ECOSTRESS ET Algorithms Overview

Evapotranspiration

- Soil evaporation and vegetation transpiration

Bottom-up: Big leaf model

\[ ET_{leaf} \approx g_s g_g / g_s + g_b (e_{sat} - e_s) \]

\[ g_s = g_{max} (f_{PAR}) f_1 (T_{leaf}) \]
\[ f_2 (\Delta e) f_3 (C_l) f_4 (\psi_s) \]

\[ ET = \int \text{Canopy} \quad ET_{leaf} \]

Under stress conditions, plants close their stomata and leaf temperature increases
ECOSTRESS approaches to mapping ET

Relationship between LST and ET

Evapotranspiration (ET)

Sensible heat (H)

Soil heat (G)

LST

Root zone

Energy balance approach:
Given known radiative energy inputs \( R_n \), how much water loss is required to keep the soil and vegetation at the observed temperatures?

\[
ET = R_n - H - G
\]

with

- \( R_n \) the net radiation
- \( H \) the sensible heat flux
- \( G \) the soil heat flux

LST dependent

\[
R_n = (1 - \text{albedo})R_{sw} - \varepsilon\sigma T_s^4 + \varepsilon R_{LW}
\]

\[
H = \rho C_p \frac{T_s - T_{air}}{r_a}
\]
Outline

• ECOSTRESS ET requirements
• Impact of revisit period on ET
• Impact of LST uncertainties on ET
• Ensemble of ET models for ECOSTRESS:
  - ALEXI from USDA (Two-source Energy balance)
  - METRIC from U. of Idaho (In-scene approach)
  - PT-JPL from JPL (Radiation based model)
Requirements

- From observations: Instantaneous ET (at varying overpass time)
- Standard product: daily ET
- Requirements

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- Ancillary information
  - Meteorological data (Air temperature and humidity, wind speed)
  - Albedo from other missions
    - Landsat 7 & 8: 8-day revisit, 30m resolution
    - ESA/Sentinel 2: two satellites, 5-day revisit, 10 to 60m resolution, launch of first satellite in April 2015
Impact of the revisit period on ET

ECOSTRESS revisit period is 3-5 days. What is the impact on monthly and seasonal fluxes?

• Empirical study based on 21 AmeriFlux sites over contiguous US (2125 months – ~9 years per sites)

• Only clear-sky conditions are considered

• Representativeness of different temporal samplings
Evapotranspiration (ET)

ET - Aurade, France - 2006

- Day/Night every 1/2 hour
Evapotranspiration (ET)

ET - Aurade, France - 2006

- Day/Night every 1/2 hour
- 1:00PM

ET (W m⁻²)

Day of Experiment
Evapotranspiration (ET)

ET - Aurade, France - 2006

ET (W m-2)

Day of Experiment

1:00PM
1:00PM clear days
Evapotranspiration (ET)
Evapotranspiration (ET)
Evapotranspiration (ET)

ET - Aurade, France - 2006

- 1:00PM
- 1:00PM, 16-day revisit
Impact of the revisit period on ET

Seasonal 13:00 ET RMSE (1-D revisit dataset as reference)

Relative

Absolute

Differences with 1-D revisit (control dataset) are twice as large for a 16-day than a 4-day revisit period
Impact of the revisit period

Seasonal ET RMSE (1-D revisit dataset as reference)

- Lowest differences for cropland and needleleaf forests (lower temporal variability)
- Similar differences at 10AM and 1PM – except for savannah
ET sensitivity to LST uncertainty

1. LST estimated from up and down-welling LW radiation
2. $R_n$ and H calculated for LST + $\Delta$LST
3. $\Delta$ET estimated using energy balance equation

Different overpass times

Different surface types

If LST meets requirements $\Rightarrow$ ET meets requirements
ECOSTRESS ensemble of ET models

ECOSTRESS is gathering ET models that are commonly used for research and operational applications

The ensemble of model simulations is used to:

- Provide the best estimates of ET for a wide range of land cover types and climates
  - ALEXI and METRIC were initially developed for managed landscape
  - PT-JPL is more used for natural ecosystems

- Evaluate the uncertainties on ET due to model physics and model parameterizations – ECOSTRESS standard ET product could be a weighting average of outputs from different models
ALEXI - The Atmosphere Land-Exchange Inverse model
Co-I: Martha C. Anderson (USDA)

Step 1: ET at 5km resolution
Coupling surface energy with ABL model to simulate air temperature $T_a$ at 50m

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

with

$H = \rho C_p \frac{T_s - T_{\text{air}}}{r_a}$

Step 2: ET at high spatial resolution
Downscaling ET at high resolution from step 1 using high resolution LST and VNIR
ALEXI – Advantage and applications

Applications of ALEXI

- Crop water use
- Crop phenology monitoring
- Drought early warning (water stress detection)

The Evaporative Stress Index from ALEXI is part of the National Integrated Drought Information System (NIDIS)
METRIC — Mapping ET with high Resolution and Internalized Calibration
Co-I: Rick G. Allen (U. of Idaho)

METRIC uses the in-scene information and ground reference from weather stations

\[
ET = R_n - H - G = \Delta T
\]

with \( H = \rho C_p \frac{T_s - T_{air}}{r_a} \)

Assumption:

\( \Delta T = a T_s + b \)

with \( a, b \) are in-scene empirical coefficients calculated from energy balance applied to:

- “hot” pixel where \( ET = 0 \)
- “cold” pixel where \( ET = 1.05 \times \text{potential ET} \)

Designed for relatively small agricultural regions (100x100 miles)

Each image provides internal and automatic calibration
METRIC – Advantage and applications

Operational applications of METRIC in Idaho:
• Quantify net depletion from ground water pumping
• Compare actual ET with water right
• Calculate natural and irrigation-induced recharge to aquifers
• Monitor crop phenology

Dedicated for high resolution imagery, METRIC is used by more western states.
PT-JPL — Priestley and Taylor approach
Co-I: Joshua B. Fisher (JPL)

\[
ET_{canopy} = \left( f_g f_T f_M \right) \alpha \frac{\Delta}{\Delta + \gamma} R_{nc}
\]

**bio-physiological constraints** due to light, temperature and water stress limitations

**potential ET** represents the atmospheric moisture demand

with

\[
R_{nc} = (1 - \text{albedo})R_{SW} - \epsilon \sigma T_s^4 + \epsilon R_{LW}
\]

the canopy net radiation

- \(R_{SW}, R_{LW}\) the shortwave and longwave incoming radiation
- \(\Delta = \frac{de_d}{dT}\) the slope of the saturation water vapor function
- \(\gamma, \sigma\) the psychrometric constant and the Steffan-Boltzmann
- \(\alpha\) the Priestley-Taylor coefficient = 1.26 (empirical value)
- \(\epsilon\) the surface emissivity
PT-JPL – Advantage and applications

PT-JPL has shown the best performance in simulating daily to monthly ET average in recent model comparison studies

PT-JPL is used to derive ET at various spatial resolutions:
- Global scale (MODIS)
- Field scale (Landsat)
Conclusion

• Next step will be focused on model uncertainty estimates and model intercomparison

• A detailed description of the models and the validation procedure of the ECOSTRESS ET product are coming after the break...