Presented at the 13th Annual CMAS Conference, Chapel Hill, NC, October 27-29, 2014

Evaluating the Area Effectively Represented by a Meteorological Measurement Station and the Impact of Inadequate Data on Air Dispersion Modelling

Hamish Corbett-Hains*, Nick Walters, Xin Qiu
Novus Environmental, Guelph, ON, Canada

1. INTRODUCTION

Air dispersion modelling is used to assess how an individual industry, a roadway system or even an entire city is performing against air quality goals and regulations. One of the key inputs into a dispersion model is the meteorology of the study area; a typical model will consider five years of meteorology as well as terrain, emission parameters and surrounding buildings in its prediction of point-of-impingement concentrations. Current practice is to use approved meteorology, often provided by a regulatory agency, from a nearby measurement site - typically a local airport. While this approach maintains consistency between assessments, it sacrifices accuracy by assuming that one meteorological set is representative of a whole city or county. Given that meteorological measurement stations (met stations) are typically in open areas such as an airport, this approach can ignore the urbanization of a study area as well as the effects of the surrounding lands.

This study aims to assess the impact using site-specific met can have on an air dispersion modelling.

2. SELECTION OF A MODELLING DOMAIN

Urban features such as skyscrapers can have a significant impact on local meteorology, as can natural features such as agricultural land and water. Toronto, Ontario was chosen given the size of the city and variability in land uses. Two locations within the city were chosen for the assessment; one downtown location in the center of the city and one location on Toronto Island which is less than a kilometer off-shore. Meteorological modelling has shown that Toronto has widely varying meteorology as shown in Figure 1. Figure 2 shows the monitoring and modelling locations in Toronto that were used in this study.

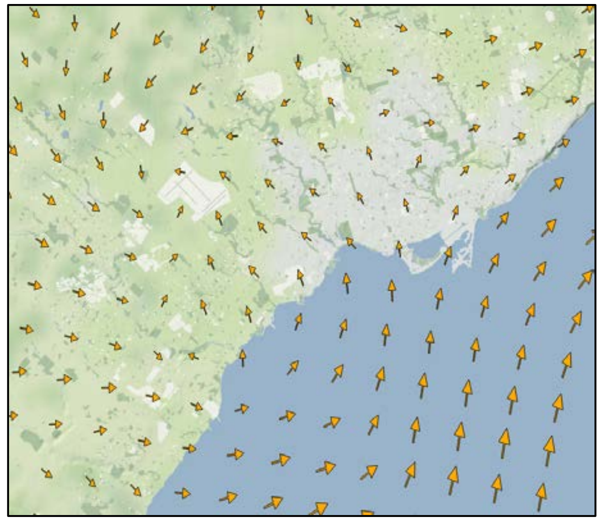

Fig. 1. Wind vectors across the Greater Toronto Area during a typical hour.

Fig. 2. Monitoring and modelling locations across the Greater Toronto Area.

3. METEOROLOGICAL DATA

This assessment aims to compare 'regulatory' met data, as would be provided by local regulatory bodies, with modelled data generated using the Weather Research and Forecasting (WRF) model. However, this research is not aimed at evaluating WRF's efficacy in replicating measured data.

**Corresponding author:* Hamish Corbett-Hains, Novus Environmental, 150 Research Lane, Suite 105, Guelph, Ontario, Canada. 226.706.8080 x 215. hamishh@novusenv.com

Therefore, as opposed to using met data supplied by a regulatory agency and comparing it against modelled met data, WRF data was used to represent both data sources. Model outputs were extracted for the regulatory sampling location, as well as from the study areas. It is worth noting that only wind speed, wind direction, and temperature were taken from the WRF model; the remaining surface parameters (e.g. cloud cover, ceiling height) were taken from measured data.

The WRF model was run using 4-km grid cells over the City of Toronto and surrounding area. The model used local measurement stations and land uses, as well as complex physics models, to develop a time-series of met conditions over the domain. The WRF model predicted meteorology for a one-year period (2008) at Lester B. Pearson International Airport was used to represent 'regulatory' data. Using the US EPA's AERMET pre-processor, the WRF-generated Pearson data was processed to reflect the two study sites and combined with upper air data from the Buffalo International Airport (as recommended for Toronto).

WRF data was selected for the study areas from the nearest modelling grid point (the center of the 4 km modelling grid). These data sets were processed with AERMET using the same land-use classifications as the Pearson Airport data. Wind roses from the WRF output from Pearson Airport and the two study areas are shown in Figure 3.

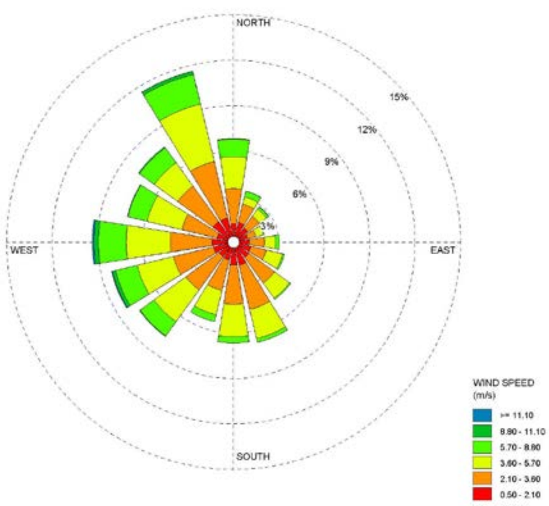

Fig. 3.1 WRF generated wind roses for Toronto Pearson Airport.

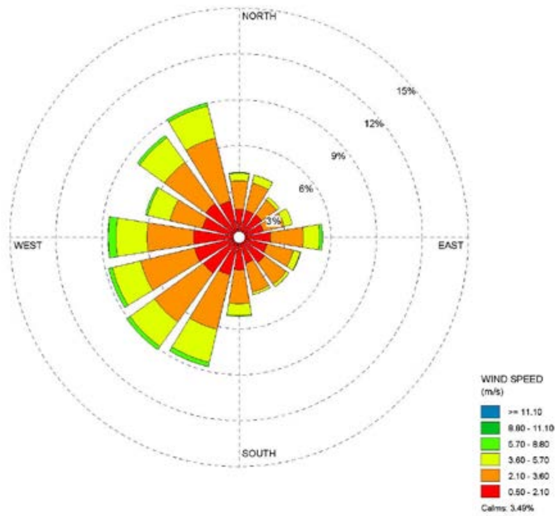

Fig. 3.2 WRF generated wind for Toronto Downtown.

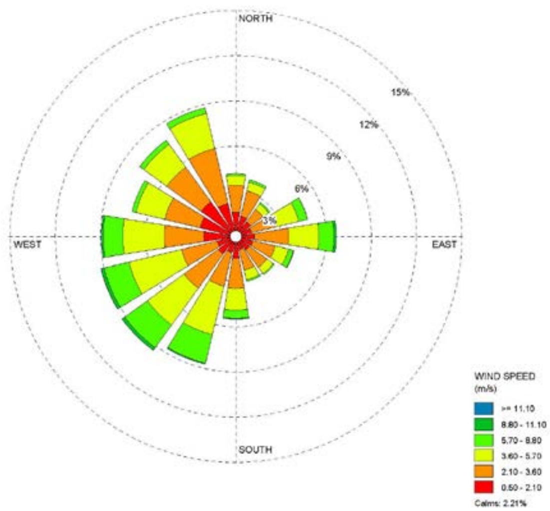

Fig. 3.3 WRF generated wind for Toronto Island.

4. AIR DISPERSION MODELLING

Modelling was performed using the US EPA's AERMOD model, version 14134, following accepted local regulatory methods. Two scenarios were run at each location; one with a single stack with no downwash and one with a single stack on top of a building, subject to same-structure downwash. These simple scenarios were chosen to isolate the effect of meteorology. Stack parameters were chosen to represent a typical scenario: 5 meter exhaust height, 10 cm diameter, 25 ft/s velocity and a 1 g/s emission rate.

The model was run for a one-year period (2008) to coincide with the met data being used.

Local topography was obtained from the Ontario Ministry of the Environment and Climate Change. Building downwash was developed with the BPIP-PRIME algorithm and a nested grid of receptors was used. The modelling was set up to identify the maximum, 95th percentile, 90th percentile and 50th percentile hourly concentrations over the year.

5. Results

5.1 Toronto Downtown

Figure 4 shows the results of the air dispersion modelling at the Toronto downtown location with recommended and site-specific meteorology. The impacts of building downwash were not considered. It can be seen that both sources have similar maximum values (<1% difference between met sources), but that site-specific met produces higher 98th percentile (9% greater), 90th percentile (45% greater) and 50th percentile (31% greater) values.

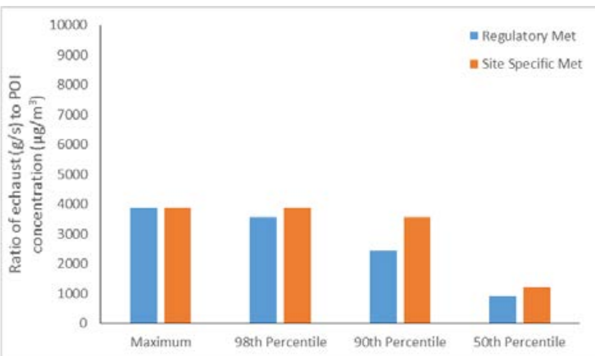

Fig. 4. Predicted magnitude of impacts from air dispersion modelling at a Downtown Toronto location using recommended meteorology data and WRF generated site-specific meteorology. Building downwash not included.

Figure 5 shows the results of the air dispersion modelling at the Toronto downtown location with recommended and site-specific meteorology and the impacts of building downwash. It can be seen that both sources have similar maximum values (<1% difference between met sources), but that site-specific met produces higher 98th percentile (28% greater), 90th percentile (26% greater) and 50th percentile (23% greater) values.

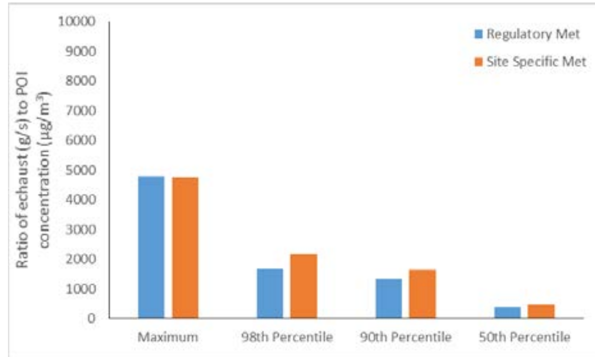

Fig. 5. Predicted magnitude of impacts from air dispersion modelling at a Downtown Toronto location using recommended meteorology data and WRF generated site-specific meteorology. Building downwash was accounted for.

5.2 Toronto Island

Figure 6 shows the results of the air dispersion modelling at the Toronto Island location with recommended and site-specific meteorology. The impacts of building downwash were not considered. It can be seen that both sources have similar maximum values (2% difference between met sources), but that site-specific met produces higher 98th percentile (44% greater), 90th percentile (52% greater) and 50th percentile (18% greater) values.

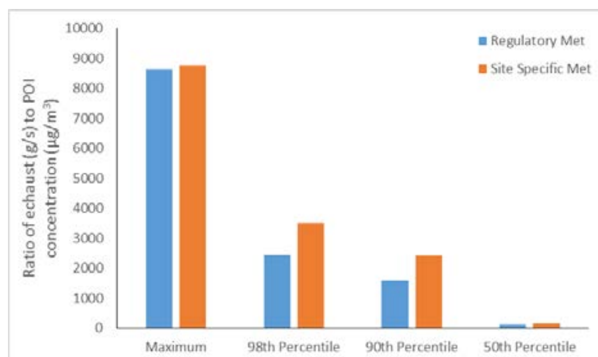

Fig. 6. Predicted magnitude of impacts from air dispersion modelling at a Toronto Island location using recommended meteorology data and WRF generated site-specific meteorology. Building downwash not included.

Figure 7 shows the results of the air dispersion modelling at the Toronto Island location with recommended and site-specific meteorology and the impacts of building downwash. It can be seen that both sources have similar maximum values (2% difference between met sources), but that site-specific met produces higher 98th percentile (29% greater), 90th percentile (22% greater) and 50th percentile (10% greater) values.

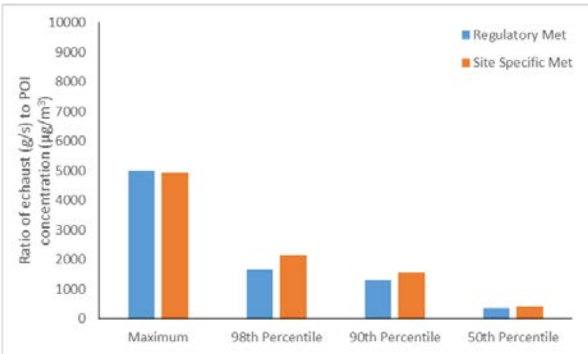

Fig. 7. Predicted magnitude of impacts from air dispersion modelling at a Toronto Island location using recommended meteorology data and WRF generated site-specific meteorology. Building downwash was accounted for.

6. DISCUSSION

The air dispersion modelling results show that using site-specific meteorology when performing air dispersion modelling can have a substantial impact. Comparing the results of models run with recommended meteorological data and WRF-generated site-specific meteorological data showed that both data sets produce similar maximum values, but differences between 95th percentile (up to 44%), 90th percentile (up to 52%) and 50th percentile (up to 31%) were seen.

6. CONCLUSION

Choosing appropriate meteorological data is a key factor in air dispersion modelling. The impact of using site-specific meteorology generated with the Weather Research and Forecasting (WRF) model was assessed by performing air dispersion modelling at two sites in the Toronto area with meteorology from Toronto's Pearson International Airport as well as site-specific modelled. The results showed that there were differences as great as 52% between the modelled results from the two sources. The greatest differences were seen between percentile values, while the maximum values from the two models were quite similar.