Mapping quantities of surface radiation budget from AVIRIS and MASTER data

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• The land surface responds to climate variability and also modulates the climate through the exchange of energy, matter and momentum.

• Funded by the NASA HyspIRI program, we have developed algorithms to estimate a series of surface radiation budget components from the airborne AVIRIS and MASTER data.
Objectives

Quantification of the variations in land surface radiation and energy budget over different land cover types in response of climate variability from the AVIRIS and MASTER data to support the development of the HyspIRI mission.

1. Mapping the surface radiation and energy budget components from both AVIRIS and MASTER data.
   - Algorithm development/refinement
   - Algorithm and data validation
   - Mapping of surface radiation and energy budget components

2. Quantifying the variations in surface energy budget of different surface types.
   - Mapping land cover types from AVIRIS and MASTER data
   - Assessing variations in those surface radiation and energy budget components of different cover types under various climate conditions
   - Addressing a set of scientific questions using these datasets

NASA Grant, Characterizing land surface energy budget under varying climatic conditions from the AVIRIS and MASTER data, Program Manager: Woody Turner, 2012-2015
\[ R_n = R_n^s + R_n^l = (1 - \alpha) F_d^s + F_d^l - \sigma \varepsilon T^4 \]

Net radiation

albedo

Insolation

Emissivity

Longwave downward radiation

Skin temperature

Radiation budget

Energy budget

\[ R_n = H + ET + G \]

Heating the air

Moisturizing the air

Heating the ground
Inter-comparison of 30-year global albedo climatology derived from satellite products and CMIP5 model outputs.

Land surface albedo trend in the past decades

Trends in January albedo (per decade):
- GLASS: 0.0029***
- GEWEX: 0.0047
- ISCCP: N/A
- CLARA-SAL: 0.0002

Trends in July albedo (per decade):
- GLASS: -0.0013***
- GEWEX: -0.0053
- ISCCP: -0.0086***
- CLARA-SAL: N/A

Long-term trend in surface albedo over the Northern Hemisphere

(He, et al., 2014. JGR)
Direct estimation of surface albedo


Validation results of 16-day mean albedo from VIIRS BRDF LUT (left), and MODIS (right), using data from 2012 non-snow seasons (May-September) at seven SURFRAD sites.

Flowchart of albedo estimation from AVIRIS data
Spectral vs. angular information in broadband albedo direct estimation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
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<tbody>
<tr>
<td>View zenith angle (°)</td>
<td></td>
</tr>
<tr>
<td>RMSE</td>
<td>0.0155 0.0100 0.0091 0.0104 0.0147</td>
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<tr>
<td>$R^2$</td>
<td>0.9181 0.9505 0.9493 0.9261 0.8596</td>
</tr>
</tbody>
</table>

Hyperspectral information is MORE important than angular information in surface broadband albedo estimation for snow-free surfaces

He, T., S. Liang, D. Wang, and Q. Shi, (2014). Estimation of high-resolution land surface shortwave albedo from AVIRIS data. *IEEE JSTARS, in press*
Validation of AVIRIS albedo estimates

Validation of surface shortwave albedos at sites from (a) AmeriFlux network and (b) UCI network

He et al. 2013; He et al. 2014
Mapping surface albedo: AVIRIS vs. Landsat

Shortwave albedo estimations from:
(a) Landsat TM on Aug 18\textsuperscript{th}, 2010;
(b) AVIRIS on Aug 26\textsuperscript{th}, 2010 using the stepwise regression algorithm; and (c) scatter plot. Image is centered at 43.08°N, 89.41°W in Madison, WI, USA.

He et al. 2013
Estimation of shortwave net radiation

Algorithm refinement for Landsat data

Comparison between instantaneous and daily SSNR (in W/m²) using the method of water vapor correction and in situ measurements at six AmeriFlux sites from 2003-2005.

Estimating shortwave net radiation from AVIRIS

He, T., S. Liang, D. Wang, Q. Shi, and M. Goulden. Estimation of high-resolution land surface net shortwave radiation from AVIRIS data: Algorithm development and preliminary results submitted to RSE
Advantages of hyperspectral information in net shortwave radiation estimation

Statistics of NSR direct estimation based on simulation data

<table>
<thead>
<tr>
<th>RMSE (W/m²)</th>
<th>Solar zenith angle (°)</th>
<th>20</th>
<th>25</th>
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<th>35</th>
<th>40</th>
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<td>View 5</td>
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<td>0.963</td>
<td>0.957</td>
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</tr>
</tbody>
</table>

Conversion of cumulated radiation from AVIRIS bands to shortwave radiation (W/m²)

Method A
Method B

AVIRIS Band Estimation

y = 1.0311x - 4.2724
AVIRIS water vapor estimation has an overestimation compared with MODIS product. Net radiation estimation W/m² is more accurate using AVIRIS-derived water vapor.

Impacts of water vapor estimation uncertainty on AVIRIS shortwave net radiation direct estimation (He et al. 2014, RSE)
Comparison of ground measurements AVIRIS downward radiation (a) and net radiation from Method A (b) and Method B (c) estimates (W/m²) at AmeriFlux sites.

Two methods had similar estimation accuracies. N is smaller in (b) than that in (c) because surface albedo estimates were not available under cloud/shadow conditions.
Combined VSWIR and TIR to estimate clear-sky all-wave net radiation

• Previous methods to estimate all-wave net radiation
  – Component-based, summation of all the components
    • VSWIR: shortwave fluxes
    • TIR: long wave fluxes
  – Errors add up

• New method:
  – Combine VSWIR and TIR data to directly estimate all-wave net radiation as one integral quantity.

Validation: net radiation

- Seven SURFRAD stations.
- One year measurements.
Map from MASTER data

R²=0.70
RMSE=28.2
Bias=7.4
Conclusions

• Hyperspectral AVIRIS data can be used for estimating land surface shortwave albedo and net radiation accurately.
• Clear-sky all-wave net radiation can be directly estimated with improved accuracy from the synergic use of VSWIR and TIR data.
• More validations are needed for algorithm refinement and improvement.