Assessment of the probability of being able to produce Landsat-resolution images of annual (or growing season) evapotranspiration in southern Idaho – and effect of the number of satellites

Dr. Richard Allen, Univ. Idaho, March 24, 2010, edited May 2010

This document summarizes statistics on the probability of being able to process sufficiently clear and sufficiently frequent Landsat-resolution images in southcentral Idaho to produce a dependable and accurate estimate of annual (growing season) evapotranspiration. The analysis was made using image clearness ratings (i.e., clearness from clouds) that the University of Idaho Remote Sensing of ET team has compiled for Landsat 5 (1984-2009) and Landsat 7 (2000-2009) for path 40 row 30 and path 39 row 30 in Idaho,. Knowledge of annual ET is essential for managing surface and ground-water resources, and it requires frequent enough satellite image coverage to be able to follow the progression of vegetation development and other cultural and water management factors affecting the ET process through time. Generally, we strongly recommend that at least one image per month be processed to produce ET images that follow these trends during the growing season.

I have based this analysis on two requirements:

1. The areas of interest in the scene (generally irrigated areas) must have a 'clearness' rating of 0.8. The clearness rating is the fraction of total area of interest that is cloud free in the image.   (the index was relaxed to 0.7 during analyses to evaluate the effect of the tolerance of occluded areas)

2. The maximum time between qualifying images must be no longer than 32 days (one month) during the April - October growing season. This was relaxed to 48 days (seven weeks) to evaluate the effect of a longer period of extrapolation of ET information between processed image dates. We appreciate that extrapolating ETrF (fraction of ET) over seven weeks can create substantial uncertainty in the seasonal ET estimate.

Based on the analyses, I make the following conclusions:

Given the 0.8 clearness tolerance and the 32 day maximum time-between-clear-image requirement,
For **path 39** row 30 (eastern Idaho),
-- over the 26 year Landsat 5 record, **only one of 26 years (4%) qualified**.
-- over the 10 year Landsat 7 record, **none of 10 years (0%) qualified**.

For **path 40** row 30 (southcentral Idaho),
-- over the 26 year Landsat 5 record, only two of 26 years (8%) qualified.
-- over the 10 year Landsat 7 record, only one of 10 years (10%) qualified.

When the **two Landsat** satellites were operated in combination over the 2000-2009 period:
For path 39 row 30 (eastern Idaho),
-- over the 10 year overlapping record, **four of 10 years (40%) qualified**
For path 40 row 30 (southcentral Idaho)
-- over the 10 year overlapping record, **five of 10 years (50%) qualified**

Therefore, the eight day return time afforded by two satellites flying in eight day formation increased the likelihood of producing an annual ET product from about 5% probability to about 45% probability. **This is a factor of 9 increase by reducing satellite return time (overpass time) from 16 days to 8 days.**

With a four day return time, the probability is expected to increase to 80% or more.

Sensitivity to processing requirements. When I relax the clearness threshold to 0.7 (so that only 70% of the areas of interest have to be clear enough to process in an image) and extend the maximum time between qualifying images to 48 days (seven weeks), I obtain the following results:

Given a 0.7 clearness tolerance and a 48 day maximum time-spread requirement,
For **path 39** row 30 (eastern Idaho),
-- over the 26 year Landsat 5 record, ten of 26 years (38%) qualified. *(with relaxed requirement)*
-- over the 10 year Landsat 7 record, five of 10 years (5%) qualified.

For **path 40** row 30 (southcentral Idaho),
-- over the 26 year Landsat 5 record, ten of 26 years (38%) qualified. *(with relaxed requirement)*
-- over the 10 year Landsat 7 record, only three of 10 years (30%) qualified.

When the two Landsat satellites were operated in combination over the 2000-2009 period:
For **path 39** row 30 (eastern Idaho),
-- over the 10 year overlapping record, nine of 10 years (90%) qualified.*(with relaxed requirement)*
For **path 40** row 30 (southcentral Idaho)
-- over the 10 year overlapping record, nine of 10 years (90%) qualified

Therefore, the eight day return time afforded by two satellites flying in eight day formationincreased the likelihood of producing an annual ET product from about 30% probability to about 90% probability.   This is a factor of 3 increase by reducing satellite return time (overpass time) from 16 days to 8 days. **I note that the 70% clearness threshold and the 48 days between images <u>are generally not tolerable</u>**, and therefore, the statistics given for 80% threshold and 32 days between images are the more representative and realistic.

These analyses are for southern Idaho, which is known to be a relatively low-cloud region. Other regions of the US, notably the midwest will have substantially lower probabilities of successful estimation of annual ET. Knowledge of annual ET that is essential for managing surface and ground-water resources.

Supporting Material

The following section provides more statistics for varying combinations of required clearness over areas of interest (80 and 70%) and maximum allowed time between clear images (32 and 48 days and additionally 40 days when two satellites are flying).

With only one Landsat satellite having 16 day return time:

Landsat 5, path 39 row 30 (eastern Idaho):   26 years of record

One of 26 years (4%) had monthly coverage at a 0.8 clearness threshold over areas of interest
Three of 26 years (12%) had monthly coverage at a 0.7 clearness threshold over areas of interest
Eight of 26 years (30%) had coverage each seven weeks at a 0.8 clearness threshold over areas of interest
Ten of 26 years (38%) had coverage each seven weeks at a 0.7 clearness threshold over areas of interest

Landsat 7, path 39 row 30 (eastern Idaho):   10 years of record

None of 10 years (0%) had monthly coverage at a 0.8 clearness threshold over areas of interest
None of 10 years (0%) had monthly coverage at a 0.7 clearness threshold over areas of interest
Five of 10 years (50%) had coverage each seven weeks at a 0.8 clearness threshold over areas of interest
Five of 10 years (50%) had coverage each seven weeks at a 0.7 clearness threshold over areas of interest

Landsat 5, path 40 row 30 (southcentral Idaho):   26 years of record

Two of 26 years (8%) had monthly coverage at a 0.8 clearness threshold over areas of interest
Three of 26 years (12%) had monthly coverage at a 0.7 clearness threshold over areas of interest

Eight of 26 years (30%) had coverage each seven weeks at a 0.8 clearness threshold over areas of interest

Ten of 26 years (38%) had coverage each seven weeks at a 0.7 clearness threshold over areas of interest

Landsat 7, path 40 row 30 (southcentral Idaho):   10 years of record

One of 10 years (10%) had monthly coverage at a 0.8 clearness threshold over areas of interest

One of 10 years (10%) had monthly coverage at a 0.7 clearness threshold over areas of interest

Three of 10 years (30%) had coverage each seven weeks at a 0.8 clearness threshold over areas of interest

Three of 10 years (30%) had coverage each seven weeks at a 0.7 clearness threshold over areas of interest

With Two Landsat satellites having 8 day return time:

Landsat 5 and Landsat 7, path 39 row 30 (eastern Idaho):   10 years of overlapping record

Four of 10 years (40%) had monthly coverage at a 0.8 clearness threshold over areas of interest

Four of 10 years (40%) had monthly coverage at a 0.7 clearness threshold over areas of interest

Seven of 10 years (70%) had coverage each six weeks at a 0.8 clearness threshold over areas of interest

Eight of 10 years (80%) had coverage each six weeks at a 0.7 clearness threshold over areas of interest

Nine of 10 years (90%) had coverage each seven weeks at a 0.8 clearness threshold over areas of interest

Nine of 10 years (90%) had coverage each seven weeks at a 0.7 clearness threshold over areas of interest

Landsat 5 and Landsat 7, path 40 row 30 (southcentral Idaho):   10 years of overlapping record

Five of 10 years (50%) had monthly coverage at a 0.8 clearness threshold over areas of interest

six of 10 years (60%) had monthly coverage at a 0.7 clearness threshold over areas of interest

Seven of 10 years (70%) had coverage each six weeks at a 0.8 clearness threshold over areas of interest

Nine of 10 years (90%) had coverage each six weeks at a 0.7 clearness threshold over areas of interest

Nine of 10 years (90%) had coverage each seven weeks at a 0.8 clearness threshold over areas of interest

Nine of 10 years (90%) had coverage each seven weeks at a 0.7 clearness threshold over areas of interest

The following graphic shows the outline of Path 40 Row 30 in Southern Idaho. Path 39 Row 30 is immediately to the right of the outline. These two Landsat scenes contain over 2 million acres of irrigated farmland (displaying as green in the two scenes).