A brighter future

Panagiotis Kosmopoulos, **Michael Taylor** and **Stelios Kazadzis** talk about their work modelling solar radiation, the implications that it may have and some of the challenges they had to overcome to develop a novel and accurate nowcast and short-term forecasting system

Can you outline the principal objectives of your research into solar energy and its environmental impact?

Solar radiation reaching the Earth's surface is life's motor – it drives photosynthesis and warms the air, land and oceans. It is one of the most sensitive parameters determining the delicate balance of conditions necessary for our continued existence on this planet. Our research at the National Observatory of Athens (NOA) is motivated by a need to increase our understanding of the state of the solar radiation environment and the potential for evolving technologies based on solar energy.

What are the main benefits of the solar UV radiation spectrum for emerging solar energy technologies?

Emerging technologies based on the UV part of the solar radiation spectrum are associated with the protection of public health and the environment on the one hand, and the potential for its exploitation on the other. The provision of specialised solar UV radiation data of high spectral precision for private and public sectors is key to the development of these technologies in areas dealing with health (eg. protecting against DNA or eye damage and photo-ageing, and monitoring vitamin D_3 production) and the environment (eg. protecting aquatic life).

Can you describe the methods used to retrieve solar radiation information at NOA?

Members of the team are actively involved in the development of a real-time system for obtaining the solar radiation spectrum that combines radiative transfer simulations, neural network models, global climatology of atmospheric parameters and satellite-based data analysis. The system has evolved out of a number of successful national and EU projects involving surface-based aerosol and solar radiation monitoring, satellite-based cloud and aerosol measurements, and atmospheric models conducted by NOA, which is a member of various global measuring networks.

Using available datasets, your team has been able to create climatological time series on a monthly and seasonal scale. Have these uncovered any surprising results?

With the growth in our database of 'nowcast' products, we are calculating accurate climatological time series of important factors such as: solar energy, UV index, effective vitamin D dose, DNA damage and photosynthetically active radiation across hourly, daily, monthly and seasonal timescales. Analysis of trends in these time series on the regional and continental scale is a crucial area of research for members of the team. Several studies using surface-based measurements, for example, have revealed important changes in some of the above parameters through time. The high spatial coverage provided by our real-time system is a major advantage for such future studies.

What role does collaboration play in advancing your research endeavours?

As a team of Earth observation (EO) scientists modelling and monitoring the complex interplay of clouds, aerosols and radiation, the development of a state-of-the-art system for accurately calculating the surface solar radiation spectrum from space and its dependence on atmospheric variables was a crystallisation of our existing expertise. Each one of us participated by adding our piece of individual expertise into the puzzle, which led to our novel solar energy nowcast system.

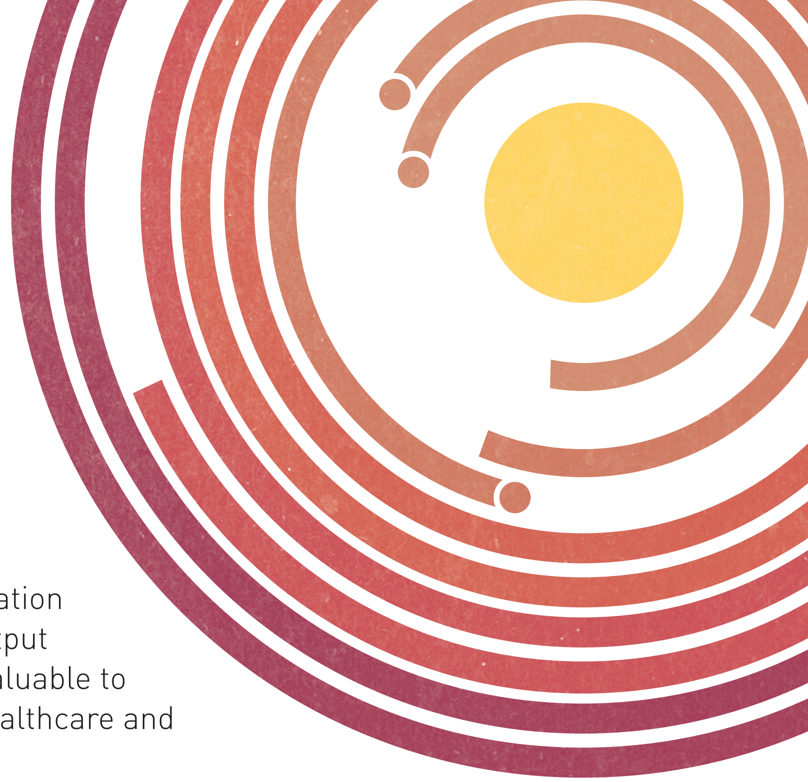
Have you encountered any specific difficulties in retrieving, processing and providing online, real-time data from the Meteosat Second Generation-3 (MSG3) satellite?

The spinning enhanced visible and infrared imager (SEVIRI) onboard the MSG-3 satellite provides images of the Earth disk, which are retrieved by the infrastructure of the Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS)/NOA. From these images, the cloud type and phase, as well as the cloud optical thickness are retrieved. The major challenge here is the identification of clouds and extraction of their properties during both day and night. This is achieved using the high-performance Satellite Application Facility for Nowcasting Weather Conditions (SAFNWC) software together with Global Forecasting System (GFS) forecasts from the US National Climatic Data Center.

With data processing of cloud properties producing impact both nationally and on a larger scale, are there any discoveries of which you are particularly proud?

We are very pleased that our system produces surface solar direct normal and global and diffuse horizontal irradiance (DNI, GHI and DHI) spectra of high spectral resolution that take into account the effects of clouds and aerosols in the atmosphere. This is a major advance in the field as it addresses the problem of the complex state of the atmosphere on the amount of surface radiation. One important finding was that the novel speed-up provided by the use of a neural network in our system to replace slow and unwieldy radiative-transfer look-up tables has worked with high accuracy.

Applications from the solar spectrum



A team from the **National Observatory of Athens** has made a significant contribution to the understanding of solar radiation at the surface of our planet. A novel real-time system developed by the team is able to reliably calculate short-term forecasts of the solar radiation spectrum across the globe from space. This output information and its derived products will be invaluable to the international solar renewable energy, UV healthcare and environmental protection industries

THE SUN BATHES the surface of the Earth in life-giving energy, but there exists a fine balance between help and harm. Most organisms have evolved to reap the benefits of the Sun's energy. Humans, for example, require periodic exposure to UV radiation to produce vitamin D, vital for health and wellbeing. However, overexposure to solar radiation can cause harmful effects such as sunburn, photo-ageing or even DNA damage. As such, accurate and detailed knowledge of predictable exposure to the Sun's energy is required. In addition, stakeholders involved in the solar energy industry are keen to locate areas that are subject to consistently high and predictable solar radiation. These regions ultimately represent the best locations for solar power production – a fast growing industry with enormous potential.

While it is clear that solar energy and human health industries have different objectives, they do share one common factor – the need to predict the strength of solar radiation across both temporal and spatial scales. It is this imperative that has been acknowledged by scientists working at the National Observatory of Athens (NOA), including Panagiotis Kosmopoulos, Dr Michael Taylor and Dr Stelios Kazadzis together with their colleagues Dr Iphigenia Keramitsoglou and Professor Chris Kiranoudis.

THE NOWCAST

By exploiting the full-Earth viewing potential of geostationary satellites, the team has developed a system that delivers regional 'nowcasts' of the solar radiation spectrum calculated on a high resolution grid at 15-minute intervals. "We use satellite-derived cloud optical properties and other atmospheric parameters (eg. aerosols and trace gases) in combination with radiative transfer modelling and neural networks in order to achieve this goal," explains Kazadzis.

> This highly expert team unites a diverse set of expertise that has enabled the development of the world's leading system for mapping and predicting solar radiation

The system and frequency of measurement is dependent on the Meteosat Second Generation 3 (MSG -3) satellite orbiting the Earth at an altitude of 36,000 km. "This satellite continuously monitors the Earth's disk every 15 minutes with a spatial resolution of approximately 0.05° longitude by 0.05° latitude," outlines Kosmopoulos. In each of these pixels, the team calculates the solar radiation spectrum and an array of new solar energy products.

Armed with this system, the NOA team accurately measures surface radiation at high spatial and temporal resolution, analysing past levels, monitoring current levels and even accurately forecasting radiation up to one hour ahead, whatever the weather. "The quality of their forecasts has been validated by comparisons with actual measurements from solar radiometer instruments as part of the national project Thespia," explains Taylor.

CLOUDS AND AEROSOLS

Alternative models and methodologies for calculating surface radiation have, of course, existed for several years. While there is considerable heterogeneity in these models, most share a similar limitation associated with the accuracy of accounting for the effect of cloud cover and atmospheric aerosols on large-area nowcasting estimates of solar radiation. This is a crucial limitation as the complex vertical profile and high spatial and temporal variability of clouds, and aerosol properties, in the atmosphere impact on the nature of the solar radiation reaching the ground.

Seen by the NOA researchers, this limitation was addressed by developing a reliable way of incorporating these effects into their models. Fortunately, members of the team are involved in Earth observation and satellite remote sensing science and the development of cloud retrieval and global aerosol models. Furthermore, NOA itself has a long tradition of solar radiation monitoring since the beginning of the 20th Century and also is an important node in both European Aerosol Research Lidar Network (EARLINET) and NASA sunphotometer (AERONET) networks. As such, the team possessed the necessary expertise to be able to develop the most advanced and reliable system for modelling solar radiation at the Earth's surface.

DATA DISSEMINATION

Due to the inherent importance for solar energy, health and environmental protection industries, it is essential that the NOA team makes its results as accessible as possible. The researchers have already achieved some success in this context, contributing regular UV maps and forecasts to Greek weather information websites. In further support of this

INTELLIGENCE

OBJECTIVE

A state-of-the-art system for determining the solar radiation spectrum at the Earth's surface directly from geostationary satellite cloud products and radiative-transfer models, boosted by the computing power provided by neural networks.

PARTNERS

Institute for Environmental Research and Sustainable Development (IERSD/NOA), Greece

Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS/NOA), Greece

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

National Technical University of Athens (NTUA), Greece

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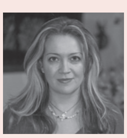
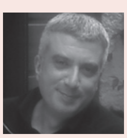


DR IPHIGENIA KERAMITSOGLOU is Senior Researcher at IAASARS/NOA in Earth Observation. She holds a PhD from Imperial College London.



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regions at the centre of development

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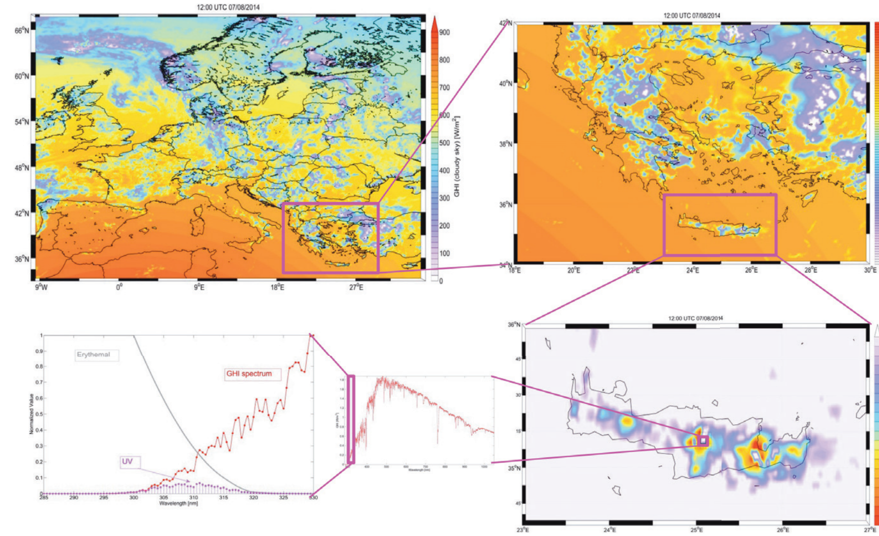

A zoom sequence showing a selection of the team's solar energy products. Going clockwise: the GHI for Europe, the UV index for Greece, the clear sky factor on the island of Crete, the insolation spectrum in a single pixel, and finally, the total UV radiation.

activity, the team is also keen to directly contact relevant stakeholders across the political and business spectrum to maximise the potential utility of their system.

While it is impossible to fully predict the future benefits and opportunities created by the information that the NOA team now provides, it is clear that an improved and real-time understanding of the strength of solar radiation will be highly useful. This information will enable the solar industry to better plan photovoltaic, artificial photosynthetic or solar biofuel installations, which in turn will boost the relative contribution of these clean energies to national portfolios. In addition, the ability to monitor and even predict UV radiation will allow healthcare providers and other stakeholders to develop tools and products required to ameliorate this risk. In countries such as Australia, where UV exposure is a significant contributor to health outcomes, this knowledge could become an essential cornerstone of health planning.

One of the most exciting applications in this context is giving the general public the power and responsibility to monitor its own UV exposure, and as such encourage grassroots management of both over- and underexposure. Crucially, all of these potential applications are underpinned by the NOA group's efforts. The modelling system the researchers have developed has required expertise from Earth observation and environmental scientists to mathematicians and systems engineers. This highly skilled and multidisciplinary team has made a significant contribution to the appreciation of the fundamental relationship between the Sun, the atmosphere and the environment.

THE APPLICATION OF INFORMATION

One of the most exciting applications of solar radiation spectra, in addition to solar energy forecasting, is being able to provide real-time UV radiation alerts to the general public. In the not-too-distant future, app developers will be able to create mobile applications that pull data from the NOA solar energy applications website (www.solea.gr) and combine them with users' GPS information to provide real-time estimates of solar power generation as well as UV health alerts. Smartphone apps that help engineers decipher where best to install solar panels or let people know how high the level of UV radiation is in their area, can use these results.

Looking further ahead still, this project has important implications for a range of emerging technologies: "Exciting prospective technologies like artificial photosynthesis and cyanobacteria solar biofuel storage systems are highly sensitive to UV radiation," enthuses Taylor. These industries – perhaps even more so than the photovoltaics industry – will need a detailed and continuous analysis of solar radiation spectral patterns and trends.

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solar energy applications