Model Estimation of the HIRDLS Exit Aperture Fractional Open Area

Tom Eden

National Center for Atmospheric Research

2008 San Diego SPIE Meeting

Paper 7082-38

Overview

- Introduction
  - Description of Problem
  - Type of Data Needed
    - Spacecraft maneuver
    - Orbital radiance profiles
    - Scan table
- Model Estimation of Exit-aperture Open Area
- Current Results and Understanding
- Future Plans

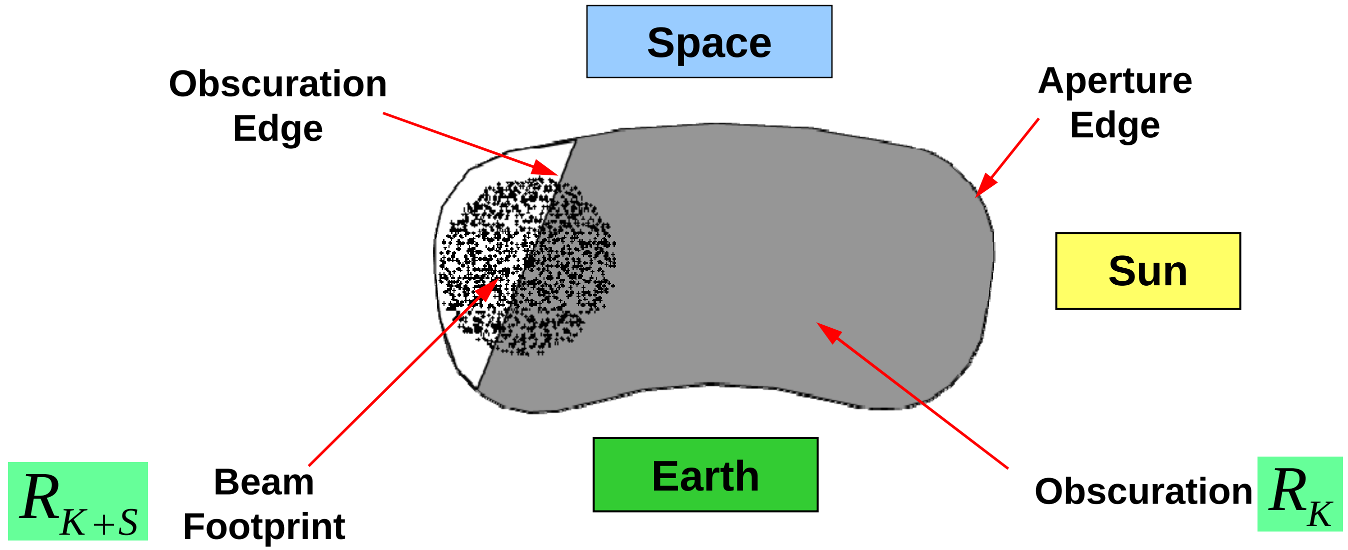
Description of Problem (I)

- HIRDLS experienced a debilitating event during launch (July 2004). From lengthy investigations, it has since been surmised that a piece(s) of poorly vented inner fore-optics cavity sheathing (Kapton®) had blown out during the rapid de-pressurization of launch.
- The post-event material configuration obstructs most of the view outward through the exit aperture, except for a small area at large anti-sunward azimuth angles (line-of-sight angle at –47°).
- Further, the scan mirror makes physical contact with the obstructing material, which modulates the channel radiance signal by way of material oscillations.

Description of Problem (II)

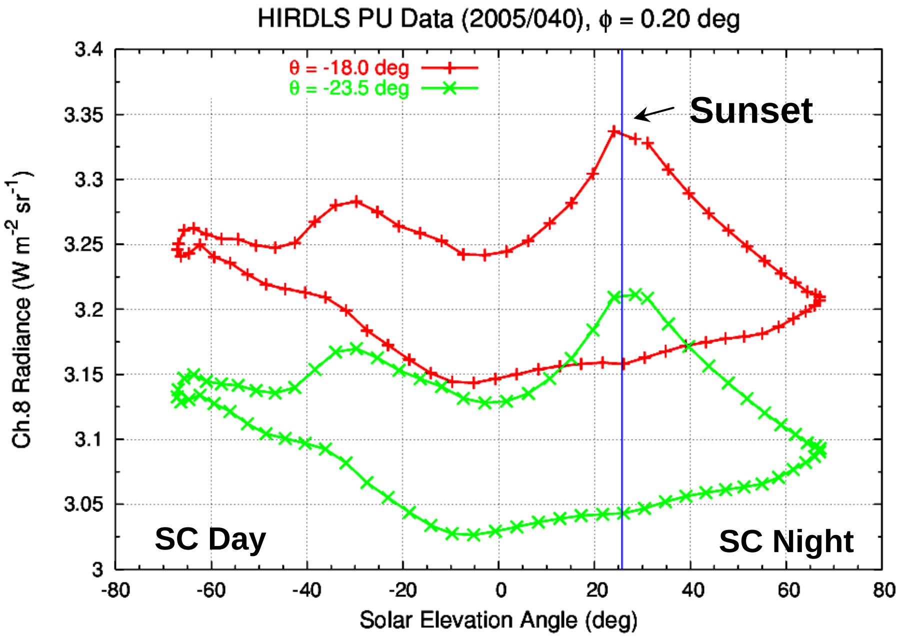
- After a period of characterizing the problem, attempts were made to move the obstructing material, all to no avail. To move forward, we had to live with the problem, and essentially "work around" it.
- Keeping the scan mirror at a fixed science-scan azimuth angle, the primary job has been to remove the influences of the obscuration from the channel radiances that feed into the Level-2 retrieval algorithms. There are three main components to this process:
  - Remove oscillation from vertical scan channel radiance profiles.
  - Subtract obscuration contribution to the channel radiances (R_{SS} - R_K)
  - Normalize radiance profile by the fraction of exit aperture area that is open, to obtain "clear-view" radiances. (R_{SS} - R_K) / OAF

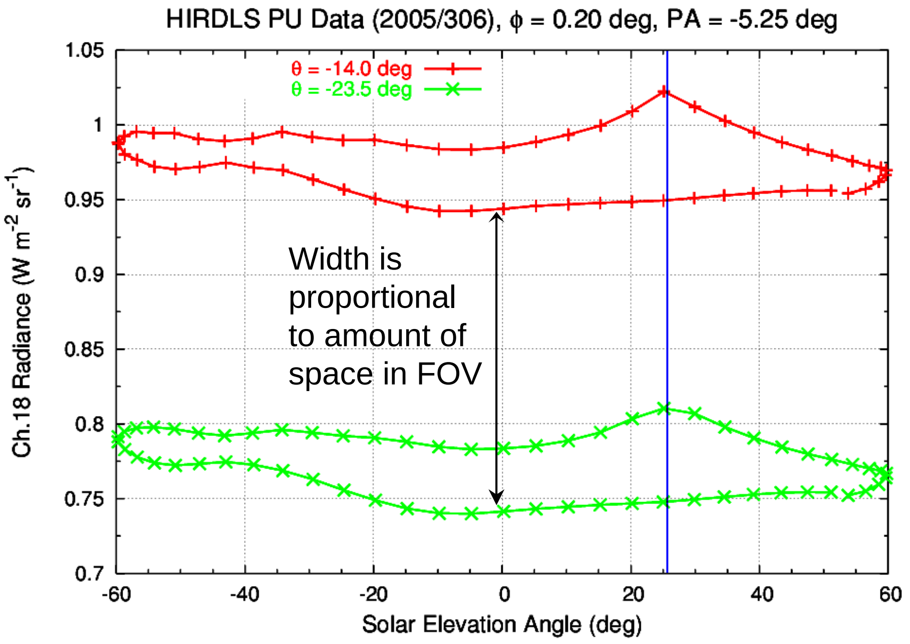
Schematic of HIRDLS Reduced Aperture



- Aperture open area fraction is elevation-shaft angle and channel dependent.
- Science scans are performed at one azimuth angle; namely, $\theta = -23.5°$.
- **The $64 question:** *How can the obscuration be characterized as a function of SM elevation-shaft angle in the presence of atmospheric effects?*
  Clue: A change in spacecraft (SC) orientation might do the trick…

Orbital Radiance Values at a Fixed ϕ

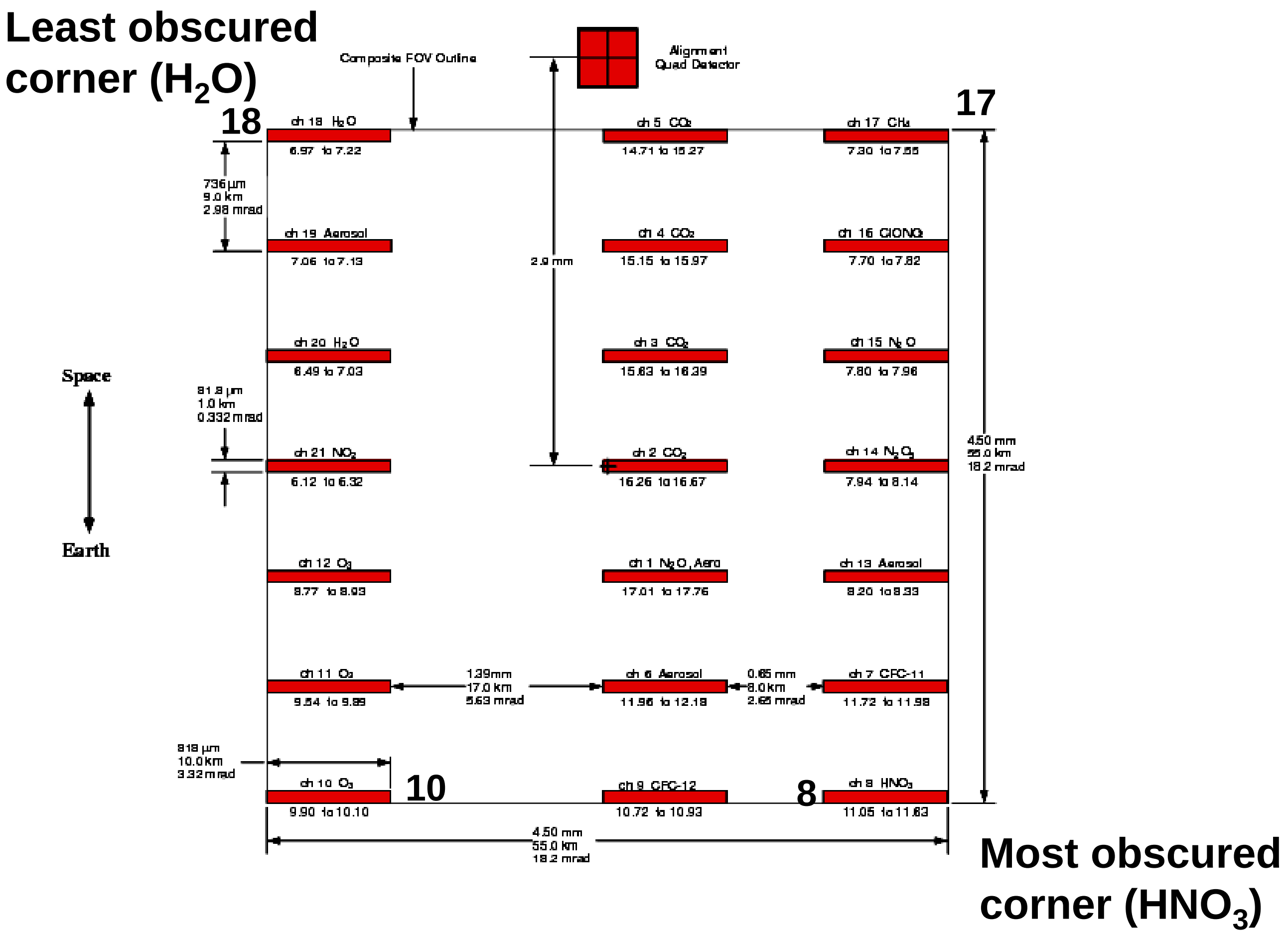




- Overall orbital morphologies are similar between Kapton & Kapton-only scans.
- Nighttime radiances show less orbit-to-orbit variability than daytime ones.

Detector Focal-plane Layout

Field-of-View Map

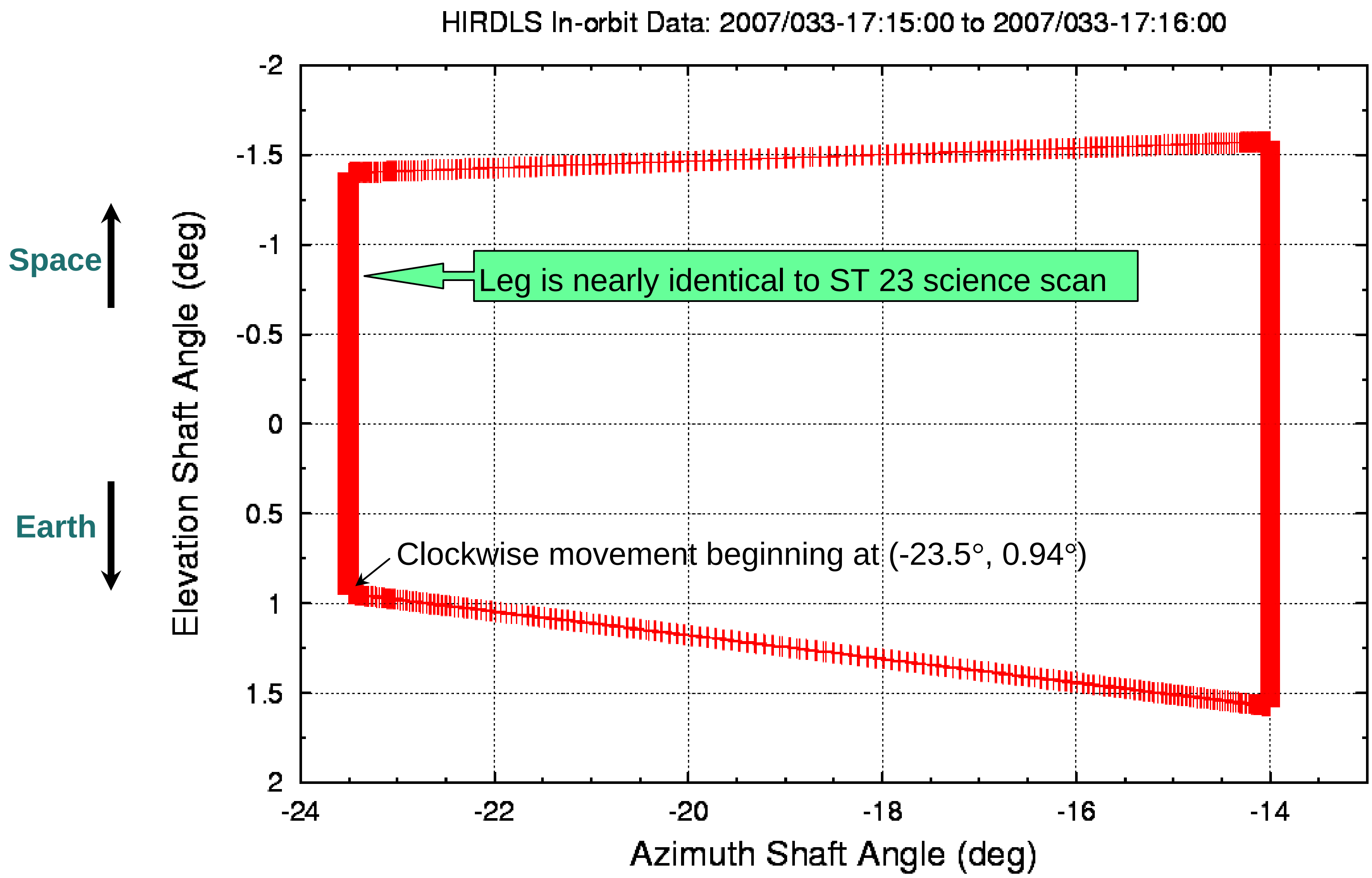


Spacecraft Pitch-maneuver Data

- Pitch-maneuver data are used to characterize the obscuration emission component of the scene radiance throughout the entire vertical scan range of interest.
- By pitching the SC a certain amount (most maneuvers use an angle of –5.25°), the obscuration signal is convolved with the infrared emission of cold space (essentially zero radiance). Measure R_{K+S} with $R_S = 0$ all ϕ.
- Pitch-maneuver data used for current OAF profiles:
  - March 2007 (pitch angle: –5.25°; mid solar-β angle)
  - November 2007 (pitch angle: –5.25°; minimum solar β angle)
- Scan tables used provided good temporal coverage over an orbit.

Scan Table 24

(Test Day: 2007/033, Normal Orientation)



General Data Analysis Methodology

- Kapton-only scans were co-located with its science scan counterpart (of same scan cycle) by linear interpolation.
- SC nighttime radiances were used if the entire scan had a solar-elevation angle of $\theta > 25.7°$.
  - SC night scans were used because the radiances and relevant instrument temperatures were both decreasing through the night (see Slide 11).
- Relevant instrument temperatures were tracked during a scan, and blackbody-equivalent radiances were calculated from these temperatures and used as independent-variable input in the model (next slide).
- Results for Channel 17 (CH_4), and the temperature sounding channels (CO_2), will be shown.

OAF Modeling Method

- Modeling the orbital radiances $R(\phi)$ for a given elevation-shaft angle, by select instrument temperature sensors for ***spacecraft nighttime*** scans, is a plausible concept because these select sensors show a fair amount of correlation with the orbital radiance values.

Difference in scalar fitting coefficient sums between Kapton and Kapton+space orbital fits yields the open-area fraction.

$$R(\phi) = \sum_{i=1}^{n} \alpha_i B_i(\phi)$$

Vector of instrument temp BB radiances.

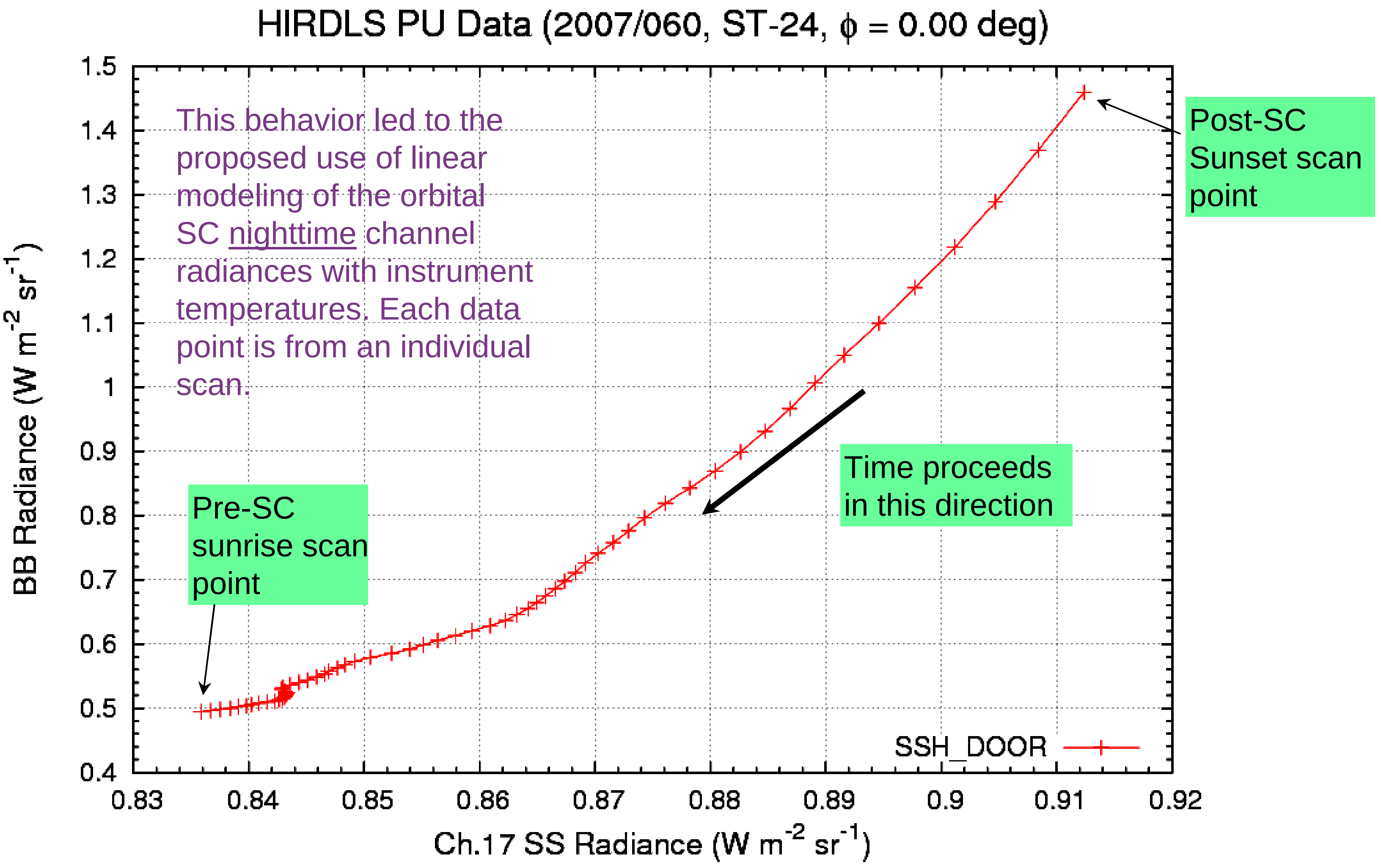
Fitting coefficients

$$OAF(-23.5°, \phi) = \sum_{i=1}^{N} \alpha_i^K - \sum_{i=1}^{N} \alpha_i^{SS}$$

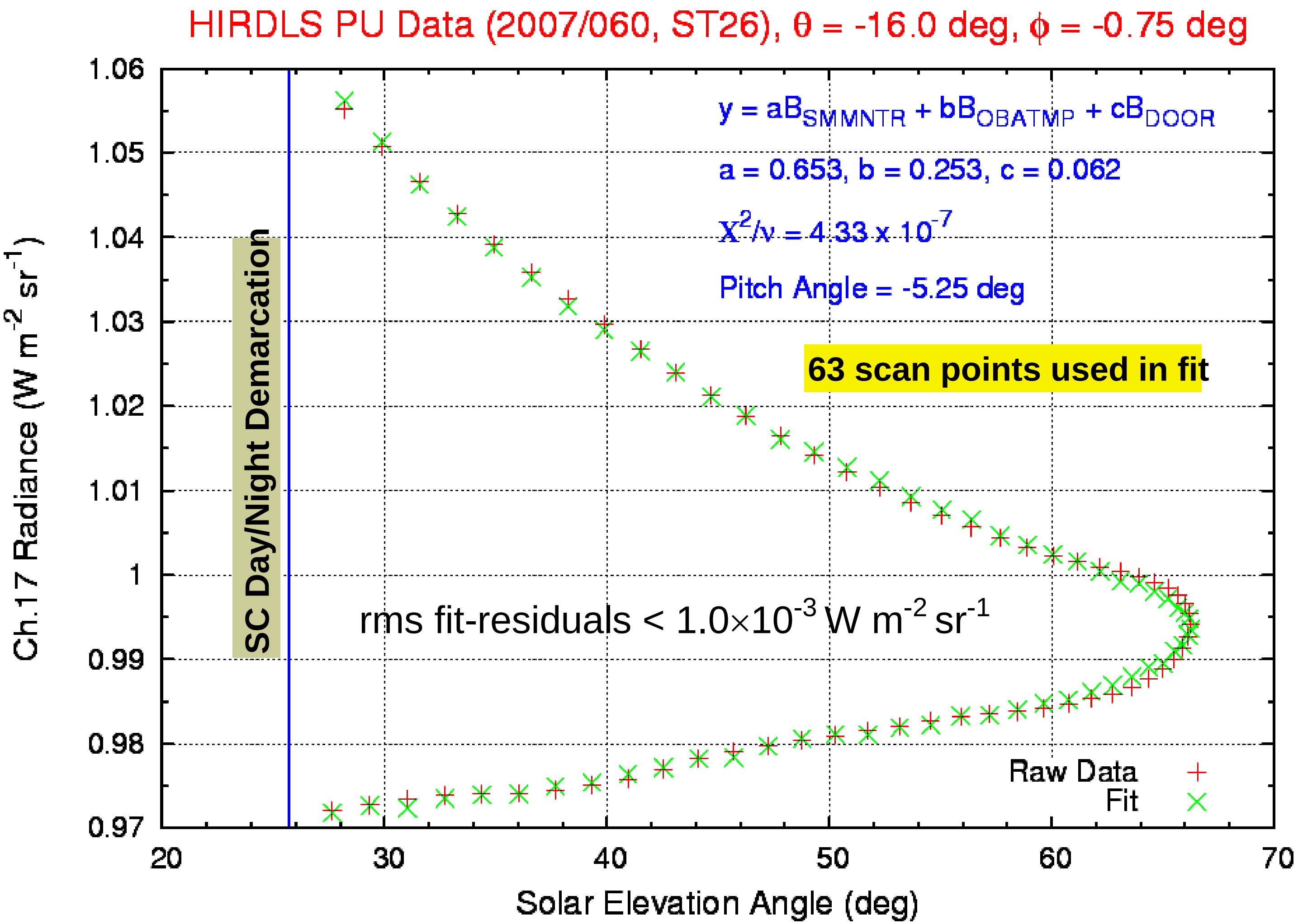
Sensors:
SSH_DOOR
OBA_TMP
SM_MTRING

These parameters provide the best fit and seem physically reasonable (*i.e.*, location of the sensors) in capturing the Kapton orbital NT variability.

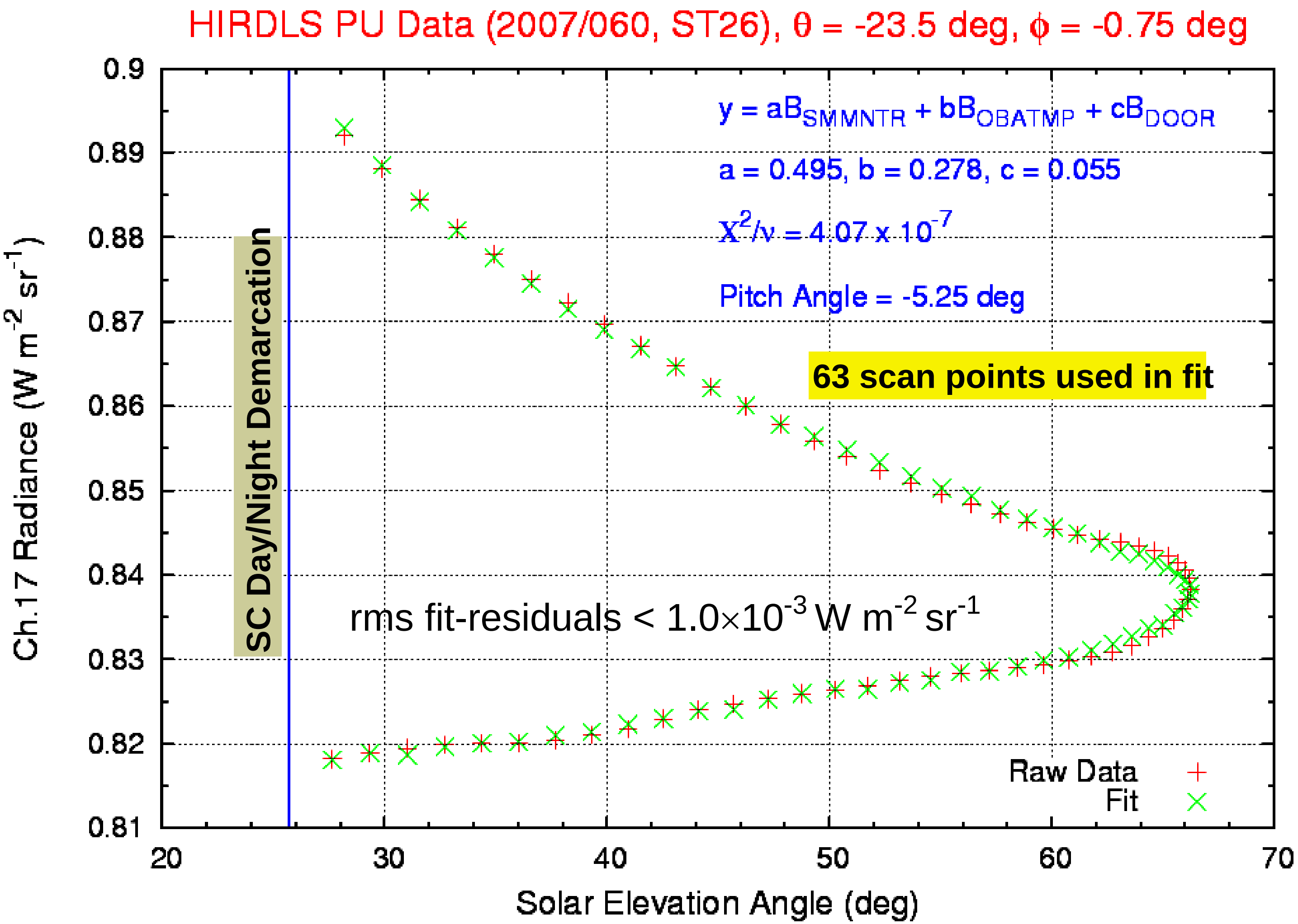
Sunshield Door Equivalent Blackbody Radiances Against Ch.17 Radiances



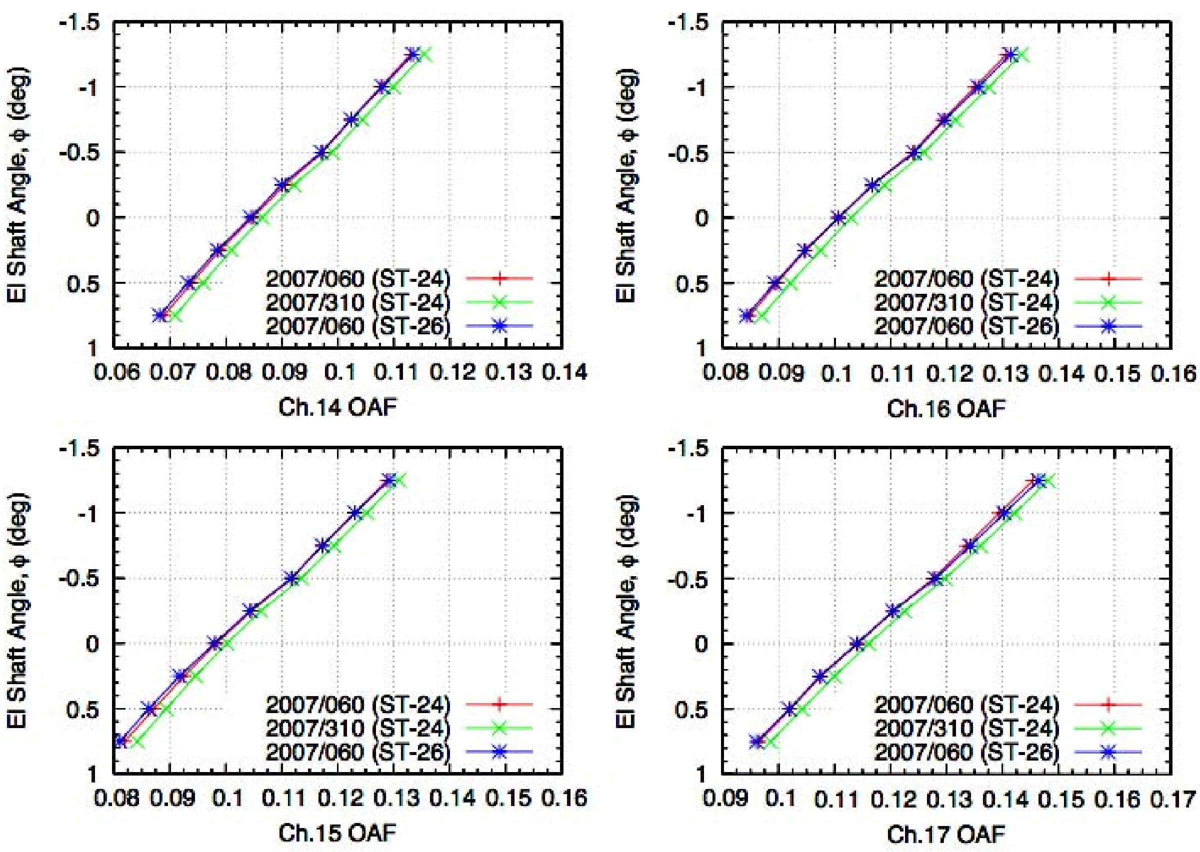
Model Performance
(Ch.17 SC Nighttime Kapton-only Scans)



Model Performance
(Ch.17 SC Nighttime Science Scans)



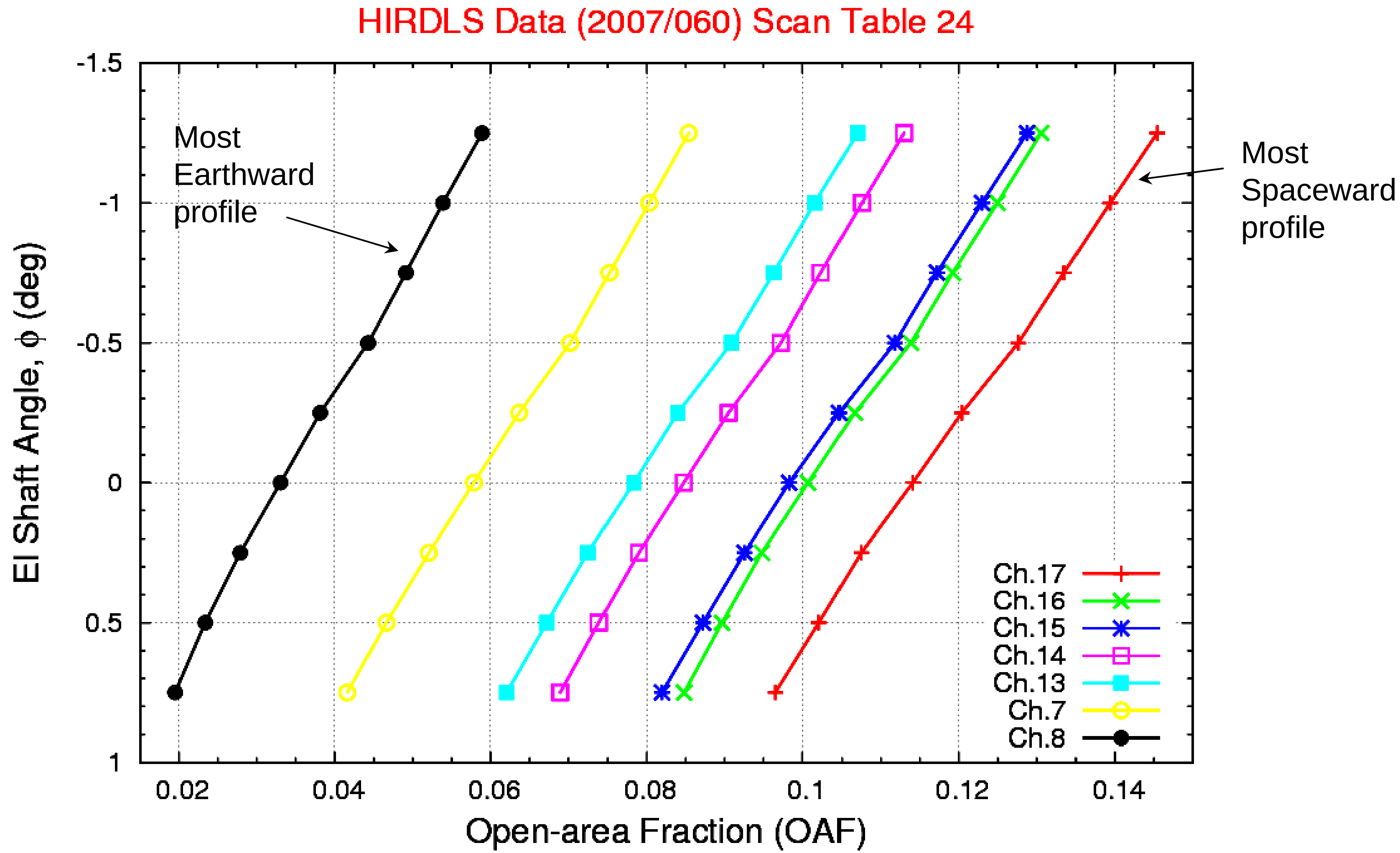
“Gang-of-four” Channels (14, 15, 16, & 17)



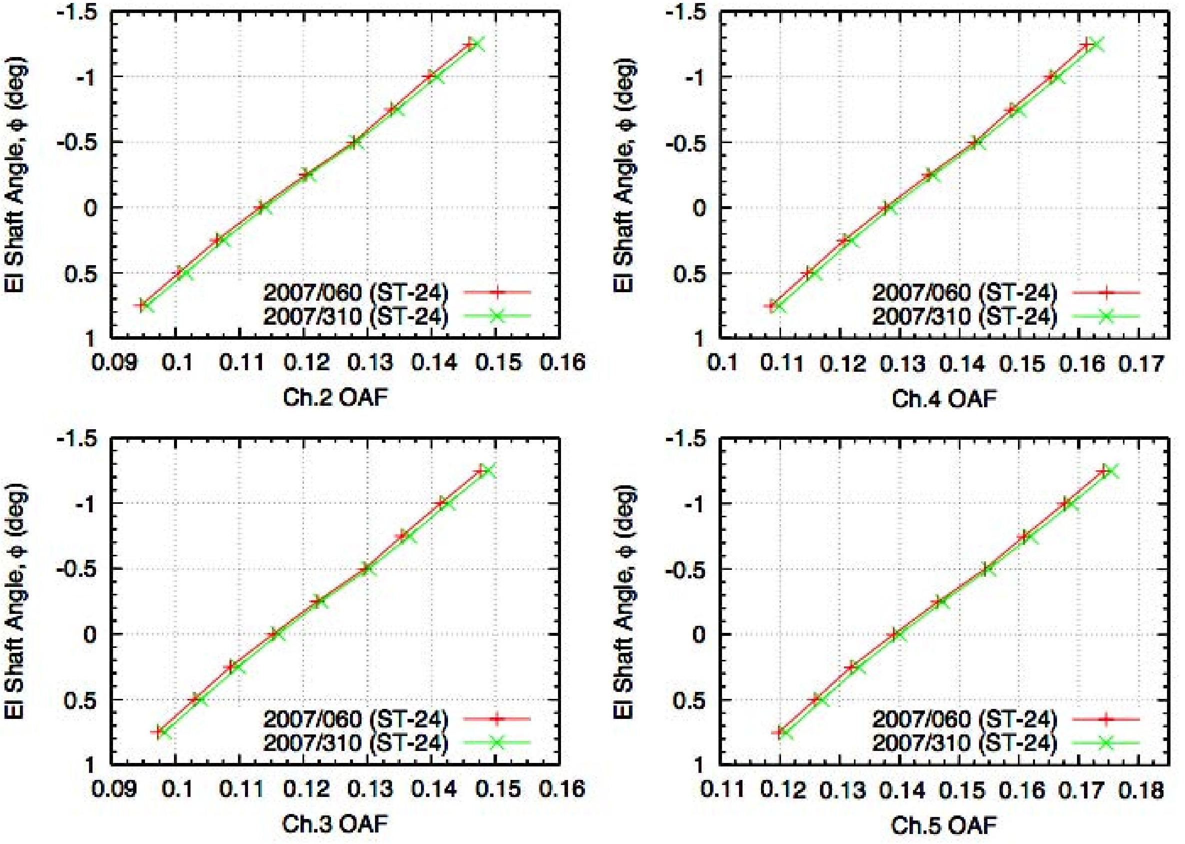
2007/060 OAF profiles are nearly identical. 2007/310 profile (ST-24) is slightly larger, but statistically is the same. Near-term improvements should rectify this minor dilemma.

Shapes are independent of season, scan direction, and SC orientation (at least where R_{K+S} is observed).

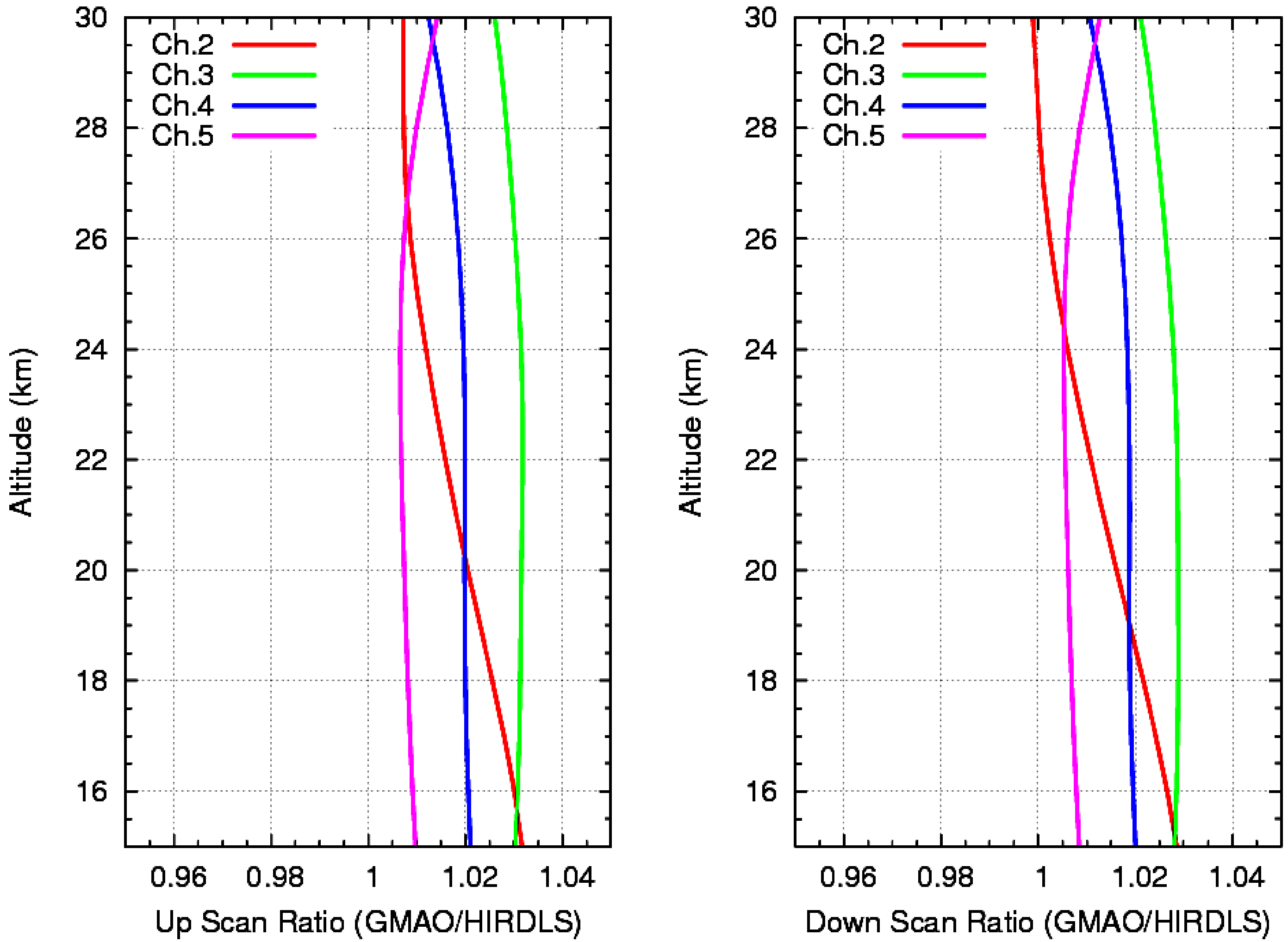
Ch.17 Column OAF Profiles



Temperature Channels (2, 3, 4, & 5)



OAF Diagnostic Ratios (CO_2 Channels) (2006/138)



GMAO temperature data is co-located to HIRDLS scan times. Simulated radiances are produced, and an average profile is generated.

Profiles are smoothly varying and close to unity. Main conclusion: Global correction is giving realistic numbers & behaviors.

Future Improvements and Conclusions

- Future improvements will deal with examining areas of clear linear correlation, and may include data after SC sunrise.
- Preliminary results show better model fits, which is the main goal.
- In summary, the HIRDLS OAF is on solid ground, and can be attributed to several factors:
  – Pitch maneuver data (2007) is of much better quality.
  – Analysis methodology is on firm ground.
  – Diagnostic profiles are a decent assessment tool.