Operational High Resolution Infrared Radiation Sounder (HIRS) Calibration Algorithms and Their Effects on Calibration Accuracy

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Background

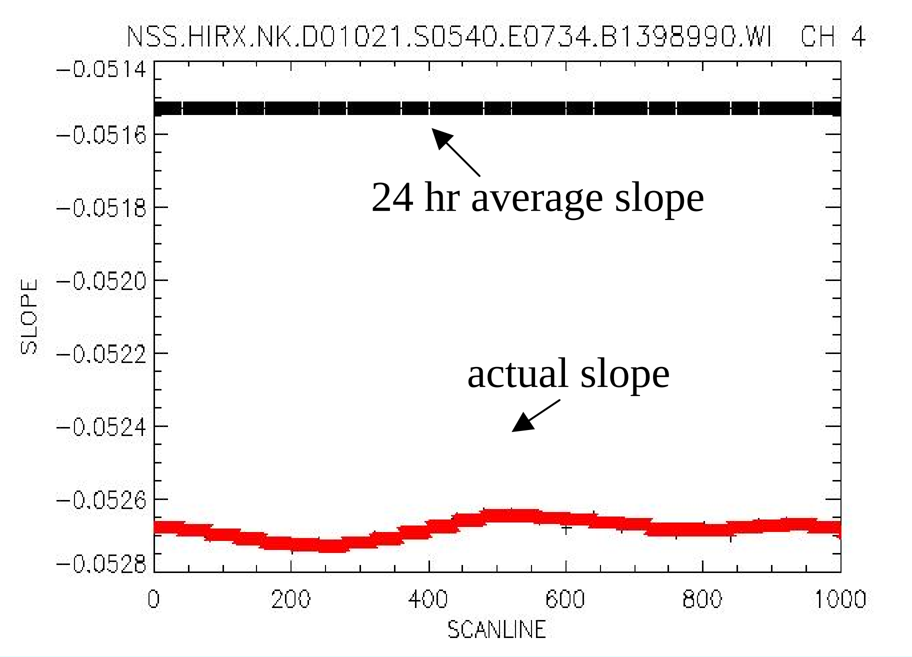
- Operational HIRS instrument calibration has significant impact on products at all levels.
- Before NOAA-KLM(-15 to –17), a simple calibration algorithm was used for HIRS/2 series which introduced artifacts in the middle of a superswath.
- For algorithm V3.0, which has been operational since 1998 for NOAA-KLM, this artifact has been removed.
- However, recent studies suggest that while version 3.0 solved the previous problems, it also introduced new problems.
- Version 4.0 is developed to address these issues.

NOAA-KLM/HIRS Algorithm (Version 3.0)

Based on the assumption that the instrument gain does not change appreciably during 24 hour period. Therefore a 24 hr average slope (inverse of gain) is used for calibrating all data during the period.

Comments:

- Good enough during normal instrument operations, because the instrument gain is mainly affected by the background flux reaching the detector from the filter wheel, which is normally stable (ITT, 1996)
- Becomes invalid when the instrument background flux changes significantly and rapidly (e.g., filter wheel temperature, which is not controlled).
- When this occurs, it introduces significant biases due to the use of outdated calibration slopes, and has a long lasting effect on calibration (24 hrs).



Issues in the slopes

- Occasionally, differences between the current slopes (in the calibration cycle) and the 24 hr average slopes causes errors in the level 1b radiance data as much as 3K. This is observed via inter-satellite calibrations using simultaneous nadir observations, and such events occurred frequently for NOAA-15, less so for NOAA-16 and –17.

- Filter wheel temperature variation is small under normal conditions (~0.1K/orbit). However, it is not controlled and has a large operating range (~273K–333K).

- Filter wheel temperature change may also cause spectral shifts in the filters.

Issues in the intercepts

- Telescope temperature variation contributes to the orbital fluctuations in the intercept and slope. This is calibrated out at calibration cycles.

- Between two calibration cycles, intercepts are interpolated by:

$$I_n = \left(I_0 + n \cdot \frac{I_{40} - I_0}{40} \right) + b_1 \cdot \left((T_n - T_0) + n \cdot \frac{T_{40} - T_0}{40} \right)$$

(1) (2)

two parts :

  - Linear interpolation of the intercepts between the two adjacent calibration cycles (first order effect).
  - Correction based on the linear correlation between the intercept and SMT from 24 hour worth of data. This effect is normally a small secondary effect,

  for example, at 700cm^{-1}:

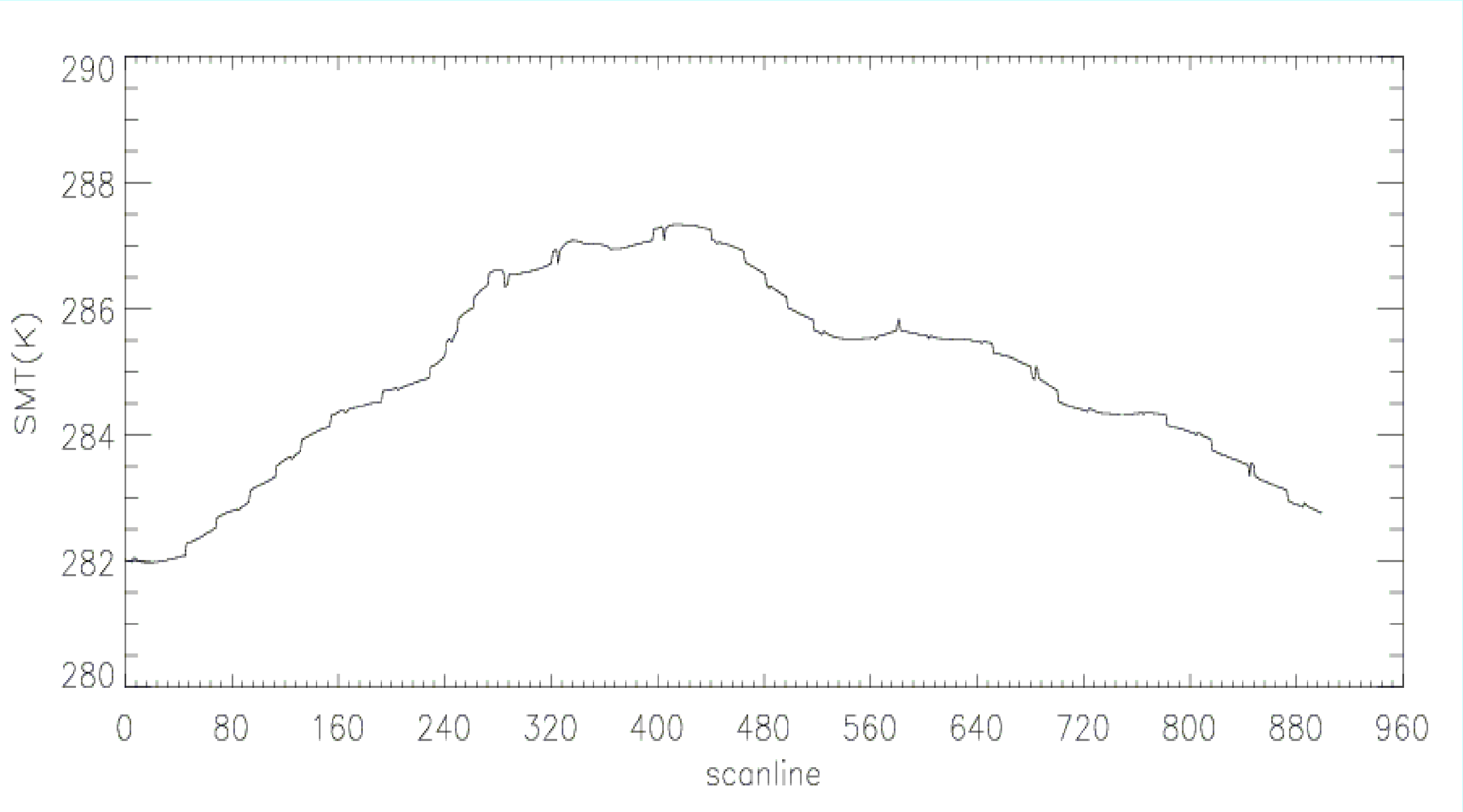
  the correlation between the intercept and SMT (b_1) ~ 0.5 mW/m^2 sr cm^{-1}/SMT

  residual effect < 0.1K

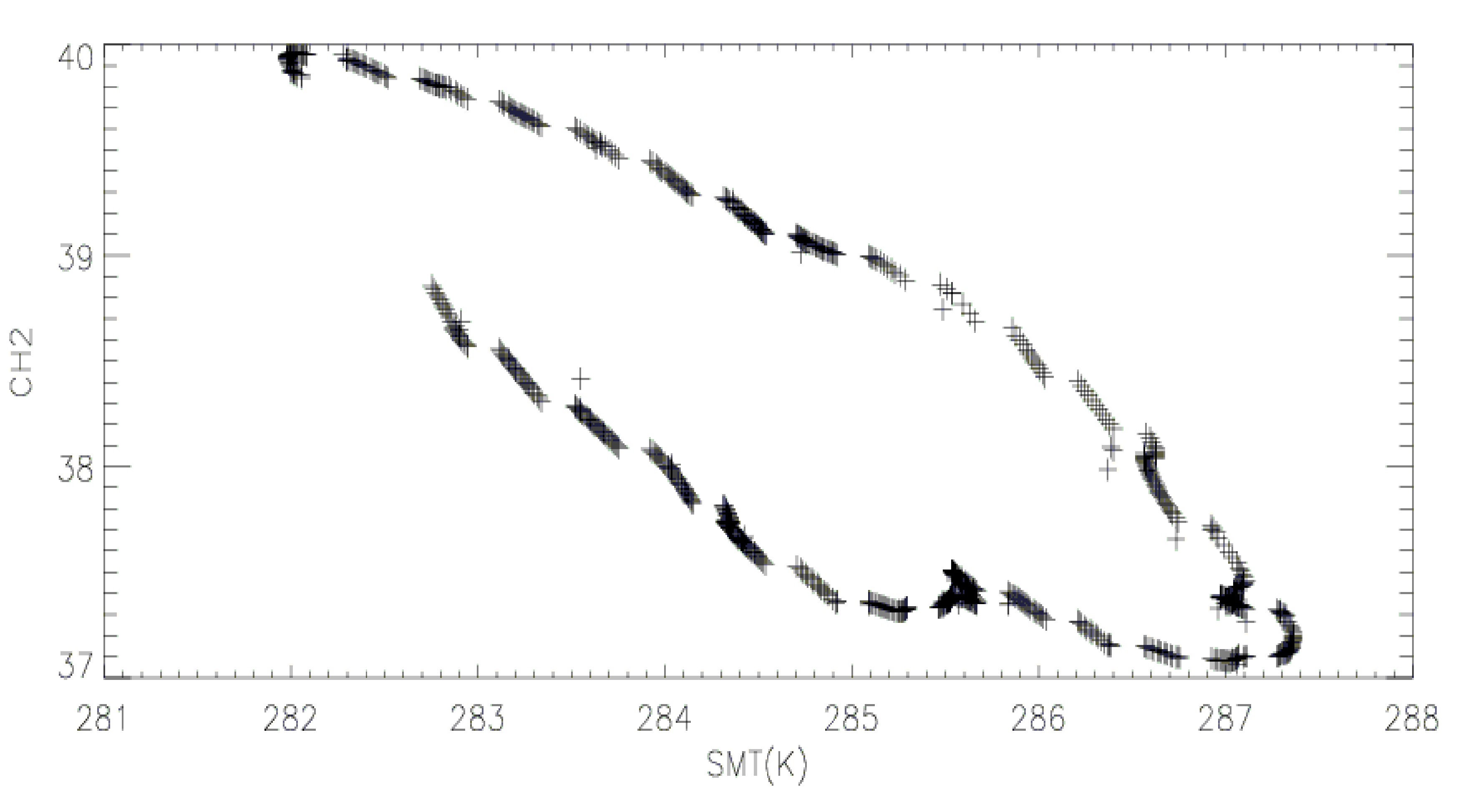
- However, the intercept is determined from the slope, therefore, changing the slopes will substantially affect the intercepts.

$$Intercept = -c_{sp} \cdot slope$$

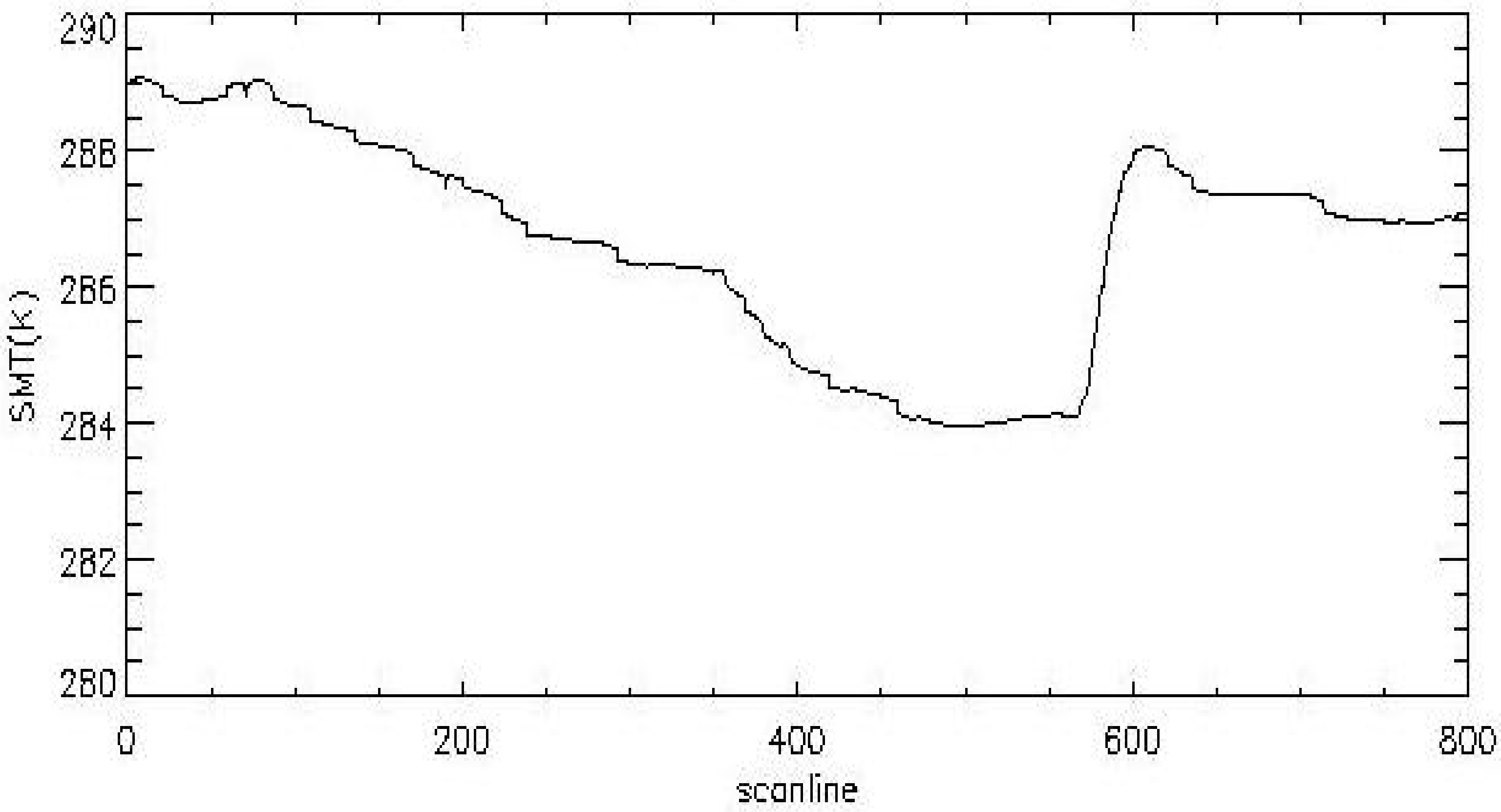
Secondary mirror temperature variation
One orbit (NOAA-M/JD03065)



Secondary mirror temperature vs. Intercept for Channel 2
NOAA-17/HIRS (NOAA-M/JD03065)



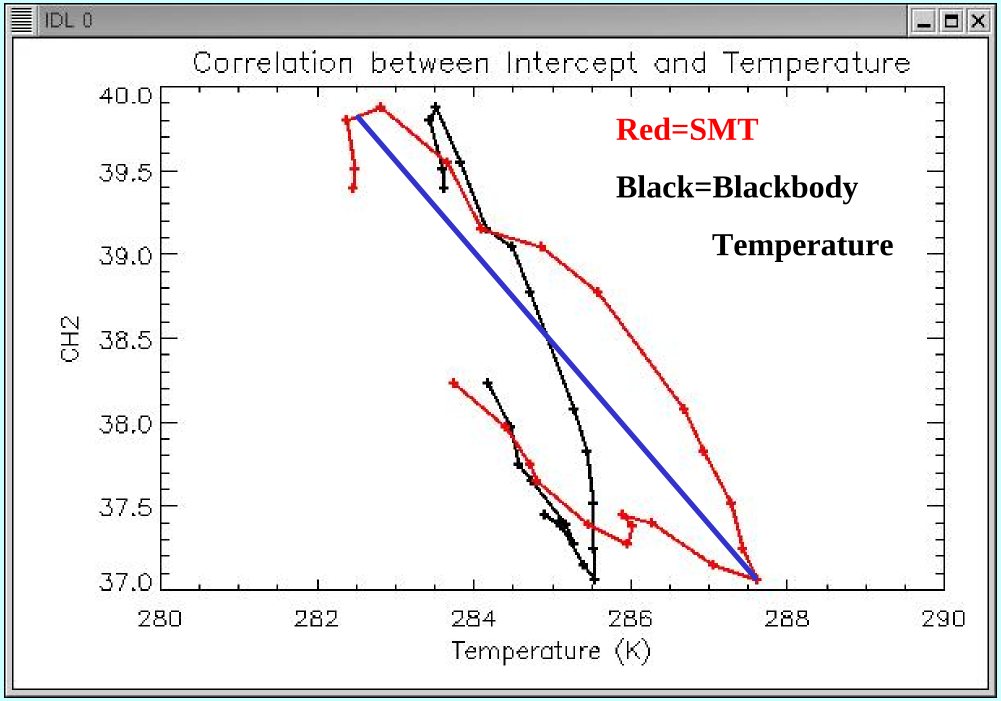
Secondary mirror temperature variation
One orbit (NOAA-K/JD01156)



Open issue in the intercepts

- The correlation between intercept and SMT is not linear (different between day and night) as it is assumed by the algorithm (similar conclusion by Dr. Pascal Brunel).

- This issue will be revisited once the third temperature sensor data (near the field stop) for HIRS/4 become available, and this correlation will probably be determined using a thermal model in the future.



Algorithm V4.0: Major improvement in the slopes

- Slopes: running average for the slopes from three calibration cycles to better reflect the changes in slopes while maintaining the stability

  slope = (previous+current+next)/3

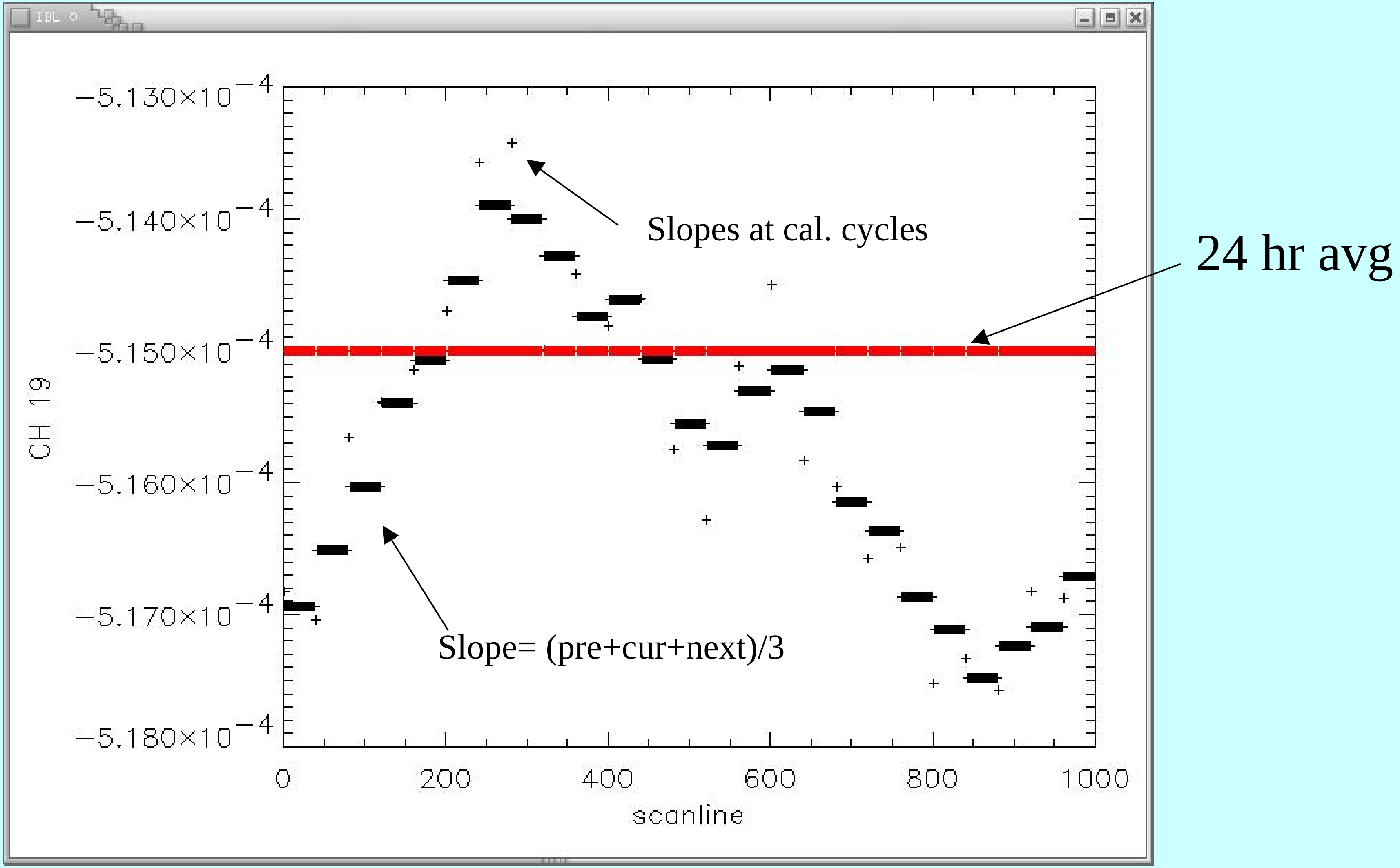
- Intercepts: essentially the algorithm is not changed, except a switch is added to turn off the correction term based on SMT temperature. And this correction will likely be better modeled in the future.

- However, intercept values will be different as a result of new slope values

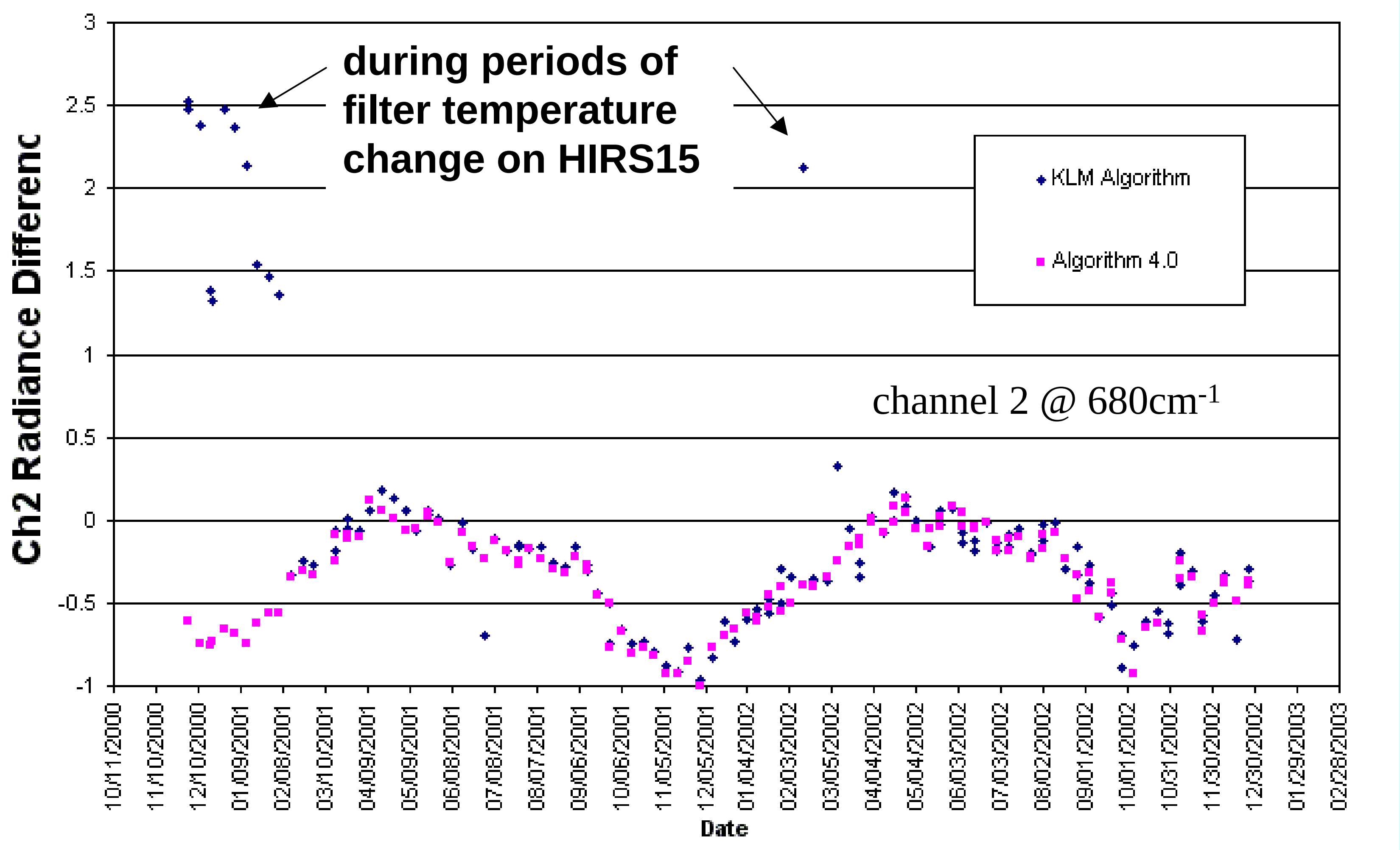
- In the data **reprocessing** where the entire orbit of data can be easily analyzed (not the case in the operational preprocessor), the correlation between the intercept and SMT can be better determined within the one orbit data itself. For local receiving stations, this correlation can be better estimated based on the local data sets (for example, a line fit based on the calibration cycles available, separating day/night).

Slope – Running Average

one example orbit



Radiance Difference via Inter-satellite Calibration using Simultaneous Nadir Observations
(HIRS/NOAA-16 – HIRS/NOAA-15)



Summary

- The current operational HIRS calibration algorithm is based on assumptions that may become invalid from time to time, and may cause large calibration biases.
- A new algorithm is developed to address this issue and will be implemented for NOAA-N
- Future refinements are planned to further improve calibration accuracy

Future Work

- Moon contamination of space view (study in progress)
- Blackbody (or solar) contamination requires further study (most significant for the shortwave channels in the polar regions)
- The third temperature sensor data from HIRS/4 to be studied.
- Algorithm implemented and tested in IDL, to be implemented in operations