Analyzing Measurement Difference Between Satellite and Ground Data for Land Surface Temperature Validation

MODIS/VIIRS Science Meeting

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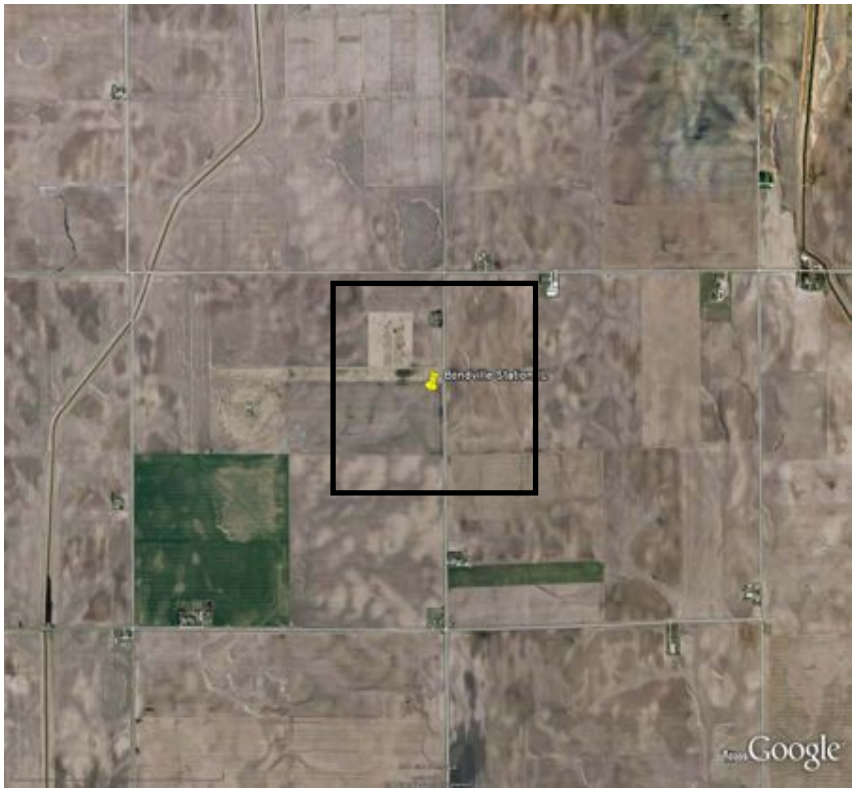
Outline

- Motivation
- Approach
- Preliminary Work and Results
- 2010 Plan and Schedule

Motivation

LST Validation Difficulties

- *In Situ* data limitation
  - Measurement difficulty
  - Effect of cloud contamination
  - Partial or thin cloudy pixels: needs stringent filter
- Spatial and temporal variations
  - Spot vs pixel difference
  - Accurate match-up process
- Others (i.e., angle effect)



Surface heterogeneity is shown in a 4km x 4km Google map (1km x 1km, in the center box) around the Bondville station area

Two-measurement model :

$$LST_{satellite} = LST_{truth} + Noise_{satellite}$$

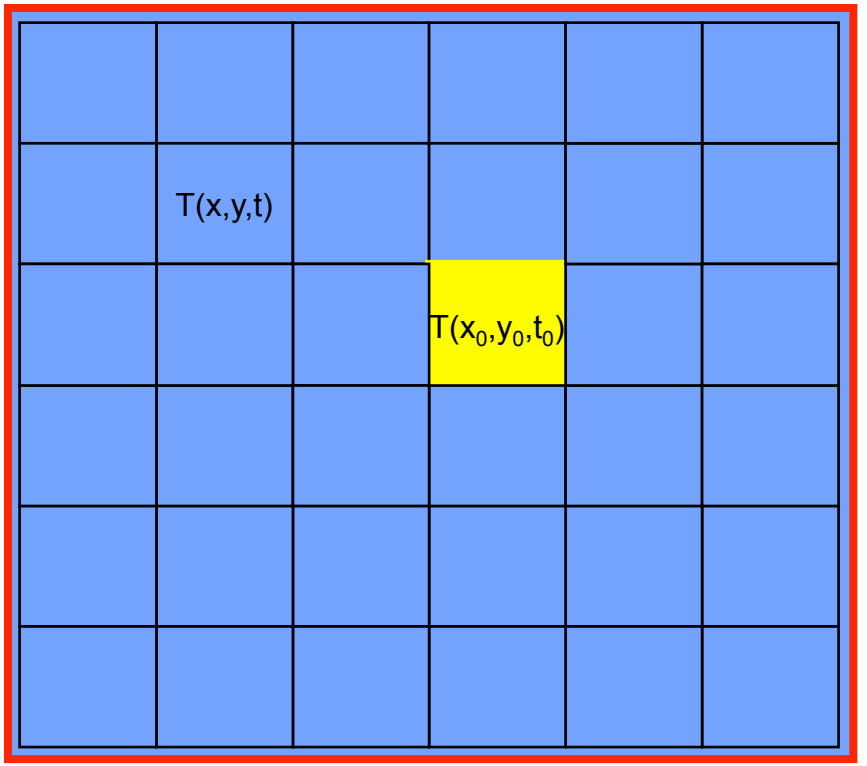
$$LST_{ground} = LST_{truth} + Noise_{ground}$$

Understanding $Noise_{ground}$ is crucial for understanding $Noise_{satellite}$

Approach

Method: Synthetic pixel analysis using ASTER data

- Quantitatively characterize the sub-pixel heterogeneity and decide whether a ground site is adequately representative for the satellite pixel. The sub-pixels may be defined as the pixels of a higher-resolution satellite.
- For pixel that is relatively homogeneous, build up the relationship of the ground-site with the surrounding sub-pixels defined by collocated higher-resolution observations : $\{T(x,y)\} \sim T(x_0,y_0)$
- Establish relationship between the objective pixel and its sub-pixels (i.e., up-scaling model), e.g.,
  $T_{pixel} = T(x,y) + \Delta T$ (time dependent?)

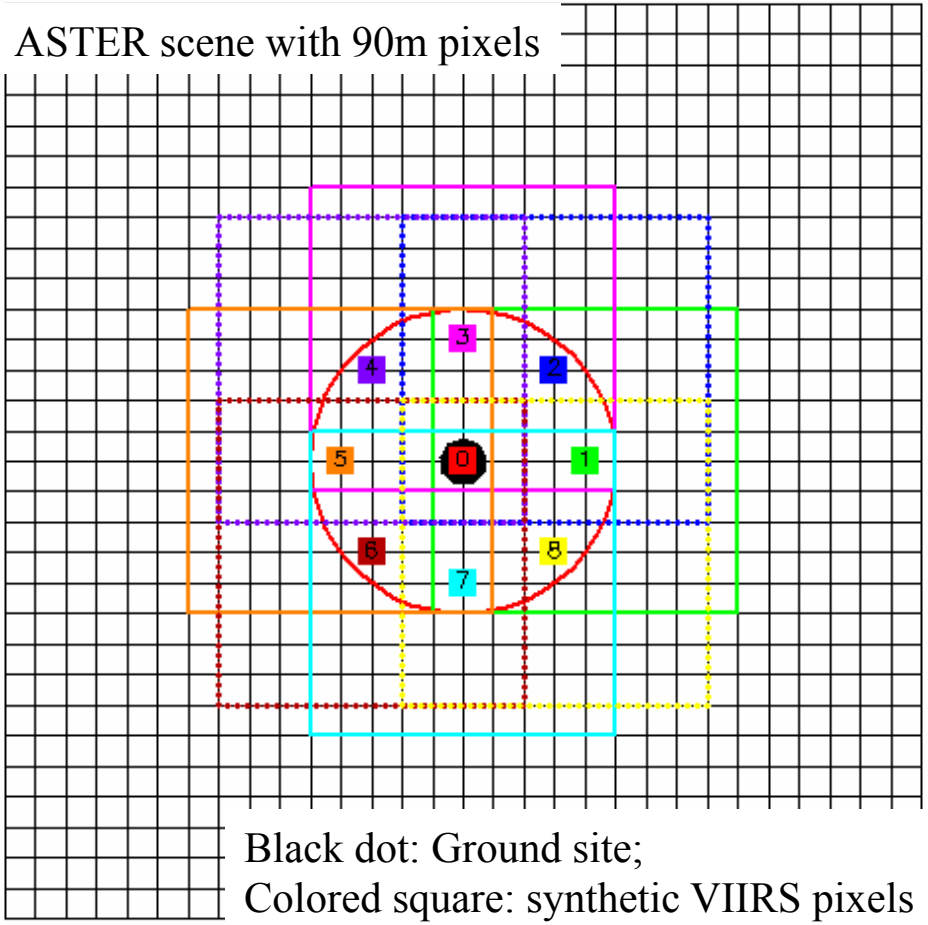


Approach

Test on Impact of Center Shifting of the Satellite Pixel

Pixels synthesized from fine-resolution (90m) ASTER TIR pixels.

- *Each synthetic pixel has the target ground site enclosed, but the distance between the ground site and the center of synthetic pixel varies, which mimics the possible over-passing VIIRS swaths.*
- *Distance of every synthetic pixel center from the ground site is within the pixel size (~1Km).*
- *Different colors are used for the 9 synthetic pixels, and the center of each pixel is marked with a small numbered square of the same corresponding color.*
- *The numbers on the squares are the pixel IDs used in the relevant analysis.*



Approach

Satellite-ground data match up process

Satellite LST: MODIS LST, ASTER, and GOES LST
Ground LST: Derived from SURFRAD site measurements

Duration: Jan 1 – Dec 31, 2001

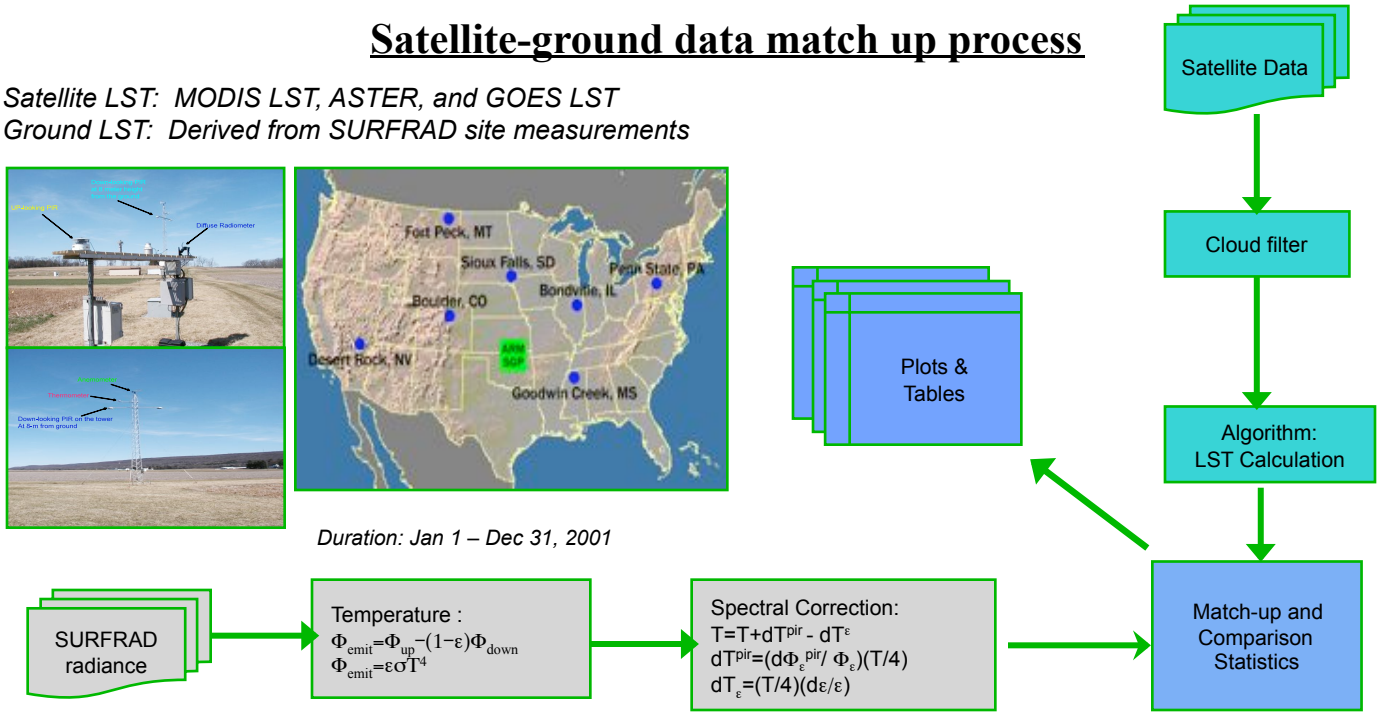


Table: Matched ASTER Data

Stations	Clear Cases (ASTER cloud mask)	Clear Cases (additional cloud filter)
Desert Rock	63	46
Bondville, IL	115	51
PennState, PA	61	20
Boulder, CO	35	13
Fort Peck, MT	12	8

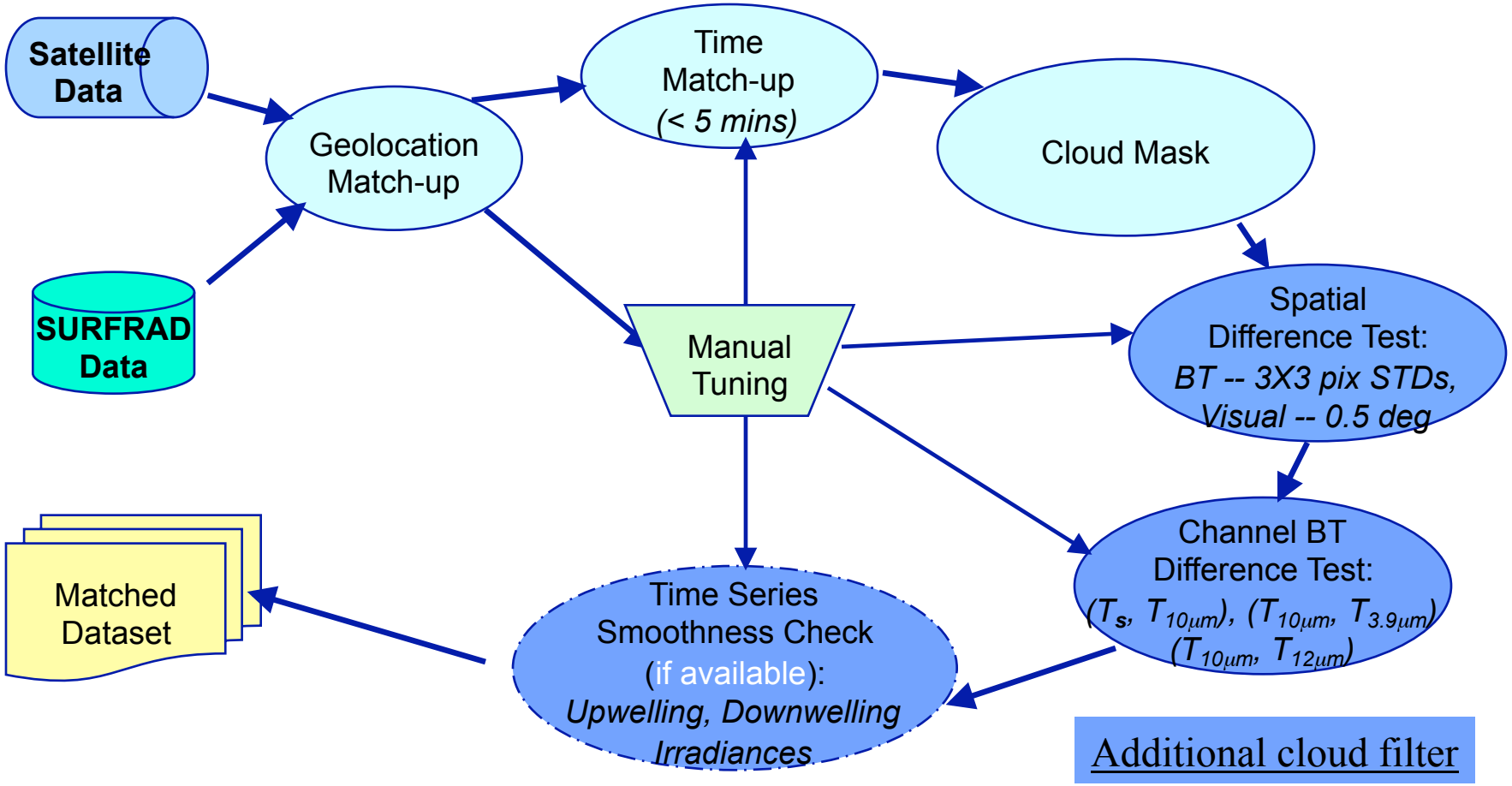
Dataset Used

- SURFRAD data
- ASTER data
- Data period: 2000-2007

ASTER data is courtesy by *Shunlin Liang*

Approach

Match-up Flow Chart

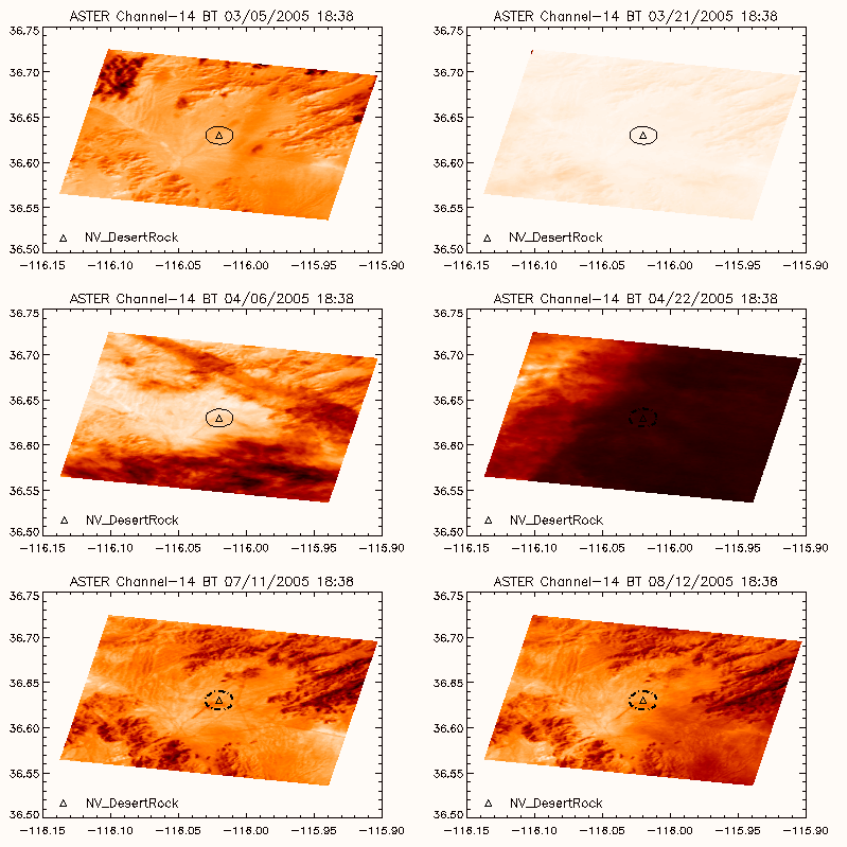


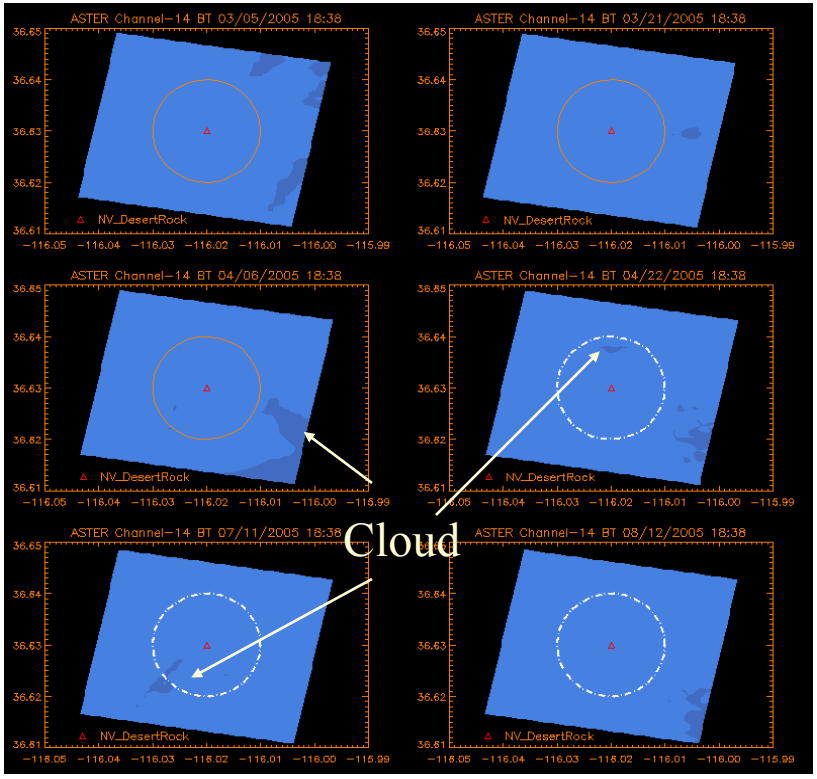
Note: this flow chart is specifically for GOES Imager
Similar procedure is/will be applied for the ASTER and MODIS/VIIRS data

Results

Additional cloud filtering is need for obtaining high quality satellite-ground match-up dataset

Left: ATSER cloud free dataset. Right: possible cloud contamination.

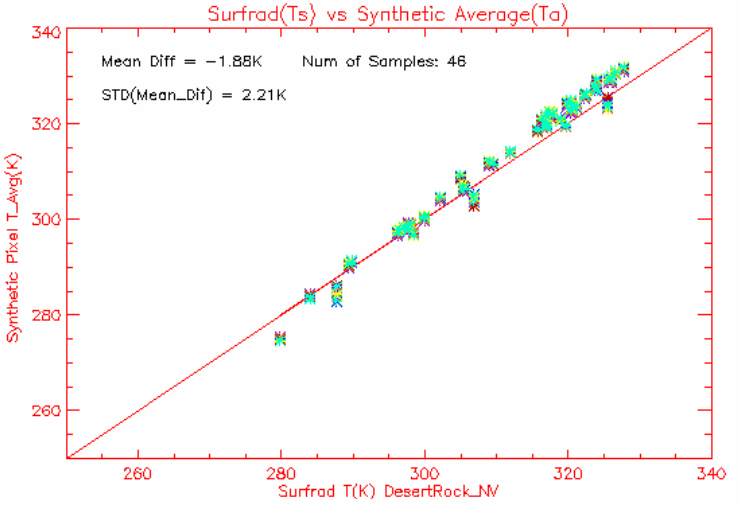


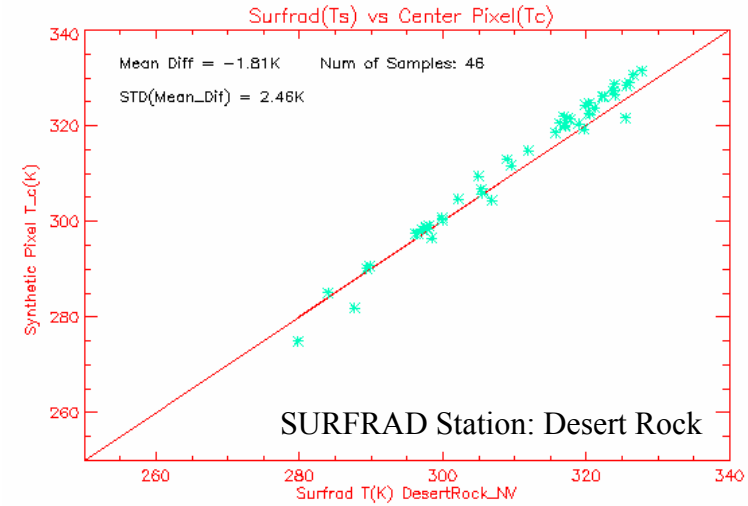


Results

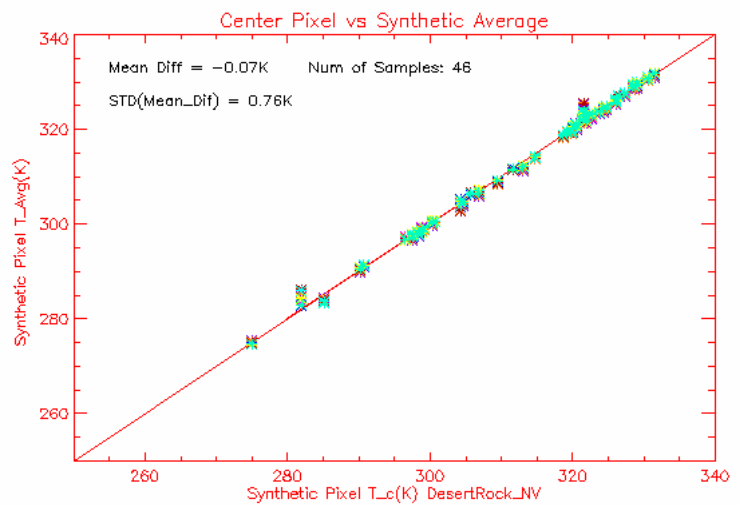
Comparison of the temperatures calculated from synthetic pixel average (top-right), center-pixel (bottom-left), and nearest pixel (bottom-right) with the ground site temperature. Note the different colors represent for the 9 different synthetic pixels shown previously.

For this particular site the ground site location within the satellite pixel does not have significance impact to the validation process, simply because the land surface thermal emission at Desert Rock is fairly homogeneous.

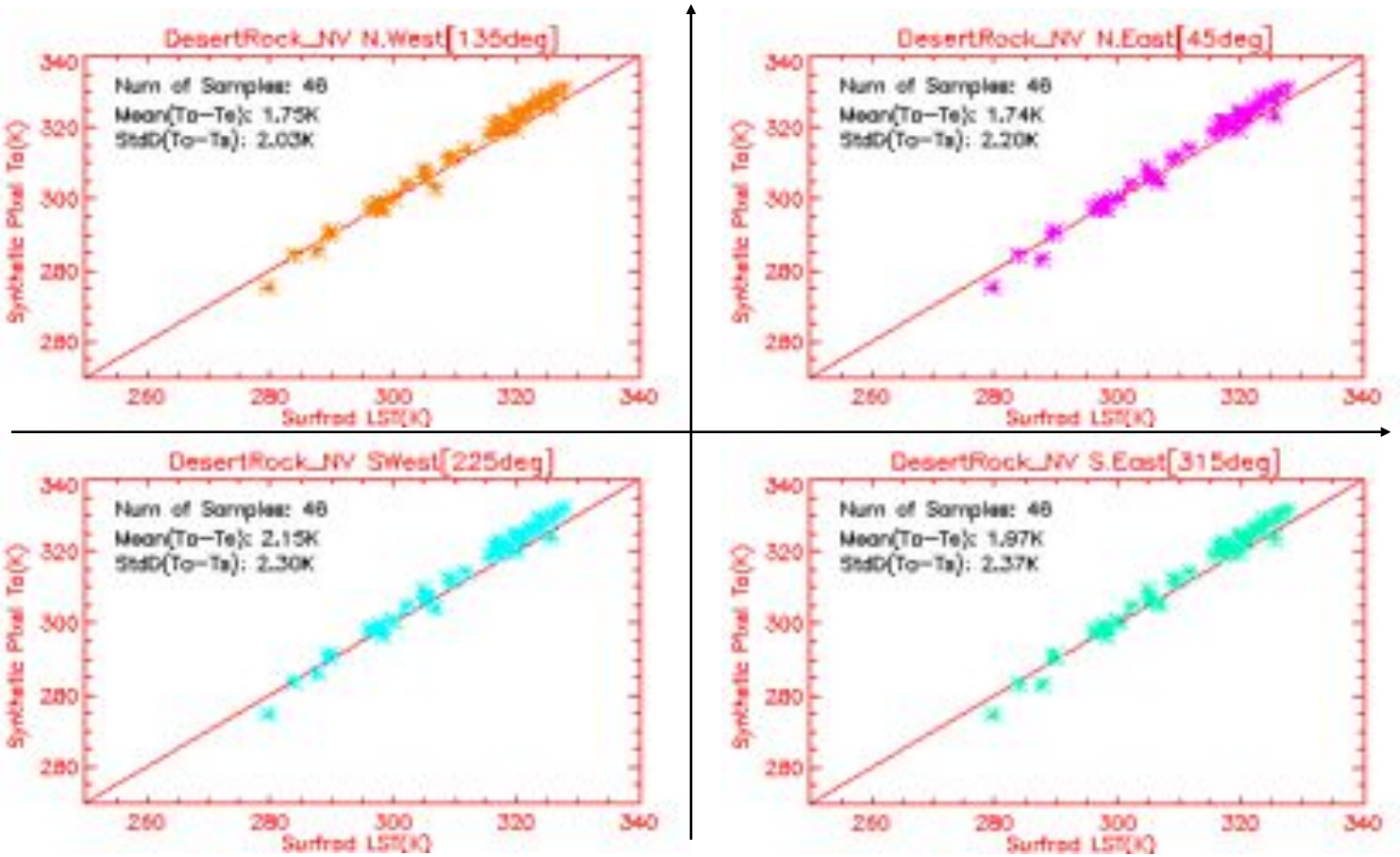




SURFRAD Station: Desert Rock

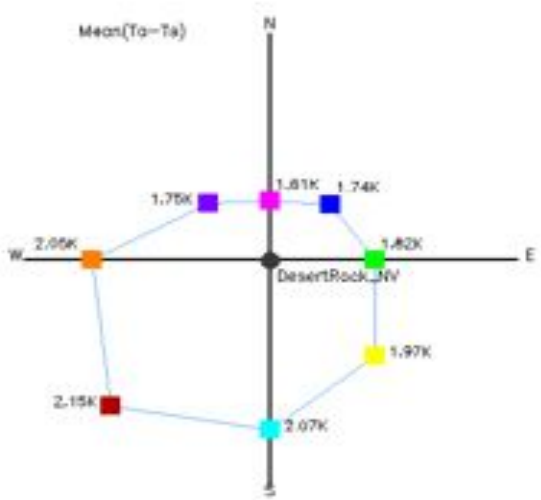


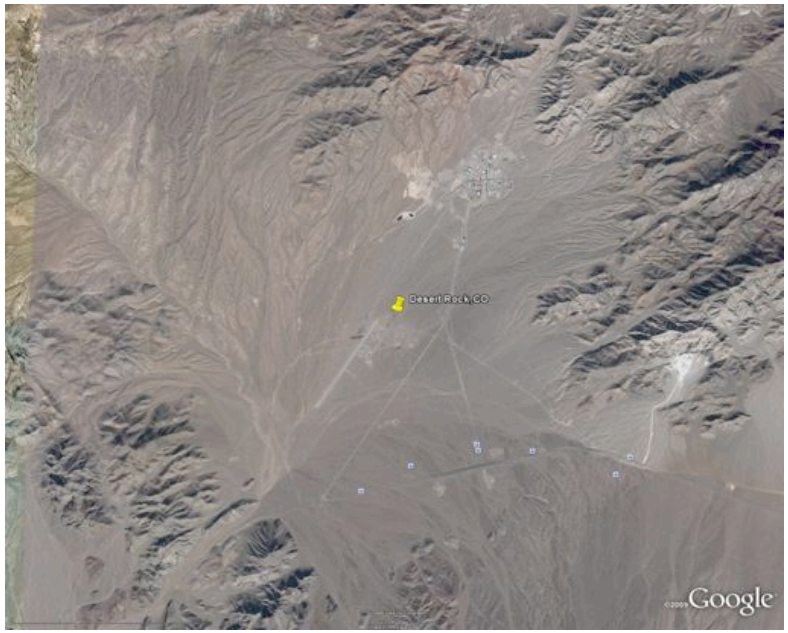
Impact of pixel location bias to the ground site



Results

Impact of pixel location bias to the ground site (con't)





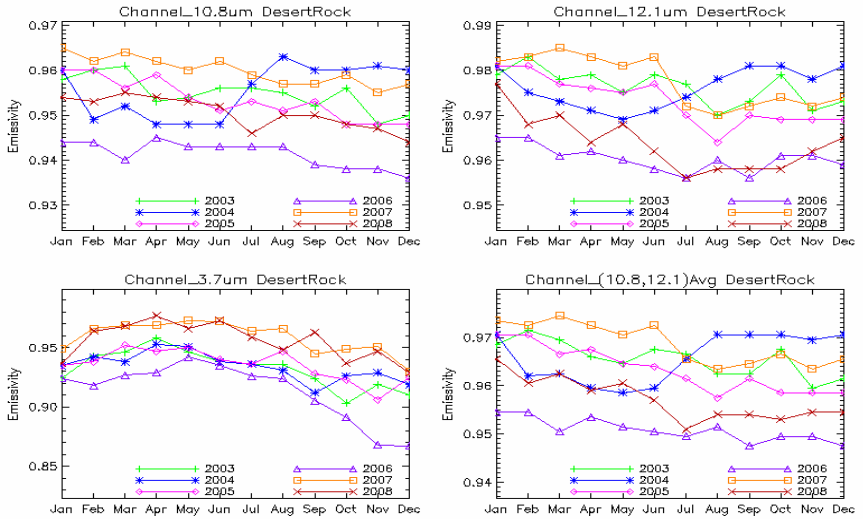
The Ta and Ts difference is tested by comparing its spatial structure to the site geographic structure.

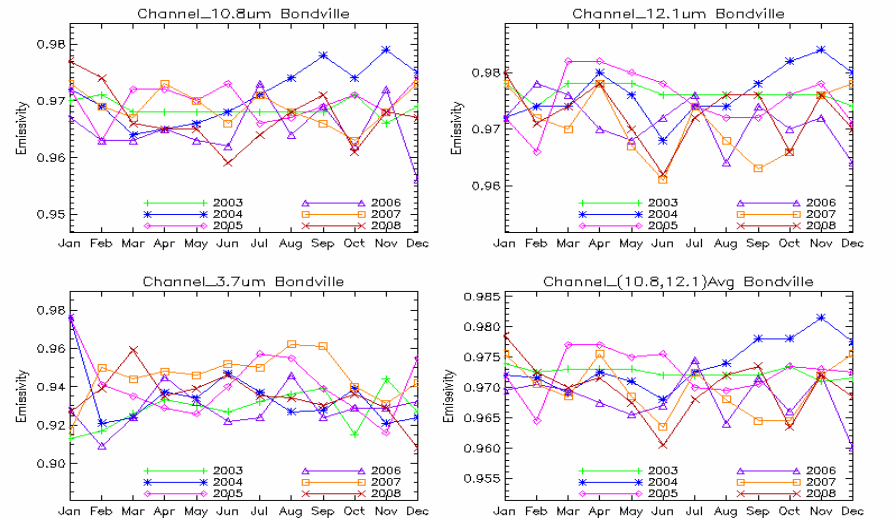
It shows that such Ta and Ts difference matchs the site geographic feature well, which imlies that the synthetic pixel temparture calculation is reasonable.

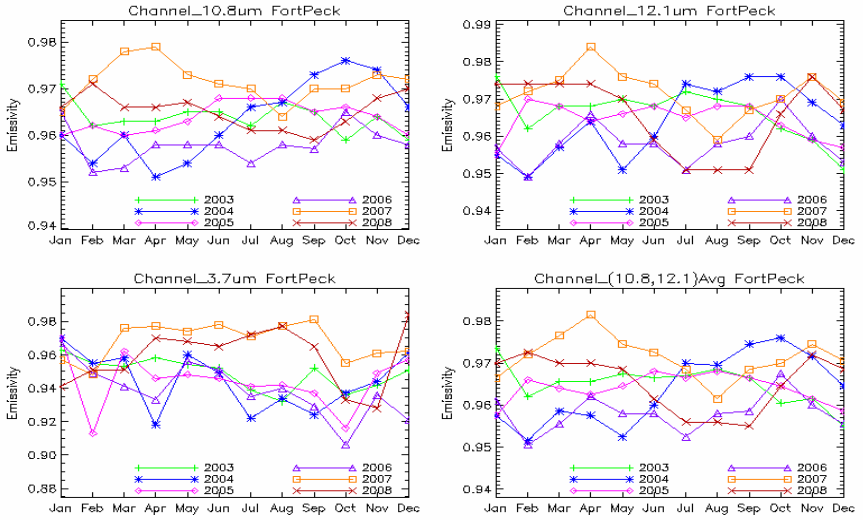
Results

Emissivity variation is another difficulty.

Emissivities at three sites, from MODIS monthly emissivity map







Results

Statistical analysis result on three SURFRAD sites. Noise level of the ground LST can be estimated from that.

Ts: LST of SURFRAD site
Ta: average LST over 13x13 ASTER pixels
Tc: LST of ASTER pixel nearest to the site

Site=Bondville, IL

Case	Ts – Ta		Tc-Ta		Ts - Tc	
	Mean	STD	Mean	STD`	Mean	STD
0	-0.66	2.04	-0.07	0.92	-0.59	2.01
1	-0.73	2.01	-0.14	1.04		
2	-0.64	2.05	-0.05	1.07		
3	-0.64	2.17	-0.05	1.27		
4	-0.68	2.10	-0.03	1.15		
5	-0.60	2.14	-0.09	1.10		
6	-0.62	2.12	-0.001	0.97		
7	-0.77	2.05	-0.03	0.95		
8	-0.77	2.02	-0.18	0.97		
Average	-0.80	2.08	-0.09	1.05		

Site=Boulder, CO

Case	Ts – Ta		Tc-Ta		Ts - Tc	
	Mean	STD	Mean	STD`	Mean	STD
0	-0.84	2.62	-0.07	0.58	-0.77	2.60
1	-1.15	2.61	-0.38	0.85		
2	-1.03	2.30	-0.27	0.91		
3	-0.91	2.27	-0.14	0.84		
4	-0.80	2.54	-0.03	0.61		
5	-0.67	2.64	-0.10	0.61		
6	-0.77	2.75	-0.00	0.69		
7	-0.87	2.80	-0.10	0.70		
8	-1.02	2.70	-0.25	0.70		
Average	-0.90	2.58	-0.13	0.72		

Site=Penn State, PA

Case	Ts – Ta		Tc-Ta		Ts - Tc	
	Mean	STD	Mean	STD`	Mean	STD
0	0.01	1.99	-0.15	1.05	0.25	2.09
1	0.43	1.93	0.18	1.13		
2	0.41	2.07	0.15	1.36		
3	0.20	2.19	-0.05	1.38		
4	0.09	1.91	-0.16	1.07		
5	0.10	1.96	-0.15	1.14		
6	0.01	1.93	-0.25	1.13		
7	0.04	1.91	-0.21	1.03		
8	0.19	1.98	-0.06	0.99		
Average	0.17	1.99	-0.08	1.14		

Results

–Summary

- Synthetic pixel analysis model is created for analyzing ground site temperature heterogeneous feature. ASTER data are used to generate synthetic VIIRS pixel data (LST) and compared to the SURFRAD site data
- Impact of possible VIIRS pixel location bias to the site is analyzed. Overall, it is not significant.
- Noise level of the ground LST for representing the satellite pixel LST can be estimated by comparing the individual ASTER pixel LST to the synthetic VIIRS pixel LSTs. Such noise level varies from site to site.
- The limited datasets doesn't allow us to characterize the seasonal variation of heterogeneities, which is more desirable than a simple mean difference. More datasets are expected.

Plan and Schedule

- Satellite and Ground data collection
  - Year round
- SURFRAD sites characterization
  - Synthetic model analysis (04/2010)
  - Error correction table/noise level determination for the ground LST (06/2010)
- Dataset match-up system generation
  - Software readiness for matching the ground and satellite observations (08/2010)
  - System test (using SURFRAD and MODIS data) report (09/2010)
- Comparison analysis tool development
  - Statistical analysis method development (10/2010)
  - Proxy data (MODIS) testing report (12/2010)