Changes in the spectral composition of surface solar radiation under the presence of stratospheric aerosols: a case study for the Pinatubo eruption

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Introduction

The Mount Pinatubo (15°N, 120°E) eruption in June 1991 resulted in a massive stratospheric aerosol layer which through the stratospheric circulation covered the globe in three weeks and then remained in the stratosphere for several months. The presence of aerosols in the stratosphere alters the spectral shape, the amount and the spatial distribution of the solar light that reaches the Earth surface. While such changes in surface solar radiation have been discussed in a few studies, these studies did not consider the role of the underlaying tropospheric aerosol layer in the presence of the stratospheric aerosols. In this study we investigate the changes in the direct, diffuse and global spectral surface solar irradiances in the range 380 – 750 nm considering the vertical stratospheric aerosol profile that was measured a few months after the eruption of Mount Pinatubo. Changes in the spectral composition and the distribution of surface solar radiation in the considered spectral range play a key role in many biological processes (e.g., photosynthesis), as well as for solar energy production.

Methodology

We have considered different optical properties for the stratosphere and the troposphere.

- **Stratosphere:** Optical properties from MOPSMAP considering the profile that was measured at Banderbach, Germany in December 1991 (6 months after the eruption) and **fine sulfuric** aerosols (mode radius = 0.35, 2 sigma = 1.2)
- **Troposphere:** Exponential profile considering 3 aerosol types: **dust, urban polluted**, and **fine sulfuric** aerosols
- **Surface:** Simulations have been performed for **grass** and **desert** (surface albedo from the libRadtran library)

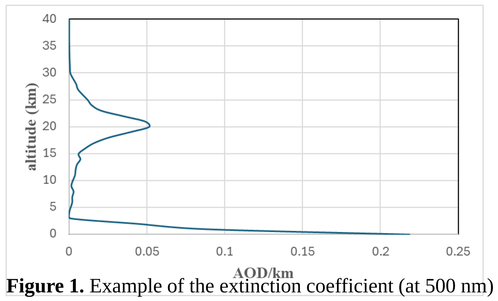


Figure 1. Example of the extinction coefficient (at 500 nm) profile

Radiative transfer simulations:

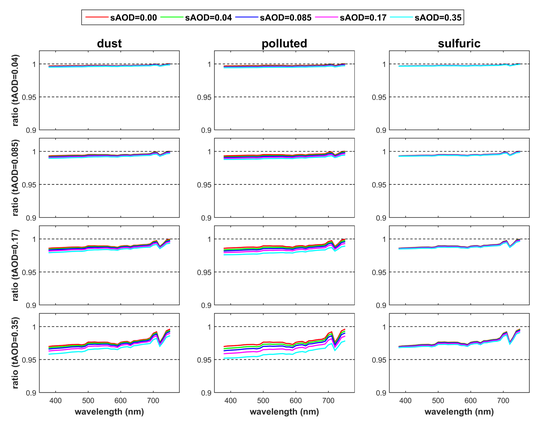
- Using the model UVSPEC from libRadtran
  - ✓ sdisort pseudospherical
  - ✓ 6 stream
  - ✓ SZA: 30º/60º
- Outputs: direct/diffuse/global irradiance at 380 – 750 nm

- Different stratospheric/tropospheric AOD combinations (0, 0.04, 0.088, 0.17, 0.35) corresponding to different forcing (0, -1 W/m^2, -2 W/m^2, -4 W/m^2, - 8 W/m^2, assuming global distribution)

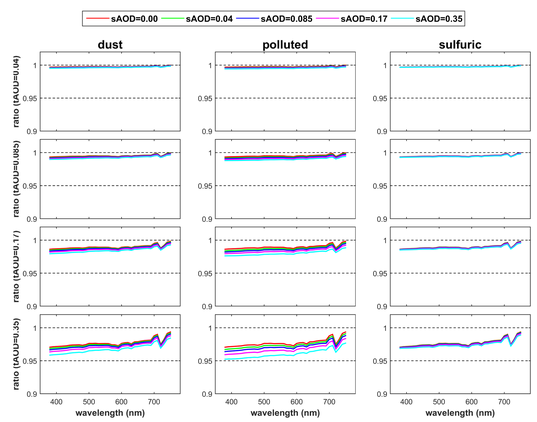
- Stratospheric aerosols over different surfaces (grass/desert) have a very similar impact if all other conditions are the same.
- The impact of stratospheric aerosols on the absolute irradiance levels as well as on the direct/global ratio increases with increasing tropospheric AOD
- The differences for different tropospheric aerosol types are small. In general, the impact increases towards the smaller wavelengths with increasing Angstrom Exponent.
- The reduction of the absolute irradiance levels depends mainly on the stratospheric AOD
- Changes in the direct/global ratio depend strongly on the tropospheric AOD

Change in surface solar spectral irradiance due to the presence of tropospheric aerosols

Grass, SZA=30°

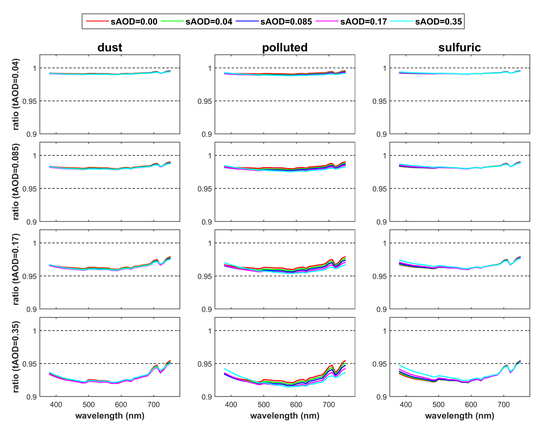


Desert, SZA=30°

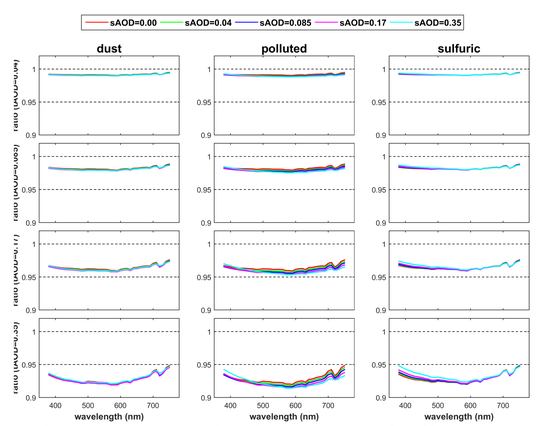


tAOD: tropospheric AOD
sAOD: stratospheric AOD

Grass, SZA=60°



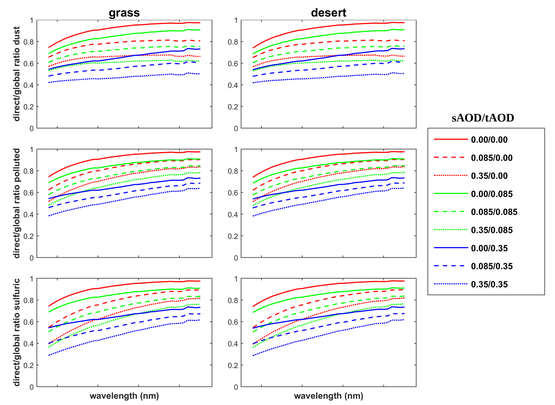
Desert, SZA=60°



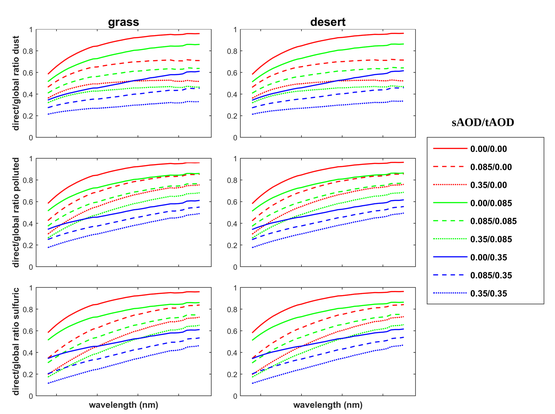
Ratios between the irradiances with and without stratospheric aerosols under the presence of different amounts of tropospheric aerosols

Change in the direct/global ratio for different stratospheric/tropospheric aerosol combinations

SZA=30°



SZA=60°



Summary and Conclusions

- Stratospheric aerosols from volcanic eruptions have a relatively small impact on the absolute surface global irradiance levels
- Larger impact of stratospheric aerosols on the direct/global ratio that increases if tropospheric aerosols are present
- The role of tropospheric aerosols should be considered to study the distribution of surface solar radiation under volcanic eruptions or SRM deployment.

Acknowledgments
This work has been supported by the action titled “Support for upgrading the operation of the National Network for Climate Change (CLIMPACT II)”, funded by the Public Investment Program of Greece, General Secretary of Research and Technology/Ministry of Development and Investments.