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Implementation of a regional parametric model for potential evapotranspiration assessment

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Abstract

Potential evapotranspiration (PET) is key input in water resources, agricultural and environmental modelling. For many decades, several approaches have been proposed for the consistent estimation of PET at several time scales of interest. The most recognized is the Penman-Monteith formula, which is yet difficult to apply, since it requires simultaneous measurements of four meteorological variables (temperature, sunshine duration, humidity, wind velocity). For this reason, simplified approaches prove very useful in absence of a complete data set and are strongly preferred.

In the present study, we implement a recent parametric formula to model PET in the Arta plain, located in the Region of Epirus - Greece, which is based on a simplified formulation of the original Penman-Monteith expression and requires only mean hourly, daily or monthly temperature data, depending on the desired time step. The methodology is generic, yet parsimonious in terms of the input data, with its parameters adjusted through calibration, to the available PET data.

A spatial analysis concerning the regionalization of the parameters and PET estimates of the proposed methodology by implementing interpolation techniques is performed.

The results are very satisfactory, illustrating that the proposed framework is efficient and constitutes a reliable alternative in the assessment of potential evapotranspiration field.

The parametric model

- In the Penman-Monteith formula (Monteith 1965, Allen *et al.* 1989), the numerator is the sum of a term related to net solar radiation, R_n, and a term related to the rest of meteorological variables, while the denominator is function of temperature, T_a, i.e.:

$$E = \frac{1}{\lambda \rho} \frac{R_n + \gamma \lambda F(u) D}{1 + \gamma' / \Delta}$$

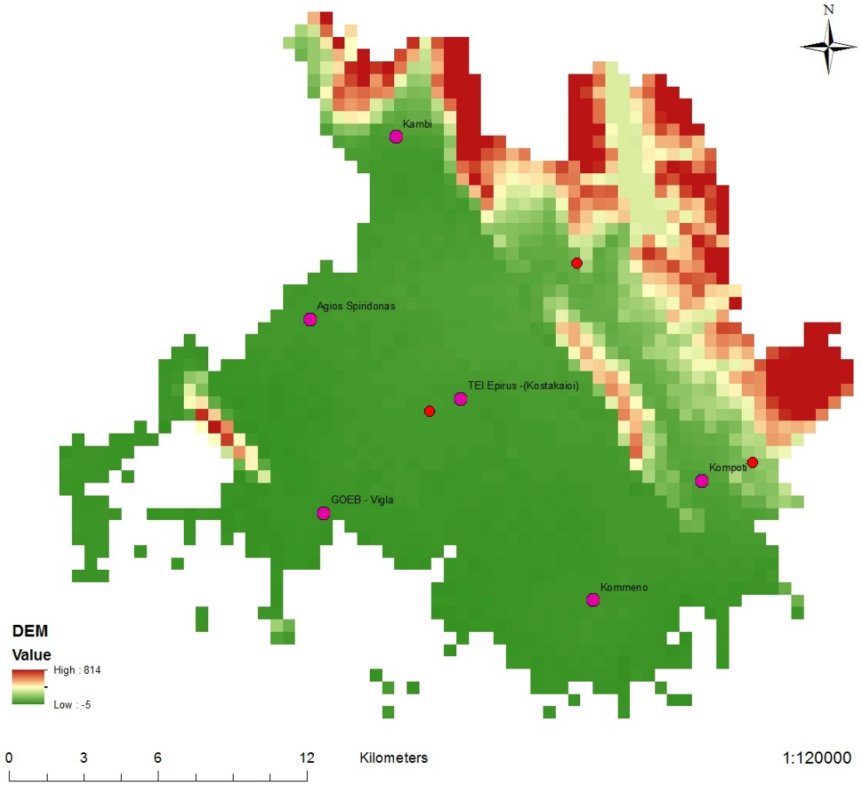
- In the parametric simplification of the Penman-Monteith formula (Koutsoyiannis and Xanthopoulos 1999, Tegos *et al*. 2009, Tegos *et al*. 2013, Tegos *et al*. 2015, Tegos *et al*. 2015) , the numerator is approximated by a linear function of extraterrestrial solar radiation, R_a, while the denominator is approximated by a linear descending function of temperature, i.e.:

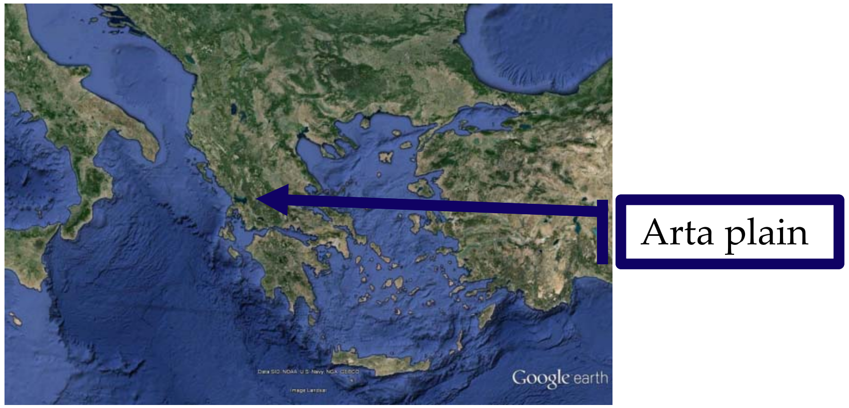
$$E = \frac{a R_a + b}{1 - c T_a}$$

- Physical interpretation of model parameters, a (kg/kJ), b (kg/m^2) and c (°C^{-1}):
  - Dimensionless term $a / \lambda \rho$ represents the average percentage of the energy provided by the sun (in terms of R_a) and, after reaching the Earth's terrain, is transformed to latent heat, thus driving the evapotranspiration process.
  - Parameter b lumps the missing information associated with aerodynamic processes, driven by the wind and the vapour deficit in the atmosphere.
  - Term $1 - c T_a$ approximates $1 + \gamma'/\Delta$; γ' is function of surface and aerodynamic resistance and Δ is the slope vapour pressure curve, which is function of T_a.

Case study in the Arta Plain

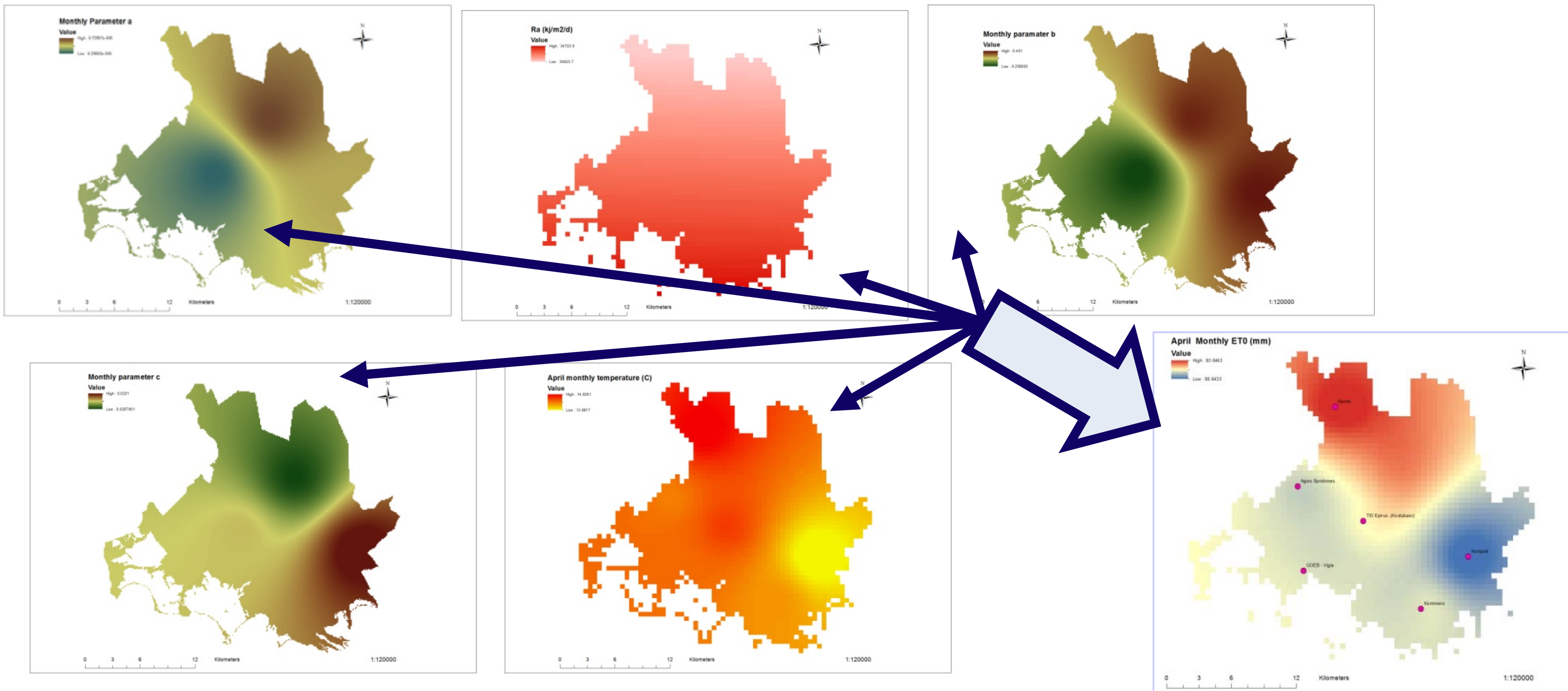
- Arta plain is placed in Epirus, Western Greece and contains several agricultural cultivations
- Use of historical data from 3 meteorological stations for daily and monthly PET estimation using the parametric formula
- Fit of the parameters *a*, *b*, *c* for both time scales (daily and monthly)
- High efficiency (CE) for the parametric model in all time scales and for all the points of interest.
- Apply the method to acquire daily and monthly PET maps based on measurements from newly installed meteorological stations network for the current year (2015)





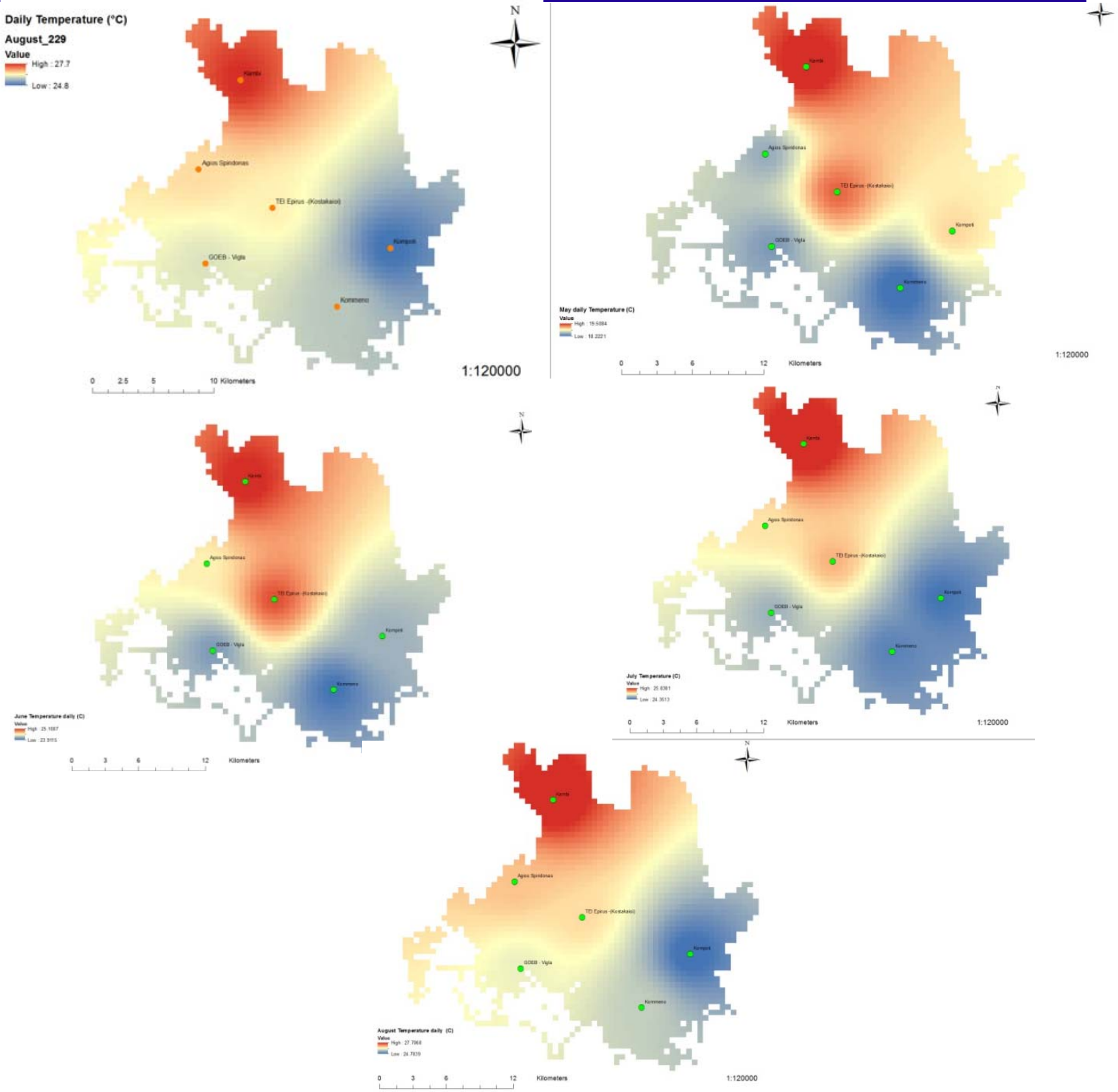
Calibration strategy and G.I.S technique

- Calibration of the parametric formula using historical data from 3 stations and regionalization of the parameters throughout the Arta plain
- Regionalization of daily and monthly temperatures from 6 new stations located in the Arta plain, using I.D.W. method (Tegos et al. 2015)
- Appropriate coding of Extraterrestrial Radiation, R_a, and creation of the corresponding raster files
- Development of an integrated and automated framework for the spatial estimation of PET in daily and monthly time scales.



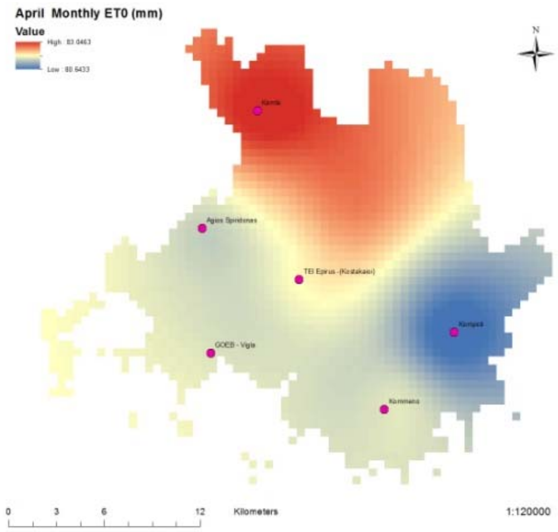
Spatial variability of temperature

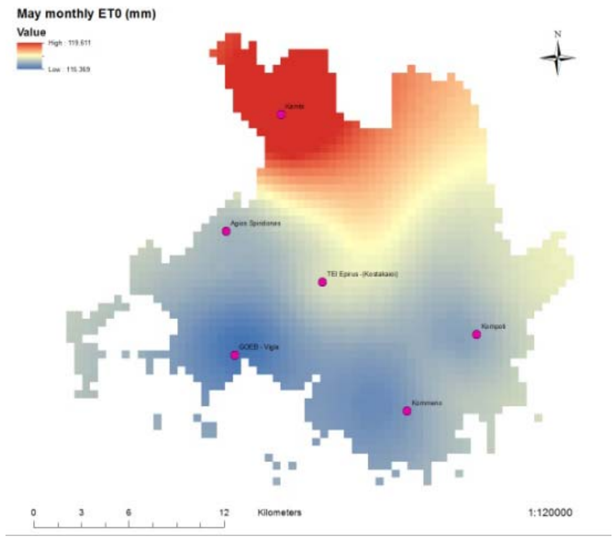
- Daily and monthly data from 6 meteorological stations distributed in the plain.
- Implementation of the IDW framework and extrapolation of the temperature in the whole plain.
- Production of 10 raster maps, i.e. 5 for mean monthly temperature and 5 for mean daily of 15th of every month.
- Gradient of the temperature from N-NW to South.

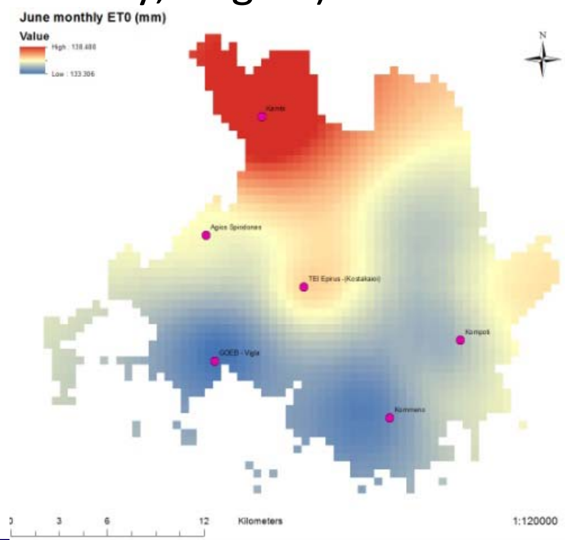


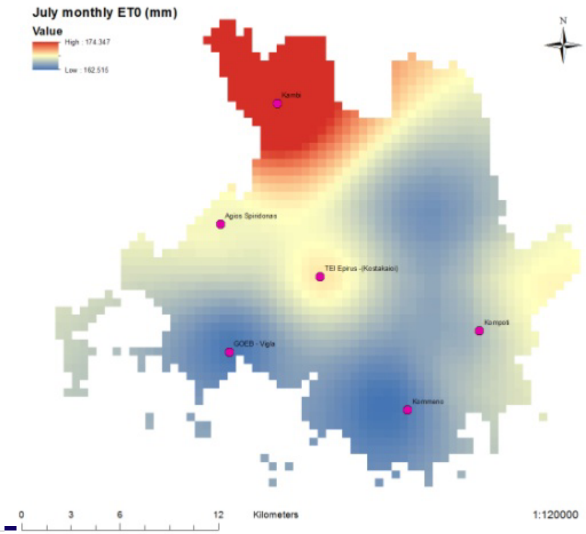
Spatial variability of monthly PET

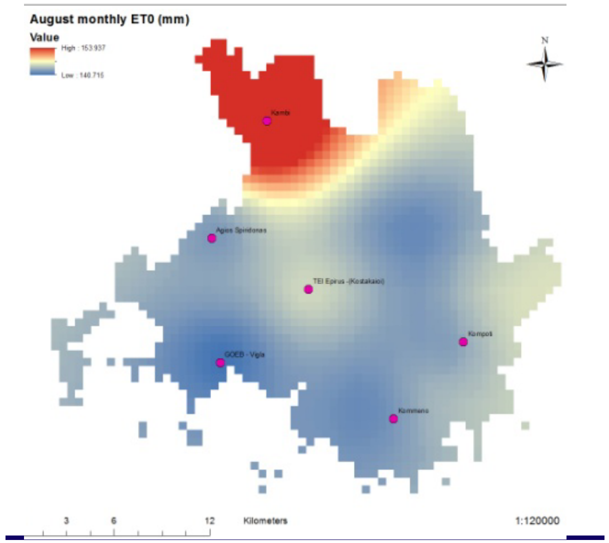
- Gradient of the monthly PET from North to South direction (limited in April).
- Mean monthly PET ranges between 80.6 mm (April) and 174 mm (July)
- Insignificant spatial variation in spring months (April, May) and significant in summer months (June, July, August)





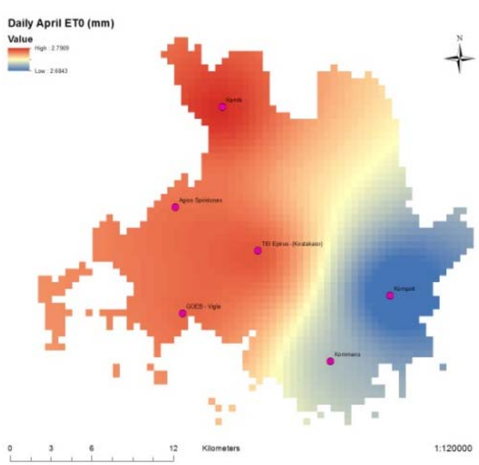


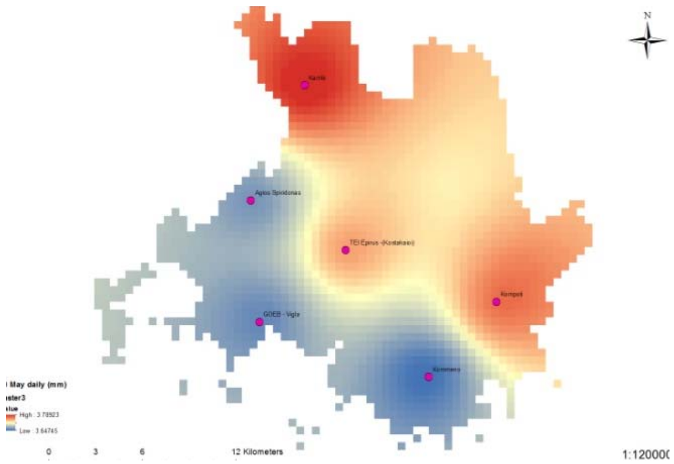


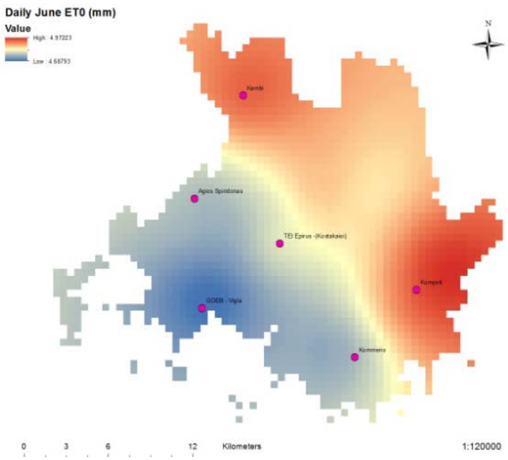


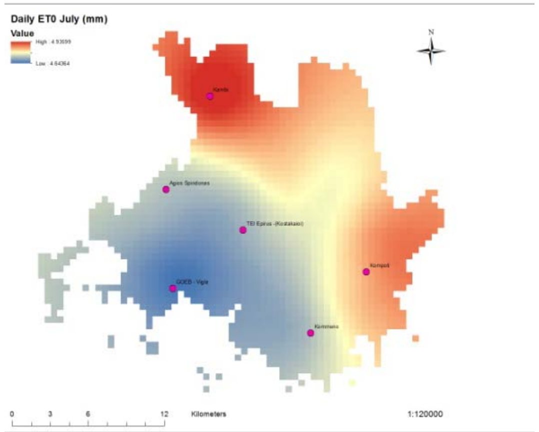
Spatial variability of daily PET

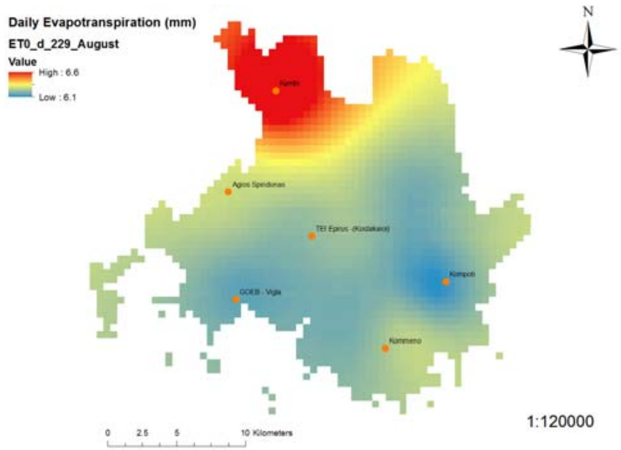
- High daily values in the North plain for every month.
- Low values in the South near shore area.
- Mean daily PET ranges from 2 mm (April) to 4.9 mm (July).
- Significant spatial variation in daily scale and for all months.
- Non standard spatial direction for every month in the study period.











Conclusions

- The parametric model can be considered as a simplification of the Penman-Monteith formula, in an attempt to compromise parsimony, in terms of model structure and data requirements, and physical consistency.
- Near a decade of the first application in Greece, the method has similar results with Penman-Monteith including easy-fast calibration in the local climatic conditions.
- A new holistic and automated G.I.S approach for the reliable estimations of PET in irrigated area with high water needs.
- The proposed framework will be useful for the spatial consistency of PET and especially in the irrigation water conservation and in the reliable short term PET forecast.

References

- Allen, R. G., Jensen, M. E., Wright, J. L., & Burman, R. D. (1989). Operational estimates of reference evapotranspiration. *Agronomy journal*, *81*(4), 650-662.
- Koutsoyiannis, D., and Th. Xanthopoulos, *Engineering Hydrology*, National Technical University of Athens, 1999.
- Monteith, J. L. "Evaporation and environment." *Symp. Soc. Exp. Biol*. Vol. 19. No. 205-23. 1965.
- Tegos, A., N. Mamassis, and D. Koutsoyiannis. "Estimation of potential evapotranspiration with minimal data dependence." *EGU General Assembly Conference Abstracts*. Vol. 11. 2009.
- Tegos, A., A. Efstratiadis, and D. Koutsoyiannis, A parametric model for potential evapotranspiration estimation based on a simplified formulation of the Penman-Monteith equation, *Evapotranspiration - An Overview*, edited by S. Alexandris, 143–165, InTech, 2013.
- Tegos, Aristoteles, Andreas Efstratiadis, Nikolaos Malamos, Nikolaos Mamassis, and Demetris Koutsoyiannis. "Evaluation of a parametric approach for estimating potential evapotranspiration across different climates." Agriculture and Agricultural Science Procedia 4 (2015): 2-9.
- Tegos, A., N. Malamos, and D. Koutsoyiannis. "A parsimonious regional parametric evapotranspiration model based on a simplification of the Penman–Monteith formula." Journal of Hydrology 524 (2015): 708-717.