Structure and parameter identification of au

October 16, 2019

1 Experimental data

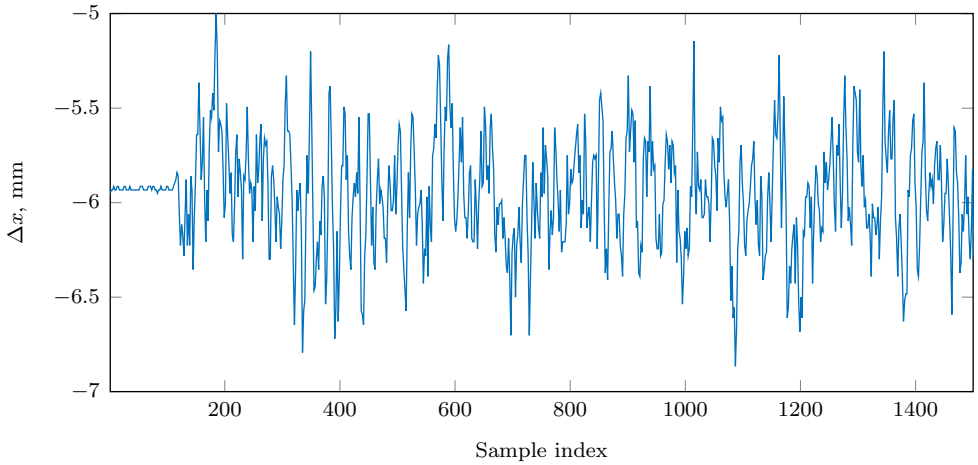


Figure 1: The input for the set C.

2 Structure identification

The following model structure is assumed. The output of the NARX model $\boldsymbol{y}(t)$ is the measured load. The input vector is composed as

$$\boldsymbol{x}(t) = \{x_i(t)\}_{i=1}^{d} = \left[\{y(t-k+1)\}_{k=1}^{n_y} \quad \{u(t-k+n_y+1)\}_{k=n_y+1}^{n_y+n_u}\right]^\top, \tag{1}$$

where n_u is the length of the input lag and n_y is the length of the output lag in discrete time, and where $d = n_u + n_y$. In this case, the identification is performed under the following assumptions:

- only the input signal affects the output ($n_y = 0$).
- the input signal has a lag of length $n_u = 4$.

The unknown model is approximated with a sum of polynomial basis functions up to second degree ($\lambda = 2$), rendering the following structure

$$\boldsymbol{y}(t) = \theta^0 + \sum_{i=1}^{d} \theta_i x_i(t) + \sum_{i=1}^{d}\sum_{j=1}^{d} \theta_{i,j} x_i(t) x_j(t) + e(t). \tag{2}$$

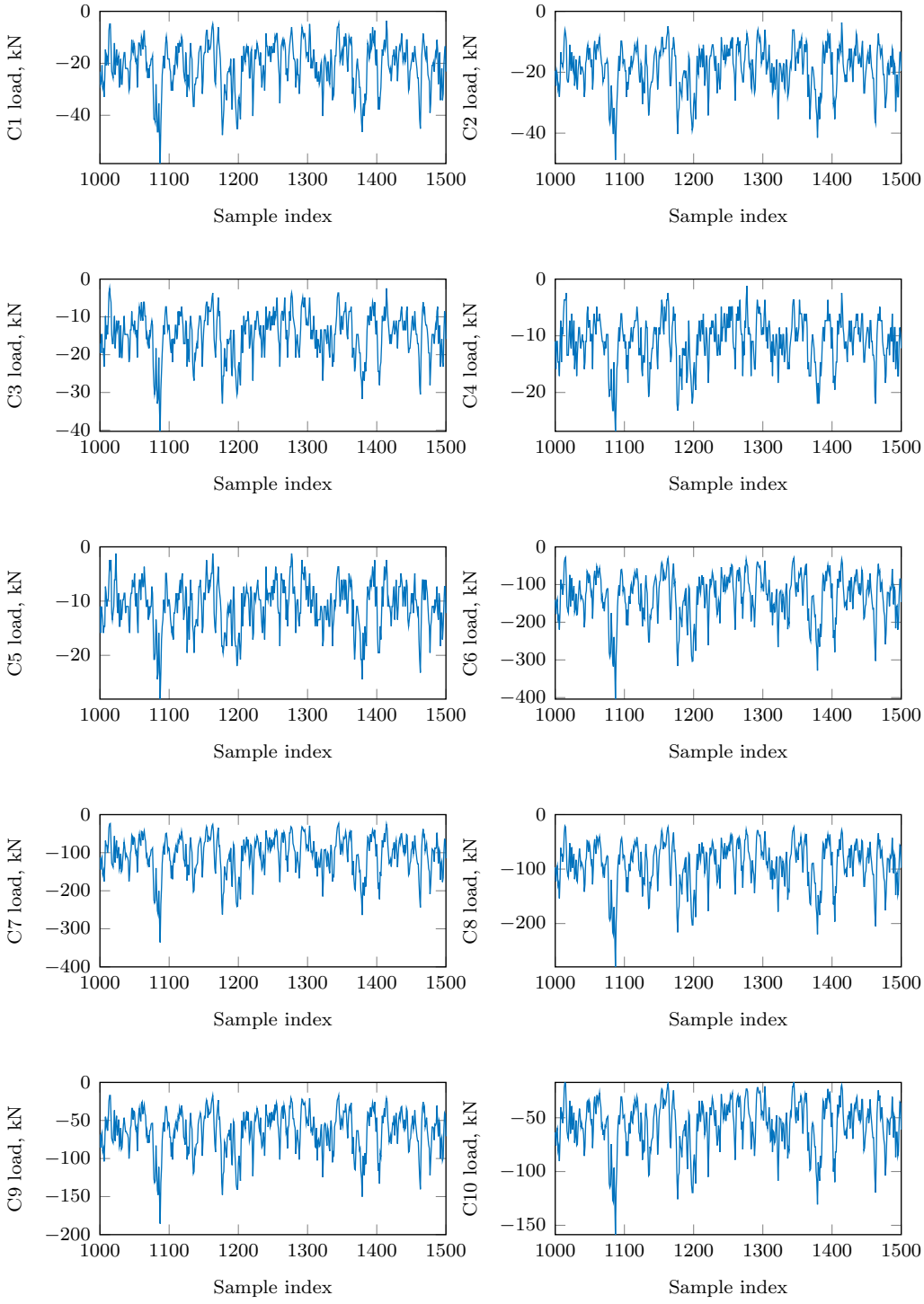
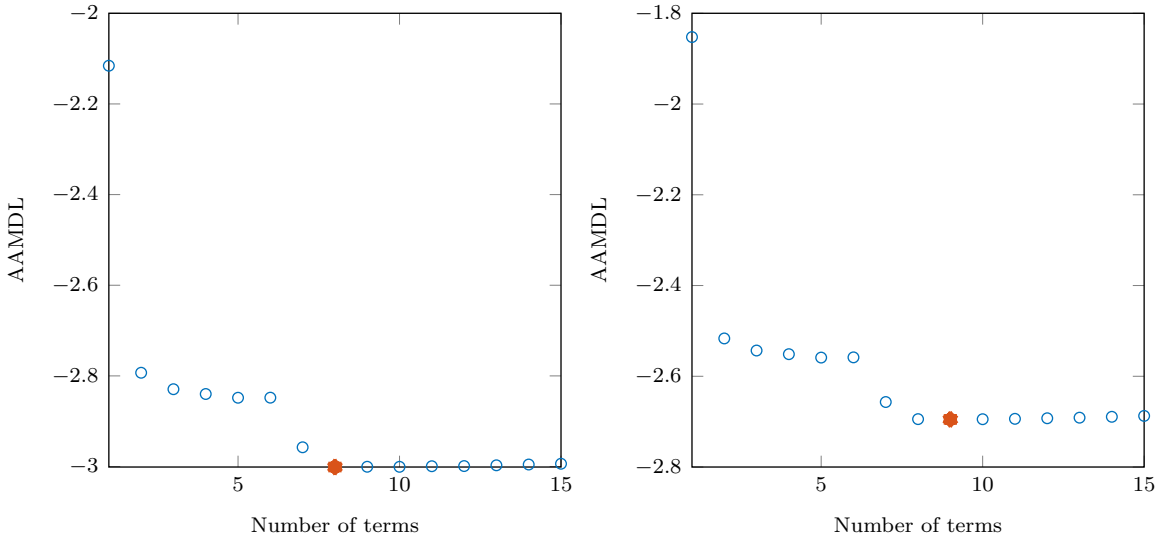


Figure 2: Experimental data.

The number and order of significant terms are identified within the EFOR-CMSS algorithm based on the data from 8 out of 10 datasets. Figure 3 illustrates the relationship between the number of model terms and the selected criterion of significance, AAMDL.



(a) Sample size 2000.

(b) Sample size 4000.

Figure 3: AAMDL evolution with the growing number of terms for samples of different size.

3 Parameter estimation

Results of internal parameter estimation via EFOR-CMSS for different sample sizes are presented in Tables 2 and 3 Visualised

Table 1: Estimated parameters for the sample length 2000.

Step	Terms	C1	C2	C4	C5	C6	C7	C9	C10	AEER(%)
1	x_4, x_4	-26.04	-20.99	-10.69	-10.96	-191.78	-157.64	-87.42	-69.8	89.511
2	x_3	75.42	59.58	33	26.06	508.94	419.54	242.35	195.15	8.849
3	x_1, x_4	0.62	0.76	0.32	0.48	8.55	7.83	2.66	1.15	0.139
4	x_1, x_1	0.01	-0.19	-0.15	-0.22	0.05	-0.48	0.44	0.76	0.045
5	x_2	0.71	-0.73	-2.24	-0.66	45.94	36.57	18.4	12.68	0.032
6	x_4	-171.24	-139.22	-69.61	-73.69	-1273.02	-1046.38	-579.72	-465.59	0.006
7	c	-233.16	-200.83	-93.74	-119.7	-1805.9	-1488.55	-803.7	-648.8	0.308
8	x_3, x_4	15.47	12.1	6.36	5.68	110.13	90.43	51.77	41.43	0.093

In order to link the external and internal parameters an arbitrary polynomial function is selected for two arguments

$$content... \tag{3}$$

Curve fitting results are presented in Tablels 4 and 5.

Table 2: Estimated parameters for the sample length 4000.

Step	Terms	C1	C2	C4	C5	C6	C7	C9	C10	AEER(%)
1	x_4, x_4	-18.97	-15.33	-8.34	-8.94	-138.21	-114.23	-63.58	-50.3	88.667
2	x_3	63.2	53.09	30.09	24.55	426.09	362.14	208.4	168.78	9.494
3	x_1, x_4	4.29	3.45	2.03	3.11	34.39	27.1	14.45	10.2	0.12
4	x_1, x_1	0.6	0.87	0.31	0.56	9.24	5.54	4.15	4.1	0.042
5	x_2	2.34	0.07	-1.9	-2.13	43.4	34.96	18.62	12.71	0.036
6	x_4	-157.87	-128.81	-69.1	-69.29	-1153.95	-964.72	-539.51	-431.83	0.006
7	c	-226.03	-187.69	-100.5	-116.41	-1722.47	-1432.4	-789.68	-632.3	0.335
8	x_3, x_3	9.21	7.92	4.31	4.67	70	55.98	32.65	26.32	0.103
9	x_1, x_3	-4.8	-4.8	-2.64	-4.26	-45.05	-31.95	-19.47	-15.95	0.007

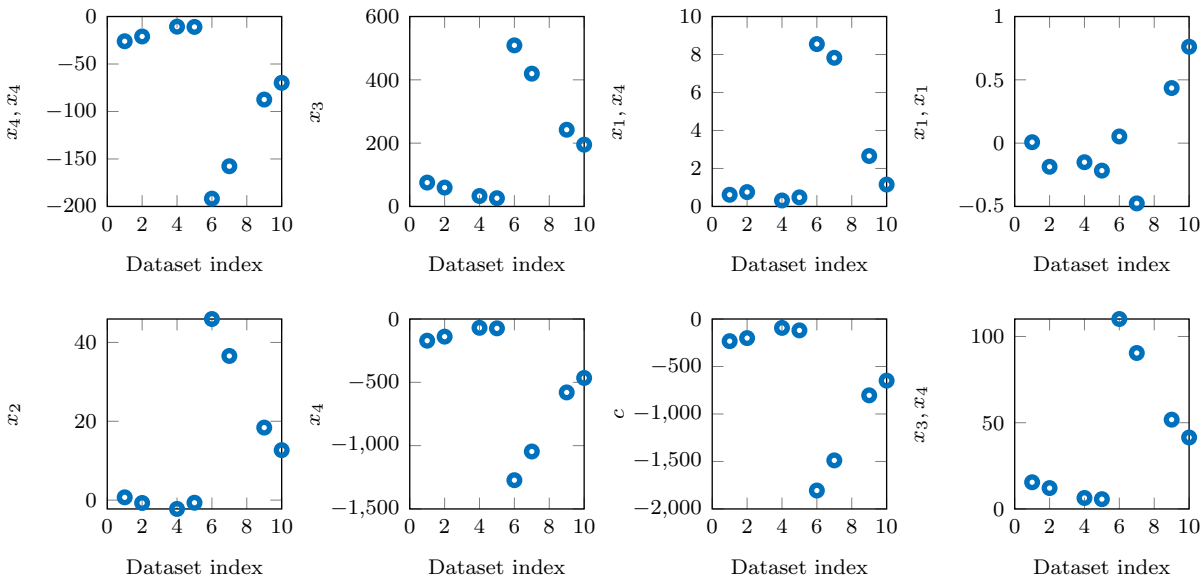


Figure 4: Estimated values of internal parameters.

Table 3: Estimated polynomial coefficients for the sample length 2000.

Terms	β_0	β_1	β_2	β_3	β_4	β_5
x_4, x_4	-170.31	4.27	831.86	-2.02	-0.03	-4562.38
x_3	143.25	-3.37	-1382.17	-3.9	0.04	11446.44
x_1, x_4	5.32	0.17	-203.84	2.88	0	161.25
x_1, x_1	1.85	-0.2	78.58	-1.4	0	39.42
x_2	76.05	-1.76	-434.89	5.27	0.01	953.45
x_4	-1216.06	31.23	5342.46	-8.72	-0.25	-30672.05
c	-2427.76	63.16	8882.74	-21.5	-0.49	-45523.06
x_3, x_4	61.26	-1.53	-370.55	0.3	0.01	2478.05

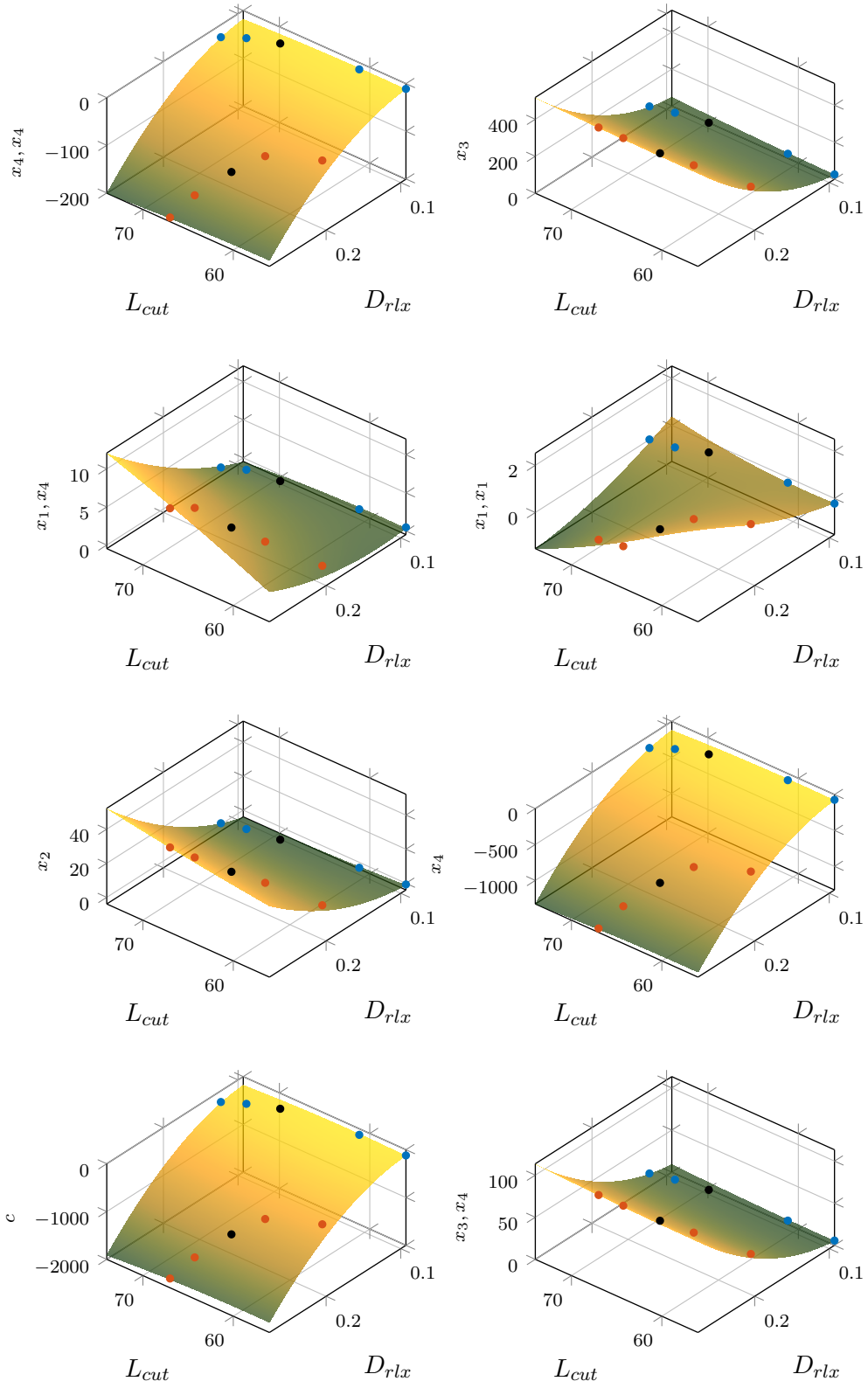


Figure 5: Parameter maps reconstructed with LS surface fitting to the internal parameters estimated from the data sample of length 2000.

Table 4: Estimated polynomial coefficients for the sample length 4000.

Terms	β_0	β_1	β_2	β_3	β_4	β_5
x_4, x_4	-125.63	2.93	707.07	-4.21	-0.02	-3082.44
x_3	-11.09	1.62	-1300.85	5.5	-0.01	8416.59
x_1, x_4	68.38	-1.52	-356.04	3.41	0.01	826.42
x_1, x_1	16.4	-0.72	129.23	-4.4	0.01	559.78
x_2	19.92	-0.36	-304.69	4.27	0	729.42
x_4	-760.18	17	5145.74	-29.05	-0.12	-24830.84
c	-1758.23	41.83	8866.02	-51.35	-0.29	-38902.3
x_3, x_3	55.85	-1.48	-198.99	-1.75	0.01	1812.12
x_1, x_3	-94.37	2.78	58.97	5.49	-0.03	-1745

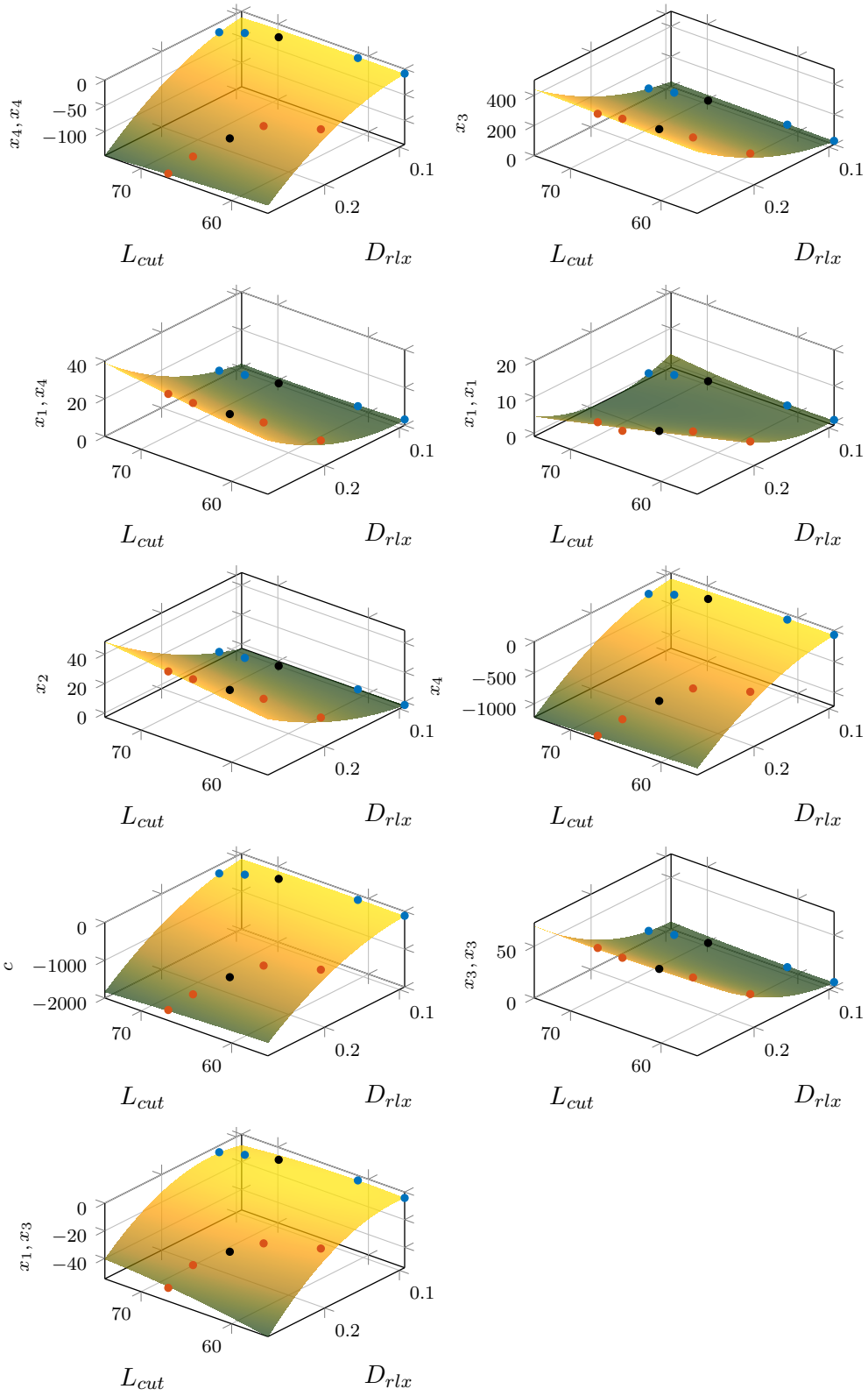


Figure 6: Parameter maps reconstructed with LS surface fitting to the internal parameters estimated from the data sample of length 4000.