SAND2016-7247PE

Exceptional service in the national interest

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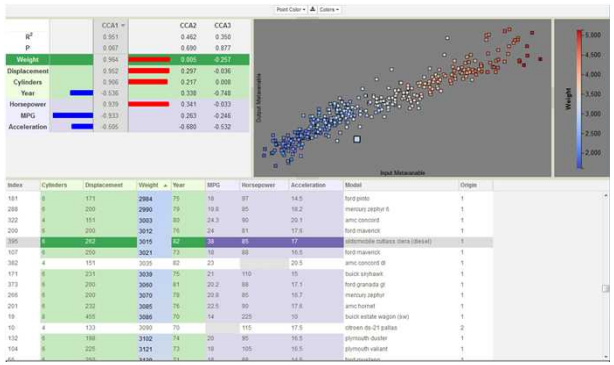

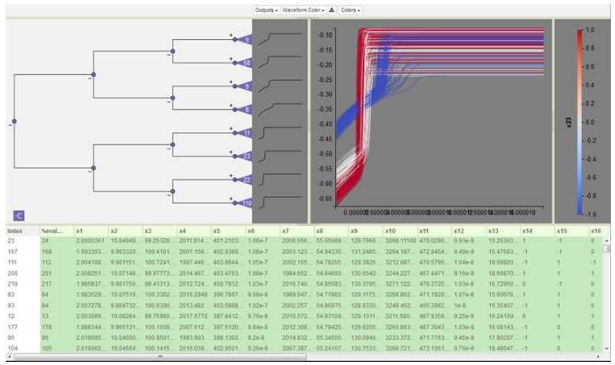

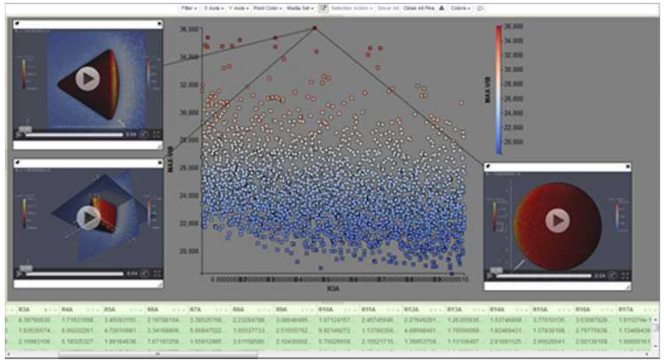

Slycat Analysis and Visualization

Patricia Crossno, PhD

U.S. DEPARTMENT OF ENERGY | National Nuclear Security Administration | CCR Center for Computing Research

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What is an Ensemble?

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- A set of related simulation runs, each sampling a shared problem space
- Used in parameter studies, sensitivity analysis, and Validation & Verification
- Each simulation described by:
  - Multiple input parameters
  - Multiple outputs
    - Scalar metrics (e.g. max/min quantities, event times)
    - Time series (variables changing over time)
    - Images and videos
    - 3D surface models
    - 2D/3D finite element models

The Magnitude of the Problem

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- Imagine 1K runs, EACH run has:
  - 10 input parameters
  - 5 scalar outputs
  - 8 outputs over time (time series)
  - 6 images
  - 5 movies (30 sec each)
- Data is stored remotely on the High Performance Computer (HPC) that ran the simulations
- We need to interpret our results
- How do we make sense of 6K images?
- View 5K movies? (5K * 30 sec / 60 sec / 60 min = 41.6 hours)
- What if we had 10K runs? 60K images? 50K movies?

Approach - Analysis as a Service

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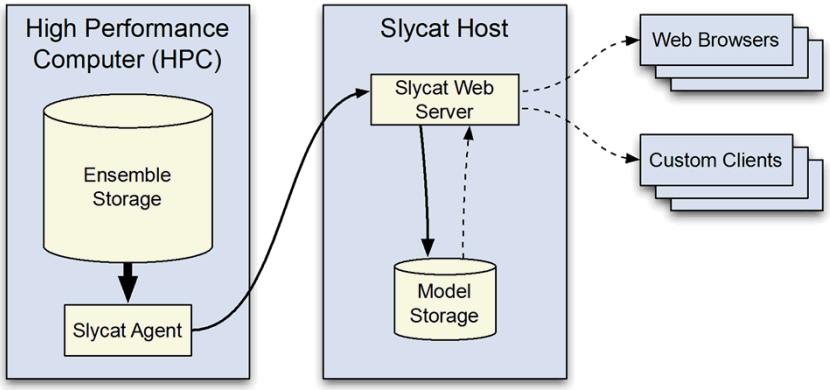
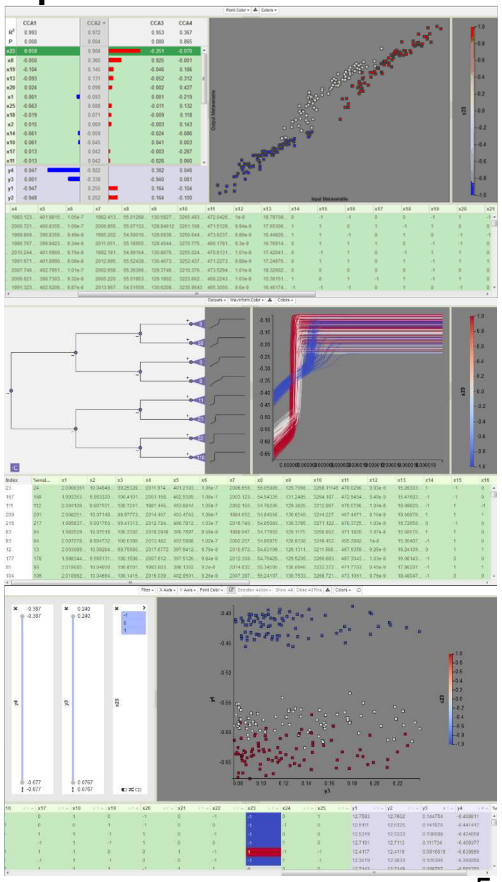
Slycat Server with Remote Desktop Delivery

- HPC-based agents operate on ensemble data in place
- Slycat server stores and manipulates analysis models
- Models are visualized remotely, interactively, and collaboratively
- Models support sensitivity analysis, anomaly detection, and parameter space exploration



Slycat Models

- Models of result data, not physics models used by simulations
- Different models provide complementary perspectives
- Main model types
  - Canonical Correlation Analysis (CCA)
    - Correlations between two sets of variables
    - Sensitivity analysis, anomaly detection
  - Time Series Clustering
    - Time series similarity, shape filtering
    - Map output variability to inputs, find outliers
  - Parameter Space
    - Visual exploration, filtering, image/video retrieval
    - Parameter studies, multi-objective optimization
- Each model has multiple levels of abstraction



Canonical Correlation Analysis (CCA)

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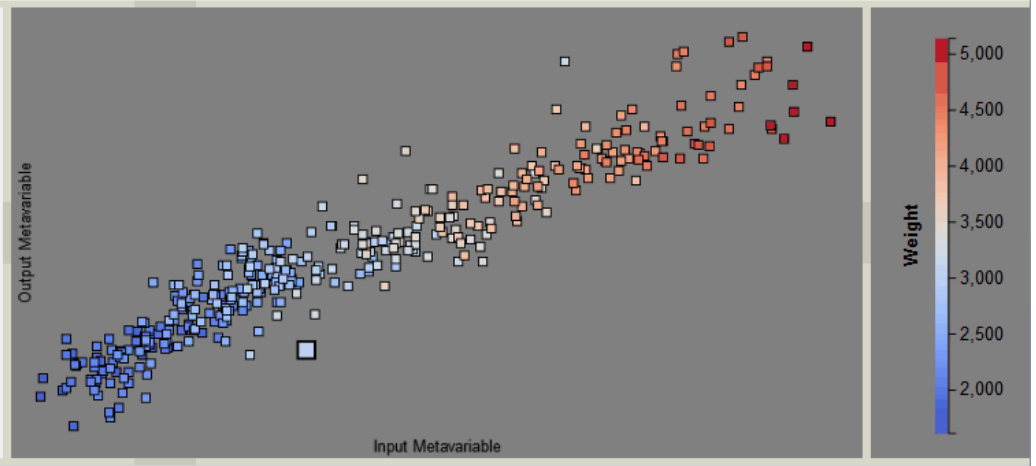
	CCA1	CCA2	CCA3
R^2	0.951	0.462	0.350
P	0.067	0.690	0.877
Weight	0.964	0.005	-0.257
Displacement	0.952	0.297	-0.036
Cylinders	0.906	0.217	0.008
Year	-0.536	0.338	-0.748
Horsepower	0.939	0.341	-0.033
MPG	-0.933	0.263	-0.246
Acceleration	-0.505	-0.680	-0.532



Index	Cylinders	Displacement	Weight	Year	MPG	Horsepower	Acceleration	Model	Origin
181	6	171	2984	75	18	97	14.5	ford pinto	1
288	6	200	2990	79	19.8	85	18.2	mercury zephyr 6	1
322	4	151	3003	80	24.3	90	20.1	amc concord	1
200	6	200	3012	76	24	81	17.6	ford maverick	1
395	6	262	3015	82	38	85	17	oldsmobile cutlass ciera (diesel)	1
107	6	250	3021	73	18	88	16.5	ford maverick	1
382	4	151	3035	82	23		20.5	amc concord dl	1
171	6	231	3039	75	21	110	15	buick skyhawk	1
373	6	200	3060	81	20.2	88	17.1	ford granada gl	1
266	6	200	3070	78	20.8	85	16.7	mercury zephyr	1
201	6	232	3085	76	22.5	90	17.6	amc hornet	1
19	8	455	3086	70	14	225	10	buick estate wagon (sw)	1
10	4	133	3090	70		115	17.5	citroen ds-21 pallas	2
132	6	198	3102	74	20	95	16.5	plymouth duster	1
104	6	225	3121	73	18	105	16.5	plymouth valiant	1
55	6	250	3139	71	18	88	14.5	ford mustang	1

Canonical Correlation Analysis (CCA)

Sandia National Laboratories

Point Color ▾ | Colors ▾

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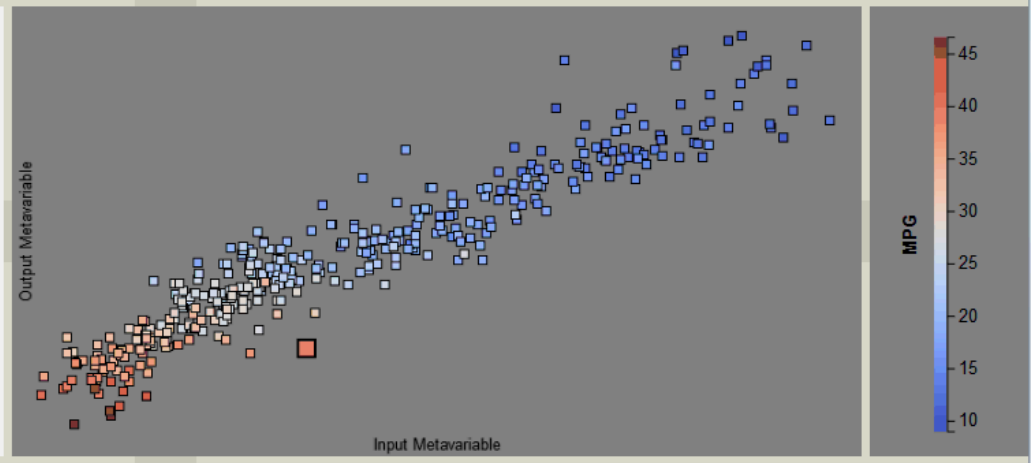

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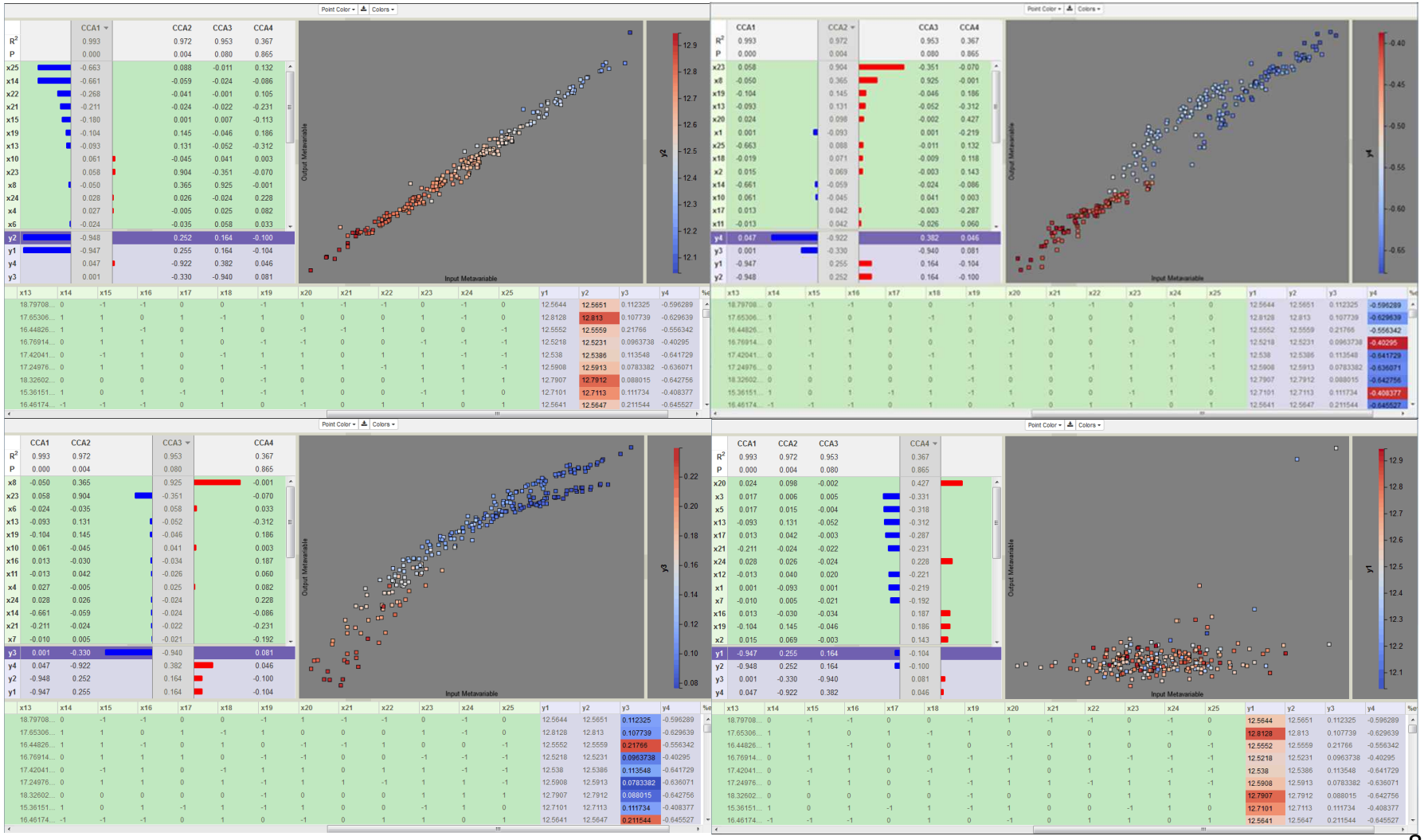
Canonical Correlation Analysis (CCA)



Canonical Correlation Analysis (CCA)

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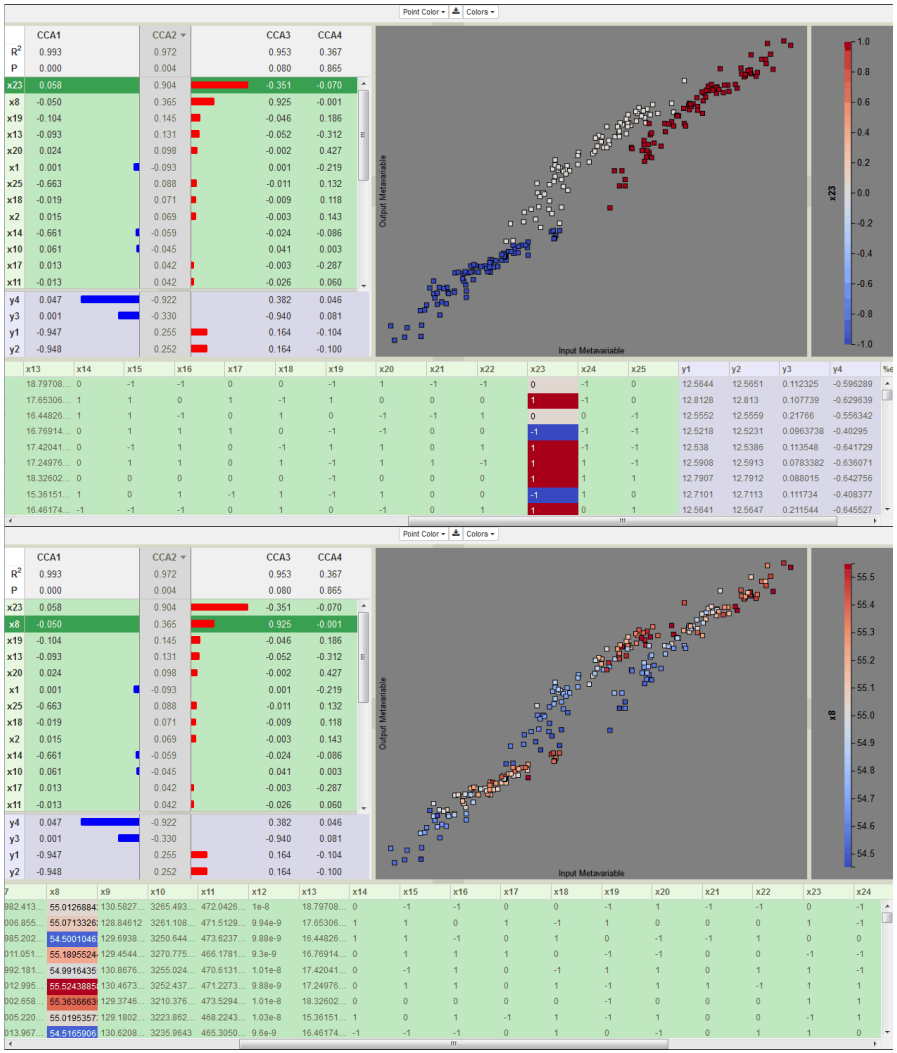
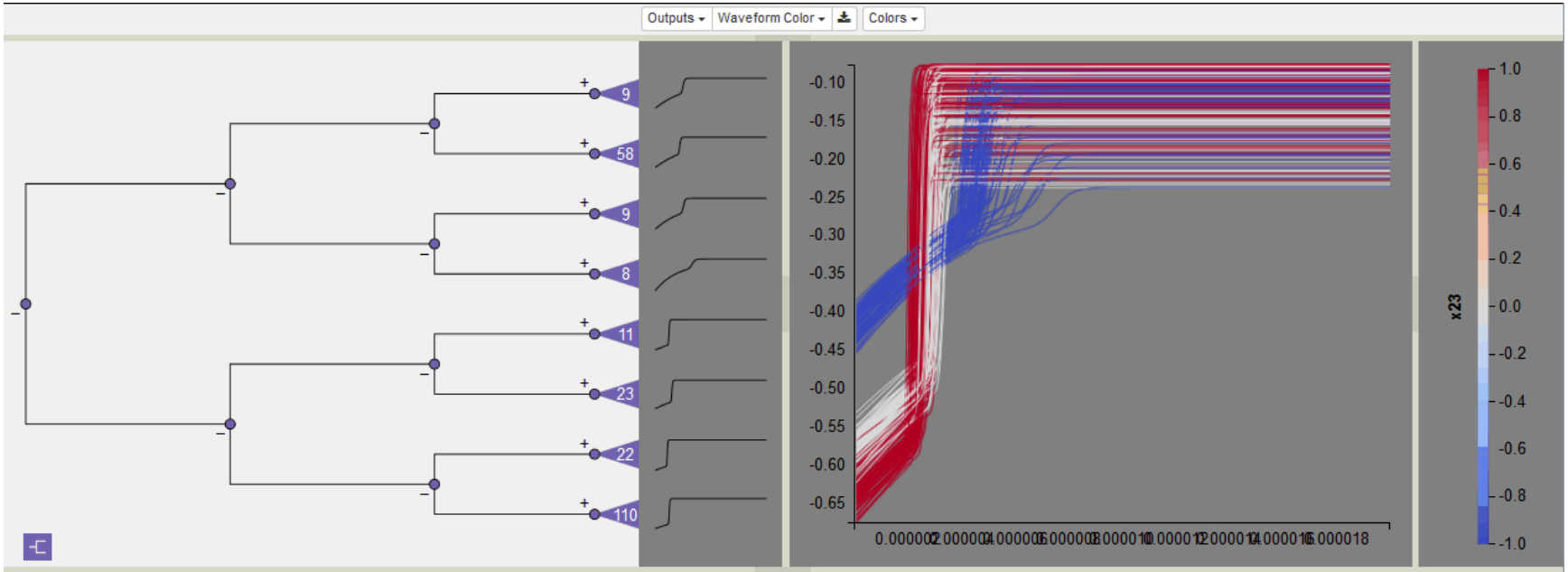
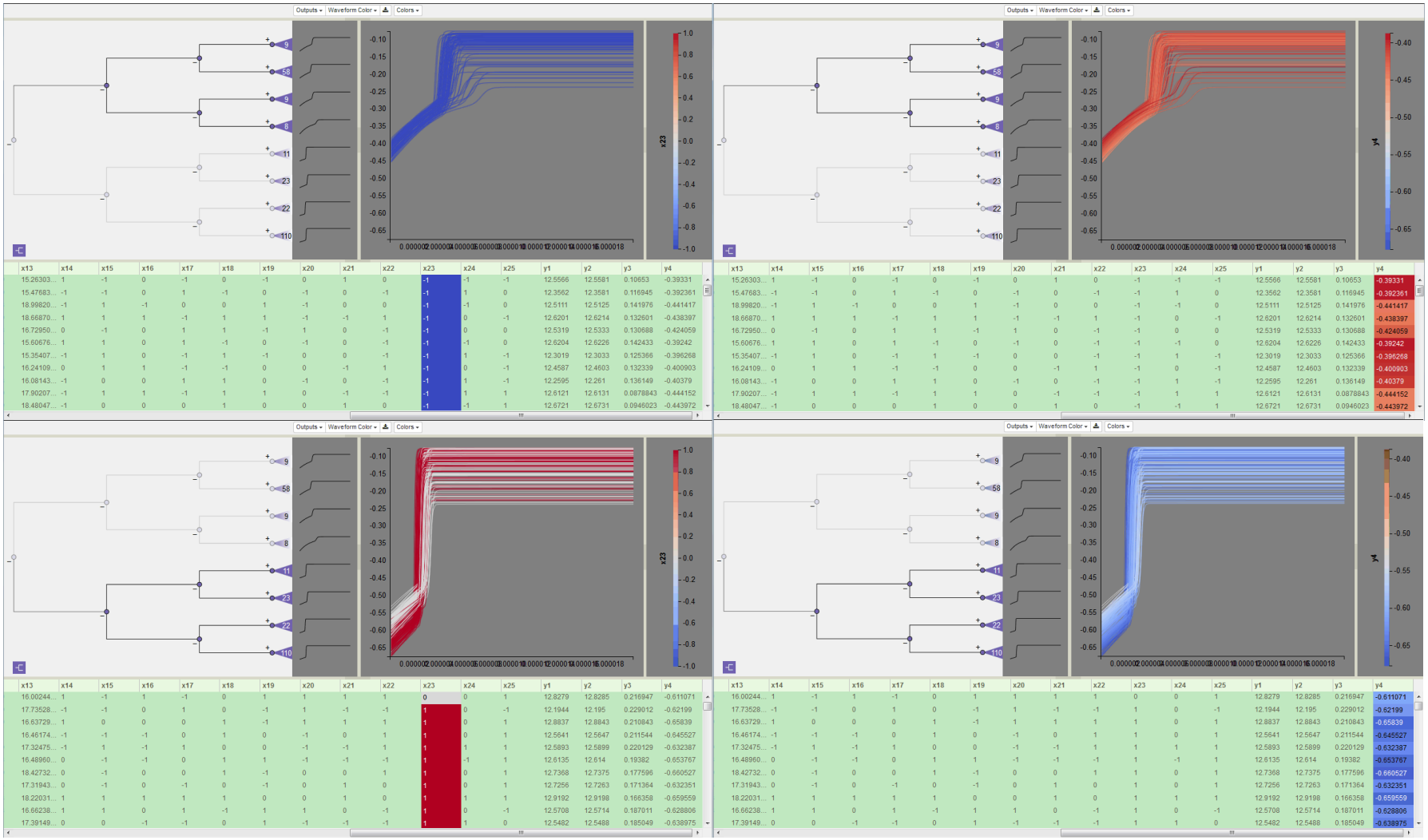


Time Series Clustering

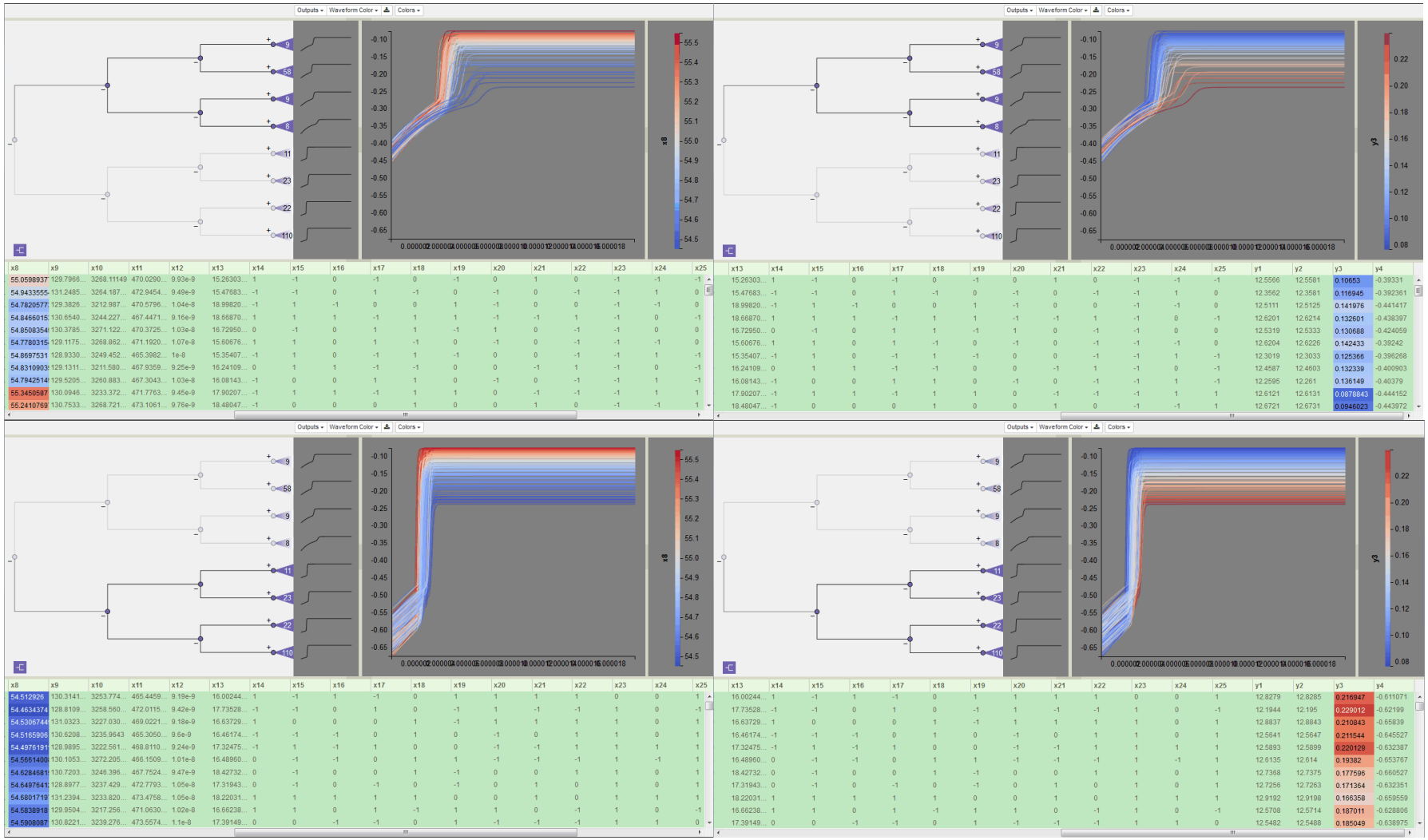


Index	%eval...	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16
23	24	2.0000361	10.04949...	99.25328...	2011.914...	401.2103...	1.06e-7	2006.656...	55.05989...	129.7966...	3268.11149	470.0290...	9.93e-9	15.26303...	1	-1	0
167	168	1.993353...	9.963320...	100.4101...	2001.158...	402.9389...	1.08e-7	2003.123...	54.94335...	131.2485...	3264.187...	472.9454...	9.49e-9	15.47683...	-1	-1	0
111	112	2.004108...	9.901151...	100.7241...	1987.446...	403.8844...	1.05e-7	2002.165...	54.78205...	129.3826...	3212.987...	470.5796...	1.04e-8	18.99820...	-1	1	-1
200	201	2.008251...	10.07148...	99.97773...	2014.467...	403.4763...	1.08e-7	1984.652...	54.84660...	130.6540...	3244.227...	467.4471...	9.16e-9	18.66870...	1	1	1
216	217	1.985837...	9.901750...	99.41313...	2012.724...	400.7812...	1.03e-7	2016.740...	54.85083...	130.3785...	3271.122...	470.3725...	1.03e-8	16.72950...	0	-1	0
83	84	1.983529...	10.07519...	100.3302...	2019.2948	396.7897...	9.68e-8	1989.047...	54.77803...	129.1175...	3268.862...	471.1920...	1.07e-8	15.60676...	1	1	0
93	94	2.007278...	9.904732...	100.6390...	2013.482...	403.5888...	1.02e-7	2002.257...	54.86975...	128.9330...	3249.452...	465.3982...	1e-8	15.35407...	-1	1	0
12	13	2.003089...	10.08284...	99.75980...	2017.6772	397.9412...	9.76e-8	2010.572...	54.83109...	129.1311...	3211.580...	467.9359...	9.25e-9	16.24109...	0	1	1
177	178	1.988344...	9.965131...	100.1508...	2007.612...	397.5120...	9.84e-8	2012.308...	54.79425...	129.5205...	3260.883...	467.3043...	1.03e-8	16.08143...	-1	0	0
95	96	2.019685...	10.04000...	100.8501...	1983.903...	398.1303...	9.2e-8	2014.832...	55.34505...	130.0946...	3233.372...	471.7763...	9.45e-9	17.90207...	-1	1	1
104	105	2.018962...	10.04664...	100.1415...	2016.039...	402.9501...	9.26e-8	2007.387...	55.24107...	130.7533...	3268.721...	473.1061...	9.76e-9	18.48047...	-1	0	0

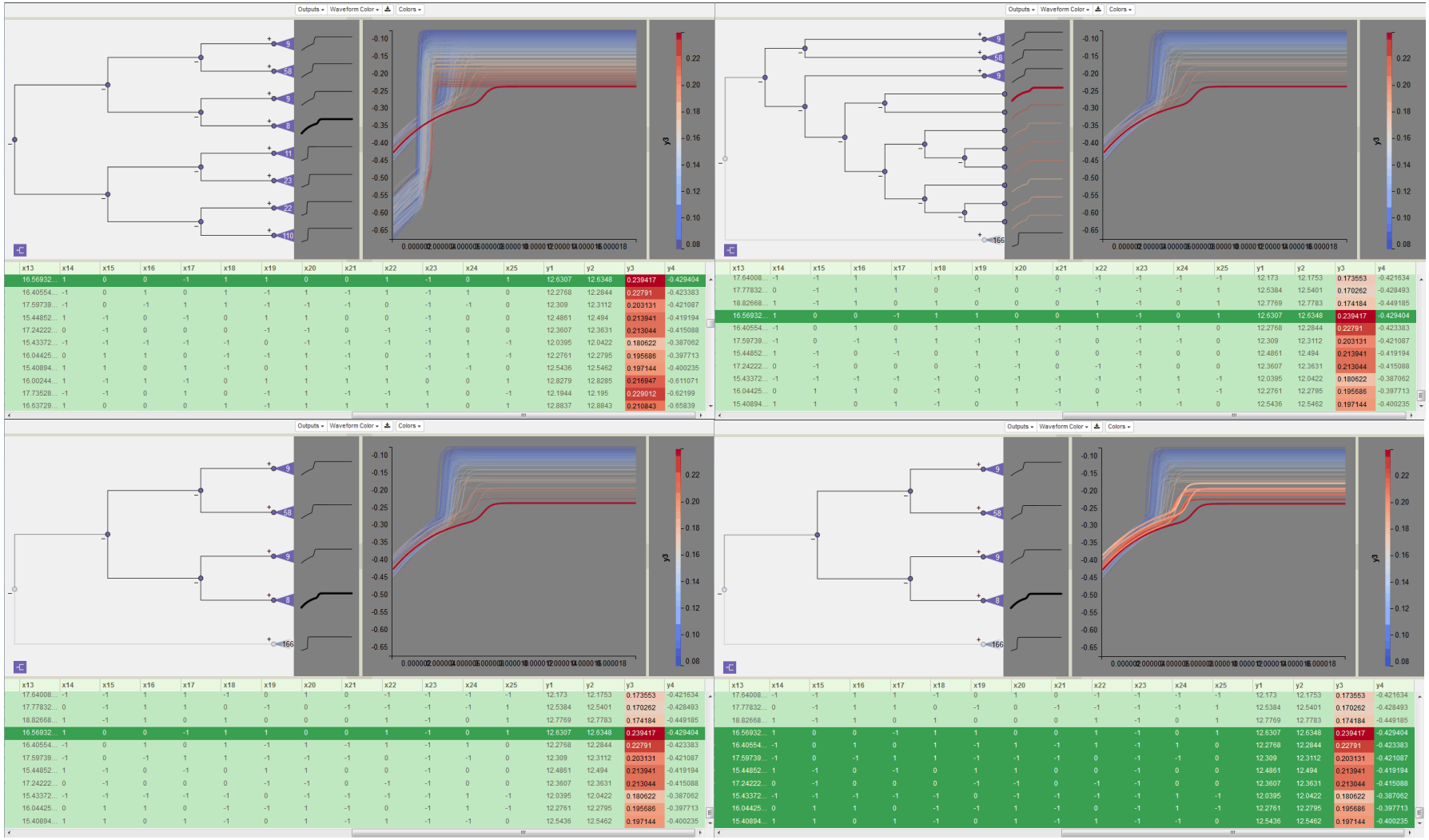
Time Series Clustering



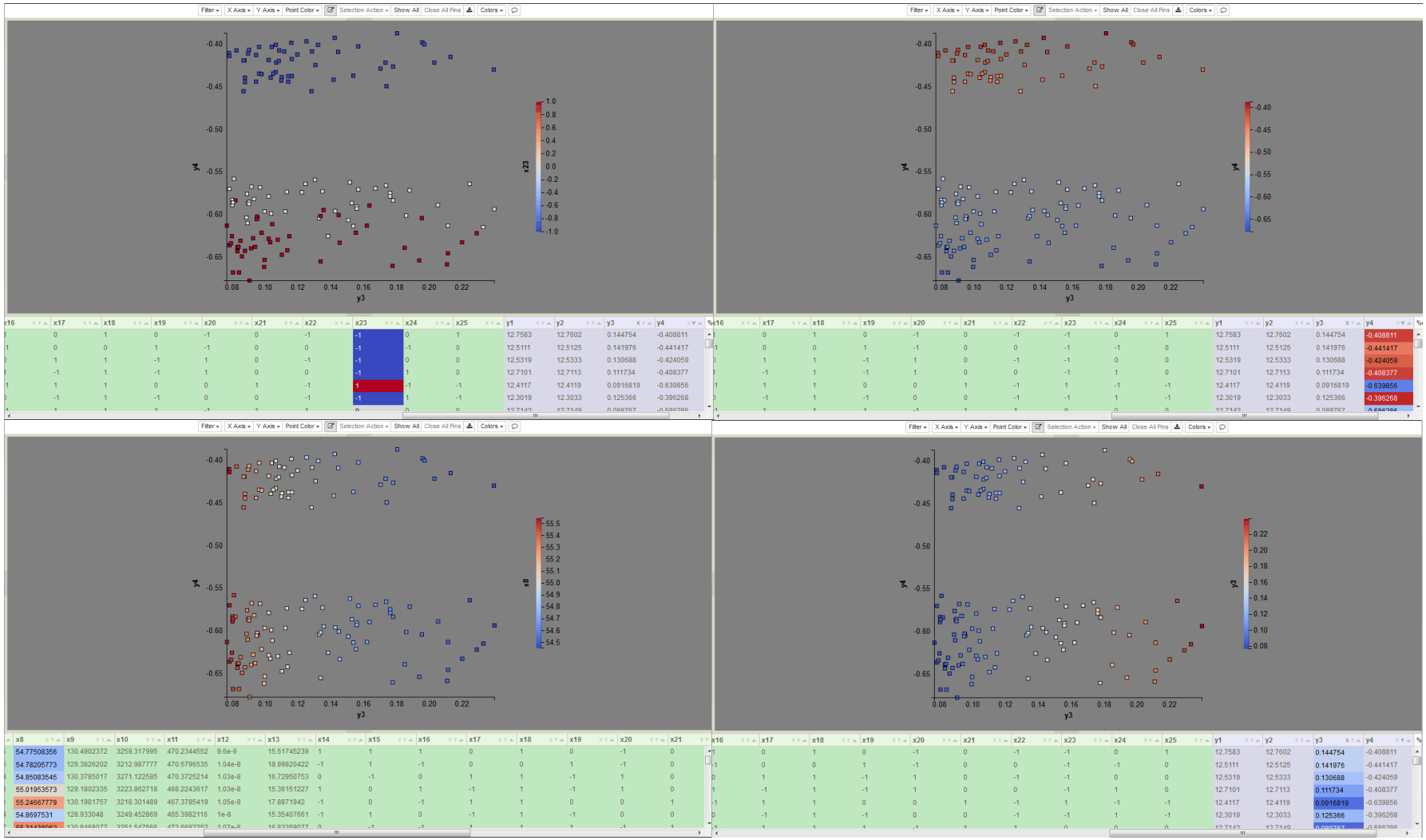
Time Series Clustering



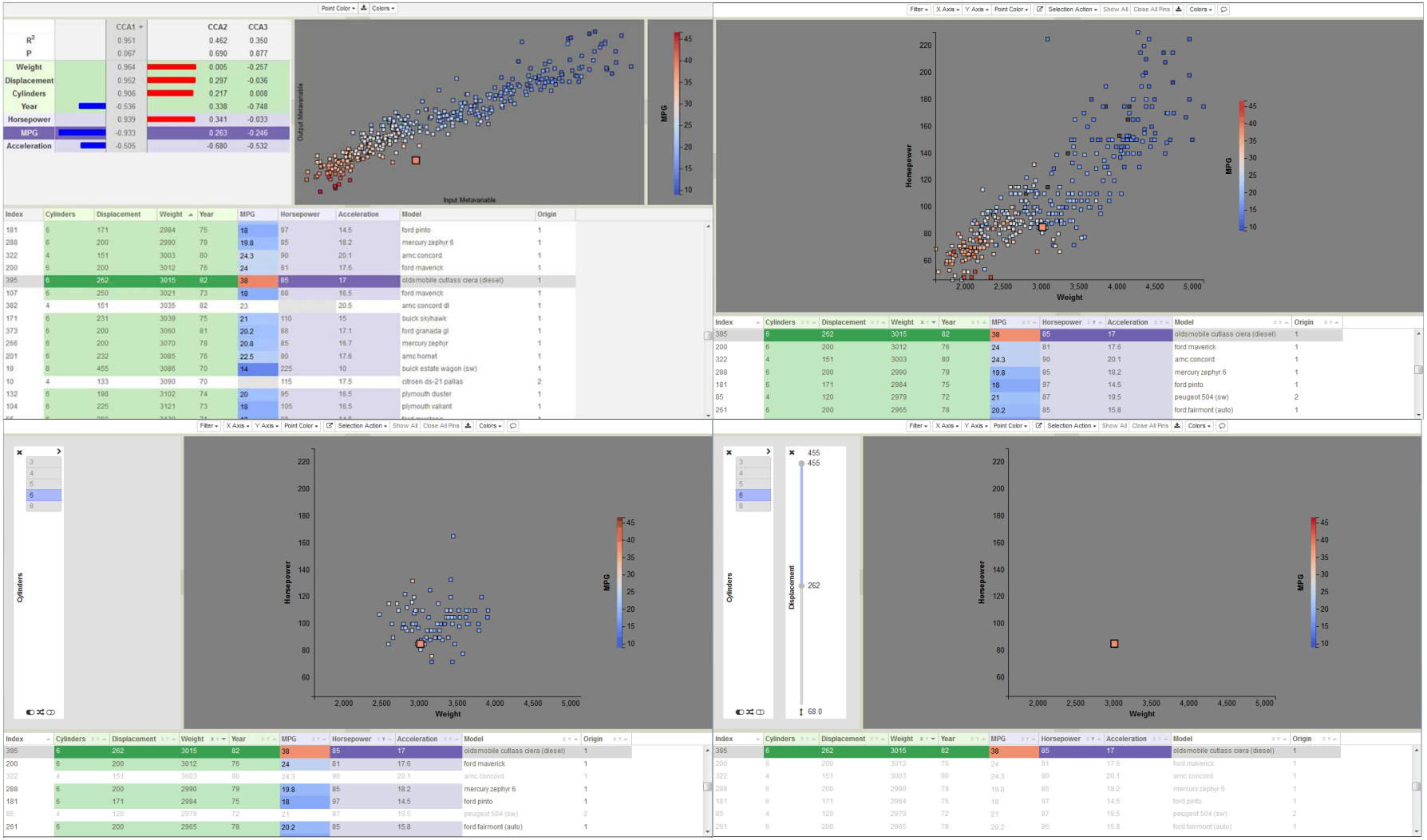
Time Series Clustering



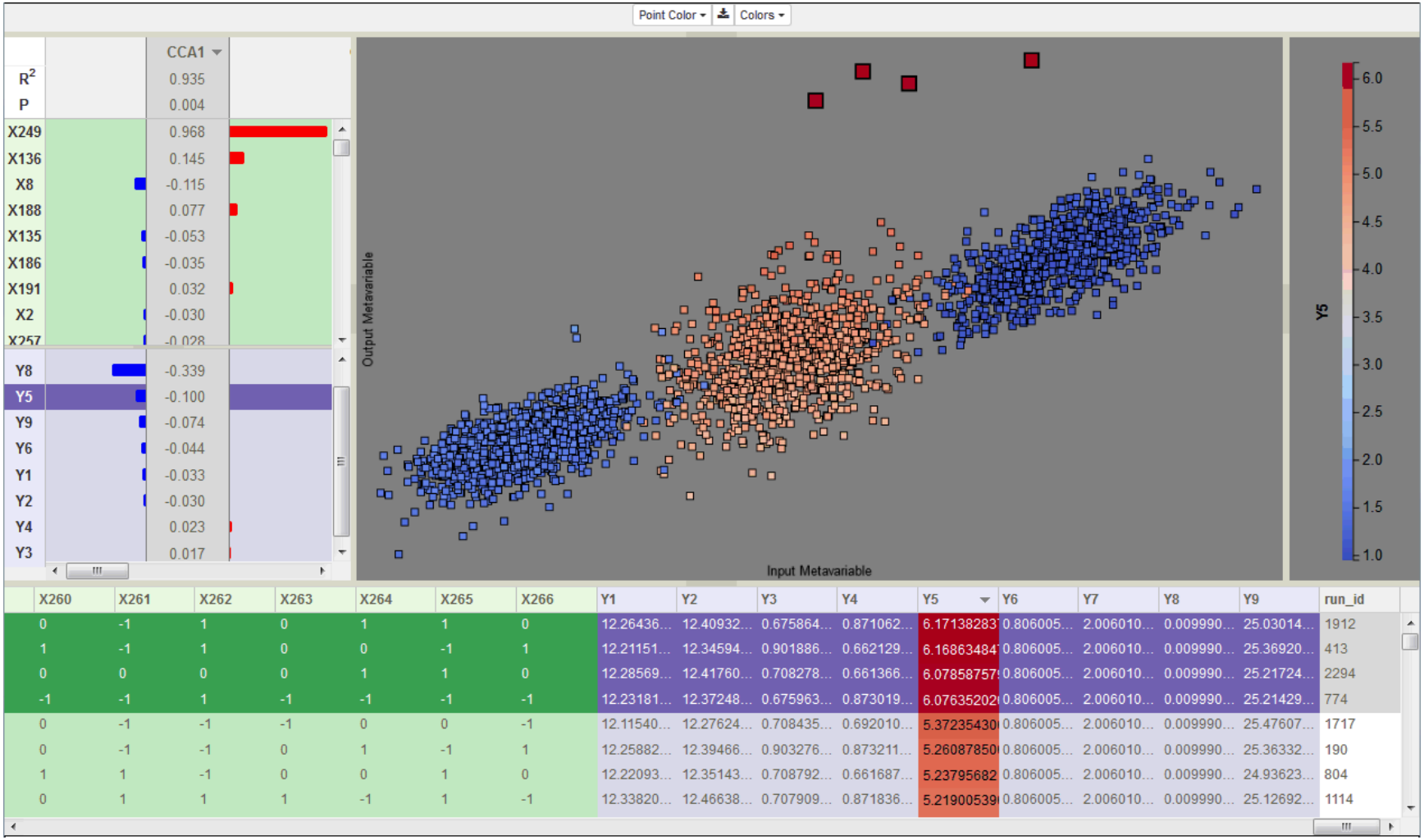
Parameter Space



Parameter Space

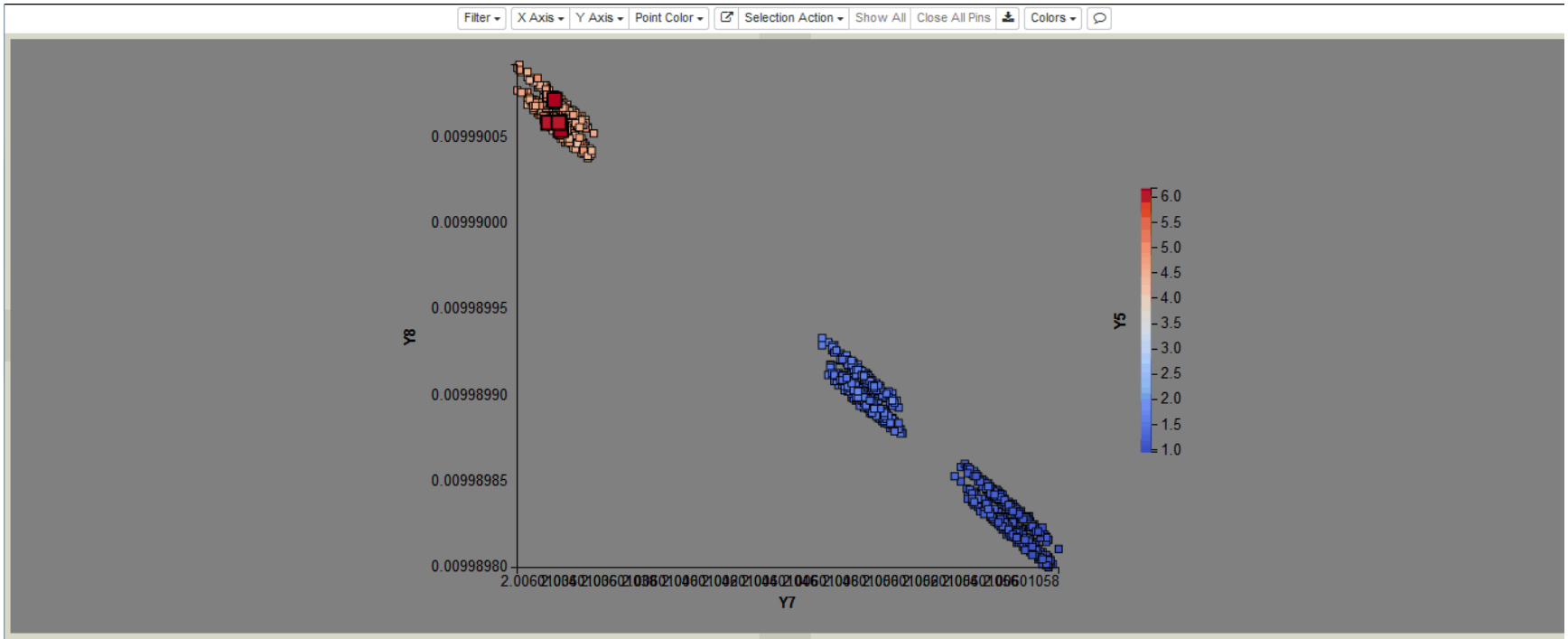


Parameter Space



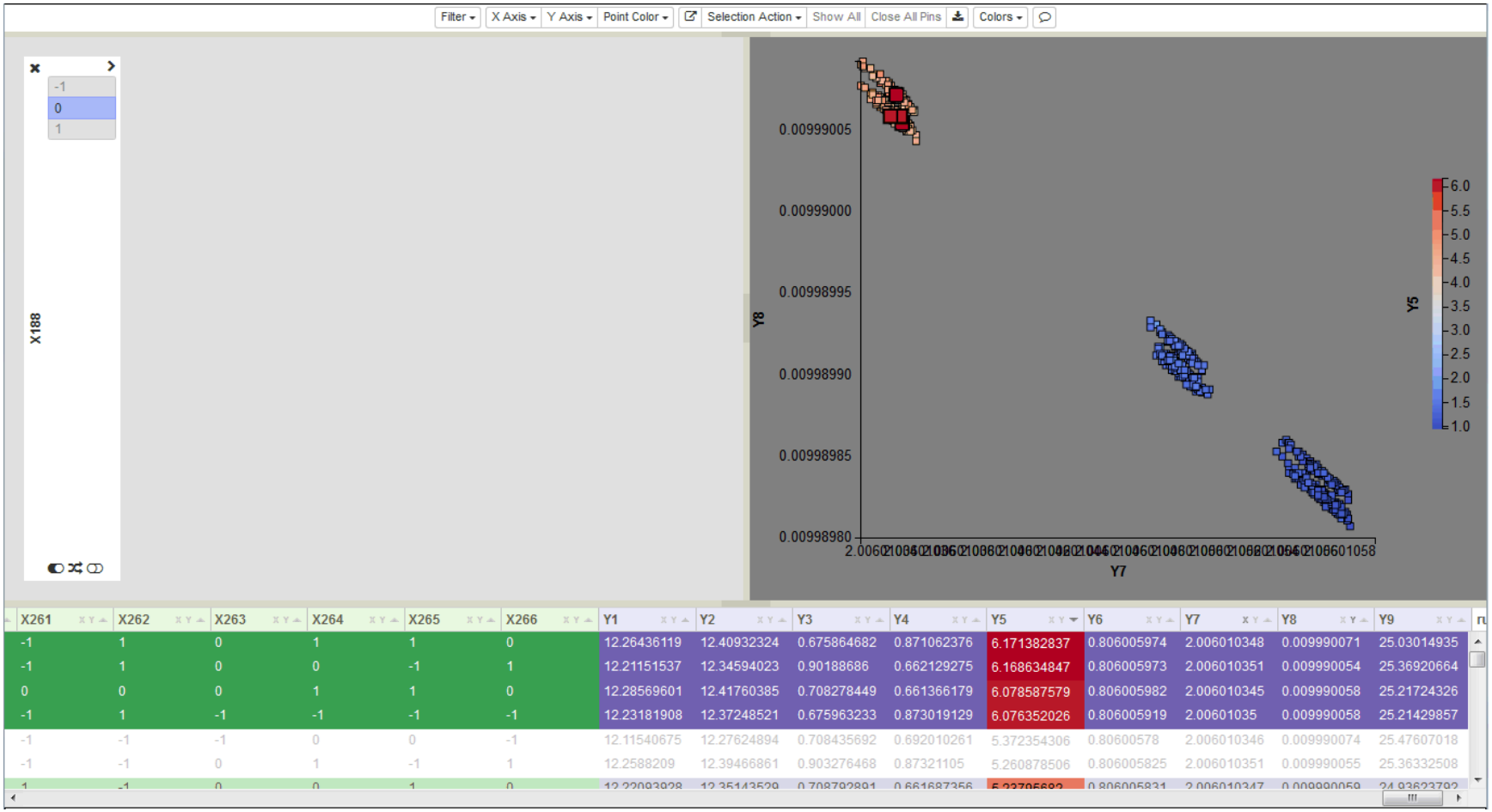
X260	X261	X262	X263	X264	X265	X266	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	run_id
0	-1	1	0	1	1	0	12.26436...	12.40932...	0.675864...	0.871062...	6.17138283	0.806005...	2.006010...	0.009990...	25.03014...	1912
1	-1	1	0	0	-1	1	12.21151...	12.34594...	0.901886...	0.662129...	6.16863484	0.806005...	2.006010...	0.009990...	25.36920...	413
0	0	0	0	1	1	0	12.28569...	12.41760...	0.708278...	0.661366...	6.07858757	0.806005...	2.006010...	0.009990...	25.21724...	2294
-1	-1	1	-1	-1	-1	-1	12.23181...	12.37248...	0.675963...	0.873019...	6.07635202	0.806005...	2.006010...	0.009990...	25.21429...	774
0	-1	-1	-1	0	0	-1	12.11540...	12.27624...	0.708435...	0.692010...	5.37235430	0.806005...	2.006010...	0.009990...	25.47607...	1717
0	-1	-1	0	1	-1	1	12.25882...	12.39466...	0.903276...	0.873211...	5.26087850	0.806005...	2.006010...	0.009990...	25.36332...	190
1	1	-1	0	0	1	0	12.22093...	12.35143...	0.708792...	0.661687...	5.23795682	0.806005...	2.006010...	0.009990...	24.93623...	804
0	1	1	1	-1	1	-1	12.33820...	12.46638...	0.707909...	0.871836...	5.21900539	0.806005...	2.006010...	0.009990...	25.12692...	1114

Parameter Space



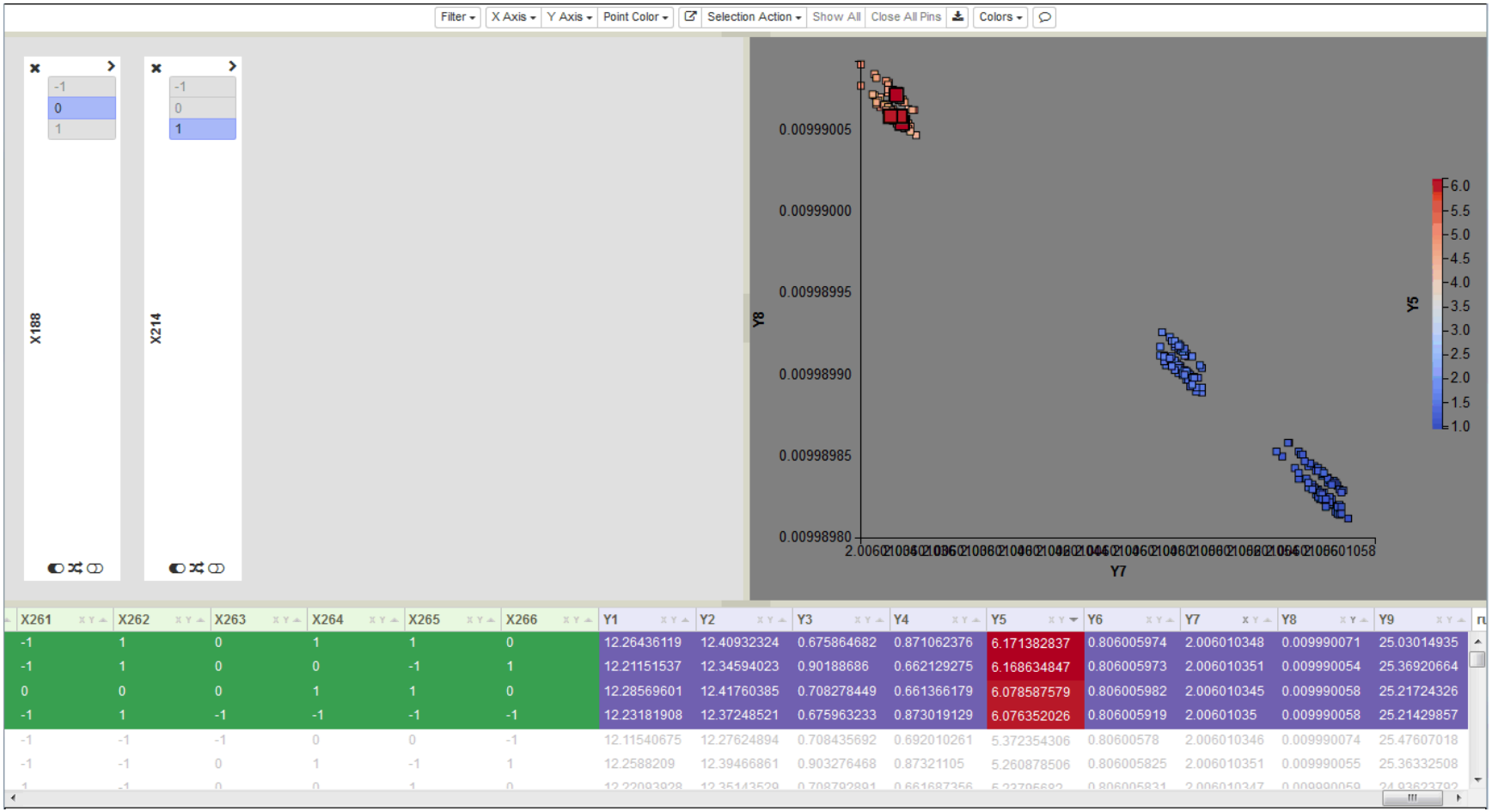
X261	X262	X263	X264	X265	X266	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
-1	1	0	1	1	0	12.26436119	12.40932324	0.675864682	0.871062376	6.171382837	0.806005974	2.006010348	0.009990071	25.03014935
-1	1	0	0	-1	1	12.21151537	12.34594023	0.90188686	0.662129275	6.168634847	0.806005973	2.006010351	0.009990054	25.36920664
0	0	0	1	1	0	12.28569601	12.41760385	0.708278449	0.661366179	6.078587579	0.806005982	2.006010345	0.009990058	25.21724326
-1	1	-1	-1	-1	-1	12.23181908	12.37248521	0.675963233	0.873019129	6.076352026	0.806005919	2.00601035	0.009990058	25.21429857
-1	-1	-1	0	0	-1	12.11540675	12.27624894	0.708435692	0.692010261	5.372354306	0.80600578	2.006010346	0.009990074	25.47607018
-1	-1	0	1	-1	1	12.2588209	12.39466861	0.903276468	0.87321105	5.260878506	0.806005825	2.006010351	0.009990055	25.36332508

Parameter Space



X261	X262	X263	X264	X265	X266	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
-1	1	0	1	1	0	12.26436119	12.40932324	0.675864682	0.871062376	6.171382837	0.806005974	2.006010348	0.009990071	25.03014935
-1	1	0	0	-1	1	12.21151537	12.34594023	0.90188686	0.662129275	6.168634847	0.806005973	2.006010351	0.009990054	25.36920664
0	0	0	1	1	0	12.28569601	12.41760385	0.708278449	0.661366179	6.078587579	0.806005982	2.006010345	0.009990058	25.21724326
-1	1	-1	-1	-1	-1	12.23181908	12.37248521	0.675963233	0.873019129	6.076352026	0.806005919	2.00601035	0.009990058	25.21429857
-1	-1	-1	0	0	-1	12.11540675	12.27624894	0.708435692	0.692010261	5.372354306	0.80600578	2.006010346	0.009990074	25.47607018
-1	-1	0	1	-1	1	12.2588209	12.39466861	0.903276468	0.87321105	5.260878506	0.806005825	2.006010351	0.009990055	25.36332508
-1	-1	0	0	1	0	12.22093928	12.35143529	0.708792891	0.661687356	5.23796683	0.806005831	2.006010347	0.009990059	24.93623702

Parameter Space



X261	X262	X263	X264	X265	X266	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
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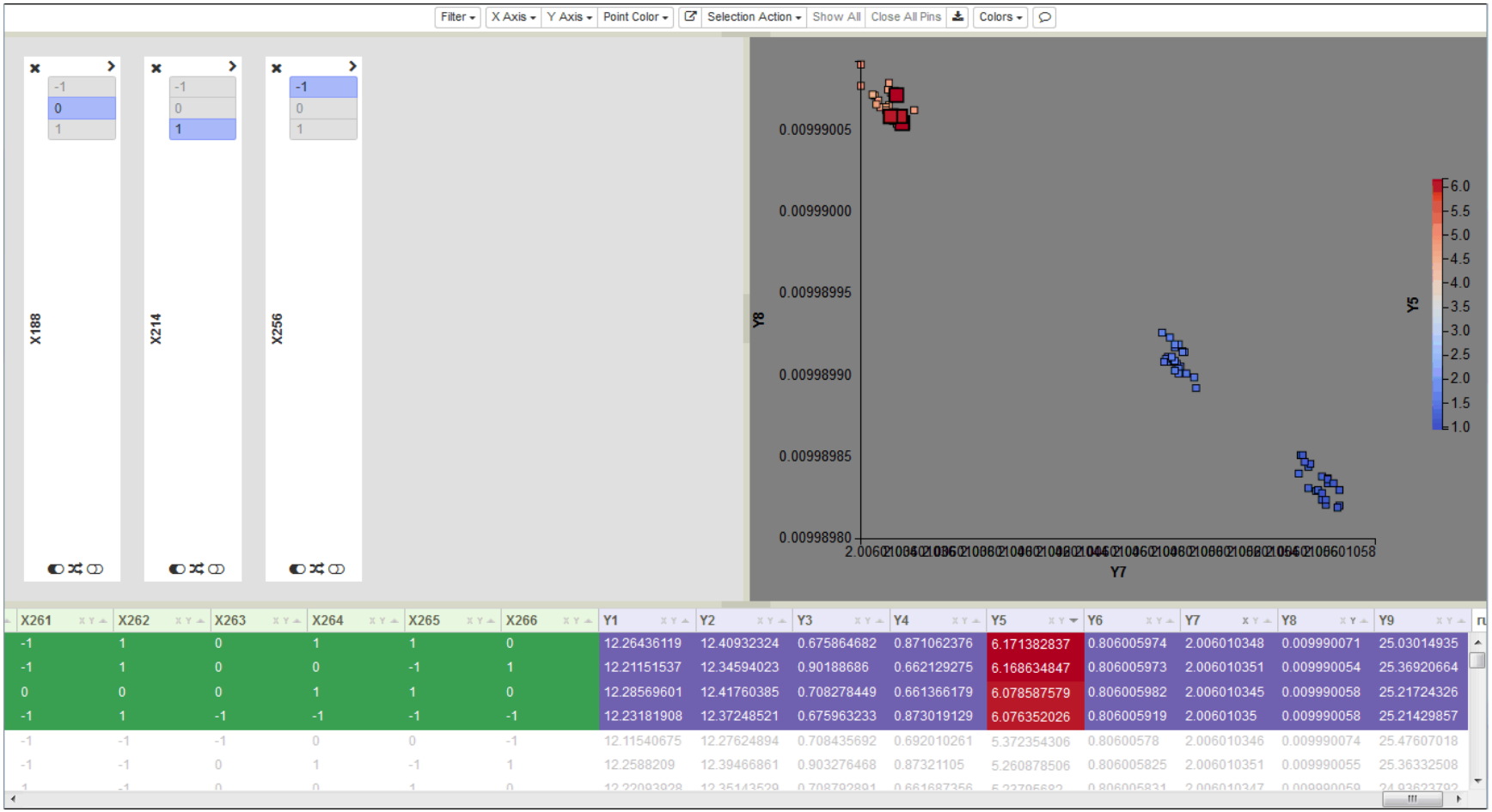
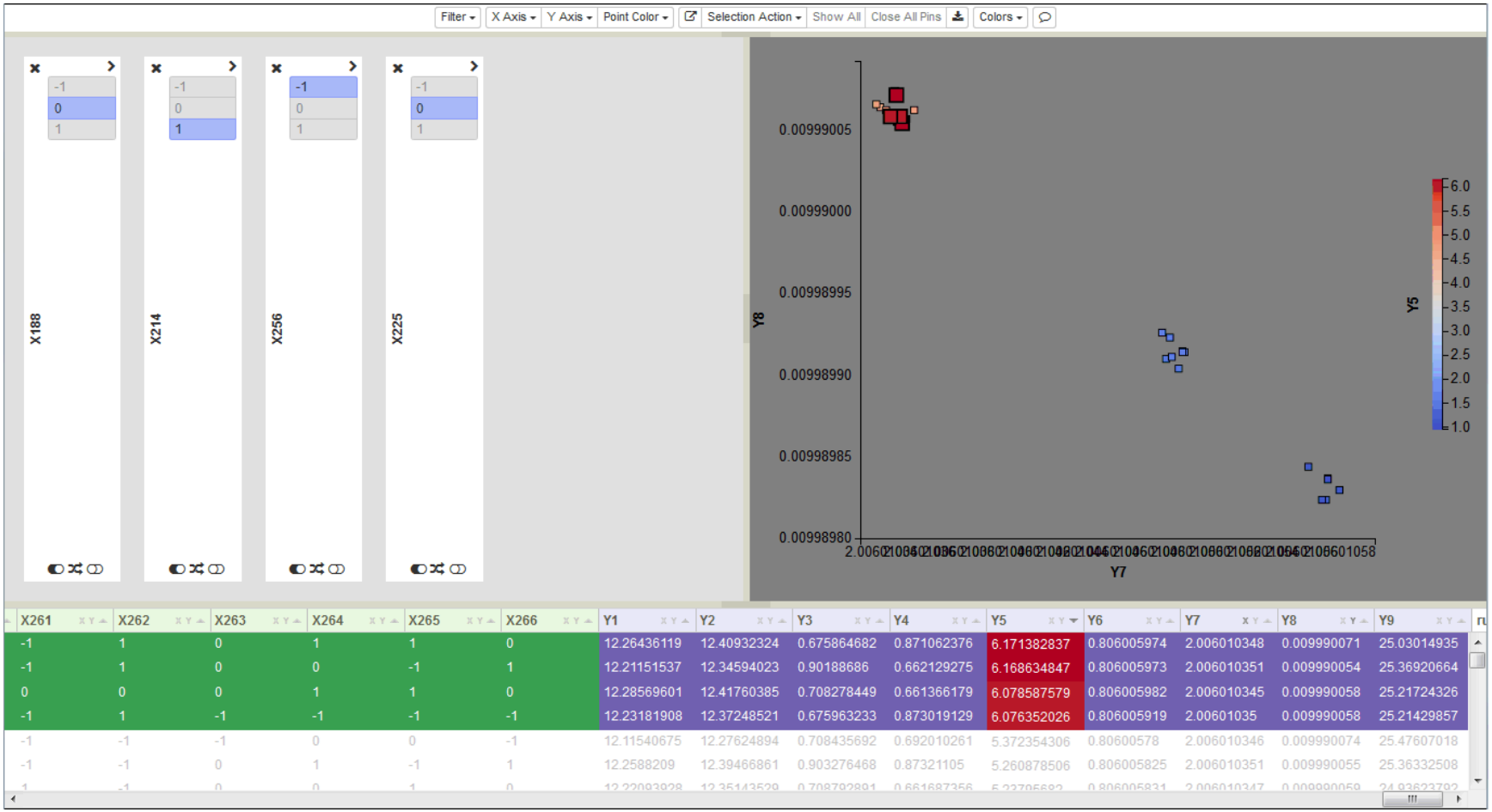
-1	1	0	0	-1	1	12.21151537	12.34594023	0.90188686	0.662129275	6.168634847	0.806005973	2.006010351	0.009990054	25.36920664
0	0	0	1	1	0	12.28569601	12.41760385	0.708278449	0.661366179	6.078587579	0.806005982	2.006010345	0.009990058	25.21724326
-1	1	-1	-1	-1	-1	12.23181908	12.37248521	0.675963233	0.873019129	6.076352026	0.806005919	2.00601035	0.009990058	25.21429857
-1	-1	-1	0	0	-1	12.11540675	12.27624894	0.708435692	0.692010261	5.372354306	0.80600578	2.006010346	0.009990074	25.47607018
-1	-1	0	1	-1	1	12.2588209	12.39466861	0.903276468	0.87321105	5.260878506	0.806005825	2.006010351	0.009990055	25.36332508

Parameter Space



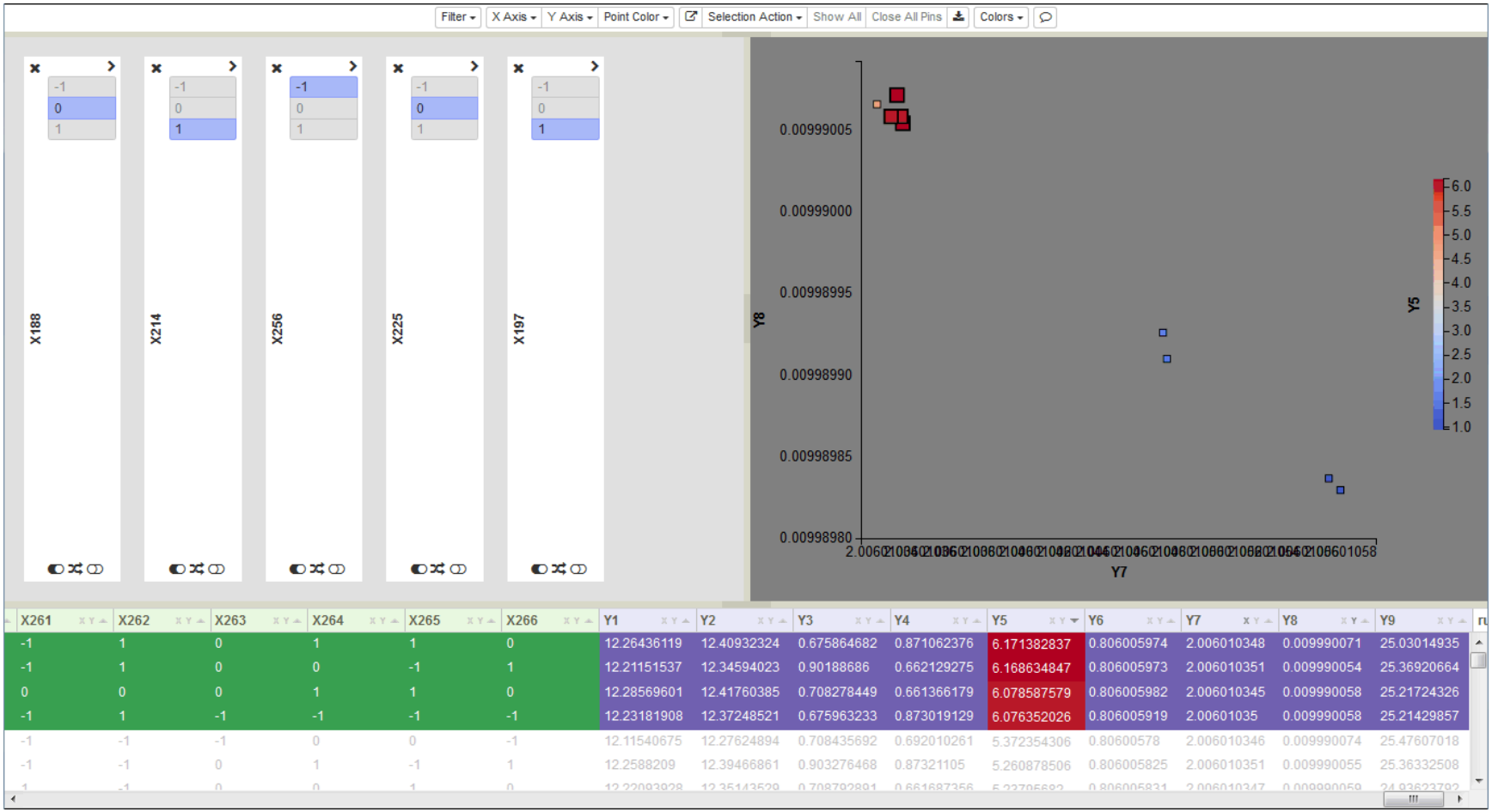
X261	X262	X263	X264	X265	X266	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
-1	1	0	1	1	0	12.26436119	12.40932324	0.675864682	0.871062376	6.171382837	0.806005974	2.006010348	0.009990071	25.03014935
-1	1	0	0	-1	1	12.21151537	12.34594023	0.90188686	0.662129275	6.168634847	0.806005973	2.006010351	0.009990054	25.36920664
0	0	0	1	1	0	12.28569601	12.41760385	0.708278449	0.661366179	6.078587579	0.806005982	2.006010345	0.009990058	25.21724326
-1	1	-1	-1	-1	-1	12.23181908	12.37248521	0.675963233	0.873019129	6.076352026	0.806005919	2.00601035	0.009990058	25.21429857
-1	-1	-1	0	0	-1	12.11540675	12.27624894	0.708435692	0.692010261	5.372354306	0.80600578	2.006010346	0.009990074	25.47607018
-1	-1	0	1	-1	1	12.2588209	12.39466861	0.903276468	0.87321105	5.260878506	0.806005825	2.006010351	0.009990055	25.36332508

Parameter Space



X261	X262	X263	X264	X265	X266	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
-1	1	0	1	1	0	12.26436119	12.40932324	0.675864682	0.871062376	6.171382837	0.806005974	2.006010348	0.009990071	25.03014935
-1	1	0	0	-1	1	12.21151537	12.34594023	0.90188686	0.662129275	6.168634847	0.806005973	2.006010351	0.009990054	25.36920664
0	0	0	1	1	0	12.28569601	12.41760385	0.708278449	0.661366179	6.078587579	0.806005982	2.006010345	0.009990058	25.21724326
-1	1	-1	-1	-1	-1	12.23181908	12.37248521	0.675963233	0.873019129	6.076352026	0.806005919	2.00601035	0.009990058	25.21429857
-1	-1	-1	0	0	-1	12.11540675	12.27624894	0.708435692	0.692010261	5.372354306	0.80600578	2.006010346	0.009990074	25.47607018
-1	-1	0	1	-1	1	12.2588209	12.39466861	0.903276468	0.87321105	5.260878506	0.806005825	2.006010351	0.009990055	25.36332508

Parameter Space



X261	X262	X263	X264	X265	X266	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
-1	1	0	1	1	0	12.26436119	12.40932324	0.675864682	0.871062376	6.171382837	0.806005974	2.006010348	0.009990071	25.03014935
-1	1	0	0	-1	1	12.21151537	12.34594023	0.90188686	0.662129275	6.168634847	0.806005973	2.006010351	0.009990054	25.36920664
0	0	0	1	1	0	12.28569601	12.41760385	0.708278449	0.661366179	6.078587579	0.806005982	2.006010345	0.009990058	25.21724326
-1	1	-1	-1	-1	-1	12.23181908	12.37248521	0.675963233	0.873019129	6.076352026	0.806005919	2.00601035	0.009990058	25.21429857
-1	-1	-1	0	0	-1	12.11540675	12.27624894	0.708435692	0.692010261	5.372354306	0.80600578	2.006010346	0.009990074	25.47607018
-1	-1	0	1	-1	1	12.2588209	12.39466861	0.903276468	0.87321105	5.260878506	0.806005825	2.006010351	0.009990055	25.36332508

Parameter Space

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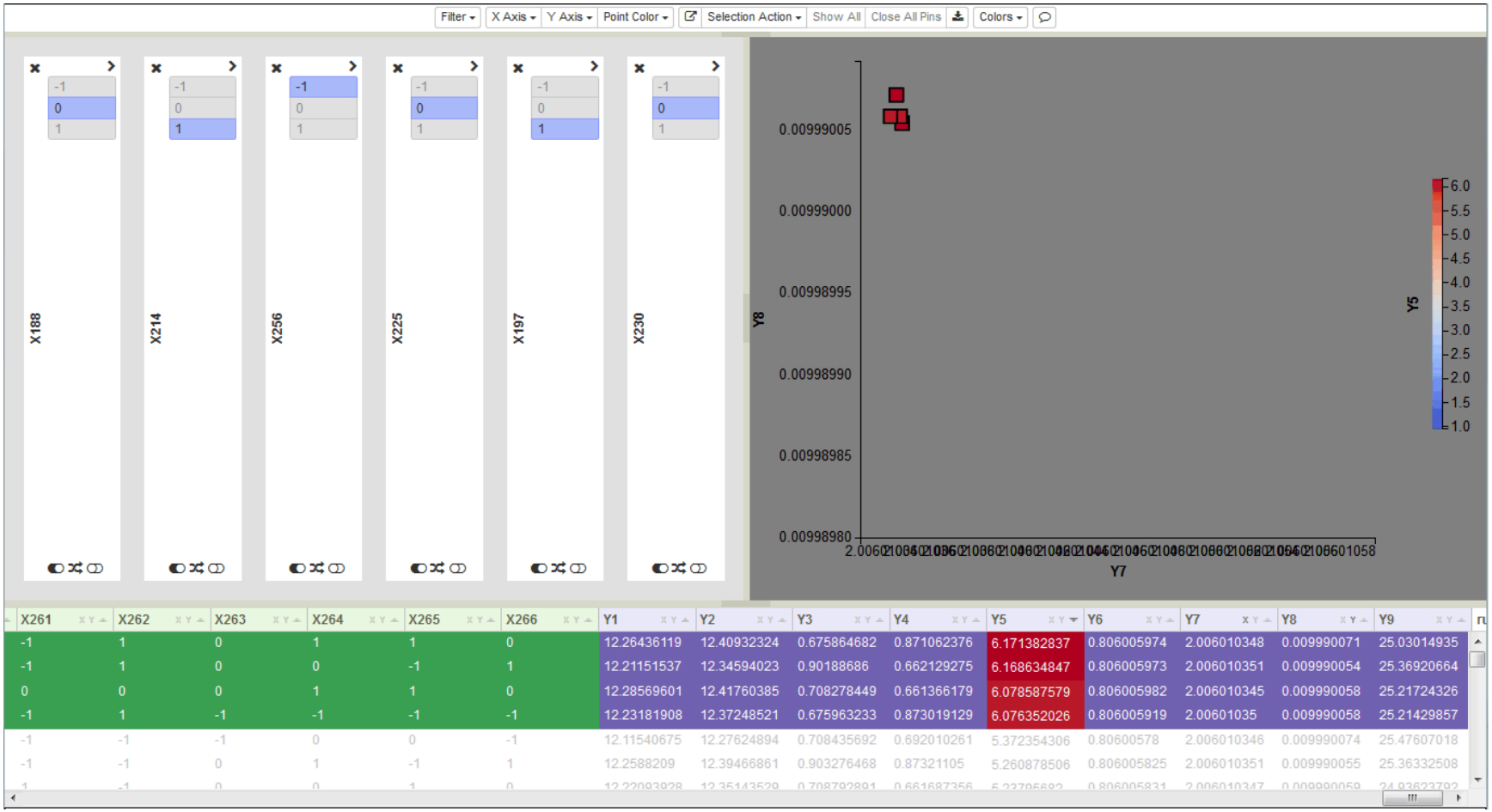
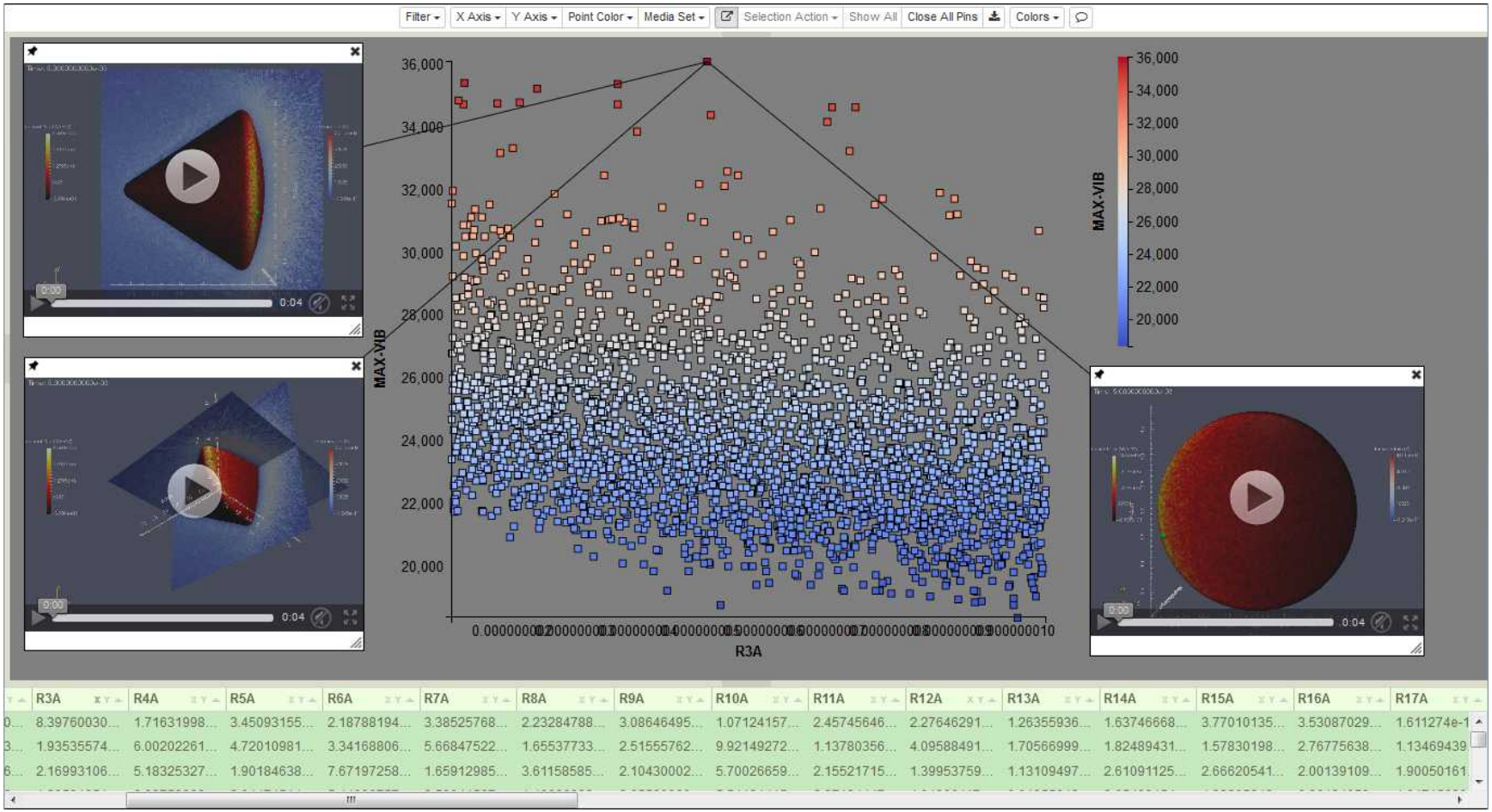


X261	X262	X263	X264	X265	X266	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
-1	1	0	1	1	0	12.26436119	12.40932324	0.675864682	0.871062376	6.171382837	0.806005974	2.006010348	0.009990071	25.03014935
-1	1	0	0	-1	1	12.21151537	12.34594023	0.90188686	0.662129275	6.168634847	0.806005973	2.006010351	0.009990054	25.36920664
0	0	0	1	1	0	12.28569601	12.41760385	0.708278449	0.661366179	6.078587579	0.806005982	2.006010345	0.009990058	25.21724326
-1	1	-1	-1	-1	-1	12.23181908	12.37248521	0.675963233	0.873019129	6.076352026	0.806005919	2.00601035	0.009990058	25.21429857
-1	-1	-1	0	0	-1	12.11540675	12.27624894	0.708435692	0.692010261	5.372354306	0.80600578	2.006010346	0.009990074	25.47607018
-1	-1	0	1	-1	1	12.2588209	12.39466861	0.903276468	0.87321105	5.260878506	0.806005825	2.006010351	0.009990055	25.36332508

Parameter Space



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