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

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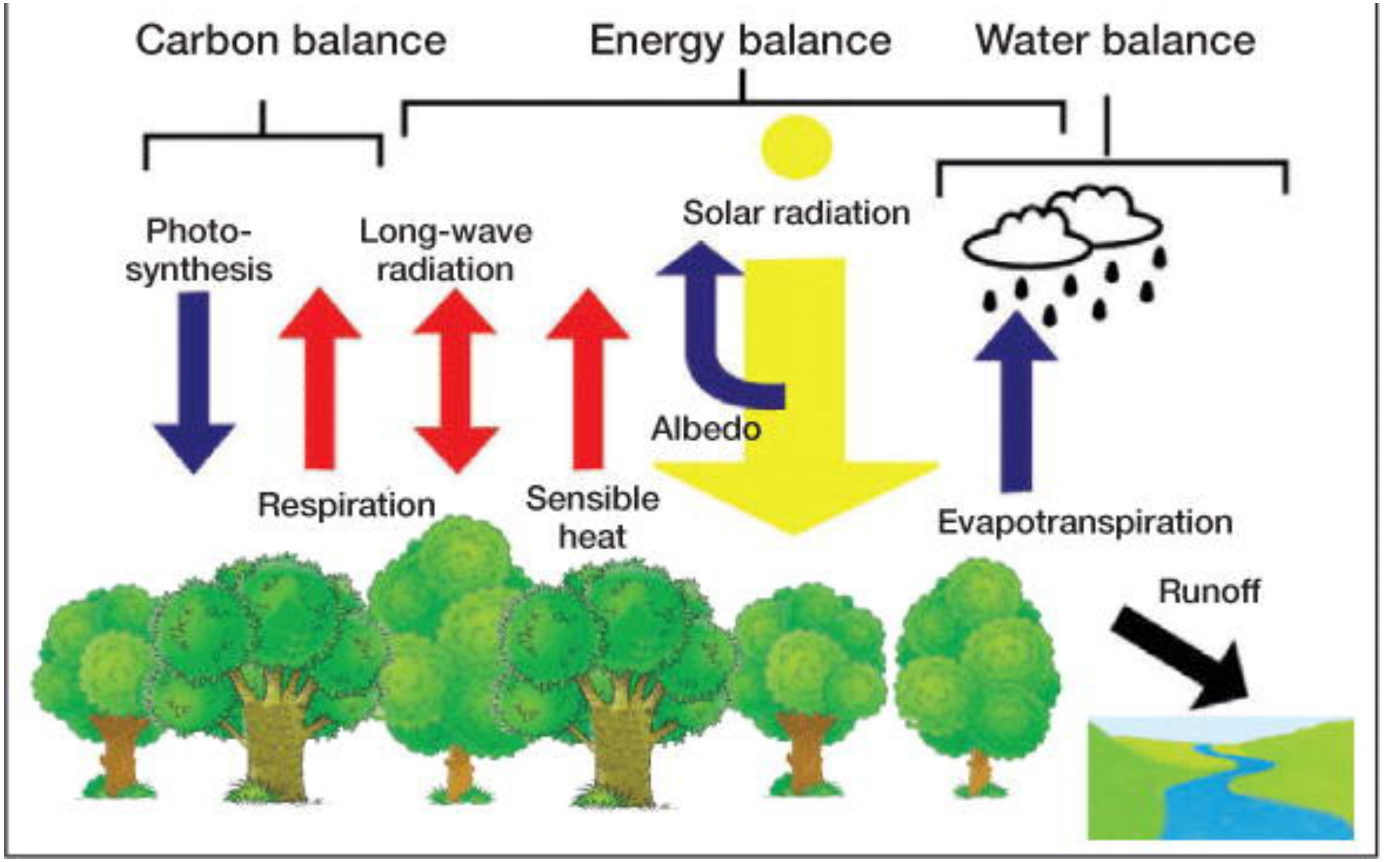


Chapin et al. 2008

- 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

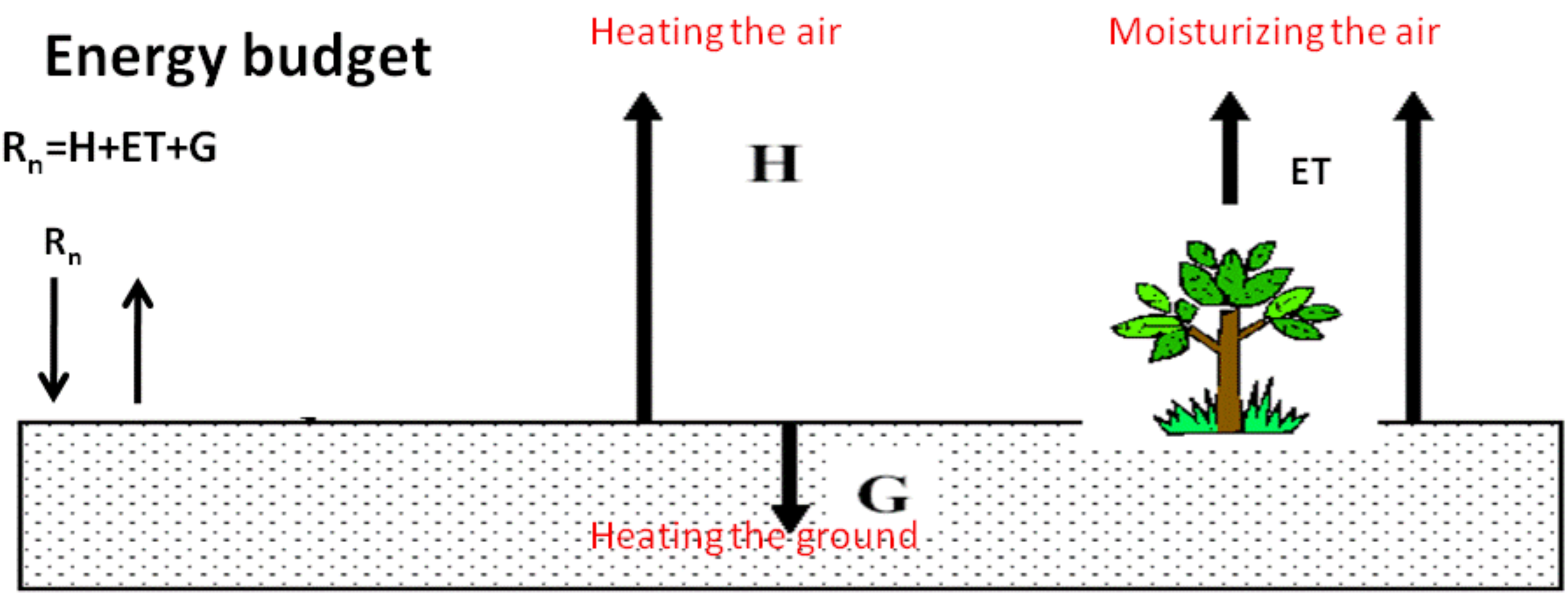
$$R_n = R_n^s + R_n^l = (1-\alpha)F_d^s + F_d^l - \sigma\varepsilon T^4$$

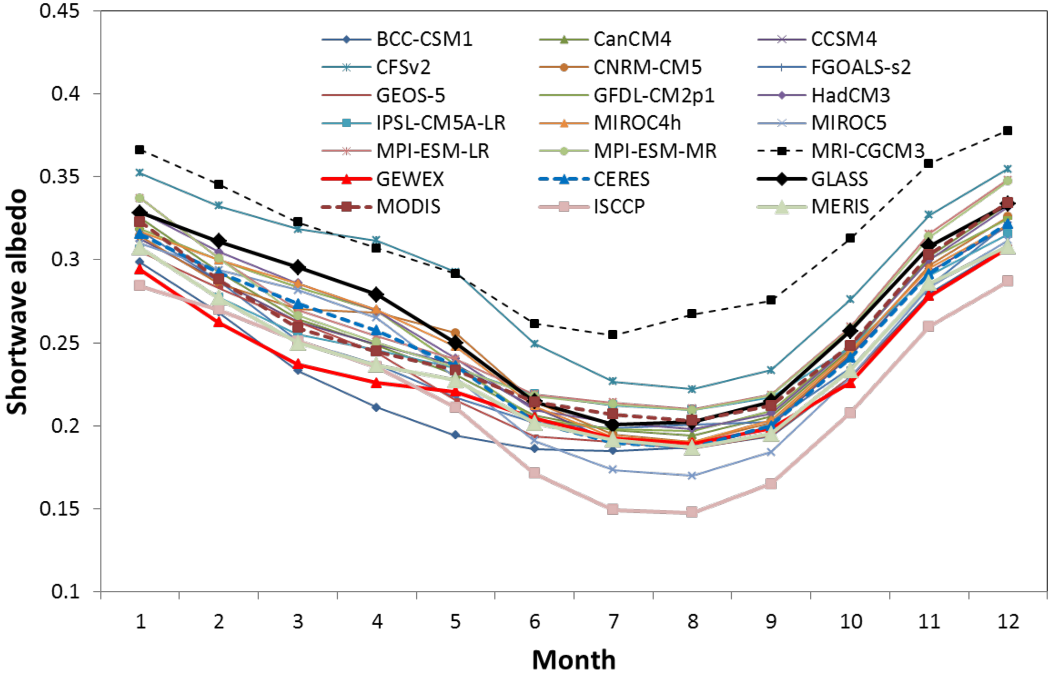
- R_n: Net radiation
- α: albedo
- F_d^s: Insolation
- F_d^l: Longwave downward radiation
- ε: Emissivity
- T: Skin temperature

Radiation budget

Energy budget

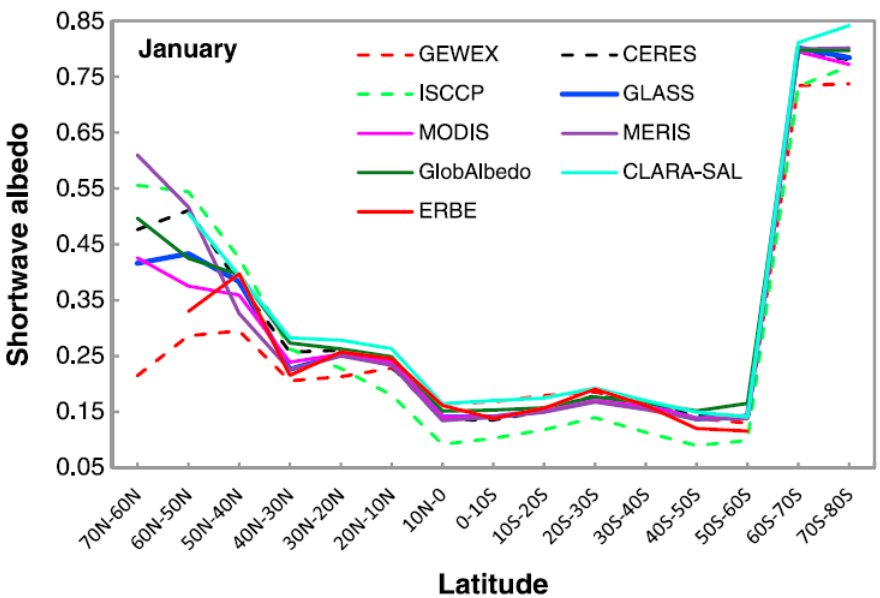
$R_n = H + ET + G$

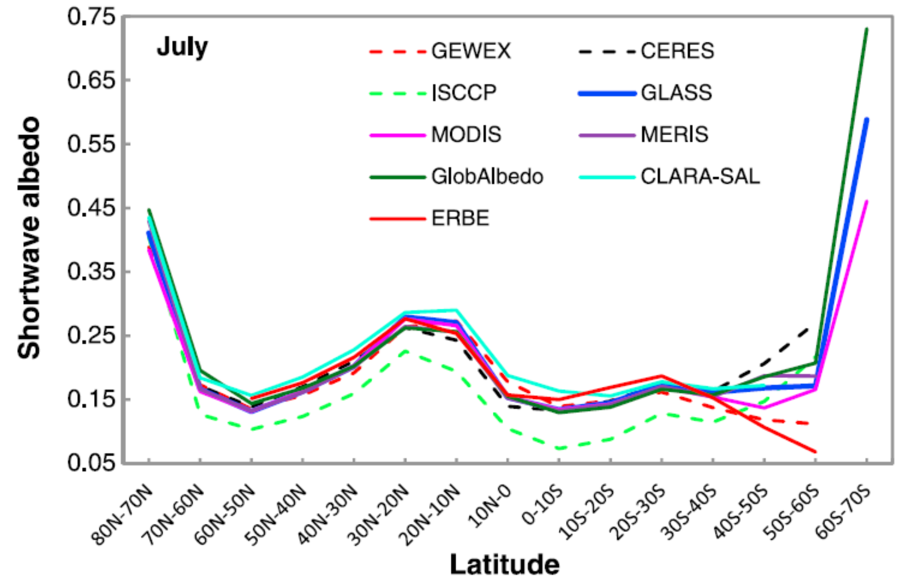




Inter-comparison of 30-year global albedo climatology derived from satellite products and CMIP5 model outputs.

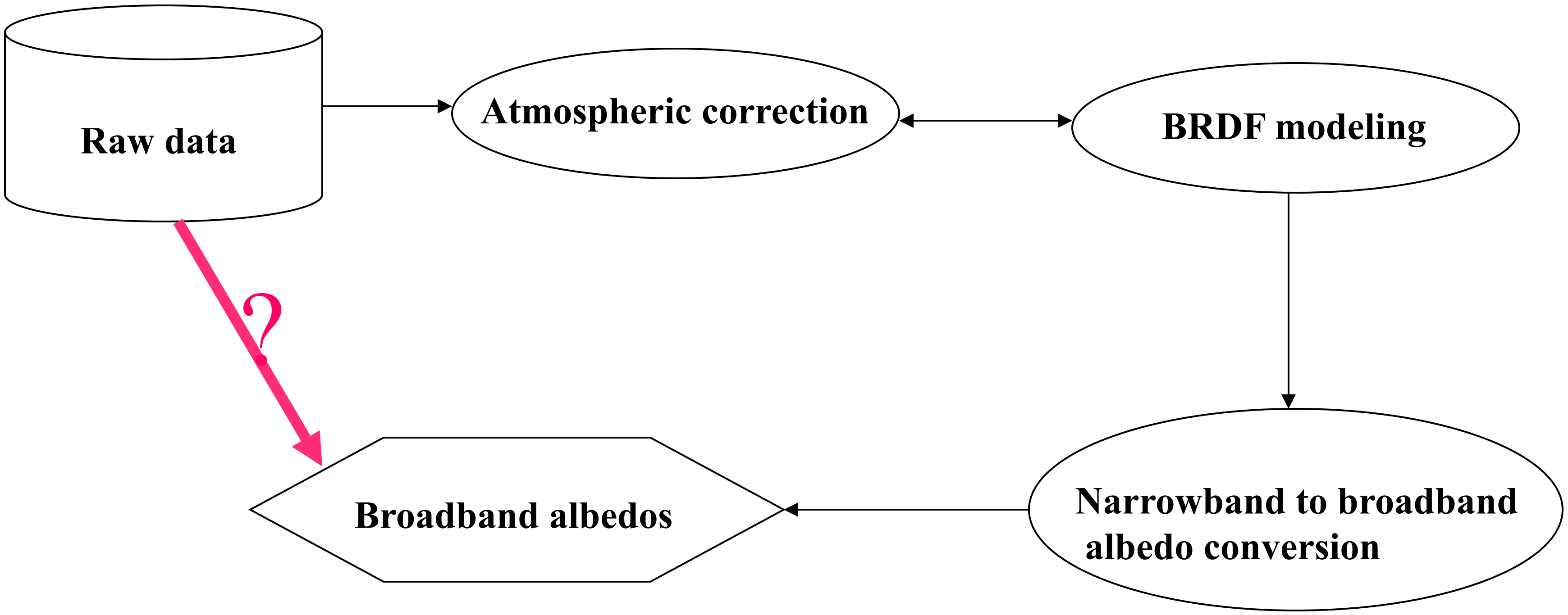
Model mean: 0.21
Standard dev.: 0.02
MODIS: 0.24





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*

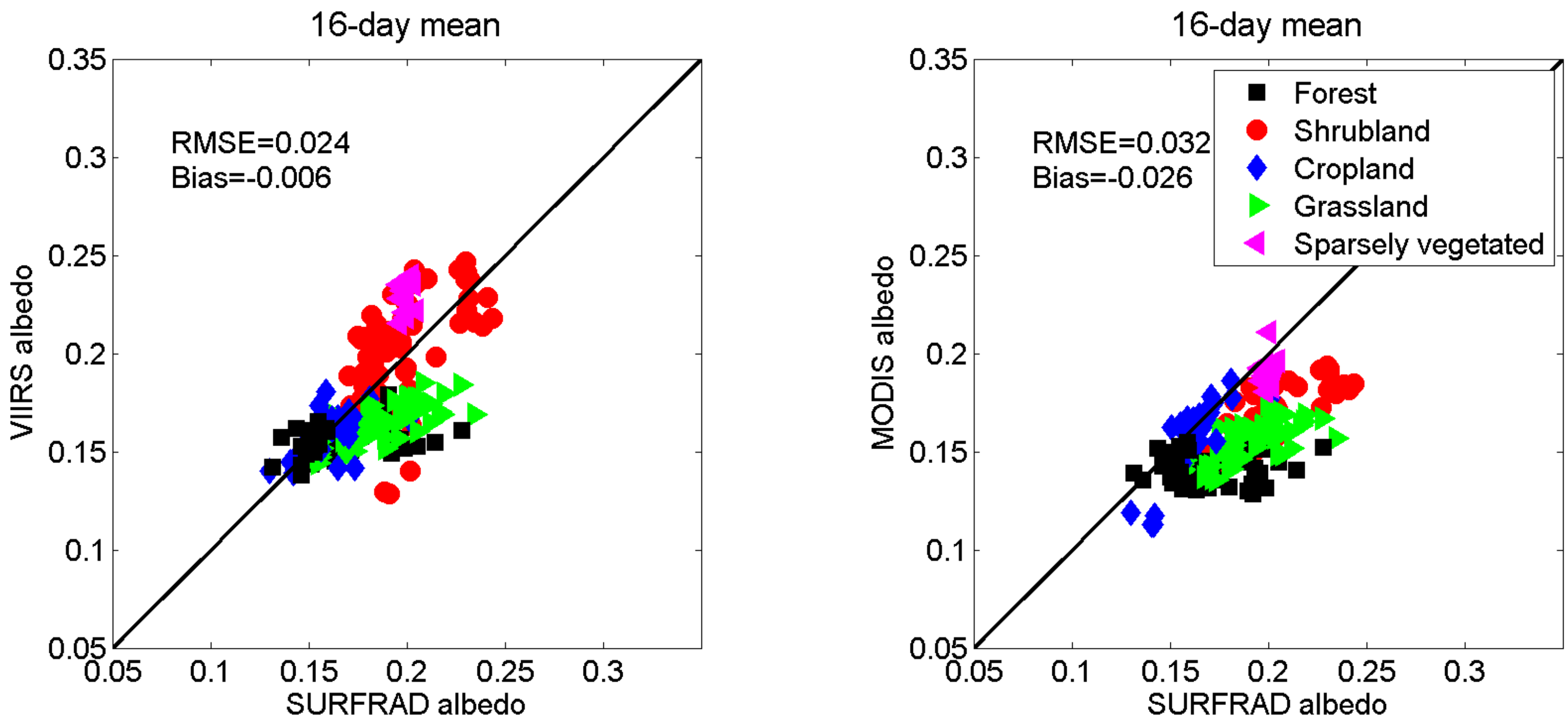
Direct estimation of surface albedo



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

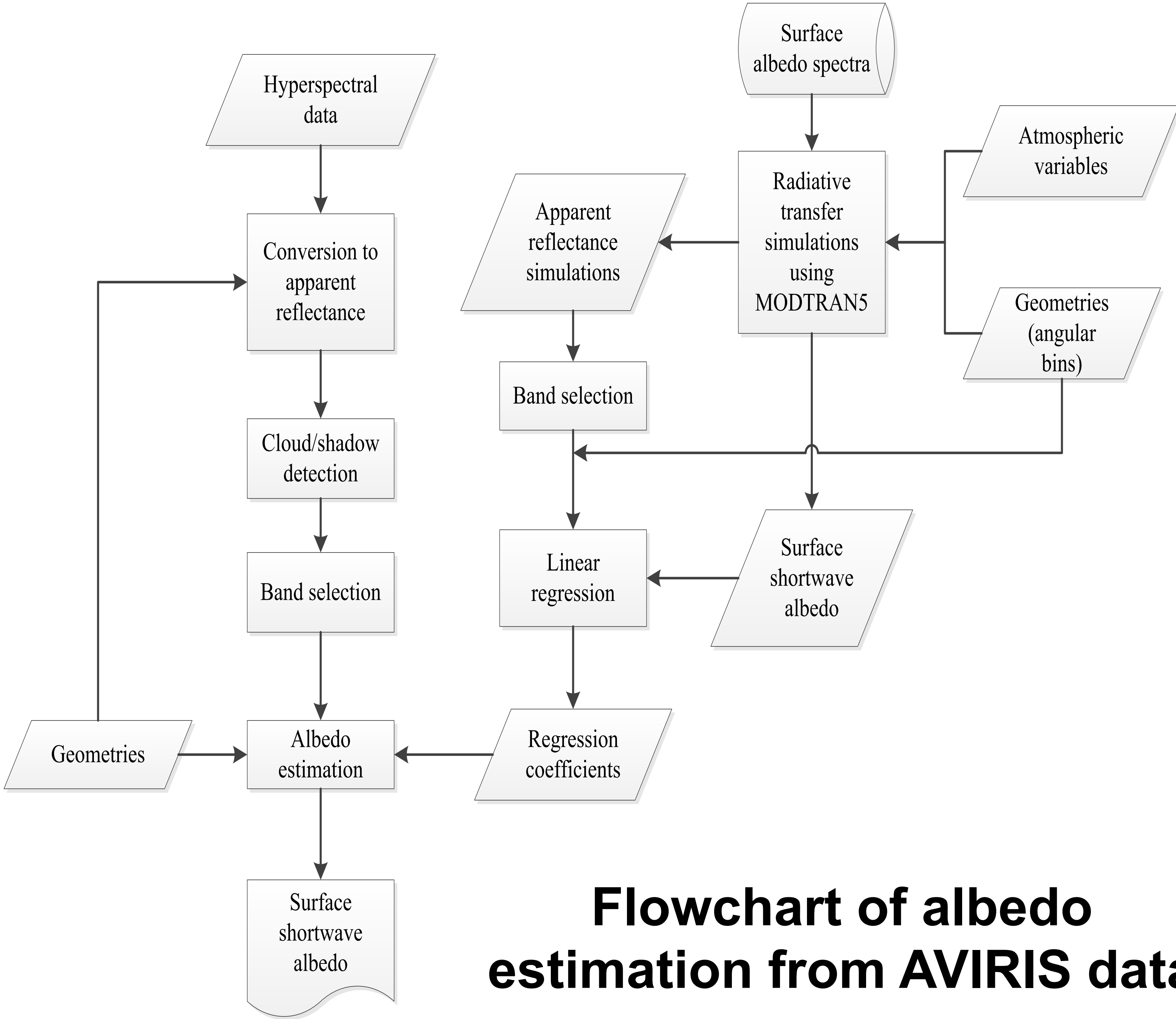
Liang, S., J. Stroeve and J. Box, (2005), Mapping daily snow shortwave broadband albedo from MODIS: The improved direct estimation algorithm and validation, *Journal of Geophysical Research.* 110 (D10): Art. No. D10109.

VIIRS shortwave albedo product



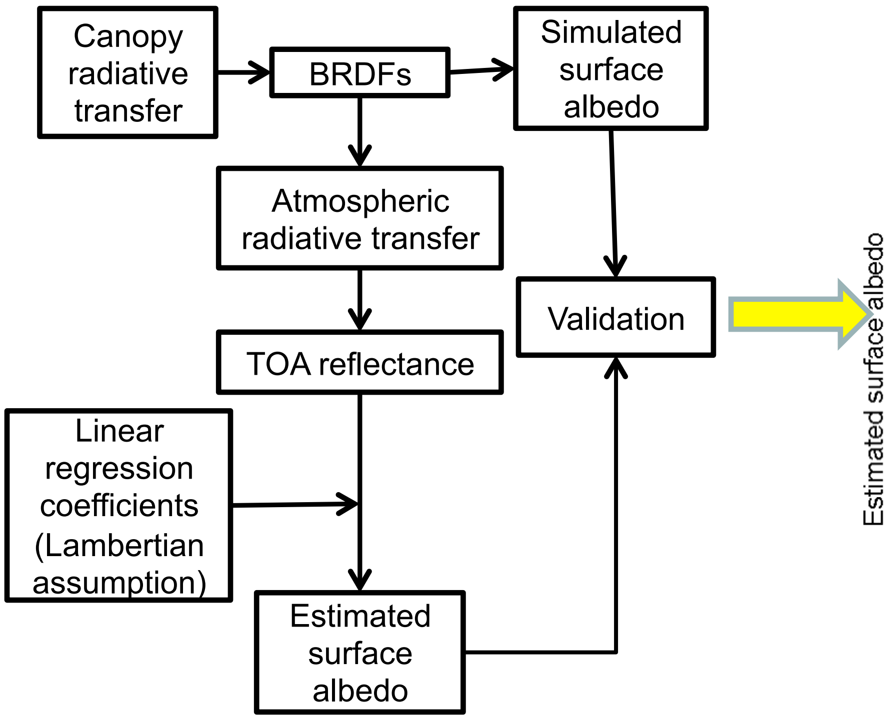
Validation results of 16-day mean albedo from VIIRS BRDF LUT (left), and MODIS (right), using data from 2012 non-snow seasons (May-September) at seven SURFRAD sites.

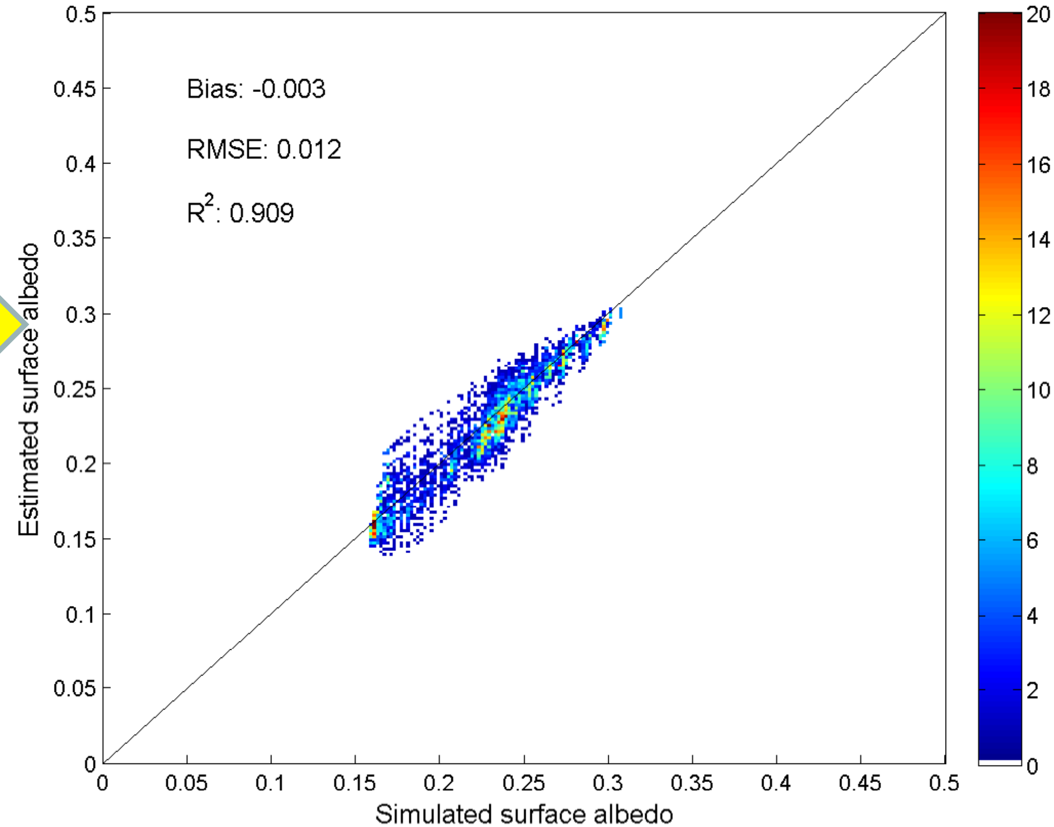
Wang, D., Liang, S., He, T., Yu, Y. 2013. Direct Estimation of Land Surface Albedo from VIIRS Data: Algorithm Improvement and Preliminary Validation. *JGR-Atmosphere*. *118*, 12577-12586, doi: 10.1002/2013jd020417.



Flowchart of albedo estimation from AVIRIS data

Spectral vs. angular information in broadband albedo direct estimation





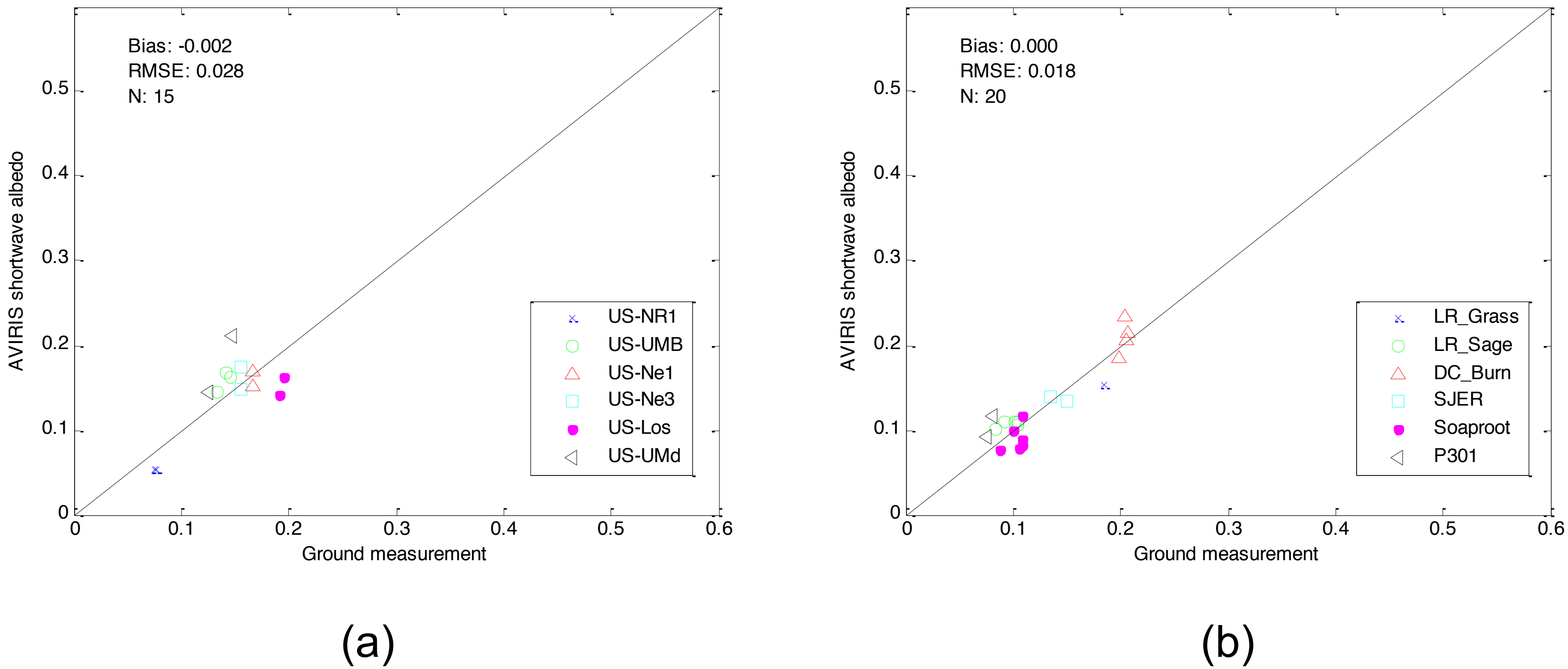
Hyperspectral information is MORE important than angular information in surface broadband albedo estimation for snow-free surfaces

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

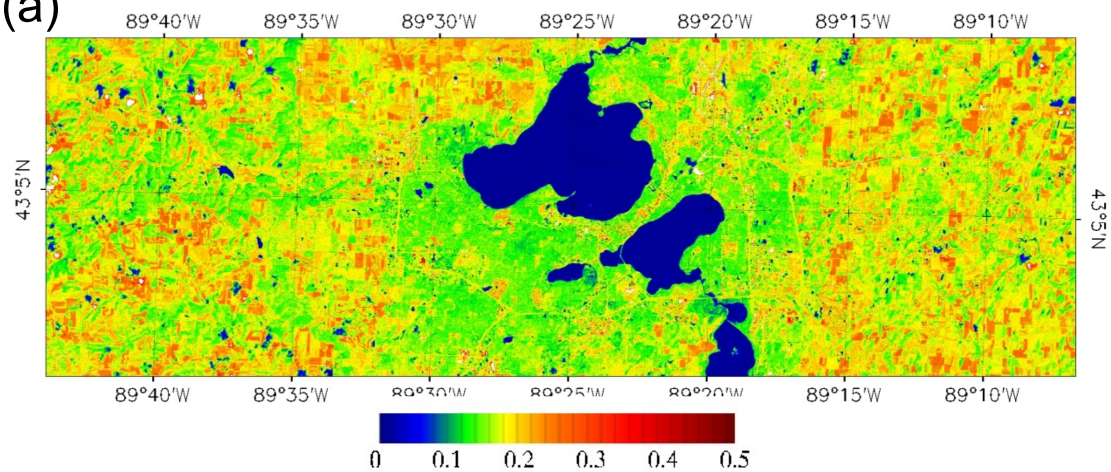


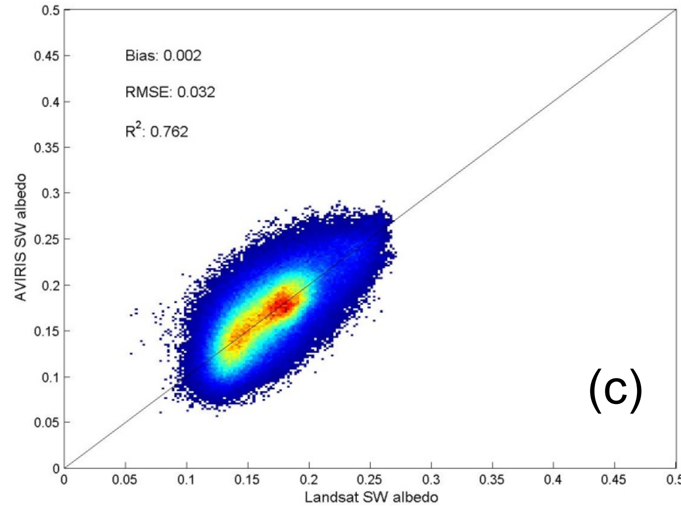
Validation of surface shortwave albedos at sites from (a) AmeriFlux network and (b) UCI network

He et al. 2013; He et al. 2014

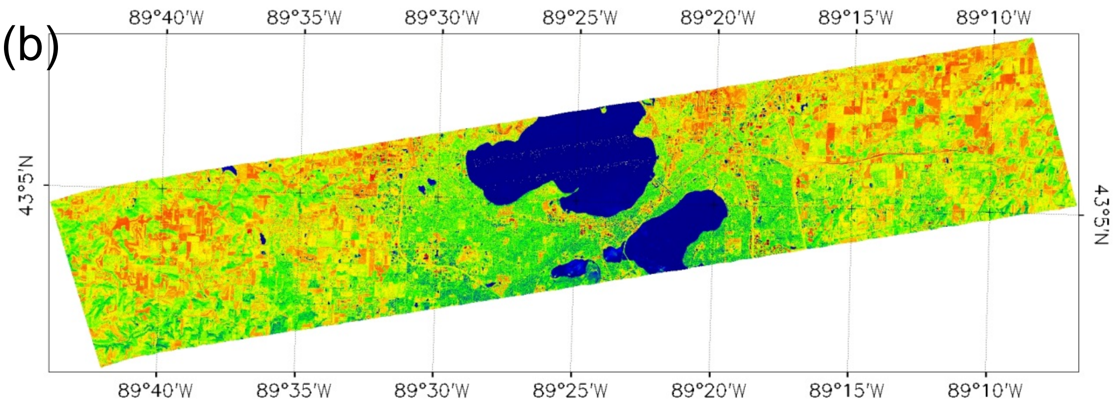
Mapping surface albedo: AVIRIS vs. Landsat

(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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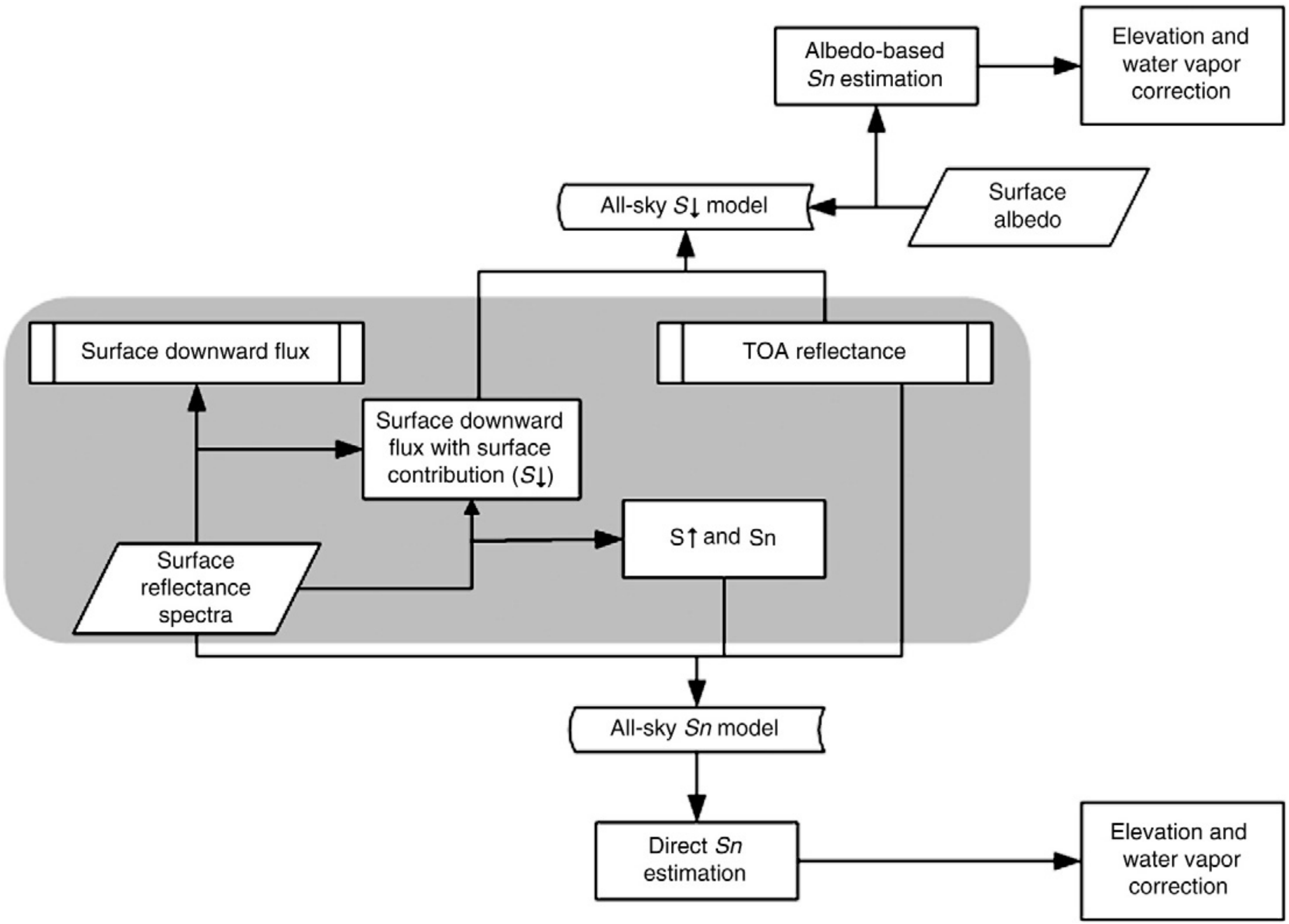
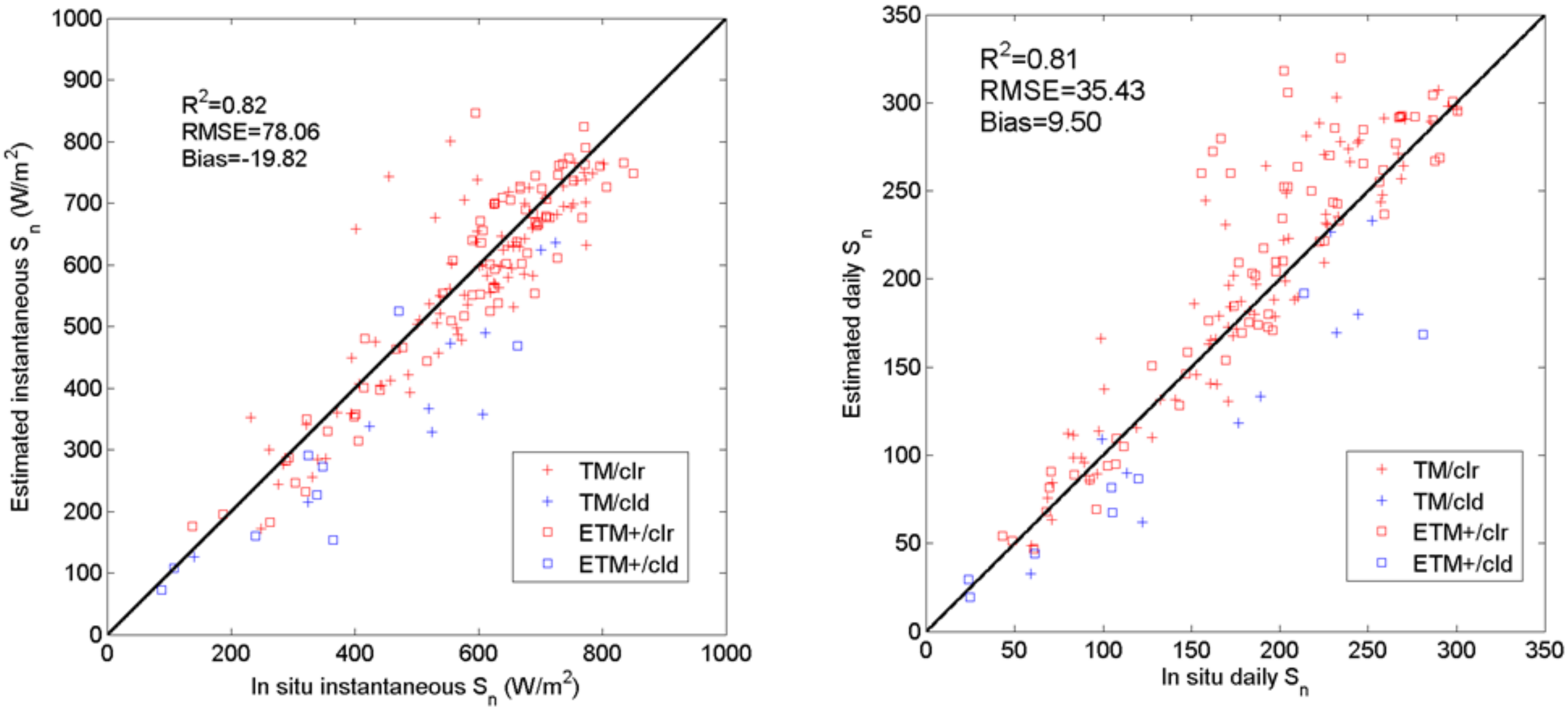
Estimation of shortwave net radiation



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/m^2) 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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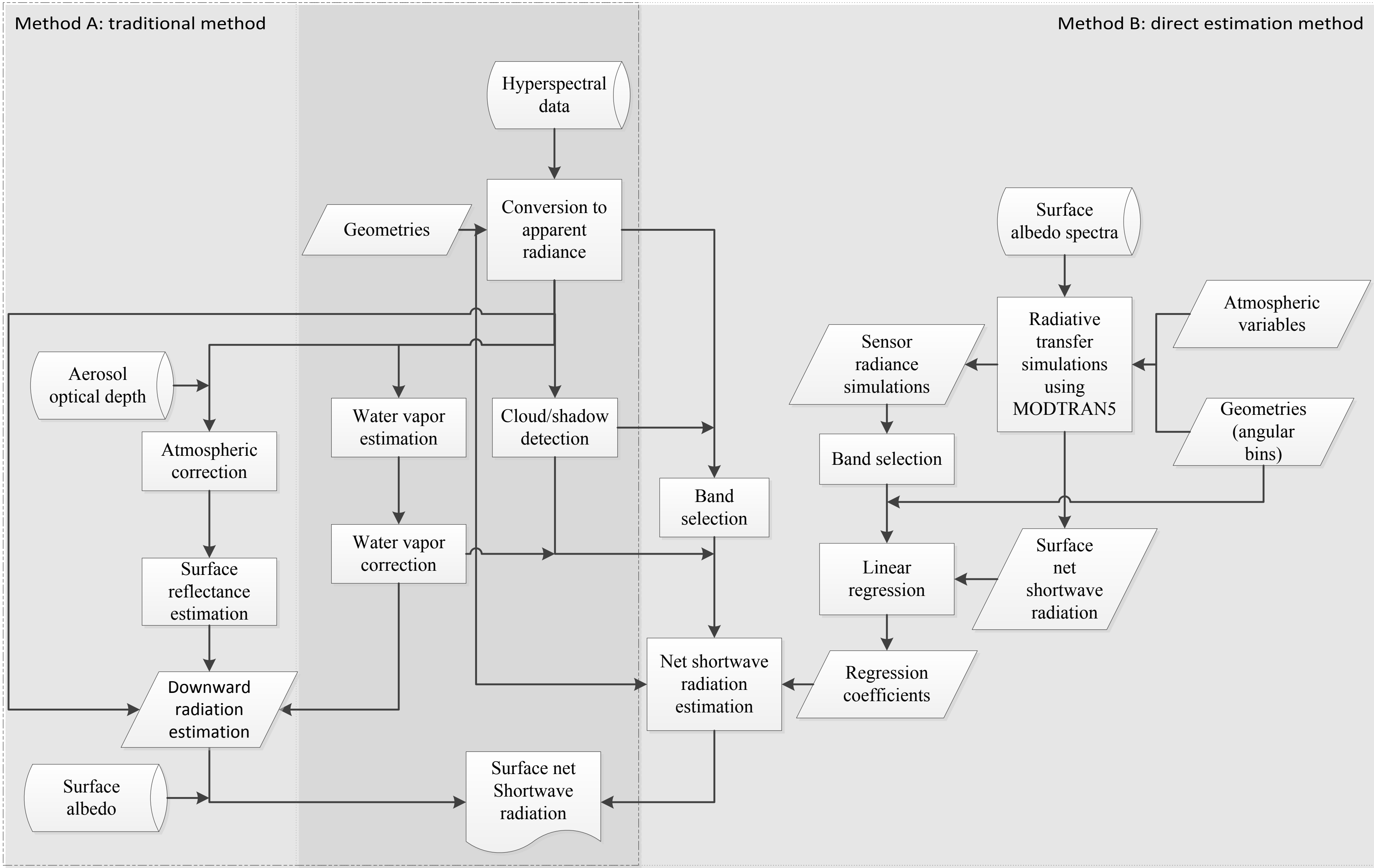
Estimating shortwave net radiation from AVIRIS



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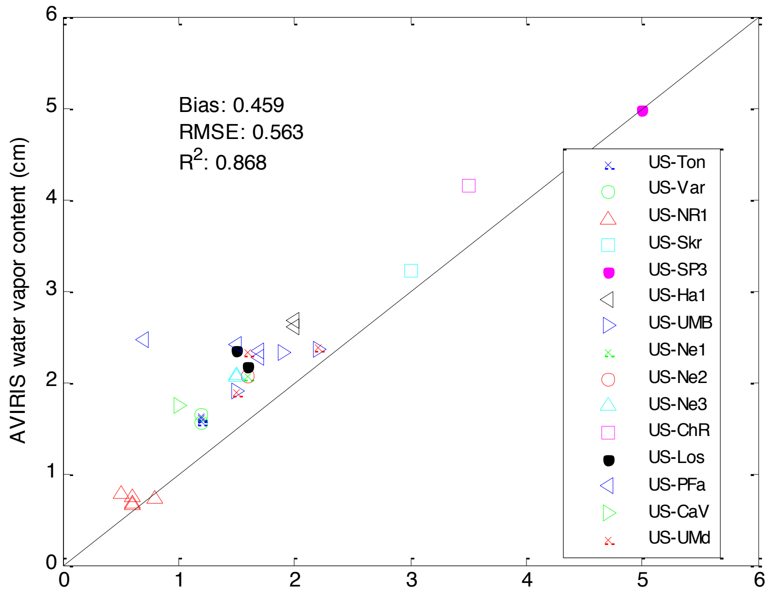
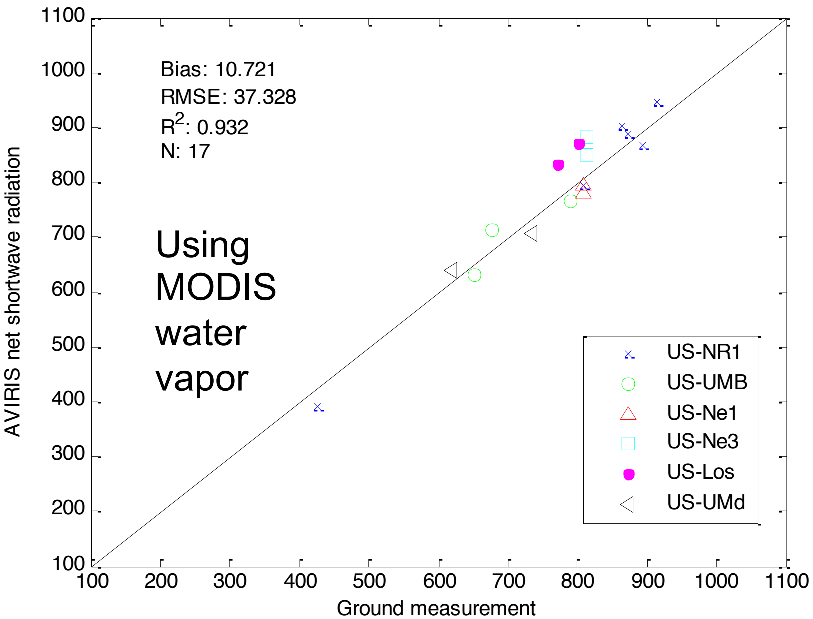
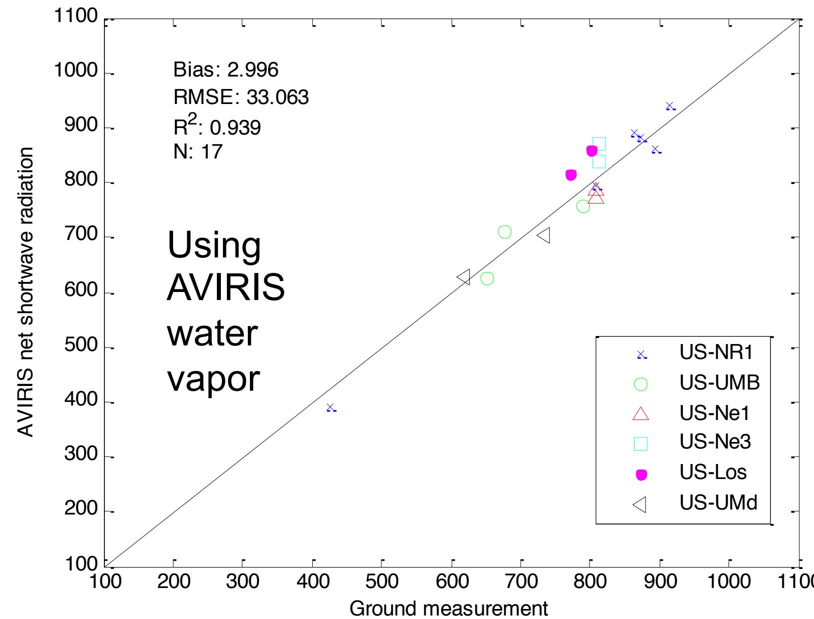
Impacts of water vapor estimation uncertainty on AVIRIS shortwave net radiation direct estimation

(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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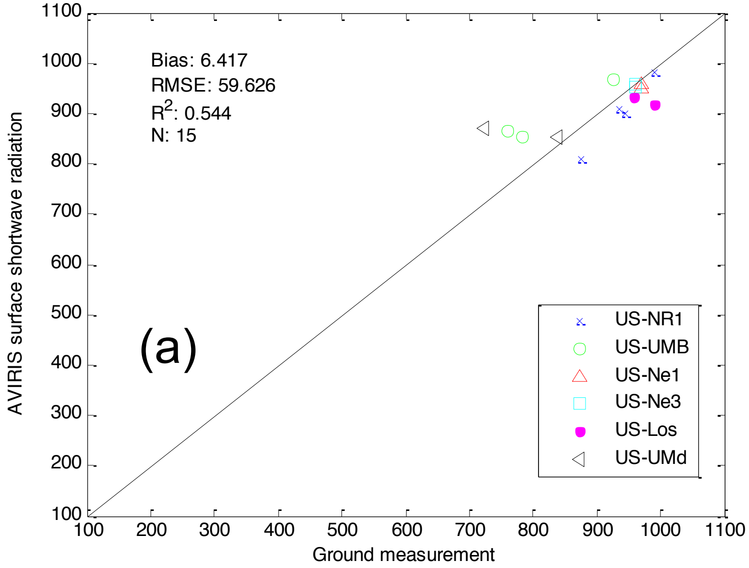
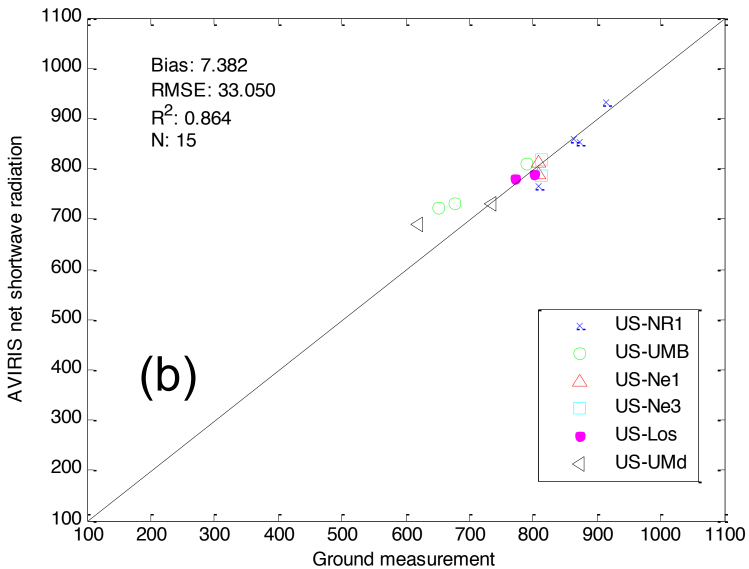
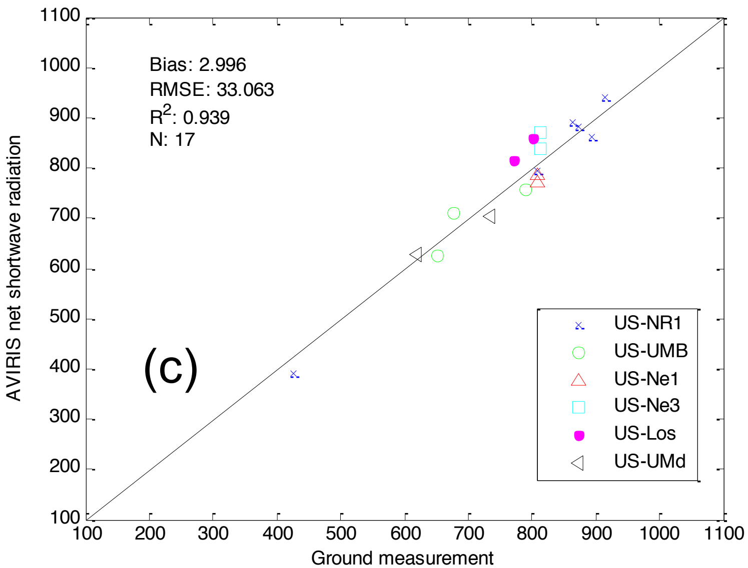
Shortwave downward and net radiation estimation: AVIRIS

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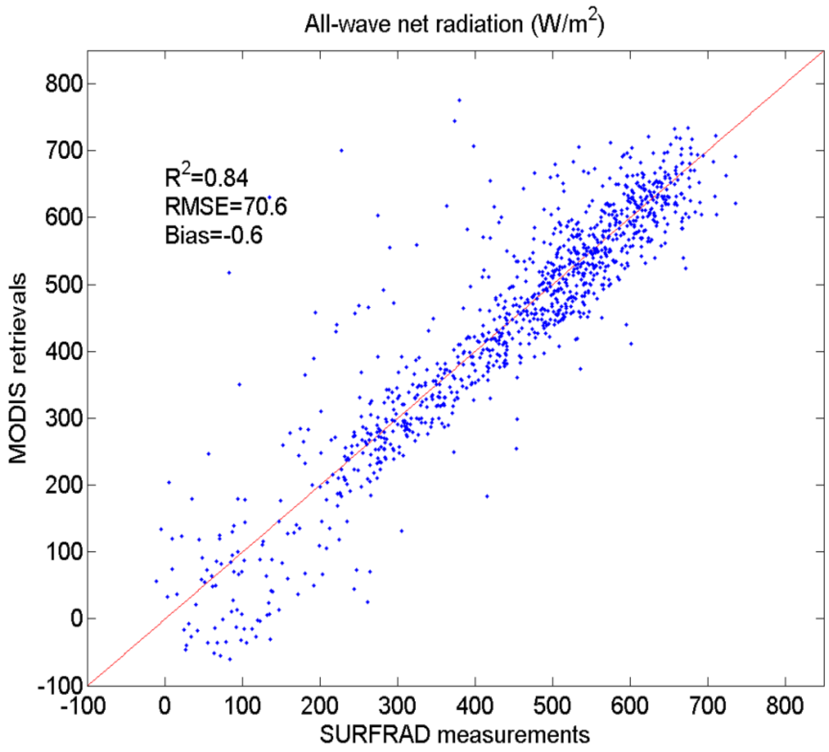
Combined VSWIR and TIR to estimate clear-sky all-wave net radiation

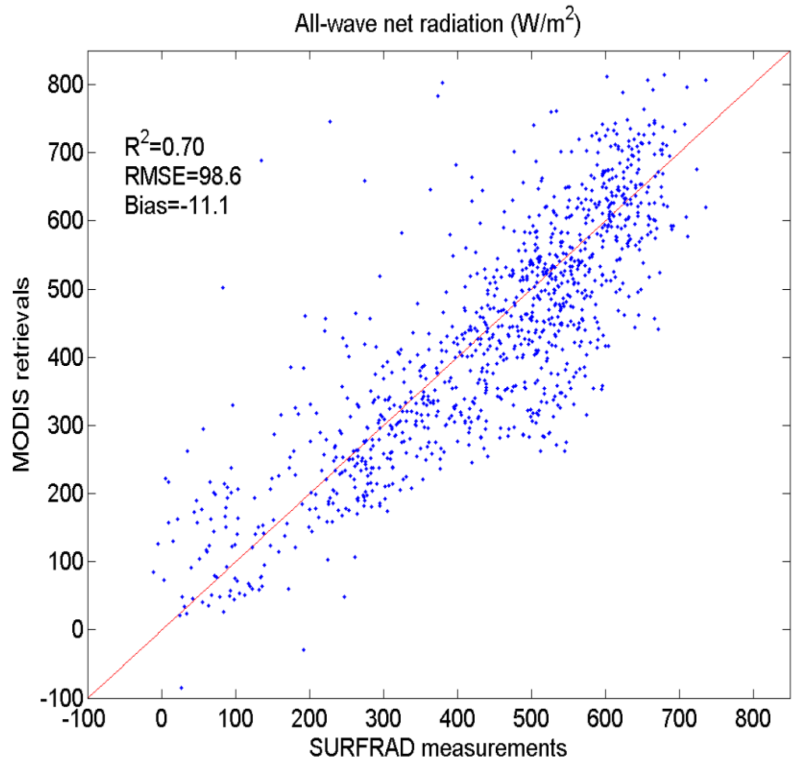
- Previous methods to estimate all-wave net radiation
  - Component-based, summation of all the components
    - VSWIR: shortwave fluxes
    - TIR: long wave fluxes
  - Errors add up
- New method:
  - Combine VSWIR and TIR data to directly estimate all-wave net radiation as one integral quantity.

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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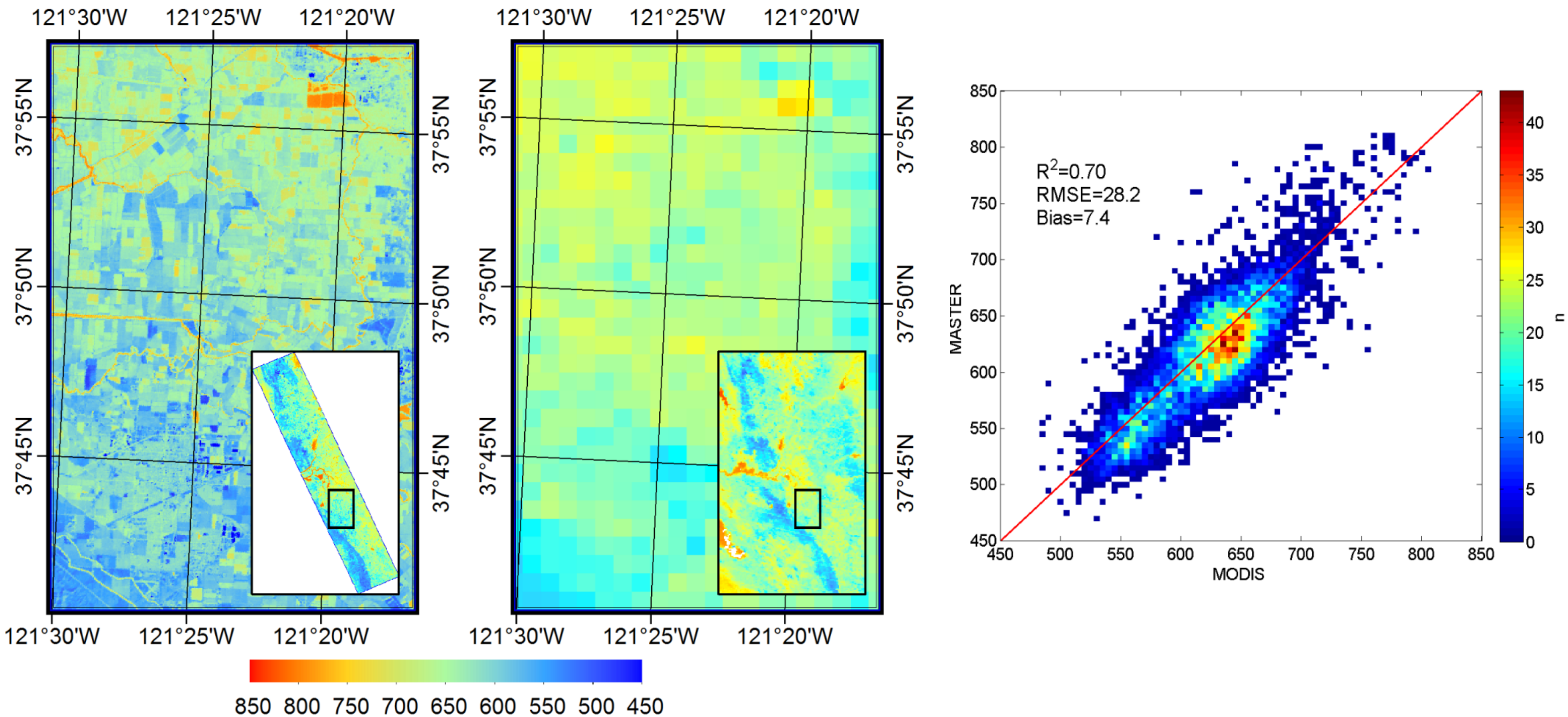
Map from MASTER data



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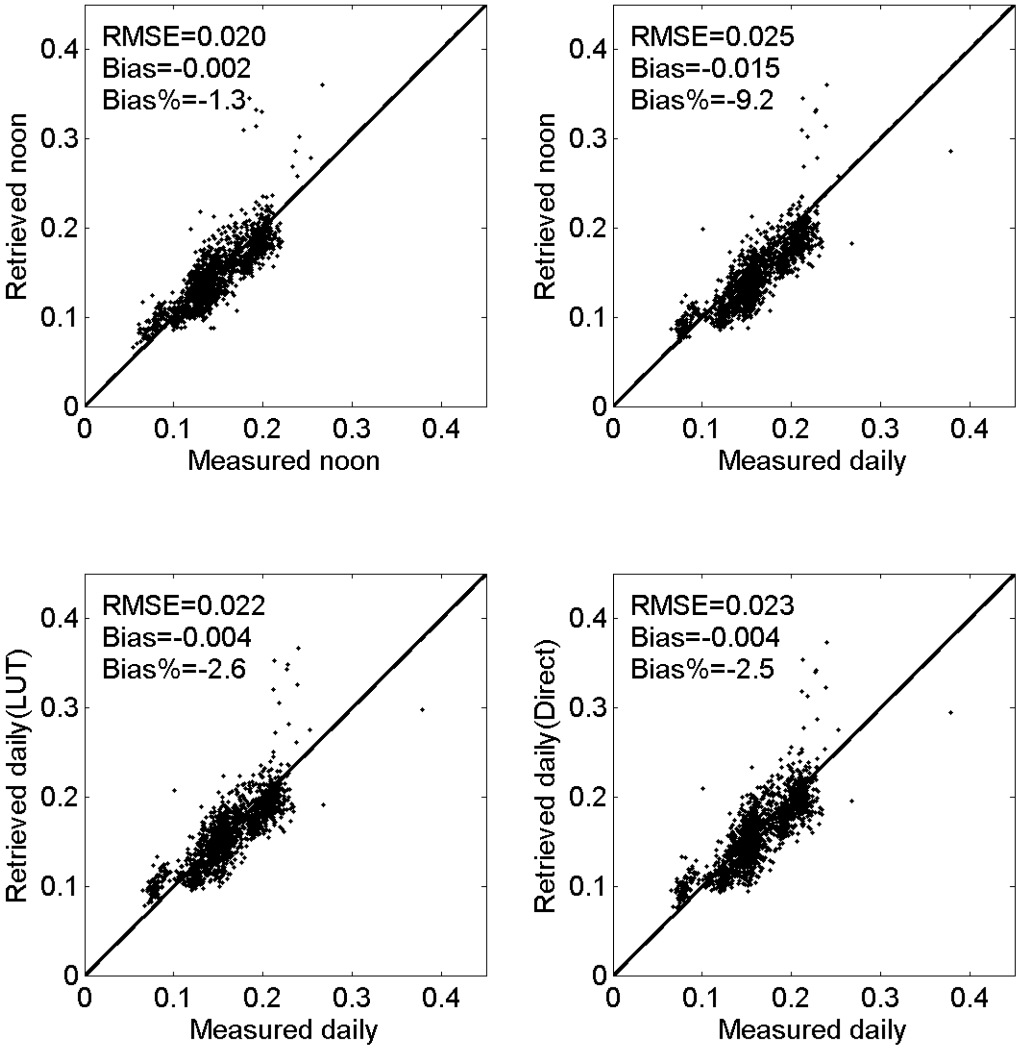
Temporal scaling of radiative variables



- Land surface albedo
  - Satellite products typically provide instantaneous albedo values (e.g. local noon)
  - Analysis shows such data will lead to bias in calculation of daily radiation budget
  - We developed methods to retrieve daily mean albedo from MODIS (Wang et al. JGR 2015)

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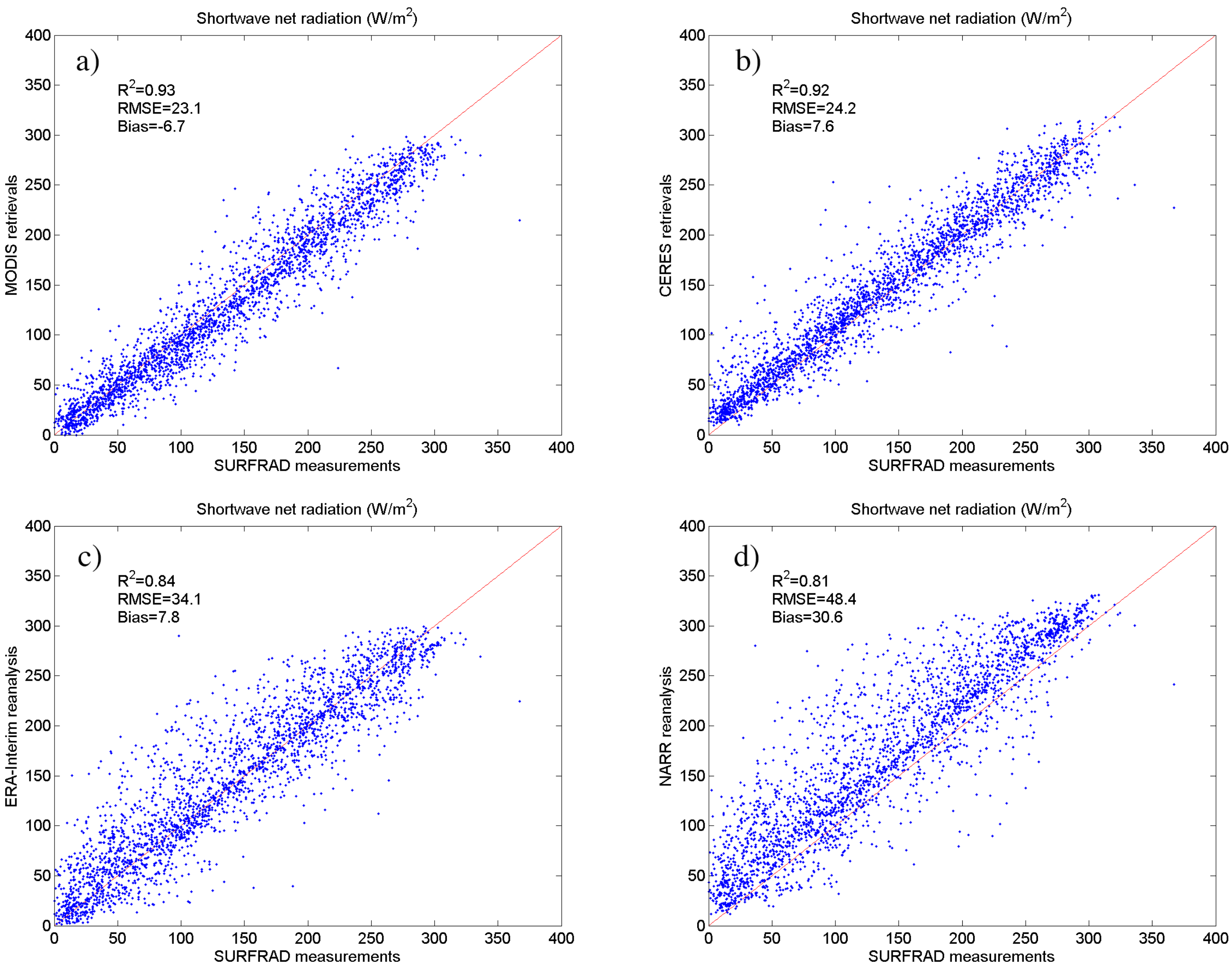
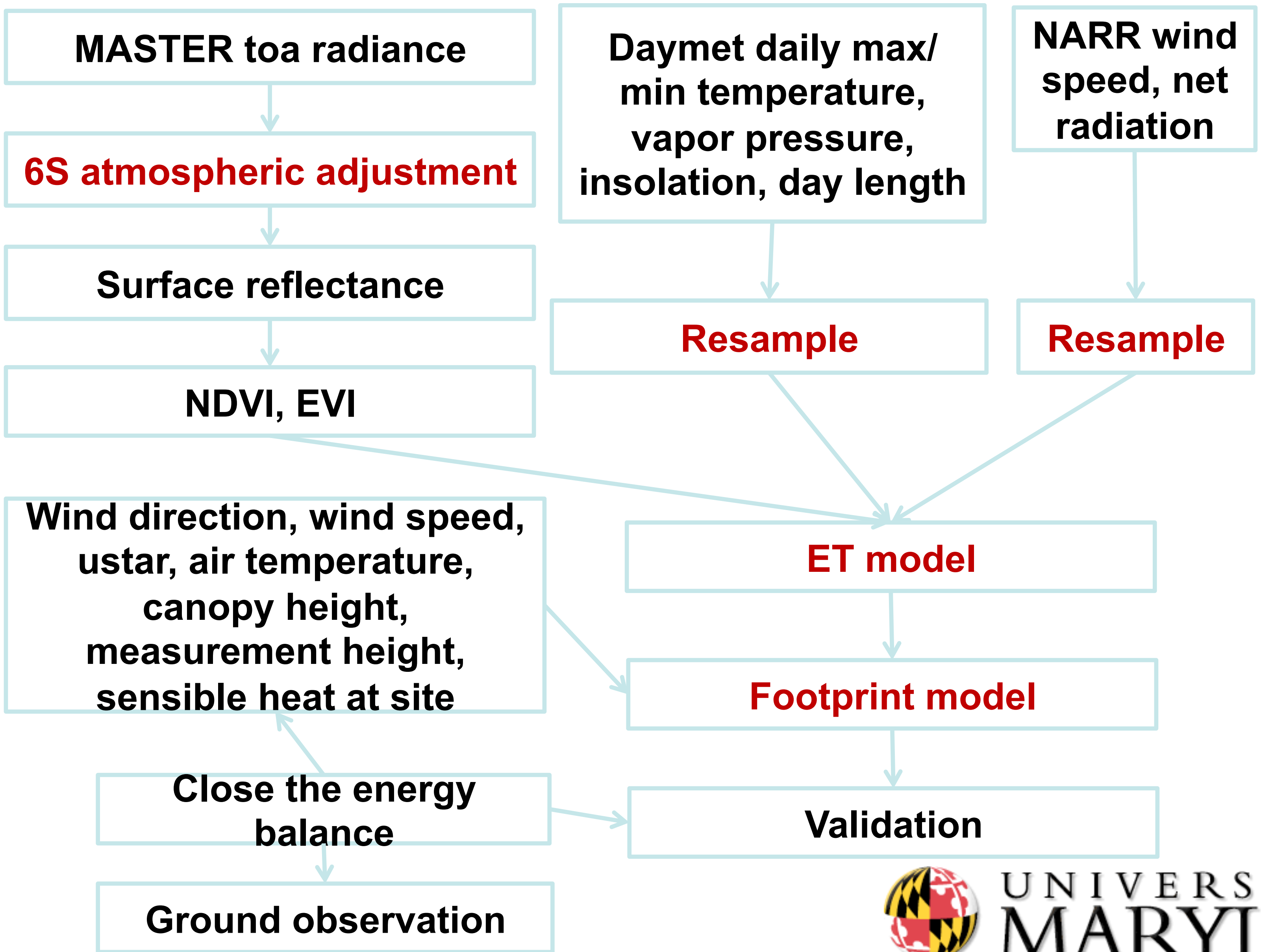
Daily surface shortwave net radiation

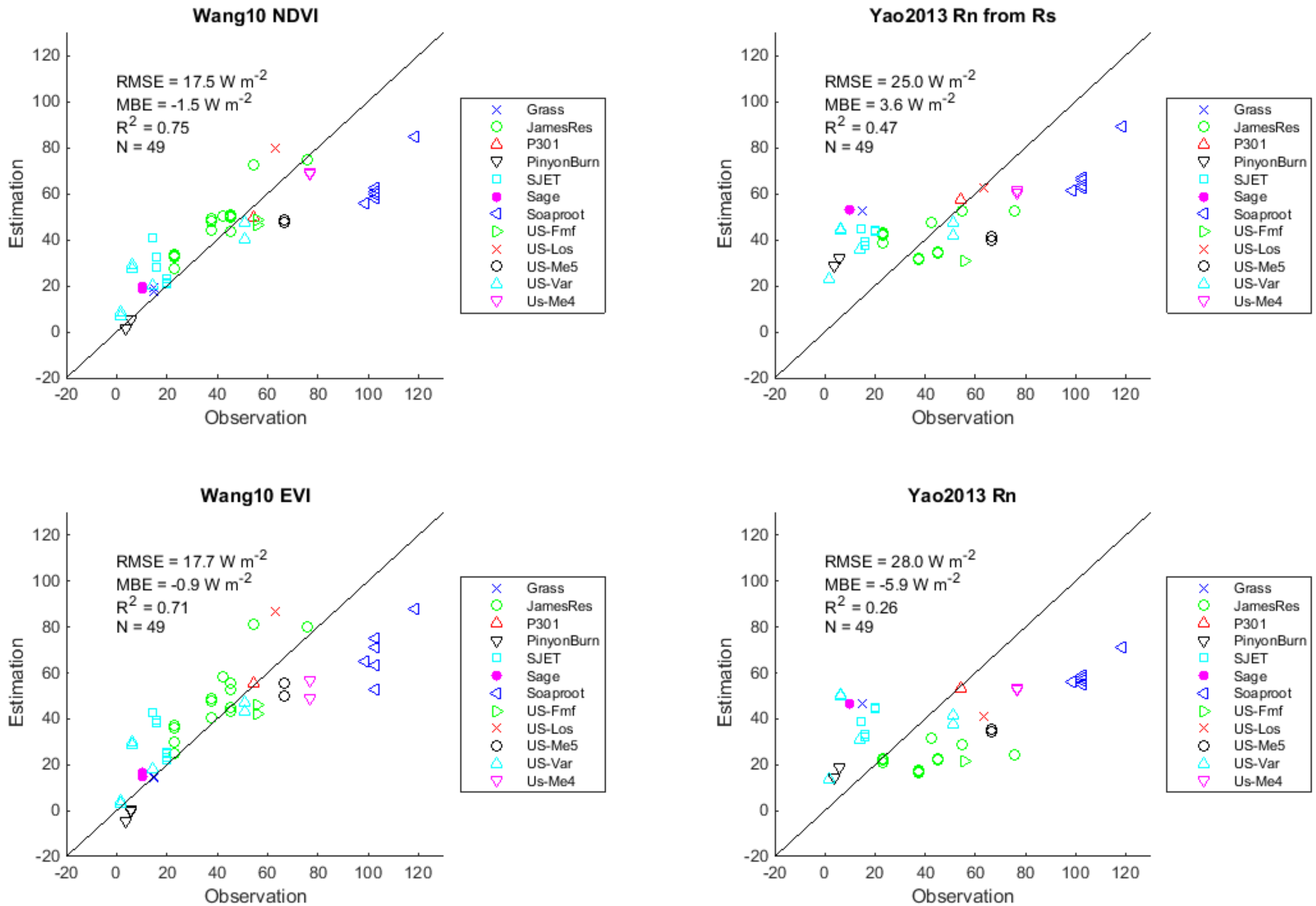


- We also studied temporal scaling of SSNR.
- Daily SSNR can be estimated with high accuracy from am and pm MODIS.

Mapping ET from MASTER and ancillary data



Validating latent heat flux at AmeriFlux sites



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Publications

- Wang, D., S. Liang, T. He, and Q. Shi (2015), Estimating clear-sky all-wave net radiation from combined visible and shortwave infrared (VSWIR) and thermal infrared (TIR) remote sensing data, *Remote Sens. Environ.*, *167*, 31-39, doi: 10.1016/j.rse. 2015.03.022.
- Wang, D., S. Liang, T. He, Y. Yu, C. Schaaf, and Z. Wang (2015), Estimating daily mean land surface albedo from MODIS data, *Journal of Geophysical Research-Atmospheres*, 120(10), 4825-4841, doi: 10.1002/2015jd023178.
- Wang, D., S. Liang, T. He, and Q. Shi (2015), Estimation of Daily Surface Shortwave Net Radiation From the Combined MODIS Data, *IEEE Transactions on Geoscience and Remote Sensing*, 53(10), 5519-5529, doi: 10.1109/tgrs.2015.2424716.
- He, T., S. Liang, D. Wang, Q. Shi, and M. L. Goulden (2015), Estimation of high-resolution land surface net shortwave radiation from AVIRIS data: Algorithm development and preliminary results, *Remote Sens. Environ.*, *167*, 20-30, doi: 10.1016/j.rse.2015.03.021.
- He, T., S. Liang, D. Wang, X. Chen, D. Song, and B. Jiang (2015). Land surface albedo estimation from Chinese HJ satellite data based on the direct estimation approach. *Remote Sensing*, 7(5), 5495-5510, doi: 10.3390/rs70505495
- He, T., Liang, S., Wang, D., Shi, Q., Tao, X. 2014. Estimation of High-Resolution Land Surface Shortwave Albedo From AVIRIS Data. *Journal of Selected Topics in Applied Earth Observations and Remote Sensing*. *doi: 10.1109/JSTARS. 2014.2302234*.

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