CYPRUS ERYTHEMAL RADIATION FORECASTING SYSTEM (CERYFOS)

Georgia Charalampous[1,2], Konstantinos Fragkos[1], Andreas Karpasitis[3], Ilias Fountoulakis[4,5], Argyro Nisantzi[1,2], Kyriakoula Papachristopoulou[4], Diofantos Hadjimitsis[1,2], Stelios Kazadzis[6]

(1) Eratosthenes Centre of Excellence, Department of Resilient Society, Fragklinou Rousvelt 82, Limassol 3012, Cyprus

(2) Cyprus University of Technology, Department of Civil Engineering & Geomatics, 3036 Limassol, Cyprus

(3) The Cyprus Institute, Climate and Atmosphere Research Center (CARE-C), 20 Konstantinou Kavafi, Aglantzia. Nicosia, Cyprus.

(4) Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens (IAASARS/NOA), GR15236 Athens, Greece

(5) Research Centre for Atmospheric Physics and Climatology, Academy of Athens, 106 79 Athens, Greece

(6) Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center (PMOD/WRC), Davos 7260, Switzerland

ABSTRACT

Ultraviolet B (UVB) radiation plays a crucial role in supporting life on Earth and sustaining ecosystems; however, excessive exposure poses risks, such as sunburns, premature aging, and an elevated susceptibility to skin cancers. The Ultraviolet Index (UVI), a numerical scale quantifying solar UV radiation intensity with respect to its efficiency in causing erythema in the human skin, serves as a valuable tool for guiding sun exposure practices and implementing protective measures.

Cyprus, a sun-drenched country, experiences exceptionally high UVI levels (10+) during the summer months. Despite this, there is currently no official forecast or related information available regarding UV levels on the island. To address this gap, we introduce the Cyprus Erythemal Radiation Forecasting System (CERYFOS), a novel initiative designed to provide guidance on prudent sun exposure. By delivering UVI forecasts and harnessing Cyprus-specific UV radiation data, CERYFOS aims to educate the public on optimal sun exposure durations and empower authorities to proactively address risks associated with prolonged exposure to UV radiation. **Index Terms—** UV-Index, forecast, Cyprus, solar, radiation.

1. INTRODUCTION

Solar ultraviolet-B (UV-B) radiation has played a pivotal role in shaping the evolution of life on Earth. Exposure to UV radiation presents a dual scenario for humans, with both risks and benefits. On the positive side, UV-B radiation is essential for the synthesis of vitamin D in the skin, a crucial factor for maintaining optimal bone health. It also contributes to the maintenance of a good physical and mental health through various processes. However, overexposure to UV-B can lead to undesirable outcomes such as sunburns, premature skin aging, and an increased susceptibility to skin cancers, including basal cell carcinoma, squamous cell carcinoma, and melanoma [1]. Additionally, excessive exposure to solar radiation is a primary cause of several ocular conditions [2], such as cataracts [3], and it can also compromise immune system functionality [4], thereby impairing the body's ability to ward off infections. For example, ultraviolet (UV) radiation exposure can lead to the reactivation of the herpes virus [5]. These findings underscore the critical need for individuals to adopt prudent sun exposure habits to maintain optimal health.

Determining the ideal behaviors for UV-B exposure is a complex task, depending on many environmental and physiological factors. Geographical location, altitude, time of day, ozone and aerosol concentrations and their seasonal variations influence the intensity of UV radiation, while individual factors such as skin type, genetics, and susceptibility to sun damage further complicate the

equation. Achieving a balance between the risks and benefits involves adopting sun protection measures, such as the use of sunscreen, protective clothing, sunglasses, and seeking shade during peak UV hours.

The UV Index serves as a practical tool for making informed decisions about sun exposure duration and the necessary protective measures [6]. Its numerical scale (from 0 to 11+) indicates the intensity of solar UV radiation, with higher indices signifying increased radiation potency and a higher likelihood of accelerated cutaneous burns.

In Cyprus, a European country known for its elevated solar irradiance, a new platform has been established to deliver forecasts of the UVI. The Cyprus Erythemal RadIation FOrecasting System (CERYFOS) strives to disseminate guidance on judicious sun exposure. This initiative is dedicated to provide guidance on prudent sun exposure. Through the dissemination of UVI forecasts, CERYFOS aims to educate the public about the optimal durations for sun exposure. Additionally, by harnessing climatological UV radiation data specific to Cyprus, this platform empowers relevant authorities to proactively institute measures aimed at mitigating the potential risks and adverse consequences associated with prolonged sun exposure. This forward-looking approach aligns with the overarching goal of safeguarding public health and promoting informed choices in sun-related activities.

2. CERYFOS MODEL SOURCES

The CERYFOS platform provides hourly UVI forecasts for the upcoming two days, with a spatial resolution of 0.1x0.1 degrees specifically tailored for Cyprus. The model relies on simulations performed using the radiative transfer model libRadtran [7], by exploiting forecasted total ozone column and aerosol optical properties to determine the clear sky UVI. Additionally, it incorporates the Cloud Modification Factor based on numerical weather prediction models to provide allskies forecasts.

The key data sources for the CERYFOS model are outlined in Table 1, reflecting a comprehensive approach to simulations. Cloud Modification Factors, defined as the ratio between the all-sky and clear sky surface solar radiation, are derived every 1 hour from the Weather Research and Forecasting (WRF) model, with a resolution of 2x2 km. Aerosol optical properties (aerosol optical depth AOD, single scattering albedo SSA, asymmetry factor and angstrom exponent -AE) are obtained from the Copernicus Atmosphere Monitoring Service (CAMS) global atmospheric composition forecasts [8][9] with a spatial resolution of 40 km.

The model incorporates total ozone column levels from the Tropospheric Emission Monitoring Internet Service (TEMIS) utilizing Assimilated Ozone Fields from GOME-2 (METOP-B), providing a forecast of total ozone column (TOC) at a spatial resolution of 1x1 degree [10].

The model incorporates surface elevation data obtained from elevation observations with a precision of 1 m, utilizing a Digital Elevation Model (DEM) from NOAA [11].

Table 1: CERYFOS input parameters.

Parameter	***Description (spatial–temporal resolution)***	***Source***
Cloud	2 days forecast (2x2 km – 1 hour)	Weather Research and Forecasting (WRF-ARW v4.5.1)
Aerosol optical properties	1 day forecast AOD, SSA, asymmetry factor, AE (40 km – 1 hour)	Copernicus Atmosphere Monitoring Service (CAMS)
Ozone	1 day forecast total ozone column (TOC) (0.25° by 0.25° – 1 day)	Tropospheric Emission Monitoring Internet Service (TEMIS) with Assimilated Ozone Fields from GOME-2 (METOP-B)
Surface elevation	Elevation observation (ELE) (1 m – fixed)	Digital elevation model (DEM) In-house database (NOAA)

3. CERYFOS PLATFORM

The CERYFOS platform, accessible via the UVI Nexus Hub (https://uvi.nexushub.eratosthenes.org.cy/web) of the Eratosthenes Centre of Excellence page, presents a comprehensive depiction of its functionalities. Figure 1 displays the platform's main interface, introducing the concept of UVI alongside real-time forecasted UVI values for the major cities in Cyprus (Nicosia, Limassol, Paphos, Larnaca, Famagusta), giving users a detailed overview of its capabilities. UVI forecast maps are accessible through two methods on the platform: either by selecting the UVI MAP button located under the “Calculating and forecasting Ultraviolet Index (UVI) in Cyprus” section as shown in Figure 1, or by clicking the map icon at the top of the webpage. Clicking these options opens a new page displaying the UVI forecast map for Cyprus, available for the current and subsequent day across three time periods: morning, noon, and afternoon. These forecasts are presented for both cloudadapted and cloudless conditions, in accordance with World Meteorological Organization guidelines, which stipulate that forecasts should be available for at least the next day at solar noon under clear sky conditions [12][13]. The

maps use the standard UVI scale, visible on the right side of Figure 2. Furthermore, users can interact with a specific area on the map to access hourly UVI forecasts, presented as bar plots and tabular values, as illustrated in Figure 3 (right part). The model evaluation will be conducted by comparing its predictions with the actual measurements of UVI obtained from a network of five stations installed throughout the island, as depicted in the bottom part of Figure 1. This network consists of five Kipp & Zonen SUV-E radiometers [https://www.kippzonen.com/Product/428/SUV-E-UVERadiometer] installed in selected areas over the Cyprus territory to serve as the primary model evaluation areas. Further details regarding the instrumentation and locations can be found in Fragkos et al [14].

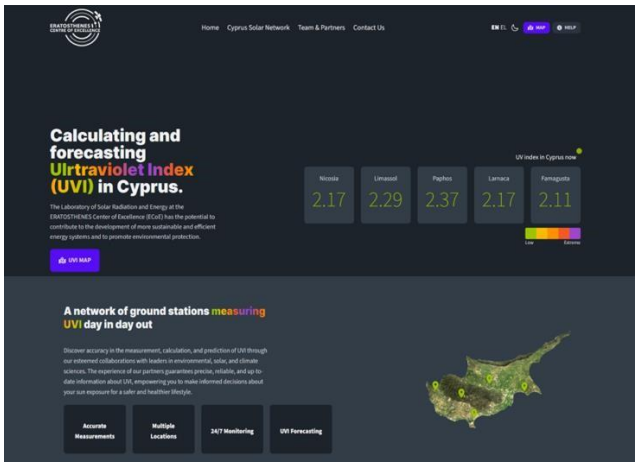

Figure 1: CERYFOS platform interface.

Figure 2: UV Index forecast map of Cyprus.

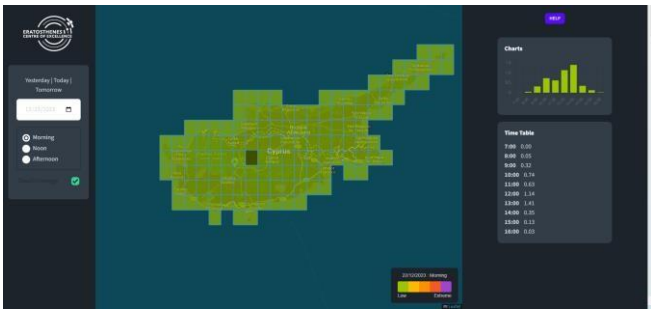

Figure 3: UV Index forecast map of Cyprus, along with the daily evolution for the area of interest.

4. PRELIMINARY EVALUATION

This section provides a preliminary evaluation of the forecast system. Figure 4 illustrates the forecasted UVI values under cloud-free and all-sky conditions (top panel) and the discrepancies between forecasted and measured UVI values (bottom panel) in Limassol during the period from February 9 to February 14, 2024. The analysis period included days with clear skies (February 9, 10, 11), partly cloudy (February 12 and 14), and overcast conditions (February 13).

The model demonstrates high performance under clear sky conditions, with discrepancies generally within ±0.5 UVI units. However, the accuracy under cloudy conditions varies, depending on the cloud coverage forecast. Notably, the NWP model accurately depicted cloud conditions on February 12 but failed on February 13 and 14. Overall, the model accurately estimates UVI levels under clear skies, indicating reliable forecasts for ozone and aerosol properties that are used in the RT model. Nevertheless, it occasionally fails to predict cloud conditions accurately, resulting in larger deviations.

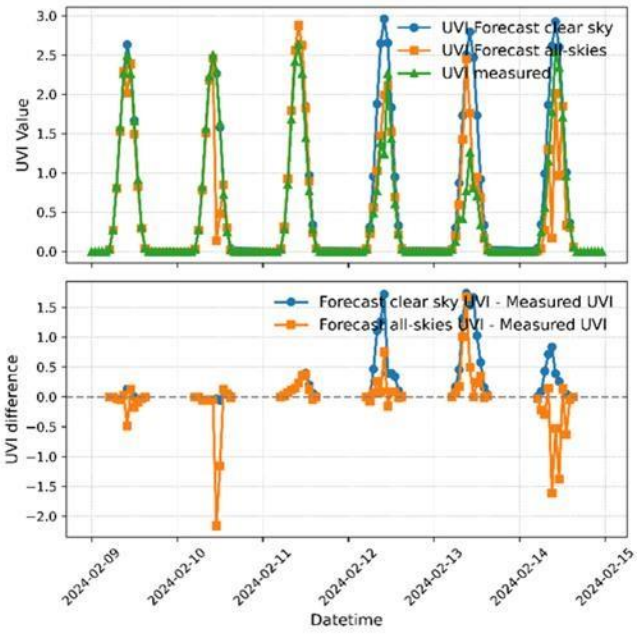

Figure 4: Time series of the forecasted UVI under clear sky (blue) and all-skies (orange) conditions, along with the measured UVI (green) over Limassol (top panel). Differences between forecasted and measured UVI values (bottom panel)

5. CONCLUSIONS

In this study, we introduce the CERYFOS platform, designed to deliver a two-day forecast of the Ultraviolet Index (UVI) specifically for Cyprus. As both CERYFOS and the erythemal UV actinometer stations have been recently implemented, a comprehensive evaluation of CERYFOS performance is currently unavailable. Nevertheless, initial evaluation of the model shows quite good performance under cloudless conditions, with some deviations observed under cloudy conditions. Ongoing assessments of the UVI forecasts will be conducted through continuous comparisons with measured UVI values. Subsequent improvements to the model will be undertaken if deemed necessary, ensuring the refinement and reliability of the forecasting system over time. This iterative evaluation process underscores our commitment to providing accurate and trustworthy UVI forecasts for the benefit of public awareness and sun safety in the region.

5. REFERENCES

[1] Neale, R.E., Lucas, R.M., Byrne, S.N. et al. The effects of exposure to solar radiation on human health. Photochem Photobiol Sci 22, 1011–1047 (2023). https://doi.org/10.1007/s43630-023-00375-8

[2] Oliva, Matthew S MD; Taylor, Hugh AC, MD. Ultraviolet Radiation and the Eye. International Ophthalmology Clinics 45(1):p 1-17, Winter 2005. | DOI: 10.1097/01.iio.0000148389.44889.3b

[3] Dolin PJ. Ultraviolet radiation and cataract: a review of the epidemiological evidence. Br J Ophthalmol. 1994 Jun;78(6):478-82. doi: 10.1136/bjo.78.6.478. PMID: 8060933; PMCID: PMC504827.

[4] Bernard, J.J., Gallo, R.L. & Krutmann, J. Photoimmunology: how ultraviolet radiation affects the immune system. Nat Rev Immunol 19, 688–701 (2019). https://doi.org/10.1038/s41577-019-0185-9

[5] [5] Perna, J. J., Mannix, M. L., Rooney, J. F., Notkins, A. L., & Straus, S. E. (1987). Reactivation of latent herpes simplex virus infection by ultraviolet light: a human model. Journal of the American Academy of Dermatology, 17(3), 473-478.

[6] World Health Organization (WHO). Radiation: The ultraviolet (UV) index Retrieved April 10, 2023, from: https://www.who.int/uv/faq/ radiation-the-ultraviolet-(uv)-index.htm

[7] Mayer, B. and Kylling, A.: Technical note: The libRadtran software package for radiative transfer calculations - description and examples of use, Atmos. Chem. Phys., 5, 1855–1877, https://doi.org/10.5194/acp-5-1855-2005, 2005.

[8] Peuch, V., and Coauthors, 2022: The Copernicus Atmosphere Monitoring Service: From Research to Operations. *Bull. Amer. Meteor. Soc.*, **103**, E2650–E2668, https://doi.org/10.1175/BAMS-D-21-0314.1

[9] Rémy, S., Kipling, Z., Flemming, J., Boucher, O., Nabat, P., Michou, M., Bozzo, A., Ades, M., Huijnen, V., Benedetti, A., Engelen, R., Peuch, V.-H., & Morcrette, J.J. (2019). Description and evaluation of the tropospheric aerosol scheme in the European Centre for MediumRange Weather Forecasts (ECMWF) Integrated Forecasting System (IFS-AER, cycle 45R1). *Geoscientific Model Development*, *12*(11), 4627–4659. https://doi.org/10.5194/gmd-12-4627-2019.

[10] Eskes, H. J., Velthoven, P. F. J. V., Valks, P. J. M., and Kelder, H. M.: Assimilation of GOME total-ozone satellite observations in a three-dimensional tracertransport model, Q. J. Roy. Meteor. Soc., 129, 1663–1681, https://doi.org/10.1256/qj.02.14, 2003.

[11] NOAA: Data Announcement 88-MGG-02, Digital relief of the surface of the Earth. NOAA, National Geopgysical Data Center, Boulder, Colorado, USA, 1988.

[12] WMO, 1994, Report on the WMO meeting of experts on UV-B measurements, data quality and standardization of UV Indices, WMO GAW No 95.

[13] WMO, 1997, Report on the WMO-WHO meeting of experts on standardization of UV Indices and their dissemination to the public, WMO GAW No 127.

[14] Fragkos K, Nisantzi A, Fountoulakis I, Michaelides S, Charalampous G, Papachristopoulou K, Kontoes C, Hadjimitsis D, Kazadzis S. Introducing the Solar Radiation and Energy Laboratory of the Eratosthenes' Centre of Excellence: Overview of Activities. Environmental Sciences Proceedings. 2023; 26(1):45. https://doi.org/10.3390/environsciproc2023026045

Acknowledgments

The authors acknowledge the EXCELSIOR: ERATOSTHENES:

Excellence Research Centre for Earth Surveillance and Space-Based Monitoring of the Environment H2020 Widespread Teaming project (www.excelsior2020.eu, accessed on 13 March 2023). The EXCELSIOR project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 857510, from the Government of the Republic of Cyprus through the Directorate General for the European Programmes, Coordination and Development and the Cyprus University of Technology.