

Excelsior: Solar energy estimation in Cyprus

Ilias Fountoulakis

National Observatory of Athens

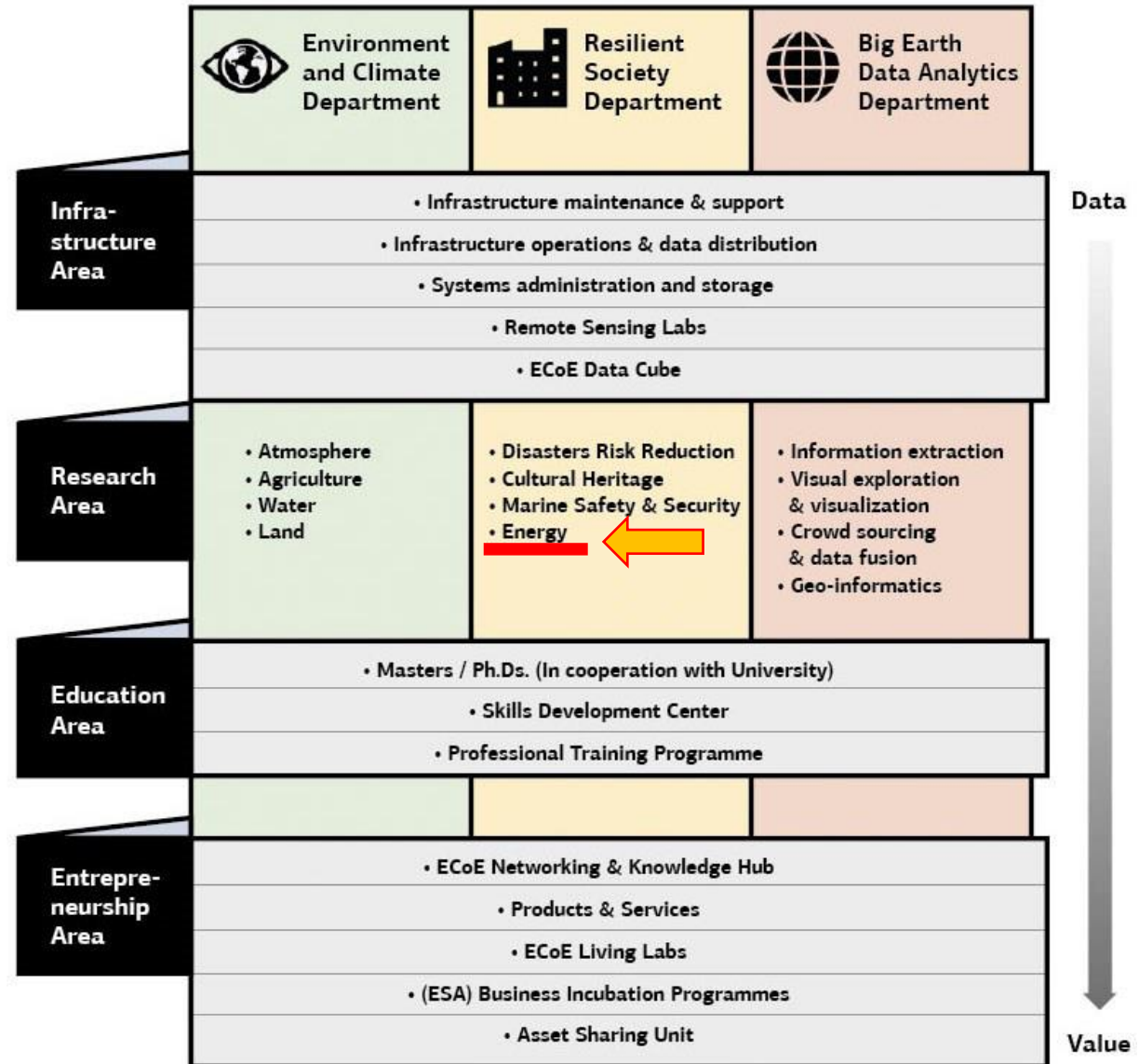
What is Excelsior?

- Excelsior is a Horizon 2020 Teaming project which aims to the development of a new, autonomous and self-sustained Centre of Excellence entitled as ‘ERATOSTHENES Centre of Excellence for Earth Surveillance and Space-Based Monitoring of the Environment’
- **MISSION:** To upgrade the existing Remote Sensing & Geo-Environment Lab (ERATOSTHENES Research Centre), established within the Faculty of Engineering & Technology of the Cyprus University of Technology (since 2007), into a sustainable, viable and autonomous Centre of Excellence, the Eratosthenes Centre of Excellence (ECoE)
- **VISION:** Within the next 7 years, the ECoE will become a world-class Digital Innovation Hub (DIH) for EO and Geospatial Information - the reference Centre in the Eastern Mediterranean, Middle East and North Africa (EMMENA)

Partners

- Cyprus University of Technology (**CUT-TEPAK**)
- National Observatory of Athens (**NOA**)
- Leibniz Institute for Tropospheric Research (**TROPOS**)
- German Aerospace Centre (**DLR**)

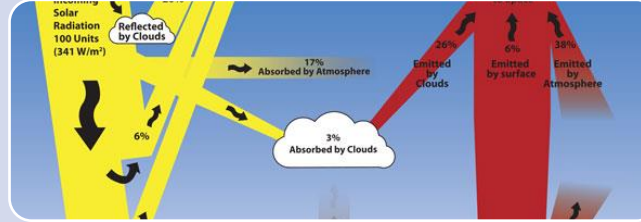
Thematic Clusters for sustained excellence in research of the ECoE



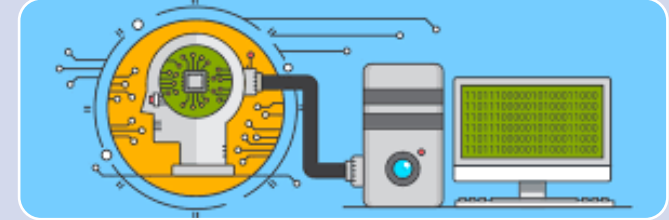
Solar energy related research



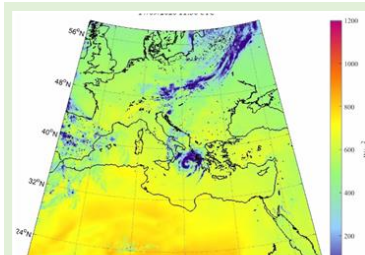
Earth
observation



Physical
modelling



Machine
learning



Accurate nowcasting and
forecasting for solar energy

Climatological study of solar energy in Cyprus

Aerosol optical depth (**AOD**) and Dust Optical Depth (**DOD**) from **MODIS/MIDAS** (Gkikas et al., 2021)

Climatological **water vapor, ozone, SSA, Asymmetry factor, Angstrom exponent**, etc

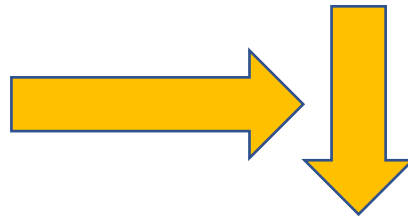


LUT of spectra corresponding to different conditions - radiative transfer simulations from UVspec **libRadtran** (Emde et al., 2016)



Spectral solar irradiance (290 – 3000 nm) in timesteps of 15 mins for 2004 - 2017

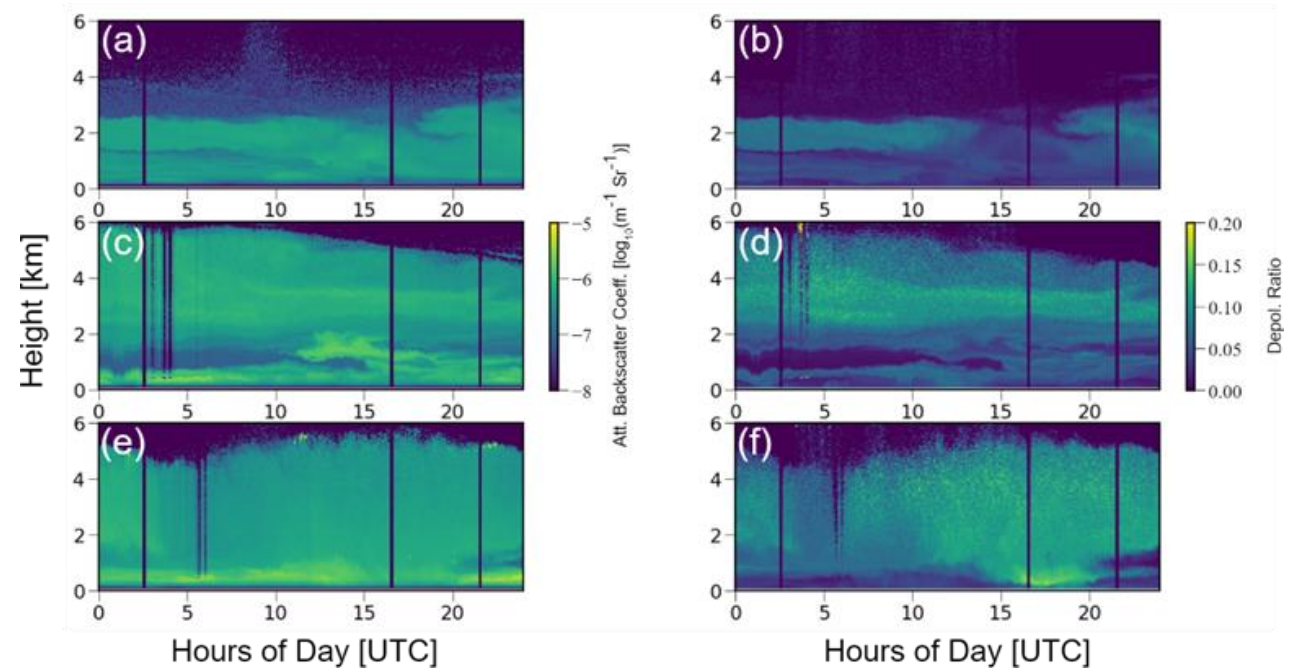
Attenuation by **clouds** from **CMSAF-SARAH2** (Pfeifroth et al., 2017)



- climatology of **GHI** and **DNI** on $0.1^\circ \times 0.1^\circ$ grid
- study the effects of clouds, aerosols & dust on the production of solar energy

Dust in Cyprus

- Dust is a significant fraction of the aerosol mixture, not only in Cyprus, but in general over the EMMENA region
- In Cyprus, dust transfer from North Africa and middle East is frequent, especially in Spring

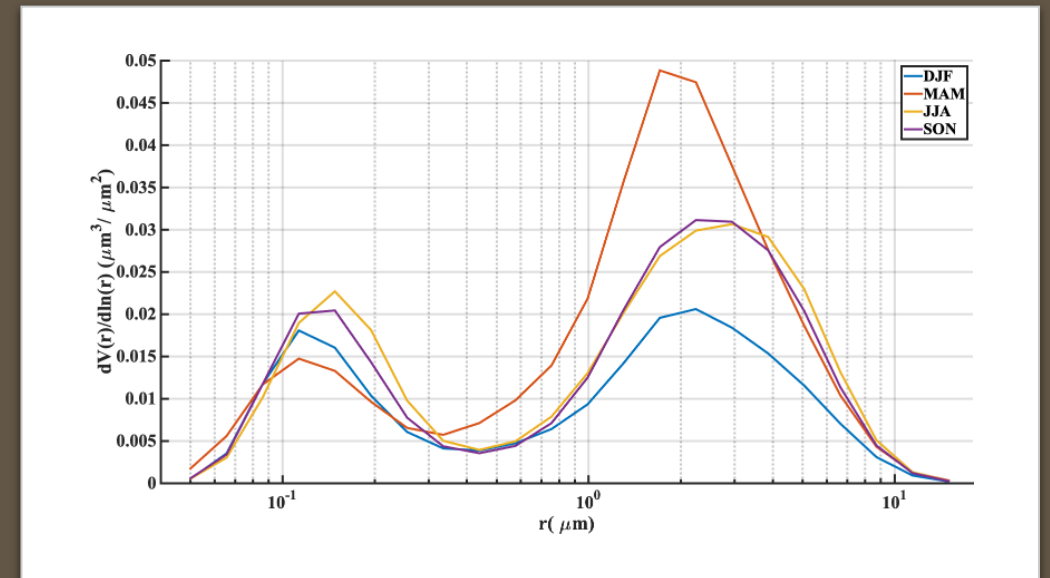
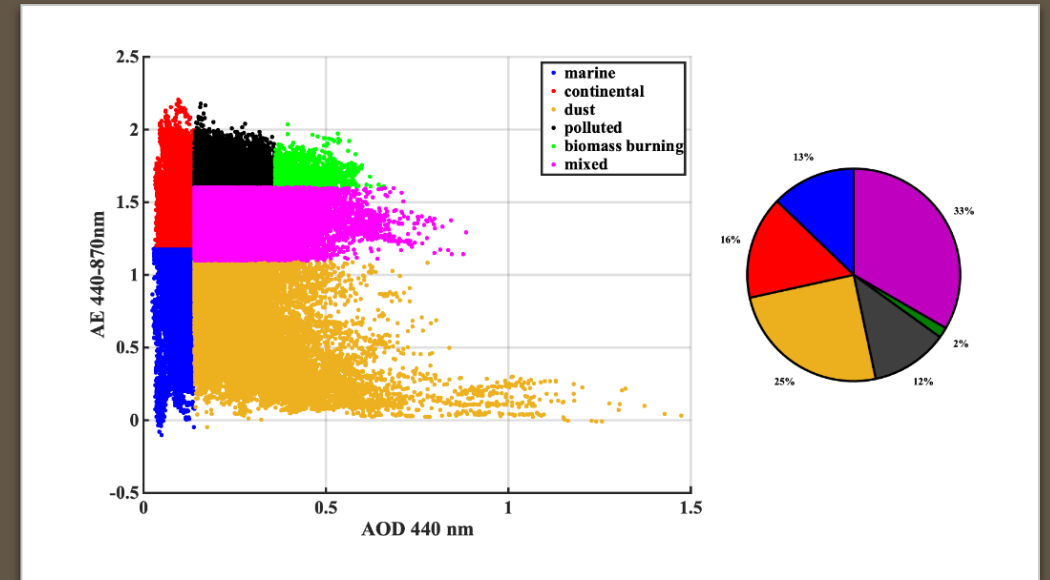


Lidar attenuated backscatter coefficient (left column) and particle linear depolarization ratio (right column) / measurements performed at CUT

- Reference case: 10 September 2017 (a,b)
- Dust from Middle East: 15 of September 2017 (c,d)
- Saharan dust: 21 September 2017 (e,f).

Dust in Cyprus

- In ~30% of AERONET measurements at Limassol (in 2010 - 2020) the dominant type in the aerosol mixture was dust
- Large amount of coarse particles in spring



Dust

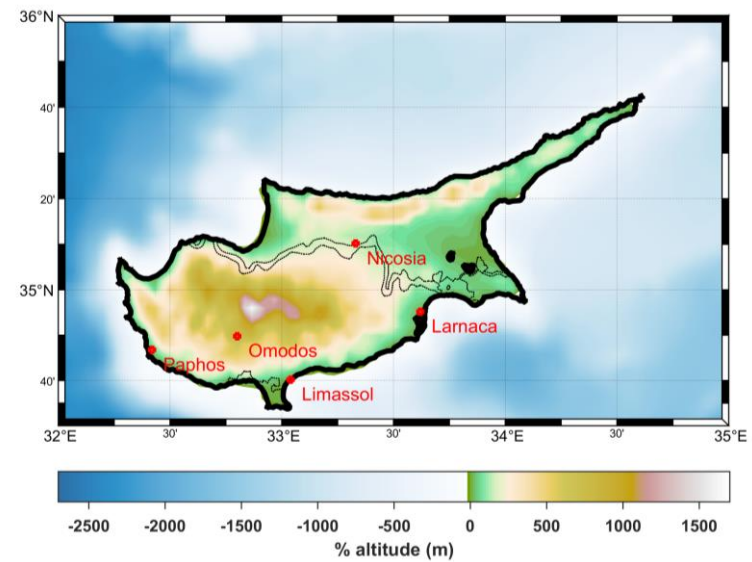
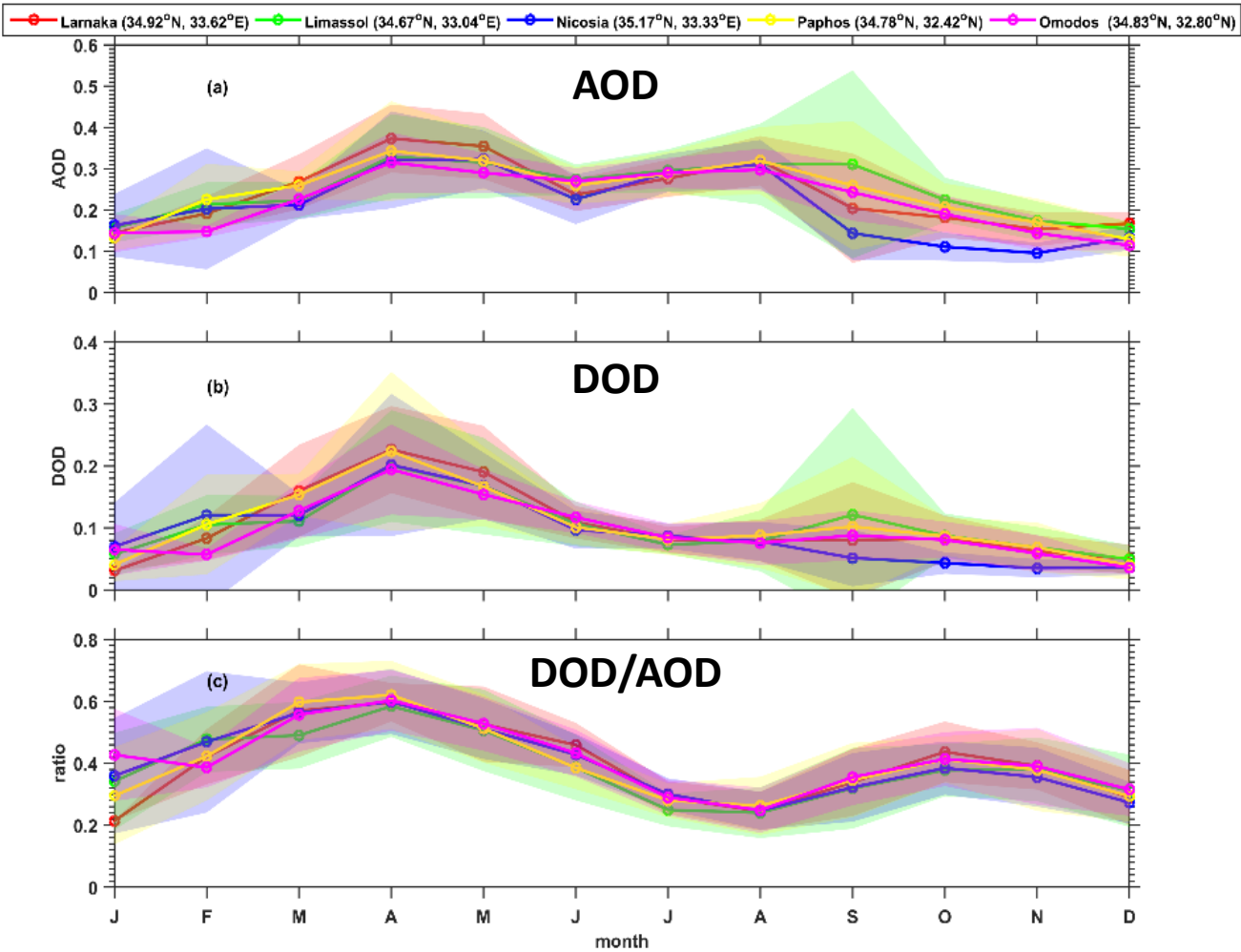


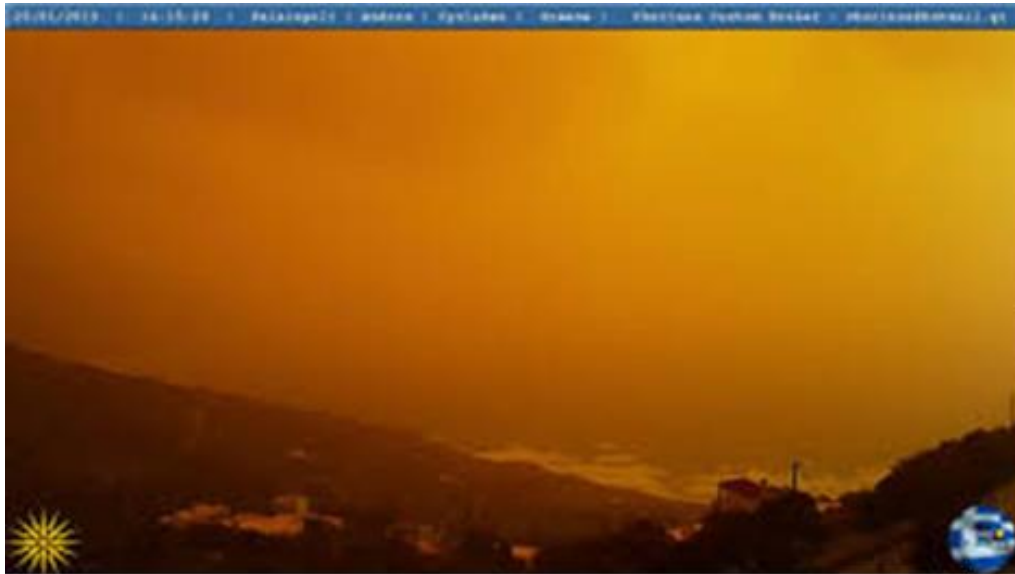
Table 3. Trends (absolute change per year) of the seasonal AOD and DOD. Values in red represent statistically significant trends.

	Larnaca		Limassol		Nicosia		Paphos		Omodos	
	AOD	DOD	AOD	DOD	AOD	DOD	AOD	DOD	AOD	DOD
Winter	-0.004	-0.003	-0.001	-0.001	-0.008	-0.008	0.005	0.003	-0.005	-0.003
Spring	-0.005	-0.004	-0.011	-0.011	0.000	-0.001	-0.001	-0.003	0.000	-0.001
Summer	-0.003	-0.003	-0.001	-0.002	0.003	-0.001	0.000	-0.003	0.000	-0.002
Autumn	-0.001	0.000	0.007	0.004	0.000	0.000	0.002	0.001	-0.001	-0.001

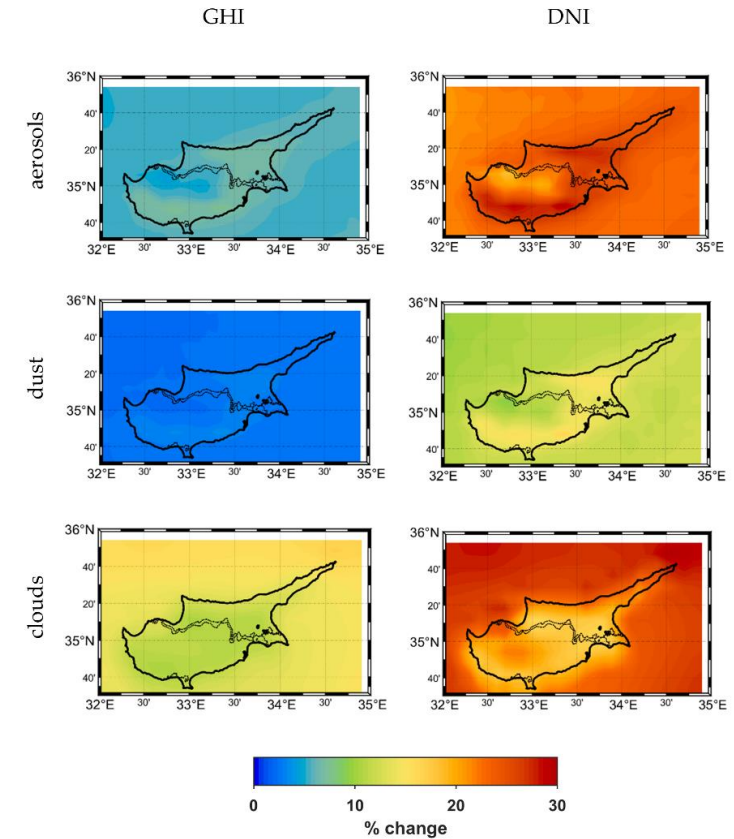
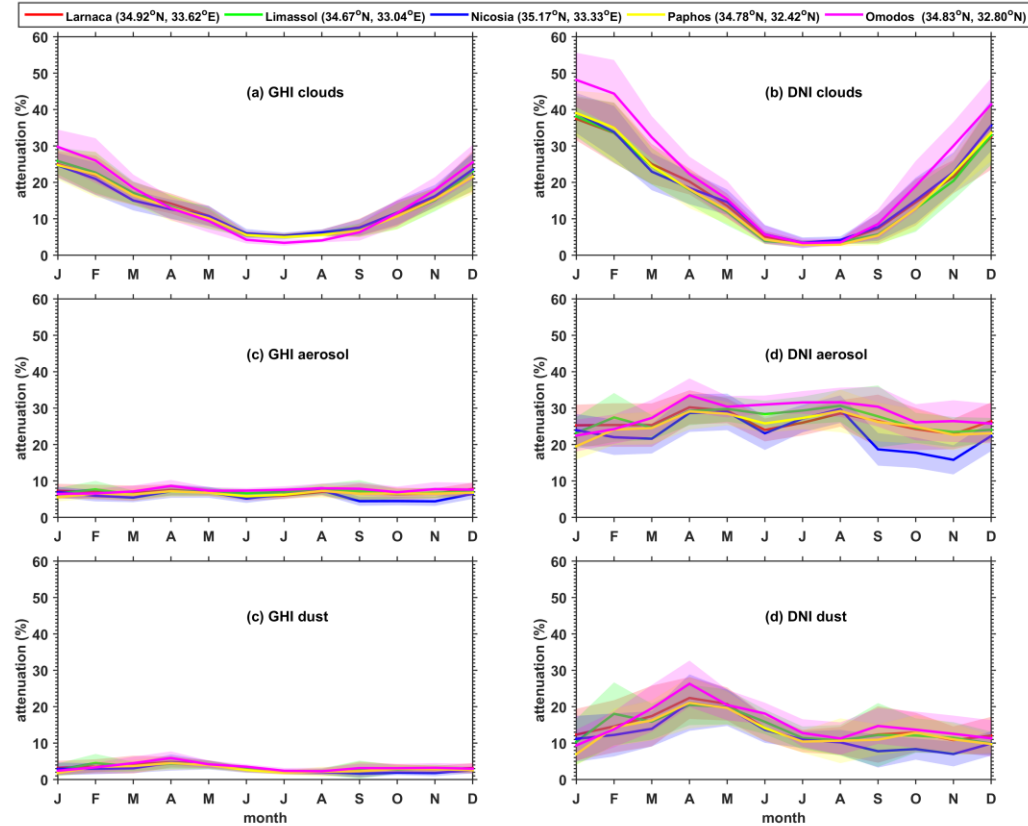
2004 – 2017 climatology



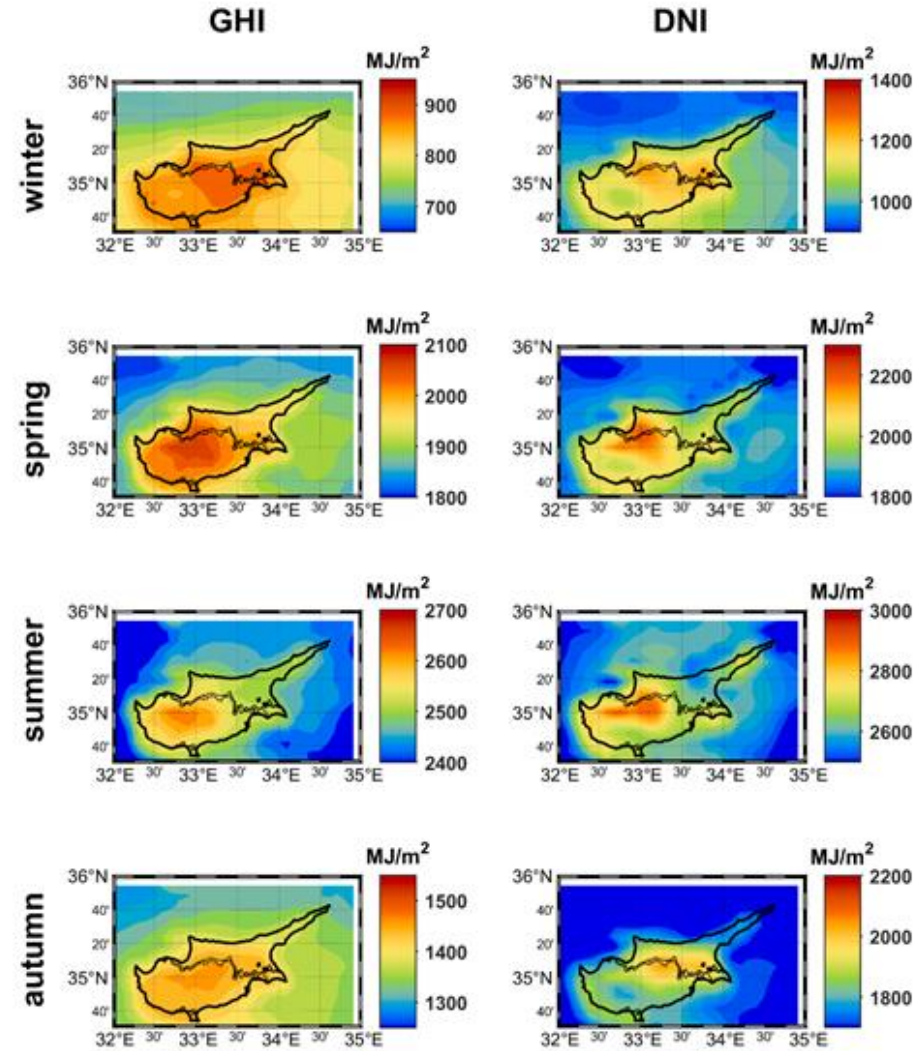
Dust in Cyprus



Attenuation of GHI and DNI by clouds, aerosol and dust

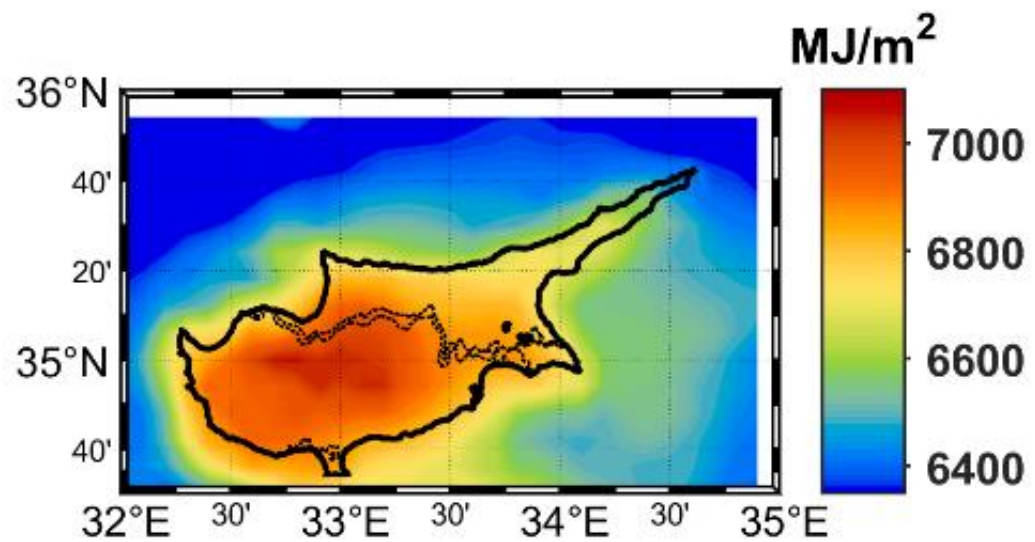


Total seasonal GHI and DNI in Cyprus

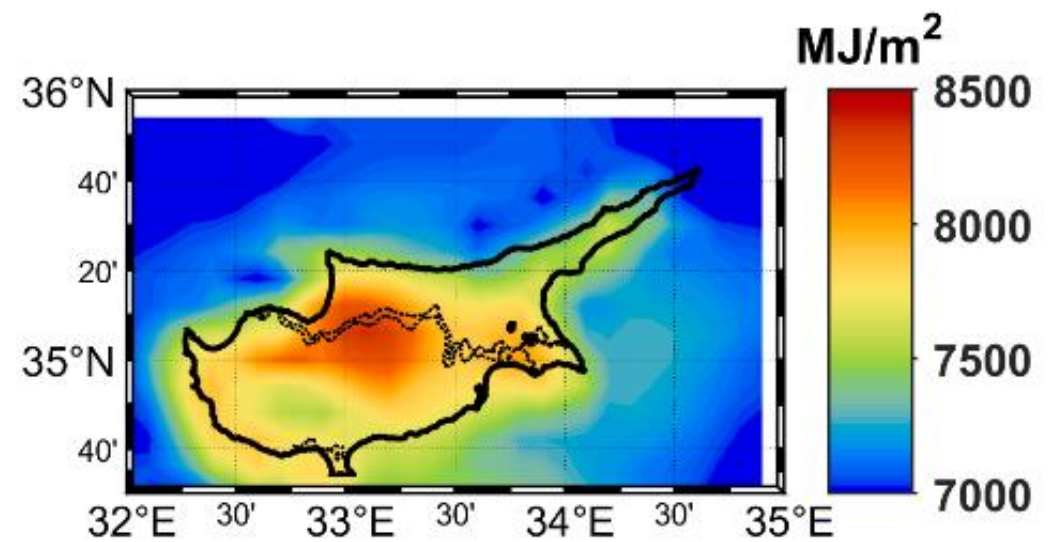


Annual GHI and DNI

GHI

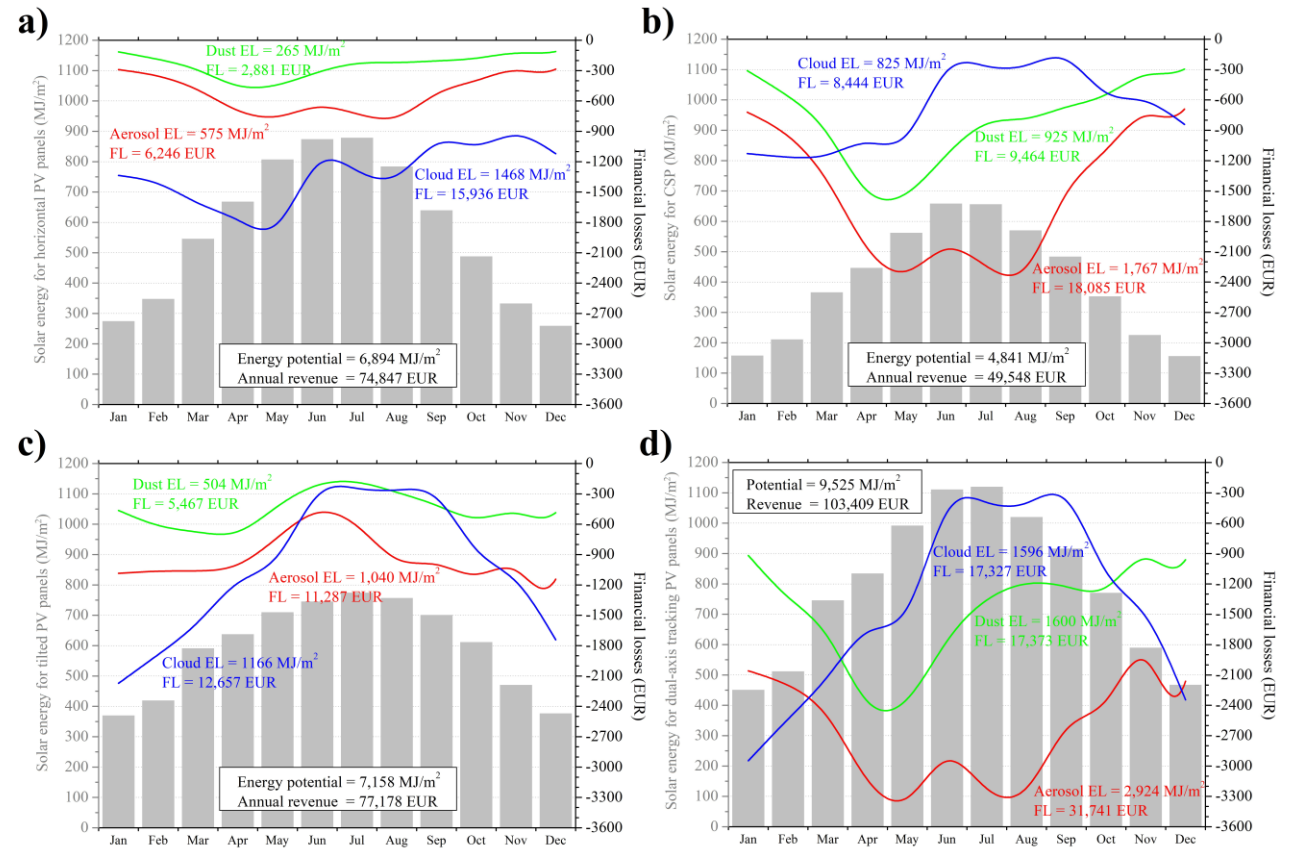


DNI



Financial analysis of the effects of clouds, aerosols, and dust

- (a) PV on horizontal surface (zero tilt angle)
- (b) CSP
- (c) PV – tilted panels (tilt angle = latitude of the location)
- (d) PV - panels on solar tracking system
- nominal power = 500kW.



Summary

- Annual GHI in Cyprus $\sim 6500 - 7100 \text{ MJ/m}^2$
- Annual DNI in Cyprus $\sim 7500 - 8500 \text{ MJ/m}^2$
- Similar levels of GHI and DNI with Malta & Andalusia, Spain – highest in Europe
- Main factors attenuating surface solar radiation are clouds and aerosols
- The role of dust is very significant

Summary

- Dust contributes ~30% in the aerosol mixture (~50% in spring)
- Horizontal PV panels → Effect of clouds is dominant / attenuate ~3 times more GHI than aerosol
- optimally inclined PV panels → Effect of aerosols is comparable with the effect of clouds
- CSP and solar tracking PV systems → Effect of dust similar to the effect of clouds - aerosol attenuate ~2 times more irradiance than clouds

More information for Excelsior:

- More information for Excelsior: <https://excelsior2020.eu/>

- More information for solar radiation and solar energy at Cyprus:

Fountoulakis, I.; Kosmopoulos, P.; Papachristopoulou, K.; Raptis, P.; Mamouri, R.; Nisantzi, A.; Gkikas, A.; Witthuhn, J.; Bley, S.; Moustaka, A.; Buehl, J.; Seifert, P.; Hadjimitsis, D.G.; Kontoes, C.; Kazadzis, S. **Effects of Aerosols and Clouds on the Levels of Surface Solar Radiation and Solar Energy in Cyprus**. Preprints 2021, 2021050138 (doi: 10.20944/preprints202105.0138.v1).
<https://www.preprints.org/manuscript/202105.0138/v1>

Thank you for your attention!