AGU FALL MEETING

AGU Fall Meeting 2007

Near Real Time Evapotranspiration Estimation Using Remote Sensing Data

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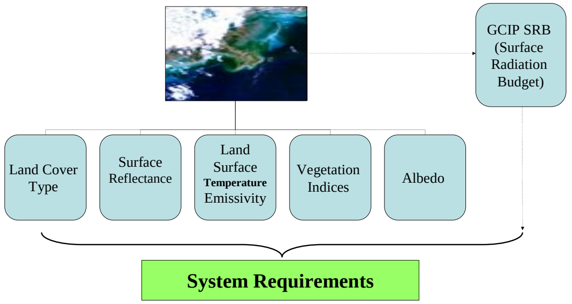
❶ Background

Measurement of evapotranspiration (ET) is important to water management as irrigation is by far the largest consumptive use of water, both globally and in the western U.S. Nonetheless, most water management models are based on water allocations, and not on actual (measured) water use, in part because direct observations of irrigation water use are difficult to obtain. For instance, traditional methods of estimating ET typically provide potential or reference ET at points, rather than spatial information about actual ET,

Satellite remote sensing is a promising tool for estimating the spatial distribution of ET at regional (and larger) scales. Different methods have been developed to use satellite remote sensing data in surface flux estimation schemes. However, most existing schemes for ET estimation require ground observations that may be difficult to obtain at large scales. There remain open questions as to the ability of satellite remote sensing to provide large area ET estimates independent of ground observations.

❷ Objective

The objective of this study is to map the spatial distribution of near real time ET over large areas using remote sensing data (without in situ data) and to evaluate the potential for use of the standard MODIS ET algorithm (*Nishida, K., et al., 2003*) for possible use to estimate agricultural water use in real-time for irrigated areas.



GCIP SRB (Surface Radiation Budget)

Land Cover Type

Surface Reflectance

Land Surface Temperature Emissivity

Vegetation Indices

Albedo

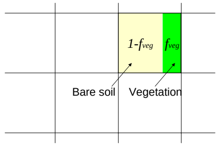
System Requirements

- **Critical model input and parameters must be available in near real-time (~1 day lag).**
- **The algorithm must be robust. ET estimations are constrained by energy and mass conservation and have relatively lower sensitivity to input data errors.**
- **The algorithm must be insensitive to constraints imposed by the twice-daily overpass of the satellite and cloud screening.**

❸ Methodology

Linear Two-Source Model (from *Nishida et al, 2003*)

- The landscape is simplified as a mixture of vegetation and bare soil.
- The proportion of vegetation, f_{veg} whose value is between 0 and 1, is related to normalized difference vegetation index (NDVI).



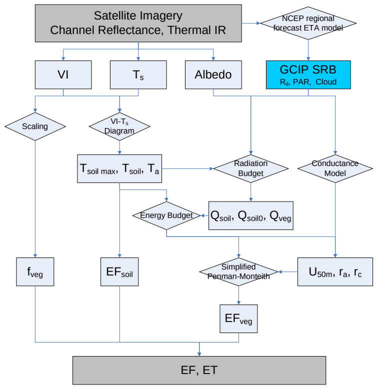
$$NDVI = \frac{R_{nir} - R_{red}}{R_{nir} + R_{red}}$$

$$f_{veg} = (NDVI - NDVI_{min}) \big/ (NDVI_{max} - NDVI_{min})$$

$$ET = f_{veg} ET_{veg} + (1 - f_{veg}) ET_{soil}$$

Algorithm – our implementation

- A combination of vegetation index and surface temperature (T_s), known as the VI-T_s diagram method, is used.
- Evaporation Fraction (EF) is estimated using remote sensing data and scaled to get daily ET.



Satellite Imagery
Channel Reflectance, Thermal IR

NCEP regional forecast ETA model

VI

T_s

Albedo

GCIP SRB
R_d, PAR, Cloud

Scaling

VI-T_s Diagram

$T_{soil\ max}$, T_{soil}, T_a

Radiation Budget

Conductance Model

Energy Budget

Q_{soil}, Q_{soil0}, Q_{veg}

f_{veg}

EF_{soil}

Simplified Penman-Monteith

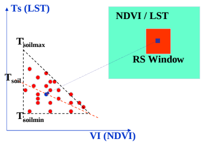
U_{50m}, r_a, r_c

EF_{veg}

EF, ET

VI: Vegetation Index; T_s: surface radiant temperature; $T_{soil\ max}$: highest soil temperature; T_{soil}: soil temperature; T_a: air temperature; f_{veg}: fractional vegetation cover; Q: available energy; Rd: incoming shortwave radiation; PAR: photosynthetic active radiation; U_{50m}: wind speed; r_a: aerodynamic resistance; r_c: surface resistance of the vegetation canopy; EF=ET/Q.

Nishida, K., et al., 2003.



$$ET_{veg} = \frac{\alpha\Delta}{\Delta + \gamma(1 + r_c/r_a)}$$

$$r_c = f_1(T_a) f_2(PAR) f_3(VPD) f_4(\psi) f_1(CO_2) / r_{cMIN} + 1/r_{cuicle}$$

$$1/r_a = 0.008U_{50m} \quad \text{for forest canopy}$$

$$1/r_a = 0.003U_{1m} \quad \text{for grassland and cropland}$$

$$EF_{soil} = \frac{T_{soil\ max} - T_{soil}}{T_{soil\ max} - T_a} \frac{Q_{soil0}}{Q_{soil}}$$

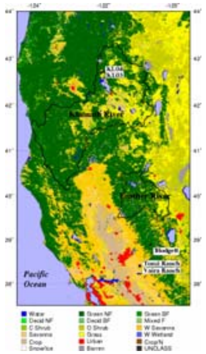
Nemani, R., et al., 1993.

Key Features of the ET Estimation System

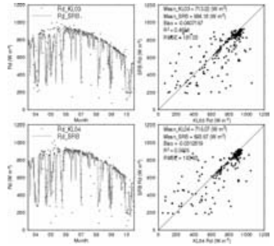
- Estimates actual ET and does not require ground weather observations.
- Combines currently available remote sensing products (MODIS and NOAA SRB) and makes the process operational in near real-time.

❹ Implementation and Evaluation

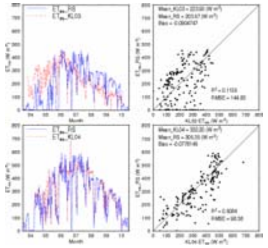
Our study area is the western United States domain of (124.5W, 119.5W, 37.5N, 44N). Test tower flux sites at Blodgett Forest, Vaira Ranch and Tonzi Ranch (AmeriFlux) and Klamath River Basin (courtesy Richard Cuenca) are used.



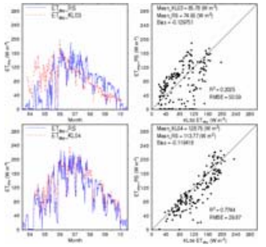
Westwide United States ET estimation
Spatial: 0.0025 degree (~250m);
Time step: daily;
Time lag: about 3 days;
Calibration and validation (2004)



Incoming shortwave radiation (2004)
GCIP SRB product vs KL03/KL04

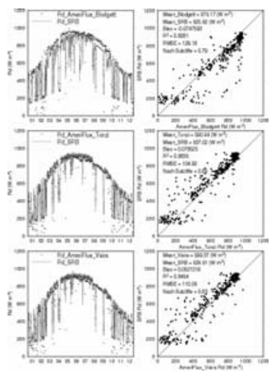


Instantaneous ET (ET_{ins}, 2004)
Remote Sensing Algorithm vs OBS

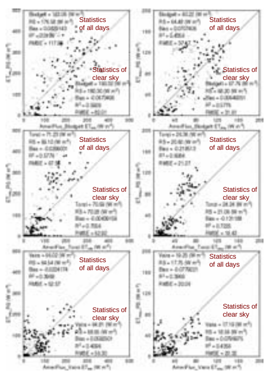


Daily ET (ET_{day}, 2004)
Remote Sensing Algorithm vs OBS

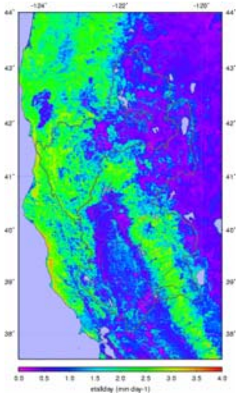
FLuxes data at KL03 (unirrigated) and KL04 (irrigated) in Klamath River basin are courtesy Professor Richard Cuenca, Oregon State University



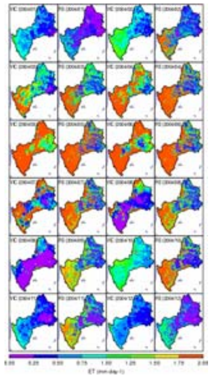
Incoming shortwave radiation (2004)
GCIP SRB product vs AmeriFlux



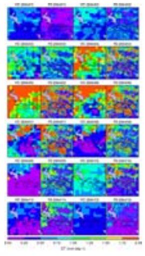
ET_{ins} and ET_{day} (2004)
Remote Sensing Algorithm vs AmeriFlux

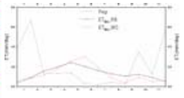


Annual Remote sensing ET (2004)

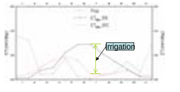


Monthly ET (Klamath, 2004)
Remote sensing vs VIC 1/16 º



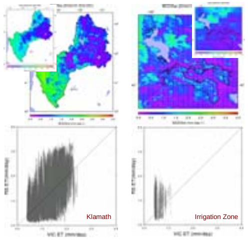


Monthly ET (Klamath, 2004)
Remote sensing vs VIC 1/8 º



Monthly ET (Irrigation, 2004)
Remote sensing vs VIC 1/16 º

Annual mean ET (RS vs VIC, 2004)



Acknowledgement

We are grateful to Professor Richard Cuenca, Department of Biological & Ecological Engineering, Oregon State University who provided flux observations at sites KL03/KL04 in the Klamath River Basin.

http://www.hydro.washington.edu/forecast/rset_ca/

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❺ **References** *Nishida, K., R. R. Nemani, S. W. Running, and J. M. Glassy (2003), An operational remote sensing algorithm of land surface evaporation, J. Geophys. Res., 108(D9), 4270, doi:10.1029/2002JD002062. Nemani, R., L. Pierce, S. Running, and S. Goward, 1993: Developing Satellite-derived Estimates of Surface Moisture Status. J. Appl. Meteor., 32, 548–557. MODIS products: http://edcdaac.usgs.gov/modis/dataproducts.asp. AmeriFlux Data: http://public.ornl.gov/ameriflux/ . Liang, X., D. P. Lettenmaier, E. F. Wood, and S. J. Burges, A Simple hydrologically Based Model of Land Surface Water and Energy Fluxes for GCMs, J. Geophys. Res., 99(D7), 14,415-14,428, 1994.*