Implications of BRF uncertainties to AOD retrievals

from single-view and intensity-only data.

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AOD retrieval on imaging spectroscopy data

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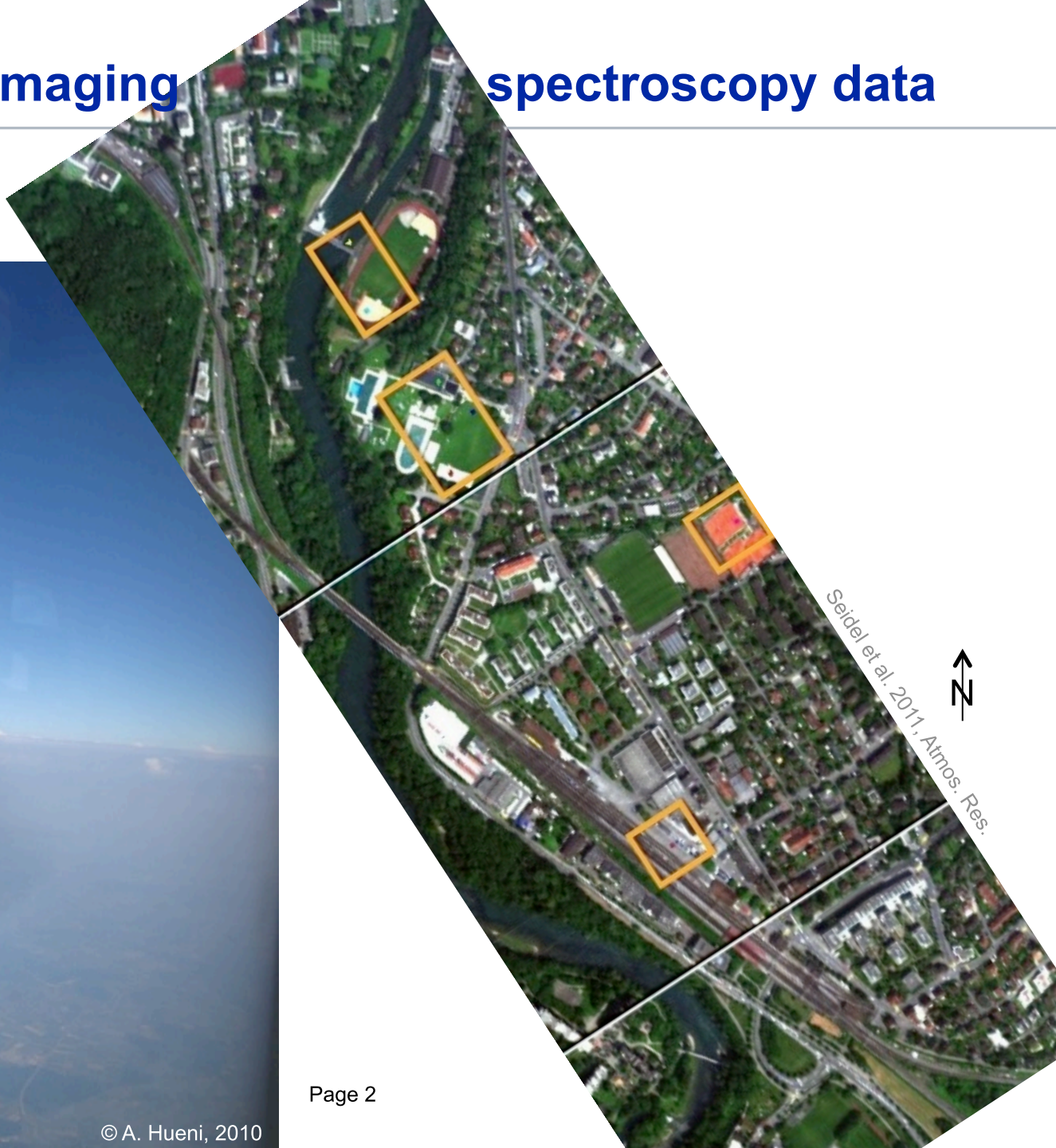
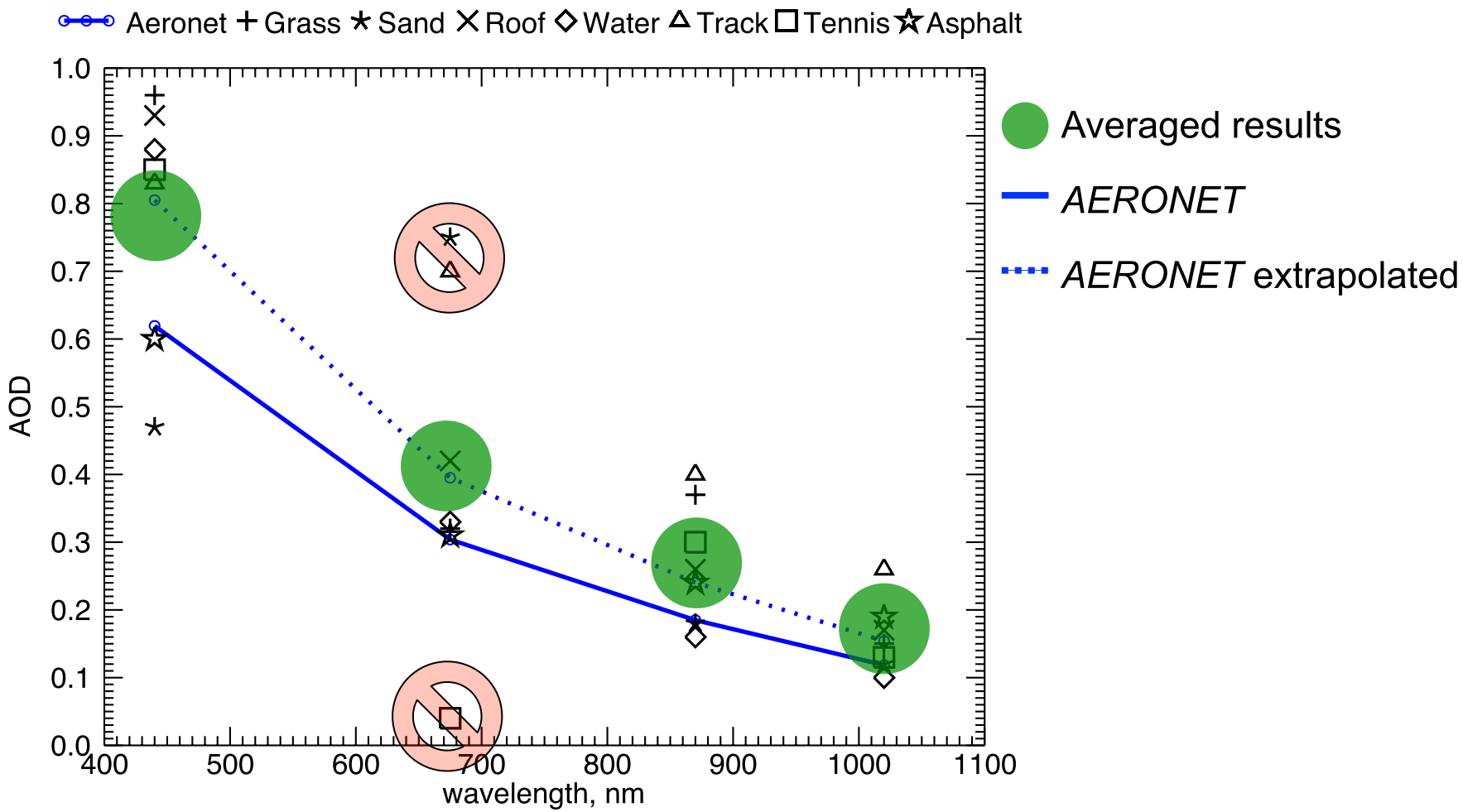


Seidel et al. 2011, Atmos. Res.

Comparison of iSMART with AERONET

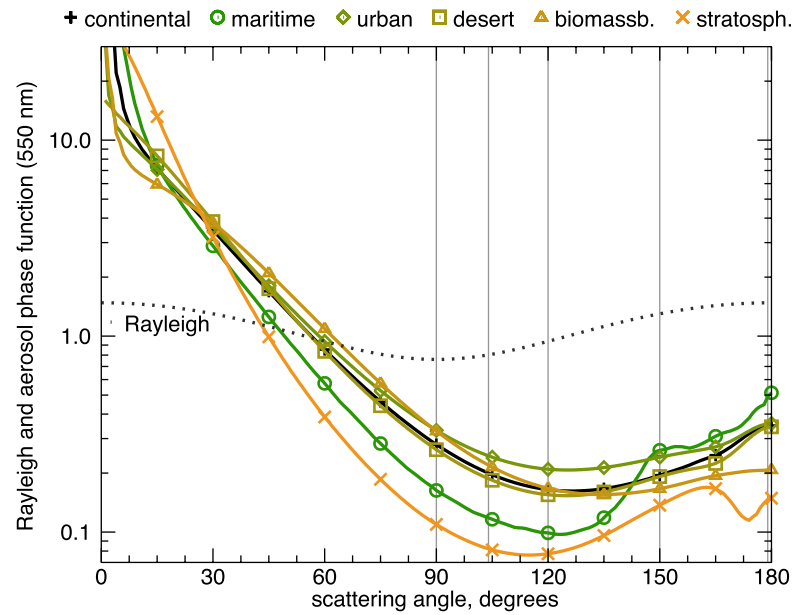


Seidel et al. 2011, Atmos. Res.

Synthetic Data

Parameters used to run 6S

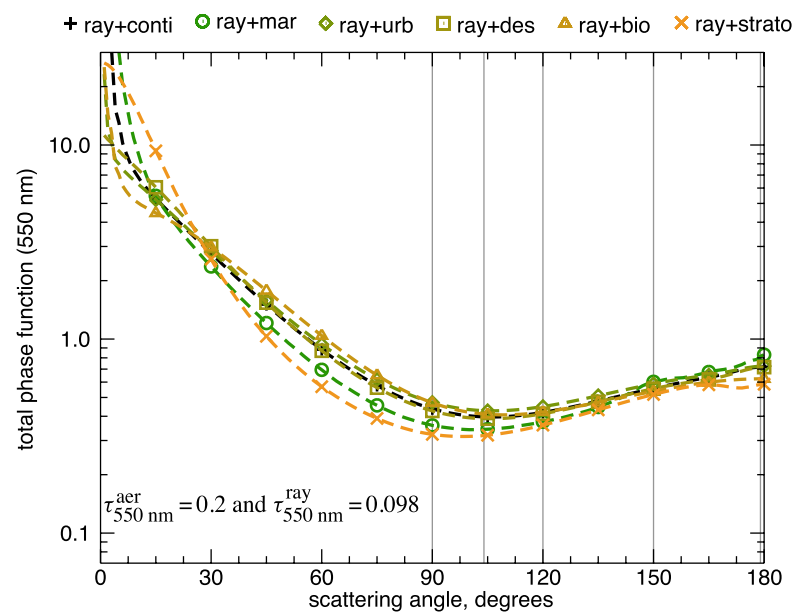
Viewing azimuth angle, ϕ	$0°, 90°, 180°$
Viewing zenith angle, θ	$0°, 30°, 60°$
Solar azimuth angle, ϕ_0	$180°$
Solar zenith angle, θ_0	$0°, 15°, 30°, 45°, 60°$
Surface albedo, a_λ	0.0(0.1)1.0
Wavelength, λ	412 nm, 550 nm, 865 nm
AOD, $\tau_{550\ \mathrm{nm}}$	0.0, 0.05, 0.1(0.1)0.5, 0.75, 1.0
Sensor-, Target level	TOA, Sea level



Aerosol Model Properties (from 6S)

	$\omega_{412\ \mathrm{nm}}$	$\omega_{550\ \mathrm{nm}}$	$\omega_{865\ \mathrm{nm}}$	g	α
Continental	0.901	0.893	0.857	0.619	1.327
Maritime	0.989	0.989	0.987	0.638	1.323
Urban	0.696	0.689	0.630	0.515	1.350
Desert	0.924	0.966	0.992	0.665	1.008
Biomass	0.943	0.932	0.896	0.623	2.004
Stratospheric	1.000	1.000	1.000	0.808	0.302

D'Almeida et al. 1991 Dubovik et al. 2002 Russell et al. 1996



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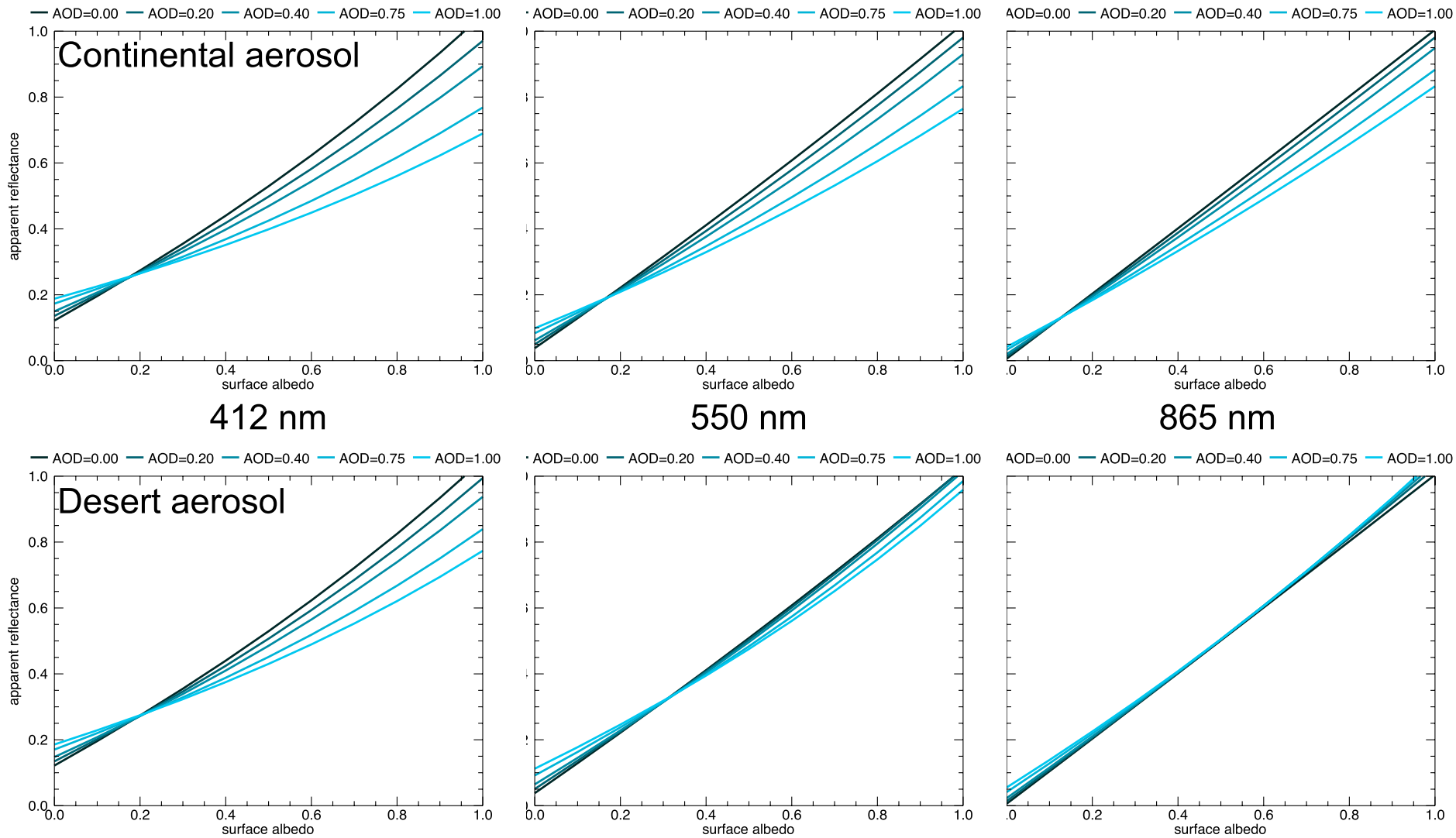
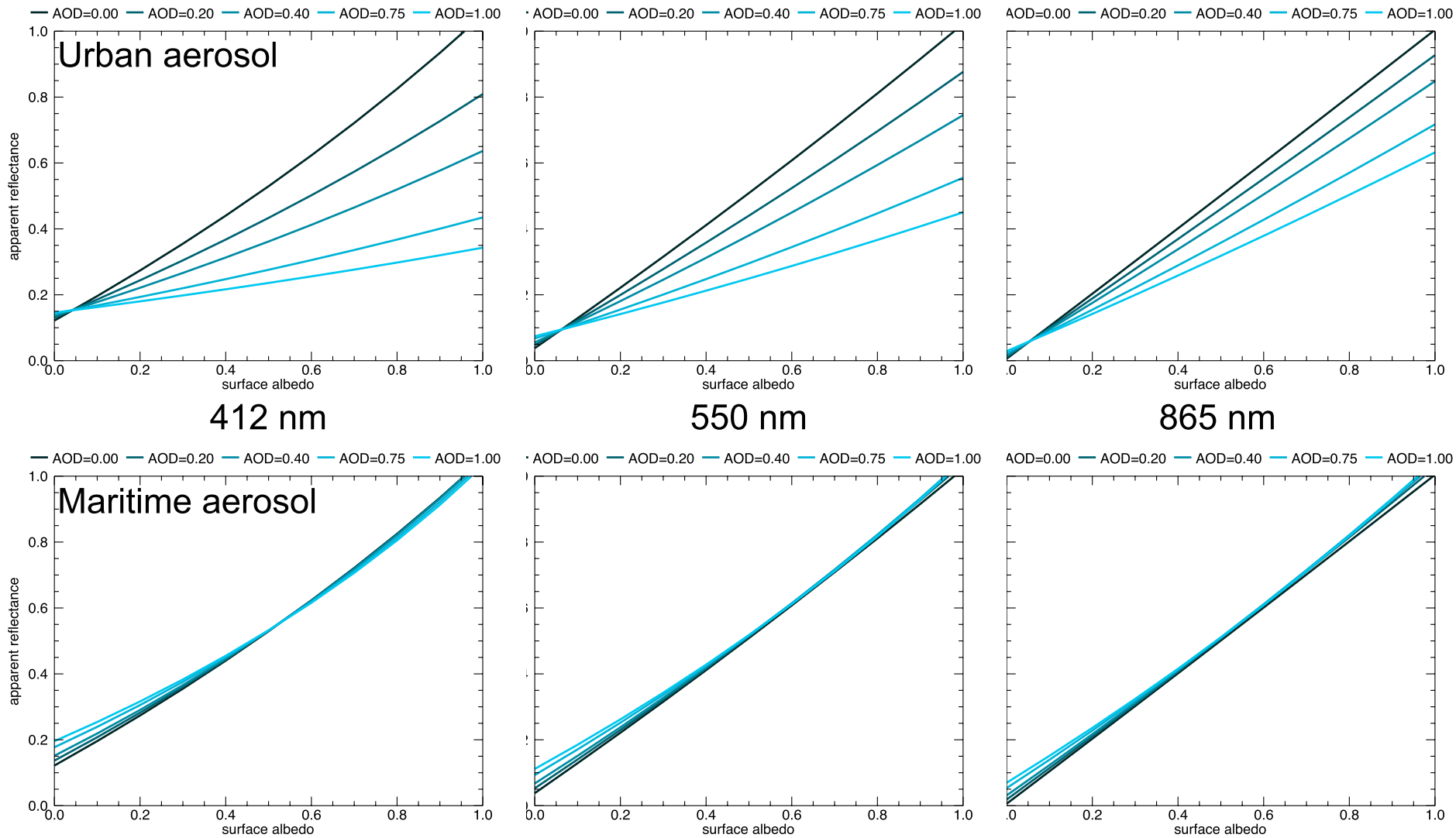
R^{TOA} as function of surface albedo



$\phi = 0^\circ,\ \theta_0 = 0^\circ,\ \theta = 30^\circ,\ \Theta = 150^\circ$

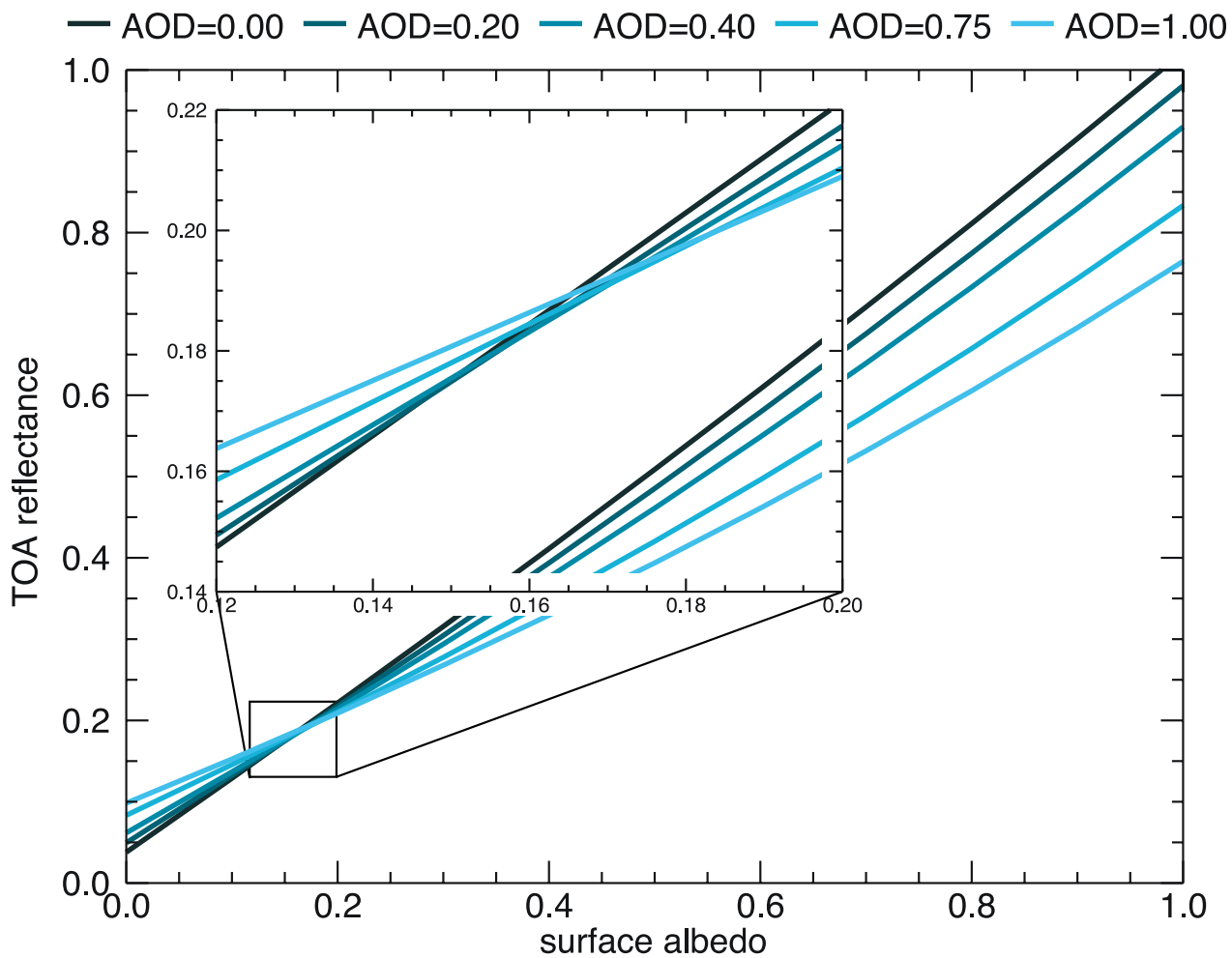
R^{TOA} as function of surface albedo



$\phi = 0^\circ,\ \theta_0 = 0^\circ,\ \theta = 30^\circ,\ \Theta = 150^\circ$

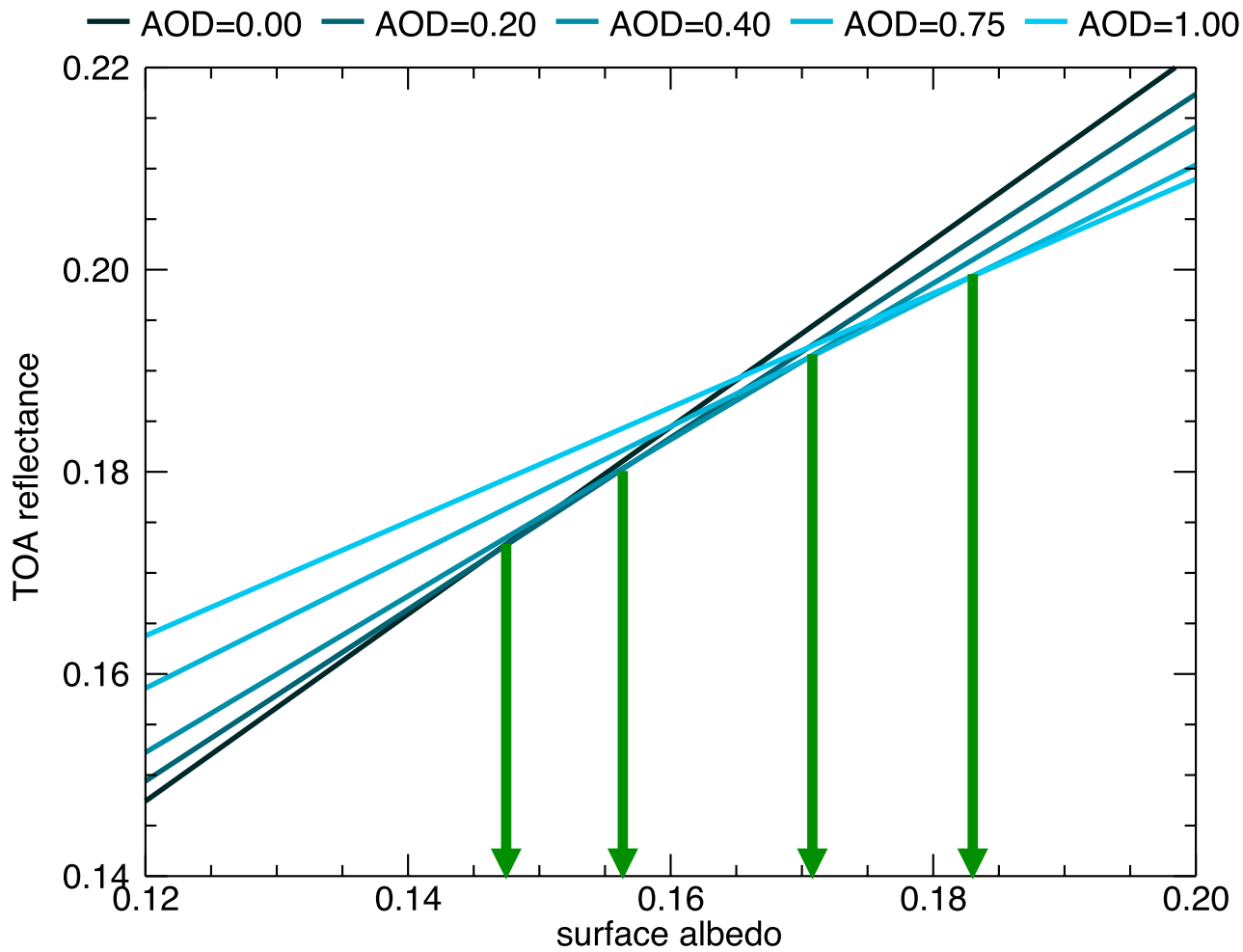
Critical Surface Albedo / Critical Reflectance

$$\frac{dR_\lambda^{TOA}}{d\tau_\lambda^{\mathrm{aer}}} = 0$$

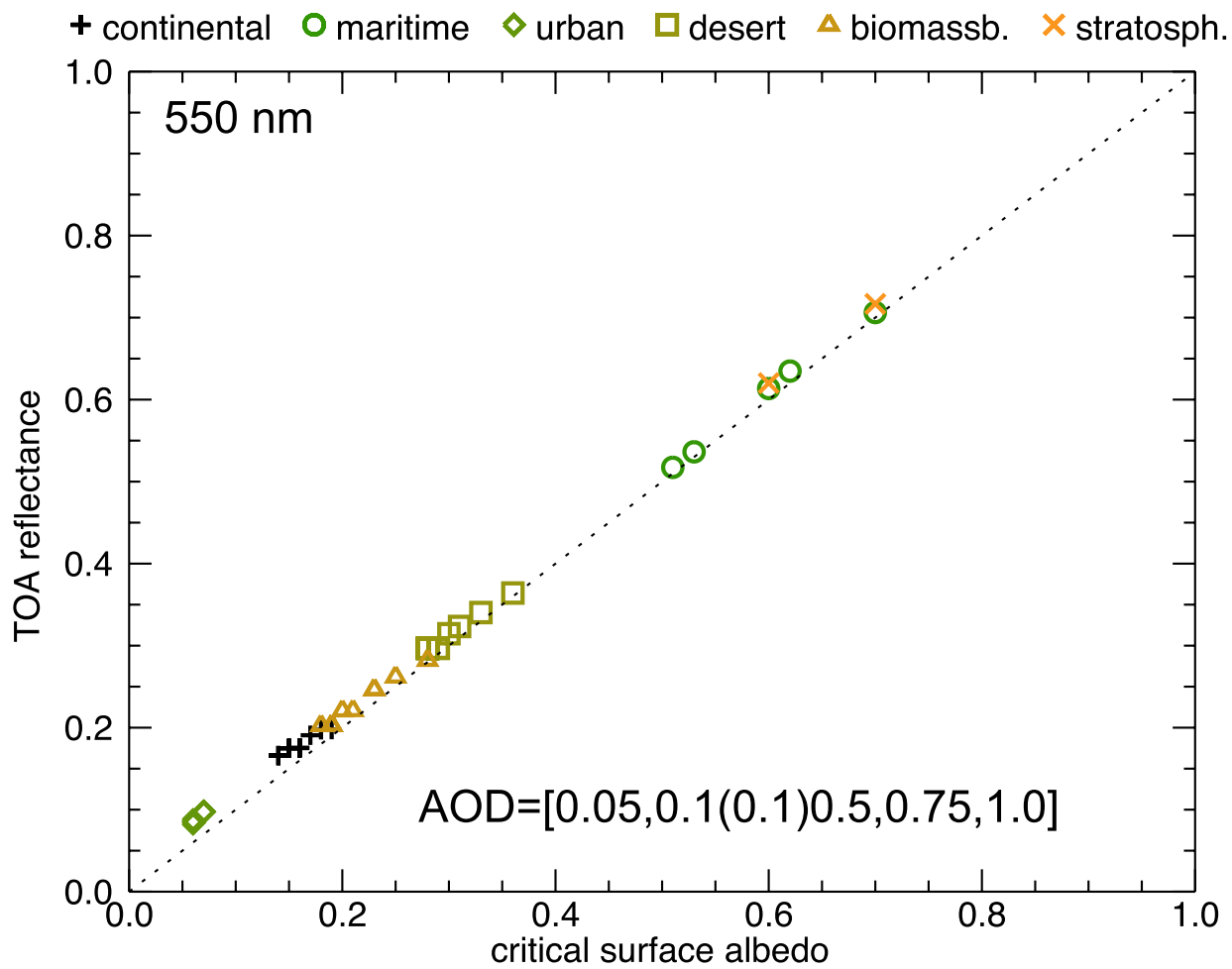


Seidel and Popp 2012, AMT

Critical Surface Albedo / Critical Reflectance



Critical Surface Albedo / Critical Reflectance

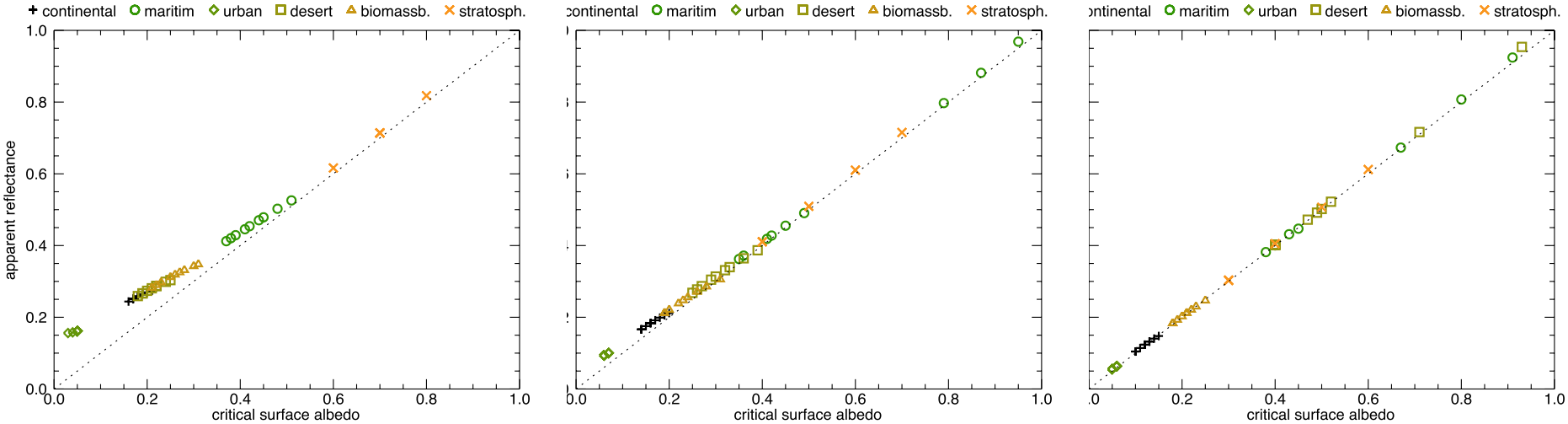


$$\phi = 0^\circ,\ \theta_0 = 0^\circ,\ \theta = 30^\circ,\ \Theta = 150^\circ$$

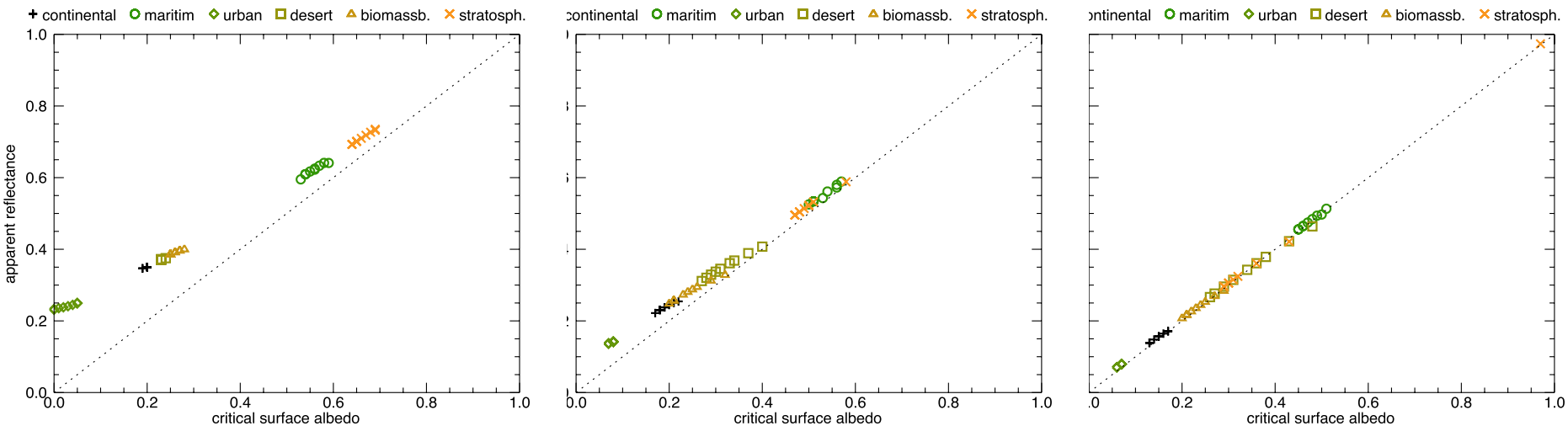
Seidel and Popp 2012, AMT

Critical Surface Albedo / Critical Reflectance

$\phi_{rel} = 90°,\ \theta_0 = 30°,\ \theta = 30°,\ \Theta = 138.5°$

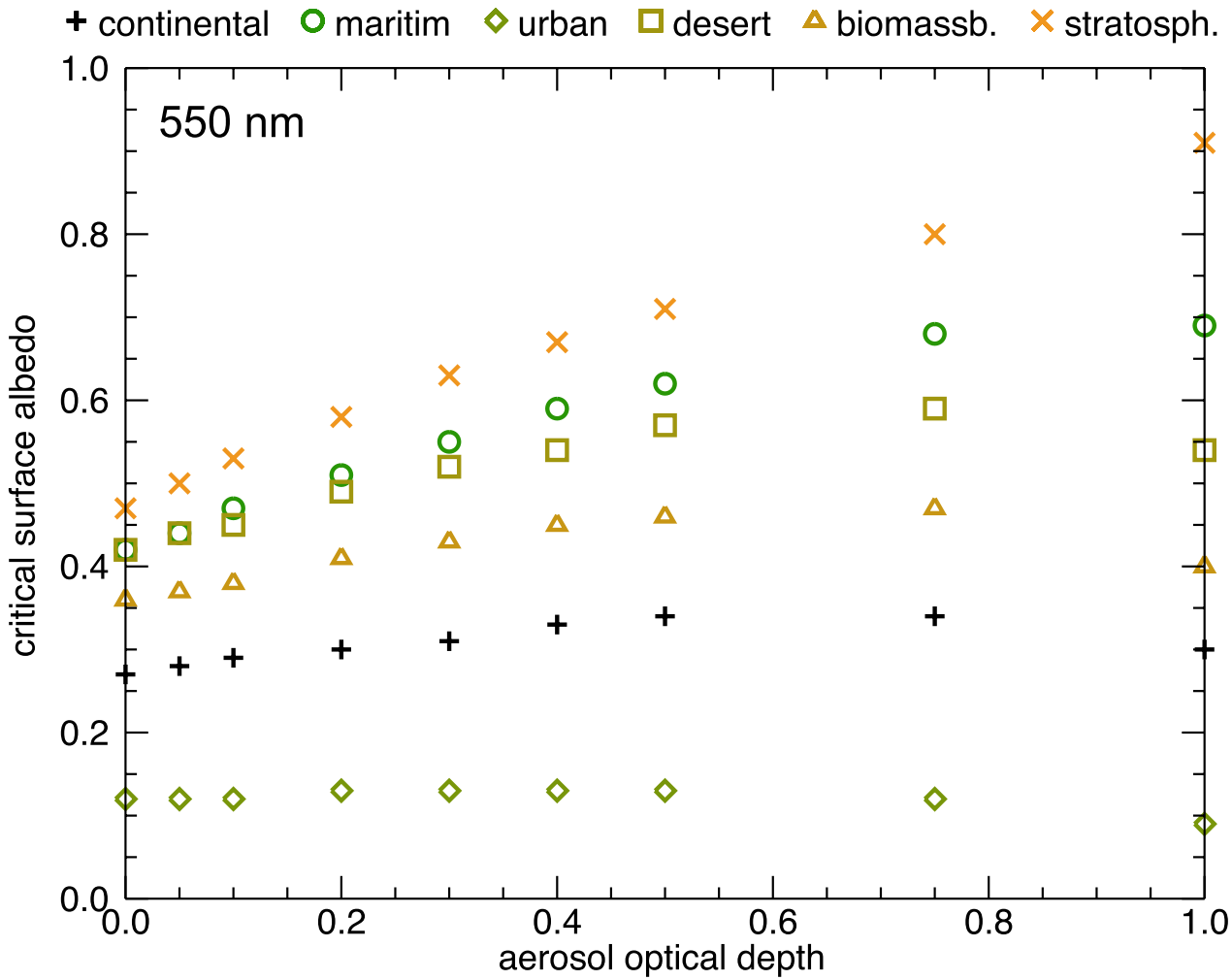


412 nm 550 nm 865 nm



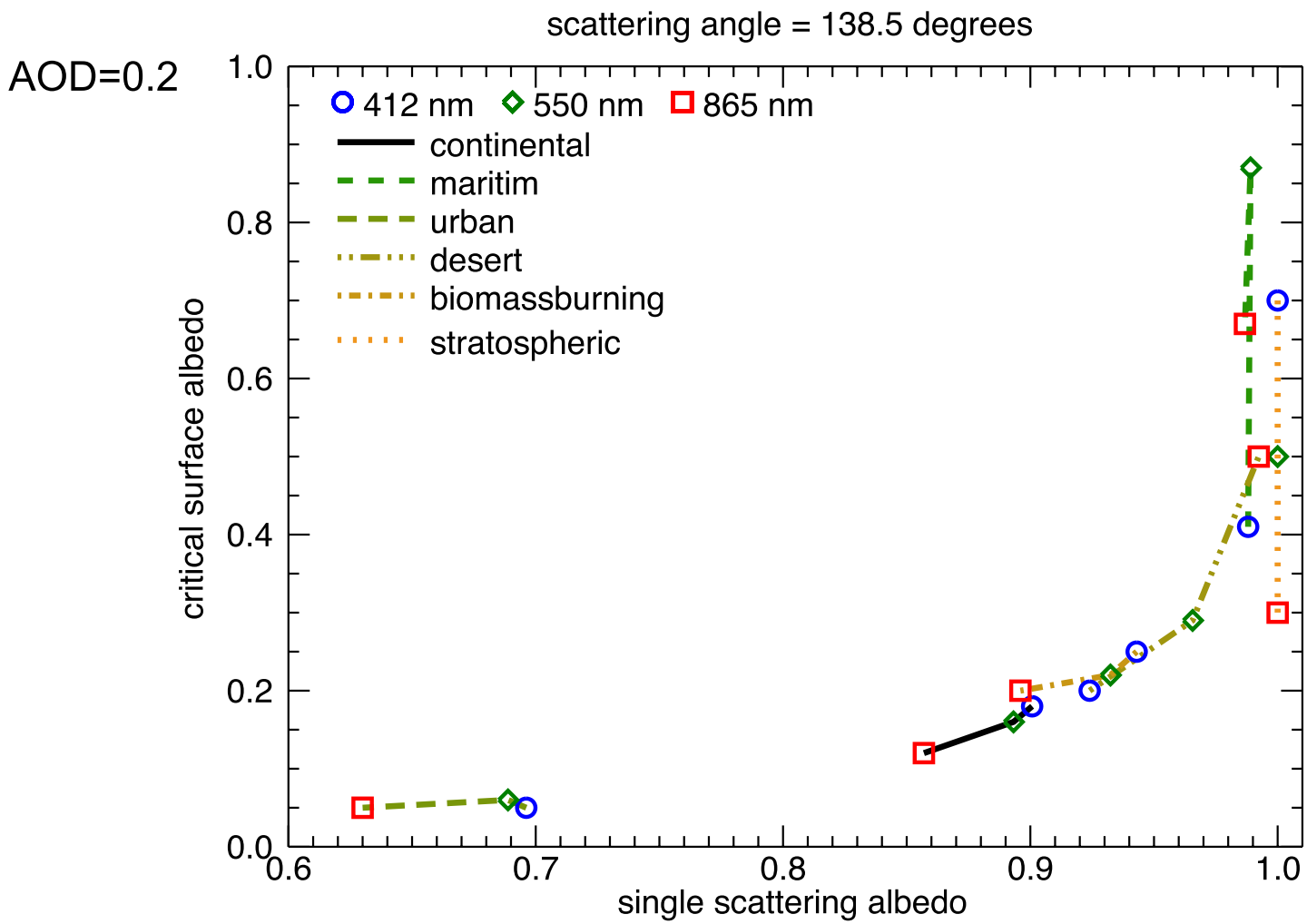
$\phi_{rel} = 180°,\ \theta_0 = 30°,\ \theta = 60°,\ \Theta = 150°$

Critical Surface Albedo wrt AOD



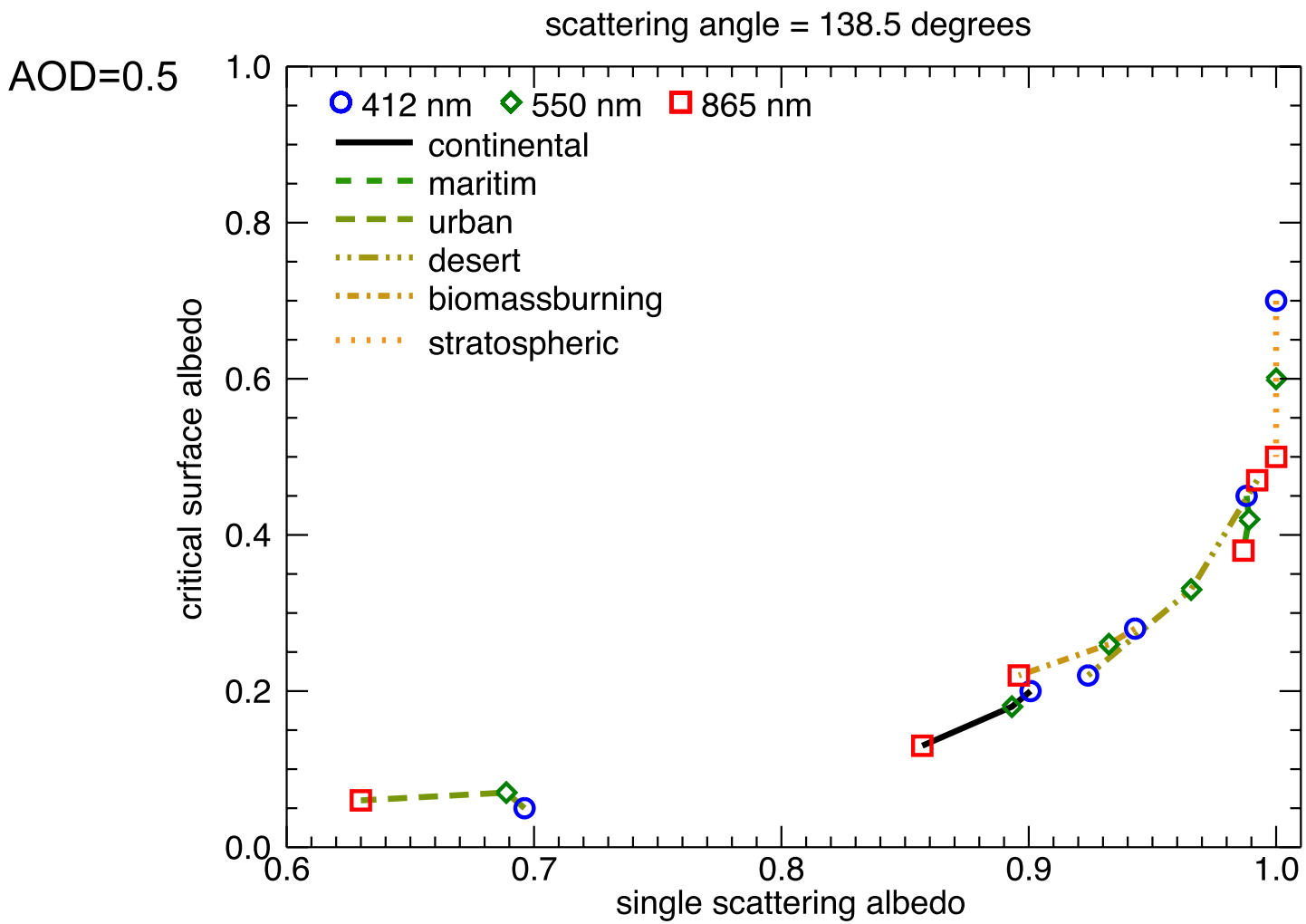
$$\phi_{rel} = 90^\circ,\ \theta_0 = 60^\circ,\ \theta = 60^\circ,\ \Theta = 104.4^\circ$$

Critical Surface Albedo wrt Single Scattering Albedo



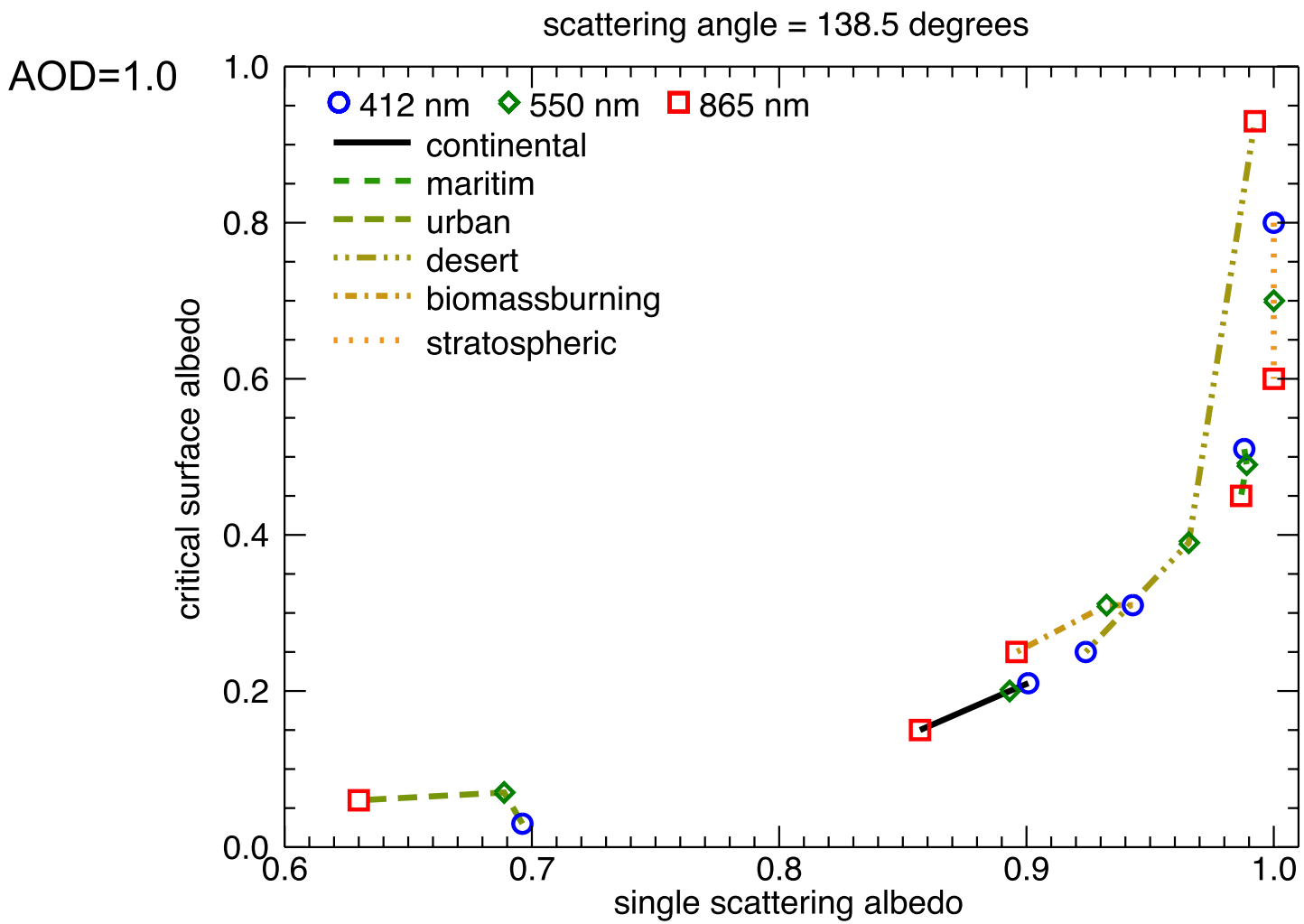
$$\phi_{rel} = 90^\circ,\ \theta_0 = 30^\circ,\ \theta = 30^\circ,\ \Theta = 138.5^\circ$$

Critical Surface Albedo wrt Single Scattering Albedo

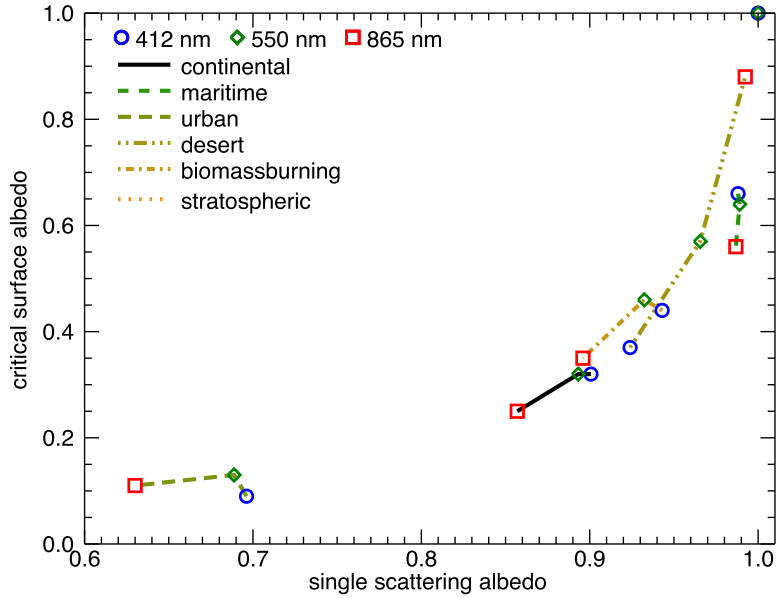


$$\phi_{rel} = 90^\circ,\ \theta_0 = 30^\circ,\ \theta = 30^\circ,\ \Theta = 138.5^\circ$$

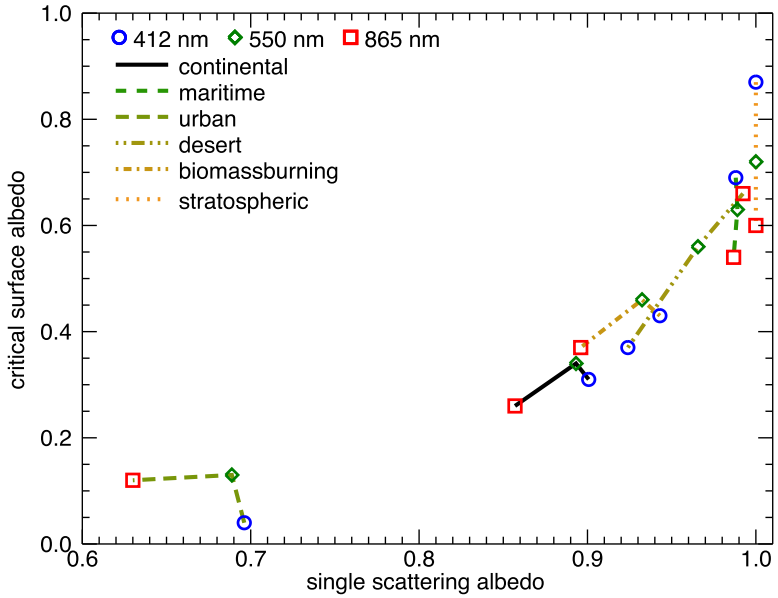
Critical Surface Albedo wrt Single Scattering Albedo



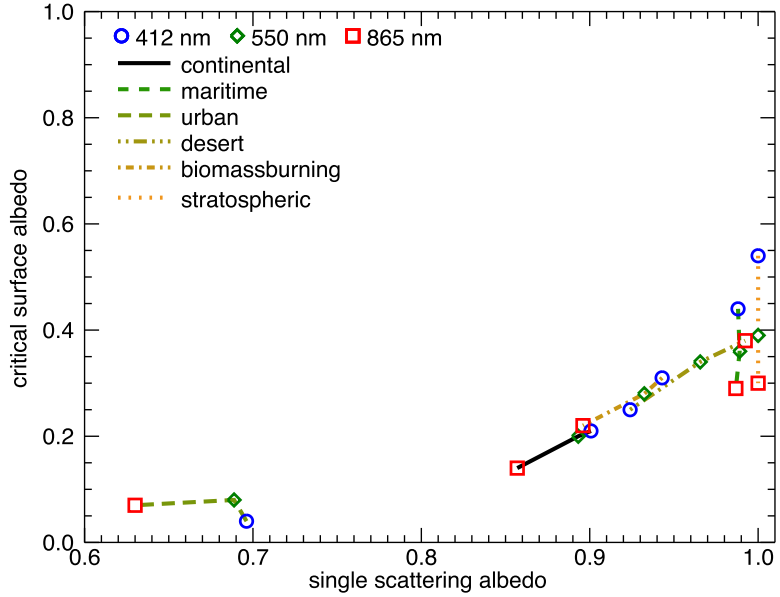
$$\phi_{rel} = 90^\circ,\ \theta_0 = 30^\circ,\ \theta = 30^\circ,\ \Theta = 138.5^\circ$$



(a) $\phi = 0°, \theta_0 = 30°, \theta = 60°, \Theta = 90°$

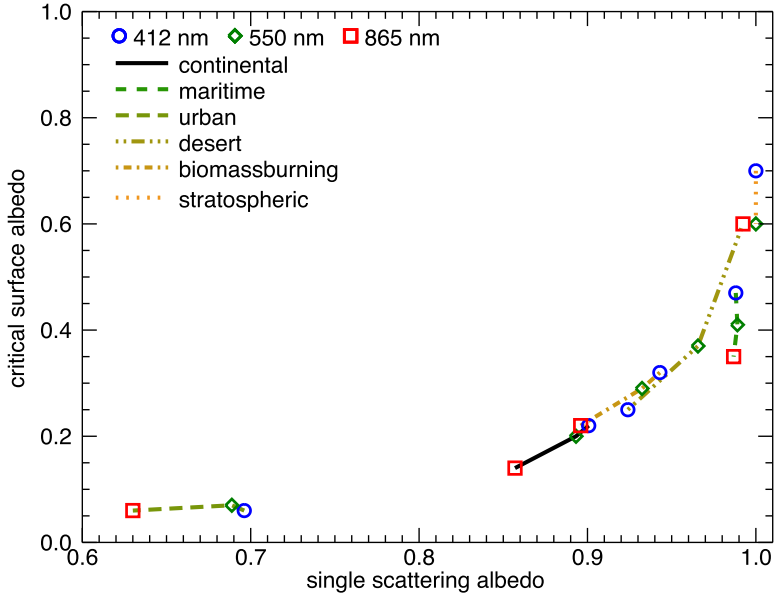


(b) $\phi = 90°, \theta_0 = 60°, \theta = 60°, \Theta = 104°$



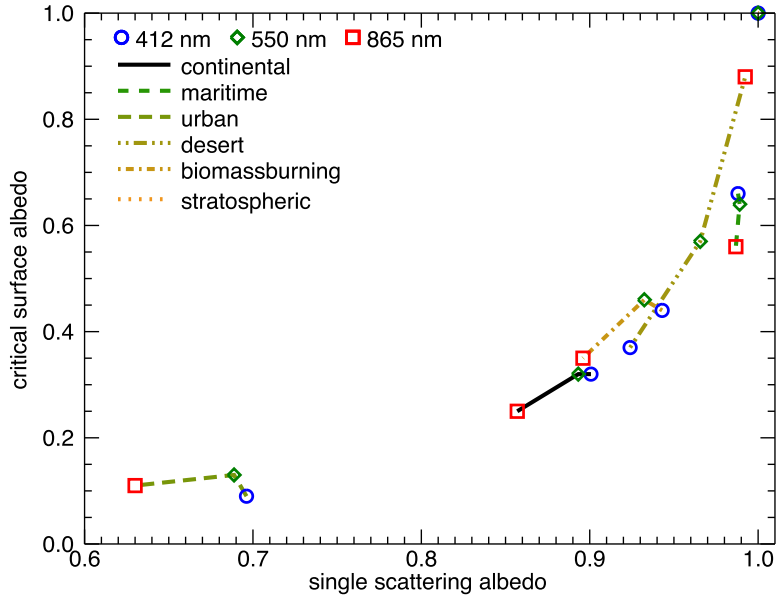
(c) $\phi = 0°, \theta_0 = 0°, \theta = 60°, \Theta = 120°$

AOD=0.2

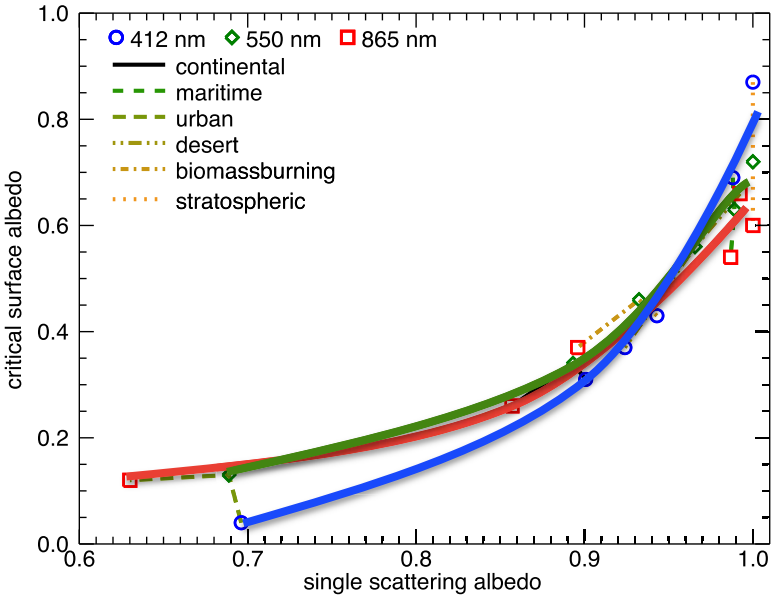


(d) $\phi = 0°, \theta_0 = 30°, \theta = 30°, \Theta = 120°$

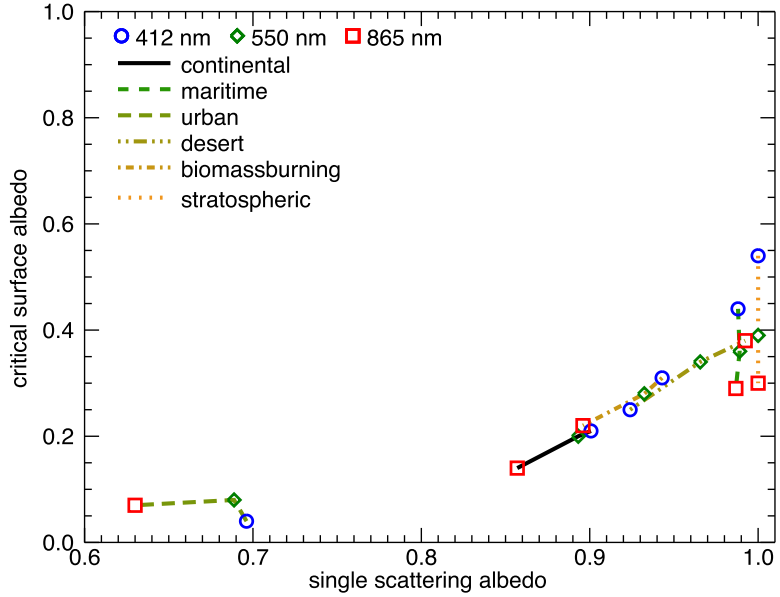
Seidel and Popp 2012, AMT



(a) $\phi = 0°, \theta_0 = 30°, \theta = 60°, \Theta = 90°$



(b) $\phi = 90°, \theta_0 = 60°, \theta = 60°, \Theta = 104°$



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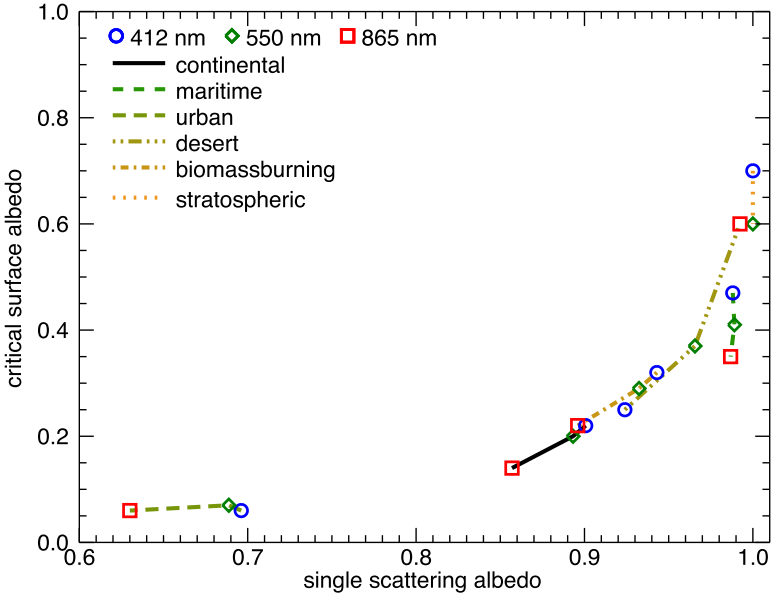


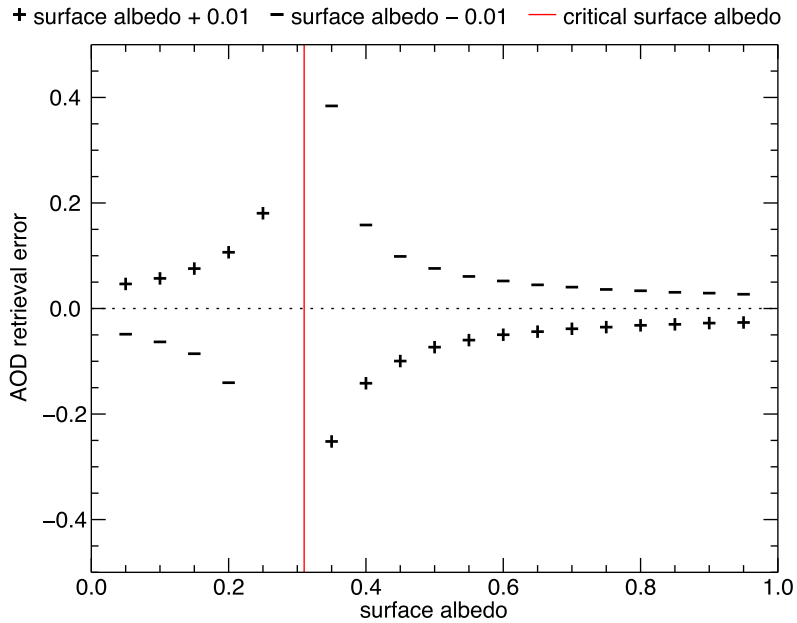
(d) $\phi = 0°, \theta_0 = 30°, \theta = 30°, \Theta = 120°$

Seidel and Popp 2012, AMT

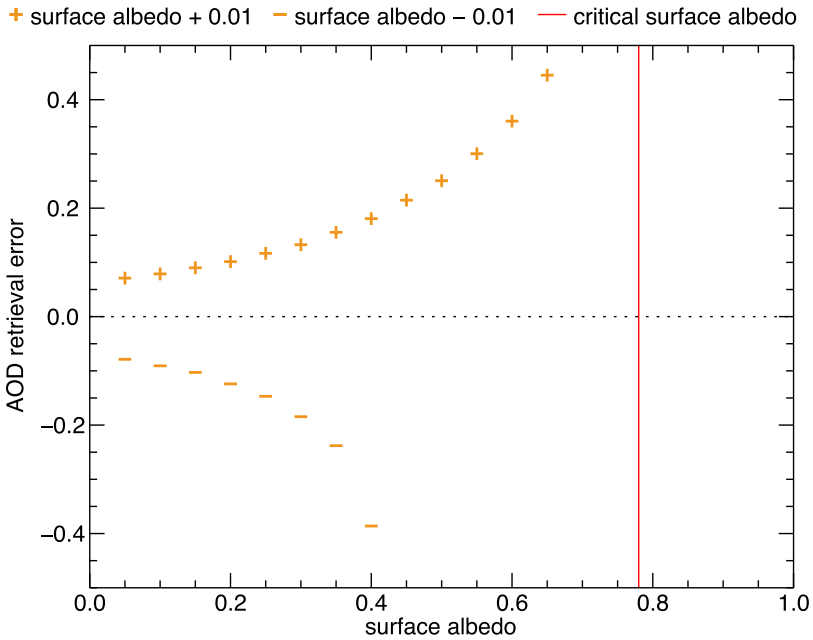
Implication albedo to AOD retrieval

How much error in AOD retrieval due to error in albedo:

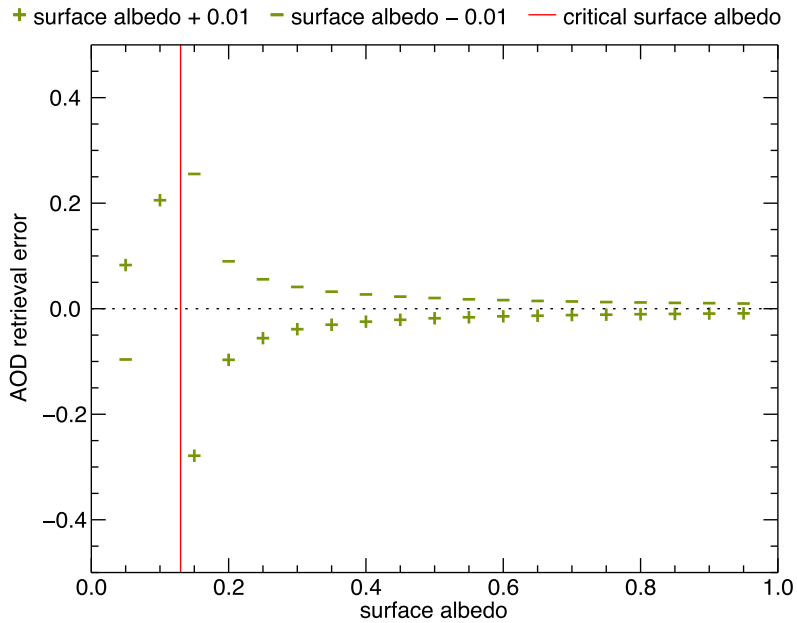
$$R^{\mathrm{TOA}} \begin{cases} a = true \Rightarrow \tau & \dfrac{\omega_\tau P_\tau(\Theta)\left(1-e^{-\tau[\frac{1}{\mu_0}+\frac{1}{\mu}]}\right)}{4(\mu_0+\mu)} + R_\tau^{\mathrm{MS}} + \dfrac{T_\tau a}{1-s_\tau a} \\ a - 0.01 \Rightarrow \delta\tau = \tau - \tau_{fit} & \dfrac{\omega_{\tau_{fit}} P_{\tau_{fit}}(\Theta)\left(1-e^{-\tau_{fit}[\frac{1}{\mu_0}+\frac{1}{\mu}]}\right)}{4(\mu_0+\mu)} + R_{\tau_{fit}}^{\mathrm{MS}} + \dfrac{T_{\tau_{fit}}(a-0.01)}{1-s_{\tau_{fit}}(a-0.01)} \\ a + 0.01 \Rightarrow \delta\tau = \tau - \tau_{fit} & \underbrace{\dfrac{\omega_{\tau_{fit}} P_{\tau_{fit}}(\Theta)\left(1-e^{-\tau_{fit}[\frac{1}{\mu_0}+\frac{1}{\mu}]}\right)}{4(\mu_0+\mu)} + R_{\tau_{fit}}^{\mathrm{MS}}}_{R^{atmos}} + \underbrace{\dfrac{T_{\tau_{fit}}(a+0.01)}{1-s_{\tau_{fit}}(a+0.01)}}_{R^{surface}} \end{cases}$$



(a) Continental aerosol model



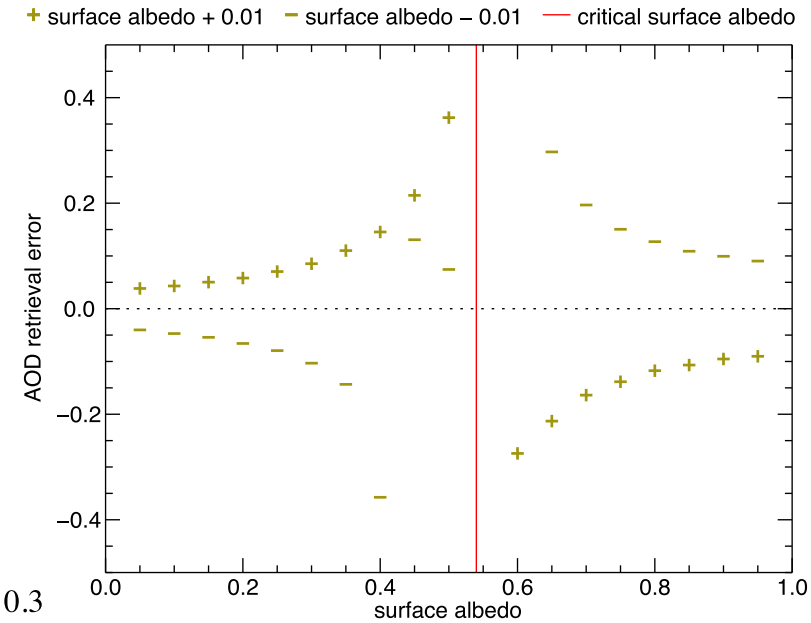
(f) Stratospheric aerosol model



(c) Urban aerosol model

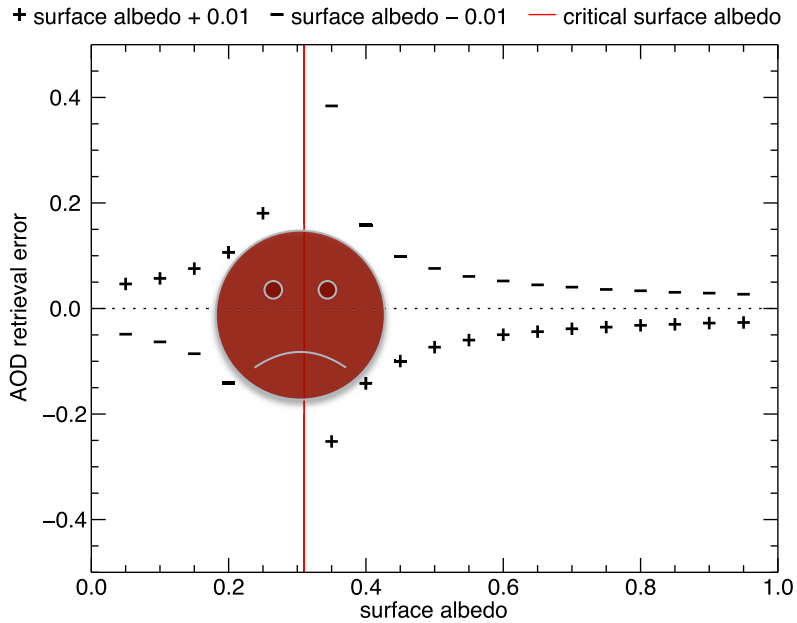
$\tau_{\text{true}}^{\text{aer}} = 0.3$

$\phi = 0°$, $\theta_0 = 30°$, $\theta = 30°$, $\Theta = 120°$



(d) Desert aerosol model

Seidel and Popp 2012, AMT



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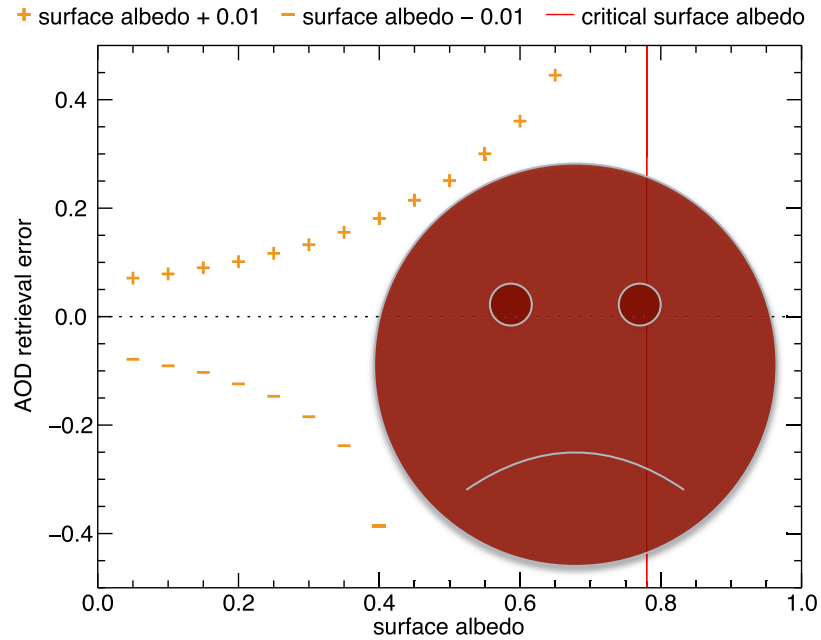

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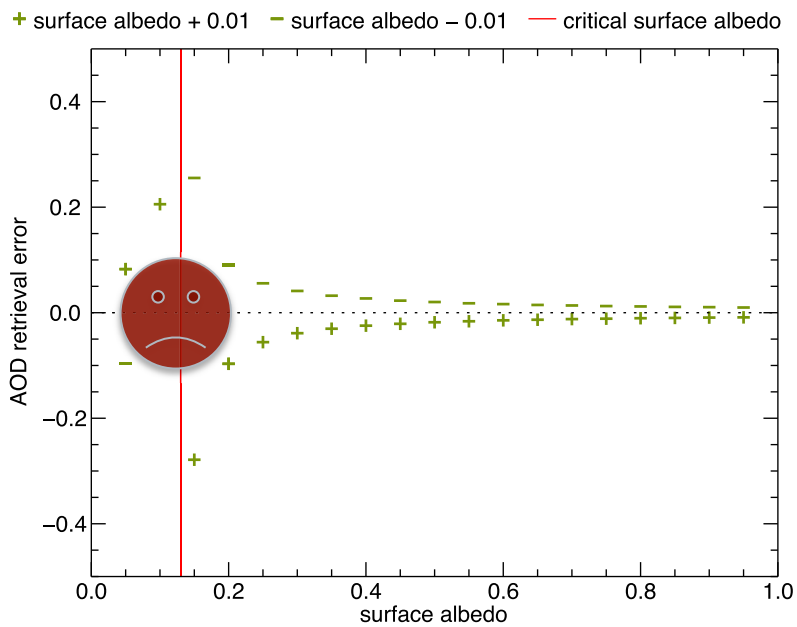

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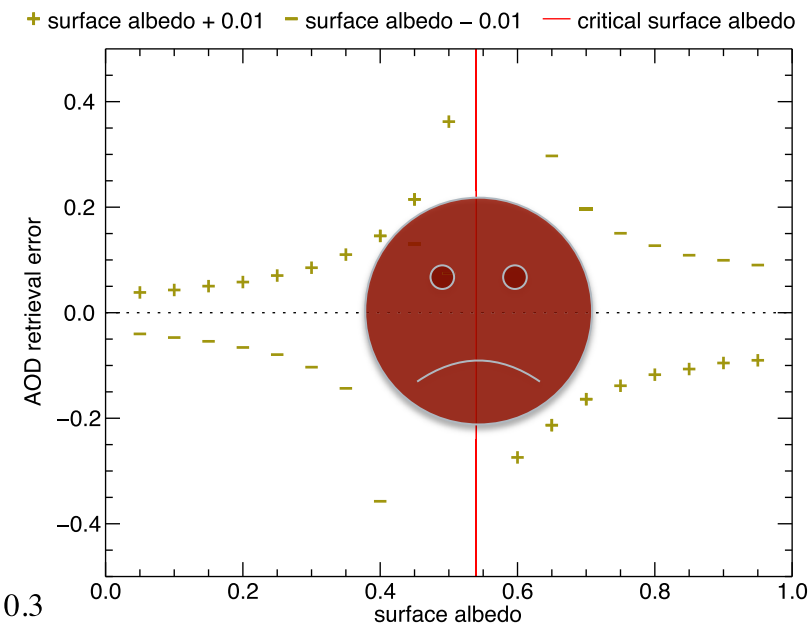

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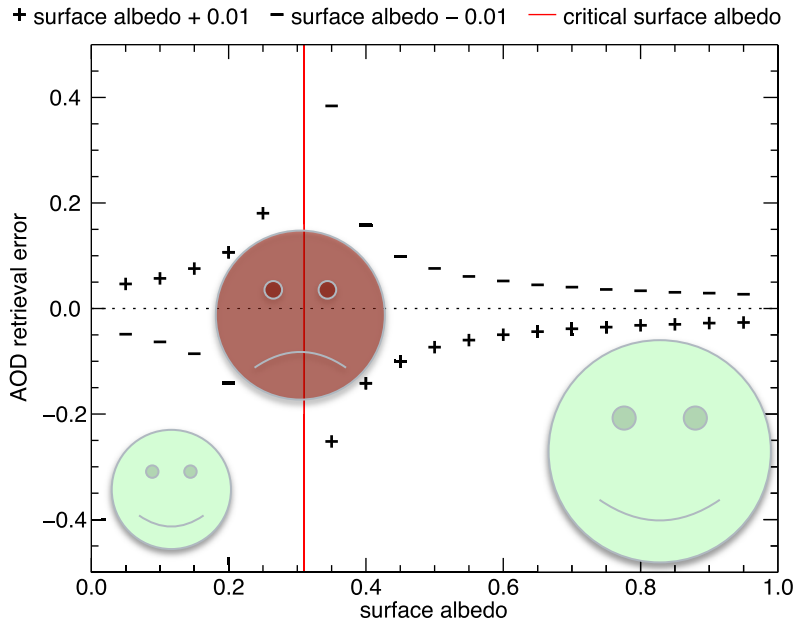
Seidel and Popp 2012, AMT



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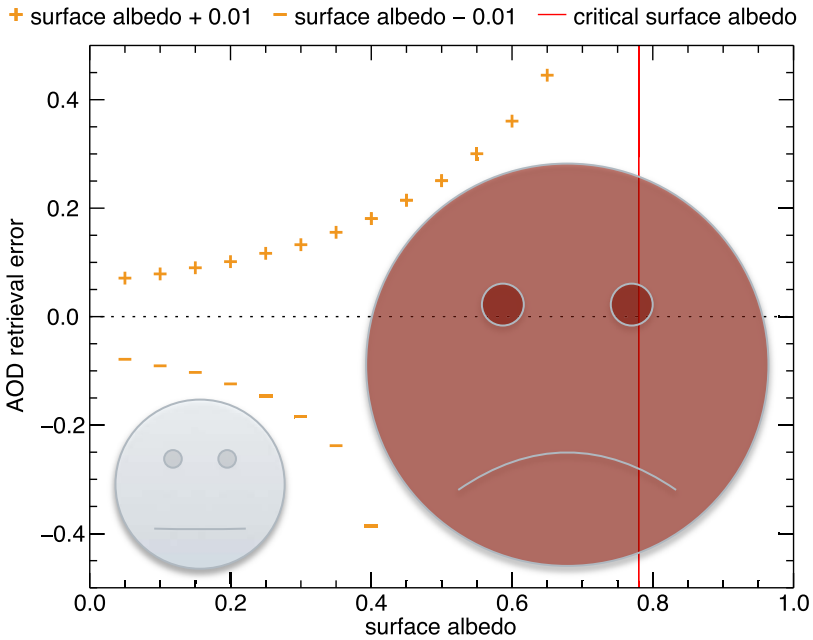
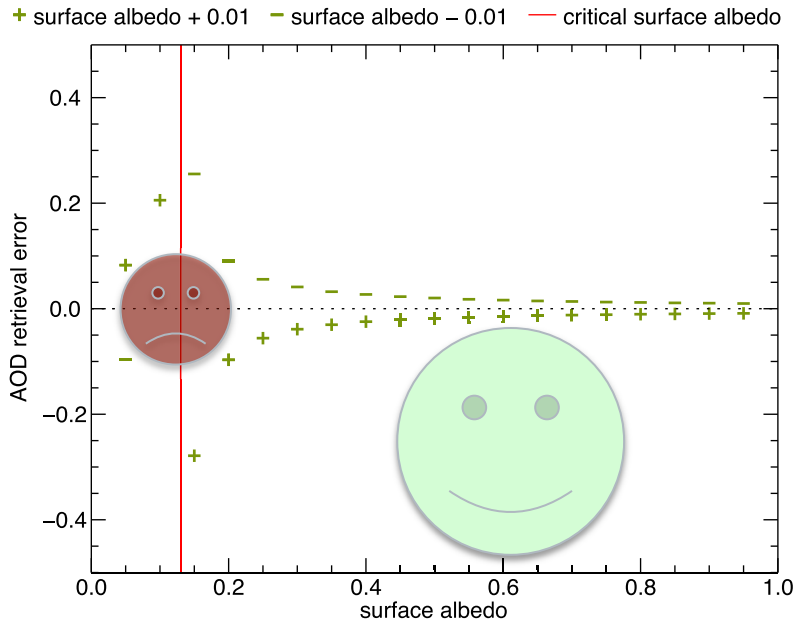


(f) Stratospheric aerosol model



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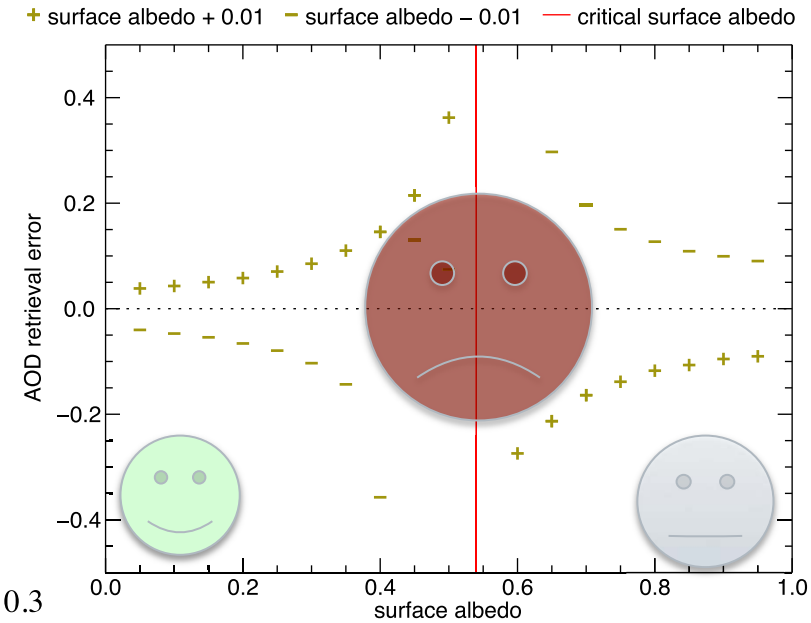
$\phi = 0°$, $\theta_0 = 30°$, $\theta = 30°$, $\Theta = 120°$



(d) Desert aerosol model

Seidel and Popp 2012, AMT

Conclusions

- Aerosol must ‘contrast’ to surface (and Rayleigh scattering) to retrieve AOD by intensity only observations.

- Retrieval sensitivities:

  ++ for strongly absorbing aerosol over bright surfaces

  + for medium absorbing aerosol over bright and dark surfaces

  ~ weakly/non-absorbing aerosol over very dark surfaces (if only)

- Critical surface albedo/reflectance exists for most observational geometries.

- Using additional information from different geometries and from polarimetry is essential to avoid large errors.

Suggestions

- Critical albedo is rather a range of surface reflectance with low/no sensitivities.

Thoughts:

- Pre-calculated sensitivities (Jacobian) allow to:
  - avoid (mask) calculations for low/no sensitivities.
  - choose complexity of RT model (#streams, #of quadrature points, orders of scattering, etc.).

- Use simple model to get close to the solution. Then more complex model.

Outlook

- Plot AOD retrieval sensitivity for MODIS on the Globe (given solar and obs. geometry and surface reflectance product).

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