Joint Center for Satellite Data Assimilation

Office Note CRTM-3

CRTM: INSAT-3D Imager and Sounder Spectral Response Function Processing

Paul van Delst[a]
NCEP/EMC/IMSG

July 7, 2014; rev42581

---

[a]paul.vandelst@noaa.gov

Change History

Date	Author	Change
2013-11-21	Paul van Delst	Initial draft.
2014-07-07	Paul van Delst	Modified for updated SRF data.

1 Introduction

This document describes the pre-processing applied to the INSAT-3D Imager and Sounder instruments updated spectral response functions (SRFs), obtained from Kishtawal [2014] in June 2014, to prepare for use in the CRTM processing chain. The SRFs are used to generate channel central frequencies, as well as in the convolution of monochromatic quantities such as Planck radiances or line-by-line (LBL) model generated transmittances to produce such things as polychromatic correction coefficients and instrument resolution transmittances. The latter, for a diverse set of atmospheric profiles, are then regressed against a set of predictors to produce the fast transmittance model coefficients used by the CRTM.

Comparisons are also made with the original SRF dataset [Hooda, 2013] obtained in October 2013.

1.1 Computation of the channel central frequency

The computed imager and sounder channel central frequencies, ν_0, are the first moments of the defined SRF, $\phi(\nu)$,

$$\nu_0 = \frac{\int \nu\, \phi(\nu)\, \mathrm{d}\nu}{\int \phi(\nu)\, \mathrm{d}\nu} \tag{1.1}$$

1.2 Computation of polychromatic correction coefficients

In the CRTM, the conversion of *channel resolution* radiances to brightness temperatures has to take the channel bandwidth into account. For any channel, the regression relation to be solved is

$$a_0 + a_1 T + \ldots = \frac{k_1}{\ln\left[\dfrac{k_2}{R(T)} + 1\right]} = Y(T) \tag{1.2}$$

where

$$\begin{aligned} T &= \text{brightness temperature} \\ a_j &= \text{regression coefficients} \\ k_1, k_2 &= \text{Planck coefficients} \\ R(T) &= \text{channel radiance} \\ Y(T) &= \text{“effective” brightness temperature, or } T_{eff} \end{aligned}$$

and the channel radiances used to determine the effective temperatures, $Y(T)$, are computed the usual way

$$R(T) = \frac{\int B(T,\nu)\, \phi(\nu)\, \mathrm{d}\nu}{\int \phi(\nu)\, \mathrm{d}\nu} \tag{1.3}$$

The quantity minimised to obtain the a_j coefficients is

$$\left[\sum_{j=0}^{M} a_j T_i - Y(T_i)\right]^2 \quad \text{for} \quad T_i = 150K, \ldots, 340K \ \text{ in 5K steps.} \tag{1.4}$$

Currently the number of coefficients is fixed at two (i.e. $M = 1$).

2 Summary

The following tables list the computed central frequencies and polychromatic correction coefficients for the imager and sounder instruments, as well the differences with the same quantities obtained from the original set of SRFs.

2.1 Imager

Plots of the Imager SRF data, and their differences, are shown in appendix A. The temperature fit residuals for each channel, and their differences from those of the original SRF dataset, are shown in appendix B.

Imager Channel	ν_0 (cm^{-1})	a_0 (offset) (K)	a_1 (slope) (K/K)
3	2548.42014	0.39830363	0.99942687
4	1454.40973	0.62372841	0.99852040
5	925.09803	0.38137920	0.99868532
6	837.38593	0.26594109	0.99899992

Table 2.1: The computed INSAT-3D Imager channel central frequencies and polychromatic correction coefficients.

Imager Channel	$\Delta\nu_0$ (cm^{-1})	Δa_0 (offset) (K)	Δa_1 (slope) (K/K)
3	1.222473e-01	5.340637e-03	-7.614884e-06
4	-2.330886e-01	-5.954575e-03	1.229867e-05
5	2.532271e-01	9.930551e-04	-3.163284e-06
6	5.192023e-01	1.575004e-03	-5.534034e-06

Table 2.2: The difference between the computed INSAT-3D Imager channel central frequencies and polychromatic correction coefficients for the updated SRFs.

2.2 Sounder

Plots of the Sounder SRF data, and their differences, are shown in appendix C. The temperature fit residuals for each channel, and their differences from those of the original SRF dataset, are shown in appendix D.

It should be noted here that there are significant SRF differences for some of the sounder channels, in particular the shortware channels 13-18. For these channels there is a sgnificant shift of the SRFs to lower frequencies. This is reflected in the central frequency differences shown in table 2.4, with $\Delta\nu_0$ values for channels 13-18 ranging from 7-15cm^{-1}. See figures C.13 to C.18 for plots of those particular SRFs.

Sounder Channel	ν_0 (cm^{-1})	a_0 (offset) (K)	a_1 (slope) (K/K)
1	681.62206	0.03046981	0.99986043
2	698.62139	0.01879741	0.99991614
3	712.58032	0.02289618	0.99989992
4	733.35257	0.03227880	0.99986293
5	750.09886	0.03643214	0.99984866
6	794.15150	0.09316524	0.99963313
7	834.32264	0.19522736	0.99926418
8	909.58337	0.17639610	0.99938313
9	1031.98619	0.06386464	0.99979895
10	1346.10910	0.18572004	0.99952975
11	1420.56284	0.39893243	0.99903751
12	1533.28319	0.23487739	0.99946755
13	2167.56741	0.03284663	0.99994502
14	2202.05890	0.03255260	0.99994615
15	2232.00124	0.03692231	0.99993955
16	2407.95850	0.06765204	0.99989696
17	2495.40576	0.07411556	0.99989035
18	2642.07962	0.29912655	0.99958143

Table 2.3: The computed INSAT-3D Sounder channel central frequencies and polychromatic correction coefficients.

Sounder Channel	$\Delta\nu_0$ (cm^{-1})	Δa_0 (offset) (K)	Δa_1 (slope) (K/K)
1	-2.384271e-02	-3.624546e-03	1.668416e-05
2	8.865027e-02	-1.526845e-02	6.818310e-05
3	4.900753e-01	-4.772684e-03	2.092925e-05
4	3.295078e-01	-8.518261e-03	3.620886e-05
5	-6.201422e-01	-5.343381e-03	2.205690e-05
6	1.554839e+00	-6.541811e-03	2.635550e-05
7	7.305848e-02	-6.097686e-03	2.316287e-05
8	3.525065e+00	3.889811e-03	-1.204881e-05
9	2.663744e+00	7.985571e-03	-2.478078e-05
10	1.640695e+00	-4.912065e-02	1.249970e-04
11	-1.523594e+00	-1.921560e-01	4.823958e-04
12	2.733226e+00	-1.121861e-01	2.577023e-04
13	-1.597081e+01	9.645771e-04	-1.859146e-06
14	-7.024429e+00	7.376784e-04	-1.467514e-06
15	-9.069491e+00	-1.235584e-03	1.723795e-06
16	-1.180761e+01	2.795438e-03	-4.620730e-06
17	-1.464507e+01	5.941099e-04	-1.262977e-06
18	-1.554782e+01	2.980200e-02	-4.402094e-05

Table 2.4: The difference between the computed INSAT-3D Sounder channel central frequencies and polychromatic correction coefficients for the updated SRFs.

3 Truncation of SRF data

The SRFs were reported on the same frequency grid for all channels in an instrument, with out-of-band responses set to zero. To minimise the number of frequencies for which LBL calculations would be done, the SRF data were truncated to eliminate the zero-valued out-of-band elements. The truncation points were selected automatically by determining the first non-zero point either side of the SRF, and then extending back 20 data points.

3.1 Imager

The truncation frequencies for the imager instrument are shown in table 3.1. The "character" of the imager SRFs at low response levels near the truncations points are shown in figure 3.1

Sounder Channel	ν_1 (cm^{-1})	ν_2 (cm^{-1})
3	2449.10	2647.40
4	1338.60	1564.40
5	869.20	986.20
6	788.00	882.20

Table 3.1: The frequencies at which the INSAT-3D Imager channel SRFs were truncated prior to processing.

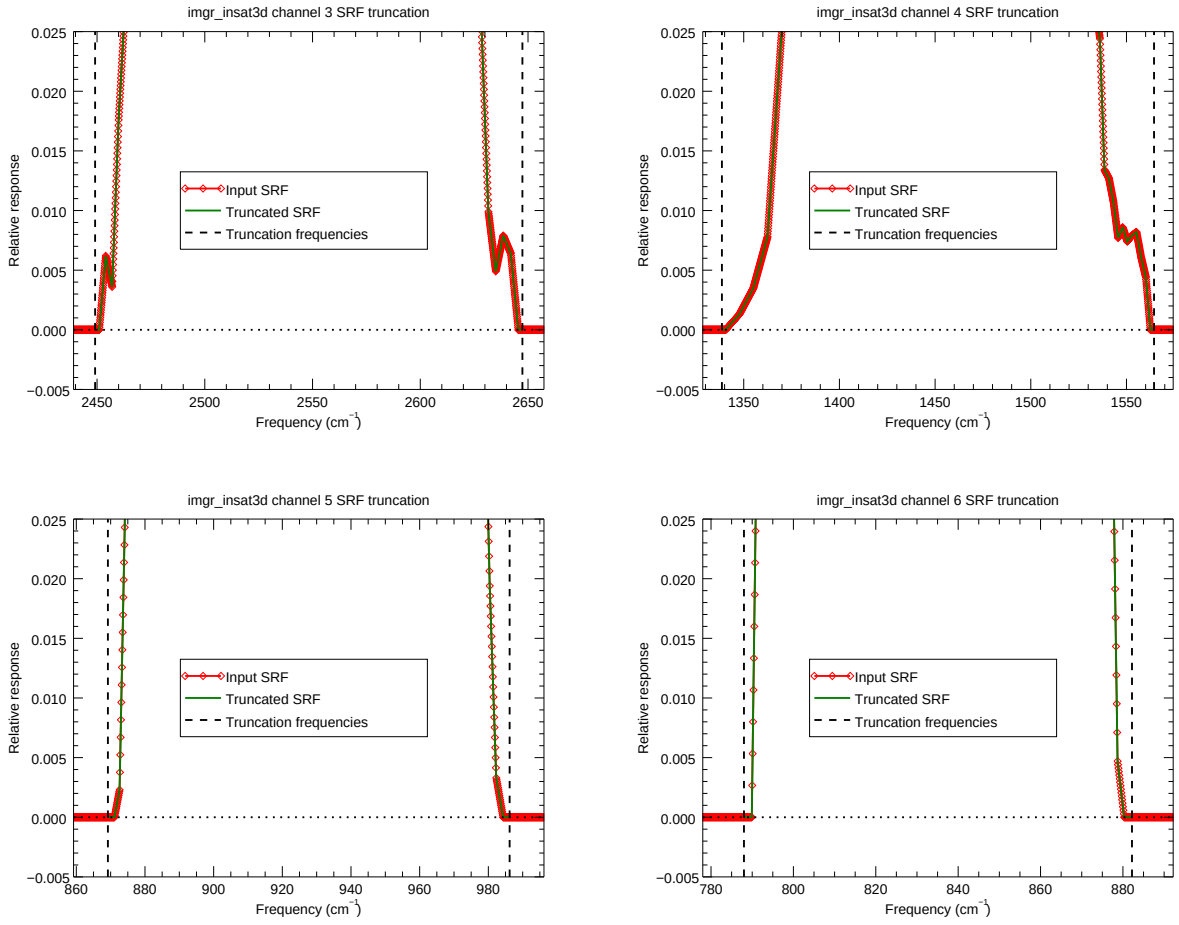

Figure 3.1: INSAT-3D Imager channels 3-6 SRFs at low response levels near the truncation frequencies.

3.2 Sounder

The truncation frequencies for the sounder instrument are shown in table 3.2. The "character" of the sounder SRFs, for a selection of channels, at low response levels near the truncations points are shown in figure 3.2.

Sounder Channel	ν_1 (cm^{-1})	ν_2 (cm^{-1})
1	660.90	704.70
2	683.30	715.20
3	695.50	730.00
4	712.70	757.30
5	727.50	776.60
6	758.30	831.60
7	781.50	884.30
8	861.20	962.80
9	996.90	1068.90
10	1271.50	1409.20
11	1319.40	1524.90
12	1458.30	1605.50
13	2135.20	2208.10
14	2168.50	2237.70
15	2197.20	2268.10
16	2363.60	2457.40
17	2447.00	2547.40
18	2552.00	2736.80

Table 3.2: The frequencies at which the INSAT-3D Sounder channel SRFs were truncated prior to processing.

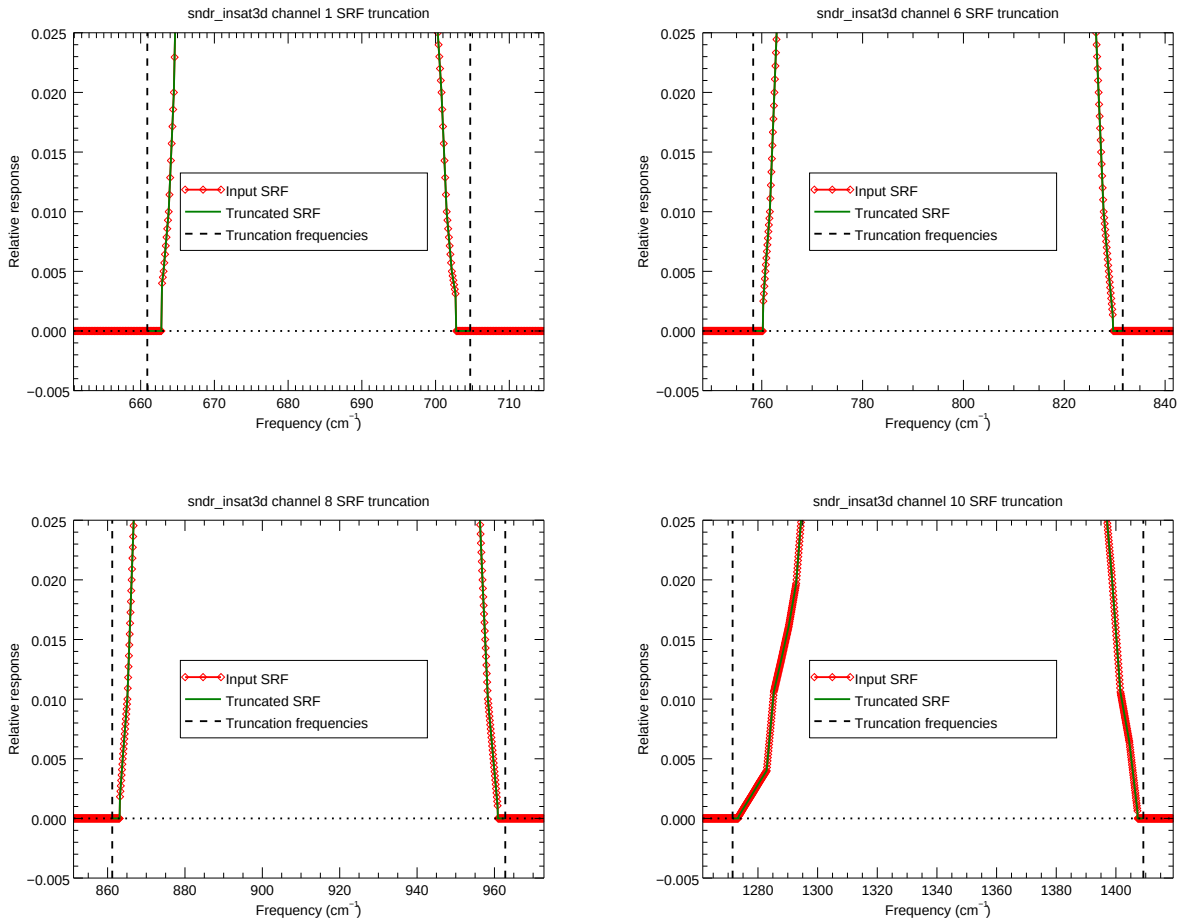

Figure 3.2: A selection of INSAT-3D Sounder channel SRFs at low response levels near the trunction frequencies.

4 Impact of updated SRFs on convolved radiances

To determine the impact of the updated SRFs on the convolved channel radiancesd, both sets of data (original and updated SRFs) were convolved with LBL-model generated radiances.

LBLRTM [Clough et al., 2005] v12.2 was used with the ECMWF83 atmospheric profile dataset to generate radiance spectra. The radiance spectra were convovled with the SRFs to yield channel resolution radiances which were then converted to brightness temperatures for each SRF set. The statistics of the brightness temperature differences for the Imager instrument are shown in figure 4.1, and in 4.2 for the Sounder. For the Imager, the largest individual differences are the hundredths of a Kelvin level. For the Sounder, however, the large differences between the original and updated SRF datasets for the shortwave channels, 13-18 (see figures C.13-C.18), are reflected in the 4-8K brightness temperatures differences for some of those channels, 13-16. Channels 17 and 18 are less affected by the SRF shifts as they are window channels.

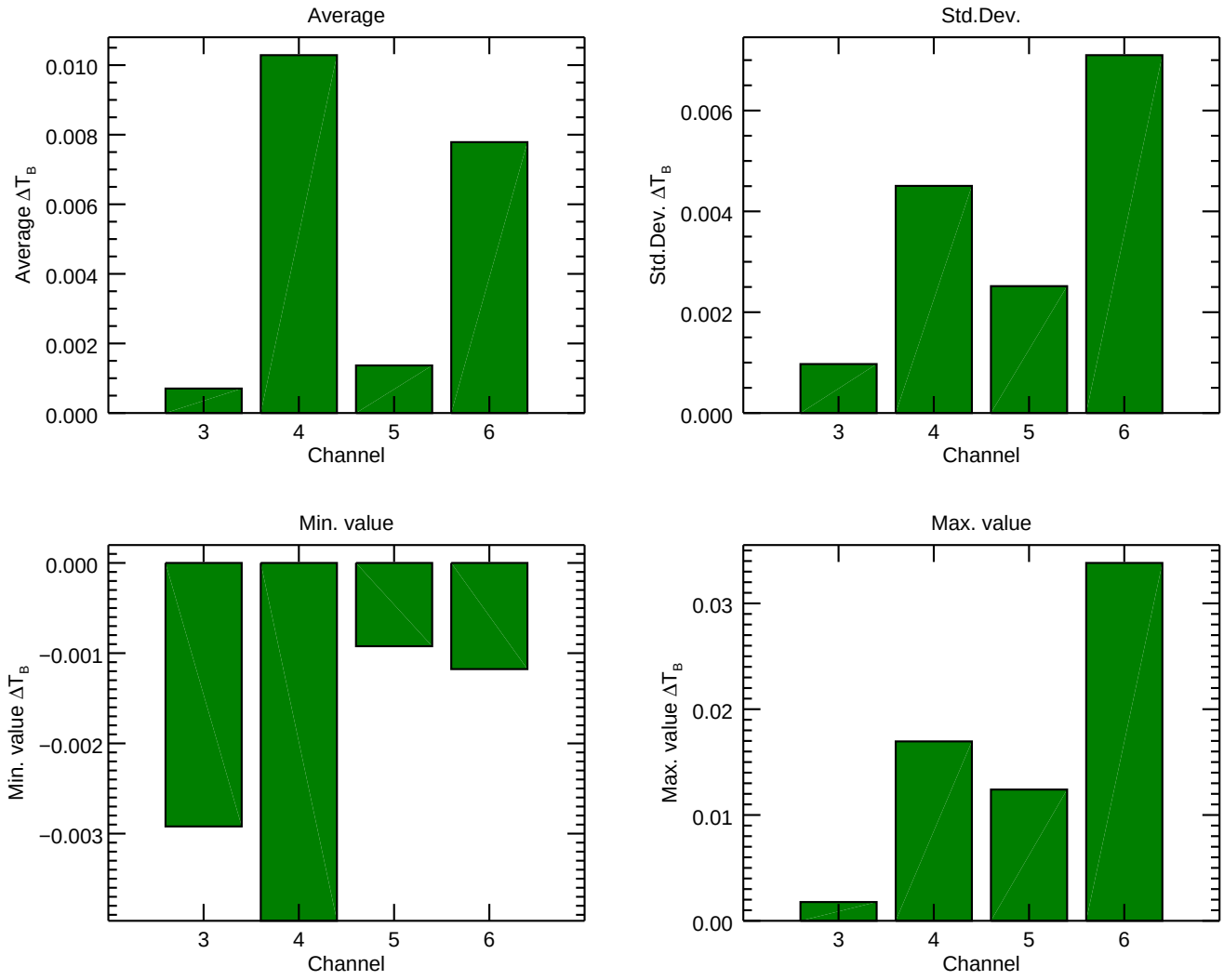

Figure 4.1: Statistics of the brightness temperature differences between the original and updated INSAT-3D Imager SRFs. The calculations used LBLRTM v12.2 and the ECMWF83 profile dataset with a surface emissivity of 0.95.

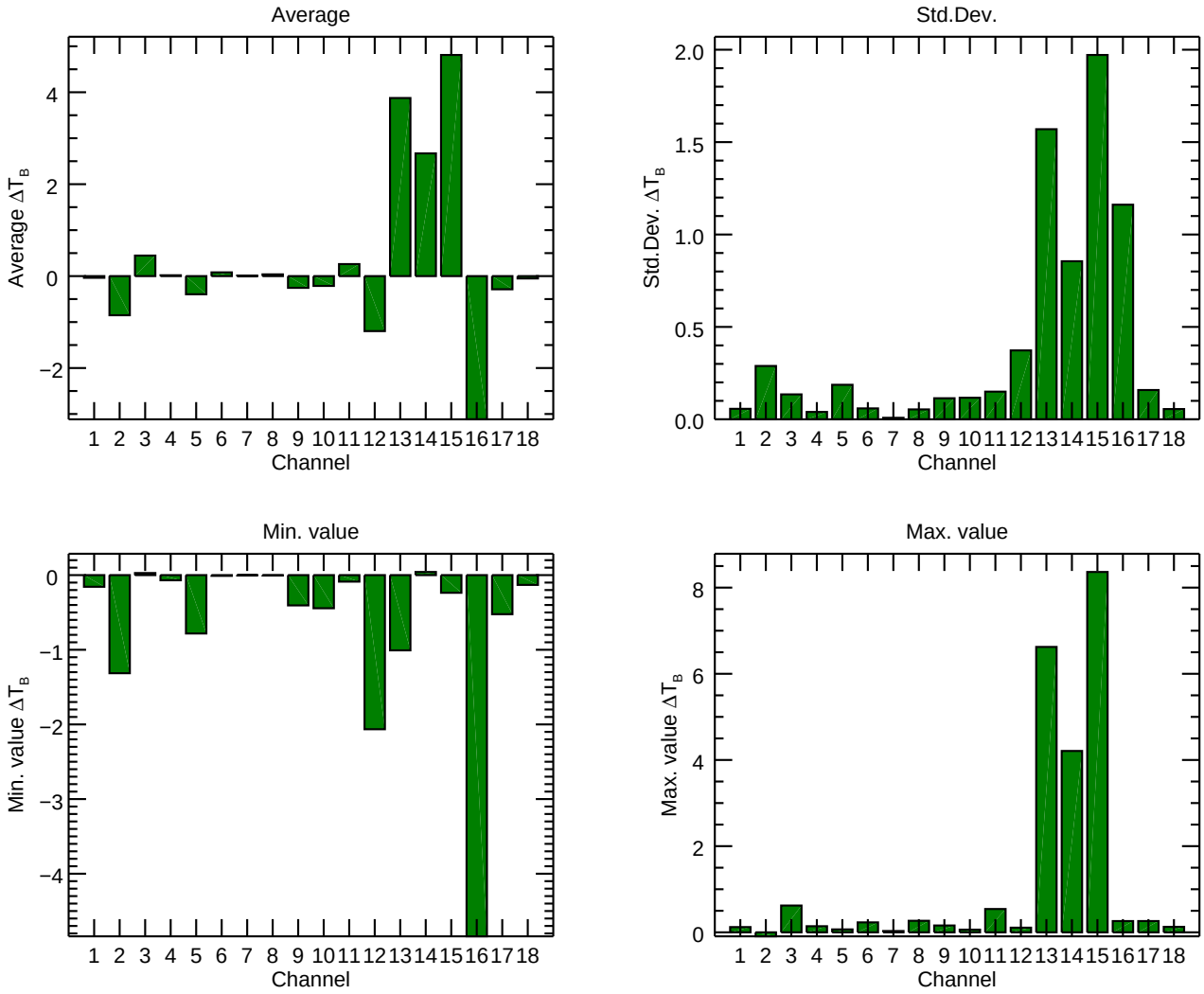

Figure 4.2: Statistics of the brightness temperature differences between the original and updated INSAT-3D Sounder SRFs. The calculations used LBLRTM v12.2 and the ECMWF83 profile dataset with a surface emissivity of 0.95.

References

S.A. Clough, M.W. Shephard, E.J. Mlawer, J.S. Delamere, M.J. Iacono, K. Cady-Pereira, S. Boukabara, and P. D. Brown. Atmospheric radiative transfer modeling: a summary of the AER codes. *J. Quant. Spectrosc. Radiat. Transfer*, 91:233–244, 2005.

R.S. Hooda. INSAT-3D Imager and Sounder Spectral Response Function (SRF, or RSR) Data. Private communication, Oct. 2013.

C.M. Kishtawal. INSAT-3D Imager and Sounder Spectral Response Function (SRF, or RSR) Data. Private communication, Jun. 2014.

A INSAT-3D Imager SRFs

A.1 Channel 3

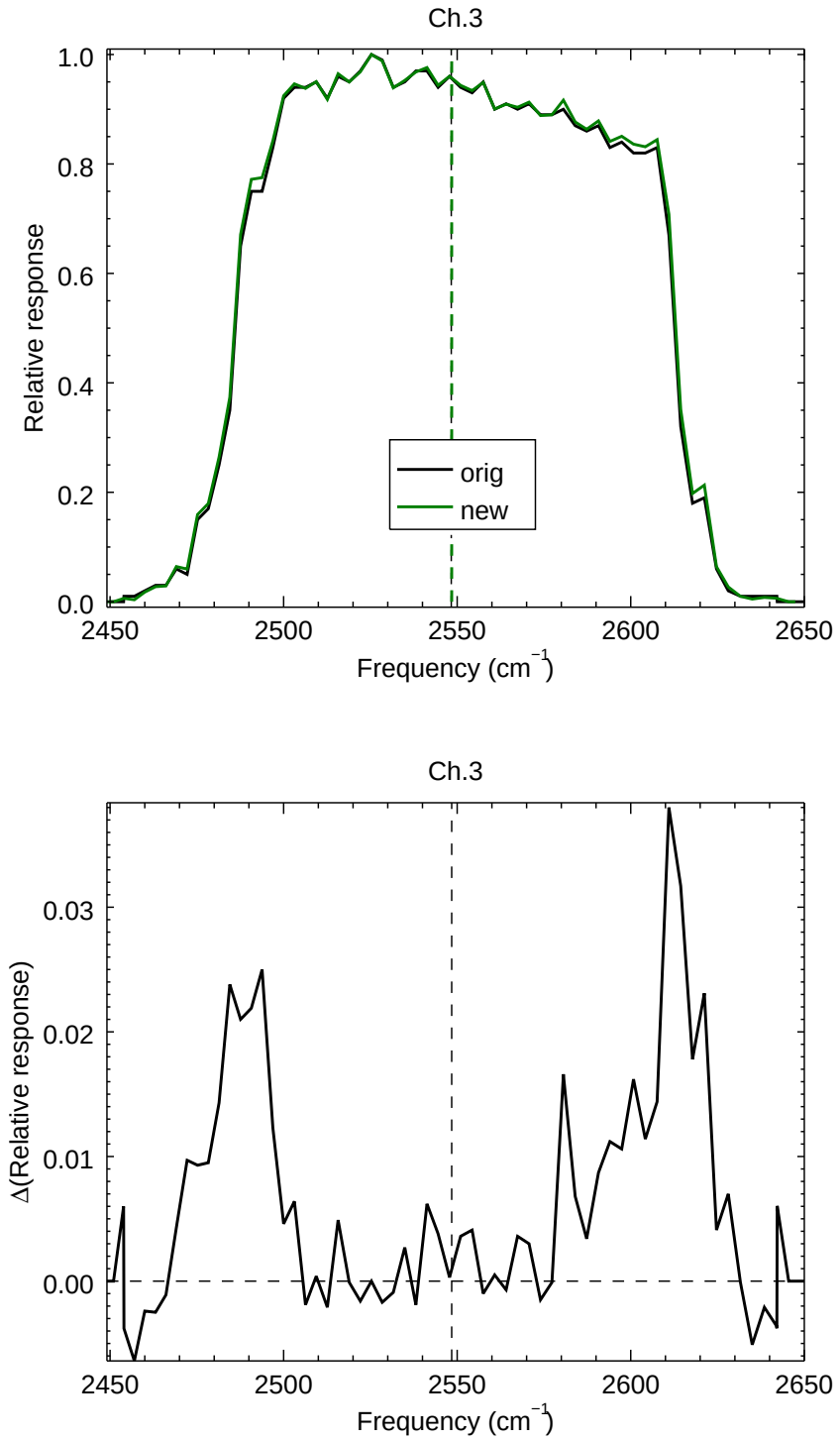

Figure A.1: INSAT-3D Imager channel 3 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

A.2 Channel 4

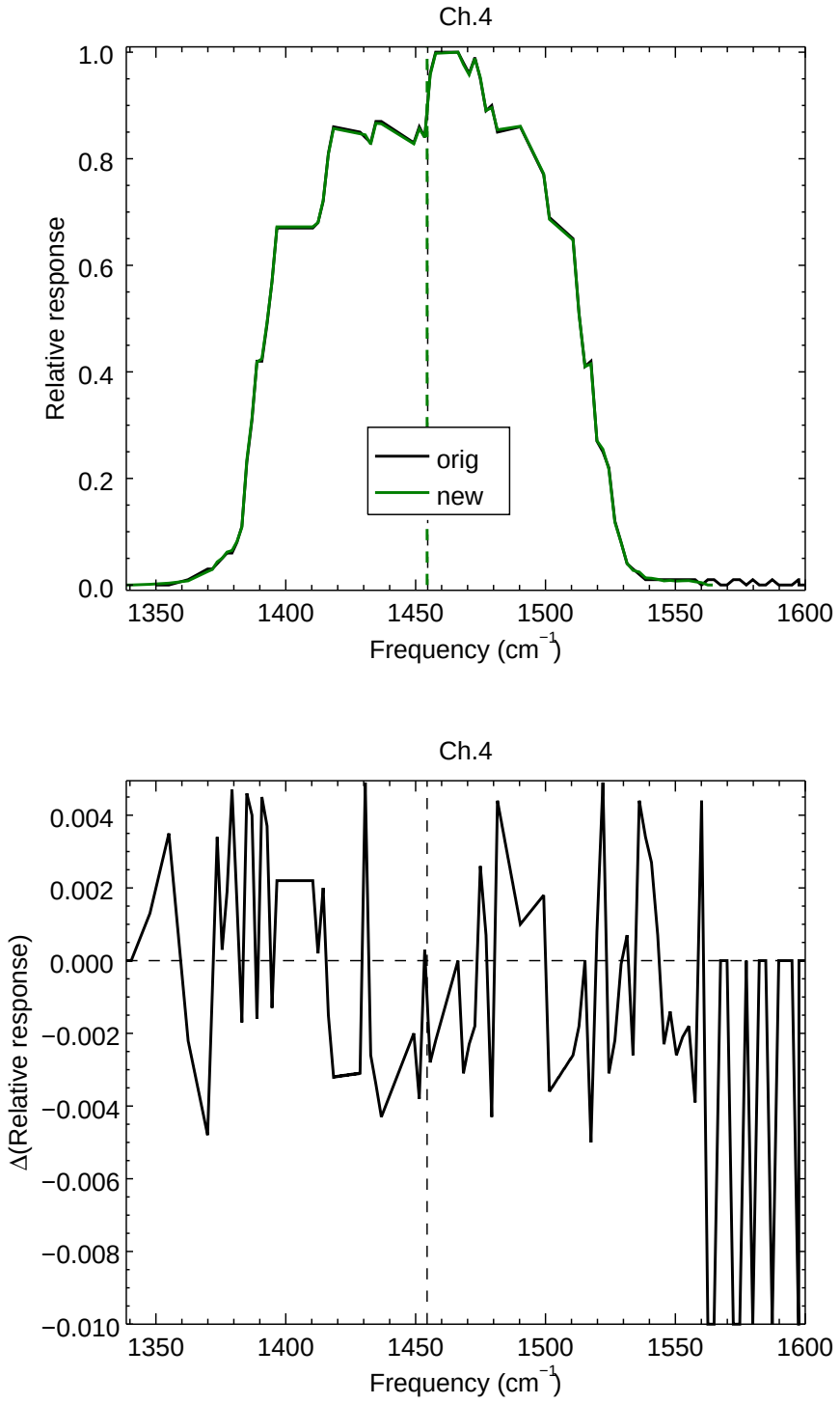

Figure A.2: INSAT-3D Imager channel 4 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

A.3 Channel 5

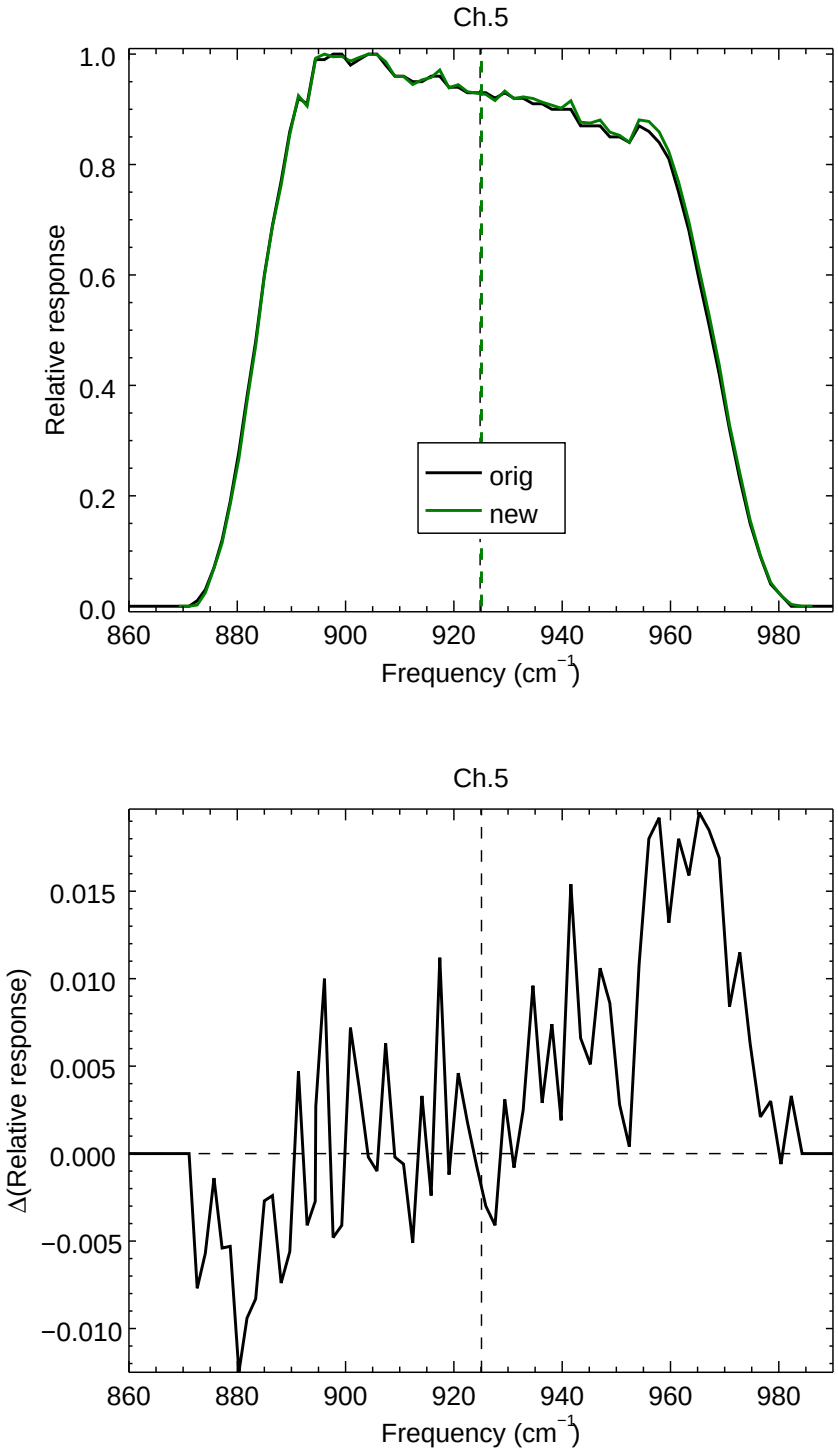

Figure A.3: INSAT-3D Imager channel 5 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

A.4 Channel 6

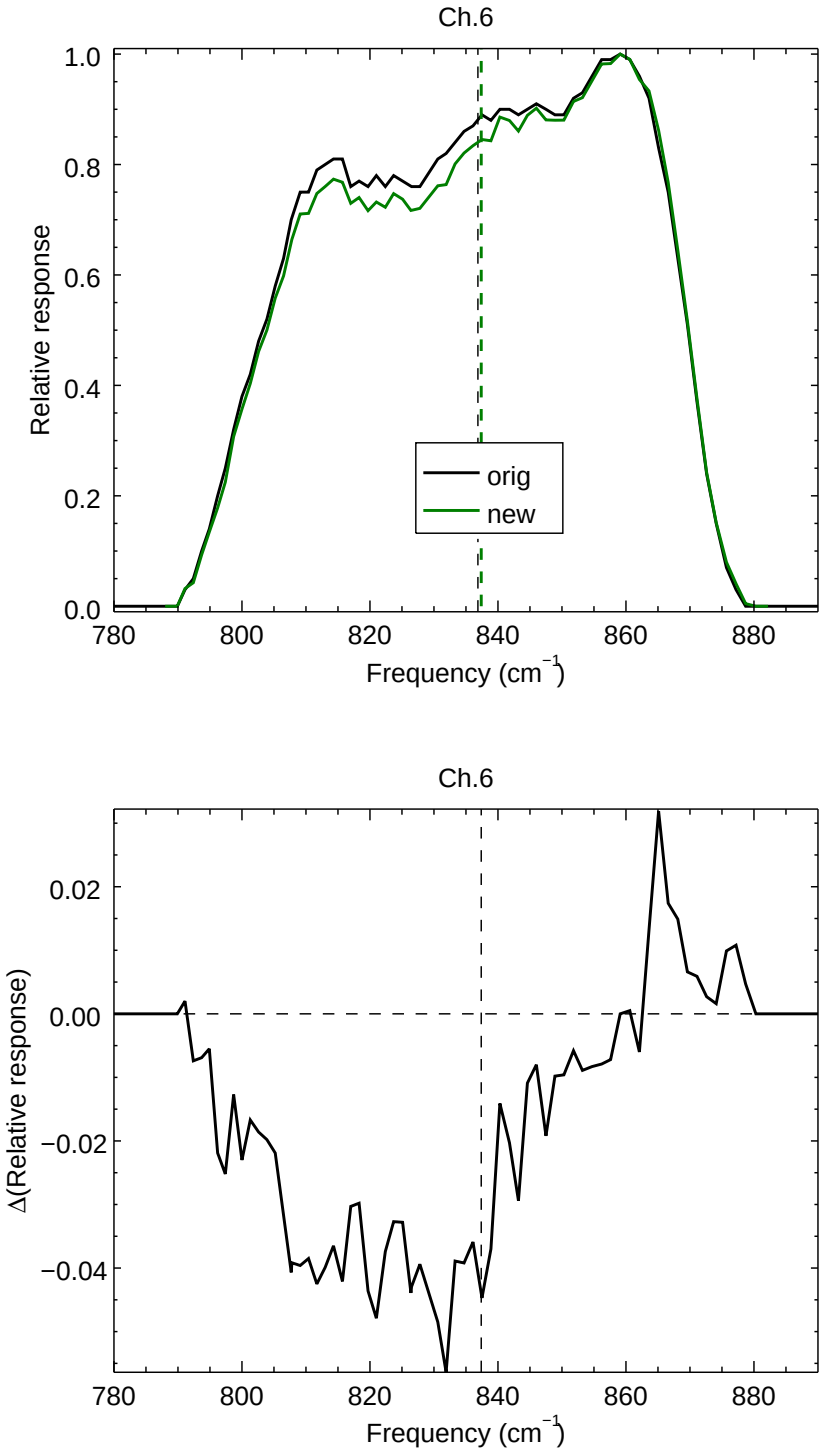

Figure A.4: INSAT-3D Imager channel 6 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

B INSAT-3D Imager Polychromatic Correction Temperature Fit Residuals

B.1 Channel 3

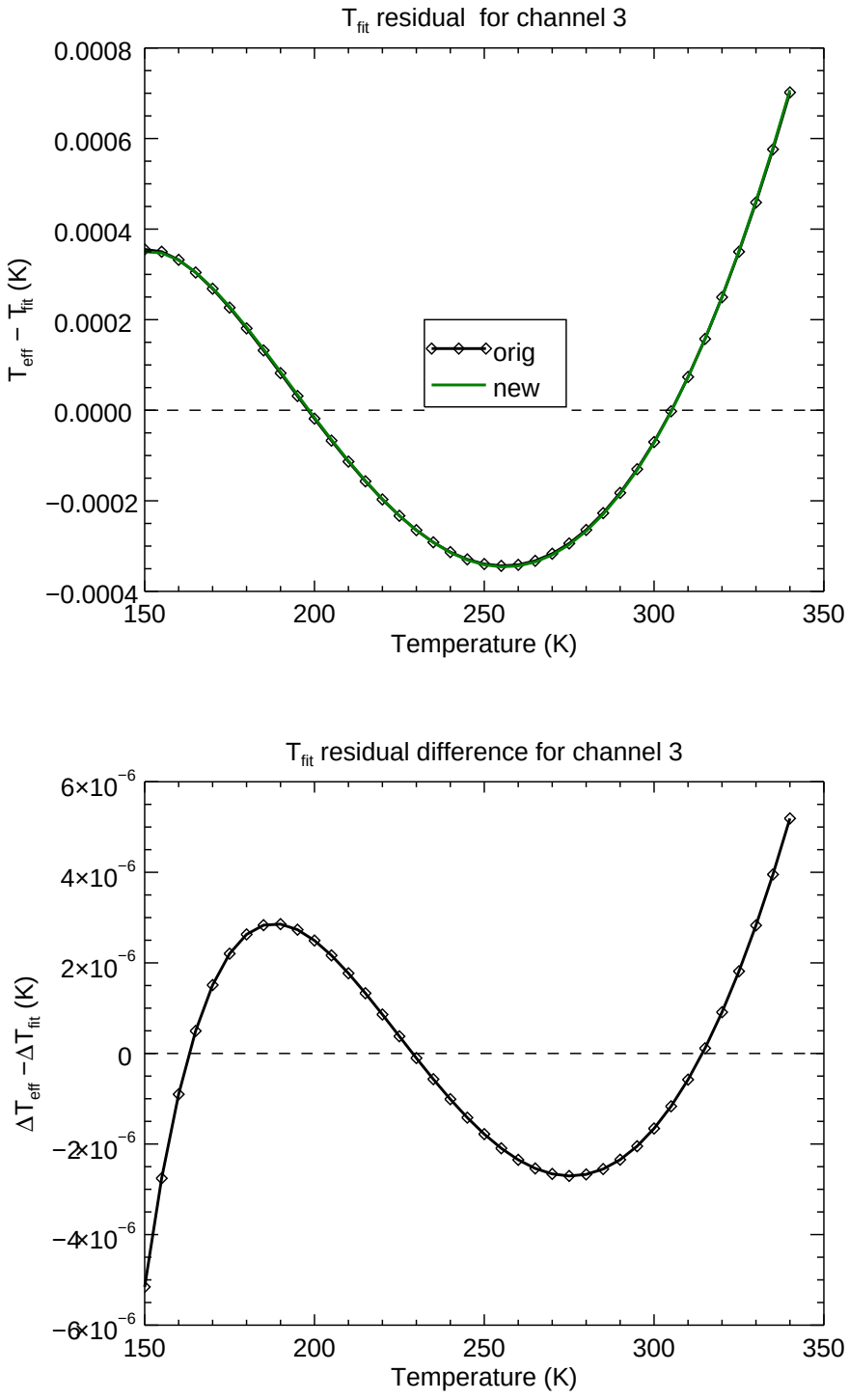

Figure B.1: INSAT-3D Imager channel 3 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

B.2 Channel 4

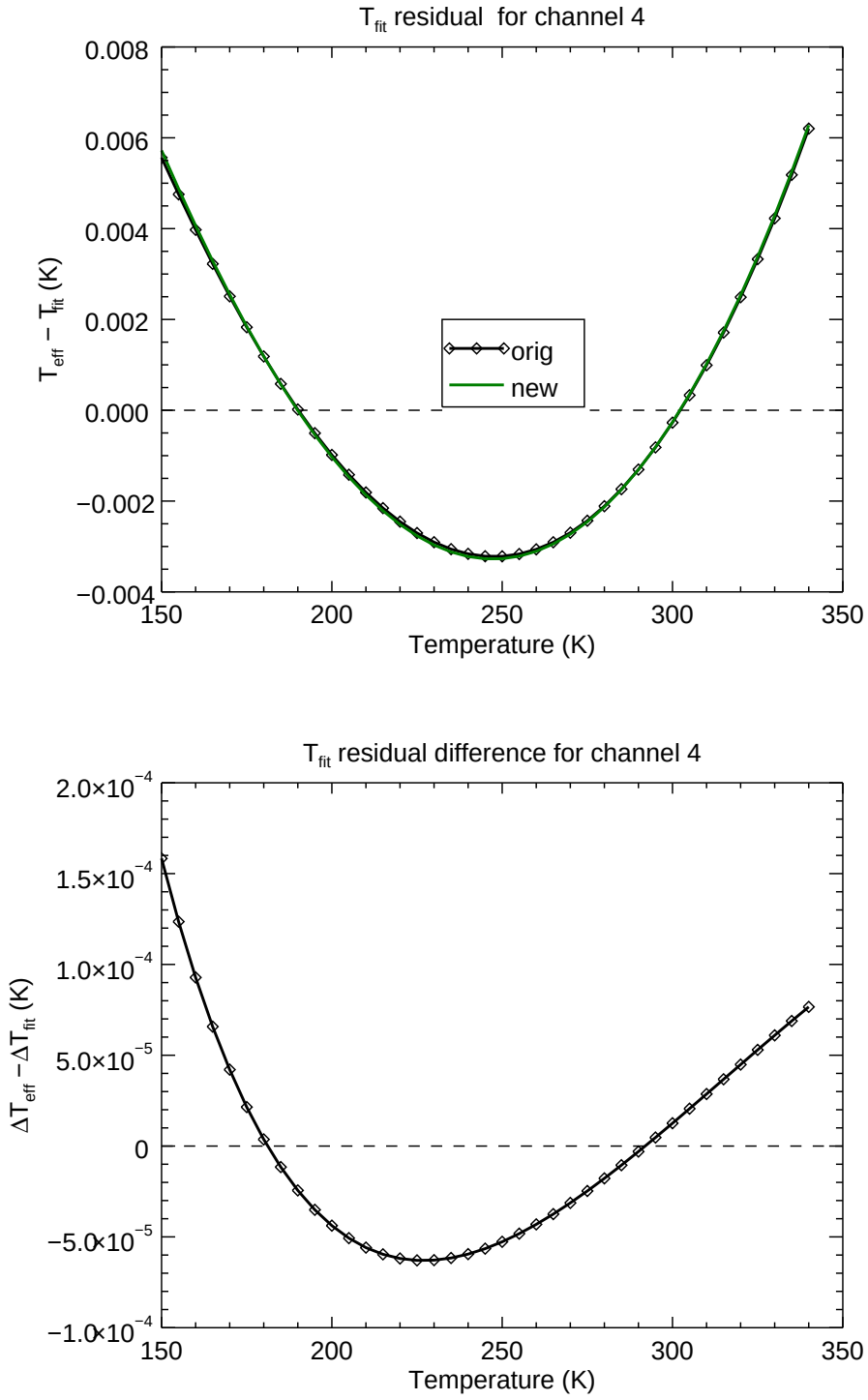

Figure B.2: INSAT-3D Imager channel 4 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

B.3 Channel 5

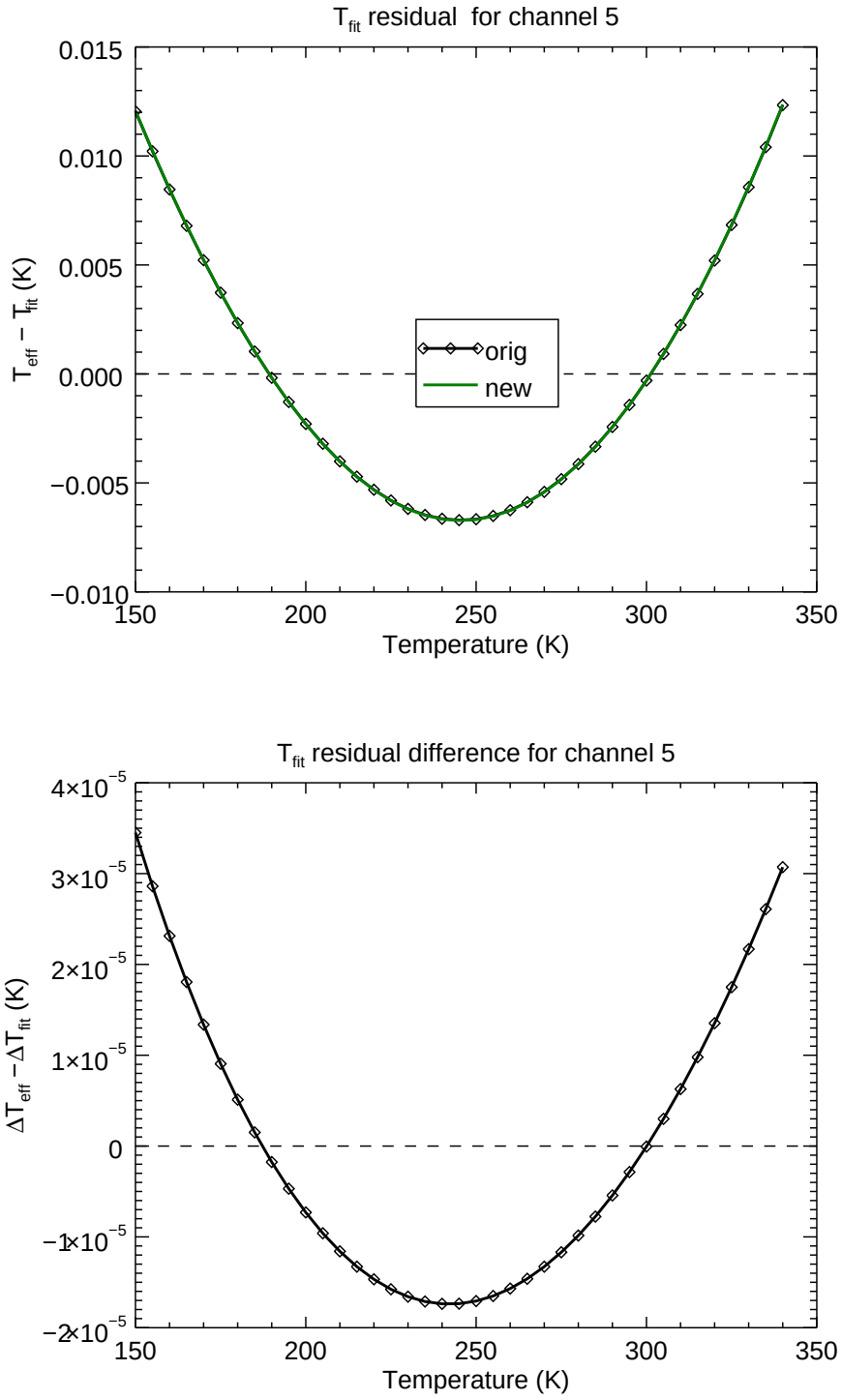

Figure B.3: INSAT-3D Imager channel 5 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

B.4 Channel 6

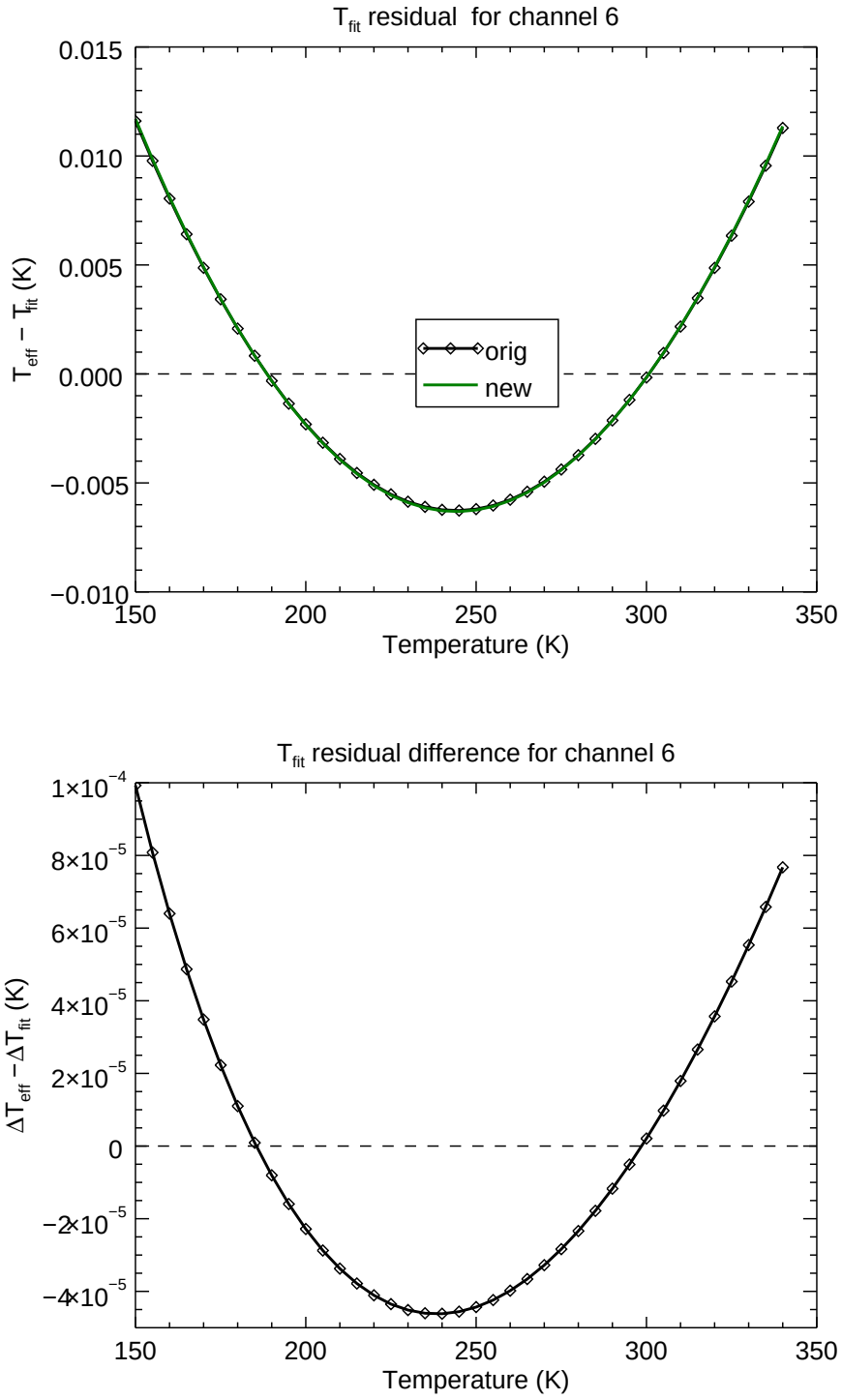

Figure B.4: INSAT-3D Imager channel 6 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

C INSAT-3D Sounder SRFs

C.1 Channel 1

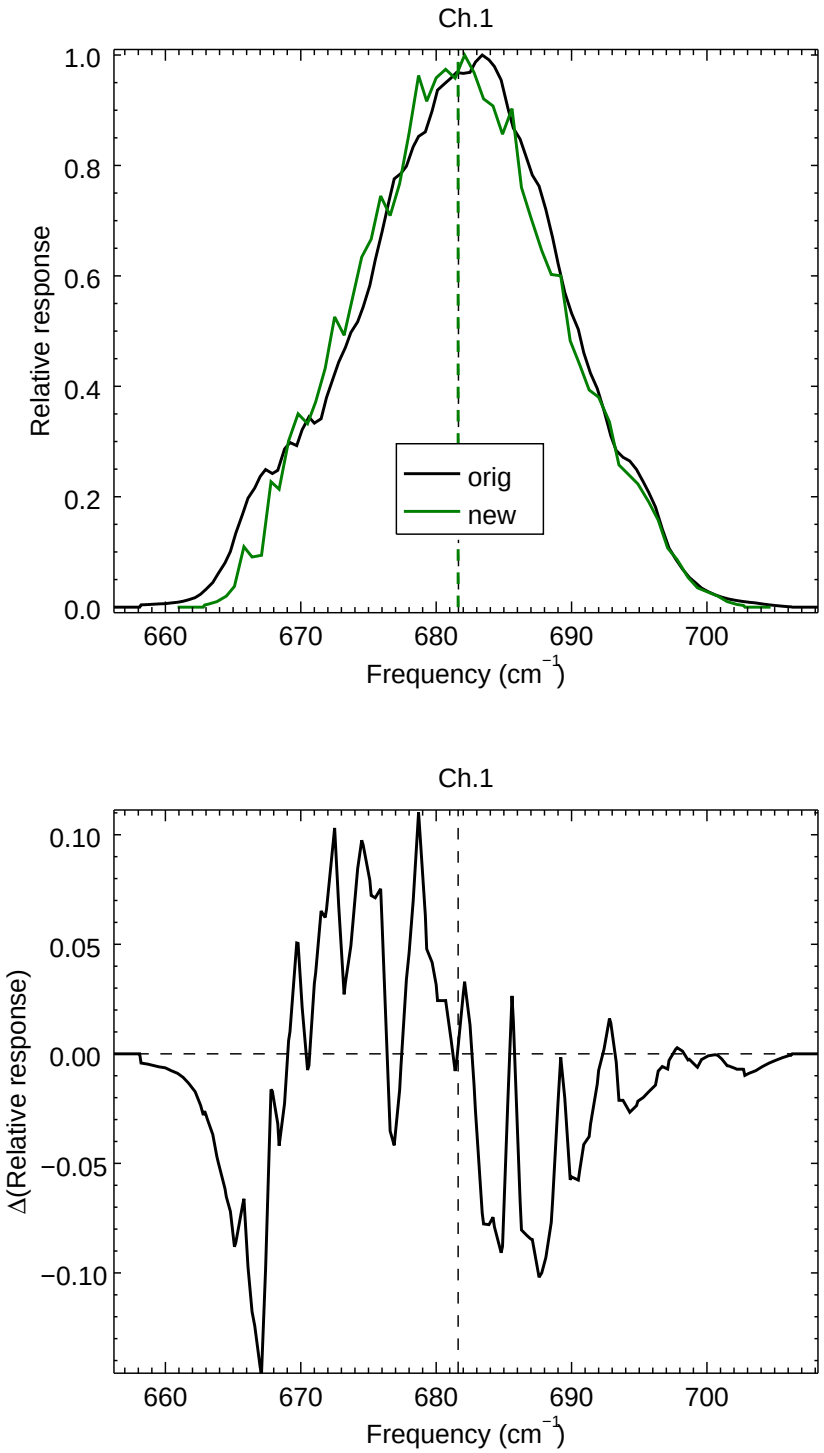

Figure C.1: INSAT-3D Sounder channel 1 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.2 Channel 2

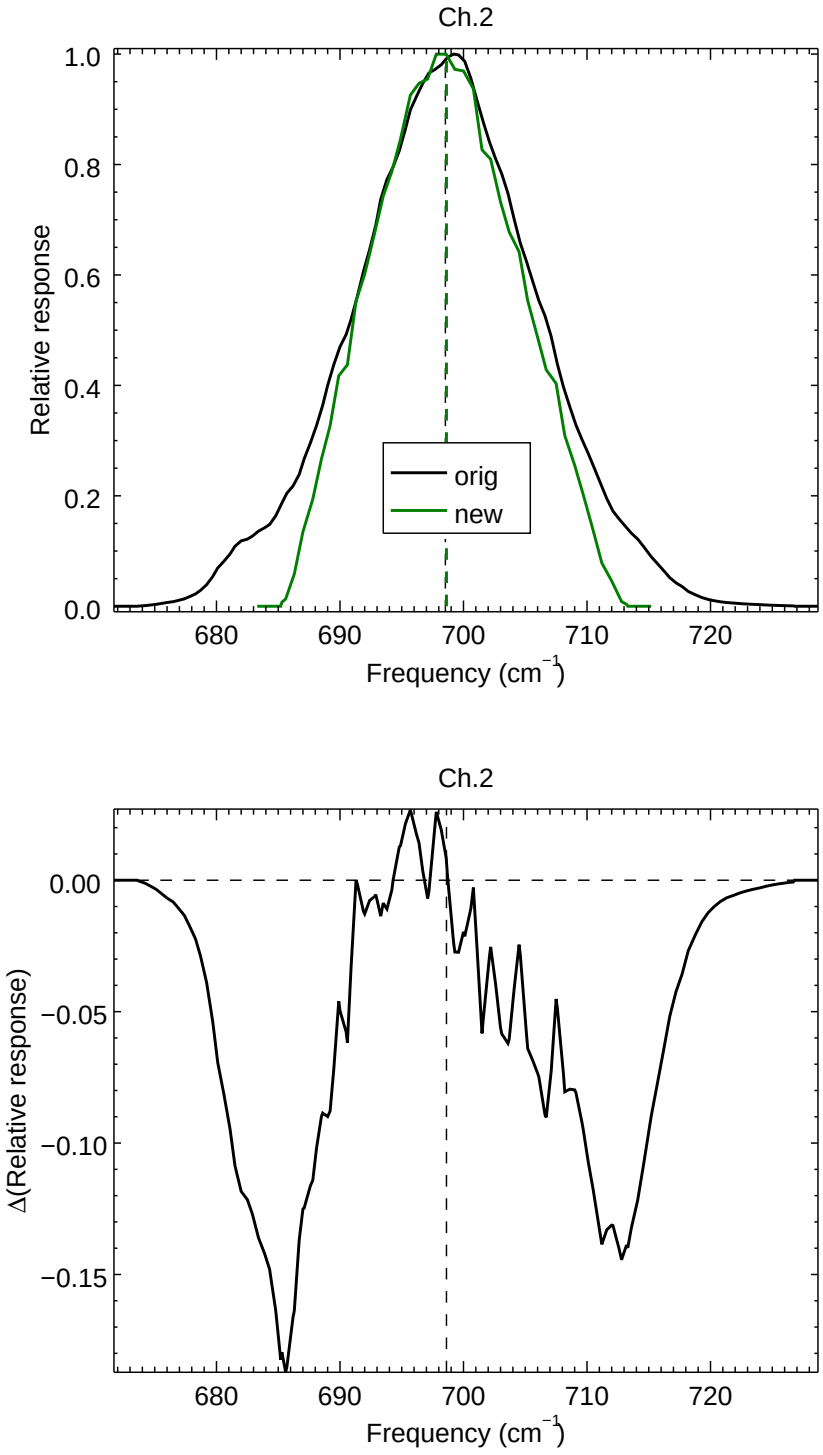

Figure C.2: INSAT-3D Sounder channel 2 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.3 Channel 3

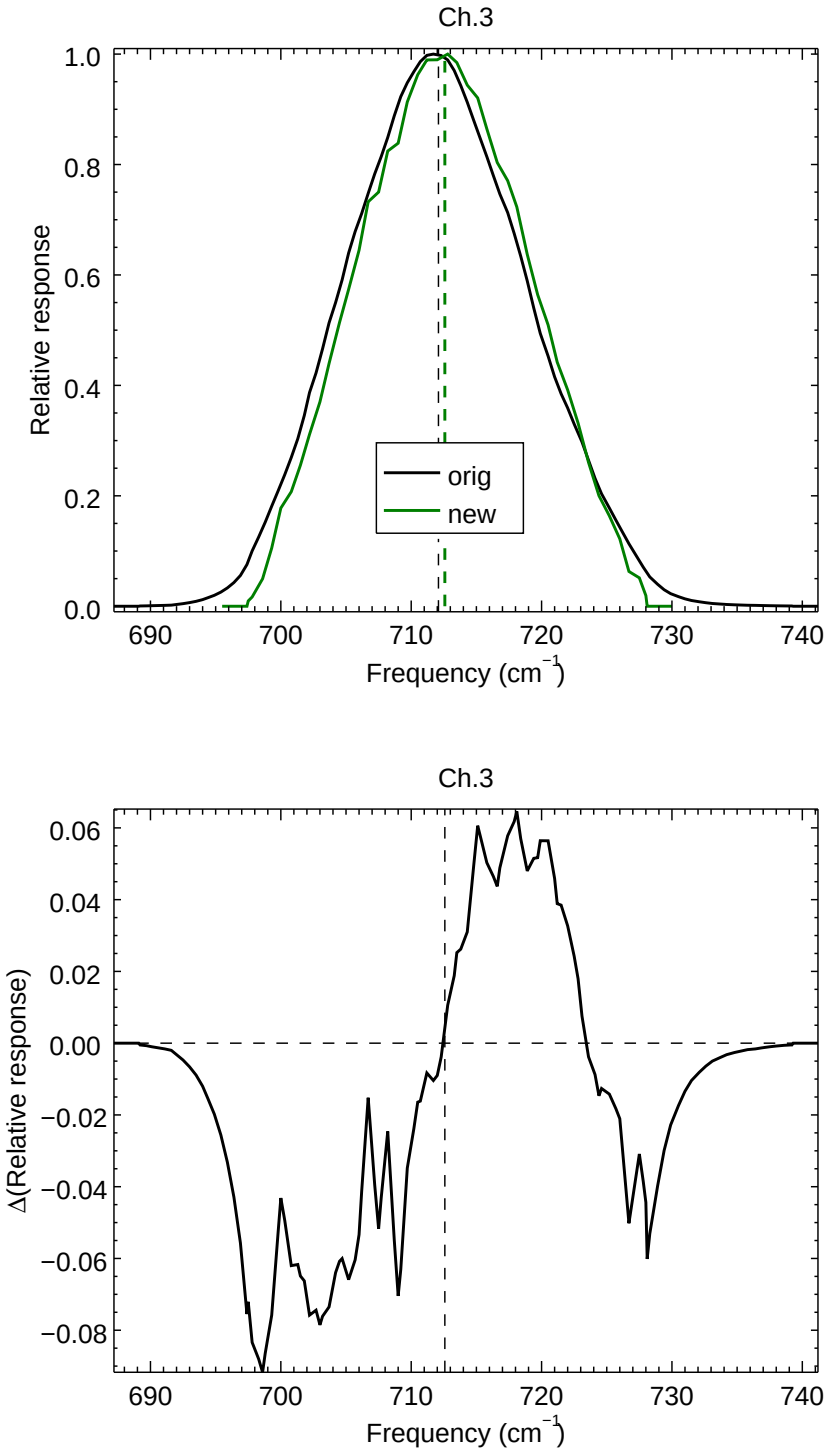

Figure C.3: INSAT-3D Sounder channel 3 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.4 Channel 4

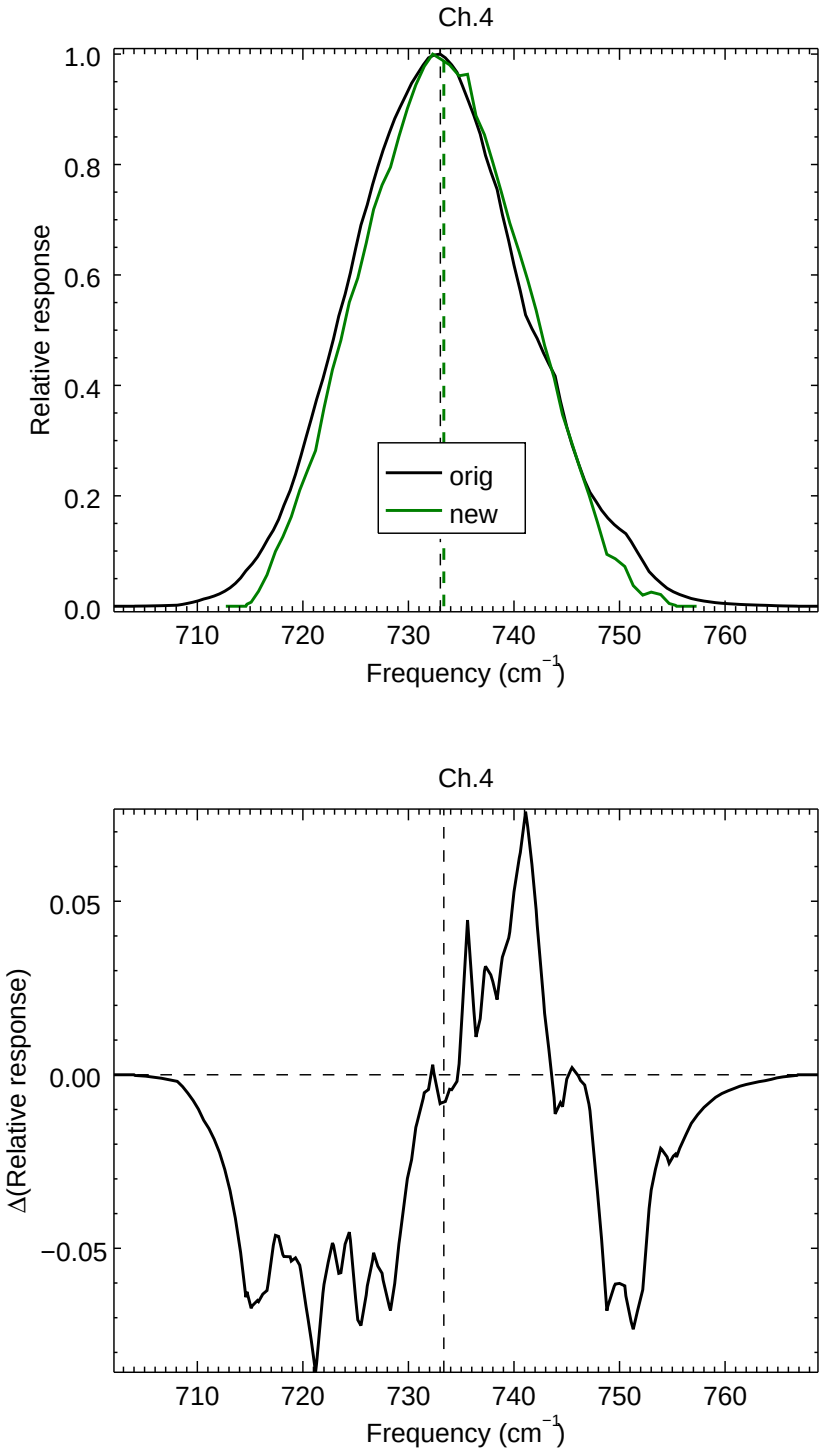

Figure C.4: INSAT-3D Sounder channel 4 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.5 Channel 5

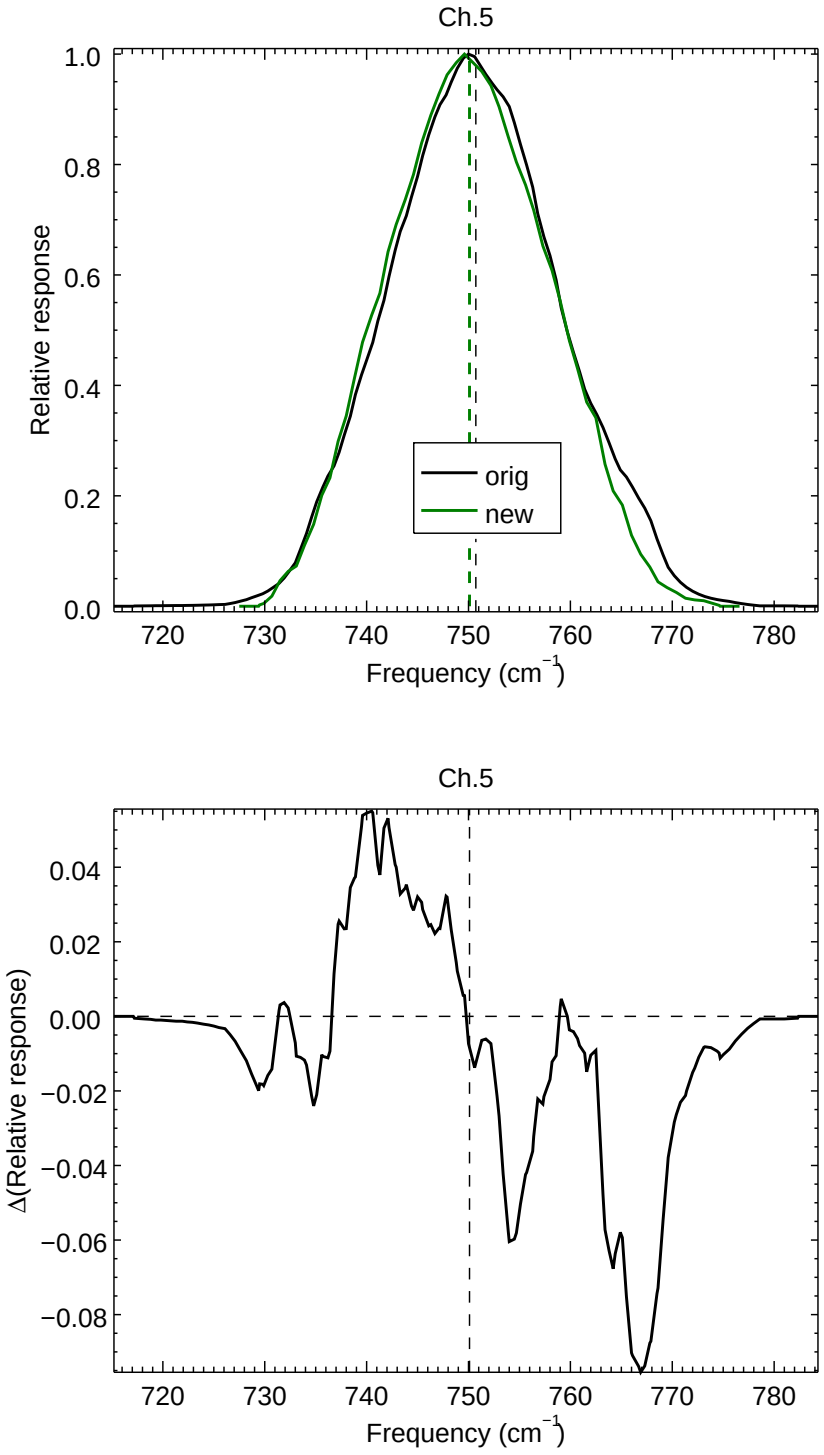

Figure C.5: INSAT-3D Sounder channel 5 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.6 Channel 6

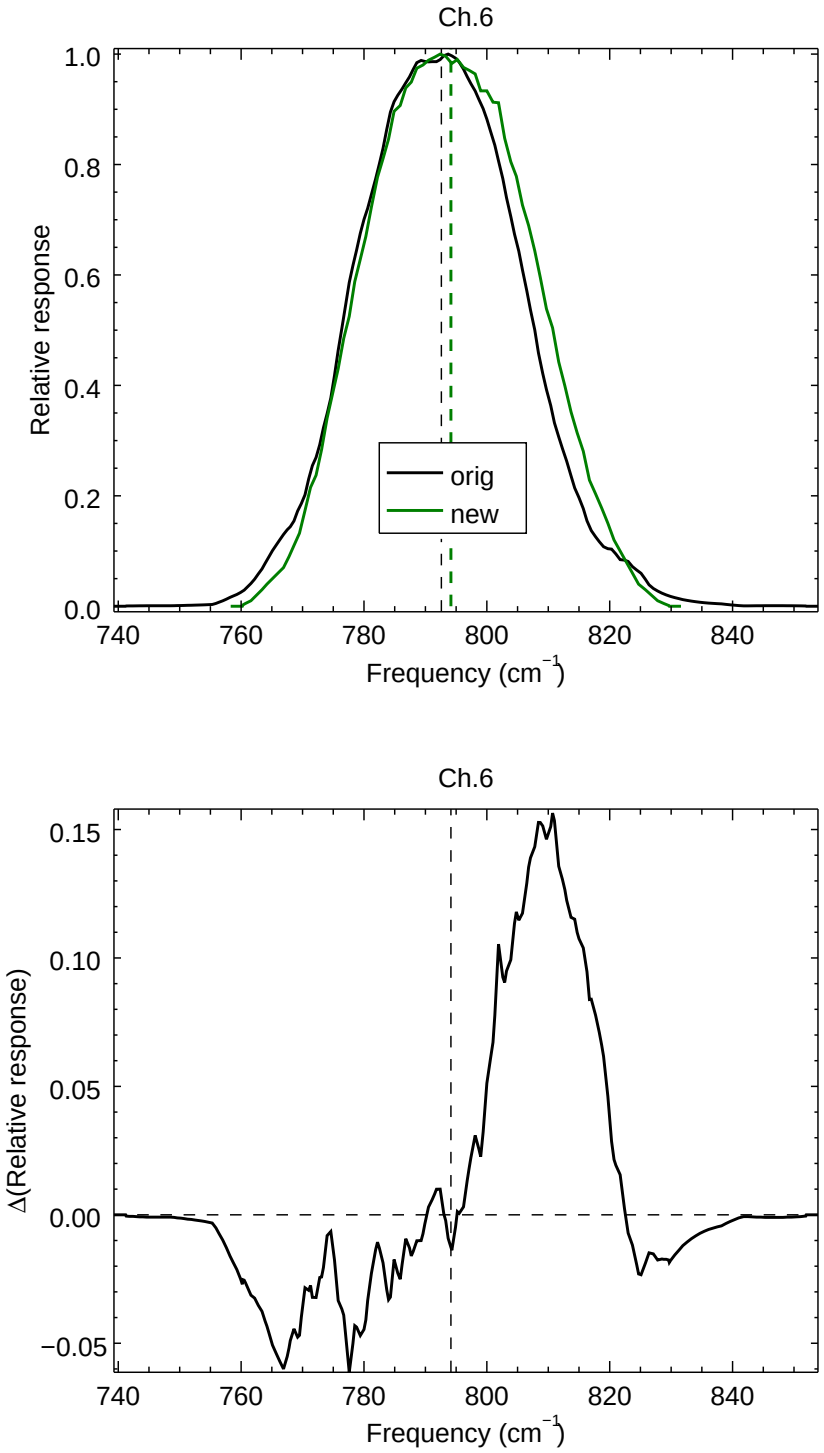

Figure C.6: INSAT-3D Sounder channel 6 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.7 Channel 7

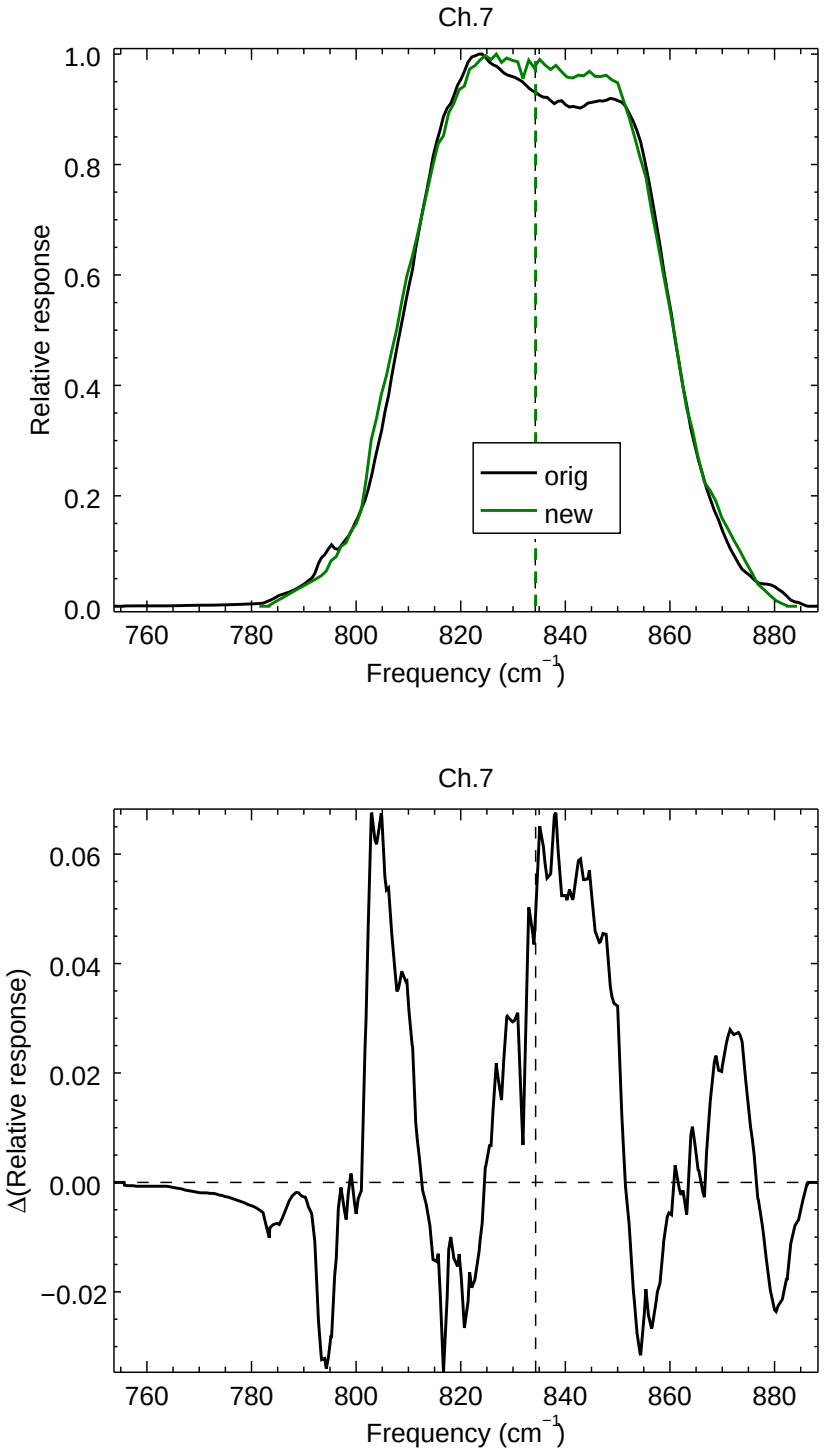

Figure C.7: INSAT-3D Sounder channel 7 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.8 Channel 8

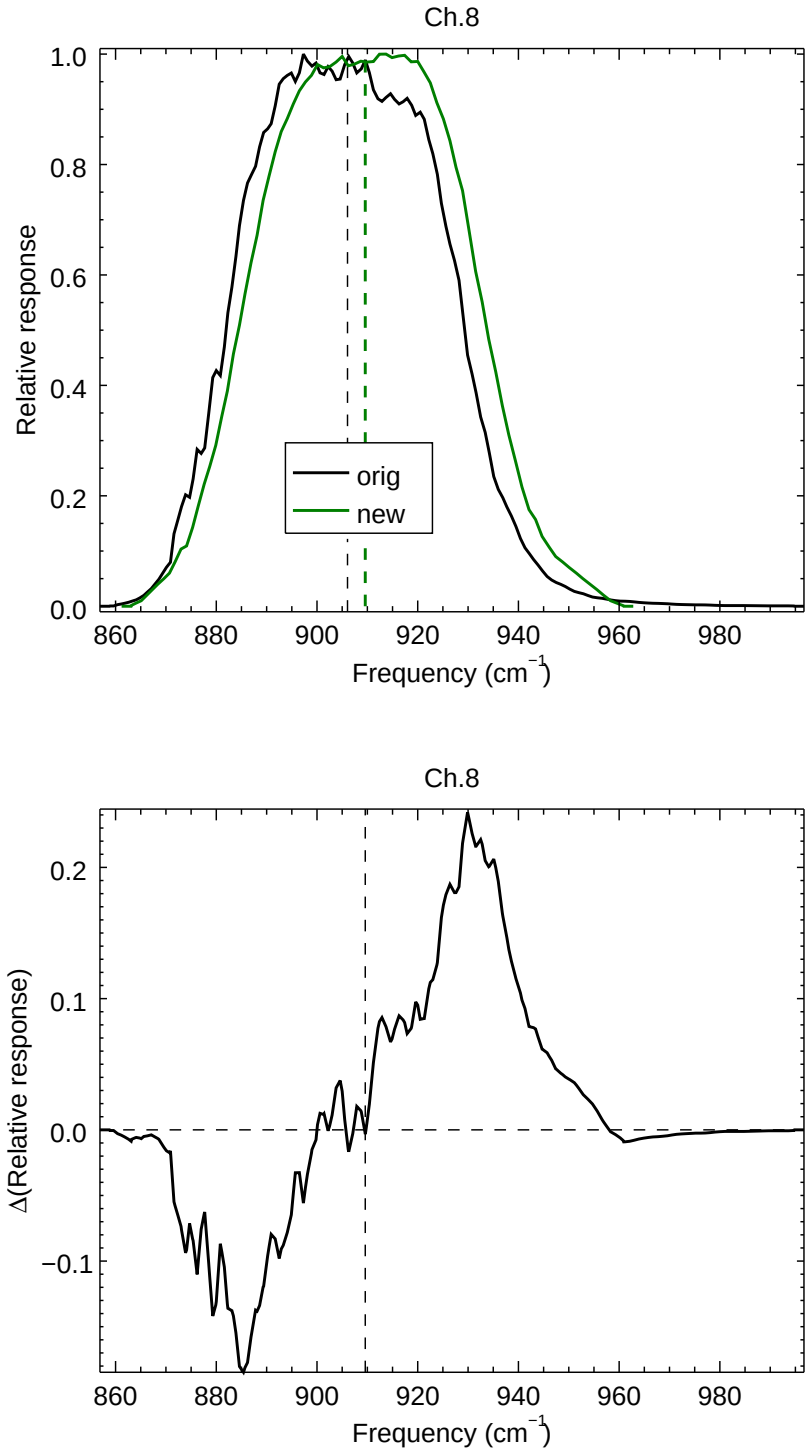

Figure C.8: INSAT-3D Sounder channel 8 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.9 Channel 9

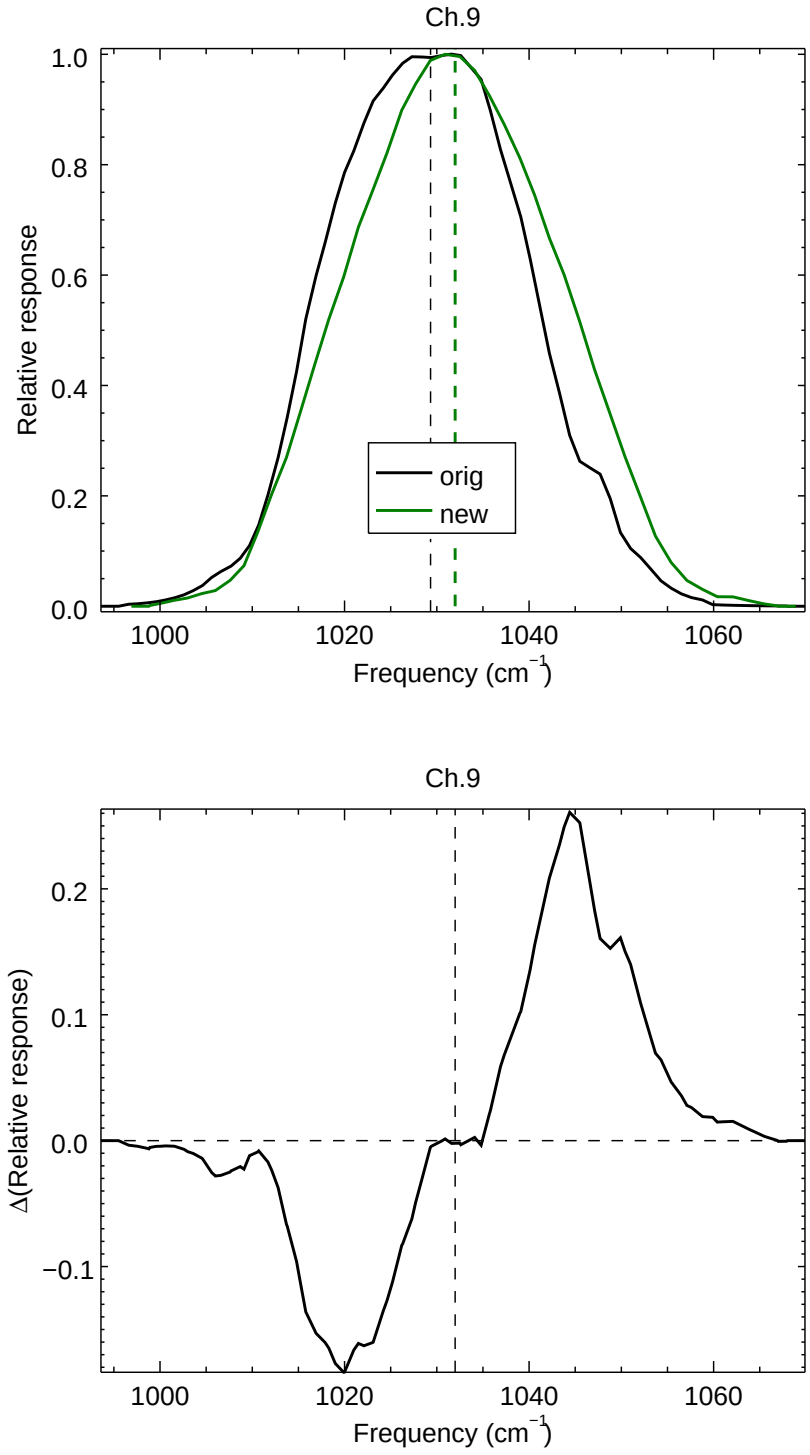

Figure C.9: INSAT-3D Sounder channel 9 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.10 Channel 10

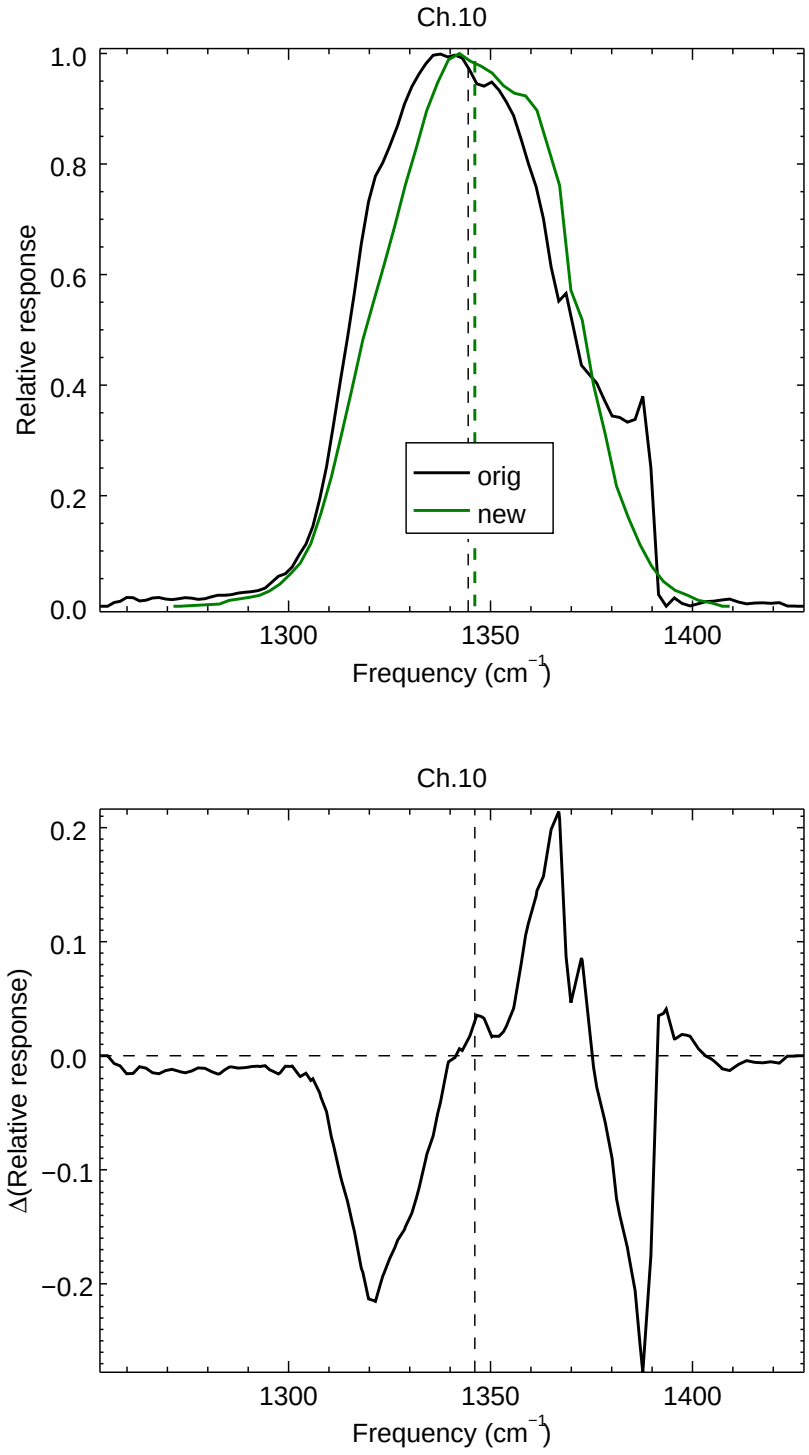

Figure C.10: INSAT-3D Sounder channel 10 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.11 Channel 11

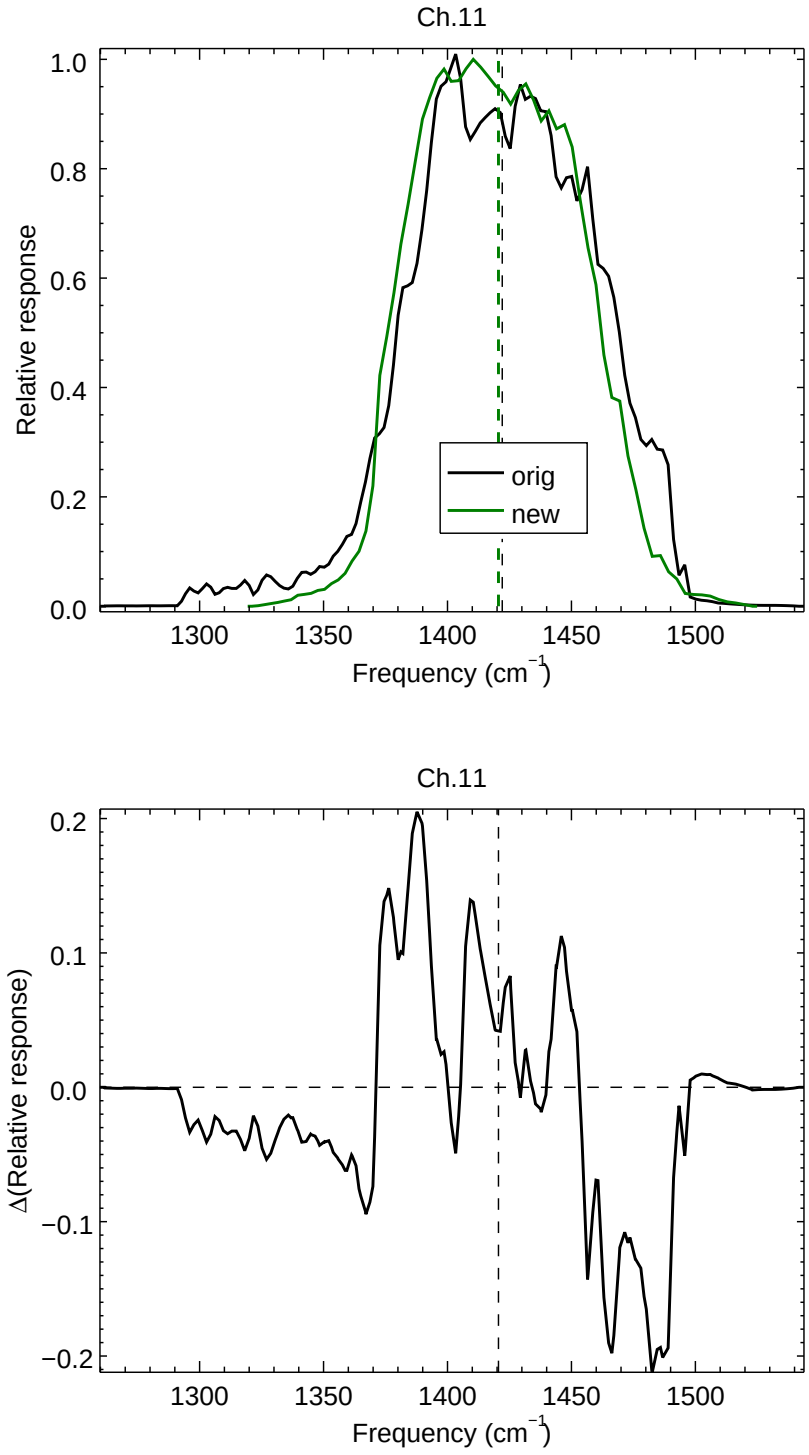

Figure C.11: INSAT-3D Sounder channel 11 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.12 Channel 12

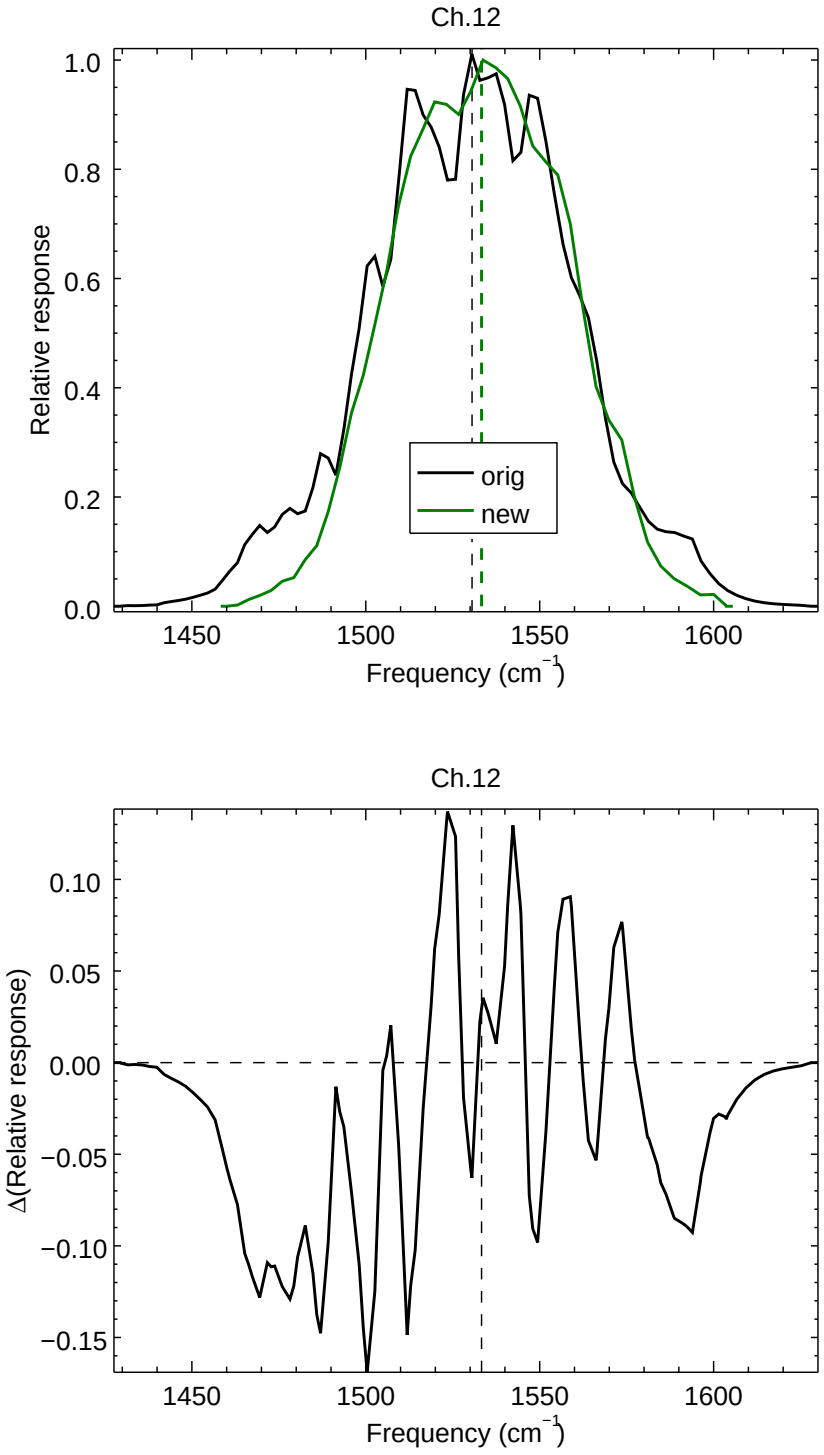

Figure C.12: INSAT-3D Sounder channel 12 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.13 Channel 13

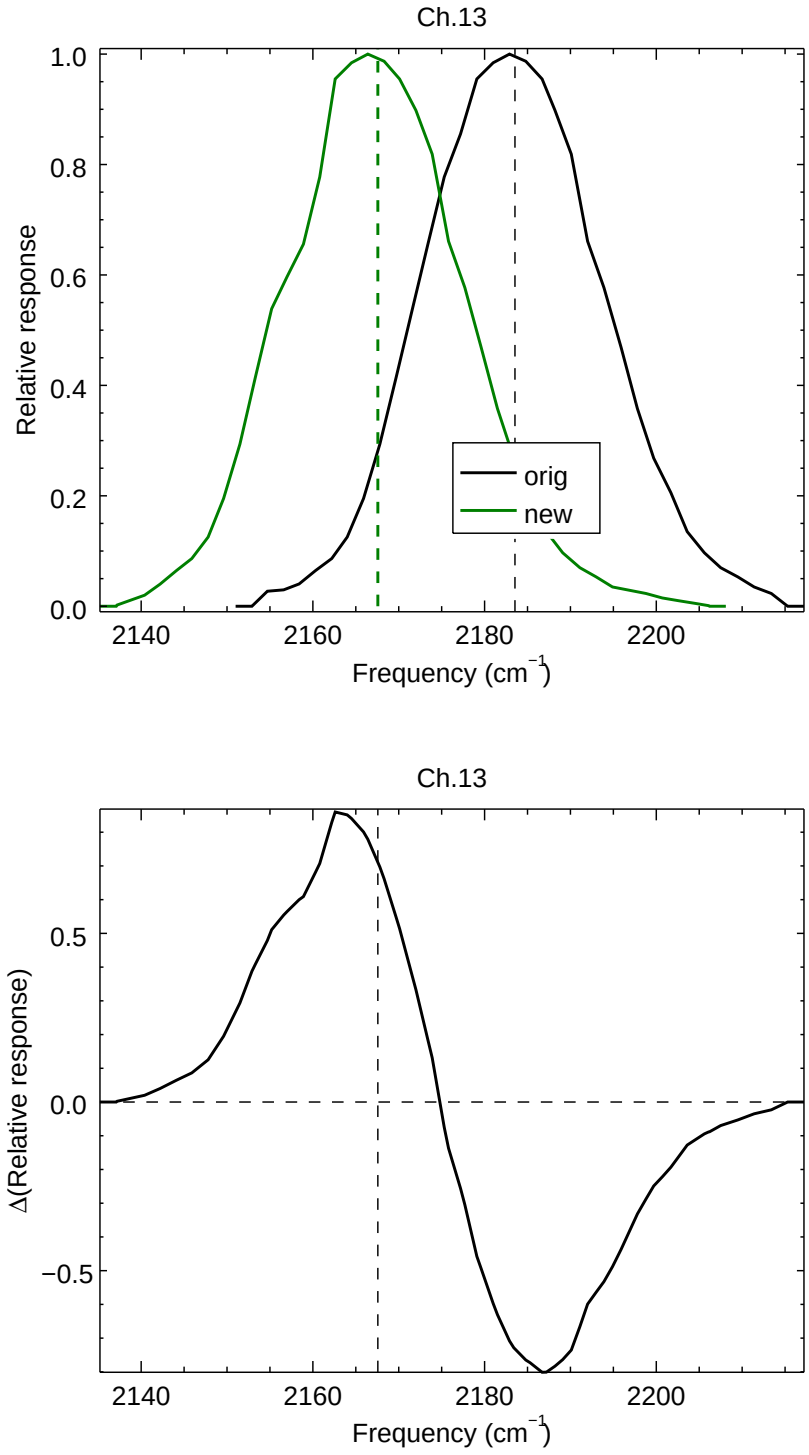

Figure C.13: INSAT-3D Sounder channel 13 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.14 Channel 14

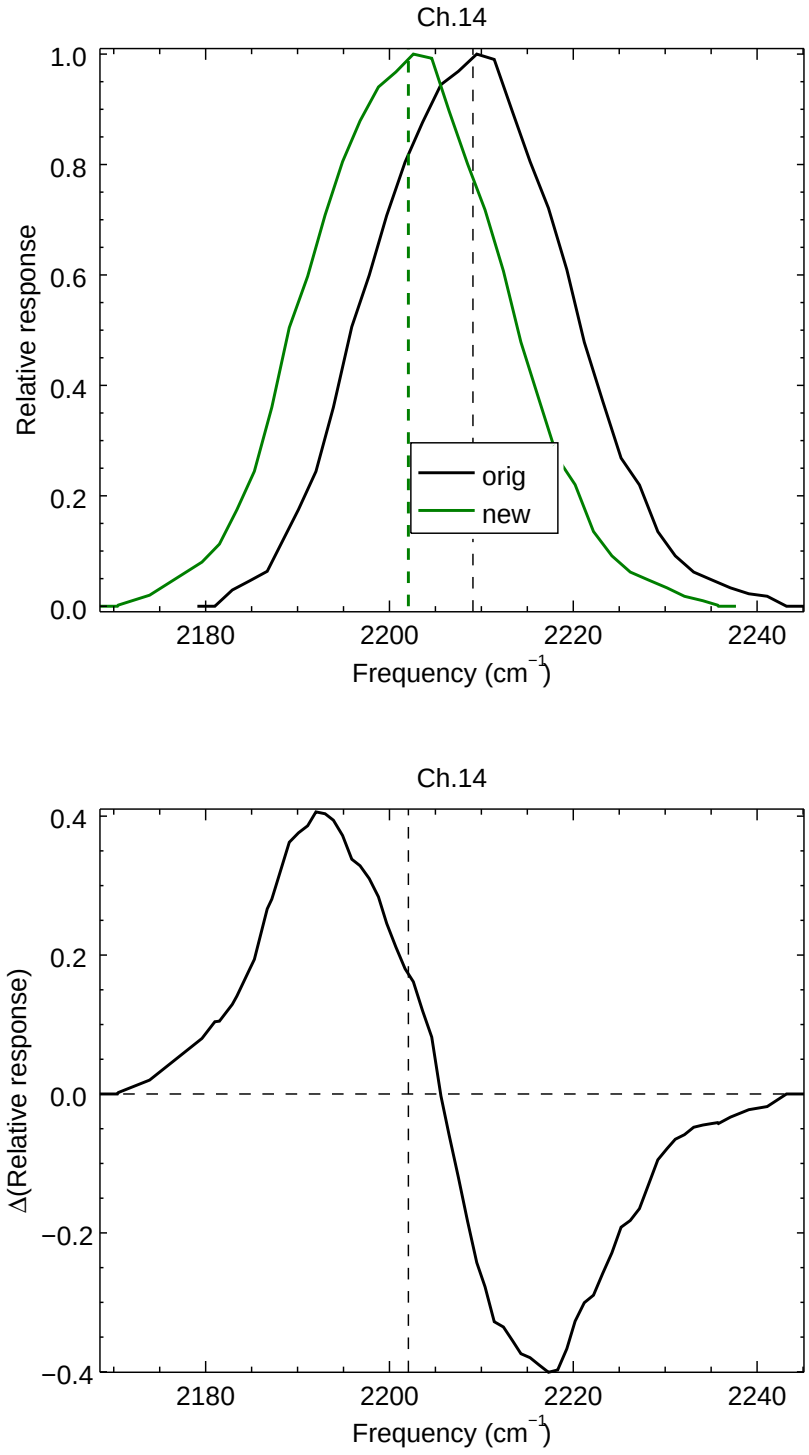

Figure C.14: INSAT-3D Sounder channel 14 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.15 Channel 15

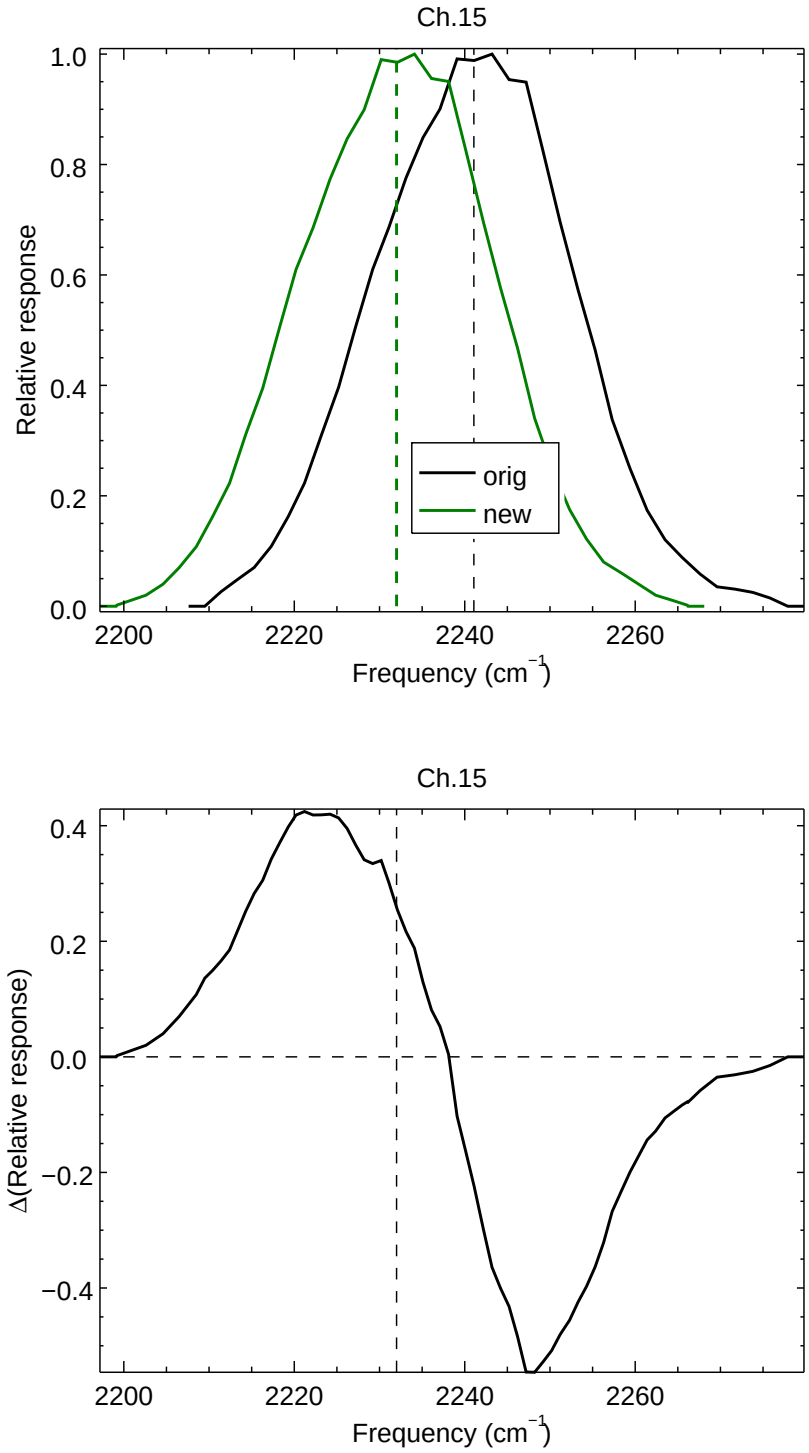

Figure C.15: INSAT-3D Sounder channel 15 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.16 Channel 16

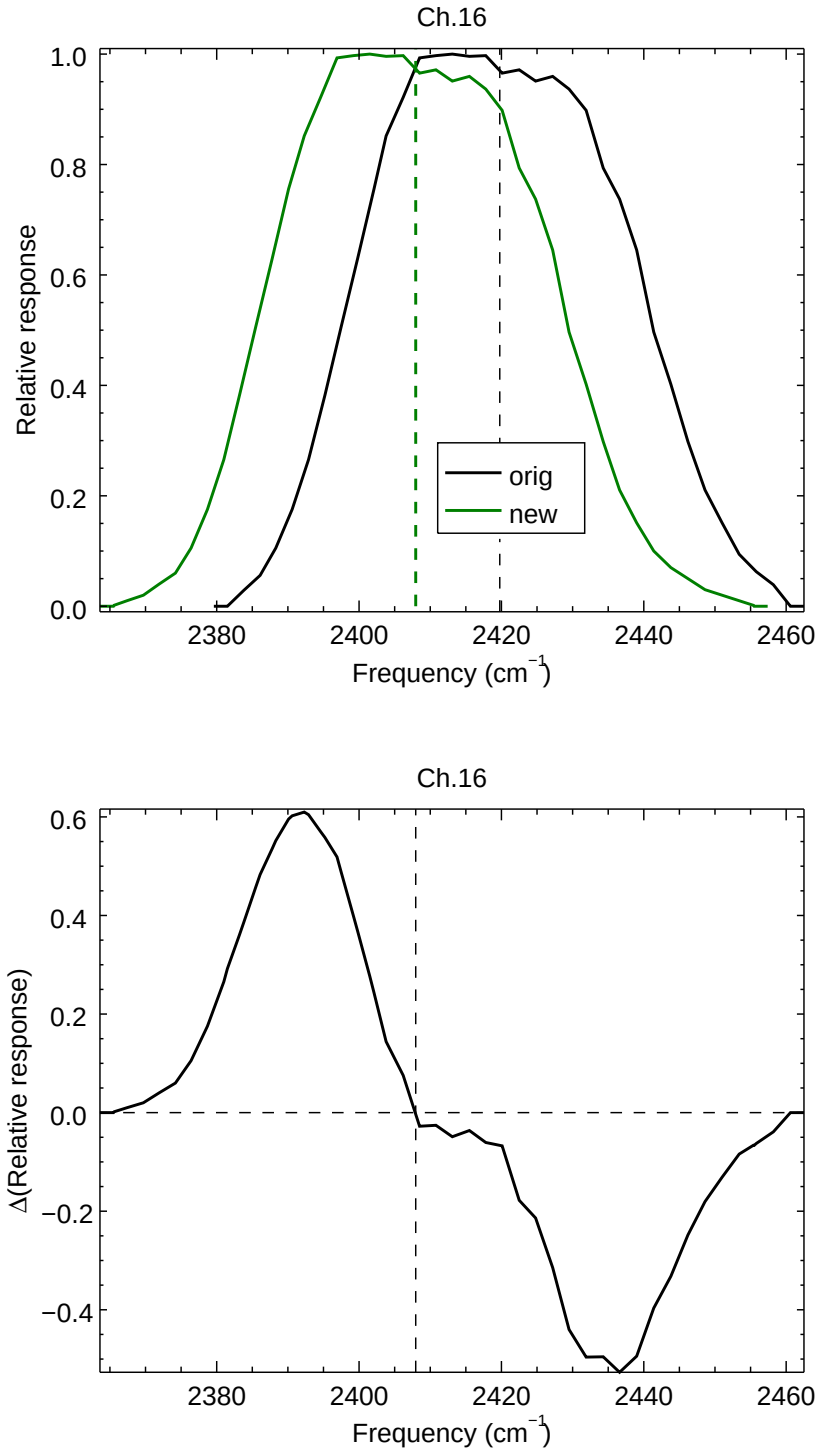

Figure C.16: INSAT-3D Sounder channel 16 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.17 Channel 17

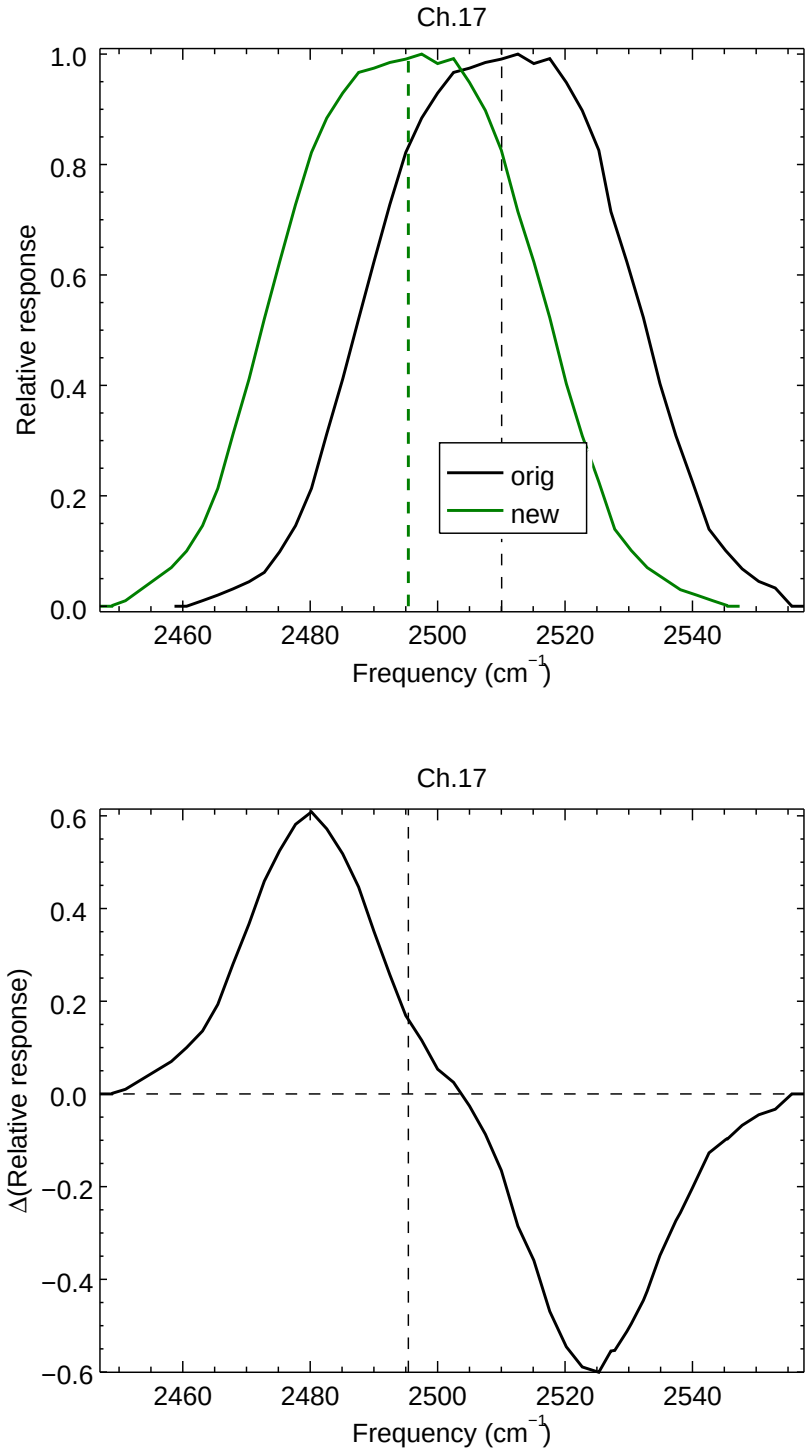

Figure C.17: INSAT-3D Sounder channel 17 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

C.18 Channel 18

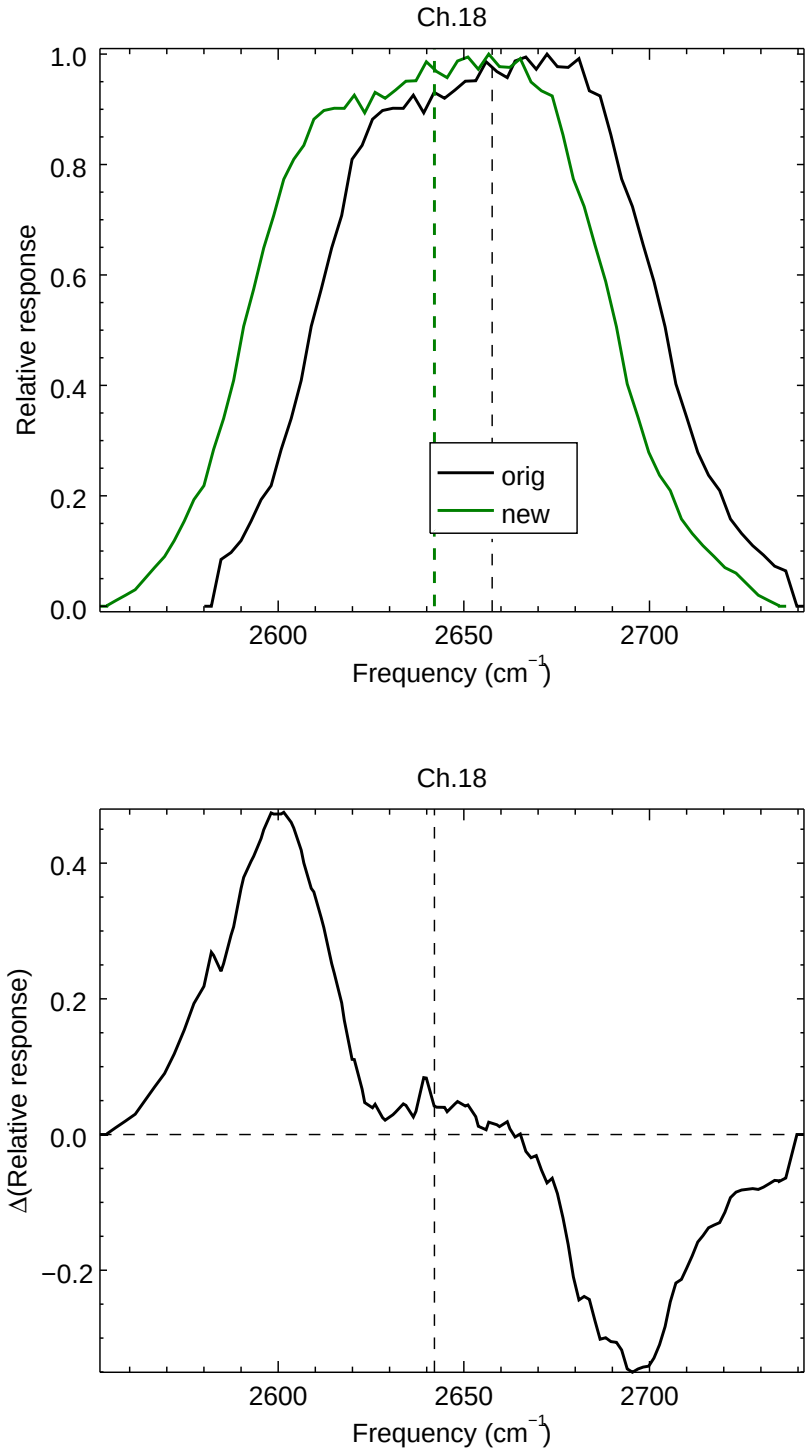

Figure C.18: INSAT-3D Sounder channel 18 spectral responses. Vertical dashed lines are the locations of the computed central frequencies. *(Top)* Comparison of original and new SRFs. *(Bottom)* Response difference between the original and new SRFs.

D INSAT-3D Sounder Polychromatic Correction Temperature Fit Residuals

D.1 Channel 1

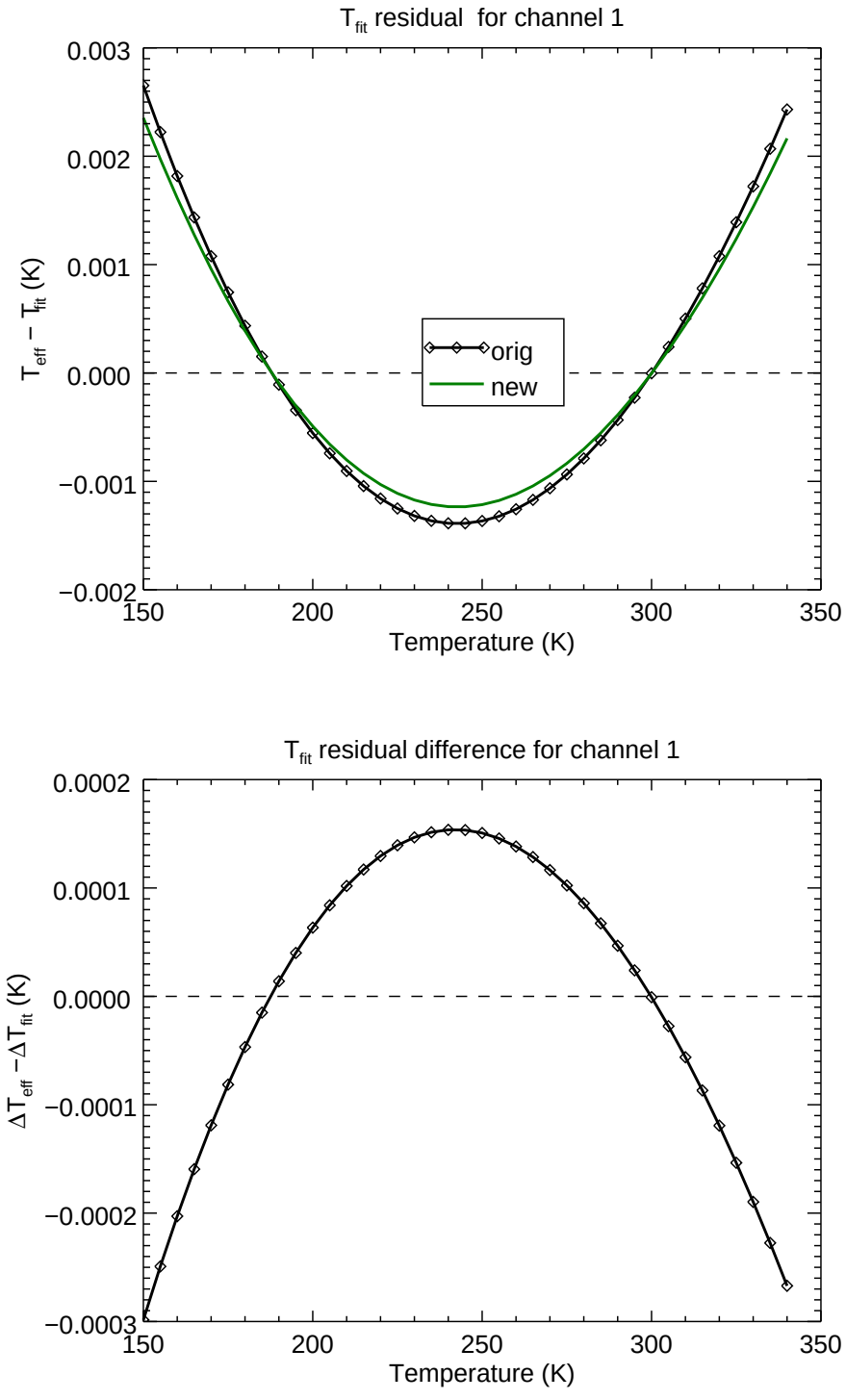

Figure D.1: INSAT-3D Sounder channel 1 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.2 Channel 2

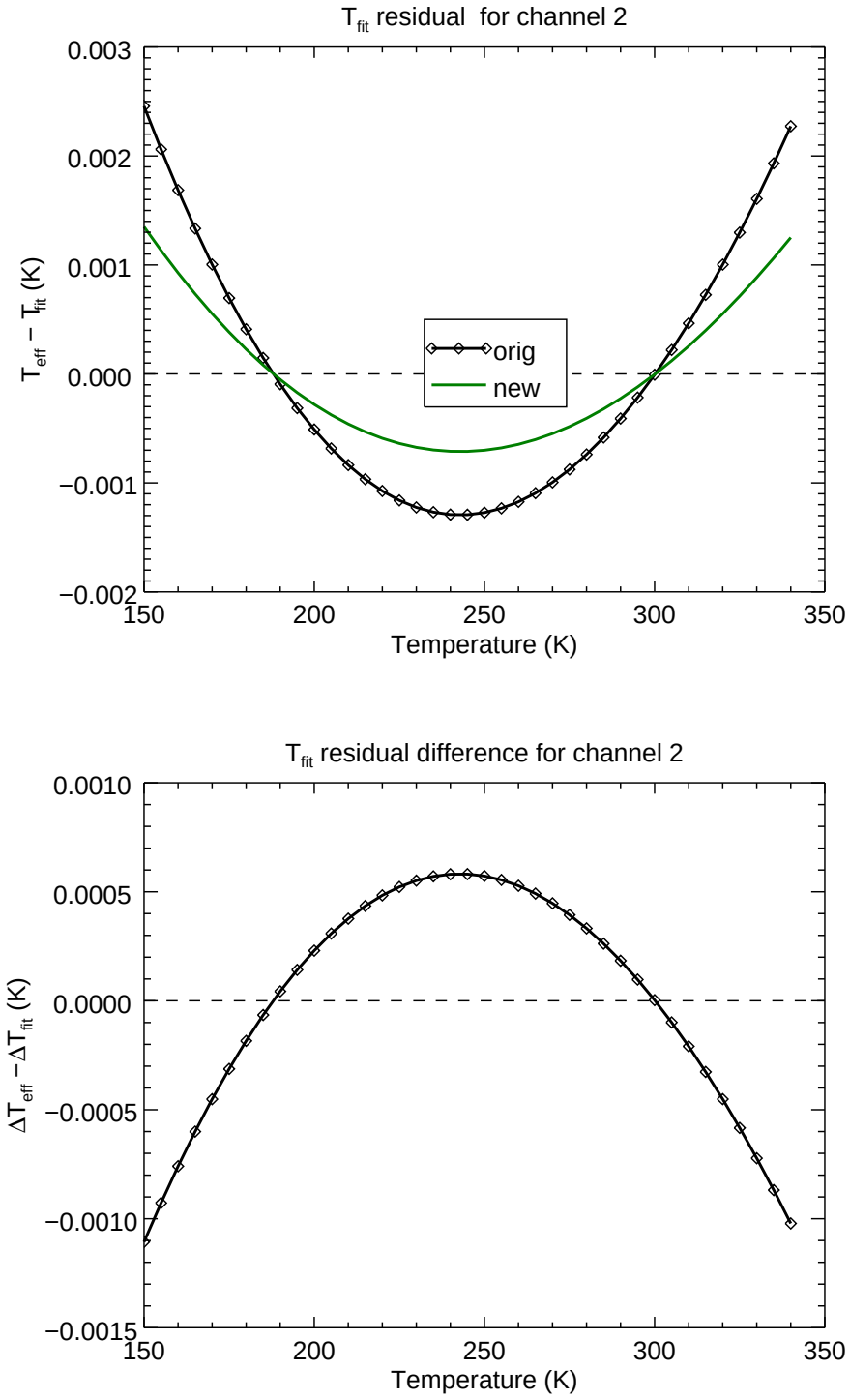

Figure D.2: INSAT-3D Sounder channel 2 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.3 Channel 3

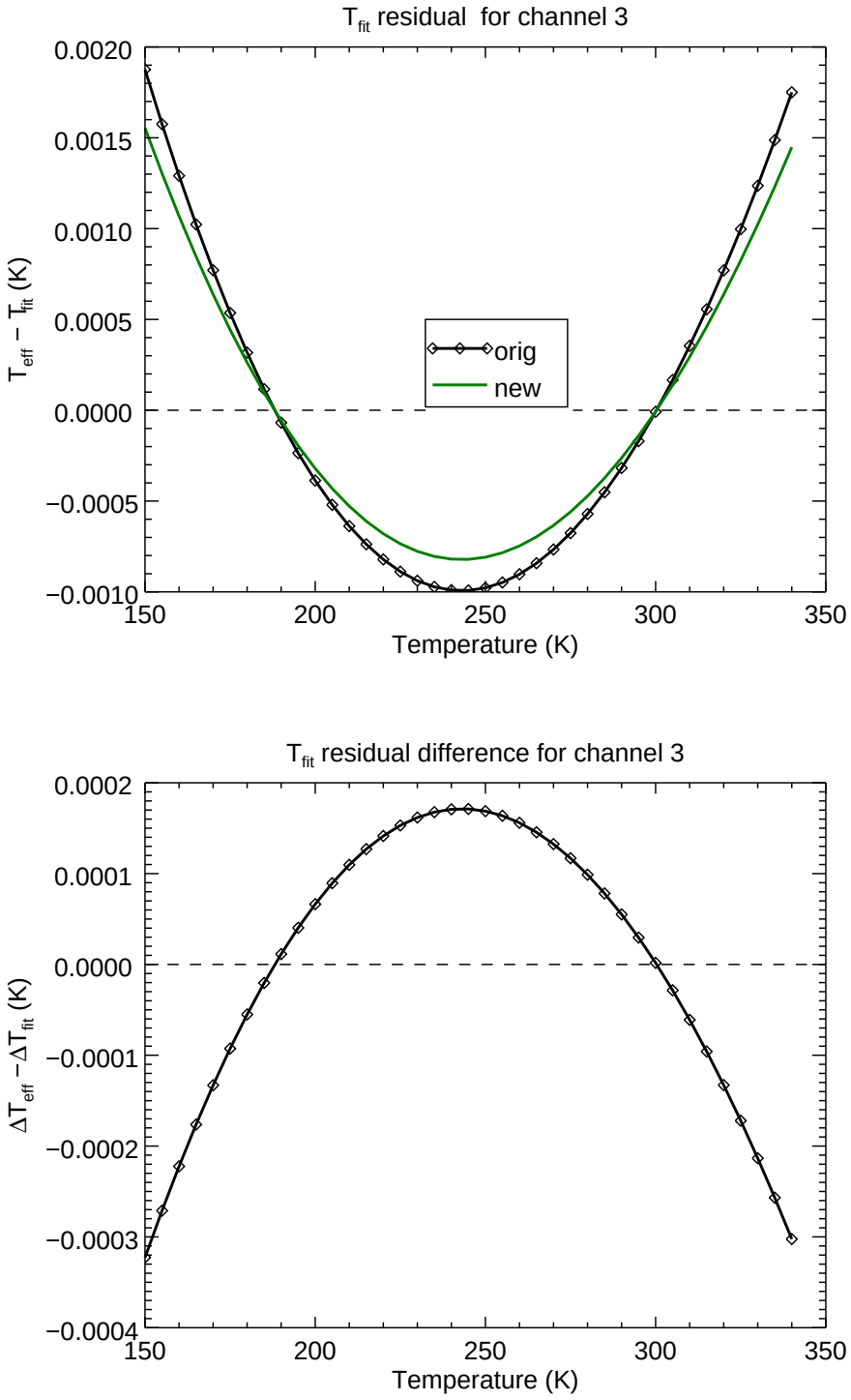

Figure D.3: INSAT-3D Sounder channel 3 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.4 Channel 4

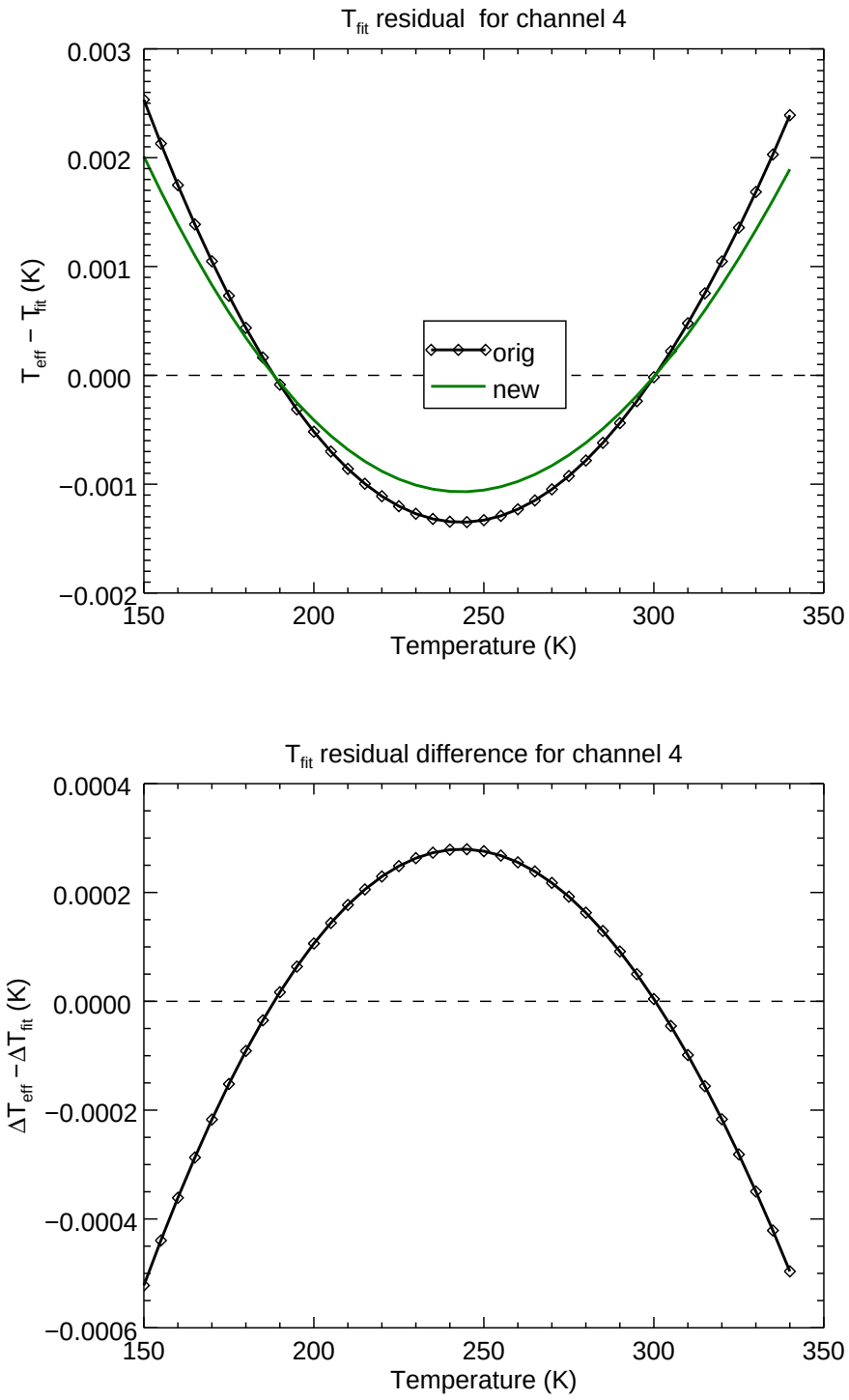

Figure D.4: INSAT-3D Sounder channel 4 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.5 Channel 5

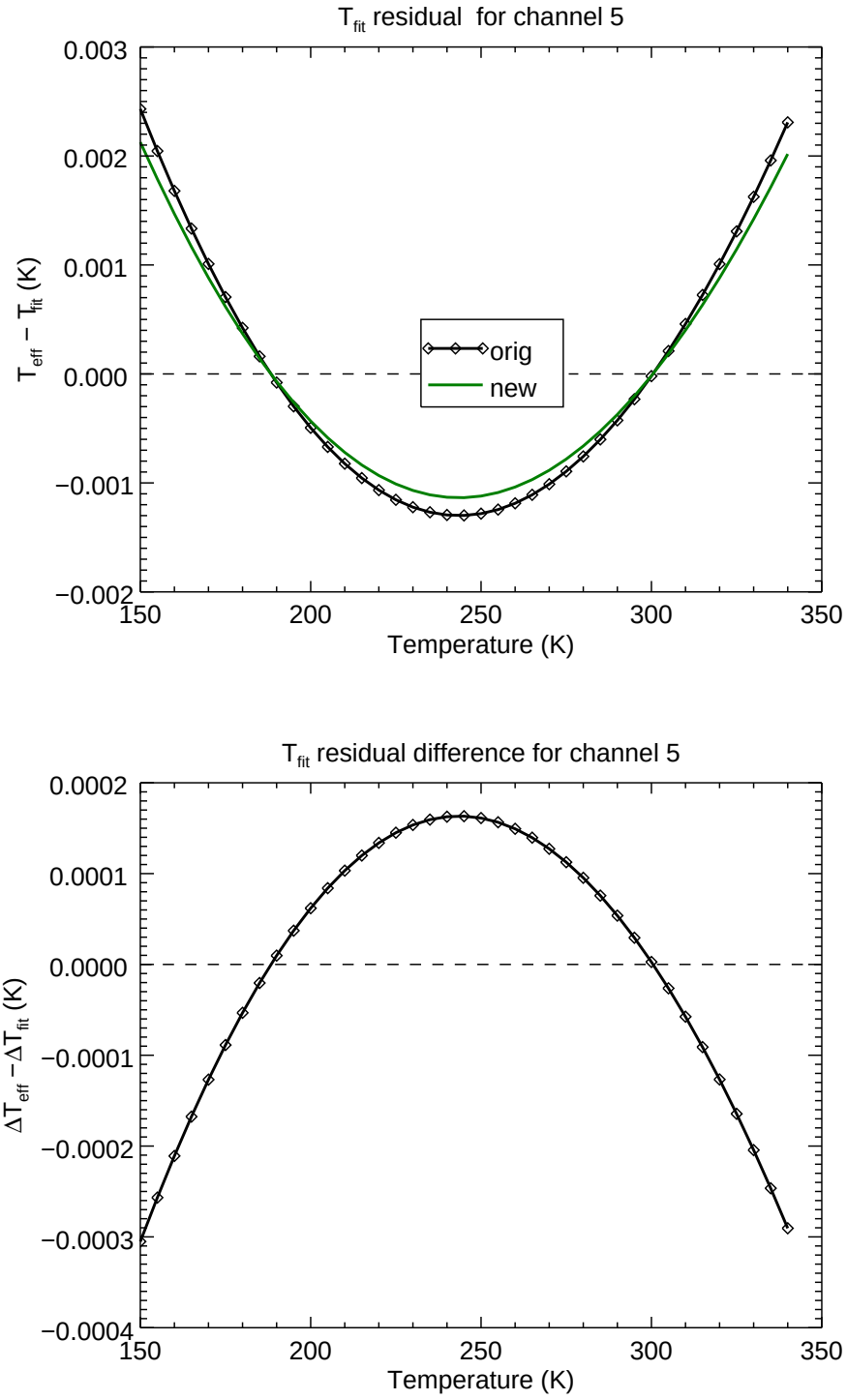

Figure D.5: INSAT-3D Sounder channel 5 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.6 Channel 6

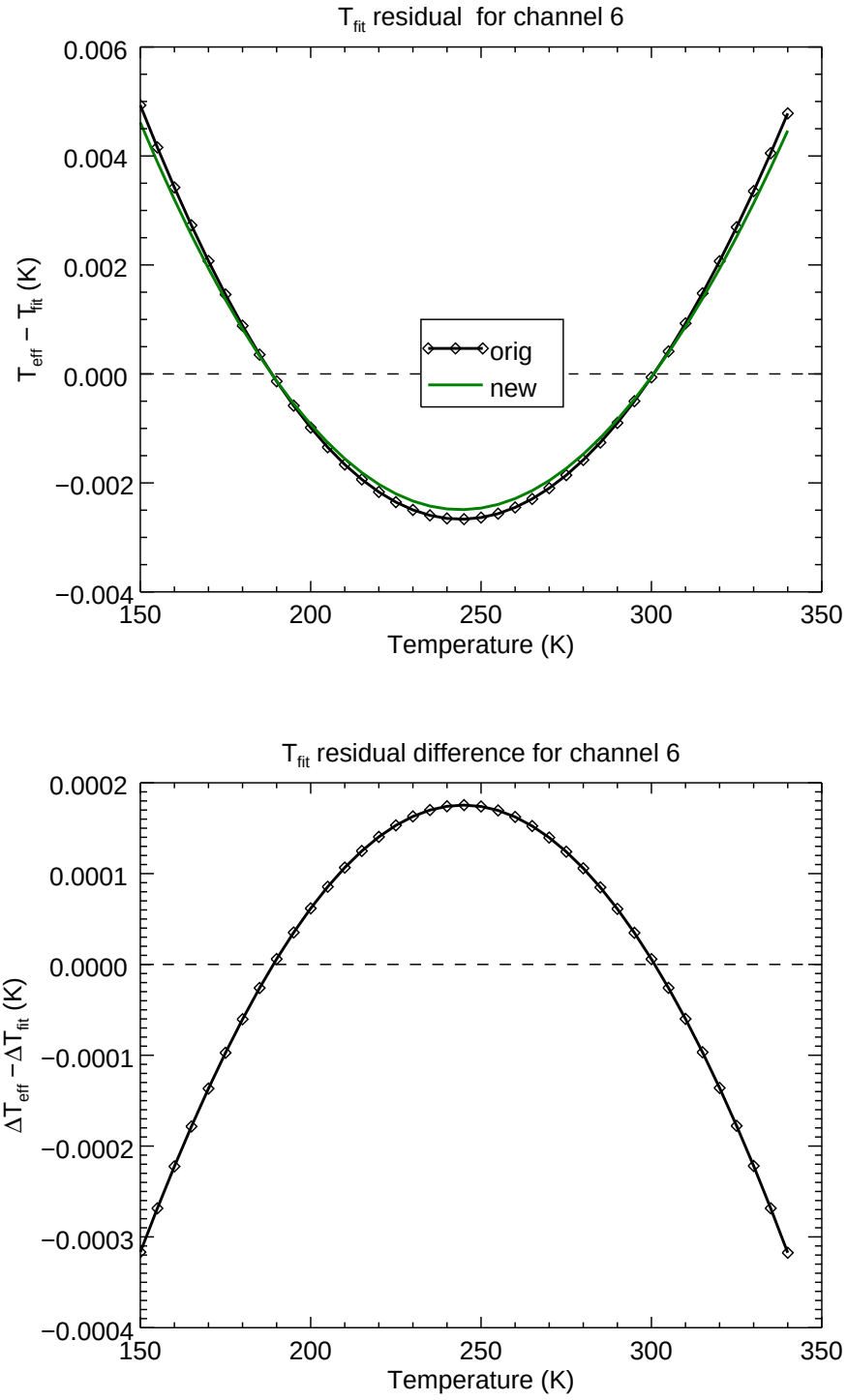

Figure D.6: INSAT-3D Sounder channel 6 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.7 Channel 7

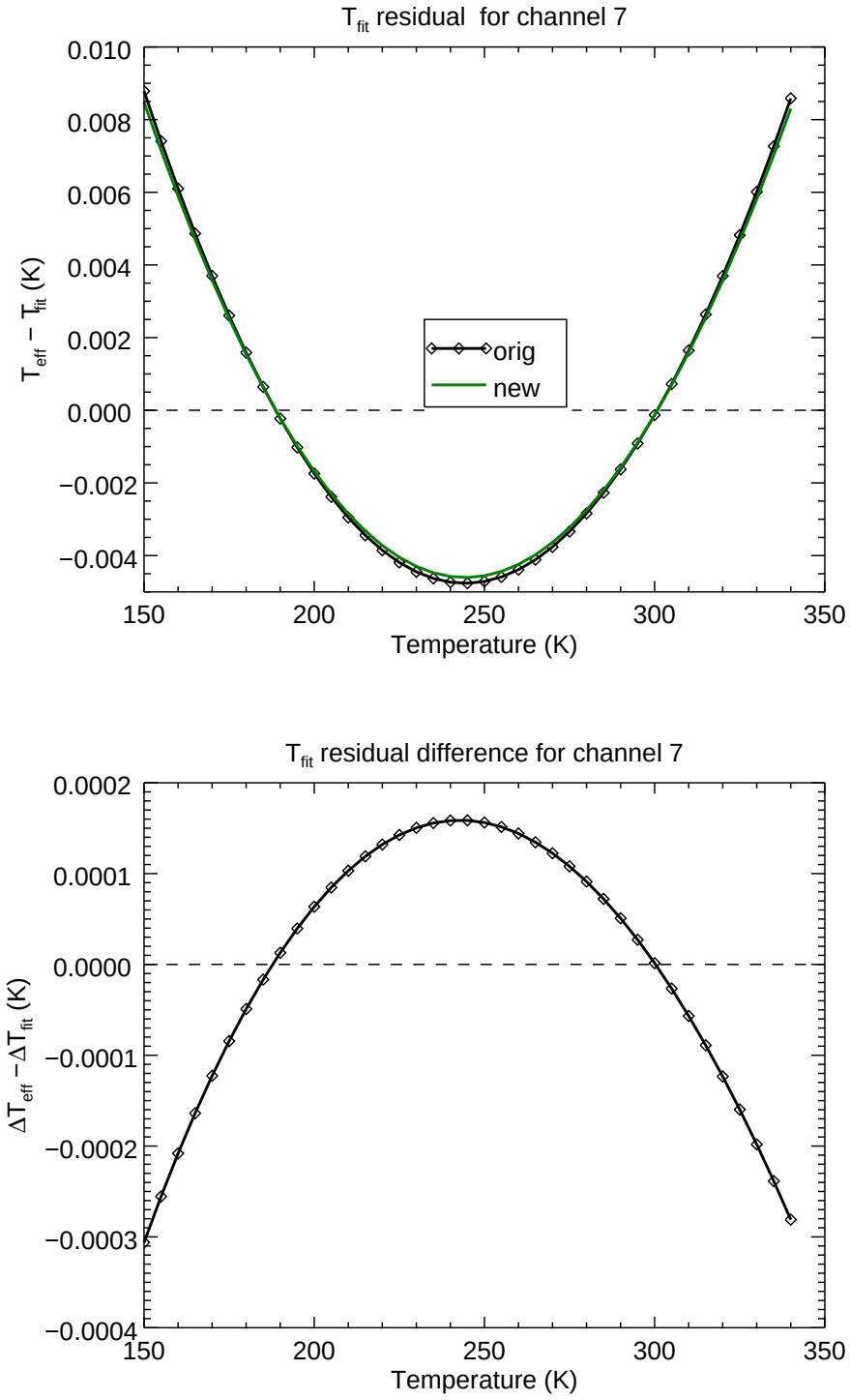

Figure D.7: INSAT-3D Sounder channel 7 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.8 Channel 8

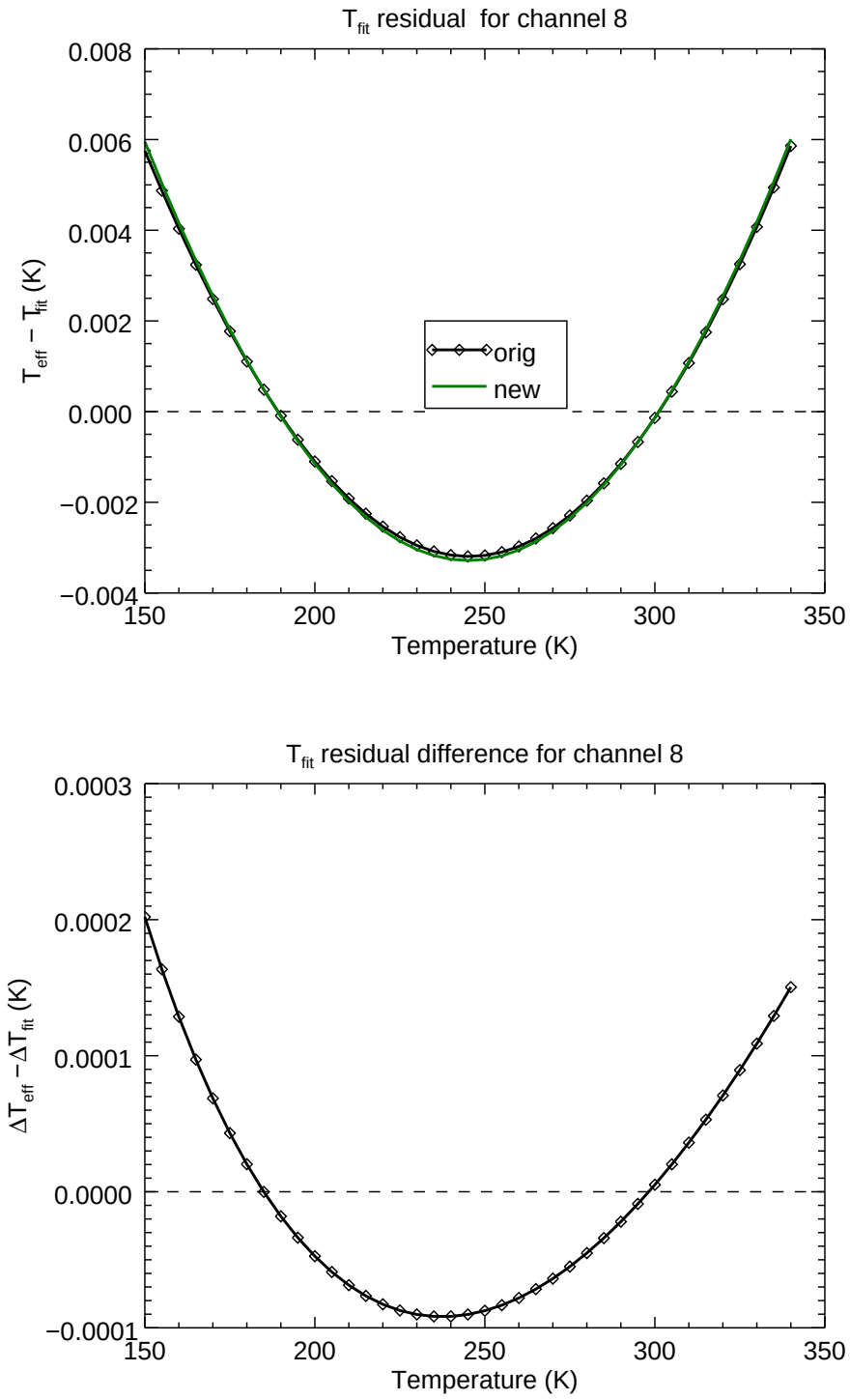

Figure D.8: INSAT-3D Sounder channel 8 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.9 Channel 9

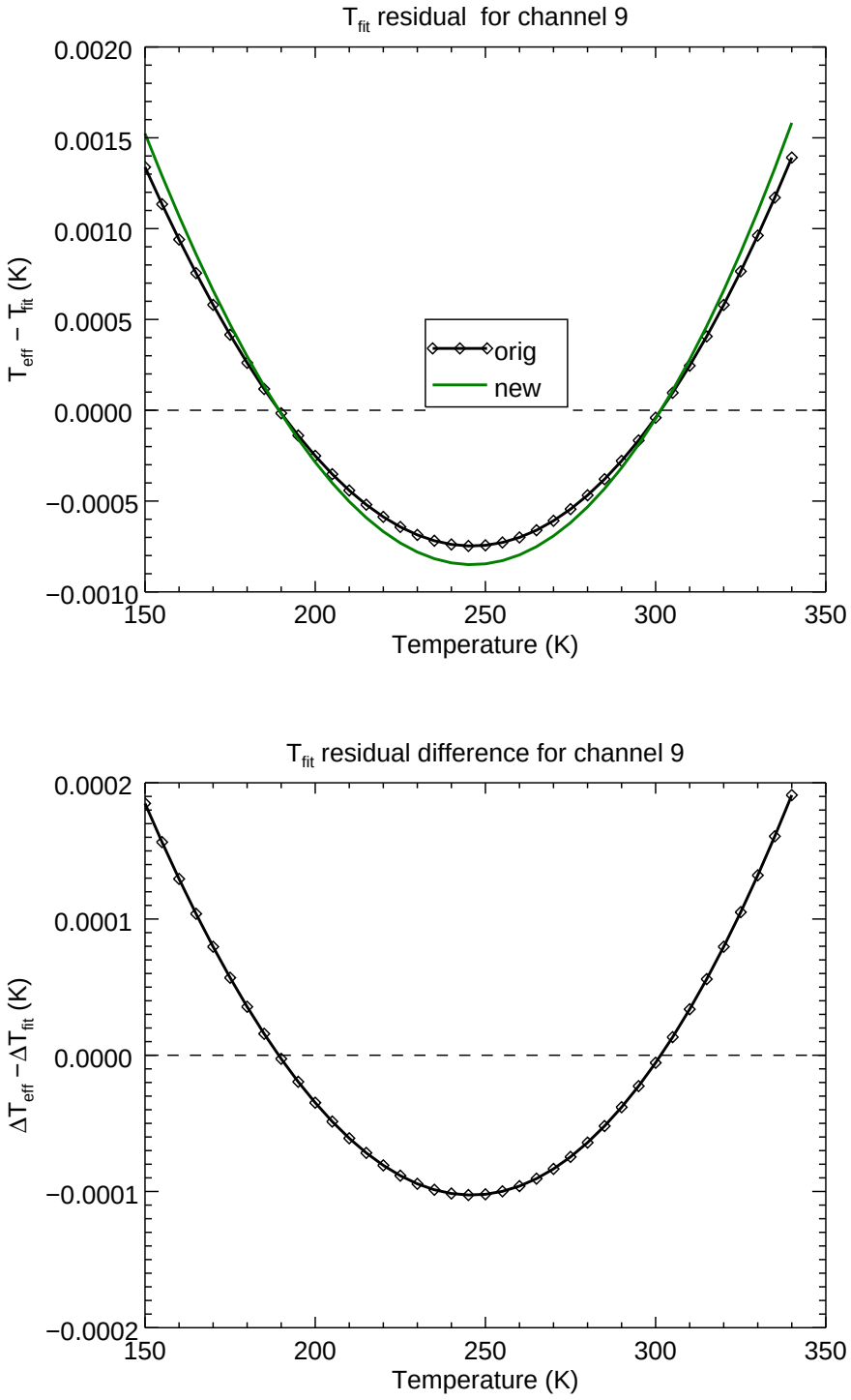

Figure D.9: INSAT-3D Sounder channel 9 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.10 Channel 10

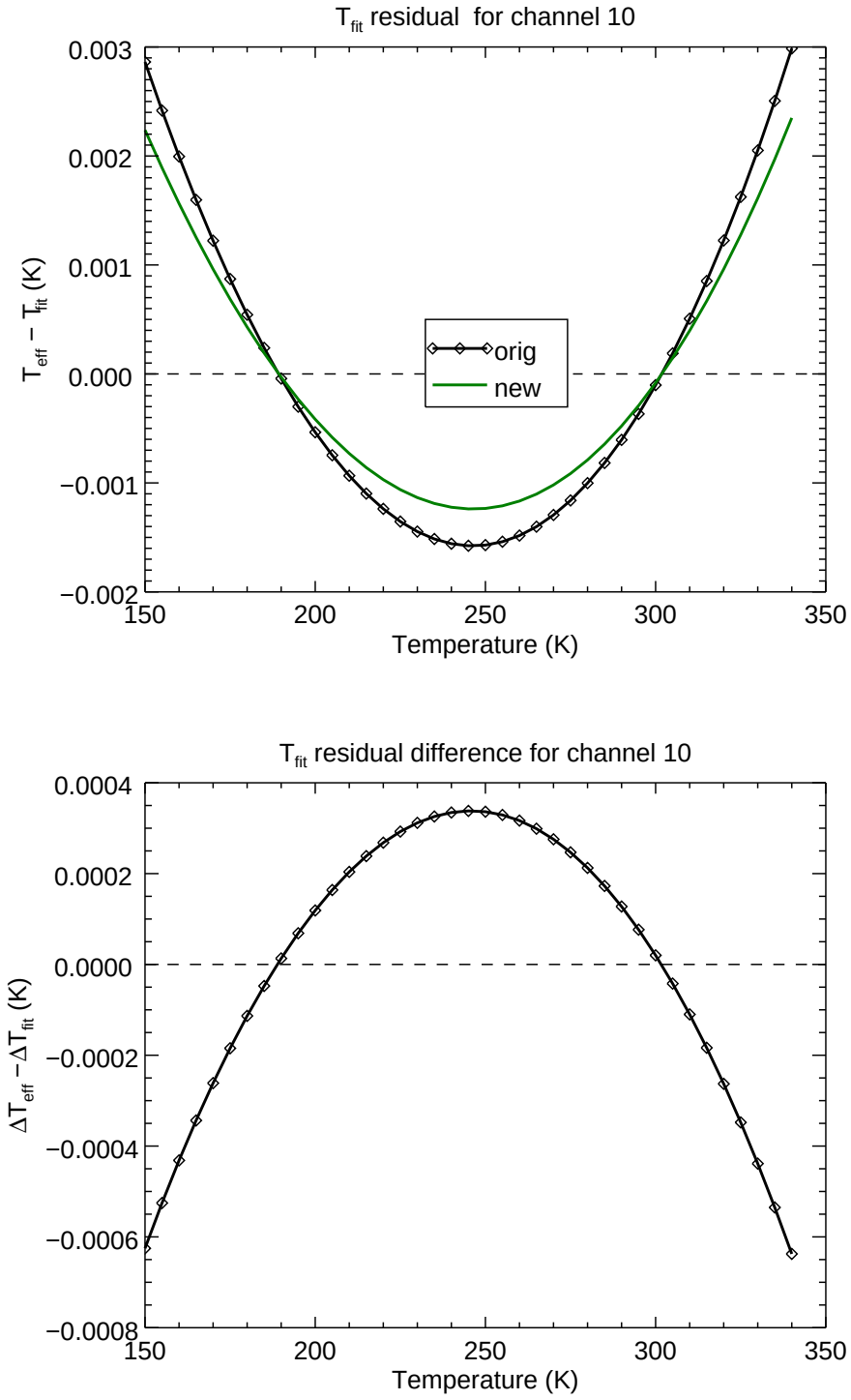

Figure D.10: INSAT-3D Sounder channel 10 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.11 Channel 11

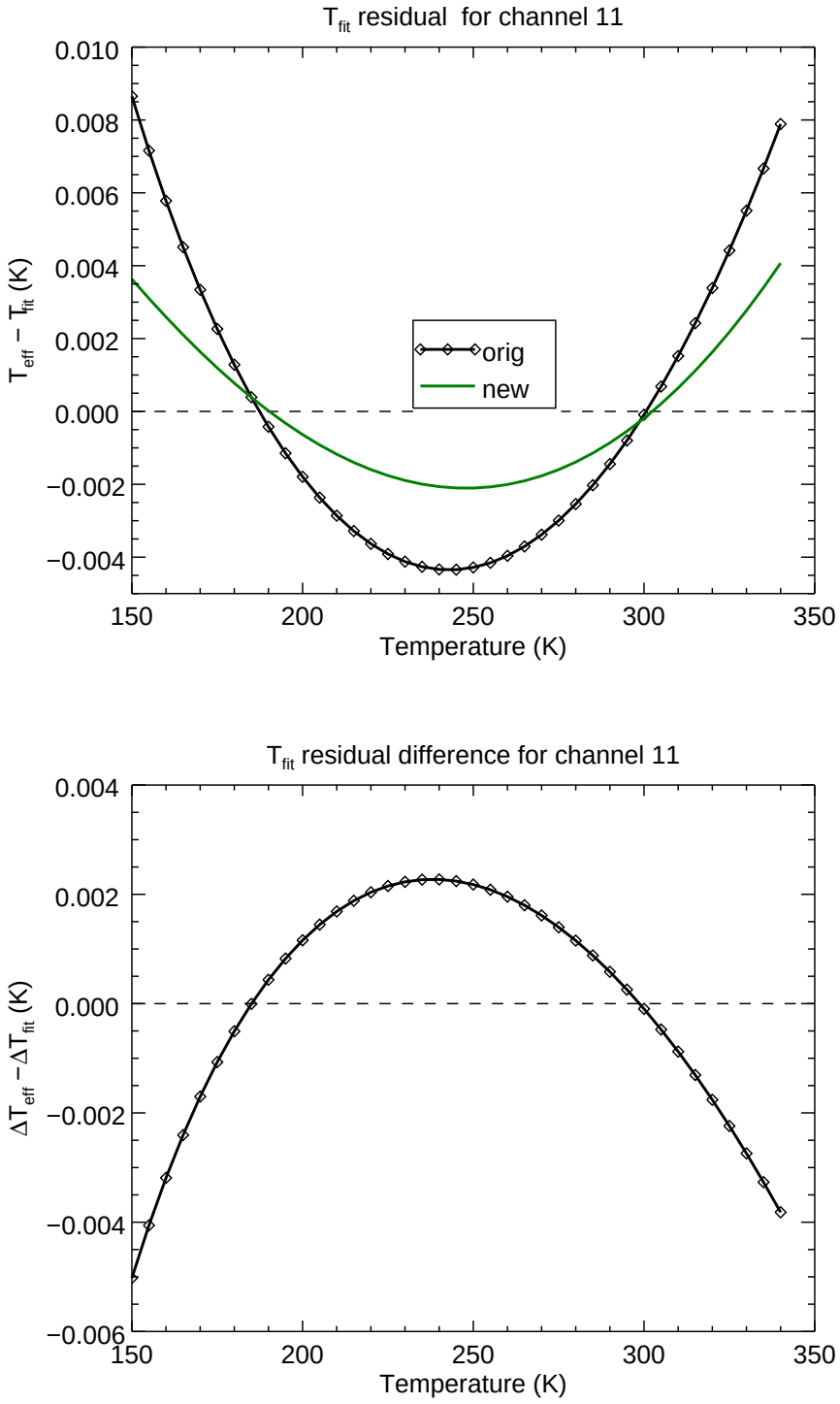

Figure D.11: INSAT-3D Sounder channel 11 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.12 Channel 12

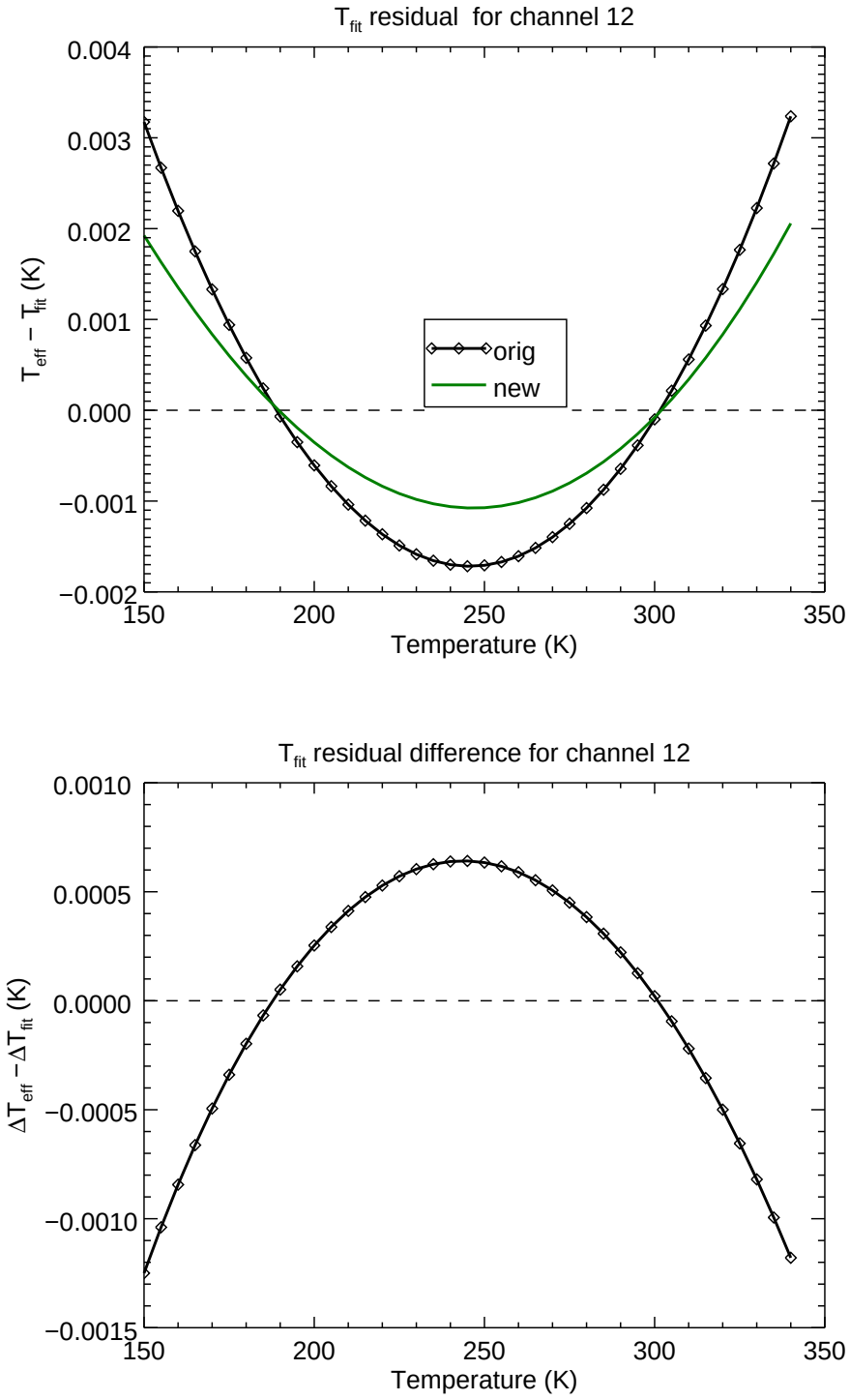

Figure D.12: INSAT-3D Sounder channel 12 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.13 Channel 13

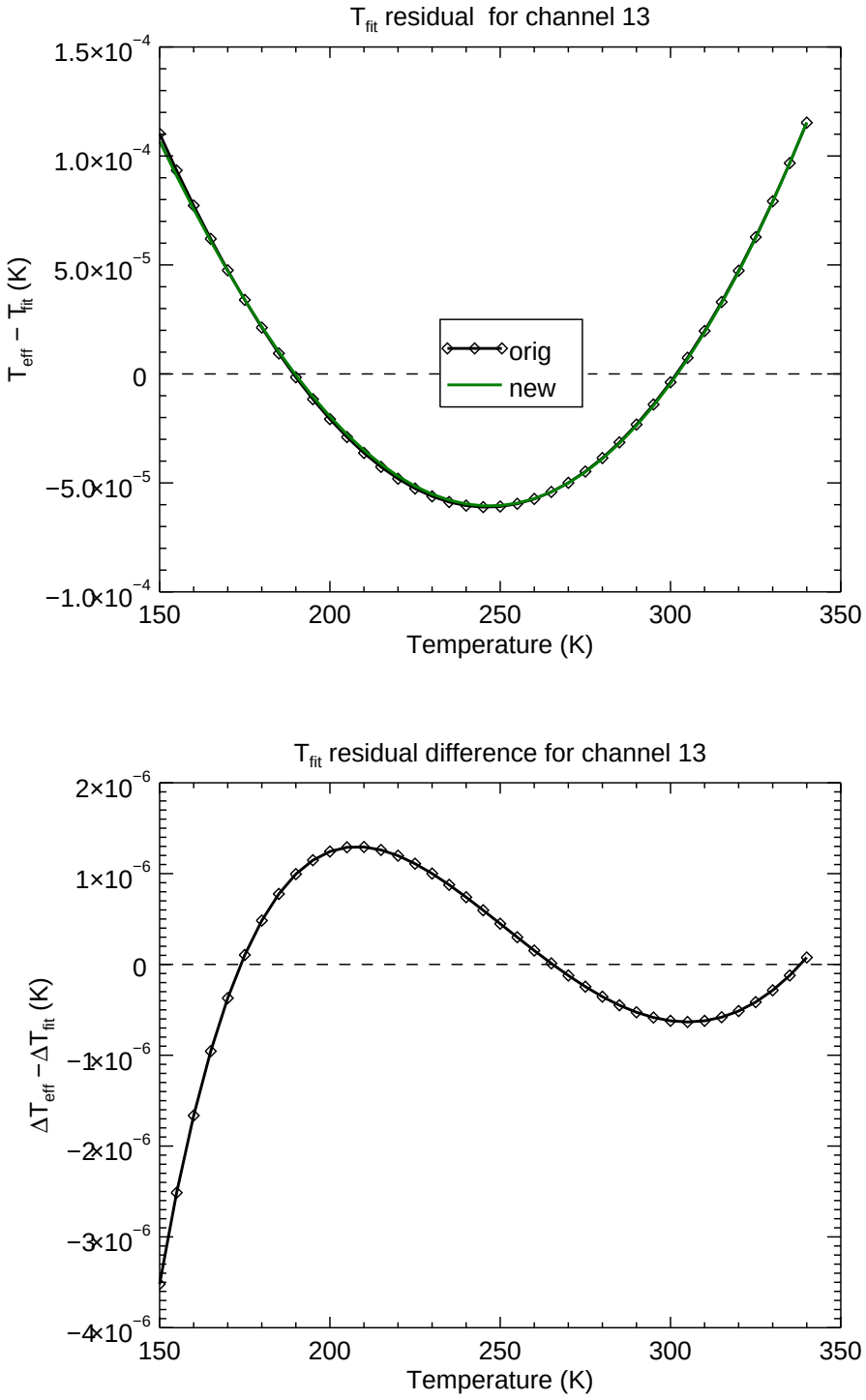

Figure D.13: INSAT-3D Sounder channel 13 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.14 Channel 14

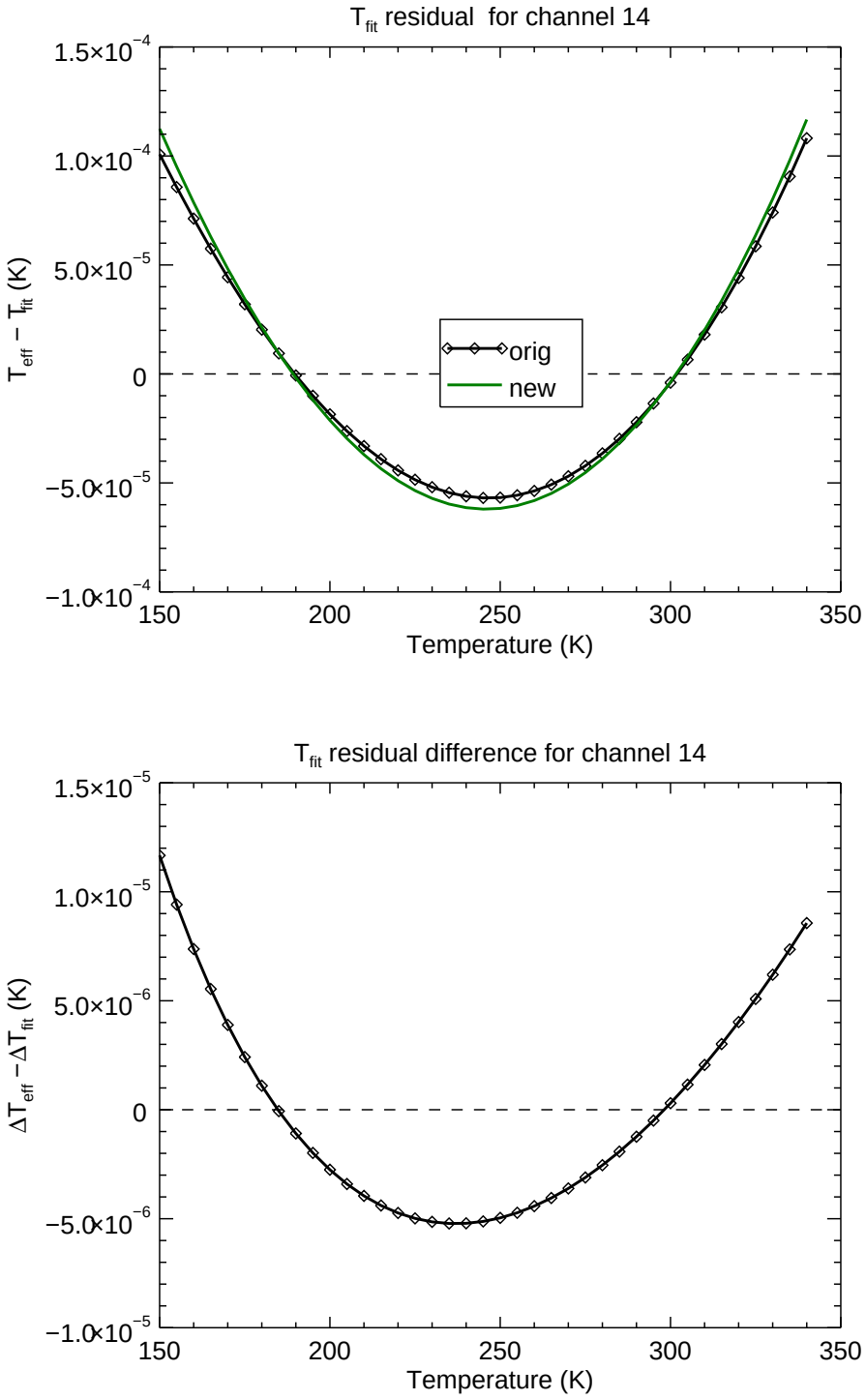

Figure D.14: INSAT-3D Sounder channel 14 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.15 Channel 15

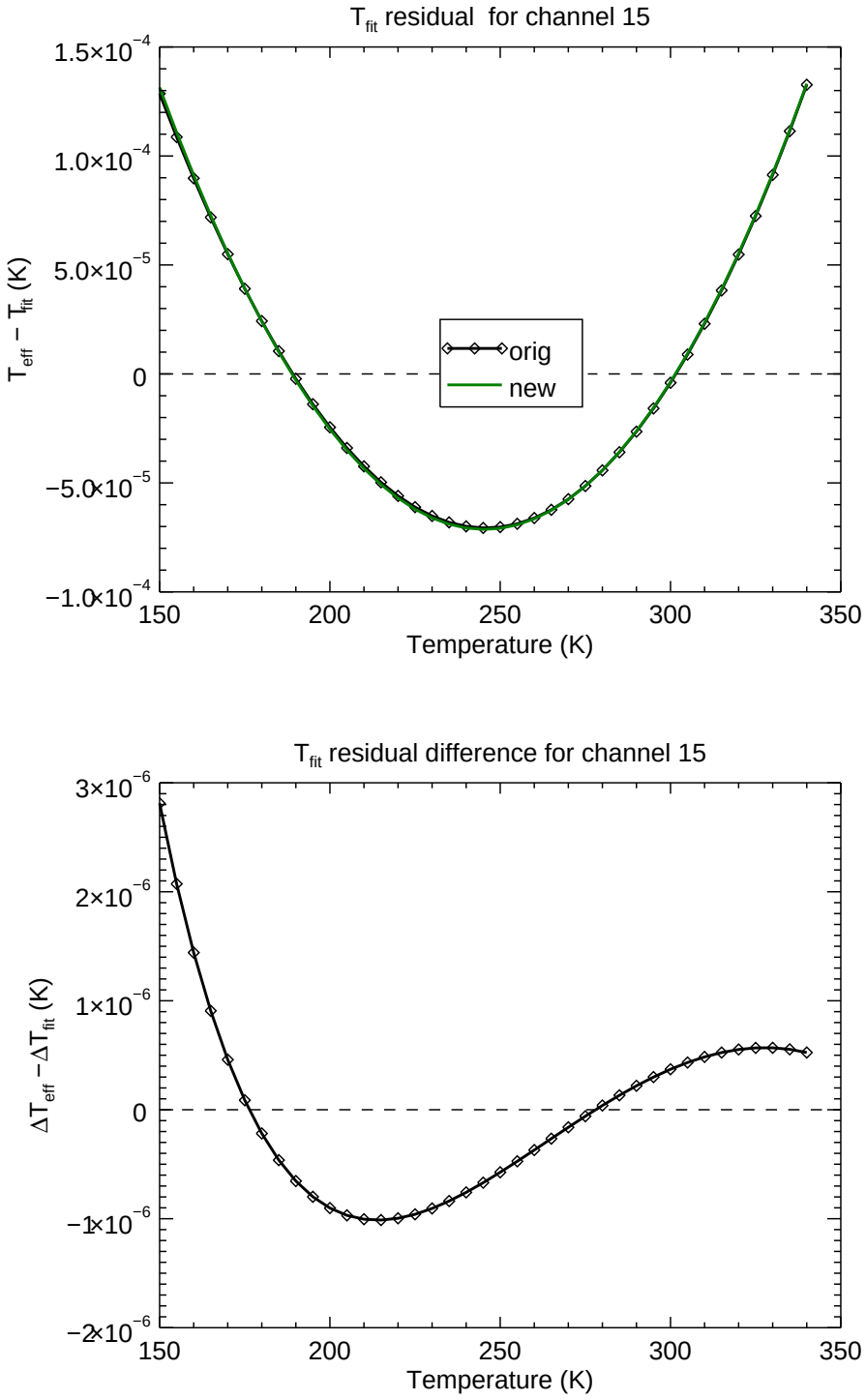

Figure D.15: INSAT-3D Sounder channel 15 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.16 Channel 16

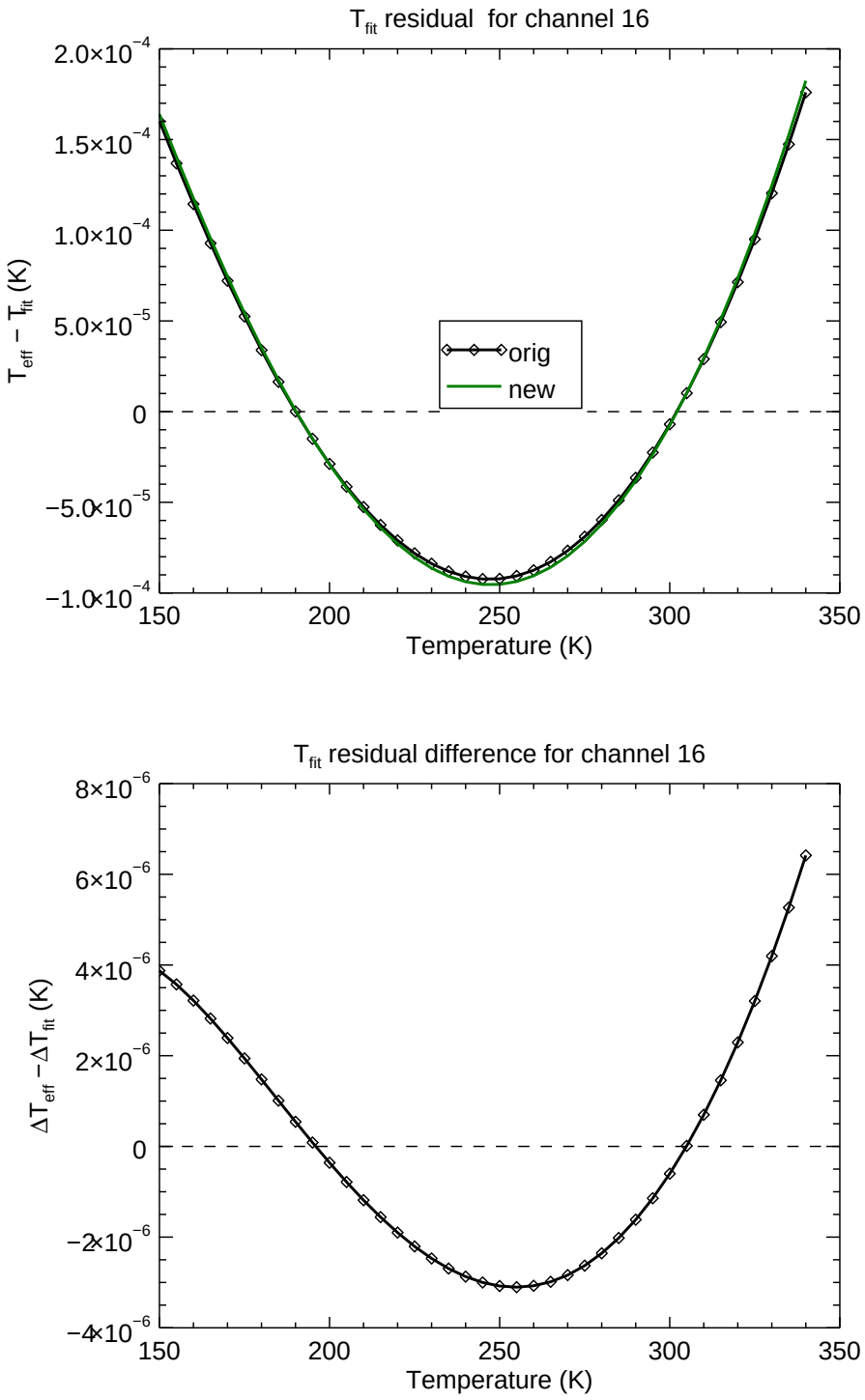

Figure D.16: INSAT-3D Sounder channel 16 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.17 Channel 17

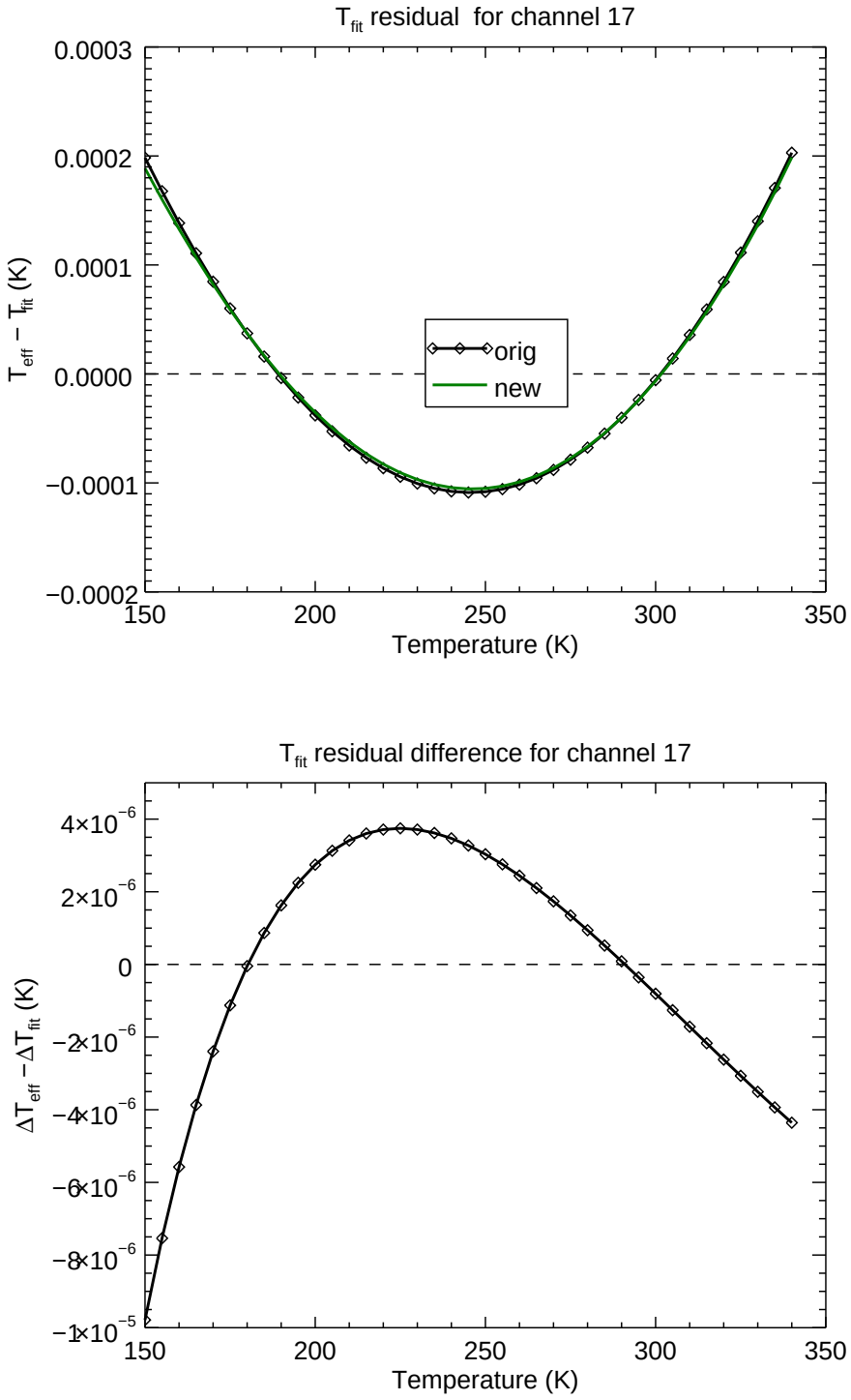

Figure D.17: INSAT-3D Sounder channel 17 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.

D.18 Channel 18

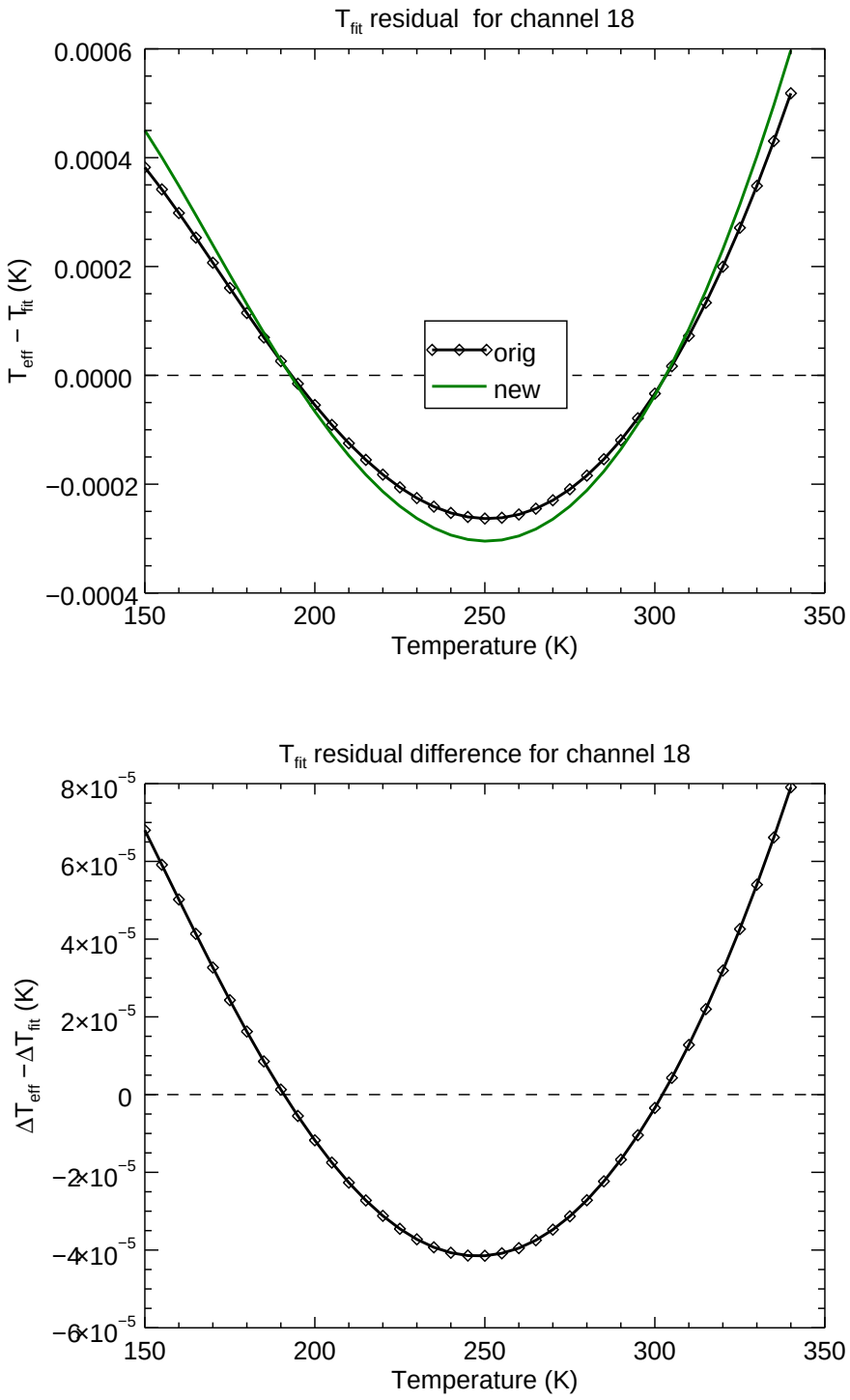

Figure D.18: INSAT-3D Sounder channel 18 polychromatic correction temperature fit residuals. *(Top)* Comparison of residuals for original and new SRFs. *(Bottom)* Residual differences for the original and new SRFs.