RS/GIS Awareness Workshop
Observing River Basins from Space: Why is it Important for IWMI
A Remote Sensing and GIS (RS/GIS) Workshop for IWMI by IWMI
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ET Krishna Basin

by

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SEBAL: A technical introduction (da-nitty-gritty)

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Outline

• Basic assumptions
• What matters?
• Why the over-estimation in Krishna Basin?
• When/where/why to apply?
SEBAL—Surface Energy Balance Algorithm

\[ \lambda ET = (IN - OUT - G) - H \]

IN (Solar)

\[ OUT = IN \times albedo + I.w. \]

Air sensible Heat (\( H \)) = f(Temperature)

Latent Heat (\( \lambda ET \))

Soil sensible heat (G) = f(Veg cover)

SEBAL’s Main Assumption:

\[ ET = IN - OUT - G - (a + bT_0) \]

ET = 0 for “dry” pixel

ET = ET_{max} for “wet” pixel
Other Assumptions:

• Uniform wind speed over whole image
• Vertical heat transport only (no horizontal exchange between cells)
• Evaporative fraction remains constant over day, and between images

• These assumptions are difficult to validate...

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List of the variables: Looks complicated!  
> 20 variables

- **Input variables**
  - Met station (1 location)
    - Wind speed
    - Air temp
  - Satellite image
    - Visible, NIR bands
    - Cloud-free
    - Center of image (!)

- **Derived variables**
  - $R_n$ 10 variables
    - Albedo
    - Tau (atmos transmiss)
    - Longwave radiation
  - G 6 variables
    - NDVI, albedo, $T_o$
  - H 16 variables
    - Thermal emissivity
    - Aerodynamic properties
    - $zom$
    - $zoh$

Details: Important and not-so-much (IN-OUT-G)

- **$Tau$** (atmospheric transmissivity) -- determines IN
  (SWAT assumes 0.8, measured values ~0.69)
- **Albedo** -- determines OUT
- Wet and dry pixel selection
- Assumption that $\lambda ET=(IN-OUT-G)$ wet, and $ET=0$ dry
- Calculation of $G$—especially over water bodies

- Unimportant: Most of the H details
  - Wind speed—other variables (rah, a, b) adjust to fit the assumed $H$ vs $T$ curve
  - Absolute value of surface temperature—only relative values important
Why wind speed, $r_{ah}$ irrelevant?

\[ \lambda E T = (IN - OUT - G) - H \]

\[ H = \rho C_p dT \]

\[ H = \rho C_p (a + bT_0) \]

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Why the ET overestimation?
1. Too high ET from “Wet” pixel
   (…but gives deceptively reasonable results, since ET is forced to scale between 0 and potential ET)

\[ \text{Potential ET} = \text{IN-OUT-G} \]

"Soil" heat balance for reservoirs

\[ \text{SEBAL assumes:} \]
\[ G_0 \sim 8-13\% \text{ of IN-OUT} \]
\[ G_{24} \sim 0 \]

** Both too low. **

\( G_0 \) is up to 60\% of \( R_n \) during lake warming (in the temperate zone)
Overestimation: Possibility 2 
Heterogeneity and scaling effect

Oasis effect:
Wind can blow heat from one pixel to the next, 
messing up TO – H relationship

Heterogeneity—
Many studies find average variables work ok…. 
but more uncertain in highly heterogeneous gwtr irrigated envt

Landsat7 ETM+, 
December 2001

Source: Mobin
Scale discrepancy: MODIS vs Landsat

Scene Average:
MODIS ET: 1.2 mm
Landsat: 1.6 mm

...but this takes us in the wrong direction!

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Past successful applications

- Rechna Doab—5-20% error in ET
- Sri Lanka – 5% error

Most valid for:
1. Large, homogeneous irrigated areas
2. Crops—aerodynamics better understood and uniform
3. Situations where ET is close to PET for "wet pixels...less likely overestimation"

What can we learn? A Hierarchy of certainties

\[\begin{align*}
\text{Certain} & \quad \text{Highly uncertain} \\
\text{Spatial patterns in NDVI, albedo} & \quad \text{Increasing uncertainty} \\
\text{Spatial patterns in relative ET values} & \\
\text{Snapshot comparisons of relative values} & \\
\text{Dry season trends} & \\
\text{Dry season ET, water productivity} & \\
\text{Annual trends} & \\
\text{Annual water balances} & \\
\text{Inter-annual water balances} & \\
\text{Crop production} & \\
\text{Stream flow prediction/modeling} & \\
\end{align*}\]
Conclusions

• SEBAL most useful for spatial distribution of relative ET
• Not plug-and-play for seasonal ET; other methods (crop growth modeling + Penman-Monteith) might prove more robust
• Fairly easy to learn and apply—~10 hours from beginning to end for 1 image
• Needs refining, but what's the alternative?