CHANDRA
X-ray Center

MEMORANDUM

October 28, 2002

To: ACIS Operations Team

From: Joseph DePasquale, Paul Plucinsky

Subject: ACIS PSMC, DPA & DEA Temperatures Trends and Excursions

1 Introduction

Recent thermal trends analysis has shown that a number of ACIS MSIDs are encroaching on their so-called "Data Quality (DQ)" yellow limits. All ACIS MSIDs maintain a comfortable margin against the "Health & Safety" limits, except for the "PSMC Temp 1A (1PIN1AT)" (for a history of the changes in the ACIS limit sets see Reference #1). The values which have come closest to the DQ yellow limits are some of the temperatures for the ACIS Power Supply and Mechanism Controller (PSMC), Digital Processing Assembly (DPA) and Detector Electronics Assembly (DEA). There was a gradual upward trend in the temperature data for the first two years of the mission, but this trend appears to have subsided in the third year of the mission. The focus of this memo is on a number of "excursions" in which a particular temperature shows a sharp peak for a short period of time. It is only during these excursions in which the DQ yellow limit is in danger of being reached, the average values remain well below the DQ yellow limits. The ACIS Operations Team identified these intervals and examined the spacecraft and ACIS configuration over a 6 month period in 2002. These sharp peaks correspond to intervals in which the spacecraft pitch angle is between 45^o and 60^o and 120^o and 180^o (See Figure 1 for an illustration of the 45^o case.) On two occasions, 1PIN1AT has exceeded its yellow upper limit. If such violations were to become more common, it might be necessary to increase the DQ limits back to the values used at launch.

2 ACIS Limit Set Philosophy

The CXC ACIS Operations Team (AOT) and CXC Monitoring & Trends Analysis (M&TA) teams adopted a limit set philosophy recommended by the MIT ACIS engineering team which included two sets of limits. One set is the so-called "Health & Safety (HS)" set and is analogous to the limit sets used by the rest of the subsystems on the *Chandra* spacecraft. The second set is the so-called "Data Quality (DQ)" set and is intended to indicate conditions which *might* affect the quality of the science data from ACIS but which represent no threat to the hardware. The CXC AOT conducted a review of the ACIS telemetry limits in the Fall of 2001 with the MIT ACIS Engineering team and the FOT Thermal team. The review analyzed the temperature data from the first two years of the mission and compared them to the existing limits. Both the HS and DQ limits were modified based on this review. The HS limits were then incorporated into the OCC Operations DataBase (ODB). The DQ limits were incorporated into the CXC AOT realtime TLM checks and the CXC M&TA SSR dump checks. In general, the HS and DQ limits were changed to a narrower range of values since none of the ACIS values had exceeded a yellow limit during the first two years of the mission during normal operations (excluding special events such as focal plane bakeouts and shutdowns for radiation events). In some cases, the HS and DQ limit values are identical.

3 Excursions

There are 6 MSIDs that are being monitored closely now as they have recently shown significant excursions from normal operating temperatures which have approached the DQ yellow upper limits. The relevant MSIDs and yellow and red upper limits (YH,RH) for both limit sets are listed in Table 1. There is still a significant margin against the lower limits, so we have omitted those limits from Table 1 for simplicity's sake.

The analysis of the excursions involved obtaining temperature data over time for each MSID. This was done using the "Dataseeker" software implemented by M&TA. The data from this retrieval software is comprised of 5 minute averages over the life of the mission. We obtained data for each MSID in the above table as well as the Solar Array Angle (SAA)

Table 1: **ACIS PSMC, DEA, & DPA Temperature MSIDs and Limits**

MSID	Description	Data Quality		Health & Safety	
		YH(C)	RH(C)	YH(C)	RH(C)
1PDEAAT	PSMC DEA Power Supply Temp A	50.00	58.50	50.00	58.50
1PDEABT	PSMC DEA Power Supply Temp B	50.00	58.50	50.00	58.50
1PIN1AT	PSMC Temp 1A	30.00	36.50	30.00	36.50
1DEAMZT	DEA -Z Panel Temp (RT830)	12.00	40.50	20.00	40.50
1DPAMYT	DPA -Y Panel Temp (RT810)	14.00	40.50	20.00	40.50
1DPAMZT	DPA -Z Panel Temp (RT830)	17.00	40.50	20.00	40.50

[MSID: AOSARES1, AOSARES2] between January 1 - June 27, 2002. In addition to this, we obtained data for each MSID from August 2001 through July 2002. Excel spreadsheets were created as well as plots for each MSID detailing the excursions over this 6 month period, pointing out the approximate time of the excursion and the temperature. Additionally, data from the ACIS load review archive were obtained for the status of the instruments at the time of each excursion for both the 1PIN1AT and 1DEAMZT MSIDs. In particular, there were four excursions in 1PIN1AT for which the peak temperature came within 4^o of the "Data Quality" yellow hi limit. The excursions all share very similar characteristics that resemble a classic heating and exponential cooling curve, suggesting undesirable attitudes in which part of the SIM is exposed to sunlight. This is what prompted the inclusion of SAA data, plotting it along with each MSID to seek out a correlation.

4 Sources of Heating

4.1 ACIS Electronics

The ACIS power dissipation depends on the number of CCDs being clocked; the ACIS electronics dissipate the highest amount of power when 6 CCDs are clocked. The majority of ACIS observations are conducted in Timed Exposure (TE) mode, while a smaller number are conducted in Continuous Clocking (CC) mode. In order to determine if the ACIS power dissipation was an important factor in the temperature excursions, we examined the ACIS configuration before, during and after the excursions. For all of the exursions analyzed, the ACIS instrument was performing observations in standard configurations, using 5 or 6 chips in TE mode with full chip, 3/4, 1/8, or CUSTOM subarrays. To compute the power, we first obtained the ACIS MSIDs listed in Table 2.

Table 2: **ACIS DPA & DEA Electrical MSIDs**

	MSID	Description
1.	1DP28AVO	DPA +28V Input A
2.	1DPICACU	DPA Input Current A
3.	1DP28BVO	DPA +28V Input B
4.	1DPICBCU	DPA Input Current B
5.	1DE28AVO	DEA +28V Input A
6.	1DEICACU	DEA Input Current A

We downloaded the data for the 6 month interval and computed power in the following way:

DPA A power = 1DP28AVO $\times$ 1DPICACU

DPA B power = 1DP28BVO $\times$ 1DPICBCU

DEA A power = 1DE28AVO $\times$ 1DEICACU

Table 3 lists the computed average power for the science observations around each excursion for 1PIN1AT and 1DEAMZT. Note that the values tend to remain consistent for the DPA A & B before, during and after the excursions. However, the DEA power can vary significantly. For example, the DEA power dropped by almost a factor of two from OBSID 3455 to OBSID 61237 and by $\sim$ 20% from OBSID 2566 to OBSID 3670.

Based on this knowledge, we conclude that the ACIS configuration is not a significant contributor to the thermal excursions seen for the PSMC and DPA values but may be a contributor for the DEA excursions.

4.2 Spacecraft Attitude

In his thermal analysis, Tan Trinh included plots of temperature peaks and the SAA at the peak. Interestingly, the data do show a strong correlation between the peaks and the SAA. Chandra has a limited range of SAA (45^o-180^o) to keep the sun on one side of the spacecraft at all times. Angles between 45^o-60^o correlate to peaks that have occurred in 1PIN1AT, 1PDEAAT, and 1PDEABT. The PSMC is located on the -Z side of the SIM. SAA of 45^o have also been noted to correlate with an increase in the -Z SIM Flexure C temperature

Table 3: **ACIS DPA & DEA Power Consumption**

– 1PIN1AT Excursions –

Excursion	OBSID	DPA A (W)	DPA B (W)	DEA A (W)
1	3433	40.90	34.93	53.94
1	1935	41.47	35.86	52.88
1	3401	41.43	35.80	52.81
1	3434	40.68	34.41	28.82
2	2827	41.36	35.79	52.96
2	2787	41.36	35.87	52.54
2	3202	40.69	35.91	47.28
3	2745	41.90	36.14	56.63
3	3455	41.51	35.83	52.31
3	61237	40.19	34.28	27.27
4	3345	40.97	33.81	50.72
4	2916	41.20	35.53	52.58
4	2583	41.51	35.85	52.54
4	3346	41.33	35.88	52.75
4	3138	41.37	35.79	52.46

– 1DEAMZT Excursions –

Excursion	OBSID	DPA A (W)	DPA B (W)	DEA A (W)
1	61327	41.18	35.41	53.00
1	3436	41.28	35.65	52.62
1	2575	41.40	35.80	52.60
2	61229	41.32	35.59	50.94
2	3043	41.31	35.71	51.43
2	2953	40.66	35.76	47.49
3	61166	41.40	35.58	51.92
3	2566	41.33	35.78	51.96
3	3670	40.88	35.24	42.60
3	2581	41.31	35.76	52.19
3	3185	40.80	35.94	47.00

in Flight Notes 234a, and 303. Flexure C is located at the connection of the SIM to the Optical Bench near the PSMC and the RCTU. In Flight Note 303, Mark Freeman stated, "The temperature variation is caused by sunlight entering the gap between the SIM thermal skirt and the OBA. It was noted during Thermal/Vac testing at Ball that this gap was large; calculations showed that 20 watts or more could be entering at that area." Additionally, angles between 120^o-180^o correlate to peaks in 1DEAMZT, 1DPAMYT and 1DPAMZT. The DEA and DPA are located on the +Z side of the SIM which are next to the ACIS camera body. The ACIS radiatiors are also on this side of the SIM (see Figure 1).

The figures attached to this memo give an overview of the temperature data over a one year period (AUG 01 through JUL 02) as well as detail the recent excursions for the 2 MSID's, 1PIN1AT and 1DEAMZT; thus, representing each side of the SIM over the 6 month period from January to June 2002. For each MSID we include a plot of the temperature data over the 1 year period, the 6 month period, and more detailed figures of each temperature excursion plotted simultaneously with SAA. The largest effect in the 1 year plots for 1PIN1AT (Figure 2) and 1DEAMZT (Figure 12) is the variation in temperature from 0 to 27 C for 1PIN1AT and 4.5 to 11.5 C for 1DEAMZT. Any change in the average temperature with time is swamped by the larger variations in these temperatures from observation to observation.

We concern ourselves most with the dramatic excursions that are indicated in Figures 3 and 13. The excursion plots for both MSIDs illustrate the ACIS configuration at the time of the excursion. We have indicated the ACIS configuration on the temperature profiles in Figures 4, 6, 8 and 10 of 1PIN1AT, and Figures 14, 16, and 18 of 1DEAMZT's excursions. Directly following each of these plots (Figures 5, 7, 9, 11, 15, 17 and 19) is the same view of the change in temperature plotted simultaneously with SAA. Both 1PIN1AT and 1DEAMZT excursions were preceeded and followed by a stop science, OBSID change and subsequent start science. Typically, the spacecraft starts the maneuver to the target attitude soon after the OBSID update, although maneuvers can range from a few minutes to an hour. Since the temperatures continue to rise while the spacecraft is in a given attitude and fall only after the attitude has been changed while the ACIS configuration consumes a similar amount of power, we conclude that these excursions are predominantly due to the spacecraft attitude, specifically SAA. We examined the spacecraft SAA during these excursions and found that they occurred during a range of angles. It is believed that angles between $45 < \mathrm{SAA} < 60$ result in more sunlight reflecting off of the telescope body onto the SIM thus increasing the temperature in this compartment. And, obviously SAA between $120 < \mathrm{SAA} < 180$ produce the most direct sunlight on the -X side of the SIM.

Figures 4 and 8 provide clear examples of cases in which the ACIS internal power consumption has remained relatively constant yet the value of 1PIN1AT has increased by ~ 13 C. In Figure 4, OBSID 3433 clocked 6 CCDs with a 528 row subarray and 1PIN1AT was constant at 12.8 C. The following observation, OBSID 1935, clocked 6 CCDs with no subarray and 1PIN1AT increased to a maximum of 26.8 C. Figure 5 shows that the SAA was $\sim 95^o$ for OBSID 3433 and was $\sim 48^o$ for OBSID 1935. The average total DPA A, DPA B, and DEA A power dissipation for OBSID 3433 was 129.7 W and was 130.2 W for OBSID 1935. Another clear example is presented in Figure 8. OBSID 2745 clocked 6 CCDs in CC mode and 1PIN1AT was stable at 12.8 C. The following observation, OBSID 3455, clocked 6 CCDs with a 774 row subarray and 1PIN1AT increased from 11.5 C to 26.8 C. In fact, the average total DPA A, DPA B, and DEA A power dissipation *decreases* from OBSID 2745 to OBSID 3455. It was 134.7 W for OBSID 2745 and it dropped to 129.7 W for OBSID 3455. Figure 9 shows that the SAA changed from 115^o to 48^o while the temperature begins to rise soon after the OBSID update. Soon after the SAA returns to 115^o, the temperature begins to decrease. In general, all four of the 1PIN1AT excursions show a similar dependence on the SAA, although the excursion plotted in Figure 7 is clearly more complicated than the others and warrants additional analysis. We have examined the excursions for 1PDEAAT and 1PDEABT and they occur in the same time intervals as the 1PIN1AT excursions. We have omitted the plots from the memo in order to save space.

The behavior is more complicated for the 1DEAMZT excursions. It appears that the largest excursions are due to a combination of an unfavorable pitch angle and a relatively high value of the DEA power dissipation. The best example is presented in Figure 19. The observations in the middle of the plot, OBSIDs 2566, 3670, and 2581, are at similar SAA values. Yet, the value of 1DEAMZT dropped from ~ 11.2 C for OBSID 2566 to ~ 9.3 C for OBSID 3670 and increased to ~ 11.3 C for OBSID 2581. The DEA power consumption for OBSIDs 2566 and 2581 was ~ 52 W while the power consumption for OBSID 3670 was 42.6 W. Therefore, it seems clear that values approaching 12 C for 1DEAMZT are reached only when both the SAA and DEA power consumption are unfavorable. The excursions for 1DPAMZT and 1DPAMYT occur at different times than the excursions for 1DEAMZT and require some additional analysis. In general, the excursions for 1DPAMZT and 1DPAMYT occured at SAA between $120 < \mathrm{SAA} < 180$. Again, we have omitted the plots from the memo in order to save space.

Please refer to the following directory for excel spreadsheets from this analysis detailing the excursions for all 6 MSIDs: `/data/acis32/depasquale/limits/ACIS_Thermal_Memo` in the following subdirectories: `/POWER, /TEMPERATURE, and /SAA`

5 Operational Impact

The observed behavior is that the highest values for 1PIN1AT, 1PDEAAT, and 1PDEABT are reached when the SAA approaches 45^o and the highest values of 1DEAMZT are reached when the SAA value approaches 180^o. For 1DPAMYT and 1DPAMZT, the highest values are reached at SAA values above 120^0. The physical explanation seems clear, the PSMC temperatures are highest when the +X side of the SIM is receiving the maximum direct and reflected sunlight and the DEA and DPA temperatures are highest when the -X side of the SIM is receiving the maximum sunlight (with the additional complication that the internal DEA power can vary by a factor of two). Since only the yellow upper limit for 1PIN1AT has been exceeded and this limit has been reduced several times from its pre-launch value (see Reference #1), the first action taken will be to relax the limit to its pre-launch values. This particular limit (and others like it) was intentionally lowered after launch to provide an early warning when temperatures were trending beyond previous values. Therefore, for the immediate future, there should be no change to *Chandra* operations based on these limit violations. If the temperature trends were to continue and the value of 1PIN1AT were to exceed the pre-launch yellow limit of +35 C and approach the pre-launch red limit of +40 C, we would have to consider restricting the SAA for *Chandra* observations.

6 Future

For the immediate future, the ACIS Operations Team will continue to monitor these MSIDs and their peaks. We will also continue to monitor the long-term trend in these temperatures. If violations occur and become frequent, it may become necessary to revise the DQ and/or HS limits back to the launch values. Given the current trends, a rather small increase in the Yellow HI limits of on the order of 2 C may be sufficient to prevent violations for many years into the future.

7 References

1. Plucinsky, P. *Revision History of ACIS PSMC, DPA & DEA Temperature Limits.* Internal CXC Memo. September 2001. `http://asc.harvard.edu/acis/memos/ACIS_thermal_rev_history.ps`

2. DePasquale, J. *Updated ACIS Telemetry Limits Table.* Internal CXC Memo. October 2001. `http://asc.harvard.edu/acis/memos/limits_philosophy.ps`

see also: DePasquale, J. *Overview of the ACIS Limit Pager Script.* Internal CXC Memo. October 2001. `http://asc.harvard.edu/acis/memos/limitpager_memo.ps`

3. Podgorski, W., Freeman, M., Cameron, R. *SIM Flexure Heating and FID Light Motion.* Chandra Flight Note 234a. August 7, 1999.

4. Freeman, M. *SIM Heating and FID Light Motion (cont'd).* Chandra Flight Note 303. August 23, 1999.

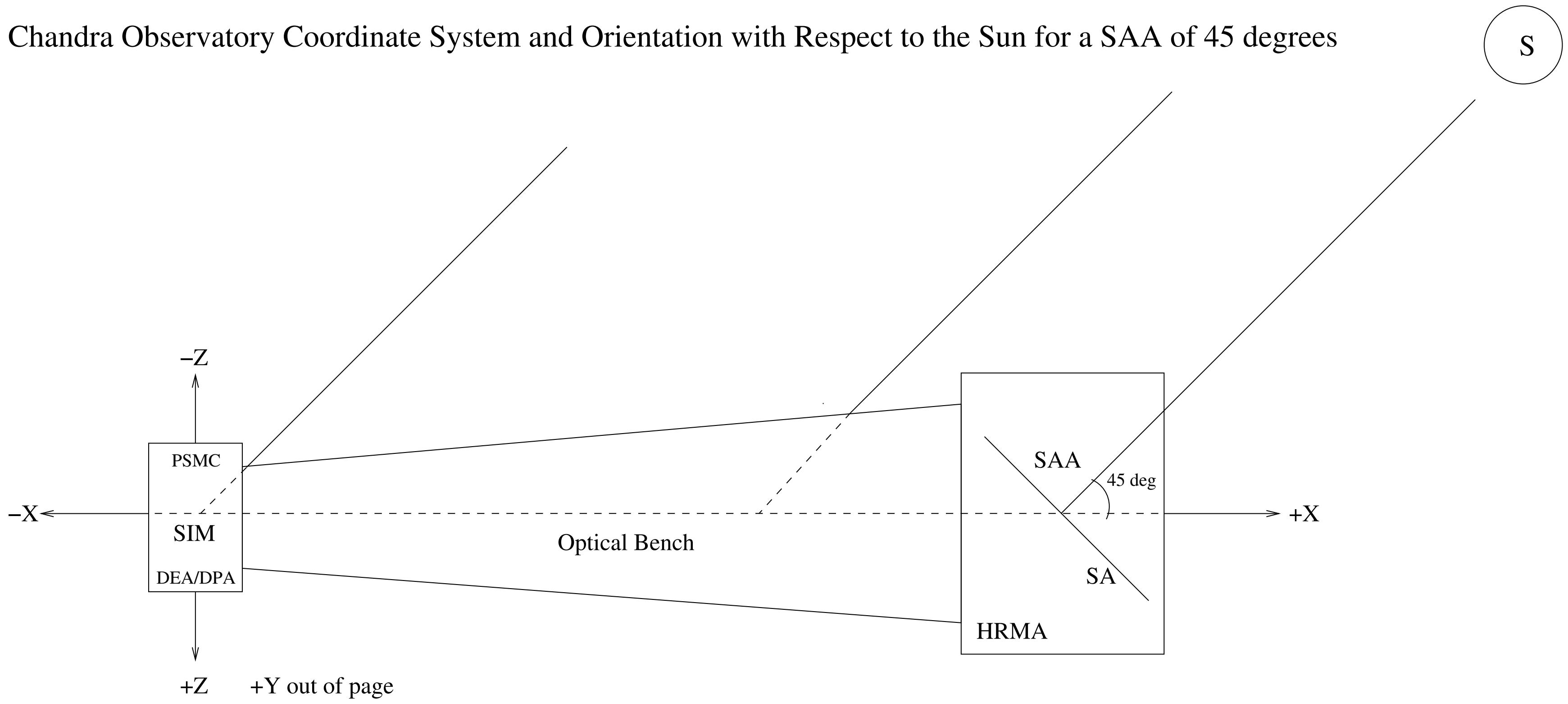

Figure 1: Chandra Coordinate System and Heating Diagram

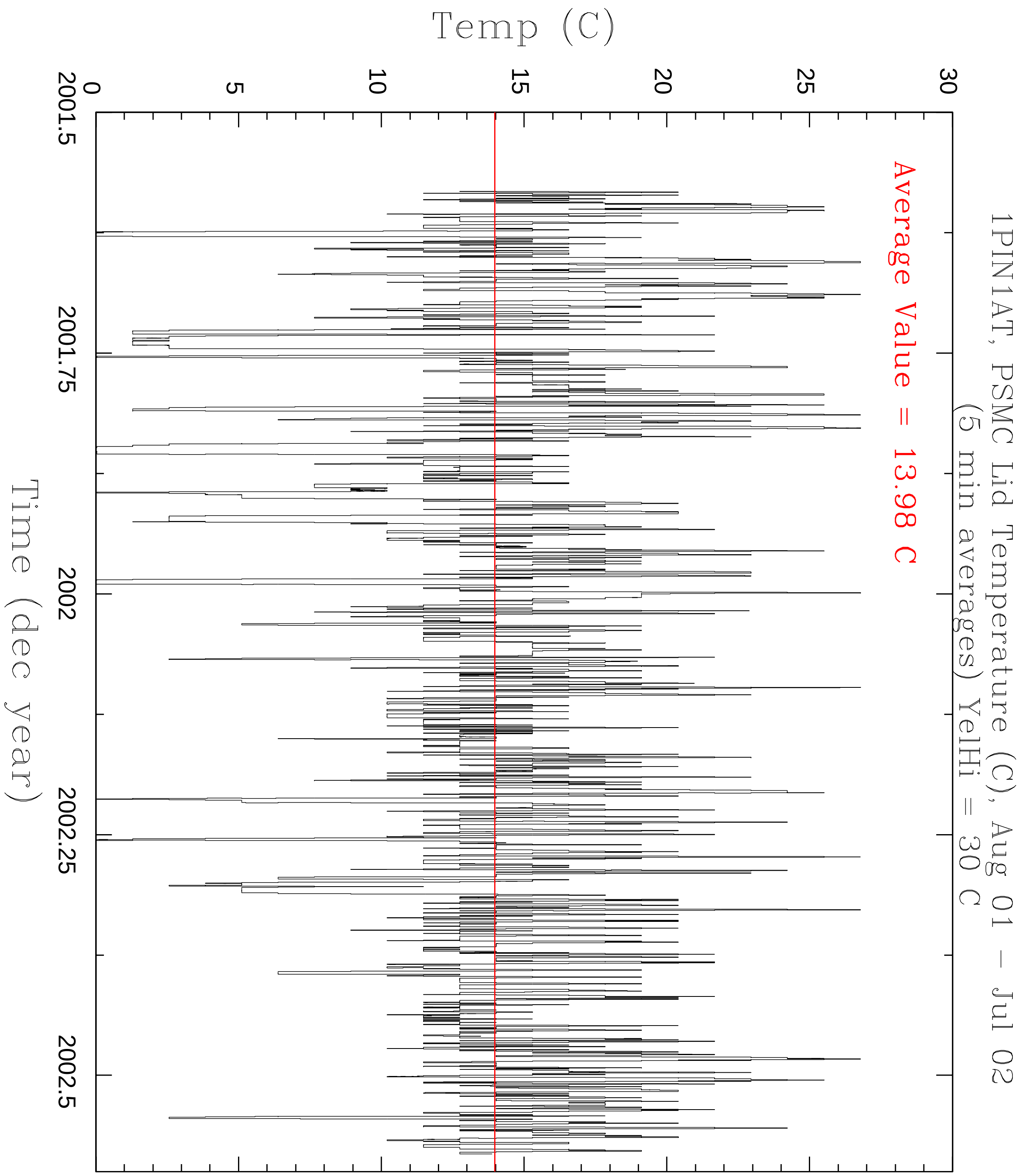

Figure 2: 1PIN1AT, PSMC Lid Temperature vs. Time for August 2001 - July 2002

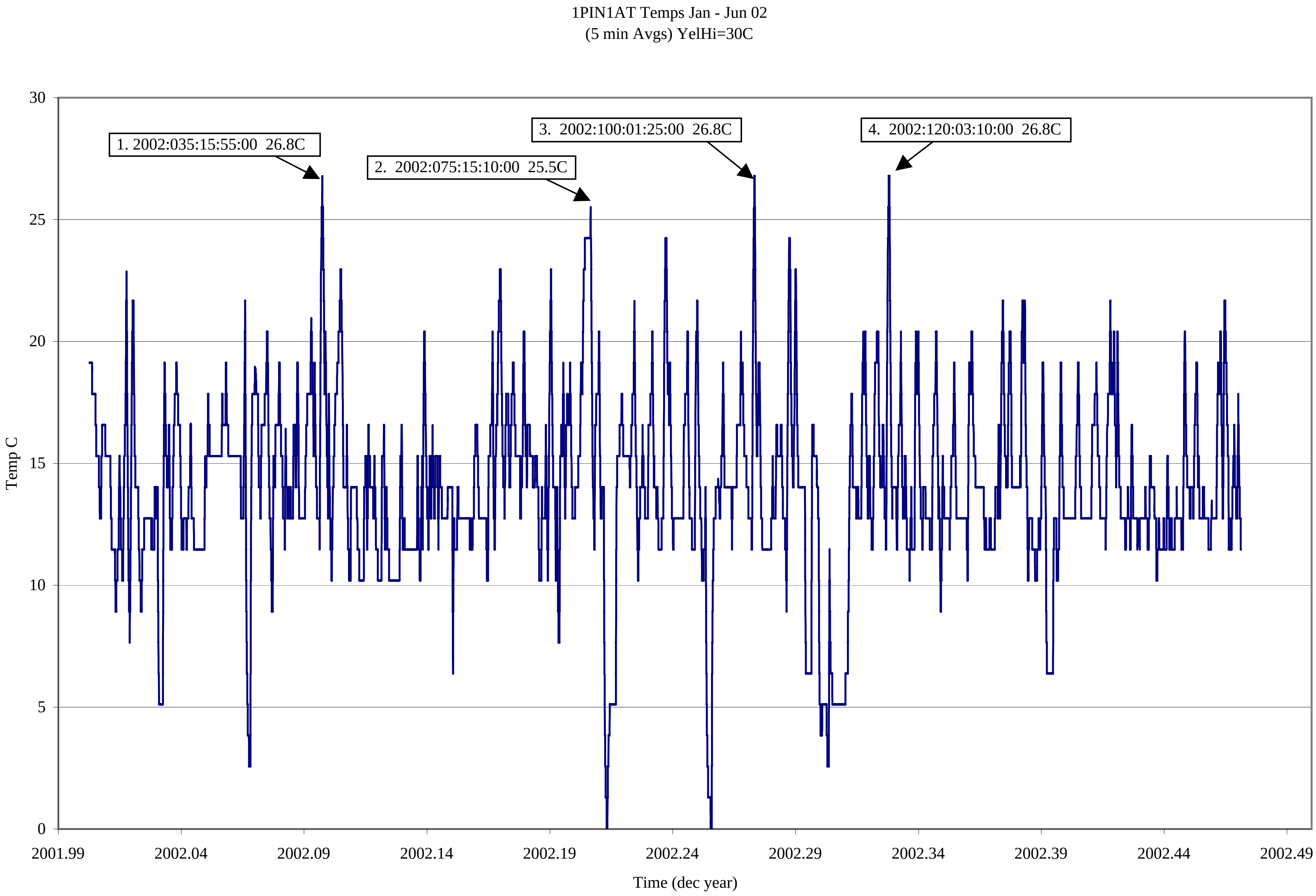

Figure 3: 1PIN1AT, PSMC Lid Temperature vs. Time for January - June 2002 Excursions Labeled

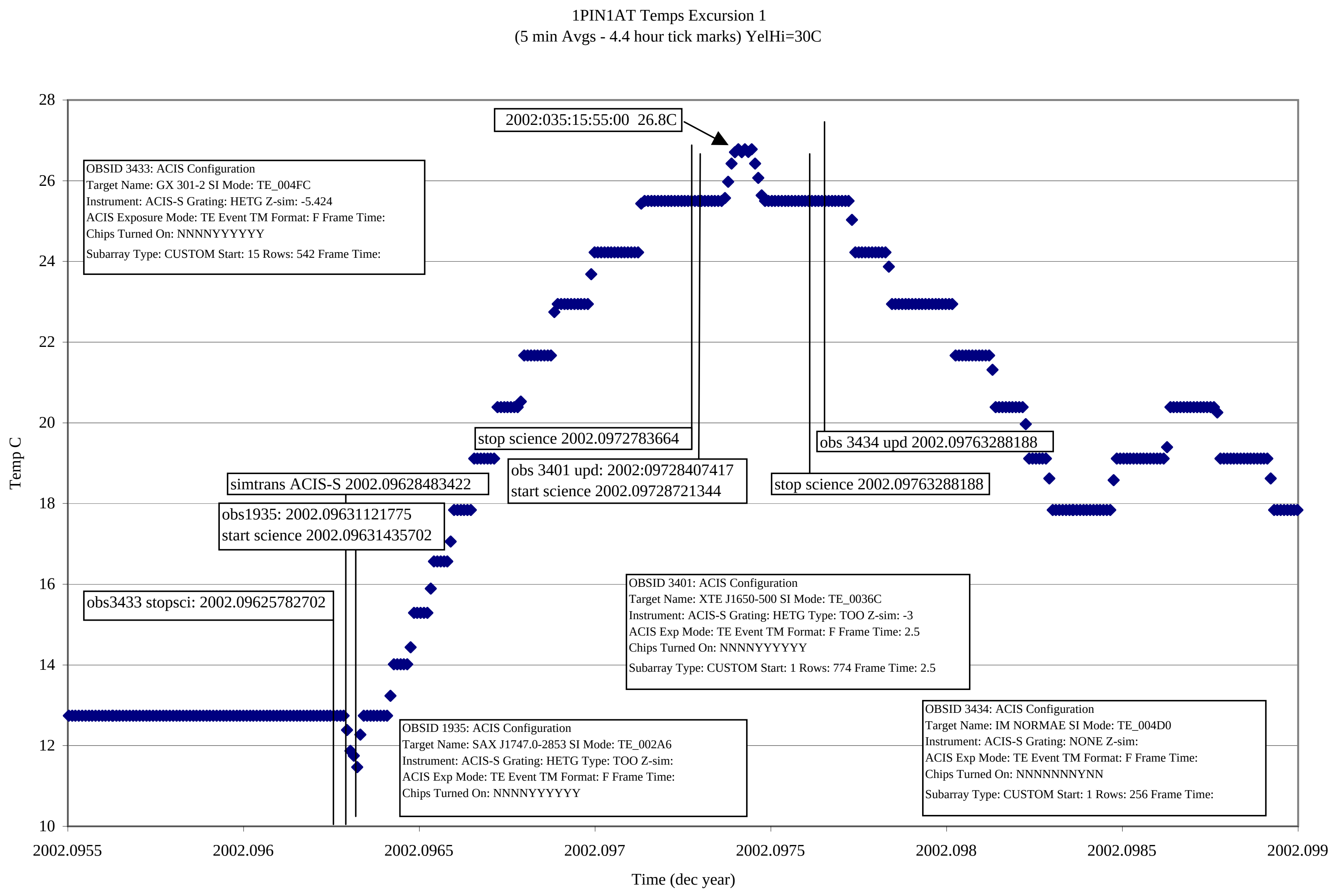

Figure 4: 1PIN1AT, PSMC Lid Temperature vs. Time: Excursion 1 with ACIS Config.

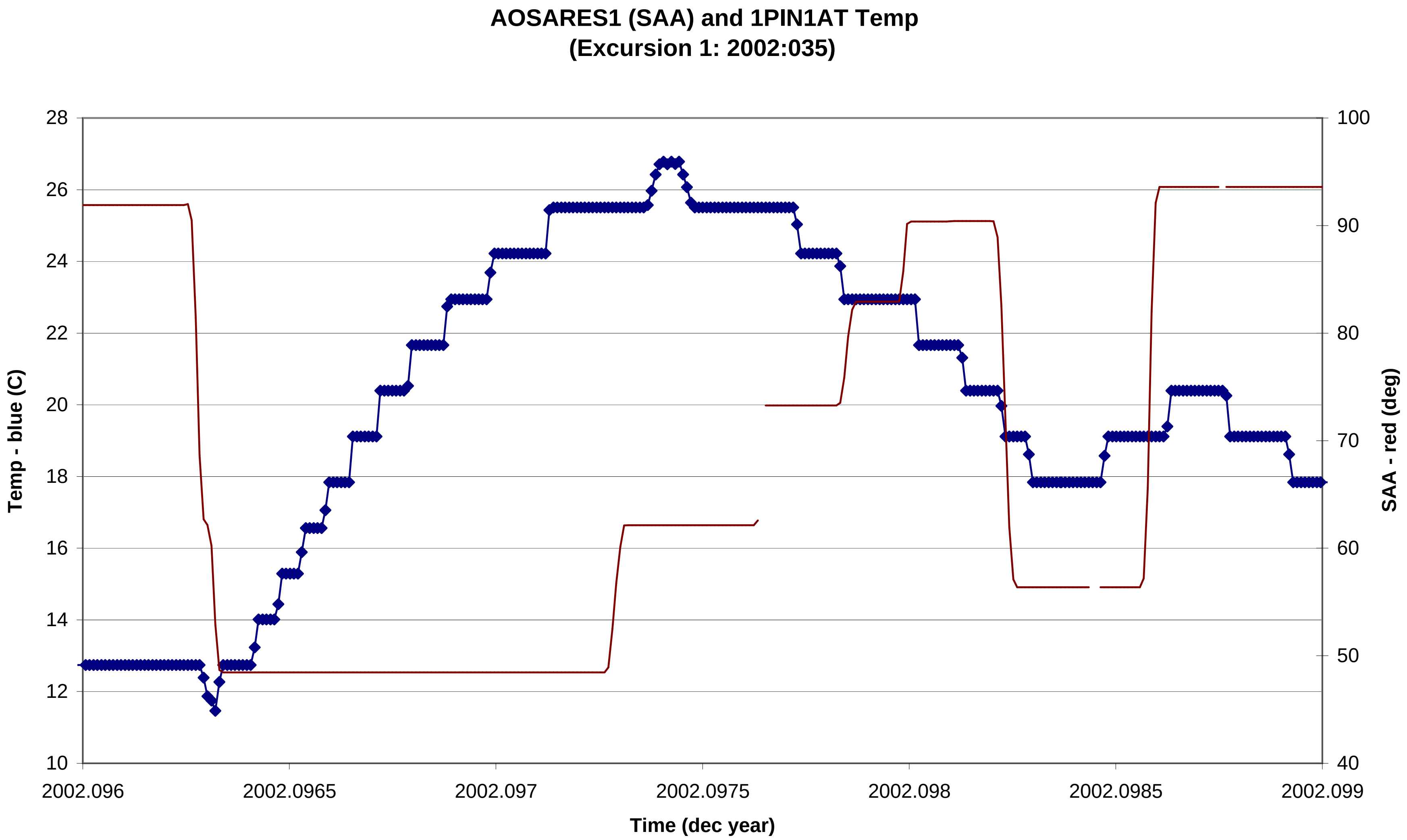

Figure 5: 1PIN1AT, PSMC Lid Temperature vs. Time: Excursion 1 with SAA

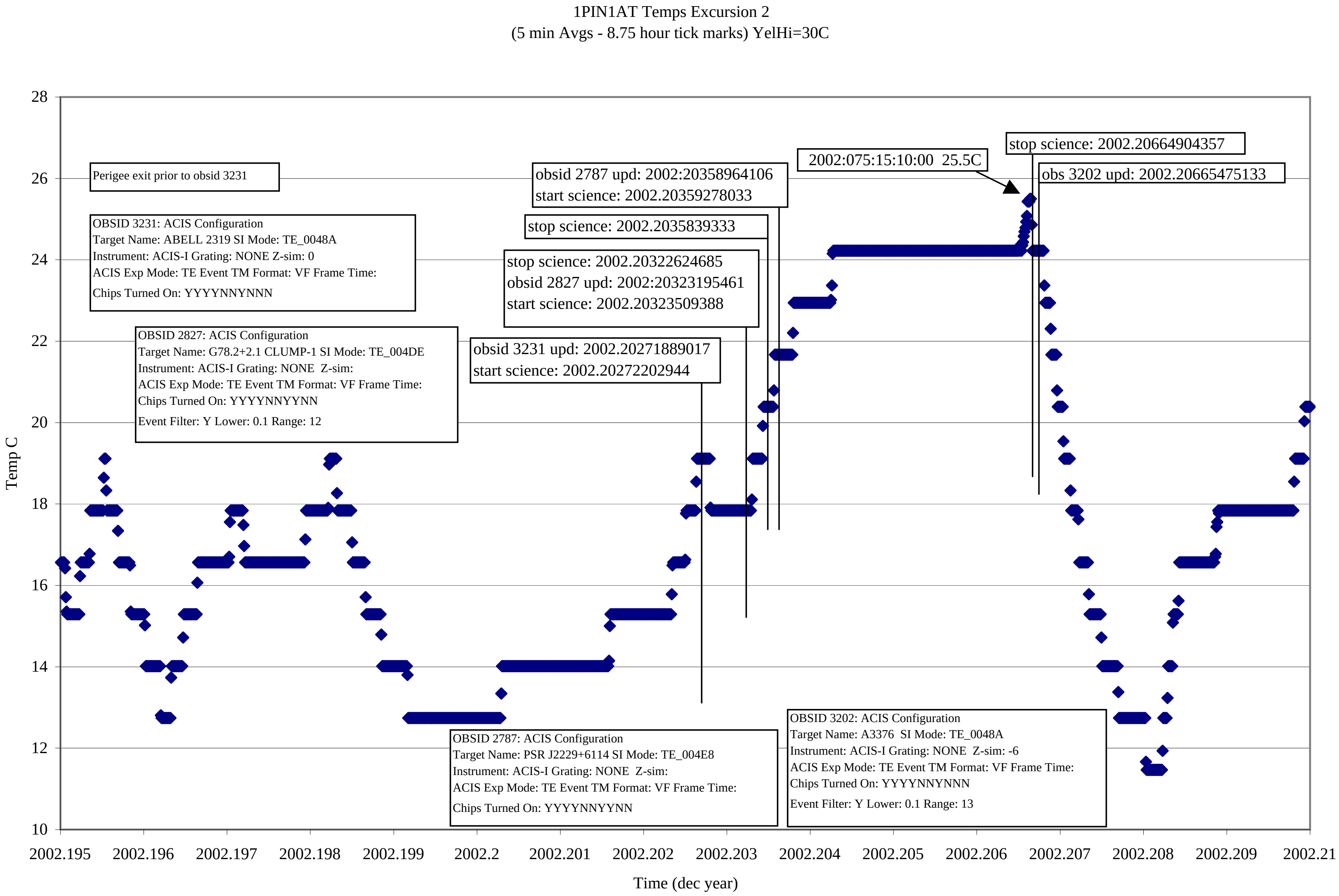

Figure 6: 1PIN1AT, PSMC Lid Temperature vs. Time: Excursion 2 with ACIS Config.

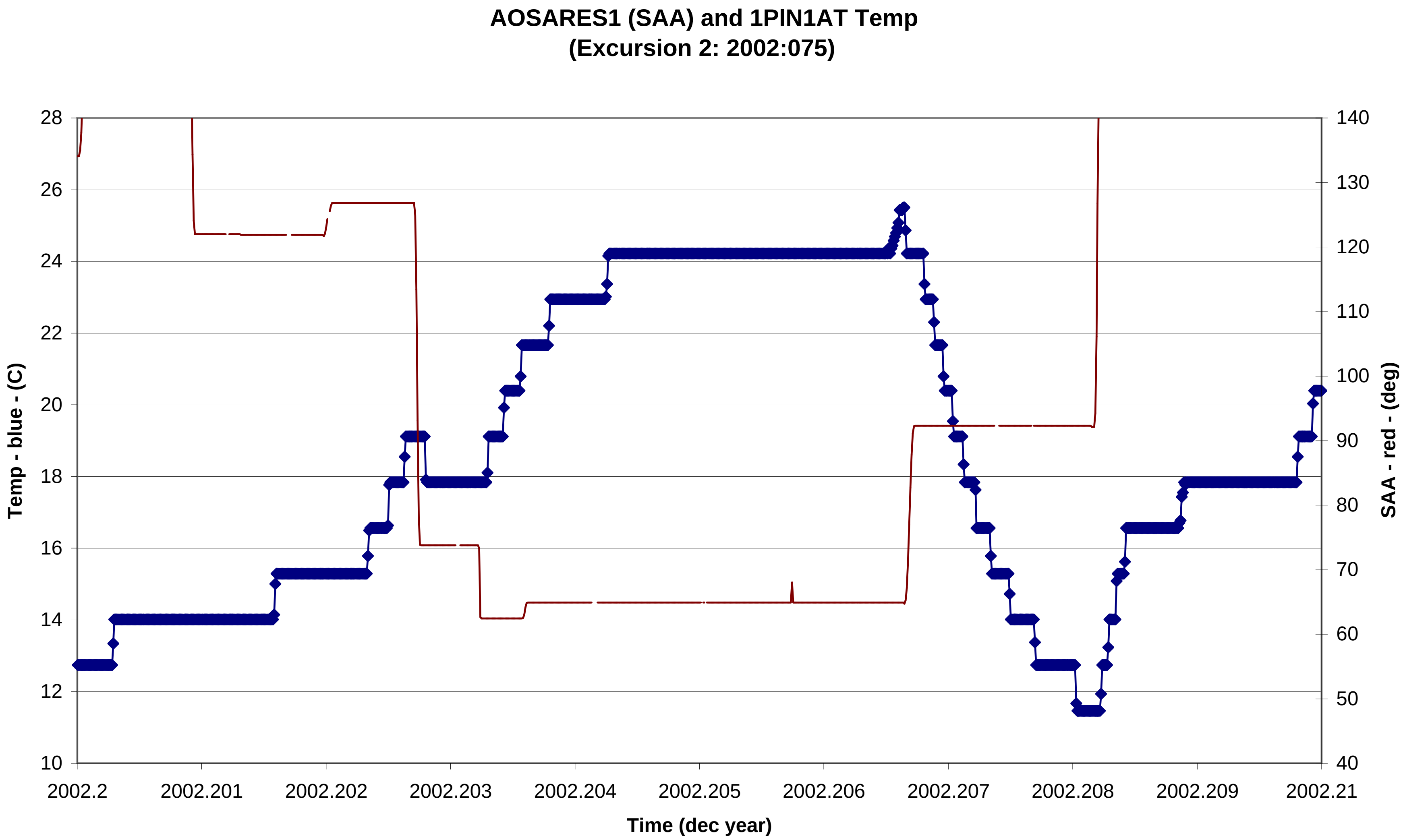

Figure 7: 1PIN1AT, PSMC Lid Temperature vs. Time: Excursion 2 with SAA

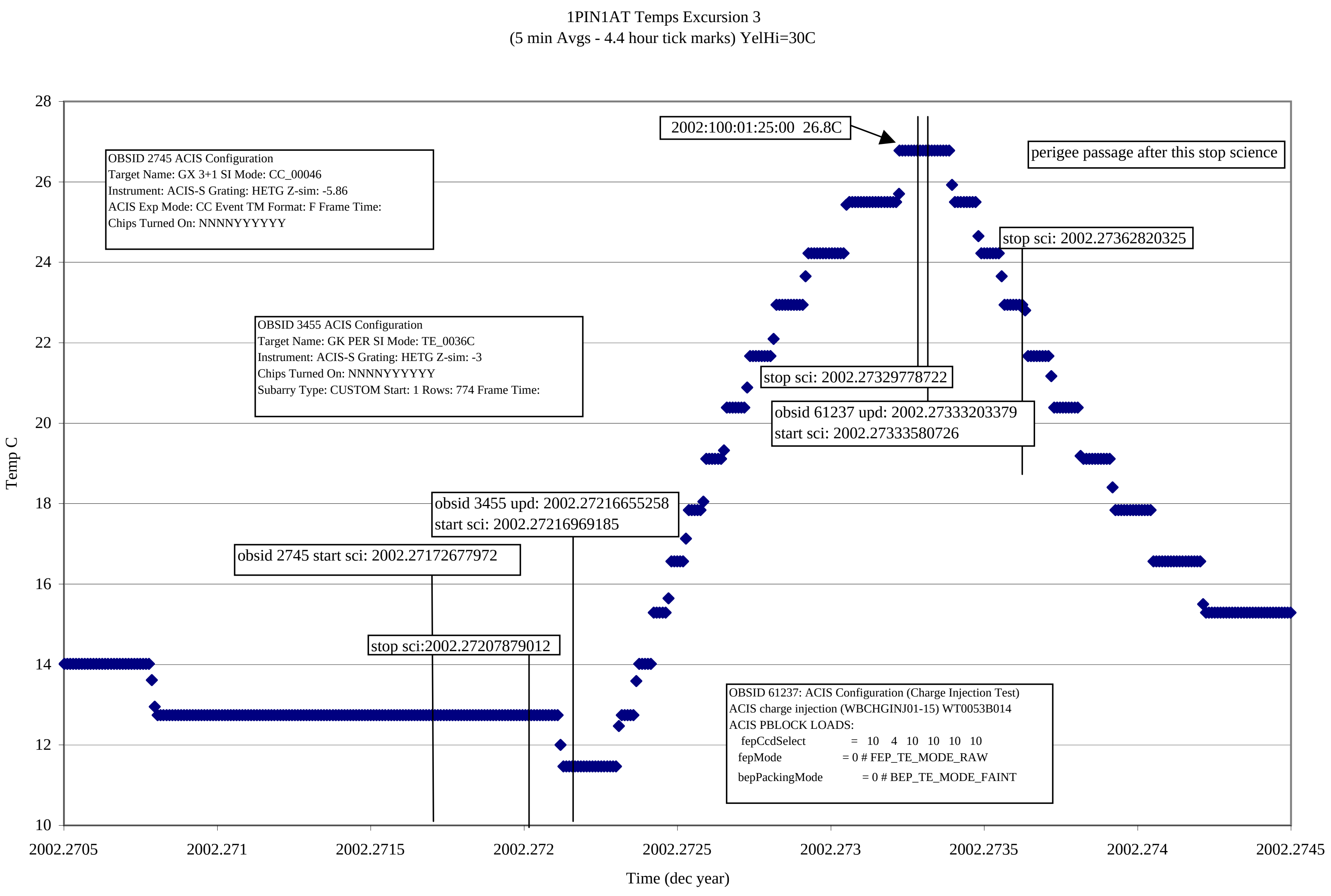

Figure 8: 1PIN1AT, PSMC Lid Temperature vs. Time: Excursion 3 with ACIS Config.

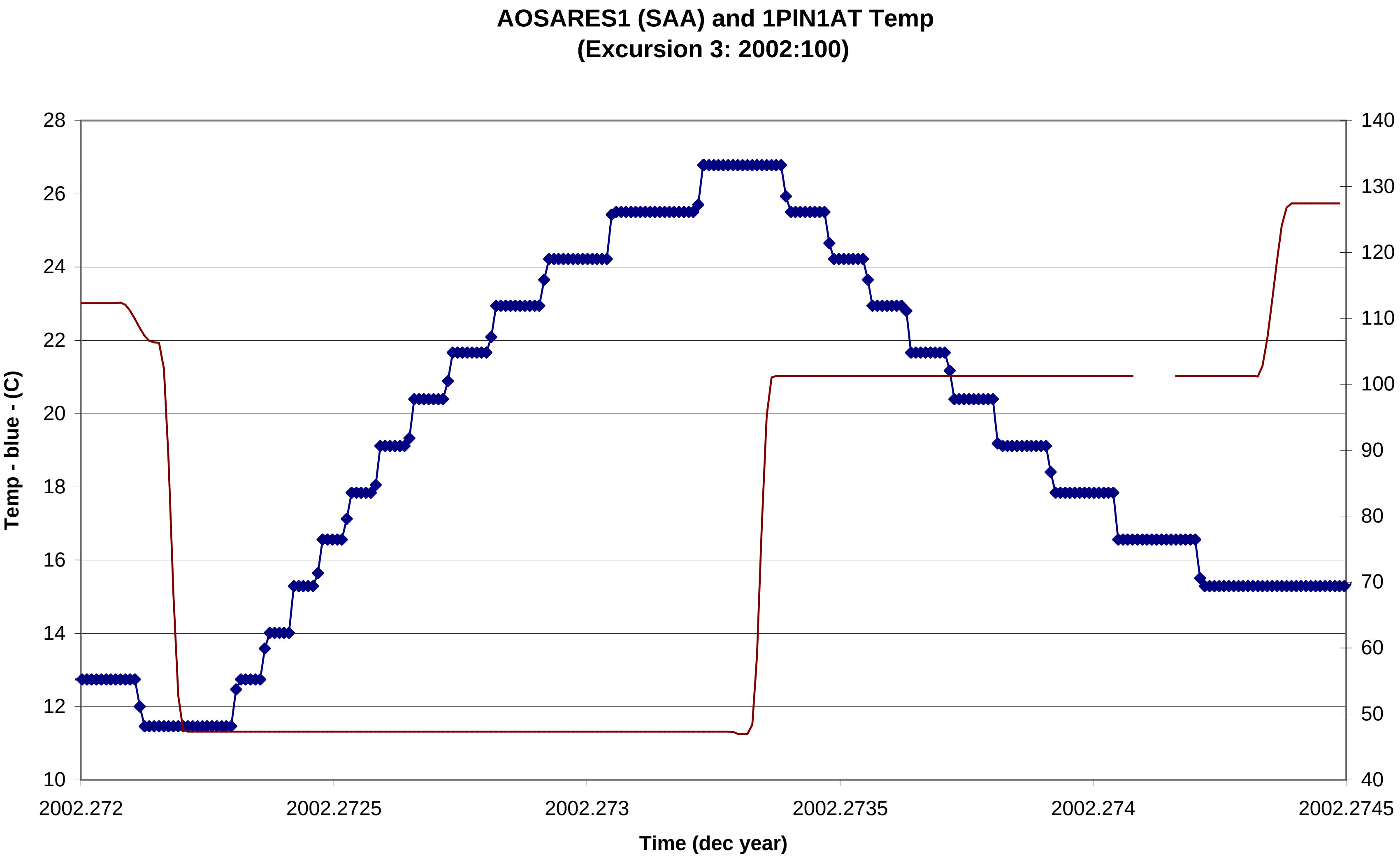

Figure 9: 1PIN1AT, PSMC Lid Temperature vs. Time: Excursion 3 with SAA

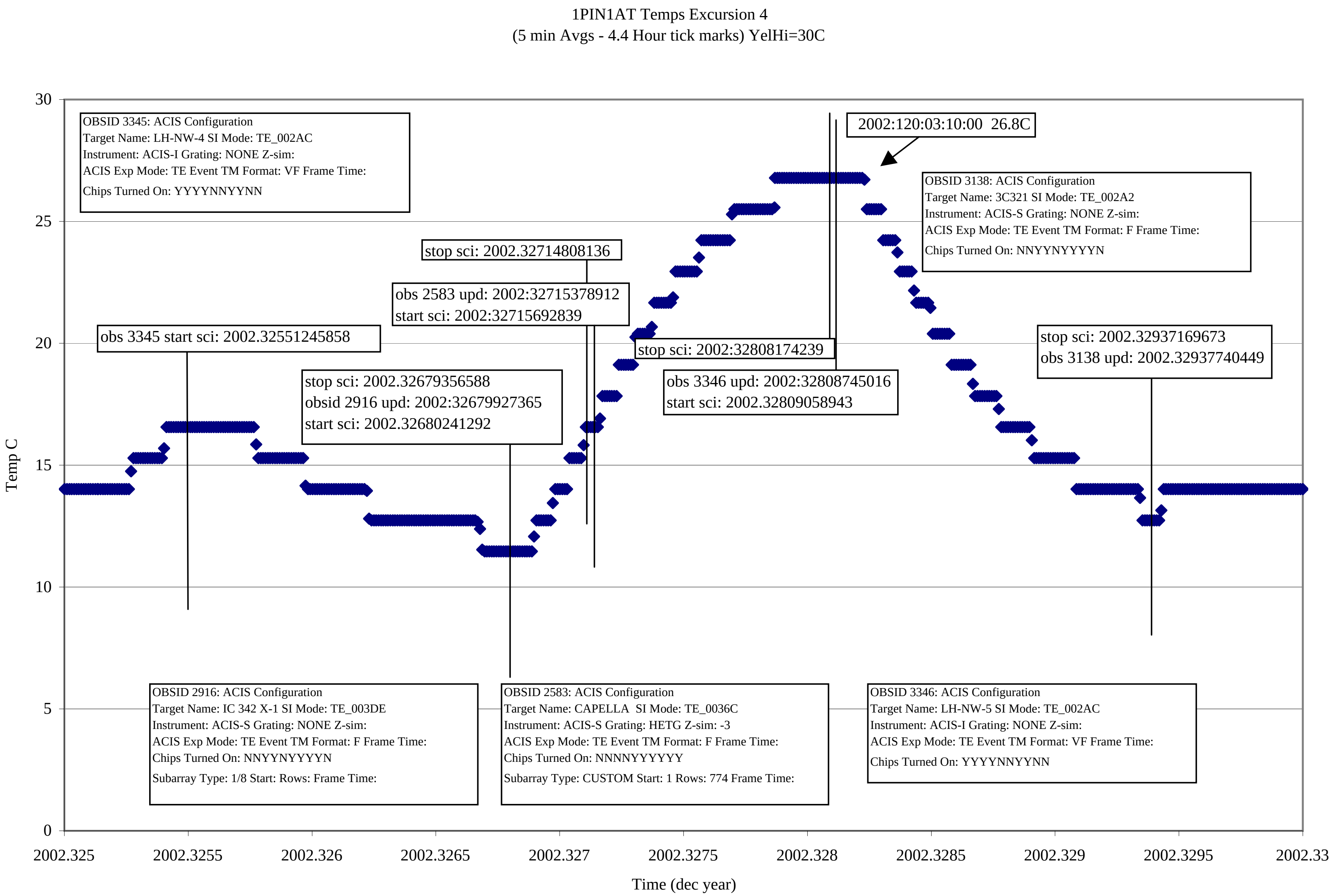

Figure 10: 1PIN1AT, PSMC Lid Temperature vs. Time: Excursion 4 with ACIS Config.

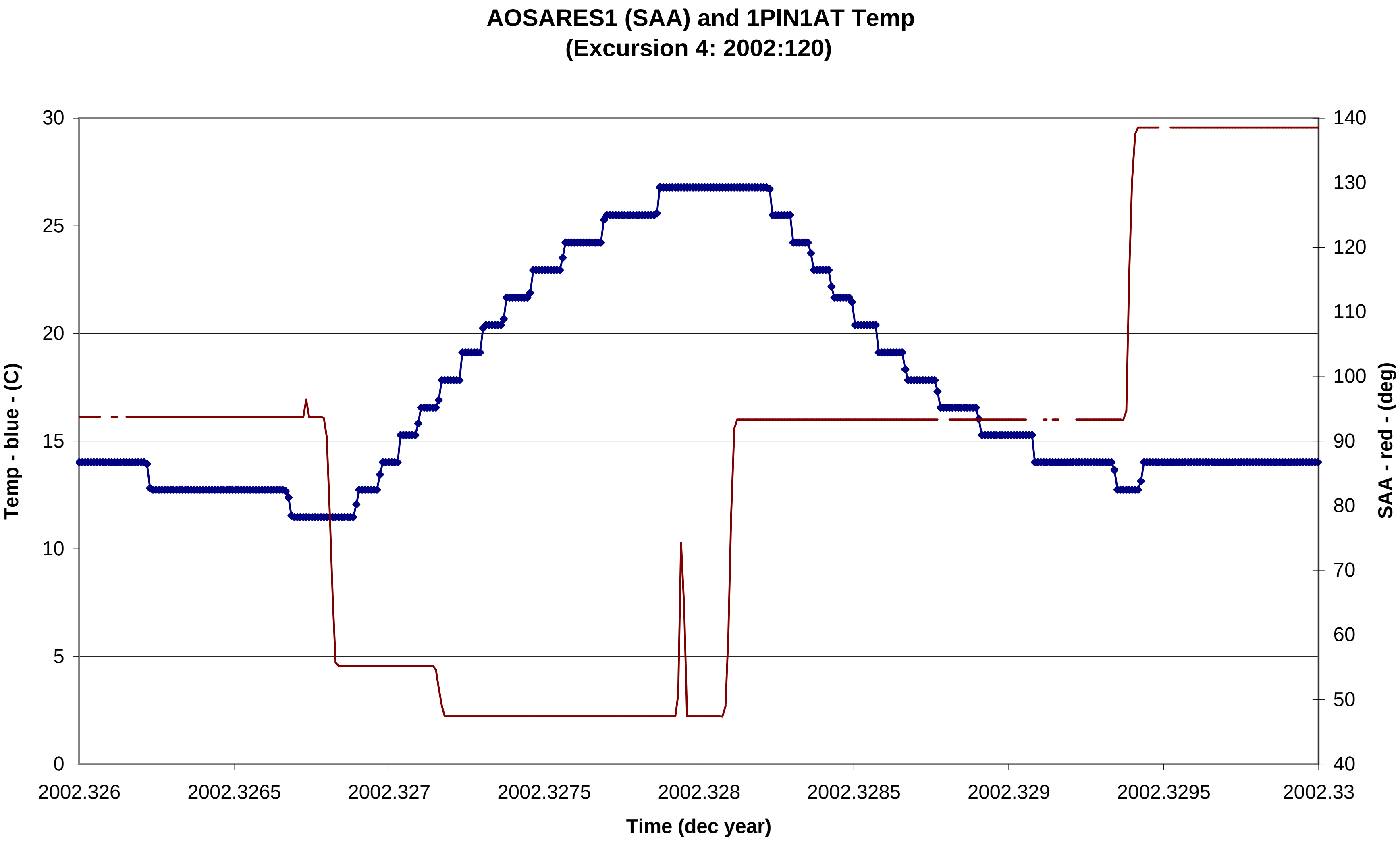

Figure 11: 1PIN1AT, PSMC Lid Temperature vs. Time: Excursion 4 with SAA

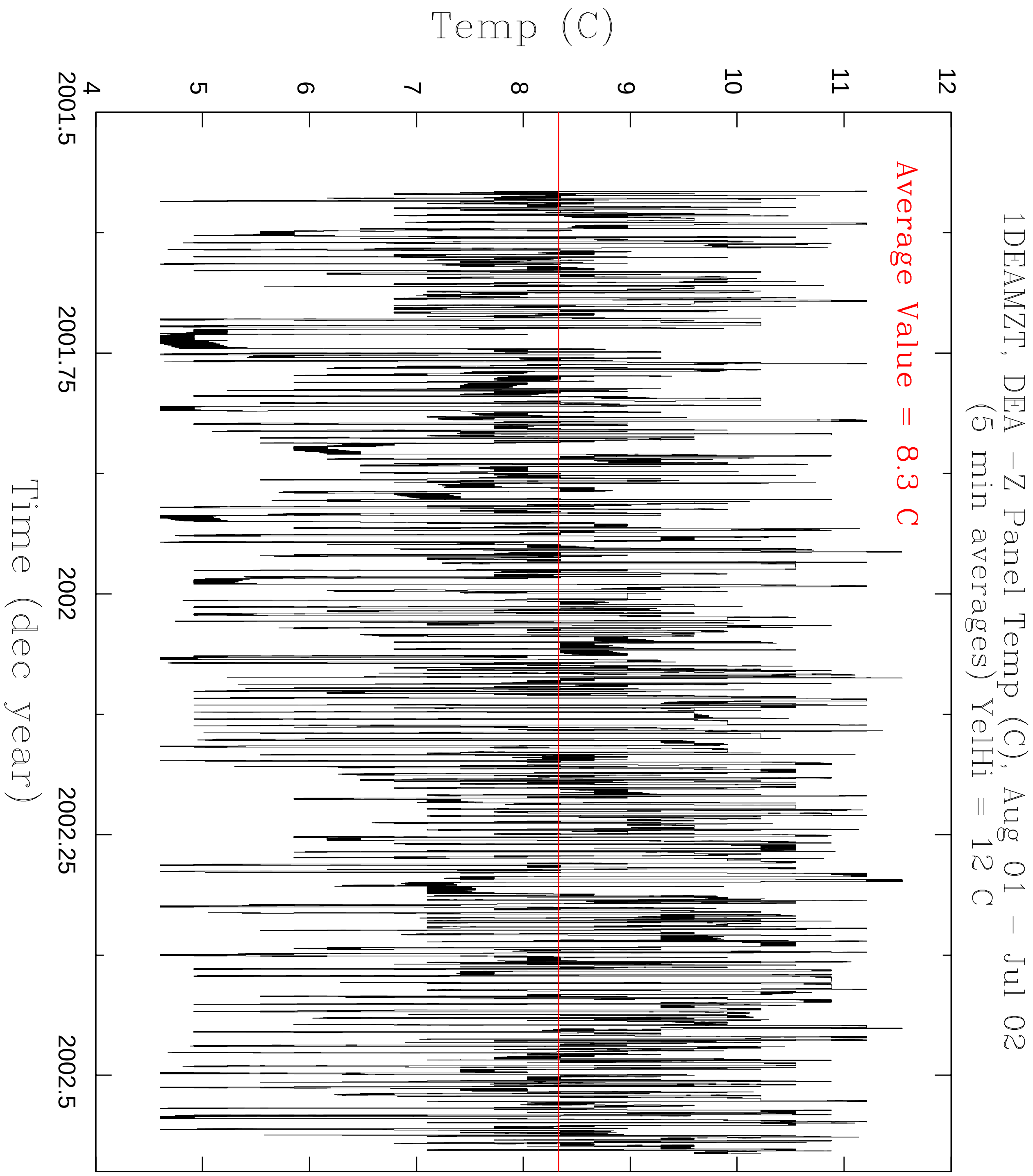

Figure 12: 1DEAMZT, DEA Temperature vs. Time for August 2001 - July 2002

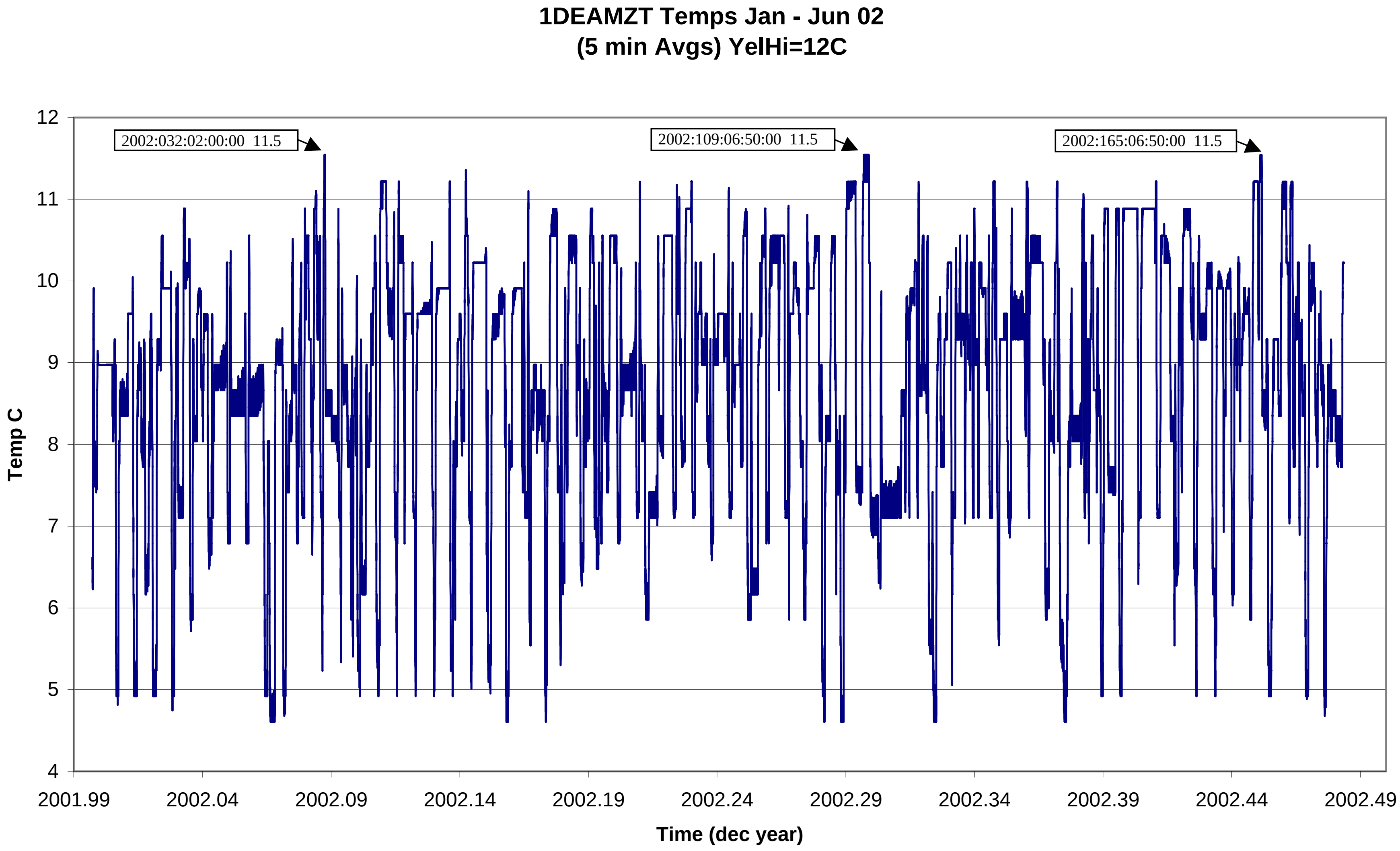

Figure 13: 1DEAMZT, DEA Temperature vs. Time for January - June 2002 Excursions Labeled

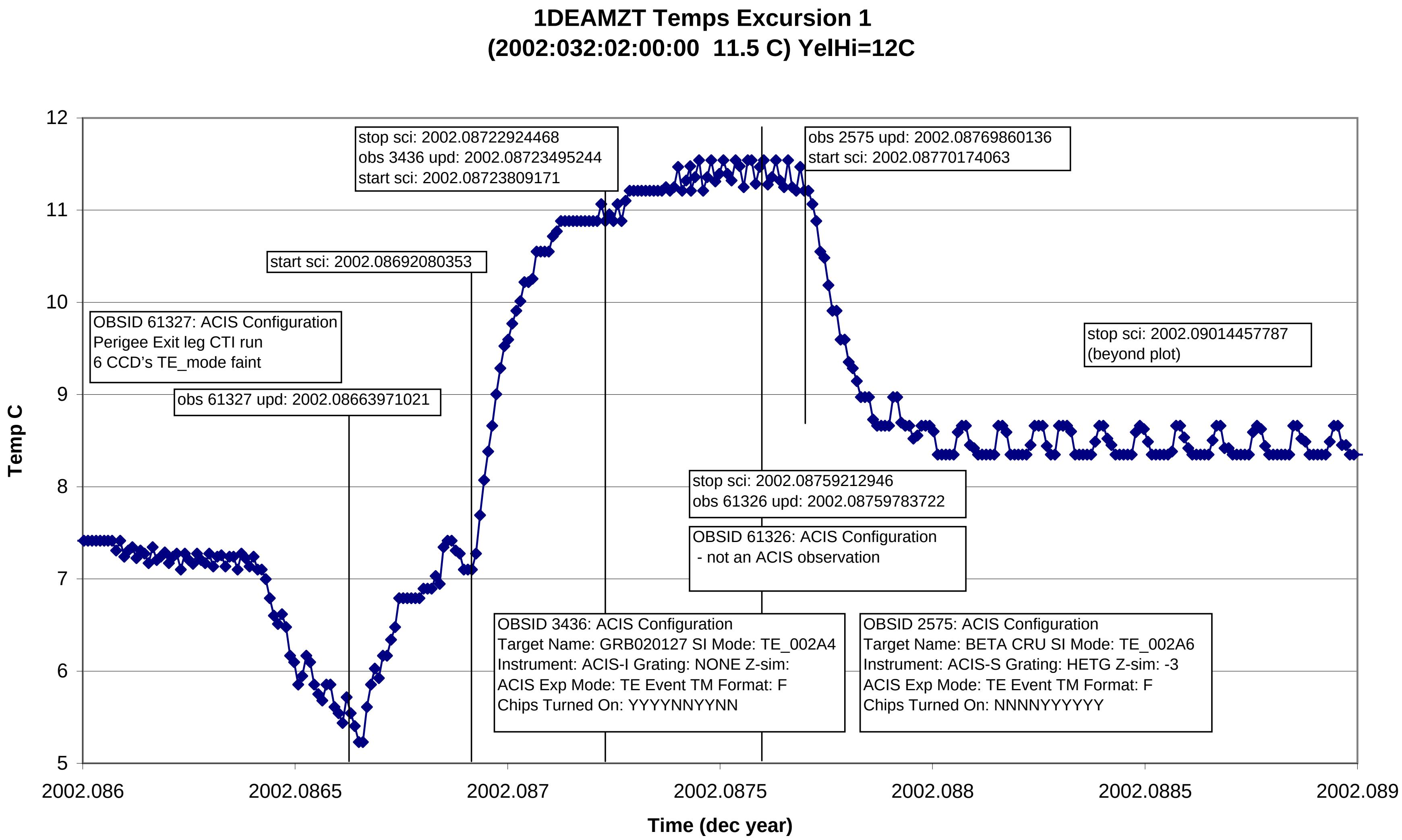

Figure 14: 1DEAMZT, DEA Temperature vs. Time: Excursion 1 with ACIS Config.

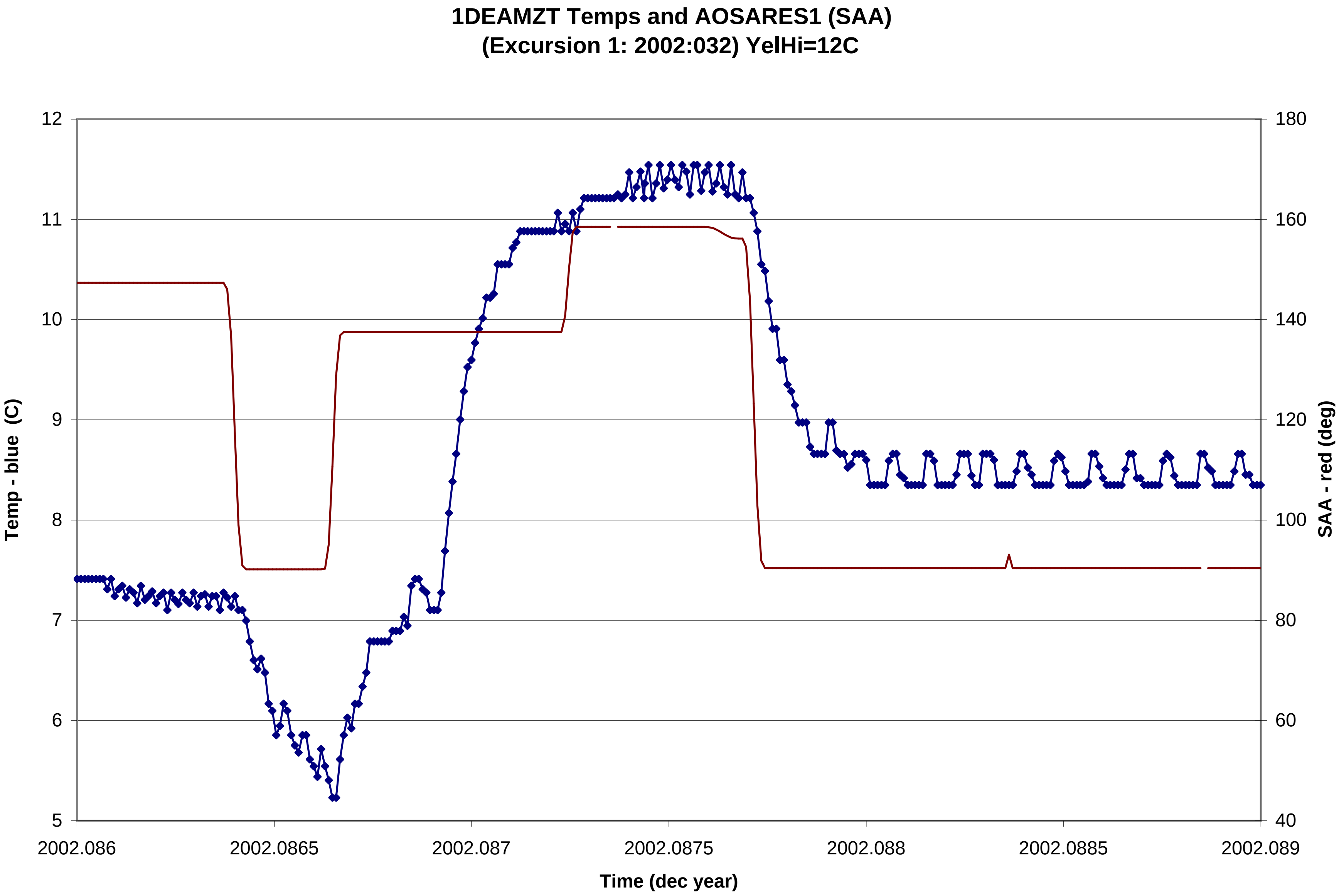

Figure 15: 1DEAMZT, DEA Temperature vs. Time: Excursion 1 with SAA

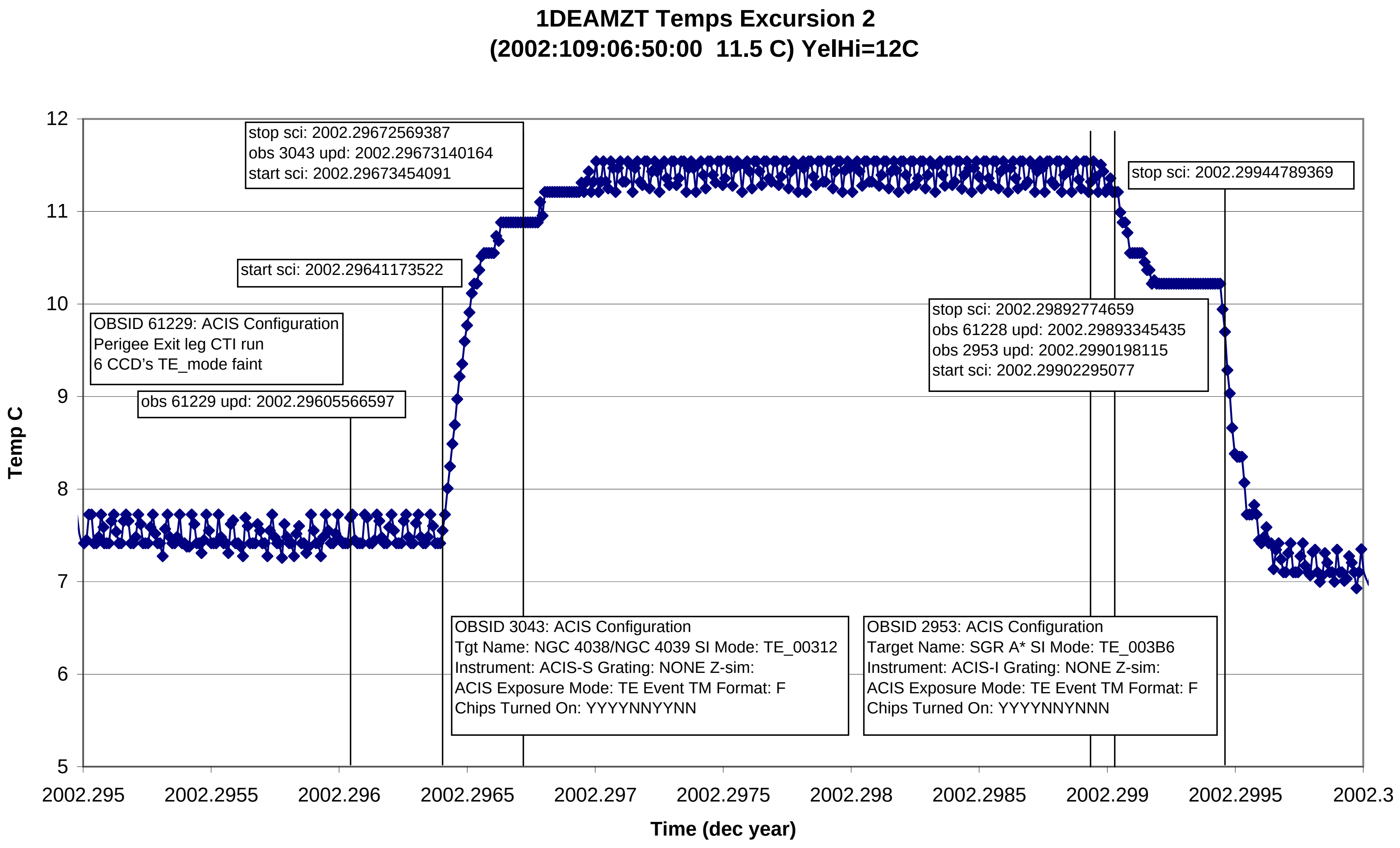

Figure 16: 1DEAMZT, DEA Temperature vs. Time: Excursion 2 with ACIS Config.

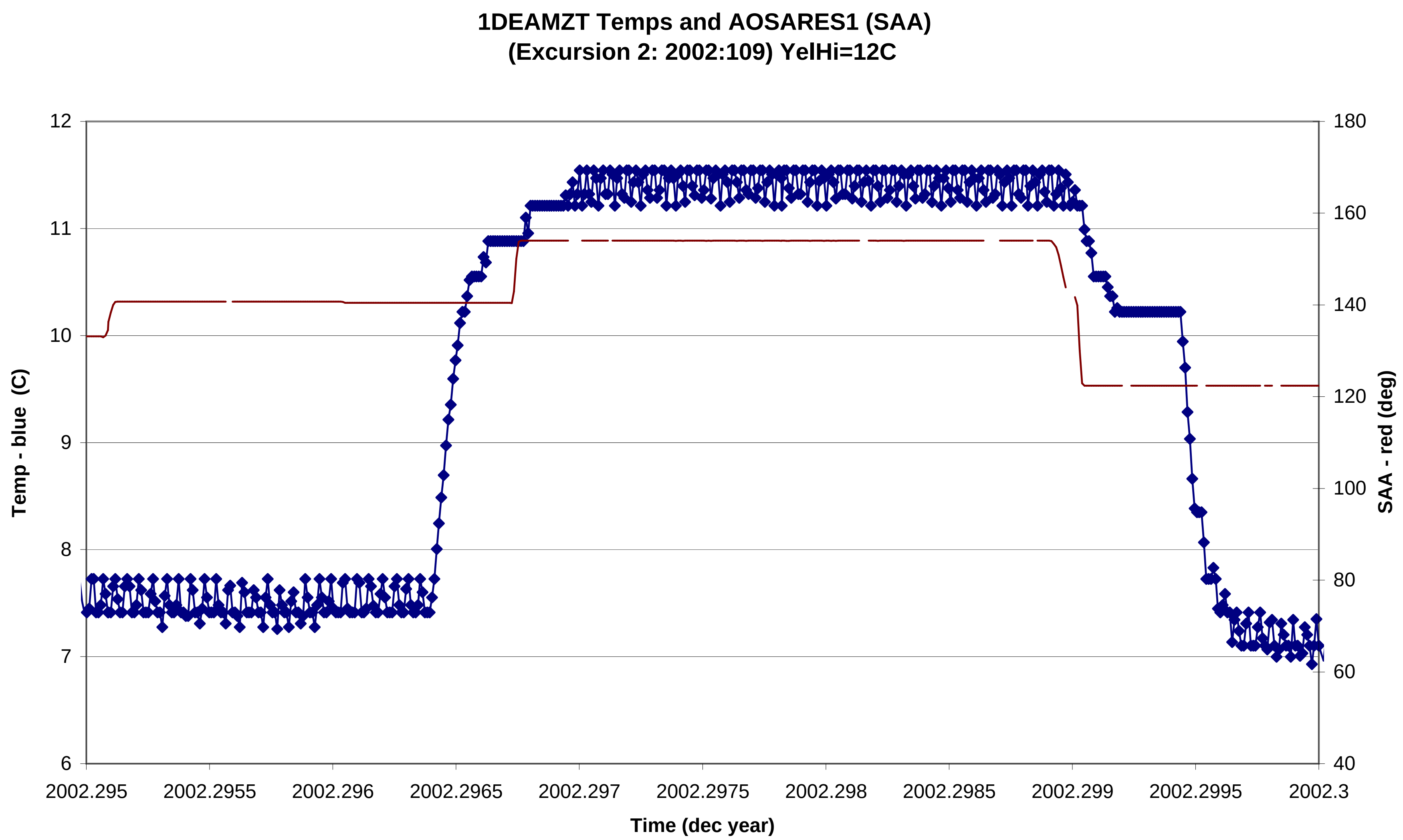

Figure 17: 1DEAMZT, DEA Temperature vs. Time: Excursion 2 with SAA

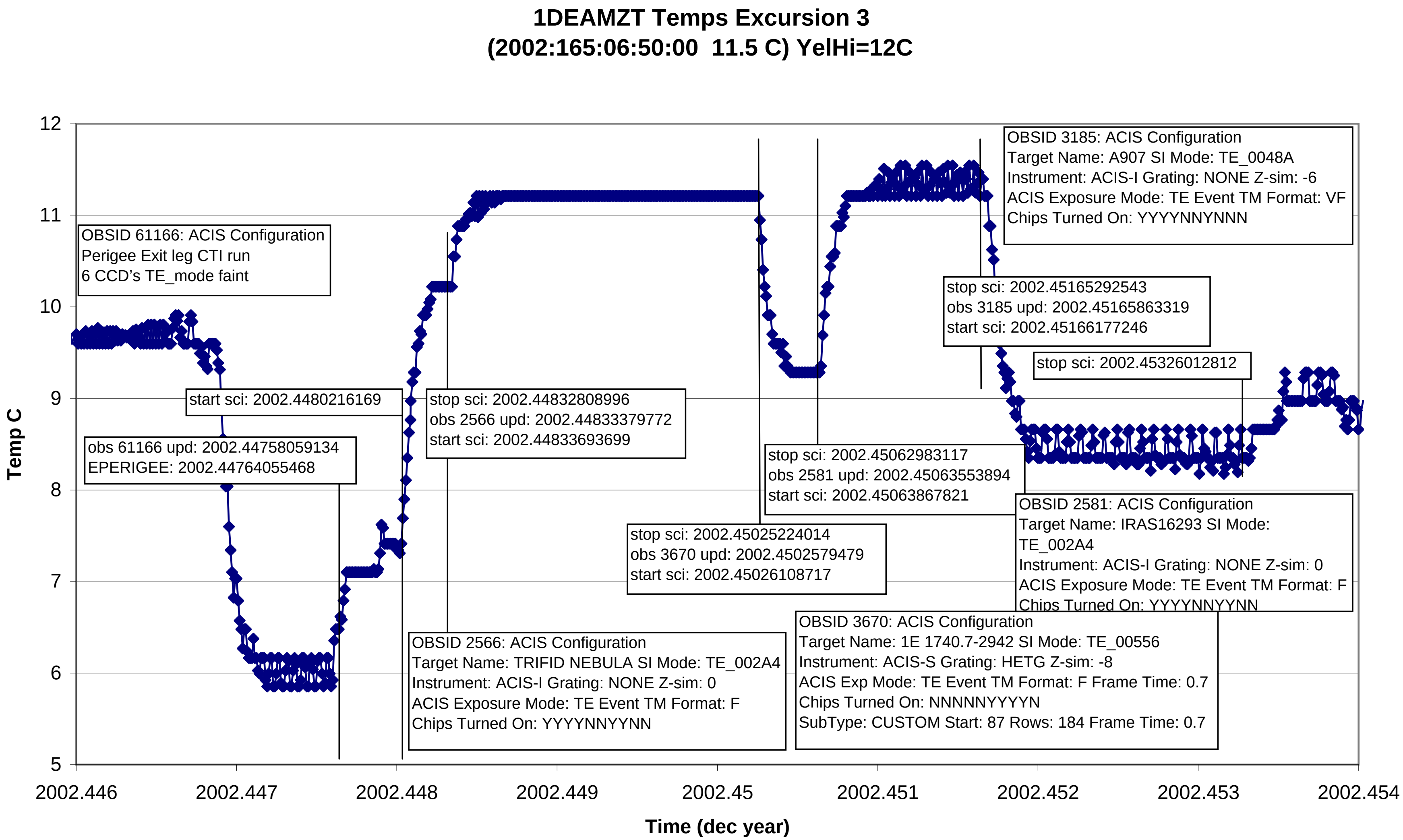

Figure 18: 1DEAMZT, DEA Temperature vs. Time: Excursion 3 with ACIS Config.

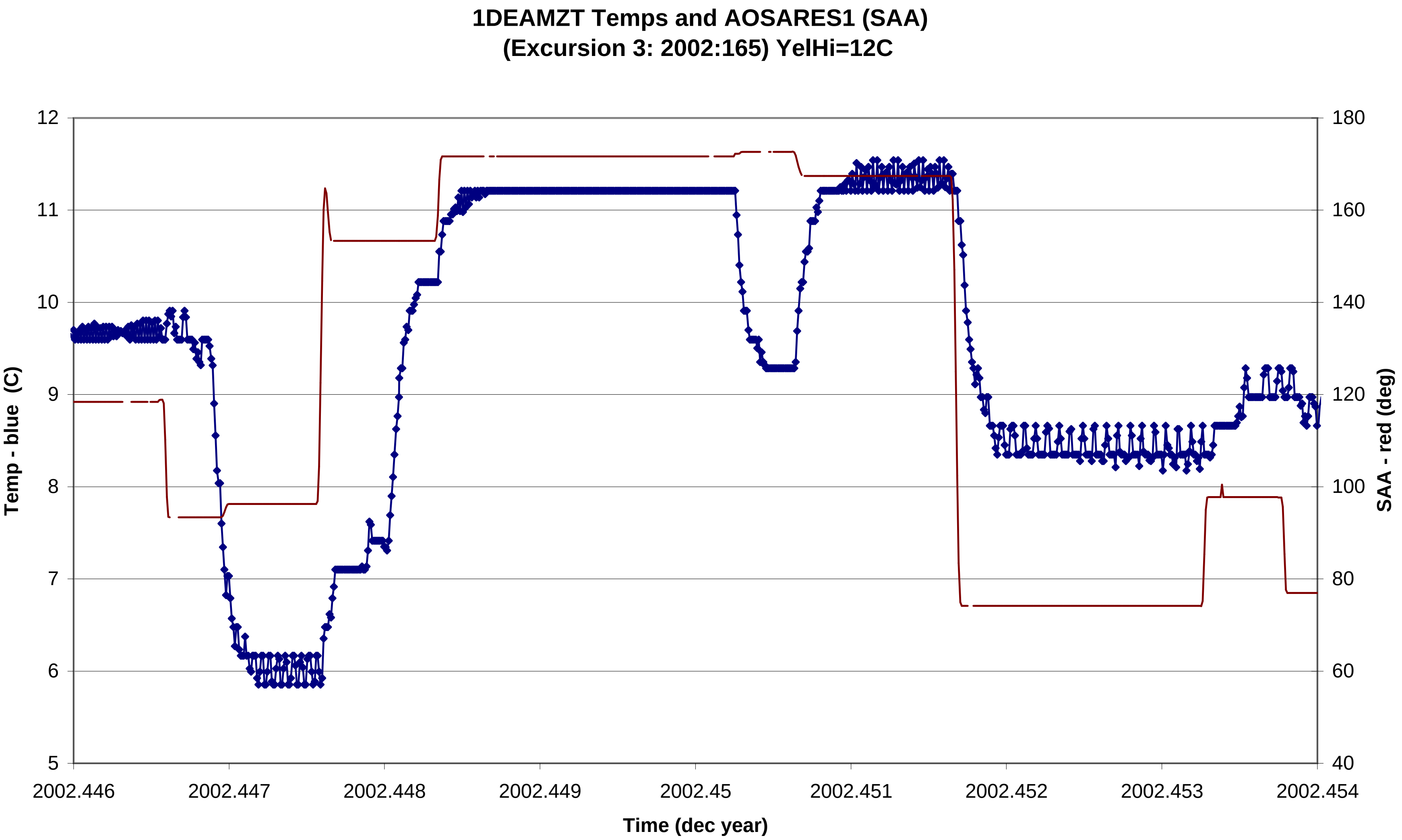

Figure 19: 1DEAMZT, DEA Temperature vs. Time: Excursion 3 with SAA