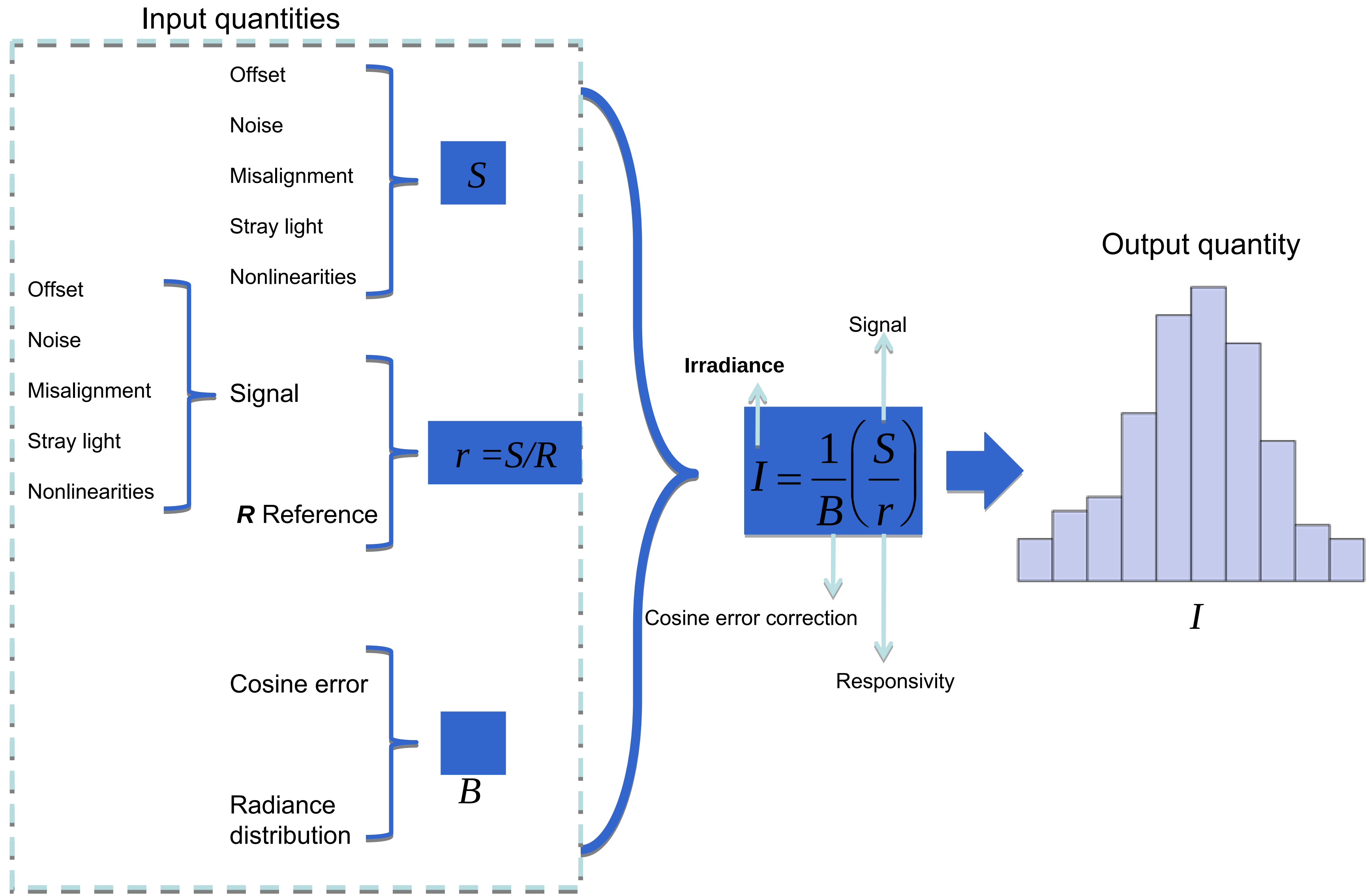
c) 21:00 UTC
NIWA / IMUK
BSI / IMUK
1.15
1.10
1.05
1.00
0.95
0.90
0.85
300
350
400
450
500
550
600
Wavelength [nm]



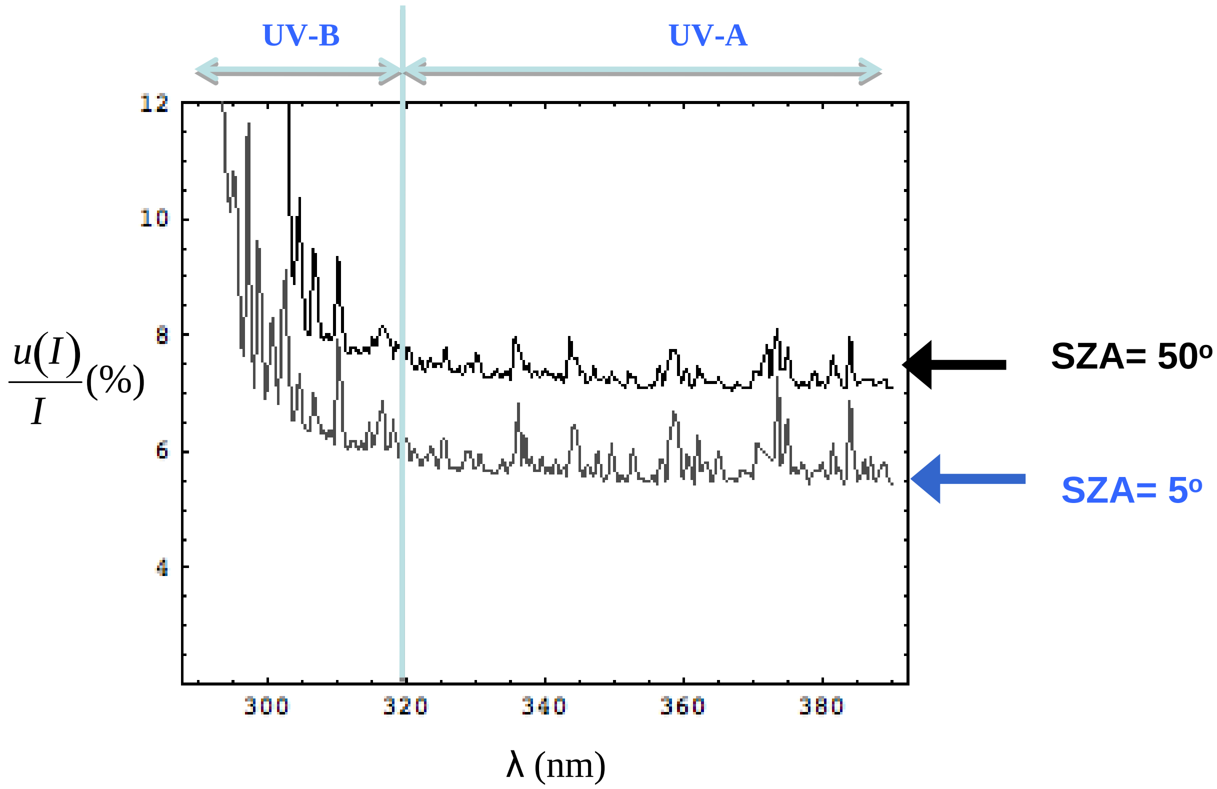
Wuttke S., König-Lango G., Seckmeyer G., Annales Geophysicae, 2006



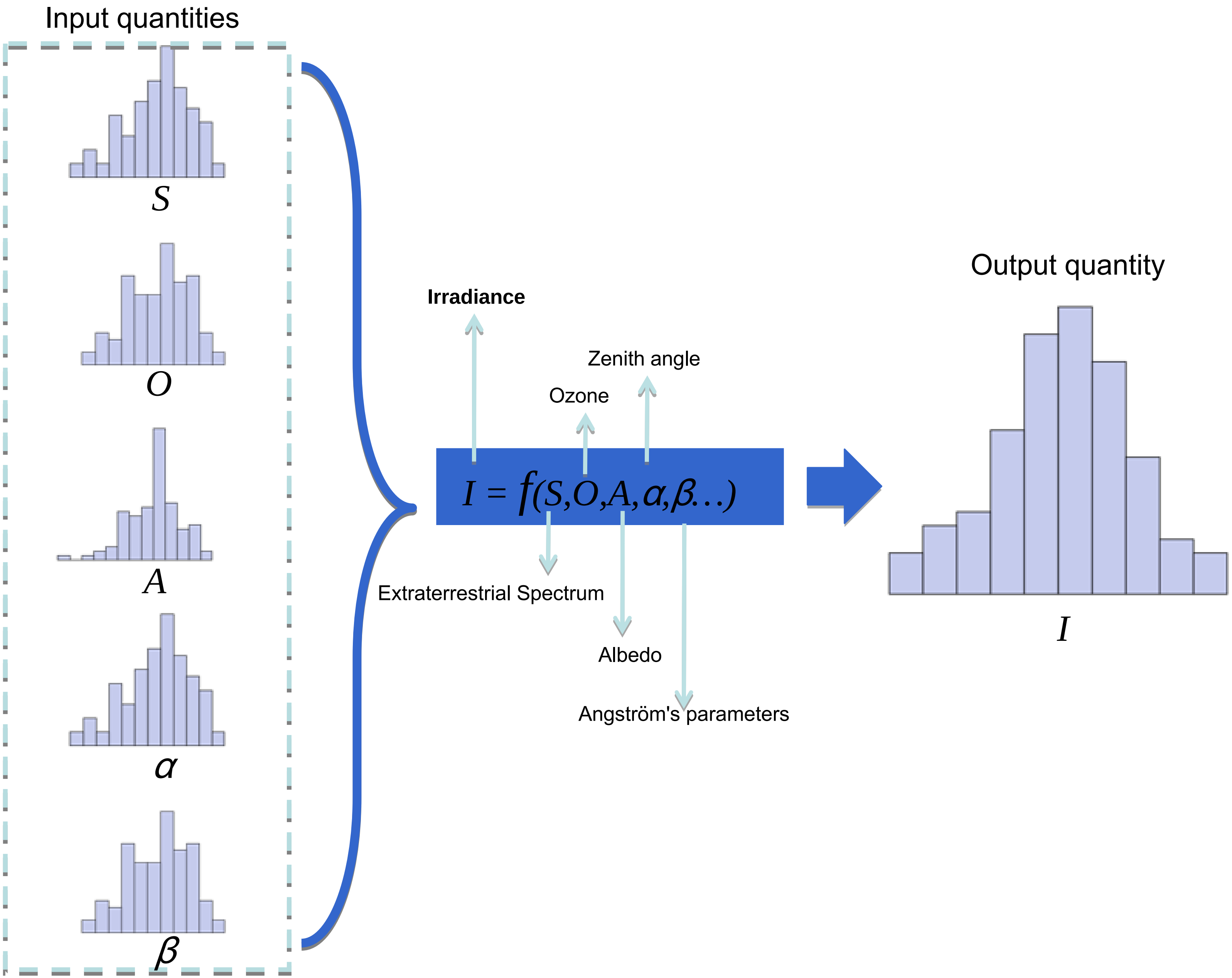
Monte Carlo-based Methods. This method allows efficiently propagating the uncertainty through any model. It implies first generating randomly a large set of values of the input quantities. Next, it requires sequentially evaluating the output quantity (which is determined by the input quantities through a measurement model). Finally, the dispersion of the computed output values can be used to evaluate both the estimate and the uncertainty of output quantity. The latter is taken as being equal to the standard deviation of the set of computed data.



Uncertainty evaluation of ground-based measurements of the UV irradiance. The irradiance value is determined by the error sources affecting the measurements of the signal during the field measurements but also during the needed prior adjustments of the measuring instrument: the absolute calibration process, the wavelength calibration and the nonlinearity correction.

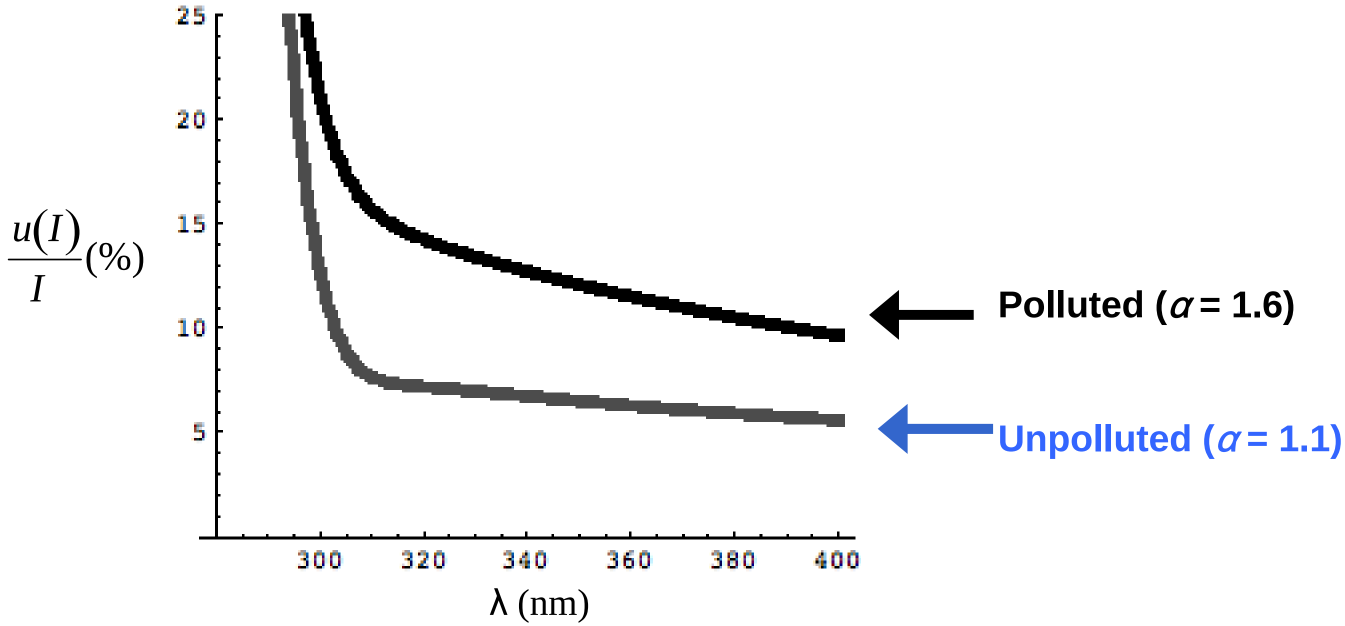


Relative expanded uncertainties of the global irradiances on June 9th, 2005 (cloudless conditions) at Izaña observatory. The measurements were performed by using the the spectroradiometer system of the Leibniz Universität Hannover (Institut für Meterologie und Klimatologie, IMUK). The main uncertainty sources are the cosine error and the error involve in the absolute calibration. From: Cordero RR. Seckmeyer G. Pissulla D. DaSilva L. Labbe F. “Uncertainty Evaluation of Spectral UV Irradiance Measurements“ Meas. Sci. Technol. **19** (2008) 1-15

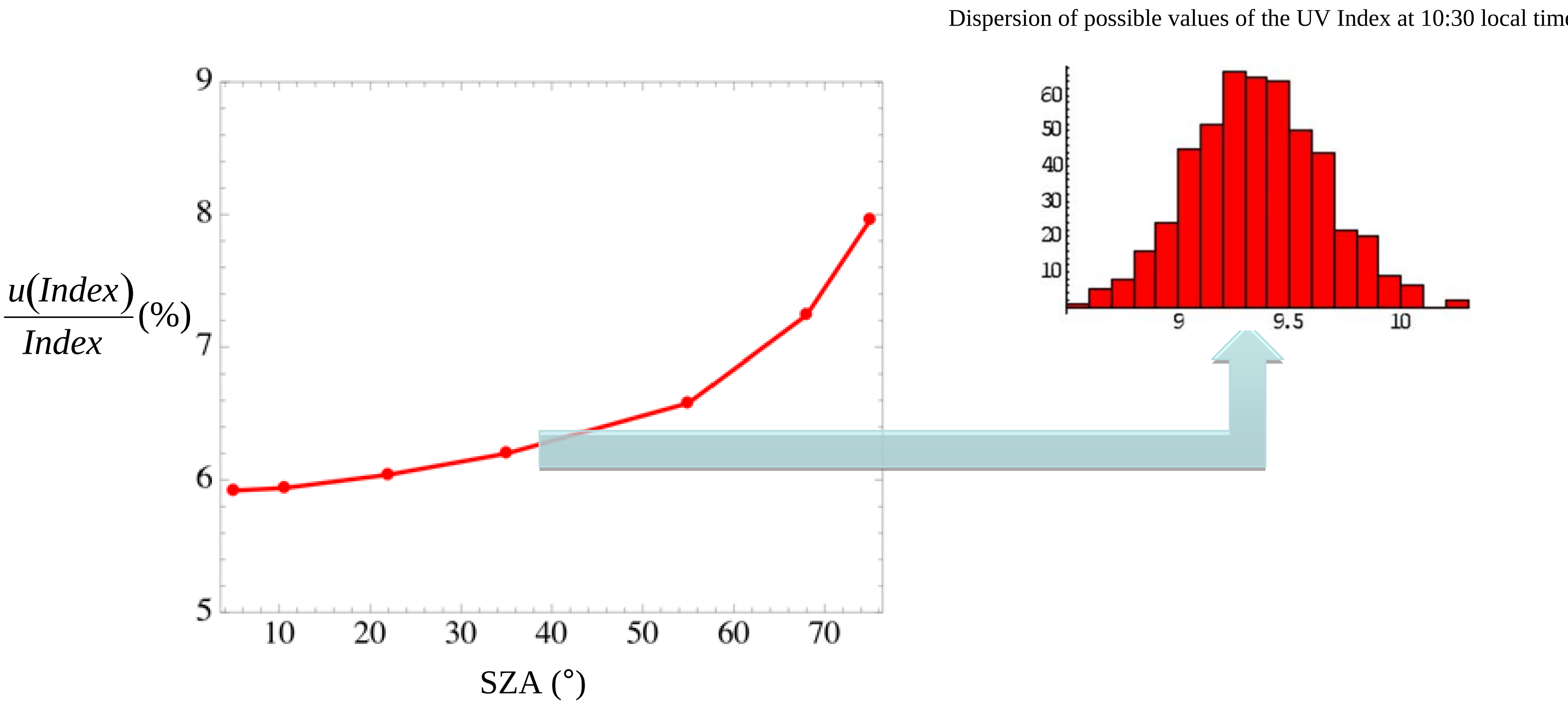


Uncertainty evaluation of the UV irradiance evaluated by using the UVSPEC Model. Attending to the observed conditions, a large set of values for the input quantities was generated. Then the spectral irradiance can be sequentially calculated. Finally, the dispersion of the computed values of the irradiance can be used to evaluate its uncertainty.

Input quantity		Estimated value	Error bound
Extraterrestrial Spectrum	S	Gueymard CA, Solar Energy 76, 423–453, 2004	5%
Albedo	A	0.2	25%
Solar zenith angle	θ	35°	0.2°
Ozone column	O	305 DU	5%
Single scattering albedo	ω	0.8	0.05
Asymmetry factor	g	0.6	0.05
Angström's parameters	α	1.1 1.6	0.04
	β	0.5	0.04



Uncertainty of the UV irradiance computed by using the UVSPEC Model. From: Cordero RR. Seckmeyer G. Pissulla D. DaSilva L. Labbe F "Uncertainty evaluation of the spectral UV irradiance evaluated by using the UVSPEC Radiative Transfer Model" Optics Communications **276** (2007) 44-53



Uncertainty of the UV Index. Relative expanded uncertainty of the UV index at different solar zenith angles. The measurements were performed on June 9th, 2005 at Izaña observatory by using the the spectroradiometer system of the Leibniz Universität Hannover (Institut für Meterologie und Klimatologie, IMUK)From: Cordero RR. Seckmeyer G. Pissulla D. Labbe F. “Uncertainty of experimental integrals: application to the UV index calculation” Metrologia **45** (2008) 1-10

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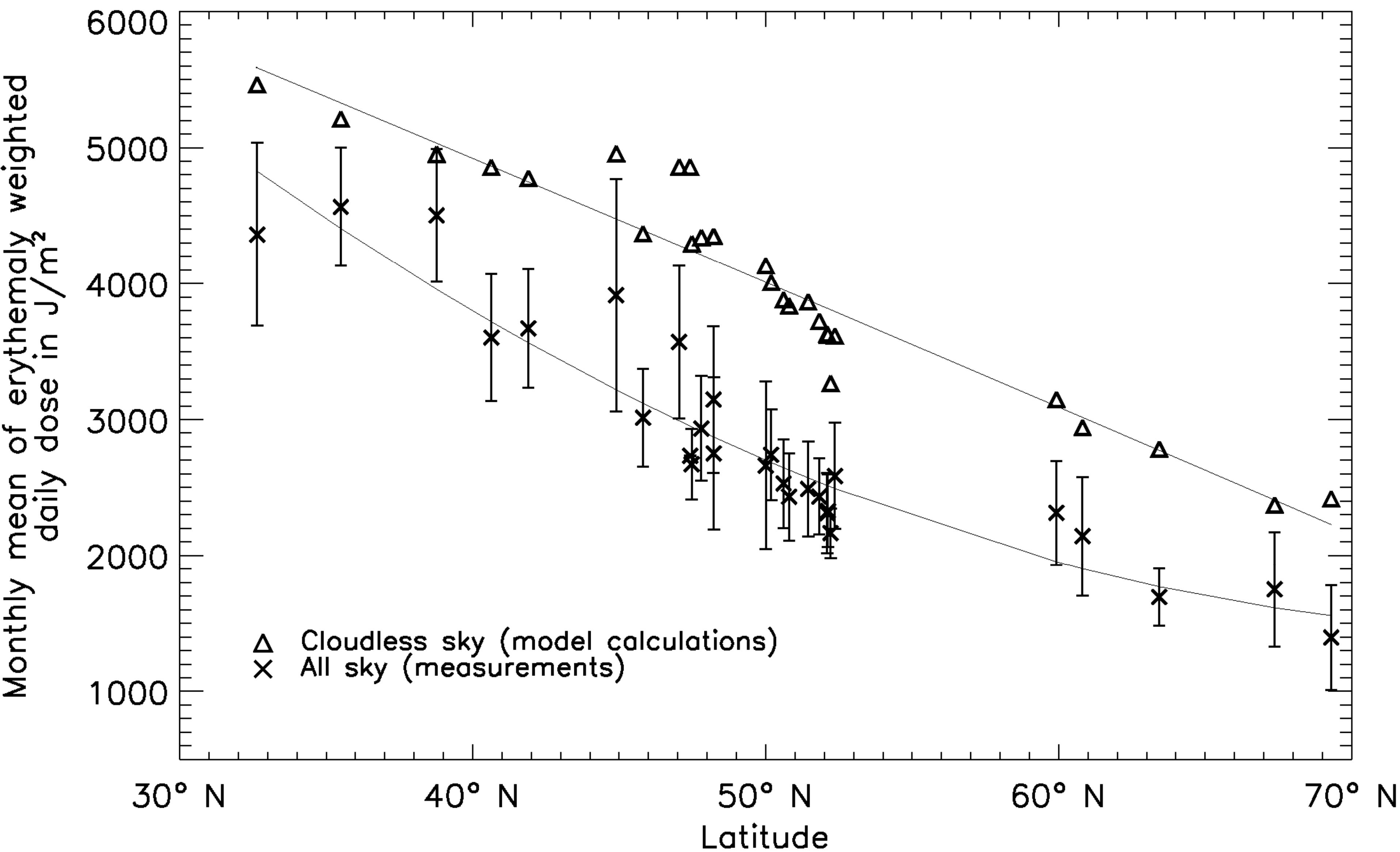
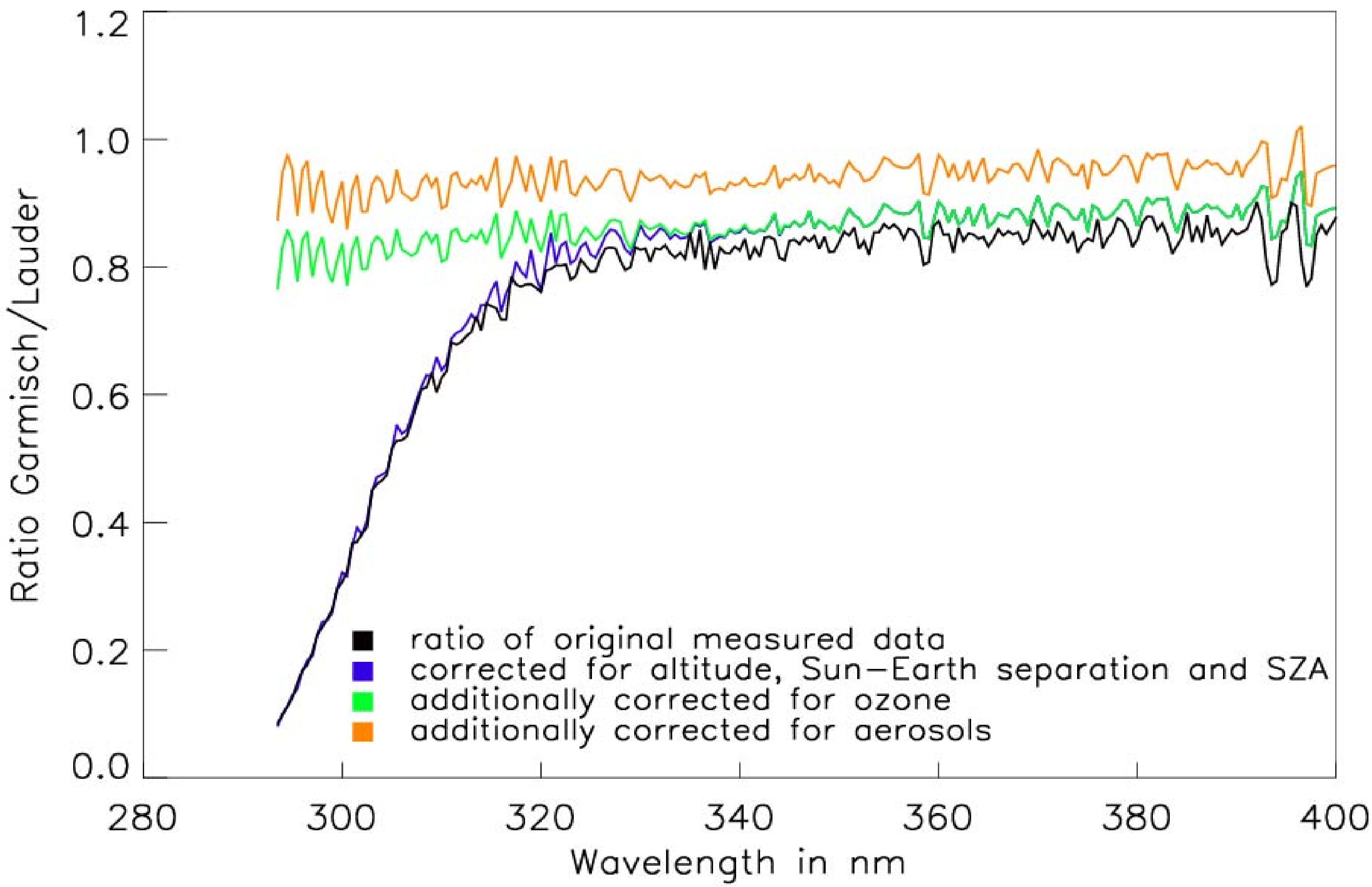
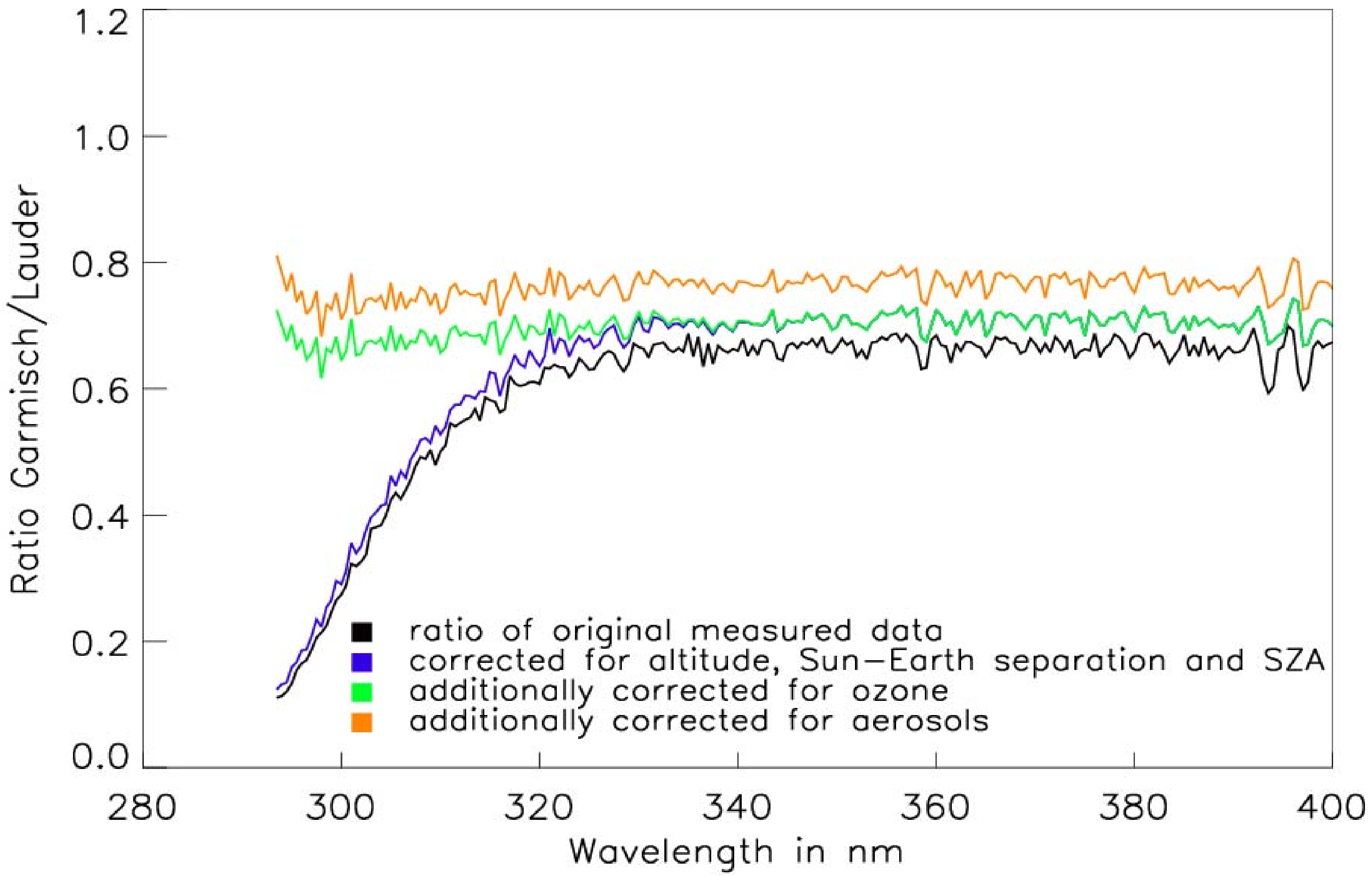


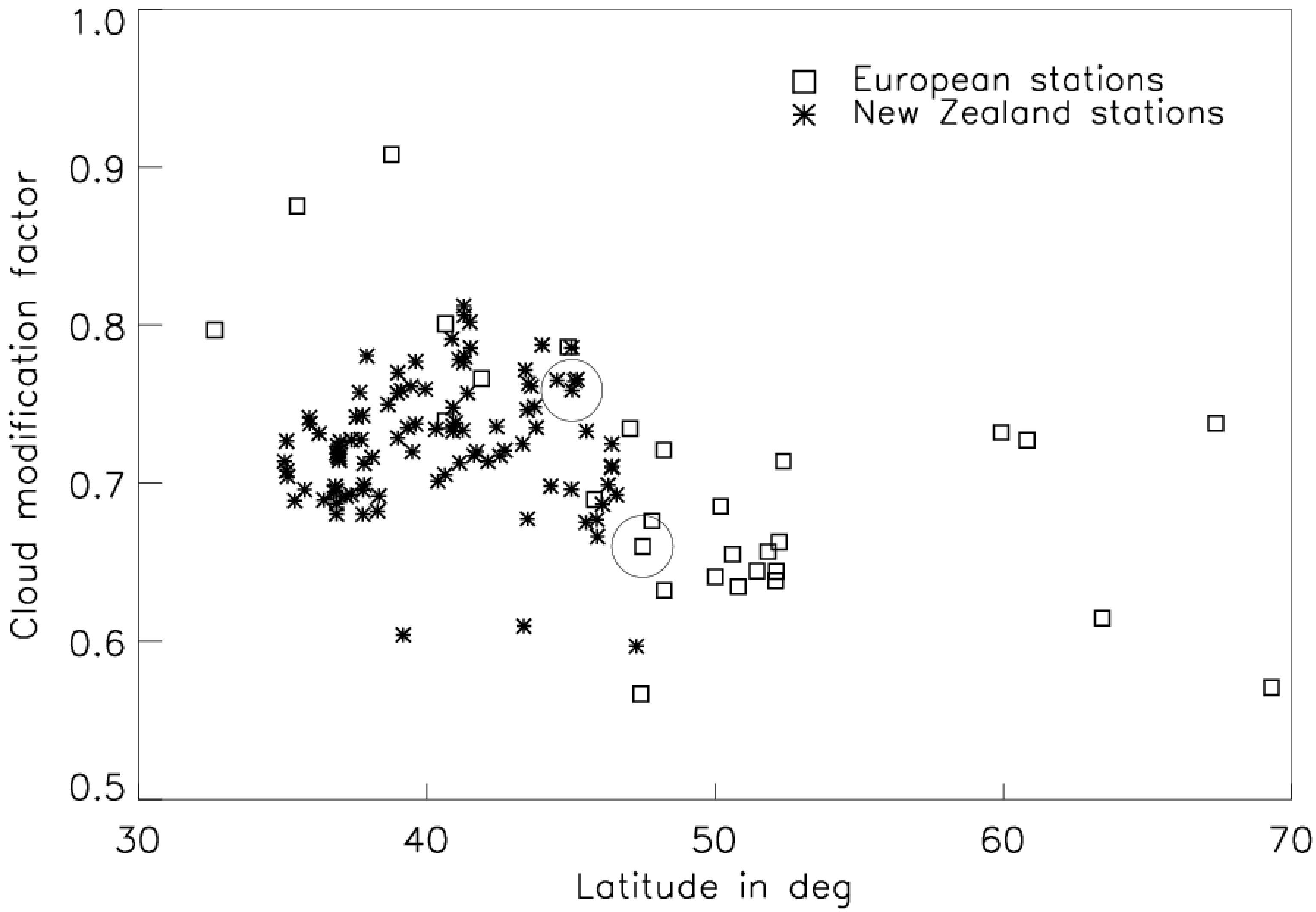
Comparison between cloudless sky calculations and actual measurements of monthly mean erythemally weighted irradiance. The two curves are spline fitted lines. The error bars denote the year-to-year variability (one sigma standard deviation) in the measured monthly mean, no measurement uncertainties are included.



Ratios of daily spectral irradiation for cloudless skies from Garmisch (10th of August 1997) and Lauder (10th of February 1998). From: Seckmeyer G., Glandorf M., Wichers C., McKenzie R.L., Henriques D., Carvalho F., Webb A., Siani A.-M., Bais A., Kjeldstad B., Brogniez C., Werle P., Koskela T., Lakkala K., Gröbner J., Slaper H., denOuter P, Feister U.: Europe's darker atmosphere in the UV-B, Photochem. and Photobiol. Sci., **7**, 925 – 930, 2 August, 2008



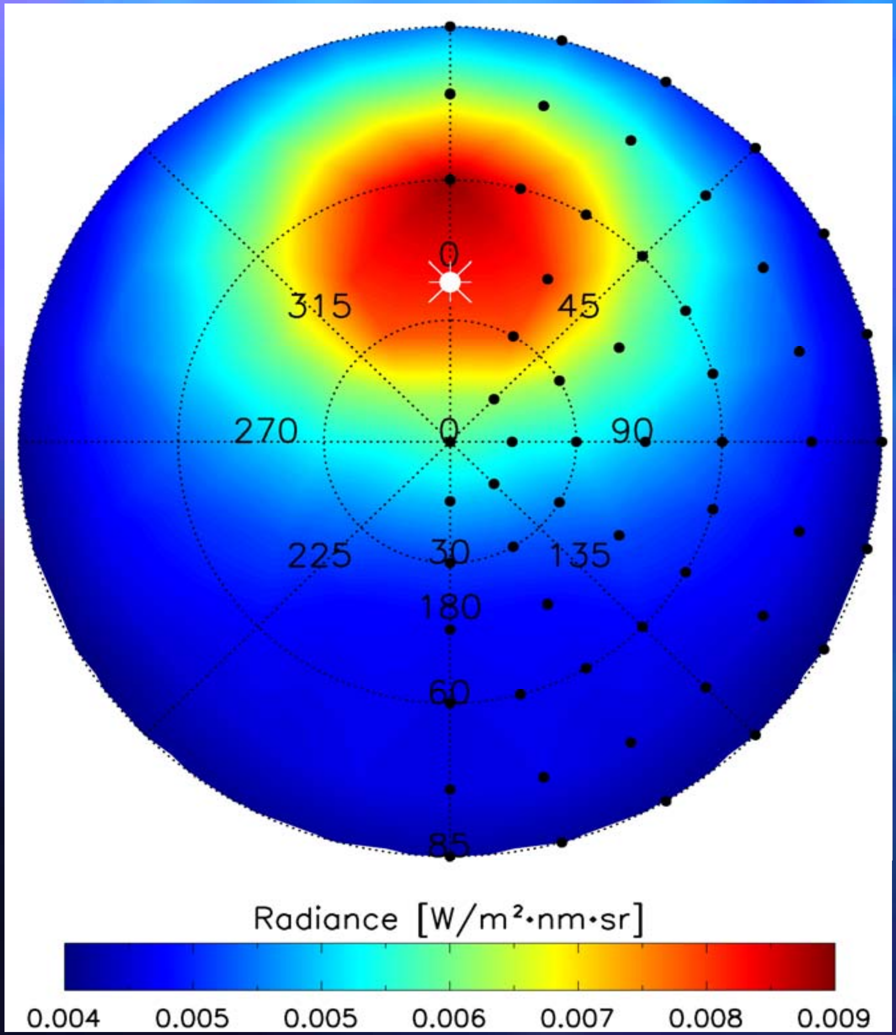
Ratios of the average daily spectral irradiation for July/January 1998/99 from Garmisch and Lauder. By introducing modelled ratios to account for the differences of the major influencing parameter a spectrally flat graph can be produced. The remaining 20-25 % difference can be attributed to cloud differences between both stations. uncertainties are included.



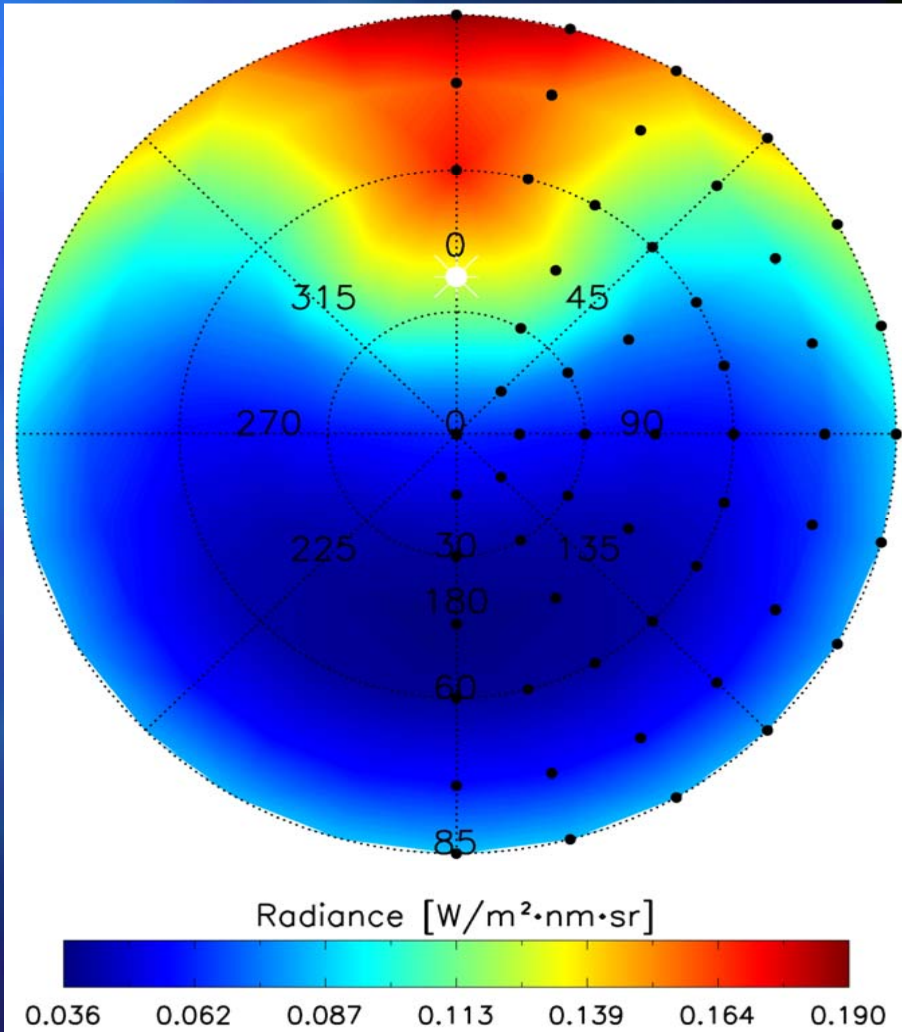
Cloud modification factors for stations in Europe and New Zealand. The CMFs are calculated from erythemal doses and are average values for all available summer data since August 1996 (Europe) and November 1995 (New Zealand). Each symbol represents a mean CMF at one station. The encircled symbols denote the CMFs for Garmisch (Europe) and Lauder (New Zealand).

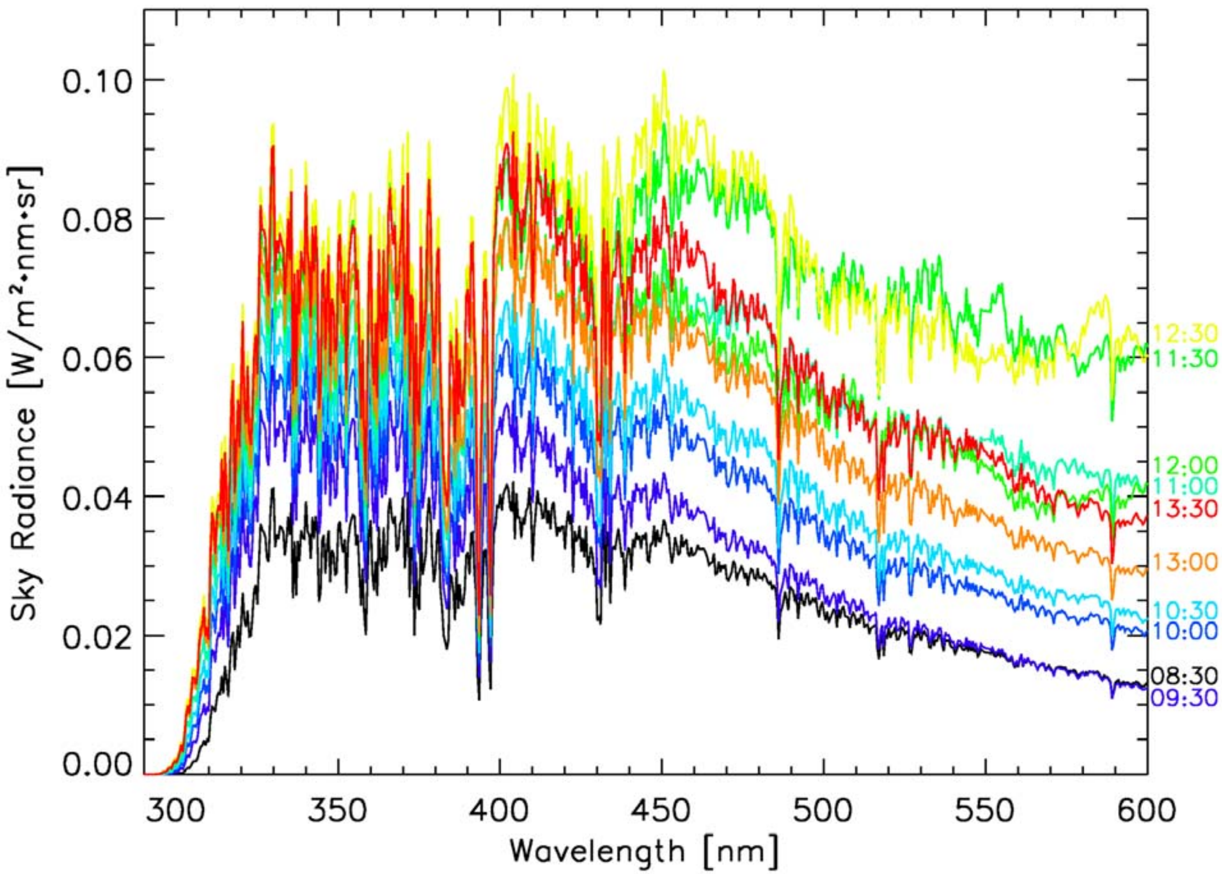
Spectral radiance L_λ in $\frac{W}{m^2 \cdot nm \cdot sr}$ in Hannover, clear sky

305 nm



500 nm





Starting time [UTC]	SZA/°	SAA/°
08:00	67	75
08:30	61	78
09:00	54	80
09:30	48	83
10:00	41	86
10:30	35	90
11:00	28	94
11:30	22	99
12:00	15	107
12:30	9	123
13:00	5	169
13:30	7	227

Spectral sky radiance spectra measured half-hourly in Izana on 6th of June, 2005. From: Pissulla D, G. Seckmeyer, R. R. Cordero, M. Blumthaler, B. Schallhart, A. Webb, R. Kift, A. Smedley, A. F. Bais, N. Kouremeti, A. Cede, J. Herman, M. Kowalewski, “Comparison of atmospheric spectral radiance measurements from four independently calibrated systems”, Photochem. Photobiol. Sci. 8, (2009) 516–527

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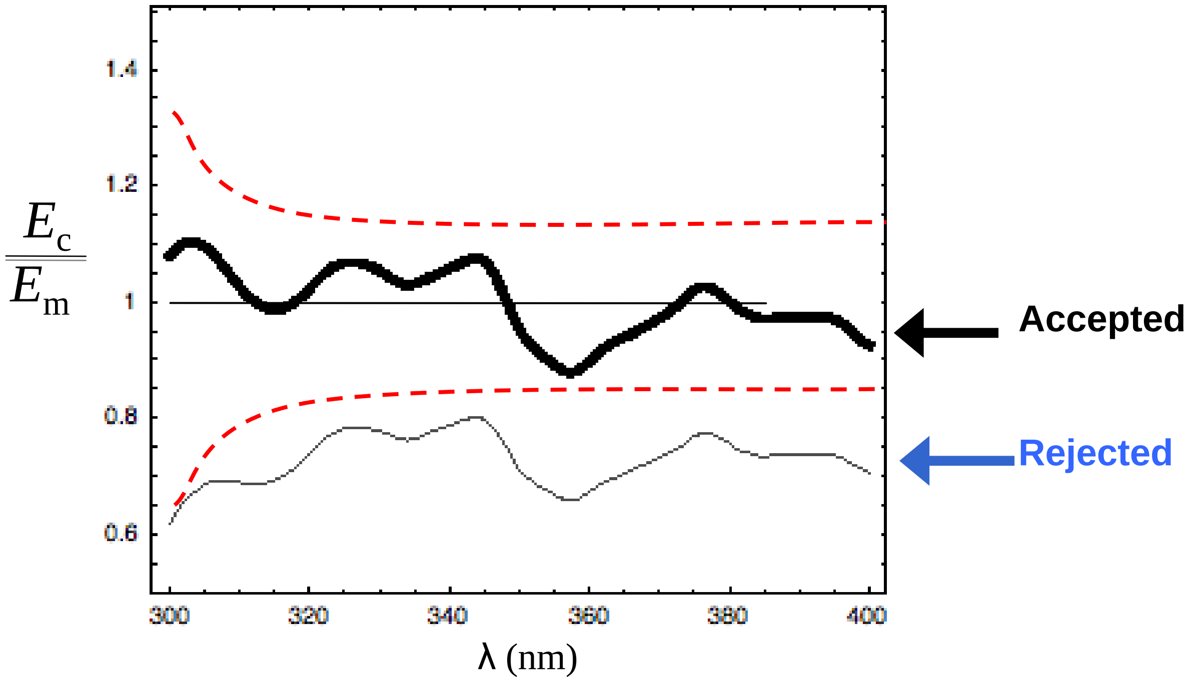

Comparison criterion. Comparison between the calculated E_c and the measured E_m spectra. The bound between the dotted lines is dtermined by the uncertainty of both E_c and E_m. From: Cordero RR, Seckmeyer G, Pissulla D, Labbe F, "Exploitation of Spectral Direct UV Irradiance Measurements" Metrologia **46** (2009) 19-25

Click on the figure to start the movies

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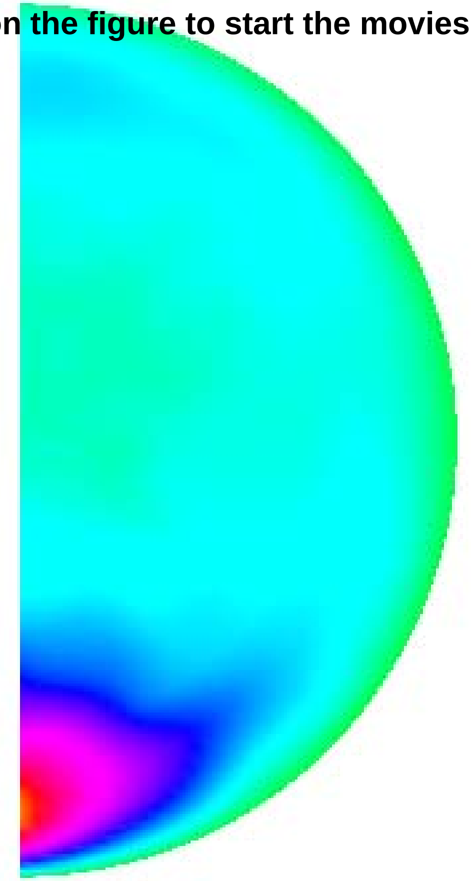
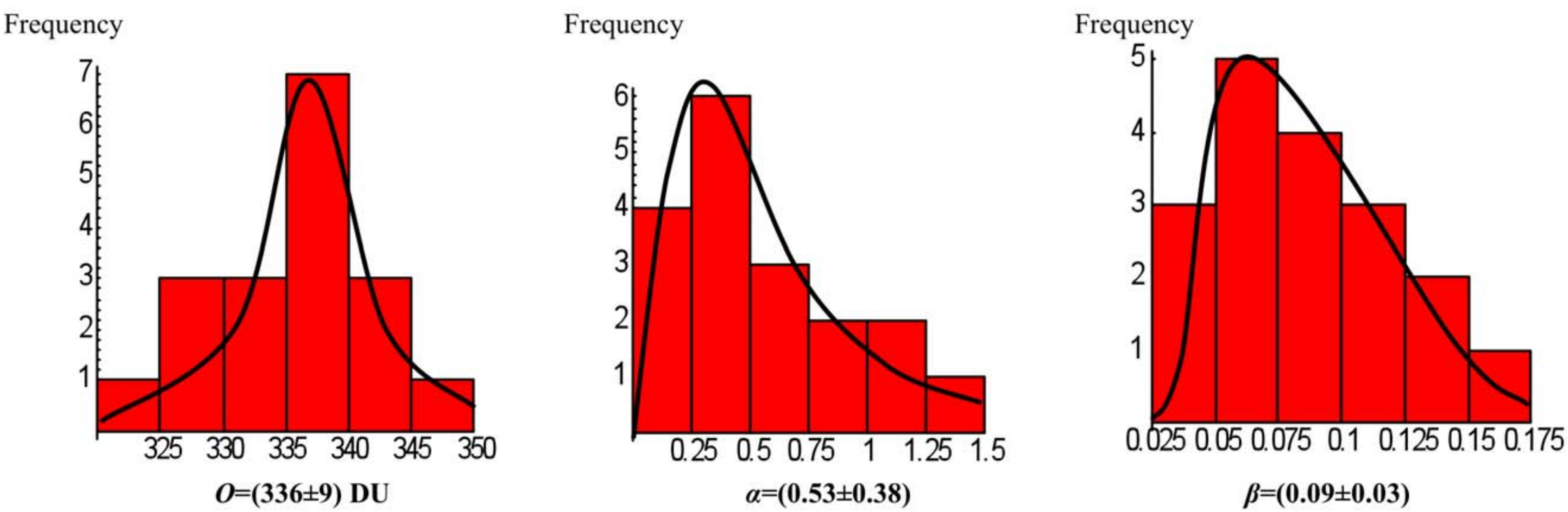
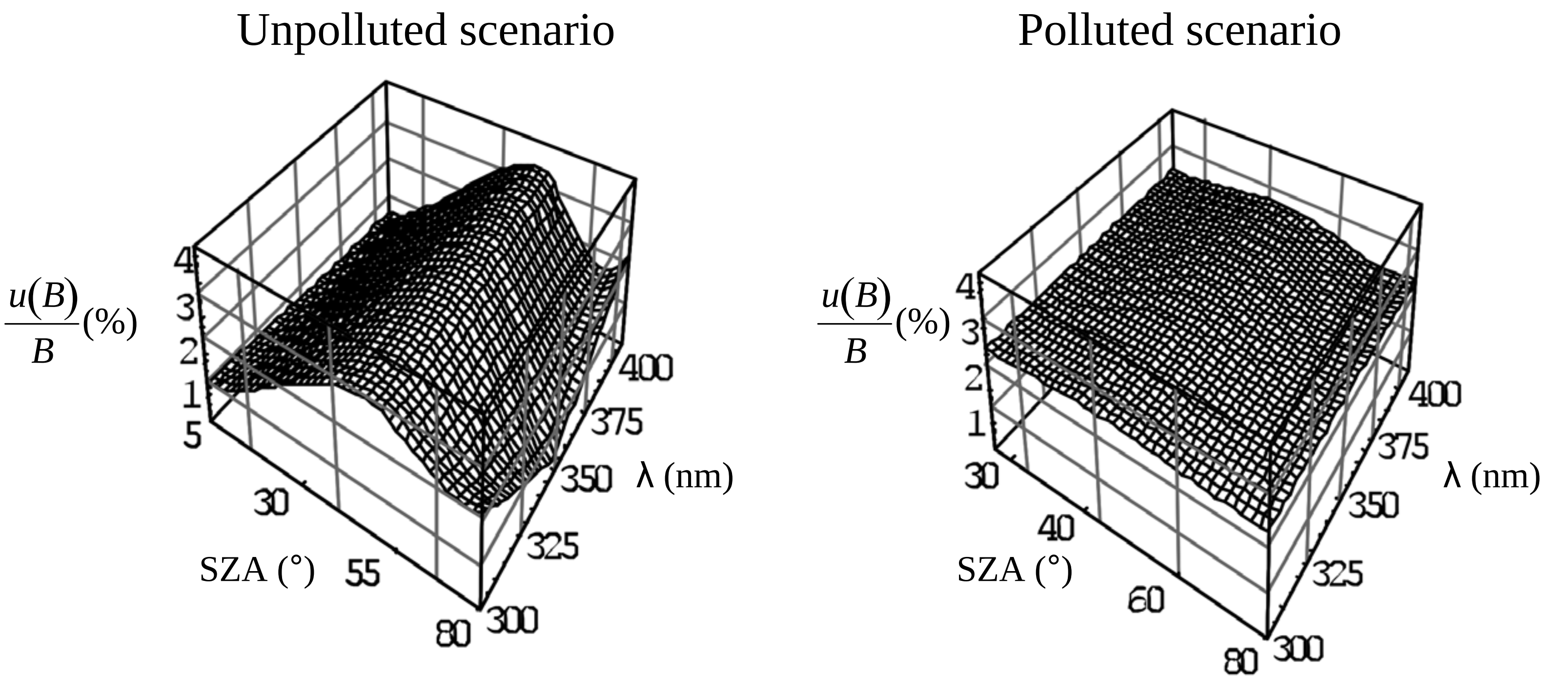


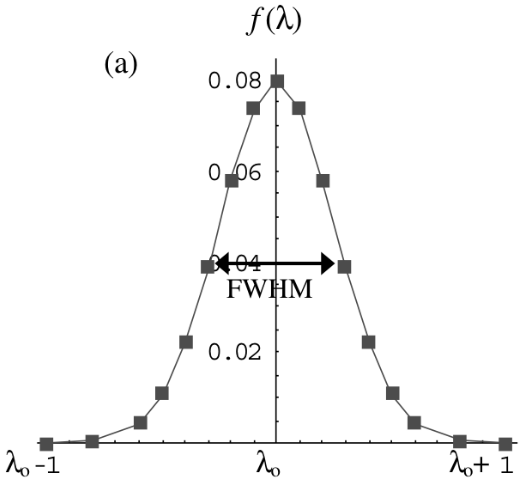
Spectral sky radiance spectra measured in Hannover on 18th of February, 2009. The measurements were taken each 3 minutes, during 30 min, by using an array spectroradiometer. The input optics was driven by using a Pan Tilt Unit. The measurement points were 100.



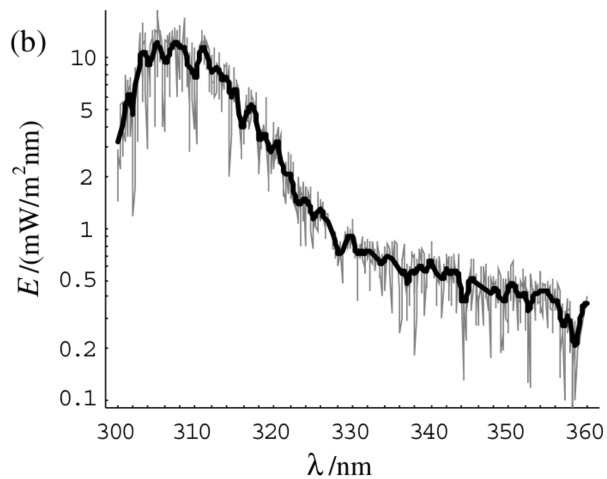
Parameters Retrieved from Spectral Direct UV Irradiance Measurements. The dispersion of the generated values that led to acceptable matches between the measured and calculated spectra allows computing both the estimates and the uncertainties of the retrieved parameters. Dispersion of possible values of Ozone column *and the* Angström parameters, for the conditions observed at 12:30 h on May 1st, 2007 (cloudless conditions) at IMUK (Hannover, Germany). From: Cordero RR, Seckmeyer G, Pissulla D, Labbe F, “Exploitation of Spectral Direct UV Irradiance Measurements” Metrologia **46** (2009) 19-25



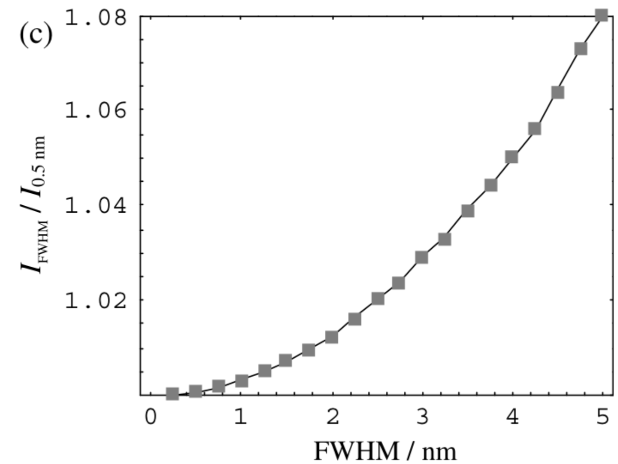
Cosine error influence computed by using radiance distributions corresponding to a polluted scenario and an unpolluted scenario. From: Cordero RR. Seckmeyer G. Labbe F. Cosine error influence on ground-based spectral UV irradiance measurements" Metrologia **45** (2008) 406-414



Slit Function of IMUK Instrument

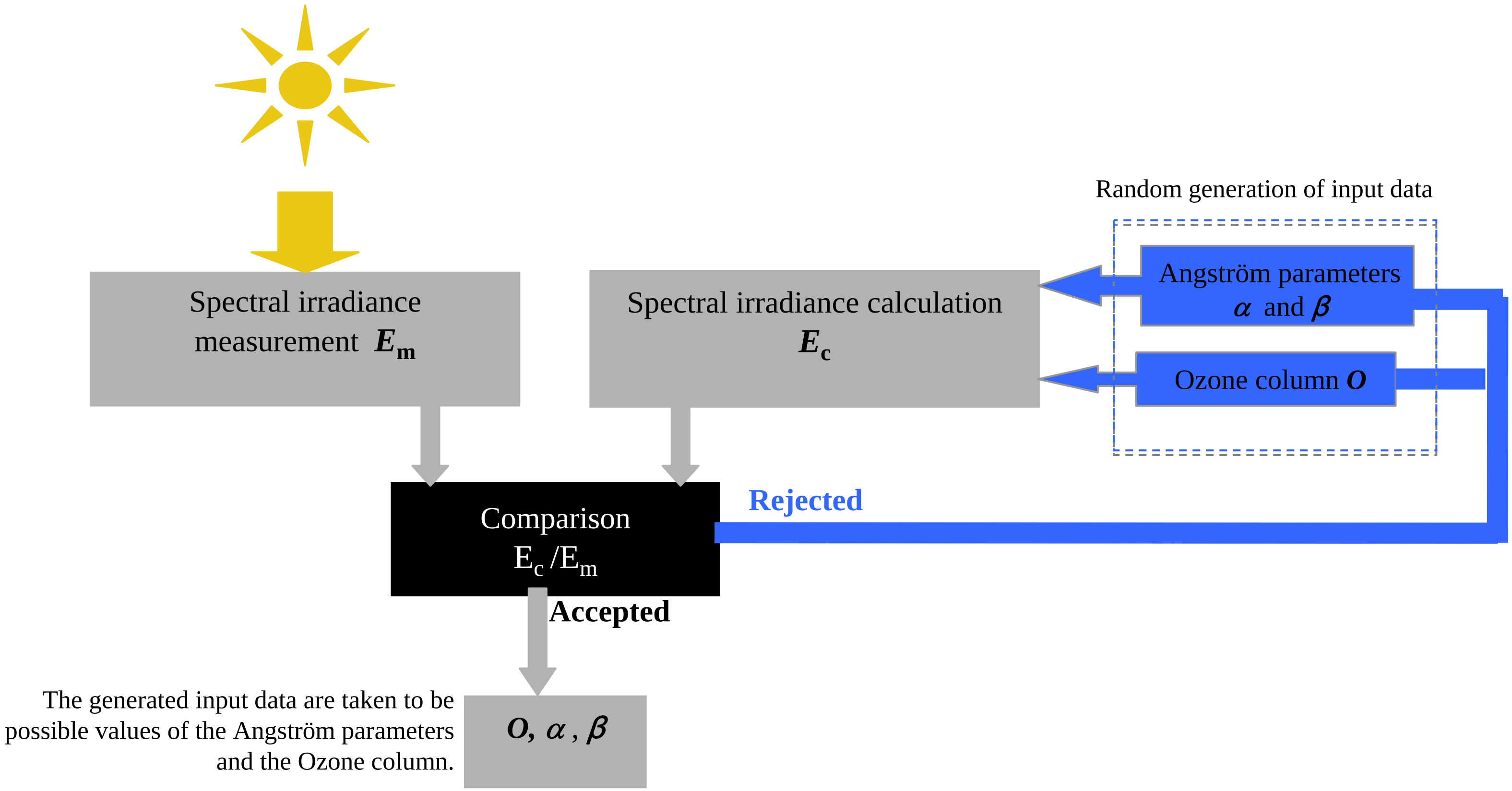


Effect of the slit function on the spectrum



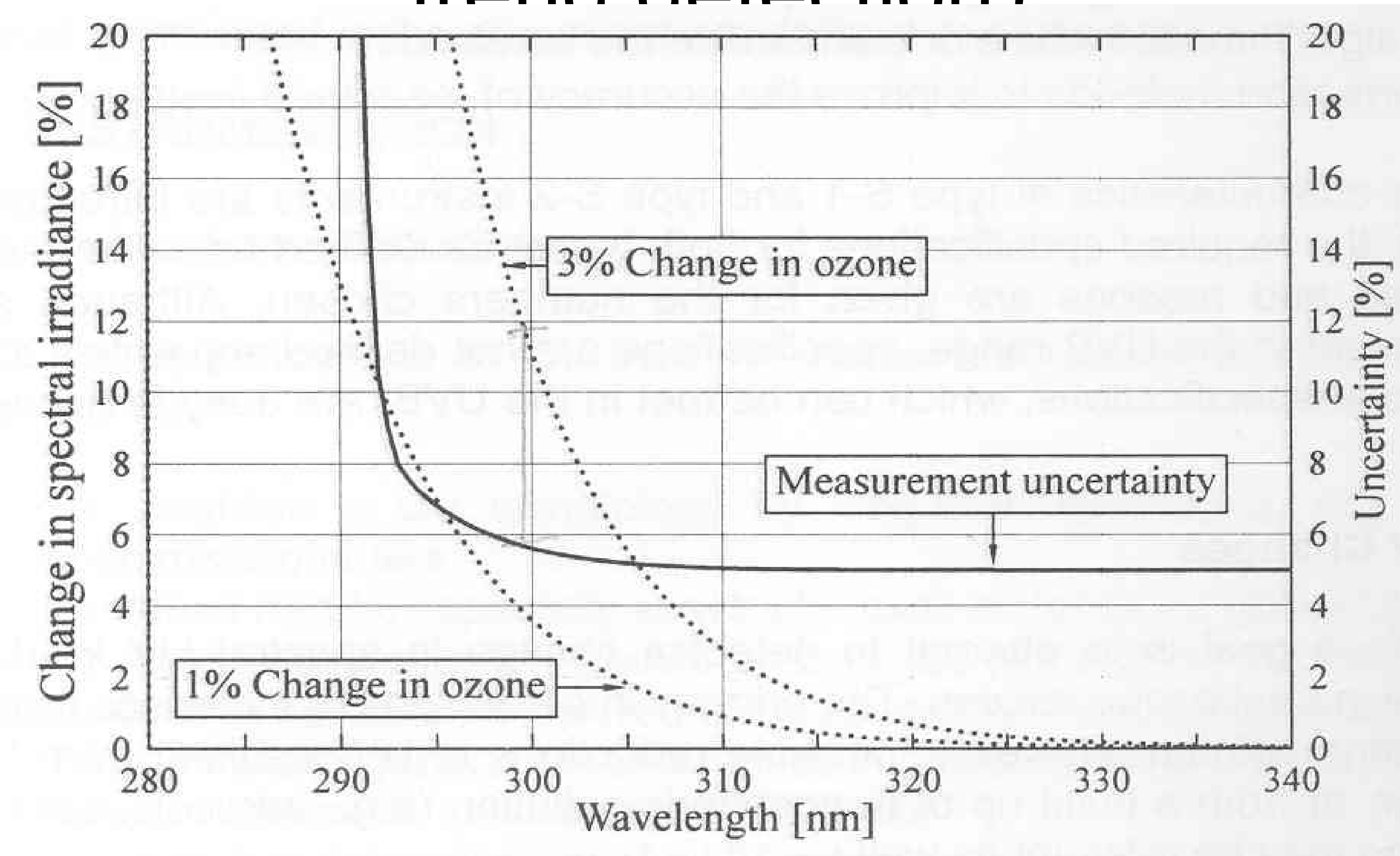
Biases due to a larger slit function

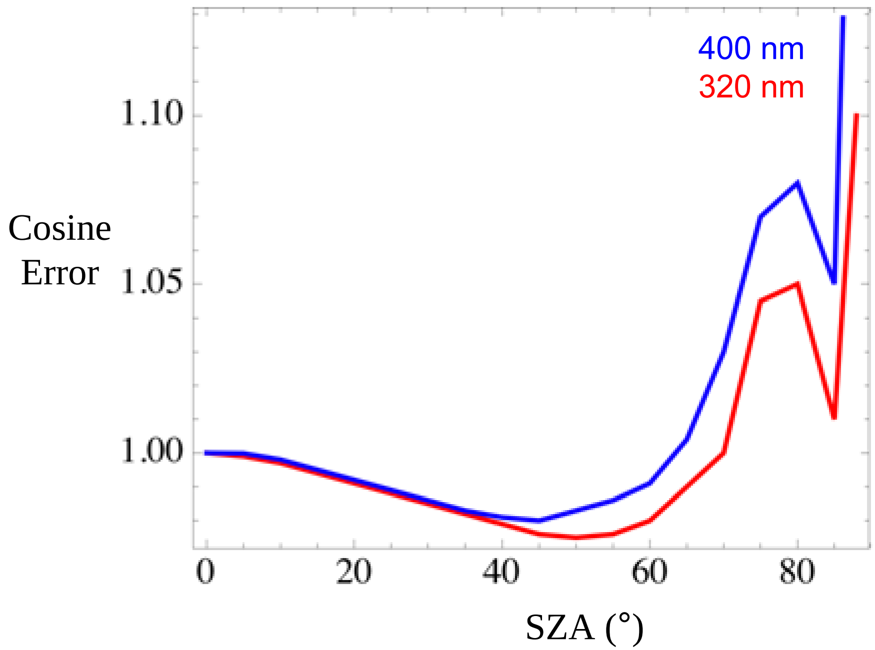
UV Index. The lack of significant biases in the integrals needed to computed the UV Index is ensured if the irradiance measurements are performed by using an instrument with an appropriate slit function. From: Cordero RR. Seckmeyer G. Pissulla D. Labbe F. “Uncertainty of experimental integrals: application to the UV index calculation” Metrologia **45** (2008) 1-10

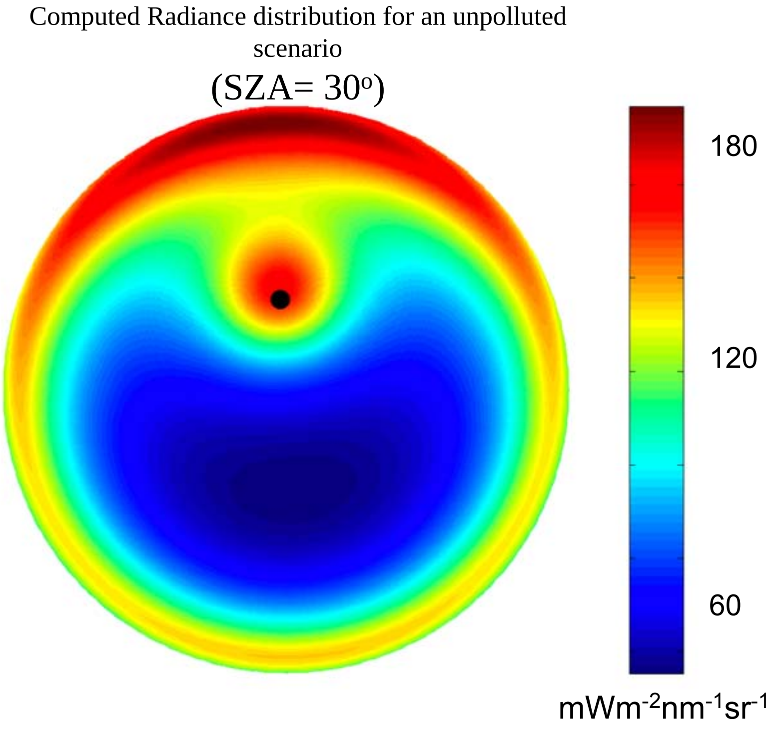


Exploitation scheme of Spectral Direct UV Irradiance Measurements (It allows retrieving ozone and aerosol parameters also by using a Monte Carlo-based approach). It required sequentially comparing the ground-based measurements with a large number of spectra, each of them calculated by a radiative transfer model with randomly generated values of input parameters (i.e. the ozone column and aerosol properties). The dispersion of the generated values that led to acceptable matches between the measured and calculated spectra allowed us to compute both the estimates and the uncertainties of the retrieved parameters. From: Cordero RR, Seckmeyer G, Pissulla D, Labbe F, “Exploitation of Spectral Direct UV Irradiance Measurements” Metrologia **46** (2009) 19-25

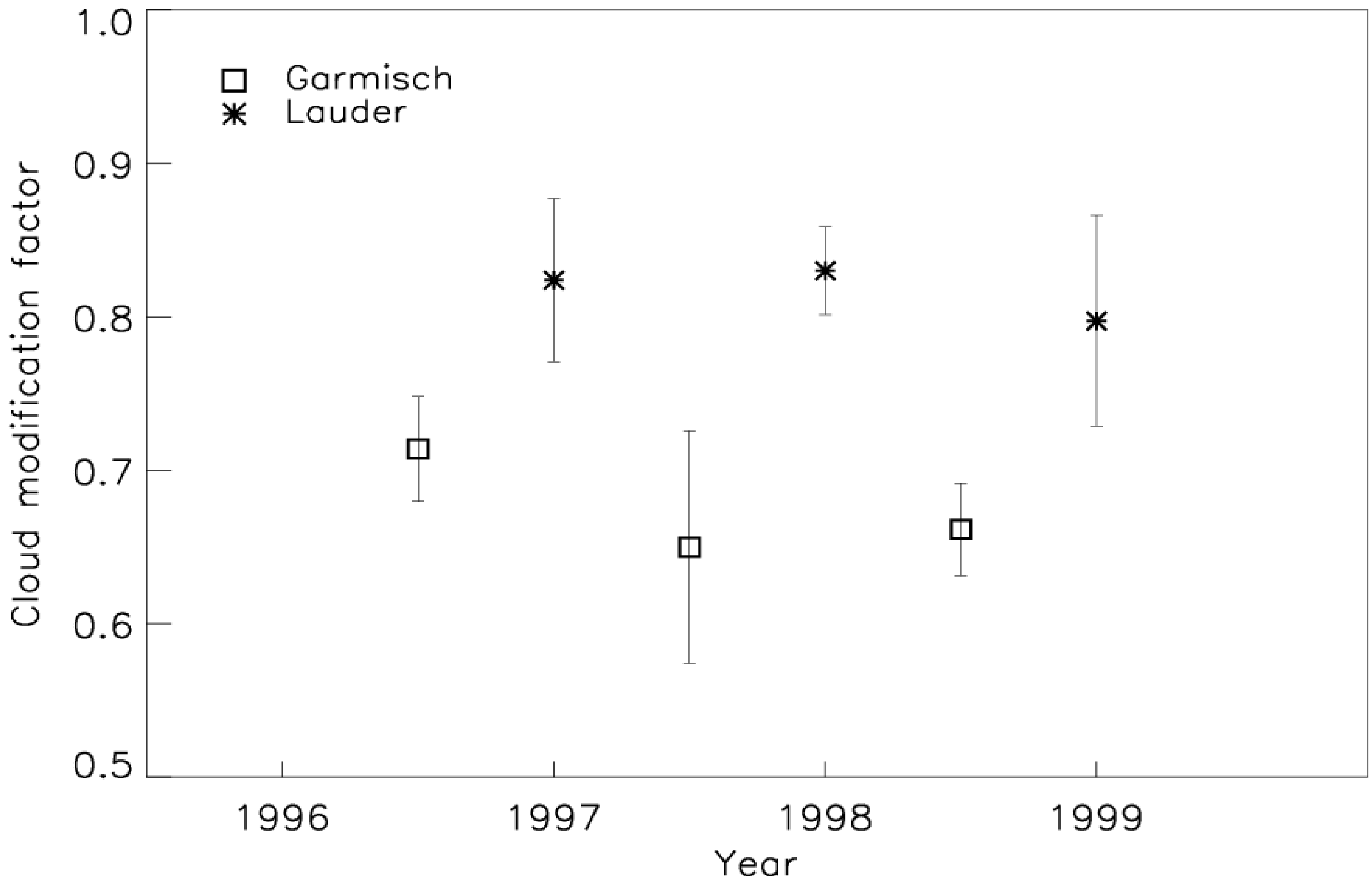
Why spectral measurements for trend detection?



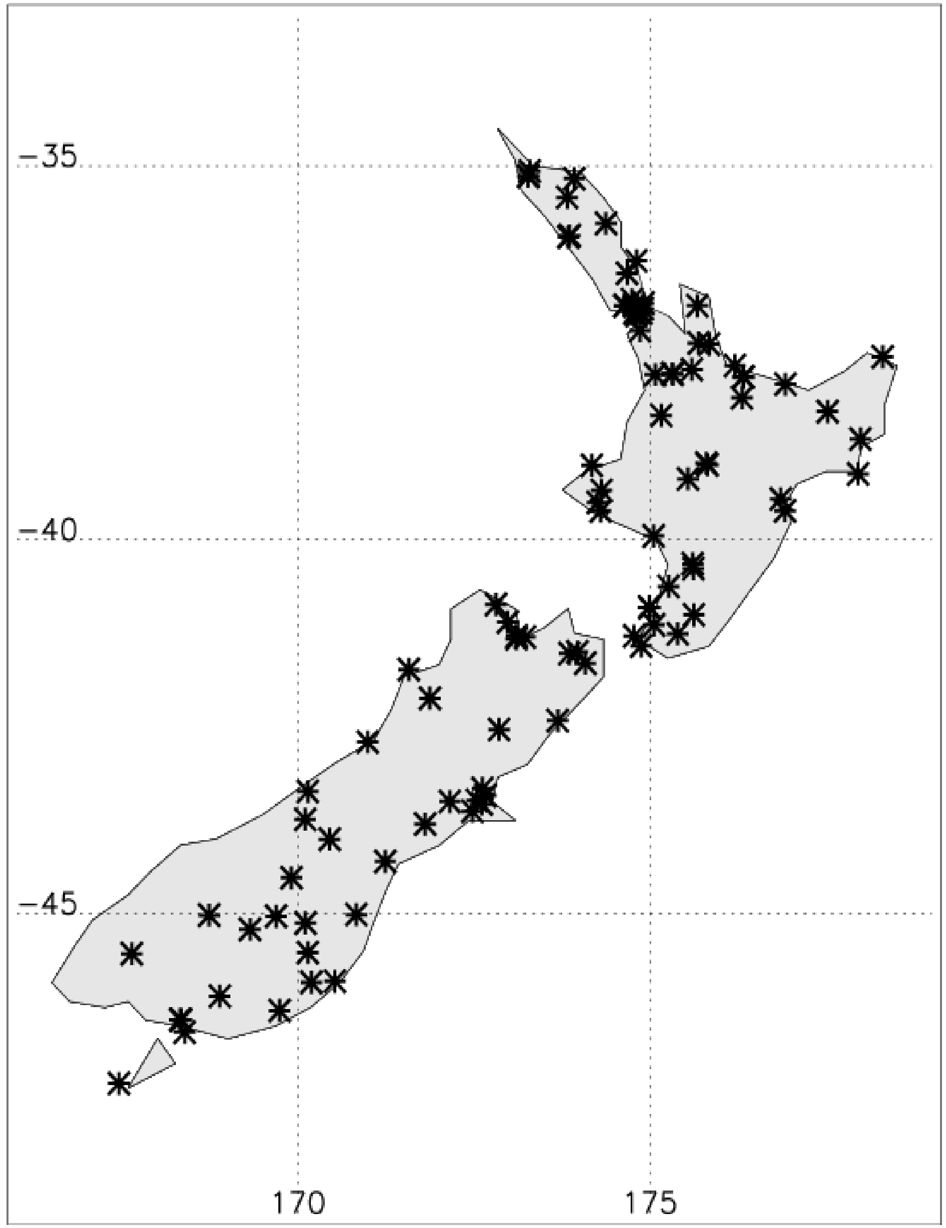




Uncertainty due to the cosine error. It can be computed from the cosine error of the input optics and from the radiance distribution. Since the latter normally is not available, it can be difficult to counteract the cosine error influence. By assuming some radiance distributions the Uncertainty due to the cosine error can be estimated. From: Cordero RR. Seckmeyer G. Labbe F. Cosine error influence on ground-based spectral UV irradiance measurements" Metrologia **45** (2008) 406-414

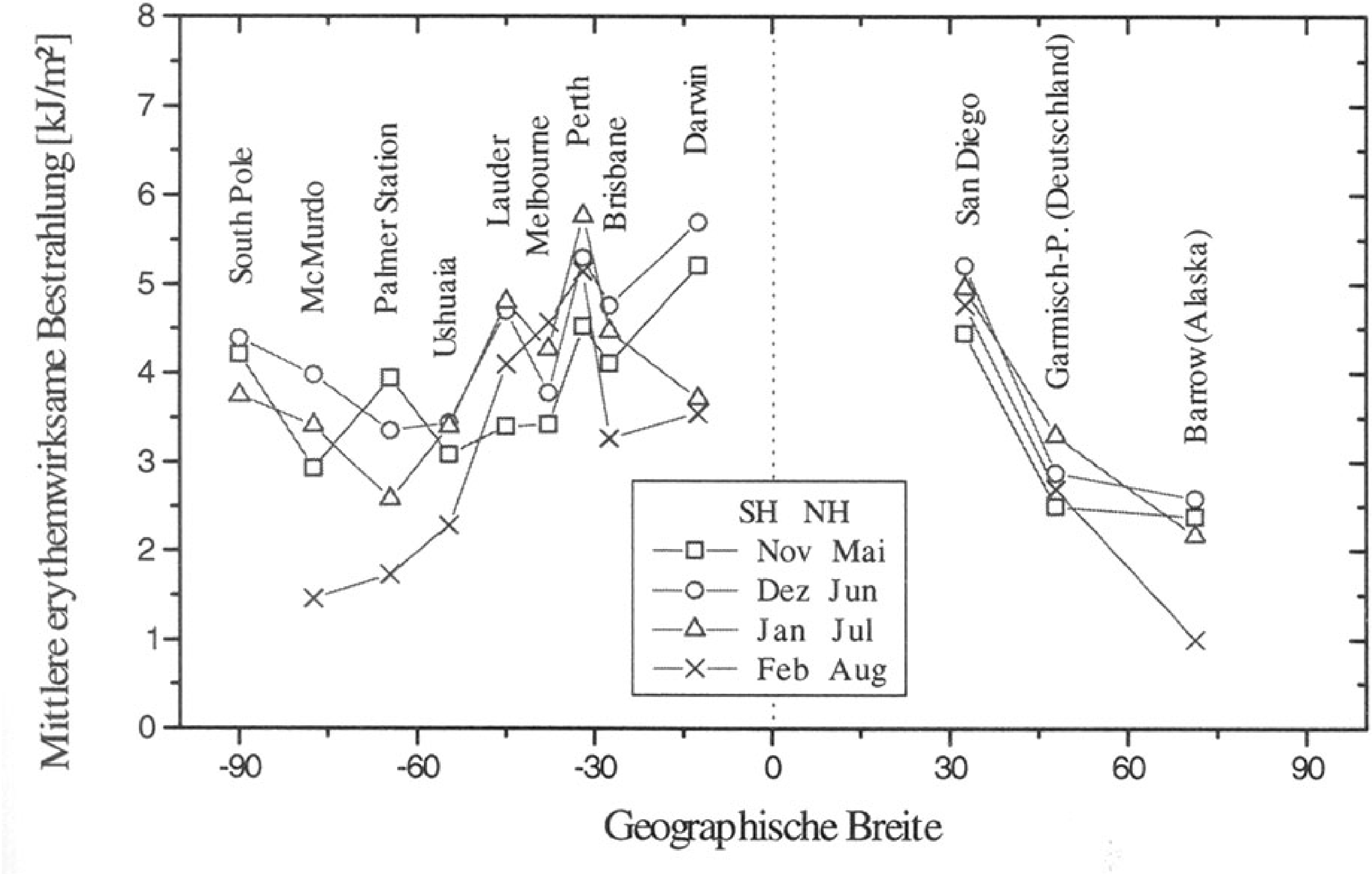


Mean cloud modification factors (CMFs) for the summer months (north: May to August, south: November to February) 1996 to 1998/99 at Garmisch and Lauder. The CMFs are calculated from monthly means of erythemal doses obtained from spectral measurements and uvspec model calculations. The standard deviation is indicated by error bars.



Map showing location of the New Zealand stations where radiation data have been extracted from the NIWA UV Atlas. The three sites with lower CMFs (~0.6) are marked with *.**

Erythemal irradiance monthly mean dose during the summer



Seckmeyer et al., Geophys. Res. Letters, 1995

Ozone and UV are very different quantities!

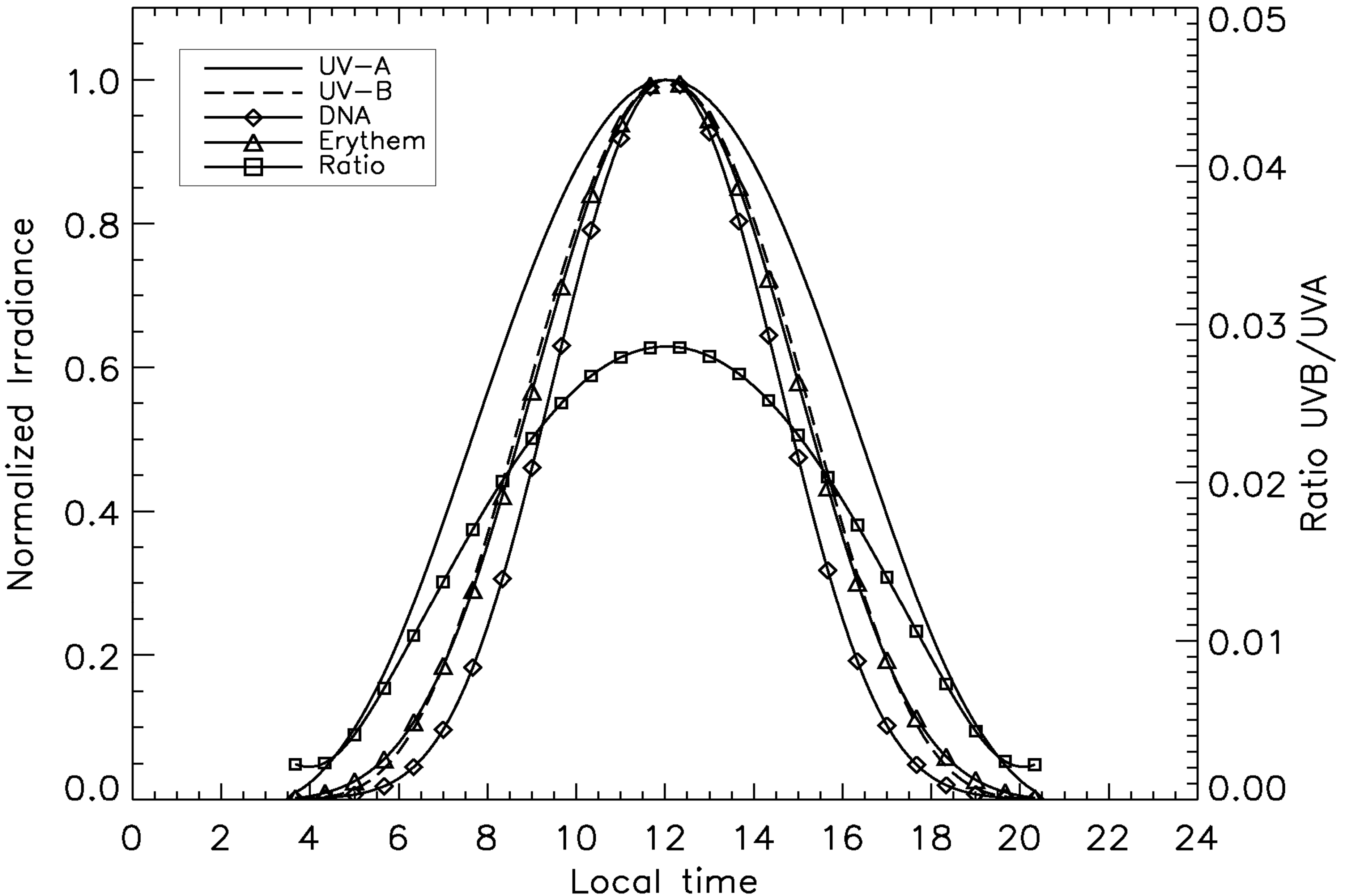
- Ozone varies slowly with time (hours, days)
- UV varies rapidly with time (seconds) → 3-4 order of magnitude higher variability
- Ozone depends on latitude, longitude and height.

→ Ozone (la,lo,h,t)

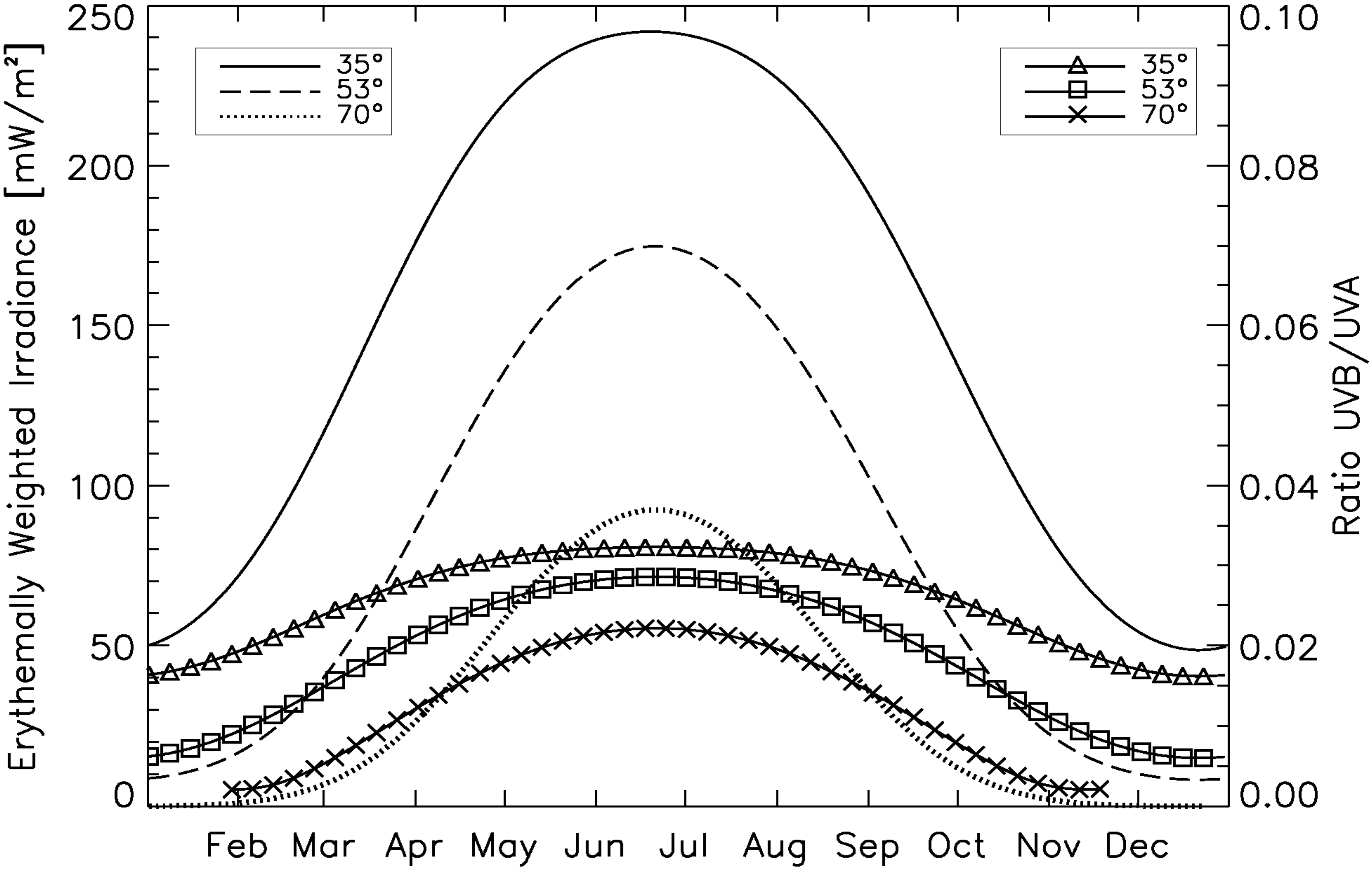
- UV depends on latitude, longitude, height, incident angle, azimuth angle, wavelength and Polarization.

→ UV (la,lo,h,t,θ,φ,λ,pol)

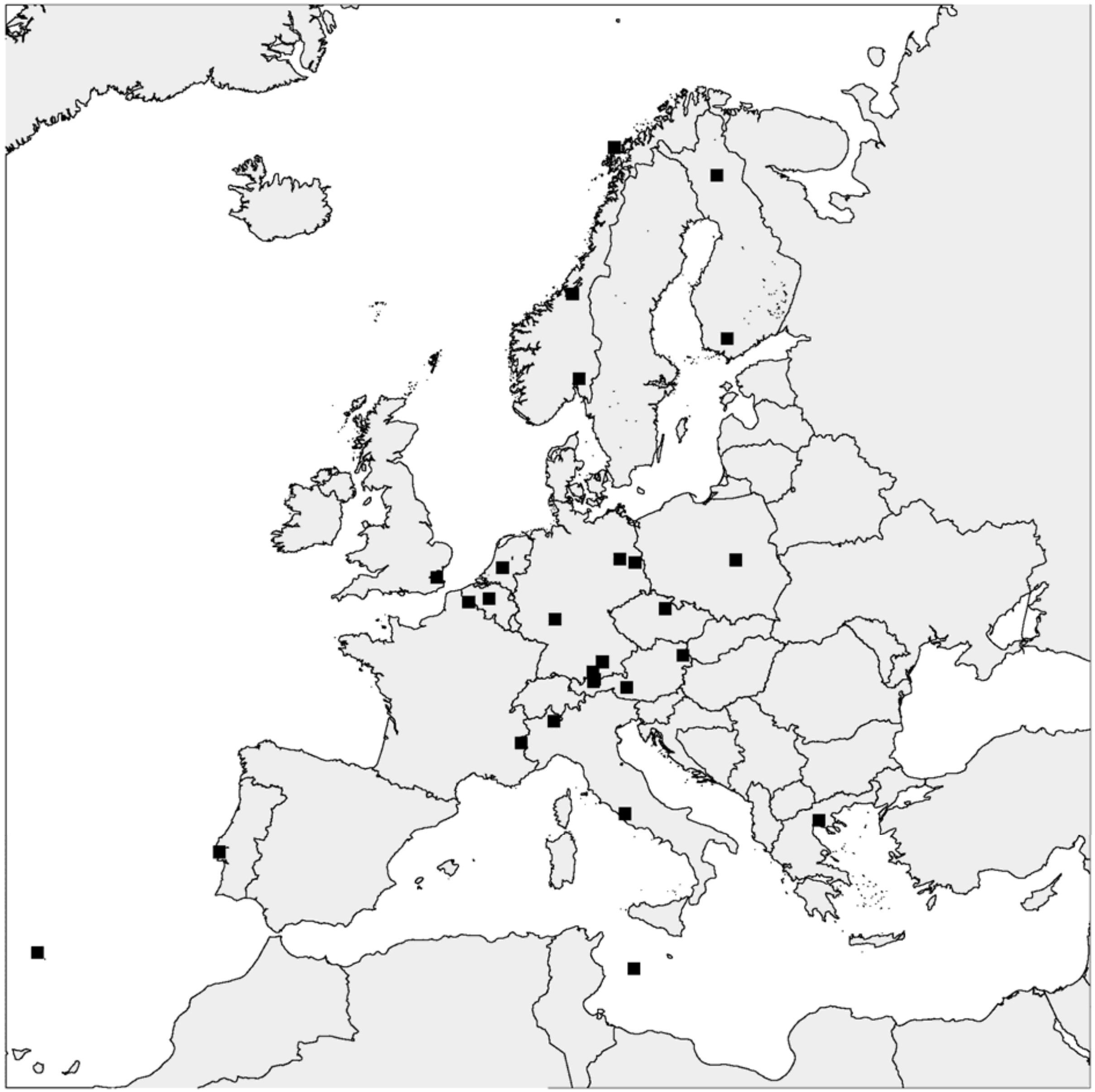
- How can we deal with a 10D quantity, varying very rapidly, like with a 4D quantity?
- → we help ourselves by integration over θ,φ and λ and ignore polarization.
- At least the integration over t and λ are



Modeled diurnal variation of normalized integrated weighted irradiance (left axis) and the ratio of UV-B to UV-A irradiance (right axis) for June 21 at 53° N. Normalization factors are given in the main text. Compared to the UV-A the UV-B, erythemal and DNA weighted irradiance distributions are narrower and more confined to the period around noon. The ratio UV-B/UV-A becomes very small in the early morning and the evening.



Annual variation of the erythemally weighted irradiance for noon at 35o (solid line), 53° (dashed line) and 70° (dotted line) northern latitude with ratios of UV-B to UV-A irradiance (right axis) for the same latitudes. See upper right legend for the symbols on the curves. The ratio UV-B/UV-A becomes very small for latitudes below 65° N since the sun is below the horizon at nighttimes.



Location of stations with measurements of spectral irradiance fulfilling the selection criteria.

Conclusions

- Most UV data sets show an upward gradient
- „Significant trends“ does not mean that they are physically valid
- Over the years we have different processes influencing UV radiation (e.g. ozone changes, aerosol changes).
- Time series are too short to resolve these influences by statistical methods

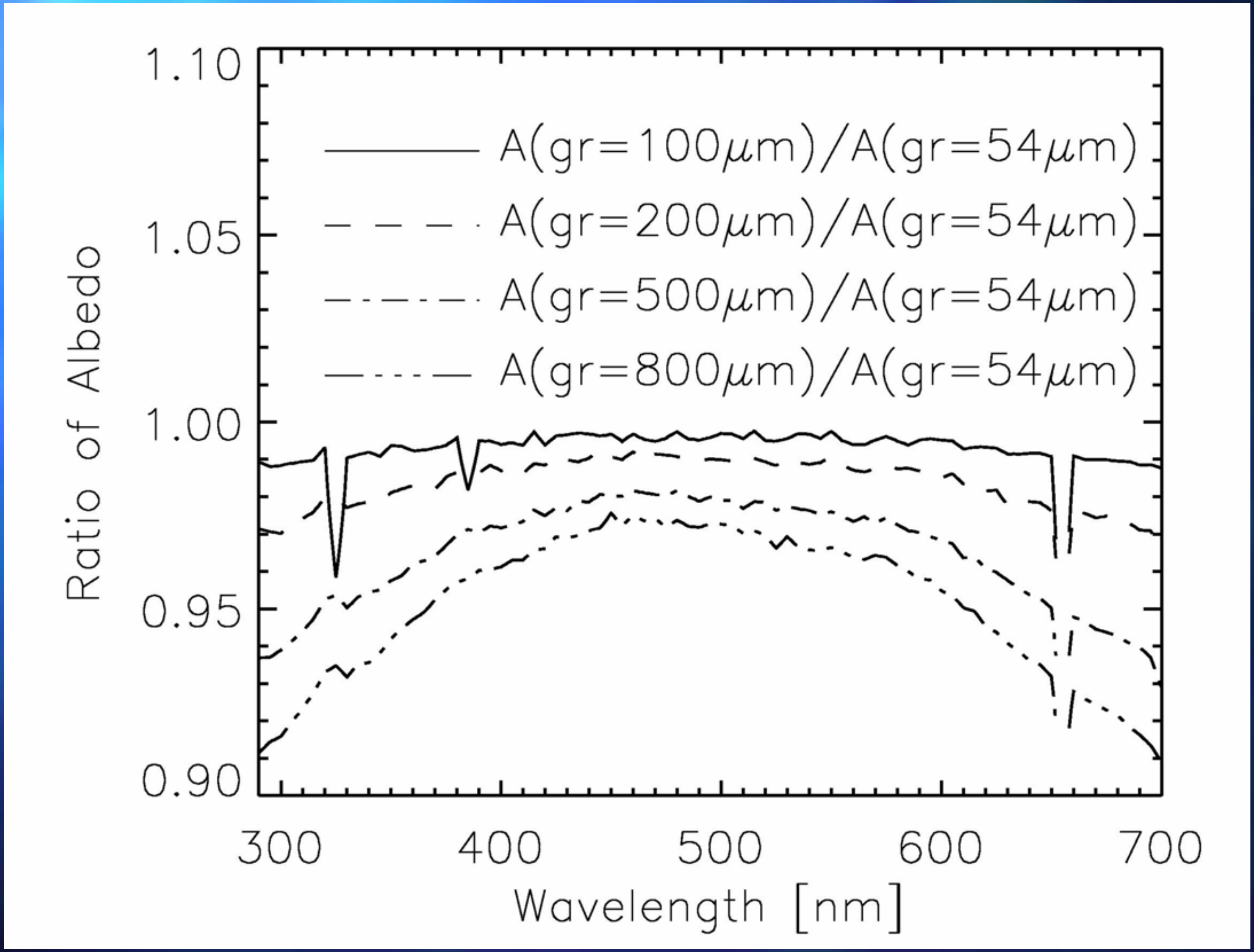
→We are presently not in a position to derive trends in the UV reliably


AWI

Table 1. Albedo of snow and grass for different wavelengths. The albedo of grass is taken from Feister and Grewe (1995) [26] and the albedo of snow was measured at Neumayer on 4 January 2004.[15]

Wavelength [nm]	Albedo of grass	Albedo of snow
305	0.017	0.971
320	0.017	0.961
350	0.018	0.966
400	0.022	0.967
499	0.035	0.965
550	0.089	0.962
695	0.040	0.900
800	0.587	0.830

Ratios of snow albedo modelled with different grain size radii



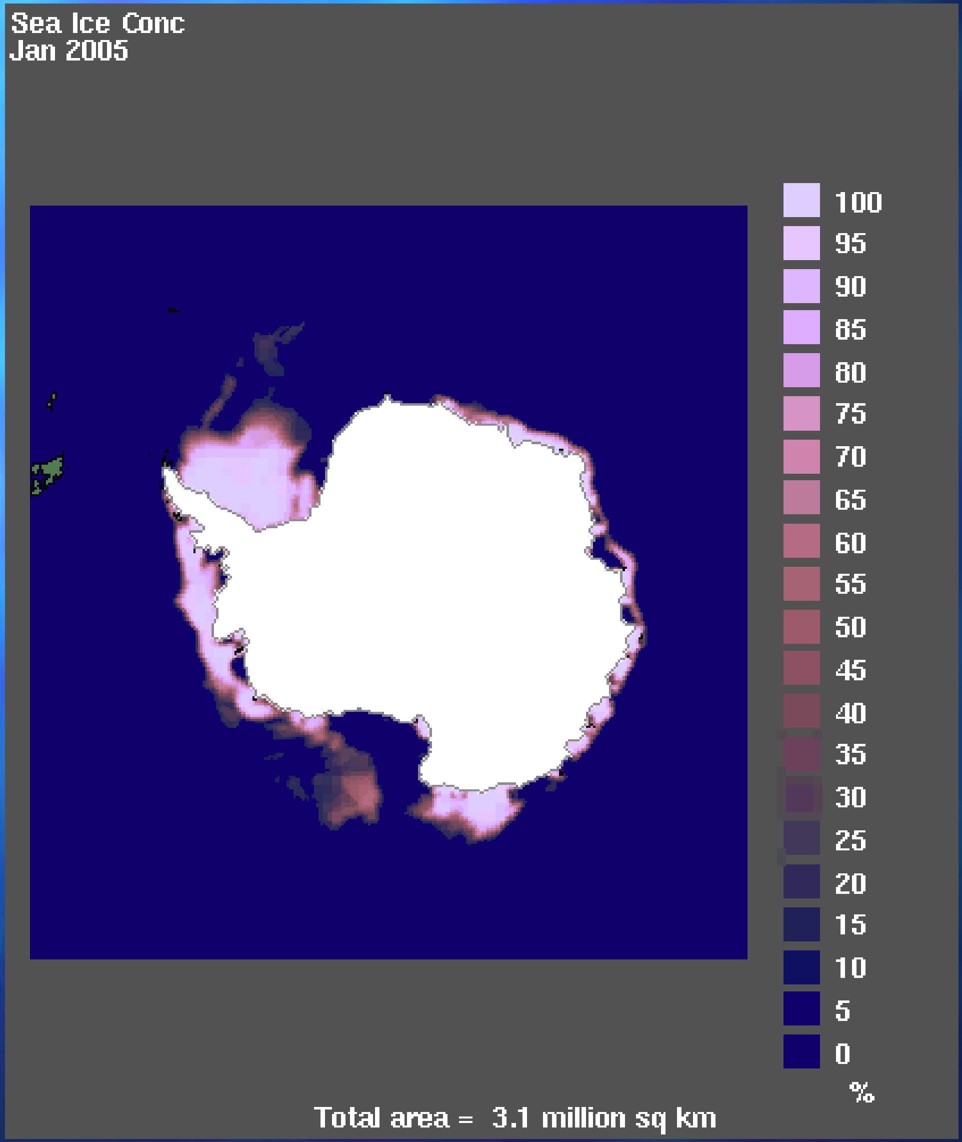
Wuttke S. et al., Annales Geophysicae, 2005

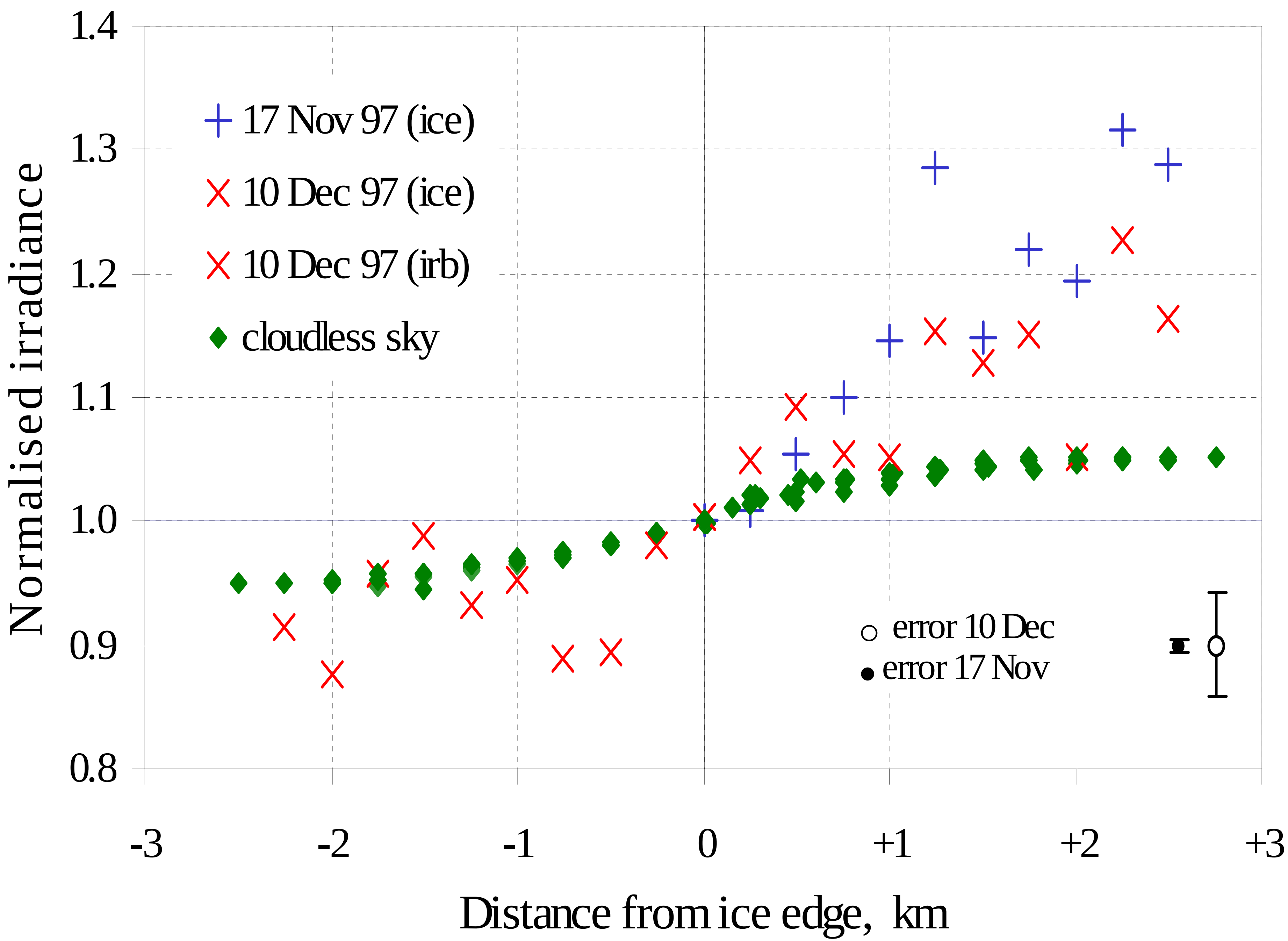
What area is affected by the surface albedo?

- Answer to be found in:

- Deguenther M., Meerkoetter R., Albold A., Seckmeyer G.: Case study on the influence of inhomogeneous surface albedo on UV irradiance, Geophysical Research Letters, Vol. 25, 3587-3590, 1998

Sea ice extent





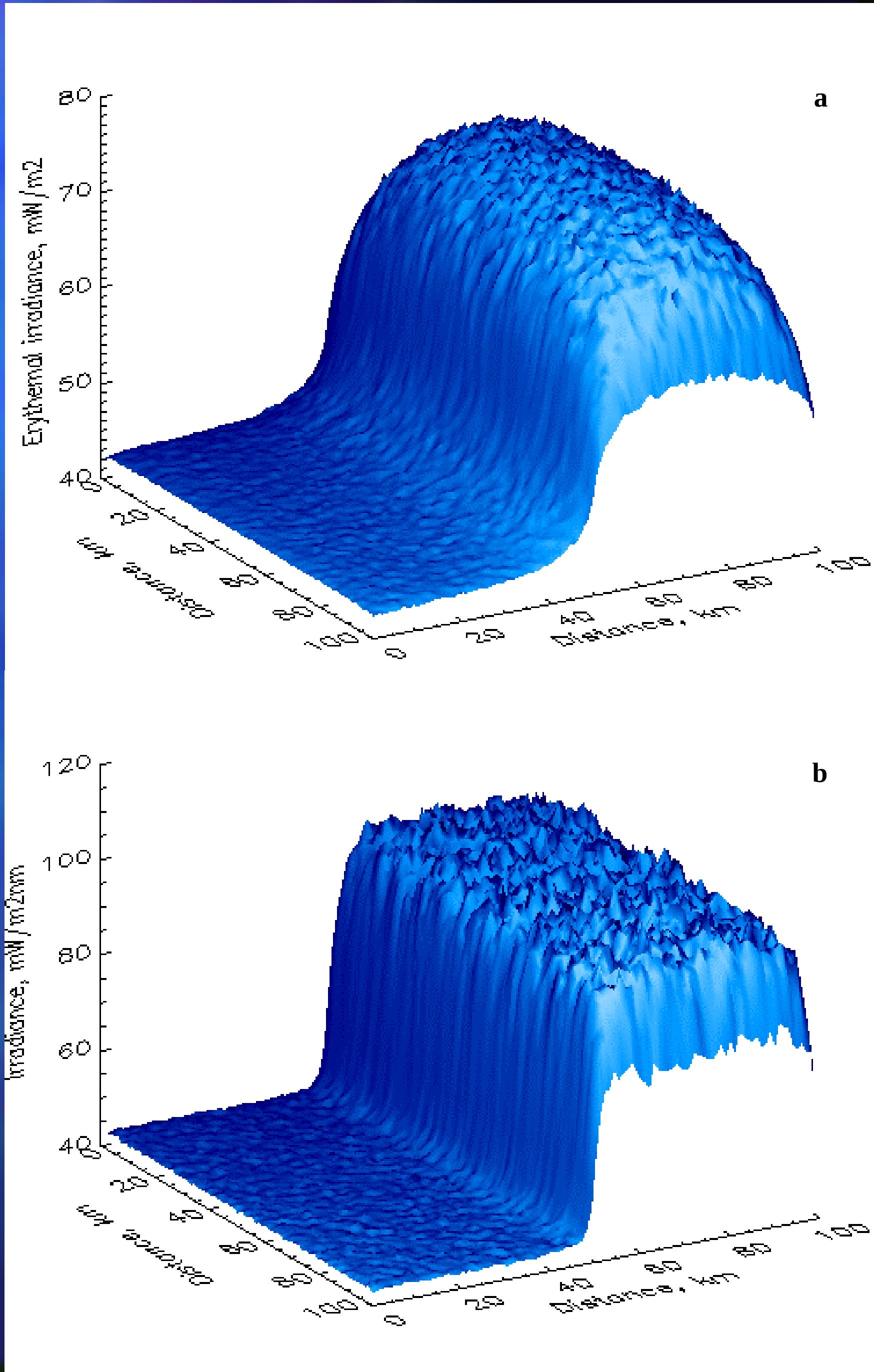
Normalised irradiance
1.4
1.3
1.2
1.1
1.0
0.9
0.8
17 Nov 97 (ice)
10 Dec 97 (ice)
10 Dec 97 (irb)
cloudless sky
error 10 Dec
error 17 Nov
-3
-2
-1
0
+1
+2
+3
Distance from ice edge, km

Erythemal irradiance calculated by the 3D Monte Carlo model

- For cloudless sky at the ice edge

- For overcast sky

snow is assumed to be a Lambertian reflector and water a specular reflector with albedos of 0.9 and 0.05, respectively



Smolskaia I., Annales Geophysicae, 2000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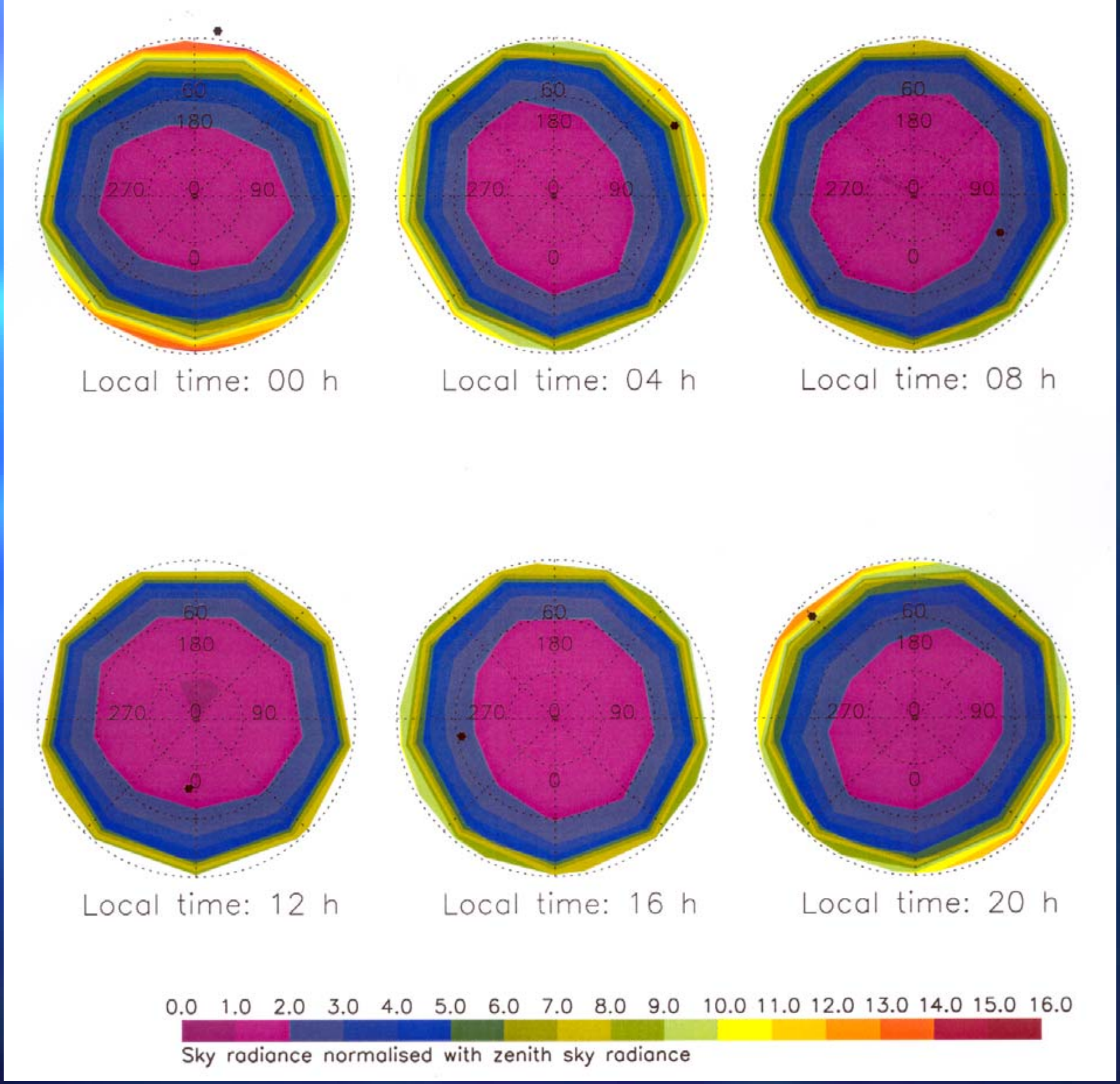
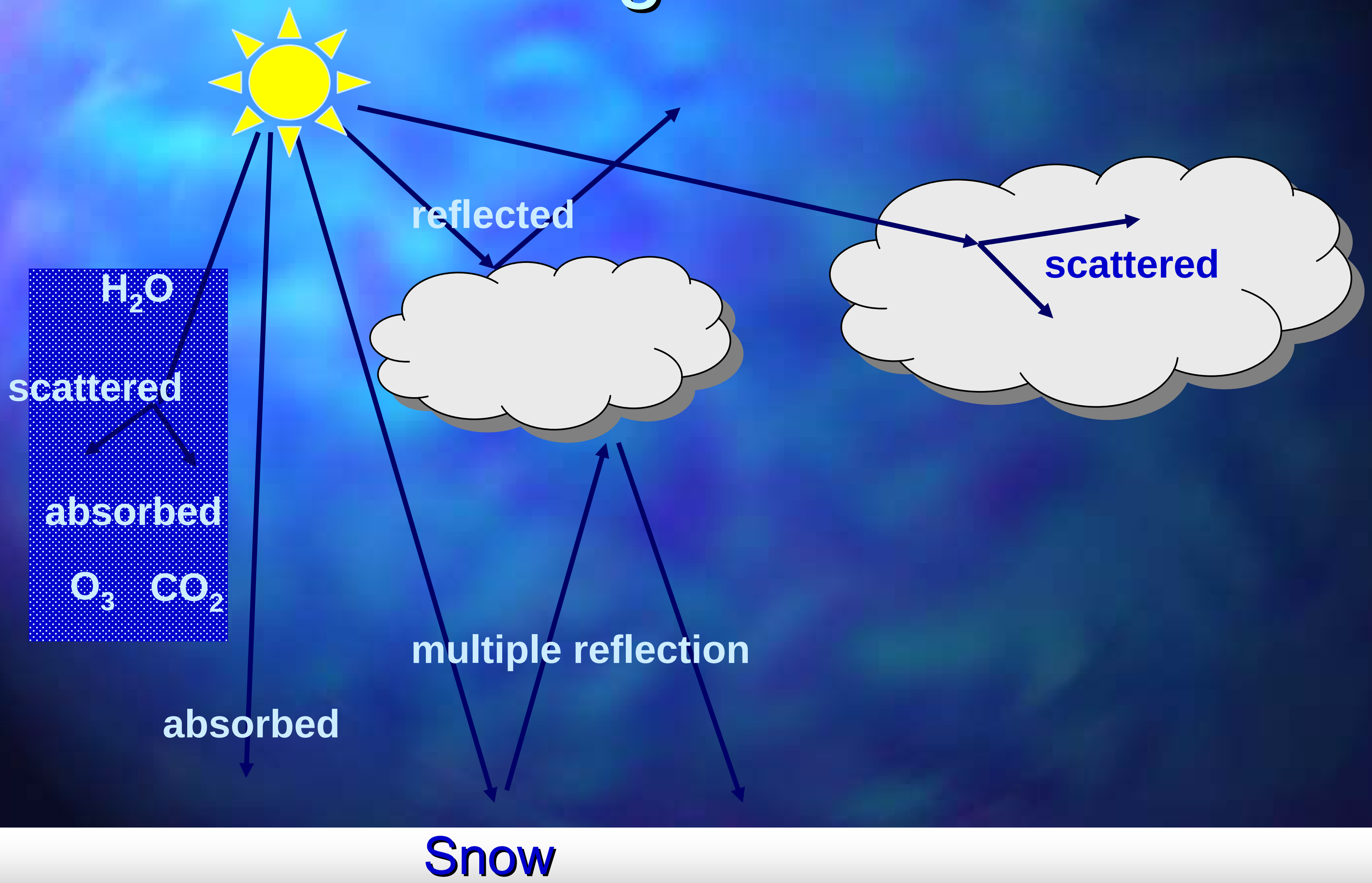
AWI 204

Räumliche Verteilung der Strahldichte bei 695nm

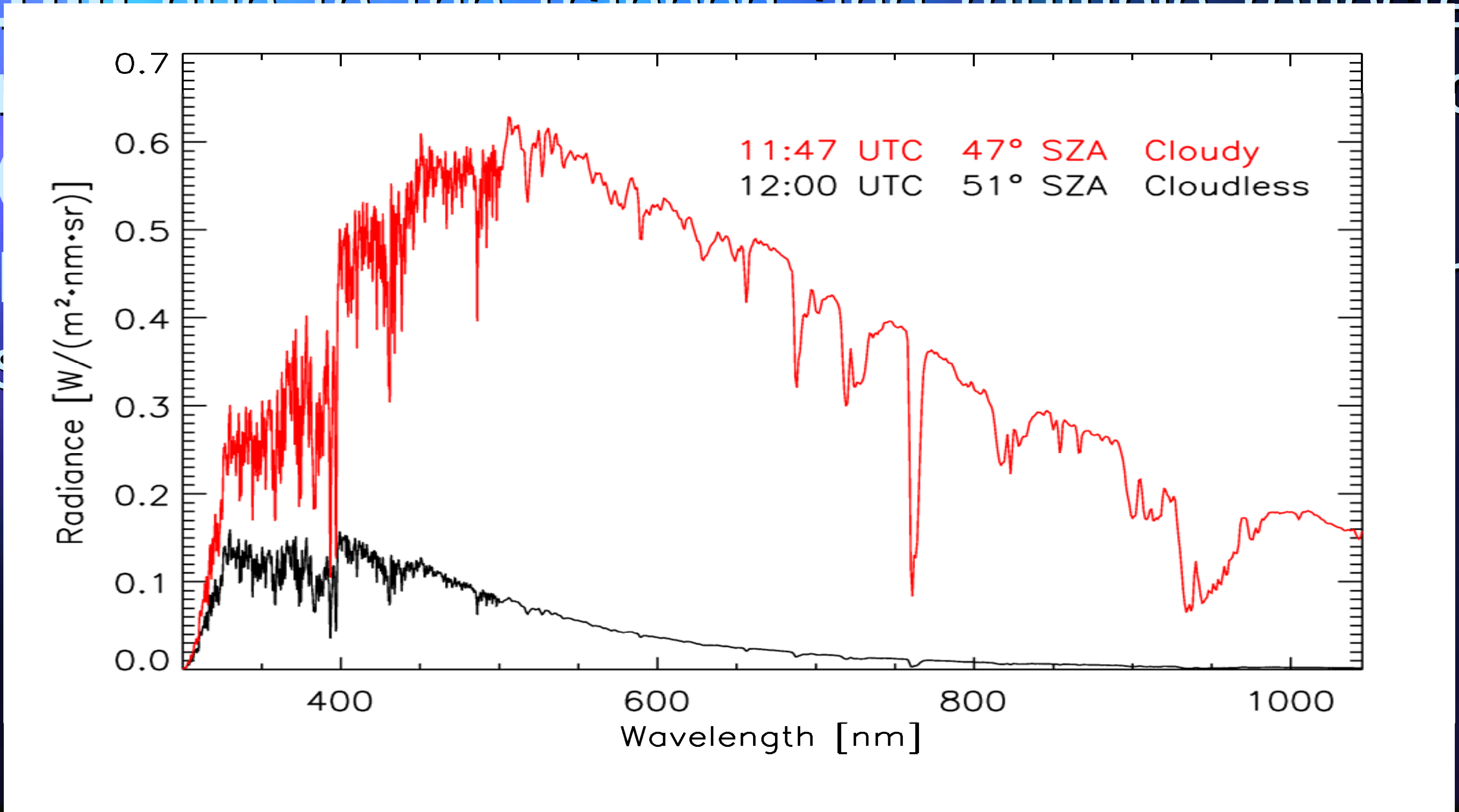


Interaction of solar radiation with clouds and high albedo surface



Previous Results from Antarctica

- The overcast spectral sky radiance **exceeds** the cloud free spectrum by up to a **factor of 100** due to the trapped and multiple reflected

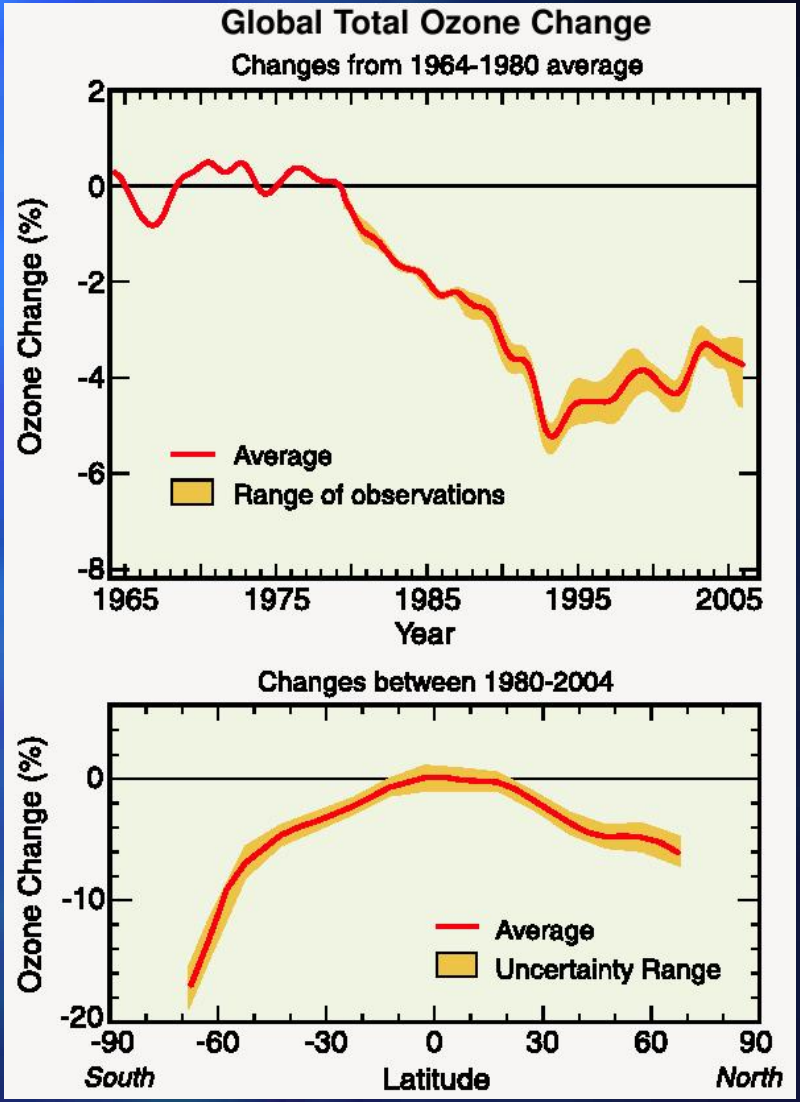


Summary:

- Snow can enhance the irradiance on a horizontal surface by up to 50%. The effects peaks at 320 nm
- The albedo of snow is wavelength dependent with values of about 1 in Antarctica for wavelength up to 700 nm. Above 700 nm the snow albedo is lower
- The snow albedo is affected by grain size, older snow has a lower albedo
- It has been theoretically predicted and experimentally proven that the the albedo significantly influcences locations more than 50 km apart from the high surface albedo area
- High surface albedo increases the sky radiance near the horizon. This effect increases with increasing wavelength
- Changes in snow albedo might cause climate change even before the snow is melting

Motivation – Development of the ozone

- Total ozone has decreased in global average since 1980 by about 2 % per decade
- Ozone trends depend on latitude; higher latitudes are



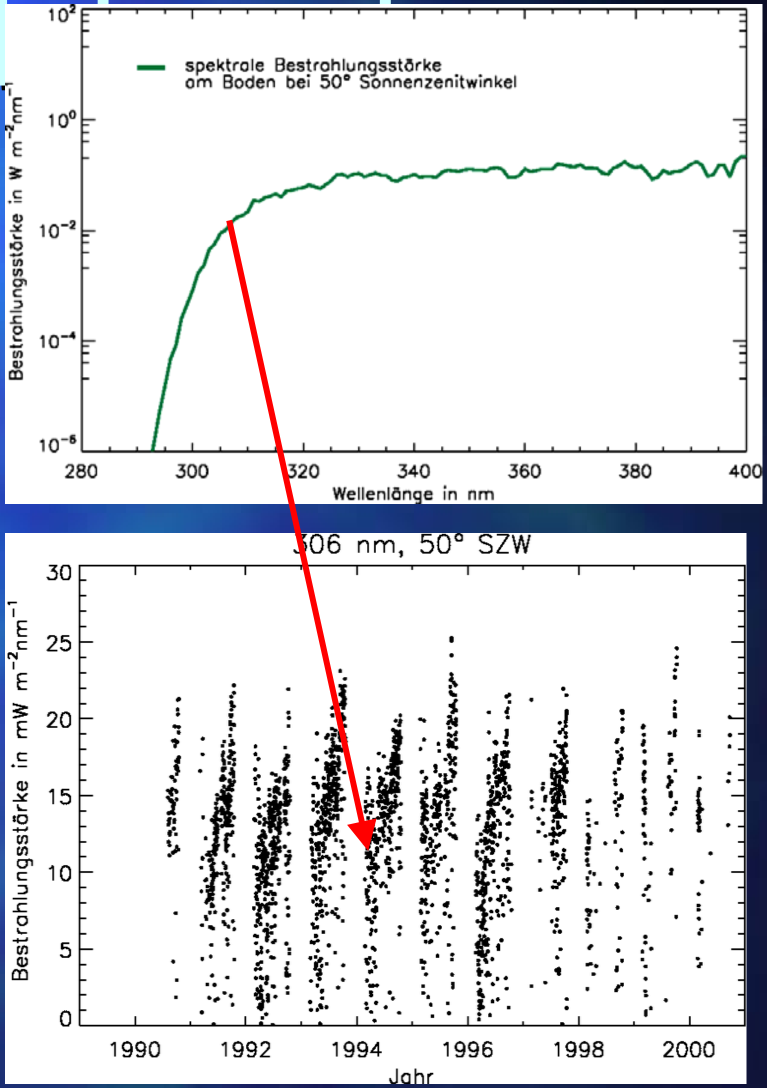
Quelle: Ozone Assessment 2006

WMO SAG on UV monitoring

- Seckmeyer G., Bais A., Bernhard G., Blumthaler M., Eriksen P., McKenzie R.L., Roy C., Miyauchi M.: Instruments to measure solar ultraviolet radiation, part 1: spectral instruments, WMO-GAW report No.126, 2001
- Seckmeyer G., Bais A., Bernhard G., Blumthaler M., Booth C.R., Lantz K., McKenzie R.L.: Instruments to measure solar ultraviolet radiation, part 2: Broadband instruments measuring erythemally weighted solar irradiance, WMO-GAW report, 2006, in press

Method for Trend

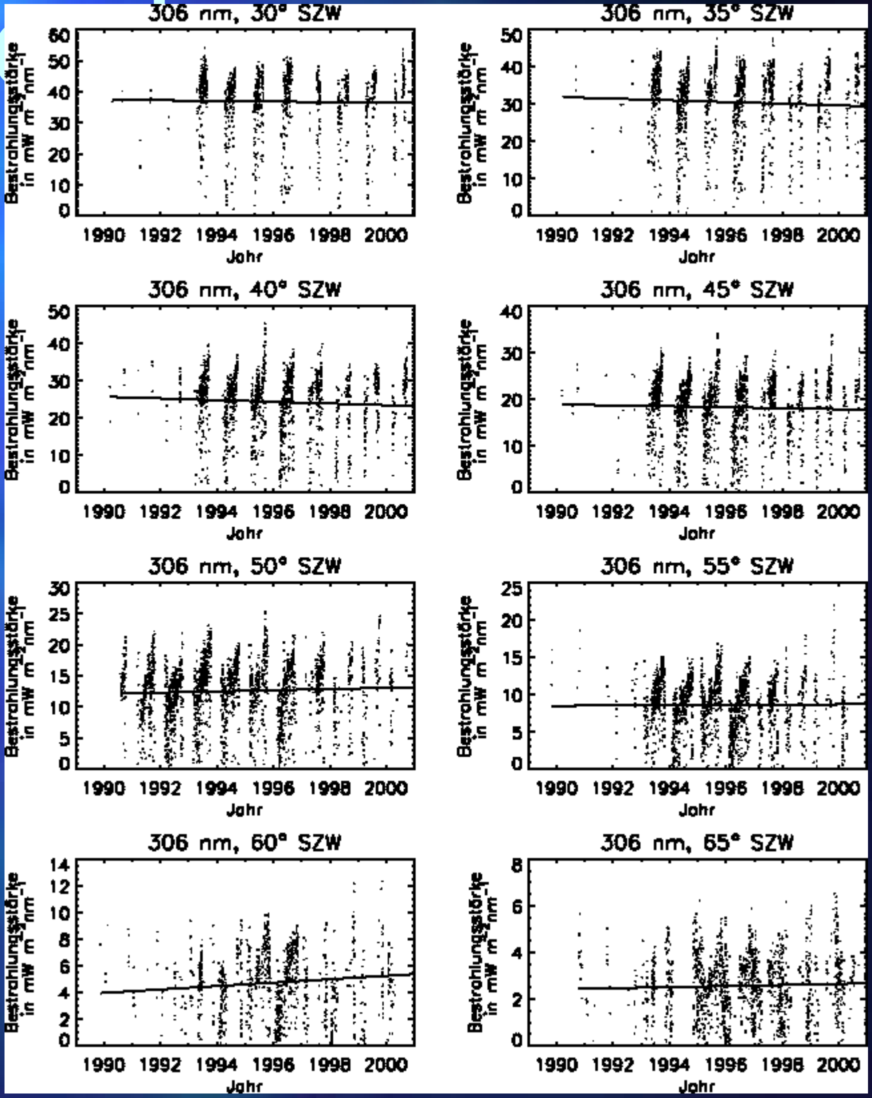
- Separate data to gain data dependent on wavelength and solar zenith angle (e.g. 306 nm and 50° sza
- Advantage: reduce the trend detection to variabilities in ozone, cloudiness,



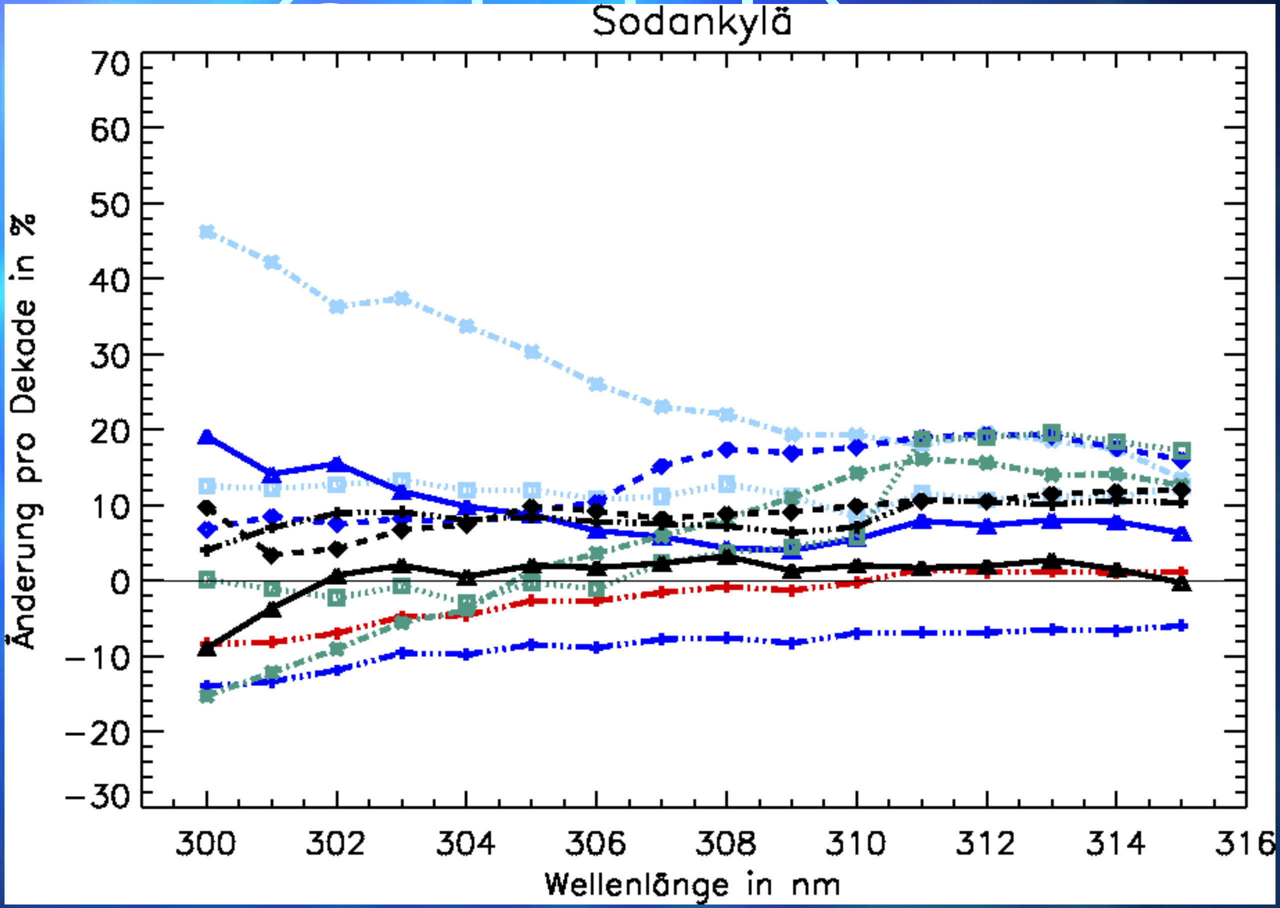
Trend dete

Investigate every data set

- Linear regression
- Significance test according to Mann



Results of trenddetektion



- Majority of regressions are positive (in Thessaloniki and in Sodankylä)
- Have we proven that there is a significant positive trend?