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Minimum Daily Ambient Air Temperatures at the MMT Observatory, Mt. Hopkins, Arizona, December 2003 through January 2008

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Introduction

Chamber and outside ambient air temperature data have been logged at the MMT Observatory for the past four years, beginning in December 2003. These data are critical for proper control of the primary mirror ventilation system[1], minimization of mirror and dome seeing[2,3], and in operational activities in which freezing and icing are a potential issue. A major objective of the primary mirror ventilation system is to minimize the air-glass thermal contrast as well as to provide thermal uniformity of the glass itself[1]. Local atmospheric turbulence related to air-glass temperature contrast is a major component of mirror seeing.

Environmental logging was started at the MMT Observatory in the fall of 2003. Since then, a variety of sensors have been used to sample chamber and outside ambient air temperature, including: 1) a SensaTronics/TempTrax model E16 temperature monitor with probes both in the chamber and outside; 2) two Vaisala model WXT 510 weather multi-sensors, one mounted outside east of the telescope and one outside west of the telescope; 3) a Vaisala HMP 243 unit for temperature and relative humidity measurements in the chamber; and 4) E-series (Chromel/Constantan) thermocouples that are part of thermal system of the primary mirror[1]. These E-series thermocouples measure chamber and outside temperatures as well as primary mirror glass and other temperatures. The thermocouples are monitored through the primary mirror cell computer and are referred to as the "cell E-series" thermocouples. None of the chamber or outside temperature sensors have a completely continuous log for this period because of operational issues, such as summer shutdown and non-observing nights. The SensaTronics/TempTrax and Vaisala HMP 243 data are the most complete. Other temperature data sets, such as from the Vaisala model HMI 36 and the Yankee MET-2010 thermohygrometer, are not presented here.

The manufacturer's technical specifications for the SensaTronics/TempTrax model E16 (http://www.sensatronics.com/ products_temperature_model_e16.html) include:

Operating Range:	0°F to 122°F
Resolution:	0.1°
Probe Accuracy:	0.5°F from -20°F to +120°F
	1.5°F from -40°F to -20°F
	1.5°F from +120°F to +175°F

The temperature sensing unit is a proprietary, heavy-duty thermistor with a 75-foot, PVC-jacketed and shielded cable. The sensor is housed in a stainless steel cylinder.

The temperature measurement of the Vaisala model WXT 510 (http://www.vaisala.com/ instruments/products/weathermulti-sensor), which is based on the ceramic Vaisala THERMOCAP® sensor, has the following temperature sensing specifications:

Measurement range: -52 to +60 °C (-60 to +140 °F)
Accuracy at +20 °C (+68 °F): ±0.3 °C (±0.5 °F)

The manufacturer's technical specifications for the Vaisala model HMP 243 include:

Operating Range: -40°C to +180°C
Typical Accuracy at +20°C (+68°F): ±0.1°C
Typical temperature dependence on electronics: 0.005 °C/°C

The temperature sensor for the Vaisala HMP 243 is a Pt100 Resistance Temperature Detector (RTD) DIN IEC 751, class 1/4 B probe.

Details of the cell E-series thermocouples and thermal ventilation for the primary mirror and mirror cell are described in Williams *et al.*[1]

Data

Figure 1 presents minimum daily chamber and outside ambient air temperature data from December 2003 through January 2008 at the MMT. The minimum daily temperature, ranging from -40°C to +25°C, is plotted on the horizontal axis, while the percentage of days with that observed minimum daily temperature is shown on the vertical axis. Seven different temperature sources are included in the graph: three measuring outside ambient air temperature and four measuring ambient air temperature within the chamber. The seven data sets vary in size up to over 1,000,000 temperature measurements, sampled over the four-year period. The data from the two Vaisala XWT 510 units have been combined since the second unit has only recently been installed.

Chamber temperatures are obtained from several locations. Most of the chamber temperatures are obtained near the yoke of the telescope. However, SensaTronics/TempTrax, Probe 6, is located within the secondary hub. Temperatures at this location can be influenced by electronics associated with the secondary mirror systems. This location is within the observing light path.

Figure 2 presents details of the sub-zero portion of Figure 1. Of particular importance in Figure 2 is the percentage of days that have sub-zero temperatures as well as the percentage of days that are colder than -10°C, the current limit for glycol coolant temperatures of the Carrier 30GN-040 chiller, the main component of the primary mirror ventilation system[1].

Discussion

A summary of logged outside ambient temperature data for the MMT Observatory for a four-year period (December 2003 through January 2008) is presented here, with emphasis on the minimum daily temperature. Of the different measurement devices, the cell E-series thermocouples systematically record the coldest temperatures, while the SensaTronics/TempTrax and Vaisala units results are comparable. These differences in measured temperature result from different sensor types, sensor characteristics, and local thermal conditions. The chamber temperatures presented here are for the same time period as the outside temperatures. During a portion of this time, the chamber was close, which would contribute to the overall warmer chamber temperatures compared to outside temperatures.

It is interesting to note that the MMT Observatory has freezing outside temperatures during approximately 25% of the days during the year. This makes potential freezing and icing of equipment and facilities a major concern. In addition, the thermal ventilation system must be able to chill the primary mirror well below freezing in order to minimize air-mirror temperature contrasts. Although chamber conditions are somewhat warmer than outside temperatures, particularly when the chamber is not opened for observing, sub-zero temperatures occurred within the chamber for a significant number of days. Characteristics and performance of the current thermal system at the MMT Observatory will be discussed elsewhere.

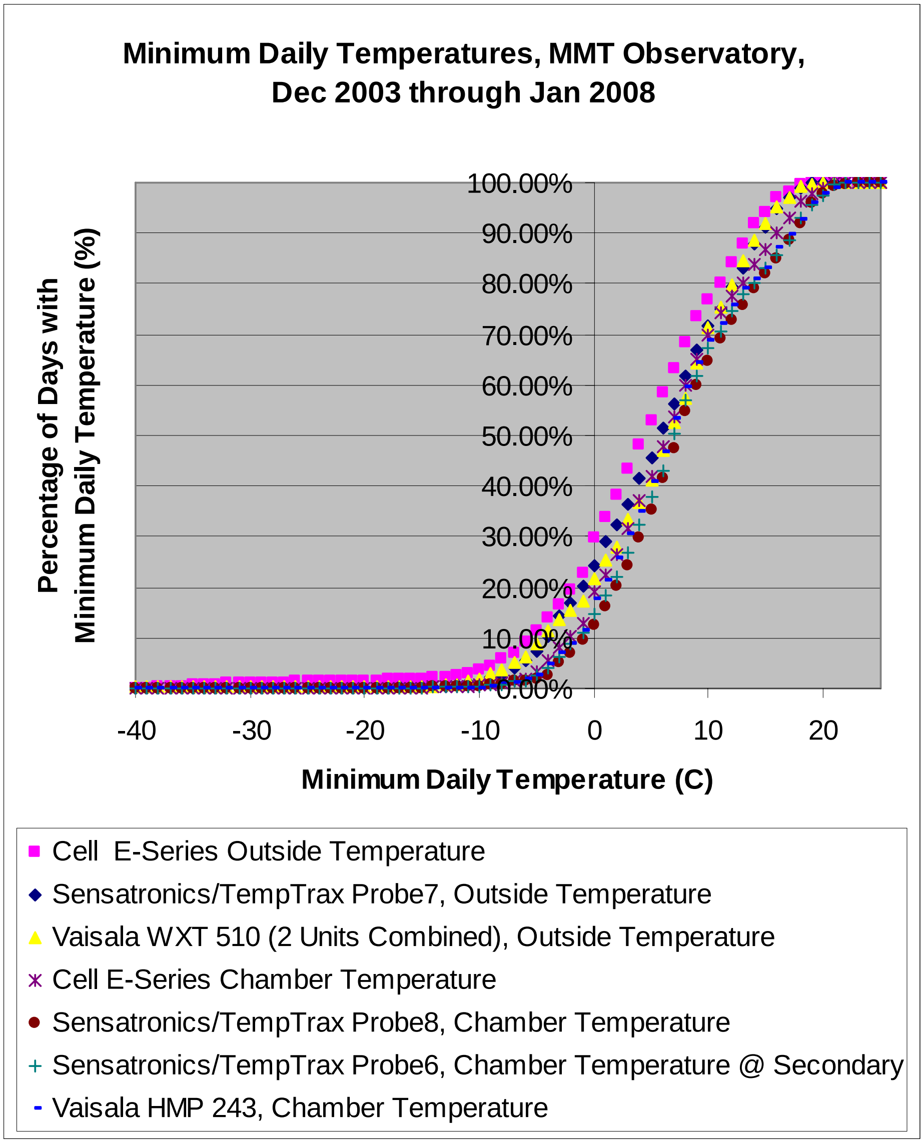

Figure 1: Graph of the percentage of days with a minimum daily temperature below a given temperature from December 2003 to January 2008. See text for details.

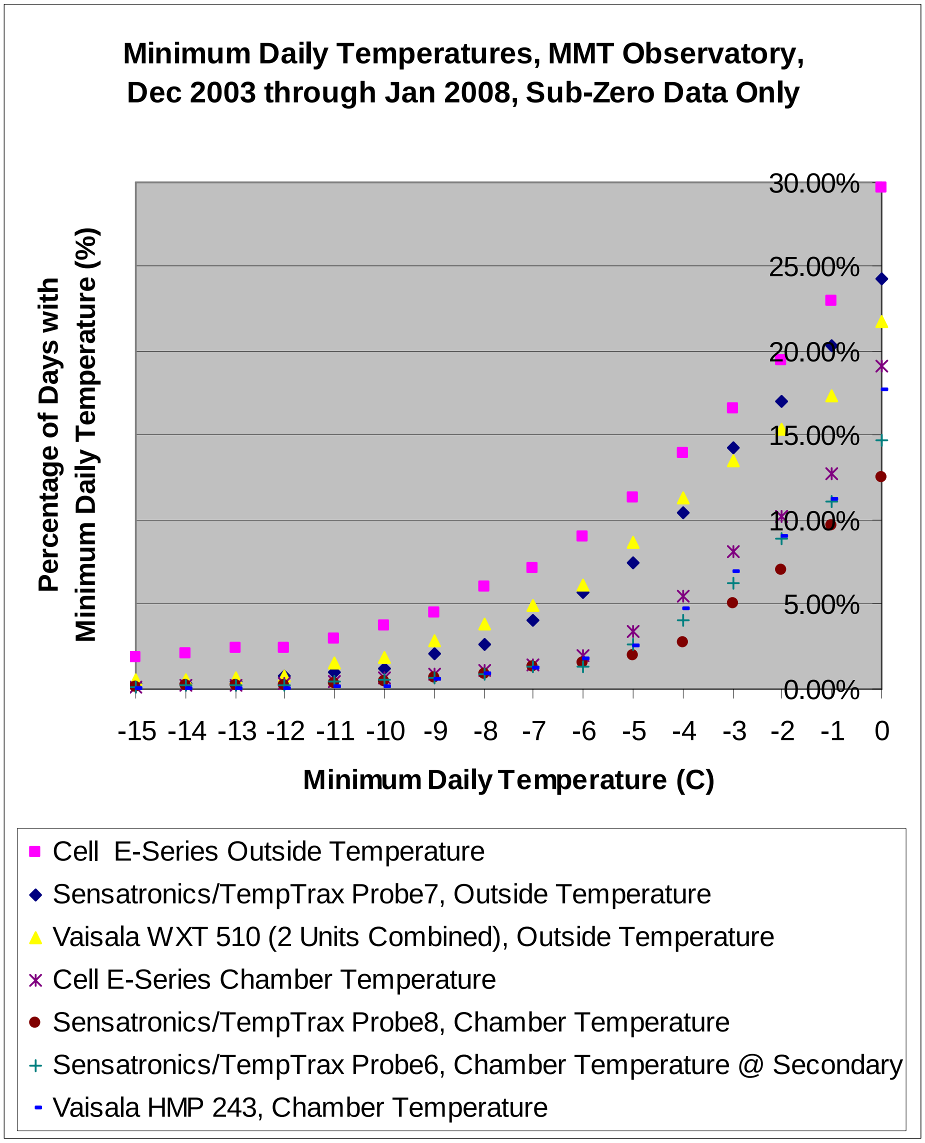

Figure 2. Details of days with sub-zero minimum daily temperature from December 2003 to January 2008. See text for details.

References

1. G. G. Williams, J. D. Gibson, S. Callahan, D. Blanco, J. T. Williams, and P. Spencer, 2004, "Performance and Control of the MMT Thermal System," Proceedings, *SPIE*, **5489**, 938.

2. M. T. Bridgeland and C. R. Jenkens, 1997, "Measurements of Mirror Seeing in the Laboratory and at the Telescope," *Mon. Not. R. Astron. Soc.*, **287**, 87-109.

3. Zago, Lorenzo, 1997, "An Engineering Handbook for Local and Dome Seeing," Proceedings, *SPIE*, **2871**, 726-736, *Optical Telescopes of Today and Tomorrow*, Arne L. Ardeberg, ed.