ELSEVIER

Europ. J. Agronomy 18 (2003) 363–367

European Journal of Agronomy

www.elsevier.com/locate/eja

Short communication

RadEst3.00: software to estimate daily radiation data from commonly available meteorological variables

Marcello Donatelli *, Gianni Bellocchi, Fioravante Fontana

Research Institute for Industrial Crops (ISCI), via di Corticella, 133 40128 Bologna, Italy

Abstract

RadEst3.00 estimates and evaluates daily global solar radiation values at given latitudes. Radiation is calculated as the product of the atmospheric transmissivity of radiation times the radiation outside the earth atmosphere. Four models estimate the atmospheric transmissivity, based on the daily temperature range. Model parameters can be fitted over one or more years of data by iterative procedures. Graphical and statistical evaluations of the estimates are presented. Reports of the analysis can be exported in a variety of formats. Penman–Monteith or Priestley–Taylor reference evapotranspiration is estimated, using both measured and estimated radiation. Utilities are provided to process numerous files, or correct possible constant biases in the data. Samples of data for tropical and temperate sites are supplied with the software.
© 2002 Elsevier Science B.V. All rights reserved.

Keywords: Global radiation models; Solar radiation; Transmissivity; Air temperature

1. Introduction

Solar radiation is an important weather variable for several agro-environmental studies. The number of ground-level weather stations recording daily radiation is very small compared to the number recording air temperature and precipitation (McVicar and Jupp, 1999; Thornton and Running, 1999). This can be a severe limitation for agricultural model applications. The need for solar radiation estimates at sites where it is not measured has grown in the past years, as the spatial scope of research into land-surface processes has expanded from local, to regional, continental, and global scale (e.g. Bechini et al., 2000). Solar radiation estimates from satellite images (e.g. Diak et al., 1996; Stewart et al., 1999) require resources not always available, and still appear of limited utility in the construction of historical databases.

Bristow and Campbell (1984) demonstrated that a relationship exists between radiation transmissivity through the atmosphere and the diurnal range in near-surface air temperature. The Bristow–Campbell model has been used in numerous studies, and improvements have been developed over the last years. In the models Donatelli–Marletto (Donatelli and Marletto, 1994) and

* Corresponding author. Tel.: +39-051-6316843; fax: +39-051-374857

E-mail addresses: m.donatelli@isci.it (M. Donatelli), g.bellocchi@isci.it (G. Bellocchi), f.fontana@isci.it (F. Fontana).

1161-0301/02/$ - see front matter © 2002 Elsevier Science B.V. All rights reserved.
PII: S1161-0301(02)00130-2

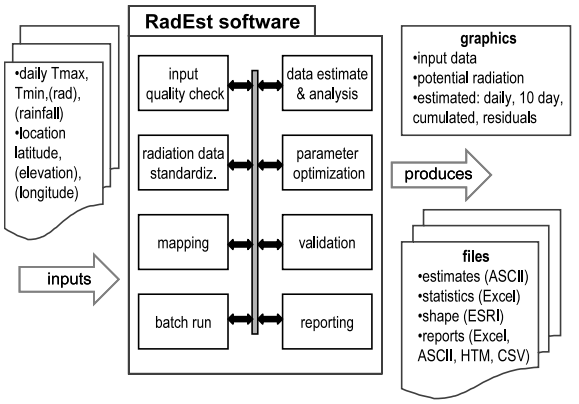

Fig. 1. Diagram representing the software RadEst3.00.

Campbell–Donatelli (Donatelli and Campbell, 1998) a correction factor accounting for seasonality effects occurring in mid-latitude areas was introduced. The Campbell–Donatelli method was implemented in the weather generators MarkSim (Jones and Thornton, 2000) and ClimGen (Stöckle et al., 2001). More recently, a further improvement was proposed (Donatelli and Bellocchi, 2001), better accounting for seasonality at a wide variety of sites.

This paper describes a software tool that allows the user to estimate daily global solar radiation data from air temperature, and produce output that can be used by a wide range of crop models and other analytical tools.

2. Software description

RadEst3.00 is a MS WINDOWS (98/NT/2000/XP) program that allows performing daily estimates of global solar radiation at a given location by three basic models, and to evaluate the results by statistical and graphical tools. The procedures available in RadEst3.00 and the inputs/outputs are summarized in Fig. 1. A user-friendly interface allows users to easily manipulate input files, calibrate model parameters, execute single and batch run simulations, calculate potential evapotranspiration, select out of different outputs, and produce reports, which can be exported into a variety of formats. The program reads daily weather data from space separated ASCII files. A utility allows standardizing data affected by a constant bias. If more than 1 year of weather data

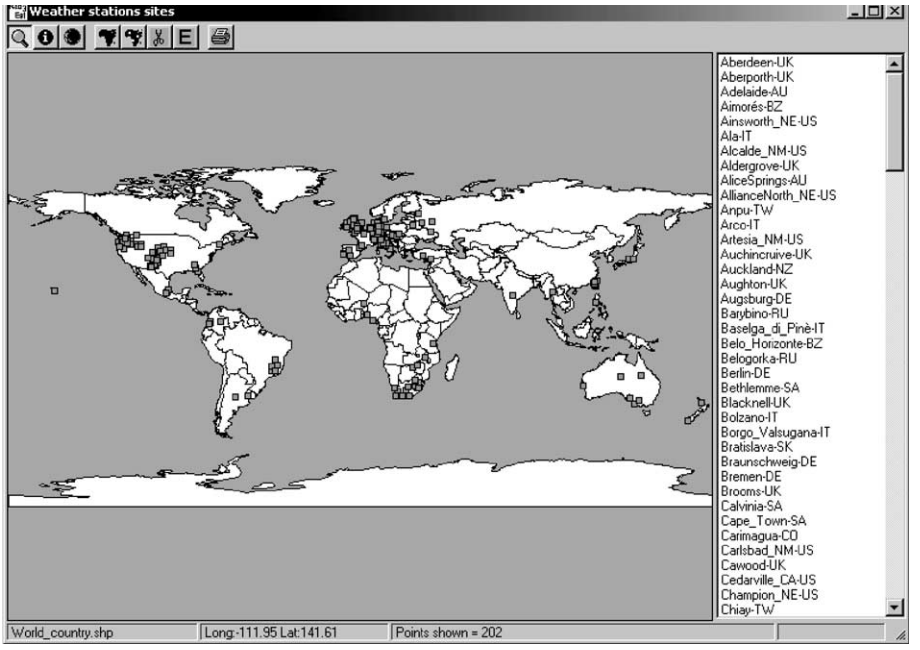

Fig. 2. Global distribution of the location data sets.

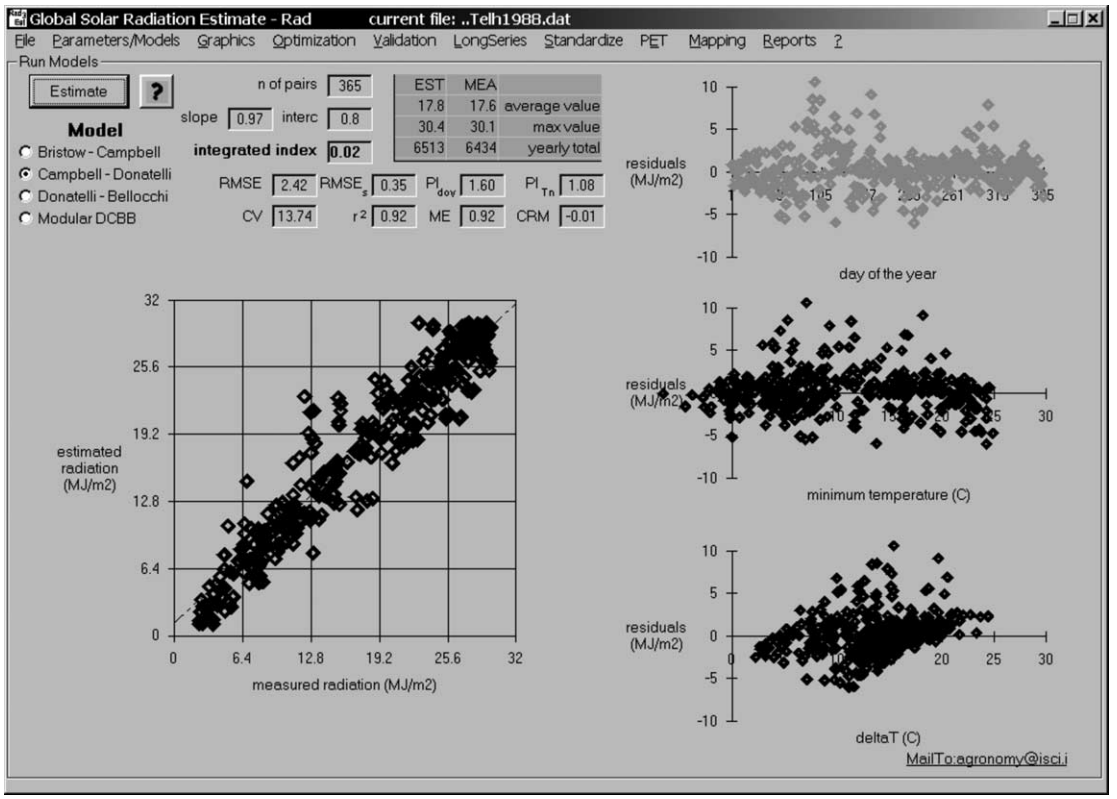

Fig. 3. Screen of radiation estimate by the model Campbell–Donatelli for Tel Hadya (Syria) in 1988.

are available, graphical long-term evaluation of the inputs can be performed.

Geo-referenced weather stations can be shown overlaying on a user chosen map, by loading weather stations from the RadEst database and creating an ESRI (http://www.esri.com) shape file. A mapping of the sites from the calibration data set of 200 stations shows the sites for which parameters were estimated by each model (Fig. 2).

2.1. Summary of analysis capabilities

RadEst3.00 implements three radiation models: Bristow–Campbell, Campbell–Donatelli, and Donatelli–Bellocchi. A modular model is also available, which allows including/excluding different components from the three models implemented. If radiation data are available, the program allows parameters of each model to be iteratively optimized for one or more years according to different cost functions. A location file stores and archives location-specific information (i.e. latitude, longitude, elevation, clear sky transmissivity coefficient), as well as model parameters for each of the models available. When radiation is estimated, statistical indices are calculated and shown. Graphical tools help assessing the estimated results. As an example, the estimates of daily radiation for Tel Hadya (Syria) in 1988, by using the model Campbell–Donatelli, are presented in Fig. 3. Fig. 4 reports the estimates of daily radiation for the same site in the years 1987–1991. The estimated radiation values can be either saved into ASCII files or exported into MS Excel files, that can be used for further analysis.

Potential evapotranspiration is estimated with either the Penman–Monteith (Monteith, 1965; Allen et al., 1998) or the Priestley–Taylor (Priestley and Taylor, 1972; Steiner et al., 1991) methods, using both measured and estimated radiation data.

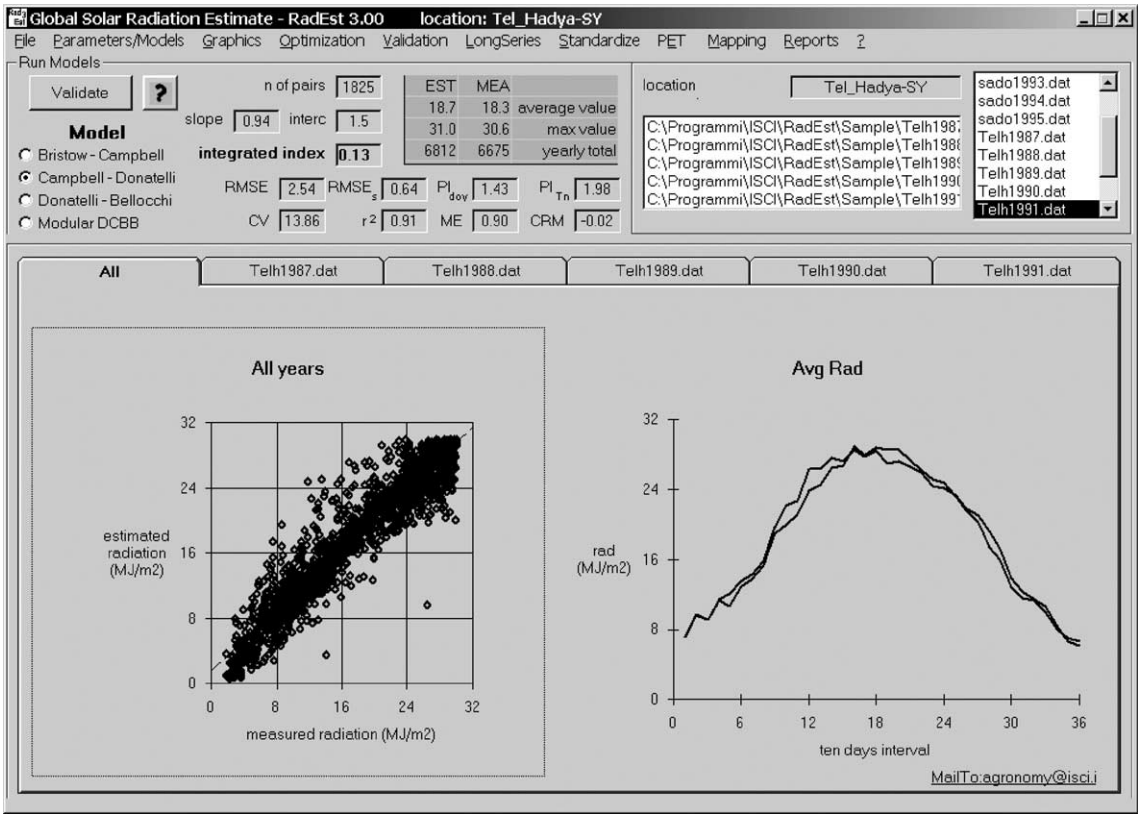

Fig. 4. Screen of radiation estimate by the model Campbell–Donatelli for Tel Hadya (Syria) in 1987–1991.

2.2. Availability and feed-back

RadEst3.00 is available free of charge for non commercial purposes. The installation package is available for downloading at: http://www.isci.it/tools. The program is fully documented in the users manual, which gives detailed description of both the techniques being implemented and the scientific background. The manual is provided with the software package and is available both on-line from the RadEst interface, and as a standalone help. Comments about RadEst may be sent to agronomy@isci.it.

Acknowledgements

The authors gratefully acknowledge the numerous individuals and institutions which contributed making available data, and providing a feed-back for model improvement. The list of contributors is in the acknowledgements section of the help file.

References

Allen, R.G., Pereira, L.S., Raes, D., Smith, M, 1998. Crop evapotranspiration: guidelines for computing crop water requirements. Irr. & Drain. Paper 56. UN-FAO, Rome, Italy.

Bechini, L., Ducco, G., Donatelli, M., Stein, A., 2000. Modelling, interpolation and stochastic simulation in space and time of global solar radiation. Agric. Ecosyst. Environ. 81, 29–42.

Bristow, K.L., Campbell, G.S., 1984. On the relationship between incoming solar radiation and daily maximum and minimum temperature. Agric. For. Meteorol. 31, 159–166.

Diak, G.R., Bland, W.L., Mecikalski, J., 1996. A note on first estimates of surface insolation from GOES-8 visible satellite data. Agric. For. Meteorol. 82, 219–226.

Donatelli, M., Bellocchi, G., 2001. Estimate of daily global solar radiation: new developments in the software RadEst3.00. In: Proceedings of the Second International Symposium Modelling Cropping Systems, 16–18 July. Florence, Italy, pp. 213–214.

Donatelli, M., Campbell, G.S., 1998. A simple model to estimate global solar radiation. In: Proceedings of the Fifth Congress of the European Society for Agronomy. Nitra, Slovakia, II, pp. 133–134.

Donatelli, M., Marletto, V., 1994. Estimating surface solar radiation by means of air temperature. In: Proceedings of the third European Society for Agronomy Congress. Padova, Italy, pp. 352–353.

Jones, P.G., Thornton, P.K., 2000. MarkSim: software to generate daily weather data for Latin America and Africa. Agron. J. 92, 445–453.

McVicar, T.R., Jupp, D.L.B., 1999. Estimating one-time-of-day meteorological data from standard daily data as inputs to thermal remote sensing based energy balance models. Agric. For. Meteorol. 96, 219–238.

Monteith, J., 1965. Climate and the efficiency of crop production in Britain. Philos. Tans. R. Soc. Lond. 281, 277–329.

Priestley, C.H.B., Taylor, R.J., 1972. On the assessment of surface heat flux and evaporation using large-scale parameters. Mon. Weat. Rev. 100, 81–82.

Steiner, J.L., Howell, T.A., Schneider, A.D., 1991. Lysimetric evaluation of daily potential evapotranspiration models for grain sorghum. Agron. J. 83, 240–247.

Stewart, J.B., Watts, C.J., Rodriguez, J.C., De Bruin, H.A.R., van den Berg, A.R., Garatuza-Payán, J., 1999. Use of satellite data to estimate radiation and evaporation for Northwest Mexico. Agric. Wat. Manage. 38, 181–193.

Stöckle, C.O., Nelson, R.L., Donatelli, M., Castellvì, F., 2001. ClimGen: a flexible weather generation pogram. In: Proceedings of the Second International Symposium Modelling Cropping Systems, 16–18 July. Florence, Italy, pp. 229–230.

Thornton, P.E., Running, S.W., 1999. An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation. Agric. For. Meteorol. 93, 211–228.