USING A SURFACE ENERGY MODEL (RESET) TO DETERMINE THE SPATIAL VARIABILITY OF ET WITHIN AND BETWEEN AGRICULTURAL FIELDS

Aymn Elhaddad

Research Scientist
Integrated Decision Support Group, Dept. of Civil and Environmental Engineering (1372)
Colorado State University, Fort Collins, CO. 80523

Luis A. Garcia

Director, Integrated Decision Support Group and
Professor, Dept. of Civil and Environmental Engineering (1372)
Colorado State Univ., Fort Collins, CO. 80523

ABSTRACT

Remote sensing algorithms are currently being used to estimate regional surface fluxes (e.g. evapotranspiration (ET)). Many of these surface energy balance models use information derived from satellite imagery such as aircraft, Landsat, AVHRR, ASTER, and MODIS to estimate ET. The remote sensing approach to estimating ET provides advantages over traditional methods. One of the most important advantages is that it can provide estimates of actual ET for each pixel in the image. Most conventional methods are based on point measurements, limiting their ability to capture the spatial variability of ET. Another advantage of remote sensing/surface energy balance ET models is that they are able to estimate the actual crop ET as a residual of the energy balance without the need of using reference crop ET and crop coefficients. This presentation will focus on the use of an energy balance model developed by the authors (Remote Sensing of ET – ReSET) that uses an enhanced procedure to deal with the spatial and temporal variability of ET. ET estimates from several years of data for fields in the Arkansas River Basin, South Platte and Palo Verde Irrigation District will be presented. The presentation will focus on how remote sensing of ET can be used to quantify the spatial variability of ET inside a field and identify problem areas. This technology can also be used to determine the amount of water used by plants inside a field which could be the basis for determining how much water to apply in order to meet the crop water demand for each area in a field.

REMOTE SENSING OF ET (RESET) MODEL

ReSET is a surface energy balance model built on the same theoretical basis of its two predecessors METRIC (Allen et al., 2007 a,b) and SEBAL (Bastiaanssen, 1998 a,b) with the additional ability to handle data from multiple weather stations, which enhances regional ET estimates by taking into consideration the spatial variability of weather conditions through data acquired from different weather stations (across the area covered by the remote sensing system/imagery). ReSET can be used in both the calibrated and the un-calibrated modes. The calibrated mode is similar to METRIC in which the reference ET from weather stations is used to set the maximum ET value in the processed area, while in the un-calibrated mode the model follows a similar procedure as SEBAL where no maximum ET value is imposed.

Model Application in Palo Verde Irrigation District (PVID)

The Palo Verde Irrigation District service area (Figure 1) falls on the overlap between two Landsat scenes (path/row 39/37 and path/row 38/37), which made it possible to collect over 30 usable images for this area in 2002 (using both Landsat 5 and 7 scenes). Two seasonal estimates were calculated from single ET grids processed using both the un-calibrated and the calibrated ReSET model modes. The maximum annual ET for alfalfa fields in this area was estimated by the ReSET model to be 1,748 mm/yr when using the calibrated mode. The Penman-Monteith annual reference ET for alfalfa obtained from the Blythe weather station of the California Irrigation Management Information System (CIMIS) as reported in the Lower Colorado River Accounting System (LCRAS) (US Department of Interior, 2004) was 1,774 mm/yr which was only 1.5 percent more than that estimated by the calibrated ReSET model (Table 1). Comparing the maximum value of the ReSET model ET for each field to the LCRAS alfalfa ET shows that 76 percent of the alfalfa fields have a ratio between 0.9 and 1.0. Twenty three percent of the fields have a ratio between 0.7 and 0.8 which indicates that these fields might have some condition(s) that limited ET, and 1 percent of the fields had ratios below 0.7 which indicates a large shortage in irrigation water, these fields might not be cultivated or were only cultivated for part of the year.

Table 1. Comparison between the maximum annual alfalfa ET estimated by ReSET and the LCRAS report.

Run Type	Annual ET from the ReSET Model (mm/yr)	Annual ET from the LCRAS Report in (mm/yr)	Difference (%)
Un-calibrated	1,612	1,774	-9.1%
Calibrated	1,748	1,774	-1.5%

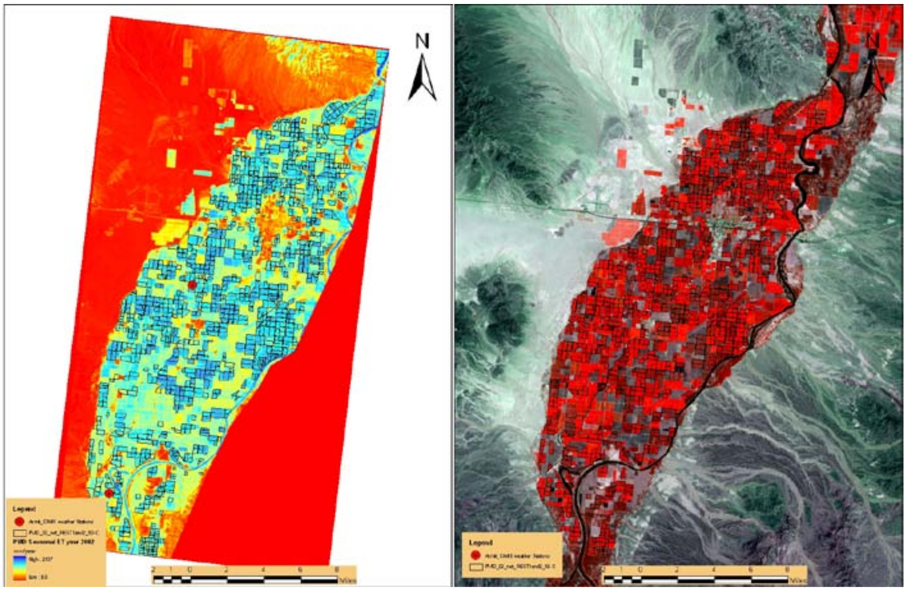

Figure (1). Seasonal ReSET ET and Landsat 7 image for the Palo Verde Irrigation district.

Annual ET estimates from the ReSET model can be used to generate a distribution of ET values to compare between fields. The results from the ReSET model can also be used to show the variability in ET inside the fields themselves. Figure 2 shows fields with a high standard deviation in the annual ET which indicates high variability in ET within the field. This normally is caused by a non uniform crop, such information can be used to identify fields that might have issues with the irrigation system, pest infestations, soil problems, etc. ReSET can also be used to detect the start and development of problems inside fields by looking at ET data for a particular field from previous years. This information allows farmers to evaluate the efficacy of any mitigation that they might have undertaken such as if a high water table was detected in some areas of a field and a drainage system was installed. The field performance in the following years can be evaluated based on the homogeneity of the ET calculated from ReSET to evaluate the efficacy of the drainage system.

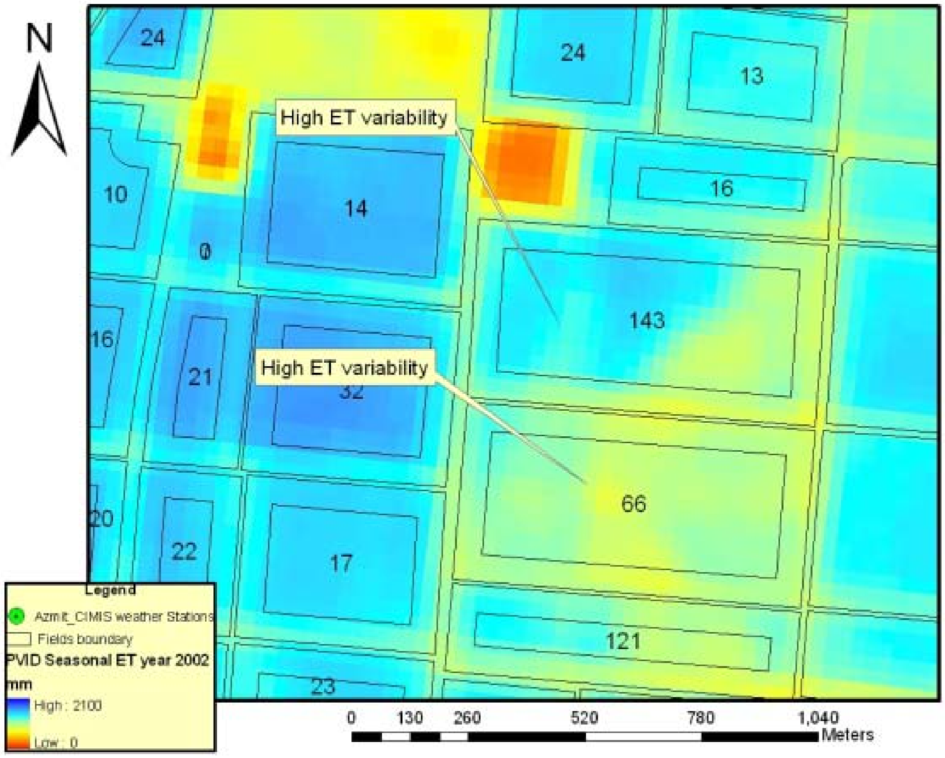

Figure (2). Annual ET grid showing fields with a high standard deviation in the annual ET which indicate that the crop is non uniform inside the field.

Lower Arkansas River Basin in Colorado

The model was applied to the Lower Arkansas River Basin in Colorado to calculate the total ET for a canal service area. This region grows a variety of crops, most commonly corn and alfalfa, but also a number of vegetable crops such as onions and melons. Using the ReSET model, daily ET grids were developed for nine Landsat 5 images for 2007 starting on April 28 and ending on October 5th. Seasonal ET was estimated using the ReSET seasonal tool which uses individual ET grids and interpolates between them. The interpolated ET grids for days between the scenes were created based on temporal and spatial interpolation between the Landsat image dates using the daily reference ET from weather stations in the region.

The seasonal ET results of the ReSET model were combined with a Geographic Information System (GIS) to determine the total water consumption per pixel (900 m^2) which were aggregated for each field and then to a canal service area. The actual water consumption can be compared to the water requirements of the crops (i.e., potential ET under no agronomic and water stress conditions), and this information can be used to identify areas of water stress. This information can also be used to help farmers or water managers improve their irrigation management.

Seasonal ET for Canal Service Areas

The model can also be used to evaluate different aspects of irrigation efficiency for a canal service area such as: a) The total ET for a canal service area; b) The water supply losses by comparing the total ET for the canal service area to the diversion records for the area; c) The water distribution uniformity between fields at the head and tail of the canal. The Catlin canal in the Lower Arkansas River Basin in Colorado was selected as an example of how to calculate the total ET for a canal service area. Using GIS, the service area of the canal and the ReSET estimated ET were combined to show spatial information for this canal as well as the sum of the water consumed by the crops grown in the fields in the canal service area (Figure 3). Such approach can be used to show water consumption distribution by crop or by spatial location inside different parts of a canal service area (head of the canal vs tail of the canal).

CONCLUSION

The ReSET model was used to estimate daily and seasonal ET for several regions in the USA (Arkansas river basin, CO and Palo Verde Irrigation District, CA). The maximum yearly ET for reference alfalfa estimated by the calibrated ReSET model was 1,748 mm/yr while the estimated ET from the Blythe weather station was 1,774 mm/yr which represents a 1.5 percent difference. The results presented support the idea of using the ReSET model as a tool for water management, such as the example from the Arkansas river valley in Colorado where the model was used to estimate the ET for a group of fields based on the service area for a canals. This information can be used to calculate canal efficiency and irrigation system efficiency. The applications presented in this paper show that remote sensing of ET provides a valuable tool for water management.

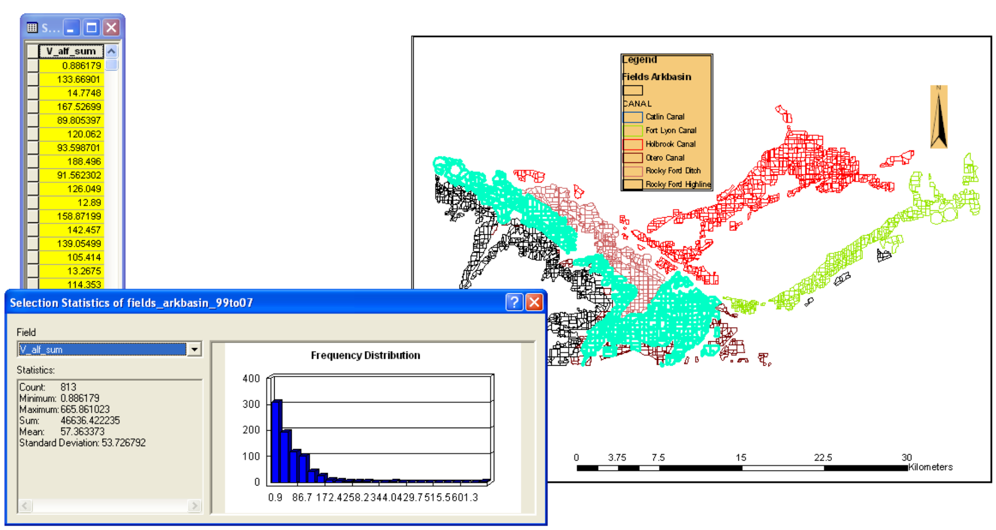

Figure (3). Seasonal evapotranspiration for the Catlin Canal service area

References

Allen, R.G., Tasumi, M. Trezza, R. (2007[a]) . Satellite-based energy balance for mapping evapotranspiration with internalized calibration (METRIC) – Model". Journal of Irrigation and Drainage Engineering, 133(4):380-394, July/August 2007.

Elhaddad, A. and Garcia, L.A. (2008). Surface energy balance-based model for estimating evapotranspiration taking into account spatial variability in weather. Journal of Irrigation and Drainage Engineering, 134(6), 681-689.
Bastiaanssen, W.G.M., Menenti, M., Feddes, R.A., Holtslag, A.A.M. (1998a). Remote sensing surface energy balance algorithm for land (SEBAL): 1. Formulation. Journal of Hydrology 212-213(1-4), 198-212.

U.S. Department of the Interior, 2004 "Lower Colorado River Accounting System Calendar Year 2002", Bureau of Reclamation, Lower Colorado Regional Office, Boulder City, Nevada.