ASSESSING INTERMITTENT SOURCES IN MODELLING

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1. Introduction

In the context of dispersion modelling, **intermittent discharges** can be defined as:

> *"A discharge with a maximum frequency or duration of operation shorter than a contaminant exposure period in need of assessing"*

These limitations often form part of local or regional government discharge consent conditions, aimed at controlling effects of contaminants, for example: an asphalt plant that only operates for 100 days in a calendar year, or a load-shedding generator that only operates for a maximum of 13 hours per day.

Assessing these discharges can be difficult for modellers as they must consider multiple possible operational scenarios within the exposure period, however dispersion models often only allow for a single time-series of input source data.

The most conservative approach used to deal with this problem is to adopt a **continuous operation, maximum rate** method. This approach simulates all meteorological conditions but overestimates total emissions. Often, results are too conservative. Refinements to this approach, which still use a single time-series of input source data are the **single scenario** and **continuous operation, distributed rate** methods, or a **probabilistic** method.

The **single scenario** method preserves the correct emission rates but limits the source discharge to an arbitrarily chosen subset of the exposure period. This can miss or over-sample critical meteorological conditions. The **continuous operation, distributed rate** method models the source operating continually (sampling all meteorological conditions) but scales down the emission rate, so the correct total mass of emissions occurs over the exposure period.

The **probabilistic** method involves modelling multiple possible operational scenarios, using the correct emission rate, and relying on a large sample size to ensure all meteorological conditions are adequately sampled. Probabilistic methods are best applied to model results that are **scalable** - where the ground level concentrations (GLCs) are directly proportional to the emission rate of the source(s). It allows for the simulation of multiple operational scenarios in software packages, such as Python, without re-running the dispersion model each time.

Modellers using a single scenario or continuous operation, distributed rate method to assess intermittent sources should understand the potential variation in GLCs that might arise during actual operation, relative to their simplified model scenario.

To understand this we have generated annual average GLCs from a generic source in CALPUFF using a continuous operation, distributed rate method. These GLCs have been compared to a range of annual GLCs calculated using probabilistic methods to highlight potential over- or under-estimates of GLCs.

2. Assessment Methodology

CALPUFF (a Lagrangian puff modelling system for the simulation of atmospheric pollution dispersion) was run for one year of meteorological data (2020), for a generic source, shown in **Table 1**. The model was centred at the Christchurch airport, which is located on flat terrain, away from significant terrain (i.e., hill), or coastal effects. The model included 180 receptors, placed at 10º intervals at 25, 50, 100, 200 and 500 metres from the source.

Table 1. CALPUFF Model Inputs

VARIABLE	VALUE
Stack Height	8 m
Stack Diameter	0.75 m
Exit Velocity	20 m/s
Exit Temperature	423.15 ºC (200 ºC)

Time-series' of the 1-hour average, 24-hour average and annual average GLCs were exported for each receptor.

Two intermittent sources were modelled using probabilistic methods: one with an annual limit to the **days** of operation, and one with an annual limit to the **hours** of operation. Each source was modelled for five different annual operation limits (i.e., levels of intermittency), shown in **Table 2**. Each source combination (**scenario**) discharged the same total mass of emissions.

The probabilistic analysis of each scenario involved simulating 750 random sequences (day on/off, or hours on/off), for each operational limit. This was then used to scale the raw model results file, and an annual average GLC calculated for each receptor. The analysis produced 750 annual-average GLCs for each receptor and each scenario. Finally, all GLCs were normalised to the GLCs produced using the '**baseline**' method (a source with continuous operation and distributed emission rate).

Table 2. Source Summary: Frequency of Operation

SOURCE	OPERATION LIMIT	EMISSION
Continuous	8760 hrs (100%)	1
Daily Limit	50 days (14%)	7.3
	100 days (27%)	3.7
	150 days (41%)	2.4
	200 days (55%)	1.8
	250 days (68%)	1.5
Hourly Limit	4380 hrs (50%)	2
	2920 hrs (33%)	3
	2190 hrs (25%)	4
	1752 hrs (20%)	5
	876 hrs (10%)	10

3. Results and Discussion

Figure 1 shows the results of the five daily operational limit scenarios for a representative receptor (#42, 50 m to the north-east - a common downwind direction). Note that GLCs are presented as relative percentages of those calculated using the continuous operation, distributed emission rate method.

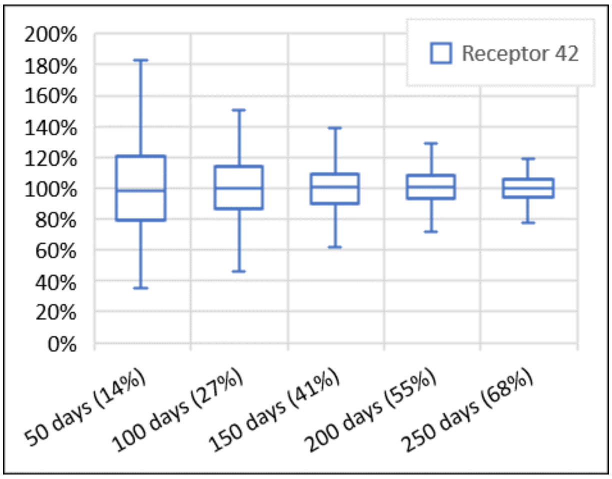

Figure 1. Daily Limit: Annual GLCs - Receptor 42

The results for receptor 42 shows that the median annual GLC across 750 scenarios matches the baseline (approx. 100%). This was expected and indicates that a 750-scenario sample size is likely large enough for this analysis.

At high intermittency (operating only 14% of the days of the year), actual annual average GLCs can vary between +80% and -60% from the continuous operation, distributed emission rate method. This range of variation decreases as the source becomes less intermittent.

The results from the probabilistic analysis do not show an identical distribution at other receptors in the modelling domain. Analysing the data across multiple receptors, such as when presenting isopleth plots, requires some statistical simplification of the 750 iterated results. A conservative approach is to present the maximum annual concentration at each receptor, across all potential iterations. **Figure 2** presents maximum and minimum concentration at each receptor, for the five daily limit scenarios. These represent the greatest potential deviations in GLCs from the continuous operation, distributed emission rate method.

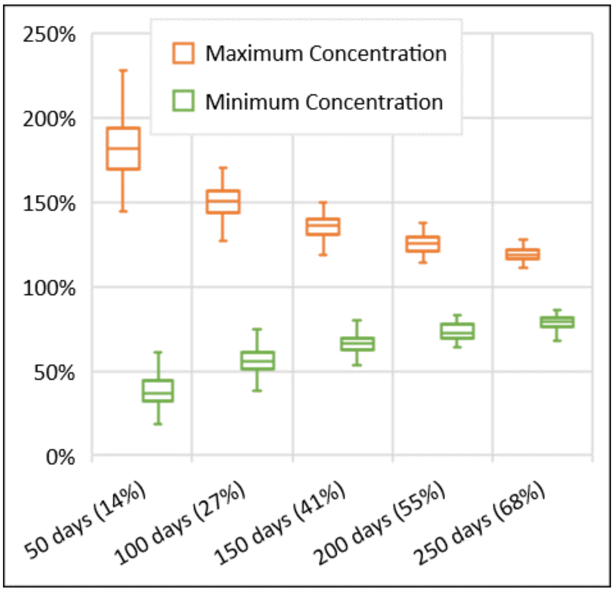

Figure 2. Daily Limit - Maximum and Minimum Annual GLCs - Receptor Variation

Figure 2 shows that there can be a significant variation in how much the maximum GLC (across 750 iterations) can deviate from the GLC calculated by the continuous operation, distributed emission rate method - with maximum deviations ranging from 145% to 228% at 14% intermittency. The maximum deviation decreases in both size and range as the intermittency of the source decreases - ranging from 111% to 129% at 68% intermittency.

These results provide an indicative upper bound to the potential variation in GLCs that might arise during actual operation, relative to GLC predicted by a continuous operation, distributed emission rate.

The replication of this assessment using a source with the hourly limit showed broadly similar results, although the potential variation was slightly lower with intermittent hourly operation compared to the intermittent daily operation.

There is no single correct answer when using a probabilistic method. The method provides a range of potential GLCs. The modeller should consider this range and the frequency of occurrence of GLCs within the range. The modeller should also consider whether a simplified assessment is appropriate for highly intermittent sources, and how sensitive their assessment's conclusion is to the potential variation.