Contact Details

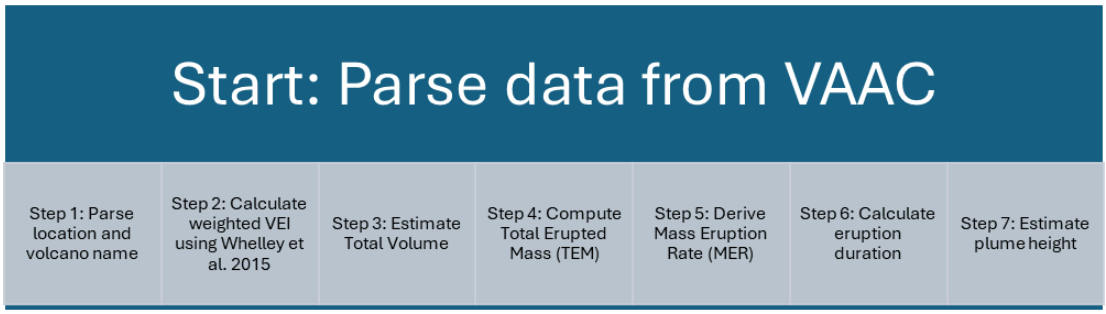
Dr. Mahmud Muhammad
(PhD, MSc, and BSc in Geology)
Email: mahmud.geology@hotmail.com
Website: mahmudm.com

Objective

The goal of this project is to develop a suite of probability density functions (PDFs) that describe Eruption Source Parameter (ESP) inputs required by the NAME model. These estimations are crucial for accurate volcanic ash dispersion modeling.

Key Tasks:

1. **Automated Retrieval and Parsing of Volcanic Advisory Reports (VAA):**
    - Implement a system to automatically retrieve and parse real-time Volcanic Advisory Reports (VAA) from the Tokyo Volcanic Ash Advisory Center (TVAAC).
2. **Annual VEI Probability Parsing:**
    - Utilize the methodology outlined in Whelley et al. (2015) to extract annual Volcanic Explosivity Index (VEI) probabilities for the volcano of concern using data from VAA reports.
3. **Bayesian Sampling for Total Eruption Mass (TEM):**
    - Estimate the range of Total Eruption Mass (TEM) for a known VEI level using Bayesian probability sampling. This estimation will account for a range of tephra particl densities.
4. **Mass Eruption Rate (MER) Estimation:**
    - Calculate the Mass Eruption Rate (MER) based on the derived Total Eruption Mass (TEM).
5. **Eruption Duration Calculation:**
    - Derive the eruption duration by integrating the MER and TEM values.
6. **Plume Height Estimation from MER:**
    - Estimate the volcanic plume height using the Mass Eruption Rate (MER).
7. **MER Estimation from Plume Height:**
    - Estimate the MER using observed Plume Height.
8. **Estimation of Mass fraction of ash particle size below 63 microns:**
    - Estimate the Mass fraction of ash particle size below 63 microns using the Mass Eruption Rate (MER).



Parsing of Volcanic Advisory Reports (VAA)

In [2]:
```
# Using Whelley et al., 2015  paper that calculated VEI Level eruption for 750 v

# first we load Whelley 2015 Volcano Database later will be use to filter Volcan

import vei

data_loader=vei.LOADDATA()


whelley_data=data_loader.whelley_2015(as_geodataframe=True)
```

In [3]:
```
# import Libraries and classes required to parse VAA reports and filter dataset

import vep_vaa_text
from vep_vaa_text import VEP_TVAAC_VAAText
scraper = VEP_TVAAC_VAAText()
scraper.fetch_webpage()
tables = scraper.extract_all_tables()
tables
# Perform a search Note: for realtime operation set all parameters to None to re
search_results = scraper.search(query='SINABUNG', date_time=None, advisory_numbe
downloaded_VAA_report, latest_VAA_report , latest_date_data=scraper.download_vaa

downloaded_VAA_report.head(2)
```

```
CSV file created: ./vaa_texts_2\vaa_texts.csv
```

Out[3]:

	DTG	VAAC	VOLCANO	VOLCANO CODE	PSN	AREA	SUMMIT ELEV	ADV
0	20200810/1635Z	DARWIN	SINABUNG	261080	N0310 E09824	INDONESIA	2460M	2
1	20200810/1030Z	DARWIN	SINABUNG	261080	N0310 E09824	INDONESIA	2460M	2

2 rows × 23 columns

In [4]:
```
latest_date_data
```

Out[4]:

	DTG	VAAC	VOLCANO	VOLCANO CODE	PSN	AREA	SUMMIT ELEV	ADV
0	20200810/1635Z	DARWIN	SINABUNG	261080	N0310 E09824	INDONESIA	2460M	2

1 rows × 24 columns

In [5]:
```
# Retrive data from the latest report date
from rich.console import Console
from rich.table import Table

# Initialize the console
console = Console()

# Create a table for a professional and structured output
table = Table(title="Volcanic Activity Observations", show_lines=True, title_sty

# Define table columns
table.add_column("Parameter", style="dim", width=25)
table.add_column("Value", style="bold white", justify="center")

# Populate the table with data, if available
if 'VOLCANO' in latest_date_data.columns:
```

```
    volcano_name = latest_date_data['VOLCANO'].to_list()[0]
    table.add_row("Site of Volcanic Activity", volcano_name)

if 'Altitude_Meters' in latest_date_data.columns:
    observed_ash_altitude_meter = latest_date_data['Altitude_Meters'].to_list()[
    table.add_row("Observed Ash Altitude (m ASL)", str(observed_ash_altitude_met

if 'Latitude' in latest_date_data.columns:
    latitude = latest_date_data['Latitude'].to_list()[0]
    table.add_row("Latitude", str(latitude))

if 'Longitude' in latest_date_data.columns:
    longitude = latest_date_data['Longitude'].to_list()[0]
    table.add_row("Longitude", str(longitude))



# Call the search_whelley_2015 method on the instance
search_results, vei_range = data_loader.search_whelley_2015(Volcano=volcano_name

# View the search results
#print(f"Potential VEI Levels for  Volcano site {volcano_name} is based on Whell
#print(search_results)

table.add_row(f"Possible VEI Levels for  Volcano  {volcano_name}  based on Whell

# Render the table
console.print(table)

import pandas as pd
import plotly.graph_objects as go

search_results = pd.DataFrame(search_results)

# Create a table
fig = go.Figure(data=[go.Table(
    header=dict(values=list(search_results.columns),
                fill_color='paleturquoise',
                align='left'),
    cells=dict(values=[search_results[col] for col in search_results.columns],
               fill_color='lavender',
               align='left'))
])

# Add a bold title
fig.update_layout(
    title=dict(
        text=f"Search Results for Whelley et al. 2015 show possible VEI activity
        x=0.5,  # Center the title
        font=dict(size=20, family="Arial Black", color="black")  # Use bold font
    )
)

fig.show()
```

```
Top VEI values returned: [2, 3, 4, 5]
```

Volcanic Activity Observations

Parameter	Value
Site of Volcanic Activity	SINABUNG
Observed Ash Altitude (m ASL)	4267.2
Latitude	3.09
Longitude	9.92
Possible VEI Levels for Volcano SINABUNG based on Whelley et al. 2015 paper	[2, 3, 4, 5]

Search Results for Whelley et al. 2015 show possible VEI activity for the volcano SINABUNG

Volcano Number	GVP Volcano Number	Volcano	Other name or Sub-Feature	Latitude	Longitude	Elevation (m)	Classification	Eruption history source	VEI 2	VEI 3	VEI 4	VEI 5	VEI 6	VEI 7	VEI 8
3	261080	SINABUNG	null	3.166666	98.391666	2460	Semi-plugged stratocone	Class	0.022451791	0.002424242	0.001443001	0.0000909091	0	0	0

Step 1: Define Total Eruption Mass (TEM) from VEI

This cell initializes the `VEI_BulkVolume_Mass` class to perform probabilistic calculations of total eruption mass based on known VEI values.

Key Parameters:

- `use_default_densities=True` : Applies default density values for tephra deposits.
- `density_min=800` and `density_max=1700` (kg/m^3): Define the density range for volcanic materials.
- `num_samples=1000` : Specifies the number of Monte Carlo samples for probabilistic calculations.

Outcome:

The `vei_toMass` object enables generating probabilistic TEM values for subsequent calculations.

In [25]:
```
from vei import VEI_BulkVolume_Mass
```

```
# Initialize the class
vei_toMass = VEI_BulkVolume_Mass(use_default_densities=False, density_min=800, d


# Generate probabilistic volumes
vei_toMass.generate_probabilistic_volumes()

# Calculate masses using probabilistic volumes
vei_toMass.calculate_mass(calculate_emperical=True, calculate_probabilistic=True

vei_toMass.calculate_percentile_bands()



# # Generate summary statistics
vei_toMass.generate_summary_statistics()

# # Visualize the results
vei_toMass.visualize_statistics()

# # Calculate and plot percentile bands

vei_toMass.plot_percentile_bands()

# # Export results
#vei_toMass.export_statistics(filename="summary_statistics.csv")
vei_toMass.export_volumes_and_masses()

vei_toMass.export_data()

#vei_toMass.save_outputs_to_pdf()
```

```
Generating probabilistic volumes...
Probabilistic volumes successfully generated.
Best density sampling strategy: normal
### Volume Percentiles ###
   VEI  emp_Volume_5th  Uncertainty_emp_Volume_5th  Prob_Volume_5th  \
0    0       2300000.0                    230000.0     2.528941e+07
1    1       2300000.0                    230000.0     2.528941e+07
2    2       2300000.0                    230000.0     2.528941e+07
3    3       2300000.0                    230000.0     2.528941e+07
4    4       2300000.0                    230000.0     2.528941e+07
5    5       2300000.0                    230000.0     2.528941e+07
6    6       2300000.0                    230000.0     2.528941e+07
7    7       2300000.0                    230000.0     2.528941e+07
8    8       2300000.0                    230000.0     2.528941e+07

   Uncertainty_Prob_Volume_5th  emp_Volume_25th  Uncertainty_emp_Volume_25th  \
0                 2.528941e+06      100000000.0                   10000000.0
1                 2.528941e+06      100000000.0                   10000000.0
2                 2.528941e+06      100000000.0                   10000000.0
3                 2.528941e+06      100000000.0                   10000000.0
4                 2.528941e+06      100000000.0                   10000000.0
5                 2.528941e+06      100000000.0                   10000000.0
6                 2.528941e+06      100000000.0                   10000000.0
7                 2.528941e+06      100000000.0                   10000000.0
8                 2.528941e+06      100000000.0                   10000000.0

   Prob_Volume_25th  Uncertainty_Prob_Volume_25th  emp_Volume_50th  ...  \
0     5.498412e+08                  5.498412e+07     3.000000e+10  ...
1     5.498412e+08                  5.498412e+07     3.000000e+10  ...
2     5.498412e+08                  5.498412e+07     3.000000e+10  ...
3     5.498412e+08                  5.498412e+07     3.000000e+10  ...
4     5.498412e+08                  5.498412e+07     3.000000e+10  ...
5     5.498412e+08                  5.498412e+07     3.000000e+10  ...
6     5.498412e+08                  5.498412e+07     3.000000e+10  ...
7     5.498412e+08                  5.498412e+07     3.000000e+10  ...
8     5.498412e+08                  5.498412e+07     3.000000e+10  ...

   Prob_Volume_50th  Uncertainty_Prob_Volume_50th  emp_Volume_75th  \
0     5.496897e+10                  5.496897e+09     5.000000e+11
1     5.496897e+10                  5.496897e+09     5.000000e+11
2     5.496897e+10                  5.496897e+09     5.000000e+11
3     5.496897e+10                  5.496897e+09     5.000000e+11
4     5.496897e+10                  5.496897e+09     5.000000e+11
5     5.496897e+10                  5.496897e+09     5.000000e+11
6     5.496897e+10                  5.496897e+09     5.000000e+11
7     5.496897e+10                  5.496897e+09     5.000000e+11
8     5.496897e+10                  5.496897e+09     5.000000e+11

   Uncertainty_emp_Volume_75th  Prob_Volume_75th  \
0                 5.000000e+10      5.499184e+12
1                 5.000000e+10      5.499184e+12
2                 5.000000e+10      5.499184e+12
3                 5.000000e+10      5.499184e+12
4                 5.000000e+10      5.499184e+12
5                 5.000000e+10      5.499184e+12
6                 5.000000e+10      5.499184e+12
7                 5.000000e+10      5.499184e+12
8                 5.000000e+10      5.499184e+12

   Uncertainty_Prob_Volume_75th  emp_Volume_95th  Uncertainty_emp_Volume_95th  \
```

```
0                  5.499184e+11     1.900000e+12                 1.900000e+11
1                  5.499184e+11     1.900000e+12                 1.900000e+11
2                  5.499184e+11     1.900000e+12                 1.900000e+11
3                  5.499184e+11     1.900000e+12                 1.900000e+11
4                  5.499184e+11     1.900000e+12                 1.900000e+11
5                  5.499184e+11     1.900000e+12                 1.900000e+11
6                  5.499184e+11     1.900000e+12                 1.900000e+11
7                  5.499184e+11     1.900000e+12                 1.900000e+11
8                  5.499184e+11     1.900000e+12                 1.900000e+11

   Prob_Volume_95th  Uncertainty_Prob_Volume_95th
0      3.519900e+14                  3.519900e+13
1      3.519900e+14                  3.519900e+13
2      3.519900e+14                  3.519900e+13
3      3.519900e+14                  3.519900e+13
4      3.519900e+14                  3.519900e+13
5      3.519900e+14                  3.519900e+13
6      3.519900e+14                  3.519900e+13
7      3.519900e+14                  3.519900e+13
8      3.519900e+14                  3.519900e+13

[9 rows x 21 columns]
### Mass Percentiles ###
   VEI      Mass_5th     Mass_25th     Mass_50th     Mass_75th     Mass_95th  \
0    0  4.323678e+09  5.296240e+09  5.973196e+09  6.649864e+09  7.623536e+09
1    1  4.318758e+10  5.290707e+10  5.966745e+10  6.643474e+10  7.615098e+10
2    2  4.320693e+11  5.293171e+11  5.969547e+11  6.646344e+11  7.618763e+11
3    3  4.321326e+12  5.294734e+12  5.970550e+12  6.647372e+12  7.621213e+12
4    4  4.318416e+13  5.290895e+13  5.966591e+13  6.642700e+13  7.615413e+13
5    5  4.319608e+14  5.293744e+14  5.970898e+14  6.647567e+14  7.621085e+14
6    6  4.320823e+15  5.293540e+15  5.969779e+15  6.646075e+15  7.619693e+15
7    7  4.317606e+16  5.291018e+16  5.966578e+16  6.642399e+16  7.614434e+16
8    8  4.320384e+17  5.293882e+17  5.970276e+17  6.646589e+17  7.618751e+17

   90%_interpercentile_Mass_Estimate
0                       3.299858e+09
1                       3.296340e+10
2                       3.298070e+11
3                       3.299887e+12
4                       3.296997e+13
5                       3.301477e+14
6                       3.298870e+15
7                       3.296828e+16
8                       3.298367e+17

### Generating Summary Statistics Grouped by VEI Level ###
Ensuring VEI is a Series...
Flattening and cleaning VEI column...
Unique VEI values after cleaning: ['0' '1' '2' '3' '4' '5' '6' '7' '8']
Performing groupby operation...

### Summary Statistics Grouped by VEI ###
+--------+-----------------------------------+-----------------------------------+----
-------------------------------+-------------------------------------+-----------
------------------------+-------------------------------------+---------------
----------+------------------------+---------------------------+-----------------
---------+-------------------------+---------------------------+
|   VEI_ |   emperical_Bulk_Volume_m3_mean |   emperical_Bulk_Volume_m3_std |   e
mperical_Bulk_Volume_m3_median |   Probabilistic_Bulk_Volume_m3_mean |   Probabil
istic_Bulk_Volume_m3_std |   Probabilistic_Bulk_Volume_m3_median |   Mean_Mass_em
```

```
p_kg_mean |   Mean_Mass_emp_kg_std |   Mean_Mass_emp_kg_median |   Mean_Mass_Prob
_kg_mean |   Mean_Mass_Prob_kg_std |   Mean_Mass_Prob_kg_median |
+========+==================================+==================================+====
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=========+========================+============================+
|      0 |                     500000       |                             nan |
500000       |                         5.50227e+06 |
nan |                           5.50227e+06 |             4.99982e+08 |
nan |               4.99982e+08 |              5.97306e+09 |
nan |                5.97306e+09 |
+--------+----------------------------------+----------------------------------+----
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------------------------+------------------------------------+--------------
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|      1 |                        5e+06   |                             nan |
5e+06   |                        5.49701e+07 |                                  na
n |                        5.49701e+07 |             4.99988e+09 |
nan |               4.99988e+09 |              5.96691e+10 |
nan |                5.96691e+10 |
+--------+----------------------------------+----------------------------------+----
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|      2 |                        1e+08   |                             nan |
1e+08   |                        5.49841e+08 |                                  na
n |                        5.49841e+08 |             9.99968e+10 |
nan |               9.99968e+10 |              5.96962e+11 |
nan |                5.96962e+11 |
+--------+----------------------------------+----------------------------------+----
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---------+------------------------+----------------------------+
|      3 |                        3e+09   |                             nan |
3e+09   |                        5.50081e+09 |                                  na
n |                        5.50081e+09 |             2.99985e+12 |
nan |               2.99985e+12 |              5.97108e+12 |
nan |                5.97108e+12 |
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|      4 |                        3e+10   |                             nan |
3e+10   |                        5.4969e+10  |                                  na
n |                        5.4969e+10  |             3.00003e+13 |
nan |               3.00003e+13 |              5.96677e+13 |
nan |                5.96677e+13 |
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|      5 |                        1e+11   |                             nan |
1e+11   |                        5.50046e+11 |                                  na
n |                        5.50046e+11 |             1.00003e+14 |
```

```
nan |               1.00003e+14 |              5.97059e+14 |
nan |                5.97059e+14 |
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|      6 |                         5e+11   |                              nan |
5e+11   |                        5.49918e+12 |                              na
n |                        5.49918e+12 |             5.00004e+14 |
nan |               5.00004e+14 |              5.96994e+15 |
nan |                5.96994e+15 |
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|      7 |                         1e+12   |                              nan |
1e+12   |                        5.49655e+13 |                              na
n |                        5.49655e+13 |             9.99991e+14 |
nan |               9.99991e+14 |              5.96664e+16 |
nan |                5.96664e+16 |
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|      8 |                         2.5e+12 |                              nan |
2.5e+12 |                        5.50006e+14 |                              na
n |                        5.50006e+14 |             2.50005e+15 |
nan |               2.50005e+15 |              5.9702e+17  |
nan |                5.9702e+17  |
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### Overall Dataset Statistics ###
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|       |   Bulk_Volume_km3 |   emperical_Bulk_Volume_m3 |   Probabilistic_Bulk_V
olume_m3 |   Mean_Mass_emp_kg |   Std_Mass_emp_kg |   Mean_Mass_Prob_kg |   Std_M
ass_Prob_kg |   emp_Volume_5th |   Uncertainty_emp_Volume_5th |   Prob_Volume_5th
|   Uncertainty_Prob_Volume_5th |   emp_Volume_25th |   Uncertainty_emp_Volume_25
th |   Prob_Volume_25th |   Uncertainty_Prob_Volume_25th |   emp_Volume_50th |
Uncertainty_emp_Volume_50th |   Prob_Volume_50th |   Uncertainty_Prob_Volume_50th
|   emp_Volume_75th |   Uncertainty_emp_Volume_75th |   Prob_Volume_75th |   Unce
rtainty_Prob_Volume_75th |   emp_Volume_95th |   Uncertainty_emp_Volume_95th |
Prob_Volume_95th |   Uncertainty_Prob_Volume_95th |    Mass_5th |   Mass_25th |
Mass_50th |   Mass_75th |   Mass_95th |   90%_interpercentile_Mass_Estimate |
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| count |            9      |                9          |                     9
|        9          |       9          |         9          |        9
|          9       |                              9 |       9          |
9           |             9     |                          9     |        9
|                     9          |             9     |                           9
|        9          |                      9         |             9     |
9     |        9          |                     9          |        9          |
9       |         9          |                    9          | 9          | 9
| 9           | 9           | 9           |                          9          |
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| mean  |          459.234  |               4.59234e+11 |                     6.7
898e+13  |        4.59239e+14 |       5.30198e+13 |         7.37022e+16 |
1.23764e+16 |          2.3e+06 |                         230000 |       2.52894e+07
|                   2.52894e+06 |             1e+08 |                           1e+
07 |        5.49841e+08 |                     5.49841e+07 |             3e+10 |
3e+09 |        5.4969e+10  |                     5.4969e+09 |             5e+11 |
5e+10 |        5.49918e+12 |                     5.49918e+11 |        1.9e+12    |
1.9e+11 |         3.5199e+14 |                        3.5199e+13 | 5.3335e+16  | 6.5
3533e+16 | 7.37029e+16 | 8.20519e+16 | 9.4054e+16  |                          4.07
19e+16  |
+-------+--------------------+----------------------------+-----------------------
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| std   |          837.619  |               8.37619e+11 |                     1.8
1682e+14 |        8.37632e+14 |       9.66937e+13 |         1.97212e+17 |
3.3116e+16  |          0       |                              0 |       3.95127e-09
|                   0           |             0     |                           0
|        0           |                    7.90253e-09 |             0     |
0     |        8.09219e-06 |                      0          |             0     |
0     |        0           |                      0          |        0.00025895 |
0       |         0.0662913  |                        0          | 1.42714e+17 | 1.7
4871e+17 | 1.97215e+17 | 2.19555e+17 | 2.51668e+17 |                          1.08
954e+17 |
+-------+--------------------+----------------------------+-----------------------
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-------------+-------------+-------------+-----------------------------------+
| min   |            0.0005 |           500000           |                     5.5
0227e+06 |        4.99982e+08 |       5.77406e+07 |         5.97306e+09 |
1.00317e+09 |          2.3e+06 |                       230000 |       2.52894e+07
|                   2.52894e+06 |             1e+08 |                          1e+
07 |        5.49841e+08 |                     5.49841e+07 |             3e+10 |
3e+09 |        5.4969e+10  |                      5.4969e+09 |             5e+11 |
5e+10 |        5.49918e+12 |                     5.49918e+11 |        1.9e+12    |
1.9e+11 |         3.5199e+14 |                        3.5199e+13 | 4.32368e+09 | 5.2
9624e+09 | 5.9732e+09  | 6.64986e+09 | 7.62354e+09 |                          3.29
986e+09 |
+-------+------------------+-----------------------------+----------------------
---------+--------------------+------------------+--------------------+--------
------------+------------------+-----------------------------+------------------
-+-------------------------------+------------------+-------------------------
----+--------------------+-------------------------------+------------------+--
---------------------------+--------------------+-----------------------------
--+------------------+-------------------------------+--------------------+-----
-------------------------+------------------+-------------------------------+-
------------------+-------------------------------+-------------+-------------+
-------------+-------------+-------------+-----------------------------------+
| 25%   |            0.1    |               1e+08       |                     5.4
9841e+08 |        9.99968e+10 |       1.15475e+10 |         5.96962e+11 |
1.00256e+11 |          2.3e+06 |                       230000 |       2.52894e+07
|                   2.52894e+06 |             1e+08 |                          1e+
07 |        5.49841e+08 |                     5.49841e+07 |             3e+10 |
3e+09 |        5.4969e+10  |                      5.4969e+09 |             5e+11 |
5e+10 |        5.49918e+12 |                     5.49918e+11 |        1.9e+12    |
1.9e+11 |         3.5199e+14 |                        3.5199e+13 | 4.32069e+11 | 5.2
9317e+11 | 5.96955e+11 | 6.64634e+11 | 7.61876e+11 |                          3.29
807e+11 |
+-------+------------------+-----------------------------+----------------------
---------+--------------------+------------------+--------------------+--------
------------+------------------+-----------------------------+------------------
-+-------------------------------+------------------+-------------------------
----+--------------------+-------------------------------+------------------+--
---------------------------+--------------------+-----------------------------
--+------------------+-------------------------------+--------------------+-----
-------------------------+------------------+-------------------------------+-
------------------+-------------------------------+-------------+-------------+
-------------+-------------+-------------+-----------------------------------+
| 50%   |           30      |               3e+10       |                     5.4
969e+10  |        3.00003e+13 |       3.46484e+12 |         5.96677e+13 |
1.0021e+13  |          2.3e+06 |                       230000 |       2.52894e+07
|                   2.52894e+06 |             1e+08 |                          1e+
07 |        5.49841e+08 |                     5.49841e+07 |             3e+10 |
3e+09 |        5.4969e+10  |                      5.4969e+09 |             5e+11 |
5e+10 |        5.49918e+12 |                     5.49918e+11 |        1.9e+12    |
1.9e+11 |         3.5199e+14 |                        3.5199e+13 | 4.31842e+13 | 5.2
909e+13  | 5.96659e+13 | 6.6427e+13  | 7.61541e+13 |                          3.29
7e+13   |
+-------+------------------+-----------------------------+----------------------
---------+--------------------+------------------+--------------------+--------
```

```
------------+-----------------+----------------------------+-----------------
-+----------------------------+------------------+--------------------------
----+--------------------+--------------------------------+------------------+--
---------------------------+--------------------+----------------------------
--+------------------+--------------------------------+--------------------+-----
-------------------------+------------------+-----------------------------+-
------------------+--------------------------------+-------------+-------------+
-------------+-------------+-------------+-----------------------------------+
| 75%   |          500      |                5e+11       |                     5.4
9918e+12 |        5.00004e+14 |       5.77352e+13 |         5.96994e+15 |
1.00278e+15 |          2.3e+06 |                         230000 |       2.52894e+07
|                    2.52894e+06 |             1e+08 |                           1e+
07 |        5.49841e+08 |                      5.49841e+07 |             3e+10 |
3e+09 |        5.4969e+10  |                         5.4969e+09 |             5e+11 |
5e+10 |        5.49918e+12 |                      5.49918e+11 |        1.9e+12    |
1.9e+11 |         3.5199e+14 |                         3.5199e+13 | 4.32082e+15 | 5.2
9354e+15 | 5.96978e+15 | 6.64608e+15 | 7.61969e+15 |                          3.29
887e+15 |
+-------+------------------+----------------------------+----------------------
---------+--------------------+------------------+--------------------+--------
------------+------------------+----------------------------+------------------
-+--------------------------------+------------------+--------------------------
----+--------------------+--------------------------------+------------------+--
---------------------------+--------------------+----------------------------
--+------------------+--------------------------------+--------------------+-----
-------------------------+------------------+-----------------------------+-
------------------+--------------------------------+-------------+-------------+
-------------+-------------+-------------+-----------------------------------+
| max   |         2500      |                2.5e+12     |                     5.5
0006e+14 |        2.50005e+15 |       2.88584e+14 |         5.9702e+17  |
1.00252e+17 |          2.3e+06 |                         230000 |       2.52894e+07
|                    2.52894e+06 |             1e+08 |                           1e+
07 |        5.49841e+08 |                      5.49841e+07 |             3e+10 |
3e+09 |        5.4969e+10  |                         5.4969e+09 |             5e+11 |
5e+10 |        5.49918e+12 |                      5.49918e+11 |        1.9e+12    |
1.9e+11 |         3.5199e+14 |                         3.5199e+13 | 4.32038e+17 | 5.2
9388e+17 | 5.97028e+17 | 6.64659e+17 | 7.61875e+17 |                          3.29
837e+17 |
+-------+------------------+----------------------------+----------------------
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------------------+--------------------------------+-------------+-------------+
-------------+-------------+-------------+-----------------------------------+
```
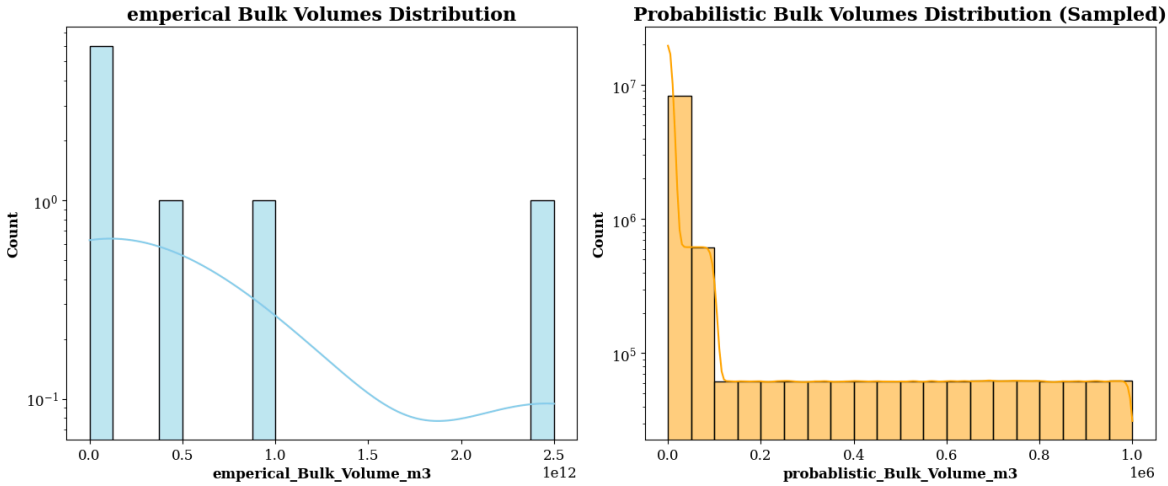
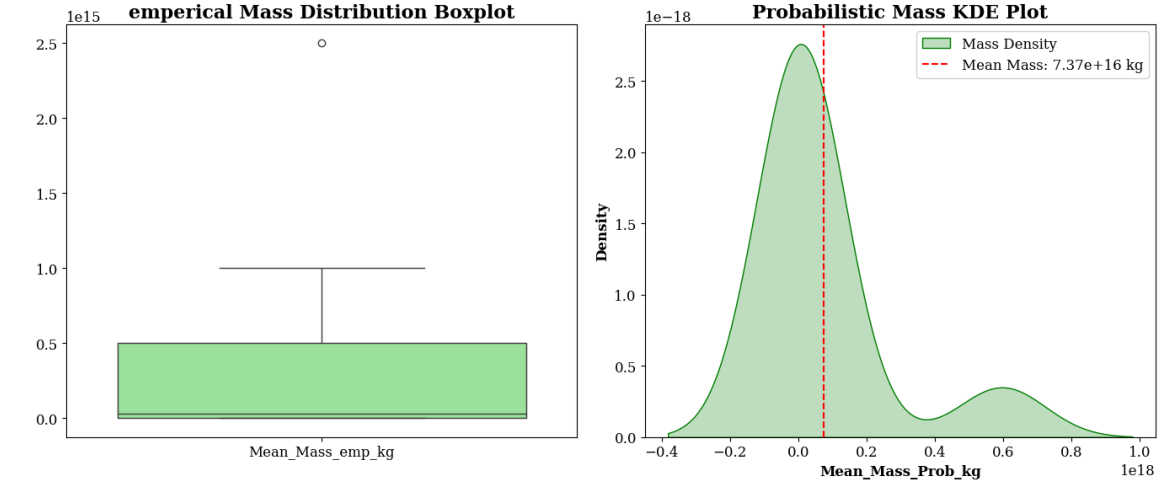
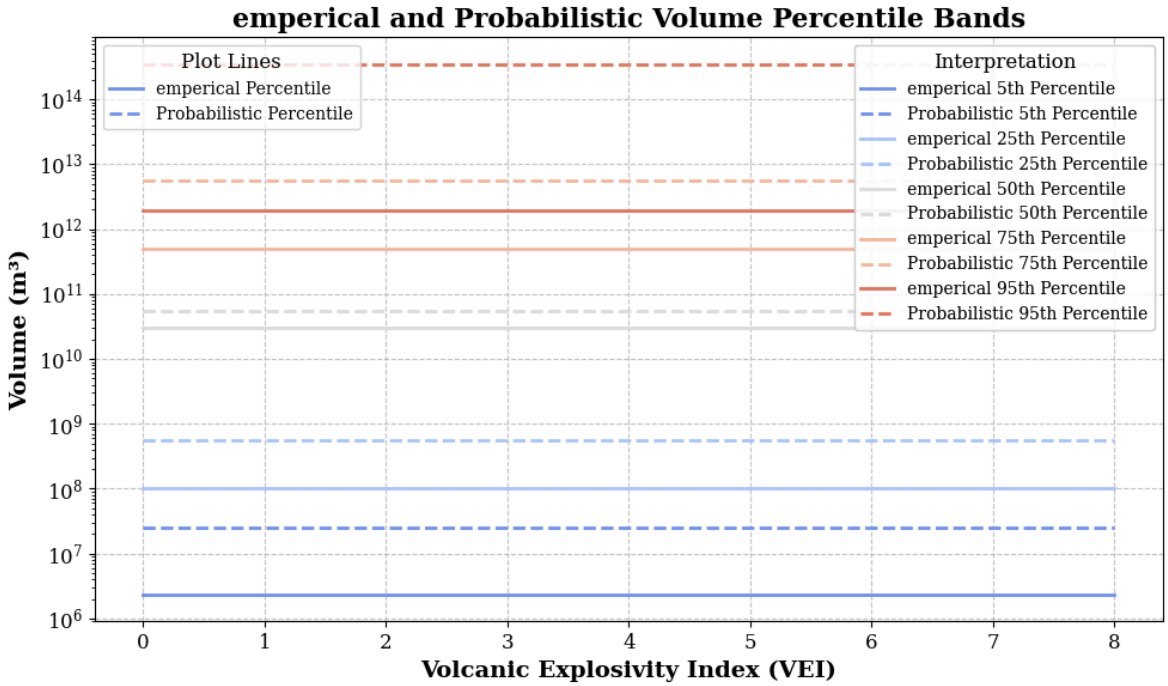
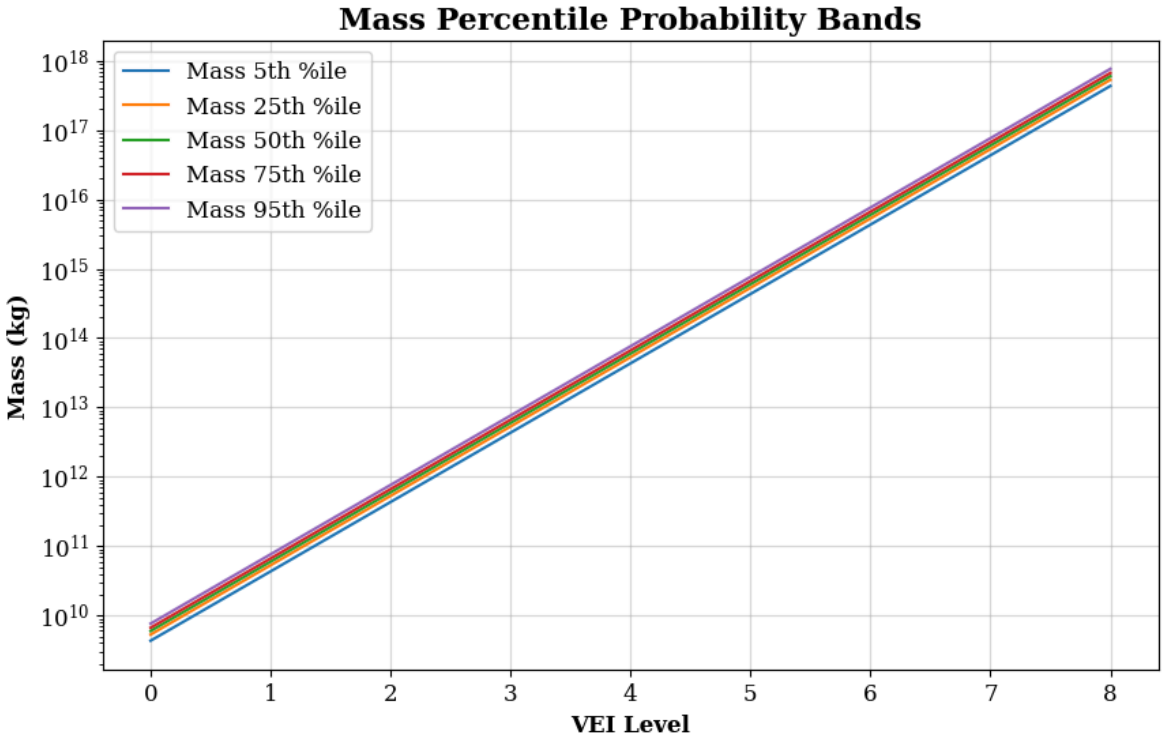
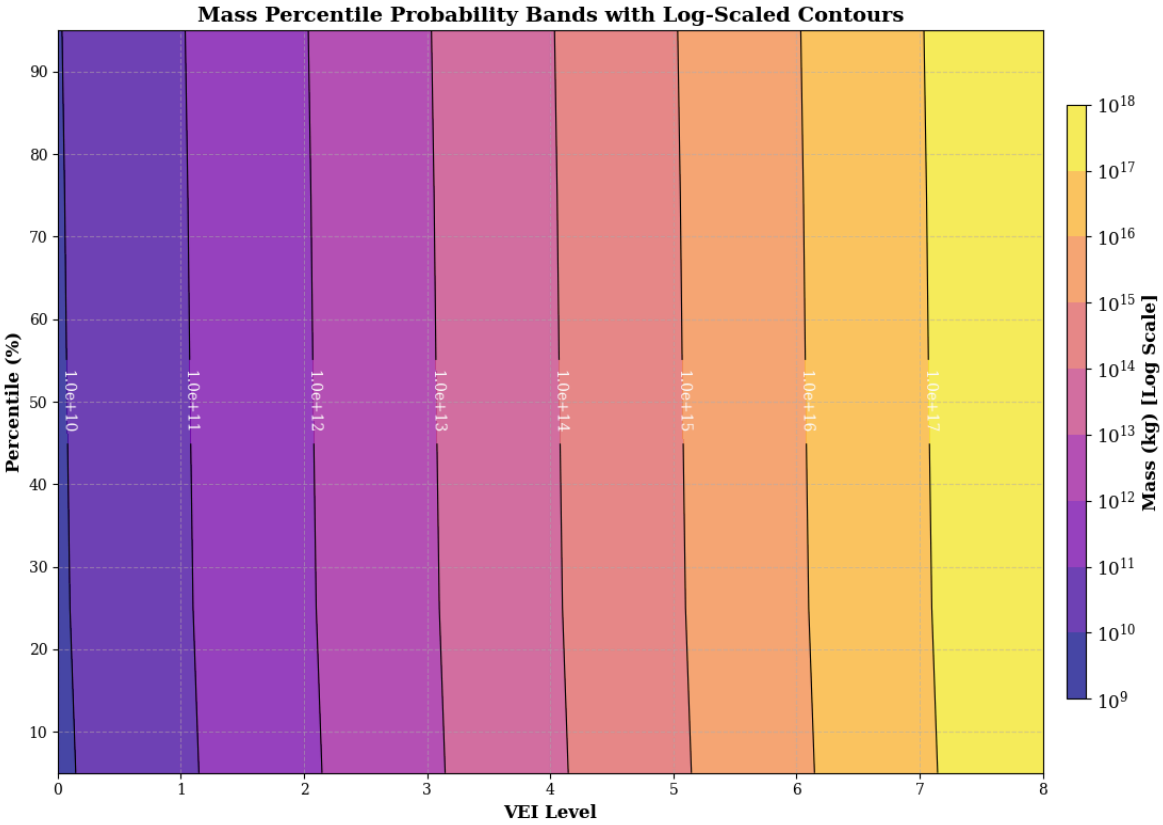

```
c:\Users\mahmud\OneDrive\Singapore_project\data\Modules\phase_1\vei.py:789: UserW
arning:

Mismatched number of handles and labels: len(handles) = 0 len(labels) = 4
```


emperical Bulk Volumes Distribution
Count
emperical_Bulk_Volume_m3
1e12
Probabilistic Bulk Volumes Distribution (Sampled)
Count
probablistic_Bulk_Volume_m3
1e6


emperical Mass Distribution Boxplot
1e15
Mean_Mass_emp_kg
Probabilistic Mass KDE Plot
1e−18
Mass Density
Mean Mass: 7.37e+16 kg
Density
Mean_Mass_Prob_kg
1e18


emperical and Probabilistic Volume Percentile Bands
Plot Lines
emperical Percentile
Probabilistic Percentile
Interpretation
emperical 5th Percentile
Probabilistic 5th Percentile
emperical 25th Percentile
Probabilistic 25th Percentile
emperical 50th Percentile
Probabilistic 50th Percentile
emperical 75th Percentile
Probabilistic 75th Percentile
emperical 95th Percentile
Probabilistic 95th Percentile
Volume (m³)
Volcanic Explosivity Index (VEI)






```
Volume data successfully exported to volumes_data.csv
Mass data successfully exported to masses_data.csv
Data successfully exported to VEI_MASS_VolumeResults.csv
```

Step 2: Load Volcanic Data for Model Inputs and Validation

This cell loads datasets containing eruption source parameters and metadata.

Data Sources:

1. `Mastin` : Dataset of VEI-related eruption parameters.
2. `Aubrey` : Dataset with parameters for eruption dynamics.
3. `IVESPA` : Integrated Volcanic Eruption Source Parameters Archive for further modeling.

Purpose:

- These datasets provide observational constraints and inputs for modeling eruption parameters.
- Support statistical analysis and correlation studies to validate models.

In [7]:
```
import vei
from vei import  analyze_correlations

data_loader=vei.LOADDATA()


Mastin = data_loader.load_Mastin(as_geodataframe=False)
Aubrey=data_loader.load_Aubry(as_geodataframe=False)
IVESPA=data_loader.load_IVESPA(as_geodataframe=False)
Sparks=data_loader.load_Sparks(as_geodataframe=False)
mastin_a=data_loader.load_Mastin_a(as_geodataframe=True)

# analyze_correlations(Mastin, 'Mastin', threshold=0.7)

# analyze_correlations(Aubrey, 'Aubrey', threshold=0.7)

# analyze_correlations(Sparks, 'Sparks', threshold=0.7)

# analyze_correlations(IVESPA, 'IVESPA', threshold=0.7)

#analyze_correlations(mastin_a, 'IVESPA', threshold=0.9)

import pandas as pd

Combined_datasets= pd.concat([ Aubrey, IVESPA, mastin_a], axis=0, join='inner')

aubrey_datacombined= pd.concat([ Aubrey, IVESPA], axis=0, join='inner')
```

Step 3: Estimate Mass Eruption Rate (MER)

This cell prepares TEM data for use with the `MERPredictor` class.

Inputs:

- `tem_values` : Extracted mean probabilistic TEM values (`Mean_Mass_Prob_kg`) generated by the VEI model.

Purpose:

- `tem_values` serve as input to estimate MER, an essential eruption source parameter.
- MER will be used in subsequent steps to calculate eruption duration and plume rise.

In [8]:
```
import pandas as pd

data=vei_toMass.data

# Drop first row (VEI zero) because VEI zero is None Explosive

#data = data.drop(index=data.index[0]).reset_index(drop=True)


# Ensuring the VEI column is numeric
data['VEI'] = pd.to_numeric(data['VEI'], errors='coerce')

# Filtering the dataframe based on VEI column and list
data = data[data['VEI'].isin(vei_range)].reset_index(drop=True)

data
```

Out[8]:

	VEI	Bulk_Volume_km3	emperical_Bulk_Volume_m3	Probabilistic_Bulk_Volume_m3	M
0	2	0.1	1.000000e+08	5.500434e+08	
1	3	3.0	3.000000e+09	5.502371e+09	
2	4	30.0	3.000000e+10	5.500256e+10	
3	5	100.0	1.000000e+11	5.498882e+11	

4 rows × 34 columns

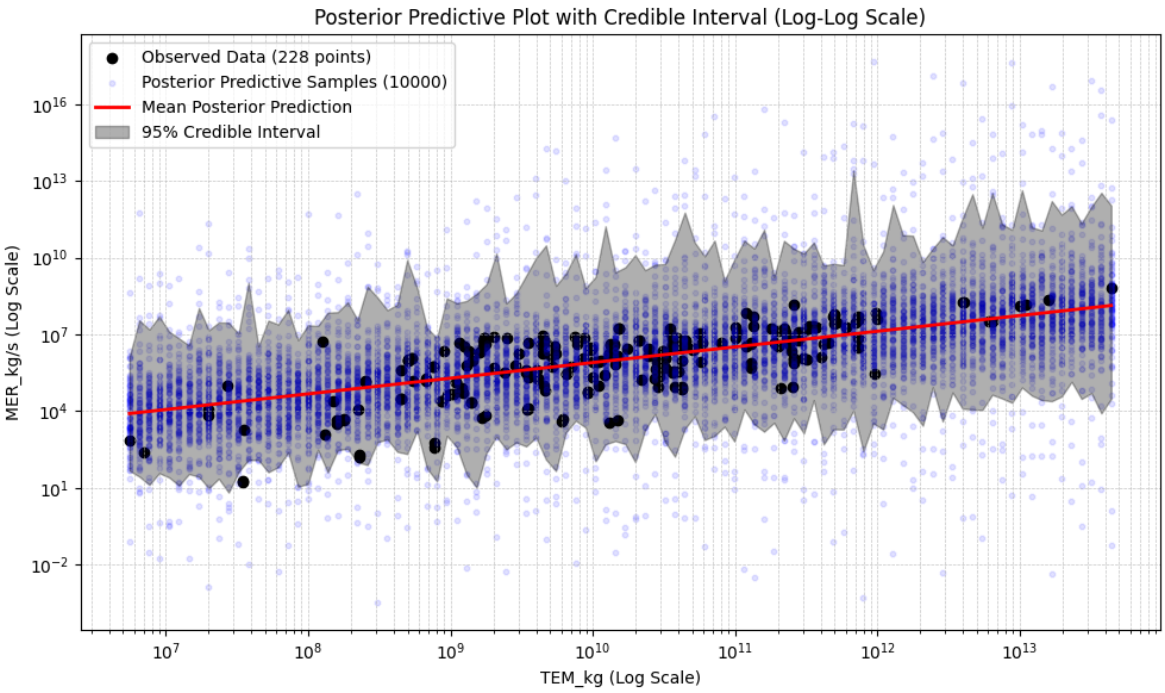
In [9]:
```
data.columns
```

Out[9]:
```
Index(['VEI', 'Bulk_Volume_km3', 'emperical_Bulk_Volume_m3',
       'Probabilistic_Bulk_Volume_m3', 'Mean_Mass_emp_kg', 'Std_Mass_emp_kg',
       'Mean_Mass_Prob_kg', 'Std_Mass_Prob_kg', 'emp_Volume_5th',
       'Uncertainty_emp_Volume_5th', 'Prob_Volume_5th',
       'Uncertainty_Prob_Volume_5th', 'emp_Volume_25th',
       'Uncertainty_emp_Volume_25th', 'Prob_Volume_25th',
       'Uncertainty_Prob_Volume_25th', 'emp_Volume_50th',
       'Uncertainty_emp_Volume_50th', 'Prob_Volume_50th',
       'Uncertainty_Prob_Volume_50th', 'emp_Volume_75th',
       'Uncertainty_emp_Volume_75th', 'Prob_Volume_75th',
       'Uncertainty_Prob_Volume_75th', 'emp_Volume_95th',
       'Uncertainty_emp_Volume_95th', 'Prob_Volume_95th',
       'Uncertainty_Prob_Volume_95th', 'Mass_5th', 'Mass_25th', 'Mass_50th',
       'Mass_75th', 'Mass_95th', '90%_interpercentile_Mass_Estimate'],
      dtype='object')
```

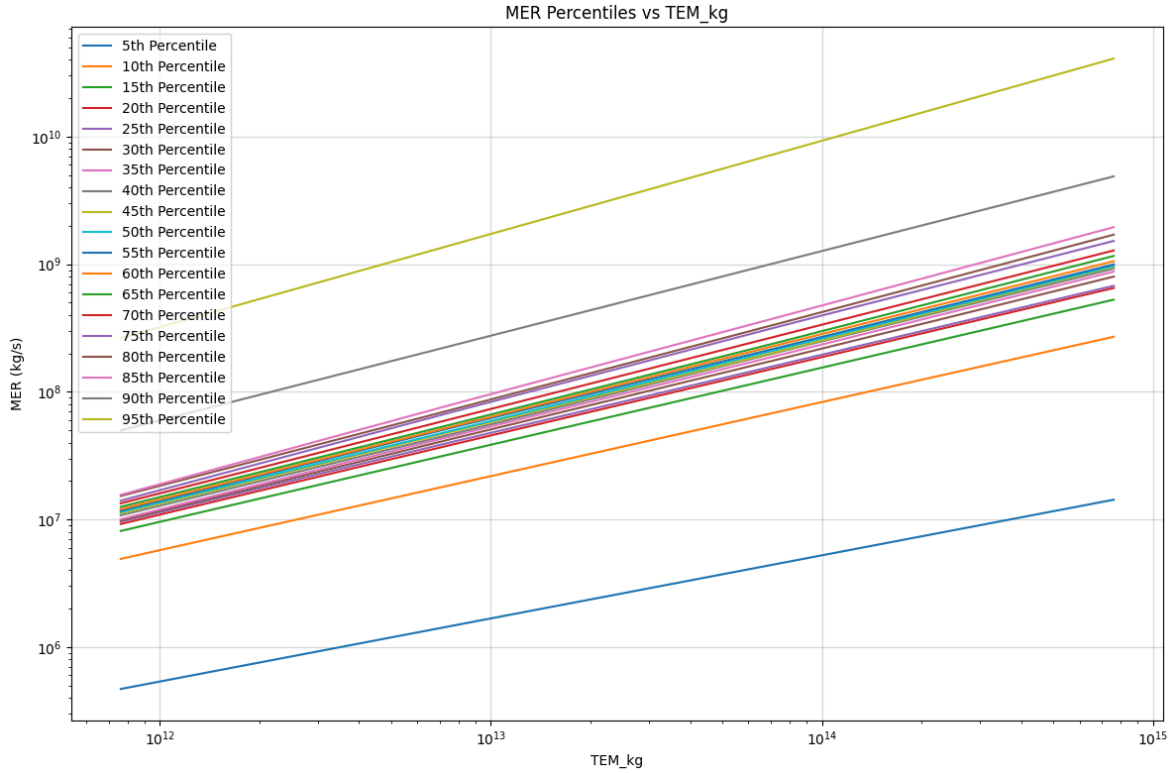
In [10]:
```
from mer_predict import MERPredictor

tem_values=data.Mass_95th.to_list()
```

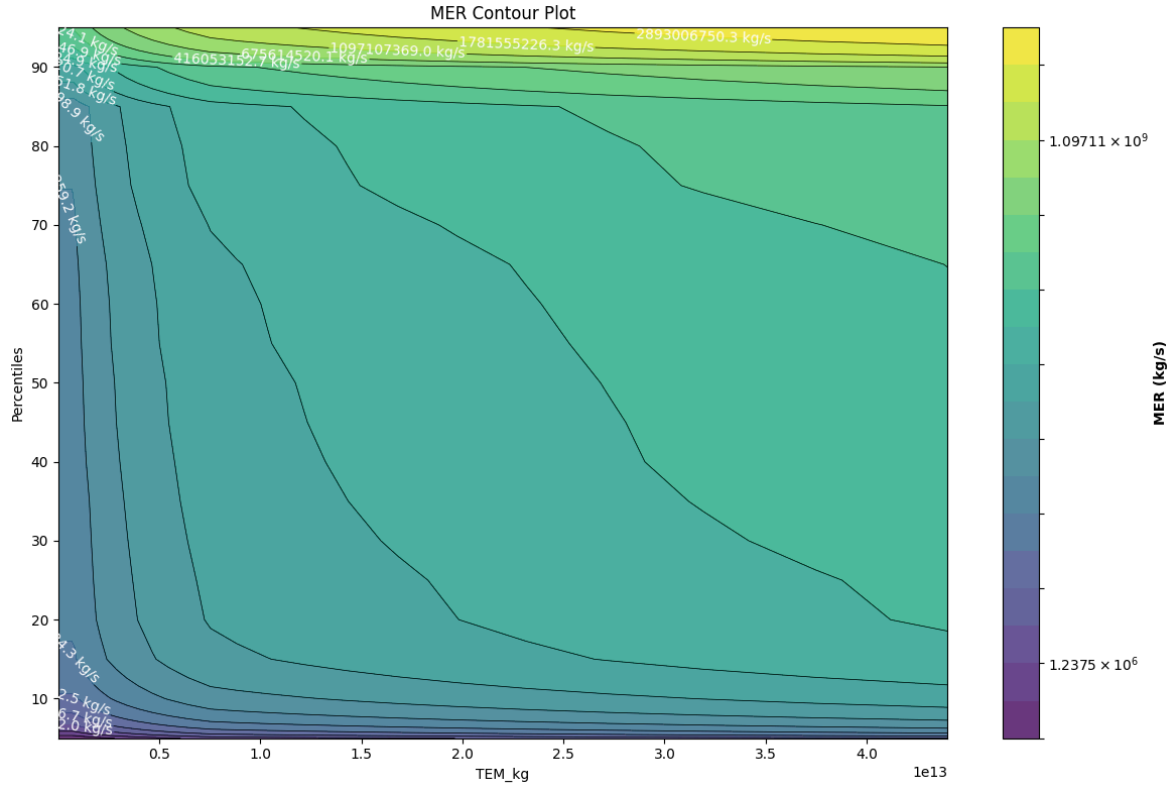
```
#tem_values=[1.998468e+11 , 3.585472e+14 ]



model = MERPredictor(aubrey_datacombined)

percentiles=list(range(5, 96, 5))

model.plot_posterior_predictive()
mer_results=model.predict_mer(tem_values, percentiles=percentiles)
#model.plot_percentiles_vs_tem()
# durations = model.convert_percentiles_to_duration(tem_values)
# print(durations)
```

```
WARNING:tensorflow:From c:\Users\mahmud\anaconda3\Lib\site-packages\keras\src\los
ses.py:2976: The name tf.losses.sparse_softmax_cross_entropy is deprecated. Pleas
e use tf.compat.v1.losses.sparse_softmax_cross_entropy instead.

WARNING:tensorflow:From c:\Users\mahmud\anaconda3\Lib\site-packages\tensorflow_pr
obability\python\internal\backend\numpy\_utils.py:48: The name tf.logging.TaskLev
elStatusMessage is deprecated. Please use tf.compat.v1.logging.TaskLevelStatusMes
sage instead.

WARNING:tensorflow:From c:\Users\mahmud\anaconda3\Lib\site-packages\tensorflow_pr
obability\python\internal\backend\numpy\_utils.py:48: The name tf.control_flow_v2
_enabled is deprecated. Please use tf.compat.v1.control_flow_v2_enabled instead.

Selected model: linear with BIC = 628.8633422851562
```




```
Predictions saved to predicted_mer.csv
```


MER Percentiles vs TEM_kg
5th Percentile
10th Percentile
15th Percentile
20th Percentile
25th Percentile
30th Percentile
35th Percentile
40th Percentile
45th Percentile
50th Percentile
55th Percentile
60th Percentile
65th Percentile
70th Percentile
75th Percentile
80th Percentile
85th Percentile
90th Percentile
95th Percentile
MER (kg/s)
TEM_kg


MER Contour Plot
2893006750.3 kg/s
1781555226.3 kg/s
1097107369.0 kg/s
675614520.1 kg/s
416053152.7 kg/s
Percentiles
TEM_kg
1e13
MER (kg/s)
1.09711 × 10^9
1.2375 × 10^6

Step 4: Correlate VEI with MER Results

This cell adds the VEI values from the processed data into the `mer_results` DataFrame.

Purpose:

- Ensures that MER results are directly associated with their corresponding VEI values.
- Facilitates traceability and cross-comparison during analysis.

In [11]:
```
mer_results["VEI"]=data['VEI']
```

Step 5: Review Mass Eruption Rate (MER) Results

This cell displays the `mer_results` DataFrame, which includes the calculated MER values and associated VEI data.

Purpose:

- Provides an overview of the MER estimates to verify accuracy and consistency.

In [12]:
```
mer_results.columns
```

Out[12]:
```
Index(['TEM_kg', 'MERPercentile_5', 'MERPercentile_10', 'MERPercentile_15',
       'MERPercentile_20', 'MERPercentile_25', 'MERPercentile_30',
       'MERPercentile_35', 'MERPercentile_40', 'MERPercentile_45',
       'MERPercentile_50', 'MERPercentile_55', 'MERPercentile_60',
       'MERPercentile_65', 'MERPercentile_70', 'MERPercentile_75',
       'MERPercentile_80', 'MERPercentile_85', 'MERPercentile_90',
       'MERPercentile_95', '90%_interpercentile_MERrange_kg/s',
       'Duration_hr_P5', 'Duration_hr_P10', 'Duration_hr_P15',
       'Duration_hr_P20', 'Duration_hr_P25', 'Duration_hr_P30',
       'Duration_hr_P35', 'Duration_hr_P40', 'Duration_hr_P45',
       'Duration_hr_P50', 'Duration_hr_P55', 'Duration_hr_P60',
       'Duration_hr_P65', 'Duration_hr_P70', 'Duration_hr_P75',
       'Duration_hr_P80', 'Duration_hr_P85', 'Duration_hr_P90',
       'Duration_hr_P95', 'Duration_hr_90%_interpercentile', 'VEI'],
      dtype='object')
```

Step 6: Select Central MER Values for Plume Height Prediction

This cell extracts the 50th percentile (median) MER values from the `mer_results` DataFrame.

Purpose:

- Focuses on the central tendency of the MER distribution, minimizing the influence of outliers.
- The Best MER values (`mer_list`) are determined using the range between the (`95th and 5th percentiles`) and are used as input for plume height predictions..

In [13]:
```
mer_list=mer_results['MERPercentile_95'].to_list()
vei_list=mer_results.VEI.to_list()
vei_list
```

Out[13]:
```
[2, 3, 4, 5]
```

Step 7: Estimate Plume Rise Based on MER

This cell initializes the `PlumeHeightPredictor` class and calculates plume heights using the median MER values.

Methodology:

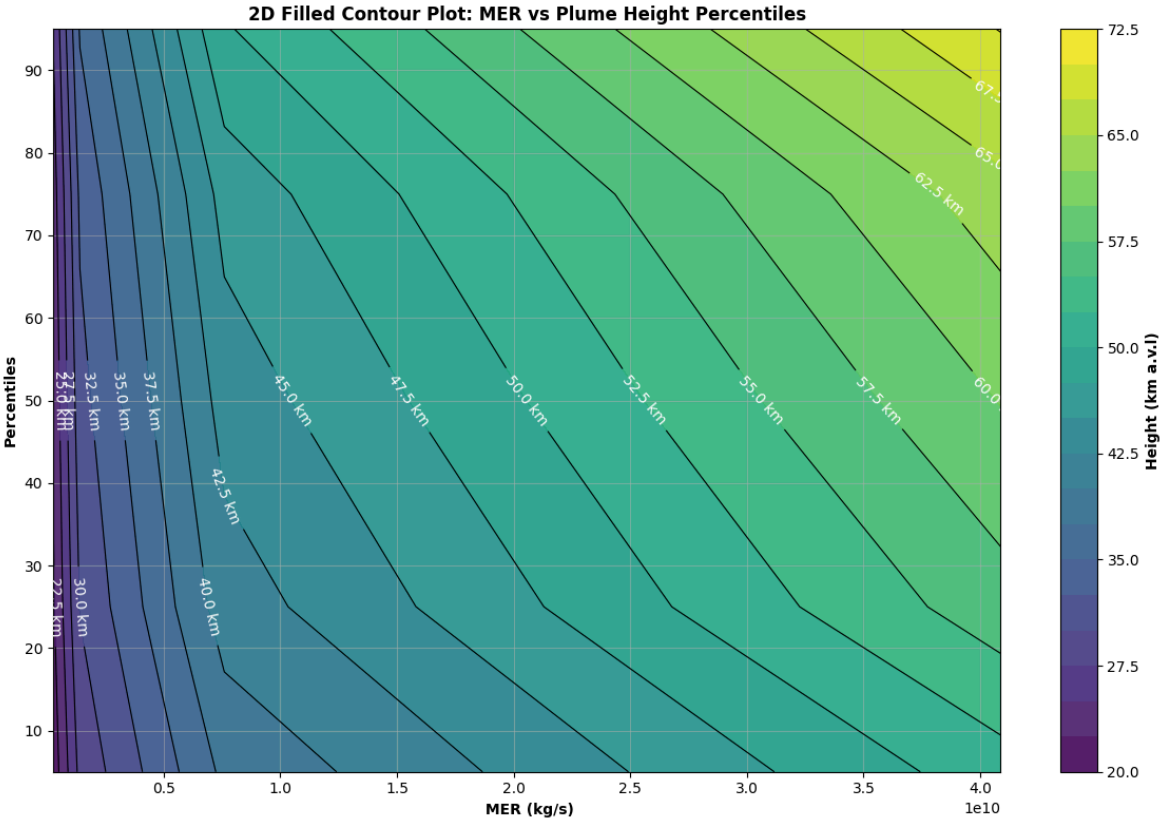
- Utilizes the `IVESPA` dataset for plume height predictions with uncertainty quantification.
- Outputs plume height estimates based on the MER values (`mer_list`).

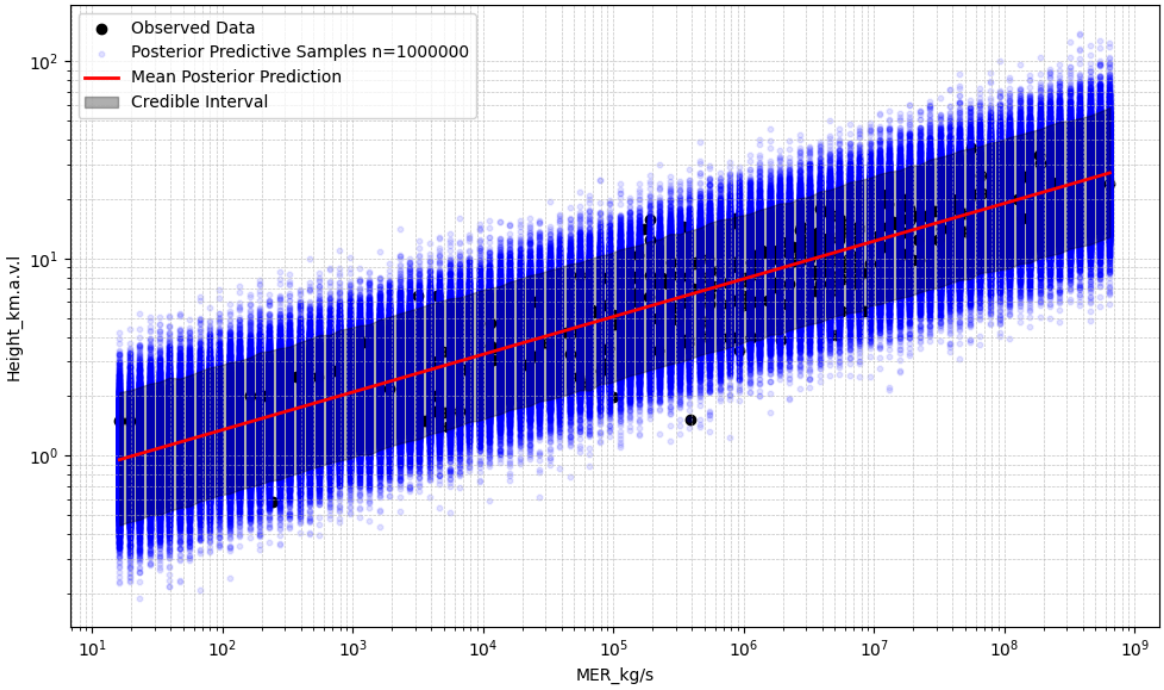
Purpose:

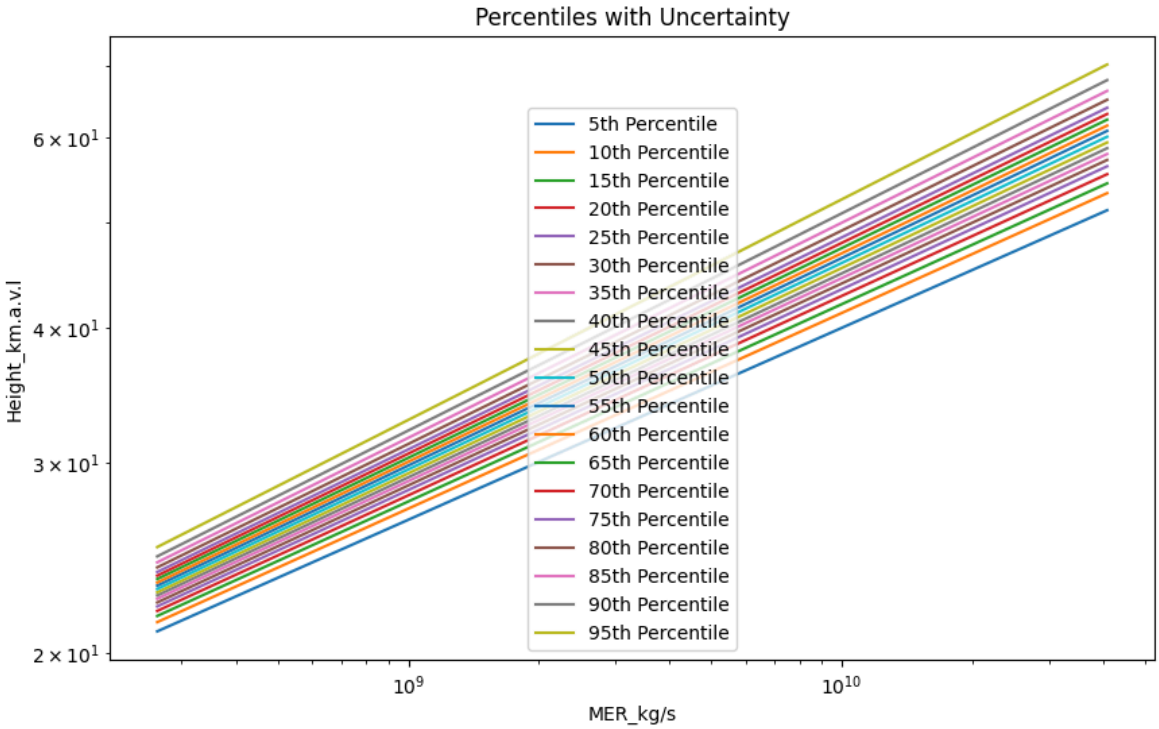
- Plume rise estimation is critical for assessing the environmental and aviation impacts of volcanic eruptions.

In [14]:
```
from plume_rise_predict import PlumeHeightPredictor

# Initialize the PlumeHeightPredictor
predictor = PlumeHeightPredictor(aubrey_datacombined)

heights=predictor.predict_height_with_uncertainty(mer_results['MERPercentile_95'


heights
```

```
Predictions with uncertainty saved to predicted_height_with_uncertainty.csv
```


2D Filled Contour Plot: MER vs Plume Height Percentiles
Percentiles
MER (kg/s)
1e10
Height (km a.v.l)
22.5 km
25.0 km
27.5 km
30.0 km
32.5 km
35.0 km
37.5 km
40.0 km
42.5 km
45.0 km
47.5 km
50.0 km
52.5 km
55.0 km
57.5 km
60.0 km
62.5 km
65.0
67.5


Observed Data
Posterior Predictive Samples n=1000000
Mean Posterior Prediction
Credible Interval
Height_km.a.v.l
MER_kg/s



Out[14]:

	MER_kg/s	HeightPercentile_5	HeightPercentile_10	HeightPercentile_15	HeightPe
0	2.637347e+08	20.915370	21.331430	21.613819	
1	1.416006e+09	28.241585	28.951933	29.411540	
2	7.603739e+09	38.076356	39.267137	39.994580	
3	4.087218e+10	51.375579	53.282612	54.406904	

4 rows × 21 columns

Step 8: Review Plume Height Estimates

This cell displays the predicted plume heights.

Purpose:

- Offers an immediate review of the plume height results for quality control and interpretation.

In [15]:
```
mer_results.columns
```

Out[15]:
```
Index(['TEM_kg', 'MERPercentile_5', 'MERPercentile_10', 'MERPercentile_15',
       'MERPercentile_20', 'MERPercentile_25', 'MERPercentile_30',
       'MERPercentile_35', 'MERPercentile_40', 'MERPercentile_45',
       'MERPercentile_50', 'MERPercentile_55', 'MERPercentile_60',
       'MERPercentile_65', 'MERPercentile_70', 'MERPercentile_75',
       'MERPercentile_80', 'MERPercentile_85', 'MERPercentile_90',
       'MERPercentile_95', '90%_interpercentile_MERrange_kg/s',
       'Duration_hr_P5', 'Duration_hr_P10', 'Duration_hr_P15',
       'Duration_hr_P20', 'Duration_hr_P25', 'Duration_hr_P30',
       'Duration_hr_P35', 'Duration_hr_P40', 'Duration_hr_P45',
       'Duration_hr_P50', 'Duration_hr_P55', 'Duration_hr_P60',
       'Duration_hr_P65', 'Duration_hr_P70', 'Duration_hr_P75',
       'Duration_hr_P80', 'Duration_hr_P85', 'Duration_hr_P90',
       'Duration_hr_P95', 'Duration_hr_90%_interpercentile', 'VEI'],
      dtype='object')
```

In [16]:
```
heights['VEI']=mer_results['VEI']
# List of columns to be assigned
columns_to_assign = ['Duration_hr_P5', 'Duration_hr_P25', 'Duration_hr_P50', 'Du

# Assign values from mer_results to heights for these columns
heights[columns_to_assign] = mer_results[columns_to_assign]



heights.to_csv('Final_prediction_results.csv')

heights
```

Out[16]:

	MER_kg/s	HeightPercentile_5	HeightPercentile_10	HeightPercentile_15	HeightPe
0	2.637347e+08	20.915370	21.331430	21.613819	
1	1.416006e+09	28.241585	28.951933	29.411540	
2	7.603739e+09	38.076356	39.267137	39.994580	
3	4.087218e+10	51.375579	53.282612	54.406904	

4 rows × 28 columns

In [17]:
```
# Add a bold title using Styler
styled_table = heights.style.set_caption("<b>VEI and Related Data</b>")
styled_table
```

Out[17]:

	MER_kg/s	HeightPercentile_5	HeightPercentile_10	HeightPercentile_15	He
0	263734738.339319	20.915370	21.331430	21.613819	
1	1416005871.096091	28.241585	28.951933	29.411540	
2	7603738971.918003	38.076356	39.267137	39.994580	
3	40872184089.891838	51.375579	53.282612	54.406904	

In [18]:
```
from rich.console import Console
from rich.table import Table

# Ensure VEI is first
if "VEI" not in heights.columns:
    raise KeyError("The 'VEI' column is missing from the DataFrame.")

cols = ["VEI"] + [col for col in heights.columns if col != "VEI"]
heights = heights[cols]

# Rich Console for better formatting
console = Console()

# Function to print DataFrame in chunks of six columns, keeping VEI first
def print_six_columns_with_vei_first(df):
    num_cols = len(df.columns)
    for i in range(1, num_cols, 3):  # 5 because VEI is fixed
        # Slice five columns at a time, after the first column
        cols = ["VEI"] + list(df.columns[i:i+3])

        # Create a table for this chunk
        table = Table(title="VEI and Related Data")
        for col in cols:
            table.add_column(col, justify="center")

        # Add rows to the table
        for _, row in df[cols].iterrows():
            table.add_row(*[str(cell) for cell in row])

        # Print the table
        console.print(table)

# Display the DataFrame
print_six_columns_with_vei_first(heights)
```

VEI and Related Data

VEI	MER_kg/s	HeightPercentile_5	HeightPercentile_10
2.0	263734738.33931884	20.915369546884616	21.331429911766858
3.0	1416005871.0960913	28.241585300901246	28.951933087831016
4.0	7603738971.918003	38.076355785647905	39.26713707196505
5.0	40872184089.89184	51.3755789018824	53.28261213731151

VEI and Related Data

VEI	HeightPercentile_15	HeightPercentile_20	HeightPercentile_25
2.0	21.613819391639456	21.84697161894229	22.059057606035502
3.0	29.411540437974523	29.81827314889459	30.17056664361438
4.0	39.99457973600822	40.69399355593317	41.25235061535111
5.0	54.40690431501138	55.48377603870605	56.42732532401312

VEI and Related Data

VEI	HeightPercentile_30	HeightPercentile_35	HeightPercentile_40
2.0	22.246575114862893	22.42380470257502	22.583176414439016
3.0	30.480590876761344	30.77094562365109	31.029135834526937
4.0	41.75617598951781	42.22386736536354	42.63804386288488
5.0	57.19328215742592	57.92714138033494	58.647136971993596

VEI and Related Data

VEI	HeightPercentile_45	HeightPercentile_50	HeightPercentile_55
2.0	22.732436772142417	22.895094282778047	23.057808700834116
3.0	31.30713665639755	31.583727871348618	31.858484018109245
4.0	43.11619637338617	43.57611610958067	44.022723092844224
5.0	59.37024344739864	60.10179441562113	60.85501749374209

VEI and Related Data

VEI	HeightPercentile_60	HeightPercentile_65	HeightPercentile_70
2.0	23.210689842837628	23.38711907299264	23.556670431727383
3.0	32.126472858206355	32.40471585358821	32.70933202652877
4.0	44.45889992344718	44.9396743140395	45.43292225100868
5.0	61.544014895480494	62.33085820499958	63.09128261246717

VEI and Related Data

VEI	HeightPercentile_75	HeightPercentile_80	HeightPercentile_85
2.0	23.74006439707223	23.975066627420354	24.233408623387593
3.0	33.02066981132512	33.41823569886797	33.88019987500591
4.0	45.952392748571384	46.6053622940062	47.372896412347515
5.0	63.932873853739785	65.03316438470173	66.27556073642538

VEI and Related Data

VEI	HeightPercentile_90	HeightPercentile_95	90%_interpercentile_He
2.0	24.544383099325774	25.03701982289551	4.12165027601
3.0	34.44034604949838	35.25366217166669	7.01207687076
4.0	48.301665797482215	49.73164840773057	11.65529262208
5.0	67.81830086317025	70.11745295185922	18.74187404997

VEI and Related Data

VEI	Duration_hr_P5	Duration_hr_P25	Duration_hr_P50
2.0	451.1485341090696	22.069162047488895	18.53108808511808
3.0	1445.3410022229234	52.41710686727613	42.63583418923697
4.0	4628.288861281014	128.05703457866034	96.56884214551671
5.0	14822.270572316527	312.27834475899505	218.34901134200308

VEI and Related Data

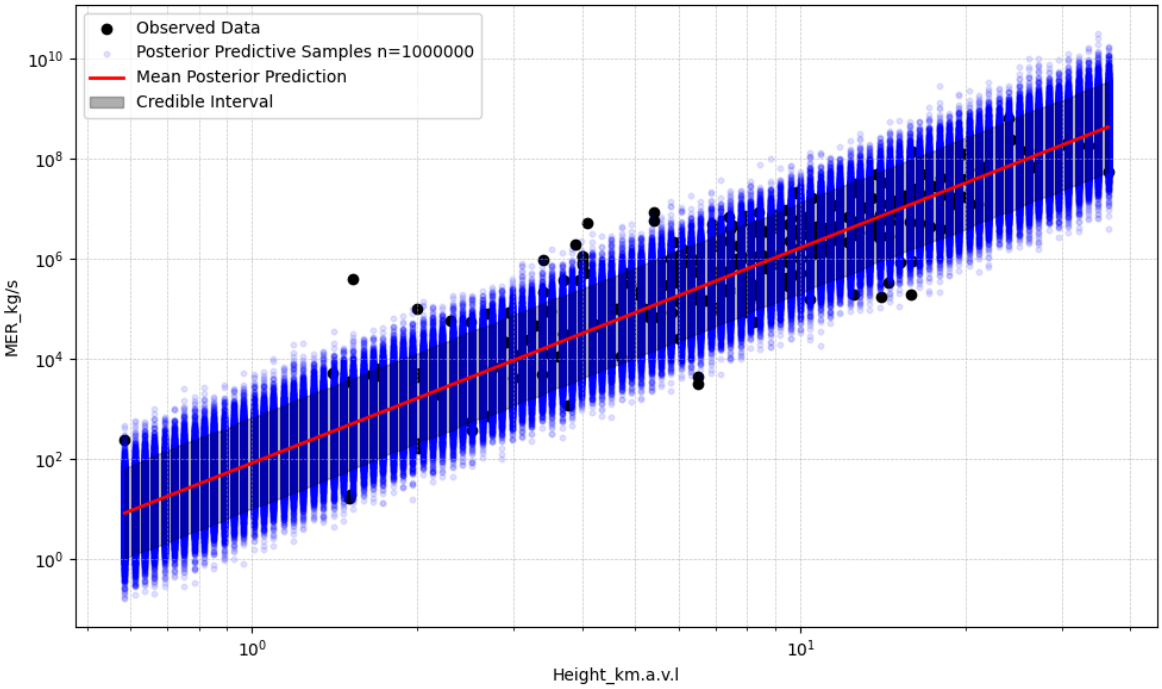
VEI	Duration_hr_P75	Duration_hr_P95	Duration_hr_90%_interper
2.0	15.088151759080407	0.8027842183454168	0.8042152577221199
3.0	30.553609033576713	1.495757453709167	1.4973069898304596
4.0	63.98295122142996	2.7840138361930653	2.785689487456169
5.0	139.0063660800366	5.17773024112124	5.179539563012893

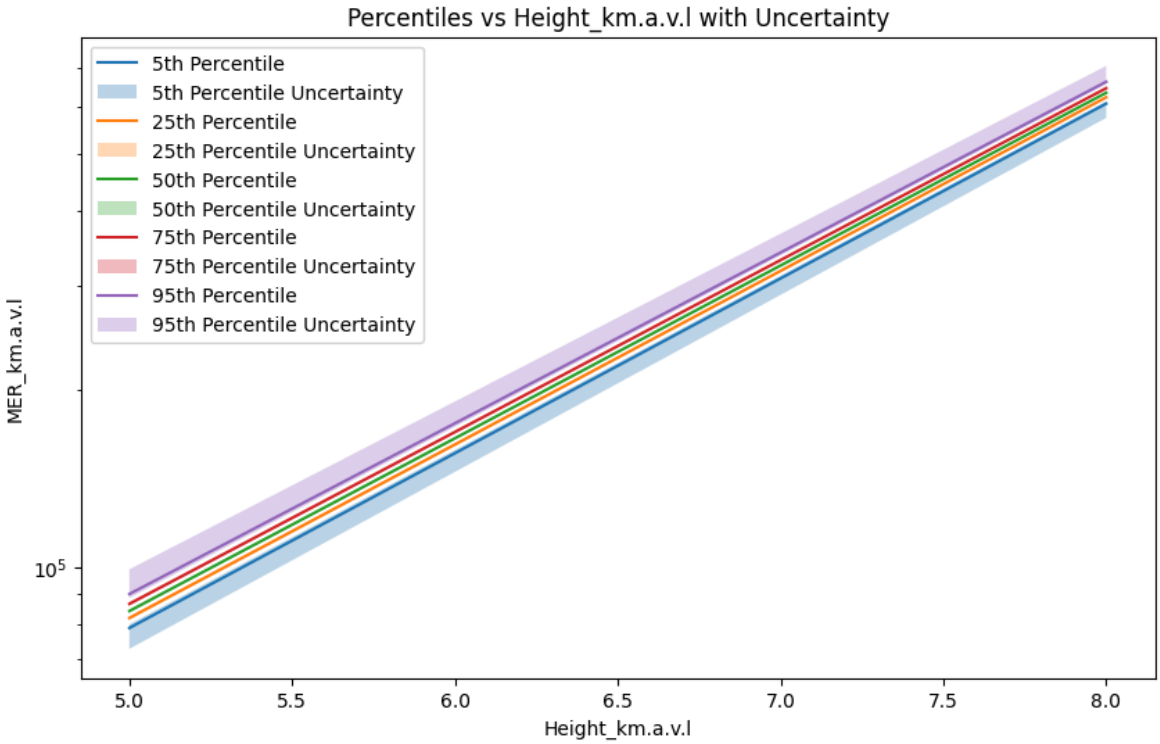
Refining Mass Eruption Rate (MER) Estimates Using Observed Plume Height

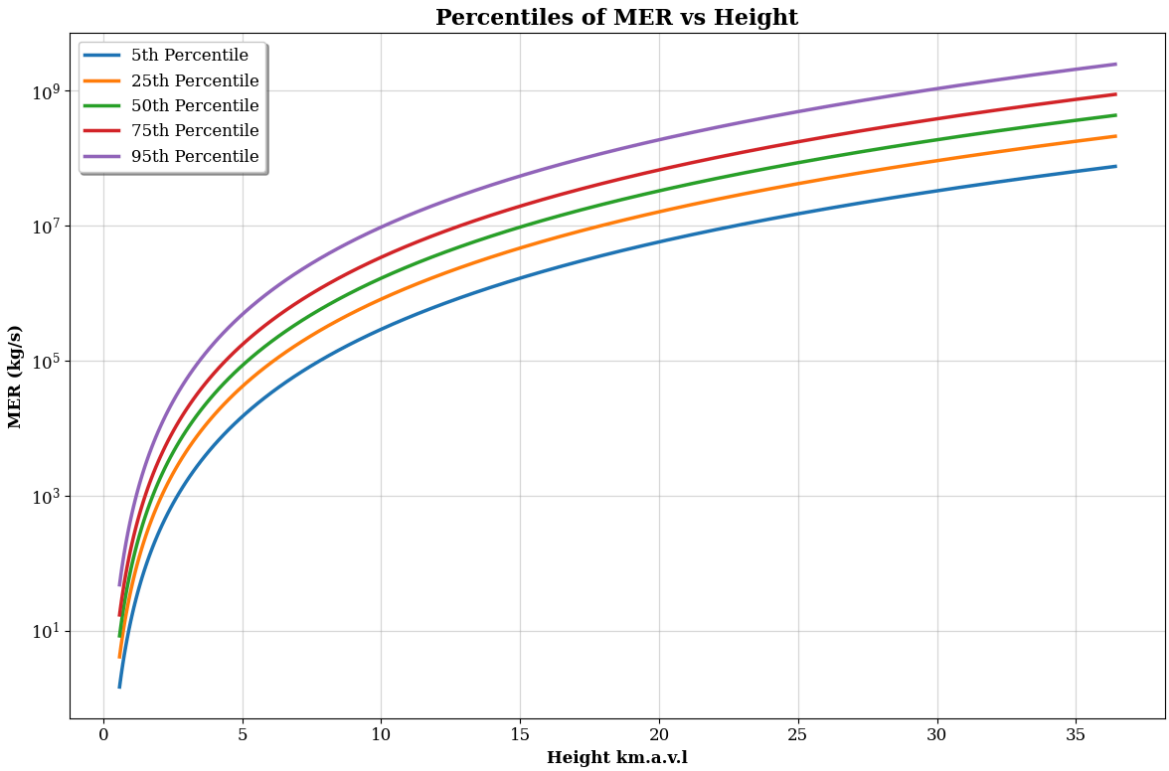
When plume height is observed through satellite imagery or infrasound data, it provides an opportunity to enhance previously predicted MER values. By leveraging this direct observation of plume height, we can derive a more accurate estimate of the MER, aligning it closely with the actual eruption dynamics.

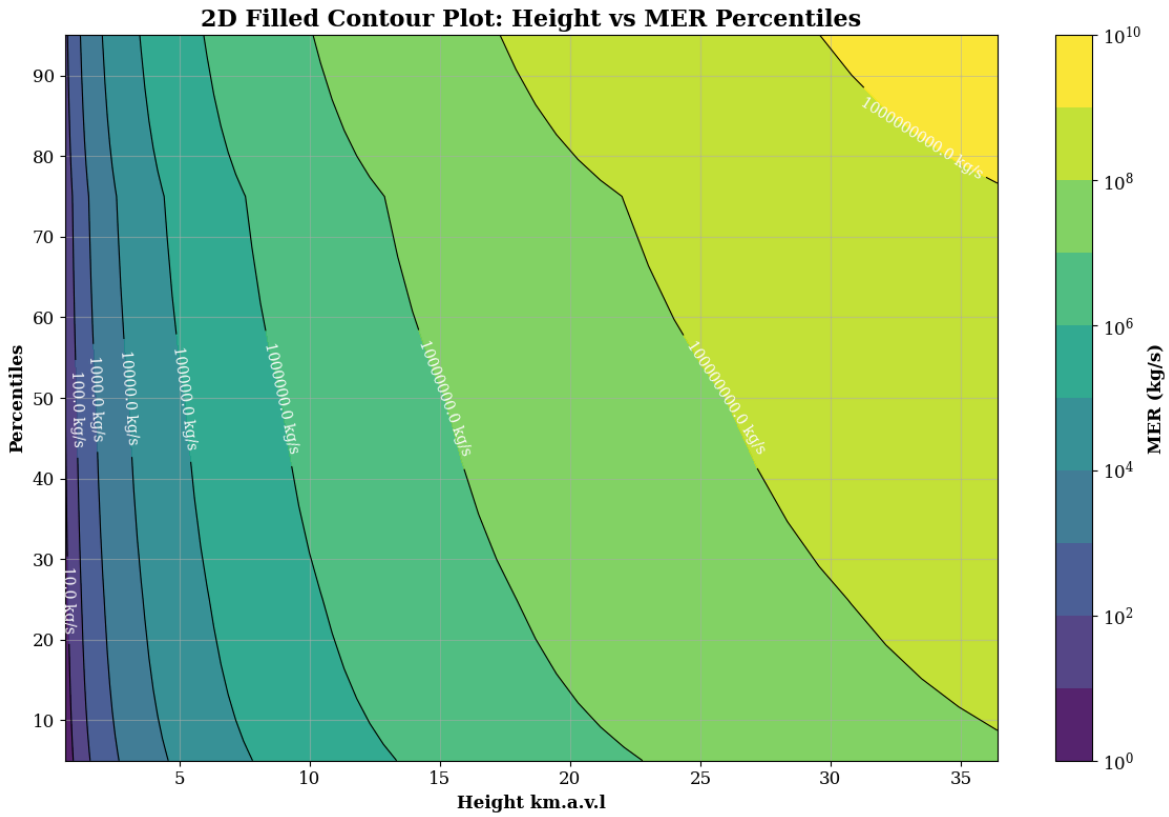
In [19]:
```
from mer_from_height import MERPredictorFromHeight

predictor = MERPredictorFromHeight(Combined_datasets)
# Predict MER for specific heights
# Save predictions to a CSV
Observed_plume_height=[5,8]
predictions=predictor.predict_MER_with_uncertainty(Observed_plume_height, output


# Visualize the posterior predictive distribution
predictor.plot_posterior_predictive()

# Visualize percentiles with uncertainty
predictor.plot_percentiles_with_uncertainty(Observed_plume_height)

predictor.plot_percentiles_vs_mer()

predictions
```

```
Predictions with uncertainty saved to predicted_mer_fromheight.csv
```


Observed Data
Posterior Predictive Samples n=1000000
Mean Posterior Prediction
Credible Interval
MER_kg/s
Height_km.a.v.l


Percentiles vs Height_km.a.v.l with Uncertainty
5th Percentile
5th Percentile Uncertainty
25th Percentile
25th Percentile Uncertainty
50th Percentile
50th Percentile Uncertainty
75th Percentile
75th Percentile Uncertainty
95th Percentile
95th Percentile Uncertainty
MER_km.a.v.l
Height_km.a.v.l





Out[19]:

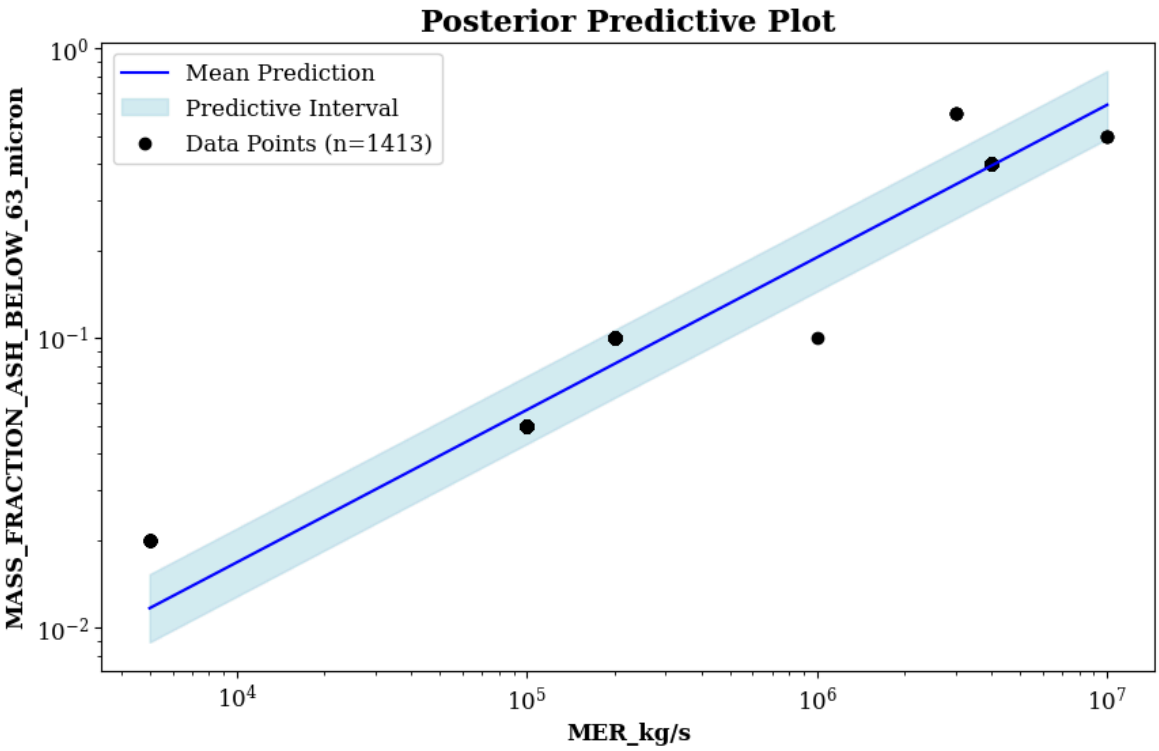
	Height_km.a.v.l	MERPercentile_5	Uncertainty_Lower_5	Uncertainty_Upper_5	MERPer
0	5	78892.286871	72753.555476	80015.857555	820
1	8	608619.516516	575831.605351	614226.709984	6237

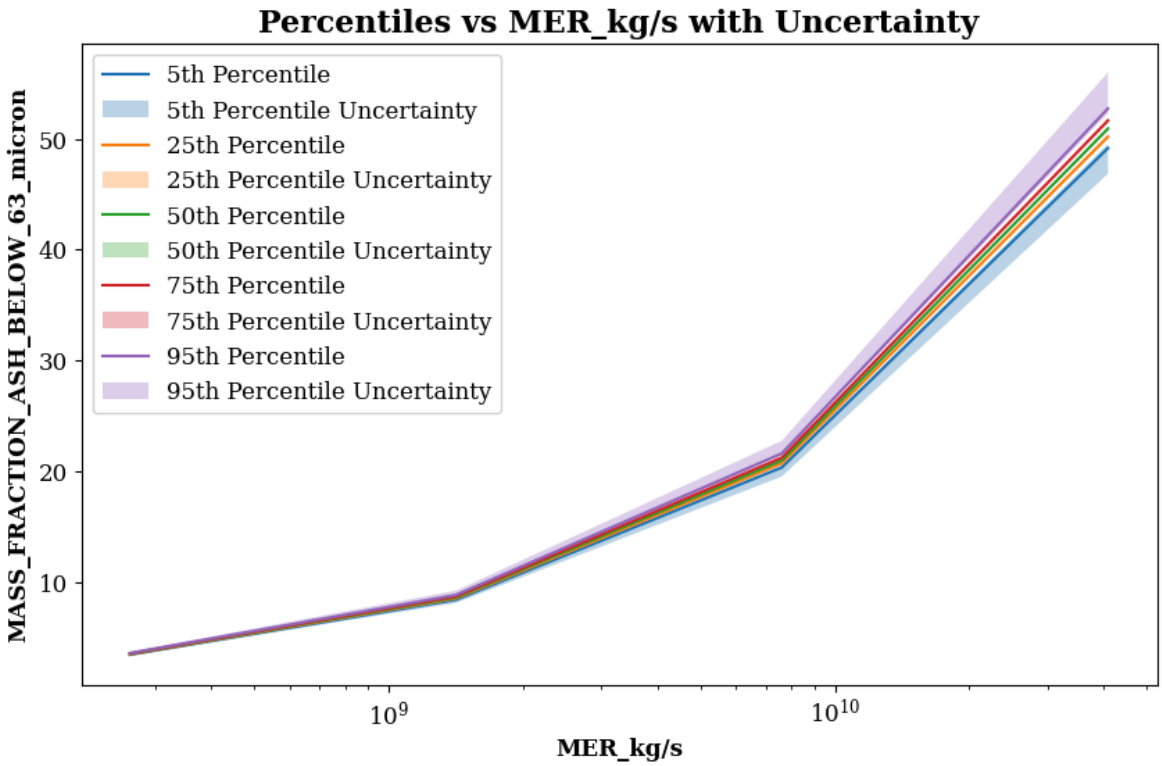
In [20]:

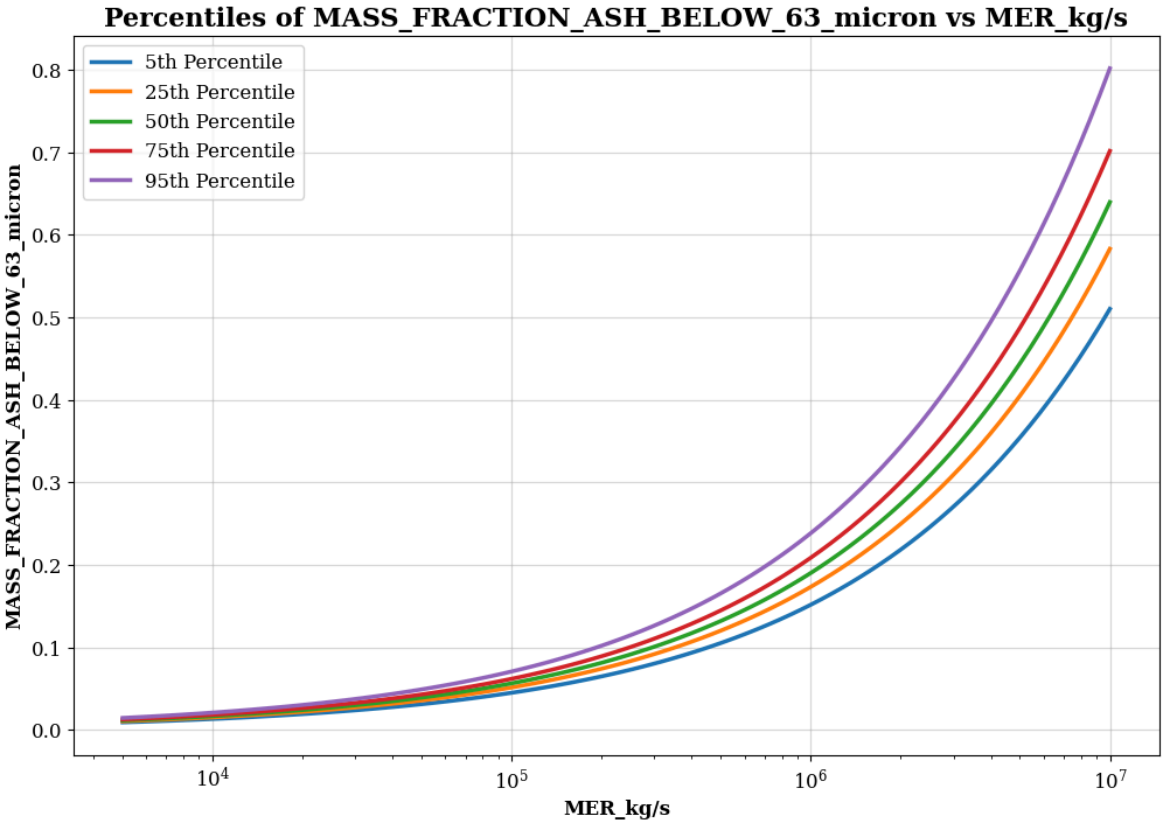
```
from ParticleSize_MER import Predict_ASH_BELOW_63_Micron

from vei import data_loader
```

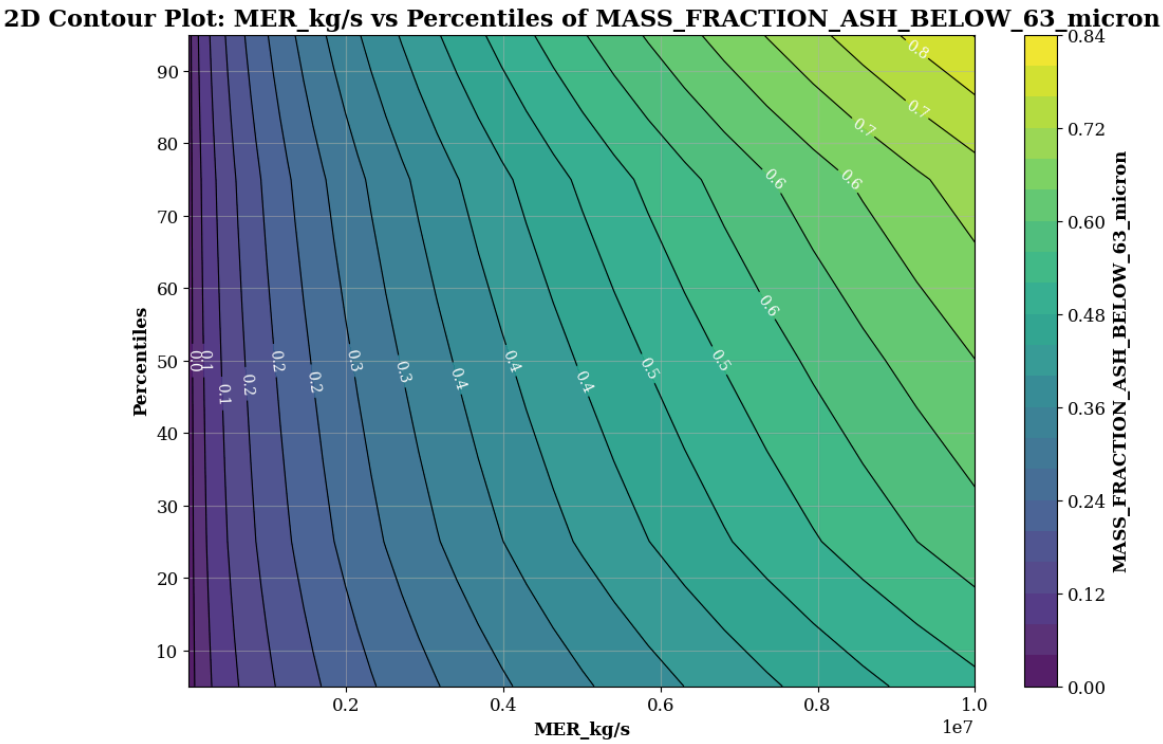
```
#mastin_a=data_loader.load_Mastin_a(as_geodataframe=True)

psize_model=Predict_ASH_BELOW_63_Micron(mastin_a)

psize_model.set_xvar('MER_kg/s')
psize_model.set_yvar('MASS_FRACTION_ASH_BELOW_63_micron')


psize_model.calculate_percentiles_with_uncertainty(mer_list)
psize_model.predict_with_uncertainty(mer_list)

psize_model.plot_posterior_predictive()


# Visualize percentiles with uncertainty
psize_model.plot_percentiles_with_uncertainty(mer_list)

psize_model.plot_percentiles()

psize_predictions=psize_model.predict_with_uncertainty(mer_list)
```

```
Model updated with xvar='MER_kg/s' and yvar='MER_kg/s'.
Model updated with xvar='MER_kg/s' and yvar='MASS_FRACTION_ASH_BELOW_63_micron'.
```




Percentiles vs MER_kg/s with Uncertainty
5th Percentile
5th Percentile Uncertainty
25th Percentile
25th Percentile Uncertainty
50th Percentile
50th Percentile Uncertainty
75th Percentile
75th Percentile Uncertainty
95th Percentile
95th Percentile Uncertainty
MASS_FRACTION_ASH_BELOW_63_micron
10
20
30
40
50
10^9
10^{10}
MER_kg/s


Percentiles of MASS_FRACTION_ASH_BELOW_63_micron vs MER_kg/s
5th Percentile
25th Percentile
50th Percentile
75th Percentile
95th Percentile
MASS_FRACTION_ASH_BELOW_63_micron
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
10^4
10^5
10^6
10^7
MER_kg/s



In [21]:
```
psize_predictions
```

Out[21]:

	MER_kg/s	MASS_FRACTION_ASH_BELOW_63_micron_Percentile_5	Uncertainty_Lowe
0	2.637347e+08	3.510268	3.415
1	1.416006e+09	8.459594	8.174
2	7.603739e+09	20.388173	19.569
3	4.087218e+10	49.159041	46.852

In [22]:
```
columns_to_assign=list(psize_predictions.columns)
columns_to_assign=columns_to_assign[1:]

# Assuming `columns_to_assign` contains column names and `heights` and `psize_pr

heights.loc[:, columns_to_assign] = psize_predictions[columns_to_assign]


heights.to_csv('Final_prediction_results.csv')
```

In [23]:
```
psize_predictions
```

Out[23]:

	MER_kg/s	MASS_FRACTION_ASH_BELOW_63_micron_Percentile_5	Uncertainty_Lowe
0	2.637347e+08	3.510268	3.415
1	1.416006e+09	8.459594	8.174
2	7.603739e+09	20.388173	19.569
3	4.087218e+10	49.159041	46.852