Effect of polarization on UV sky radiance during twilight

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Representation of polarised radiance

Stokes vector $\mathbf{I} = \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$ characterizes the polarized light in an atmosphere.

I describes the intensity measured by a polarization non-sensitive instrument. And the others define the plane and ellipticity of polarization. I, V, and $\sqrt{Q^2 + U^2}$ are invariant under a rotation of axes, while Q and U are defined with respect to a certain reference plane.

The degree of linear polarization: $P_{lin} = \sqrt{Q^2 + U^2} / I$.

Main goals

- To investigate UV radiance during twilight which is under strong influence of ozone, aerosol and surface albedo, and is interesting for estimation of radiative budget and for climatic research
  - To evaluate accuracy of scalar calculation relative to more accurate vector modeling of scattered radiance
- To simulate the polarized radiance measured from the ground during twilight which may be exploited for remote sensing

Factors affecting on polarization at twilight

- Strong polarization due to:
  - Rayleigh single scattering at 90 degree
- Decrease of polarization because of:
  - Multiple scattering
  - Aerosol scattering
  - Scattering angle differ from 90 degree

Radiative transfer model MCC++

See also posters E27, G35, and oral E8

- was designed for use in algorithms for retrieval of the aerosol and gas distributions in the Earth atmosphere basing on measurements of the visual and UV scattered solar radiation:
  - polarization
  - spherical atmosphere (spherically symmetrical)
  - surface reflectance
  - simultaneous calculation of **derivatives** with respect to absorption, and **intensities**
  - multiple scattering **for both**

Radiative transfer model MCC++

See also posters E27

Methods used for calculations:

- Monte Carlo method of conjugate walk (backward method) for multiple scattering
- Monte Carlo method of modified double local estimation for multiple scattering at twilight
- direct integration of source function for single scattering

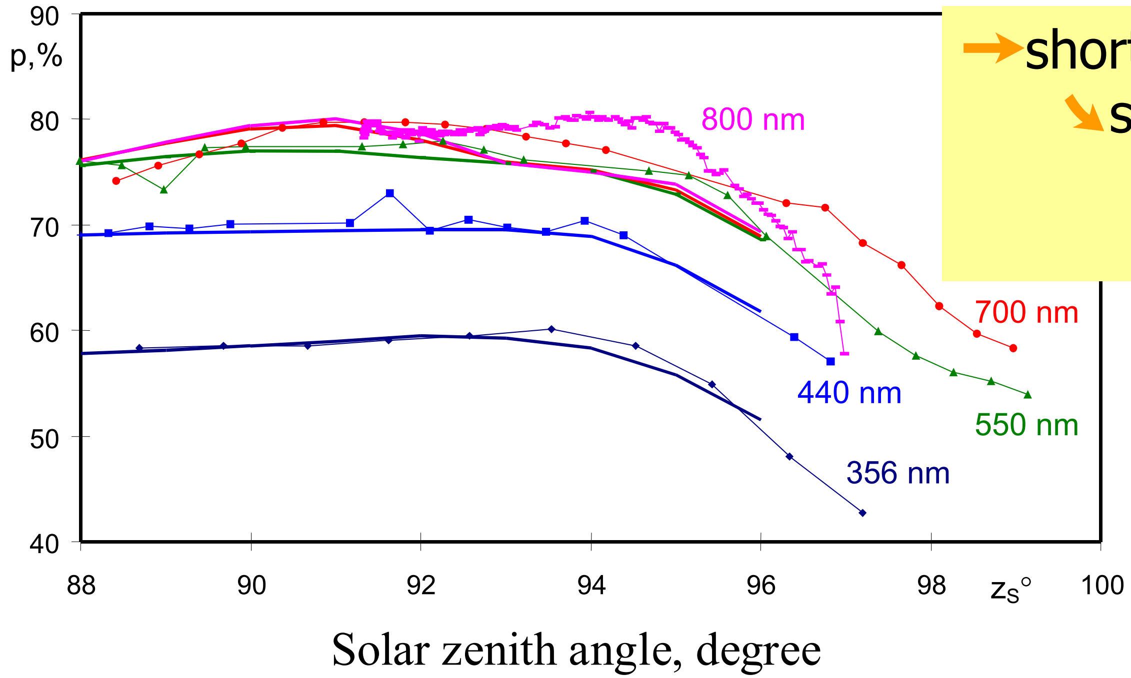
Validation of the MCC++ model

See also posters E27

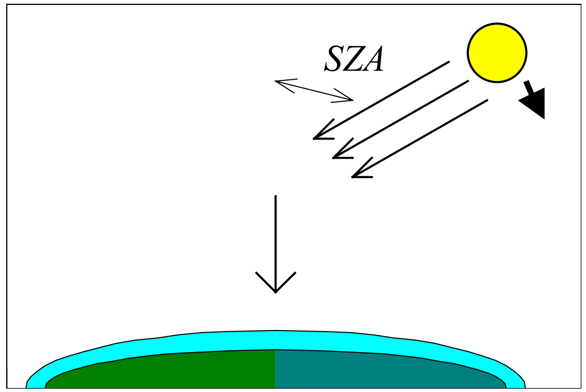
Model	Authors	Projects
GOMETRAN, CDI, CDIPI, SCITRAN	V. Rozanov, A. Rozanov	GOME, SCIAMACHY
-	Sh.Nikolaishvili, Yu.Belikov	Some projects in Russia
GSS	B. Herman	Umkehr method, TOMS, SBUV
-	J.B. Dave	Umkehr method
SIRO	Oikarinen L., E. Sihvola	OSIRIS/Odin
LIMBTRAN	Griffioen, E.	OSIRIS/Odin
GSLS	D. E. Flittner, R. Loughman	SAGE III - limb

Polarization at the zenith during twilight

See also posters G35

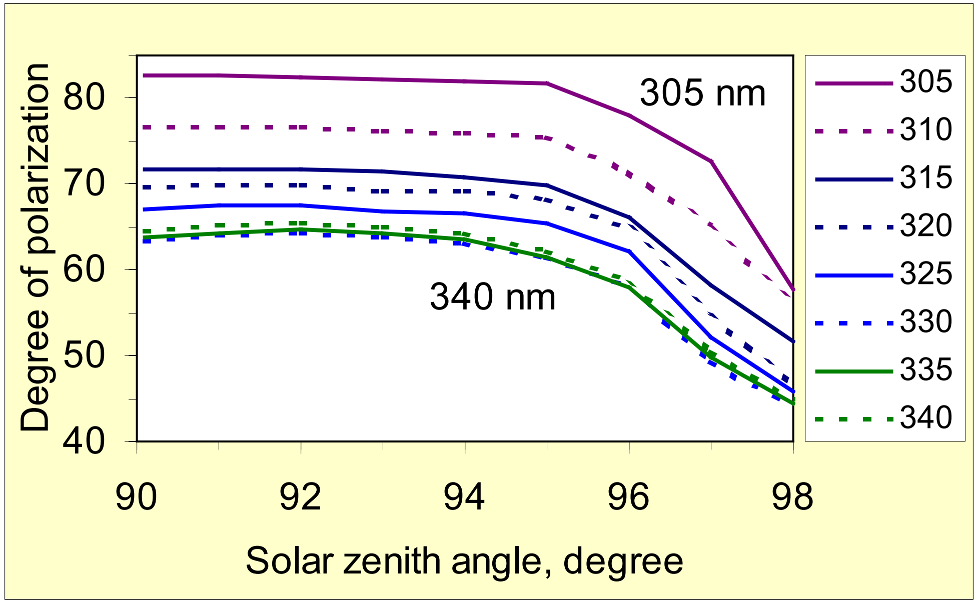


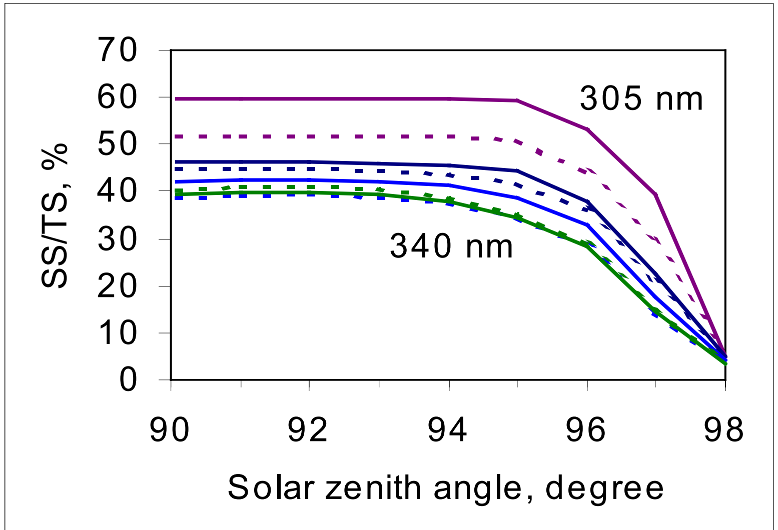
→shorter wavelength
↘stronger Rayleigh scattering
↘more multiple scattering
↘smaller polarization

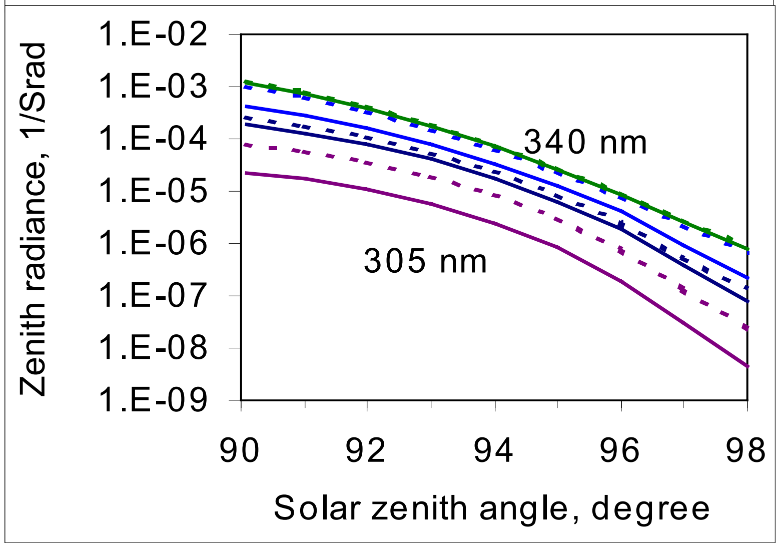


Comparison of the **calculated** (bold solid lines) and **measured** (solid lines with markers) degree of linear polarization, **p**, at the zenith for different wavelengths: 356 nm (the evening, July 31th, 1997), 440 nm (the morning, July 28th, 2000), 550 nm and 700 nm (the evening, August 4th, 2000), 800 nm (the evening, December 17th, 1999). Calculation for the urban type of aerosol..

Polarization at the zenith during twilight







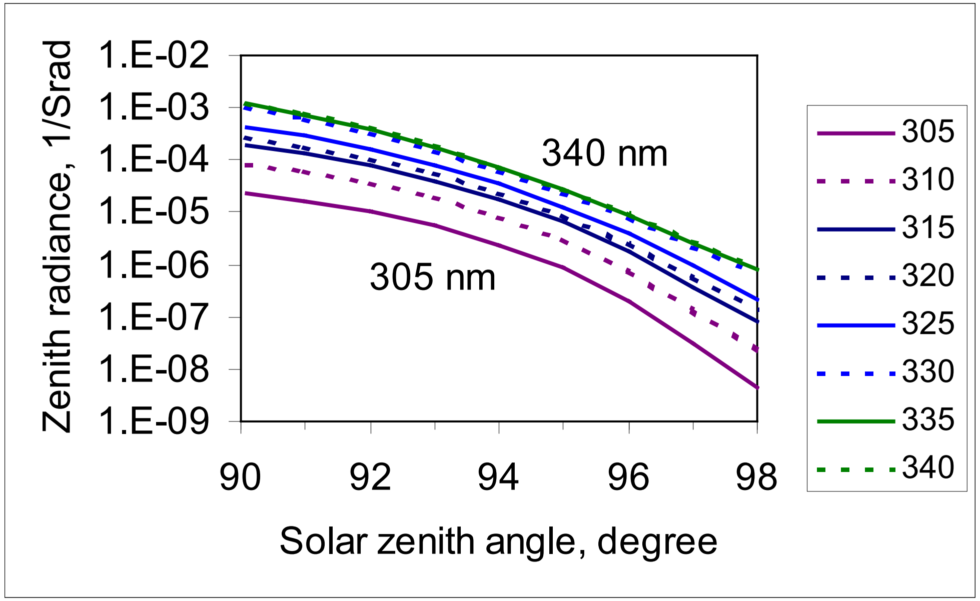
→ shorter wavelength

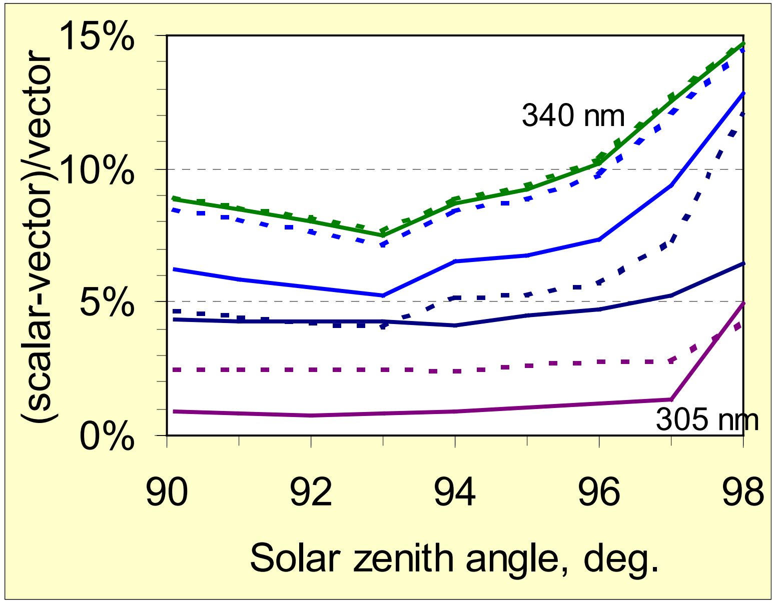
↘ stronger ozone absorbtion

↘ more Rayleigh single scattered photons

↘ larger polarization

Error of the scalar calculation of the zenith intensity

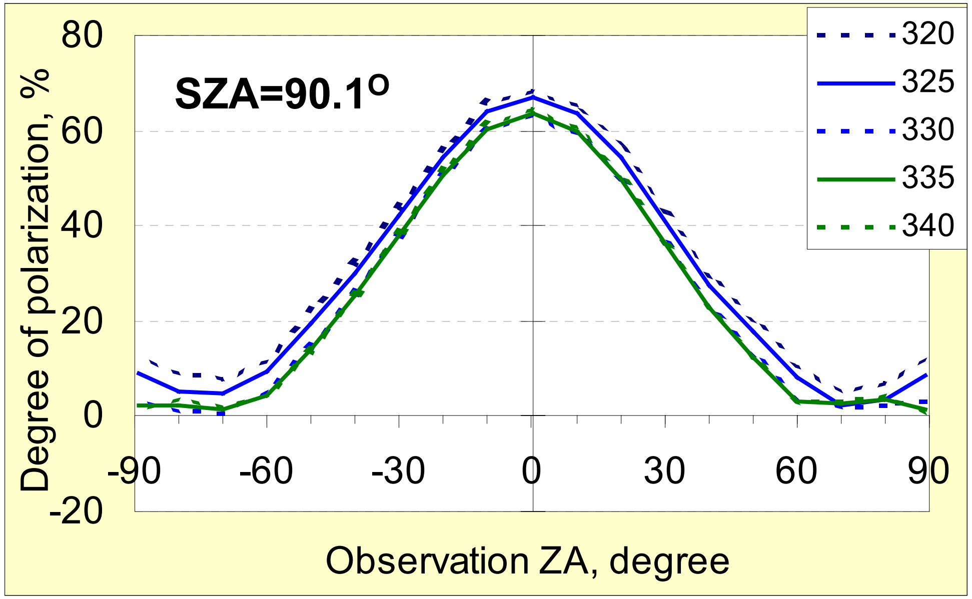


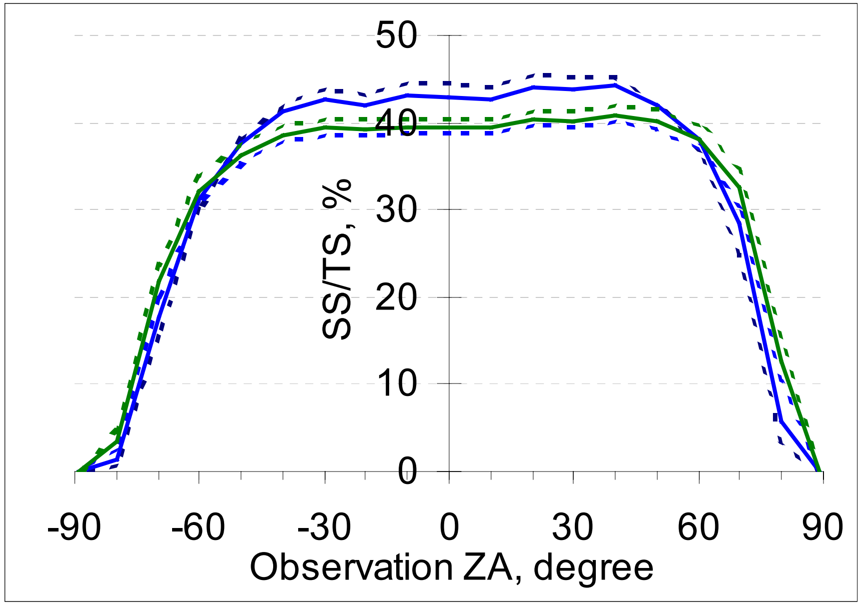


- unpolarized light from the Sun
  - Rayleigh or aerosol first scattering
    - partially polarized light
      - different source functions of the components in two perpendicular polarization directions for second scattering
- resulting intensity field differ from the scalar calculation

Scalar calculation of intensity may overestimate zenith radiance up to 15%

Polarization of the sky during twilight

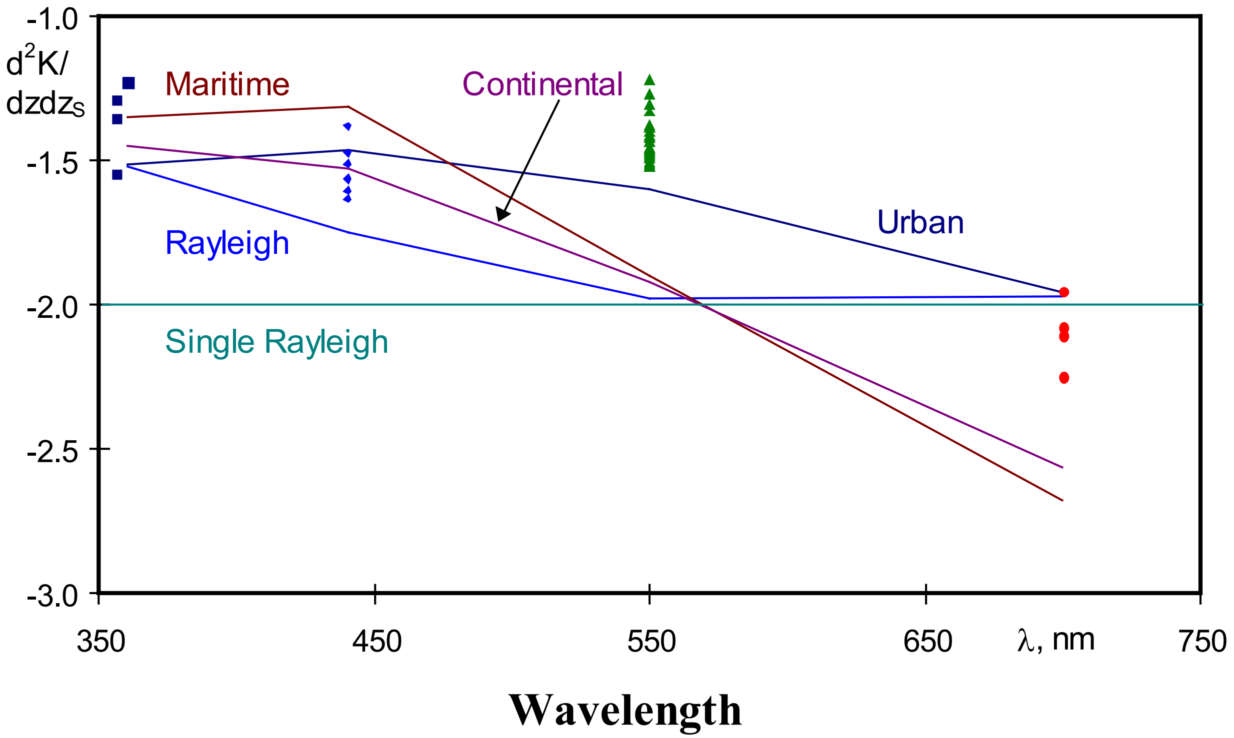




- -50^{o} < Observation ZA < 50^{o}
  - SS/TS changes slightly
  - polarization depends on the phase matrix of aerosol/molecules mixture
    - angle dependence of polarization may be used for remote sensing of the phase matrix

Use of second derivatives of polarization

See also posters G35

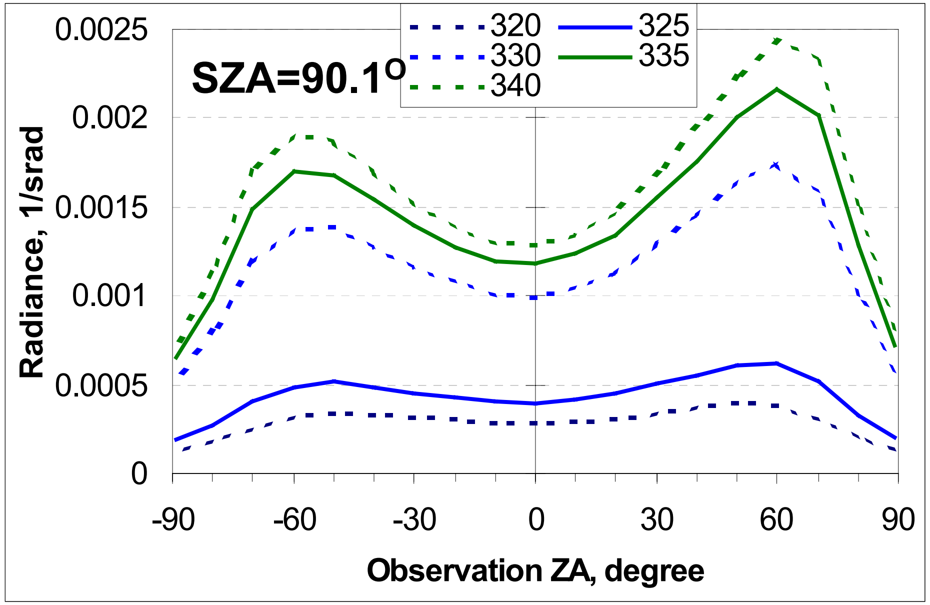


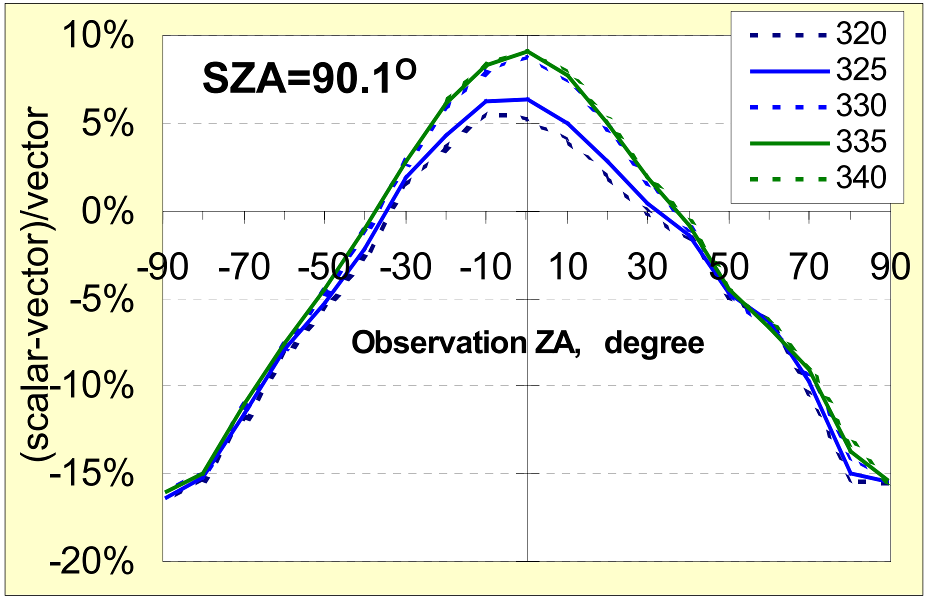
The polarization ratio second mixed derivative $\mathbf{d^2K/dzdz_S}$ obtained from 1997, 2000 and 2002 observations (dots) compared with radiative transfer simulation for pure Rayleigh scattering and different types of aerosol (solid lines). Solar zenith angle is equal to 90°.

Urban, Maritime, Continental aerosol taken from:

WMO, World Climate Program: A preliminary cloudless standard atmosphere for radiation computation // WCP-112, Radiation Commission, Int. Assoc. of Meteorol. and Atmos. Phys. 1986.

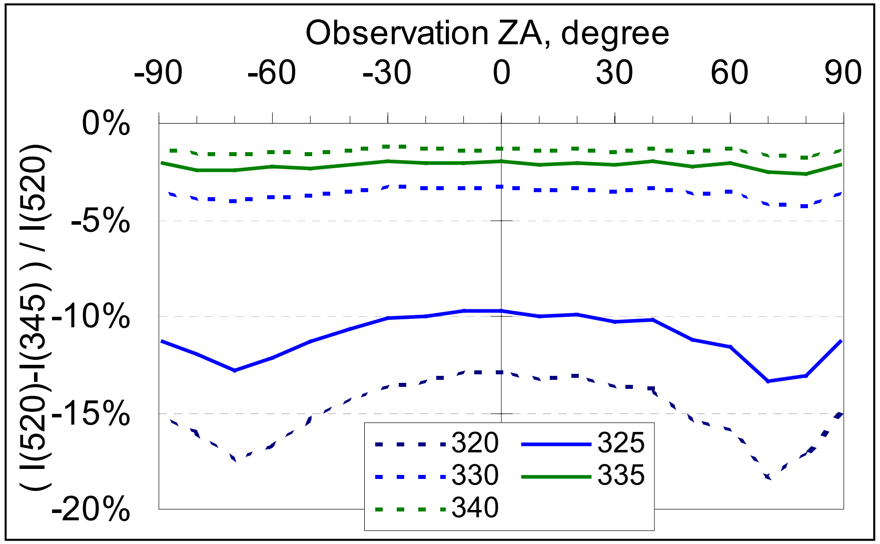
Error of the scalar calculation of the zenith intensity

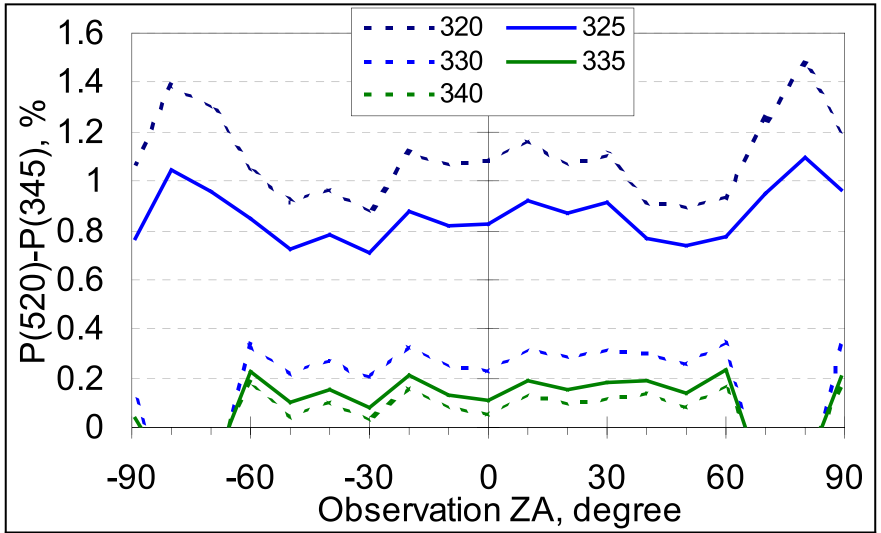


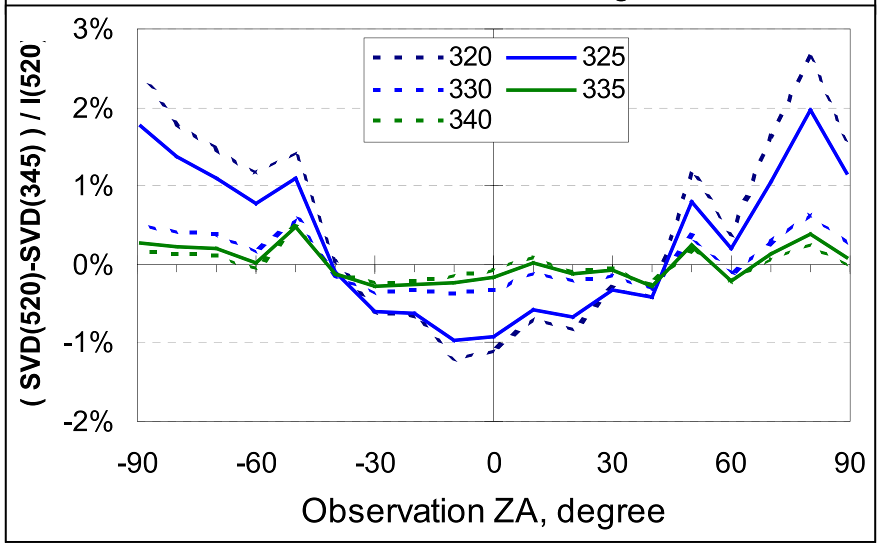


- Scalar calculations of the skylight intensity have error at SZA=90.1°
- Error depends on the direction of observation
- Scalar RT model
  - overestimate intensity in the zenith direction up to 9±1%
  - underestimate intensity in the horizontal direction up to 16±1%
  - underestimate integral intensity in principal plane up to 3±1%

Radiance changes due to TOC increase







TOC increase from
345 to 520 DU

Scalar RT model errors decrease due to increase of single scattering part of light

Conclusion

- Scalar RT model calculates UV intensity during twilight with significant error. The error strongly varies with wavelength, direction of observation, and solar position.
- Uncovered distortion of radiance field by scalar model reaches maximum of 16±1% at 340 nm. It may be underestimation or overestimation of radiance intensity depending on the solar ZA and the observation ZA.
- Shorter wavelengths has smaller error - about 5% at 305 nm due to larger part of single scattered light.
- A scalar RT model underestimate integral intensity in principal plane up to 3±1% at SZA=90.1^{o} for wavelengths from 320 to 340 nm.
- Multiangle observations of polarization have informationabout aerosol phase function

Thanks!