[redacted]

Assignment 3: Gaussian Plume Modelling

Online Gaussian Plume Model Runs

Stable:

Gaussian Plume Model

Tabular results:

- Wind velocities in meters per second
- Effective Stack heights in meters
- Concentrations in mmg per cubic meter

Wind Velocity	Effective Stack Height	Concentration at 0 meters	Concentration at 1 meters	Concentration at 2 meters	Concentration at 3 meters	Concentration at 4 meters	Concentration at 5 meters	Concentration at 6 meters	Concentration at 7 meters	Concentration at 8 meters	Concentration at 9 meters	Concentration at 10 meters
1	45	0	3	87	120	122	114	103	94	87	80	75
3	45	0	1	29	40	41	38	34	31	29	27	25
5	45	0	1	17	24	24	23	21	19	17	16	15
7	45	0	0	12	17	17	16	15	13	12	11	11
9	45	0	0	10	13	14	13	11	10	10	9	8
11	45	0	0	8	11	11	10	9	9	8	7	7
13	45	0	0	7	9	9	9	8	7	7	6	6
15	45	0	0	6	8	8	8	7	6	6	5	5
17	45	0	0	5	7	7	7	6	6	5	5	4
19	45	0	0	5	6	6	6	5	5	5	4	4
21	45	0	0	4	6	6	5	5	4	4	4	4

Somewhat Stable:

Gaussian Plume Model

Tabular results:

- Wind velocities in meters per second
- Effective Stack heights in meters
- Concentrations in mmg per cubic meter

Wind Velocity	Effective Stack Height	Concentration at 0 meters	Concentration at 1 meters	Concentration at 2 meters	Concentration at 3 meters	Concentration at 4 meters	Concentration at 5 meters	Concentration at 6 meters	Concentration at 7 meters	Concentration at 8 meters	Concentration at 9 meters	Concentration at 10 meters
1	45	0	179	189	136	102	82	68	58	51	46	42
3	45	0	60	63	45	34	27	23	19	17	15	14
5	45	0	36	38	27	20	16	14	12	10	9	8
7	45	0	26	27	19	15	12	10	8	7	7	6
9	45	0	20	21	15	11	9	8	6	6	5	5
11	45	0	16	17	12	9	7	6	5	5	4	4
13	45	0	14	15	10	8	6	5	4	4	4	3
15	45	0	12	13	9	7	5	5	4	3	3	3
17	45	0	11	11	8	6	5	4	3	3	3	2
19	45	0	9	10	7	5	4	4	3	3	2	2
21	45	0	9	9	6	5	4	3	3	2	2	2

Neutral:

Gaussian Plume Model

Tabular results:

- Wind velocities in meters per second
- Effective Stack heights in meters
- Concentrations in mmg per cubic meter

Wind Velocity	Effective Stack Height	Concentration at 0 meters	Concentration at 1 meters	Concentration at 2 meters	Concentration at 3 meters	Concentration at 4 meters	Concentration at 5 meters	Concentration at 6 meters	Concentration at 7 meters	Concentration at 8 meters	Concentration at 9 meters	Concentration at 10 meters
1	147	0	0	9	16	18	17	16	15	14	13	12
3	79	0	21	25	19	15	12	10	8	7	6	5
5	65	0	26	20	14	10	8	6	5	4	4	3
7	60	0	23	16	10	7	6	5	4	3	3	2
9	56	0	21	13	8	6	5	4	3	3	2	2
11	54	0	18	11	7	5	4	3	2	2	2	2
13	53	0	16	9	6	4	3	3	2	2	2	1
15	52	0	14	8	5	4	3	2	2	2	1	1
17	51	0	13	7	5	3	2	2	2	1	1	1
19	50	0	12	7	4	3	2	2	1	1	1	1
21	50	0	11	6	4	3	2	2	1	1	1	1

Slightly Unstable:

Gaussian Plume Model

Tabular results:

- Wind velocities in meters per second
- Effective Stack heights in meters
- Concentrations in mmg per cubic meter

Wind Velocity	Effective Stack Height	Concentration at 0 meters	Concentration at 1 meters	Concentration at 2 meters	Concentration at 3 meters	Concentration at 4 meters	Concentration at 5 meters	Concentration at 6 meters	Concentration at 7 meters	Concentration at 8 meters	Concentration at 9 meters	Concentration at 10 meters
1	147	0	27	32	21	15	11	8	7	6	5	4
3	79	0	39	16	9	6	4	3	2	2	2	1
5	65	0	28	10	5	3	2	2	1	1	1	1
7	60	0	21	8	4	2	2	1	1	1	1	1
9	56	0	17	6	3	2	1	1	1	1	1	0
11	54	0	14	5	3	2	1	1	1	1	0	0
13	53	0	12	4	2	1	1	1	1	0	0	0
15	52	0	11	4	2	1	1	1	0	0	0	0
17	51	0	10	3	2	1	1	1	0	0	0	0
19	50	0	9	3	1	1	1	0	0	0	0	0
21	50	0	8	3	1	1	1	0	0	0	0	0

Moderately Unstable:

Gaussian Plume Model

Tabular results:

- Wind velocities in meters per second
- Effective Stack heights in meters
- Concentrations in mmg per cubic meter

Wind Velocity	Effective Stack Height	Concentration at 0 meters	Concentration at 1 meters	Concentration at 2 meters	Concentration at 3 meters	Concentration at 4 meters	Concentration at 5 meters	Concentration at 6 meters	Concentration at 7 meters	Concentration at 8 meters	Concentration at 9 meters	Concentration at 10 meters
1	147	0	41	19	10	6	4	3	2	2	1	1
3	79	0	23	7	3	2	1	1	1	1	0	0
5	65	0	15	4	2	1	1	1	0	0	0	0
7	60	0	11	3	1	1	1	0	0	0	0	0
9	56	0	9	2	1	1	0	0	0	0	0	0
11	54	0	7	2	1	1	0	0	0	0	0	0
13	53	0	6	2	1	0	0	0	0	0	0	0
15	52	0	5	1	1	0	0	0	0	0	0	0
17	51	0	5	1	1	0	0	0	0	0	0	0
19	50	0	4	1	1	0	0	0	0	0	0	0
21	50	0	4	1	0	0	0	0	0	0	0	0

Very Unstable:

Gaussian Plume Model

Tabular results:

- Wind velocities in meters per second
- Effective Stack heights in meters
- Concentrations in mmg per cubic meter

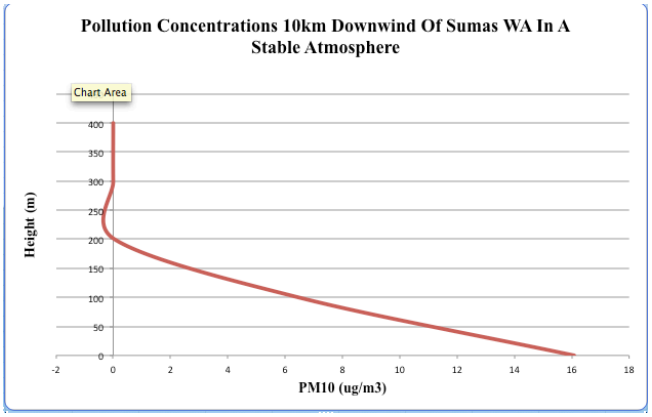
Wind Velocity	Effective Stack Height	Concentration at 0 meters	Concentration at 1 meters	Concentration at 2 meters	Concentration at 3 meters	Concentration at 4 meters	Concentration at 5 meters	Concentration at 6 meters	Concentration at 7 meters	Concentration at 8 meters	Concentration at 9 meters	Concentration at 10 meters
1	147	0	29	9	4	3	2	1	1	1	1	1
3	79	0	12	3	2	1	1	0	0	0	0	0
5	65	0	7	2	1	1	0	0	0	0	0	0
7	60	0	5	1	1	0	0	0	0	0	0	0
9	56	0	4	1	1	0	0	0	0	0	0	0
11	54	0	3	1	0	0	0	0	0	0	0	0
13	53	0	3	1	0	0	0	0	0	0	0	0
15	52	0	2	1	0	0	0	0	0	0	0	0
17	51	0	2	1	0	0	0	0	0	0	0	0
19	50	0	2	1	0	0	0	0	0	0	0	0
21	50	0	2	0	0	0	0	0	0	0	0	0

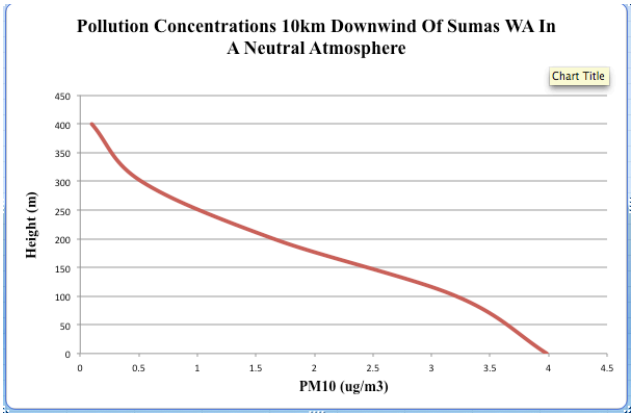
Source for the 6 charts: *http://www.shodor.org/master/environmental/air/plume/*

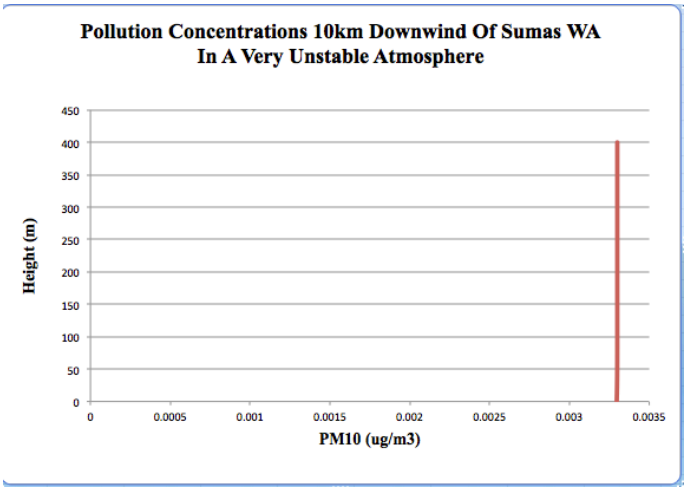
As you can see in the above figures stability plays a major role in pollutant concentrations downwind from a source. Pollutant concentrations become lower 10km away from the pollutant source as stability changes from stable to unstable. This can be seen in highlighted black columns in the charts above. The lower PM10 concentrations in unstable conditions are due to greater mixing and turbulence which causes the pollutants to disperse faster after release compared to stable conditions. PM10 concentration also decreases when wind speed increases. The highest PM10 concentrations 10km downwind of a pollutant source occur in stable conditions with light winds and the lowest concentrations occur in unstable conditions with high winds. It should be noted that effective stack height increases in more unstable environments. In following section PM10 concentration graphs will explain how the pollution plume varies with height and stability.

Results

For the following calculations of PM10 concentrations I used a constant wind speed of 5m/s and effective stack height at that wind speed for stable, neutral, and very unstable situations. This can be seen in the red highlighted areas in the columns above. Below are the graphs that summarize how PM10 concentration changes with height 10km down wind from the proposed Sumas power station:



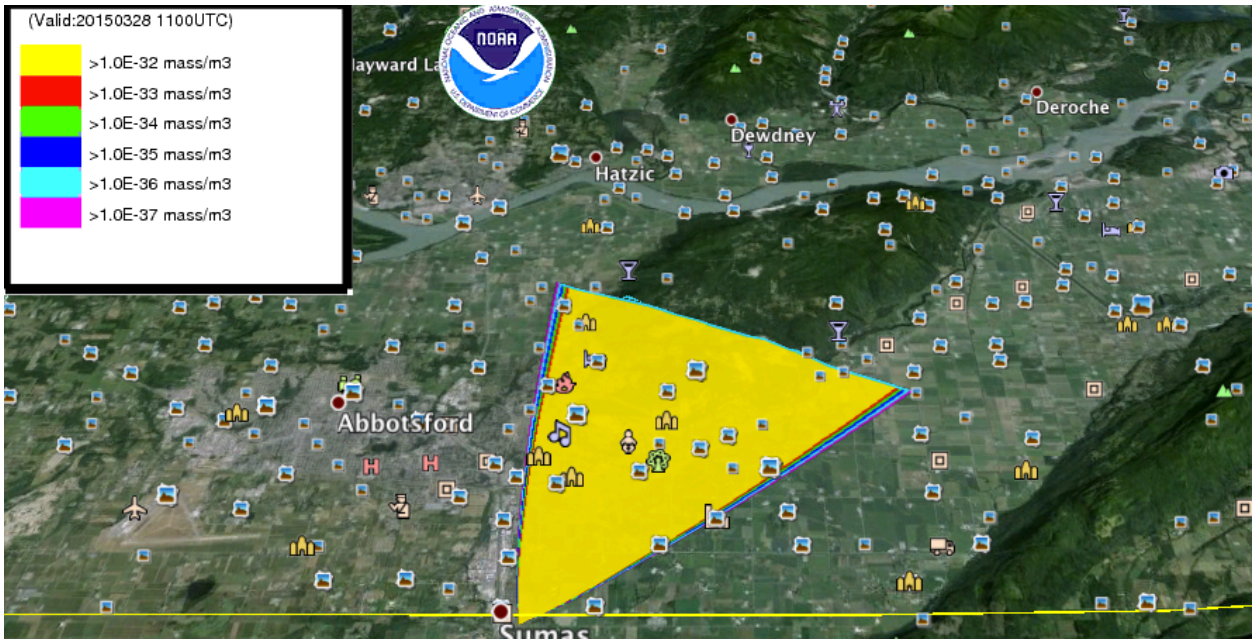




As you can see the pollution concentrations vary with height and stability. In a stable and neutral stability case there is very little mixing and turbulence. The PM10 concentrations are highest and strike the hill roughly at ground level and then decrease with height. This means that during stable and neutral stability cases the plume has the highest PM10 concentrations at ground level 10km downwind from the Sumas plant. During a very unstable situation there is more turbulence and mixing, thus the PM10 concentrations are much lower and are equal from 0-400m, 10km downwind from the Sumas plant. The results for each case are summarized below:

- Stable Conditions: Highest PM10 concentrations of 16.0968 at 0m high
- Neutral Conditions: Highest PM10 concentrations of 3.9867 at 0m high
- Very Unstable Conditions: Equal PM10 concentrations of 0.0033 from 0-400m high

If we compare these values with typical PM10 concentrations in the Lower Fraser Valley which are usually less than 50 ug/m3 we can see that the values from this plume are much lower and would also be very localized and depend on wind direction, wind speed, stability and mixing in the atmosphere. The figure below shows the PM10 plume striking Sumas Mountain in a stable atmosphere.



Source: *READY Gaussian Plume Model/ Google Earth*

This data is important to understand how high and where to build industrial plants that emit pollution. The placement of these industrial plants could prove to be very dangerous to human health if all the necessary meteorological parameters are not accounted for.

Conclusions

The Gaussian Plume Model is a very useful tool in predicting pollution concentrations downwind from a source no greater than 10km away. It is very important that you consider all types of meteorological conditions when using this model to get an accurate measurement. From the above data if the Sumas 2 Facility was built, the PM10 emissions would be lower in all three stability cases than what is typically seen in the Lower Fraser Valley assuming that the wind speed at release is 5m/s.

Sources

1. http://www.shodor.org/master/environmental/air/plume/
2. http://www.csun.edu/~vchsc006/469/gauss1.html
3. READY Gaussian Plume Model
4. Google Earth
5. Ian McKendry: *PM10 levels in the Lower Fraser Valley, British Columbia, Canada: an overview of spatiotemporal variations and meteorological control*