RELIABILITY OF GIS-BASED SOLAR RADIATION MODELS AND THEIR UTILISATION IN AGRO-METEOROLOGICAL RESEARCH

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Abstract - Solar radiation is a critical driver of many processes on the earth's surface. It is an important parameter in ecological process modelling, hydrological modelling and biophysical modelling. However, one of the reasons for solar radiation not that widely being utilised in process models is that it is a difficult parameter to measure for all locations, unlike rainfall that can be measured at sample points and interpolated. For GIS-based solar radiation models and the modelled data to be more widely used in biophysical models, one has to have confidence in the accuracy of the modelled data. This paper compares GIS-modelled solar radiation with ground recorded meteorological data for a number of locations and highlight the strong correlation between the two sets. It shows how modelled data can be converted to actual ground data and be used in biophysical models with increased confidence.

Keywords: Meteorology, Ecosystem, GIS, Environment

1. Introduction

Solar radiation is an important environmental variable that is measured at many ground stations around the globe. Most of these sites, however, are concentrated in developing countries and even in developing countries they are mostly in areas of intensive research or hot spots. A lot of these research based stations are temporary and mobile. The other stations are scattered around the country and mainly record data for meteorological stations. For a lot of environmental models solar radiation data is required on a per pixel basis and, unfortunately, this data does not exist as it is almost impossible to record it at this spatial resolution. For this reason solar radiation models have been developed that can predict potential solar radiation from a few commonly available parameters.

Numerous solar radiation models that estimate potential solar radiation on the earth's surface using just a few input parameters have been developed (Kumar *et al*, 1997; Dubayah and Rich, 1995; Duguay, 1993; Fu, 2000; Fu and Rich, 2000, 2002; Rich *et al*, 1994). Solar radiation models are becoming increasingly popular for the investigation of relationships between flora and fauna and the environment, for solar energy applications (Younes and Muneer, 2007; Myers, 2005), and in micrometeorology. Simple radiation estimation models are often used in the applications requiring rough estimations of solar radiation, such as radiation – vegetation relationships (Austin *et al*, 1983; Kumar and Skidmore, 2000; Nunez 1980; Kirkpatrick and Nunez, 1980; Hong *et al*, 2004). However, for applications in the solar energy and micrometeorolgy/evapotranspiration studies, one needs fairly accurate radiation data. There is a need to link solar radiation models that provide continuous spatial coverage with point based instrument recorded data so that there is increased confidence in the accuracy and viability of modelled data in applications that require higher accuracy data.

2. Methods

The Bureau of Meteorology (BoM) in Australia has numerous weather stations spread across the country that record daily, hourly and, in some cases, sub-hourly solar radiation data. For this research, we obtained hourly direct solar radiation from 14 stations, shown in Figure 1. For each station we had 8 years of data. For each day of the year and for all 8 years, clear sky days were separated from cloudy days, and then for each day the maximum recorded solar radiation was selected. This was done since we wanted to investigate the correlation between modelled and recorded radiation under clear sky conditions.

For calculating modelled radiation we used the model developed by Kumar *et al.* (1997) as it has been used extensively for environmental studies and due to its parsimonious nature. The model does not require any site specific data except for a digital elevation model (DEM) and hence can be used in areas where site specific data is not available or difficult to obtain or measure. For each of the 14 stations DEMs were obtained that covered the station point as well as the surrounding areas. The Kumar solar radiation model was run for each of these stations for the full year, with the output potential radiation calculated every 15 minutes and integrated for the full day. Therefore we had modelled daily solar radiation data for each of the stations for every single day of the year.

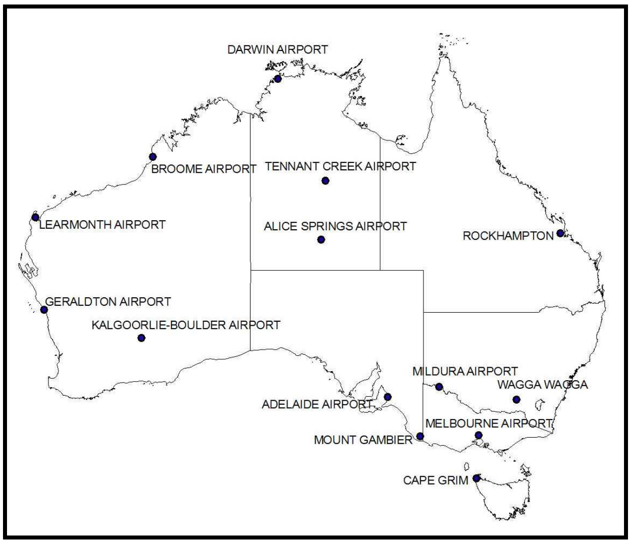


Figure 1 Map of Australia showing the location of the 14 Bureau of Meteorology stations recording solar radiation data used in this research.

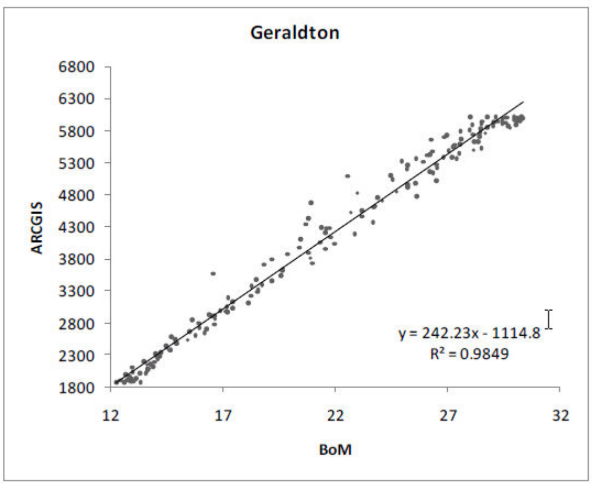
The modelled data and the Bureau of Meteorology data were then divided into two sets. One set was used to derive the regression equations and the second one to use the regression equations to predict values and to compare with observed BoM data. Simple regression analysis was used to derive relationships between the recorded and the modelled data. The data was first tested for normality using the Shapiro-Wilk Normality test. Analysis of Covariance was utilised to decide whether there were seasonal differences in the regression plots or whether one regression equation could be used for all seasons.

3. Results and Discussion

Unweighted least squares linear regression showed that there was a high degree of correlation between the BOM and modelled data, with up to 96% of the variance explained when using pooled data (all 14 stations combined). Once the pooled data was split into seasonal data, there was considerable difference between the regression equations, with different slopes. Summer season had a distinctively different line to the others.

Splitting the data station-wise, it was found that there was a high degree of correlation between the BoM and ARCGIS modelled data. The R^2 value for 13 of the 14 stations was greater than 0.94. The highest correlations were around 0.98. The lowest correlation was for the Darwin station and it was also noticed that it was the Darwin data that had affected the summer regression line when pooled data had been considered. It is assumed that the high humidity levels in the atmosphere in Darwin during the summer months may have caused the deviation in recorded and modelled values. Figure 2 gives the regression plots for the Geraldton and Wagga Wagga stations as examples. The R^2 and regression equations are also given. Units for BoM data is MJ/m^2 and for ARCGIS data it is WH/m^2.

The regression equations obtained as part of the correlation analysis were then used to convert the modelled ARGIS data to compare with the BoM recorded data. Note that this was an independent data set not used in developing the regression equations. The correlation between the observed and predicted values were very good, with R^2 being 0.93 or above. Most of the stations had R^2 values above 0.97. Figure 3 shows the relationship between the predicted values obtained from the regression equations and the BoM data for Geraldton and Wagga Wagga stations.



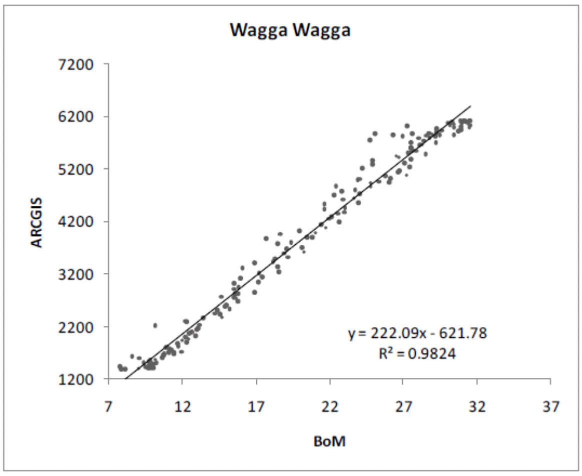
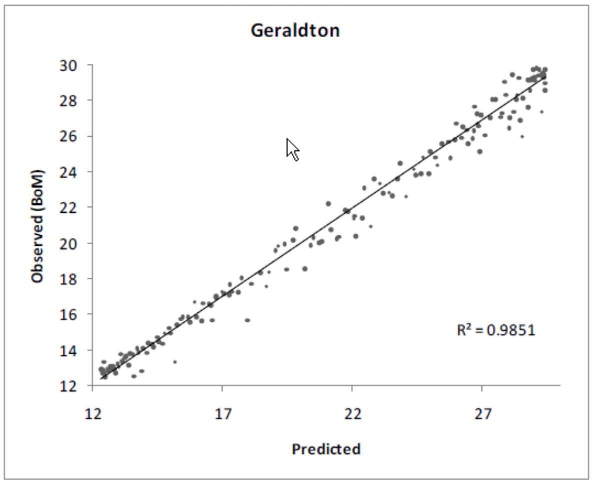


Figure 2 Regression plots for the Geraldton and Wagga Wagga stations. The R^2 and regression equations are also given. Units for BoM data is MJ/m^2 and for ARCGIS data it is WH/m^2.



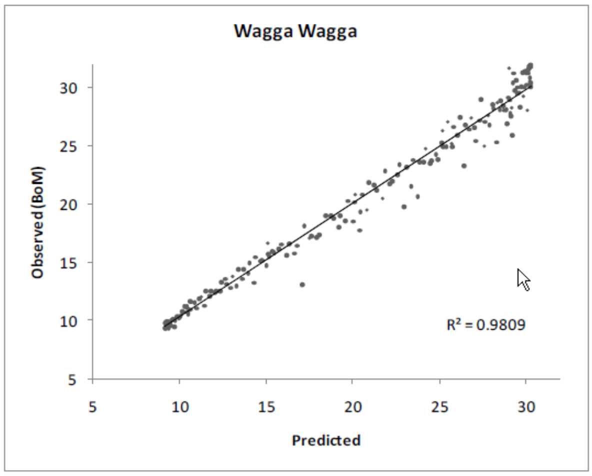


Figure 3 Comparison of predicted solar radiation values (from regression equations of Figure 2) and observed Bureau of Meteorology data.

The Darwin station had the worst predictive power of all the stations used. The ARCGIS model assumed clear sky conditions and used the same empirical equations for aerosol content and atmospheric absorptions for all the stations. It seems that the regressions suggest that for modelling in the high tropics and especially in very humid regions one has to use a different set of parameters.

However, for all other stations, with their distribution all over Australia as shown in Figure 1, the modelled data can be converted and used in place of recorded data with a high degree of confidence. This means that in micrometeorological and evapotranspiration research, where intensive data is required, modelled data can play an important role. For most of the stations tested, the predicted values of solar radiation were within 2% of the actual recorded data. The modelled data can also play an important role in hard to get locations, mountainous areas and areas where there is a sparse network of recording stations.

4. Conclusion

The results of this research suggest that, with appropriate verification, GIS modelled data can be used in lieu of field recorded data for areas where field data is not available or would be too expensive to record. Overall the predicted values differed by an average of around 2% from the Bureau of Meteorology data for most of the stations tested. This low error suggests that modelled data can be utilized in micrometeorology and evapotranspiration related studies with a high degree of confidence.

Unlike rainfall and temperature that can be measured at a few locations and interpolated for other areas within reason, solar radiation cannot be interpolated with any degree of confidence due to its high dependence on terrain variables like slope, aspect and shading from adjacent features. Setting up a high density network for recording solar radiation is also expensive and time consuming. Hence modelled radiation can play an important role in environmental models where solar radiation data at high spatial densities is required. One issue in using modelled data has been the accuracy of the data. This research shows that there is a very high correlation between recorded and modelled solar radiation data and that, with appropriate verification, modelled radiation data can be used with a high degree of confidence.

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