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Reflected solar radiation's polarization as function of wavelength: Pristine ocean and water clouds

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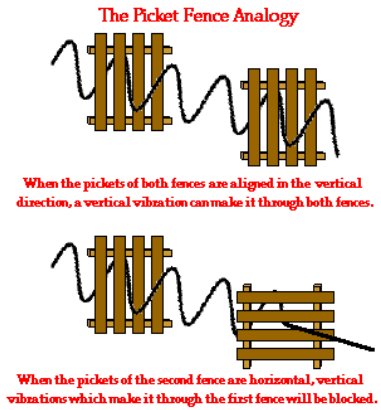
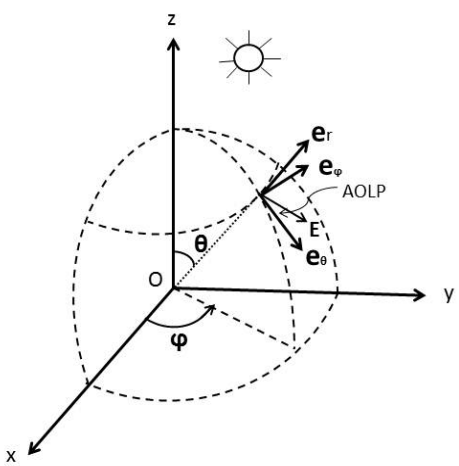
Introduction



Solar radiation reflected from the Earth-atmosphere system is polarized, it has not only I, but also Q, U, and V(~0).

$$DOP = \frac{\sqrt{Q^2 + U^2 + V^2}}{I} = I_{pol} / I$$

$$\tan(2AOLP) = \frac{U}{Q}$$



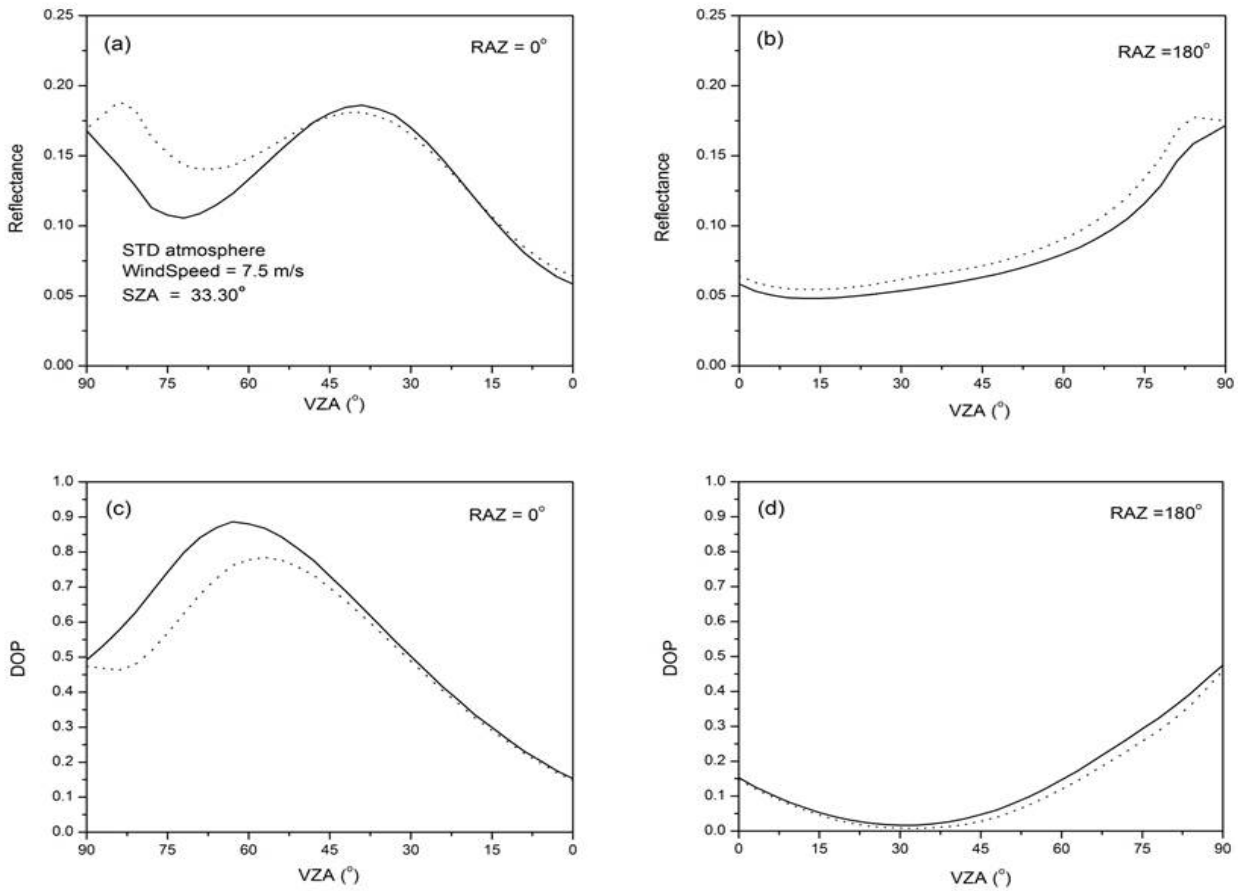
Correction of polarization error is done as

$$I = \frac{(C_m / G_0)}{1 + \left[\frac{G_p(AOLP) - G_0}{G_0} \right] \cdot DOP}$$

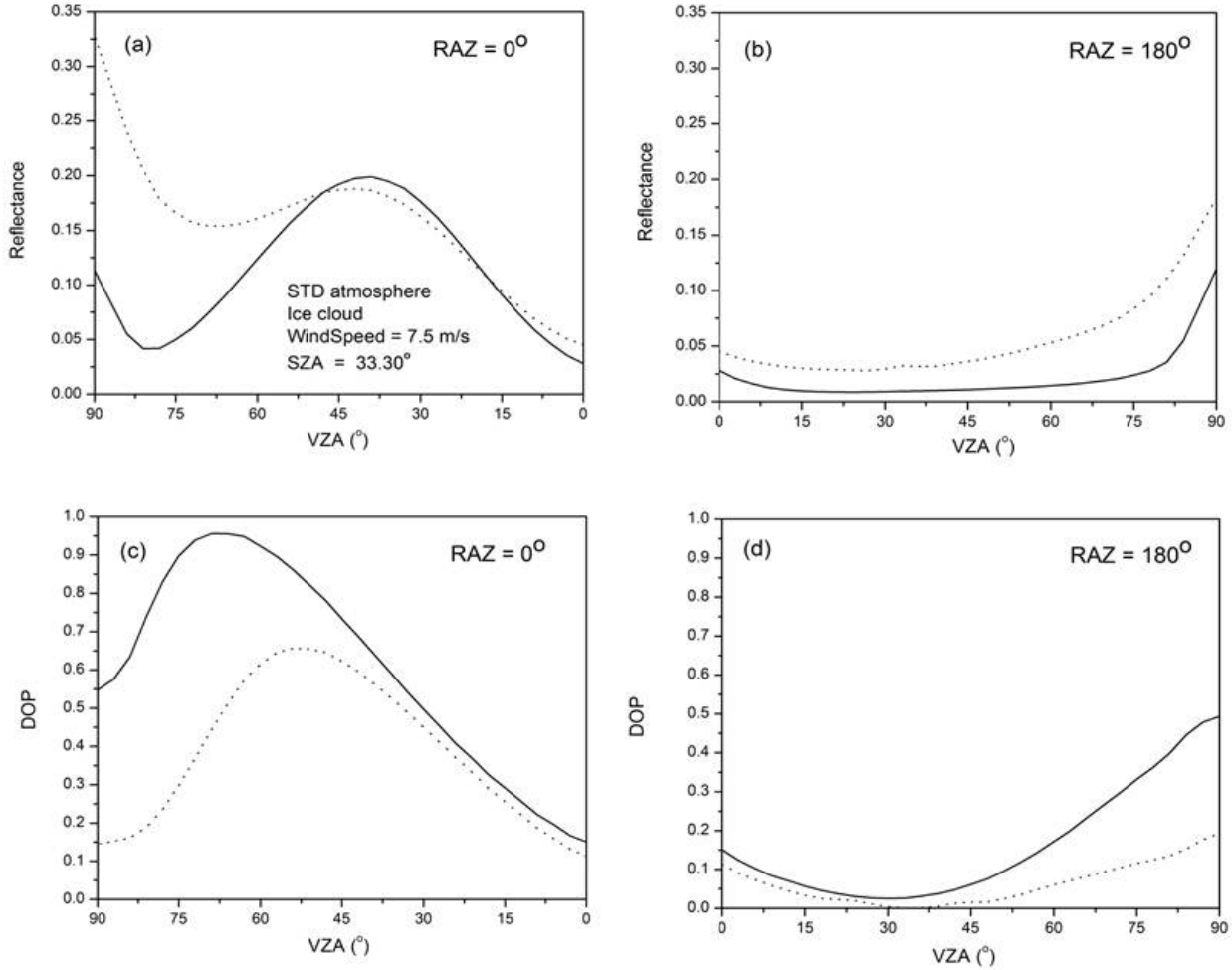
Status of the adding-doubling radiative transfer model (ADRTM)

1. ADRTM:
   Calculate full Stokes parameters (I, Q, U, V).
2. Atmospheric profiles:
   Any atmosphere profile.
3. Spectral gas absorption:
   Line-by-Line and *k*-distribution plus ozone cross-section table.
4. Molecular scattering:
   Rayleigh with depolarization factor.
5. Particulate absorption and scattering:
   Mie for water clouds (Gamma size distribution);
   PML/UPML FDTD for fine-mode aerosols;
   CPML PSTD code is developed for coarse-mode aerosols;
   FDTD, PSTD, and GOM for ice clouds are being considered.
6. Surface reflection model:
   Lambert surface for land now.
   More practical model for land is being considered with PARASOL data.
   Cox & Munk with/without Gram-Charlier expansion plus foam for ocean;
   Wave shadowing effect is integrated in the ocean surface model;
   Lambert model for water-leaving radiance from ocean water volume.
   More practical model for water-leaving radiance is being considered.
7. Goal:
   PDMs of whole CLARREO solar spectra for all major scene types.
8. Under study:
   Spectral light scattering properties of ice cloud and aerosol particles.

Aerosol and super-thin clouds effect on reflected solar polarization

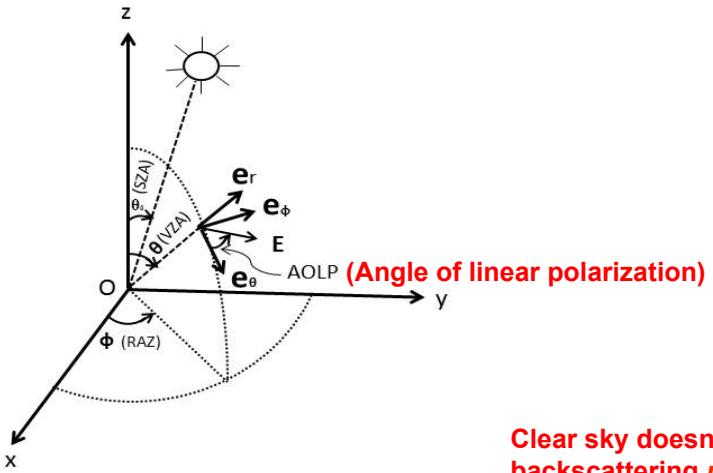


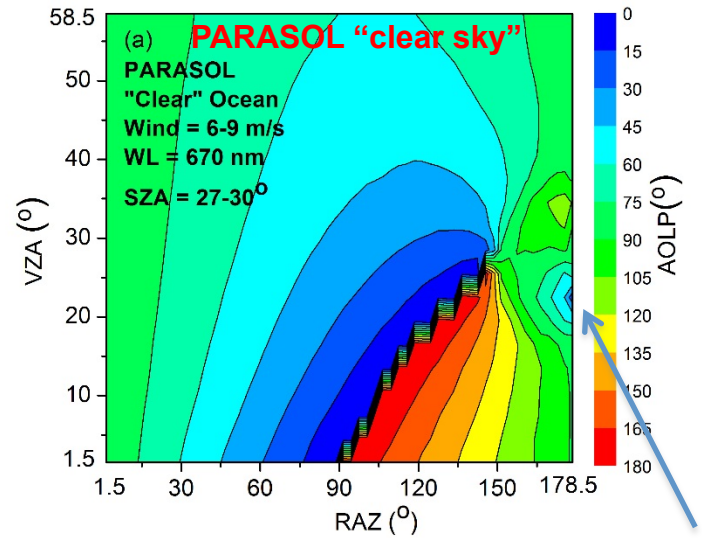
The total reflectance and DOP on the principal plane at the wavelengths of 550 *nm* from the ocean-atmosphere system without aerosols (solid curve) and with sea-salt aerosols (dashed curve) of optical thickness *0.1*. The ocean wind speed is 7.5 *m/s*. The SZA is 33.30°. The U. S. standard (STD) atmosphere is used.



The total reflectance and DOP on the principal plane from the ocean-atmosphere system for an ice cloud layer with OD = 0.3 (dashed curve) and for pristine atmosphere (solid curve) at 865 *nm*. The ocean wind speed is 7.5 *m/s*. The SZA is 33.30°. The U. S. standard (STD) atmosphere is used.

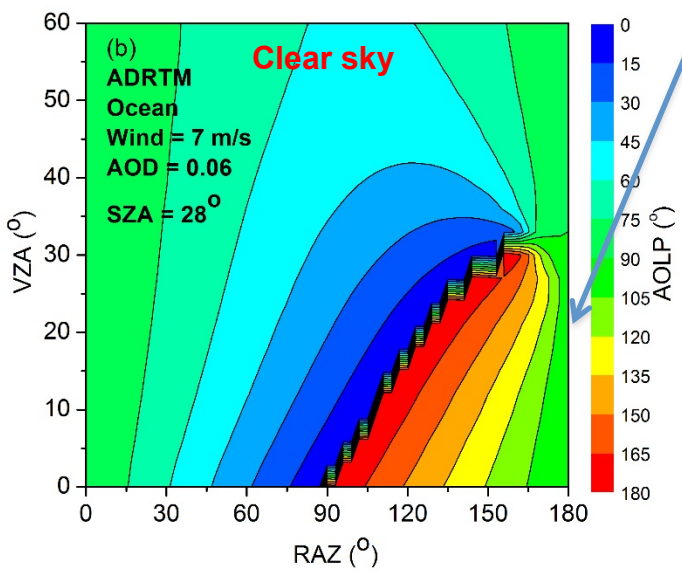
P-polarization feature of clouds (ice)

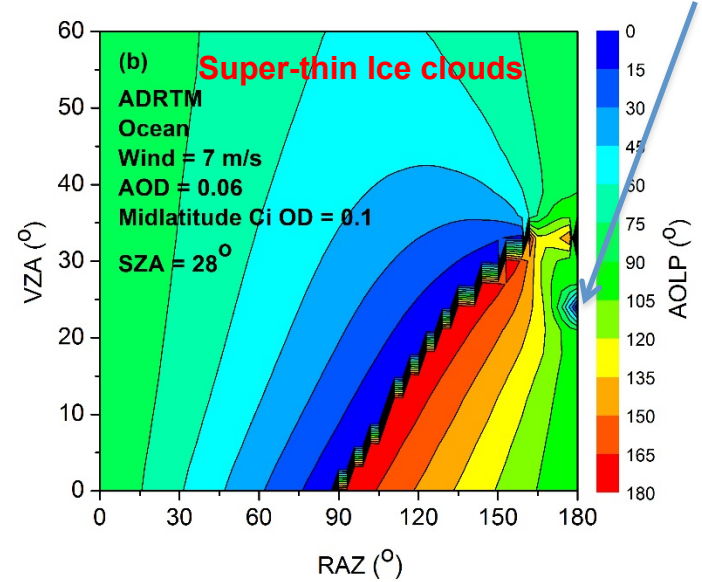




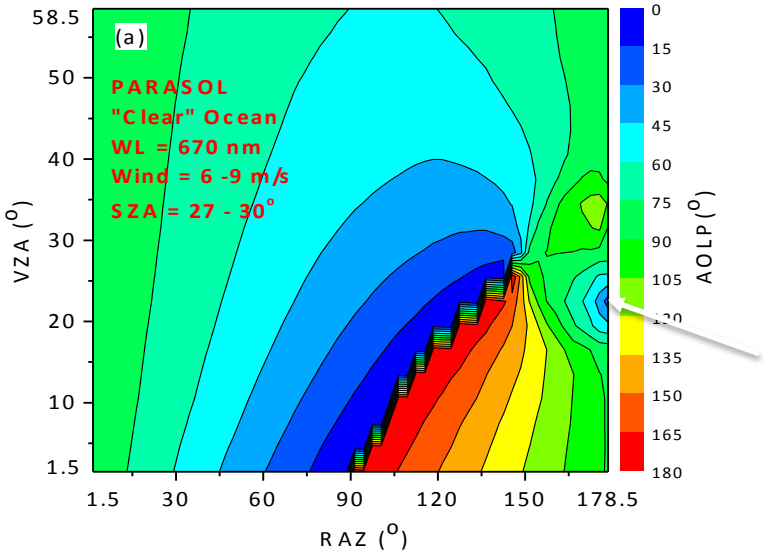
Clear sky doesn't have backscattering *p*-polarization feature

Backscattering *p*-polarization feature



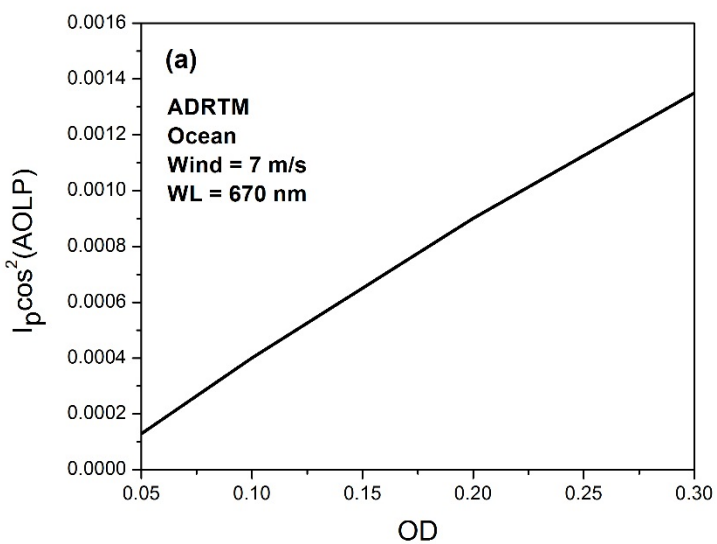


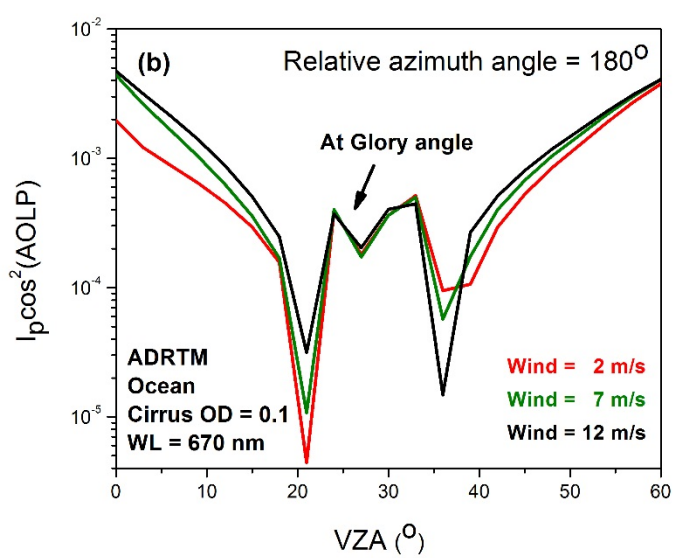
How to retrieve the OD of the super-thin clouds?



$$OD = f^{-1}[I_{pol}\cos^2(AOLP)]$$

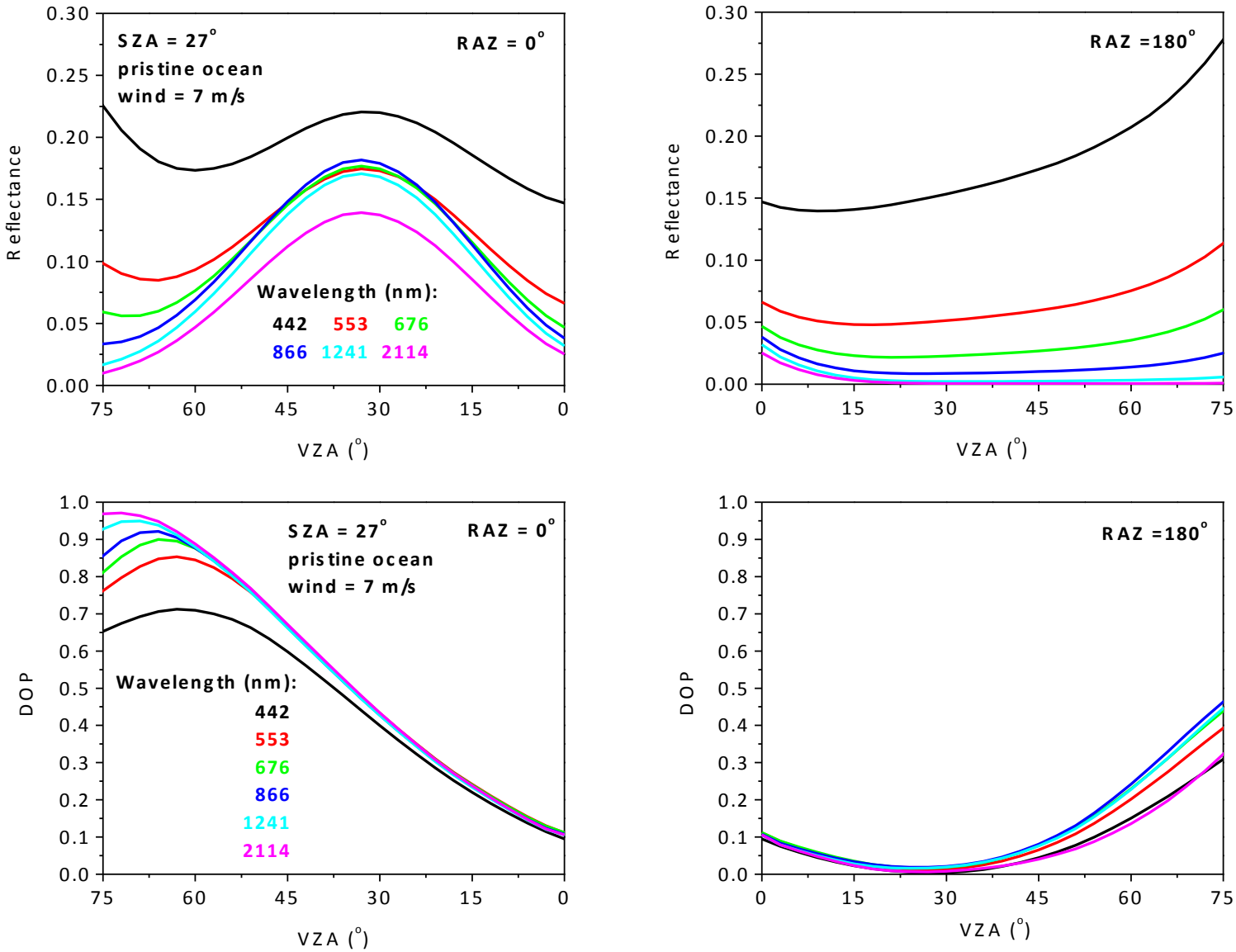
The retrieval is done at "Glory angle". At these viewing angles, perpendicularly polarized intensity is free from surface reflection effect.





Reflected solar polarization as function of wavelength for pristine ocean and water clouds

SZA = 27 deg, Pristine Ocean



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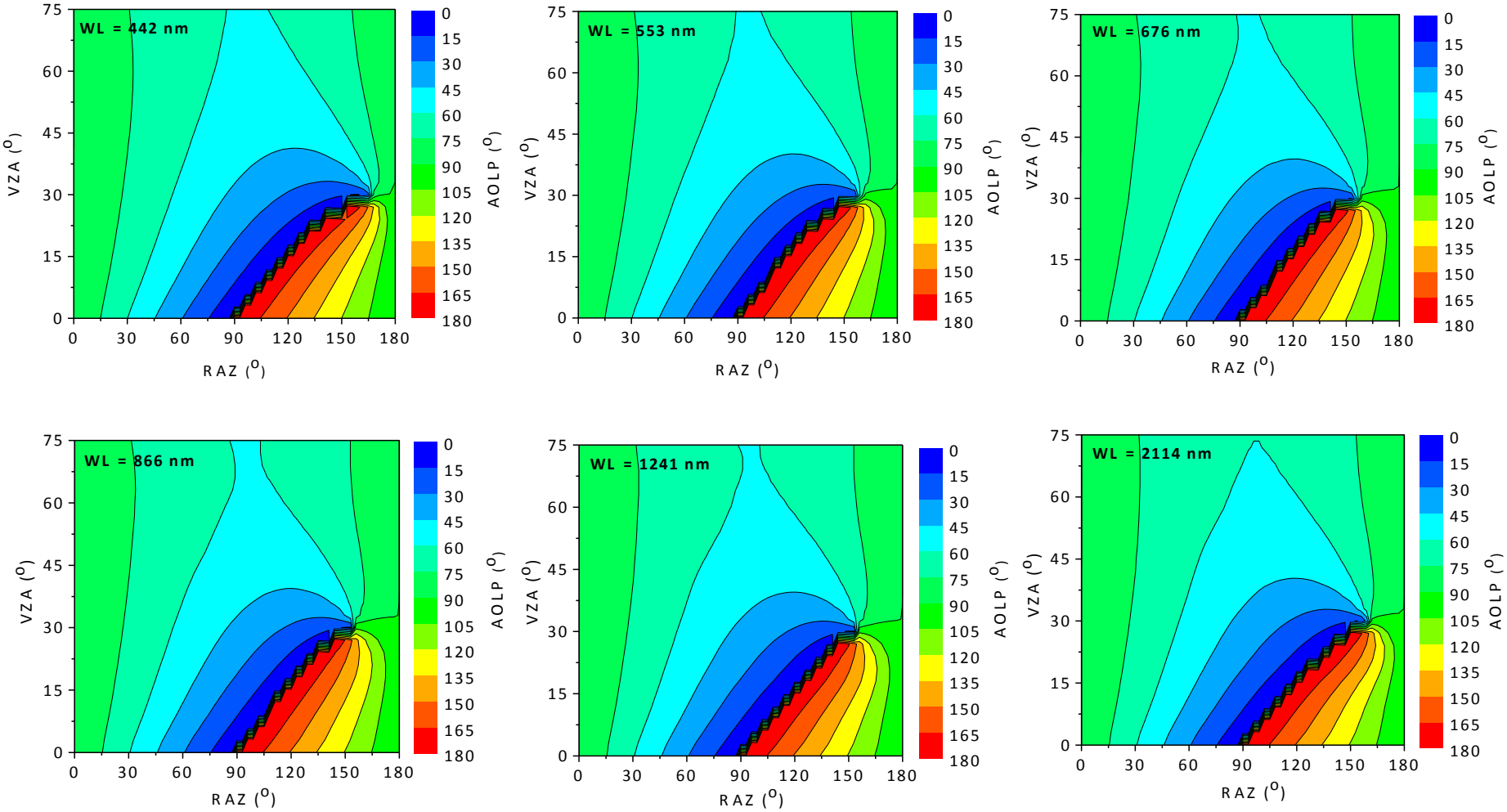
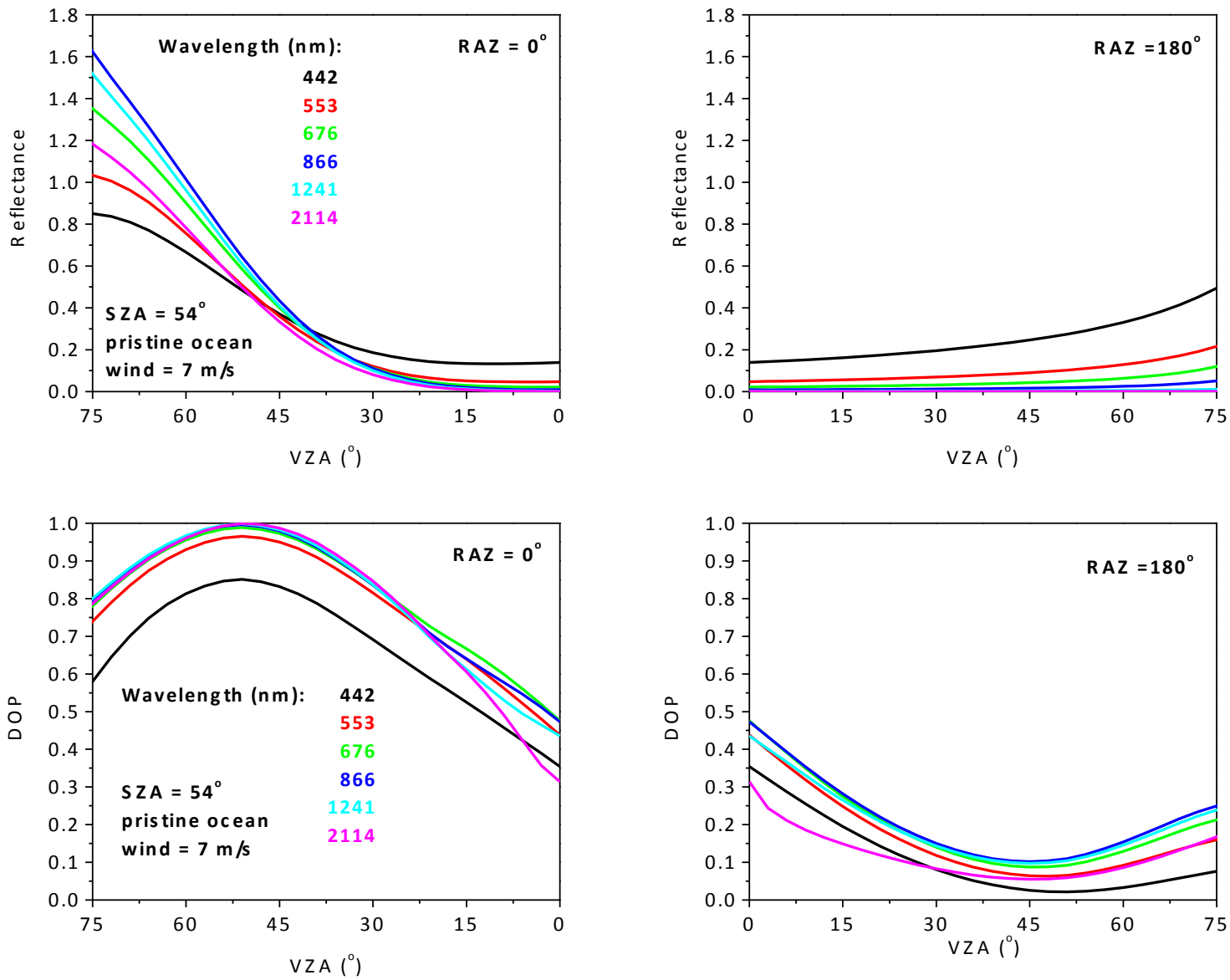


SZA = 54 deg, Pristine Ocean



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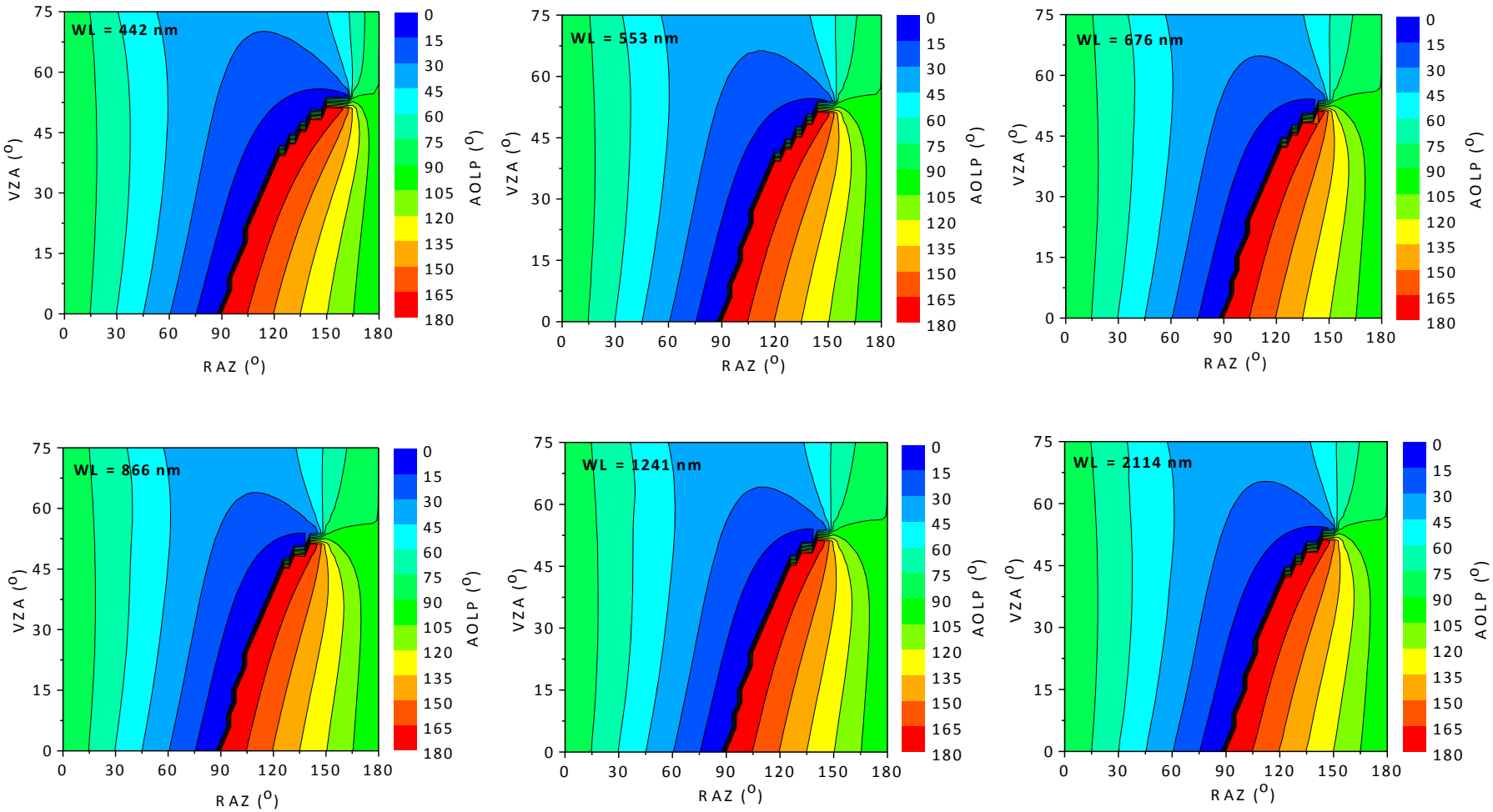
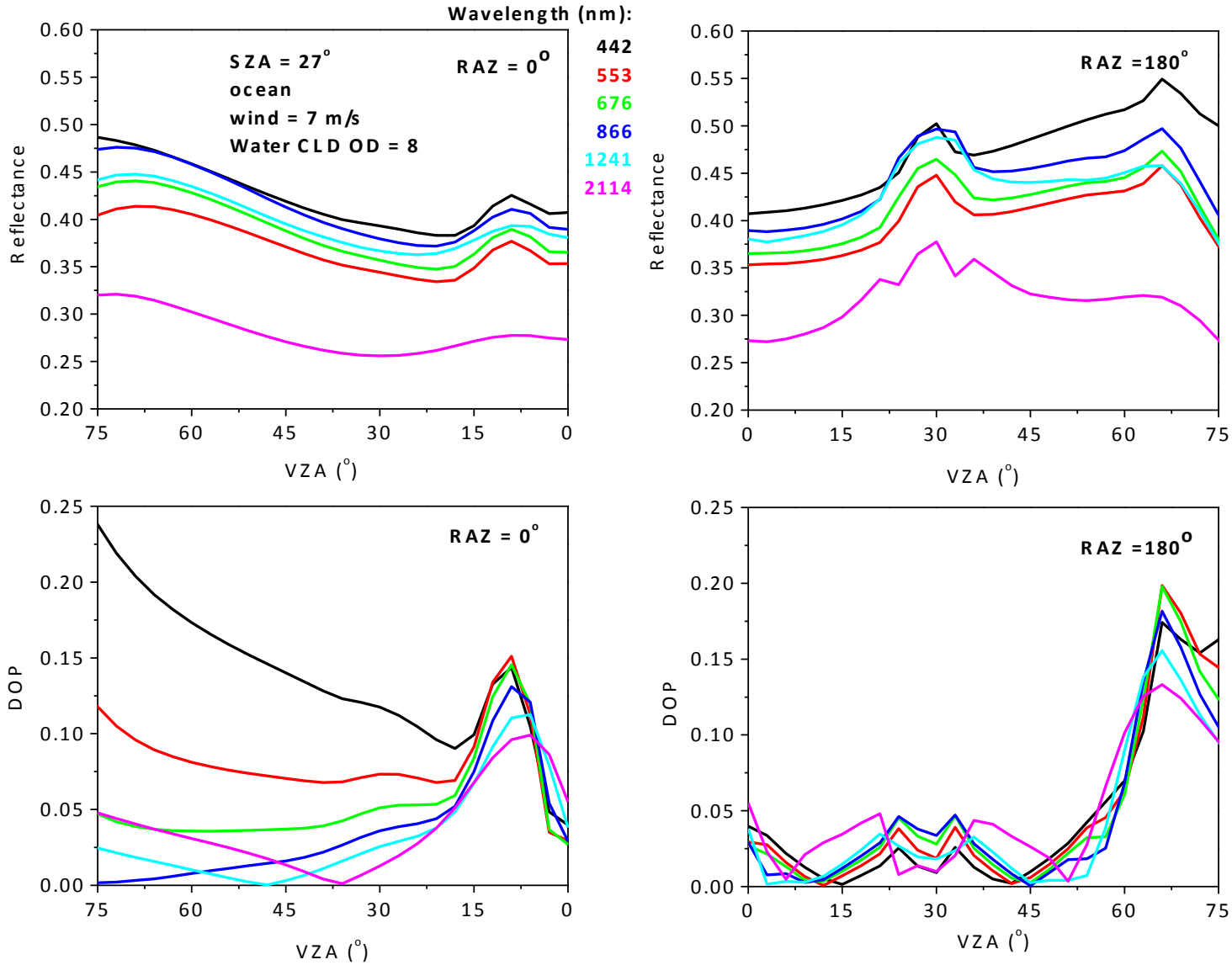


SZA = 27 deg, Water Cloud OD = 8



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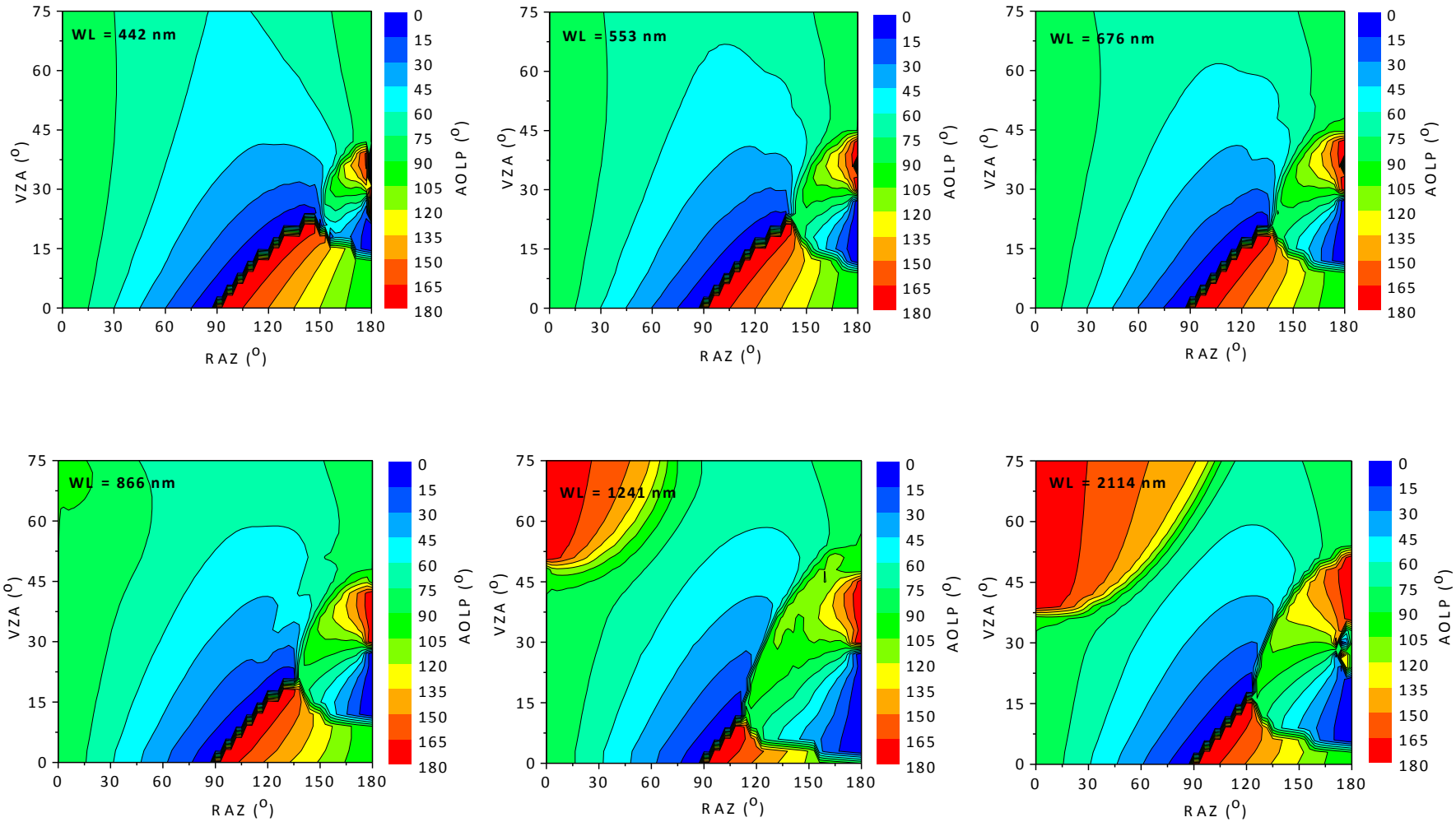

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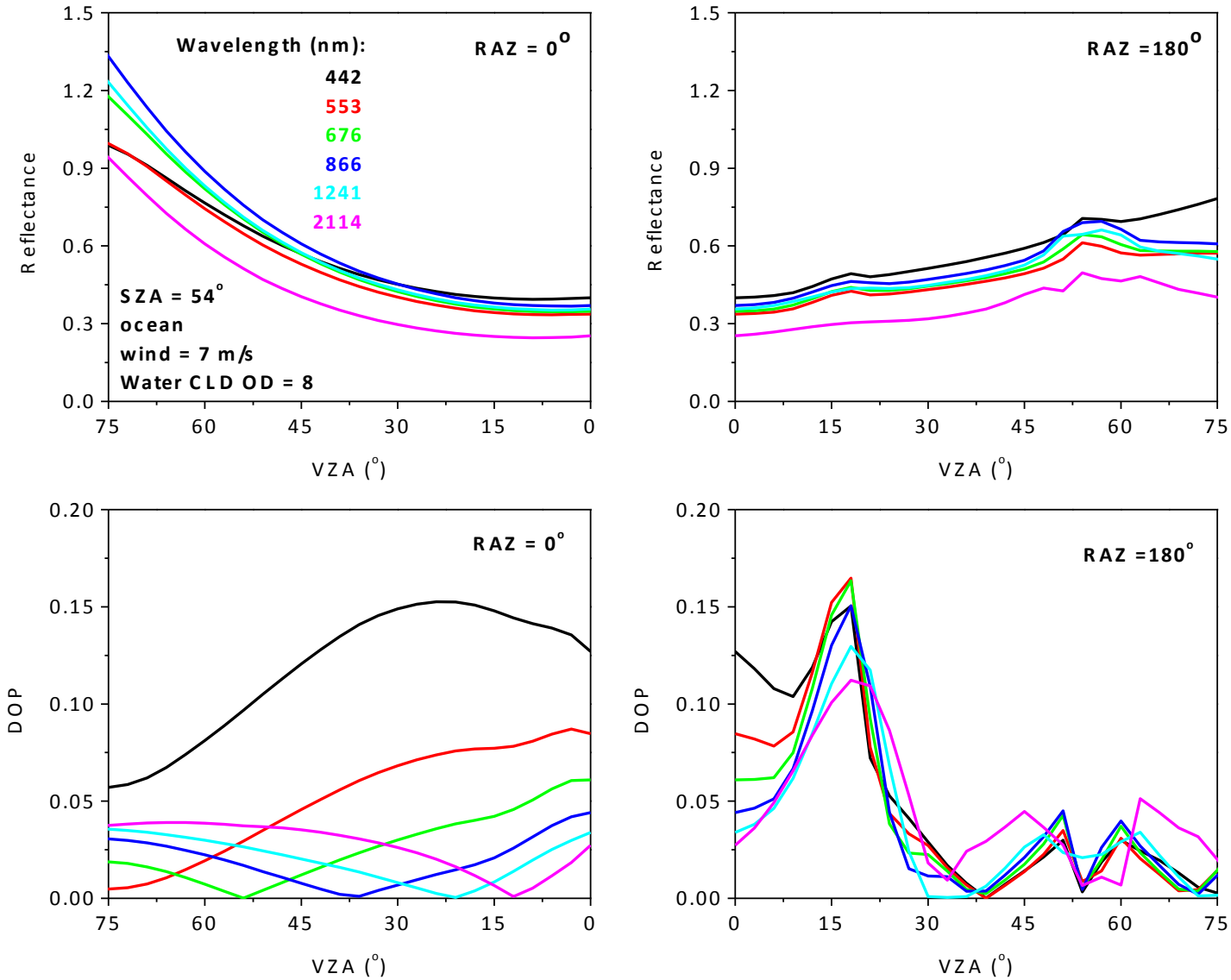

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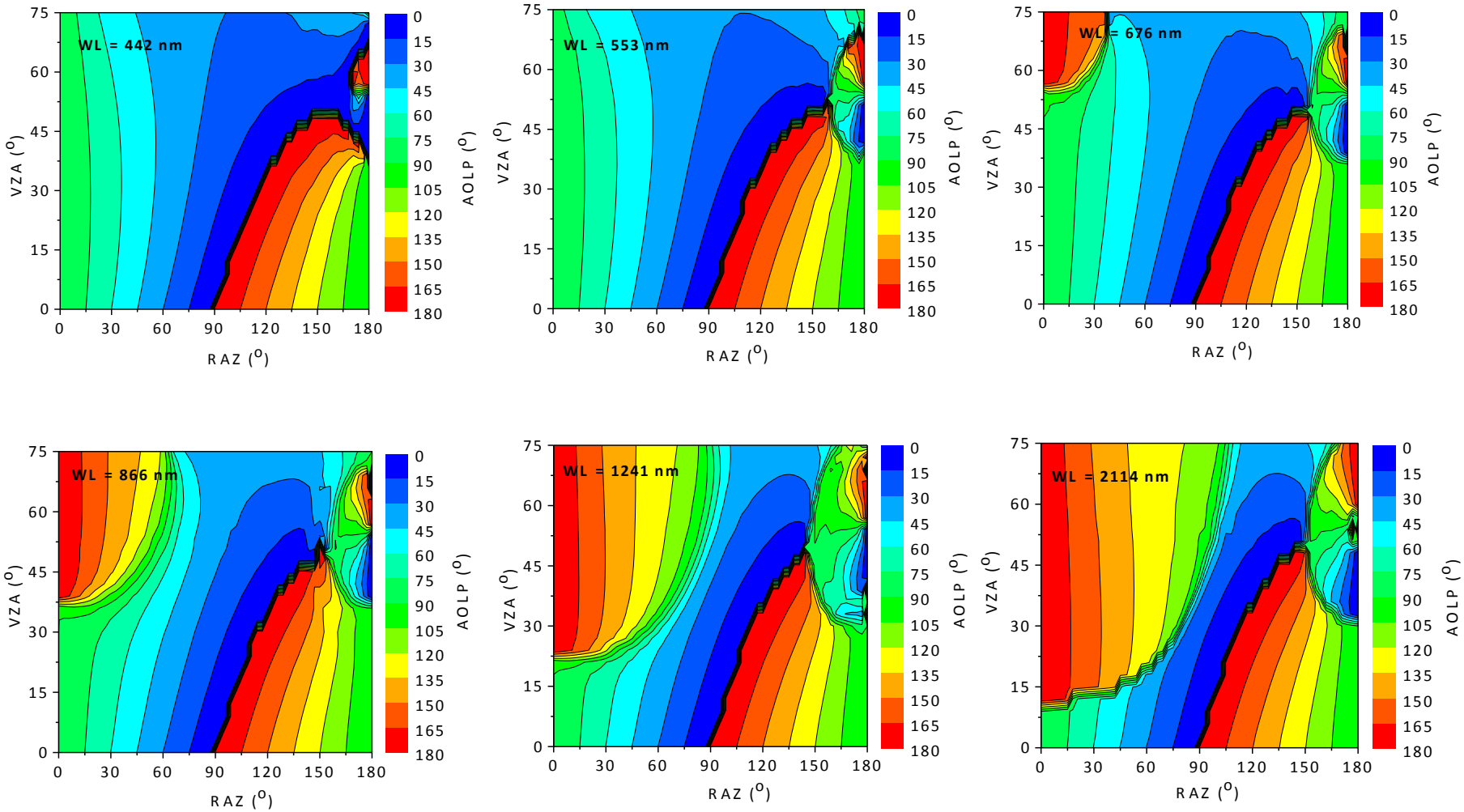
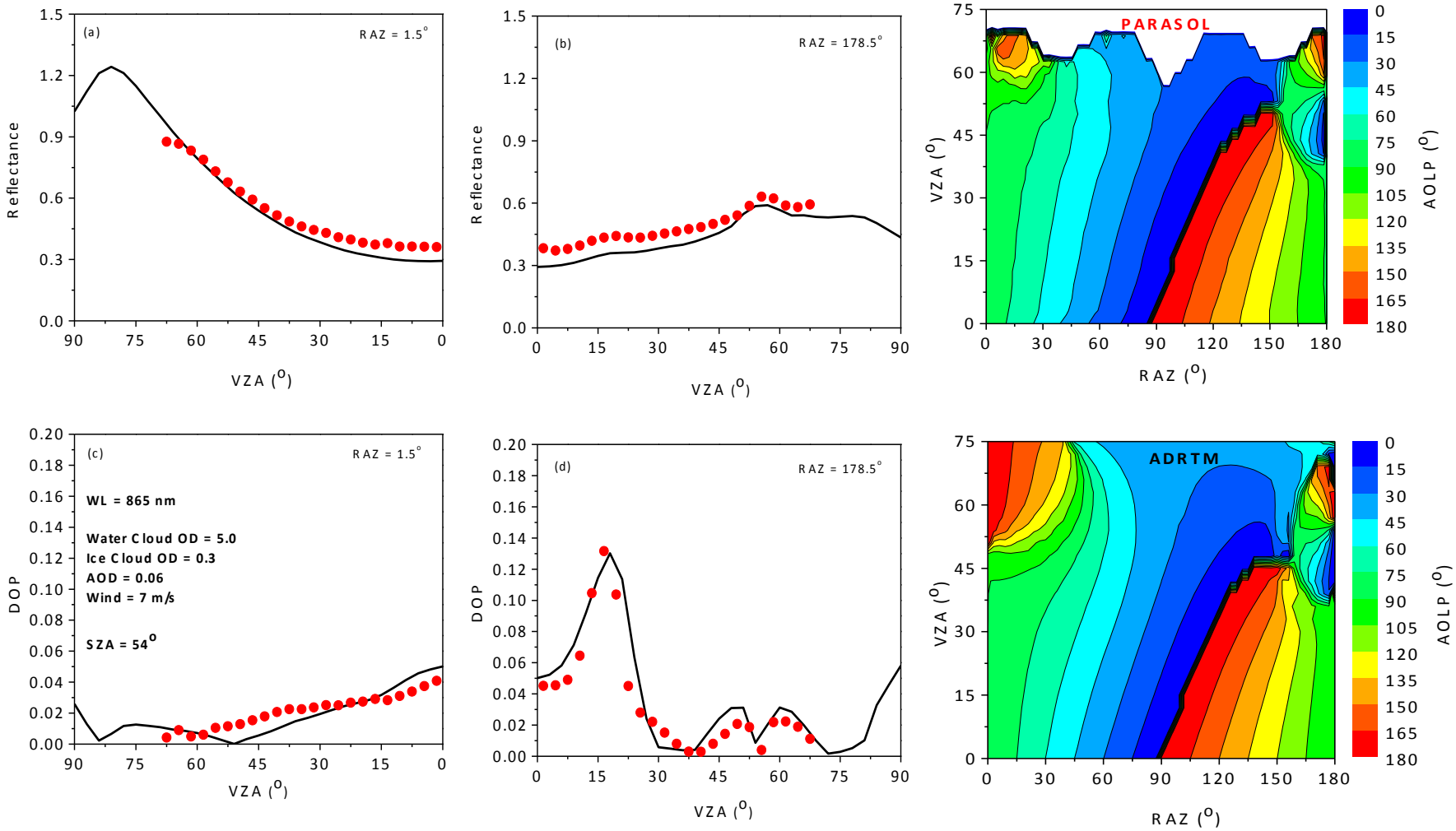


Comparison of ADRTM results at 865 nm with PARASOL data for clouds



Conclusion

- **For clear oceans, when SZA is small, DOP and AOLP are weak functions of wavelength. When SZA is large, DOP and AOLP significantly change with the wavelength.**

- **For water clouds, DOP and AOLP significantly change with the wavelength. DOP generally decreases with the increase of wavelength at the maxima of DOP.**

- **Spectral PDM must be made to account for the polarization at different wavelengths.**

- **Work on the spectral polarization parameters of aerosol and ice clouds is being conducted.**