UV research by simultaneous spectral radiance measurements

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UV research by simultaneous spectral radiance measurements

- Multidirectional Spectroradiometer (MUDIS)
- Vitamin D weighted Exposure
- Spectral radiance versus irradiance

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Cloud Movie from Lauder New Zealand

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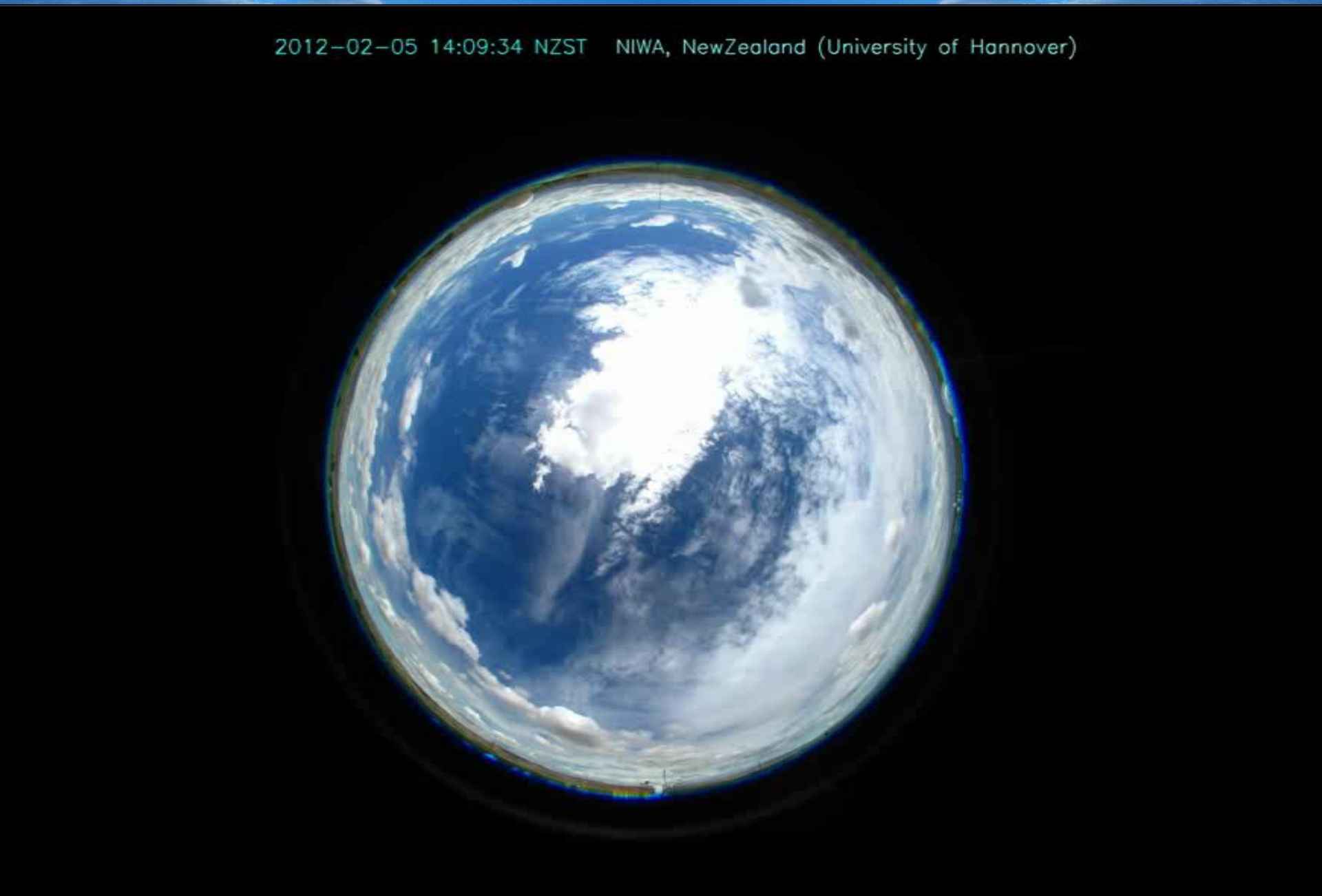
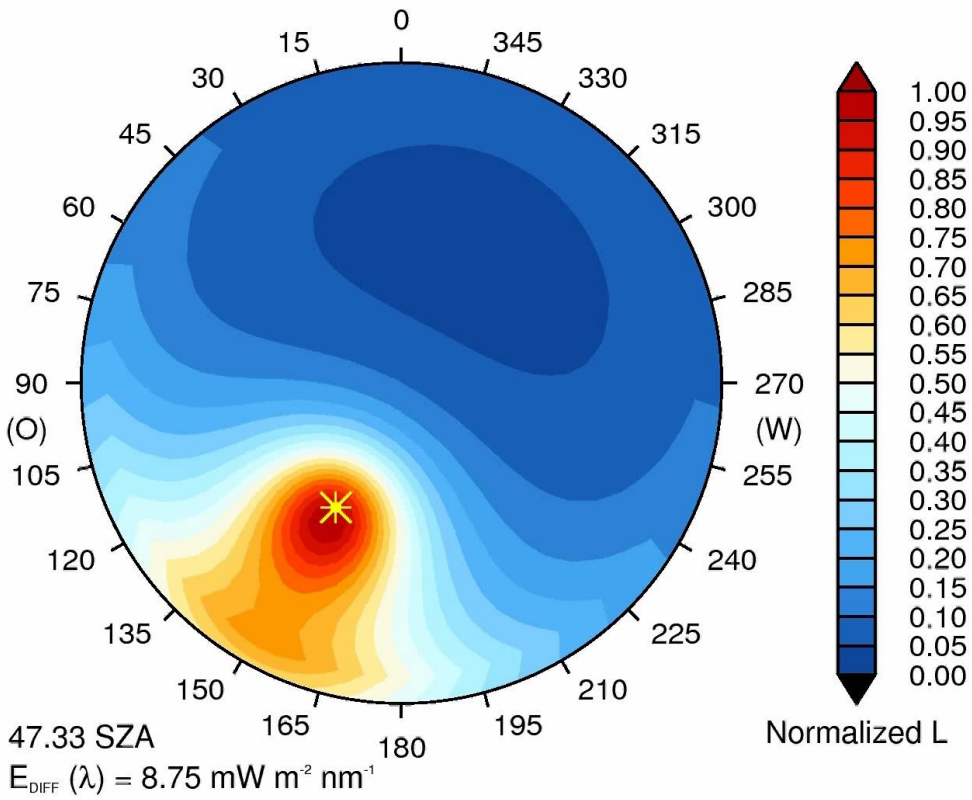
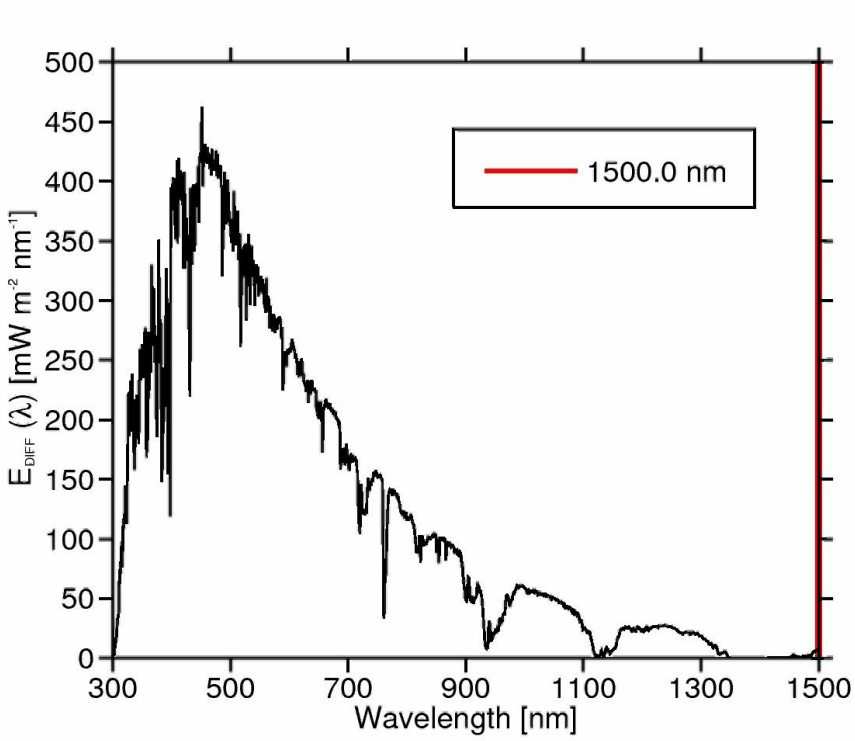
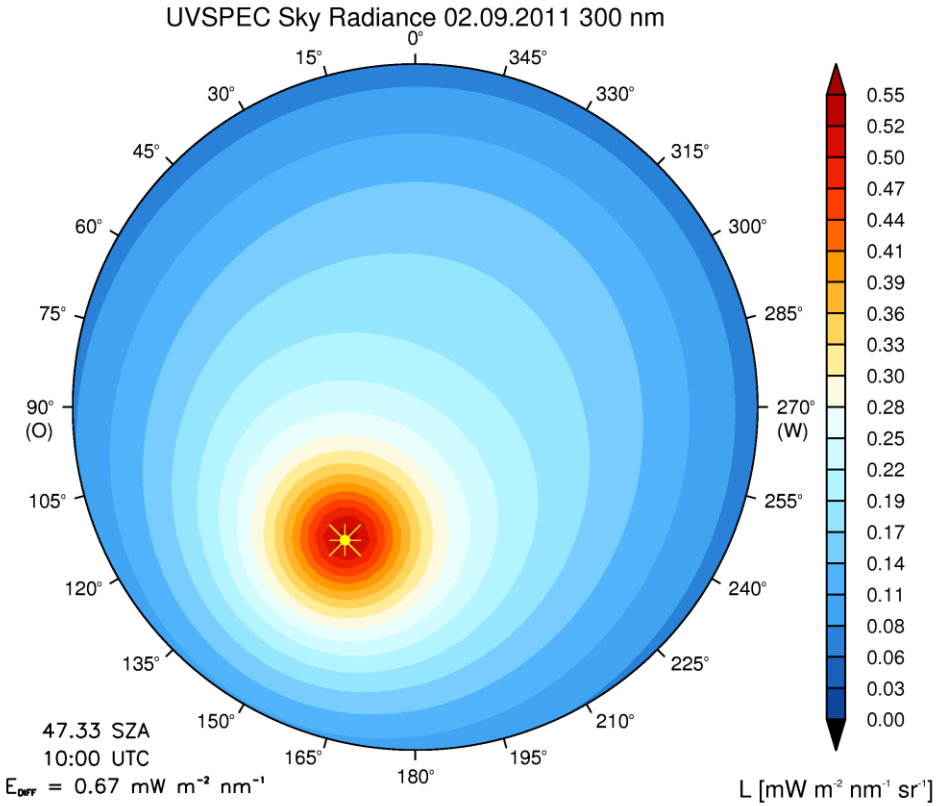


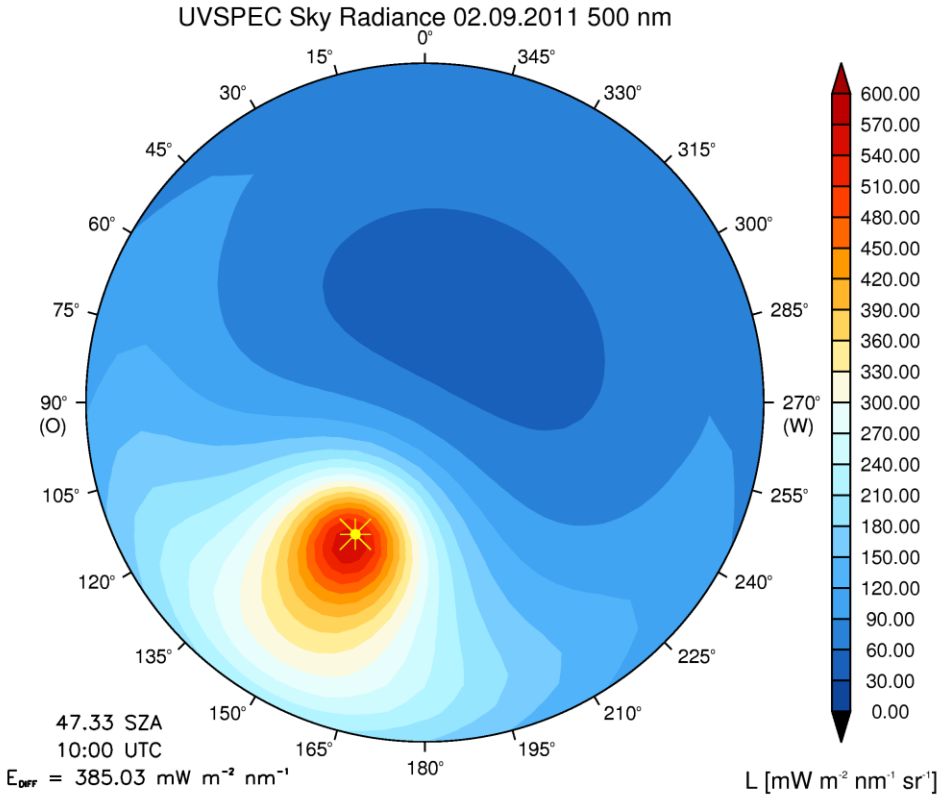
Spectral Radiance for cloudless sky in Hannover 300 DU, visibility 20 km



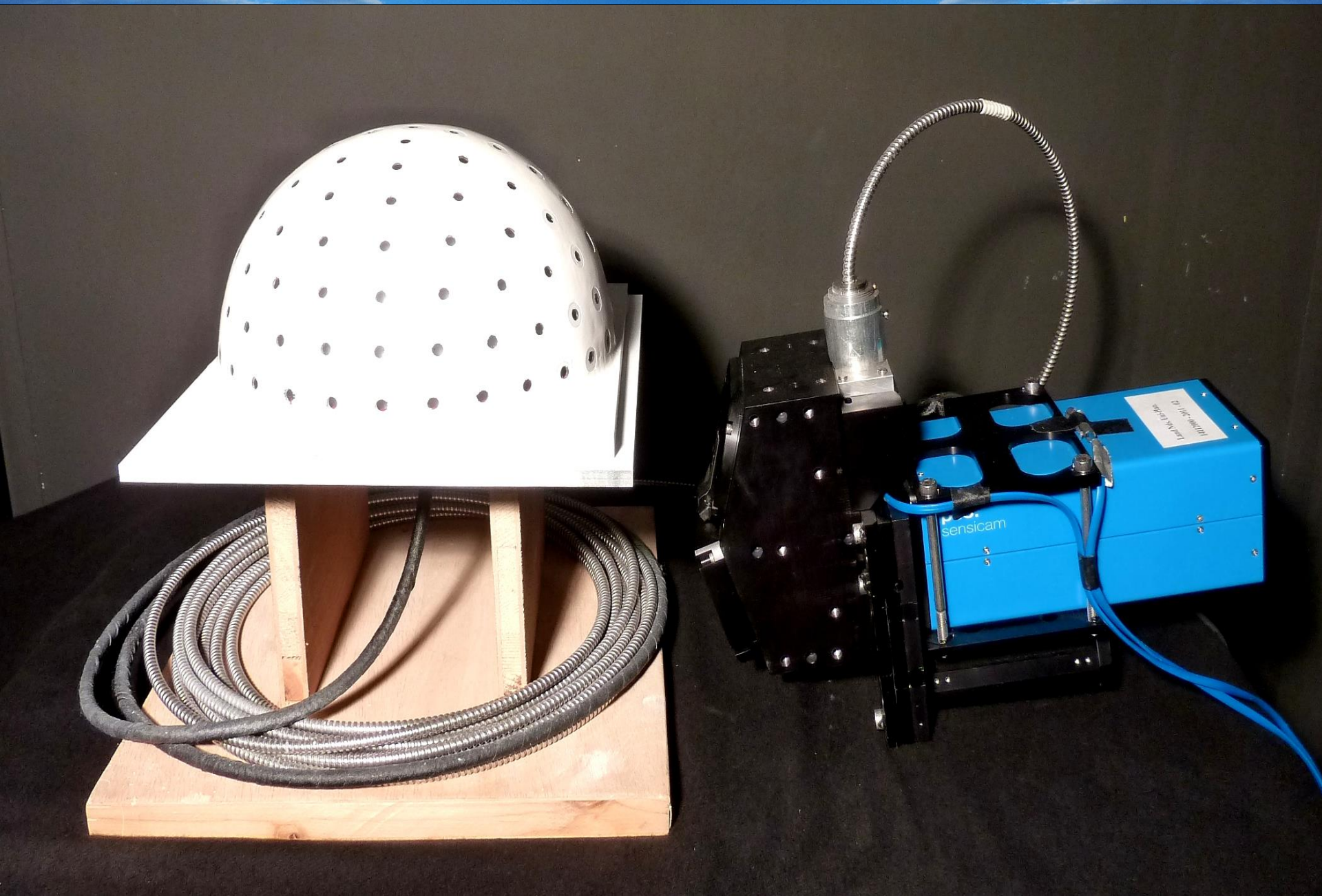


Spectral Radiance for cloudless sky in Hannover 300 DU, visibility 20 km

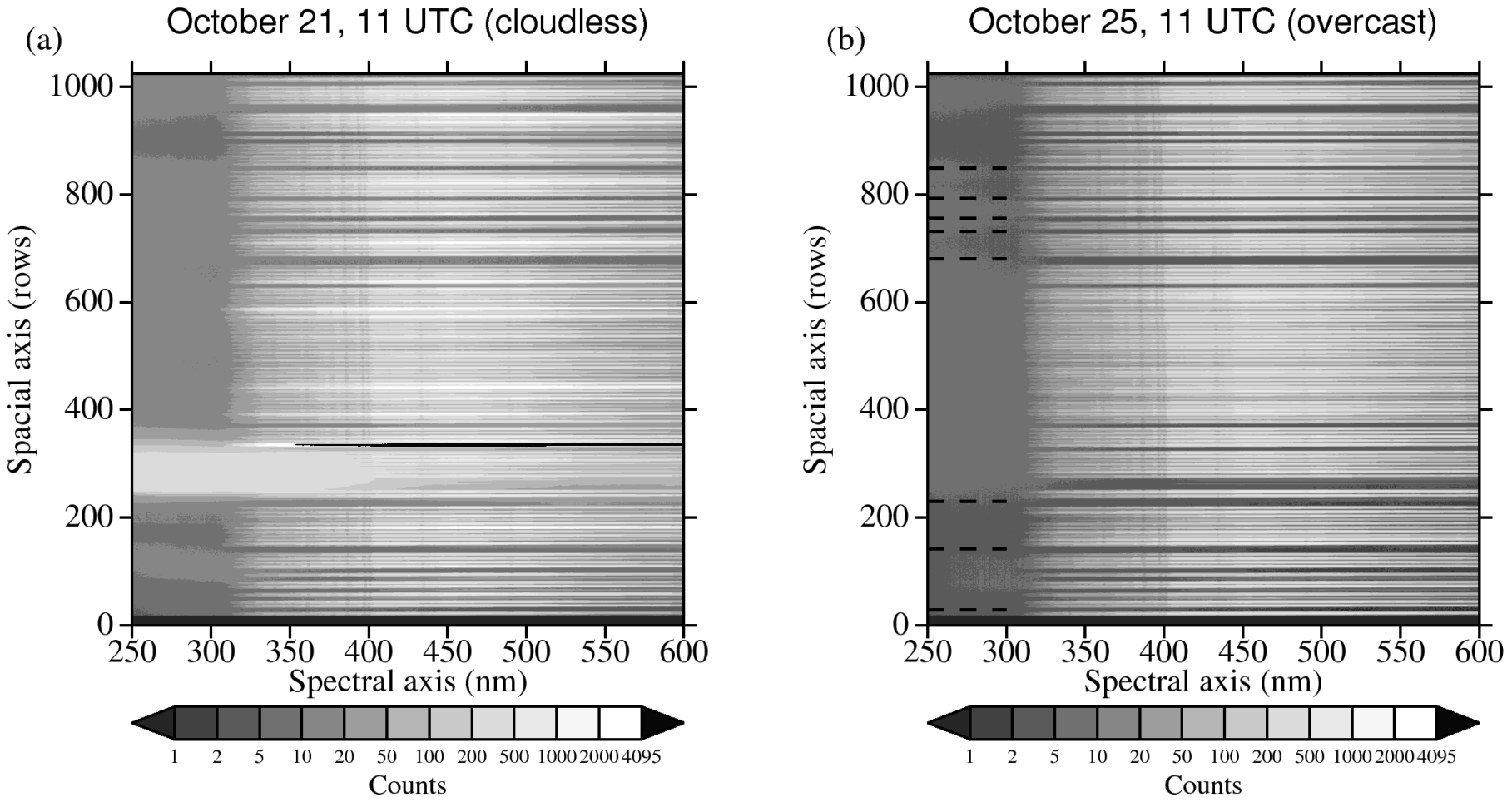




MUDIS, new development from Hannover



MUDIS Measurement



Riechelmann *et al.* 2013, *Measurement Science and Technology*

Spectral Radiance at 500 nm from MUDIS Images from all-sky imager

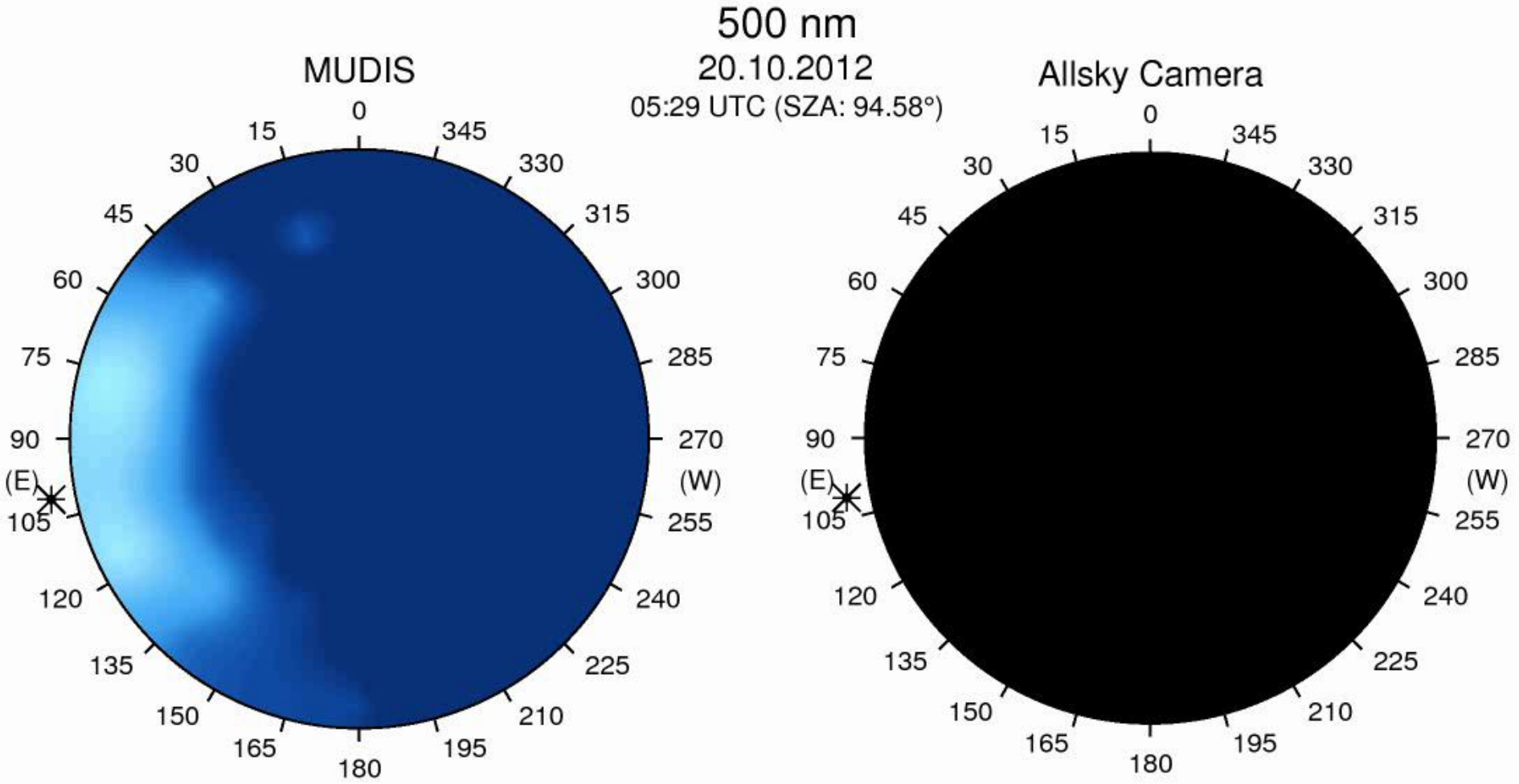
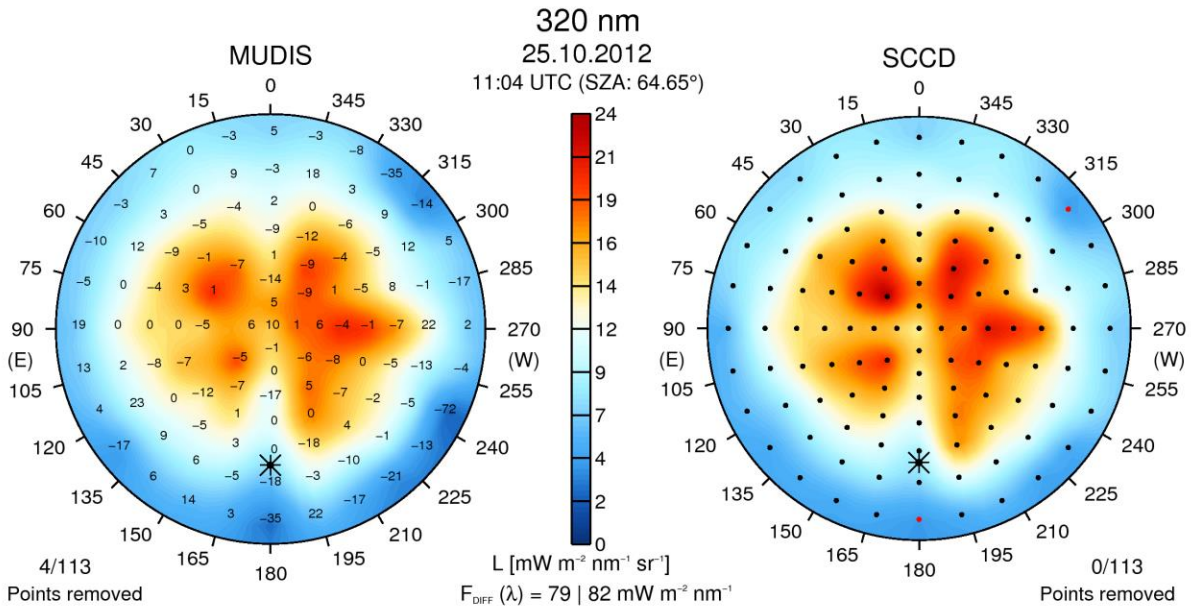
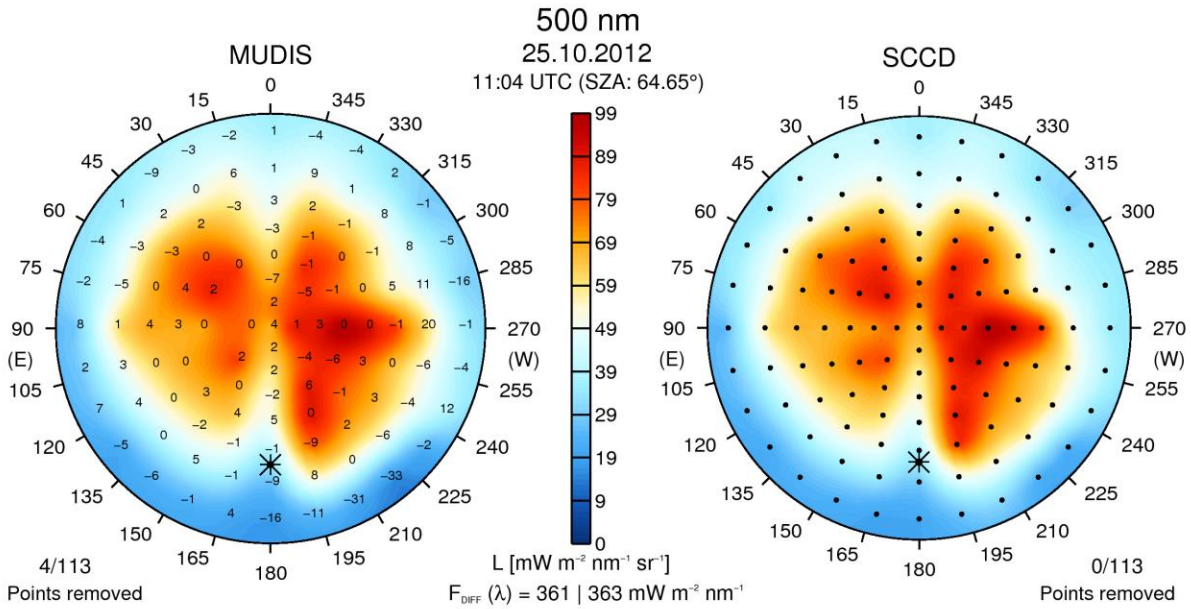
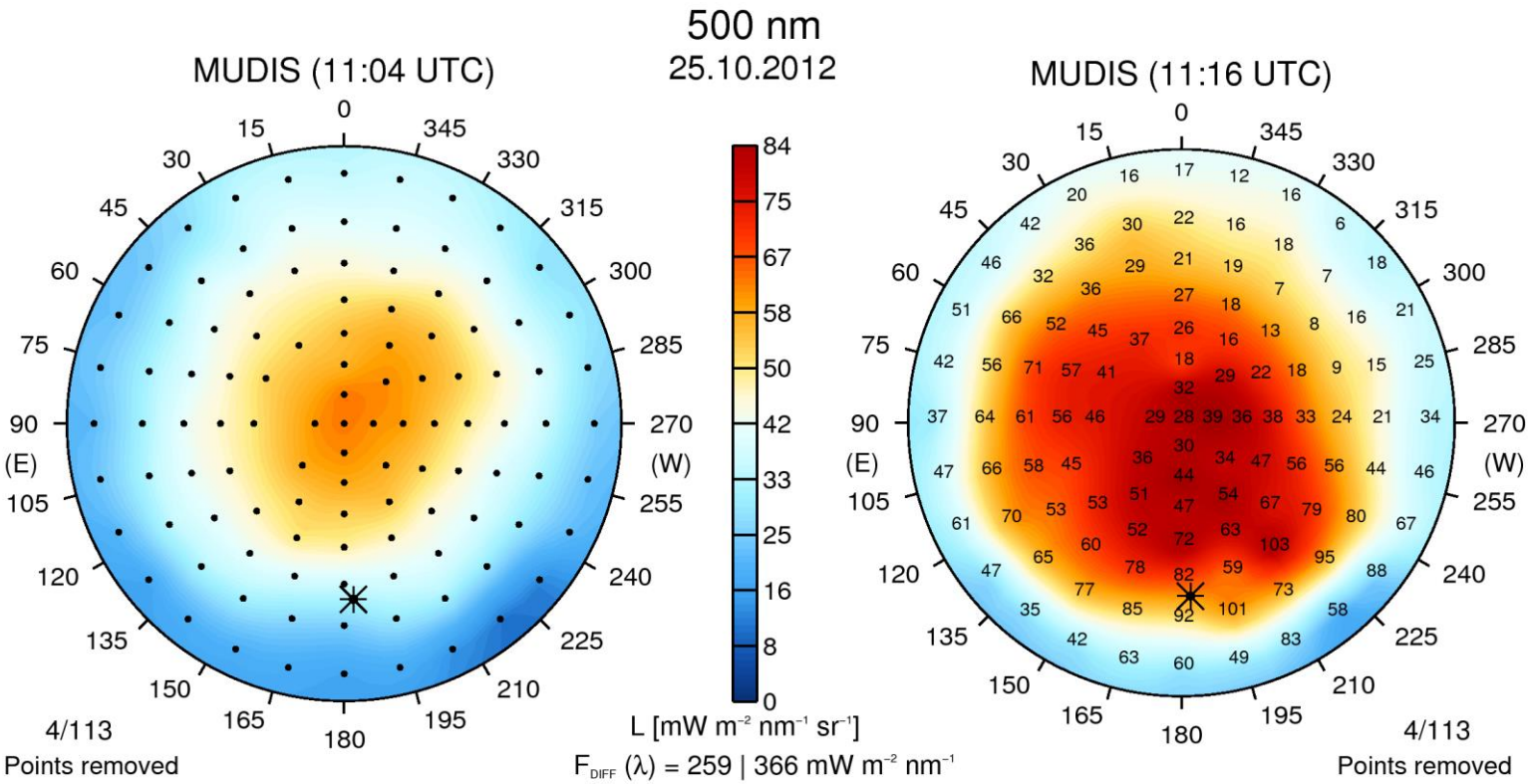


Figure 7


320 nm
25.10.2012
11:04 UTC (SZA: 64.65°)
MUDIS
SCCD
4/113
Points removed
0/113
Points removed
L [mW m⁻² nm⁻¹ sr⁻¹]
F_DIFF (λ) = 79 | 82 mW m⁻² nm⁻¹

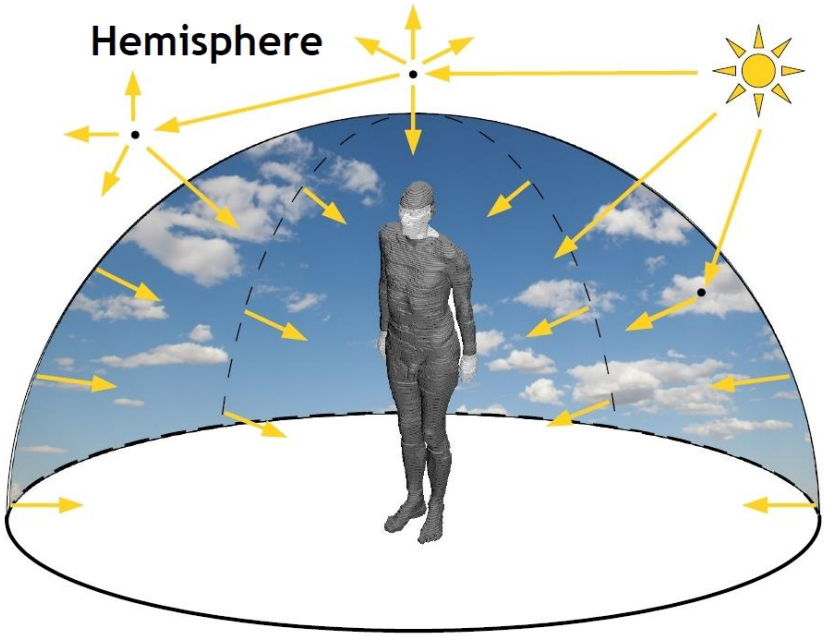

500 nm
25.10.2012
11:04 UTC (SZA: 64.65°)
MUDIS
SCCD
4/113
Points removed
0/113
Points removed
L [mW m⁻² nm⁻¹ sr⁻¹]
F_DIFF (λ) = 361 | 363 mW m⁻² nm⁻¹

Capable of measuring rapid changes



Riechelmann *et al.* 2013, *Measurement Science and Technology*

UV-Exposure of a human



necessary input for the calculation of the exposure:

- Spectral radiance
- Human geometry (projection areas)

$$Ex = \int \ldots$$

Calculation

Vitamin D_3 Exposure

Formula for Exposure Calculations

Definition of Radiance

$$L_\lambda = \frac{d^2\Phi_\lambda}{d\Omega \cdot dA \cdot \cos\varepsilon}$$

$d\Phi$ = radiant energy
$d\Omega$ = solid angle
dA = area element
$d\varepsilon$ = incident angle

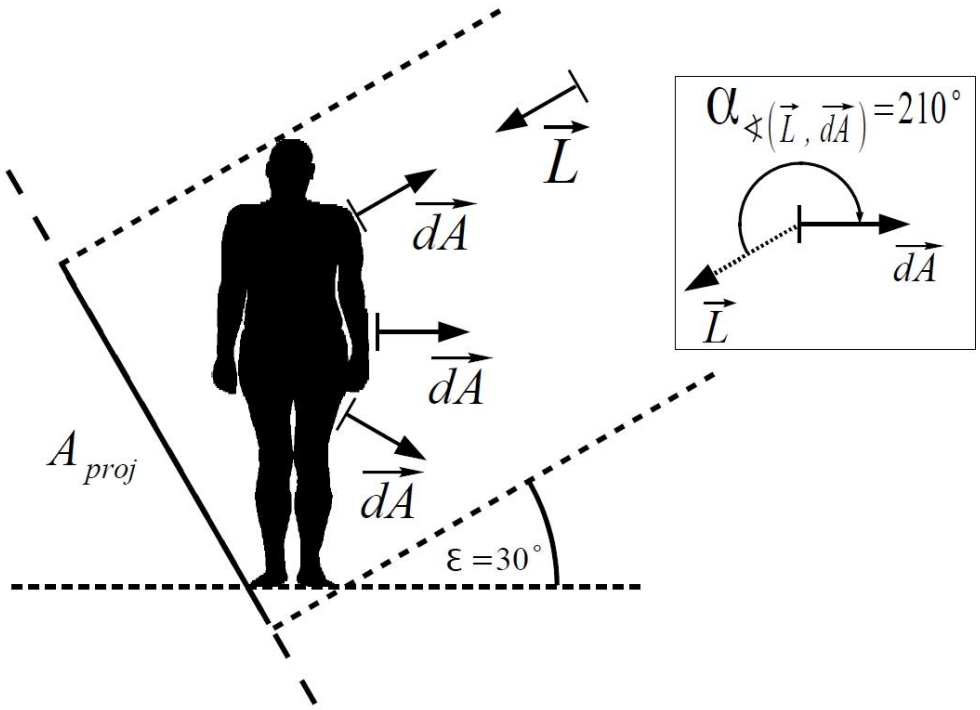
the Exposure E_x is calculated by integrating the weighted radiance over all solid angles $d\Omega$ and all area elements dA and the exposure time

$$Ex = \int_{\lambda}^{\lambda} \int_{t_1}^{t_2} \int_{\Omega} \int_{A(\varepsilon,\varphi)} L_\lambda(\varepsilon, \varphi, t, \lambda) \cdot S(\lambda) \cdot \cos\alpha \cdot dA \cdot d\Omega \cdot dt \cdot d\lambda$$

S = biological action spectrum
α = angle between area normal and radiance

Formula for Exposure Calculations

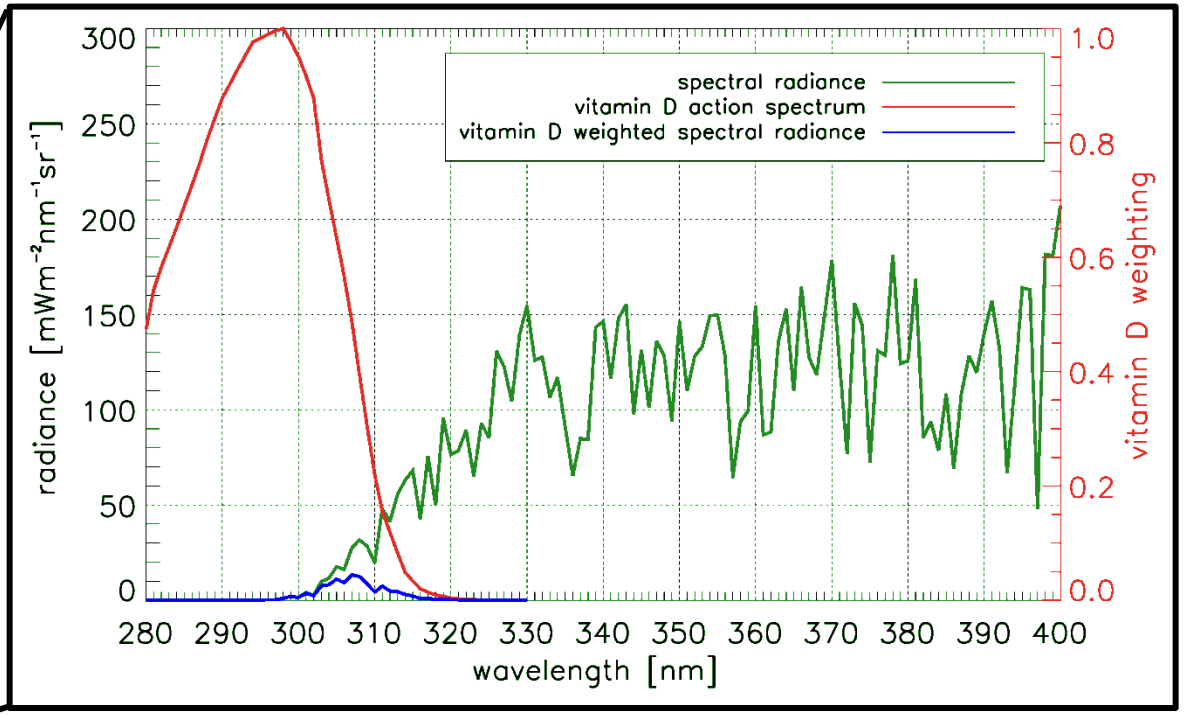
$$Ex = \int_{\lambda}^{\lambda} \int_{t_1}^{t_2} \int_{\Omega} \int_{A(\varepsilon,\varphi)} L_\lambda(\varepsilon,\varphi,t,\lambda) \cdot S(\lambda) \cdot \cos\alpha \cdot dA \cdot d\Omega \cdot dt \cdot d\lambda$$



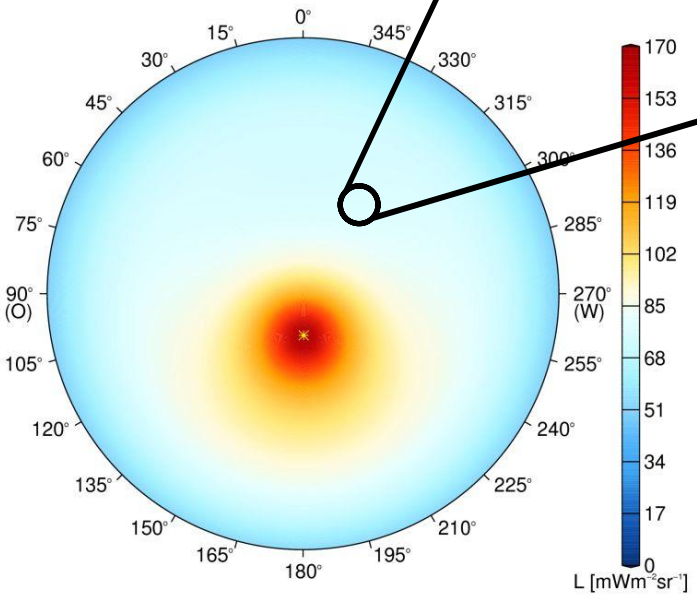
The Vitamin D weighted Exposure Ex_{vitD} *may* be calculated by:

$$Ex_{vit\,D} = \int_{\lambda}^{\lambda} \int_{t_1}^{t_2} \left(\int_{\Omega} L_\lambda(\varepsilon,\varphi,t,\lambda) \cdot S_{vit\,D}(\lambda) \cdot \underbrace{\left(\int_{A} dA \cdot \cos\alpha \right)}_{A_{proj}(\varepsilon,\varphi)} \cdot d\Omega \right) dt\, d\lambda$$

Vitamin D weighted UV-Exposure

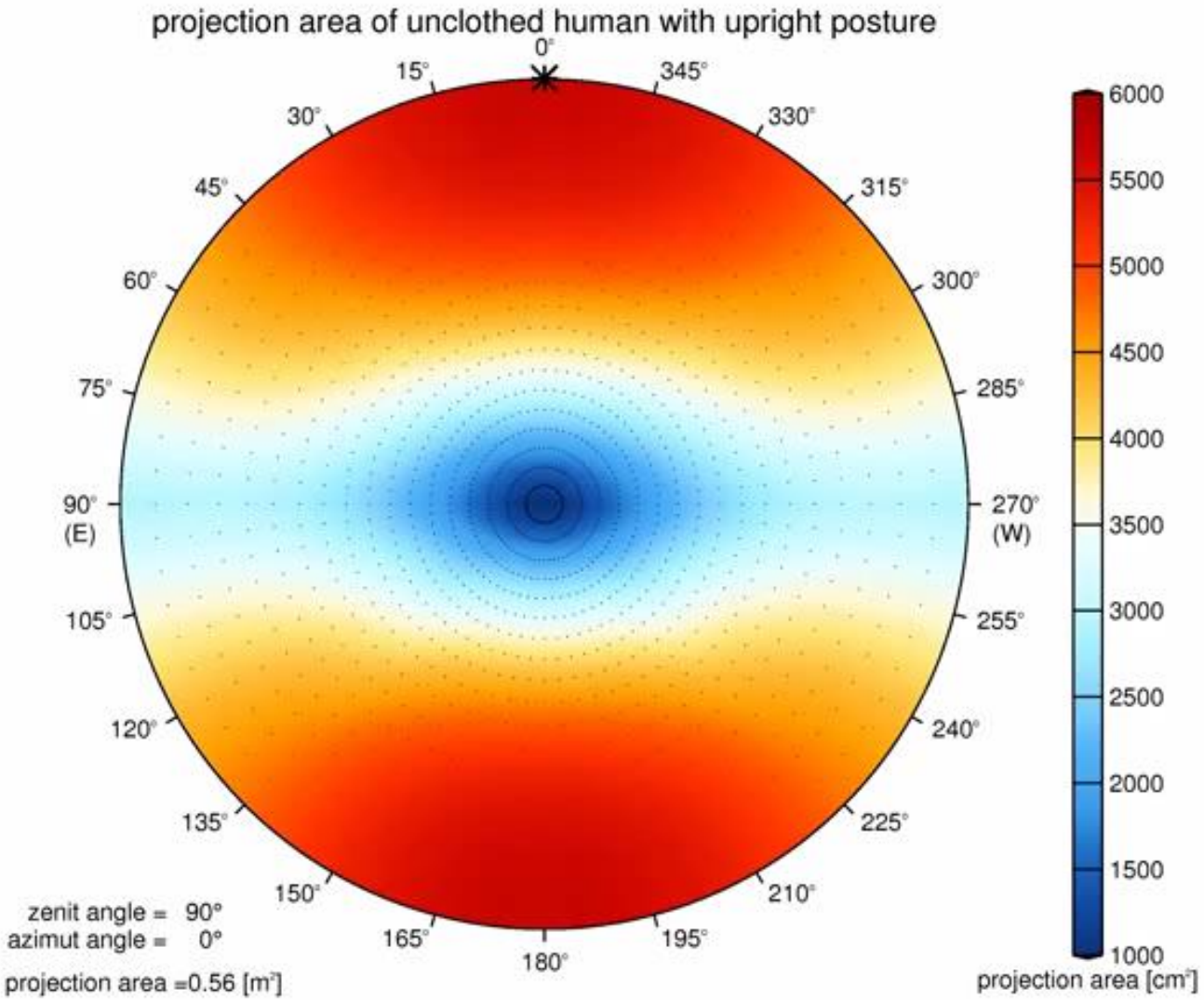


Vitamin D weighted spectral radiance



Weighting of radiance spectrum with vitamin D action spectrum

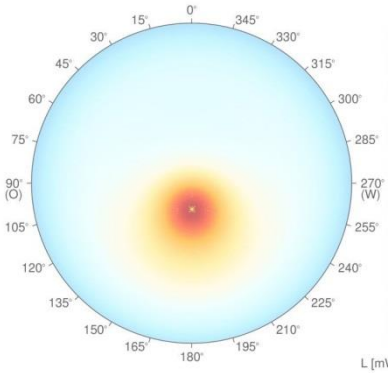
Projection area

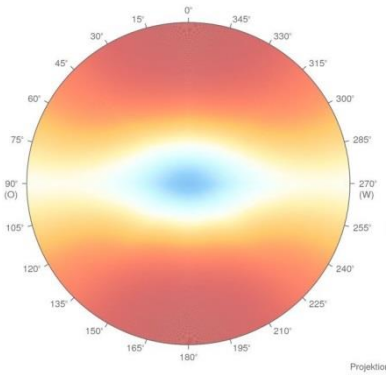


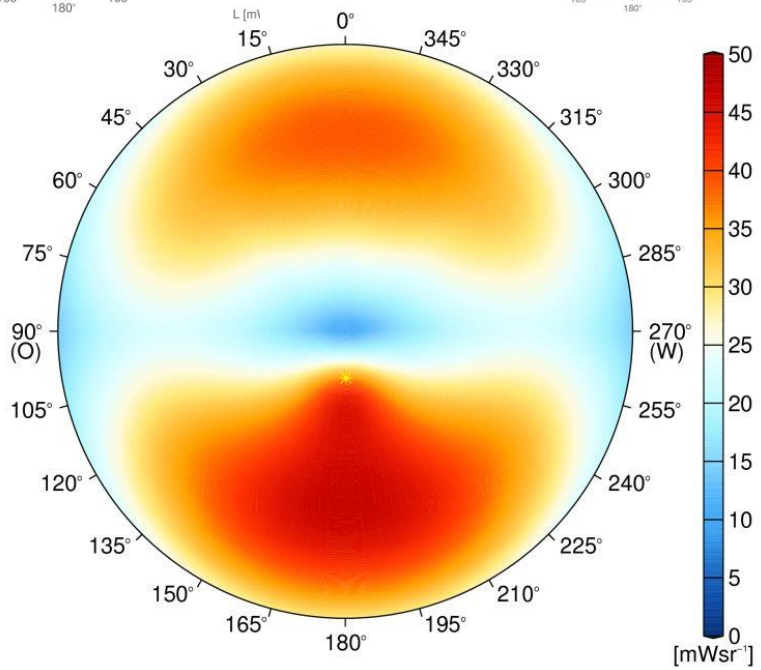
Vitamin D weighted UV-Exposure

Vitamin D weighted radiance

projection area of unclothed model with







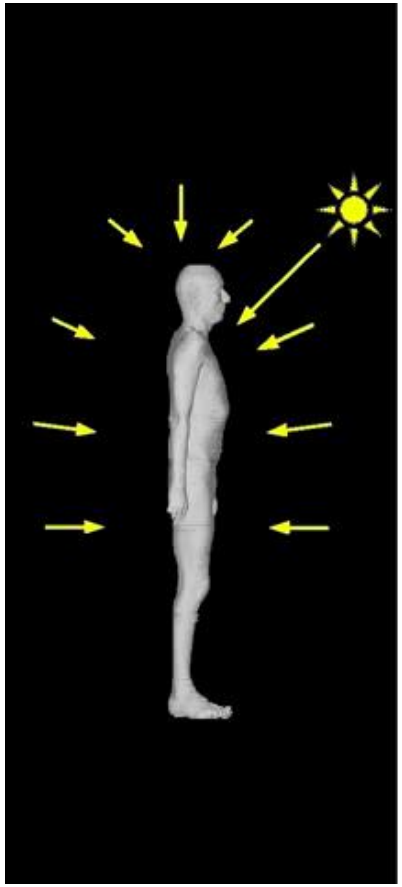
Exposure for:

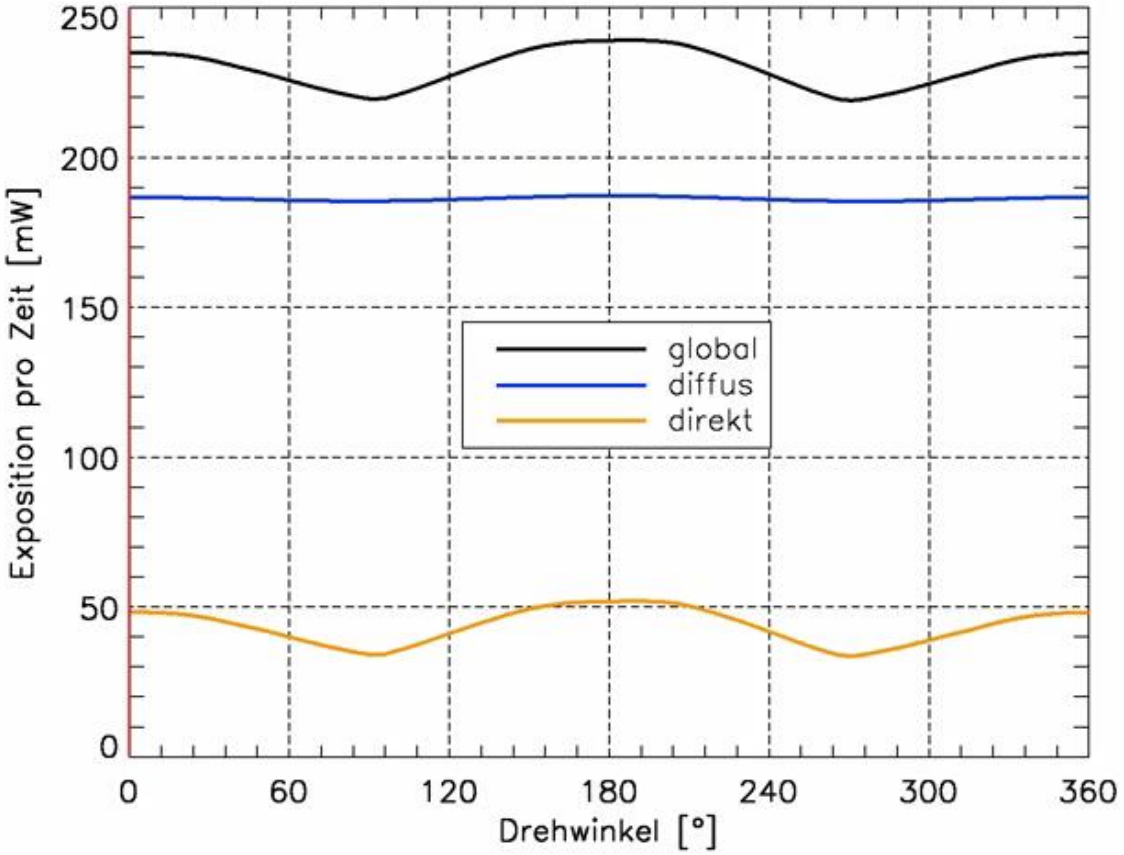
- June 21st at noon
- in Rome
- for clearsky
- (UV Index 10)

Vitamin D weighted radiance weighted with the geometry of an human

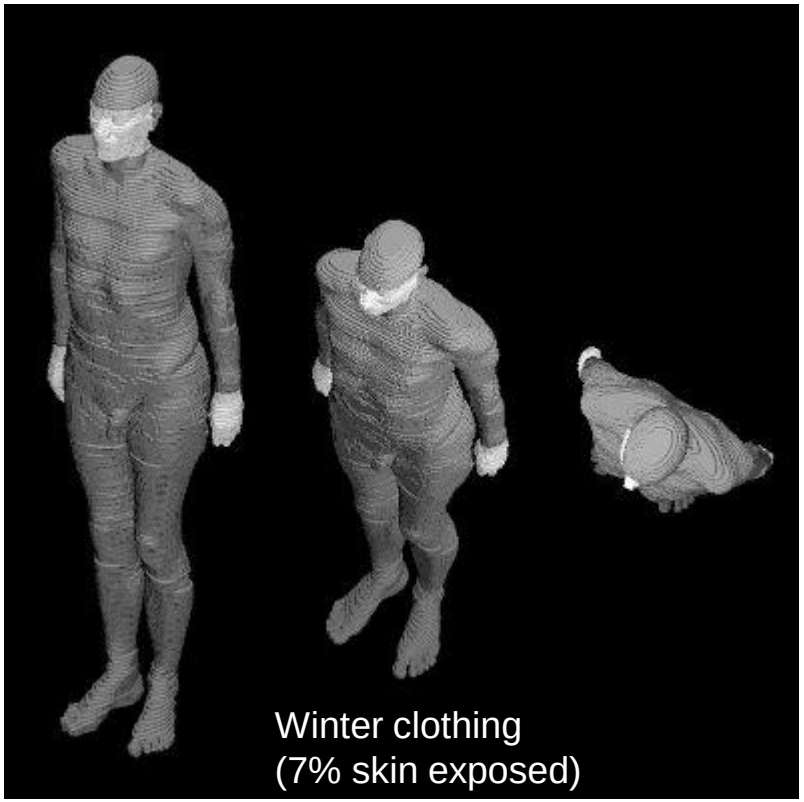
Dependency of Orientation

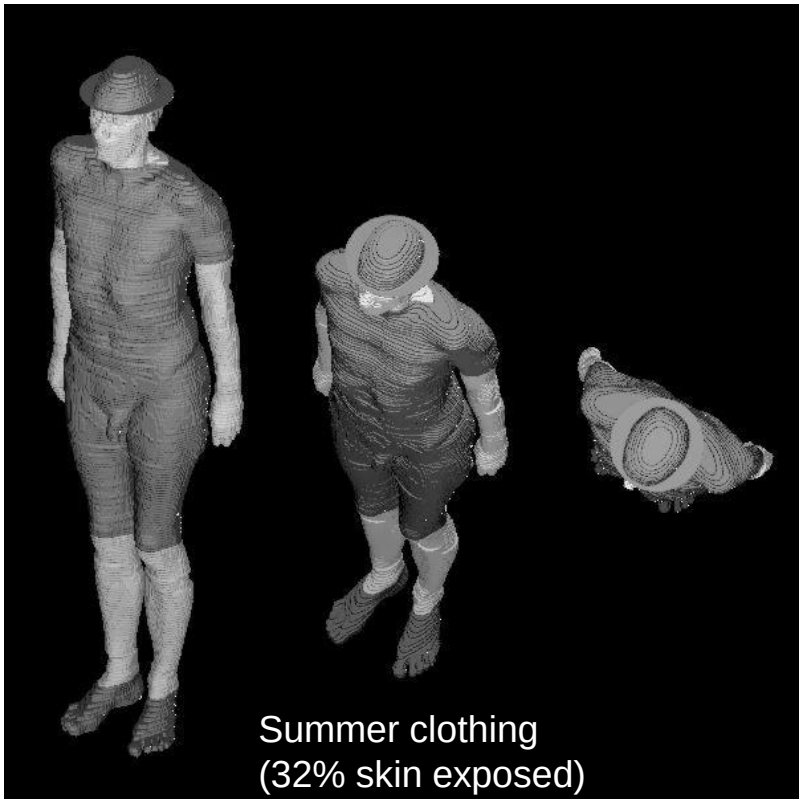
- Exposure as a function of azimuthal rotation angle for 21 June (clear sky)
- The values for the “global” component varies by less than 4%.





Model human with clothing



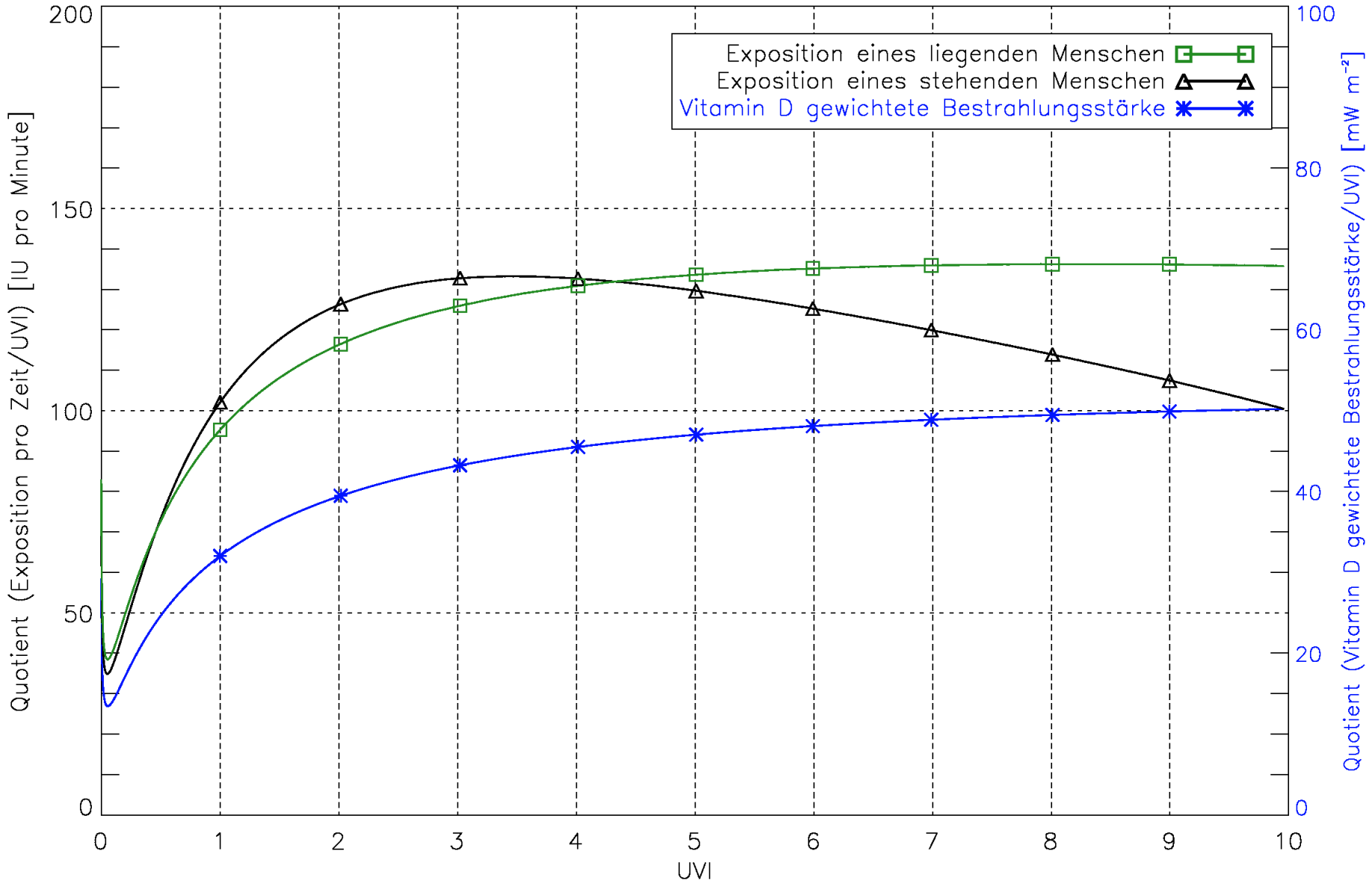


projections of the model for incident angles 30°, 60° and 90° with the front turned by 30° in azimuth.

Exposure Times

Rom	Han.	Han.	Han.	Han.	Han.	Han.
21.June. Clear Sky	21.June. Clear Sky	21.June Overcast	21. March Clear Sky	21. March Overcast	21.Dec Clear Sky	21. Dec Overcast
UVI						
10	8	1	3	0,5	0,4	0,04
Unclothed, upright posture						
1,0 min	1,1 min	6,6 min	2,3 min	19 min	39 min	2,1 d
Unclothed, horizontal posture						
0,7 min	0,9 min	5,8 min	2,4 min	16 min	38 min	1,9 d
Winter clothing, upright posture						
17 min	18 min	1,9 h	37 min	9,6 h	3,0 d	35 d

Radiance versus Irradiance



Summary

- Newly developed Instrument: multidirectional spectroradiometer (MUDIS)
  - simultaneous measurement of spectral radiance
  - more than 100 directions
  - high temporal and spectral resolution
  - good agreement with scanning array spectroradiometer

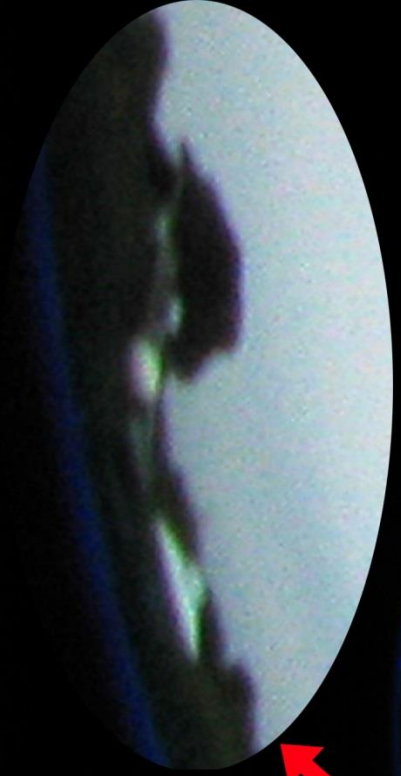
- Novel method to calculate vitamin D weighted exposure of a human
  - complex geometry of a human
  - clothing
  - geometry of the radiation field (spectral radiance)
  - Integration using projection areas

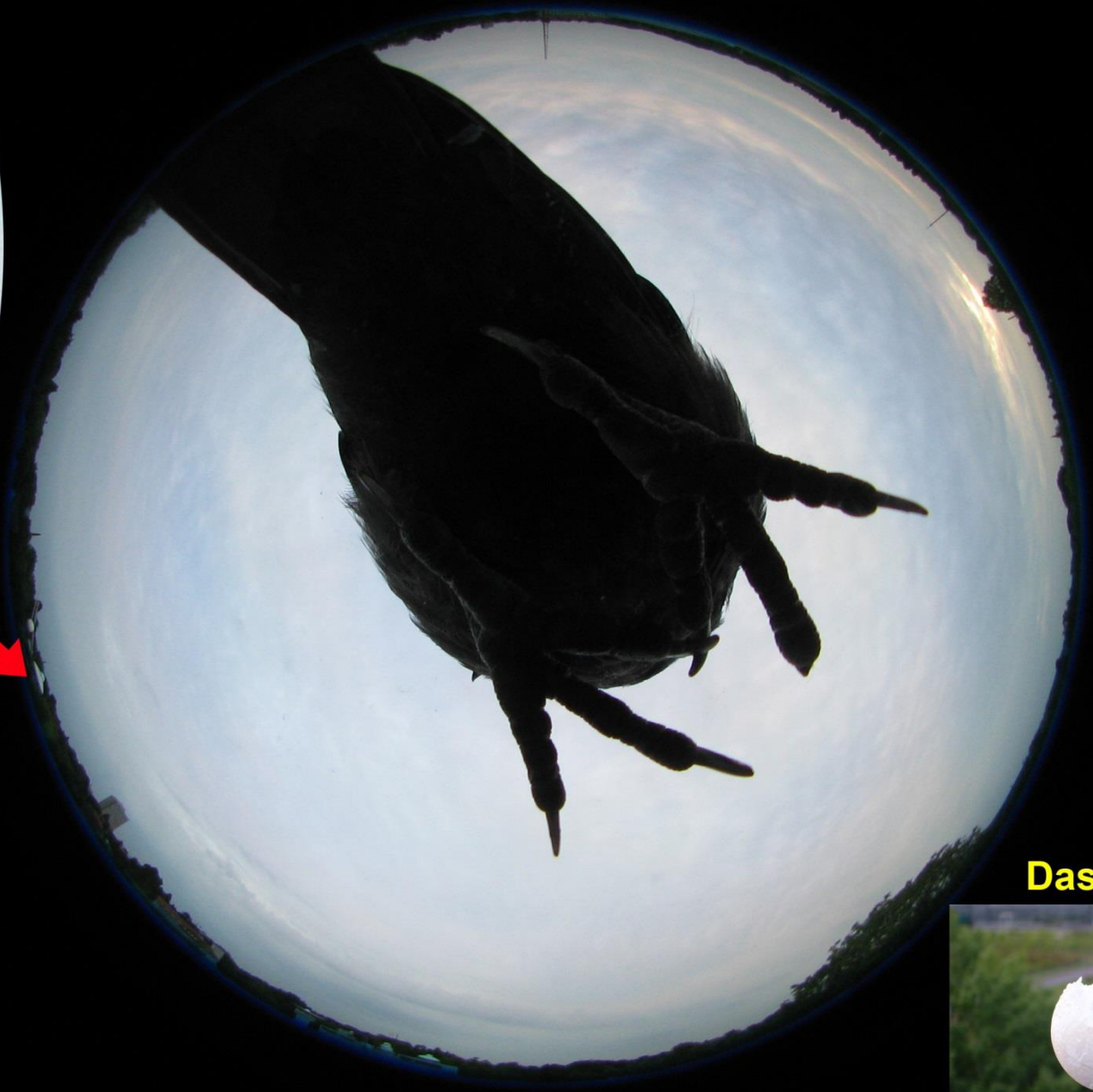
- Weighted diffuse radiance accounts for more than 80% to the total exposure

- On 21 December and overcast sky, sufficient vitamin D cannot be obtained

- The UV index is not a good indicator for the Vitamin D exposure of humans

21.06.2009 21:00 MESZ





Das Ergebnis

Auf frischer Tat ertappt...

Impact on humans

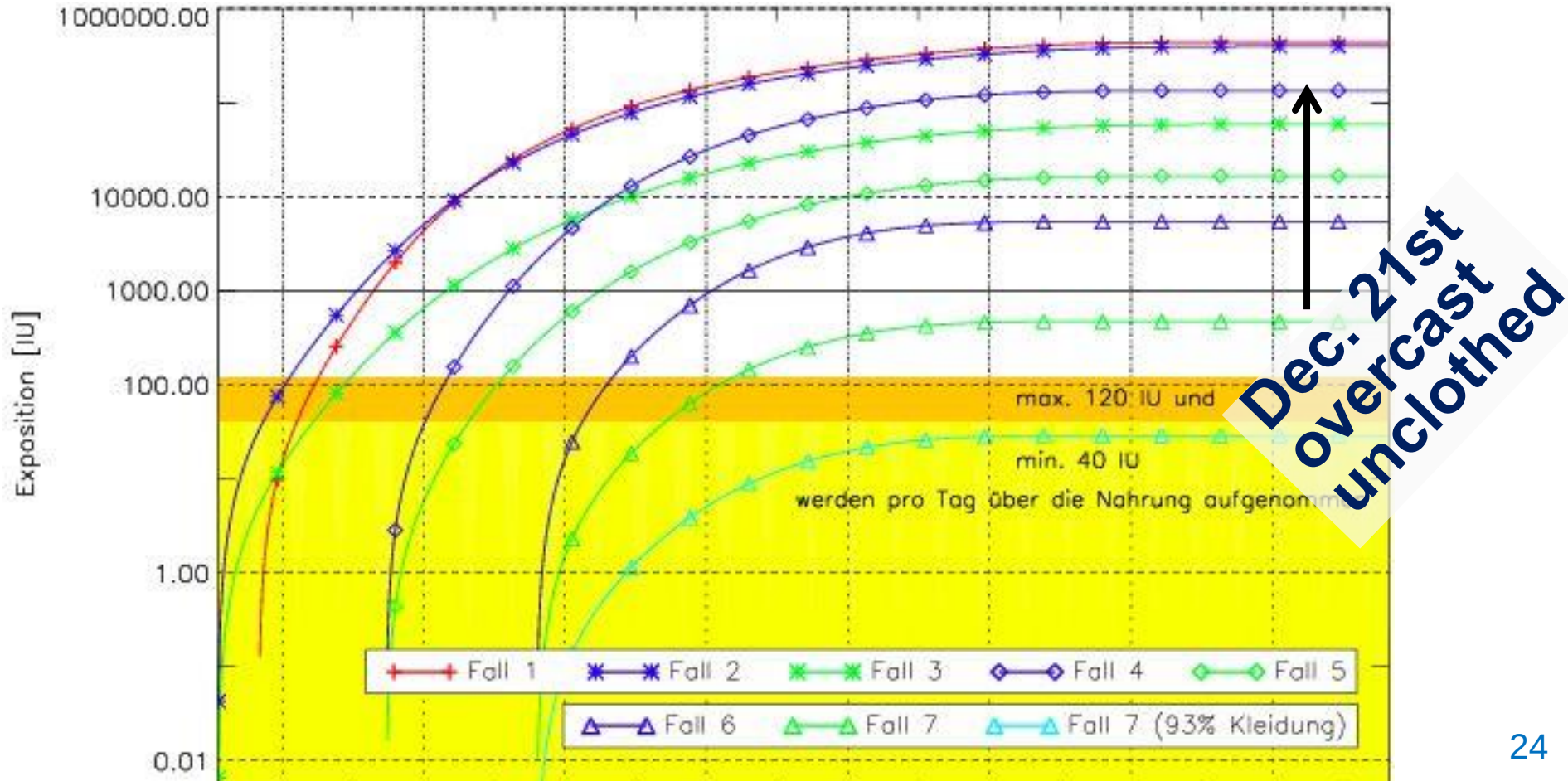
Negative effects of **UV-Radiation**

- Sunburn (Erythema)
- Skin aging
- Skin cancer
- Immunosuppression
- Eye deseases
- Photodermatitis

Positive effects of **UV-Radiation**

- Vitamin-D-Synthesis
- improvement for some skin diseases

Diurnal variation of UV Exposure



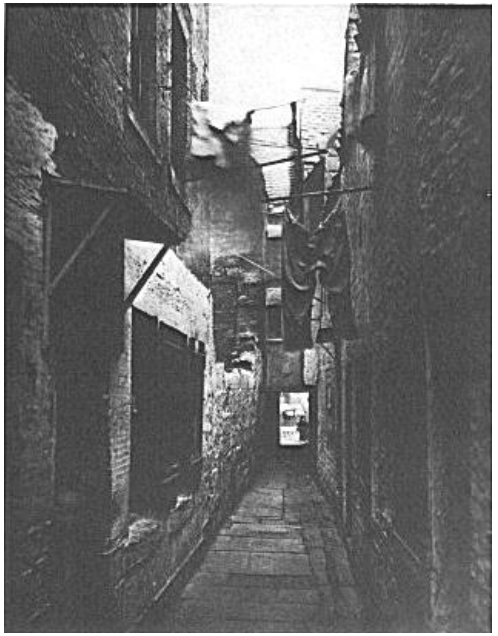
Vitamin D **synthesized by UV**

- well-known effects necessary for calcium metabolism

  deficiency >> Rickets, Osteoporosis)

  improves bone health, immune function

In addition a poor Vitamin D is linked with:



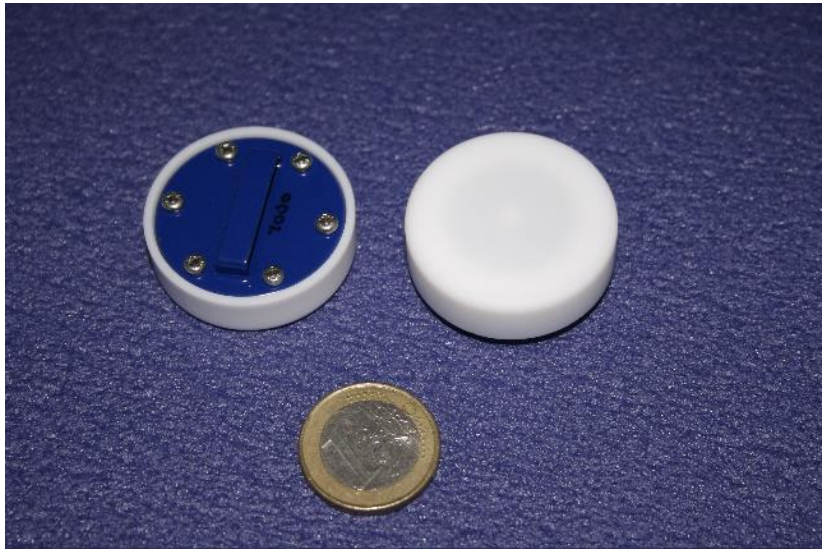
- breast cancer
- prostate cancer
- colon cancer
- Diabetes mellitus
- Cardiovascular deseases
- high blood pressure
- Multiple sclerosis
- …

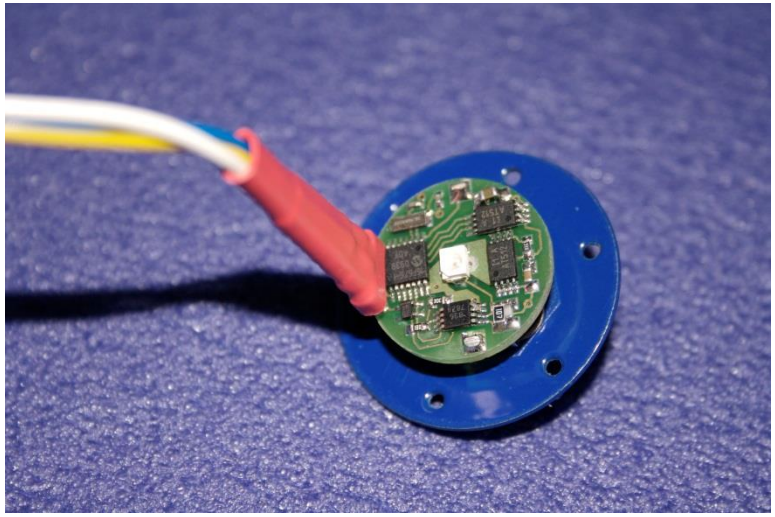
  Food contains insufficient Vitamin D

Possible application for the new MUDIS instrument:

- Vitamin D weighted Exposure
- Solar Energy Applications
- Derivation of trace gases by DOAS techniques
- Aging of materials (e.g. on facades)
- Radiance and plant growth

Small UV Dosimeters





Dosimeter Presentation Rome 2012

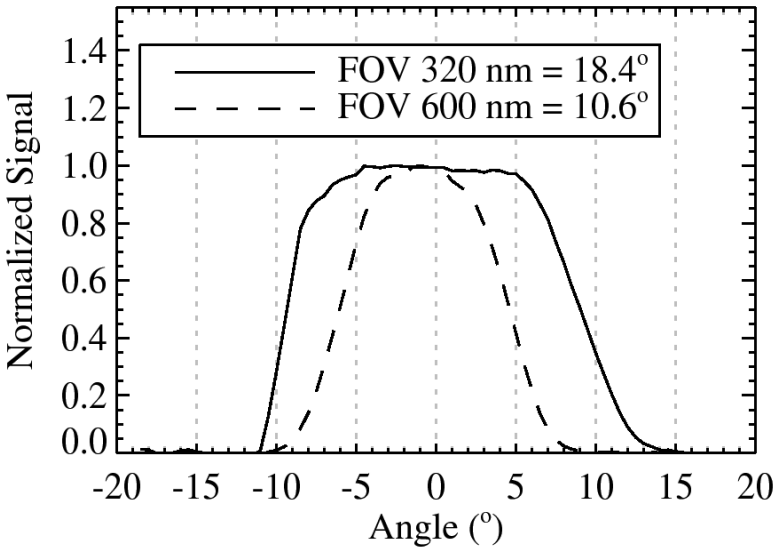
Sonne ist wichtig,

nur zu viel ist schädlich.

„Allein die Dosis macht, dass ein Ding kein Gift ist."

(Paracelsus)

Figure 2


FOV 320 nm = 18.4°
FOV 600 nm = 10.6°
Normalized Signal
Angle (°)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-20
-15
-10
-5
0
5
10
15
20

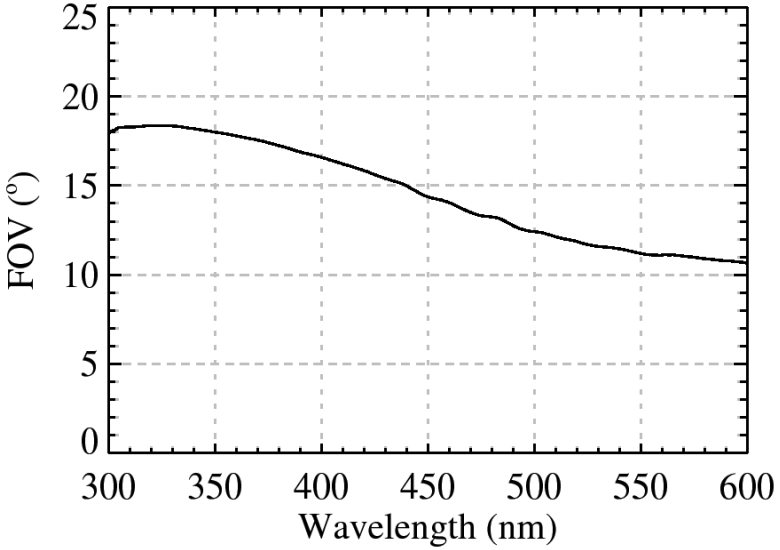
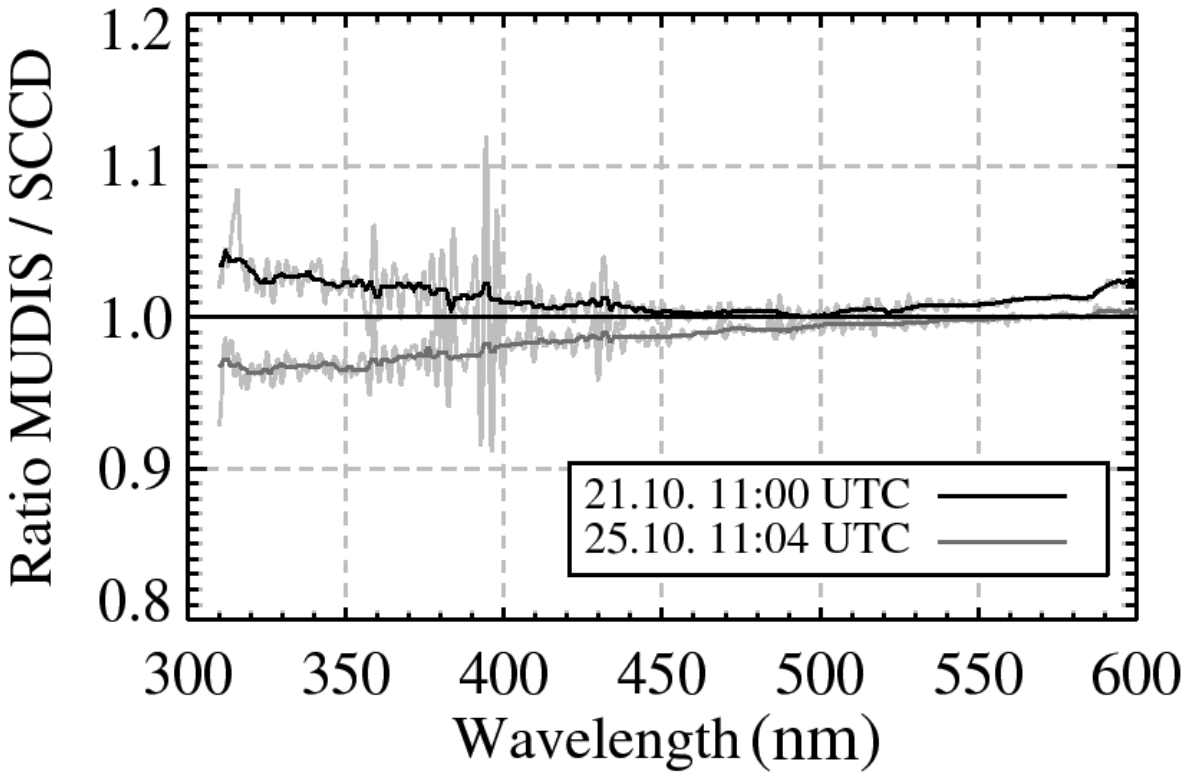

FOV (°)
Wavelength (nm)
25
20
15
10
5
0
300
350
400
450
500
550
600

Figure 4


Ratio MUDIS / SCCD
1.2
1.1
1.0
0.9
0.8
300
350
400
450
500
550
600
Wavelength (nm)
21.10. 11:00 UTC
25.10. 11:04 UTC

Definition of the weighted exposure

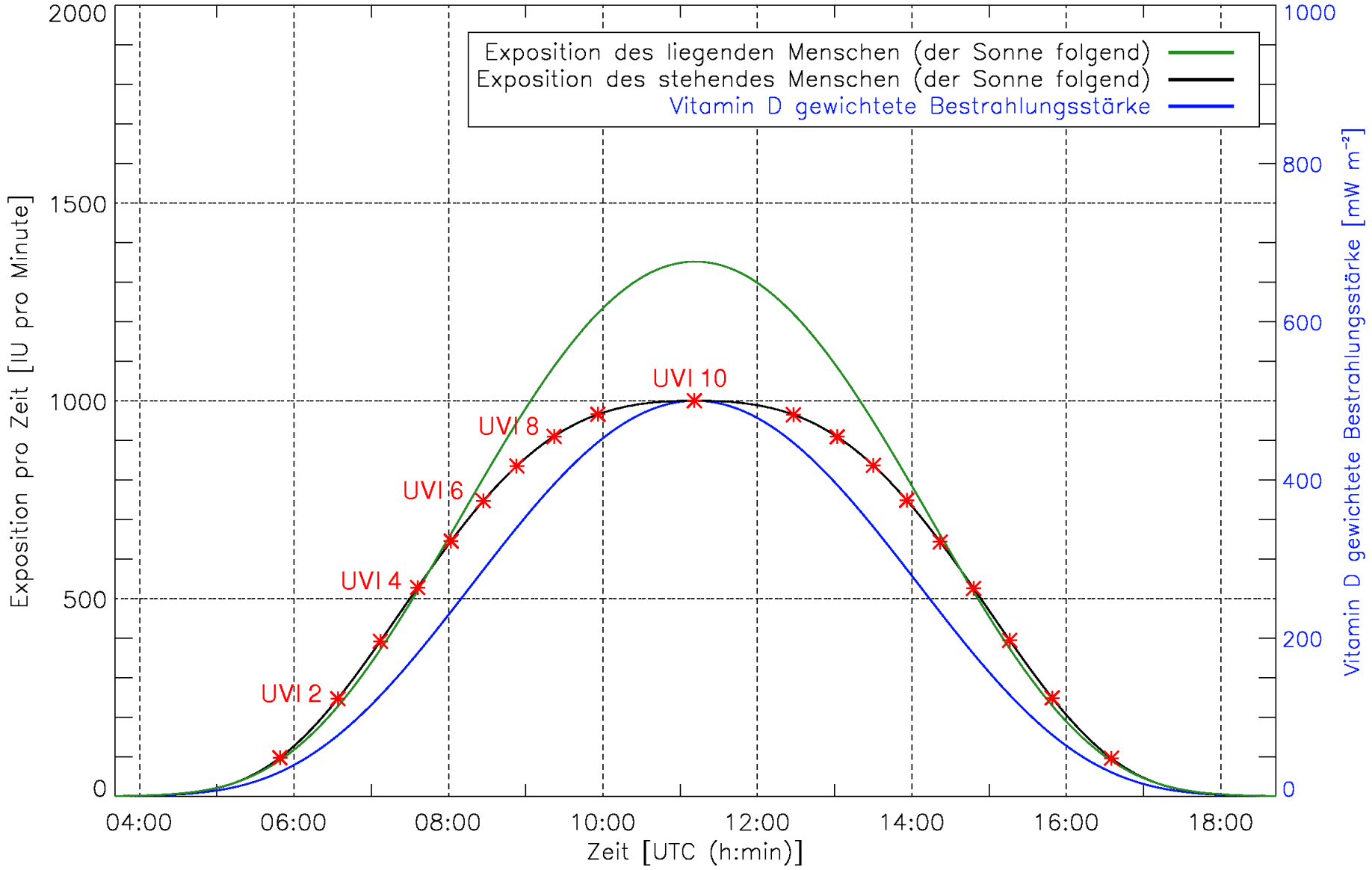
The spectral exposure may be weighted with a biological action spectrum integrated over all relevant wavelengths to assess its biological impact. In this case the exposure is no longer a function of the wavelength and has the unit J.

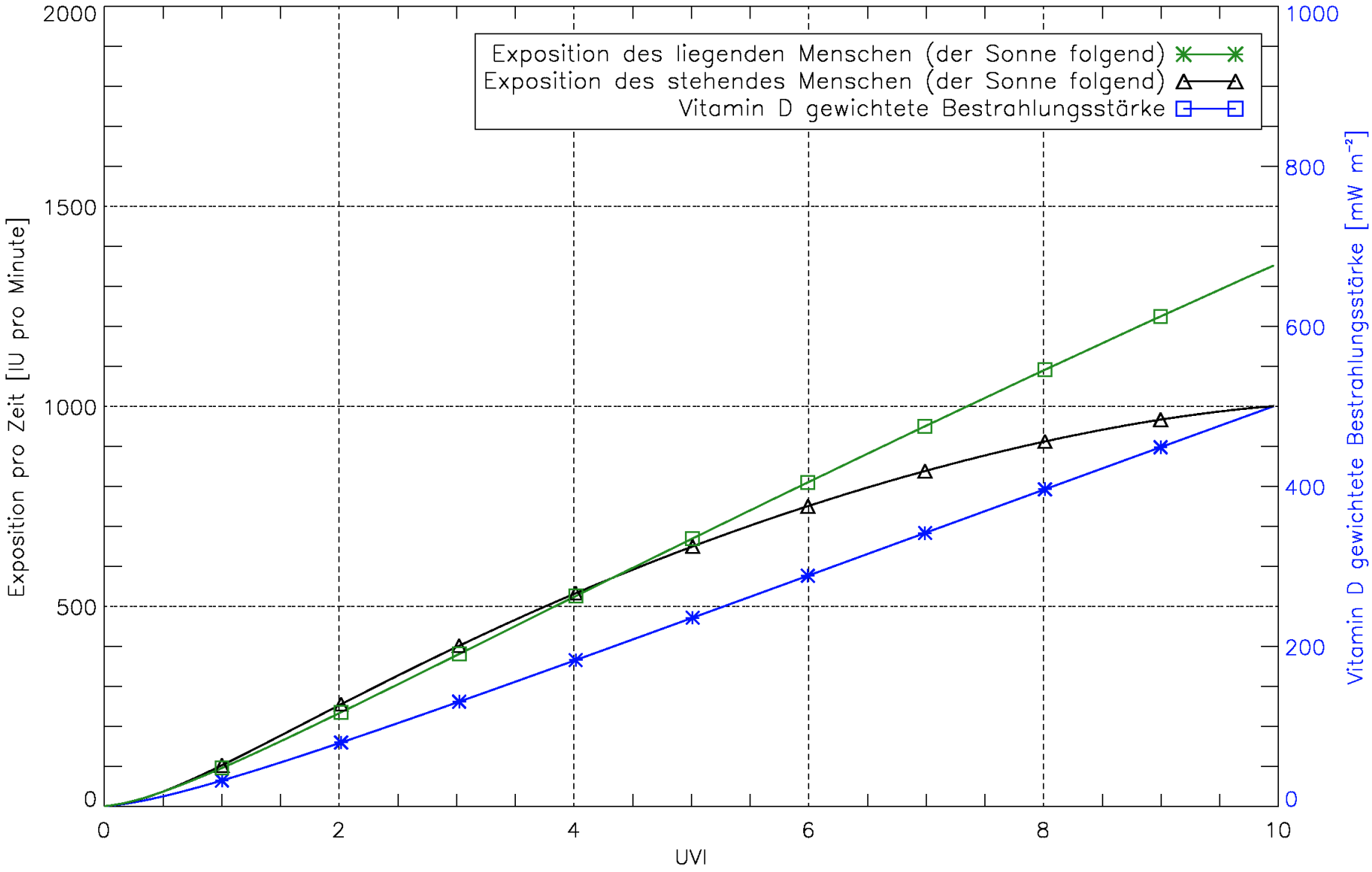
If different areas of the human body have the different biological weightings the weighted exposure Ex_{wei} can be calculated by the following formula:

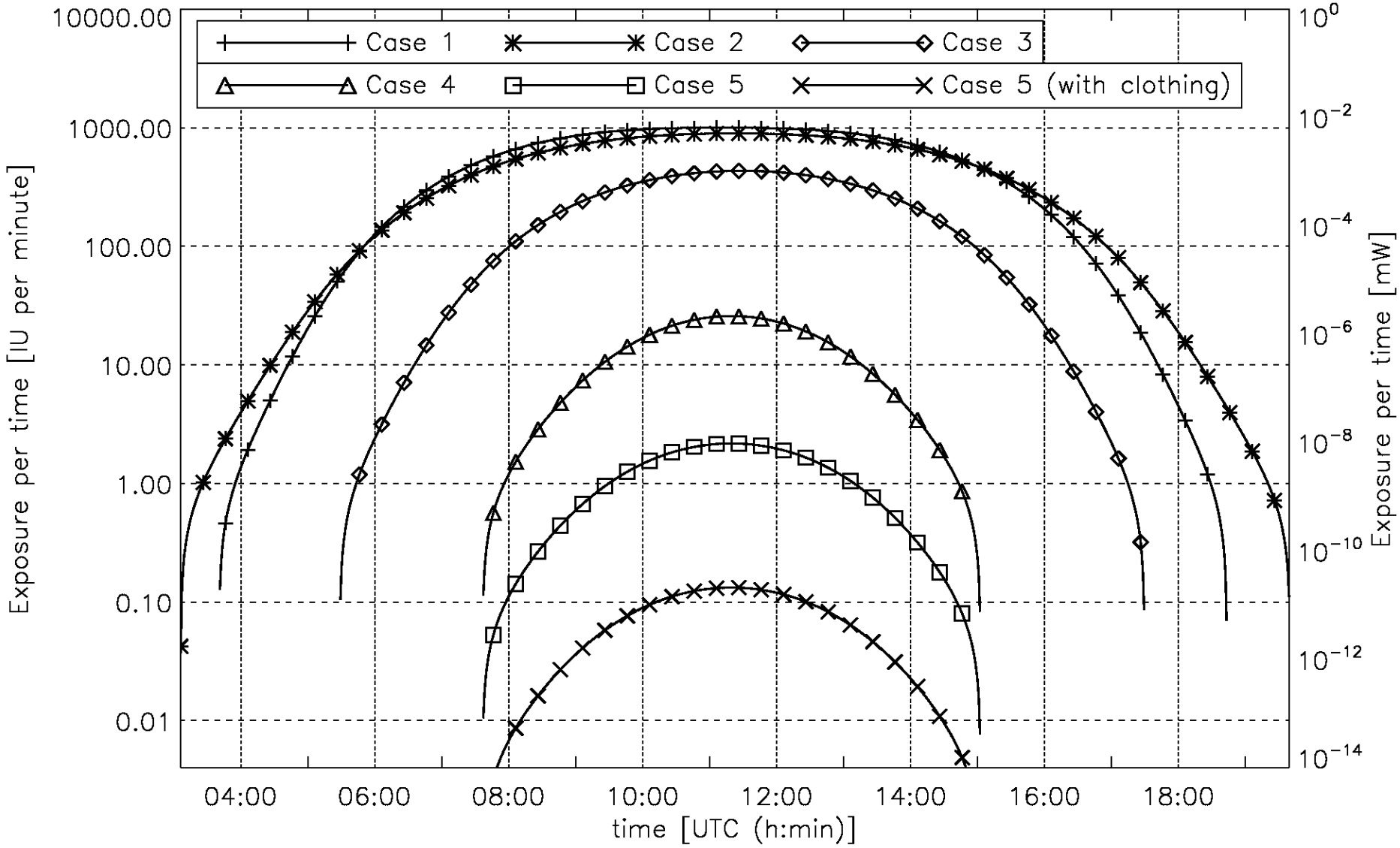
$$Ex_{wei} = \int_{\lambda_1}^{\lambda_2}\int_{t_1}^{t_2}\left(\int_{-\pi/2}^{\pi/2}\int_{0}^{2\pi}\left(\oint_{(A(\varepsilon,\varphi))} L_\lambda(\varepsilon,\varphi,t,\lambda)\cdot dA\cdot C(\lambda,dA)\cdot\cos(\varepsilon)\right)\sin(\varepsilon)\,d\varepsilon\,d\varphi\right)dt\cdot d\lambda$$

where t1 is the start of the exposure and t2 the end of the exposure

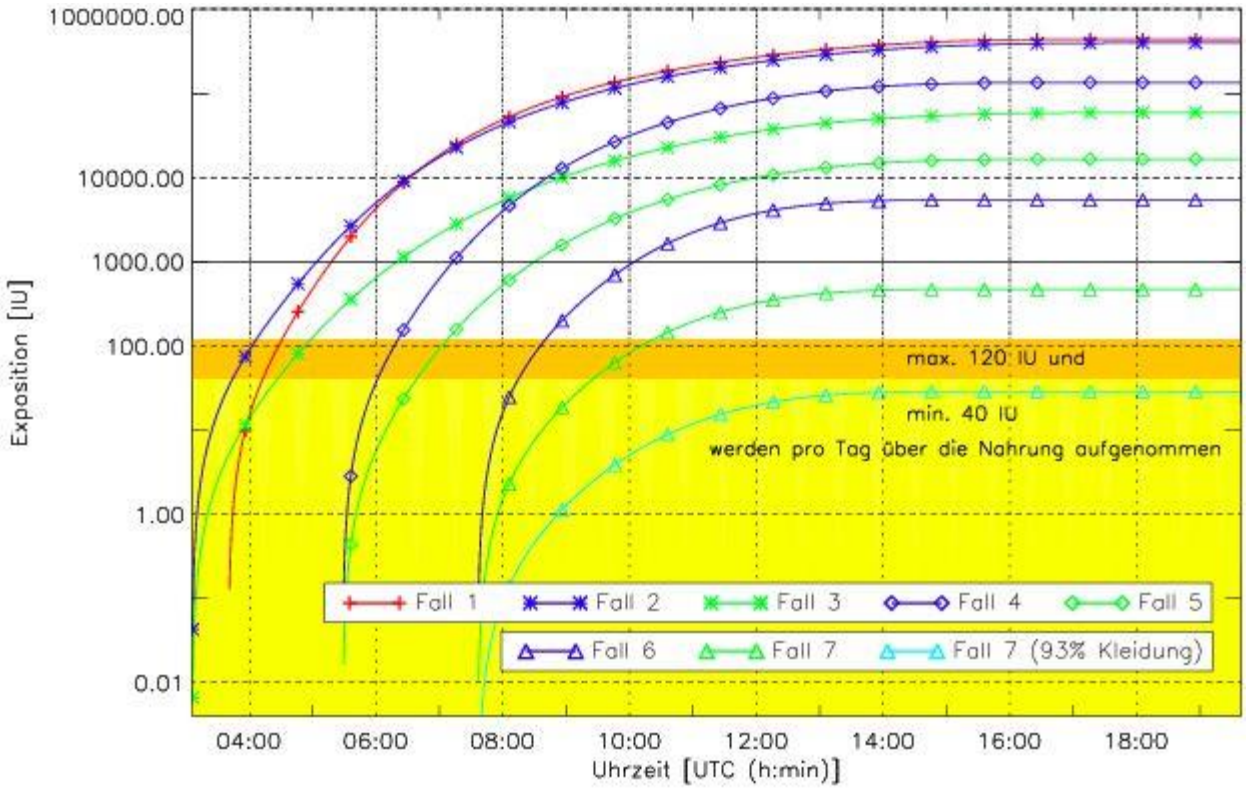
4. Vergleich von Exposition und Bestrahlungsstärke




Exposition des liegenden Menschen (der Sonne folgend)
Exposition des stehendes Menschen (der Sonne folgend)
Vitamin D gewichtete Bestrahlungsstärke
Exposition pro Zeit [IU pro Minute]
Vitamin D gewichtete Bestrahlungsstärke [mW m⁻²]
UVI
0
500
1000
1500
2000
200
400
600
800
1000
2
4
6
8
10


Case 1
Case 2
Case 3
Case 4
Case 5
Case 5 (with clothing)
10000.00
1000.00
100.00
10.00
1.00
0.10
0.01
Exposure per time [IU per minute]
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-14}
Exposure per time [mW]
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
time [UTC (h:min)]

Tagesgang der UV Exposition

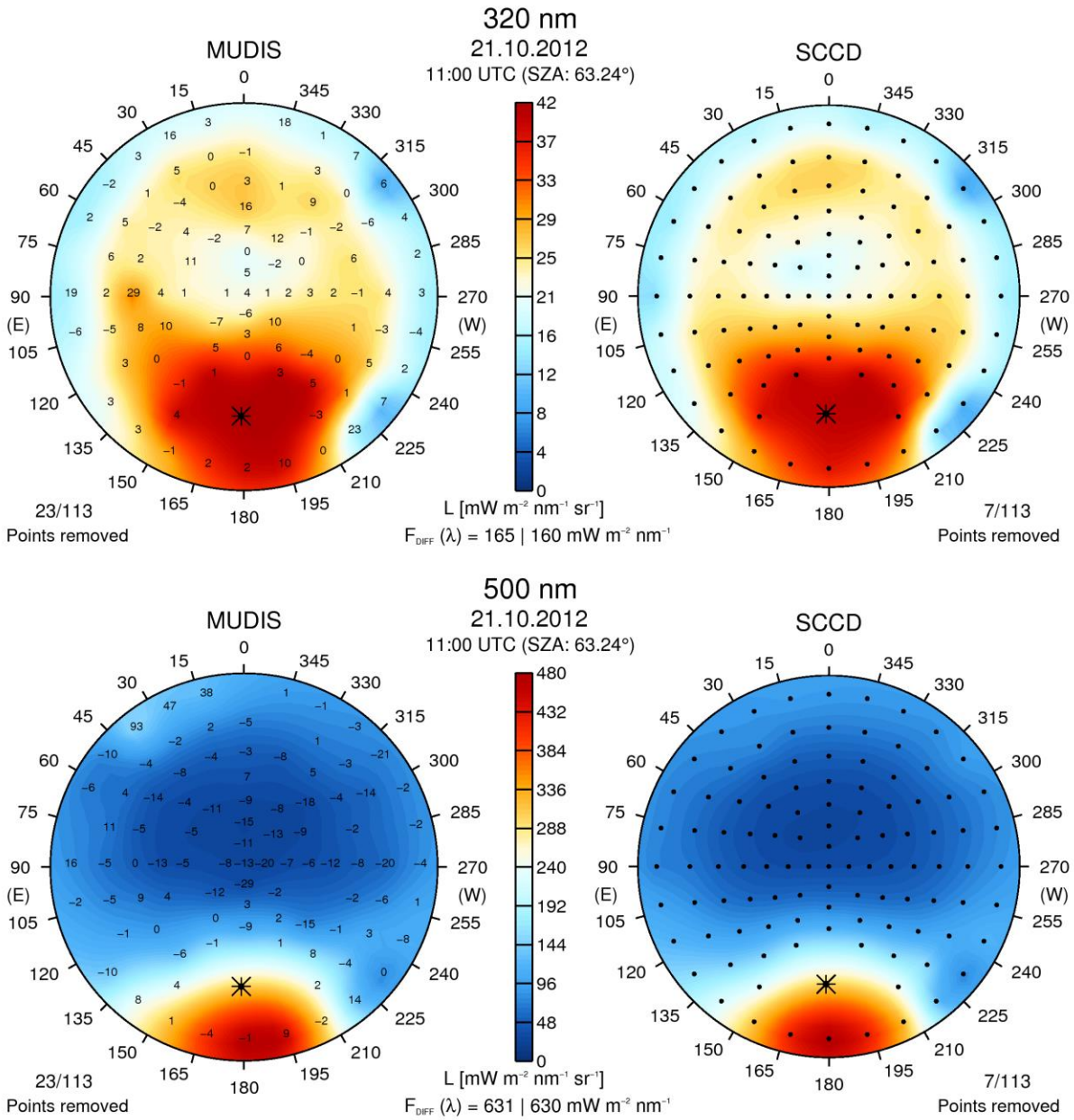
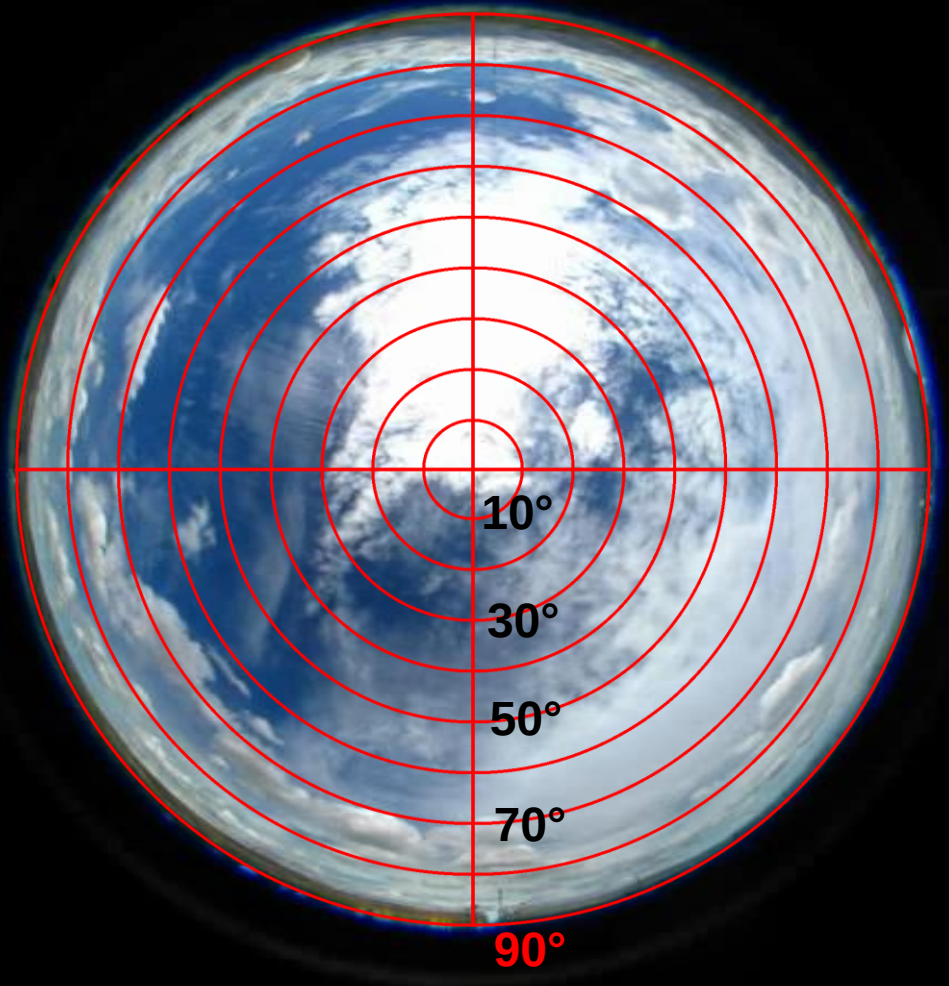


ungskomponente nicht nötig

21. Dezember, bewölkt, Winterkleidung (Fall 7, 93% Kleidung): weniger Vitamin D als durch Nahrung

Vitamin D_3 Nahrungsergänzung vor allem für die Wintermonate sinnvoll.
→ müsste noch besser angepasst werden

Figure 6


320 nm
21.10.2012
11:00 UTC (SZA: 63.24°)
MUDIS
SCCD
23/113
Points removed
7/113
Points removed
L [mW m⁻² nm⁻¹ sr⁻¹]
F_DIFF (λ) = 165 | 160 mW m⁻² nm⁻¹
500 nm
21.10.2012
11:00 UTC (SZA: 63.24°)
MUDIS
SCCD
23/113
Points removed
7/113
Points removed
L [mW m⁻² nm⁻¹ sr⁻¹]
F_DIFF (λ) = 631 | 630 mW m⁻² nm⁻¹

2012-02-05 14:12:53 NZST NIWA, NewZealand (University of Hannover)