Study of Climate Effect on the Atmospheric Conversion in Coal Mine: A Case Study of Lignite Coal Mine in Thailand

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Abstract. This study aimed to simulate the climate effect on the atmospheric conversion in an open pit coal mine during 2016. Climate data, including wind speed, wind direction, temperature, relative humidity, surface pressure, ceiling height and cloud cover, was collected in order to determine the daily mixing height over the pit area. The model was simulated, using CALMET meteorological diagnostic model with 50 x 50 m resolution grid scale. In this study, the mixing height 225 km² of the operating area in the mine was simulated based on 50x50 resolution). Three meteorological monitoring stations were set up, and upper air data were simulated by WRF model. The simulation assigned 11 vertical layers ranging from 0 to 4,000 m. According to the results of this study, the lowest of mixing height could be detected in the winter season with a downward trend starting from 07.00 PM to 07.00 AM. Conversely, the mixing height varied and gradually increased during daytime, depending on the temperature in that period. The low mixing height indicated air blockage could reduce pollution’s circulation rate in the pit area. This directly affected the health of the people who worked in this mine.

1. Introduction
Northern Thailand has one large-scale lignite coal mine, which started to operate in 1993, about four decades after the coal had been discovered. It has been estimated that the lignite reserve accounts for approximately 630 million tonnes within the area of 32,000 km². Since the establishment, about 16 million tonnes of lignite from this mine have been used to generate 2,400 MW of electricity, which is then distributed throughout the regions in the north, central and northeast of Thailand. The fact that this mine has been operated for a long time has drastically changed the depth and width of the mine operation. By the end of 2016, the depth of the mine stood at approximately 300 meters from the surface. The mine pit is expected to reach the depth of 500-600 meters by the end of 2051. The increase in the pit depth has generated a number of challenges for mining environment control, such as pit ventilation and dust dispersion, which directly affects health and safety of the mine workers leading to the reduction in their work performance. This research studied the climate condition in this open pit at the depth of 300 meters. The climate simulation in this study was constructed to investigate how mixing height affected occupational health of the mine workers and which season in the year 2016 caused the mixing height to reach the lowest level. Climate data, including wind speed, wind direction, temperatures, relative humidity, surface pressure, ceiling height and cloud cover, were collected in order to determine the daily mixing height over the pit area during the year 2016 [1]. This research study focused on the elevation of atmosphere at which the mixing height was found, including the period and season in which it occurred the most and the least. Siwapan Choo-in (2016) states in his article the atmosphere temperature is subject to height. This phenomenon is called the
adiabatic process, where the changing rate of temperature layer can be categorized into 4 types according to the degree of stability, namely unstable condition, neutral condition, stable condition and inversion. The contributing factors to these 4 types include temperature gradient and atmospheric turbulence due to the wind condition and wind speed. The knowledge of the atmospheric elevation at which the mixing height occurs provides more understanding about the dispersion level of pollutants in the atmosphere. The increase in atmospheric level leads to the decrease in the intensity of pollutants, which in turn reduces their danger. In particular, the buoyant force caused by the surface heat is an indicator of the mixing height (MH). It was mentioned in the studies of Suthin Yoosook et, al. (2001) that mixing height is the boundary layer where air pollution can occur [2-4].

2. Meteorological simulation
The open mine pit for this study is located in northern part of Thailand. It is represented by 50 x 50 m grid resolution map, which covers 15 km² area as shown in Figure 1. This includes surrounding community center as well as the mine operating fields. Three meteorological monitoring surface stations have been set up while the upper air data was obtained from WRF model. The simulation assigned 11 vertical layers ranging from 0 to 4,000 m. (20, 40, 80, 180, 260, 460, 800, 1200, 2000, 3000 and 4000 agl-m), which can be applied in analysing the climate condition from season to season [5].

Figure 1. Surrounding area (LCC coordinates, Lambert Conic Conformal projection, WGS-84 data; in km.) and physical geography (topographic lines in meters) of the simulation domain around the study area
3. Meteorological Modelling

In this study, the WRF (The Weather Research and Forecasting) v.3.8.1 model (Skamarock and Klemp, 2008) was applied to collect initial data from a 101 km² grid every 6 hours with the configuration of 30 vertical layers and 3 levels of two-way nested domains based on the data from NCEP-GFS, which analyzed surface meteorological and upper air meteorological parameters. This initial data was simulated to construct the first study area or Domain 1 (D1) of 27x27 km² grid, the second study area or Domain 2 (D2) of 9x9 km² grid, and the third study area or Domain 3 (D3) of 3x3 km² grid. The Domain 3 area had the highest resolution of all the parameters, and then the data from this area was subsequently applied with the CALMET. The CALMET model was proceeded to adjust the meteorological fields on accounting of the local influence of high-resolution terrain and land use data in the study area [6].

![Figure 2. WRF nested domains. The mine area was located in D3 providing input data to the CALMET simulation. Different CALMET model horizontal resolutions were tested in order to investigate complex terrain and coastal influences (Scire et al., 2000a).](image)

4. The CALMET simulation method

Initially, this study established a 15x15 km² area for CALMET horizontal resolution. To construct the CALMET meteorological model, the input data of climate condition in the mine area were divided into 2 categories, namely meteorological data and geophysical data. The former consisted of meteorological data from three surface stations, including wind speed, wind direction, temperature, relative humidity, surface pressure, ceiling height and cloud cover. To enhance the efficiency of climate analysis model, the upper air data (from WRF Model) was added to the CALMET Model. Secondly, geophysical data presented the study area database in the form of digital elevation model (DEM), showing gridded terrain data and land use. During the climate simulation, an output was calculated every single hour each month throughout the year 2016 in order to find coefficient correlation of the model. During the CALMET simulation process, two types of input data, namely...
surface parameter and WRF, were observed to vary due to the change in seasons and the weather, causing the CALMET simulation of each month during the year 2016 to be different from one another. The output obtained from CALMET simulation presented the mixing height level, which was different in each month, and indicated the month and the season that accounted for the lowest and the highest mixing height level [7]. The temperatures from the model were compared with the data from surface stations in order to get correlation coefficient of the model.

![Flow chart CALMET](image)

**Figure 3.** Flow chart CALMET.

5. Analysis
The climate model measurement in the mine pit used the data collected on a daily basis from January to December 2016. The database from 3 surface monitoring stations and upper-air data from WRF were integrated to evaluate the climate data of the mine area that covered 300 grid solutions. The temperature between one of the three surface stations and climate simulation was chosen as a main factor, which was mathematically measured for coefficient correlation as shown in table 1. The data comparison from the CALMET model with the actual measured output at the surface station pointed out that the dataset was significantly correct. The correlation coefficient of all seasons was as follows; 0.958 in winter (Jan, Feb, Nov, Dec ), 0.955 in summer (Mar, Apr, May, Jun) and 0.931 in rainy season (Jul, Aug, Sep, Oct).

| Season  | Month | Count | CORREL   | R²     | AVG CORREL | AVG R² |
|---------|-------|-------|----------|--------|------------|--------|
| Winter  | JAN   | 744   | 0.99994  | 0.9254 | 0.95824    | 0.9182 |
|         | FEB   | 696   | 0.99982  | 0.9145 |            |        |
|         | NOV   | 720   | 0.99774  | 0.8955 | 0.95584    | 0.91363|
|         | DEC   | 744   | 0.99864  | 0.8971 |            |        |
| Summer  | MAR   | 744   | 0.99994  | 0.9072 |            |        |
|         | APR   | 720   | 0.99747  | 0.9151 |            |        |
|         | MAY   | 744   | 0.99572  | 0.9104 |            |        |
|         | JUN   | 720   | 0.99944  | 0.8619 |            |        |
The analysis of the correlation coefficient shown that CAMEL models could be applied to accurately analyze meteorological simulation, which was eventually used to analyze the mixing height and to observe the change of mixing height that occurred in each month for every 24 hours as shown in Table 2 and Figure 4.

Table 2. The hourly average of mixing height of each month

| Hour | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | 2016 |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0    | 66  | 65  | 86  | 79  | 62  | 82  | 59  | 73  | 56  | 42  | 46  | 51  | 64  |
| 1    | 59  | 62  | 66  | 75  | 64  | 77  | 52  | 71  | 55  | 42  | 54  | 47  | 60  |
| 2    | 52  | 62  | 57  | 80  | 56  | 74  | 48  | 51  | 62  | 39  | 55  | 48  | 57  |
| 3    | 49  | 67  | 60  | 74  | 48  | 78  | 42  | 57  | 57  | 52  | 65  | 63  | 59  |
| 4    | 46  | 69  | 58  | 73  | 49  | 73  | 39  | 58  | 68  | 55  | 58  | 62  | 58  |
| 5    | 48  | 71  | 58  | 67  | 48  | 48  | 35  | 56  | 55  | 48  | 61  | 61  | 54  |
| 6    | 46  | 75  | 54  | 56  | 43  | 41  | 40  | 67  | 51  | 56  | 54  | 58  | 53  |
| 7    | 44  | 63  | 47  | 63  | 149 | 151 | 93  | 71  | 46  | 59  | 77  | 48  | 76  |
| 8    | 52  | 129 | 230 | 358 | 485 | 481 | 395 | 419 | 408 | 329 | 232 | 111 | 302 |
| 9    | 338 | 389 | 497 | 672 | 787 | 721 | 627 | 628 | 659 | 576 | 440 | 356 | 557 |
| 10   | 545 | 629 | 804 | 942 | 1,040| 915 | 832 | 823 | 862 | 810 | 686 | 572 | 787 |
| 11   | 778 | 922 | 1,148| 1,249| 1,328| 1,087| 1,019| 983 | 1,054| 1,042| 933 | 810 | 1,028|
| 12   | 980 | 1,190| 1,516| 1,649| 1,651| 1,256| 1,211| 1,161| 1,223| 1,257| 1,112| 1,047| 1,270|
| 13   | 1,152| 1,394| 1,842| 2,097| 1,919| 1,413| 1,353| 1,314| 1,384| 1,407| 1,242| 1,247| 1,479|
| 14   | 1,289| 1,543| 2,074| 2,426| 2,095| 1,540| 1,475| 1,441| 1,596| 1,514| 1,332| 1,375| 1,633|
| 15   | 1,371| 1,628| 2,206| 2,584| 2,193| 1,637| 1,567| 1,534| 1,585| 1,581| 1,396| 1,435| 1,725|
| 16   | 1,410| 1,673| 2,260| 2,658| 2,222| 1,700| 1,642| 1,609| 1,623| 1,617| 1,425| 1,458| 1,773|
| 17   | 1,414| 1,683| 2,319| 2,694| 2,259| 1,724| 1,674| 1,640| 1,637| 1,601| 1,393| 1,429| 1,787|
| 18   | 573 | 1,616| 2,279| 2,643| 2,222| 1,719| 1,649| 1,614| 1,576| 452 | 51  | 85  | 1,369|
| 19   | 69  | 102 | 164 | 165 | 135 | 501 | 520 | 82  | 54  | 49  | 48  | 65  | 163 |
| 20   | 61  | 88  | 141 | 171 | 106 | 146 | 75  | 95  | 52  | 42  | 48  | 54  | 90  |
| 21   | 74  | 80  | 139 | 120 | 84  | 114 | 70  | 84  | 50  | 40  | 45  | 46  | 79  |
| 22   | 71  | 84  | 135 | 128 | 100 | 100 | 73  | 86  | 47  | 42  | 50  | 48  | 80  |
| 23   | 67  | 83  | 118 | 92  | 96  | 95  | 61  | 74  | 47  | 36  | 54  | 60  | 74  |

MIN  | 44  | 62  | 47  | 56  | 43  | 41  | 35  | 51  | 46  | 36  | 45  | 46  | 53  |
MAX  | 1,414| 1,683| 2,319| 2,694| 2,259| 1,724| 1,674| 1,640| 1,637| 1,617| 1,425| 1,458| 1,787|
AVG  | 444 | 574 | 765 | 884 | 802 | 657 | 610 | 587 | 592 | 533 | 457 | 443 | 612|

6. Result
The results show that the highest level of the mixing height occurs in summer, reaching 2,600 m. during the daytime, and the lowest mixing height occurs in winter (particularly in January), while the mixing height in rainy season stood at just 1,600 m [8]. However, the level of mixing height was similarly low at night in every season as shown in Figure 3. The mixing height varied seasonally but it could be evaluated by using the CALMET model.
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Figure 4. The Level of Mixing Height in 2016.
The climate CALMET model was created by using the hourly basis data as shown in Figure 5. The study result indicated that there were the positive correlations between the level of temperature and that of the mixing height. This means that during the day, the temperature and the mixing height increased, but during the night, the temperature and the mixing height decreased [9-10].

Figure 5. The hourly average of Temperature (℃) of each month.

7. Discussion
The study results show that the lowest mixing height can be detected between the night time and the dawn because the temperature during these two periods are lower than that in the day time. Regarding the season, it was found that the lowest mixing height occurred in the winter while the highest mixing height occurred in the summer. During the period of data collection, it was discovered that from the hours of 07:00 PM to 07:00 AM of every single day was the time when the mixing height occurred at 40-60 meters from the bottom of the pit [11]. In 2016 when this study was conducted, the deepest point of the pit area was 300 meters from the surfaces or about 10 meters above the mean sea level, at
which the mine workers operated 24 hours a day. It can be concluded that the night shift workers who operate at the depth of 40-60 meters from bottom of the pit would be more harmfully affected than the dayshift workers. This occurs due to the stability of the air in such restricted area resulting in unacceptably high concentration of exhaust from running engines and fugitive dust from mine operations [12].

According to the obtained modeling data of the mixing height in each month, the result shown that the highest mixing height was in April (summer season) and the lowest one was in January (winter season). The temperature and the mixing height level increased during the day but decreased during the night, causing the air in the mine pit area to be blocked, especially between the nighttime and the dawn, which generates the accumulation of pollution within the mine pit.

8. Conclusion
Meteorological simulation is an evaluation of climate in an open pit at the specific area, where the mine workers worked 24 hours. This research was carried out to find whether the climate condition at this place was appropriate for the workers. This study collected hourly-based data form surface stations and WRF in each month of the year 2016, which were applied with the CALMET system in order to analyze the parameters including wind speed, wind direction, temperature, relative humidity and surface pressure. The data calculation shows that the accuracy rate of the correlation coefficient between the CALMET model and the surface stations stood at approximately 95%.

9. References
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Acknowledgements
Firstly, I would like to express my sincere gratitude to my thesis advisors, Dr. Komsoon Somprasong and Assoc.Prof. Dr. Panlop Huttagosol for the continuous support of my study and related research, for their patience, motivation, and immense knowledge. Their guidance helped me in all the time of research and writing of this thesis.