Land Surface Thermal-IR Emissivity Modeling

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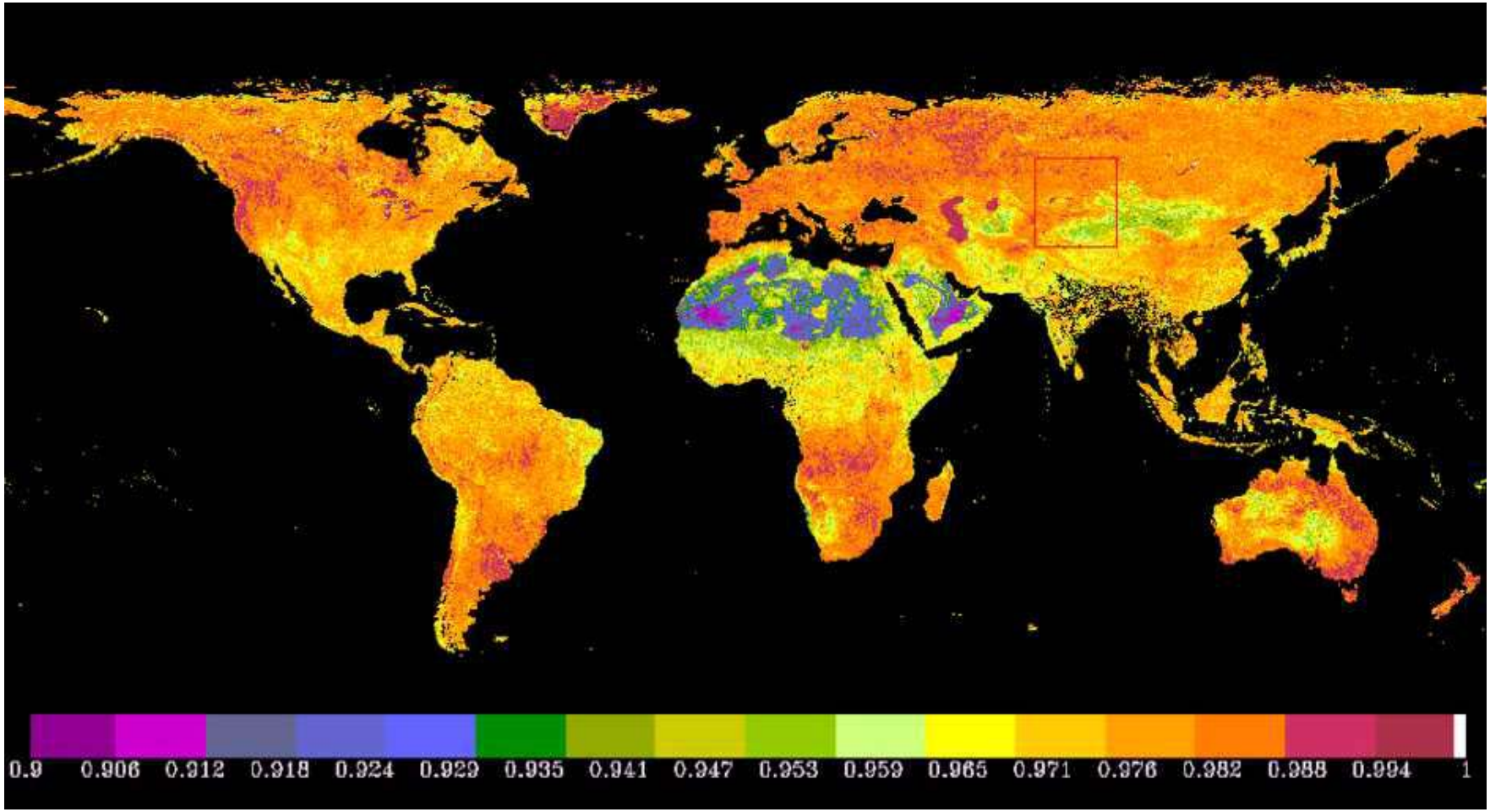
Introduction (1)

- Land surface thermal infrared emissivity ε is a critical variable in surface longwave radiation budget
- However, it has been treated very approximately by various operational models

Introduction (2)

- **Noah LSM sets $\varepsilon = 1$ for all land surfaces except for snow**
- **ECMWF model sets ε as a constant.**
- **Radiative Transfer for TOVS sets $\varepsilon = 0.98$ for all land surfaces, and $\varepsilon = 0.99$ for sea ice.**
- **Actually, emissivity have a very large spatial variation. It may be as low as 0.7-0.8, which will results in 10% error in surface longwave radiation budget (Jin and Liang, J. Climate, 2006).**

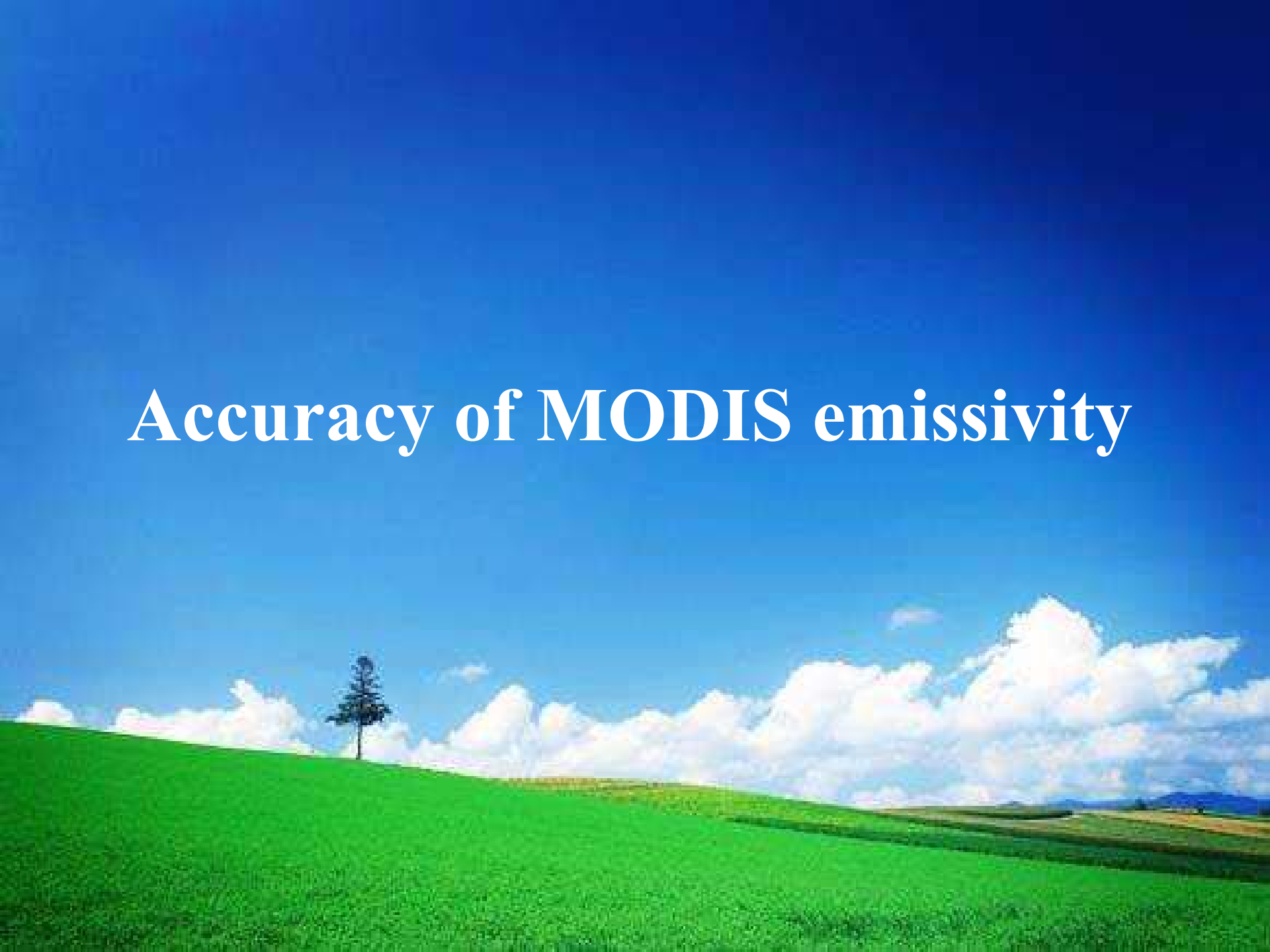
MODIS monthly emissivity
(June 2002, version 5)



Our overall objectives

- **Develop a high-resolution emissivity database from multiple satellite sensors (e.g., MODIS, ASTER) using a data fusion approach.**
- **Establish the empirical relations between emissivity and various land surface biogeophysical variables.**
- **Assess, calibrate and improve existing radiative transfer emissivity models.**

Accuracy of MODIS emissivity



Evaluation of emissivity

- **It is the first step to evaluate the accuracy of the current available emissivity retrievals before data fusion.**
- **However, *in-situ* land surface emissivity measurements are not available.**
- **Land surface longwave radiation including information on land surface temperature (LST) and emissivity can be used to evaluate satellite emissivity retrievals.**

Longwave radiation and emissivity

- **Relationship longwave radiation and emissivity can be written as (Wang et al., JGR, 2005, Liang, 2004):**

$$T_s = \left[\frac{L_\uparrow - (1-\varepsilon_b)\cdot L_\downarrow}{\varepsilon_b \cdot \sigma} \right]^{1/4} \qquad L_\uparrow = \varepsilon_b \cdot \sigma \cdot T_s^{\,4} + (1-\varepsilon_b)\cdot L_\downarrow$$

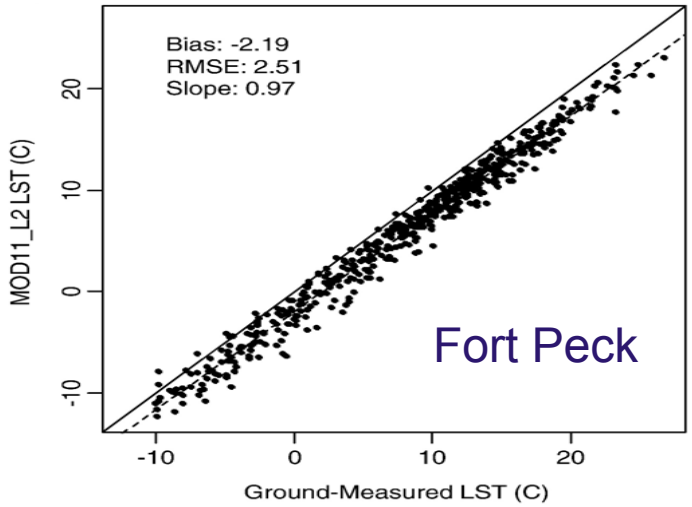
- **Broad band emissivity ε_b can be estimate from MODIS narrowband retrievals in thermal-IR region (Wang et al., J.G. R., 2005):**

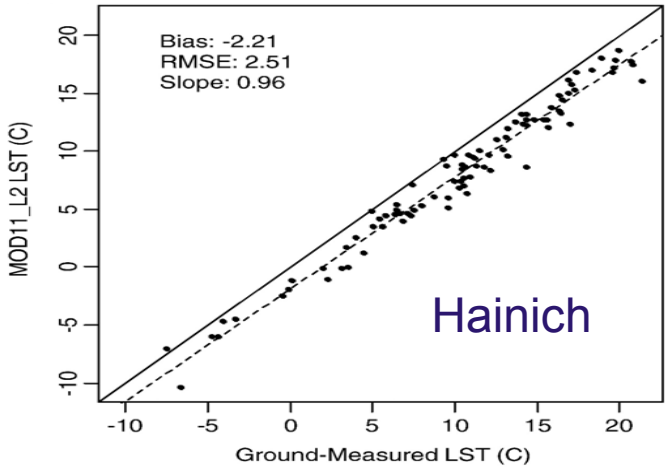
$$\varepsilon_b = 0.2122 \cdot \varepsilon_{29} + 0.3859 \cdot \varepsilon_{31} + 0.4029 \cdot \varepsilon_{32}$$

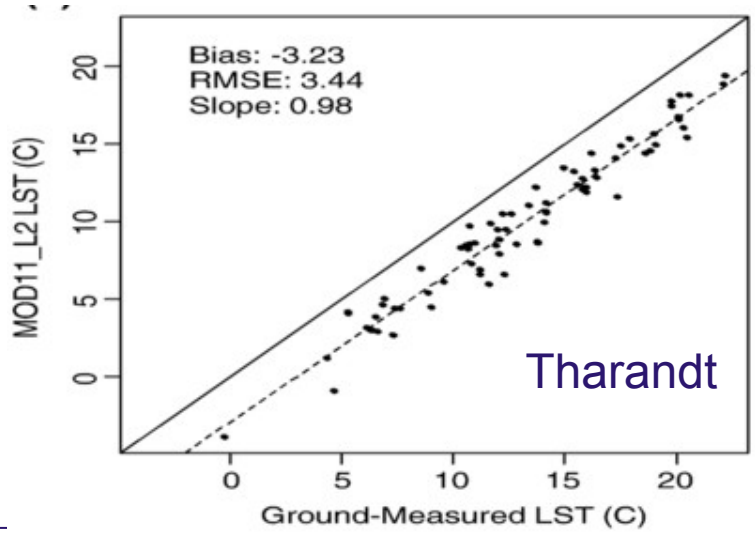
Method

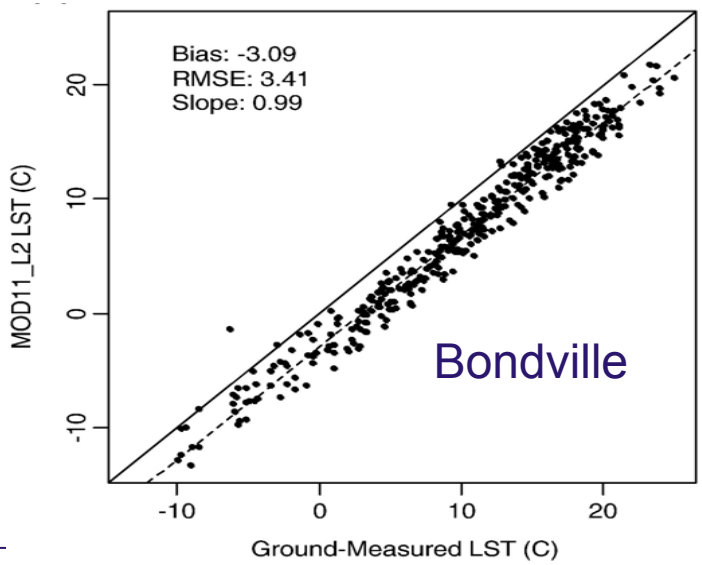
- **First, estimate broadband emissivity from satellite narrowband retrievals (MODIS day/night LST algorithm).**
- **Second, estimate LST from longave radiation measurements.**
- **Third, compare LST from ground-based measurements and satellite retrievals from independent algorithm (split-window algorithm).**
- **Studies have shown that there is no bias in the MODIS LST from split-window algorithm. We can infer: If the ground-based LST is larger, it seems that the emissivity is underestimated, and vice versa.**

Validation MODIS version 4 LST at FLUXNET sites
(Wang et al., RSE, 2008)

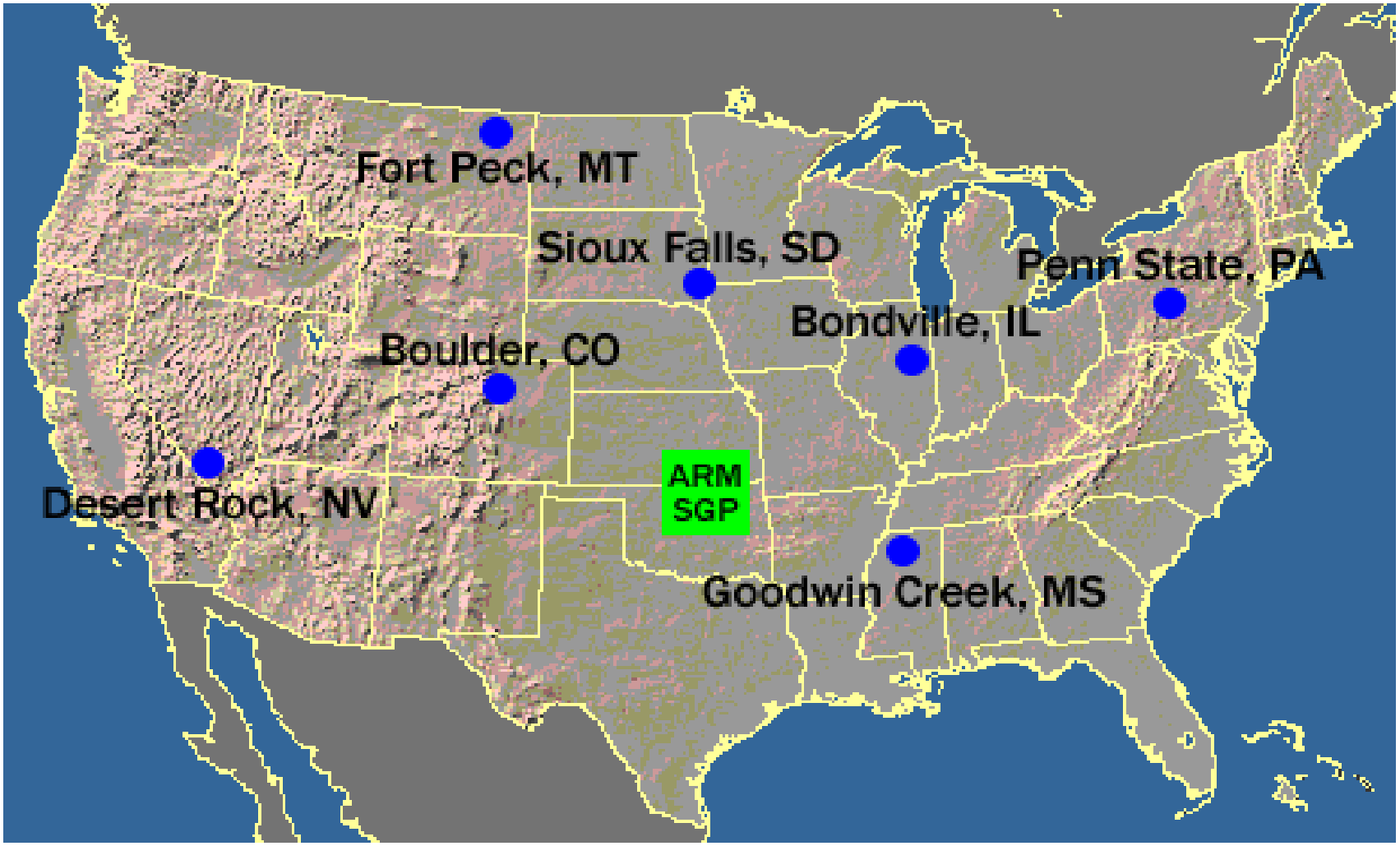








Validation of $L_{\uparrow}$ from MODIS version 4 emissivity at SURFRAD sites



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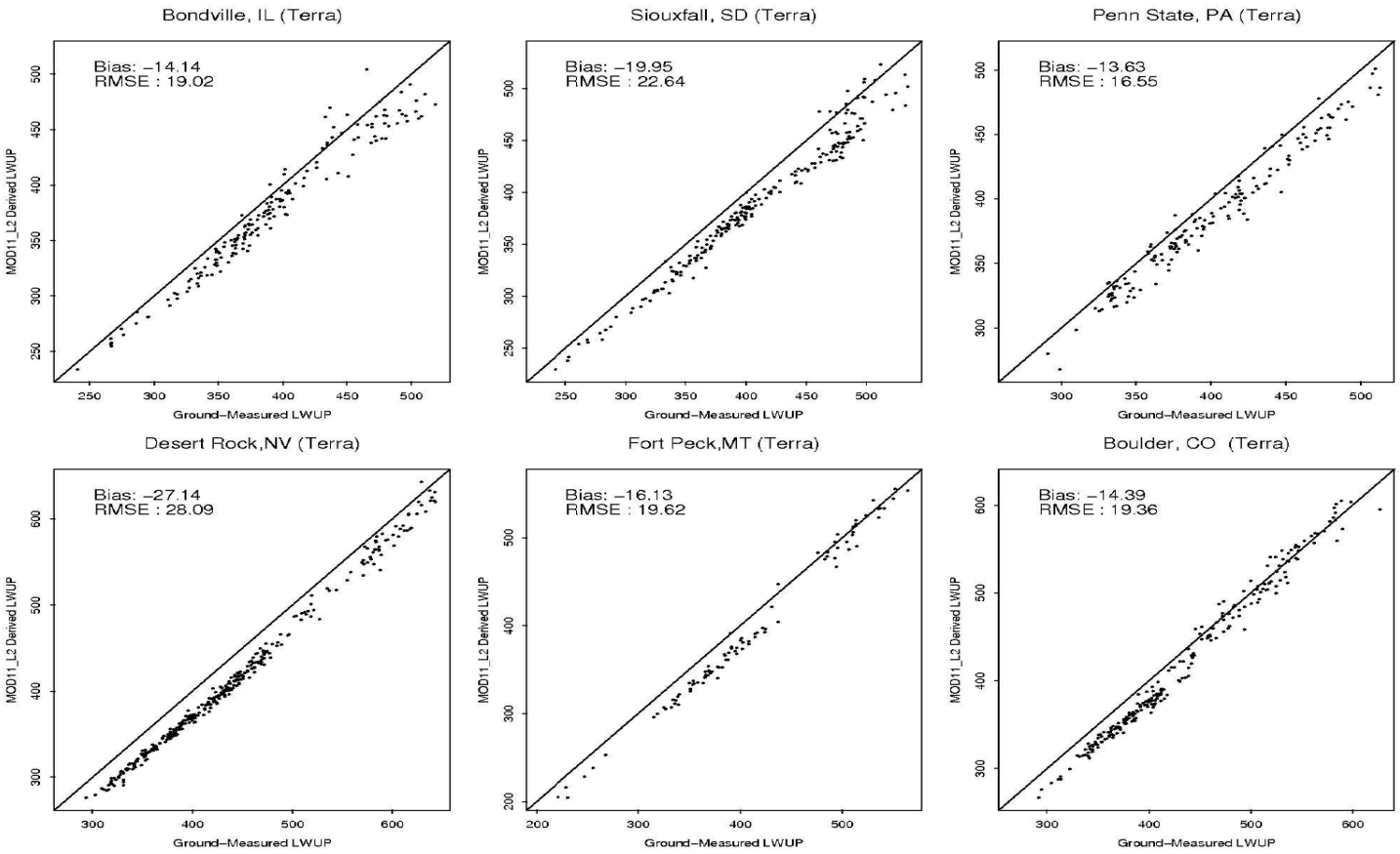
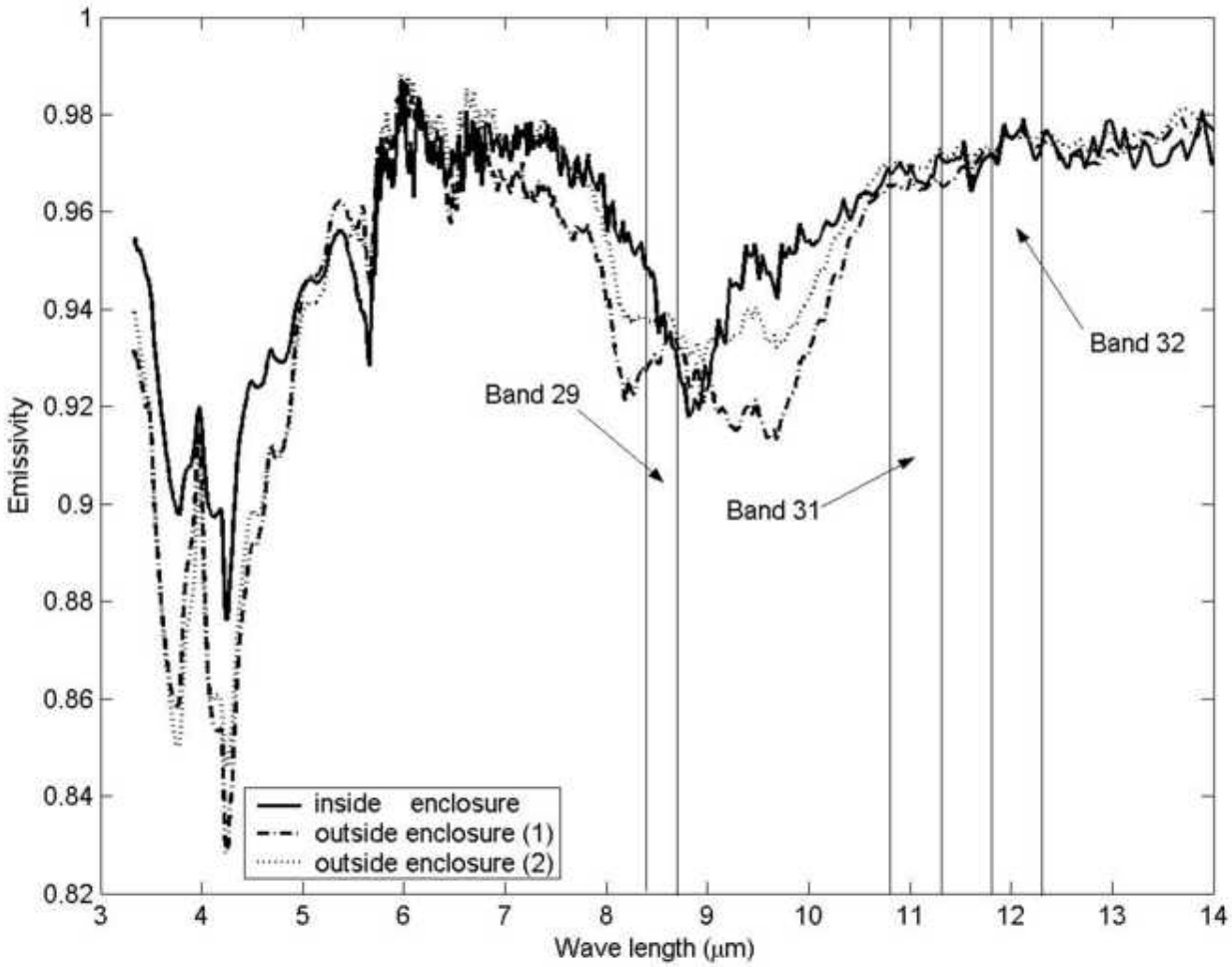
MODIS



Ground measurements

Validation of Emissivity at Tibetan Plateau

(Wang et al., Int. J. Remote Sens., 2007)



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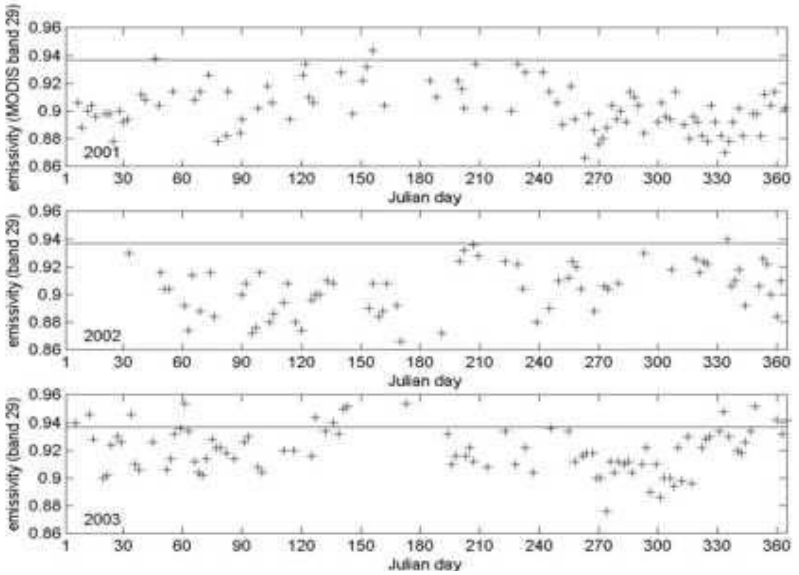
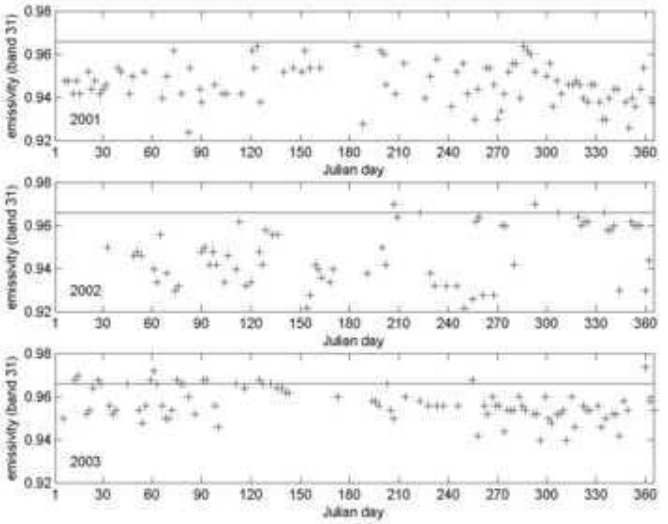
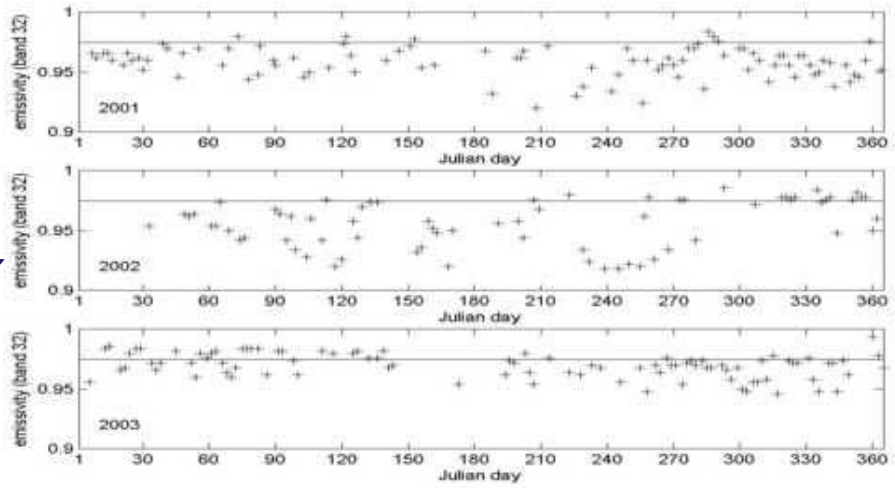


MODIS band 29



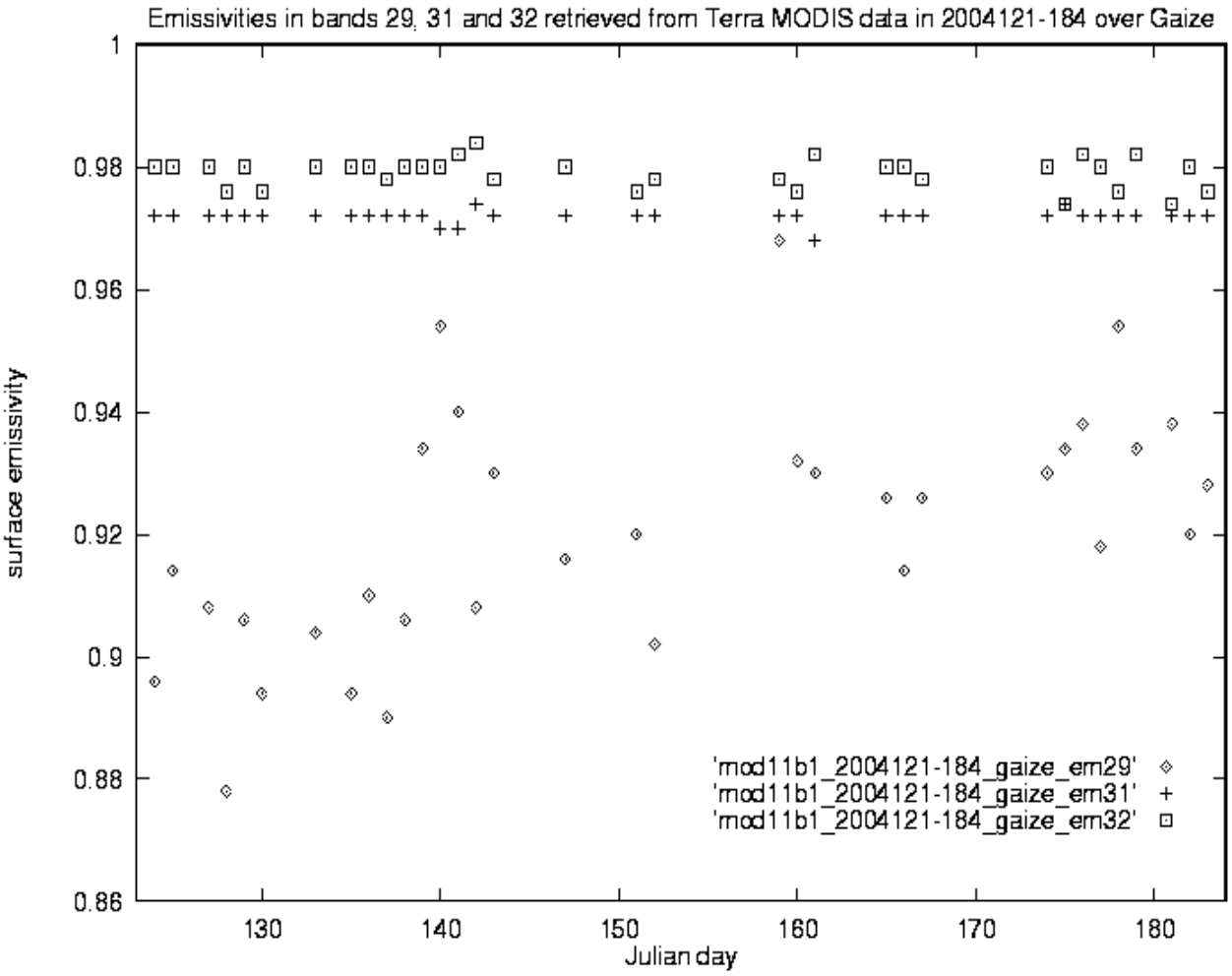
MODIS band 31



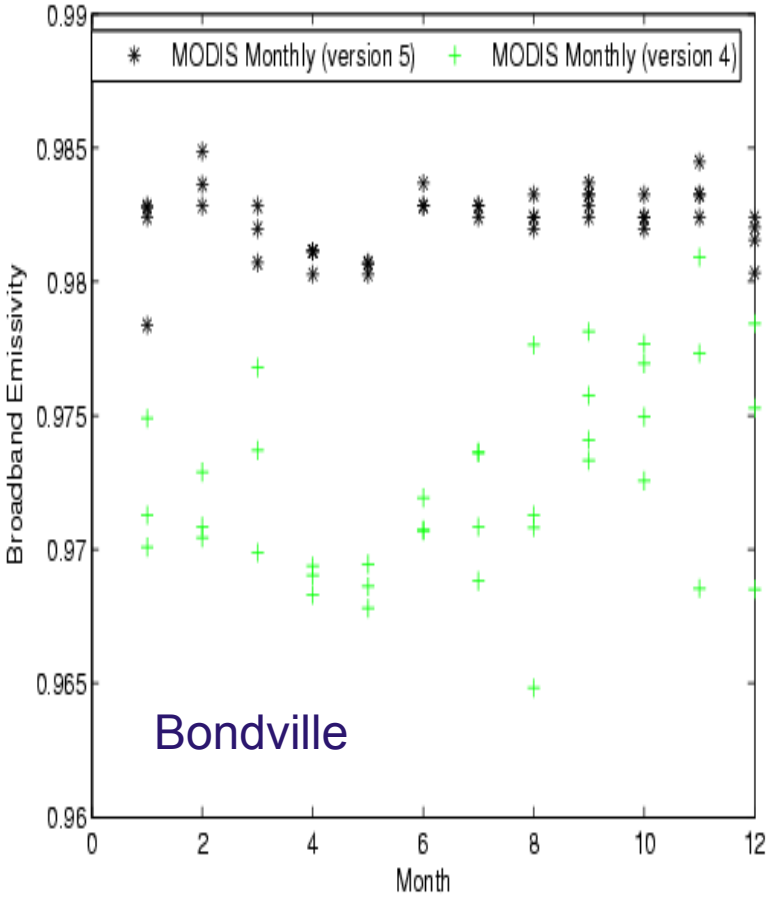
MODIS band 32

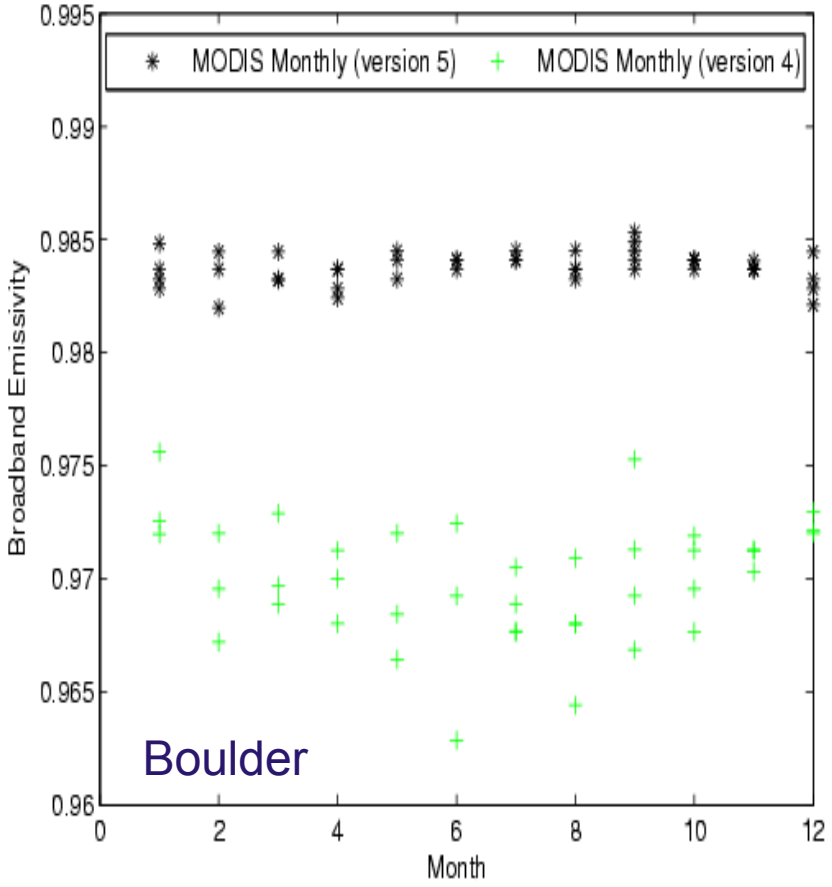
MODIS emissivity improvement

(version 5, Wang et al., Int. J. Remote Sens., 2007; Wan, RSE, 2008)



Comparison of MODIS version 4 and 5 broadband emissivity at SURFRAD sites (Wang and Liang, RSE, 2008, under review)





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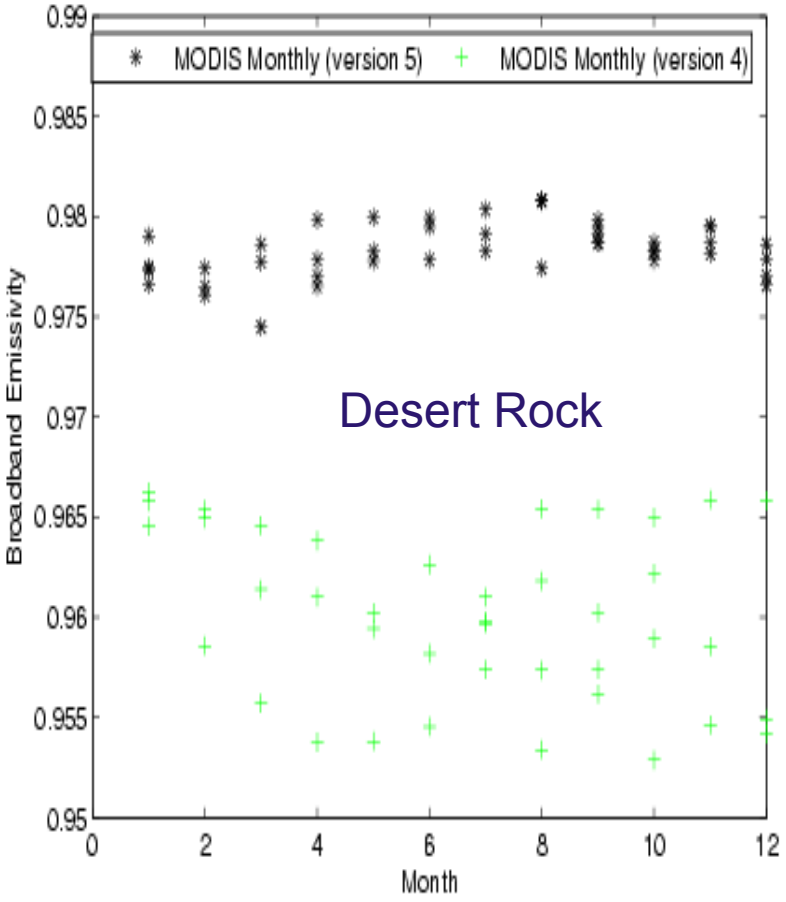

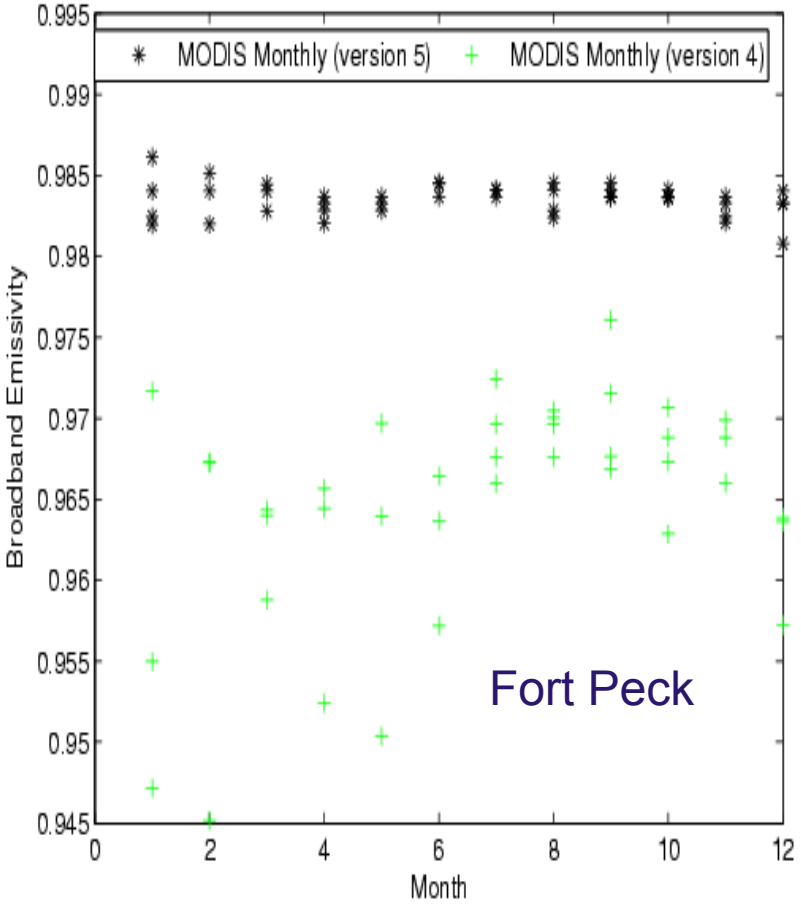

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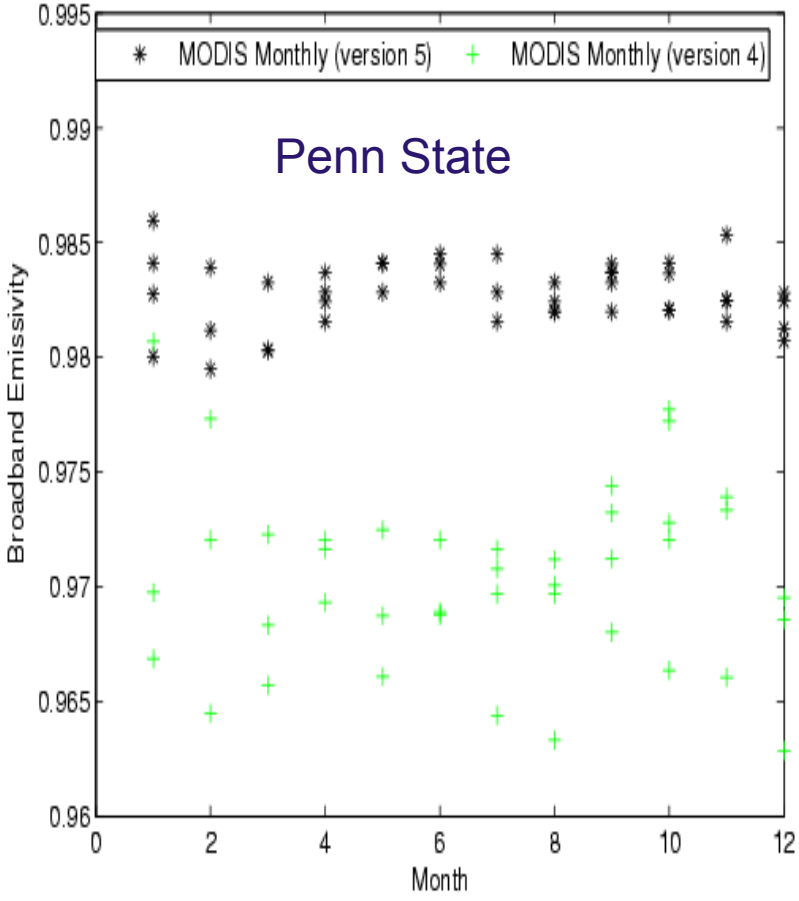

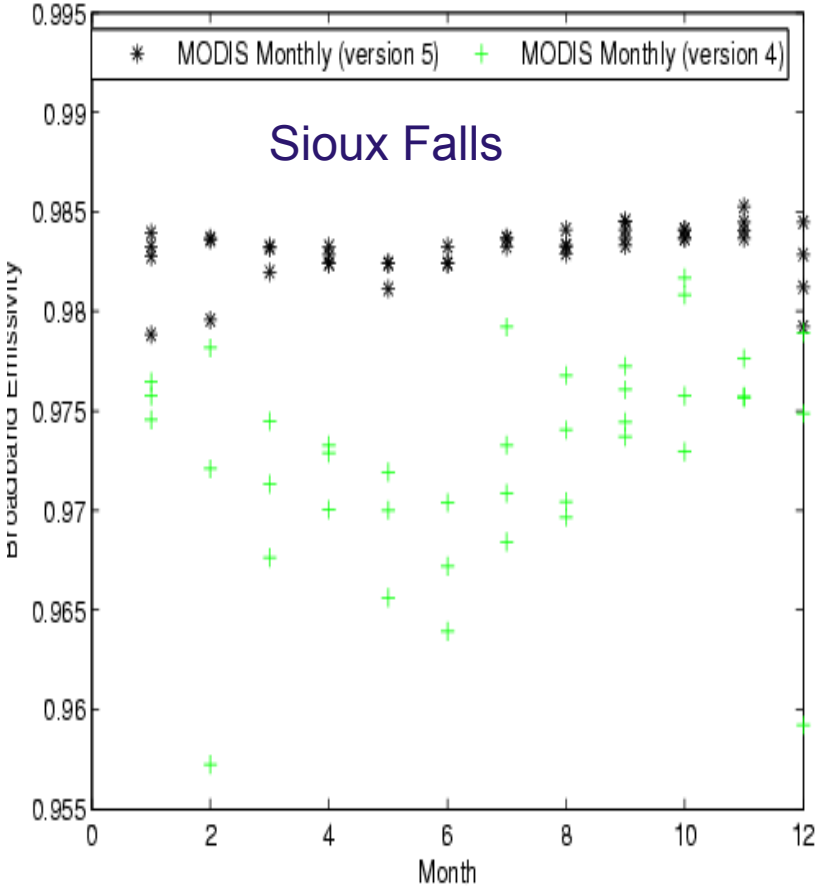

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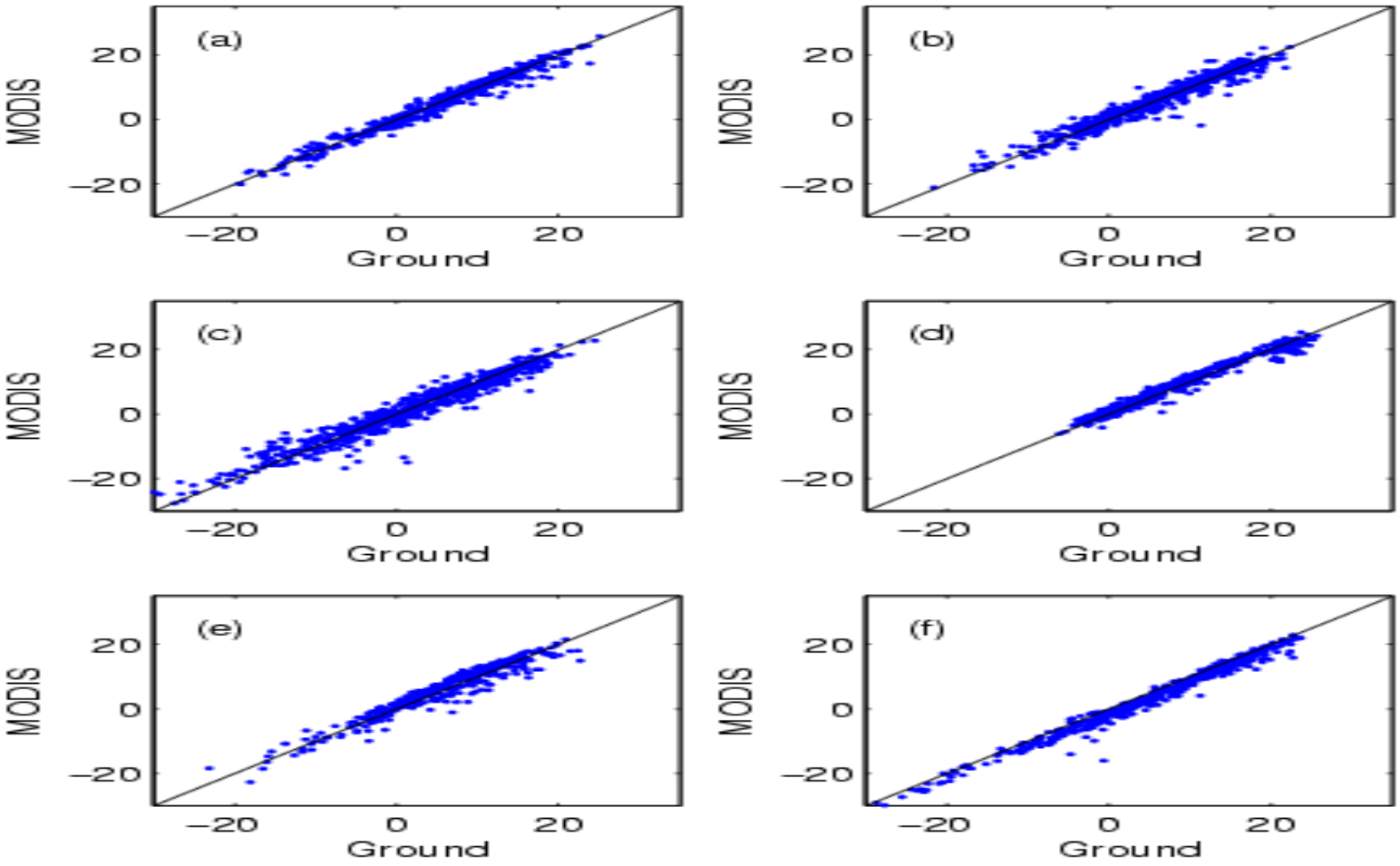
Comparison of LST calculated from MODIS version 5 emissivity and LST from split-window algorithm at SURFRAD sites

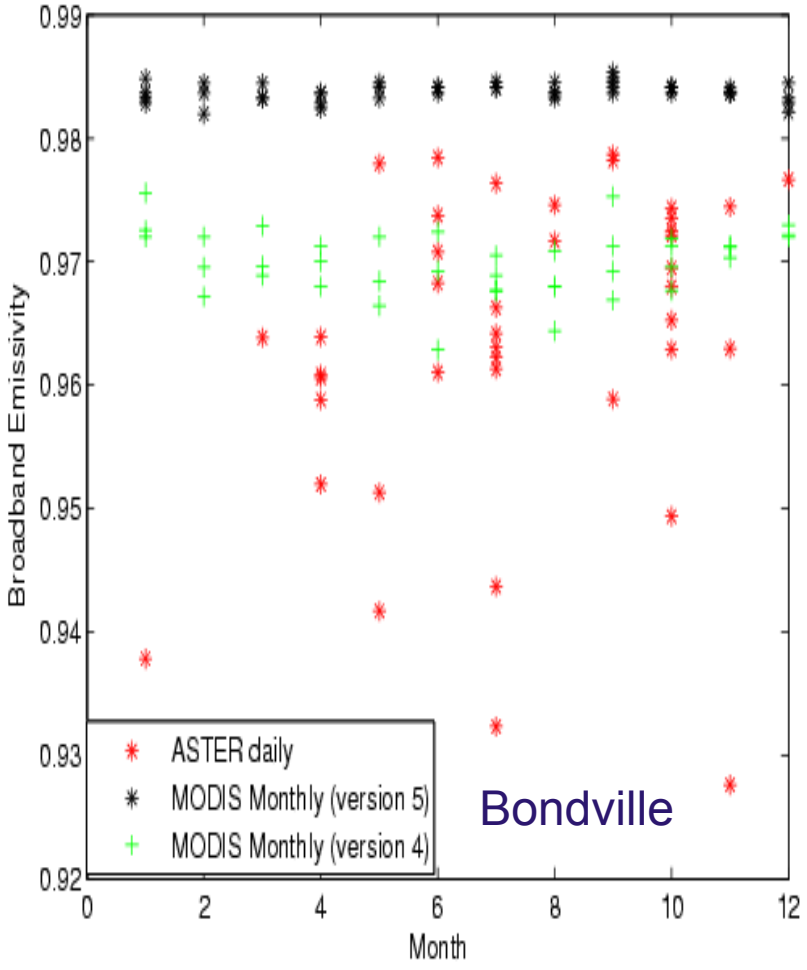
(Wang and Liang, RSE., 2008, under review)

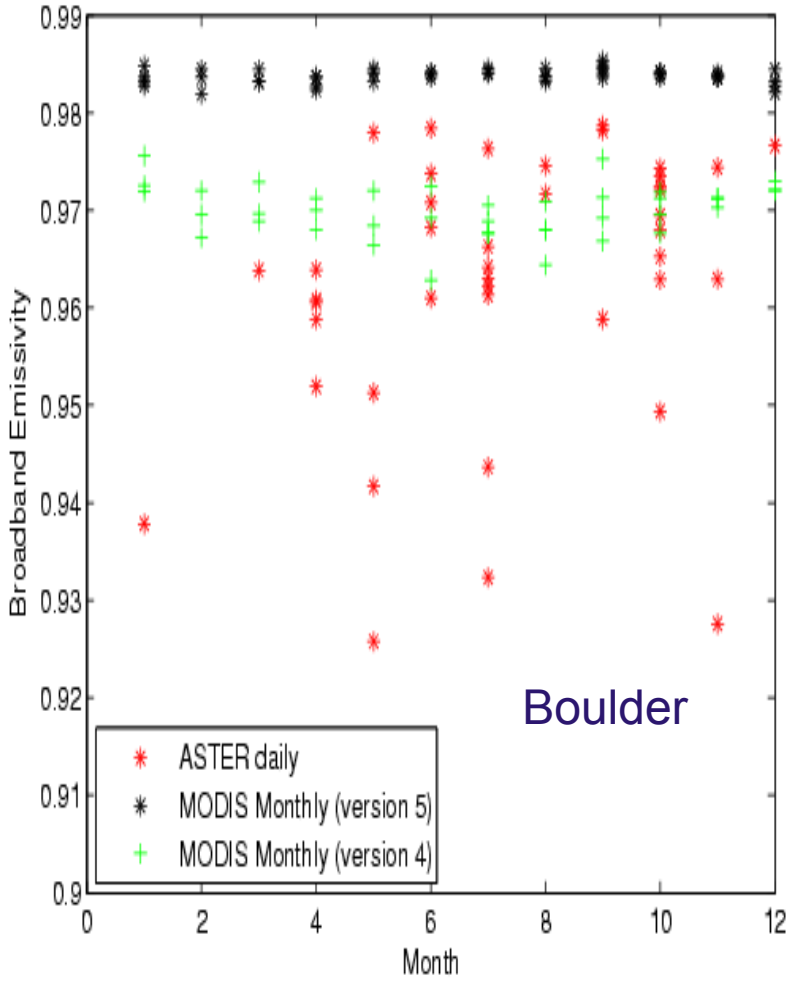
Averaged bias over the six sites is about 0.2 K



Accuracy of ASTER emissivity

Comparison of MODIS and ASTER broadband emissivity at SURFRAD sites (Wang and Liang, 2008, under review)





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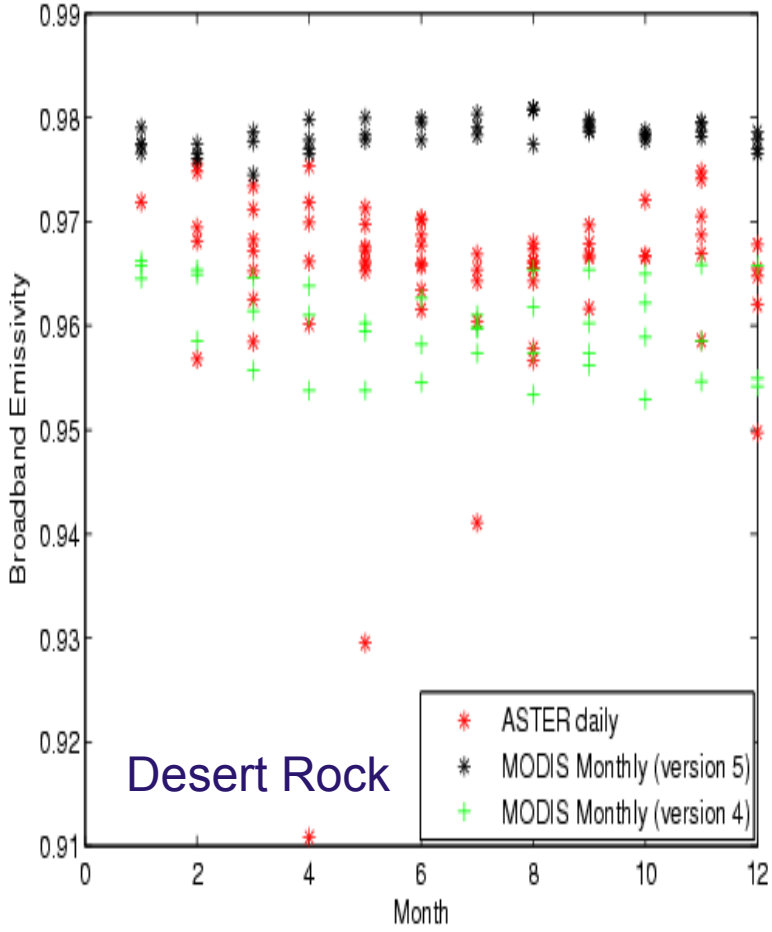

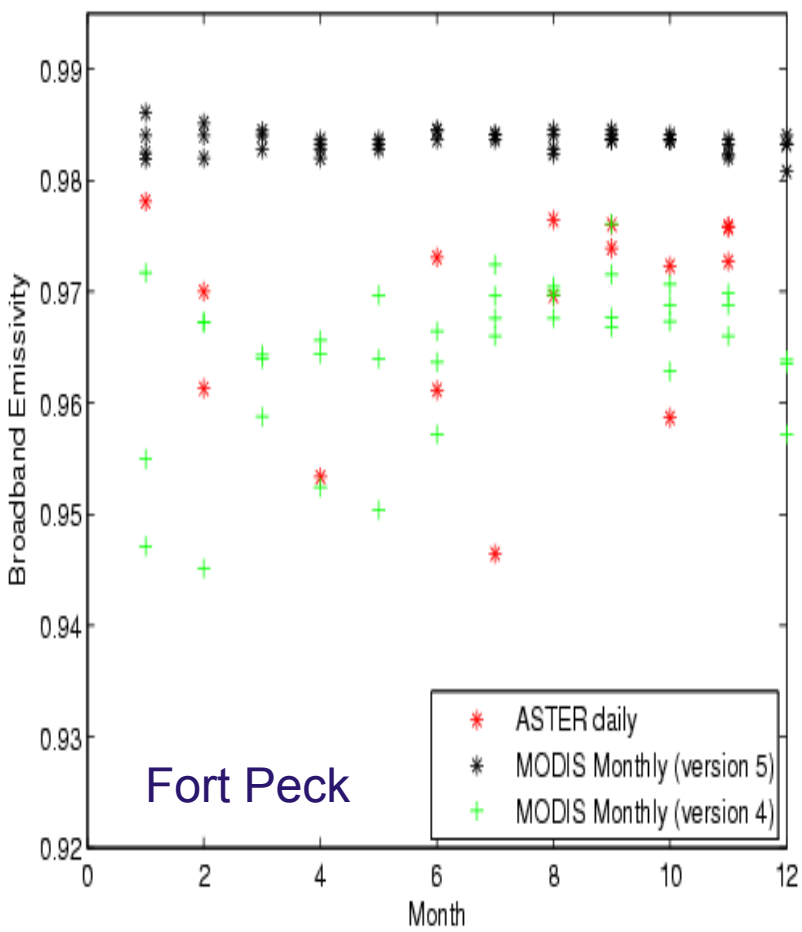

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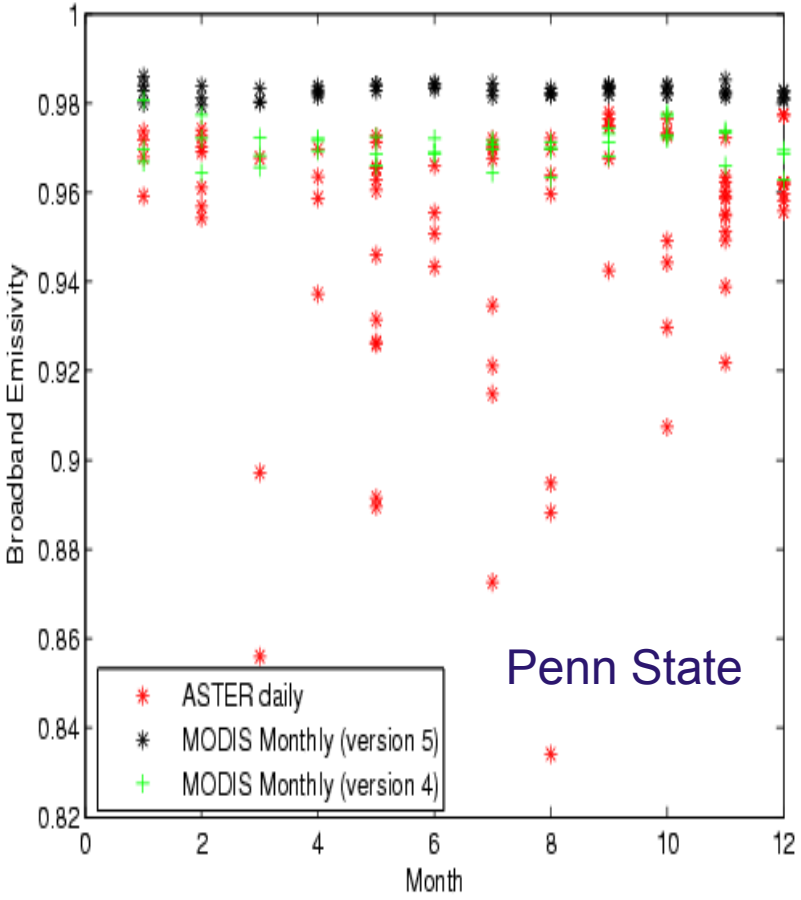

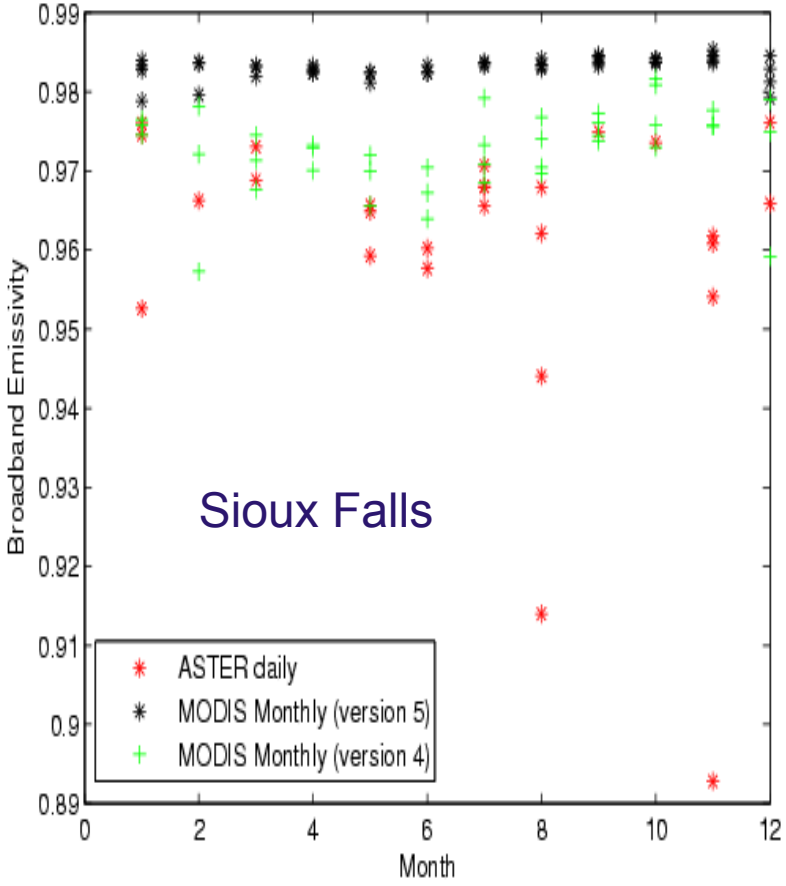

Summary

- Longwave radiation is helpful to evaluate satellite emissivity products.
- MODIS version 5 emissivity corrects the underestimations of MODIS version 4 for vegetated surfaces.
- ASTER product tends to underestimate emissivity, especially for summer time.

Accomplishments in first year

- Downloading satellite emissivity products from multiple sensors, such as MODIS, ASTER, SEVIRI, AIRS, etc.
- Developing data fusion algorithms to integrate multiple emissivity products.
- Developing a consistent parametric emissivity modeling scheme for different land cover types.

Future plan

- Processing and analyzing different emissivity products and developing an integrated land surface emissivity database;
- Continuing to develop the emissivity models

Reference (1)

- Jin, M., S. Liang, (2006), Improved emissivity parametrization for land surface modeling using global remote sensing observations, *Journal of Climate*. 19(12) :2867-2881.
- Liang, S., Quantitative Remote Sensing of Land Surfaces, John Wiley and Sons, Inc., 534 pages, 2004.
- Wang, K., Wan, Z., Wang, P., Sparrow, M., Liu, J., Zhou, X., et al. (2005). Estimation of surface long wave radiation and broadband emissivity using Moderate Resolution Imaging Spectroradiometer (MODIS) land surface temperature/emissivity products. *Journal of Geophysical Research*, 110, D11109, doi:10.1029/2004JD005566.
- Wang, K., Z. Wan, P. Wang, J. Liu, and M. Sparrow (2007). Evaluation and Improvement of the MODIS Land Surface Temperature/Emissivity Products Using Ground-based Measurements at a Semi-desert Site on the Western Tibetan Plateau. *International Journal of Remote Sensing*, 28, 2549-2565.
- Wang, W., S. Liang, , and T. Meyer, (2008a), Validating MODIS land surface temperature products, *Remote Sensing of Environment*, 112:623-635

Reference (2)

- **Wan, Z. (2008), New refinements and validation of the MODIS Land-Surface Temperature/Emissivity products. *Remote Sensing of Environment*, 112, 59−74.**
- **Wang, W., S. Liang, J. A. Augustine (2008b), Estimating clear-sky land surface upwelling longwave radiation from MODIS data, *IEEE Transactions on Geoscience and Remote Sensing*, in press.**
- **Wang, K. and Liang (2008). Evaluation of ASTER and MODIS collection 5 land surface temperature/emissivity products with surface longwave radiation and ASTER retrievals at SURFRAD sites, *Remote Sensing of Environment*, under review.**


Thank You !