Particle Pollution Forecasting: An Initial Performance Evaluation for Charlotte

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Background

On October 1, 2003, the North Carolina Division of Air Quality (NCDAQ) began forecasting particle pollution (PM 2.5) in the Charlotte Metropolitan area.

NCDAQ issues 1-day forecasts Monday-Friday for the Tuesday-Saturday time period. Friday's forecast (covering 3 days) includes the Sunday-Monday time period.

Motivation

Particle pollution has become an important component of air quality forecasting over the past few years. The NCDAQ has been forecasting ozone since 1997, however, particle pollution forecasting is new to the agency. In order to increase forecast accuracy, it is important to evaluate initial forecast performance. A comparison of human forecaster skill versus other forecasting techniques is also good metric for improving accuracy. To assess the current skill of the forecast program, the following questions were asked:

- How are we performing versus a persistence forecast?
- Does accuracy differ between one, two, and three day forecasts?
- How are we performing in relation to statistical forecast methods, specifically the MARAMA/SAI CART tool?

Forecast Verification Process

1) NCDAQ's forecasts are verified based on a 24-hour average concentration beginning at 12 a.m. (midnight) and ending at 11:59 p.m. on the forecast day.

2) 24-hour averages are calculated using hourly data from two continuous (TEOM) PM 2.5 monitors in the Charlotte forecast area.

Excerpt from Table for Converting 24-Hour PM 2.5 Concentration in Micrograms per Cubic Meter ($\mu g/m^3$) to the Air Quality Index (AQI)

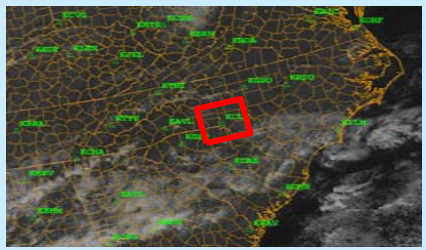
$PM_{2.5}$ Conc.	AQI	$PM_{2.5}$ Conc.	AQI	$PM_{2.5}$ Conc.	AQI
0.20 - 0.40	1	15.5 - 15.7	51	40.5 - 40.7	101
0.50 - 0.70	2	15.8 - 16.2	52	40.8 - 41.2	102
0.80 - 1.00	3	16.3 - 16.7	53	41.3 - 41.7	103
1.10 - 1.30	4	16.8 - 17.2	54	41.8 - 42.2	104
1.40 - 1.60	5	17.3 - 17.7	55	42.3 - 42.7	105
1.70 - 2.00	6	17.8 - 18.2	56	42.8 - 43.2	106
2.10 - 2.30	7	18.3 - 18.8	57	43.3 - 43.8	107
2.40 - 2.60	8	18.9 - 19.3	58	43.9 - 44.3	108
2.70 - 2.90	9	19.4 - 19.8	59	44.4 - 44.8	109
3.00 - 3.20	10	19.9 - 20.3	60	44.9 - 45.3	110
3.30 - 3.50	11	20.4 - 20.8	61	45.4 - 45.8	111
3.60 - 3.80	12	20.9 - 21.3	62	45.9 - 46.3	112
3.90 - 4.10	13	21.4 - 21.8	63	46.4 - 46.8	113
4.20 - 4.40	14	21.9 - 22.3	64	46.9 - 47.3	114
4.50 - 4.70	15	22.4 - 22.8	65	47.4 - 47.8	115
4.80 - 5.00	16	22.9 - 23.3	66	47.9 - 48.3	116
5.10 - 5.30	17	23.4 - 23.8	67	48.4 - 48.8	117
5.40 - 5.60	18	23.9 - 24.3	68	48.9 - 49.3	118
5.70 - 6.00	19	24.4 - 24.9	69	49.4 - 49.9	119
6.10 - 6.30	20	25.0 - 25.4	70	50.0 - 50.4	120

3) Monitored data are discarded if greater than 25% (6 hours) of the 24-hour period are missing or erroneous.

4) Valid 24-hour averages are converted from $\mu g/m^3$ to AQI using the table* on left.

*Table shown here is an excerpt from a more complete version

Charlotte Forecast Area



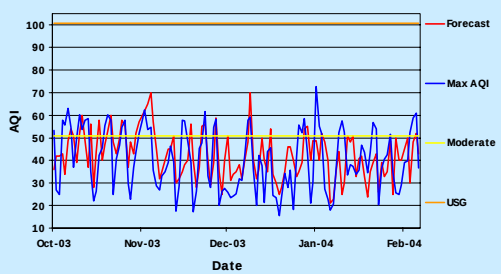
▲ Garinger TEOM Monitor

▲ Montclaire TEOM Monitor

Forecast Statistics

Statistics are based on an Air Quality Index (AQI) forecast versus the observed AQI. Forecasting the observed AQI color code was considered a "hit." Not forecasting the correct AQI color code was a considered a "miss." The evaluation took place over a 129 day period, from October 1, 2003 – February 6, 2004.

All (1, 2, and 3-day) NCDAQ forecasts (AQI) vs. Observed (AQI)



Forecast Method	Forecast Period	Count	Accuracy	Mean Absolute Error	Bias
Persistence	Next Day	129	75.2	10.7	0.0
Human	Next Day	92	73.9	10.3	3.3
Human	Next, 2nd and 3rd	129	72.1	10.5	2.2
Human	2nd Day	19	68.4	10.2	-3.5
Human	3rd Day	18	66.7	12.2	2.4
CART only	Next Day	86	66.3	N/A	N/A

NCDAQ Official Forecast - Contingency Matrix

Observed \ NCDAQ Forecast	Good	Moderate	USG	Total
Good	75	13	0	88
Moderate	23	18	0	41
USG	0	0	0	0
Total	98	31	0	129

CART-Only Contingency Matrix

Observed \ CART Forecast	Good	Moderate	USG	Total
Good	46	15	0	61
Moderate	14	11	0	25
USG	0	0	0	0
Total	60	26	0	86

Forecast Period Details

Persistence - Next Day: A persistence forecast that predicts the next day's AQI value

Human - Next Day: All NCDAQ next day forecasts (includes CART tool influence)

Human - Next, 2nd and 3rd: All NCDAQ forecasts during the 129 day evaluation period

Human - 2nd Day: NCDAQ two day forecast only

Human - 3rd Day: NCDAQ three day forecast only

CART only - Next Day: CART tool forecast of AQI color code only

Stats Definitions

Count – Number of days forecasted by particular method

Accuracy – Percentage of days where color code was accurately forecast. Higher numbers are better.

Mean Absolute Error – Measures the average "closeness" between the forecast and observed AQI values

Bias – Average under-prediction or over-prediction. Values near zero are best

Classification and Regression Tree (CART) Tool

A collaboration between the Mid-Atlantic Region Air Management Association (MARAMA) and Systems Applications International (SAI) provided NCDAQ with a particle pollution forecast tool.

1999-2002 meteorological and fine particle data were used to correlate certain meteorological conditions with fine particle concentrations.

The CART tool provides 1-day predictions using model forecast surface and upper air meteorological data. NCDAQ used the following forecast data as input:

Data Type	Data Source
Previous Day's Fine Particle Concentration	TEOM data recorded in Charlotte, Winston-Salem, and Greenville, SC.
Surface	12Z MOS from ETA, NGM, or GFS (forecaster's preference)
Upper Air	12Z BUFKIT-ETA forecast soundings for the CLT gridpoint

Conclusions

- Persistence forecasting provides decent accuracy in the winter season when there are less dramatic changes in particle pollution levels.
- The relative success of persistence forecasting can be attributed to its ability to "know" the concentration from the previous day. A human forecaster must create their forecast at 15:00 before the day's 24-hour average concentration is complete.
- Accurately projecting the current day's observed value can improve the human forecaster's skill.
- There is an improvement in skill for next day forecasts over 2nd/3rd day predictions.

Future Work

- Further evaluation in spring and summer months that typically have higher fine particle concentrations.
- Determine an accurate method for projecting the current day's observed value for use in making the next day's forecast.