Evaluation of the impact of clouds on the retrieval of aerosol properties

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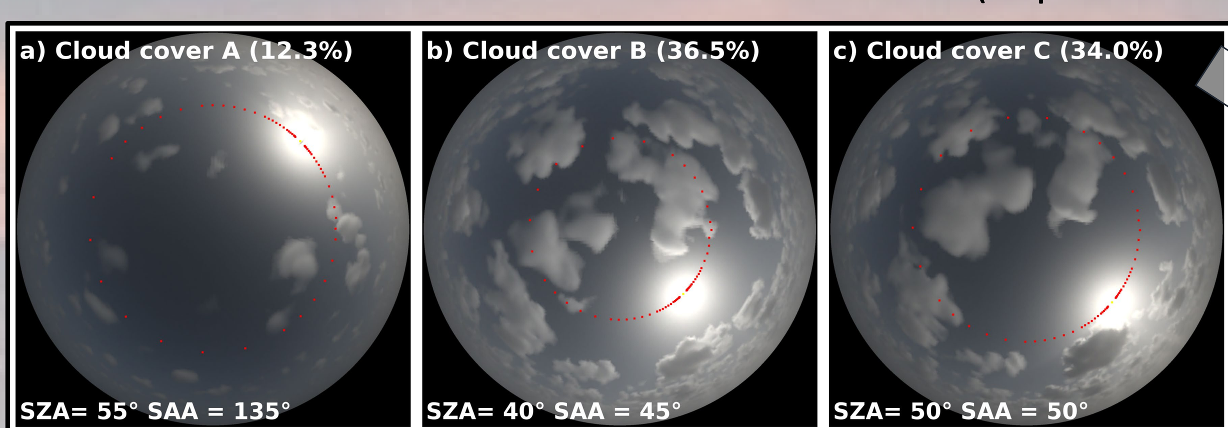
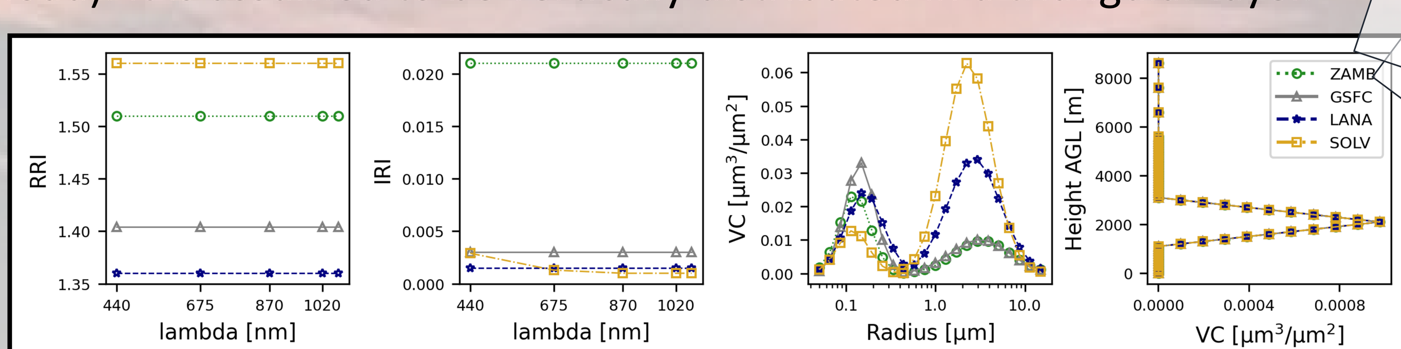
Introduction

An accurate knowledge of the microphysical and optical properties of aerosols is key to assess their impact on climate. **Sky radiances** contain **useful information** about the **aerosol properties**; henceforth, they are commonly used in inversion algorithms to retrieve them. Nevertheless, they can be **affected** by the presence of **clouds**, what consequently can show an impact on the retrieved aerosol properties if the inversion algorithm used considers a cloud-free sky. To evaluate this impact, different partially cloudy skies (and the corresponding cloud-free ones) have been used in the **3D solver MYSTIC from libRadtran** (*Emde et al., 2016*) to simulate sky radiances for different known aerosol scenarios. The ratio cloudy to cloud-free radiances, named cloud enhancement factor (CEF), has been used to study the effect of clouds on sky radiances and to generate the sky radiances under partially cloudy scenarios. Finally, **GRASP** (Generalized Retrieval of Atmosphere and Surface Properties; *Dubovik et al., 2021*) is used to **retrieve aerosol properties** using the observations generated for partially cloudy and the corresponding cloud-free scenarios.

PARTIALLY CLOUDY SCENARIOS: **3D partially cloudy fields** have been extracted from *Jakub and Gregor (2022)* and correspond to single layer shallow cumulus clouds with **different cloud fraction** (in parenthesis).

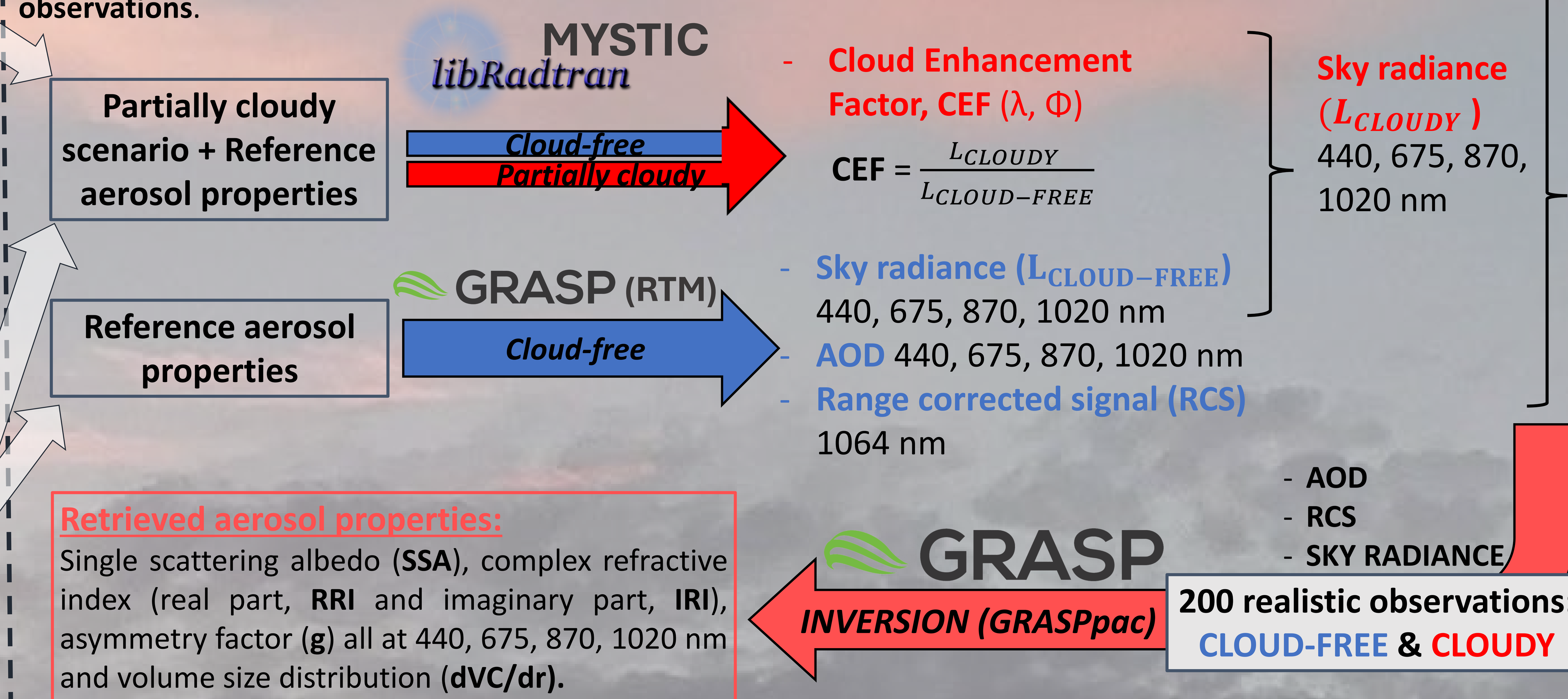


AEROSOL SCENARIOS: **Reference properties** from **four aerosol types** have been extracted from the climatology by *Dubovik et al. (2002)*: urban (**GSFC**), biomass burning (**ZAMB**), oceanic (**LANA**) and dust (**SOLV**). For **four aerosol loads**: aerosol optical depth (**AOD**) **at 440 nm** of **0.1** (low load), **0.2** (moderate load), **0.4** (high load) and **1.0** (extreme load). It is assumed to be vertically distributed in a triangular layer.



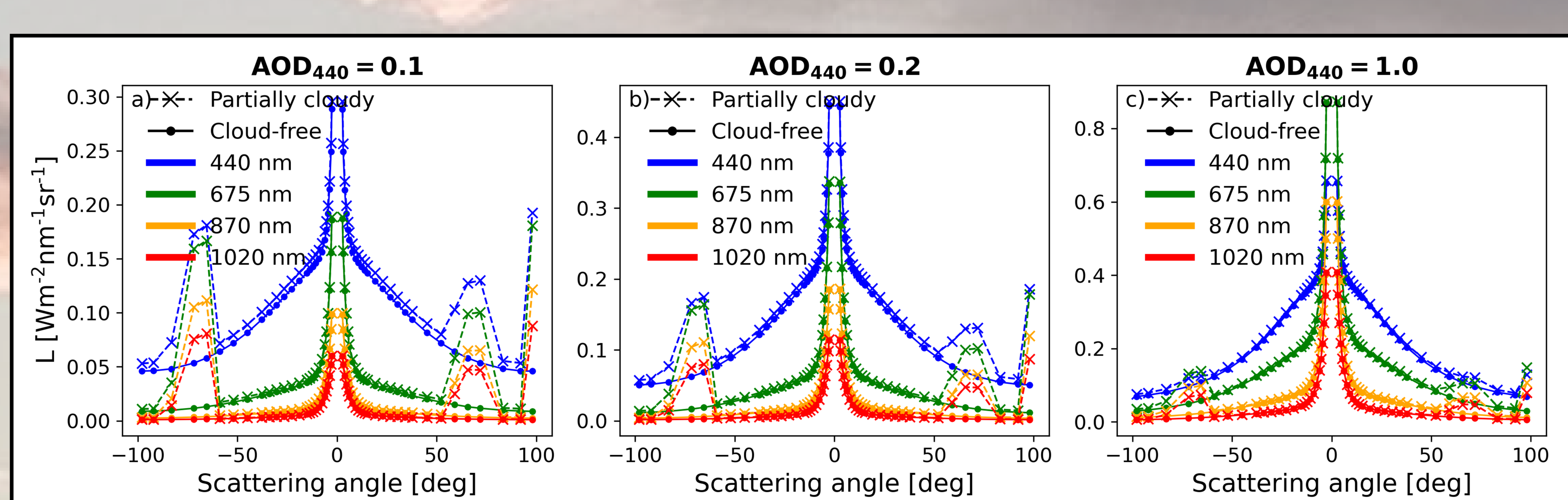
Methodology

For **each aerosol-cloudy scenario** the **synthetic observations** required by the inversion strategy (GRASPpac; *Román et al., 2018*) have been generated using two radiative transfer models (RTM). Only MYSTIC can be used to simulate the sky radiances under the presence of clouds. For each aerosol-cloudy scenario, the synthetic observations have been perturbed as described by *Román et al. (2018)* to create **200 realistic observations**.

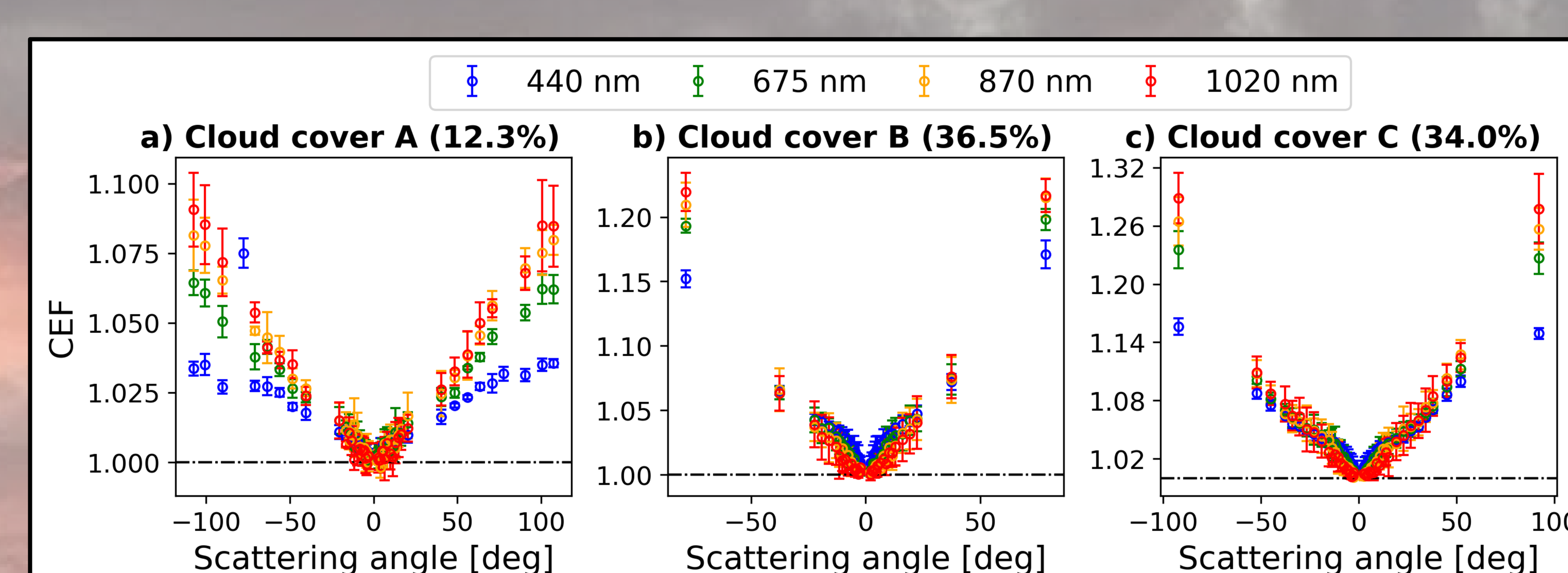


Cloud enhancement factor under partially cloudy scenarios

The sky radiances at the points where clouds are located are much higher than in the cloud-free conditions, therefore the corresponding CEFs are very high too. These **points (cloud-contaminated)** are usually identified with **cloud-screening algorithms**, like the one from AERONET (*Holben et al., 2006*), which has been used to **reject** those **observations** not useful for inversion.

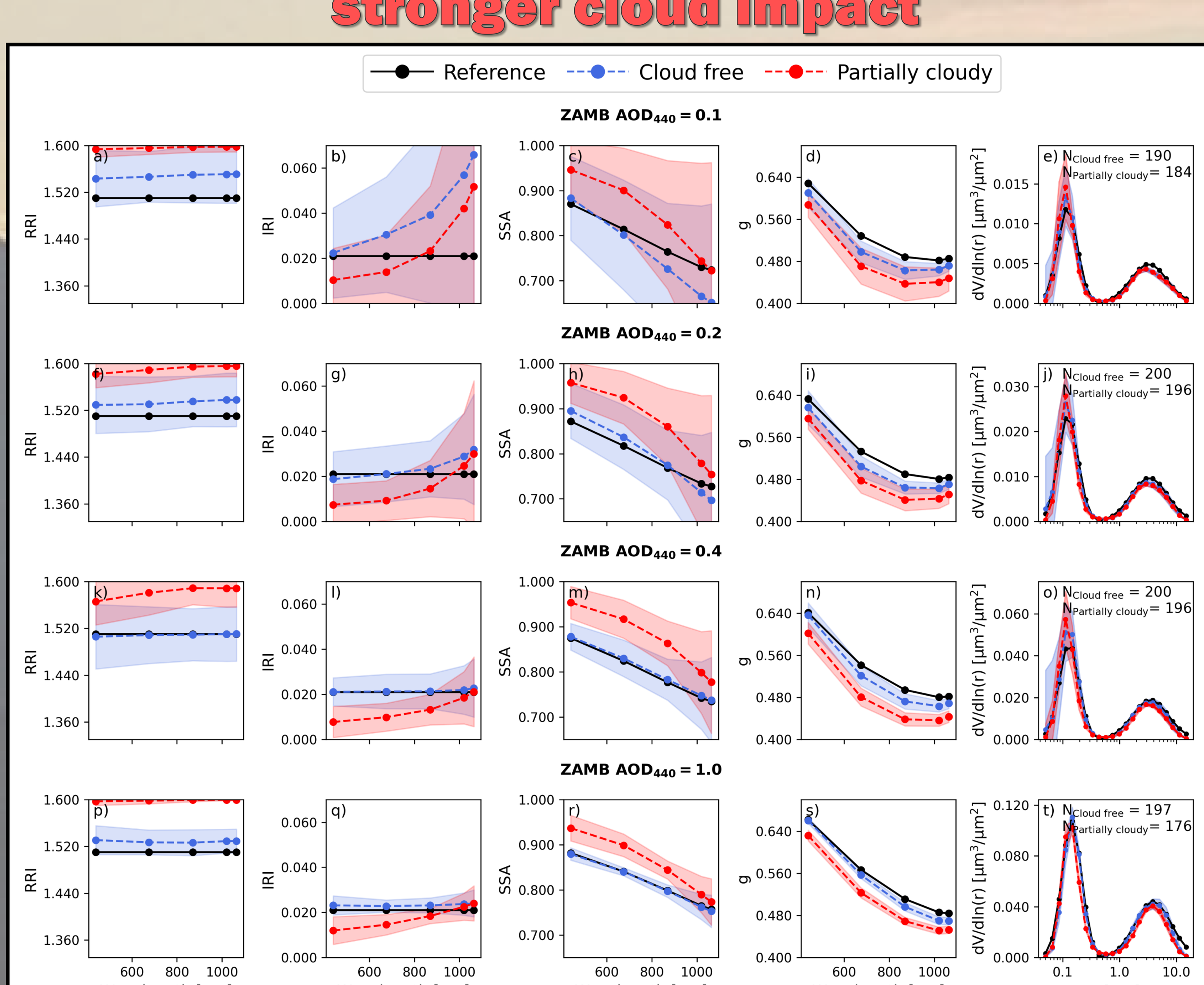


Sky radiances (L) in the almucantar for **ZAMB** at different aerosol loads in the **Cloud cover C (34.0%)** and the corresponding for the **cloud-free** situation simulated with MYSTIC, together with their CEF.



Error bar plots of the **CEF averaged** over the four types of aerosol for each cloud cover and moderate aerosol load (AOD_{440}= 0.2). The CEF values corresponding to sky radiances identified as **cloud-contaminated** have **not** been **included.**

Retrieved aerosol properties in a scenario with stronger cloud impact



Aerosol properties retrieved under partially cloudy conditions for the **cloud cover C (34.0%)** and the corresponding cloud-free conditions for **ZAMB** at different aerosol loads.

Results & Conclusions

- The **sky radiance** usually **increases** even far **away from** the **clouds**. This enhancement depends on the partially cloudy scenario. The major enhancement for cloud-free sky points occurs at the scattering angles furthest from the Sun and with larger **enhancement** near cloud edges, with values generally between **0 - 20%**. This enhancement is higher for longer wavelengths, except at the solar aureole due to aerosol scattering.
- The **optical properties** are **less accurate** when the retrieval is conducted under the **presence of clouds**. This bias depends on the partially cloudy scenario, and becomes more evident when the CEF increases.
- In partially cloudy scenarios which show a significant CEF, it has been observed an underestimation of the aerosol absorption, introducing a **bias** in the **SSA** of **0.05-0.06** for a **low aerosol load**, and of about **0.03** for **extreme AOD** values. A positive bias of **0.05-0.06** is observed in the **RRI** and a negative bias in the **g** of about **-0.0**2. On the other hand, a **negligible** effect has been observed **on** the **aerosol size distribution** parameters.
- It has been assessed that the **presence of clouds** in the sky can significantly **affect** the **accuracy of the aerosol properties** when they are retrieved using sky radiances, even when these clouds are not in the direction of the sky points used.

References. Dubovik et al., 2002 (Journal of the atmospheric sciences 59.3: 590-608); Dubovik et al., 2021 (doi:10.17169/refubium-36696); Emde et al., 2016 (doi:10.5194/gmd-9-1647-2016); Holben et al., 2006 (doi:10.1117/12.706524); Jakub and Gregor, 2022 (doi: 10.57970/5d0k9-q2n86); Román et al., 2018 (doi:10.1016/j.atmosres.2018.01.021).

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