Main Topics:

- **Validations** of SEBAL ET estimation model in northwestern U.S.
- Results of sensitivity analyses (atmospheric correction etc.).
- Some **field-level application** examples.
U.S. Validation Tests on the SEBAL Model for Evapotranspiration via Satellite

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Abstract:
SEBAL (Surface Energy Balance Algorithm for Land) is a widely applied remote-sensing evapotranspiration (ET) estimation model. The model has been applied for semi-arid conditions in Idaho, USA, during 2000-2003 by University of Idaho satellite image, by land surface energy balance. Results of two validations show ET to be estimated accurately in agricultural settings. Comparisons of SEBAL results with traditional crop coefficient curves show good agreement. Sensitivity analyses show that the model is accurate without atmospheric correction. Repeatability tests show that SEBAL results are only somewhat impacted by differences in images, data and operators.

What is SEBAL and how does it work?

SEBAL ET estimation model:
• Developed by Bastiaanssen, 1995
• Applied in more than 25 countries
• Validated through previous studies

Data Requirements:
• Minimum Requirements
  - Satellite Image (with temperature band)
    - Landsat, NOAA-AVHRR, MODIS or ASTER
  - Windspeed (general measurements)
• Additional Requirements for high definition of ET in irrigated areas
  - Digital elevation map (for sloping surfaces)
  - Weather data, may include:
    - Reference evapotranspiration from agricultural weather stations, solar radiation, air temperature, humidity, precipitation.

ET Estimation method:
(a) “Instantaneous” (around 11:00am for Landsat) ET from a satellite image, by land surface energy balance

$$\text{ET} = R_n - H - G$$

where, $R_n$ is net radiation, $H$ is sensible heat (heat lost to air), $G$ is soil heat (heat lost to ground)

$$R_n = (1 - \alpha)R_s + (\epsilon L_{in} - L_{out})$$

$$G = \left[ \frac{T_s}{\alpha} (0.0038 \alpha + 0.0074 \alpha^2)(1 - 0.98 \text{NDVI})^4 \right] R_n$$

$$H = \rho_a C_p (a + b \cdot T_s)$$

(b) 24-hour ET, using the EF (or ETrF) from the instantaneous satellite image (assumes EF or ETrF are constant over the day)

$$\text{ET}_{(24)} = \text{EF}(R_n - G)_{(24)}$$

(c) Monthly/Seasonal ET by interpolating ET, F

$$\text{ET}_F = \text{K}_c \cdot \text{ET}$$

Evaporative Fraction:
$$\text{EF} = \frac{\text{ET}}{R_n - G}$$

Reference ET Fraction ( = Crop Coefficient):
$$\text{ET}, F = \text{K}_c \cdot \text{ET}$$

SATellite picture (with temperature band) and wind speed are the two basic inputs for SEBAL.
Validation Tests

Validation Results in Idaho (using lysimeters):

Two validations were conducted in southern Idaho agricultural conditions using lysimeter ET. ET by SEBAL corresponded well to the lysimeter measurements.

Monthly and seasonal ET Estimation:

Satellite-based remote sensing provides daily ET for only of the days that satellite images are available. For field-level applications, providing monthly and seasonal ET is important.

Impact of atmospheric correction:

SEBAL does not require atmospheric corrections to surface temperature and albedo. The “internal calibration” procedure incorporated in the model eliminates errors caused by lack of atmospheric correction. This increases the accuracy and simplicity of SEBAL in routine ET monitoring.

Internal Calibration

ET values for two extreme pixels in the satellite image are “assigned” by the operator (therefore any errors goes to H and not to ET for those pixels). The energy balance at all other pixels are proportionally adjusted.

Cold Pixel:

$ET = R_n - G$  or  $ET = 0$, when assigned by water balance using precipitation record.

Hot Pixel:

$ET = 1.05 \times alfalfa$ ET reference, with and without MODTRAN determined surface temperature (top) and albedo (bottom).
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**Additional applications**

**Impact of different:** Two independent applications showed good correspondence in seasonal values.

- **Operators**
- **Images**
- **Image dates**
- **Weather data**

> The repeatability of the SEBAL model is considered to be high.

In most cases, path 39 images used for application 1 were one-day behind path 40 images used for application 2.

**Comparisons with “traditional” crop coefficient curves from previous studies:**

![Image](image1.png)

*Figure: Mean Kc curves by SEBAL (derived from nearly 4000 sample fields near Kimberly, Idaho).*

![Image](image2.png)

*Figure: Kc and NDVI from 546 spring grain sample fields.*

- **SEBAL Kc curves corresponded well to the traditional curves.**
- **Kc of individual fields can be very different from the average Kc.**

**Comparison of predicted 24-hour ET with measured 24-hour ET using instantaneous EF or ET,F:**

The assumption that “EF is constant during the day” is frequently applied with SEBAL and other models. However, in advective conditions, ET,F might be a better extension parameter because the reference ET incorporates impacts of afternoon advection.

**Conclusions**

- **SEBAL can estimate ET with 30-120m spatial resolution, using Landsat Images.**
- **Our validations show that SEBAL can estimate ET from agric. fields accurately.**
- **The “internal calibration” of SEBAL effectively eliminates errors that may occur from applying only simple atmospheric correction.**
- **SEBAL derived crop coefficient curves derived by SEBAL corresponded well to traditional curves from previous studies. This indicates that SEBAL can be used to calibrate or develop Kc curves.**
- **Applying ETrF instead of EF to extend instantaneous ET to daily or longer ET might improve ET estimation in advective conditions.**
- **Two independently conducted applications agreed well. This means that SEBAL has good repeatability and stability under different of image/weather data and operator preferences.**

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