Solar energy related EO data for Greece through the GEOSS portal

14th International Conference on Meteorology, Climatology and Atmospheric Physics (COMECAP 2018), 15-17 October 2018, Alexandroupolis, Greece

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Motivation

The continuous monitoring of the atmosphere and solar energy from space through Earth observation (EO)-based systems and relevant services is critical for the sustainable yield of renewable resources, as well as in human-health-related emerging technologies. In the framework of GEO initiatives and networking platforms (e.g. H2020 GEO-CRADLE), we exploited and produced added value solar energy related products and services with direct links to the GEOSS portal. The provided data are based on the synergy of Copernicus data and the Solar Energy Nowcasting SystEm (SENSE) pilot. To this direction, we introduce long-term (15 years) databases of solar power and energy in terms of global horizontal (GHI) and direct normal irradiance (DNI) and in high spatial resolution (3 km) for the region of Greece. These climatological outputs are complemented by an operational and real-time monitoring service of the solar energy potential in high temporal frequency (5-15 min). Simultaneously, we present agricultural-related databases of the photosynthetically active radiation (PAR), in support to the local decision makers and relevant public authorities. Therefore, such EO data will be able to assist various scientific communities dealing with atmospheric studies, crop production, efficient solar energy exploitation and control of the electricity balancing and distribution.

The SENSE pilot

During the GEO-CRADLE coordination and support action (http://geocradle.eu/en/), we introduced the SENSE pilot (http://beyond-eocenter.eu/index.php/web-services/solarhub) in order to coordinate the local and regional solar energy related EO capacities and research activities for the development of reliable, high resolution data in terms of climatological and real-time products and services. For the case of Greece, SENSE engraved strategy methods on how to integrate such a solar energy nowcasting system into a wider GEOSS driven system in Greece.

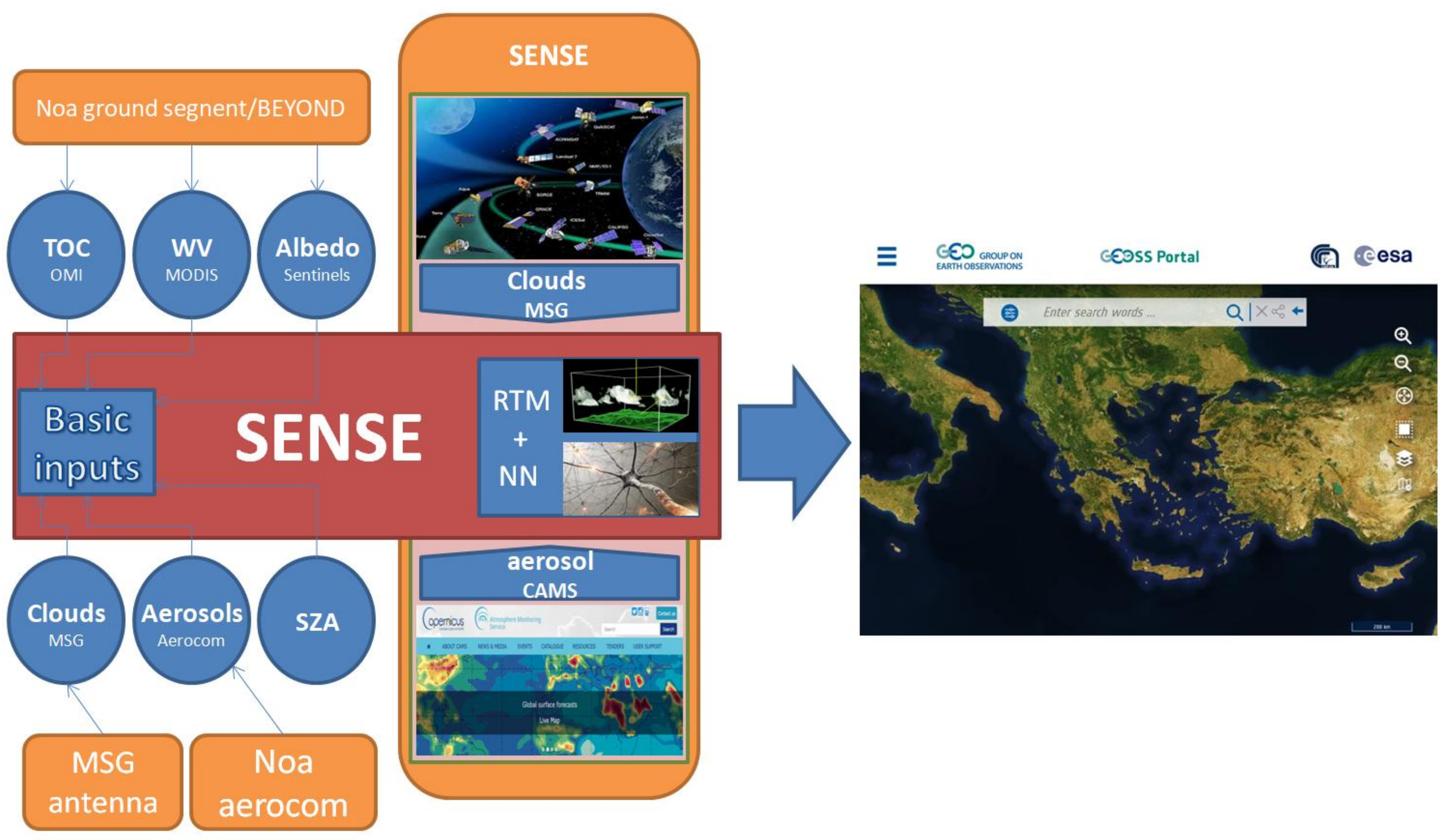


Figure 1: Flowchart illustration of SENSE pilot.

The climatological services are based on a 15-year climatology (1/1999 - 12/2013) from the solar radiation databases and products of the EUMETSAT's Satellite Application Facility on Climate Monitoring (CM SAF), taking into account the clouds and aerosols impact on DNI and GHI, while the spatial resolution is almost 3 km at nadir, maximizing the exploitative value of the solar energy technologies. The DNI apply to CSP while the components of the GHI (in terms of sums of direct and diffuse incoming irradiances at horizontal or inclined surfaces) apply to PV installations. The climatological radiation data have been downloaded from the EUMETSAT's (http://www.eumetsat.int/website/home/index.html) Satellite Application Facility on Climate Monitoring (http://www.cmsaf.eu/EN/Home/home_node.html) Surface Solar Radiation Data Set - Heliosat (SARAH) which is a satellite-based climatology of the solar surface irradiance and the surface direct normalized irradiance, derived from satellite observations of the MVIRI and SEVIRI instruments onboard the geostationary Meteosat satellites.

The real-time system SENSE is based on the synergy of radiative transfer model simulations, speed-up technologies (by using neural networks and multi-regression functions) and real-time atmospheric inputs from the Spinning Enhanced Visible and InfRared Imager onboard the Meteosat Second Generation satellite and the Copernicus Atmosphere Monitoring Service (Kosmopoulos et al., 2018). As a result, solar energy EO data were operationally produced in high spectral, spatial and temporal resolutions (1 nm, 0.05 x 0.05 degrees, 15 min).

The GEOSS portal

All the above methodologies were implemented and disseminated through the developed GEO-CRADLE's RDH (http://datahub.geocradle.eu/dataset/solar-atlas) with active interaction and direct links to GEOSS portal (http://www.geoportal.org/), while it uses inputs from the SENSE pilot and the EO-stakeholders datasets (e.g. Copernicus). The RDH is build on the Drupal-based Knowledge Archive Network (DKAN) which is an open data management platform and was created in order to be online, connected with GEOSS and multiple remote data sources, act as a gateway to the users, be efficient and user friendly. In order to connect the GEOSS to our RDH we used the GEO Discovery and Access Broker Application Programming Interfaces (DAB APIs), and in particular the OpenSearch API which in reality is plug and play. The result is a stable data service with full interoperability with GCI (GEOSS Common infrastructure) and GEO DAB APIs, as well as connection with data available through the SENSE pilot (Kosmopoulos et al., 2018b).

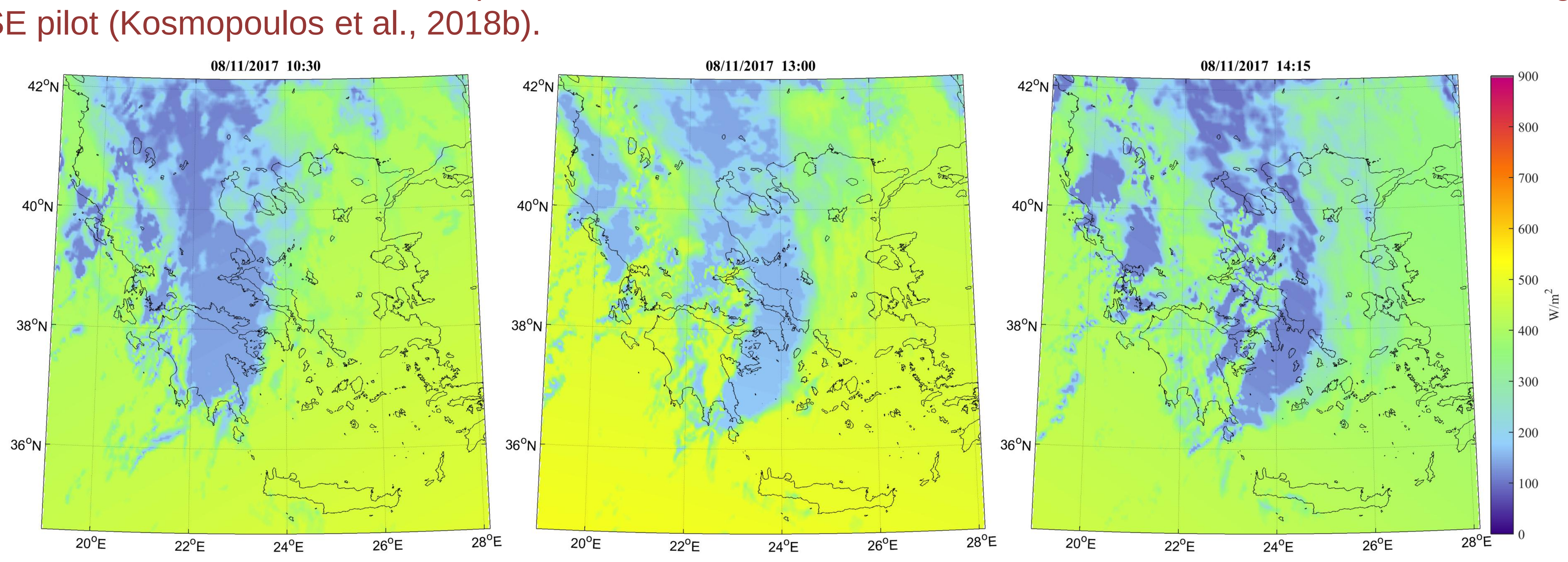


Figure 4: Time-step example maps of GHI in W/m² from the SENSE nowcasting service.

The application fields of such methodologies include the production planning support on large scale solar farm projects (PV and CSP) and the efficient control of the electricity balancing and distribution (in support to the TSOs and DSOs), by incorporating the produced energy of the solar farms into the electricity grid. At the same time, the surface solar radiation in different spectral regions highlight spectrally-weighted outputs like the UV-index, the Vitamin D efficiency and a number of agriculture and oceanographical related processes.

Validation of data

The reliability and accuracy of the climatological (EUMETSAT-based data) and the real-time (SENSE-based data) outputs has been verified against ground-based measurements (Muller et al., 2015; Kosmopoulos et al., 2018) from the Baseline Surface Radiation Network (BSRN). The evaluation of the performance was based on mean bias error (MBE), the root mean square error (RMSE) and their relative components (rMBE and rRMSE):

$$MBE = \bar{\varepsilon} = \frac{1}{N}\sum_{i=1}^{N}\varepsilon_i \qquad RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\varepsilon_i^2}$$

The estimation errors, $\varepsilon_i = x_e - x_o$, are calculated as the difference between the estimated values by the SARAH and the SENSE data (x_e) and the measured values (x_o) by BSRN, where N is the total number of data. MBE measures the overall bias and detects the model's overestimation (MBE>0) or underestimation (MBE<0), while RMSE quantifies the spread in the distribution of errors. The results showed a dependence on the quality and resolution of the atmospheric inputs to the models, while increasing the calculation speed decreases the model accuracy. Indicatively, the SENSE system revealed rRMSE values below 29 % under high energy potential conditions and MBE values below 30 W/m² under various geographical, atmospheric and altitudinal conditions (Kosmopoulos et al., 2018). The SENSE uncertainty ranges from -100 to 40 and -20 to 20 W/m², for the 15min and monthly mean GHI averages respectively, while for the EUMETSAT-based climatological data (post processed data using past data series) the rRMSE was found to range from 14.1 to 37.9 % for the 15 min averages (Thomas et al., 2016) and almost 5.5 to 12.1 W/m² for the mean monthly and daily errors, respectively, with additional uncertainties in terms of spatial representativeness and measurements quality of about ±12 W/m² (Muller et al., 2015).

Solar energy data & applications

The above solar energy related methodologies and data were transformed into EO-based SOLar Energy Applications (SOLEA; http://solea.gr/) and were submitted to GEOSS portal as open access services and databases. Through GEOSS portal, SOLEA aims to fulfil the Greek and regional needs for optimum solar energy exploitation and for active and effective integration of these technologies to the national sustainable development economies and strategies.

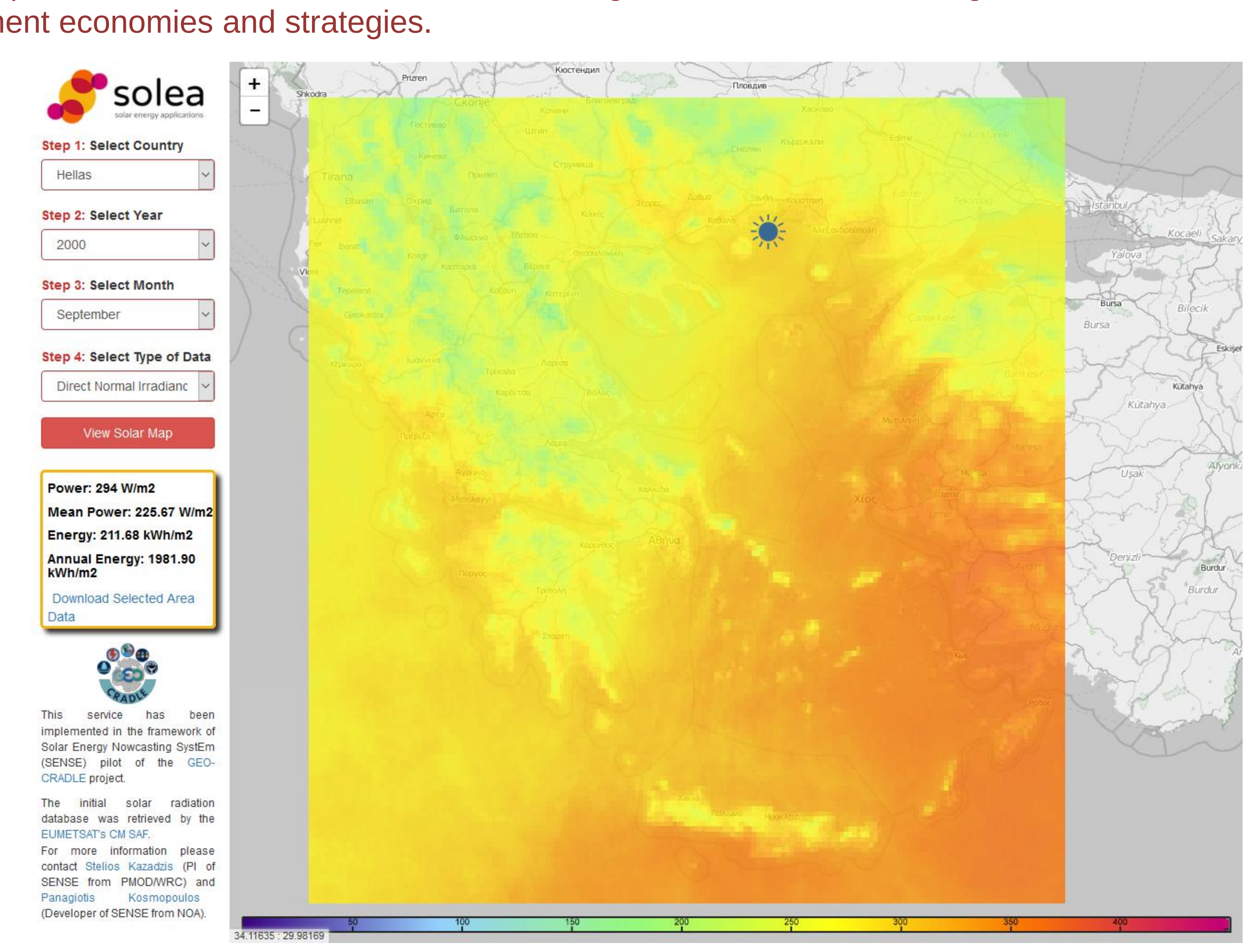
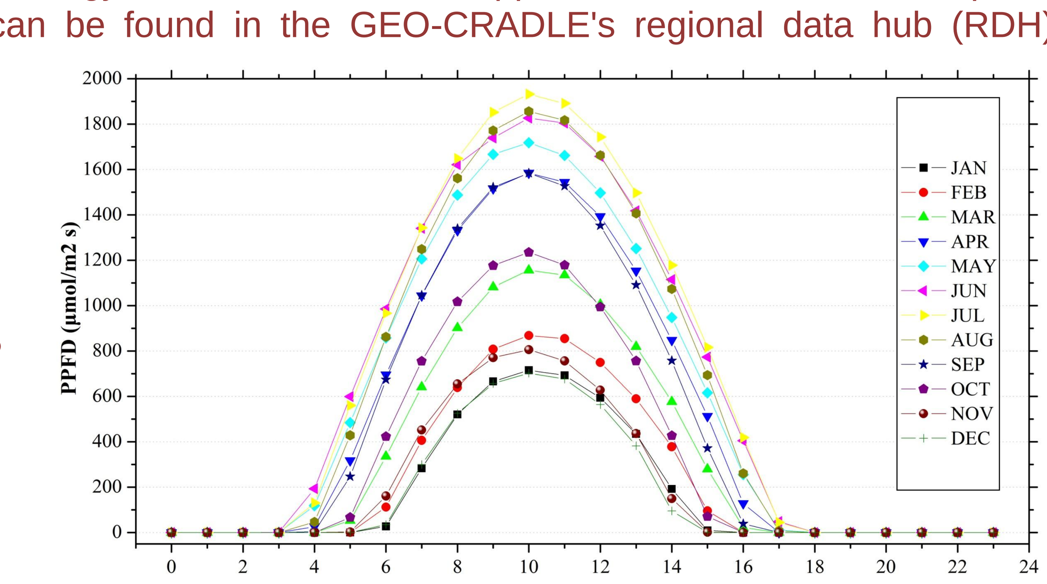


Figure 2: A screenshot of the dynamic application with background databases and on-the-fly calculations for solar power, energy and PAR (http://beyond-eocenter.eu/solarapp/).

The application in Figure 2 is a dynamic service with background climatological databases from Copernicus data for Greece, Cyprus and Egypt. In particular, the user is able to find for any specific location useful EO data of solar power and energy, in terms of W/m² and kWh/m² respectively, for the GHI and DNI. Simultaneously, the PAR is also available in terms of power (W/m²) and photosynthetic photon flux density (PPFD) in μmol/m² s. PAR was calculated by using the spectral GHI output from SENSE and was applied for various scientific purposes (Dimitropoulou et al., 2018). In Figure 3 the analytical climatological hourly mean PAR per month for Greece was depicted. Finally, Figure 4 presents time-step example maps from the SENSE pilot nowcasting service. Additional solar energy related EO data and apps can be found in GEOSS portal at http://www.geoportal.org/. An example can be found in the GEO-CRADLE's regional data hub (RDH) at http://datahub.geocradle.eu/solar/.

Figure 3: SENSE's analytical climatological hourly average PAR (in PPFD) per month for Greece.



References & acknowledgments

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This study has been implemented in the framework of the GEO-CRADLE project which has received funding from the EU's Horizon 2020 research and innovation programme under grant agreement No 690133.