Temperature Variability of AWS Sensors Operating at the Greenland Summit (2008-13)

Christopher A. Shuman[1], Dorothy K. Hall[2], Thomas K. Mefford[3], Michael O'Neill[3], and Michael J. Schnaubelt[4]

[1]Joint Center for Earth Systems Technology, University of Maryland, Baltimore County, Baltimore, and NASA Goddard Space Flight Center, Greenbelt, Maryland

[2]Cryospheric Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, Maryland

[3]Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, and NOAA/Earth System Research Laboratory, Boulder, Colorado

[4]Joint Center for Earth Systems Technology, University of Maryland, Baltimore County, Baltimore, Maryland

Abstract

The ability to record temperatures accurately enough to derive climate trends is an area of ongoing research. Originally intended to obtain reasonably accurate meteorological data year-round in support of ice sheet field operations, automatic weather stations (AWS) at locations such as the Greenland Summit are being utilized for more challenging goals. These goals include measuring temperature over the decadal time spans necessary for assessing climate trends and to assess satellite- or model-derived parameters. This research compares two traditional, decadal+ length AWS air temperature (T_A) records to more recent 'climate quality' data from NOAA's instrument suite at Summit (see Table 1 and Figure 1). The primary goal of the study is to quantify uncertainties in the near-surface T_A measurements at typical temporal resolutions using data acquired during 2008-2013 and to explore possible reasons for any observed temperature differences.

Four near-surface air temperature data sets from near Summit Station, Greenland, were investigated in this study. The availability of climate-quality T_A data from a NOAA Global Monitoring Division observatory at Summit Station has enabled the study of both passive and actively-ventilated T_A data. During a >5-yr period (July 2008–December 2013), data from both the Greenland Climate Network (GC-Net) AWS and the Danish Meteorological Institute (DMI) AWS were compared to averages created from the 1-minute average T_A values from NOAA's primary 2-m temperature Logan sensor. The Logan sensor was assessed by similar intercomparisons with the NOAA backup Vaisala sensor as both were enclosed in fan-ventilated shields. The principal findings of this study show 1) that the DMI data are more consistent than the GC-Net data during the study period; 2) that there is a pattern in most years of the passively-ventilated data that suggests those sensors are impacted by solar heating during the summer months; and 3) that the year by year consistency between the two NOAA sensors suggests that a high-quality temperature record can be extended at least until May 2006.

Table 1 - Details on the temperature sensors used in this study

Sensor Name	Start Date	Temperature Sensor	Shield Type (source)
NOAA-L	26 June 2008	Logan ITS-90 Model 4150	Active Ventilation (Cambridge 137)
NOAA-V	19 May 2006	Vaisala HMP45D with YSI 44034 Thermistor	Active Ventilation (Cambridge 137)
NOAA-V	12 Aug. 2005	Vaisala HMP45D with YSI 44034 Thermistor	Active Ventilation (Met One 077)
DMI	4 Nov. 1997	Aanderaa PT2000 3145S/3444B	Passive Ventilation (Aanderaa)
GC-Net Summit	14 May 1996	Type-E Thermocouple (TC1 and 2, TC1 used)	Passive Ventilation (Gill 7 plate)

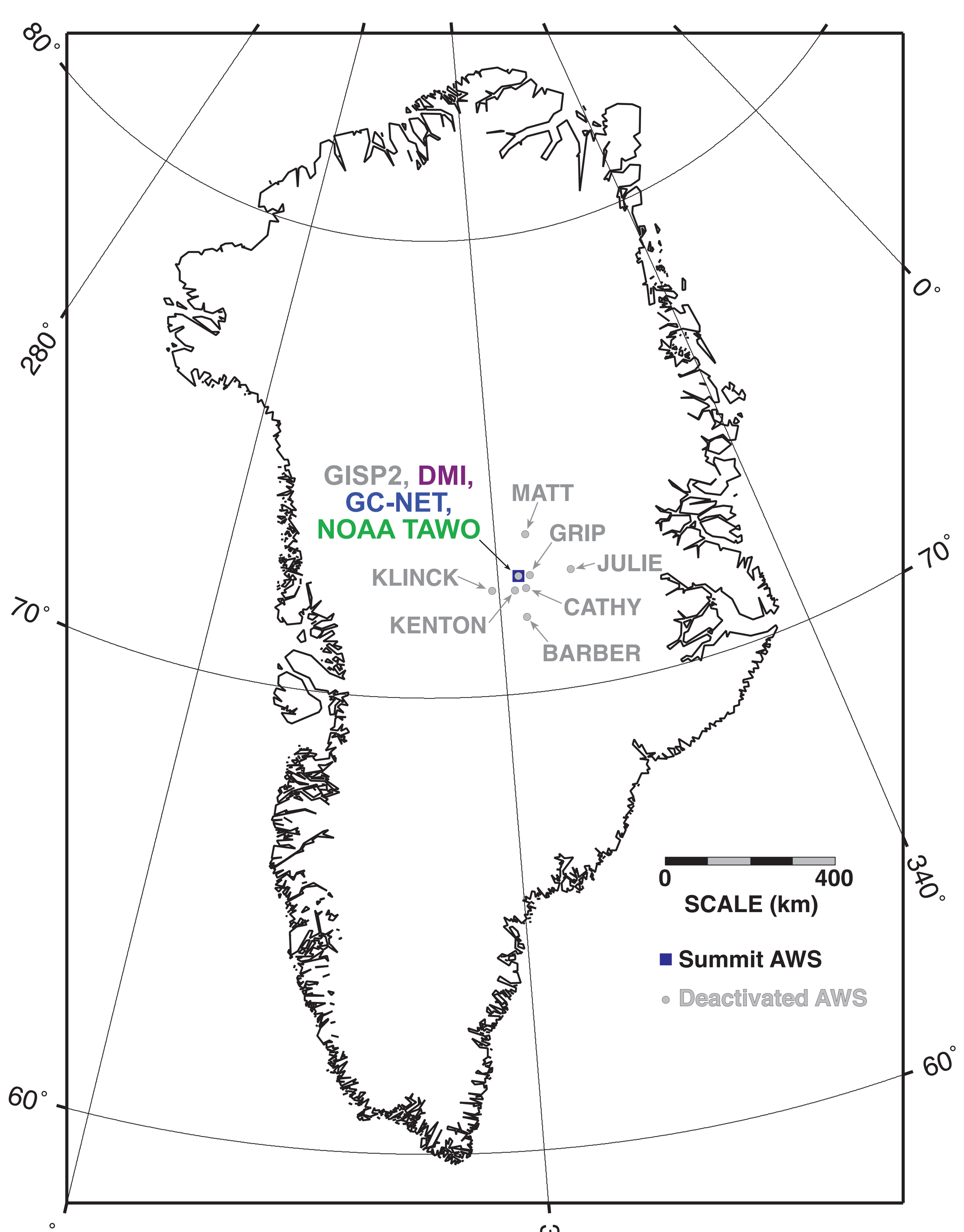

Figure 1
The locations of current and past temperature sensors at or near the Greenland Summit since the beginning of the Greenland Ice Sheet Project 2 (GISP2) in 1987. NOAA's temperature sensors are part of the Temporary Atmospheric Watch Observatory (TAWO).

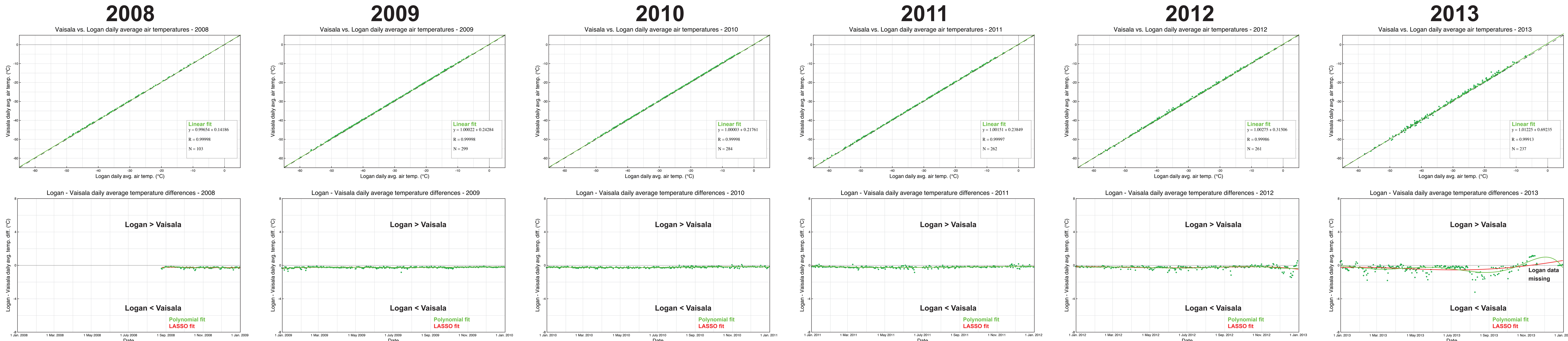

Figure 2 - Illustration of the relationship between temporally-matched Logan and Vaisala daily-average temperatures for each year in the study period (upper plots) and their differences L-V, (lower plots)

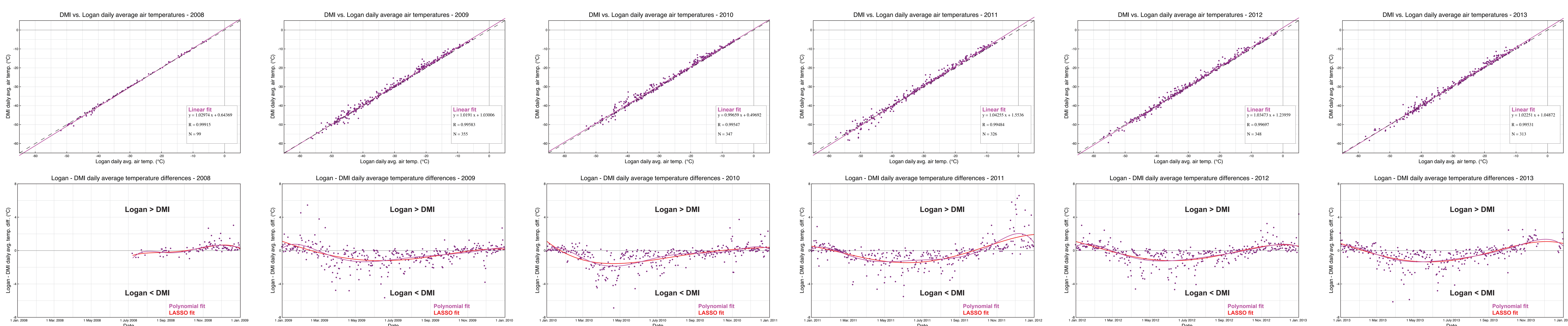

Figure 3 - Illustration of the relationship between temporally-matched Logan and DMI daily-average temperatures for each year in the study period (upper plots) and their differences L-D, (lower plots)

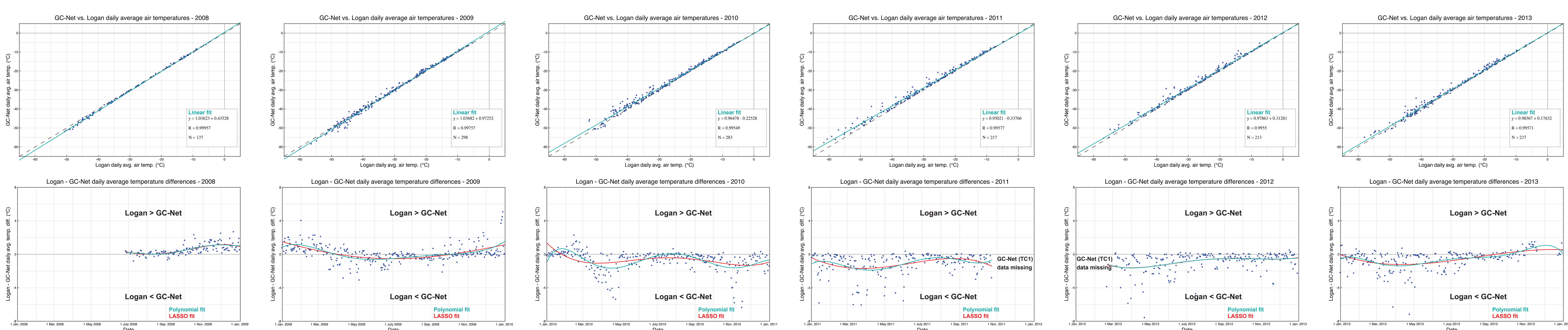

Figure 4 - Illustration of the relationship between temporally-matched Logan and GC-Net daily-average temperatures for each year in the study period (upper plots) and their differences L-G, (lower plots)

Table 2 - NOAA Logan vs Vaisala Annual Statistics

3-hour difference summary

Year	Mean Diff. °C	Abs. Mean Diff. °C	Std. Dev. °C	Percent of Year	Comments
2008	-0.258	0.259	0.137	34.32	Logan, begins 26 June
2009	-0.235	0.236	0.130	96.92	
2010	-0.215	0.225	0.146	96.37	
2011	-0.187	0.213	0.195	93.90	
2012	-0.223	0.257	0.299	95.80	
2013*	-0.316	0.493	0.783	87.33	No Logan, late Nov. into Dec.

Daily difference summary

Year	Mean Diff. °C	Abs. Mean Diff. °C	Std. Dev. °C	Percent of Year	Comments
2008	-0.256	0.256	0.085	28.14	Logan, begins 26 June
2009	-0.236	0.236	0.082	81.92	
2010	-0.217	0.218	0.074	77.81	
2011	-0.191	0.198	0.111	71.78	
2012	-0.235	0.247	0.224	71.31	
2013*	-0.327	0.442	0.536	64.93	No Logan, late Nov. into Dec.

Monthly difference summary

Year	Mean Diff. °C	Abs. Mean Diff. °C	Std. Dev. °C	Percent of Year	Comments
2008	-0.262	0.262	0.036	34.32	Logan, begins 26 June
2009	-0.235	0.235	0.034	96.92	
2010	-0.216	0.216	0.039	96.37	
2011	-0.187	0.187	0.046	93.90	
2012	-0.233	0.233	0.075	95.80	
2013*	-0.270	0.404	0.444	87.33	No Logan, late Nov. into Dec.

2008 and 2012 were leap years
*During 2013, performance issues with these sensors are under study

Table 3 - NOAA Logan vs DMI Annual Statistics

3-hour difference summary

Year	Mean Diff. °C	Abs. Mean Diff. °C	Std. Dev. °C	Percent of Year	Comments
2008	0.066	0.759	1.356	44.77	Logan, begins 26 June
2009	-0.476	1.391	2.389	99.08	
2010	-0.580	1.183	1.950	98.66	
2011	-0.280	1.352	2.220	96.88	
2012	-0.255	1.129	1.878	98.77	
2013	-0.395	1.158	1.885	89.73	No Logan, late Nov. into Dec.

Daily difference summary

Year	Mean Diff. °C	Abs. Mean Diff. °C	Std. Dev. °C	Percent of Year	Comments
2008	0.307	0.480	0.640	27.05	Logan, begins 26 June
2009	-0.456	0.857	1.193	97.26	
2010	-0.587	0.845	1.182	95.07	
2011	-0.264	0.997	1.499	89.32	
2012	-0.251	0.770	1.127	95.08	
2013	-0.392	0.863	1.203	85.75	No Logan, late Nov. into Dec.

Monthly difference summary

Year	Mean Diff. °C	Abs. Mean Diff. °C	Std. Dev. °C	Percent of Year	Comments
2008	-0.018	0.377	0.462	44.77	Logan, begins 26 June
2009	-0.472	0.708	0.679	99.08	
2010	-0.578	0.701	0.823	98.66	
2011	-0.287	0.985	1.159	96.88	
2012	-0.259	0.723	0.802	98.77	
2013	-0.289	0.769	0.913	89.73	No Logan, late Nov. into Dec.

2008 and 2012 were leap years

Table 4 - NOAA Logan vs GC-Net Annual Statistics

3-hour difference summary

Year	Mean Diff. °C	Abs. Mean Diff. °C	Std. Dev. °C	Percent of Year	Comments
2008	0.524	0.714	0.925	49.39	Logan, begins 26 June
2009	0.144	1.046	1.733	96.61	
2010	-0.759	1.153	2.007	96.34	
2011	-1.090	1.177	1.638	76.44	No GC-Net starting late Oct.
2012	-0.895	1.071	1.601	79.99	No GC-Net into Feb.
2013	-0.523	0.937	1.568	87.33	No Logan, late Nov. into Dec.

Daily difference summary

Year	Mean Diff. °C	Abs. Mean Diff. °C	Std. Dev. °C	Percent of Year	Comments
2008	0.579	0.640	0.636	37.43	Logan, begins 26 June
2009	0.151	0.681	1.026	81.64	
2010	-0.701	0.863	1.227	77.53	
2011	-1.100	1.113	1.349	59.45	No GC-Net starting late Oct.
2012	-0.878	0.910	1.185	58.20	No GC-Net into Feb.
2013	-0.604	0.827	1.128	64.93	No Logan, late Nov. into Dec.

Monthly difference summary

Year	Mean Diff. °C	Abs. Mean Diff. °C	Std. Dev. °C	Percent of Year	Comments
2008	0.491	0.491	0.469	49.39	Logan, begins 26 June
2009	0.141	0.515	0.604	96.61	
2010	-0.753	0.844	0.837	96.34	
2011	-1.084	1.084	0.489	76.44	No GC-Net starting late Oct.
2012	-1.030	1.030	0.661	79.99	No GC-Net into Feb.
2013	-0.425	0.645	0.749	87.33	No Logan, late Nov. into Dec.

2008 and 2012 were leap years

Tables 2-4 - Statistics were generated at 3-hour resolution (the temporal sampling rate available from DMI) for each pair of sensors as well as at daily, and monthly resolutions. We required that each 'day' be complete, hence the lower percentages. Monthly averages used the matched 3-hour data.

Results, Conclusions, and Future Work

The ability to compare aspirated (Logan and Vaisala) and passively-ventilated (DMI and GC-Net) temperature data sets has revealed both the magnitude and consistency of an expected 'solar heating' bias in the passively ventilated data sets. The plots above show the small offset but very consistent relationship between the temperatures recorded by the two aspirated sensors into mid-2013 (Figure 2 plots) and the generally warmer temperatures for periods of higher solar gain recorded by the passively-ventilated sensors (see Figure 3 and 4 plots).

The DMI data appears more consistent relative to the Logan data from year-to-year (warmer in the summer but also colder in the winter time) especially compared to the GC-Net data from 2010 to 2012. The trends in the difference data, suggested by the polynomial or LASSO* fits, provide a sense of the yearly variability of the passively shielded data's accuracy and Tables 2-4 provide statistics for the analyses done at 3-hour, daily, and monthly resolutions.

Additional work will include assessing the variability between the two aspirated sensors from mid-2013 onward and extending the Logan T_A record back to mid-May 2006 using an empirical correction to the early Vaisala data (see Table 1, a problematic Met One housing used initially). The goal is to create a longer, climate-quality, near surface temperature record to use for calibration/validation studies of model or satellite-derived near-surface temperature. This analysis suggests (see Figure 3 and 4 plots) that standard AWS records are valuable for meteorological studies but are not reliable enough for the most accurate assessments.

*http://statweb.stanford.edu/~tibs/lasso/simple.html