Effect of polarization on UV sky radiance during twilight

O.V. Postylyakov (1), J. Lenoble (2), I.V. Mitin (3),

(1) A.M. Obukhov Institute of Atmospheric Physics, RAS, Moscow, Russia

ovp@ifaran.ru

(2) IRSA, UJF, Grenoble and LOA, USTL, Lille, France

(3) M.V. Lomonosov Moscow State University, Moscow, Russia

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++

- 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), including twilight conditions
  - surface reflectance
  - simultaneous calculation of **derivatives** with respect to absorption, and **intensities**
  - multiple scattering **for both**

Radiative transfer model MCC++

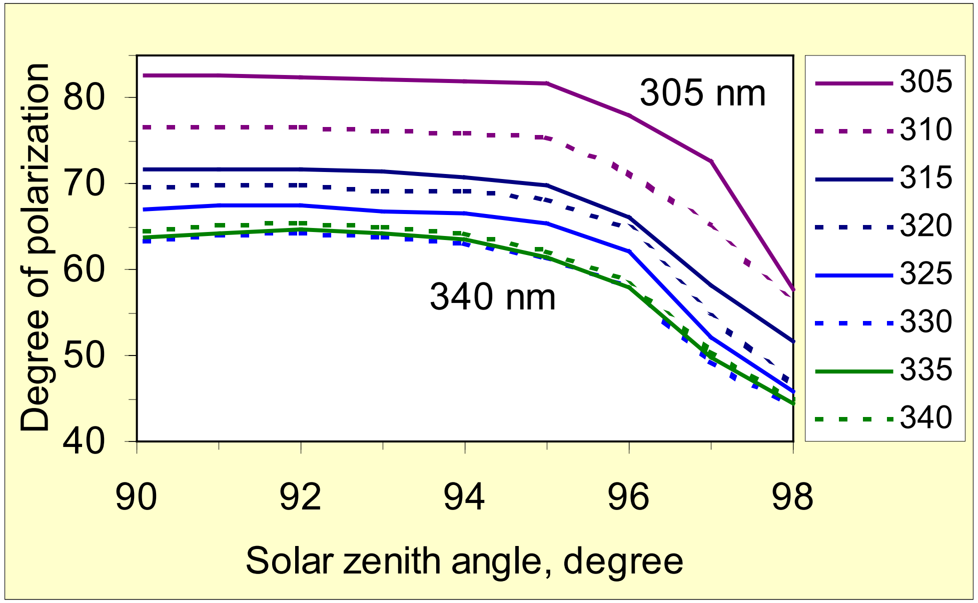
Methods used for calculations:

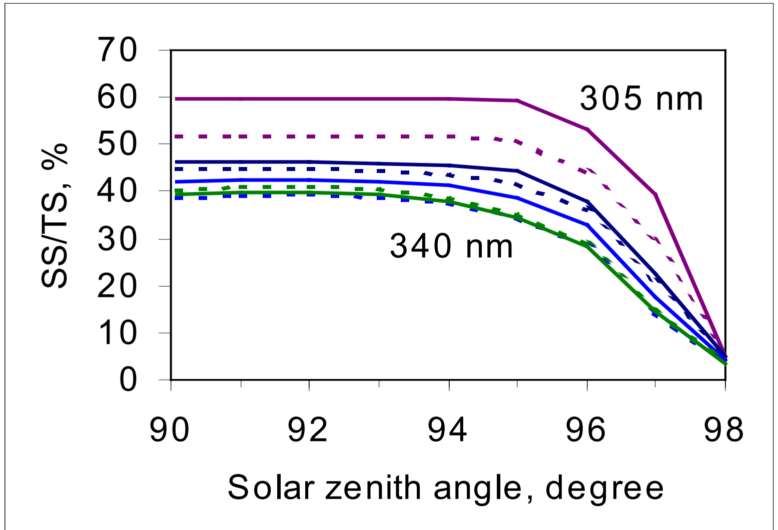
- Monte Carlo method of conjugate walk (backward method) for multiple scattering
- Monte Carlo method of modified double local estimation for multiple scattering at twilight
- direct integration of source function for single scattering

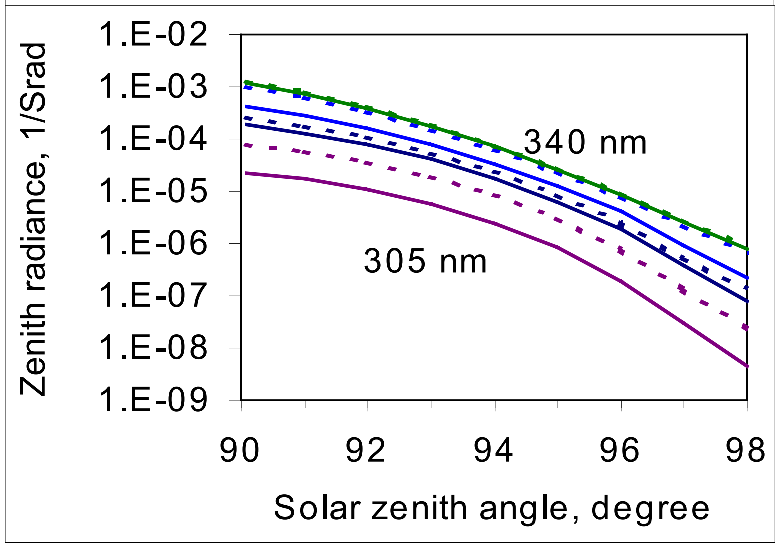
Validation of the MCC++ model

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







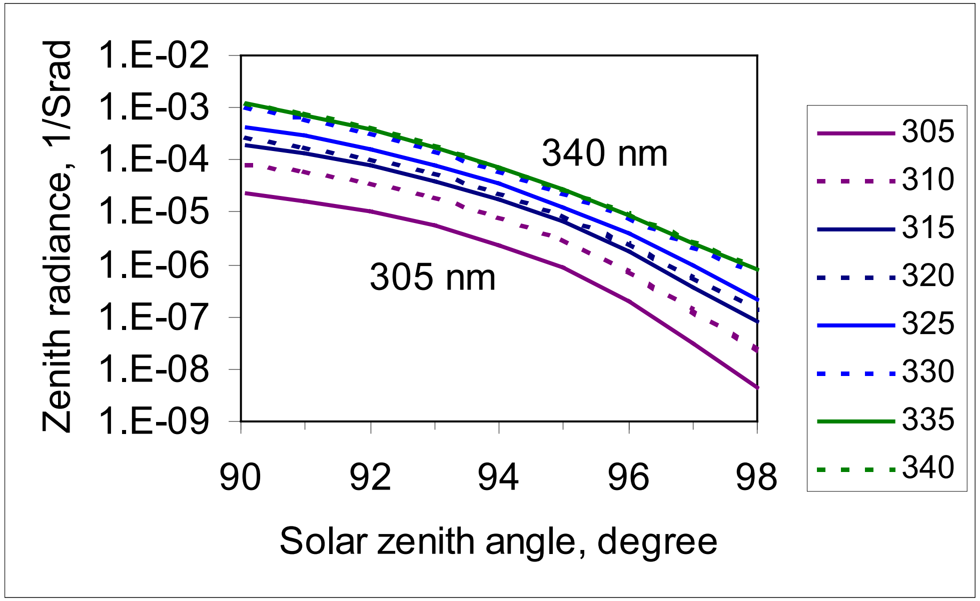
→ shorter wavelength

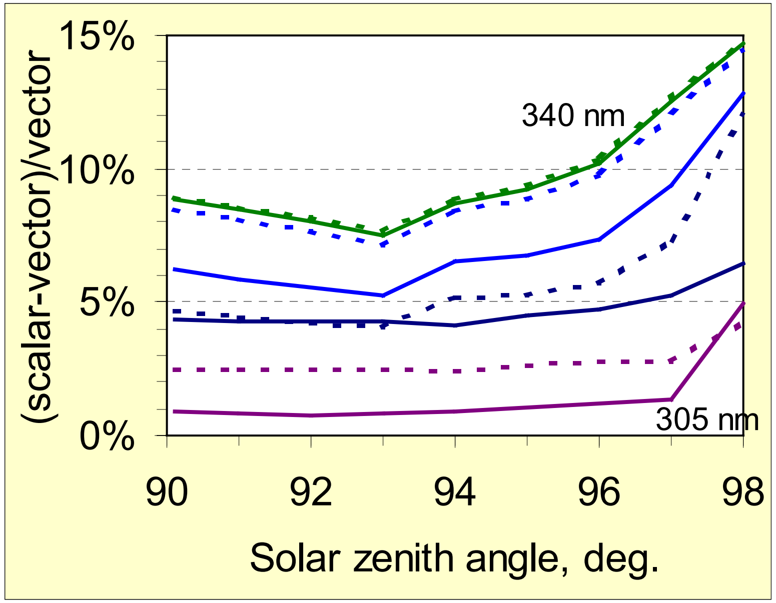
↘ stronger ozone absorbtion

↘ more Rayleigh single scattered photons

↘ larger polarization

Error of the scalar calculation of the zenith intensity

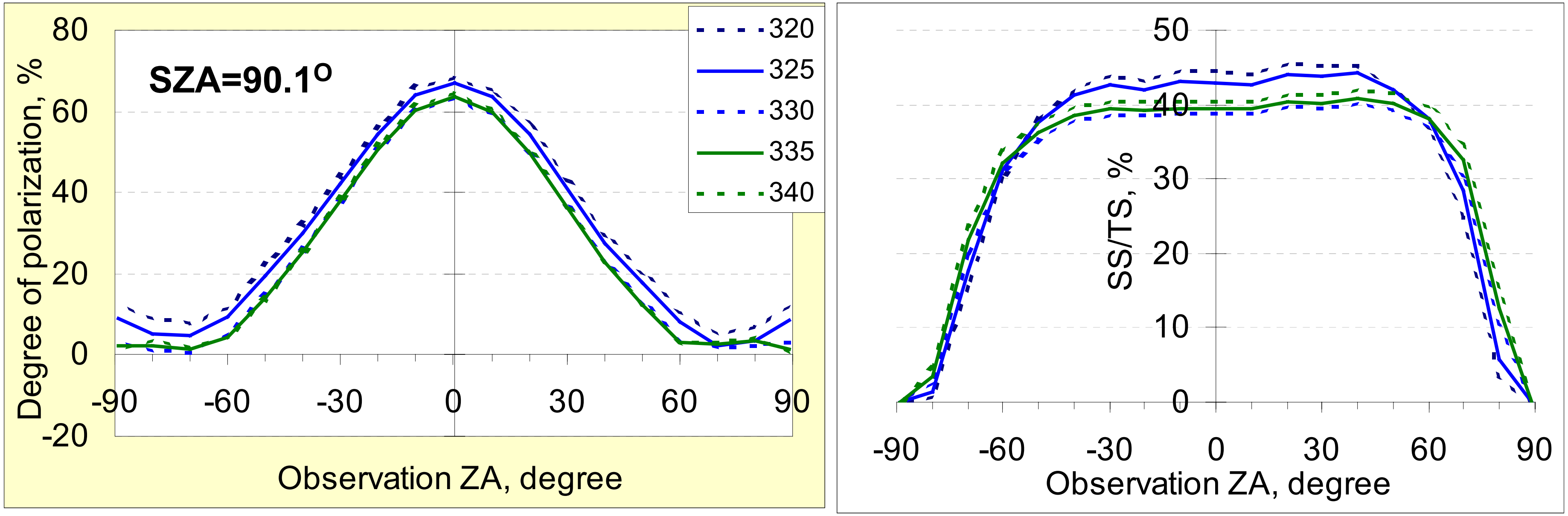




Scalar calculation of intensity may overestimate zenith radiance up to 15%

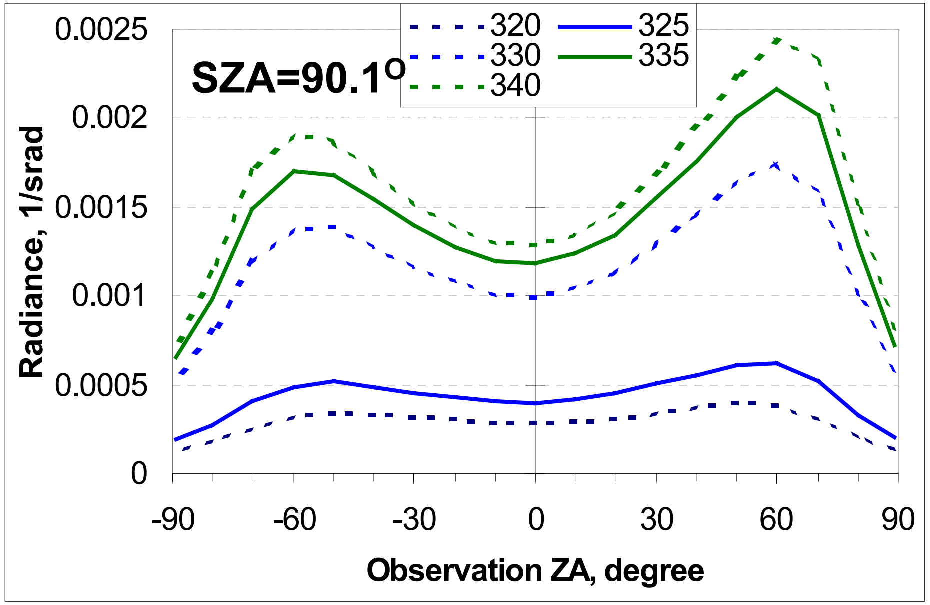
- unpolarized light from the Sun
  - Rayleigh or aerosol first scattering
    - partially polarized light
      - different source functions of the components in two perpendicular polarization directions for second scattering
- resulting intensity field differ from the scalar calculation

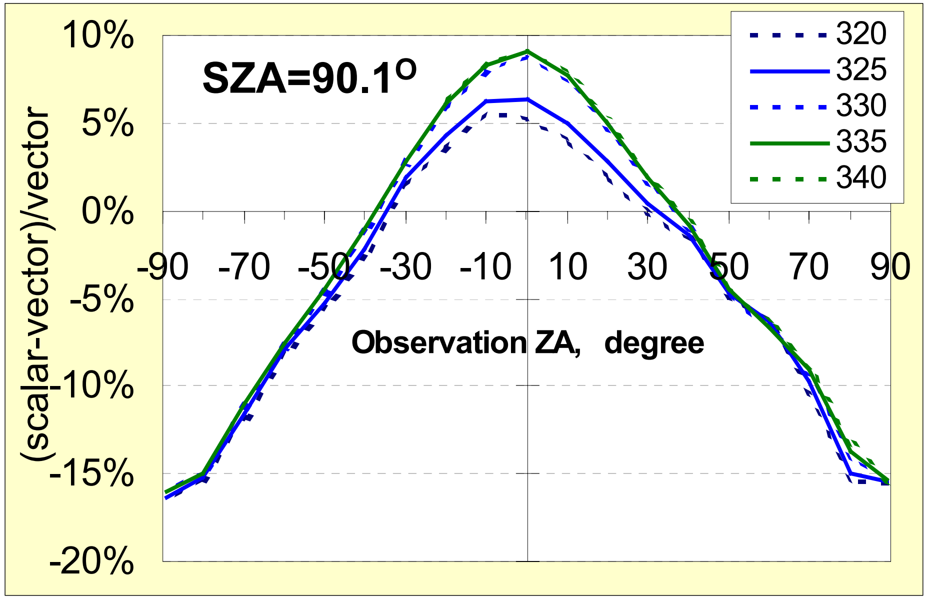
Polarization of the sky during twilight



- -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

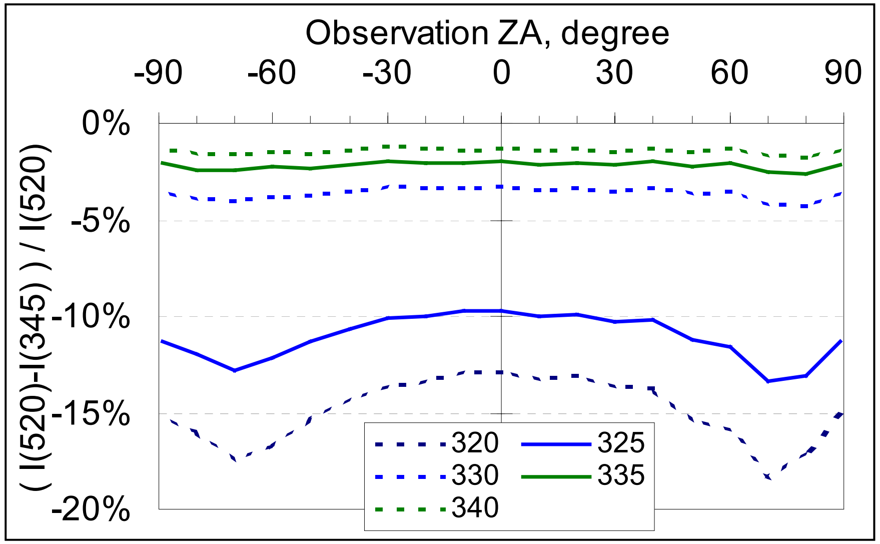
Error of the scalar calculation of the zenith intensity

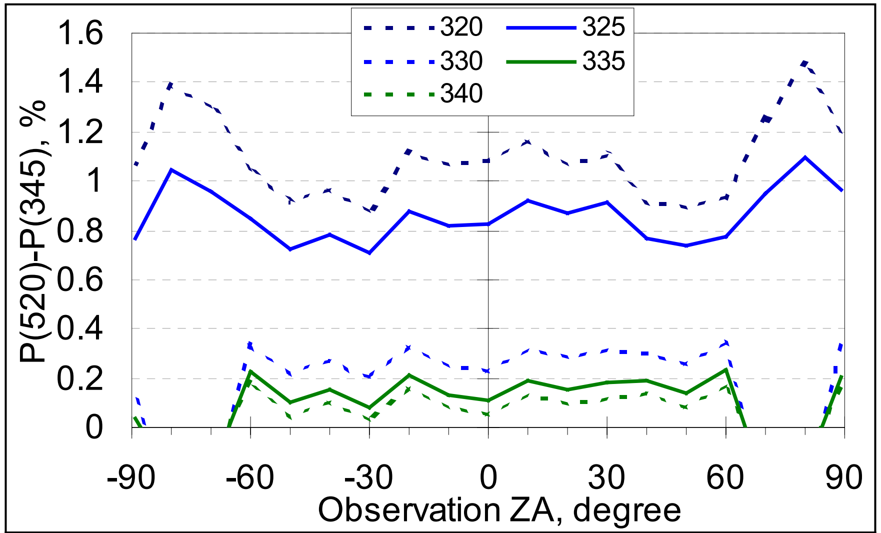


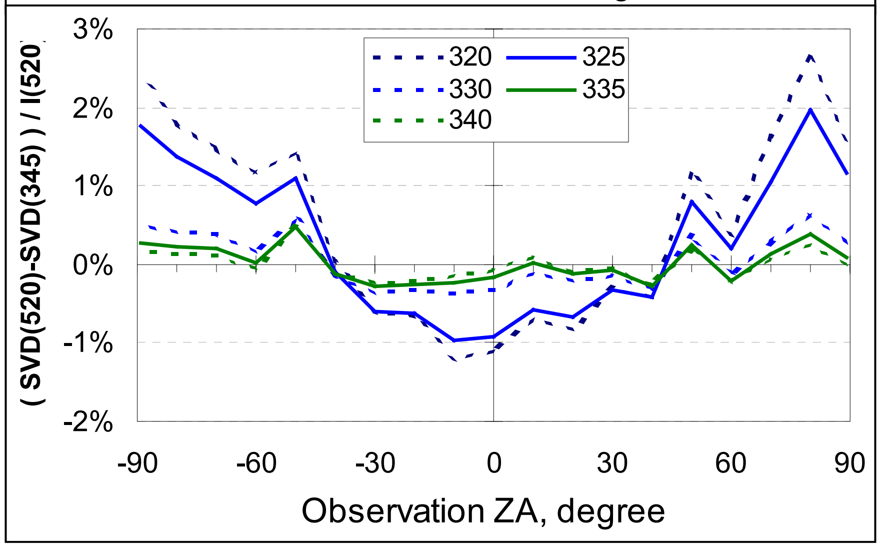


- Scalar calculations of the skylight intensity have error at SZA=90.1°
- Error depends on the direction of observation
- Scalar RT model
  - overestimate intensity in the zenith direction up to 9±1%
  - underestimate intensity in the horizontal direction up to 16±1%
  - underestimate integral intensity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

Thanks!