On the effect of aerosols, tropospheric NO_2 and clouds on surface solar radiation over the Eastern Mediterranean (Greece)

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Abstract

In this work, the effect of aerosols, tropospheric NO_2 and clouds on surface solar radiation (SSR) is studied, for several locations in Greece, in the heart of the Eastern Mediterranean. State-of-the-art satellite-based observations and climatological data are used along with a freshly developed radiative transfer system based on a modified version of the Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART) model **(Alexandri et al., 2021)**.

Introduction

Among other regions, various aspects of the SSR have been studied so far by different groups over the Mediterranean Basin, a climate change hot spot **(Giorgi 2006)**. The last decade, the role of aerosols, clouds, and water vapor on the SSR levels has been studied, mostly at a coarse spatial resolution, for all- and clear-sky conditions based on satellite data **(e.g., Papadimas et al., 2012)**. Our study focuses on the Eastern Mediterranean which is a key region at the crossroads of different transport pathways that mix air masses from Europe, Africa, and Asia.

SSR in this region depends on several parameters, the most important being clouds, aerosols, and water vapor **(Alexandri et al., 2017)**. SSR may also be affected by ozone (O_3) and gaseous atmospheric pollutants such as Nitrogen Dioxide (NO_2), depending on the season and the local human activities. Specifically, for the effect of tropospheric NO_2, a basic air quality index, to our knowledge, there are only a couple of studies which suggest that this gas may potentially play a significant role in local radiative forcing under certain conditions and over heavily polluted areas **(Solomon et al., 1999, Vasilkov et al., 2009)**.

Here, we investigate for the first time together the effect of two basic air quality indexes, aerosols and tropospheric NO_2, on the SSR under different sky conditions (all-sky conditions, clear skies, and liquid and ice cloud covered skies) along with the effect of different cloud types (liquid/ice) using high resolution state-of-the-art satellite-based observations and climatological data for the 15-years period 2005-2019. We focus on 16 different locations in Greece, in the heart of the Eastern Mediterranean. It must be noted that only the direct radiative effect of aerosols (scattering and absorption of solar radiation) and trop. NO_2 (absorption) is investigated here.

Data & Methods

1. Level-2 MODIS/Aqua aerosol, cloud, and water vapor measurements
2. CALIOP/CALIPSO aerosol profile climatology
3. MACv2 aerosol climatology
4. OMI/Aura tropospheric and stratospheric NO_2
5. CM SAF SARAH-2.1 SSR
6. CERES EBAF Ed.4.1 SSR
7. Ground-based SSR from Athens, Thessaloniki and HCMR
8. Ancillary data (e.g., OMI/Aura O_3, CLARA-A2.1 surf. Albedo, CLAAS-2.1 cloud cover)

The MODIS/Aqua aerosol, cloud, and water vapor data were gridded on a monthly basis at a standard 0.125° × 0.125° grid. While gridding, each single-pixel observation is weighted by its fractional area within the grid cell following the gridding methodology of the KNMI for the OMI/Aura tropospheric and stratospheric NO_2 data. All the other datasets were gridded (at the same 0.125◦ × 0.125◦ grid) on a monthly climatological basis (12 values per grid cell) using bilinear interpolation.

A system that implements radiative transfer calculations at any spatial and temporal resolution using gridded atmospheric properties data was developed. It comprises an interactive data language (IDL) interface and an updated version of the well established SBDART radiative transfer model. The interface gathers all the information from the gridded data and builds all the necessary input parameters for the radiative transfer model. Then, it executes SBDART for the following three sky conditions: clear, liquid and ice cloud-covered. SBDART is mostly oriented on aerosol- and cloud-related studies and the spectral absorption of NO_2 in the UV/Vis is missing. To account for the radiative effect of NO_2, we updated SBDART by incorporating into the model NO_2 cross sections. The updated version of SBDART (hereafter denoted as SBDART-NO2) was further modified to account for tropospheric and stratospheric NO_2, separately.

Results

Our monthly SSR simulations are in good agreement to ground-based observations, and the CM SAF SARAH-2.1 and CERES EBAF edition 4.1 satellite-based products giving confidence to our radiative effect calculations.

Liquid clouds dominate with an annual radiative effect of -36 W/m², with ice clouds (-19 W/m²) and aerosols (-13 W/m²) following. The radiative effect of tropospheric NO_2 is smaller by 2 orders of magnitude (-0.074 W/m²). Under clear skies, RE_{aer} is ~3-4 times larger than for liquid and ice cloud covered skies while RE_{NO2} doubles.

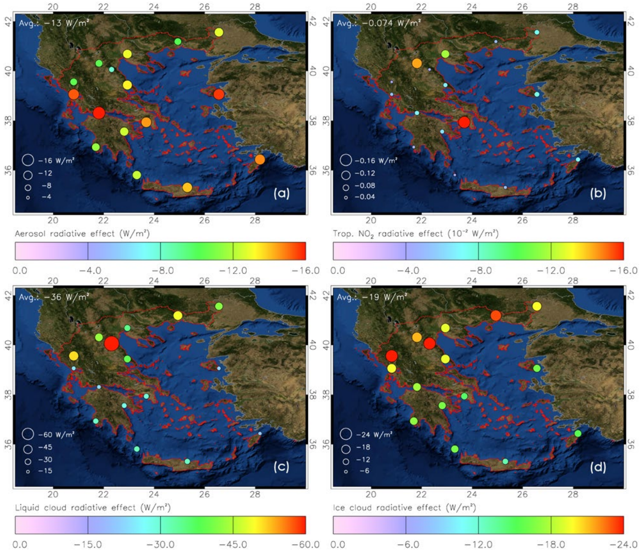

Fig. 1. Annual average radiative effect of (a) aerosols, (b) tropospheric NO_2, (c) liquid clouds and (d) ice clouds

Location	Urban/Rural	RE_{aer}	RE_{NO2}	RE_{lc}	RE_{ic}
Antikythera	R	-12±7	-0.043±0.018	-31±17	-16±12
Argos	R	-12±7	-0.064±0.023	-28±14	-16±11
Athens	U	-15±12	-0.166±0.059	-29±15	-15±11
HCMR	R	-14±7	-0.052±0.027	-31±19	-13±11
Ioannina	R	-10±7	-0.042±0.016	-51±24	-26±16
Kozani	U	-10±9	-0.144±0.063	-43±18	-21±13
Mytilene	R	-16±9	-0.076±0.023	-22±13	-16±13
Olympus	R	-8±6	-0.046±0.014	-79±31	-25±16
Orestiada	R	-13±10	-0.073±0.025	-42±16	-20±14
Patras	U	-18±10	-0.068±0.023	-23±15	-18±13
Preveza	R	-15±9	-0.053±0.021	-24±13	-20±13
Pylos	R	-12±6	-0.047±0.020	-31±14	-17±13
Rhodes	R	-15±9	-0.068±0.029	-21±13	-15±12
Thessaloniki	U	-13±10	-0.118±0.030	-35±15	-19±13
Volos	U	-13±9	-0.067±0.024	-39±18	-19±14
Xanthi	R	-10±7	-0.051±0.022	-49±22	-23±16

Table 1 Values from Fig. 1.

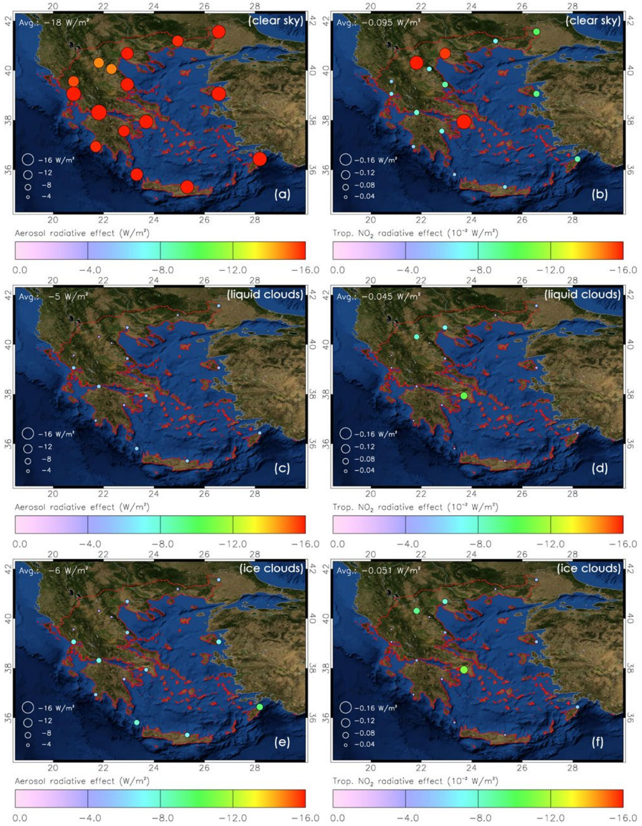

Fig. 2. Annual average radiative effect of aerosols and tropospheric NO_2 for (a,b) clear, (c,d) liquid and (e,f) ice cloud covered skies.

References

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