Assessment of AIRS Surface Air Temperatures

Glynn Hulley

Jet Propulsion Laboratory, California Institute of Technology

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AIRS Science Meeting
Pasadena, CA
May 21-22, 2013

Outline

- Motivation
- Surface temperature (ST) in situ data
  - SURFRAD, USCRN, NOAA NCDC
- AIRS comparisons with SURFRAD ST data
  - Ts – Tair relationships
  - Ts – Tair dynamics
  - Ts – Tair statistical modeling
- Proposed Methodology
- Conclusions

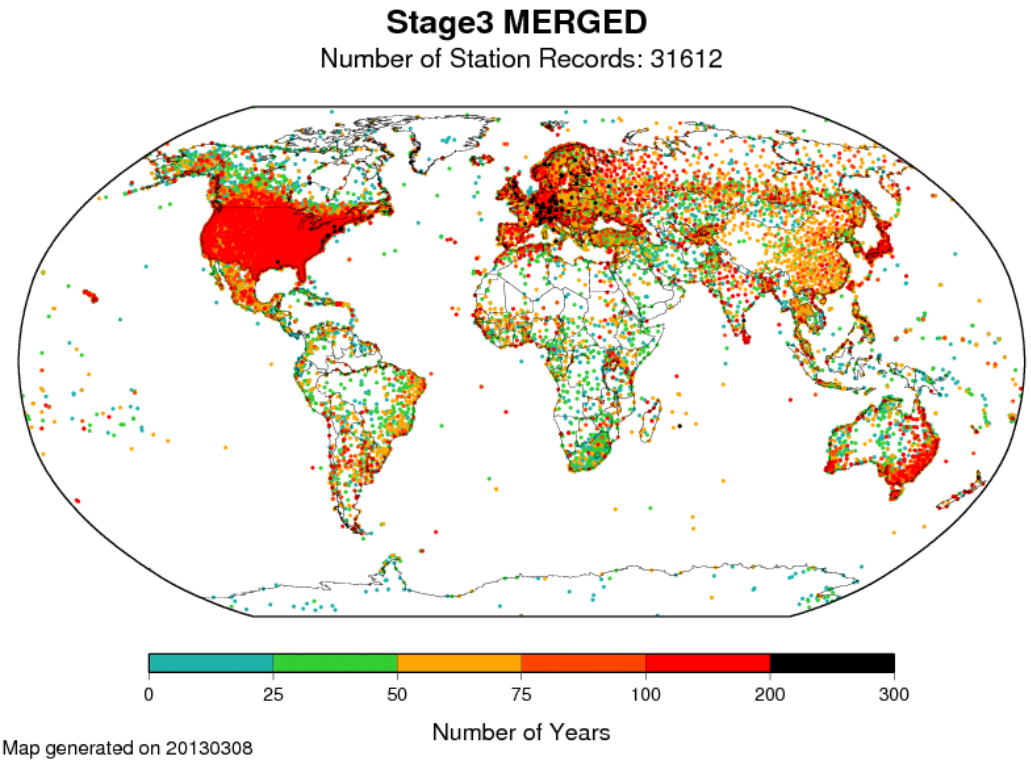
Motivation

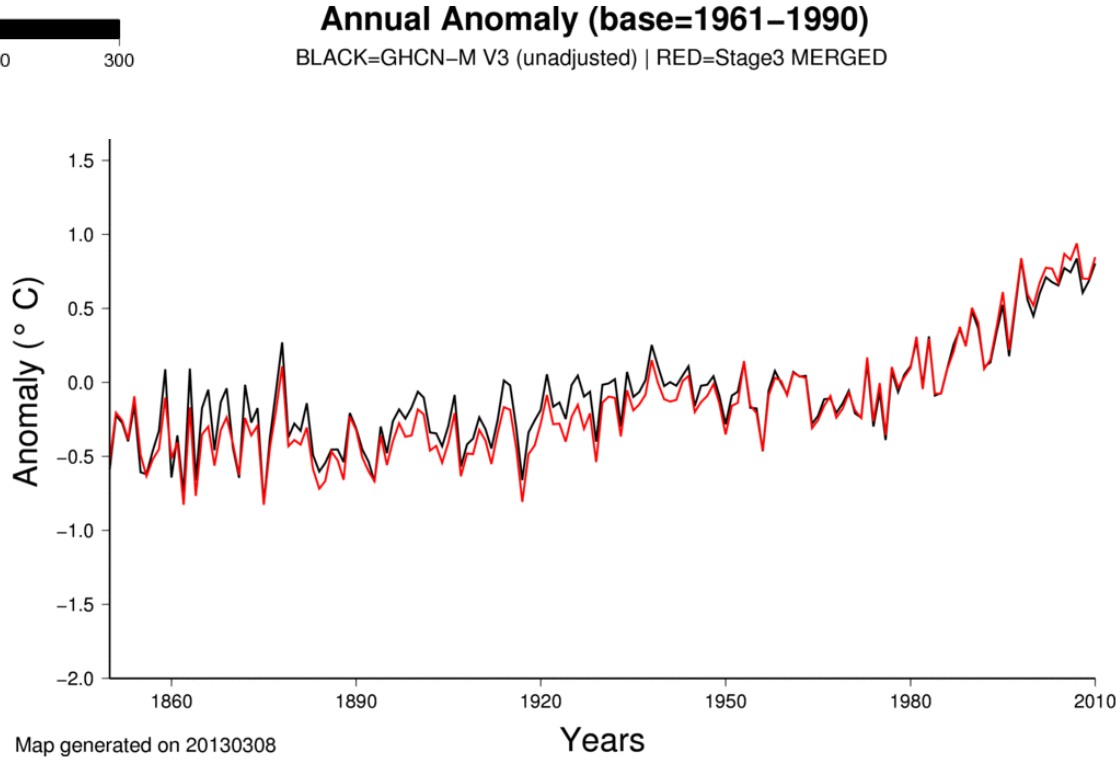
- Knowledge of Surface Temperatures (STs) from in situ met stations and oceanographic for past >150 years (remote sensing past 30 years):
  - Essential to weather forecasting
  - Environmental sciences
  - Attribution of Climate change

- Surface temperatures (STs) affect:
  - Ecosystems (e.g. pine beetle outbreaks) and human life (e.g. heatwaves)
  - Interactions between surface and atmosphere (energy balance)
  - Main indicator of “global warming”

- Several ST networks recently developed:
  - EarthTemp
  - International Surface Temperature Initiative (ISTI)

ISTI Data Bank



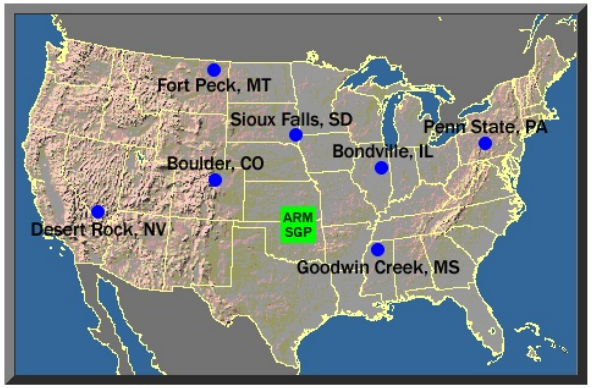


NOAA Surface Radiation Network (SURFRAD)

- 7 Stations
- 10 m surface air temperatures measured every 3 min
- All data at JPL (included in *ValSites* matchups)

SURFRAD Site Information

For information about a specific station within the SURFRAD network, click on its location on the map below, or use the links at the bottom of this page:



Code	Name	Latitude	Longitude	Elevation	Time Zone	Installed
BND*	Bondville, Illinois	40.05° N	88.37° W	230 m	6 hours from UTC	April 1994
TBL	Table Mountain, Boulder, Colorado	40.13° N	105.24° W	1689 m	7 hours from UTC	July 1995
DRA	Desert Rock, Nevada	36.63° N	116.02° W	1007 m	8 hours from UTC	March 1998
FPK	Fort Peck, Montana	48.31° N	105.10° W	634 m	7 hours from UTC	November 1994
GCM	Goodwin Creek, Mississippi	34.25° N	89.87° W	98 m	6 hours from UTC	December 1994
PSU	Penn. State Univ., Pennsylvania	40.72° N	77.93° W	376 m	5 hours from UTC	June 1998
SXF	Sioux Falls, South Dakota	43.73° N	96.62° W	473 m	6 hours from UTC	June 2003
SGP	ARM Southern Great Plains Facility, Oklahoma	36.80° N	97.50° W	314 m	6 hours from UTC	

High Resolution Station Coordinates

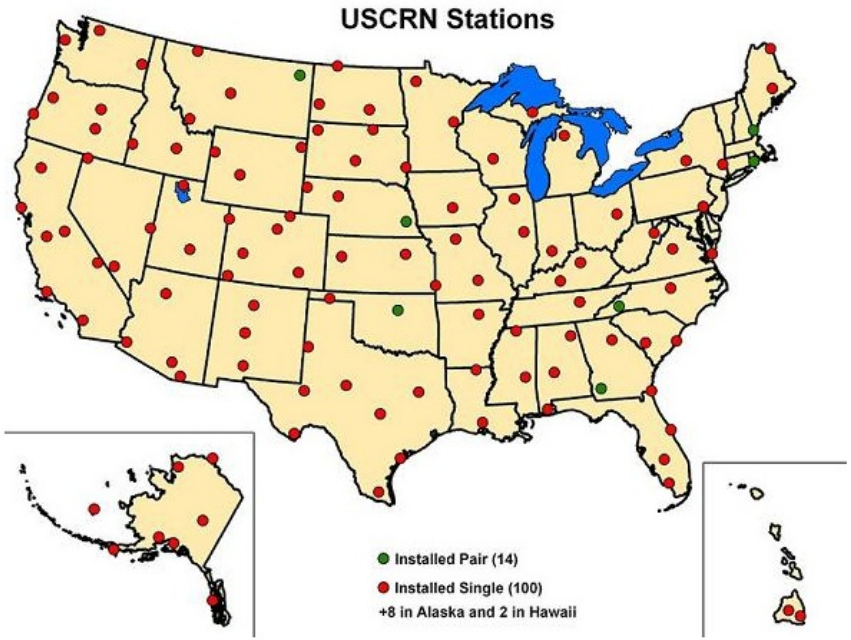
* - SURFRAD data files use 'BON' as the station code in file names.

US Climate Reference Network (USCRN)

- 114 Stations
- 1.5 m surface air temperatures measured hourly

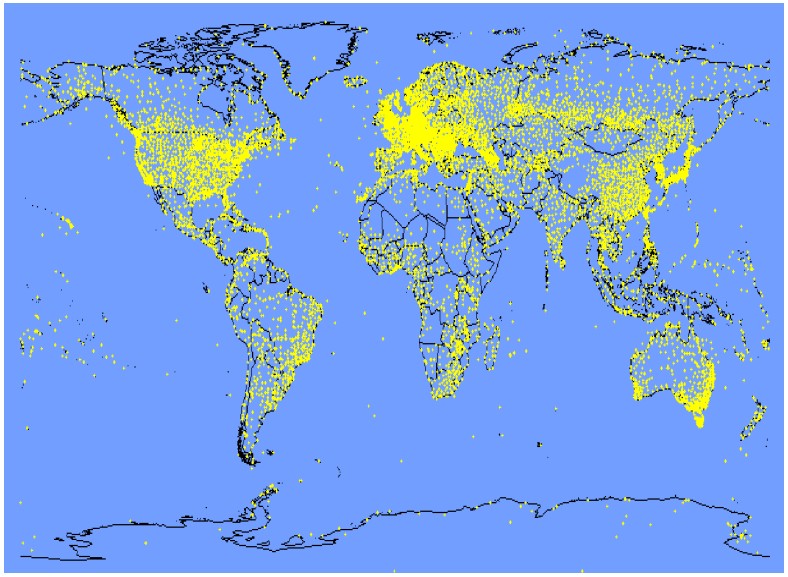
US Climate Reference Network USRCRN

Map of USCRN Stations



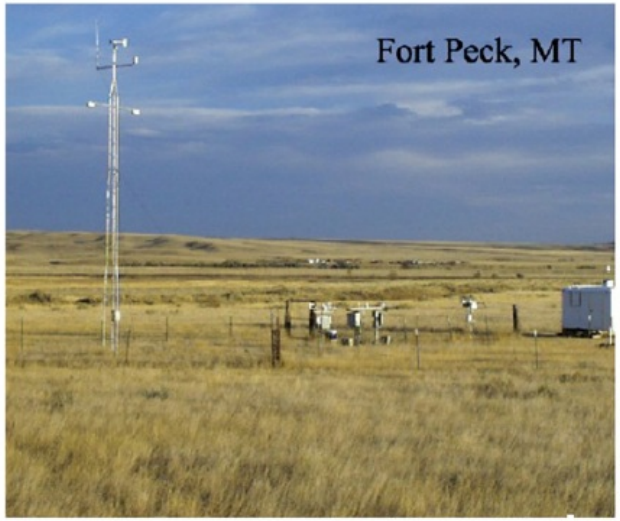
NOAA-NCDC

- NOAA-NCDC SAT datasets:
  1. Global Surface Summary of Day (GSOD)
     - Mean, Max, Min 2m air temperatures per day from 1973
     - ~9,000 global stations
  2. Integrated Surface Database (ISD)
     - Hourly summaries of 2m air temperatures



- Mean temperature (.1 Fahrenheit)
- Mean dew point (.1 Fahrenheit)
- Mean sea level pressure (.1 mb)
- Mean station pressure (.1 mb)
- Mean visibility (.1 miles)
- Mean wind speed (.1 knots)
- Maximum sustained wind speed (.1 knots)
- Maximum wind gust (.1 knots)
- Maximum temperature (.1 Fahrenheit)
- Minimum temperature (.1 Fahrenheit)
- Precipitation amount (.01 inches)
- Snow depth (.1 inches)
- Indicator for occurrence of: Fog Rain/Drizzle Snow/Ice Pellets Hail Thunder Tornado/Funnel Cloud

SURFRAD sites



SURFRAD spatial homogeneity analysis (for MODIS at 1-km)

Site	Rank	Score	Variogram Range [km]		Variogram Sill [K]		CV [%]	
			Summer	Winter	Summer	Winter	Summer	Winter
Desert Rock, NV 36.63N, 116.02W	1	2.67	0.44	0.64	0.81	0.51	0.33	0.26
Fort Peck, MT 48.31N, 105.10 W	2	1.83	1.42	0.96	3.66	1.93	0.31	0.32
Bondville, IL 40.05N, 88.37 W	3	1.34	0.77	0.58	6.74	0.49	0.43	0.15
Penn State, PA 40.72N, 77.93 W	4	1.32	2.02	2.96	6.36	3.45	0.54	0.26
Goodwin Creek, MS 34.25N, 89.87W	5	0.95	0.78	0.58	7.48	3.29	0.66	0.42
Table Mtn, CO 40.12N, 105.24W	6	0.83	1.52	1.12	10.69	0.96	0.80	0.41
Sioux Falls, SD 43.73N, 96.62W	7	0.50	1.57	1.68	12.14	16.82	0.76	1.08

SURFRAD Skin Temperature Derivation

Stefan-Boltzmann law:

$$L_{\uparrow} = \varepsilon_b \cdot \sigma \cdot T_s^4 + (1 - \varepsilon_b) \cdot L_{\downarrow}$$

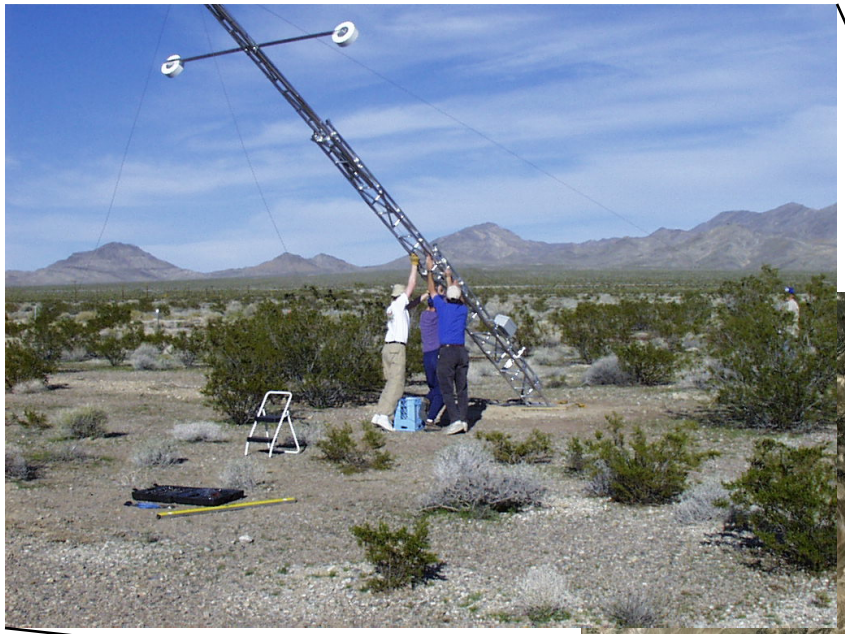
$L_{\uparrow}$= surface upwelling radiation
$L_{\downarrow}$= surface downwelling radiation
ε = broadband emissivity (8-13.5 μm)
Ts = skin temperature
σ = Stefan-Boltzmann constant

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

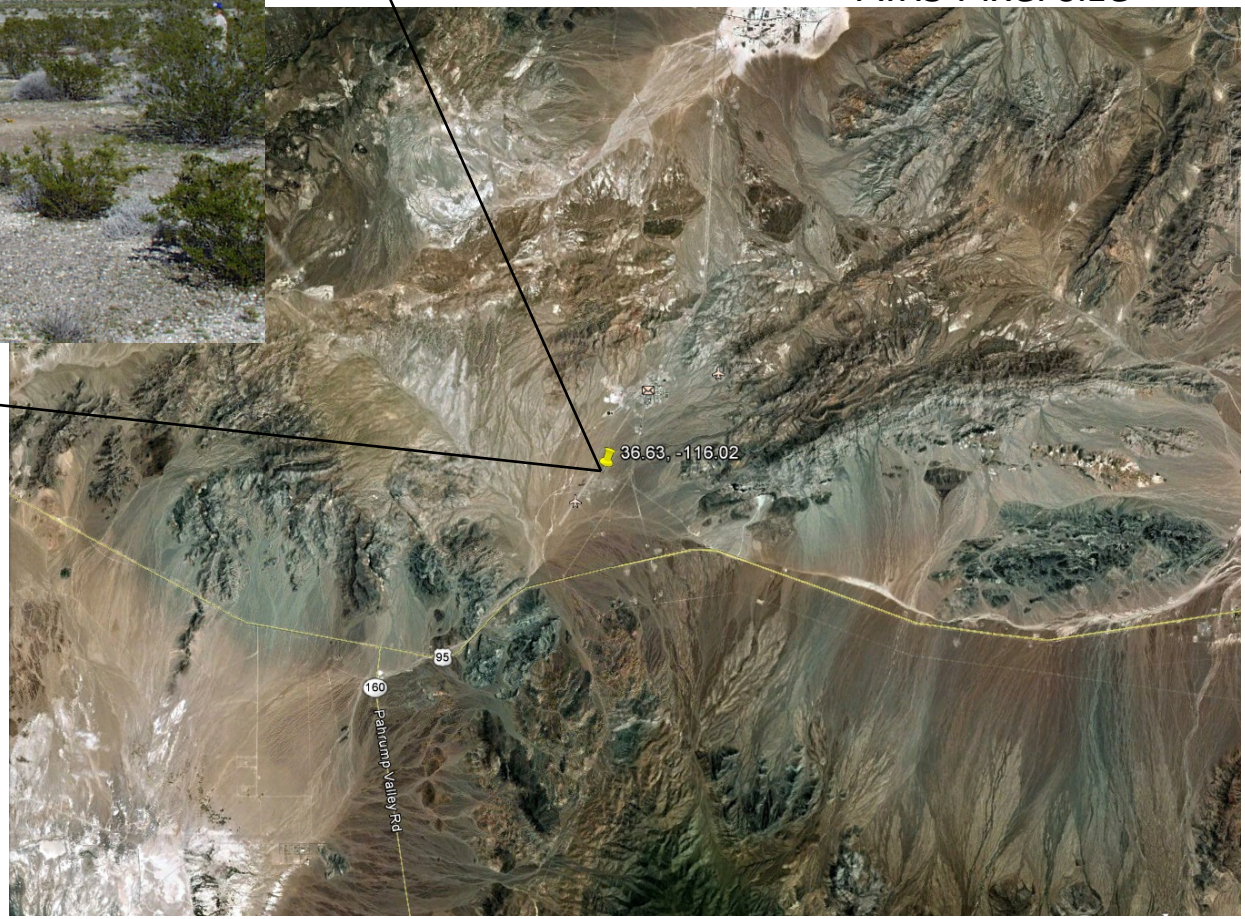
ASTER Broadband Emissivity

$$\varepsilon_{8-13.5} = 0.026\,\varepsilon_{11} + 0.269\,\varepsilon_{12} + 0.357\,\varepsilon_{13} + 0.359.$$

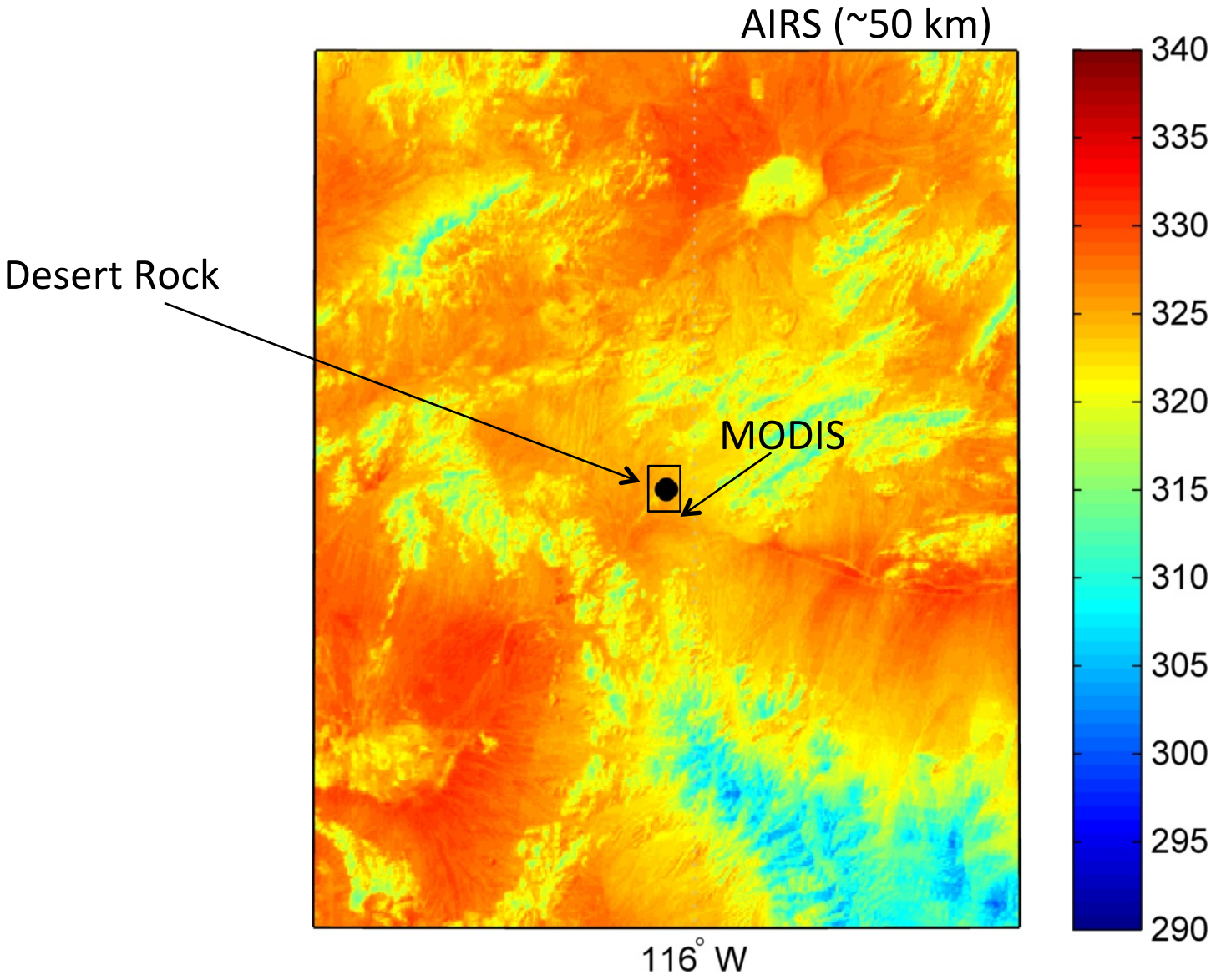
Rank 1: Desert Rock, NV (desert shrubland)



AIRS Pixel size



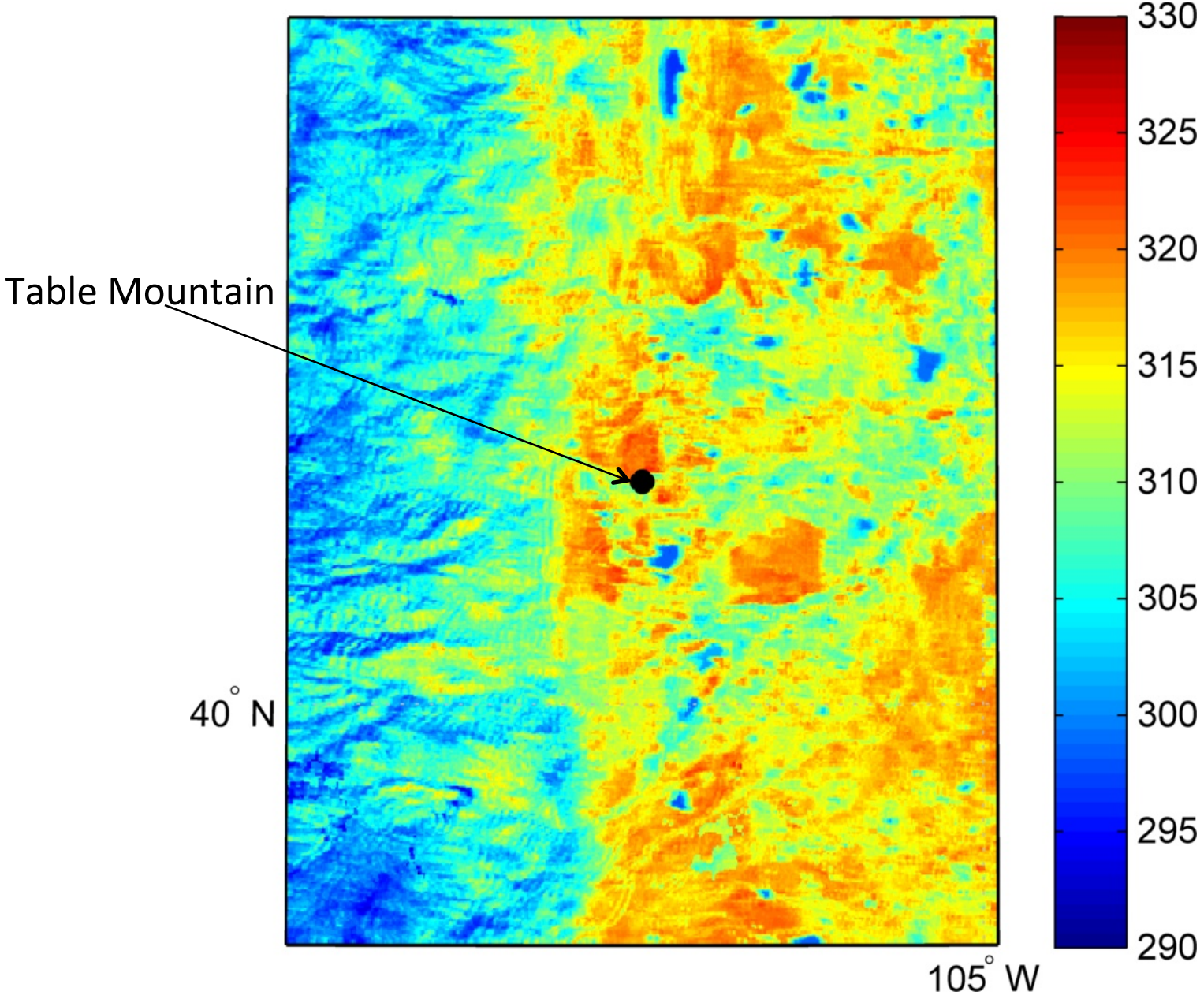
ASTER mean Ts



Rank 7: Table Mountain (Boulder, CO)

AIRS 50 km pixel

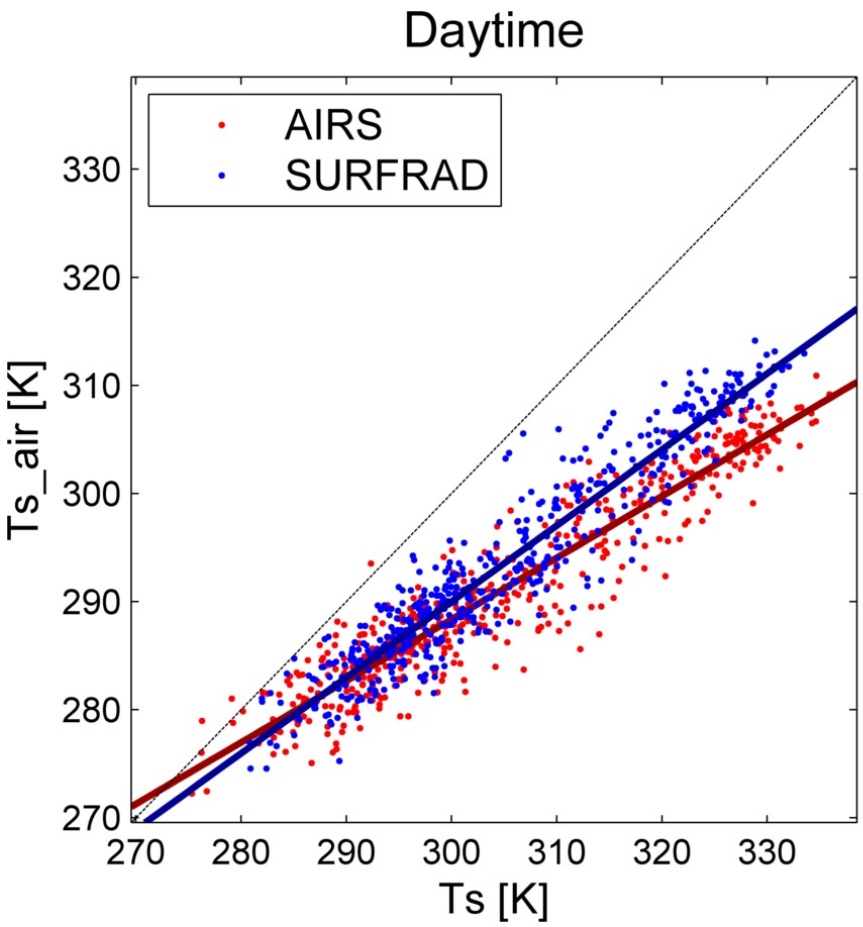
ASTER mean Ts

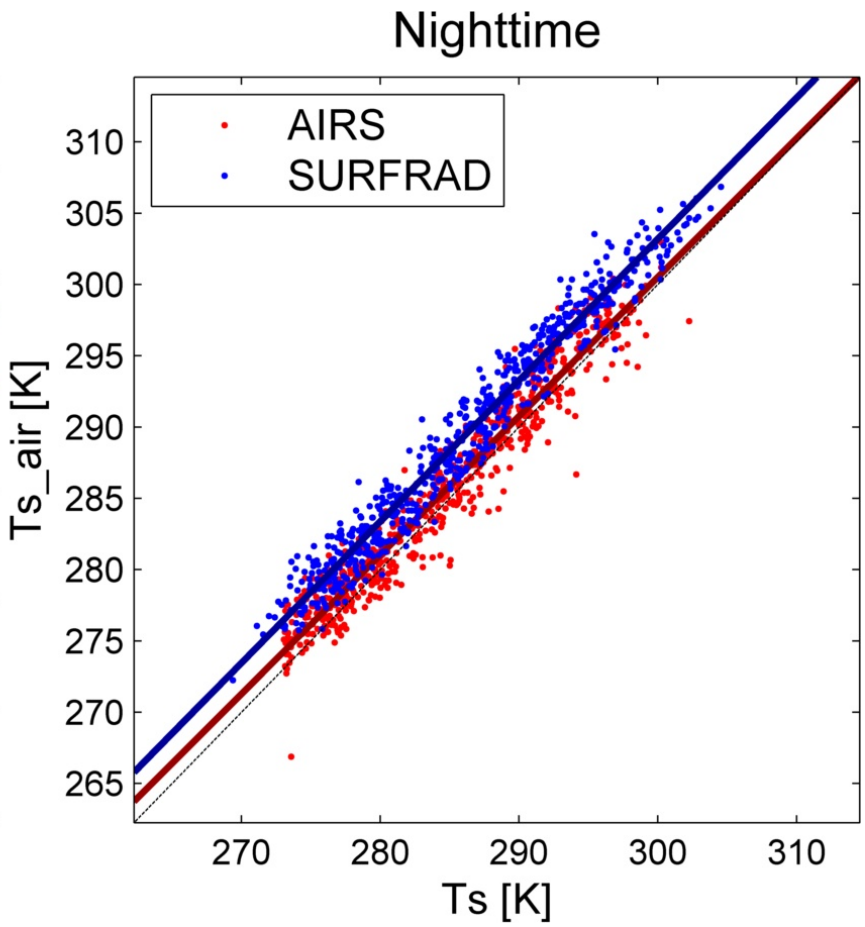


Desert Rock, NV (desert shrubland)

2010-2012

Tserror<5 K

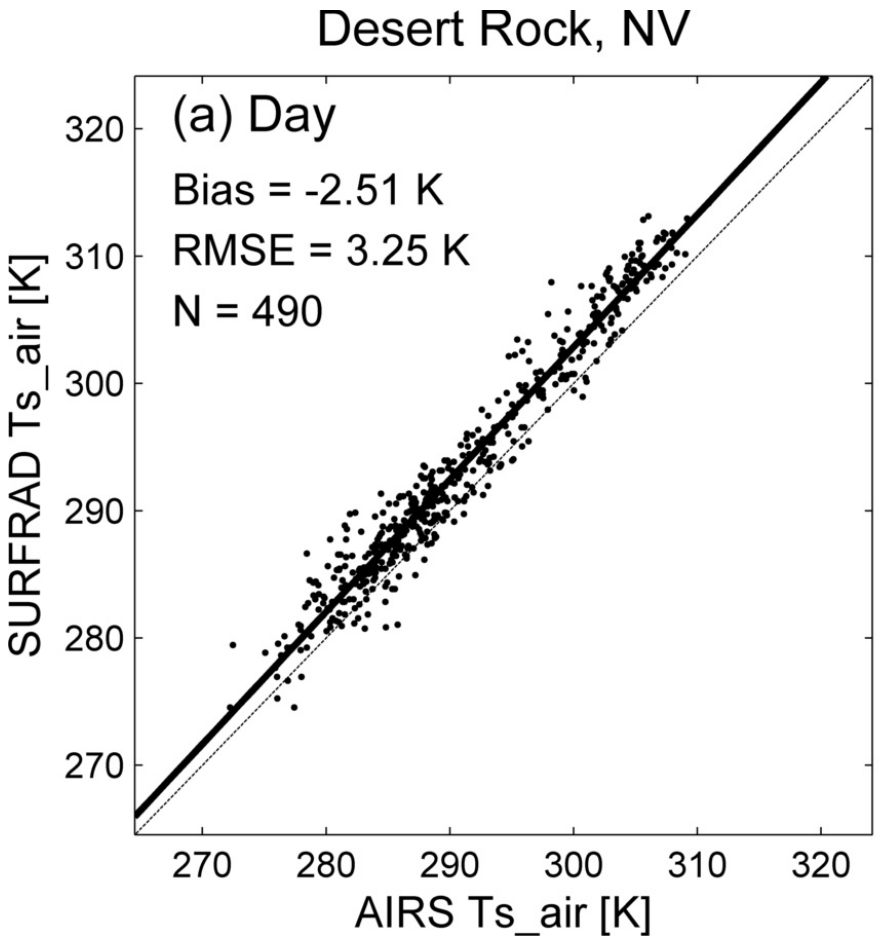


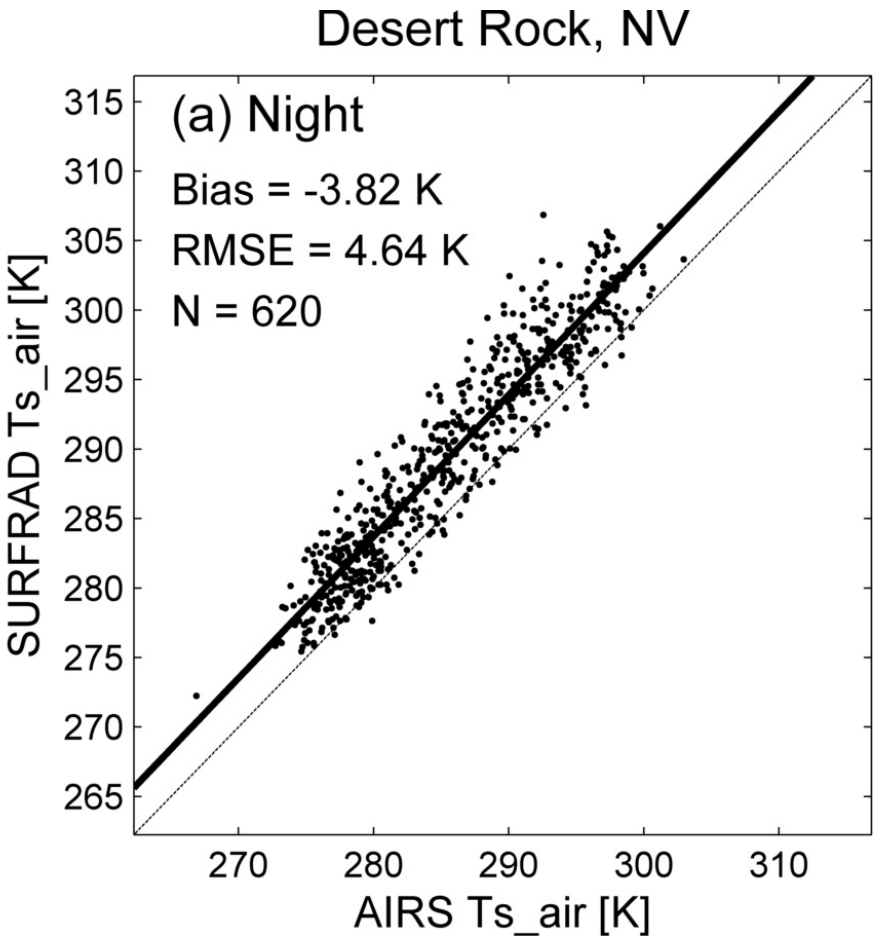


AIRS Ts_air = interp1[pressStd(1),T(1), PSurfStd]

Ts_air Scatterplots

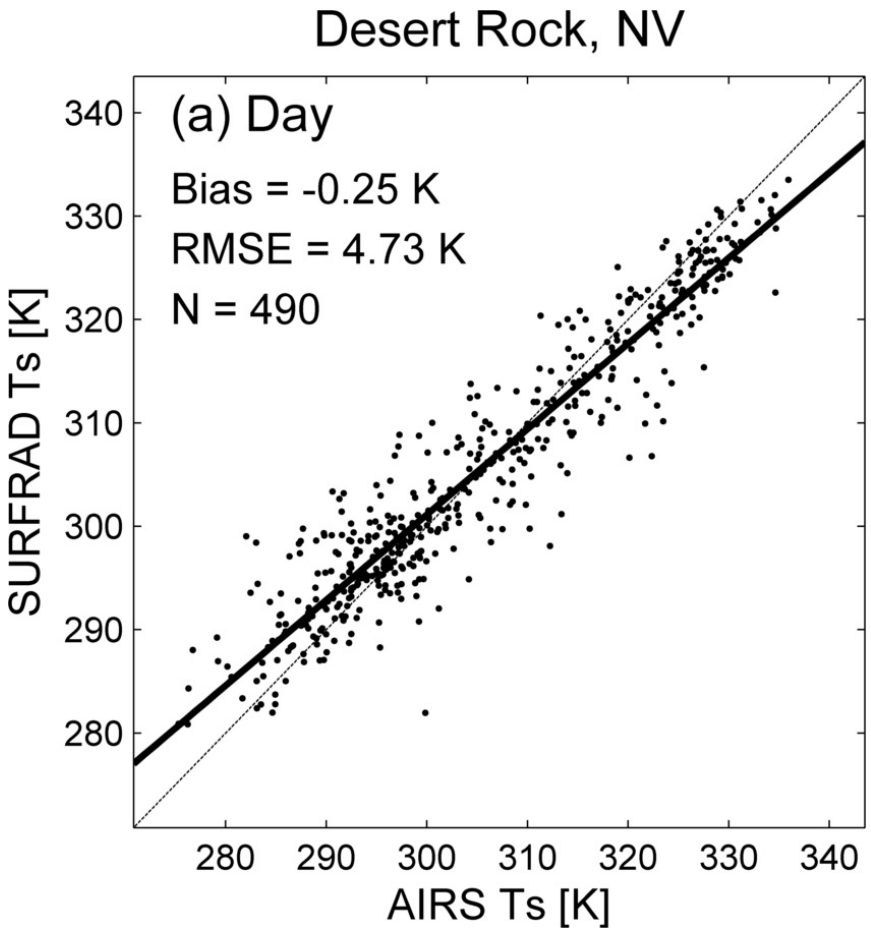
2010-2012
Tserror<5 K

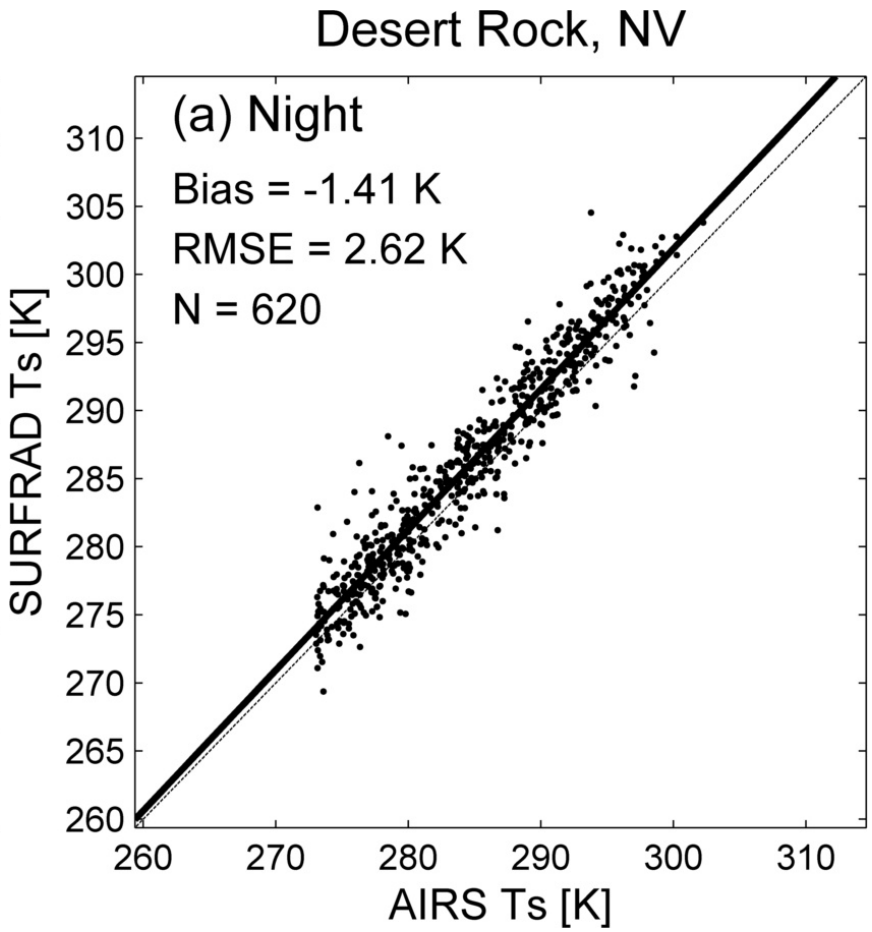




Ts Scatterplots

2010-2012
Tserror<5 K

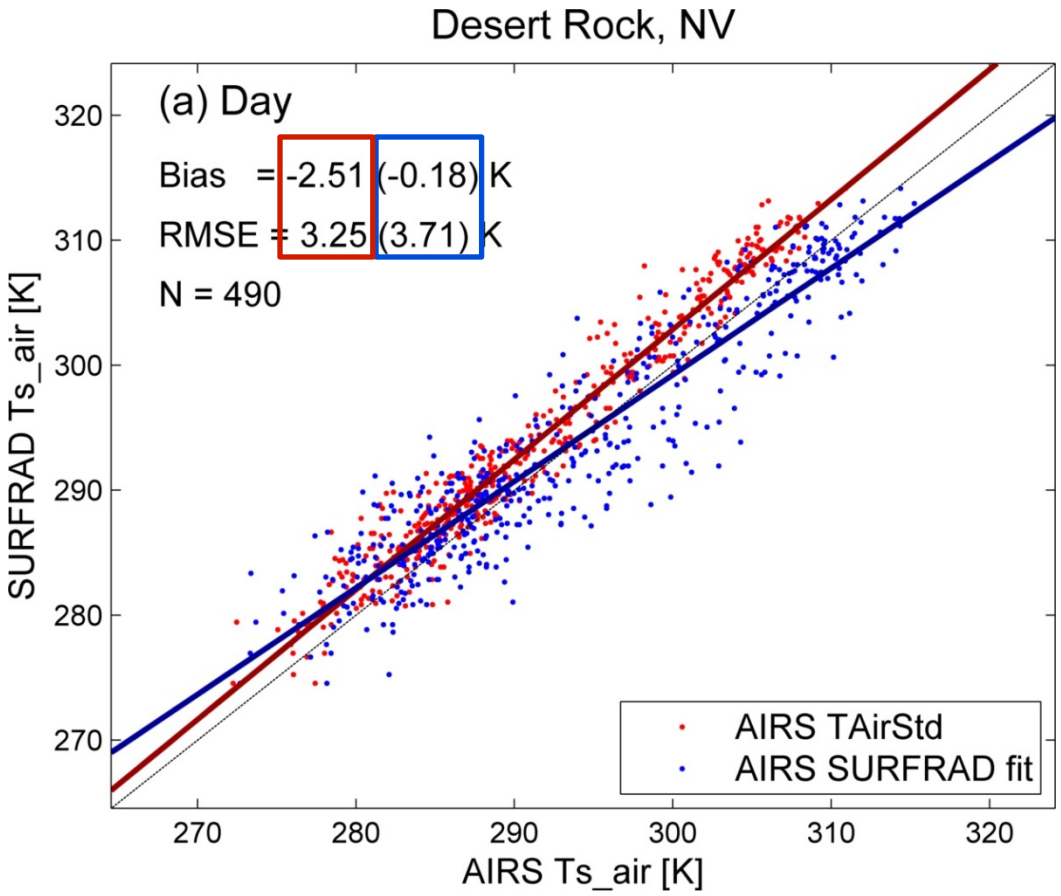


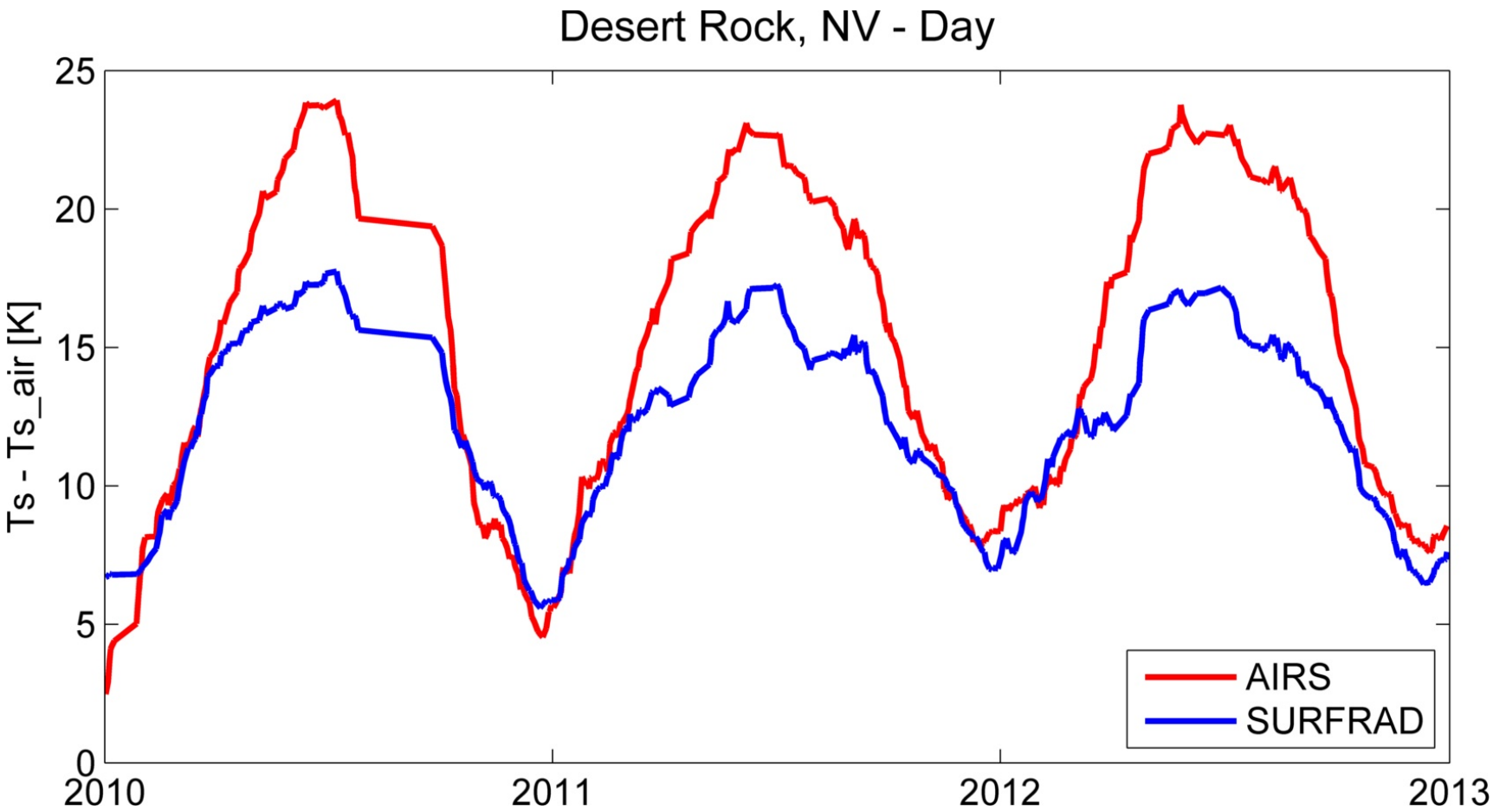


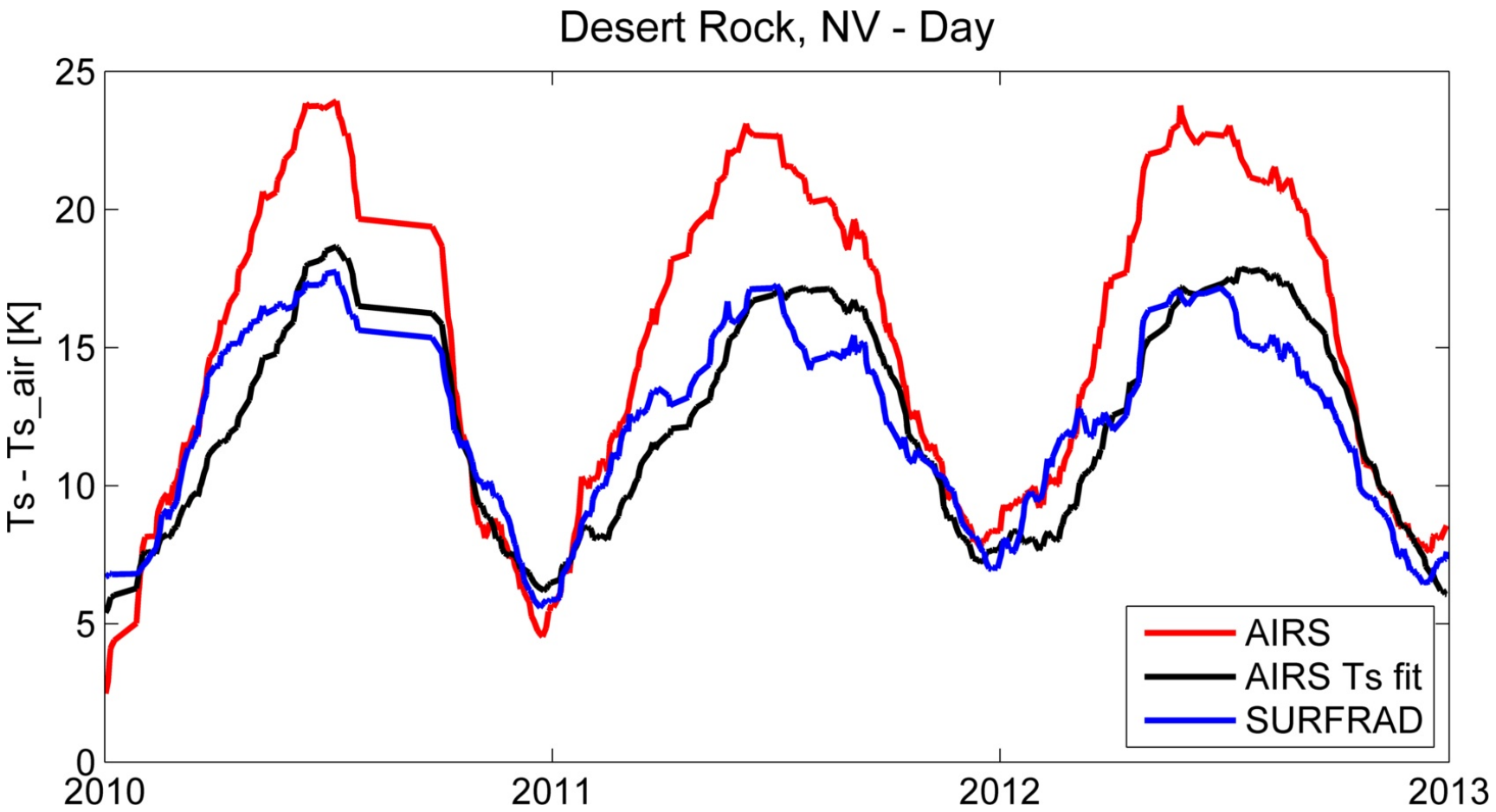
Linear Fit:

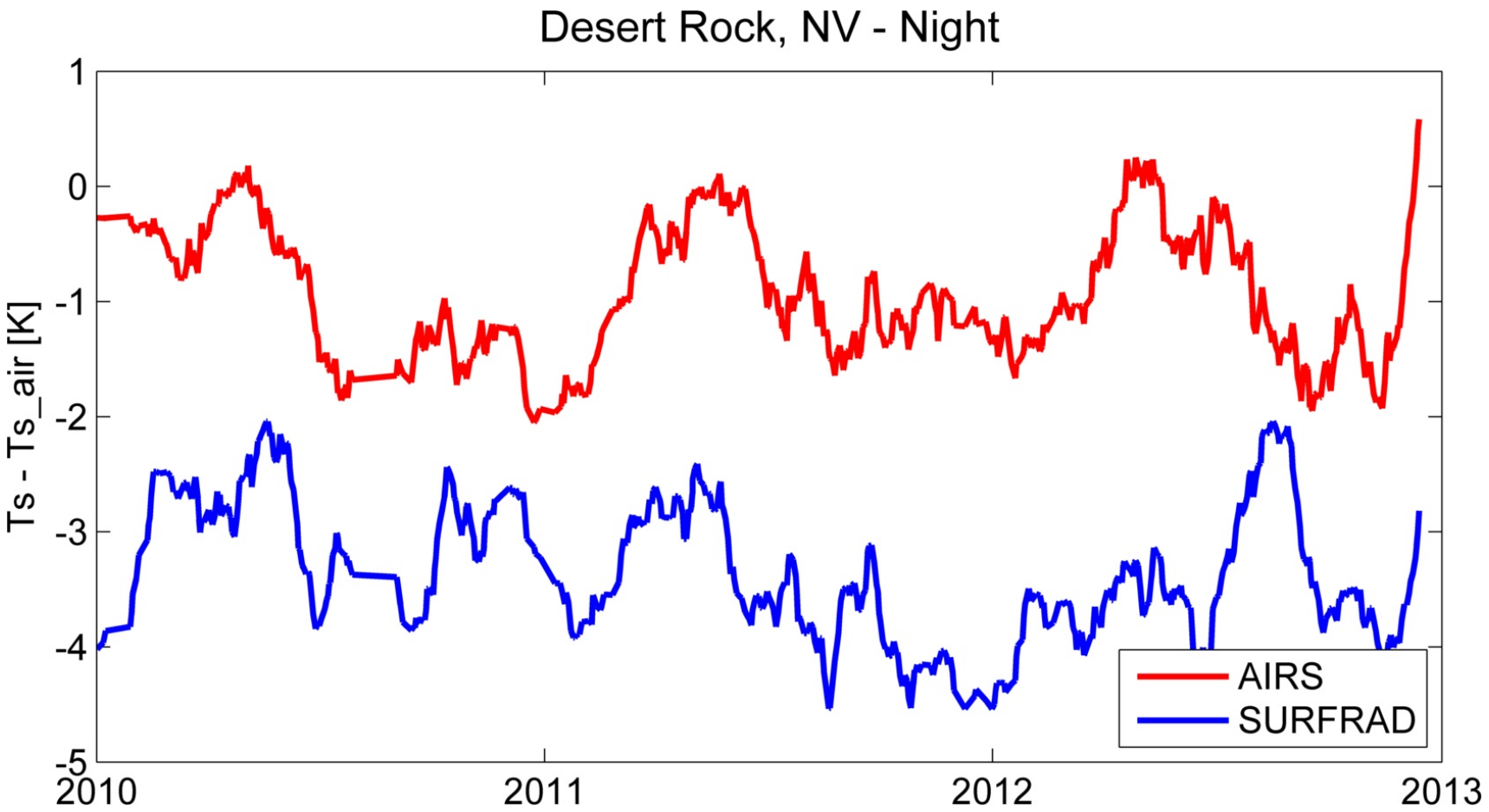
Ts_air = a + b*(Ts)

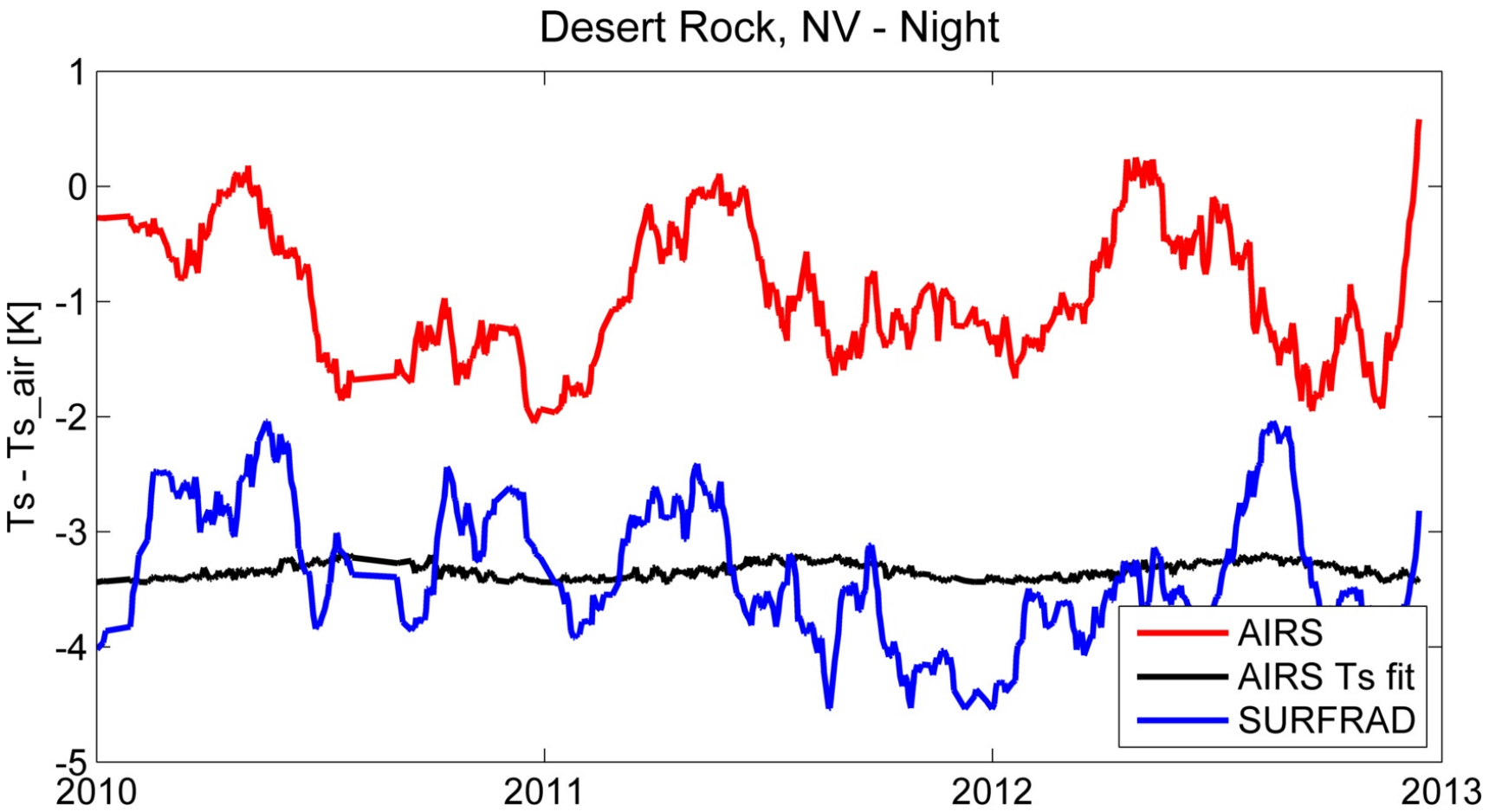
a, b determined from SURFRAD measurements

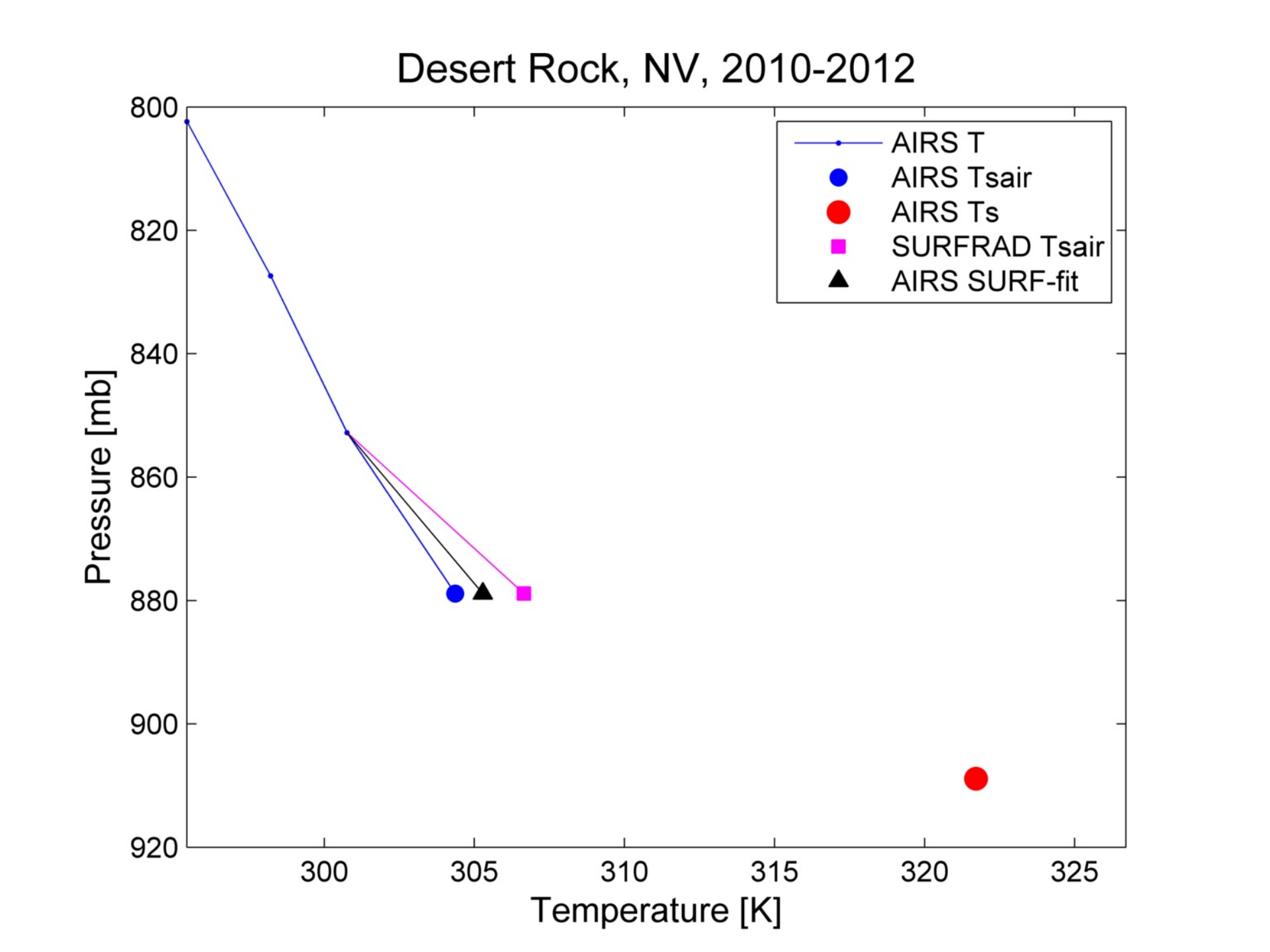



Desert Rock, NV - Day
Ts - Ts_air [K]
25
20
15
10
5
0
2010
2011
2012
2013
AIRS
SURFRAD

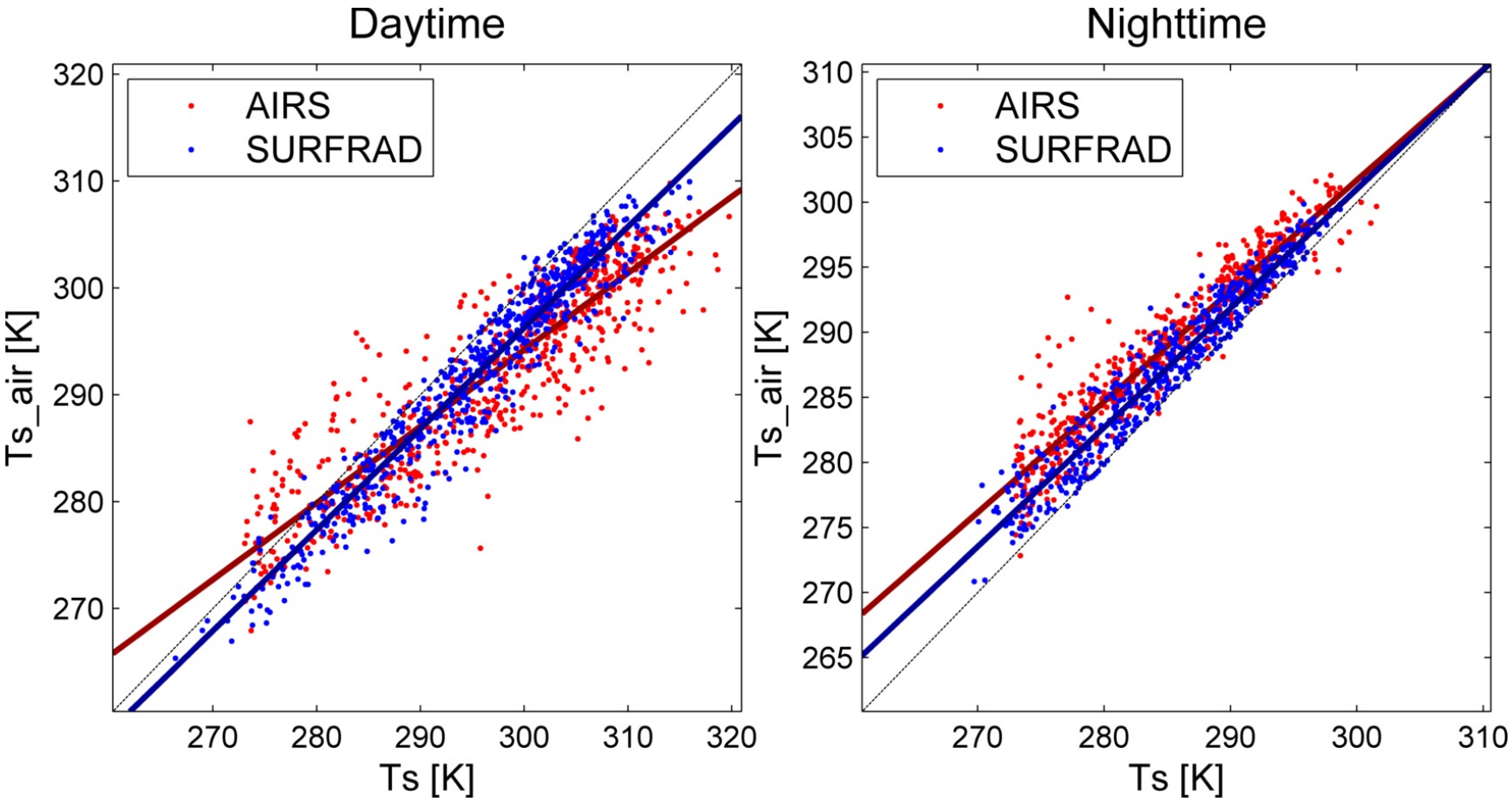

Desert Rock, NV - Day
Ts - Ts_air [K]
25
20
15
10
5
0
2010
2011
2012
2013
AIRS
AIRS Ts fit
SURFRAD


Desert Rock, NV - Night
Ts - Ts_air [K]
1
0
-1
-2
-3
-4
-5
2010
2011
2012
2013
AIRS
SURFRAD


Desert Rock, NV - Night
Ts - Ts_air [K]
1
0
-1
-2
-3
-4
-5
2010
2011
2012
2013
AIRS
AIRS Ts fit
SURFRAD

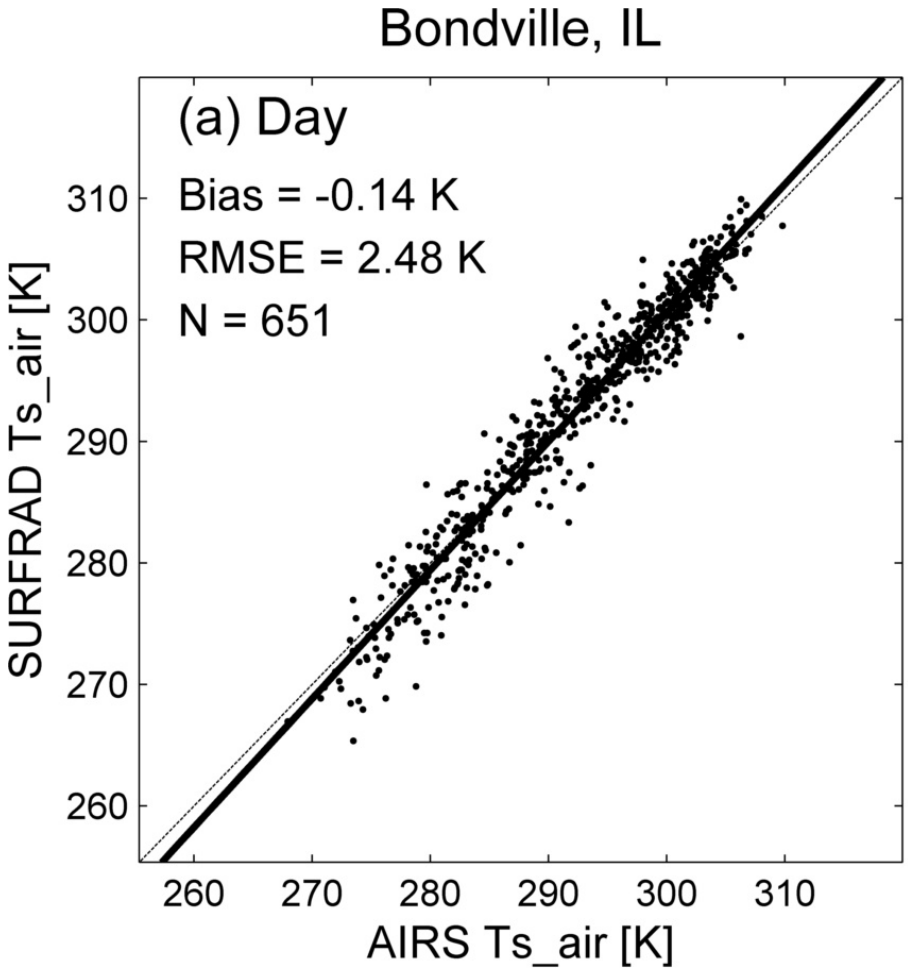

Desert Rock, NV, 2010-2012
AIRS T
AIRS Tsair
AIRS Ts
SURFRAD Tsair
AIRS SURF-fit
Pressure [mb]
Temperature [K]
800
820
840
860
880
900
920
300
305
310
315
320
325

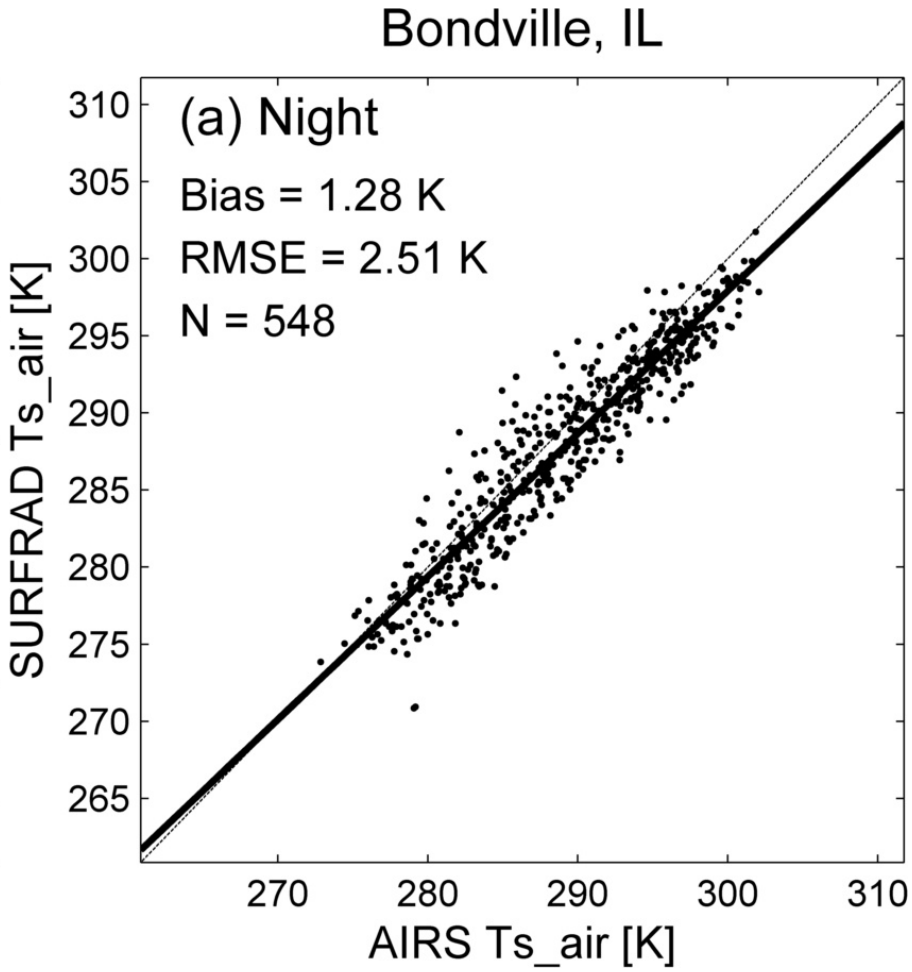
Bondville, IL (croplands)



Ts_air Scatterplots

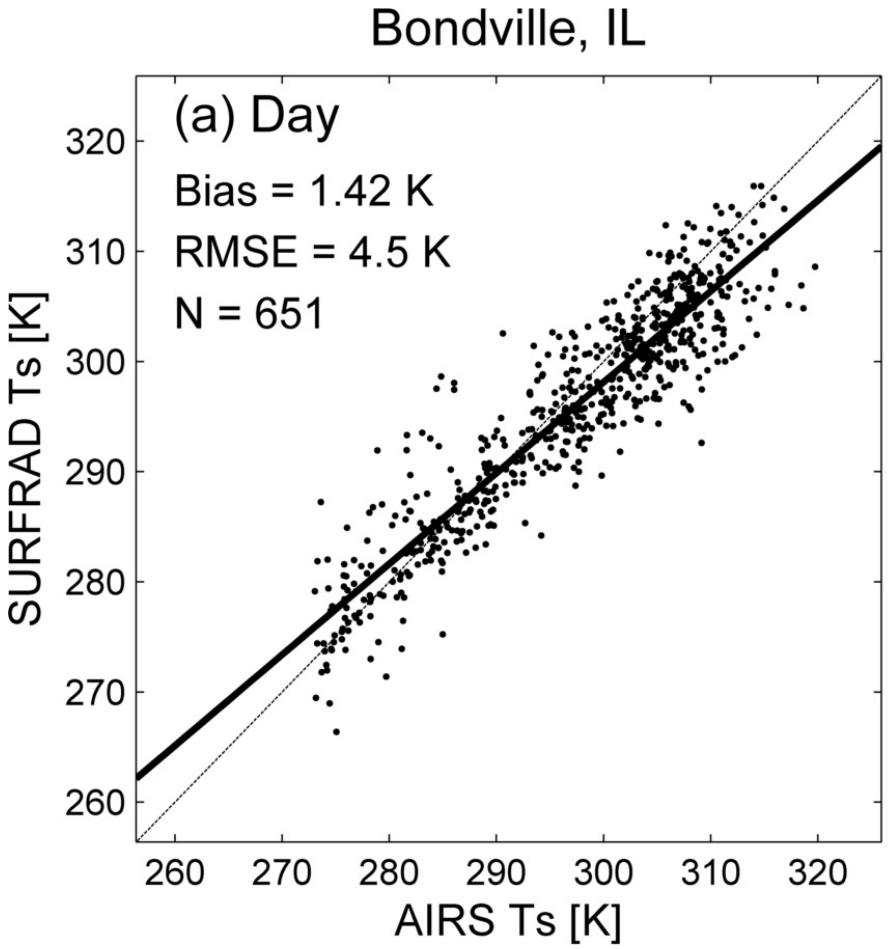
2010-2012
Tserror<5 K

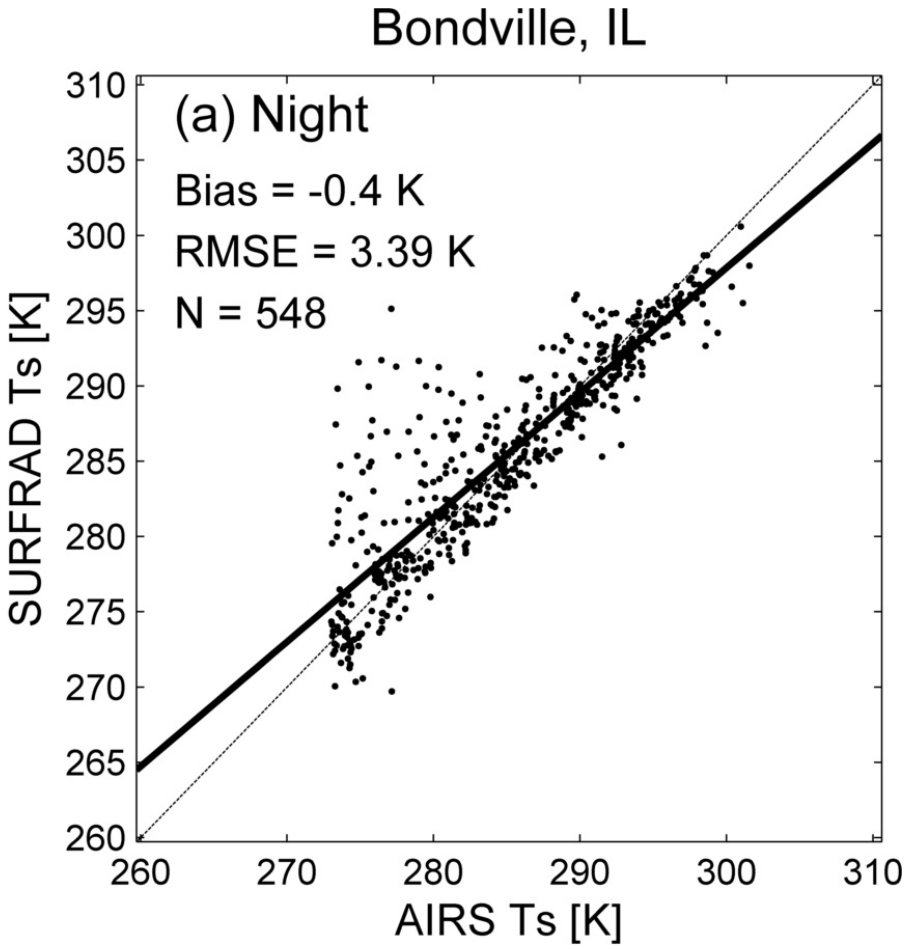


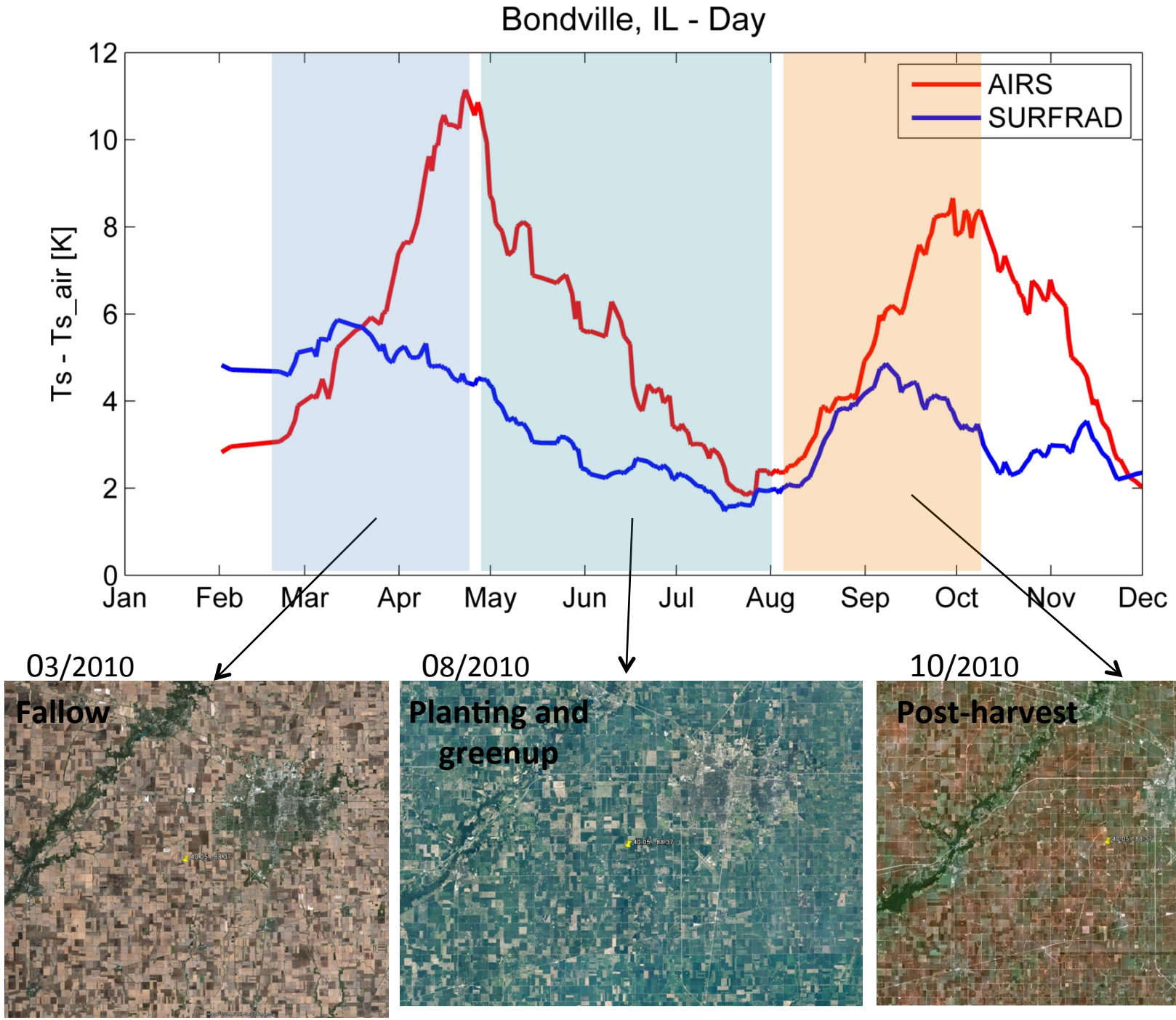


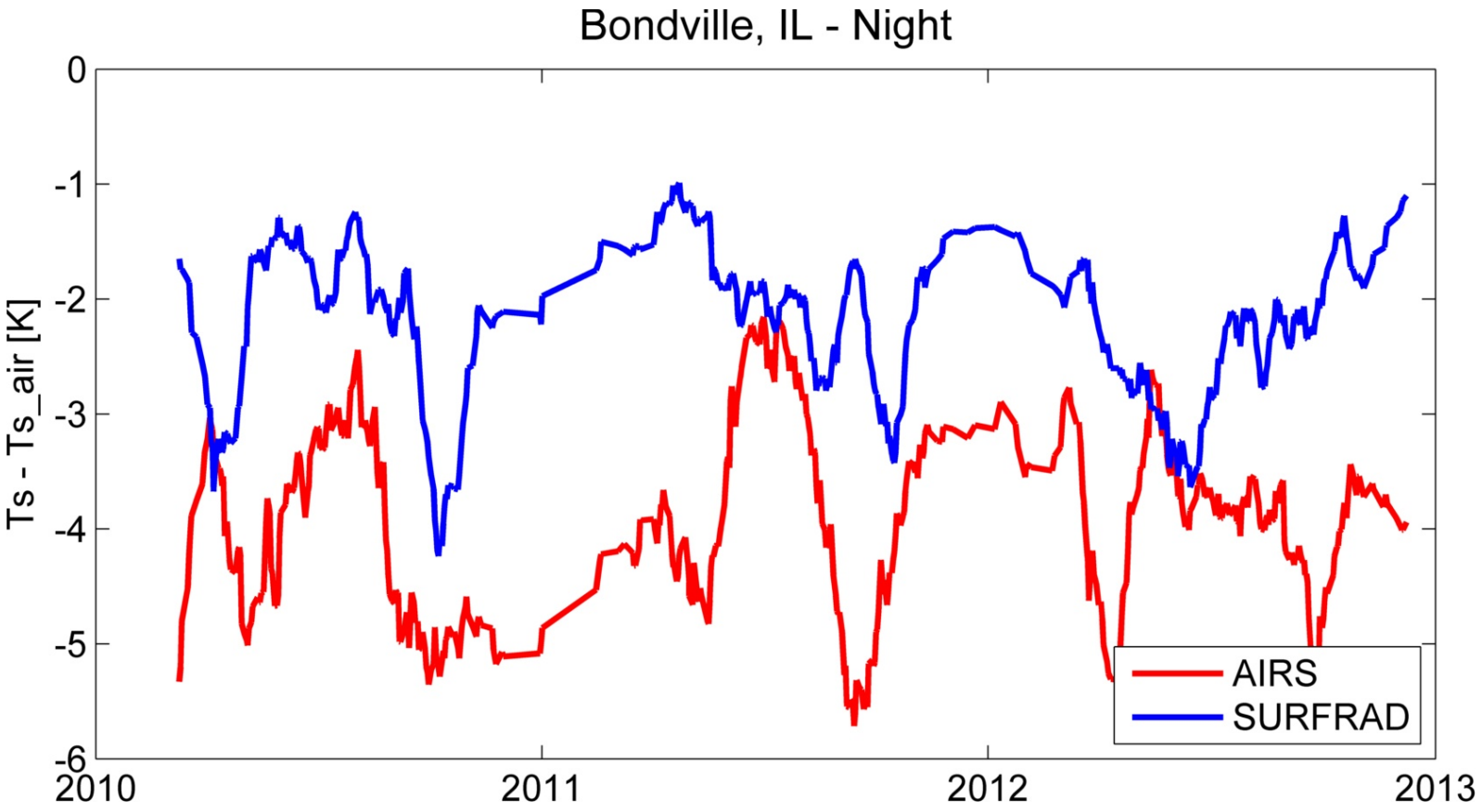
Ts Scatterplots

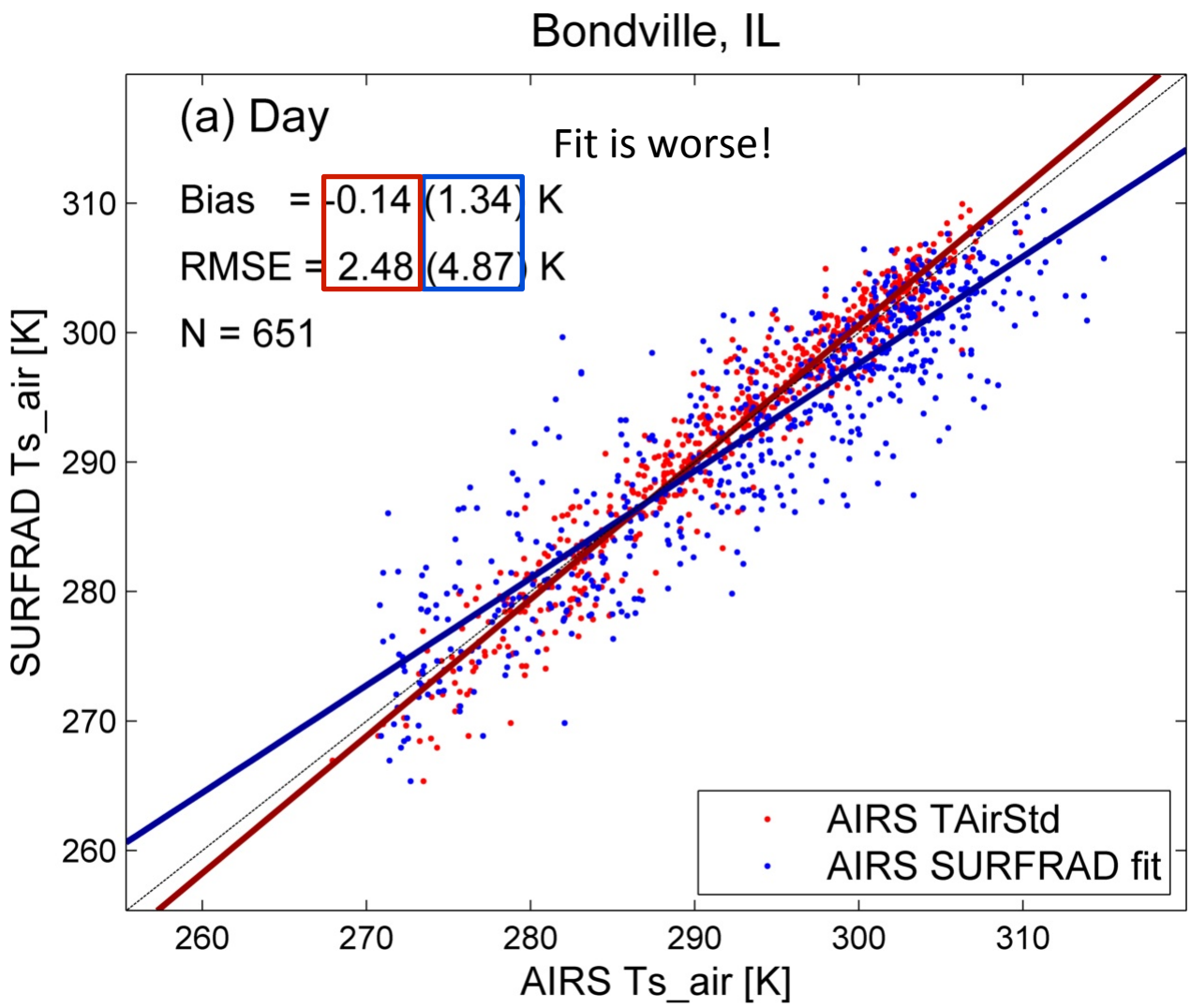
2010-2012
Tserror<5 K






Bondville, IL - Day
AIRS
SURFRAD
Ts - Ts_air [K]
0
2
4
6
8
10
12
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
03/2010
Fallow
08/2010
Planting and greenup
10/2010
Post-harvest


Bondville, IL - Night
Ts - Ts_air [K]
0
-1
-2
-3
-4
-5
-6
2010
2011
2012
2013
AIRS
SURFRAD

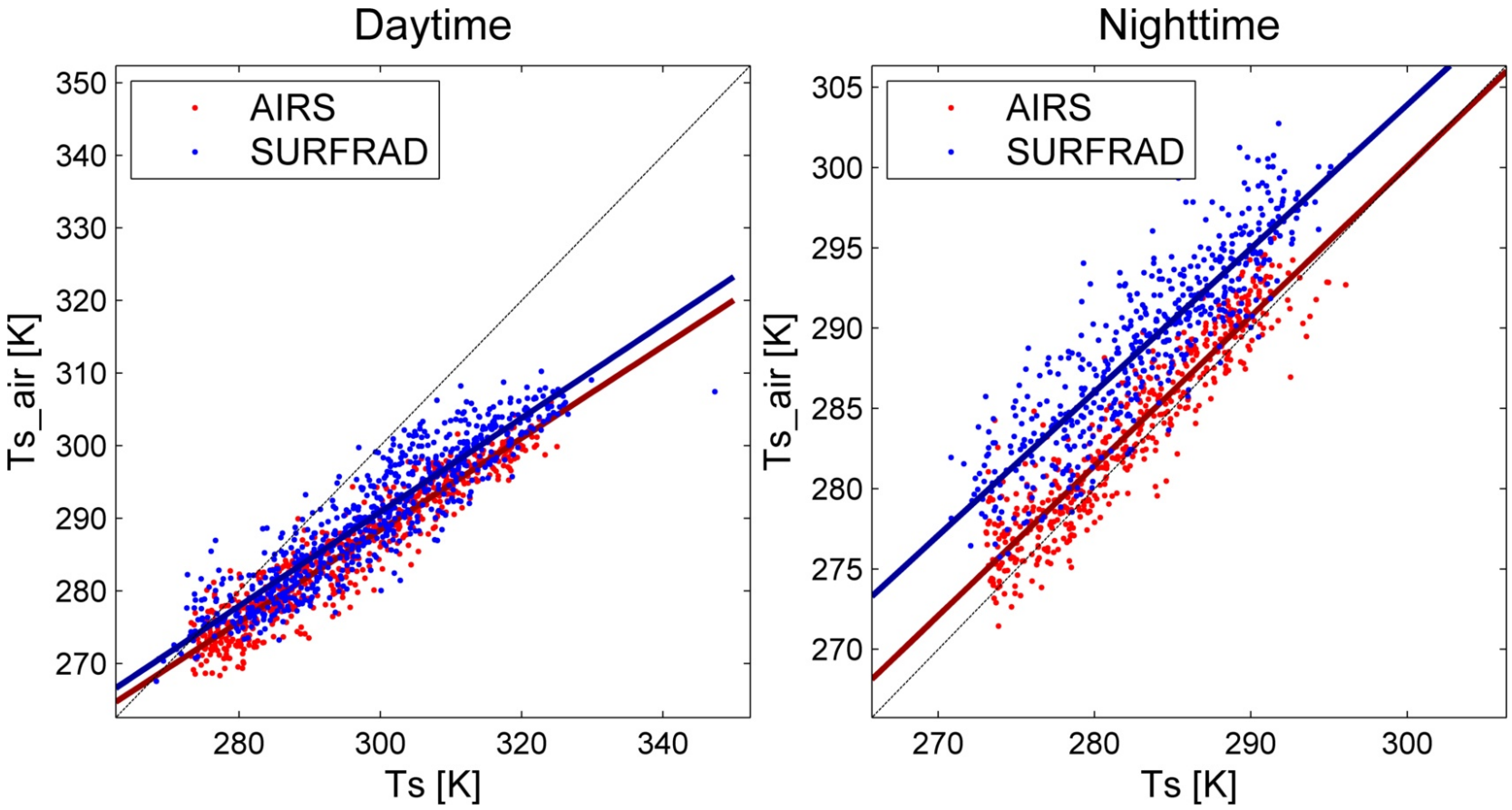

Bondville, IL
(a) Day
Fit is worse!
Bias = -0.14 (1.34) K
RMSE = 2.48 (4.87) K
N = 651
AIRS TAirStd
AIRS SURFRAD fit
SURFRAD Ts_air [K]
AIRS Ts_air [K]
260
270
280
290
300
310

Proposed Methodology

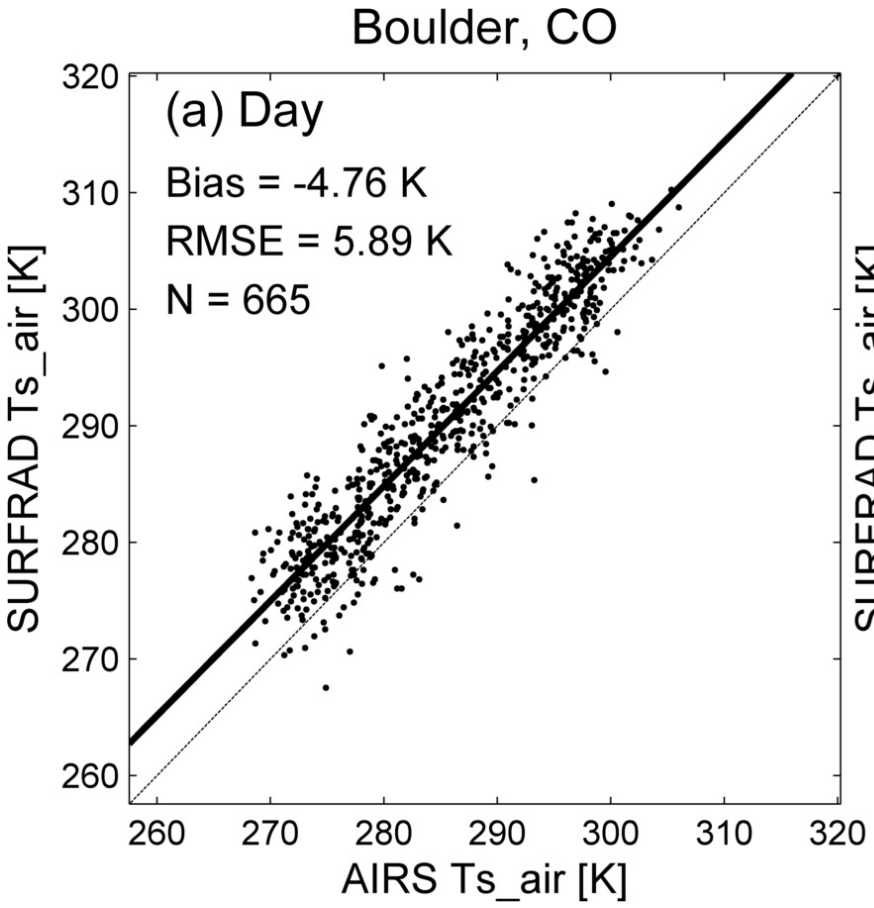
1. Statistical regression approach
    1. Find stations that are thermally homogeneous at AIRS pixel scale
    2. Use combinations of emissivity, NDVI (ASTER, MODIS) to classify sites
    3. Determine statistical relationships between Ts and Tair, e.g. linear, quadratic
2. Monin-Obukhov similarity theory?

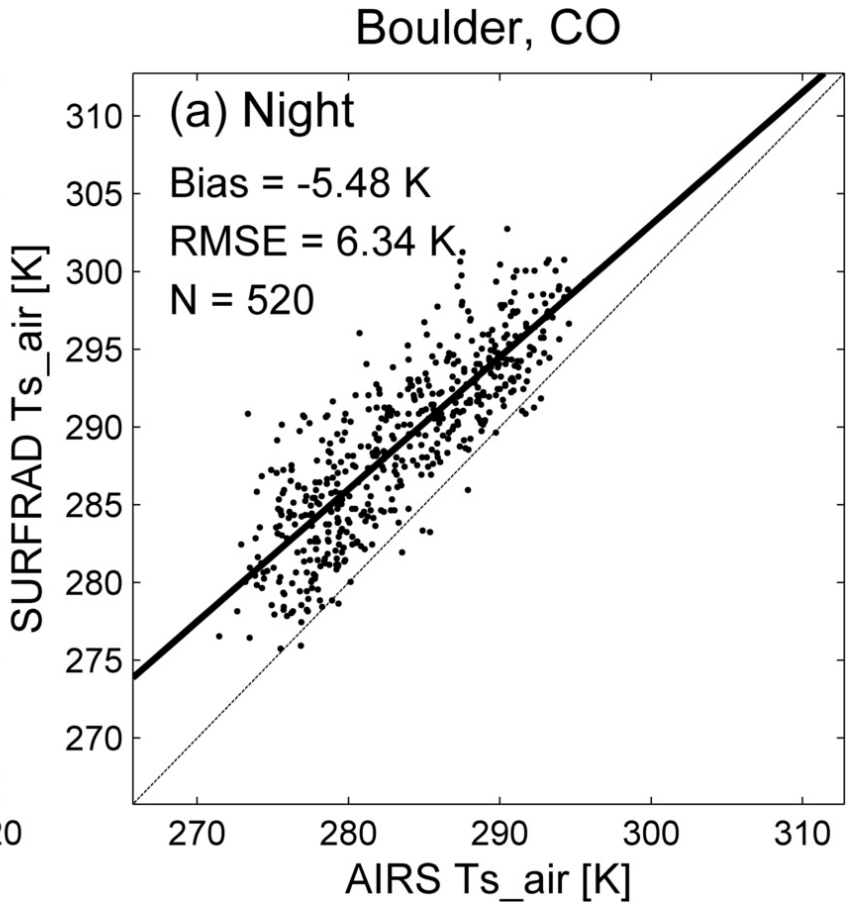
Conclusions

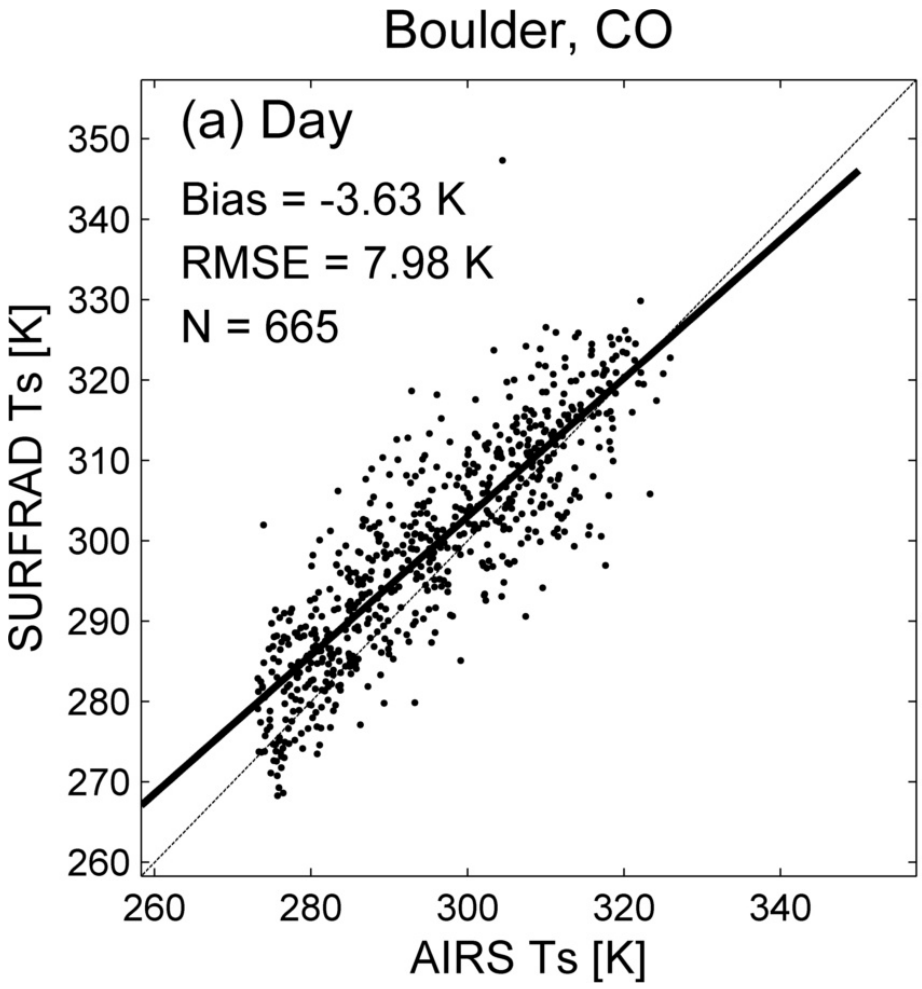
- Most SURFRAD sites not representative of surface dynamics at AIRS 50 km scale
- AIRS underestimation of surface air temperature at Desert Rock semi-arid site (2-3 K biases)
- Linear fit to SURFRAD data improves AIRS Tsair at Desert rock (<1 K bias)
- AIRS standard linear interpolation (TAirStd) works at vegetated sites such as Bondville (~1 K biases)
- Need to find sites representative of AIRS 50 km scale
- Generate Tair-Tskin regression fits for range of surface types at homogenous sites
- Explore Monin-Obukhov BL similarity theory

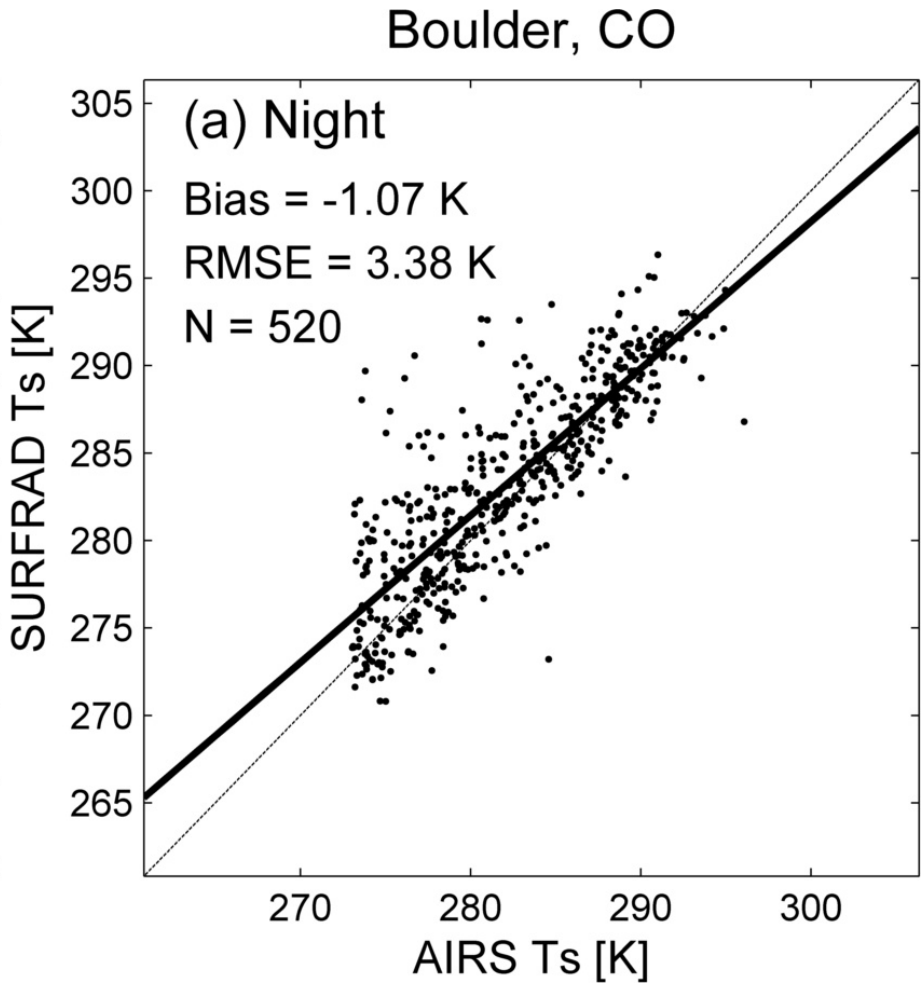


AIRS Ts_air = interp1[pressStd(1),T(1), PSurfStd]


Boulder, CO
(a) Day
Bias = -4.76 K
RMSE = 5.89 K
N = 665
SURFRAD Ts_air [K]
AIRS Ts_air [K]
320
310
300
290
280
270
260
260
270
280
290
300
310
320


Boulder, CO
(a) Night
Bias = -5.48 K
RMSE = 6.34 K
N = 520
SURFRAD Ts_air [K]
AIRS Ts_air [K]
310
305
300
295
290
285
280
275
270
270
280
290
300
310


Boulder, CO
(a) Day
Bias = -3.63 K
RMSE = 7.98 K
N = 665
SURFRAD Ts [K]
AIRS Ts [K]
260
270
280
290
300
310
320
330
340
350


Boulder, CO
(a) Night
Bias = -1.07 K
RMSE = 3.38 K
N = 520
SURFRAD Ts [K]
AIRS Ts [K]
265
270
275
280
285
290
295
300
305

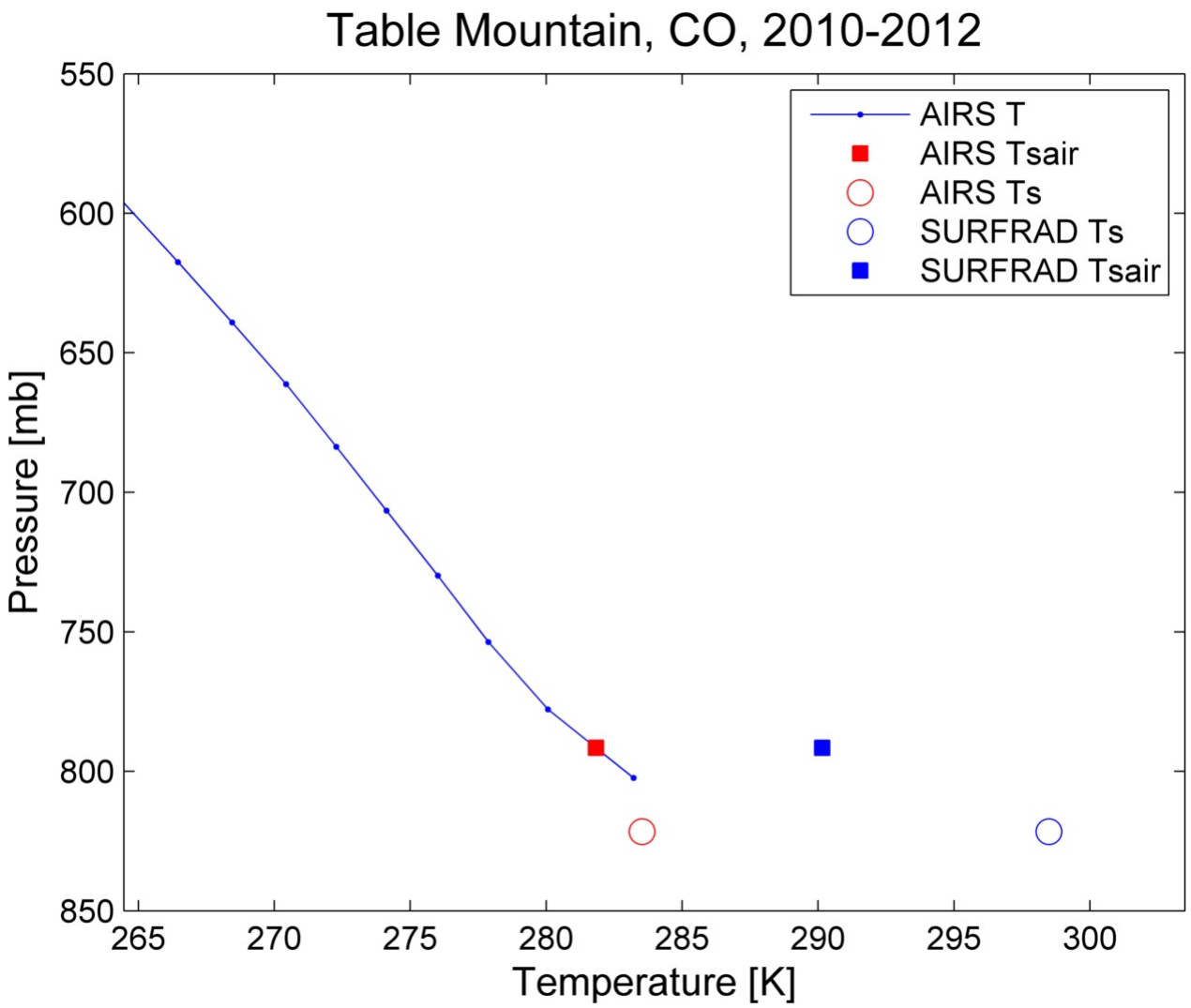


Table Mountain, CO, 2010-2012
Pressure [mb]
Temperature [K]
550
600
650
700
750
800
850
265
270
275
280
285
290
295
300
AIRS T
AIRS Tsair
AIRS Ts
SURFRAD Ts
SURFRAD Tsair

Day		Bias		RMSE	
Site	N	TAirStd	SURF-Fit	TAirStd	SURF-Fit
Desert Rock	490	-2.51	-0.18	3.25	3.71
Bondville	651	-0.14	1.34	2.48	4.87
Fort Peck	644	-1.71	1.31	3.19	3.95
Table Mountain	665	-4.76	-2.35	5.89	4.72

better worse

Night		Bias		RMSE	
Site	N	TAirStd	SURF-Fit	TAirStd	SURF-Fit
Desert Rock	490	-3.80	-1.39	4.64	2.77
Bondville	548	1.28	-0.37	2.51	2.74
Fort Peck	485	1.42	-0.22	3.29	2.88
Table Mountain	520	-5.48	-0.96	6.34	3.26
		2.98	0.73	4.43	2.91