



Department for
Business, Energy
& Industrial Strategy

Measurement of the in-situ performance of solid biomass boilers



Annex B: Field trial results

Trust
Quality
Progress

Measurement of the in-situ performance of solid biomass boilers

Annex B: Field trial results

Report number: 30663-P3-B

Prepared for: BEIS

Date: 31 July 2018

Status: Final

Lead authors: James Thomas, Samuel Cottrill and Iain Summerfield

Approved by: Mark Eldridge

Commercial in confidence

Preface

This document is the field trial results annex to “Measurement of the in-situ performance of solid biomass boilers”, a report prepared for BEIS which details work carried out from 2015 to 2018 where the real-life efficiencies and pollutant emissions of a range of biomass boilers were measured.

Contained within is a summary of the results collected from the field trial. Full results from the field trial will be published on the UK Data Archive, including:

- Raw data with channel mappings
- Processed data with efficiencies
- Daily data summaries
- Weekly data summaries
- Monthly data summaries

The work was carried out by a consortium of Kiwa Gastec, Ricardo Energy and Environment, Energy Saving Trust, HETAS, and Optimum Consultancy.

Table of contents

1	Summary of results	1
2	Monthly efficiency by fuel type	4
3	Monthly efficiency and heat output by site.....	7
4	Oxygen, flue temperature and heat output tapestries	52
5	Oxygen and flue temperature density plots	141
6	Efficiency and DDH plots.....	158

1 Field trial data for all sites over the first year of monitoring



Site ID	Average Outside Temperature (°C)	Total Heat Output (kWh)	Total Electricity Used (kWh)	Calculated Total Losses Net (kWh)	Calculated Total Losses Gross (kWh)	Efficiency Net (%)	Efficiency Gross (%)	Number of Days With Data (Days)	Load Factor (%)	Average Fuel Net CV (MJ/kg)	Average Fuel Gross CV (MJ/kg)	Estimated Fuel Used (kg)	Degree Days Heating (K.Day, Base 15.5 °C)	Number Of Hours Of Operation (Hours)	Average Number Of Starts Per Day (Starts/Day)	Fuel Type
B001 (1)	12	561,310	7,071	247,520	356,497	69%	61%	365	29%	11.443	13.150	248,219	1,611	349,709	3	Chip
B001 (2)	12	375,560	6,765	197,854	271,013	65%	58%	357	20%	11.443	13.150	176,907	1,611	307,446	10	Chip
B005	15	195,000	1,330	41,127	58,561	83%	77%	365	7%	17.407	18.826	48,449	1,003	46,428	1	Pellet
B013	11	520,000	8,038	82,045	144,282	86%	78%	268	18%	14.488	16.062	148,864	1,402	220,474	0	Chip
B014	12	473,000	3,859	434,455	547,036	50%	44%	263	23%	10.767	12.493	283,821	1,815	224,536	7	Chip
B046	12	1,424,826	15,550	501,034	740,029	74%	66%	365	20%	12.287	13.993	550,113	1,898	310,861	2	Chip
B055	9	61,230	N/A	13,877	26,436	82%	70%	365	14%	12.870	14.485	21,788	2,567	143,656	5	Chip
B069	12	239,200	4,230	89,071	119,286	73%	67%	365	21%	14.458	15.976	80,803	1,700	265,652	10	Chip
B076	12	148,400	3,451	115,548	144,014	56%	51%	365	3%	12.274	13.871	75,840	1,530	40,213	1	Chip
B081	14	514,100	5,919	109,370	168,582	82%	75%	365	49%	14.789	16.304	150,742	1,406	271,707	3	Chip
B112 (1)	13	424,520	3,952	93,367	128,638	70%	63%	360	13%	12.623	14.196	88,214	1,598	136,735	2	Chip
B112 (2)	13	424,520	2,404	90,089	122,161	68%	61%	360	12%	12.623	14.196	79,961	1,598	128,021	2	Chip
B127	10	43,680	732	10,892	19,125	80%	70%	365	10%	10.524	12.257	18,446	2,291	166,949	3	Chip
B180	11	210,390	972	56,271	74,990	79%	74%	365	16%	17.648	18.991	54,096	1,865	261,904	6	Pellet
B182	12	107,170	1,971	24,346	35,324	81%	75%	365	25%	16.196	17.637	29,085	1,477	317,699	4	Chip
B222	11	60,610	15,545	13,010	18,602	82%	77%	365	14%	16.789	18.188	15,679	1,815	116,388	4	Chip
B250	12	401,290	278	78,572	114,899	84%	78%	365	24%	17.584	18.980	97,907	1,665	277,144	1	Pellet
B260	12	611,330	22,371	281,850	346,034	68%	64%	365	17%	17.346	18.707	184,231	1,763	26,032	1	Pellet
B271	12	468,416	4,255	67,882	115,677	87%	80%	365	18%	15.311	16.771	125,383	1,675	185,753	2	Chip
B287	12	245,100	2,592	99,642	124,331	71%	66%	365	5%	17.374	18.782	70,791	1,881	100,503	3	Pellet
B315	10	397,240	328	301,591	350,059	57%	53%	365	23%	17.469	18.872	142,570	2,048	259,167	10	Pellet
B323	12	553,849	1,419	59,078	105,521	90%	84%	365	90%	17.187	18.572	127,813	1,461	361,562	4	Pellet
B358	12	716,697	4,762	139,425	199,892	84%	78%	365	18%	17.189	18.570	177,688	1,682	188,083	7	Pellet
B365	12	322,200	744	121,569	167,396	70%	63%	215	9%	12.070	13.757	115,714	1,686	151,708	4	Chip
B369 (1)	10	73,740	4,854	26,539	38,707	74%	66%	365	8%	11.440	13.164	30,751	2,207	196,019	8	Chip
B369 (2)	10	86,320	1,522	34,655	49,014	71%	64%	365	7%	11.440	13.164	37,010	2,207	218,129	9	Chip
B418 (1)	11	247,950	3,751	79,288	110,005	76%	69%	365	14%	14.808	16.343	78,850	2,035	146,397	3	Chip
B418 (2)	10	99,610	2,260	27,584	40,011	78%	71%	365	17%	14.492	16.039	31,337	2,162	176,927	4	Chip
B434 (1)	11	351,580	1,532	33,994	57,266	84%	75%	363	20%	13.453	15.095	55,330	2,004	193,036	5	Chip
B434 (2)	11	351,580	1,084	28,584	51,657	86%	77%	363	21%	13.453	15.095	54,489	2,004	194,162	5	Chip
B445	14	64,297	N/A	12,673	22,966	83%	74%	365	10%	11.474	13.140	23,766	1,439	102,880	2	Chip
B458	11	77,890	N/A	30,874	37,887	72%	67%	352	10%	17.482	18.848	22,072	1,893	181,899	12	Pellet
B464	11	157,560	644	78,647	94,964	67%	62%	365	15%	17.749	19.184	47,388	1,987	320,018	15	Pellet
B477	10	40,500	N/A	5,809	9,106	87%	82%	365	12%	17.885	19.233	9,285	2,246	182,429	3	Pellet

Site ID	Average Outside Temperature (°C)	Total Heat Output (kWh)	Total Electricity Used (kWh)	Calculated Total Losses Net (kWh)	Calculated Total Losses Gross (kWh)	Efficiency Net (%)	Efficiency Gross (%)	Number of Days With Data (Days)	Load Factor (%)	Average Fuel Net CV (MJ/kg)	Average Fuel Gross CV (MJ/kg)	Estimated Fuel Used (kg)	Degree Days Heating (K.Day, Base 15.5 °C)	Number Of Hours Of Operation (Hours)	Average Number Of Starts Per Day (Starts/Day)	Fuel Type
B499	9	14,526	169	7,737	9,352	65%	61%	365	12%	17,235	18,612	4,622	2,495	73,886	3	Pellet
B542	11	15,532	185	6,304	8,071	71%	66%	365	12%	17,399	18,936	4,487	1,885	99,789	3	Pellet
B586	11	42,130	N/A	7,604	12,051	85%	78%	365	8%	15,921	17,256	11,303	1,881	60,287	1	Log
B609	11	50,370	N/A	17,556	23,774	74%	68%	365	7%	15,921	17,256	15,376	1,825	299,969	4	Log
B622	12	2,052	261	683	924	75%	69%	350	1%	15,764	17,262	618	1,598	12,171	0	Log
B625	9	25,282	227	7,349	9,838	77%	72%	365	11%	17,319	18,727	6,752	2,485	158,986	3	Pellet
B630	11	27,820	1,017	7,927	10,562	78%	72%	365	13%	17,172	18,580	7,437	1,796	144,058	7	Pellet
B650	11	13,048	N/A	3,120	4,499	81%	74%	365	4%	16,482	18,029	3,504	1,847	69,965	3	Pellet
B900	11	423,300	970	152,751	195,123	73%	68%	365	24%	17,981	19,428	114,590	1,930	234,097	5	Pellet
B901	12	397,480	1,290	163,850	205,560	71%	66%	365	23%	17,981	19,428	111,739	1,821	401,151	8	Pellet
B902	12	145,100	2,575	57,739	72,203	72%	67%	365	8%	17,981	19,428	40,266	1,890	138,240	4	Pellet
B903	11	306,900	4,023	107,658	137,371	74%	69%	365	18%	17,689	19,100	83,739	1,965	197,786	5	Pellet
B906	10	116,150	1,055	58,296	79,553	67%	59%	277	9%	11,904	13,605	51,782	1,730	77,068	5	Chip
B907	11	384,680	5,625	107,451	166,971	78%	70%	365	22%	12,545	14,196	139,892	1,908	274,603	4	Chip
B908	13	185,400	1,578	109,383	147,444	63%	56%	365	11%	11,134	12,814	93,439	1,536	166,742	6	Chip
B909	11	11,583	224	3,366	4,739	77%	71%	365	5%	15,713	17,022	3,433	1,835	94,178	1	Log
B910	11	191,187	572	91,600	123,272	68%	61%	365	20%	12,608	14,258	79,397	1,908	250,291	7	Chip
B912	12	158,030	N/A	54,554	68,999	74%	70%	365	8%	17,407	18,826	43,414	1,632	114,102	4	Pellet
B915 (1)	11	5,460	N/A	838	1,331	87%	80%	365	1%	16,404	17,790	1,362	1,956	11,692	0	Log
B915 (2)	11	192,950	3,897	145,287	169,221	57%	53%	365	15%	17,150	18,556	70,250	1,935	129,890	5	Pellet
B916	12	242,510	260	51,668	73,515	82%	77%	365	73%	17,407	18,826	60,386	1,617	68,266	1	Pellet
B918	12	30,374	N/A	6,132	8,864	83%	77%	365	11%	17,407	18,809	7,510	1,651	111,880	2	Pellet
B919	11	31,508	285	7,535	10,341	81%	75%	365	14%	17,456	18,826	8,003	1,904	126,904	3	Pellet
B920	9	69,360	935	32,257	40,320	68%	63%	365	6%	17,157	18,707	21,107	2,277	128,605	6	Pellet
B921	10	93,680	542	8,706	12,218	80%	73%	365	9%	17,157	18,707	8,861	2,239	84,762	4	Pellet
B922	10	28,760	357	4,861	7,288	86%	80%	365	22%	18,017	19,412	6,685	2,302	140,625	4	Pellet
B923	11	15,366	N/A	2,422	3,687	86%	80%	309	18%	17,470	18,828	3,576	2,004	157,727	3	Pellet
B925	12	219,760	290	64,261	84,105	77%	72%	365	13%	18,061	19,397	56,396	1,605	164,914	1	Pellet
B926	12	75,464	791	11,740	19,072	87%	80%	361	17%	16,127	17,564	19,376	1,757	150,314	1	Log
B927 (1)	10	122,970	1,867	10,790	15,558	83%	77%	300	15%	17,131	18,543	13,188	1,868	140,655	5	Pellet
B927 (2)	10	122,970	1,867	13,111	19,205	84%	78%	300	19%	17,131	18,543	16,831	1,868	161,247	6	Pellet

N/A = Not available

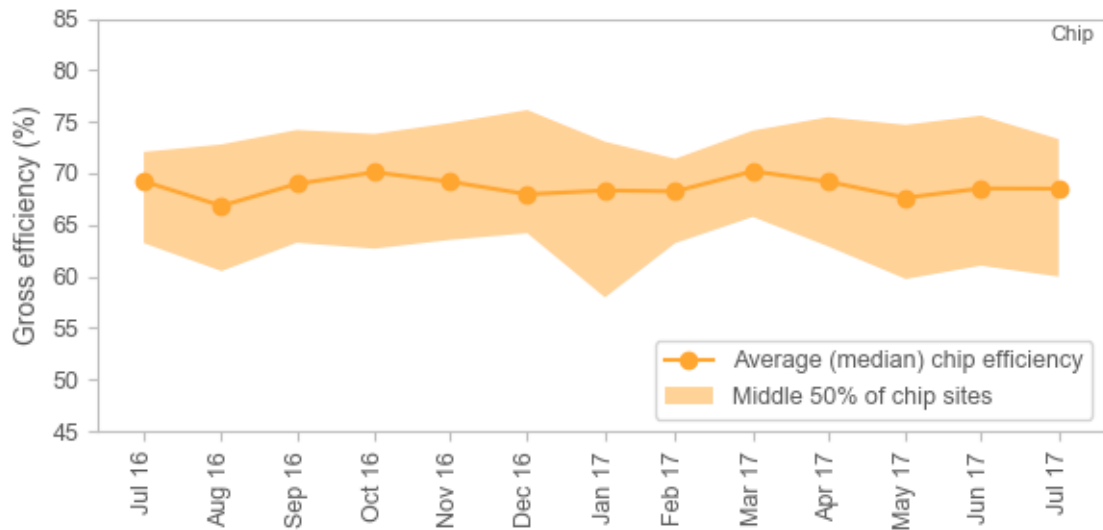
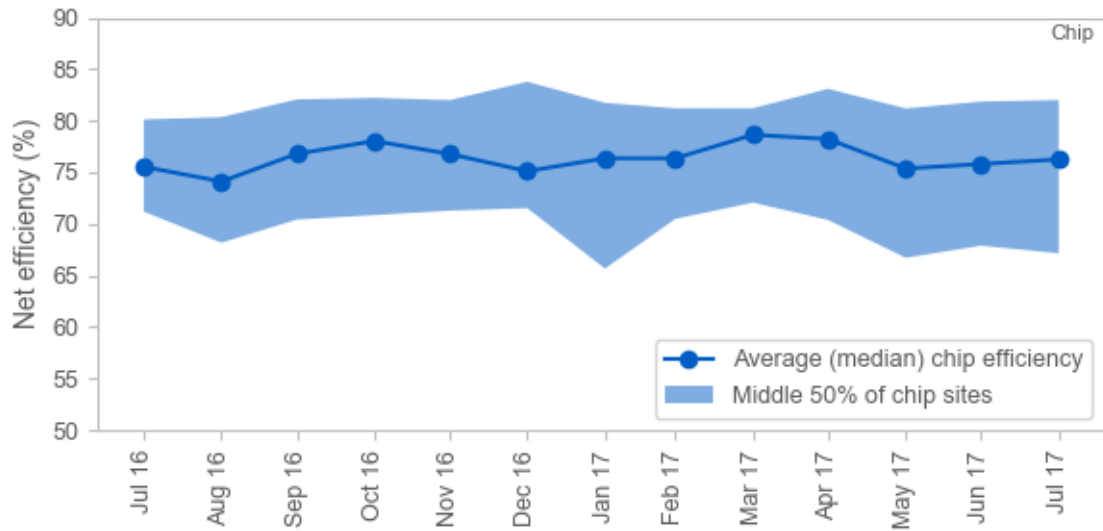
Field trial data for intervention sites over the second year of monitoring

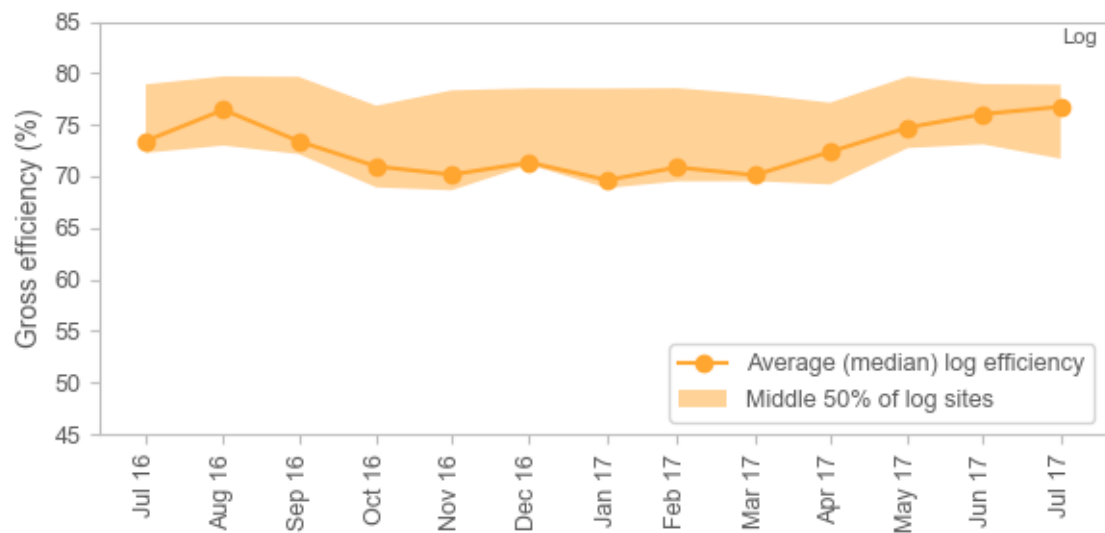
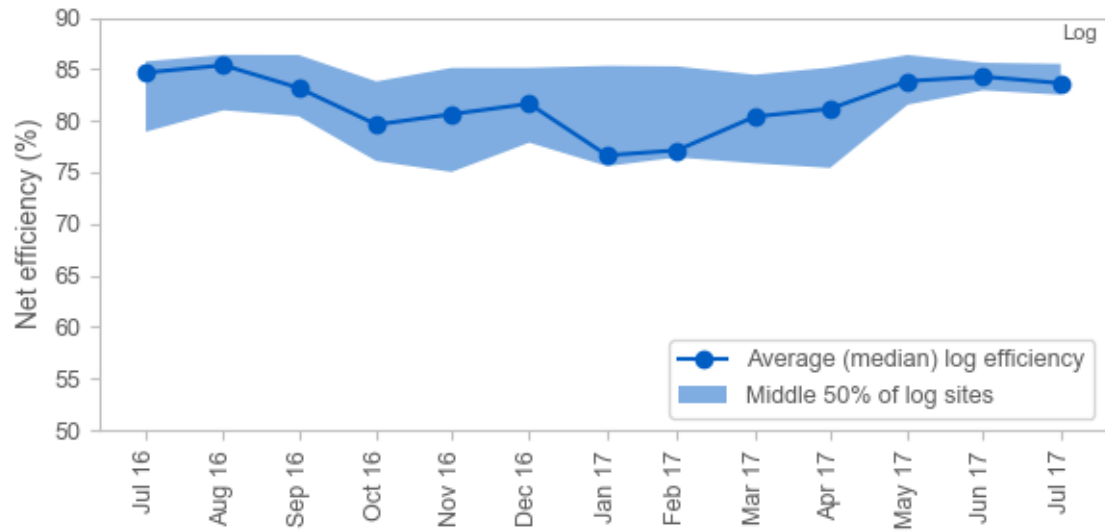


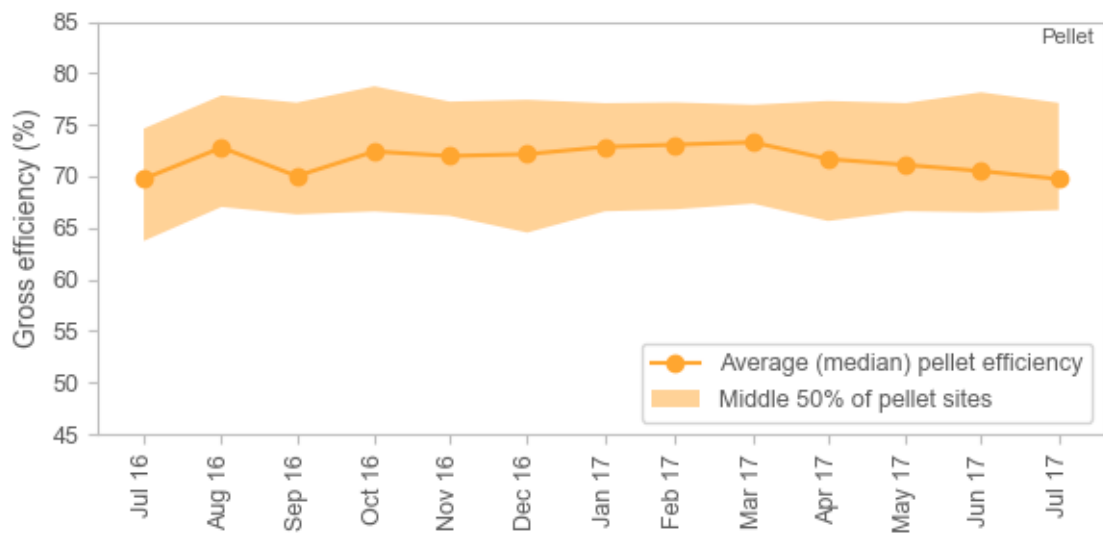
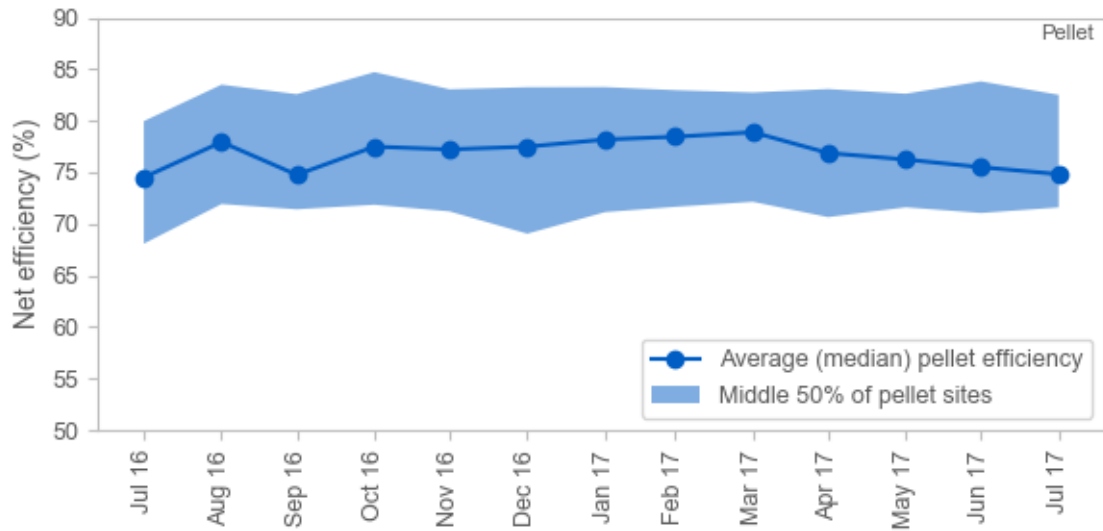
Site ID	Average Outside Temperature (°C)	Total Heat Output (kWh)	Total Electricity Used (kWh)	Calculated Total Losses Net (kWh)	Calculated Total Losses Gross (kWh)	Efficiency Net (%)	Efficiency Gross (%)	Number of Days With Data (Days)	Load Factor (%)	Average Fuel Net CV (MJ/kg)	Average Fuel Gross CV (MJ/kg)	Estimated Fuel Used (kg)	Degree Days Heating (K.Day, Base 15.5 °C)	Number Of Hours Of Operation (Hours)	Average Number Of Starts Per Day (Starts/Day)	Fuel Type
B001 (1)	11	380,990	5,769	181,617	234,385	68%	62%	336	21%	14.630	16.146	137,196	1,806	266,958	5	Chip
B001 (2)	11	510,300	7,460	259,612	329,803	66%	61%	336	29%	14.630	16.146	187,305	1,806	316,029	12	Chip
B046	10	1,652,500	13,335	441,781	696,841	79%	70%	336	26%	12.619	14.310	590,780	2,068	271,434	2	Chip
B127	8	60,210	931	12,738	19,438	83%	76%	336	15%	15.109	16.607	17,264	2,558	221,674	5	Chip
B180	10	191,740	1,452	63,220	80,909	75%	70%	336	16%	17.648	18.991	51,673	2,001	288,692	9	Pellet
B250	11	217,760	311	40,293	60,055	84%	78%	320	15%	17.254	18.632	53,674	1,897	197,748	0	Pellet
B271	15	475,969	1,015	70,028	128,614	87%	79%	336	20%	13.606	15.170	143,422	855	184,552	1	Chip
B358	11	740,180	5,206	140,617	201,889	84%	79%	336	20%	17.343	18.712	181,230	1,921	171,788	6	Pellet
B445	13	57,253	N/A	9,290	16,711	86%	77%	336	9%	12.956	14.510	18,334	1,462	88,166	2	Chip
B464	10	158,630	517	63,047	78,479	72%	67%	336	16%	17.425	18.825	45,341	2,182	269,218	12	Pellet
B477	9	48,450	123	6,336	10,248	88%	83%	336	15%	17.885	19.233	10,987	2,420	165,829	2	Pellet
B542	10	15,881	130	5,785	7,334	73%	68%	336	13%	17.382	18.743	4,457	2,085	97,282	3	Pellet
B586	10	46,310	N/A	8,272	13,318	85%	78%	336	10%	14.882	16.362	13,091	1,982	66,783	1	Log
B900	10	435,580	996	139,310	181,665	76%	71%	336	27%	17.160	18.542	119,825	2,039	268,027	6	Pellet
B901	11	311,390	1,255	71,472	99,695	81%	76%	336	19%	17.160	18.542	79,802	1,925	293,617	8	Pellet
B907	10	387,400	4,032	125,614	186,740	76%	67%	336	24%	12.545	14.196	145,562	2,071	233,973	5	Chip
B908	13	98,900	1,944	71,868	93,055	58%	52%	202	10%	11.134	12.814	53,916	813	158,884	15	Chip
B909	10	10,388	212	2,519	3,582	80%	74%	336	5%	16.391	17.754	2,807	2,005	83,531	1	Log
B912	11	185,320	N/A	55,830	71,991	77%	72%	336	10%	17.434	18.797	49,250	1,752	110,432	5	Pellet
B919	10	32,837	290	6,368	9,037	84%	78%	336	16%	17.269	18.538	8,126	2,074	145,321	2	Pellet
B920	8	21,450	282	7,742	9,940	73%	68%	271	3%	17.157	18.707	6,041	2,125	44,991	4	Pellet
B921	8	116,387	N/A	24,979	36,897	82%	76%	336	32%	17.157	18.707	29,487	2,471	262,406	6	Pellet

N/A = Not available

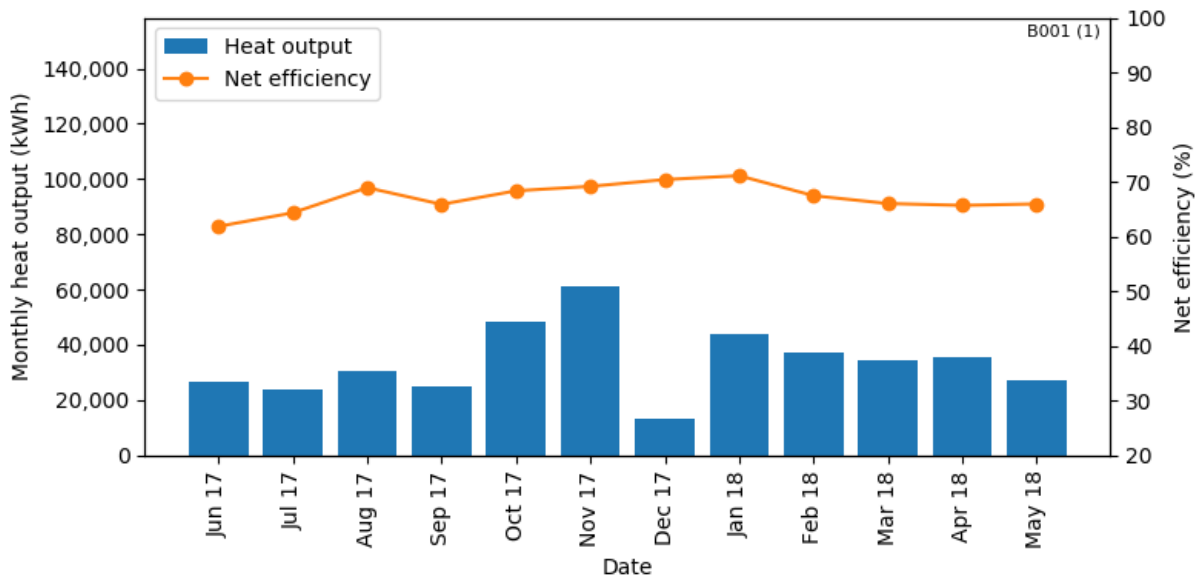
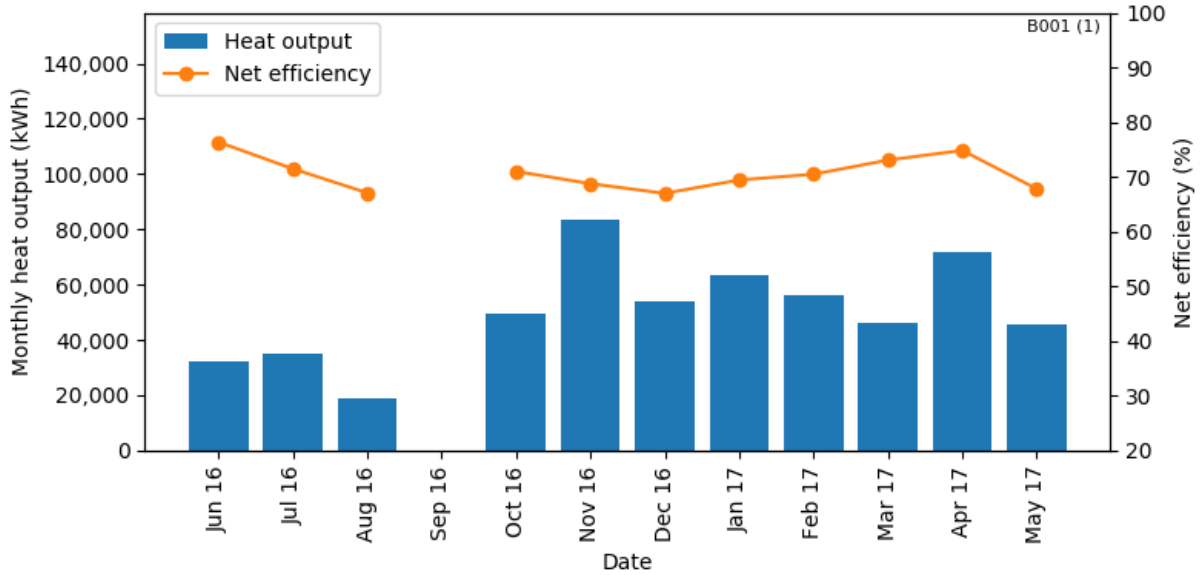
2 Monthly efficiency by fuel type

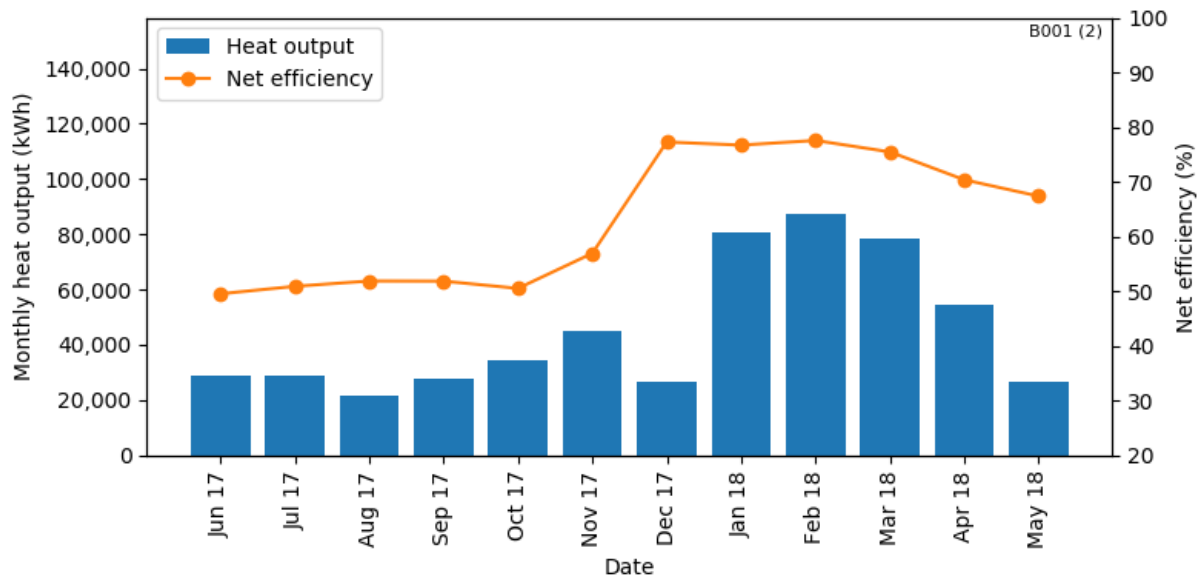
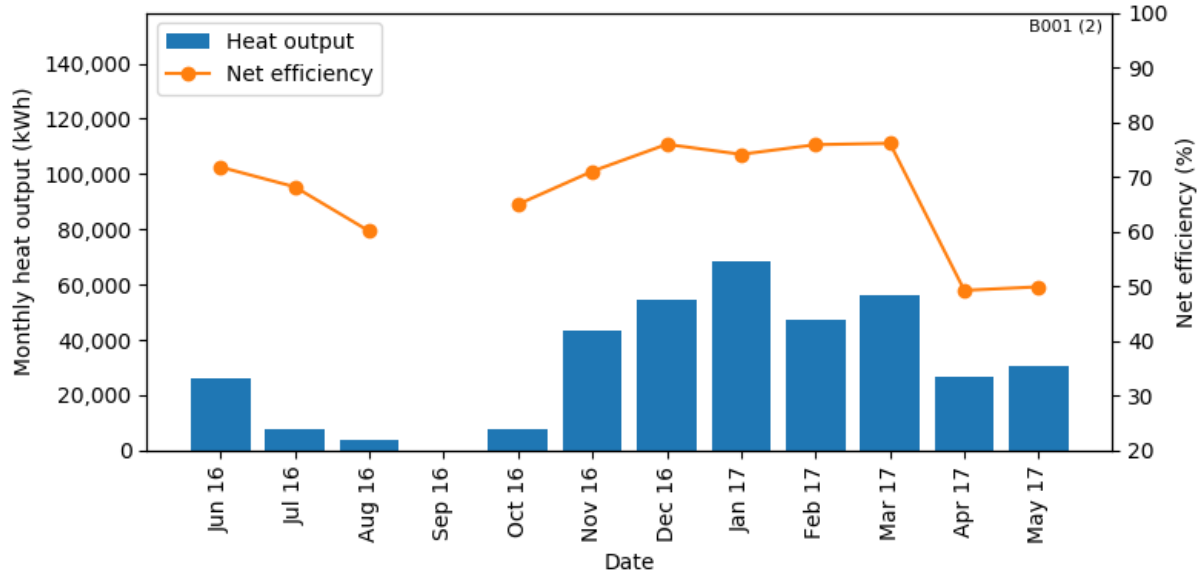


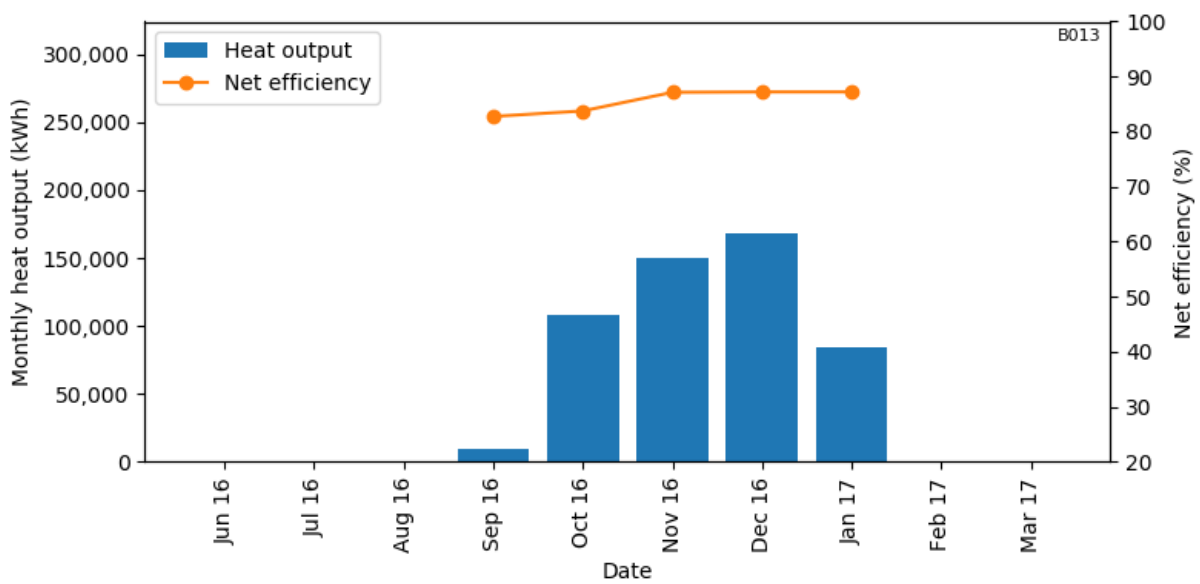
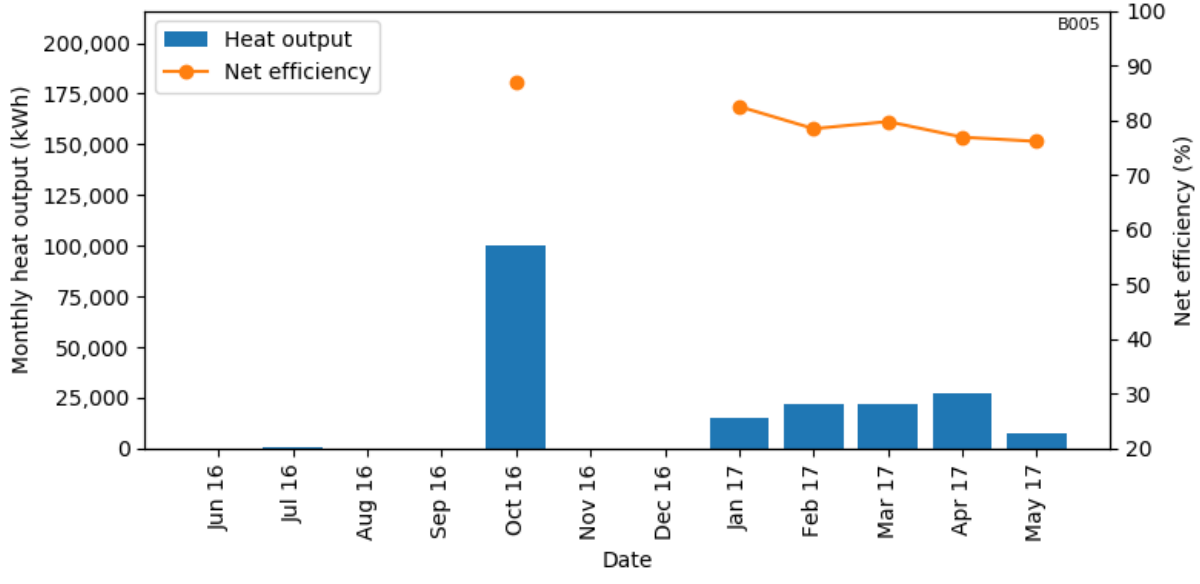


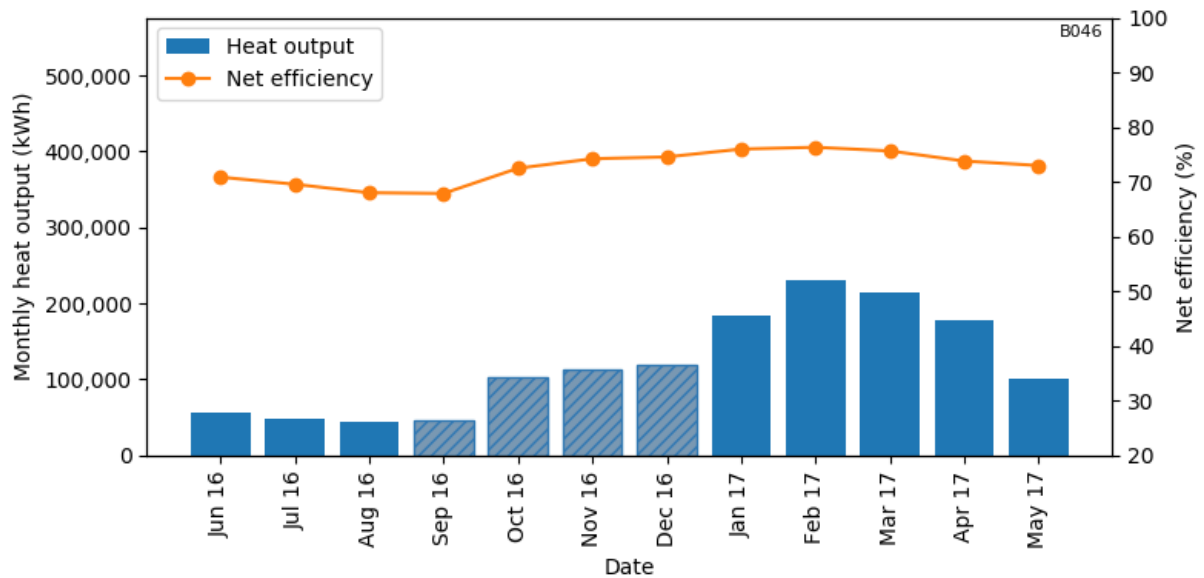
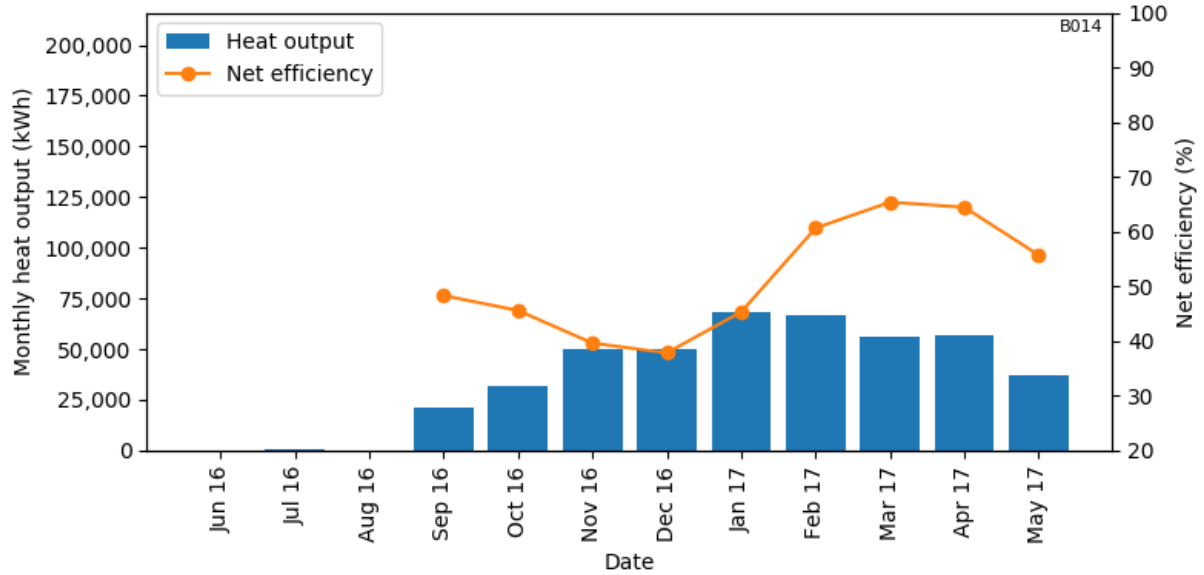


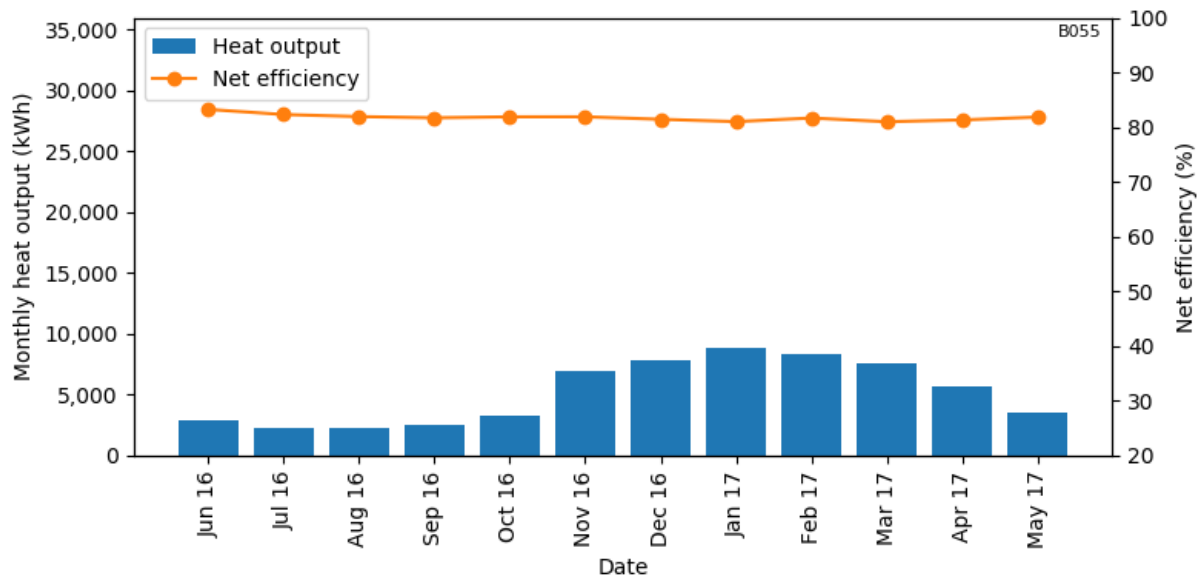
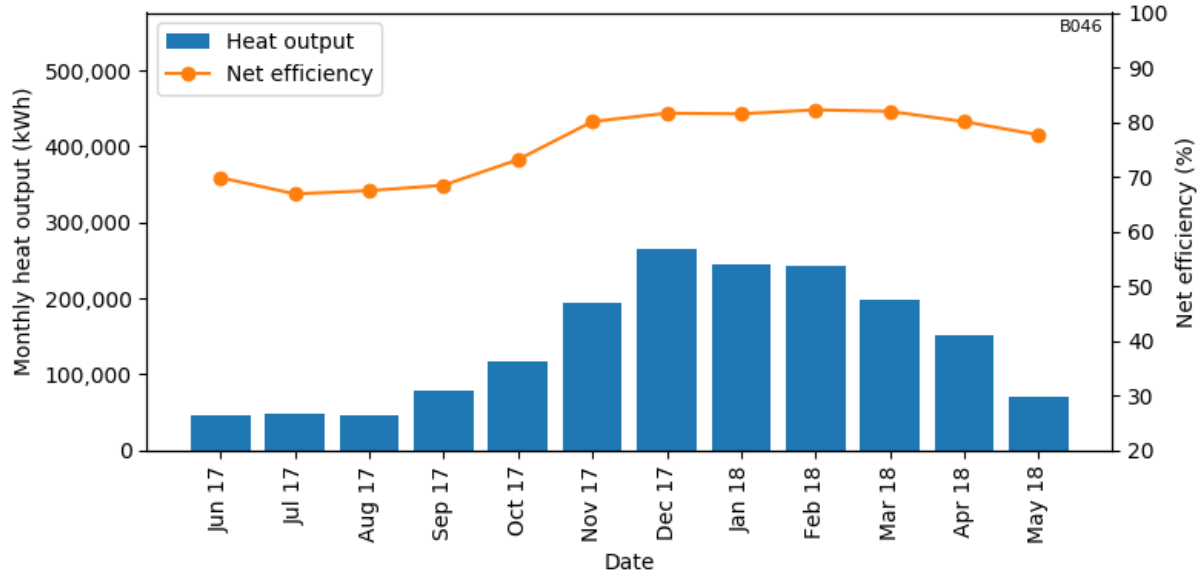
3 Monthly efficiency and heat output by site

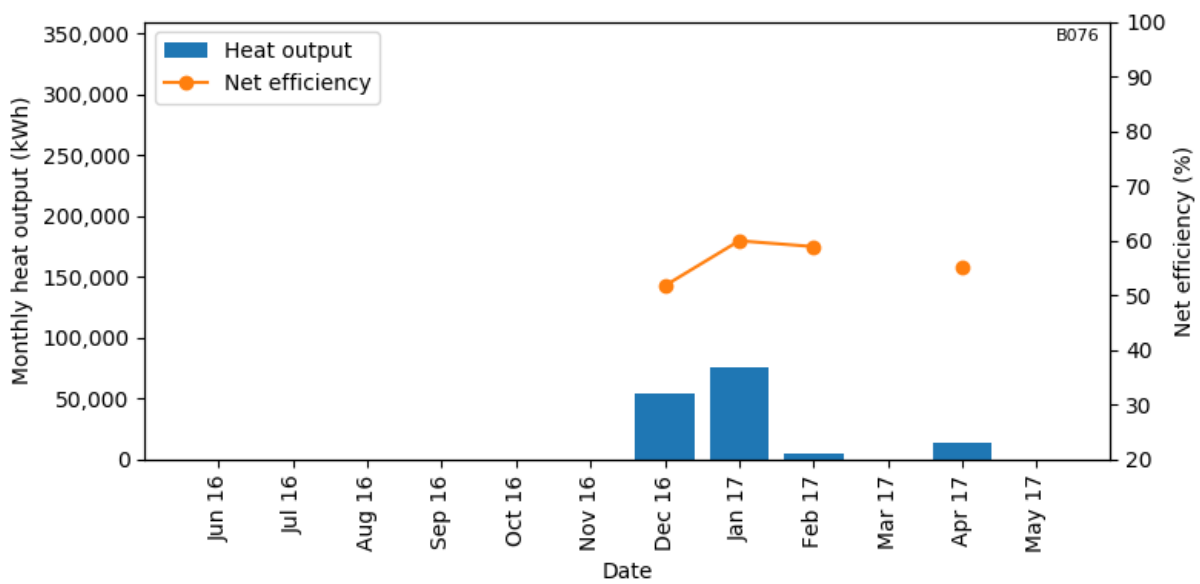
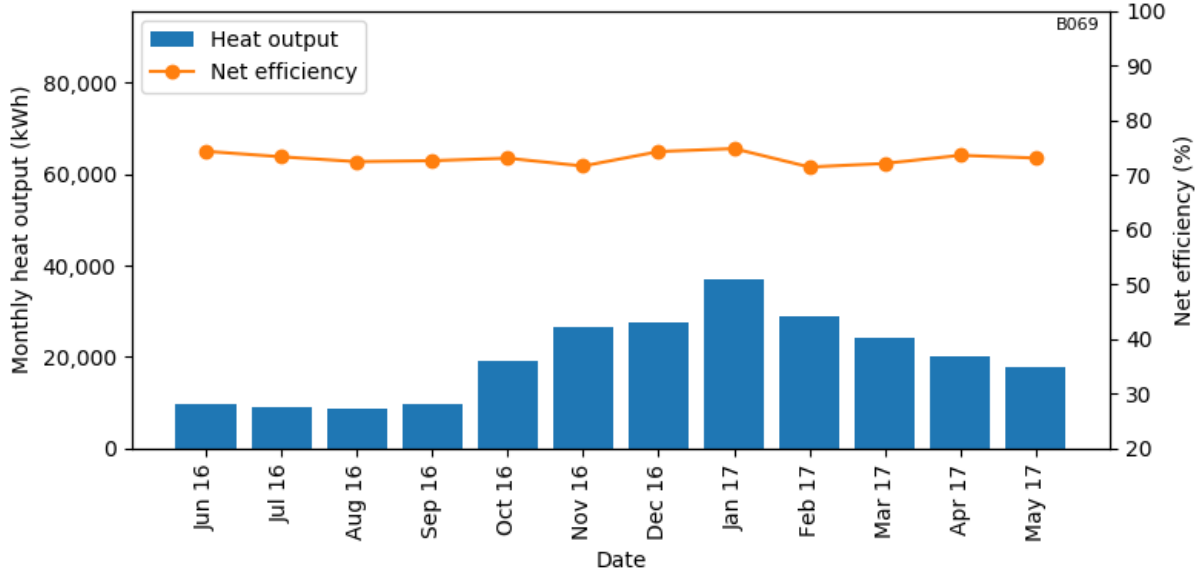


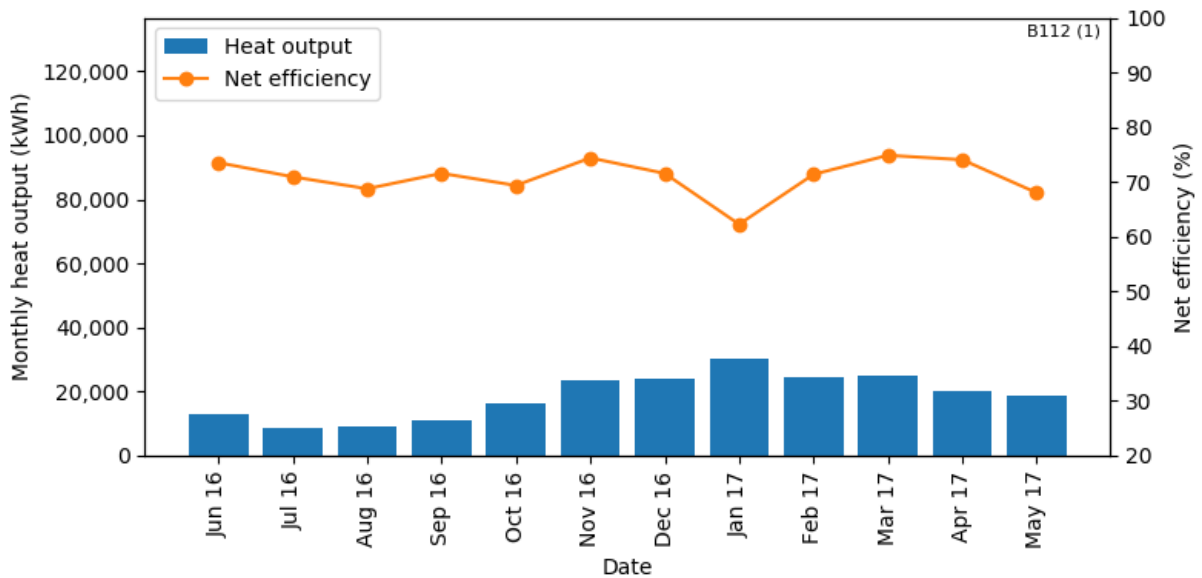
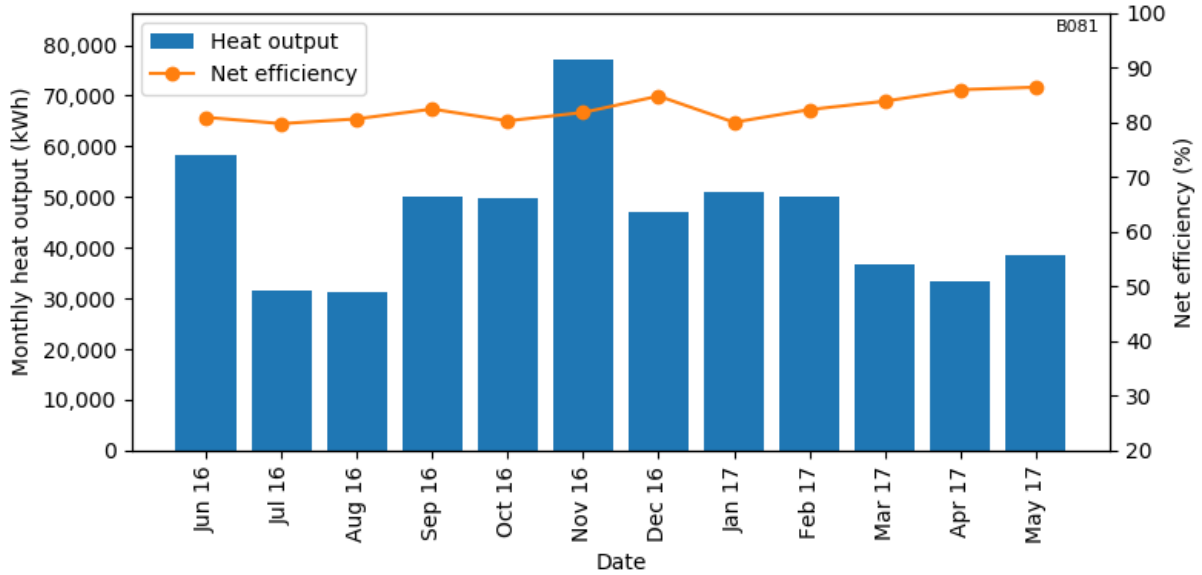


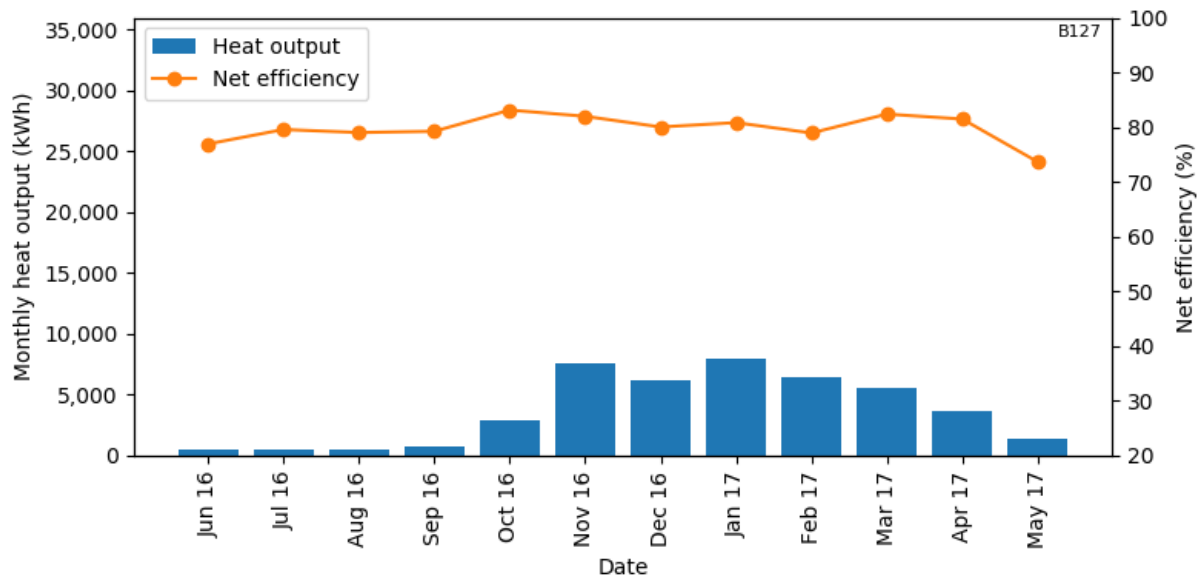
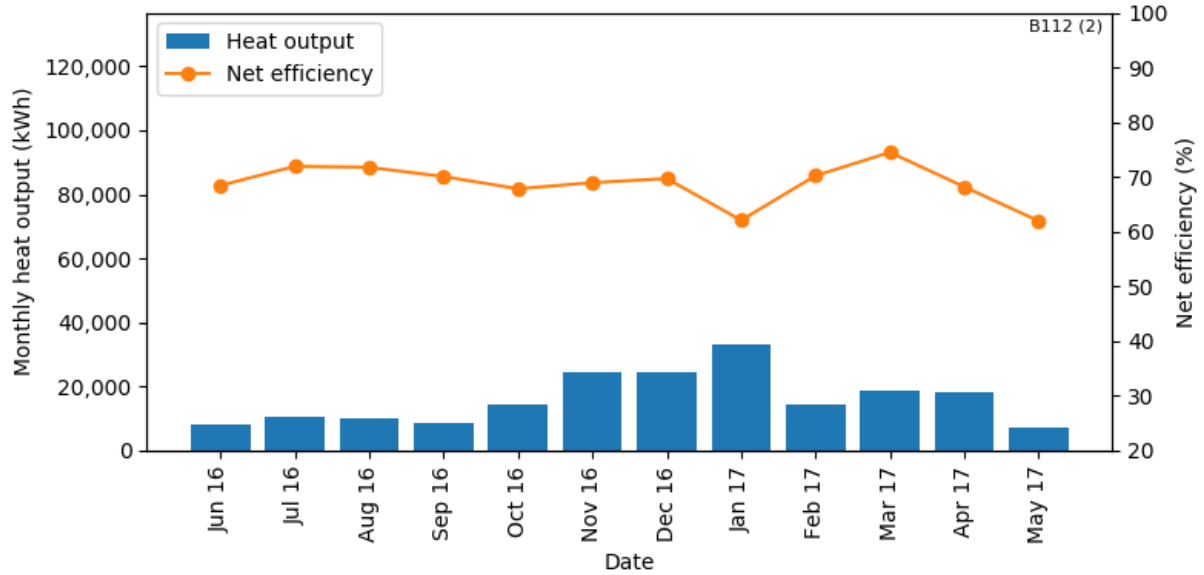


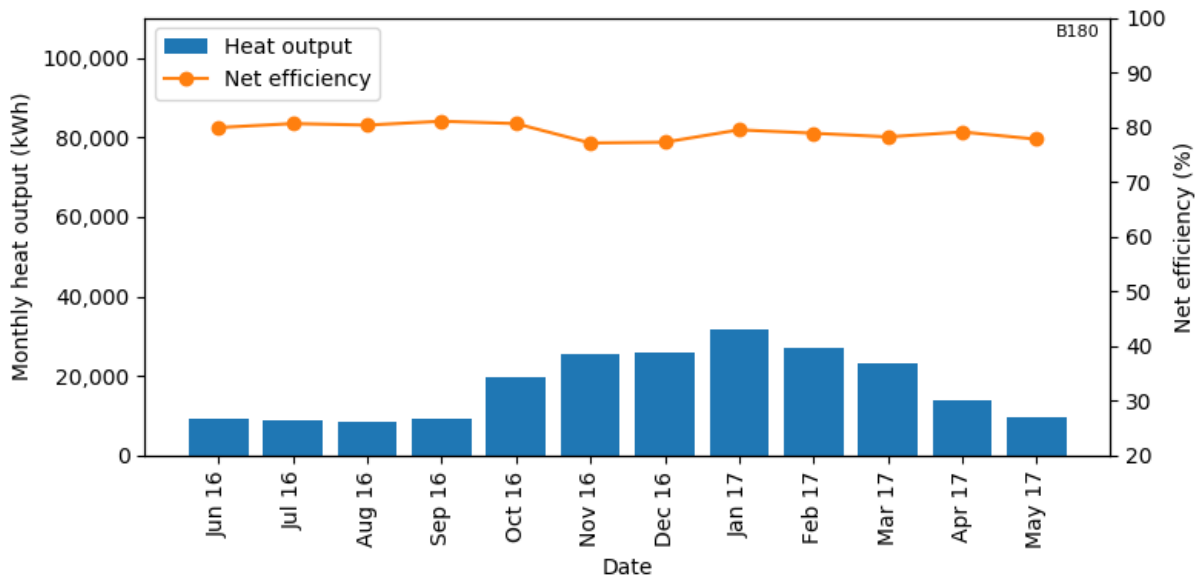
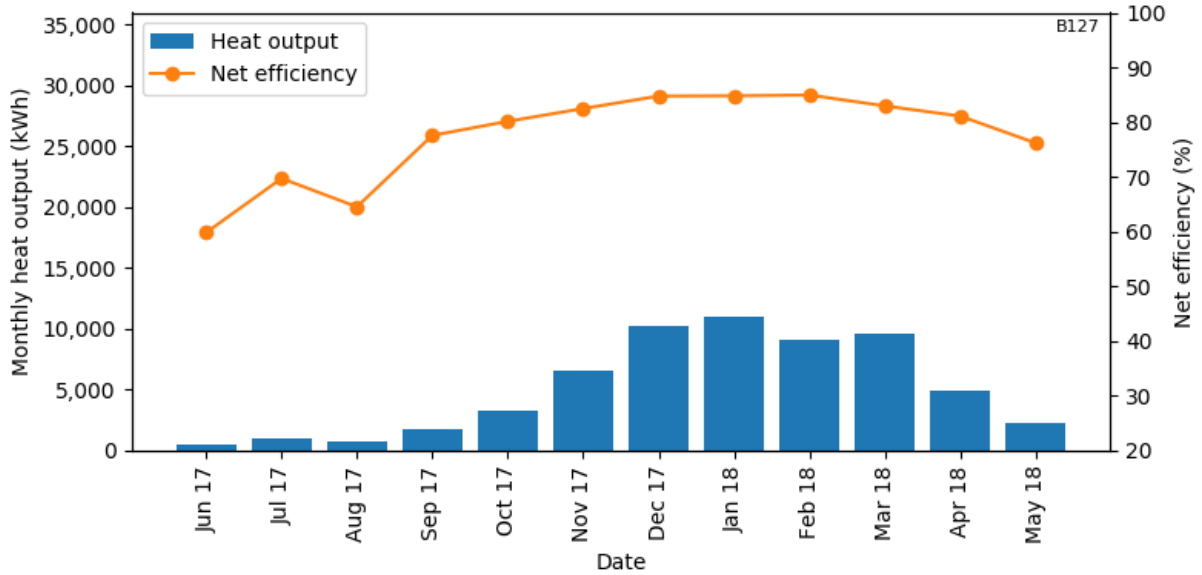


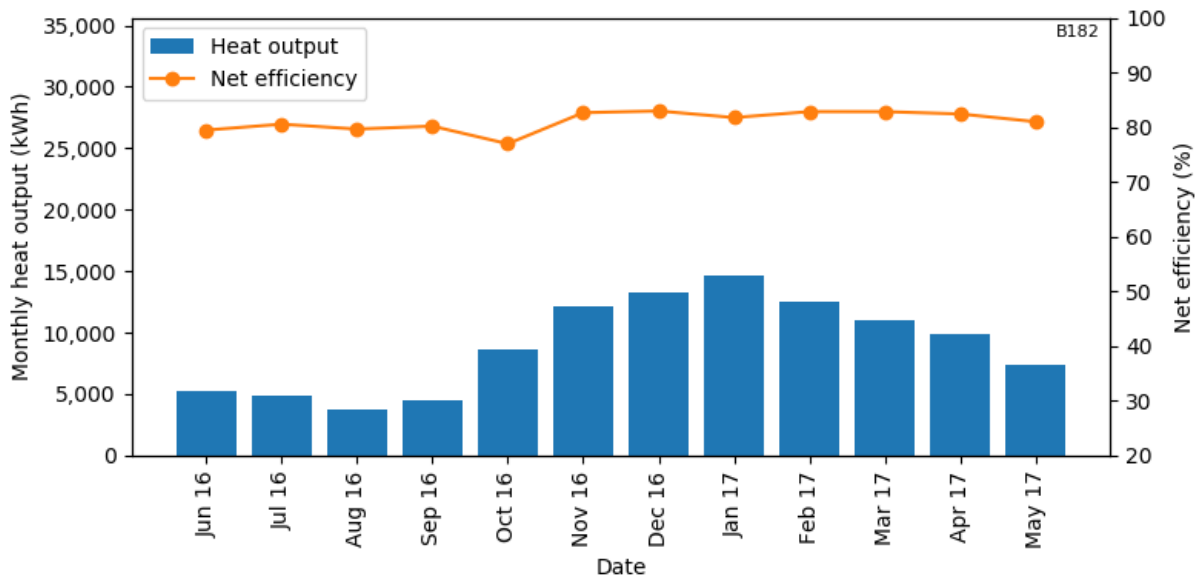
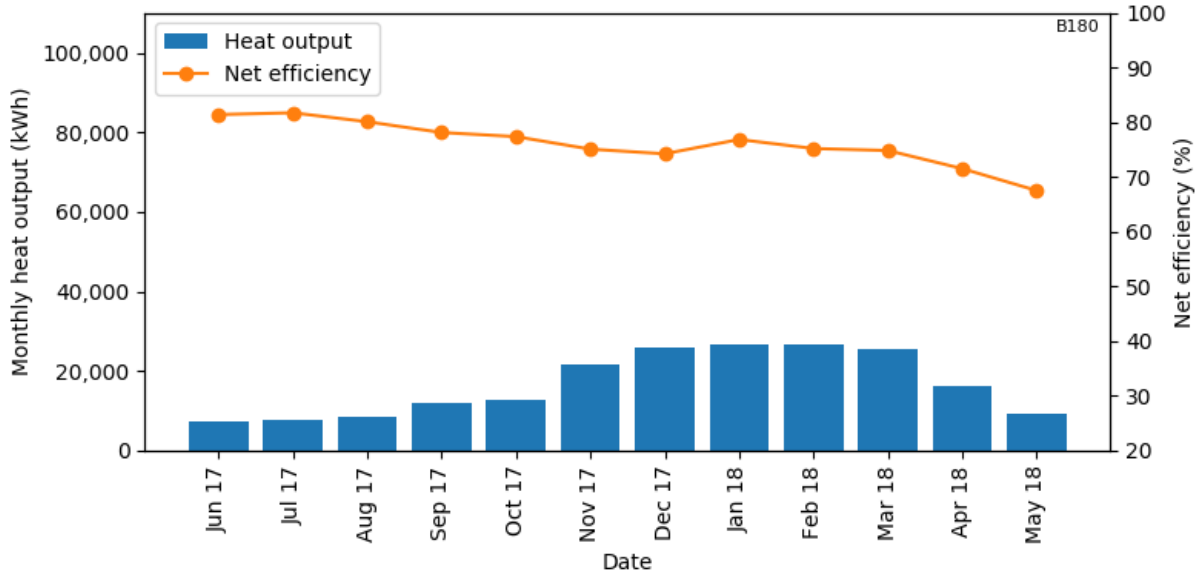


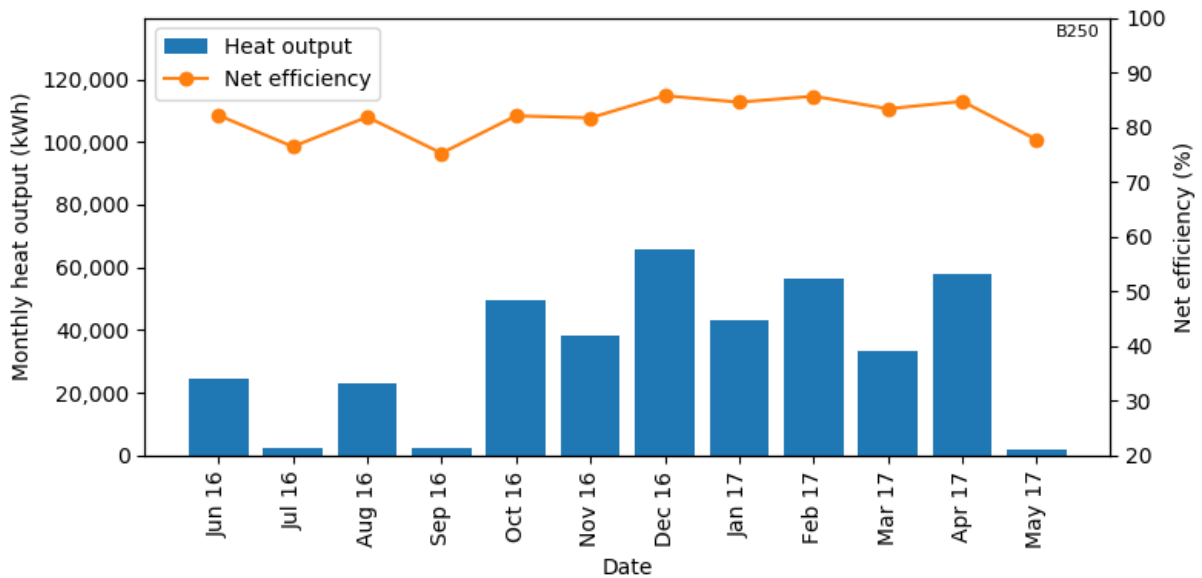
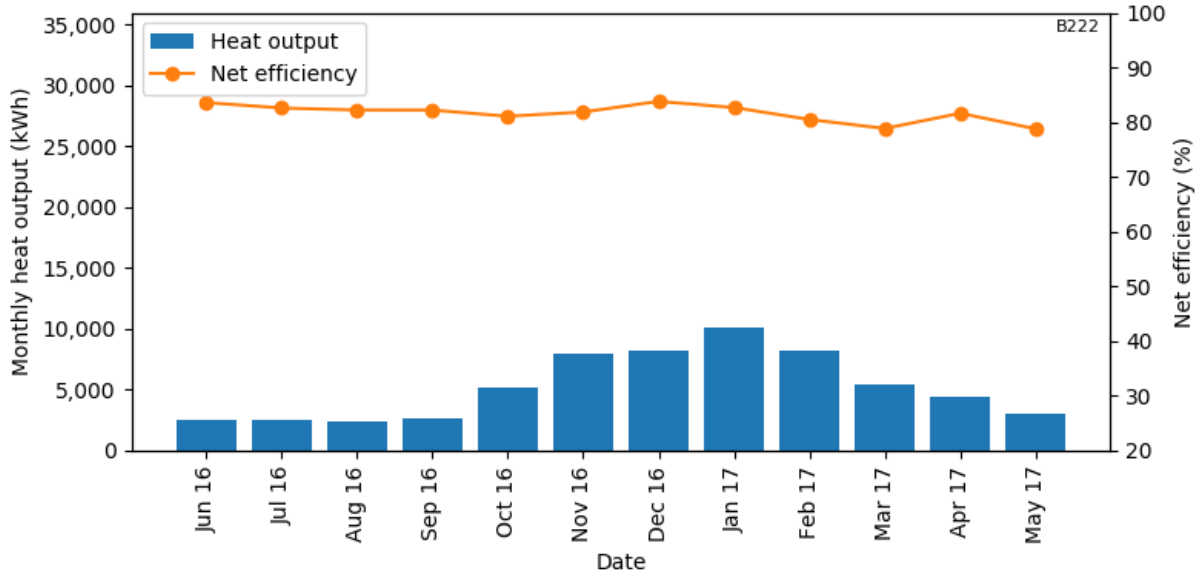


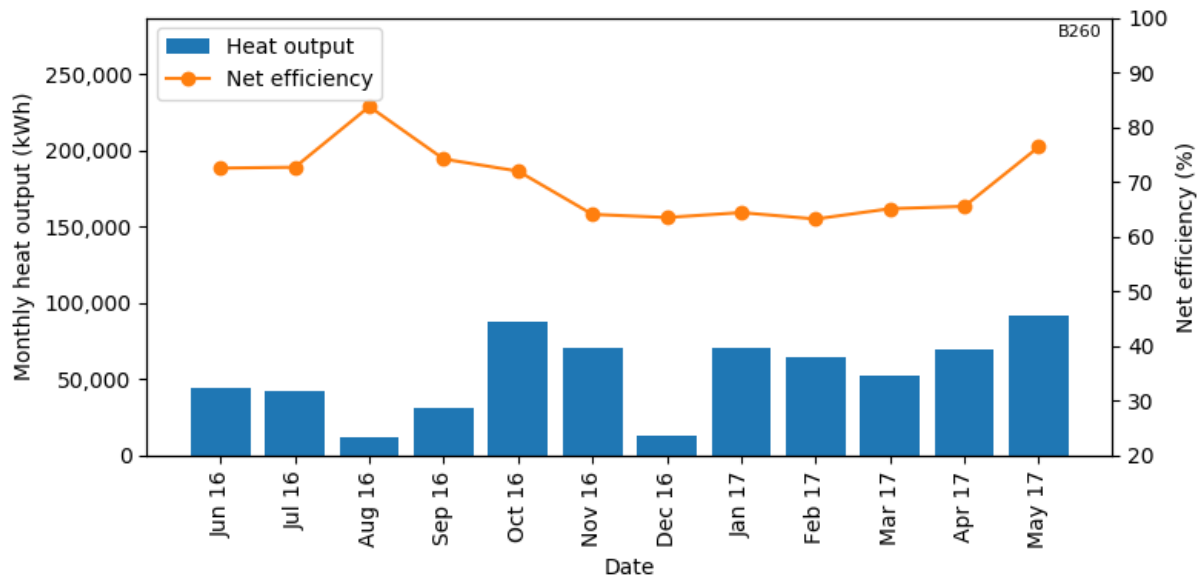
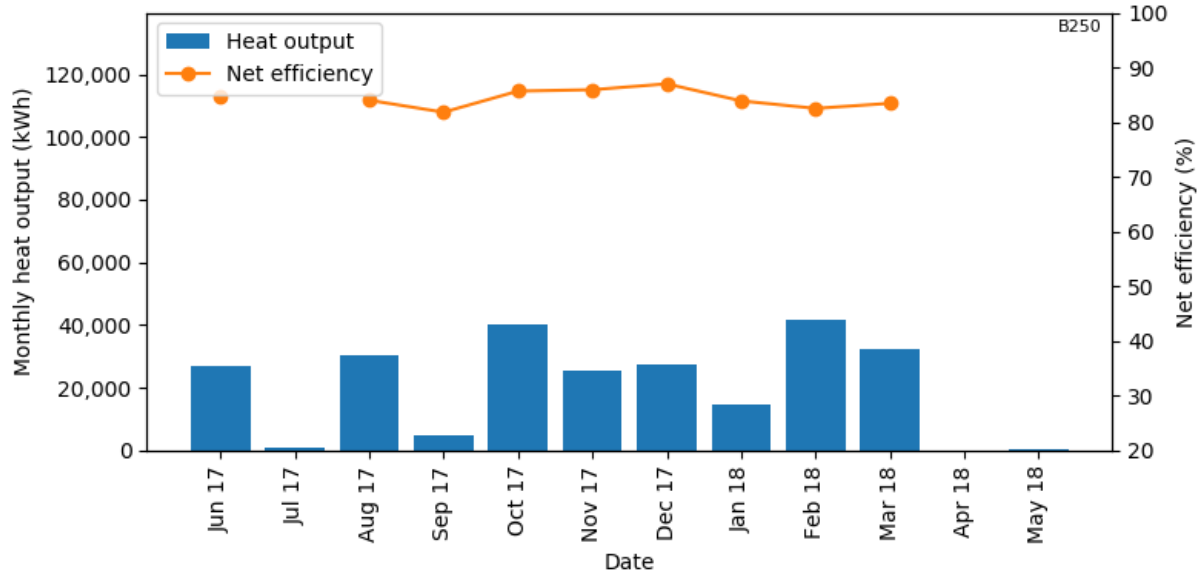


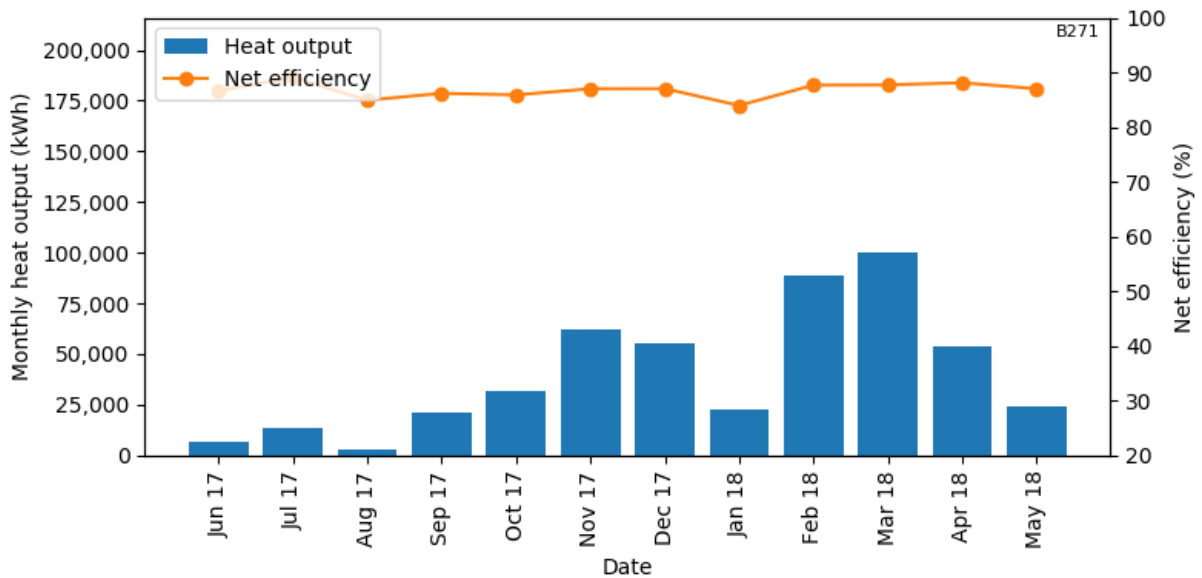
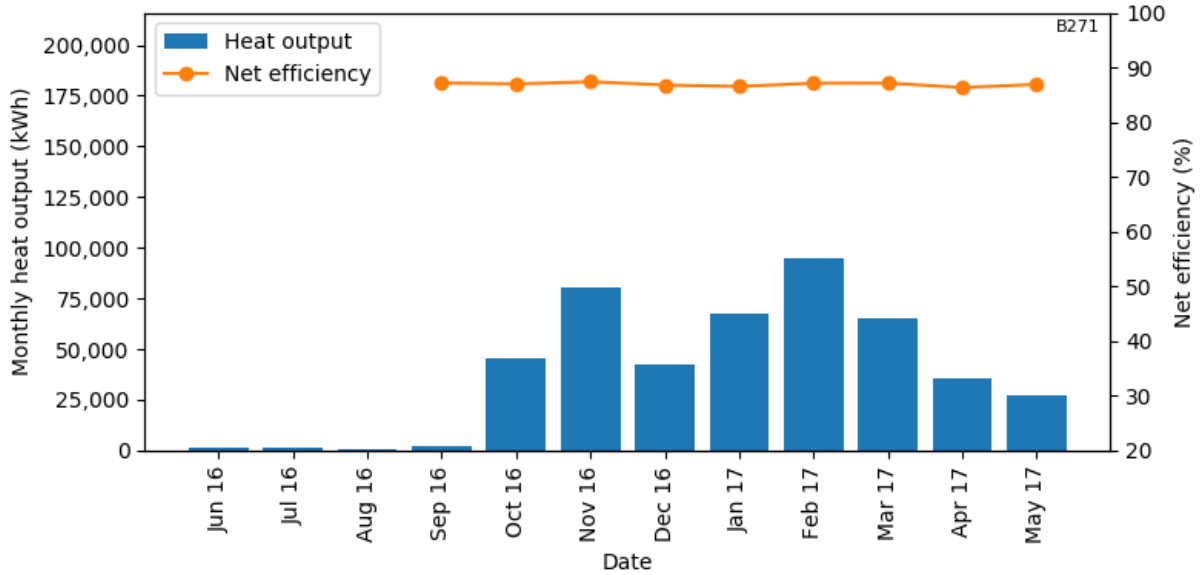


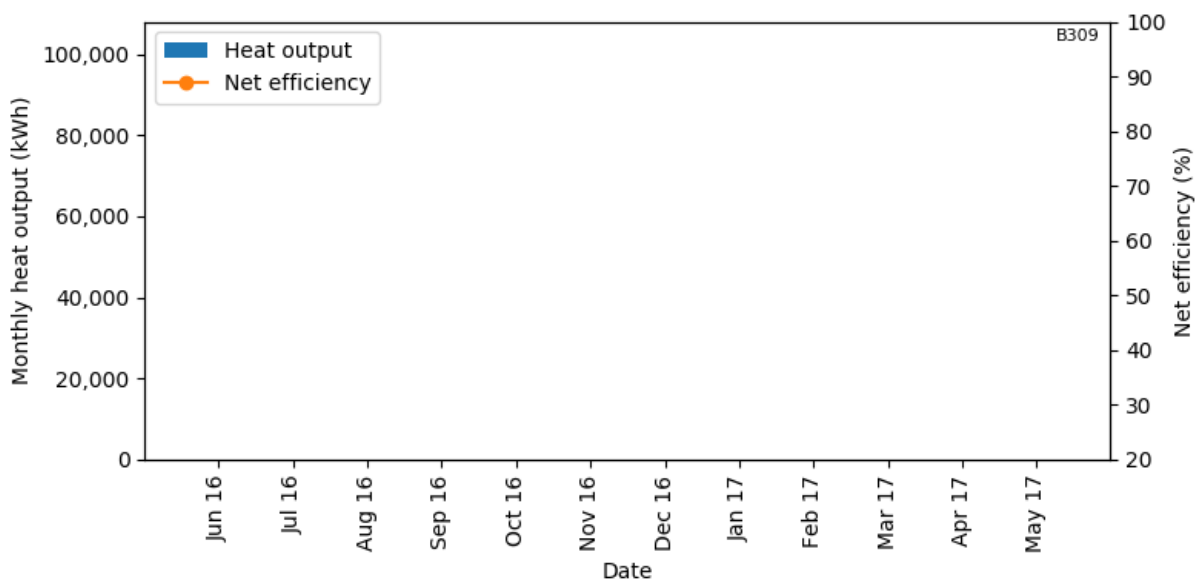
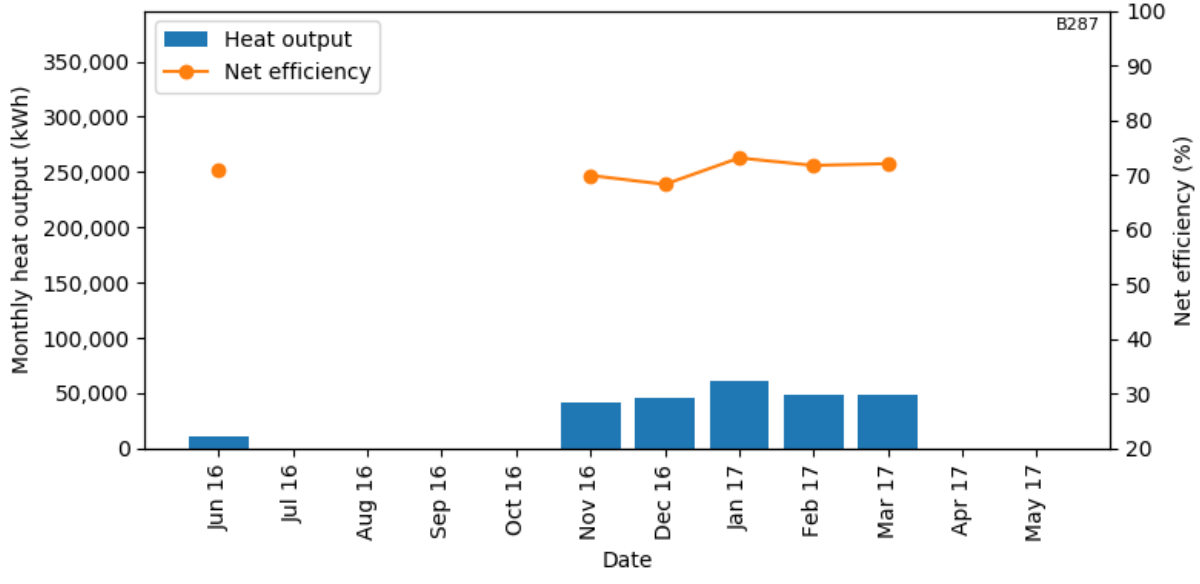


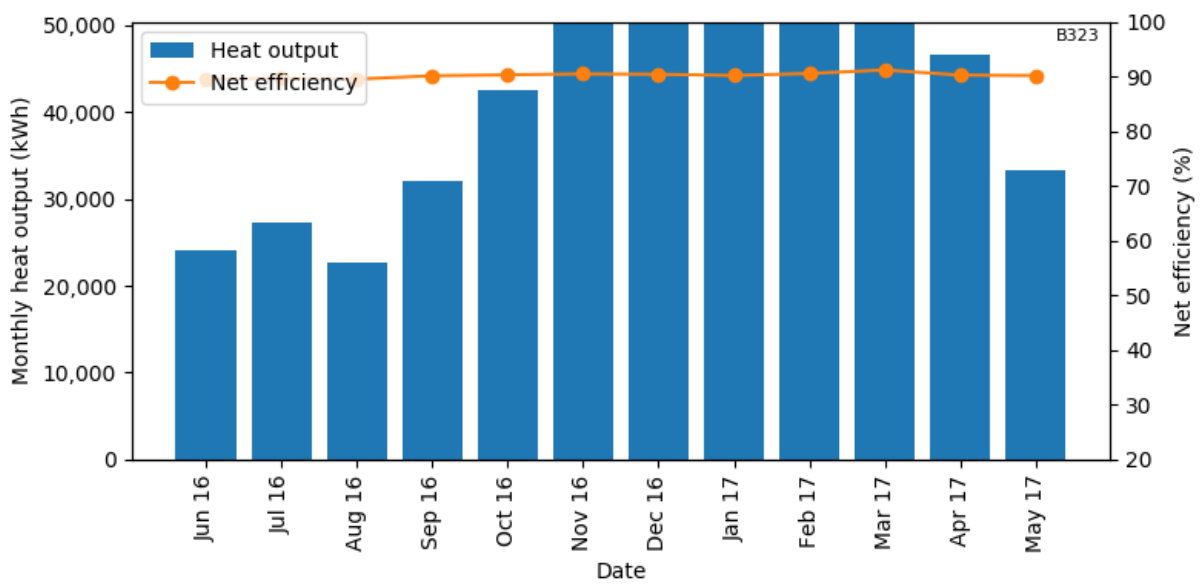
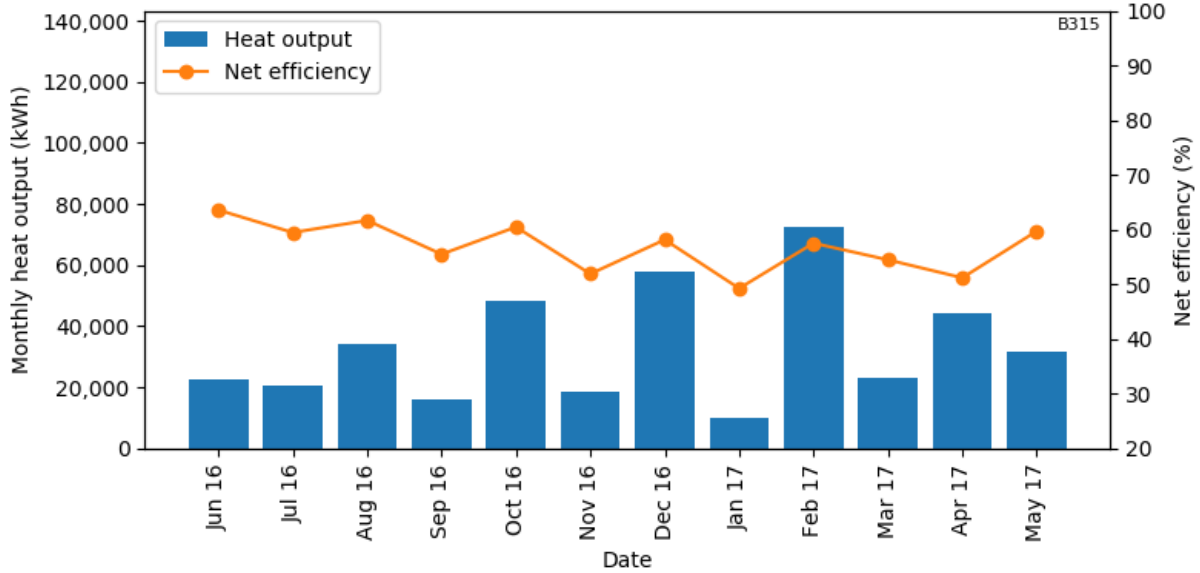


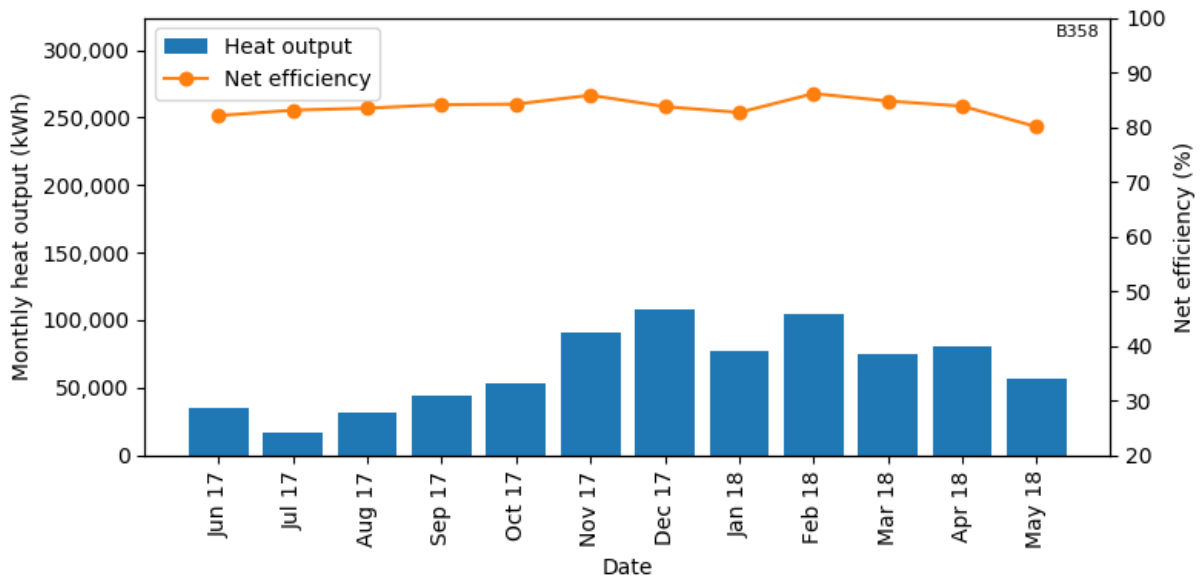
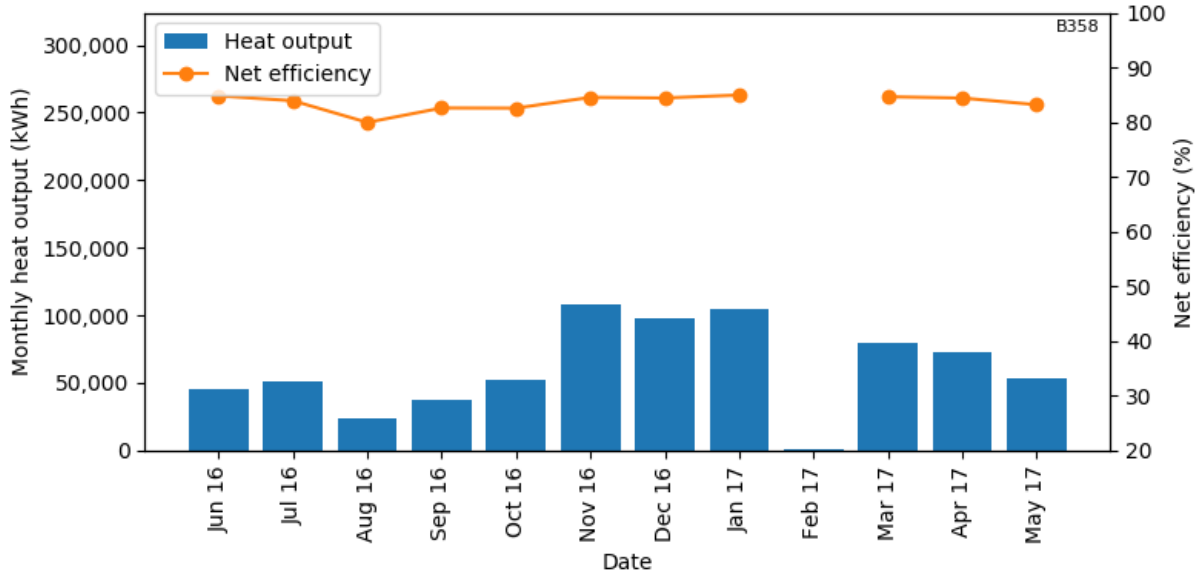


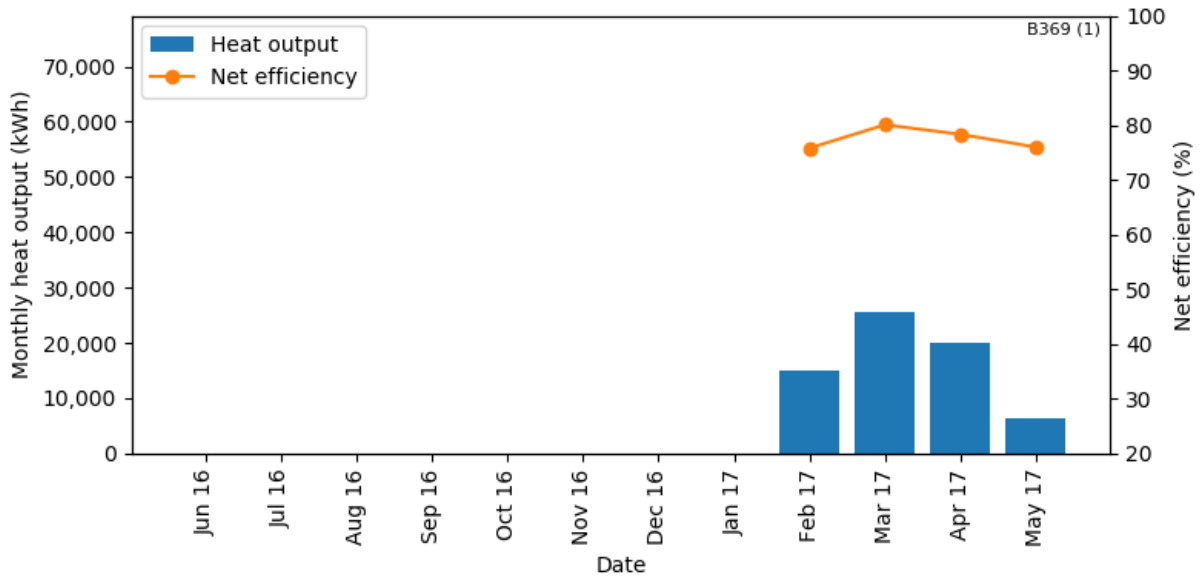
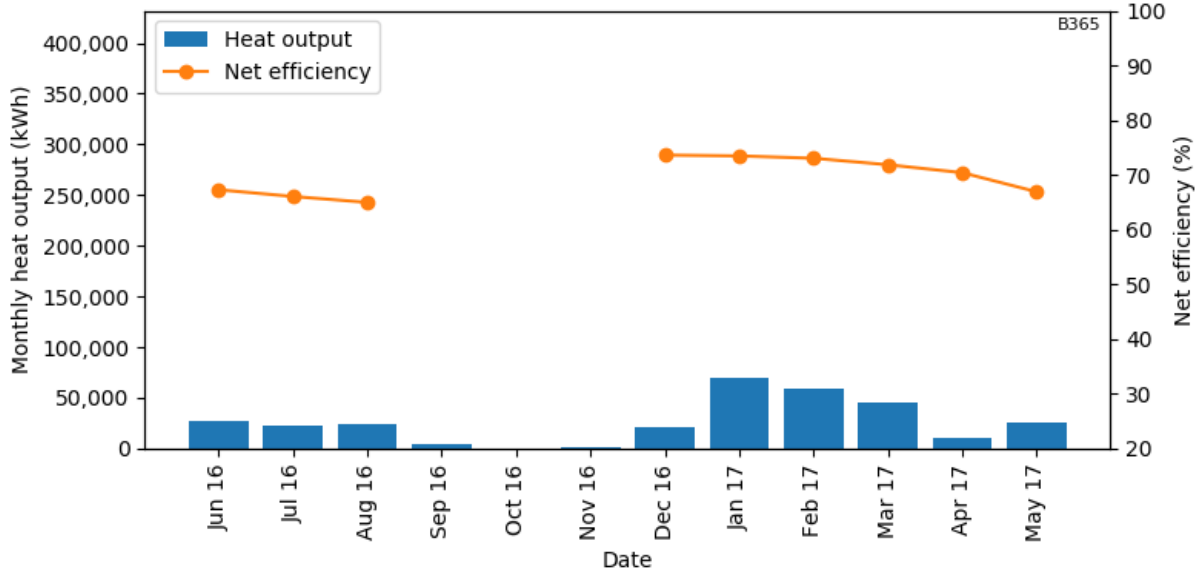


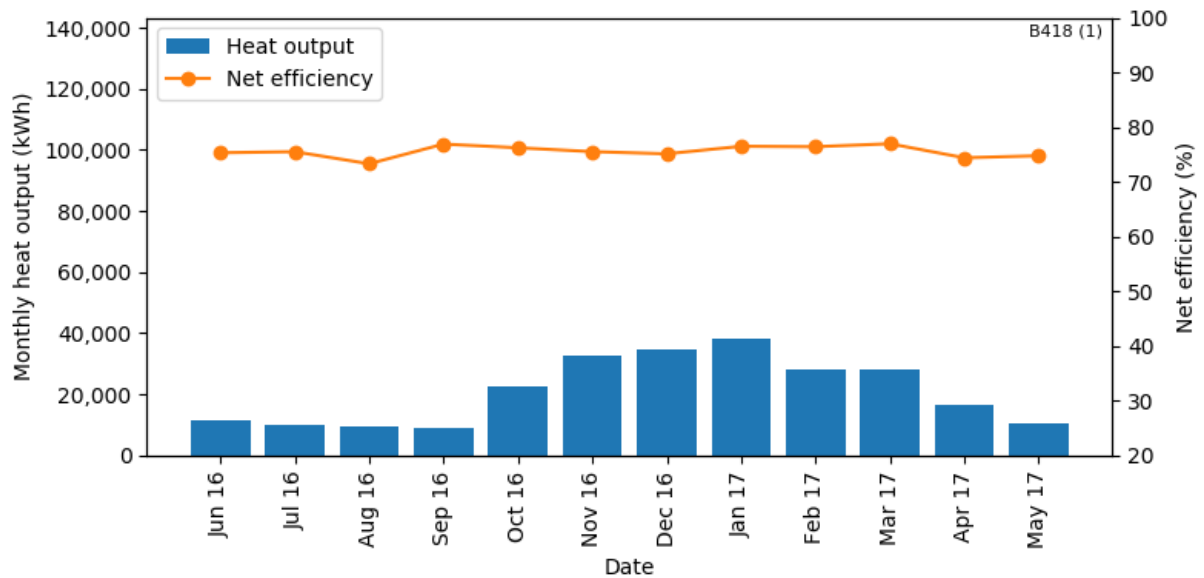
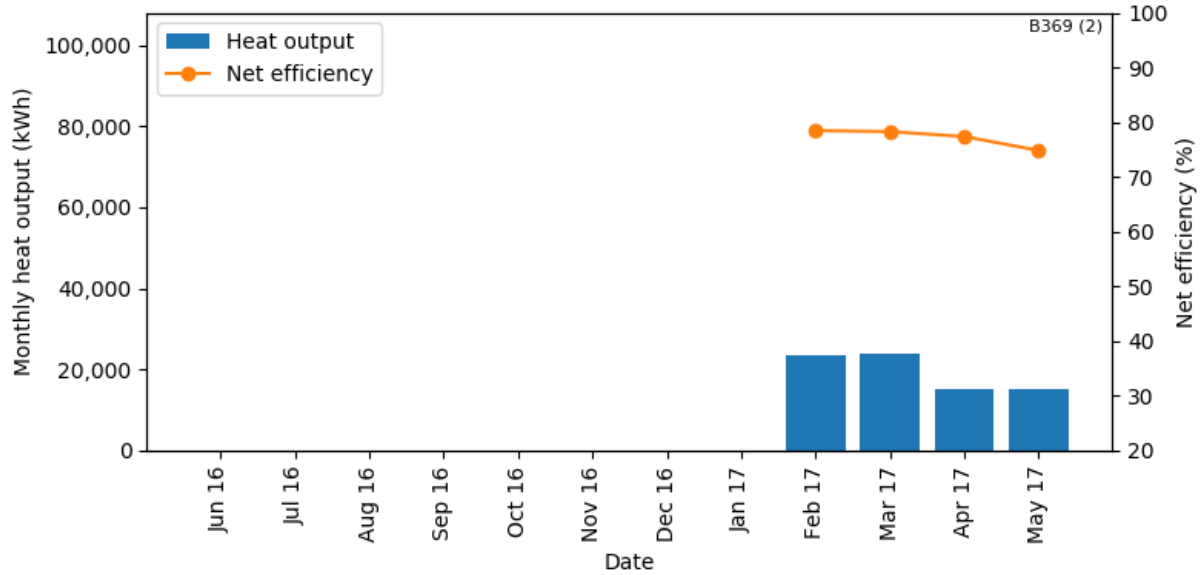


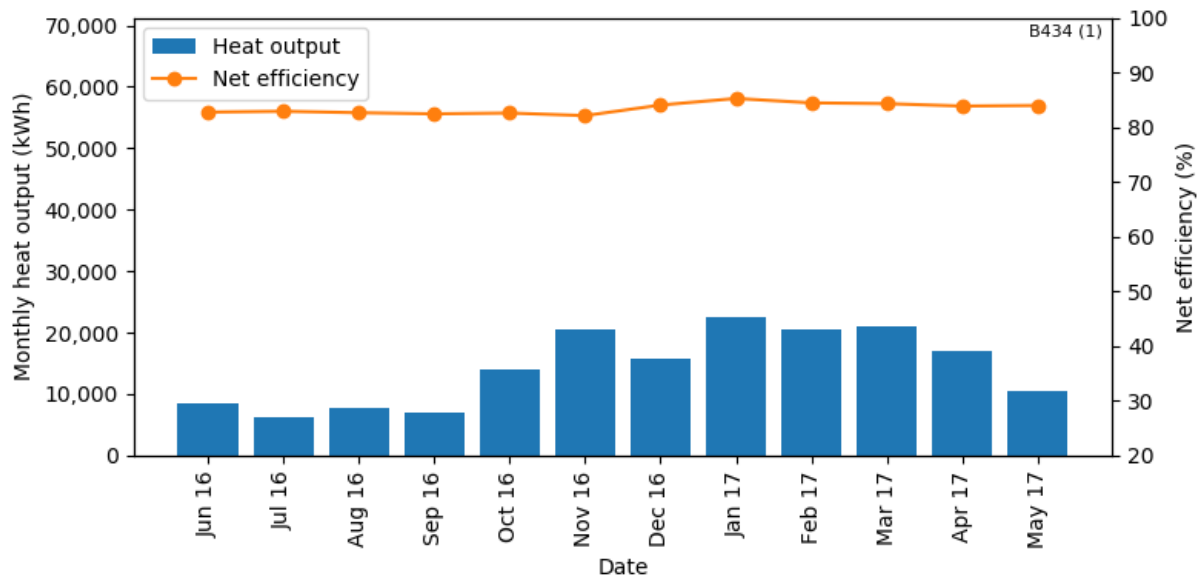
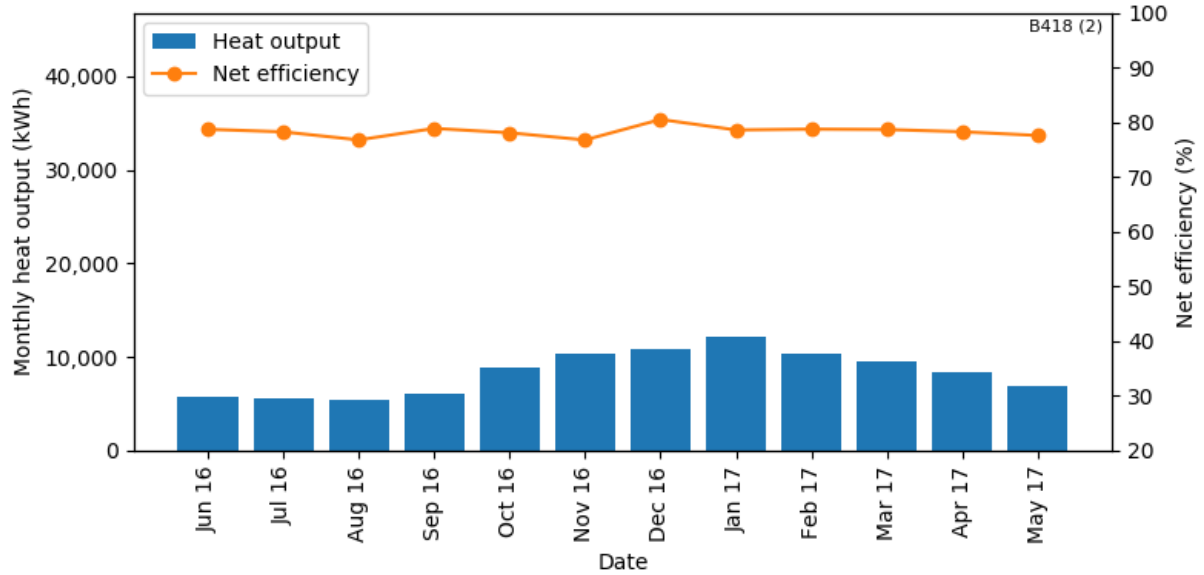


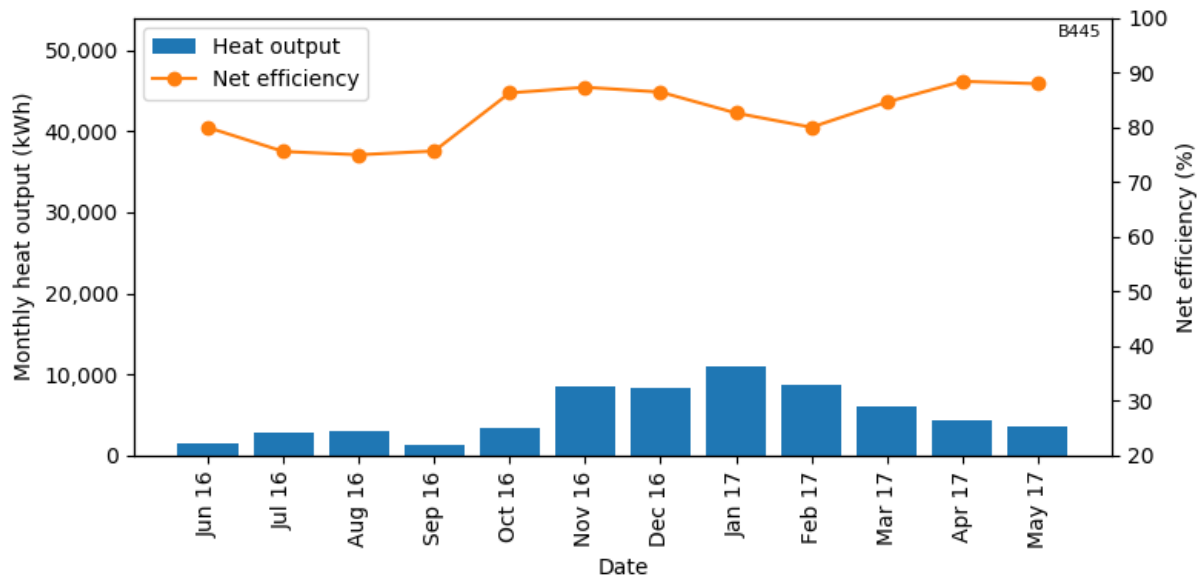
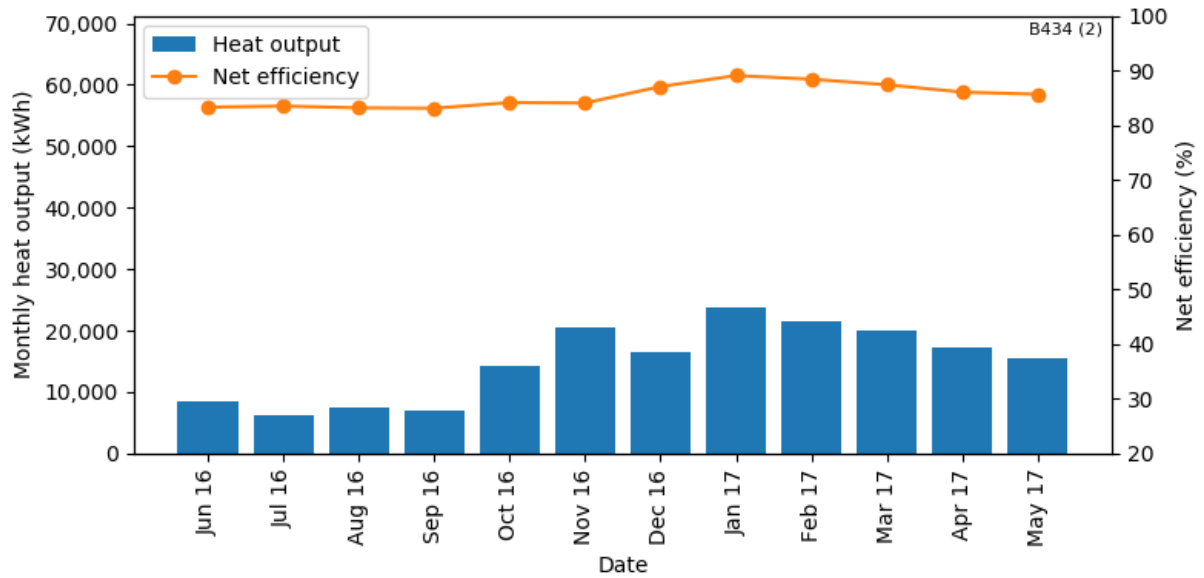


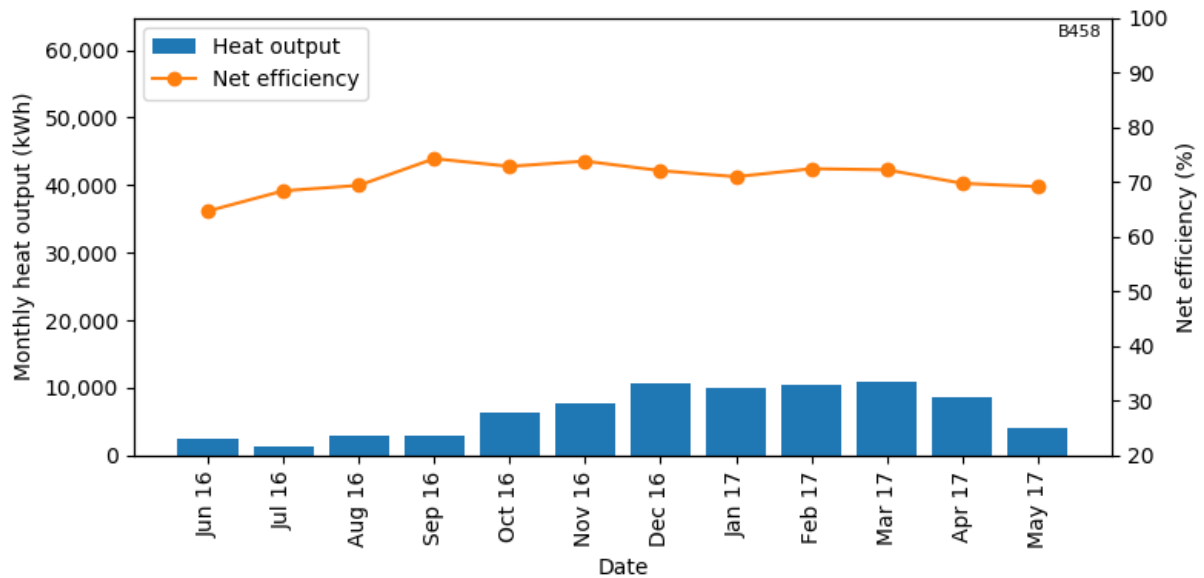
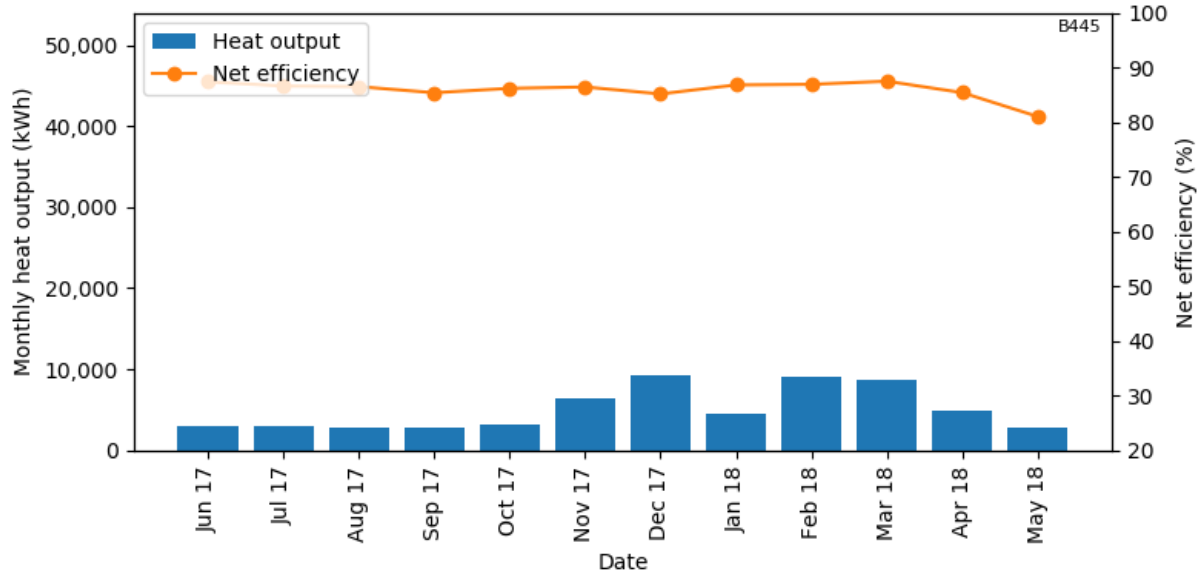


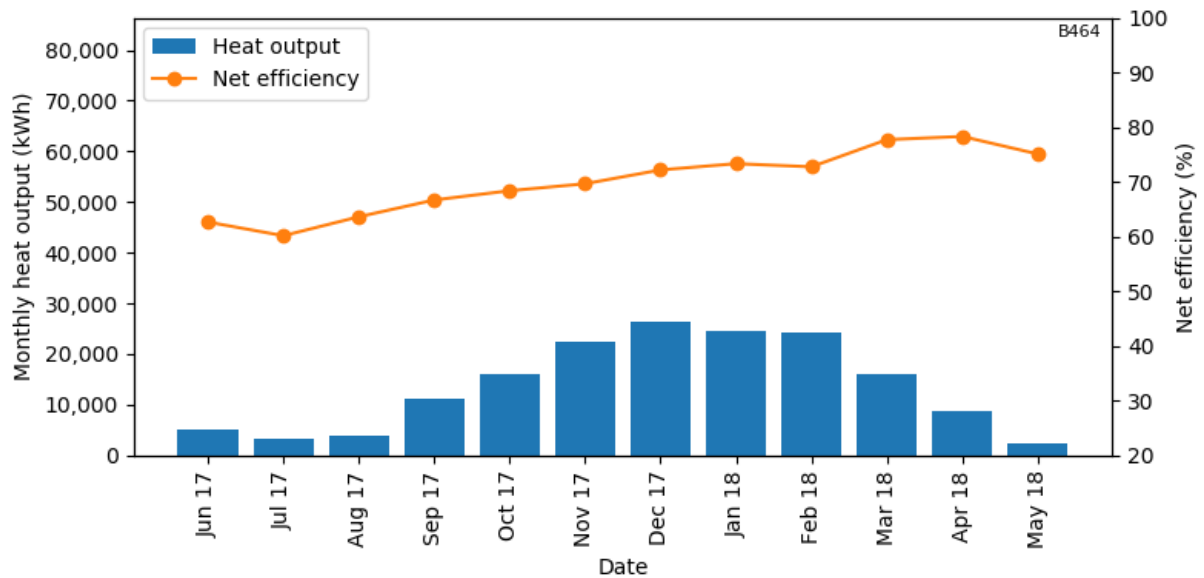
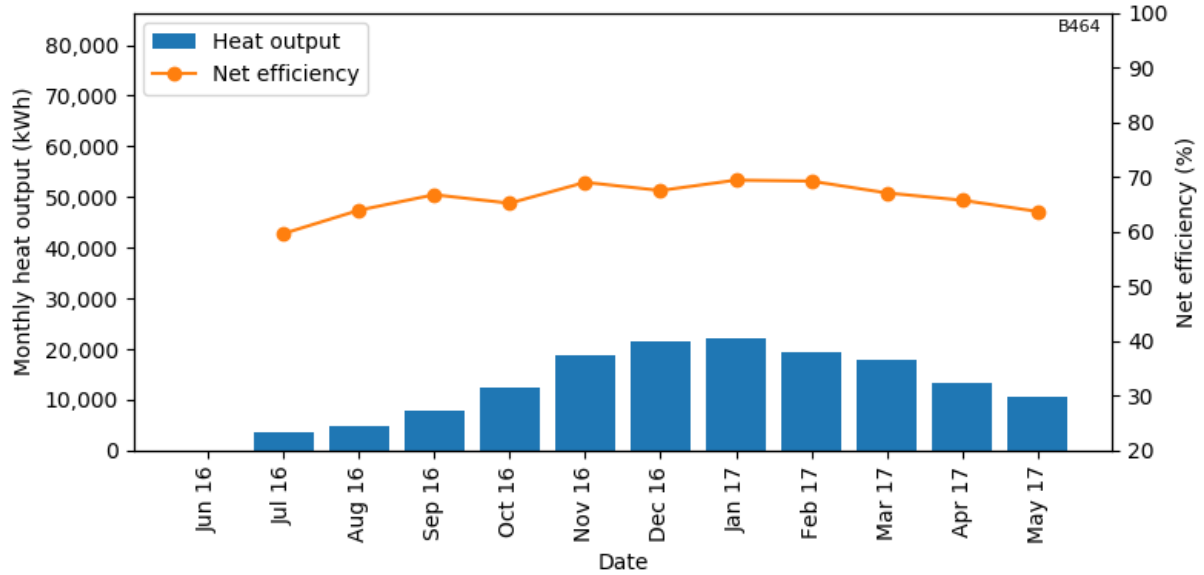


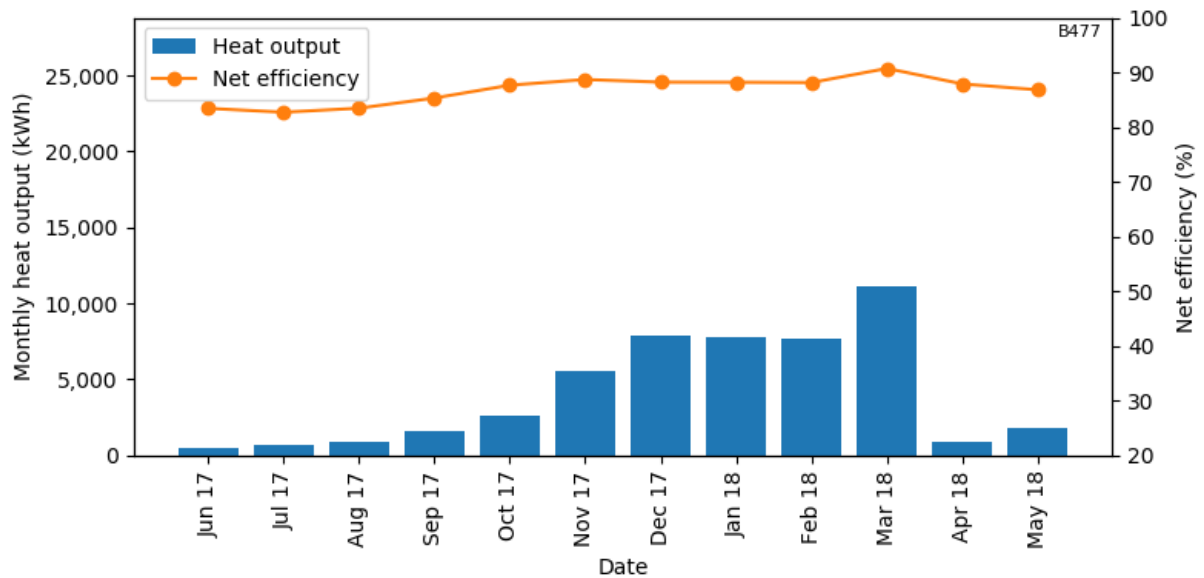
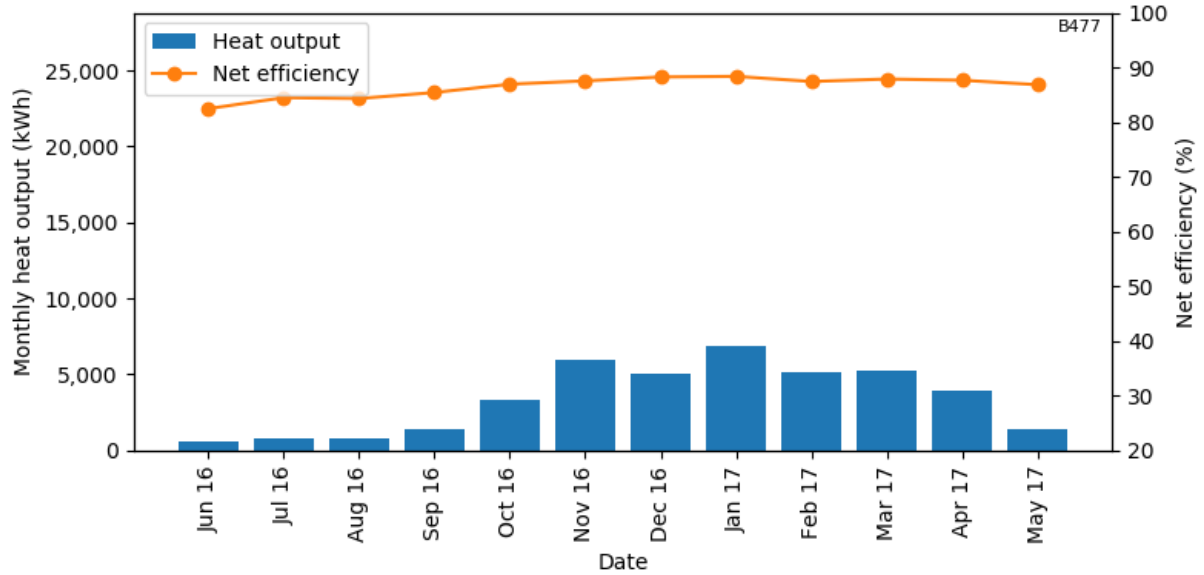


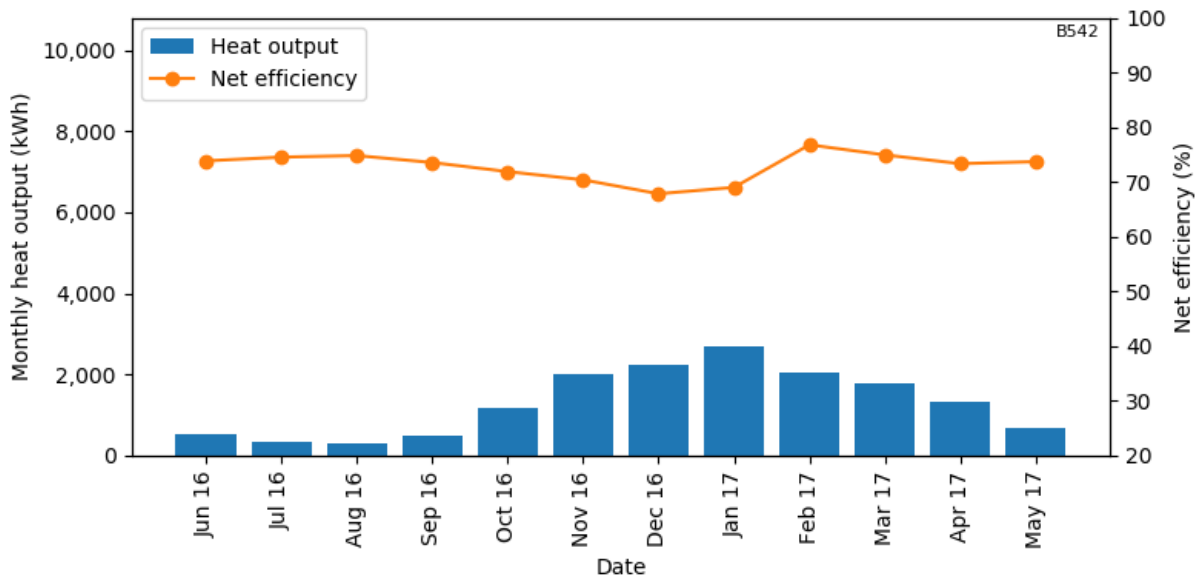
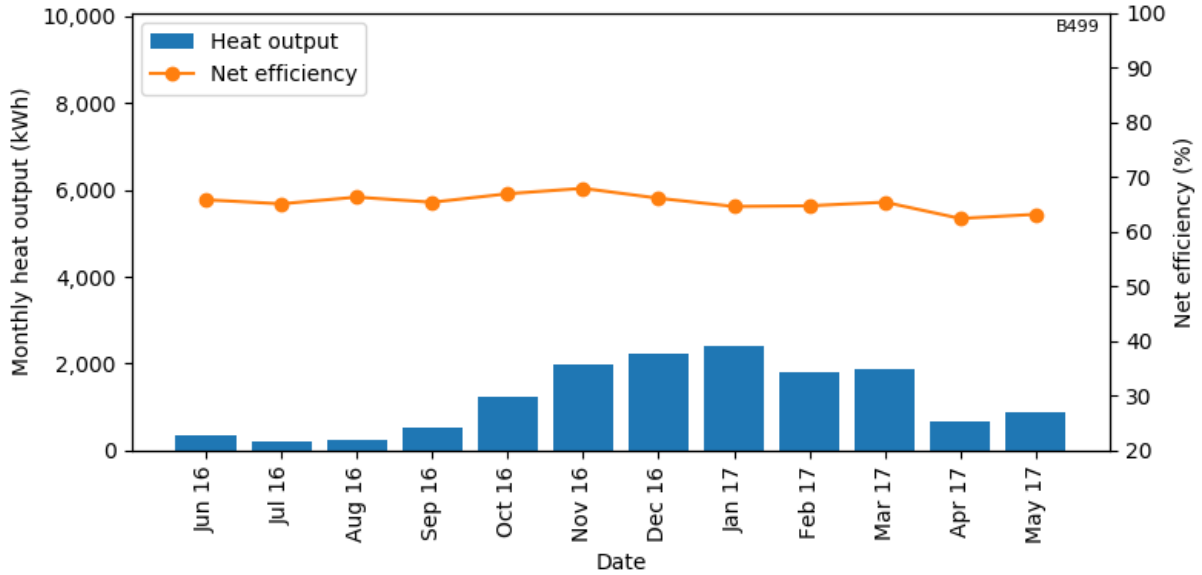


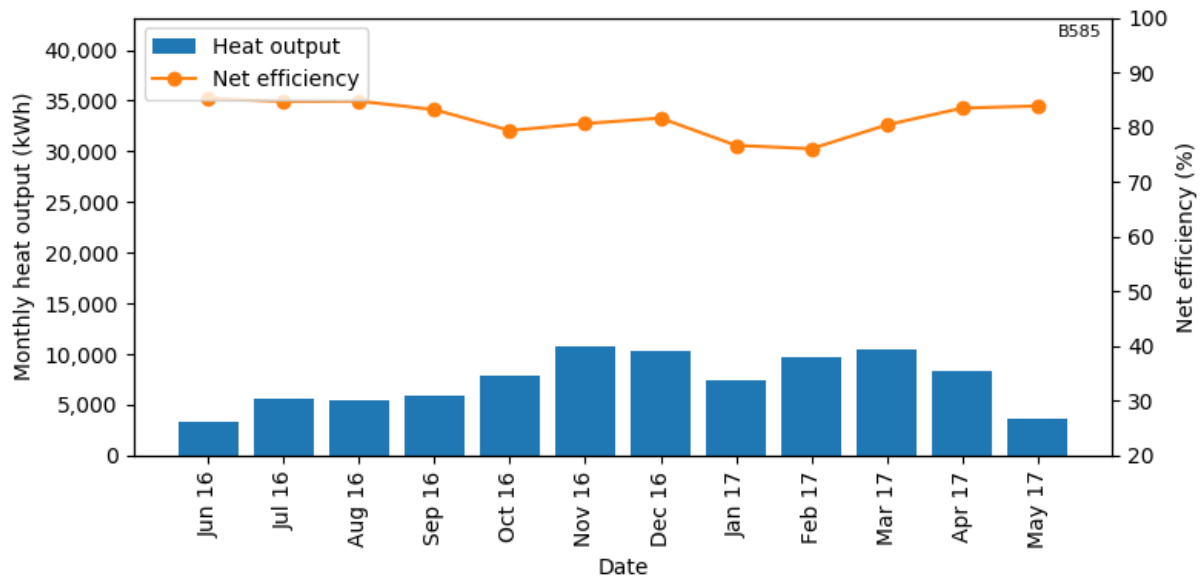
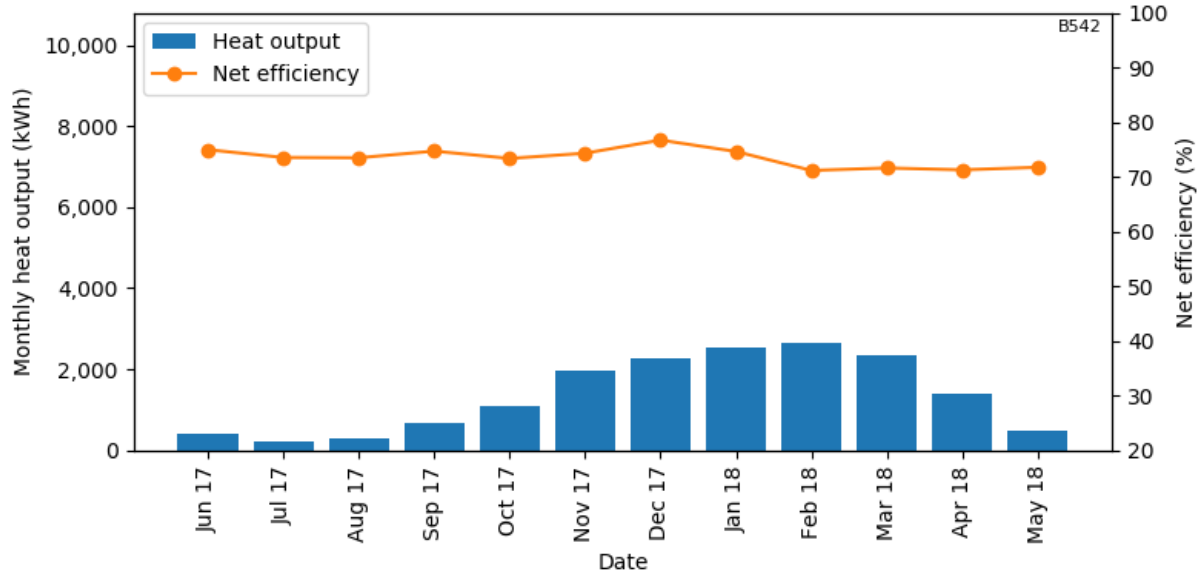


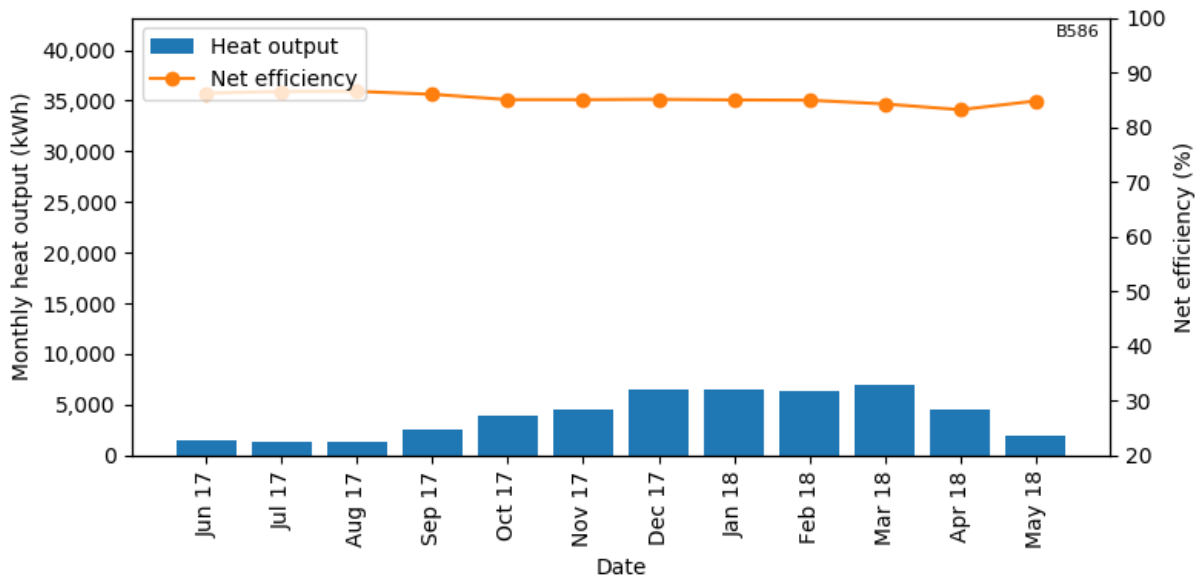
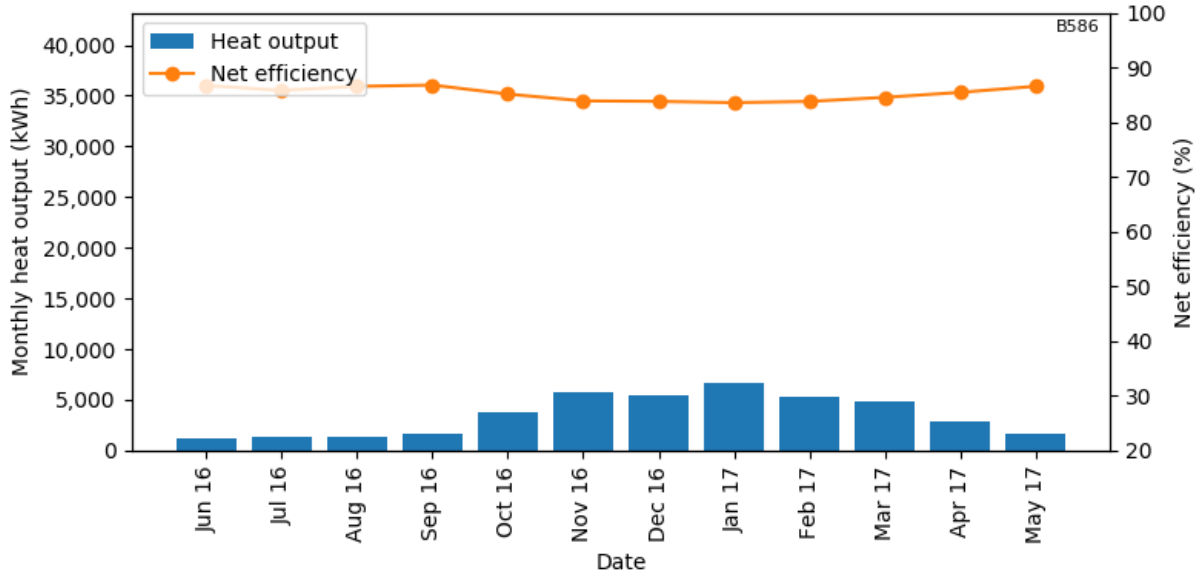


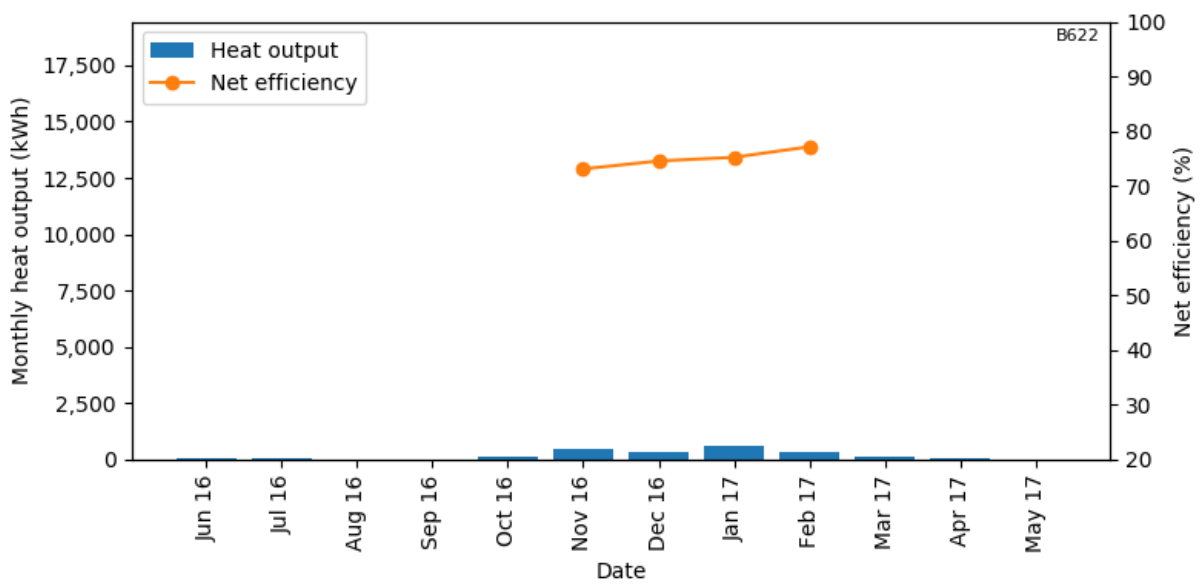
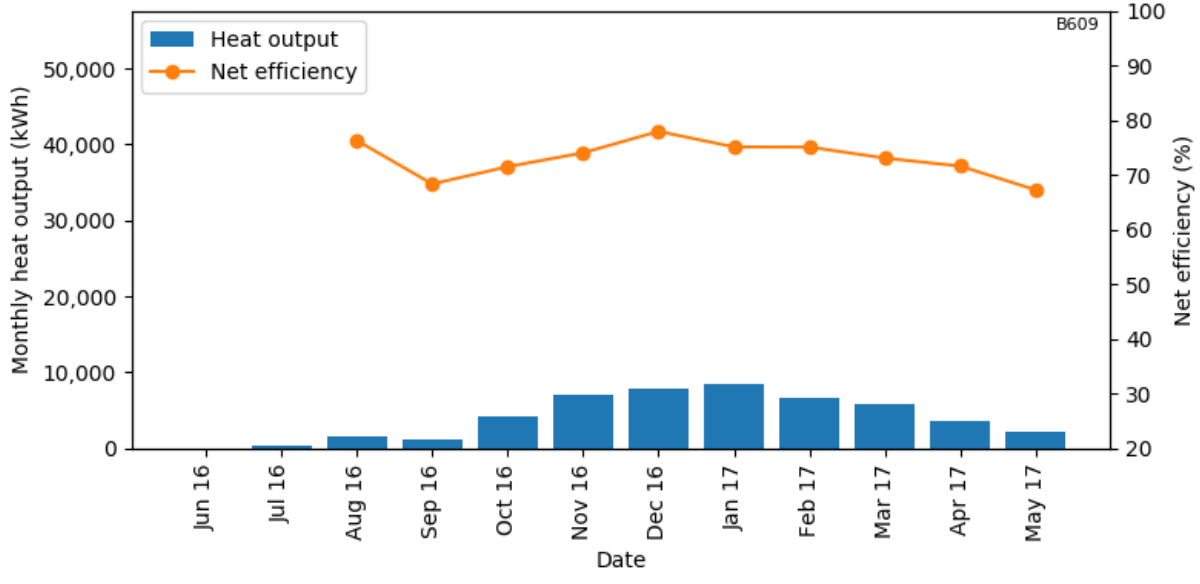


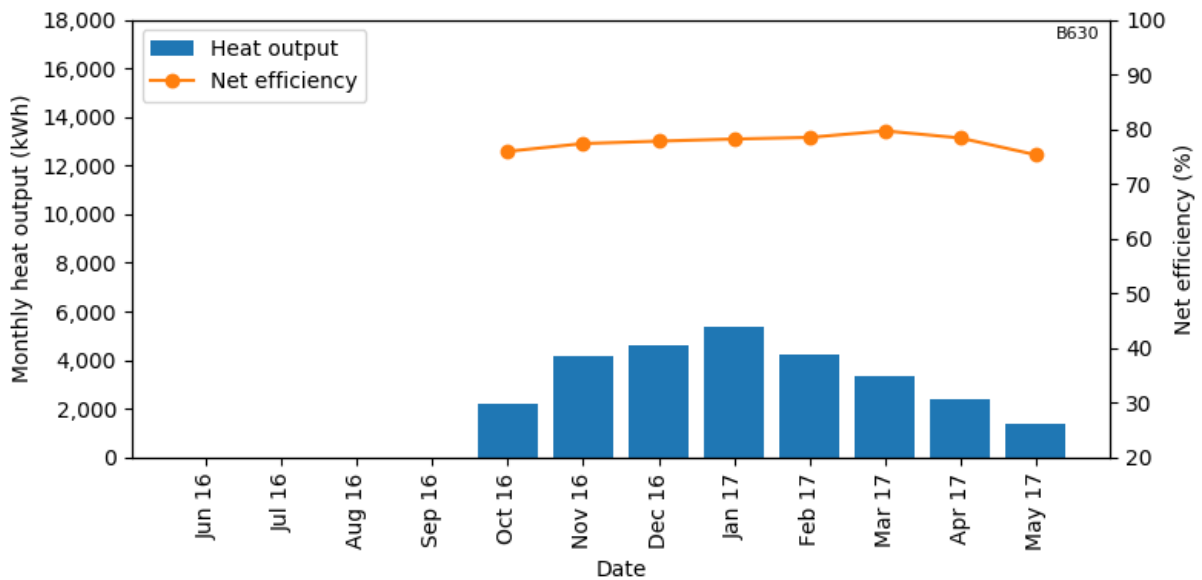
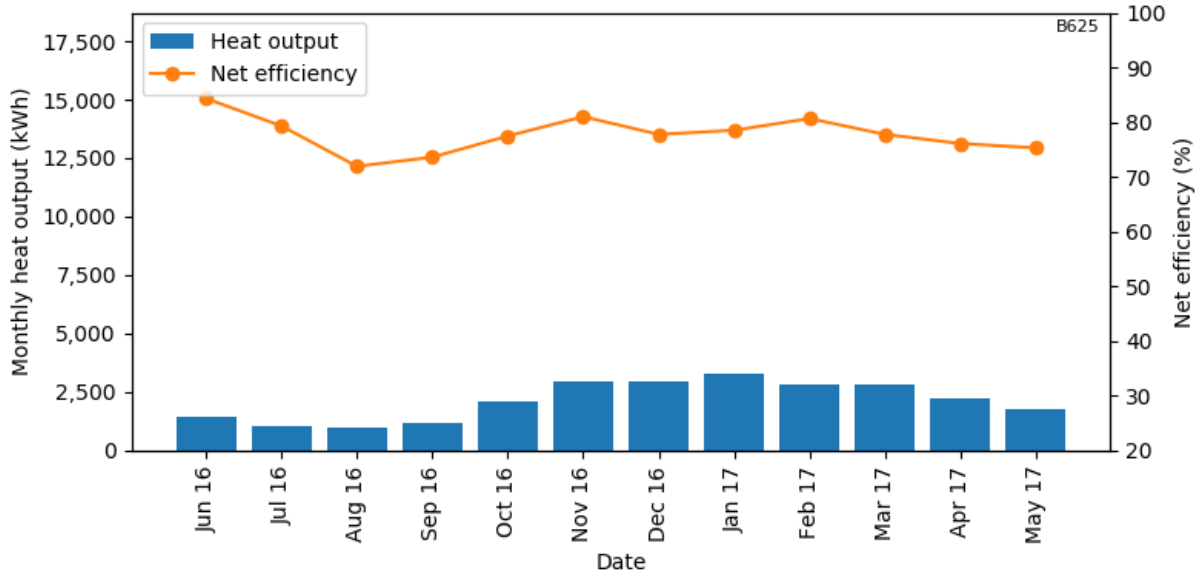


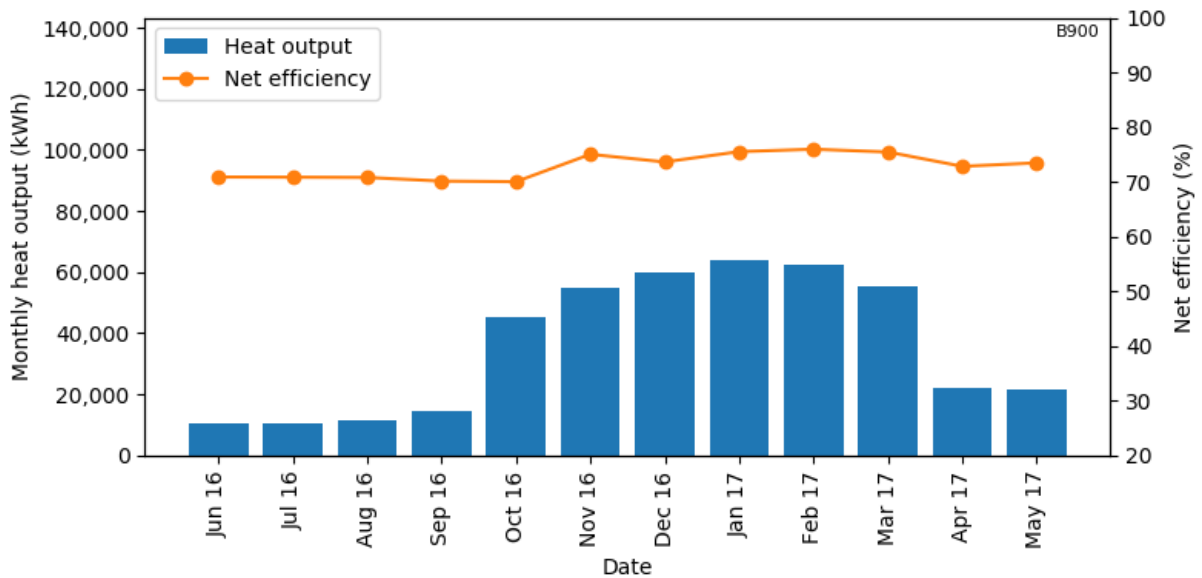
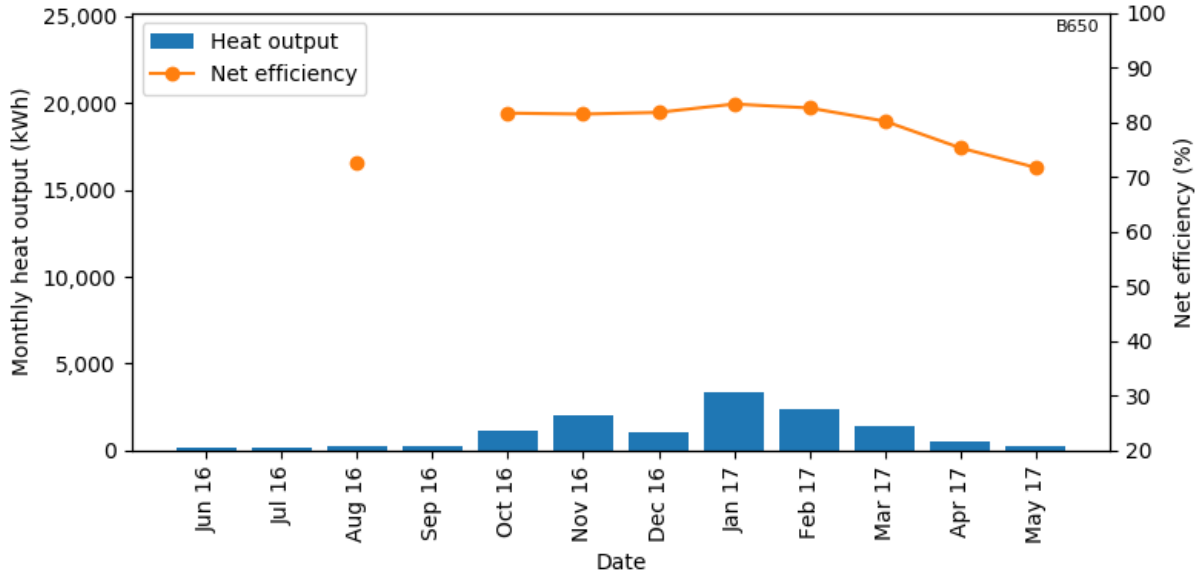


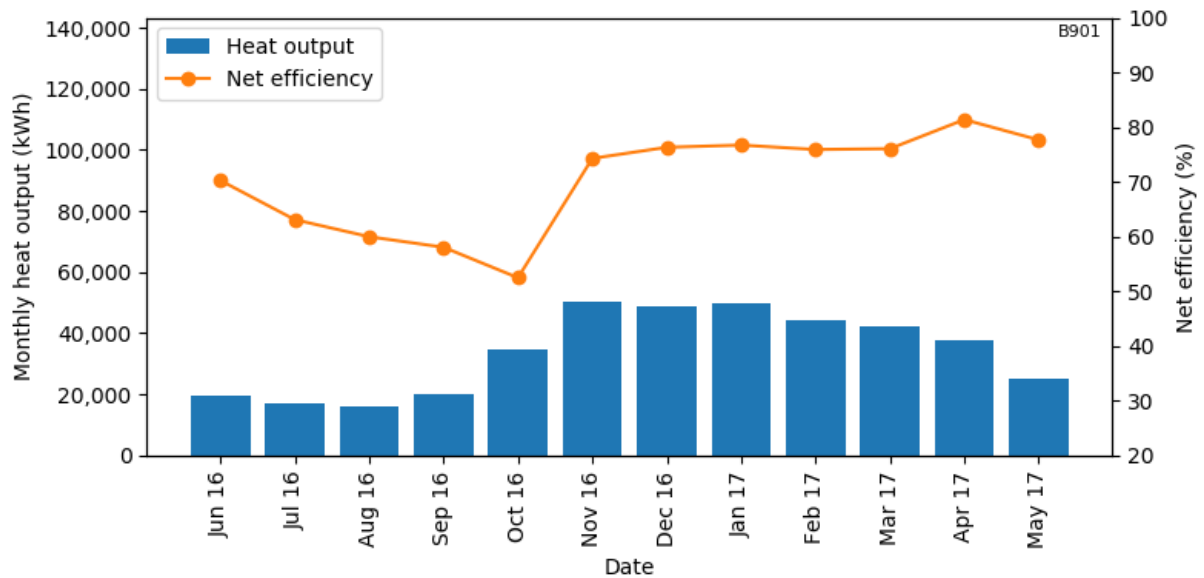
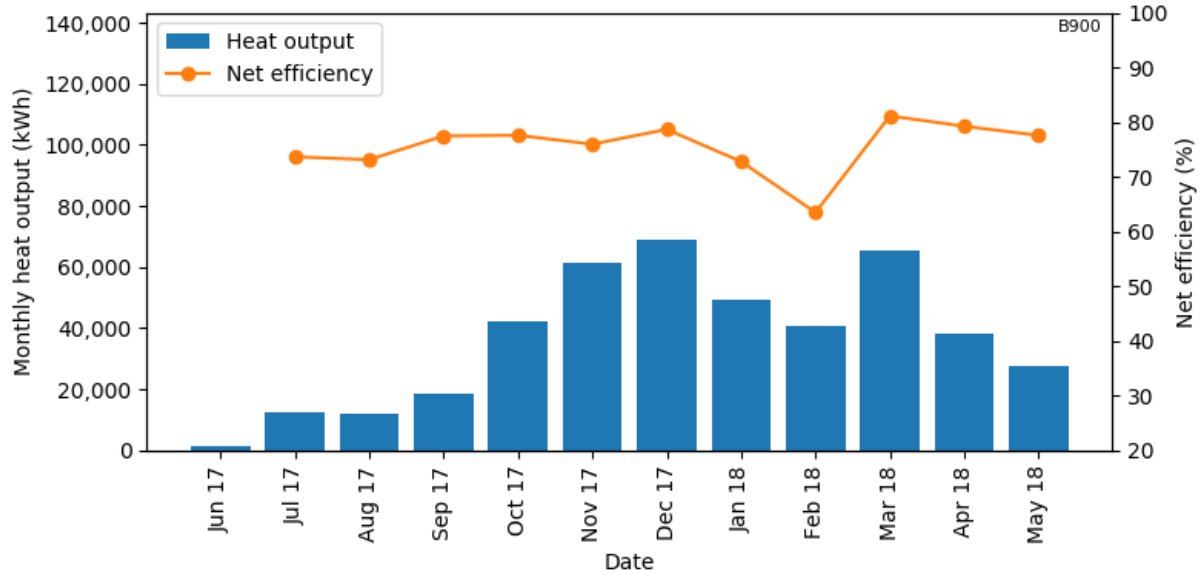


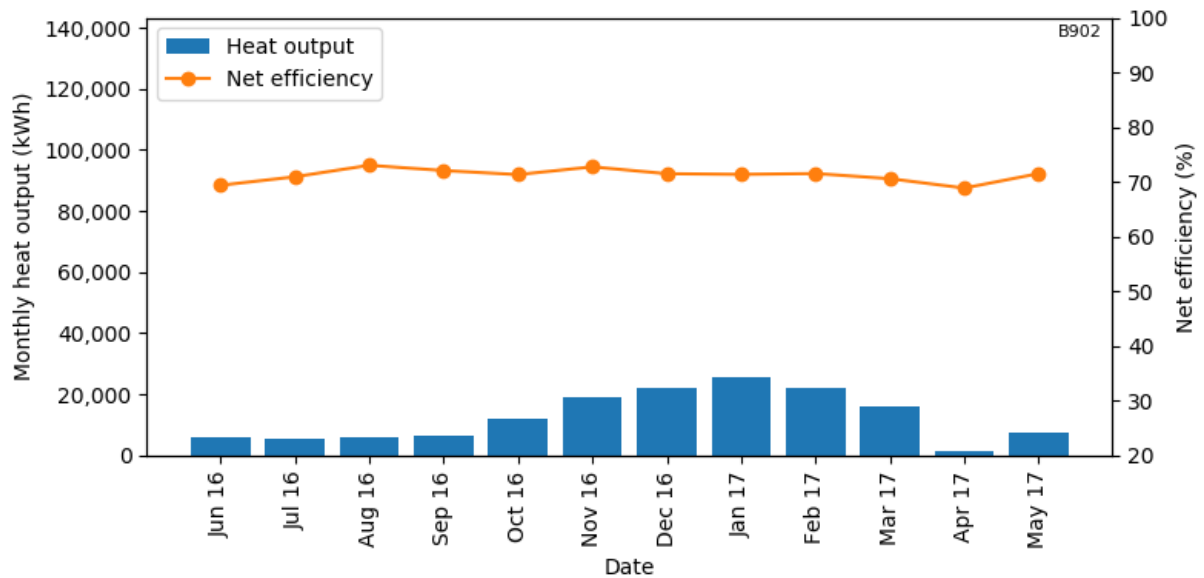
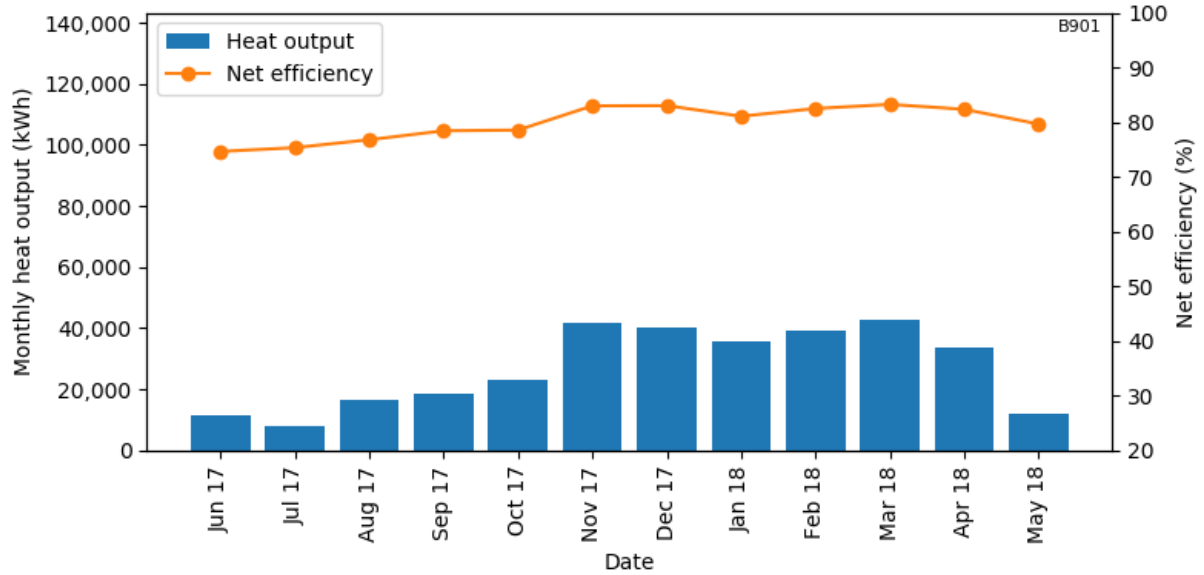


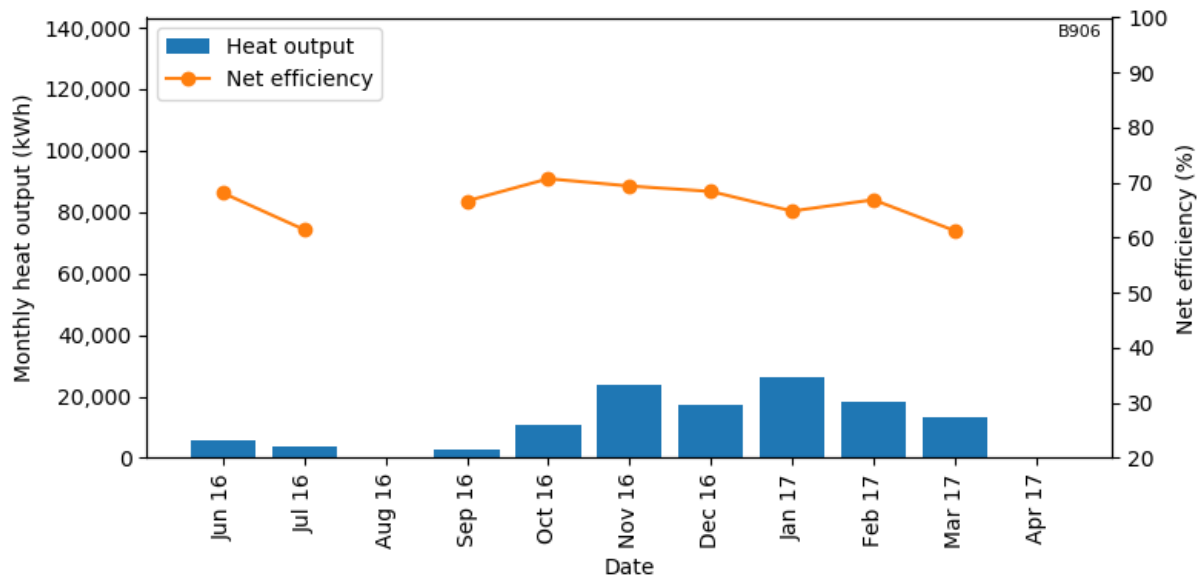
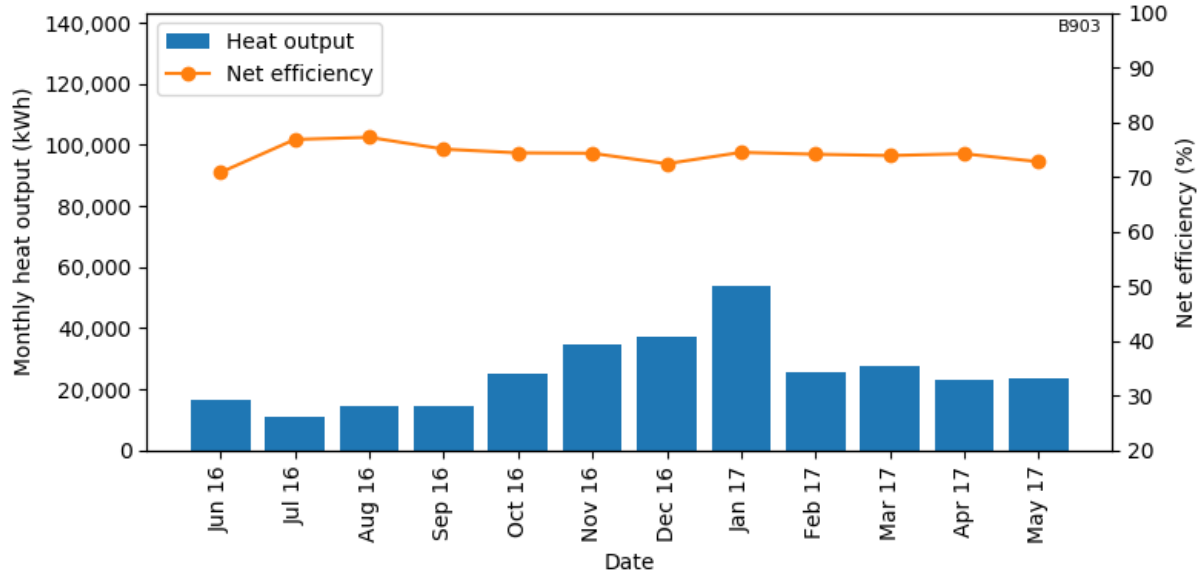


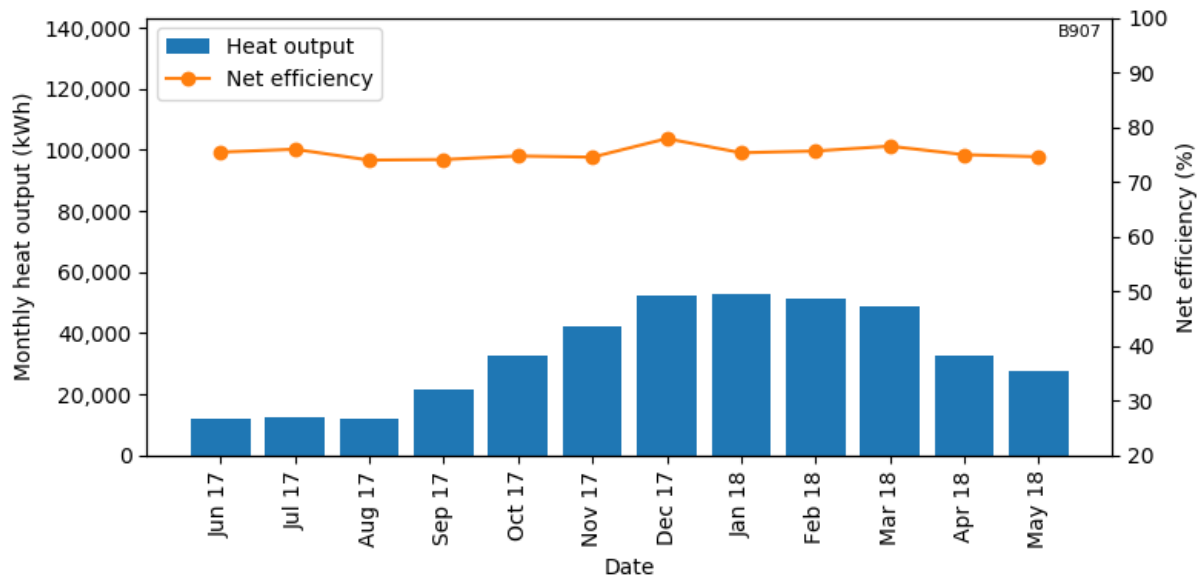
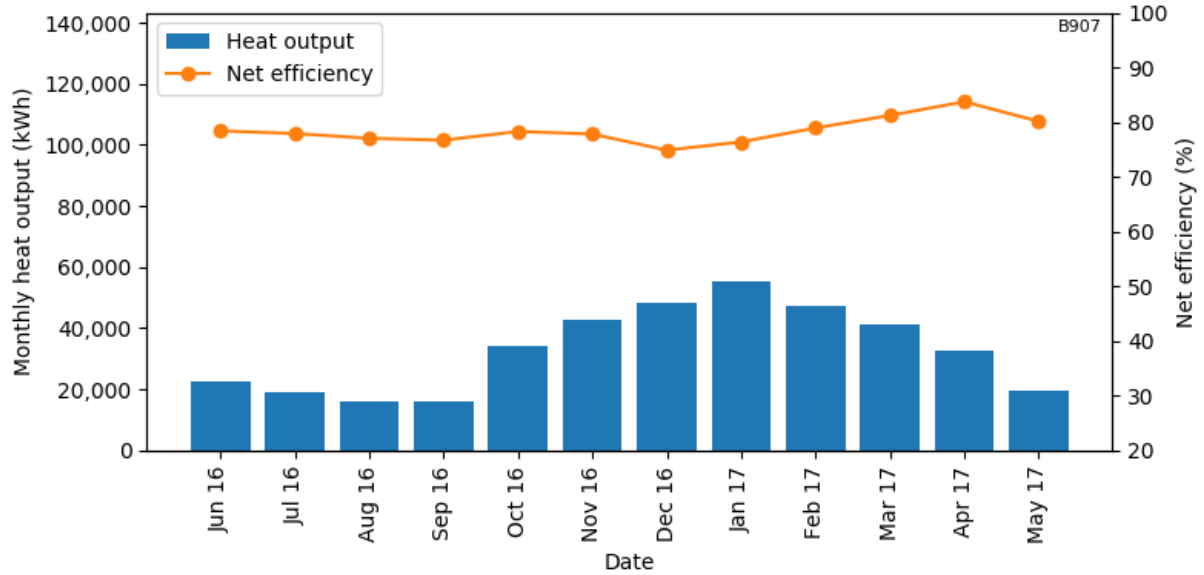


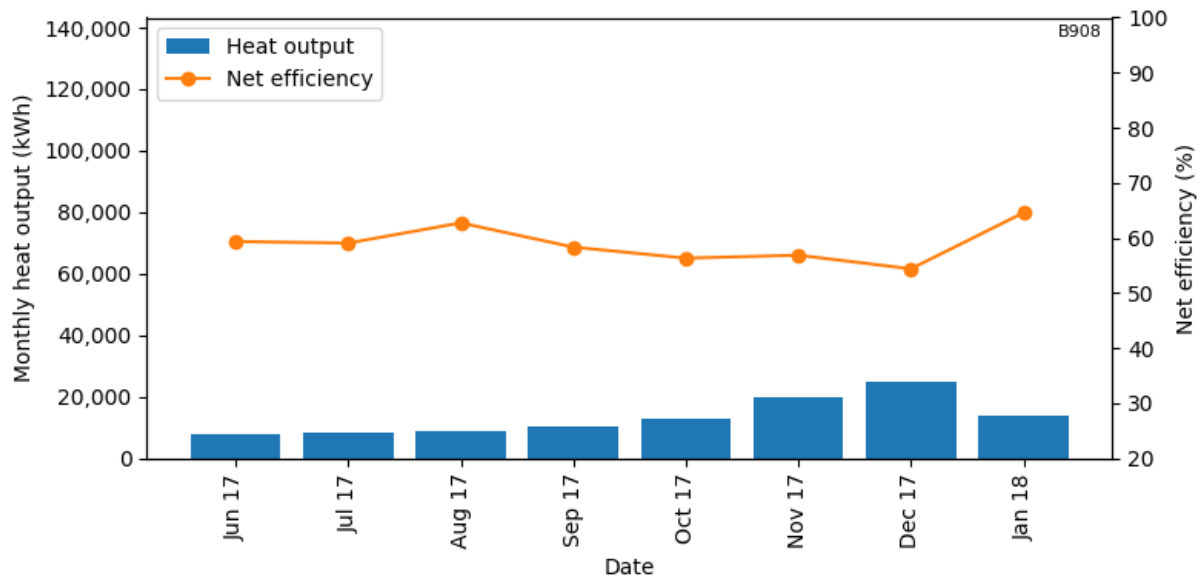
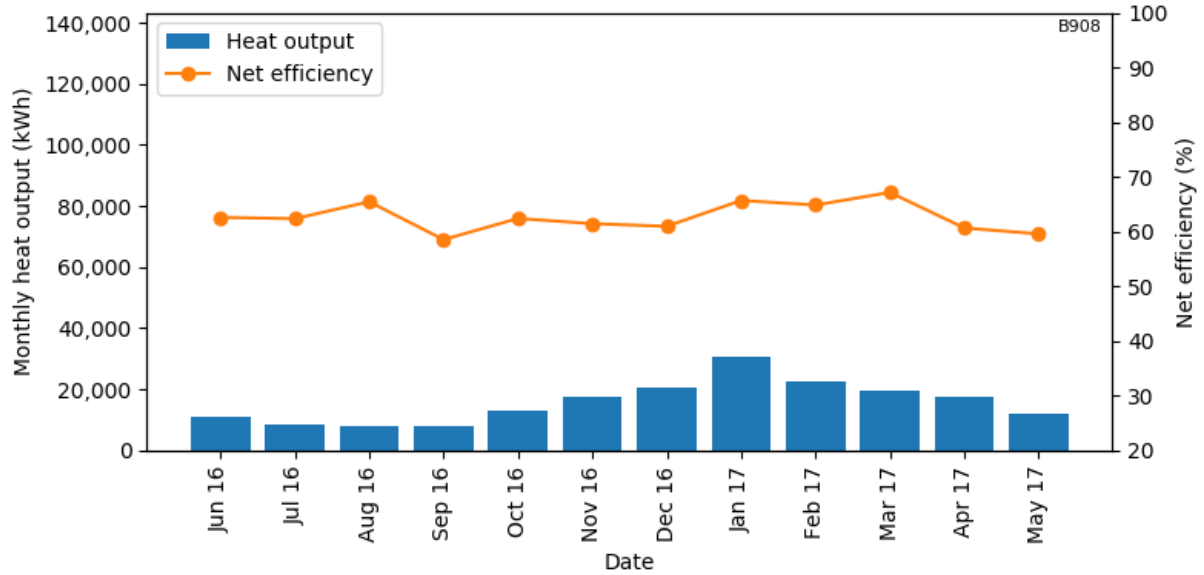


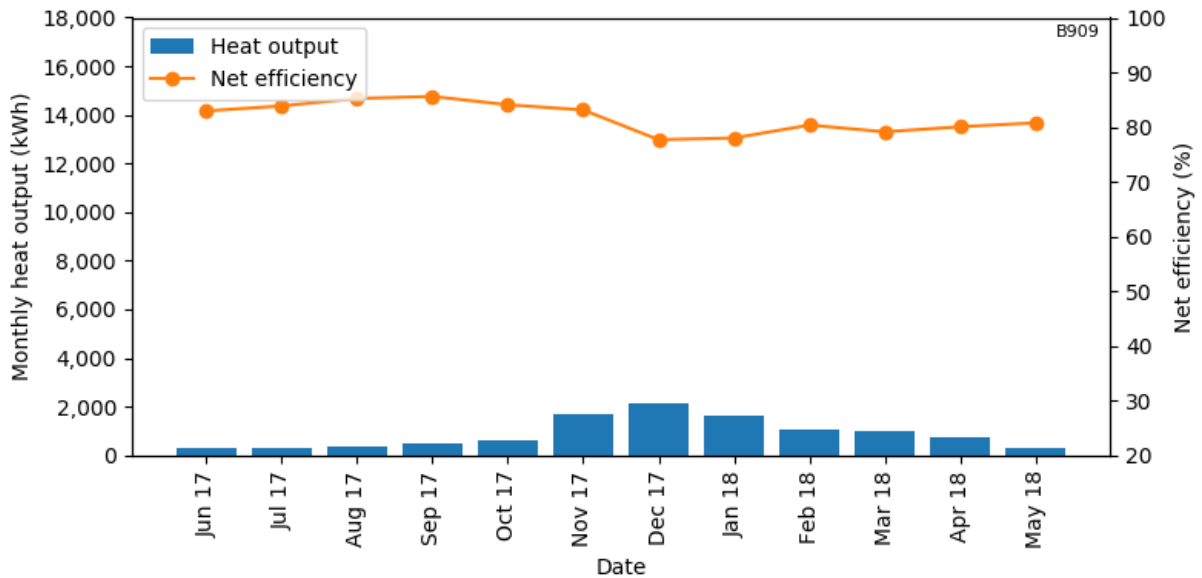
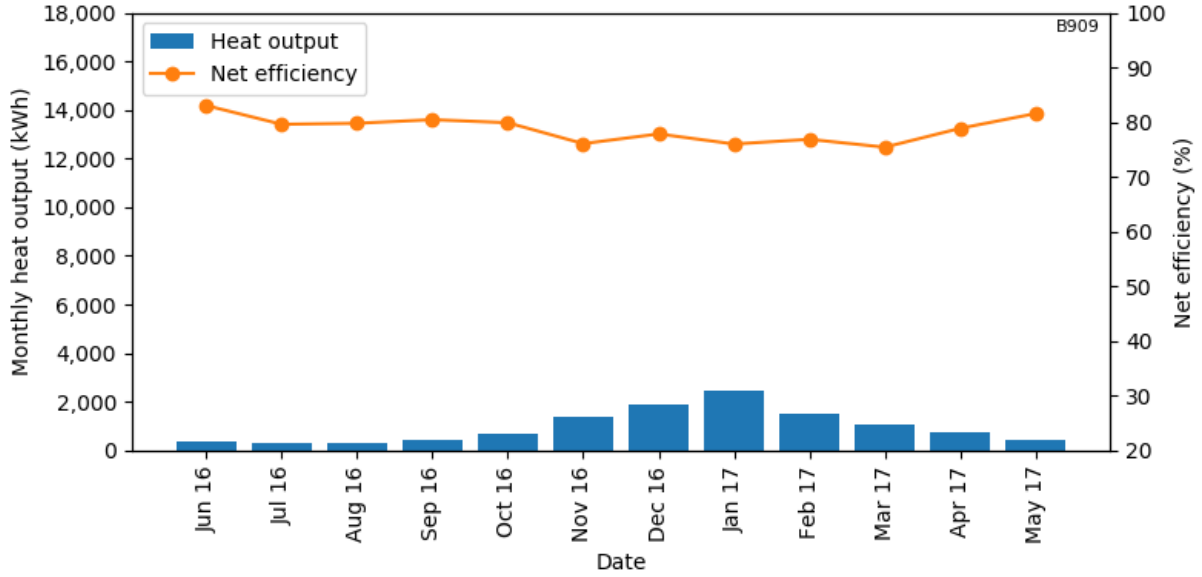


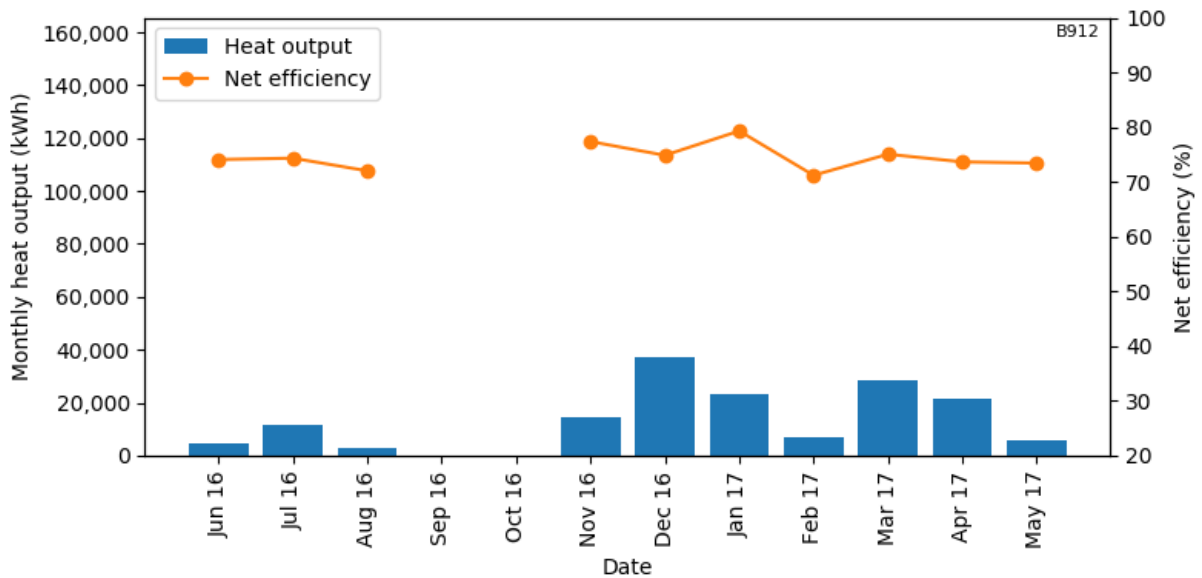
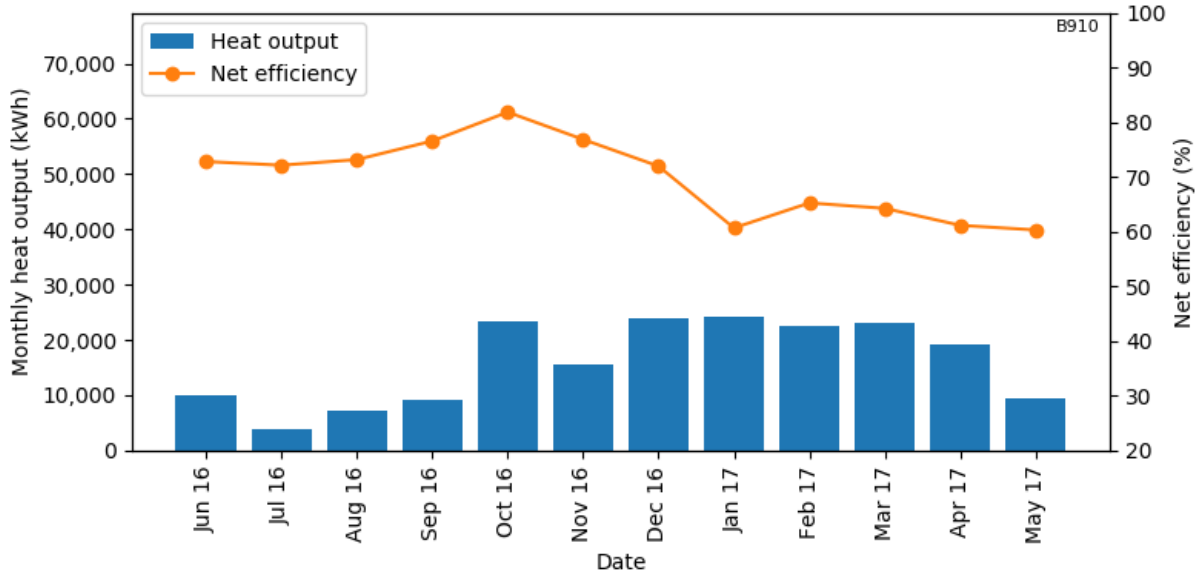


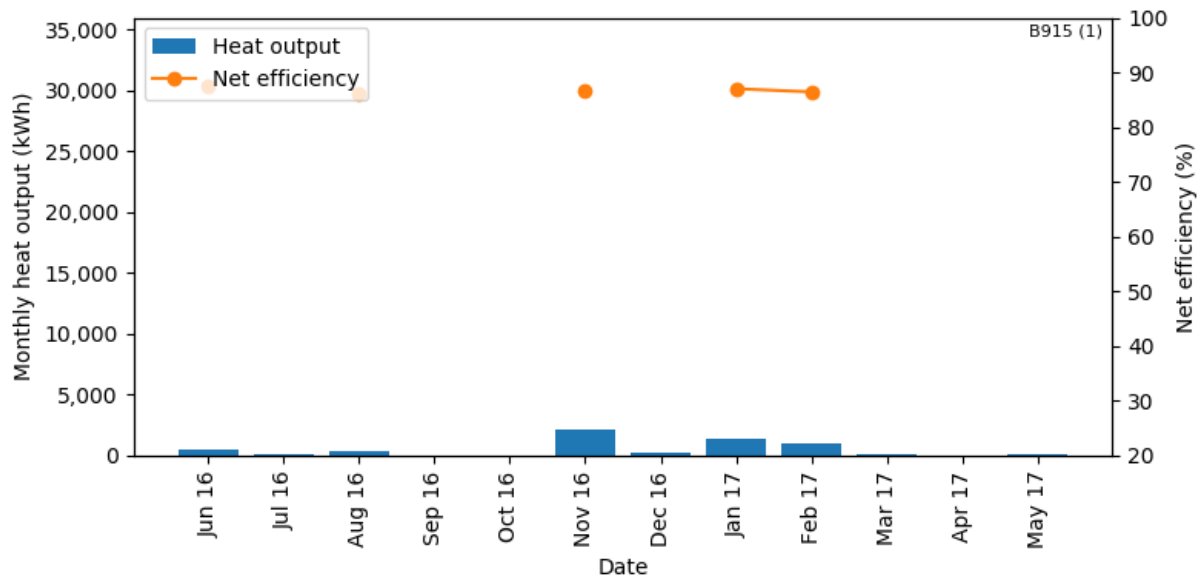
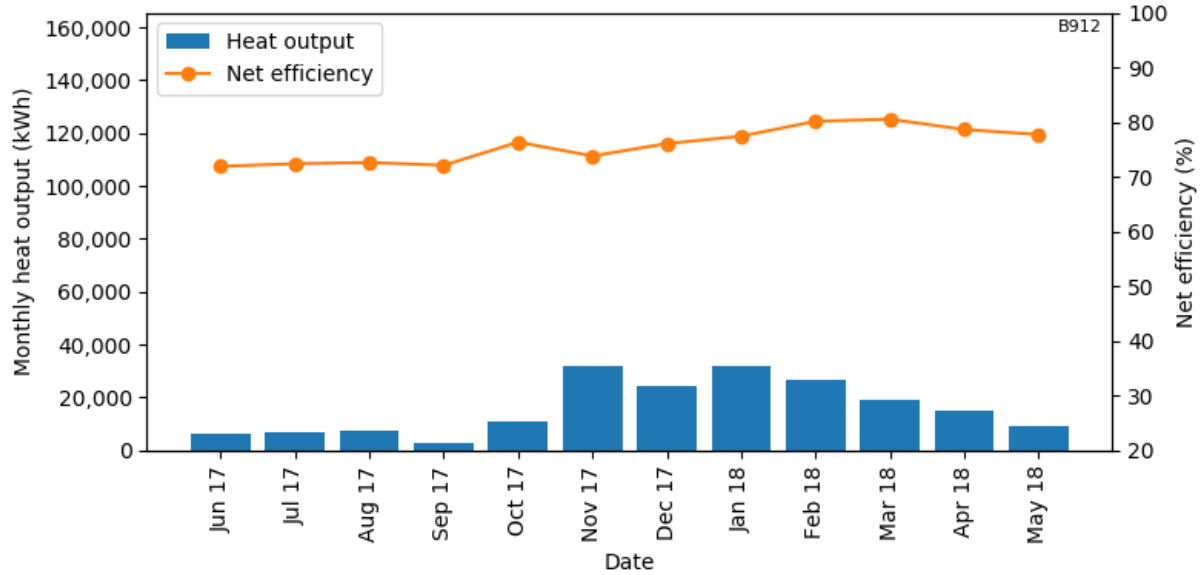


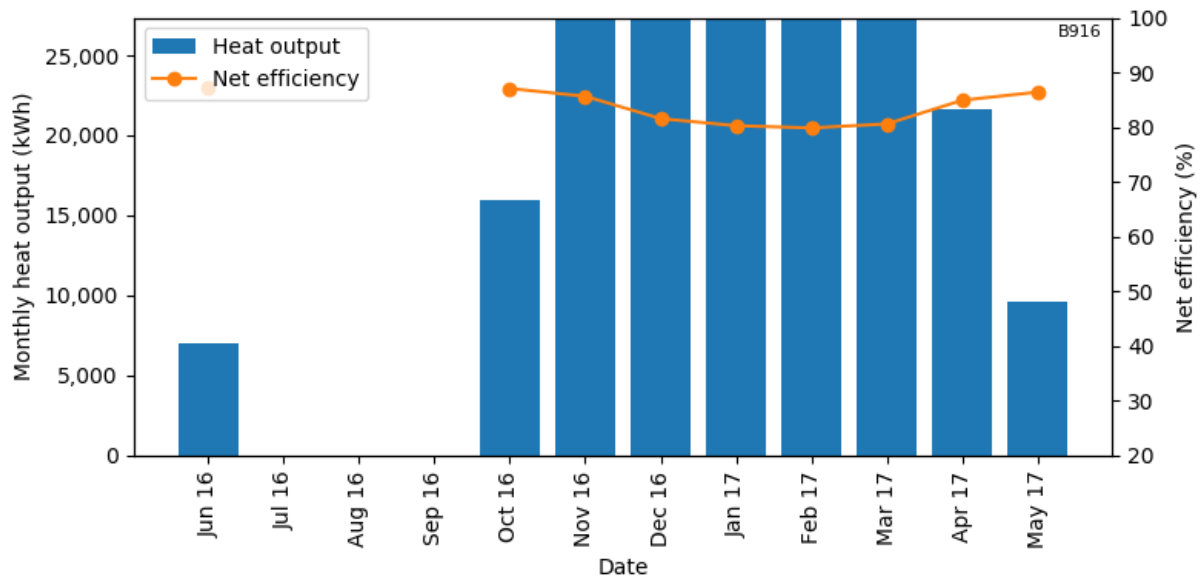
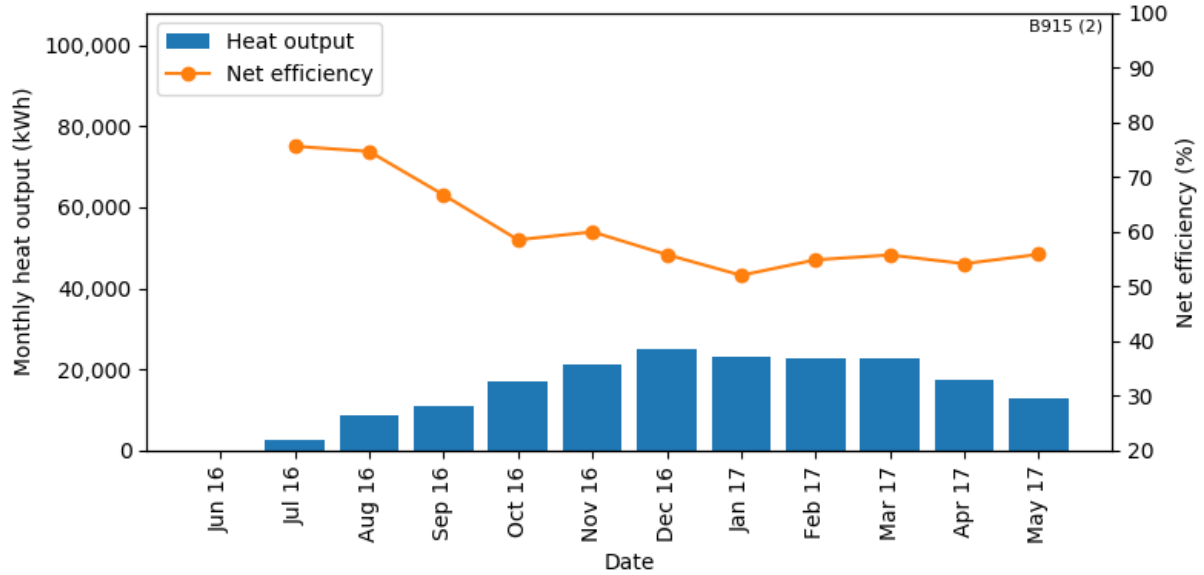


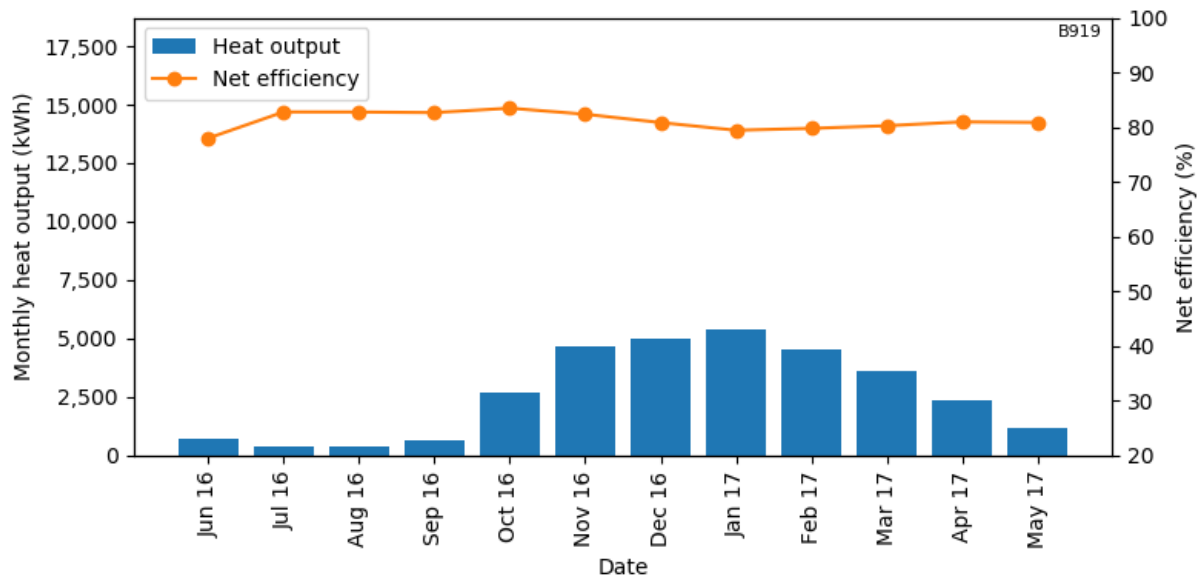
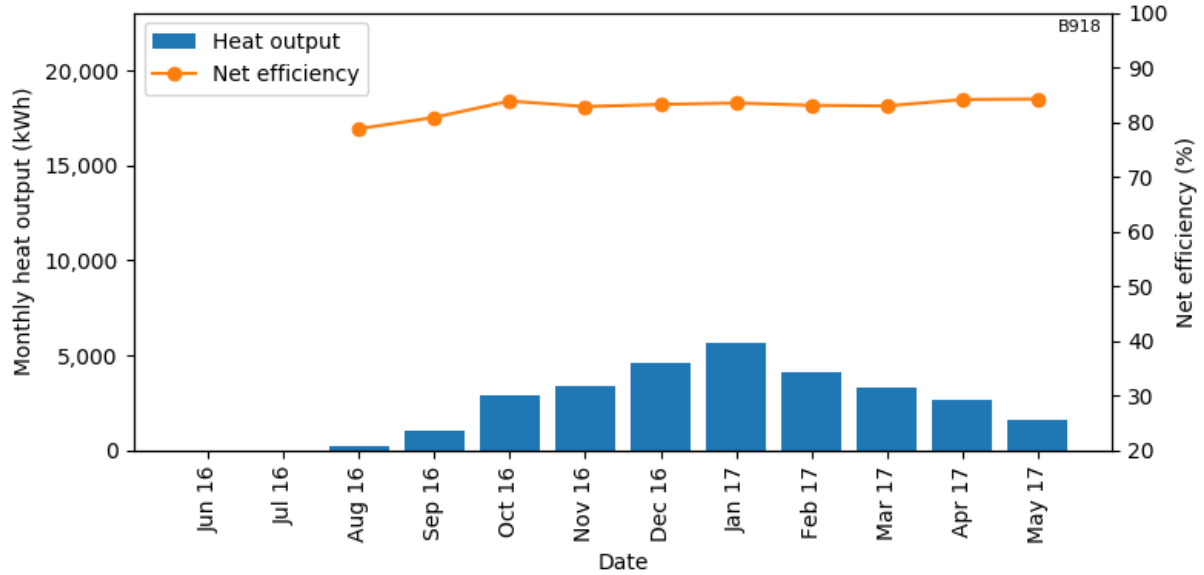


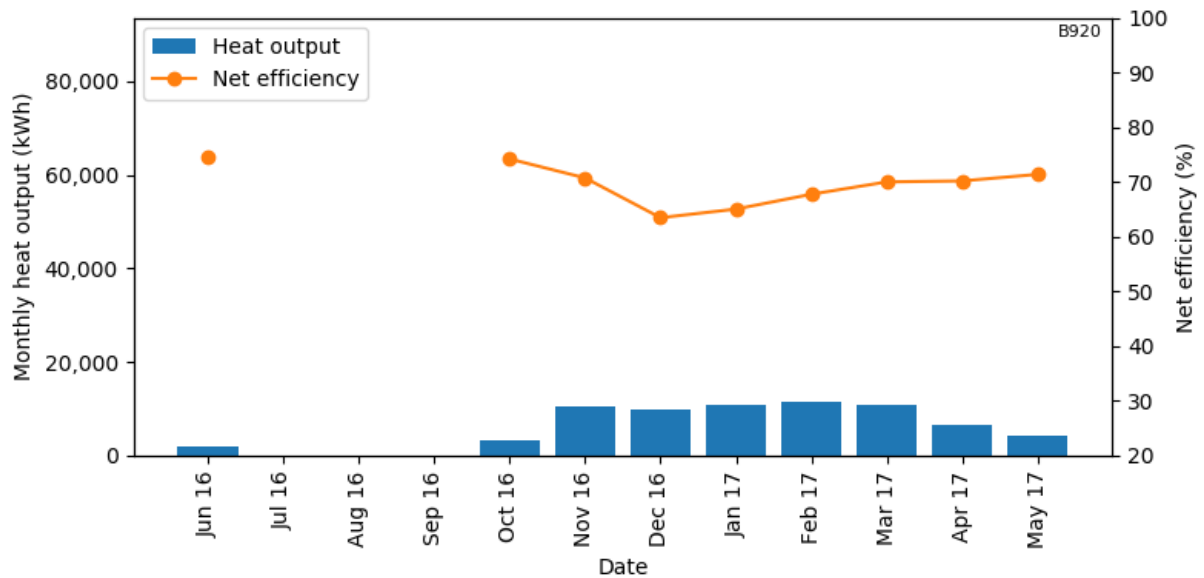
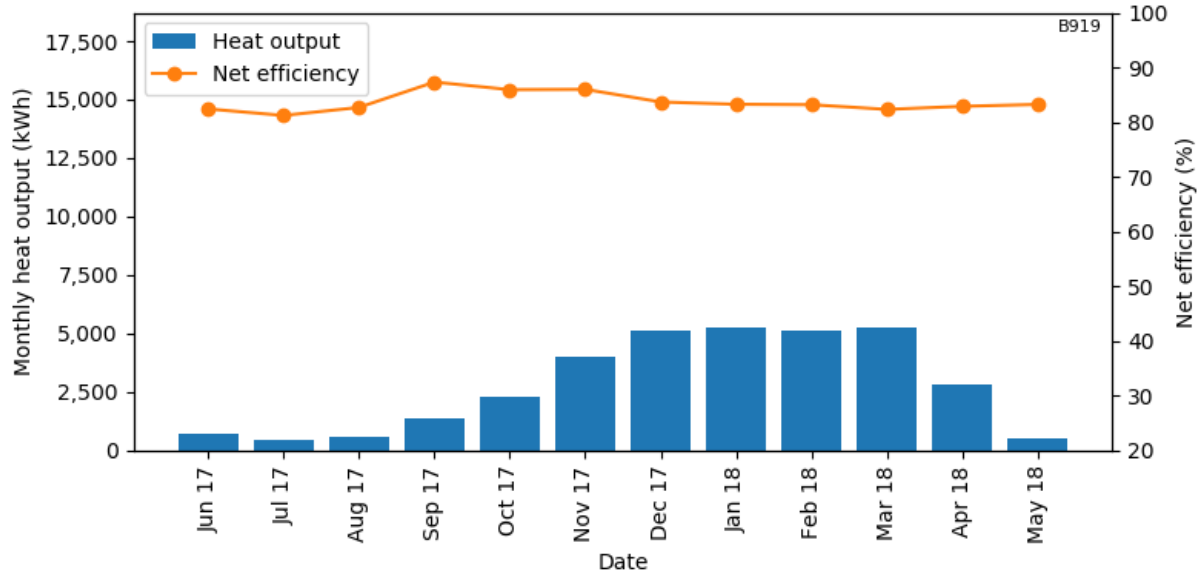


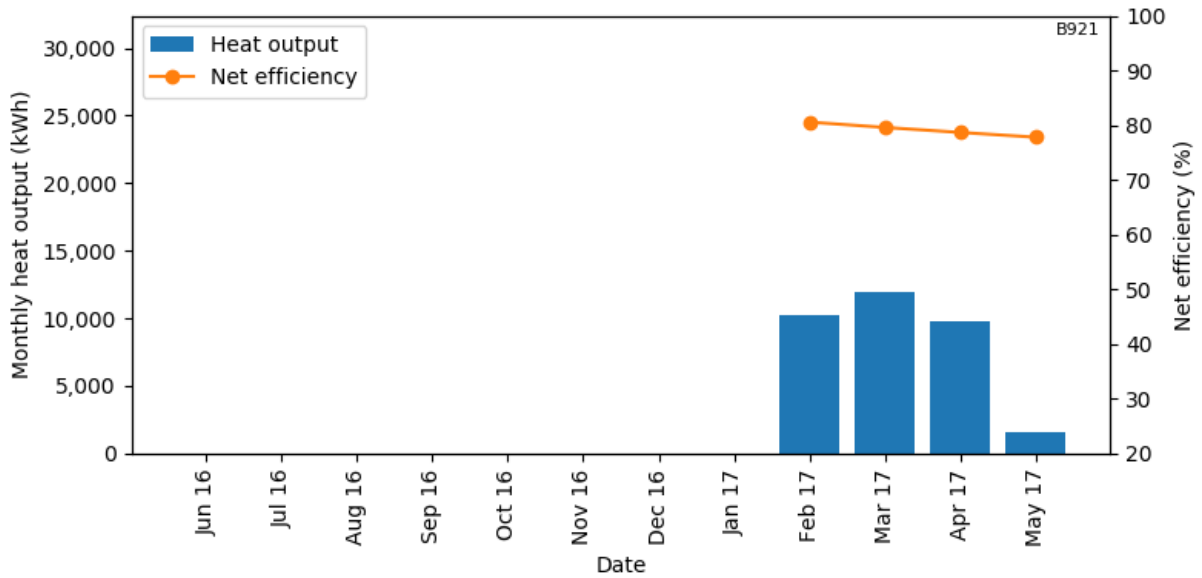
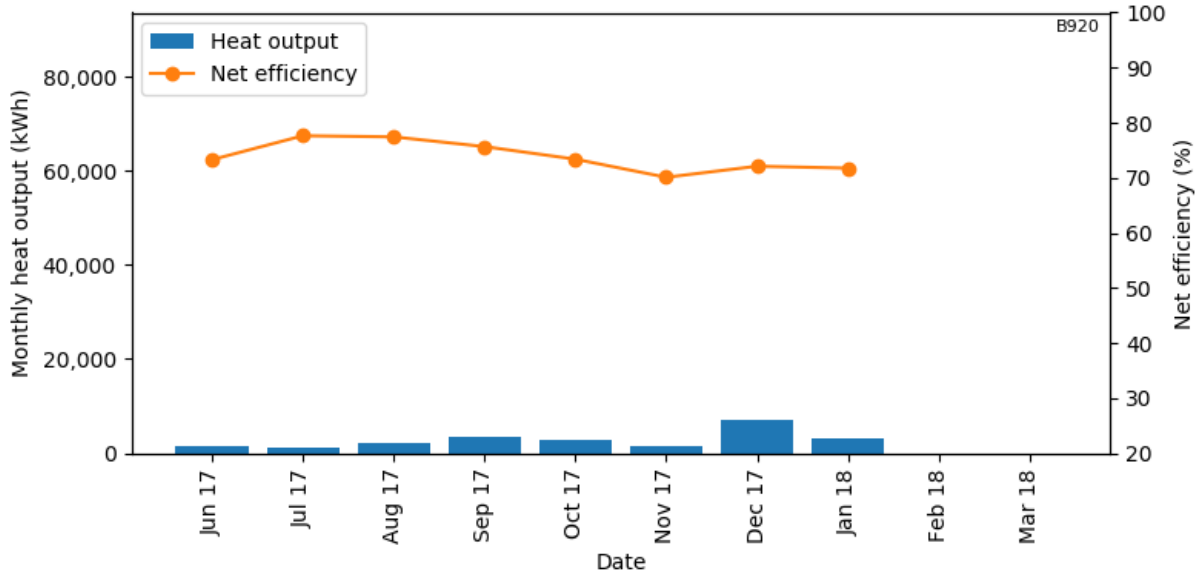


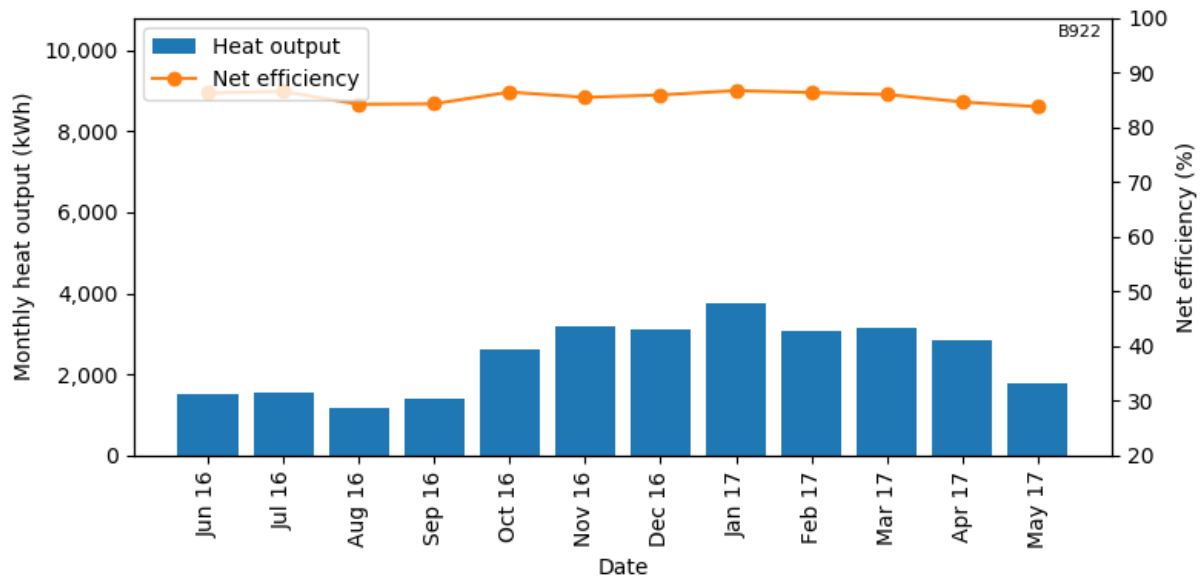
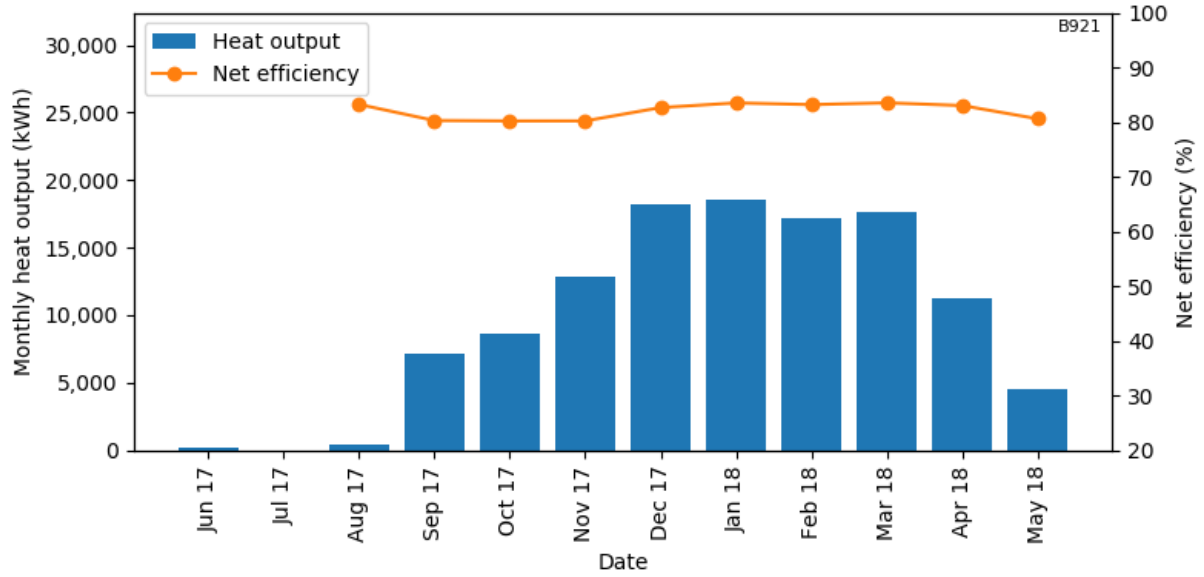


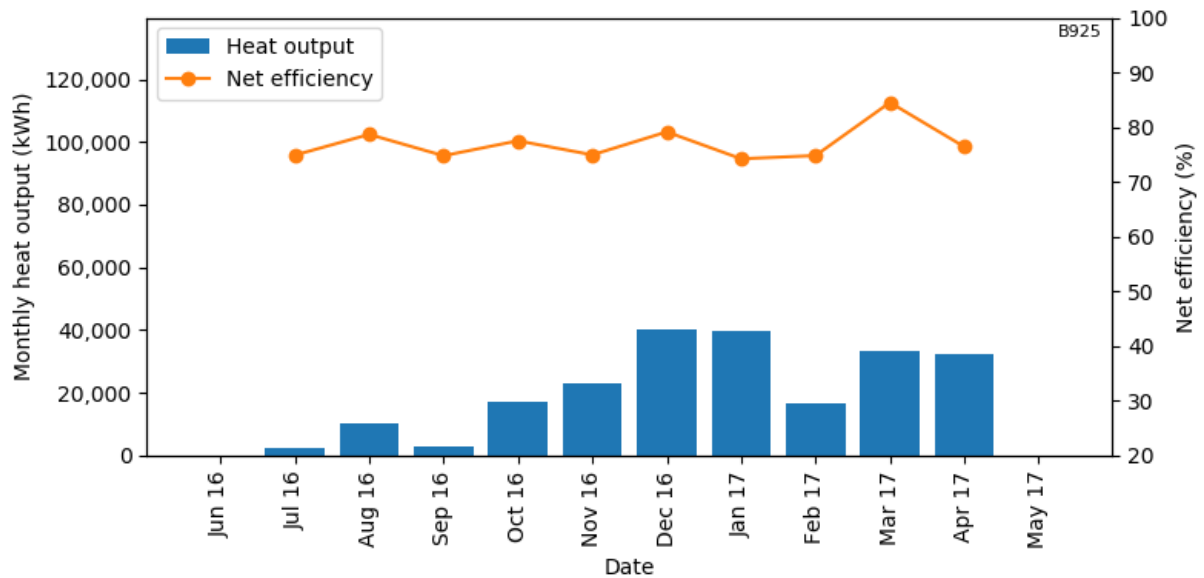
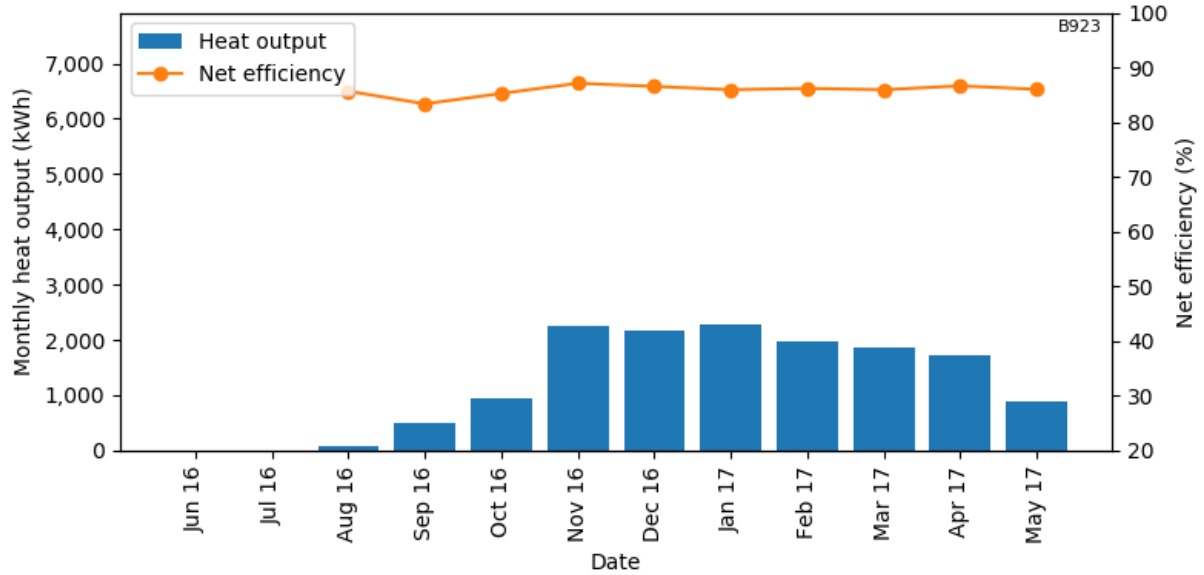


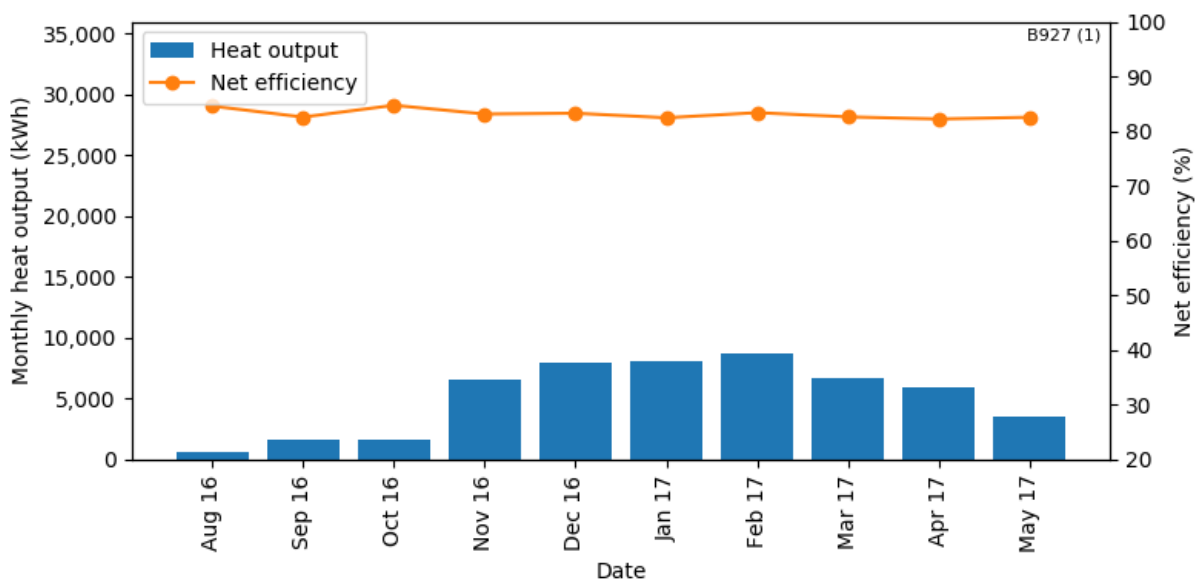
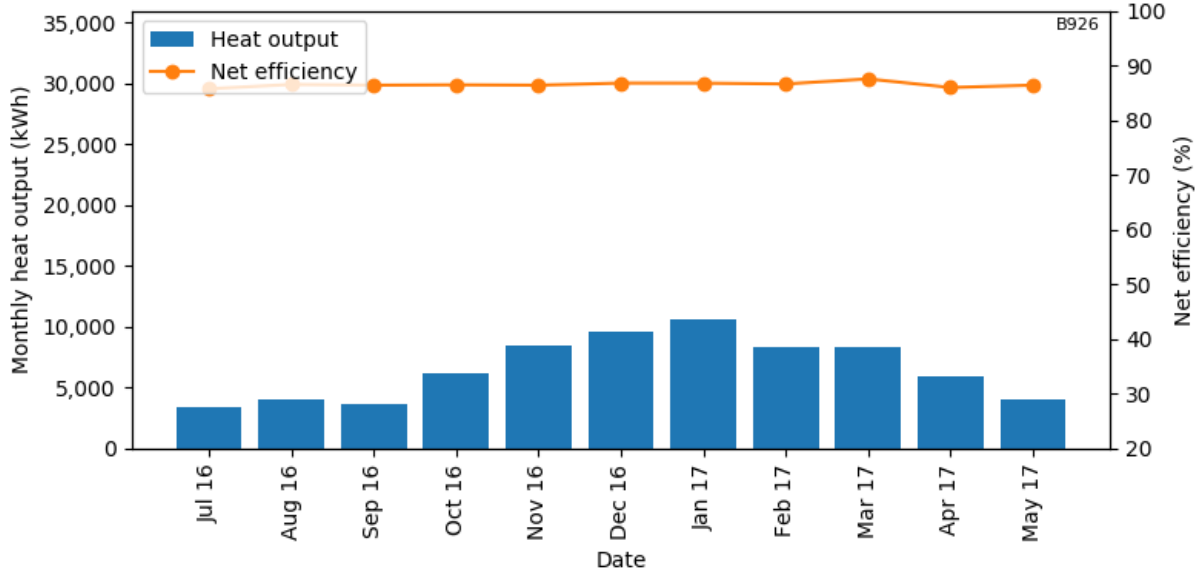


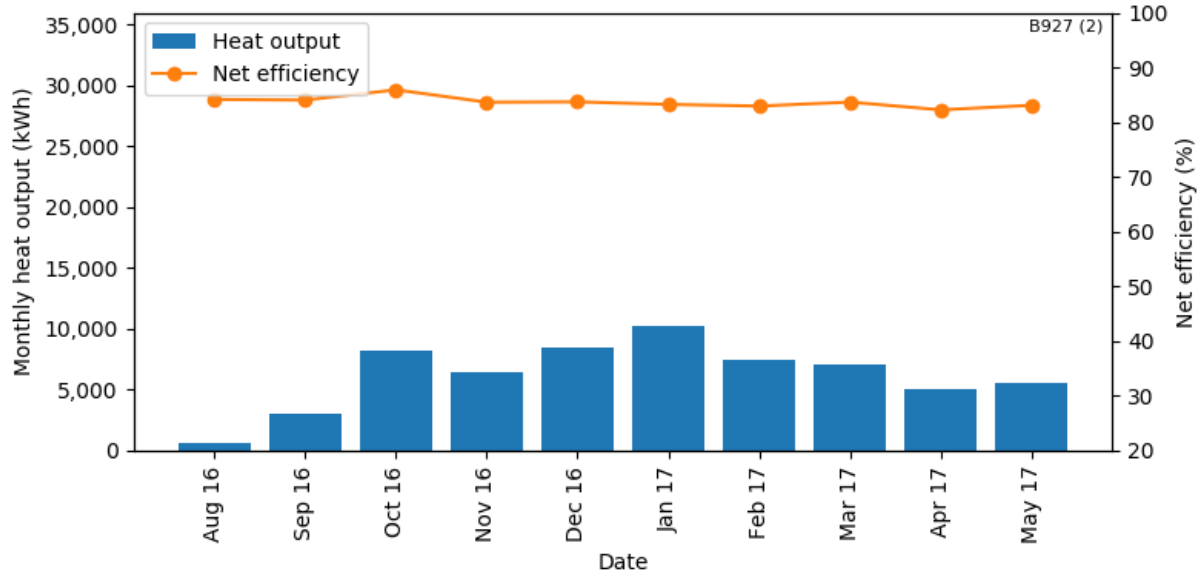










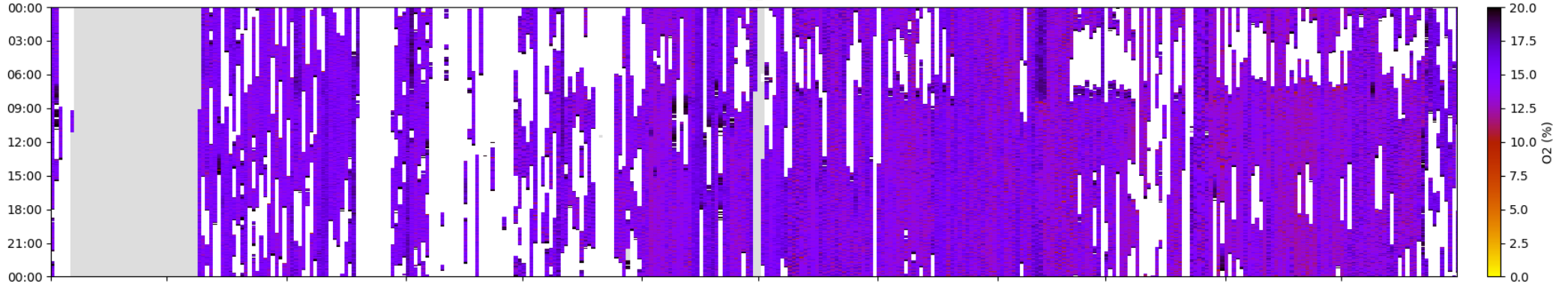


4 Oxygen, flue temperature and heat output tapestries

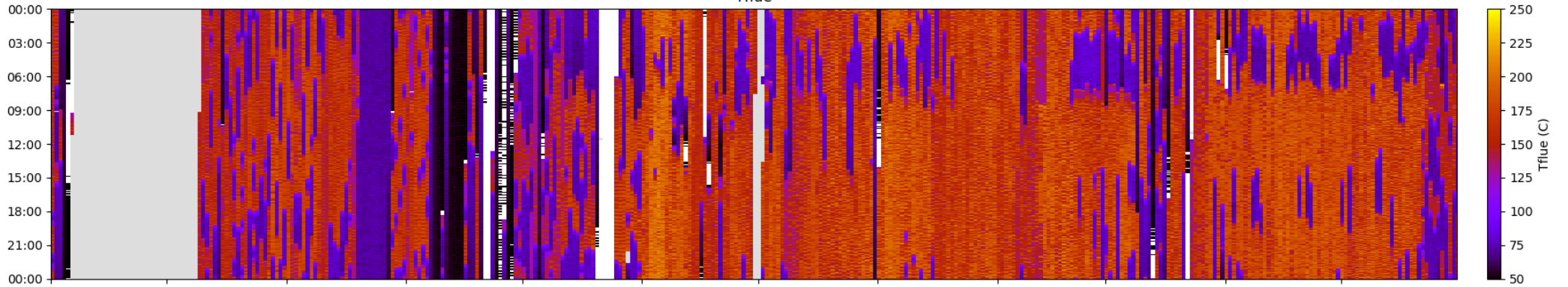


First Year Tapestries B001 (1)

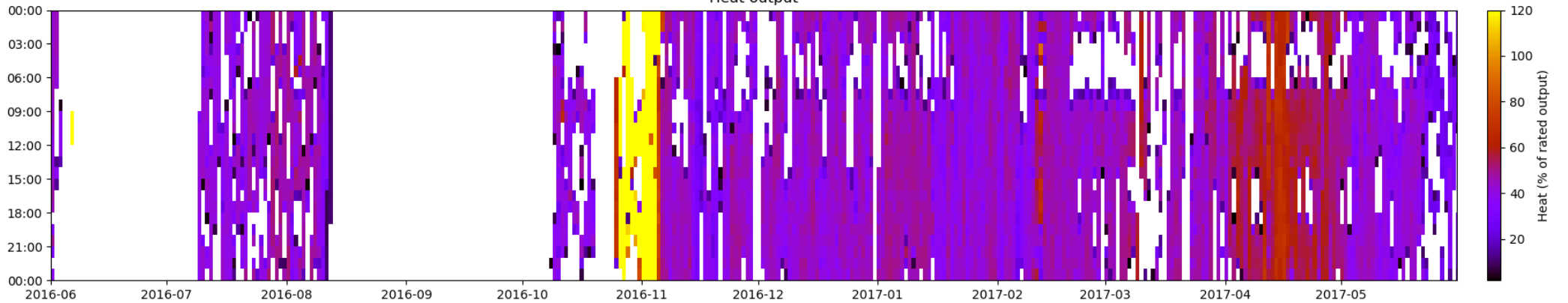
O2



Tflue

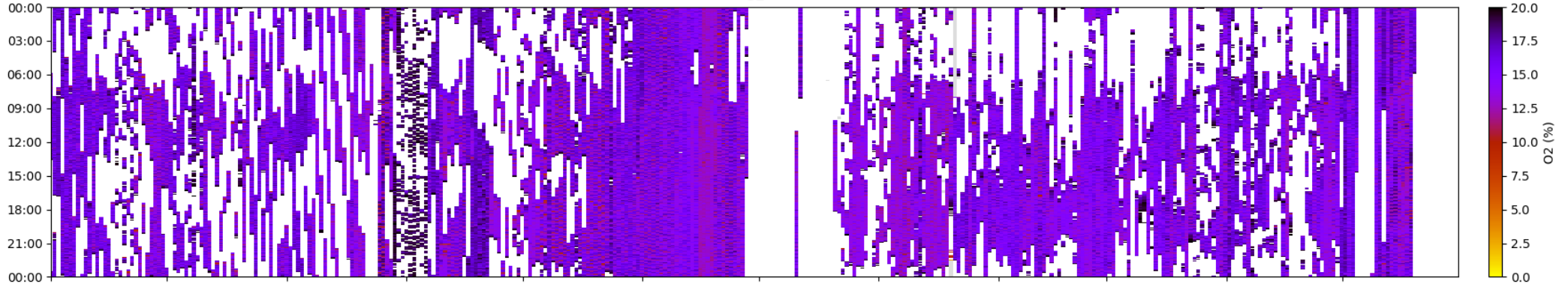


Heat output

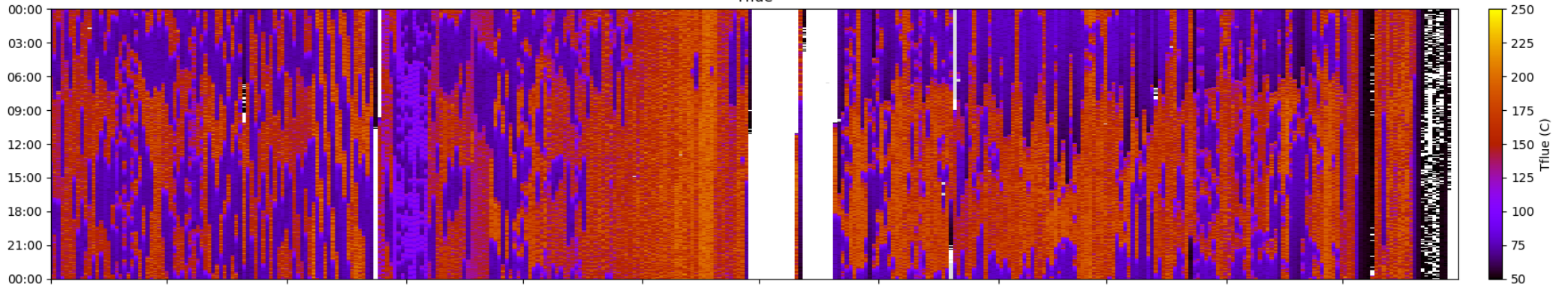


Second Year Tapestries B001 (1)

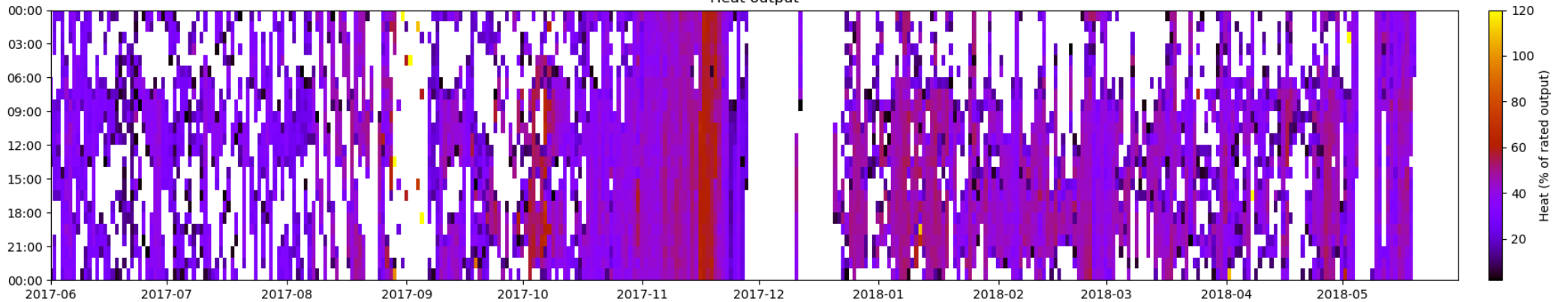
O2



Tflue

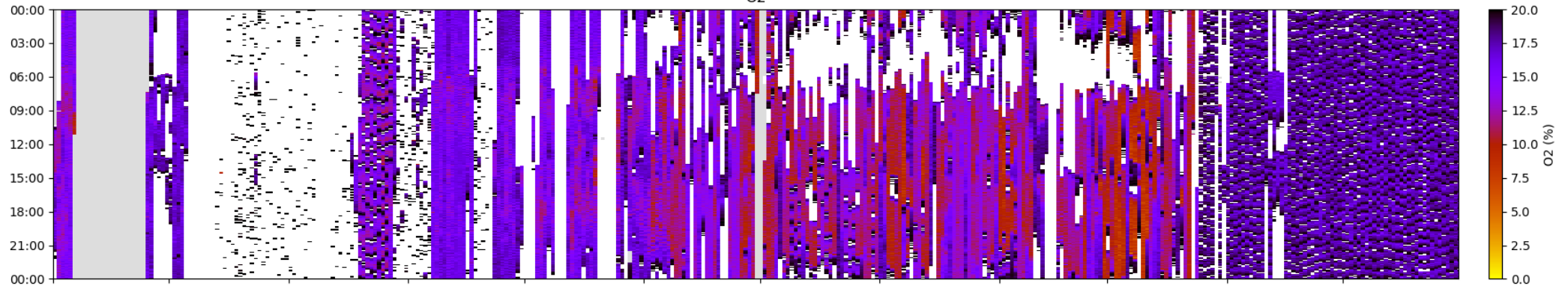


Heat output

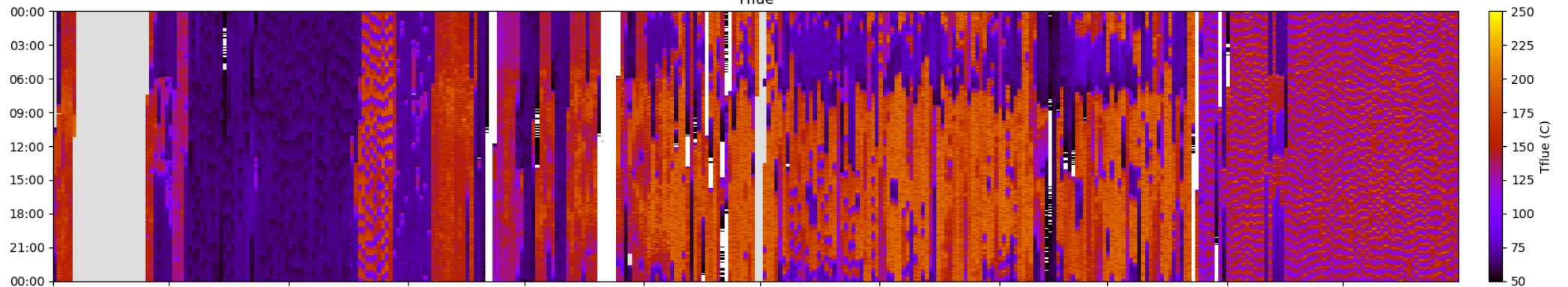


First Year Tapestries B001 (2)

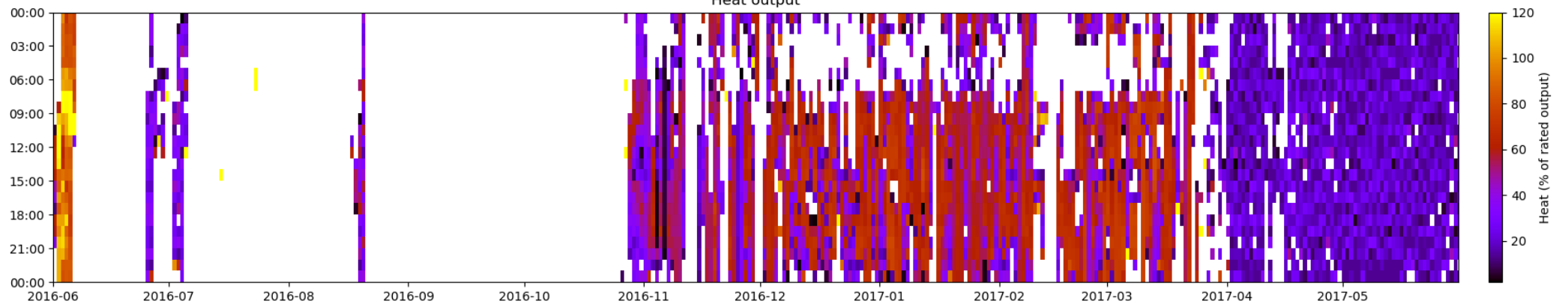
O2



Tflue

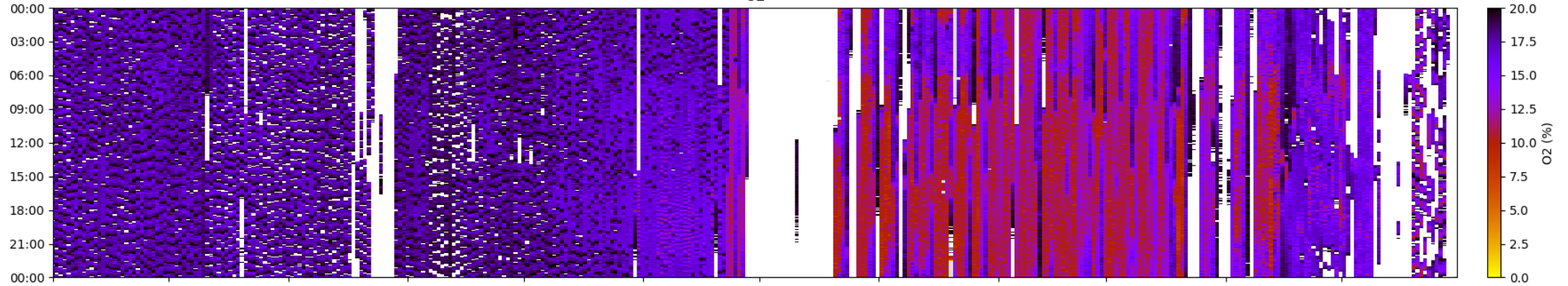


Heat output

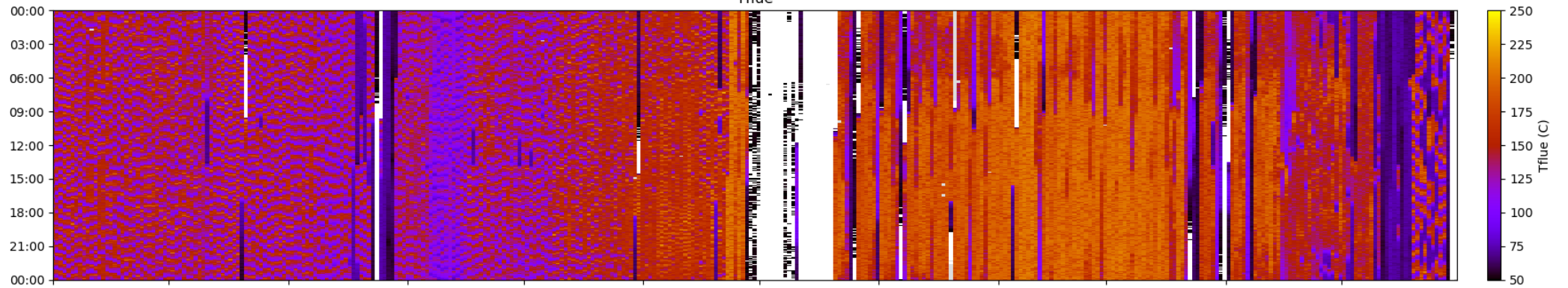


Second Year Tapestries B001 (2)

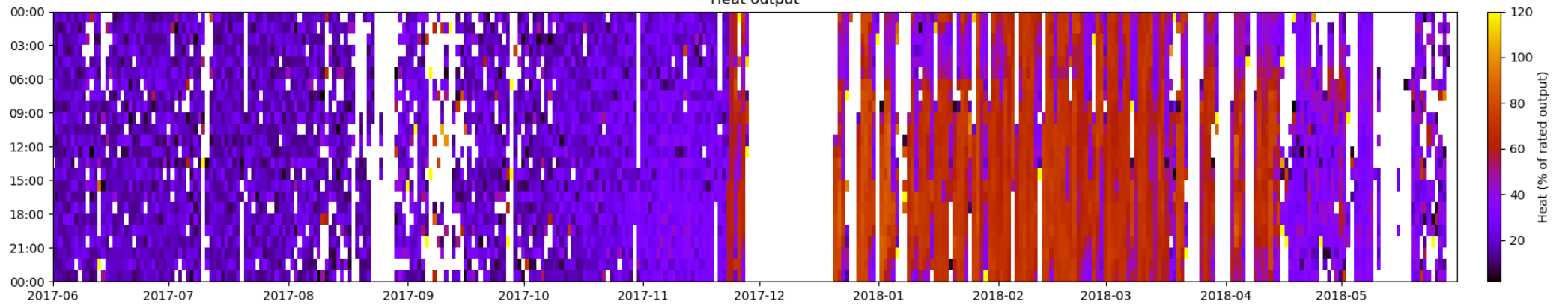
O2



Tflue

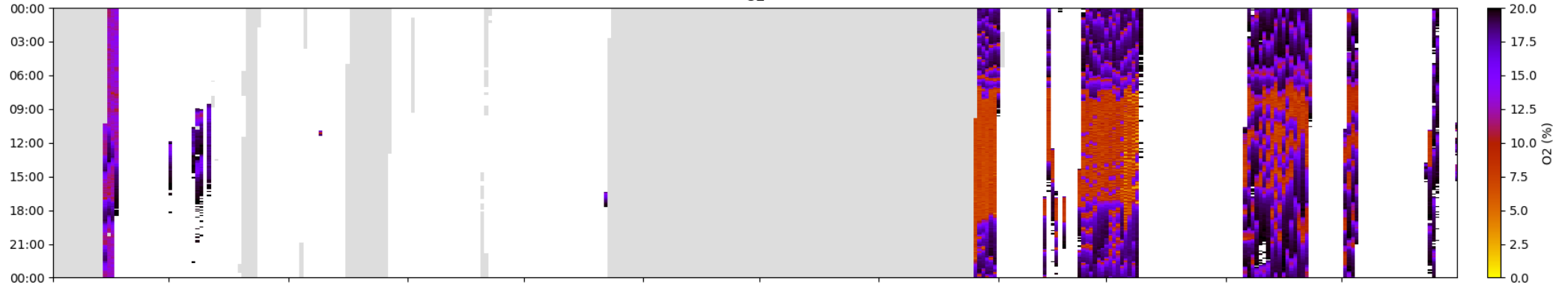


Heat output

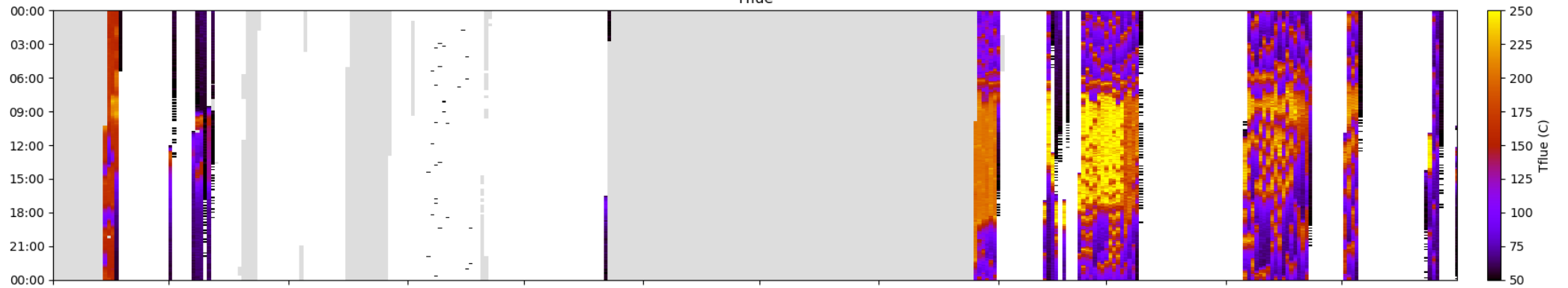


First Year Tapestries B005

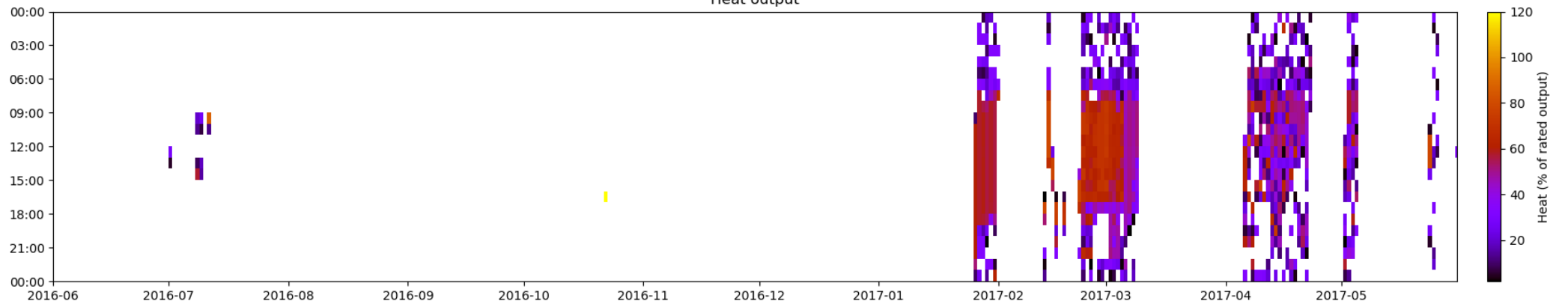
O2



Tflue

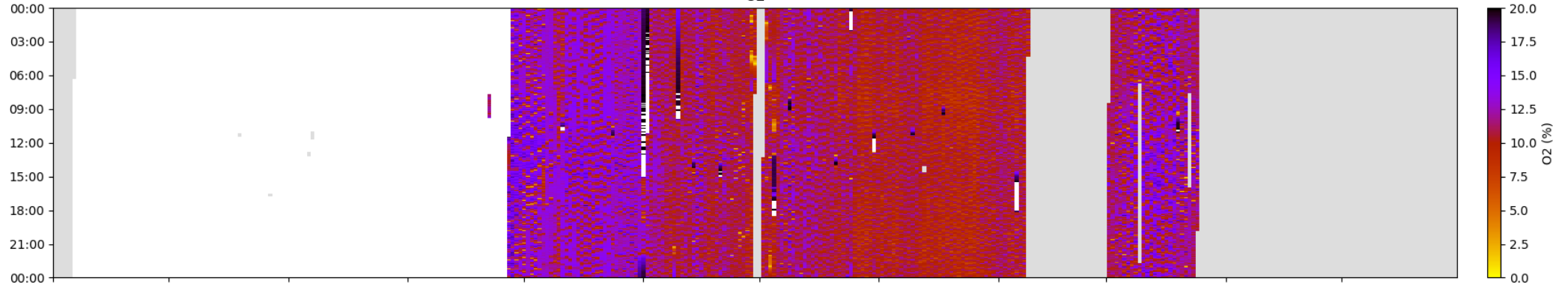


Heat output

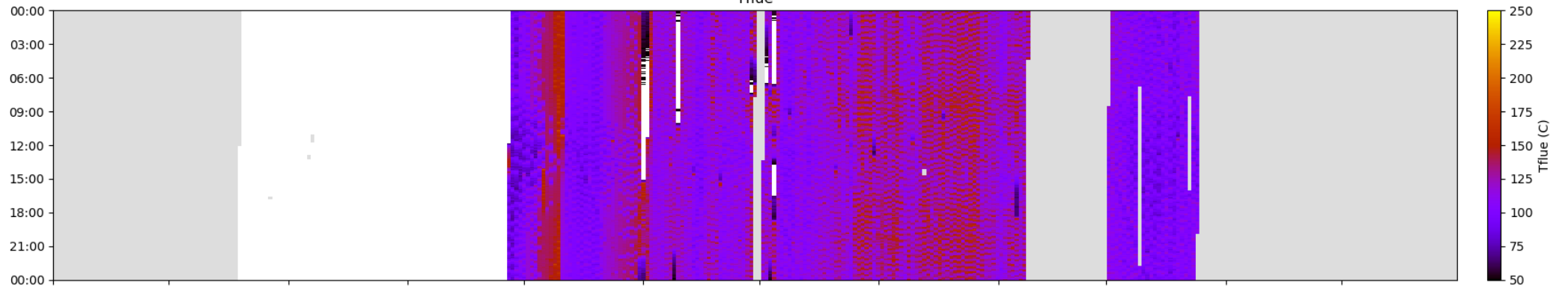


First Year Tapestries B013

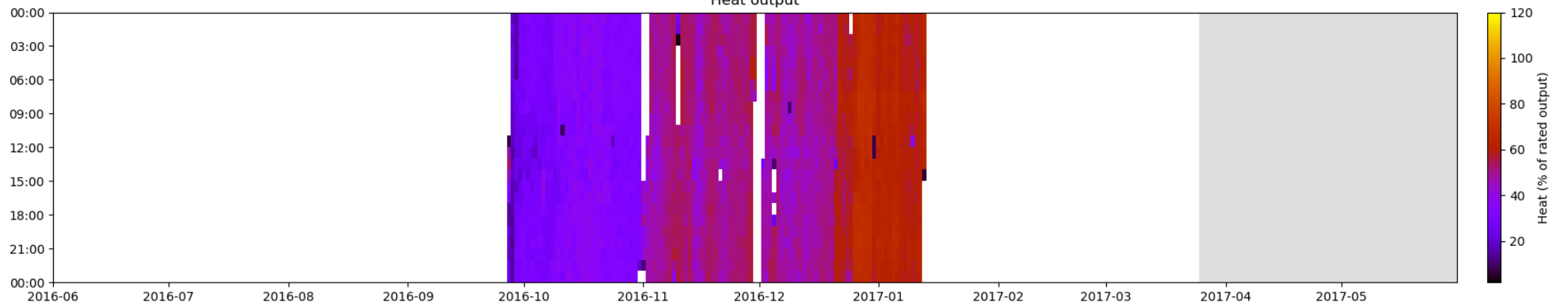
O2



Tflue

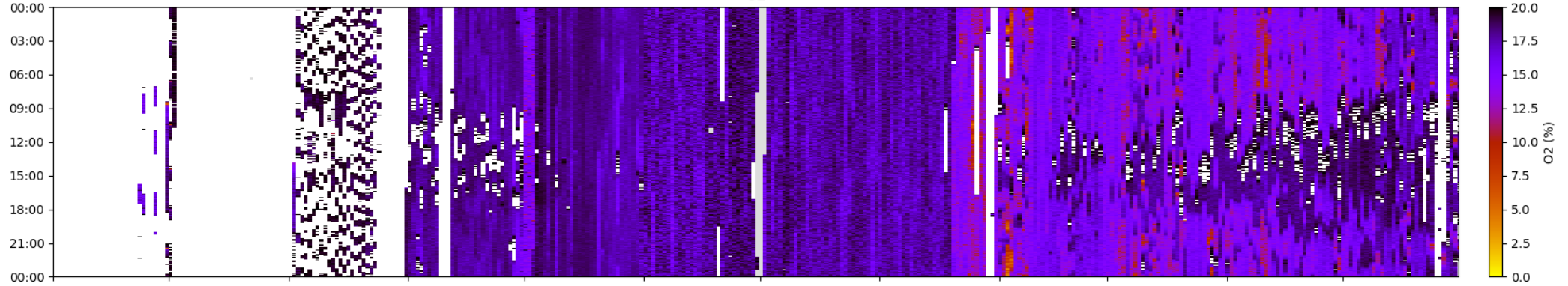


Heat output

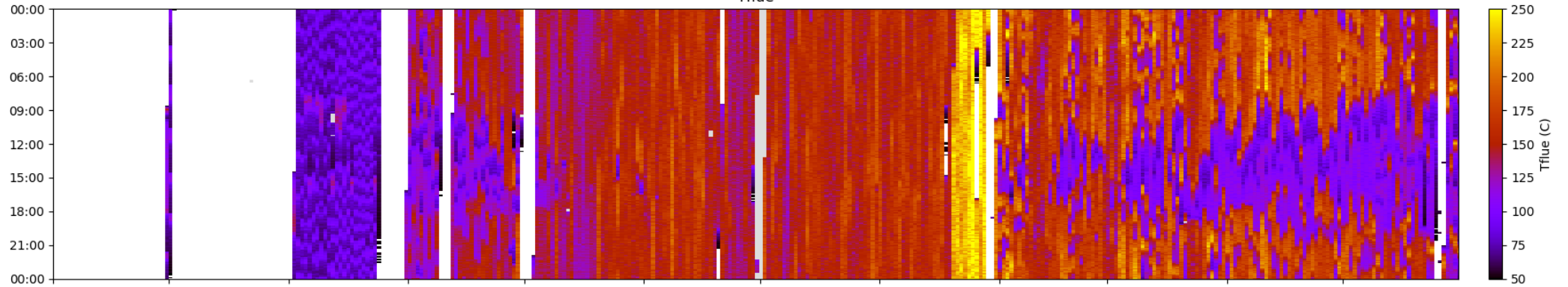


First Year Tapestries B014

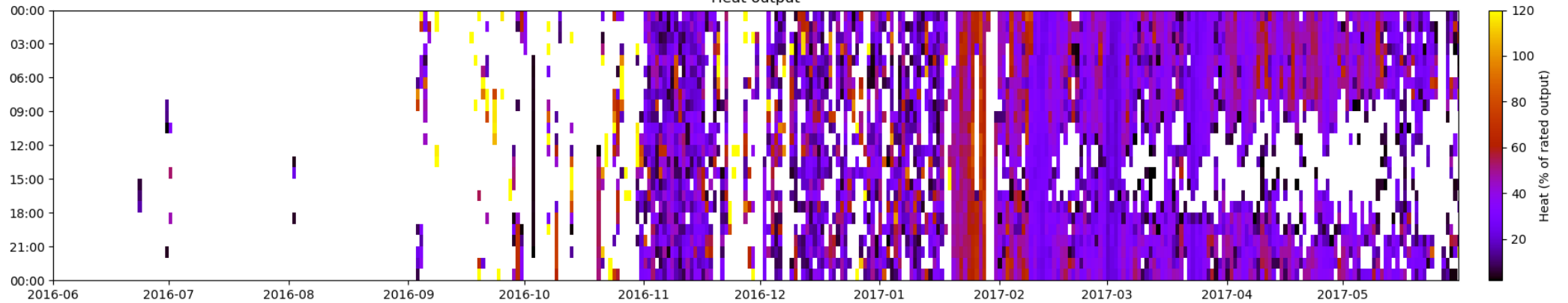
O2



Tflue

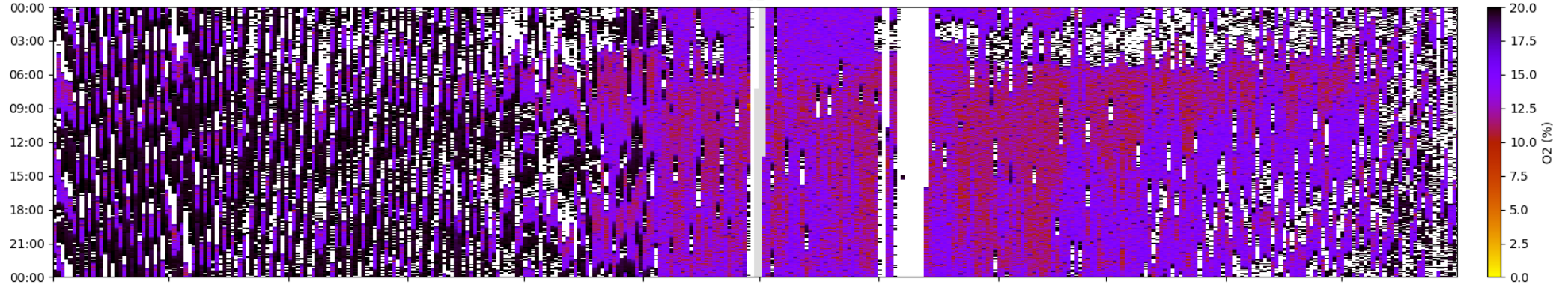


Heat output

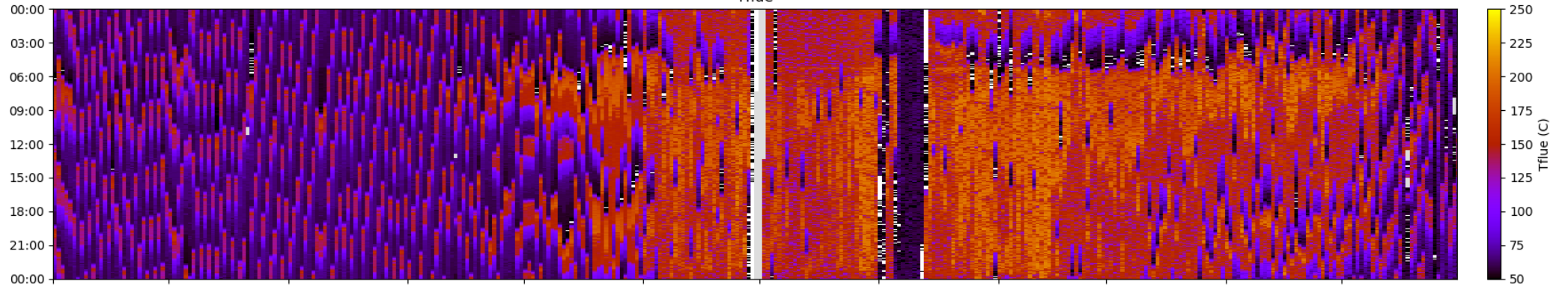


First Year Tapestries B046

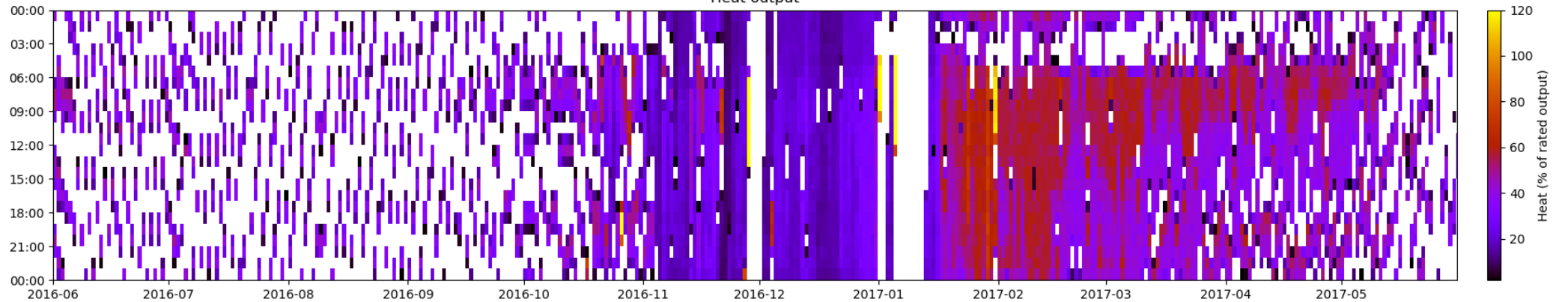
O2



Tflue

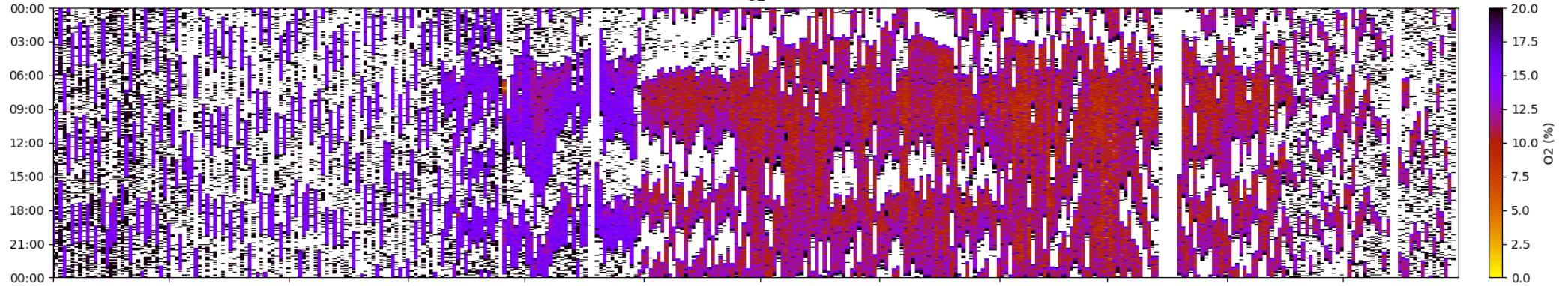


Heat output

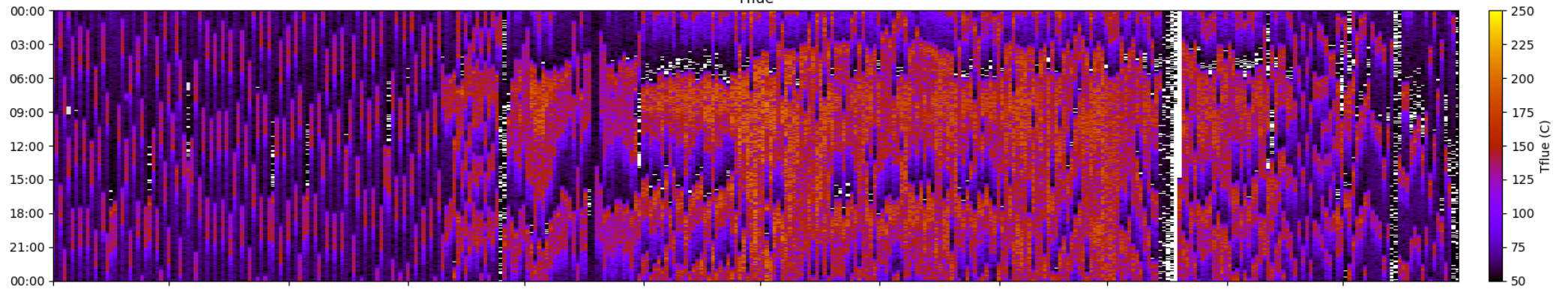


Second Year Tapestries B046

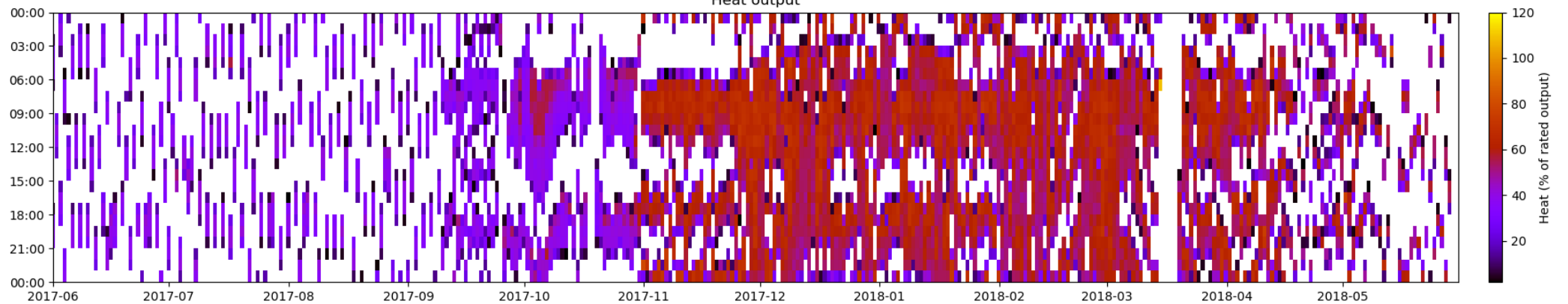
O2



Tflue

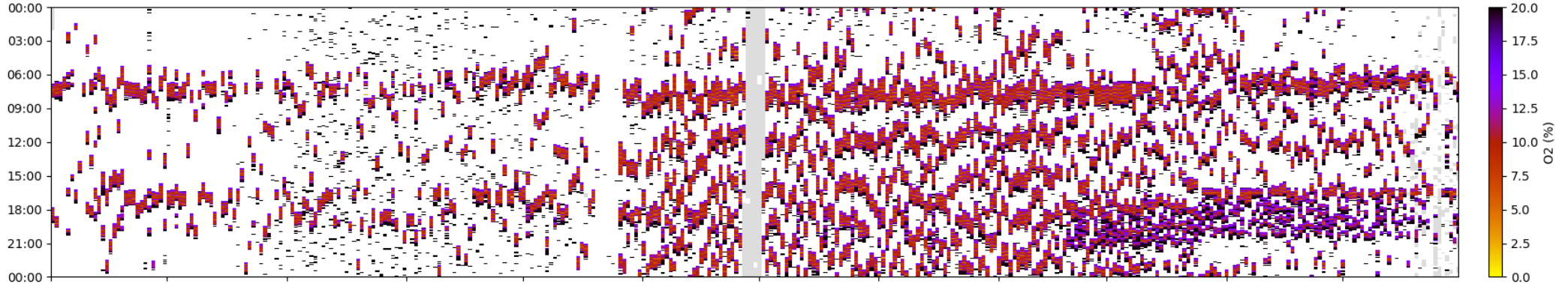


Heat output

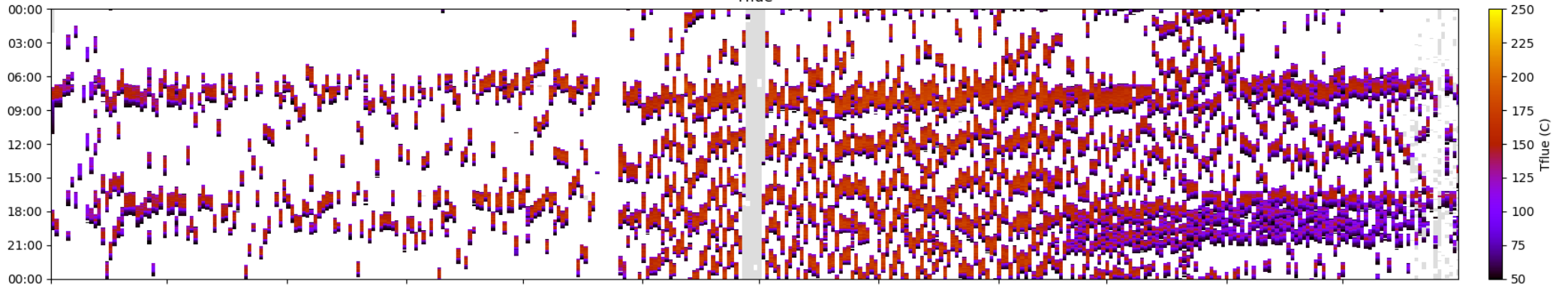


First Year Tapestries B055

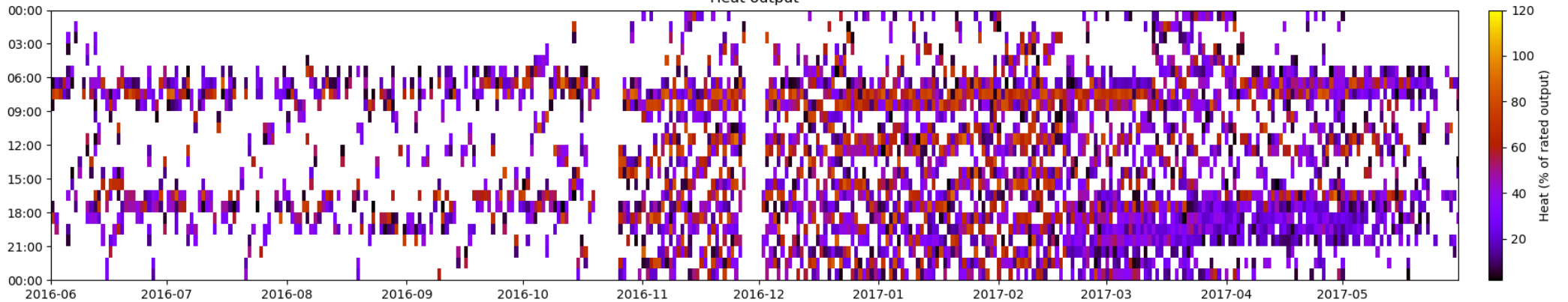
O2



Tflue

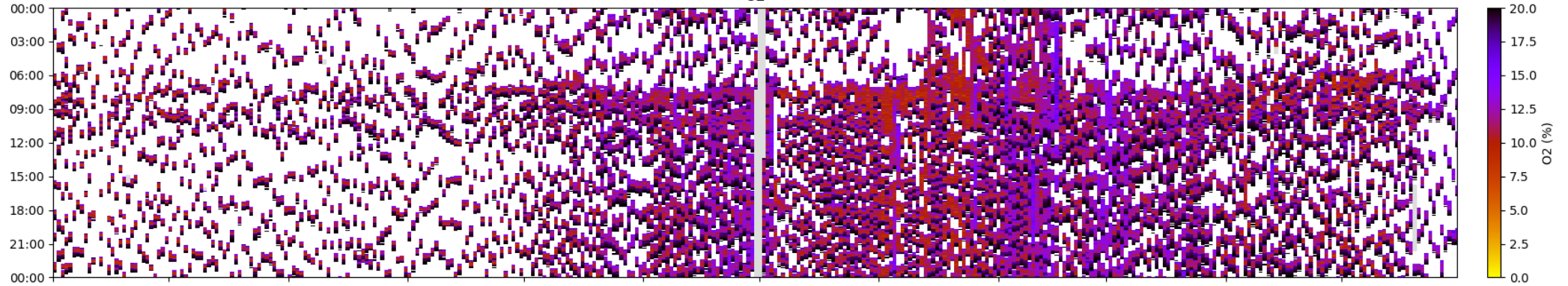


Heat output

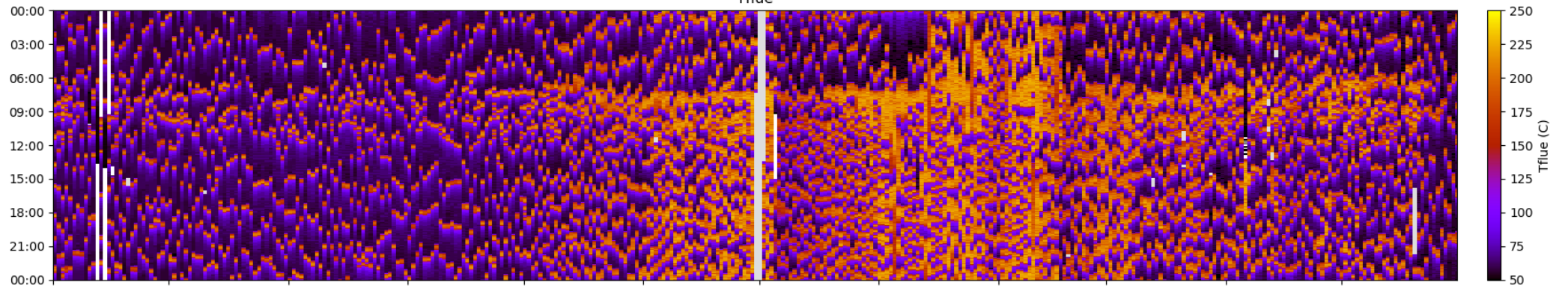


First Year Tapestries B069

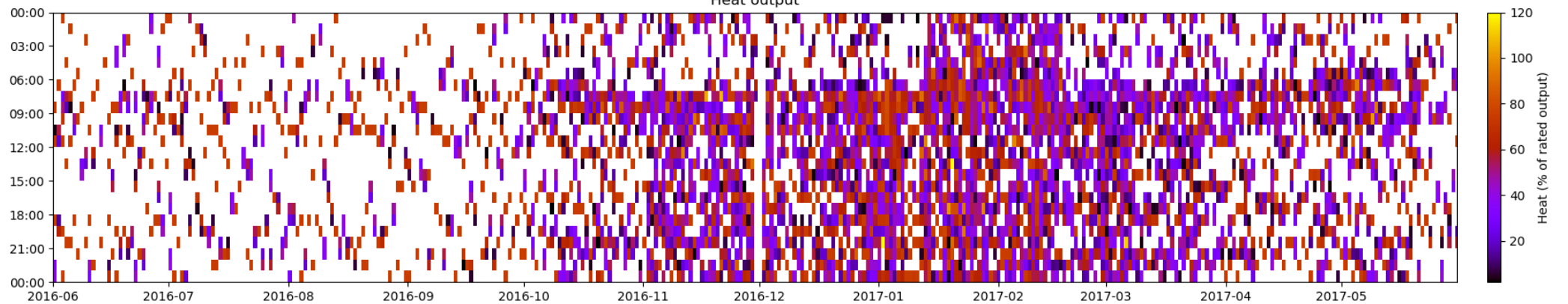
O2



Tflue

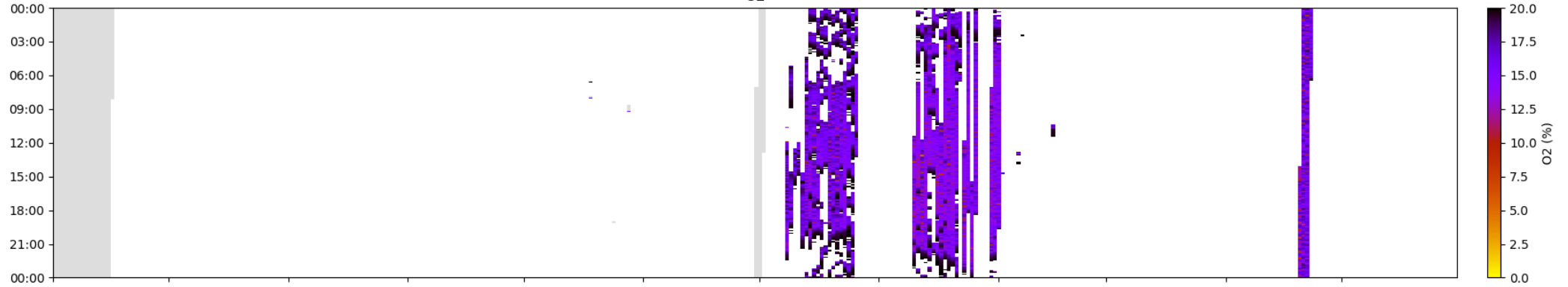


Heat output

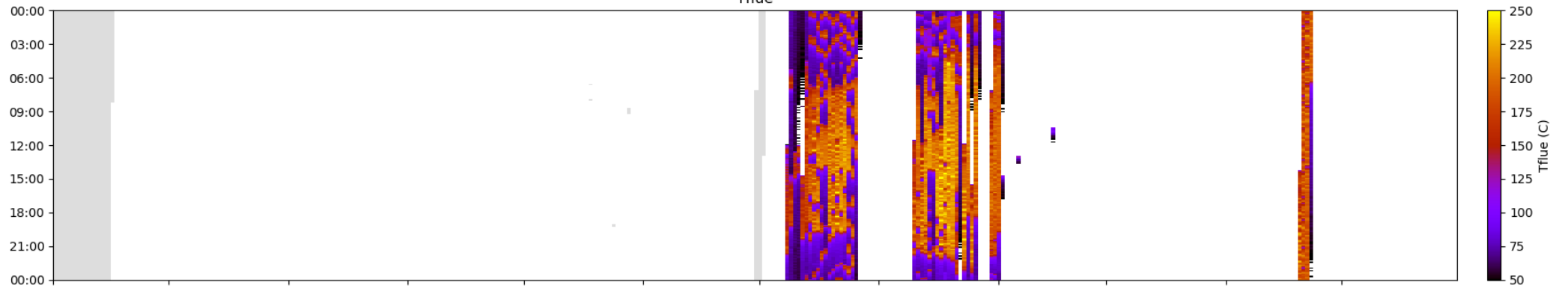


First Year Tapestries B076

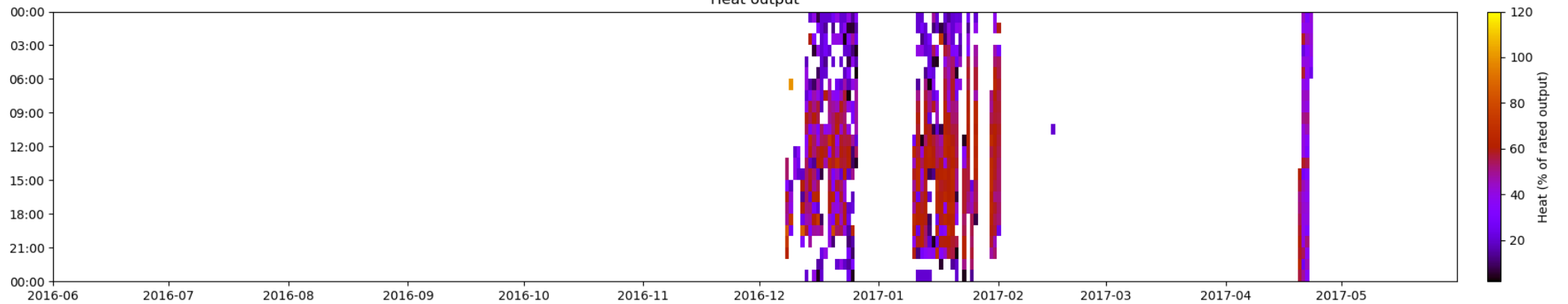
O2



Tflue

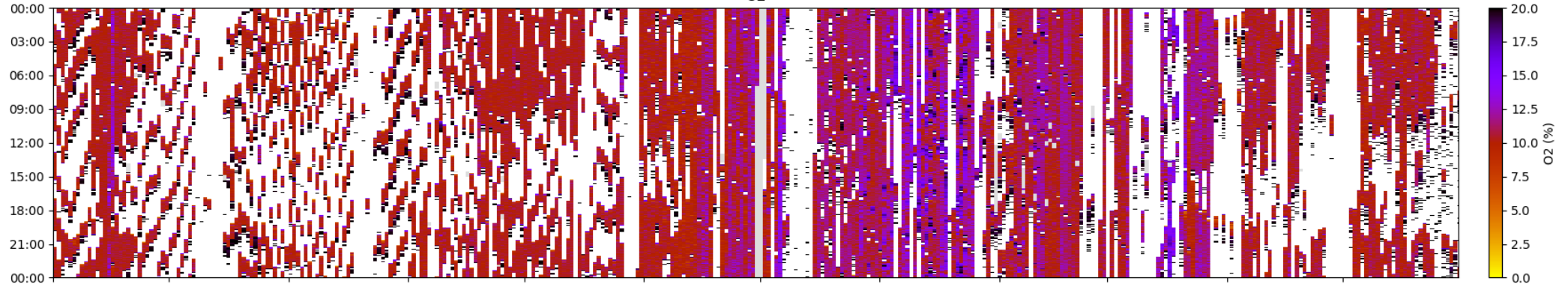


Heat output

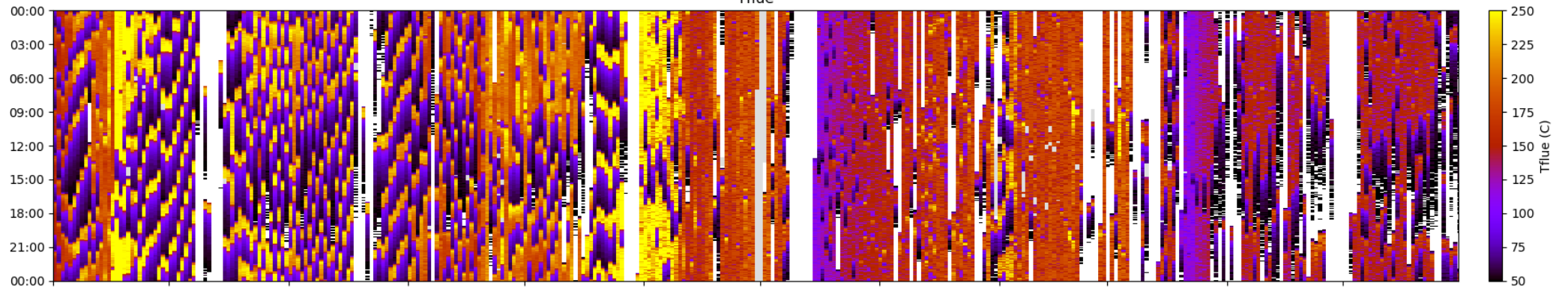


First Year Tapestries B081

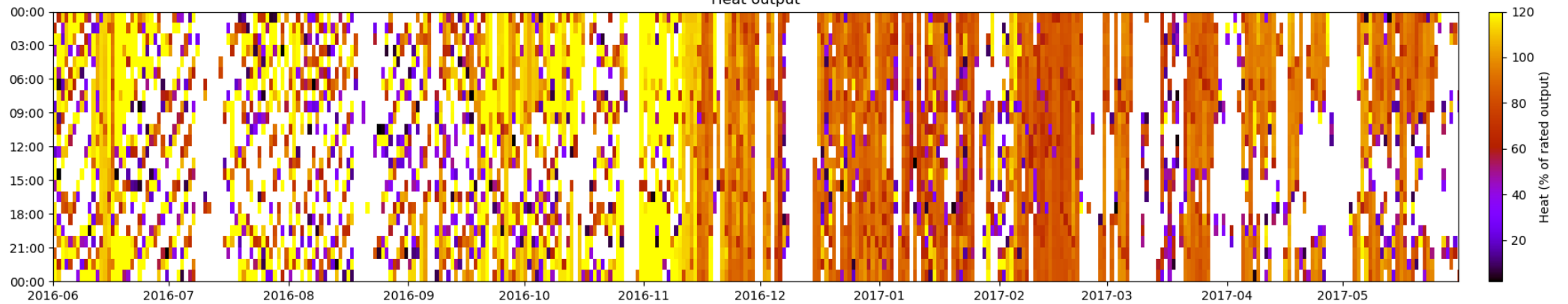
O2



Tflue

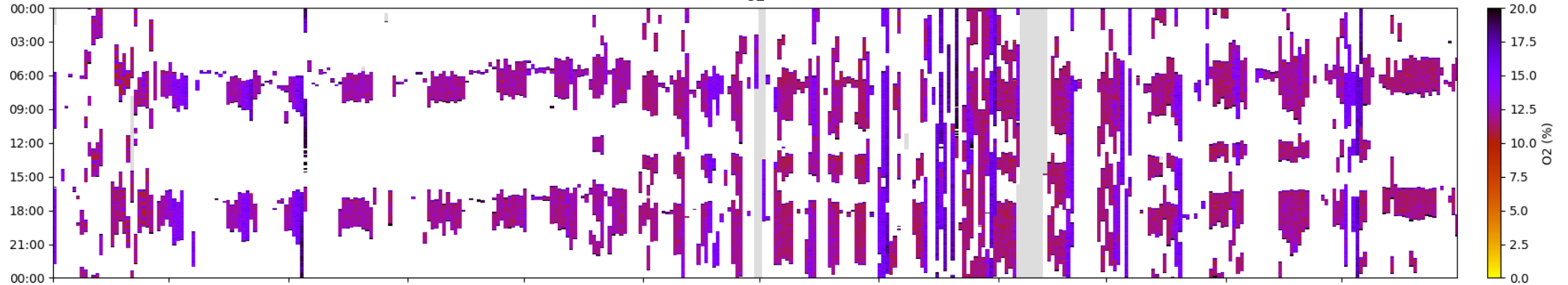


Heat output

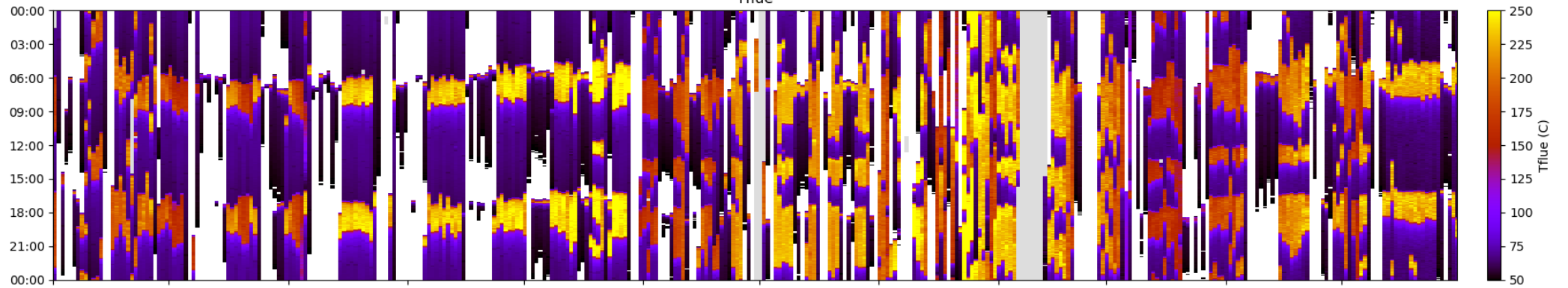


First Year Tapestries B112 (1)

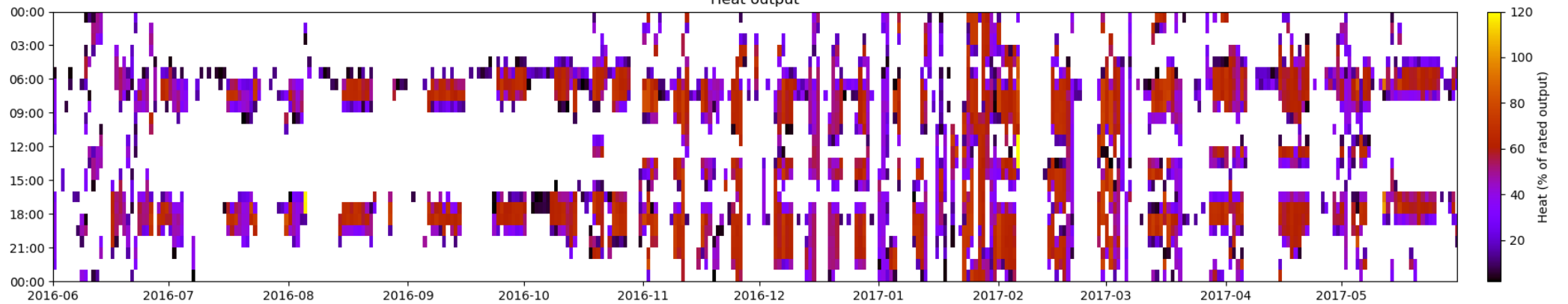
O₂



T_{flue}

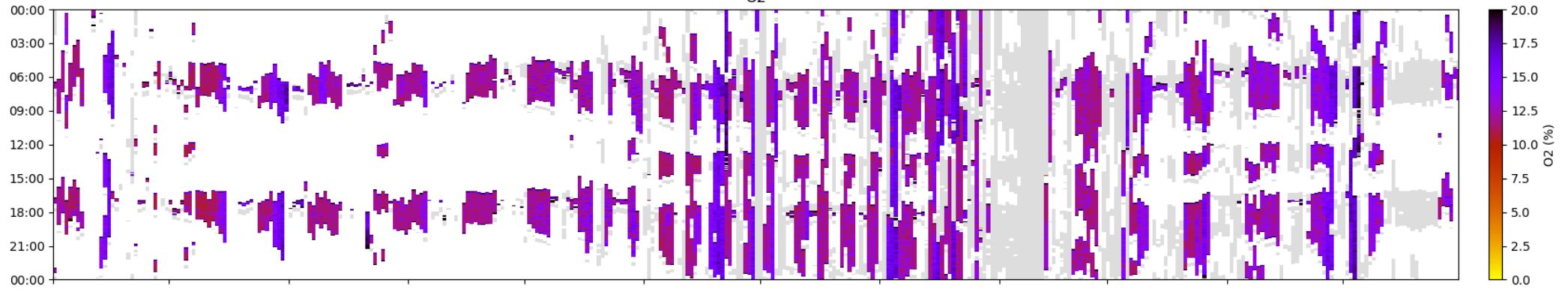


Heat output

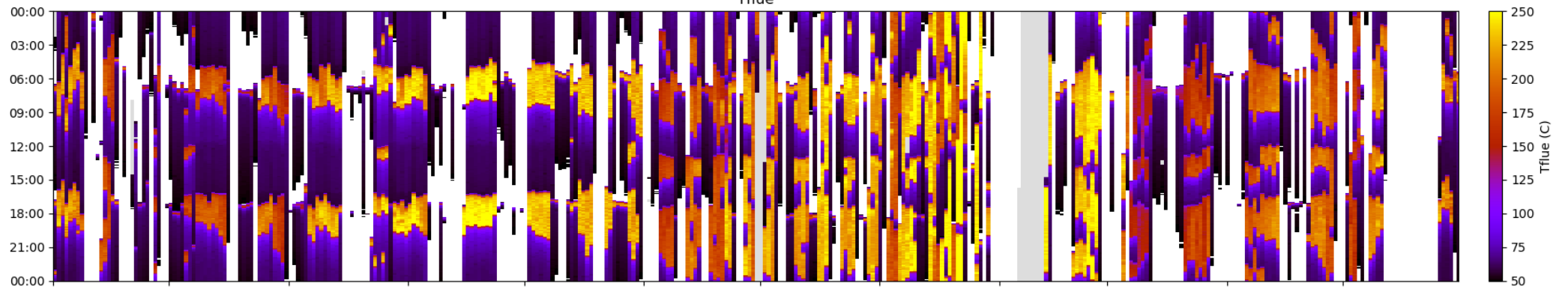


First Year Tapestries B112 (2)

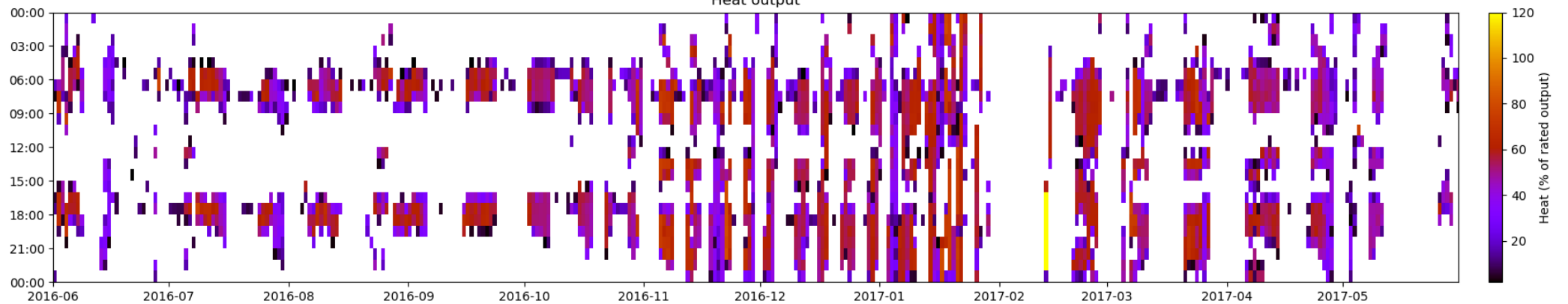
O2



Tflue

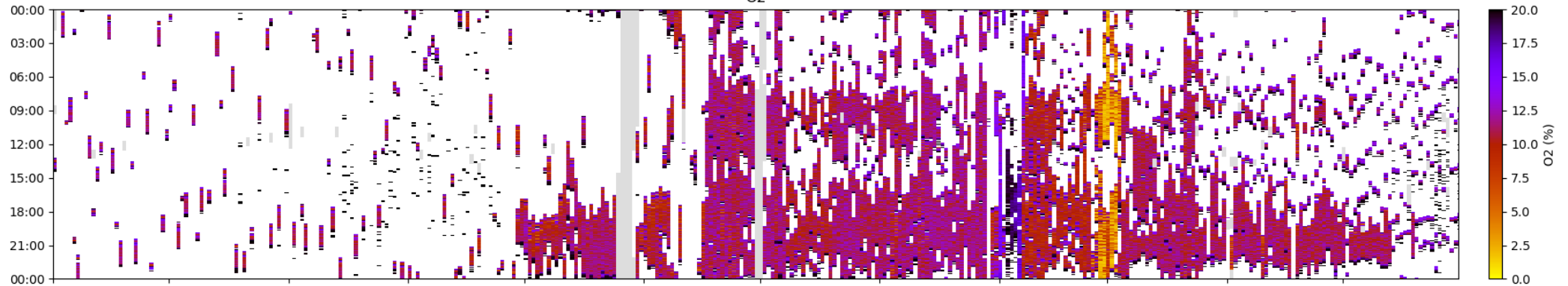


Heat output

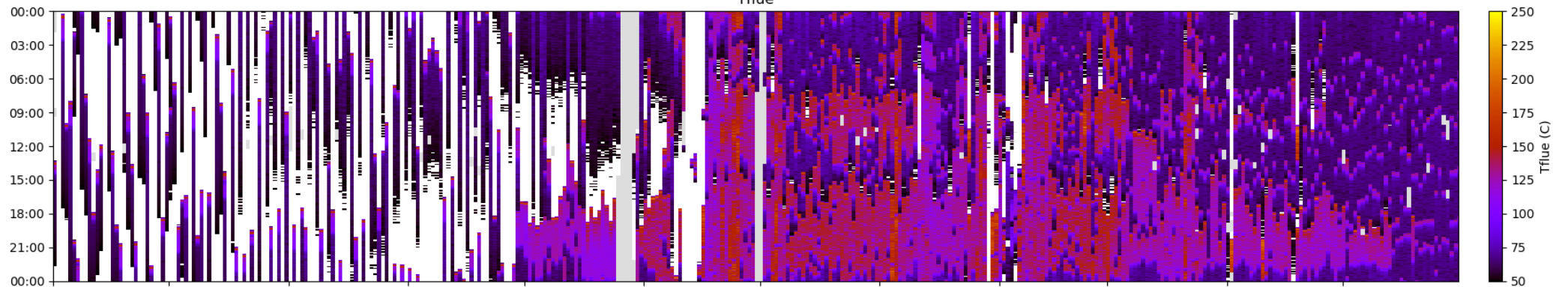


First Year Tapestries B127

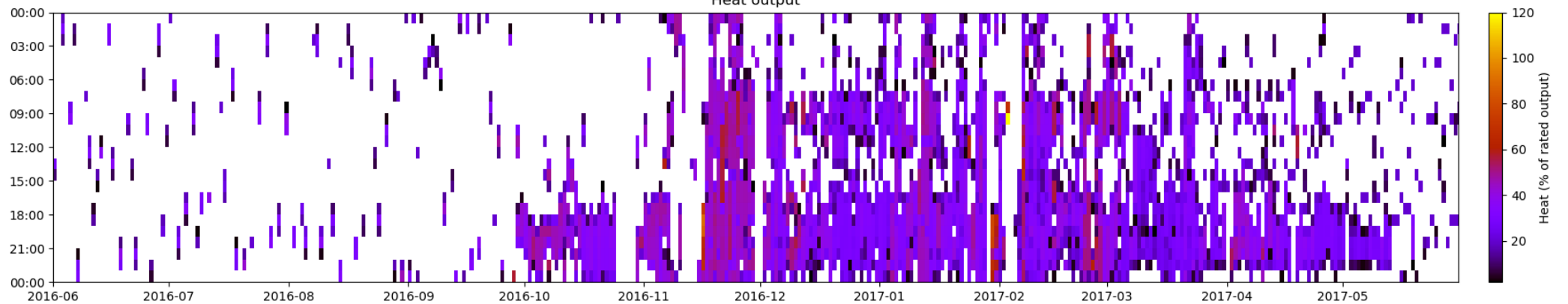
O2



Tflue

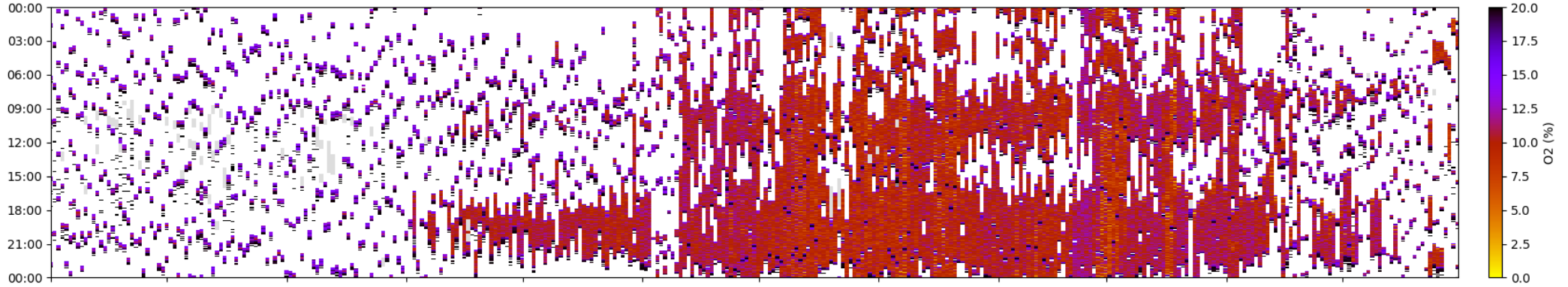


Heat output

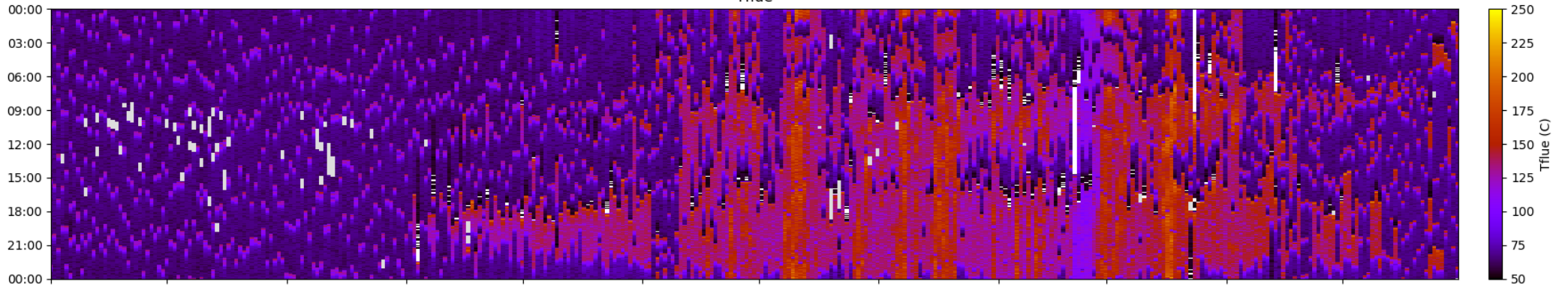


Second Year Tapestries B127

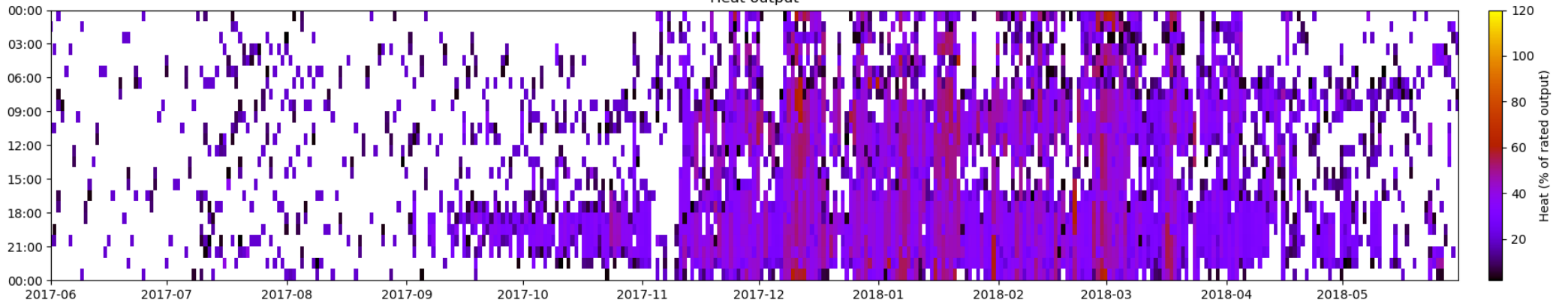
O2



Tflue

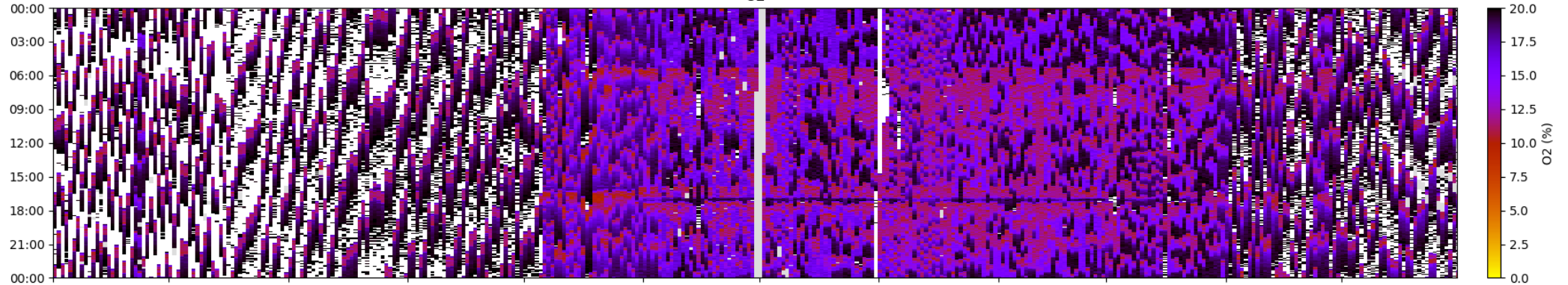


Heat output

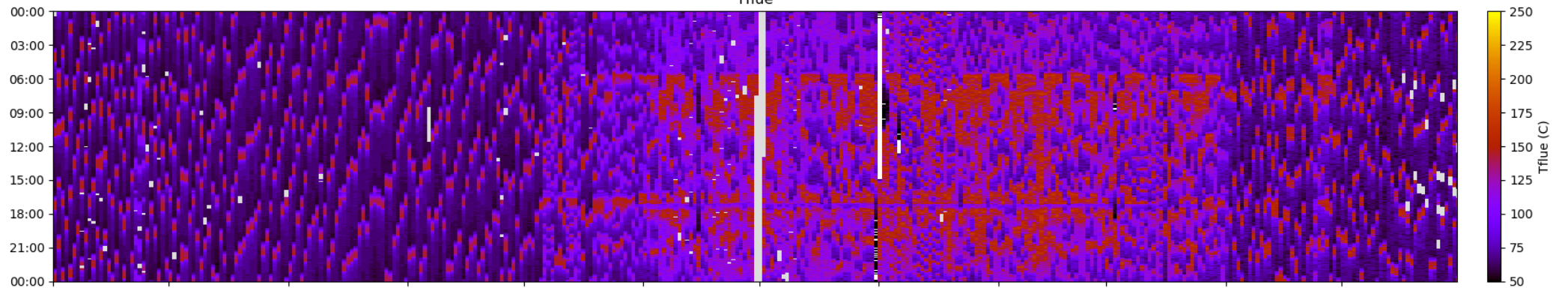


First Year Tapestries B180

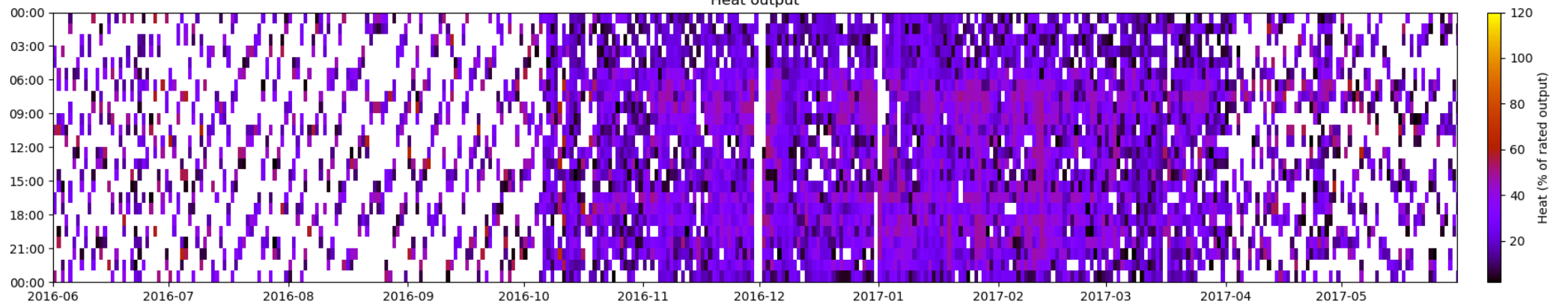
O2



Tflue

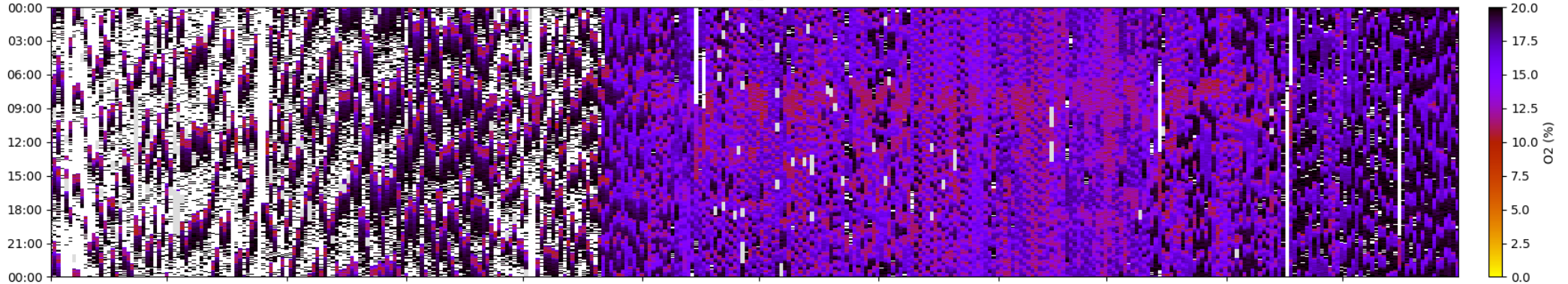


Heat output

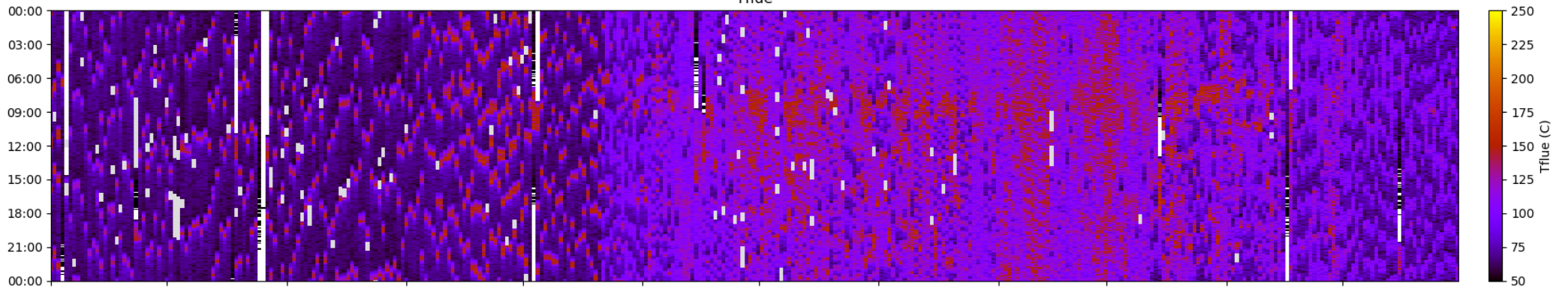


Second Year Tapestries B180

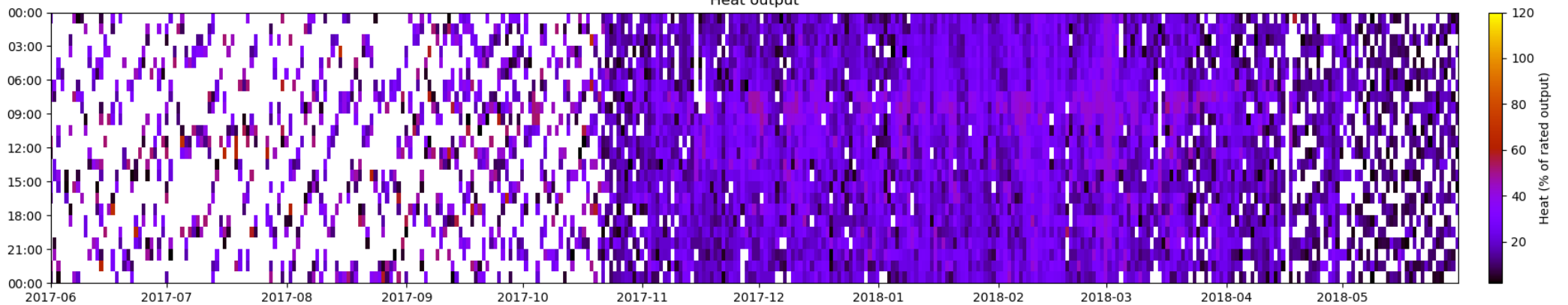
O2



Tflue

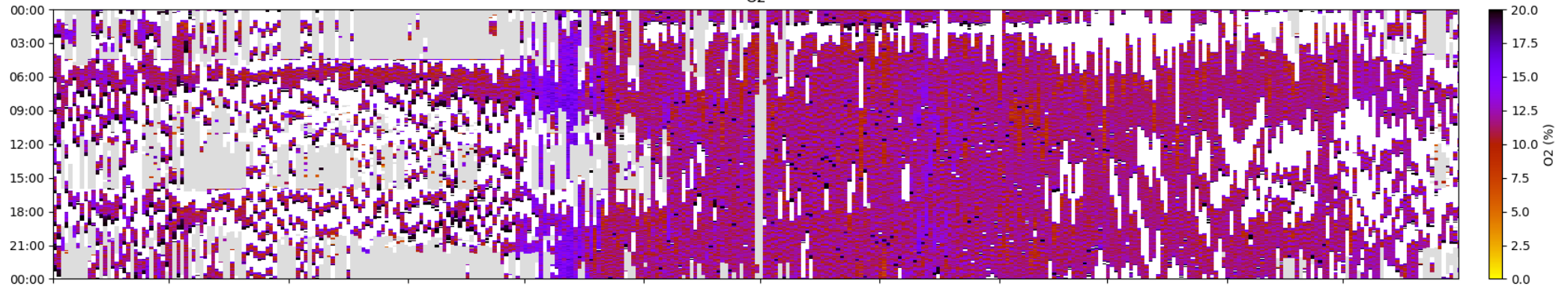


Heat output

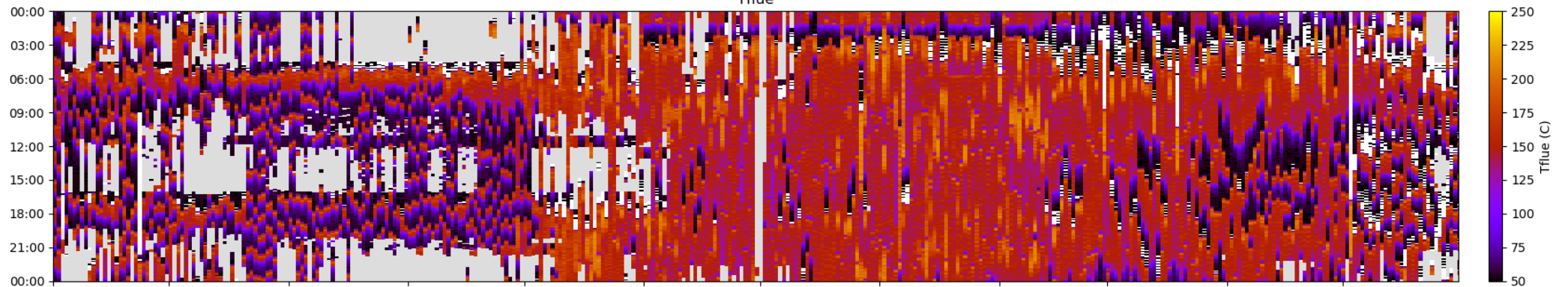


First Year Tapestries B182

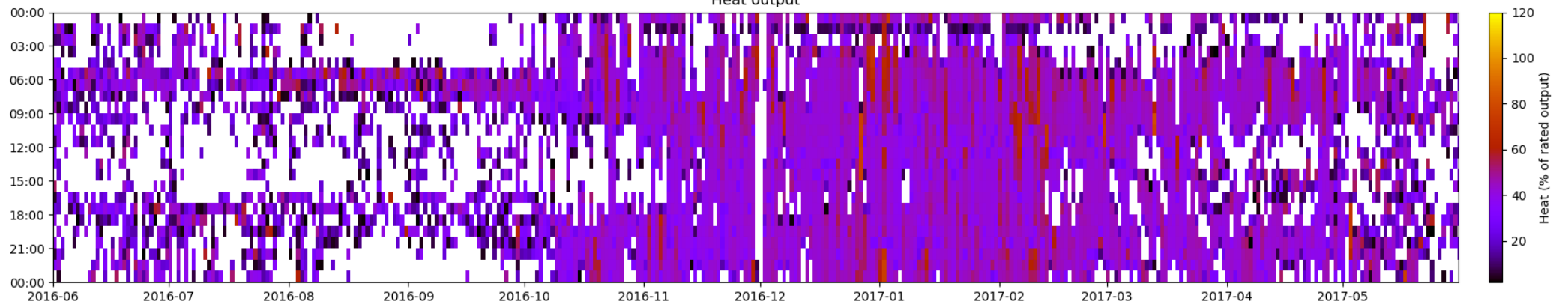
O2



Tflue

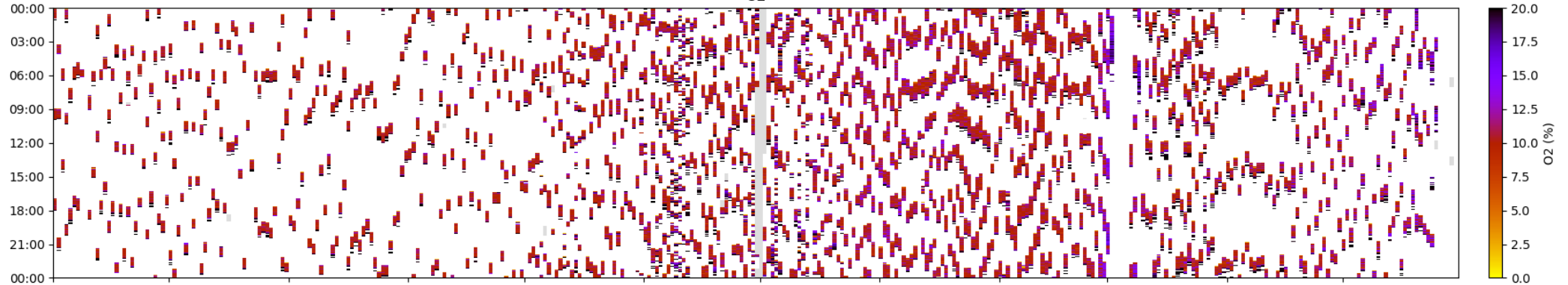


Heat output

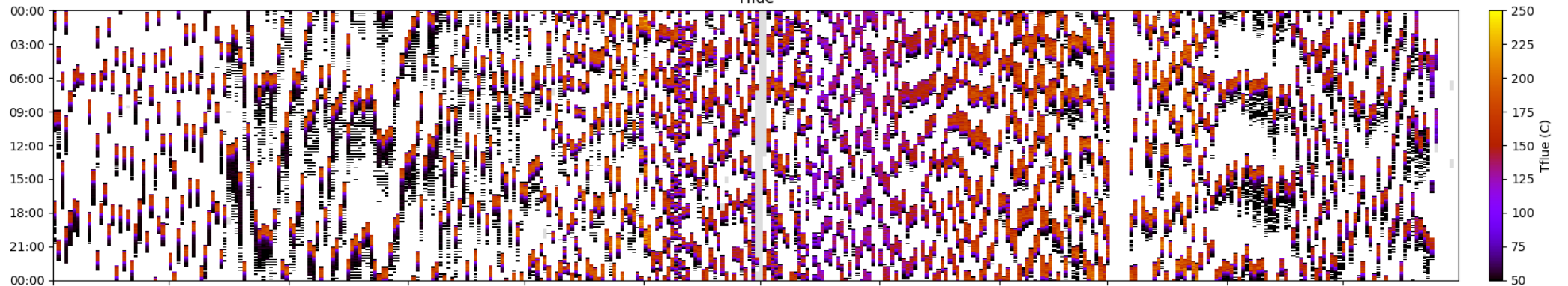


First Year Tapestries B222

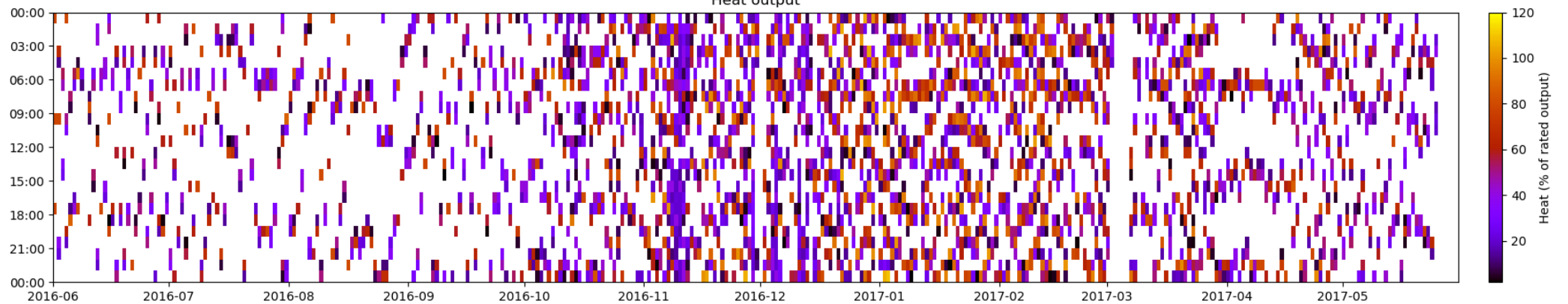
O2



Tflue

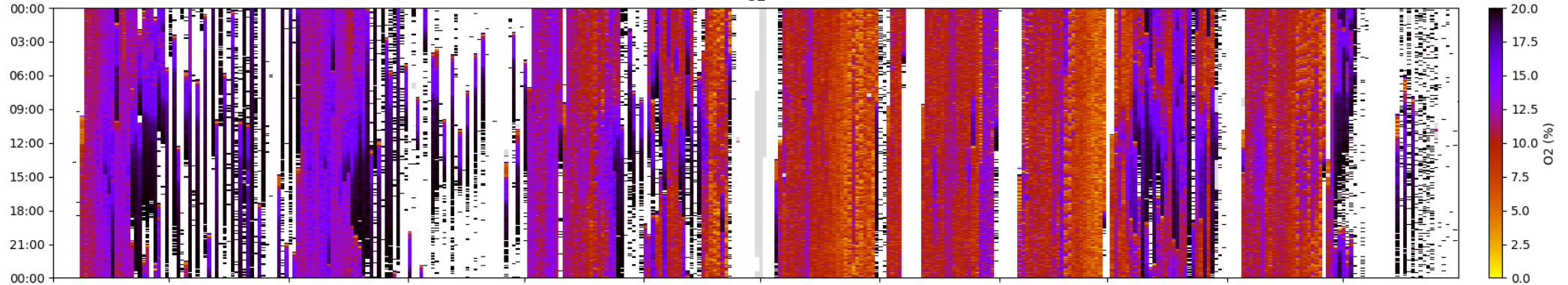


Heat output

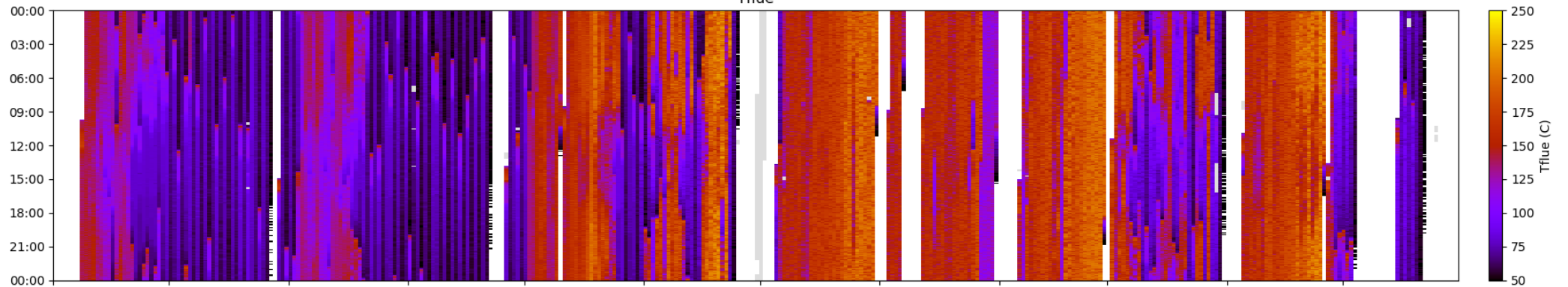


First Year Tapestries B250

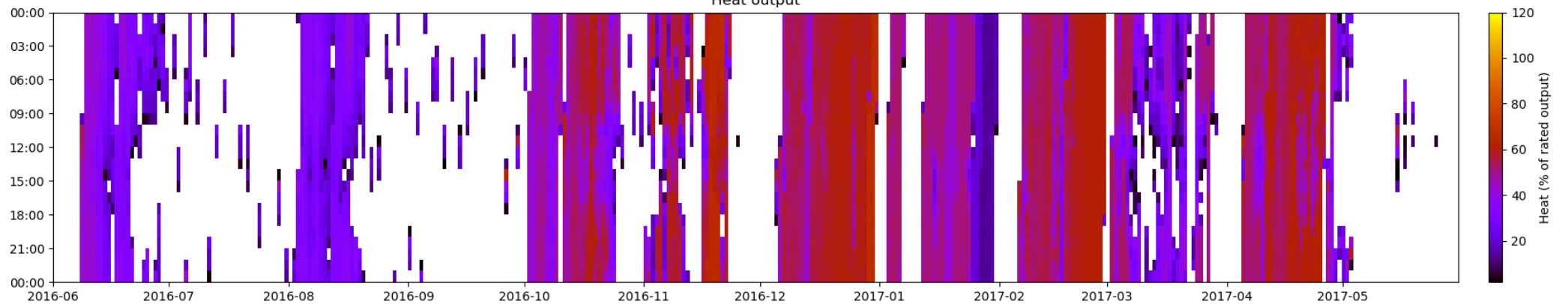
O2



Tflue

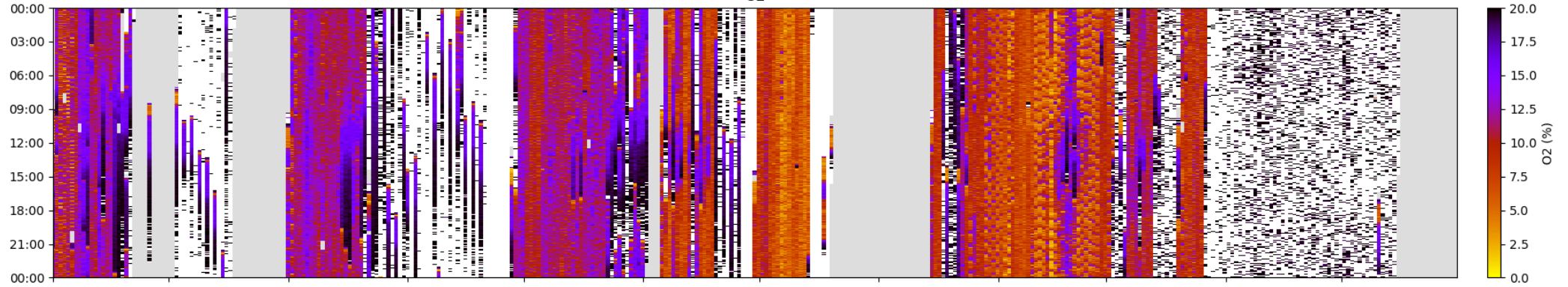


Heat output

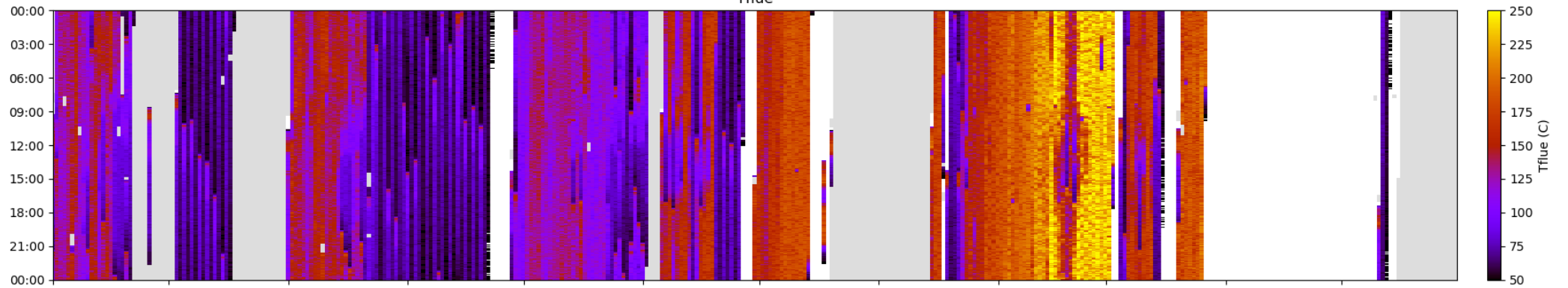


Second Year Tapestries B250

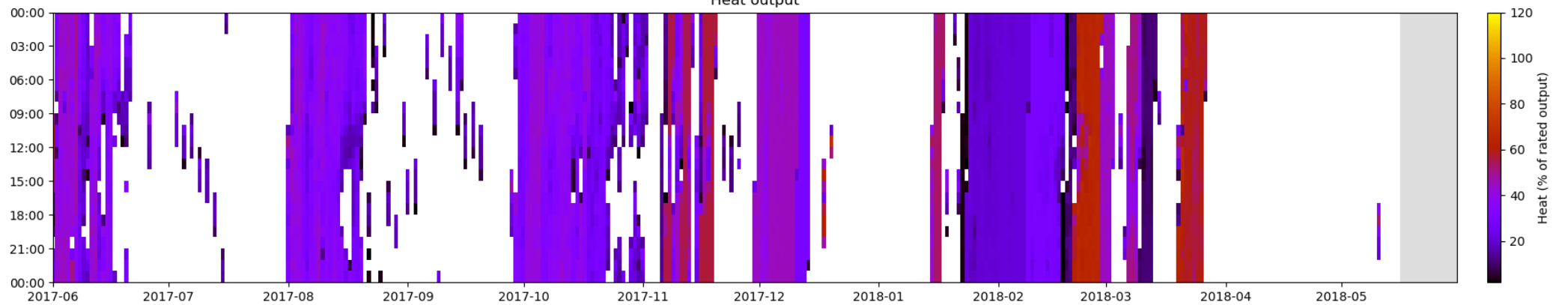
O2



Tflue

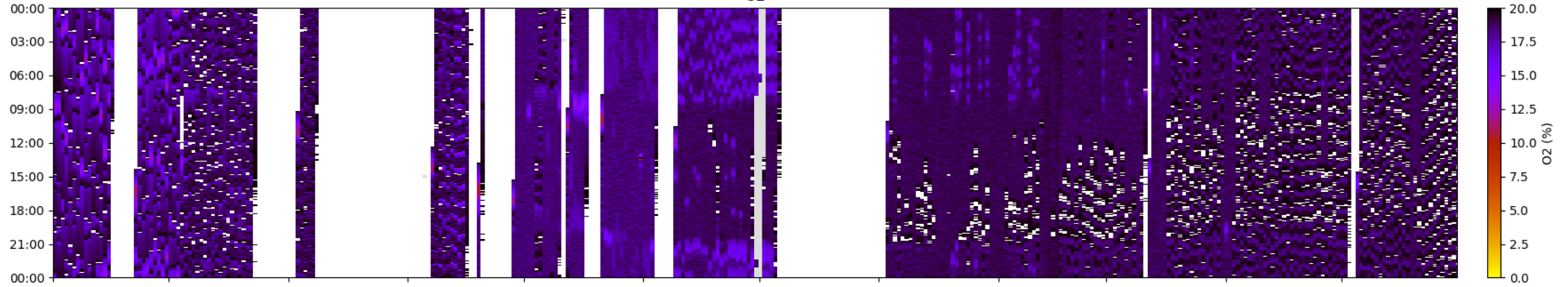


Heat output

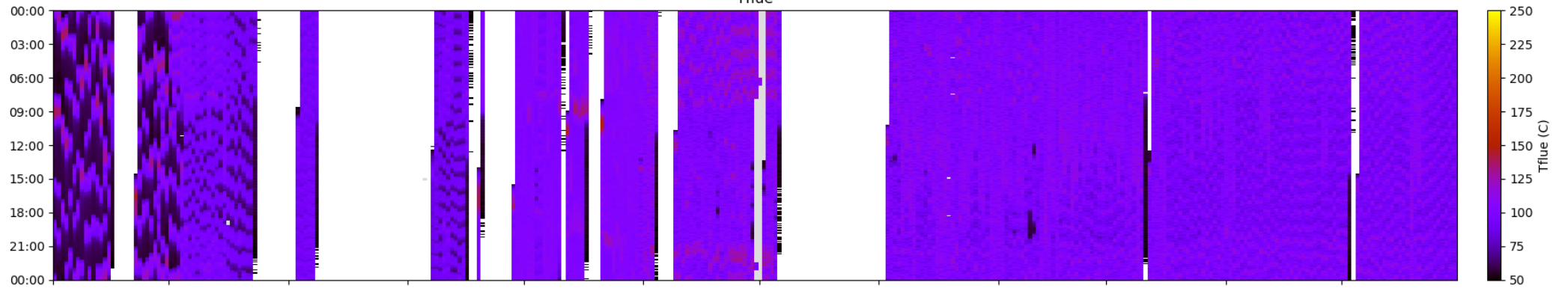


First Year Tapestries B260

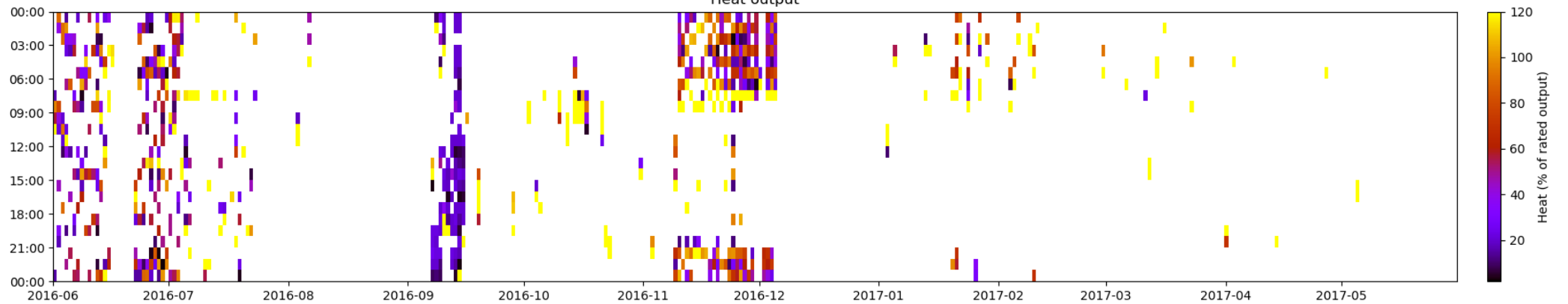
O2



Tflue

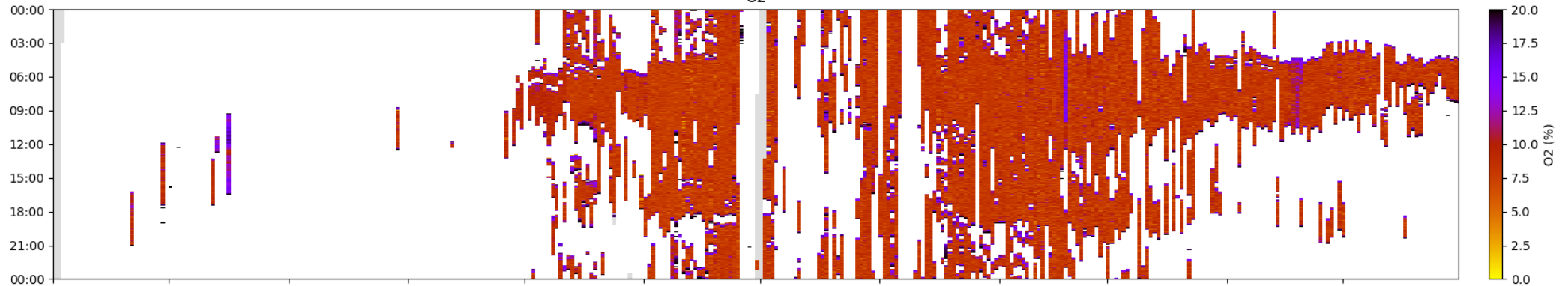


Heat output

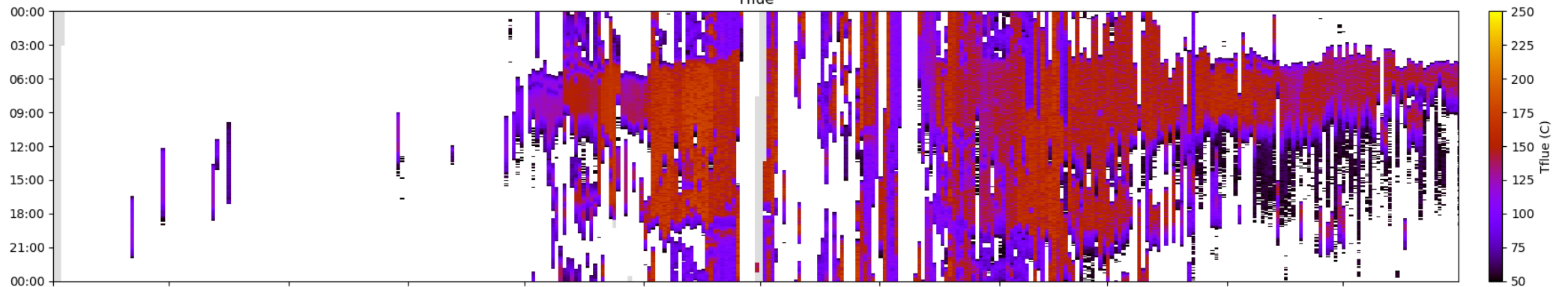


First Year Tapestries B271

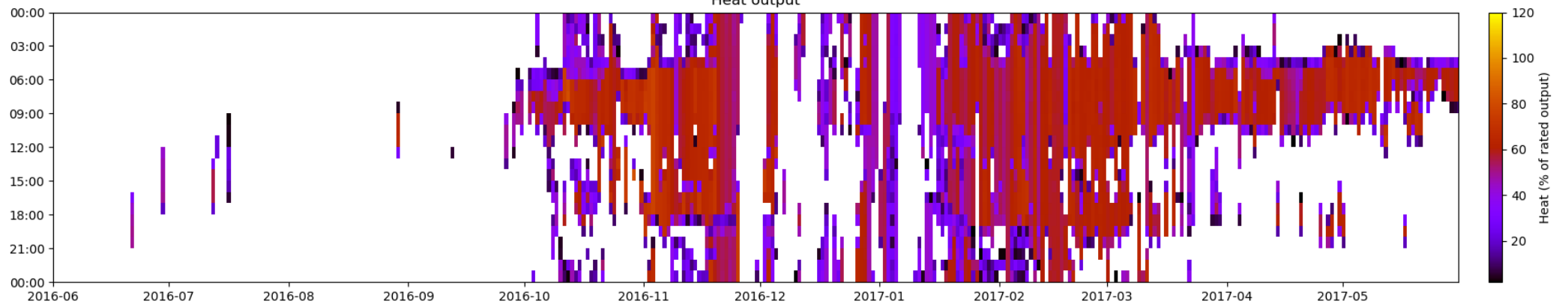
O2



Tflue

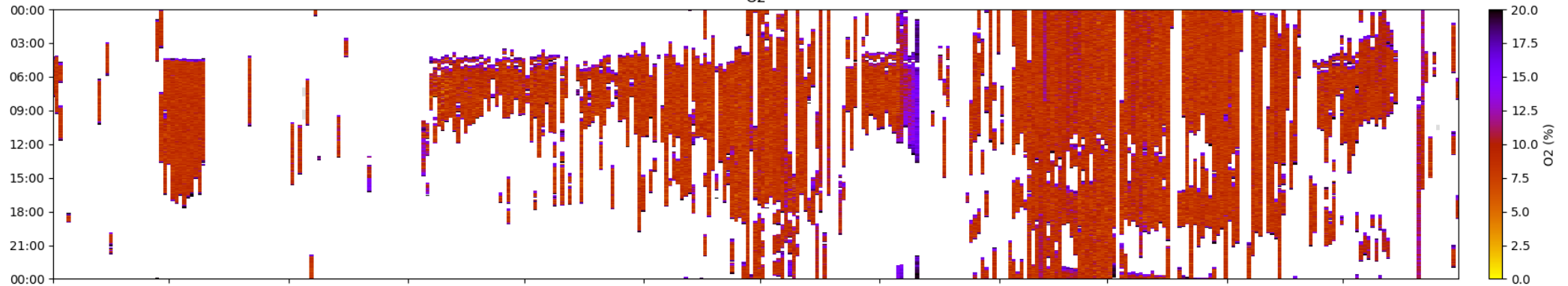


Heat output

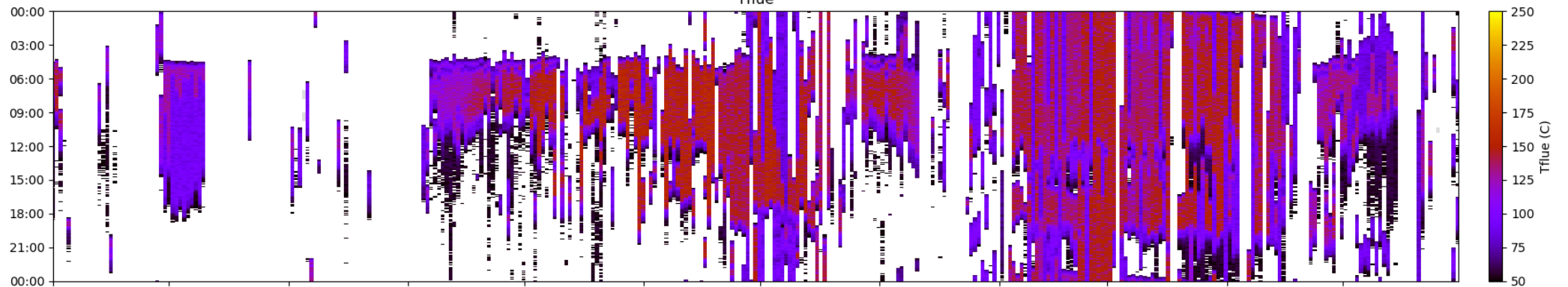


Second Year Tapestries B271

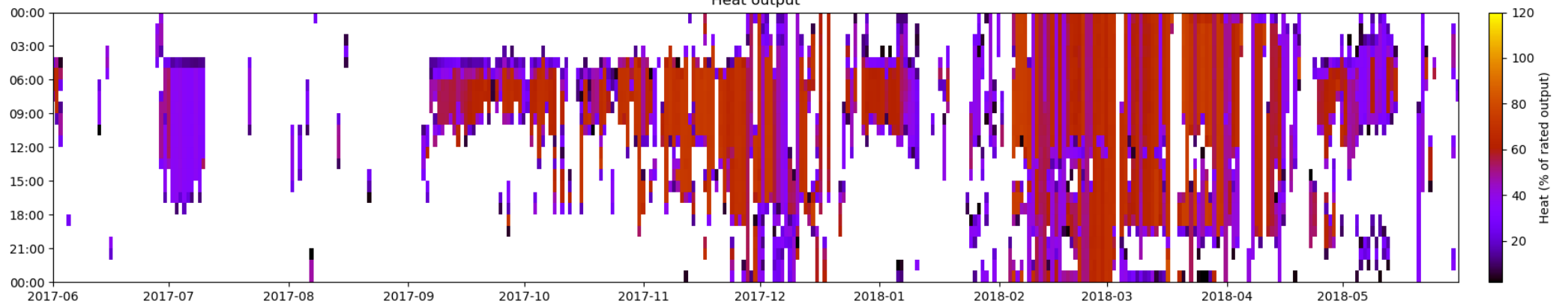
O2



Tflue

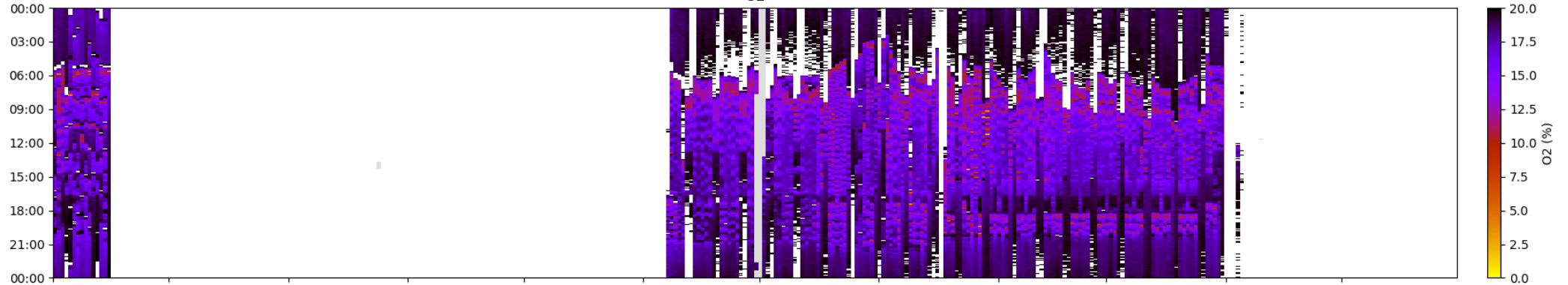


Heat output

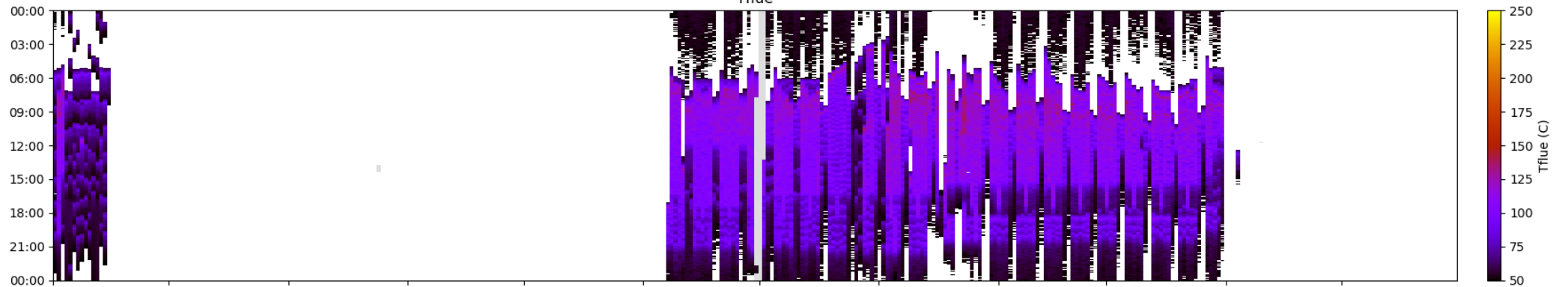


First Year Tapestries B287

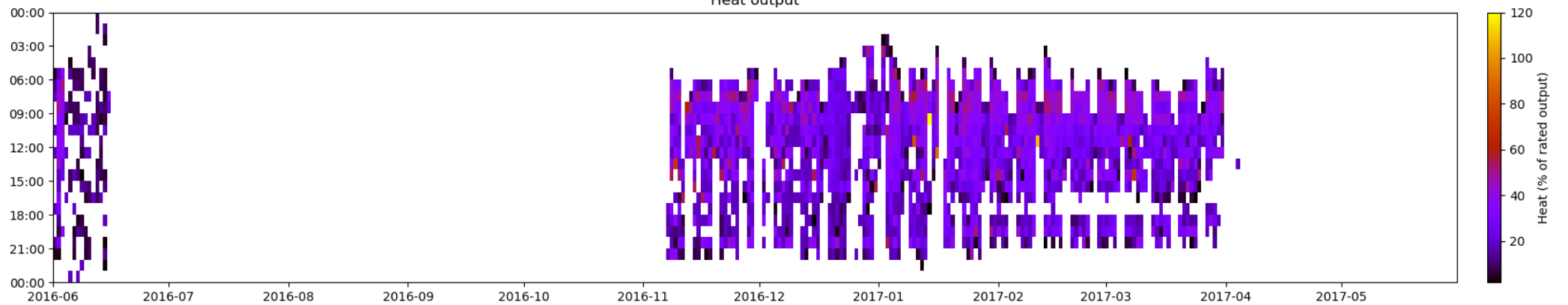
O2



Tflue

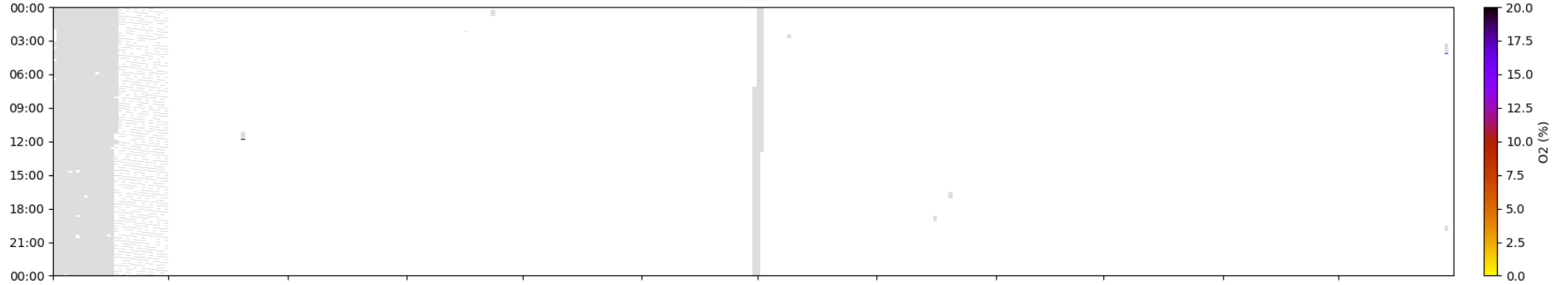


Heat output

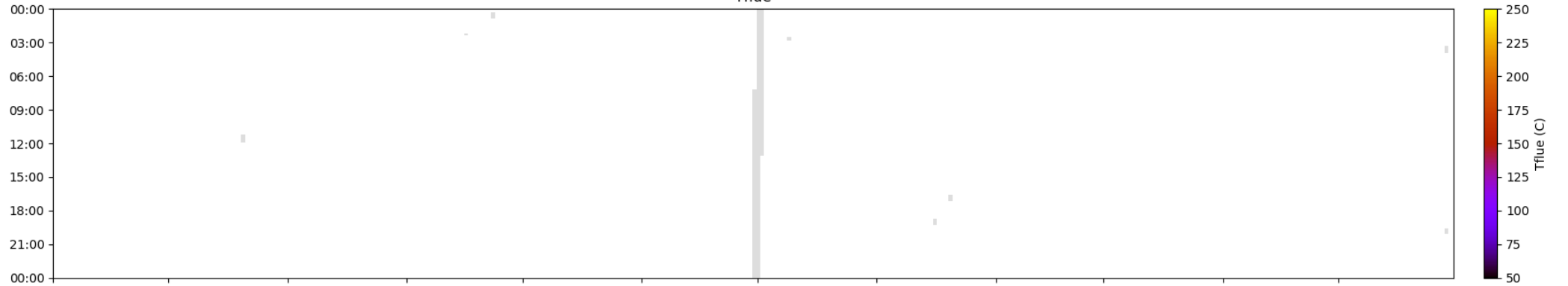


First Year Tapestries B309

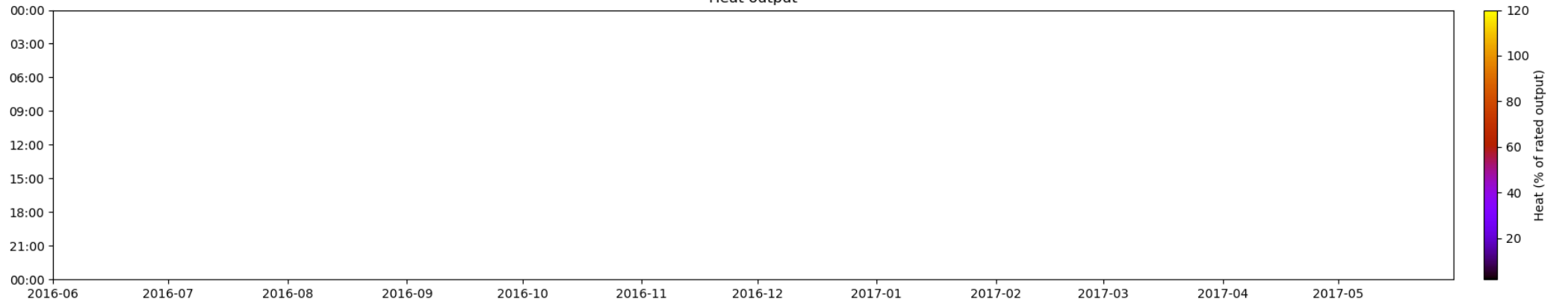
O2



Tflue

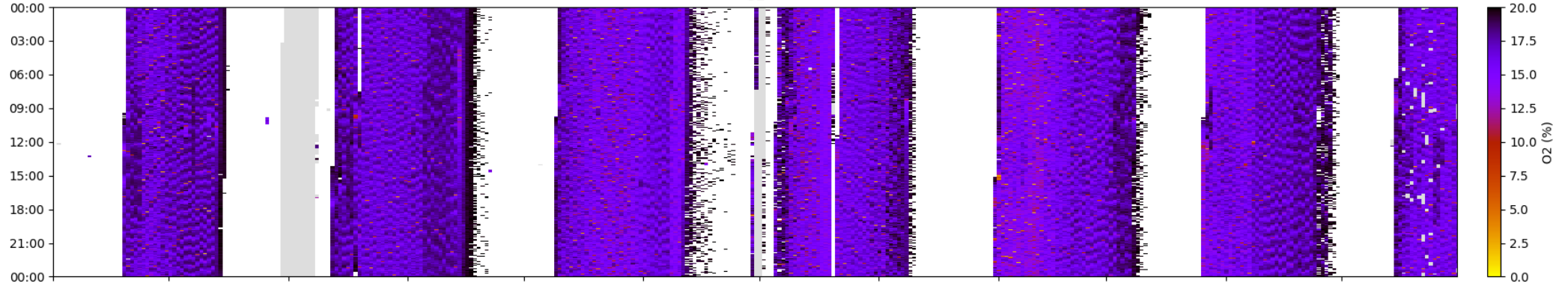


Heat output

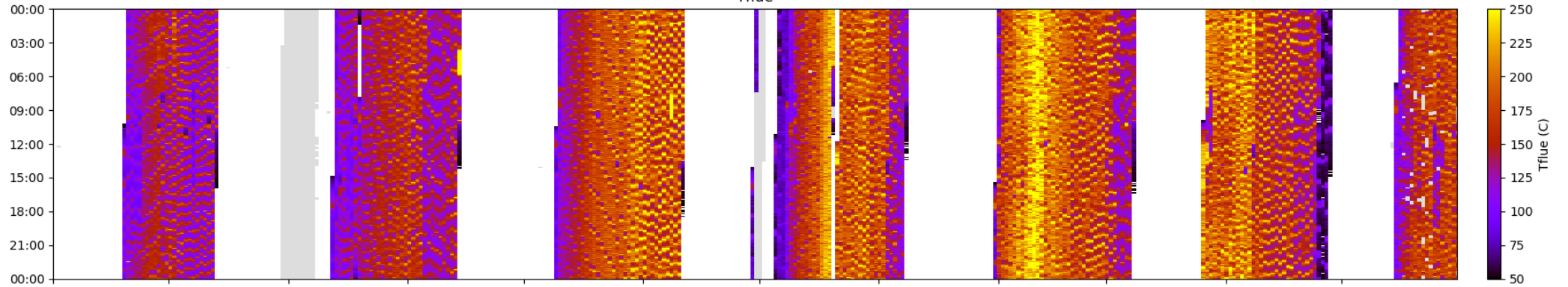


First Year Tapestries B315

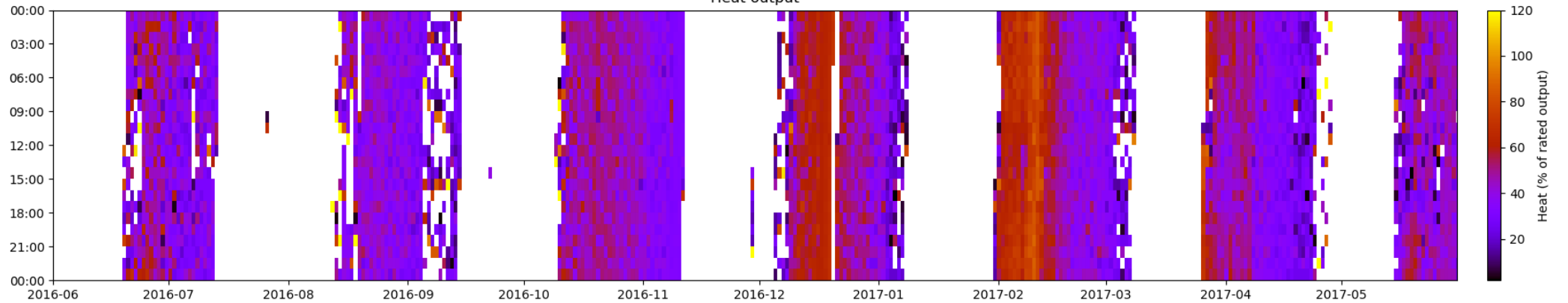
O2



Tflue

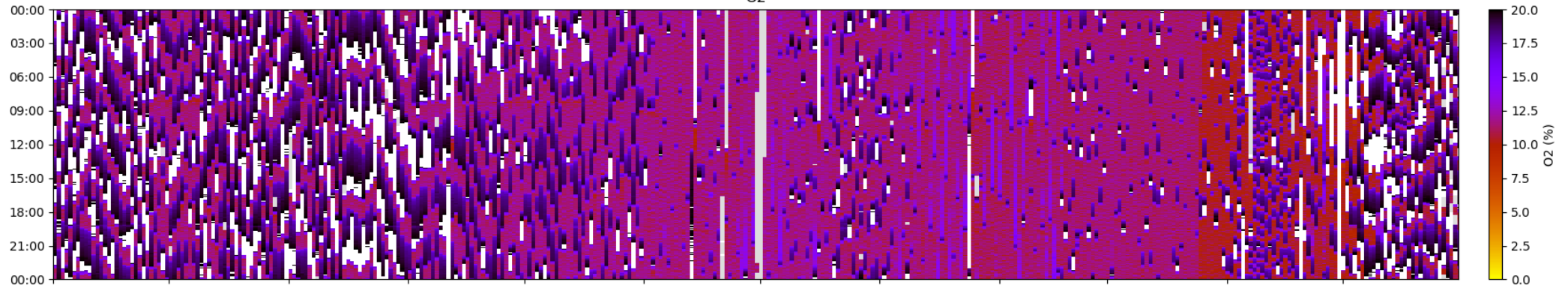


Heat output

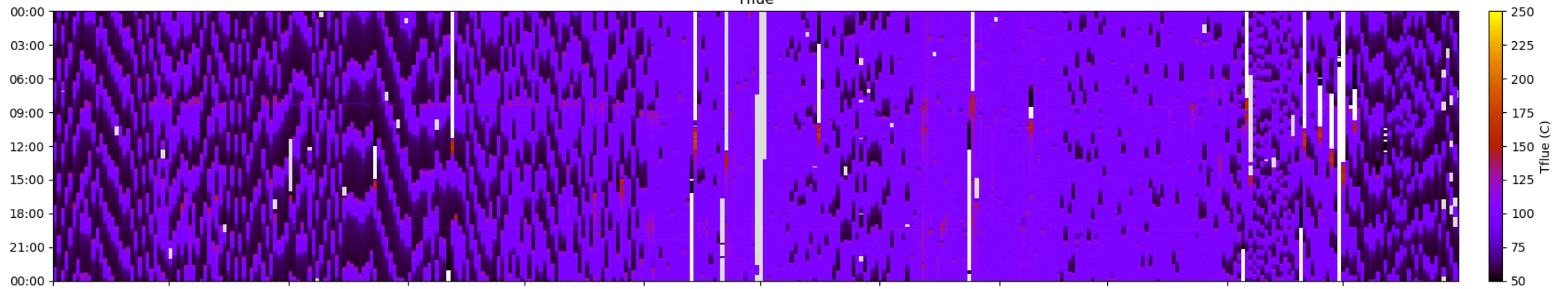


First Year Tapestries B323

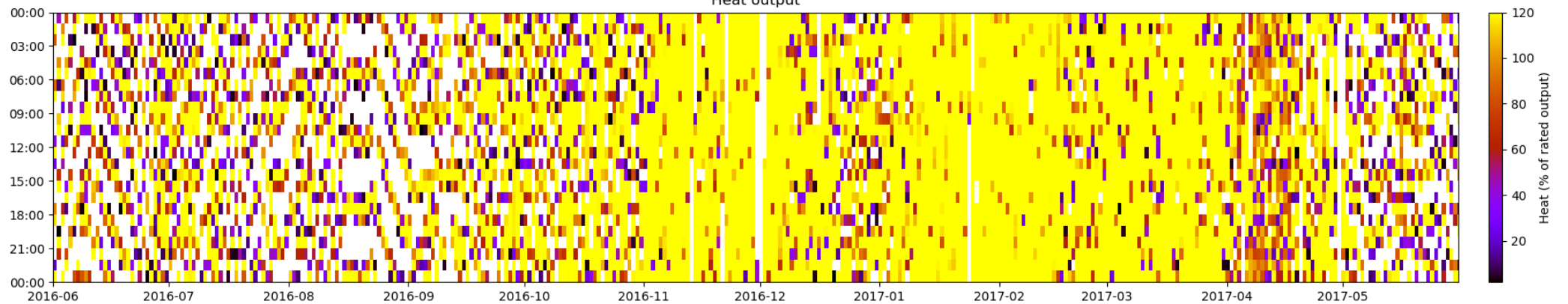
O2



Tflue

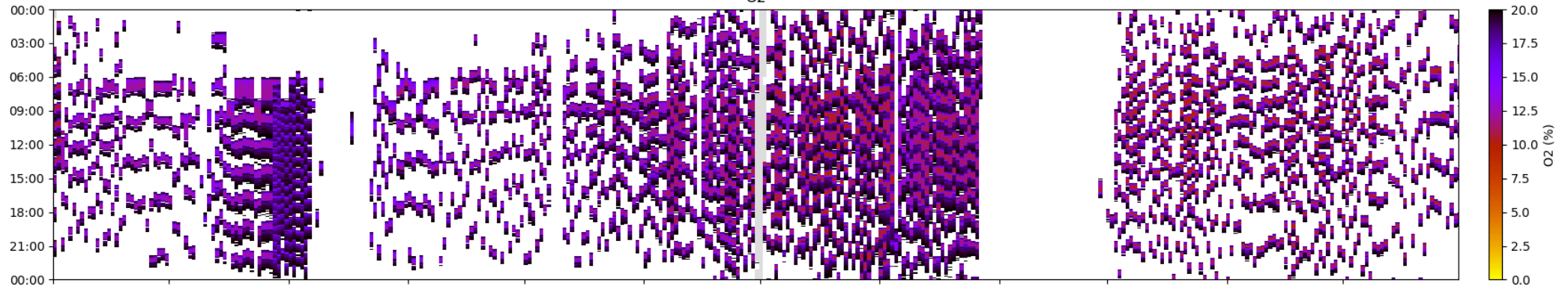


Heat output

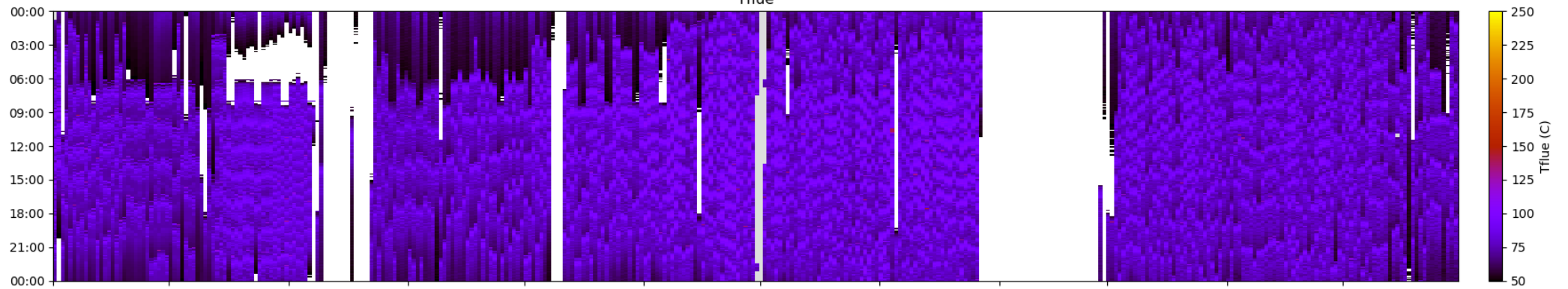


First Year Tapestries B358

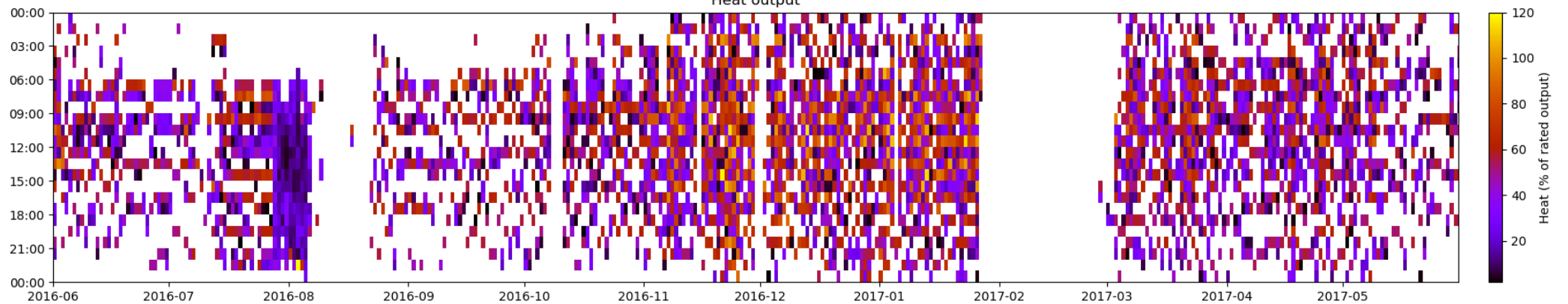
O2



Tflue

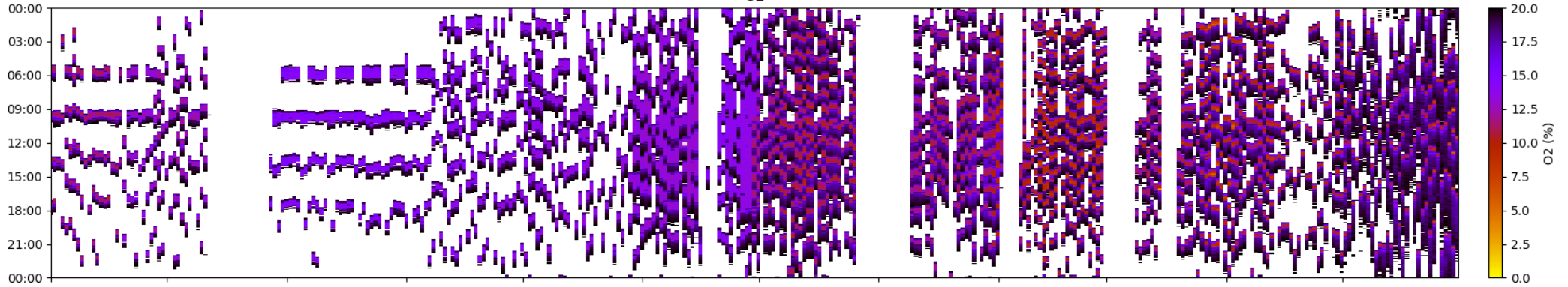


Heat output

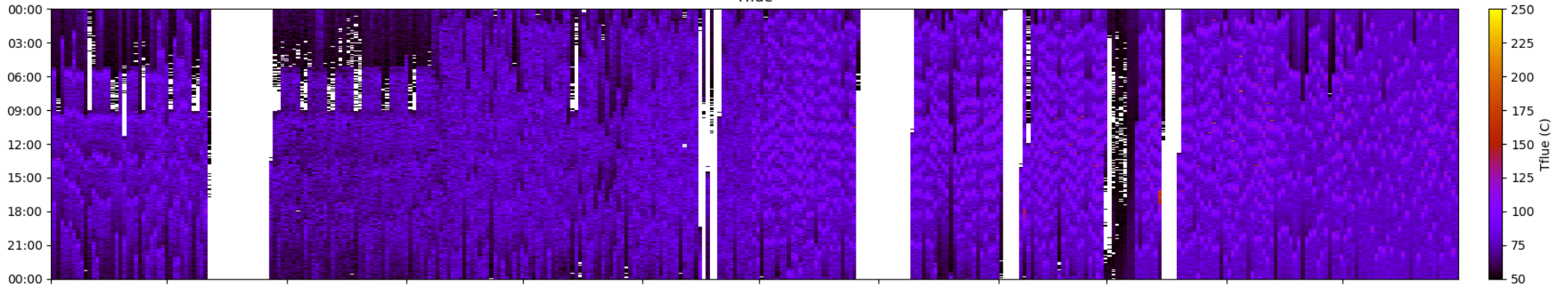


Second Year Tapestries B358

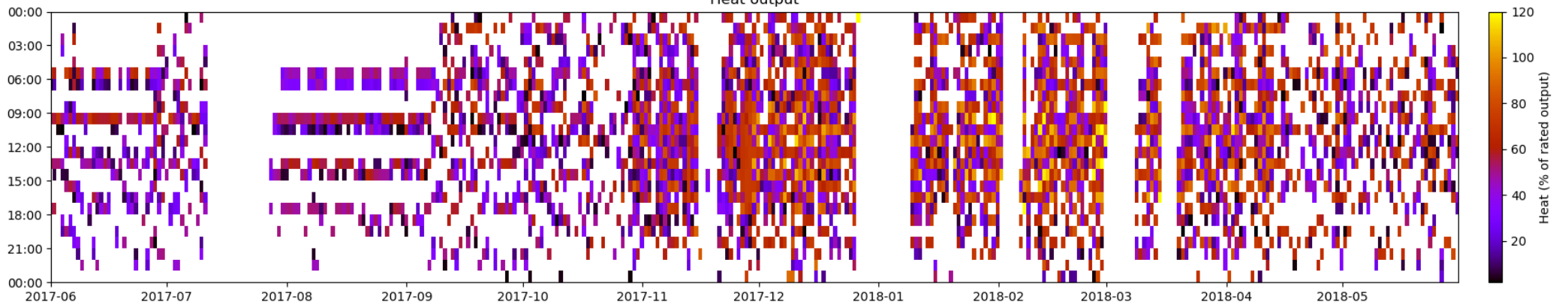
O2



Tflue

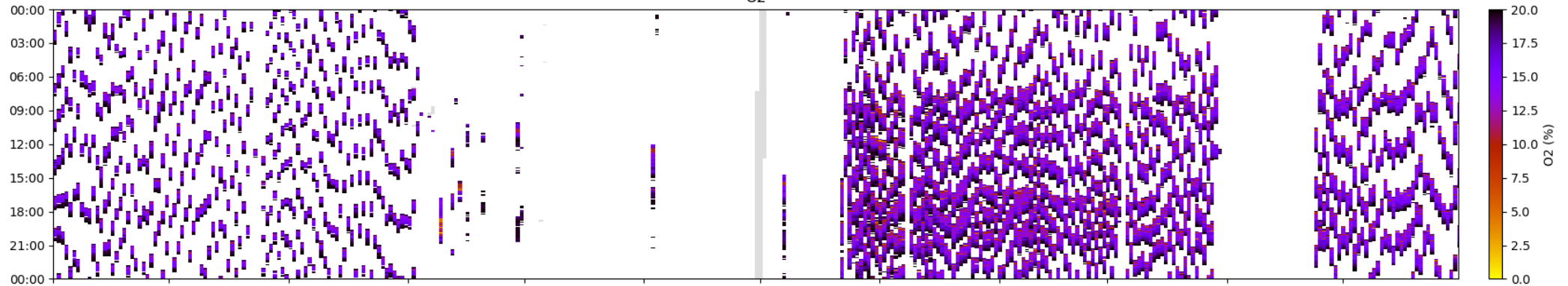


Heat output

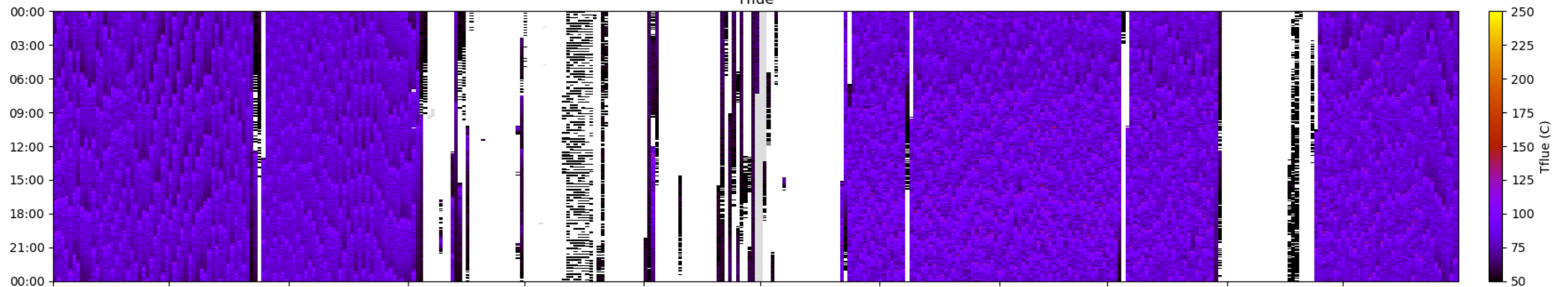


First Year Tapestries B365

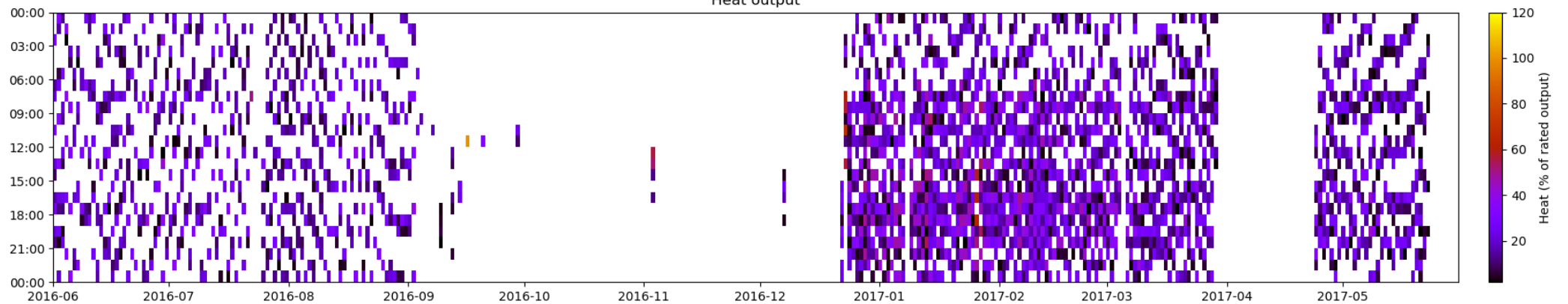
O2



Tflue

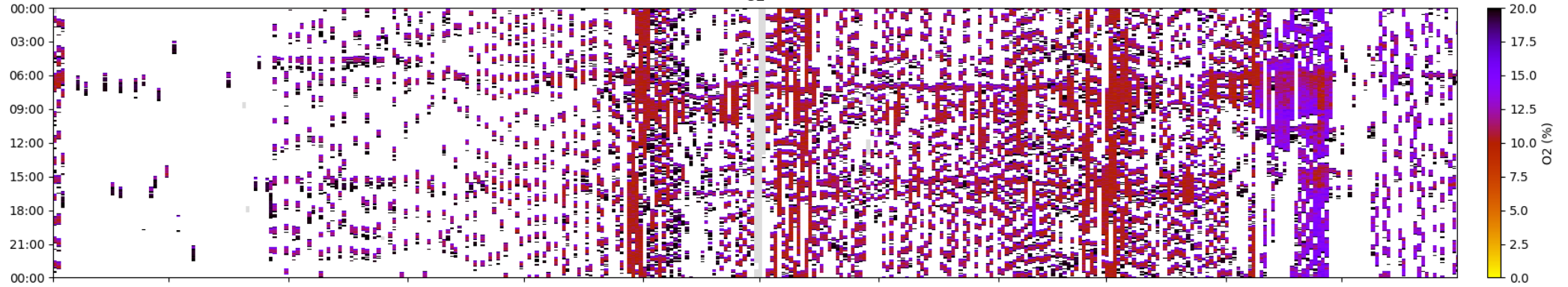


Heat output

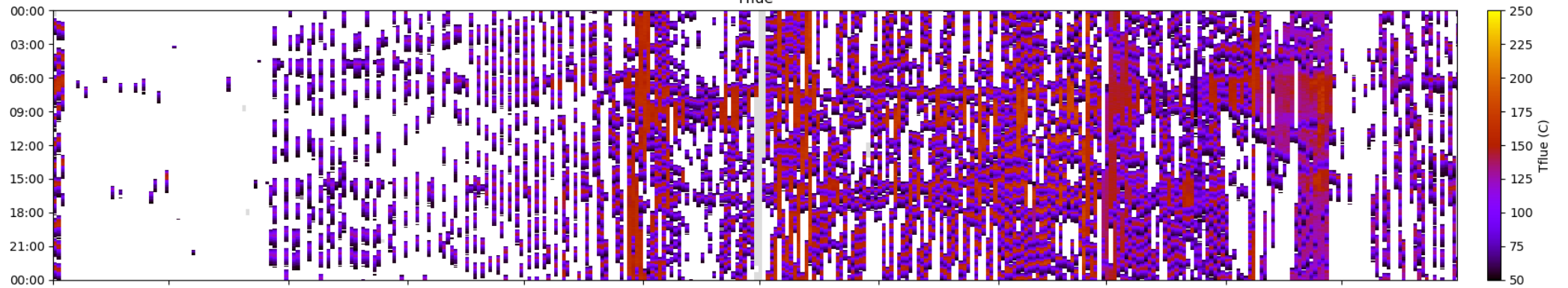


First Year Tapestries B369 (1)

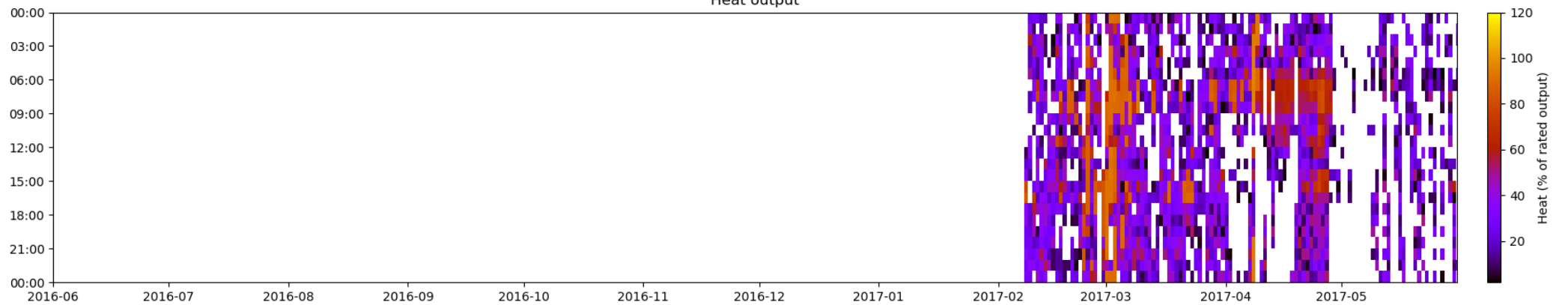
O2



Tflue

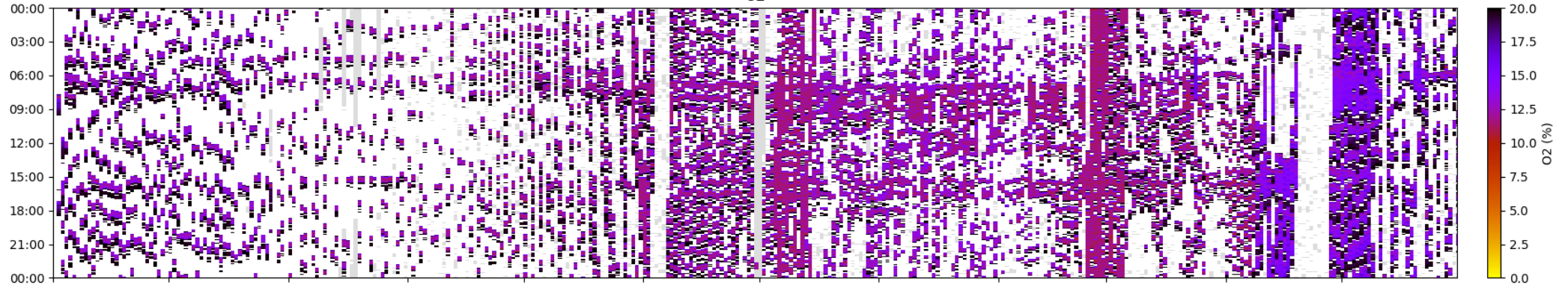


Heat output

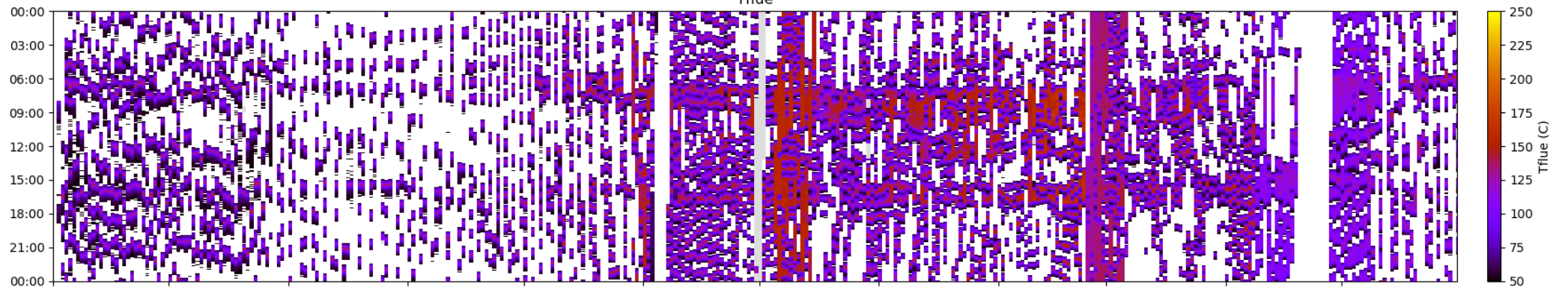


First Year Tapestries B369 (2)

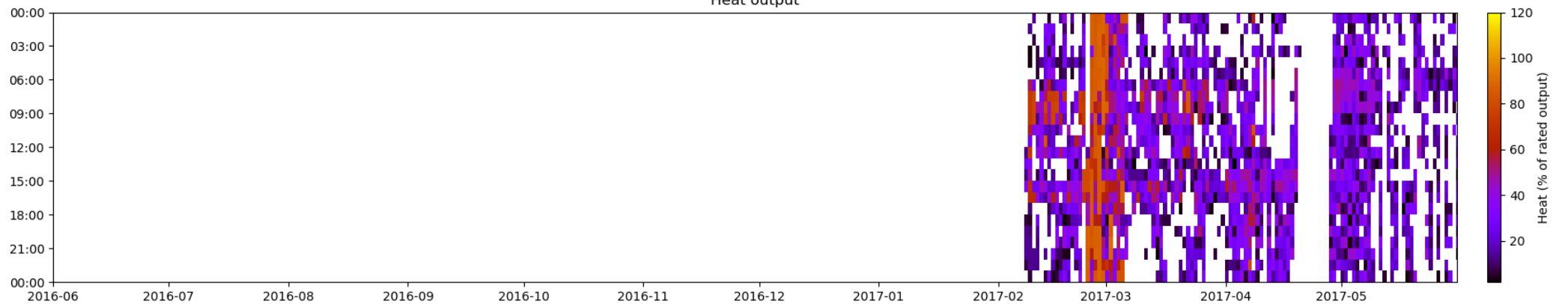
O2



Tflue

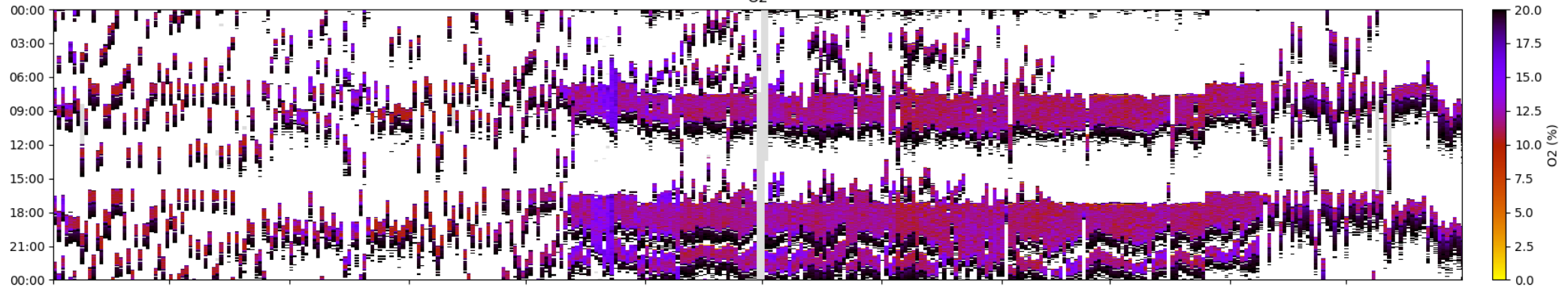


Heat output

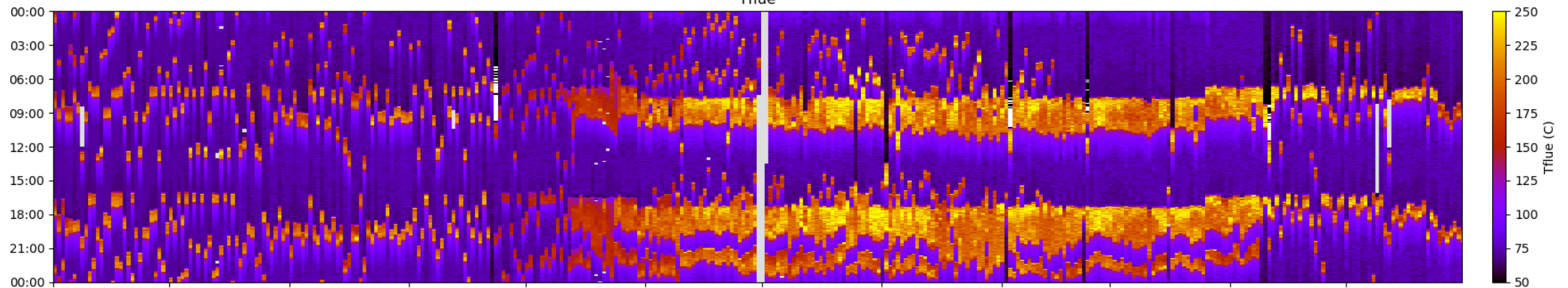


First Year Tapestries B418 (1)

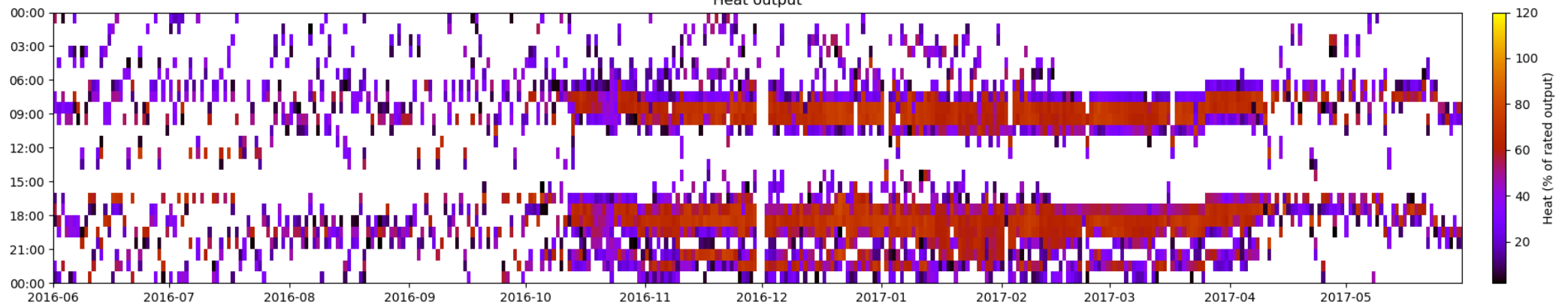
O2



Tflue



Heat output

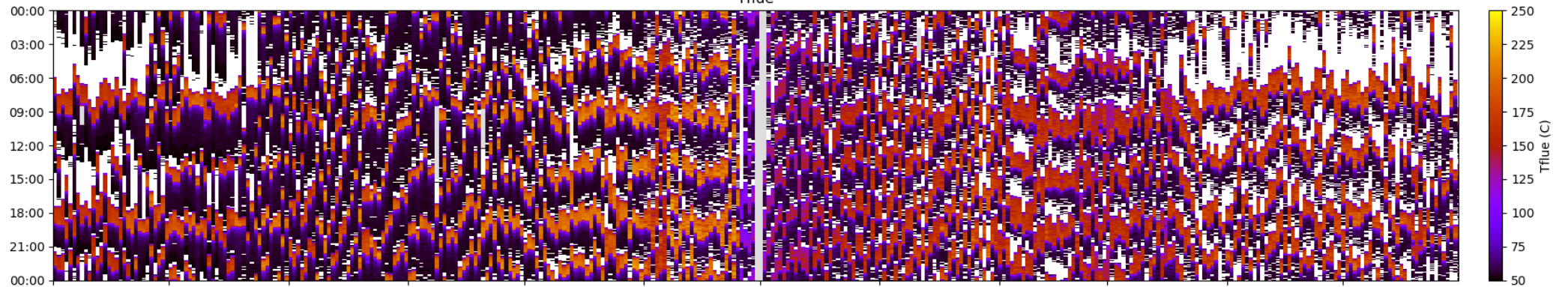


First Year Tapestries B418 (2)

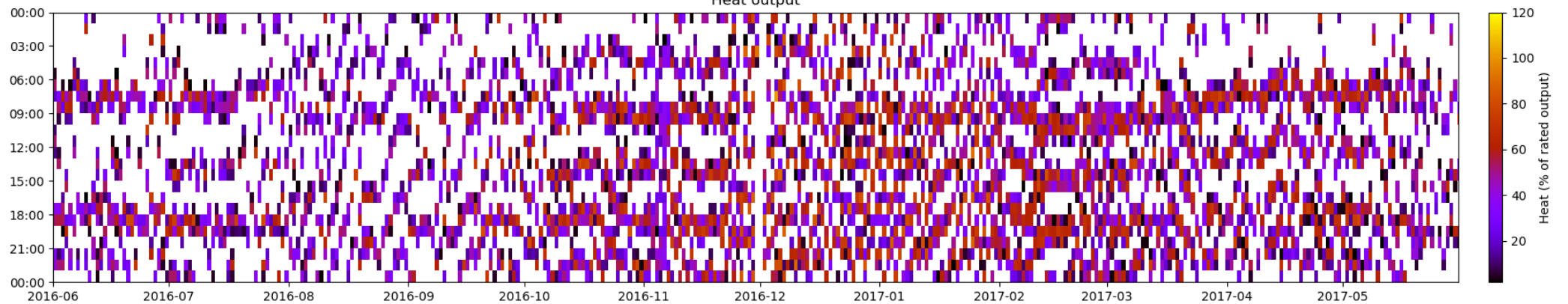
O2



Tflue

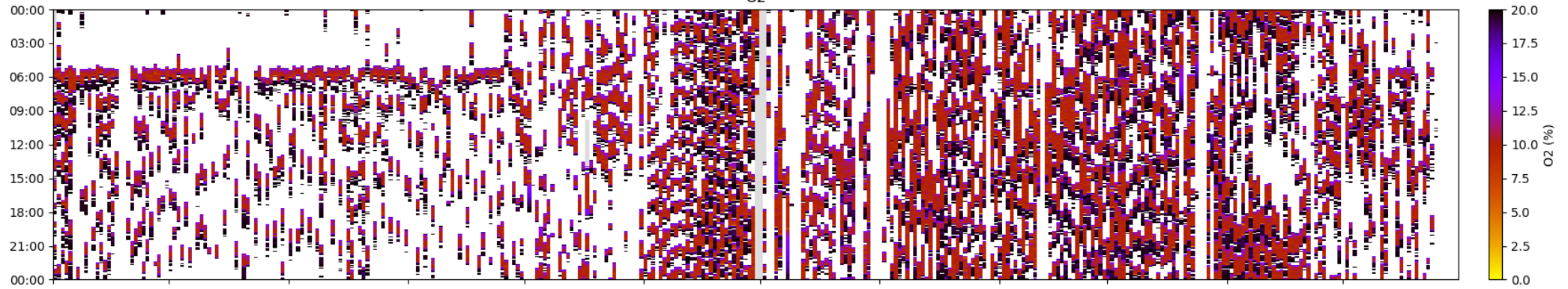


Heat output

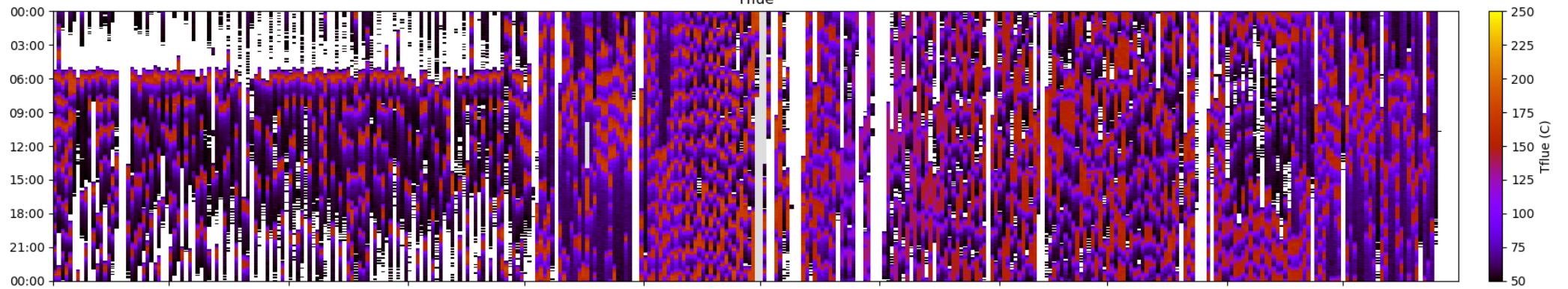


First Year Tapestries B434 (1)

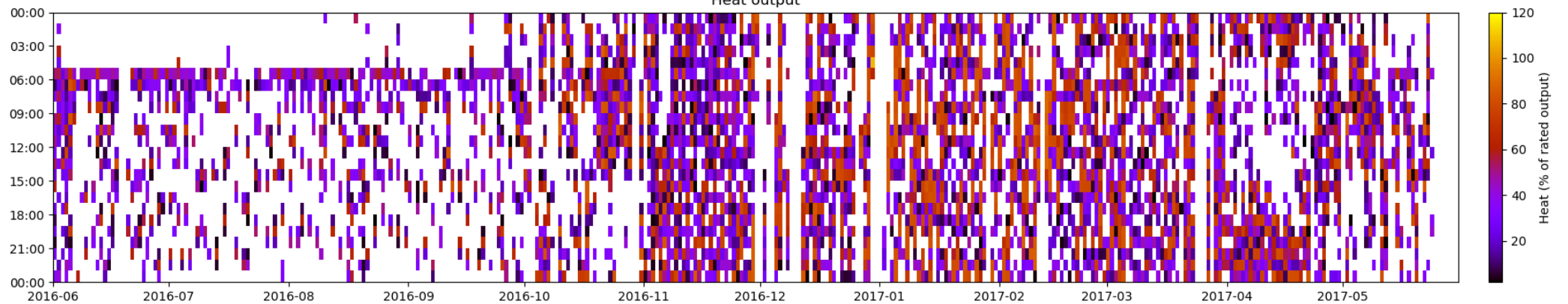
O2



Tflue

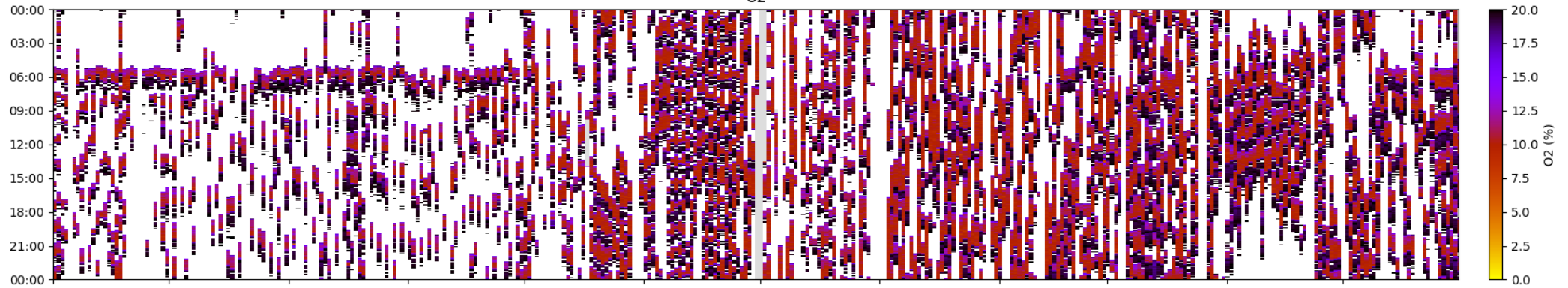


Heat output

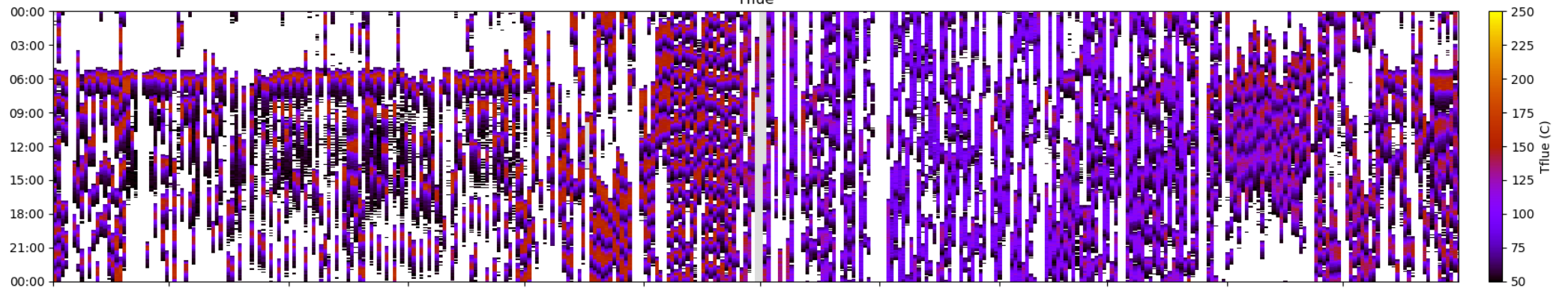


First Year Tapestries B434 (2)

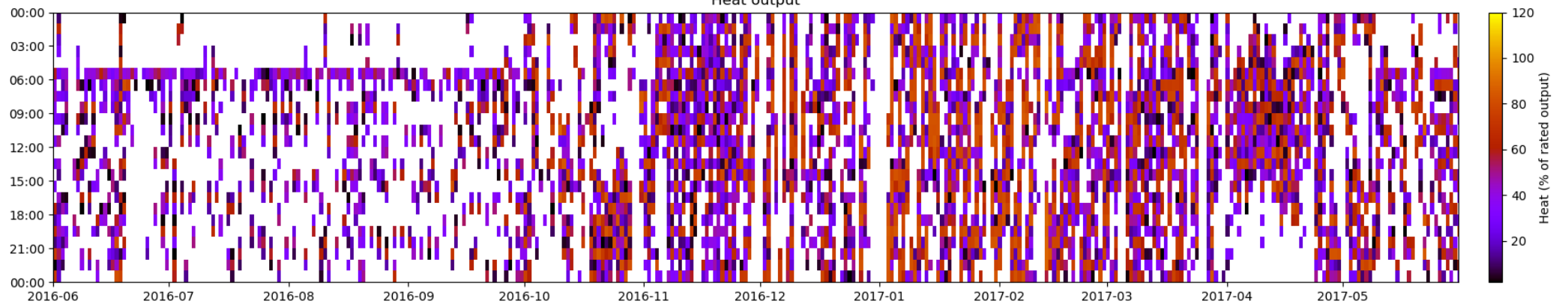
O2



Tflue

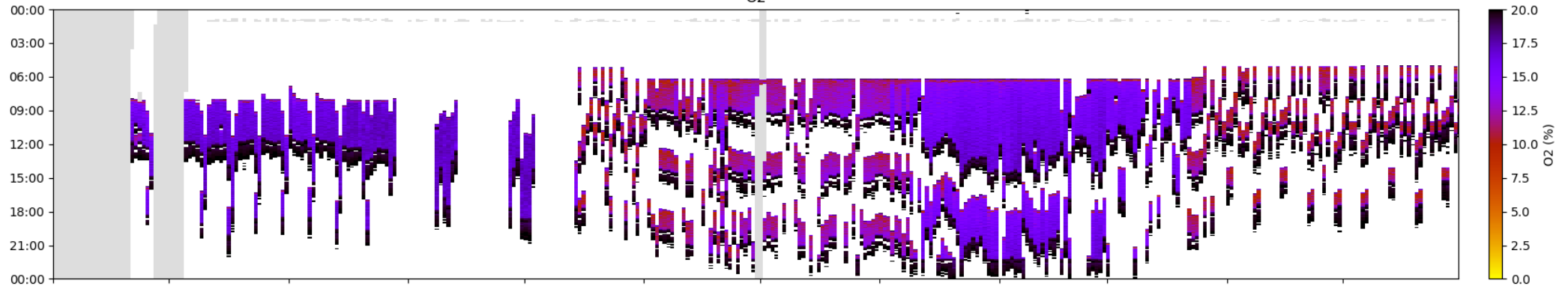


Heat output

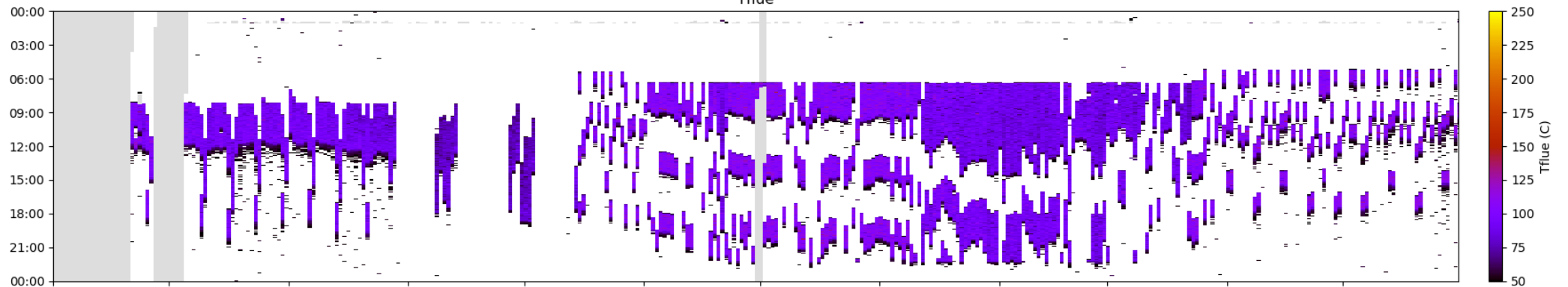


First Year Tapestries B445

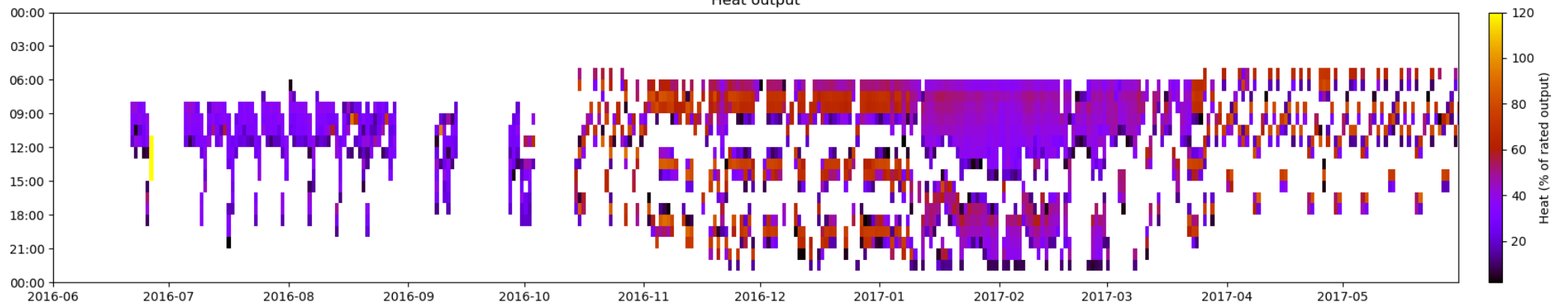
O₂



T_{flue}

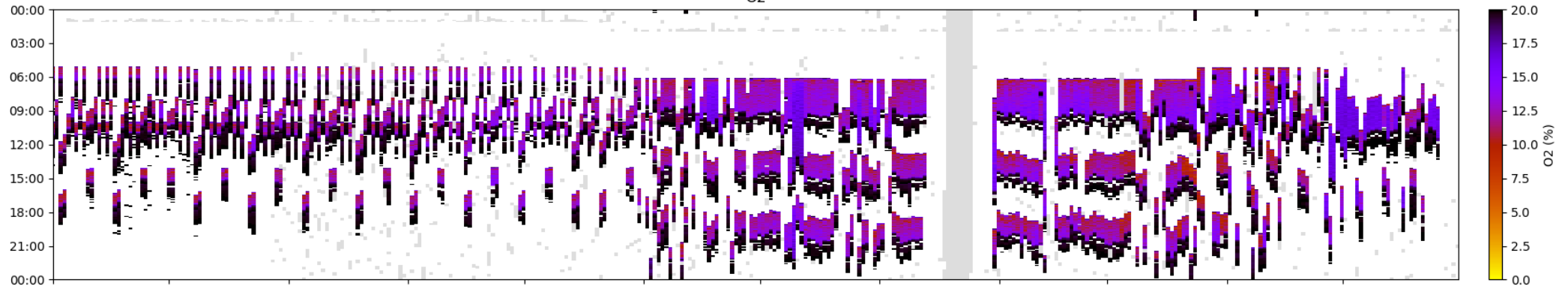


Heat output

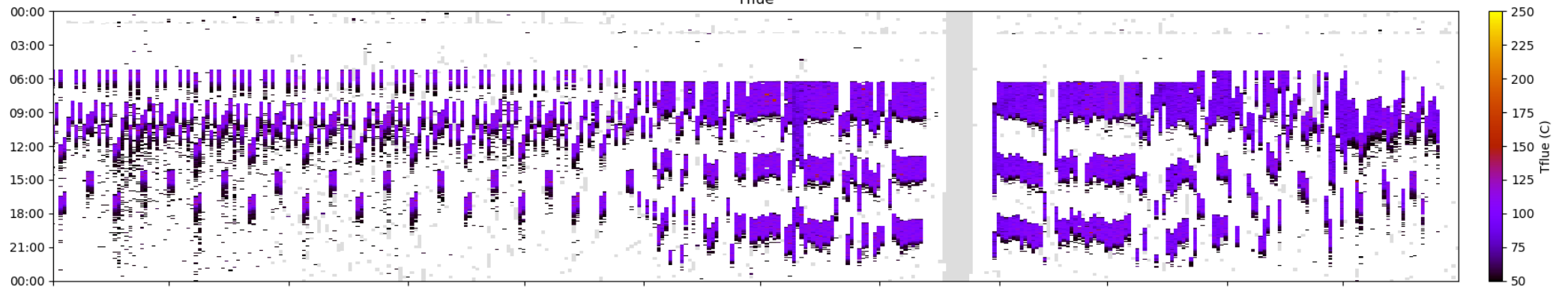


Second Year Tapestries B445

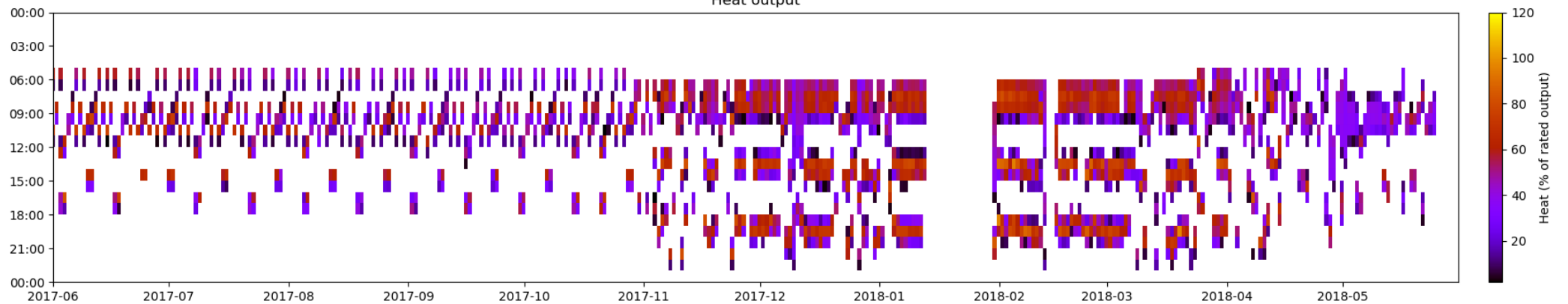
O2



Tflue

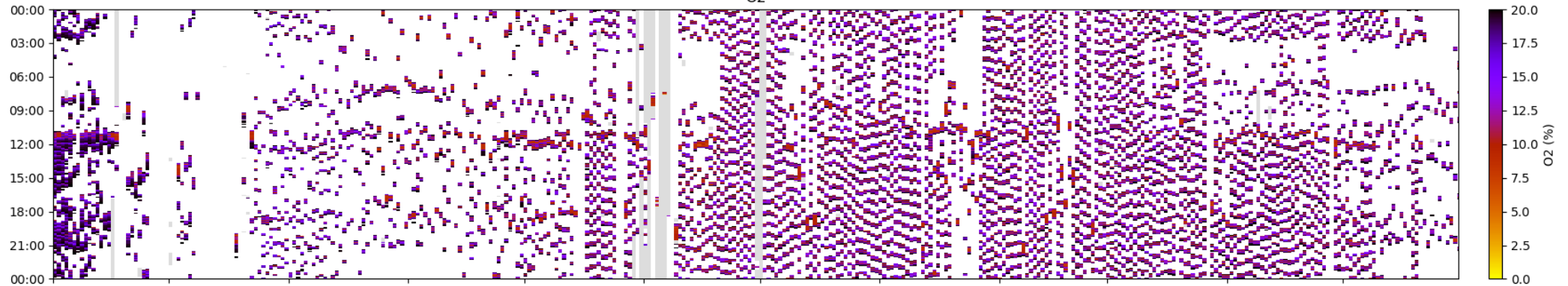


Heat output

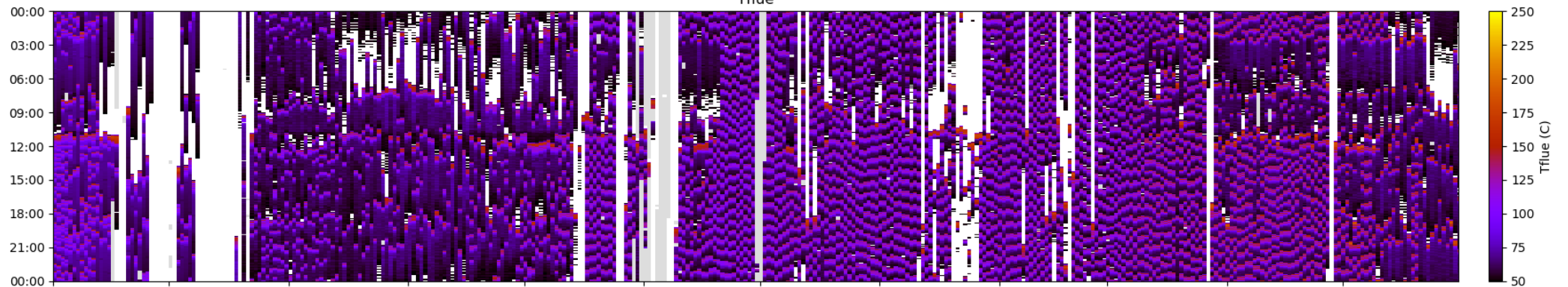


First Year Tapestries B458

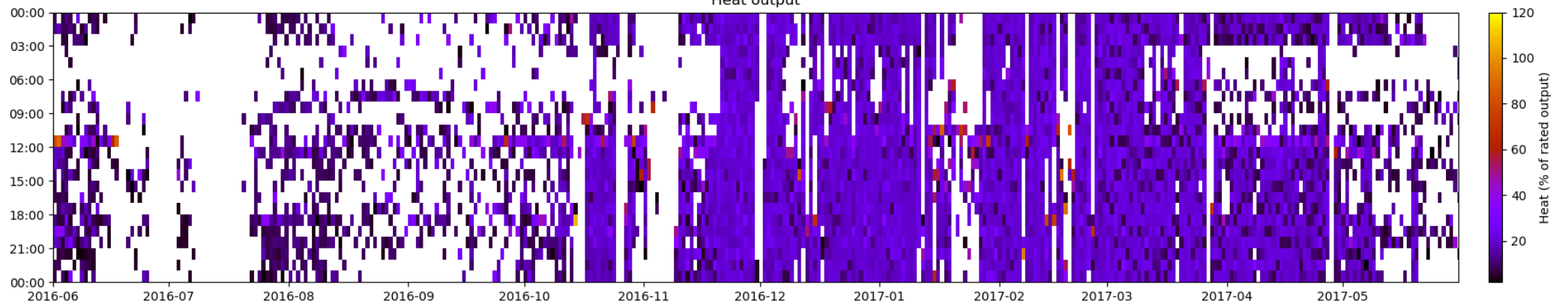
O2



Tflue

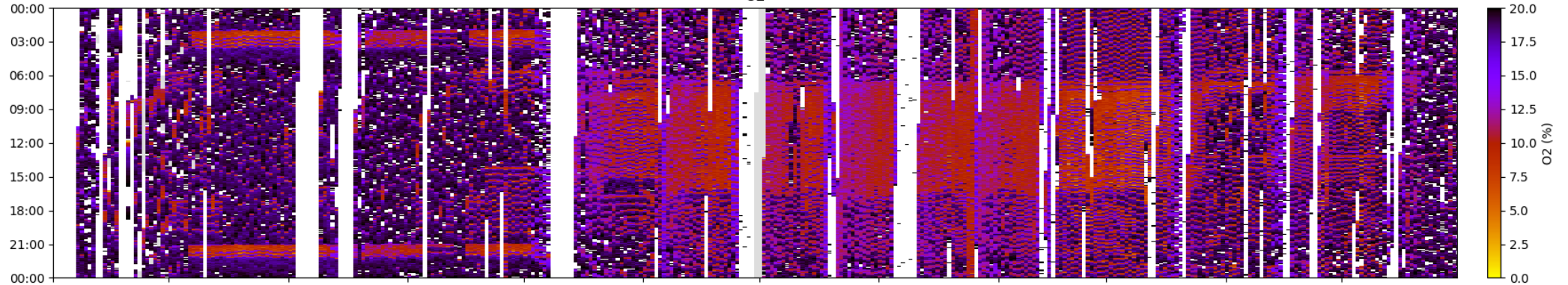


Heat output

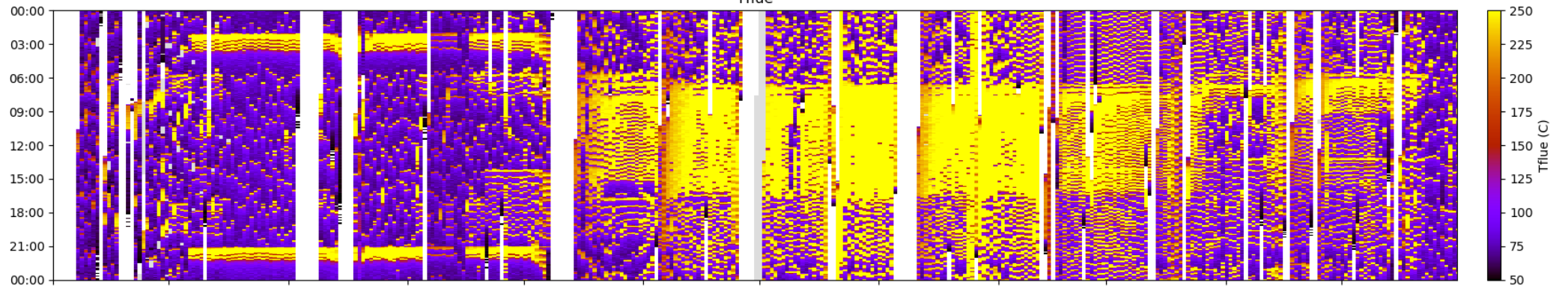


First Year Tapestries B464

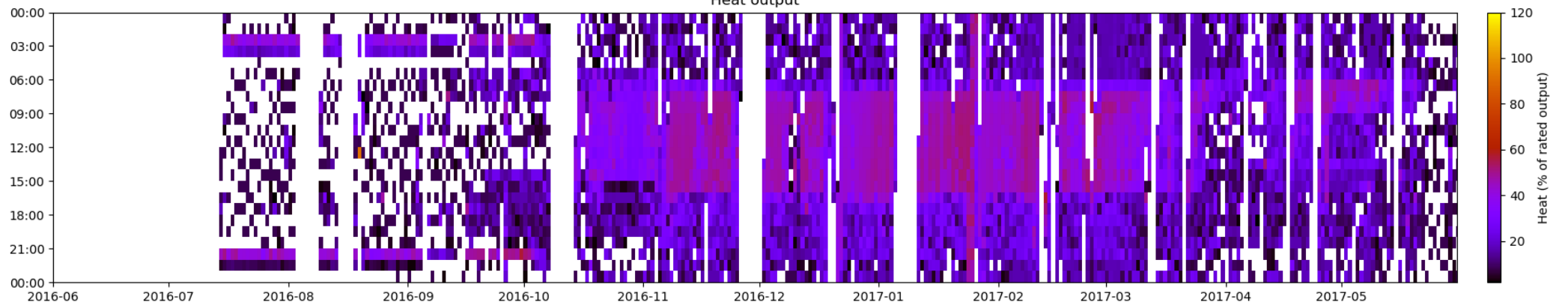
O2



Tflue

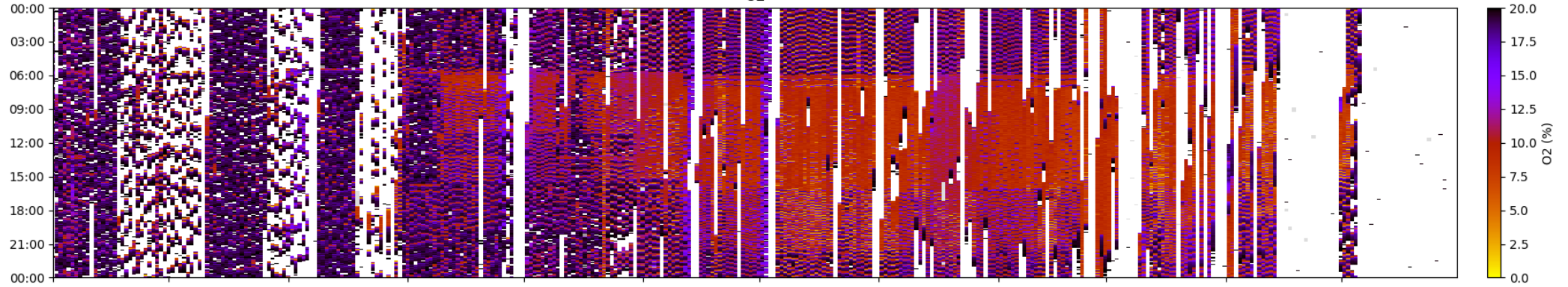


Heat output

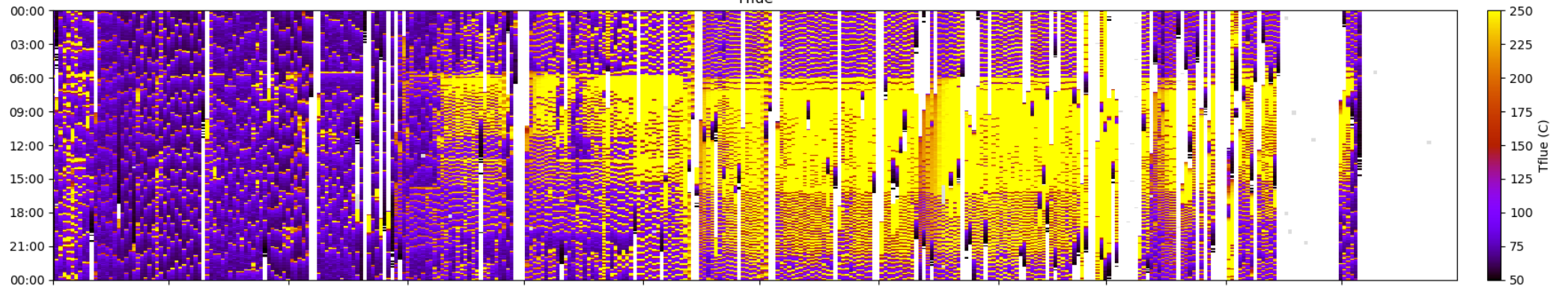


Second Year Tapestries B464

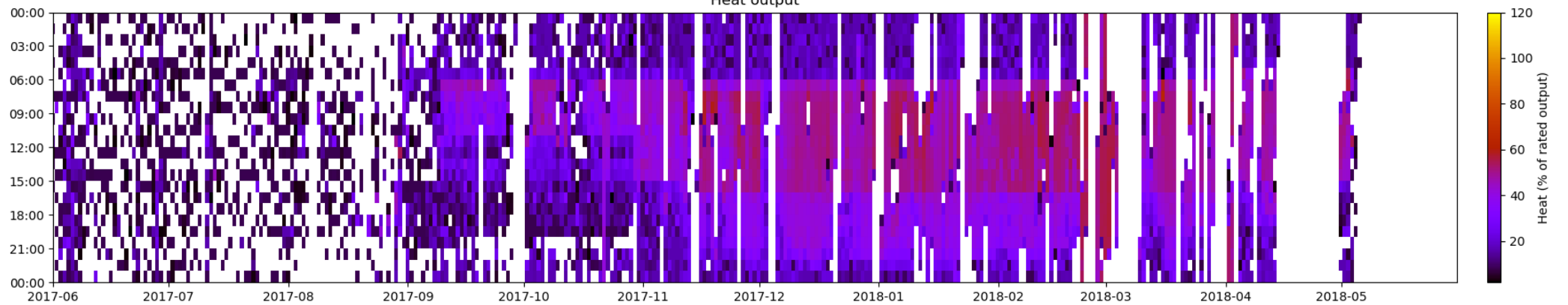
O2



Tflue

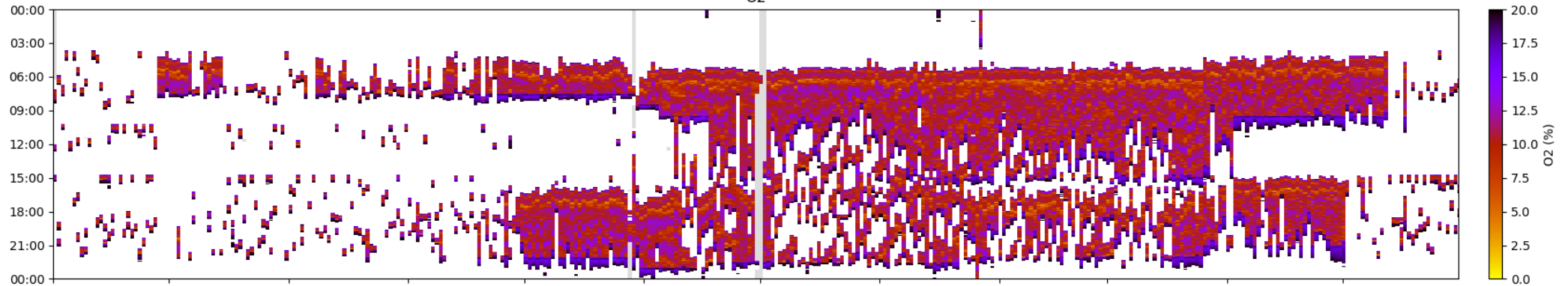


Heat output

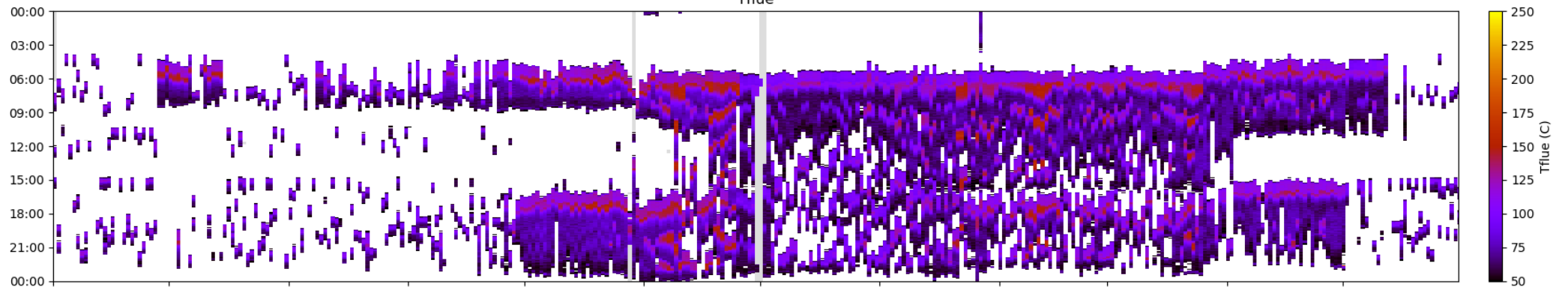


First Year Tapestries B477

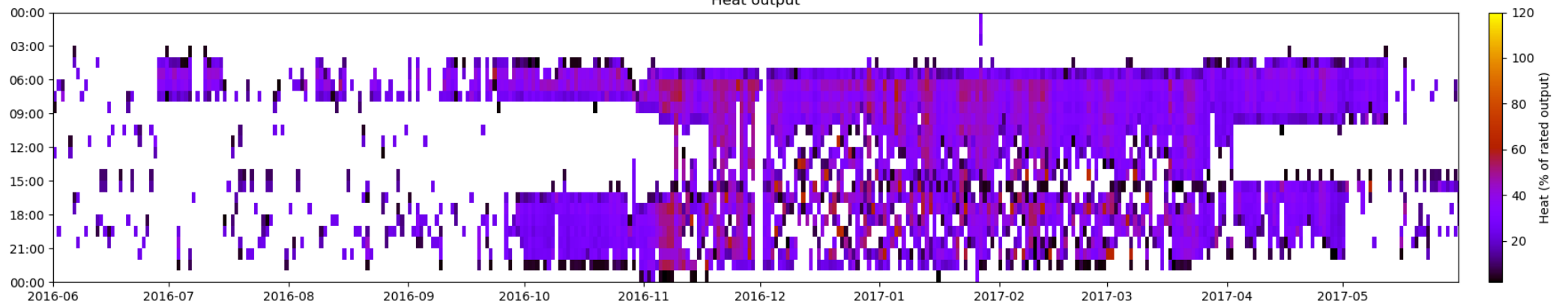
O2



Tflue

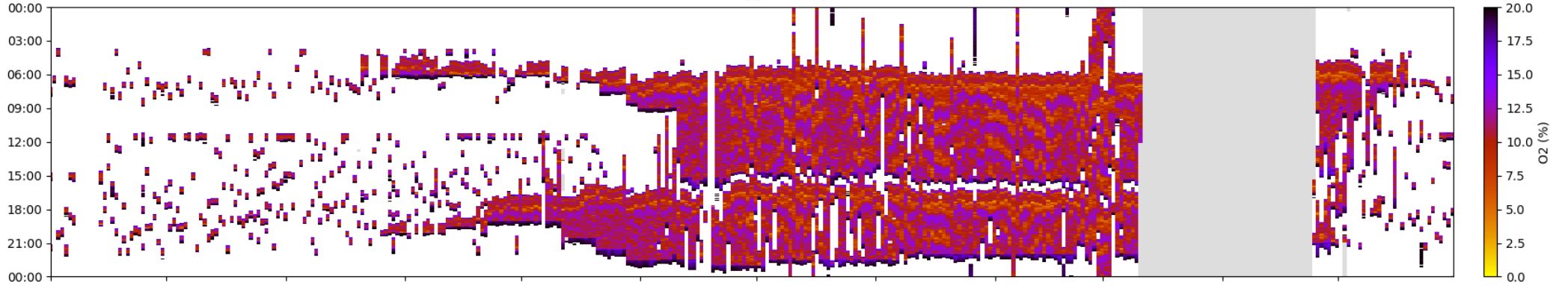


Heat output

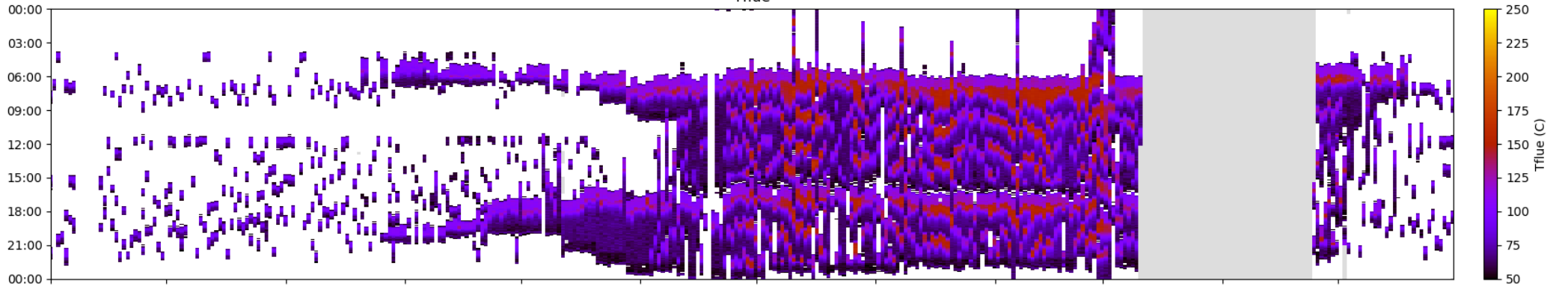


Second Year Tapestries B477

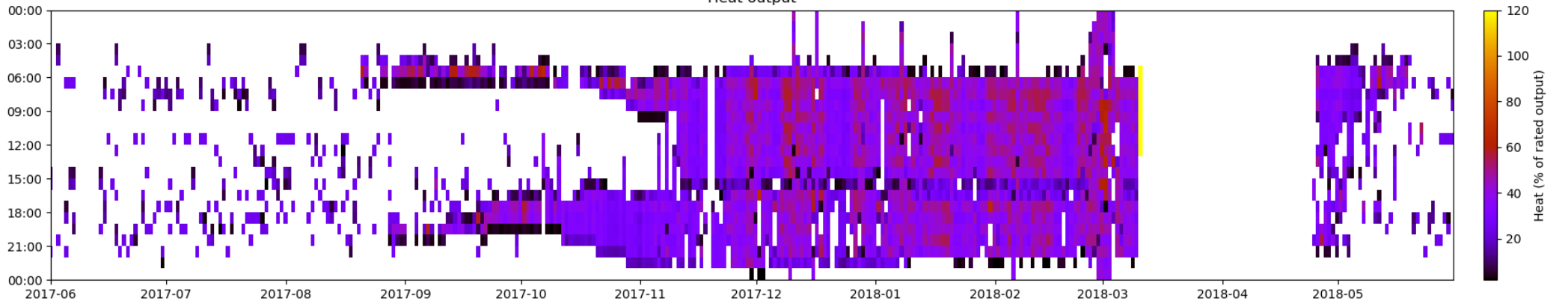
O₂



T_{flue}

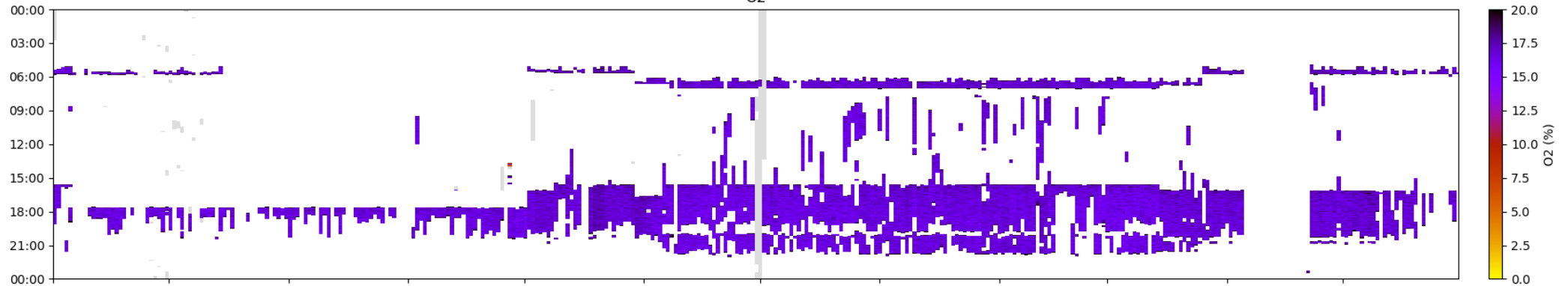


Heat output

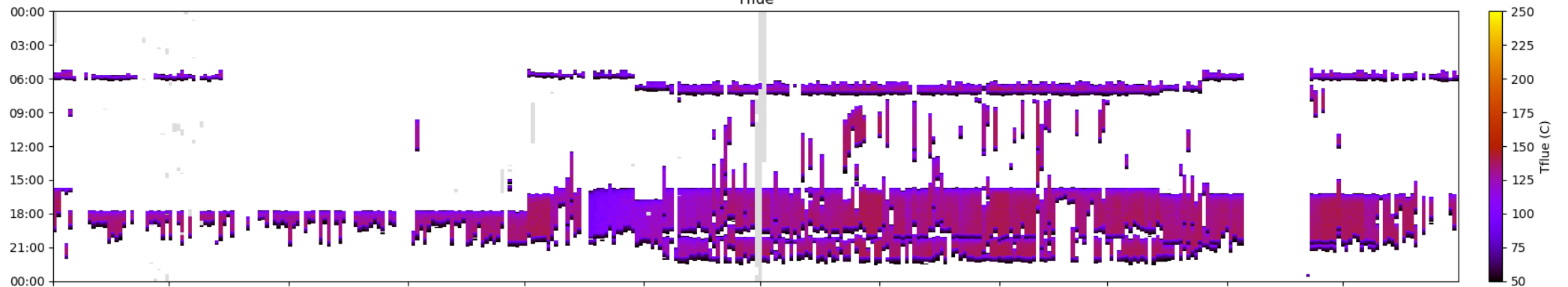


First Year Tapestries B499

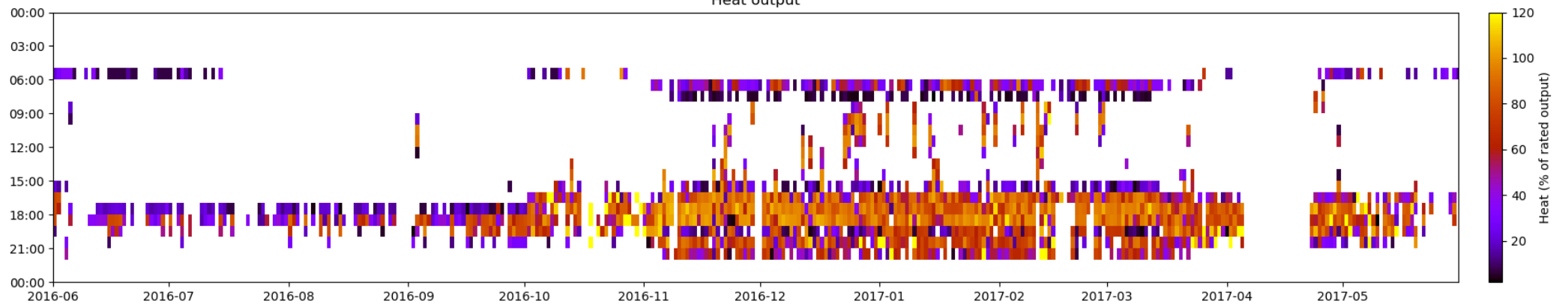
O2



Tflue

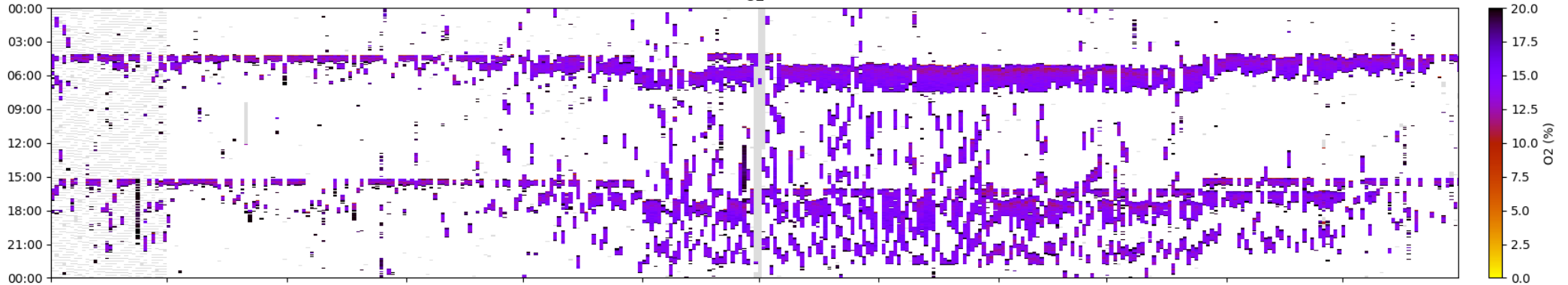


Heat output

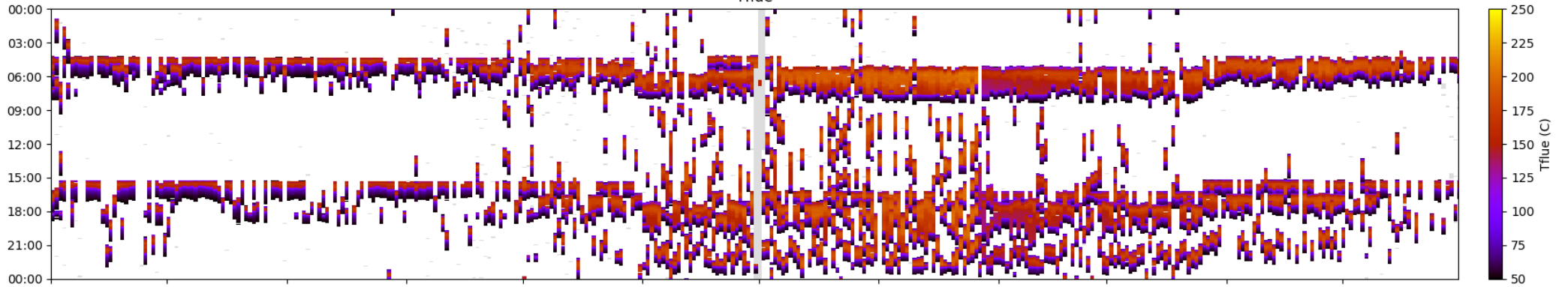


First Year Tapestries B542

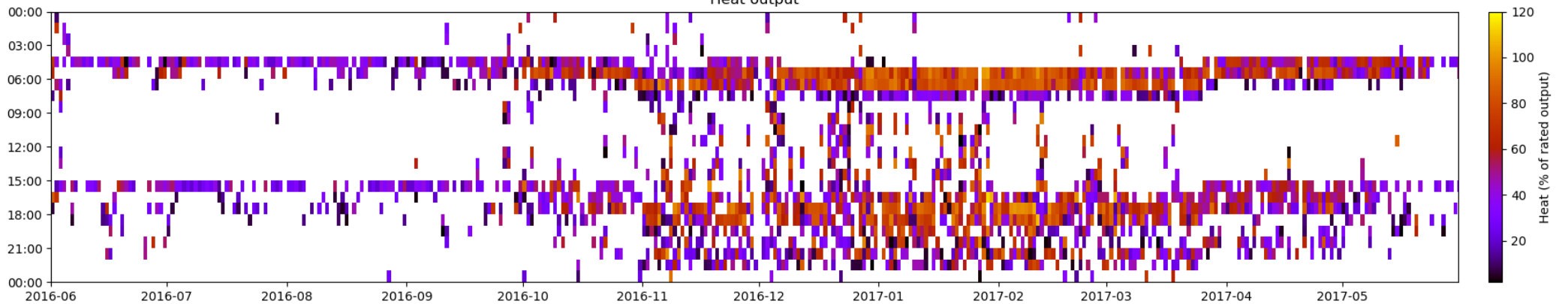
O2



Tflue

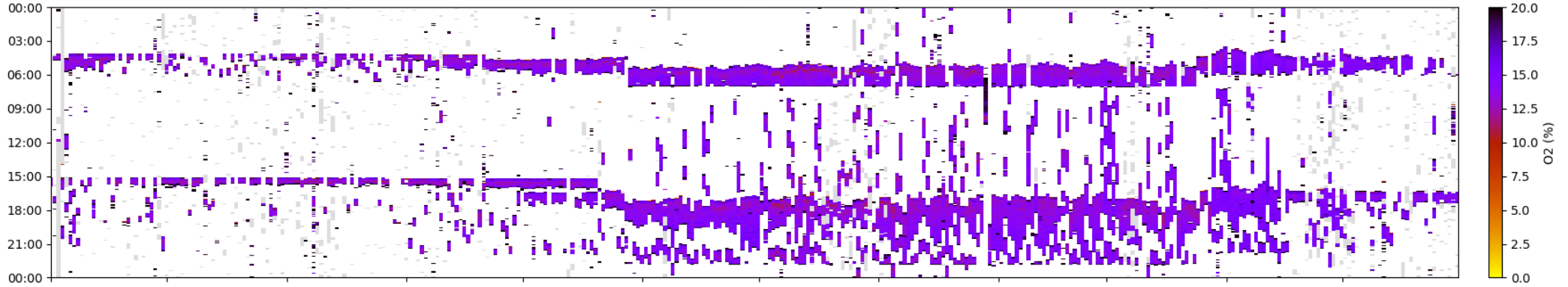


Heat output

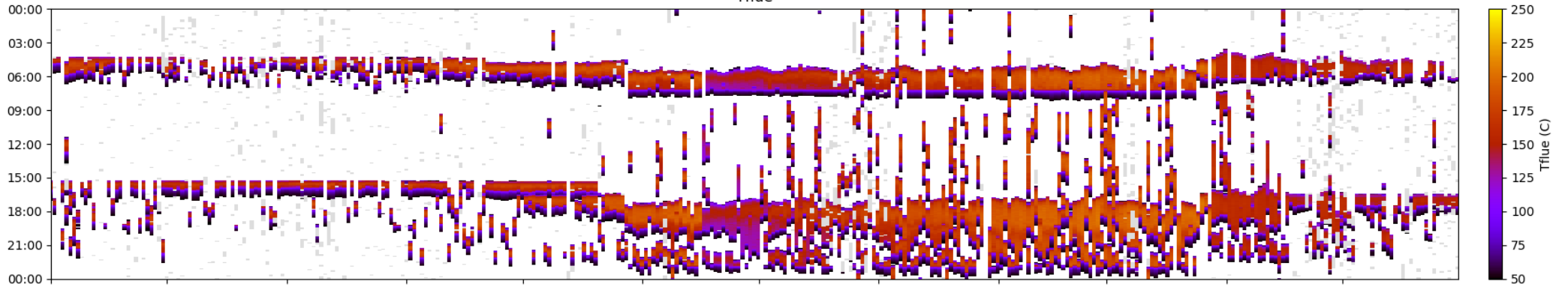


Second Year Tapestries B542

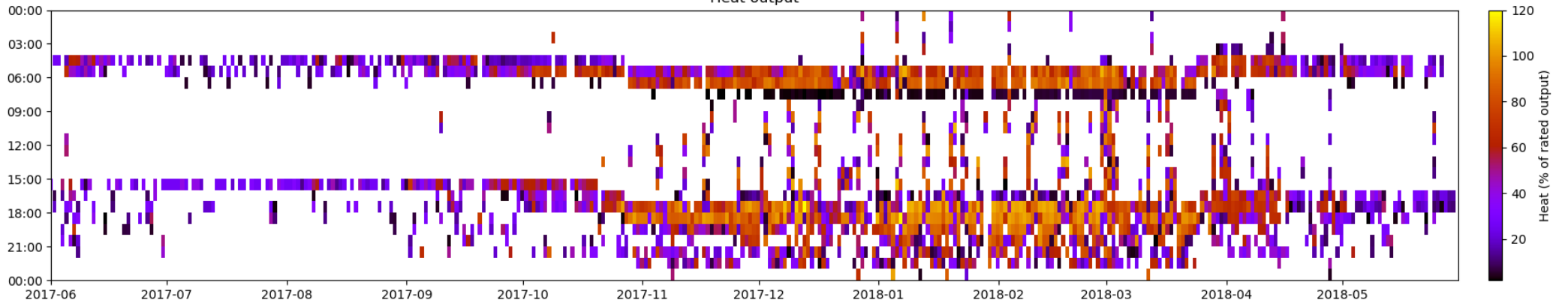
O2



Tflue

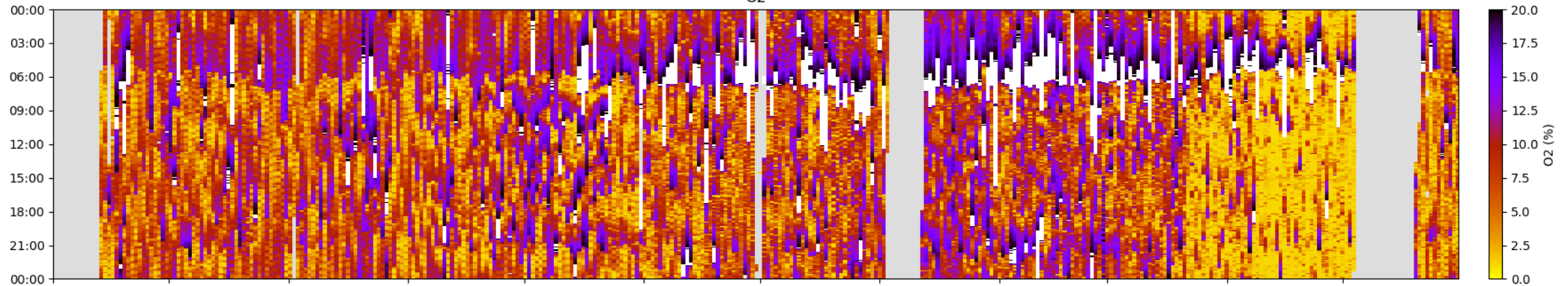


Heat output

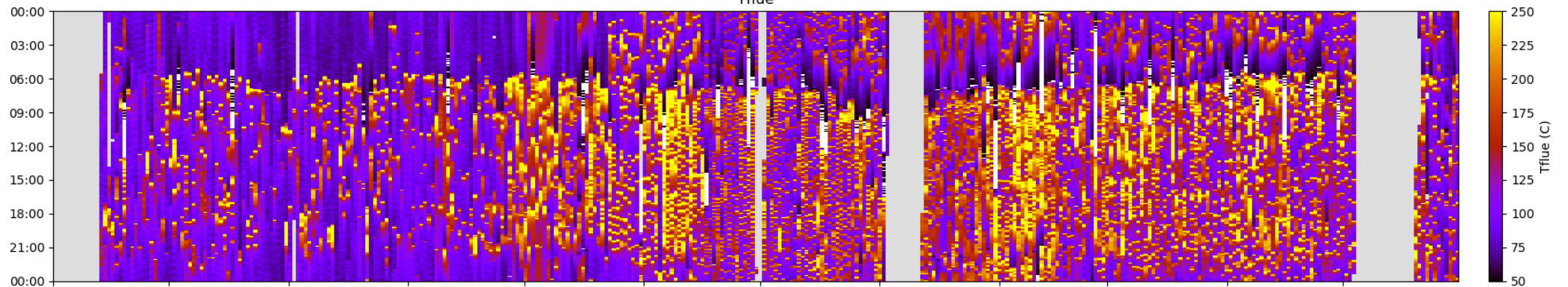


First Year Tapestries B585

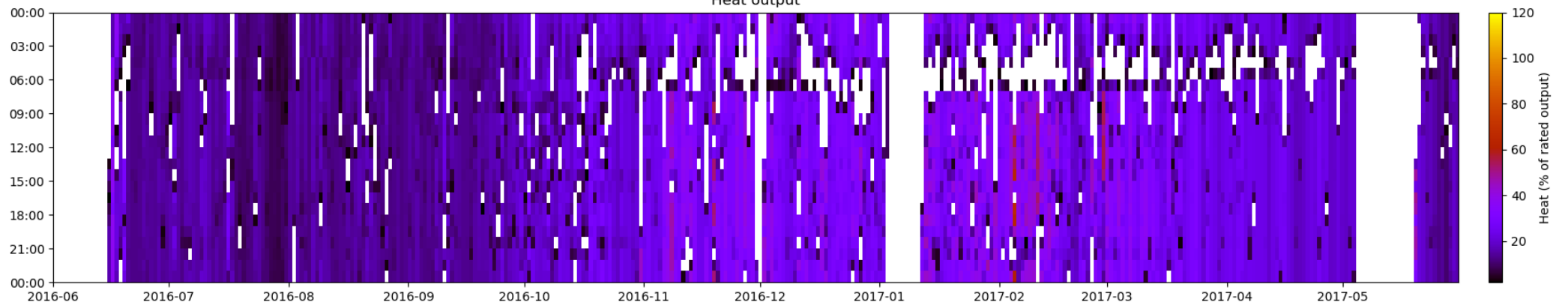
O₂



T_{flue}

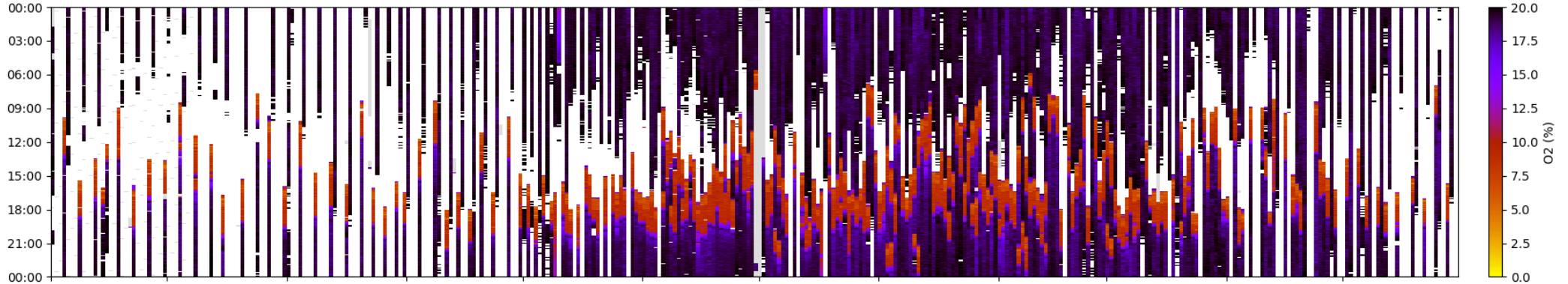


Heat output

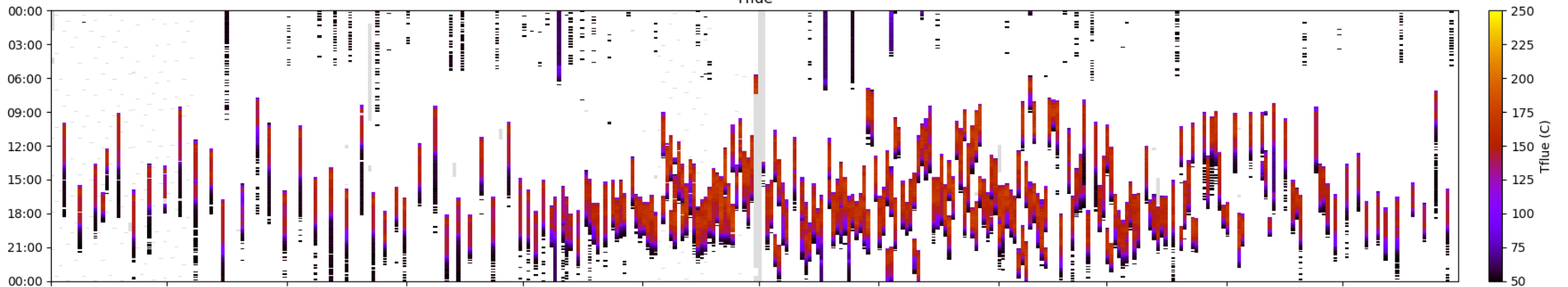


First Year Tapestries B586

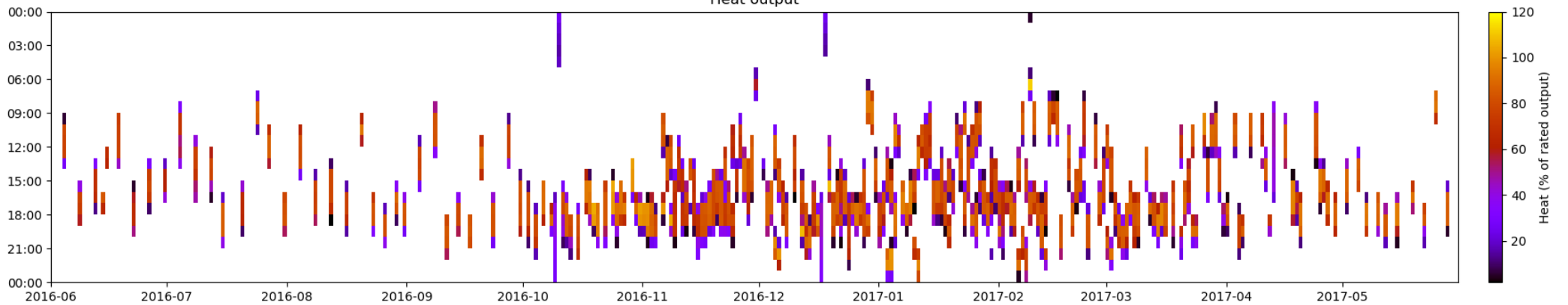
O2



Tflue

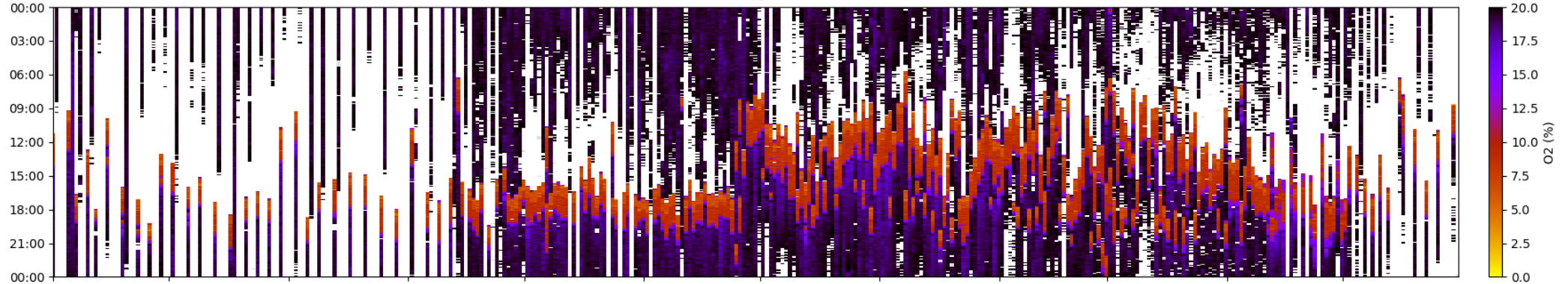


Heat output

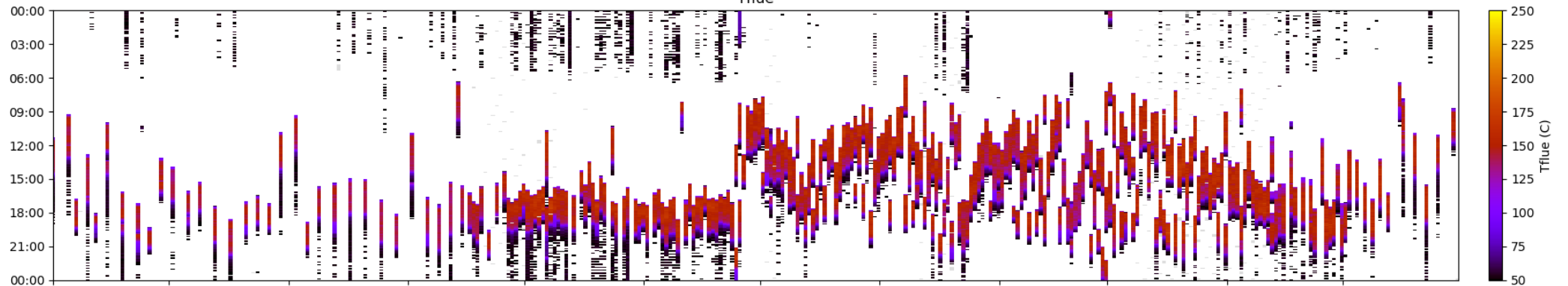


Second Year Tapestries B586

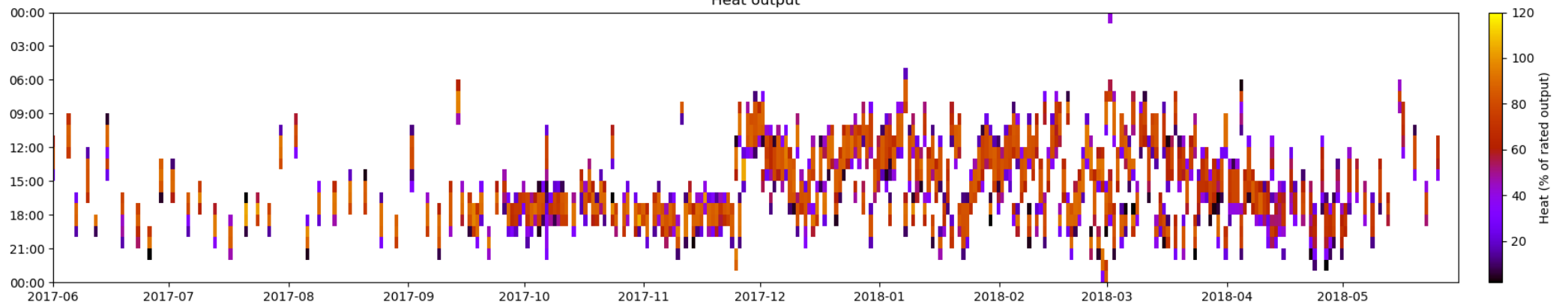
O2



Tflue

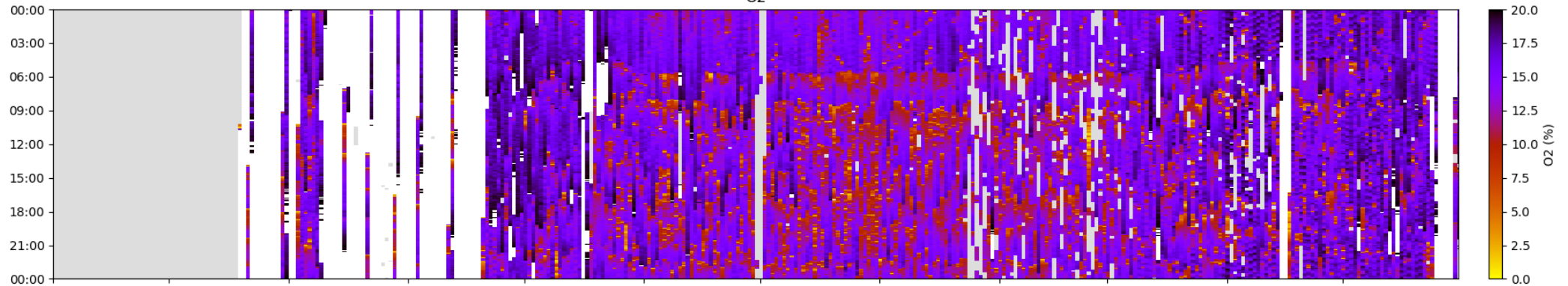


Heat output

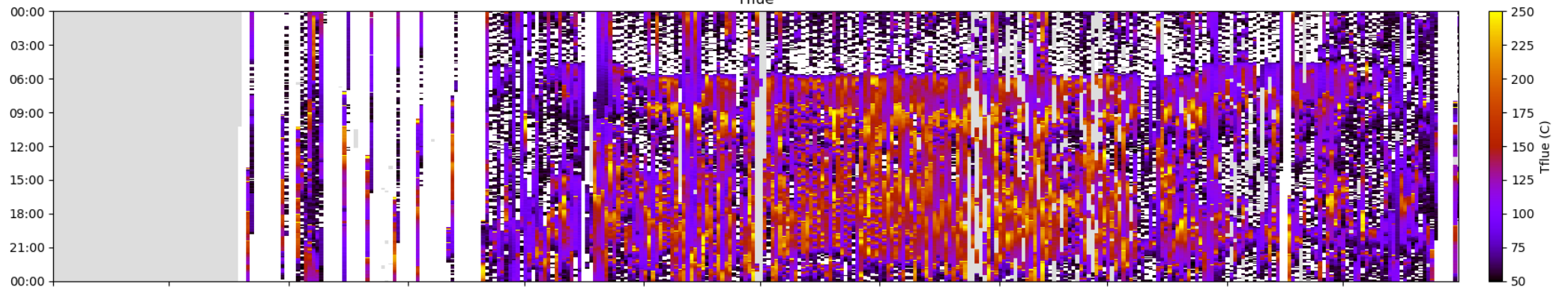


First Year Tapestries B609

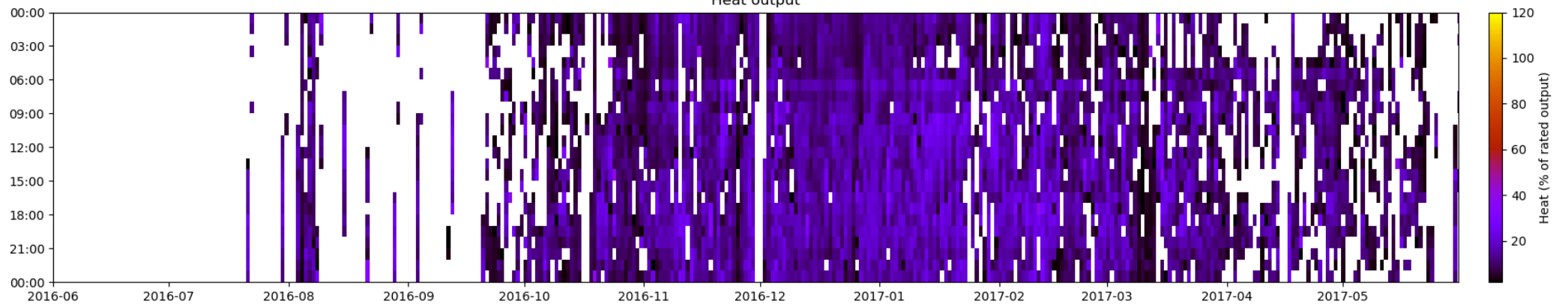
O2



Tflue

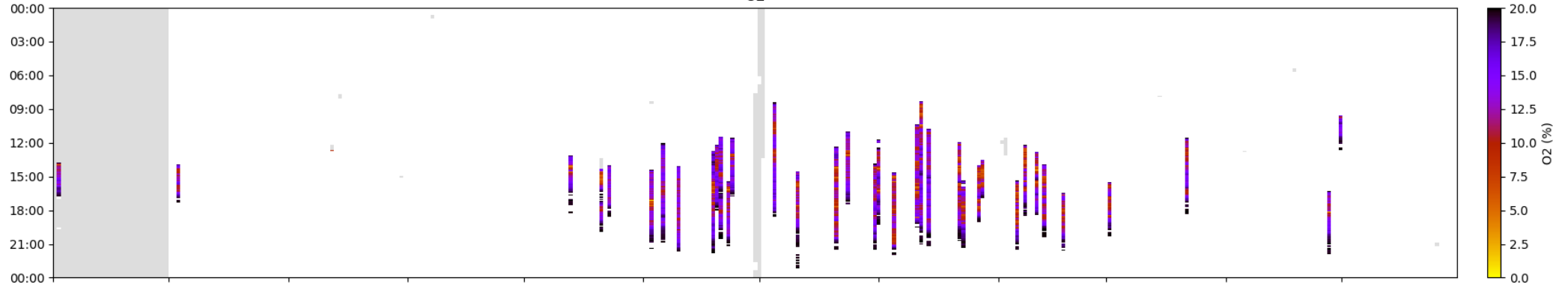


Heat output

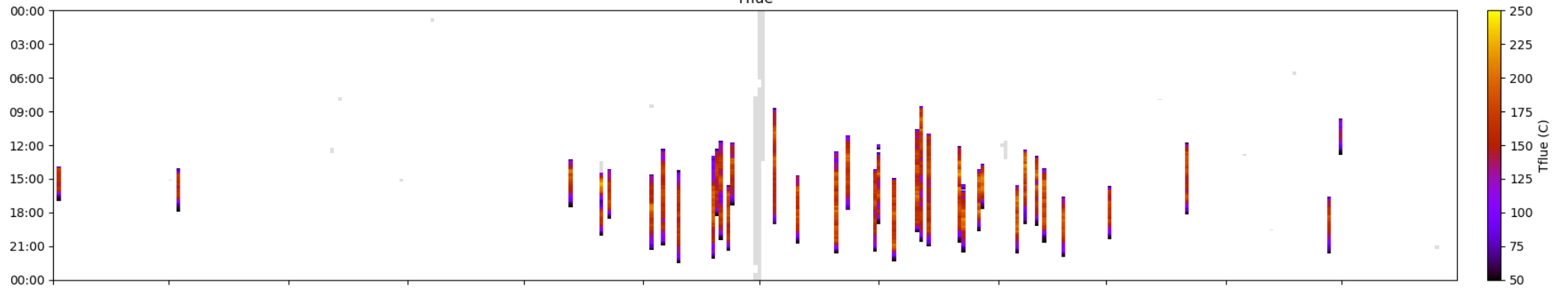


First Year Tapestries B622

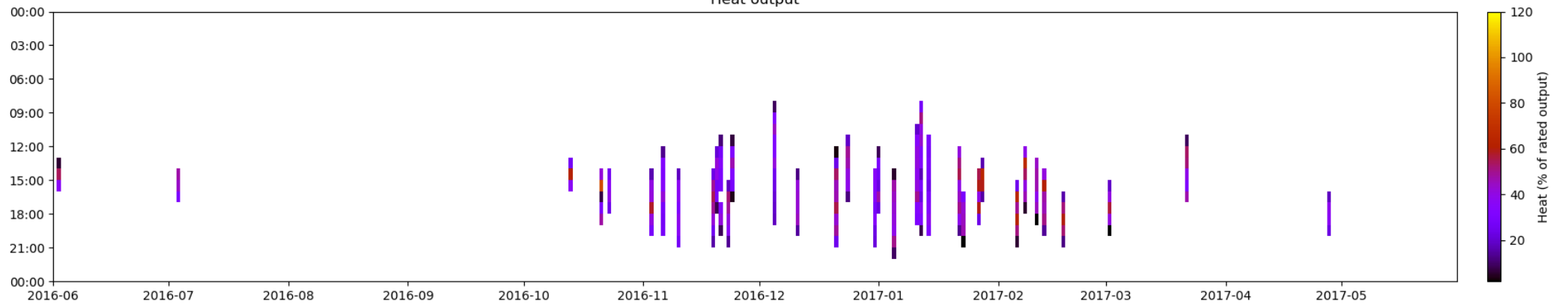
O2



Tflue

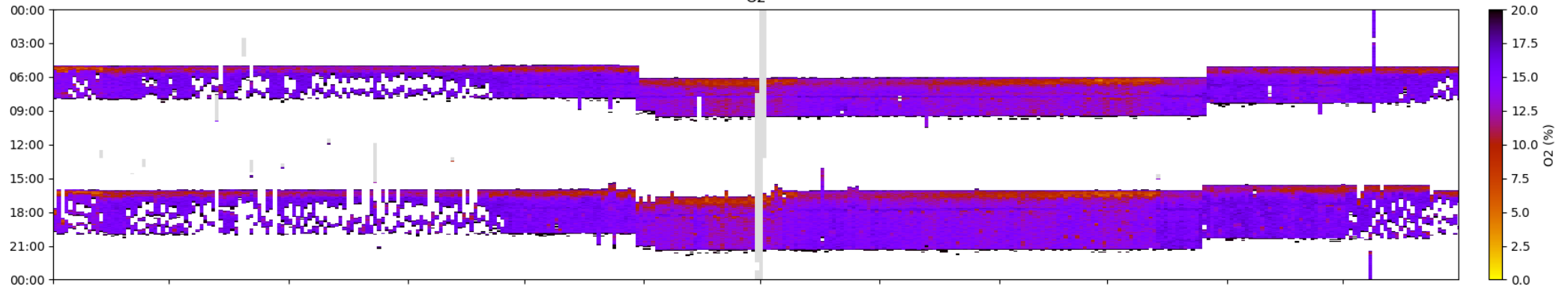


Heat output

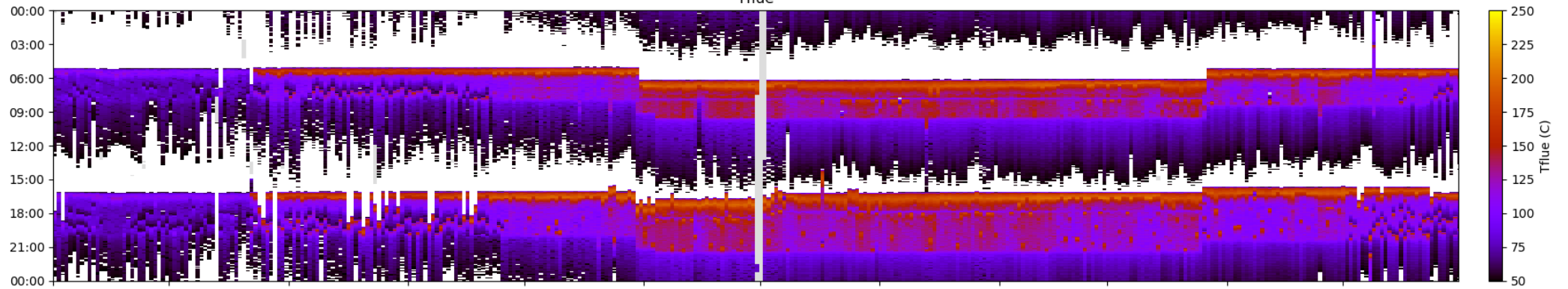


First Year Tapestries B625

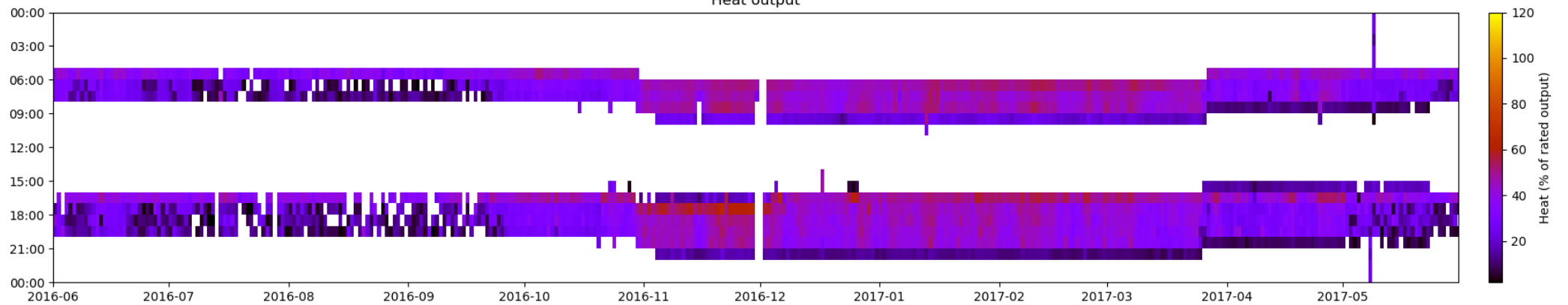
O2



Tflue

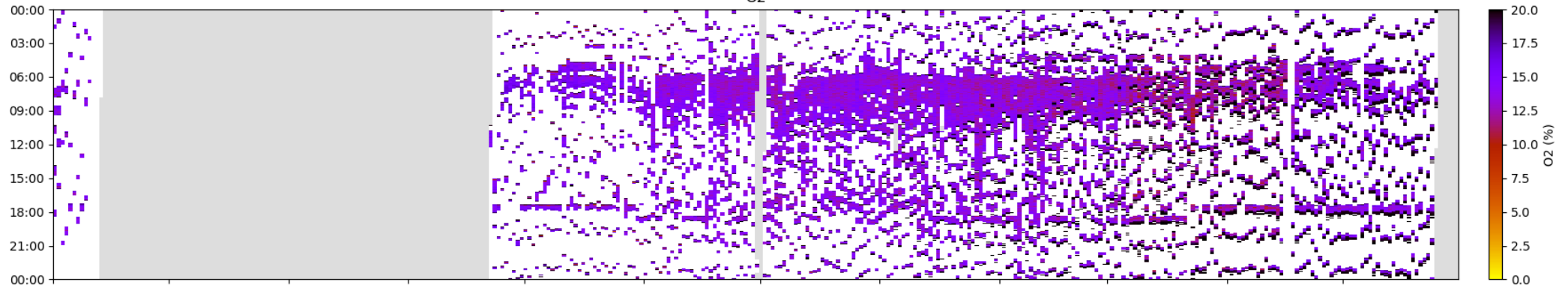


Heat output

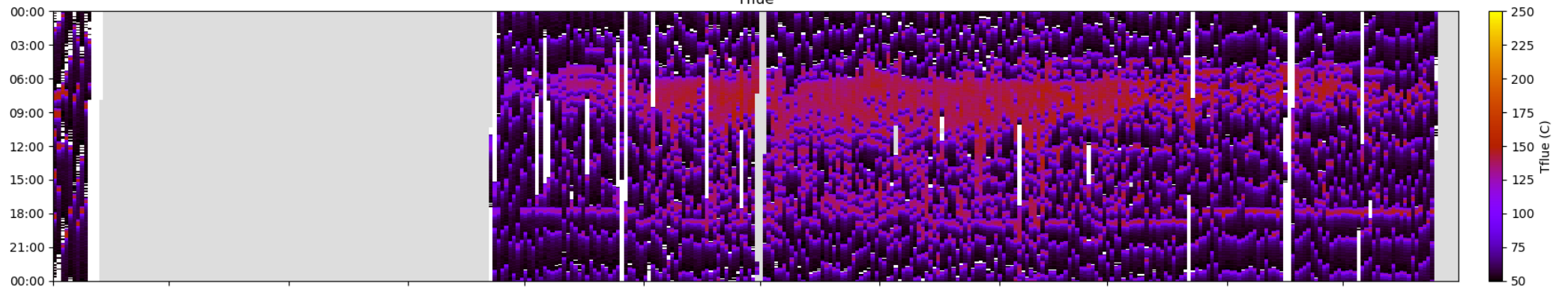


First Year Tapestries B630

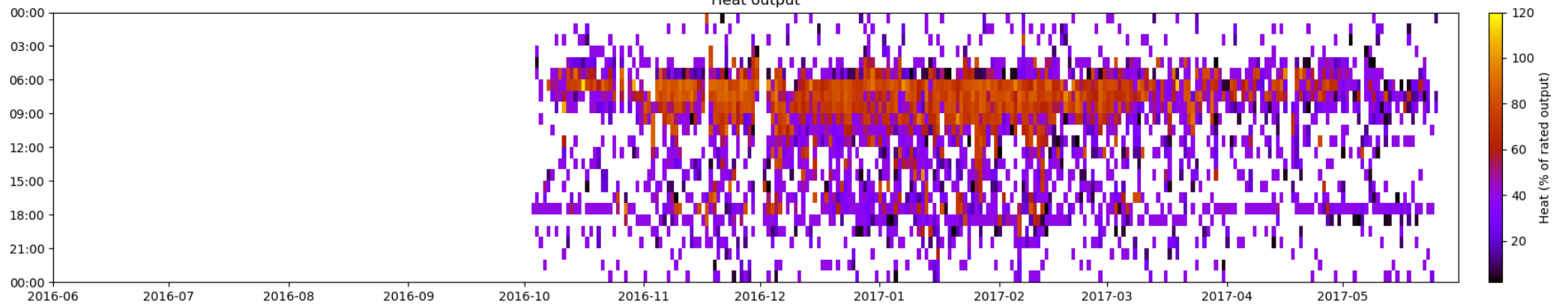
O2



Tflue



Heat output

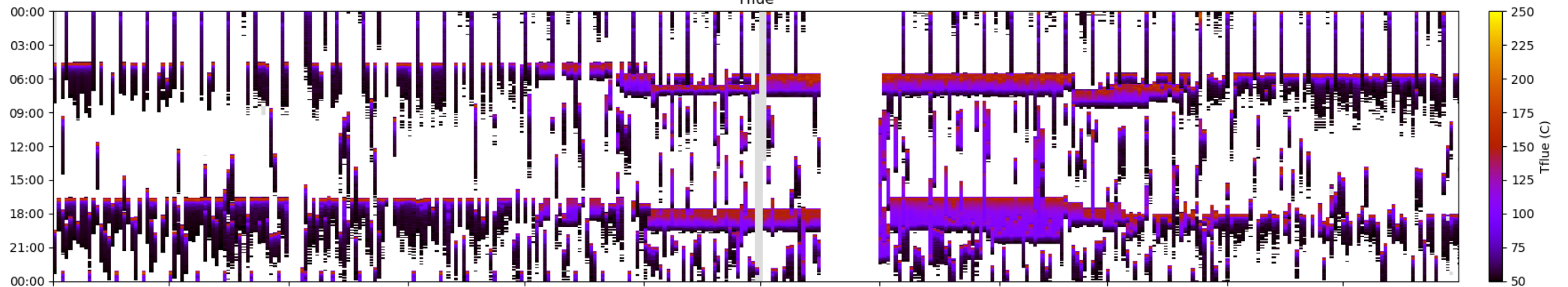


First Year Tapestries B650

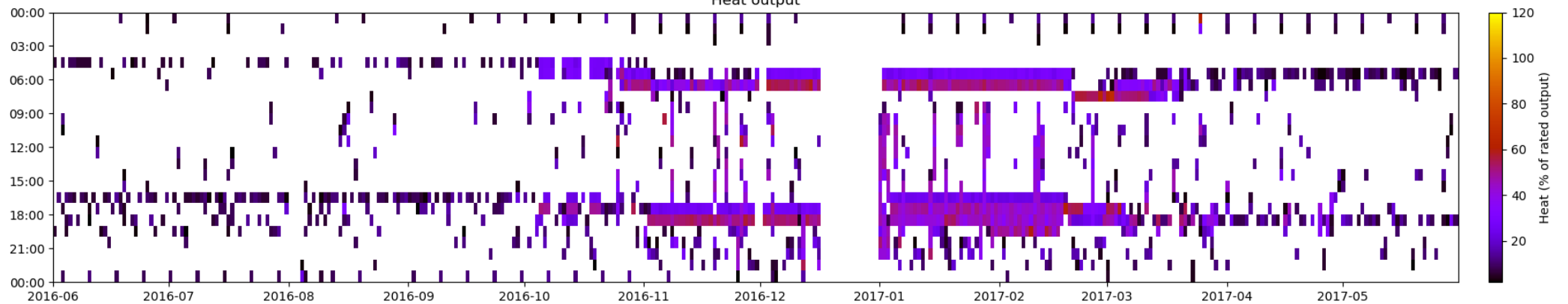
O2



Tflue

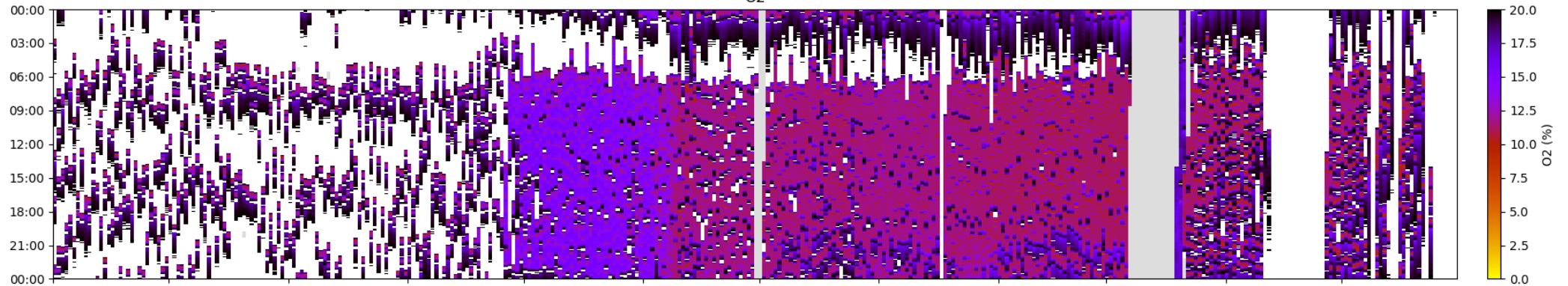


Heat output

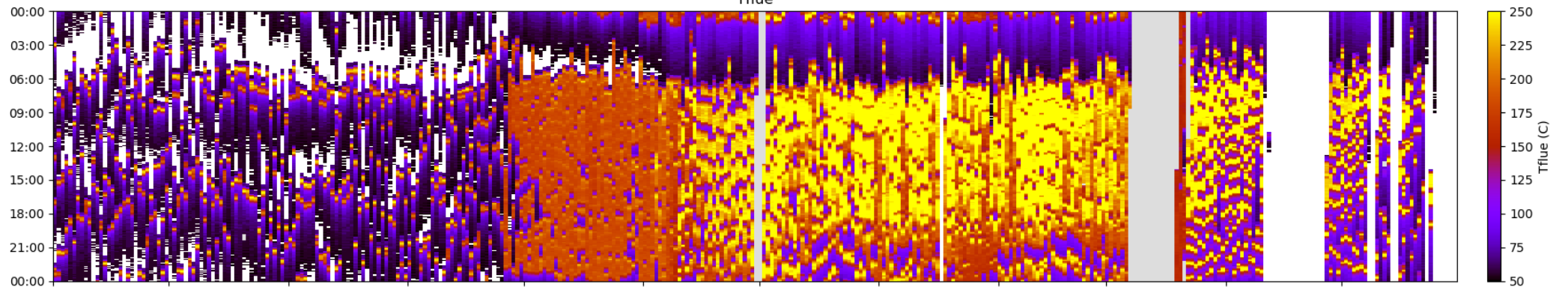


First Year Tapestries B900

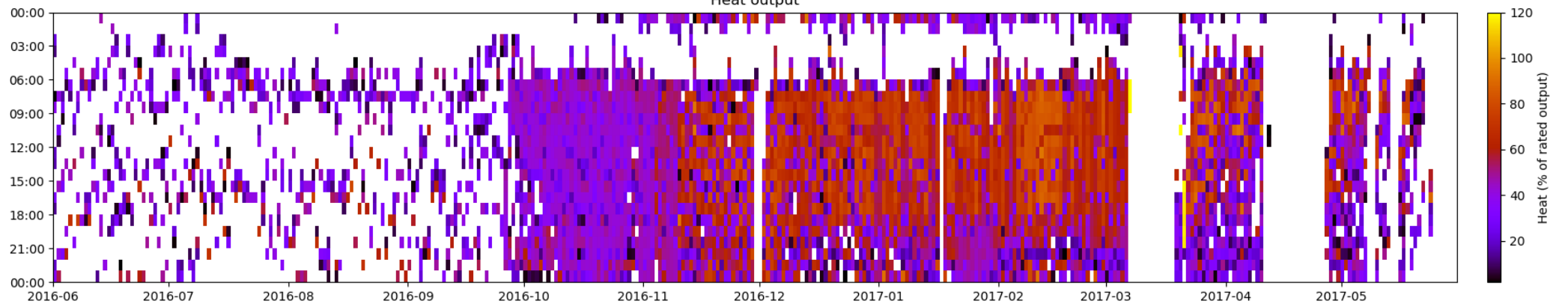
O2



Tflue

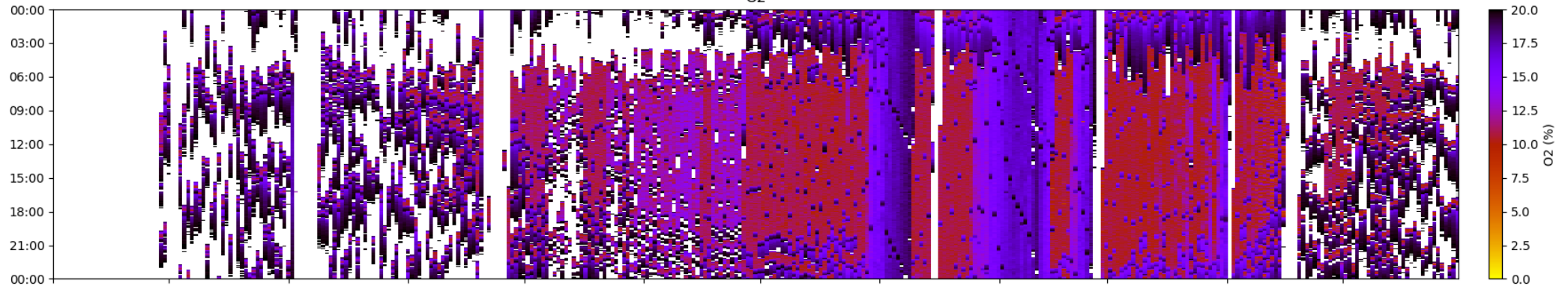


Heat output

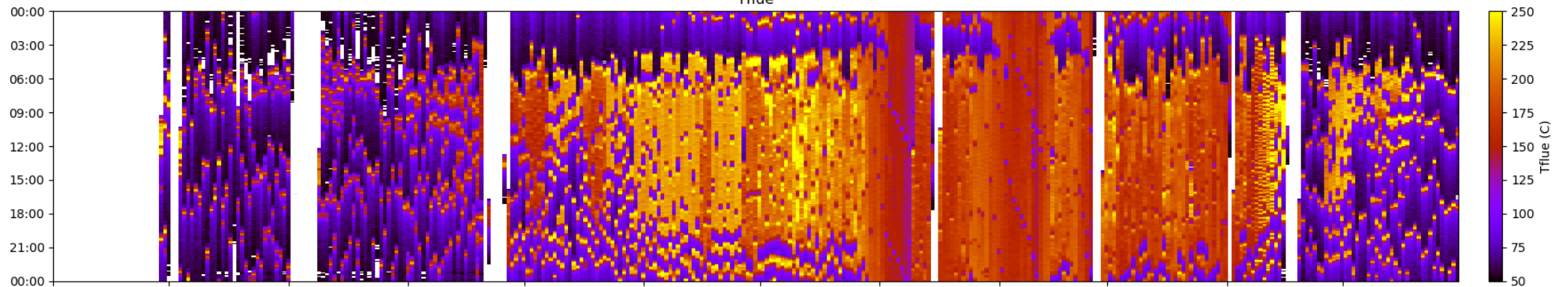


Second Year Tapestries B900

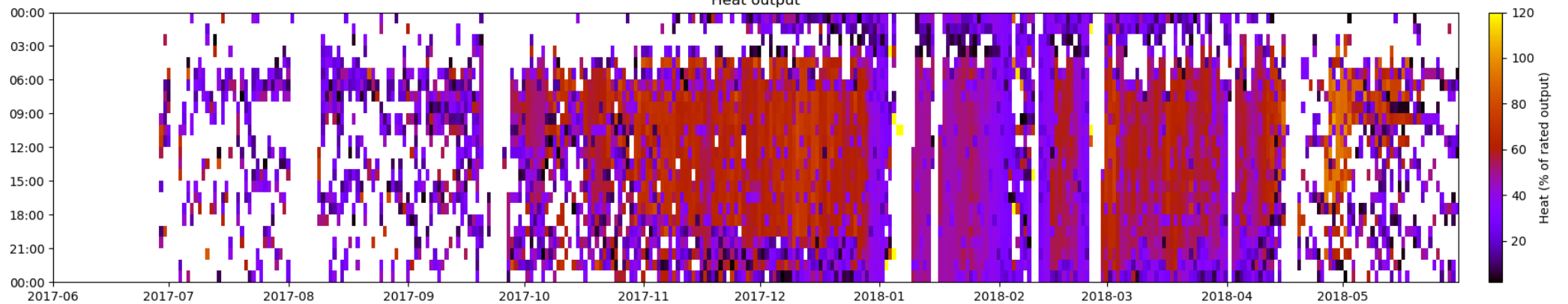
O2



Tflue

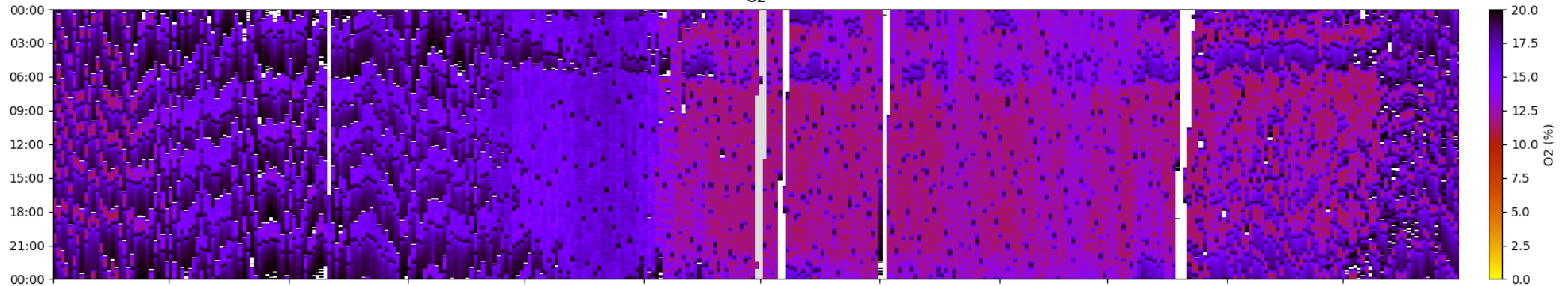


Heat output

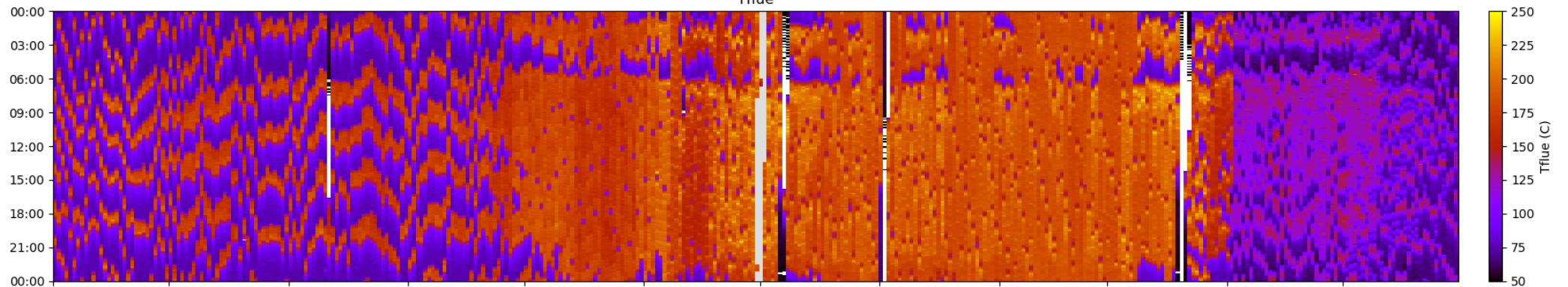


First Year Tapestries B901

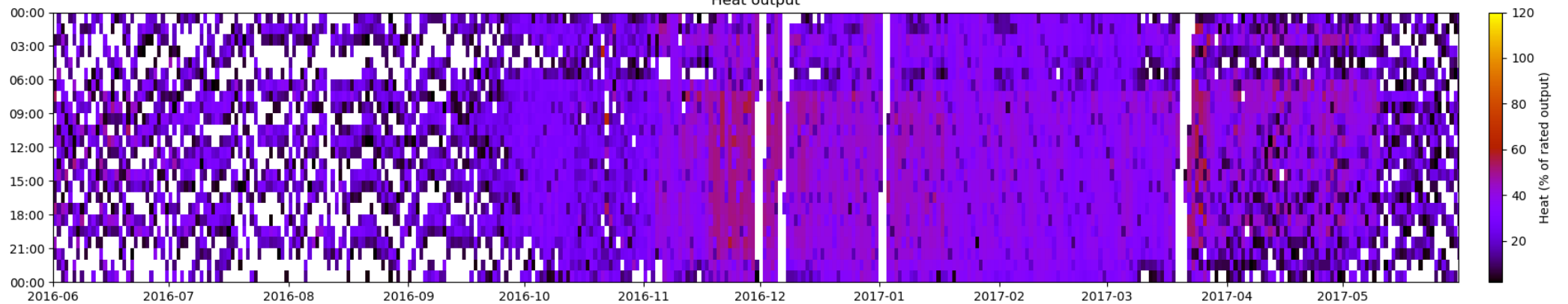
O2



Tflue

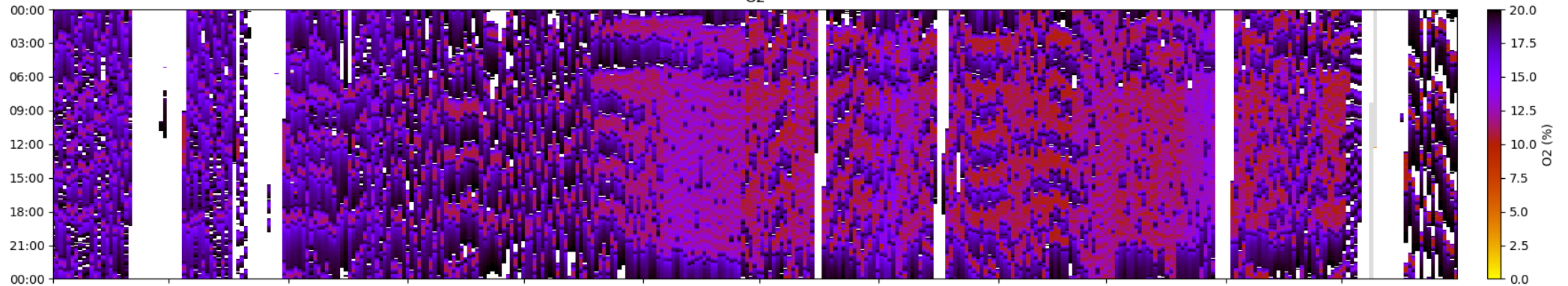


Heat output

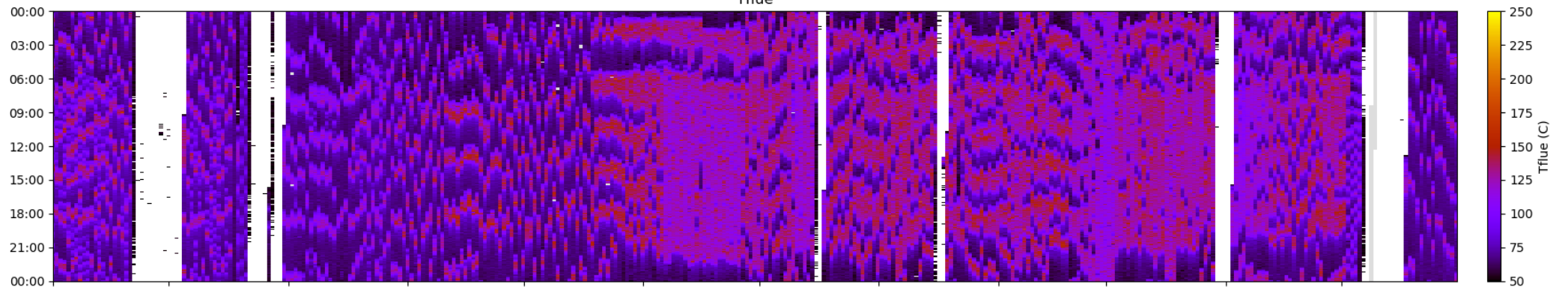


Second Year Tapestries B901

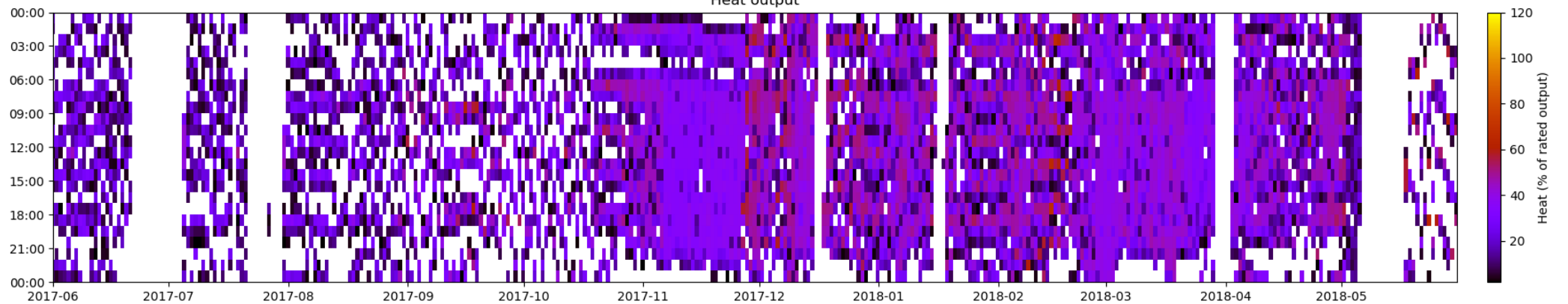
O2



Tflue

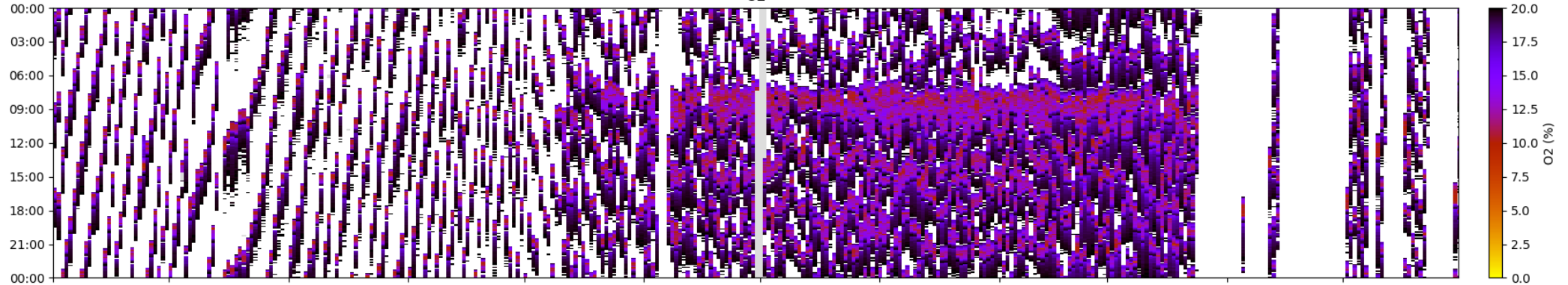


Heat output

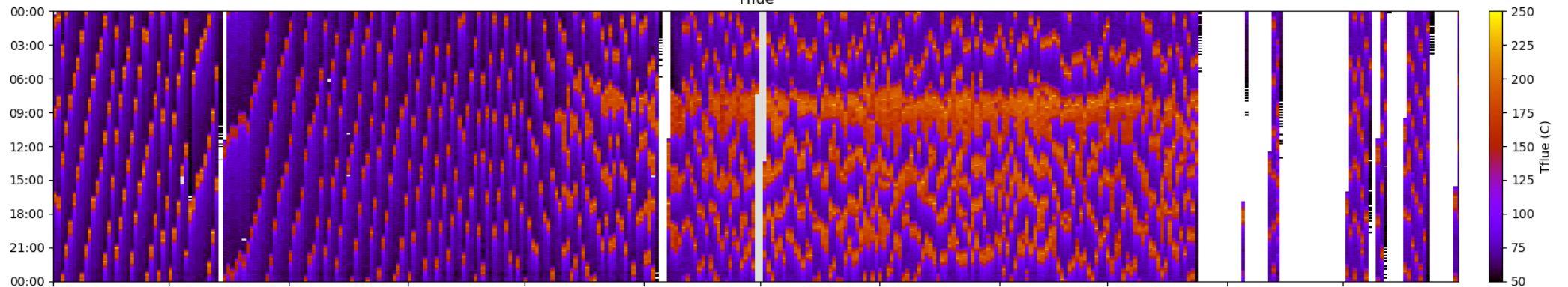


First Year Tapestries B902

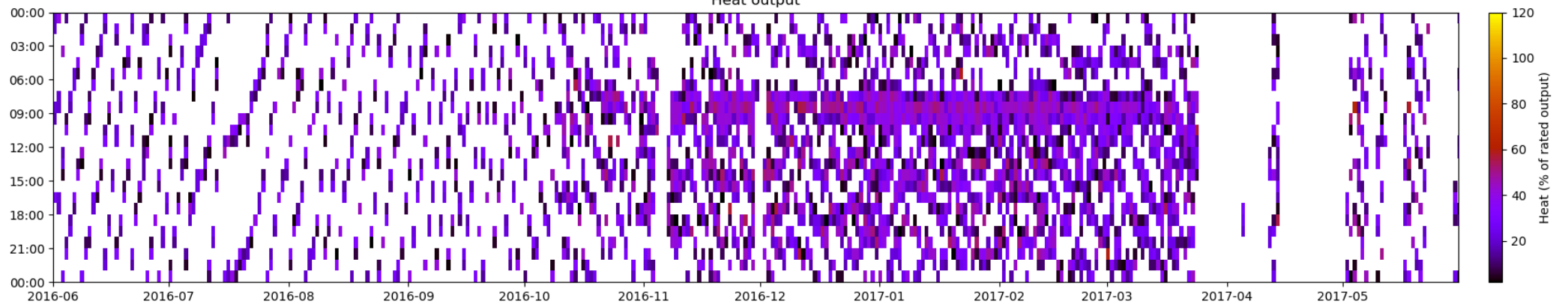
O2



Tflue

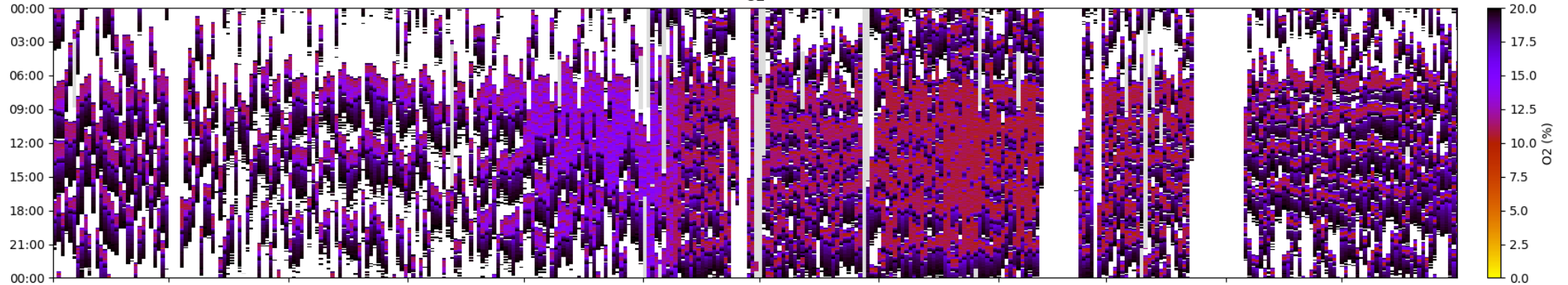


Heat output

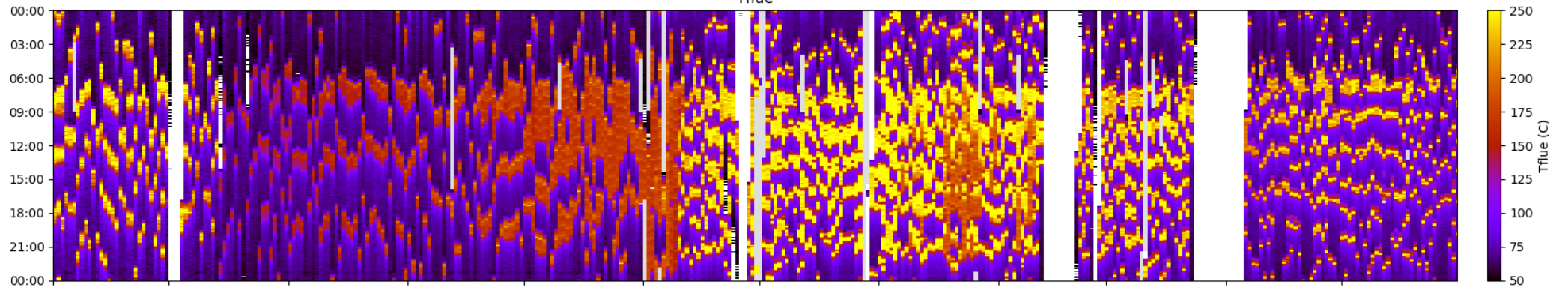


First Year Tapestries B903

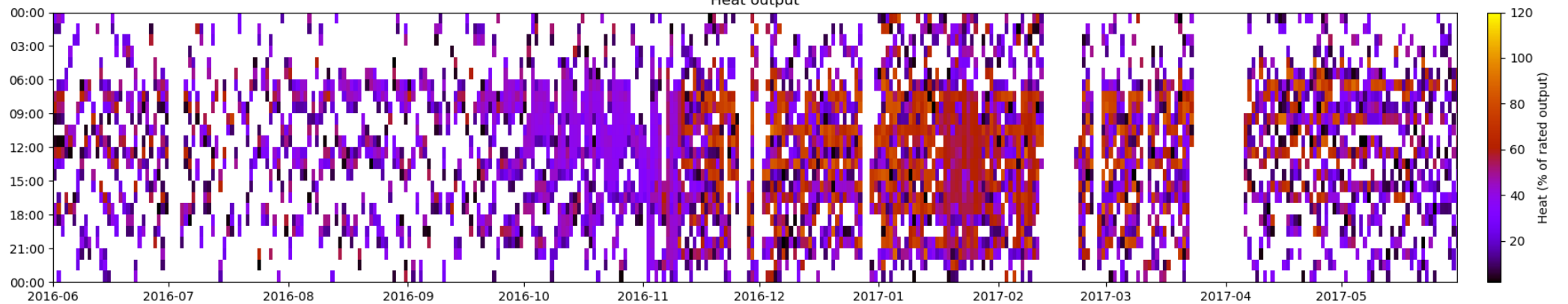
O2



Tflue

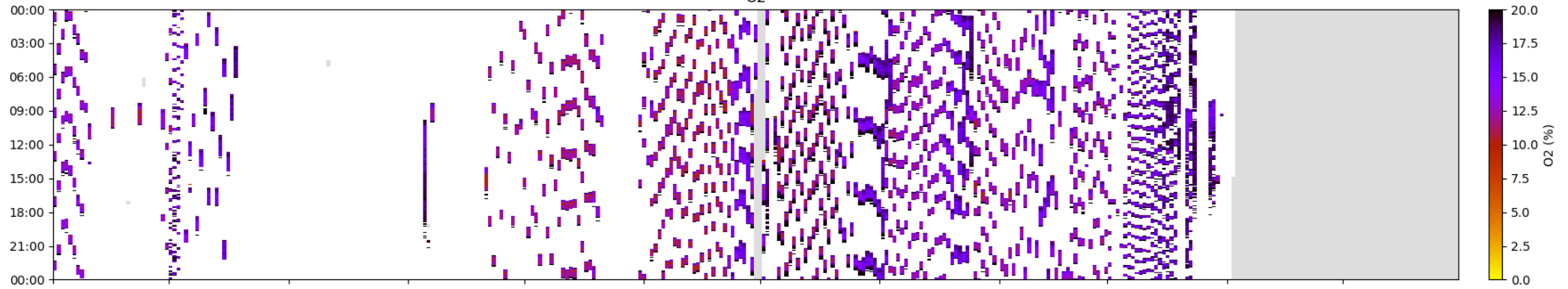


Heat output

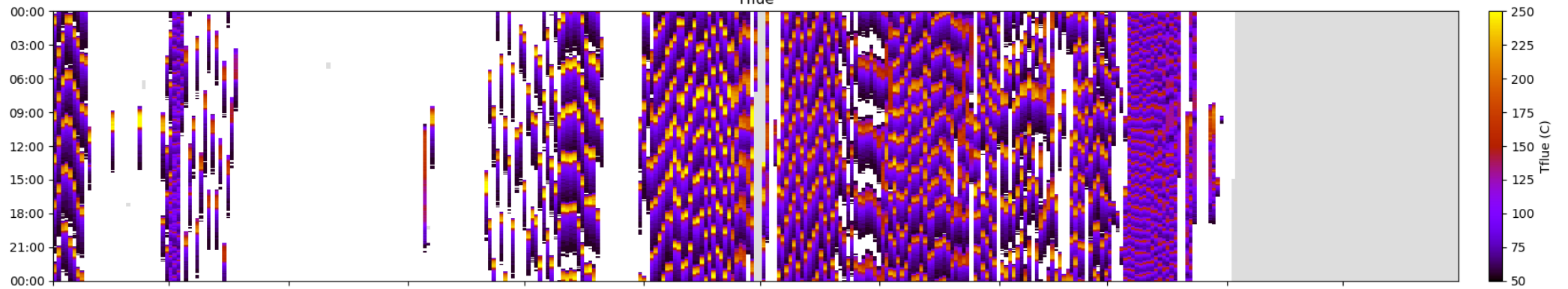


First Year Tapestries B906

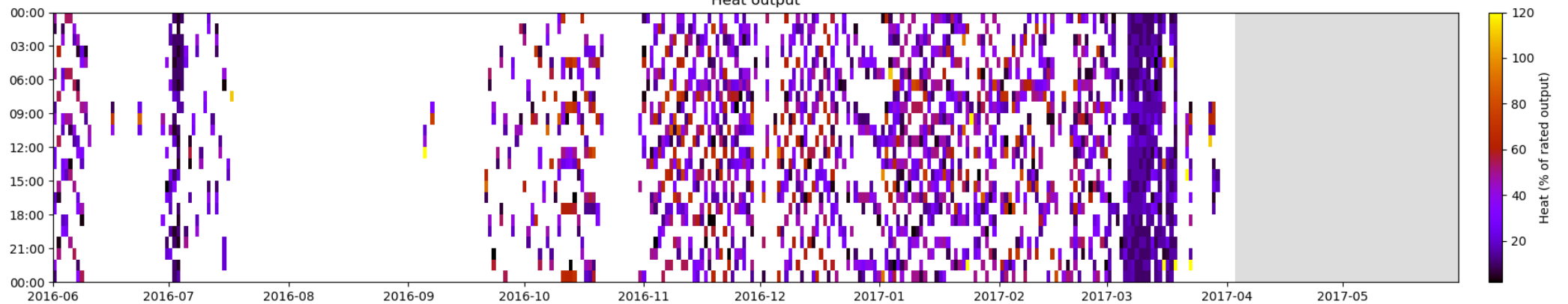
O2



Tflue

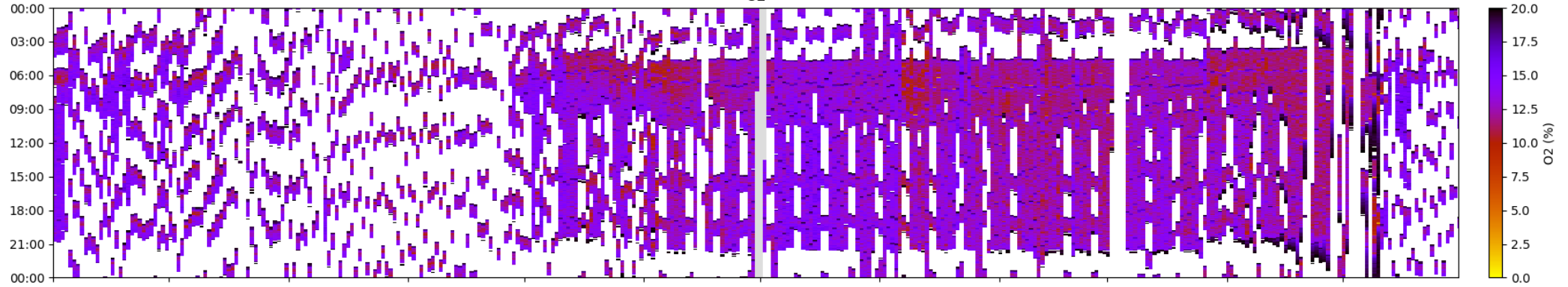


Heat output

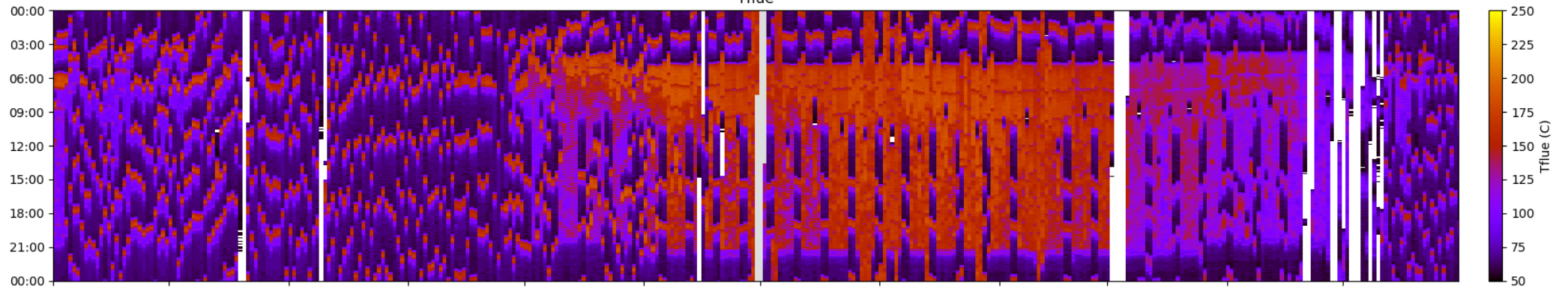


First Year Tapestries B907

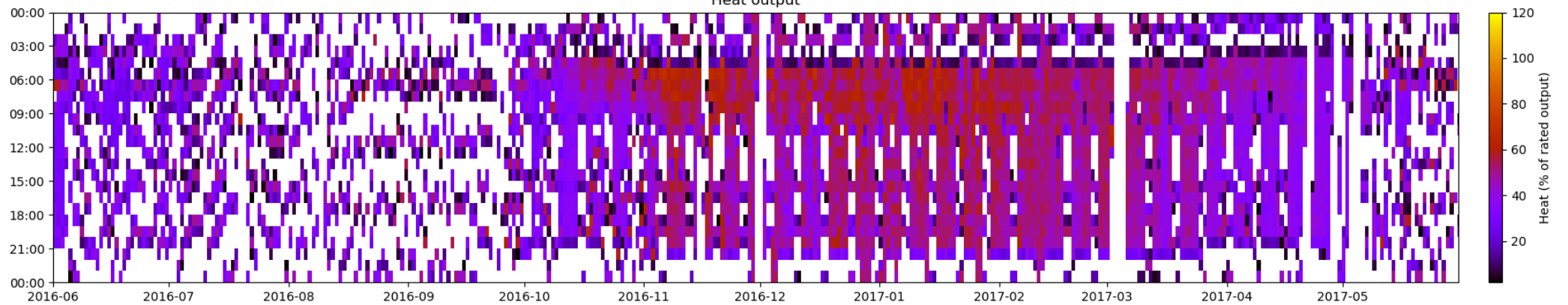
O2



Tflue

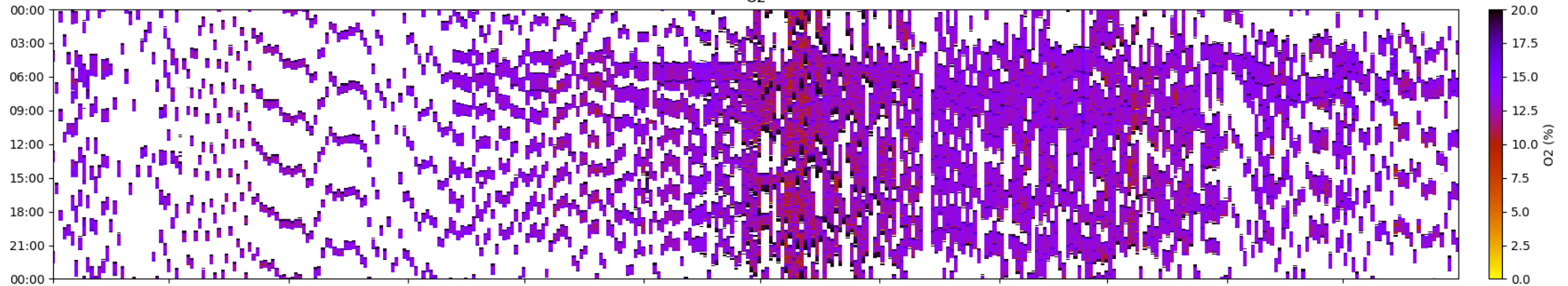


Heat output

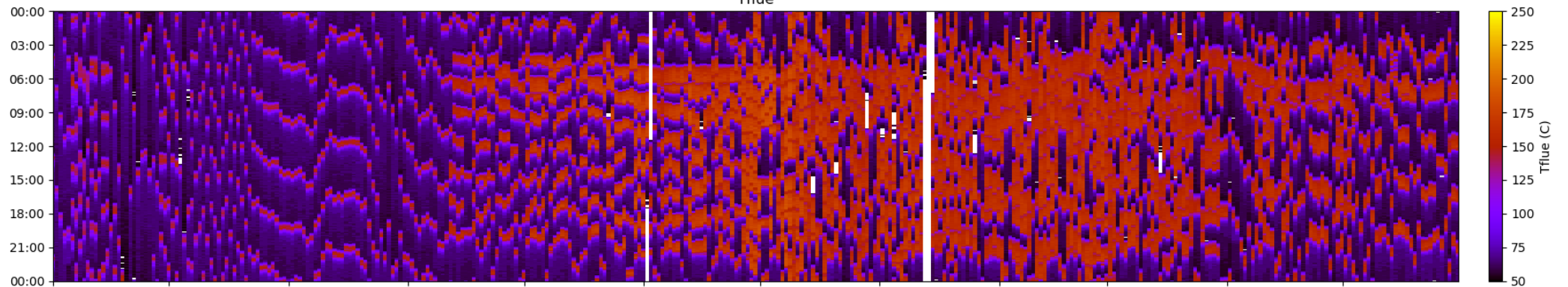


Second Year Tapestries B907

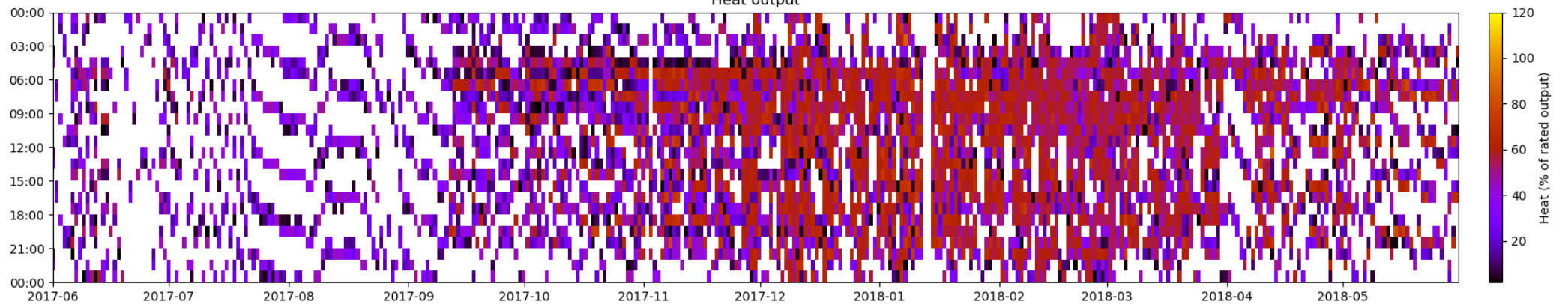
O2



Tflue

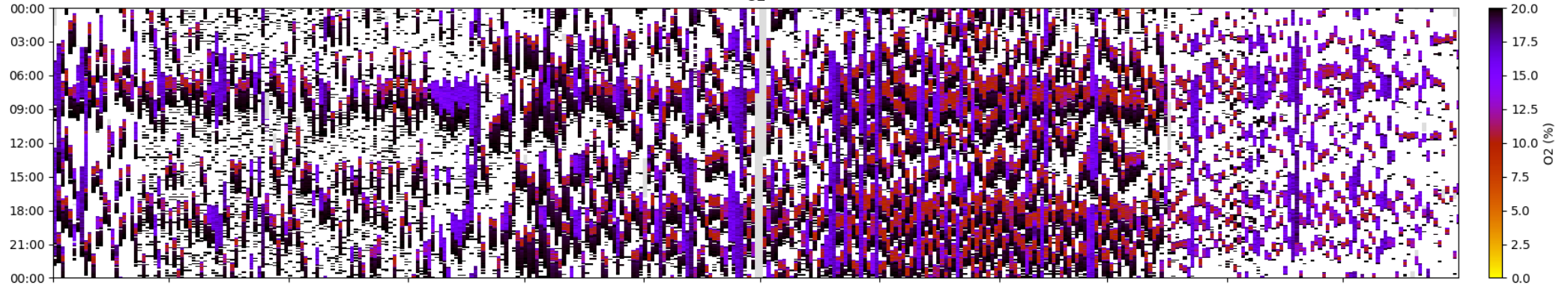


Heat output

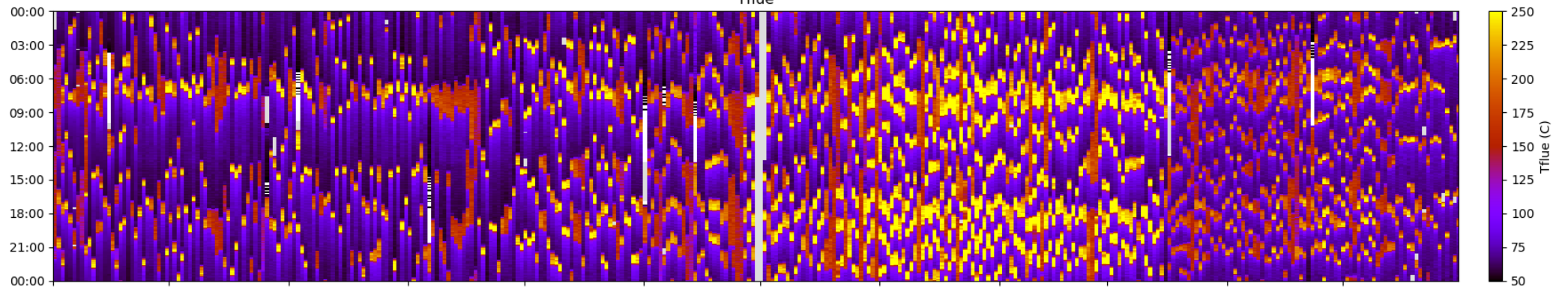


First Year Tapestries B908

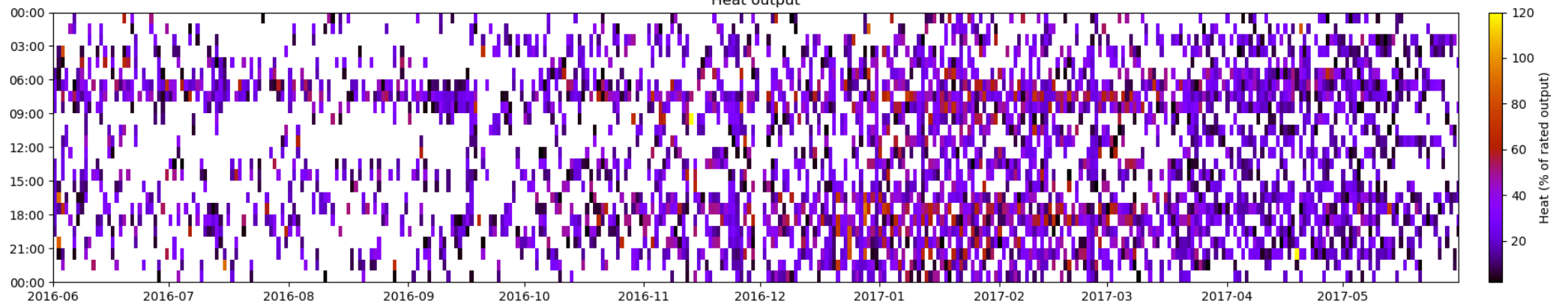
O2



Tflue

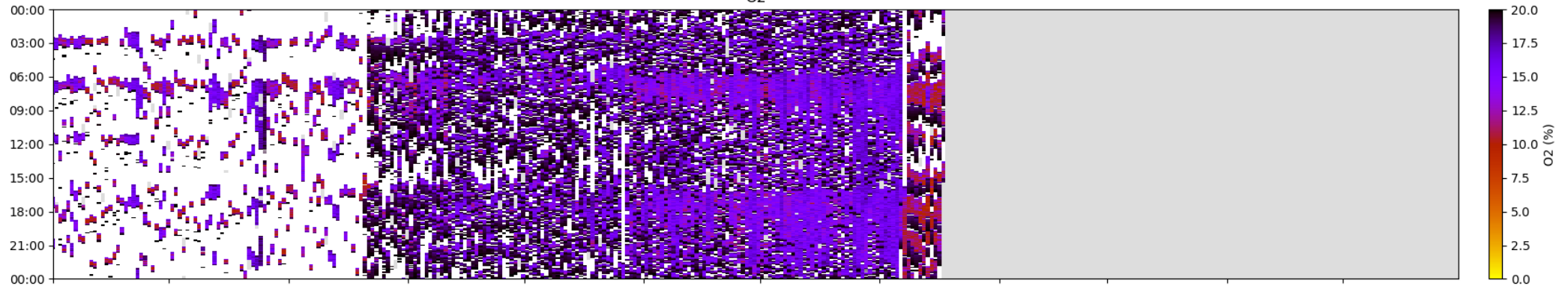


Heat output

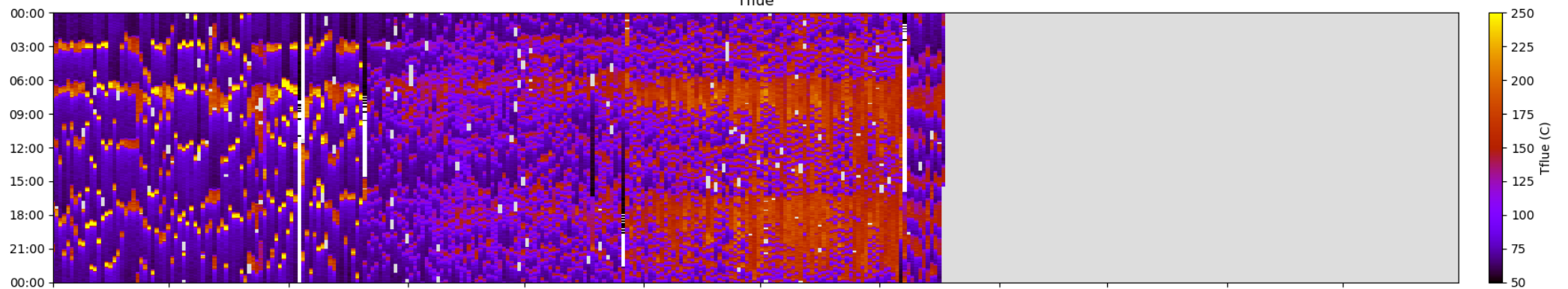


Second Year Tapestries B908

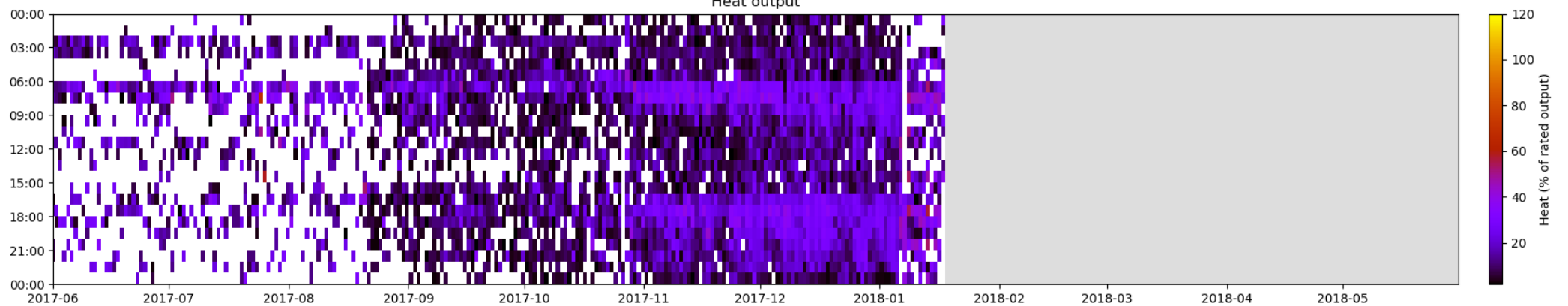
O2



Tflue

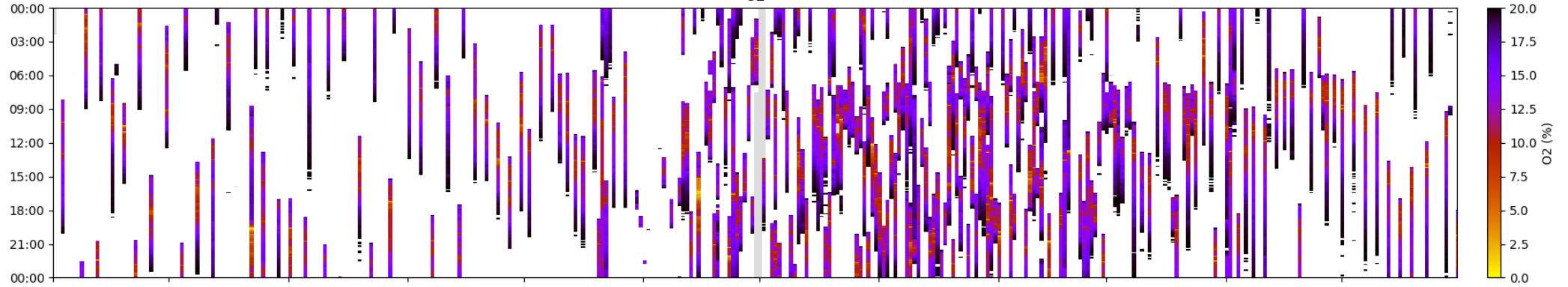


Heat output

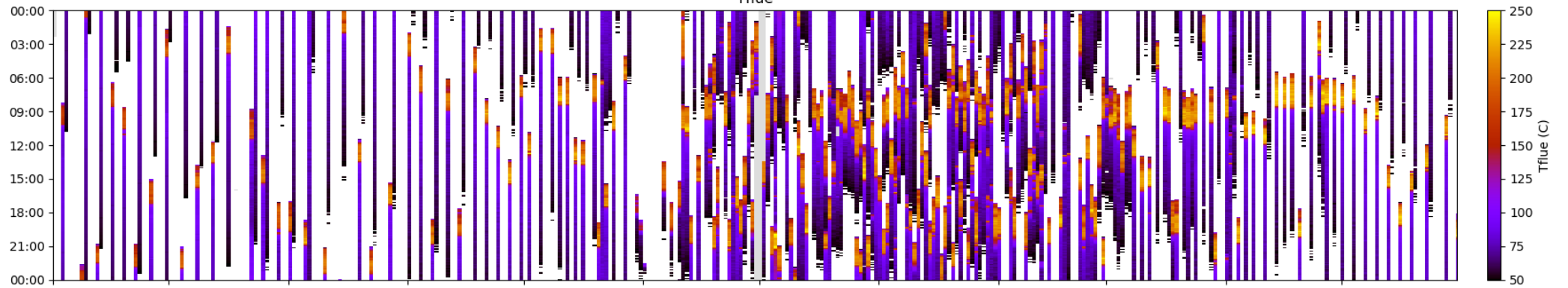


First Year Tapestries B909

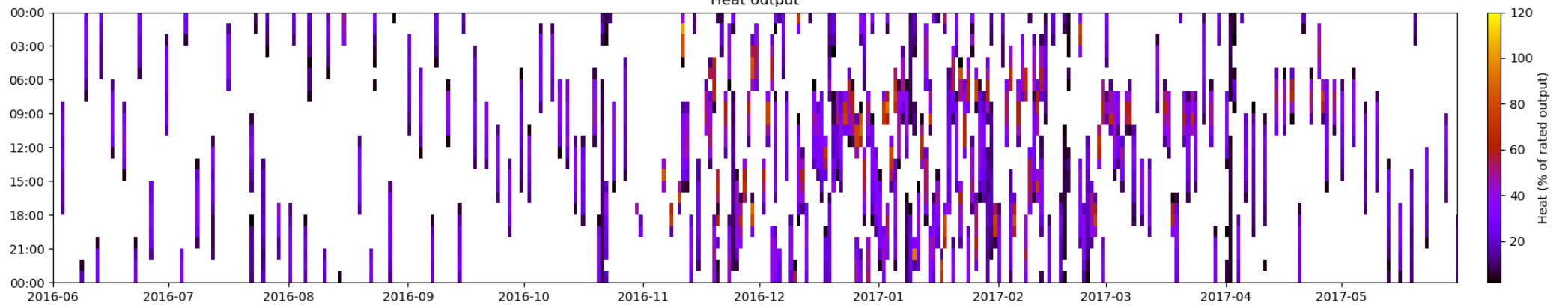
O2



Tflue

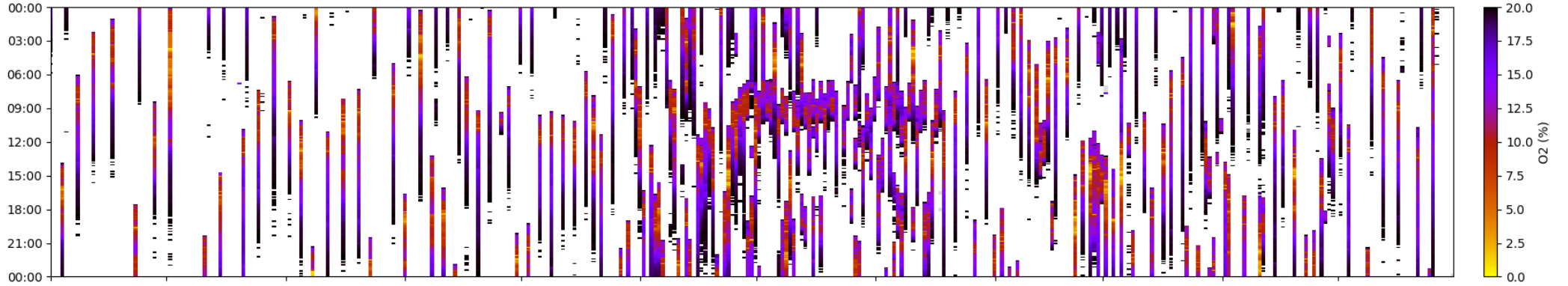


Heat output

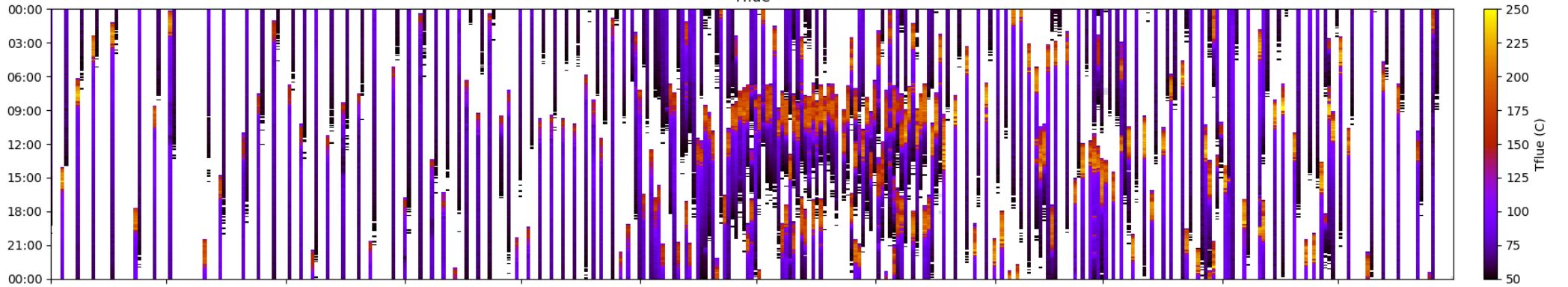


Second Year Tapestries B909

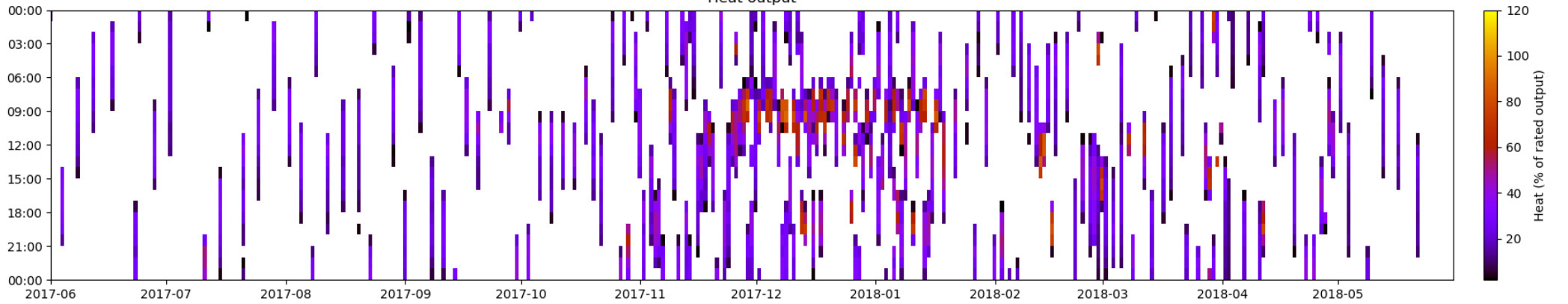
O2



Tflue

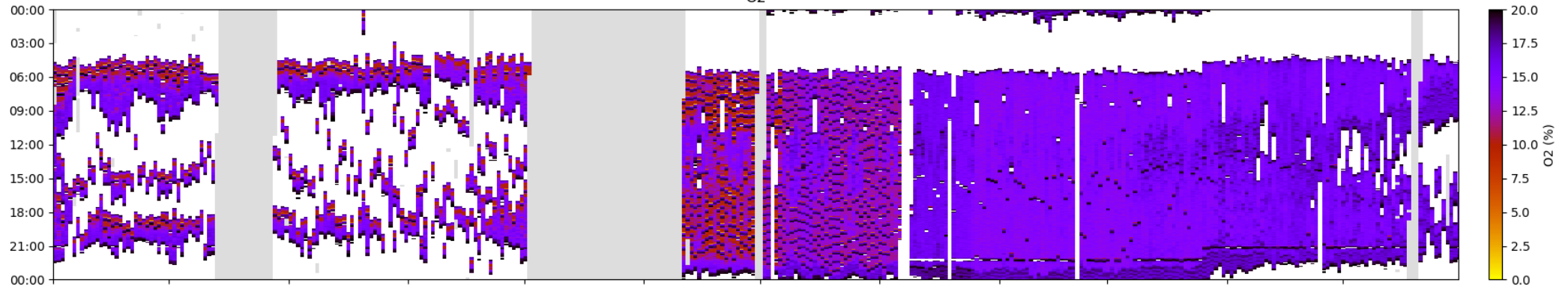


Heat output

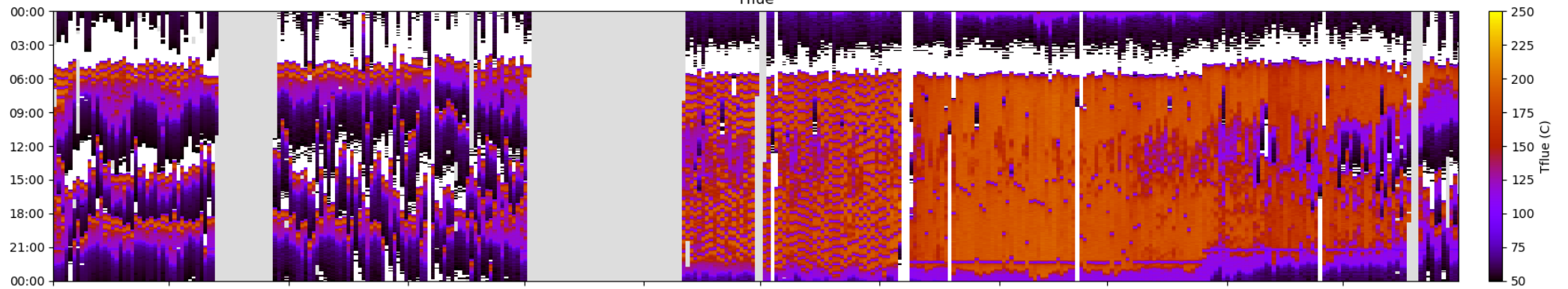


First Year Tapestries B910

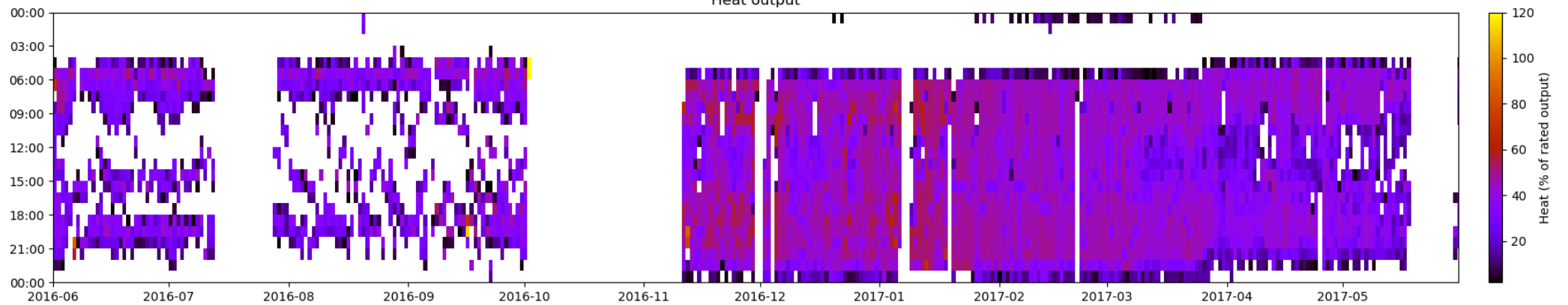
O2



Tflue

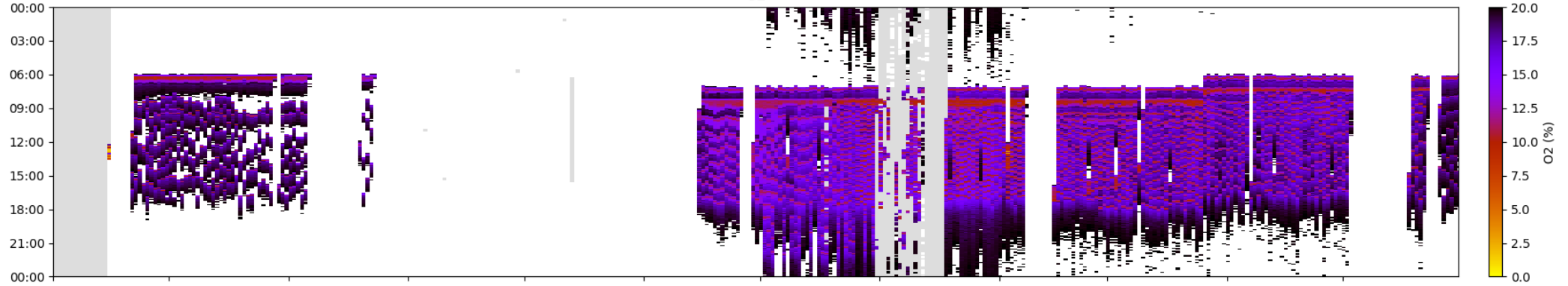


Heat output

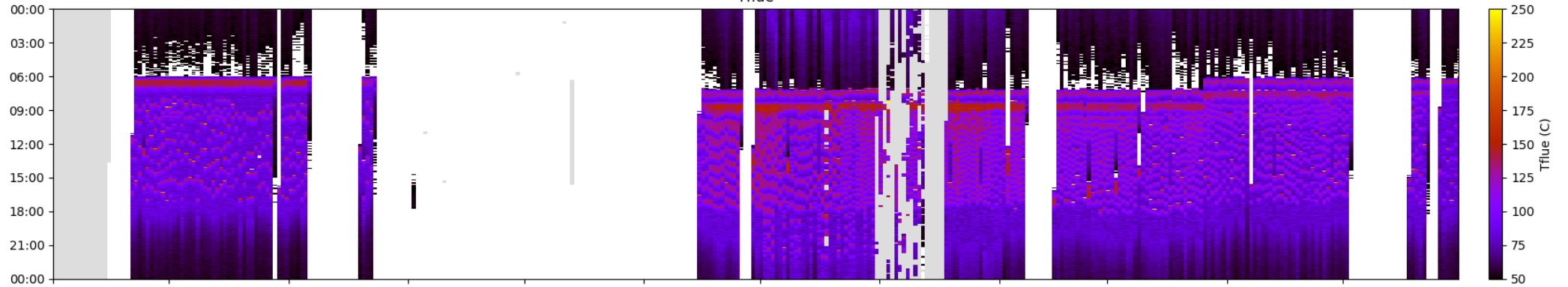


First Year Tapestries B912

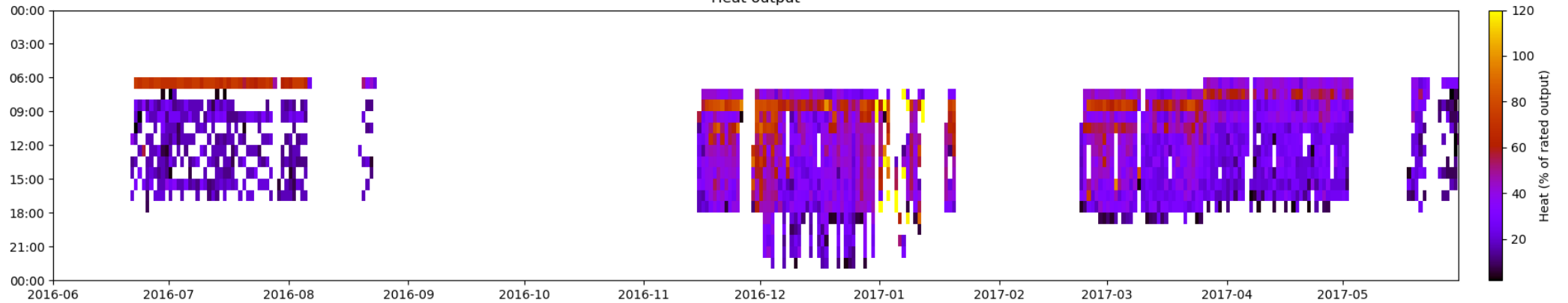
O2



Tflue

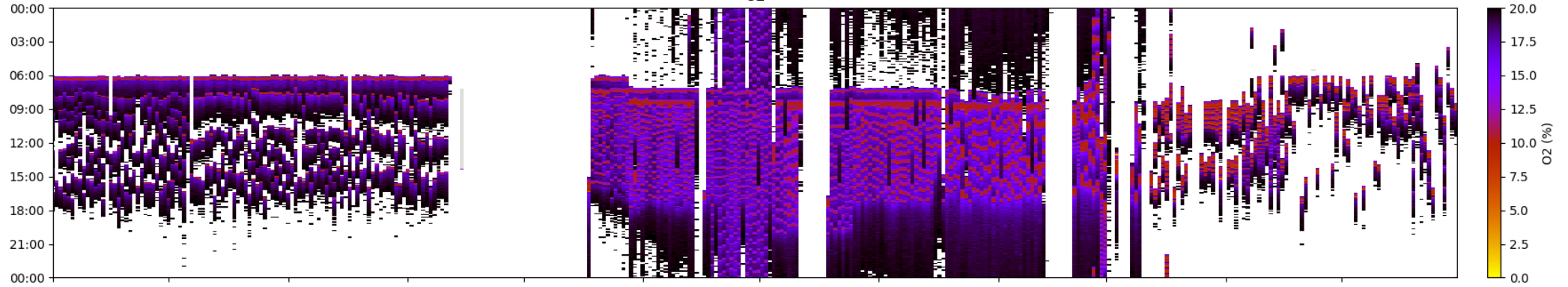


Heat output

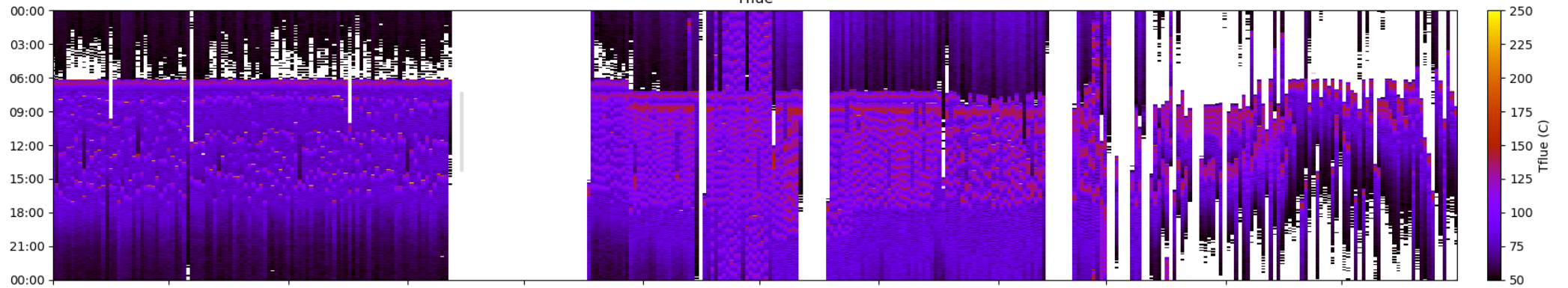


Second Year Tapestries B912

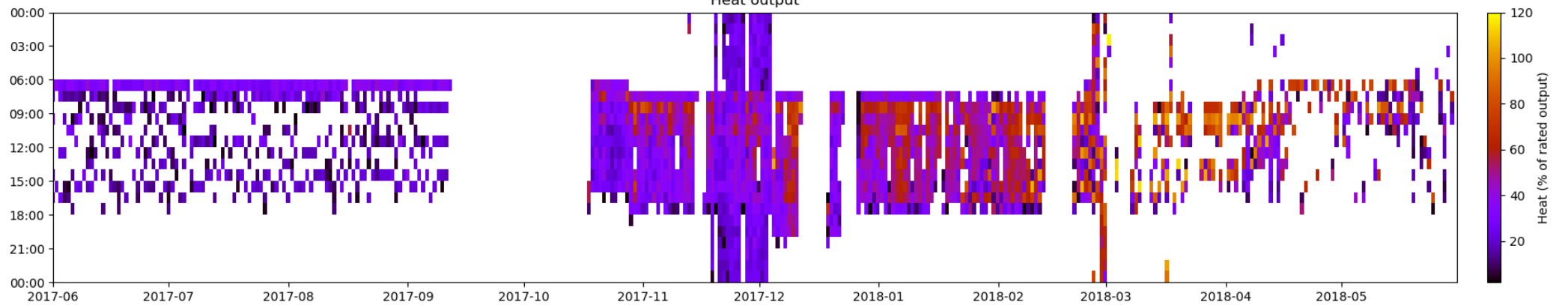
O2



Tflue

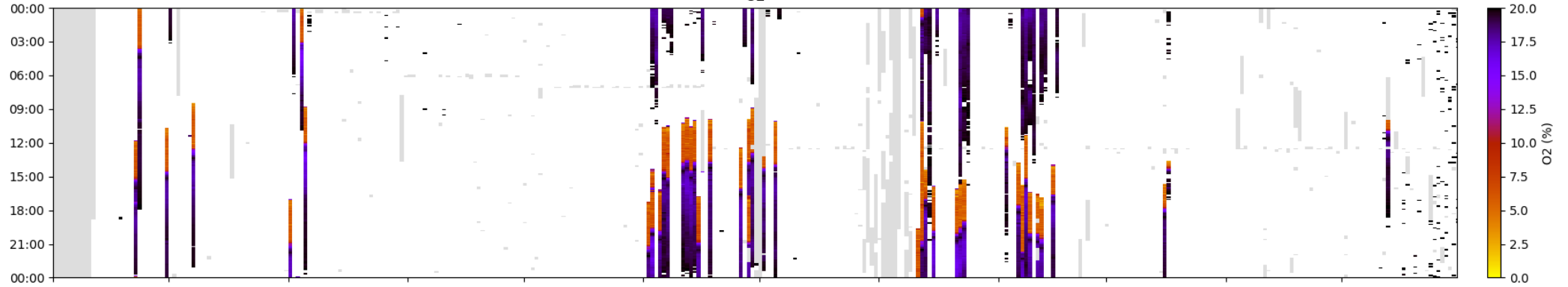


Heat output

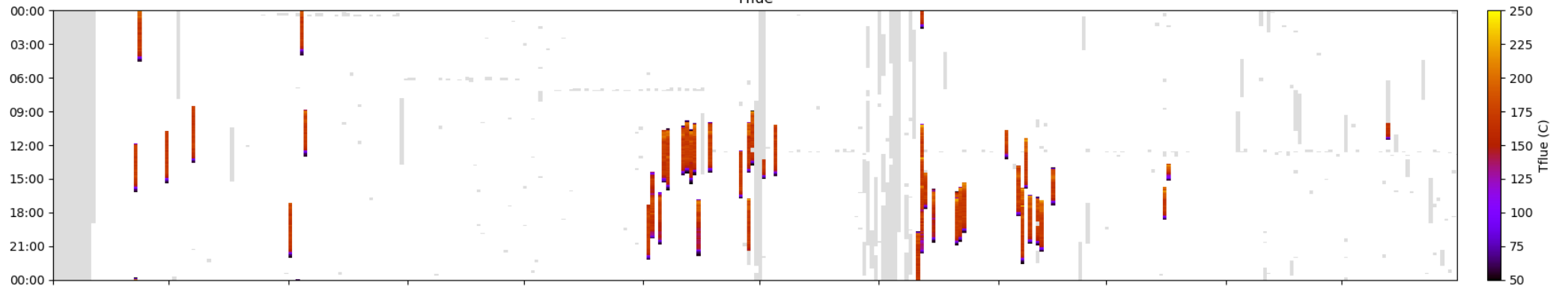


First Year Tapestries B915 (1)

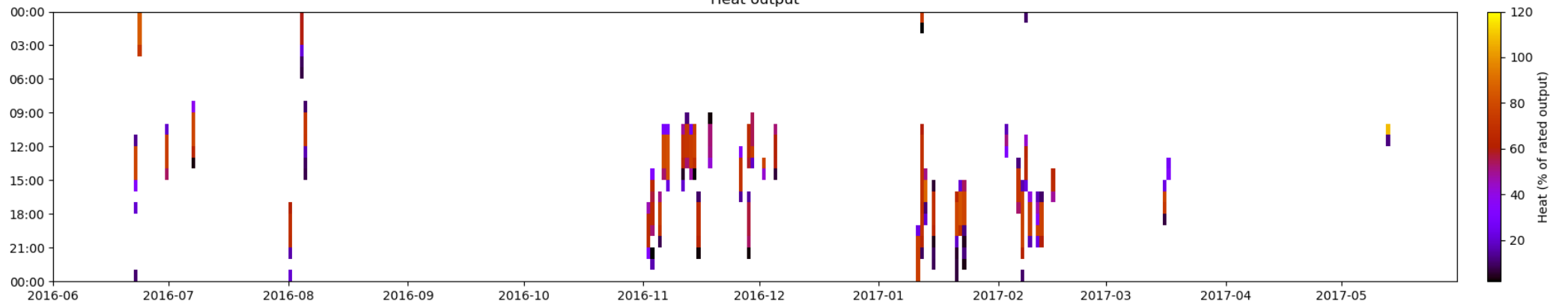
O2



Tflue



Heat output

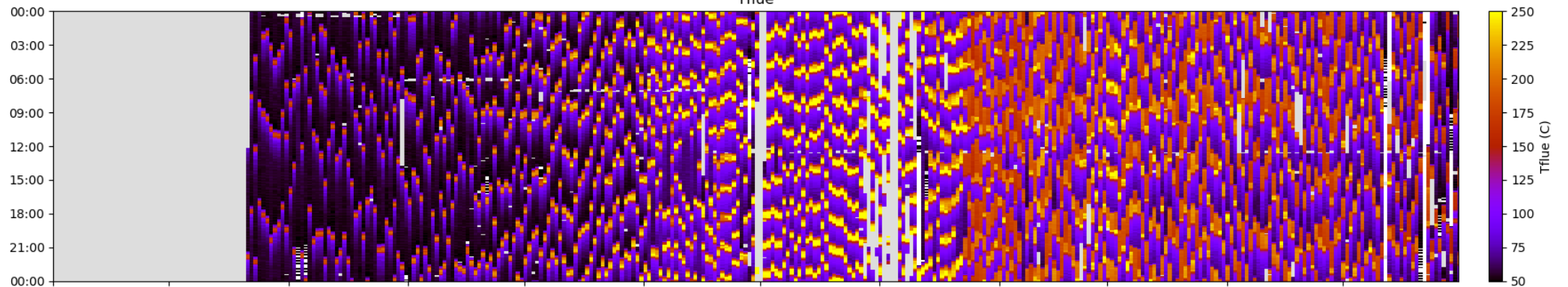


First Year Tapestries B915 (2)

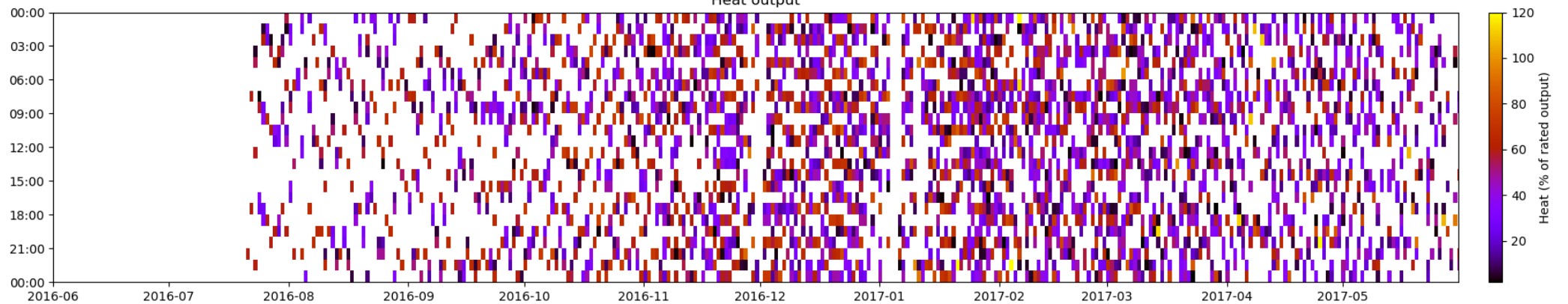
O2



Tflue

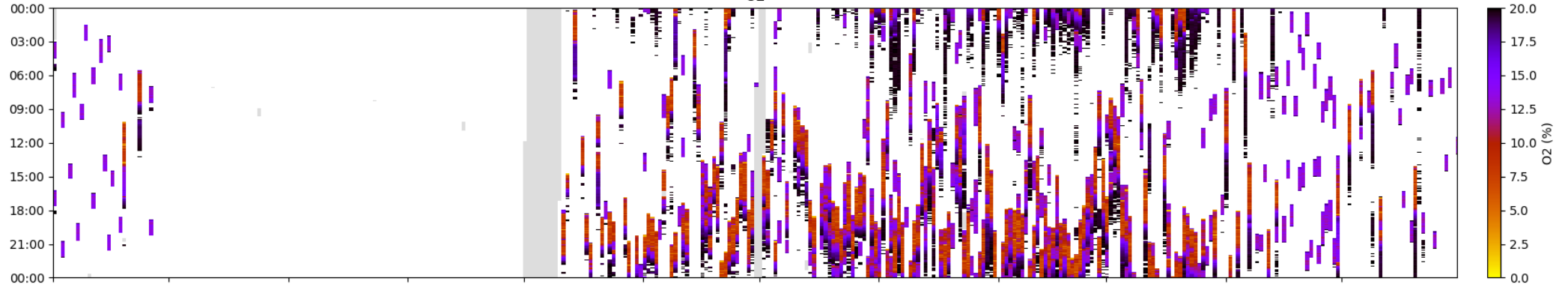


Heat output

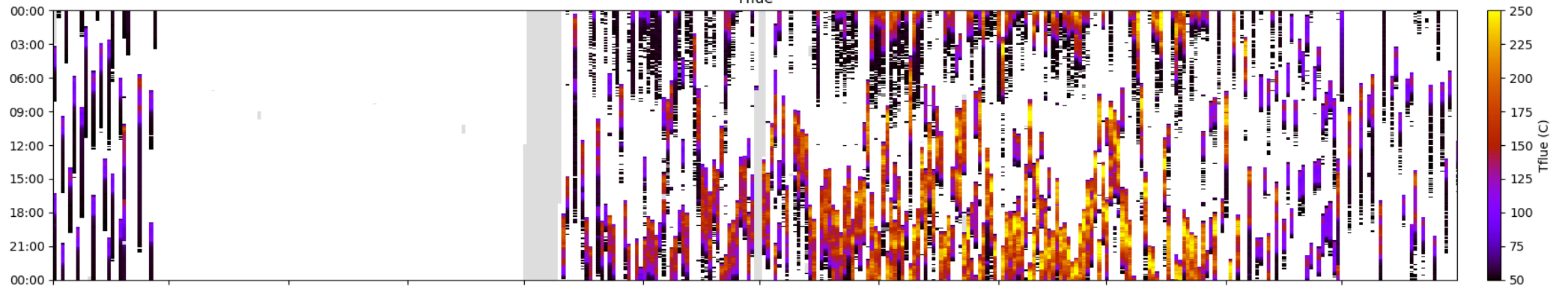


First Year Tapestries B916

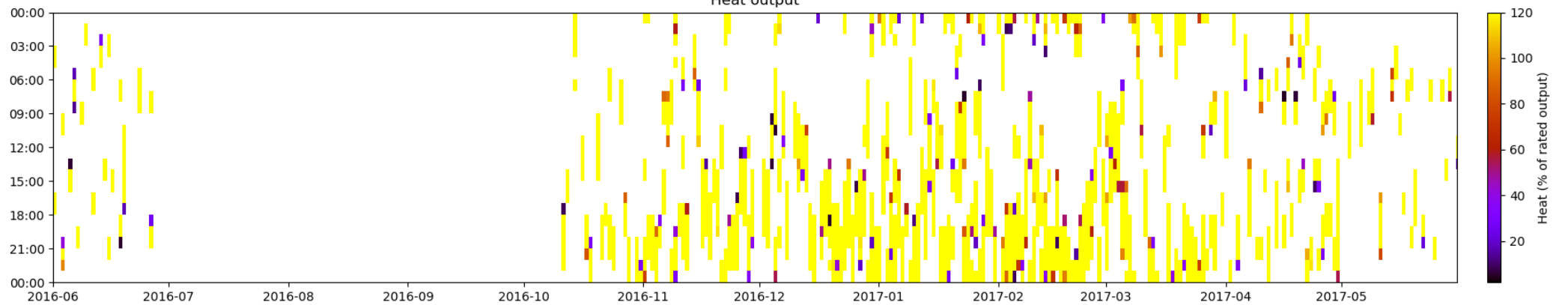
O2



Tflue

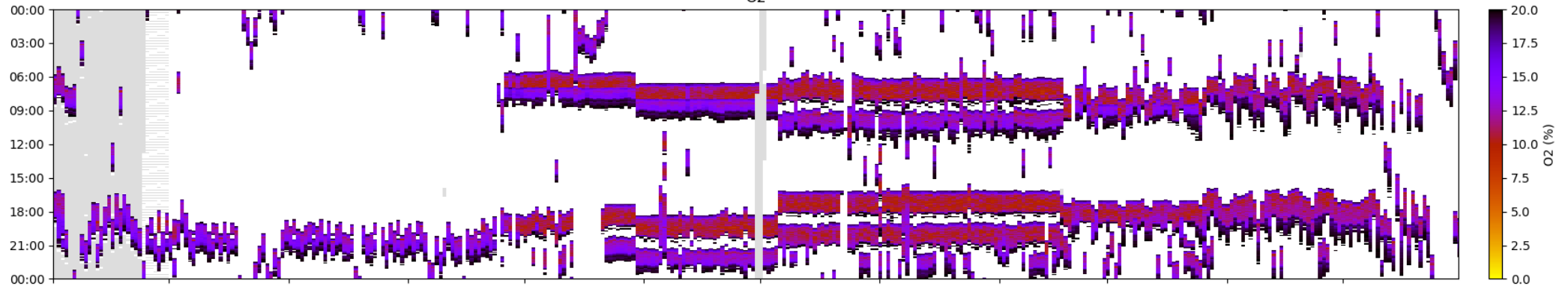


Heat output

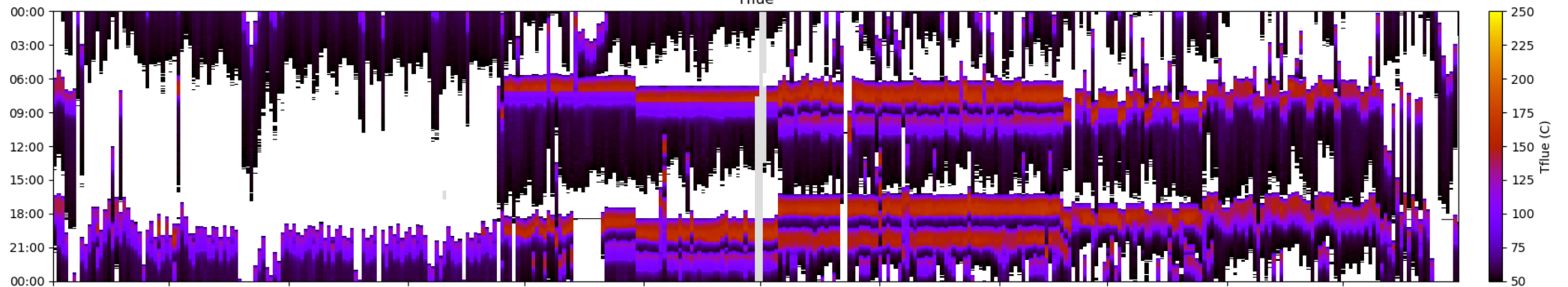


First Year Tapestries B918

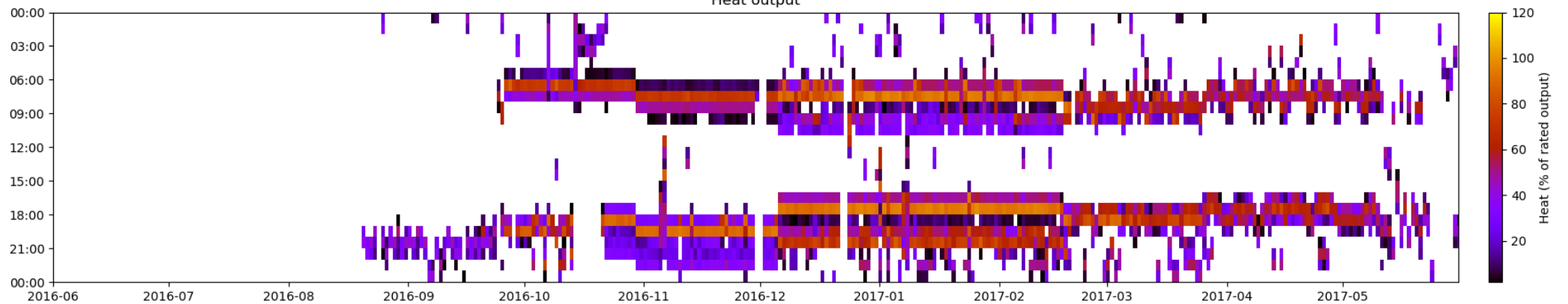
O2



Tflue

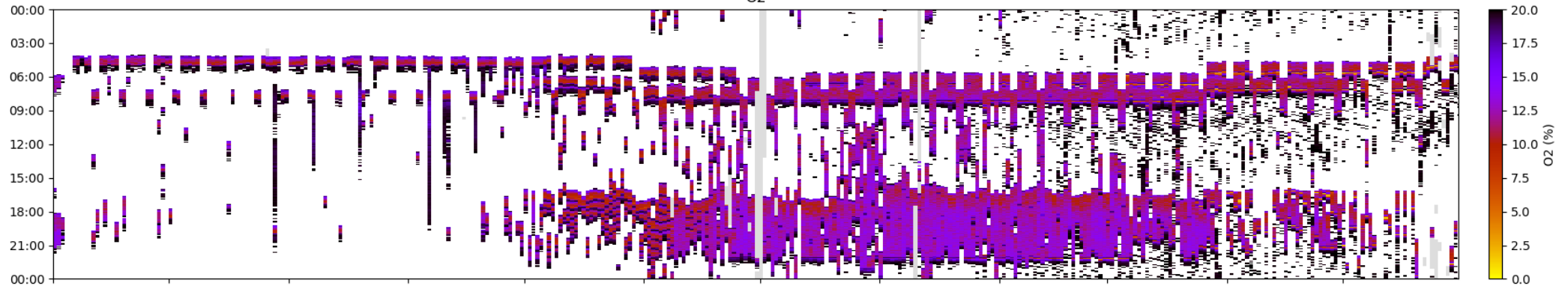


Heat output

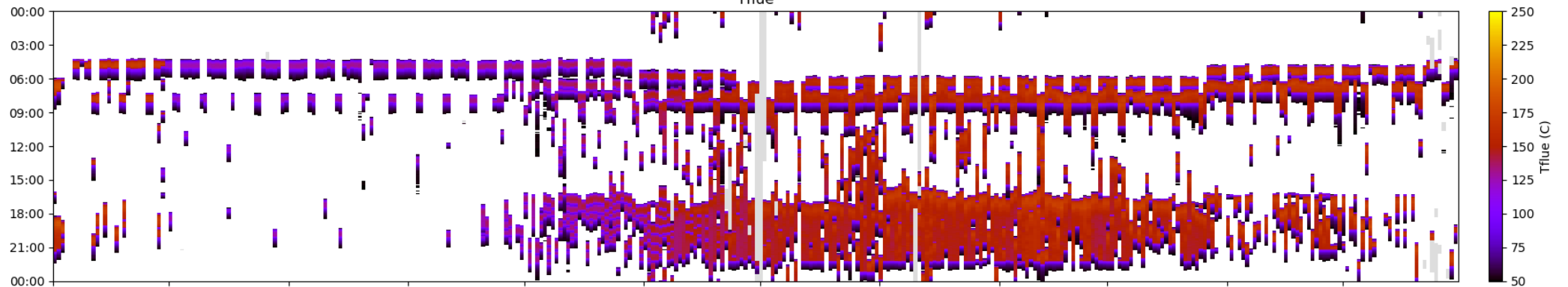


First Year Tapestries B919

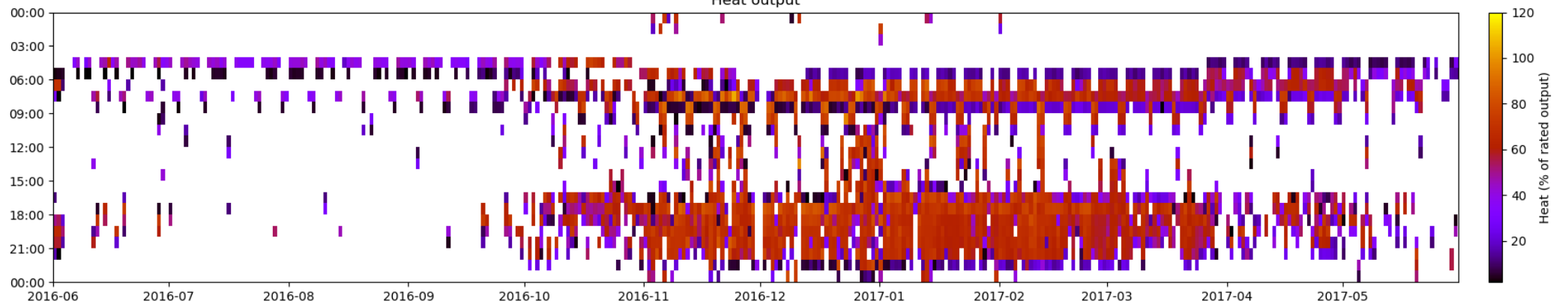
O2



Tflue

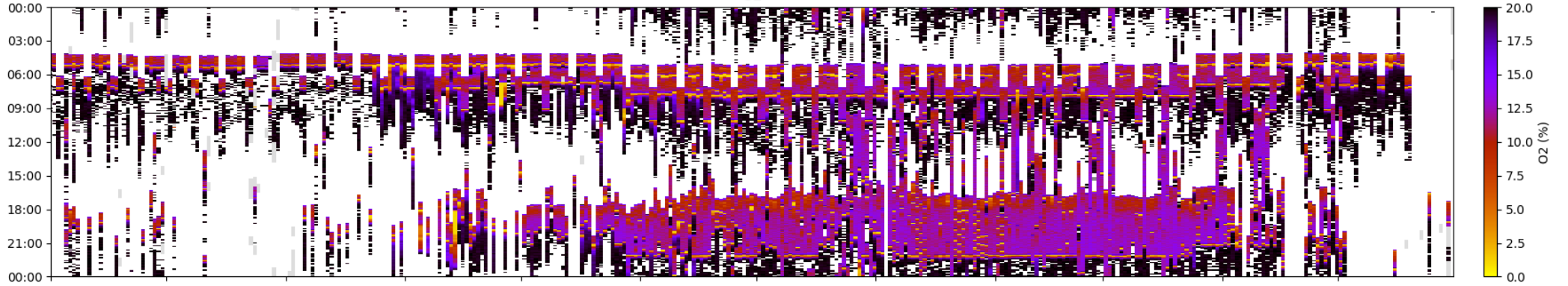


Heat output

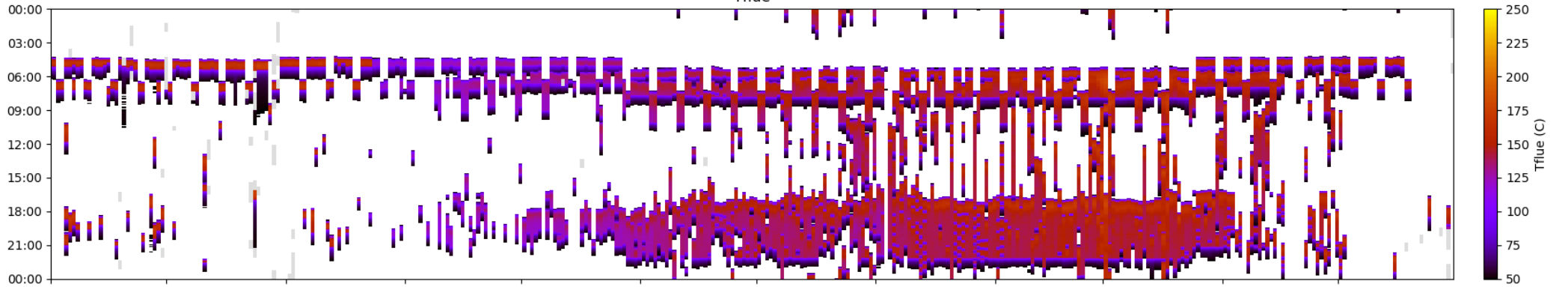


Second Year Tapestries B919

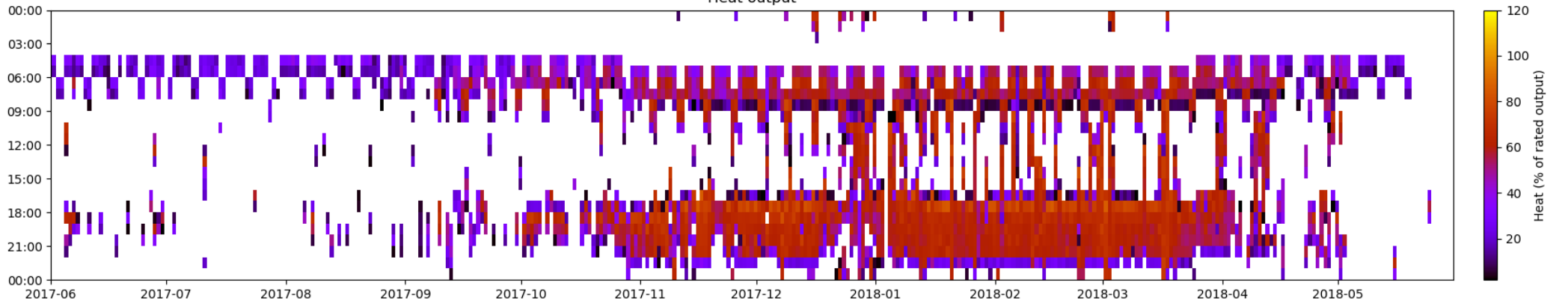
O2



Tflue

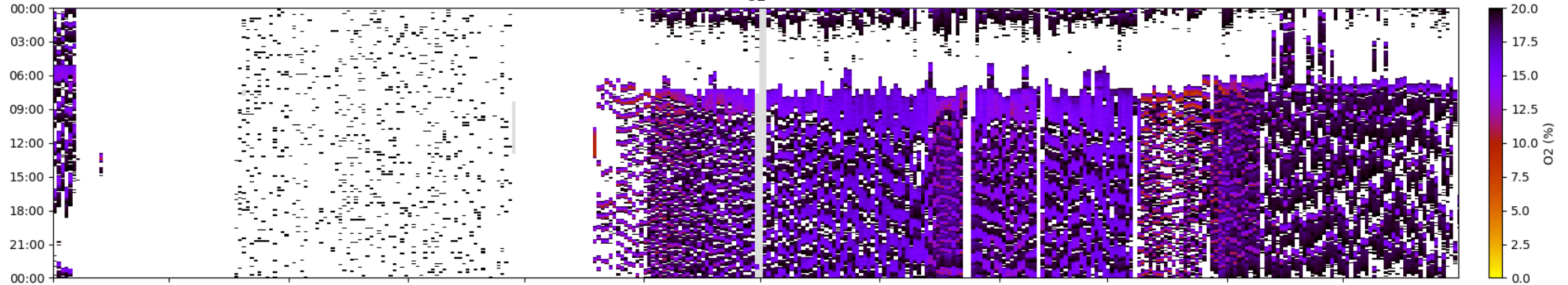


Heat output

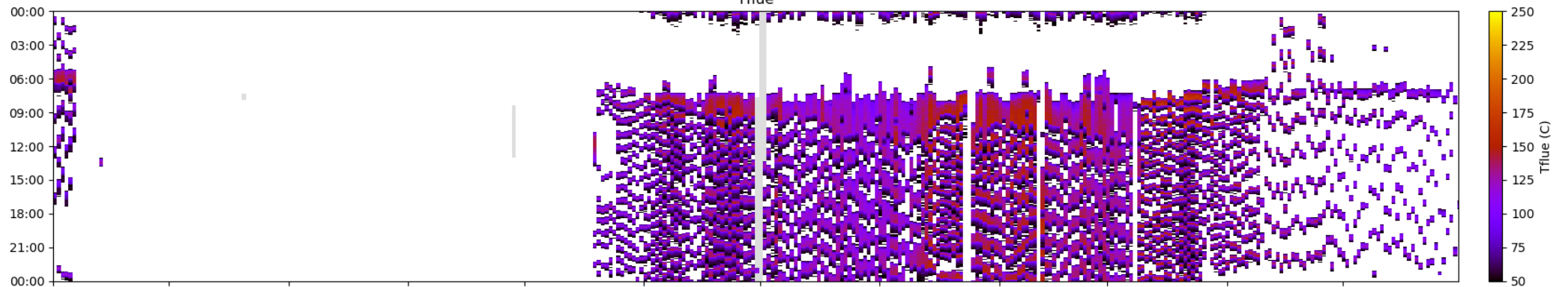


First Year Tapestries B920

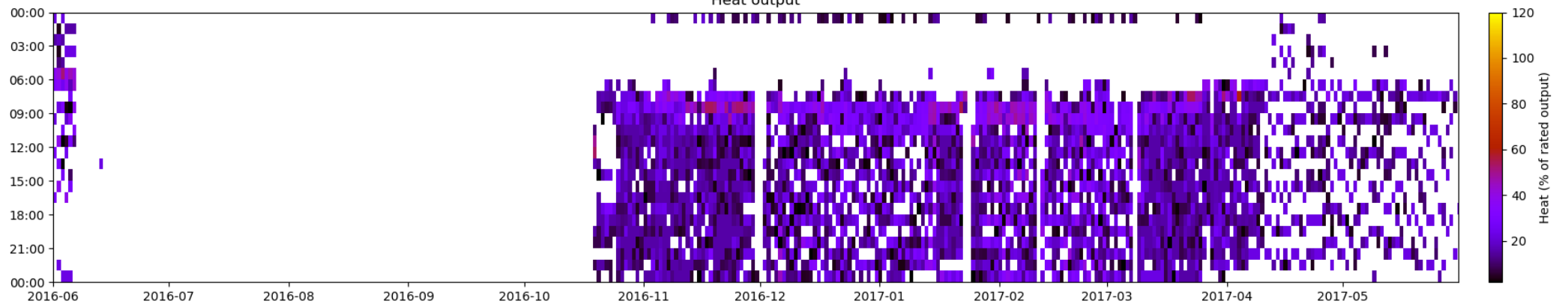
O2



Tflue

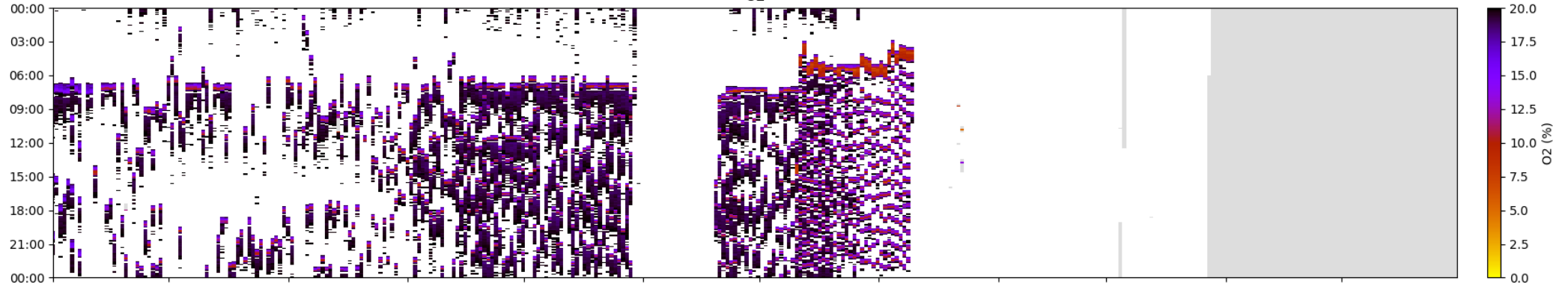


Heat output

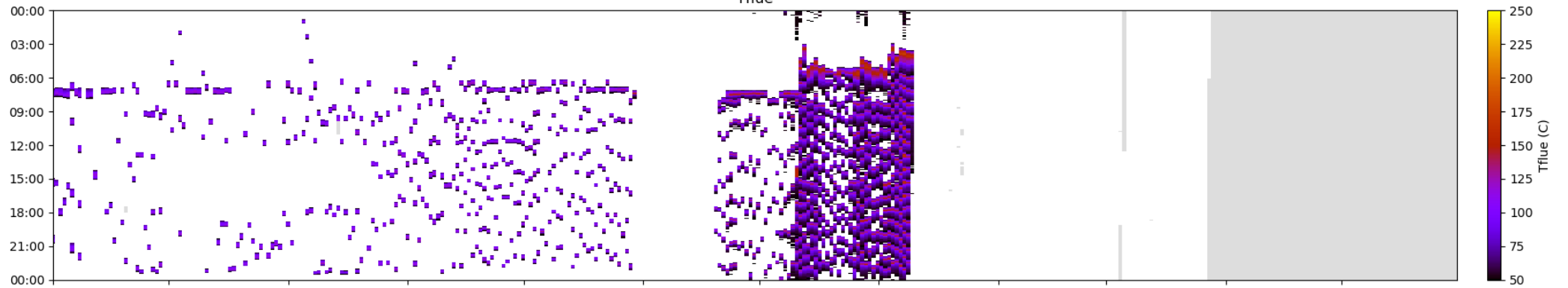


Second Year Tapestries B920

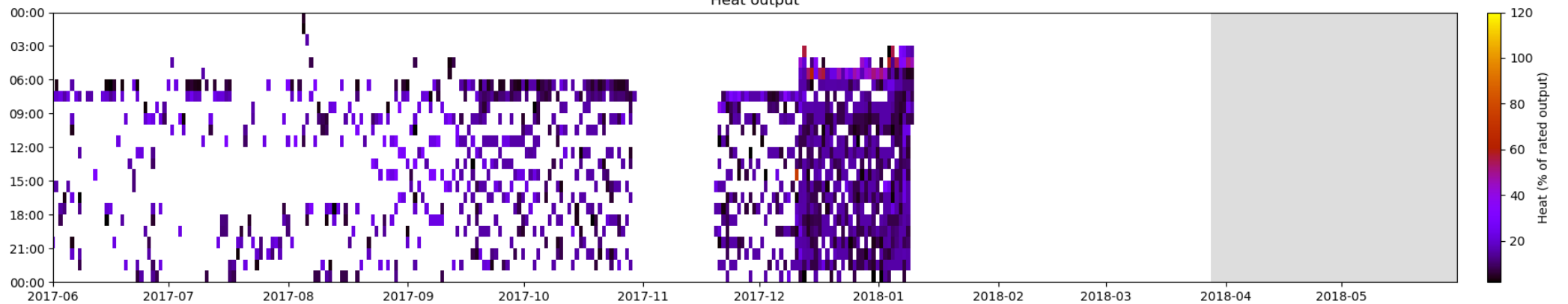
O2



Tflue

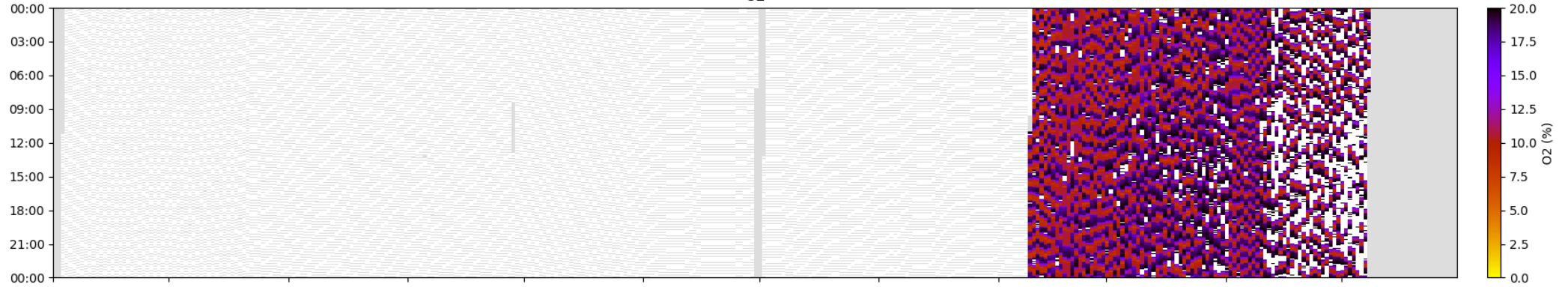


Heat output

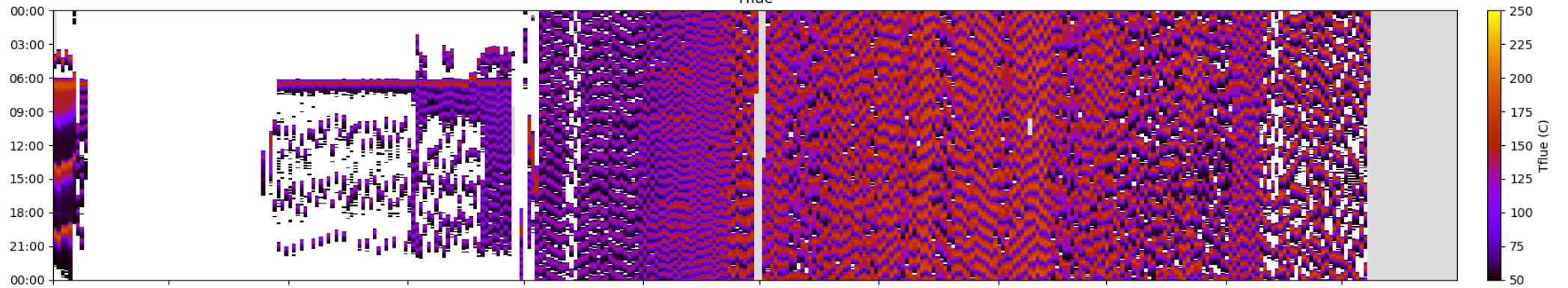


First Year Tapestries B921

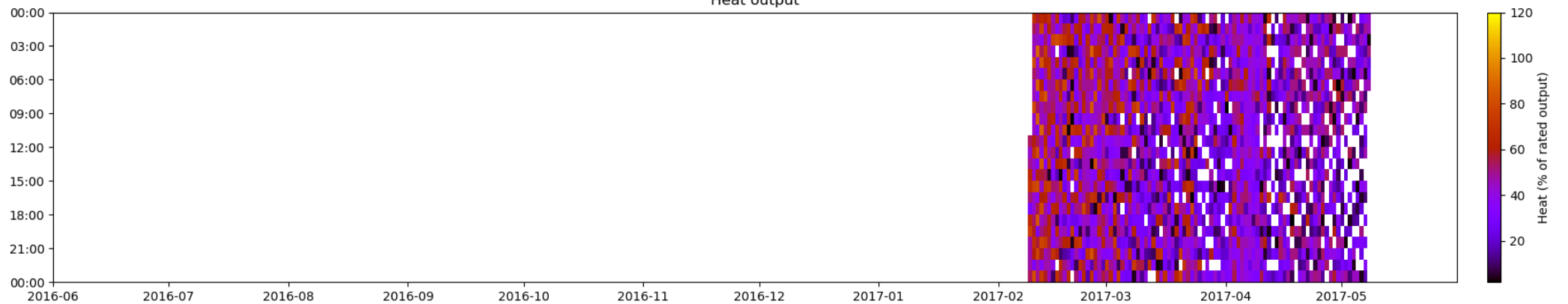
O2



Tflue

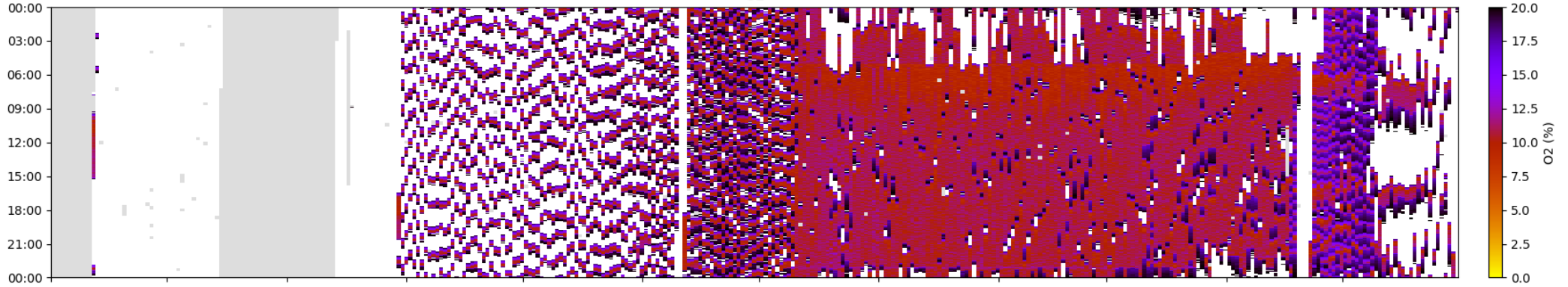


Heat output

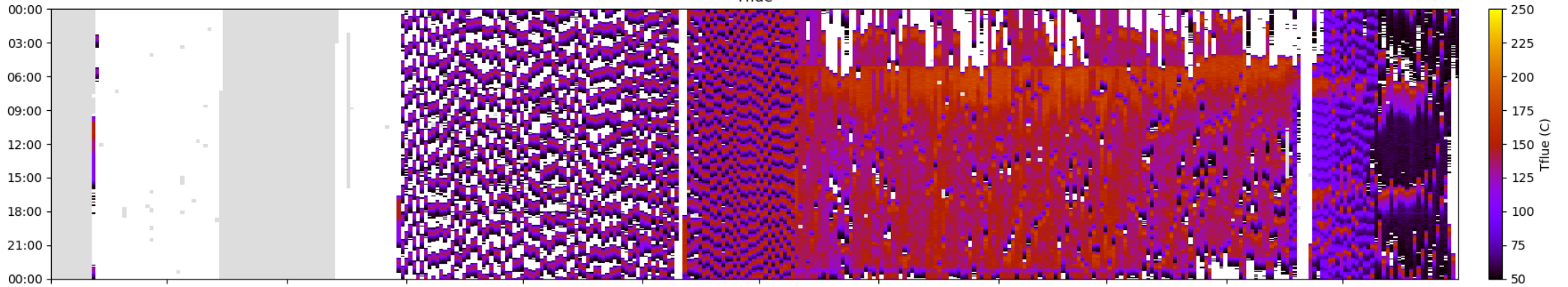


Second Year Tapestries B921

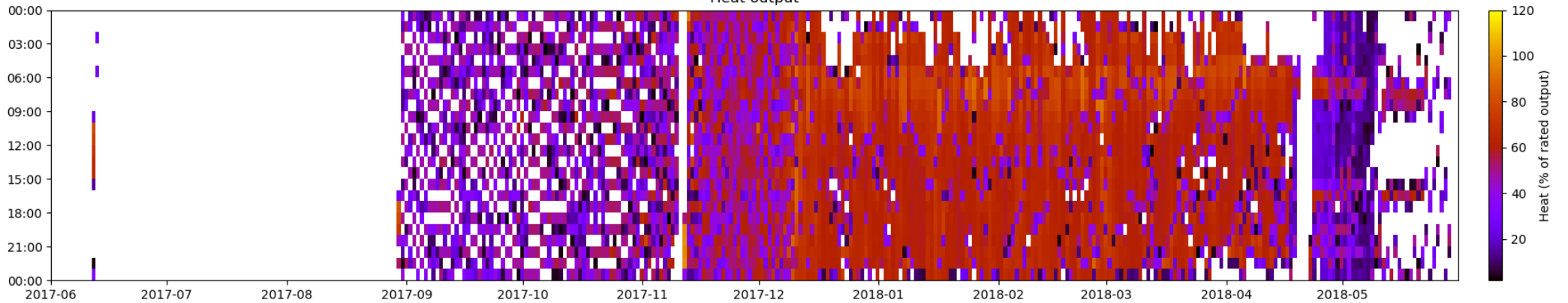
O2



Tflue

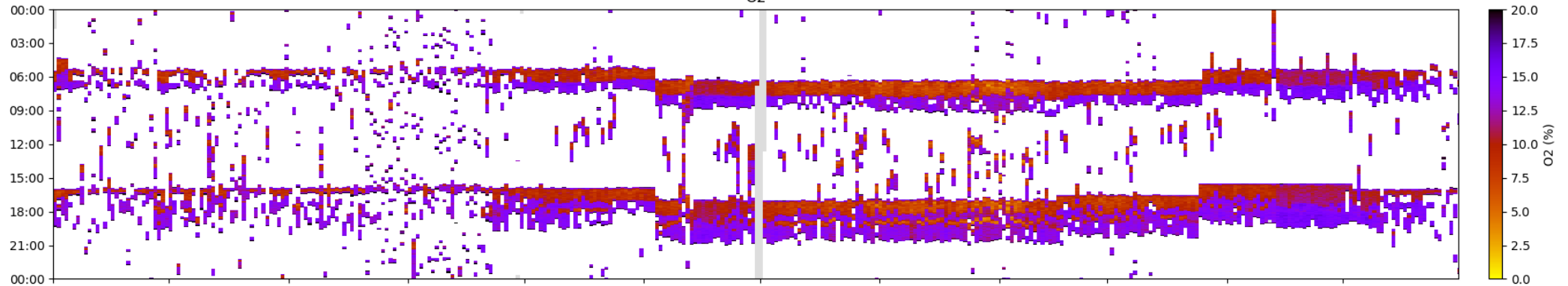


Heat output

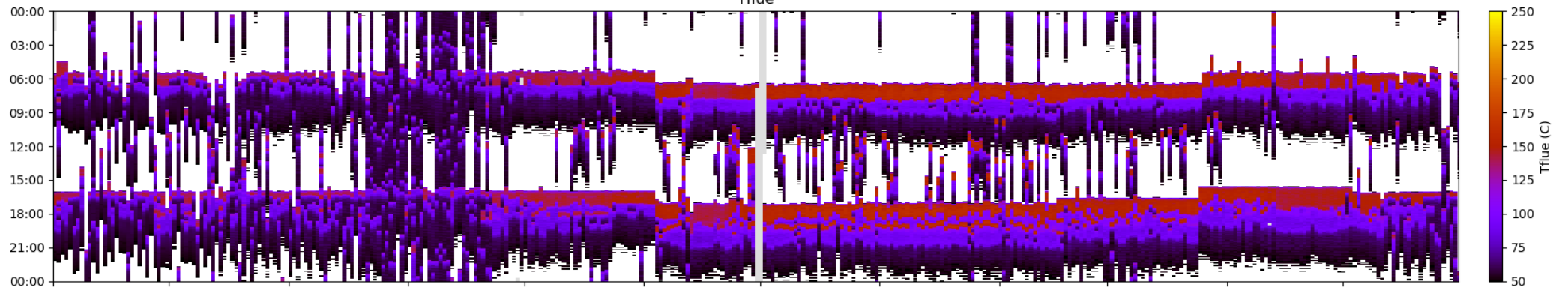


First Year Tapestries B922

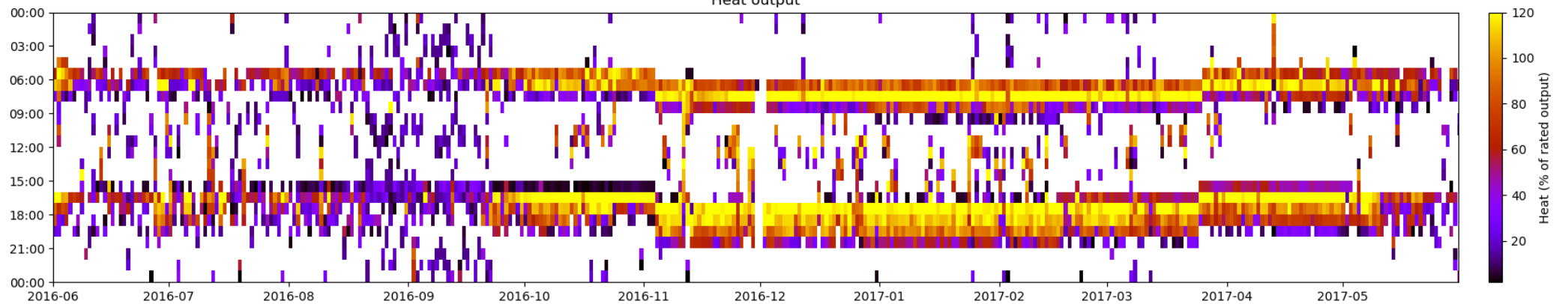
O2



Tflue

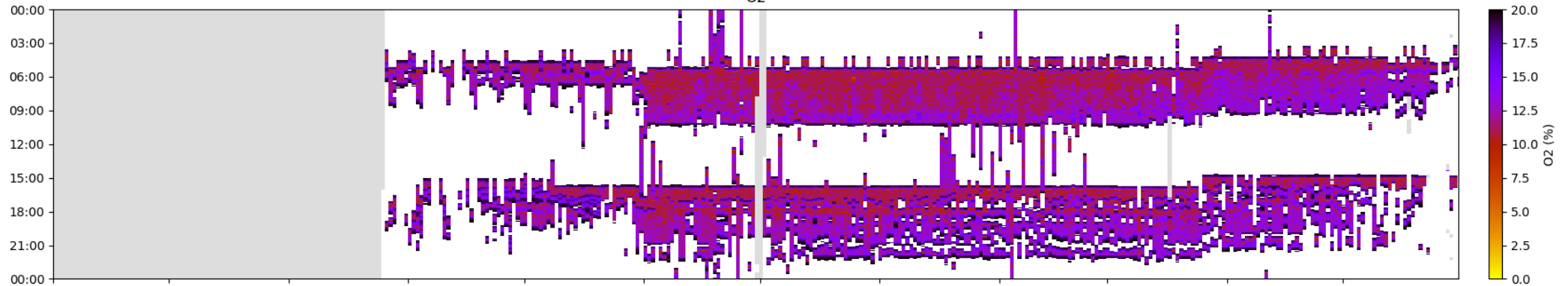


Heat output

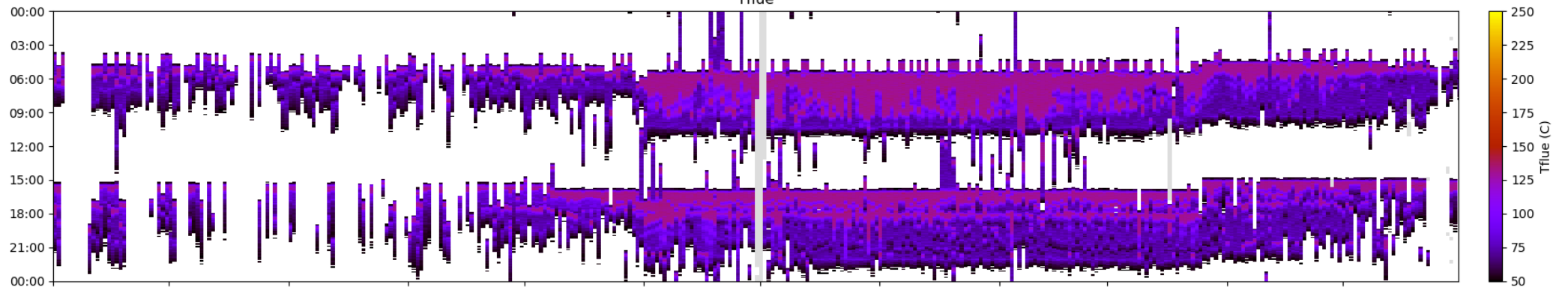


First Year Tapestries B923

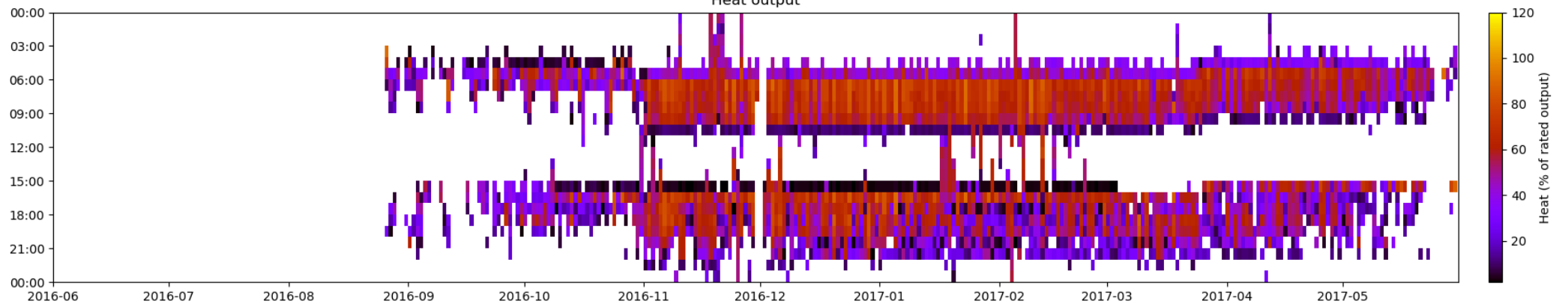
O₂



T_{flue}

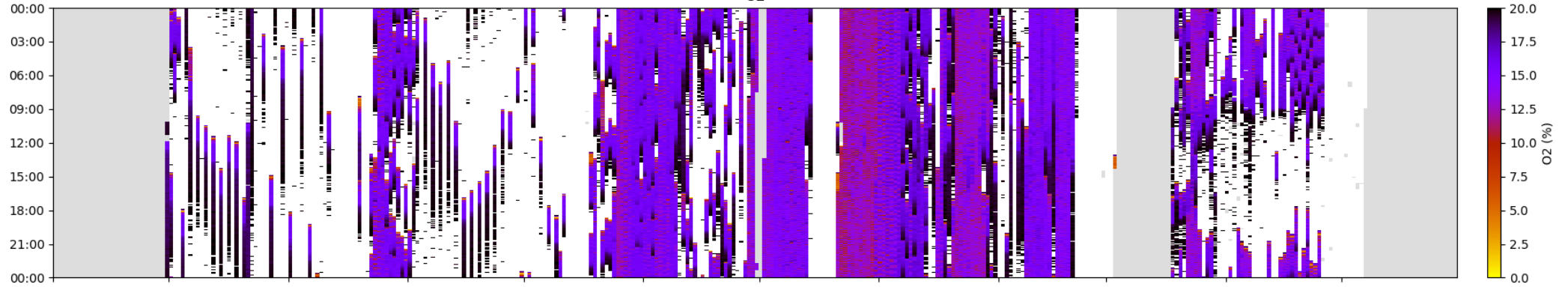


Heat output

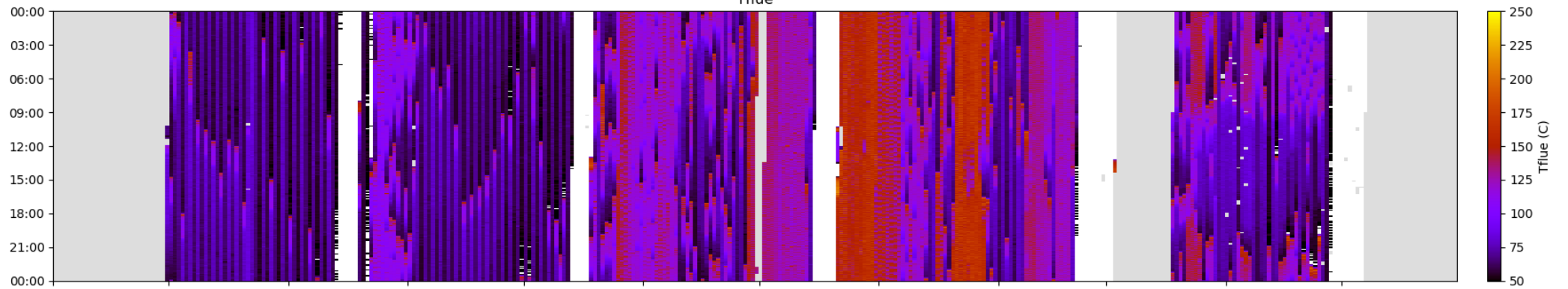


First Year Tapestries B925

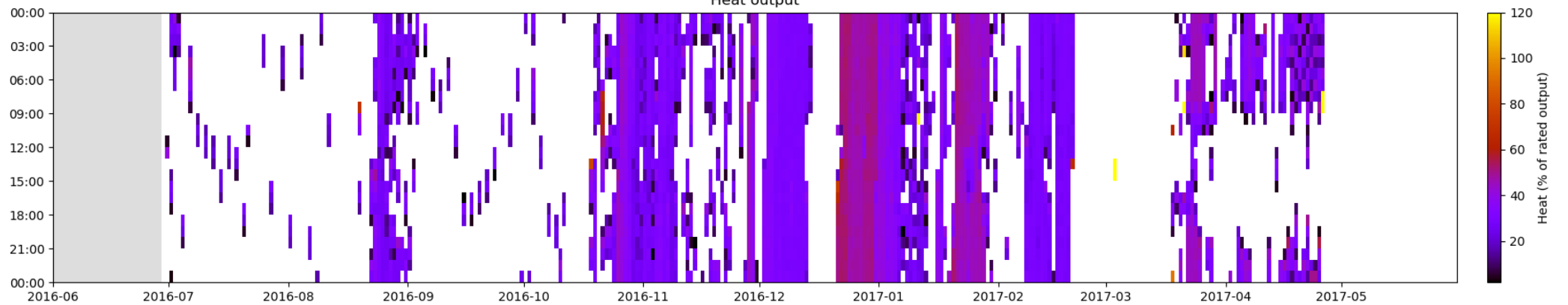
O2



Tflue

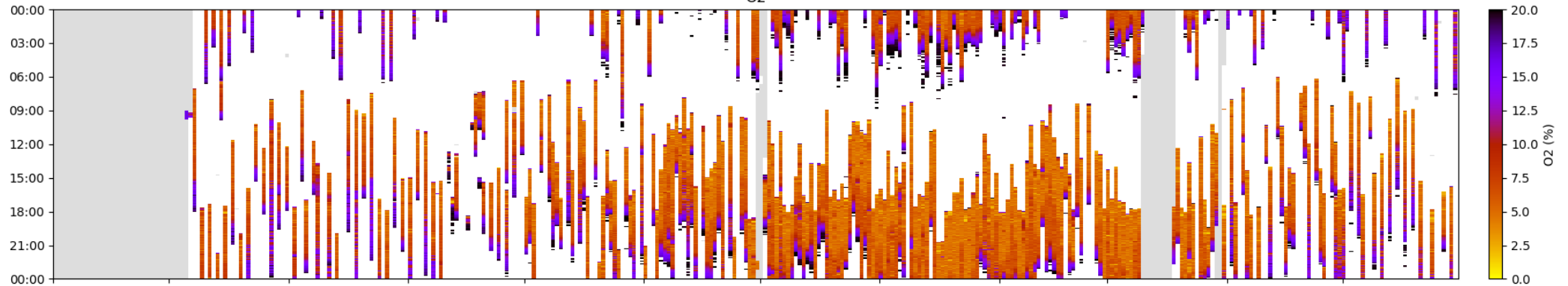


Heat output

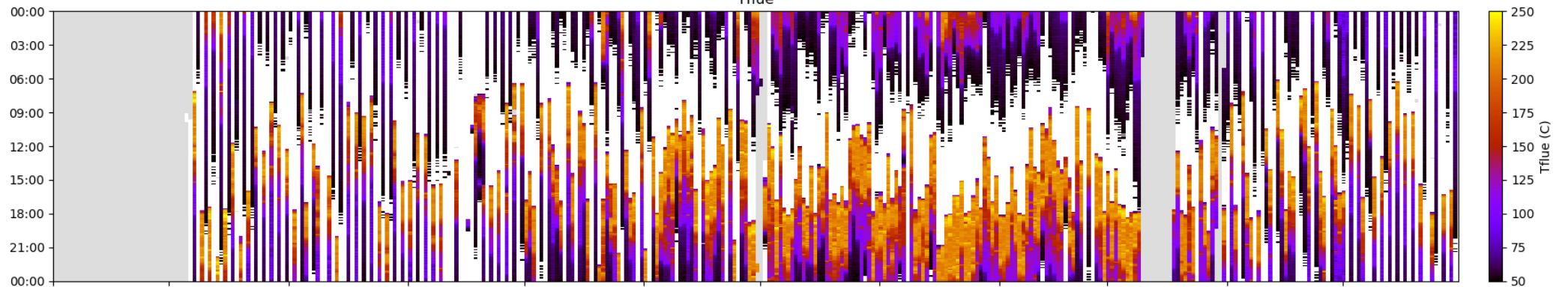


First Year Tapestries B926

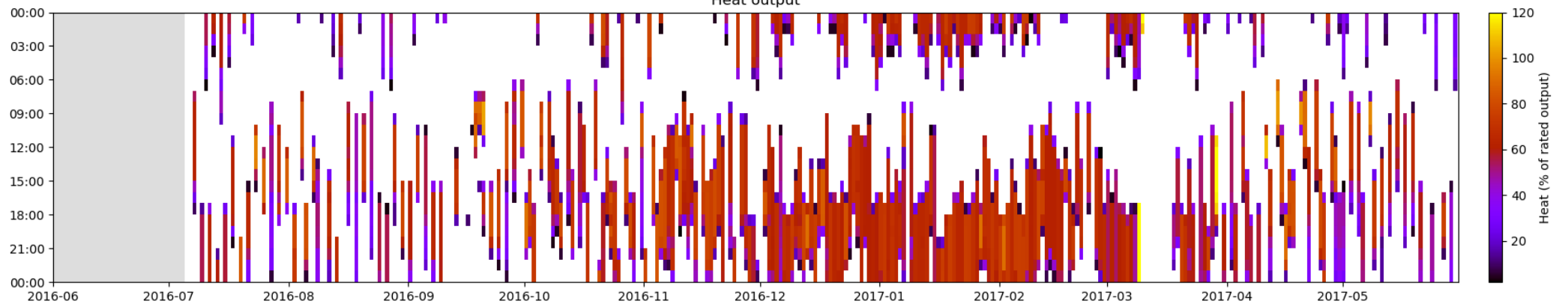
O2



Tflue

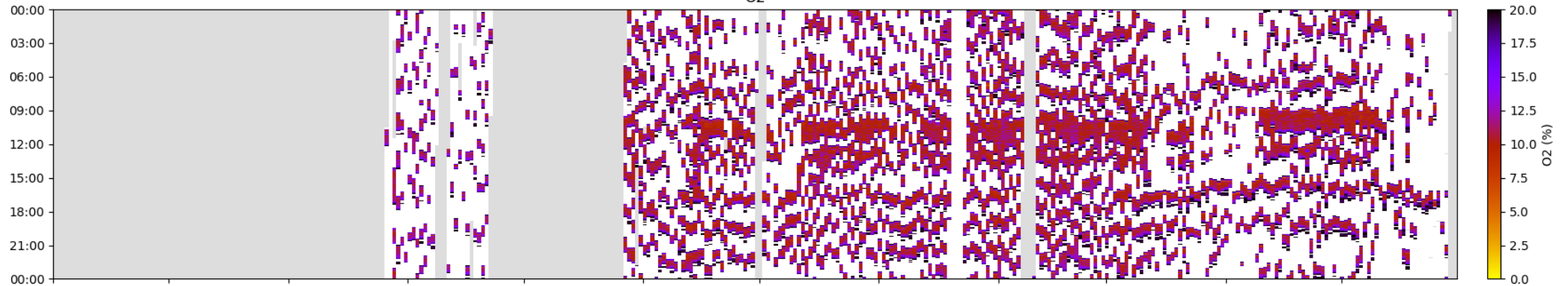


Heat output

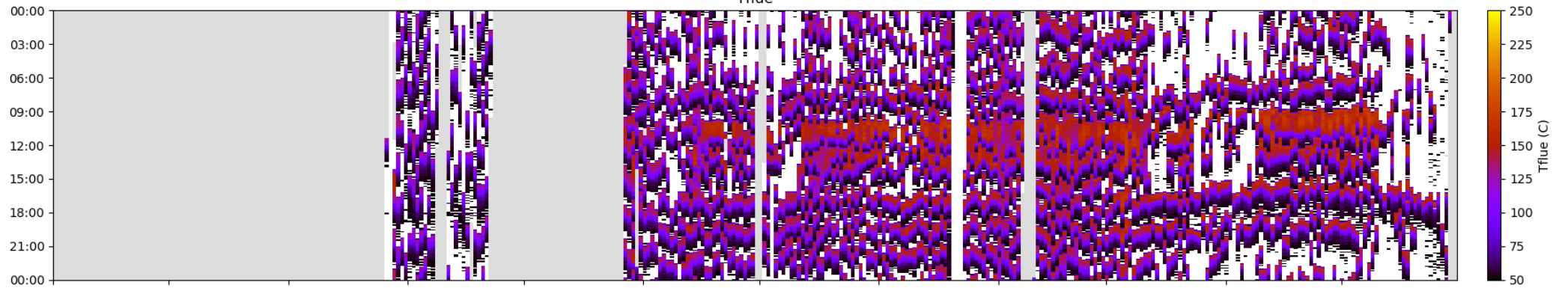


First Year Tapestries B927 (1)

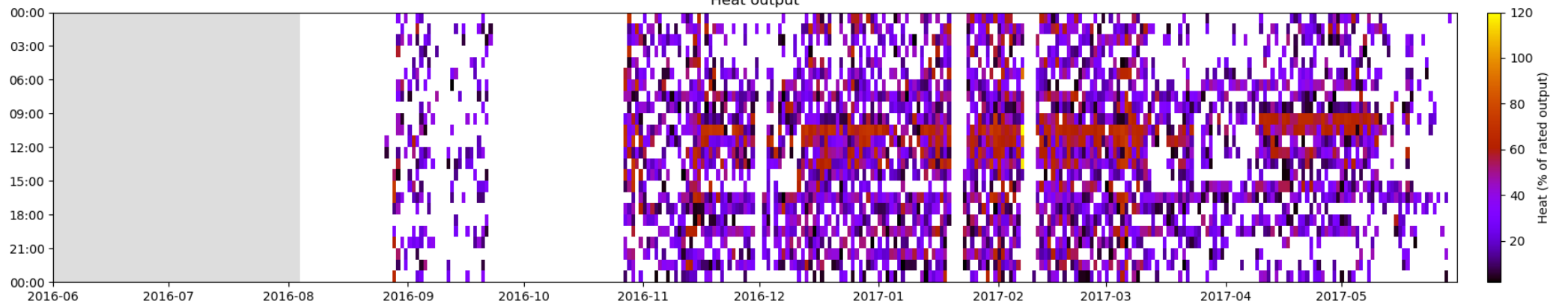
O2



Tflue

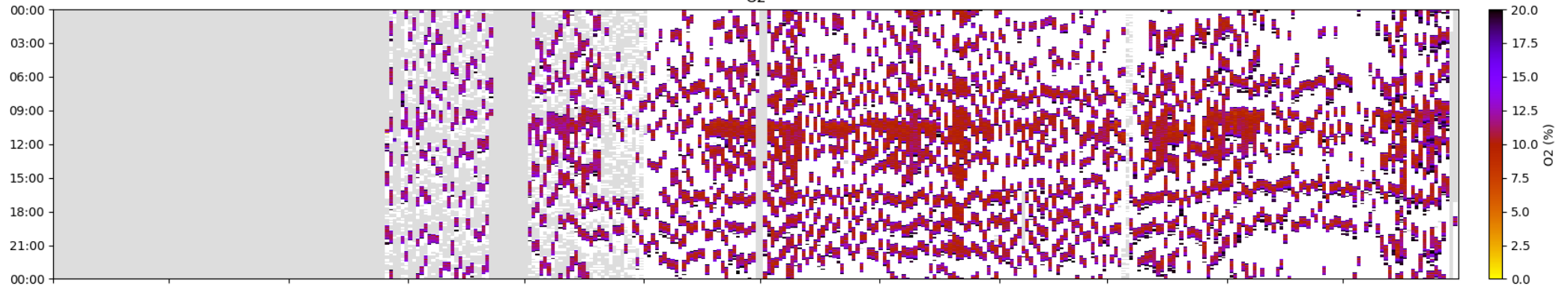


Heat output

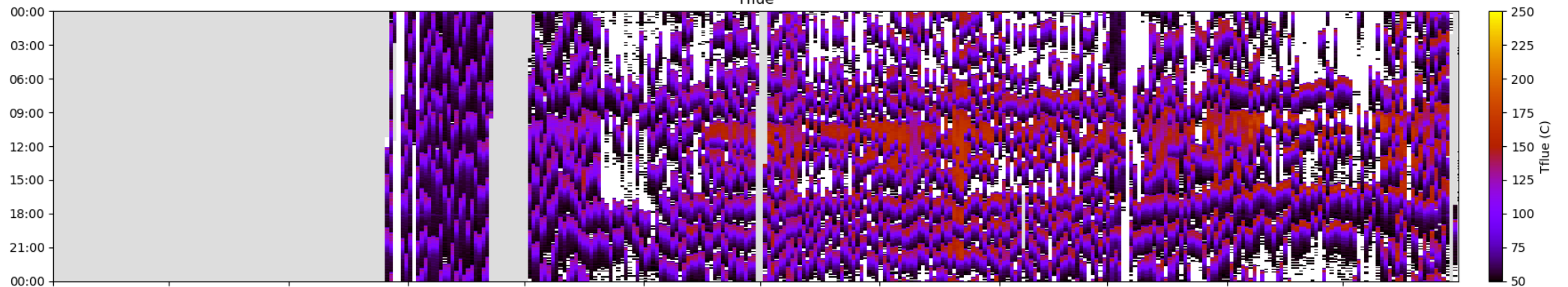


First Year Tapestries B927 (2)

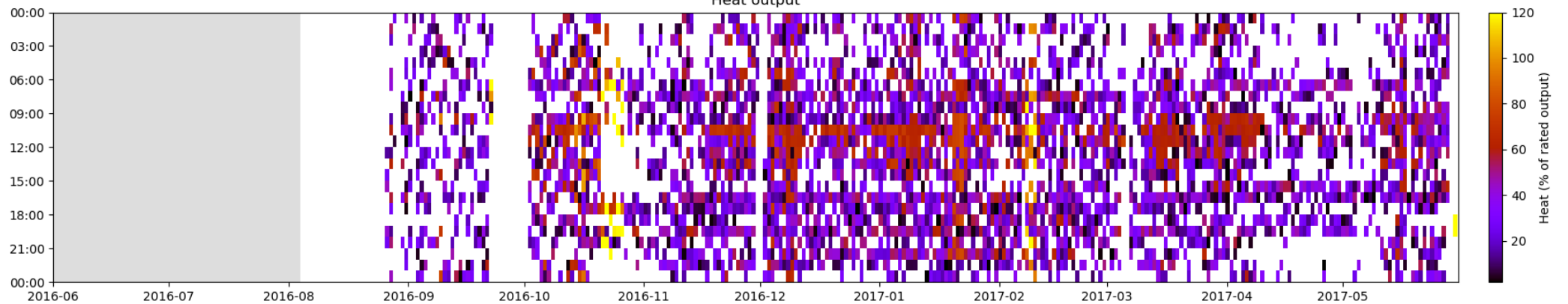
O2



Tflue



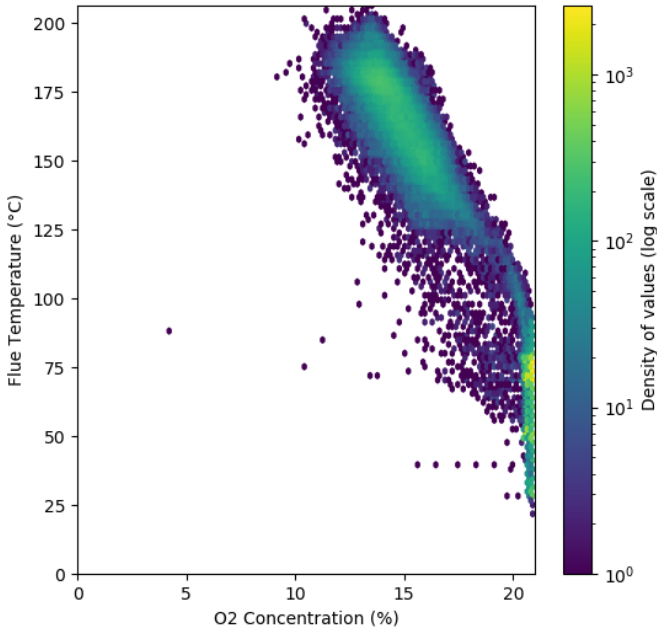
Heat output



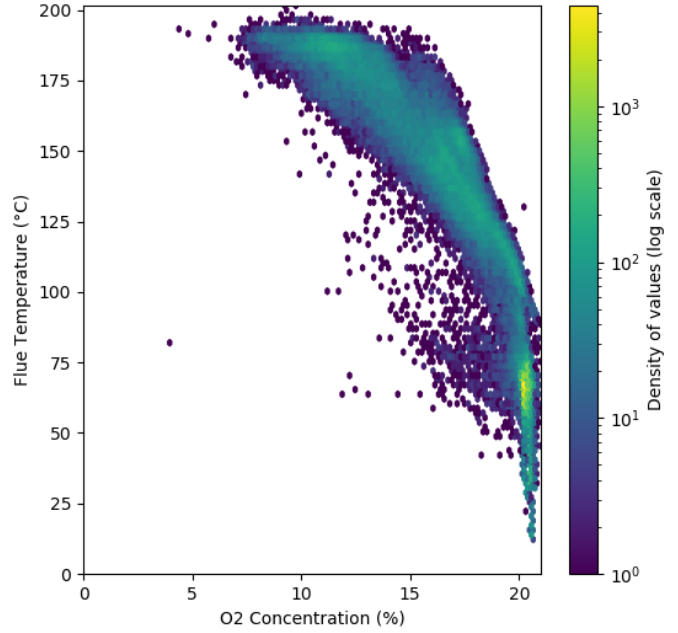
5 Oxygen and flue temperature density plots



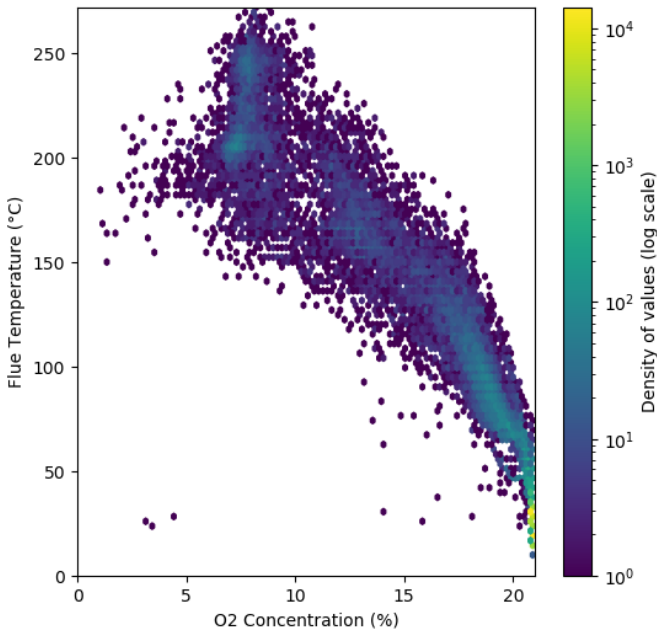
B001 (1)



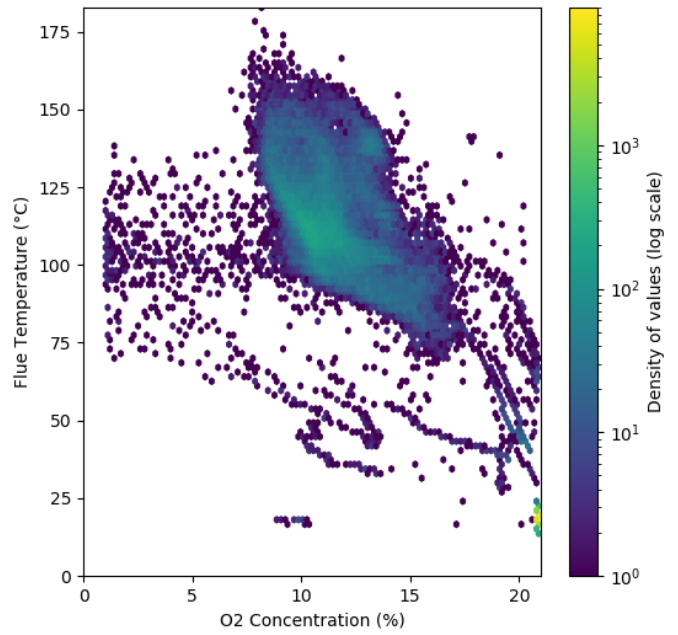
B001 (2)



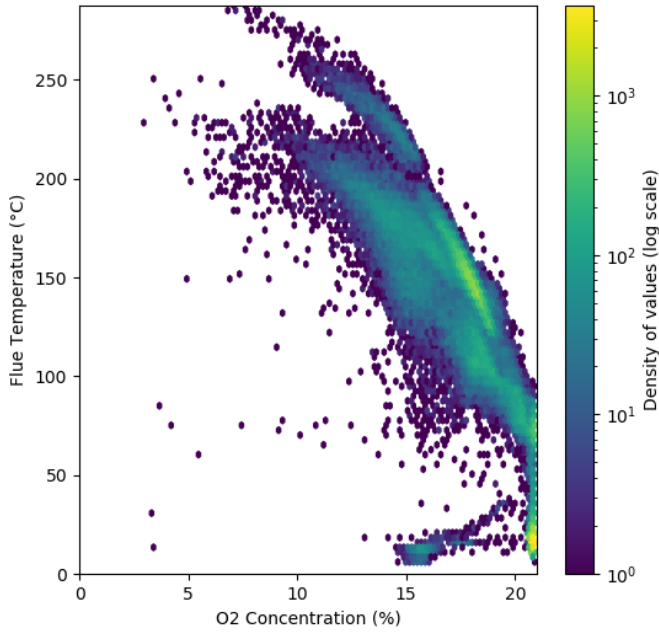
B005



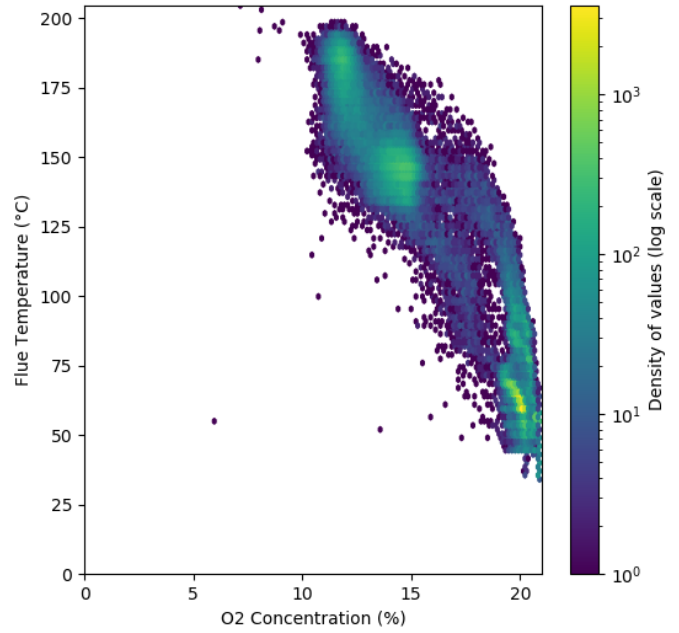
B013



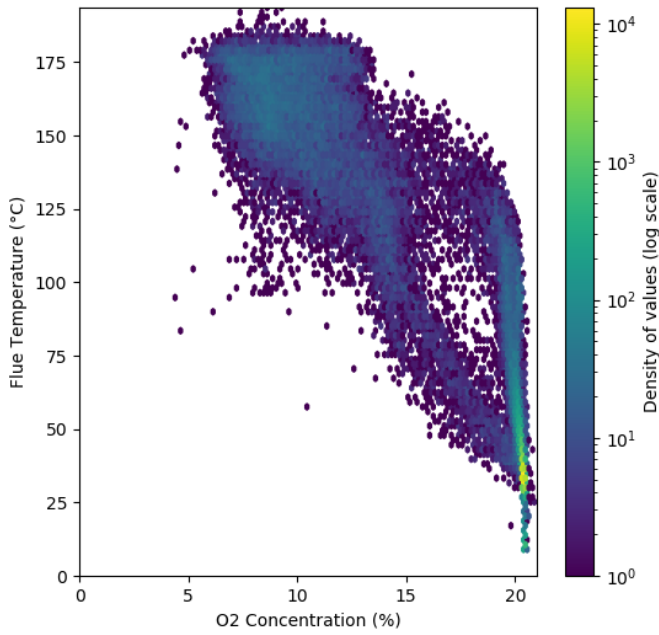
B014



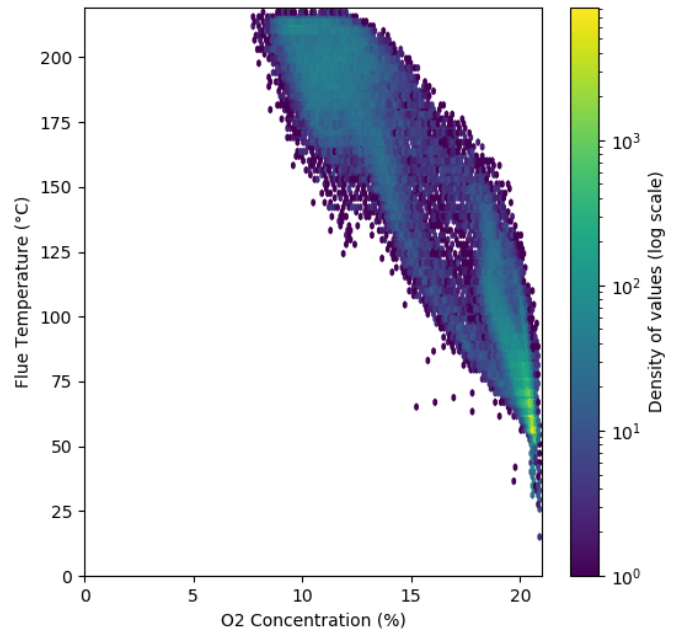
B046



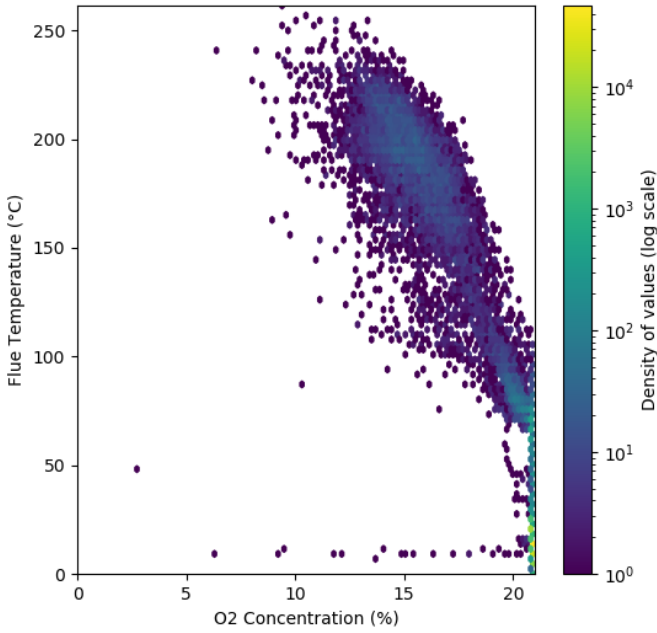
B055



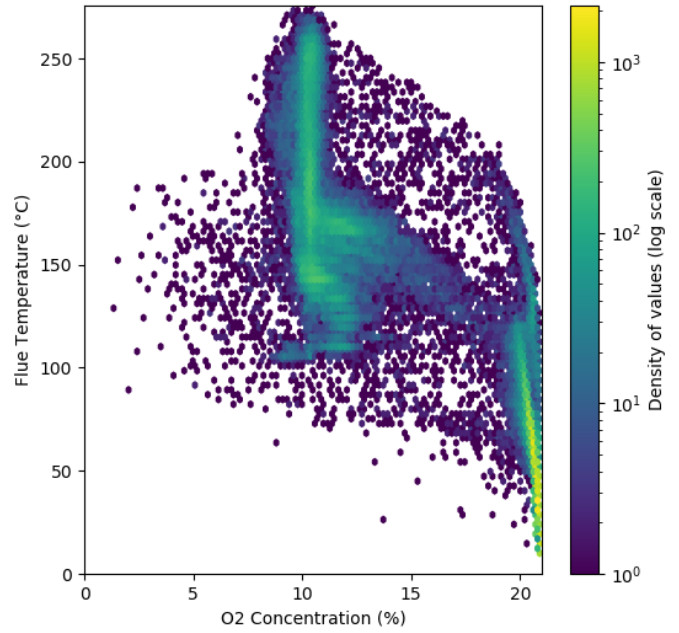
B069



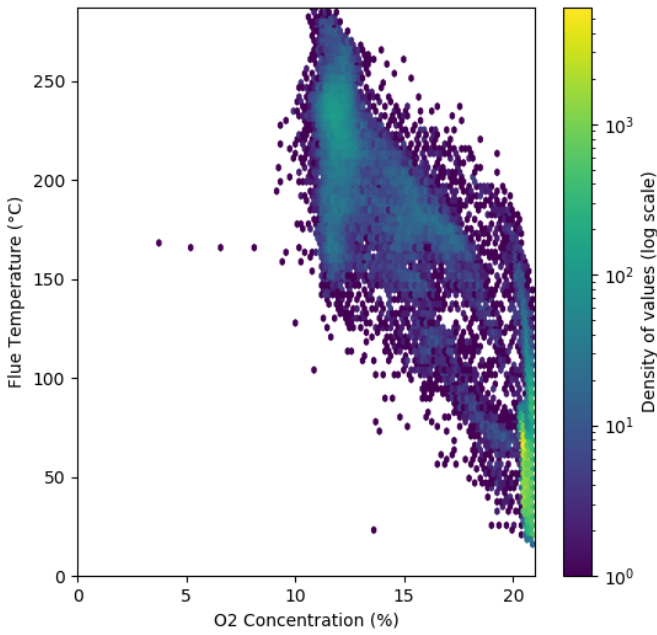
B076



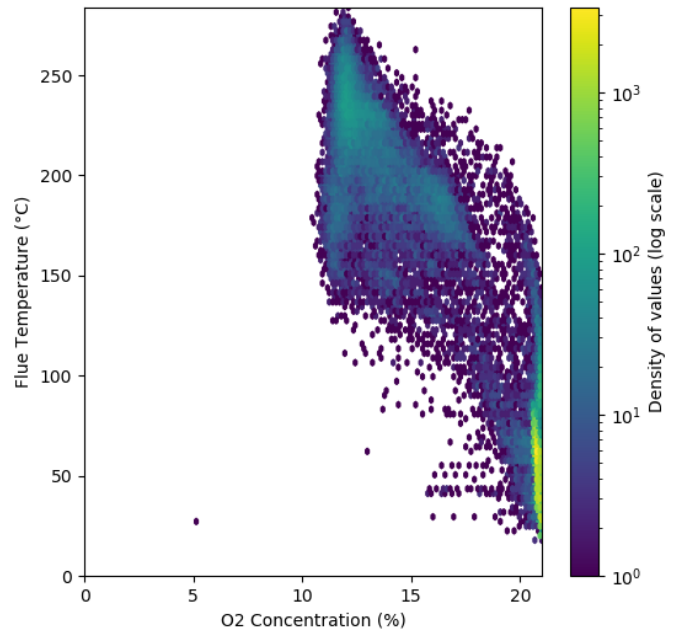
B081



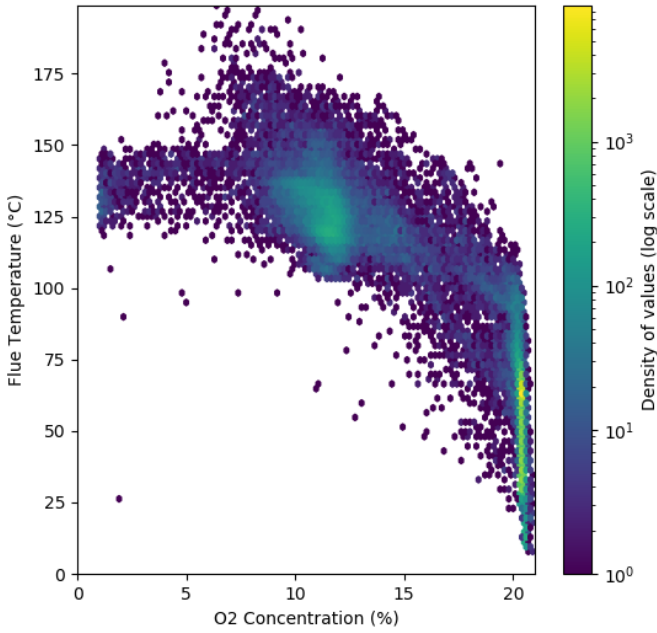
B112 (1)



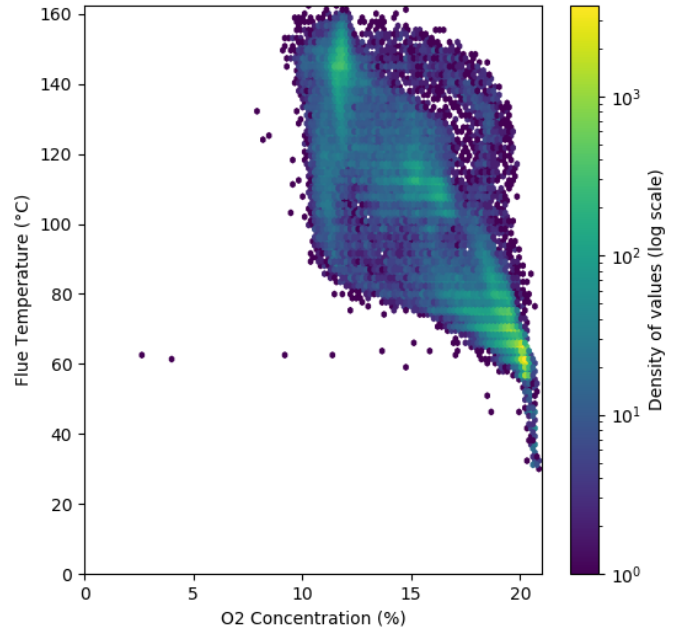
B112 (2)



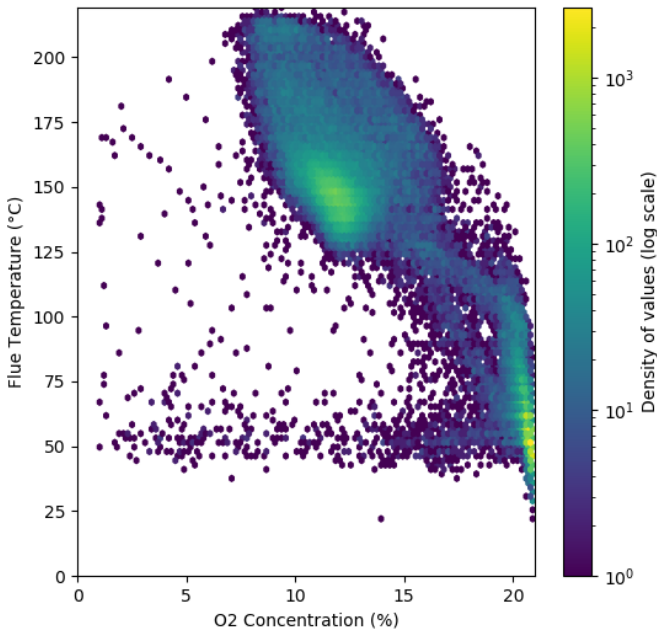
B127



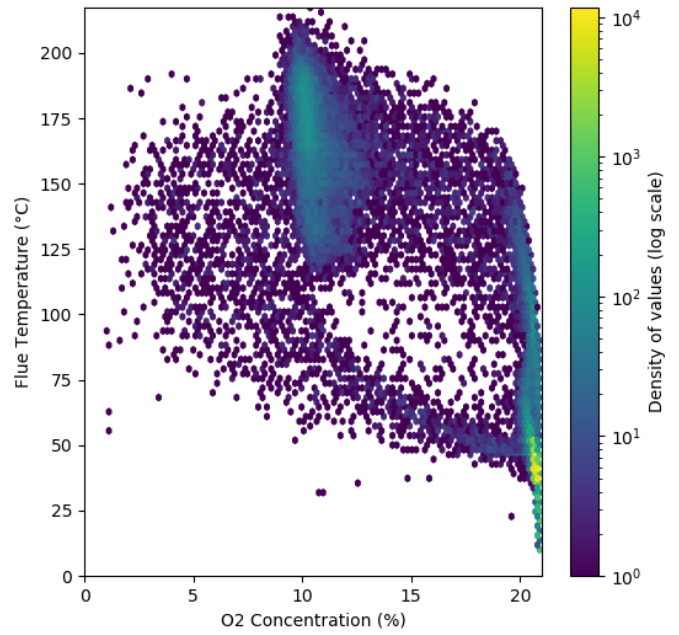
B180



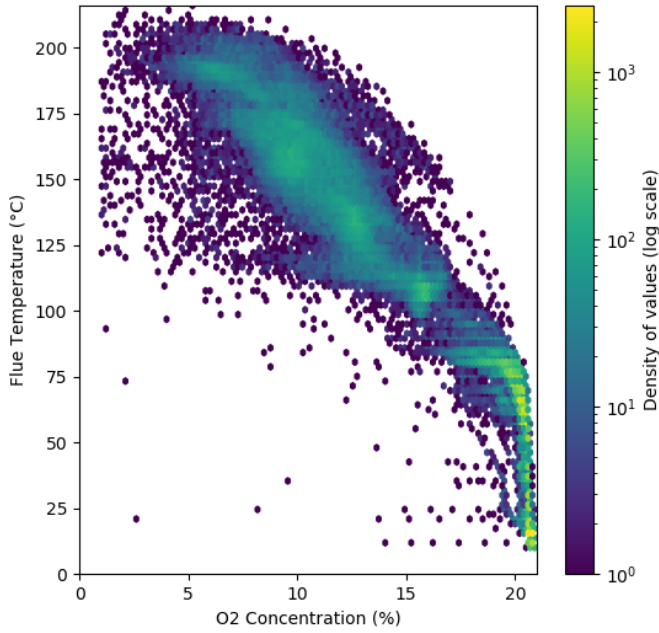
B182



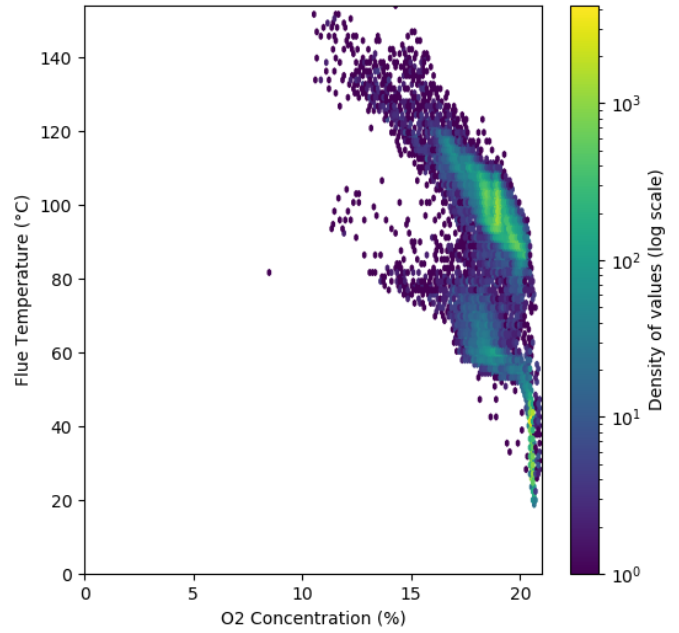
B222



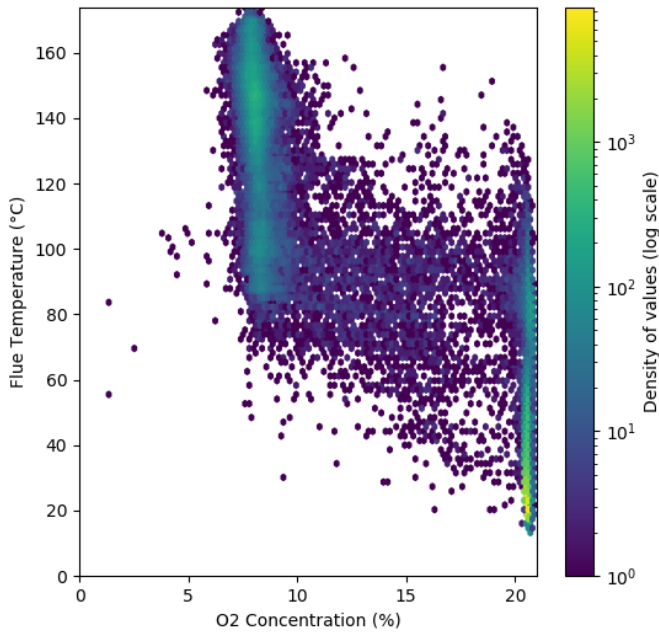
B250



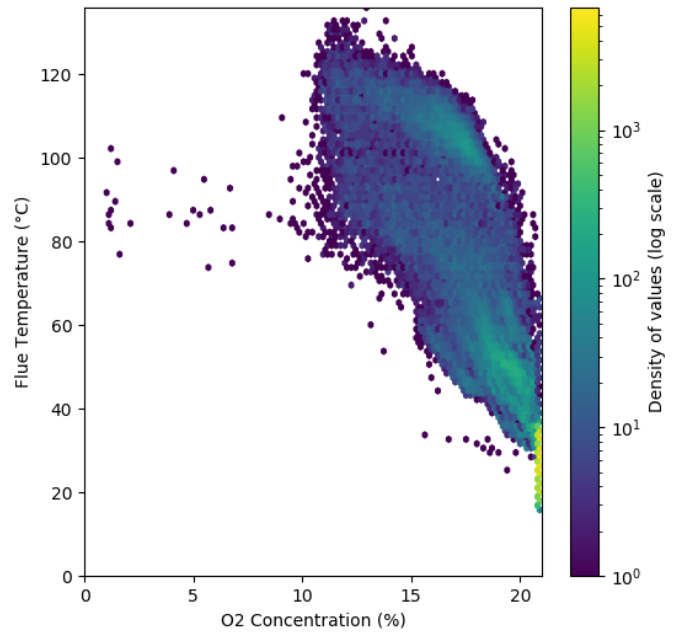
B260



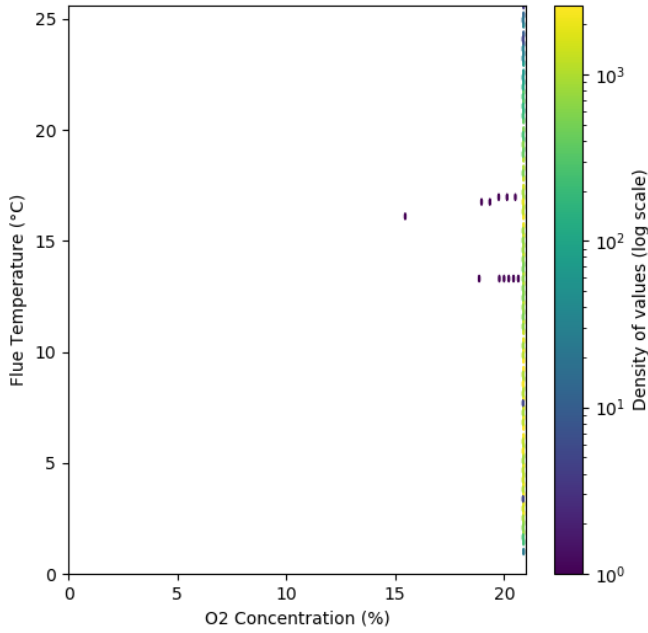
B271



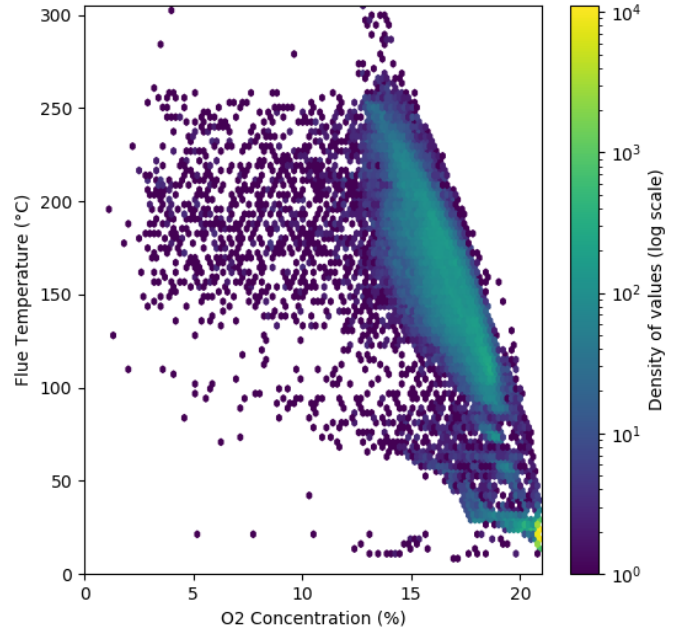
B287



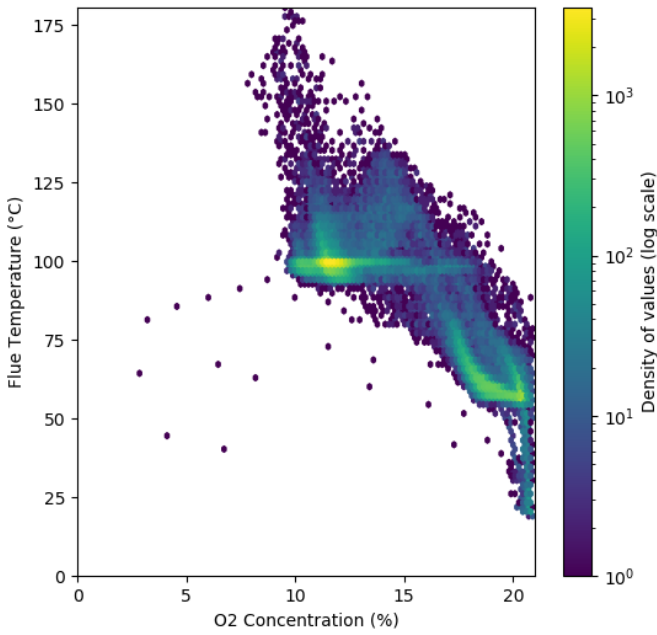
B309



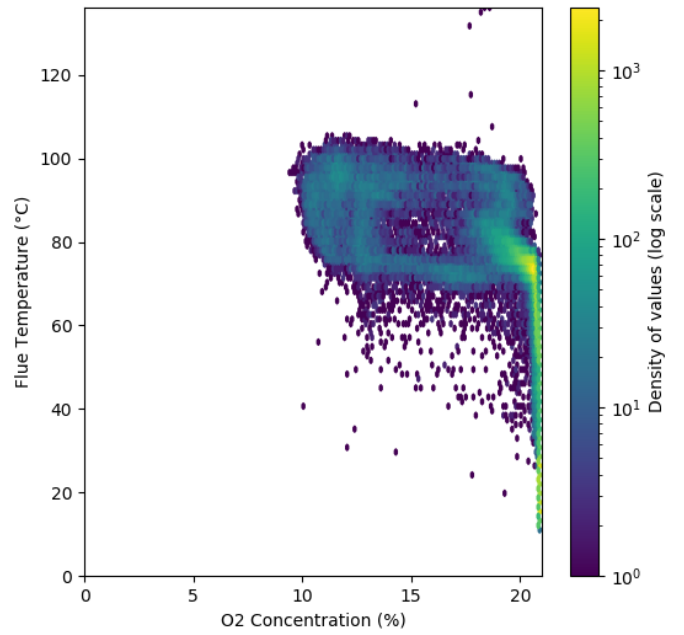
B315



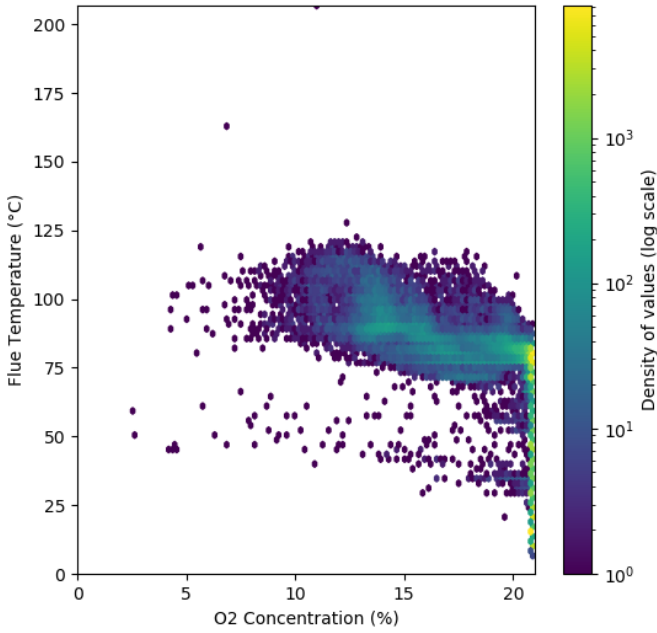
B323



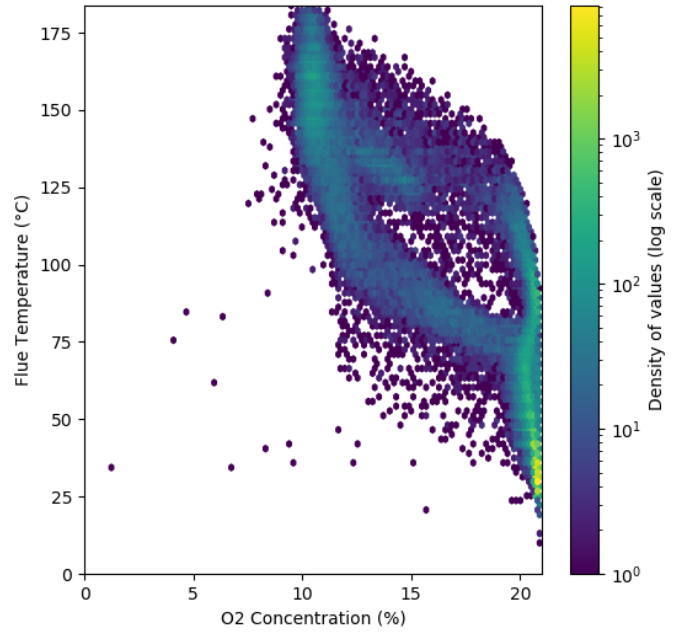
B358



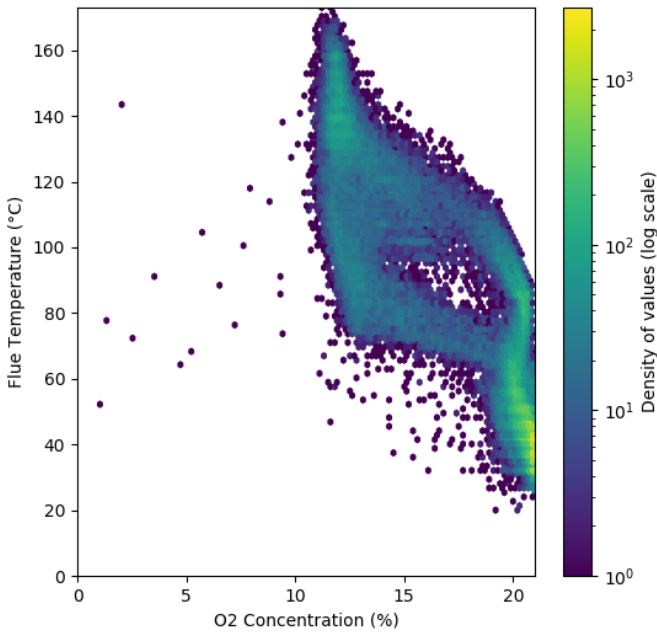
B365



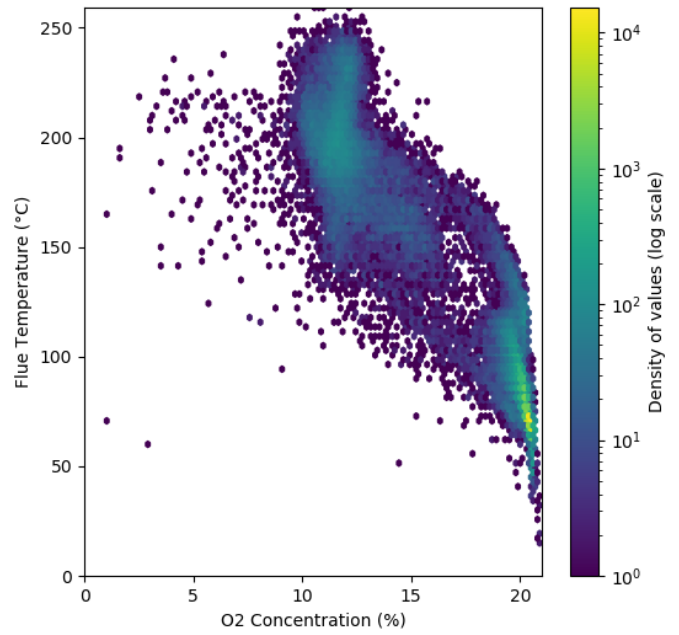
B369 (1)



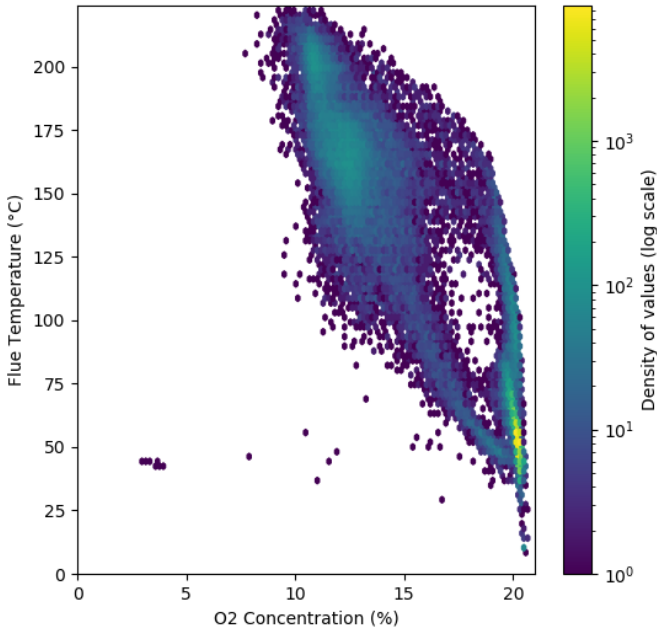
B369 (2)



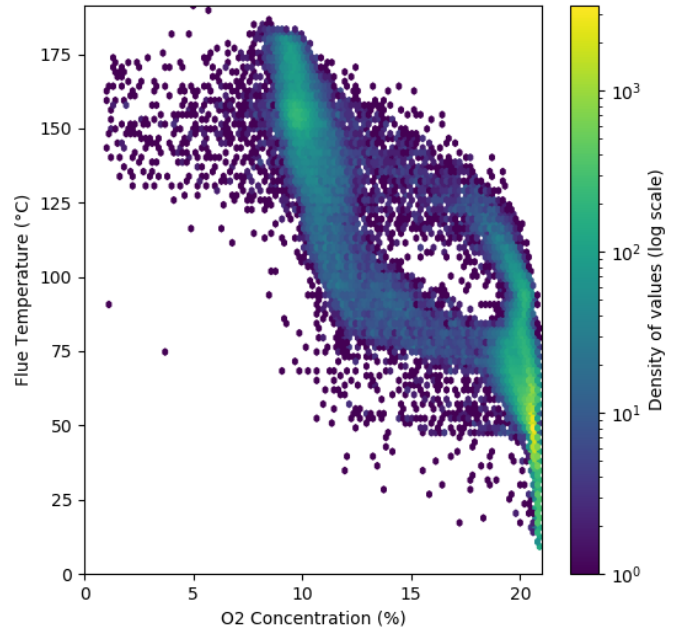
B418 (1)



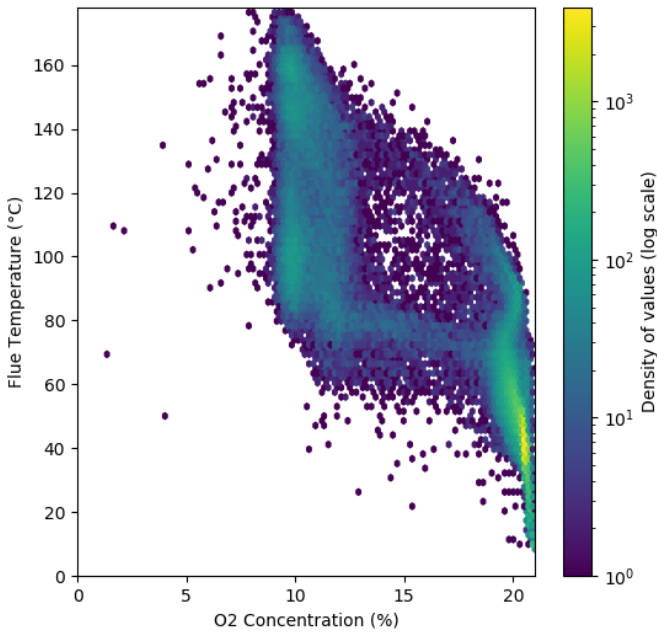
B418 (2)



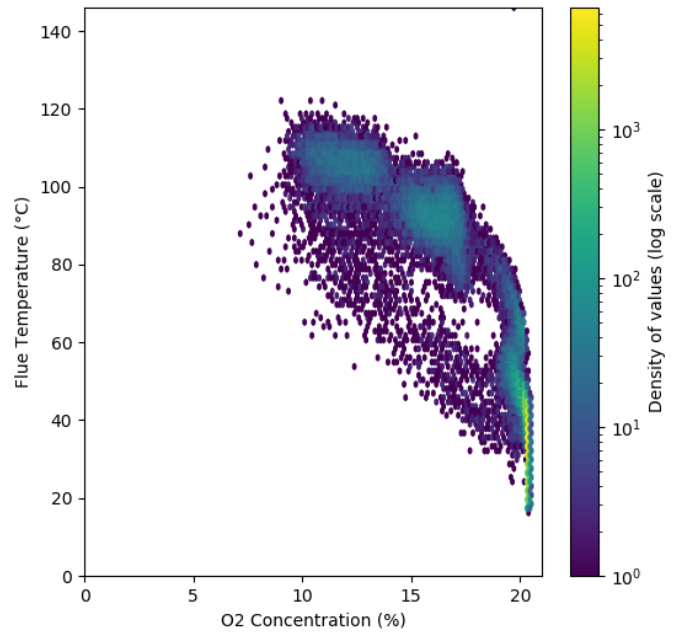
B434 (1)



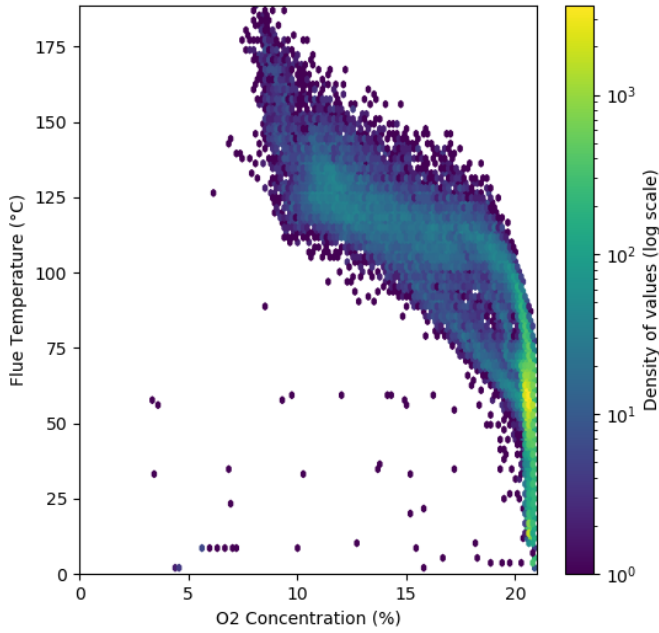
B434 (2)



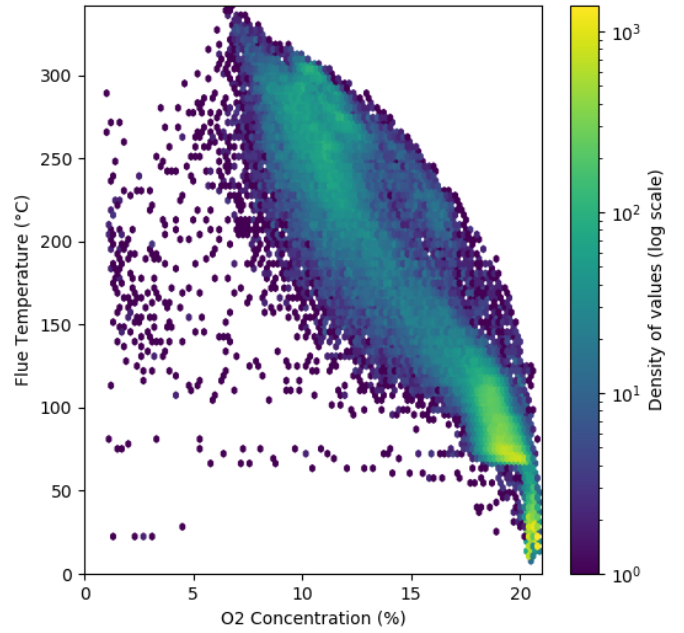
B445



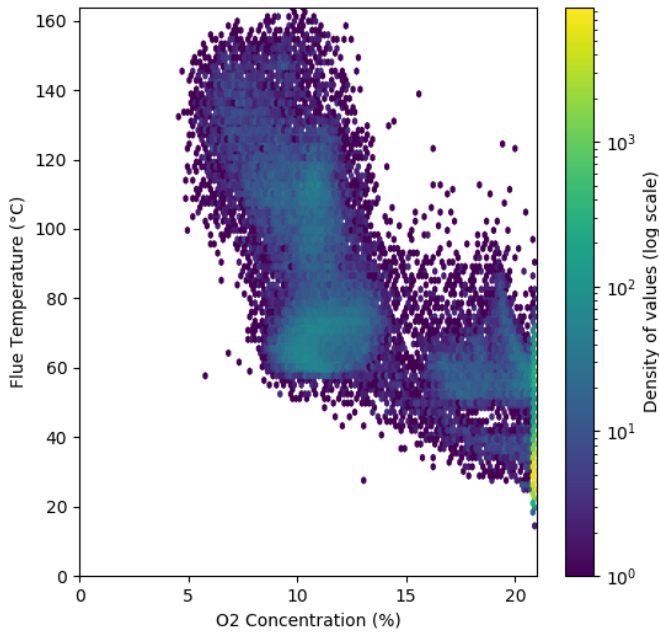
B458



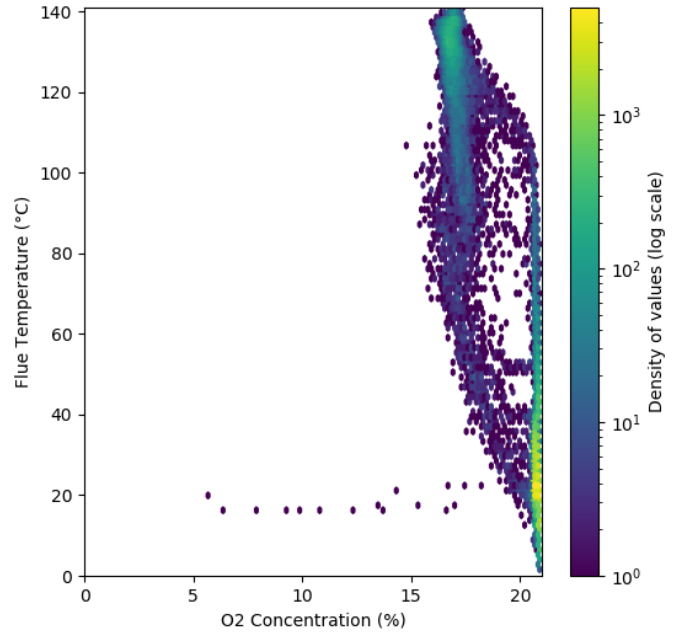
B464



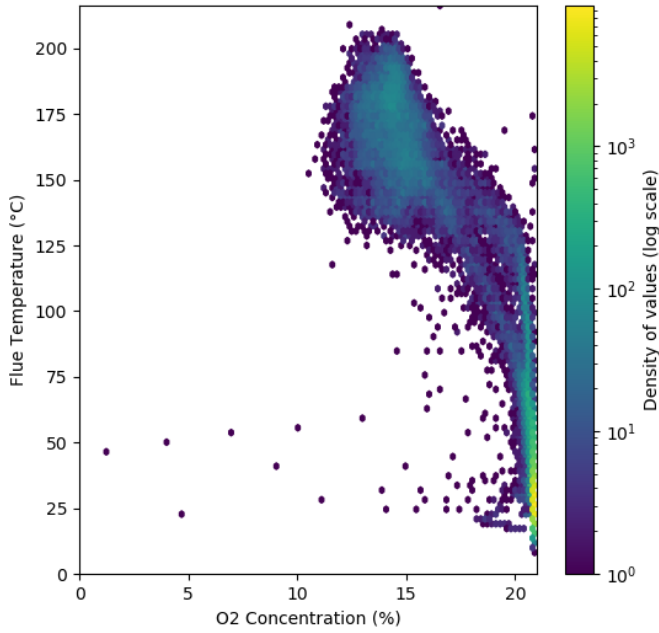
B477



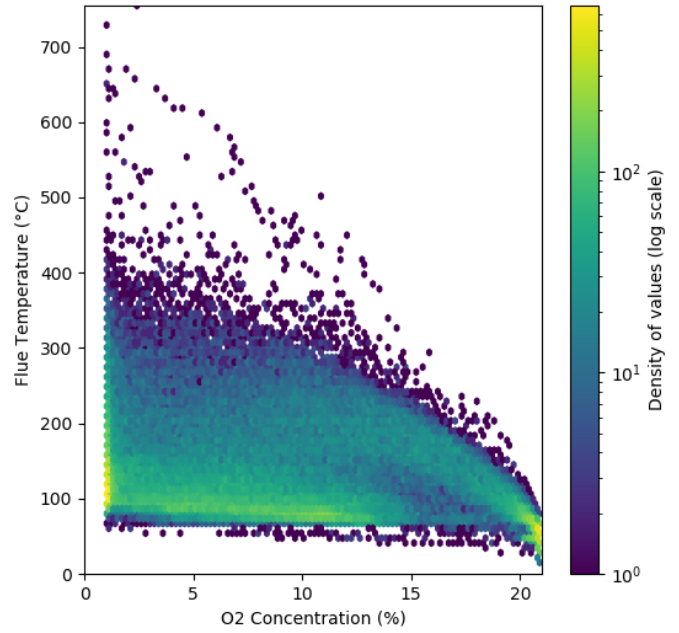
B499



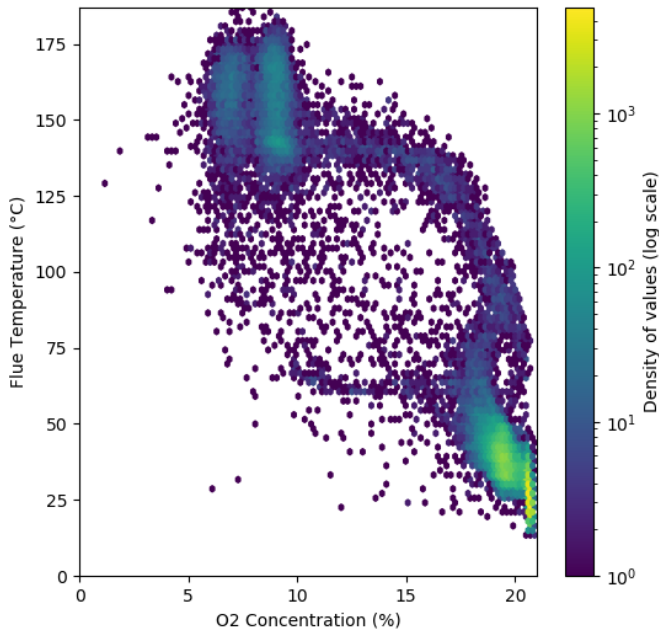
B542



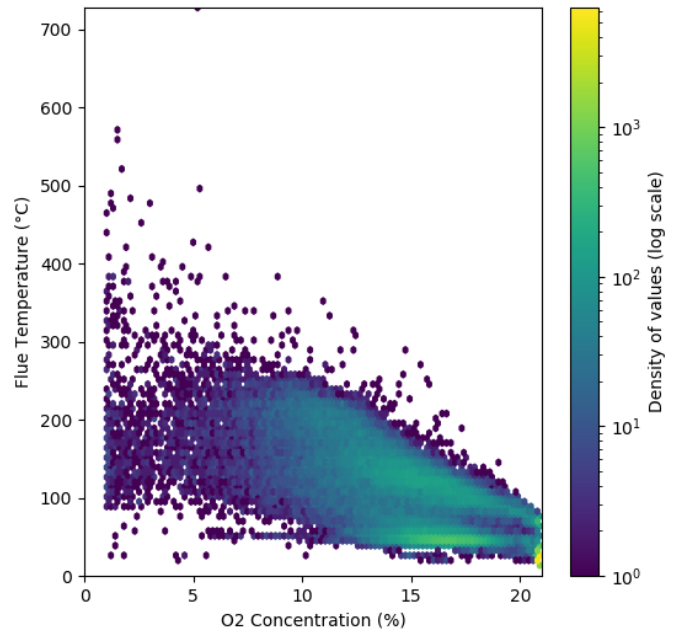
B585



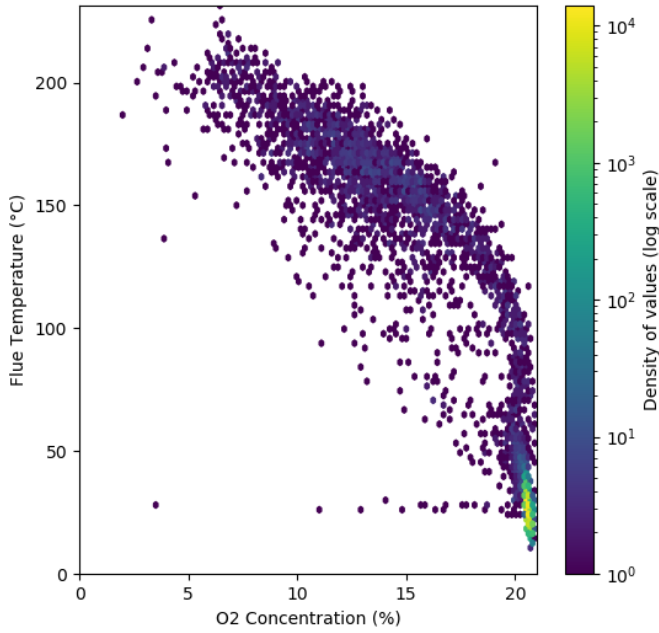
B586



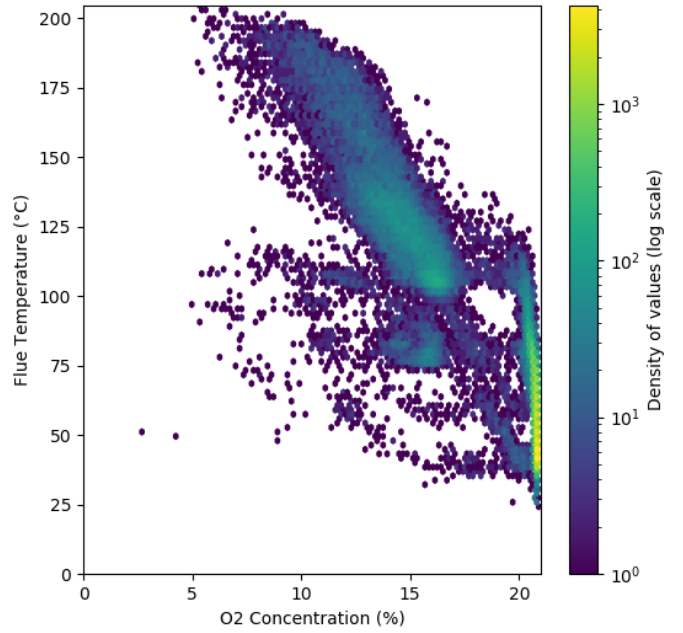
B609



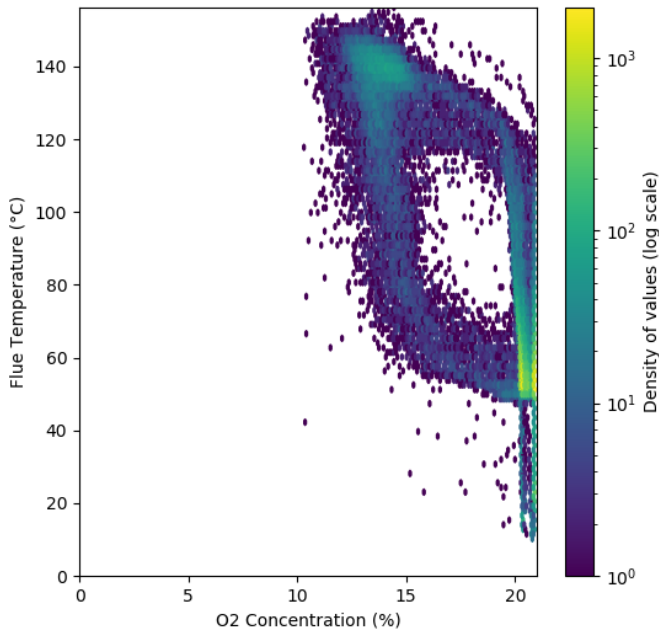
B622



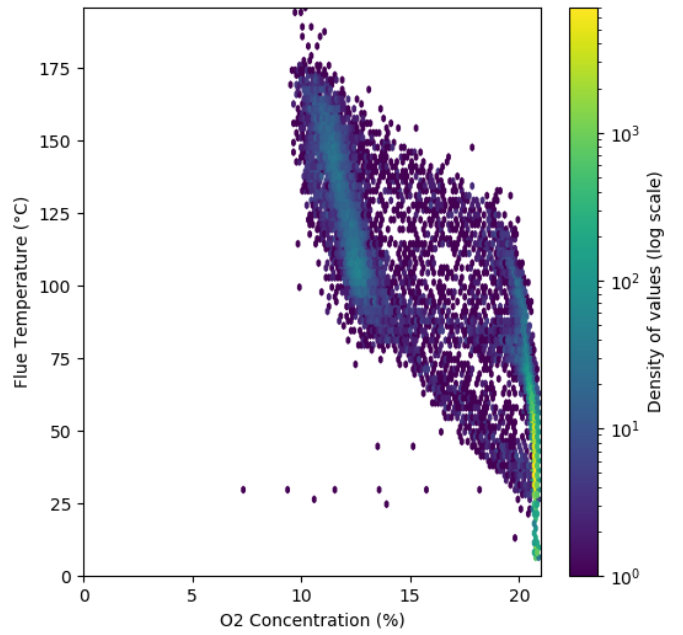
B625



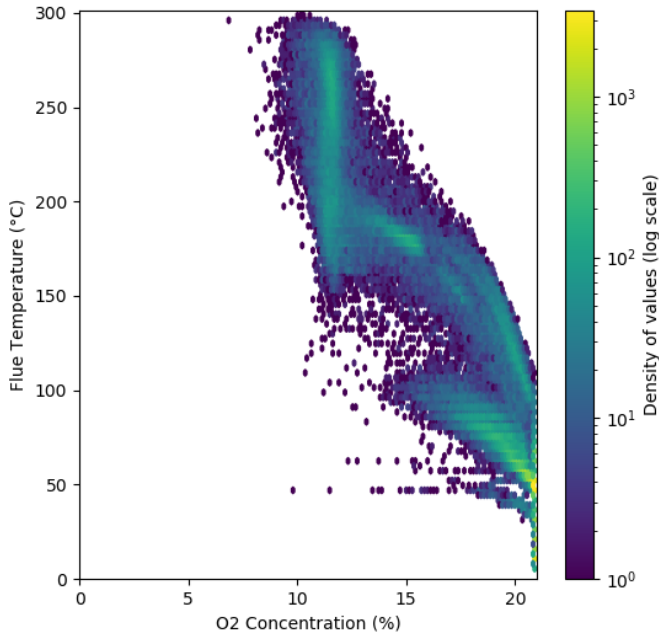
B630



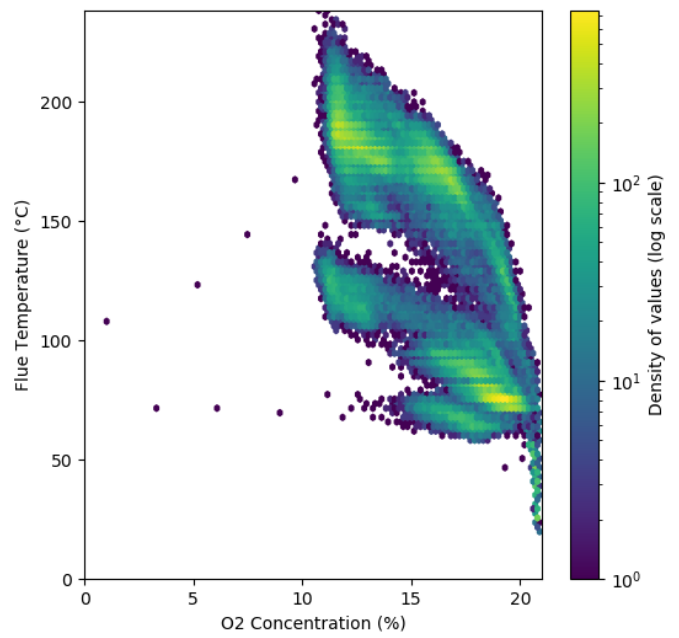
B650



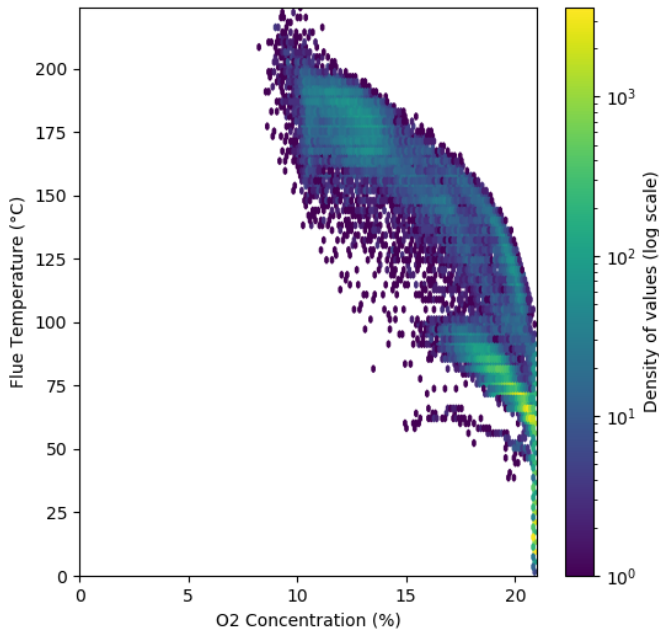
B900



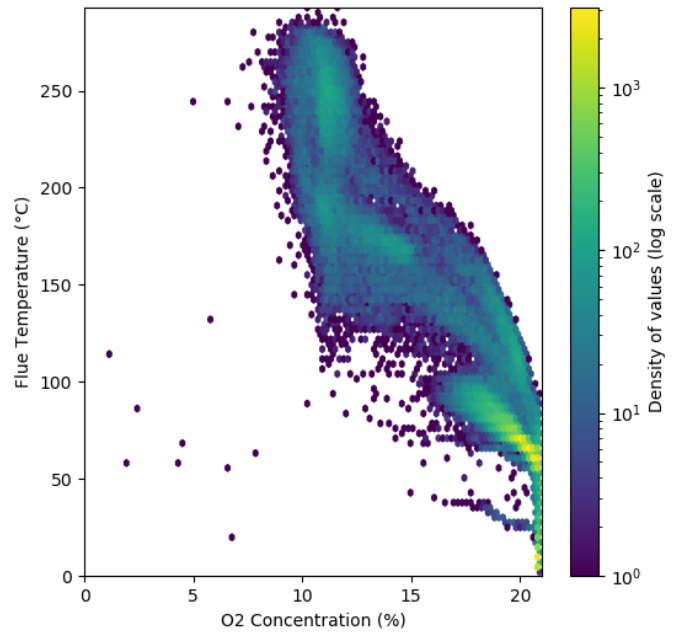
B901



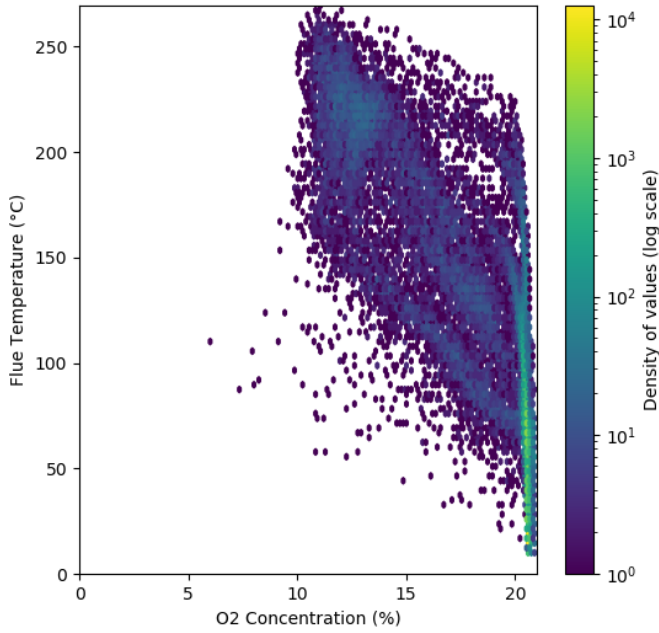
B902



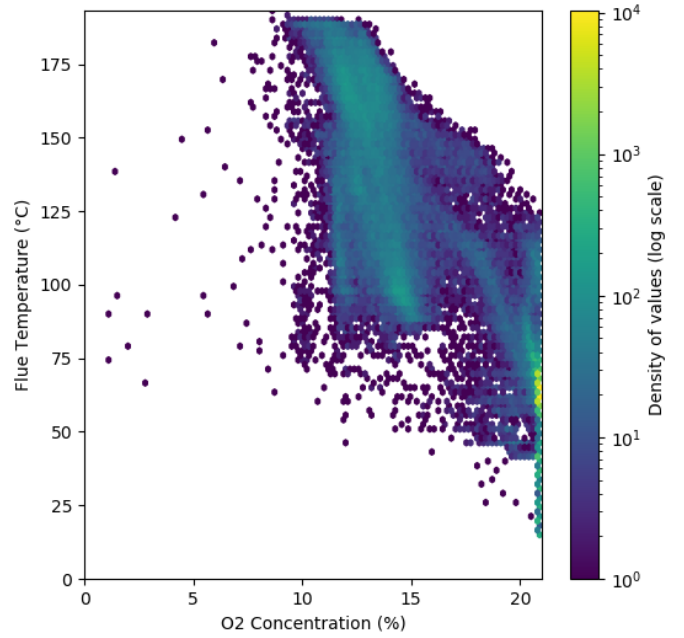
B903



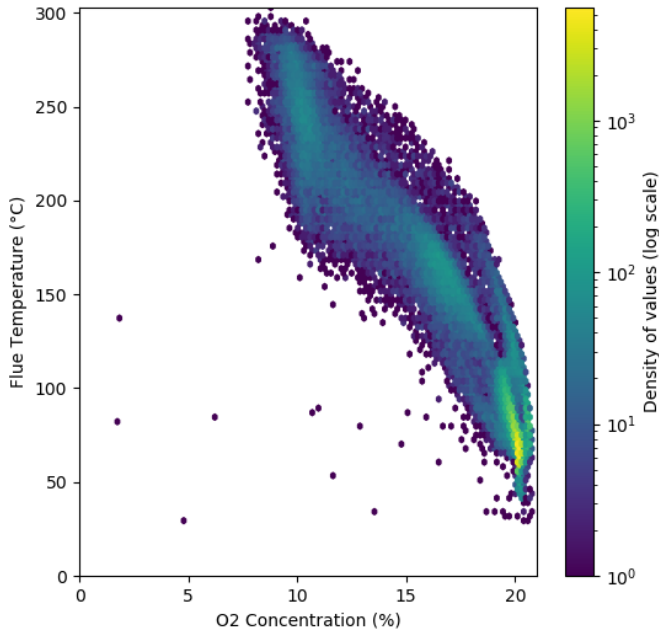
B906



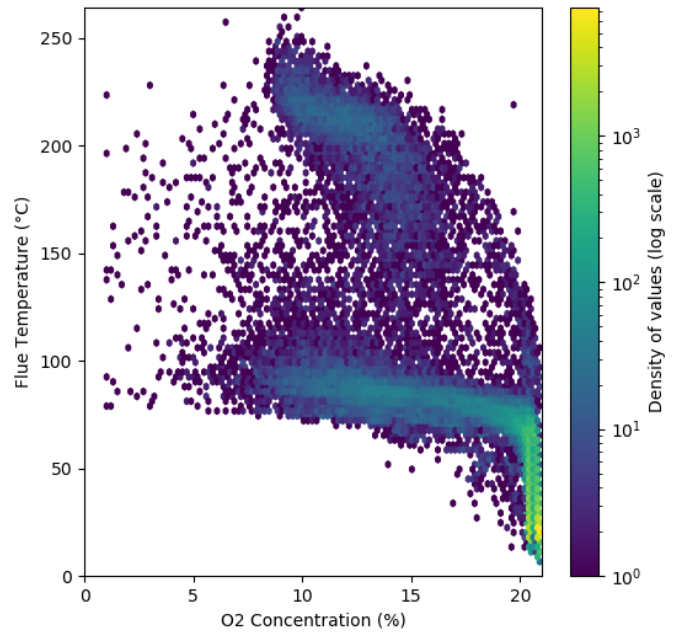
B907



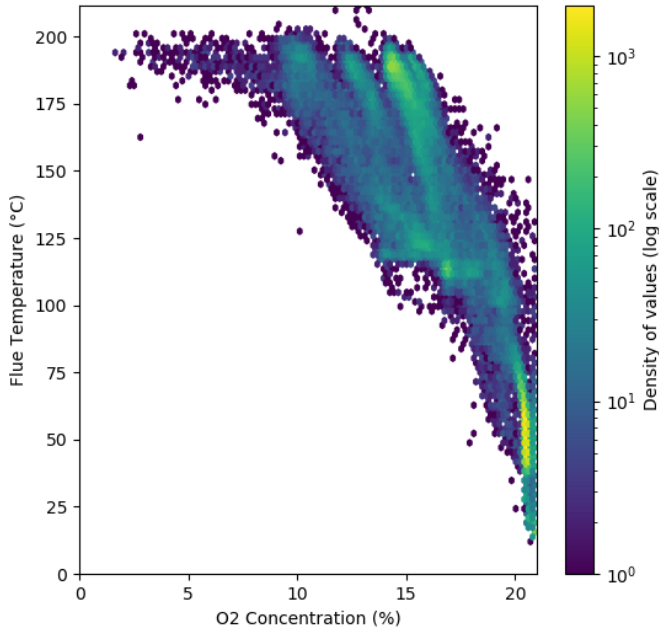
B908



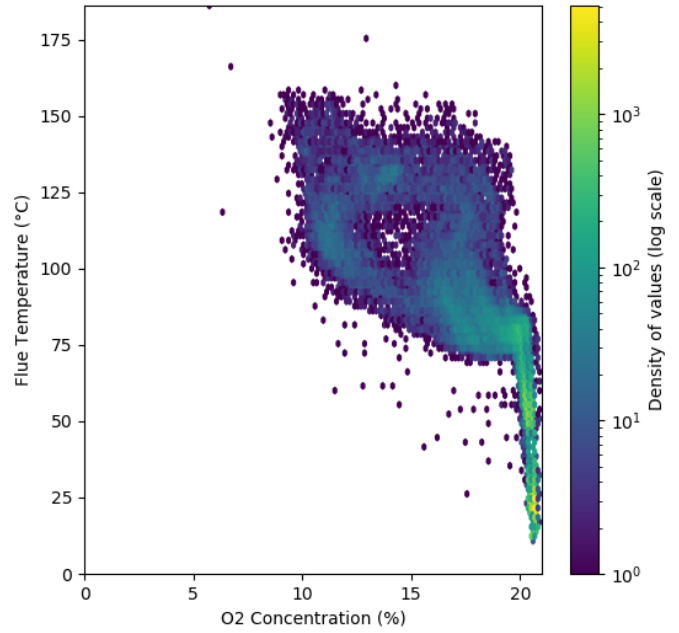
B909



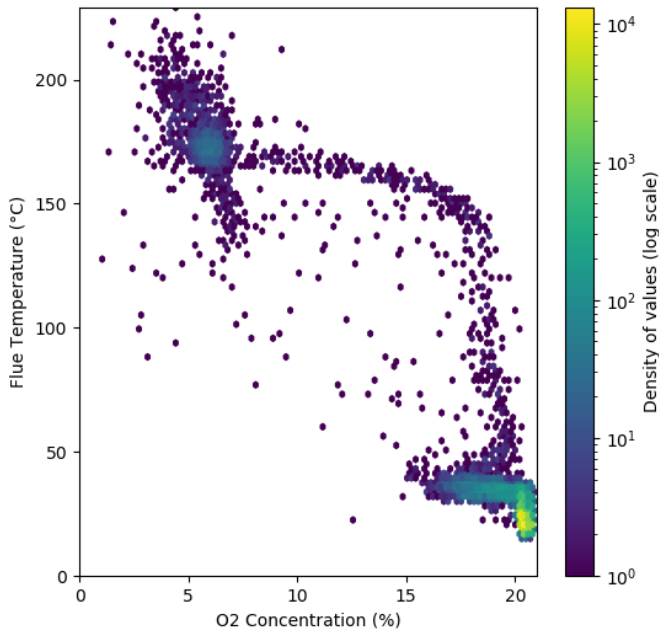
B910



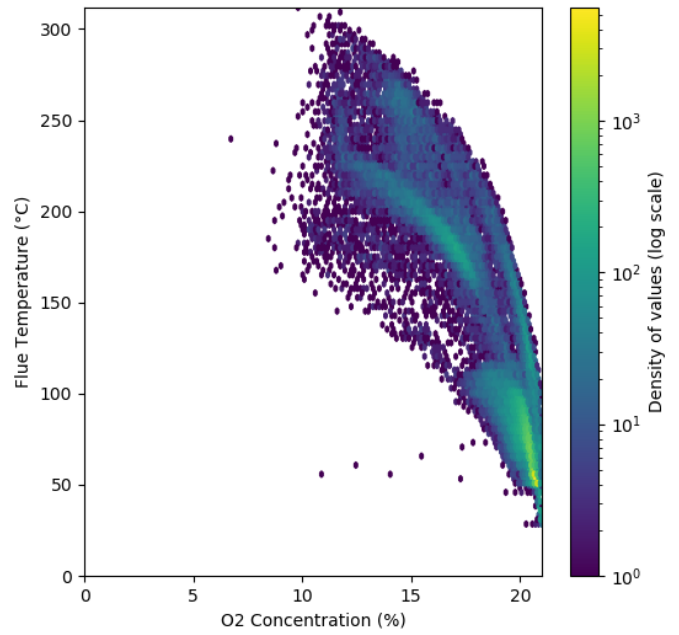
B912



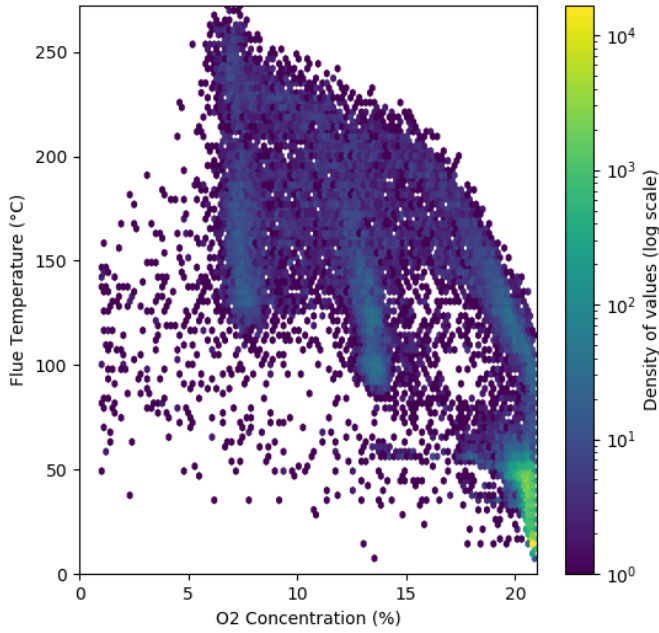
B915 (1)



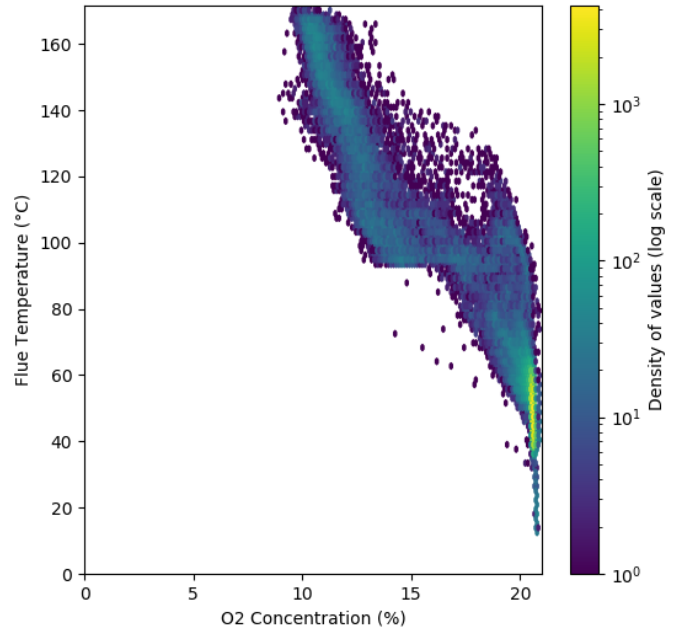
B915 (2)



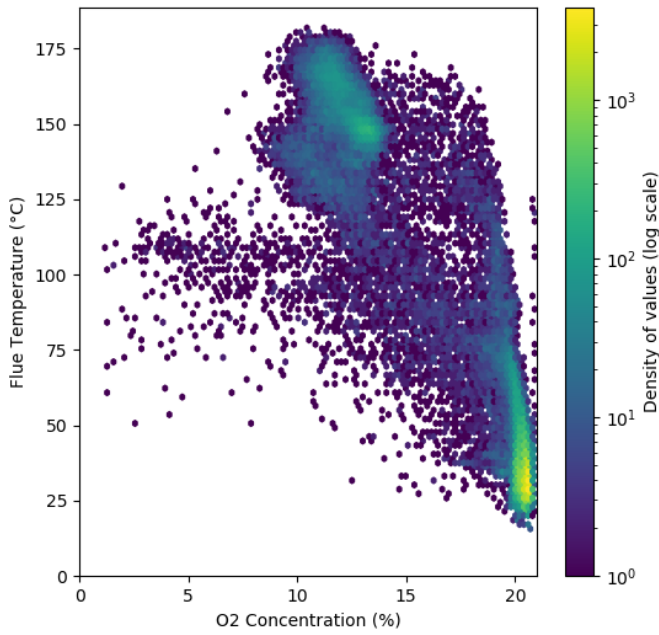
B916



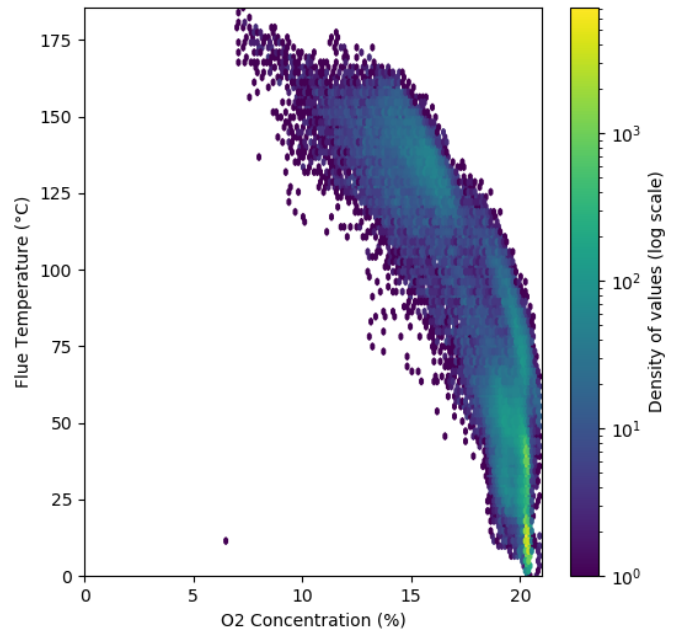
B918



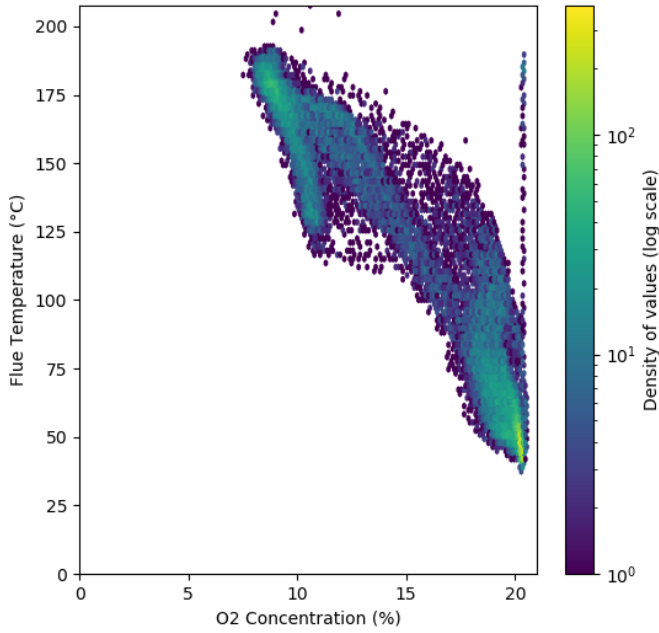
B919



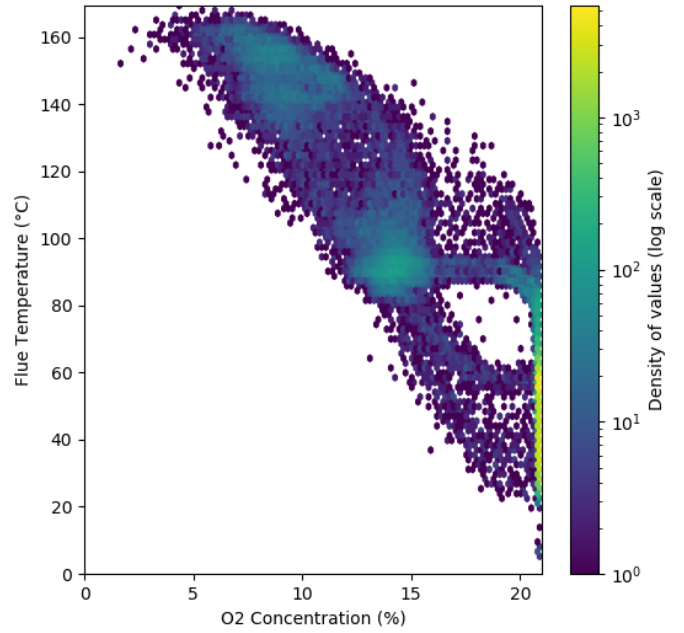
B920



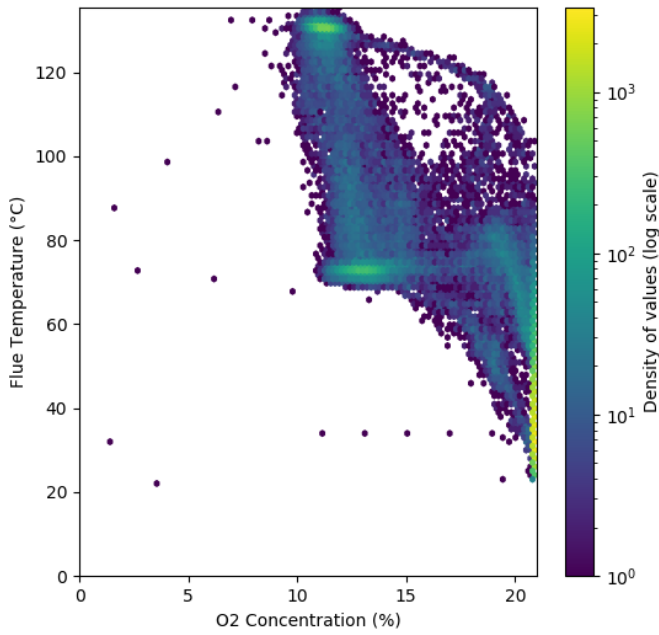
B921



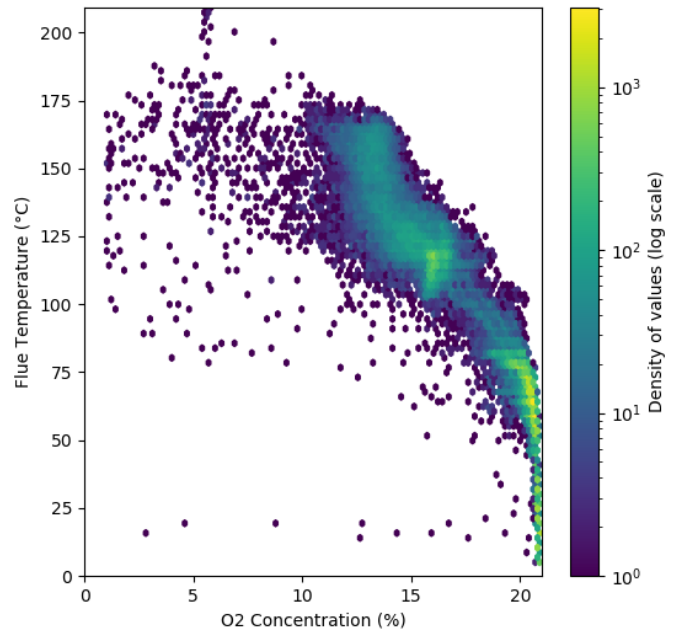
B922



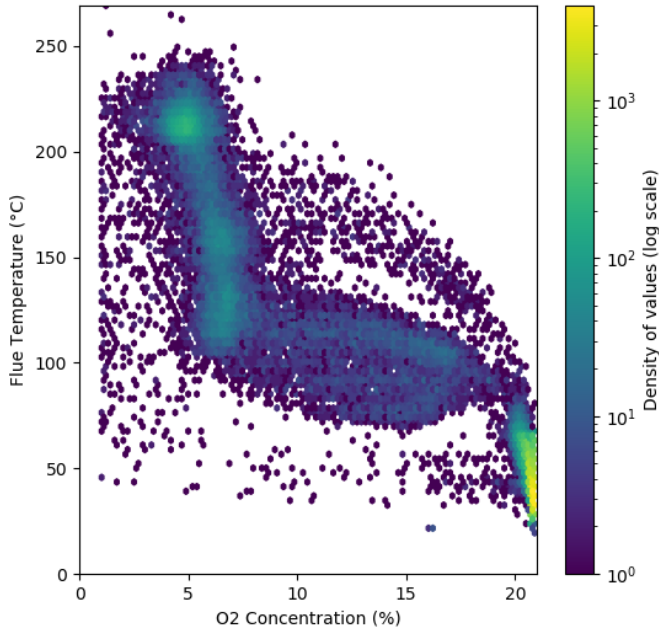
B923



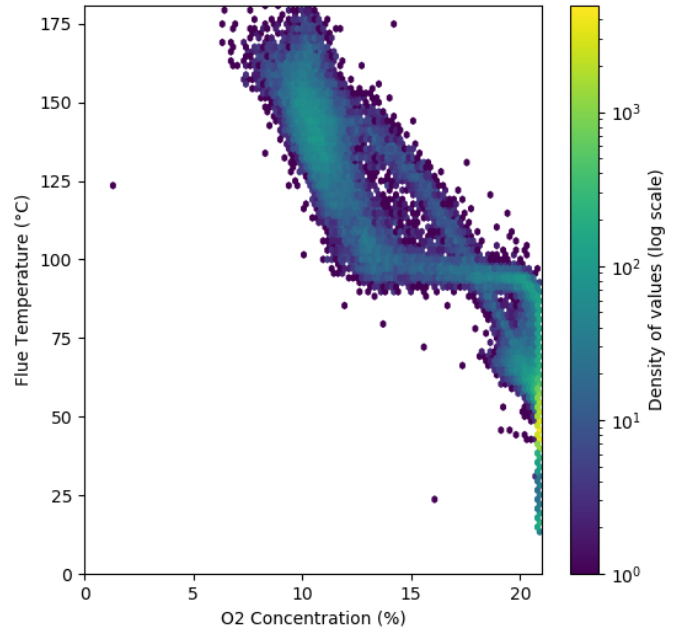
B925



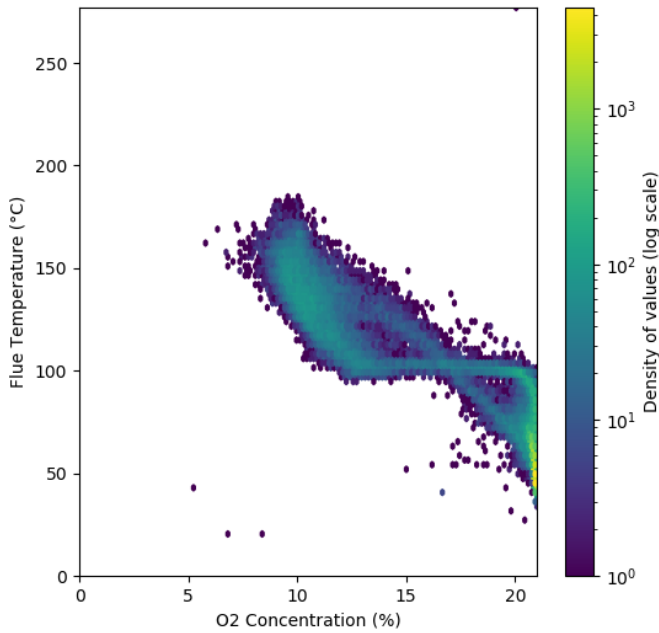
B926



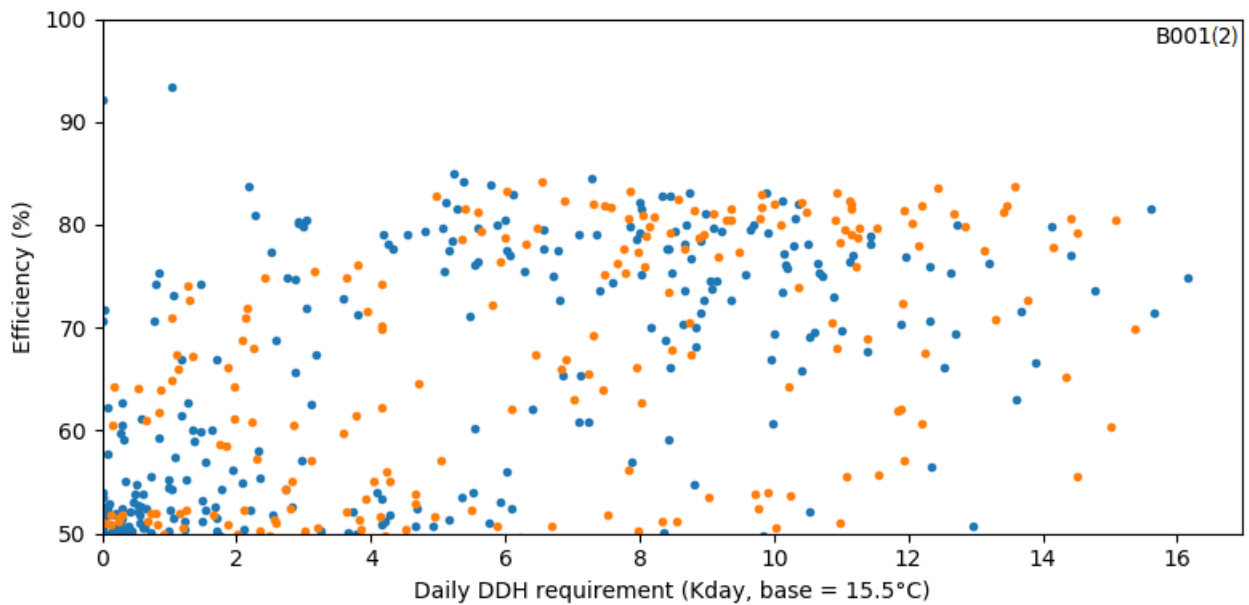
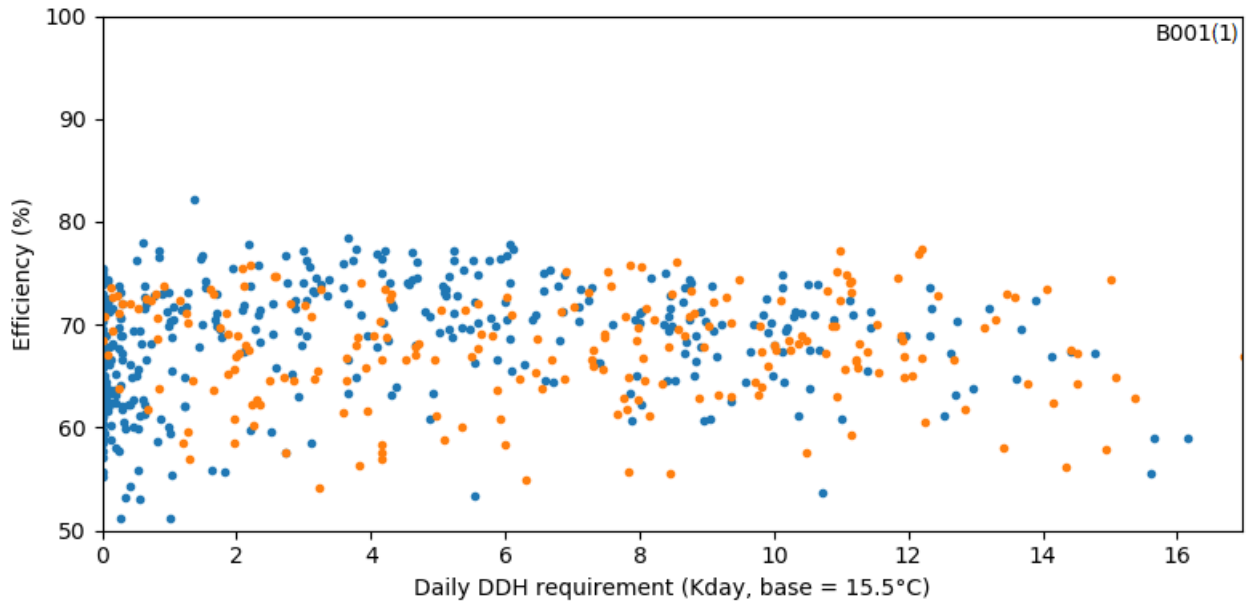
B927 (1)

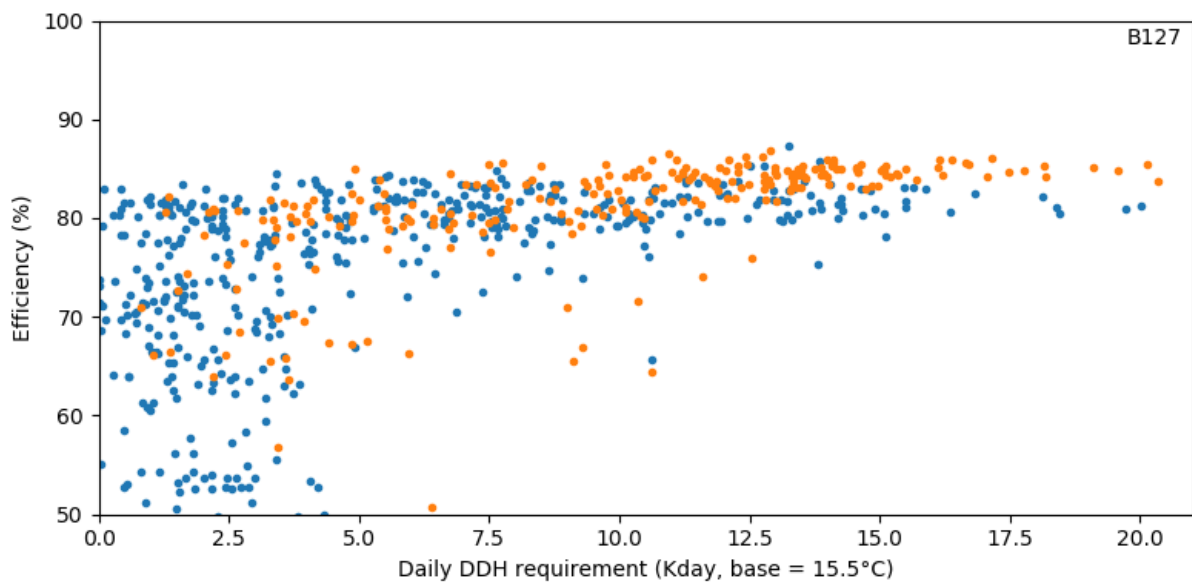
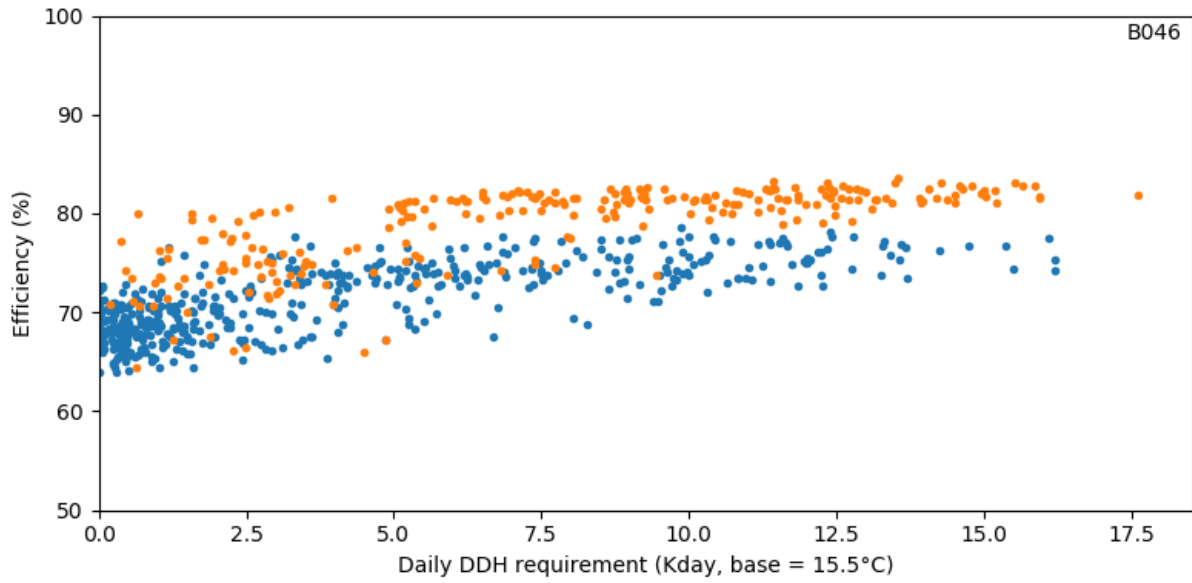


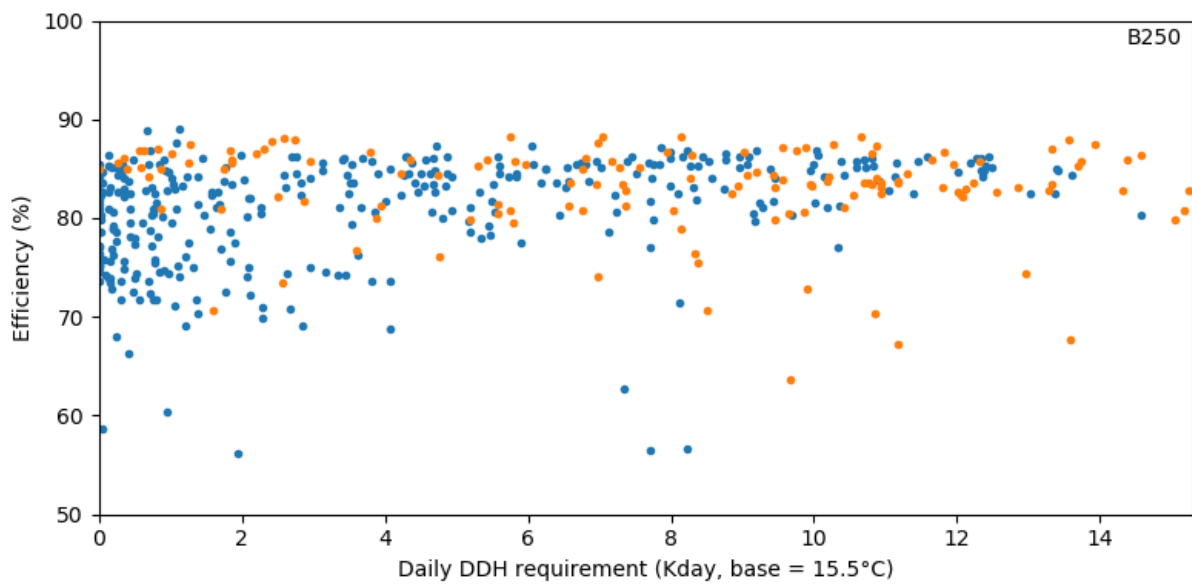
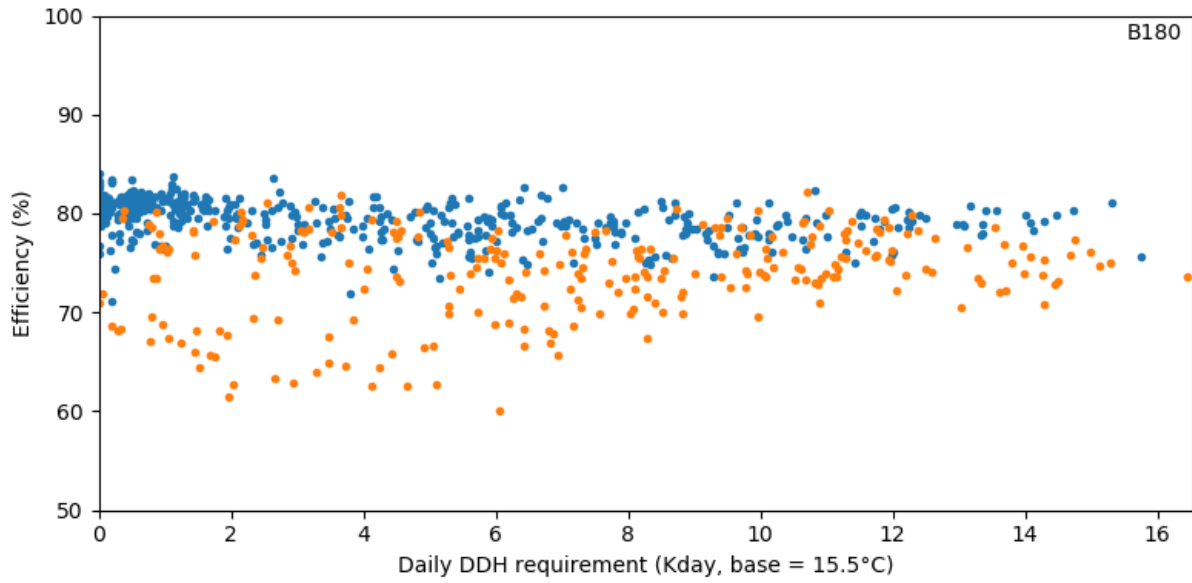
B927 (2)

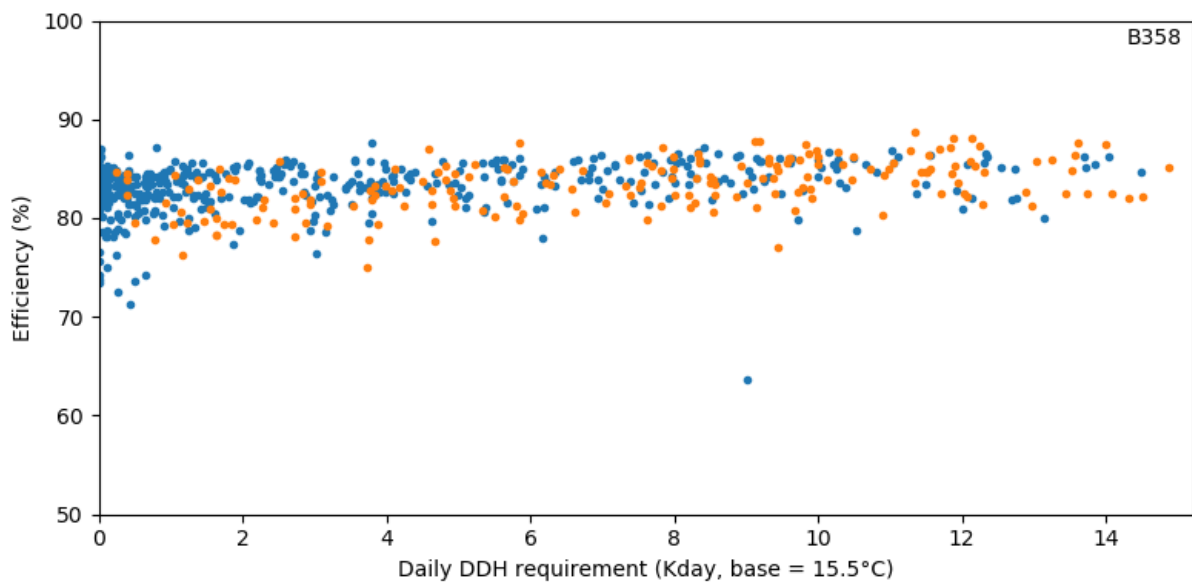
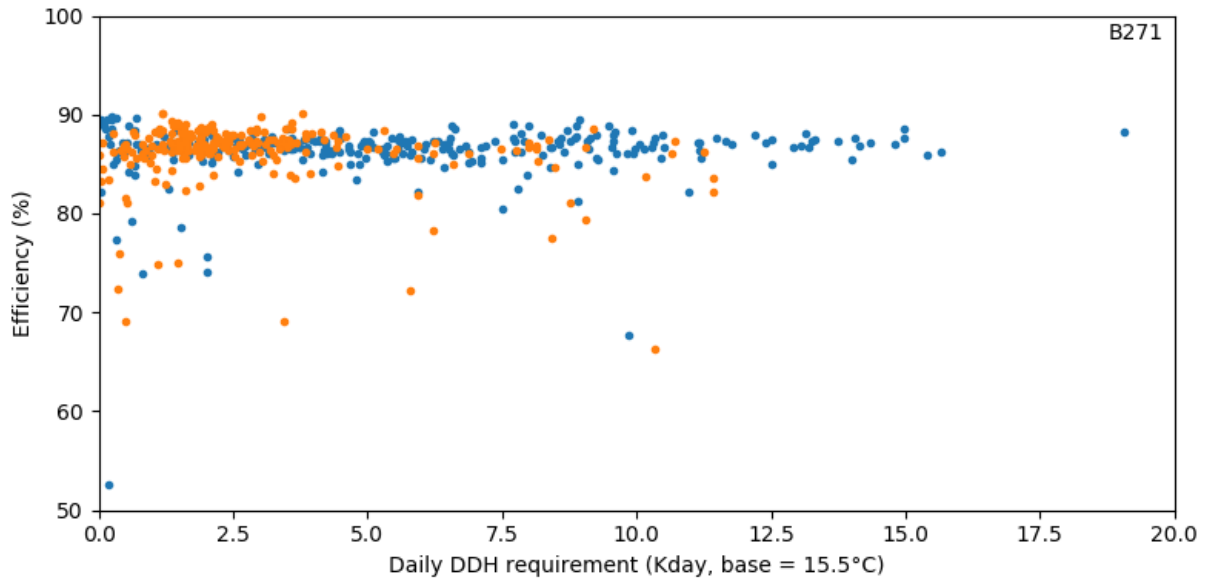


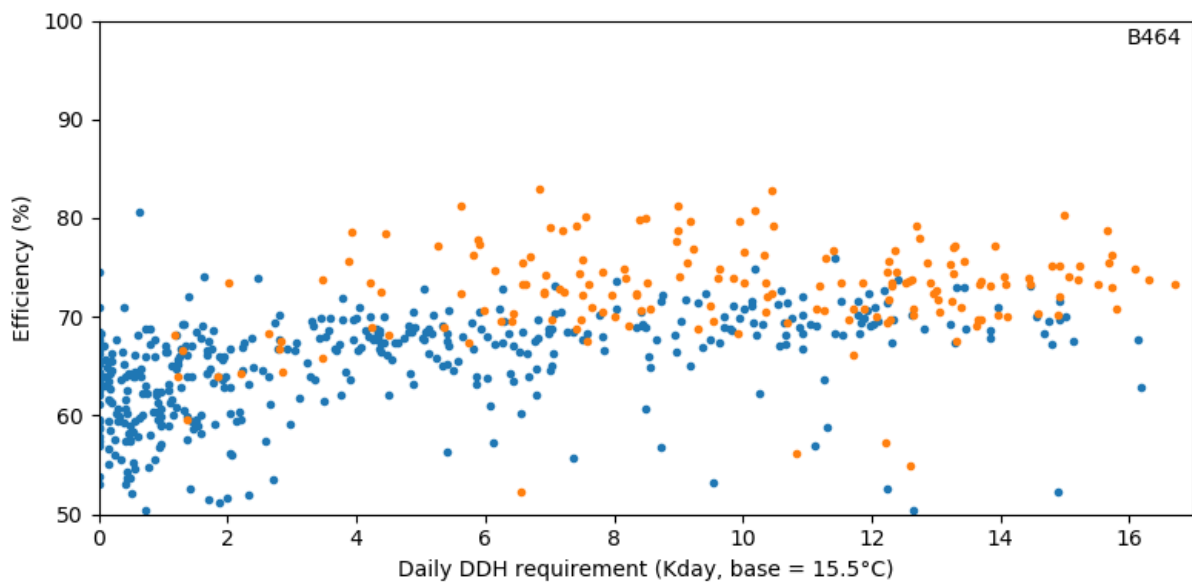
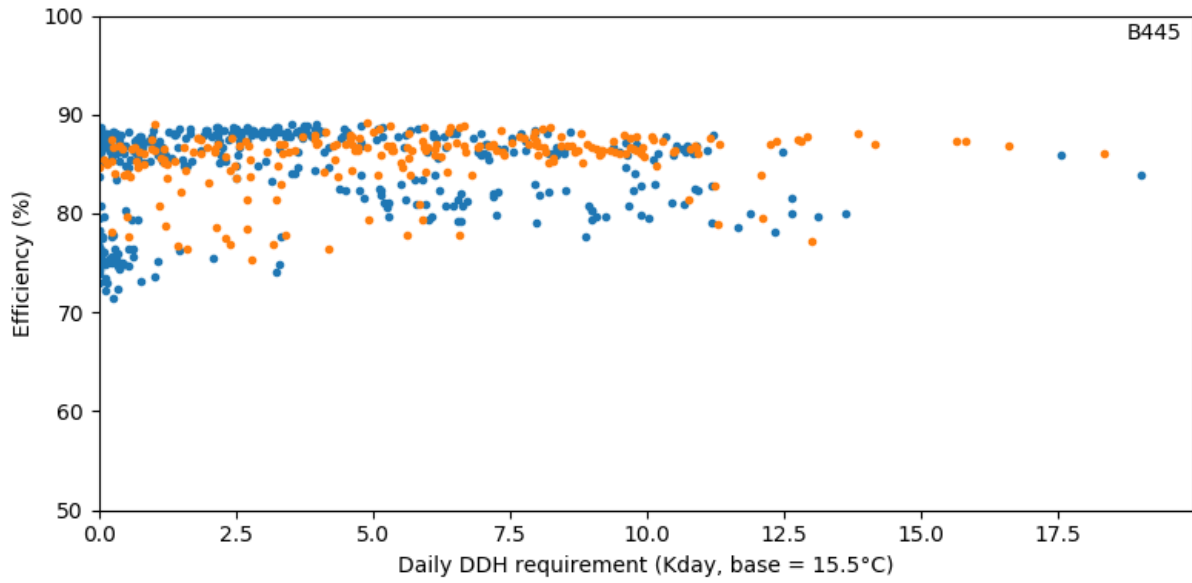
6 Net efficiency and DDH plots

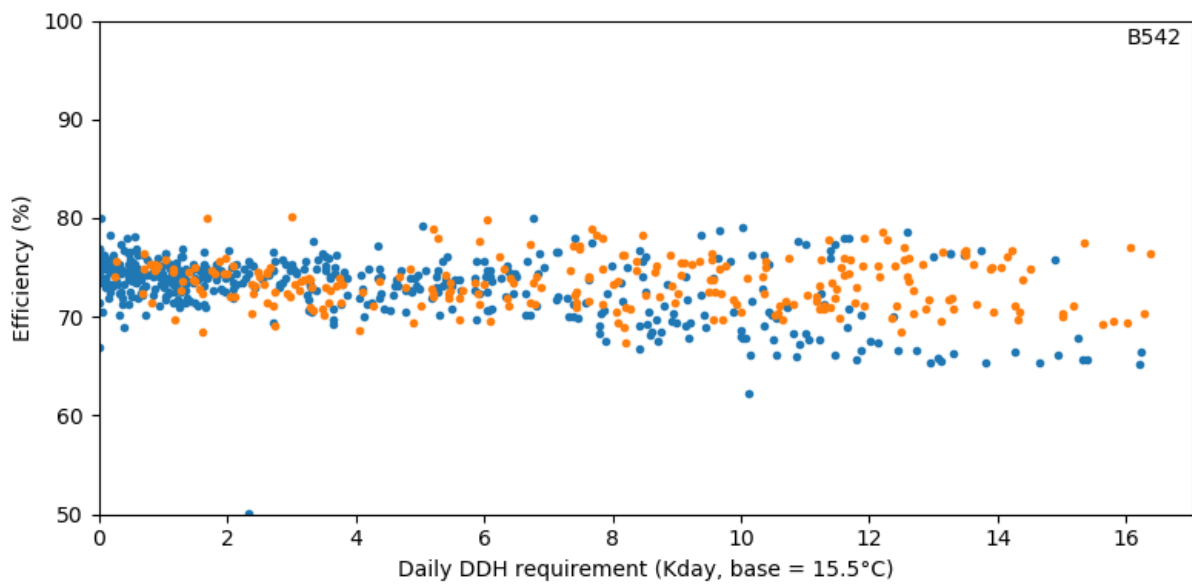
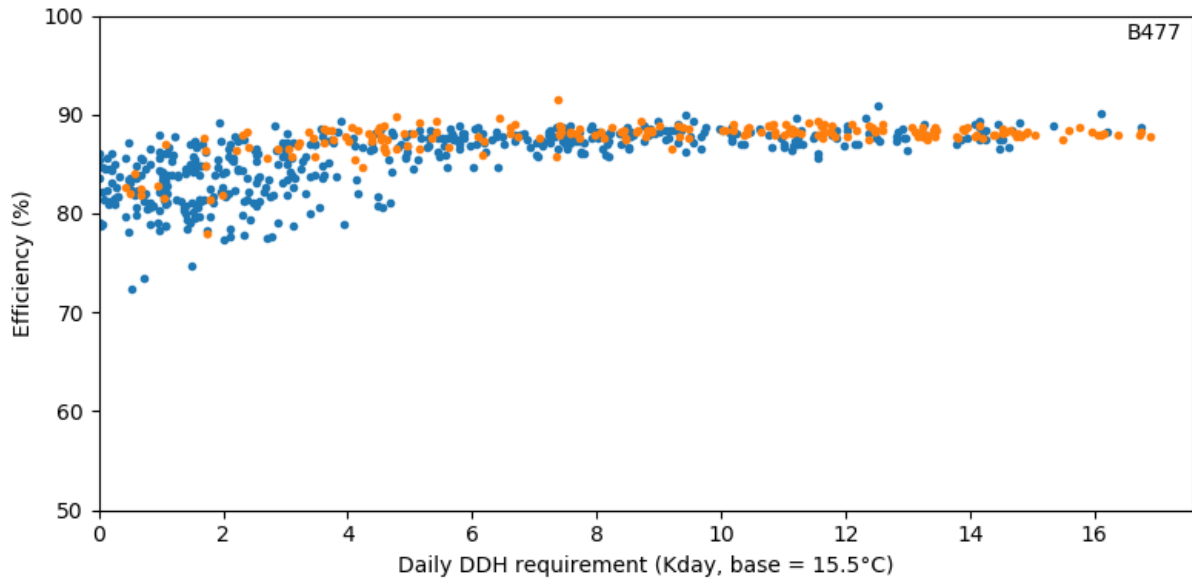


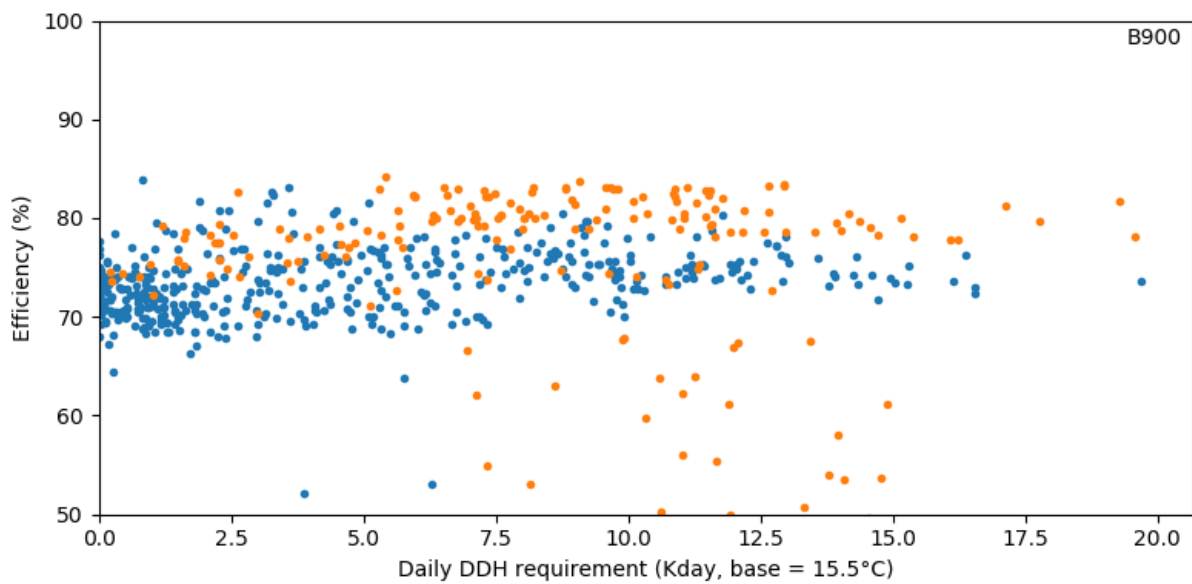
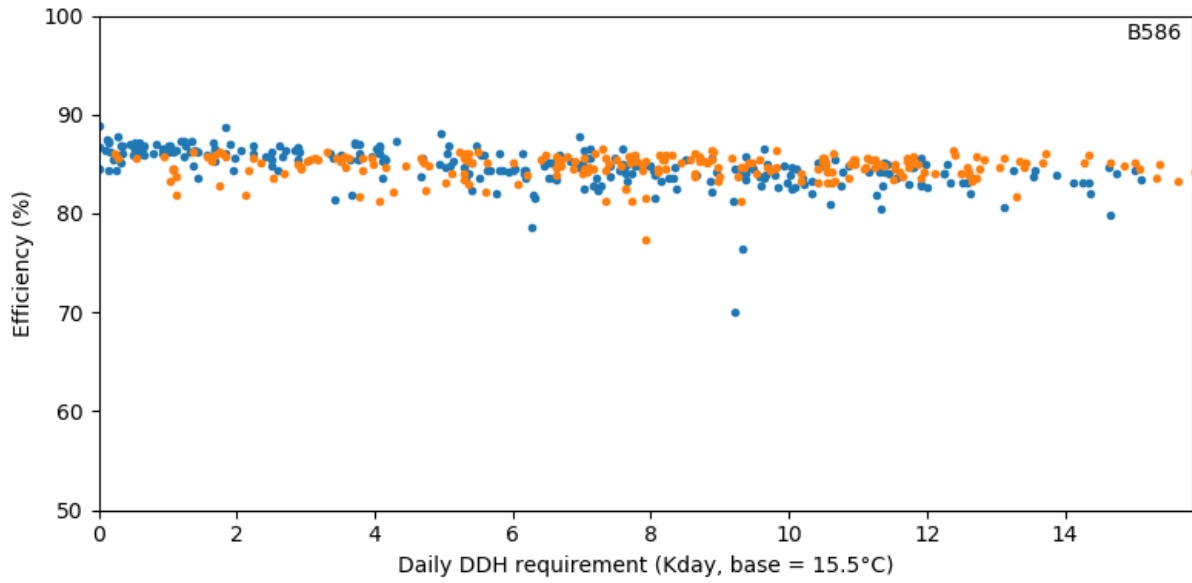


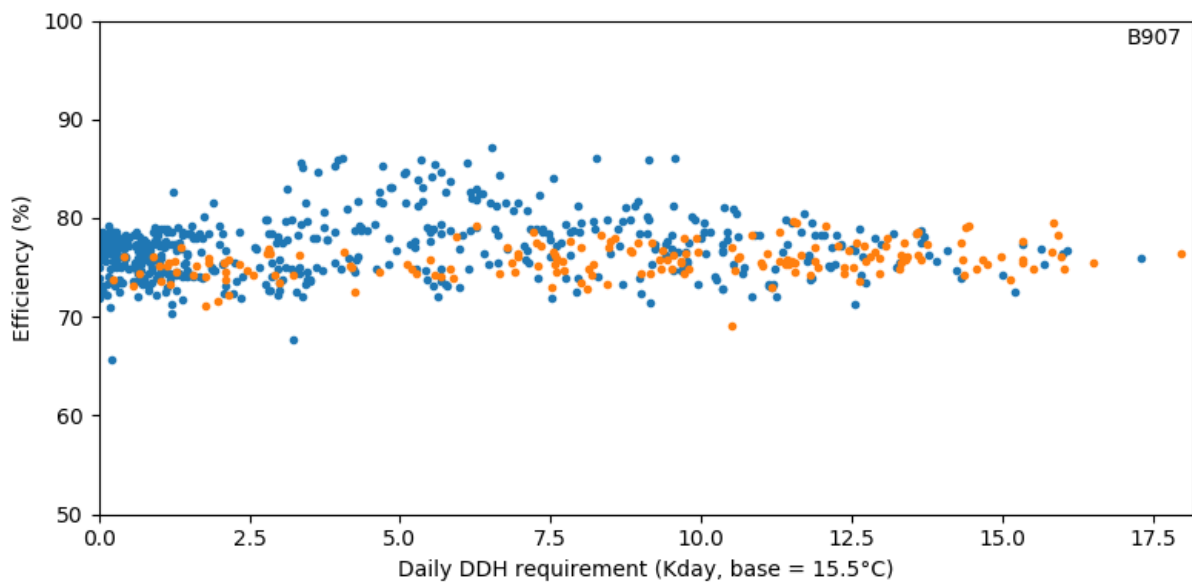
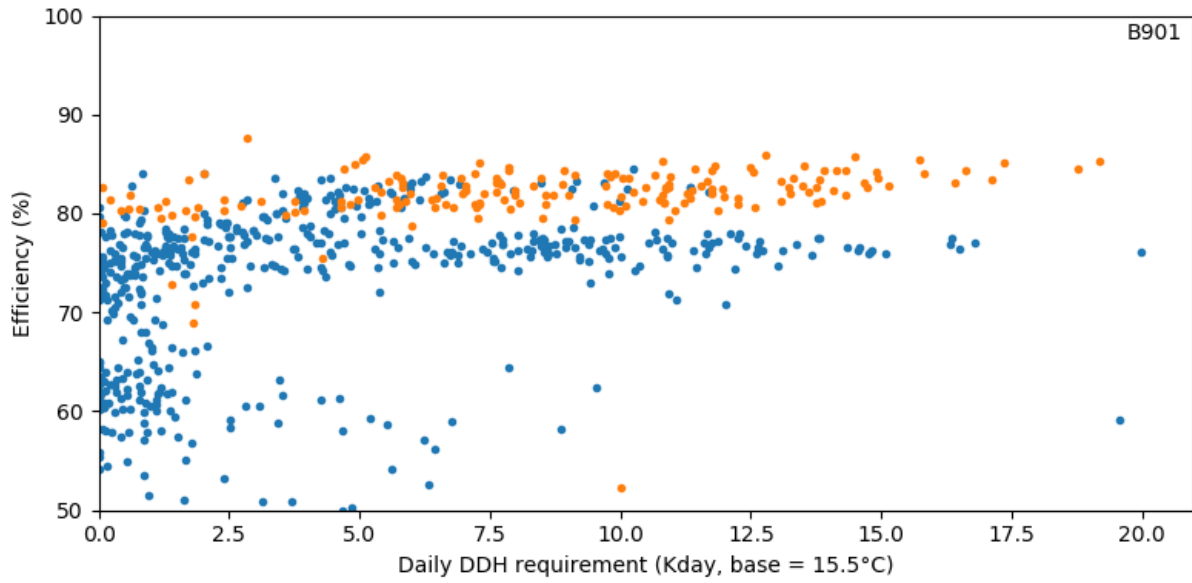


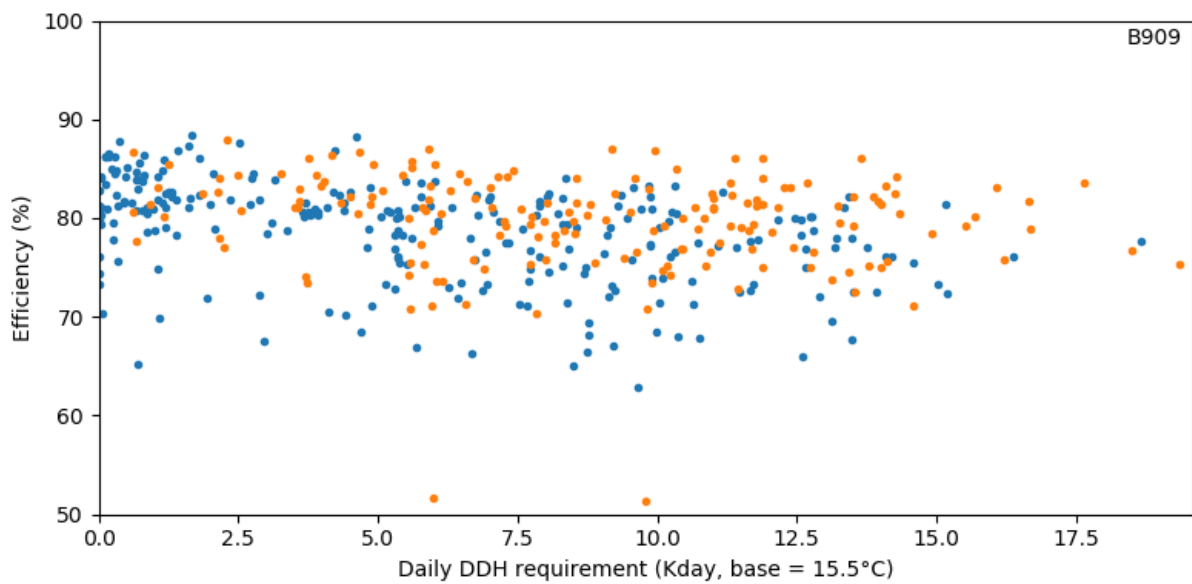
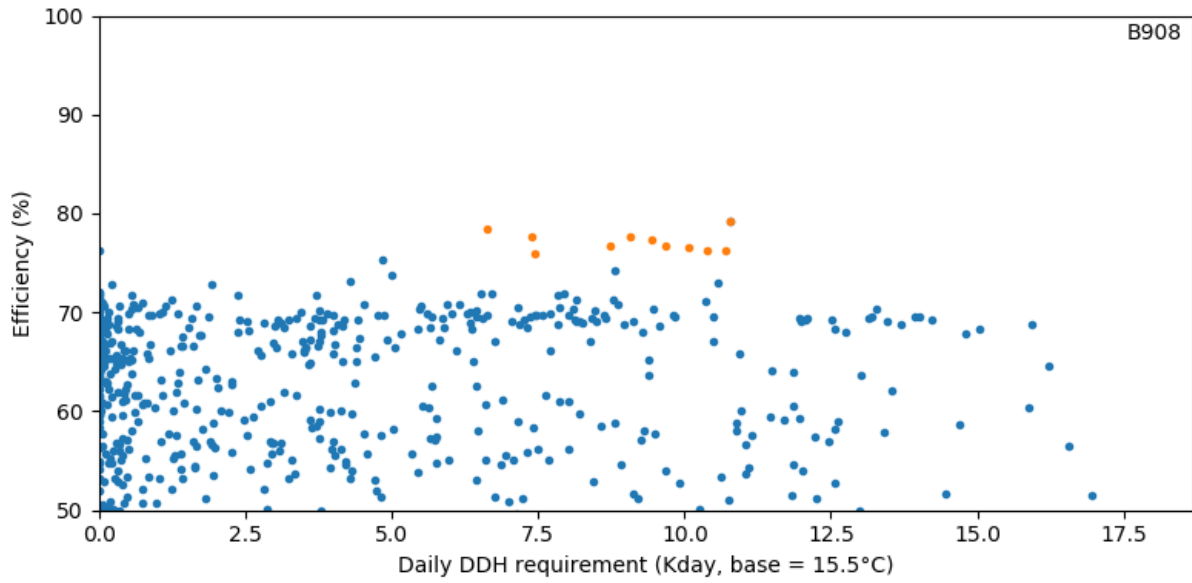


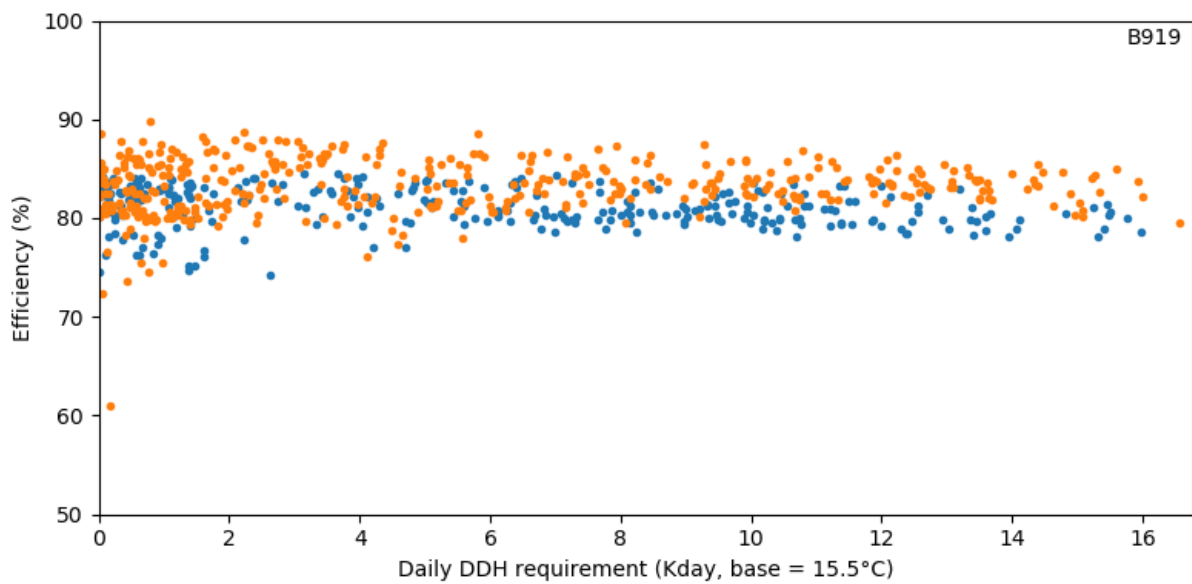
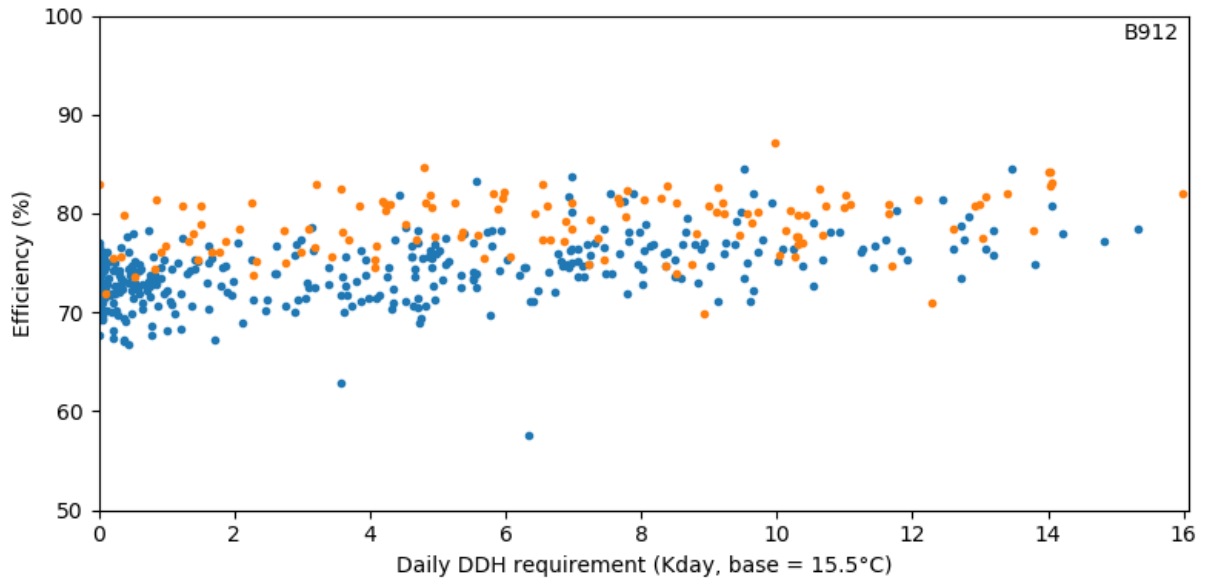


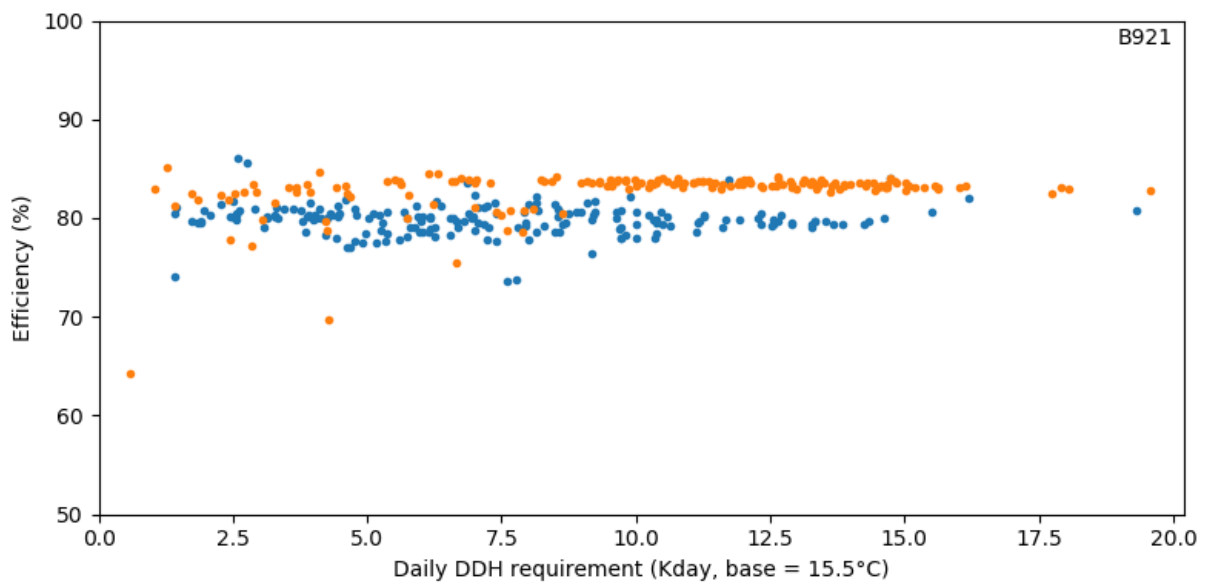
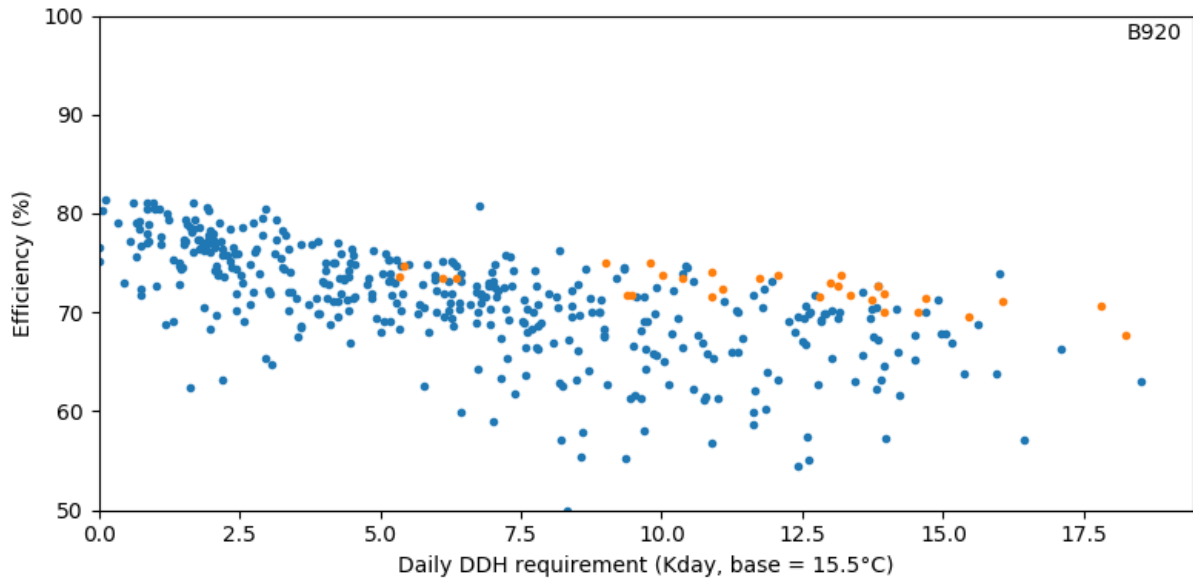












Kiwa Gastec

Kiwa Ltd, Kiwa House,
Malvern View Business Park,
Bishops Cleeve, Cheltenham,
GL52 7DQ, UK

Tel +44 (0)1242 677877
Email enquiries@kiwa.co.uk



www.kiwa.co.uk