Optimization of polarization measurements for AERONET aerosol retrievals

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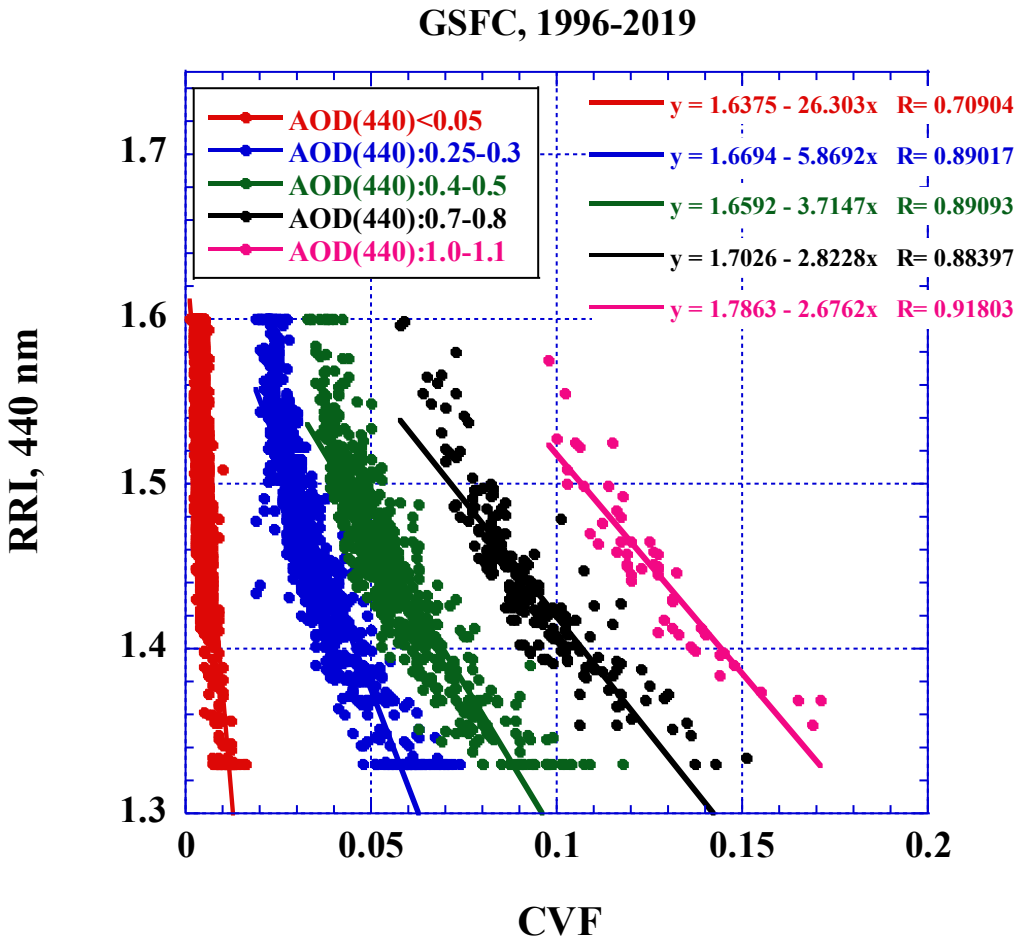
Summary of improvements in the accuracy of aerosol parameters retrieved from ground-based observations by adding polarization measurements, current state.

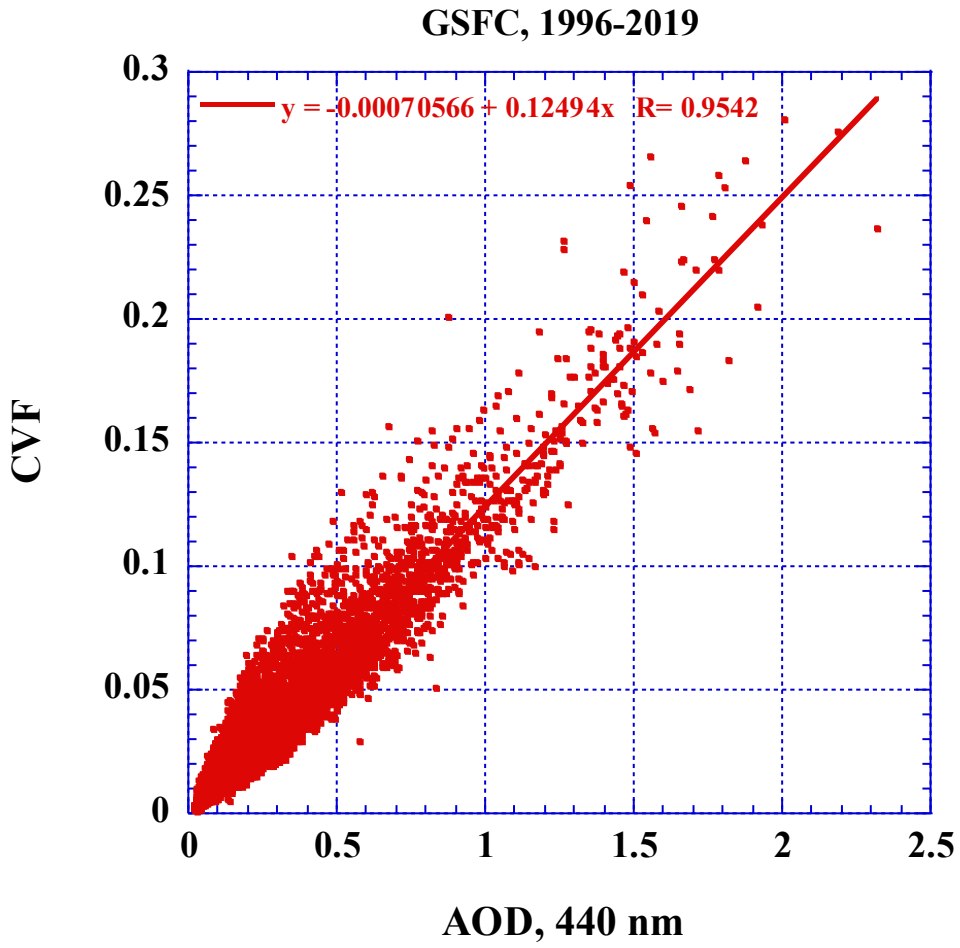
1. Improves accuracy of the real part of refractive index (RPRI).
2. Improves accuracy of particles shape (sphericity parameter).
3. Does not improve the accuracy of the imaginary part of refractive index (IPRI).
4. Improvements encountered mostly for fine mode dominated aerosol types.

References:

1. Zhengquiang Li at al., JQSRT, v. 110, p. 1954-1961, 2009.
2. Fedarenka A., at al., JQSRT, v. 179, p. 72-97, 2016.

The real part of refractive index is under-constrained by intensity only measurements.





DLP measurements and operational processing

CIMEL CE318-DP sun-photometer provides both intensity and polarization measurements using dual polar wheel system.
For almucantar (ALM) geometry, latest (T) version of sun-photometer makes un-polarized and polarized ALMs sequentially with AOD measurement in between.
The time of acquisition is ~ 7 minutes and ~ 14 minutes for un-polarized and polarized ALM respectively which creates a large temporal gaps in AOD in the AOD time series.
Additionally, the aerosol properties might change during the total time (~20 minutes) needed to acquire the whole data set.

Way to reduce the acquisition time: optimize (reduce) the number of DLP wavelengths.

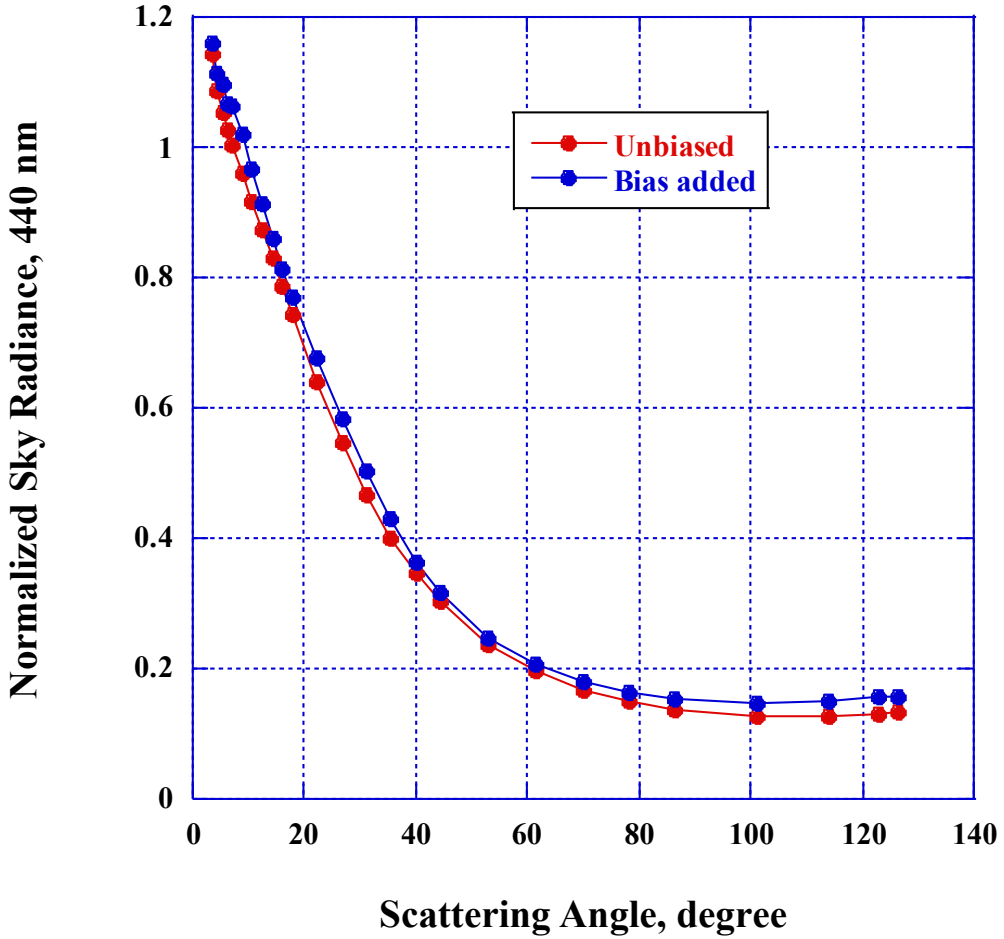
Sensitivity analysis.

1. Actual measurements noise is never random. Modeling of realistic noise in synthetic sky radiance measurements can be done by superimposing bias signature extracted from the fit of real measurements by inversion code for the cases of large residuals.
2. Estimate improvements in retrieved RPRI and SSA (if any) by adding non-biased synthetic measurements of degree of linear polarization (DLP).
3. Optimize the combination of sky and polarization measurements.

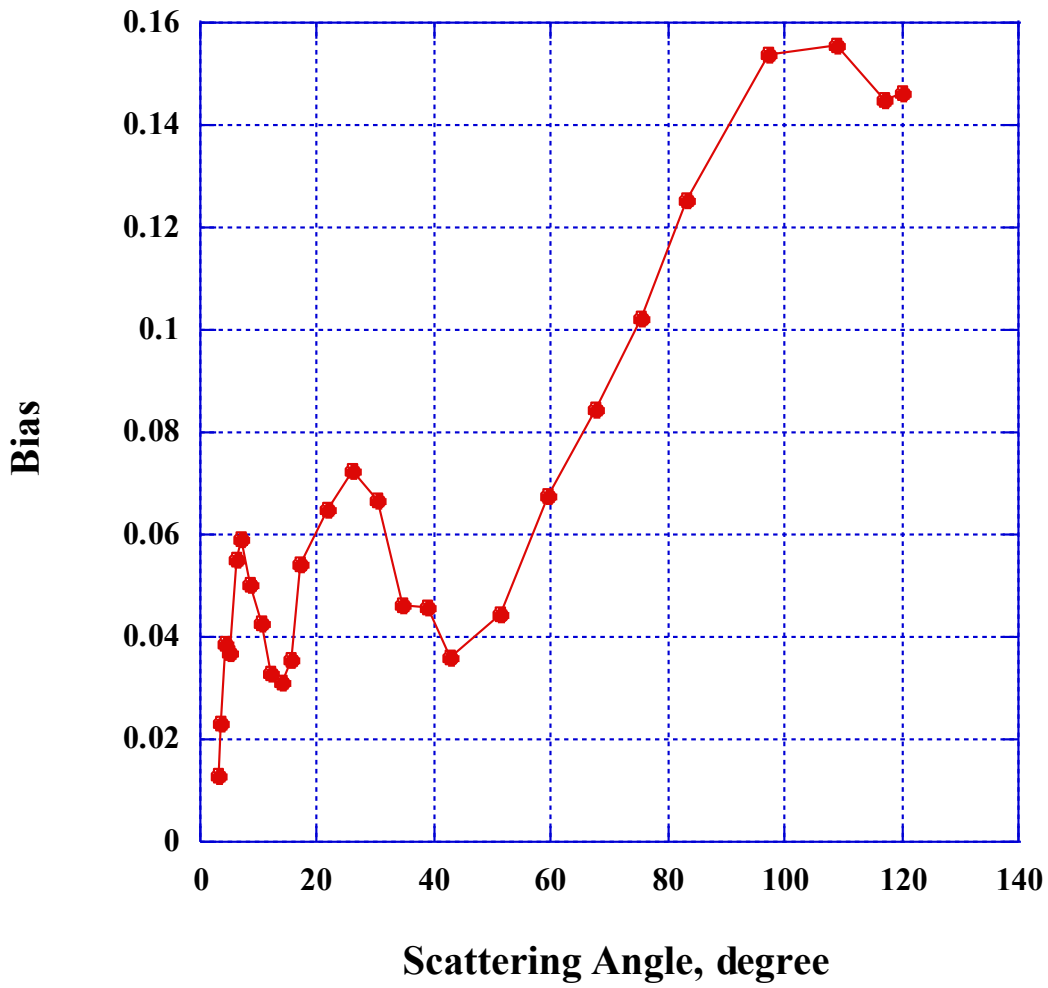
Synthetic measurements

1. Aerosol model is inferred from climatology GSFC aerosol retrievals for angstrom parameter ~ 1.8, aerosol optical depth (AOD) is 0.5.
2. Fitting bias is extracted from the fit angular signature for GSFC inversion from October 7 2000, 13:57

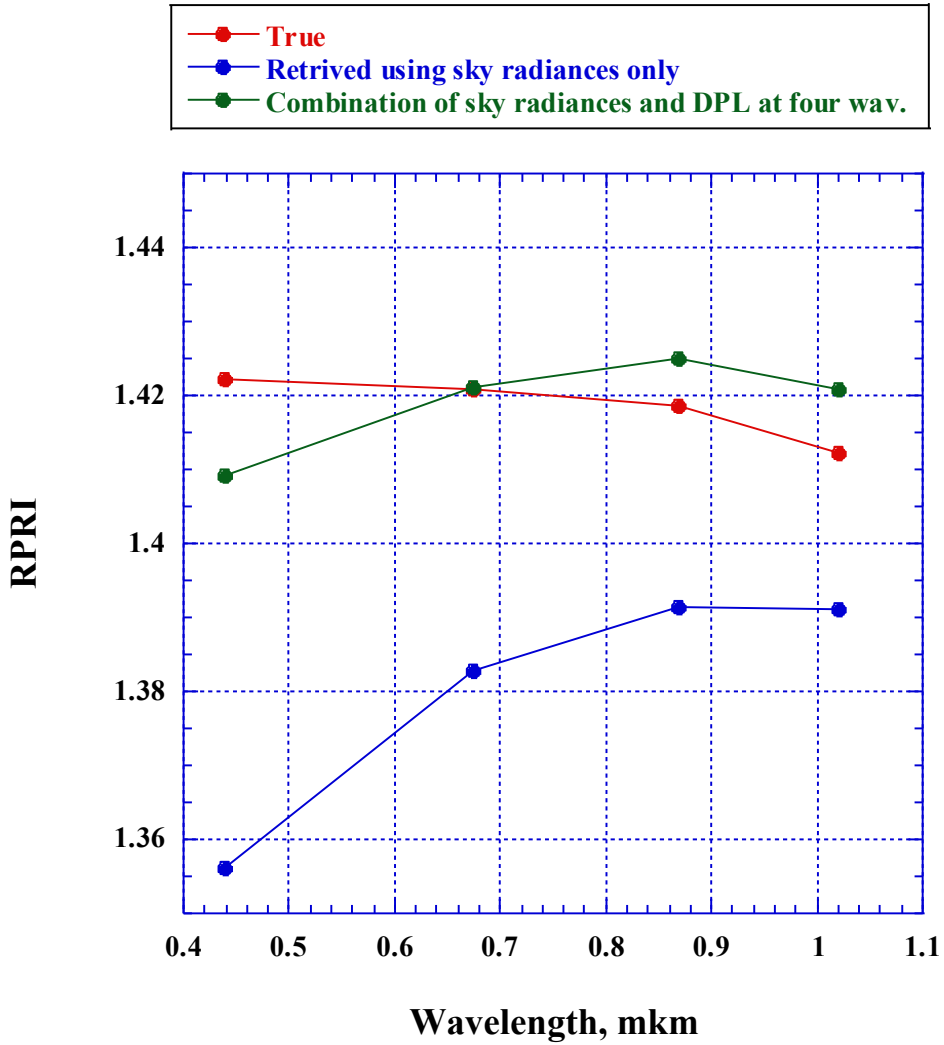
AOD(440)=0.14 and Sky error =4.6%

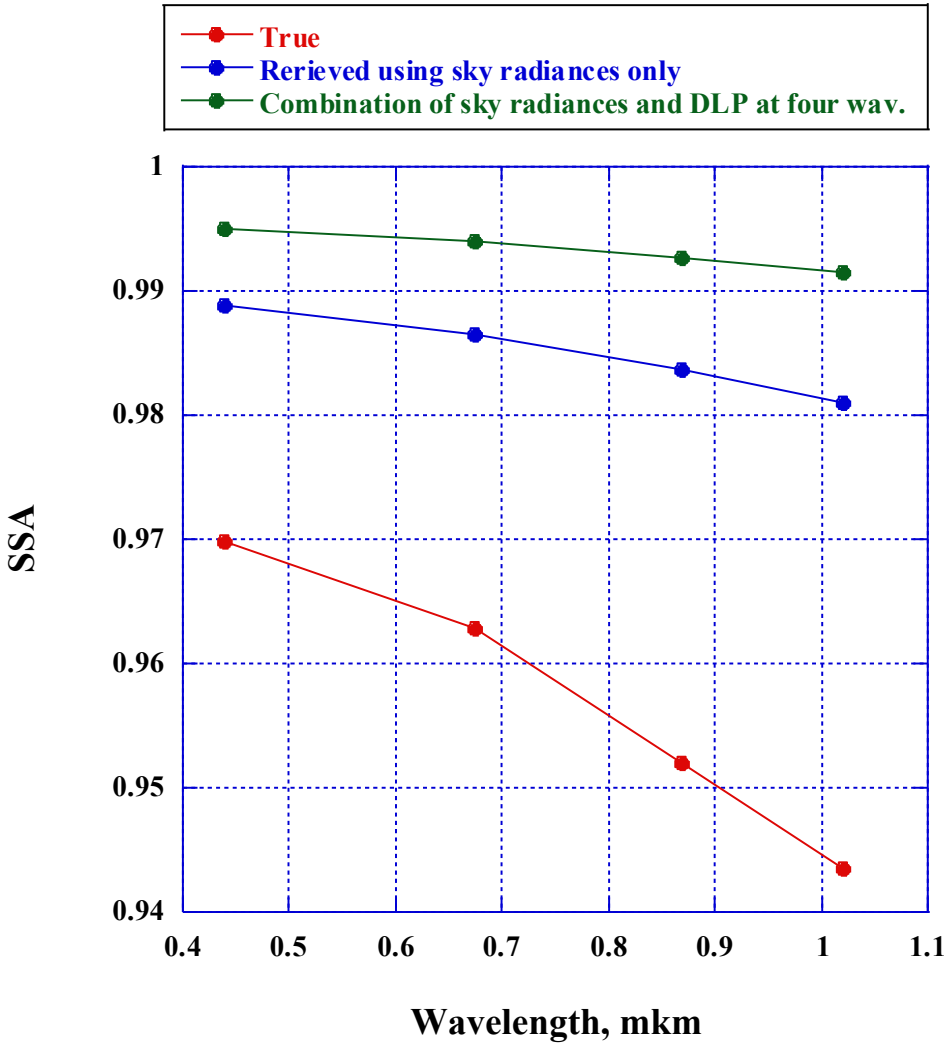


Averaged bias ~ 6.8% 440 nm channel

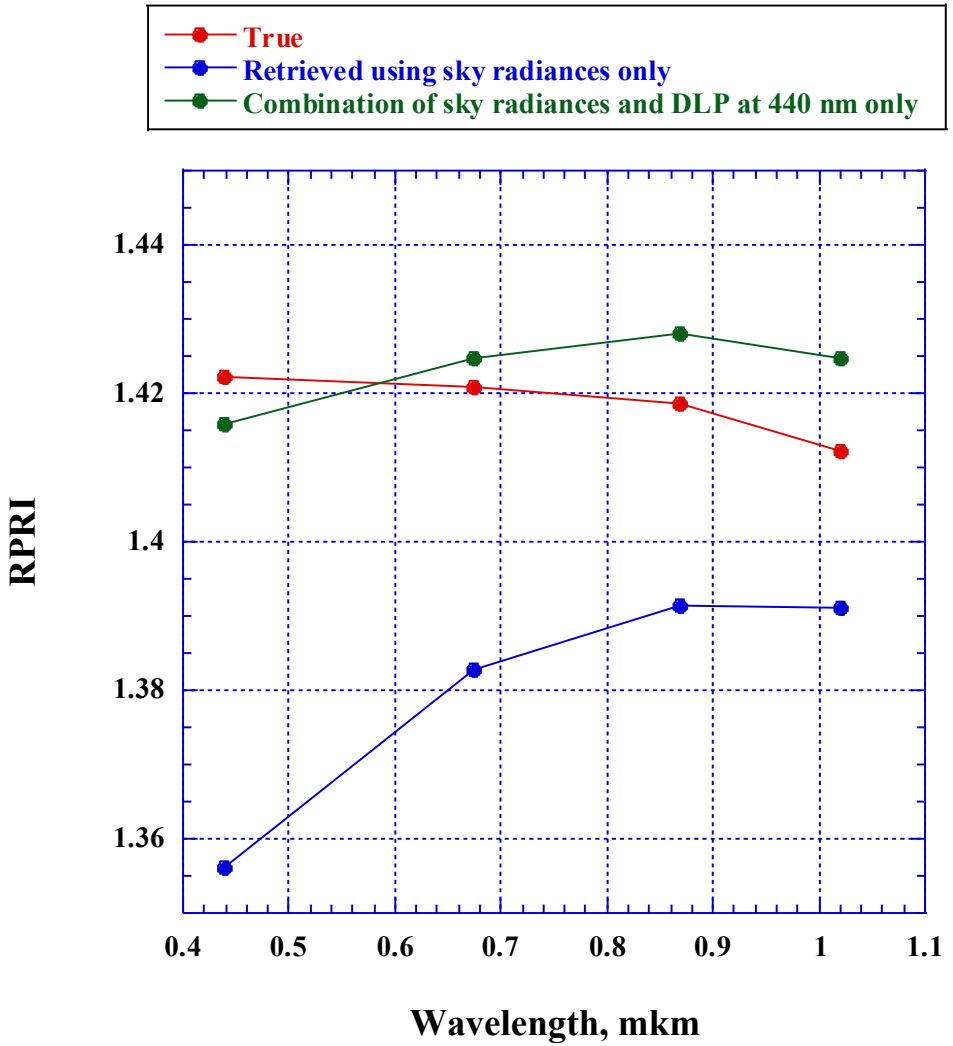


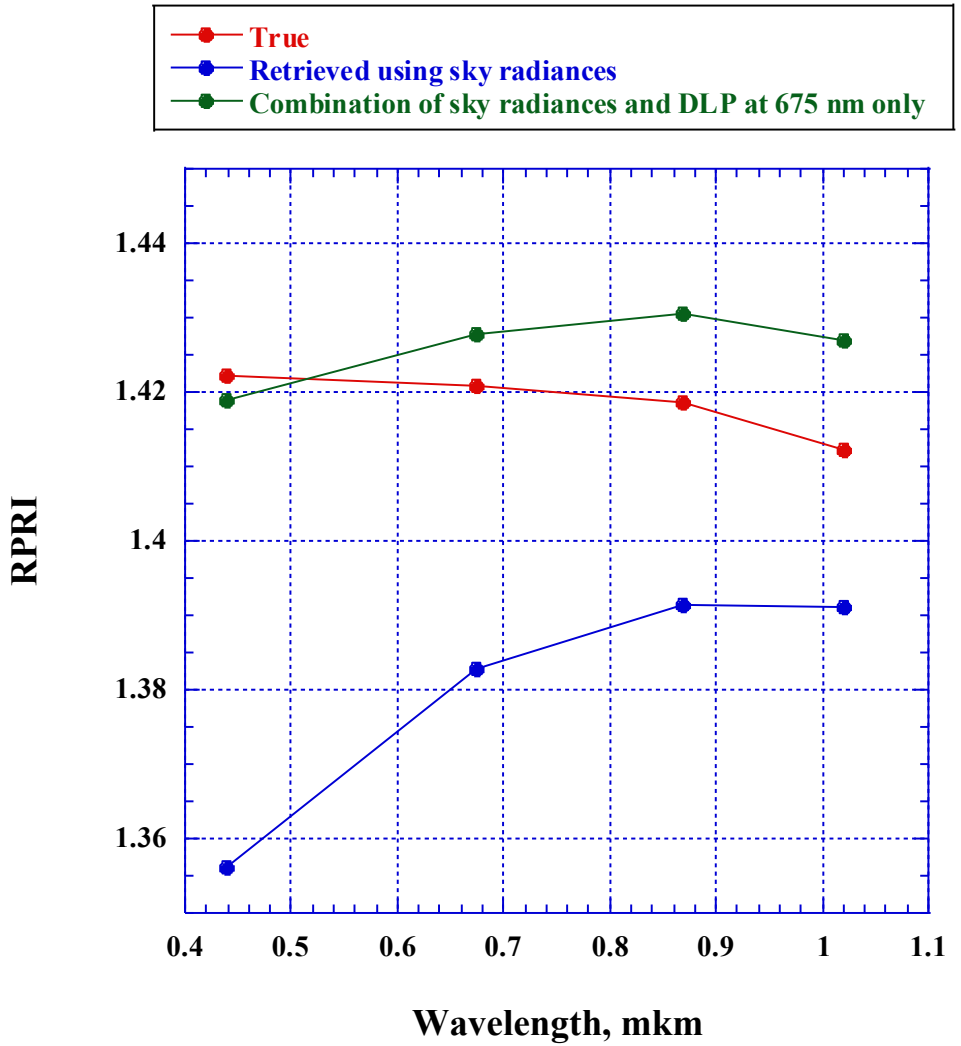
Improvements in accuracy of RPRI and no improvements SSA



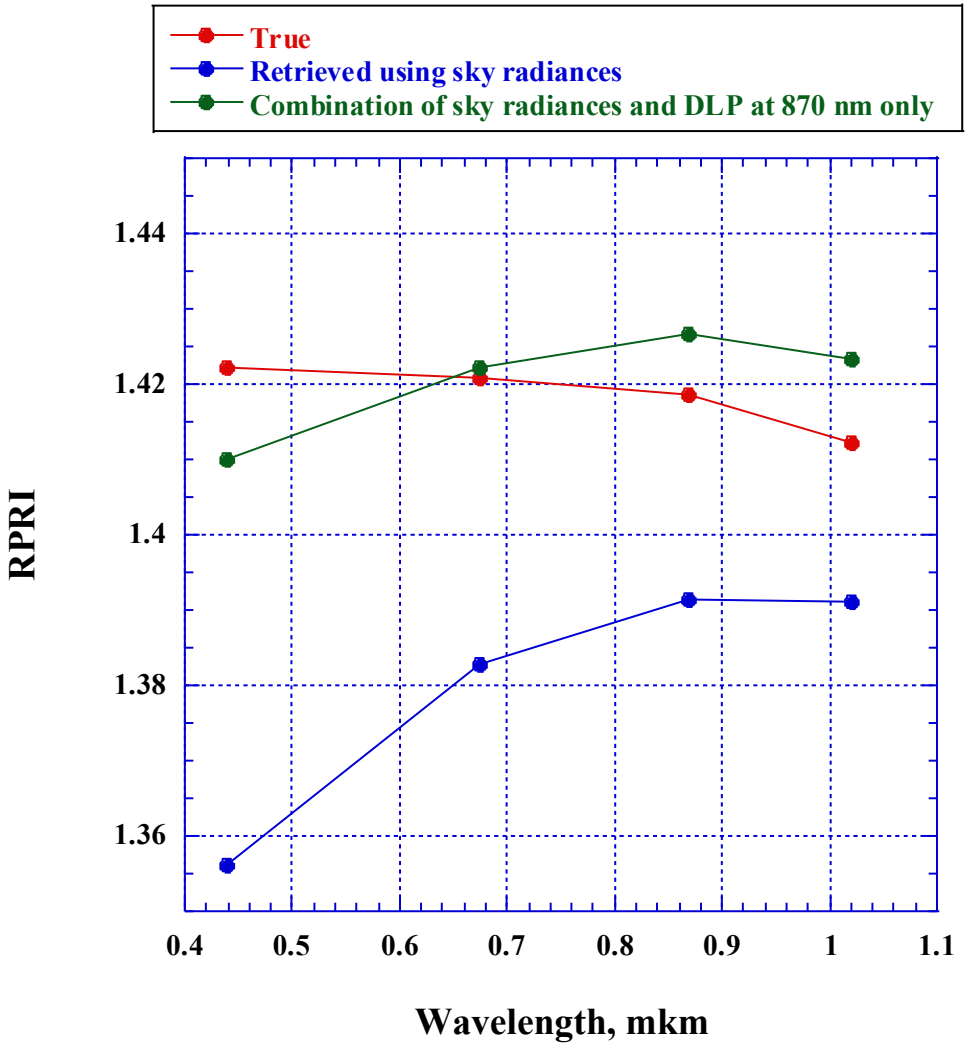


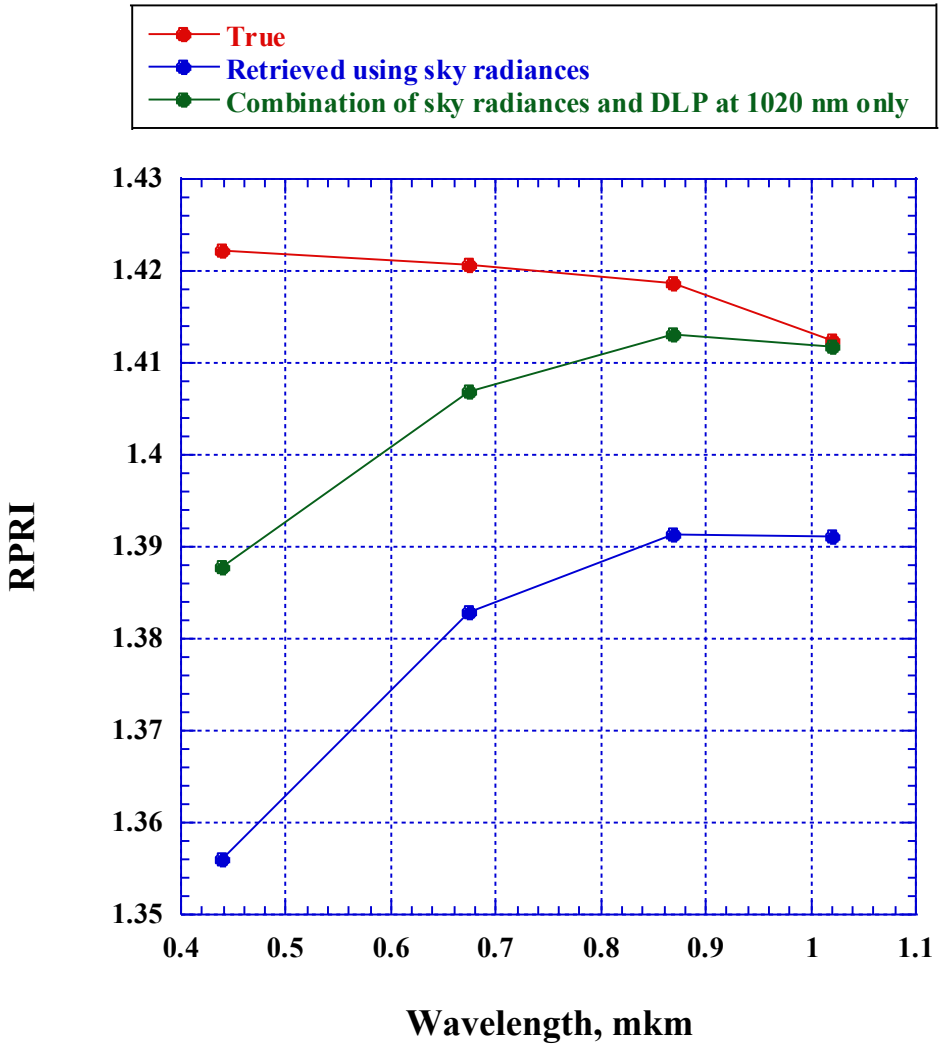
Combining sky radiances with DLP at one wavelength





Combining sky radiances with DLP at one wavelength, cont.





Summary of sensitivity study

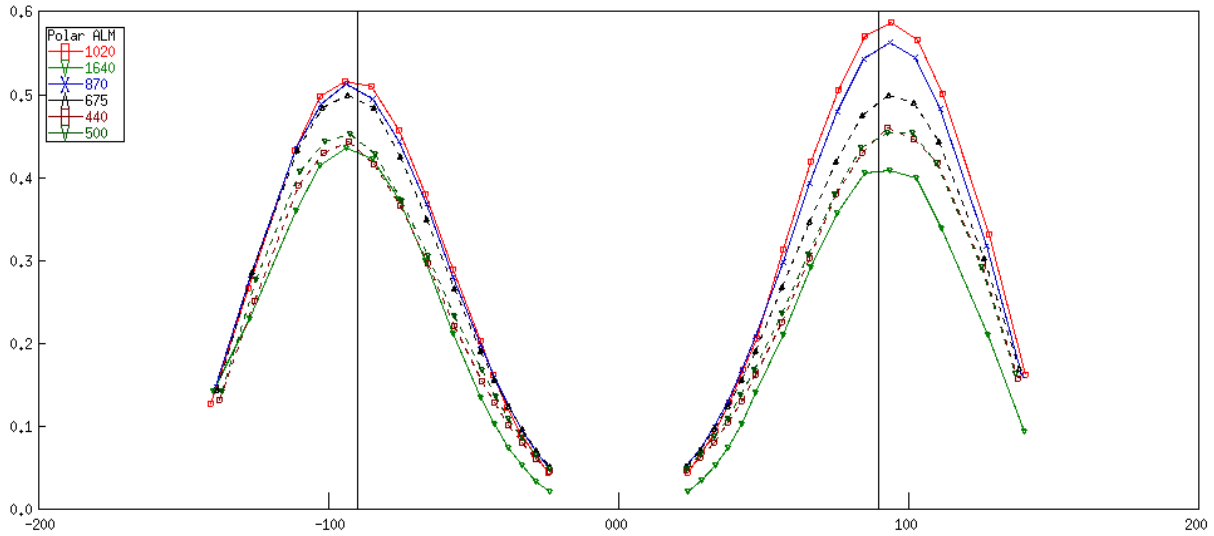
1. **Significant** improvement in accuracy of RPRI.

2. **No improvements** in the accuracy of SSA.

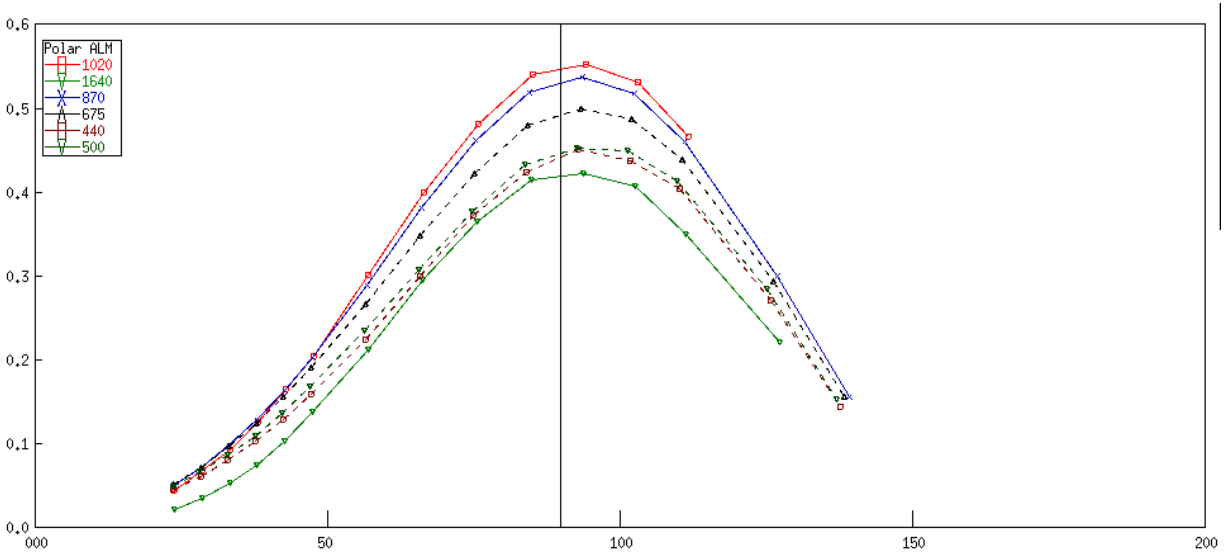
3. DLP measurements can be optimized by using **only one wavelength**. Adding DLP at 440, 675, or 870 nm results in the similar accuracy of RPRI as with DLP at all the four wavelength. Adding DLP at 1020 nm does not produce comparable improvement.

Case study 1: Welgelund (South Africa) , 21.09.19, Input DLP measurement

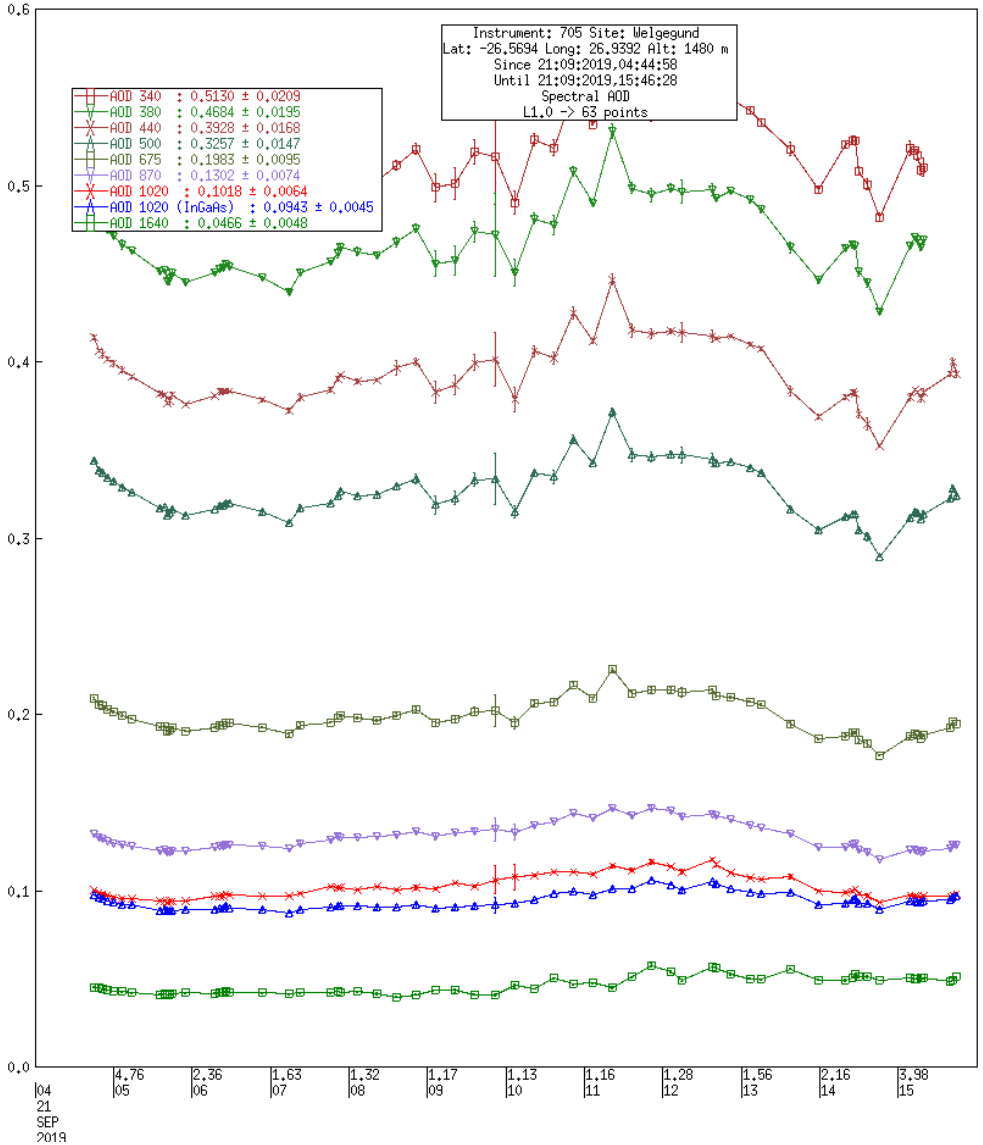
1. Symmetry check between left and right scans. Difference should be less than certain threshold value. In this case 40%.

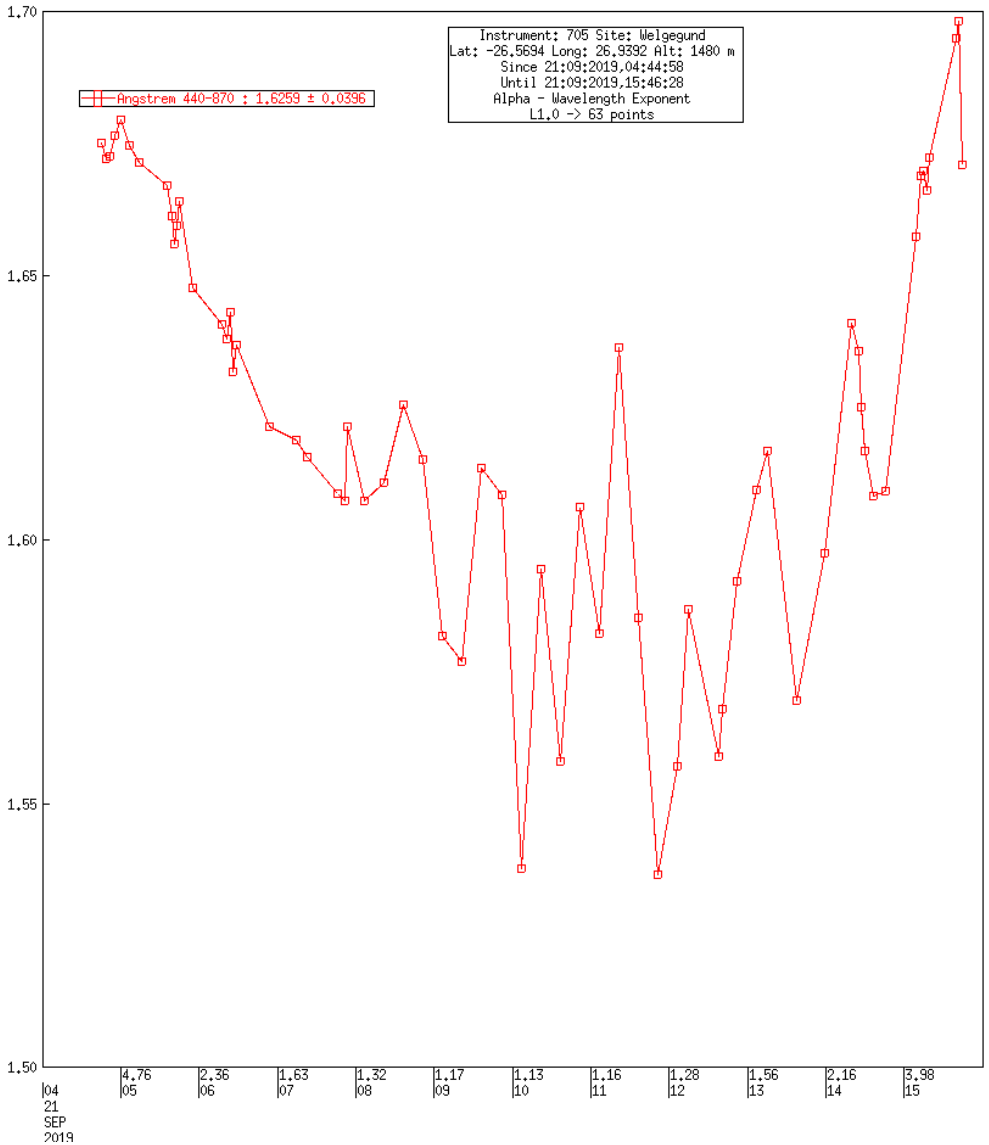


2. Average of left and right scans constitutes input to inversion.

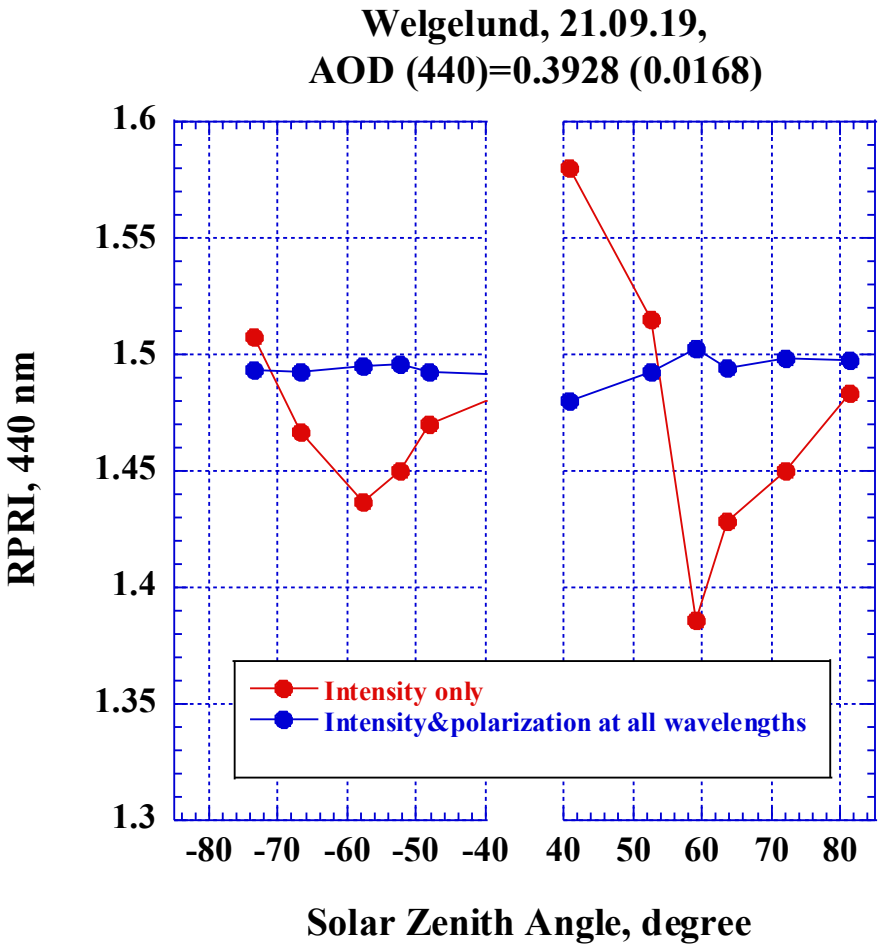


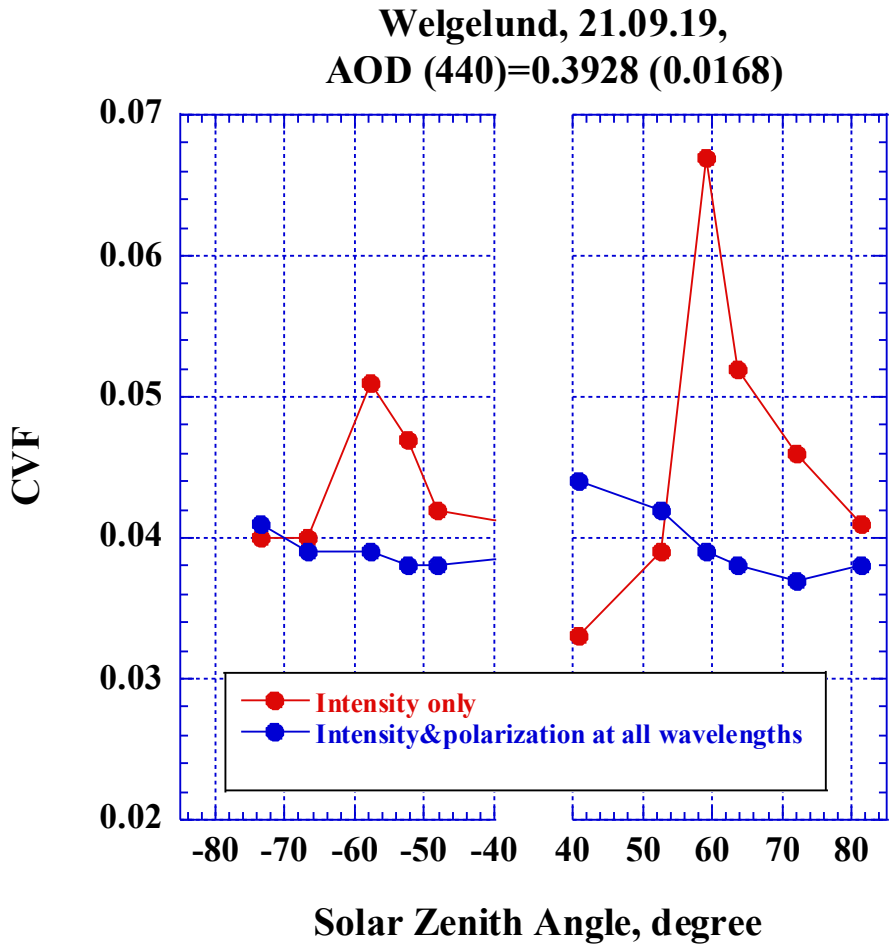
Case study 1: Welgelund , 21.09.19, AOD and wavelength exponent



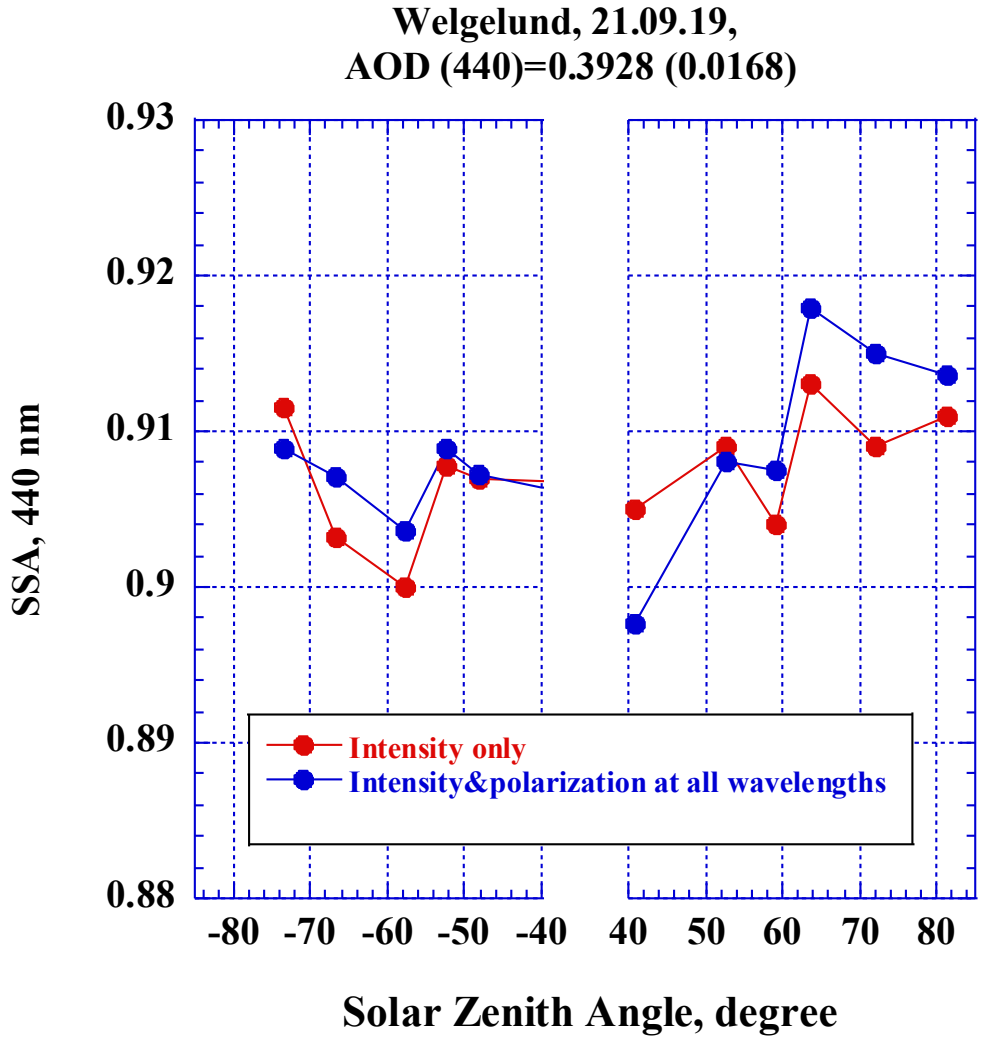


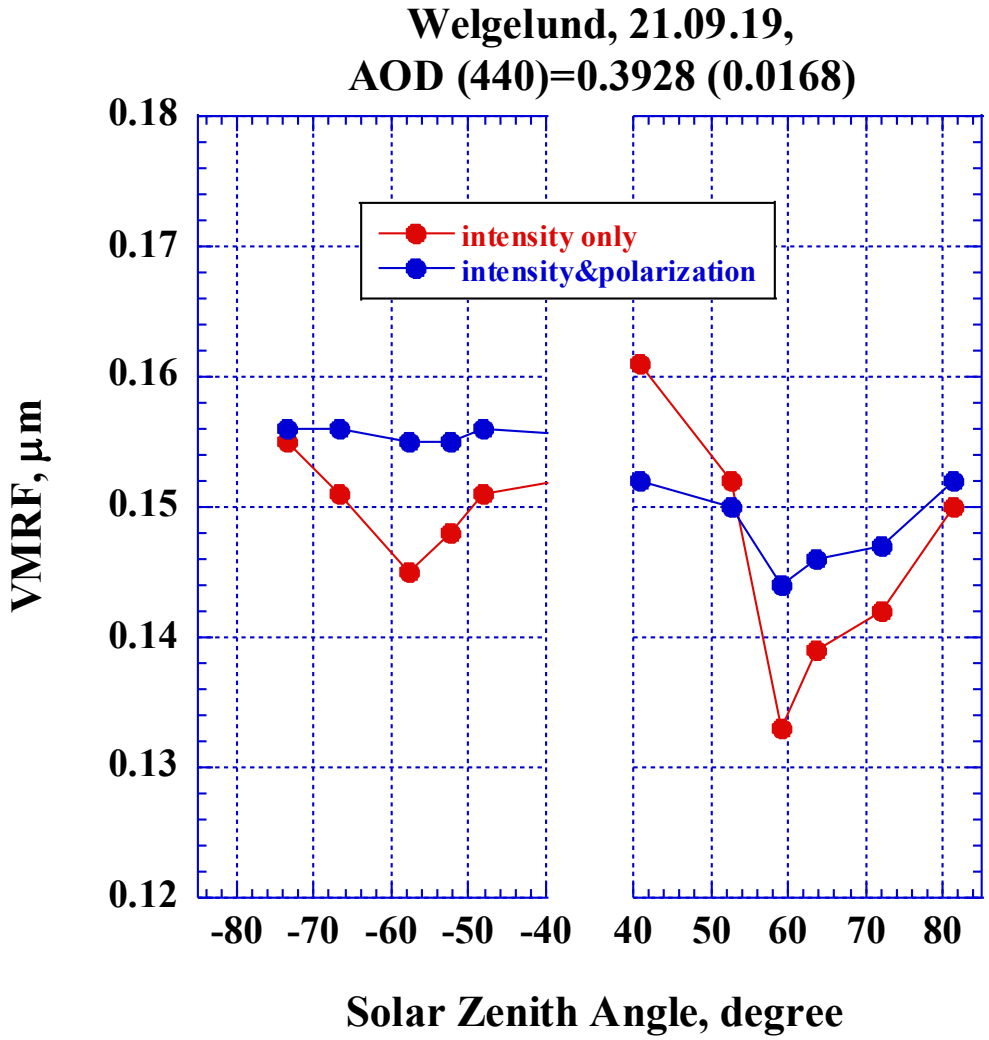
Case study 1: Welgelund, 21.09.19, RPRI and CVF retrievals.





Case study 1: Welgelund, 21.09.19, SSA and VMRF retrievals.

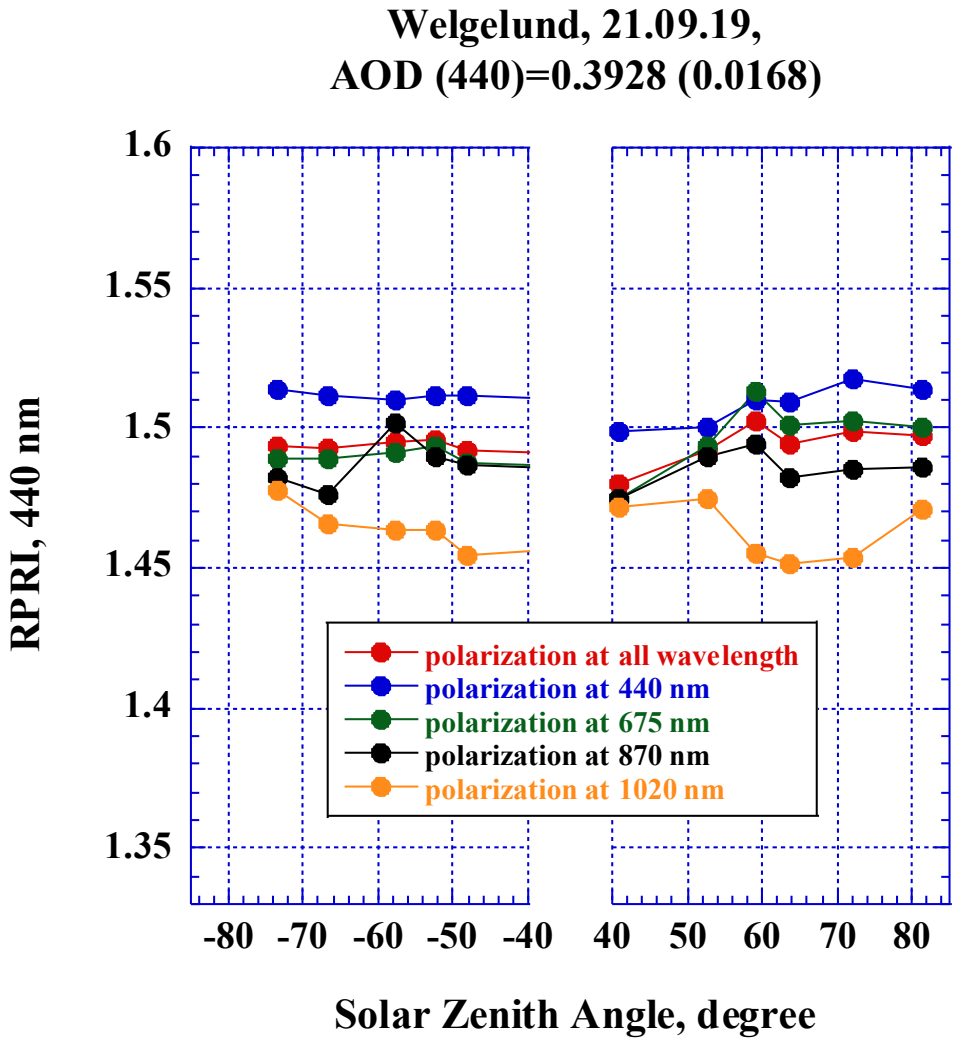


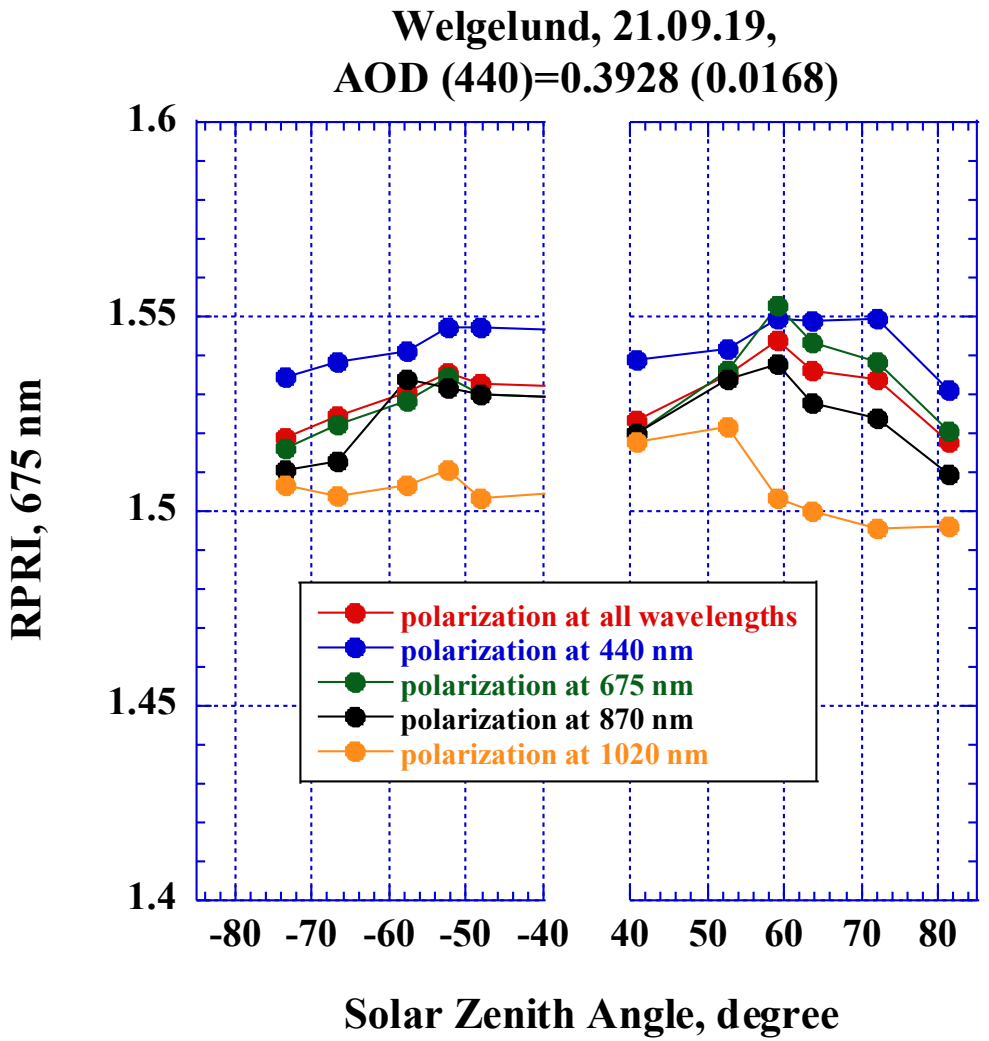


Maximal SSA difference ~ 0.008

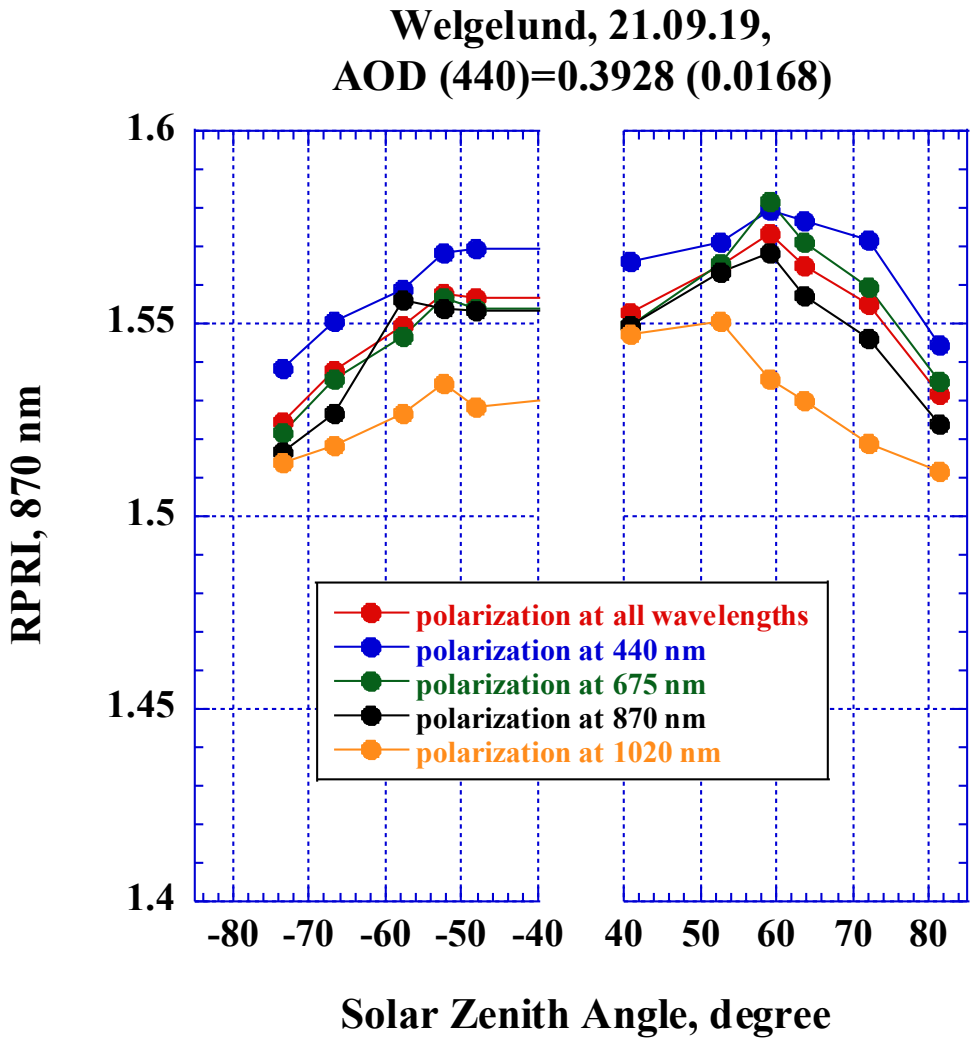
Maximal VMRF difference ~ 0.01

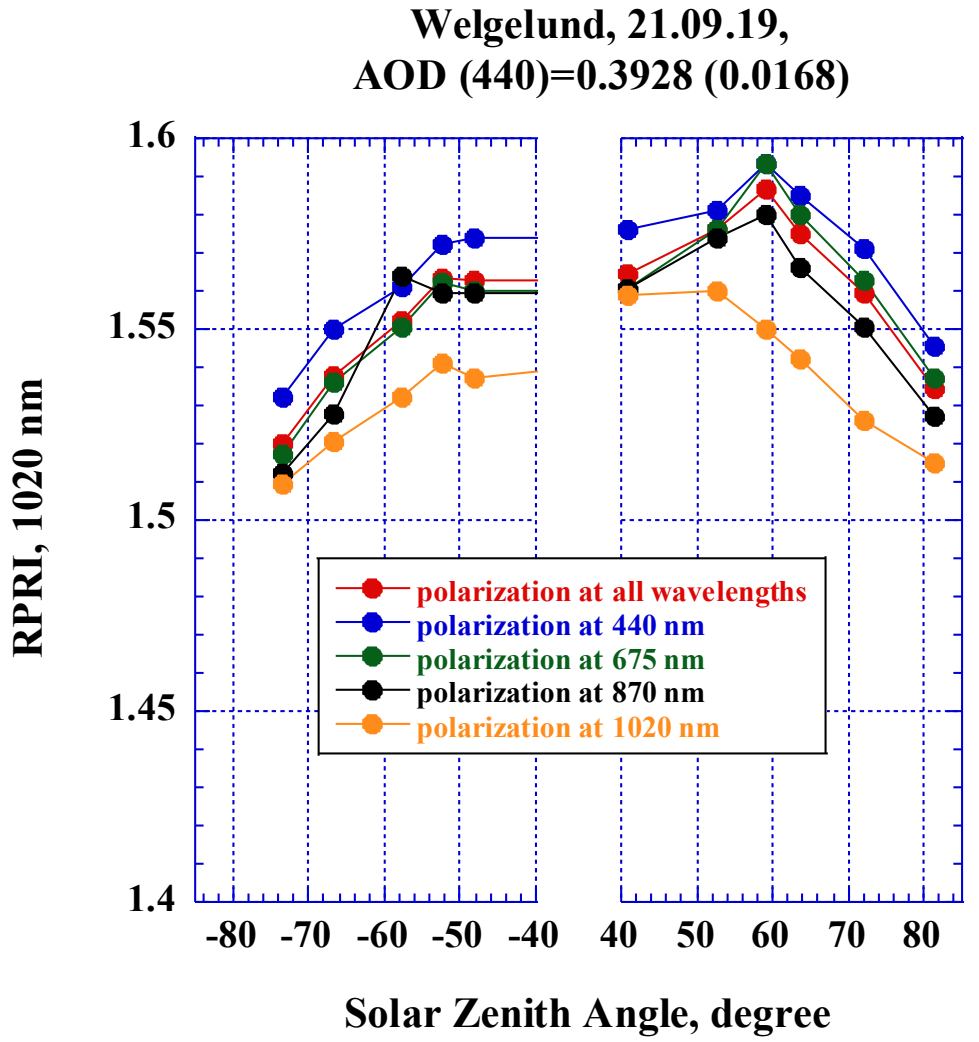
Case study 1: Welgelund, 21.09.19, All channels vs one channel DPL



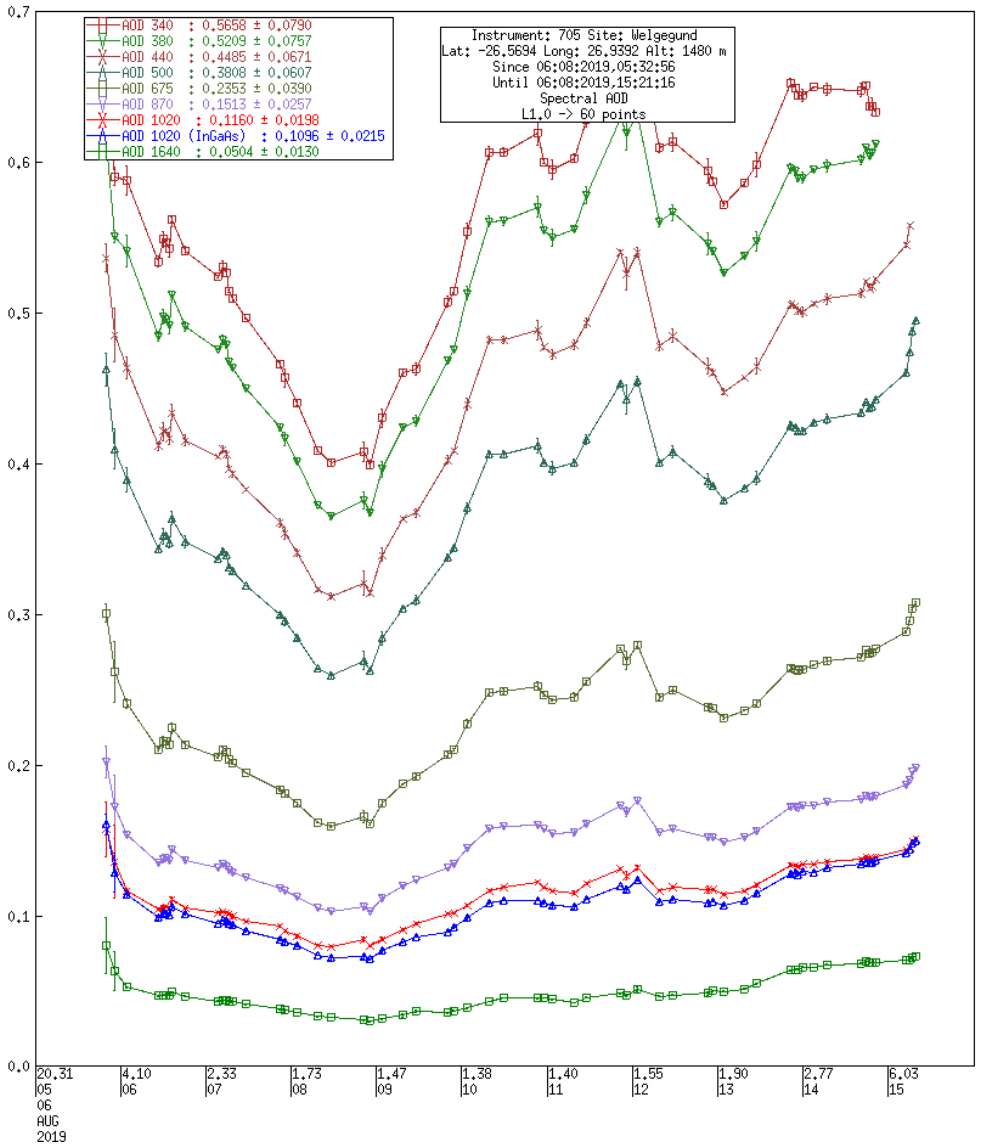


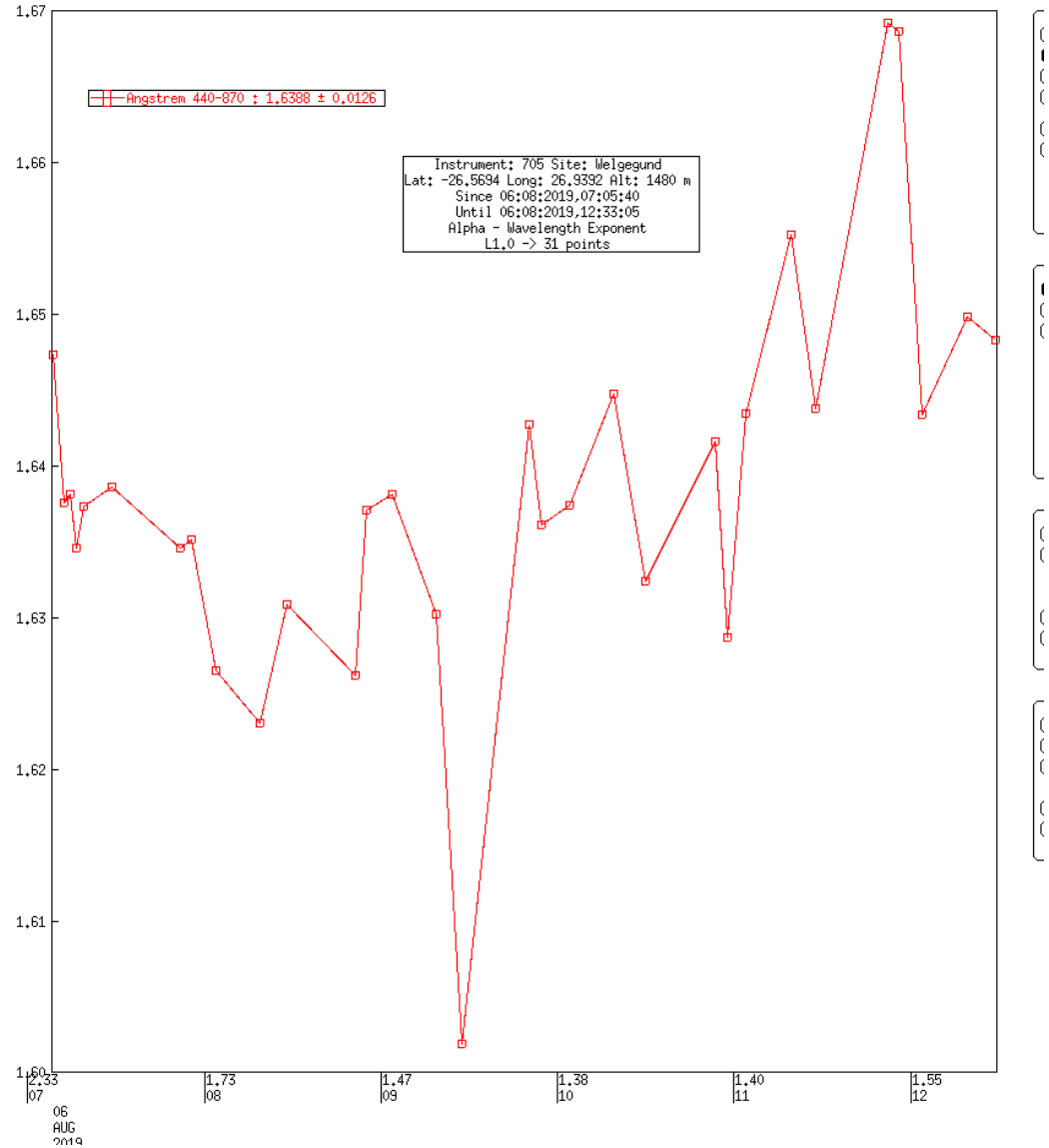
Case study 1: Welgelund, 21.09.19, All channels vs one channel DPL, cont.



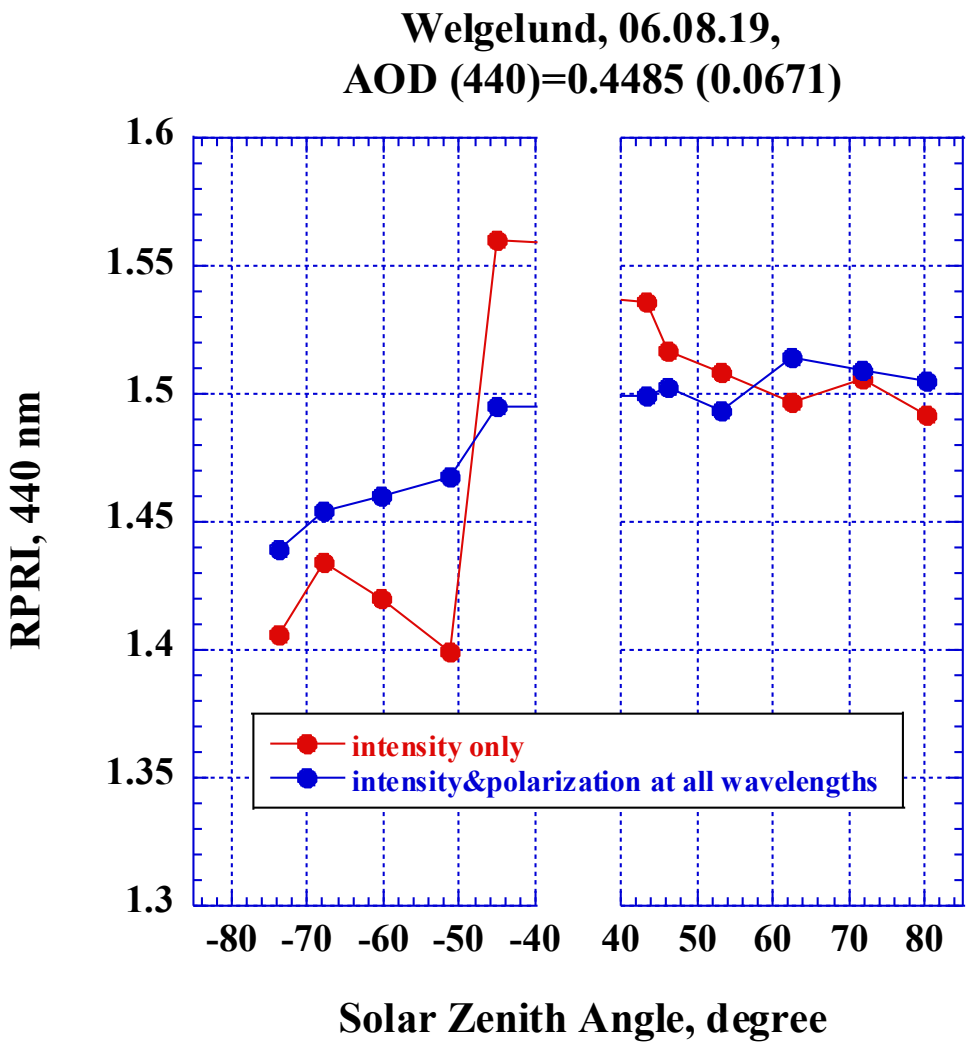


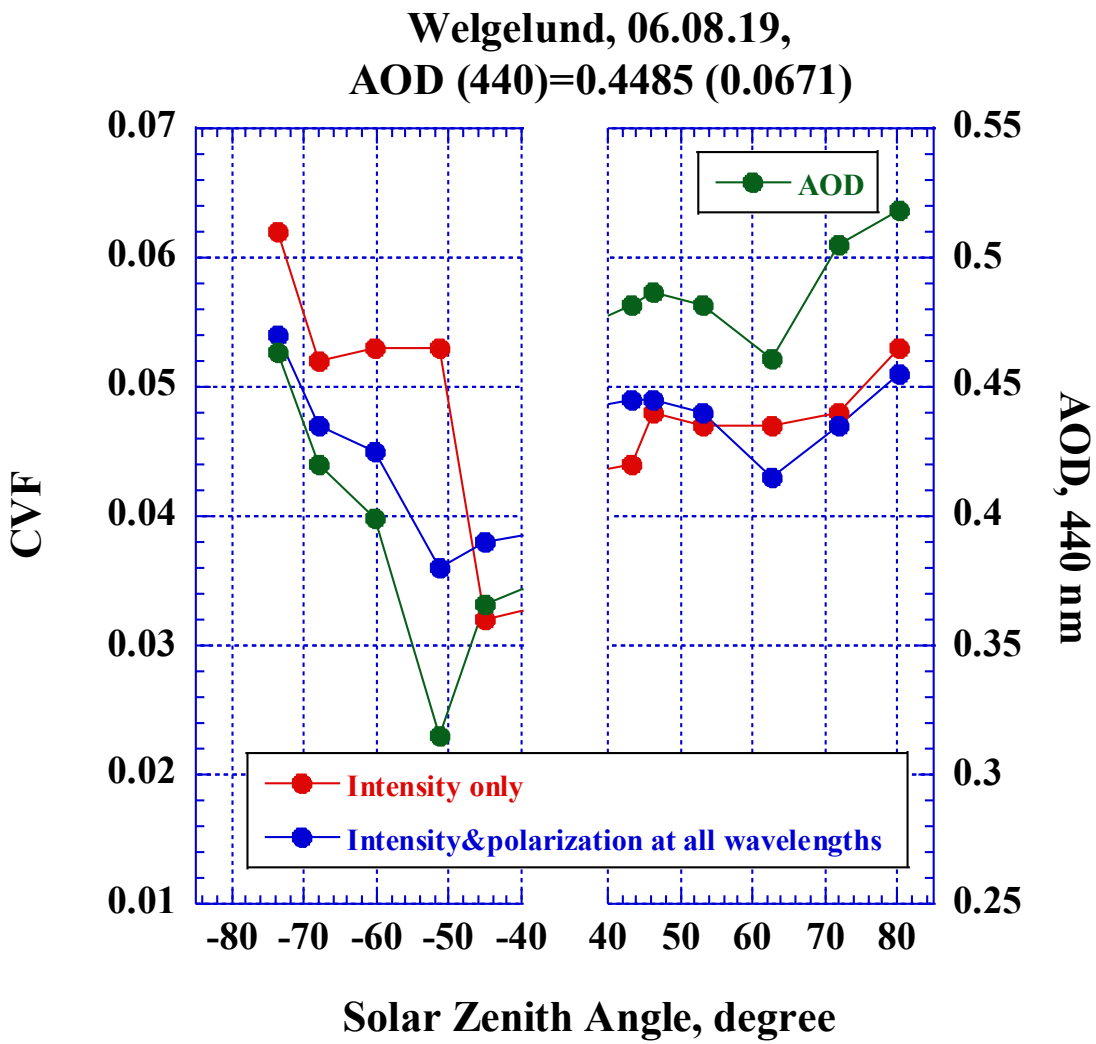
Case study 2: Welgelund, 06.08.19, AOD and wavelength exponent



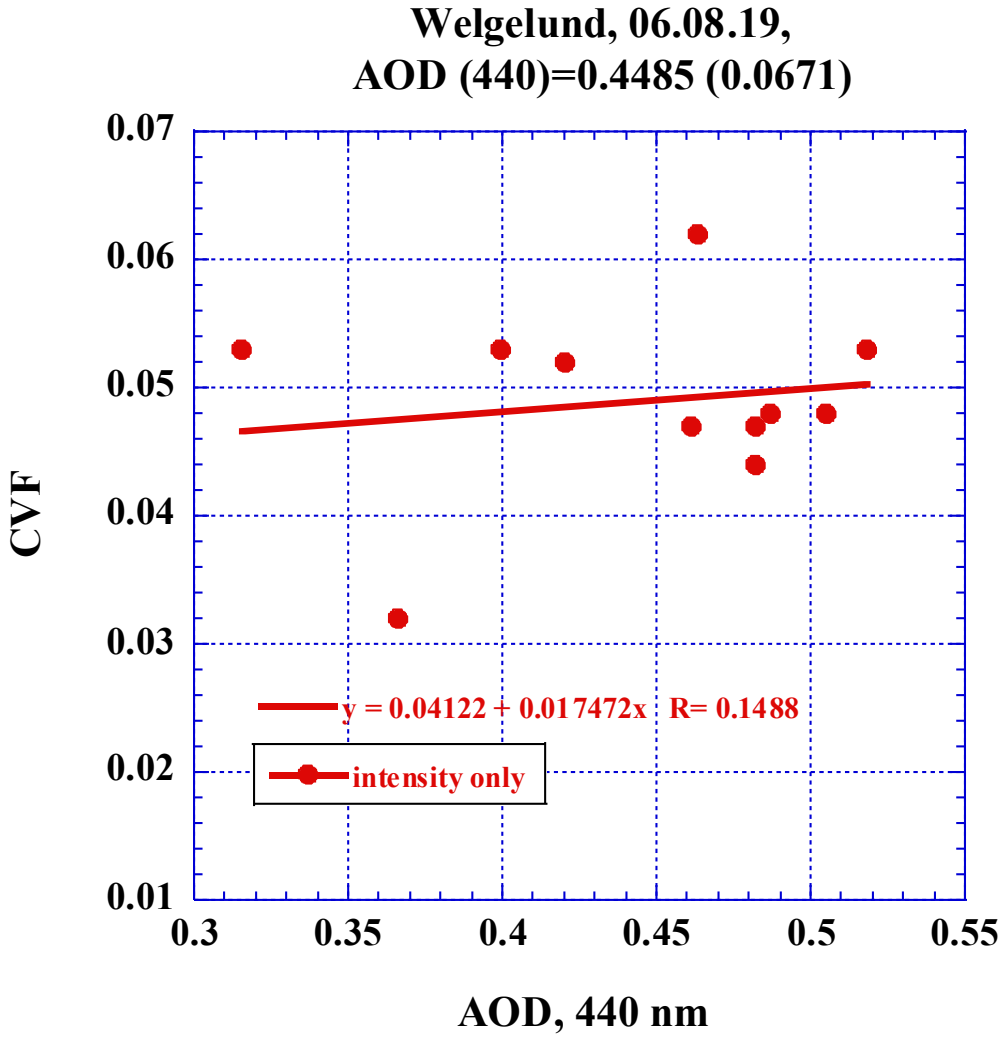


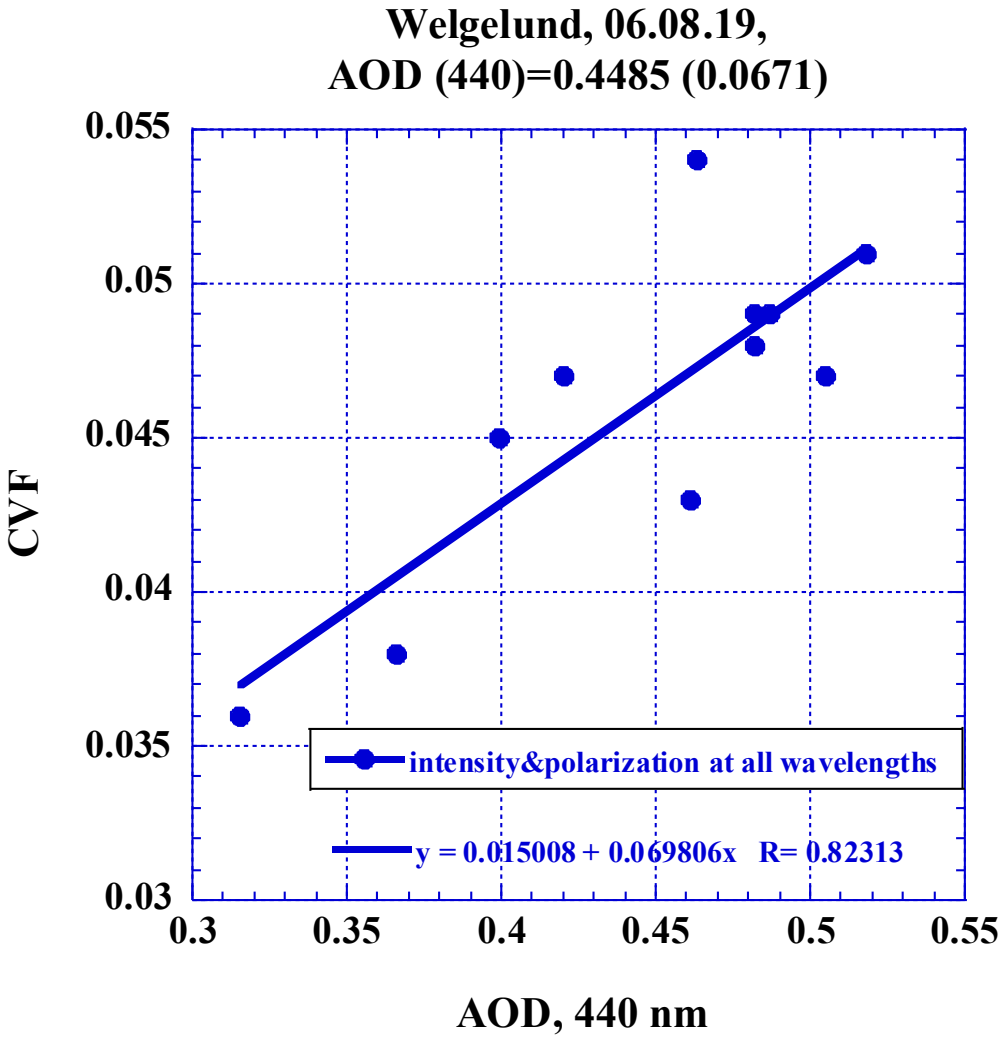
Case study 2: Welgelund, 06.08.19, RPRI and CVF retrievals.



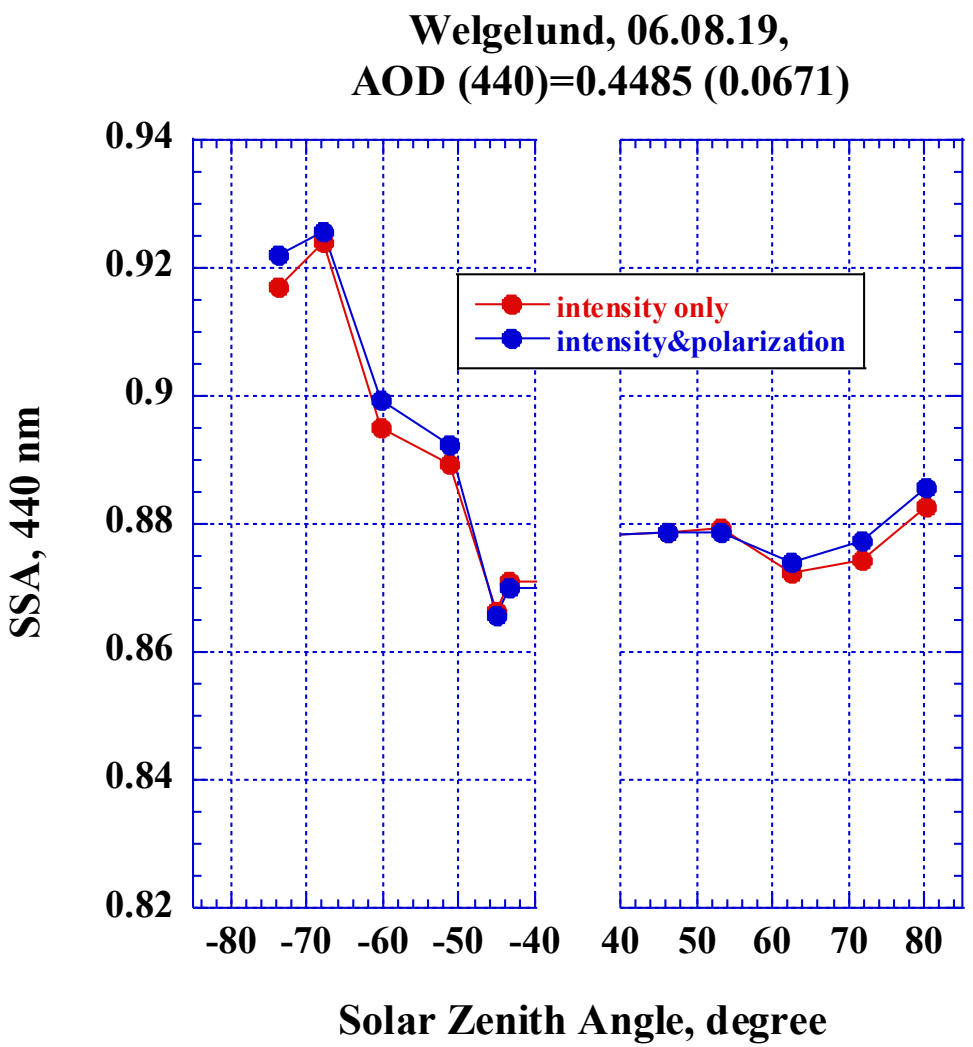


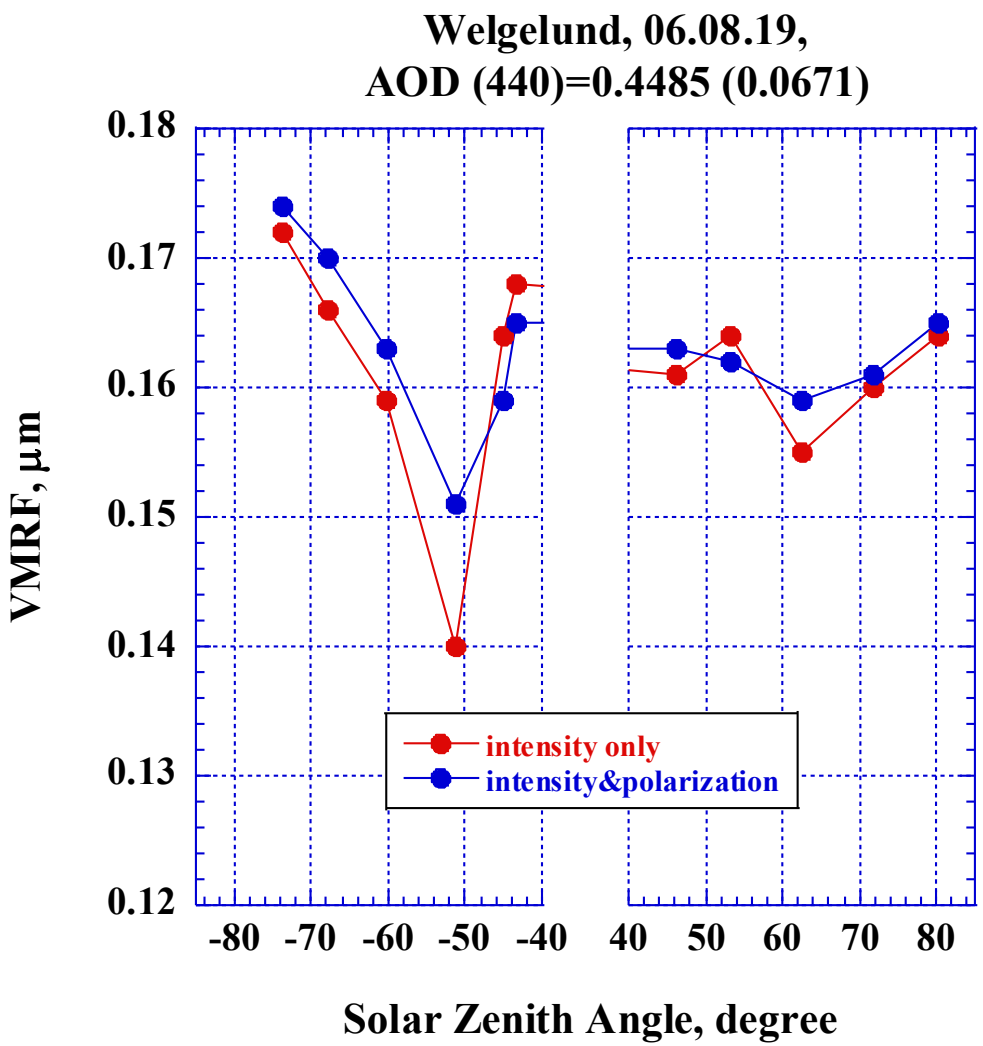
Case study 2: Welgelund, 06.08.19, CVF –AOD correlation





Case study 2: Welgelund, 06.08.19, SSA and VMRF retrievals.

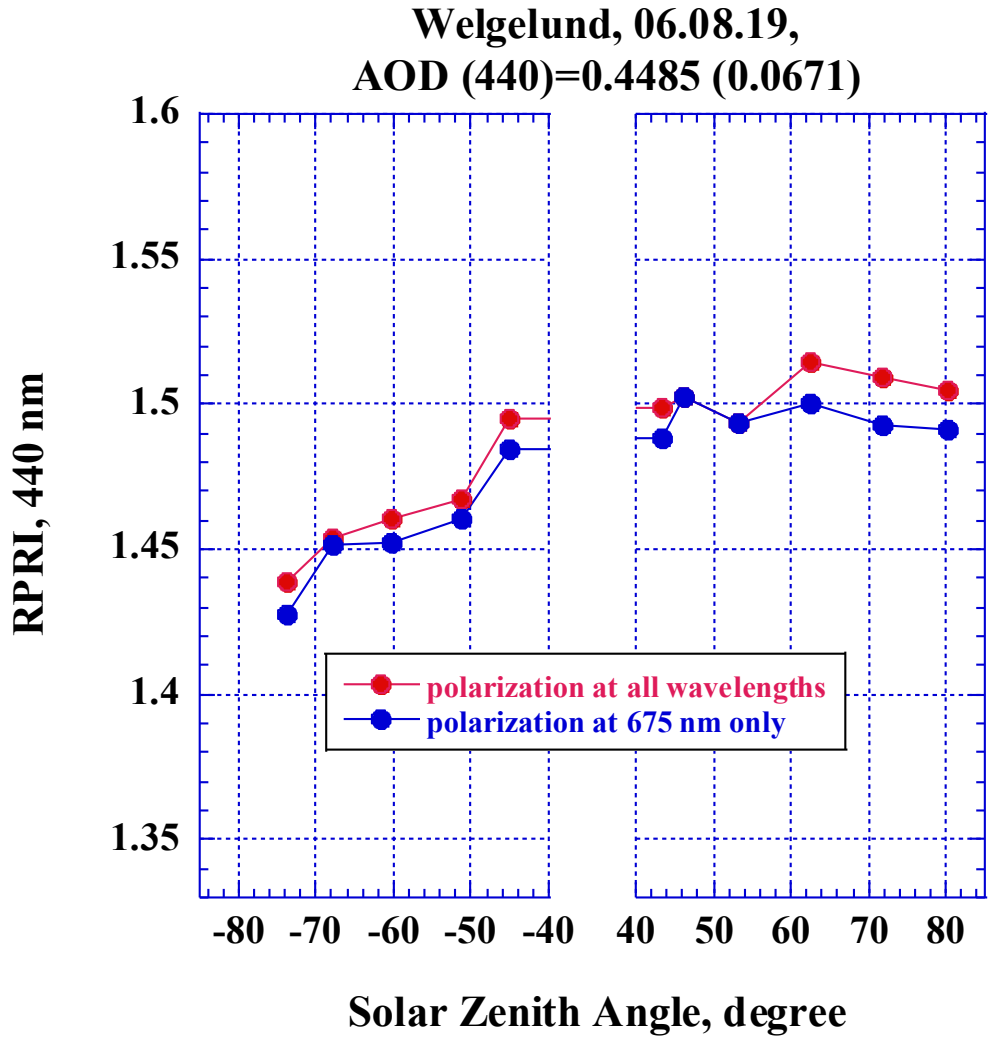


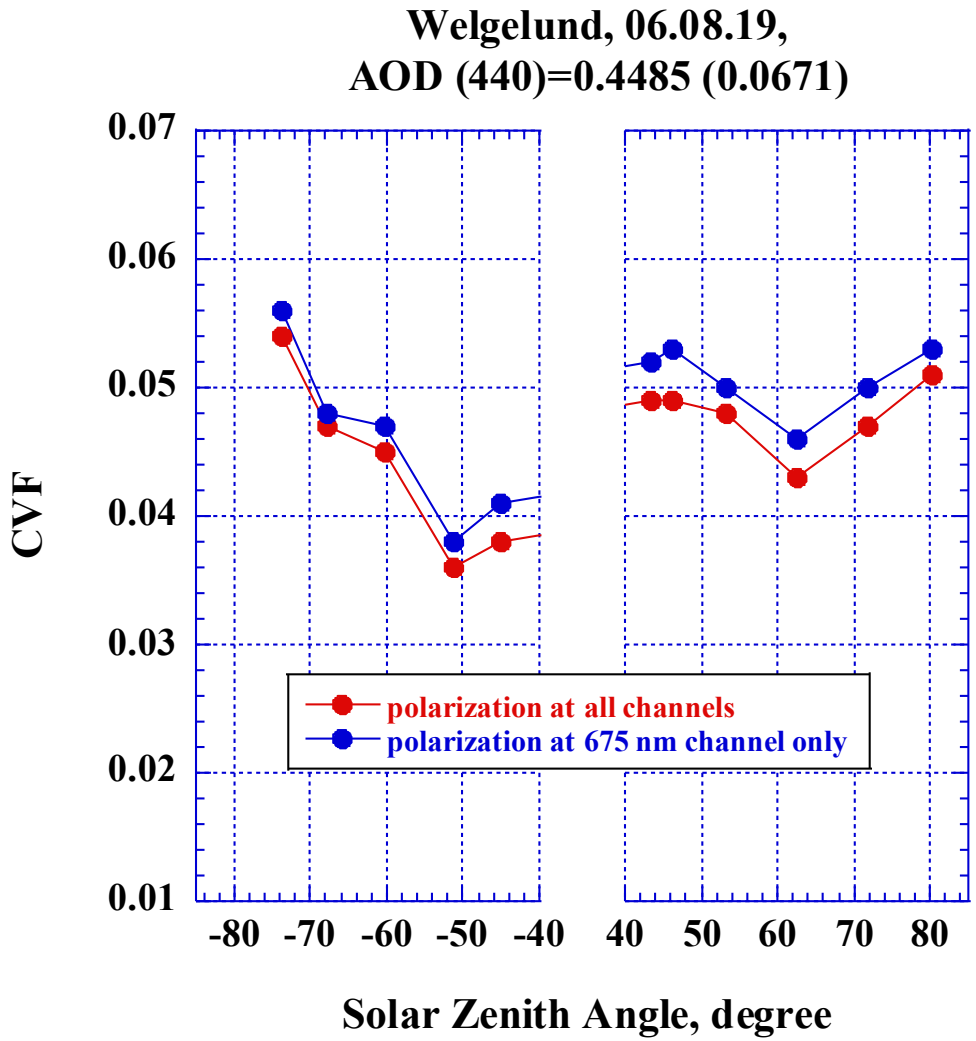


Maximal SSA difference ~ 0.005

Maximal VMRF difference ~ 0.011

Case study 2: Welgelund, 06.08.19, All channels vs 675 nm channel DLP





Summary

It is shown that in along with improvement the accuracy of RPRI, adding polarization measurements stabilizes retrievals of volume concentration of fine mode aerosol.

It is shown that polarized measurements can be optimizing by reducing the number of polarized channels included in inversion input. The initial analysis demonstrated that both 675 nm and 870 nm channels are suited for this goal, although eventually 675 nm channel might be selected due to higher value of corresponding aerosol optical depth.