No: 103 July 1998

OBSERVATIONS OF SPECTRAL SKY RADIANCE AND SOLAR IRRADIANCE

Jo Høkedal
Eyvind Aas

INSTITUTT FOR GEOFYSIKK

UNIVERSITETET I OSLO

UNIVERSITAS OSLOENSIS

INSTITUTE REPORT SERIES

e s trykk-Oslo

No: 103 July 1998

OBSERVATIONS OF SPECTRAL SKY RADIANCE AND SOLAR IRRADIANCE

Jo Høkedal
Eyvind Aas

Abstract

Ninety observation series of solar irradiance and angular distributions of sky radiance at different sun angles and wavelengths from ultraviolet to red are presented in tabular form. The observed distributions of spectral sky radiance do not compare well with the algorithm for clear sky luminance proposed by CIE. From the observations of polarized radiance it is found that polarization has little effect on the irradiance reflectance of the sea surface.

Department of Geophysics
University of Oslo
POB 1022 Blindern
N-0315 Oslo
Norway

1. Introduction

Examples of the angular distribution of atmospheric spectral radiance were needed as an input to our studies, and we wanted the examples to represent possible conditions at sea level in the Oslofjord. Because only a few such recordings had been made earlier within the area, additional measurements were made as a part of a project supported by the Norwegian Research Council. This paper presents these observations. The altitude of the sun in Oslo never exceeds 53.5°, and to obtain a more complete set of possible radiance distributions similar observations from latitudes with a higher sun have been included. A few recordings of sky polarization are also presented. The errors induced when polarization is neglected in reflectance calculations for the sea surface are estimated from these examples.

Several authors have discussed the angular distribution of sky radiance and its description by analytic functions (e.g. Pokrowski, 1929; Steven, 1977; Hooper and Brunger, 1980; Hooper et al., 1987; Harrison and Coombes, 1988; Zibordi and Voss, 1989; Siala et al., 1990; Harrison, 1991; Rosen, 1991; Perez et al., 1992; Perez et al., 1993; Littlefair, 1994). In this paper we have compared the observed distribution of radiance at 405, 550 and 650 nm with the algorithm for clear sky luminance proposed by the Commission Internationale de L'Eclairage - CIE (as quoted by e.g. Jeske, 1988).

2. Material and methods

2.1. Observations

Some recordings of sky radiance (26 series) were made on the coasts of Gran Canary (27.8°N) and Crete (35.3°N) in 1985 and 1994, respectively, but the majority of the data (64 series) were collected in Oslo (60.0°N) during 1985 and 1996-97. Table 1 presents a list of the different series of measurement with the corresponding solar zenith angles and wavelengths. For five of the series in 1997 the degree of polarization was also recorded.

2.2. Instrument

The radiance meter consists of a Gershun tube and a silicon detector S351A with radiometric filter from United Detector Technology, California. The instrument has been calibrated with regard to linearity, opening solid angle and spectral sensitivity (Aas, 1993). The tube receives radiance within a solid angle of 0.0286 sr, which corresponds to a half-opening angle of 5.5°. This rather wide field of view reduces the power of resolution, but it also increases the signals and makes them more stable during field work. Double interference filters with 10-16 nm widths of the passband at half of the peak transmittance were mounted before the detector to select different wavelengths. The peak wavelengths of the applied filters were 370, 405, 450, 470, 520, 550, 600 and 650 nm. The range of radiance detection is 6 decades.

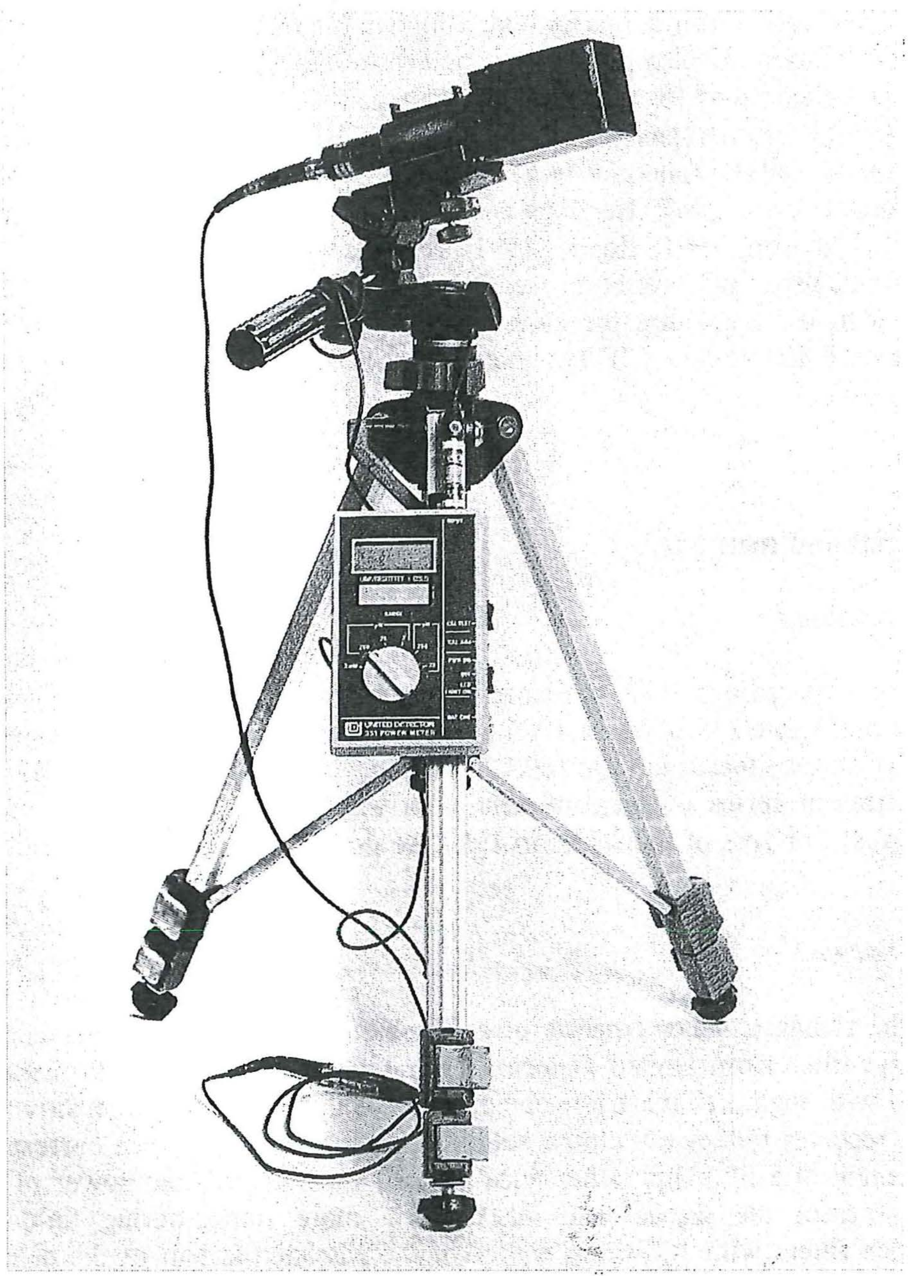

Figure 1. The radiance meter consisting of a tripod, a display unit, and a Gershun tube prolonged with a field-stop box containing the interference filter.

2.3. Method of measurement

The instrument was mounted on a tripod (Fig. 1), and for different zenith angles (0°-15°-30°-45°-60° and 75°) it was rotated manually in the horizonthal plane. The position of this plane was determined by a spirit level. At different azimuth angles (usually 0°-24°-48°-72°-96°-120°-144°-180° in Oslo) the signal of the sky radiance L was recorded.

Although the Gershun tube contains several field stops, it was discovered that direct solar radiation from forward directions incident against the opening of the tube would increase the signal significantly. Consequently these rays were shaded by placing a hand between the opening and the sun. This method worked in a satisfactory way except for directions close to the sun, where the hand sometimes involuntary would shade some of the sky radiance within the instrument's field of view and at other times permit some sun rays to hit the entrance of the instrument. As a result measurements closer to the sun than 15° could not be trusted and were rejected. They were substituted by estimates based on extrapolation.

The solar contribution to scalar irradiance, E_{oS}, was measured by directing the radiance meter towards the sun. Since the angle across the sun's radius is only about 0.25°, the solar disk will be completely contained within the field of view of the instrument. In this position it will also receive the sky radiance within 5.5° from the sun.

2.4. Solar aureole

Solar aureole is a region of enhanced radiance around the sun due to the strong forward Mie-scattering caused by atmospheric aeorosols. Observations of circumsolar radiance, especially of radiance with the same zenith angle as the sun, have been presented by Pokrowsky (1925a,b), Stranz (1940), Deepak et al. (1982), Harrison and Coombes (1988), and Harrison (1991).

Harrison and Coombes (1988) suggested an expression for the circumsolar radiance which may be written

$$L(\alpha) = L_o \qquad \textit{for} \quad 0° \le \alpha \le 1°$$
$$L(\alpha) = (\alpha / 1°)^{-K} L_o \qquad \textit{for} \quad 1° \le \alpha \le 20° \qquad (1)$$

where α is in units of degrees. L_o and K are constants, and $L(\alpha)$ represents the mean circumsolar radiance at an angular distance α from the sun. Harrison and Coombes (1988) applied K=0.5 for spectrally integrated radiance and a "clean continental atmosphere". However, the observations presented by Deepak et al. (1982) indicate that the constant K may obtain values in the ranges 0.6-0.8 at 400 nm, 0.8-1.0 at 500 nm and 1.0-1.2 at 600 nm. Because the relative irradiance contribution from the circumsolar radiance is greatest in the UV-blue part of the spectrum, we have chosen K=0.7 for our discussion here.

When the angle α between the direction of observation and the direction to the sun was less than 15° the observations of the circumsolar radiance $L(\alpha)$ were rejected and substituted by estimates based on extrapolations from nearby directions. The mean sky radiance within the interval α=0°-10° may be found by integration of Eq.1:

$$\bar{L}(0° - 10°) = \frac{2\pi \int_{0°}^{10°} L(\alpha) \sin\alpha \, d\alpha}{2\pi \int_{0°}^{10°} \sin\alpha \, d\alpha} \approx \frac{\int_{0°}^{10°} L(\alpha) \, \alpha \, d\alpha}{\int_{0°}^{10°} \sin\alpha \, d\alpha} \approx 0.30 \, L_o \qquad (2)$$

At a distance of 15° from the sun $L(\alpha)$ will be, according to Eq. 1,

$$L(15°) = 15^{-0.7} \, L_o \approx 0.15 \, L_o \qquad (3)$$

By combining Eqs. 1-3 the mean sky radiance in the range 0°-10° from the sun can then be estimated from the radiance observed at a distance of 15° as

$$\bar{L}(0° - 10°)_{est} \approx 2.0 \, L(15°)_{obs} \qquad (4)$$

Similar estimates of $\bar{L}(0°\text{-}10°)$ were made for other distances from the sun. Calculations by Nagel et al. (1978) show the same order of magnitude for the radiances close to the sun as Eq. 4.

The observed solar contribution to scalar irradiance, $(E_{oS})_{obs}$, is related to the true irradiance $(E_{oS})_{true}$ and the sky radiance received within the instrument's field of view by

$$\left(E_{oS}\right)_{obs} = \left(E_{oS}\right)_{true} + 2\pi \int_{0°}^{5.5°} L(\alpha) \sin\alpha \, d\alpha \qquad (5)$$

If the relative error ϵ_r of the observed irradiance is defined as

$$\epsilon_r = \frac{\left(E_{oS}\right)_{obs} - \left(E_{oS}\right)_{true}}{\left(E_{oS}\right)_{true}} = \frac{2\pi \int_{0°}^{5.5°} L(\alpha) \sin\alpha \, d\alpha}{\left(E_{oS}\right)_{true}} \qquad (6)$$

this fraction becomes, by applying Eqs. 1, 3 and 4,

$$\epsilon_r = \frac{0.013 \, L_o}{\left(E_{oS}\right)_{true}} = \frac{0.086 \, L(15°)}{\left(E_{oS}\right)_{true}} = \frac{0.043 \, \bar{L}(0° - 10°)}{\left(E_{oS}\right)_{true}} \qquad (7)$$

Our observations show that for a clear sky in Oslo the error ϵ_r will typically be 2-0.5% within the spectral range 405-650 nm, but during hazy conditions it may increase to 10%. We have then concluded that the quantity measured with the instrument directed towards the sun will usually be approximately equal to the true value of E_{oS}. However, the values of E_{oS} presented in Tables 3.1.1-3.16.2 have all been corrected by Eq. 7. (By "true value of E_{oS}" is meant the irradiance contribution from radiance within the solid angle that encloses the sun. This radiance will also contain scattered light.)

2.5. Irradiances and mean cosines

The downward solar irradiance E_S at sea level is related to the corresponding scalar irradiance E_{oS} and the solar zenith angle θ_S by

$$E_S = E_{oS} \cos\theta_S \tag{8}$$

The contribution to the downward scalar irradiance from the diffuse sky, E_{oD}, is obtained by integration of the sky radiance $L(\theta,\phi)$ over all zenith angles θ and azimuth angles ϕ within the upper hemisphere:

$$E_{oD} = 2 \int_{\theta=0}^{\theta=\pi/2} \int_{\phi=0}^{\phi=\pi} L(\theta,\phi) \sin\theta \, d\phi \, d\theta \tag{9}$$

Similarly the downward diffuse irradiance E_D is defined as

$$E_D = 2 \int_{\theta=0}^{\theta=\pi/2} \int_{\phi=0}^{\phi=\pi} L(\theta,\phi) \sin\theta \cos\theta \, d\phi \, d\theta \tag{10}$$

In the integrals of Eqs. 9-10 it has been assumed that the sky is clear and that the radiance distribution is a symmetric function of ϕ when ϕ is defined with $\phi=0$ towards the sun. Between the directions of observation $L(\theta,\phi)$ has been interpolated by cubic splines. Other authors have observed that the radiance may increase towards the horizon (e.g. Lee, 1994), but because we lack reliable algorithms for this effect it has been assumed in our irradiance calculations that $L(\theta,\phi)$ is constant for constant ϕ from the greatest observed zenith angle (75° or 83°) and down to the horizon (θ=90°). According to data by Lee (1994) the mean radiance in the angular range θ=75°-90° may then be underestimated by up to 40%. By comparison with our observations we find that this leads to an underestimation of E_{oD} by <15%, and of E_D by <5%.

At some of the regular azimuth angles radiance was not observed. Because of the large angular intervals ($\Delta\phi$>45°) the cubic spline method was not considered safe, and interpolated values were obtained by Eq. 41 derived in *Appendix 1*.

The total downward scalar irradiance E_{od} is the sum of the solar and diffuse contributions:

$$E_{od} = E_{oS} + E_{oD} \tag{11}$$

and the total downward irradiance E_d is similarly

$$E_d = E_S + E_D \tag{12}$$

The mean cosine of the downward diffuse radiance μ_D is defined as

$$\mu_D = \frac{E_D}{E_{oD}} \tag{13}$$

The mean cosine μ_d of the total downward irradiance is defined similarly, and by applying Eqs. 8 and 11-13 it can be deduced that μ_d is related to μ_D, $\cos\theta_S$ and the ratio E_D / E_d by

$$\mu_d = \frac{E_d}{E_{od}} = \frac{\mu_D \cos\theta_S}{\mu_D + (\cos\theta_S - \mu_D)(E_D/E_d)} \tag{14}$$

2.6. Irradiance transmittances

The irradiance transmittance T is defined by

$$T \equiv \frac{E_d}{S_o \cos\theta_S} \tag{15}$$

where S_o is the extraterrestrial irradiance on a plane normal to the solar rays (the spectral solar constant). Similarly the transmittance T_S of solar irradiance is defined as

$$T_S \equiv \frac{E_S}{S_o \cos\theta_S} \equiv \frac{E_{oS}}{S_o} \equiv T\left(1 - \frac{E_D}{E_d}\right) \tag{16}$$

The values of S_o applied here were obtained from Iqbal (1983) (Table 2). Because of the varying distance between earth and sun S_o will vary approximately $\pm 3.5\%$ from its mean value through the year. A useful table for this effect has been provided by Iqbal (1983), and it was taken into account when the values of T and T_S in Table 1 were calculated.

In a single-scattering atmosphere T_S would be related to the beam attenuation coefficient c by Bouguer-Lambert's law on the form

$$T_S \equiv \frac{E_{oS}}{S_o} = e^{-\int_0^R c(r)\,dr} \tag{17}$$

where r is the distance along the path of the solar ray through the atmosphere, and R is the total length of this path from the bottom to the top of the atmosphere. The relative optical air mass m and the optical depth τ are defined by the relations

$$\int_0^R c(r)\,dr = m\int_0^H c(z)\,dz = m\tau \tag{18}$$

Here z is the vertical coordinate and H is the height of the atmosphere. According to Eqs. 17-18 T_S is related to τ and m by

$$\ln T_S = -\tau m \tag{19}$$

implying that $\ln(T_S)$ should be a linear function of m in a single-scattering atmosphere. For solar zenith angles θ_S less than 73° m may be approximated by $m \approx \sec\theta_S$ with an error less than 1%. Accurate values of $m(\theta_S)$ have been calculated by Kasten and Young (1989), and truncated numbers are shown in Table 1.

2.7. Polarization

The scattering plane is defined by the direction of a ray incident at a small volume of the atmosphere and the direction of the observed scattered light from this volume. In a single-scattering Rayleigh atmosphere the incident ray will be the solar radiance, and the scattered ray will be the direction of observation. The scattered light will be polarized and have its minimum electric vector parallel to the scattering plane and its maximum electric vector normal to it. In a multi-scattering real atmosphere only a fraction of the radiance will be polarized, but it is a well known fact that the maximum and minimum of the electric vector will still be directed approximately normally and in parallel, respectively, to the scattering plane.

The sky radiance may be divided into an unpolarized fraction L_{un} and a polarized fraction L_{pol}:

$$L = L_{un} + L_{pol} \tag{20}$$

The polarized fraction will have its electric vector normal to the scattering plane, while the electric vector of the unpolarized fraction will rotate through all possible angles (Fig. 2).

According to Malus' law a perfect polaroid filter will transmit a component of the polarized fraction equal to $L_{pol}\cos^2\sigma$, where σ is the angle between the electric vector of this fraction and the vector direction for 100% transmittance. The mean value of $\cos^2\sigma$ for all possible angles σ of the electric vector is 1/2, and consequently the transmitted part of the unpolarized fraction of the radiance will always be $L_{un}/2$, independent of the orientation of

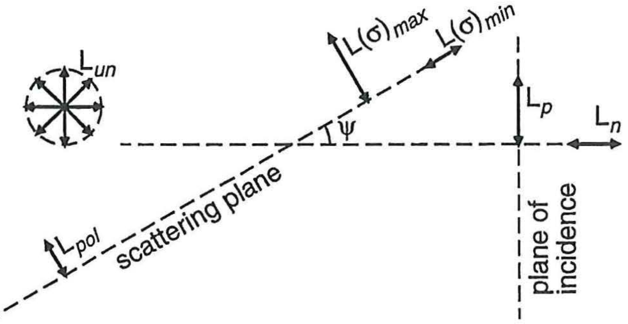

Figure 2. The different pairs of radiance components: L_{un} and L_{pol}, $L(\sigma)_{max}$ and $L(\sigma)_{min}$, and L_p and L_n. The arrows indicate the directions of the corresponding electric vectors.

the polaroid filter. The total radiance transmitted by this perfect filter will then be

$$L(\sigma) = \frac{1}{2} L_{un} + \cos^2\sigma \, L_{pol} \tag{21}$$

Obviously the maximum and minimum values obtained by rotating the polaroid filter become

$$L(\sigma)_{\max} = \frac{1}{2} L_{un} + L_{pol} \tag{22}$$

$$L(\sigma)_{\min} = \frac{1}{2} L_{un} \tag{23}$$

The degree of polarization P may according to Eqs. 20 and 22-23 be written

$$P \equiv \frac{L_{pol}}{L} = \frac{L(\sigma)_{\max} - L(\sigma)_{\min}}{L(\sigma)_{\max} + L(\sigma)_{\min}} \tag{24}$$

2.8 Reflectance of the sea surface

The radiance reflectance of a flat sea surface may be calculated by the Fresnel equations. These have one reflectance ρ_p for radiance L_p where the electric vector is parallel to the plane of incidence,

$$\rho_p = \frac{\tan^2(\theta - \theta_w)}{\tan^2(\theta + \theta_w)} \tag{25}$$

and another reflectance ρ_n for radiance L_n with the electric vector normal to the plane of incidence

$$\rho_n = \frac{\sin^2(\theta - \theta_w)}{\sin^2(\theta + \theta_w)} \tag{26}$$

In these expressions θ is the zenith angle of the direction of observation, which is also termed the angle of incidence, and θ_w is the angle of refraction, related to θ by Snell's law:

$$\sin\theta = n \sin\theta_w \tag{27}$$

Here n is the refractive index of sea water, the applied value being 1.338.

For unpolarized light the reflectance ρ will be

$$\rho = \frac{\rho_p}{2} + \frac{\rho_n}{2} \tag{28}$$

The solar radiance is practically unpolarized, and the reflectance ρ_S of the solar irradiance E_S becomes

$$\rho_S(\theta_S) = \rho(\theta_S) \tag{29}$$

where ρ is defined by Eq. 28. The reflectance ρ_D of the diffuse sky irradiance E_D is obtained from

$$\rho_D = \frac{2}{E_D} \int_{\theta=0}^{\theta=\pi/2} \int_{\phi=0}^{\phi=\pi} [\rho_p(\theta) L_p(\theta,\phi) + \rho_n(\theta) L_n(\theta,\phi)] \sin\theta \cos\theta \, d\theta \, d\phi \tag{30}$$

By means of Eq. 12 it can be deduced that the reflectance ρ_d of the total downward irradiance E_d is related to ρ_S, ρ_D and the ratio E_D/E_d by

$$\rho_d = (1 - \frac{E_D}{E_d}) \rho_S + \frac{E_D}{E_d} \rho_D \tag{31}$$

The electric vectors of the components L_p and L_n will generally differ in magnitude and direction from the electric vectors of the earlier defined components L_{max} and L_{min} (Fig. 2). The derivation of a useful expression for the angle ψ between the scattering plane and the normal to the plane of incidence requires some calculation, and it is shown in *Appendix 2* that

$$\cos\psi = \frac{\sin\theta_S \sin\phi}{\sin\alpha} \tag{32}$$

Here θ_S is the solar zenith angle, α is the angle between the direction to the sun and the direction of observation, and ϕ is the azimuth angle of the direction of observation (ϕ=0 towards the sun). The angle α is related to θ_S and ϕ by

$$\cos\alpha = \sin\theta_S \sin\theta \cos\phi + \cos\theta_S \cos\theta \tag{33}$$

as demonstrated in *Appendix 2*.

According to Malus' law the components L_p and L_n will be related to L_{un} and L_{pol} by

$$L_p = \frac{1}{2} L_{un} + \cos^2\psi \, L_{pol} = L(\sigma)_{\min} + \cos^2\psi \, (L(\sigma)_{\max} - L(\sigma)_{\min}) = L\left(\frac{1-P}{2} + \cos^2\psi \, P\right) \tag{34}$$

$$L_n = \frac{1}{2} L_{un} + \sin^2\psi \, L_{pol} = L(\sigma)_{\min} + \sin^2\psi \, (L(\sigma)_{\max} - L(\sigma)_{\min}) = L\left(\frac{1-P}{2} + \sin^2\psi \, P\right) \tag{35}$$

It may finally be noted that while L_p and L_n are always easily obtained from observed L_{max} and L_{min}, the opposite procedure becomes much more difficult and sensitive to uncertainties. This occurs especially when L_p is close to L_n, either because ψ is close to 45° or because P is close to 0.

3. Results

The irradiance transmittances T and T_S are presented in Table 1. The values of T_S are significantly smaller than what could be expected on 20 August 1996, and the sky on this day was described in the recordings as "hazy". On those days when T_S was recorded for different sun angles and different values of the relative optical air mass m, $\ln(T_S)$ was not the linear function of m which is suggested by Eq. 19. For instance, on 6 June 1997 E_{oS} at 650 nm was 30% greater with $\theta_S=69°$ than expected from Eq. 19 and the recording with $\theta_S=40°$, indicating that multiple scattering from the surrounding atmosphere contributed at least 30% to the recorded "direct solar radiation". In our observations the calculated value of θ would invariably decrease with increasing values of m. The same lack of linearity was observed for $\ln(T)$ as a function of m.

(There is a certain similarity between this phenomenon and the corresponding one in the ocean. It has been observed for clear ocean waters (Højerslev, 1974) as well as for turbid fjord waters (Nielsen and Aas, 1977) that the vertical attenuation coefficient of downward spectral irradiance is less dependent on the sun's angle than predicted from a $\sec\theta_{S,w}$ relation, where $\theta_{S,w}$ is the zenith angle of the refracted solar rays.)

Our 90 cases of observed angular sky radiance distribution are presented in Tables 3.1.1-3.16.2. As typical examples the radiance distributions on two different dates and two different locations are depicted in Figs. 3-10. The figures present one half of the upper hemisphere, and the horizontal line is the principal plane through the sun. The upper semicircle represents the horizon and the dashed semicircles $\theta=30°$ and $\theta=60°$. The positions of the sun and the anti-solar point are shown by a large and a small dot, respectively. Iso-lines of radiance have been drawn for steps of 20 mW m^{-2} nm^{-1} sr^{-1} up to 200 mW m^{-2} nm^{-1} sr^{-1} by a computer program. It should be remembered that radiances within 15° from the sun are mean values obtained by tentative extrapolations.

Tables 3.1.1-3.16.2 also present the azimuthal mean values of the radiance, and the dependence of these values on the zenith angle is demonstrated by Fig. 11. It is clearly seen that the radiance distributions tend to be more constant in the UV/blue part of the spectrum than in the red, obviously due to more multi-scattered light.

If a spectral curve of sky irradiance is multiplied by the luminous efficiency curve (e.g. Jeske, 1988), the product will usually obtain its maximum at 550 nm. Consequently we have compared the expression for clear sky luminance L_{CIE} proposed by CIE (e.g. Jeske, 1988) with the observed distribution of radiance L_{obs} at 550 nm. The CIE luminance for a clear sky, normalized with its zenith value, is

$$L_{CIE}(\theta_S,\theta,\phi) = \frac{1-e^{-0.32\sec\theta}}{1-e^{-0.32}} \; \frac{0.91+10e^{-3\alpha}+0.45\cos^2\alpha}{0.91+10e^{-3\theta_S}+0.45\cos^2\theta_S} \tag{36}$$

where α is the angle between the direction to the sun and the direction of observation,

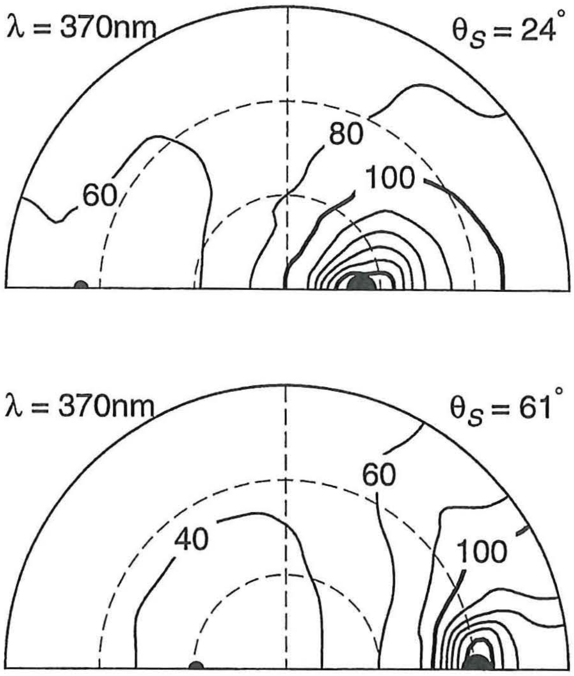

Figure 3. Ultraviolet radiance distribution on Crete, 26 June 1994, in units of mW m^{-2} nm^{-1} sr^{-1}. Upper part: E_D=280 mW m^{-2} nm^{-1}, E_S=338 mW m^{-2} nm^{-1}. Lower part: E_D=150 mW m^{-2} nm^{-1}, E_S=95 mW m^{-2} nm^{-1}. The sun's position an the anti-solar point are marked by dots.

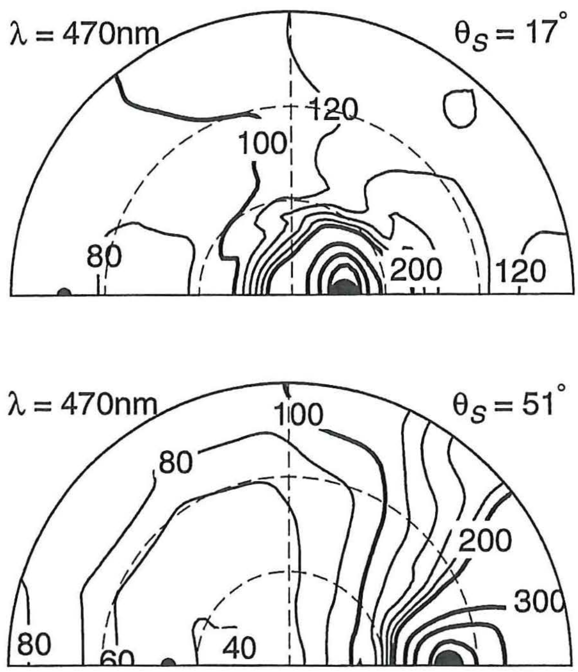

Figure 4. Blue radiance distribution on Crete, 1994, in mW m^{-2} nm^{-1} sr^{-1}. Upper: 21 June, E_D=475 mW m^{-2} nm^{-1}, E_S=985 mW m^{-2} nm^{-1}. Lower: 26 June, E_D=281 mW m^{-2} nm^{-1}, E_S=605 mW m^{-2} nm^{-1}.

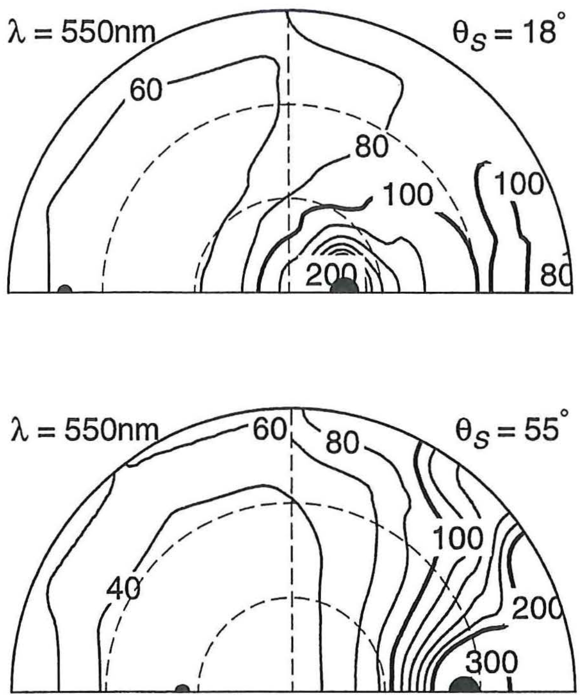

Figure 5. Green radiance distribution on Crete, 26 June 1994, in mW m^{-2} nm^{-1} sr^{-1}. Upper: E_D=286 mW m^{-2} nm^{-1}, E_S=1150 mW m^{-2} nm^{-1}. Lower: E_D=168 mW m^{-2} nm^{-1}, E_S=523 mW m^{-2} nm^{-1}.

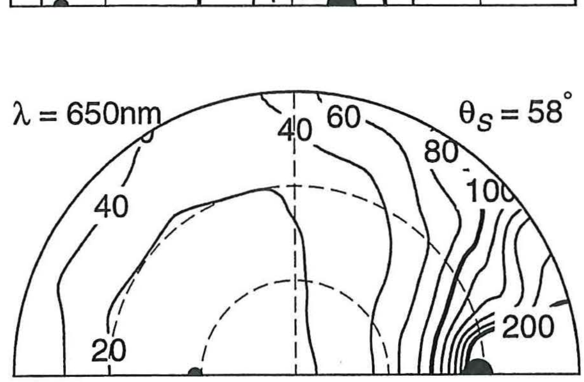

Figure 6. Red radiance distribution on Crete, 26 June 1994, in mW m^{-2} nm^{-1} sr^{-1}. Upper: E_D=184 mW m^{-2} nm^{-1}, E_S=1080 mW m^{-2} nm^{-1}. Lower: E_D=103 mW m^{-2} nm^{-1}, E_S=523 mW m^{-2} nm^{-1}.

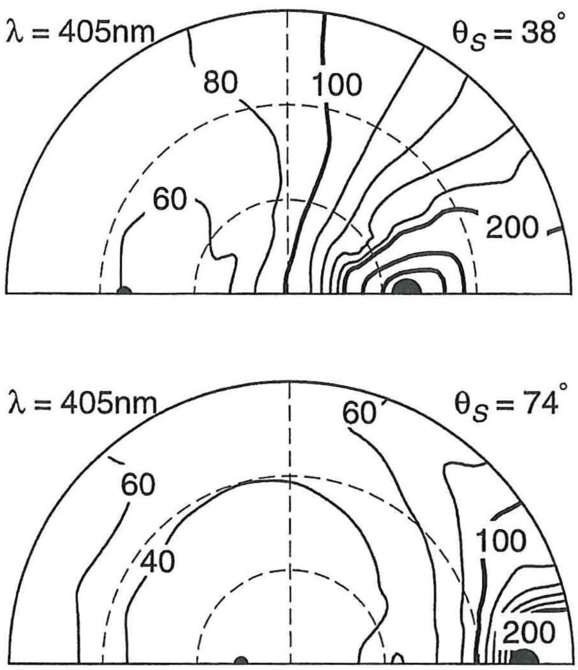

Figure 7. Violet radiance distribution in Oslo, 6 June 1997, in mW m^{-2} nm^{-1} sr^{-1}. Upper: E_D=366 mW m^{-2} nm^{-1}, E_S=474 mW m^{-2} nm^{-1}. Lower: E_D=125 mW m^{-2} nm^{-1}, E_S=69 mW m^{-2} nm^{-1}.

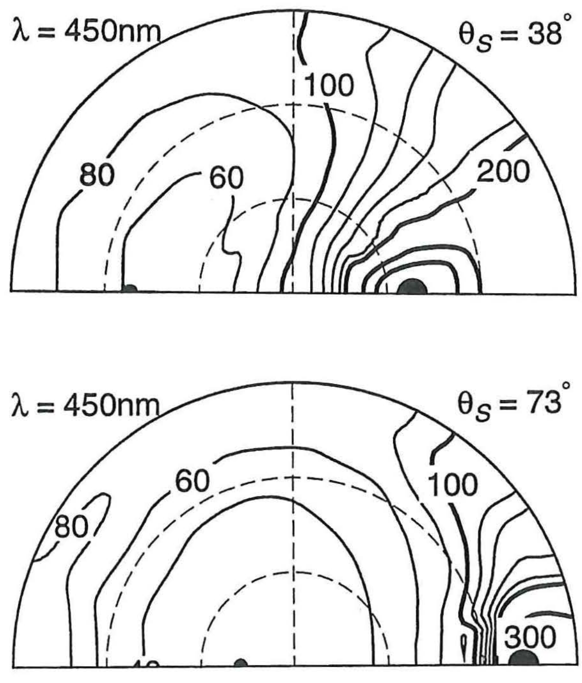

Figure 8. Blue radiance distribution in Oslo, 6 June 1997, in mW m^{-2} nm^{-1} sr^{-1}. Upper: E_D=388 mW m^{-2} nm^{-1}, E_S=676 mW m^{-2} nm^{-1}. Lower: E_D=141 mW m^{-2} nm^{-1}, E_S=156 mW m^{-2} nm^{-1}.

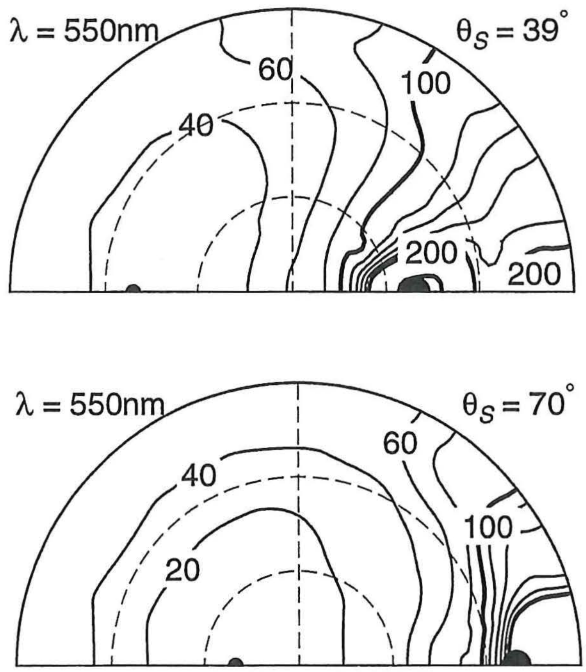

Figure 9. Green radiance distribution in Oslo, 6 June 1997, in mW m^{-2} nm^{-1} sr^{-1}. Upper: E_D=233 mW m^{-2} nm^{-1}, E_S=870 mW m^{-2} nm^{-1}. Lower: E_D=92 mW m^{-2} nm^{-1}, E_S=311 mW m^{-2} nm^{-1}.

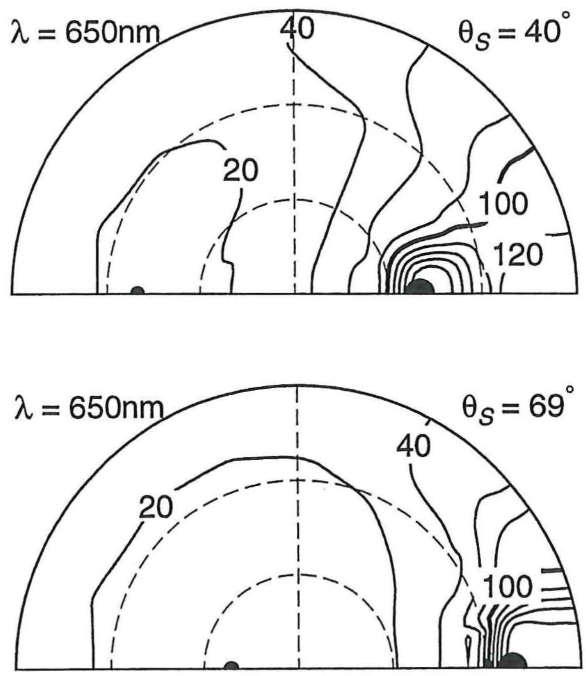

Figure 10. Red radiance distribution in Oslo, 6 June 1997, in mW m^{-2} nm^{-1} sr^{-1}. Upper: E_D=135 mW m^{-2} nm^{-1}, E_S=820 mW m^{-2} nm^{-1}. Lower: E_D=55 mW m^{-2} nm^{-1}, E_S=334 mW m^{-2} nm^{-1}.

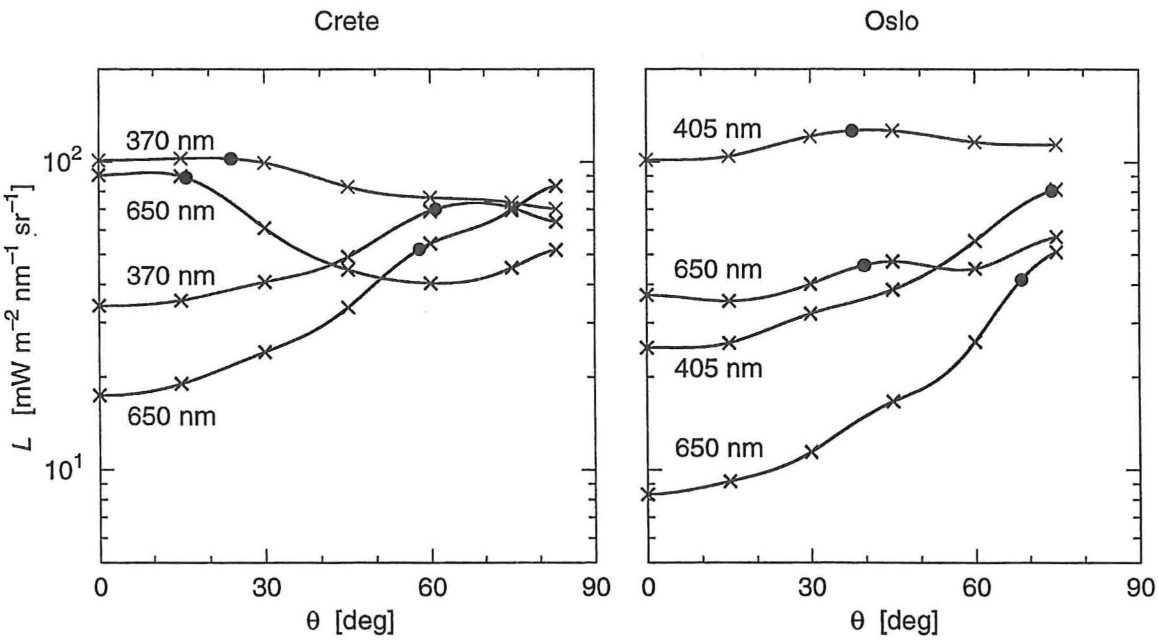

Figure 11. Azimuthal mean values of the radiance as a function of the zenith angle, on the same dates and locations as in Figs. 3-10. Sun angles are marked by dots.

defined by Eq. 33. All angles are in units of radians. The ratio L_{obs}/L_{CIE}, where also L_{obs} was normalized with its zenith value, obtained mean values in the range 0.8-1.3 for the different cases. The standard deviation of the ratio for each case was typically 20%. Comparison of the observed distributions at 405 and 650 nm with the CIE function produced similar results. It is noteworthy that also the distributions of spectral radiance calculated by Nagel et al. (1978) show deviations from our observations of the same average magnitude, implying that such distributions are difficult to predict and should be observed locally. We think it may be possible to develop functions with better agreement for the clear sky conditions in Oslo.

On 9 July 1997 $L(\sigma)_{max}$ and $L(\sigma)_{min}$ were measured at 405, 520 and 650 nm, and the degree of polarization was calculated (Tables 4.1-4.3). From these observations the radiance components L_p and L_n were derived by Eqs. 32, 34 and 35. On 15 August 1997 L_p and L_n were measured directly at 405 and 650 nm. The relative errors introduced in calculations of radiance reflectance by assuming unpolarized radiance could now be estimated. The results are presented in Tables 5.1.1-5.2.2. At the Brewster angle θ_B=53° the reflectance ρ_p (Eq. 25) becomes zero, and Tables 5.1.1-5.2.2 show that the largest errors occur for ϕ=180° and θ close to θ_B.

The errors of the diffuse irradiance reflectance induced by assuming unpolarized radiance are presented in Table 6. Due to the smoothing effect of integration the errors for the irradiance become much smaller than for the radiance, and the table shows that the reflectance of diffuse irradiance obtains errors in the range 0.0015-0.0049 or 2-5% of the true reflectance. This result confirms that polarization effects can be neglected in studies of irradiance reflectance, as stated by Kattawar and Adams (1990).

Tables 3.1.1-3.16.2 also present observations of solar irradiance, together with calculated values of diffuse irradiance, mean cosines, and the ratio E_D/E_d. Estimates of the reflectances ρ_S, ρ_D and ρ_d were obtained by assuming the radiance to be unpolarized.

Acknowledgements

Parts of this work have been supported by the Norwegian Research Council through Project No. 109229/122.

Appendix 1

Lundgren and Højerslev (1971) suggested that the azimuthal radiance distribution $L(\phi)$ in the sea could be approximated by an elliptic shape expressed as

$$L(\phi) = L(180°)\,\frac{1+\epsilon}{1-\epsilon\cos\phi} \tag{37}$$

where ϕ is the azimuth angle ($\phi=0$ towards the sun) and ϵ is the eccentricity. The azimuthal mean value of $L(\theta,\phi)$ becomes

$$\bar{L}(\theta) = \sqrt{L(\theta,0°)\,L(\theta,180°)} \tag{38}$$

The ratio between the left and right side of Eq. 38 has been calculated for our 90 data sets, and the results are presented in Table 7. It seems that the approximation suggested by Eq. 37 can be applied in the atmosphere for the smaller zenith angles $\theta \leq 30°$ with a probable error less than 5%. Almost all our interpolations occur at $\theta=15°$.

We have assumed that Eq. 37 can be expanded in series with $(\cos\phi_i - \cos\phi)\,\epsilon$ as the variable in a small domain around $\phi=\phi_i$. The series, truncated to the first terms, obtains the form

$$L(\phi) \approx A + (\cos\phi_i - \cos\phi)\,\epsilon B \tag{39}$$

where A and B are constants. If ϕ_1 and ϕ_2 are two nearby azimuth angles smaller and larger than ϕ_i, respectively, where $L(\phi_1)$ and $L(\phi_2)$ have been observed, A and B can be determined. The interpolated radiance $L(\phi_i)$ becomes

$$L(\phi_i) \approx L(\phi_1)\frac{\cos\phi_i - \cos\phi_2}{\cos\phi_1 - \cos\phi_2} + L(\phi_2)\frac{\cos\phi_1 - \cos\phi_i}{\cos\phi_1 - \cos\phi_2} \tag{40}$$

Appendix 2

The solar plane is the vertical plane containing both the sun and the point of observation. We define $\underline{i}$ as the horizontal unit vector in this plane, directed towards the sun, and $\underline{k}$ is the vertical unit vector. The horizontal unit vector $\underline{j}$ is normal to the solar plane and directed 90° to the left of $\underline{i}$. The direction towards the sun will have the unit vector $\underline{s}$ defined as

$$\underline{s} = \sin\theta_S \, \underline{i} + \cos\theta_S \, \underline{k} \tag{41}$$

where θ_S is the solar zenith angle.

The unit vector $\underline{r}$ in the direction of observation may be written

$$\underline{r} = \sin\theta \cos\phi \, \underline{i} + \sin\theta \sin\phi \, \underline{j} + \cos\theta \, \underline{k} \tag{42}$$

where θ is the zenith angle and ϕ the azimuth angle (ϕ=0 in the solar plane towards the sun).

The vectors $\underline{s}$ and $\underline{r}$ define the scattering plane. A unit vector normal to this plane has the same direction as the maximum electric vector and will be denoted $\underline{i}_{max}$:

$$\underline{i}_{\max} = \frac{\underline{s} \times \underline{r}}{\sin\alpha} \tag{43}$$

where the scattering angle α is the angle between $\underline{s}$ and $\underline{r}$. This angle is related to the directions of $\underline{s}$ and $\underline{r}$ by their scalar product:

$$\cos\alpha = \underline{s} \cdot \underline{r} = \sin\theta_S \sin\theta \cos\phi + \cos\theta_S \cos\theta \tag{44}$$

A unit vector $\underline{i}_{min}$ normal to $\underline{i}_{max}$ and $\underline{r}$ will have the same direction as the minimum electric vector:

$$\underline{i}_{\min} = \frac{\underline{i}_{\max} \times \underline{r}}{\sin\alpha} = \frac{(\underline{s} \times \underline{r}) \times \underline{r}}{\sin\alpha} \tag{45}$$

Because the scattering plane consists of all vectors normal to $\underline{s} \times \underline{r}$, the unit vector $\underline{i}_{min}$ will also be contained within the scattering plane.

A horizontal unit vector $\underline{i}_h$ normal to $\underline{r}$ may be written

$$\underline{i}_h = \frac{\underline{k} \times \underline{r}}{\sin\theta} \tag{46}$$

The angle ψ is now obtained from the scalar product of $\underline{i}_{min}$ and $\underline{i}_h$:

$$\cos\psi = \underline{i}_{\min} \cdot \underline{i}_h = \frac{(\underline{s} \times \underline{r}) \times \underline{r}}{\sin\alpha} \cdot \frac{\underline{k} \times \underline{r}}{\sin\theta} = \frac{-\underline{s}}{\sin\alpha} \cdot \frac{\underline{k} \times \underline{r}}{\sin\theta} = \frac{\sin\theta_S \sin\phi}{\sin\alpha} \tag{47}$$

References

Aas, E., 1993. Calibration of a marine radiance and colour index meter. Rep. Dept. Geophys., Univ. Oslo, **87**, 24 pp.

Deepak, A., Box, G. P., and Box, M. A., 1982. Experimental validation of the solar aureole technique for determining aerosole size distributions. *Appl. Opt.*, **21**: 2236-2243.

Harrison, A. W., 1991. Directional sky luminance versus cloud cover and solar position. *Solar Energy*, **46**: 13-19.

Harrison, A. W., and Coombes, C. A., 1988. Angular distribution of clear sky short wavelength radiance. *Solar Energy*, **40**: 57-63.

Hooper, F. C., and Brunger, A. P., 1980. A model for the angular distribution of sky radiance. *J. Solar Energy Eng.*, **102**: 196-202.

Hooper, F. C., Brunger, A. P., and Chan, C. S., 1987. A clear sky model of diffuse sky radiance. *J. Solar Energy Eng.*, **109**: 9-14.

Højerslev, N. K., 1974. Daylight measurements for photosynthetic studies in the Western Mediterranean, *Rep. Inst. Phys. Oceanogr. Univ. Copenhagen, 26*, 38 pp.

Iqbal, M., 1983. *An introduction to solar radiation.* Academic Press, Toronto. 390 pp.

Jeske, H., 1988. Meteorological optics and radiometeorology. In G. Fischer (ed.): *Landolt-Börnstein numerical data and functional relationships in science and technology. New series vol. 4b. Physical and chemical properties of the air.* Springer-Verlag, Berlin-Heidelberg, pp. 187-348.

Kasten, F., and Young, A. T., 1989. Revised optical air mass tables and approximation formula. *Appl. Opt.*, **28**: 4735-4738.

Kattawar, G. W., and Adams, C. N., 1990. Errors in radiance calculations induced by using scalar rather than Stokes vector theory in a realistic atmosphere-ocean system. In R. W. Spinrad (ed.): *Ocean Optics X*, Proc. SPIE **1302**: 2-12.

Lee, R. L. Jr., 1994. Horizon brightness revisited: measurements and a model of clear-sky radiances. *Appl. Opt.*, **33**: 4620-4628.

Littlefair, P. J., 1994. A comparison of sky luminance models with measured data from Garston, United Kingdom. *Solar Energy*, **53**: 315-322.

Lundgren, B. and Højerslev, N., 1971. Daylight measurements in the Sargasso Sea. Results from the "Dana" Expedition January-April 1966. Rep. Dept. Phys. Oceanogr., Univ. Copenhagen, **14**, 44 pp.

Nagel, M. R., Quenzel, H., Kweta, W., and Wendling, R., 1978. *Daylight illumination - color-contrast tables for full-form objects*. Academic Press, New York. 494 pp.

Nilsen, J. and Aas, E., 1977. Relation between solar elevation and the vertical attenuation coefficient of irradiance in Oslofjorden. Rep. Dept. Geophys., Univ. Oslo, **31**, 42 pp.

Perez, R., Michalsky, J., and Seals, R., 1992. Modeling sky lumimance angular distribution for real sky conditions: Experimental evaluation of existing algorithms. *J. Ill. Eng. Soc.*, **21**: 84-92.

Perez, R., Seals, R., and Michalsky, J., 1993. All-weather model for sky luminance distribution - preliminary configuration and validation. *Solar Energy*, **50**: 235-245.

Pokrowski, G. I., 1925a. Über die Lichtzerstreuung in der Atmosphäre. *Z. Physik*, **34**: 49-58.

Pokrowski, G. I., 1925b. Über die Helligkeit einer leuchtenden Schicht. *Z. Physik*, **34**: 496-498.

Pokrowski, G. I., 1929. Über die Helligkeitsverteilung am Himmel. *Physik. Z.*, **30**: 697-700.

Rosen, M. A., 1991. The angular distribution of diffuse sky radiance: An assessment of the effects of haze. *J. Solar Energy Eng.*, **113**: 200-205.

Siala, F. M., Rosen, M. A., and Hooper, F. C., 1990. Models for the directional distribution of the diffuse sky radiance. *J. Solar Energy Eng.*, **112**: 102-109.

Steven, M. D., 1977. Standard distributions of clear sky radiance. *Quart. J. R. Met. Soc.*, **103**: 457-465.

Stranz, D., 1940. Untersuchungen der Himmelshelligkeit in der Umgebung der Sonne. Veröff. Geophys. Inst. Univ. Leipzig, 2. Serie, **12**: 227-302.

Zibordi, G., and Voss, K. J., 1989. Geometrical and spectral distribution of sky radiance: comparison between simulations and field measurements. *Remote Sens. Environ.*, **27**: 343-358.

List of symbols in tables

E_D	diffuse irradiance
E_d	total (diffuse + solar) irradiance
E_{oS}	scalar irradiance from sun
L	radiance
m	relative optical air mass
S_o	extraterrestrial solar irradiance
T	transmittance of total irradiance
T_S	transmittance of solar irradiance
θ	zenith angle
θ_S	solar zenith angle
λ	wavelength
μ_D	mean cosine of diffuse radiance
μ_d	mean cosine of total radiance
ρ_D	reflectance of diffuse irradiance
ρ_d	reflectance of total irradiance
ρ_S	reflectance of solar irradiance
ϕ	azimuth angle (ϕ=0° towards sun)

Table 1. List of radiance observations

λ nm	θ_S deg	m	T	T_S	Location	Date	Table
370	12	1.02	0.64	0.32	Crete	94.06.20	3.4.1
370	17	1.05	0.63	0.32	Gran Canary	85.08.23	3.2.1
370	20	1.06	0.59	0.27	Gran Canary	85.08.22	3.1.1
370	24	1.09	0.60	0.33	Crete	94.06.26	3.6.1
370	52	1.62	0.52	0.31	Oslo	96.04.14	3.8.1
370	58	1.88	0.54	0.31	Oslo	85.09.18	3.3.1
370	61	2.06	0.45	0.17	Crete	94.06.26	3.6.7
370	62	2.12	0.47	0.23	Oslo	96.04.14	3.8.8
370	67	2.54	0.35	0.10	Crete	94.06.21	3.5.5
405	37	1.25	0.66	0.49	Oslo	96.07.11	3.9.1
405	38	1.27	0.65	0.37	Oslo	97.06.06	3.14.1
405	39	1.29	0.68	0.51	Oslo	97.07.09	3.15.3
405	45	1.41	0.63	0.42	Oslo	97.08.15	3.16.2
405	51	1.59	0.46	0.14	Oslo	96.08.20	3.11.1
405	52	1.62	0.58	0.40	Oslo	96.04.14	3.8.2
405	56	1.78	0.56	0.35	Oslo	96.08.05	3.10.1
405	58	1.88	0.59	0.38	Oslo	96.09.19	3.13.1
405	62	2.12	0.54	0.33	Oslo	96.09.17	3.12.1
405	71	3.05	0.33	0.03	Oslo	96.08.20	3.11.6

Table 1. List of radiance observations (cont.)

λ nm	θ_S deg	m	T	T_S	Location	Date	Table
405	74	3.58	0.43	0.15	Oslo	97.06.06	3.14.10
405	81	6.16	0.27	0.03	Oslo	96.08.05	3.10.10
405	84	8.85	-	-	Oslo	96.08.20	3.11.11
450	12	1.02	0.75	0.51	Crete	94.06.20	3.4.2
450	21	1.07	0.79	0.58	Crete	94.06.21	3.5.1
450	38	1.27	0.66	0.42	Oslo	97.06.06	3.14.2
450	40	1.30	0.69	0.55	Oslo	96.07.11	3.9.2
450	53	1.66	0.52	0.20	Oslo	96.08.20	3.11.2
450	54	1.70	0.66	0.50	Oslo	96.04.14	3.8.3
450	57	1.83	0.59	0.41	Oslo	96.08.05	3.10.2
450	58	1.88	0.60	0.44	Oslo	96.09.19	3.13.2
450	63	2.19	0.61	0.43	Oslo	96.04.14	3.8.9
450	63	2.19	0.56	0.39	Oslo	96.09.17	3.12.2
450	73	3.38	0.50	0.26	Oslo	97.06.06	3.14.9
450	74	3.58	0.37	0.05	Oslo	96.08.20	3.11.7
450	81	6.16	0.36	0.10	Oslo	96.08.05	3.10.9
450	84	8.85	-	-	Oslo	96.08.20	3.11.12
470	17	1.05	0.79	0.54	Crete	94.06.21	3.5.4
470	18	1.05	0.88	0.53	Gran Canary	85.08.23	3.2.3
470	27	1.12	0.75	0.43	Gran Canary	85.08.22	3.1.3
470	49	1.52	0.75	0.59	Crete	94.06.28	3.7.1
470	51	1.59	0.74	0.50	Crete	94.06.26	3.6.4
470	58	1.88	0.74	0.60	Oslo	85.09.18	3.3.2
470	65	2.36	0.66	0.41	Crete	94.06.20	3.4.3
520	38	1.27	0.80	0.70	Oslo	97.07.09	3.15.2
520	39	1.29	0.78	0.57	Oslo	97.06.06	3.14.3
520	55	1.74	0.76	0.65	Oslo	96.04.14	3.8.4
520	55	1.74	0.60	0.28	Oslo	96.08.20	3.11.3
520	59	1.94	0.71	0.58	Oslo	96.09.19	3.13.3
520	60	1.99	0.71	0.56	Oslo	96.08.05	3.10.3
520	65	2.36	0.73	0.57	Oslo	96.09.17	3.12.3
520	71	3.05	0.61	0.44	Oslo	97.06.06	3.14.8
520	75	3.81	0.42	0.11	Oslo	96.08.20	3.11.8
520	79	5.11	0.49	0.28	Oslo	96.08.05	3.10.8
550	15	1.04	0.82	0.58	Crete	94.06.21	3.5.3
550	18	1.05	0.82	0.66	Crete	94.06.26	3.6.2
550	20	1.06	0.87	0.55	Gran Canary	85.08.23	3.2.4
550	31	1.17	0.80	0.51	Gran Canary	85.08.22	3.1.4
550	39	1.29	0.77	0.61	Oslo	97.06.06	3.14.4

Table 1. List of radiance observations (cont.)

λ nm	θ_S deg	m	T	T_S	**Location**	**Date**	**Table**
550	55	1.74	0.72	0.56	Crete	94.06.26	3.6.5
550	55	1.74	0.60	0.32	Oslo	96.08.20	3.11.4
550	57	1.83	0.75	0.66	Oslo	96.04.14	3.8.5
550	58	1.88	0.80	0.71	Oslo	85.09.18	3.3.3
550	60	1.99	0.76	0.66	Oslo	96.09.19	3.13.4
550	62	2.17	0.61	0.50	Oslo	96.08.05	3.10.4
550	66	2.45	0.73	0.62	Oslo	96.04.14	3.8.10
550	66	2.45	0.66	0.53	Oslo	96.09.17	3.12.4
550	68	2.65	0.65	0.45	Crete	94.06.20	3.4.4
550	70	2.90	0.64	0.49	Oslo	97.06.06	3.14.7
550	76	4.07	0.53	0.37	Oslo	96.08.05	3.10.7
550	76	4.07	0.39	0.13	Oslo	96.08.20	3.11.9
600	59	1.94	0.71	0.64	Oslo	96.04.14	3.8.6
650	13	1.03	0.85	0.62	Crete	94.96.21	3.5.2
650	16	1.04	0.85	0.73	Crete	94.06.26	3.6.3
650	17	1.05	0.77	0.48	Gran Canary	85.08.22	3.1.2
650	17	1.05	0.82	0.49	Gran Canary	85.08.23	3.2.2
650	38	1.27	0.84	0.79	Oslo	97.07.09	3.15.1
650	40	1.30	0.80	0.69	Oslo	97.06.06	3.14.5
650	45	1.41	0.81	0.71	Oslo	97.08.15	3.16.1
650	57	1.83	0.61	0.35	Oslo	96.08.20	3.11.5
650	58	1.88	0.72	0.65	Oslo	85.09.18	3.3.4
650	58	1.88	0.76	0.64	Crete	94.06.26	3.6.6
650	59	1.99	0.79	0.72	Oslo	96.04.14	3.8.7
650	60	1.99	0.79	0.72	Oslo	96.09.19	3.13.5
650	64	2.27	0.74	0.66	Oslo	96.08.05	3.10.5
650	68	2.65	0.77	0.69	Oslo	96.04.14	3.8.11
650	68	2.65	0.60	0.53	Oslo	96.09.17	3.12.5
650	69	2.77	0.70	0.60	Oslo	97.06.06	3.14.6
650	70	2.90	0.55	0.41	Crete	94.06.20	3.4.5
650	76	4.07	0.65	0.53	Oslo	96.08.05	3.10.6
650	78	4.71	0.42	0.17	Oslo	96.08.20	3.11.10

Table 2. Extraterrestrial solar irradiance S_o at the applied wavelengths λ

λ (nm)	370	405	450	470	520	550	600	650
S_o (W m^{-2} nm^{-1})	1.17	1.69	2.10	1.98	1.81	1.90	1.75	1.60

Table 3.1.1. Ultraviolet sky radiance (370 nm) on Gran Canary

θ_S=20°	GMT:1220	Date:85.08.22
$\cos\theta_S$=0.94	μ_D=0.57	μ_d=0.70
E_{oS}=305 mW m^{-2} nm^{-1}	E_D=309 mW m^{-2} nm^{-1}	E_D/E_d=0.519
ρ_S=2.1%	ρ_D=5.5%	ρ_d=3.9%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	167							167
15°	(350)	(350)	229	144	104	89.4	86.7	172
30°	260	180	135	105	82.1	72.5	67.9	115
45°	114	106	92.0	80.9	68.7	61.8	51.5	79.2
60°	95.9	93.6	86.3	79.4	70.6	(65)	(59)	77.1
75°	87.4	84.4	79.8	74.8	(69)	(66)	(60)	73.7
83°	77.1	75.6	71.8	68.7	(67)	(64)	(57)	68.7

Table 3.1.2. Red sky radiance (650 nm) on Gran Canary

θ_S=17°	GMT:1305	Date:85.08.22
$\cos\theta_S$=0.96	μ_D=0.62	μ_d=0.80
E_{oS}=715 mW m^{-2} nm^{-1}	E_D=378 mW m^{-2} nm^{-1}	E_D/E_d=0.356
ρ_S=2.1%	ρ_D=4.8%	ρ_d=3.1%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	177							177
15°	(700)	(460)	272	166	110	83.7	73.9	218
30°	699	469	191	112	68.4	54.4	50.2	183
45°	220	181	116	78.1	54.4	43.2	43.2	91.0
60°	113	93.5	72.5	58.6	47.4	44.6	46.0	62.5
75°	120	116	97.6	80.9	(58)	(56)	(59)	78.7
83°	105	90.7	54.4	(54)	(54)	(50)	(54)	61.8

Table 3.1.3. Blue sky radiance (470 nm) on Gran Canary

θ_S=27°	GMT:1425	Date:85.08.22
$\cos\theta_S$=0.89	μ_D=0.55	μ_d=0.71
E_{oS}=837 mW m^{-2} nm^{-1}	E_D=523 mW m^{-2} nm^{-1}	E_D/E_d=0.412
ρ_S=2.2%	ρ_D=5.8%	ρ_d=3.7%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	180							180
15°	(690)	480	247	176	127	107	105	230
30°	(690)	522	237	148	103	83.9	81.2	217
45°	336	265	179	128	93.2	77.1	73.4	144
60°	217	197	156	124	95.3	81.8	80.2	126
75°	197	188	160	134	(121)	(107)	(98)	138
83°	163	164	146	125	(115)	(105)	(103)	128

Table 3.1.4. Green sky radiance (550 nm) on Gran Canary

θ_S=31°	GMT:1447	Date:85.08.22
$\cos\theta_S$=0.86	μ_D=0.55	μ_d=0.71
E_{oS}=940 mW m^{-2} nm^{-1}	E_D=462 mW m^{-2} nm^{-1}	E_D/E_d=0.364
ρ_S=2.2%	ρ_D=5.8%	ρ_d=3.5%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	139							139
15°	471	308	198	138	99.5	81.4	78.5	166
30°	(840)	527	195	116	75.7	61.5	58.7	205
45°	439	292	163	105	70.0	57.0	54.1	138
60°	220	191	138	101	72.3	62.1	60.9	108
75°	192	180	145	116	(88)	(83)	(89)	119
83°	174	168	143	117	(97)	(89)	(92)	119

Table 3.2.1. Ultraviolet sky radiance (370 nm) on Gran Canary

θ_S=17°	GMT:1245	Date:85.08.23
$\cos\theta_S$=0.96	μ_D=0.56	μ_d=0.72
E_{oS}=366 mW m^{-2} nm^{-1}	E_D=300 mW m^{-2} nm^{-1}	E_D/E_d=0.462
ρ_S=2.1%	ρ_D=5.6%	ρ_d=3.7%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	167							167
15°	(370)	(370)	217	133	102	89.0	86.3	172
30°	192	157	119	97.8	78.6	71.0	68.3	103
45°	108	103	91.7	80.2	69.5	63.0	61.4	79.4
60°	94.3	90.1	84.8	76.7	66.8	(64)	(62)	75.1
75°	87.8	85.1	80.2	74.4	(67)	(66)	(65)	73.8
83°	77.9	77.9	75.6	72.1	(66)	(66)	(64)	70.9

Table 3.2.2. Red sky radiance (650 nm) on Gran Canary

θ_S=17°	GMT:1310	Date:85.08.23
$\cos\theta_S$=0.96	μ_D=0.62	μ_d=0.80
E_{oS}=765 mW m^{-2} nm^{-1}	E_D=407 mW m^{-2} nm^{-1}	E_D/E_d=0.357
ρ_S=2.1%	ρ_D=4.8%	ρ_d=3.1%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	332							332
15°	(770)	642	451	262	153	114	105	304
30°	399	371	225	141	87.9	68.4	62.8	167
45°	144	142	116	87.9	61.4	48.8	48.8	85.5
60°	102	99.0	86.5	72.5	55.8	(46)	(46)	68.6
75°	102	97.6	86.5	76.7	(62)	(54)	(57)	73.1
83°	100	97.6	92.1	82.3	(72)	(63)	(68)	79.6

Table 3.2.3. Blue sky radiance (470 nm) on Gran Canary

θ_S=18°				GMT:1325				Date:85.08.23
$\cos\theta_S$=0.95				μ_D=0.58				μ_d=0.77
E_{oS}=1030 mW m^{-2} nm^{-1}				E_D=563 mW m^{-2} nm^{-1}				E_D/E_d=0.365
ρ_S=2.1%				ρ_D=5.3%				ρ_d=3.3%
ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	305							305
15°	(820)	(820)	443	270	182	154	137	349
30°	526	487	293	191	127	104	95.3	227
45°	215	206	171	141	105	87.5	84.4	135
60°	167	164	143	124	87.0	(82)	(82)	115
75°	163	159	144	(138)	(112)	(101)	(99)	127
83°	147	148	141	(140)	(111)	(108)	(108)	127

Table 3.2.4. Green sky radiance (550 nm) on Gran Canary

θ_S=20°				GMT:1340				Date:85.08.23
$\cos\theta_S$=0.94				μ_D=0.59				μ_d=0.78
E_{oS}=1020 mW m^{-2} nm^{-1}				E_D=498 mW m^{-2} nm^{-1}				E_D/E_d=0.342
ρ_S=2.1%				ρ_D=5.1%				ρ_d=3.1%
ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	282							282
15°	(840)	836	439	244	145	113	103	328
30°	722	495	247	145	97.3	78.0	73.4	213
45°	218	189	140	106	75.7	64.9	63.8	111
60°	151	140	116	(99)	(73)	(63)	(62)	94.2
75°	147	141	124	(99)	(79)	(74)	(79)	100
83°	146	143	127	(120)	(94)	(89)	(94)	112

Table 3.3.1. Ultraviolet sky radiance (370 nm) in Oslo

$\theta_S=58°$				GMT:1100				Date:85.09.18
$\cos\theta_S=0.53$				$\mu_D=0.43$				$\mu_d=0.48$
$E_{oS}=362$ mW m^{-2} nm^{-1}				$E_D=172$ mW m^{-2} nm^{-1}				$E_D/E_d=0.472$
$\rho_S=5.3\%$				$\rho_D=8.5\%$				$\rho_d=6.8\%$
ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	35.8							35.8
15°	42.7	42.7	40.8	38.9	35.4	33.5	32.3	37.6
30°	55.7	53.0	47.7	42.3	36.2	33.9	33.1	41.6
45°	79.8	67.9	57.2	47.7	40.8	39.2	39.6	50.0
60°	(180)	91.3	70.2	58.0	49.9	51.1	52.6	68.6
75°	117	104	84.8	73.3	64.9	70.6	76.7	80.2

Table 3.3.2. Blue sky radiance (470 nm) in Oslo

$\theta_S=58°$				GMT:1130				Date:85.09.18
$\cos\theta_S=0.53$				$\mu_D=0.39$				$\mu_d=0.49$
$E_{oS}=1180$ mW m^{-2} nm^{-1}				$E_D=196$ mW m^{-2} nm^{-1}				$E_D/E_d=0.239$
$\rho_S=5.3\%$				$\rho_D=9.9\%$				$\rho_d=6.4\%$
ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	31.4							31.4
15°	41.2	40.6	37.8	34.7	30.2	27.5	26.4	33.3
30°	62.5	57.8	47.9	39.3	31.4	28.1	27.3	39.5
45°	120	85.9	60.9	47.4	37.0	34.9	35.4	53.4
60°	(280)	126	80.2	62.5	49.5	52.1	54.2	82.0
75°	205	169	123	98.4	85.4	94.8	104	116

Table 3.3.3. Green sky radiance (550 nm) in Oslo

θ_S=58°	GMT:1145	Date:85.09.18
$\cos\theta_S$=0.53	μ_D=0.38	μ_d=0.50
E_{oS}=1330 mW m^{-2} nm^{-1}	E_D=118 mW m^{-2} nm^{-1}	E_D/E_d=0.144
ρ_S=5.3%	ρ_D=10.3%	ρ_d=6.0%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	15.2							15.2
15°	22.9	22.1	19.7	17.2	14.5	12.9	12.4	16.7
30°	38.5	33.9	26.7	21.4	15.5	13.4	12.8	21.3
45°	83.6	52.6	34.9	24.8	18.4	17.5	18.3	30.4
60°	(220)	93.8	49.1	34.9	26.1	32.9	29.3	54.1
75°	159	112	76.8	65.5	48.5	50.7	59.8	72.5

Table 3.3.4. Red sky radiance (650 nm) in Oslo

θ_S=58°	GMT:1115	Date:85.09.18
$\cos\theta_S$=0.53	μ_D=0.38	μ_d=0.51
E_{oS}=1050 mW m^{-2} nm^{-1}	E_D=65.2 mW m^{-2} nm^{-1}	E_D/E_d=0.105
ρ_S=5.3%	ρ_D=10.3%	ρ_d=5.8%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	8.09							8.09
15°	12.6	12.1	10.5	9.21	7.67	6.97	6.70	8.99
30°	23.0	19.7	13.7	10.7	7.81	6.97	6.70	11.4
45°	52.3	35.4	18.0	12.4	8.93	8.37	8.37	16.9
60°	(130)	61.0	28.6	17.7	12.6	12.7	13.5	29.8
75°	94.4	79.1	43.8	30.8	23.7	24.4	28.3	40.1

Table 3.4.1. Ultraviolet sky radiance (370 nm) on Crete

θ_S=12°	GMT:1008	Date:94.06.20
$\cos\theta_S$=0.98	μ_D=0.60	μ_d=0.75
E_{oS}=364 mW m^{-2} nm^{-1}	E_D=340 mW m^{-2} nm^{-1}	E_D/E_d=0.489
ρ_S=2.1%	ρ_D=5.0%	ρ_d=3.5%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	(500)							500
15°	(620)	(620)	445	146	111	98.6	92.2	258
30°	130	124	118	102	82.7	76.3	70.0	87.1
45°	98.6	95.4	92.2	82.7	70.0	63.6	60.4	78.4
60°	85.9	85.9	82.7	73.1	66.8	63.6	63.6	73.1
75°	76.3	66.8	66.8	70.0	66.8	66.8	63.6	68.2

Table 3.4.2. Blue sky radiance (450 nm) on Crete

θ_S=12°	GMT:1026	Date:94.06.20
$\cos\theta_S$=0.98	μ_D=0.57	μ_d=0.80
E_{oS}=1040 mW m^{-2} nm^{-1}	E_D=453 mW m^{-2} nm^{-1}	E_D/E_d=0.308
ρ_S=2.1%	ρ_D=5.5%	ρ_d=3.1%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	(400)							400
15°	(500)	(500)	(500)	255	244	162	139	303
30°	232	188	168	150	118	103	97.4	142
45°	152	147	136	117	97.4	85.8	80.0	112
60°	131	128	119	110	92.8	84.7	81.2	104
75°	113	109	114	111	102	97.4	94.0	106
83°	-	-	-	-	-	-	96.3	-

Table 3.4.3. Blue sky radiance (470 nm) on Crete

θ_S=65°	GMT:1512	Date:94.06.20
$\cos\theta_S$=0.42	μ_D=0.45	μ_d=0.43
E_{oS}=781 mW m^{-2} nm^{-1}	E_D=244 mW m^{-2} nm^{-1}	E_D/E_d=0.425
ρ_S=8.8%	ρ_D=7.8%	ρ_d=8.4%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	42.0							42.0
15°	61.0	58.2	53.0	46.8	38.9	34.5	33.2	44.8
30°	92.2	83.9	67.8	54.4	41.7	34.5	32.1	53.9
45°	176	146	95.2	62.4	45.9	39.6	39.3	75.2
60°	(500)	226	120	69.3	51.5	50.2	50.8	116
75°	194	177	127	76.2	57.1	51.2	53.6	93.0

Table 3.4.4. Green sky radiance (550 nm) on Crete

θ_S=68°	GMT:1531	Date:94.06.20
$\cos\theta_S$=0.37	μ_D=0.38	μ_d=0.38
E_{oS}=829 mW m^{-2} nm^{-1}	E_D=189 mW m^{-2} nm^{-1}	E_D/E_d=0.379
ρ_S=11.3%	ρ_D=10.1%	ρ_d=10.8%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	21.8							21.8
15°	35.9	34.6	30.7	26.4	20.7	18.2	17.3	25.0
30°	51.3	54.5	42.5	30.4	20.9	18.0	17.2	30.9
45°	113	92.4	59.2	37.4	24.0	21.4	21.5	45.1
60°	(450)	218	110	58.1	33.3	29.8	31.6	98.4
75°	(450)	219	116	69.8	45.4	48.2	52.2	110

Table 3.4.5. Red sky radiance (650 nm) on Crete

θ_S=70°	GMT:1545	Date:94.06.20
$\cos\theta_S$=0.34	μ_D=0.36	μ_d=0.35
E_{oS}=637 mW m^{-2} nm^{-1}	E_D=105 mW m^{-2} nm^{-1}	E_D/E_d=0.325
ρ_S=13.5%	ρ_D=11.1%	ρ_d=12.7%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	13.2							13.2
15°	20.1	19.2	17.3	15.1	12.1	10.2	9.64	14.2
30°	35.9	31.9	23.9	18.0	11.7	9.76	9.40	18.0
45°	73.5	55.3	34.0	21.8	13.2	11.5	11.4	26.4
60°	(180)	92.9	50.2	30.8	17.4	16.3	17.0	44.4
75°	(300)	154	82.0	46.8	27.4	28.0	31.5	73.0

Table 3.5.1. Blue sky radiance (450 nm) on Crete

θ_S=21°	GMT:0903	Date:94.06.21
$\cos\theta_S$=0.93	μ_D=0.52	μ_d=0.78
E_{oS}=1180 mW m^{-2} nm^{-1}	E_D=377 mW m^{-2} nm^{-1}	E_D/E_d=0.255
ρ_S=2.1%	ρ_D=6.3%	ρ_d=3.2%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	171							171
15°	(320)	226	196	159	126	109	109	162
30°	245	218	171	132	96.4	79.7	79.7	133
45°	190	176	145	109	84.5	69.0	65.5	111
60°	158	148	126	92.8	75.0	66.6	67.8	97.7
75°	151	143	132	114	98.8	85.7	83.3	111
83°	(150)	(140)	131	118	98.8	91.6	91.6	113

Table 3.5.2. Red sky radiance (650 nm) on Crete

θ_S=13°	GMT:1041	Date:94.06.21
$\cos\theta_S$=0.97	μ_D=0.58	μ_d=0.84
E_{oS}=952 mW m^{-2} nm^{-1}	E_D=309 mW m^{-2} nm^{-1}	E_D/E_d=0.250
ρ_S=2.1%	ρ_D=5.3%	ρ_d=2.9%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	(360)							360
15°	(430)	(430)	309	232	143	118	101	228
30°	179	174	127	105	76.2	63.1	52.4	103
45°	91.6	92.8	85.7	73.8	58.3	46.4	41.7	67.5
60°	77.4	76.2	70.2	61.9	51.2	42.8	39.3	57.9
75°	(100)	(94)	82.1	78.5	64.3	54.7	48.8	72.3

Table 3.5.3. Green sky radiance (550 nm) on Crete

θ_S=15°	GMT:1100	Date:94.06.21
$\cos\theta_S$=0.97	μ_D=0.56	μ_d=0.81
E_{oS}=1060 mW m^{-2} nm^{-1}	E_D=378 mW m^{-2} nm^{-1}	E_D/E_d=0.270
ρ_S=2.1%	ρ_D=5.7%	ρ_d=3.1%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	310							310
15°	(600)	(600)	385	229	156	122	144	278
30°	225	151	145	113	84.7	70.2	66.6	111
45°	133	126	108	92.0	71.4	60.5	55.7	87.6
60°	110	110	102	89.5	71.4	61.7	56.9	83.1
75°	(125)	(125)	115	108	88.3	76.2	69.0	98.6

Table 3.5.4. Blue sky radiance (470 nm) on Crete

θ_S=17°	GMT:1312	Date:94.06.21
cos θ_S=0.96	μ_D=0.55	μ_d=0.78
E_{oS}=1030 mW m^{-2} nm^{-1}	E_D=447 mW m^{-2} nm^{-1}	E_D/E_d=0.312
ρ_S=2.1%	ρ_D=5.8%	ρ_d=3.2%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	251							251
15°	(550)	(550)	321	219	159	136	126	261
30°	277	224	173	139	114	95.2	86.9	145
45°	167	165	148	126	98.8	83.3	75.0	118
60°	145	145	137	121	100	84.5	78.5	113
75°	117	126	140	129	112	97.6	91.6	116

Table 3.5.5. Ultraviolet sky radiance (370 nm) on Crete

θ_S=67°	GMT:1523	Date:94.06.21
cos θ_S=0.39	μ_D=0.46	μ_d=0.44
E_{oS}=108 mW m^{-2} nm^{-1}	E_D=124 mW m^{-2} nm^{-1}	E_D/E_d=0.747
ρ_S=10.4%	ρ_D=7.8%	ρ_d=8.5%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	26.8							26.8
15°	33.7	32.8	30.8	28.9	26.4	25.1	25.1	28.4
30°	44.2	41.3	35.9	31.5	27.3	26.4	26.7	32.0
45°	61.7	52.8	41.7	33.7	29.6	29.9	30.5	37.4
60°	162	69.3	45.8	36.3	33.4	35.9	36.9	49.6
75°	172	76.0	49.0	38.2	35.6	39.1	39.4	53.3
83°	114	63.9	42.3	34.0	31.5	33.4	31.2	43.6

Table 3.6.1. Ultraviolet sky radiance (370 nm) on Crete

θ_S=24°	GMT:0840	Date:94.06.26
$\cos\theta_S$=0.91	μ_D=0.53	μ_d=0.69
E_{oS}=370 mW m^{-2} nm^{-1}	E_D=271 mW m^{-2} nm^{-1}	E_D/E_d=0.445
ρ_S=2.1%	ρ_D=6.0%	ρ_d=3.8%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	101							101
15°	(210)	134	114	98.6	83.0	74.7	73.8	103
30°	(210)	(165)	114	90.6	73.1	62.3	57.9	99.4
45°	137	126	103	82.7	64.6	55.7	53.1	83.0
60°	110	104	90.9	77.0	63.9	58.5	56.3	76.5
75°	94.1	91.9	84.0	73.8	65.2	61.7	59.8	73.7
83°	83.3	83.6	78.9	70.9	64.2	61.4	58.8	70.4

Table 3.6.2. Green sky radiance (550 nm) on Crete

θ_S=18°	GMT:0919	Date:94.06.26
$\cos\theta_S$=0.95	μ_D=0.53	μ_d=0.83
E_{oS}=1210 mW m^{-2} nm^{-1}	E_D=267 mW m^{-2} nm^{-1}	E_D/E_d=0.189
ρ_S=2.1%	ρ_D=6.1%	ρ_d=2.8%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	127							127
15°	(250)	(250)	148	117	100	84.7	80.0	134
30°	161	140	114	95.6	70.2	58.1	56.9	92.0
45°	117	114	95.6	78.7	58.1	47.2	44.8	74.5
60°	100	98.0	85.9	73.8	54.5	46.0	44.8	68.1
75°	104	102	92.0	73.8	59.3	54.5	56.9	73.6
83°	79.9	94.4	95.6	90.8	71.4	65.3	67.8	80.1

Table 3.6.3. Red sky radiance (650 nm) on Crete

θ_S=16°	GMT:0934	Date:94.06.26
$\cos\theta_S$=0.96	μ_D=0.54	μ_d=0.87
E_{oS}=1120 mW m^{-2} nm^{-1}	E_D=169 mW m^{-2} nm^{-1}	E_D/E_d=0.136
ρ_S=2.1%	ρ_D=6.1%	ρ_d=2.6%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	90.4							90.4
15°	(170)	(170)	102	80.9	61.9	54.7	52.4	89.8
30°	100	92.8	75.0	60.7	48.8	40.5	39.3	61.0
45°	71.4	63.1	54.7	46.4	35.7	31.2	30.0	44.6
60°	63.4	58.7	49.5	41.4	32.2	27.8	27.4	40.3
75°	68.8	62.2	54.3	46.4	36.2	33.3	34.7	45.3
83°	69.1	66.9	61.5	53.3	44.0	40.1	42.5	51.7

Table 3.6.4. Blue sky radiance (470 nm) on Crete

θ_S=51°	GMT:1409	Date:94.06.26
$\cos\theta_S$=0.63	μ_D=0.44	μ_d=0.55
E_{oS}=962 mW m^{-2} nm^{-1}	E_D=317 mW m^{-2} nm^{-1}	E_D/E_d=0.343
ρ_S=3.6%	ρ_D=8.2%	ρ_d=5.2%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	54.7							54.7
15°	88.4	85.0	74.5	63.4	50.0	43.0	41.8	60.6
30°	143	125	91.9	67.9	47.2	40.6	40.0	71.2
45°	(500)	192	111	72.6	49.7	46.0	47.0	108
60°	(500)	226	124	79.7	60.9	63.4	67.6	124
75°	343	245	148	101	81.6	89.8	92.7	136
83°	340	276	164	113	91.9	83.9	78.9	143

Table 3.6.5. Green sky radiance (550 nm) on Crete

θ_S=55°	GMT:1427	Date:94.06.26
$\cos\theta_S$=0.57	μ_D=0.41	μ_d=0.52
E_{oS}=1020 mW m^{-2} nm^{-1}	E_D=194 mW m^{-2} nm^{-1}	E_D/E_d=0.249
ρ_S=4.4%	ρ_D=9.2%	ρ_d=5.6%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	31.1							31.1
15°	49.7	46.7	41.1	34.7	30.3	24.8	23.6	34.2
30°	88.6	79.1	5.7	40.2	27.2	22.0	21.5	42.5
45°	201	125	68.7	43.3	28.2	25.5	25.9	59.6
60°	(320)	159	85.9	50.2	34.6	35.3	37.3	79.6
75°	282	184	106	66.1	48.6	54.9	60.0	95.1
83°	265	227	142	84.7	60.1	60.1	64.3	111

Table 3.6.6. Red sky radiance (650 nm) on Crete

θ_S=58°	GMT:1442	Date:94.06.26
$\cos\theta_S$=0.53	μ_D=0.38	μ_d=0.49
E_{oS}=987 mW m^{-2} nm^{-1}	E_D=124 mW m^{-2} nm^{-1}	E_D/E_d=0.191
ρ_S=5.3%	ρ_D=10.2%	ρ_d=6.2%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	17.4							17.4
15°	27.4	27.0	23.9	20.2	15.5	13.2	12.5	19.0
30°	50.9	45.6	32.6	23.1	15.1	11.8	11.2	24.1
45°	109	74.0	40.0	25.6	15.7	13.0	12.9	33.7
60°	(240)	120	55.2	31.8	20.0	19.3	20.3	54.2
75°	217	144	79.7	46.9	31.8	35.7	40.8	69.5
83°	225	179	101	61.0	39.4	42.4	48.4	83.5

Table 3.6.7. Ultraviolet sky radiance (370 nm) on Crete

θ_S=61°	GMT:1457	Date:94.06.26
$\cos\theta_S$=0.48	μ_D=0.45	μ_d=0.46
E_{oS}=195 mW m^{-2} nm^{-1}	E_D=165 mW m^{-2} nm^{-1}	E_D/E_d=0.636
ρ_S=6.5%	ρ_D=8.0%	ρ_d=7.5%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	34.0							34.0
15°	42.9	41.7	38.8	36.3	32.4	30.8	30.2	35.4
30°	60.4	54.7	46.1	40.4	33.7	32.4	32.1	40.7
45°	88.1	73.5	55.0	44.8	37.2	36.9	37.5	49.1
60°	(210)	102	70.6	53.7	44.8	47.4	49.3	69.2
75°	157	114	77.9	57.6	48.7	51.2	51.2	70.9
83°	146	104	69.3	52.8	43.9	44.8	43.2	63.8

Table 3.7.1. Blue sky radiance (470 nm) on Crete

θ_S=49°	GMT:1403	Date:94.06.28
$\cos\theta_S$=0.66	μ_D=0.42	μ_d=0.58
E_{oS}=1170 mW m^{-2} nm^{-1}	E_D=235 mW m^{-2} nm^{-1}	E_D/E_d=0.234
ρ_S=3.3%	ρ_D=8.8%	ρ_d=4.6%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	108°	144°	180°	mean
0°	44.3							44.3
15°	68.2	65.3	58.8	50.2	40.7	35.8	34.2	48.3
30°	102	90.6	69.5	54.0	40.3	33.8	32.4	55.2
45°	(330)	127	80.1	55.6	41.5	37.0	36.2	77.4
60°	220	146	96.4	69.3	51.5	50.2	50.8	83.9
75°	194	177	127	96.6	79.5	85.7	88.3	112
83°	184	181	148	112	95.0	107	116	127

Table 3.8.1. Ultraviolet sky radiance (370 nm) in Oslo

θ_S=52°	GMT:1200	Date:96.04.14
$\cos\theta_S$=0.62	μ_D=0.45	μ_d=0.53
E_{oS}=355 mW m^{-2} nm^{-1}	E_D=166 mW m^{-2} nm^{-1}	E_D/E_d=0.429
ρ_S=3.8%	ρ_D=8.0%	ρ_d=5.6%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	36.9								36.9
15°	45.2	(44)	41.3	(39)	35.9	(34)	32.8	31.8	37.6
30°	60.4	55.3	50.2	42.3	37.5	34.3	32.8	32.4	42.0
45°	(140)	70.9	58.8	47.4	42.3	38.8	38.2	39.1	53.8
60°	(90)	81.7	68.4	56.3	49.6	48.7	50.9	52.8	60.4
75°	105	89.0	76.6	63.9	58.8	59.8	63.0	64.9	70.4

Table 3.8.2. Blue sky radiance (405 nm) in Oslo

θ_S=52°	GMT:1220	Date:96.04.14
$\cos\theta_S$=0.62	μ_D=0.42	μ_d=0.53
E_{oS}=665 mW m^{-2} nm^{-1}	E_D=215 mW m^{-2} nm^{-1}	E_D/E_d=0.347
ρ_S=3.8%	ρ_D=8.8%	ρ_d=5.5%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	43.2								43.2
15°	56.9	(55)	51.3	(47)	42.8	(40)	38.5	37.7	45.6
30°	73.0	67.7	58.9	50.8	44.8	41.2	39.5	39.0	50.5
45°	(180)	91.3	72.7	58.6	50.6	47.1	47.0	47.8	67.1
60°	125	112	88.1	72.0	62.9	61.3	64.2	68.7	78.8
75°	163	140	115	95.8	86.3	88.3	94.3	101	107

Table 3.8.3. Blue sky radiance (450 nm) in Oslo

θ_S=54°	GMT:1245	Date:96.04.14
$\cos\theta_S$=0.59	μ_D=0.41	μ_d=0.53
E_{oS}=1050 mW m^{-2} nm^{-1}	E_D=211 mW m^{-2} nm^{-1}	E_D/E_d=0.254
ρ_S=4.2%	ρ_D=9.2%	ρ_d=5.5%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	38.0								38.0
15°	49.9	(49)	44.7	(42)	37.9	(36)	34.3	33.4	40.2
30°	69.6	63.8	53.4	45.6	39.9	36.7	35.4	34.7	45.9
45°	(190)	92.8	65.9	52.9	44.9	42.2	42.8	43.6	63.8
60°	(230)	113	83.8	66.4	57.0	56.3	60.3	65.3	82.0
75°	173	148	117	94.2	85.8	90.8	101	111	111

Table 3.8.4. Green sky radiance (520 nm) in Oslo

θ_S=55°	GMT:1310	Date:96.04.14
$\cos\theta_S$=0.57	μ_D=0.40	μ_d=0.53
E_{oS}=1160 mW m^{-2} nm^{-1}	E_D=140 mW m^{-2} nm^{-1}	E_D/E_d=0.175
ρ_S=4.4%	ρ_D=9.5%	ρ_d=5.3%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	22.3								22.3
15°	31.2	(30)	27.0	(25)	22.2	(21)	19.6	18.9	23.8
30°	47.8	45.8	32.6	27.1	23.1	20.8	20.0	19.2	28.3
45°	177	59.4	42.2	32.2	26.2	24.1	24.2	24.3	42.3
60°	(180)	82.2	55.1	41.1	34.5	33.6	35.9	39.2	54.5
75°	138	113	83.8	64.5	56.7	59.4	66.4	73.0	78.0

Table 3.8.5. Green sky radiance (550 nm) in Oslo

θ_S=57°	GMT:1330	Date:96.04.14
$\cos\theta_S$=0.54	μ_D=0.39	μ_d=0.52
E_{oS}=1240 mW m^{-2} nm^{-1}	E_D=107 mW m^{-2} nm^{-1}	E_D/E_d=0.137
ρ_S=5.0%	ρ_D=9.8%	ρ_d=5.7%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	17.3								17.3
15°	23.8	(23)	20.9	(19)	16.9	(16)	14.9	14.4	18.3
30°	38.7	32.1	26.0	21.1	17.8	16.0	15.1	14.9	21.6
45°	75.0	54.8	33.9	25.3	20.2	18.5	18.6	19.0	30.4
60°	(150)	72.6	42.7	31.1	25.3	24.3	26.1	28.4	43.2
75°	128	95.7	67.5	49.1	41.7	43.4	49.9	56.5	62.3

Table 3.8.6. Red sky radiance (600 nm) in Oslo

θ_S=59°	GMT:1350	Date:96.04.14
$\cos\theta_S$=0.52	μ_D=0.37	μ_d=0.49
E_{oS}=1100 mW m^{-2} nm^{-1}	E_D=81.1 mW m^{-2} nm^{-1}	E_D/E_d=0.125
ρ_S=5.7%	ρ_D=10.7%	ρ_d=6.3%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	11.8								11.8
15°	16.5	(16)	14.5	(13)	11.7	(11)	10.3	10.0	12.6
30°	25.3	21.8	17.8	14.5	12.2	11.1	10.6	10.2	14.8
45°	(50)	36.1	24.1	17.8	14.4	13.3	13.6	13.7	21.1
60°	(120)	56.2	32.1	23.1	19.0	18.7	20.3	21.8	33.3
75°	110	78.7	55.4	41.4	36.5	39.1	45.7	47.5	53.2

Table 3.8.7. Red sky radiance (650 nm) in Oslo

θ_S=60°	GMT:1406	Date:96.04.14
$\cos\theta_S$=0.50	μ_D=0.37	μ_d=0.48
E_{oS}=1150 mW m^{-2} nm^{-1}	E_D=60.6 mW m^{-2} nm^{-1}	E_D/E_d=0.0956
ρ_S=6.1%	ρ_D=10.6%	ρ_d=6.5%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	8.21								8.21
15°	11.8	(11)	10.4	(9.4)	8.33	(7.8)	7.38	7.62	9.03
30°	19.6	17.1	13.6	10.7	8.93	8.09	7.74	7.62	11.1
45°	41.8	27.4	17.7	12.9	10.4	9.52	9.64	9.88	15.7
60°	(100)	41.9	24.2	16.9	13.7	13.3	14.8	16.1	25.2
75°	95.2	60.5	39.9	28.7	25.1	26.8	32.2	35.6	39.4

Table 3.8.8. Ultraviolet sky radiance (370 nm) in Oslo

θ_S=62°	GMT:1425	Date:96.04.14
$\cos\theta_S$=0.47	μ_D=0.43	μ_d=0.44
E_{oS}=272 mW m^{-2} nm^{-1}	E_D=142 mW m^{-2} nm^{-1}	E_D/E_d=0.528
ρ_S=7.0%	ρ_D=8.4%	ρ_d=7.7%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	28.0								28.0
15°	35.6	(35)	33.1	(31)	28.6	(27)	26.1	25.8	29.9
30°	47.4	44.5	39.8	34.7	30.8	28.6	28.0	28.0	34.4
45°	65.8	57.9	48.3	40.4	35.0	33.1	33.4	34.3	42.0
60°	(150)	72.8	58.8	47.7	42.0	41.3	43.9	47.1	56.9
75°	91.6	84.3	70.0	57.2	51.8	53.4	59.1	63.6	64.6

Table 3.8.9. Blue sky radiance (450 nm) in Oslo

θ_S=63°	GMT:1438	Date:96.04.14
$\cos\theta_S$=0.45	μ_D=0.39	μ_d=0.43
E_{oS}=902 mW m^{-2} nm^{-1}	E_D=194 mW m^{-2} nm^{-1}	E_D/E_d=0.325
ρ_S=7.5%	ρ_D=9.8%	ρ_d=8.2%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	31.2								31.2
15°	43.4	(41)	35.8	(33)	30.5	(30)	29.1	28.5	33.4
30°	58.3	54.8	47.7	40.4	35.1	32.5	31.4	31.1	40.3
45°	94.0	77.7	61.5	49.0	41.4	38.9	39.3	40.0	52.6
60°	(230)	114	81.9	63.6	54.2	53.4	57.9	61.2	79.7
75°	186	158	122	95.6	83.9	87.3	98.7	107	113

Table 3.8.10. Green sky radiance (550 nm) in Oslo

θ_S=66°	GMT:1455	Date:96.04.14
$\cos\theta_S$=0.41	μ_D=0.37	μ_d=0.40
E_{oS}=1160 mW m^{-2} nm^{-1}	E_D=105 mW m^{-2} nm^{-1}	E_D/E_d=0.180
ρ_S=9.6%	ρ_D=10.8%	ρ_d=9.8%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	14.8								14.8
15°	20.8	(20)	18.4	(17)	14.9	(14)	13.1	12.7	16.1
30°	32.4	29.2	23.8	19.2	16.1	14.5	13.9	13.8	19.6
45°	60.6	44.8	31.5	23.5	19.0	17.4	17.4	17.5	26.8
60°	(150)	71.4	43.9	31.7	25.2	24.4	26.1	27.2	43.1
75°	145	115	79.6	57.5	46.8	47.1	52.5	55.8	70.2

Table 3.8.11. Red sky radiance (650 nm) in Oslo

θ_S=68°	GMT:1510	Date:96.04.14
$\cos\theta_S$=0.37	μ_D=0.35	μ_d=0.37
E_{oS}=1090 mW m^{-2} nm^{-1}	E_D=61.8 mW m^{-2} nm^{-1}	E_D/E_d=0.132
ρ_S=11.3%	ρ_D=11.5%	ρ_d=11.3%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	7.38								7.38
15°	10.8	(11)	9.52	(8.7)	7.74	(7.1)	6.66	6.43	8.28
30°	18.2	16.1	12.6	10.1	8.21	7.38	7.02	7.02	10.3
45°	38.1	26.2	17.3	12.4	9.64	8.69	8.69	8.81	14.7
60°	(100)	46.4	25.7	17.5	13.6	12.9	13.8	14.6	25.8
75°	(150)	77.1	47.6	31.9	24.9	24.6	27.8	30.0	45.0

Table 3.9.1. Violet sky radiance (405 nm) in Oslo

θ_S=37°	GMT:1138	Date:96.07.11
$\cos\theta_S$=0.80	μ_D=0.46	μ_d=0.67
E_{oS}=806 mW m^{-2} nm^{-1}	E_D=236 mW m^{-2} nm^{-1}	E_D/E_d=0.268
ρ_S=2.4%	ρ_D=7.7%	ρ_d=3.8%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	55.9								55.9
15°	74.7	(73)	66.2	(61)	55.3	(51)	48.1	46.1	58.4
30°	(200)	(100)	78.7	64.4	54.4	43.2	44.5	(42)	70.1
45°	(200)	111	85.7	67.7	56.4	49.8	47.1	(45)	74.8
60°	125	115	86.3	74.7	64.1	58.9	59.4	(59)	77.2
75°	140	130	111	95.1	85.8	83.3	(77)	(76)	96.9

Table 3.9.2. Blue sky radiance (450 nm) in Oslo

θ_S=40°	GMT:1204	Date:96.07.11
$\cos\theta_S$=0.77	μ_D=0.45	μ_d=0.67
E_{oS}=1120 mW m^{-2} nm^{-1}	E_D=223 mW m^{-2} nm^{-1}	E_D/E_d=0.206
ρ_S=2.5%	ρ_D=8.0%	ρ_d=3.6%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	51.6								51.6
15°	69.0	(67)	62.4	(57)	50.3	(46)	42.8	40.9	53.5
30°	(140)	90.7	74.2	59.2	49.5	43.2	40.0	(38)	61.9
45°	(230)	114	80.5	62.2	50.7	44.9	(41)	(40)	72.7
60°	126	113	89.8	69.7	58.8	(51)	(48)	(46)	71.9
75°	146	135	111	(91)	81.9	80.0	(79)	(78)	97.1

Table 3.10.1. Violet sky radiance (405 nm) in Oslo

θ_S=56°	GMT:1655	Date:96.08.05
$\cos\theta_S$=0.56	μ_D=0.42	μ_d=0.49
E_{oS}=576 mW m^{-2} nm^{-1}	E_D=214 mW m^{-2} nm^{-1}	E_D/E_d=0.400
ρ_S=4.7%	ρ_D=8.9%	ρ_d=6.4%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	40.2								40.2
15°	52.5	(51)	46.8	(43)	39.3	(37)	35.4	34.5	41.8
30°	78.0	70.2	58.3	48.3	41.5	37.5	35.9	35.0	48.8
45°	120	98.1	73.9	56.1	46.8	43.0	42.3	42.3	61.6
60°	(270)	136	93.3	69.1	57.9	55.6	57.8	59.6	88.2
75°	198	166	117	88.3	76.4	76.2	82.2	88.1	106

Table 3.10.2. Blue sky radiance (450 nm) in Oslo

θ_S=57°	GMT:1710	Date:96.08.05
$\cos\theta_S$=0.54	μ_D=0.41	μ_d=0.49
E_{oS}=843 mW m^{-2} nm^{-1}	E_D=224 mW m^{-2} nm^{-1}	E_D/E_d=0.328
ρ_S=5.0%	ρ_D=9.3%	ρ_d=6.4%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	37.1								37.1
15°	51.0	(50)	45.2	(41)	36.0	(33)	31.3	31.3	39.1
30°	81.2	71.9	58.0	47.6	39.4	34.8	32.5	32.5	47.6
45°	(180)	107	75.4	54.5	44.1	39.4	39.4	39.4	64.8
60°	(300)	152	101	69.6	55.7	53.4	55.7	59.2	92.4
75°	248	197	135	96.3	81.2	81.2	88.2	95.1	120

Table 3.10.3. Green sky radiance (520 nm) in Oslo

θ_S=60°	GMT:1725	Date:96.08.05
$\cos\theta_S$=0.50	μ_D=0.39	μ_d=0.47
E_{oS}=991 mW m^{-2} nm^{-1}	E_D=146 mW m^{-2} nm^{-1}	E_D/E_d=0.228
ρ_S=6.1%	ρ_D=10.0%	ρ_d=7.0%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	21.8								21.8
15°	31.2	(30)	27.0	(25)	21.8	(20)	18.7	18.7	23.6
30°	52.0	44.7	35.4	28.1	22.9	19.8	19.8	17.7	28.6
45°	94.6	68.6	47.8	33.3	27.0	23.9	22.9	22.9	39.2
60°	(220)	110	66.6	44.7	34.3	32.2	33.3	35.4	62.0
75°	218	150	98.8	67.6	53.0	54.1	59.3	64.5	87.3

Table 3.10.4. Green sky radiance (550 nm) in Oslo

θ_S=62°	GMT:1740	Date:96.08.05
$\cos\theta_S$=0.47	μ_D=0.37	μ_d=0.44
E_{oS}=932 mW m^{-2} nm^{-1}	E_D=106 mW m^{-2} nm^{-1}	E_D/E_d=0.194
ρ_S=7.0%	ρ_D=10.9%	ρ_d=7.8%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	14.6								14.6
15°	20.0	(19)	17.5	(16)	14.0	(13)	12.4	12.1	15.2
30°	31.5	28.2	22.8	18.2	15.0	13.1	12.4	12.1	18.3
45°	60.3	47.6	32.2	22.6	17.5	15.5	15.4	15.6	26.2
60°	(170)	82.5	47.6	31.0	24.0	22.8	24.2	25.8	45.5
75°	172	128	79.5	52.6	42.3	42.6	48.0	53.4	70.8

Table 3.10.5. Red sky radiance (650 nm) in Oslo

θ_S=64°	GMT:1800	Date:96.08.05
$\cos\theta_S$=0.44	μ_D=0.37	μ_d=0.43
E_{oS}=1030 mW m^{-2} nm^{-1}	E_D=65.0 mW m^{-2} nm^{-1}	E_D/E_d=0.126
ρ_S=8.2%	ρ_D=10.7%	ρ_d=8.5%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	8.81								8.81
15°	12.6	(12)	10.9	(9.9)	8.69	(8.0)	7.50	7.14	9.43
30°	20.7	18.4	14.8	11.3	9.16	7.85	7.26	7.14	11.5
45°	40.9	30.0	20.3	13.8	10.4	9.04	8.81	8.93	16.2
60°	(110)	54.7	29.8	18.8	13.9	12.7	13.7	14.2	28.3
75°	(100)	86.2	49.5	31.3	23.9	23.3	26.3	29.4	42.6

Table 3.10.6. Red sky radiance (650 nm) in Oslo

θ_S=76°	GMT:1915	Date:96.08.05
$\cos\theta_S$=0.24	μ_D=0.34	μ_d=0.26
E_{oS}=820 mW m^{-2} nm^{-1}	E_D=55.6 mW m^{-2} nm^{-1}	E_D/E_d=0.219
ρ_S=23.6%	ρ_D=12.1%	ρ_d=21.1%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	6.55								6.55
15°	9.52	(9.2)	8.21	(7.4)	6.55	(6.2)	5.83	5.83	7.19
30°	14.8	13.2	10.8	8.45	7.14	6.43	6.31	6.43	8.82
45°	30.1	23.0	16.2	11.1	8.69	7.97	8.33	8.93	13.2
60°	60.7	1.4	25.0	15.7	11.9	11.3	12.7	14.3	21.7
75°	(170)	83.3	44.5	26.8	20.5	20.8	24.6	28.3	44.3

Table 3.10.7. Green sky radiance (550 nm) in Oslo

θ_S=76°	GMT:1930	Date:96.08.05
$\cos\theta_S$=0.24	μ_D=0.34	μ_d=0.27
E_{oS}=689 mW m^{-2} nm^{-1}	E_D=86.3 mW m^{-2} nm^{-1}	E_D/E_d=0.341
ρ_S=23.6%	ρ_D=12.0%	ρ_d=19.6%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	10.6								10.6
15°	13.7	(13)	12.5	(12)	10.6	(10)	9.80	9.80	11.3
30°	21.5	19.7	16.7	13.7	11.7	10.9	10.9	11.1	14.1
45°	41.5	34.2	24.8	17.9	14.4	13.7	14.5	15.5	20.8
60°	82.3	61.6	39.1	25.0	19.7	19.5	21.8	24.4	33.6
75°	(240)	119	69.8	43.8	34.0	35.2	41.1	47.3	67.6

Table 3.10.8. Green sky radiance (520 nm) in Oslo

θ_S=79°	GMT:2000	Date:96.08.05
$\cos\theta_S$=0.19	μ_D=0.35	μ_d=0.25
E_{oS}=486 mW m^{-2} nm^{-1}	E_D=87.2 mW m^{-2} nm^{-1}	E_D/E_d=0.485
ρ_S=31.6%	ρ_D=11.4%	ρ_d=21.8%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	11.9								11.9
15°	15.0	(15)	13.6	(13)	12.0	(12)	11.2	11.2	12.6
30°	22.6	20.8	17.6	14.8	13.0	12.6	12.7	12.9	15.4
45°	39.8	33.3	24.8	18.7	15.9	15.7	16.7	17.7	21.7
60°	80.8	57.7	37.0	26.0	21.7	22.4	25.5	27.7	34.4
75°	(210)	105	61.6	42.0	34.5	37.1	43.2	48.4	63.3

Table 3.10.9. Blue sky radiance (450 nm) in Oslo

θ_S=81°	GMT:2010	Date:96.08.05
$\cos\theta_S$=0.16	μ_D=0.37	μ_d=0.28
E_{oS}=202 mW m^{-2} nm^{-1}	E_D=97.9 mW m^{-2} nm^{-1}	E_D/E_d=0.756
ρ_S=38.7%	ρ_D=10.5%	ρ_d=17.4%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	15.0								15.0
15°	17.7	(17)	16.7	(16)	15.2	(15)	14.7	14.7	15.8
30°	25.3	23.8	21.0	18.4	16.9	16.6	16.9	17.3	19.1
45°	40.1	35.8	28.3	23.0	20.4	20.4	21.8	23.1	25.7
60°	74.5	60.2	42.0	31.3	27.3	28.4	31.8	34.6	39.0
75°	(190)	95.2	62.1	44.8	38.5	41.2	47.6	53.0	63.3

Table 3.10.10. Violet sky radiance (405 nm) in Oslo

θ_S=81°	GMT:2020	Date:96.08.05
$\cos\theta_S$=0.16	μ_D=0.40	μ_d=0.35
E_{oS}=47.8 mW m^{-2} nm^{-1}	E_D=69.1 mW m^{-2} nm^{-1}	E_D/E_d=0.902
ρ_S=38.7%	ρ_D=9.5%	ρ_d=12.4%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	11.5								11.5
15°	13.9	(14)	12.9	(12)	12.0	(12)	11.6	11.6	12.4
30°	19.1	18.1	16.3	14.4	13.4	13.4	13.9	14.1	15.1
45°	27.7	24.9	20.8	17.4	15.8	16.3	17.4	18.4	19.3
60°	60.9	37.4	28.2	22.4	20.3	21.2	23.7	25.7	27.9
75°	(100)	52.1	37.2	28.7	25.9	27.7	31.5	34.5	38.2

Table 3.11.1. Violet sky radiance (405 nm) in Oslo

θ_S=51°	GMT:1305	Date:96.08.20
$\cos\theta_S$=0.63	μ_D=0.48	μ_d=0.51
E_{oS}=236 mW m^{-2} nm^{-1}	E_D=353 mW m^{-2} nm^{-1}	E_D/E_d=0.704
ρ_S=3.6%	ρ_D=7.2%	ρ_d=6.1%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	72.4								72.4
15°	110	(110)	90.3	(81)	70.2	(65)	61.3	60.6	78.4
30°	208	163	116	84.7	67.6	(61)	55.6	54.8	94.1
45°	(500)	249	136	91.0	71.5	(65)	59.1	58.1	130
60°	(290)	257	146	99.3	76.5	(71)	67.2	66.4	124
75°	334	234	144	98.6	78.4	(74)	69.7	62.1	124

Table 3.11.2. Blue sky radiance (450 nm) in Oslo

θ_S=53°		GMT:1323	Date:96.08.20
$\cos\theta_S$=0.60		μ_D=0.46	μ_d=0.50
E_{oS}=406 mW m^{-2} nm^{-1}		E_D=424 mW m^{-2} nm^{-1}	E_D/E_d=0.634
ρ_S=4.0%		ρ_D=7.7%	ρ_d=6.3%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	83.5								83.5
15°	132	(120)	103	(90)	74.2	(68)	63.8	62.6	86.9
30°	239	188	131	92.8	71.9	(62)	54.5	53.4	103
45°	(570)	285	160	101	74.2	(65)	58.0	55.7	144
60°	(700)	348	181	111	83.5	(74)	67.3	66.1	169
75°	(400)	341	195	121	90.5	(83)	76.4	74.6	161

Table 3.11.3. Green sky radiance (520 nm) in Oslo

θ_S=55°		GMT:1341	Date:96.08.20
$\cos\theta_S$=0.57		μ_D=0.43	μ_d=0.48
E_{oS}=497 mW m^{-2} nm^{-1}		E_D=364 mW m^{-2} nm^{-1}	E_D/E_d=0.561
ρ_S=4.4%		ρ_D=8.4%	ρ_d=6.6%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	61.4								61.4
15°	107	(100)	83.2	(72)	58.2	(51)	45.8	44.7	67.9
30°	200	159	108	74.9	54.1	(45)	38.5	36.4	82.2
45°	(300)	246	139	83.	57.2	(49)	42.6	38.5	108
60°	(700)	348	168	95.7	67.6	(65)	63.4	48.9	161
75°	510	370	203	114	79.0	(69)	61.4	60.3	162

Table 3.11.4. Green sky radiance (550 nm) in Oslo

θ_S=55°	GMT:1359	Date:96.08.20
$\cos\theta_S$=0.57	μ_D=0.43	μ_d=0.49
E_{oS}=598 mW m^{-2} nm^{-1}	E_D=346 mW m^{-2} nm^{-1}	E_D/E_d=0.502
ρ_S=4.4%	ρ_D=8.6%	ρ_d=6.5%

ϕ / θ	0°	24°	48°	72°	96°	120°	144°	180°	mean
				(mW m^{-2} nm^{-1} sr^{-1})					
0°	54.5								54.5
15°	94.4	(89)	75.0	(65)	53.2	(47)	42.4	39.9	61.2
30°	180	150	105	72.6	52.0	(43)	36.3	32.7	77.7
45°	(300)	243	134	77.4	53.2	(44)	36.3	35.1	103
60°	(680)	341	162	90.8	60.5	(52)	44.8	41.1	150
75°	508	374	204	111	73.8	(64)	55.7	54.5	159

Table 3.11.5. Red sky radiance (650 nm) in Oslo

θ_S=57°	GMT:1417	Date:96.08.20
$\cos\theta_S$=0.54	μ_D=0.41	μ_d=0.47
E_{oS}=548 mW m^{-2} nm^{-1}	E_D=247 mW m^{-2} nm^{-1}	E_D/E_d=0.453
ρ_S=5.0%	ρ_D=9.1%	ρ_d=6.9%

ϕ / θ	0°	24°	48°	72°	96°	120°	144°	180°	mean
				(mW m^{-2} nm^{-1} sr^{-1})					
0°	35.7								35.7
15°	61.9	(59)	50.0	(43)	35.7	(30)	26.2	25.0	40.0
30°	118	96.4	69.0	48.8	33.3	(27)	22.6	20.2	50.2
45°	(220)	165	94.0	51.2	33.3	(27)	22.6	20.2	69.9
60°	(530)	265	127	60.7	40.5	(35)	29.8	25.0	113
75°	417	303	167	85.7	51.2	(43)	36.9	34.5	124

Table 3.11.6. Violet sky radiance (405 nm) in Oslo

θ_S=71°	GMT:1625	Date:96.08.20
$\cos\theta_S$=0.33	μ_D=0.43	μ_d=0.42
E_{oS}=56.3 mW m^{-2} nm^{-1}	E_D=177 mW m^{-2} nm^{-1}	E_D/E_d=0.906
ρ_S=14.7%	ρ_D=8.6%	ρ_d=9.2%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	33.2								33.2
15°	42.3	(41)	38.7	(37)	34.0	(33)	31.5	31.2	35.6
30°	61.8	56.4	48.1	40.3	36.0	(33)	33.2	33.2	41.6
45°	102	84.7	63.1	48.5	40.7	(39)	38.2	39.0	53.9
60°	(150)	129	80.3	58.3	47.1	(46)	45.5	47.5	70.4
75°	(290)	143	85.0	58.6	47.6	(47)	46.6	48.6	82.5

Table 3.11.7. Blue sky radiance (450 nm) in Oslo

θ_S=74°	GMT:1636	Date:96.08.20
$\cos\theta_S$=0.28	μ_D=0.41	μ_d=0.38
E_{oS}=109 mW m^{-2} nm^{-1}	E_D=203 mW m^{-2} nm^{-1}	E_D/E_d=0.871
ρ_S=19.5%	ρ_D=9.3%	ρ_d=10.6%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	34.1								34.1
15°	44.1	(43)	40.0	(37)	34.3	(33)	31.3	30.9	36.2
30°	69.5	63.3	52.5	42.9	36.8	33.6	32.6	32.6	43.9
45°	120	101	72.0	52.7	42.0	(40)	38.3	39.3	59.3
60°	(180)	162	98.5	65.2	49.9	(48)	46.9	49.5	81.5
75°	(410)	207	113	72.2	55.4	(54)	53.1	55.7	108

Table 3.11.8. Green sky radiance (520 nm) in Oslo

θ_S=75°	GMT:1647	Date:96.08.20
$\cos\theta_S$=0.26	μ_D=0.37	μ_d=0.34
E_{oS}=196 mW m^{-2} nm^{-1}	E_D=164 mW m^{-2} nm^{-1}	E_D/E_d=0.763
ρ_S=21.4%	ρ_D=10.5%	ρ_d=13.1%

ϕ / θ	0°	24°	48°	72°	96°	120°	144°	180°	mean
				(mW m^{-2} nm^{-1} sr^{-1})					
0°	24.1								24.1
15°	33.6	(32)	28.9	(26)	23.5	(22)	21.0	20.7	25.6
30°	52.9	46.6	37.8	30.0	25.1	22.6	21.5	21.2	30.8
45°	99.8	80.0	55.0	38.0	29.0	26.0	25.8	26.1	44.0
60°	(160)	141	85.2	51.6	37.0	32.4	33.2	34.7	66.0
75°	(440)	218	114	65.0	46.8	40.9	42.6	44.9	105

Table 3.11.9. Green sky radiance (550 nm) in Oslo

θ_S=76°	GMT:1658	Date:96.08.20
$\cos\theta_S$=0.24	μ_D=0.36	μ_d=0.32
E_{oS}=236 mW m^{-2} nm^{-1}	E_D=145 mW m^{-2} nm^{-1}	E_D/E_d=0.717
ρ_S=23.6%	ρ_D=11.0%	ρ_d=14.6%

ϕ / θ	0°	24°	48°	72°	96°	120°	144°	180°	mean
				(mW m^{-2} nm^{-1} sr^{-1})					
0°	19.2								19.2
15°	27.6	(27)	24.1	(22)	19.6	(18)	17.3	16.9	21.2
30°	46.1	40.4	32.2	25.2	20.6	18.4	17.5	17.2	25.9
45°	83.5	66.8	45.7	31.5	23.7	20.8	20.3	20.6	36.1
60°	(180)	123	76.8	45.6	31.9	27.1	27.0	28.4	59.9
75°	(420)	212	110	60.4	42.6	32.5	37.1	39.0	98.8

Table 3.11.10. Red sky radiance (650 nm) in Oslo

θ_S=78°	GMT:1709	Date:96.08.20
$\cos\theta_S$=0.21	μ_D=0.35	μ_d=0.28
E_{oS}=273 mW m^{-2} nm^{-1}	E_D=96.8 mW m^{-2} nm^{-1}	E_D/E_d=0.630
ρ_S=28.6%	ρ_D=11.5%	ρ_d=17.8%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	12.0								12.0
15°	17.7	(17)	15.4	(14)	12.1	(11)	10.4	10.0	13.2
30°	30.5	26.3	20.8	15.9	12.6	10.9	10.1	9.88	16.2
45°	61.0	46.9	31.4	20.5	14.9	12.6	12.1	12.1	24.1
60°	120	82.3	49.9	29.6	19.6	16.3	16.3	16.8	38.8
75°	(310)	156	79.4	43.9	28.6	23.6	24.3	25.3	71.2

Table 3.11.11. Violet sky radiance (405 nm) in Oslo

θ_S=84°	GMT:1755	Date:96.08.20
$\cos\theta_S$=0.10	μ_D=0.45	μ_d=0.45
E_{oS}<1 mW m^{-2} nm^{-1}	E_D=47.8 mW m^{-2} nm^{-1}	$E_D/E_d \approx$ 1.00
ρ_S=52.7%	ρ_D=7.8%	$\rho_d \approx$ 8%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	10.1								10.1
15°	11.5	(11)	11.1	(11)	10.5	(10)	10.5	10.3	10.8
30°	14.6	13.9	13.1	12.1	11.5	11.5	11.8	11.8	12.4
45°	19.8	18.4	16.1	14.3	13.4	13.6	14.1	14.6	15.3
60°	26.2	23.2	19.1	16.4	15.3	15.8	16.9	17.8	18.3
75°	(43)	21.4	19.4	16.4	15.3	15.3	16.4	17.6	19.0

Table 3.11.12. Blue sky radiance (450 nm) in Oslo

θ_S=84°	GMT:1807	Date:96.08.20
$\cos\theta_s$=0.10	μ_D=0.44	μ_d=0.42
$E_{oS}\approx$5 mW m^{-2} nm^{-1}	E_D=44.8 mW m^{-2} nm^{-1}	$E_D/E_d\approx$0.99
ρ_S=52.7%	ρ_D=8.3%	$\rho_d\approx$8.7%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	8.70								8.70
15°	10.1	(10)	9.51	(9.3)	9.05	(9.0)	8.93	8.93	9.29
30°	12.9	12.4	11.4	10.6	10.1	10.1	10.3	10.4	10.9
45°	18.4	17.3	14.5	12.8	11.8	12.1	12.8	13.3	13.8
60°	26.4	23.2	18.9	15.7	14.3	14.8	16.1	17.1	17.8
75°	(50)	24.7	19.4	16.0	14.7	15.3	16.6	17.9	19.9

Table 3.12.1. Violet sky radiance (405 nm) in Oslo

θ_S=62°	GMT:1315	Date:96.09.17
$\cos\theta_S$=0.47	μ_D=0.42	μ_d=0.45
E_{oS}=557 mW m^{-2} nm^{-1}	E_D=182 mW m^{-2} nm^{-1}	E_D/E_d=0.411
ρ_S=7.0%	ρ_D=8.7%	ρ_d=7.7%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	33.5								33.5
15°	42.5	(42)	38.8	(37)	33.9	(32)	31.2	30.9	35.5
30°	58.6	53.5	48.1	41.7	36.7	33.9	33.2	34.7	41.4
45°	89.6	79.5	63.4	48.5	42.5	41.5	42.3	44.5	54.2
60°	(220)	110	75.7	58.1	49.0	49.1	54.4	58.4	75.0
75°	146	122	93.0	71.9	62.7	64.7	76.4	88.8	86.8

Table 3.12.2. Blue sky radiance (450 nm) in Oslo

θ_S=63°	GMT:1330	Date:96.09.17
$\cos\theta_S$=0.45	μ_D=0.41	μ_d=0.44
E_{oS}=803 mW m^{-2} nm^{-1}	E_D=185 mW m^{-2} nm^{-1}	E_D/E_d=0.337
ρ_S=7.5%	ρ_D=9.3%	ρ_d=8.1%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	30.6								30.6
15°	38.4	(38)	34.9	(33)	30.3	(29)	27.7	28.4	31.9
30°	59.2	52.2	44.2	36.8	32.4	30.0	29.6	31.0	38.1
45°	121	79.7	60.0	45.4	39.3	36.9	37.8	41.3	53.3
60°	(230)	113	78.8	59.2	54.6	54.3	55.4	58.9	78.1
75°	158	142	109	76.6	65.8	71.5	89.3	97.2	97.3

Table 3.12.3. Green sky radiance (520 nm) in Oslo

θ_S=65°	GMT:1350	Date:96.09.17
$\cos\theta_S$=0.42	μ_D=0.39	μ_d=0.42
E_{oS}=1020 mW m^{-2} nm^{-1}	E_D=142 mW m^{-2} nm^{-1}	E_D/E_d=0.247
ρ_S=8.8%	ρ_D=9.7%	ρ_d=9.0%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	22.9								22.9
15°	26.1	(25)	(23)	(22)	20.2	(20)	20.2	20.6	21.9
30°	49.0	39.9	34.7	23.4	21.0	21.2	23.3	22.9	28.1
45°	93.3	69.7	44.8	27.1	23.1	22.0	23.4	28.8	37.9
60°	(250)	126	56.3	34.4	29.0	29.6	33.2	42.1	63.0
75°	166	131	77.4	56.3	53.2	58.0	66.9	77.3	80.2

Table 3.12.4. Green sky radiance (550 nm) in Oslo

θ_S=66°	GMT:1405	Date:96.09.17
$\cos\theta_S$=0.41	μ_D=0.38	μ_d=0.40
E_{oS}=999 mW m^{-2} nm^{-1}	E_D=118 mW m^{-2} nm^{-1}	E_D/E_d=0.227
ρ_S=9.6%	ρ_D=10.3%	ρ_d=9.8%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	13.1								13.1
15°	18.0	(17)	15.0	(14)	13.1	(13)	12.7	12.2	14.2
30°	43.1	28.3	20.4	16.3	14.4	12.9	12.9	13.8	18.7
45°	120	64.1	29.0	20.3	16.9	16.2	17.4	18.3	32.2
60°	(250)	125	38.6	27.1	23.7	23.8	26.4	30.6	55.8
75°	169	148	61.2	46.1	43.6	46.3	53.1	59.3	72.1

Table 3.12.5. Red sky radiance (650 nm) in Oslo

θ_S=68°	GMT:1420	Date:96.09.17
$\cos\theta_S$=0.37	μ_D=0.33	μ_d=0.37
E_{oS}=845 mW m^{-2} nm^{-1}	E_D=51.9 mW m^{-2} nm^{-1}	E_D/E_d=0.142
ρ_S=11.3%	ρ_D=12.4%	ρ_d=11.5%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	6.31								6.31
15°	7.97	(7.8)	7.14	(6.6)	6.07	(5.8)	5.59	5.59	6.47
30°	13.1	10.8	9.04	7.62	6.90	6.31	6.19	6.19	7.95
45°	41.7	16.3	12.0	10.1	9.04	9.04	8.21	8.45	12.4
60°	(60)	29.9	18.3	13.8	12.1	13.0	15.8	13.6	19.6
75°	(140)	72.0	35.5	27.0	24.9	28.2	31.5	30.7	42.6

Table 3.13.1. Violet sky radiance (405 nm) in Oslo

θ_S=58°	GMT:1145	Date:96.09.19
$\cos\theta_S$=0.53	μ_D=0.42	μ_d=0.47
E_{oS}=639 mW m^{-2} nm^{-1}	E_D=207 mW m^{-2} nm^{-1}	E_D/E_d=0.383
ρ_S=5.3%	ρ_D=9.0%	ρ_d=6.7%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	39.0								39.0
15°	49.6	(46)	44.8	(42)	38.0	(36)	34.4	33.7	40.0
30°	70.9	65.1	55.3	46.5	40.3	36.9	35.5	35.4	46.7
45°	110	93.1	69.2	54.9	45.5	42.5	42.7	44.0	59.6
60°	(240)	119	90.0	68.1	56.9	55.3	58.8	63.2	83.7
75°	196	161	111	85.3	75.2	76.7	84.5	93.3	104

Table 3.13.2. Blue sky radiance (450 nm) in Oslo

θ_S=58°	GMT:1156	Date:96.09.19
$\cos\theta_s$=0.53	μ_D=0.40	μ_d=0.48
E_{oS}=919 mW m^{-2} nm^{-1}	E_D=202 mW m^{-2} nm^{-1}	E_D/E_d=0.298
ρ_S=5.3%	ρ_D=9.5%	ρ_d=6.6%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	36.1								36.1
15°	47.4	(46)	41.8	(38)	34.2	(32)	30.7	30.3	36.9
30°	69.8	61.9	50.6	41.8	36.0	32.7	31.7	31.4	42.8
45°	151	91.6	65.8	49.9	40.9	38.3	38.7	39.9	58.6
60°	(230)	116	87.5	62.2	53.2	51.3	54.9	59.2	79.5
75°	220	179	115	86.5	76.4	79.1	89.1	97.9	111

Table 3.13.3. Green sky radiance (520 nm) in Oslo

θ_S=59°	GMT:1207	Date:96.09.19
$\cos\theta_S$=0.52	μ_D=0.38	μ_d=0.48
E_{oS}=1040 mW m^{-2} nm^{-1}	E_D=137 mW m^{-2} nm^{-1}	E_D/E_d=0.205
ρ_S=5.7%	ρ_D=10.2%	ρ_d=6.6%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	21.7								21.7
15°	30.3	(29)	26.0	(24)	21.0	(20)	18.5	18.3	22.9
30°	51.9	42.2	33.5	26.5	21.9	19.7	18.9	18.7	27.7
45°	86.3	64.3	43.8	31.1	24.9	22.6	22.8	23.5	36.8
60°	(180)	92.4	57.9	40.1	31.7	30.3	32.3	35.0	54.4
75°	198	146	90.2	63.9	53.5	55.2	62.7	70.0	85.2

Table 3.13.4. Green sky radiance (550 nm) in Oslo

θ_S=60°	GMT:1218	Date:96.09.19
$\cos\theta_S$=0.50	μ_D=0.38	μ_d=0.48
E_{oS}=1240 mW m^{-2} nm^{-1}	E_D=114 mW m^{-2} nm^{-1}	E_D/E_d=0.154
ρ_S=6.1%	ρ_D=10.3%	ρ_d=6.7%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	17.5								17.5
15°	25.7	(25)	21.7	(19)	16.9	(16)	14.8	14.4	18.7
30°	39.9	34.4	27.1	21.1	17.5	15.5	14.8	14.6	22.0
45°	72.6	54.2	36.3	25.7	19.8	18.0	18.0	18.6	30.2
60°	(160)	79.9	48.9	36.7	26.0	24.4	25.9	28.1	46.4
75°	172	130	77.8	52.5	43.0	43.8	49.1	56.0	71.6

Table 3.13.5. Red sky radiance (650 nm) in Oslo

θ_S=60°				GMT:1230				Date:96.09.19	
$\cos\theta_S$=0.50				μ_D=0.37				μ_d=0.48	
E_{oS}=1140 mW m^{-2} nm^{-1}				E_D=65.8 mW m^{-2} nm^{-1}				E_D/E_d=0.104	
ρ_S=6.1%				ρ_D=10.6%				ρ_d=6.6%	
ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	9.40								9.40
15°	14.2	(14)	11.8	(10)	8.81	(8.2)	7.72	7.38	9.98
30°	26.2	21.8	15.6	11.7	9.16	7.97	7.50	7.50	12.6
45°	46.5	34.7	20.9	14.0	10.4	9.04	8.93	9.16	17.4
60°	(100)	51.2	29.0	17.9	13.8	12.3	12.9	13.8	26.7
75°	113	84.3	47.8	29.8	23.6	23.4	26.1	29.8	42.8

Table 3.14.1. Violet sky radiance (405 nm) in Oslo

θ_S=38°				GMT:1152				Date:97.06.06	
$\cos\theta_S$=0.79				μ_D=0.50				μ_d=0.63	
E_{oS}=601 mW m^{-2} nm^{-1}				E_D=371 mW m^{-2} nm^{-1}				E_D/E_d=0.439	
ρ_S=2.4%				ρ_D=6.6%				ρ_d=4.2%	
ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	101								101
15°	173	157	130	108	88.5	76.9	(68)	66.9	104
30°	(400)	199	142	105	80.2	67.7	60.4	56.8	121
45°	(440)	221	150	103	78.2	65.2	58.6	55.6	126
60°	259	209	143	106	82.8	70.9	65.1	64.7	116
75°	215	185	141	107	87.2	77.7	74.9	76.0	114

Table 3.14.2. Blue sky radiance (450 nm) in Oslo

θ_S=38°	GMT:1155	Date:97.06.06
$\cos\theta_S$=0.79	μ_D=0.50	μ_d=0.65
E_{oS}=858 mW m^{-2} nm^{-1}	E_D=396 mW m^{-2} nm^{-1}	E_D/E_d=0.370
ρ_S=2.4%	ρ_D=6.8%	ρ_d=4.0%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	106								106
15°	179	(170)	135	(120)	91.6	(79)	69.6	68.4	109
30°	(460)	229	154	106	78.9	65.0	58.0	54.5	129
45°	(490)	247	155	103	74.2	61.5	55.7	54.5	132
60°	297	223	157	109	82.4	70.8	67.3	65.0	123
75°	259	219	165	119	95.1	82.4	81.2	80.0	130

Table 3.14.3. Green sky radiance (520 nm) in Oslo

θ_S=39°	GMT:1210	Date:97.06.06
$\cos\theta_S$=0.78	μ_D=0.49	μ_d=0.67
E_{oS}=993 mW m^{-2} nm^{-1}	E_D=294 mW m^{-2} nm^{-1}	E_D/E_d=0.275
ρ_S=2.5%	ρ_D=7.0%	ρ_d=3.7%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	70.7								70.7
15°	130	(120)	97.8	(81)	62.4	(54)	47.8	45.8	76.8
30°	(340)	171	119	80.1	57.2	43.7	37.4	34.3	94.5
45°	(390)	196	124	77.0	51.0	40.6	35.4	33.3	99.8
60°	218	184	120	78.0	56.2	45.8	42.6	41.6	90.3
75°	217	183	131	91.5	70.7	61.4	59.3	58.2	102

Table 3.14.4. Green sky radiance (550 nm) in Oslo

θ_S=39°	GMT:1222	Date:97.06.06
$\cos\theta_S$=0.78	μ_D=0.47	μ_d=0.68
E_{oS}=1120 mW m^{-2} nm^{-1}	E_D=242 mW m^{-2} nm^{-1}	E_D/E_d=0.218
ρ_S=2.5%	ρ_D=7.3%	ρ_d=3.5%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	61.7								61.7
15°	98.0	(93)	77.4	(66)	52.0	(46)	41.1	38.7	61.7
30°	(270)	133	92.0	62.9	46.0	35.1	31.5	30.3	75.1
45°	(310)	155	94.4	61.7	43.6	33.9	30.3	27.8	79.9
60°	192	151	98.0	65.3	48.4	38.7	35.1	35.1	75.7
75°	206	162	116	79.9	61.7	53.2	52.0	52.0	90.7

Table 3.14.5. Red sky radiance (650 nm) in Oslo

θ_S=40°	GMT:1234	Date:97.06.06
$\cos\theta_S$=0.77	μ_D=0.46	μ_d=0.70
E_{oS}=1070 mW m^{-2} nm^{-1}	E_D=141 mW m^{-2} nm^{-1}	E_D/E_d=0.147
ρ_S=2.5%	ρ_D=7.7%	ρ_d=3.3%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	36.9								36.9
15°	55.9	51.2	44.0	35.7	30.9	26.2	25.0	23.8	35.3
30°	102	77.4	52.4	35.7	26.2	21.4	19.0	17.9	40.2
45°	(190)	95.2	55.9	35.7	25.0	19.0	16.7	15.5	47.6
60°	126	92.8	59.5	38.1	26.2	21.4	19.0	17.9	45.1
75°	130	104	73.8	52.4	38.1	32.1	32.1	30.9	57.1

Table 3.14.6. Red sky radiance (650 nm) in Oslo

θ_S=69°	GMT:1700	Date:97.06.06
$\cos\theta_S$=0.36	μ_D=0.35	μ_d=0.36
E_{oS}=931 mW m^{-2} nm^{-1}	E_D=67.3 mW m^{-2} nm^{-1}	E_D/E_d=0.165
ρ_S=12.3%	ρ_D=11.7%	ρ_d=12.2%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	8.33								8.33
15°	12.5	(12)	10.7	(9.6)	8.33	(7.7)	7.14	7.14	9.17
30°	19.0	17.9	14.3	10.7	9.52	8.33	7.74	7.74	11.4
45°	40.5	30.9	20.2	14.3	10.7	9.52	9.52	9.52	16.7
60°	(77)	52.4	30.9	20.2	14.3	11.9	13.1	14.3	26.0
75°	(190)	94.0	54.7	33.3	25.0	27.4	27.4	29.8	51.0

Table 3.14.7. Green sky radiance (550 nm) in Oslo

θ_S=70°	GMT:1710	Date:97.06.06
$\cos\theta_S$=0.34	μ_D=0.35	μ_d=0.35
E_{oS}=908 mW m^{-2} nm^{-1}	E_D=112 mW m^{-2} nm^{-1}	E_D/E_d=0.264
ρ_S=13.5%	ρ_D=11.6%	ρ_d=13.0%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	14.5								14.5
15°	20.6	(20)	18.2	(17)	14.5	(14)	12.7	12.1	15.7
30°	31.5	27.8	23.0	19.4	15.7	14.5	13.9	13.9	19.2
45°	69.0	44.8	31.5	23.6	18.2	17.5	18.2	18.2	27.5
60°	(110)	78.7	49.6	32.7	26.6	26.6	28.4	29.6	43.6
75°	(290)	145	84.7	55.7	46.0	47.2	53.8	57.5	84.3

Table 3.14.8. Green sky radiance (520 nm) in Oslo

θ_S=71°	GMT:1722	Date:97.06.06
$\cos\theta_S$=0.33	μ_D=0.36	μ_d=0.33
E_{oS}=763 mW m^{-2} nm^{-1}	E_D=119 mW m^{-2} nm^{-1}	E_D/E_d=0.328
ρ_S=14.7%	ρ_D=10.9%	ρ_d=13.5%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	17.7								17.7
15°	22.9	(22)	20.3	(19)	17.7	(17)	15.6	16.1	18.5
30°	34.3	31.2	26.0	22.4	18.7	17.7	17.2	16.6	22.3
45°	59.3	48.9	37.0	28.1	21.8	21.3	22.4	22.4	30.9
60°	(110)	80.1	52.0	37.4	30.7	29.1	31.7	33.8	46.6
75°	(270)	135	82.2	56.2	45.8	47.8	55.1	58.2	81.8

Table 3.14.9. Blue sky radiance (450 nm) in Oslo

θ_S=73°	GMT:1734	Date:97.06.06
$\cos\theta_S$=0.29	μ_D=0.38	μ_d=0.33
E_{oS}=532 mW m^{-2} nm^{-1}	E_D=165 mW m^{-2} nm^{-1}	E_D/E_d=0.512
ρ_S=17.7%	ρ_D=10.4%	ρ_d=14.0%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	25.5								25.5
15°	32.5	(32)	29.0	(28)	26.7	(25)	24.4	24.4	27.4
30°	45.8	42.9	37.1	31.9	29.0	27.3	27.3	27.3	32.8
45°	75.4	63.8	49.9	40.6	34.8	33.6	36.0	37.1	44.5
60°	(130)	99.8	69.6	52.2	45.2	46.4	51.0	54.5	64.4
75°	(320)	158	103	75.4	66.1	69.6	78.9	85.8	106

Table 3.14.10. Violet sky radiance (405 nm) in Oslo

θ_S=74°				GMT:1746			Date:97.06.06		
$\cos\theta_S$=0.28				μ_D=0.40			μ_d=0.34		
E_{oS}=250 mW m^{-2} nm^{-1}				E_D=142 mW m^{-2} nm^{-1}			E_D/E_d=0.676		
ρ_S=19.5%				ρ_D=9.7%			ρ_d=12.9%		
ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	24.9								24.9
15°	29.5	(29)	27.6	(26)	24.7	(24)	23.7	23.4	25.8
30°	58.1	39.0	34.4	30.2	27.6	26.9	26.9	27.2	32.1
45°	57.4	52.1	42.7	35.5	31.7	31.4	32.9	33.7	38.5
60°	(110)	79.2	59.3	46.3	40.8	41.8	46.5	48.8	55.4
75°	(230)	115	79.5	59.8	53.3	56.4	64.6	69.6	81.5

Table 3.15.1. Red sky radiance (650 nm) in Oslo

θ_S=38°				GMT:1140			Date:97.07.09		
$\cos\theta_S$=0.79				μ_D=0.43			μ_d=0.75		
E_{oS}=1220 mW m^{-2} nm^{-1}				E_D=65.3 mW m^{-2} nm^{-1}			E_D/E_d=0.0635		
ρ_S=2.4%				ρ_D=8.4%			ρ_d=2.8%		
ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	14.1								14.1
15°	(18)	(18)	17.9	(16)	13.1	(12)	10.5	10.6	13.2
30°	(60)	31.2	21.4	16.1	13.7	10.6	9.28	9.28	18.7
45°	(75)	36.5	23.6	17.3	13.4	11.3	10.3	9.76	21.1
60°	38.6	32.0	25.2	18.7	14.9	13.4	13.4	13.7	20.0
75°	48.3	41.9	33.7	27.0	24.5	(26)	26.8	30.1	31.0

Table 3.15.2. Green sky radiance (520 nm) in Oslo

θ_S=38°	GMT:1158	Date:97.07.09
$\cos\theta_S$=0.79	μ_D=0.44	μ_d=0.71
E_{oS}=1230 mW m^{-2} nm^{-1}	E_D=147 mW m^{-2} nm^{-1}	E_D/E_d=0.132
ρ_S=2.4%	ρ_D=8.4%	ρ_d=3.2%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	31.4								31.4
15°	46.1	52.1	38.5	34.5	30.1	27.4	25.6	24.0	34.0
30°	(100)	(85)	46.9	37.0	30.4	26.3	24.6	27.7	47.4
45°	(130)	65.8	52.1	39.5	30.9	27.8	26.6	25.0	44.2
60°	82.3	67.4	56.5	45.2	38.3	36.5	35.3	36.6	47.7
75°	98.5	88.2	72.6	60.4	60.0	58.6	60.6	67.5	69.1

Table 3.15.3. Violet sky radiance (405 nm) in Oslo

θ_S=39°	GMT:1219	Date:97.07.09
$\cos\theta_S$=0.78	μ_D=0.45	μ_d=0.65
E_{oS}=829 mW m^{-2} nm^{-1}	E_D=229 mW m^{-2} nm^{-1}	E_D/E_d=0.263
ρ_S=2.5%	ρ_D=8.0%	ρ_d=3.9%

ϕ / θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	56.4								56.4
15°	74.5	(70)	65.2	(60)	53.2	(49)	45.2	42.2	56.3
30°	(165)	84.3	74.1	61.3	51.9	44.8	43.5	41.3	64.5
45°	(190)	96.7	82.1	66.1	53.7	49.7	47.5	46.1	71.4
60°	118	97.6	91.4	74.1	67.0	61.3	69.2	61.2	78.0
75°	138	129	110	92.3	84.3	83.8	83.4	86.1	98.2

Table 3.16.1. Red sky radiance (650 nm) in Oslo

θ_S=45°	GMT:1105	Date:97.08.15
$\cos\theta_S$=0.71	μ_D=0.44	μ_d=0.65
E_{oS}=1110 mW m^{-2} nm^{-1}	E_D=116 mW m^{-2} nm^{-1}	E_D/E_d=0.130
ρ_S=2.9%	ρ_D=8.2%	ρ_d=3.6%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	22.1								22.1
15°	36.3	(35)	31.5	26.4	20.7	(18)	15.1	13.6	23.7
30°	(110)	(55)	43.4	28.9	19.4	14.6	12.1	11.1	31.8
45°	(150)	(75)	48.4	29.5	19.6	14.3	12.3	11.4	37.9
60°	(105)	87.4	54.4	32.3	21.7	17.3	15.9	15.9	39.7
75°	119	99.3	68.5	43.6	31.5	27.2	27.2	29.0	51.5

Table 3.16.2. Violet sky radiance (405 nm) in Oslo

θ_S=45°	GMT:1201	Date:97.08.15
$\cos\theta_S$=0.71	μ_D=0.46	μ_d=0.59
E_{oS}=698 mW m^{-2} nm^{-1}	E_D=256 mW m^{-2} nm^{-1}	E_D/E_d=0.343
ρ_S=2.9%	ρ_D=7.7%	ρ_d=4.5%

ϕ θ	0°	24°	48°	72° (mW m^{-2} nm^{-1} sr^{-1})	96°	120°	144°	180°	mean
0°	69.6								69.6
15°	79.8	(75)	71.0	(65)	56.2	(50)	44.8	42.2	59.3
30°	117	112	87.4	67.0	54.5	46.1	41.7	39.9	67.6
45°	(250)	(125)	106	71.9	56.4	47.9	44.8	43.5	82.1
60°	(215)	180	110	77.6	62.1	56.4	55.0	56.4	94.1
75°	197	170	116	87.0	73.6	70.1	72.8	76.3	102

Table 4.1. Polarization of red sky radiance (650 nm) in Oslo

θ_s=45°				GMT:1105			Date:97.08.15	
ϕ / θ	0°	24°	48°	72° (%)	96°	120°	144°	180°
0°	23.3							
15°	11.4	-	13.7	-	21.6	-	34.1	39.0
30°	-	-	11.5	18.4	28.2	43.2	53.4	58.2
45°	-	-	6.8	21.3	37.3	53.5	62.2	65.2
60°	-	6.3	12.8	30.3	51.1	63.5	62.5	54.2
75°	7.7	11.5	21.5	42.2	58.9	62.2	48.8	37.1

Table 4.2. Polarization of violet sky radiance (405 nm) in Oslo

θ_s=45°				GMT:1136			Date:97.08.15	
ϕ / θ	0°	24°	48°	72° (%)	96°	120°	144°	180°
0°	21.3							
15°	7.8	-	11.3	-	23.6	-	36.6	41.1
30°	3.8	4.0	7.6	17.9	28.5	40.4	48.9	53.3
45°	0.4	7.0	10.5	23.5	40.2	53.7	58.4	59.2
60°	1.0	5.7	14.9	32.6	50.0	59.1	56.5	49.6
75°	2.9	7.8	23.7	38.7	56.6	55.7	45.1	32.6

Table 5.1.1. Relative error of reflected red sky radiance (650 nm) in Oslo

θ_s=45°				GMT:1105			Date:97.08.15	
ϕ / θ	0°	24°	48°	72° (%)	96°	120°	144°	180°
0°	0							
15°	-3.8	-	-1.5	-	-0.4	-	-4.5	-6.9
30°	-	-	2.9	5.3	4.0	-3.5	-14.6	-22.3
45°	-	-	5.1	12.7	9.1	-8.2	-26.4	-36.8
60°	-	-0.7	3.3	8.2	3.9	-13.0	-27.8	-34.1
75°	-3.3	-2.5	-0.1	1.9	0.8	-5.8	-12.0	-14.9

Table 5.1.2. Relative error of reflected violet sky radiance (405 nm) in Oslo

θ_s=45°				GMT:1136			Date:97.08.15	
ϕ / θ	0°	24°	48°	72° (%)	96°	120°	144°	180°
0°	0							
15°	-3.4	-	-1.7	-	-0.2	-	-4.6	-7.1
30°	-3.9	-2.0	1.0	5.1	4.1	-3.5	-13.7	-21.0
45°	-	-	8.5	14.4	9.9	-8.3	-25.1	-34.6
60°	-	-0.6	4.2	9.2	3.9	-12.2	-25.8	-32.2
75°	-1.2	-1.7	-0.1	2.2	0.8	-5.2	-11.2	-13.3

Table 5.2.1. Relative error of reflected red sky radiance (650 nm) in Oslo

θ_s=51°				GMT:1140			Date:97.07.09	
ϕ / θ	0°	24°	48°	72° (%)	96°	120°	144°	180°
0°	0							
15°	-2.6	-	-1.8	-	-0.4	-	-4.5	-7.4
30°	-	-4.1	-0.6	3.8	3.5	-3.7	-14.5	-22.0
45°	-	-3.4	9.7	9.4	8.4	-9.5	-27.2	-39.4
60°	-3.5	-0.8	0.4	3.4	-2.9	-18.6	-31.6	-39.6
75°	-6.4	-4.6	-2.3	0.6	-1.7	-12.7	-13.1	-16.1

Table 5.2.2. Relative error of reflected green sky radiance (520 nm) in Oslo

θ_S=50°				GMT:1158			Date:97.07.09	
ϕ / θ	0°	24°	48°	72° (%)	96°	120°	144°	180°
0°	0							
15°	-3.6	-5.3	-1.9	-0.6	-0.1	-1.6	-4.1	-7.0
30°	-	-	2.7	4.5	3.3	-4.6	-13.6	-22.9
45°	-	-2.9	6.9	12.1	4.4	-15.0	-29.0	-38.8
60°	-4.1	-9.6	-0.1	5.1	-1.9	-17.4	-30.6	-37.5
75°	-5.6	-4.7	-2.0	-0.7	-4.4	-8.7	-13.9	-15.9

Table 5.2.3. Relative error of reflected violet sky radiance (405 nm) in Oslo

θ_S=49°				GMT:1219			Date:97.07.09	
ϕ / θ	0°	24°	48°	72° (%)	96°	120°	144°	180°
0°	0							
15°	-3.3	-	-1.9	-	-0.4	-	-4.7	-7.3
30°	-	0.0	2.3	5.8	6.1	-1.9	-14.0	-22.0
45°	-	3.4	7.8	16.0	10.6	-11.3	-27.3	-36.2
60°	0.0	7.4	3.9	8.2	-1.5	-13.7	-20.7	-34.5
75°	-4.5	-3.7	-1.1	0.0	-1.3	-6.2	-10.7	-12.5

Table 6. Reflectance ρ_D of polarized and unpolarized diffuse irradiance in Oslo and the corresponding error $\rho_{D,pol}$ - $\rho_{D,unpol}$

Date	θ_S °	λ nm	$\rho_{D,pol}$	$\rho_{D,unpol}$	$\rho_{D,pol} - \rho_{D,unpol}$
97.07.09	49	405	0.0858	0.0830	0.0028
97.07.09	50	520	0.0930	0.0881	0.0049
97.07.09	51	650	0.0934	0.0893	0.0041
97.08.15	45	405	0.0780	0.0762	0.0018
97.08.15	45	650	0.0796	0.0781	0.0015

Table 7. The ratio between the azimuthal mean $\bar{L}(\theta)$ and $[L(0°)\,L(180°)]^{0.5}$ for all 90 observation series

θ °	Mean value	Standard Deviation
15	1.02	0.08
30	1.05	0.05
45	1.09	0.13
60	1.18	0.21
75	1.14	0.17