Mapping land surface radiation and energy budget from the AVIRIS and MASTER data

Dongdong Wang, Shunlin Liang, Tao He, Qinqing Shi

Department of Geographical Sciences

University of Maryland, College Park

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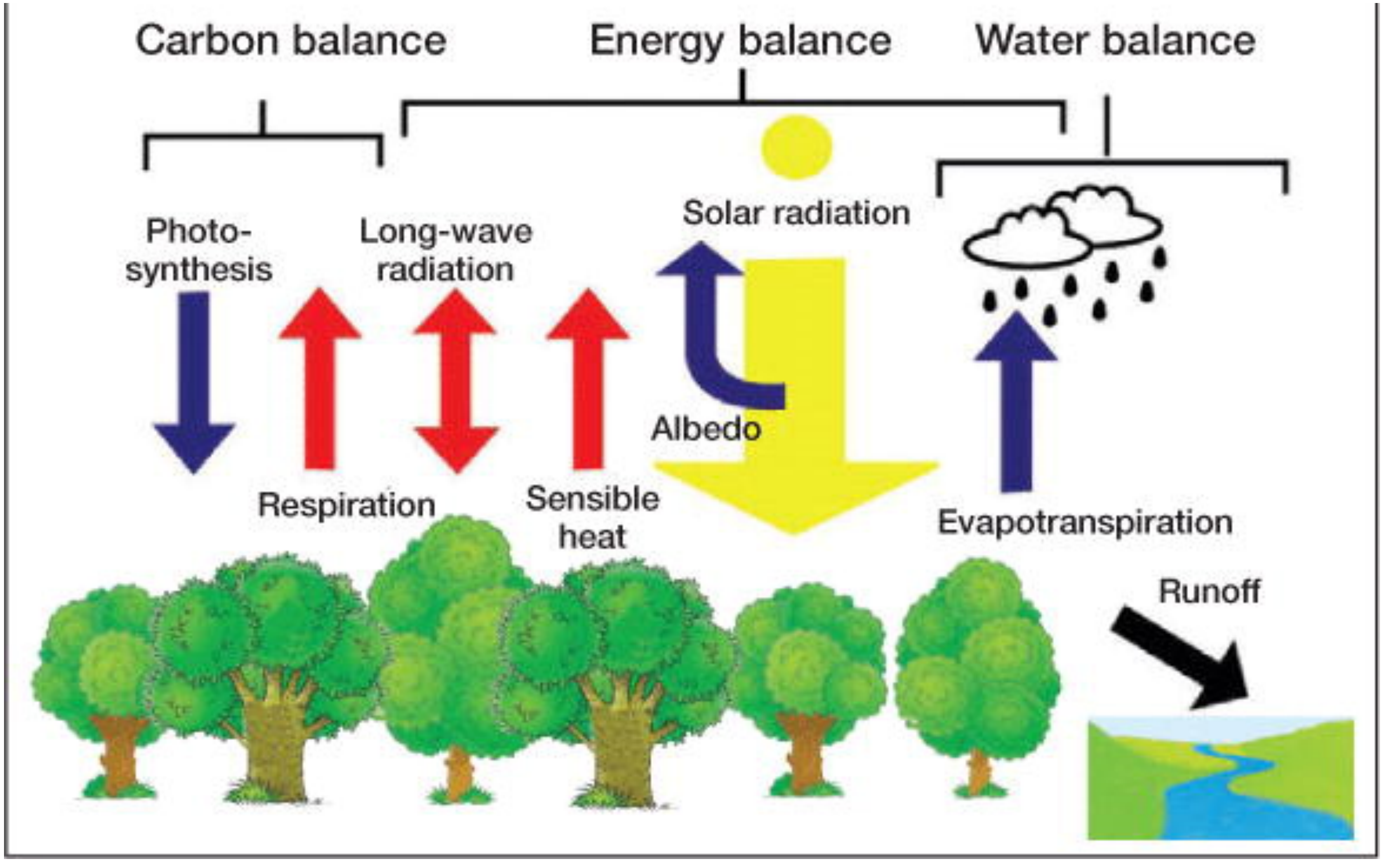


Chapin et al. 2008

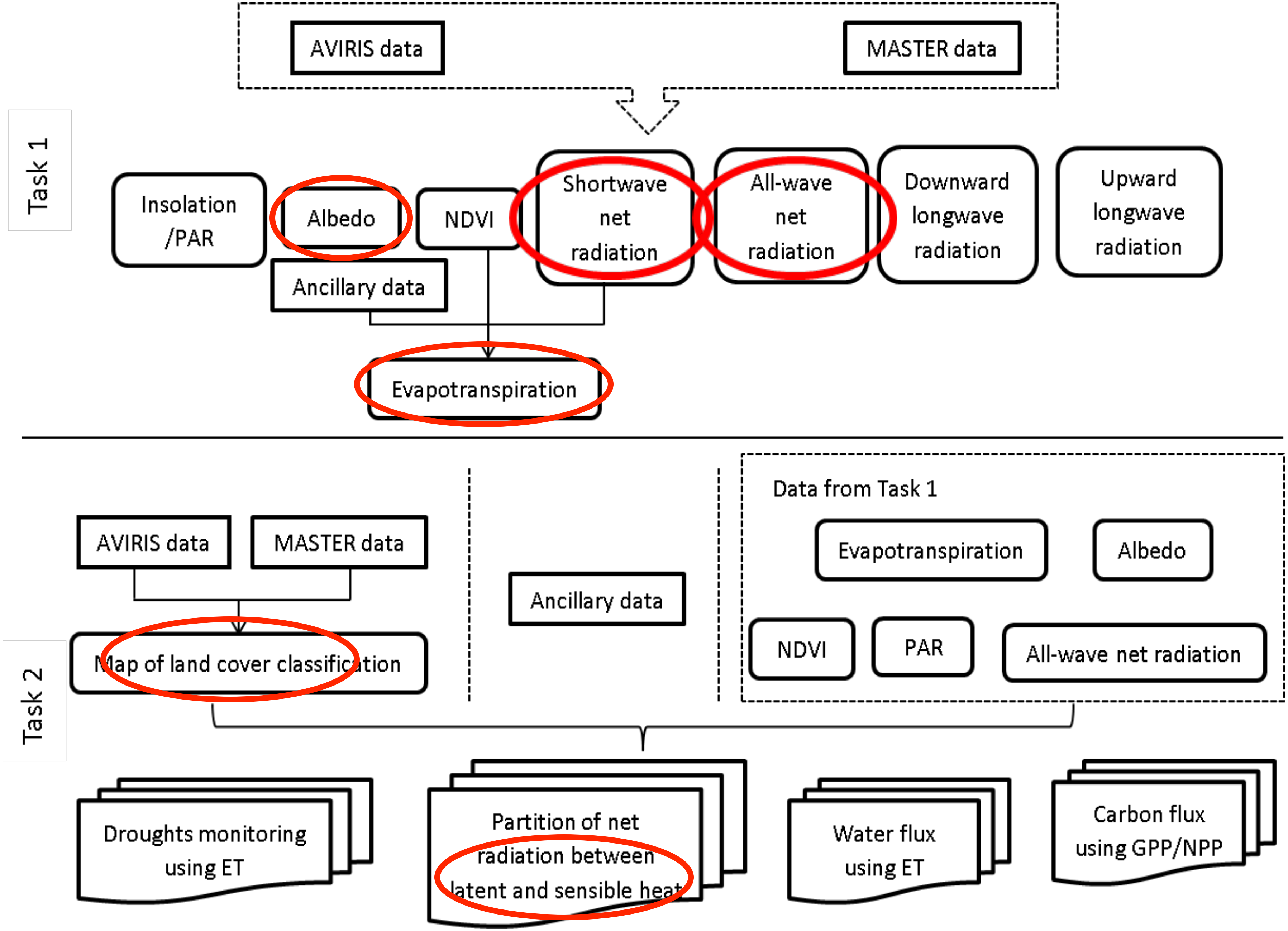
- The land surface responds to climate variability and also modulates the climate through the exchange of energy, matter and momentum.
- Funded by the NASA HyspIRI program, we have developed algorithms to estimate a series of surface radiation budget components from the airborne AVIRIS and MASTER data.

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


AVIRIS data
MASTER data
Task 1
Insolation /PAR
Albedo
NDVI
Shortwave net radiation
All-wave net radiation
Downward longwave radiation
Upward longwave radiation
Ancillary data
Evapotranspiration
Task 2
AVIRIS data
MASTER data
Map of land cover classification
Ancillary data
Data from Task 1
Evapotranspiration
Albedo
NDVI
PAR
All-wave net radiation
Droughts monitoring using ET
Partition of net radiation between latent and sensible heat
Water flux using ET
Carbon flux using GPP/NPP

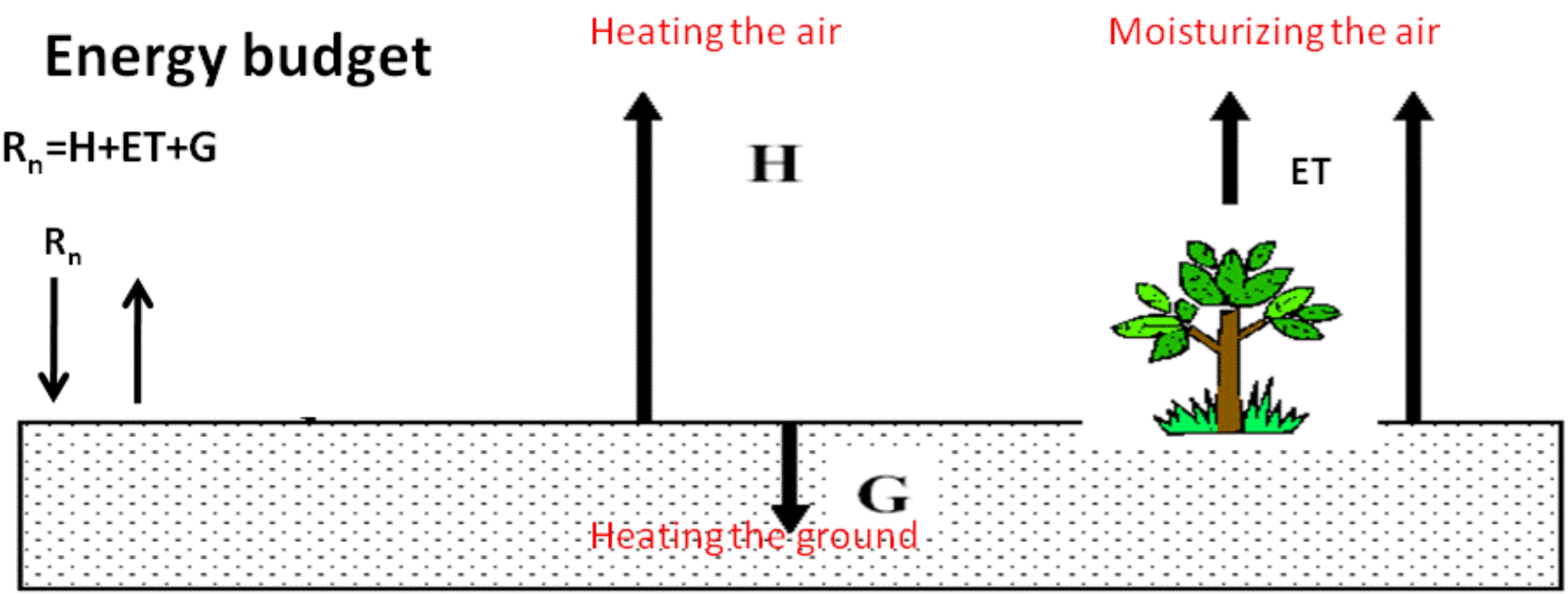
$$R_n = R_n^s + R_n^l = (1-\alpha)F_d^s + F_d^l - \sigma\varepsilon T^4$$

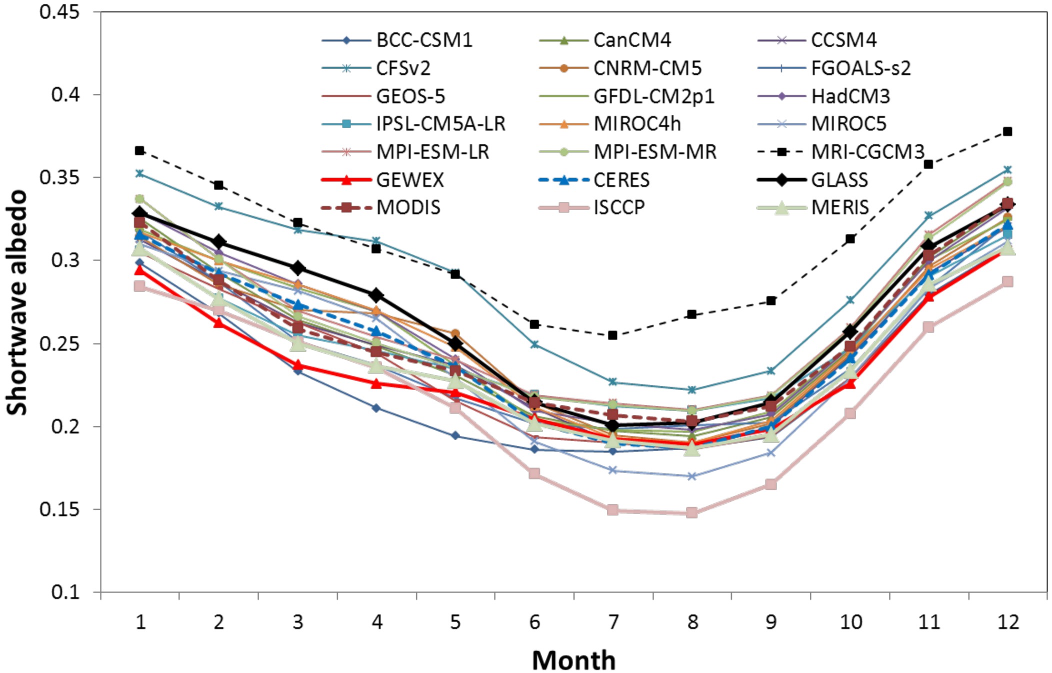
- R_n: Net radiation
- α: albedo
- F_d^s: Insolation
- F_d^l: Longwave downward radiation
- ε: Emissivity
- T: Skin temperature

Radiation budget

Energy budget

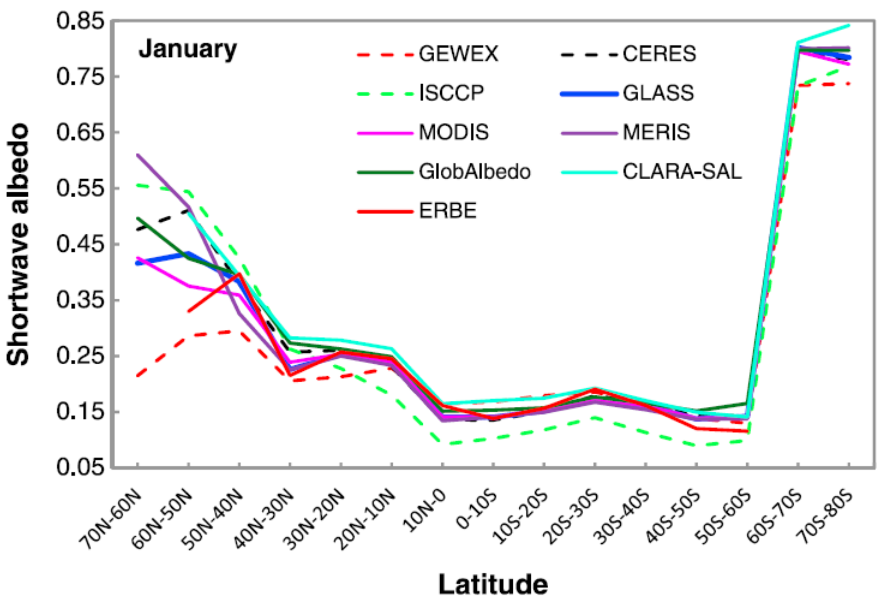
R_n=H+ET+G

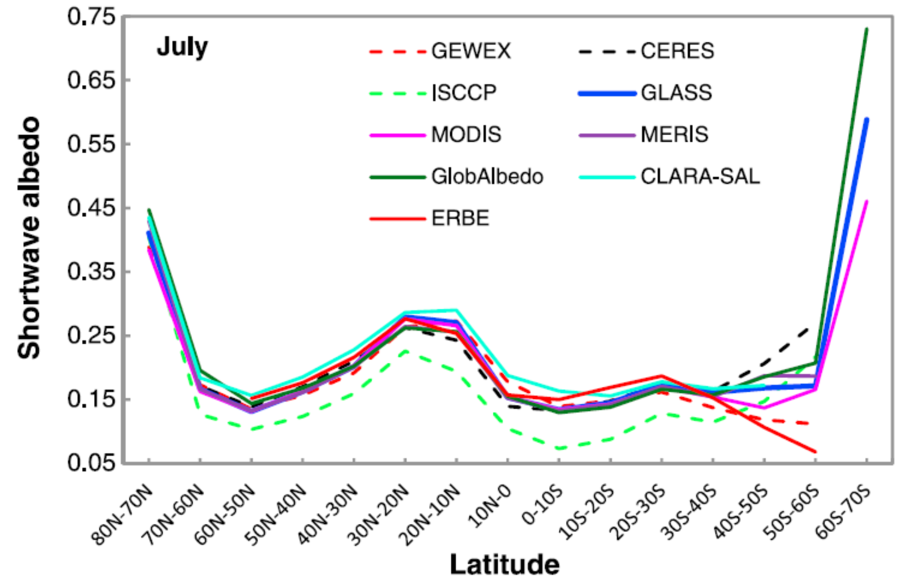




Inter-comparison of 30-year global albedo climatology derived from satellite products and CMIP5 model outputs.

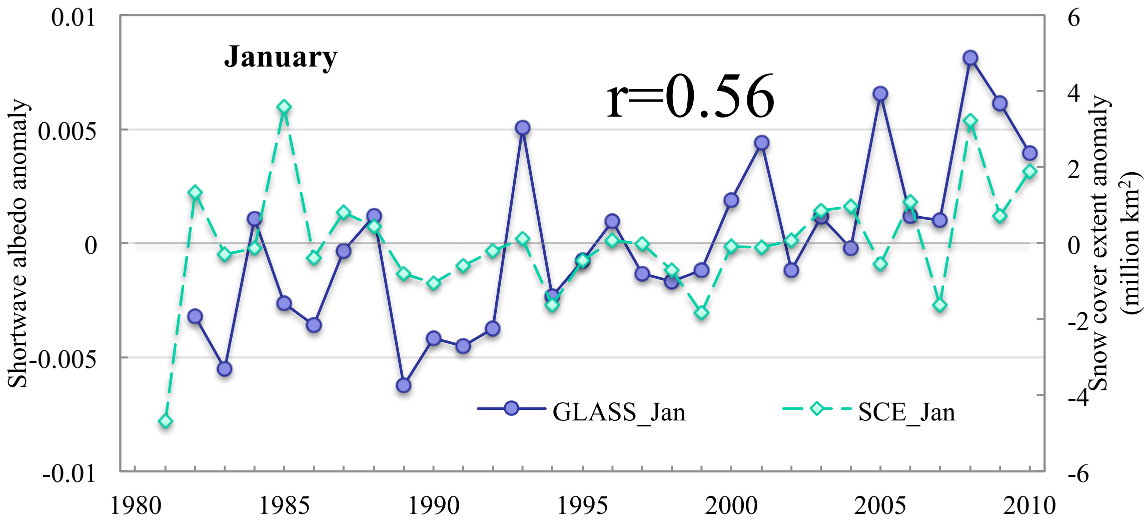
Model mean: 0.21
Standard dev.: 0.02
MODIS: 0.24



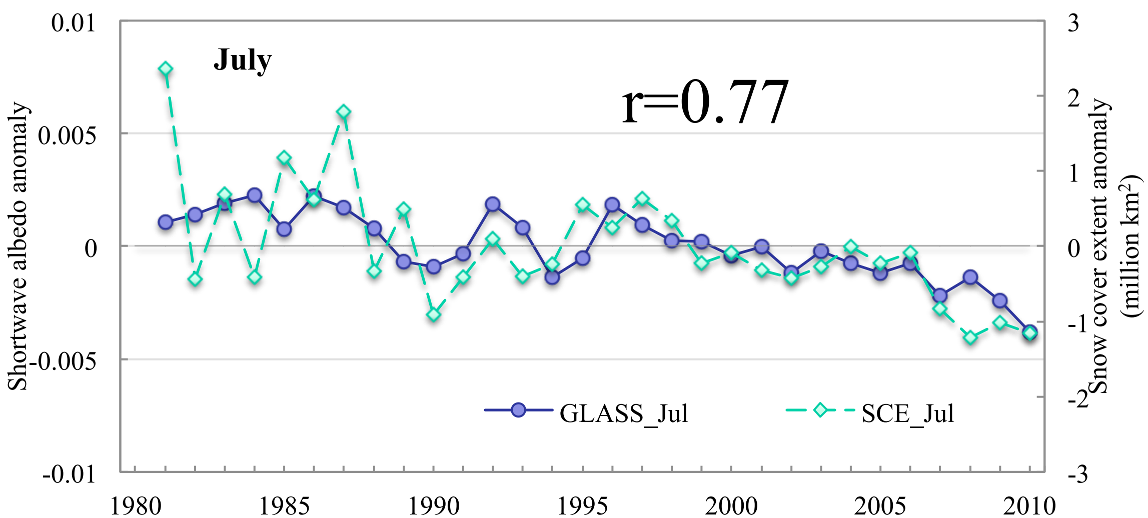


He, et al, (*2014*). Analysis of global land surface albedo climatology and spatial-temporal variation during 1981-2010 from multiple satellite products. *Journal of Geophysical Research: Atmospheres, 119, 10281-10298*

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)

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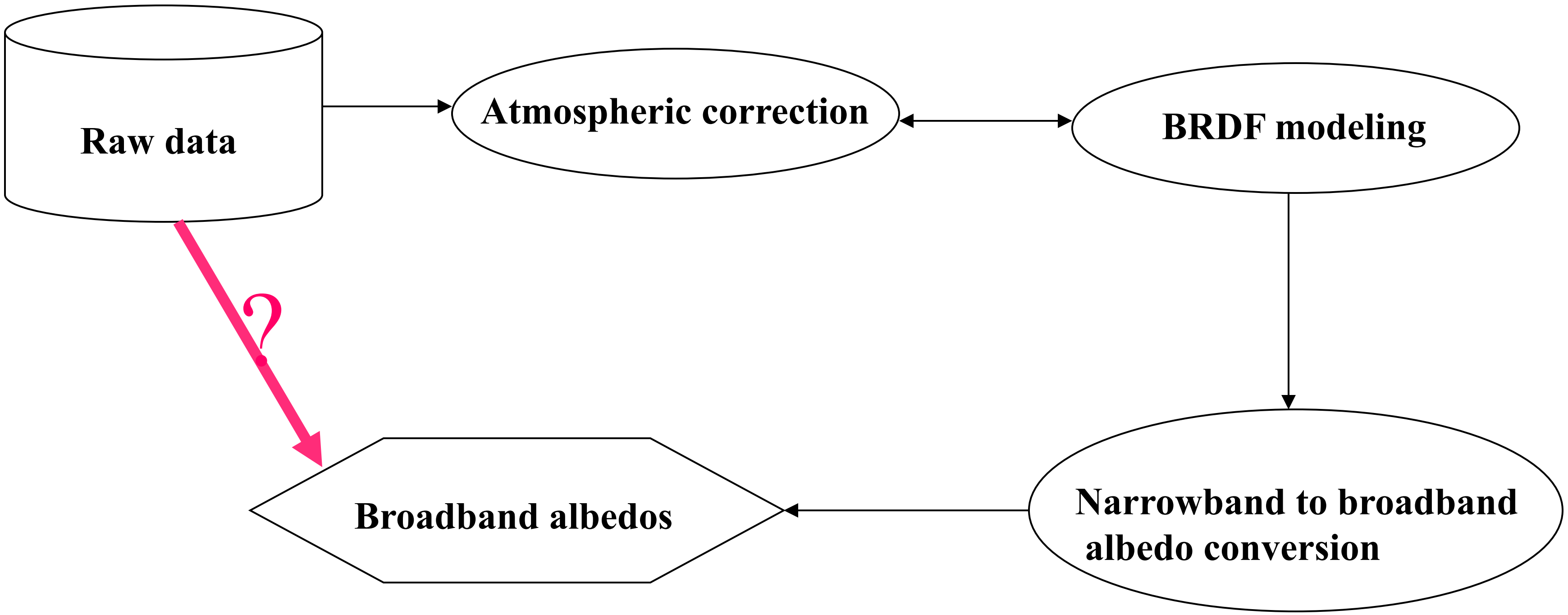
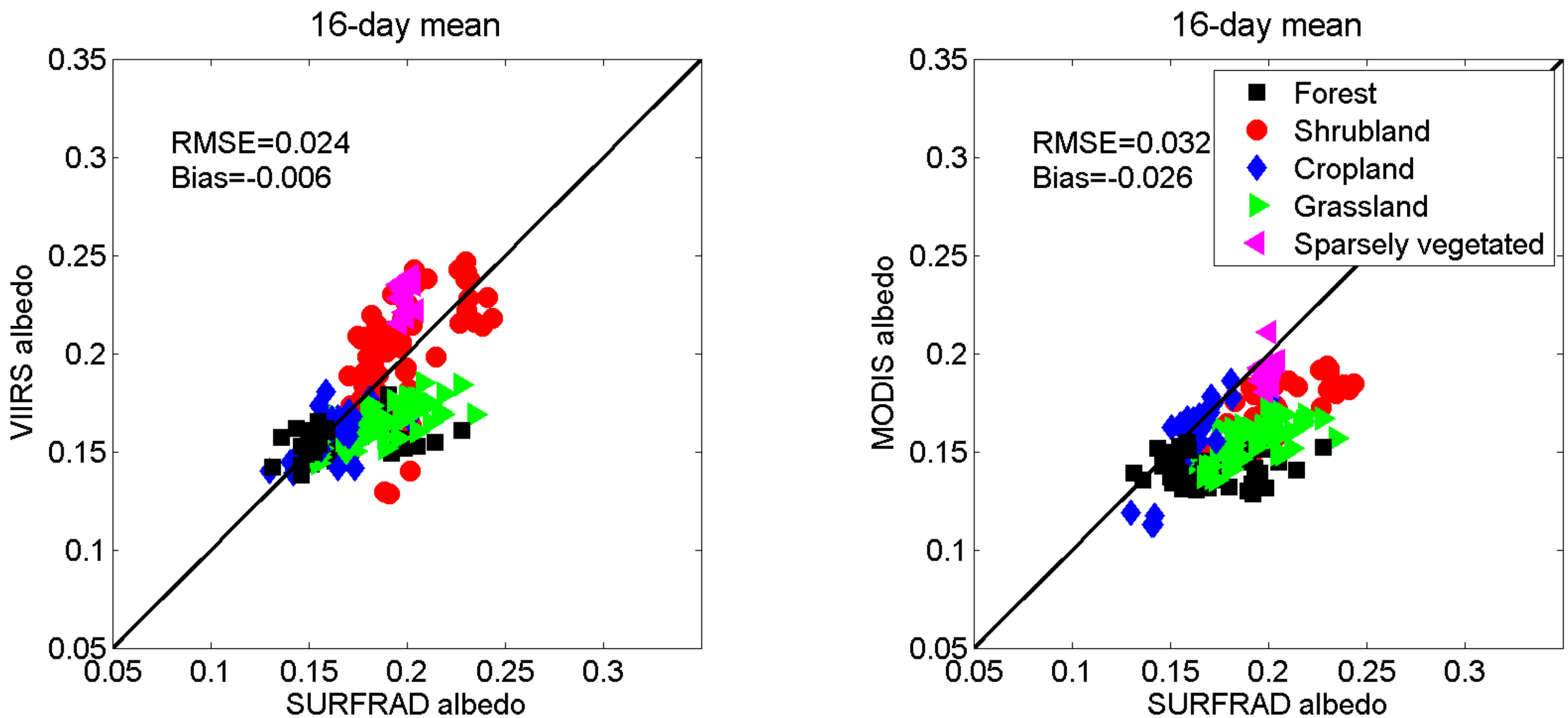
Direct estimation of surface albedo



Liang, S., (2003), A direct algorithm for estimating land surface broadband albedos from MODIS imagery, *IEEE Trans. Geosci. Remote Sen.*, 41(1):136-145;

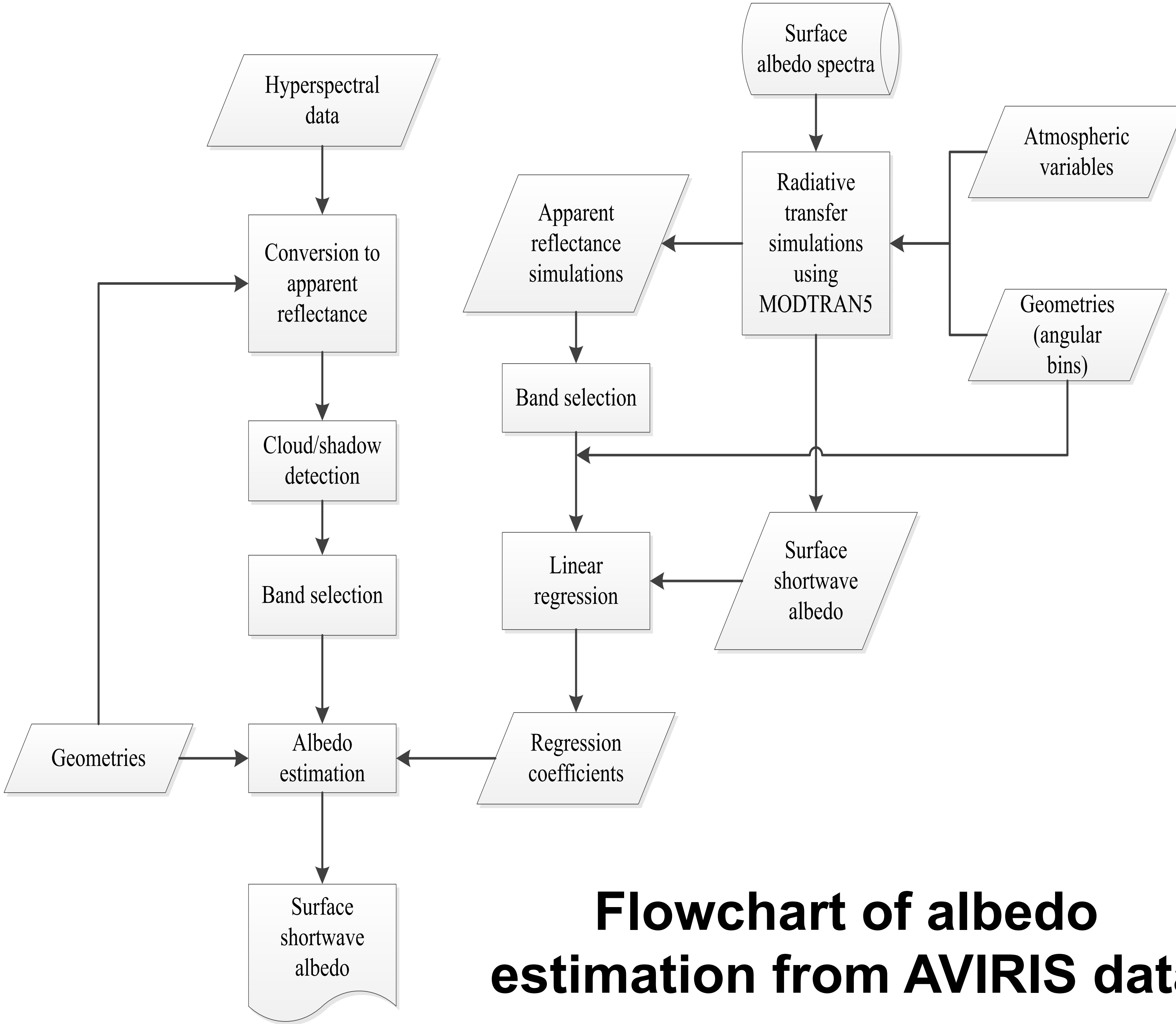
Liang, S., J. Stroeve and J. Box, (2005), Mapping daily snow shortwave broadband albedo from MODIS: The improved direct estimation algorithm and validation, *Journal of Geophysical Research.* 110 (D10): Art. No. D10109.

VIIRS shortwave albedo product



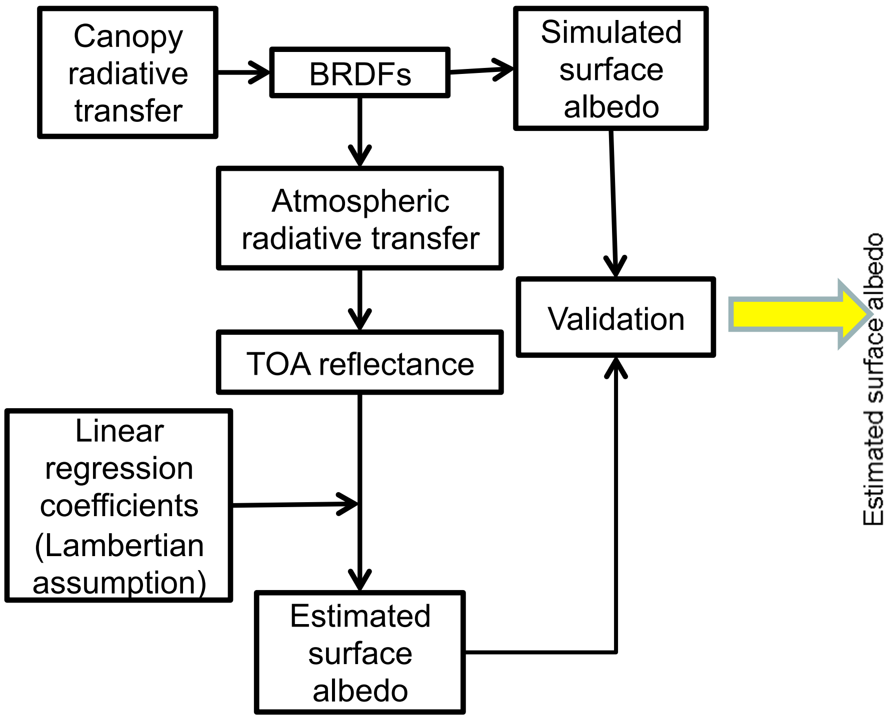
Validation results of 16-day mean albedo from VIIRS BRDF LUT (left), and MODIS (right), using data from 2012 non-snow seasons (May-September) at seven SURFRAD sites.

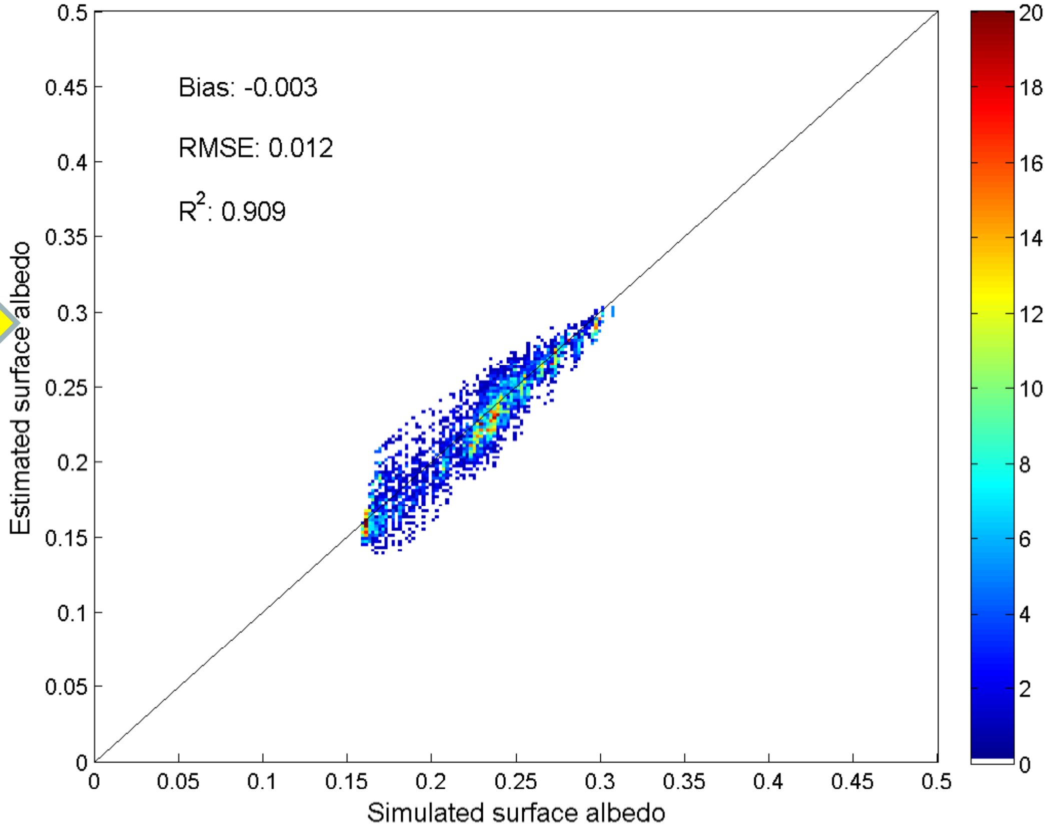
Wang, D., Liang, S., He, T., Yu, Y. 2013. Direct Estimation of Land Surface Albedo from VIIRS Data: Algorithm Improvement and Preliminary Validation. *JGR-Atmosphere*. *118*, 12577-12586, doi: 10.1002/2013jd020417.



Flowchart of albedo estimation from AVIRIS data

Spectral vs. angular information in broadband albedo direct estimation





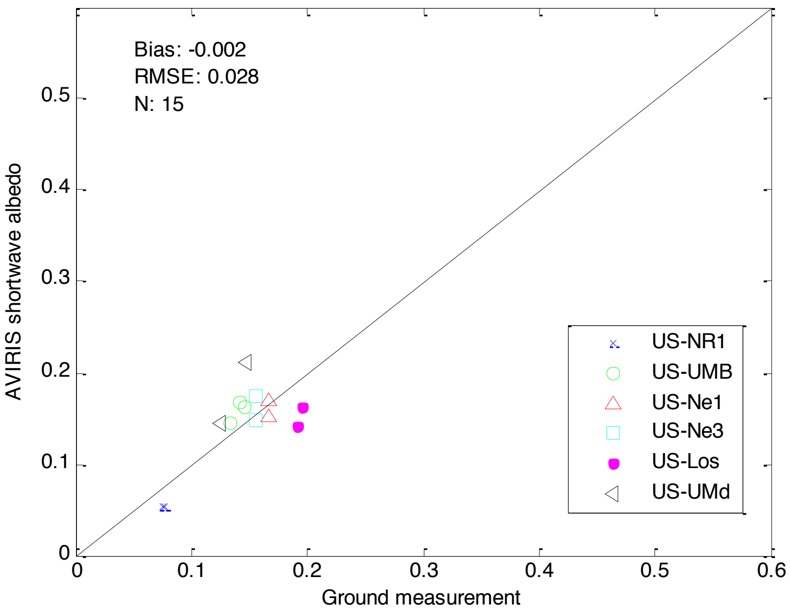
Hyperspectral information is MORE important than angular information in surface broadband albedo estimation for snow-free surfaces

Albedo estimation accuracy and view zenith angle (solar zenith angle=35°)

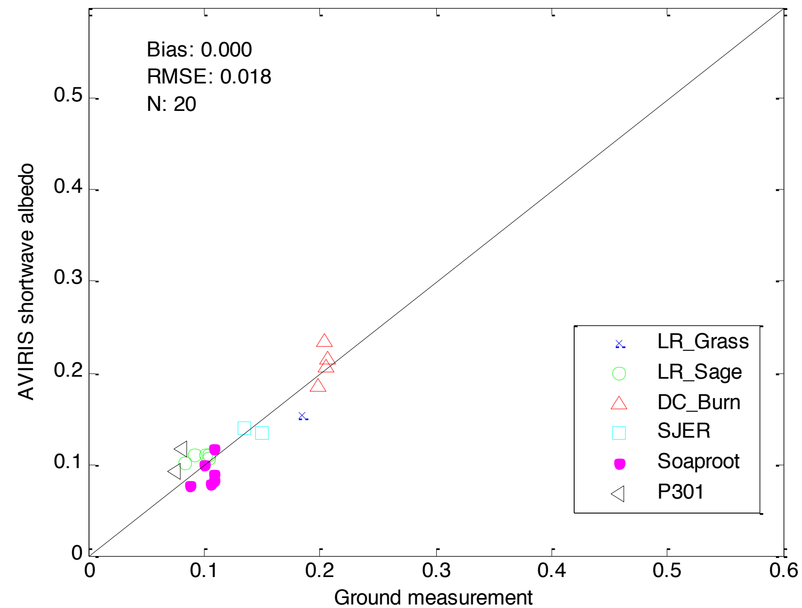
Variable	Value				
View zenith angle (°)	0	15	30	45	60
RMSE	0.0155	0.0100	0.0091	0.0104	0.0147
R^2	0.9181	0.9505	0.9493	0.9261	0.8596

He, T., S. Liang, D. Wang, and Q. Shi, (2014). Estimation of high-resolution land surface shortwave albedo from AVIRIS data. *IEEE JSTARS, 7*, 4919-4928

Validation of AVIRIS albedo estimates



(a)



(b)

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

He et al. 2013; He et al. 2014

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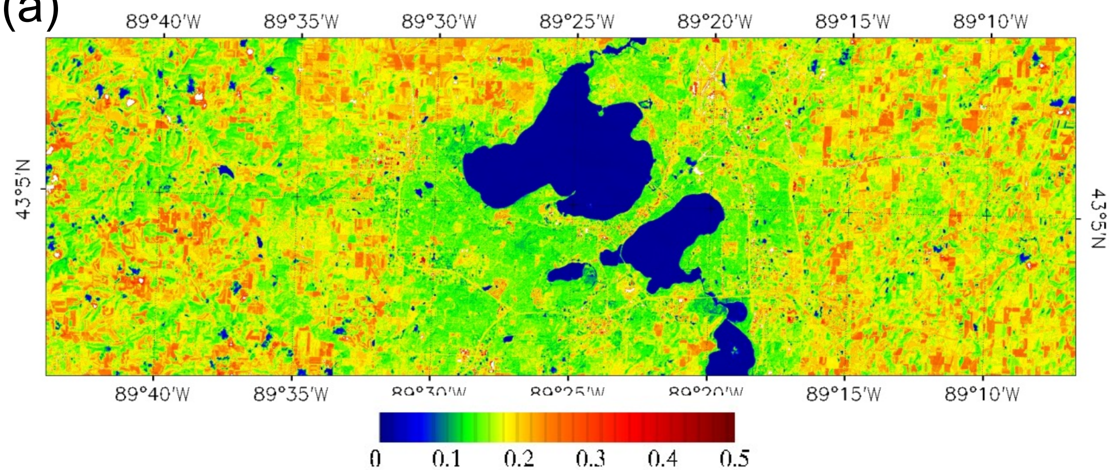
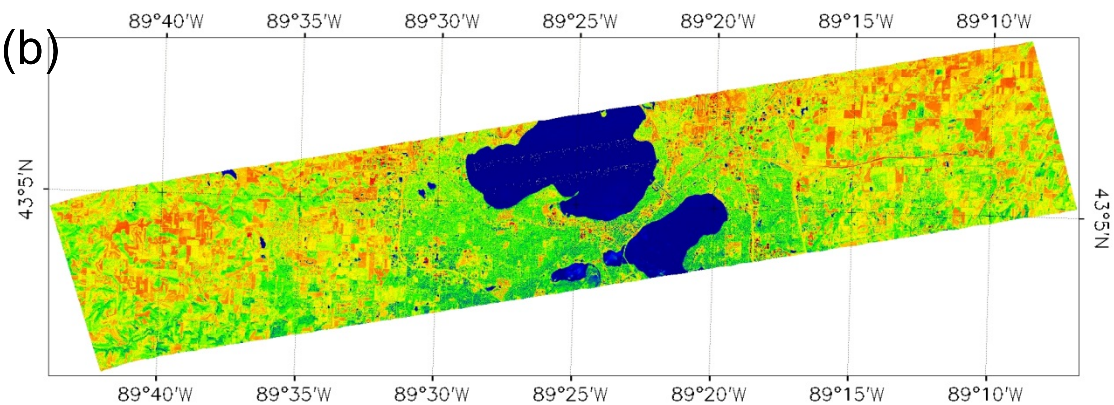
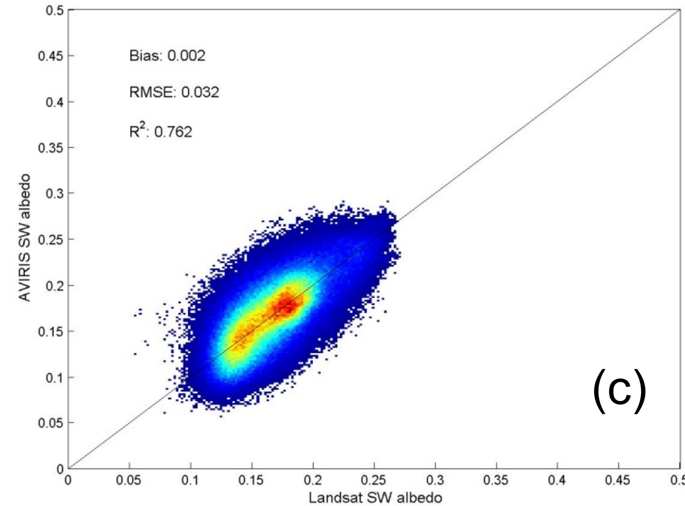
Mapping surface albedo: AVIRIS vs. Landsat

(a)



(b)





Shortwave albedo estimations from: (a) Landsat TM on Aug 18th, 2010; (b) AVIRIS on Aug 26th, 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

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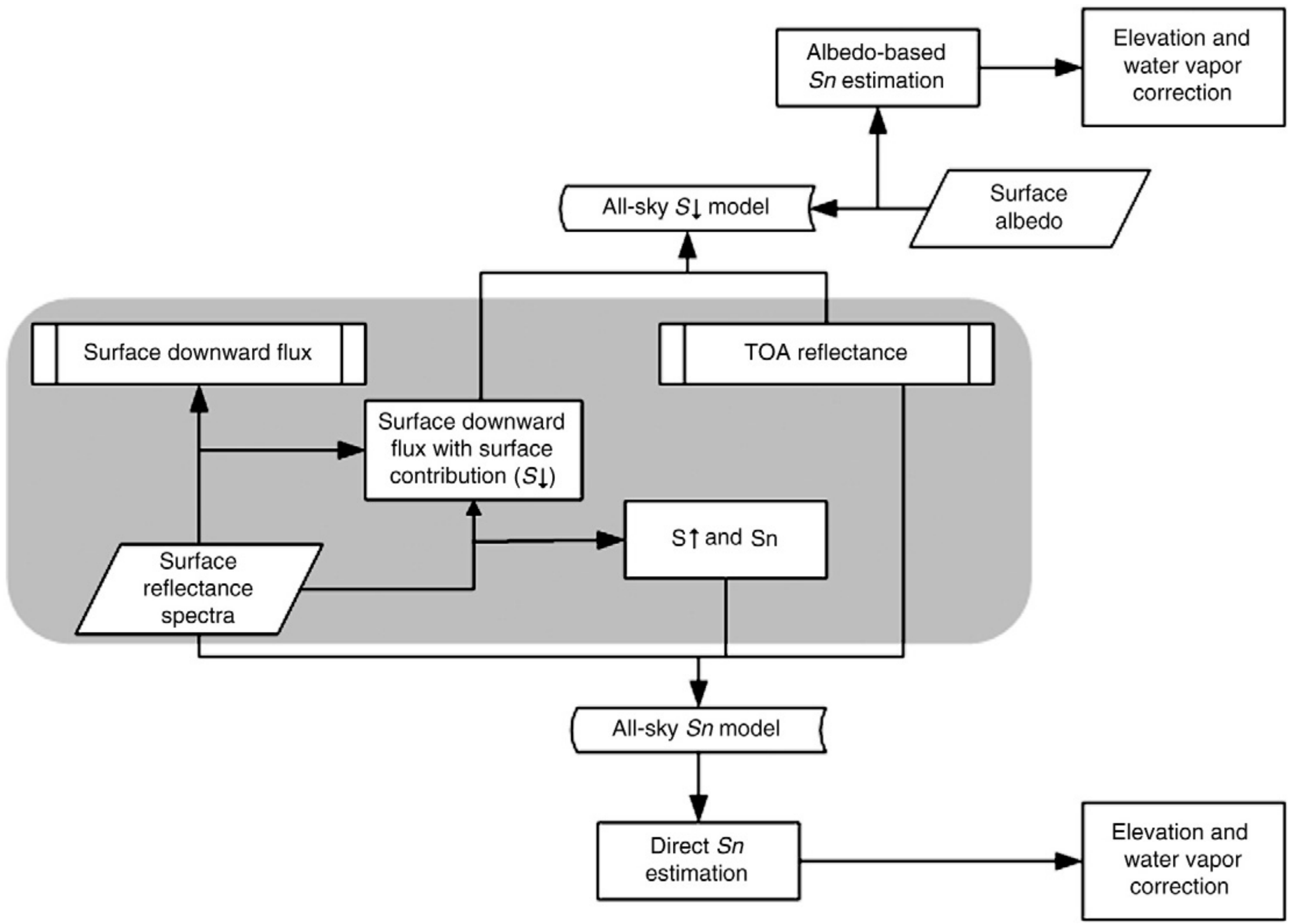
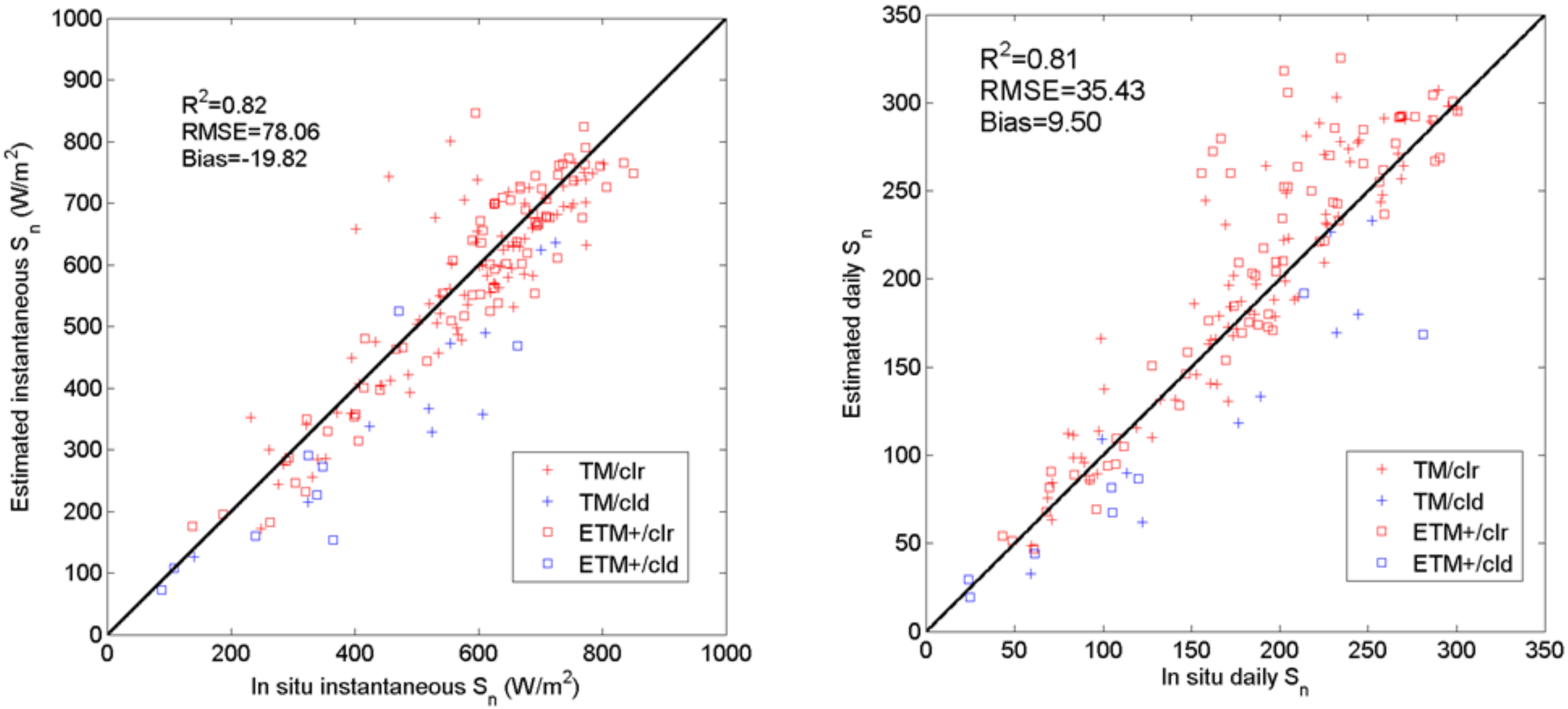
Estimation of shortwave net radiation



Kim, H.Y., & Liang, S. (2010). Development of a hybrid method for estimating land surface shortwave net radiation from MODIS data. *Remote Sensing of Environment*, 114, 2393-2402

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.

Wang, D., & Liang, S. (2014). Mapping High-Resolution Surface Shortwave Net Radiation From Landsat Data. *Ieee Geoscience and Remote Sensing Letters, 11*, 459-463

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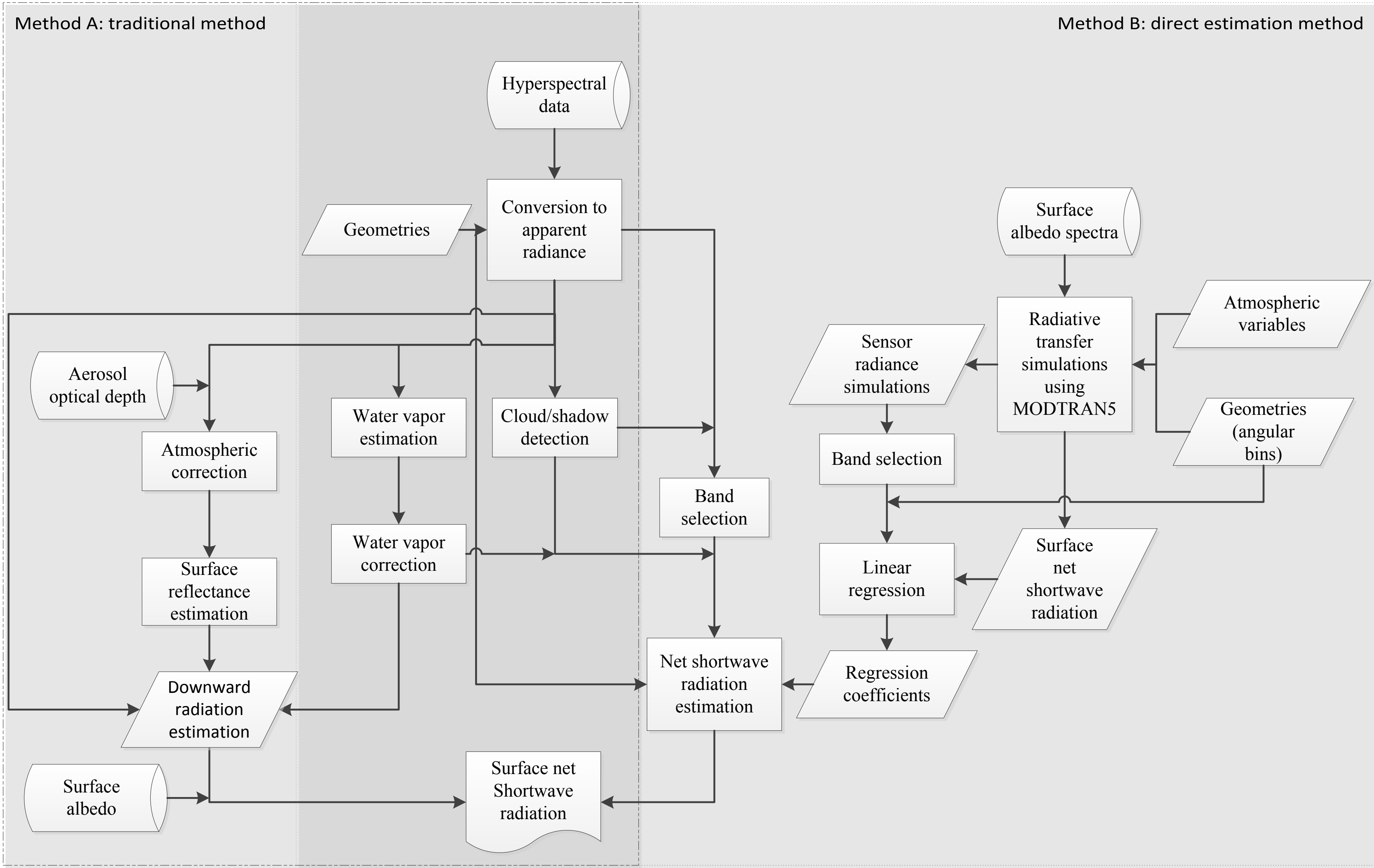
Estimating shortwave net radiation from AVIRIS



He, T.,.S. Liang, D. Wang, Q. Shi, and M. Goulden. 2015. **Estimation of high-resolution land surface net shortwave radiation from AVIRIS data: Algorithm development and preliminary results**, *RSE, 167*, 20-30

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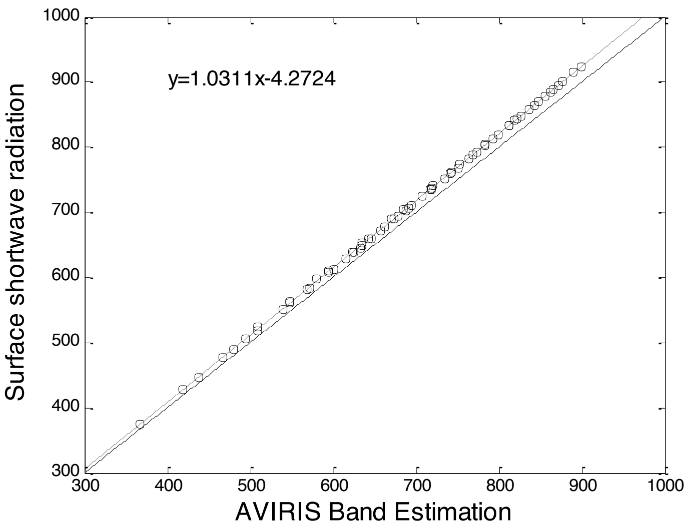
Advantages of hyperspectral information in net shortwave radiation estimation



Method A

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

Method B

Statistics of NSR direct estimation based on simulation data

RMSE (W/m^2)		Solar zenith angle (°) 20	25	30	35	40	45
View zenith angle (°)	0	19.396	19.422	19.394	19.290	19.088	18.768
	5	19.412	19.434	19.429	19.358	19.192	18.906
	10	19.369	19.403	19.397	19.346	19.210	18.954
	15	19.276	19.319	19.312	19.267	19.150	18.921
	20	19.159	19.186	19.184	19.130	19.026	18.815

R^2		Solar zenith angle (°) 20	25	30	35	40	45
View zenith angle (°)	0	0.975	0.973	0.970	0.967	0.963	0.957
	5	0.975	0.973	0.970	0.967	0.962	0.957
	10	0.975	0.973	0.970	0.967	0.962	0.956
	15	0.976	0.973	0.971	0.967	0.962	0.957
	20	0.976	0.974	0.971	0.968	0.963	0.957

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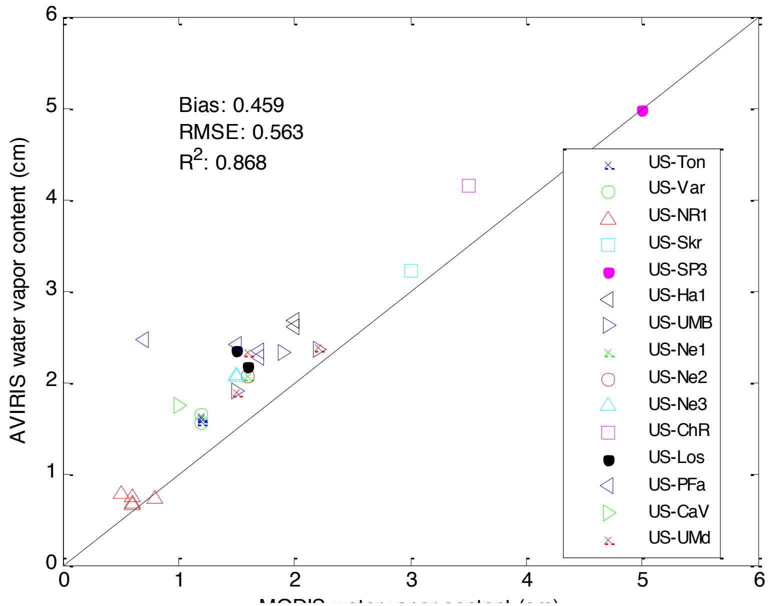
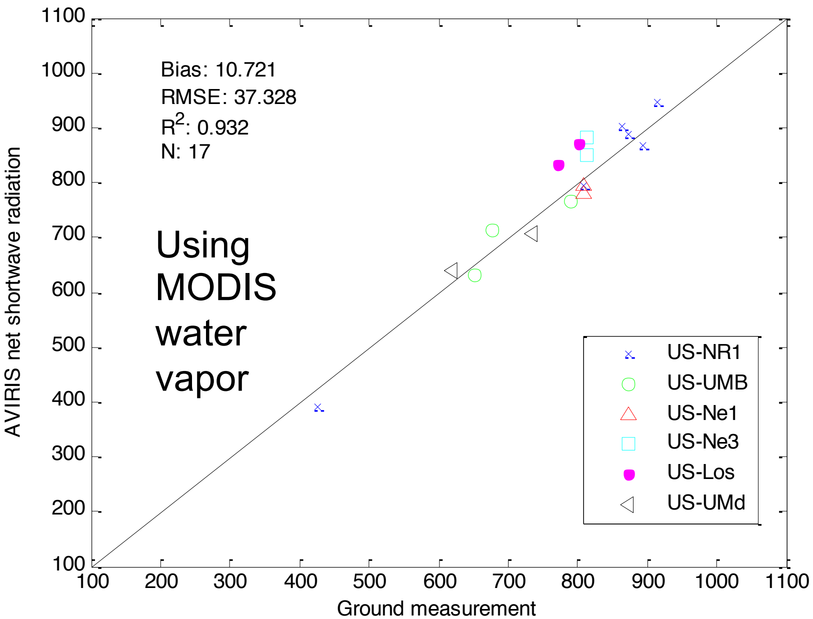
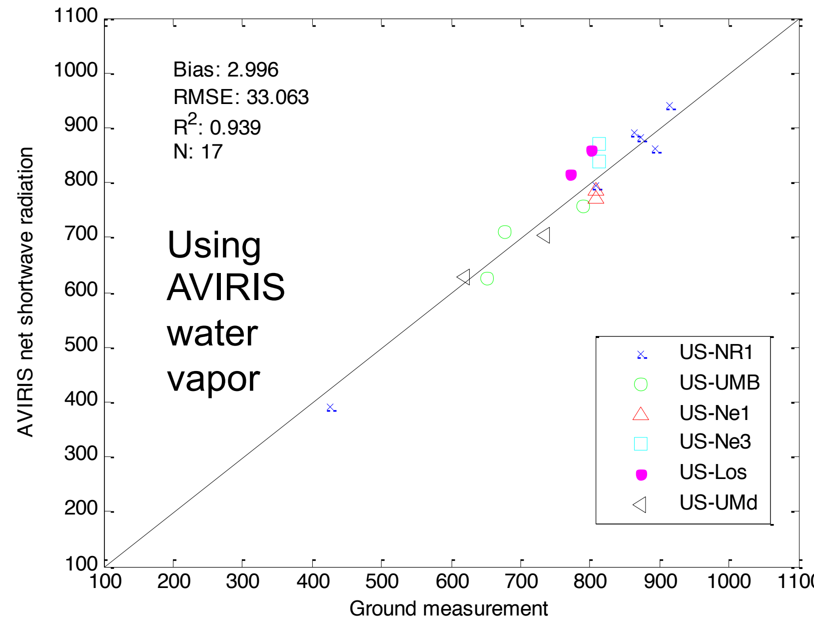
Impacts of water vapor estimation uncertainty on AVIRIS shortwave net radiation direct estimation

(He et al. 2015, *RSE*)







AVIRIS water vapor estimation has an overestimation compared with MODIS product. Net radiation estimation W/m^2 is more accurate using AVIRIS-derived water vapor.

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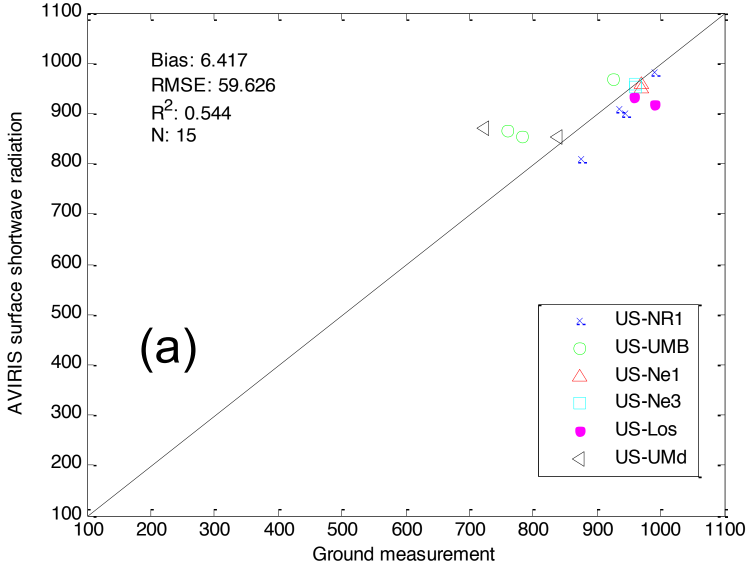
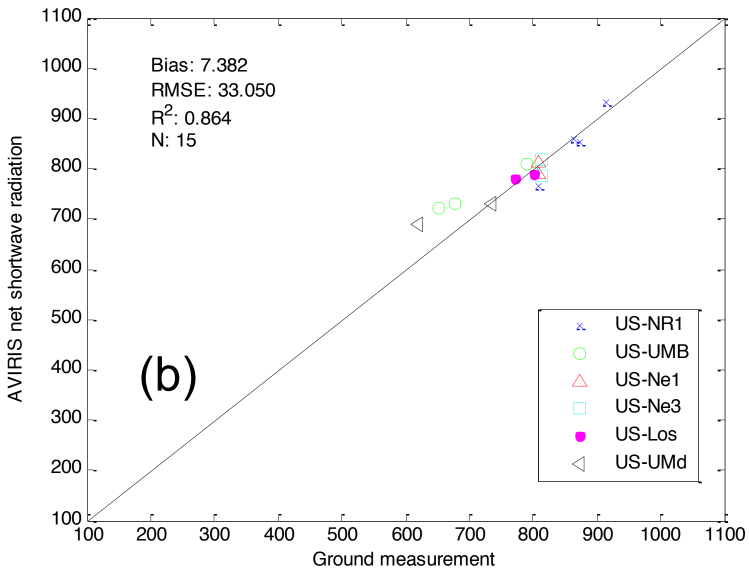
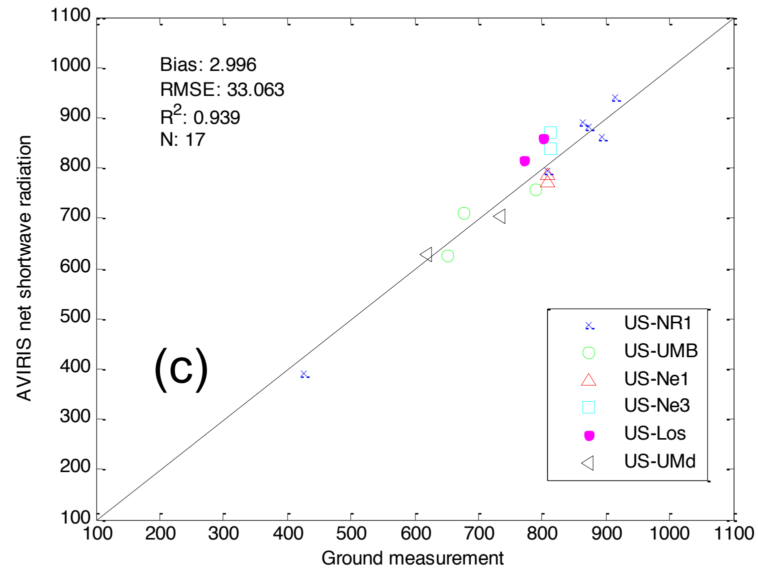
Shortwave downward and net radiation estimation: AVIRIS

(He et al. 2015, *RSE*)







Comparison of ground measurements AVIRIS downward radiation (a) and net radiation from Method A (b) and Method B (c) estimates (W/m^2) 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.

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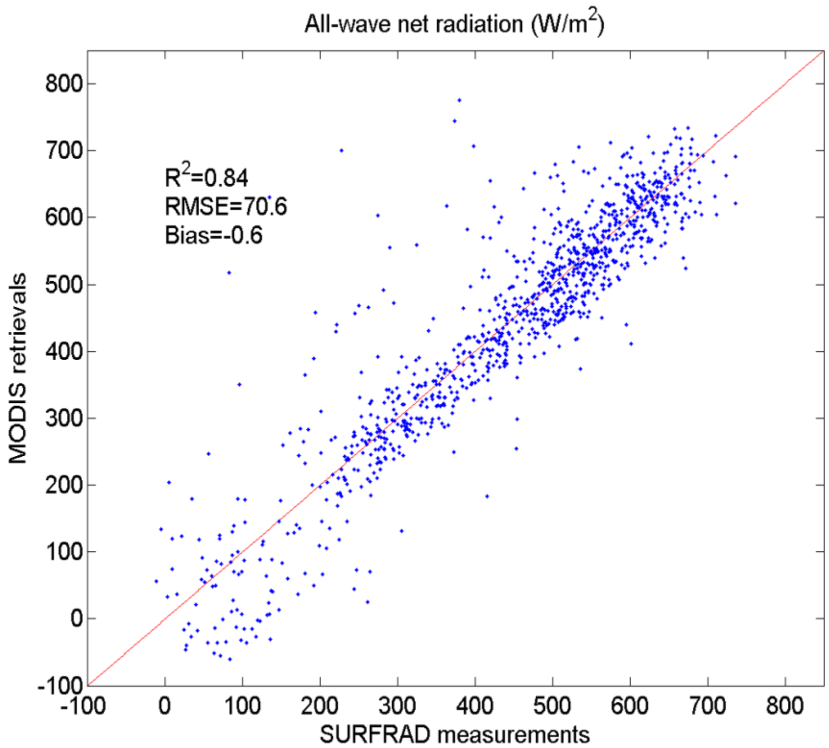
Combined VSWIR and TIR to estimate clear-sky all-wave net radiation

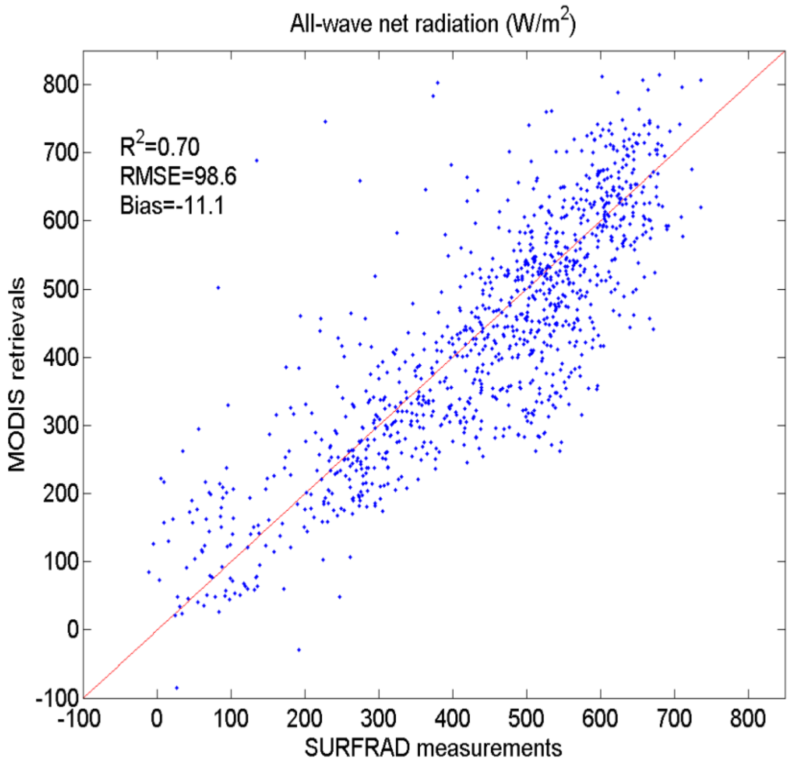
- Previous methods to estimate all-wave net radiation
  - Component-based, summation of all the components
    - VSWIR: shortwave fluxes
    - TIR: long wave fluxes
  - Errors add up
- New method:
  - Combine VSWIR and TIR data to directly estimate all-wave net radiation as one integral quantity.

Wang, D., Liang, S., He, T., & Shi, Q. (2015). Estimating clear-sky all-wave net radiation from combined visible and shortwave infrared (VSWIR) and thermal infrared (TIR) remote sensing data. *Remote Sensing of Environment, RSE, 167*, 31-39.

Validation: net radiation

- Seven SURFRAD stations.
- One year measurements.





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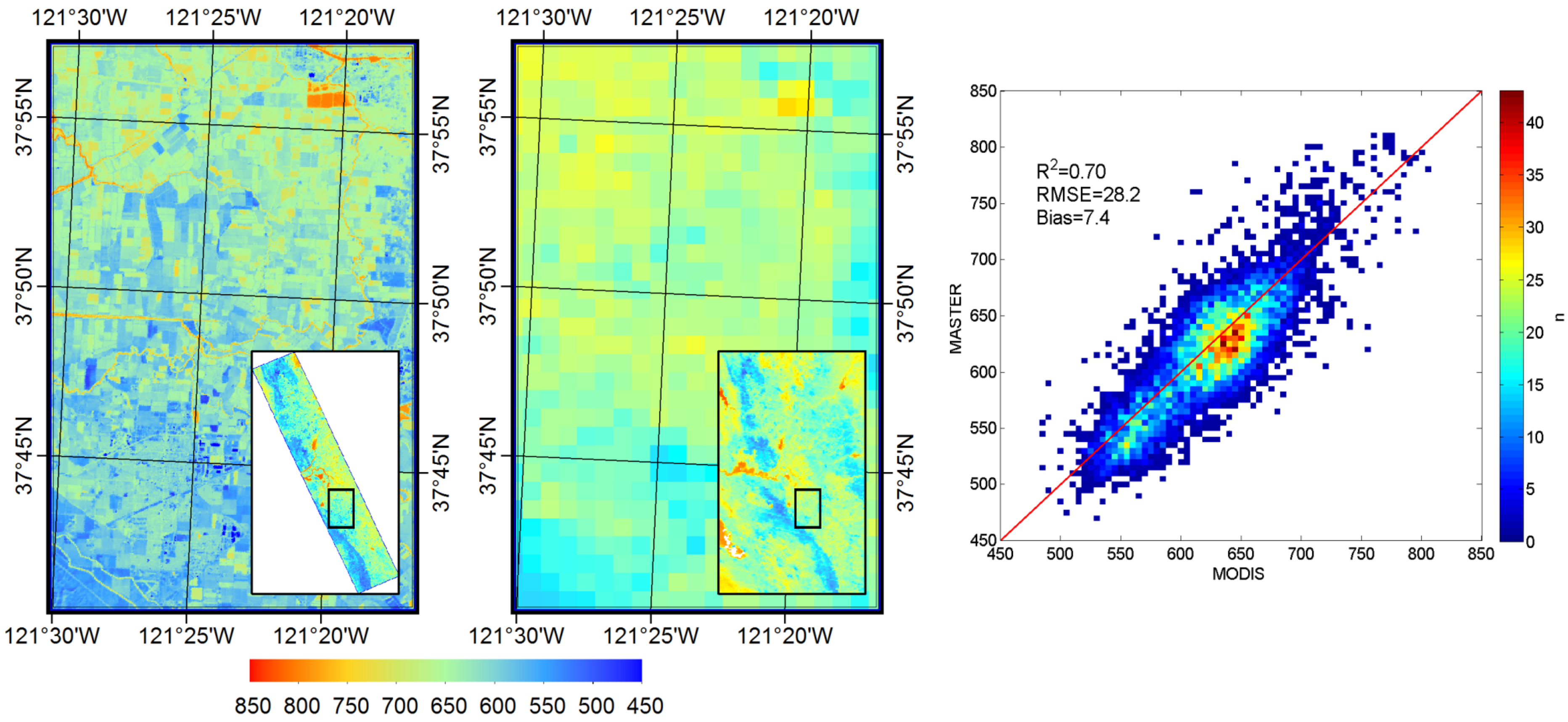
Map from MASTER data



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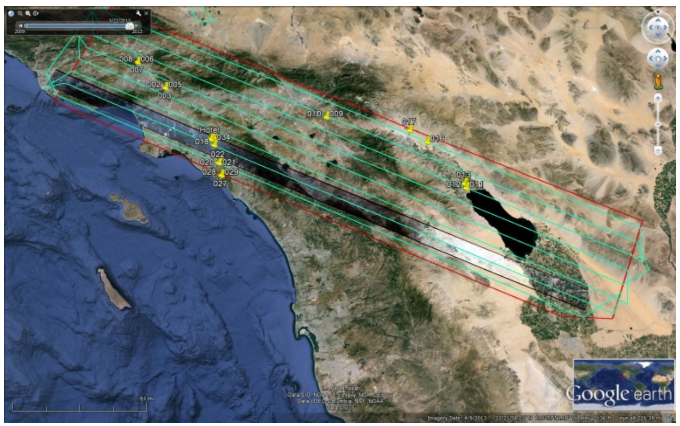
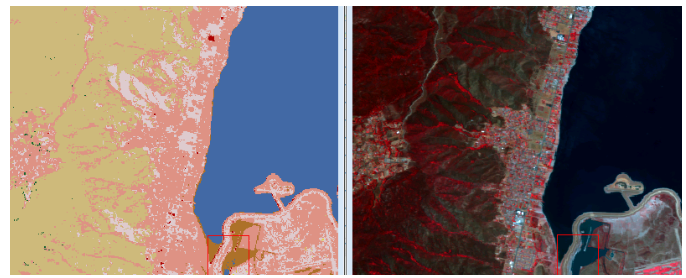
Preliminary Result of Land Cover Mapping

- Method: Maximum Likelihood Classification (MLC)
- Data: AVIRIS band10-60 surface reflectance

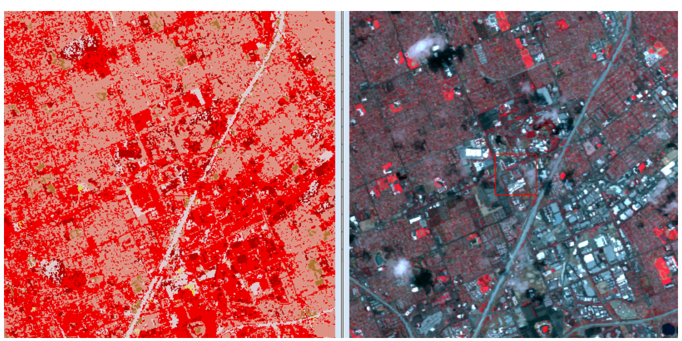


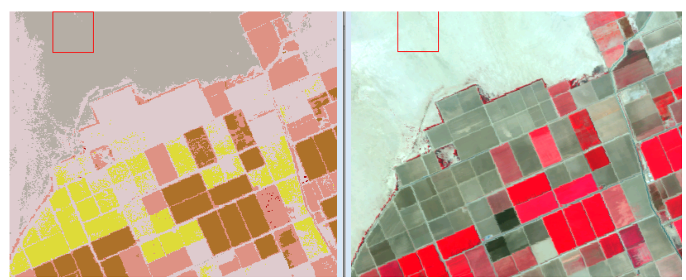


RGB: Band 53,30,20
(850 nm, 650 nm, 550 nm)

NLCD Land Cover Classification Legend
- 11 Open Water
- 12 Perennial Ice/ Snow
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land (Rock/Sand/Clay)
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 51 Dwarf Scrub*
- 52 Shrub/Scrub
- 71 Grassland/Herbaceous
- 72 Sedge/Herbaceous*
- 73 Lichens*
- 74 Moss*
- 81 Pasture/Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

* Alaska only





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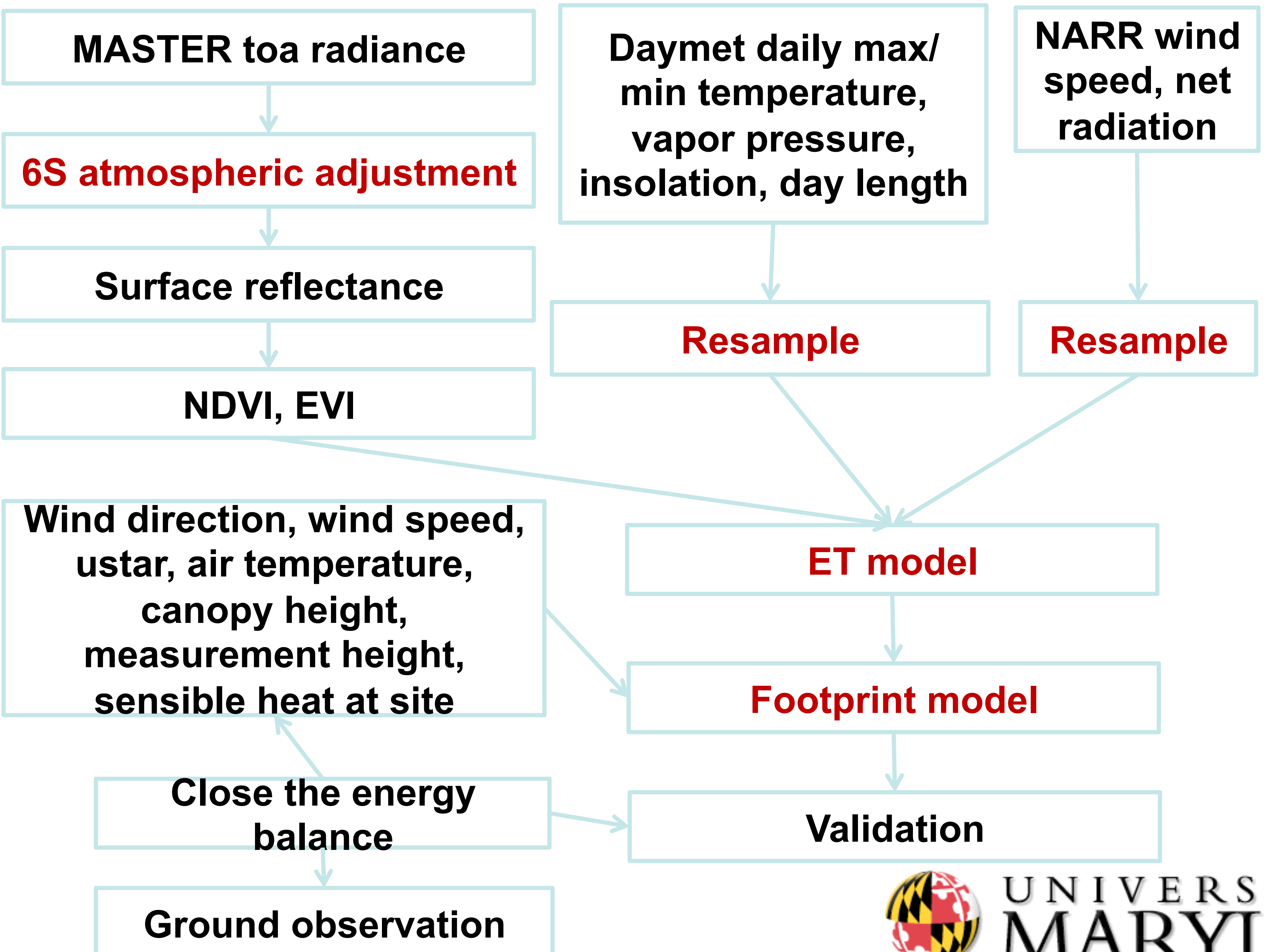
Mapping ET from MASTER and ancillary data



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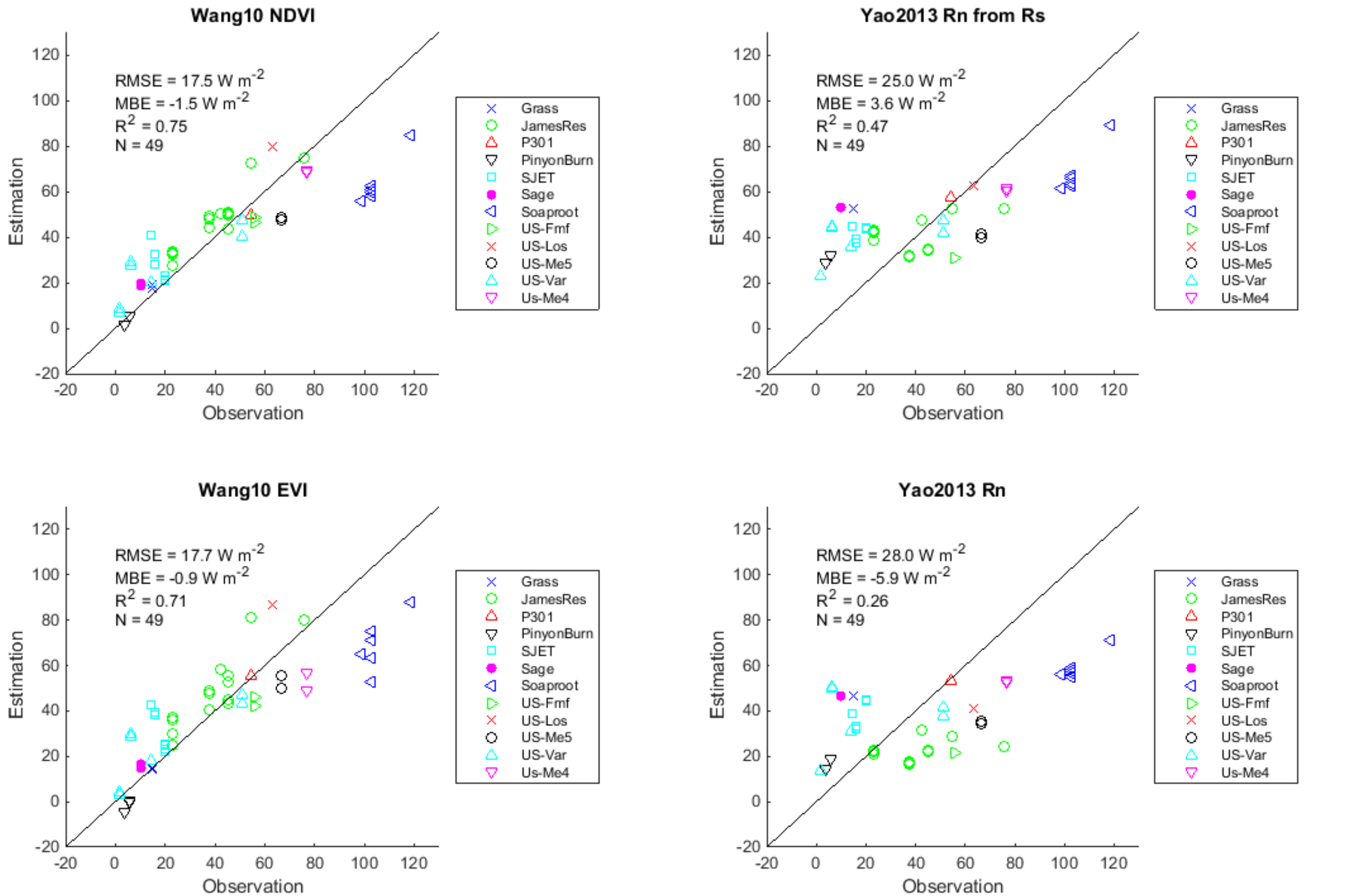
Validating latent heat flux at AmeriFlux sites



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Summary

- Fine spectral and spatial resolution in both shortwave (VSWIR) and longwave (TIR) spectrum provides the scientific community an unprecedented opportunity to map the surface radiation and energy budget over heterogeneous landscapes.
- 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.
- Hyperspectral data provide ample information for land cover classification.
- ET can be estimated with high accuracy at most sites. Additional algorithm tuning is needed to further improve the estuation.

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