Development of a Greek solar map based on solar model estimations

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Introduction

- Due to the climate change, the renewable energy sources are the most environmentally-friendly.
- The global energy market of solar power systems has been increasing in the recent decade.
- To calculate as exact power output from a solar system as possible, solar radiation data is needed.
- Solar radiation stations are still scarce worldwide due to their initial cost and maintenance.
- Therefore, solar radiation modelling comes into place.
- The *Meteorological Radiation Model* (MRM) is a broadband solar radiation deterministic code, now in version 5, developed at NOA; version 1 in the end of 80's.
- MRM gives global, diffuse and direct radiation components on horizontal surface.
- To run the code, hourly values of air temperature, relative humidity, barometric pressure and daily value of sunshine duration are required as input.

Data collection

3-hourly values of the required meteorological parameters from 39 stations (see map) of the *Hellenic National Meteorological Service* (HNMS) were collected for 1985-1999.

Missing values were substituted by linear interpolation.

MRM used above hourly values to estimate the solar radiation components at the 39 locations.

Methodology

During clear-sky conditions, I_g, I_b, I_d are the global, direct and diffuse components of solar radiation, so that:

$$I_g = I_b + I_d \quad (1)$$

$$I_b = I_{ex} \cdot cos\theta_z \cdot T_w \cdot T_r \cdot T_o \cdot T_{mg} \cdot T_a \quad (2)$$

where θ_z is the solar zenith angle, I_{ex} is the normal incidence extra-terrestrial solar radiation on the n_i-th day of the year, T_w is the solar radiation transmittance in the atmosphere for the water-vapour absorption, T_{mg} for the absorption of the uniformly-mixed gases $(CO_2, CO, N_2O, CH_4\ and\ O_2)$, T_o *for the absorption of* O_3, and T_r, T_a for the scattering and absorption by molecules and aerosols in the atmosphere, *respectively*.

Methodology (continued)

Also, $I_d = I_{ds} + I_{dm}$ (3)

$$I_{ds} = I_{ex} \cdot cos\theta_z \cdot T_w \cdot T_{mg} \cdot T_o \cdot T_{aa} \cdot 0.5 \cdot (1 - T_{as} \cdot T_r) \quad (4)$$

$$I_{dm} = I_{ex} \cdot (I_b + Id_s)[\frac{\rho_g \rho_s}{1 - \rho_g \rho_s}] \quad (5)$$

where $T_{\alpha\alpha}$ and $T_{\alpha s}$ *are* the aerosol transmittances due to absorption and scattering, respectively; ρ_g and ρ_s is the ground and sky albedo, respectively.

<u>During cloudy-sky conditions</u>, I_{gc}, I_{bc}, I_{dc} are the global, direct and diffuse components of solar radiation, so that:

$I_{gc} = I_{bc} + I_{dc}$ (6)

Methodology (continued)

$I_{bc} = I_b \, . \, T_c$ (7)

T_c is the cloud transmittance.

Also, $I_{dc} = I_{dcs} + I_{dcm}$ (8)

$$I_{dcs} = I_{ds} \cdot T_c + k^* \cdot (1 - T_c) \cdot (I_b + I_{ds}) \quad (9)$$

$$I_{dcm} = (I_{bc} + I_{dcs}) \frac{\rho_g \cdot \rho_{cs}}{1 - \rho_g \cdot \rho_{cs}} \quad (10)$$

where k^* is an empirical coefficient, ρ_g and ρ_{cs} is the ground and cloudy-sky albedo, respectively.

Methodology (continued)

A *Typical Meteorological Year* (TMY) was prepared from the 15-year available data of air temperature, relative humidity, barometric pressure, sunshine duration and solar radiation.

The *Sandia* method was used based on the *Filnkestein-Schafer* statistical methodology.

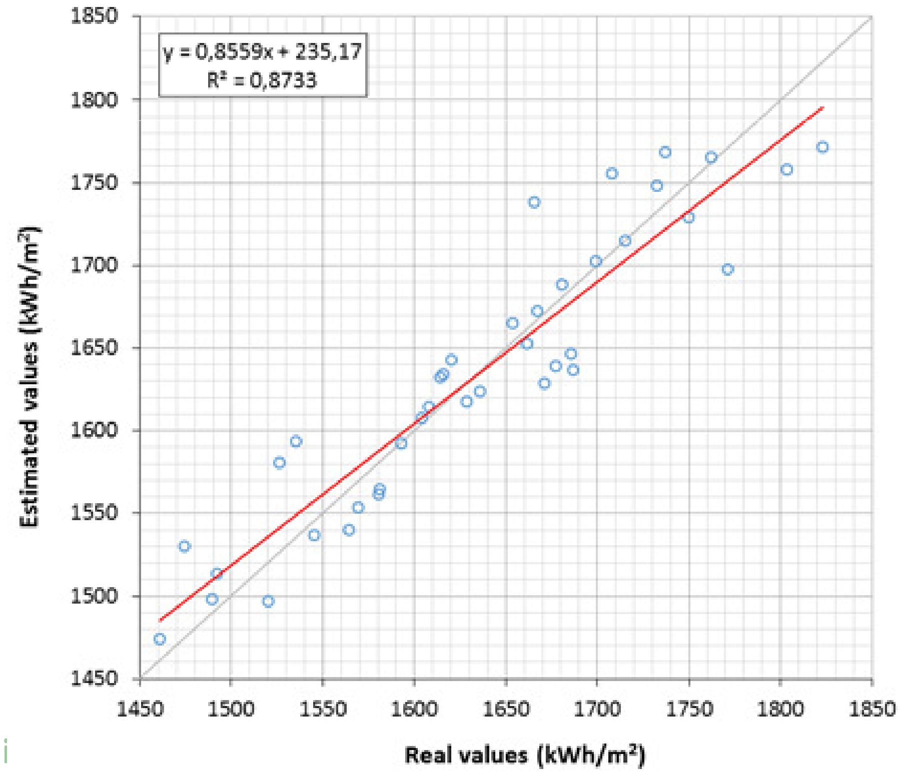
Having a data base of TMYs at the 39 locations in Greece, the *Empirical Bayesian Kriging* (EBK) methodology was applied to estimate solar radiation with spatial interpolation all over the country.

Results

The graph shows the comparison between the annual solar irradiation estimated by the TMY data base (real values) and the EBK methodology (estimated values) at the 39 locations in Greece.

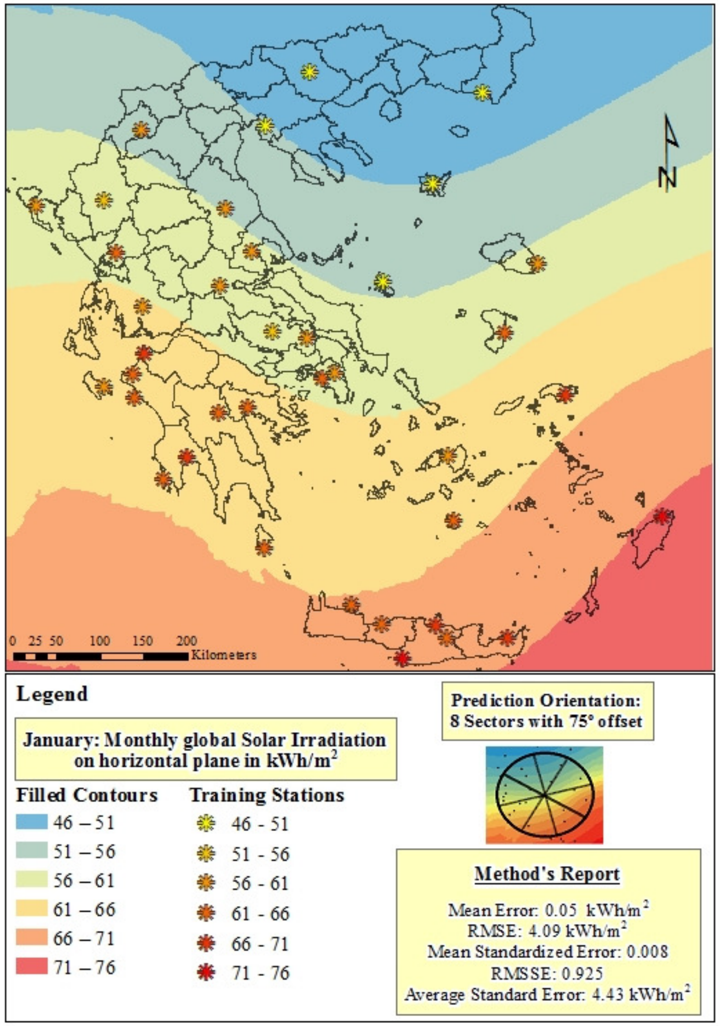
The red line is a linear best fit with $R^2 = 0.8733$.

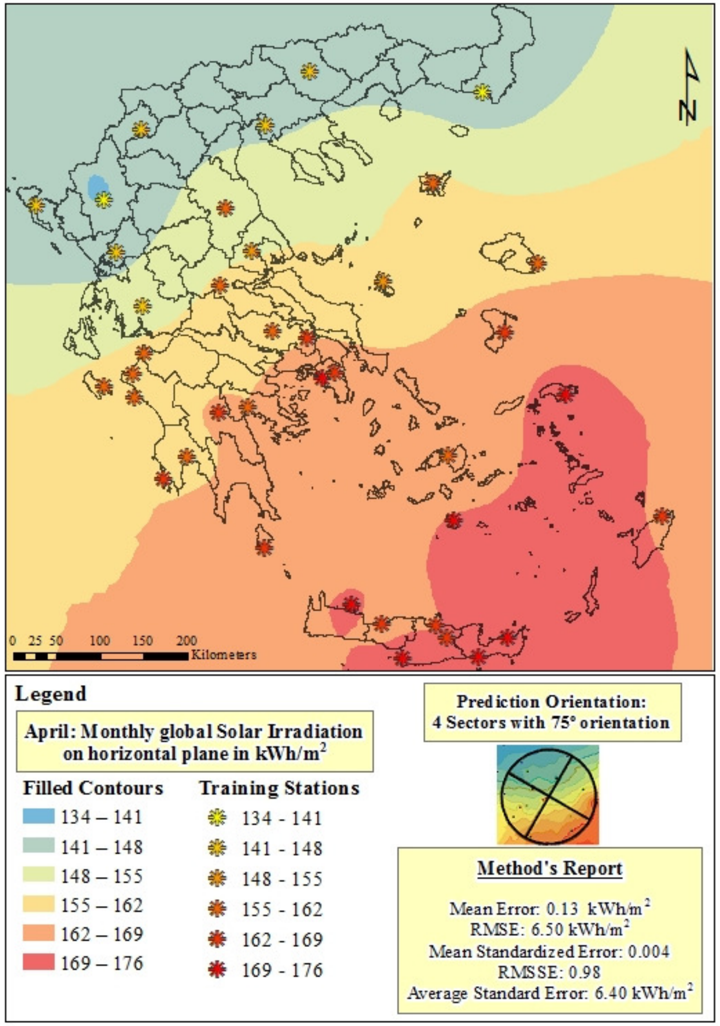
The 1:1 line is also shown.



Results (continued)

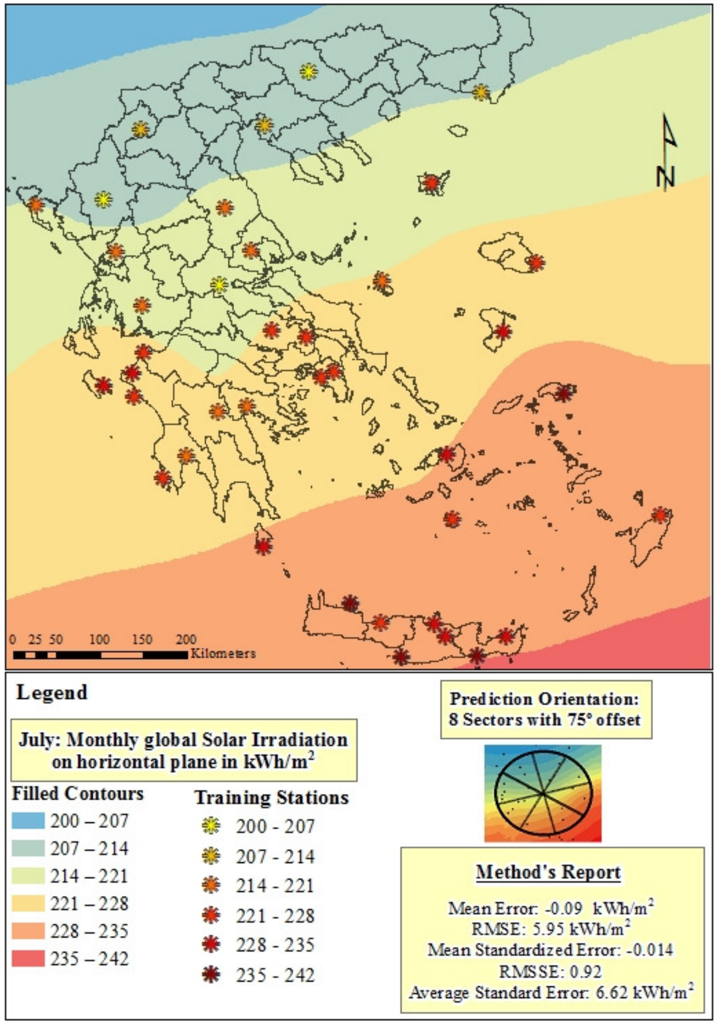
By applying the EBK methodology, maps with the monthly received global solar irradiations were generated for Greece. Here Jan and Apr.

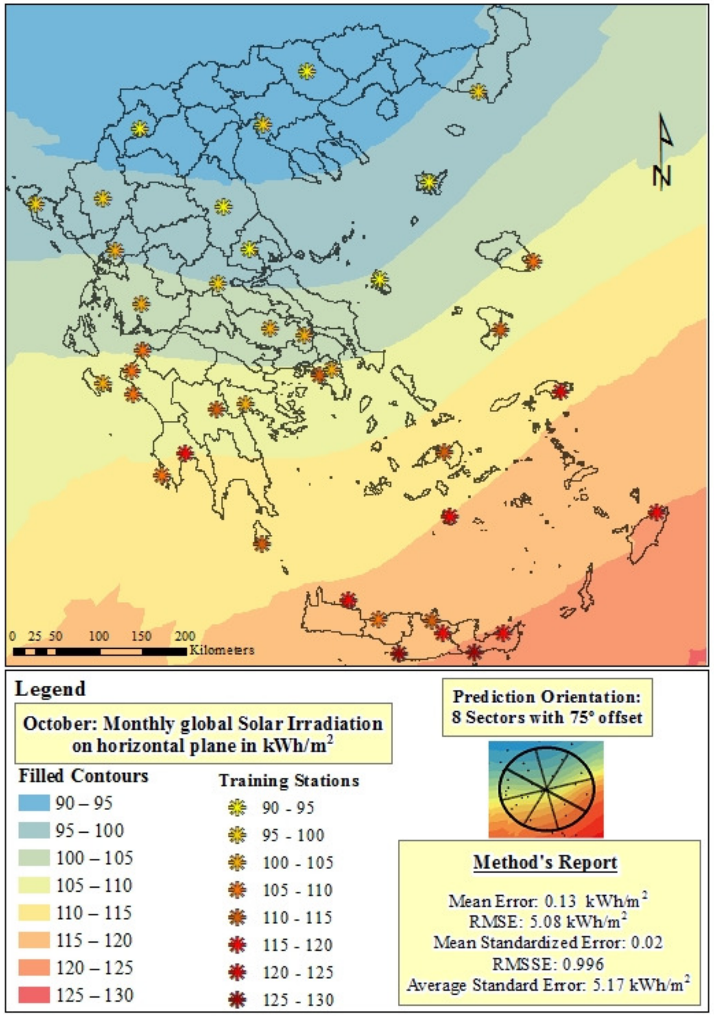




Results (continued)

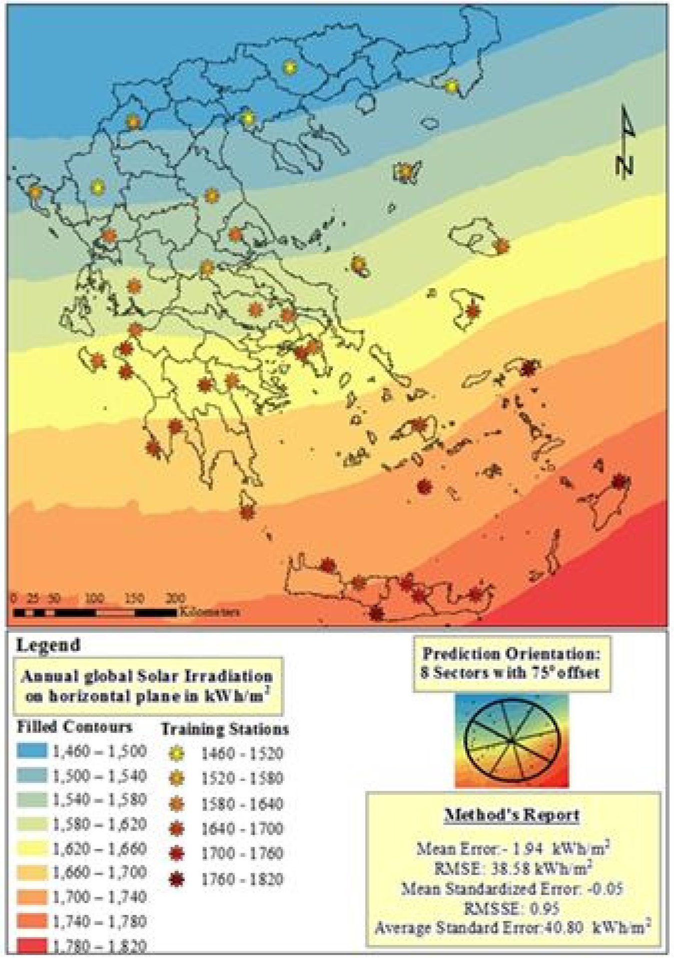
By applying the EBK methodology, maps with the monthly received global solar irradiations were generated for Greece. Here Jul and Oct.

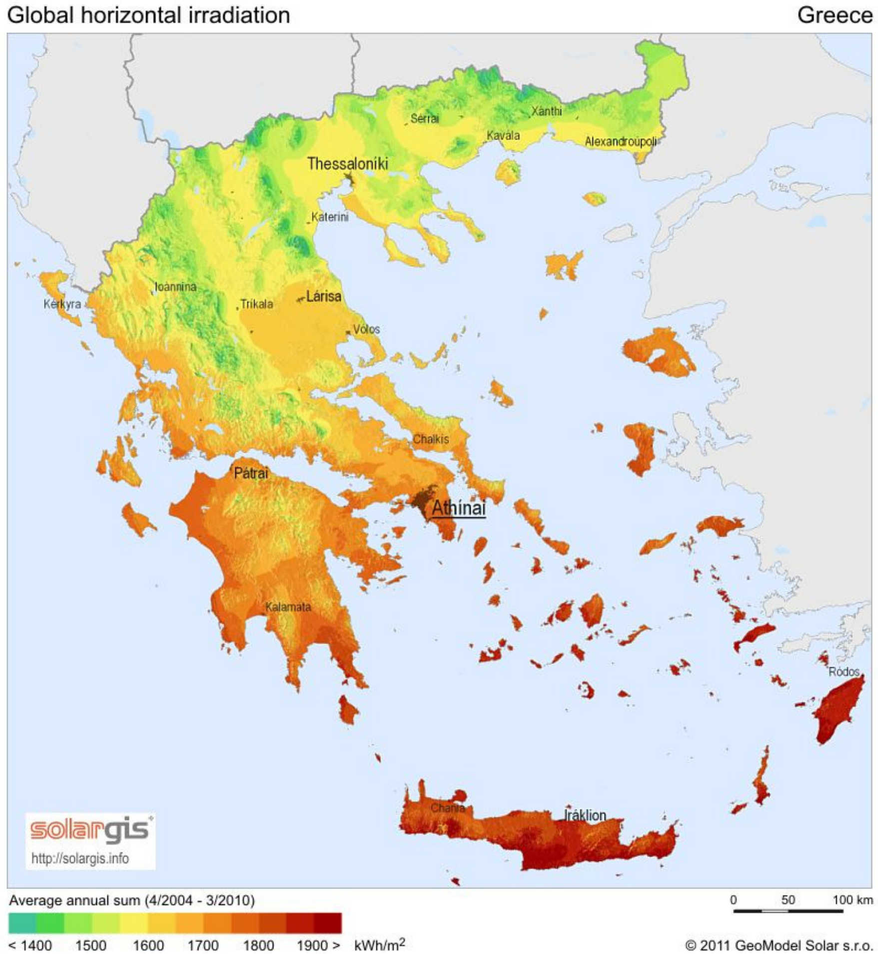




Results (continued)

By applying the EBK methodology, maps with the annually received Ig was generated for Greece. Compare with SolarGIS-derived annual map.





Conclusions

- Up-to-date and accurate solar radiation information plays a key role in energy-resource assessment of solar power systems.
- The low density and limited number of solar radiation measuring stations makes the use of solar radiation models imperative.
- The present work presented an integrated procedure for the development of an updated Greek solar map based on solar radiation data estimations by the MRM at 39 meteorological stations belonging to the HNMS network.
- The solar energy map so created provides updated solar resource information at any location in Greece.

MRM is a universal freeware code (contact H. Kambezidis harry@noa.gr). MRM can be applied in any region of the world for estimating solar energy. Now MRM version 6 is in preparation.