Sensitivity study of the radiance to optical and microphysical properties of nonspherical dust aerosols

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1. Background and method

Aerosols influence the atmospheric radiation balance not only through directly absorbing and scattering solar radiation, but also altering the radiation properties of clouds by acting as cloud condensation nuclei. Tropospheric aerosols have been considered the most uncertain part of the climate forcing. For a cloud-free and dusty pixel, the radiance measured by the airborne instrument is affected by the optical depth and single-scattering properties. Single-scattering properties are mainly determined by particle size, complex refractive index and particle aspect ratio.

To understand and quantify how much these parameters affect the visible and infrared radiance measured by the Airborne Multiangle SpectroPolarimetric Imager (AirMSPI), the sensitivities of the radiance to the optical and microphysical properties (i.e., aerosol optical thickness, complex refractive index and particle aspect ratio) of nonspherical aerosol were studied at the wavelengths of AirMSPI's bands with polarization (i.e., 470, 660, and 865 nm).

In this study, an existing tri-axial ellipsoidal mineral dust aerosol database was used. And an adding-doubling radiative transfer model was used to simulate the radiance received by the AirMSPI.

2. Bulk scattering phase matrix for different AR

We assumed that the dust particle size distribution is lognormal and the effective radius and radius variance are 1.6μm and 2μm, respectively.

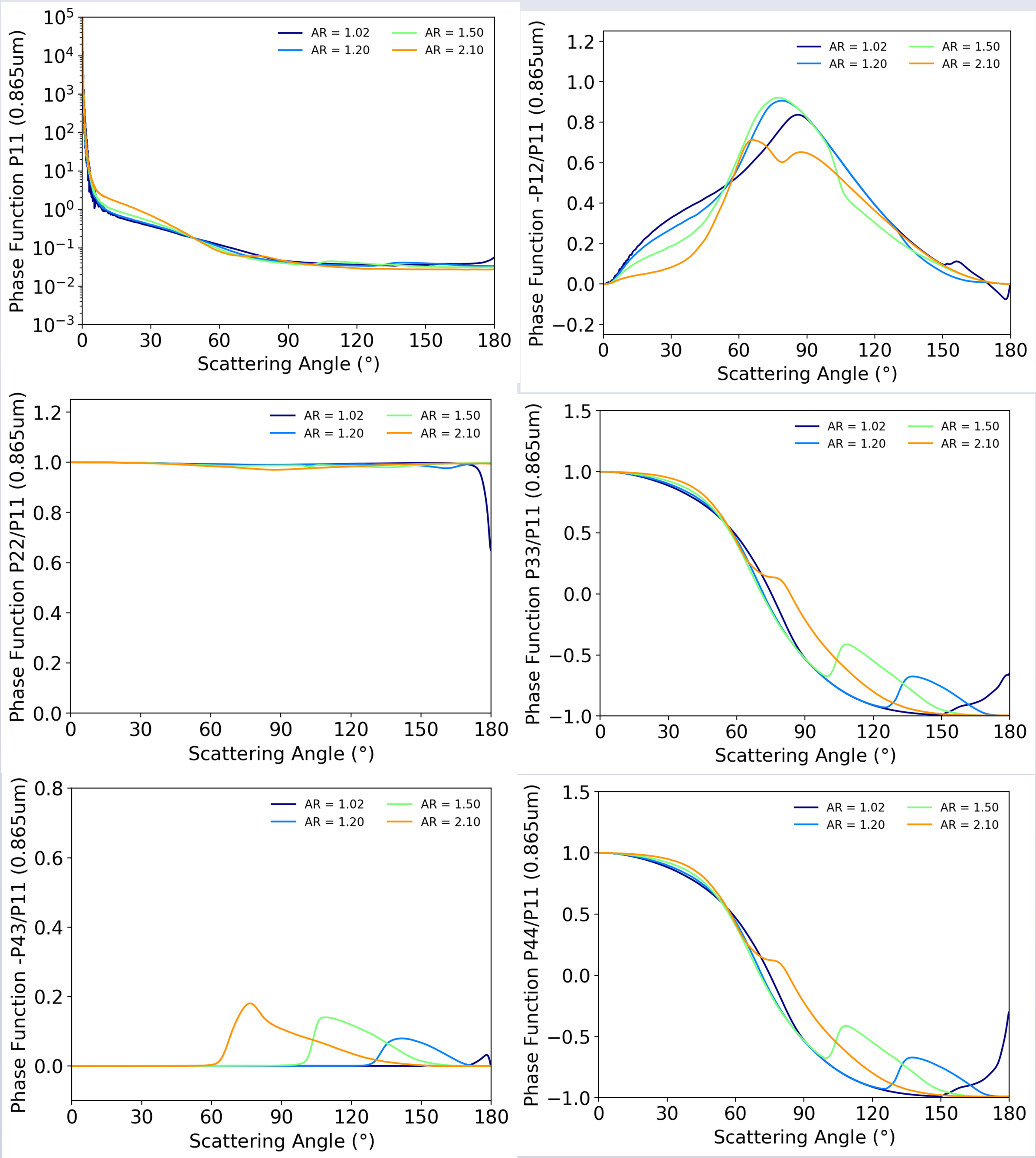

Fig 1. The elements of the scattering phase matrix of the dust aerosol with 4 kinds of aspect ratio (1.02, 1.20, 1.50 and 2.10) at the wavelength of 865nm. Aspect ratio is defined as *a/b*, where *a* is the long axis and *b* is the short axis of the prolate dust particle. The complex refractive index is set to be 1.50+0.001i.

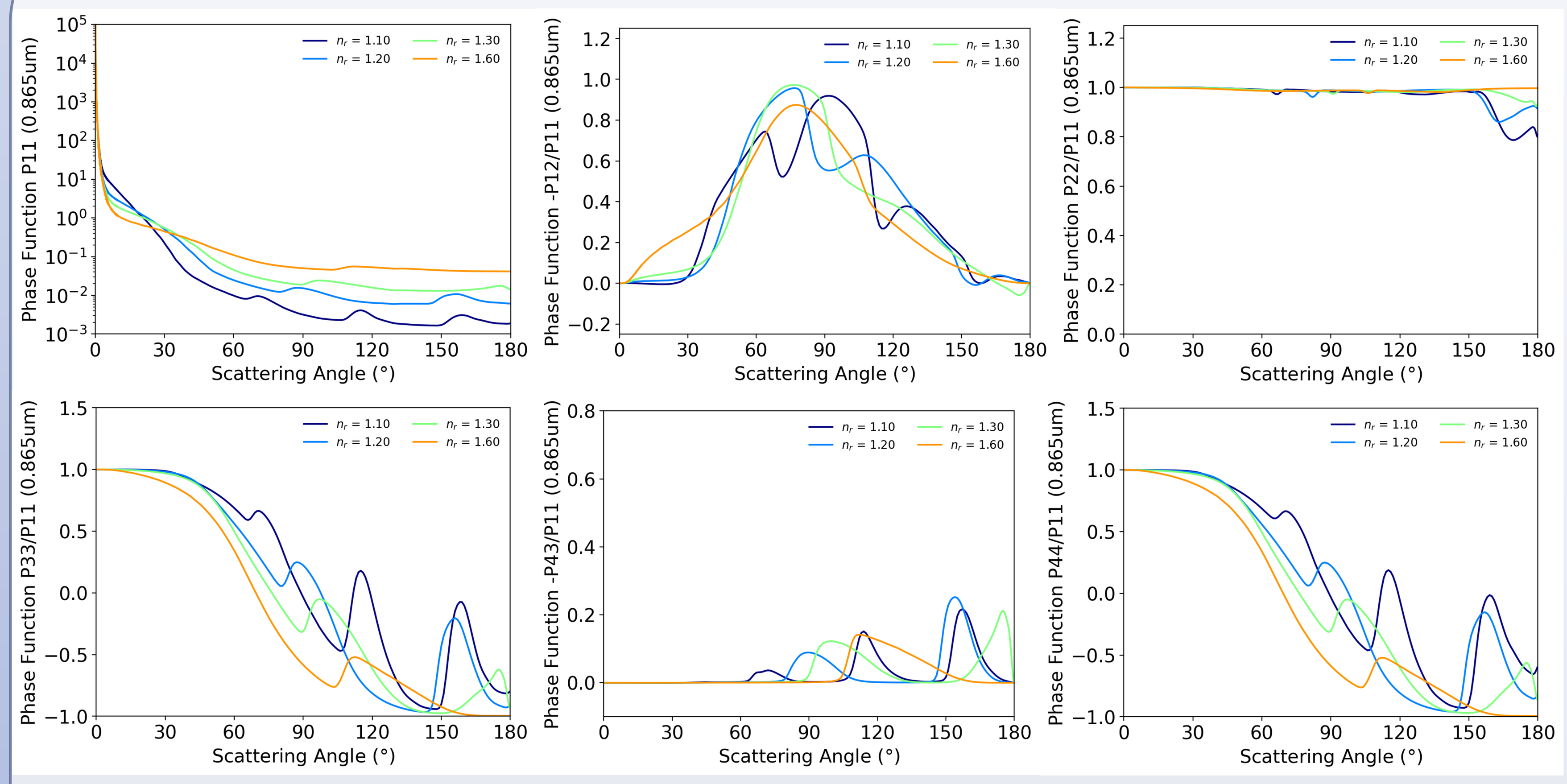

Fig 2. The elements of the scattering phase matrix of the dust aerosol with 4 different values of the real part (n_r) of the refractive index at the wavelength of 865nm. The four n_r are 1.10, 1.20, 1.30 and 1.60. The imaginary part of the refractive index is set to be 0.001 and the aspect ratio is set to be 1.5.

3. Single scattering albedo for different aspect ratio and n_r

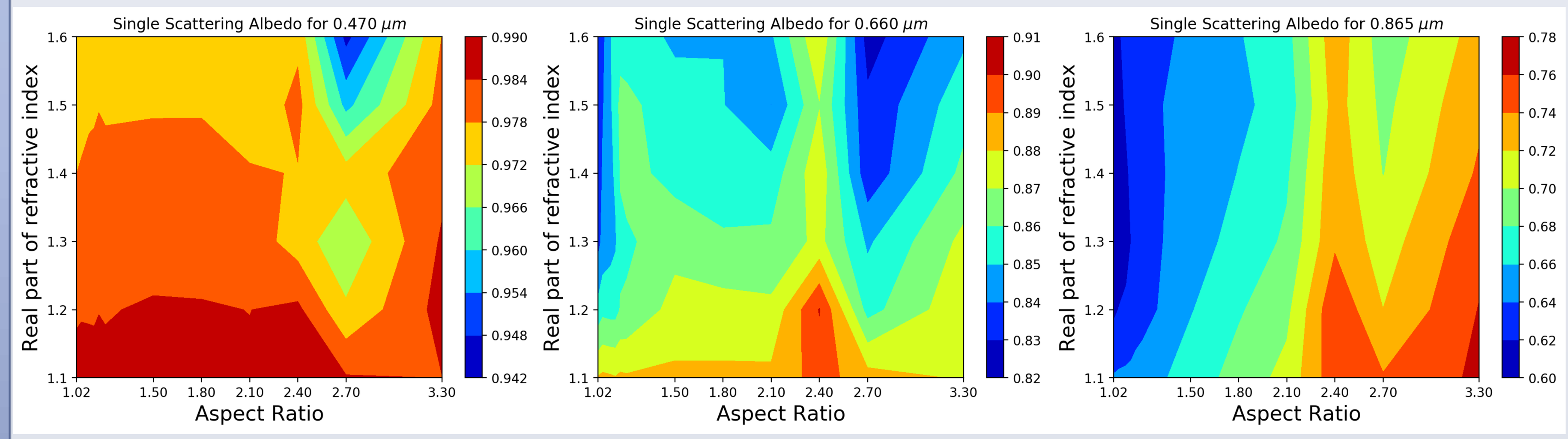

Fig 3. The single scattering albedo for the three wavelengths of 470nm, 660nm and 865nm with different particle aspect ratio and real part of the refractive index. The imaginary part of the refractive index is set to be 0.001.

4. Radiance and DOLP for different aspect ratio and n_r

In this part, an adding-doubling radiative transfer model was used to simulate the Stokes vector component (I, Q, U, V). To investigate the sensitivity of the polarization signal to the aspect ratio and the refractive index, the Degree of Linearized Polarization (DOLP) was calculated using I, Q and U. The aerosol optical thickness was set to 1.5 in this simulation.

$$DOLP = \frac{\sqrt{Q^2 + U^2}}{I}$$

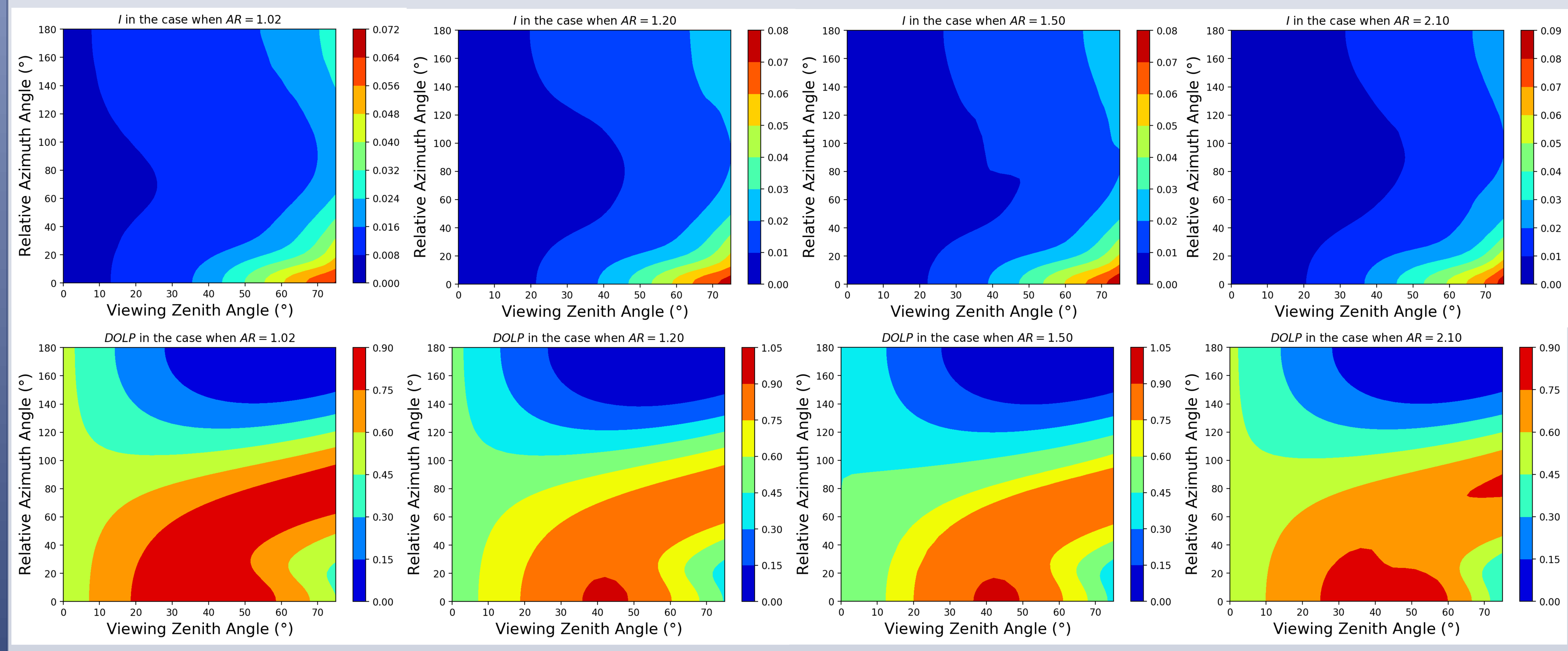

Fig 4. The Stokes component I and the DOLP for 4 kinds of aspect ratio (1.02, 1.20, 1.50 and 2.10) at the wavelength of 865nm. The complex refractive index is set to be 1.50+0.001i.

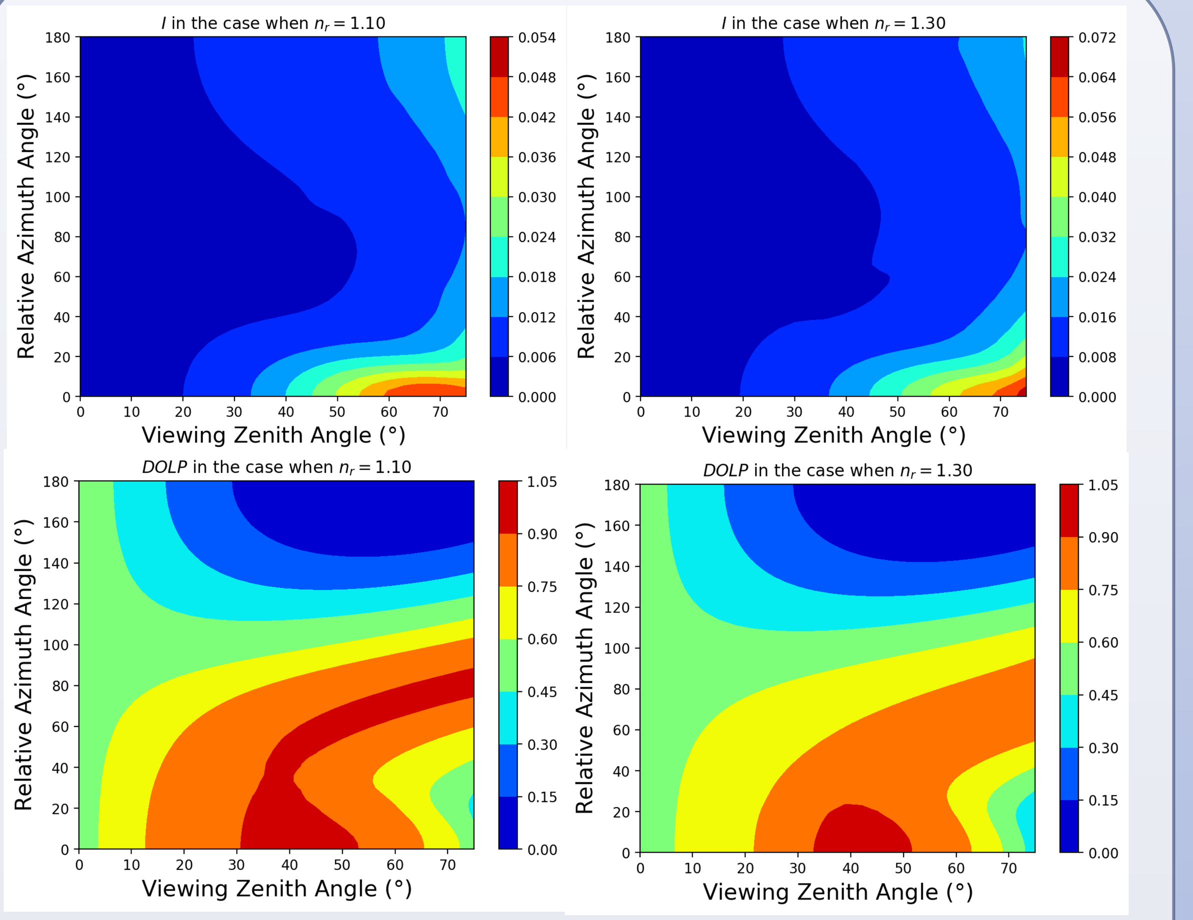

Fig 5. The Stokes component I and the DOLP for 2 different values of the real part (n_r) of the refractive index at the wavelength of 865nm. The aspect ratio is set to be 1.5.

5. Radiance and DOLP for different AOT

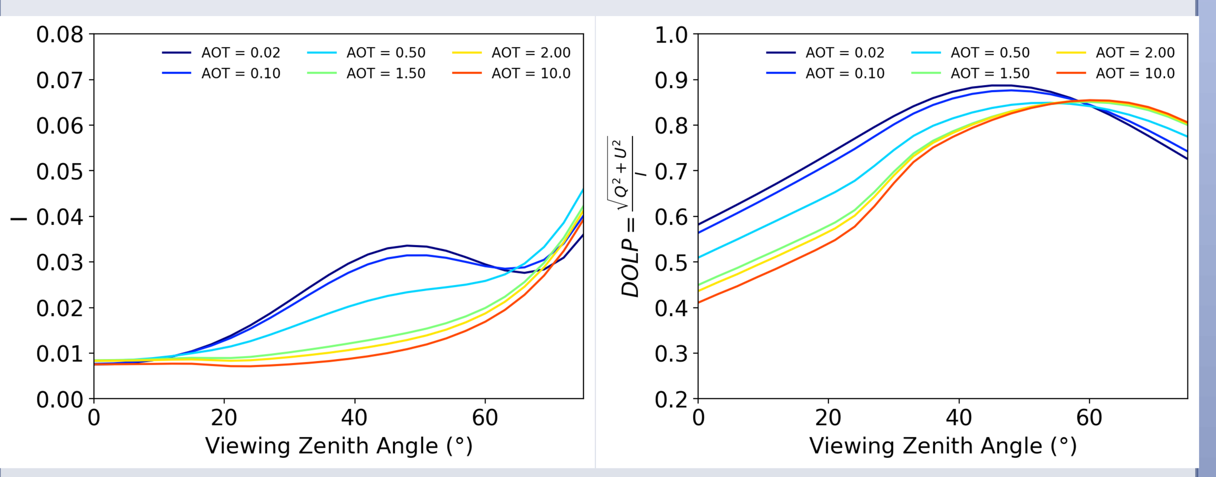

Fig 6. The Stokes component I and the DOLP for 6 different values of the aerosol optical thickness (AOT) at the wavelength of 865nm. The aspect ratio is set to be 1.5 and the refractive index is set to be 1.5+0.001i.

Summary and conclusion

- In this study, we used a ellipsoidal dust aerosol database to investigate the sensitivity of the scattering phase matrix and single scattering albedo to the dust particle aspect ratio and refractive index (the real part). In addition, we investigated the Stokes vector *I* and the DOLP in different aspect ratio, refractive index and AOT.
- The results shows that particles with different aspect ratio and refractive index shows different scattering properties, including scattering phase matrix and single scattering albedo.
- Different AOT shows different response of Stokes vector to viewing zenith angle.
- The polarization signal would significantly improve the ability to retrieve the particle aspect ratio and refractive index.

References

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- Yang, P., Feng, Q., Hong, G., *et al.*, 2007: Modeling of the scattering and radiative properties of nonspherical dust-like aerosols. *J. Aerosol Sci.* **38**, 995–1014.
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