Estimating Distributed Soil Evaporation to Account for Background Evaporation Between Satellite Image Dates

University of Idaho

J. Kjaersgaard[1], R. Allen[1], A. Irmak[2], I. Ratcliffe[2], P. Ranade[2],

[1]*University of Idaho, Kimberly Research and Extension Center, Kimberly, Idaho*

[2]*University of Nebraska-Lincoln, Lincoln, Nebraska*

University of Nebraska Lincoln

Satellite-Based Evapotranspiration Estimation

Satellite based surface energy balance models are now routinely operated to produce evapotranspiration (ET) products on an operational basis for use in water resources management. Landsat satellite imagery is commonly used to produce estimates of ET at field scale with energy balance methods because of the onboard thermal imager and the high spatial resolution. Two Landsat satellites are currently in operation, Landsat 5 and Landsat 7, each flying in the same orbit but eight days apart.

Because of cloudiness not all images or portions of images are suitable for processing. Although areas having cloud cover vary between different dates, it is common to find only one good image per month suitable for processing. As a result, monthly and ultimately seasonal ET depths are generally based on only one "snapshot" of ET per month. In METRIC (Mapping Evapotranspiration at high Resolution using Internalized Calibration), daily ET are commonly expressed as the relative ET_r fraction, ET_rF, calculated as

$$ET_rF = ET / ET_r \qquad (1)$$

where ET_r is tall reference ET computed from weather data. Monthly ET depths are estimated as the ET_rF values estimated using energy balance for the image dates interpolated to all days falling between image dates using a cubic spline function, Figure 1, and multiplied by the corresponding daily reference ET (Allen et al., 2007a,b)

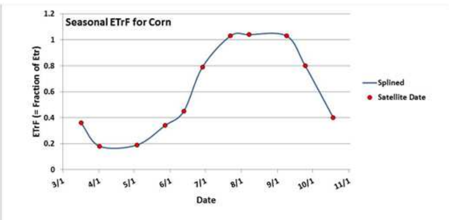

Figure 1. Interpolation of ETrF between satellite image dates using a cubic spline function (blue line, schematic). The red circles indicate the ETrF value at the overpass dates.

A potential shortfall in basing integrated ET averages on periodic snapshots from satellite images is that local or regional precipitation events antecedent to the satellite images may unduly dominate the ET_rF image and may not represent evaporation from rainfall averaged over the monthly period. Rain events occurring between satellite images may not be 'seen' in a subsequent image, and therefore those evaporation amounts are not fully accounted for.

This phenomena is shown in Figure 2 from nearly cloud free Landsat 5 path 33 row 31 images from the Nebraska Panhandle in 1997 (black vertical bars) and precipitation recorded at the Scottsbluff HPRCC weather station (red bars). When interpolating between image dates each image roughly represents the ET halfway, in time, between the previous and the following image date. The August 13 1997 image fell immediately after a relatively wet period resulting in a high ET estimate from non-irrigated areas including dryland agriculture and rangeland. Because the period following the image was dry, the ET estimates for that image are too high for the period it is representing.

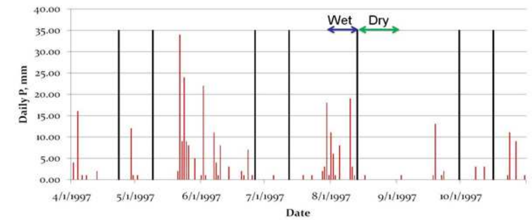

Figure 2. Satellite overpass dates (black bars) relative to precipitation events at the Scottsbluff weather station (red bars) during 1997.

Soil Evaporation Estimation

We have developed a soil-water balance procedure to adjust the ET_rF derived from the satellite overpass date and the METRIC surface energy balance model to account for background evaporation from soil caused by rainfall over monthly or longer integration periods.

The result of the adjustment is an ET_rF image to be used during the spline procedure and consequently final ET map that better represents the average evaporative conditions over the period.

The method currently uses the FAO-56 evaporation model (Allen et al., 1998), but with an enhancement for skin evaporation on a grid covering the image area. As input, information about the distributed ET_r, precipitation and soil properties for the study area is needed.

The ET_rF for each image pixel is adjusted by the ratio of the average evaporation over the month from bare soil to the evaporation estimated for the image date. This ratio is moderated using the Normalized Difference Vegetation Index (NDVI) to account for shading effects of vegetation on reducing the signature of evaporation from soil.

The method was tested for the 1997 growing season in the south-west corner of the Nebraska Panhandle, Figure 3, which is characterized by having somewhat frequent and local summer rain events. Soil information from the NRCS SSURGO soil database, ET_r from 14 weather station and precipitation information from 52 NWS COOP precipitation gauges was used to parameterize the daily soil water balance model for the entire year of 1997.

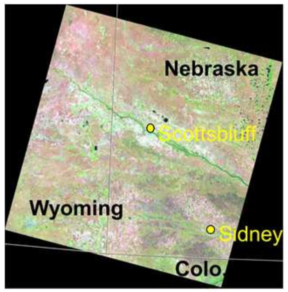

Figure 3. Landsat image path 31 row 33 from 06/26-1997 covering the study area in the south western corner of the Nebraska Panhandle. White lines indicate state boundaries.

Adjusting for background evaporation

The output from the soil evaporation model for a pixel near Scottsbluff is shown in Figure 4. After wetting events the evaporation from the surface is limited only by the amount of energy that is available and the evaporation is high. As the soil surface dries out to progressively deeper layers, the evaporation rates is reduced.

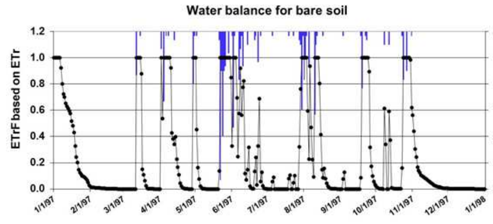

Figure 4. Output from the soil evaporation models sampled for one point during 1997.

The results of the adjustment for the August 13 1997 image date is shown in Figure 5. The fully vegetated irrigated areas along the North Platte River have not been adjusted, while the ET_rF from the surrounding rangeland areas have been reduced. The average ET_rF values for ten randomly sampled non-irrigated rangeland locations are shown in Figure 6.

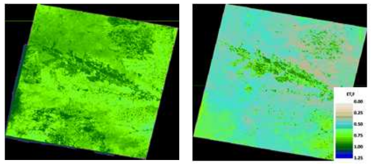

Figure 5. Maps of ETrF from August 13 1997 before (left) and after (right) adjustment for background evaporation.

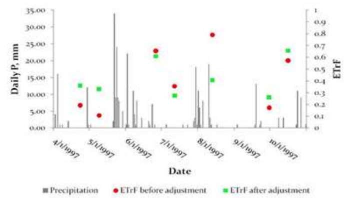

Figure 6. Daily precipitation from the Scottsbluff HPRCC weather station and the average ETrF of ten randomly sampled rangeland locations before and after adjustment of background evaporation.

References

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