LYRA Calibration Methods

IED, 25 Oct 2006, rev. 21 Sep 2007 (additional sample spectra), rev. 07 Apr 2008 (updated responsivities)

In an earlier report (*IED_20060818_LYRA_Radiometric.pdf*), it was considered how to calculate the solar signal (in absolute physical units, e.g., W m-2) from its corresponding LYRA channel output (e.g., converted to A). It was argued that this estimation must involve the (potentially variable) purity, the (constant) aperture size, and a factor (linear or else) that combines the integrals of filter transmittance and detector responsivity in the spectral interval of interest.

Simulations showed the following: For the Lyman-alpha channels (*-1), purity grows with irradiance. For the Herzberg channels (*-2), purities and resulting calibration factors appear to be constant. For the Aluminium channels (*-3), purity varies heavily with irradiance. For the Zirconium channels (*-4), purity appears to be constant but responsivity grows with irradiance.

The question was asked if one could use the LYRA channel signal itself to calculate calibration factors that depend on the signal strength, maybe in a non-linear way. This was discussed at the LYRA meeting in Davos (05/06 Oct 2006) on the basis of the information shown in an earlier version of Figure 0 (see next page). It was suggested to try and use information from *other* LYRA channels instead, in order to enhance the purity of certain problematic channels. In particular, it is clearly visible from the spectral responsivities of the Lyman-alpha channels that they are influenced by the neighbouring longer-wavelength continuum around 180-230 nm. Likewise, it is visible that the spectral responsivities of the Aluminium channels are influenced by the neighbouring shorter-wavelength signals around 1-10 nm. Since these disturbing signals are in fact observed and measured by LYRA via the Herzberg and Zirconium channels, respectively, it was suggested to subtract these signals in an appropriate way.

In the following, I suggest an attempt for procedures and resulting software for all twelve LYRA channels. First, in Figures 1-1 etc., the measured combined responsivity is graphically presented for each channel together with seven simulated spectral output signals. These signals were simulated with the help of TIMED/SEE spectral data sets called “min”, “high”, “max”, “pre1”, “fla1”, “pre2”, and “fla2”, taken on different days and representing a variety of solar irradiances to be expected. A longer-wavelength extension concerning wavelengths above ~200 nm was added to the TIMED/SEE data sets; this extension does not vary. Nominal intervals are marked in red.- Below these figures, the simulated values for the LYRA end signals are shown in a table: the “total” expected output signal, the “pure” signal of interest (defined by the nominal spectral interval of the channel), and the resulting “residual” difference signal (all in nA), together with the “solar” signal, i.e. the integrated input from the TIMED/SEE interval of interest (in W m-2). - Subsequently, methods are suggested to calculate the latter from the former.

The procedures suggested here are solely based on the seven data sets mentioned above, plus the assumption that zero solar input should lead to zero LYRA output. As soon as the assumed models look “reasonable”, linear interpolation between data points is suggested (channels *-3 and *-4) instead of assuming higher-order polynomial or exponential functions in the case of sublinear or superlinear relations. In the other cases, simple linear factors can be used (channels *-1 and *-2).

Figures 1-1a etc. show the relations between total or pure LYRA signals to the solar signal in the upper row, as well as the relation between the channel signal or – where applicable – the neighbouring channel signal and the residual signal in the lower row. The arguments are similar for all three heads (only the numerical values vary), but different for all four channels.

In the case of higher values in the Aluminium channels (*-3), where more than 90% contamination have to be estimated and subtracted, the success appears doubtful, and the initial approach may be suggested, namely, using the signal of the channel itself (instead of the neighbouring channel) to deduce the pure signal.

The seven TIMED/SEE samples used for the simulations are the following:

min	24 Feb 2005	solar minimum
high	11 Nov 2003	high solar flux
max	28 Oct 2003	solar maximum
pre1	28 Oct 2003	before X17 flare
fla1	28 Oct 2003	briefly after X17 flare
pre2	03 Nov 2003	before X3.9 flare
fla2	03 Nov 2003	briefly after X3.9 flare

According to my information, these observations are "modeled" below 27 nm. - For the wavelength range above 193 nm up to 1 mm, spectral values from another source were added, identically for all seven samples.

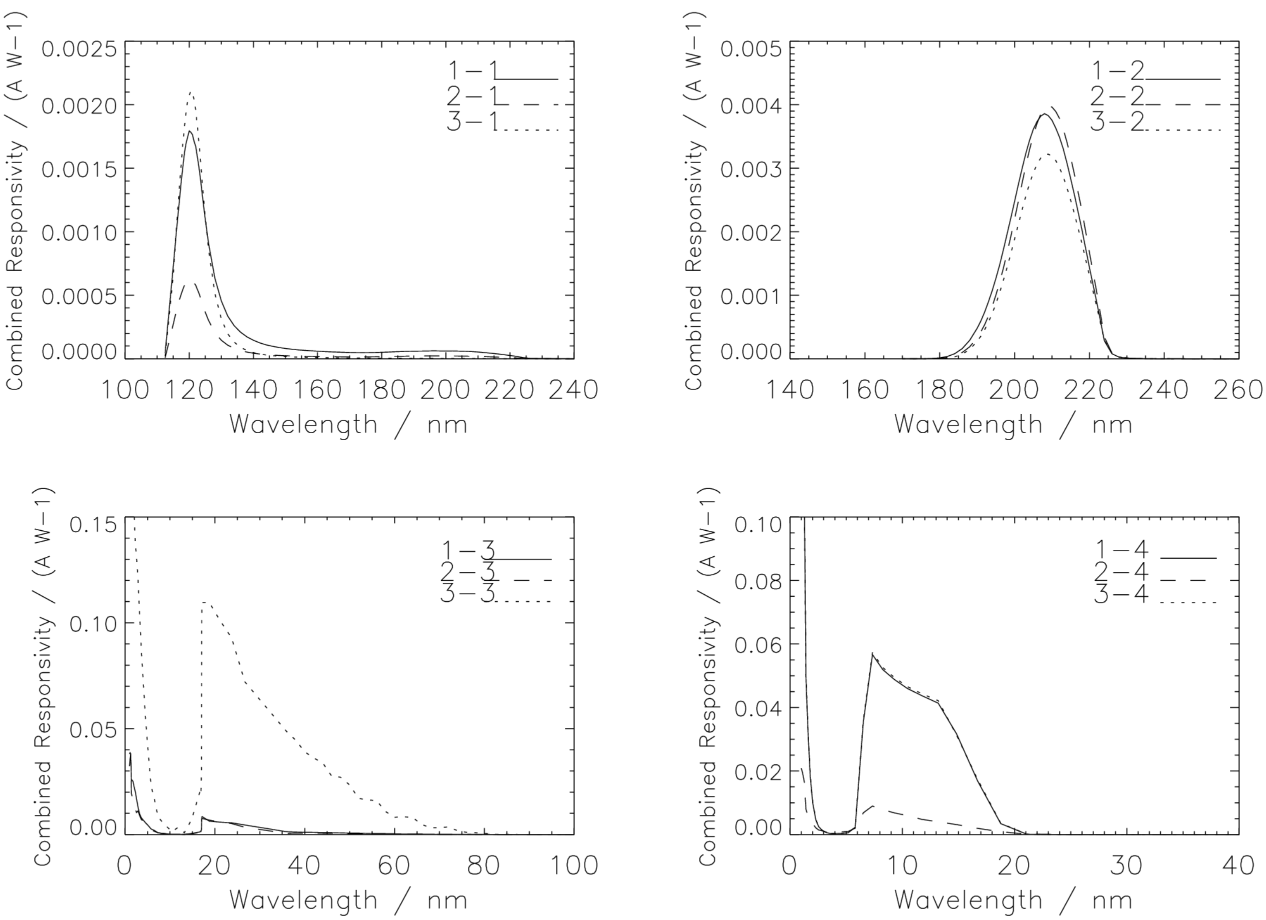

Figure 0. LYRA channel responsivities, similar to those presented at the Davos meeting, but updated with the latest responsivity measurements: Combination of filter and detector effects measured as a function of wavelength. *-1 = Lyman-alpha channels, *-2 = Herzberg channels, *-3 = Aluminium channels, *-4 = Zirconium channels.

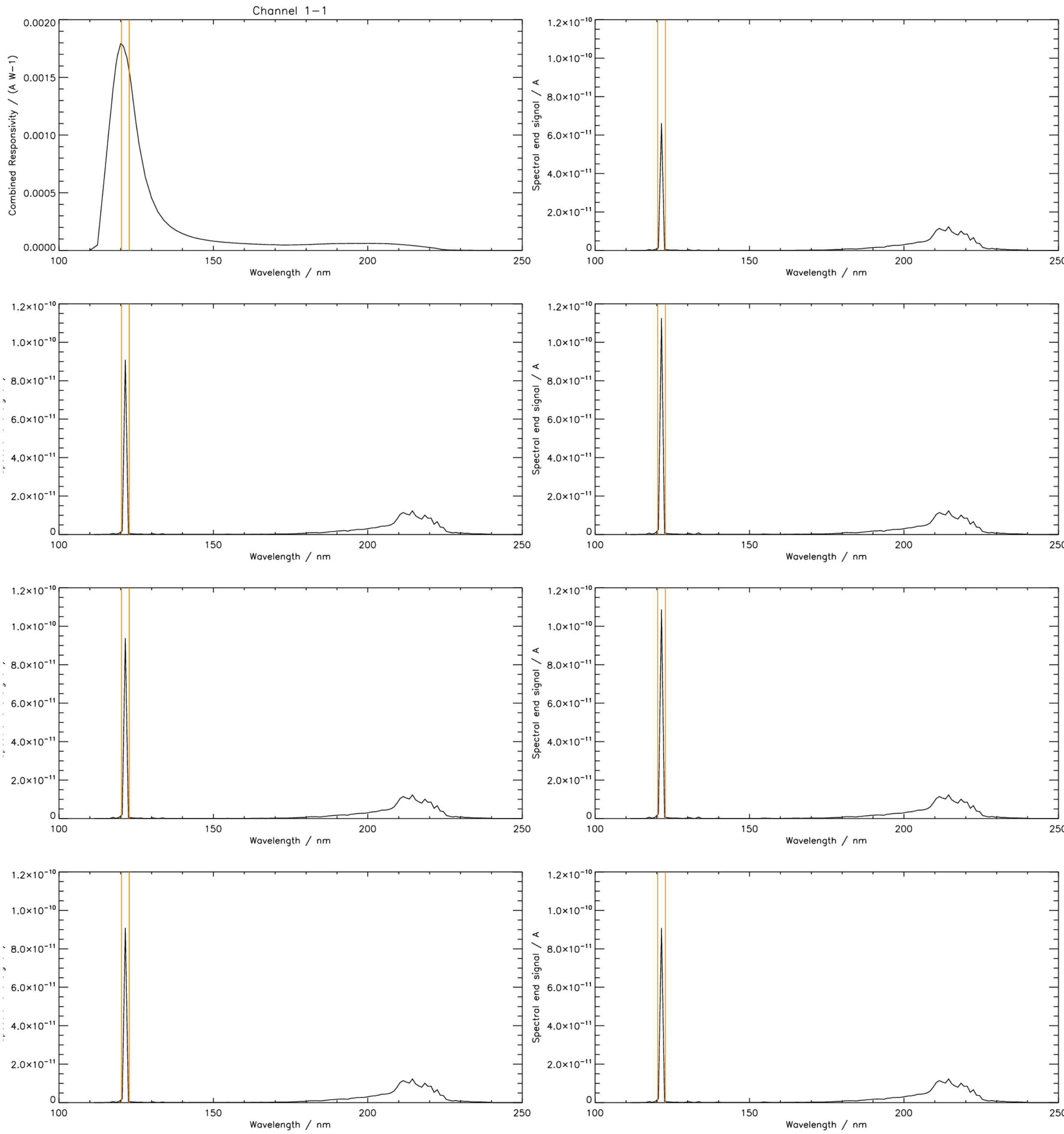

Figure 1-1. Measured responsivity and simulated output for LYRA channel 1-1
Ly XN + MSM12 (121.5 +/- nm)

sample	total	pure	residual	solar
min	0.293985 nA	0.0680782 nA (23.2%)	0.225907 nA	0.00564762 Wm-2
high	0.325132 nA	0.0934120 nA (28.7%)	0.231720 nA	0.00774904 Wm-2
max	0.349462 nA	0.115835 nA (33.1%)	0.233627 nA	0.00960818 Wm-2
pre1	0.325528 nA	0.0965149 nA (29.6%)	0.229013 nA	0.00800550 Wm-2
fla1	0.343065 nA	0.111881 nA (32.6%)	0.231184 nA	0.00928009 Wm-2
pre2	0.322433 nA	0.0934496 nA (29.0%)	0.228983 nA	0.00775156 Wm-2
fla2	0.323225 nA	0.0933691 nA (28.9%)	0.229856 nA	0.00774487 Wm-2

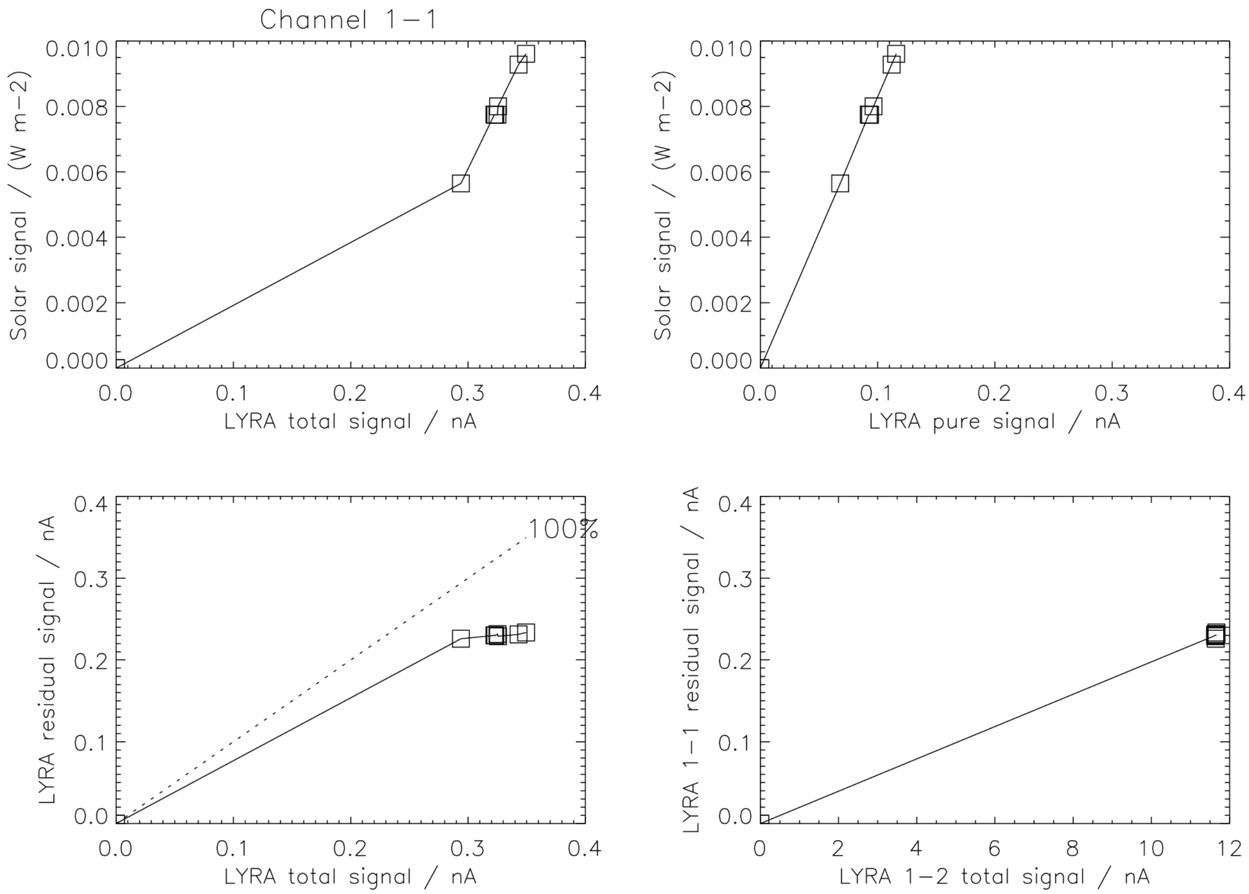

Figure 1-1a. Simulated relations between input and output for LYRA channel 1-1.

The functional relation between the solar signal and the LYRA total signal is obviously not straightforward (see upper left image). The reason is a contamination due to the influence of the interval 180-230 nm, which is not part of the nominal interval around the Lyman-alpha line. But this residual signal can obviously be estimated with the help of the output signal from LYRA channel 1-2 in a simple way (see lower right image):

[LYRA 1-1 residual signal / nA] = 0.0197673 [LYRA 1-2 total signal / nA]*

On the other hand, it can also be estimated as a linear function of the total signal from LYRA channel 1-1 itself, at least above 0.29 nA (see lower left image):

*[LYRA 1-1 residual signal / nA] = 0.189483 + 0.124804 * [LYRA 1-1 total signal / nA]*

Both variants will be tested in the commissioning phase, before one will eventually be selected.

The pure signal can be estimated as the difference:

[LYRA 1-1 pure signal / nA] = [LYRA 1-1 total signal / nA] – [LYRA 1-1 residual signal / nA]

And the solar signal can again be estimated from the pure signal in a simple way (see upper right image):

*[“Lyman-alpha” solar signal / (W m-2)] = 0.0827306 * [LYRA 1-1 pure signal / nA]*

Remarks: Defining 2.5 nm around 121.5 nm as nominal interval leads to just three TIMED/SEE data points (120.5, 121.5, and 122.5 nm), of which only 121.5 nm is significant. This means that the simulation is essentially based on one value; a small variation of the nominal interval would not lead to different simulation results. - Due to the simple linear factors, the estimation error is within 6.6% for the first variant, and 1.5% for the second.

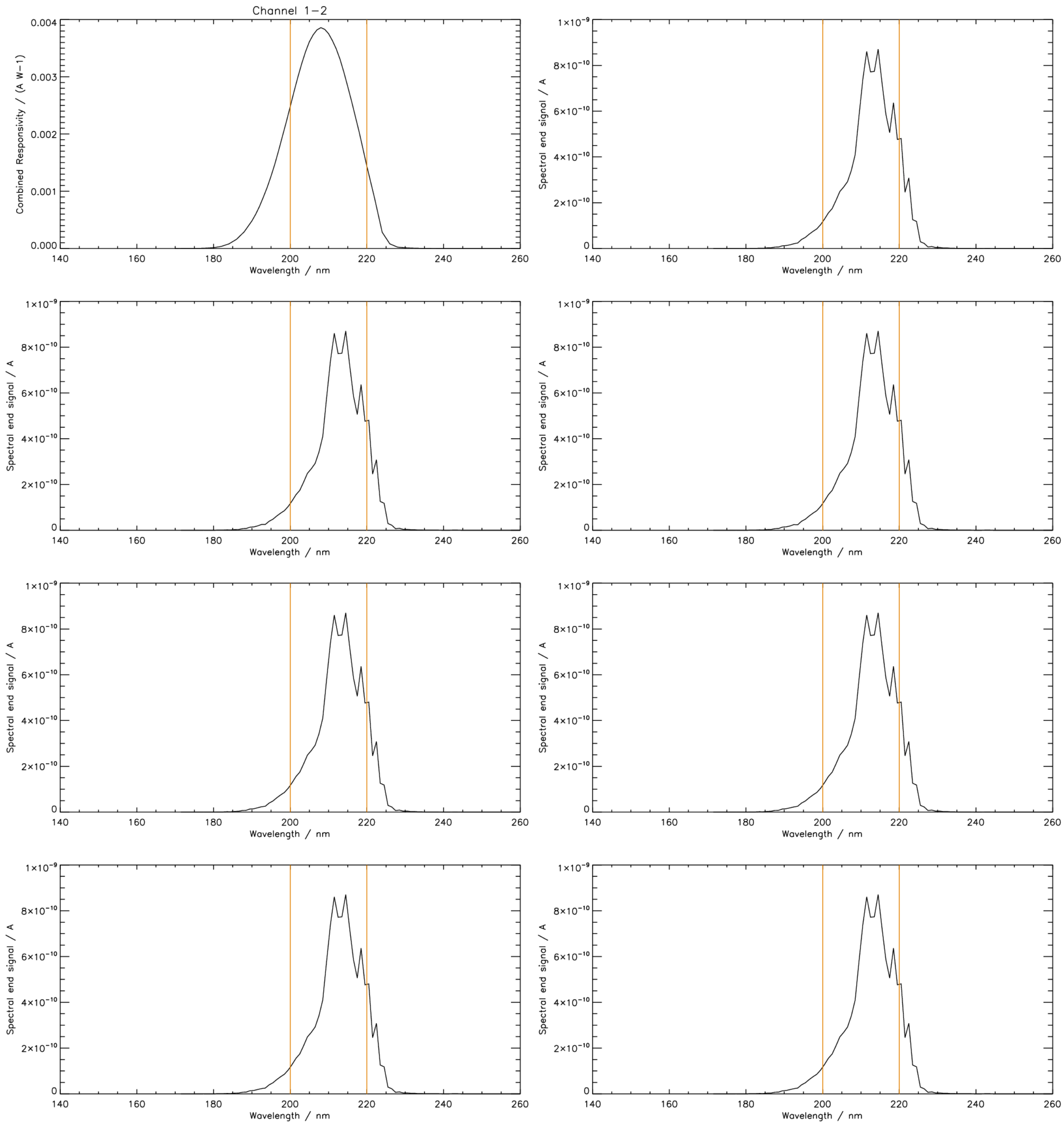

Figure 1-2. Measured responsivity and simulated output for LYRA channel 1-2
Herzberg + PIN10 (200-220 nm)

sample	total	pure	residual	solar
min	11.6467 nA	9.75500 nA (83.8%)	1.89174 nA	0.474210 Wm-2
high	11.6637 nA	9.75500 nA (83.6%)	1.90870 nA	0.474210 Wm-2
max	11.6622 nA	9.75500 nA (83.6%)	1.90721 nA	0.474210 Wm-2
pre1	11.6350 nA	9.75500 nA (83.8%)	1.87998 nA	0.474210 Wm-2
fla1	11.6342 nA	9.75500 nA (83.8%)	1.87920 nA	0.474210 Wm-2
pre2	11.6356 nA	9.75500 nA (83.8%)	1.88063 nA	0.474210 Wm-2
fla2	11.6352 nA	9.75500 nA (83.8%)	1.88023 nA	0.474210 Wm-2

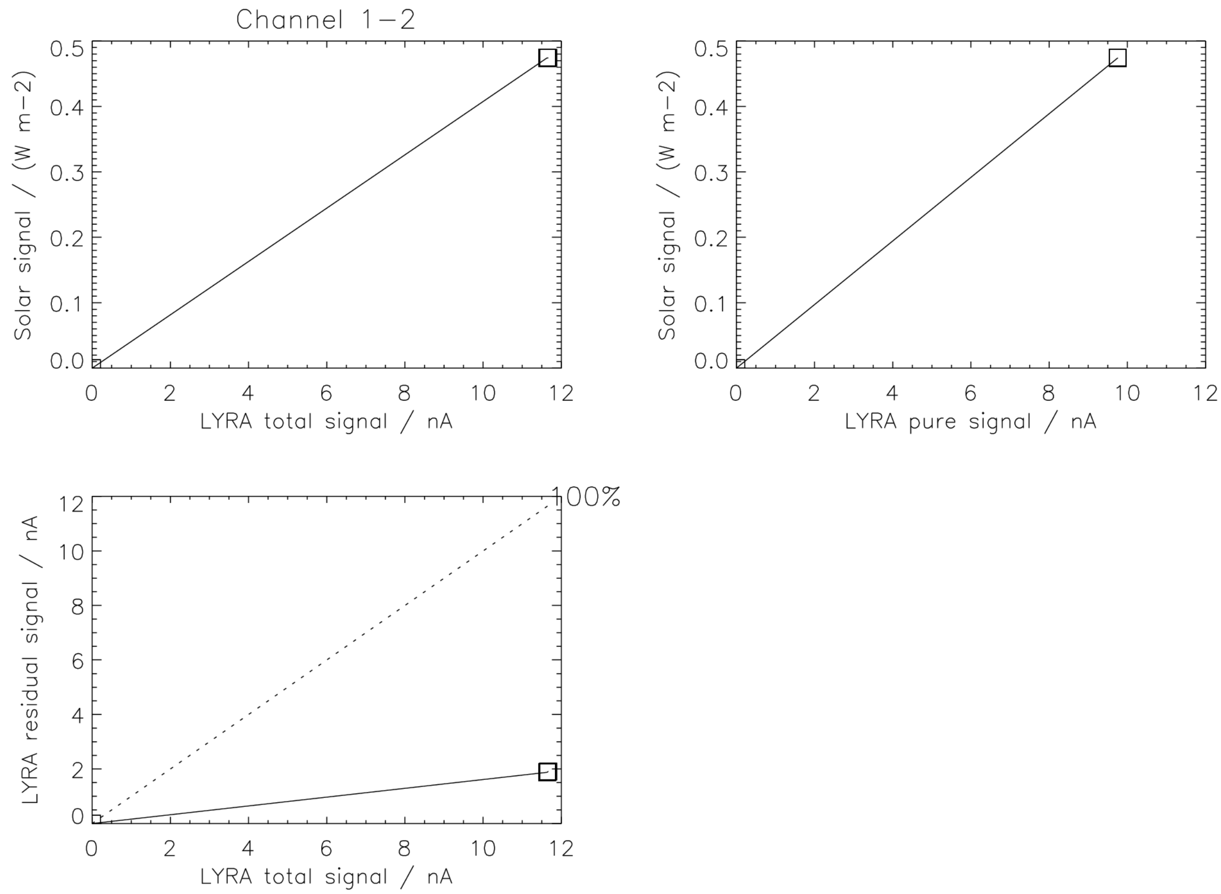

Figure 1-2a. Simulated relations between input and output for LYRA channel 1-2.

The functional relation between the solar signal and the LYRA total signal looks straightforward at first sight. The pure signal or the residual signal can simply be estimated by a linear factor (see table last page). Following the scheme of channel 1-1, the residual signal is calculated as:

*[LYRA 1-2 residual signal / nA] = 0.162276 * [LYRA 1-2 total signal / nA]*

The pure signal can be estimated as the difference:

[LYRA 1-2 pure signal / nA] = [LYRA 1-2 total signal / nA] – [LYRA 1-2 residual signal / nA]

And the solar signal can be estimated from the pure signal in a simple way (see upper right image):

*[“Herzberg” solar signal / (W m-2)] = 0.0486120 * [LYRA 1-2 pure signal / nA]*

Remarks: The estimate is actually only based on one sample instead of seven, because the TIMED/SEE data extensions above 200 nm are identical. - If other limits of the nominal interval were chosen, the purity could naturally be improved (rough estimates):
200 – 220 nm => 84 % purity, 197 – 223 nm => 95 % purity, 195 – 225 nm => 98 % purity,
190 – 230 nm => 99.5 % purity, 180 – 230 nm => 99.9 % purity.

Despite the simple linear factors, the estimation error is within 0.2%. But since the estimates are based on identical spectra above 200 nm, this is probably unrealistic.

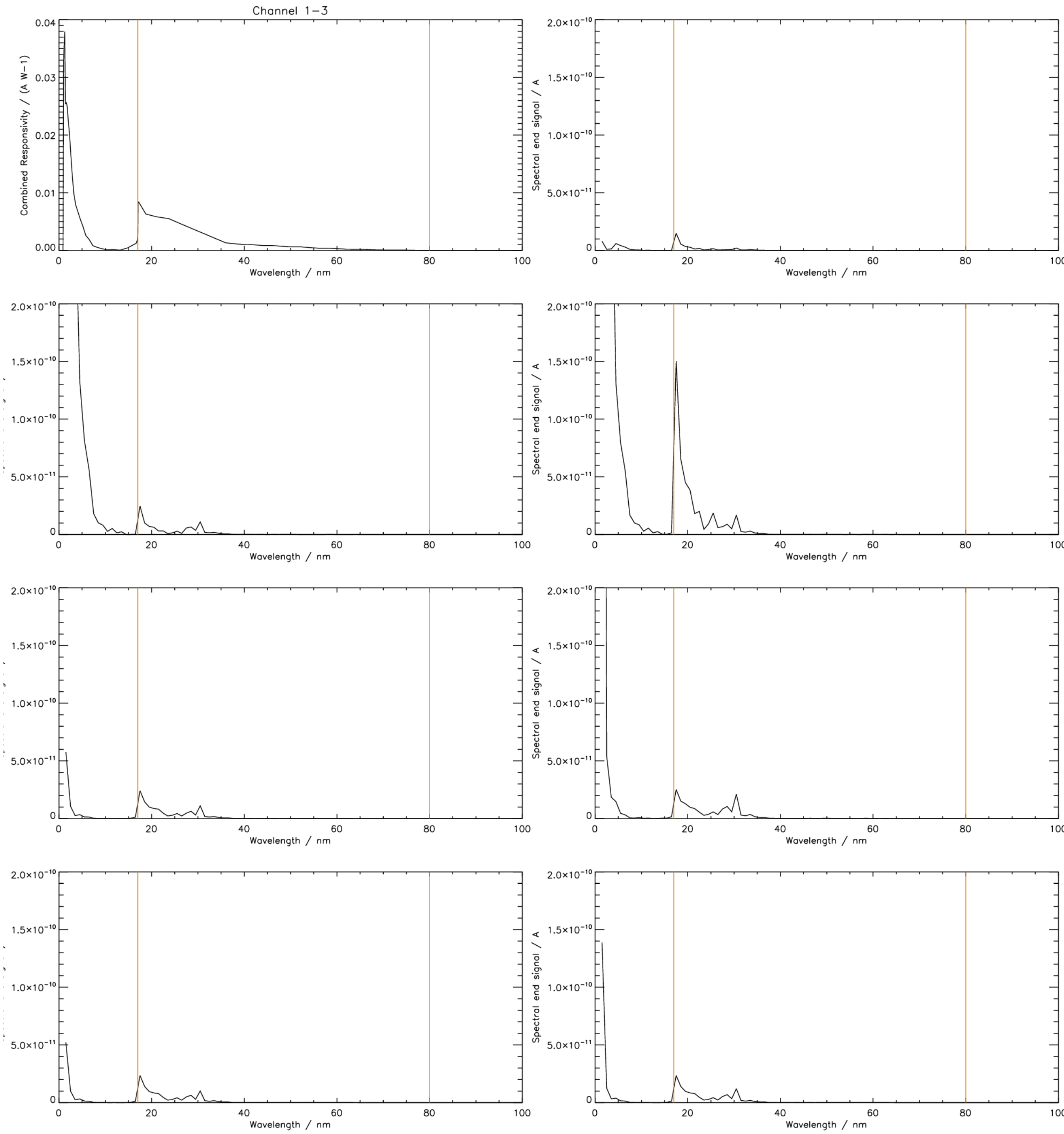

Figure 1-3. Measured responsivity and simulated output for LYRA channel 1-3
Aluminium + MSM11 (17-80 nm)

sample	total	pure	residual	solar
min	0.0664836 nA	0.0402148 nA (60.5%)	0.0262688 nA	0.00131051 Wm-2
high	3.92300 nA	0.0962918 nA (2.5%)	3.82671 nA	0.00340476 Wm-2
max	8.74248 nA	0.426782 nA (4.9%)	8.31570 nA	0.0111131 Wm-2
pre1	0.194409 nA	0.115238 nA (59.3%)	0.0791705 nA	0.00376518 Wm-2
fla1	1.77233 nA	0.154482 nA (8.7%)	1.61785 nA	0.00570166 Wm-2
pre2	0.183451 nA	0.111148 nA (60.6%)	0.0723025 nA	0.00362499 Wm-2
fla2	0.279541 nA	0.116044 nA (41.5%)	0.163496 nA	0.00394254 Wm-2

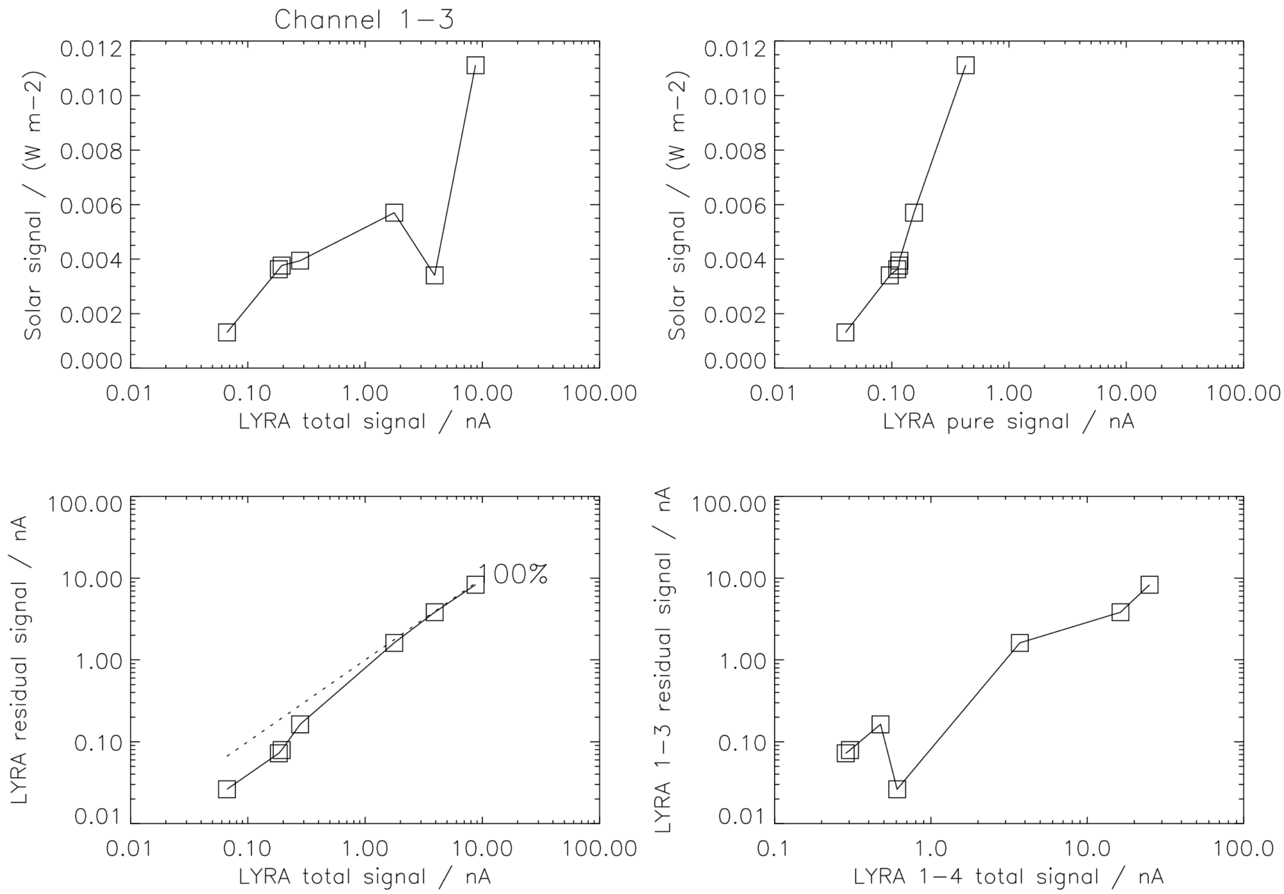

Figure 1-3a. Simulated relations between input and output for LYRA channel 1-3.

The functional relation between the solar signal and the LYRA total signal is obviously not straightforward (rather zigzag, see upper left image). The reason is a contamination due to the influence of the interval 1-10 nm, which is not part of the 17-80 nm nominal interval of the "Aluminium" channels. This residual signal can possibly be estimated with the help of the output signal from LYRA channel 1-4; not as simple as in the case of channel 1-1, but with linear interpolation between the points of the relationship as visible in the lower right image:

[LYRA 1-3 residual signal / nA] = interp[LYRA 1-4 total signal / nA]

On the other hand, it can also be estimated as an almost linear function of the total signal from LYRA channel 1-3 itself (see lower left image):

[LYRA 1-3 residual signal / nA] = interp[LYRA 1-3 total signal / nA]

Both variants will be tested in the commissioning phase, before one will eventually be selected.

The pure signal can be estimated as the difference:

[LYRA 1-3 pure signal / nA] = [LYRA 1-3 total signal / nA] – [LYRA 1-3 residual signal / nA]

And the solar signal can be estimated from the pure signal, again not in a simple way but with linear interpolation between the points of a slightly nonlinear relationship as visible in the upper right image:

["Aluminium" solar signal / (W m-2)] = interp[LYRA 1-3 pure signal / nA]

Remarks: Although the channel interval nominally reaches up to 80 nm, effectively it appears to end at 35 nm (see Figure 1-3). - If a large subset of these channels' solar signal is similar to the "high", "max" or "fla1" simulation data, then the uncalibrated data (before subtraction of the substantial short-wavelength contamination) will probably not be very meaningful. - Due to the linear interpolation, the estimation error is 0%, but this is unrealistic.

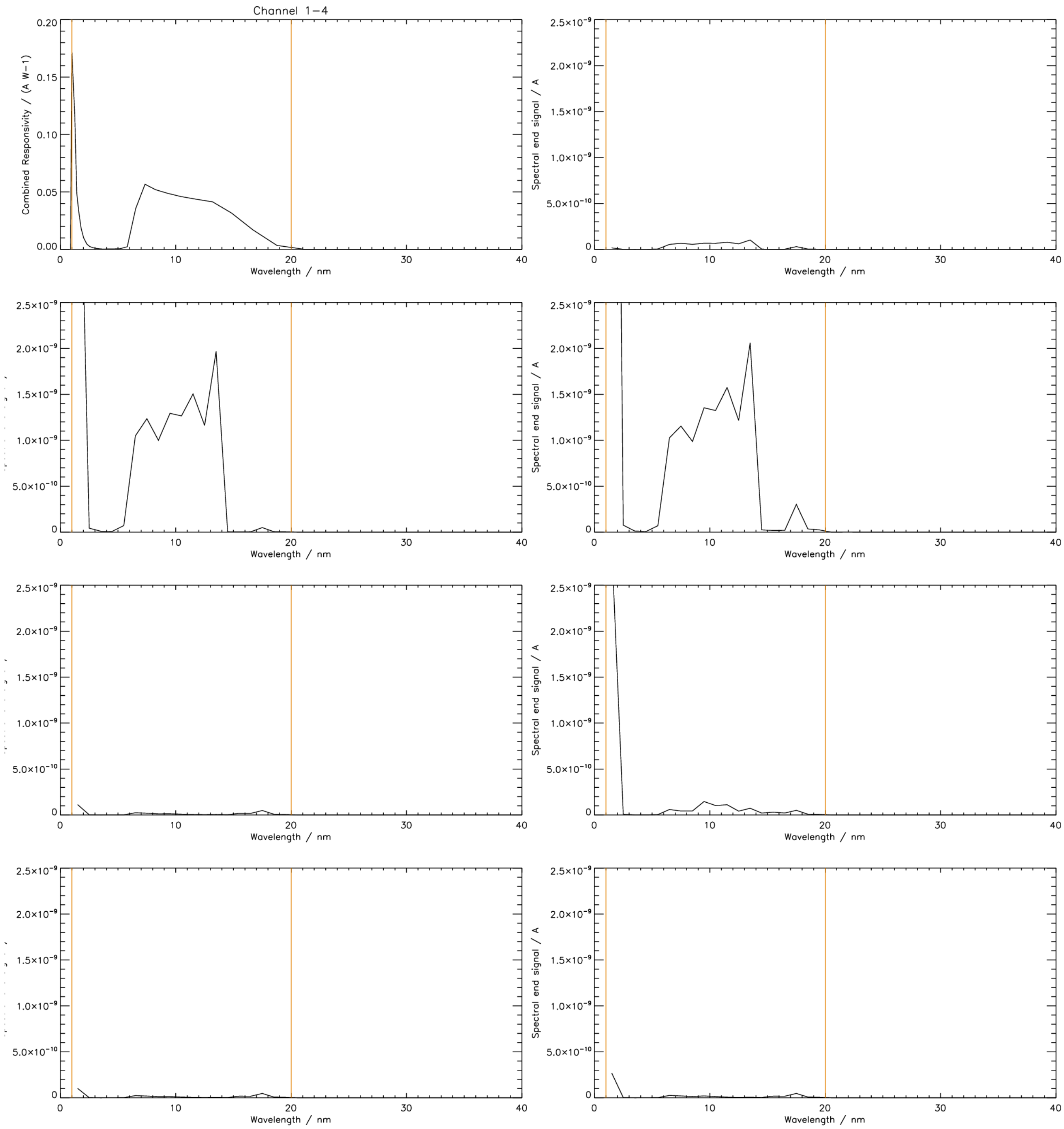

Figure 1-4. Measured responsivity and simulated output for LYRA channel 1-4
Zr(300nm) + AXUV20D (1-20 nm)

sample	total	pure	residual	solar
min	0.607805 nA	0.605892 nA (99.7%)	0.00191291 nA	0.00267627 Wm-2
high	16.3034 nA	16.3014 nA (100.%)	0.00198597 nA	0.0659849 Wm-2
max	25.0345 nA	25.0319 nA (100.%)	0.00256506 nA	0.0975310 Wm-2
pre1	0.304138 nA	0.302066 nA (99.3%)	0.00207209 nA	0.00208323 Wm-2
fla1	3.70440 nA	3.70230 nA (99.9%)	0.00209743 nA	0.0132763 Wm-2
pre2	0.285317 nA	0.283253 nA (99.3%)	0.00206379 nA	0.00198338 Wm-2
fla2	0.476253 nA	0.474187 nA (99.6%)	0.00206574 nA	0.00261203 Wm-2

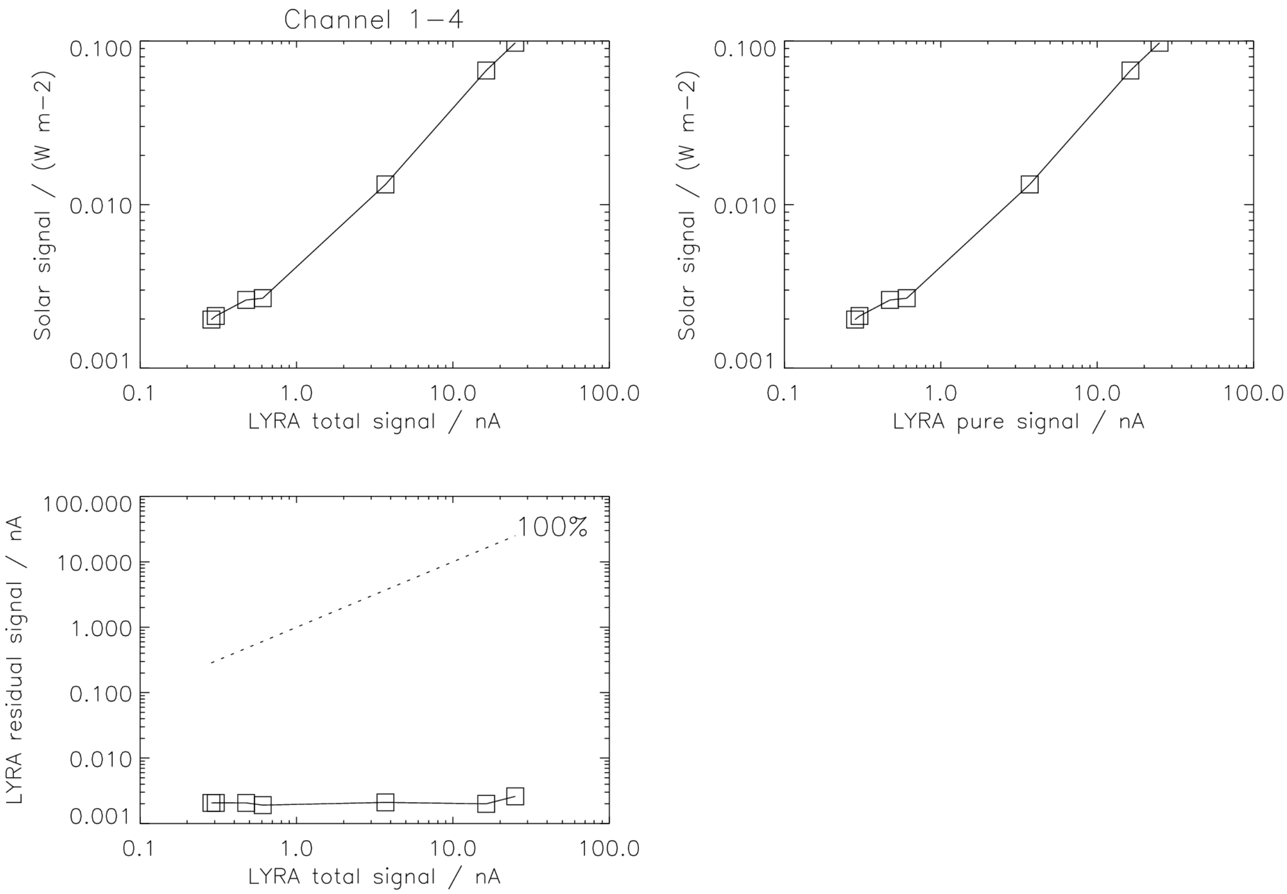

Figure 1-4a. Simulated relations between input and output for LYRA channel 1-4.

The functional relation between the solar signal and the LYRA total signal looks straightforward. Since the purity of the Zirconium channels is always around 100%, the residual signal is almost negligible (see lower figure) and can simply be set to the average. Following the usual scheme:

[LYRA 1-4 residual signal / nA] = 0.00211651

The pure signal can be estimated as the difference, which is almost the total signal:

[LYRA 1-4 pure signal / nA] = [LYRA 1-4 total signal / nA] – [LYRA 1-4 residual signal / nA]

And the solar signal can be estimated from the pure signal with linear interpolation between the points of a slightly nonlinear relationship as visible in the upper right image:

["Zirconium" solar signal / (W m-2)] = interp[LYRA 1-4 pure signal / nA]

Remarks: Due to the linear interpolation, the estimation error (caused by the averaging) is below 0.1%, but this is unrealistic.

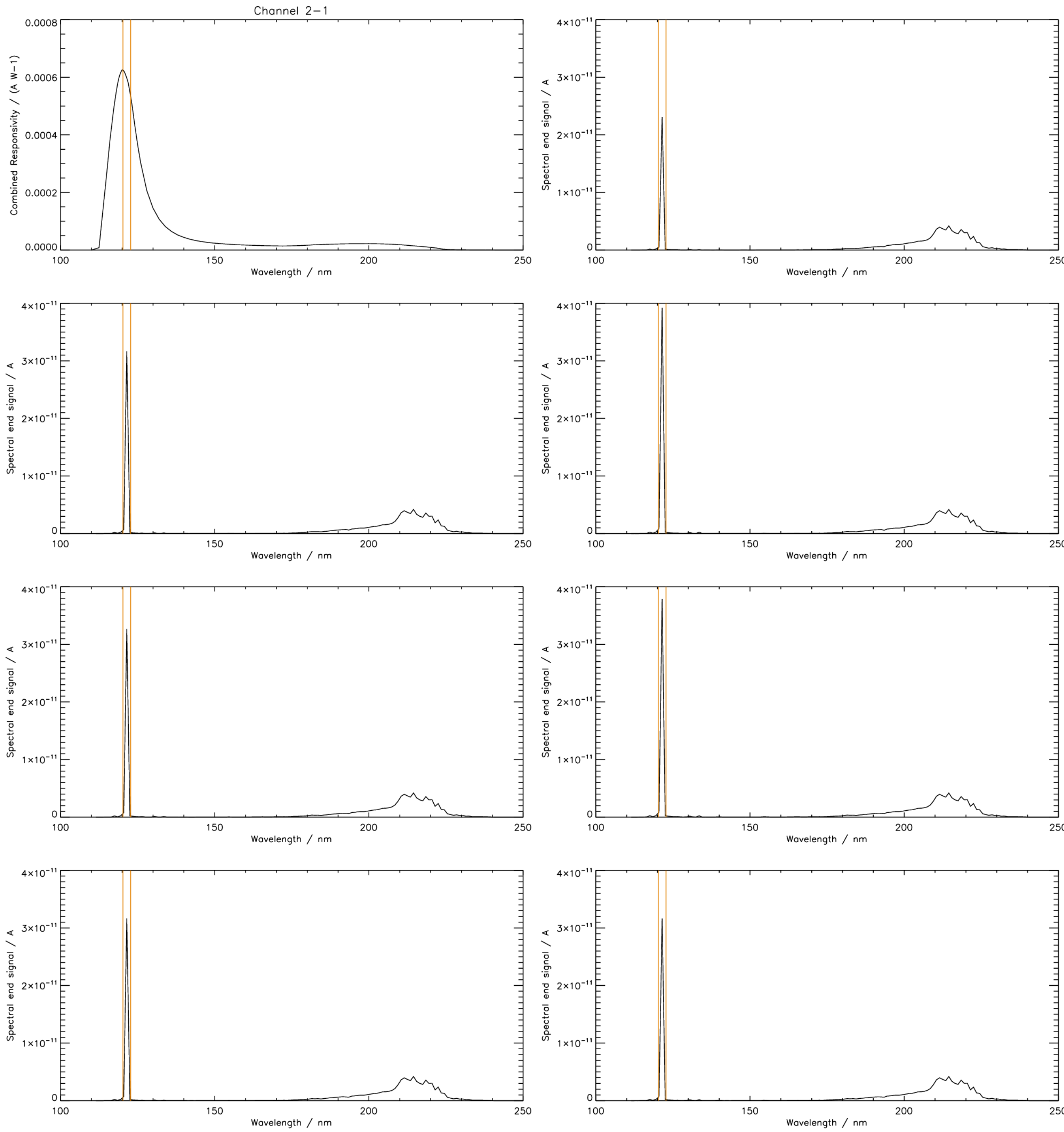

Figure 2-1. Measured responsivity and simulated output for LYRA channel 2-1
Ly XN + MSM21 (121.5 +/- nm)

sample	total	pure	residual	solar
min	0.103072 nA	0.0237219 nA (23.0%)	0.0793497 nA	0.00564762 Wm-2
high	0.113818 nA	0.0325496 nA (28.6%)	0.0812689 nA	0.00774904 Wm-2
max	0.122237 nA	0.0403633 nA (33.0%)	0.0818737 nA	0.00960818 Wm-2
pre1	0.113973 nA	0.0336311 nA (29.5%)	0.0803422 nA	0.00800550 Wm-2
fla1	0.120003 nA	0.0389857 nA (32.5%)	0.0810169 nA	0.00928009 Wm-2
pre2	0.112900 nA	0.0325630 nA (28.8%)	0.0803366 nA	0.00775156 Wm-2
fla2	0.113277 nA	0.0325349 nA (28.7%)	0.0807421 nA	0.00774487 Wm-2

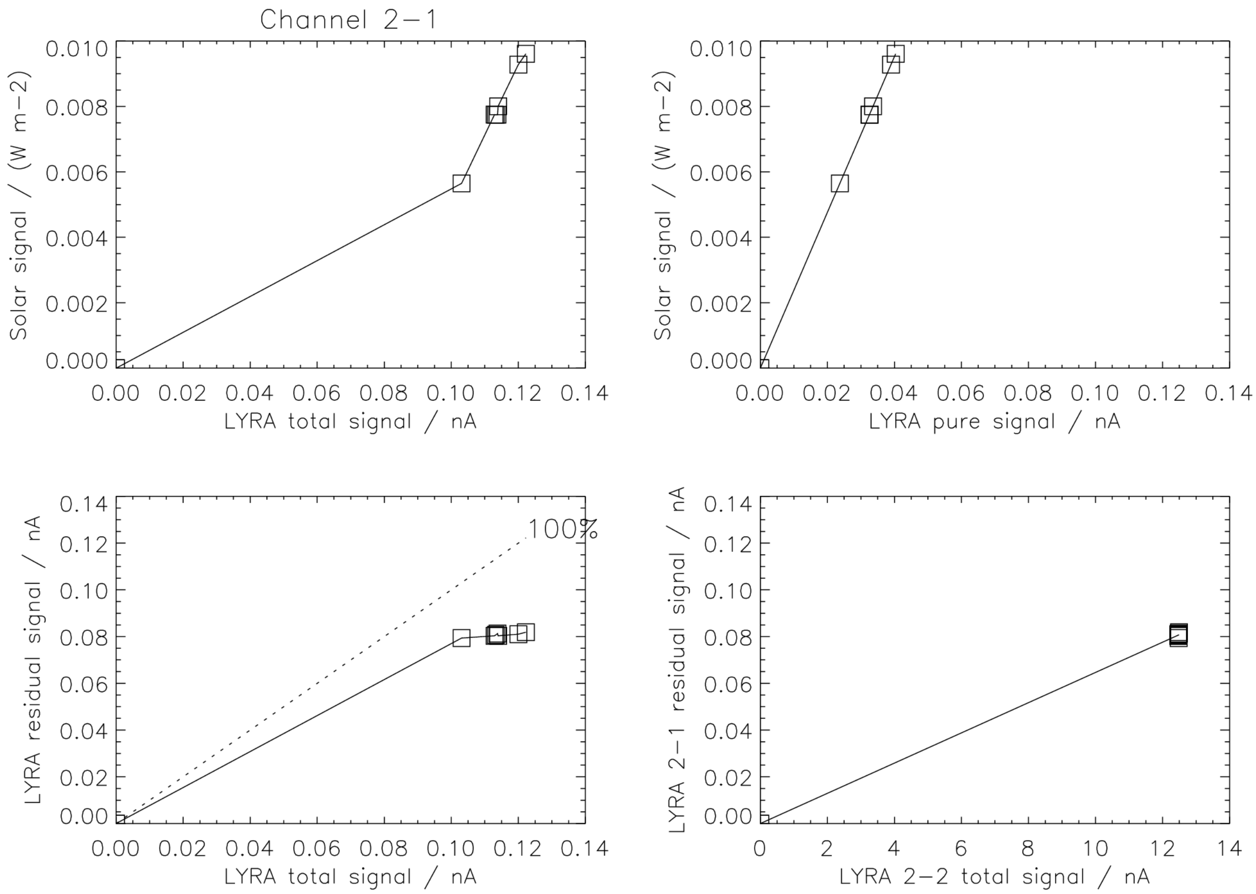

Figure 2-1a. Simulated relations between input and output for LYRA channel 2-1.

The functional relation between the solar signal and the LYRA total signal is obviously not straightforward (see upper left image). The reason is a contamination due to the influence of the interval 180-230 nm, which is not part of the nominal interval around the Lyman-alpha line. But this residual signal can obviously be estimated with the help of the output signal from LYRA channel 2-2 in a simple way (see lower right image):

[LYRA 2-1 residual signal / nA] = 0.00646836 [LYRA 2-2 total signal / nA]*

On the other hand, it can also be estimated as a linear function of the total signal from LYRA channel 2-1 itself, at least above 0.10 nA (see lower left image):

*[LYRA 2-1 residual signal / nA] = 0.0671988 + 0.118280 * [LYRA 2-1 total signal / nA]*

Both variants will be tested in the commissioning phase, before one will eventually be selected.

The pure signal can be estimated as the difference:

[LYRA 2-1 pure signal / nA] = [LYRA 2-1 total signal / nA] – [LYRA 2-1 residual signal / nA]

And the solar signal can again be estimated from the pure signal in a simple way (see upper right image):

*[“Lyman-alpha” solar signal / (W m-2)] = 0.237986 * [LYRA 2-1 pure signal / nA]*

Remarks: Defining 2.5 nm around 121.5 nm as nominal interval leads to just three TIMED/SEE data points (120.5, 121.5, and 122.5 nm), of which only 121.5 nm is significant. This means that the simulation is essentially based on one value; a small variation of the nominal interval would not lead to different simulation results. - Due to the simple linear factors, the estimation error is within 5.8% for the first variant, and 1.9% for the second.

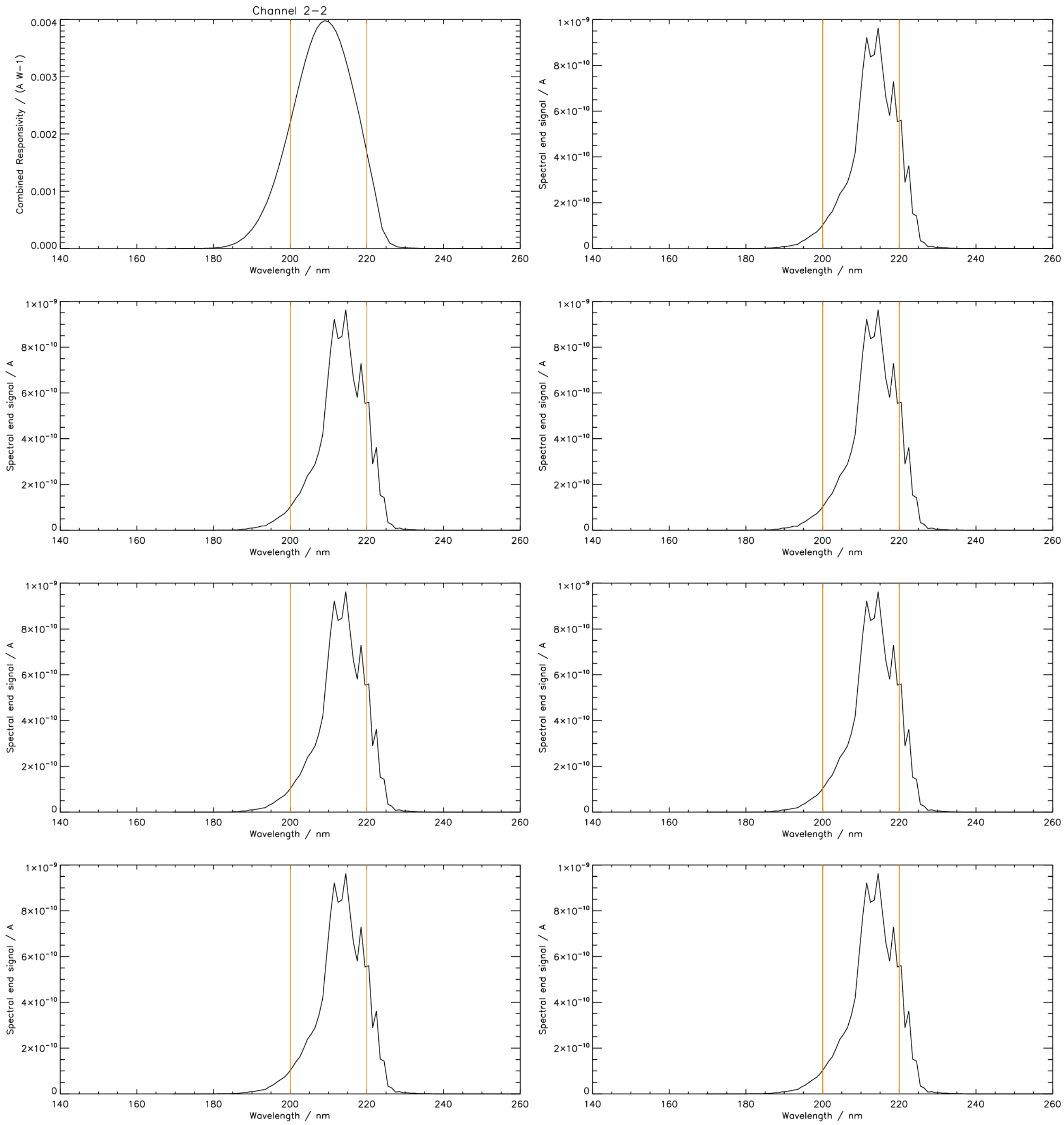

Figure 2-2. Measured responsivity and simulated output for LYRA channel 2-2
Herzberg + PIN11 (200-220 nm)

sample	total	pure	residual	solar
min	12.4790 nA	10.4529 nA (83.8%)	2.02608 nA	0.474210 Wm-2
high	12.4908 nA	10.4529 nA (83.7%)	2.03788 nA	0.474210 Wm-2
max	12.4897 nA	10.4529 nA (83.7%)	2.03673 nA	0.474210 Wm-2
pre1	12.4694 nA	10.4529 nA (83.8%)	2.01649 nA	0.474210 Wm-2
fla1	12.4689 nA	10.4529 nA (83.8%)	2.01591 nA	0.474210 Wm-2
pre2	12.4699 nA	10.4529 nA (83.8%)	2.01690 nA	0.474210 Wm-2
fla2	12.4696 nA	10.4529 nA (83.8%)	2.01660 nA	0.474210 Wm-2

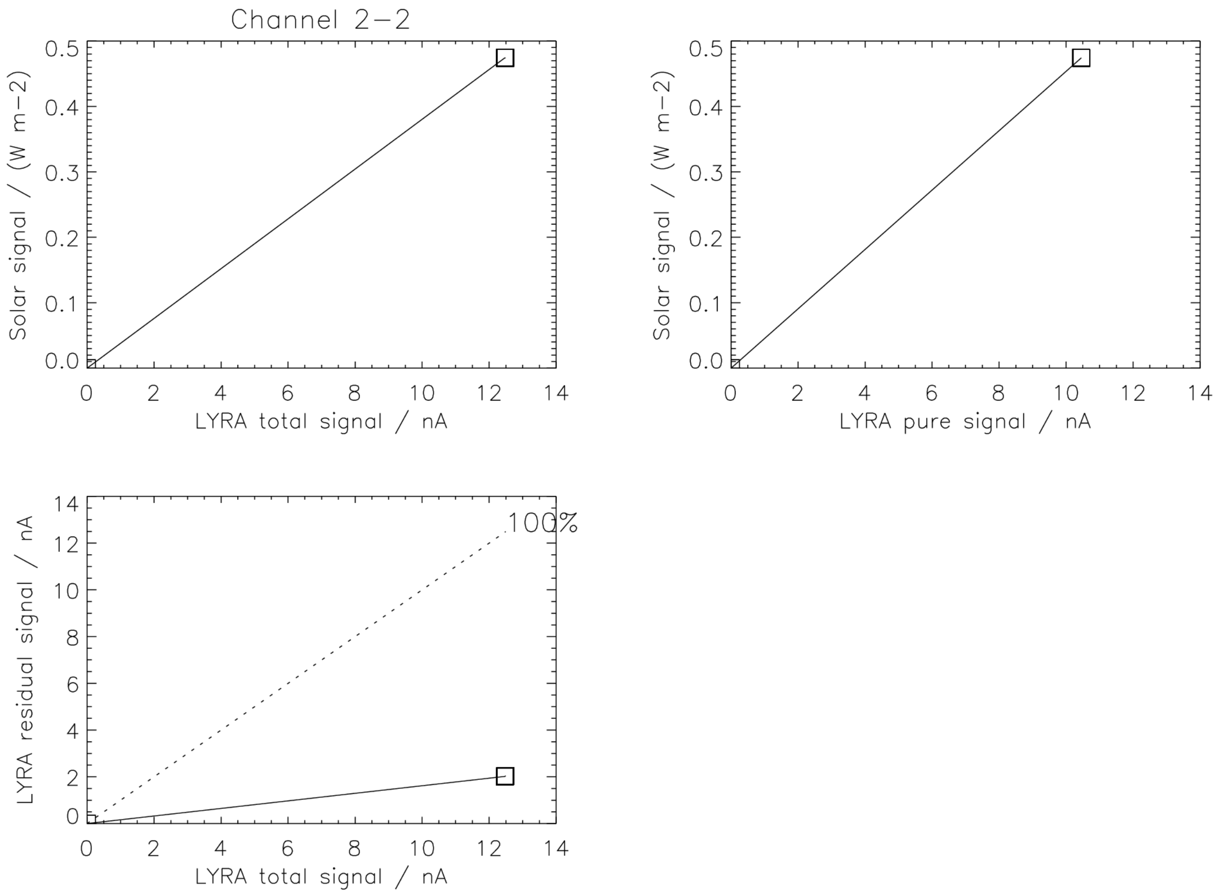

Figure 2-2a. Simulated relations between input and output for LYRA channel 2-2.

The functional relation between the solar signal and the LYRA total signal looks straightforward at first sight. The pure signal or the residual signal can simply be estimated by a linear factor (see table last page). Following the scheme of channel 2-1, the residual signal is calculated as:

*[LYRA 2-2 residual signal / nA] = 0.162210 * [LYRA 2-2 total signal / nA]*

The pure signal can be estimated as the difference:

[LYRA 2-2 pure signal / nA] = [LYRA 2-2 total signal / nA] – [LYRA 2-2 residual signal / nA]

And the solar signal can be estimated from the pure signal in a simple way (see upper right image):

*[“Herzberg” solar signal / (W m-2)] = 0.0453664 * [LYRA 2-2 pure signal / nA]*

Remarks: The estimate is actually only based on one sample instead of seven, because the TIMED/SEE data extensions above 200 nm are identical. - If other limits of the nominal interval were chosen, the purity could naturally be improved (rough estimates):
200 – 220 nm => 84 % purity, 197 – 223 nm => 95 % purity, 195 – 225 nm => 98 % purity,
190 – 230 nm => 99.5 % purity, 180 – 230 nm => 99.9 % purity.

Despite the simple linear factors, the estimation error is within 0.2%. But since the estimates are based on identical spectra above 200 nm, this is probably unrealistic.

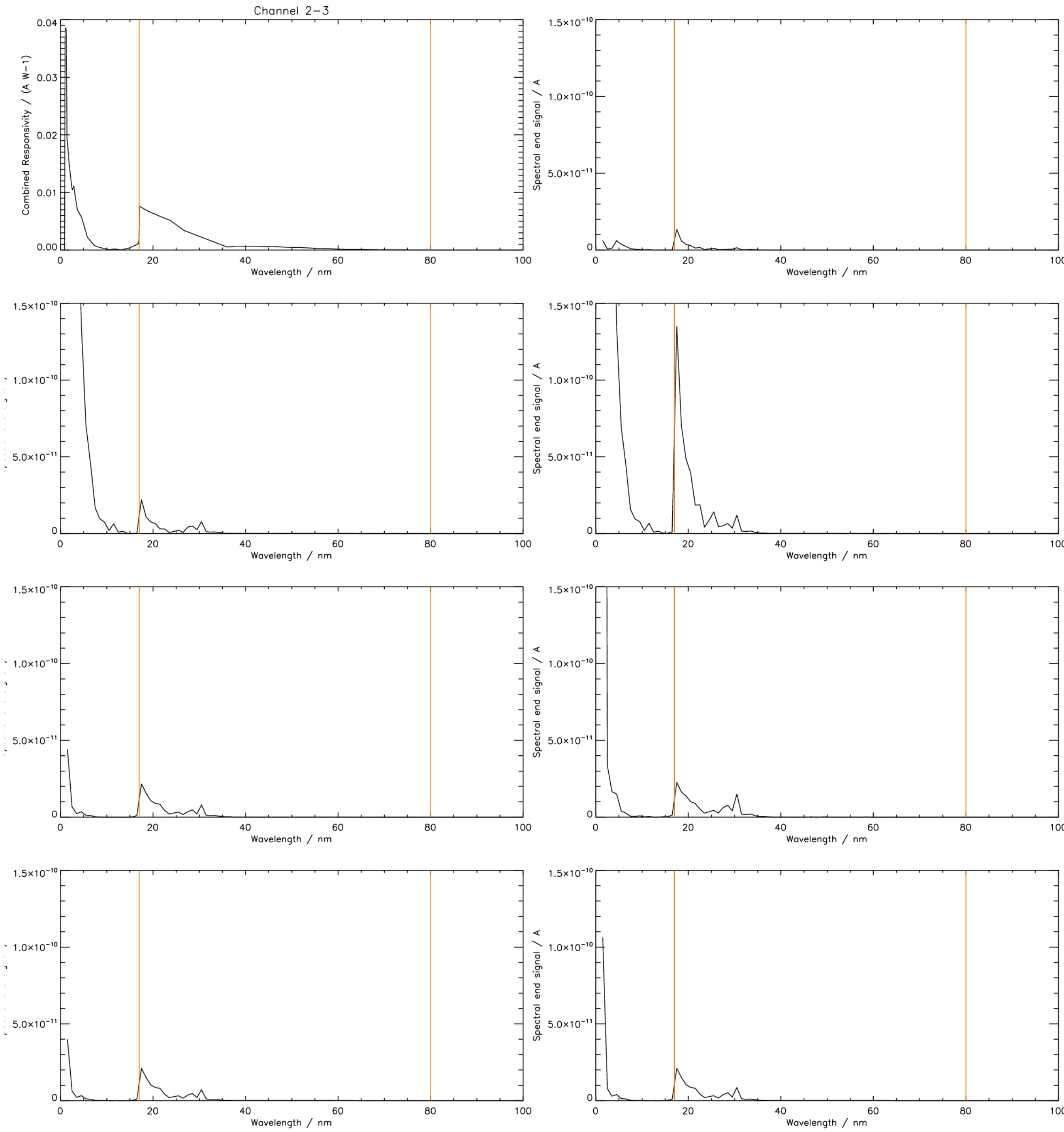

Figure 2-3. Measured responsivity and simulated output for LYRA channel 2-3
Aluminium + MSM15 (17-80 nm)

sample	total	pure	residual	solar
min	0.0589362 nA	0.0363000 nA (61.6%)	0.0226362 nA	0.00131051 Wm-2
high	3.05886 nA	0.0828718 nA (2.7%)	2.97598 nA	0.00340476 Wm-2
max	6.78451 nA	0.397402 nA (5.9%)	6.38711 nA	0.0111131 Wm-2
pre1	0.163001 nA	0.102442 nA (62.8%)	0.0605590 nA	0.00376518 Wm-2
fla1	1.37035 nA	0.132347 nA (9.7%)	1.23801 nA	0.00570166 Wm-2
pre2	0.154173 nA	0.0988576 nA (64.1%)	0.0553156 nA	0.00362499 Wm-2
fla2	0.227546 nA	0.102436 nA (45.0%)	0.125110 nA	0.00394254 Wm-2

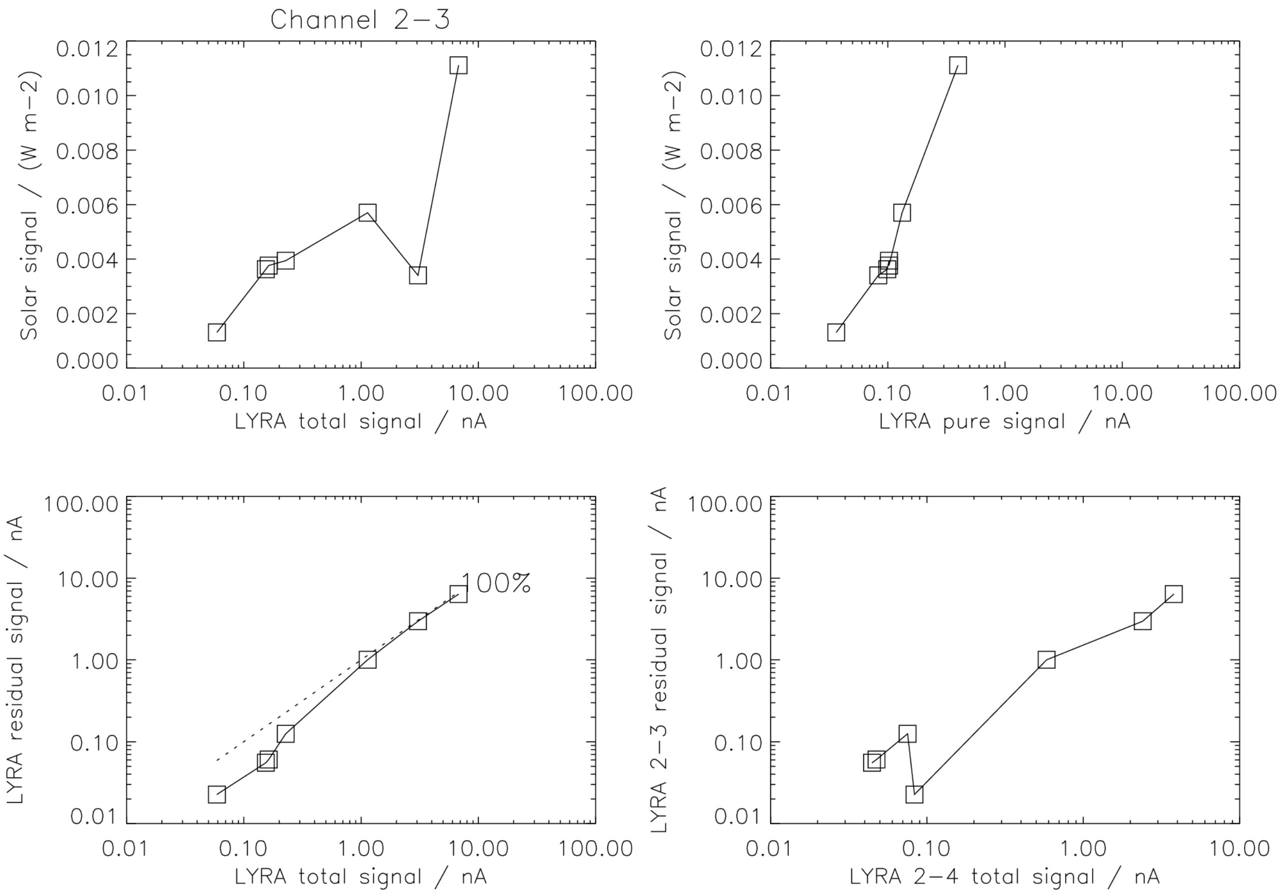

Figure 2-3a. Simulated relations between input and output for LYRA channel 2-3.

The functional relation between the solar signal and the LYRA total signal is obviously not straightforward (rather zigzag, see upper left image). The reason is a contamination due to the influence of the interval 1-10 nm, which is not part of the 17-80 nm nominal interval of the "Aluminium" channels. This residual signal can possibly be estimated with the help of the output signal from LYRA channel 2-4; not as simple as in the case of channel 2-1, but with linear interpolation between the points of the relationship as visible in the lower right image:

[LYRA 2-3 residual signal / nA] = interp[LYRA 2-4 total signal / nA]

On the other hand, it can also be estimated as an almost linear function of the total signal from LYRA channel 2-3 itself (see lower left image):

[LYRA 2-3 residual signal / nA] = interp[LYRA 2-3 total signal / nA]

Both variants will be tested in the commissioning phase, before one will eventually be selected.

The pure signal can be estimated as the difference:

[LYRA 2-3 pure signal / nA] = [LYRA 2-3 total signal / nA] – [LYRA 2-3 residual signal / nA]

And the solar signal can be estimated from the pure signal, again not in a simple way but with linear interpolation between the points of a slightly nonlinear relationship as visible in the upper right image:

["Aluminium" solar signal / (W m-2)] = interp[LYRA 2-3 pure signal / nA]

Remarks: Although the channel interval nominally reaches up to 80 nm, effectively it appears to end at 35 nm (see Figure 2-3). - If a large subset of these channels' solar signal is similar to the "high", "max" or "fla1" simulation data, then the uncalibrated data (before subtraction of the substantial short-wavelength contamination) will probably not be very meaningful. - Due to the linear interpolation, the estimation error is 0%, but this is unrealistic.

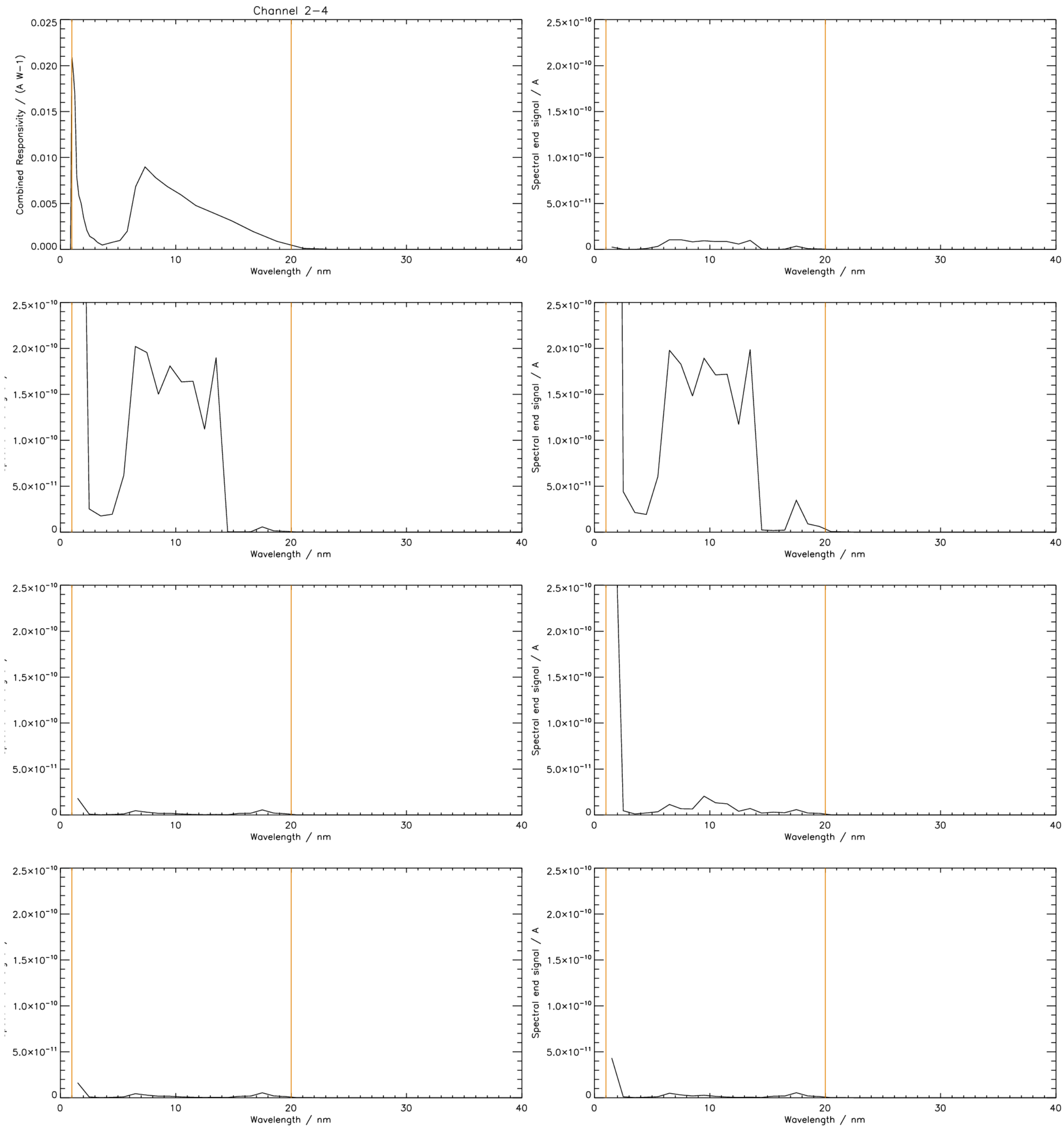

Figure 2-4. Measured responsivity and simulated output for LYRA channel 2-4
Zr(150nm) + MSM19 (1-20 nm)

sample	total	pure	residual	solar
min	0.0833134 nA	0.0829392 nA (99.6%)	0.00037427 nA	0.00267627 Wm-2
high	2.39919 nA	2.39874 nA (100.%)	0.00045031 nA	0.0659849 Wm-2
max	3.79721 nA	3.79595 nA (100.%)	0.00126255 nA	0.0975310 Wm-2
pre1	0.0475881 nA	0.0469921 nA (98.7%)	0.00059595 nA	0.00208323 Wm-2
fla1	0.583392 nA	0.582767 nA (99.9%)	0.00062461 nA	0.0132763 Wm-2
pre2	0.0445983 nA	0.0440140 nA (98.7%)	0.00058434 nA	0.00198338 Wm-2
fla2	0.0752809 nA	0.0746944 nA (99.2%)	0.00058652 nA	0.00261203 Wm-2

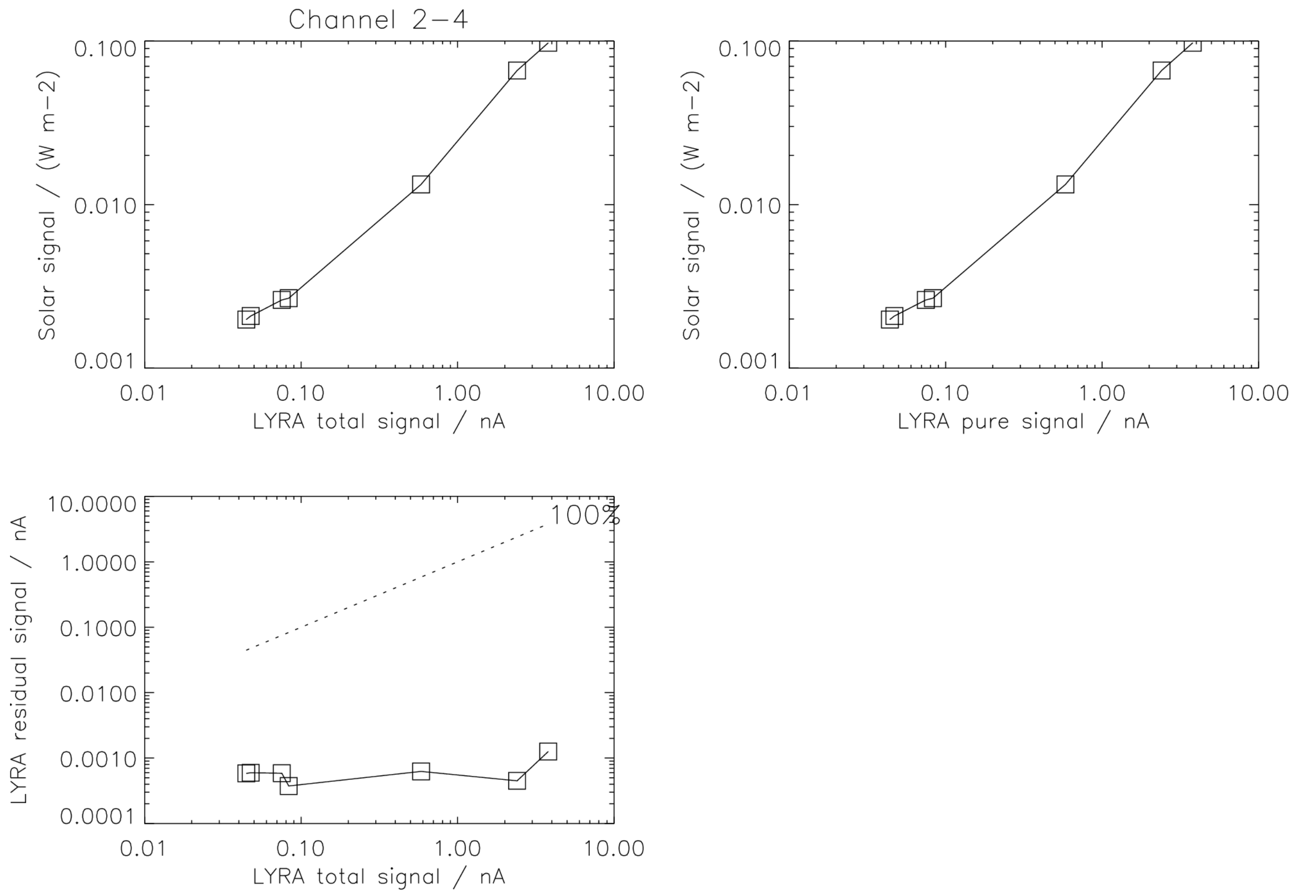

Figure 2-4a. Simulated relations between input and output for LYRA channel 2-4.

The functional relation between the solar signal and the LYRA total signal looks straightforward. Since the purity of the Zirconium channels is always around 100%, the residual signal is almost negligible (see lower figure) and can simply be set to the average. Following the usual scheme:

[LYRA 2-4 residual signal / nA] = 0.000639421

The pure signal can be estimated as the difference, which is almost the total signal:

[LYRA 2-4 pure signal / nA] = [LYRA 2-4 total signal / nA] – [LYRA 2-4 residual signal / nA]

And the solar signal can be estimated from the pure signal with linear interpolation between the points of a slightly nonlinear relationship as visible in the upper right image:

["Zirconium" solar signal / (W m-2)] = interp[LYRA 2-4 pure signal / nA]

Remarks: Due to the linear interpolation, the estimation error (caused by the averaging) is below 0.4%, but this is unrealistic.

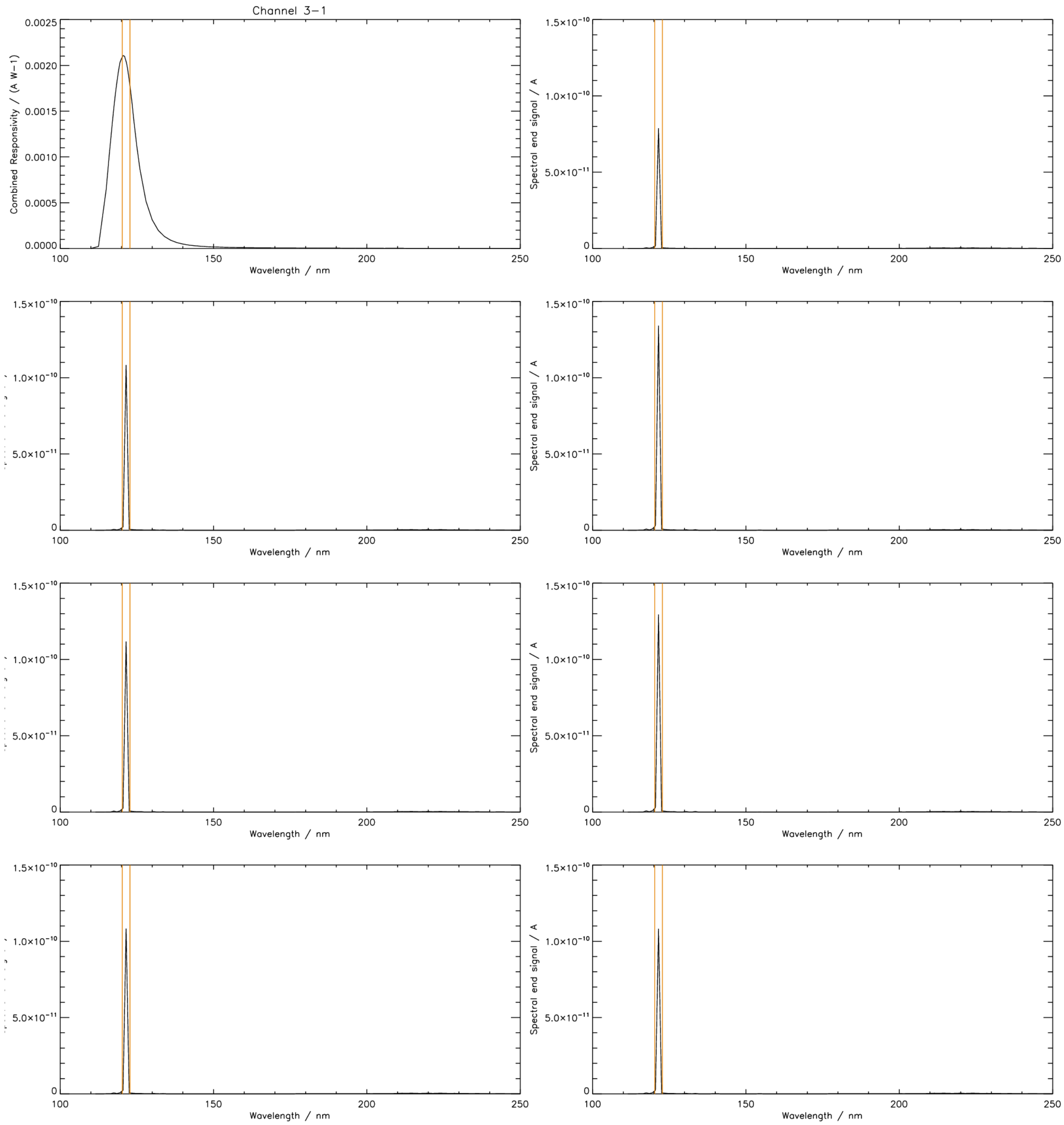

Figure 3-1. Measured responsivity and simulated output for LYRA channel 3-1
Ly N+XN + AXUV20A (121.5 +/- nm)

sample	total	pure	residual	solar
min	0.261423 nA	0.0810812 nA (31.0%)	0.180342 nA	0.00564762 Wm-2
high	0.293110 nA	0.111255 nA (38.0%)	0.181855 nA	0.00774904 Wm-2
max	0.320996 nA	0.137961 nA (43.0%)	0.183035 nA	0.00960818 Wm-2
pre1	0.296441 nA	0.114951 nA (38.8%)	0.181490 nA	0.00800550 Wm-2
fla1	0.315890 nA	0.133253 nA (42.2%)	0.182637 nA	0.00928009 Wm-2
pre2	0.292659 nA	0.111301 nA (38.0%)	0.181358 nA	0.00775156 Wm-2
fla2	0.293046 nA	0.111205 nA (38.0%)	0.181841 nA	0.00774487 Wm-2

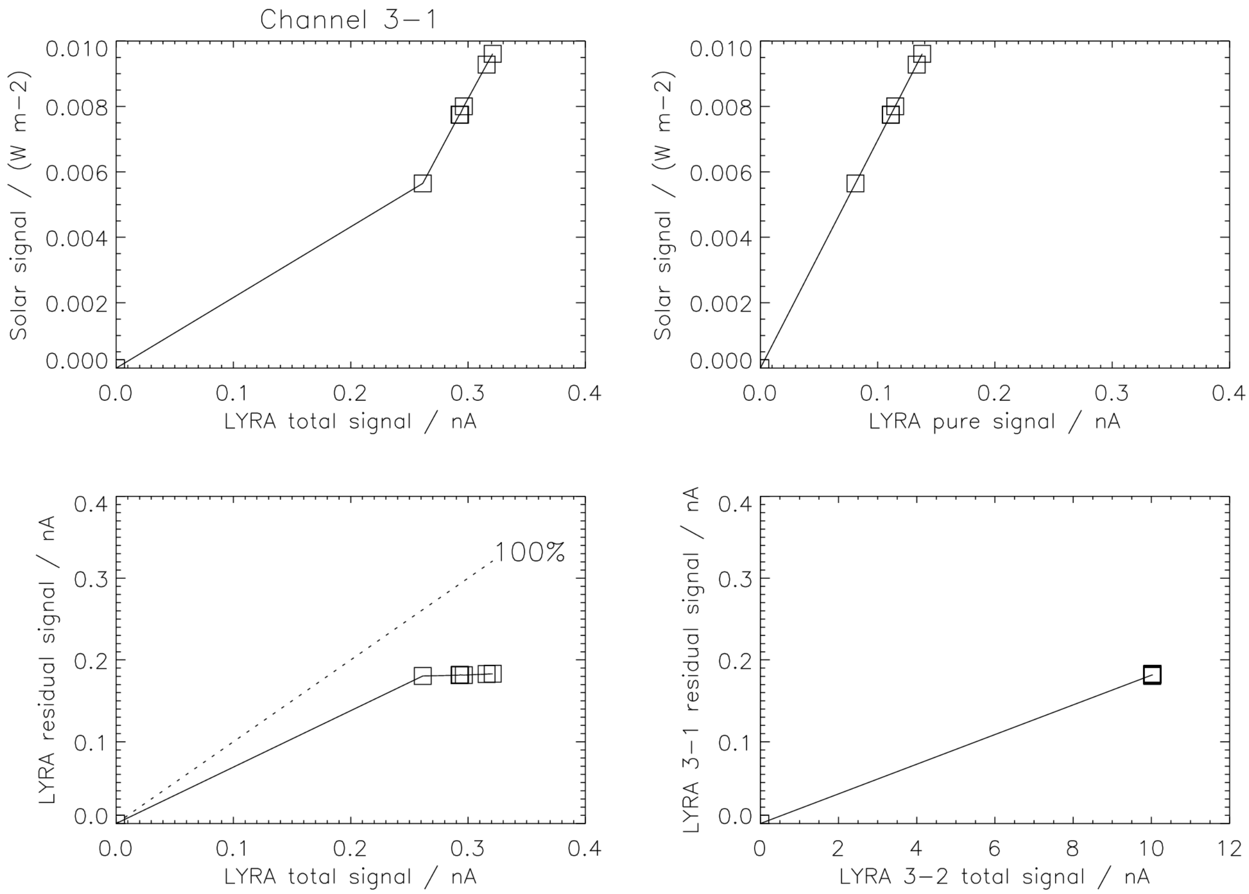

Figure 3-1a. Simulated relations between input and output for LYRA channel 3-1.

The functional relation between the solar signal and the LYRA total signal is obviously not straightforward (see upper left image). The reason is a contamination due to the influence of the visual and infrared, which is not part of the nominal interval around the Lyman-alpha line. But this residual signal may be estimated with the help of the output signal from LYRA channel 3-2 in a simple way (see lower right image):

[LYRA 3-1 residual signal / nA] = 0.0181442 [LYRA 3-2 total signal / nA]*

On the other hand, it can also be estimated as a linear function of the total signal from LYRA channel 3-1 itself, at least above 0.26 nA (see lower left image):

*[LYRA 3-1 residual signal / nA] = 0.168725 + 0.0441198 * [LYRA 3-1 total signal / nA]*

Both variants will be tested in the commissioning phase, before one will eventually be selected.

The pure signal can be estimated as the difference:

[LYRA 3-1 pure signal / nA] = [LYRA 3-1 total signal / nA] – [LYRA 3-1 residual signal / nA]

And the solar signal can again be estimated from the pure signal in a simple way (see upper right image):

*[“Lyman-alpha” solar signal / (W m-2)] = 0.0696280 * [LYRA 3-1 pure signal / nA]*

Remarks: Defining 2.5 nm around 121.5 nm as nominal interval leads to just three TIMED/SEE data points (120.5, 121.5, and 122.5 nm), of which only 121.5 nm is significant. This means that the simulation is essentially based on one value; a small variation of the nominal interval would not lead to different simulation results. - Due to the simple linear factors, the estimation error is within 1.9% for the first variant, and 0.3% for the second.

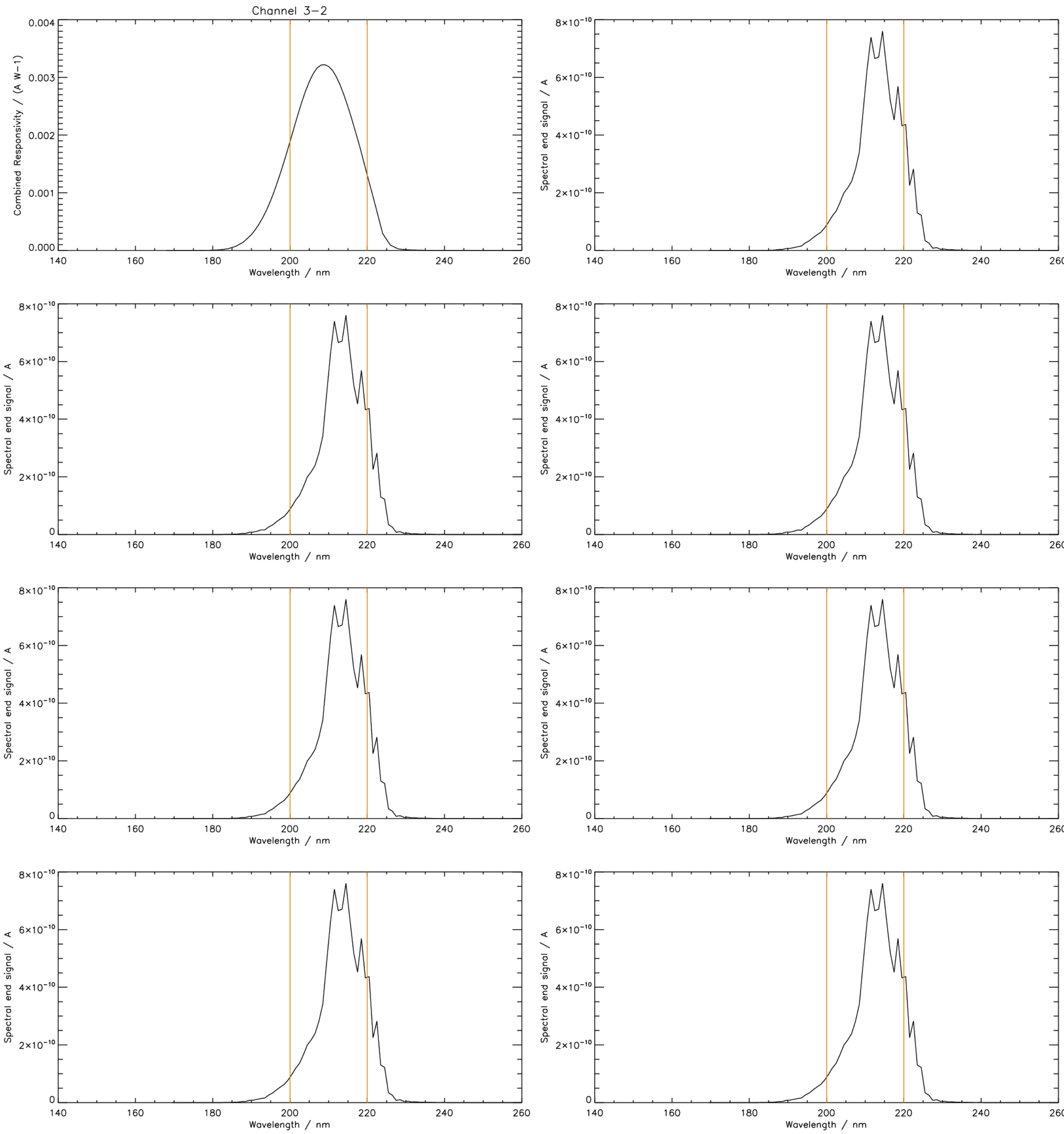

Figure 3-2. Measured responsivity and simulated output for LYRA channel 3-2
Herzberg + PIN12 (200-220 nm)

sample	total	pure	residual	solar
min	10.0217 nA	8.36497 nA (83.5%)	1.65673 nA	0.474210 Wm-2
high	10.0314 nA	8.36497 nA (83.4%)	1.66641 nA	0.474210 Wm-2
max	10.0304 nA	8.36497 nA (83.4%)	1.66541 nA	0.474210 Wm-2
pre1	10.0131 nA	8.36497 nA (83.5%)	1.64815 nA	0.474210 Wm-2
fla1	10.0126 nA	8.36497 nA (83.5%)	1.64766 nA	0.474210 Wm-2
pre2	10.0134 nA	8.36497 nA (83.5%)	1.64847 nA	0.474210 Wm-2
fla2	10.0132 nA	8.36497 nA (83.5%)	1.64820 nA	0.474210 Wm-2

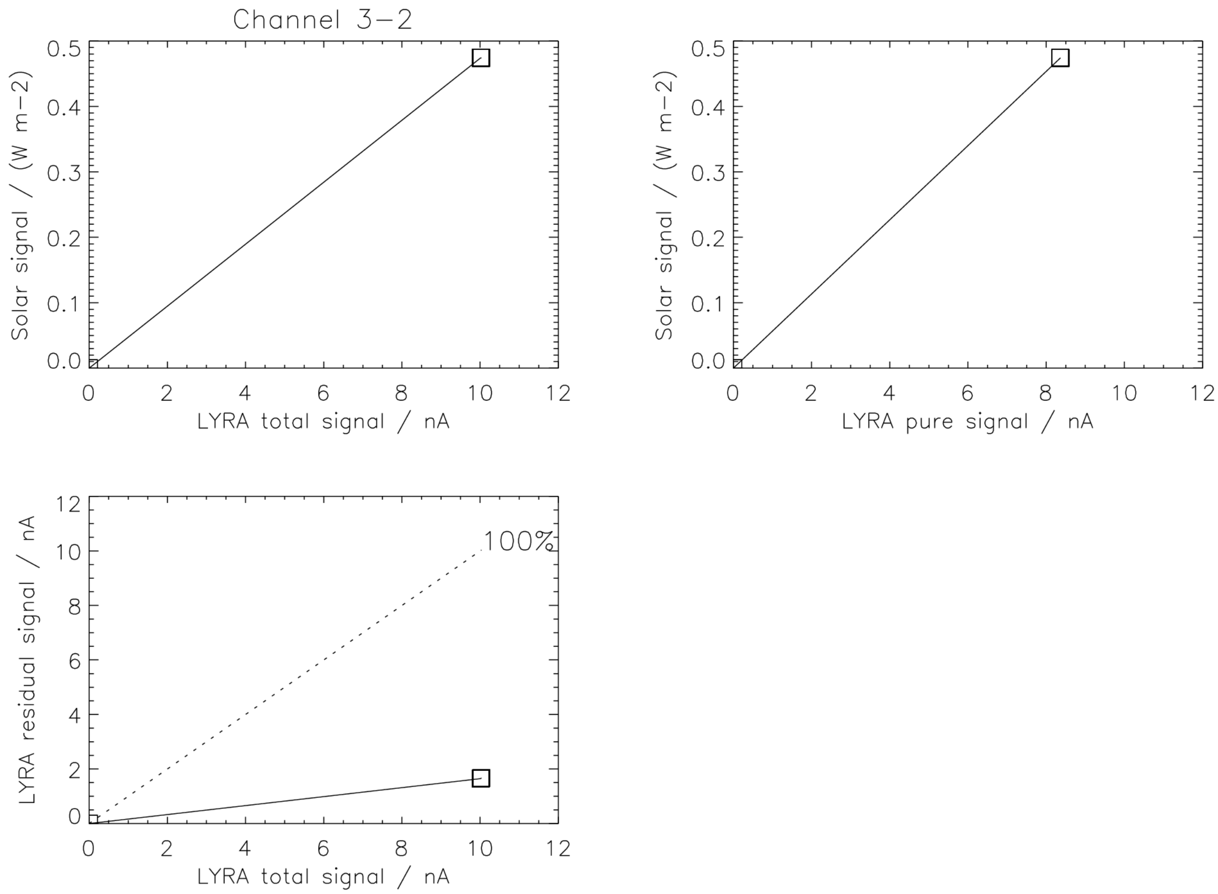

Figure 3-2a. Simulated relations between input and output for LYRA channel 3-2.

The functional relation between the solar signal and the LYRA total signal looks straightforward at first sight. The pure signal or the residual signal can simply be estimated by a linear factor (see table last page). Following the scheme of channel 3-1, the residual signal is calculated as:

*[LYRA 3-2 residual signal / nA] = 0.165122 * [LYRA 3-2 total signal / nA]*

The pure signal can be estimated as the difference:

[LYRA 3-2 pure signal / nA] = [LYRA 3-2 total signal / nA] – [LYRA 3-2 residual signal / nA]

And the solar signal can be estimated from the pure signal in a simple way (see upper right image):

*["Herzberg" solar signal / (W m-2)] = 0.0566900 * [LYRA 3-2 pure signal / nA]*

Remarks: The estimate is actually only based on one sample instead of seven, because the TIMED/SEE data extensions above 200 nm are identical. - If other limits of the nominal interval were chosen, the purity could naturally be improved (rough estimates):
200 – 220 nm => 84 % purity, 197 – 223 nm => 95 % purity, 195 – 225 nm => 98 % purity,
190 – 230 nm => 99.5 % purity, 180 – 230 nm => 99.9 % purity.

Despite the simple linear factors, the estimation error is within 0.2%. But since the estimates are based on identical spectra above 200 nm, this is probably unrealistic.

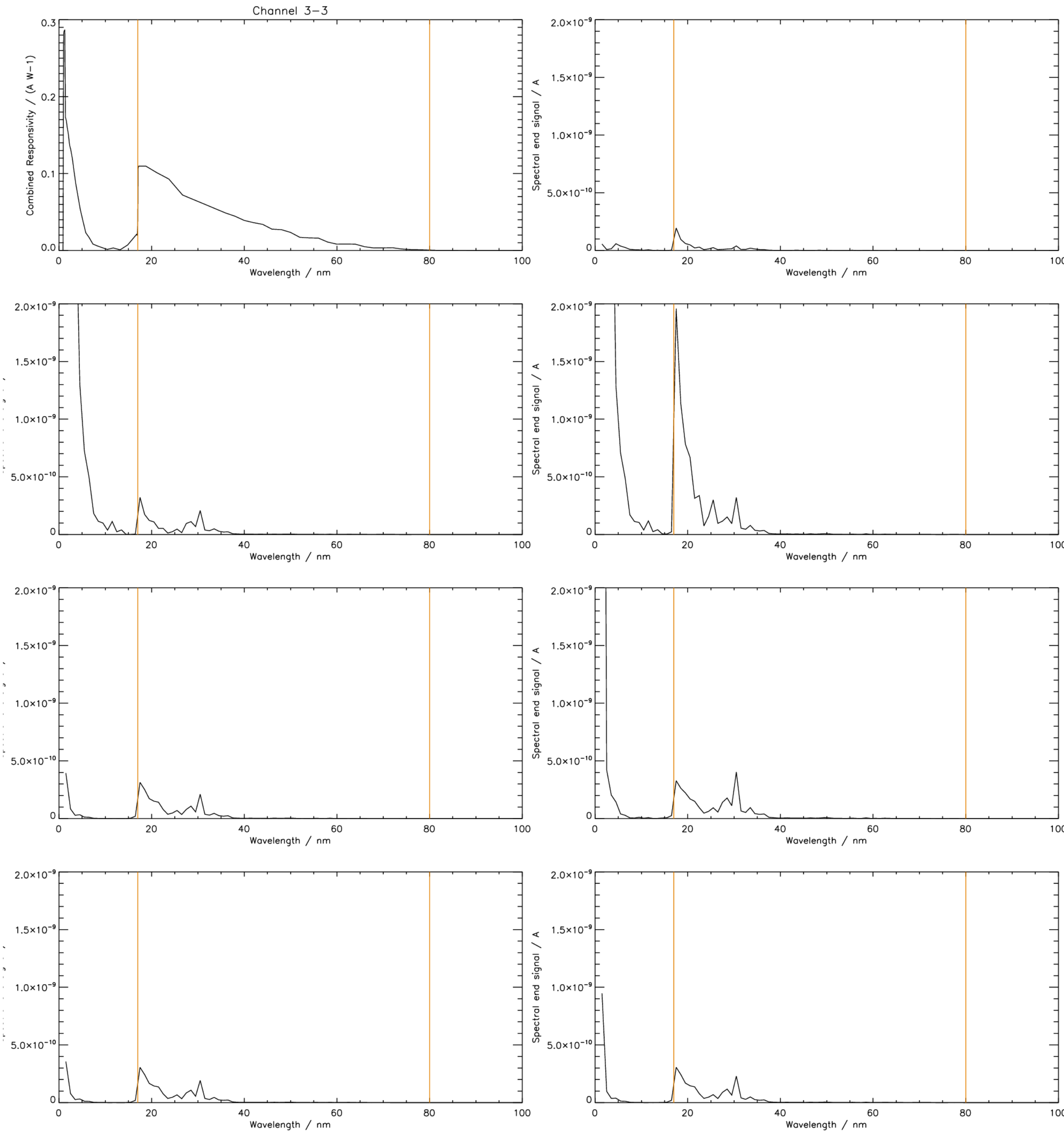

Figure 3-3. Measured responsivity and simulated output (min, high, max) for LYRA channel 3-3.
Aluminium + AXUV20B (17-80 nm)

sample	total	pure	residual	solar
min	0.918268 nA	0.673852 nA (73.4%)	0.244415 nA	0.00131051 Wm-2
high	30.2865 nA	1.67754 nA (5.5%)	28.6090 nA	0.00340476 Wm-2
max	66.6039 nA	6.88920 nA (10.3%)	59.7147 nA	0.0111131 Wm-2
pre1	2.59772 nA	1.99496 nA (76.8%)	0.602758 nA	0.00376518 Wm-2
fla1	14.0374 nA	2.76441 nA (19.7%)	11.2730 nA	0.00570166 Wm-2
pre2	2.47387 nA	1.92050 nA (77.6%)	0.553370 nA	0.00362499 Wm-2
fla2	3.20343 nA	2.01814 nA (63.0%)	1.18529 nA	0.00394254 Wm-2

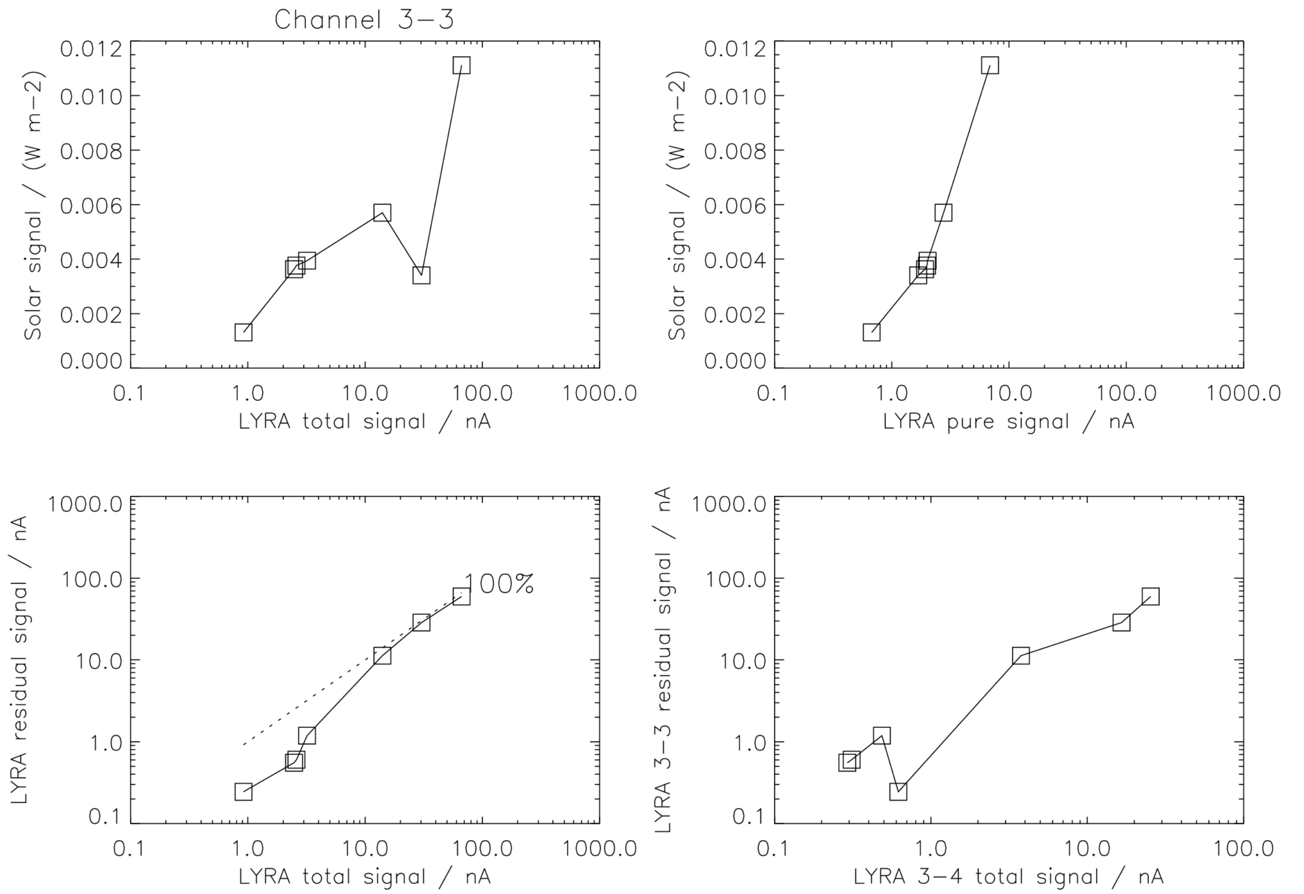

Figure 3-3a. Simulated relations between input and output for LYRA channel 3-3.

The functional relation between the solar signal and the LYRA total signal is obviously not straightforward (rather zigzag, see upper left image). The reason is a contamination due to the influence of the interval 1-10 nm, which is not part of the 17-80 nm nominal interval of the "Aluminium" channels. This residual signal can possibly be estimated with the help of the output signal from LYRA channel 3-4; not as simple as in the case of channel 3-1, but with linear interpolation between the points of the relationship as visible in the lower right image:

[LYRA 3-3 residual signal / nA] = interp[LYRA 3-4 total signal / nA]

On the other hand, it can also be estimated as an almost linear function of the total signal from LYRA channel 3-3 itself (see lower left image):

[LYRA 3-3 residual signal / nA] = interp[LYRA 3-3 total signal / nA]

Both variants will be tested in the commissioning phase, before one will eventually be selected.

The pure signal can be estimated as the difference:

[LYRA 3-3 pure signal / nA] = [LYRA 3-3 total signal / nA] – [LYRA 3-3 residual signal / nA]

And the solar signal can be estimated from the pure signal, again not in a simple way but with linear interpolation between the points of a slightly nonlinear relationship as visible in the upper right image:

["Aluminium" solar signal / (W m-2)] = interp[LYRA 3-3 pure signal / nA]

Remarks: Although the channel interval nominally reaches up to 80 nm, effectively it appears to end at 35 nm (see Figure 3-3). - If a large subset of these channels' solar signal is similar to the "high", "max" or "fla1" simulation data, then the uncalibrated data (before subtraction of the substantial short-wavelength contamination) will probably not be very meaningful. - Due to the linear interpolation, the estimation error is 0%, but this is unrealistic.

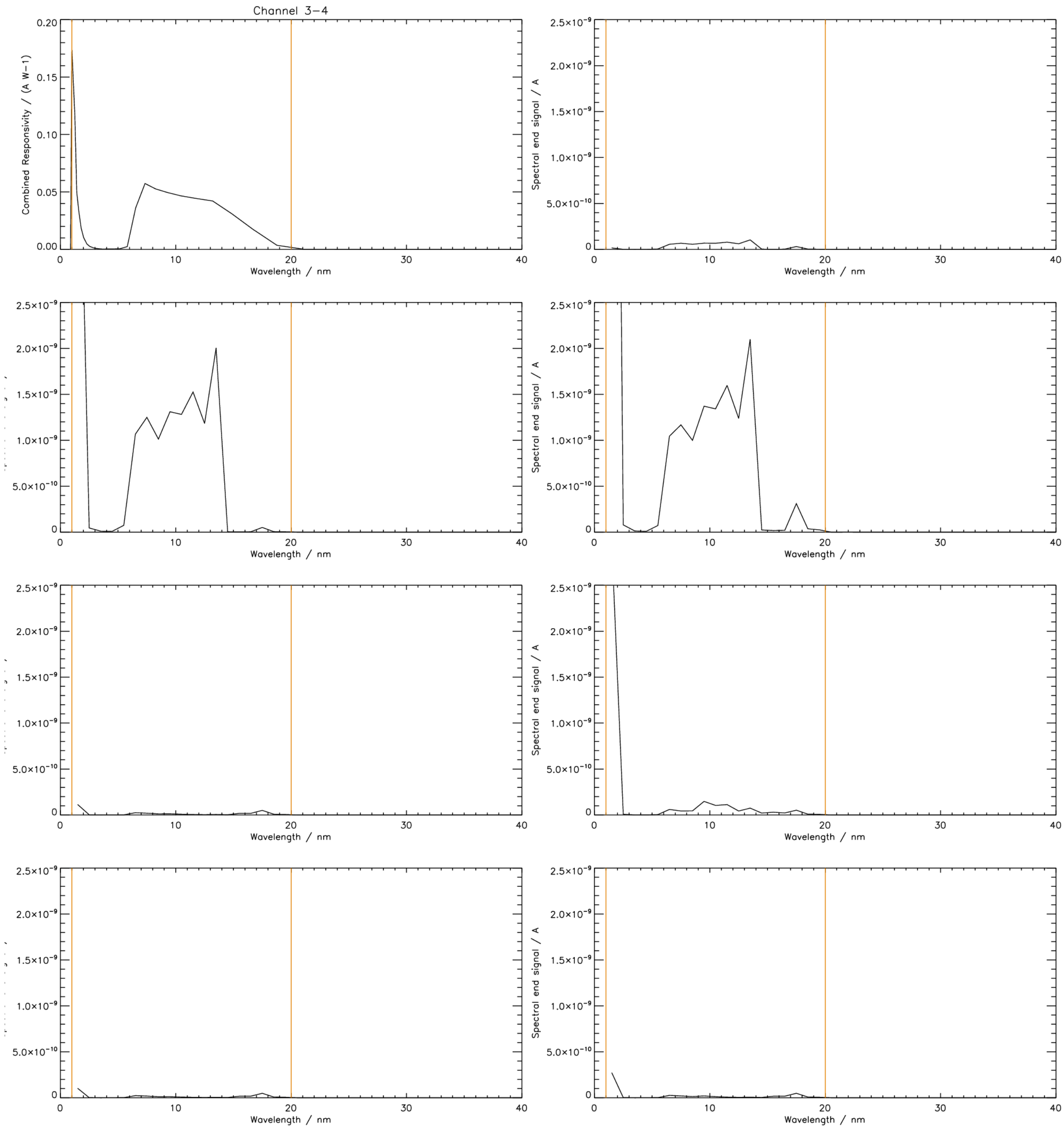

Figure 3-4. Measured responsivity and simulated output for LYRA channel 3-4
Zr(300nm) + AXUV20C (1-20 nm)

sample	total	pure	residual	solar
min	0.619372 nA	0.615587 nA (99.4%)	0.00378508 nA	0.00267627 Wm-2
high	16.5645 nA	16.5607 nA (100.%)	0.00382805 nA	0.0659849 Wm-2
max	25.4431 nA	25.4386 nA (100.%)	0.00450306 nA	0.0975310 Wm-2
pre1	0.311225 nA	0.307252 nA (98.7%)	0.00397385 nA	0.00208323 Wm-2
fla1	3.76600 nA	3.76199 nA (99.9%)	0.00400835 nA	0.0132763 Wm-2
pre2	0.292093 nA	0.288129 nA (98.6%)	0.00396394 nA	0.00198338 Wm-2
fla2	0.486125 nA	0.482159 nA (99.2%)	0.00396694 nA	0.00261203 Wm-2

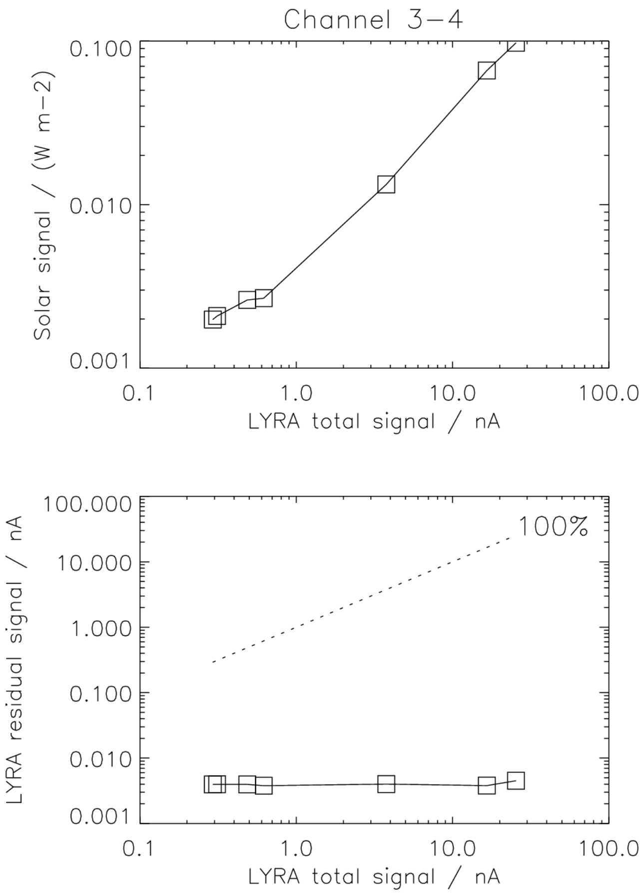

Figure 3-4a. Simulated relations between input and output for LYRA channel 3-4.

The functional relation between the solar signal and the LYRA total signal looks straightforward. Since the purity of the Zirconium channels is always around 100%, the residual signal is almost negligible (see lower figure) and can simply be set to the average. Following the usual scheme:

[LYRA 3-4 residual signal / nA] = 0.00399983

The pure signal can be estimated as the difference, which is almost the total signal:

[LYRA 3-4 pure signal / nA] = [LYRA 3-4 total signal / nA] – [LYRA 3-4 residual signal / nA]

And the solar signal can be estimated from the pure signal with linear interpolation between the points of a slightly nonlinear relationship as visible in the upper right image:

[“Zirconium” solar signal / (W m-2)] = interp[LYRA 3-4 pure signal / nA]

Remarks: Due to the linear interpolation, the estimation error (caused by the averaging) is below 0.1%, but this is unrealistic.