Evaluation and analysis of the AIRPACT regional air quality forecast system for ozone and VOCs in the Seattle area

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Introduction

The Air Indicator Report for Public Access and Community Tracking (AIRPACT) provides daily air quality forecasts for the Pacific Northwest. Numerical weather forecasts produced using the Weather Research Forecast (WRF) model (operated by the University of Washington) are used as input to the Community Multi-scale Air Quality (CMAQ) model, which is a photochemical transport model. In AIRPACT, CMAQ simulates ozone, PM2.5, and related pollutant concentrations for Idaho, Oregon, Washington, and surrounding areas on an hourly basis using 12 km x 12 km grid cells with 21 vertical layers. Anthropogenic and biogenic emissions are treated dynamically to account for temporal urban activity patterns and for meteorological effects. Forecasts extend to 64 hours for each forecast simulation.

Objective

Regional air quality managers use AIRPACT to help guide air quality management decisions on a day-to-day basis. The AIRPACT framework is also used in a retrospective approach to assess the effectiveness of potential control strategies by local, state and federal agencies in the region. These AIRPACT applications are particularly important in light of proposed, more stringent ambient air quality standards for ozone. As a result, it is important to understand the overall accuracy of the modeling system and to continue to identify ways to improve the modeling framework. In this research, surface observations from one winter and one summer month are used to assess model performance for ozone and ozone precursors in the Puget Sound urban region. The objective was to conduct a performance assessment to determine how well the model simulates ozone, particularly in the summer, and how well the model represents CO, NOx, and VOCs as precursors to ozone.

Approach

Puget Sound Clean Air Agency (PSCAA) observations for ozone, VOCs, CO, and NOx were compiled for January 2009 and July – August 2009 for Seattle-area sites:

1) Beacon Hill, a central urban location immediately next to the I-5 freeway. O3, CO, and NOx measurements are available at this site.
2) Enumclaw and North Bend are sites downwind of Seattle and often exhibit elevated ozone levels. Only ozone is measured at these sites.
3) Duwamish is located near the industrial area of Seattle within the urban core. PSCAA operated an automated gas chromatograph to measure individual VOC species on an hourly basis during selected periods in 2009.
4) Mt. Rainer is a remote, elevated mountain site located downwind of urban Seattle. Only ozone is measured at this site.

Pollutant emission rates for the Beacon Hill location (grid) and pollutant concentrations for each monitoring site were extracted from AIRPACT archived forecast results on an hourly basis for the winter and summer months. For ozone, the observations and predictions were used to create 8 hr running means as the basis for model evaluation. Other pollutant species were treated on an hourly basis. The resulting paired in space and time data were used to analyze model performance.

Ozone (8hr Running Avg) – Beacon Hill, Summer 2009

AIRPACT Prediction			PSCAA Observation		
Site	Mean (ppb)	Peak (ppb)		Mean (ppb)	Peak (ppb)
North Bend	48	64	North Bend	25	84
Enumclaw	52	70	Enumclaw		
Mud Mt			Mud Mt	30	84
Beacon Hill	32	63	Beacon Hill	18	40
Mt. Rainier	50	62	Mt. Rainier	33	59

Table 1: Mean predicted values are higher than observed values at each evaluated site, but the system does account for higher concentrations downwind of Beacon Hill.

CO/NO Concentration – Beacon Hill 2009

AIRPACT Prediction			PSCAA Observation		
	Mean	Peak		Mean	Peak
Winter	250	2171	Winter	251	8910
Summer	504	5692	Summer	650	27390

Table 2: Mean winter values almost the same for both data sets, but peak observed ratios are significantly higher than predicted ratios for both seasons.

CO/NO – Slopes of Trend Lines

	Beacon Hill		Boise
Data Set	Winter	Summer	Winter
Emissions	23.5	14.9	14.5
AIRPACT Prediction	25.6	17.1	13.8
Observation	5.0	3.1	4.6

Table 3: Emissions and predicted slopes are close for both seasons, and a similar pattern is seen in data from Boise, ID. Both values are significantly higher than observed ratios.

VOC Concentration – Beacon Hill, Winter 2009

AIRPACT Prediction			PSCAA Observation		
Species	Mean (ppb)	Peak (ppb)	Species	Mean (ppb)	Peak (ppb)
ARO1	3.25	8.82	ARO1	6.26	23.6
ARO2	7.04	18.4	ARO2	9.42	40.21
Benzene	0.99	2.86	Benzene	1.21	4.33

Table 4: The system generally underestimates concentrations. Observed mean and peak values are higher than predicted values in all cases.

VOC Concentration – Beacon Hill, Summer 2009

AIRPACT Prediction			PSCAA Observation		
Species	Mean (ppb)	Peak (ppb)	Species	Mean (ppb)	Peak (ppb)
ARO1	1.57	5.49	ARO1	0.61	1.99
ARO2	0.82	3.05	ARO2	0.48	2.22
Benzene	0.40	1.39	Benzene	0.21	0.59

Table 5: The system generally overestimates concentrations. Predicted mean and peak values are higher than predicted values in all cases.

Discussion

Ozone – Peak ozone values are generally modeled accurately, but daily lows are consistently missed at most sites. Lows seem especially hard to predict at downwind sites (Figure 2). The exception is Beacon Hill, where peaks are over-predicted but correct lows are modeled more regularly (Figure 1).

CO and NO – The system commonly overestimates CO concentrations during summer and winter, but underestimates NO in the summer and has mixed NO results in the winter. Analysis of AIRPACT emissions data reveals similarities between emissions and predicted CO/NO ratios at Beacon Hill and Boise, but these ratios are still significantly higher than observed ratios (Table 3).

VOCs – All evaluated VOCs have similar results, so Figure 7 and Figure 8 are accurate representations of results for ARO2 and Benzene as well. AIRPACT follows a trend of over-predicting values in the summer and underestimating values in the winter. The peak values shown in February in Figure 7 are documented by each species, but are unaccounted for in model data.

Results

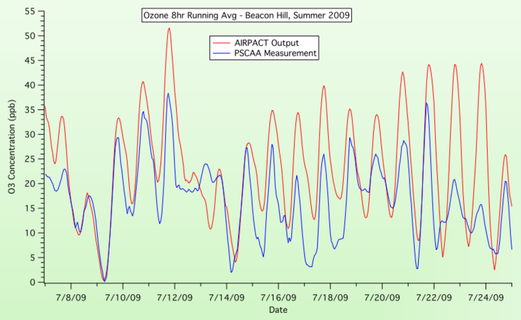

Figure 1: Ozone concentrations for Beacon Hill. AIRPACT does a good job predicting when peaks and lows occur, but generally over-predicts concentrations.

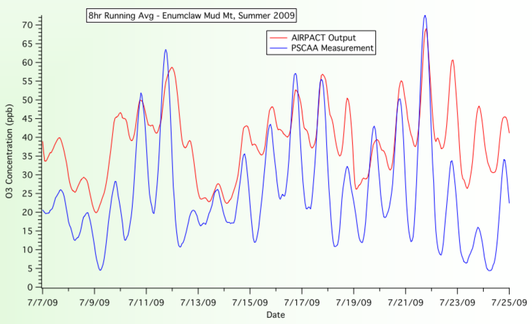

Figure 2: Ozone concentrations for Enumclaw. The system accurately predicts peaks on several days, but fails to account for daily lows.

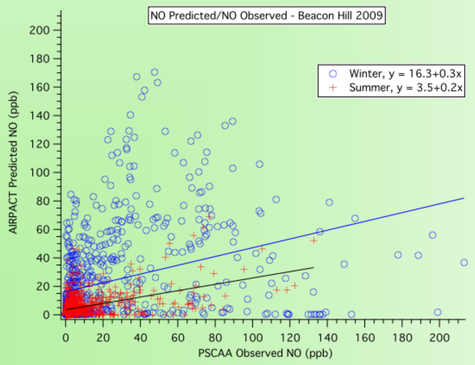

Figure 3: Predicted vs. observed NO concentrations in Beacon Hill. The ratios show predicted values are more accurate during summer.

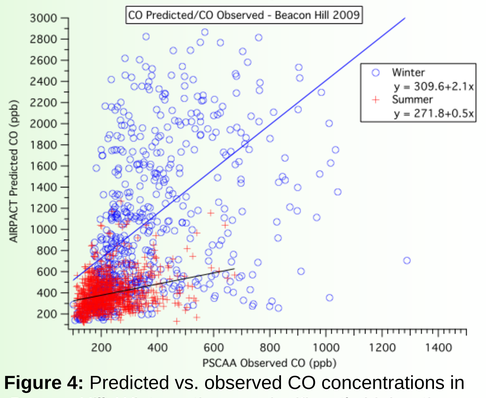

Figure 4: Predicted vs. observed CO concentrations in Beacon Hill. Winter ratios are significantly higher than summer ratios.

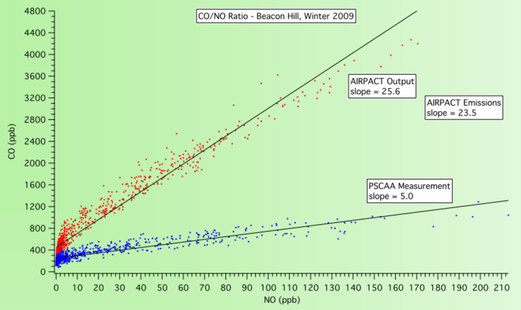

Figure 5: Observed and predicted CO/NO ratio at Beacon Hill during winter. Observed values are much lower than predicted values, and there's a significant gap between the slope of both data sets.

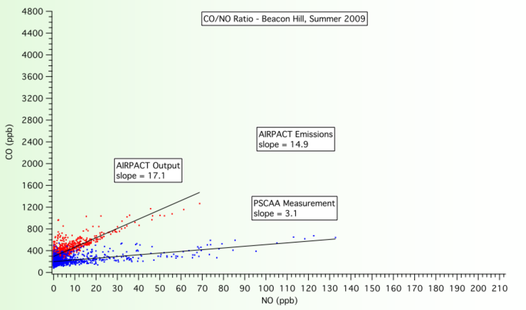

Figure 6: Observed and predicted CO/NO ratio at Beacon Hill during summer. Predicted ratios are closer to observed ratios during this period.

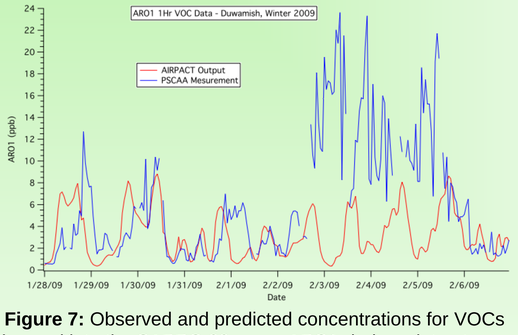

Figure 7: Observed and predicted concentrations for VOCs lumped into the SAPRC-99 group ARO1 during winter. Lows are predicted more successfully, but peaks are often missed.

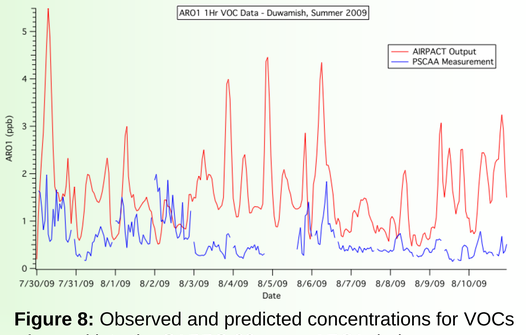

Figure 8: Observed and predicted concentrations for VOCs lumped into the SAPRC-99 group ARO1 during summer. Predicted values are consistently higher than observed values throughout the period.

References and Acknowledgements

Chen, Jack, Joe Vaughan, Jeremy Avis, Susan O, and Brian Lamb. "Enhancement and evaluation of the AIRPACT ozone and PM2.5 forecast system for the Pacific Northwest." *Journal of Geophysical Research*. 113. (2008).

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