Correction for GOES Imager Midnight Blackbody Calibration Error

SOCC Lunch-Time Seminar

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April 8, 2004

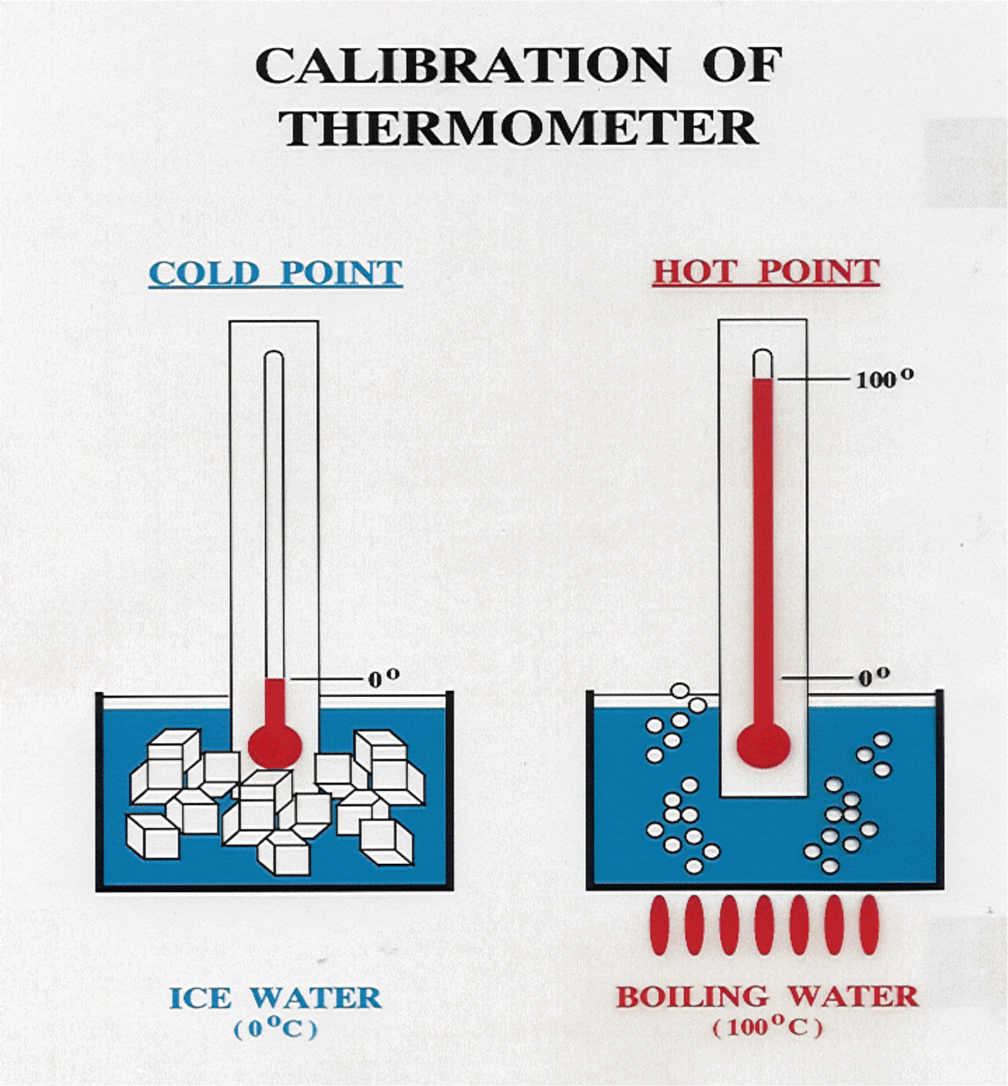
Definition of Calibration

- Radiometric calibration: The process of establishing the numerical relationship between the output of a sensor (in engineering units, e.g. digital counts), and the intensity of the radiation incident on it (in units, e.g., of power per unit area per unit solid angle).

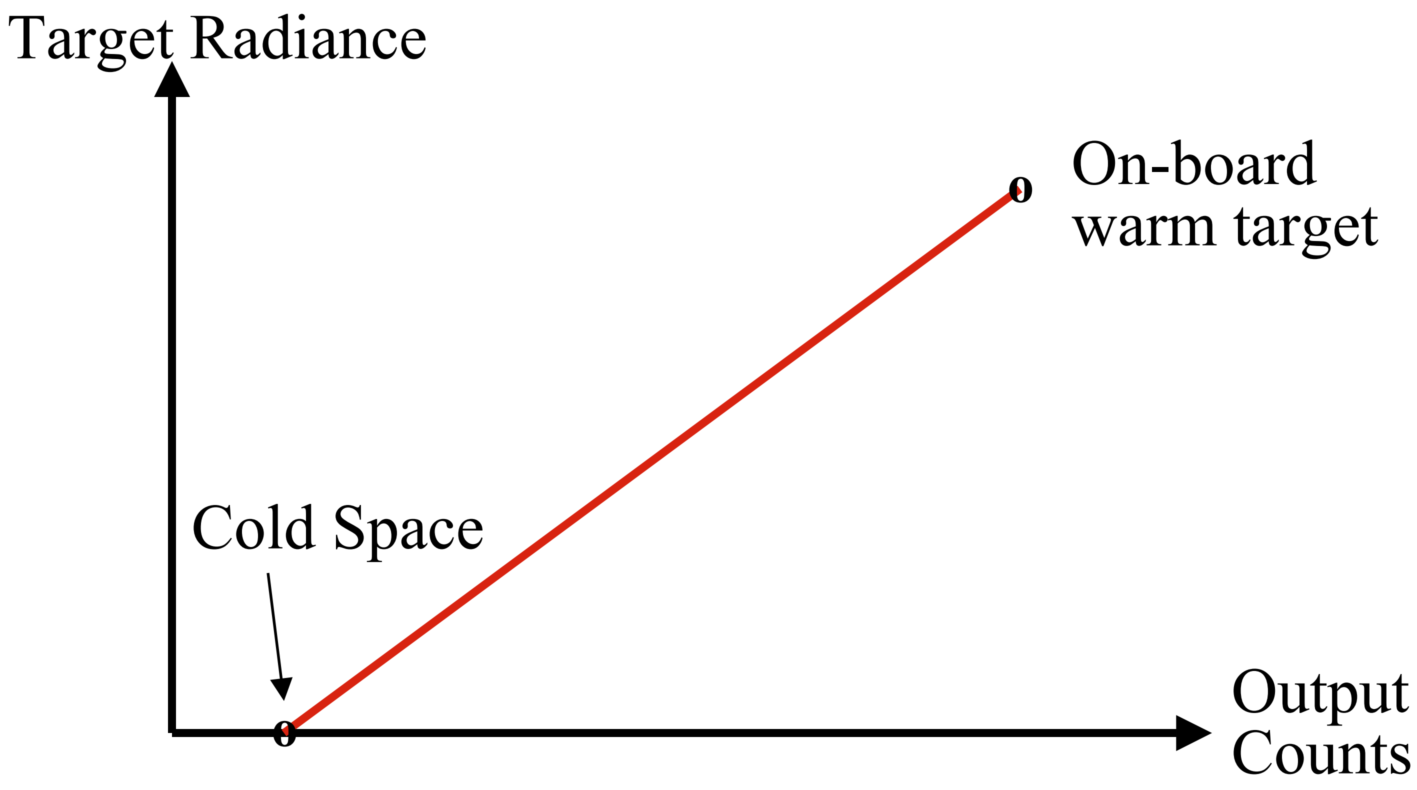
- Calibration is necessary if satellite instruments are to produce data from which properties of the environment can be inferred.

- The quality of our environmental data products depends on the quality of the calibration of our sensors in orbit.

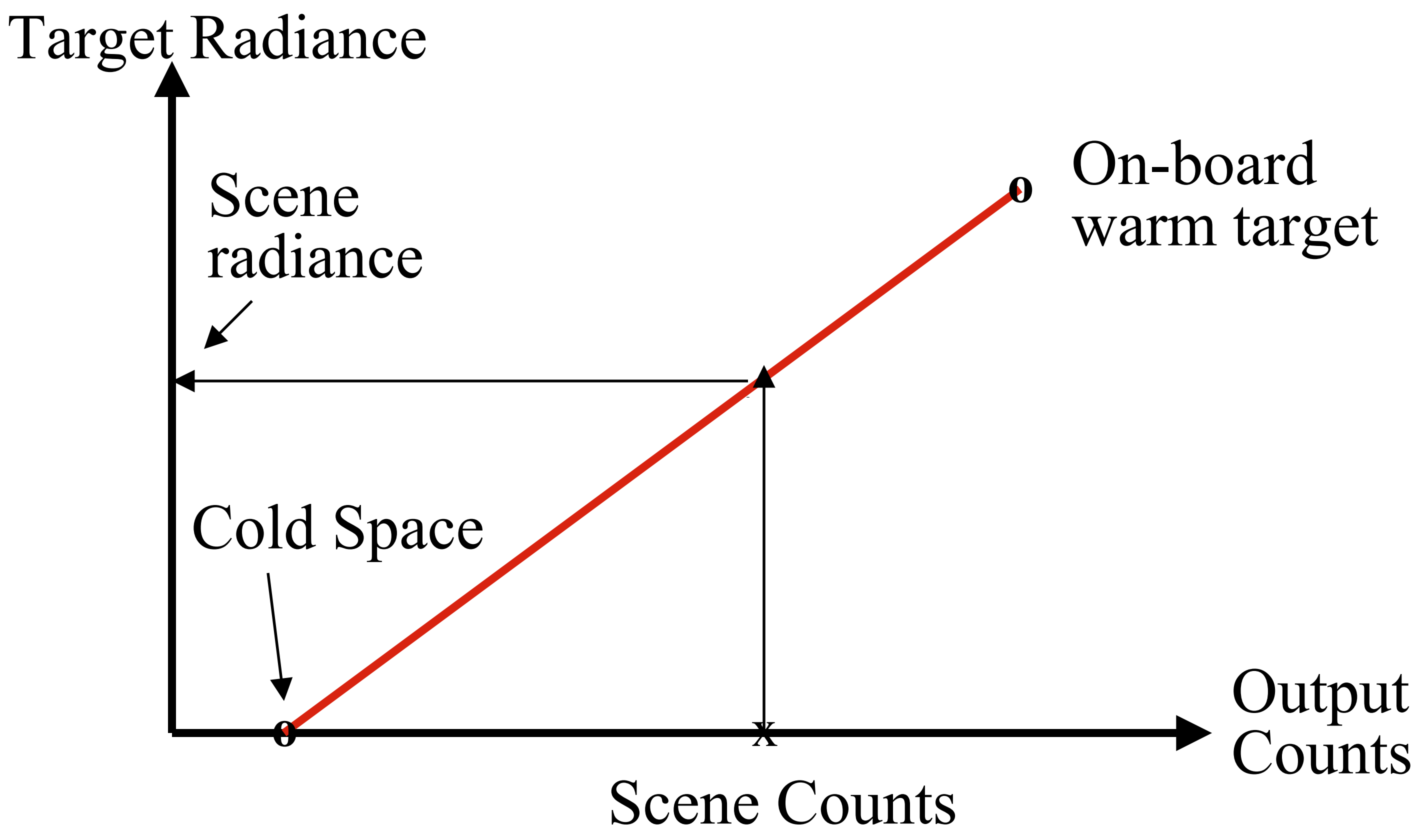
Familiar Example of Calibration



Satellite Calibration: slope & intercept of calibration line are determined from views of space & on-board warm target



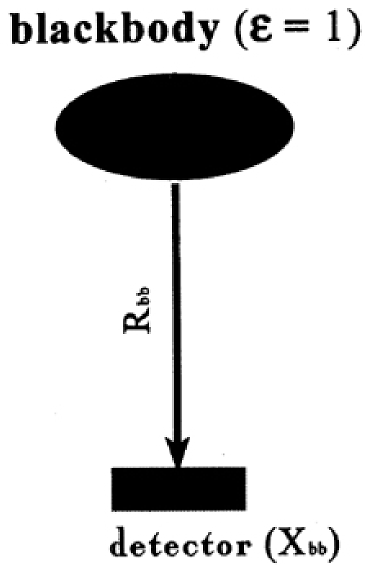
To determine scene radiance, apply equation of calibration line to measured scene counts



Midnight Blackbody Problem

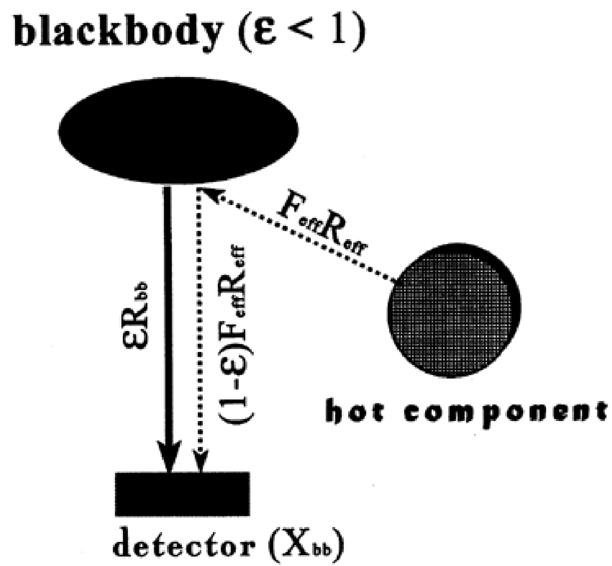
- At certain times of the year, the magnitudes of the computed calibration slopes for the GOES Imagers' infrared channels exhibit anomalous dips during the approximately six hours centered on satellite midnight.
- The amplitude of the dips is greatest for Imager channels at the shortest wavelengths.
- For GOES-8, the anomalous dips occurred from April thru October. For GOES-10 they occur all year round. For GOES-12, they seem occur year round, but they are bigger from April through October than they are at other times.
- Assuming these slope dips are errors, they will cause erroneous decreases in measured scene temperatures. Such decreases appear to have been observed.
- The cause of the slope dips is believed to be interference by radiation from solar-heated structural components that reaches the Imagers' detectors during the blackbody look—see next slide.

Normal calibration



$$m = \frac{R_{bb}}{X_{bb} - X_{sp}}$$

Calibration error from extraneous radiation



$$m_{true} = \frac{\epsilon R_{bb} + (1-\epsilon) F_{eff} R_{eff}}{X_{bb} - X_{sp}}$$

Calibration error occurs when formula on left is used for case on right. (“m” is calibration slope.)

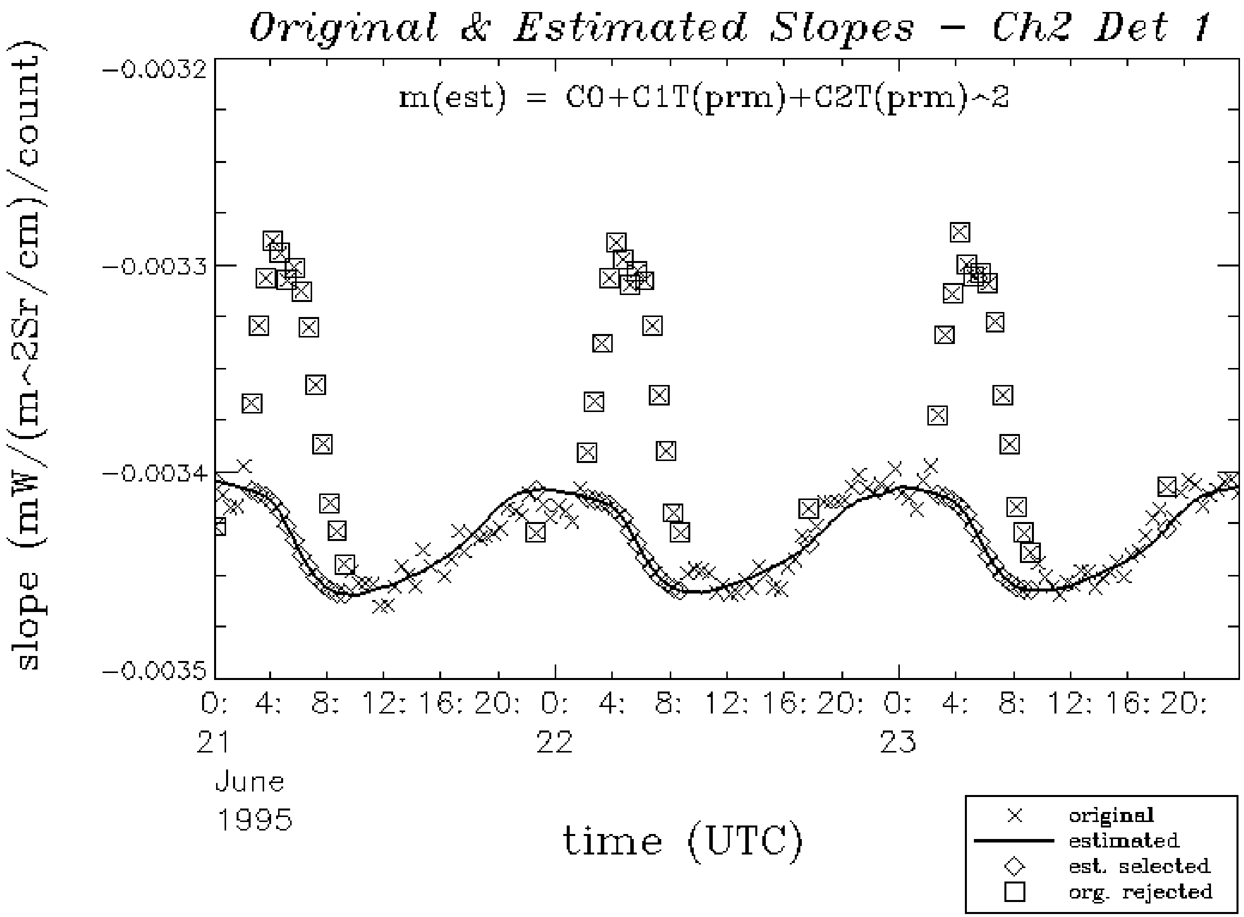
Correction Algorithm

- The Midnight Blackbody Calibration Correction (MBCC) was developed to overcome this problem.

- The algorithm is based on the observation that when this problem is absent, there is a very high correlation between the calibration slope and the temperature of several optics components, particularly the telescope's primary mirror.

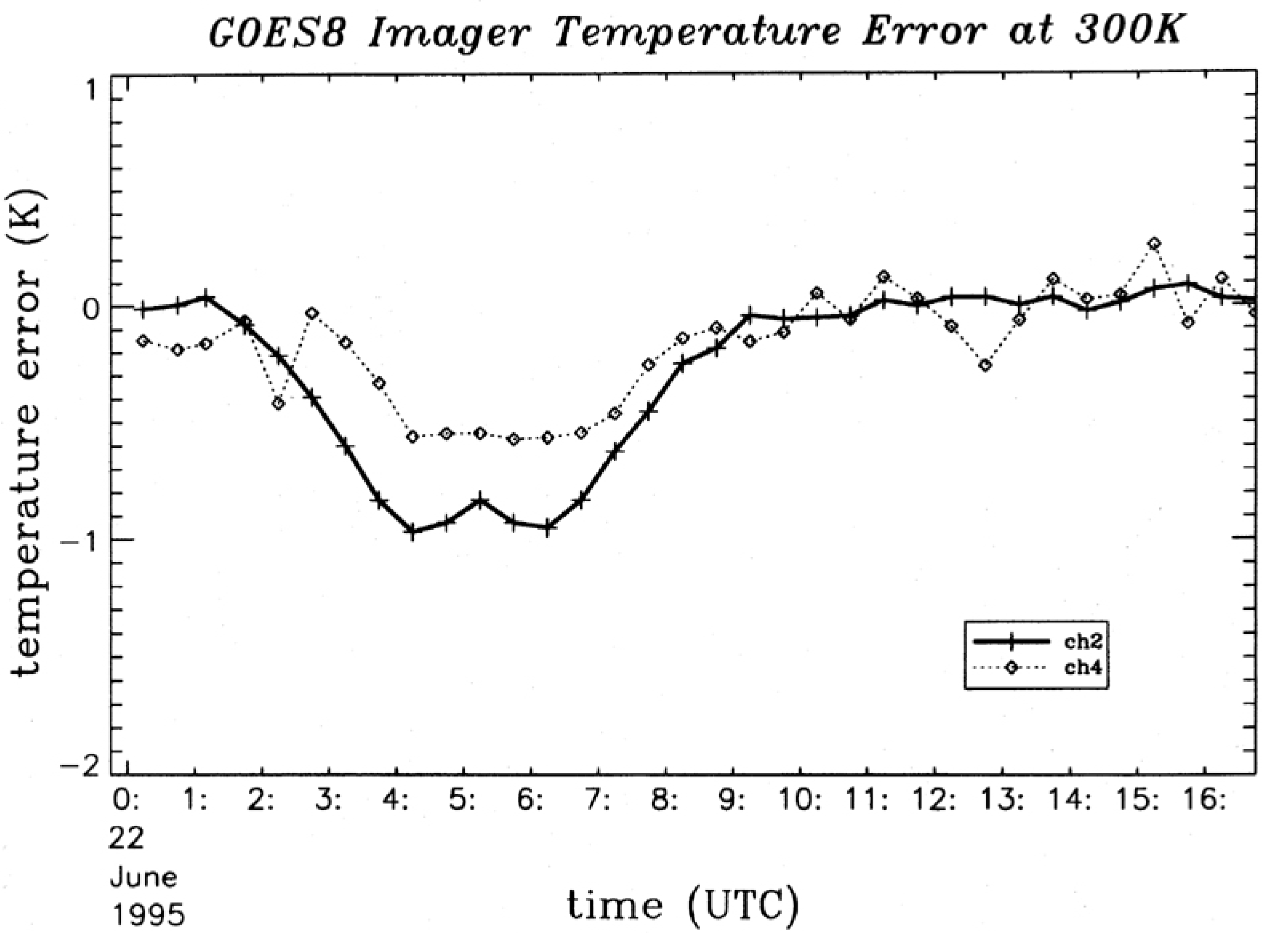
- So, when the problem occurs, we replace the bad slope values by estimates computed by regression on the primary-mirror temperature.

- Slope values in “spikes” are erroneous.
- Corrected values, based on regression, lie on curve

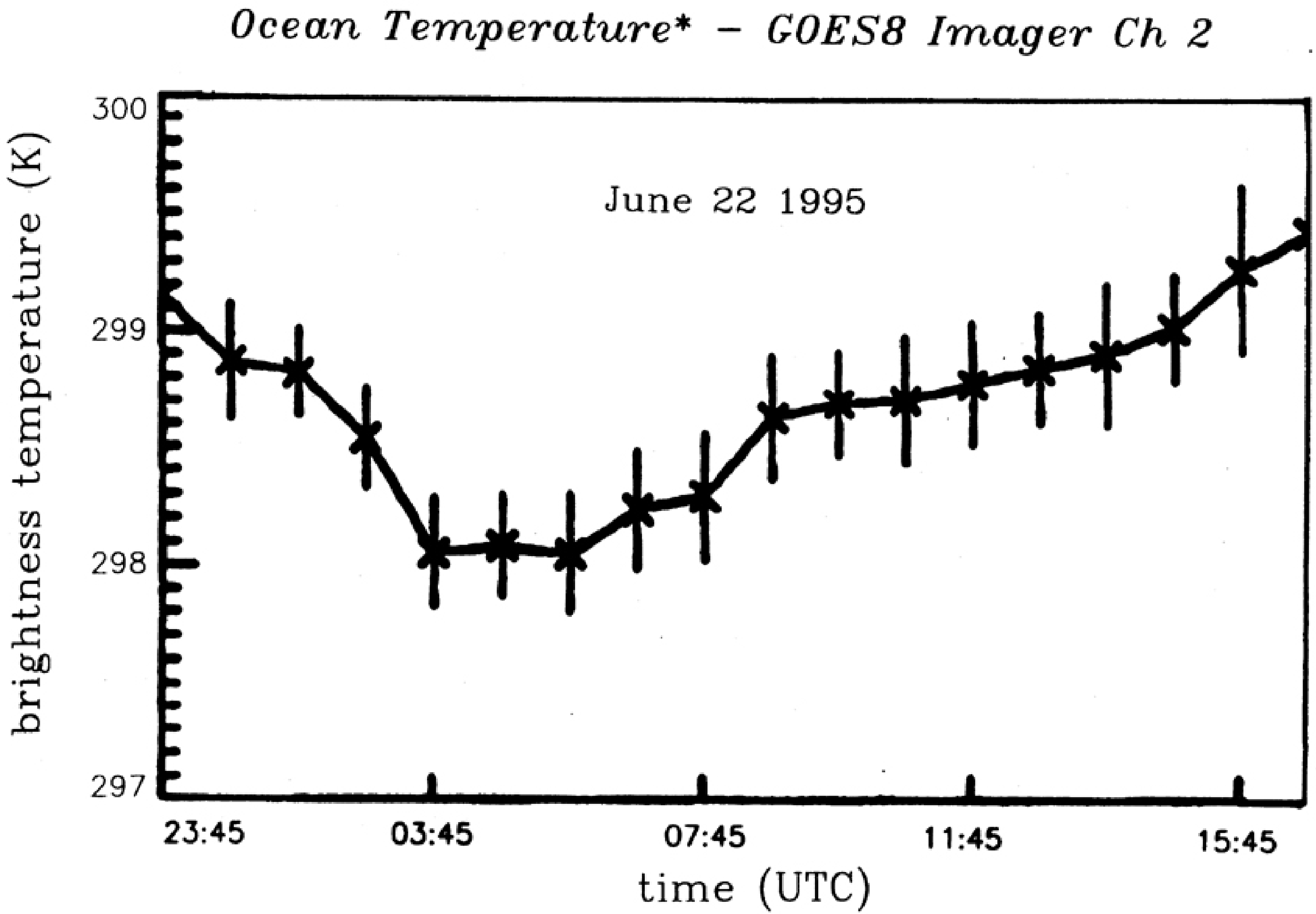


GOES-8 Imager

Scene Temperature Errors Predicted from Slope Errors vs Time



Observed Scene Temperature Errors vs Time

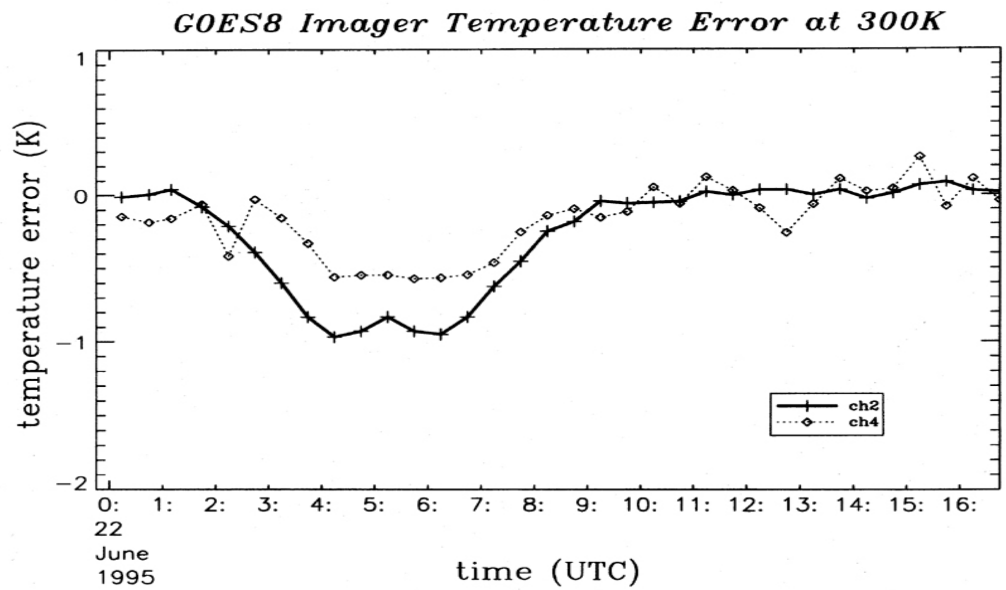


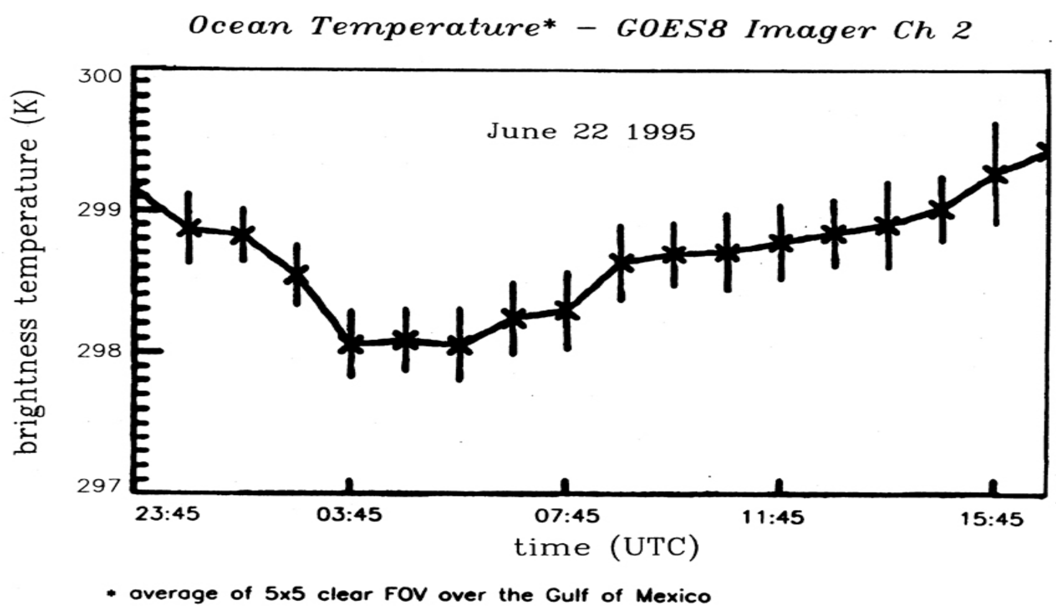
* average of 5x5 clear FOV over the Gulf of Mexico

From Paul van Delst (CIMSS)

Observed vs Predicted Errors

This slide presents the figures on the two previous slides aligned in time. The point is that the scene temperature errors predicted from the slope errors are well correlated with the observed 1 K depression, which is believed to be erroneous.





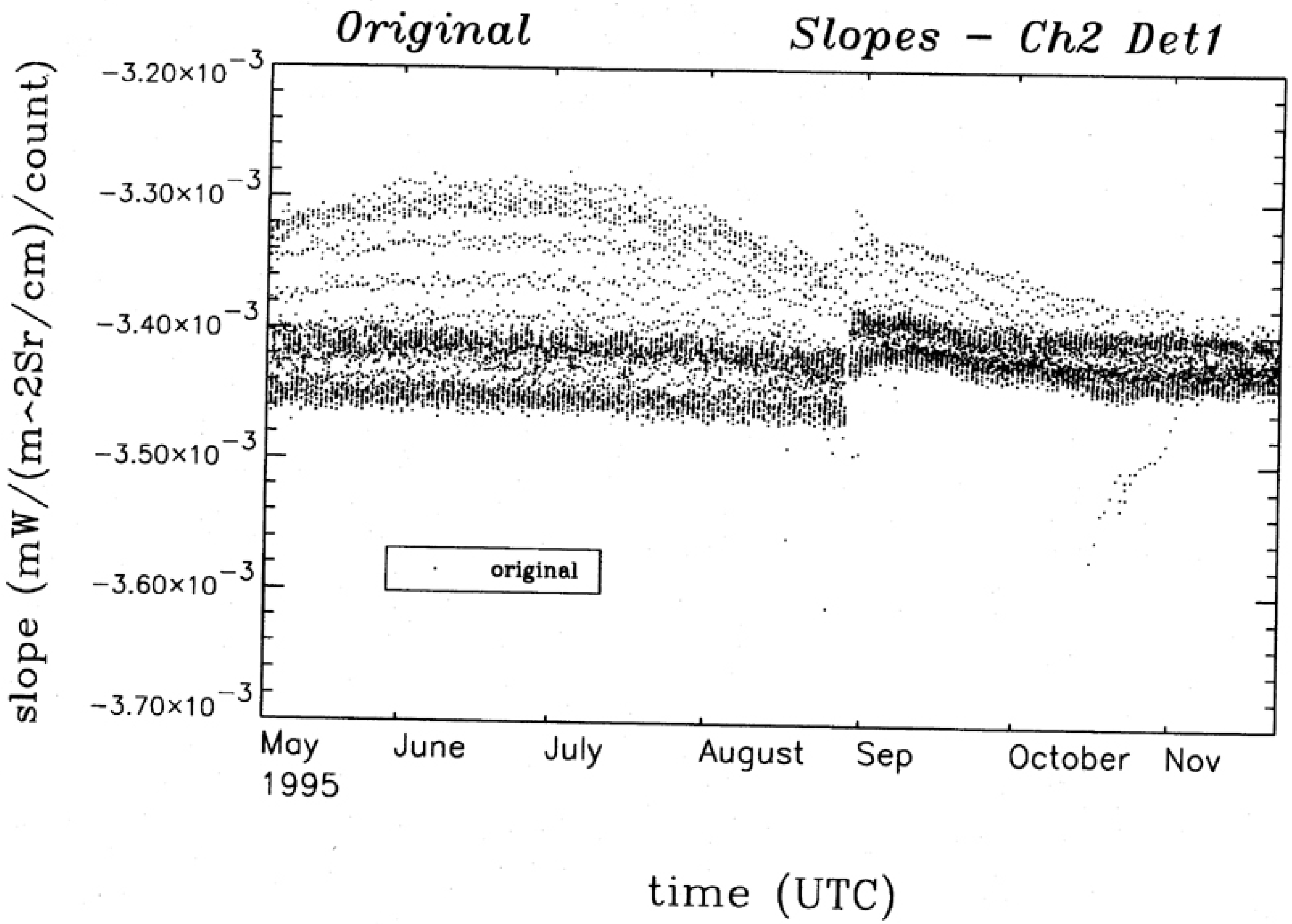
Slopes vs Time

- The next two slides show all the slopes (computed once every half hour) for channel 2 (3.8 μm), detector 1, of the GOES-8 Imager plotted over seven months as a function of time.

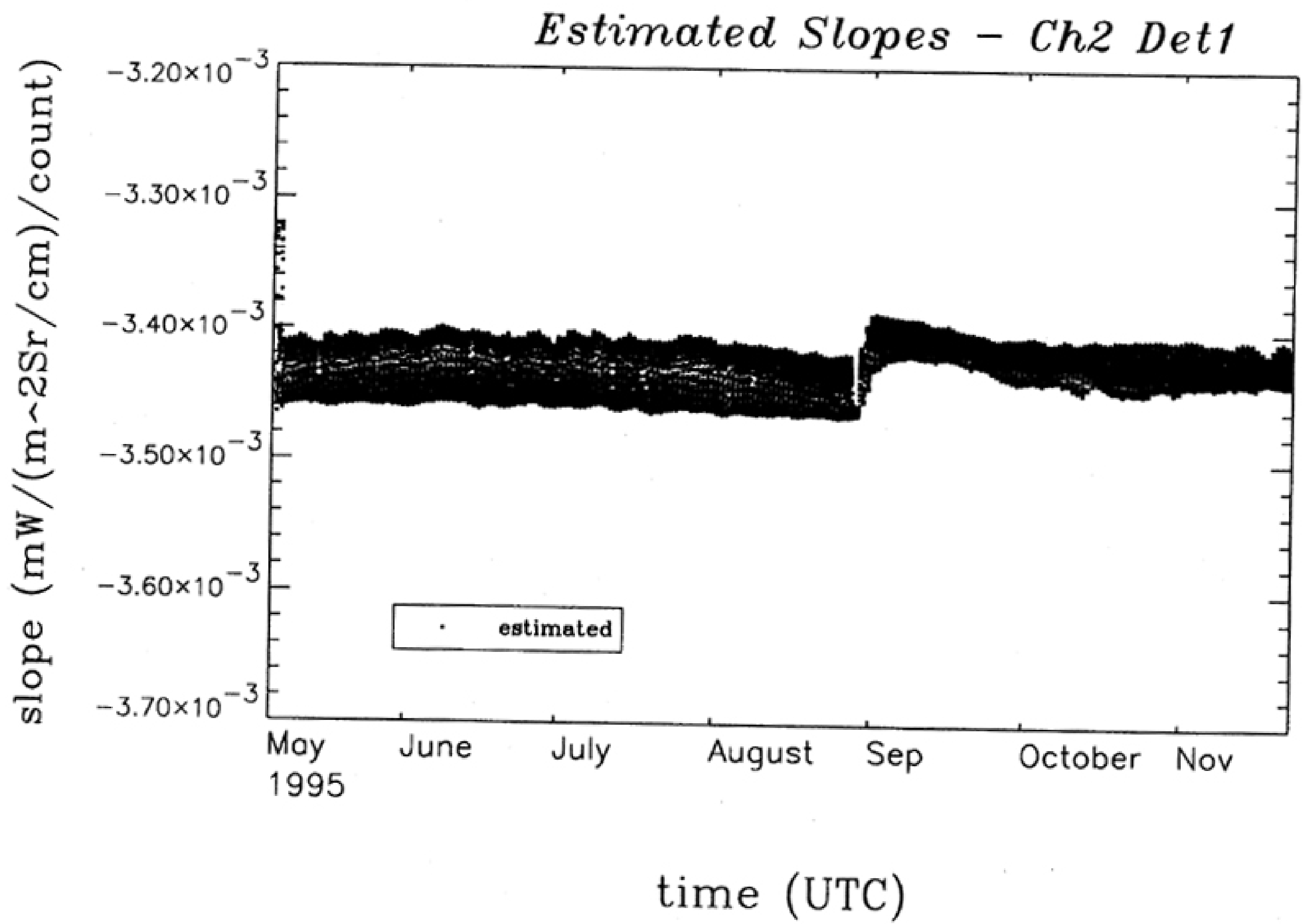
- The first slide has the original slopes, including those affected by the midnight problem. The erroneous slopes constitute the “fuzz” above the main sequence.

- The second shows all the slopes with the MBCC activated. The points that were in the fuzz are now in the main sequence.

Uncorrected Slopes vs Time



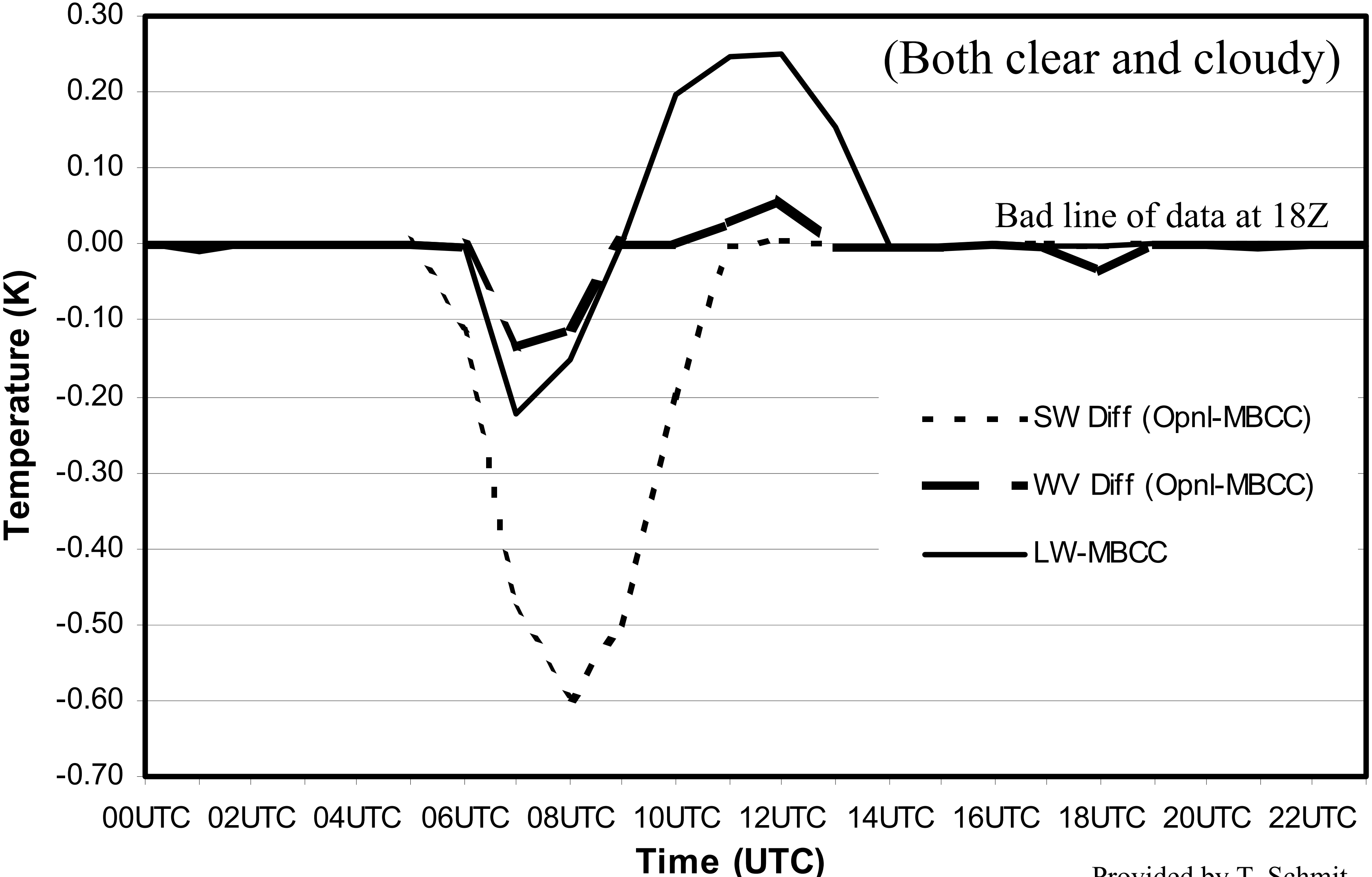
Corrected Slopes vs Time



Parallel Test of Midnight Blackbody Correction (MBCC)

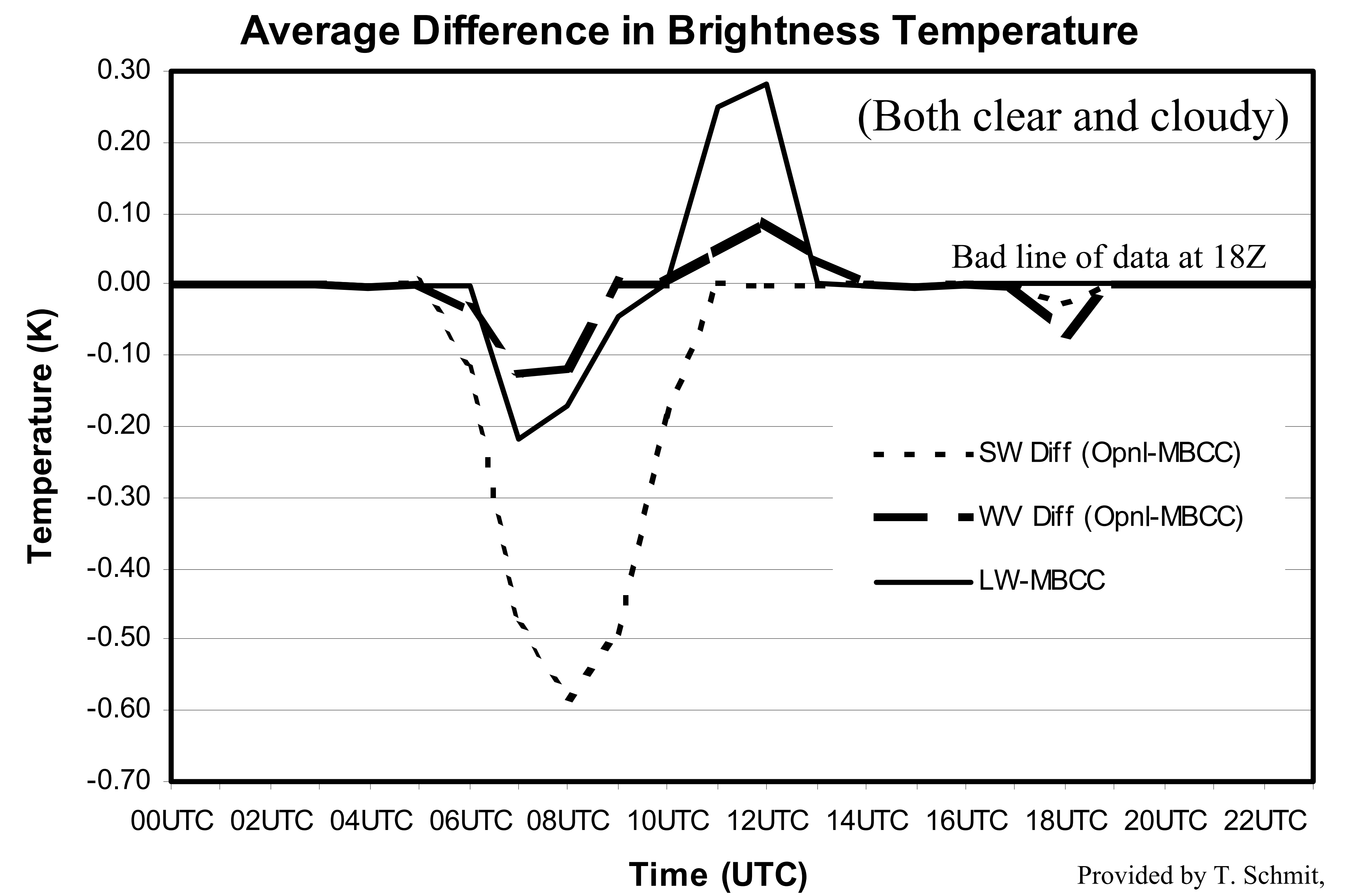
- Parallel (to operations) test of MBCC occurred Jan. 13-16, 2003, with data from GOES-10 Imager.
- Parallel (MBCC) GOES-10 GVAR stream was distributed via the GOES-9 transponder.
- Opn'l & parallel data were collected and compared at SSEC Data Center (U. Wisconsin)
- The following two figures show their results for Jan. 14 & 15
  - » The MBCC was effective from 0600 to 1000 UTC in Imager channels 2 (SW—3.8 µm), 3 (WV—6.7 µm), and 4 (LW—10.7 µm). (Local midnight for GOES-10 is at 0900 UTC.) At those times, the MBCC increased the scene temperatures, as expected.
  - » An unexpected "correction," having opposite sign, was also made between 1000 and 1300 UTC in channels 3 and 4. This "correction" is not valid and occurred because of an algorithm error. The error has since been corrected. (This catch illustrates the benefits of parallel testing. We are greatly indebted to our colleagues at U. Wisconsin.)

Average Difference in Brightness Temperature



14 January 2003

Provided by T. Schmit, (NOAA/NESDIS/ASPP) with M. Gunshor & T. Schreiner (SSEC)



Provided by T. Schmit, (NOAA/NESDIS/ASPP) with M. Gunshor & T. Schreiner (SSEC)

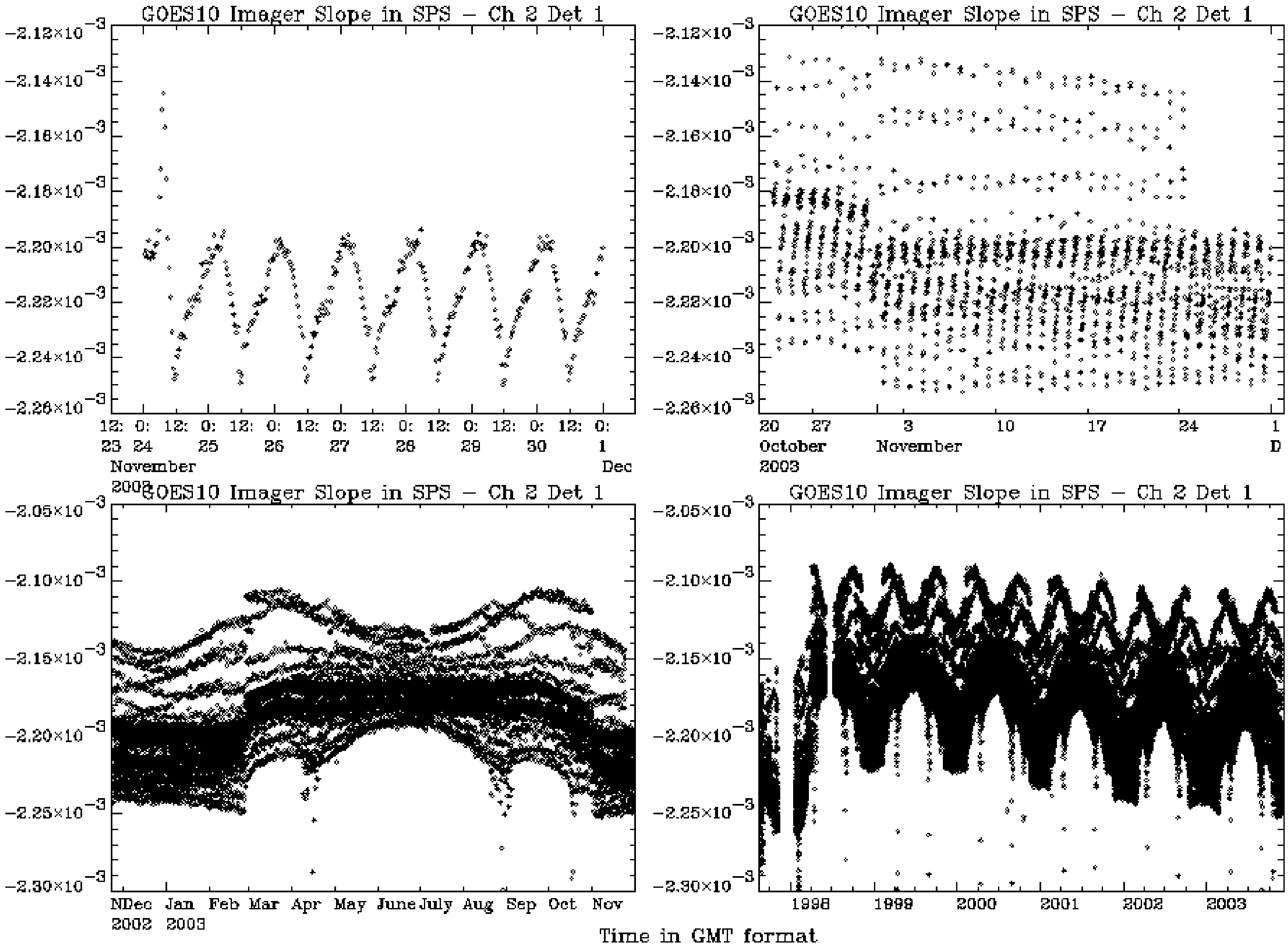
15 January 2003

Operational Results

- The MBCC was made operational on Nov. 24, 2003.

- The following two slides show time series of Imager channel-2 slopes terminating around Dec. 1, 2003.
  - » As expected, the onset of the correction on Nov. 24 is apparent in the time series.
  - » The midnight effect is larger for GOES-10 than for GOES-12 at this time of year (Oct. – Nov.)

- The third slide, from ECMWF, shows that the observations became warmer near midnight by a little less than 1K.



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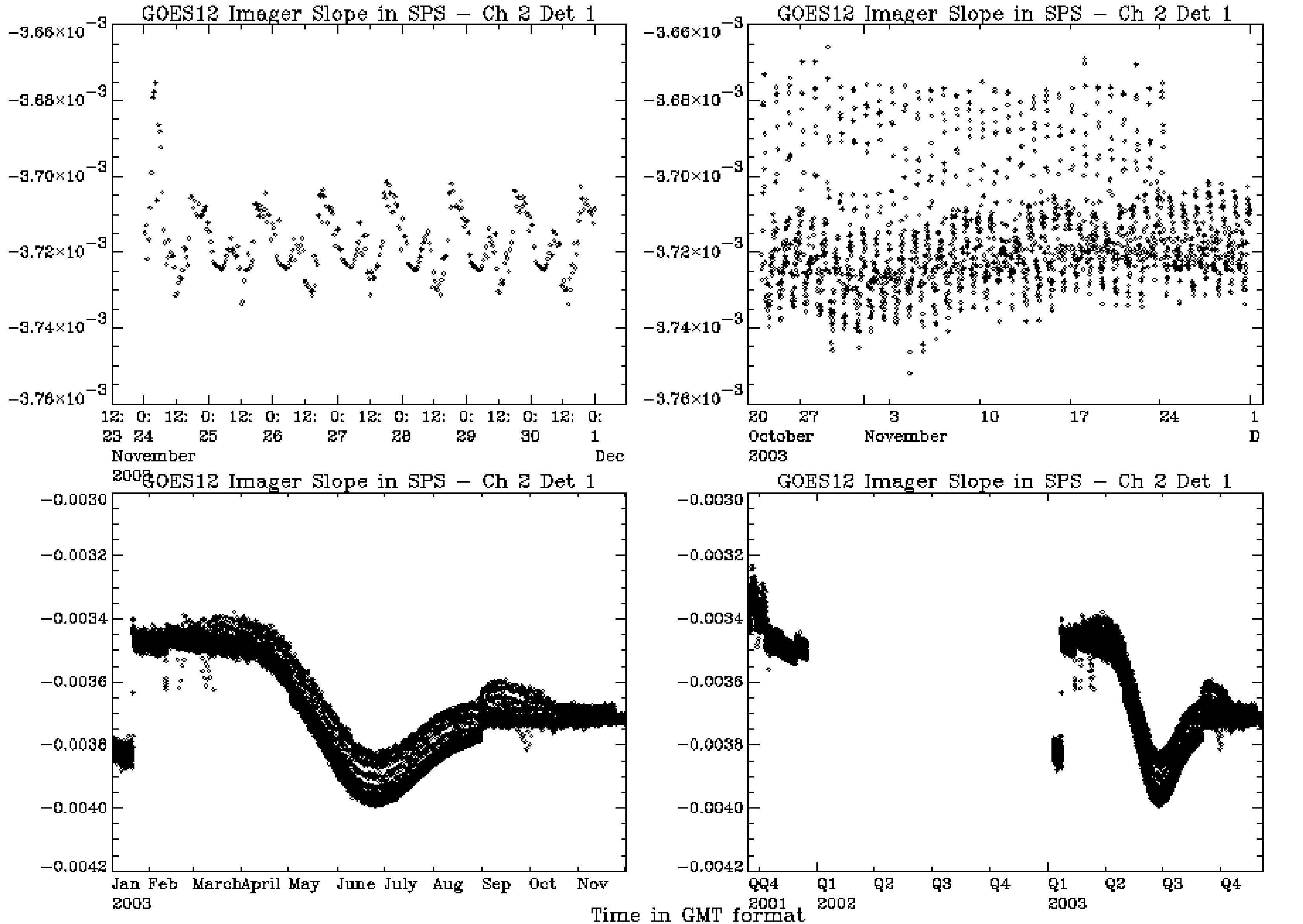

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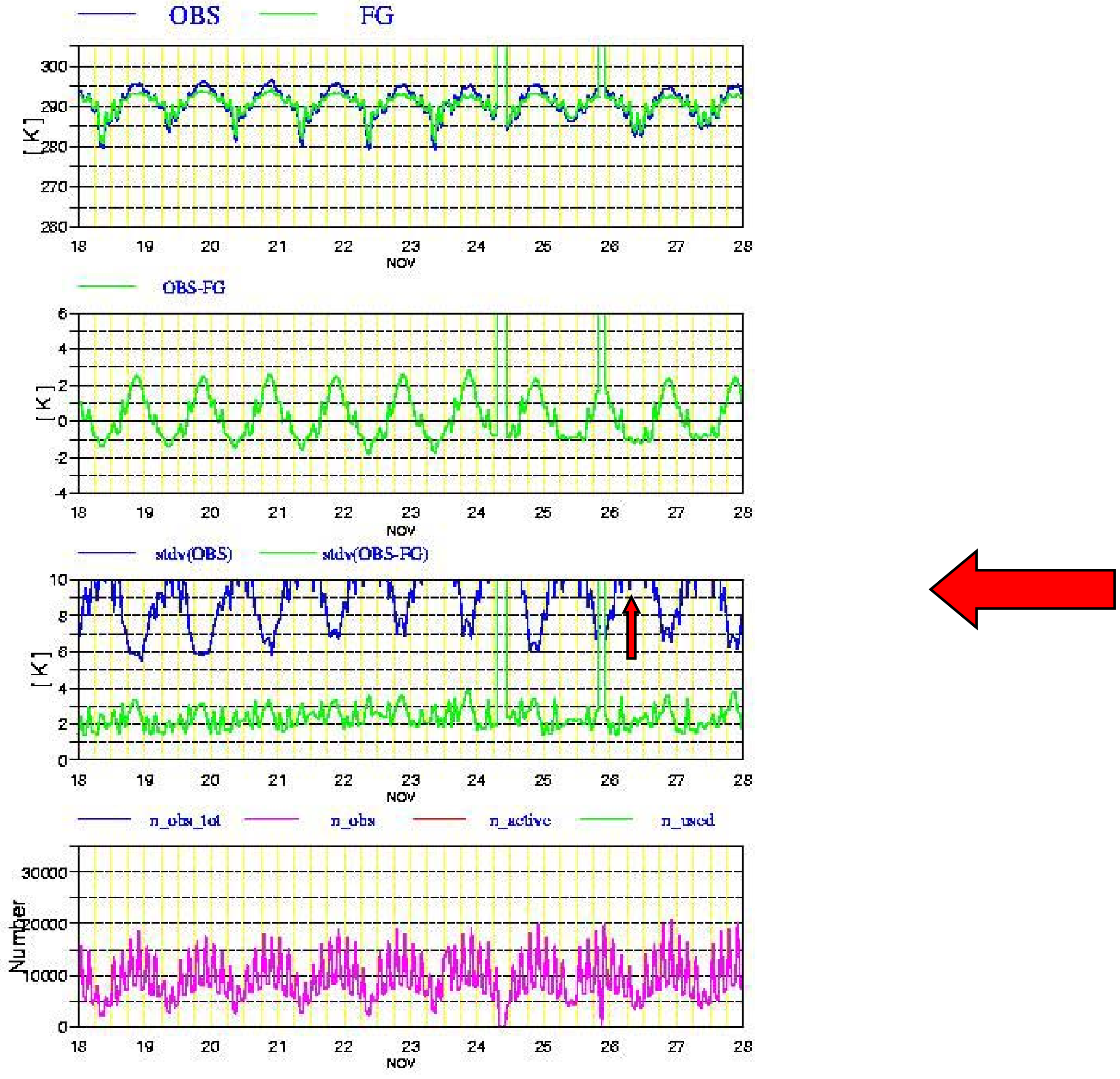
Statistics for Radiances from GOES-10 / CSR

Channel = IR3.9 , All Data

Area: lon_w= 0.0, lon_e= 360.0, lat_n= 90.0, lat_s= -90.0 (all surface types)

EXP = 0001

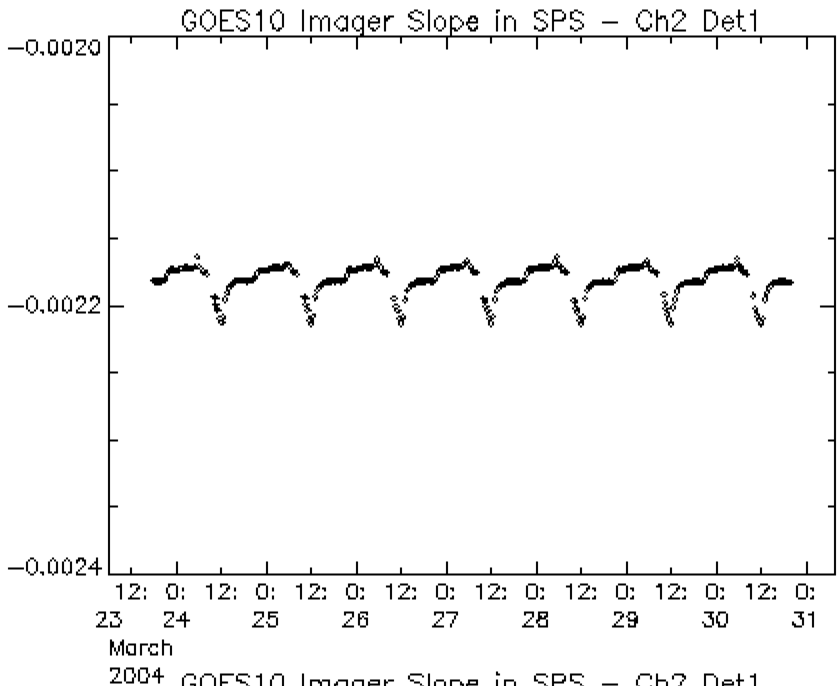


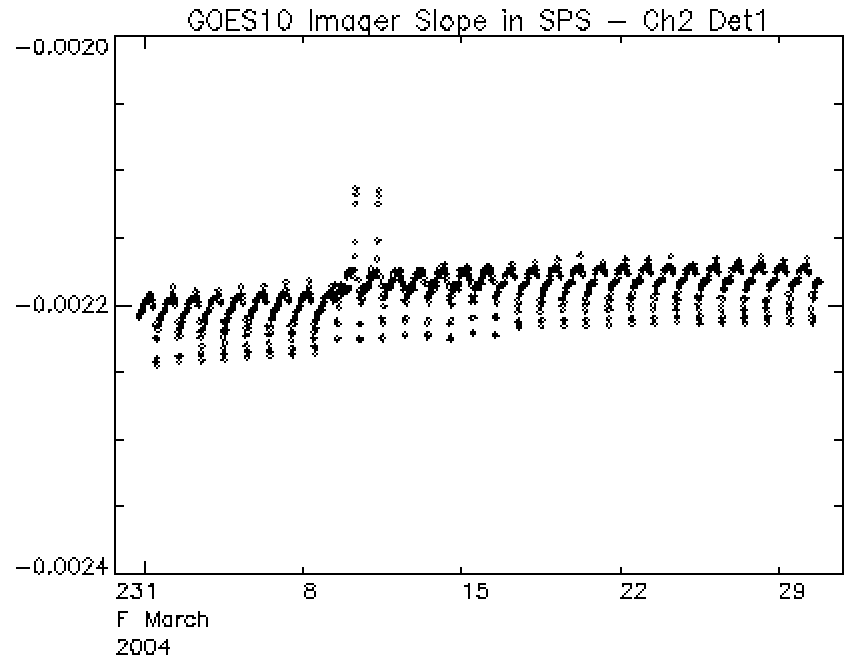
How have we been doing since Dec. ′03?

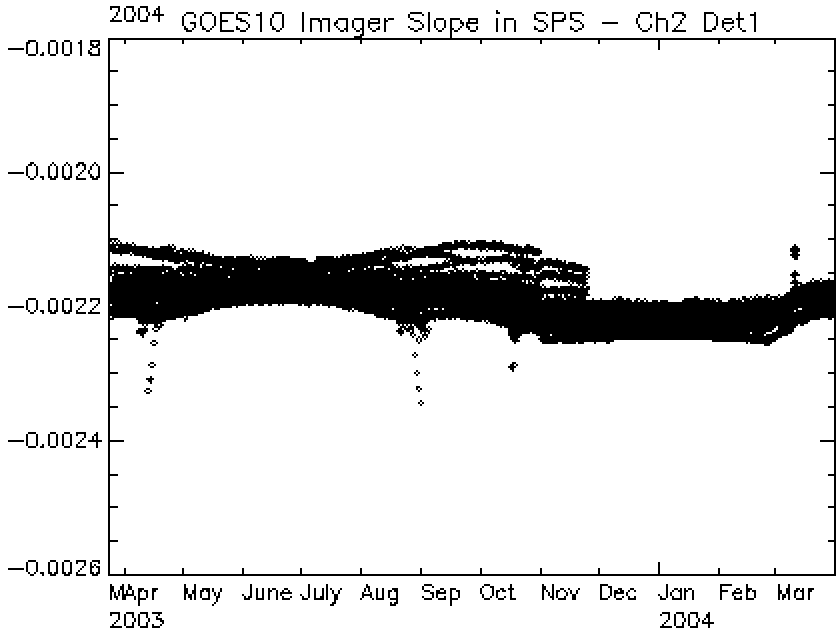
- The following two slides show the time series of slopes, for GOES-10 and GOES-12, terminating on March 30, 2004.

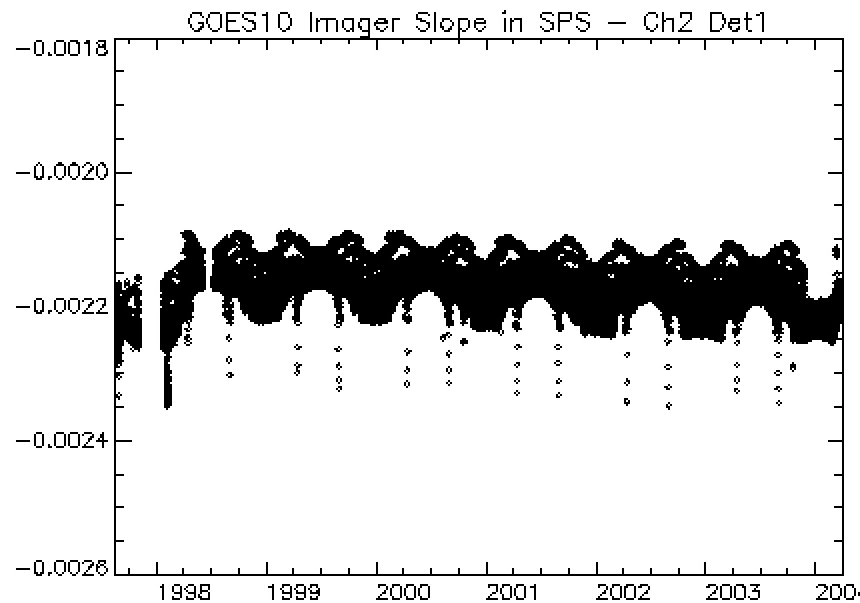
- The corrections are usually effective, but we found some anomalies:
  - » GOES-10: The slope “dips” on March 9 and 10 are a result of the necessity to turn off the MBCC for a few days after events like patch temperature changes. This was expected.
  - » GOES-12: There are big dips March 9-23 and small dips March 23-30. These were not expected and are not understood yet.

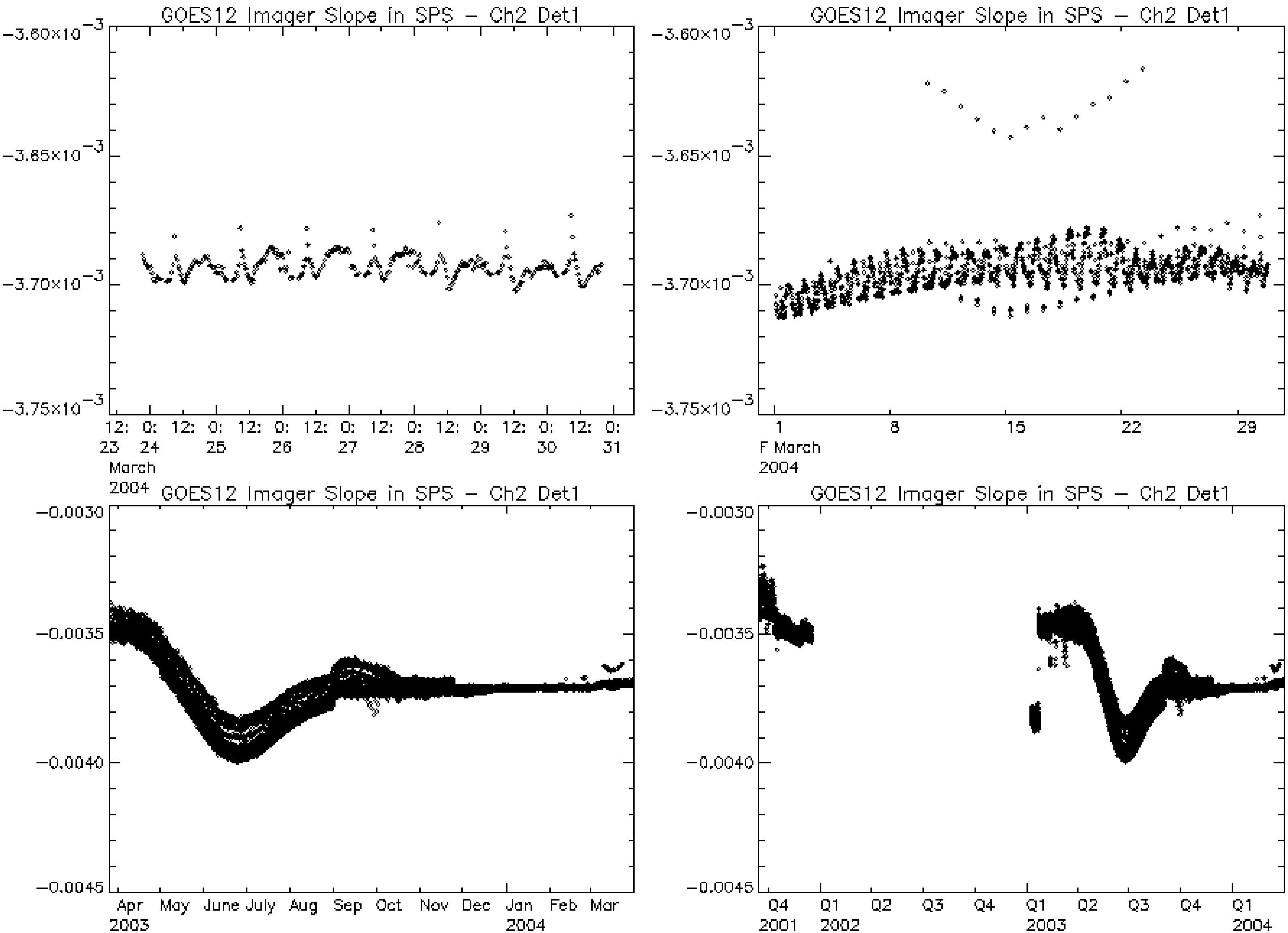
(This illustrates the benefit of giving talks on your work. We discovered the recent dips while assembling the slides for this talk.)


GOES10 Imager Slope in SPS – Ch2 Det1
–0.0020
–0.0022
–0.0024
12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0:
23 24 25 26 27 28 29 30 31
March
2004


GOES10 Imager Slope in SPS – Ch2 Det1
–0.0020
–0.0022
–0.0024
231 8 15 22 29
F March
2004


GOES10 Imager Slope in SPS – Ch2 Det1
–0.0018
–0.0020
–0.0022
–0.0024
–0.0026
MApr May June July Aug Sep Oct Nov Dec Jan Feb Mar
2003
2004


GOES10 Imager Slope in SPS – Ch2 Det1
–0.0018
–0.0020
–0.0022
–0.0024
–0.0026
1998 1999 2000 2001 2002 2003 2004


GOES12 Imager Slope in SPS – Ch2 Det1
−3.60×10⁻³
−3.65×10⁻³
−3.70×10⁻³
−3.75×10⁻³
12: 23
0: 24
12:
0: 25
12:
0: 26
12:
0: 27
12:
0: 28
12:
0: 29
12:
0: 30
12:
0: 31
March
2004
GOES12 Imager Slope in SPS – Ch2 Det1
−3.60×10⁻³
−3.65×10⁻³
−3.70×10⁻³
−3.75×10⁻³
1
8
15
22
29
F March
2004
GOES12 Imager Slope in SPS – Ch2 Det1
−0.0030
−0.0035
−0.0040
−0.0045
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
2003
2004
GOES12 Imager Slope in SPS – Ch2 Det1
−0.0030
−0.0035
−0.0040
−0.0045
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
2001
2002
2003
2004

Summary

- GOES Imager midnight blackbody calibration errors, caused by effects of solar heating in the Imager's calibration cycle, artificially depress scene temperature observations by as much as 1 K in channel 2 (the 3.8 μm channel). The errors are smaller in the channels at longer wavelengths.

- We have developed a correction algorithm, the Midnight Blackbody Calibration Correction (MBCC), and have tested it in a parallel run with GOES-10 data. The MBCC will produce significant (up to 1 K in channel 2) increases in scene temperature measurements over a period extending from 3-4 hours before local midnight to 1-2 hours after local midnight.

- The MBCC became operational November 24, 2003. Its performance has been good, but some problems need to be corrected.

- Details: **http://www.oso.noaa.gov/goes/goes-calibration/errors.htm**