Indicator for crop evapotranspiration (ET_c):

At a fairly fundamental level, the indicator for ET_c is net thermal radiant flux. This indicator is sensed by the thermal band of Landsat 5 (LS5). Given established, suitable corrections for heat imported to an area of interest (AOI) by the movement of large air masses, differences in reflection within an AOI and corrections for the flux of energy into the ground, residual variation in thermal radiant flux is a function of the amount of heat consumed by the conversion of water to water vapor - ET_c in other words – because the conversion of water to water vapor is an energy consuming process. Areas with greater ET_c appear less radiant in the image.

A LS5 image is an instantaneous snapshot of the pixel-by-pixel variation of radiant flux over an AOI. Conveniently, this radiant flux is a reasonably constant fraction of hourly reference evapo-transpiration (ET_o) as measured by DWR's CIMIS weather station network. The constancy of this relation enables extrapolation of instantaneous ET_c to a value for 24-hour ET_c using hourly CIMIS ET_o values. Seasonal ET_c is arrived at additively.

Calibration is achieved by establishing a regression relationship between the radiant flux of the cooler (high ETc) pixels, typically weather station alfalfa, and hotter (low ETc) pixels, typically bare, dry soil.

Resolution of LS5 imagery is 30 meters. LS5 passes over an area every 16 days. Interpolation between AOI image dates is done on the basis of ET_os for the intervening days using weighted values of the fraction of ET_o calculated at the bookend image dates. Other satellites with thermal band sensors are also usable, although of coarser resolution.

Comments:

Two programs that currently make use of the above technology are SEBAL and METRIC. METRIC derives from SEBAL, but adds the useful advancement of calibration utilizing ground-based weather stations. SEBAL is a commercial product. METRIC is open source.

Accuracy of METRIC has been tested at the Imperial Irrigation District, and the program performed well. Imperial I.D. was a good test bed in having little rain, and in having measured inflows and outflows. Rio Grande riparian vegetation ET has also been modeled successfully in METRIC.

The developers of METRIC (Dr. Richard Allen and his graduate group at the University of Idaho) state that the technology is comparable to the two-step ET_o X K_c method. My sense is that the accuracy of METRIC greatly exceeds that of the two-step method for the following reason: the two-step method assumes a uniformity of crop that does not exist; crop yield varies spatially; and yield is highly correlated with ET_c.

One difficulty is that METRIC is currently calibrated for use with alfalfa. It appears possible to reconfigure METRIC for use with the typical turf grown at CIMIS stations. Dr. Richard Snyder, UC-Davis, has done extensive work relating alfalfa ET_c to CIMIS ET_o. Dr. Snyder's work should facilitate reconfiguration.

METRIC technology brings the importance of irrigation of CIMIS weather stations to the fore. CIMIS staff would be well advised to increase quality control of the adequacy of irrigation at the CIMIS stations. Auditing techniques are set forth in FAO Irrigation and Drainage Paper No. 56 (senior author Richard Allen), and are doubtless well known by CIMIS staff.

METRIC is already being widely employed. The next Landsat satellite will carry a thermal band scanner at the urging of most of the Western states. The data are free, and the technology can be employed by any district, NGO and agency.

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