PART 4 – RESULTS

4.1 Introduction

This section of the report is provided to summarize and interpret the main findings from the flux and cover material measurements conducted in the study. In addition, results are provided for the gas collection efficiency analysis conducted in the study. The results are organized into twelve main sections: i) aerial measurements for 16 landfills; ii) site-specific (intra-landfill) flux analysis for 5 landfills; iii) between site (inter-landfill) flux analysis for 5 landfills; iv) seasonal comparison of flux; v) whole-site landfill emissions; vi) geotechnical properties of cover systems; vii) correlations between flux and cover/landfill characteristics; viii) gas collection efficiency calculations; ix) effect of waste tires on LFG emissions; x) characterization of raw gas; xi) temperature conditions in covers; xii) additional static flux chamber analysis-radial distance, cover thickness, temporal variation, contaminated soil waste, wet waste placement.

The results related to the flux measurements are grouped into twelve distinct chemical families (Section 1.5) and data are presented mostly for these grouped chemicals in this part of the report. These twelve individual chemical families are: baseline greenhouse gases (i.e., methane, nitrous oxide, carbon dioxide, carbon monoxide) referred to as GHGs, reduced sulfur compounds (RSC), fluorinated gases (F-gas), halogenated hydrocarbons (HH), organic alkyl nitrates (ON), alkanes (Alk), alkenes (Alke), aldehydes/alkynes (Ald/Alky), aromatic hydrocarbons (Ar), monoterpenes (Mon), alcohols (Alc), and ketones (Ket).

A complete summary of the baseline site properties (including an overview of testing locations and weather conditions), raw concentration data, and flux data is provided in Appendix files C1, C2, and C3, respectively.

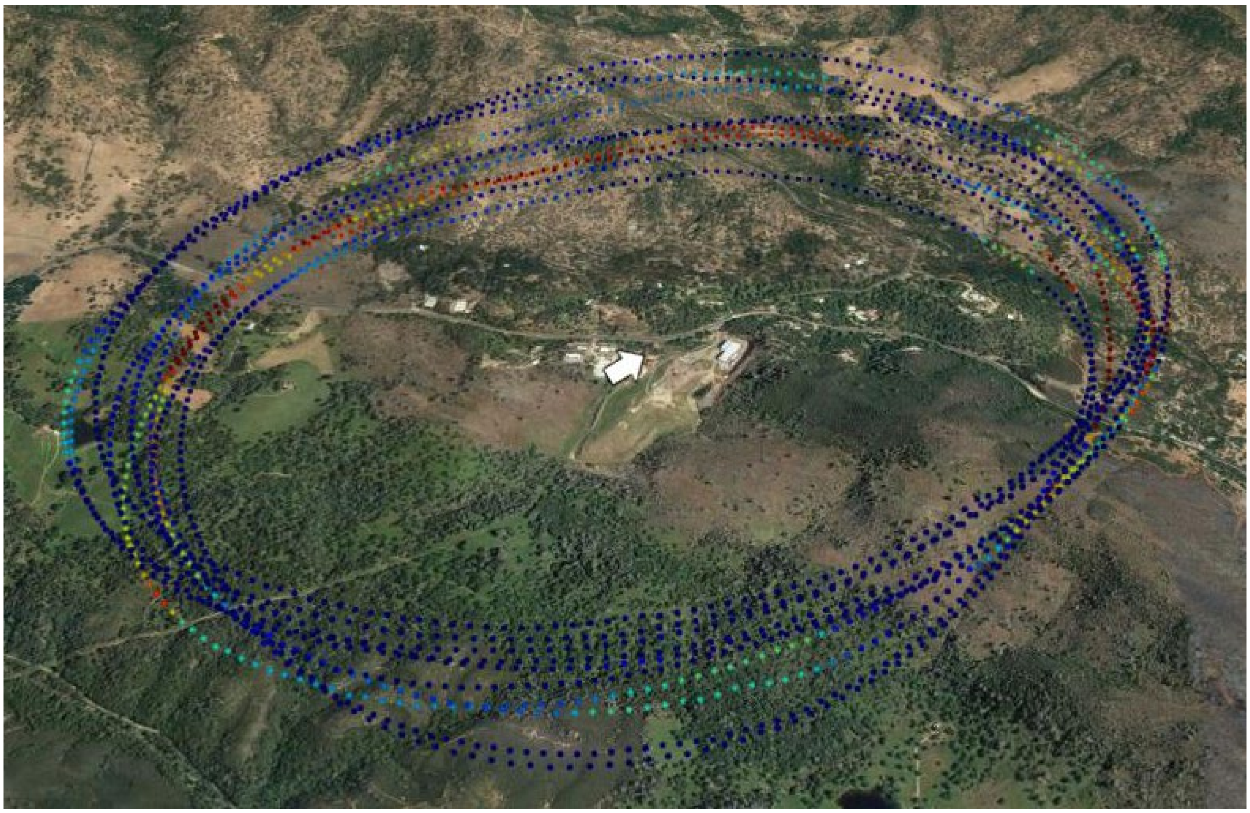
4.2 Aerial Measurements

The determination of landfill gas emissions from flyover surveys included testing at 16 different landfills. The test sites included the 15 landfills identified through the site selection process (Section 2.3) and one additional site – Sunshine Canyon Landfill. The Sunshine Canyon Landfill was included to provide direct comparison between similar nearby landfills (Chiquita Canyon Landfill and Sunshine Canyon Landfill) that differ in their operational practices for stripping intermediate covers prior to placing overlying waste (Chiquita Canyon Landfill strips intermediate cover whereas Sunshine Canyon does not strip intermediate covers). The descriptions of the aerial testing results are provided on a site-by-site basis in chronological order of the flights. A summary of the results is provided subsequent to the descriptions in Table 4.1. In all of the photos depicting the flight paths in Sections 4.2.1 through 4.2.23, the white arrows indicate the main wind direction. For the five small landfills, emissions were very low and below the detection limit of the aerial measurement system and for the sixth small landfill, the measurements were just over the detection limit. Emissions values are provided in Table 4.1 in the report for reference for the five small landfills even though the measurements were below detection limit based on the common calculation algorithm used in the test program.

4.2.1 Mariposa County Sanitary Landfill -- October 18, 2017

A total of 10 laps were flown around Mariposa County Sanitary Landfill as shown in Figure 4.1. The aircraft completed circles between 170 meters above ground level (AGL) and 495 meters AGL. Winds were out of the southwest, averaging 2.3 m s^{-1}, but changed substantially from the lower laps to the higher laps (direction of 240 at 150 m and 120 at 800 m). The wind variability resulted in a large uncertainty with the total methane emissions below the detection limit of the aerial measurement system for these conditions. The full flight path is presented in Figure 4.1.

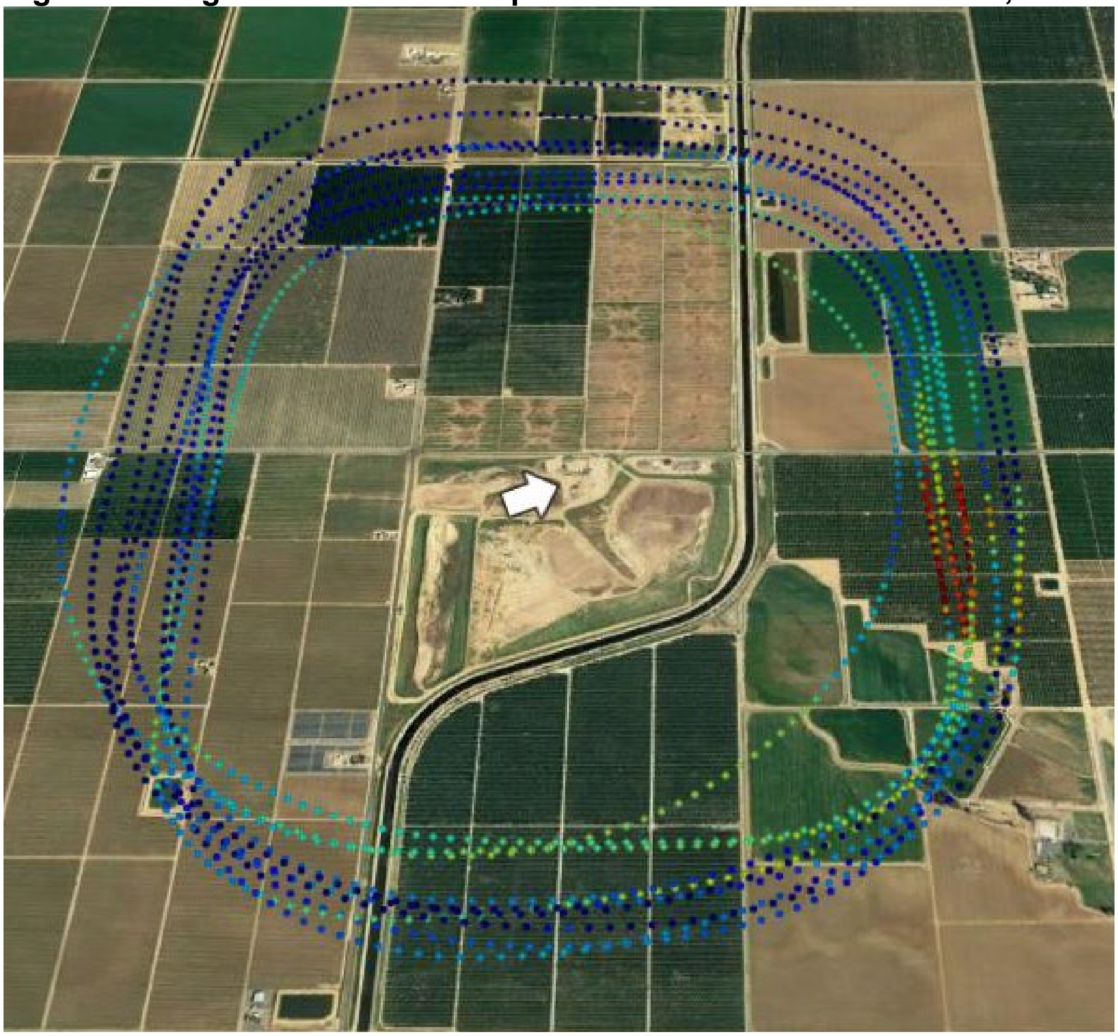
Figure 4.1 Flight Path around Mariposa County Sanitary Landfill on October 18, 2017



4.2.2 Teapot Dome Landfill -- October 18, 2017

A total of 10 laps were flown around Teapot Dome Landfill, as shown in Figure 4.2. The aircraft completed circles between 112 meters AGL and 435 meters AGL. Winds were out of the southwest, averaging 1.1 m s^{-1}. Total methane emission is estimated at 294 ± 100 kg hr^{-1}. The full flight path is presented in Figure 4.2.

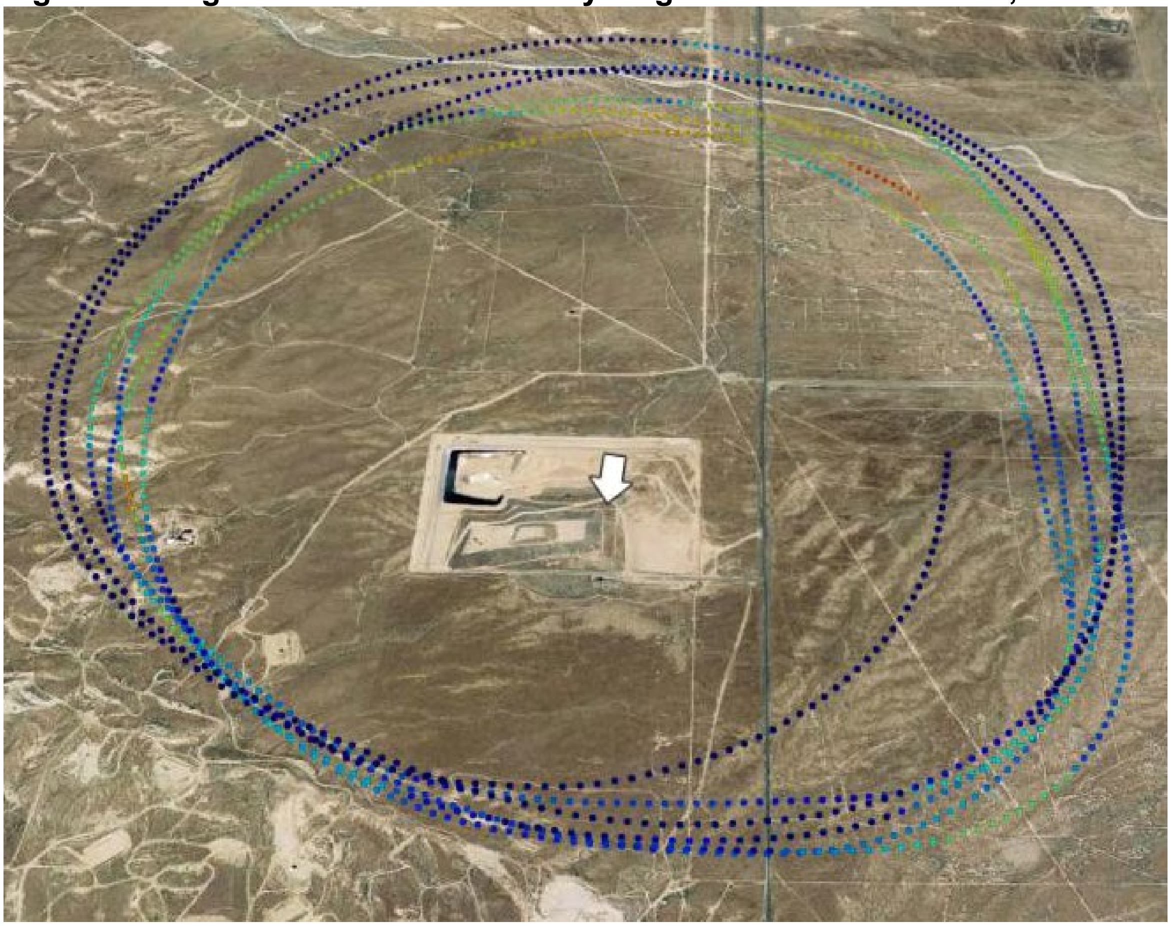
Figure 4.2 Flight Path around Teapot Dome Landfill on October 18, 2017



4.2.3 Taft Recycling Center -- October 18, 2017

A total of 6 laps (4 useable) were flown around Taft Recycling Center, as shown in Figure 4.3. The aircraft completed circles between 144 meters AGL and 543 meters AGL. Winds were out of the north, averaging 1.6 m s^{-1}. The total methane emission was below the detection limit of the aerial measurement system for these wind conditions (very low winds). This measurement was also complicated by the mountains on the downwind side (south) of the landfill. The full flight path is presented in Figure 4.3.

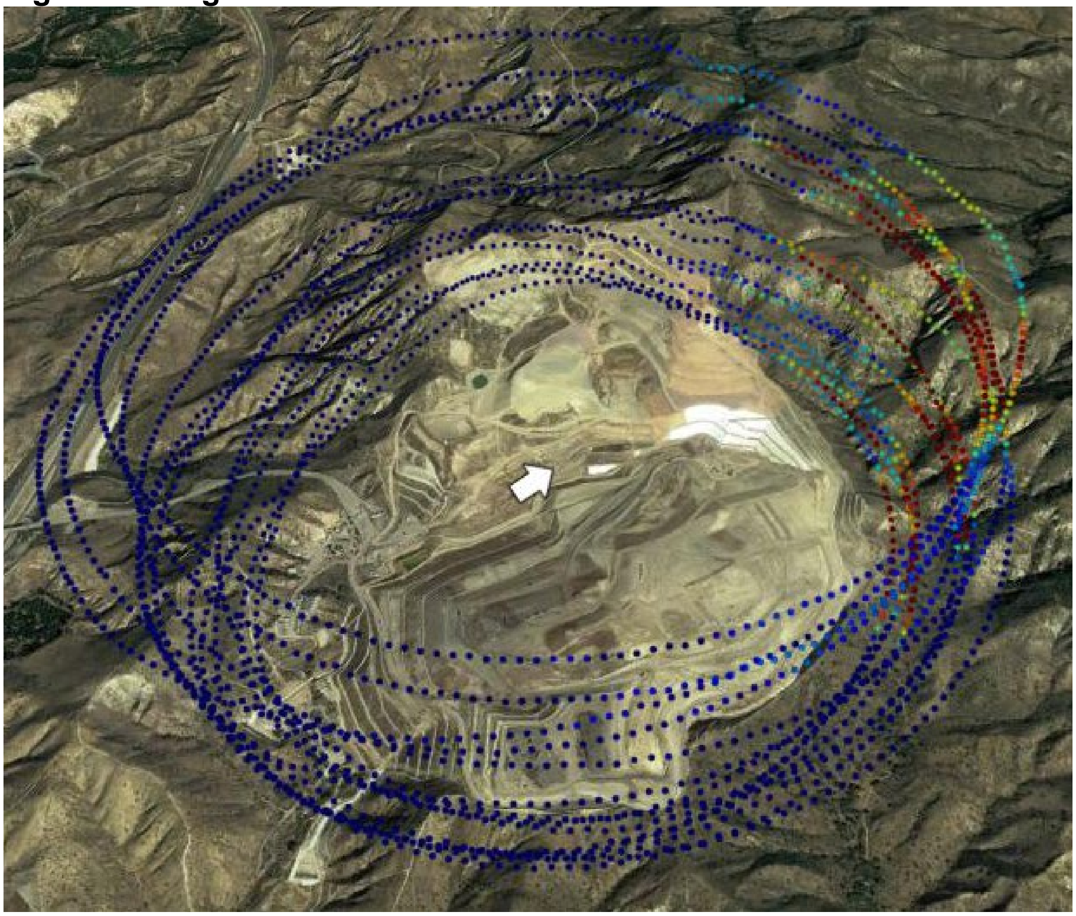
Figure 4.3 Flight Path around Taft Recycling Center on October 18, 2017



4.2.4 Frank R. Bowerman Sanitary Landfill -- November 10, 2017

A total of 16 laps (15 useable) were flown around the Frank R. Bowerman Sanitary Landfill, as shown in Figure 4.4. The aircraft completed circles between 80 meters AGL and 876 meters AGL. Winds were out of the southwest, averaging 1.7 m s^{-1}. Total methane emission is estimated at 3275 ± 669 kg hr^{-1}. The full flight path is presented in Figure 4.4.

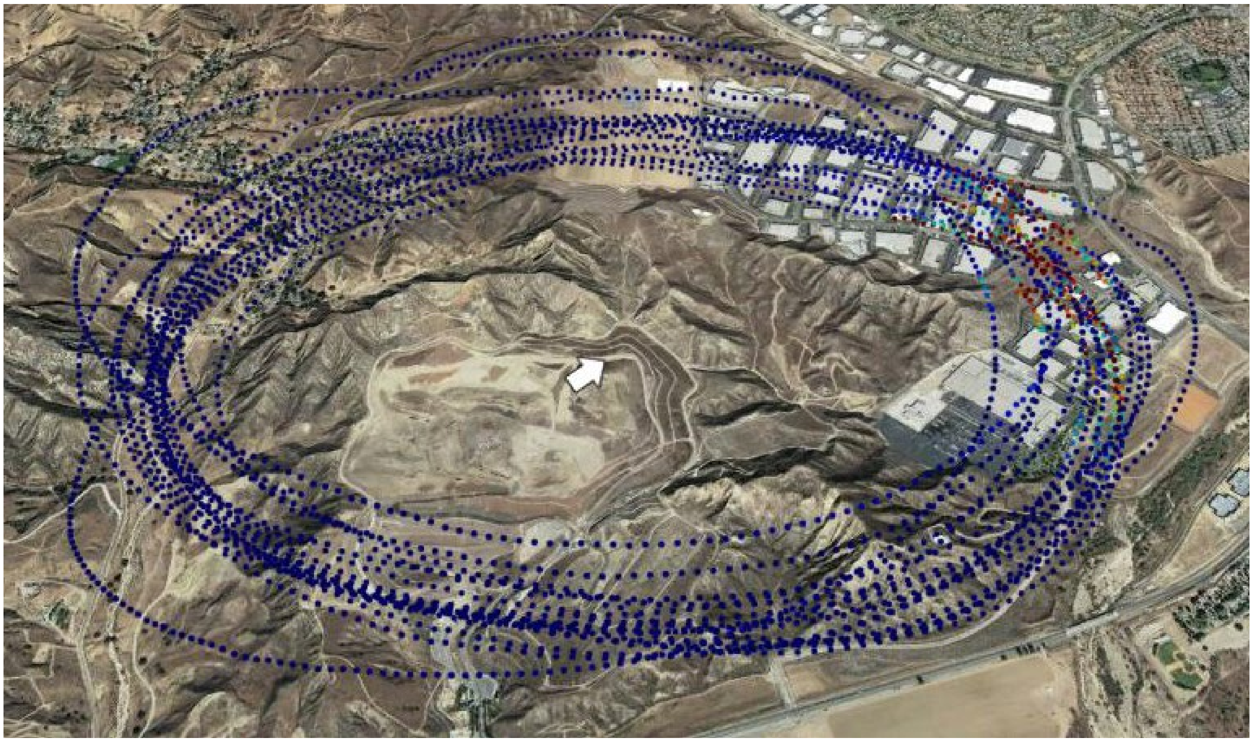
Figure 4.4 Flight Path around Frank R. Bowerman Landfill on November 10th, 2017



4.2.5 Chiquita Canyon Sanitary Landfill -- November 10, 2017

A total of 17 laps (15 useable) were flown around Chiquita Canyon Sanitary Landfill, as shown in Figure 4.5. The aircraft completed circles between 167 meters AGL and 475 meters AGL. Winds were out of the southwest, averaging 4.9 m s^{-1}. Total methane emission is estimated at 1306 ± 207 kg hr^{-1}. The full flight path is presented in Figure 4.5.

Figure 4.5 Flight Path around Chiquita Canyon Sanitary Landfill on November 10, 2017

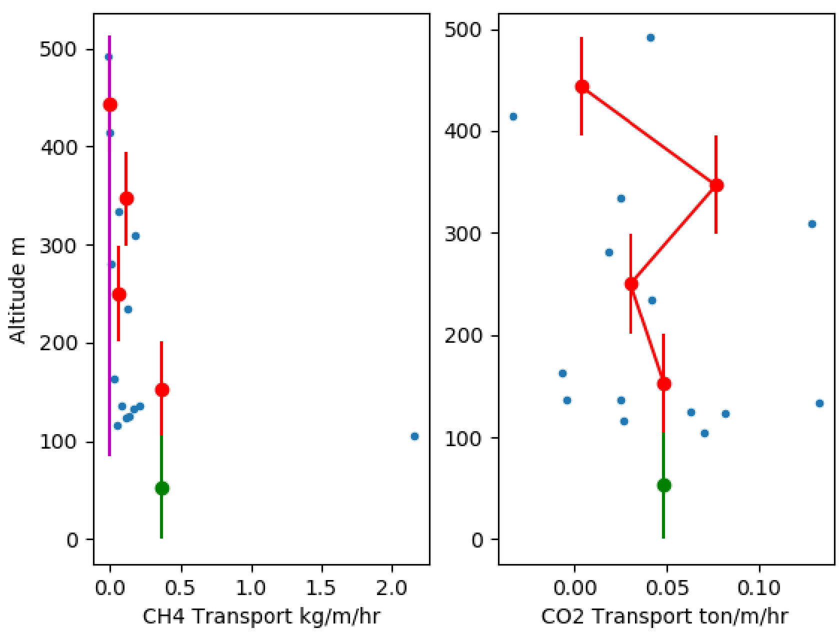


4.2.6 Santa Maria Regional Landfill -- November 10, 2017

A total of 18 laps (14 useable) were flown around Santa Maria Regional Landfill, as shown in Figure 4.6. The aircraft completed circles between 105 meters AGL and 491 meters AGL. Winds were out of the west/northwest, averaging 10.4 m s^{-1}. Total methane emission is estimated at 90 ± 39 kg hr^{-1}. The largest enhancement was seen on the lowest leg, and that enhancement was several times more than the next largest enhancement. This implies that the estimate of 90 kg hr^{-1} methane emitted is most likely an underestimate of the true emissions- due to the high wind speeds, it is possible emissions below the lowest flight altitude were not captured. The full flight path is presented in Figure 4.6. A profile of flux with elevation is presented in Figure 4.7.

Figure 4.6 Flight Path around Santa Maria Regional Landfill on November 10, 2017

Figure 4.7 Flux Profile of Santa Maria Regional Landfill



4.2.7 Redwood Landfill -- November 17, 2017

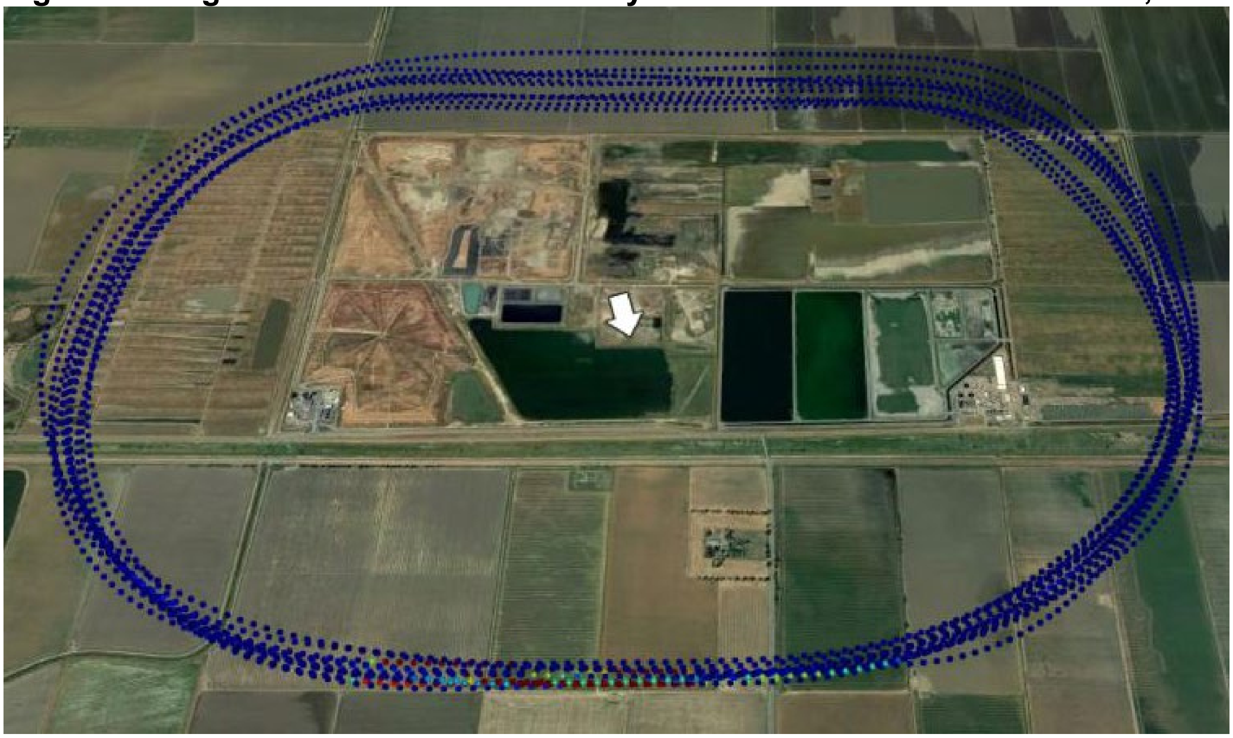
A total of 8 laps were flown around Redwood Landfill, as shown in Figure 4.8. The aircraft completed circles between 64 meters AGL and 208 meters AGL. Winds were out of the north, averaging 4.8 m s^{-1}. Total methane emission is estimated at 140 ± 42 kg hr^{-1}. The full flight path is presented in Figure 4.8.

Figure 4.8 Flight Path around Redwood Landfill on November 17, 2017

4.2.8 Yolo County Central Landfill -- November 17, 2017

A total of 11 laps were flown around Yolo County Central Landfill, as shown in Figure 4.9. The aircraft completed circles between 61 meters AGL and 306 meters AGL. Winds were out of the north/northwest, averaging 7.4 m s^{-1}. Total methane emission is estimated at 376 ± 68 kg hr^{-1}. The full flight path is presented in Figure 4.9.

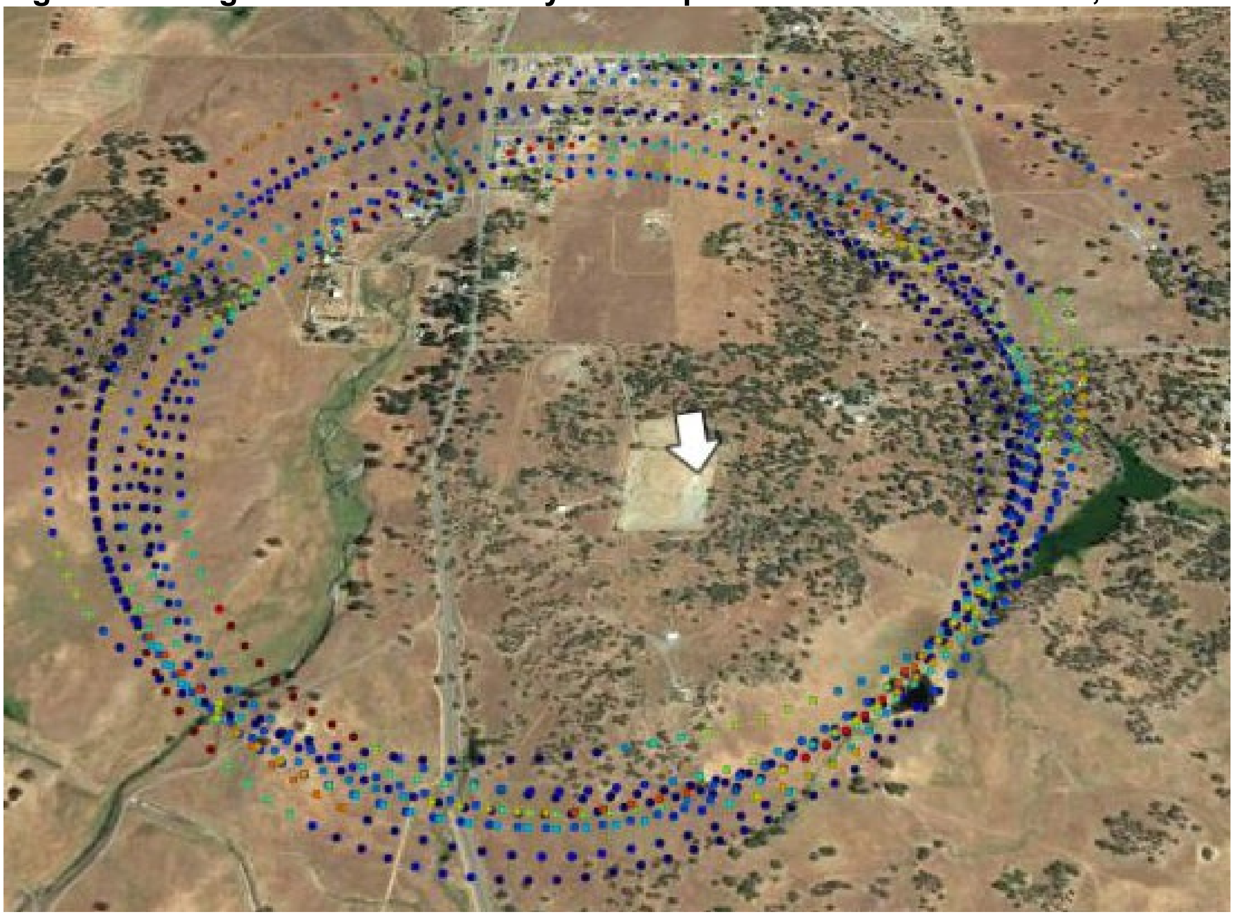
Figure 4.9 Flight Path around Yolo County Central Landfill on November 17, 2017



4.2.9 Stonyford Disposal Site -- November 17, 2017

A total of 11 laps were flown around the Stonyford Disposal Site, as shown in Figure 4.10. The aircraft completed circles between 62 meters AGL and 334 meters AGL. Winds were out of the north, averaging 4.4 m s^{-1}. No significant downwind enhancements were observed, and the total methane emission was below the detection limit of the aerial measurement system. The full flight path is presented in Figure 4.10.

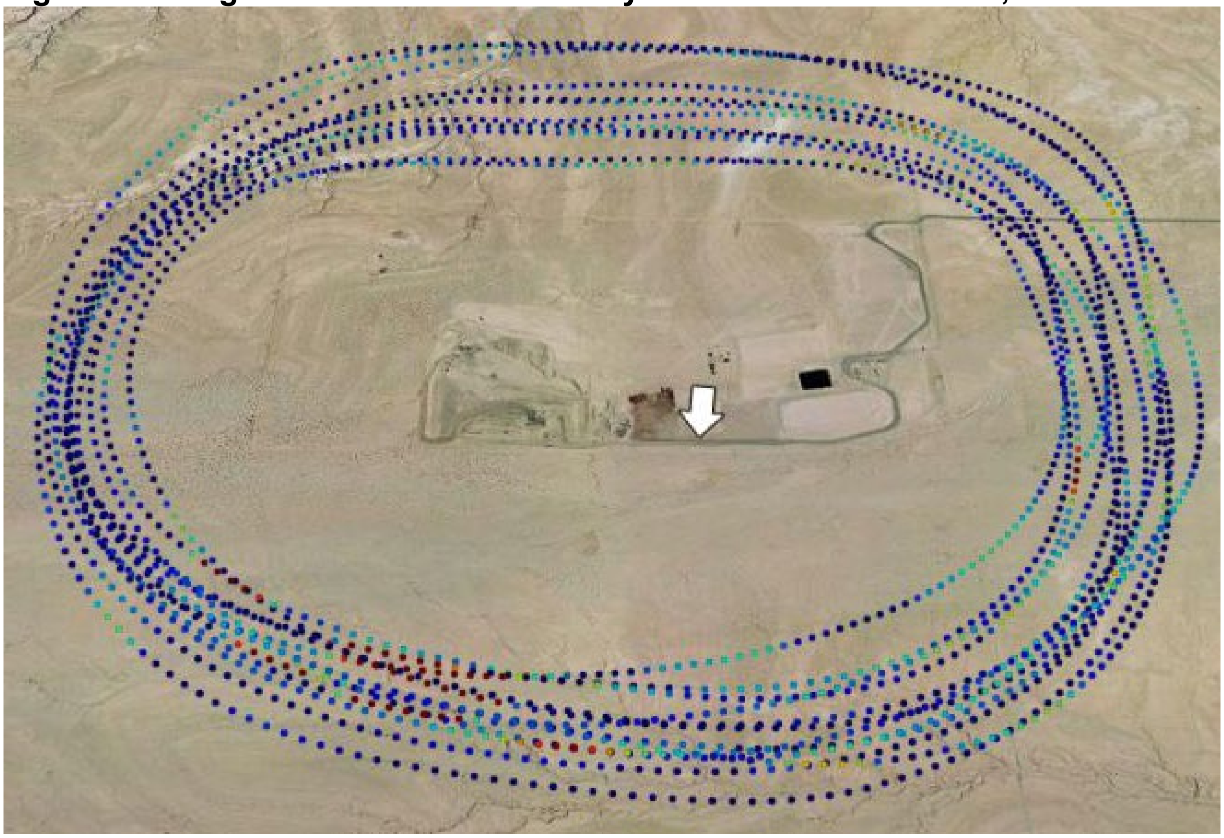
Figure 4.10 Flight Path around Stonyford Disposal Site on November 17, 2017



4.2.10 Salton City Landfill -- December 4, 2017

A total of 12 useable laps were flown around the Salton City Landfill, as shown in Figure 4.11. The aircraft completed circles between 46 meters AGL and 305 meters AGL. Winds were out of the north, averaging 9.6 m s^{-1}. Total methane emission is estimated at 11 ± 3 kg hr^{-1}. The full flight path is presented in Figure 4.11.

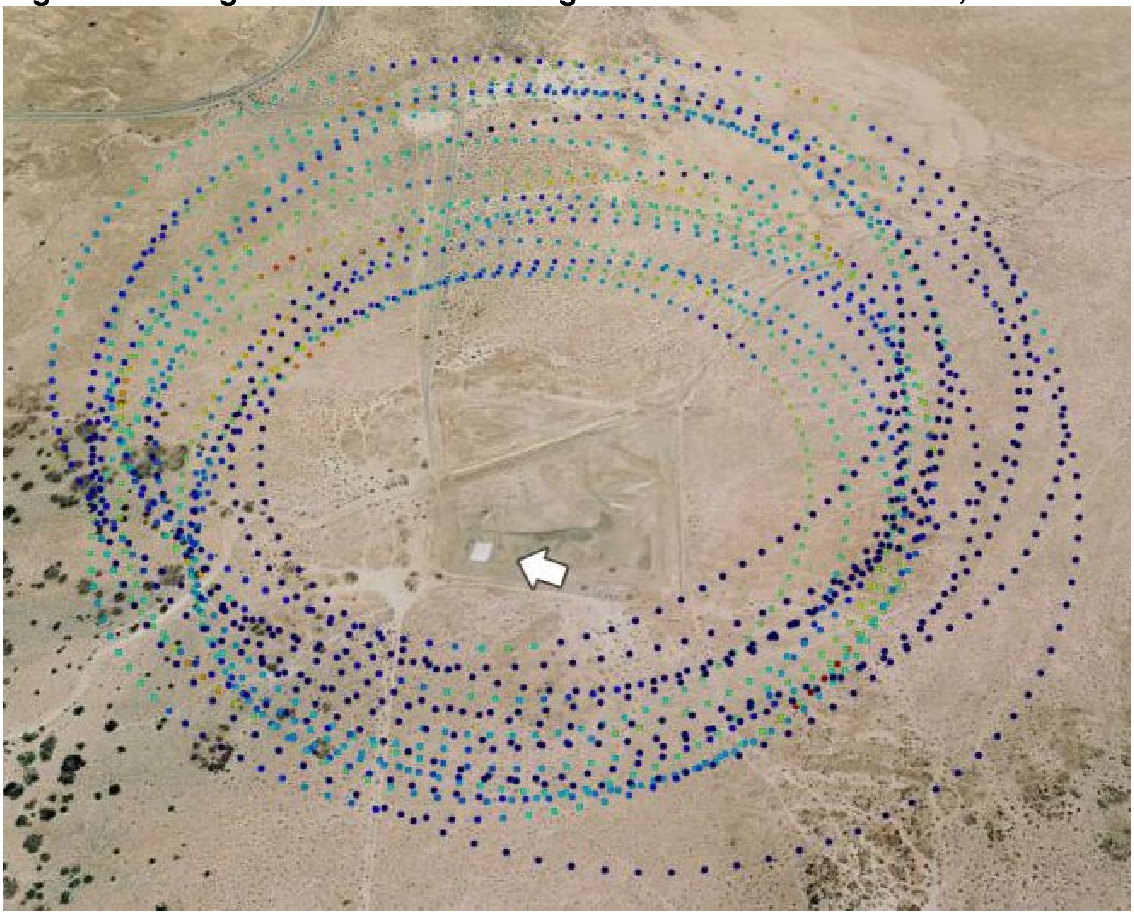
Figure 4.11 Flight Path around Salton City Landfill on December 4, 2017



4.2.11 Borrego Landfill -- December 4, 2017

A total of 17 useable laps were flown around Borrego Landfill, as shown on Figure 4.12. The aircraft completed circles between 48 meters AGL and 458 meters AGL. Winds were out of the east/southeast, averaging 2.1 m s^{-1}. Total methane emission was below the detection limit of the aerial measurement system. The full flight path is presented in Figure 4.12.

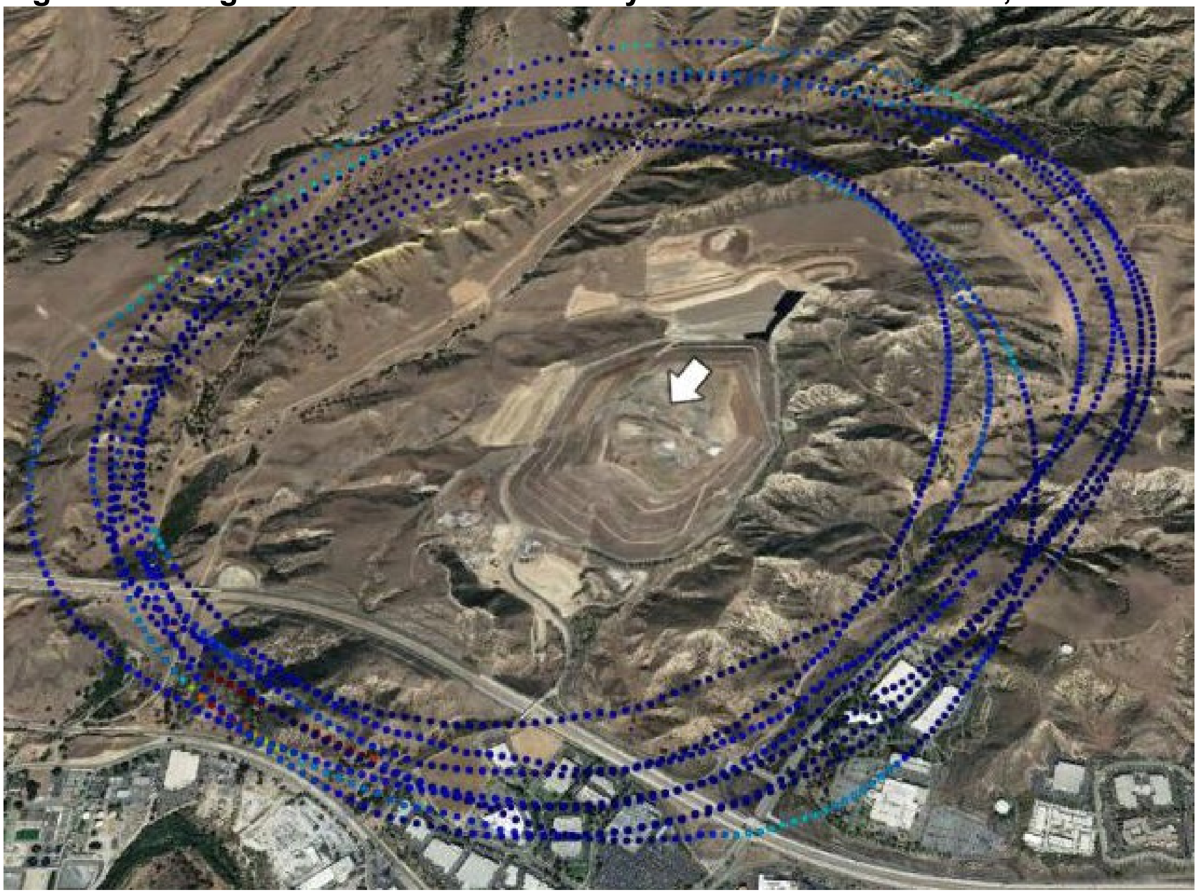
Figure 4.12 Flight Path around Borrego Landfill on December 4, 2017



4.2.12 Simi Valley Landfill -- December 4, 2017

A total of 9 laps (8 useable) were flown around Simi Valley Landfill, as shown in Figure 4.13. The aircraft completed circles between 264 meters AGL and 518 meters AGL. Winds were out of the northeast, averaging 16.2 m s^{-1}. Total methane emission is estimated at 638 ± 337 kg hr^{-1}. The full flight path is presented in Figure 4.13.

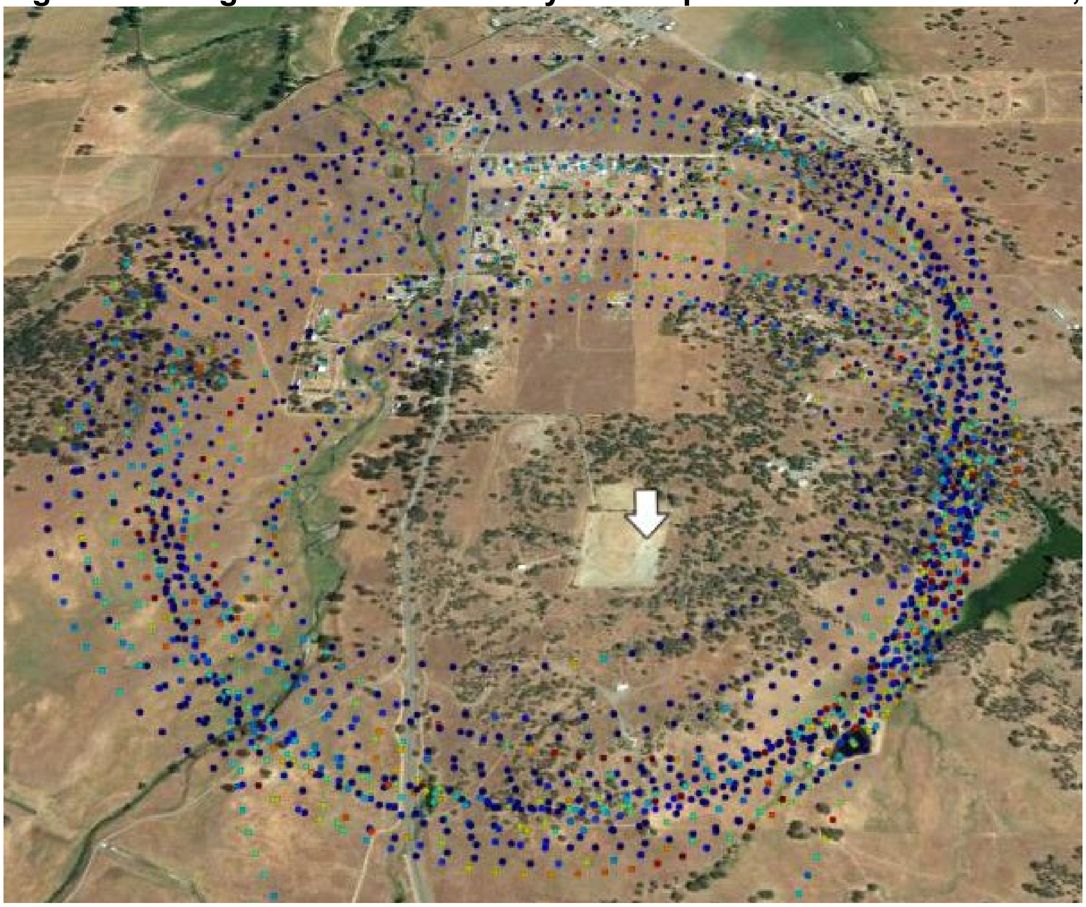
Figure 4.13 Flight Path around Simi Valley Landfill on December 4, 2017



4.2.13 Stonyford Disposal Site -- December 6, 2017

A total of 20 useable laps were flown around Stonyford Disposal Site, as shown in Figure 4.14. The aircraft completed circles between 61 meters AGL and 620 meters AGL. Winds were out of the north, at 9.6 m s^{-1}. Total methane emission is estimated at 6 ± 1 kg hr^{-1}, which is below the detection limit of 10 kg hr^{-1}. The full flight path is presented in Figure 4.14.

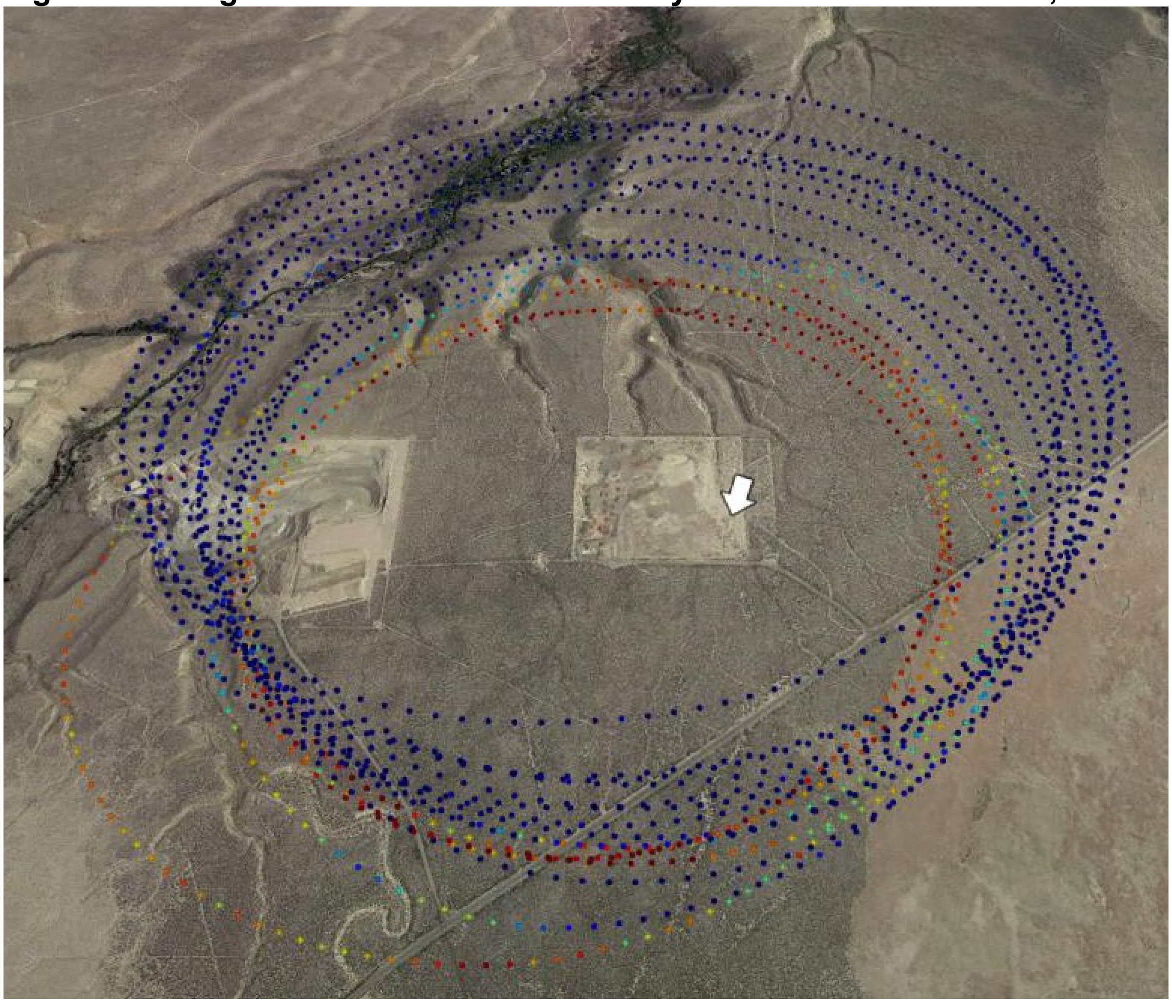
Figure 4.14 Flight Path around Stonyford Disposal Site on December 6, 2017



4.2.14 Pumice Valley Landfill -- December 6, 2017

A total of 16 useable laps were flown around Pumice Valley Landfill, as shown in Figure 4.15. The aircraft completed circles between 37 meters AGL and 620 meters AGL. Winds were out of the north/northeast, averaging 2 m s^{-1}. Total methane emission was below the detection limit of the aerial measurement system. The full flight path is presented in Figure 4.15.

Figure 4.15 Flight Path around Pumice Valley Landfill on December 6, 2017



4.2.15 Site A -- December 7, 2017

A total of 11 useable laps were flown around Site A Landfill, as shown in Figure 4.16. The aircraft completed circles between 122 meters AGL and 409 meters AGL. Winds were out of the east, averaging 3.4m s^{-1}. Total methane emission is estimated at 1358 ± 547 kg hr^{-1}. The full flight path is presented in Figure 4.16. A profile of flux with elevation is presented in Figure 4.17.

Figure 4.16 Flight Path around Site A on December 7, 2017

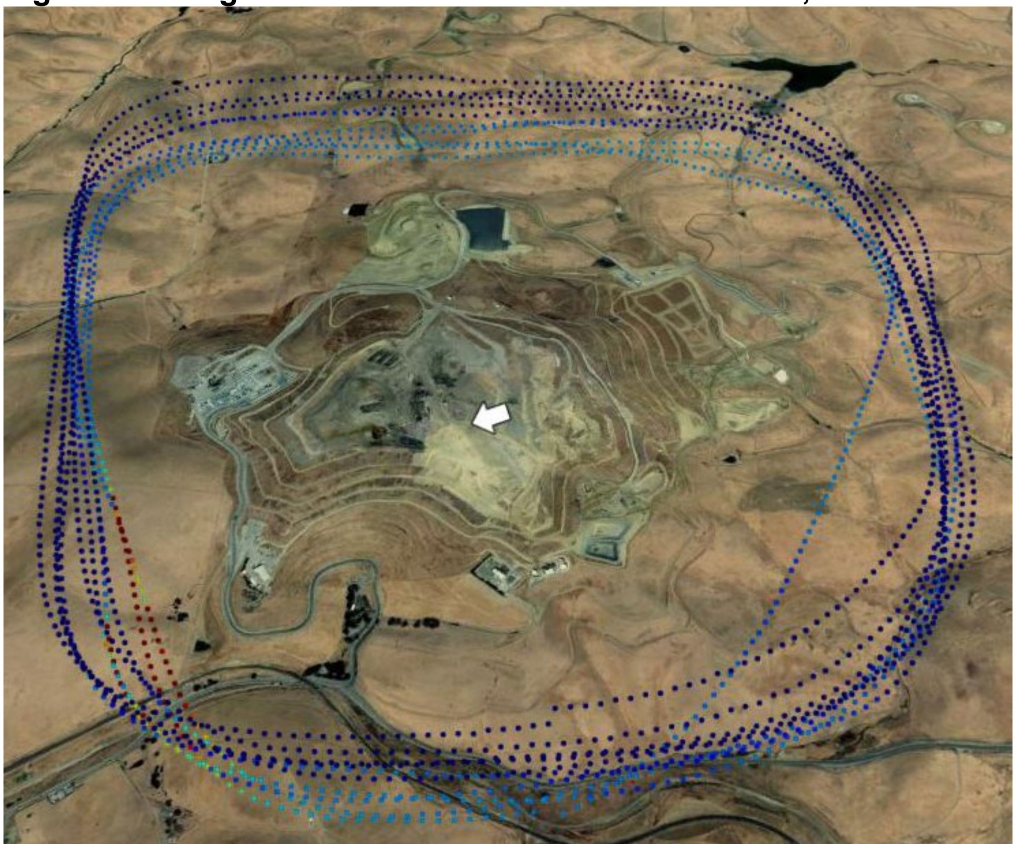
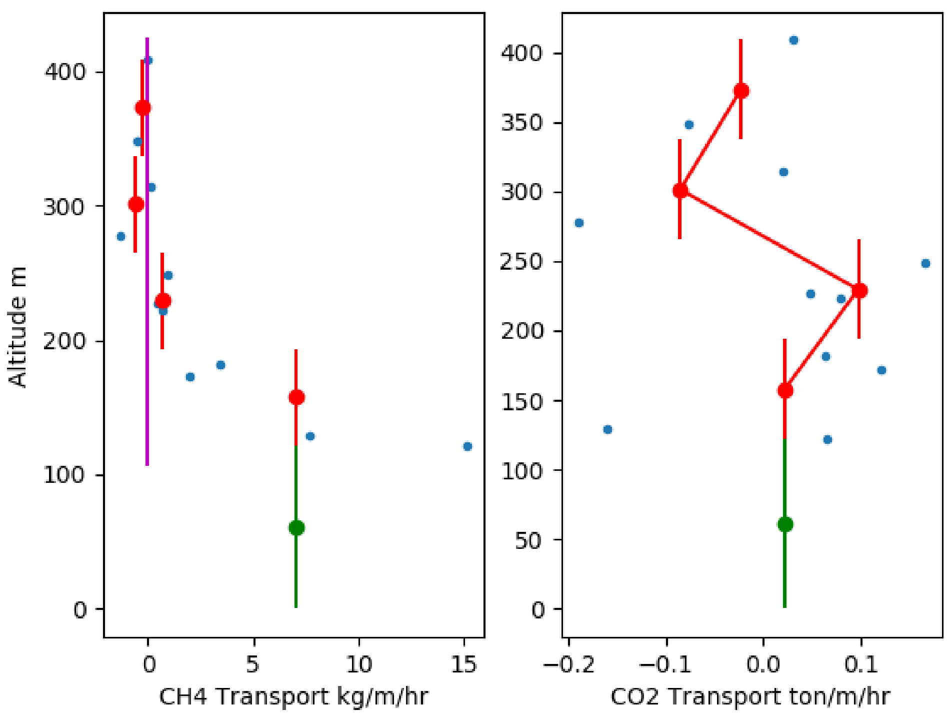


Figure 4.17 Flux Profile of Site A



4.2.16 Potrero Hills Landfill -- December 7, 2017

At total of 12 useable laps were flown around Potrero Hills Landfill, as shown in Figure 4.18. The aircraft completed circles between 59 meters AGL and 364 meters AGL. Winds were out of the northeast, averaging 8.6 m s^{-1}. Total methane emission is estimated at 2004 ± 417 kg hr^{-1}. The full flight path is presented in Figure 4.18. A profile of flux with elevation is presented in Figure 4.19.

Figure 4.18 Flight Path around Potrero Hills Landfill on December 7, 2017

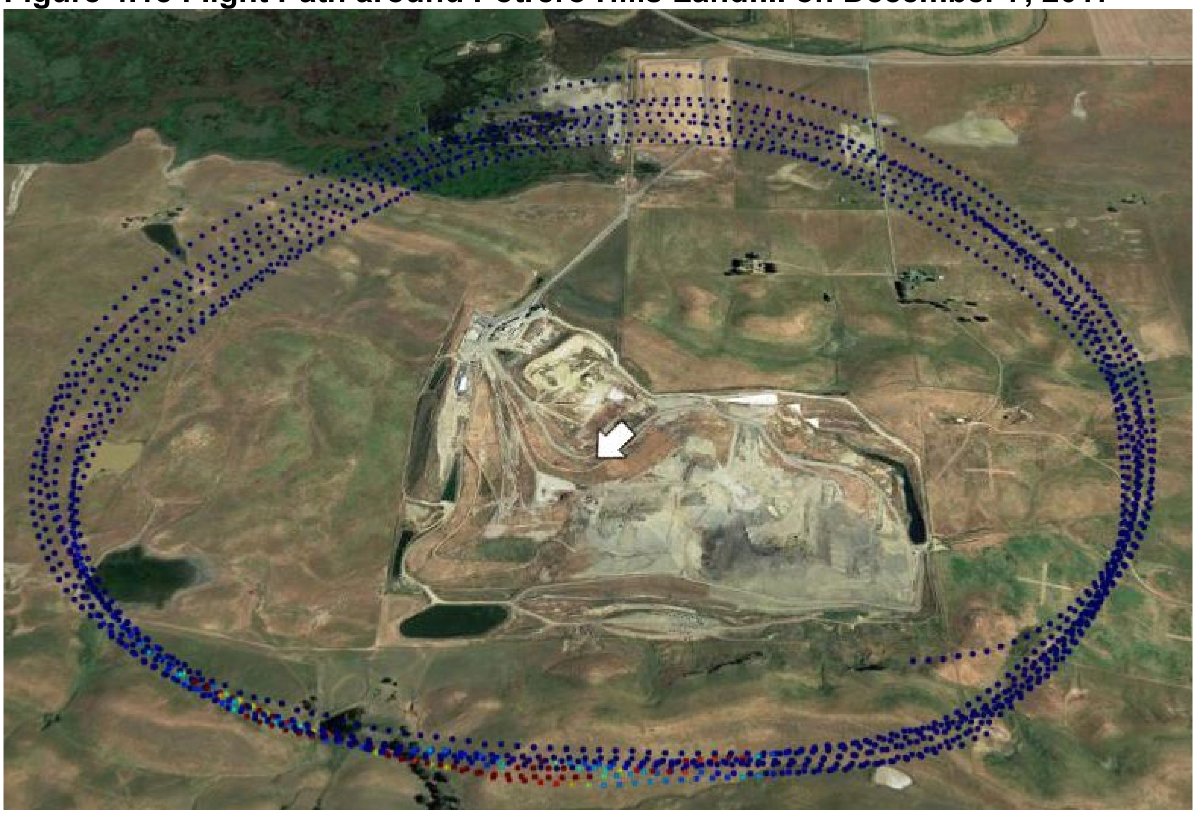
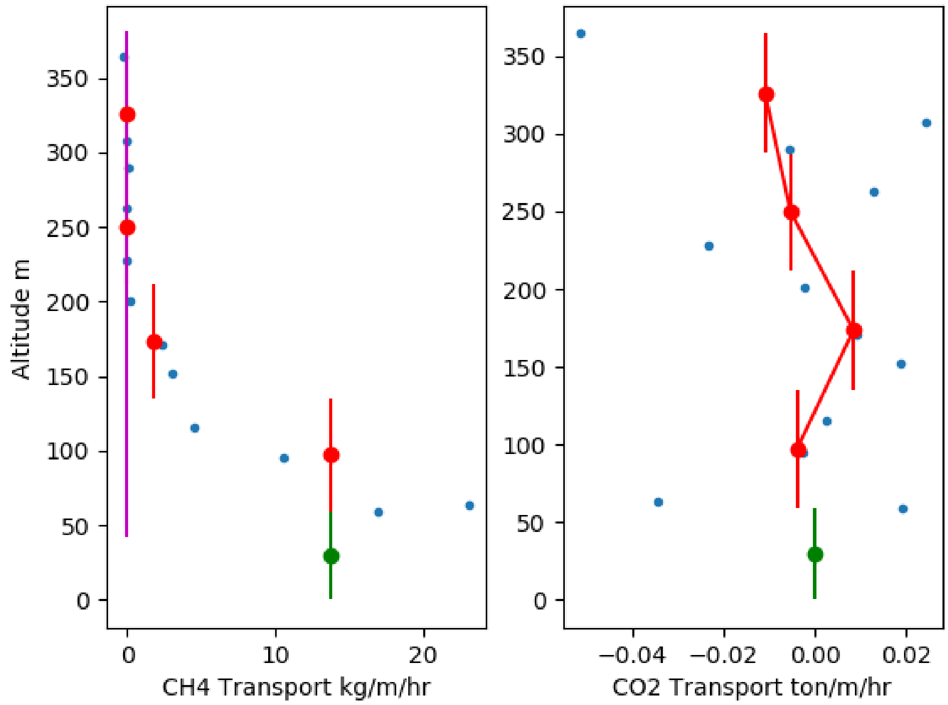


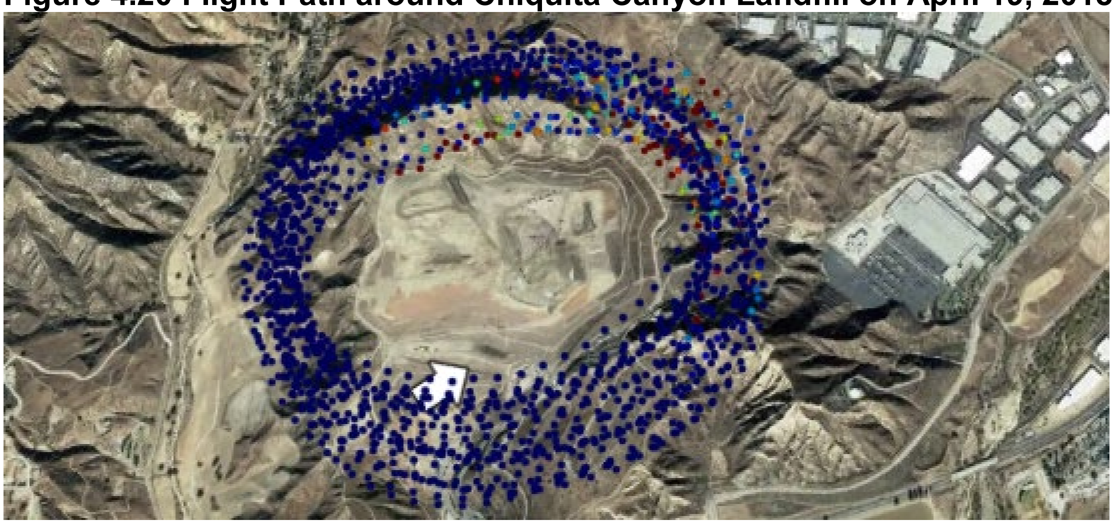
Figure 4.19 Flux Profile of Potrero Hills Landfill



4.2.17 Chiquita Canyon Sanitary Landfill -- April 19, 2018

Twenty-seven laps were flown around the site at altitudes between 81 and 589 meters AGL (Figure 4.20). Winds were from the southwest at 5 m s^{-1}. Total methane emission is estimated at 602 ± 79 kg hr^{-1}. The full flight path is presented in Figure 4.20.

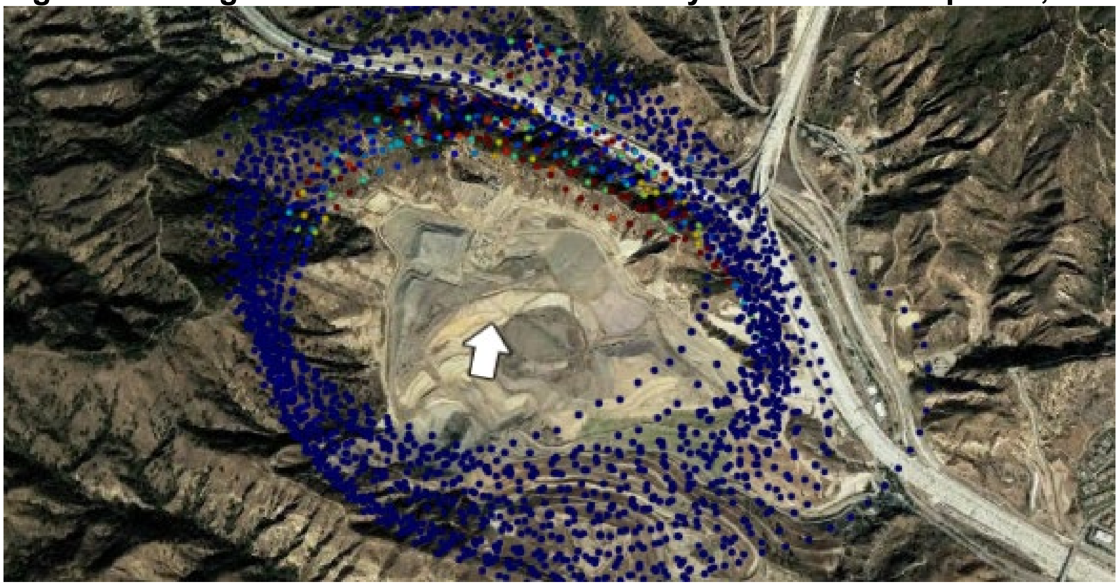
Figure 4.20 Flight Path around Chiquita Canyon Landfill on April 19, 2018



4.2.18 Sunshine Canyon Landfill -- April 19, 2018

A total of 28 laps were flown around Sunshine Canyon at altitudes of 81 to 871 meters AGL (Figure 4.21). Winds were from the south at 3.5 m s^{-1}. Total methane emission is estimated at 719 ± 155 kg hr^{-1}. The full flight path is presented in Figure 4.21.

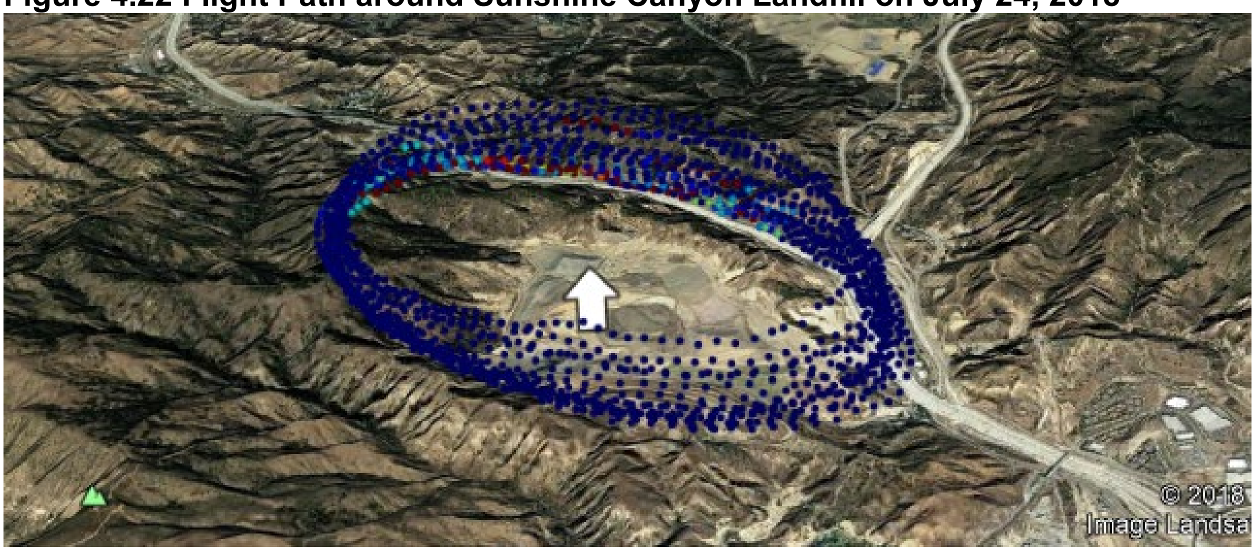
Figure 4.21 Flight Path around Sunshine Canyon Landfill on April 19, 2018



4.2.19 Sunshine Canyon Landfill -- July 24, 2018

Sixteen laps were flown around Sunshine Canyon at altitudes of 108 to 512 meters AGL (Figure 4.22). Winds were from the south at 4.9 m s^{-1}. Total methane emission is estimated at 712 ± 114 kg hr^{-1}. The full flight path is presented in Figure 4.22.

Figure 4.22 Flight Path around Sunshine Canyon Landfill on July 24, 2018



4.2.20 Chiquita Canyon Sanitary Landfill -- July 24, 2018

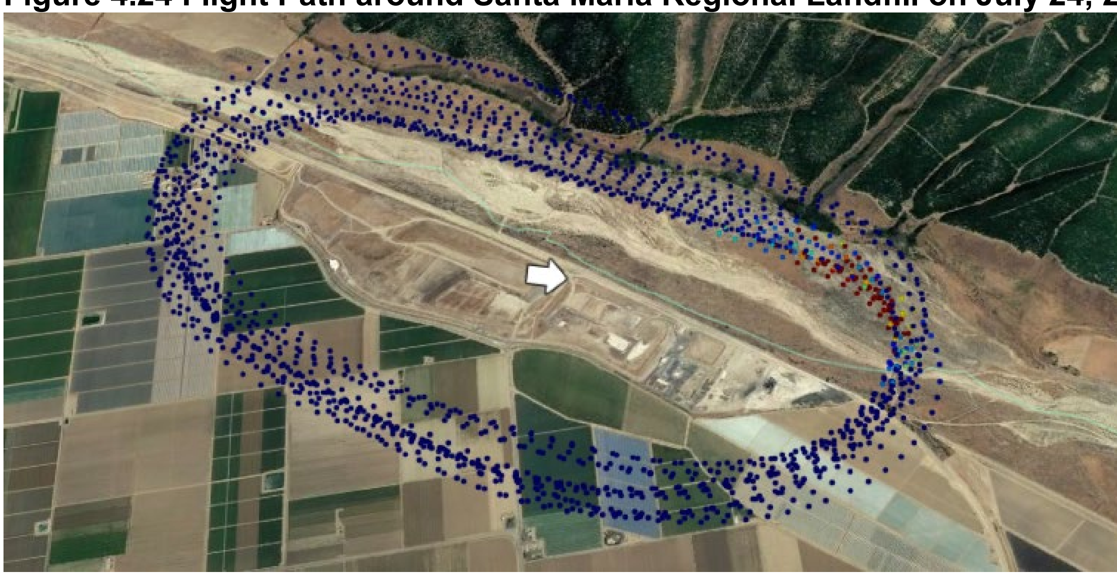
Seventeen laps were flown around Chiquita Canyon Landfill at altitudes of 166 to 617 meters AGL (Figure 4.23). Winds were from the southwest at 6.8 m s^{-1}. Total methane emission is estimated at 734 ± 128 kg hr^{-1}. The full flight path is presented in Figure 4.23.

Figure 4.23 Flight Path around Chiquita Canyon Landfill on July 24, 2018

4.2.21 Santa Maria Regional Landfill -- July 24, 2018

Seventeen laps were flown around Santa Maria Regional Landfill at altitudes of 61 to 374 meters AGL (Figure 4.24). Winds were from the west at 4.0 m s^{-1}. Total methane emission is estimated at 312±77 kg hr^{-1}. The full flight path is presented in Figure 4.24.

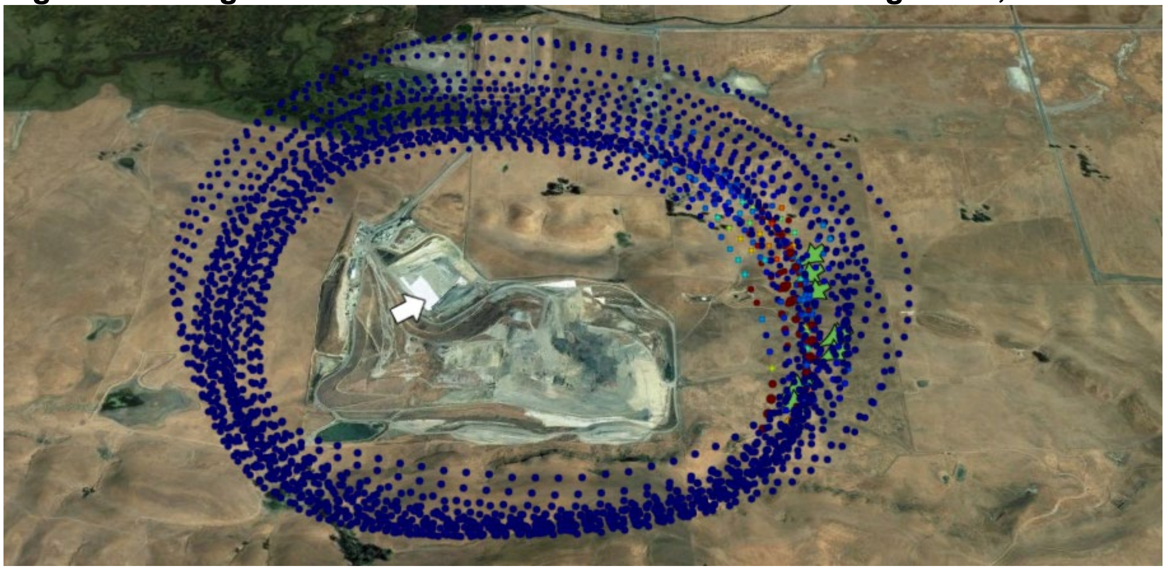
Figure 4.24 Flight Path around Santa Maria Regional Landfill on July 24, 2018



4.2.22 Potrero Hills Landfill -- August 23, 2018

Fourteen useable laps were flown around Potrero Hills Landfill at altitudes of 81 to 459 meters AGL (Figure 4.25). Winds were from the west/southwest at 8.7 m s^{-1}. Total methane emission is estimated at 1718 ± 252 kg hr^{-1}. The full flight path is presented in Figure 4.25.

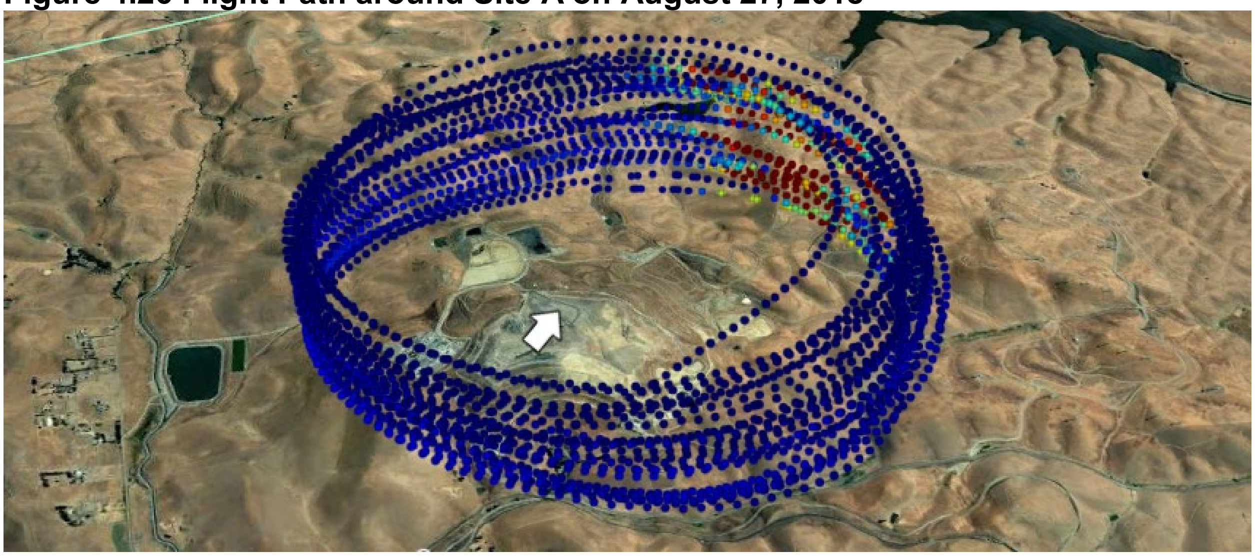
Figure 4.25 Flight Path around Potrero Hills Landfill on August 23, 2018



4.2.23 Site A -- August 27, 2018

Twenty-six laps were flown around Site A at altitudes of 111 to 843 meters AGL (Figure 4.26). Winds were from the southwest at 3.9 m/s. Total methane emission is estimated at 2077 ± 240 kg/hr. The flight path is presented in Figure 4.26.

Figure 4.26 Flight Path around Site A on August 27, 2018



4.2.24 Teapot Dome Landfill – January 11, 2020

Fourteen laps were flown around Teapot Dome Landfill at altitudes of 117 to 424 meters AGL (Figure 4.27). Winds were from the west at 2.3 m/s. Total methane emission is estimated at 283.8 ± 131.5 kg/hr. The flight path is presented in Figure 4.27.

Figure 4.27 Flight Path around Teapot Dome Landfill on January 11, 2020

4.2.25 Summary of Aerial Measurements

A summary of the aerial measurements is presented for each landfill in ascending order in terms of waste in place and time (Table 4.1). The methane emissions increased from small to medium to large landfills where the emissions from the small, medium, and large landfills varied from -25 to 11, 90 to 638, and 602 to 3275 kg/hr, respectively. The methane emissions from the large landfills were more than one to more than two orders of magnitude higher than the emissions from the small landfills, whereas the differences between the medium and large landfills were within the same order of magnitude. While the tested small landfills did not have active gas collection and removal systems, the small size including the low waste in place and low daily throughput at these sites did not lead to generation/emission of methane. The medium and large landfills had gas collection and removal systems, yet the high waste in place and high throughput at these sites resulted in high gas generation and emissions.

The methane emissions from the two large nearby landfills, Chiquita Landfill and Sunshine Canyon Landfill, were relatively similar on the measurement days: 602 kg/hr-Chiquita and 719 kg/hr-Sunshine Canyon (4/19/2018) and 734 kg/hr-Chiquita and 712 kg/hr-Sunshine Canyon (7/24/2018). For the three large sites that were also included in the ground-based static flux chamber measurements, consistent differences were not observed between the dry and wet season measurements. At Chiquita Canyon and Potrero Hills Landfills, dry season measurements were lower than wet season measurements, whereas at Site A, the dry season measurement was higher than the wet season measurement. The highest differences between the dry and wet seasons were for Site A.

Table 4.1 – Summary of Aerial Test Results

Site	Date	CH_4 Emission (kg/hr)	UC[1] (kg/hr)	Ethane Emission (kg/hr)	UC[1] (kg/hr)	Laps	Wind Direction	Wind Speed (m/s)	Lowest Altitude (m)	Highest Altitude (m)
Stonyford Disposal Site	11/17/17	0.6	0.7	0	0	11	354	4.4	62	334
Stonyford Disposal Site	12/6/17	6.1	1.4	2.4	14.1	20	359	9.6	61	620
Salton City LF	12/4/17	10.8	3	0	0	12	5	9.6	46	305
Borrego LF	12/4/17	4.1	1.2	0	0	17	109	2.1	48	458
Pumice Valley Landfill	12/6/17	-0.2	1.7	1.6	2.6	16	18	2	37	620
Mariposa County LF	10/18/17	9	14.7	0	0	10	239	2.3	171	495
Taft Recycling Center	10/18/17	-24.6	32.8	0	0	4	9	1.6	144	543
Teapot Dome LF	10/18/17	293.7	99.9	0	0	10	250	1.1	112	435
Teapot Dome LF	1/11/20	283.8	131.5	0	0	14	278	2.3	117	424
Santa Maria Regional LF	11/10/17	90.1	39.1	14	15.5	14	289	10.4	105	491
Santa Maria Reginal LF	7/24/18	312	77.1	0	0	17	288	4	61	374
Redwood Landfill	11/17/17	139.8	41.5	0	0	8	12	4.8	64	208
Simi Valley LF	12/4/17	637.7	337.2	0	0	8	39	16.2	264	518
Yolo County Central Landfill	11/17/17	375.6	68.4	0	0	11	344	7.4	61	306
Chiquita Canyon LF	11/10/17	1306.4	207.2	6.1	51.1	15	236	4.9	167	475

Site	Date	CH_4 Emission (kg/hr)	UC[1] (kg/hr)	Ethane Emission (kg/hr)	UC[1] (kg/hr)	Laps	Wind Direction	Wind Speed (m/s)	Lowest Altitude (m)	Highest Altitude (m)
Chiquita Canyon LF	4/19/18	601.9	79.4	2.3	8.5	27	236	5	81	589
Chiquita Canyon LF	7/24/18	733.8	128.4	0	0	17	234	6.8	166	617
Sunshine Canyon LF	4/19/18	718.5	155.4	-5	10.4	28	194	3.5	81	871
Sunshine Canyon LF	7/24/18	712	113.6	0	0	16	177	4.9	108	512
Site A	12/7/17	1357.6	547	-0.8	6.3	11	77	3.4	122	409
Site A	8/27/18	2076.7	239.7	0	0	26	233	3.9	111	843
Frank R Bowerman LF	11/10/17	3275.4	668.5	3.3	9.3	15	234	1.7	80	876
Potrero Hills LF	12/7/17	2004.2	416.6	2.9	8.6	12	40	8.6	59	364
Potrero Hills LF	8/23/18	1717.9	251.6	0	0	14	245	8.7	81	459

[1]Uncertainty

4.3 Static Flux Chamber Measurements – Intra-Landfill Variations

Initially, surface fluxes are presented individually for each of the 5 landfills included in the static flux chamber field campaigns. Results are presented for the two measurement seasons: dry and wet seasons. Variations in flux due to cover locations/types and chemical species are provided. Results are organized from the smallest to largest landfill site tested in terms of waste in place and this order is used throughout the report. Results obtained for the dry season testing campaigns are presented first, followed by the wet season testing campaigns. Results are presented in box plots, which include all of the data obtained in the test program.

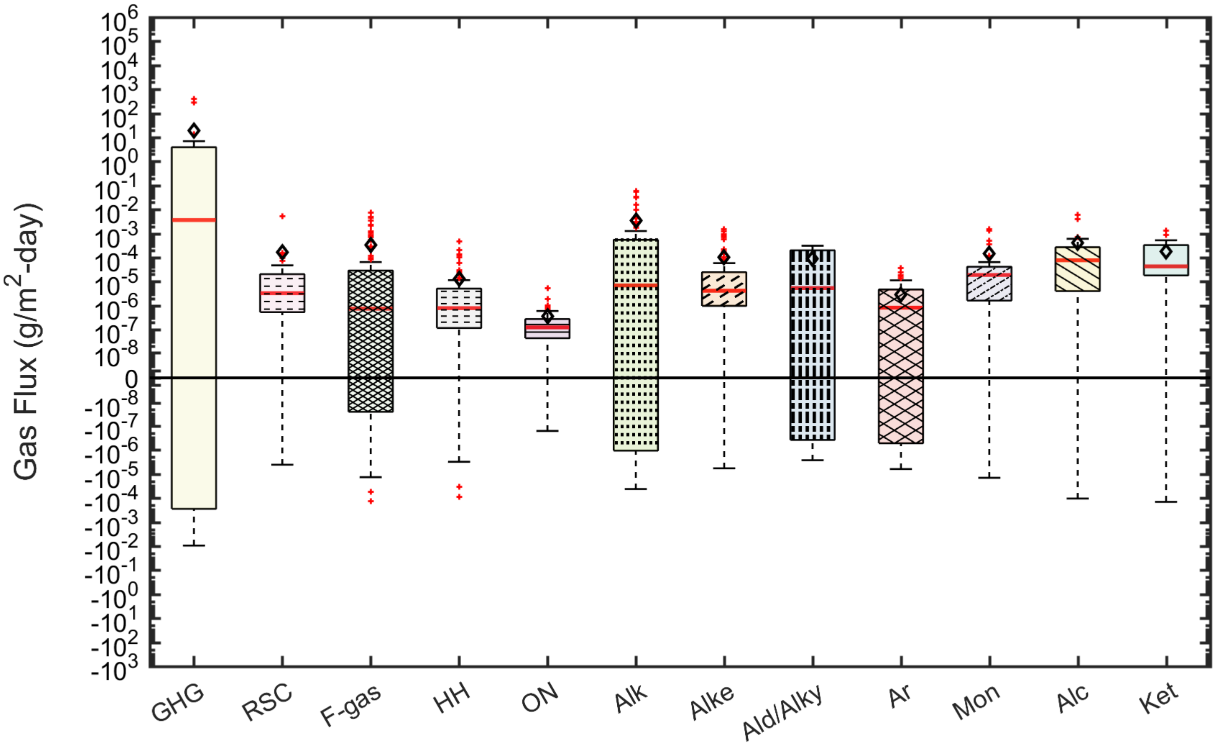
4.3.1 Santa Maria Regional Landfill

4.3.1.1 Dry Season Test Results

Figure 4.27 presents box plots summarizing the flux measurements conducted across all testing locations at Santa Maria Regional Landfill during the dry weather season organized by chemical family. Out of the 820 potential measurements that could be obtained at this site, 640 measurements (78%) were viable given the R^2 threshold applied in this study. The remaining 16.5% and 5.5% of flux measurements were not included due to low R^2 value and below detection limit/analytical measurement errors, respectively. Overall, surface fluxes (including all chemical families) for this testing campaign varied from -9.50×10^{-3} to 4.02×10^{2} g/m^2-day. A majority of the measured fluxes were positive (79%), albeit small positive numbers (median flux of 5.95×10^{-6} g/m^2-day). Positive fluxes (out of the cover) and negative fluxes (into the cover) varied by 11 orders of magnitude (from 5.7×10^{-9} to 4.02×10^{2} g/m^2-day) and 6 orders of magnitude -9.50×10^{-3} to -2.57×10^{-8} g/m^2-day), respectively.

Comparison of the median flux values indicated that the greenhouse gas emissions (methane, nitrous oxide, carbon dioxide, and carbon monoxide) were greatest out of all the chemical families included, where fluxes of methane were most dominant. The variation in GHG emissions was also highest out of all chemical families, as indicated by the wide interquartile (IQR) and inter-whisker (IWR) ranges (Figure 4.27). During the dry season, average skewness and kurtosis values were approximately 1 and 3.68, respectively, indicating that the distribution of fluxes was positively skewed and heavy tailed (e.g., high number of potential outliers or anomalies in flux values). The span of the IQR for a majority of the chemical families was greater than zero for all chemical families included, further indicating that emissions were positively skewed. Positive skewness suggests that net emissions were more likely over net uptake for all the gases and high kurtosis is indicative of high variation in the measured fluxes for a given chemical family.

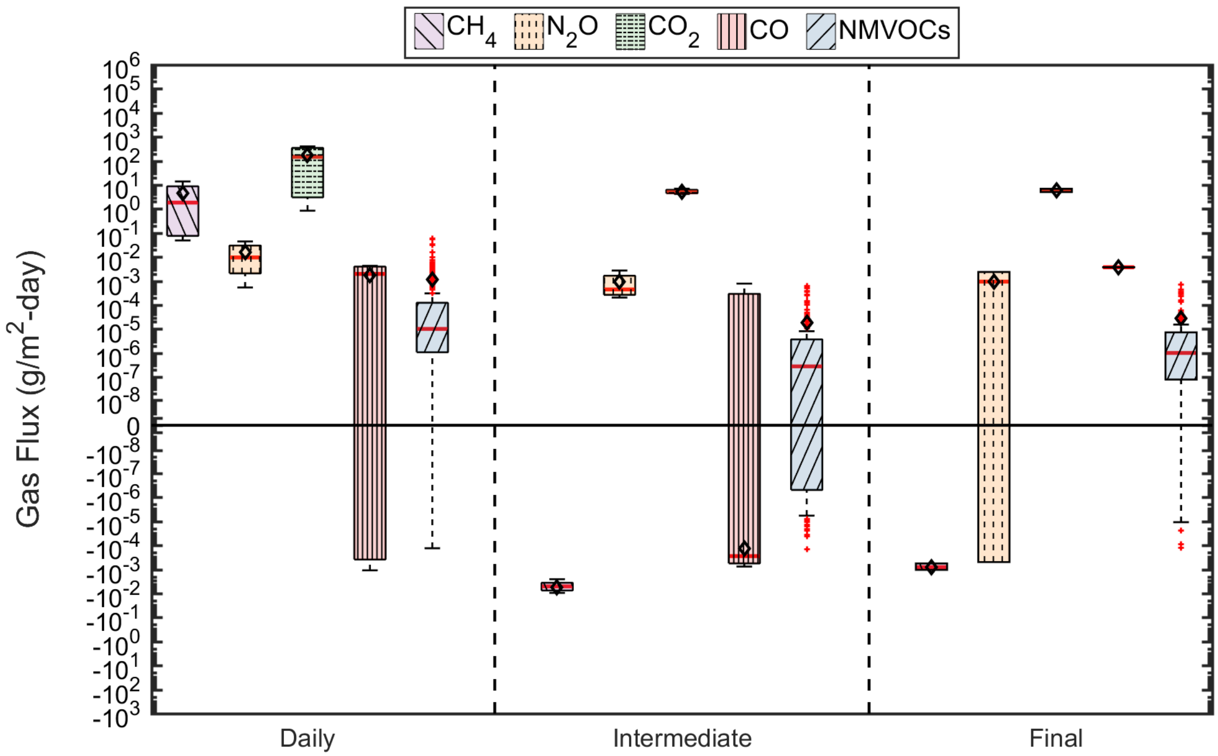
Figure 4.27 Measured Fluxes at Santa Maria Regional Landfill by Chemical Family in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



Comparison of median flux values for the NMVOCs indicated that fluxes for the sulfur compounds, F-gases, halogenated hydrocarbons, organic alkyl nitrates, alkanes, alkenes, aldehydes/alkynes, and aromatic hydrocarbon chemical families were relatively low compared to the other chemicals. Based on the median flux values presented, emissions of the alcohols, ketones, and monoterpenes categories were relatively higher than the aforementioned NMVOC families (Figure 4.27). Within each of these chemical families, methanol, acetone, and alpha-pinene demonstrated the highest median flux values. Variation in measured fluxes was highest and lowest for the alkane and organic nitrate chemical families, respectively where variation in fluxes among the remaining families (excluding the aromatics) was relatively similar (Figure 4.27). For this particular site and season, NMVOC fluxes varied from -1.44×10^{-4} to 5.82×10^{-2} g/m^2-day.

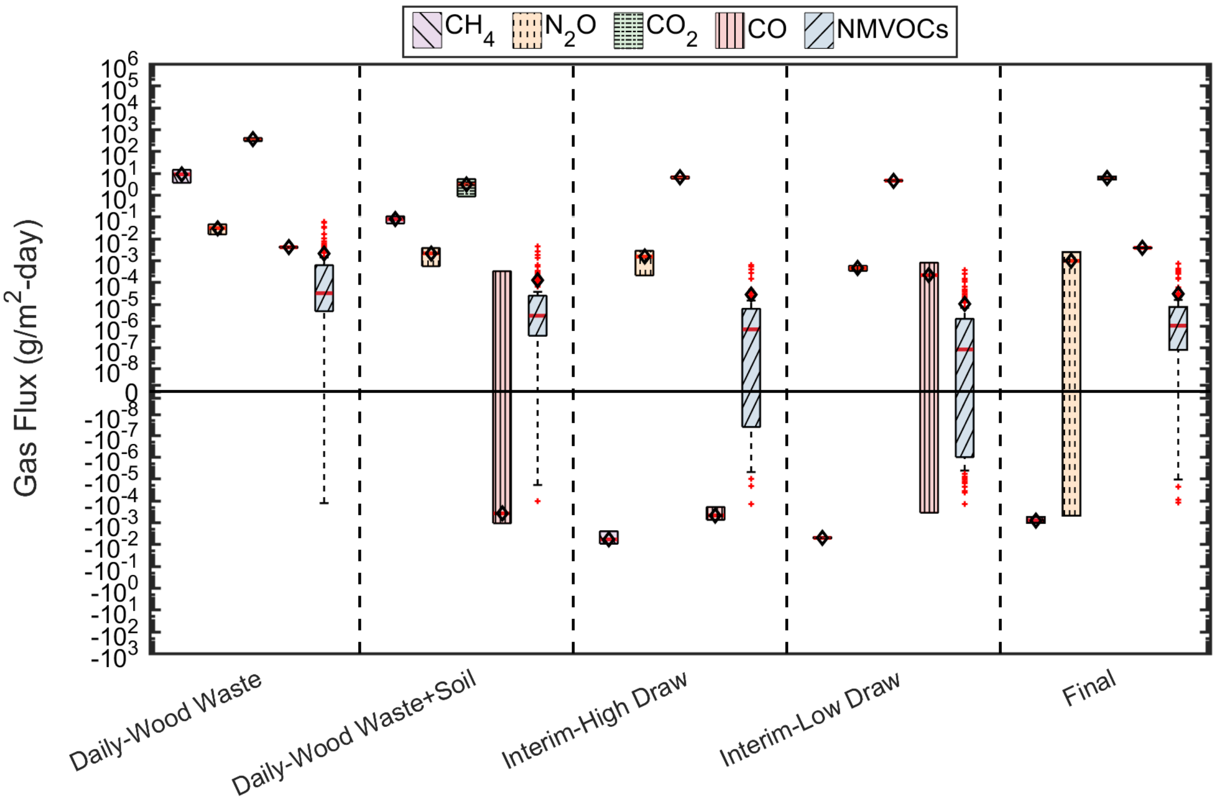
Measured fluxes of the project gases at Santa Maria Regional Landfill as a function of overall cover category are presented in Figure 4.28 for the dry season. Generally, the baseline GHGs (specifically carbon dioxide) had the highest maximum and median flux values across all cover categories. For NMVOCs, the highest median flux for daily, intermediate, and final covers were for the alkanes, alcohols, and aldehydes/alkynes, respectively. By individual chemical species, the highest flux for daily, intermediate, and final covers were for n-pentane, beta-pinene, and beta-pinene, respectively. For all gases, the fluxes generally decreased from daily to intermediate to final cover systems. For the daily cover locations, fluxes were generally positive, in particular for the baseline greenhouse gases. However, net uptake of methane was observed for both the intermediate and final cover testing locations. The carbon dioxide fluxes were highest for all cover categories investigated, reaching up to 4.02×10^2 g/m^2-day. Comparison of median flux values indicated that the flux of nitrous oxide was also greater than the NMVOCs for both the daily and intermediate cover systems investigated.

Figure 4.28 Measured Fluxes at Santa Maria Regional Landfill by Overall Cover Category in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



The fluxes for individual cover systems are presented in Figure 4.29. The intermediate-high cover represents the intermediate cover system tested at the normal vacuum pressure level of the gas collection system used at the site and is directly comparable to the daily and final covers. The intermediate-low cover represents the same intermediate cover system tested at a vacuum pressure lower than the normal vacuum pressure level used at the site. Of the cover systems investigated during the dry season field campaign, the daily cover primarily composed of wood waste was associated with the highest fluxes for all gases investigated (Figure 4.29). The presence of soil as an amendment to the wood waste significantly attenuated the fluxes of all gas species in the daily cover that consisted of wood waste and soil. The magnitude of fluxes and flux trends were relatively similar between the interim and final cover systems. The variation and magnitude of fluxes were somewhat higher during the high draw (i.e., high vacuum pressure) of the gas collection system than the low draw (i.e., low vacuum pressure) of the gas collection system for the intermediate cover system (Figure 4.29). The higher flux during high draw may have resulted from larger concentration differentials across the cover system during operation of the gas collection system at the higher level of vacuum pressure.

Figure 4.29 Measured Fluxes at Santa Maria Regional Landfill by Individual Cover Type in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

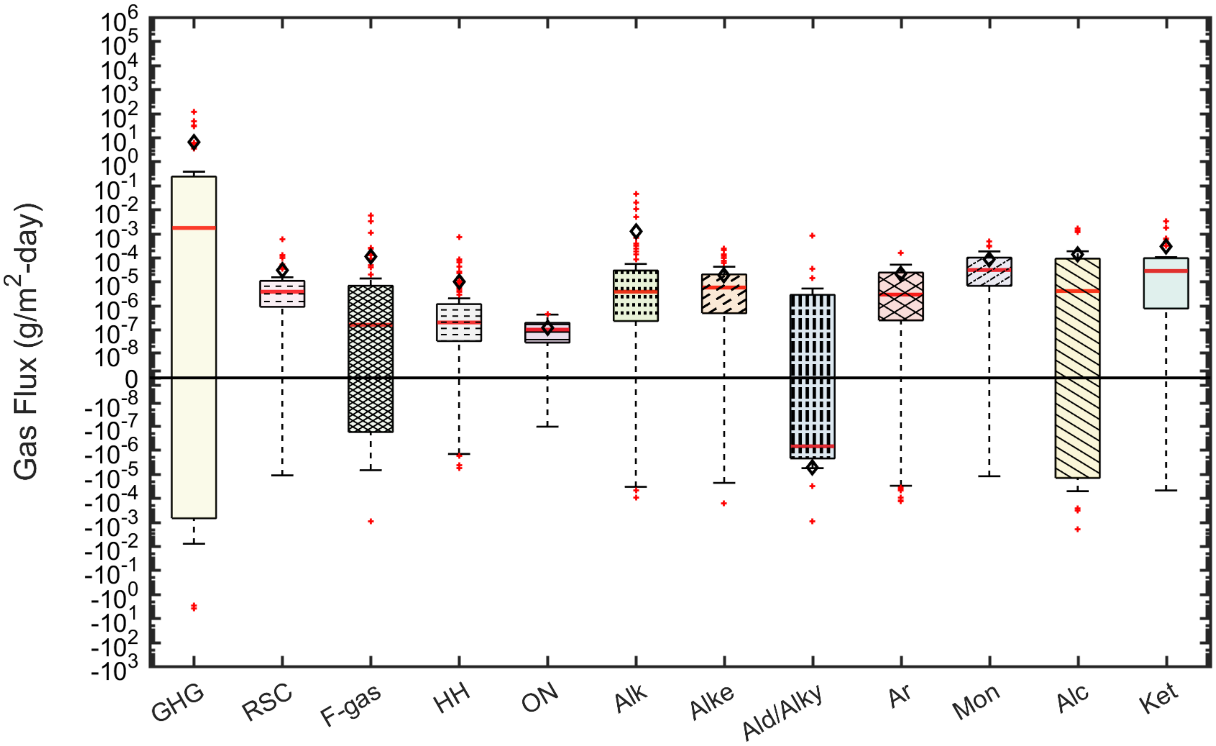


4.3.1.2 Wet Season Test Results

At Santa Maria Regional Landfill, flux testing conducted during the wet season differed from the dry season tests in various aspects. The number of acceptable flux measurements decreased slightly from approximately 78% to approximately 76% (N=623 flux measurements), where the contribution from low R^2 values were on the order of 20% and the below detection limit/analytical measurement error measurements amounted to 3%. Also, the range in baseline GHG emissions was observed to decrease compared to dry season testing program. The overall flux values in wet season testing ranged from -3.95×10^0 to 1.14×10^2 g/m^2-day. The percentage of measurements that were positive decreased slightly from 79% in the dry season to 76% in the wet season, where the median value of positive measurements also decreased (5.28×10^{-6} g/m^2-day). Positive fluxes (out of the cover) and negative fluxes (into the cover) varied by 10 (from 4.75×10^{-9} to 1.14×10^2 g/m^2-day) and 9 (-3.94 to -5.23×10^{-9} g/m^2-day) orders of magnitude, respectively.

Figure 4.30 presents box plots summarizing the flux measurements conducted across all testing locations at Santa Maria Regional Landfill during the wet weather season organized by chemical family. For the most dominant chemical family (baseline GHGs), median flux values were slightly lower in the wet season as compared to the dry season. Variation in baseline GHG emissions decreased during the wet season, based on the IQRs and IWRs observed (Figure 4.30). Distributions of measured fluxes were still positively skewed (average skewness of approximately 1) and heavy-tailed (average kurtosis approximately 3.9), indicating that net emissions were more likely over net uptake and that variation in the measured fluxes was high for a given chemical family.

Figure 4.30 Measured Fluxes at Santa Maria Regional Landfill by Chemical Family in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

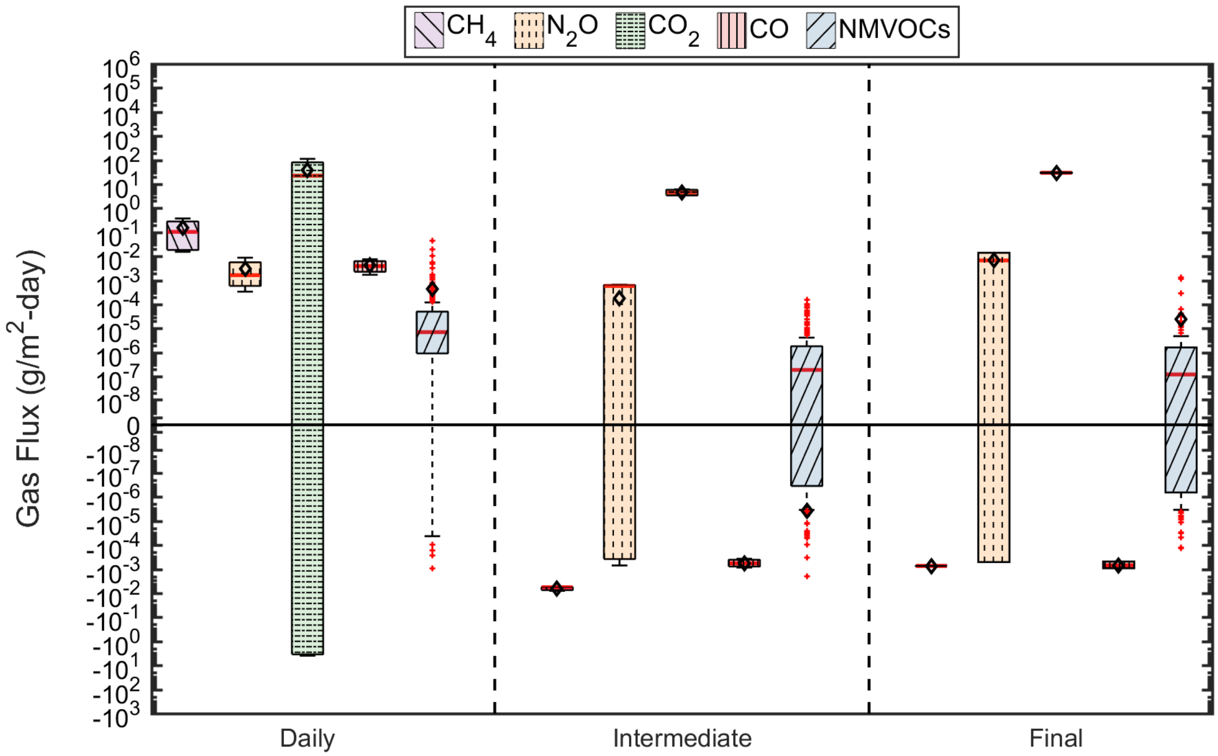


Overall, median NMVOC fluxes generally decreased during the wet season at Santa Maria Regional Landfill as compared to the dry season. In addition, the variation in NMVOC flux measurements, as assessed using the average IQR and IWR across NMVOC families, decreased during the wet season as compared to the dry season (Figure 4.30). Based on the median flux values presented in Figure 4.30, emissions of the monoterpenes, ketones, and alkenes were relatively higher than all of the NMVOC families analyzed. Within each of these chemical families, alpha-pinene, acetone, 1-pentene demonstrated the highest median flux values. Variation in measured fluxes was highest and lowest for the alcohols and organic nitrate chemical families, respectively, where variation in fluxes among the remaining families (excluding the aldehydes/alkynes) was relatively similar (Figure 4.30). For this particular site and season, NMVOC fluxes varied from -1.93×10^{-3} to 4.48×10^{-2} g/m^2-day.

Measured fluxes of the project gases at Santa Maria Regional Landfill as a function of overall cover category are presented in Figure 4.31 for the wet season. Generally, the baseline GHGs (specifically carbon dioxide) had the highest maximum and median flux values across all cover categories. For NMVOCs, the highest median fluxes for daily, intermediate, and final covers were for the monoterpenes in all cases. By individual chemical species, the highest flux for daily, intermediate, and final covers were for i-butene, 1-3-5 trimethylbenzene, and beta-pinene, respectively. During the wet weather season, median NMVOC fluxes generally decreased and the variation within chemical families was reduced as the average IQR and IWRs decreased (Figure 4.31). The monoterpenes and ketone chemical families were still dominant NMVOC families in the wet weather season, even though the emission of alcohols generally decreased as opposed to the alkane chemical family. Similar to the dry season, alpha-pinene and acetone were the NMVOCs with the highest median emissions, along with i-butane within each of these dominant chemical families. Intra-landfill NMVOC fluxes at Santa Maria Regional Landfill ranged from -1.93×10^{-3} to 4.45×10^{-2} g/m^2-day, which is comparable, yet slightly lower than the variation observed in the dry weather season.

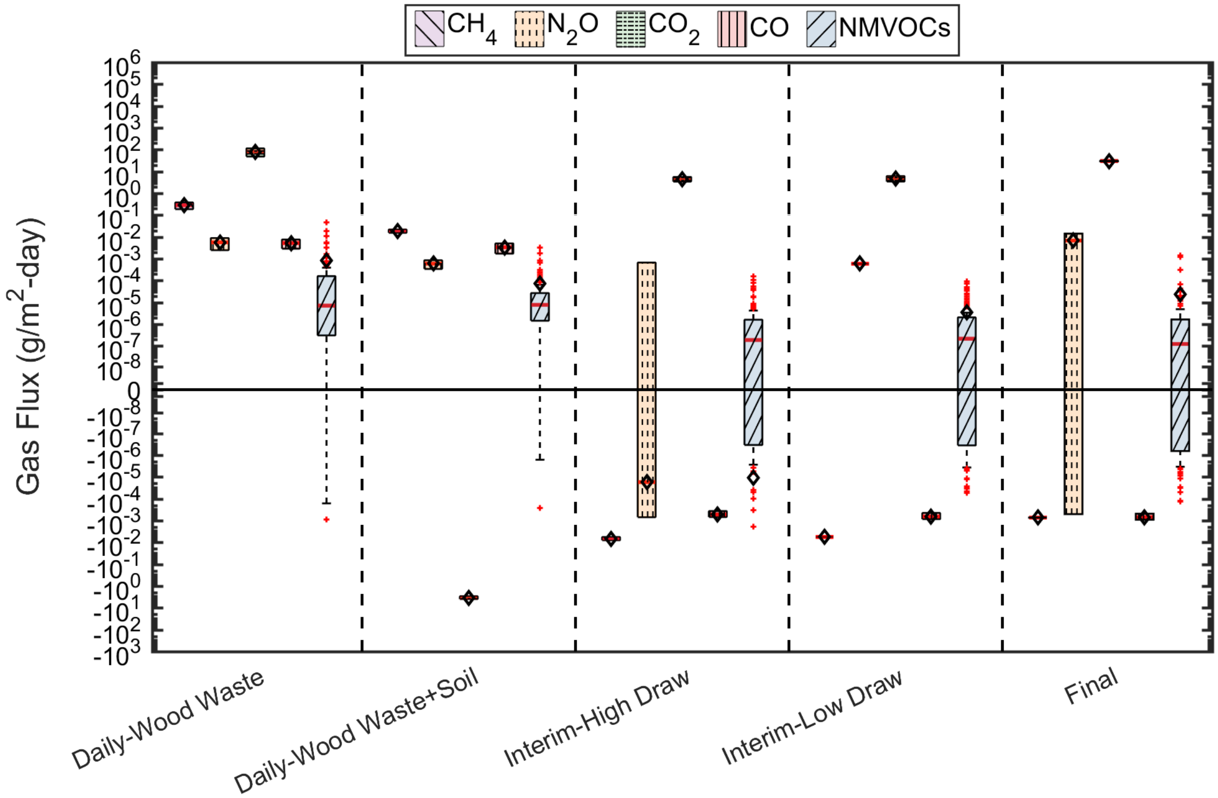
During the wet season at Santa Maria Regional Landfill, the effect of overall cover category was somewhat less pronounced on measured surface fluxes for all chemicals investigated compared to the dry season (Figure 4.31). Methane flux generally decreased from the daily to intermediate cover systems tested during the wet season, which was consistent with results obtained during the dry season field campaigns. Both carbon dioxide and nitrous oxide fluxes were highly variable as a function of cover category. In particular, for the daily cover locations tested, the interquartile range of carbon dioxide fluxes ranged from -1 to 1.00×10^2 g/m^2-day. Nitrous oxide fluxes were more variable through the final covers tested during the wet season. In contrast, for the NMVOCs, there was a general decrease in median flux values and interquartile lengths progressing from daily to final cover materials.

Figure 4.31 Measured Fluxes at Santa Maria Regional Landfill by Overall Cover Category in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



The fluxes from individual cover systems are presented in Figure 4.32 for the wet season. In the wet season differences were observed in the measured fluxes between the wood waste only and wood waste and soil mix daily cover materials in similarity to the dry season (Figure 4.32). The greatest difference between the daily cover materials was observed for the carbon dioxide fluxes, where net emissions (on the order of 1.00×10^1 g/m^2-day) were observed for the wood waste only daily cover as compared to net uptake (on the order of -5.00×10^0 g/m2-day) for the wood waste and soil daily cover location. Median flux values also decreased for methane and nitrous oxide from the wood waste to wood waste amended with soil and were relatively constant for the NMVOCs (even though the variability in measured fluxes decreased). Similar to the dry testing season, there was relatively low variation in measured fluxes across the different intermediate and final cover locations for methane, carbon dioxide, and NMVOCs. While median methane, carbon dioxide, and NMVOC fluxes were similar between the intermediate-high and intermediate-low tests, the median nitrous oxide flux increased significantly from intermediate-high to intermediate-low testing conditions. Nitrous oxide fluxes were relatively high for the final cover location in contrast to the dry season tests.

Figure 4.32 Measured Fluxes at Santa Maria Regional Landfill by Individual Cover Type in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



4.3.1.3 Summary of Flux Measurements from Santa Maria Regional Landfill

A comprehensive summary of the flux measurements obtained from the dry and wet season field campaigns at Santa Maria Regional Landfill is presented in Table 4.2. Overall minimum, maximum, and median flux values are organized in Table 4.2 according to chemical family and season. Measurements presented in Table 4.2 are intended to provide supplemental quantitative data to the boxplots included in the previous sections above to facilitate interpretation of the results.

Table 4.2 – Summary of Flux Measurements Obtained from Santa Maria Regional Landfill

Chemical Family	Dry Season (g/m^2-day)			Wet Season (g/m^2-day)		
	Min	Max	Median	Min	Max	Median
GHG	$-9.48x10^{-3}$	$4.02x10^{2}$	$3.66x10^{-3}$	$-3.95X10^{0}$	$1.14x10^{2}$	$1.72x10^{-3}$
RSC	$-4.11x10^{-6}$	$5.30x10^{-3}$	$3.32x10^{-6}$	$-1.14x10^{-5}$	$5.70x10^{-4}$	$3.83x10^{-6}$
F-gases	$-1.31x10^{-4}$	$7.25x10^{-3}$	$7.56x10^{-7}$	$-9.13x10^{-4}$	$5.70x10^{-3}$	$1.61x10^{-7}$
HH	$-8.70x10^{-5}$	$4.78x10^{-4}$	$7.97x10^{-7}$	$-5.48x10^{-6}$	$7.39x10^{-4}$	$2.01x10^{-7}$
ON	$-1.61x10^{-7}$	$5.26x10^{-6}$	$1.25x10^{-7}$	$-1.06x10^{-7}$	$4.50x10^{-7}$	$9.97x10^{-8}$
Alk	$-4.19x10^{-5}$	$5.82x10^{-2}$	$6.97x10^{-6}$	$-9.63x10^{-5}$	$4.48x10^{-2}$	$3.84x10^{-6}$
Alke	$-5.77x10^{-6}$	$1.51x10^{-3}$	$4.19x10^{-7}$	$-1.62x10^{-4}$	$2.40x10^{-4}$	$5.73x10^{-6}$
Ald/Alky	$-2.67x10^{-6}$	$3.14x10^{-4}$	$5.43x10^{-6}$	$-9.13x10^{-4}$	$7.97x10^{-4}$	$-7.00x10^{-7}$
Ar	$-6.21x10^{-6}$	$3.62x10^{-5}$	$8.30x10^{-7}$	$-1.36x10^{-4}$	$1.62x10^{-4}$	$2.91x10^{-6}$
Mon	$-1.44x10^{-5}$	$1.51x10^{-3}$	$1.91x10^{-5}$	$-1.24x10^{-5}$	$4.60x10^{-4}$	$3.08x10^{-5}$
Alc	-1.05x10-4	$6.02x10^{-3}$	$7.81x10^{-5}$	$-1.93x10^{-3}$	$1.61x10^{-3}$	$4.08x10^{-6}$
Ket	$-1.44x10^{-4}$	$1.33x10^{-3}$	$4.34x10^{-5}$	$-4.82x10^{-5}$	$3.17x10^{-3}$	$2.79x10^{-5}$

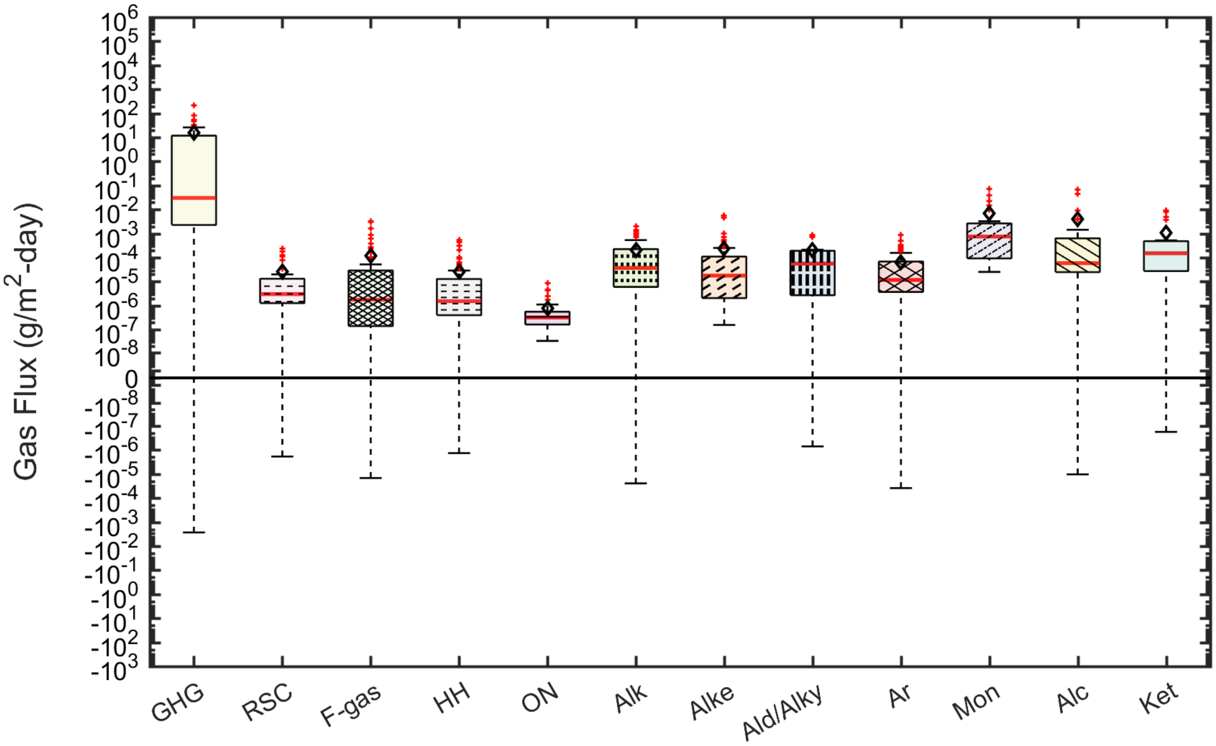
4.3.2 Teapot Dome Landfill

4.3.2.1 Dry Season Test Results

Figure 4.33 presents box plots summarizing the flux measurements conducted across all testing locations at Teapot Dome Landfill during the dry weather season organized by chemical family. Out of the 820 potential measurements that could be obtained at this site, 665 measurements (81%) were viable given the R^2 threshold applied in this study. The remaining approximately 10% and 9% of flux measurements were not included due to low R^2 value and below detection limit/analytical measurement errors, respectively. Overall, surface fluxes (including all chemical families) for this testing campaign varied from $-2.7x10^{-3}$ to $2.20x10^{2}$ g/m^2-day. A great majority of the measured fluxes were positive (92.6%) with a median flux of $1.59x10^{-5}$ g/m^2-day. Positive fluxes (out of the cover) and negative fluxes (into the cover) varied by 10 orders of magnitude (from $1.95x10^{-8}$ to $2.20x10^{2}$ g/m^2-day) and 5 orders of magnitude ($-2.70x10^{-3}$ to $-1.03x10^{-8}$ g/m^2-day), respectively.

At Teapot Dome Landfill, the baseline greenhouse gas fluxes were dominant, however exhibited a higher variation than the NMVOCs (Figure 4.33). Average skewness and kurtosis were 1.4 and 4, respectively and IQRs were above zero, indicating the higher probability of net emissions over uptake and the high variation in measured fluxes. Low probability of uptake was present for multiple chemical families. The likelihood for uptake over emissions was greatest for the GHGs, and also high for the alkanes, aromatics, and alcohols based on the extent of the lower whiskers below zero.

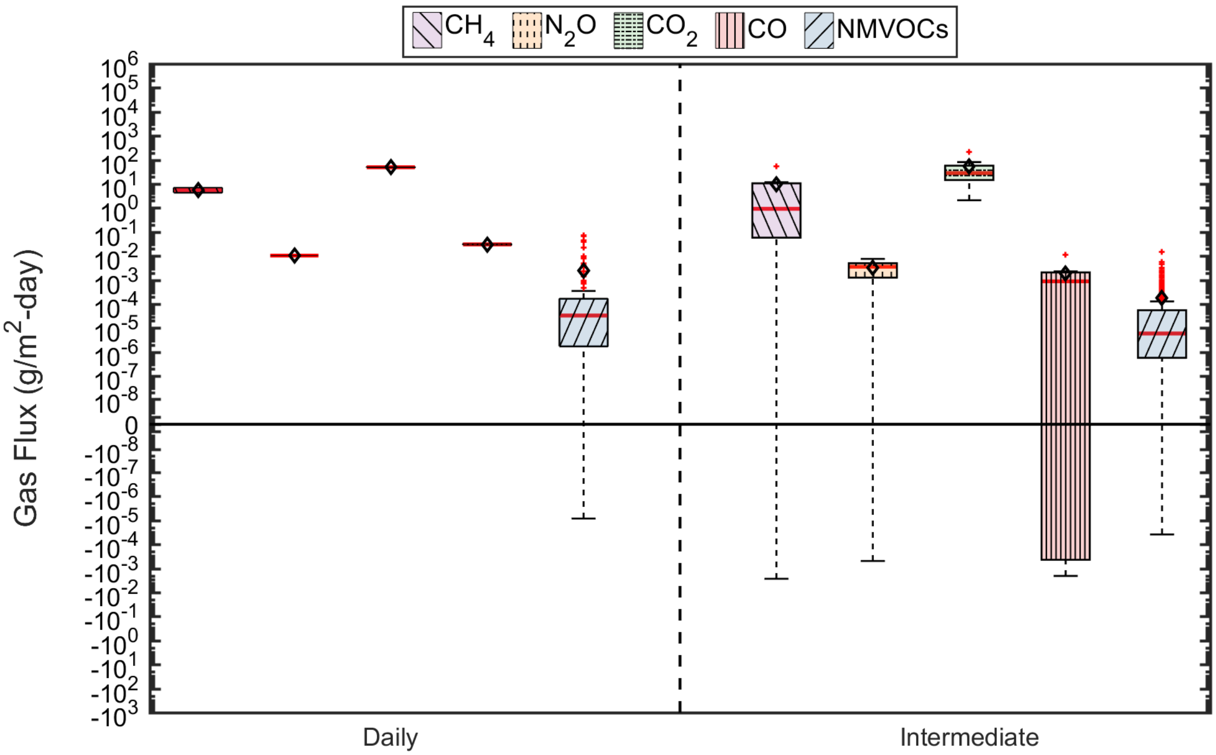
Figure 4.33 Measured Fluxes at Teapot Dome Landfill by Chemical Family in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



Among the NMVOCs investigated, the monoterpenes, ketones, alcohols, aldehydes/alkynes, and alkanes were associated with the highest fluxes based on the median flux data (Figure 4.33). Within each of these families, alpha pinene, acetone, and methanol demonstrated the highest median flux values. The NMVOC fluxes were comparable (assessed using IQR and IWR) across all NMVOC chemical families with the exception of the organic alkyl nitrates, halogenated hydrocarbons, and reduced sulfur compounds that demonstrated lower variations in measured fluxes (Figure 4.33). Overall NMVOC emissions ranged from -3.86×10^{-5} to 7.44×10^{-2} g/m^2-day.

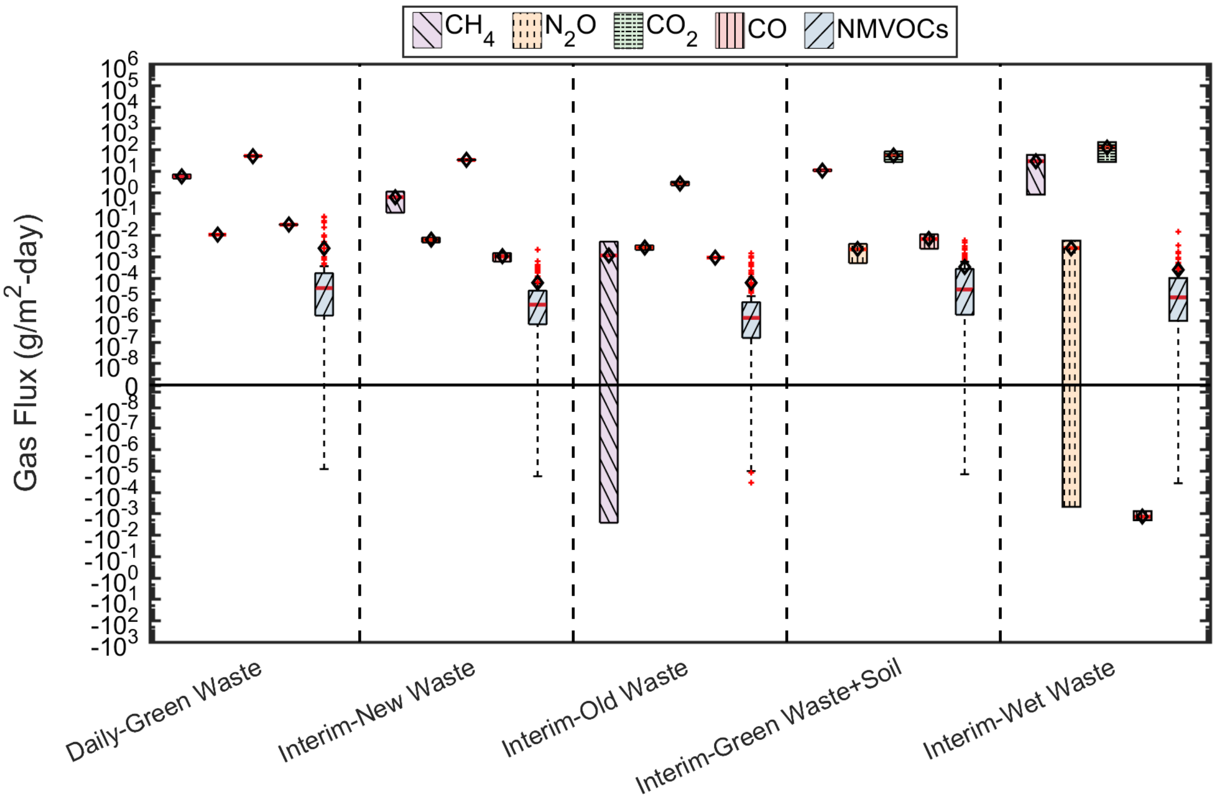
Measured fluxes of the project gases at Teapot Dome Landfill as a function of overall cover category are presented in Figure 4.34 for the dry season. Generally, the baseline GHGs (specifically carbon dioxide) had the highest median flux values across all cover categories. For NMVOCs, the highest median flux for daily and intermediate covers were for the monoterpenes. By individual chemical species, the highest fluxes observed for both daily and intermediate covers were for 1,2,4-trimethylbenzene. For all gases, the fluxes generally decreased from daily to intermediate cover locations. The decreases in flux were relatively modest and the differences in median fluxes were between 7.69×10^{-5} (NMVOCs) and 4.37×10^{0} (GHGs). For dry weather testing, a high number of uptake measurements were obtained for the intermediate covers at Teapot Dome Landfill, as indicated by the wider interquartile ranges and extent of the whiskers below zero for these locations. For a given GHG, variability in the measured fluxes were higher at the intermediate cover locations compared to the daily cover locations, whereas the variability in NMVOC measurements decreased progressing from daily to intermediate cover systems.

Figure 4.34 Measured Fluxes at Teapot Dome Landfill by Overall Cover Category in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



The fluxes from individual cover systems are presented in Figure 4.35. Of the intermediate cover systems investigated, the cover overlying the old waste was generally associated with the lowest emissions for all gases analyzed with significant uptake of methane as indicated by the extent of the interquartile range below zero. Fluxes of methane and carbon dioxide were greatest at the intermediate cover overlying the designated wet waste placement area at the site. At this cover location, nitrous oxide emissions were highly variable. The magnitude and extent of NMVOC emissions were generally comparable across all testing locations, where the daily cover location had the highest fluxes (based on the mean and median values presented in the boxplots) (Figure 4.35).

Figure 4.35 Measured Fluxes at Teapot Dome Landfill by Individual Cover Type in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

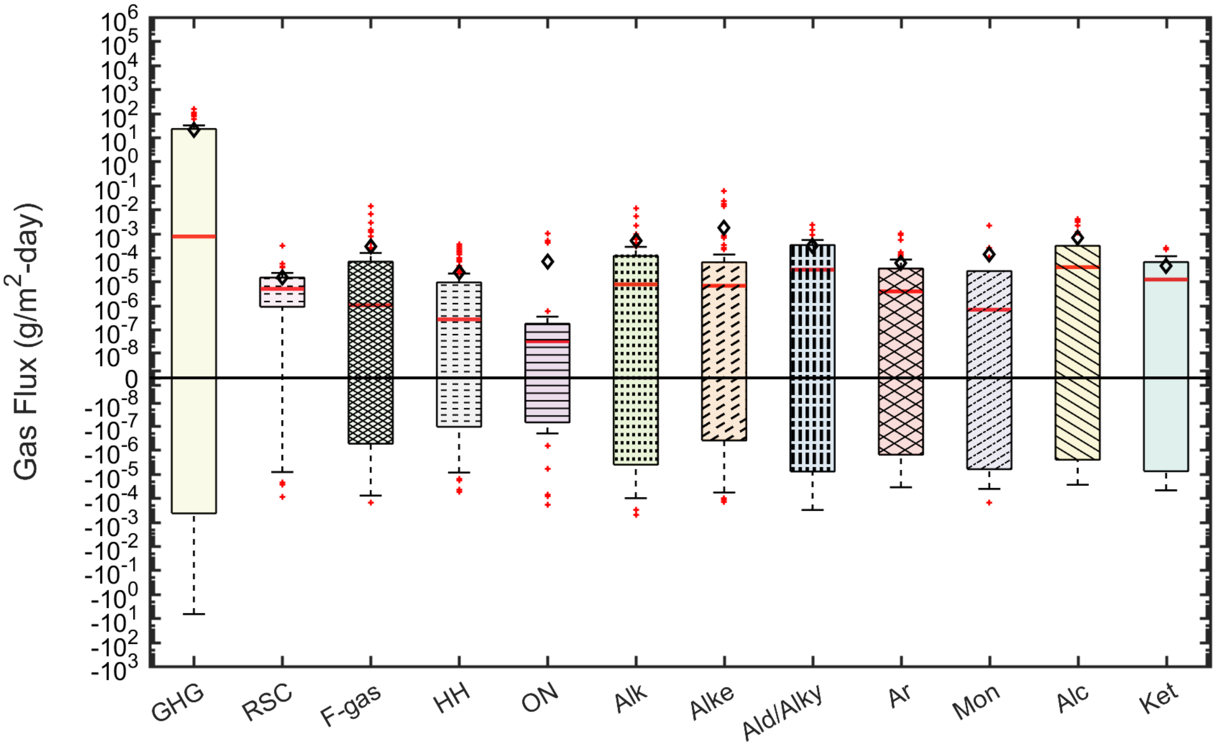


4.3.2.2 Wet Season Test Results

At Teapot Dome Landfill, flux testing conducted during the wet season differed from the dry season tests in various aspects. The number of acceptable flux measurements decreased from 81% to 76% (N=625 flux measurements), where the contribution from low R^2 values were on the order of 18% and the below detection limit measurements amounted to 6%. The overall range (including all chemical families) in measured fluxes changed from -2.7×10^{-3} to 2.20×10^{2} in the dry season to -6.70×10^{0} - 1.52×10^{2} g/m^2-day. The percentage of measurements that were positive decreased significantly from 92.6% in the dry season to 67% in the wet season. However, the median value of positive measurements increased (2.75×10^{-5} g/m^2-day). Positive fluxes (out of the cover) and negative fluxes (into the cover) varied by 11 (from (2.44×10^{-9} to 1.52×10^{2} g/m^2-day) and 10 (-6.70×10^{0} to -1.38×10^{-9} g/m^2-day) orders of magnitude, respectively.

Figure 4.36 presents box plots summarizing the flux measurements conducted across all testing locations at Teapot Dome Landfill during the wet weather season organized by chemical family. The baseline GHG fluxes remained dominant out of all chemical families included in the project. However, the variation in measured fluxes increased during wet season testing. Median flux values for the baseline GHGs decreased by two orders of magnitude. The corresponding IQRs and IWRs increased by a factor of two from the dry to wet season field measurement campaigns (Figure 4.36). Average skewness and kurtosis values summarizing the overall distributions of flux measurements decreased to 0.9 and 3.52, respectively, during the wet season campaign. The distributions of flux measurements became more symmetric and homogenous (less positively skewed and lighter tailed) as a greater proportion of measurements were observed to be negative. The somewhat lower kurtosis was indicative of a somewhat reduced yet still high variation in the measured fluxes for a given chemical family.

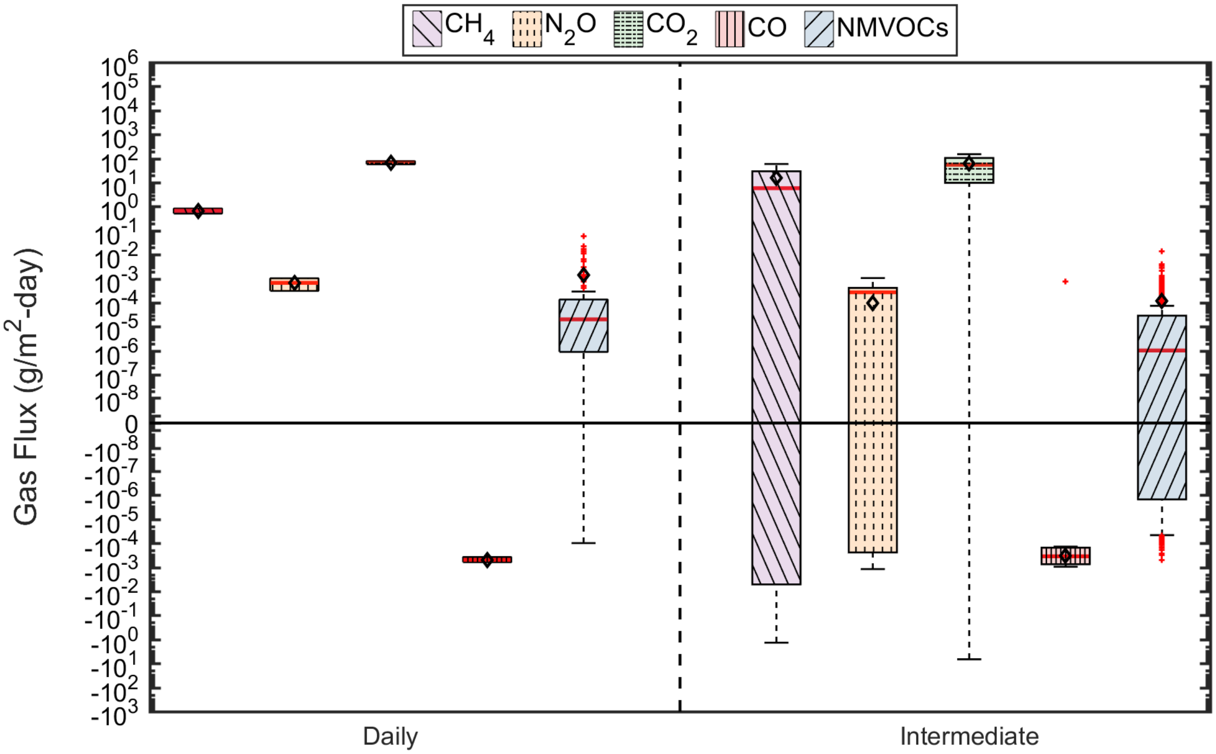
Figure 4.36 Measured Fluxes at Teapot Dome Landfill by Chemical Family in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



Overall, median NMVOC fluxes generally decreased two orders of magnitude during the wet season at Teapot Dome Landfill. In addition, the variation in NMVOC flux measurements, as assessed using the average IQR and IWR across NMVOC families, decreased by one order of magnitude during the wet season (Figure 4.36). The alcohols, aldehydes/alkynes, and ketones were the NMVOC families with the highest measured fluxes, which were comparable to those observed during the dry season. The highest median fluxes for specific chemical species within each family were measured for 2-butanol, ethyne, and methylisobutylketone. Similar to the baseline GHGs, the range in overall NMVOC emissions decreased during the wet season to -5.11×10^{-4} to 6.04×10^{-2} g/m^2-day.

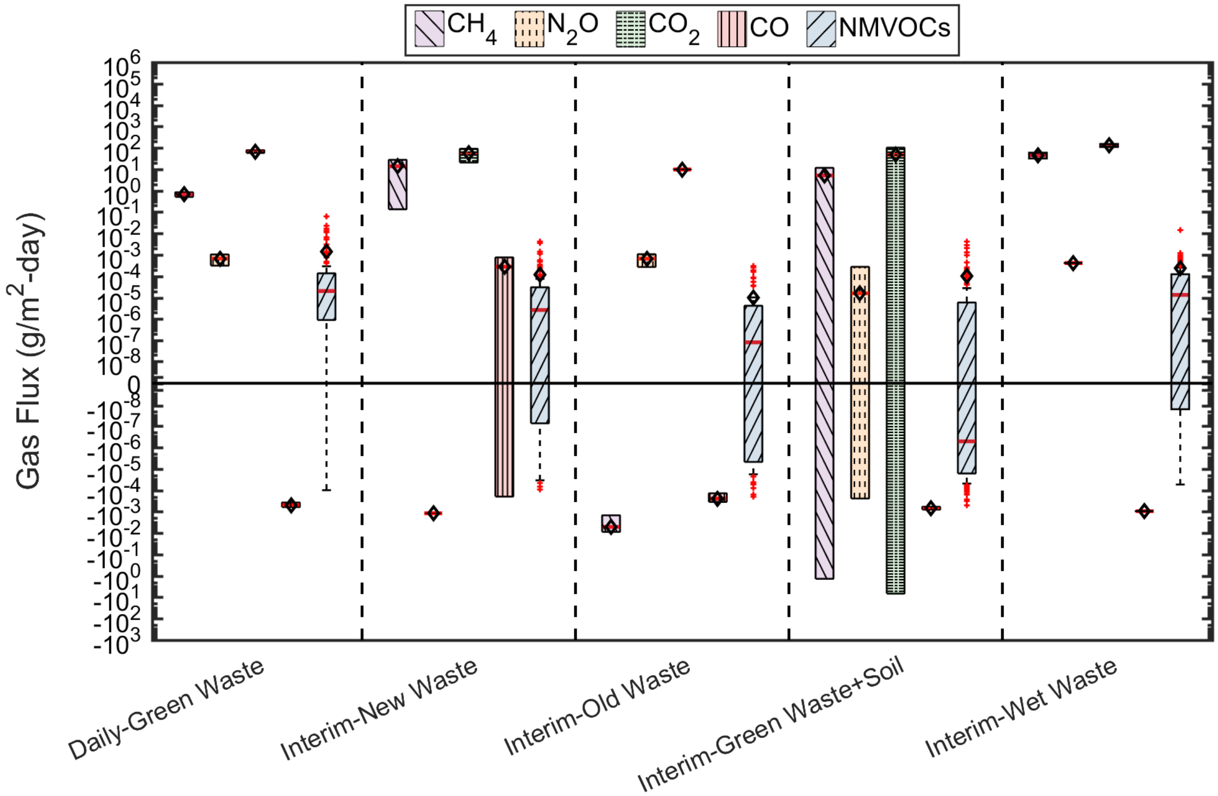
Measured fluxes of the project gases at Teapot Dome Landfill as a function of overall cover category are presented in Figure 4.37 for the wet season. Generally, the baseline GHGs (specifically carbon dioxide) had the highest median flux values across all cover categories. For NMVOCs, the highest median flux for daily and intermediate covers were obtained for the aldehydes/alkynes and alcohols, respectively. By individual chemical species, the highest flux observed for daily and intermediate covers were for 1-butene and HCFC-22. The central tendencies of methane, nitrous oxide, and carbon dioxide flux measurements were relatively similar between daily and intermediate cover systems at Teapot Dome Landfill during the wet season. However, the variation in the baseline greenhouse gas emissions increased for the intermediate cover systems, in particular for methane and carbon dioxide, where long lower whisker lengths were observed. Higher variation in flux measurements were observed for intermediate cover systems at Teapot Dome Landfill during the dry season. The variation in intermediate cover flux measurements was generally higher in the wet season than the dry season, given the longer IQR and IWR observed in Figure 4.37 as compared to Figure 4.34. Fluxes of NMVOCs generally decreased from daily to intermediate cover systems at Teapot Dome during the wet season which corresponded with a decrease in the variation of flux measurements (Figure 4.37).

Figure 4.37 Measured Fluxes at Teapot Dome Landfill by Overall Cover Category in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



The fluxes from individual cover systems are presented in Figure 4.38 for the wet season. Similar to the dry season testing, the intermediate cover overlaying wet waste was associated with the highest fluxes for all the measured gases in the wet season, even exceeding daily cover emissions (Figure 4.38). The largest variation in flux measurements was observed for the intermediate cover with green waste and soil, particularly for methane and carbon dioxide flux measurements. On average, NMVOC flux measurements at Teapot Dome Landfill were near zero to slightly negative. The intermediate cover overlying older wastes had net uptake of methane and NMVOC fluxes were on the same order of magnitude as the intermediate cover with green waste and soil. The intermediate cover overlying new waste was associated with net uptake of nitrous oxide. NMVOC emissions generally decreased from the daily cover to the intermediate covers overlying new waste and old waste, and to the intermediate cover composed of green waste and soil (Figure 4.38).

Figure 4.38 Measured Fluxes at Teapot Dome Landfill by Individual Cover Type in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



4.3.2.3 Summary of Flux Measurements from Teapot Dome Landfill

A comprehensive summary of the flux measurements obtained from the dry and wet season field campaigns at Teapot Dome Landfill is presented in Table 4.3. Overall minimum, maximum, and median flux values are organized in Table 4.3 according to chemical family and season. Measurements presented in Table 4.3 are intended to provide supplemental quantitative data to the boxplots included in the previous sections above to facilitate interpretation of the results.

Table 4.3 – Summary of Flux Measurements Obtained from Teapot Dome Landfill

Chemical Family	Dry Season (g/m^2-day)			Wet Season (g/m^2-day)		
	Min	Max	Median	Min	Max	Median
GHG	-2.69×10^{-3}	2.20×10^{2}	3.06×10^{-2}	-6.70×10^{0}	1.52×10^{2}	7.58×10^{-4}
RSC	-1.87×10^{-6}	2.42×10^{-4}	3.06×10^{-6}	-8.97×10^{-5}	3.13×10^{-4}	5.03×10^{-6}
F-gases	-1.47×10^{-5}	3.17×10^{-3}	1.79×10^{-6}	-1.59×10^{-4}	1.39×10^{-2}	1.05×10^{-6}
HH	-1.35×10^{-6}	5.50×10^{-4}	1.55×10^{-6}	-5.54×10^{-5}	3.68×10^{-4}	2.71×10^{-7}
ON	3.34×10^{-8}	8.59×10^{-6}	3.23×10^{-7}	-1.96×10^{-4}	1.00×10^{-3}	3.25×10^{-8}
Alk	-2.45×10^{-5}	2.06×10^{-3}	3.74×10^{-5}	-5.11×10^{-4}	1.15×10^{-2}	7.72×10^{-6}
Alke	1.58×10^{-7}	5.57×10^{-3}	1.80×10^{-5}	-1.49×10^{-4}	6.04×10^{-2}	6.77×10^{-6}
Ald/Alky	-7.05×10^{-7}	2.04×10^{-4}	5.67×10^{-5}	-3.13×10^{-4}	2.32×10^{-3}	3.16×10^{-5}
Ar	-3.86×10^{-5}	9.12×10^{-4}	1.18×10^{-5}	-3.55×10^{-5}	9.98×10^{-4}	3.95×10^{-6}
Mon	2.55×10^{-5}	7.44×10^{-2}	7.56×10^{-4}	-1.57×10^{-4}	2.09×10^{-3}	6.83×10^{-7}
Alc	-1.03×10^{-5}	6.84×10^{-2}	5.93×10^{-5}	-2.80×10^{-5}	4.13×10^{-3}	4.02×10^{-5}
Ket	-1.76×10^{-7}	9.15×10^{-3}	1.52×10^{-4}	-4.76×10^{-5}	2.63×10^{-4}	1.23×10^{-5}

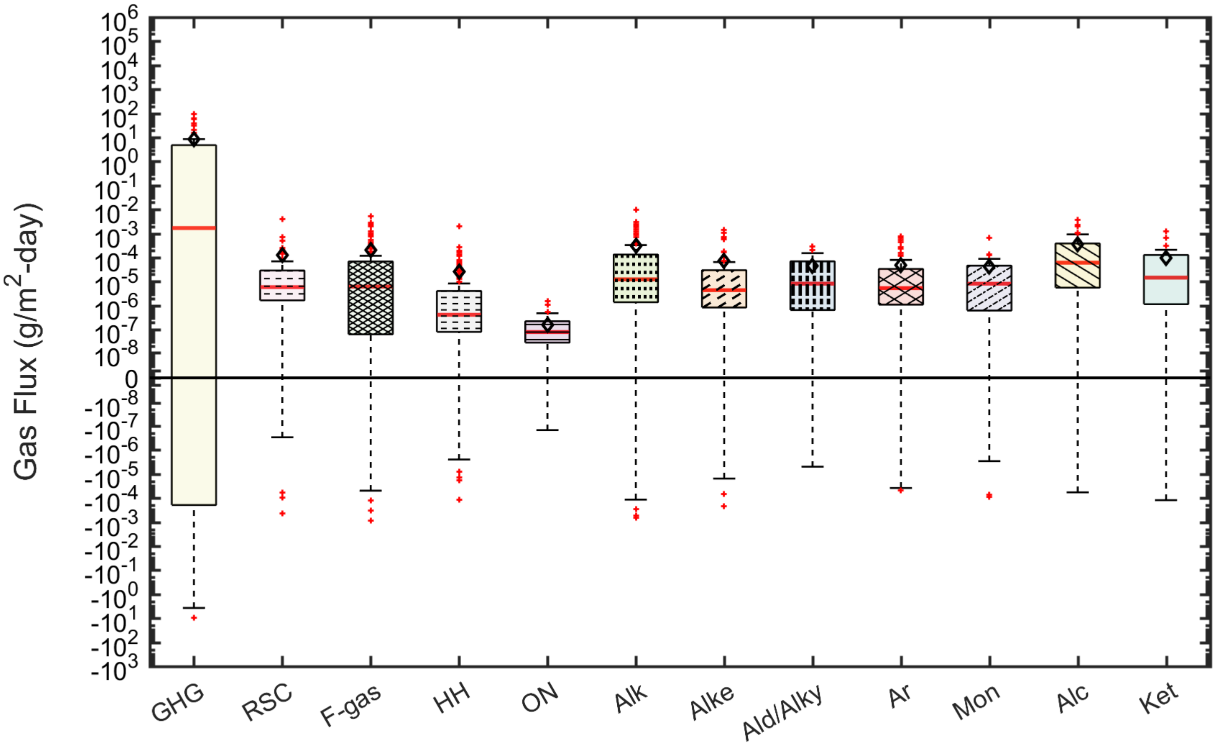
4.3.3 Potrero Hills Landfill

4.3.3.1 Dry Season Test Results

Figure 4.39 presents box plots summarizing the flux measurements conducted across all testing locations at Potrero Hills Landfill during the dry weather season organized by chemical family. Out of the 1148 potential measurements that could be obtained at this site, 916 measurements (80%) were viable given the R^2 threshold applied in this study. The remaining approximately 17% and 3% of flux measurements were not included due to low R^2 value and below detection limit/analytical measurement errors, respectively. Overall, surface fluxes (including all chemical families) for this testing campaign varied from -9.6×10^{0} to 9.48×10^{1} g/m^2-day. A high majority of the measured fluxes were positive (82%) with a median flux of 1.17×10^{-5} g/m^2-day. Positive fluxes (out of the cover) and negative fluxes (into the cover) varied by 10 orders of magnitude (from 6.99×10^{-9} to 9.48×10^{1} g/m^2-day) and 10 orders of magnitude (-9.6×10^{0} to -2.10×10^{-9} g/m^2-day), respectively.

At Potrero Hills Landfill, the baseline greenhouse gas fluxes were dominant. The variation in GHG fluxes was higher than the variation in the NMVOCs included in the investigation (Figure 4.39). Average skewness and kurtosis values were 1.6 and 5.4, respectively and IQRs were above zero, demonstrating the higher probability of net emissions over uptake and the high variation in measured fluxes. Low probability of uptake was present for multiple chemical families. The likelihood for uptake over net emissions was greatest for the GHGs, and also observed for the alkanes, aromatics, and alcohols based on the extent of the lower whiskers below zero

Figure 4.39 Measured Fluxes at Potrero Hills Landfill by Chemical Family in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

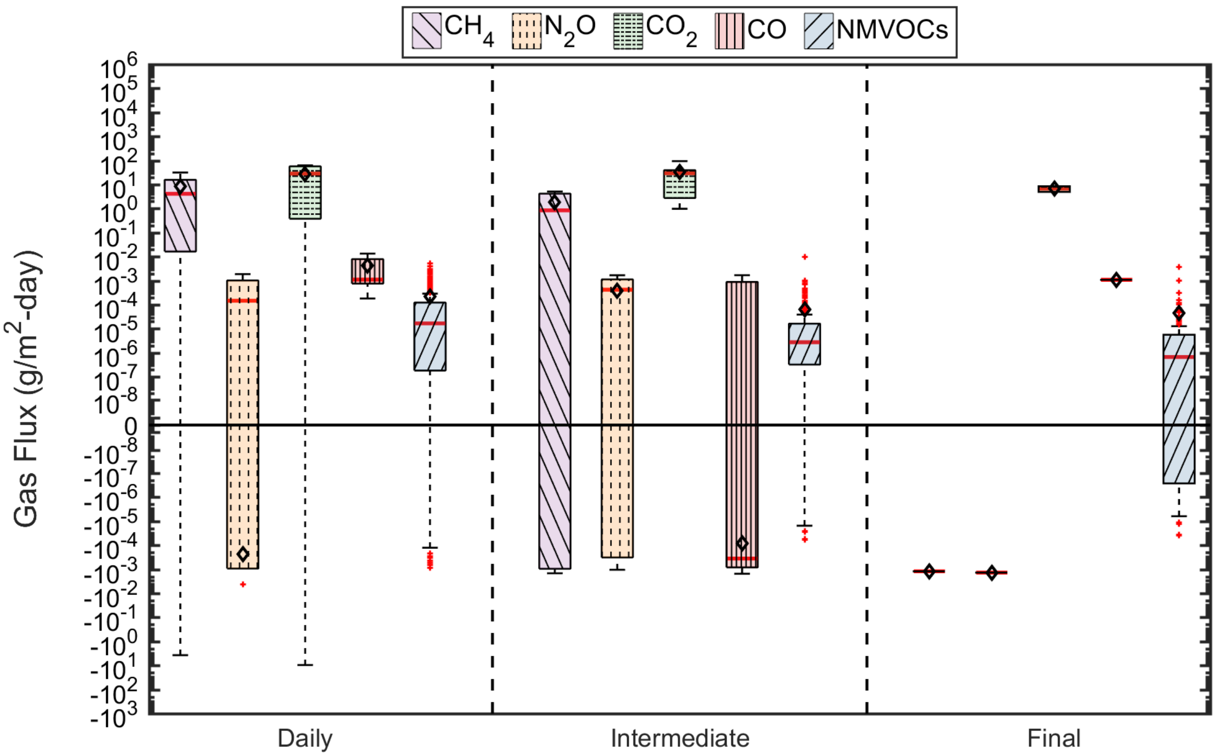


Among the NMVOCs investigated, the alcohols, ketones, and alkanes were associated with the highest fluxes based on the median flux data (Figure 4.39). The highest median fluxes for specific chemical species within each family were measured for methanol, alpha-pinene, and i-butane. The NMVOC fluxes were relatively similar (assessed using IQR and IWR) across all NMVOC chemical families with the exception of the organic alkyl nitrates and reduced sulfur compounds that demonstrated lower variations in measured fluxes (Figure 4.33). Overall NMVOC emissions ranged from -8.64×10^{-4} to 9.96×10^{-3} g/m^2-day.

Measured fluxes of the project gases at Potrero Hills Landfill as a function of overall cover category are presented in Figure 4.40 for the dry season. Generally, the baseline GHGs (specifically carbon dioxide) had the highest maximum and median flux values across all cover categories. For NMVOCs, the highest median flux for daily, intermediate, and final covers were for the alcohols, alcohols, and aldehydes/alkynes, respectively. By individual chemical species, the highest fluxes observed for the daily, intermediate, and final covers were for HCFC-245fa, n-butane, and beta pinene. For all gases, the fluxes generally decreased from daily to intermediate to final cover locations. The decreases in flux were relatively modest from daily to intermediate cover systems, where the differences in median fluxes were between 1.27×10^{-5} (NMVOCs) and 8.30×10^{-3} (GHGs). Decreases in flux were greater from intermediate to final covers, particularly for methane and nitrous oxide (Figure 4.40). For dry season testing, a high number of uptake measurements were obtained for the final cover at

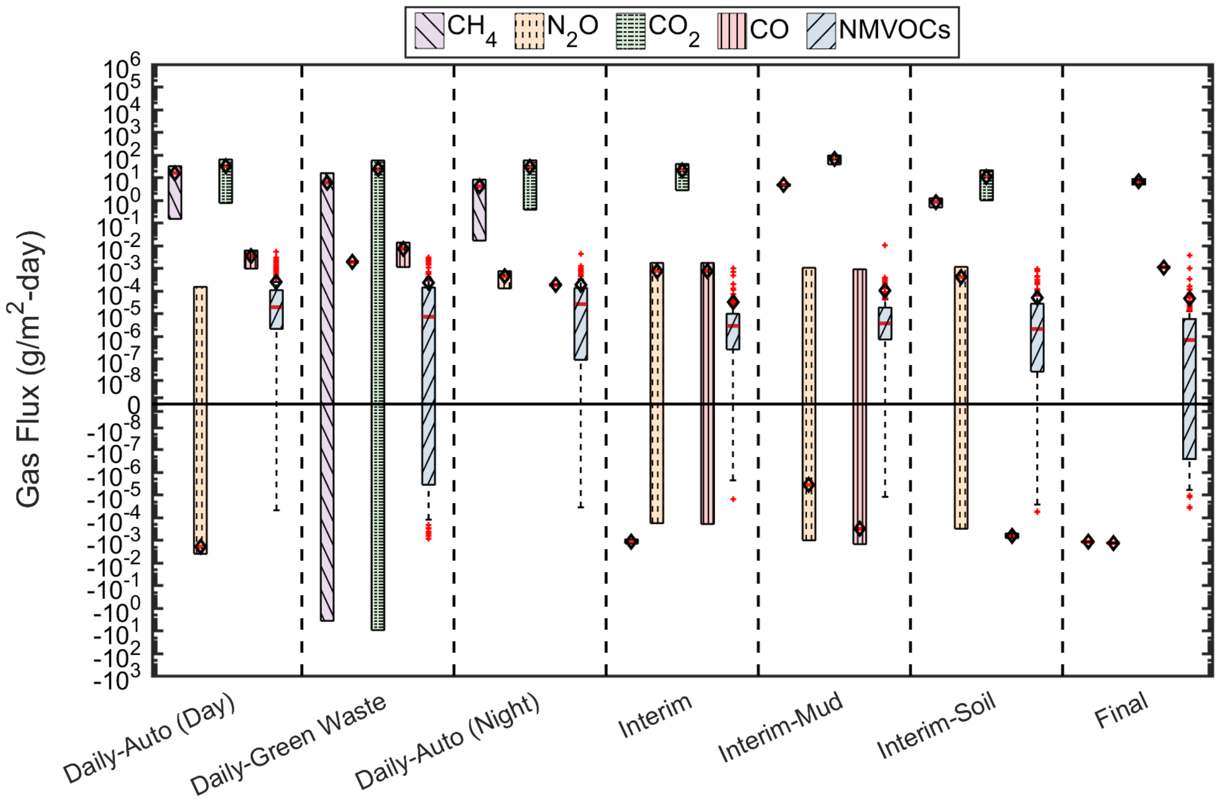
Potrero Hills Landfill, as indicated by the distribution of flux measurements below zero for methane and nitrous oxide. For a given GHG, variability in the measured fluxes were higher at the daily cover locations compared to the intermediate cover locations. The variability in NMVOC measurements decreased from daily to intermediate cover systems.

Figure 4.40 Measured Fluxes at Potrero Hills Landfill by Overall Cover Category in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



The fluxes for individual cover systems at Potrero Hills Landfill are presented in Figure 4.41 for the dry season. Aside for nitrous oxide, the daily cover system with green waste demonstrated the greatest variability in methane, carbon dioxide, and NMVOC flux measurements. Emissions of NMVOCs (both central tendencies and IQR/IWR) were comparably high at the daily cover location with autofluff during both day and nighttime testing conditions. Of the intermediate cover systems investigated, the interim cover had net uptake of methane, whereas the intermediate covers with Bay Mud and soil had high net emissions of methane. The magnitude and extent of NMVOC emissions were generally comparable for a given cover type. The autofluff daily cover (daytime) had the highest fluxes (based on the mean and median values of the boxplots) (Figure 4.41). The diurnal variations were relatively low except for nitrous oxide flux, where the N_2O flux increased by several orders of magnitude at nighttime.

Figure 4.41 Measured Fluxes at Potrero Hills Landfill by Individual Cover Type in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

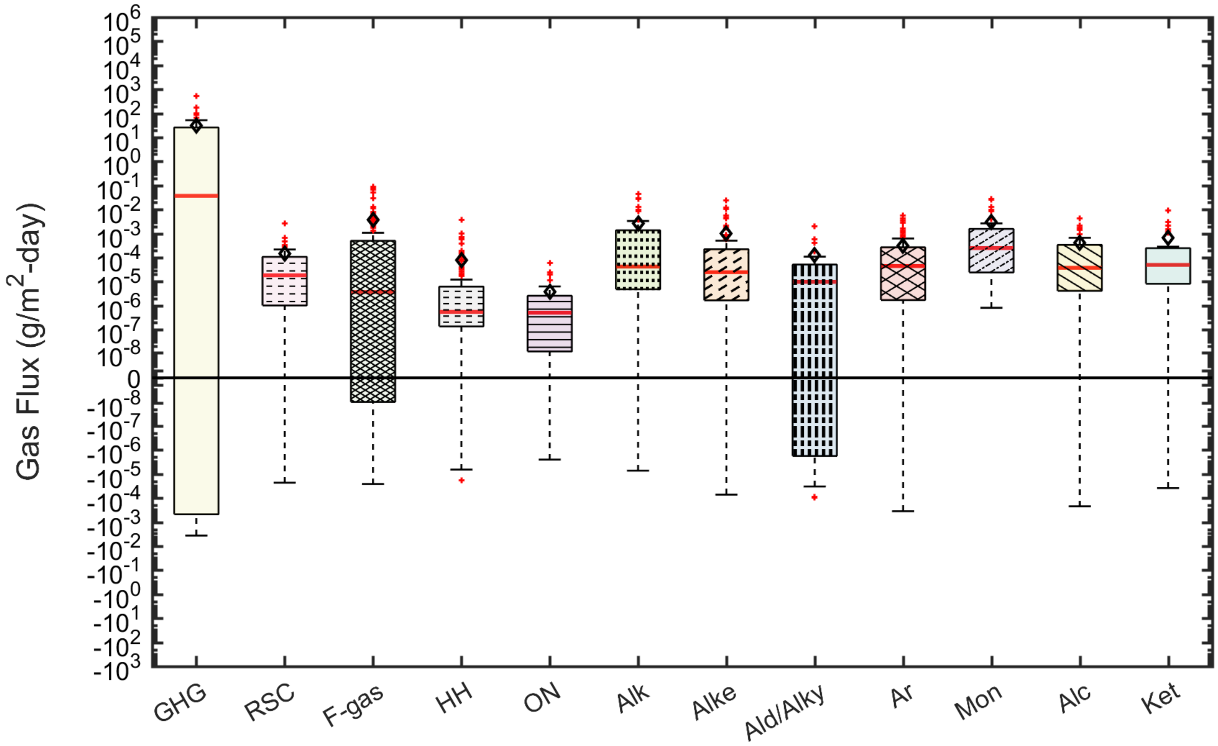


4.3.3.2 Wet Season Test Results

At Potrero Hills Landfill, flux testing conducted during the wet season differed from the dry season in various aspects. The number of acceptable flux measurements decreased from 80% to 77% (N=761 flux measurements, out of 984 potential measurements), where the contribution from low R^2 values were on the order of 22% and the below detection limit measurements amounted to 1%. The overall range (including all chemical families) in measured fluxes changed from -9.6x10^0 to 9.48x10^1 g/m^2-day in the dry season to -3.63x10^{-3} to 5.42x10^2 g/m^2-day in the wet season. The percentage of measurements that were positive increased slightly from 82% in the dry season to 83% in the wet season. The median value of positive measurements also increased (5.62x10^{-5} g/m^2-day). Positive fluxes (out of the cover) and negative fluxes (into the cover) varied by 10 orders of magnitude (from 1.74x10^{-8} to 5.42x10^2 g/m^2-day) and 6 orders of magnitude (-3.63x10^{-3} to -7.11x10^{-9} g/m^2-day), respectively.

Figure 4.42 presents box plots summarizing the flux measurements conducted across all testing locations at Potrero Hills Landfill during the wet weather season organized by chemical family. The baseline GHG fluxes remained dominant out of all chemical families included in the project. However, the variation in measured fluxes increased during wet season testing. Median flux values of the baseline GHGs increased by approximately an order of magnitude. The corresponding IQRs and IWRs increased by a factor of six from the dry to wet season field measurement campaigns (Figure 4.42). Average skewness and kurtosis values were 1.7 and 5.3, respectively, and similar to the dry season results. Higher probability of net emissions over uptake and high variation in measured fluxes were observed.

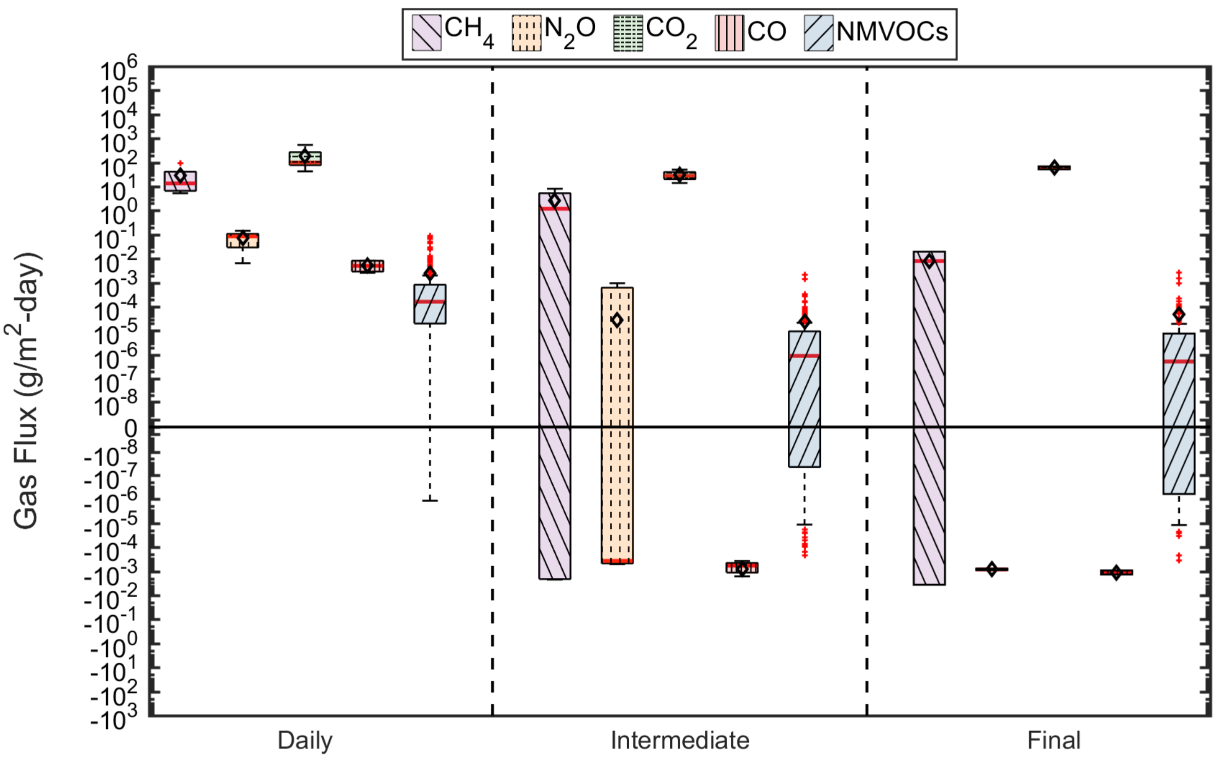
Figure 4.42 Measured Fluxes at Potrero Hills Landfill by Chemical Family in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



Overall, median NMVOC fluxes generally increased an order of magnitude during the wet season at Potrero Hills Landfill. In addition, the variation in NMVOC flux measurements, as assessed using the average IQR and IWR across NMVOC families, increased during the wet season by approximately an order of magnitude (Figure 4.42). The monoterpenes, ketones, and aromatics were NMVOC families with the highest fluxes, which were slightly different than the observations made for the dry season. The highest median fluxes for specific chemical species within each family were measured for limonene, butanone, and toluene. Similar to the baseline GHGs, the range in overall NMVOC emissions increased during the wet season to -3.53×10^{-4} to 9.00×10^{-2} g/m^2-day.

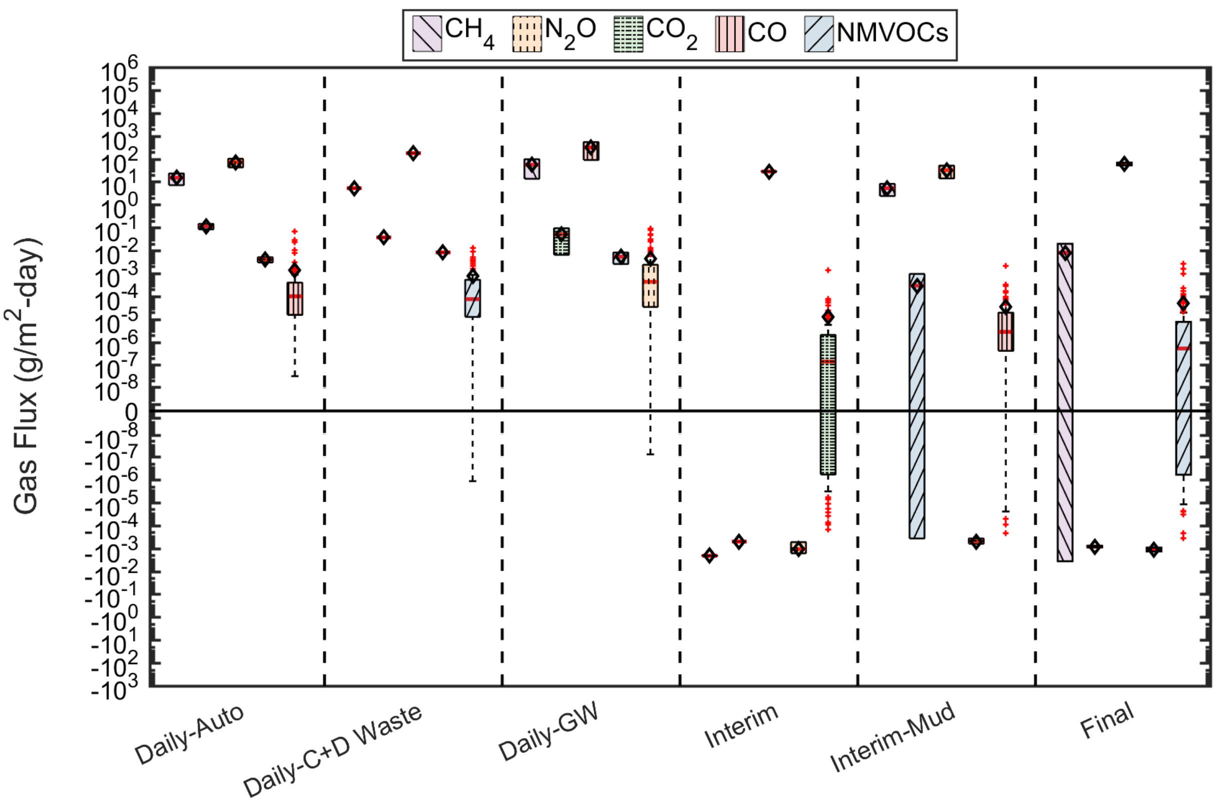
Measured fluxes of the project gases at Potrero Hills Landfill as a function of overall cover category are presented in Figure 4.43 for the wet season. In general, the baseline GHGs (specifically carbon dioxide) had the highest median flux values across all cover categories. For NMVOCs, the highest maximum and median flux for daily, intermediate, and final covers were for the alkanes, monoterpenes, and monoterpenes, respectively. By individual chemical species, the highest flux observed for daily, intermediate, and final covers were for HCFC-141b, methanol, and alpha-pinene, respectively. The central tendencies of methane, nitrous oxide, and carbon dioxide flux measurements decreased from daily to intermediate to final cover systems at Potrero Hills Landfill during the wet season. However, the variation in the baseline greenhouse gas emissions increased for the intermediate cover systems, in particular for methane and nitrous oxide, where long interquartile lengths were observed. Higher variation in flux measurements were observed for daily cover systems at Potrero Hills Landfill during the dry season. The variation in final cover flux measurements was generally higher in the wet season than the dry season for methane, given the larger IQR and IWR presented in Figure 4.43 as compared to Figure 4.40 (net emissions over uptake). Fluxes of NMVOCs generally decreased from daily to intermediate to final cover systems at Potrero Hills during the wet season which corresponded with a decrease in the variation of flux measurements (Figure 4.43).

Figure 4.43 Measured Fluxes at Potrero Hills Landfill by Overall Cover Category in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



The fluxes from individual cover systems are presented in Figure 4.44 for the wet season. The fluxes from the daily cover with green waste were generally the highest flux data obtained at this site (Figure 4.44). For the wet weather testing campaign, the C+D location also was associated with relatively high emissions of all baseline GHGs and NMVOCs. The variation in flux measurements of all target baseline greenhouse gases decreased in the wet season. The largest variation in methane flux measurements was observed for the final cover location. On average, NMVOC flux measurements were generally high at the daily cover locations and were significantly reduced at the intermediate and final cover locations. The intermediate cover composed of soil had net uptake of methane and nitrous oxide, similar to results obtained in the dry season (Figure 4.44). Sludge and sludge-derived materials include the residual solids and semi-solids from the treatment of water, wastewater, and other liquids. Concentrated placement of these materials (e.g., use in daily cover without mixing with other materials) is associated with high N_2O emissions. The region beneath Intermediate cover (Bay Mud) at Potrero Hills Landfill was known to have large quantities of sludge wastes and demonstrated higher emissions of N_2O as compared to other intermediate cover systems.

Figure 4.44 Measured Fluxes at Potrero Hills Landfill by Individual Cover Type in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



4.3.3.3 Summary of Flux Measurements from Potrero Hills Landfill

A comprehensive summary of the flux measurements obtained from the dry and wet season field campaigns at Potrero Hills Landfill is presented in Table 4.4. Overall minimum, maximum, and median flux values are organized in Table 4.4 according to chemical family and season. Measurements presented in Table 4.4 are intended to provide supplemental quantitative data to the boxplots included in the previous sections above to facilitate interpretation of the results.

Table 4.4 – Summary of Flux Measurements Obtained from Potrero Hills Landfill

Chemical Family	Dry Season (g/m^2-day)			Wet Season (g/m^2-day)		
	Min	Max	Median	Min	Max	Median
GHG	-9.60×10^{0}	9.48×10^{1}	1.70×10^{-3}	-3.63×10^{-3}	5.41×10^{2}	3.73×10^{-2}
RSC	-4.43×10^{-4}	4.12×10^{-3}	5.95×10^{-6}	-2.29×10^{-5}	2.61×10^{-3}	1.85×10^{-5}
F-gases	-8.64×10^{-4}	5.25×10^{-3}	6.25×10^{-6}	-2.59×10^{-5}	9.01×10^{-2}	3.73×10^{-6}
HH	-1.19×10^{-4}	2.03×10^{-3}	4.19×10^{-7}	-1.86×10^{-5}	3.64×10^{-3}	5.53×10^{-7}
ON	-1.48×10^{-7}	1.60×10^{-6}	7.97×10^{-8}	-2.51×10^{-6}	5.89×10^{-5}	5.11×10^{-7}
Alk	-6.54×10^{-4}	9.97×10^{-3}	1.25×10^{-5}	-7.23×10^{-6}	4.61×10^{-2}	4.27×10^{-5}
Alke	-2.21×10^{-4}	1.45×10^{-3}	4.44×10^{-6}	-7.20×10^{-5}	2.33×10^{-2}	2.49×10^{-5}
Ald/Alky	-4.96×10^{-6}	2.84×10^{-4}	8.31×10^{-6}	-9.27×10^{-5}	2.09×10^{-3}	9.87×10^{-6}
Ar	-4.88×10^{-5}	7.75×10^{-4}	5.40×10^{-6}	-3.53×10^{-4}	5.85×10^{-3}	4.48×10^{-5}
Mon	-8.76×10^{-5}	6.65×10^{-4}	8.27×10^{-6}	8.20×10^{-7}	2.83×10^{-2}	2.51×10^{-4}
Alc	-5.78×10^{-5}	3.62×10^{-3}	6.19×10^{-5}	-2.21×10^{-4}	4.23×10^{-3}	3.77×10^{-5}
Ket	-1.22×10^{-4}	1.21×10^{-3}	1.48×10^{-5}	-3.85×10^{-5}	9.00×10^{-3}	5.00×10^{-5}

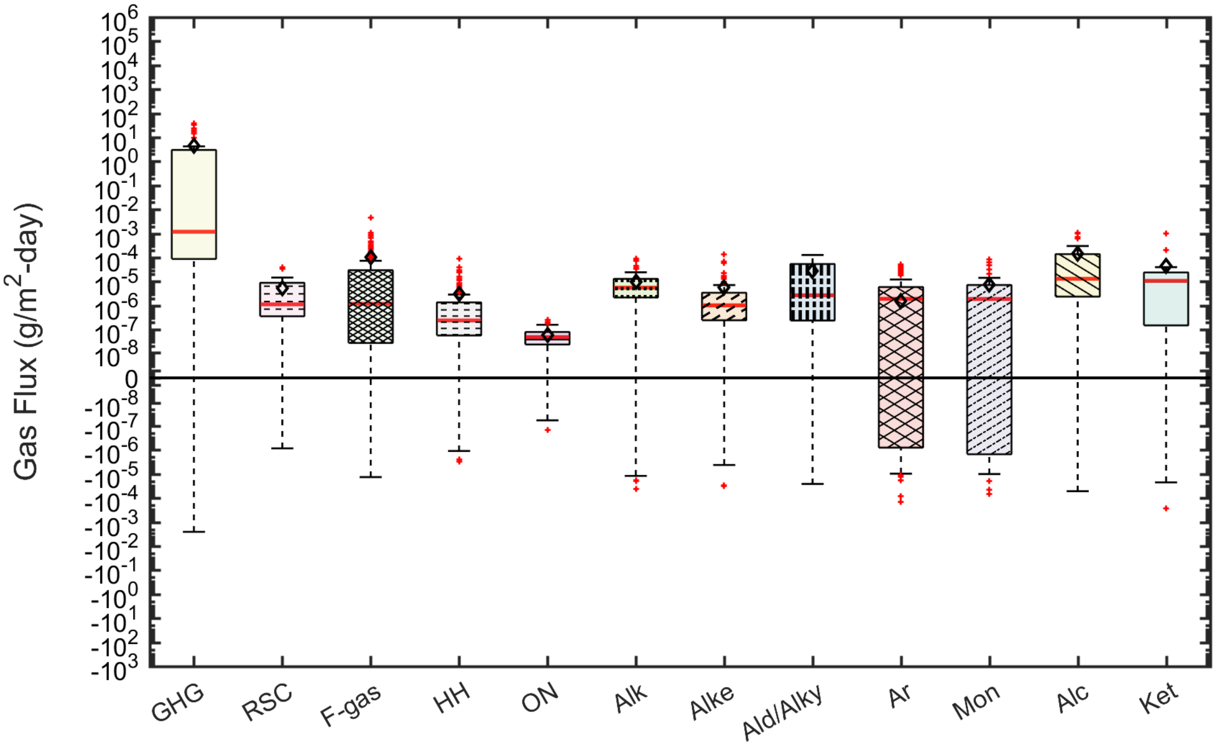
4.3.4 Landfill Site A

4.3.4.1 Dry Season Test Results

Figure 4.45 presents box plots summarizing the flux measurements conducted across all testing locations at Landfill Site A during the dry weather season organized by chemical family. Out of the 984 potential measurements that could be obtained at this site, 774 measurements (79%) were viable given the R^2 threshold applied in this study. The remaining approximately 19% and 2% of flux measurements were not included due to low R^2 value and below detection limit/analytical measurement errors, respectively. Overall, surface fluxes (including all chemical families) for this testing campaign varied from -2.54×10^{-3} to 3.77×10^{1} g/m^2-day. A high majority of the measured fluxes were positive (83%) with a median flux of 2.50×10^{-6} g/m^2-day. Positive fluxes (out of the cover) and negative fluxes (into the cover) varied by 10 orders of magnitude (from 4.18×10^{-9} to 3.77×10^{1} g/m^2-day) and 6 orders of magnitude (-2.54×10^{-3} to -7.81×10^{-9} g/m^2-day), respectively.

At Landfill Site A, the baseline greenhouse gas fluxes were dominant, however exhibited a higher variation than the NMVOCs included in the investigation (Figure 4.45). Average skewness and kurtosis values were 0.96 and 4.6, respectively and IQRs were above zero, demonstrating the high probability of net emissions over uptake and the high variation in the measured fluxes for a given chemical family. Limited probability of uptake was present for multiple chemical families, as none of the IQR extended below zero. The likelihood for uptake over emissions was greatest for the GHGs, and also observed for the alkanes, aromatics, and alcohols based on the span of the lower whiskers below zero (Figure 4.45).

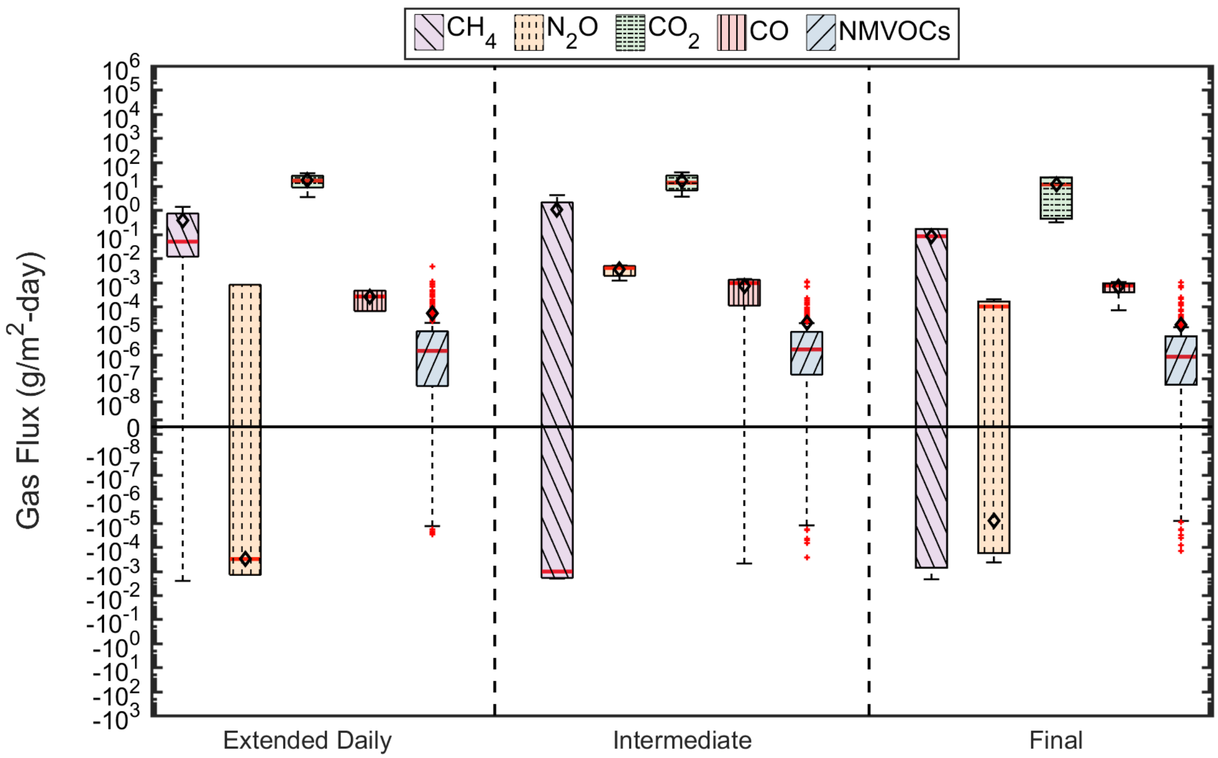
Figure 4.45 Measured Fluxes at Landfill Site A by Chemical Family in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



Comparison of median flux values for the NMVOCs indicated that fluxes for the alcohols, ketones, and alkanes were high compared to the other chemical families (Figure 4.45). The highest median fluxes for specific chemical species within each family above were measured for methanol, acetone, and i-pentane. The NMVOC fluxes were relatively similar (assessed using IQR and IWR) across all NMVOC chemical families with the exception of the F-gases, aromatics, alcohols, monoterpenes, and ketones, that demonstrated higher variations in measured fluxes (Figure 4.45). Overall NMVOC emissions ranged from $-2.67x10^{-4}$ to $4.66x10^{-3}$ g/m^2-day.

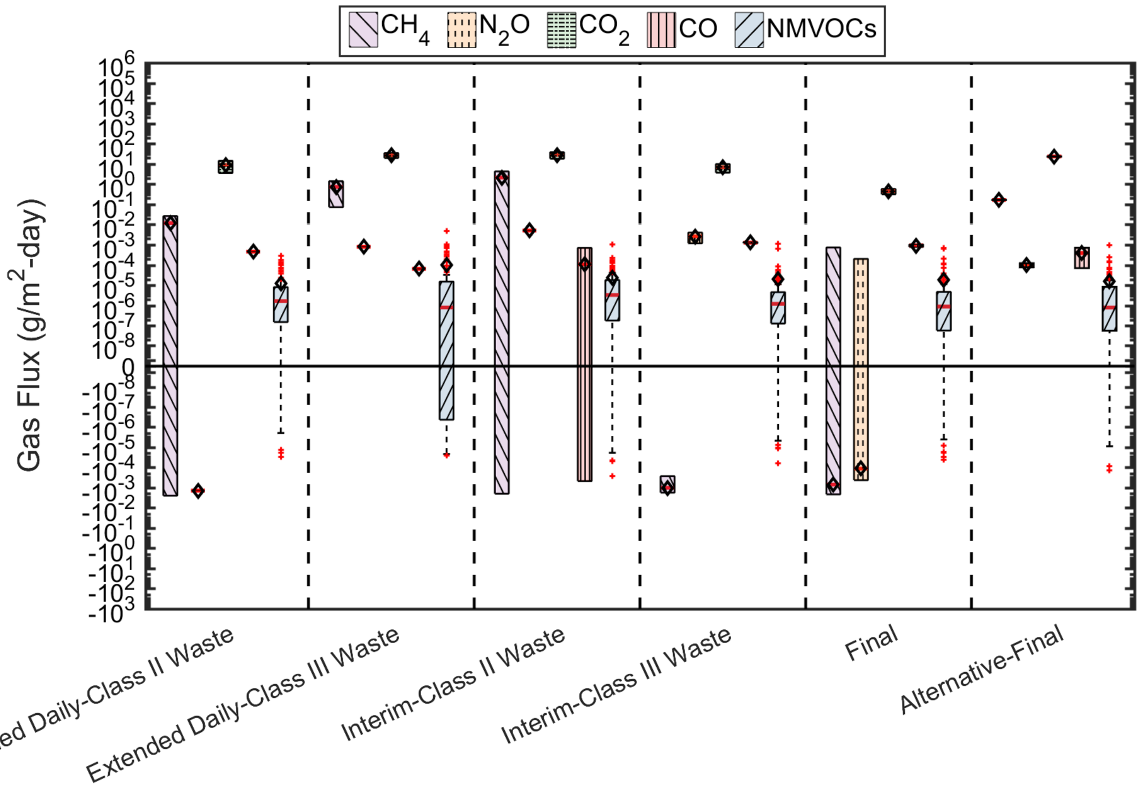
Measured fluxes of the project gases at Landfill Site A as a function of overall cover category are presented in Figure 4.46 for the dry season. Generally, the baseline GHGs (specifically carbon dioxide) had the highest maximum and median flux values across all cover categories. For NMVOCs, the highest median flux for extended daily, intermediate, and final covers were for the alcohols, ketones, and alcohols, respectively. By individual chemical species, the highest fluxes observed for the daily, intermediate, and final covers were for HFC-134a, beta pinene, and 2-butanol, respectively. The fluxes generally increased from extended daily to intermediate to final cover locations for the baseline greenhouse gases. The NMVOCs increased with the same order of the cover. The increases in flux were relatively modest from extended daily to intermediate cover systems, where the differences in median fluxes were between 1.53x10^{-6} g/m^2-day (NMVOCs) and 4.83x10^{-2} g/m^2-day (GHGs). On average, increases in flux were greater from intermediate to final covers, particularly for methane (Figure 4.46). For a given GHG, variability in the measured fluxes was lower and higher at the daily cover locations for nitrous oxide and methane, respectively, compared to the intermediate cover locations, whereas the variability in NMVOC measurements was relatively similar between daily, intermediate, and final cover systems.

Figure 4.46 Measured Fluxes at Landfill Site A by Overall Cover Category in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



The fluxes for individual cover systems at Landfill Site A are presented in Figure 4.47 for the dry weather season. Waste type (Class II or Class III) is identified as the landfill is permitted for both waste types (the only landfill in this study to have permit for Class II waste). Based on comparison of the median flux values, the Interim-II (Class II MSW) location was associated with the greatest fluxes for all gases analyzed. This location also had the greatest variability in methane emissions. The Daily-Class III cover location had higher fluxes than the Daily-Class II cover location, where the Daily-Class II cover had a higher probability of uptake over emissions (particularly for methane and nitrous oxide). The intermediate cover systems had an opposite trend, in which the Interim-Class III cover had lower emissions of all target gases. Fluxes of all target gases were significantly higher and less variable from the alternative cover system as compared to the conventional final cover system (Figure 4.47). The magnitude and extent of NMVOC fluxes were generally comparable across all testing locations, where the Interim-Class II cover had the highest fluxes (based on the mean and median values in the boxplots) (Figure 4.47).

Figure 4.47 Measured Fluxes at Landfill Site A by Individual Cover Type in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

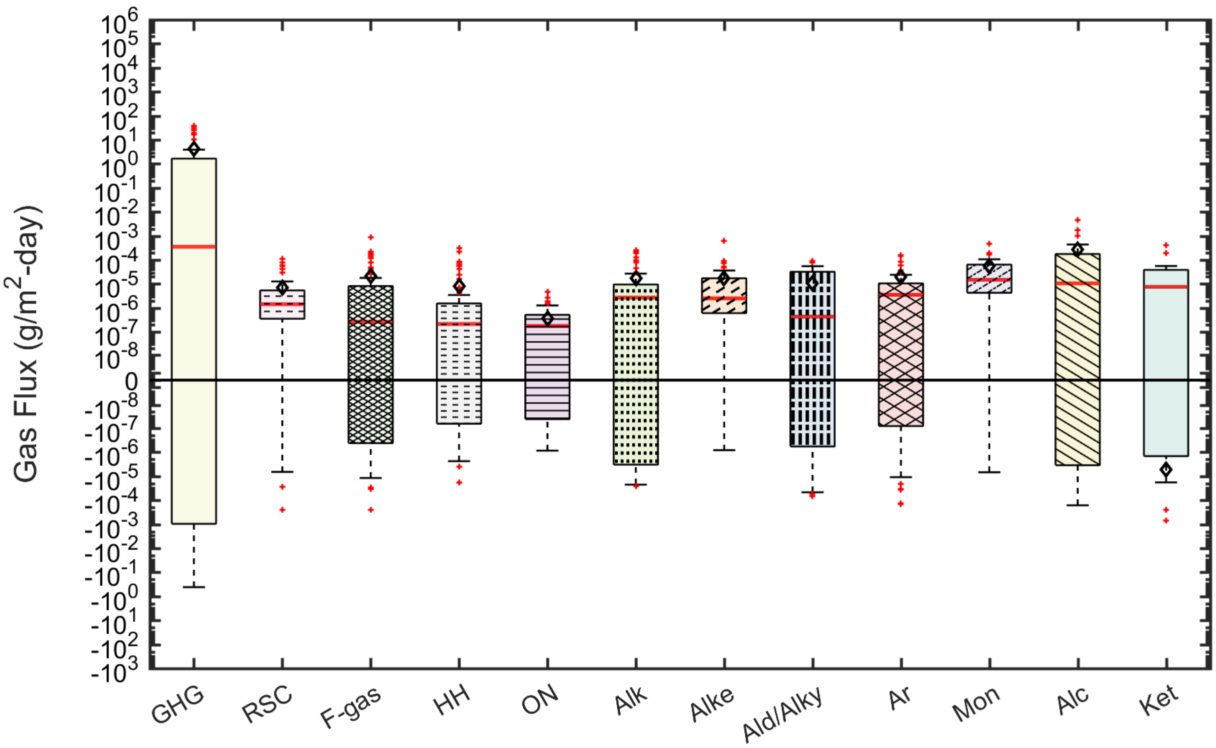


4.3.4.2 Wet Season Test Results

At Landfill Site A, flux testing conducted during the wet season differed from the dry season in several aspects. The number of acceptable flux measurements remained at 78% (N=771 flux measurements), where the contribution from low R^2 values were on the order of 19% and the below detection limit measurements amounted to 3%. The overall range (including all chemical families) in measured fluxes changed from -2.54x10^{-3} to 3.77x10^{1} g/m^2-day in the dry season to -4.15x10^{-1} to 3.97x10^{1} g/m^2-day in the wet season. The percentage of measurements that were positive deceased from 83% in the dry season to 70% in the wet season. The median value of positive measurements increased (4.21x10^{-6} g/m^2-day). Positive fluxes (out of the cover) and negative fluxes (into the cover) varied by 10 (from 1.12x10^{-8} to 3.97x10^{1} g/m^2-day) and 8 (-4.15x10^{-1} to -9.12x10^{-9} g/m^2-day) orders of magnitude, respectively.

Figure 4.48 presents box plots summarizing the flux measurements conducted across all testing locations at Landfill Site A during the wet weather season organized by chemical family. The baseline GHG fluxes remained dominant out of all chemical families included in the project. However, the variation in measured fluxes decreased during wet season testing. Median flux values of the baseline GHGs decreased approximately an order of magnitude. The corresponding IQRs and IWRs decreased by a factor of three from the dry to wet season field measurement campaigns (Figure 4.48). Average skewness and kurtosis values summarizing the overall distributions of flux measurements increased to 1.1 and 4.5, respectively, during the wet season campaign. This result implied that the distributions of flux measurements became less symmetric and homogenous (more positively skewed and heavier tailed) as a smaller proportion of measurements were observed to be negative. The higher kurtosis value indicated higher variation in the fluxes in the wet than the dry season.

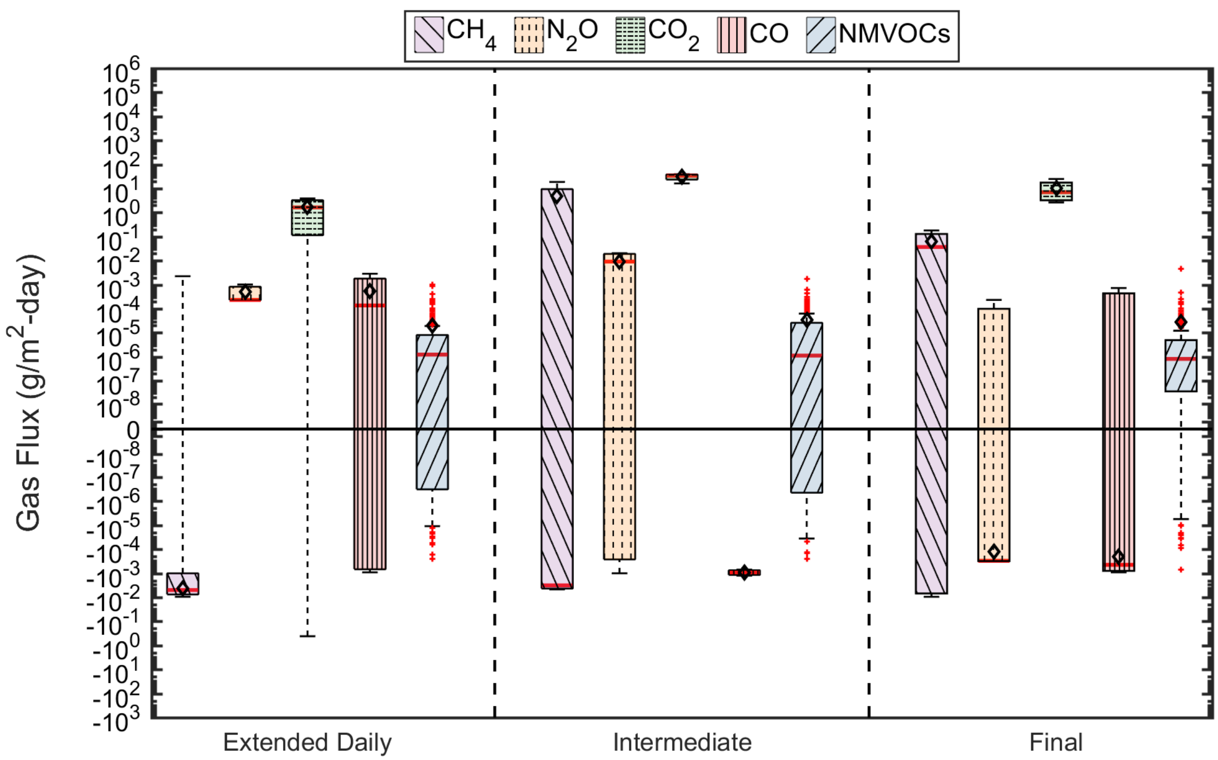
Figure 4.48 Measured Fluxes at Landfill Site A by Chemical Family in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



Overall, median NMVOC fluxes decreased by an order of magnitude during the wet season at Landfill Site A. In addition, the variation in NMVOC flux measurements, as assessed using the average IQR and IWR across NMVOC families, slightly increased during the wet season (Figure 4.48). The monoterpenes, alcohols, and ketones were the most highly emitting NMVOC families, which was slightly different than those observed during the dry season. The highest median fluxes for specific chemical species within each family were measured for alpha-Pinene, methanol, and acetone. Unlike the baseline GHGs, the range in overall NMVOC emissions decreased during the wet season to -7.13×10^{-4} to 4.52×10^{-3} g/m^2-day.

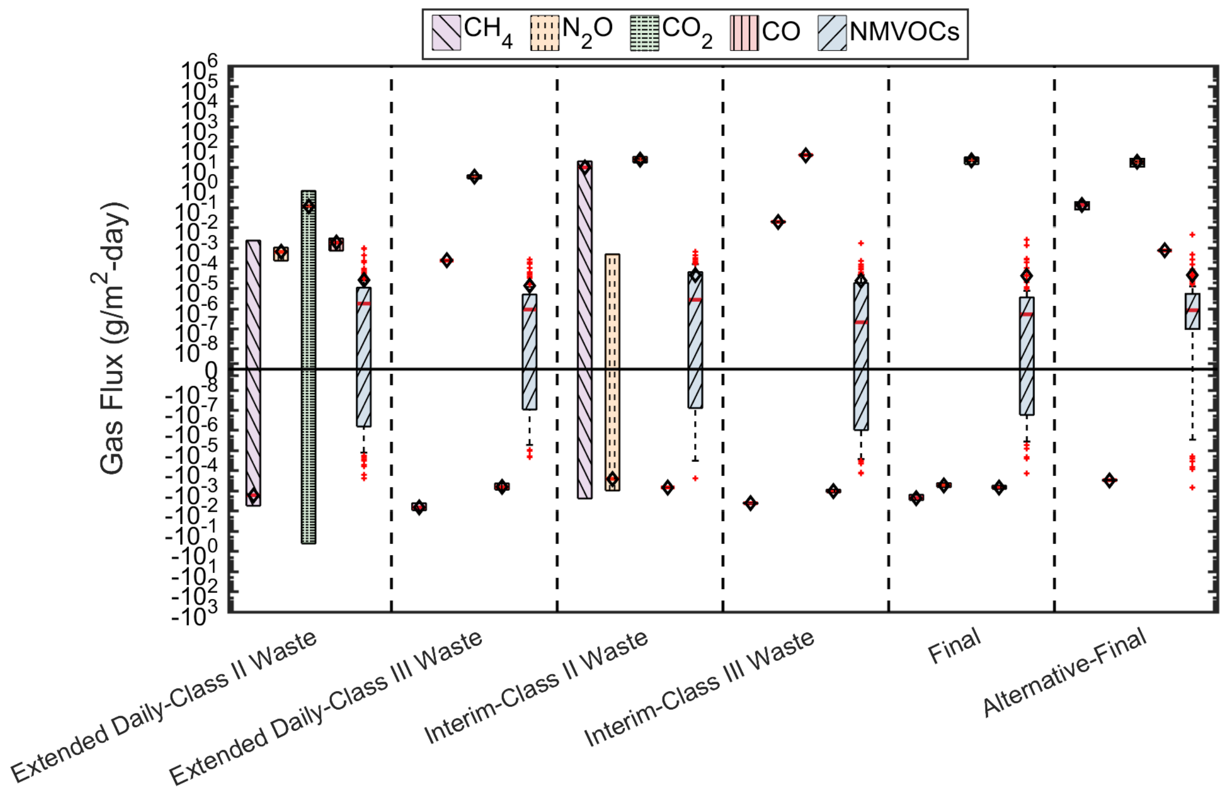
Measured fluxes of the project gases at Landfill Site A as a function of overall cover category are presented in Figure 4.49 for the wet season. Generally, the baseline GHGs (specifically carbon dioxide) had the highest median flux values across all cover categories. For NMVOCs, the highest median fluxes for extended daily, intermediate, and final covers were for the ketones, monoterpenes, and monoterpenes, respectively. By individual chemical species, the highest fluxes observed for extended daily, intermediate, and final covers were all for beta pinene. Based on mean and median data the methane fluxes did not decrease from the daily to intermediate to final covers, with low values measured at the extended daily cover locations in contrast to general trends observed for the different cover systems at the other landfills. The variation in the baseline greenhouse gas emissions increased for the intermediate cover systems, in particular for methane and nitrous oxide, where long interquartile lengths were observed. Higher variation in flux measurements were observed for extended daily cover systems in place at Site A Landfill during the dry season, particularly for methane and nitrous oxide. The variation in final cover flux measurements was generally higher in the wet season than the dry season for methane and similar for nitrous oxide, given the longer IQR and IWR observed in Figure 4.49 as compared to Figure 4.46. The NMVOC fluxes were relatively similar with lower values for the final cover compared to the other cover categories. The variation in the NMVOC flux measurements was generally highest across the intermediate cover sites (Figure 4.49).

Figure 4.49 Measured Fluxes at Landfill Site A by Overall Cover Category in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



The fluxes from individual cover systems are presented in Figure 4.50 for the wet season. Similar to the dry season, the Interim-II cover location had the largest methane and NMVOC fluxes. Nitrous oxide and carbon dioxide emissions were highest for the Daily-II and Interim-III cover locations, respectively. More variation in flux measurements were observed for the Daily-II cover location in the wet than the dry season, where the probability of uptake over net emissions increased during the wet season field campaigns. Net uptake of methane over emissions was observed for both daily cover locations, which had the reverse trend during the dry season (net emissions over uptake). Similar to results presented for the dry season, very high methane fluxes (with little variation) were observed from the alternative cover site, whereas net uptake was observed for the conventional cover system for methane and nitrous oxide (Figure 4.50) during the wet season. Moreover, NMVOC flux measurements were higher from the alternative cover as compared to the final cover, consistent with trends observed during the dry season.

Figure 4.50 Measured Fluxes at Landfill Site A by Individual Cover Type in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



4.3.4.3 Summary of Flux Measurements from Site A Landfill

A comprehensive summary of the flux measurements obtained from the dry and wet season field campaigns at Site A Landfill is presented in Table 4.5. Overall minimum, maximum, and median flux values are organized in Table 4.5 according to chemical family and season. Measurements presented in Table 4.5 are intended to provide supplemental quantitative data to the boxplots included in the previous sections above to facilitate interpretation of the results.

Table 4.5 – Summary of Flux Measurements Obtained from Site A Landfill

Chemical Family	Dry Season (g/m^2-day)			Wet Season (g/m^2-day)		
	Min	Max	Median	Min	Max	Median
GHG	-2.54×10^{-3}	3.77×10^{1}	1.19×10^{-3}	-4.15×10^{-1}	3.97×10^{1}	2.35×10^{-4}
RSC	-8.53×10^{-7}	3.93×10^{-5}	1.14×10^{-6}	-2.48×10^{-4}	1.14×10^{-4}	2.08×10^{-6}
F-gases	-1.34×10^{-5}	4.66×10^{-3}	1.21×10^{-6}	-2.51×10^{-4}	8.92×10^{-4}	2.38×10^{-7}
HH	-3.14×10^{-6}	8.97×10^{-5}	2.44×10^{-7}	-1.78×10^{-5}	3.12×10^{-4}	2.12×10^{-7}
ON	-1.45×10^{-7}	2.64×10^{-7}	4.89×10^{-8}	-8.60×10^{-7}	4.54×10^{-6}	1.45×10^{-7}
Alk	-4.09×10^{-5}	9.36×10^{-5}	5.63×10^{-6}	-2.53×10^{-5}	2.60×10^{-4}	3.76×10^{-6}
Alke	-3.07×10^{-5}	1.40×10^{-4}	1.04×10^{-6}	-8.22×10^{-7}	6.25×10^{-4}	2.27×10^{-6}
Ald/Alky	-2.58×10^{-5}	1.29×10^{-4}	2.72×10^{-6}	-6.98×10^{-5}	9.03×10^{-5}	-1.68×10^{-7}
Ar	-1.47×10^{-4}	5.40×10^{-5}	1.94×10^{-6}	-1.45×10^{-4}	1.60×10^{-4}	2.28×10^{-6}
Mon	-6.58×10^{-5}	8.49×10^{-5}	1.92×10^{-6}	-6.85×10^{-6}	4.76×10^{-4}	1.50×10^{-5}
Alc	-5.18×10^{-5}	1.11×10^{-3}	1.32×10^{-5}	-1.62×10^{-4}	4.52×10^{-3}	1.07×10^{-5}
Ket	-2.67×10^{-4}	9.84×10^{-4}	1.08×10^{-5}	-7.13×10^{-4}	4.20×10^{-4}	4.41×10^{-6}

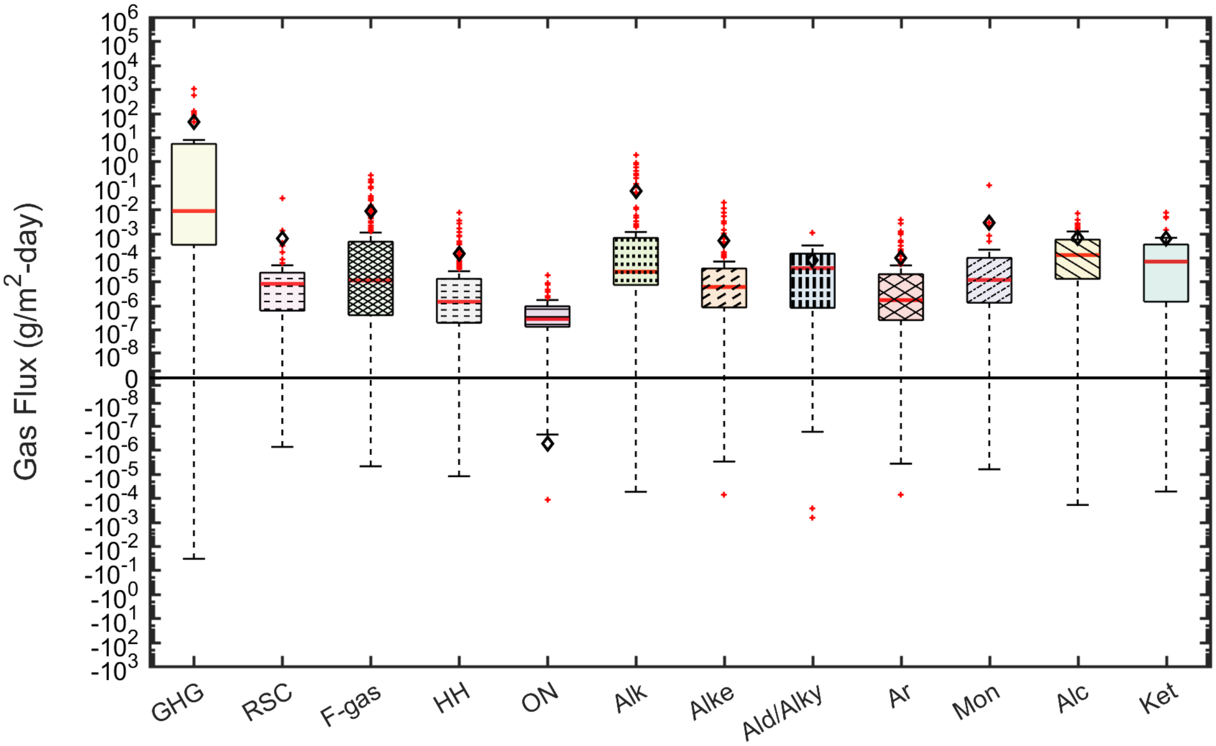
4.3.5 Chiquita Canyon Landfill

4.3.5.1 Dry Season Test Results

Figure 4.51 presents box plots summarizing the flux measurements conducted across all testing locations at Chiquita Canyon Landfill during the dry weather season organized by chemical family. Out of the 1148 potential measurements that could be obtained at this site, 937 measurements (82%) were viable given the R^2 threshold applied in this study. The remaining approximately 15% and 3% of flux measurements were not included due to low R^2 value and below detection limit/analytical measurement errors, respectively. Overall, surface fluxes (including all chemical families) for this testing campaign varied from -3.37×10^{-2} to 1.07×10^{3} g/m^2-day. A high majority of the measured fluxes were positive (90%) with a median flux of 7.66×10^{-6} g/m^2-day. Positive fluxes (out of the cover) and negative fluxes (into the cover) varied by 11 orders of magnitude (from 7.78×10^{-9} to 1.07×10^{3} g/m^2-day) and 6 orders of magnitude (-3.40×10^{-2} to -1.46×10^{-8} g/m^2-day), respectively.

At Chiquita Canyon Landfill, the baseline greenhouse gas fluxes were dominant. The variation of the GHGs was higher than the variation of the NMVOCs included in the investigation (Figure 4.51). Average skewness and kurtosis values were 2.1 and 6.9, respectively and IQRs were above zero, demonstrating the higher probability of net emissions over uptake and high variation in the measured fluxes for a given chemical family. Limited probability of uptake was present for multiple chemical families, as the IQRs did not extend below zero. The likelihood for uptake over emissions was greatest for the GHGs, and also observed for the alkanes, aromatics, monoterpenes, halogenated hydrocarbons, and alcohols based on the span of the lower whiskers below zero (Figure 4.51).

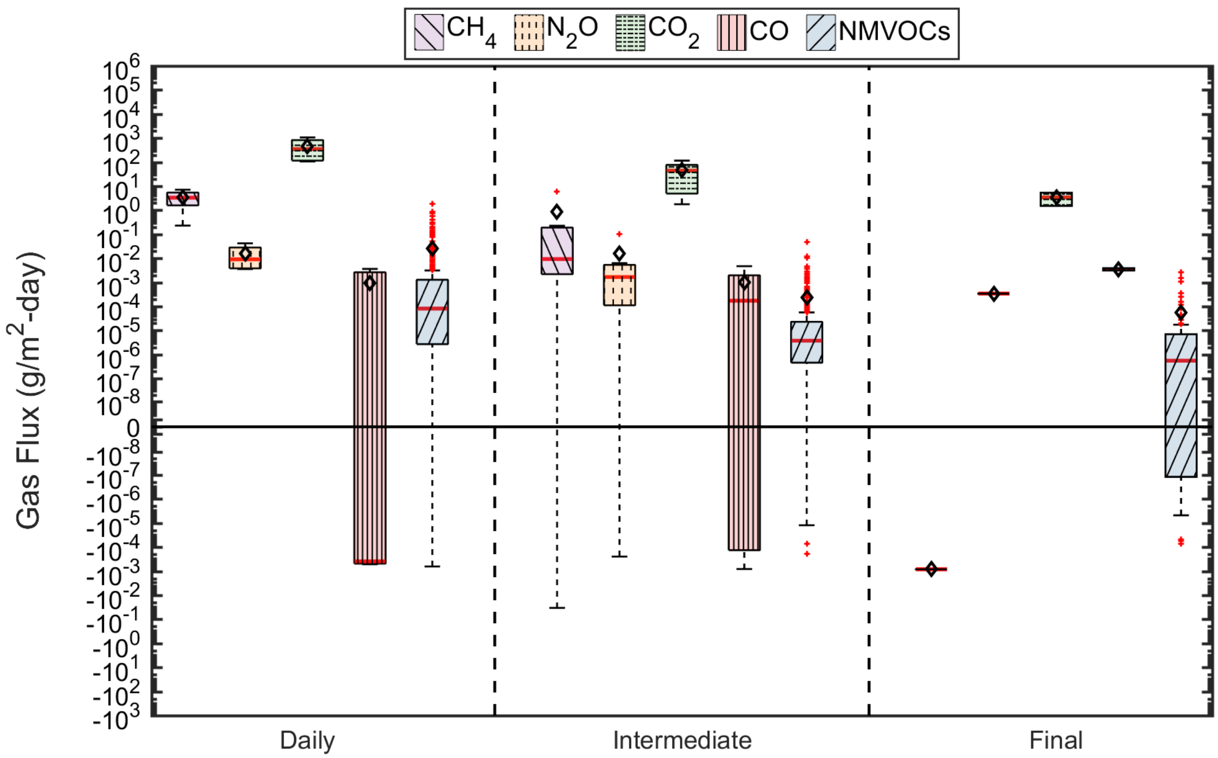
Figure 4.51 Measured Fluxes at Chiquita Canyon Landfill by Chemical Family in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



Among the NMVOCs investigated, the alcohols, ketones, and aldehydes/alkynes had the highest median flux values (Figure 4.51). The NMVOC fluxes were relatively similar (assessed using IQR and IWR) across all NMVOC chemical families with the exception of the reduced sulfur compounds, organic alkyl nitrates, and halogenated hydrocarbons, that demonstrated lower variations in measured fluxes (Figure 4.51). Overall NMVOC emissions ranged from -6.39×10^{-4} to 1.81×10^{0} g/m^2-day.

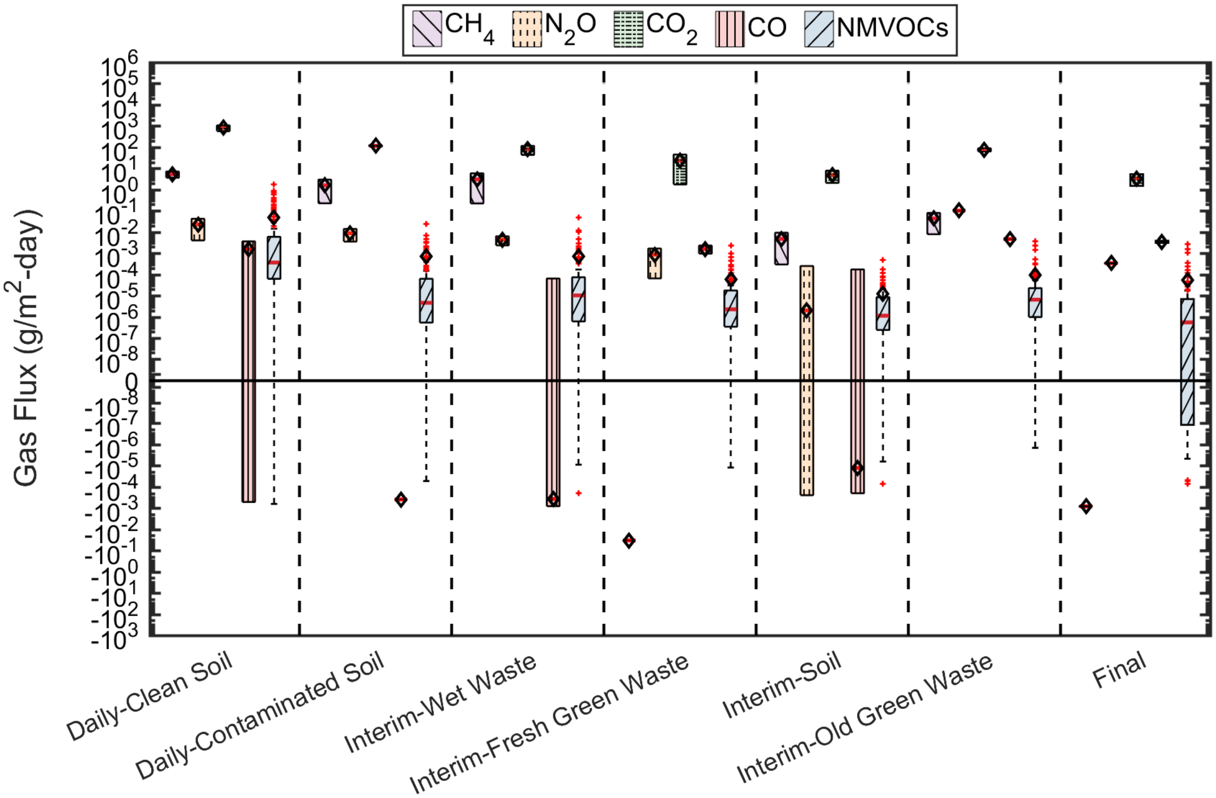
Measured fluxes of the project gases at Chiquita Canyon Landfill as a function of overall cover category are presented in Figure 4.52 for the dry season. Generally, the baseline GHGs (specifically carbon dioxide) had the highest maximum and median flux values across all cover categories. For NMVOCs, the highest median flux for daily, intermediate, and final covers were for the alkanes, alcohols, and ketones, respectively. By individual chemical species, the highest fluxes observed for the daily, intermediate, and final covers were for i-Butene, i-Butene, and limonene, respectively. The fluxes generally decreased from daily to intermediate to final cover locations for all target gases. The decreases in flux were relatively significant from daily to intermediate cover systems, where the differences in median fluxes were between 5.30×10^{-5} (NMVOCs) and 2.24×10^{-1} (GHGs). On average, decreases in flux were smaller from intermediate to final covers, particularly for nitrous oxide (Figure 4.52) For dry weather tests, a high number of uptake measurements were obtained for methane through the final covers at Chiquita Canyon Landfill, as indicated by the median values and distribution of flux measurements below zero. For a given GHG, variability in the measured fluxes were higher at the intermediate cover locations compared to the daily cover locations, whereas the variability in NMVOC measurements was relatively high at the daily cover locations, and decreased progressing from daily to intermediate to final cover systems (Figure 4.52).

Figure 4.52 Measured Fluxes at Chiquita Canyon Landfill by Overall Cover Category in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



The fluxes for individual cover systems at Chiquita Canyon Landfill are presented in Figure 4.53 for the dry weather season. Flux measurements for all target gases were generally higher at the daily cover location with clean soil than all other testing locations. The Interim-Wet Waste cover location had the highest distribution of flux measurements of all intermediate cover locations for a majority of target gases analyzed (i.e., excluding nitrous oxide). The Interim-Old Green Waste also had relatively high fluxes of methane, carbon dioxide, and nitrous oxide. The methane fluxes were low for the Interim-Fresh Green Waste cover location in comparison to the other intermediate covers (Figure 4.53). The magnitude and extent of NMVOC emissions were generally comparable across all testing locations, where the Daily-Clean Soil location had the highest fluxes (based on the mean and median values of the boxplots) (Figure 4.53).

Figure 4.53 Measured Fluxes at Chiquita Canyon Landfill by Individual Cover Type in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

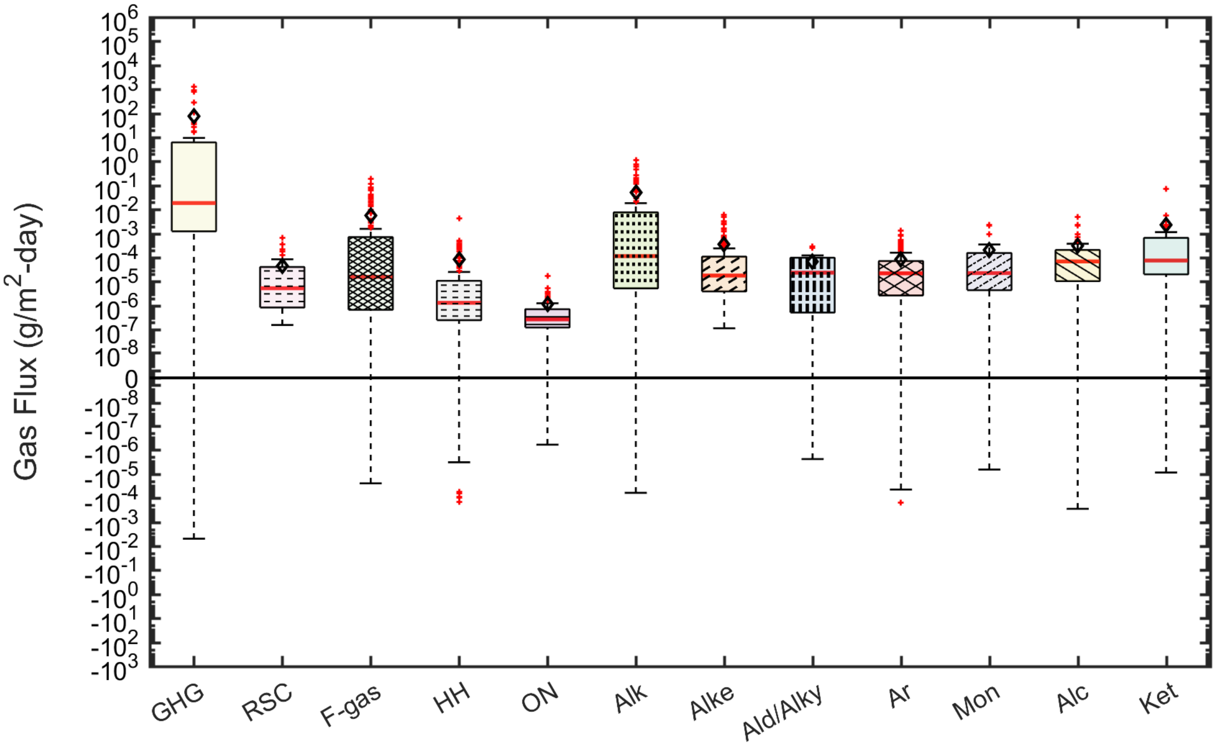


4.3.5.2 Wet Season Test Results

At Chiquita Canyon Landfill, flux testing conducted during the wet season differed from the dry season in various aspects. The number of acceptable flux measurements increased to 86% (N=987 flux measurements), where the contribution from low R^2 values were on the order of 12% and the below detection limit measurements amounted to 2%. The overall range (including all chemical families) in measured fluxes changed from -3.37×10^{-2} to 1.07×10^{3} g/m^2-day in the dry season to -4.91×10^{-3} to 1.31×10^{3} g/m^2-day in the wet season. The percentage of measurements that were positive increased from 90% in the dry season to 93% in the wet season. The median value of positive measurements also increased (1.66×10^{-5} g/m^2-day). Positive fluxes (out of the cover) and negative fluxes (into the cover) varied by 11 (from 1.24×10^{-8} to 1.31×10^{3} g/m^2-day) and 5 (-4.91×10^{-3} to -1.86×10^{-8} g/m^2-day) orders of magnitude, respectively.

Figure 4.54 presents box plots summarizing the flux measurements conducted across all testing locations at Chiquita Canyon Landfill during the wet weather season organized by chemical family. The baseline GHG fluxes remained dominant out of all chemical families included in the project. However, the variation in measured fluxes decreased during wet season testing. Median flux values of the baseline GHGs increased by approximately an order of magnitude. The corresponding IQRs and IWRs increased when progressing from the dry to wet season field campaigns (Figure 4.54). Average skewness and kurtosis values summarizing the overall distributions of flux measurements decreased to 1.86 and 5.86, respectively, during the wet season. This result implied that the distributions of flux measurements became more symmetric and homogenous (less positively skewed and lighter tailed) as a smaller proportion of measurements were observed to be negative. The higher kurtosis value was indicative of a greater probability of high fluxes for a given chemical family.

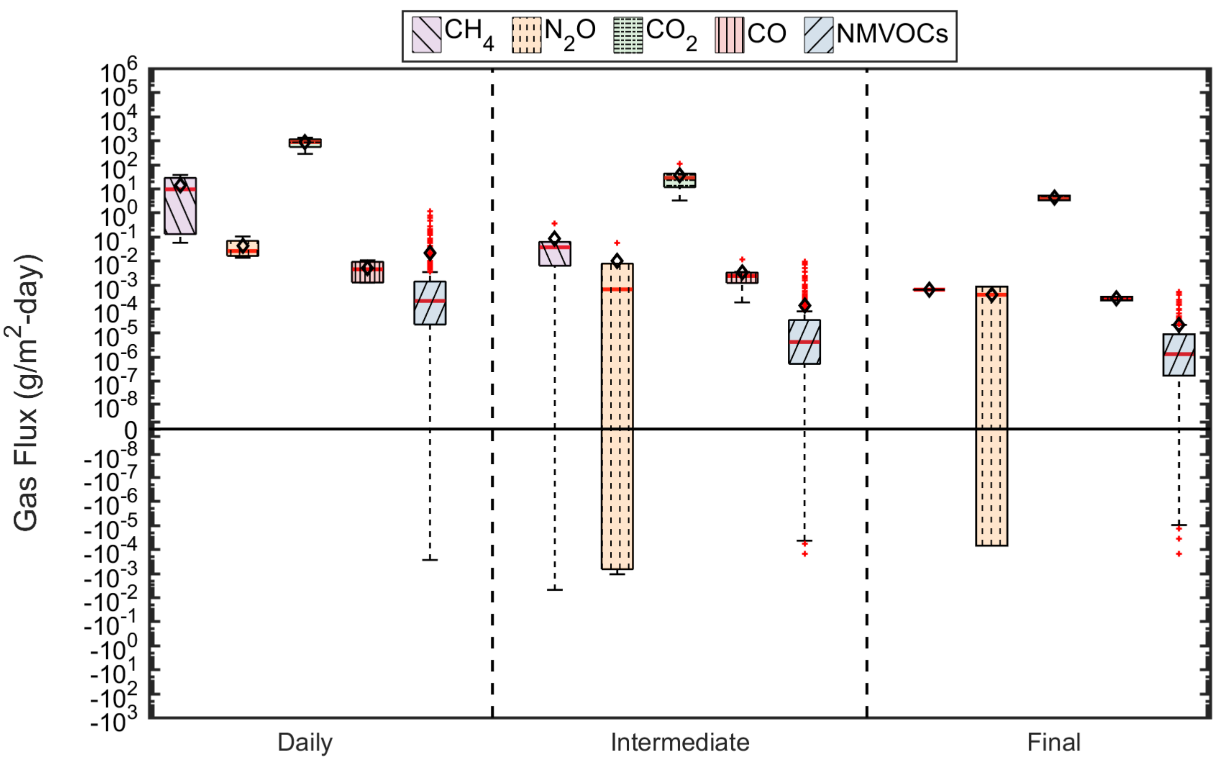
Figure 4.54 Measured Fluxes at Chiquita Canyon Landfill by Chemical Family in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



Overall, median NMVOC fluxes slightly increased during the wet season at Chiquita Canyon Landfill. In addition, the variation in NMVOC flux measurements, as assessed using the average IQR and IWR across NMVOC families, slightly increased during the wet season (Figure 4.54). The alkanes, ketones, and alcohols had the highest median fluxes among the NMVOC families, which was slightly different than the observations during the dry season. The highest median fluxes for specific chemical species within each family were measured for i-Pentane, acetone, and methanol. Similar to the baseline GHGs, the range in overall NMVOC emissions decreased during the wet season to -2.80×10^{-4} to 1.12×10^{0} g/m^2-day.

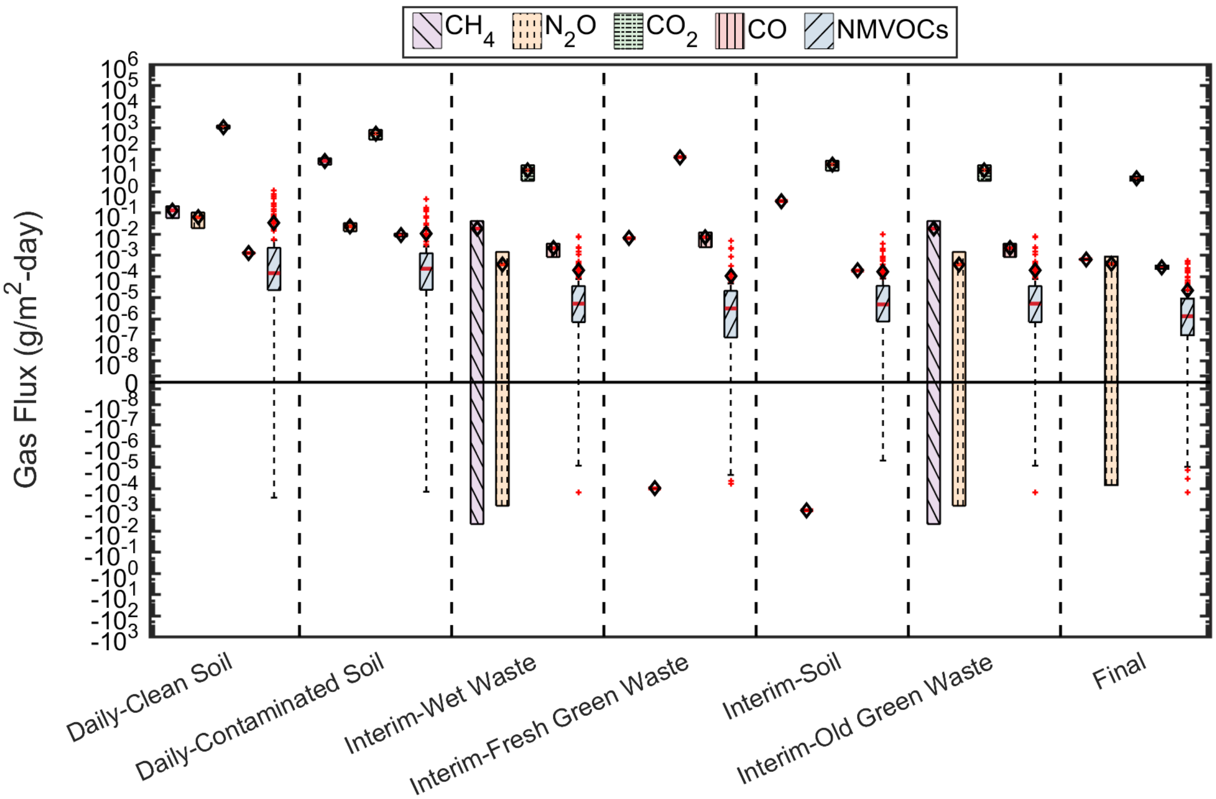
Measured fluxes of the project gases at Chiquita Canyon Landfill as a function of overall cover category are presented in Figure 4.55 for the wet season. Generally, the baseline GHGs (specifically carbon dioxide) had the highest median flux values across all cover categories. For MNVOCs, the highest median fluxes for daily, intermediate, and final covers were for the alkanes, alkanes, and aldehydes/alkynes, respectively. By individual chemical species, the highest fluxes observed for daily, intermediate, and final covers were for i-Butene, i-butene, and beta-pinene. The central tendencies of methane, nitrous oxide, and carbon dioxide flux measurements generally decreased from daily to intermediate to final cover systems at Chiquita Canyon Landfill during the wet season. However, the variation in the baseline greenhouse gas emissions increased for nitrous oxide and carbon dioxide from the daily to the intermediate cover systems, where long interquartile lengths were observed. Variation in flux measurements were observed to be relatively similar for the daily and intermediate cover systems during the dry and wet seasons. The variation in final cover flux measurements was generally higher in the wet season than the dry season for nitrous oxide, given the longer IQR and IWR observed in Figure 4.55 as compared to Figure 4.52, demonstrating some tendency for net uptake over emissions. Fluxes of NMVOCs generally decreased from daily to intermediate to final cover systems at Chiquita Canyon Landfill during the wet season which corresponded with a decrease in the variation of flux measurements (Figure 4.55).

Figure 4.55 Measured Fluxes at Chiquita Canyon Landfill by Overall Cover Category in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



The fluxes from individual cover systems are presented in Figure 4.56 for the wet season. Out of all cover categories investigated, the Interim-Soil cover location had the highest emissions of methane; however, this cover was also associated with the highest uptake of nitrous oxide. In the wet season, NMVOC emissions were greatest for the daily cover with contaminated soil, which contrasted the results obtained during the dry season. Methane and nitrous oxide emissions were most variable from the Interim-Wet Waste and Interim-Old Green Waste cover locations (Figure 4.56). Net emissions and uptake of methane and nitrous oxide, respectively, were observed from the Interim-Fresh Green Waste cover location in contrast to the observations in the dry season.

Figure 4.56 Measured Fluxes at Chiquita Canyon Landfill by Individual Cover Type in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



4.3.5.3 Summary of Flux Measurements from Chiquita Canyon Landfill

A comprehensive summary of the flux measurements obtained from the dry and wet season field campaigns at Chiquita Canyon Landfill is presented in Table 4.6. Overall minimum, maximum, and median flux values are organized in Table 4.6 according to chemical family and season. Measurements presented in Table 4.6 are intended to provide supplemental quantitative data to the boxplots included in the previous sections above to facilitate interpretation of the results.

Table 4.6 – Summary of Flux Measurements Obtained from Chiquita Canyon Landfill

Chemical Family	Dry Season (g/m^2-day)			Wet Season (g/m^2-day)		
	Min	Max	Median	Min	Max	Median
GHG	-3.37×10^{-2}	1.07×10^{3}	8.67×10^{-3}	-4.91×10^{-3}	1.31×10^{3}	1.16×10^{-2}
RSC	-7.45×10^{-7}	2.88×10^{-2}	8.12×10^{-6}	1.57×10^{-7}	6.51×10^{-4}	6.18×10^{-6}
F-gases	-4.76×10^{-6}	2.73×10^{-1}	1.12×10^{-5}	-9.84×10^{-6}	1.93×10^{-1}	1.89×10^{-5}
HH	-1.24×10^{-5}	7.29×10^{-3}	1.45×10^{-6}	-1.47×10^{-4}	4.41×10^{-3}	1.17×10^{-6}
ON	-1.16×10^{-4}	1.82×10^{-5}	2.81×10^{-7}	-6.00×10^{-7}	1.72×10^{-5}	2.24×10^{-7}
Alk	-5.48×10^{-5}	1.81×10^{0}	2.61×10^{-5}	-6.06×10^{-5}	1.12×10^{0}	2.60×10^{-4}
Alke	-7.31×10^{-5}	1.90×10^{-2}	6.04×10^{-6}	1.14×10^{-7}	6.26×10^{-3}	1.92×10^{-5}
Ald/Alky	-6.39×10^{-4}	1.06×10^{-3}	3.66×10^{-5}	-7.15×10^{-7}	2.97×10^{-4}	3.24×10^{-5}
Ar	-7.49×10^{-5}	3.66×10^{-3}	1.71×10^{-6}	-1.60×10^{-4}	1.36×10^{-3}	1.63×10^{-5}
Mon	-6.34×10^{-6}	9.91×10^{-2}	1.18×10^{-5}	-6.50×10^{-6}	2.36×10^{-3}	2.14×10^{-5}
Alc	-1.93×10^{-4}	6.89×10^{-3}	1.29×10^{-4}	-2.80×10^{-4}	4.86×10^{-3}	6.99×10^{-5}
Ket	-5.35×10^{-5}	7.28×10^{-3}	6.85×10^{-5}	-8.65×10^{-6}	7.12×10^{-2}	7.59×10^{-5}

4.4 Static Flux Chamber Measurements at 5 Landfills – Inter-Landfill Variations

Surface fluxes are now compared across all of the 5 landfills included in the static flux chamber field campaigns. Results are presented for the two measurement seasons: dry and wet seasons. Variations in flux across different landfills due to cover locations/types and chemical species are investigated. Results are organized from the smallest to largest landfill site tested in terms of waste in place consistent with the order used throughout the report. Results obtained for the dry season testing campaigns are presented first, followed by the wet season testing campaigns.

4.4.1 Dry Season Test Results

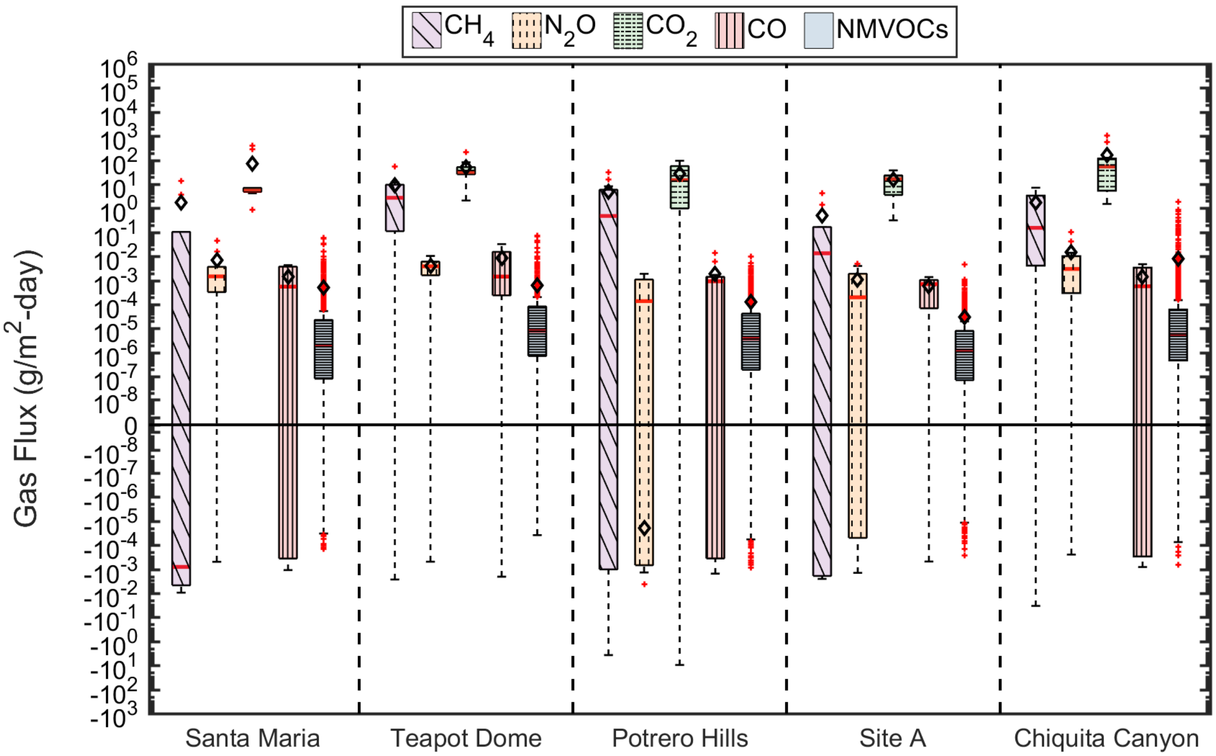
During the dry weather season testing campaigns, overall flux values ranged from -9.6×10^{0} to 1.07×10^{3} g/m^2-day across all landfills, with an overall median value of 3.66×10^{-3} g/m^2-day. The composite mean and standard deviation was 1.09 ± 21.2 g/m^2-day (N = 3937 total flux measurements) across all landfills and chemical families. The minimum and maximum fluxes were measured at Potrero Hills and Chiquita Canyon Landfills, respectively.

Median flux values were greatest for Teapot Dome Landfill across all landfills and chemical families during the dry season. The composite means of all distributions of flux measurements across chemical families indicated that Chiquita Canyon was associated with the greatest emissions, contradicting the median results. Based on IQRs and IWRs, the largest variation in flux measurements during the dry season was observed for Teapot Dome Landfill. Both the magnitude and variation in overall fluxes was smallest for Site A Landfill during the dry season. Average skewness (3.74) and kurtosis (24.5) values across all sites and chemical families indicated that the overall distribution in flux measurements was positively skewed and heavy tailed, suggesting greater probability of emissions over uptake and great variation in flux.

Across all landfill sites, positive and negative fluxes varied 11 (4.18×10^{-9} to 1.07×10^{3}) and 10 (-9.59×10^{0} to -2.10×10^{-9}) orders of magnitude, respectively. The inter-site variation in positive fluxes (11 orders of magnitude) was generally greater than the intra-site variation in positive fluxes for all landfills (10 orders of magnitude) excluding Santa Maria and Chiquita Canyon Landfills (11 orders of magnitude) during the dry season. Similarly, the inter-site variation in negative fluxes was generally greater than the intra-site variation in negative fluxes (5-10 orders of magnitude) for all landfills during the dry season.

An inter-landfill comparison of methane, nitrous oxide, carbon dioxide, carbon monoxide, and NMVOC flux measurements obtained during the dry season is presented in Figure 4.57. Median methane and nitrous oxide fluxes were generally highest from Teapot Dome and Chiquita Canyon Landfills during the dry season (Figure 4.57). Carbon dioxide and carbon monoxide fluxes were greatest at Chiquita Canyon and Teapot Dome Landfills, respectively. Analysis of the distributions in overall NMVOC flux values confirmed the trends presented above that Teapot Dome Landfill had the highest measured fluxes. The positive skewness of the distribution in NMVOC fluxes was highest for Chiquita Canyon Landfill, as indicated by the high number of positive outliers and the high mean flux values. The variation in flux measurements (based on IQR/IWR) was highest for Potrero Hills Landfill, especially for methane, nitrous oxide, carbon monoxide, and carbon dioxide gases (Figure 4.57).

Figure 4.57 Inter-Landfill Comparison of GHG and NMVOC fluxes for the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).



Figures 4.58a and 4.58b compare the overall distributions in flux measurements for each landfill site, categorized by chemical family. Based on median flux values, landfill surface flux measurements of the baseline GHGs were highest from Teapot Dome Landfill (Figure 4.58a), confirming the summary statistics presented above (Figure 4.57). Within the GHGs, methane and nitrous oxide fluxes were greatest at Teapot Dome and Santa Maria Regional Landfills, respectively (Figure 4.58b). Variation in GHG fluxes was highest for Teapot Dome and Santa Maria Regional Landfills, as indicated by the wide IQR and IWR of the boxplots. Relying on median flux values as the basis for inter-site comparison of LFG fluxes, the alcohols, ketones, and monoterpenes were the NMVOC chemical families associated with the highest fluxes across the landfills. Based on this analysis, Chiquita Canyon Landfill, Teapot Dome Landfill, and Teapot Dome Landfill were the sites with the highest median fluxes of the top three NMVOC families identified above, respectively. Considering all NMVOC families, Teapot Dome Landfill was the site with the highest median NMVOC flux value as well as the highest corresponding NMVOC IQR/IWR values during the dry season (Figure 4.58). The range in overall NMVOC fluxes was -8.64×10^{-4} to 1.81×10^{0} g/m^2-day across all landfills during the dry season.

Figure 4.58a Overall Inter-Landfill Flux Measurements in the Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

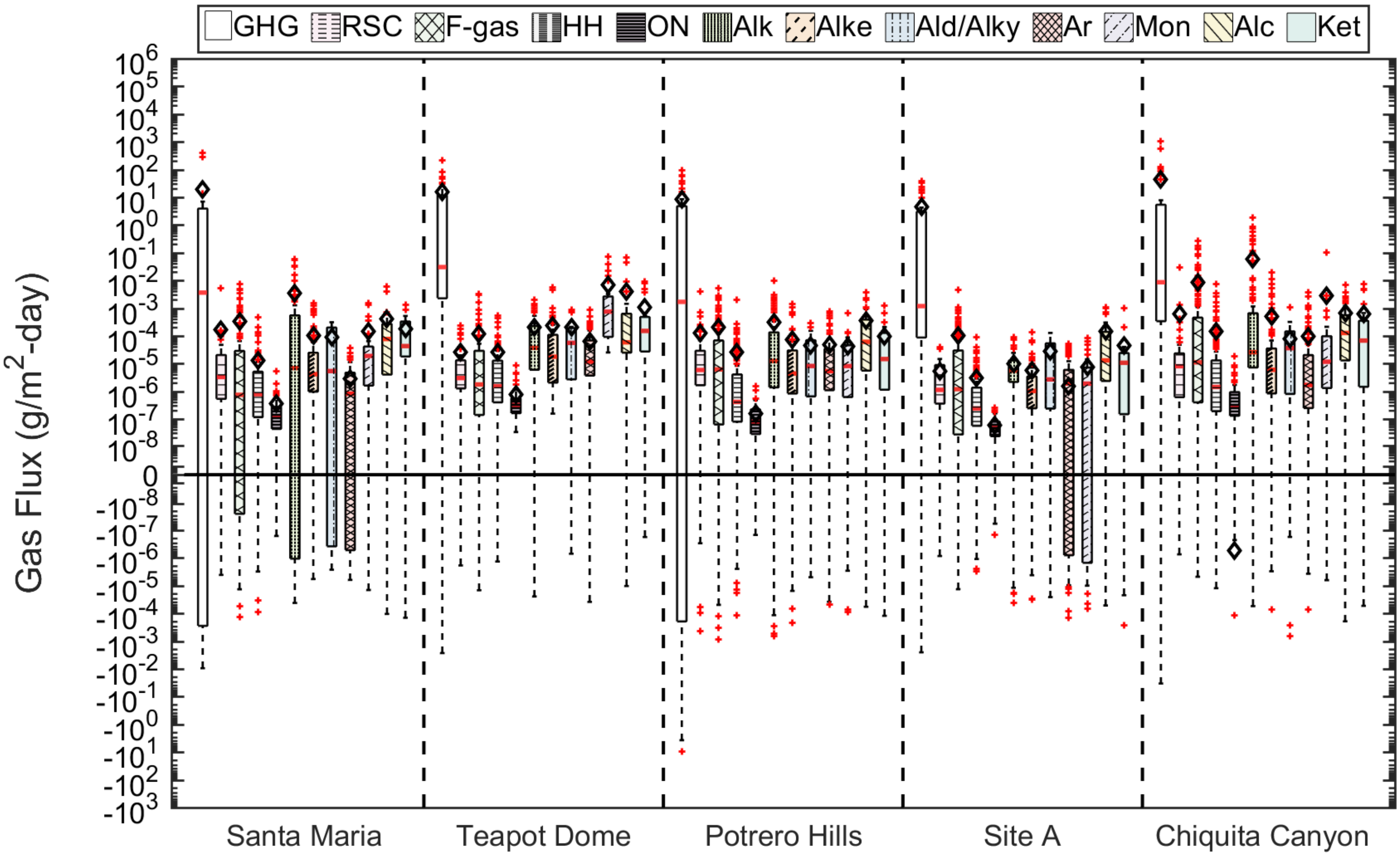


Figure 4.58b Specific GHG and NMVOC Inter-Landfill Flux Measurements in Dry Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

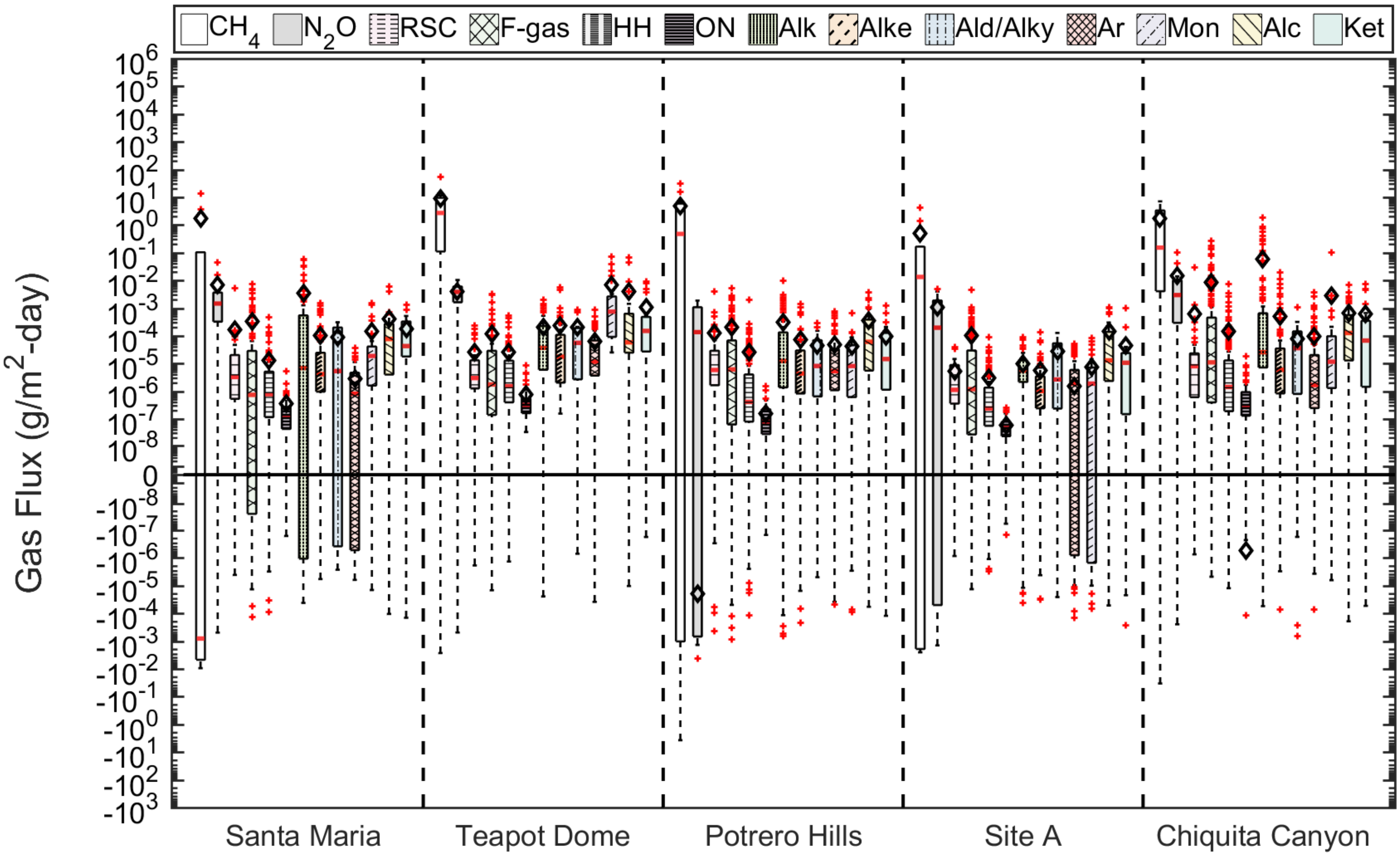


Figure 4.59 compares the GHG and NMVOC flux values collected from all daily, intermediate, and final cover locations at each landfill site during the dry season. As observed in Figure 4.59, GHG and NMVOC fluxes generally decreased progressing from daily to intermediate to final cover systems. GHG and NMVOC fluxes from the final cover of Santa Maria Regional Landfill were slightly higher than those of the intermediate cover. In general, the variation in GHG and NMVOC fluxes (as determined using the IQR/IWR) decreased progressing from daily to intermediate to final cover systems for all target gases analyzed during the dry season (Figure 4.59).

Figure 4.59 Dry Season a) GHG Fluxes and b) NMVOC Fluxes Organized by Site and Cover Category (open black diamonds, red lines, solid red dots represent means, medians, and outliers, respectively).

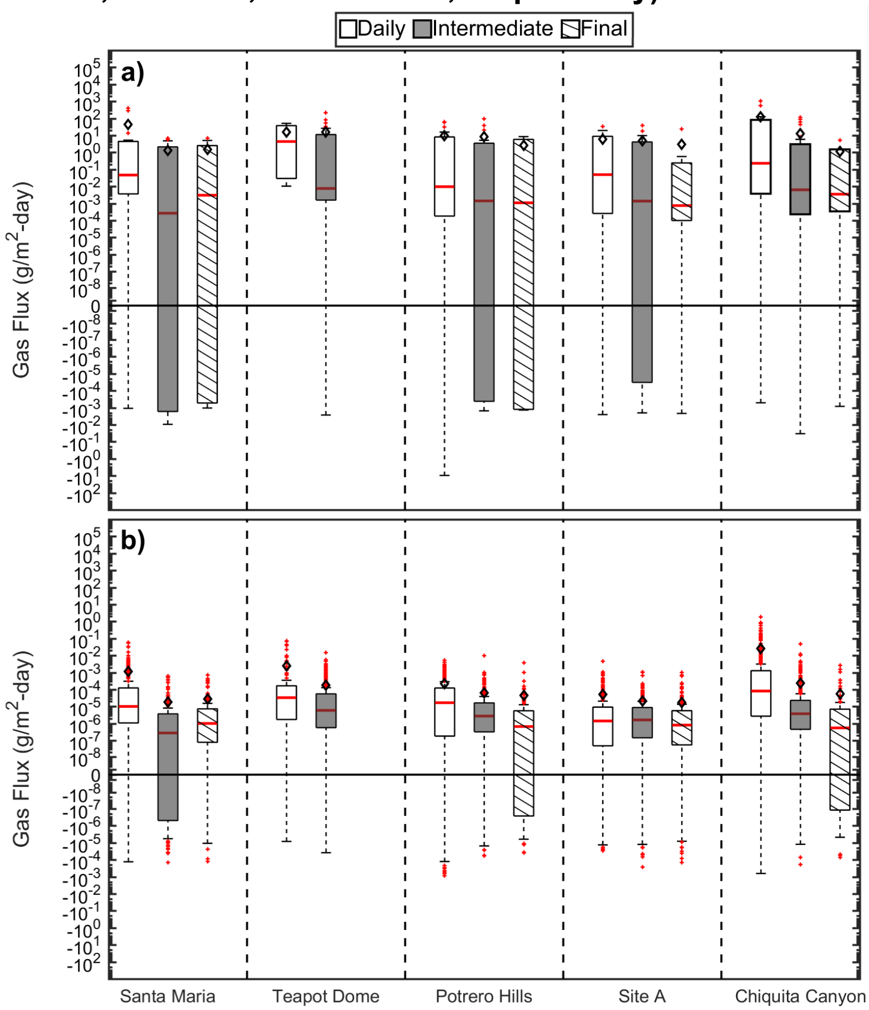
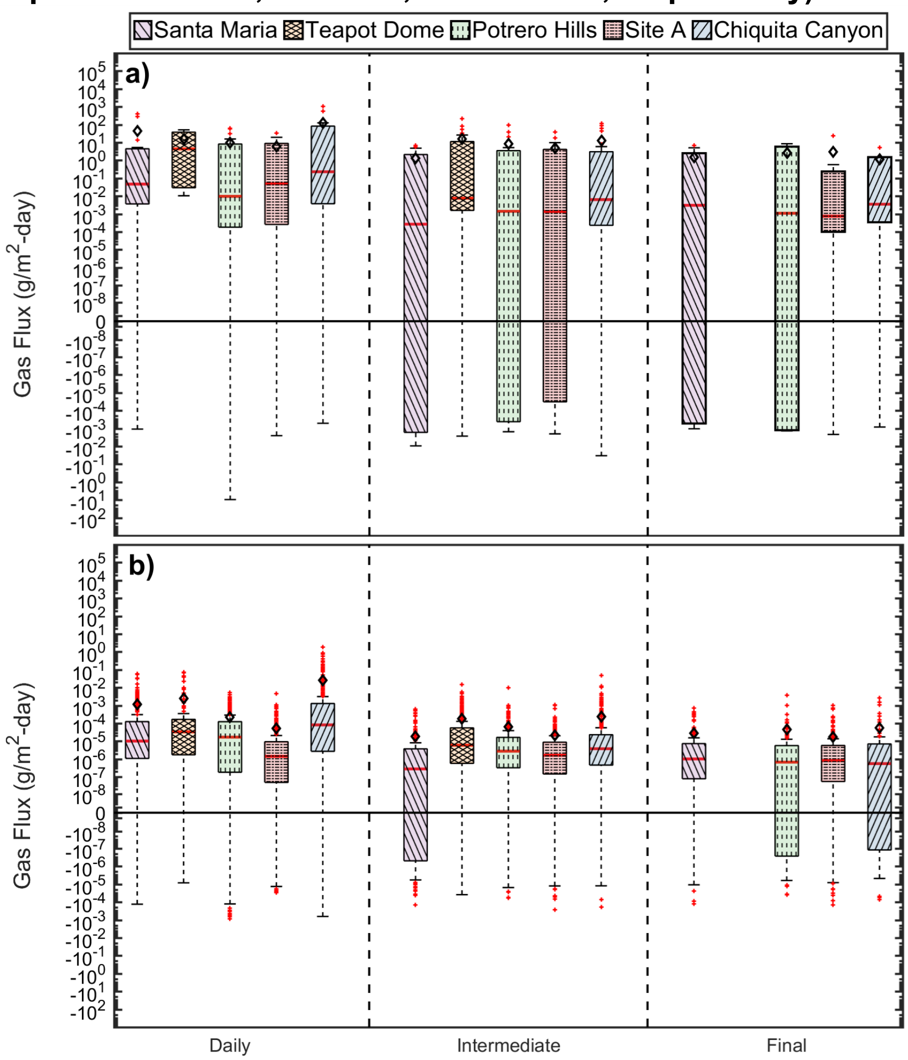


Figure 4.60 provides a detailed comparison of the differences in GHG and NMVOC flux measurements among all landfills as a function of cover category during the dry season. Daily cover flux measurements of GHGs and NMVOCs were highest from Teapot Dome and Chiquita Canyon Landfills, based on median flux values (Figure 4.60). Relying on median flux and the IQR/IWR values, the magnitude and variability of flux measurements from intermediate cover locations were greatest for Teapot

Dome Landfill for both GHGs and NMVOCs. Finally, GHG and NMVOC flux measurements from the final cover systems investigated in this study were generally highest at Santa Maria Reginonal and Chiquita Canyon Landfills, respectively. During the dry season, Chiquita Canyon Landfill had the the highest magnitude and variation of NMVOC fluxes for the final cover system locations. The highest probability of uptake was observed at the intermediate cover locations. Santa Maria Regional Landfill had the largest variation in intermediate-cover NMVOC fluxes based on IQR/IWR values (Figure 4.60).

Figure 4.60 Dry Season a) GHG Fluxes and b) NMVOC Fluxes Organized by Cover Category and Site (open black diamonds, red lines, solid red dots represent means, medians, and outliers, respectively).



4.4.2 Wet Season Test Results

During the wet weather season testing campaigns, overall flux values across all landfill sites ranged from -6.7×10^{0} to 1.31×10^{3} g/m^2-day, with an overall median value of 7.24×10^{-6} g/m^2-day. Compared to the dry weather season, the overall range in fluxes was relatively similar but shifted in the positive direction, towards net emissions over net uptake. Based on median values presented, average flux measurements across all sites were higher in the wet season than the dry season. The composite mean and standard deviation across all sites and chemical families was 1.61±31.5 g/m^2-day (N = 3767 total flux measurements). The corresponding minimum and maximum values in reported fluxes corresponded to Teapot Dome and Chiquita Landfill sites, respectively.

Median flux values, across all chemical families and landfill sites, were greatest for Potrero Hills Landfill during the wet season. Based on the IQRs and IWRs, Chiquita Canyon was concluded to have the largest variation in flux measurements during the wet season. The magnitude and variation in overall flux measurements was smallest for the Altamont and Santa Maria landfill sites, respectively. Average skewness (3.77) and kurtosis (24.7) values across all sites and chemical families indicated that the overall distribution in flux measurements was very positively skewed and heavy tailed, suggesting greater probability of emissions over uptake and presence of emission hot spots. Compared to the dry season of testing, the skewness and kurtosis values increased and decreased slightly.

Across all landfill sites, positive and negative emissions varied 12 (2.44×10^{-9} to 1.31×10^{3}) and 10 (-6.70×10^{0} to -1.40×10^{-9}) orders of magnitude, respectively. The inter-site variation in positive emissions was generally greater than the intra-site variation in positive emissions for all landfill sites (ranging from 10-11) during the wet season. Similarly, the inter-site variation in negative emissions was generally greater than the intra-site variation in negative emission for all landfill sites (ranging from 5-10) excluding Teapot Dome during the wet season.

A preliminary inter-landfill comparison of methane, nitrous oxide, carbon dioxide, carbon monoxide, and NMVOC flux measurements obtained from the wet weather season is presented in Figure 4.61. Median methane and nitrous oxide fluxes were generally highest from Potrero Hills Landfill during the wet season (Figure 4.61). Comparably, carbon dioxide and monoxide fluxes were greatest at Chiquita Canyon Landfill. Analysis of the distributions in overall NMVOC flux values indicated that Chiquita Canyon was associated with the greatest emissions of all chemical families (excluding GHGs). The distribution in NMVOC fluxes was most skewed in the positive direction for Chiquita Canyon Landfill, as indicated by the high number of positive outliers and magnitude of the mean flux value. During the wet season, the variation in flux measurements (based on IQR/IWR) was generally highest for Teapot Dome Landfill, especially for methane, carbon dioxide, and total NMVOC gases (Figure 4.57). However, variation in nitrous oxide and carbon monoxide emissions was greatest for Potrero Hills in the wet season.

Figure 4.61 Inter-Landfill Comparison of GHG and NMVOC fluxes for the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

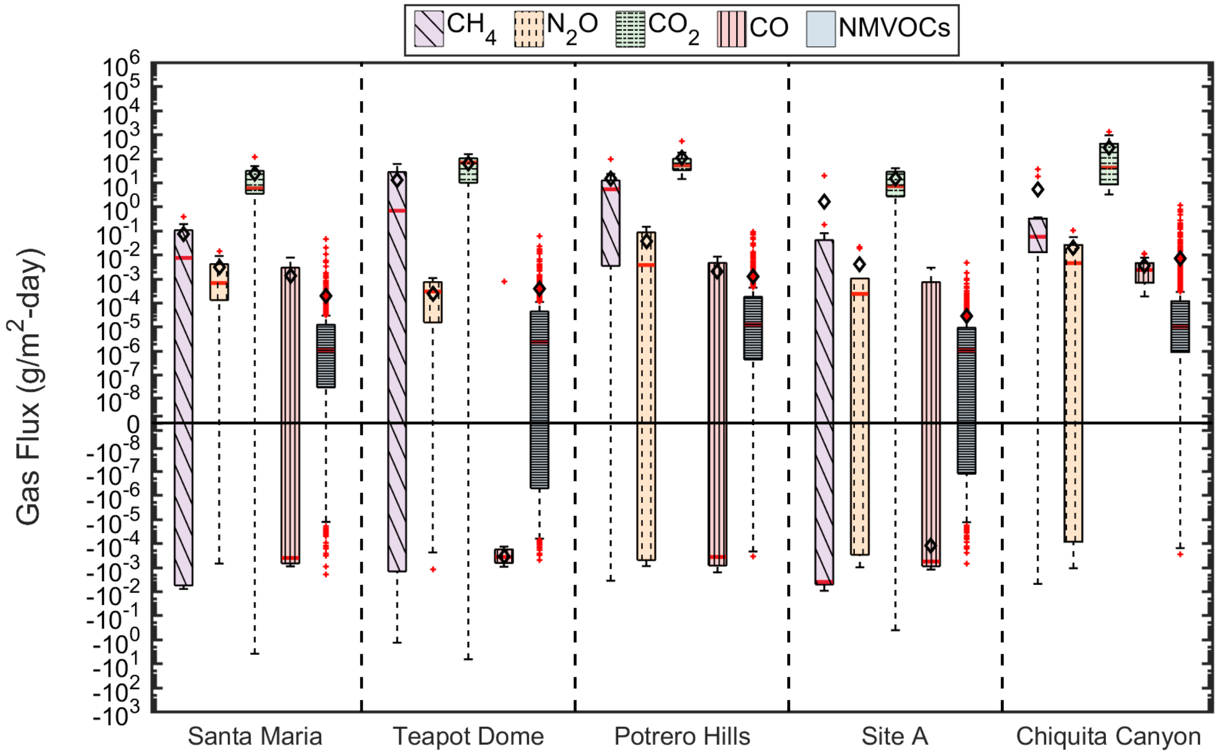


Figure 4.62 compares the overall distributions in flux measurements according to each landfill site, organized by chemical family. Based on median flux values, landfill surface flux measurements of the baseline GHGs were highest from Potrero Hills, confirming the summary statistics presented above (Figure 4.62a). Within the GHGs, methane and nitrous oxide fluxes were greatest at Potrero Hills (Figure 4.62b). Variation in GHG emissions was highest for Potrero Hills, as indicated by the wide IQR and IWR of the boxplots. Relying on median flux values as the basis for inter-site comparison of LFG emissions, the alcohols, monoterpenes, and ketones were the NMVOC chemical families associated with the highest emissions across sites, which is identical to the results obtained for the dry weather season. Based on this analysis, Chiquita Canyon, Potrero Hills, and Chiquita Canyon were the landfills associated with the highest median emissions of the top three NMVOC families identified above. Considering all NMVOC families, Chiquita Canyon was the landfill site with the highest median NMVOC emission value and the highest IQR/IWR values during the wet weather season (Figure 4.62a). The range in overall NMVOC emissions across all testing locations was on the order of -1.93×10^{-3} to 1.12×10^{0} g/m^2-day, which is shifted slightly lower than that of the dry weather season.

Figure 4.62a Overall Inter-Landfill Flux Measurements in the Wet Season (open black diamonds, red lines, and solid red dots represent means, medians, and outliers, respectively).

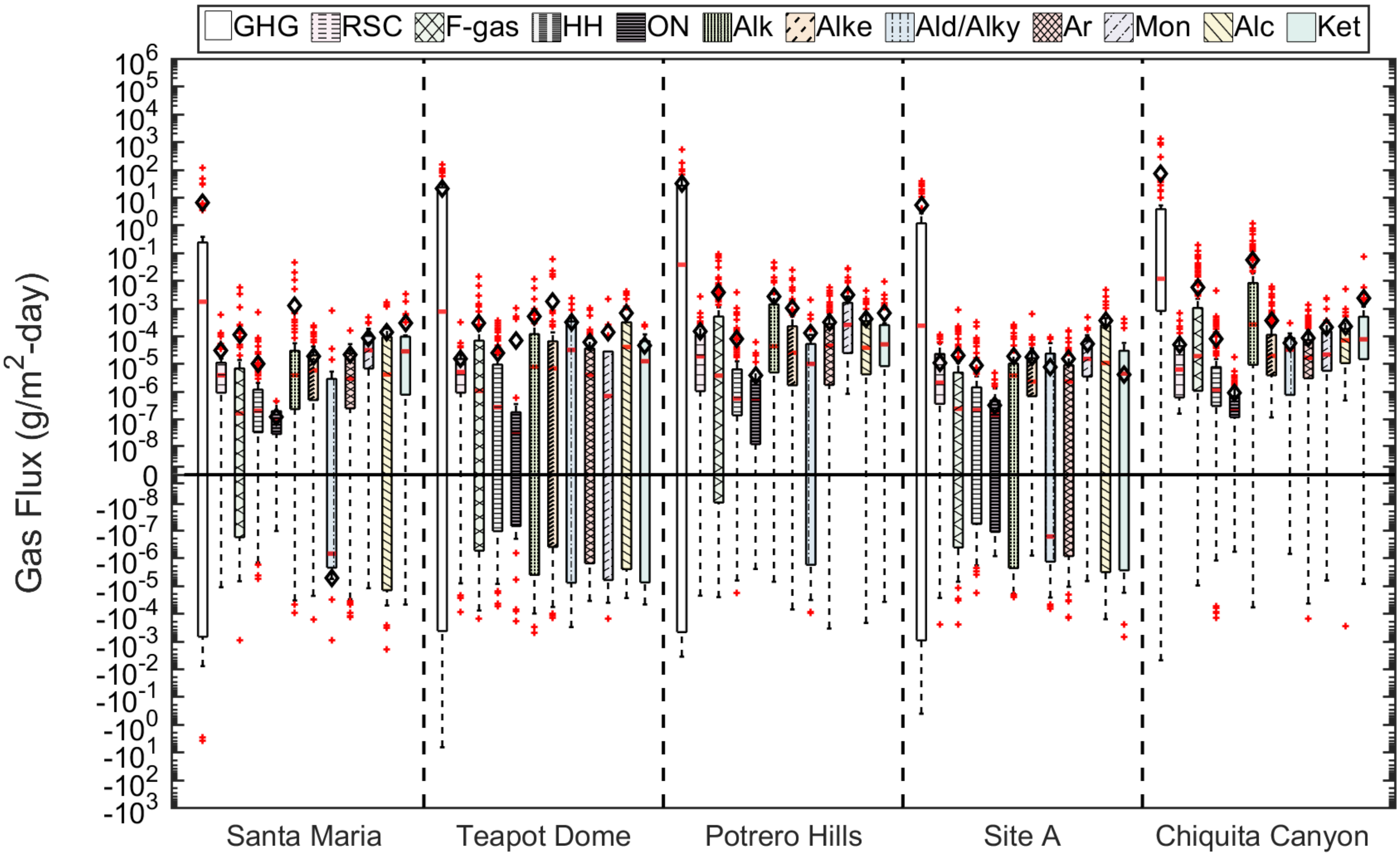


Figure 4.62b Specific GHG and NMVOC Inter-Landfill Flux Measurements in the Wet Season (open black diamonds, red lines, solid red dots represent means, medians, and outliers, respectively).

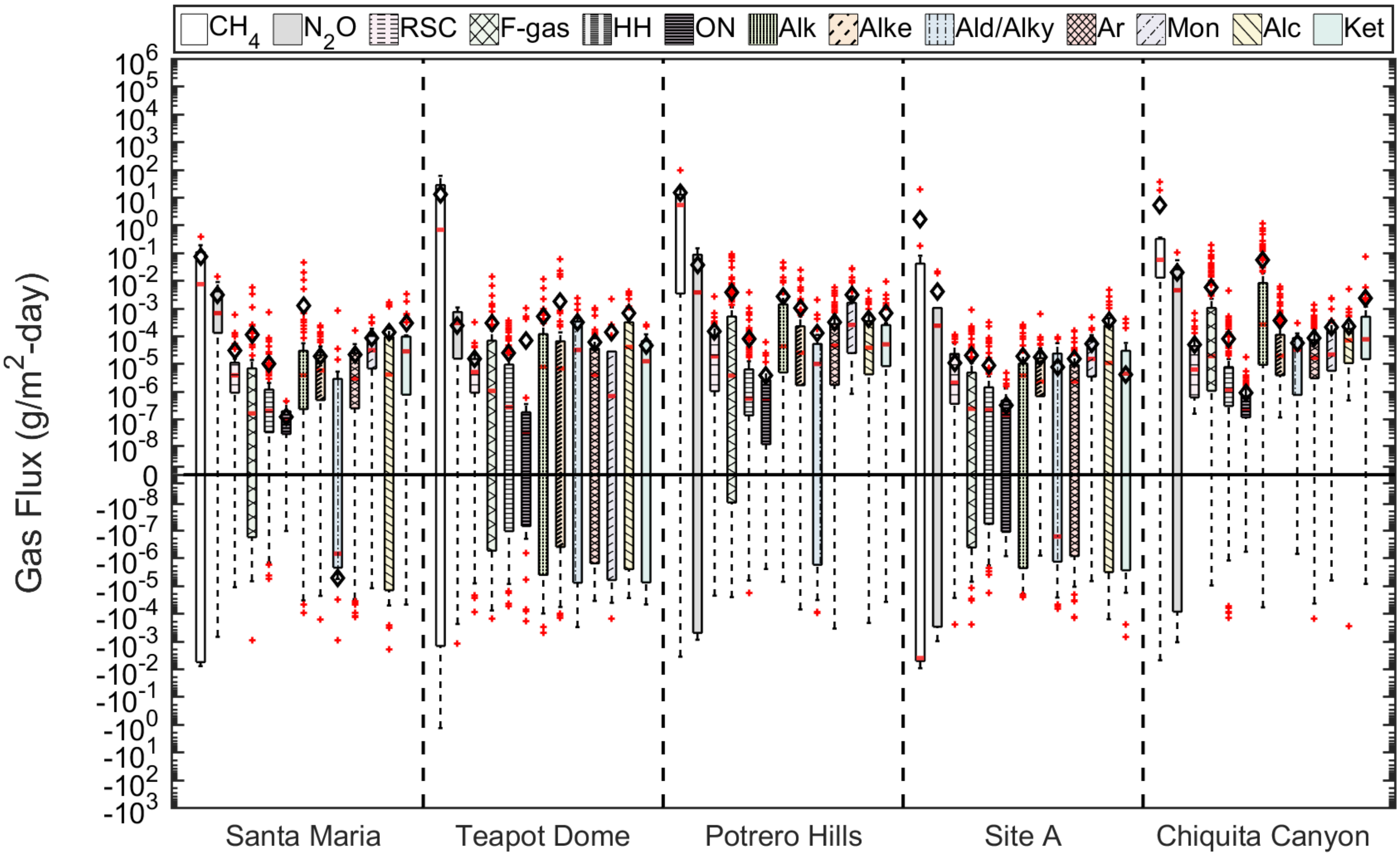


Figure 4.63 compares the GHG (a) and NMVOC (b) flux values collected from all daily, intermediate, and final cover locations at each landfill site during the wet season. As observed in Figure 4.63, GHG and NMVOC emissions generally decreased progressing from daily to intermediate to final cover systems for Teapot Dome, Potrero Hills, and Chiquita Canyon Landfill sites. However, GHG and NMVOC emissions from the final cover of Santa Maria Regional Landfill were slightly higher than those of the intermediate cover. Comparably, the trend among NMVOC emissions at the Altamont site was indicative of increasing, then decreasing flux measurements, similar to that observed in the dry season. In general, the variation in NMVOC emissions (as judged by the IQR/IWR) declined moving from daily to intermediate to final cover systems for all target gases analyzed during the dry season (Figure 4.63).

Figure 4.63 Wet Season a) GHG Fluxes and b) NMVOC Fluxes Organized by Site and Cover Category (open black diamonds, red lines, solid red dots represent means, medians, and outliers, respectively).

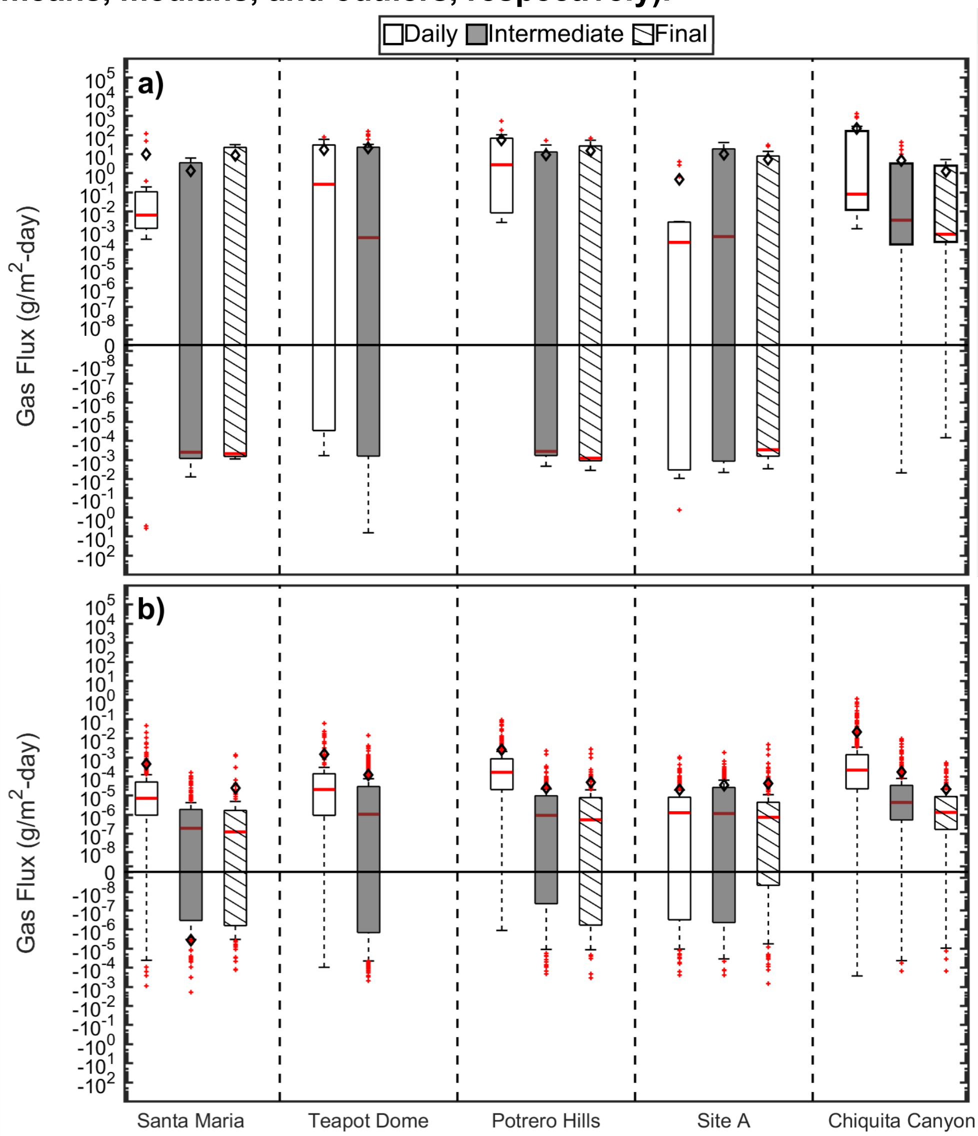


Figure 4.64 compares the differences in GHG and NMVOC flux measurements among all landfill sites as a function of cover category during the wet season. Unlike the dry season, daily cover flux measurements of GHGs and NMVOCs were highest from Potrero Hills and Chiquita Canyon landfills, respectively, based on median flux values (Figure 4.64). Relying on median flux and the IQR/IWR values, the magnitude of GHG and NMVOC flux measurements from intermediate cover locations was greatest for Chiquita Canyon Landfill (Figure 4.64). Among the intermediate cover locations, the variation in GHG and NMVOC flux measurements was generally highest for Teapot Dome Landfill. Finally, GHG and NMVOC flux measurements from the final cover systems investigated in this study were generally highest for Santa Maria and Chiquita Canyon, respectively sites during the wet season, where variation in flux measurements tended to be larger for Santa Maria and Potrero Hills landfills, based on observations of the IQRs and IWRs. In the wet season, the highest probability of uptake was observed at the intermediate cover testing locations, where Teapot Dome Landfill demonstrated the largest variation in GHG and NMVOC flux measurements among landfill sites and locations reviewed for this particular category (Figure 4.61).

Figure 4.64 Wet Season a) GHG Fluxes and b) NMVOC Fluxes Organized by Cover Category and Site (open black diamonds, red lines, solid red dots represent means, medians, and outliers, respectively).